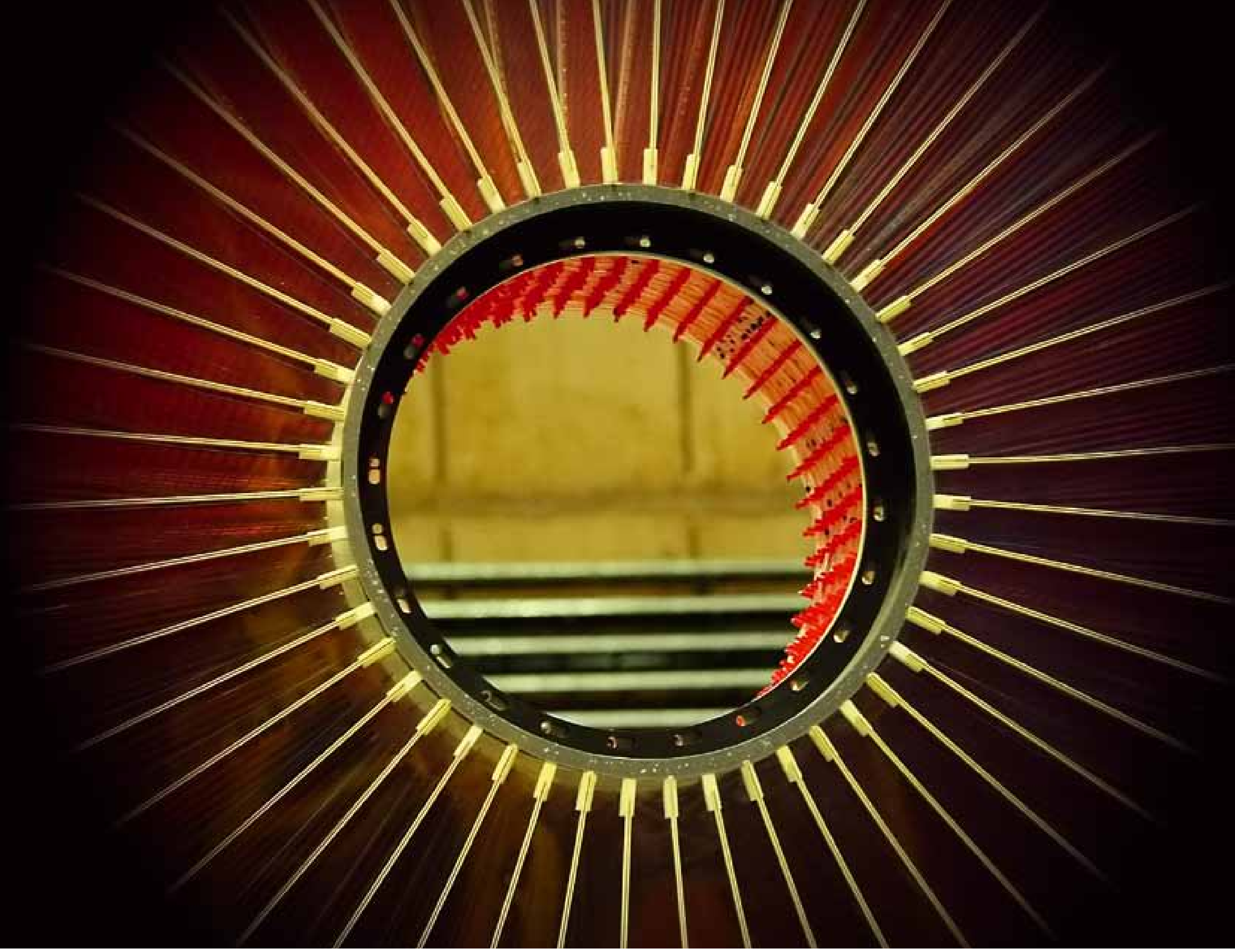


PARTICLE PHYSICS 2010.

Highlights and Annual Report

Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

Cover

Radial wire chamber of the H1 detector (Photo: Hans-Peter Hildebrandt)

PARTICLE PHYSICS 2010.

Highlights and Annual Report

Contents.

The year 2010 at DESY.

Chairman's foreword

In the fall of 2010, we celebrated the 20th anniversary of the German reunification. As part of the successful reunification, the former Institute for High Energy Physics (IfH) in Zeuthen became part of DESY. As integral part of our mission, the DESY site Zeuthen has a strong astroparticle physics profile and gained international reputation in this field. A recent highlight was the completion of the neutrino telescope IceCube at the end of 2010 after a decade of planning and six years of construction. It is the world's largest particle detector, filling a cubic kilometer of deep Antarctic ice with ultrasensitive light sensors that record the tracks from neutrinos coming from outer space. Together with the Cherenkov Telescope Array (CTA), which is currently in the preparatory phase, IceCube will allow us to retrieve information about distant galaxies using neutrinos and high-energy gamma rays as astronomical messengers.

In March 2010, the eagerly awaited LHC physics programme started with colliding beams. After years of work of many scientists worldwide, it is now tantalizing to see the transition into a new era of particle physics – exploring the world at highest energies. First results from LHC experiments were already presented at the "Physics at the LHC" conference, which was held in summer 2010 at DESY. A strong DESY commitment to the experiments ATLAS and CMS, as well as to the upgrades of the LHC detectors, are important elements of the future DESY strategy.

We are also very happy that the German Physical Society (DPG) announced in December 2010 that the Stern-Gerlach Medal – the highest award for achievements in experimental physics – will be presented to Günter Wolf, a scientist at DESY from the early days on. With this award, the society

The last digital optical module (DOM) is being deployed in the IceCube detector.

honours his scientific oeuvre in particle physics. Günter Wolf has significantly influenced both the development of this field and the establishment of the Standard Model. One of the greatest research successes of DESY was the discovery of the gluon in 1979, the force carrying particle of the strong interaction. At that time, Günter Wolf was one of the major driving forces behind the TASSO experiment – one of the four experiments at the PETRA storage ring which discovered the gluon – and later of the ZEUS experiment at the electron-proton storage ring HERA.

The University of Hamburg and DESY have won an Alexander von Humboldt professorship for the development of accelerators and particle physics. The renowned award goes to Professor Brian Foster, currently head of particle physics at the University of Oxford. Brian Foster has spent nearly three decades of his scientific life at DESY's research facilities, first at the electron-positron storage ring PETRA and later at HERA. His planned activities for his future work in Hamburg on novel accelerator and acceleration concepts are a perfect match to our Helmholtz-wide initiative to further strengthen accelerator R&D.

I would like to thank all colleagues and collaborators for their fruitful work in 2010. ●

Helmut Dosch
Chairman of the DESY Board of Directors

Particle physics at DESY.

Introduction

Press conference on the occasion of the “Physics at the LHC” 2010 workshop in Hamburg

Worldwide particle physics in the year 2010 was marked by the very successful first run of the Large Hadron Collider (LHC) at 7 TeV, the highest energy ever reached at a collider. From the first proton-proton collisions at this energy on 30 March to the successful run with lead ions until the technical stop in December, the whole year showed a constantly improving, excellent performance of the LHC machine and detectors, exceeding even the most optimistic expectations. This led to first-class physics results and publications. We are very proud that many people from DESY contributed to this success story of the LHC. The DESY contributions include technical support for the detectors, providing an excellent computing infrastructure, the calibration of detector components and carrying out data analyses.

Results from the very first LHC data were presented at DESY in June 2010 during the international conference “Physics at the LHC”. We were honoured by the visit of Dr. Georg Schütte, State Secretary at the German Federal Ministry of Education and Research, who presented a welcome address to the delegates and discussed particle physics with representatives of the German groups, stressing the ministry’s continuous support for Germany’s contribution to the LHC.

The prospects for the LHC are just as excellent. The luminosity is expected to significantly increase in the next years so that we can anticipate important new results on the Higgs boson and new physics beyond the Standard Model. At DESY we have started to plan the future and shaped our plans for upgrades of the LHC detectors, in close cooperation with our partners in the ATLAS and CMS collaborations. These projects centre on improvements and replacements of silicon tracking detectors and will be a major activity for the next years in our laboratory.

Significant progress was also made in the physics harvest of the HERA experiments. More than 40 papers, mostly based on HERA II data, were published by the collaborations. The combination of experiments leads to even more precise results and textbook measurements on the structure of the proton, providing essential input for LHC physics. The International Linear Collider (ILC) is progressing towards the technical design for the machine and detectors in 2012 with important milestones achieved this year. After five successful years the EUDET project ended in 2010. It gave a boost to ILC detector R&D in Europe and beyond. EUDET is followed by the new EU project AIDA, which puts detector R&D in Europe on an even broader basis.

Particle physics at DESY is traditionally characterized by a very close collaboration between experiments and a strong theory group. With their excellent achievements, DESY theorists bear comparison with our experimentalists. Close collaboration between experiment and theory is also a strong point of the Helmholtz Alliance “Physics at the Terascale”. The Alliance, a crucial element for particle physics at DESY and in Germany, successfully continued its programme and in particular efficiently supported German groups in the analysis of the first LHC data. It will be essential to find a way to continue and further develop the instruments of the Alliance beyond 2012.

The last digital optical module (DOM) is being deployed in the IceCube detector.

For astroparticle physics at DESY, the most important event in 2010 was certainly the completion of the IceCube neutrino observatory at the South Pole on 18 December. DESY in Zeuthen made significant hardware contributions to the detector. Now the focus will turn to the analysis of the data collected with the completed apparatus. Preparation for the future project, the Cherenkov Telescope Array (CTA), has started with the construction of first prototype devices.

This brochure looks back at a prosperous and eventful year in particle and astroparticle physics at DESY, describing the achievements of 2010 in more depth. The prospects for the coming years are bright and I look forward to exciting new results in the near future. ●

Joachim Mnich
Director in charge of High-Energy Physics
and Astroparticle Physics

Helmholtz Alliance.

Physics at the Terascale

The Helmholtz Alliance "Physics at the Terascale" brings together physicists in the field of high-energy particle physics from DESY, KIT, the MPI Munich and 18 German universities. All share a common interest in the physics at the LHC or ILC. The Alliance members are theoretical and experimental physicists. The Alliance has become a major part of the particle physics landscape in Germany.

High-energy physics these days is a truly international endeavour. The big experiments at major collider facilities like the LHC or the planned ILC have thousands of members from countries all around the world. Working in these experiments not only means working at the forefront of science and technology, but is also an exciting experiment of a truly global enterprise.

The Alliance was formed to support the German high-energy physics community beyond the actual involvement in specific experiments. It provides the means for collaborations between experimental and theoretical physicists, as well as experimental infrastructure for new developments available for common use. Training young physicists just entering the field is an essential component of the Alliance.

The Alliance builds on the already existing and very efficient structures that are in place e.g. for the LHC experiments. It adds a common and very strategically oriented layer which brings together universities, research centres and different experiments. In this way it brings a new quality of cooperation to the German high-energy physics community, with the goal of making particle physics in Germany even more visible internationally and of optimizing the impact German contributions have in the major international projects. The Alliance has also enabled a new level of cooperation between the universities and the Helmholtz research centres in Germany.

The Alliance was launched in 2007. It will receive its funding from the Helmholtz Association until the end of 2012. This money allowed the partners to hire strategically placed personnel, thus bringing missing expertise to Germany, and to invest in infrastructure and common measures which are available to all partners but would be essentially impossible to fund through other means.

Scientifically, the year 2010 was dominated by the first data collected by the LHC experiments. The accelerator performed extremely well during 2010, promising a rich harvest of physics during the upcoming run which will last until the end of 2012. The first published physics results from the LHC started to open the new era of Terascale physics. Although the number of events collected so far is not large enough for a discovery, results from the LHC already started to constrain possible new physics scenarios.

German groups played an important and very visible role in the first analyses of the LHC data. The interpretation of the results is substantially advanced by an Alliance project, a joint working group including members from the two major

LHC experiments, ATLAS and CMS, and theoreticians. This group has developed tools to analyse the results of the LHC experiments together with results from other earlier experiments, and derive limits on possible new physics scenarios.

The Alliance is organized in four working areas: analysis, computing, detectors and accelerators. Over the first years of the Alliance the large infrastructure projects in the detector area have been installed. They are now available to all partner institutions and start to see significant use in particular in the context of the LHC upgrades. A major milestone in the accelerator project was the installation of a junior research group at the University of Hamburg working in the area of novel accelerator technologies. The Alliance bundles the involvement of the German groups in the preparations for the next big project in particle physics, a linear electron-positron accelerator. The analysis project was clearly dominated by the startup of the LHC, with many studies ongoing. Progress however has also been made to profit from the legacy of HERA and optimize the input from HERA to the LHC. A major challenge has been to provide adequate computing to the LHC community. The Alliance has invested heavily into the Tier-2 centres, which are part of the worldwide LHC Computing Grid. In addition, the physics analysis is supported by the installation of the National Analysis Facility (NAF) at DESY.

Education plays a big role in all the research areas of the Alliance. In 2010, 18 schools and workshops with over 850 participants were organized. The participants ranged from bachelor students to high-ranking physicists. The schools and workshops allow young researchers to gain experience in different data analysis techniques (e.g. simulation and data analysis tools, statistics), learn about accelerator and detector techniques and exchange ideas with colleagues from other institutions.

The Alliance triggered a process by which the community as a whole agreed on the areas to support, where to invest and where to place resources. The Alliance thus gave a big boost to a common German particle physics infrastructure and community. One of the big successes of the Alliance is that a significant part of these activities, in particular people, will be available also after the end of the Alliance. About 40% of the money which currently comes from the Alliance will be taken over by the partners after 2012. The other 60%, however, which are used to fund common infrastructure, short-term projects and personnel, are currently not covered. Together the Helmholtz centres and the universities are looking for ways to ensure that the numerous and very valuable activities can be continued after 2012.

Contact:

Ties Behnke, ties.behnke@desy.de
Klaus Desch, klaus.desch@desy.de
Christian Zeitnitz, christian.zeitnitz@desy.de

Reference:

http://www.terascale.de/

News and Events.

News and events.

A busy year 2010

January

Zeuthen connected to ATLAS

Just before the restart of the LHC at CERN, a control room with two shift workplaces for monitoring the ATLAS experiment was completed in Zeuthen. It facilitates the monitoring of the data quality, the status of the detector components, data taking, offline computing and the trigger from DESY. A videoconference system will bring events from the ATLAS control room directly to DESY.

View of the new ATLAS remote-monitoring room at DESY in Zeuthen

Martin Pohl appointed professor at the University of Potsdam and DESY

“Parallel worlds: the non-thermal universe” – this was the topic of the inaugural lecture and official introduction of Martin Pohl to his colleagues and students as a newly appointed professor for theoretical astroparticle physics at the University of Potsdam.

Last year, Pohl accepted a chair at both the University of Potsdam and DESY in Zeuthen. He works on a wide area of subjects ranging from the acceleration of high-energy particles in the universe to the exploration of dark matter. He is interested in the unsolved questions of modern astroparticle physics – the origin of cosmic radiation and the emergence of extraterrestrial magnetic fields are two of the exciting topics to be intensively examined by Pohl’s workgroup.

Prior to his appointment, Pohl had been a faculty member at Iowa State University for six years, working among other things as a NASA interdisciplinary scientist for the gamma-ray observatory GLAST. Martin Pohl was born in Kempen in 1965 and obtained his doctorate at Bonn University in 1991. After several research activities, he habilitated at Ruhr University in 2002.

February

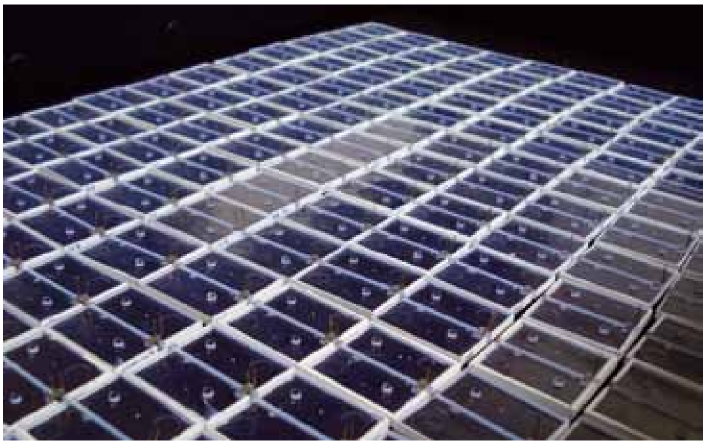
Detector experts plan the future

Sometimes detector projects that are still at a planning stage can advise detector projects that are already taking data what hardware to use. This happened at a meeting that brought experts from all areas using a new type of sensor called silicon photomultiplier (SiPM) together at DESY for two days in February.

The CALICE hadronic calorimeter (HCal) for a detector at the ILC has been using SiPMs for years. The final HCal will feature some eight million of these ultrafast and ultraprecise photodetectors and an unprecedented resolution where each particle is reconstructed individually. The team around CALICE spokesman Felix Sefkow from DESY are thus regarded as experts in their use.

The meeting at DESY took stock of the different sensors built by different companies. The participants compared characteristics and exchanged experiences. “These sensors are a hot topic in physics,” said Kerstin Borras, leader of DESY’s CMS group and the initiator of the meeting. Her experiment, the CMS detector at the LHC, is planning to use SiPMs for future upgrades of two of its subdetectors. SiPMs also have medical uses in PET scanners.

The participants left with a complete grid of sensor characteristics including size, amplification, dynamic range, recovery time, radiation hardness or resistance to magnetic fields. They now have a better idea which sensor to use for their purposes. Last point on the agenda: sightseeing of the first large array of working SiPMs – the CALICE HCal prototype,



New scintillator tiles for the CALICE HCal prototype currently resting from test beam activity at DESY. Because it is a hot current topic, the meeting was sponsored by the Landesexzellenzcluster "Connecting Particles with the Cosmos" in Hamburg. The meeting almost coincided with the third annual meeting of the Helmholtz-Russia Joint Research Group. DESY collaborates with the institutes MEPHI, ITEP and MSU. Topics in this research group are of course the SiPMs, calorimetry and physics at the LHC and the ILC.

Welcome to HERA!


Exhibition of detector components of the experiments at the electron-proton storage ring HERA

Many of the 13000 people who came to DESY during last year's open day and queued at the HERA west hall to see the HERA accelerator got a taste of particle physics research infrastructure. Regular visitor groups now have the chance to experience the real atmosphere of experiments: in February 2010, the HERA west hall became an official tour stop for all DESY visitors – nearly 8000 per year. Guided tours take them 25 metres underground where they learn more about the experiments of the only accelerator that brought protons and electrons to collision. The main attractions, many original components from the HERA detectors and the remaining HERA-B detector, are highlighted with scenic illumination.

Tate Medal for Gustav-Adolf Voss

The American Institute of Physics (AIP) awarded the Tate Medal for International Leadership in Physics to Prof. Gustav-Adolf Voss.


Professor
Gustav-Adolf Voss

He received the renowned medal on 14 February at a meeting of the American Physical Society in Washington in recognition of his outstanding success in promoting international physics for many years, especially for his effective support of Soviet and Eastern European physicists after the breakup of the Soviet Union, his stimulation of the development of accelerator technology throughout Europe and his leadership in the construction of the synchrotron radiation source SESAME in Jordan, which is to be used as a collaborative facility by nine countries in the Middle East.

Gustav-Adolf Voss is remembered at DESY particularly for his successes as project leader for the PETRA and HERA storage rings. Voss a was member of the DESY Board of Directors and head of the accelerator division from 1973 to 1994. With unorthodox, internationally oriented and very effective methods, he shaped the complete research centre. He always brought together the best experts from all over the world. For his lifetime achievements in accelerator physics, Gustav-Adolf Voss was the first to be awarded the golden DESY pin in September 2009.

Masterclasses expand to “particle world”

On 23 and 24 February, DESY in Zeuthen and the Humboldt University in Berlin Adlershof jointly organized one day for 15 teachers and one for 65 pupils. From April 2010 on, such Masterclasses will reach a considerably larger group of people. Under the auspices of the German particle world network (“Netzwerk Teilchenwelt”) initiative, which was launched on 20 April 2010, around 200 project days per year are planned at different venues. From Hamburg to Munich and Aachen to Berlin, doctoral students doing research in the field of particle physics will become mobile experts of the network, travelling to schools, museums and other educational institutions to carry out Masterclasses and cosmic-ray projects.

The particle world network is based on a collaboration of numerous institutions: twenty German research institutes and CERN. The network is supported by the Federal Ministry of Education and Research (BMBF). Its patron and partner is the German Physical Society (DPG). The project management is done by the Technical University Dresden. Thanks to this nationwide network, more than 6000 young people per year will get the opportunity to take a trip to the big bang and participate in the latest research at the LHC experiments.

Participants of the Masterclasses at Humboldt University

Astroparticle physics roadmap

On 25 and 26 February 2010, 200 participants attended the sixth meeting of German astroparticle physicists at DESY in Zeuthen. Alongside the USA and France, Germany holds a top-level position in astroparticle physics.

The Zeuthen meeting provided an impressive overview of activities in Germany and marked the beginning of a strategy debate which is due to lead to a German roadmap. This roadmap is to be developed under the coordination of the recently formed Committee for Astroparticle Physics in Germany. Christian Spiering (DESY) was elected chairman, becoming the successor of Johannes Blümer from KIT, Karlsruhe.

The roadmap will include the fields of dark matter, neutrino masses, neutrino astrophysics at low energies, high-energy astrophysics with the sectors cosmic-ray detectors, gamma-ray telescopes and neutrino telescopes, and finally gravitational-wave astronomy.

Two hundred astroparticle physicists from all over Germany came to DESY in Zeuthen to attend the conference. The agenda included both current research and future projects.

FLASH operation with long bunch trains

The FLASH workshop on linac operation with long bunch trains brought together experts from all over the world to evaluate the results of the 9 mA run at FLASH. Long bunches of almost 1 ms with up to 2400 bunches were accelerated at FLASH in September 2009. Such an operation mode is mandatory for the International Linear Collider (ILC) and key to the success of the European XFEL. The challenge of this operation mode lies in the proper control of the cavity power during beam loading, i.e. the low-level radio frequency (RF). Feedback and feed-forward mechanisms have been put in place to minimize beam energy spread during acceleration.

The participants in the workshop discussed methods to improve gradient control and assess RF power margins for operation under full load when planning their next test run at FLASH. Many experts from the Global Design Effort (GDE) of the ILC took part in these experiments and the workshop, recognizing that for the time being FLASH is the only operating linac capable of utilizing the superconducting technology in an ILC-like mode. It is hence an important testbed for the technology of the ILC.

March

First 7 TeV collisions at the LHC

“This is the culmination of years of work of many scientists and at the same time the start into a completely new era of particle physics,” DESY research director Joachim Mnich said. Just a few minutes before on 30 March, the LHC started its physics programme with the first 7 TeV particle collisions after years of planning and construction.

Media representatives witnessed the particle physics event of the year at many research facilities in Germany. Journalists at both DESY locations were also eagerly waiting for the first collisions in the remote control rooms of the LHC experiments. However, twice during the morning the circulating particle beams were lost in the LHC.

Shortly before noon, four proton bunches were shot into the ring. When they were travelling stably in the accelerator, they were simultaneously brought to collision at all four experiments.

At 13:02, loud applause and cheers came from the DESY CMS remote control room: a new team had just started their shift when they saw the first particle collisions in the CMS detector. At 13:06, all experiments had seen 7 TeV collisions; CMS recorded about 300 collisions per second.

“It’s a great day to be a particle physicist,” said CERN Director General Rolf Heuer at a press conference and congratulated his international team via videoconference from Japan.

Beaming particle physicists in the CMS control room: the LHC has just produced its first 7 TeV collision

April

Concentrated analysis power

The National Analysis Facility (NAF) was set up at both DESY sites in the framework of the Helmholtz Alliance “Physics at the Terascale”. It is intended to support the German physicists’ community in analysing data from ATLAS, CMS and LHCb as well as ILC and CALICE. Thanks to the economic stimulus package of the German government, additional investment funds from the City of Hamburg and a close collaboration with the University of Hamburg, the Hamburg facility was now extended by 50%.

Two IT experts install the last computer from Hamburg University for NAF.

With about half a million euro, the CMS group from the University of Hamburg made contributions to the hardware. Because they will provide the computing power of approximately 500 CPU cores to all CMS groups in Germany, they fit perfectly into the DESY analysis farm. The hard-disc space was also upgraded to 240 Terabytes, mainly for the dCache storage system which will supply data to both the Grid and NAF, thus playing a central role in the analysis. The goal of NAF is to make all data needed by the users available for analysis. This goes beyond DESY’s role as a Tier-2 centre in the global Grid, and it enhances the Grid with a more efficient analysis environment.

Precision maths in high-energy physics

At the end of April 2010, the international conference "Loops and Legs in Quantum Field Theory" took place for the tenth time, organized by the theory group in Zeuthen. Since 1992, about 80 to 100 theoretical physicists from all over the world, working in the field of precision mathematics of high-energy processes with quantum field theory methods, meet every two years to exchange the newest research results.

This year, the conference took place in the Garden Kingdom of Wörlitz belonging to the UNESCO World Heritage. More than 100 scientists from 15 countries, among them a large number of young scientists, discussed results and new methods of achieving continuing progress in the area of quantum field theory and its use for experimental measurements. Over the years, the workshop became an international institution that offers an important and regular forum between the poles of precision measurements and theoretical calculations.

Participants of this year's workshop "Loops and Legs in Quantum Field Theory" in Wörlitz

ATLAS upgrade week 2010 at DESY

From 20 to 24 April, the ATLAS upgrade meeting took place at DESY in Hamburg. The participants talked about the design, research and development for the replacement of the ATLAS inner detector, which is to be used to detect the smallest particles at the LHC in Geneva. Building a detector takes about five to ten years and since the ATLAS inner detector is to be replaced after about ten years, it is necessary to get the planning under way. This is the first time that the upgrade week took place outside CERN.

Because of the unexpected volcano activity in Iceland, travelling was difficult all over Europe and overseas. Only one third of the registered participants could make it to DESY. It was decided that the meeting would start anyway and that stranded people would join through the EVO Collaboration Network. Luckily DESY had the facilities for such a kind of meeting. Within no time, the team readjusted to the new situation and was ready to start the "DESY volcano meeting".

Participants of the ATLAS upgrade week 2010 at DESY

Röntgen Medal for Helmut Dosch

The chairman of the DESY Board of Directors, Prof. Helmut Dosch, was awarded the Röntgen Medal 2010 of the city of Remscheid. He received the medal for his ground-breaking work in the field of surface-sensitive X-ray scattering. It it thanks to his efforts in particular that X-ray scattering is also used in surface science today.

Professor Helmut Dosch

"I accept this very honourable distinction with pride," says Helmut Dosch. "Wilhelm Conrad Röntgen played a dominant role in my scientific career, and Röntgen would hopefully have been delighted by the novel X-ray sources that are currently operated at DESY."

Every year, the city of Remscheid, the birth place of Wilhelm Conrad Röntgen, awards the Röntgen Medal to persons who render outstanding services to the promotion and dissemination, in science and in practice, of Röntgen's discoveries.

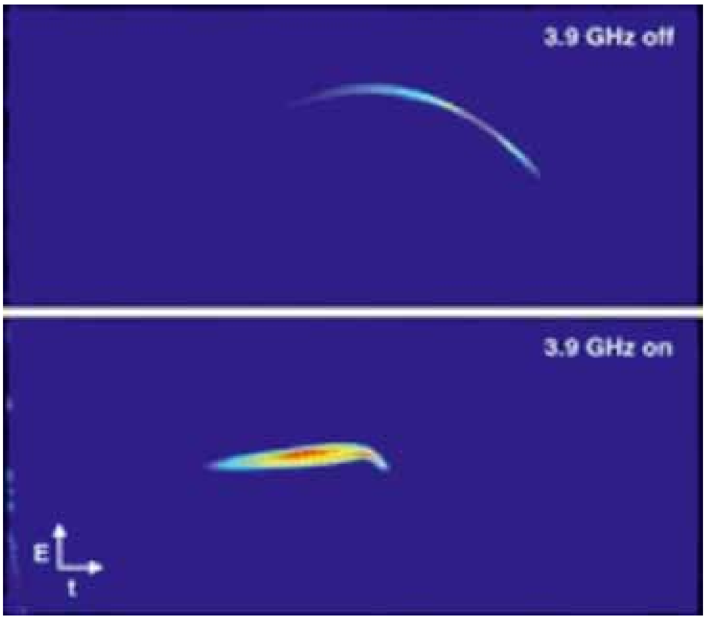
May

Flat FLASH – the 3.9 GHz system acting on beam

For the first time, one of the key components of the recent FLASH upgrade, the newly integrated 3.9 GHz RF system, demonstrated its ability to flatten the energy distribution of the electrons in a bunch – a process called phase space linearization. This will significantly improve the performance of FLASH by optimizing the creation of ultrashort bunches with high peak current and of bunches with uniform intensity and adjustable length.

The FLASH 3.9 GHz RF system is a joint international effort grouped around the two research centres DESY and Fermilab. Other US members of the TESLA Technology Collaboration like the Thomas Jefferson National Laboratory, the Argonne National Laboratory and the Cornell University contributed to the development of the 3.9 GHz module by giving advice and performing production steps. Colleagues from INFN Milano also provided technical advice. DESY contributed to the effort by providing substantial subcomponents like the RF power, RF control and other electronics, as well as by getting the RF system into operation.

The commissioning of FLASH and its new components enabled a first examination of the longitudinal phase space distribution, comparing the situation with the 3.9 GHz RF system switched on or off. This demonstration of the influence of the 3.9 GHz system on the beam is a significant milestone in the ongoing commissioning effort at FLASH.



The 3.9 GHz system acting on the FLASH beam

Towards the next 50 years!

About 2500 guests from all over the world met on 19 May in the hall of the future Accelerator Module Test Facility (AMTF) to celebrate DESY's 50th anniversary. From the “little girl DESY”, as Helmut Dosch said in his welcome address, it has been a long and successful way to this “largest test hall of its kind”, which servers as a symbol for the large-scale international future projects at DESY.

According to Bernd Reinert, Hamburg State Councillor for Science and Research, what was planned as a national particle physics centre had, in a way, “accelerated” itself to become one of the world’s leading centres of structural research. Concerning the Innovation Alliance which is to secure Hamburg’s competitiveness, he said “this won't work without DESY.”

State Secretary Georg Schütte delivers the official speech

To strengthen and maintain efficient basic research is an important task for the future, according to Georg Schütte, State Secretary at the German Federal Ministry of Education and Research (BMBF). Long-term fundamental research is the basis for groundbreaking new applications in the future. This also includes creating “freedom for clever thoughts” by removing barriers for interdisciplinary and international collaboration.

After the official ceremony, the evening programme was not so much centred on the future but firmly grounded in the enjoyment of the present. The guests were entertained with a directors' quiz show, and later on, the “Soulisten” rocked the hall until after midnight. The 50th anniversary party spectacularly demonstrated: “We are one DESY.”

June

Opera for particles: AIDA
A new project to advance research infrastructures

Out of 47 project proposals submitted to the European Commission, AIDA came second, boasting an excellent score of 14.5 out of 15. AIDA stands for Advanced European Infrastructures for Detectors at Accelerators, a project to promote detector research and development for all future particle physics projects. This includes detectors for a future linear collider, the sLHC, B-factories and neutrino experiments. The project does not only work interinstitutionally but also interdisciplinarily – this is unique.

AIDA involves more than 80 research institutes and laboratories from 23 European countries as beneficiaries or associate partners. The four-year project will receive 8 million euro from the European Commission's FP7 Research Infrastructures programme. The project will start in February 2011.

Alexander von Humboldt professorship granted for Hamburg University and DESY

The University of Hamburg and DESY won a shared Alexander von Humboldt professorship for the development of accelerators and particle physics. The renowned award goes to Prof. Brian Foster, currently head of particle physics at the University of Oxford, UK. Assuming successful conclusions to negotiations, Foster will receive up to 5 million euro over a period of five years to fund research into the development and realization of acceleration technologies for particle physics and continued analysis of data from DESY’s flagship accelerator, HERA.

Professor Brian Foster

July

Faraday Cup 2010

Kirsten Hacker (DESY) and Florian Löhl (formerly DESY, now at Cornell University) were awarded the Faraday Cup 2010 at the Beam Instrumentation Workshop BIW10.

Both laureates received the Faraday Cup Award for a newly developed diagnostic technology. The technique tested at FLASH uses short light pulses to determine the arrival time of a particle bunch in the accelerator with a precision of six femtoseconds. It also enables the determination of the beam position with an accuracy of three micrometres.

Kirsten Hacker and Florian Löhl were awarded the Faraday Cup 2010.

Hans Weise appointed leading scientist at DESY

DESY’s Administrative Council agreed in its July session to give Hans Weise the status of leading scientist in the accelerator division at DESY.

Weise will lead the work on superconducting accelerators and on the European XFEL project at DESY. He will also take over the coordination of the accelerator consortium for the European XFEL. About 12 institutes have become members of the accelerator consortium. “Among them, there are many institutes we already know well from the TESLA Technology Collaboration, but also a number of new ones,” Hans Weise said.

He will be responsible for the timely delivery and the coordination of the assembly of the individual components as well as for the corresponding tests. Starting in 2012, the cavities will be tested in DESY’s AMTF hall. Subsequently they will be transferred to Saclay for assembly into accelerator modules, which will later come back to DESY for a final test and the release for installation in the tunnel.

August

Books on the road

Two lorries, eight men, ten days and 1800 metres of books – these are the figures that describe the DESY library move. With construction work starting in its former premises, the library moved to its new location in building 1d in August. The new location offers nearly 700 new square metres of space for the library and an additional 120 square metres in the basement, tightly packed with mobile racks for the archive.

All in all, everything went fairly well, in the end it was worth the effort. Although last work is still to be done in the new rooms, the highlights are already visible: more space, warm colours and a coffee corner. There will even be a sun deck which users will be able to enjoy next spring.

Some of the library staff in their new premises

Summer students 2010

DESY´s summer student programme is the opportunity for young students to experience life and work at a large accelerator laboratory. In 2010, the eight-week programme attracted 97 students from 28 countries. The students are involved in the daily work of research groups at DESY in Hamburg and Zeuthen. Lectures in research fields such as accelerators, particle physics in experiment and theory, photon science or computing, together with visits of experimental facilities, help to prepare the physics students for their future lives as scientists.

Summer students 2010

September

EUDET lives on in AIDA

After five years of running time, a total budget of 21.5 million euro, participating institutes from Helsinki to Valencia and from Japan to Glasgow and many research infrastructures successfully in place, the EU-funded infrastructure programme for ILC detector R&D EUDET came to a close at the end of 2010. Participants met for the very last EUDET meeting at DESY in September.

But instead of final summaries, most of the talks listed future plans and milestones for the EUDET follow-up project AIDA. EUDET's goal was to create research infrastructures to facilitate detector development, like readout electronics, mechanical structures that enable the testing of different sensor technologies, Grid-ready software and a versatile beam telescope. All tasks have been successfully completed, all activities achieved their goals and milestones. The infrastructure is in place and will be used by the participating groups as well as by a wider community, including LHC-targeted projects, also in the years to come. “The EUDET community lives on in AIDA and gives it a nice starting point,” said former EUDET coordinator Joachim Mnich, now research director at DESY.

Theory Workshop

The 2010 edition of the DESY Theory Workshop was devoted to “Quantum Field Theory: Developments and Perspectives”. After more than 80 years of active development, quantum field theory (QFT) has not only been established as the basic framework for high-energy physics, it is equally fundamental for statistical physics and condensed-matter theory and has profound impact even on pure mathematics. Under the direction of Prof. H. Nicolai (AEI Golm), the organizing committee attempted to represent the many facets of this research field by carefully combining recent progress along the ‘traditional’ routes with new developments that are inspired by or consequences of string theory.

Embedded into the Theory Workshop was the 2010 Heinrich Hertz Lecture by Prof. J. Polchinski (KITP Santa Barbara). Prof. Polchinski, who was awarded the Dirac Medal in 2008 for his profound contributions to QFT and string theory, discussed the importance of thought experiments for the development of science before explaining how thought experiments carried out at the end of the last century led to a radically new holographic unification of all known interactions.

October

Hamburg's State Minister of Science and Research inaugurates extension of the DESY school lab physik.begreifen

On 13 October, Hamburg's State Minister of Science and Research Dr. Herlind Gundelach inaugurated the extension of the DESY school lab. With additional room and a broader spectrum of experiment possibilities, up to 9000 pupils per year will get the opportunity to discover the fascination of natural sciences. At the school lab, young people of all ages have the opportunity to find out more about vacuum, radioactivity and quantum physics, and to do eLab experiments. The 400 000 euro extension was funded by the economic stimulus package II of the German federal government and the City of Hamburg. The expansion with the "eLab – experiments around the electron" was supported by the Hamburg school authority.

Herlind Gundelach inaugurated the extension of the DESY school lab.

"The DESY school lab succeeds in arousing interest in the natural sciences among pupils in a wonderful way, thus making an important contribution to securing the formation of a new scientific generation in the field of natural sciences," Herling Gundelach said. "This is why the Hamburg Ministry of Science and Research readily funded the extension of the school lab."

"One of our nicest jobs is to stimulate the interest and fascination of young people in the natural sciences," said DESY research director Joachim Mnich. "We are very grateful to the German federal government and the City of Hamburg for the opportunity to expand our programme through the extension of our school lab, thus being able to reach an increased number of pupils".

The DESY school lab opened its doors in 1997 as one of the first in Germany. Up to 5000 pupils visit the school lab every year. They become researchers for one day and get in touch with the fascination of natural sciences. The main attraction at this out-of-school location is to carry out experiments under the tuition of young scientists.

Since its foundation, the DESY school lab has been continuously extended. It first offered a day with vacuum experiments. After three years, the school lab moved to its current location and included radioactivity into its programme. The Einstein Year 2005 saw the launch of the quantum laboratory, the first offer for senior pupils, which was followed by the eLab inauguration in 2010.

Max Planck back in Zeuthen

On 21 October, DESY in Zeuthen, the Bernhard Heiliger Foundation and invited guests celebrated the erection of the Max Planck monument. Bernhard Heiliger created the Max Planck monument in 1949 on behalf of the German Academy of Sciences in Berlin for the forecourt of the Humboldt University. Because of cultural-political debates, it was banished in 1950 to the guest house garden of the Academy in Zeuthen. In 1973, the former Institute for High Energy Physics – which today is DESY in Zeuthen – transferred the monument to its campus. Since 2006, the monument has been standing in its original location in the forecourt of the university.

In 2010, DESY commissioned a recast of the monument, with the authorization of the Heiliger Foundation. "Today, a decades-long Odyssey has come to a happy ending: Heiliger's Max Planck monument returns to its traditional place in Zeuthen," said the chairman of the DESY Board of Directors, Helmut Dosch, in his inaugural speech.

Helmut Dosch, Thomas Naumann and Sabine Heiliger after the unveiling of the Max Planck monument at DESY in Zeuthen

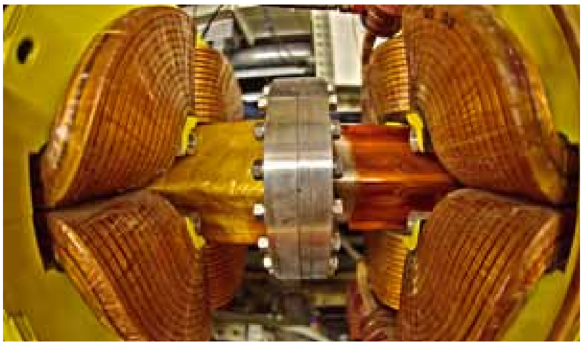
DESY triumphs in international particle physics photo competition

An international jury and a public vote confirmed it: the best particle physics photographers come from around Hamburg. The winners of the Global Particle Physics Photowalk were now announced – and four out of the six winning pictures where taken during DESY’s photowalk. The winners were determined by an international jury and a public internet vote.

The winning portrait of a wire chamber

The portrait of a wire chamber, a part of a particle detector, immediately catches the eye. Its photographer is Hans-Peter Hildebrandt from Pinneberg, normally an amateur nature photographer. “To take these technical pictures was a great challenge for me. I had visited DESY before but thanks to the photowalk I had enough time to concentrate on each subject,” said Hildebrandt. His picture had already won the local competition. It also won the public vote with a large margin and was awarded the second prize by the international jury.

A picture of two quadrupole magnets in the HERA tunnel – which the jury called the “kissing lips” – won the third prize. This picture was taken by retiree and amateur photographer Heiko Römisch. Matthias Teschkes’ picture of the HERA tunnel won the third prize in the public vote.



The “Kissing lips”

German Committee for Elementary Particle Physics (KET) defines its future strategy in particle physics

In a strategy workshop in Dortmund, the German particle physics community discussed its visions for the future of particle physics in Germany and Europe. The mandate was issued by the German Federal Ministry of Education and Research, with the aim to present the KET recommendations at next year’s “European Strategy for Particle Physics” meeting of the CERN Council. In 2012, a new strategy for Europe is to be finalized. The KET community counts more than 2000 scientists from 40 institutes, with DESY in a leading position.

The scientists met in Dortmund at the end of October as well as a the annual KET meeting in November in Bad Honnef to exchange and discuss ideas and recommendations. The result is, as a first recommendation, to operate and finalize the LHC at CERN with highest priority, including the luminosity upgrade. KET also recommends the continuation of development and planning in close international collaboration of an electron-positron linear collider like the ILC. German contributions to a Super-B factory and the promotion of neutrino physics are also on the list of recommendations.

DESY as the largest German particle physics research centre got a special mention: according to KET, DESY’s role as a national particle physics laboratory and coordination centre should be further strengthened, in particular because of its expertise in the development of accelerator and detector technologies. The recommendations were submitted to the German federal research ministry in December.

November

Helmut Dosch receives honorary doctorate from the Kurchatov Institute

The chairman of the DESY Board of Directors, Prof. Helmut Dosch, received an honorary doctorate from the Kurchatov Institute on 25 November.

In a ceremony at the Russian institute, Dosch was honoured for his outstanding contribution to the development of X-ray techniques of condensed-matter investigation including phase transitions, and for strengthening the German-Russian collaboration in the field of utilization of synchrotron radiation for a wide range of scientific problems. Dosch is the first foreigner to become a honorary doctor of the Kurchatov Institute.

PhD thesis award 2010

The PhD thesis award 2010 of the Association of the Friends and Sponsors of DESY is shared by Dr. Ulrike Frühling (DESY and University of Hamburg) for her thesis titled “Light field driven streak-camera for single-shot measurements of the temporal profile of XUV-pulses from a free-electron laser” and Dr. Christoph Weniger (DESY and University of Hamburg) for his thesis titled “From SuperWIMPs to Decaying Dark Matter: Models, Bounds and Indirect Searches”.

With its prize, the Association awarded outstanding PhD theses that were concluded in the period from 1 January 2009 to 31 March 2010. The chairman of the Association of the Friends and Sponsors of DESY, Prof. Friedrich-Wilhelm Büßer, congratulated this year’s prize winners Ulrike Frühling and Christoph Weniger at a special colloquium held on 17 November.

Ulrike Frühling (right) and Christoph Weniger (left) received the PhD award from Friedrich-Wilhelm Büßer

Stern-Gerlach Medal 2011 for Günter Wolf

Prof. Günter Wolf from DESY received the Stern-Gerlach Medal 2011 of the German Physical Society (DPG). With the highest award presented by the DPG for achievements in experimental physics, the society honours the lifework of Günter Wolf in elementary particle physics. “With his important work and discoveries, he has significantly influenced both the development of this field and the establishment of the Standard Model of elementary particles," the DPG statement reads. The medal will be presented in 2011 at the annual conference of the DPG.

Professor Günter Wolf

Günter Wolf (72) has been a scientist at DESY since the beginning of the research centre, and he had a strong influence on its scientific programme. His greatest research success is closely connected to the accelerator centre: in 1979, the TASSO collaboration was able to announce the discovery of the gluon. Prior to this discovery, Günter Wolf already worked at the first accelerator in Hamburg, the DESY synchrotron. After a stay at SLAC in California (USA), he became a senior scientist at DESY in 1971 and participated in the construction and the experimental programme of large particle detectors at the storage rings DORIS, PETRA and HERA. In 1985, he was elected spokesman of the ZEUS collaboration. Moreover, as a member of numerous scientific advisory boards, Günter Wolf has influenced the fate of particle physics worldwide.

December

World's largest neutrino telescope completed

As the culmination of a decade of planning and six years of construction, the neutrino telescope IceCube was completed on 18 December 2010. The world's largest particle detector fills a cubic kilometre of deep Antarctic ice with ultrasensitive light sensors. They record the tracks from neutrinos coming from outer space – astronomical messengers that could provide information about distant galaxies. Neutrinos are often called "ghost particles" because they pass undetected through most of matter. Thus, enormous detectors are needed to detect them.

IceCube is embedded in the deep ice below the United States' Amundsen Scott station at the geographic South Pole. IceCube consists of 86 strings, each carrying 60 glass speres, deployed in depths between 1.45 and 2.45 kilometres. The spheres protect ultrasensitive light sensors that record the tiny flashes of blue light emerging from neutrino reactions. A quarter of the required 5000 optical sensors were provided by German research groups, and previously assembled and tested at DESY in Zeuthen.

The IceCube team consists of 260 scientists from 36 research institutions in 8 countries. German institutions are: DESY, the universities RWTH Aachen, Humboldt-Universität zu Berlin, Bochum, Bonn, TU Dortmund, Mainz and Wuppertal, and the Max Planck Institute for Nuclear Physics in Heidelberg.

The last digital optical module (DOM) is being deployed in the IceCube detector.

A winter highlight

The annual general workshop of the Helmholtz Alliance "Physics at the Terascale" took place in Dresden on 1 to 3 December. This year, the winter took an early start with mountains of snow and air temperatures below minus 10°C. Many participants had very special travel experiences on their way to Dresden. By Thursday, most of the 273 registered participants had arrived and participated in the extremely well attended sessions of the workshop in the Dresden conference centre, which is located directly on the bank of the river Elbe close to the city centre.

The workshop was the first in which real data from the LHC experiments were available. Therefore the plenary and parallel sessions concentrated on the results and prospects of the LHC data analysis. The outlook on what could be expected in the coming years as well as the theoretical prospects in view of the expected measurements – and hopefully also discoveries – were the focus of the discussions. In addition, status reports were given in the parallel sessions on the Alliance projects on detectors, computing and accelerators. An outlook on future R&D activities on detector developments or novel particle accelerator within the Alliance completed the scientific programme.

Annual general workshop of the Alliance in Dresden

The vibrant activities reported at the workshop showed that the Alliance is a big success and that its structures – the common infrastructures, the backbone activities, the fellowship programme, and the Helmholtz Young Investigators Groups – stimulate the cooperation in particle physics in Germany beyond expectation. As 2012 is not far away anymore, this is the time to discuss how an extension of the Alliance's structures and programmes could be organized in view of the time when the expected harvest of the LHC experiments comes in and when key decisions on future projects need to be prepared.

Research Topics.

A very special view of the proton.

F_L or how does the proton look like in longitudinally polarized light?

Before HERA finally shut down in 2007, the last few months of operation were devoted to data taking at reduced proton energies E_p of 575 and 460 GeV. In combination with other high-precision inclusive neutral-current electron/positron-proton scattering data that were collected at higher proton energies during the years 2003 to 2007, the longitudinal structure function of the proton F_L has been directly measured by the H1 collaboration. This quantity is of great relevance since it is directly related to the gluon content in the proton. The accuracy of the H1 cross section measurements, which are performed at Q^2 values ranging from 1.5 GeV^2 to 120 GeV^2 and at small values of the Bjorken scaling variable x ($2.9 \cdot 10^{-5} < x < 0.01$), reaches 1%. It is used to perform very sensitive tests of various phenomenological and quantum chromodynamics (QCD) models that are applicable in this kinematic domain.

Deep-inelastic lepton-nucleon scattering (DIS) plays a pivotal role in determining the structure of the proton. The DIS kinematics can be described by the resolution parameter Q^2, which is the square of the four-momentum transfer between the electron and the proton, and the Bjorken scaling variable x that corresponds to the momentum fraction of the probed quark inside the proton. At low Q^2, the scattering cross section is determined by the two structure functions, F_2 and F_L, which are closely related to the cross sections for the scattering of transversely and longitudinally polarized photons off protons. In the naive quark-parton model, F_2 is given by the charge squared weighted sum of the quark densities, while F_L is zero because of helicity conservation. In quantum chromodynamics (QCD) however, gluon emissions give rise to a non-vanishing F_L. Measuring the structure function F_L therefore provides a unique way of studying the gluon density in the proton, and enables a fundamental test of perturbative QCD.

The measurement of F_L requires several sets of DIS cross sections at fixed x and Q^2 but at different inelasticity y. This was achieved by taking data at different proton beam energies whilst keeping the lepton beam energy fixed. The sensitivity to F_L is largest at high y as its contribution to the cross section is proportional to y^2. At low Q^2, high y values correspond to low values of the scattered electron energy. However, small energy depositions can also be caused by hadronic final state particles leading to fake electron signals. These are predominantly due to photoproduction processes at $Q^2 \simeq 0$. The large amount of this background makes the measurement of F_L very demanding. Experimentally the accurate determination of the charge of the electron candidate and of the reconstruction efficiency are particularly challenging.

Previously published values of F_2 at low x at HERA were based on assumptions about the size of F_L or were restricted to the kinematic region where the contribution from F_L was sufficiently suppressed. Measurements of the reduced cross section at fixed x and Q^2 but different y allow F_2 and F_L to be extracted simultaneously, thereby eliminating the assumptions about F_L when extracting F_2. The results of this combined determination are shown in Fig. 1.

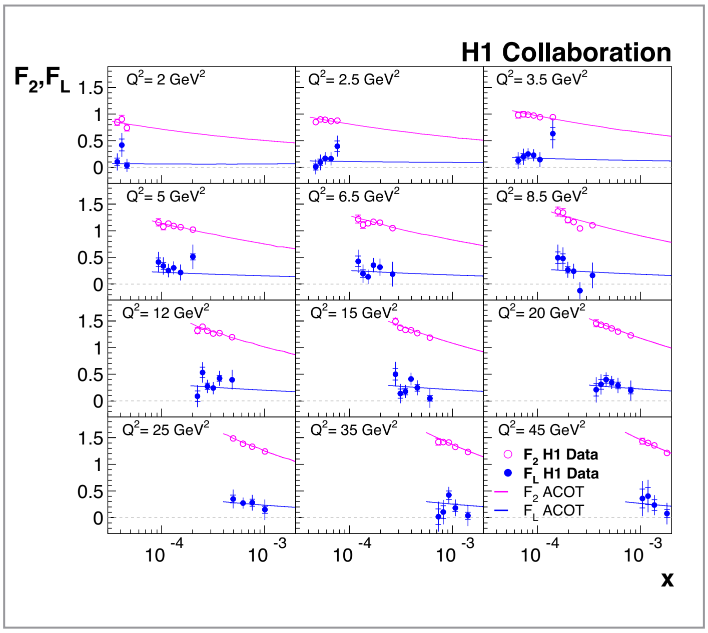


Figure 1

The proton structure functions F_2 and F_L. The curves represent predictions of the DGLAP fit in the ACOT scheme.

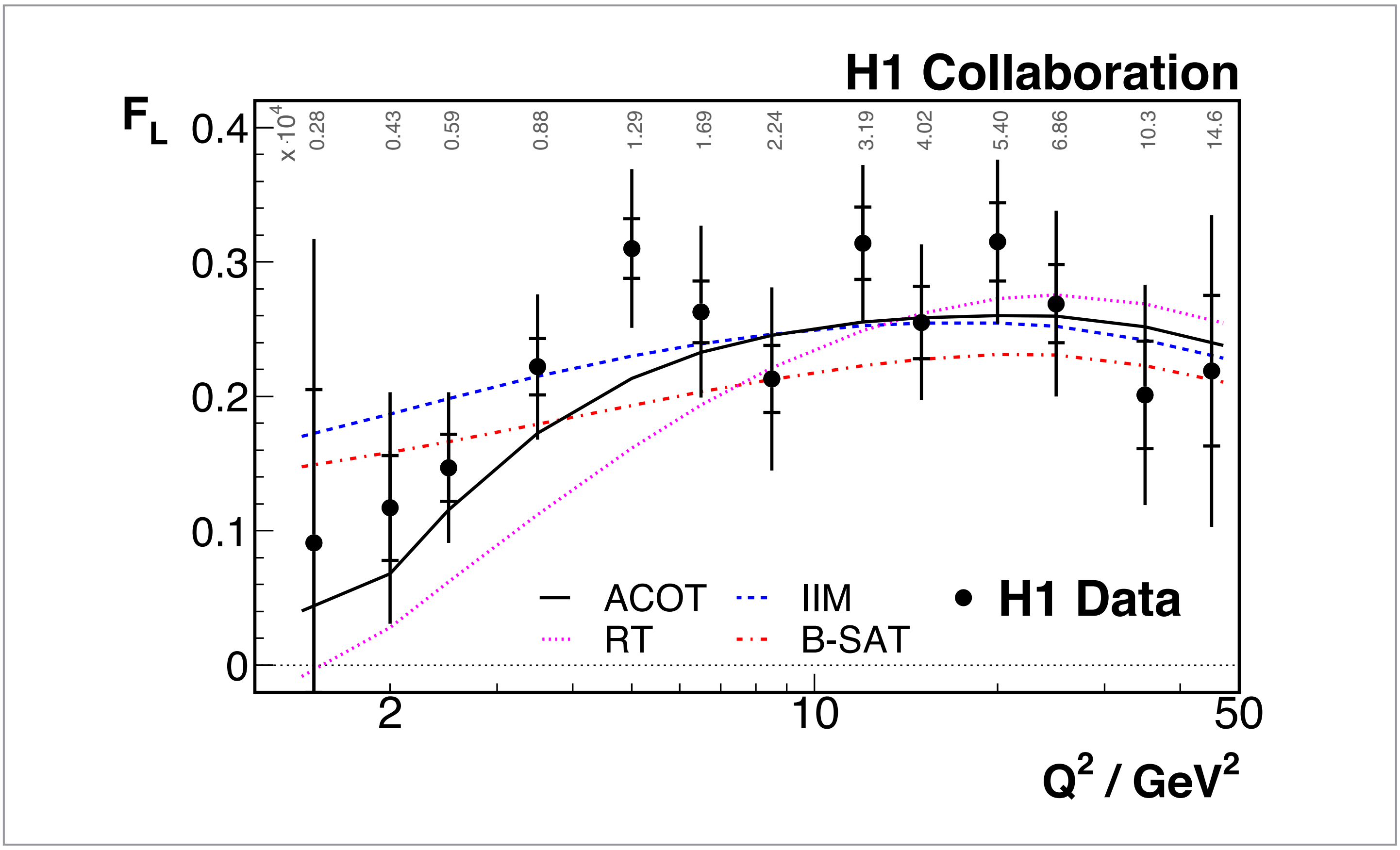


Figure 2

The proton structure function F_L shown as a function of Q^2. The average x values for each Q^2 bin are indicated. The lines represent fit results of various models.

The combined cross section data for E_p = 460, 575 and E_p = 820, 920 GeV are also used for a number of phenomenological analyses. The rise of the structure function F_2 towards low x is examined using power law fits. As in previous H1 analyses, the power law exponent λ is found to be approximately constant for $Q^2 \leq 2$ GeV^2 but increases linearly with ln Q^2 for higher Q^2 values. Closer inspection of the fits reveals, however, a deterioration of the fit quality for the region $1 \leq Q^2 \leq 10$ GeV^2. A parameterization allowing for a Q^2 dependent ln x correction to a fixed power law, for λ = 0.25, provides an improved description of the data with the same number of parameters. This observation suggests that the x dependence of the structure function F_2 may deviate from a simple power law at small x and small Q^2, exhibiting a softer rise. This confirms a long-standing QCD prediction according to which the rise of F_2 should be slower than any power of 1/x but faster than any power of ln 1/x.

The data are found to be well described by a NLO DGLAP QCD analysis. The ACOT and the RT schemes are used, which differ in the treatment of the heavy-flavour and higher-order F_L contributions to the cross section. A comparison of ACOT- and RT-based fits to the data reveals a significant preference for the ACOT treatment.

The colour dipole approach provides an attractive description of high-energy interactions since it yields a very simple and intuitive physical interpretation of the physics at small values of x. For the first time, dipole model analyses are extended to account for the non-negligible valence quark contributions at small values x < 0.01. The models considered in the analysis are the original model version (GBW), a model based on the colour glass condensate approach to the high parton density regime (IIM), and a model with the generalized impact parameter dipole saturation (B-SAT). The GBW model is unable to describe the data at larger Q^2, while the IIM and B-SAT models agree with the data generally well. The influence of the valence quarks at low x is investigated by adding their contribution as estimated from the ACOT fit. These models together with the two DGLAP fits are compared to each other by fitting the data in a common kinematic range. The DGLAP ACOT fit provides the best description of the data, followed closely by the dipole IIM and B-SAT models (see Fig. 2). All models agree well with the F_L measurement at $Q^2 > 10$ GeV^2. For lower Q^2, however, the RT fit falls significantly below the data while the other models describe the measured F_L well.

Contact:
Cristinel Diaconu, diaconu@cppm.in2p3.fr

Authors:
H1 Collaboration

Heavy flavours.

The beauty and charm of HERA data

Quarks, the constituents of nuclear matter, carry so-called flavour quantum numbers. Normal matter is mainly made of up and down-flavoured quarks, with some admixture of virtual strange quarks. These are collectively called light flavours. In high-energy interactions, such as those that occur in electron-proton collisions at the HERA collider, the production of heavy flavours, i.e. flavours with associated quark masses larger than the proton mass, starts to play an important role. At HERA energies, these flavours include in particular the charm quarks and the even heavier beauty quarks. The properties of events containing these quarks and the effect of their masses in the context of quantum chromodynamics (QCD) are studied. This contributes to testing and improving the treatment of heavy quark masses within QCD.

Deep-inelastic scattering of electrons off protons at the HERA collider is well suited to study the properties of the theory of QCD. At energy scales significantly larger than the proton mass, processes with quarks carrying heavy flavour quantum numbers such as charm (m_c ~ 1.5 GeV) and beauty (m_b ~ 5 GeV) contribute significantly to inclusive quantities like the proton structure function F_2. In the case of charm, this contribution can reach up to 36 % in reactions with the highest energy transfer. A good understanding of the influence of the heavy quark masses on the experimental and theoretical treatment of such quantities is thus of great importance.

In order to study the heavy flavour contributions, events containing such heavy quarks in the final state need to be tagged and separated from other processes. This can be achieved in essentially three ways. A charmed hadron (a final state particle containing a charm quark) is reconstructed by explicitly identifying and combining all its decay products. The long(er) lifetime of such heavy flavour hadrons (charm or beauty) with respect to other particles is used to detect secondary vertices, i.e. crossing points of the decay particles which are not consistent with originating directly from the primary interaction. Or the large mass of the parent particles (in particular for beauty) is used by detecting particles which emerge at large transverse momenta with respect to other particles in a particle jet. The three methods can also be combined.

One of the difficulties of these detection methods is that they have a very large background for heavy flavour final states in which the quark transverse momenta with respect to the beam direction are of the order of or less than the heavy quark mass,

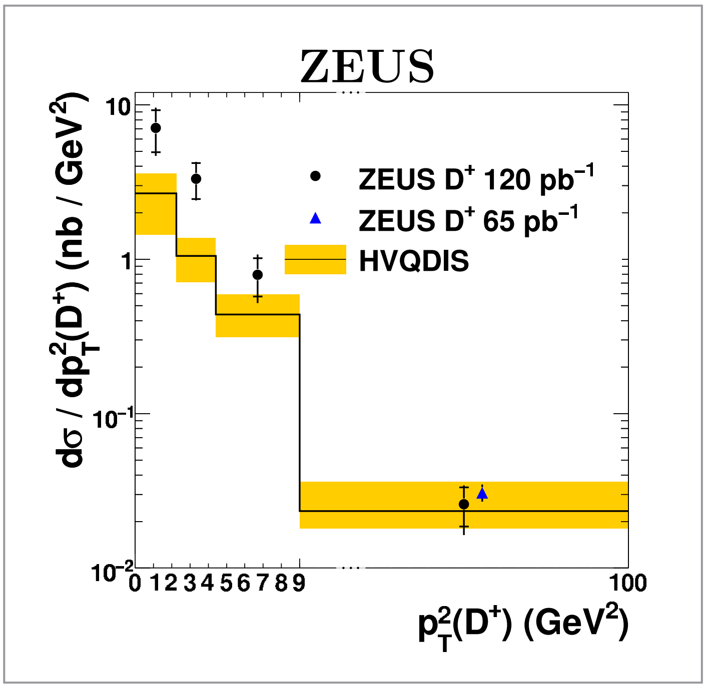


Figure 1

Cross section for the production of the charmed hadron D^+ as a function of transverse momentum with respect to the beam axis (points with error bars), compared to next-to-leading order QCD predictions from HVQDIS (shaded band).

while such final states yield a large contribution to inclusive quantities. Most analyses need to apply a lower cut on transverse momentum in order to achieve a clean measurement. Figure 1 shows a result in which, for the first time at HERA, a specific charmed hadron was measured down to the production threshold in transverse momentum, i.e. without such a transverse momentum cut-off. Reasonable agreement with QCD predictions is observed. The fact that the measurements are partially above the theoretical predictions could indicate that threshold resummation corrections, not yet included in the predictions shown, might play a significant role.

In contrast to the abundant charm final states, beauty quarks appear only in a small fraction of inclusive final states at HERA, of the order of 1 %. On the other hand, the large mass and longer lifetime of the beauty hadrons makes their inclusive detection somewhat easier. The beauty measurements typically have large statistical uncertainties, but the large beauty mass makes these measurements particularly sensitive to mass effects.

Fig. 2 shows a summary of measurements of the beauty contribution to the proton structure function F_2, compared to several theoretical QCD predictions, which differ mainly in the way they treat the heavy quark mass terms in the perturbative expansion. In particular, at low values of the virtuality of the exchanged photon, $Q^2 < m_b^2$, the data start to be sensitive to the differences between these predictions. Similar measurements of the charm contribution to F_2, combining the results of the H1 and ZEUS experiments, have already yielded significant insights into the details of the heavy flavour treatment, both for measurements at HERA and for measurements at the proton-proton collider LHC. The extension of these efforts to include the beauty data have the potential to yield complementary insights, in particular concerning the heavy flavour mass threshold treatment.

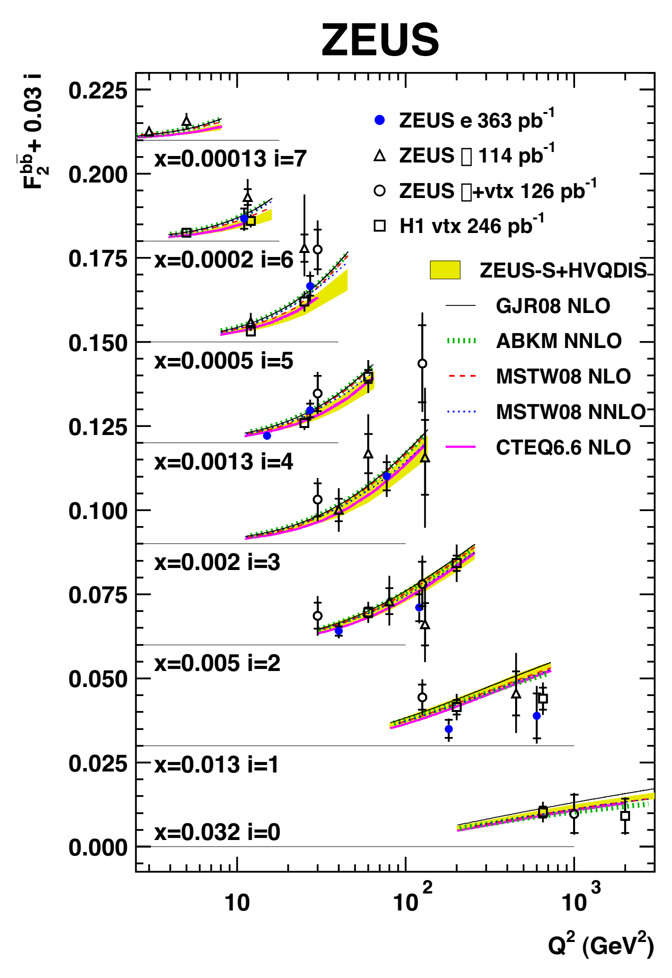


Figure 2

Beauty contribution to the proton structure function F_2 from different data sets (points with error bars), compared to different QCD predictions at next-to-leading order (NLO) or partial next-to-next-to-leading order (NNLO) (lines and band). The measurements are shown as a function of the photon virtuality, Q^2, for different values of the Bjorken scaling variable x. A vertical offset is applied for each x value.

Contact:

Achim Geiser, achim.geiser@desy.de
Aharon Levy, aharon.levy@desy.de

Authors and references:

ZEUS Collaboration
DESY-09-056, Eur. Phys. J. C65 (2010) 65
DESY-10-047, Eur. Phys. J. C69 (2010) 347
DESY-10-064, JHEP 1011:009 (2010)
DESY-11-005, to be published in Eur. Phys. J. C

Proton structure.

Combined HERA data illuminate new territory

The proton structure measurements at HERA are unique and benefit from the combination of data sets collected by the H1 and ZEUS experiments. A new step in precision was achieved in 2010 based on the data collected during the second phase of HERA, improving the constraints on the proton structure in a region of large momentum transfers which is relevant for the highest-energy proton-proton collisions at the LHC. In this region, the electron- or positron-proton interactions at HERA reveal the effects of the weak force.

The collisions of electrons or positrons with protons at HERA allow the measurement of the proton content (quark and gluons) with unprecedented precision. Most of the electron-proton interactions are taking place at a low momentum transfer Q^2 and are mediated by a virtual photon. A small but significant part of the collisions correspond to the very high momentum transfers, from a thousand up to a few tens of thousands of GeV^2. In this domain, which was reached in deep-inelastic scattering (DIS) for the first time at HERA, the collisions are also mediated by weak bosons, leading to events with spectacular signatures.

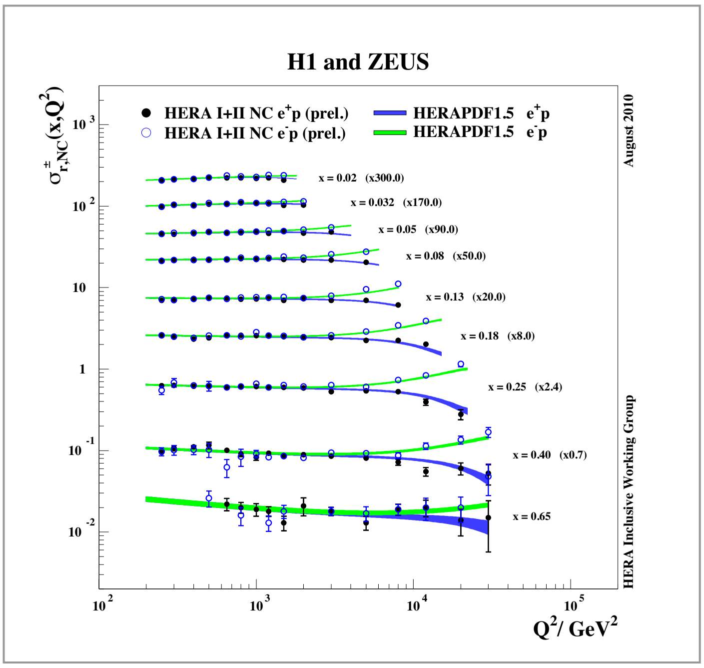


Figure 1

Neutral current DIS cross sections measured using HERA I+II data for electron-proton (e^-p) and positron-proton (e^+p) collisions as a function of Q^2 for various x values. The significant differences observed at high Q^2 are a manifestation of the weak force.

In the case of neutral-current (NC) interactions at high Q^2, the incoming electron is scattered at wide angles, similar to the classical Rutherford experiment, thereby probing the pointlike nature of the struck quarks with resolutions down to 10^{-18} m. For this type of interactions, contributions from the neutral weak boson Z are expected. The interactions at high Q^2 can also be mediated by charged weak bosons $W^{\pm}$, leading to final states with significant imbalance in the detected transverse momentum, due to the elusive neutrino produced as a result of the electron conversion. These charged-current (CC) interactions can be measured at HERA due to the hermetic construction of the two collider detectors H1 and ZEUS.

The DIS processes at large momentum transfer offer new possibilities to pin down the proton structure functions, since the interactions involve quarks that carry a large fraction x of the proton momentum. Previous results for this region where obtained using fixed nuclear targets, in a regime where the momentum transfer barely reached a few tens of GeV^2. At HERA, the absence of nuclear media around the proton allows a clean determination of the parton distribution functions (PDFs) from the measured structure functions. The PDFs are defined as the probability densities of given partons (quarks of different flavours and gluons) to carry a fraction x of the proton momentum.

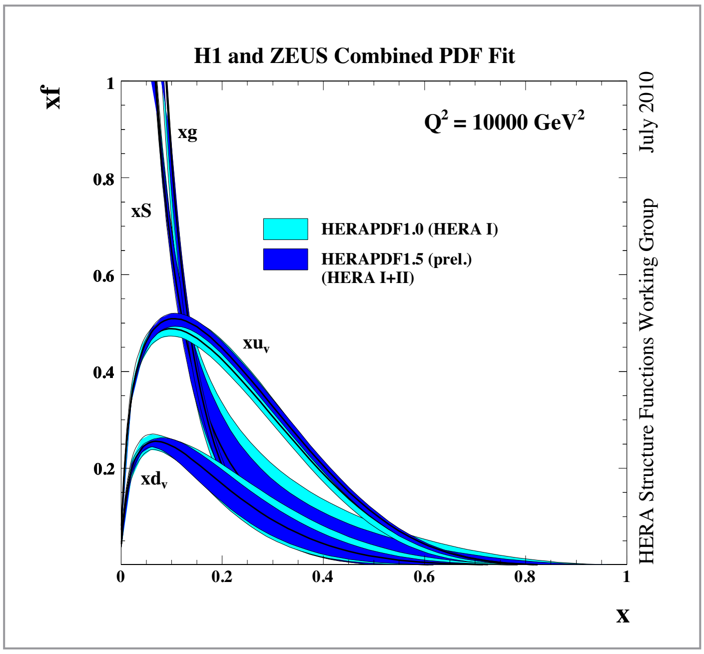


Figure 2

The improved precision of the parton distribution functions obtained by using combined HERA II data shown at a scale Q^2=10 000 GeV^2, typical for the expected interactions at the LHC.

The measurements based on the data collected by H1 and ZEUS during the first phase from 1994 to 2000 (HERA I run) were used to accurately determine the proton structure. An unprecedented precision of about 1-2 % was obtained at low Q^2, while the accuracy of the high Q^2 measurements were still dominated by statistical precision. The HERA II data sets were recorded after a luminosity upgrade and various detector improvements by H1 and ZEUS in the period from 2003 and 2007. They were analysed by both collaborations and combined during the year 2010. Finally they were also combined with the HERA I data. The gain in statistics is supplemented by an appropriate treatment of the systematic uncertainties, leading to a significant improvement in precision.

The measurements can be used to display the role of the weak force in DIS at high Q^2. For instance, in NC interactions the partons from the proton interact differently with the electron or the positron due to the nature of the Z boson couplings to fermions (electrons or positrons on one side and the various quarks of the proton on the other side). This leads to a difference in e^+p and e^-p cross sections at high Q^2, as can be seen in Fig. 1. The difference is in fact proportional to a well-defined invariant structure function xF_3 and corresponds to a specific combination of PDFs.

Since the cross sections depend on the parton content of the proton, modulated by the specific charges (couplings) corresponding to each process, the measurement of both CC and NC interactions gives access to various PDF combinations. The precise measurements at low Q^2 performed previously using HERA I data allow to constrain the PDFs at rather low x, while the measurements in the high Q^2 domain from HERA II lead to constraints of the high x region.

The combined cross section measurements from HERA I and HERA II are used to obtain the parton distribution function set called HERAPDF 1.5. The PDFs and their uncertainties obtained are shown in Fig. 2, compared to HERAPDF 1.0 obtained from the HERA I data only. As was the case for the previous fits based on HERA data only, the HERAPDF 1.5 set has the advantage to be based on a coherent data set from one collider only, composed from precise and mutually consistent samples produced by two independent experiments. The universality of the PDFs assumes that other processes and collision configurations involving protons can be calculated using the PDFs extracted from precision measurements. In particular, HERAPDF 1.5 sets can be used to predict cross sections for phenomena occurring in proton-proton collisions at the LHC.

Examples are the production of high-mass resonances or processes where the final state is detected close to the beam pipes.

The HERA inclusive data analysis is now close to its ultimate precision. Only the combination of the inclusive data with further semi-inclusive measurements (charm or jets) may allow a further increase in precision in various regions of the phase space and provide a precise test of the theory of strong interactions in DIS.

Contact:

Olaf Behnke, olaf.behnke@desy.de
Cristinel Diaconu, diaconu@cppm.in2p3.fr

Authors and reference:

H1 and ZEUS Collaboration
https://www.desy.de/h1zeus/combined_reults/index.php

Strong interactions.

From the HERAscale to the Terascale

Strong interactions result from the exchange of messenger particles, called gluons, between the matter constituents of nucleons and nuclei, the quarks, "glueing" them together. The data from the electron-proton collider HERA are very well suited to study the properties of the underlying theory, quantum chromodynamics (QCD). The high-energy processes studied are partially similar to those occurring at proton-proton colliders like the Large Hadron Collider (LHC), yet still simple enough to extract precision measurements. Measurements from the two experiments H1 and ZEUS can be merged to obtain improved precision. Insights obtained at the "HERAscale" of about 10-100 GeV can be successfully applied to the "Terascale" (TeV scale) probed by the LHC.

In the previous article it has been discussed how electrons can be used to probe the internal structure of the proton. Using the knowledge of this internal structure, based to a large extent on measurements at HERA, one can go a step further and measure effects which are solely due to QCD. One such effect is the probability of a quark to absorb or radiate a gluon, the messenger particle of strong interactions. This probability is parametrized in terms of the strong coupling constant, α_s. It has been well known since decades that this "constant" is not constant at all, but that its value rather depends on the energy scale of the interaction and decreases with increasing energy or decreasing distance scale (asymptotic freedom). On the other hand, the coupling increases with increasing distance scale, such that at some point the probability for further interactions reaches the order of unity. Thus a quark or gluon resulting from a high-energy process will always "fragment" into a whole bundle of secondary particles, called a jet, when it moves away from the interaction. The secondary particles can then be measured in a detector.

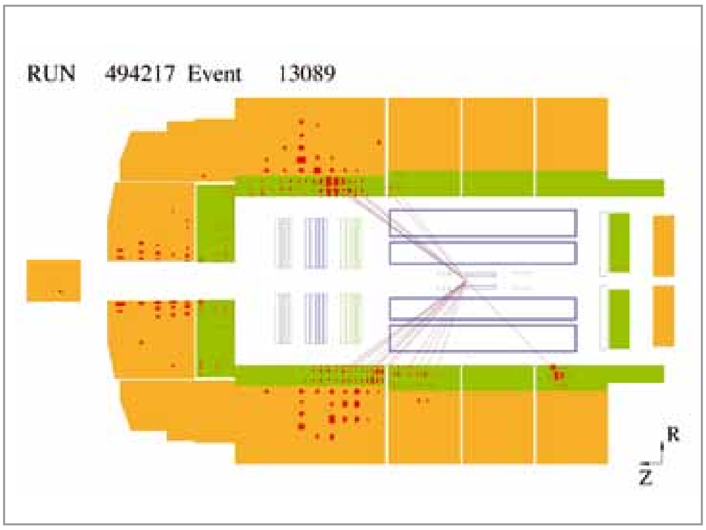


Figure 1

H1 event display with electron and 2 jets

Fig. 1 shows an event in which two such jets emerge from an electron-proton interaction, accompanied by the scattered electron. The detection of the scattered electron allows a particularly clean constraint on the initial state of the interaction. Counting the inclusive rate of jets and integrating over the remaining parts of the final state (e.g. the other jet in this example) allows an extraction of the corresponding cross section and a comparison with QCD expectations at next-to-leading order (NLO) in perturbation theory.

In particular, the probability to radiate e.g. one or two extra "hard" gluons in the final state is theoretically calculable. Such gluons will influence the shape of the energy flow in the final state, and therefore the details of how jets are reconstructed from this energy flow. Different jet algorithms exist which are sensitive to these details in different ways.

Of particular interest are algorithms which have a well-defined and unique behaviour with respect to the radiation of collinear or soft gluons. Traditionally, the so-called k_T algorithm has been used at HERA, which starts by combining the highest nearby (transverse) energy objects and ends with the association of lower-energy objects or objects at larger angles. This leads to an area of the particles associated to the jet which, despite being defined uniquely in each event, can differ a lot from one event to another. At HERA this is not a problem, since the events are very clean, but for the more complicated hadronic

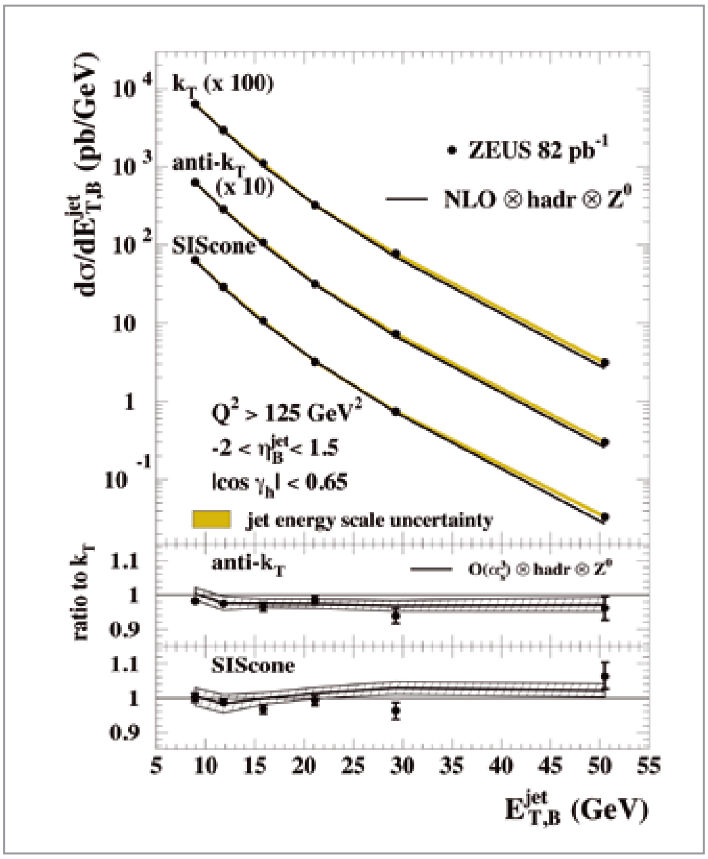


Figure 2

The measured differential cross section (points) as a function of jet transverse energy in the Breit frame, $E_{T,B}^{jet}$, for inclusive jet production using different jet algorithms. NLO QCD predictions are also shown (lines). The cross sections for the k_T and anti-k_T algorithms were multiplied by the scale factors indicated to aid visibility. The ratio of anti-k_T and SIScone to k_T is shown in the lower part (points), overlaid with the corresponding NLO QCD predictions (bands).

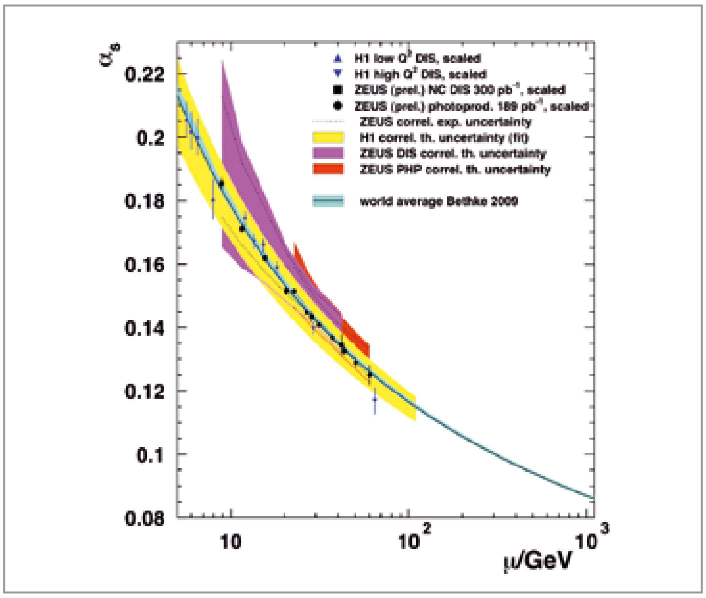


Figure 3

The running coupling constant α_s as a function of the energy scale μ. The measurements from H1 and ZEUS (symbols) have been rescaled within their respective correlated uncertainties (coloured areas) to the word average value, in order to better illustrate the running. Only the mostly (H1) or fully (ZEUS) uncorrelated experimental uncertainties are included in the error bars. The extrapolation of the world average to TeV energies (blue band) is also shown.

final states at a hadron collider like the LHC, jet algorithms leading to a more circular jet area are preferred. In the past these were often theoretically less well defined. Recently, newer algorithms were developed which combine the advantages of both classes of algorithms, including the so-called anti-k_T and SIScone algorithms.

The anti-k_T algorithm is particularly suited for the analysis of the LHC data. However, already before the first LHC data were taken and analysed, the two new algorithms were tested successfully with HERA data. Figure 2 shows the comparison of the three algorithms mentioned above applied to obtain inclusive jet cross sections, and their ratios. In all cases the measured differences and similarities are well reproduced by the theoretical calculations. Also, the values of the strong coupling constant derived from these measurements are in very good agreement with each other. This demonstrates that these algorithms can also be used at the LHC with theoretically reliable performance.

Alternatively, both jets in events like the one in Fig. 1 can be considered separately (dijets), and the properties of the dijet system can be measured. This offers additional insights into the validity of QCD to calculate jet-jet correlations. Again, good agreement with QCD predictions is observed with small uncertainties, enhancing confidence into using such predictions for the LHC. This could be important for the interpretation of any potential deviations from expectations in terms of new physics at the LHC, since the HERA data, taken at lower energies, are presumably unaffected by such new physics.

This also provides additional precision information for the determination of the strong coupling constant and the measurement of the proton structure.

Fig. 3 shows the dependence of α_s on the energy scale, as extracted from several HERA data sets of this kind. The decrease towards higher energy scales is clearly visible, and again well described by QCD calculations. The expected continuation of this dependence into the Terascale regime can be very reliably predicted. The ongoing combination of the results from H1 and ZEUS will further reduce the uncertainty of such measurements and the resulting predictions.

Contact:

Achim Geiser, achim.geiser@desy.de
Cristinel Diaconu, cristinel.diaconu@desy.de

References:

H1 Collaboration
DESY-09-032, Eur. Phys. J. C65 (2010) 363
DESY-09-162, Eur. Phys. J. C67 (2010) 1
ZEUS Collaboration
DESY-10-034, Phys. Lett. B 691 (2010) 347
DESY-10-170, Eur. Phys. J. C70 (2010) 965

From HERA to the LHC.

Physics of gluons and heavy quarks

The goal of this project is the precision measurement of the gluon density using HERA data and its application for cross section measurements at the LHC. The group consists of five postdocs and one PhD student and plays a major role in the H1 and ZEUS combination activities, in particular in the investigation of the proton structure, physics of jet and heavy flavour production. The group is also involved in the measurement of top quark pair production using CMS data and contributes to the DESY activities for the phase I upgrade of the CMS pixel detector. The group activity is a joint project of DESY and the universities of Hamburg, Mainz and Wuppertal.

H1 and ZEUS combined: HERA charm data help LHC

Precise knowledge of the proton structure is of utmost importance for the interpretation of LHC data. The proton parton density functions (PDFs) are determined at HERA with high accuracy using the method of deep-inelastic scattering (DIS). Charm quarks contribute up to 30% to the total DIS cross section through their production in the boson-gluon fusion process, in which gluons from the proton are directly involved. Therefore charm quark physics is very important for the QCD analysis of the proton structure, which is intricate due to theoretical ambiguities in the treatment of heavy quarks.

Various methods are used at HERA to identify events in which charm quarks are produced. The data of the H1 and ZEUS experiments obtained using different charm tagging techniques have been combined. As a result, the most precise charm contribution to the proton structure function is determined. For the first time, HERA combined charm data are included in the PDF fits, which enables a simultaneous determination of the charm quark mass. The results are used to calculate the $W^\pm$ and Z boson production cross sections at the LHC. The PDF uncertainty on these predictions due to the heavy quark treatment in PDFs is reduced from 7% to below 1%.

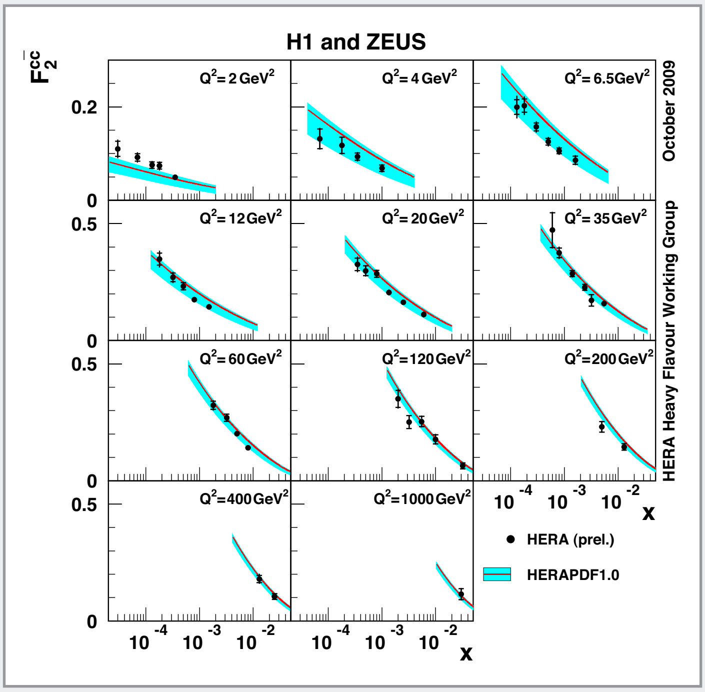


Figure 1

Charm contribution F^c_2 to the proton structure function F_2 as a function of the Bjorken scaling variable x at different values of photon virtuality Q^2, compared to the QCD prediction using parton distribution functions HERAPDF1.0.

CMS pixel upgrade: better tracking with increased redundancy

In the phase I upgrade of the CMS detector, the silicon pixel detector will gain an additional pixel layer in the barrel and one in each of the end-caps with reduced material budget. Members of the group performed simulation studies of top quark pair production to study the advantages of the new setup. To fully exploit the potential of the new geometry, an improved tracking algorithm is developed and included in the CMS software. Significant improvement in tracking performance and b-tagging efficiency of pixel stand-alone tracks for the use in the high-level trigger is shown.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_401

HELMHOLTZ
I ASSOCIATION

Helmholtz Young Investigators Group
"Physics of gluons and heavy quarks from HERA to the LHC" (VH-NG-401)

Contact:
Katerina Lipka, katerina.lipka@desy.de

Data preservation at DESY.

Safeguarding the heritage of the HERA data

An international study group was formed at the end of 2008 to address the issue of data preservation in high-energy physics (DPHEP). As the group heads towards the publication of its recommendations to the high-energy physics community, joint initiatives at DESY begin to gather pace. This article describes these common projects and the future working directions of the DESY data preservation group.

Over the last two years, a series of workshops were held by the ICFA DPHEP study group to evaluate the global picture of data preservation in high-energy physics (HEP). The first conclusions and recommendations of the group were presented in an interim publication in 2009. A full review of data preservation in HEP is to follow, with more detailed physics cases for preservation, analysis of preservation options, details of transverse global projects and strategies already in place, as well as the plans for the international coordination of data preservation in HEP.

Since the formation of the DPHEP group, the activities and models of the experiments have aligned to a certain degree and joint initiatives have been launched. At DESY, where the participation in the DPHEP group has been strong since its formation, three areas have been identified where common data preservation projects will be realized: data validation and archiving, HEP data for outreach and future electronic documentation.

The HERA data are a unique data set, unlikely to be superseded in the near future. To ensure the long-term availability of the data, the software and environment employed to access and analyse the data must also be preserved. A validation scheme will be installed at DESY-IT in close cooperation with the HERA experiments. The scheme, which is realized using a virtual environment capable of hosting an arbitrary number of virtual-machine images, is illustrated in Fig. 1. A successful test version with input from the H1 and ZEUS experiments will now be followed by the full implementation, which is by design expandable to multiple experiments, in order to safeguard the HERA data for the long term.

Figure 1

A sketch of the proposed experimental software validation scheme to be hosted by DESY-IT (Original: Y. Kemp)

The development of a HEP data format for outreach and education is an attractive proposition. In recent years there has been a notably increased global effort to improve the overall level of education in particle physics and to provide access to HEP to more people than ever before. Tutorials using a simplified format of real HEP data would be the next logical step, presented as HEP data with associated pedagogical exercises. Such schemes exist to some degree within the BaBar and Belle collaborations, and following recent discussions within DPHEP, the HERA experiments are contributing to the idea of a true, global HEP data portal for outreach.

In addition to the data and software issues, the presence of documentation and meta data is also a crucial component of a successful preservation project. Global information infrastructures, such as INSPIRE, the recognized third-party information system for HEP, are ideally situated to provide external management of such materials. The DESY Library contributes to the strategic planning, assessment of enrichment and administration of harvesting of the bibliographic data into the INSPIRE system, as well as providing a global mirror. Several joint projects are under way between the DESY Library and the HERA experiments to host additional experimental information in the SPIRES system.

Contact:

David South, david.south@desy.de

Transverse-spin effects.

Hadronization of transversely polarized quarks

Scattering the 27.6 GeV leptons of HERA of a nuclear-polarized proton target provides insights in the spin structure of the proton. From 2002 to 2005 HERMES injected transversely polarized protons into the internal HERA lepton ring target cell. The azimuthal distribution of final-state pions and charged kaons about the direction of the exchanged virtual photon was analysed to isolate the Collins effect, an asymmetry in the momentum direction of hadrons produced in the hadronization of transversely polarized quarks. This can be used to study transversity, the distribution of transversely polarized quarks inside a transversely polarized proton.

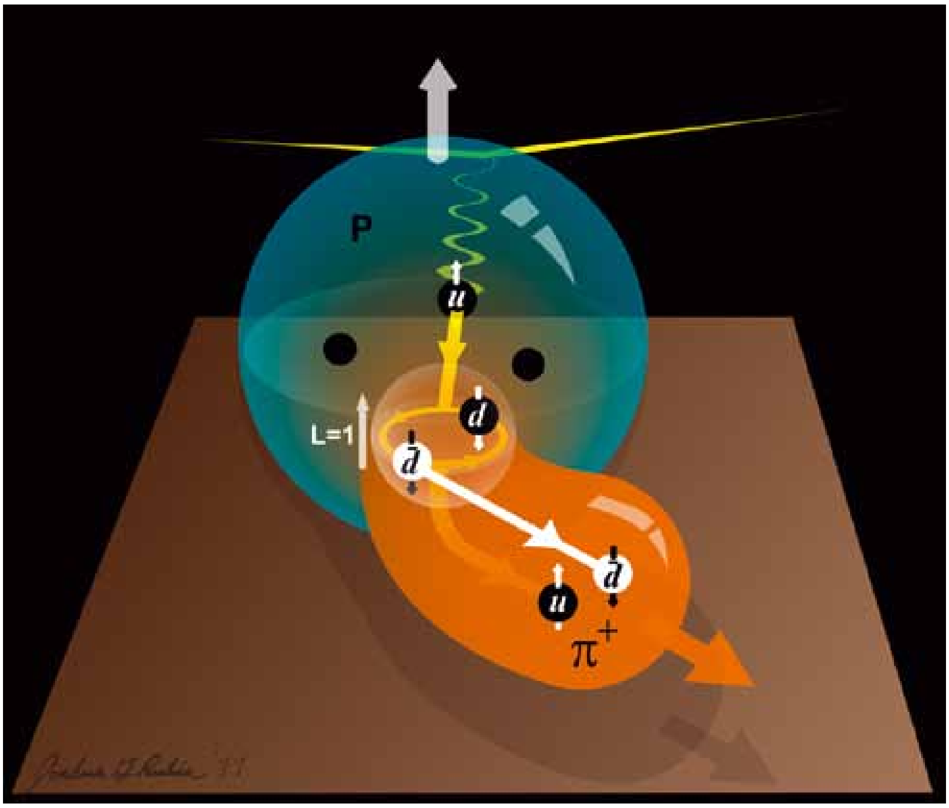


Figure 1

Illustration of the Collins effect: for a proton and a struck u-quark polarized upwards, the hadronziation into a positive pion via production of a quark pair with orbital angular momentum leads to a preferred momentum direction of the outgoing pion.

Can one distinguish quarks that possess a preferred spin orientation, i.e. polarization, from quarks without polarization merely by looking at the hadronization of these quarks into spin-less hadrons? Yes – so it was conjectured in a seminal publication by J.C. Collins when he introduced the Collins effect, a preference of the final-state hadron to move perpendicular to both the momentum and the polarization directions of the hadronizing quark (Fig.1). Yes – so it was reported some five years ago by the HERMES collaboration and confirmed by the BELLE collaboration later on. But why would this be so interesting beyond the general question of how quarks form hadrons in the hadronization process?

We know that nucleons (protons and neutrons) are composite objects: quarks and gluons are their basic building blocks. These quarks in a nucleon are confined to a tiny space with a radius of about 1 fm, that's about 1/1 000 000 000 000th of a millimetre. They move around quickly and, as they possess spin, they can be polarized. To bring order to this myriad of possible states, certain structures, i.e. correlations between the momentum and the spin directions of the quarks, were introduced. In total, eight of such structures are needed, nowadays categorized as transverse-momentum-dependent quark distributions (TMDs). That's for the theory. In praxis we would like to measure these TMDs, but there the trouble begins. While it appears not so difficult to constrain the momenta of quarks, the spin direction can only be measured via some form of polarimetry. Longitudinal polarization, i.e. polarization along the momentum direction, can be probed with a spin-1 photon, as angular-momentum conservation dictates that in a head-on collision a photon with certain helicity can couple to quarks with the same helicity only. But how about transverse polarization? Here, the Collins effect comes in rather handy as it provides the necessary sensitivity to transverse quark polarization via the left-right asymmetry in the momentum distribution of the outgoing hadron. As such the previous HERMES measurement of the Collins effect in deep-inelastic scattering (DIS) of positrons from transversely polarized protons not only demonstrated the existence of a non-zero Collins function but also the existence of transversely polarized quarks in a transversely polarized proton.

In a recent paper, all available HERMES data on transversely polarized protons are reported on. This allows not only a considerably more precise measurement of the Collins effect for charged pions but also, for the first time, for neutral pions and for charged kaons. The Collins amplitudes (measures of the strength of the left-right preference in the momentum direction of the outgoing hadron) are found to be non-zero for charged pions and positively charged kaons, whilst being compatible with zero for the other two mesons. A striking feature of these data is the opposite sign of the amplitudes for negative vs. positive pions (Fig. 2). This means that negative pions prefer to fly into the opposite direction to the one for positive pions. Not only that, the magnitude of the Collins amplitude for negative pions is even bigger than the one for positive pions. The preliminary version of these results, in combination with data from BELLE and COMPASS, allowed for a first extraction of transversity for up- and down-quarks. We now know that quarks in a transversely polarized proton can possess transverse polarization, but also conclude that when a transversely polarized quark fragments into a pion, then this pion tends to go to the left of the quark's spin when such quark is also a constituent, i.e. valence quark, in this pion. If not, then the pion prefers to go to the right side. While this behaviour can be explained quantitatively in certain hadronization models, the full complexity of this result requires further investigation. Including the kaon data will provide valuable input for understanding meson production in DIS and, in general, for the quest of unraveling the spin-momentum structure of the nucleon.

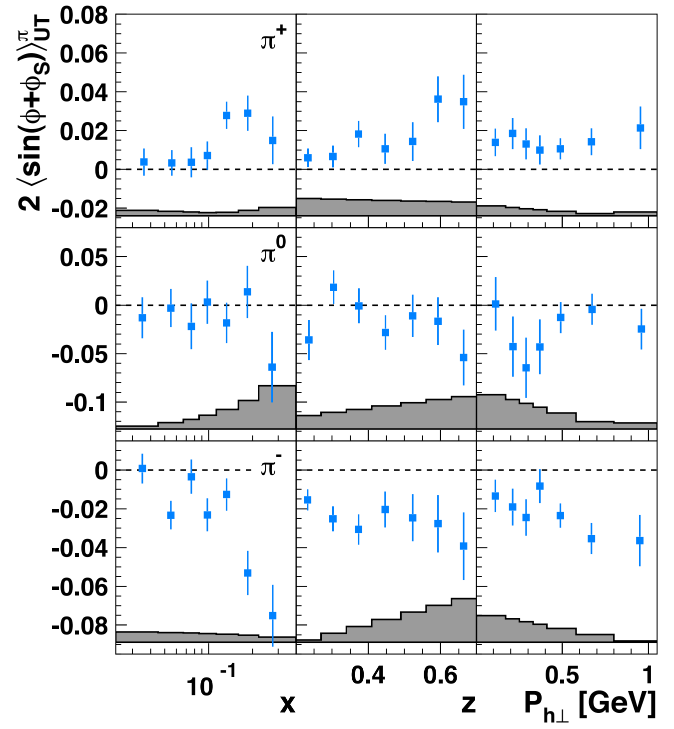


Figure 2

Collins asymmetry amplitudes for pions as a function of the proton's longitudinal momentum fraction x carried by the struck quark, the energy fraction z of the virtual photon carried by the pion and the pion's transverse momentum with respect to the virtual-photon momentum.

Contact:

Klaus Rith, klaus.rith@desy.de

References:

HERMES collaboration
Effects of transversity in deep-inelastic scattering by polarized protons,
Phys. Lett. B693, 11 (2010)

What a machine.

The quest for discoveries started

The Large Hadron Collider (LHC) is the highest-energy particle accelerator in the world and the largest man-built research facility. The start of operation in spring 2010 is a success story. In the early hours of 22 March, the proton beam was ramped up to an energy of 3.5 TeV, more than three times larger than what had ever been reached before. On 30 March already, beams moving in opposite directions were brought into collision and all four experiments started taking data at the unprecedented centre-of-mass energy of 7 TeV.

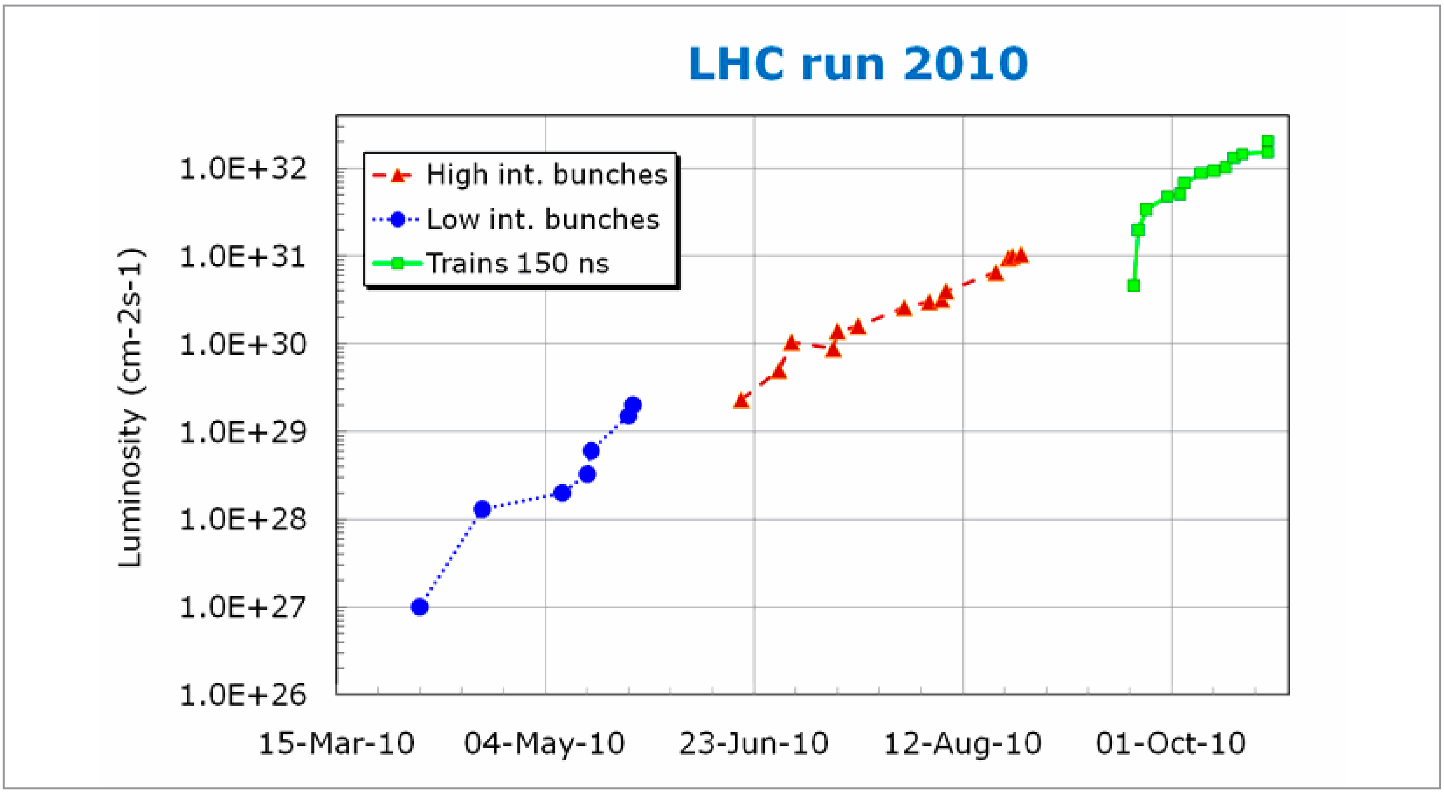


Figure 1

The luminosity of the LHC collider as a function of time in 2010 (Jörg Wenninger, CERN)

This formidable startup was possible after several month of hard maintenance work by the machine crew. The superconducting dipole magnets were powered under safe conditions up to a current of 6 kA. In parallel all feedback systems, which are an essential ingredient for establishing reliable and safe machine operation, have been commissioned.

Besides the energy, the luminosity and the stored beam energy are key parameters of the collider. The luminosity is a

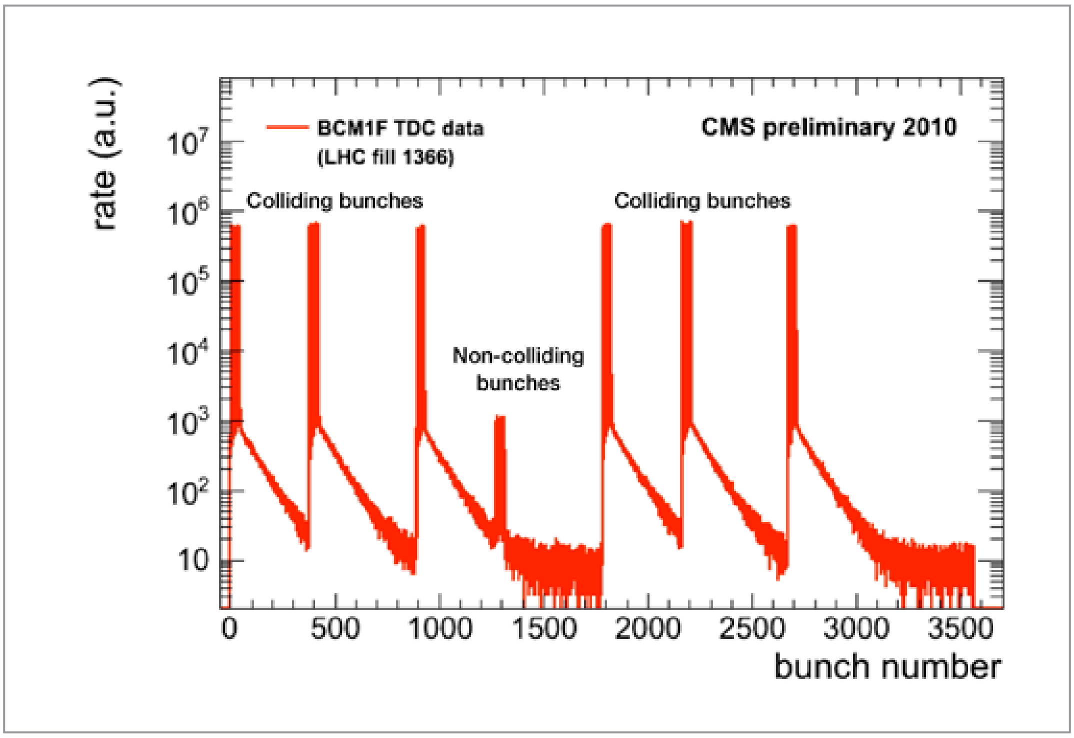


Figure 2

The count rate of the beam monitor as a function of the orbit time.

measure of the number of protons that potentially collide, and characterizes the sensitivity of the LHC for interesting physics processes. The stored beam energy is an important machine parameter.

The first days, two proton bunches circulated surprisingly stably on a nearly perfect orbit. One of the reasons for this immediate success is hidden in several years of work invested in the precise understanding of the magnets keeping the beam on the orbit, as pointed out by Jörg Wenninger, one of the responsible physicists in the control room.

To enhance the luminosity, at the end of April the bunches were squeezed to smaller sizes thanks to special current settings for the quadrupoles that are situated near the collision points. The result was an increase of luminosity by a factor of 5 to about 10^{28} cm^{-2}s^{-1}.

An important milestone was matched at the end of June, when the number of protons in each bunch reached the nominal value of 10^{11}. With six colliding bunches, the luminosity was enhanced by a factor of 100.

A technically brilliant achievement happened in July. The multiple bunch injection was successfully proven, allowing a faster filling of the collider and again enhancing the luminosity. In mid-August, a luminosity of $4 \cdot 10^{30}$ cm^{-2}s^{-1} was reached with a stored beam energy of 2 MJ. This was a record for stored beam energy in existing hadron accelerators, sufficient to melt about 2 kg of copper.

A new operation mode was introduced in September. Instead of several single bunches, bunch trains with 150 ns spacing were injected. Within only a few days, the number of bunches was tremendously enhanced, from 24 on 22 September to 150 on 30 September. The luminosity approached $5 \cdot 10^{31}$ cm^{-2}s^{-1} and the energy stored in the beams reached 6 MJ. The data taking conditions for the experiments were excellent. After filling the collider, up to 20 hours of stable running became the normal case.

At the end of the proton run on 4 November, each beam contained 368 bunches. The luminosity reached $2 \cdot 10^{32}$ cm^{-2}s^{-1}, a factor of 2 more that the goal for 2010.

Altogether, the operation of the LHC in 2010 was exceptionally good. The luminosity was enhanced by five orders of magnitude, as shown in Fig. 1. World records were broken in the centre-of-mass energy and the beam power, being at the end of the proton run ten times larger than at the Tevatron.

The last month of operation was devoted to heavy-ion collisions. With the experience acquired before, the LHC routinely delivered collisions to the experiments.

A DESY group contributed to the beam halo monitor, ensuring the safe operation of the CMS detector. The count rates of this monitor very impressively reflect the bunch trains circulating in the LHC, as can be seen from Fig. 2.

Contact:

Wolfgang Lohmann, wolfgang.lohmann@desy.de

Rediscovery of a standard candle.

Measuring and exploiting the Z boson in the ATLAS detector

When the LHC began colliding protons at the centre-of-mass energy of 7 TeV in early 2010, it inaugurated a new era in the exploration of matter and its interactions. A first task of the ATLAS collaboration was to measure already well-known processes, such as the production cross section for one of the carriers of the weak interaction, the Z boson. The measurement provides both a new test of the Standard Model and an opportunity to evaluate the performance and calibration of the detector. The ATLAS/DESY group is making prominent contributions to the study of the Z boson. We report three of them: finding and purifying the Z boson signal in its electron-positron decay mode, estimating the size of resolution and calibration errors, and evaluating the efficiency for triggering on electrons.

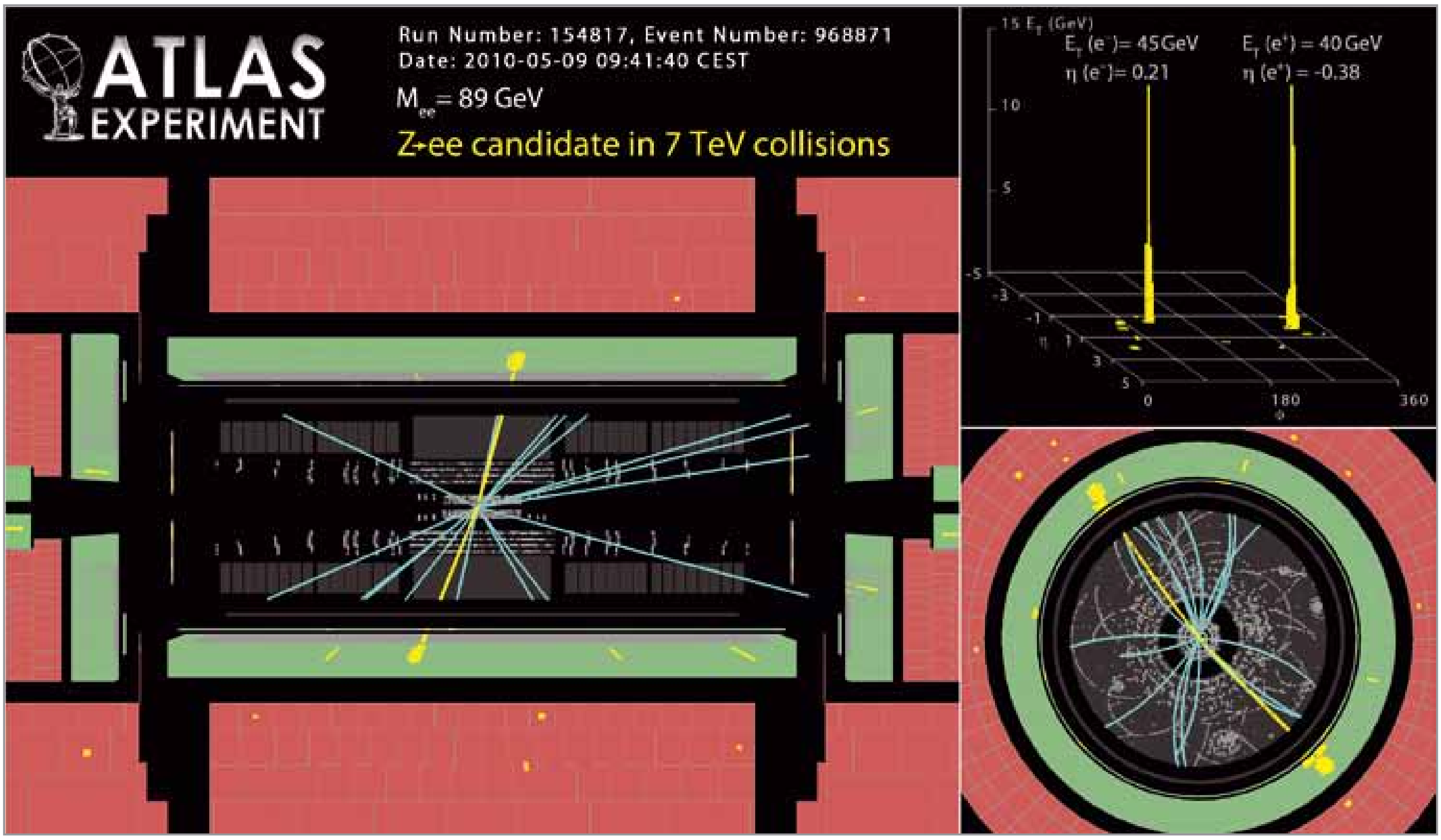


Figure 1

Event display of a Z boson decaying into an electron-positron pair in the ATLAS detector. Tracks are shown as blue and yellow lines in the left and lower right sections (yellow lines for identified electrons). The upper right section indicates the reconstructed calorimeter energy, showing two large peaks where the electrons from the Z decay deposit their energy.

Because of its well-measured properties, distinctive detector signature and the ability of the Standard Model supplemented by the proton structure functions from HERA to precisely predict its production cross section, the Z boson is widely considered to be a “standard candle” of the LHC. After production, it lives just $3 \cdot 10^{-25}$ seconds before decaying. A particularly clean decay mode is the electron-positron (e^+e^-) pair channel which is easily observed in the ATLAS detector and can be selected online (i.e. triggered) when the presence of even one of the two decay products is detected by the trigger system. Figure 1 shows a graphic display of the response of the detector to a single event containing such a Z → e^+e^- decay.

Finding and purifying the signal

The analysis of an event begins with the reconstruction of the particles produced in the collision. This includes reconstructing the particles' paths through the detector and their energies. After reconstruction, requirements on the reconstructed primary interaction vertex are made in order to eliminate false triggers such as those induced by cosmic rays. Next, tracks which satisfy kinematic and quality criteria designed to identify electrons and positrons are selected.

Fig. 2 shows the invariant mass spectrum for e^+e^- pairs selected from the full data sample collected in 2010, together with the shape predicted by the detector simulation. The close match of the predicted and observed distributions proves that the selection successfully isolates a nearly pure sample of Z bosons.

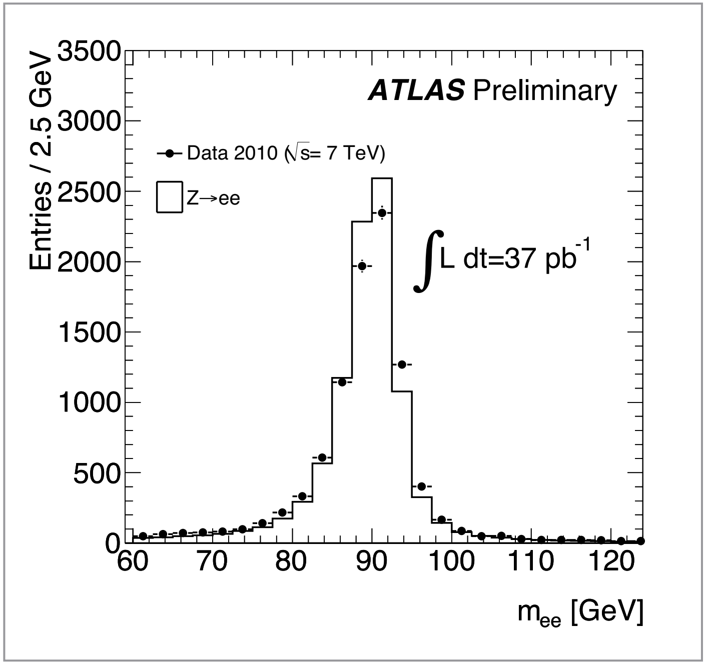


Figure 2

Invariant mass distribution of electron-positron pairs originating from Z boson decays. The black dots show the measured data, while the solid line represents the modelled distribution from Monte Carlo data.

The Z production cross section can be found by counting the number of events in the signal, applying appropriate corrections and factoring in the total luminosity. The first ATLAS estimate of the cross section using the earliest data appeared in a publication in 2010 based on just 1% of the full 2010 data sample and agrees well with the prediction of the Standard Model. Figure 2 together with an updated cross section estimate will be published in the next months.

Refining the detector energy measurement

While good, the match between data and prediction shown in Fig. 2 is not perfect. The residual mismatch is due to small imperfections in the detector simulation arising from limited knowledge of the detector resolution and calibration. The differences can be exploited to derive correction factors which can then be used in all subsequent ATLAS analysis of electrons. A detailed correction map of the full detector is being prepared by the ATLAS/DESY group by dividing the detector into sub-volumes and comparing the theoretical shape of the invariant mass distribution to the measured shape of Z candidates with decay products in each of the sub-volumes separately. The correction map can then be used together with the simulation to provide a more precise estimate of electron energies.

Improving the understanding of trigger efficiencies

The single electron trigger has small inefficiencies which are modelled by the simulation program. The accuracy of the efficiency modelling can be checked using the data itself, using the "tag & probe" method which exploits the distinctive shape of the Z signal in the invariant mass spectrum: one electron (the "tag") from the Z decay is required to fulfil the trigger requirements and the other one is used as a probe. By comparing the number of e^+e^- pairs in the Z signal (after background subtraction) with no trigger requirement on the probe electron with the number after imposing the requirement, the identification efficiency can be derived. Using this method, a detailed map of the efficiency over the detector is made. The calculated efficiencies are then compared to those from the detector simulation to produce scale factors which are then applied to the simulation. The scale factors verify that the simulation is accurate to much better than 1% for the energetic electrons used in the Z analysis.

Perspective

These results of the DESY group constitute some of the necessary groundwork for the measurement of the Z and W boson cross sections. A publication on this subject is under preparation and is scheduled to appear in the next months.

Contact:

Michael Medinnis, michael.medinnis@desy.de
Klaus Mönig, klaus.moenig@desy.de

Reference:

http://www-atlas.desy.de/

The ALFA project.

A detector to measure the luminosity of the ATLAS experiment

ALFA stands for “Absolute Luminosity Measurement For ATLAS” and is a project of the ATLAS experiment at the Large Hadron Collider (LHC) at CERN in Geneva. The luminosity is a crucial parameter of any high-energy physics experiment, as it is needed to convert any measurement of the rate of a physical process into an experiment-independent cross section.

The term “luminosity” was originally used to refer to the intensity of a light source. A well-focused torch, for example, delivers a high luminosity. At a storage ring such as the LHC, the luminosity is proportional to the collision rate, which in turn depends on the number of stored particles and the extent of focusing at the interaction point. ALFA is designed to measure the luminosity during special low-luminosity runs of the LHC and thereby to calibrate other ATLAS detectors, such as LUCID, which are responsible for monitoring the luminosity during high-luminosity running.

ALFA consists of four so-called Roman pot stations containing tracking detectors positioned in the LHC tunnel on both sides of the ATLAS detector, at a distance of 240 m. The Roman pots can be moved remotely, enabling the detectors to be positioned to within 1.5 millimetre of the LHC beam after the beam has been injected and accelerated. The position of two of the Roman pot stations, along with beam magnets and other ATLAS components, is shown in Fig. 1. A Roman pot station without detectors is shown in Fig. 2.

The ALFA luminosity measurement is based on elastic proton-proton scattering at the smallest measurable momentum transfers, in the so-called Coulomb nuclear interference region. A measurement of the event rate vs. momentum transfer can be directly related to the luminosity and the total proton-proton cross section. Using this technique, we expect to achieve a precision of 3% on the total luminosity.

Fig. 3 shows a sketch of a Roman pot station. A movable vacuum vessel houses the tracking detectors. A single ALFA tracking detector consists of 20 layers of scintillating fibres with a cross sectional area of 0.5 x 0.5 mm^2, a scintillating trigger counter and an overlap detector. Charged particles traversing the scintillating fibres produce faint light flashes which are routed via fibres to multi-anode photomultipliers tubes (MAPMT), where they are converted into electrical pulses and subsequently amplified. The signals from all layers are combined in the analysis to give tracks with a precision of 30 µm. The scintillating trigger counters are used to initiate the readout and the data acquisition when a charged particle passes. The momentum transfer measurement requires a precise measurement of the distance between the upper and lower tracking detectors with respect to the proton beam. This is the task of the overlap detectors: particles traversing the overlap layers of both upper and lower detectors give two

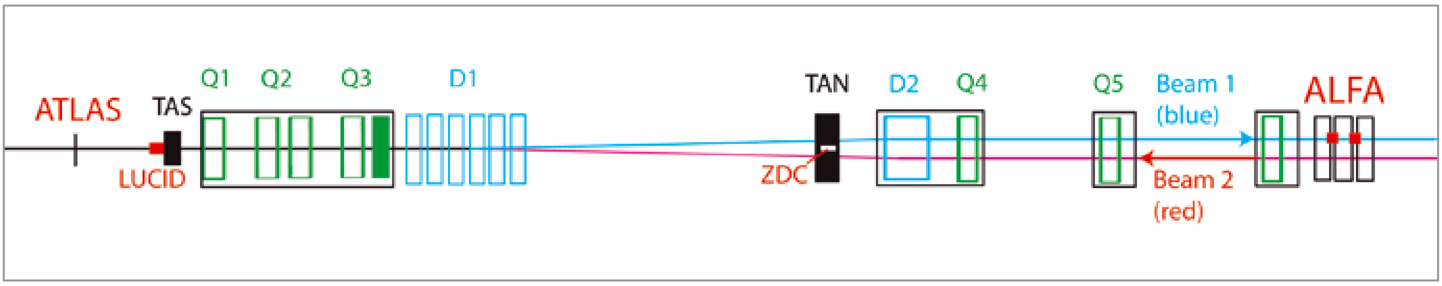


Figure 1

The ATLAS central detector is indicated on the left. Two of the ALFA detectors appear on the right, at a distant of 240 m from the interaction point. In between are several magnets (Q1-Q5, D1-D4), the LUCID detector which monitors the ATLAS luminosity during high-luminosity running, and the ZDC calorimeter which detects neutral particles leaving ATLAS with a zero-degree scattering angle.

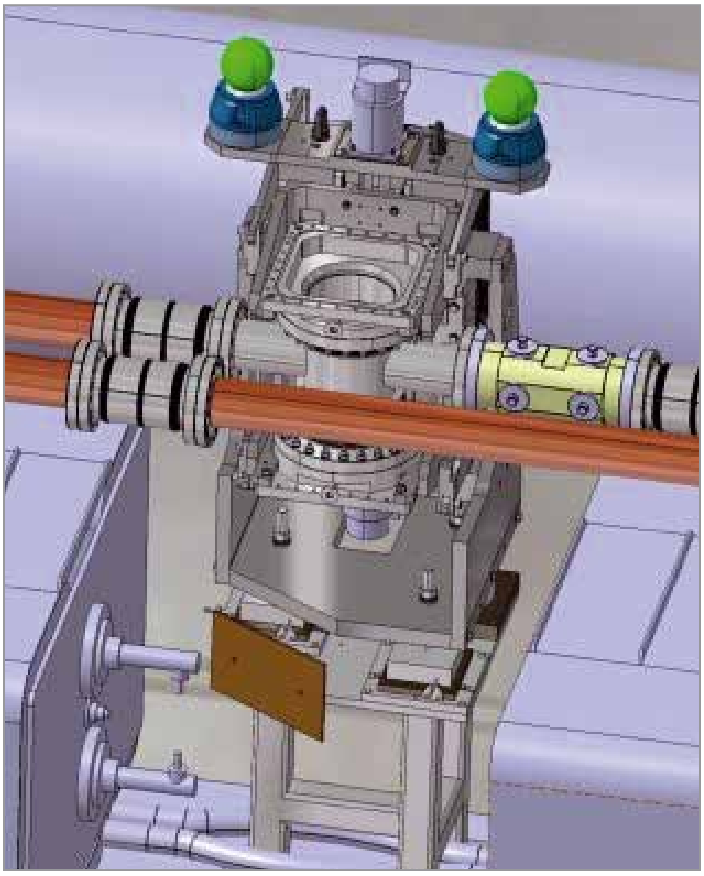


Figure 2

A Roman pot station (without detectors). The outgoing beam pipe is coupled to both sides of the station. The incoming beam pipe is in front. Detectors can be inserted from both the top and the bottom.

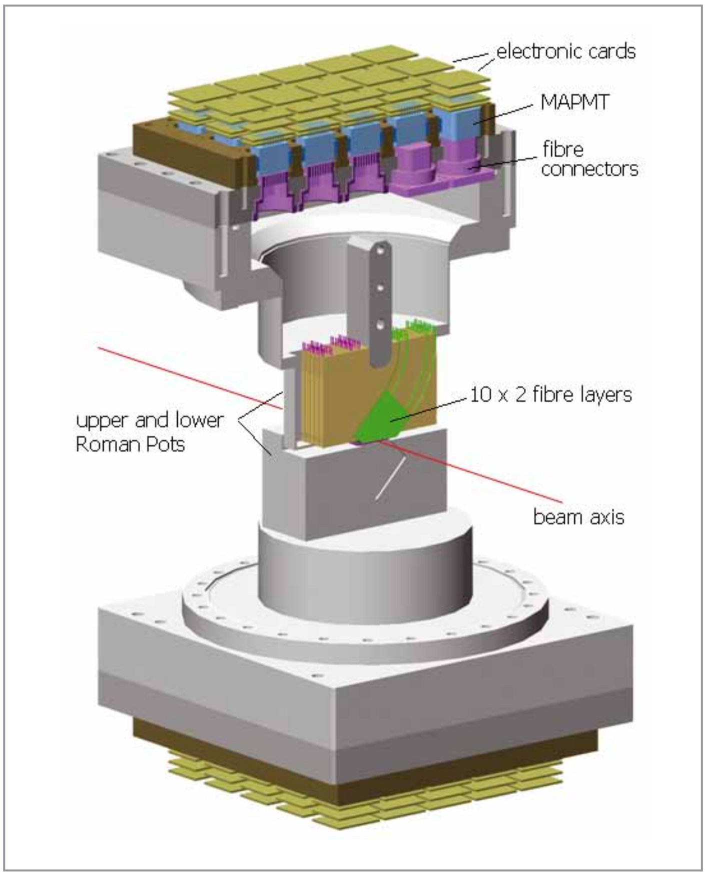


Figure 3

A sketch of one Roman pot station. The upper and lower parts can be moved towards the proton beam. The upper Roman pot has been cut away to reveal the tracking detector and associated readout system. The main detector consists of 10 titanium plates with 64 scintillation fibres glued to each side.

position measurements which can then be used to determine the distance between upper and lower detectors to a precision of 10 µm.

DESY joined the ALFA project in 2007 and has since contributed substantially to the construction, calibration and installation of the detector, as well as 20 % of the cost. These contributions include the precise measurement of all fibre positions, half of the Hamamatsu MAPMTs, as well as the design and purchase of the high-voltage system and the trigger detectors. In addition, DESY physicists are involved in the coordination of test beam campaigns, as well as in the installation and the operation.

The production of all components was completed in 2010 and all Roman pot stations including detectors and front-end electronics were extensively checked in a CERN test beam. The typical efficiency of a fibre layer was found to be 94%, close to the theoretical maximum of 96%. The expected resolution of between 25 µm at the centre and 35 µm at the inner edge of the detector was confirmed. The analysis of the large amount of data accumulated during the beam tests is still in full swing.

In December 2010, all ALFA stations were installed in the LHC tunnel and the detector positions were surveyed and calibrated with a laser tracking device to a precision of 5 µm. The full system was checked before the LHC tunnel was closed for the 2011 run, the readout was synchronized to the LHC clock and the remote ALFA motor control was integrated into the LHC control and interlock system.

The ALFA team is now waiting for beams to re-appear in the LHC so they can continue the commissioning process. The next step will be the observation of shower particles from the LHC beams while all detectors remain in safe parking positions. Later the detectors will be moved a little closer to the beam, where they will be sensitive to halo beam particles traversing two Roman pot stations. After the system is well understood, the LHC beams will be tuned for a special run and the Roman pots will be moved close to the beam for a first luminosity measurement.

Contact:

Michael Medinnis, michael.medinnis@desy.de
Klaus Mönig, klaus.moenig@desy.de

Reference:

http://www-atlas.desy.de/

T.O.P.

Top as key to LHC physics

The Helmholtz Young Investigators Group “Top as Key to LHC Physics” (T.O.P.) is involved in the ATLAS experiment at the CERN Large Hadron Collider (LHC). The group’s main research topics are top quark physics and the development of silicon detectors for the upgrade of the ATLAS detector for the high-luminosity phase of the LHC after 2020 (LHC-HL). In 2010, the group contributed to important new results in both fields of research.

First top quarks in Europe

The top quark was discovered at the Tevatron proton-antiproton collider in 1995. It plays a special role among the six quarks in more than one respect: The reconstruction of top quark events is challenging because of the complicated final state with leptons, jets and missing energy. At the same time, top events are one of the main backgrounds for the search for new physics at the LHC. The large mass of the top quark could also point to a connection between top quarks and the yet-to-be-understood mechanism of electroweak symmetry breaking.

With the start of data taking at a centre-of-mass energy of 7 TeV in March 2010, for the first time top quarks could be produced at the LHC in appreciable numbers. The “re-discovery” of the top quark was thus among the most important physics objectives of the LHC experiments in 2010. The first ATLAS measurement of top pair production in proton-proton collisions was published based on data recorded between March and August 2010. The publication includes important contributions by members of the T.O.P. group, for example data-derived determinations of lepton reconstruction and trigger efficiencies, as well as modeling of the background due to jets of particles misidentified as electrons from the data. In addition, the group contributed a comparison of measurements of the top pair production cross section at the Tevatron and the LHC with recent theoretical predictions, as shown in Fig. 1.

Preparing for the upgrade of the ATLAS silicon detectors

The tracking detectors of the ATLAS experiment are used to precisely reconstruct the tracks of charged particles close to the collision point. The innermost part of the tracking detectors is based on silicon pixel and strip detector technologies, followed by a transition radiation tracker. The increased performance of the LHC during the LHC-HL phase leads to a much larger amount of charged particles to be reconstructed in each beam crossing. Therefore it will be necessary to replace the current tracking detectors with a new and improved all-silicon tracker. The harsh radiation environment at the LHC also requires a replacement of the tracking detectors on approximately the same time scale. Such a large-scale upgrade requires significant R&D efforts.

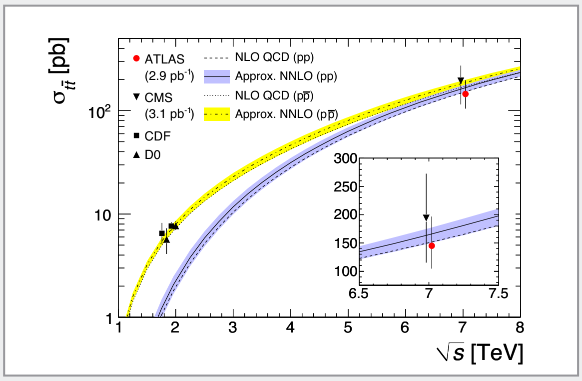


Figure 1

Measurements of the top pair cross section at the Tevatron and the LHC compared to recent theoretical calculations at next-to-leading order (NLO) and approximate next-to-next-to-leading order (NNLO).

The T.O.P. group was instrumental in establishing DESY’s role in the ATLAS tracking detector upgrade. As part of an ATLAS-wide programme, the group has started silicon sensor testing and is preparing the assembly of prototype detector modules, which will be merged on a prototype “stave” hosting 24 detector modules in 2011. Special focus lies on prototype modules for the end-cap region of the ATLAS detector, i.e. detectors mounted under small angles with respect to the beam axis. With partners from Berlin, Freiburg, Valencia, Amsterdam and Prague, the group started R&D into a fully functional full-size prototype of a “petal” that hosts 18 detector modules. This R&D effort is an important preparatory step towards the final assembly of a significant part of the upgraded ATLAS tracking detectors, which is envisioned at DESY.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_400

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
“Top as Key to LHC Physics” (VH-NG-400)

Contact:
Ulrich Husemann, ulrich.husemann@desy.de

Terascale physics.

From data taking at the LHC to understanding at the ILC

The aim of this Helmholtz Young Investigators Group (YIG) is to cover several aspects of the experiments and analyses which promise to unravel the mysteries of electroweak symmetry breaking. Electroweak symmetry breaking – or equivalently the question of how matter acquires mass – is the cornerstone of the Standard Model, the current description of all precision measurements in physics. However, neither does this model contain a natural explanation for this phenomenon, nor does it agree with several cosmological observations. It can be deduced that the energy scale of 1 TeV, the Terascale, is a natural place for new phenomena that could explain the aforementioned deficiencies. For the first time ever, since the end of 2009 and throughout 2010, experiments at the LHC are exploring this energy scale, and the YIG is covering several key aspects from data taking and analysis at the ATLAS experiment to the interpretation of the results in models of new physics. In addition, the group is contributing to physics studies for the International Linear Collider (ILC).

In 2010, the YIG contributed significantly to the ATLAS core software development in a phase of rapid development. Amongst other contributions, focus was set on automatic configuration of ATLAS reconstruction, simulation and analysis jobs, release management and on the development of bookkeeping tools for data format transformation and data analyses. After the data is taken and transformed to the data formats suitable for analysis, the understanding of the detector and tuning of the Monte Carlo simulation is another milestone in the commissioning of the experiment with data. In Fig. 1, an example of such an analysis carried out in the group can be seen. It shows a shower shape variable that can be used to disentangle hadronic decays of a heavy lepton, which could play a major role in models of new physics such as supersymmetry (SUSY), from the background. Figure 1 shows that an excellent agreement between simulation and data could be achieved, especially given the early stage of the experiment.

After these measurements, which make sure that the detector is very well understood, the next focus of the group lies on searches for SUSY, a very promising candidate for new physics. Finally, either the current non-observation of new physics at the LHC or potential future discoveries at the LHC or even the ILC can be used to constrain the parameter space (or measure the parameters) of models of new physics such as SUSY. An example of this work is shown in Fig. 2, where a parametrization of the expected limit of the ATLAS experiment using the data collected in 2010 is used to show the influence on the parameter space of a specific SUSY model in a global fit. The limit cuts into the parameter space preferred by all measurements before the LHC, and it can be seen that the best fit moves to parameters consistent with heavier masses of the new particles. This closes the loop of the work of the group to the ILC – more detailed studies reveal the exact properties of the available parameter space and help to adjust the ILC physics case to the incoming results from the LHC.

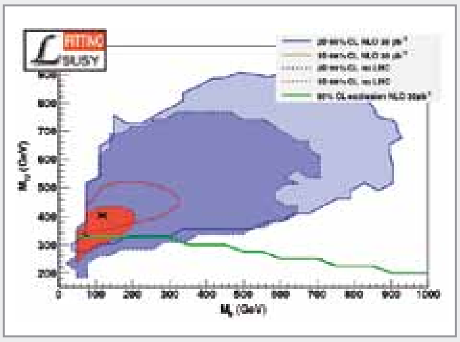


Figure 2

Influence of the non-observation of physics beyond the Standard Model at ATLAS on the allowed mSUGRA parameter space.

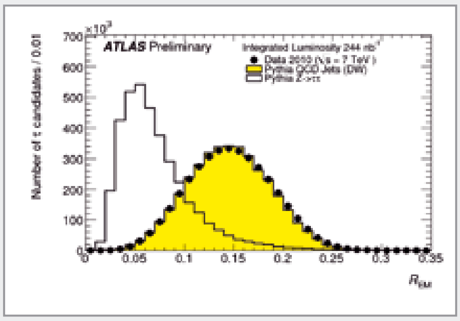


Figure 1

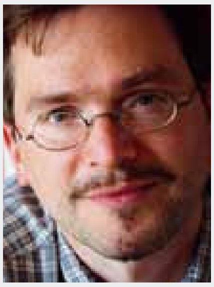
Display of the excellent agreement between ATLAS Monte Carlo simulations and the data taken in 2010.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_303

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
"From Datataking at LHC to Understanding at ILC" (VH-NG-303)

Contact:
Philip Bechtle, philip.bechtle@desy.de



Alignment and data quality.

Pushing the limits of CMS data quality and tracking precision

Excellent performance of the detector is the basis for success in physics research and discovery at the CMS experiment.. The alignment of the tracker is crucial for resolving the masses, momenta and points of origin of particles with highest possible accuracy. Data quality monitoring ensures that the detector hardware, trigger and reconstruction software are performing fully and precisely in all stages of the data recording and processing.

Alignment

The heart of the CMS experiment features the largest silicon tracking detector that has ever been built. Its ultimate tracking performance, which governs the purity with which heavy quarks are tagged, can only be achieved by a highly accurate alignment of its 16 588 silicon modules. In a joint effort with Hamburg University, DESY is playing a leading role in the development and application of the CMS alignment methodology. The Millepede II programme, created by V. Blobel in Hamburg and maintained and further developed by the Helmholtz Alliance “Physics at the Terascale” at DESY, has successfully been applied to solve the complex underlying mathematical problem. The DESY group is also involved at convener level in the CMS alignment sector.

The first long LHC high-energy run in 2010 was used to provide the best CMS tracker alignment to date. Tens of millions of collision tracks were combined with three million cosmic-ray tracks to align the silicon modules. The resulting alignment constants have warranted excellent impact parameter and momentum resolution, which is relevant for the many track-based CMS analyses performed with this data. Beyond determination of three-dimensional shifts and rotations of flat modules, the method is now being pushed even further to also determine bends and kinks within the modules. These are very small but nevertheless noticeable thanks to the high spatial resolution of the sensors. Mastering a problem with up to 200 000 unknown parameters, the sensor curvatures are determined simultaneously with all other module parameters, as illustrated in Fig. 1.

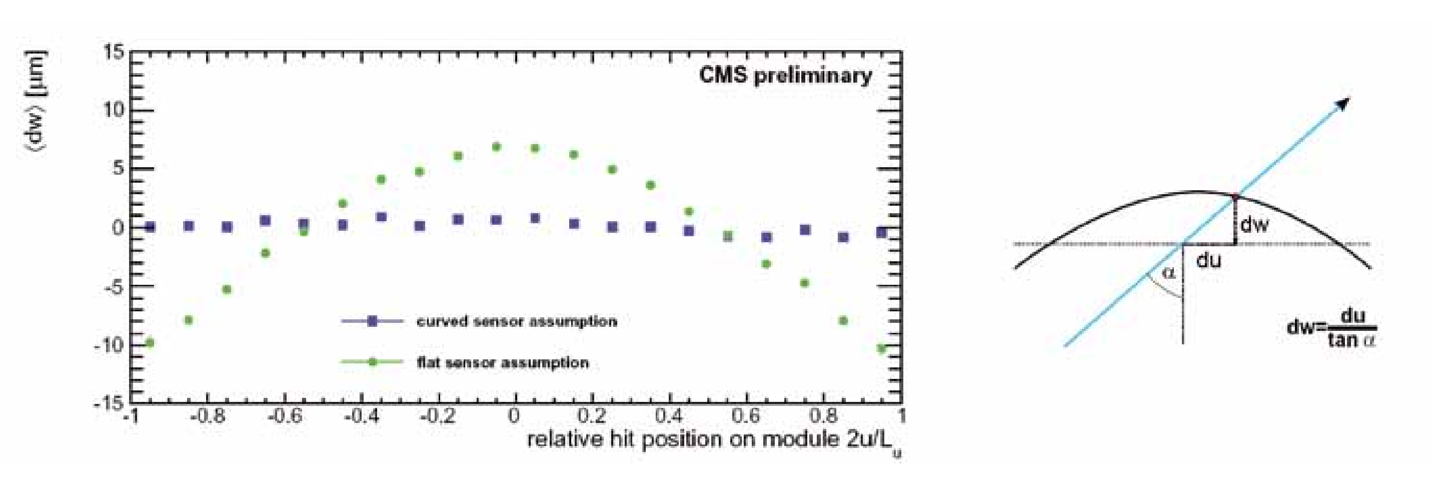


Figure 1

Effect of sensor curvature. The assumption of flat sensors leads to a systematic deviation of hits from the expected position, which can be interpreted as a vertical offset dw (see right diagram). The left plot shows the mean vertical offset as a function of relative hit position on the module before (green symbols) and after the correction for sensor curvature (blue).

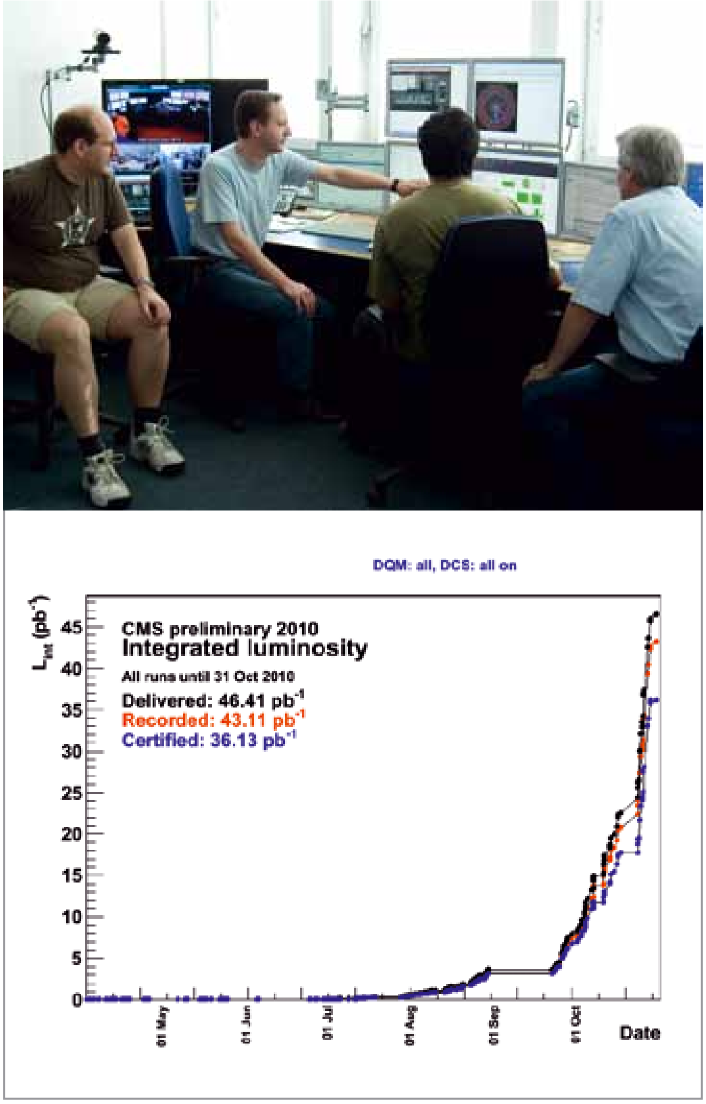


Figure 2

a) At DESY's remote CMS centre regular daily offline DQM shifts are performed.

b) The integrated luminosity collected as a function of time. The black/red/blue lines show the integrated luminosity delivered by LHC / recorded by CMS / certified as 'good' by the DQM system and shifts.

Data quality monitoring

A prerequisite to optimal detector performance and high-precision physics analysis is the continuous monitoring of the quality of the incoming data. The CMS-wide data quality monitoring (DQM) system produces event data distributions (histograms) and performs automatic quality checks, both in real time while the data is being taken (online) and during their processing and reconstruction (offline). The same DQM system is also used for the validation of calibration and alignment results, as well as for the software release and simulation validation. The results from DQM include all CMS detector, trigger and software components. They are published through a web-based application which allows CMS users worldwide to closely follow the data taking.

Continuous DQM shifts are organized to visually inspect the DQM distributions, both online at the experiment as well as offline in daily shifts at the remote centres at CERN, Fermilab and DESY (Fig. 2a). The data quality is determined for each run and each sub-detector or physics object. From the obtained data certification results, the official CMS-wide good-run list is created. In Fig. 2b, the integrated luminosity recorded by the CMS experiment in the year 2010 is shown. For 36.1 pb^{-1} of the integrated luminosity recorded in 2010, all detector components were fully functional simultaneously, as determined from DQM and data certification procedures. This fraction of the data was released for use in the CMS physics analyses.

The complete DQM infrastructure and data certification procedures had already been implemented and exercised in commissioning runs before the start of the LHC. As a result, the system worked flawlessly on day one of the data taking with LHC collisions and throughout the year 2010. The DESY group has played a key role in the design and implementation of the system and maintains a sustained involvement in the project at the convener level, with crucial contributions to the software, the computing, the data certification and shift operations.

Contact:

Rainer Mankel, rainer.mankel@desy.de
Andreas Meyer, andreas.meyer@desy.de

CMS physics harvest.

For the time being the Standard Model prevails

In 2010, a wealth of data from the first LHC proton collisions at 7 TeV was recorded. The analysis of the data, spanning topics from all areas of physics at the energy frontier, has already resulted in more than 50 publications. The DESY group at the CMS experiment contributes to the top quark analysis, Higgs and supersymmetry searches and to QCD studies.

The advent of the first LHC data in spring 2010 marked the beginning of a new era in high-energy physics. First collisions at the unprecedented centre-of-mass energy of 7 TeV were established at the end of March 2010, and throughout the year the machine delivered data at continuously increasing instantaneous luminosity. Based on an excellent performance of the CMS detector, a very fast turn-around time for the data processing and a swift certification of the data quality, results from early data analyses could already be presented at the conferences in summer 2010. The bulk of the integrated luminosity of proton-proton collisions, in total about 40 pb^{-1}, was collected toward the end of the year, before the LHC switched over to operation with heavy-ion beams in November 2010.

Several Helmholtz Young Investigators Groups contribute to the analysis efforts. In addition, the DESY group maintains a strong effort in the analysis of forward jets and energy flow, using the forward hadronic calorimeter (HF) and in particular the CASTOR forward calorimeter, to which DESY contributed substantial detector parts.

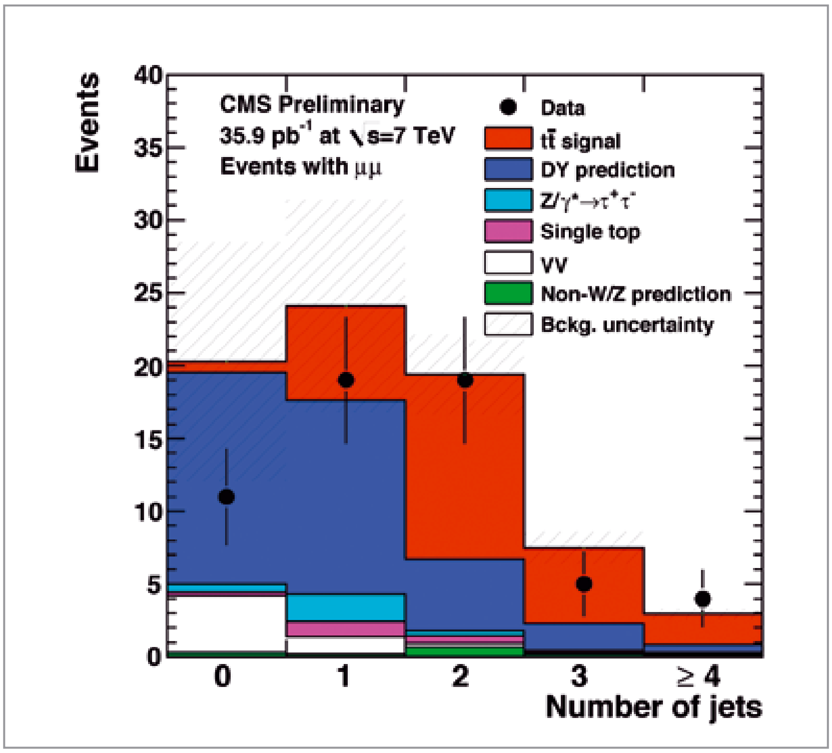


Figure 1

Jet multiplicity distribution for $t\bar{t}$ event candidates in the dimuon channel, in comparison to expectations. The shaded area indicates the uncertainty of the contribution from backgrounds. For the final event selection at least two jets are required.

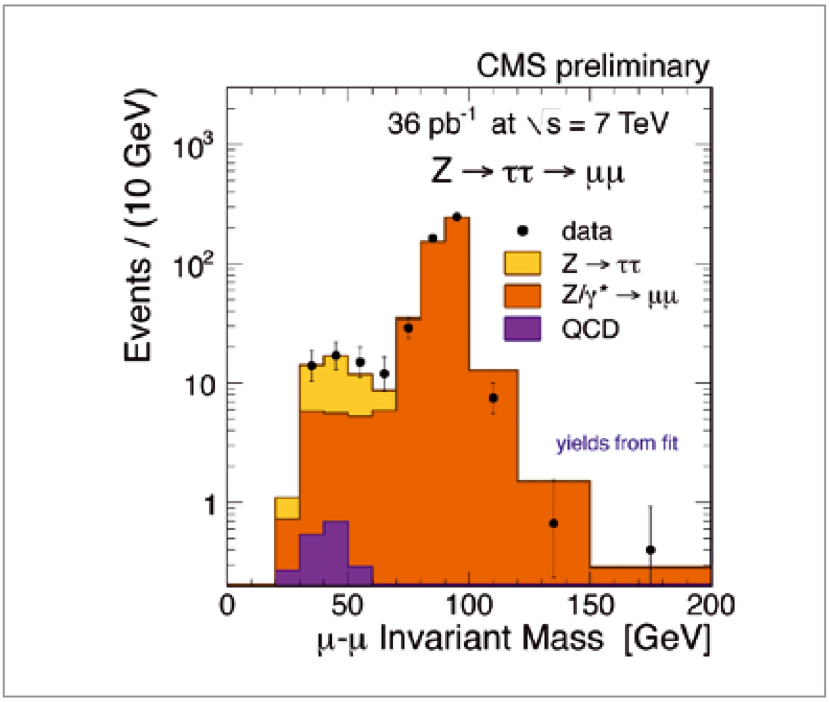


Figure 2

Reconstructed dimuon invariant mass in a sample of $Z \rightarrow \tau\tau \rightarrow \mu\mu$ events

Most analyses performed at DESY make use of data samples with a common event signature, namely two leptons (electrons and/or muons) in the final state. In the following, the most prominent analyses are described.

Using the complete 2010 data, the cross section for top quark-antiquark pair production was measured using events with two oppositely charged leptons in the final state. The 2010 data sample of top quark-antiquark pair candidates in the dimuon channel is illustrated in Fig. 1.

Specifically, the top group at DESY delivered QCD event background estimates using an independent method based on a sample of like-sign leptons, and performed studies on the final event selection using a kinematic fit of the invariant top quark mass. In addition, the uncertainty on the cross section measurement was improved by the determination of the ratio of top quark event yield in the dimuon final state over the yield of muon pairs coming from Z/γ decays. In the measurement of the ratio, a number of systematic uncertainties, especially the large uncertainty of the integrated luminosity as well as, in many aspects, the muon identification efficiencies, are reduced significantly. The DESY group also made contributions to the comparison of the top quark pair cross section measurement with theoretical predictions, e.g. using the parton density functions (HERAPDF) as determined by the HERA collaborations. The HERAPDF include a full treatment of statistical and systematic errors.

The SUSY group at DESY engages in the analysis of final states with two leptons (electrons and muons) and large missing transverse energy. Like for all searches, the challenge of SUSY analyses is the precise prediction of Standard Model events in the signal region. The data taken in 2010 allow for limits that are partially exceeding those from previous experiments, and the first publications from CMS are becoming available.

A major target of the CMS experiment is the search and possible discovery of the Higgs Boson. The DESY group contributes to this endeavour in the channels of the Higgs decaying into two τ leptons or two b-quarks. In supersymmetric scenarios, the cross section for these final states is expected to be enhanced significantly. In order to commission the search for decays of neutral supersymmetric Higgs bosons to τ leptons in the dimuon channel, the DESY group performed an analysis of Z boson production with subsequent decay of the Z into a pair of τ leptons in the channel characterized by two muons and missing transverse energy. A multi-variate analysis technique based on likelihood ratios and the distribution of the muon pair invariant mass (Fig. 2) were exploited to discriminate between the signal and the dominant Drell-Yan background and to measure the topological cross section $\sigma(pp \rightarrow Z) \cdot Br(Z \rightarrow \tau\tau)$. The measured cross section agrees with other CMS measurements performed in the channels $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$, and with theoretical predictions to next-to-next-to-leading order (NNLO).

Contact:

Andreas Meyer, andreas.meyer@desy.de
Kerstin Borras, kerstin.borras@desy.de

Reference:

http://cms.desy.de/

Supersymmetry at the Terascale.

Every particle has a supersymmetric partner

Supersymmetric models predict partner particles to all known elementary particles and provide elegant explanations for current questions in particle physics and cosmology, e.g. the unification of three of the four elementary forces and possible candidates for dark matter. The main topic of the Helmholtz Young Investigators Group (YIG) is the search for supersymmetry (SUSY) at the CMS experiment, one of the two multi-purpose experiments at the Large Hadron Collider (LHC).

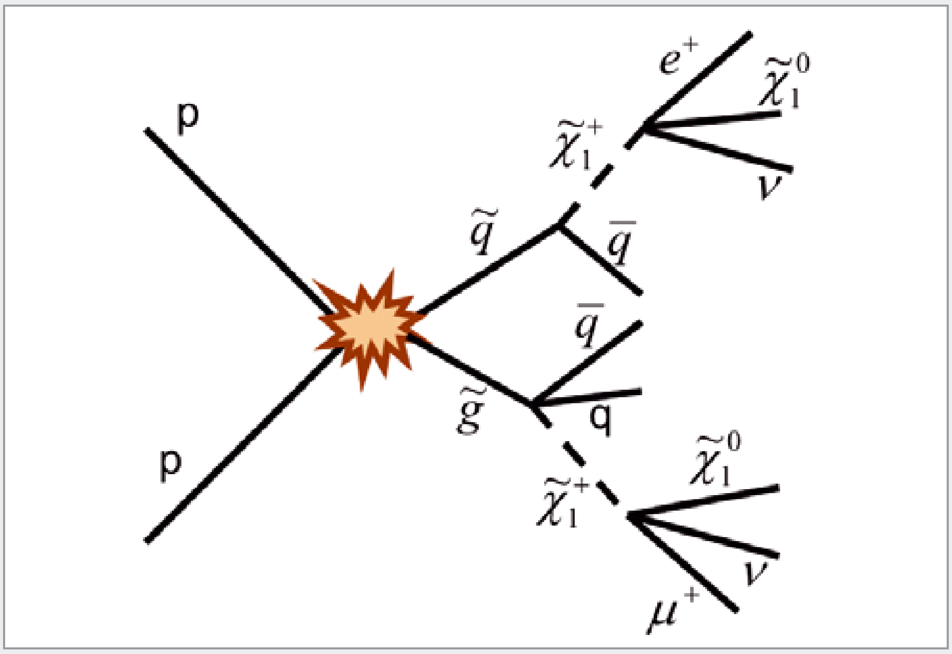


Figure 1

This diagram shows the production of supersymmetric partner particles of the quark and the gluon, which then decay into leptons and the lightest supersymmetric particles.

Searches for SUSY at CMS are divided into different final states. While the Hamburg University group, the official partner in this activity, works mainly on hadronic final states, the YIG focuses on final states with two leptons (electrons and muons), as shown in Fig. 1. Challenging for all analyses is the precise prediction of Standard Model events in the signal region. Once a signal is found, it has to be compared to a large variety of new physics models.

Recent approaches of characterization of new physics are based on simplified models. Once embedded into the official CMS Monte Carlo simulation program (as already done by the YIG for different models), they can be used to define optimal search algorithms in the largest possible kinematical phase space. Exploiting the knowledge on how to implement models into the CMS Monte Carlo program, the group also searches for well-motivated SUSY models that could not yet be analysed by other groups in the CMS experiment.

In addition to the physics analyses, the group is also working on dedicated technical tasks. These tasks include central data quality monitoring and the validation of data for specific SUSY analyses.

The group is also involved in the upgrade of the hadron calorimeter (HCal), performing simulations for additional segmentation of the HCal for the upgrade phase 1, and testing light guides and silicon photomultipliers for the replacement of hybrid photodetectors in the HCal outer ring 0, which is planned for the shutdown in 2013.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_502

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
“Supersymmetry at the Terascale” (VH-NG-502)

Contact:
Isabell Melzer-Pellmann, isabell.melzer@desy.de

Preparing for Higgs hunt at the LHC.

The CMS detector commissioning and rediscovery of the Standard Model with first LHC data

In 2010, the Large Hadron Collider (LHC) at CERN delivered first proton-proton collisions at the centre-of-mass energy of 7 TeV. The collected data has been used by the CMS collaboration to calibrate the detector, validate reconstruction software and study Standard Model processes. These contribute to the background for Higgs boson searches and searches for new physics. In addition, the LHC data, recorded at the highest collision energy attained up to now, has yielded the first physics results at the new energy frontier.

The cornerstone of the physics programme at the LHC are the exploration of the electroweak symmetry breaking (EWSB) mechanism and the search for new physics beyond the Standard Model. The studies, which aim to establish signals from the Higgs boson, a physical state predicted by the mechanism of EWSB within the Standard Model, as well as signals from new physics, e.g. supersymmetry, must be preceded by thorough work on detector calibration, validation of analysis tools and understanding of the Standard Model background processes. The DESY CMS group is closely involved in searches for Higgs bosons and new physics and has actively participated in studies establishing the basis for these searches.

Commissioning of the CMS tracker and rediscovery of strangeness

Many analyses searching for Higgs bosons and new physics will rely on the precise reconstruction of the charged particles and decay vertices in the CMS tracking system. The DESY CMS group has participated in the CMS tracker commissioning with studies of strange particles produced in proton-proton collisions. The analysis provides a test of the CMS tracker performance and validates software tools used to reconstruct charged-particle trajectories and decay vertices in the CMS detector. A number of strange resonances, such as $K^*(892)^{\pm}$, $\Sigma(1385)^{\pm}$, $\Xi(1530)^0$ and Ω^-, were reconstructed in the cascade decays involving the neutral hadrons K^0_S and Λ^0. Figure 1 shows as an example the clear signal established in the $\Xi(1530)0\rightarrow\Xi^-\pi^+$ decay channel. The extracted masses and natural widths of the states studied are in excellent agreement with the Particle Data Group values, indicating superb performance of the CMS tracker and the related reconstruction software.

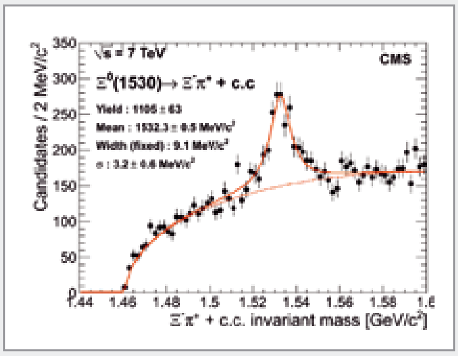


Figure 1

The $\Xi(1530)^0\rightarrow\Xi^-\pi^+$ signal established in the first data collected with the CMS detector at the centre-of-mass energy of 7 TeV.

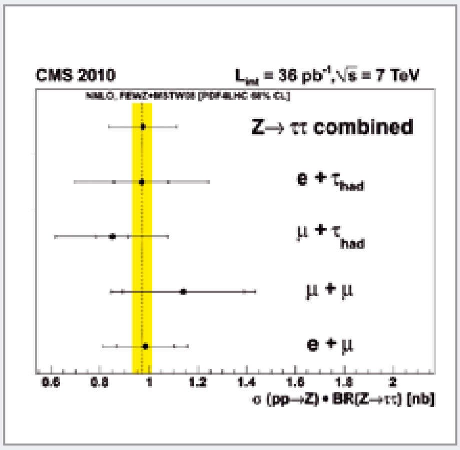


Figure 2

The cross section, $\sigma(\pi\pi\rightarrow Z)\cdot Br(Z\rightarrow\tau\tau)$, measured in different decay modes of tau leptons and the value obtained from the combined fit. Results are obtained with 36 pb^{-1} of data collected with the CMS detector at the centre-of-mass energy of 7 TeV.

Z boson decays into tau leptons

The DESY group has contributed to the study of Z boson production followed by Z decays into tau leptons. This measurement is essential for searches for new physics, such as Higgs boson decays into $\tau^+\tau^-$. Figure 2 presents results of the measurement in four distinct final states, defined by the tau lepton decay products. These are purely leptonic decays, $\tau\rightarrow e\nu_e\nu_\tau$, $\tau\rightarrow\mu\nu_\mu\nu_\tau$, denoted "$\tau_e$" and "$\tau_\mu$", respectively, and semihadronic decays, denoted "τ_{had}". The cross section values obtained in individual channels as well as by combining the measurements are consistent with the theoretical prediction in next-to-next-to-leading order (NNLO).

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_503

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group

"Probing Electroweak Symmetry Breaking at LHC: Higgs Physics with the CMS detector" (VH-NG-503)

Contact:

Alexei Raspereza, alexei.raspereza@desy.de

Giant steps validating Geant4.

A cental tool used for particle physics, life science and related areas

Geant4 is a toolkit to simulate the interaction of particles with matter. The validation of Geant4 is a central task, with the goal of improving the physics description within the programme.

All major experiments in particle physics utilize Geant4 to simulate the detector response to the traversing particles. Increasingly Geant4 is also used in other areas of experimental physics. The validation of the physics performance is currently a main activity in the Geant4 collaboration. Since 2007, DESY has been actively contributing in the fields of maintenance, improvements of the physics description and validation.

The DESY contributions include the implementation of polarized processes for accelerator physics applications, improvements in the description of electromagnetic physics processes and the development of a validation system for simulation results of electromagnetic and hadronic processes.

A library “polarized electromagnetic processes” has been developed in collaboration with the NC PHEP (Belarus State University Minsk). It targets applications with polarized photons, electrons or positrons, and implements all relevant electromagnetic processes: Compton, Bhabha and Moller scattering, positron annihilation into photons, bremsstrahlung, pair production and the photoelectric effect. Geant4 is now capable of describing polarization transport processes in matter, which is important in polarimetry applications.

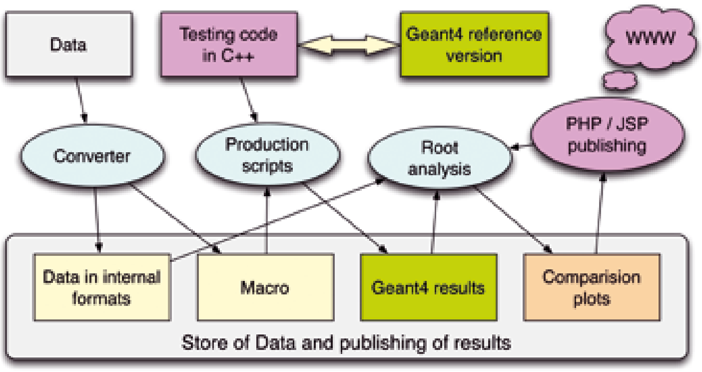


Figure 1

The Geant4 validation framework

Improvements in the electromagnetic physics of Geant4 concentrated on bremsstrahlung and pair production processes. With the consistent implementation of the Landau-Pomeranchuk-Migdal effect and the density effect, a good description of dedicated thin-target experiments at SLAC and CERN could be achieved. As a result, the simulation of electron interactions in the range from 20 to 500 GeV is now substantially improved.

Recent activities concentrate on the validation of the Geant4 physics performance. A validation system is currently under development in collaboration with groups at CERN and Fermilab. This system describes the status and monitors the stability and precision of Geant4 physics results. It includes the comparison with experimental data and theoretical predictions and allows comparisons with previous Geant4 versions. Since 2010, a dedicated database server has been hosted at DESY, providing a unique collection of Geant4 validation results for different application domains. A web interface provides an easy access to the results.

Contact:

Sabine Riemann, sabine.riemann@desy.de

Cycles and petabytes.

Just the tip of the iceberg

Capacity computing through Grid computing for the LHC, the HERA experiments and the ILC was already mentioned in the previous sections. Capability computing through high-performance parallel systems is in place for simulation in experiments and theory. Data are handled by the dCache system and stored in large silos operating automatically 24/7.

All this cannot stand alone; it needs a large infrastructure on various levels. This starts with space and power. Power consumption and efficiency is nowadays measured in power usage effectiveness (PUE). PUE is one of today's major challenges for a computing centre in order to save energy and protect the environment. IT has various projects under way to constantly improve the PUE, in particular to reduce the number of physical systems by virtualization methods and improve cooling effectiveness by using water as much as possible.

Another important issue for a computing infrastructure is the connectivity. For particle physics, connectivity on a high bandwidth level to the inside as well as to the outside world is mandatory. DESY is actively involved in an international project aiming to improve the connectivity of the Tier-2 centres for the LHC. Beside a standard general 10 Gigabit/s connection to the national science net XWiN, DESY is currently operating a special 10 Gigabit/s point-to-point connection to the Tier-1 centre at KIT in Karlsruhe. This link is highly in use for data transfer for the LHC analysis. A very important component in this orchestra is a high-performance firewall which protects the infrastructure without reducing the effective bandwidth. In addition, the Zeuthen site is connected to the Hamburg site by a 10 Gigabit/s link, which allows almost local data access speed.

Furthermore, locally all the systems have to be connected in the computer centre. In particular, the data flow from the storage elements to the computing elements requires much attention and is largely based on 10 Gigabit/s switches, which are aggregated by so-called directors base on fibre and copper cables.

As mentioned above, plenty of services for administration, alarming, reporting and monitoring are needed to supervise 10 000s of components in the computer centres and to achieve highest levels of availability and reliability. All these tools are subject to continuous further improvement by very specialized and capable experts from the IT/DV groups.

Contact:
Volker Gülzow, volker.guelzow@desy.de

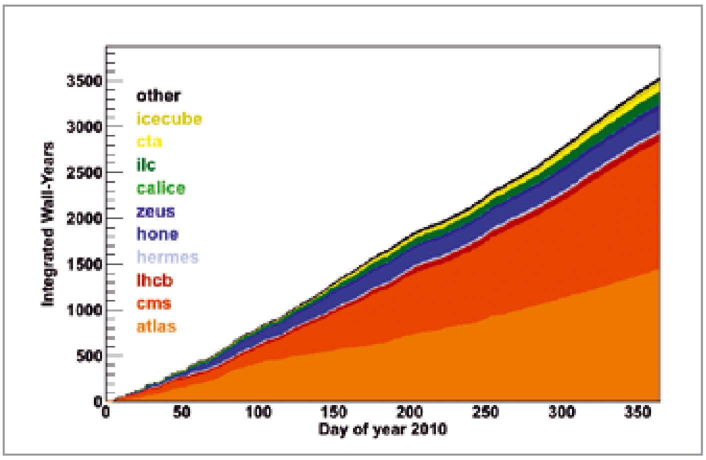
The DESY Grid Centre.

A common computing infrastructure for many experiments

In 2010, the operation of the DESY Grid infrastructure and the National Analysis Facility (NAF), together called the DESY Grid Centre, was successfully continued. With more than 4000 job slots in the Grid, the two sites at DESY in Hamburg (DESY-HH) and DESY in Zeuthen (DESY-ZN) participated in the data processing of the LHC experiments ATLAS, CMS and LHCb, and provided computing resources for the HERA experiments, ILC and astroparticle physics (IceCube, CTA). With more than 1600 job slots and 150 TB of analysis disk space, the NAF was heavily used and provided computing resources for data analysis of LHC and ILC experiments in Germany.

Introduction

Grid computing has turned out to be the key technology to meet the vast computing demands of the LHC experiments. It was implemented as the worldwide LHC Computing Grid (WLCG) [1]. The WLCG was set up and brought to operations in the course of the three times two-years project Enabling Grid for E-science (EGEE), which successfully set up a global multidisciplinary Grid infrastructure. EGEE ended in April 2010. Since 1 May 2010, DESY takes part in the EU project EGI (European Grid Infrastructure) [2], the successor of EGEE, as a member of the National Grid Initiative (NGI-DE). For 2011, it is planned to introduce middleware produced by the European Middleware Initiative (EMI) [3], which took over software developments from EGEE. Complementary to the batch-oriented Grid infrastructure, the National Analysis Facility (NAF) was set up at DESY in 2008. It was designed and built to meet the special needs of data analysis.



Grid infrastructure

DESY operates one Grid infrastructure for all supported virtual organizations (VO). It contains all node types to make it a complete Grid infrastructure with all mandatory services. VO-specific unique core services are VOMRS/VOMS to manage VO members and file catalogue services (LFC). Core services with multiple instances are the workload management (WMS), proxy server (PX) and information services (BDII). Resources are provided by computing elements (CE) and storage elements (SE). The SEs are based on dCache. Many of the services run multiple instances to ensure performance and reliability.

DESY is the home for the HERA VOs (HONE, ZEUS, HERMES), the linear collider community (ILC, CALICE), astroparticle physics (ICECUBE), lattice QCD (ILDG) and photon science (XFEL.EU). DESY supports the LHC VOs hosted at CERN (ATLAS, CMS, and LHCb), astroparticle physics (CTA) and bioinformatics (BIOMED). The commitment to provide computing and storage resources for ATLAS, CMS and LHCb as a Tier-2 centre is based on the Memorandum of Understanding (MoU) with WLCG. Furthermore, DESY operates VO-specific Grid services such as VOBoxes, PhEDEx for the CMS data transfer system, an Oracle-based tag database for ATLAS and various Squid servers to cache conditions data for ATLAS and CMS.

Figure 1

Accumulated time spent on DESY Grid and NAF resources in 2010, detailed for the different VOs. Although ATLAS and CMS consumed most of the resources, other communities like HERA, ILC and astroparticle physics also use substantial parts of the resources.

The DESY Grid resources are located at the two DESY sites in Hamburg and Zeuthen. Per job slot, 2 GB to 4 GB of memory and at least 15 GB of local disk space are provided on the compute nodes – called worker nodes (WN).
The resource distribution is listed in Table 1.

Table 1: Overview of the resources at both DESY sites

Site	Physical cores	Job slots	Hosts	Disk space
DESY-HH	2956	4236	371	1.5 PB dCache (w/o HERA data)
DESY-ZN	784	784	90	1 PB dCache
NAF	1664	1664	256	150 TB Lustre

Operations

The HERA experiments have massively used Grid resources mainly to produce Monte Carlo events worldwide. Their VOs are constantly utilizing a sizeable fraction of the resources at DESY. For ILC event simulation, campaigns for detector studies were carried out exclusively on the Grid. Comparable resources would not be available on local resources. The CALICE collaboration as well as the EUDET time projection chamber (TPC) and pixel telescope groups are using the Grid to store their test beam data, which allows for seamless access from all over the world. The Zeuthen site operates as Tier-1 centre for the IceCube project. It hosts half of the Monte Carlo data and all of the second-level data. In addition, it acts as a backup for the Tier-0 site in Madison, USA. CTA is already running large-scale Monte Carlo simulations on the Grid. This can be considered as a proof for the CTA collaboration that the Grid is ready to be used also for this new project (Fig. 1). With the transition from EGEE to EGI, the global operations model changed from centrally managed into a national mode. In the course of 2010, monitoring of the sites was moved to the NGIs, in case of DESY NGI-DE, which is located at FZ Karlsruhe. DESY regularly participates in on-duty shifts.

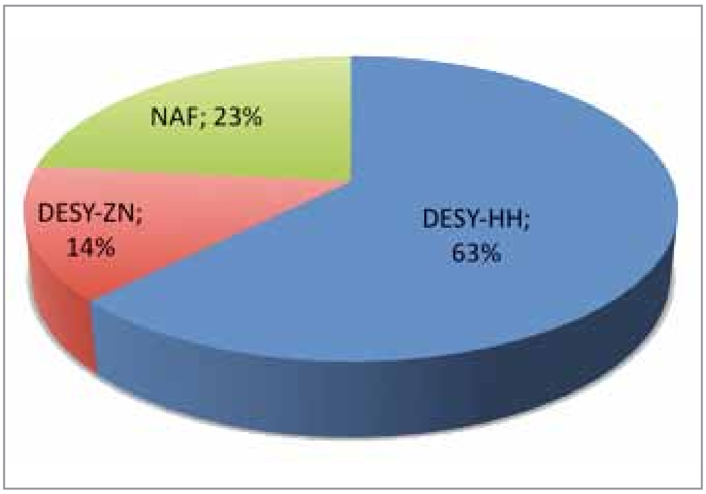


Figure 2

Repartition of CPU consumption between the Grid sites of Hamburg and Zeuthen, and the NAF

The National Analysis Facility

The NAF was set up in the context of the Helmholtz Alliance “Physics at the Terascale”, with the goal to offer the best possible infrastructure for German high-energy physicists by complementing the DESY Grid infrastructure. 2010 was a special year for the NAF, as the first real data was taken at the LHC and analysed. It was shown that the NAF is up to its task and appears to be a very important tool for data analysis.

Usage of the NAF in 2010

The most prominent cases of analysis use of the NAF are:

- The NAF provides tools for the experiment administrators to boost analyses with higher priority.
- The NAF enables users to use the PROOF facility for their data analysis. This tool spreads one analysis task over many different worker nodes while maintaining interactivity for users. Although usage is still low, it is growing with more data recorded.
- In the NAF context, the dCache storage space for ATLAS and CMS has been enlarged by 500 TB to host additional data necessary for analysis, ranging from user n-tuples to ESDs.

The NAF has attracted hardware contributions from outside. In 2010, hardware purchased by the University of Hamburg was put into service as an integral part of the NAF. This model allows the university group to profit from the NAF services. It also shows that pooling of resources into one common infrastructure, the NAF, is more economic than building separate dedicated entities. In 2010, NAF users from the LHC collaborations contributed to several early publications on LHC data.

Contact:

Andreas Gellrich, andreas.gellrich@desy.de
Andreas Haupt, andreas.haupt@desy.de
Yves Kemp, yves.kemp@desy.de
Peter Wegner, peter.wegner@desy.dee

References:

[1] http://lcg.web.cern.ch/lcg/
[2] http://www.egi.eu/
[3] http://www.eu-emi.eu/
[4] http://naf.desy.de

dCache.

The data management workhorse

With the start of the Large Hadron Collider (LHC) physics programme at the end of March 2010, the dCache technology has proven to easily cope with the requirements imposed by heavy LHC production. Several tens of petabytes of data have been transferred and stored by the various Tier-1 and Tier-2 centres around the world. dCache manages at least 50% of the total amount of data. As this was a very critical time for the LHC Computing Grid (LCG), dCache development focused on performance and stability of the deployed golden release. However, in order not to lose contact with ongoing activities in modern technologies, dCache offered new functionality in special feature releases. All those improvements will be incorporated into the next generation of the golden release expected for May 2011. In May 2010, the European Middleware Initiative (EMI) was started as part of the seventh European Framework Programme (FP7). In this context, dCache represents one of the four major components of EMI, beside ARC, gLite and UNICORE. EMI significantly contributes to the overall dCache funding in terms of development and support.

The dCache software enhancements

Imposed by the work description of EMI, dCache got the chance to focus even more on industry standards and interoperability with other Grid components.

Particularly challenging is the ongoing development of an automatic synchronization of the dCache namespace with the distributed metadata catalogues of the LHC experiments, the integration of a common-policy-based authorization system (ARGUS) and the migration from GSI to standard SSL/X509 authentication for the storage resource manager (SRM).
As in 2009, dCache is continuing to enable sites to mount the dCache file system with the NFS4.1/pNFS industry standard protocol and to allow authenticated web accesses through http(s) and WebDAV, features which are essential for non-HEP applications.

The collaboration, the support model and dCache.org

At the beginning of 2010, the dCache collaboration, composed of DESY, Fermilab and the Nordic Data Grid Facility (NDGF), was expanded by the Swedish National Infrastructure for Computing (SNIC).

Their plan is to build the Swedish national storage infrastructure on top of the dCache software. Being part of the collaboration gives them the advantage of getting more influence on the direction dCache will take in terms of technology, deployment and release procedures.

In addition to the core dCache collaboration, other groups and organizations support dCache in different ways. In Germany, the D-Grid Integration Project as well as the Helmholtz Alliance “Physics at the Terascale” are supporting dCache development

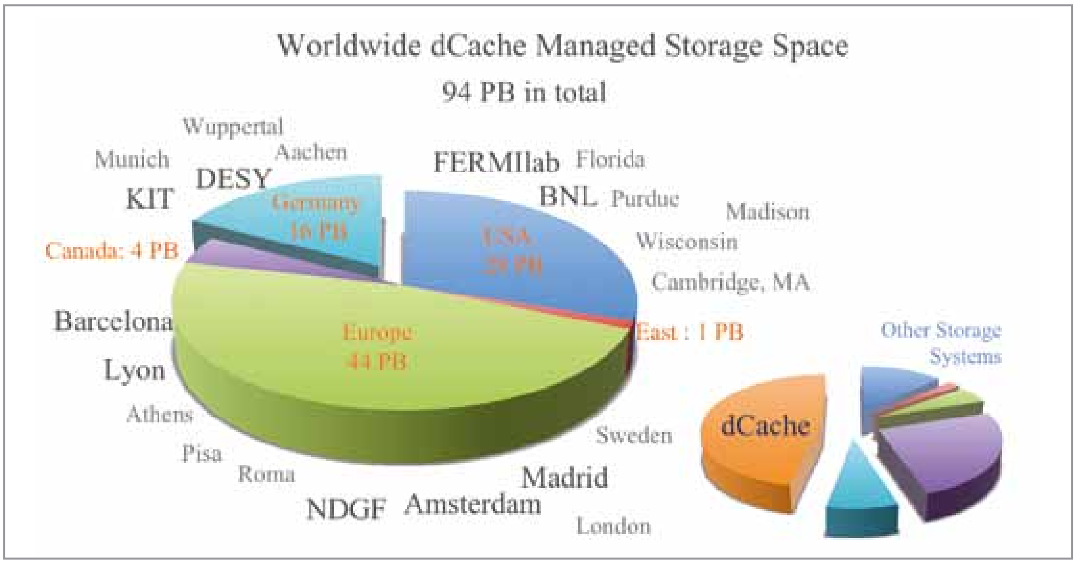


Figure 1

dCache managed storage of LHC data worldwide at DESY and dCache system administration at the various German data centres. The latter form the German dCache Support Group, coordinating activities such as regular information exchanges, tutorials and workshops, e.g. the dCache session during the GridKa School of Computing and the annual dCache users workshop. In the USA, the Open Science Grid (OSG) initiative deploys dCache trough the virtual data toolkit (VDT), their data management base system. The first-level support for the North European countries is completely covered by the Nordic Data Grid Facility. Since May 2010, dCache has been a partner in the European Middleware Initiative (EMI), with the advantage of additional funding, professional deployment and software quality control.

The glue between the distributed code development and the networking activities described above is dCache.org. It is primarily funded by DESY and provides standard interfaces to the developers and customers. It covers the overall project management, which includes representing dCache in various forums, e.g. the Grid Deployment Board, the OSG External Software Group, the German DGI-II and Physics at the Terascale, as well as to EMI. Finally, dCache.org collects requirements of potential customers and presents solutions.

Deployment

At the time being, dCache is primarily used in the context of the LHC and high-energy physics storage. Eight out of the eleven LHC Tier-1 sites in the USA, France, Spain, Canada, Northern Europe, the Netherlands and Germany run dCache, as well as about 40 Tier-2 centres around the world. In total, close to 100 petabytes of data are already stored in dCache installations, which is more than 50% of the entire LHC data.

In order to allow those sites to plan their software upgrades properly and still comply with the WLCG requirement of not applying new software during the first run period, dCache.org introduced the concept of a golden release in 2009. A golden release is guaranteed to be supported for at least a year and no new feature will be added to such a branch. The next golden release will be identical to the first production release of EMI (EMI-1). At DESY, PETRA III and CFEL will use dCache to access the back-end tape system, and the European XFEL is describing dCache in their computing technical design report as their preferred storage system. LOFAR, the Dutch-based Low Frequency Array Antenna project is using dCache at sites in Amsterdam and Jülich, and the Swedish National Infrastructure for Computing recently decided to build a nation-wide dCache infrastructure for data-intensive communities.

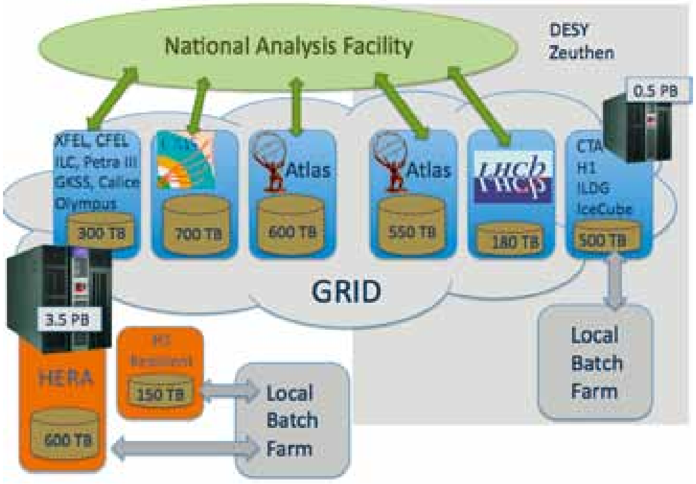


Figure 2

Overview of dCache installations at DESY

dCache at DESY

Fig. 2 gives an overview of the dCache installations at DESY. The DESY Hamburg dCache operations team (DOT) manages five dCache instances. Three are Grid-enabled storage elements (SE), two of which are dedicated to LHC experiments and their virtual organizations (ATLAS, CMS). A third one mainly serves ILC and photon science experiments. The two remanding SEs are utilized by the local HERA experiments and don't need to be accessible from within the Grid. Our colleagues in Zeuthen are managing three Grid-enabled dCache instances, one of which is attached to a tape storage system.

At the beginning of 2010, the HERA dCache was completely refurbished. Within 10 days, the hardware was renewed and more than 15 million file name entries were converted from PNFS to Chimera, the new and highly scalable dCache name space engine.

With this upgrade, the 600 TB of disk and 3.5 PB of tape data are well prepared for the demanding access profile of the HERA physics analysis of the coming years.

In the data model of the LHC experiments, Tier-2 centres only store replicas of files, with the obvious consequence that archiving data to tape is not required. That is completely different for ILC and photon science data, which are unique data from test beams for detector development and experiments from photon beamlines like PETRA III and FLASH.

The three Grid-enabled storage elements are configured for the same type of access but from different computing infrastructures like the LHC Tier-2 and the National Analysis Facility (NAF). AT the end of 2010, they reached a total disk capacity of 1.5 PB.

Contact:

Patrick Fuhrmann, patrick.fuhrmann@desy.de

Reference:

www.dcache.org

Single-shot spectroscopy of femtosecond electron bunches.

Results from FLA

The high peak current required in the free-electron laser FLASH is realized by longitudinal compression of the electron bunches to sub-picosecond length. The diagnostics of such ultrashort bunches is at the limit of time-resolved techniques. A frequency domain method has been developed that is capable of resolving structures in the femtosecond regime. A novel multichannel grating spectrometer with fast readout was built which permits broad-band spectroscopy of the coherent transition radiation emitted by single electron bunches. Test measurements show excellent performance of the spectrometer.

The electron bunches in FLASH are longitudinally compressed to achieve peak currents in the kA range which are necessary to drive the high-gain free-electron laser (FEL) process. Bunch compression is accomplished by a two-stage process: first an energy chirp (energy-position relationship) is imprinted onto the 10 ps long bunches emerging from the electron gun, and then the chirped bunches are passed through two magnetic chicanes.

Magnetic compression of intense electron bunches is strongly affected by collective effects in the chicanes. Space charge forces and coherent synchrotron radiation have a profound influence on the time profile and internal energy distribution of the compressed bunches. The collective effects have been studied by various numerical simulations but the parameter uncertainties are considerable and experimental data are thus indispensable for determining the longitudinal bunch structure. Using a transverse deflecting microwave structure, our group carried out the first time-resolved phase space tomography of the compressed bunches in FLASH. The rms time resolution was 25 fs. This resolution is insufficient for an investigation of the microbunching effects that were theoretically predicted to happen in electron bunches passing the magnetic chicanes of a bunch compression system.

Frequency domain techniques provide a complementary access to the femtosecond regime. For this purpose an ultra-broadband beamline for coherent transition radiation (CTR) was built which transports electromagnetic radiation ranging from millimetre waves down to the optical regime and permits spectroscopic measurements in a laboratory outside the accelerator tunnel. The CTR is produced by single electron bunches that are picked out of the bunch train by a fast kicker magnet and passed through a 350 μm thick polished silicon wafer with a 150 nm thick aluminium coating on the front surface. The CTR leaves the electron beam pipe through a 0.5 mm thick diamond window featuring high transmission over a large wavelength range, from visible light to the far-infrared (THz) regime. The radiation is guided through a 20 m long evacuated beamline equipped with six focusing mirrors to a laboratory outside the accelerator tunnel. The spectrometer is mounted in a vacuum vessel that is attached to the CTR beamline without an intermediate window.

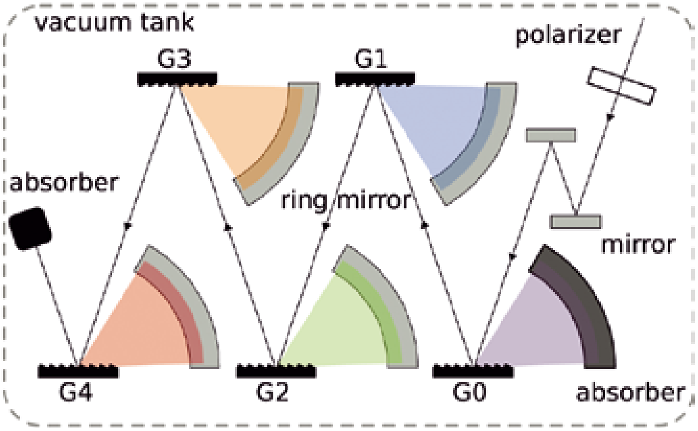


Figure 1

Principle of the four-stage spectrometer mounted in the vacuum chamber attached to the CTR beamline (not to scale). Explanations are given in the text.

We have developed a novel broad-band spectrometer with single-shot capability. With two sets of gratings, which can be interchanged by remote control, either the far-infrared wavelength range from 45 to 430 μm or the mid-infrared range from 5.1 to 43.5 μm is covered. The spectral intensity is recorded simultaneously in 120 wavelength bins. Each grating set is composed of five consecutive reflection gratings with triangular grooves. For long wavelengths ($\lambda \geq 1.33$ d, where d is the groove spacing), the gratings behave as plane mirrors. This effect is utilized in the multistage spectrometer shown in Fig. 1.

The following numbers refer to the far-infrared configuration. The radiation emerging from the CRT beamline is directed towards grating G0 which acts as a low-pass filter: the high-frequency part of the CRT spectrum (wavelengths $\lambda < 44.2$ μm) is dispersed and guided to an absorber, while all wavelengths above 44.2 μm are specularly reflected by G0 and sent to grating G1. CRT in the range from 45.3 to 77.4 μm is dispersed by G1 in first order and focused onto a multichannel detector array, while radiation with $\lambda > 77.9$ μm is specularly reflected and sent to G2. The subsequent gratings work similarly and disperse the wavelength intervals [77.0, 131.5] μm (G2), [140.0, 239.5] μm (G3) and [256.7, 434.5] μm (G4).

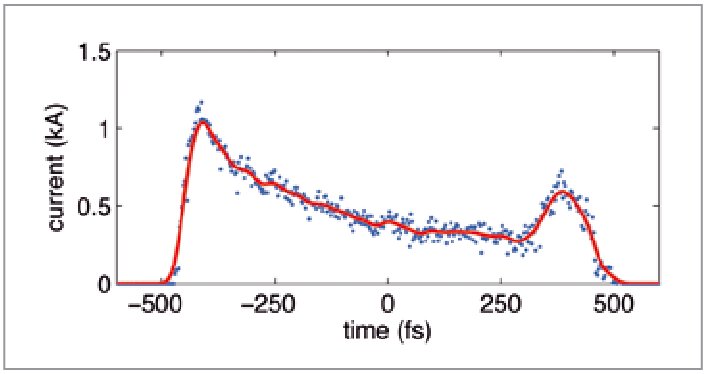


Figure 3

Measured longitudinal bunch profile

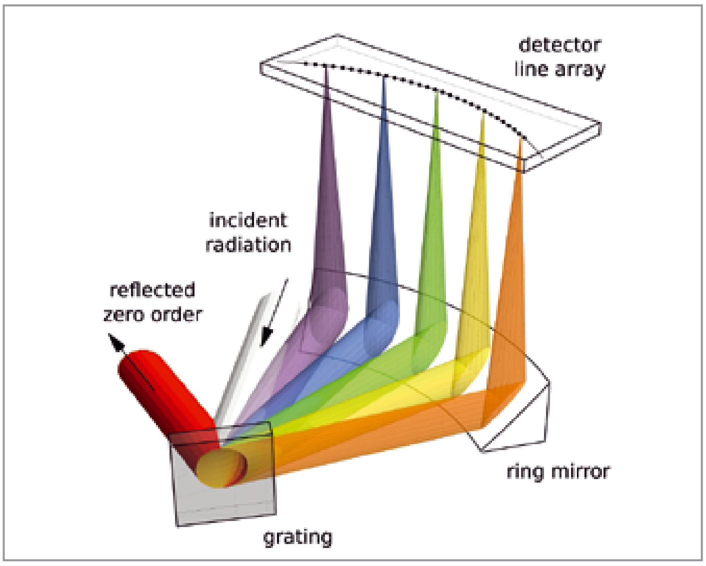


Figure 2

Arrangement of the grating, the ring mirror and the array of 30 pyroelectric detectors. The light dispersion and focusing were computed with a ray-tracing code. For clarity only 5 of the 30 wavelength channels are shown.

For each grating, the first-order diffracted radiation is focused by a ring mirror of parabolic shape onto an array of 30 pyroelectric $LiTaO_3$ detectors. This is shown schematically in Fig. 2. Special pyroelectric detectors featuring high sensitivity from the near-infrared to the far-infrared regime were developed by an industrial company (Infratec) according to our specification. These sensors have a fast readout to cope with the electron bunch spacing of 1 μs or less in the superconducting linear accelerators of FLASH and the European XFEL.

To verify the performance of the spectrometer, test measurements with bunches of known shape were carried out. The time profile of the bunches was determined with the transverse deflecting microwave structure. It is shown in Fig. 3. Using Fourier transformation, we computed the expected CTR wavelength spectrum (see top part of Fig. 4). The measured spectrum, depicted in the same figure, agrees very well with the expectations. This is a convincing demonstration of the capabilities of our multistage spectrometer.

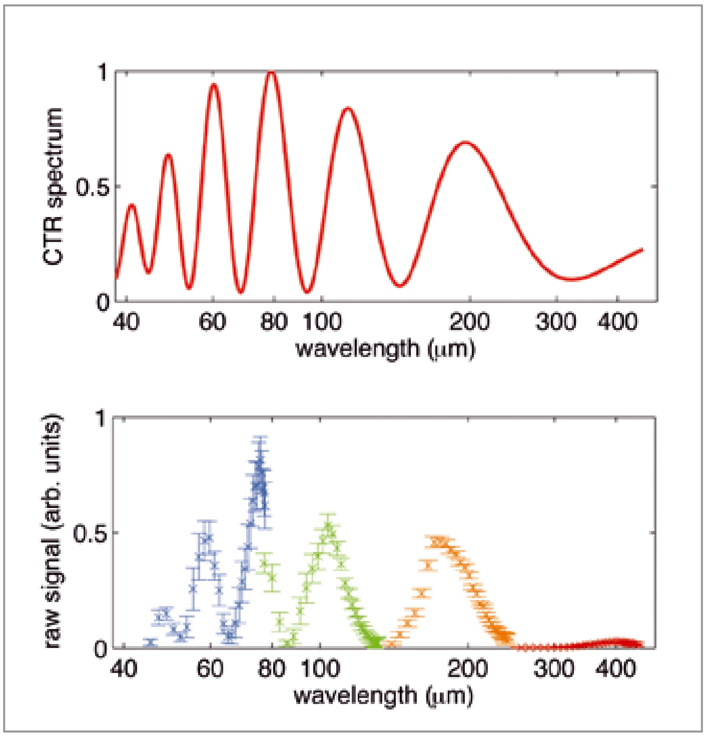


Figure 4

Top: computed CTR wavelength spectrum of the bunch shown in Fig. 3

Bottom: measured spectrum

A unique feature of the spectrometer is its ability to provide online data on the CTR spectrum in 120 wavelength bins. Any significant change in the bunch profile will be immediately visible in the spectrum. Hence the multistage spectrometer can serve as a highly specific bunch compression monitor in FLASH. Studies are under way to incorporate such a device in a bunch compression feedback system.

Contact:
Berhard Schmidt, bernhard.schmidt@desy.de
Stefan Wesch, stefan.wesch@desy.de

Solid ground.

Electromagnetic compatibility at the European XFEL

The European X-ray free-electron laser facility European XFEL is currently being constructed between DESY in Hamburg and the neighbouring town of Schenefeld. In this 3.4 km long facility, high-power radio frequency (RF) stations are operated in close vicinity to high-precision diagnostics instruments. This makes electromagnetic compatibility (EMC) an important issue to be considered already in the design phase of the project. A well-designed grounding system is an essential ingredient for EMC.

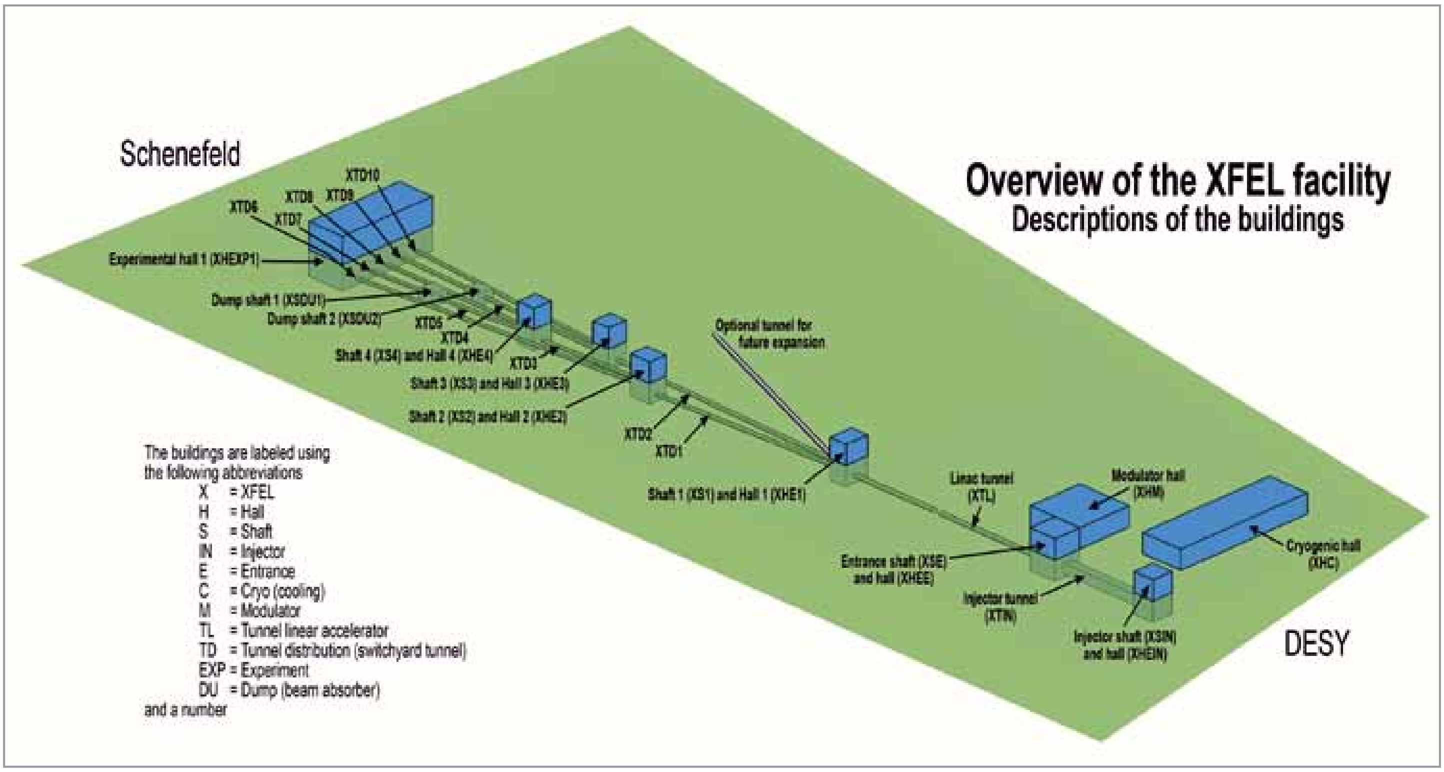


Figure 1

General layout of the European XFEL

The European XFEL facility comprises a laser injector, a superconducting electron linear accelerator (linac), several undulator beamlines to which the accelerated electrons are distributed in order to generate X-ray photons, and an experiment hall where ten sets of experiments will be set up. Being located in an inhabited area, most of the European XFEL will be built underground. The facility essentially is a set of buildings with up to seven floors below ground (shafts) and up to two floors above ground (halls). The shafts are connected by tunnels. The total length of the facility from the injector to the experiment hall is about 3.4 km. Figure 1 shows a schematic overview of the European XFEL facility.

The first two kilometres of the facility are occupied by the injector and the superconducting electron linac. Here the electrons are accelerated to an energy of 17.5 GeV. The klystrons and pulse transformers will be located in the tunnel, close to the accelerator modules, while the modulators are

Figure 2

Inclusion of the tunnel steel in the European XFEL facility ground: 1 Steel cages – 2 Ground connector – 3 Tubbing mould – 4 Produced tubbings – 5 Tubbings in place (with yellow grounding points) – 6 Connected tubbings

installed in a hall above ground. This scheme allows for modulator maintenance during Eurpean XFEL operation without an expensive service tunnel (no klystron gallery). The pulse transformers are connected to the modulators via shielded coaxial pulse cables which are up to 1.5 km long. The nominal modulator pulse data are U = 8.9 kV, I = 1.5 kA, t = 1.57 ms, f = 10 Hz. For 27 RF stations, this results in a maximum RF pulse power of 360 MW being transferred into the tunnel.

Even if only in the per mill region, current leakage from the high-power RF pulse cables might considerably interfere with the operation of nearby instruments for beam diagnostics, femtosecond synchronization, experiments etc. Under such circumstances, it was considered important to address questions of electromagnetic compatibility (EMC) already in the design phase of the European XFEL. The EMC work package was taken over by the DESY group FLA-FEL.

An important ingredient of EMC is a well-designed grounding system. The main purpose of a grounding system is to offer noise currents a low-impedance return path to their sources, thus shunting them away from delicate parts of the installation. In an extended facility like the European XFEL, the grounding system must be hierarchically organized. Local grounding systems then connect to a facility ground mesh which includes as much as possible of the metal infrastructure of the facility. An important ingredient is the reinforcement steel in the tunnel walls. The picture sequence in Fig. 2 shows how the tunnel wall segments (so-called tubbings) are incorporated into the European XFEL facility ground backbone.

Contact:

Herbert Kapitza, herbert.kapitza@desy.de

Reference:

http://xfel.desy.de/project_group/work_packages/control_and_operation/e513/index_eng.html

International Linear Collider.

Living the synergy with the European XFEL

The electron beams for the European XFEL will be accelerated in superconducting niobium cavities operating at 1.3 GHz. Contracts for the mass production of some 600 cavities have been concluded and production is foreseen for early 2012. This is the largest worldwide production of cavities so far. The same technology is foreseen for the future International Linear Collider (ILC), albeit at considerably higher gradient. The ILC will be an electron-positron (e^+e^-) collider with centre-of-mass energies of initially 500 GeV and upgradeable to 1 TeV. Since the superconducting cavities are one of the main cost drivers of the project, the production of the cavities for the European XFEL is observed with considerable interest and accompanied by specific activities, such as the ILC-HiGrade project that is mentioned elsewhere in this report.

International Linear Collider

The ILC is being optimized in a Global Design Effort of some thirty institutes worldwide. The machine will consist of two counter-running linacs of twelve kilometres length each. The beams are focused to nanometre size before colliding at the interaction point. Following the publication of the Reference Design Report for the ILC in 2007, the layout and design of the machine are now being addressed to reduce risk and cost. This technical design phase will culminate in a Technical Design Report foreseen for the end of 2012.

With the linacs being one of the cost drivers, there is considerable interest in understanding the performance of mass-produced cavities for the European XFEL and in trying to further reduce the cost of manufacture.

Performance of superconducting radio frequency cavities

There has been considerable progress in understanding the limitations of cavity performance. Field emission from sulphur compounds has been identified as a key limiting factor, which can be removed by an additional alcohol rinse. The alcohol rinse has now been included in the specification for the cavity production for both the European XFEL and ILC. With special attention to the surface cleanliness, cavities should perform at gradients of 35 MV/m foreseen for the acceptance test of the ILC cavities, and in doing so provide significant performance margin for the lower European XFEL gradient requirement.

The acceptance test for qualifying cavities was agreed to globally. A database was set up at DESY to register the cavity performance results. It is continuously updated as new results become available. A snapshot of these results is shown in Fig. 1.

The figure indicates that integrally, the fraction (or ‘yield’) of cavities that were subjected to the accepted treatment procedure and exceeded a gradient of 35 MV/m is now above 50 % – the stated R&D goal for 2010. Thus it can be speculated that every second cavity produced industrially following the agreed recipe would meet the operational goals of the ILC. The yield is to be pushed to 90% by the year 2012, the end of the ILC Technical Design Phase. This goal has already been achieved by a small series production of cavities, based on low statistics and a single cavity vendor.

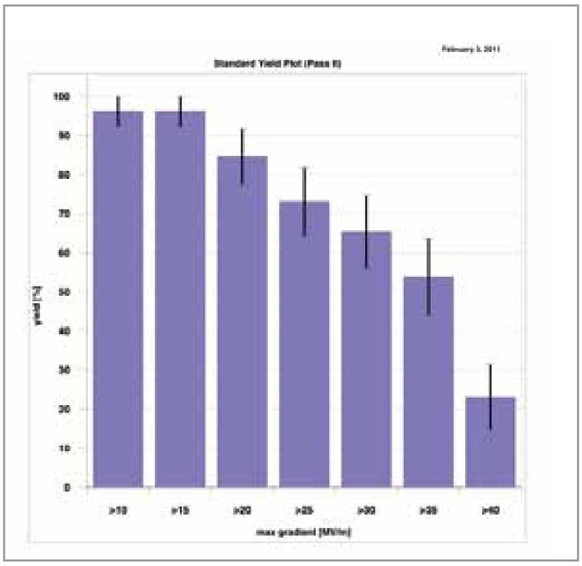


Figure 1

The yield of superconducting cavities as a function of the maximum gradient achieved after the second pass. Note that the (integral) yield for cavities above 35 MV/m exceeds 50%.

Standardizing cavity production

In addition to the recipe for manufacture, DESY has also developed standardized tools and measurement procedures relevant to the production of the cavities. Two of these tools are shown in Fig. 2 and 3. The tuner of Fig. 2 measures the RF response of cavity half-cells [1]. Figure 3 shows the tuning machine that mechanically adjusts the size of the cavity cells to meet the resonance condition for the cavities. Note that with the high quality factor of the cavities ($>10^{10}$) the geometric extent of the cavity is of extreme relevance. The tuning machine enables the manufacturing process to tweak the individual cell to meet the resonance condition.

Both automatic setups will be made available to the manufacturers of the cavities and will be used during the production. It is hence guaranteed that the recorded protocols will meet the same standards, a key ingredient in understanding the cavity performance.

Figure 2

The machine and controls for measuring the RF performance of cavity half-cells (HAZEMEMA) [1]. The protocols are automatically registered and recorded.

Figure 3

The tuning machine [2] that mechanically adjusts the size of individual cells to meet the stringent resonance requirements of the accelerator. The adjustment is done fully automatically, thus increasing reproducibility and reducing cost.

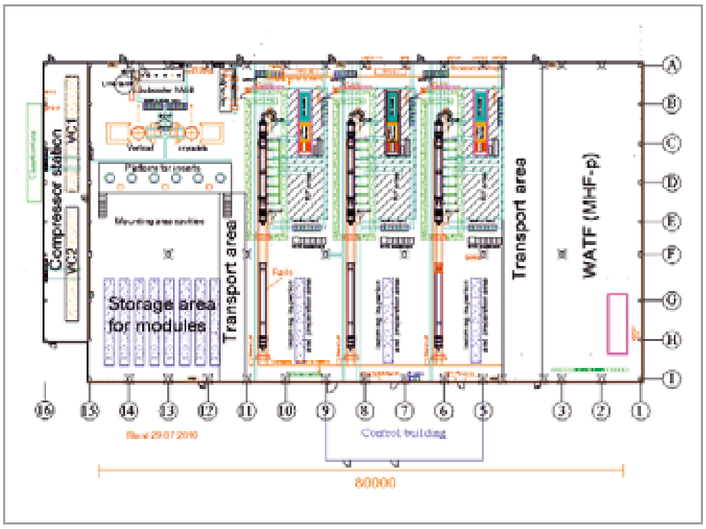


Figure 4

Sketch of the Accelerator Module Test Facility. The 80 m long building houses the vertical cryostats for the acceptance test of the delivered cavities and the high-power area for the test of the completed cryomodules.

Accelerator Module Test Facility

Over the past two years, the Accelerator Module Test Facility (AMTF) has been built at DESY. A layout of the facility is shown in Fig. 4. The AMTF hall houses the vertical cryostat for the acceptance test of the delivered cavities and the infrastructure for the high-power tests of the completed cryomodules that each accommodate eight nine-cell cavities. The FH group contributed specifically to the layout of the vertical test stands and the RF controls.

Contact:

Eckard Elsen, eckard.elsen@desy.de

Authors and references:

S. Aderhold, E. Elsen, J. Schaffran

[1] J. Iversen et al., Development and Design of a RF-Measurement Machine for the European XFEL, THPPO071, Proceedings of SRF2009, Berlin, Germany.

[2] J.-H. Thie et al., Mechanical Design of Automatic Cavity Tuning Machines, THPPO074, Proceedings of SRF2009, Berlin, Germany.

ILC-HiGrade.

Chasing quenches in niobium superconducting cavities

Superconducting niobium cavities operating at a radio frequency of 1.3 GHz were developed to maturity by the TESLA collaboration in the 1990s. They will accelerate the electron beam for the European XFEL under construction at the DESY site in Hamburg and are foreseen for the future International Linear Collider (ILC). The ILC will be an electron-positron (e^+e^-) collider with centre-of-mass energies of initially 500 GeV and upgradeable to 1 TeV. Such high energies call for the highest possible accelerating fields: the ILC currently foresees accelerating fields of 31.5 MV/m, some 50% higher than required for the European XFEL. The European Commission is supporting the project ILC-HiGrade in its Framework Programme 7 amongst other things to advance the gradient of industrially produced cavities to that required by the ILC. Surface preparation techniques have been developed for the cavities of the European XFEL, which seem equally applicable for the ILC. Defects in the surface structure may lead to quenches of the superconductor. One diagnostic tool employed in locating the origin of the quench is the method of second sound, which detects the phase transition of superfluid helium.

European Commission engages in preparation of International Linear Collider

The European Commission accepted the ILC-HiGrade proposal in 2007 to advance the preparation of the International Linear Collider (ILC), and started to support six institutes to perform key development that fosters the realization of the ILC. Following the publication of the Reference Design Report [1] for the ILC in 2007, it became obvious that the key cost driver is the superconducting technology. The component count and hence the cost could be considerably reduced by increasing the accelerating gradient of the cavities. Consequently this is the key technical task of the ILC-HiGrade work package.

ILC-HiGrade comprises institutes from CEA, CERN, CNRS, DESY, INFN and the University of Oxford. DESY and CEA are focussing on the high gradient of superconducting cavities. The DESY effort profits from the production of more than 600 cavities for the European XFEL, which is due to begin at the end of 2011.

Other efforts within ILC-HiGrade concentrate on the layout of the ILC and the optimization of the site selection. In addition, ILC-HiGrade engages in developing governance models for the ILC, which is expected to be built as a truly international project. This activity profits from the experience of other large-scale projects.

Superconducting radio frequency cavities

Superconducting radio frequency cavities profit from the very high quality factor ($>10^{10}$), which results in very high power efficiency. High axial accelerating gradients (electric fields) correspond to large magnetic fields on the surface of the superconductor, which pose a hazard for the superconducting state and set the fundamental performance limit for the technology. Small surface irregularities may cause these fields to locally exceed the critical value and cause a quench, i.e. the loss of the superconducting state. Several surface preparation methods have been introduced to assure smoothness or to examine the surface visually. A new method developed at Cornell University has now been established at DESY to routinely locate quenches in situ during the quality acceptance test.

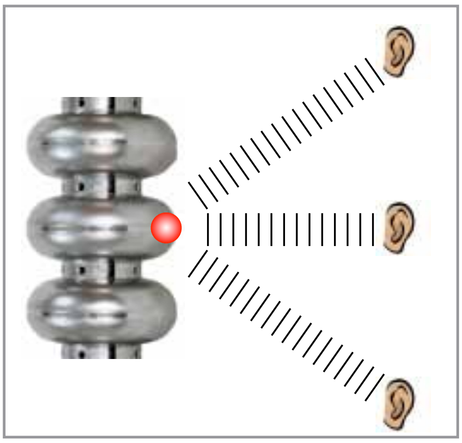


Figure 1
Quench localization by triangulation of the second-sound signals recorded in three detectors.

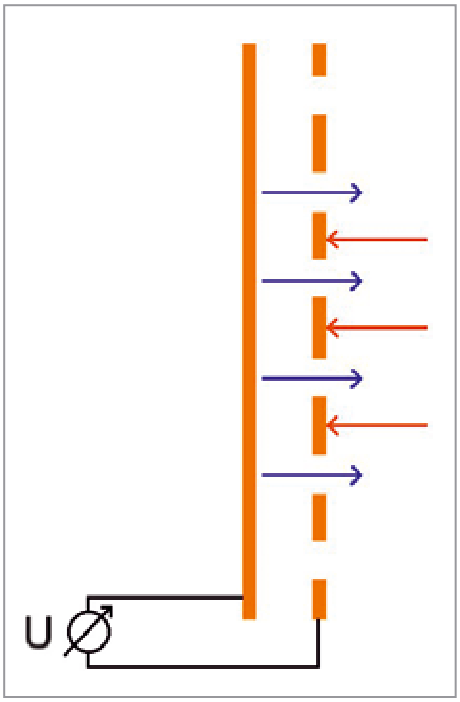


Figure 2

Principle of an oscillating superleak transducer (OST). The porous membrane is transparent for superfluid helium, while helium I is retained. The membrane is placed near the aluminium surface and acts like a condenser microphone: the helium I wave changes the distance of the membrane from the surface, which can be detected in a voltage change.

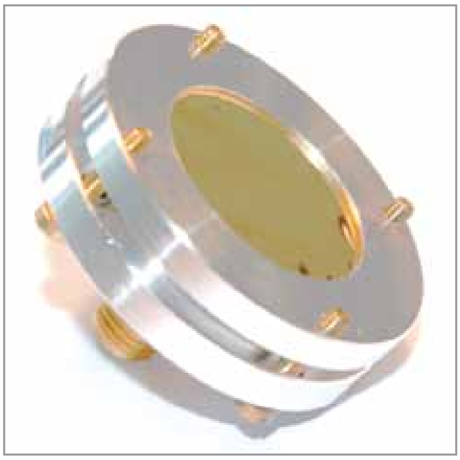


Figure 3

Photograph of an OST currently used to detect the phase transition. The porous membrane is seen at the front. The DC voltage connector appears at the back of the detector.

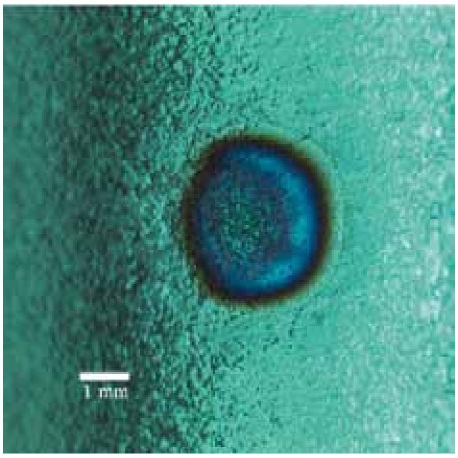


Figure 4

A defect located on the niobium surface. This macroscopic defect resulted from excessive high-pressure rinse when the rinsing nozzle „froze“ at the position.

Locating quenches

When the cavity quenches, heat is deposited locally and absorbed in the surrounding helium bath. Just above 2 K, the superfluid Helium goes into a phase transition to helium I, which is no longer superfluid. This phase transition, the second sound [2], propagates in the helium bath with a velocity of some 20 m/s. Specific microphones can be used to record the signal of the phase transition.

Fig. 1 displays the principle originally developed at Cornell University [3]: the origin of the quench can be derived from the signal recorded in several synchronized detectors using the known velocity. These detectors, oscillating superleak transducers (OST), very much resemble ordinary condenser microphones, as shown in Fig. 2. The distance of the metallized porous membrane to the detector base is varied by the second-sound wave and induces a voltage on the capacitor. The time of arrival can be precisely recorded and evaluated.

A photograph of an OST detector is shown in Fig. 3. The detector has a diameter of roughly 3 cm. Several such detectors can be suspended in the cryostat for the cavity without additional installation effort. They can be run routinely during cavity power tests. The quench-locating system using second sound has been assembled and first data were taken during 2010. The system is being further developed for automatic and routine measurements.

An example of a surface defect is shown in Fig. 4. The defect was introduced by the cleaning nozzle of the high-pressure rinsing system with ultrapure water, and caused a quench that was located by the second-sound system.

Plans for ILC-HiGrade

ILC-HiGrade will continue to develop further diagnostic tools for superconducting cavities, in particular the optical inspection. The group is thus well prepared for deriving maximum information on the field-limiting defects for superconducting cavities. It will profit from the large series production of the cavities for the European XFEL and specifically from the batch of 24 cavities for ILC-HiGrade that are expected to yield the highest possible fields, potentially after carefully chosen dedicated treatment.

Contact:

Eckhard Elsen, eckhard.elsen@desy.de

Authors and references:

S. Aderhold, E. Elsen, F. Schlander

[1] N. Walker, N. Phinney, N. Toge, editor. International Linear Collider Reference Design Report, Volume 3: ACCELERATOR. International Linear Collider Collaboration, 2007,

[2] W. M. Fairbank, C.T. Lane, Henry A. Fairbank. Second sound in liquid helium, Physical Review, 05, 1947,

[3] D. Hartill, Second sound as a cavity diagnostic tool. Jefferson lab seminar, Cornell Laboratory for Accelerator-Based Sciences and Education, 2008.

Plasma surfing.

Electron acceleration with peak gradients beyond 10 GV/m

The field of particle acceleration by laser- or beam-driven plasma wakes has seen remarkable progress in recent years. Nowadays, acceleration gradients exceeding 10 GV/m can be readily achieved, which has led to the development of compact, centimetre-scale plasma accelerators yielding femtosecond-duration, GeV-energy electron beams with charges of up to 100 pC and a normalized emittance of the order of 1 mm mrad rms. In 2010, a Young Investigators Group was installed in the framework of the Helmholtz Alliance "Physics at the Terascale" with the mission to further investigate this novel technology.

Riding the wave

An intense laser pulse or short particle beam propagating through a plasma medium excites strong co-propagating plasma waves, which feature enormous electric gradients in the 10 to 100 GV/m range. These fields can be used for the quick acceleration of charged particles that are inserted or trapped inside the wake structure. If phased right, those particles may surf down the plasma wave to gain energies on a GeV scale over just a few centimetres. This process occurs in similar fashion to a human surfer, surfing down a water wave to accelerate to high speeds.

In addition, the accelerated beams are intrinsically of femtosecond duration owing to a micrometre-scale plasma oscillation length. This property makes them attractive drivers for high peak brilliance photon sources.

Towards a plasma-based booster stage

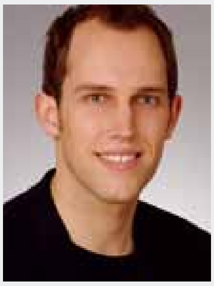
A focus of the newly established plasma acceleration team at DESY is the experimental demonstration of a plasma-based booster attached to a conventional electron accelerator. Such a system would allow for rapid acceleration while maintaining control over the initial beam properties. This scenario is being investigated with the help of numerical simulations (Fig. 1). Shown here is a 5 MeV, 10 fs electron bunch from a source similar to REGAE, which was coupled into a plasma wake driven by a 200 TW laser system. In a first study, the beam energy was found to be increased to ~185 MeV with an average gradient of 7.2 GV/m over an acceleration distance of 25 mm. An optimization of the plasma, beam and laser parameters will allow for improving this performance further. Even more important, experiments with beams from a well-characterized external source will enable the mapping of plasma wakefield properties with unprecedented accuracy. For the not-too-distant future, plasma accelerator technology holds the promise to help realize lab-scale accelerators to drive compact free-electron lasers at sub-nm wavelengths.

Reference: http://plasma.desy.de/

PHYSICS AT THE TERA SCALE Helmholtz Alliance

Young Investigators Group
"Plasma Acceleration"

Contact:
Jens Osterhoff, jens.osterhoff@desy.de



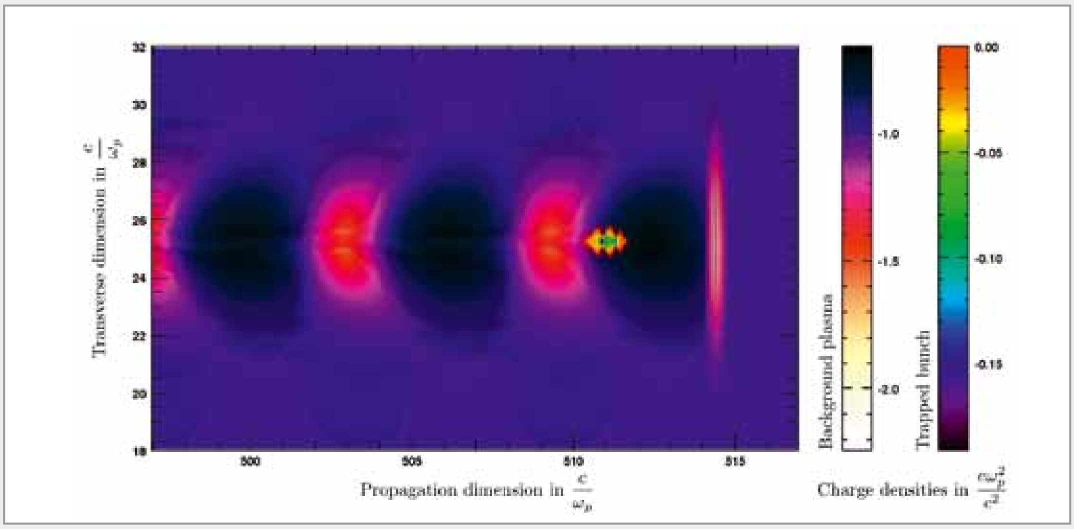


Figure 1

OSIRIS 2.0 particle-in-cell simulation of a few-femtosecond electron bunch trapped in a laser-excited plasma wakefield. The electrons are injected externally with parameters potentially achievable at a number of existing DESY facilities, e.g. at FLASH, PITZ or REGAE.

Dark matter and polarimetry.

Characterizing WIMPs with polarized electrons and positrons

The polarized electron and positron beams at a future linear collider are indispensable tools to unravel the nature of new phenomena beyond the Standard Model of particle physics. The power of these tools depends on the precision to which the actual beam polarizations can be measured before and after the collision point, and on how precisely the luminosity-weighted average polarization can be interpolated from these measurements. The Emmy Noether group of J. List combines R&D for the ILC's Compton polarimeters with case studies of the characterization of new particles employing beam polarization, and of the resulting requirements on the accelerator and the polarimeters.

About 25% of our universe consist of unknown particles called dark matter. If these particles are weakly interacting massive particles (WIMPs), they will be produced copiously in present and future collider experiments. Due to their at most weak interaction, they will escape the detectors leaving only indirect hints. These can either be exploited in cascade decays of additional, heavier new particles, or with the help of highly energetic photons emitted by the colliding particles before they produce a pair of WIMPs. The exact shape of the energy spectrum of these photons depends on the WIMPs' mass, their couplings to Standard Model particles and the orbital momentum of the dominant partial wave of the production, as well as on the detector resolution, the beam energy spread, the focusing of the beams and their polarizations. At the ILC, the polarizations can be positive or negative for both the electron and positron beams, leading to four different measurements. From these, the helicity structure of the WIMPs' couplings can be determined, as illustrated in Fig. 1.

With a total integrated luminosity of 500 fb^{-1} possible at the ILC, the measurement is limited systematically (red error bars), dominated by the contribution of a polarimeter uncertainty of $dP/P = 0.25\%$. The effect of this systematic uncertainty is reduced with a higher positron polarization. However, the assumed precision of $dP/P = 0.25\%$ has never been achieved before in Compton polarimeters. Therefore, a prototype Cherenkov detector as it could be deployed for detecting the Compton-scattered electrons at a linear collider polarimeter has been designed and operated in test beams both at DESY II and at ELSA in Bonn.

This prototype also serves the development of a calibration system, which is essential to reach the envisaged precision. These detector activities are accompanied by design studies of the complete polarimeters and simulations of the spin transport between the polarimeters and the collision point.

Reference: http://www.desy.de/~boehmej/emmy.html

DFG

Emmy Noether Junior Research Group

"Compton Polarimetry and Search for Dark Matter at the International Linear Collider"

Contact:

Jenny List, jenny.list@desy.de

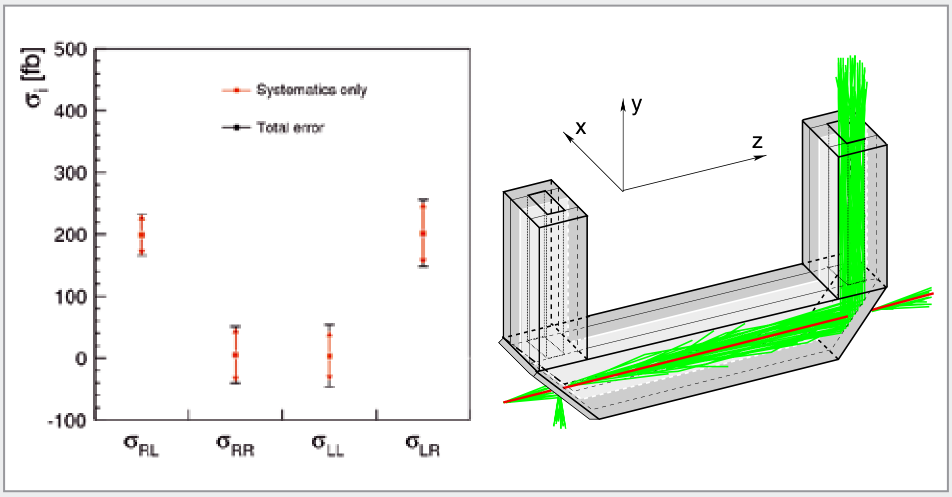


Figure 1

Left: Simulated measurements of polarized WIMP production cross sections (normalized to the unpolarized cross section) at the ILC with error bars indicating the systematic uncertainties (red) as well as the combined systematical and statistical uncertainties (black), for $P(e^+) = \pm 30\%$.

Right: Isometric view of one Cherenkov detector element with an electron (red) producing Cherenkov light (green) as simulated.

Designing the linear collider.

The impact of different accelerator and detector designs on the physics goals

A future linear collider will complement the LHC at the high-energy precision frontier. This requires not only a challenging detector design, but also a careful choice of accelerator parameters. A number of benchmark reactions have been simulated and analysed with a realistic level of detail, to study the interplay between accelerator parameters and physics capabilities. The results of these studies have a direct impact on the layout of the accelerator and on the design of the detector concept.

DESY plays a central role in studying and optimizing the physics potential of a future linear collider. After the publication of the Letter of Intent for the planned experiments at the International Linear Collider (ILC), the main focus has been on the comparison of various accelerator parameter sets.

Development of reconstruction techniques

In order to study the accelerator and detector performance, about 30 million electron-positron (e^+e^-) collisions have been simulated, reconstructed and analysed. The final performance of the experiment will result from the interplay of accelerator properties, detector technology and the algorithms employed in reconstructing and analysing the data. An example for basic development of reconstruction algorithms are kinematic fits which take into account the possibility of photon radiation emitted collinear to the colliding beams. Such a seemingly academic tool can significantly increase the precision of reconstruction for many final states, by estimating the energy which otherwise escapes undetected into the beam direction. Figure 1, which shows the fitted versus the true photon momentum, illustrates the quality of this algorithm. The resulting resolution on the photon energy is a factor two better than what can be obtained using other techniques, while at the same time the capability to improve the jet energy resolution is maintained as if no radiation were present.

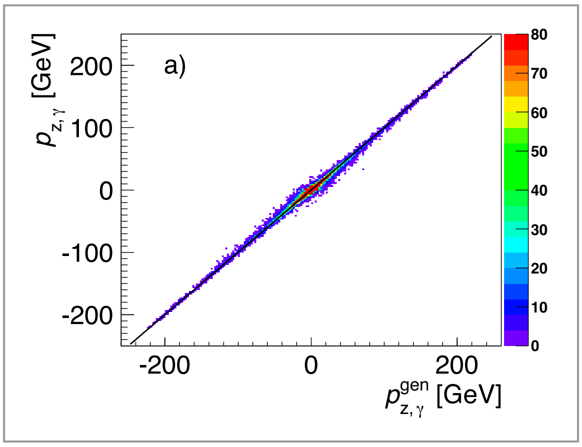


Figure 1

Reconstruction of photon radiation collinear to the colliding beams by a kinematic fit. Shown is the fitted versus the true momentum of the photon.

Benchmark reactions

DESY contributes significantly to the design of one of the detector concepts envisioned for the ILC, the International Large Detector (ILD). A main ingredient of the physics case is the capability to investigate potential new physics beyond the Standard Model.

Non-pointing photons

A number of new physics scenarios predict highly energetic photons which do not originate in the primary interaction region. The high granularity of the ILD electromagnetic calorimeter is a powerful tool to study these striking signatures. In a case study of the pair production of neutralinos decaying into photons and invisible gravitinos, it was demonstrated that both the mass and the lifetime of the neutralino can be reconstructed with sufficient accuracy. Figure 2 illustrates the lifetime measurement for two different lifetimes of 200 ps and 2 ns, respectively.

Beyond the Standard Model

One of the most popular extensions of the Standard Model is supersymmetry. Supersymmetry predicts a plethora of new particles with – sometimes – striking features. ‘The SPS1a’ model point is a specific instance of such a model, featuring a light mass spectrum for the non-coloured SUSY particles, as it is favoured by electroweak precision measurements. A comprehensive analysis of possible signatures and detection

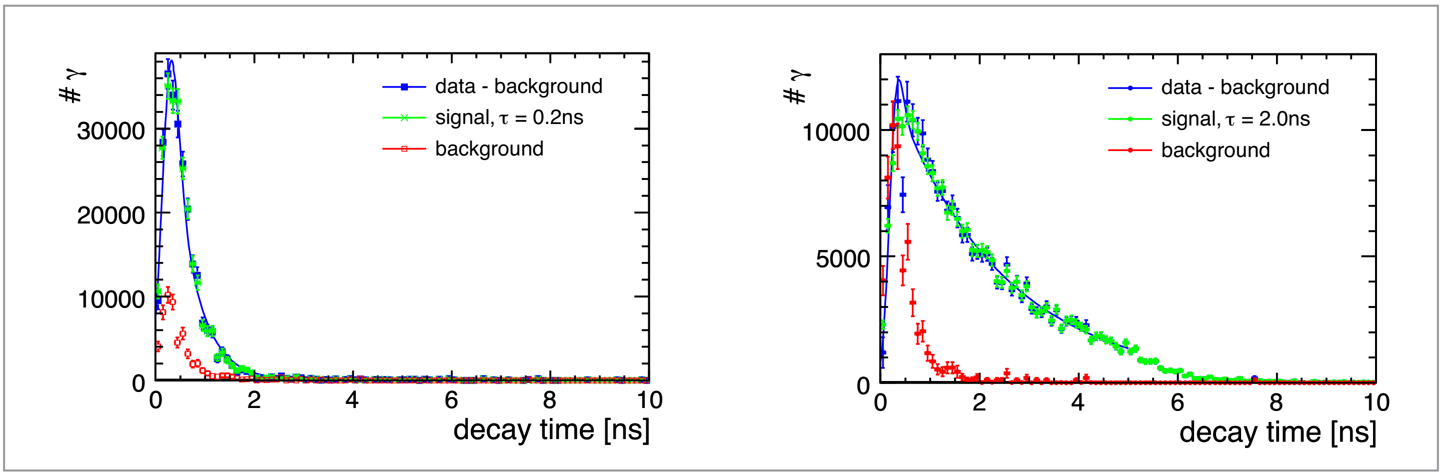


Figure 2

Reconstruction of the neutralino lifetime in decays into an invisible gravitino and a photon. Due to the highly granular electromagnetic calorimeter, the direction of the photon can be measured from the shower shape, allowing the determination of the neutralino mass and lifetime.

strategies was performed based on a large sample of simulated events. As an example the mass spectra of candidates for the second lightest neutralino are shown in Fig. 3, reconstructed in a simulated sample of 500 GeV events. The precision is comparable to the one obtained in a dedicated threshold scan.

Alternative accelerator designs

The choice of accelerator parameters not only determines the achievable beam energy, luminosity and polarization, but also quantities like the beam energy spread, the amount of beamstrahlung and machine-induced backgrounds. All of them have an impact on the precision with which important observables can be determined. As an example, the measurements of masses and production rates of the supersymmetric partners of the τ leptons have been studied in five different accelerator 'cases'. The mass of the lighter of the two supersymmetric τ's might be intimately linked to unveiling the nature of dark matter and is thus an especially important quantity to measure.

As illustrated in Fig. 4, the running time to obtain a certain precision can vary up to a factor of two between different accelerator parameter sets. These results are influencing the current choice of accelerator parameters for the technical design phase.

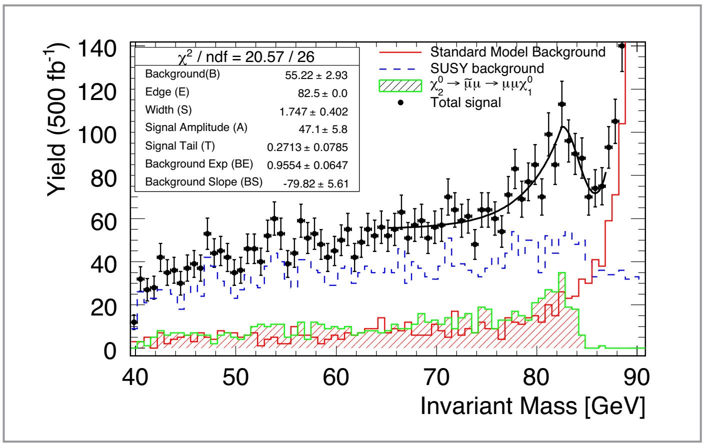


Figure 3

Mass measurement of the second lightest neutralino in decays into muons and the lightest neutralino at a centre-of-mass energy of 500 GeV. The resulting resolution is comparable to the one of a threshold scan.

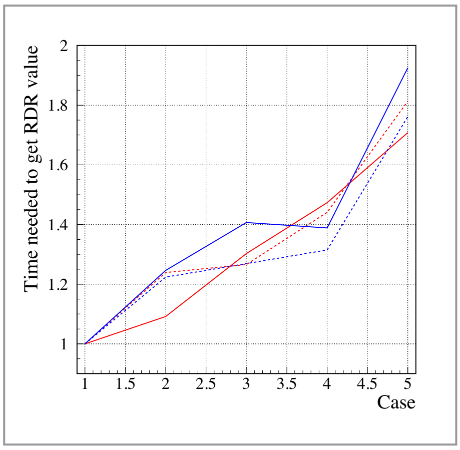


Figure 4

Running time needed to achieve the same precision on properties of the supersymmetric partners of the τ leptons for different sets of ILC accelerator parameters (normalized to the most favourable case).

Contact:

Ties Behnke, ties.behnke@desy.de

Reference:

www-flc.desy.de

Integration on large scales.

Engineering design for a particle physics detector

The International Large Detector (ILD) is one of two proposed detector concepts at the future International Linear Collider (ILC). Its engineering design and integration into the accelerator pose many challenges.

The International Large Detector (ILD) concept has been developed in the last years by an international team with strong participation from DESY. The design requirements of the detector are dominated by the technological needs – in hardware and software – that would allow the best exploitation of the physics potential of the linear electron-positron collider ILC. Emphasis has therefore been put mainly on the development of sub-detector technologies and on the optimization of the detector concept design with respect to the physics benchmark parameters. The results of these efforts were published in the ILD Letter of Intent ("ILD The Large International Detector – Letter of Intent", DESY-2009-87). In the current phase of the ILC effort that aims for the publication of the Technical Design Report in 2012, the detector concepts are moving towards a more realistic design that should also include a basic study of the engineering feasibility and the impact of technical realism to the physics performance.

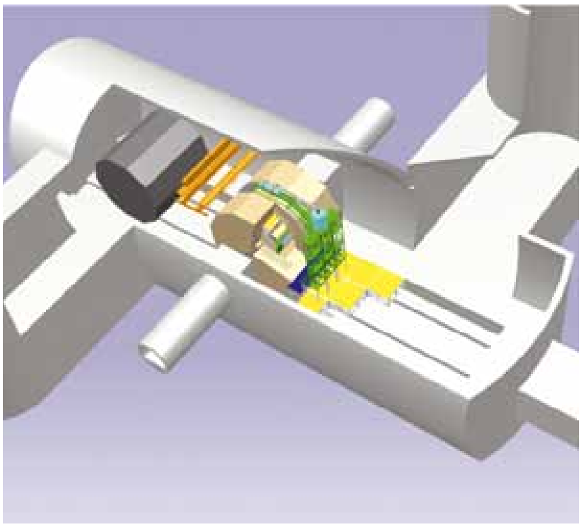


Figure 1

Study of underground hall with two detectors in push-pull configuration ("ILD The Large International Detector – Letter of Intent", DESY-2009-87)

The engineering paradigm of the ILD concept is defined by the boundary conditions in the special ILC environment. In contrast to a storage ring, the integrated luminosity sum of all experiments at a linear collider does not scale with the number of interaction regions. Nevertheless it is seen as mandatory to have more than one detector at the ILC to benefit from complementary detector designs and redundancy. The ILC design therefore foresees one interaction region in which two detectors share one beamline in a push-pull configuration. A possible solution to this challenge is studied within the ILD concept group, where the detectors would move on concrete platforms that are carried by air pads in and out of the beam position. The envisaged turnover times for the change of the two detectors are of the order of a few days to keep the luminosity loss from dead time as short as possible. Figure 1 shows a design study of the underground experimental hall with two detectors in such a push-pull configuration.

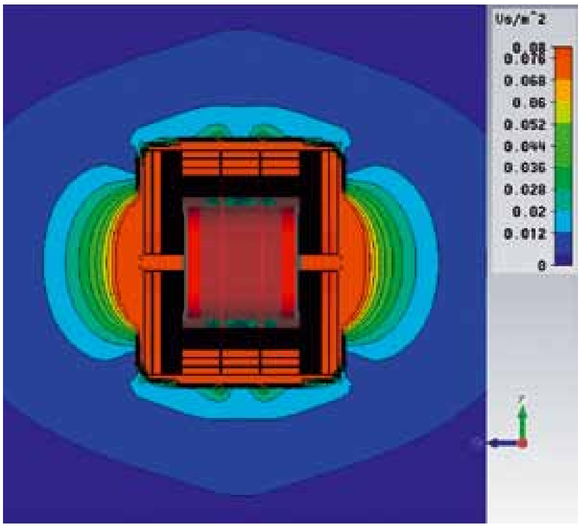


Figure 2

Magnetic field simulation of the ILD detector for a field strength of 4 T at the interaction point

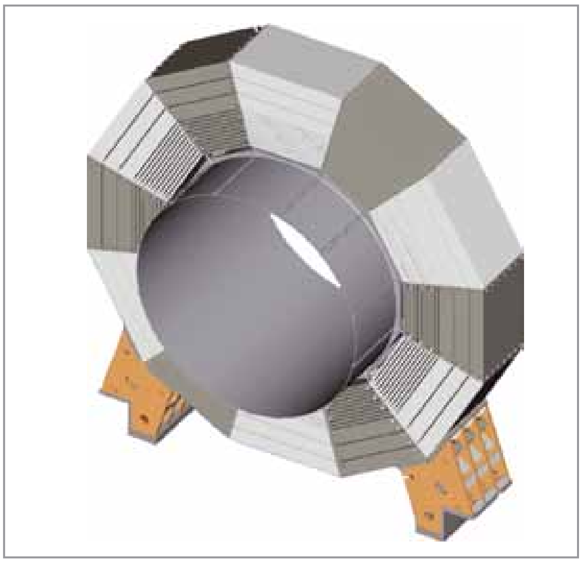


Figure 3

Cryostat supported from barrel iron yoke

The integration of the detectors in the interaction region needs to follow a set of ground rules allowing the co-existence of the detectors and the machine in the hall. These requirements comprise mechanical boundary conditions like the definition of the beam height as well as physical limitations on allowed vibrations or radiation fields. One example with a direct impact on the engineering design of the detector is the magnetic field. The detector on the beamline needs to be shielded well enough so that the detector in the parking position could be maintained using standard tools. Therefore the magnetic stray fields need to be shielded to below 5 mT at a distance of 15 m from the beam pipe. Figure 2 shows a simulation of the magnetic field that was used to determine the amount of iron in the return yoke of the detector. The current design foresees an iron thickness of about 3 m in the barrel region, which brings the total mass of the detector close to 15 000 tons.

A detailed engineering study has been performed to find a technical solution of the iron yoke that can withstand the magnetic forces and meets the requirements on stability for a push-pull detector. Figure 3 shows a design of the central barrel yoke ring which supports the cryostat of the detector solenoid magnet. This cryostat will support the barrel calorimeter system of the detector as well. Figure 4 shows the deformation of the cryostat, a result of a finite-element simulation.

The detector integration task also comprises a realistic design of the material distribution in the detector. In particular, the ways for cables, cooling and other supplies for the sub-detectors need to be defined. Balancing the supply needs of the different technologies with the physics impacts of dead spaces and additional material is a task that requires close collaboration with the physics performance and detector optimization groups within the ILD concept team. Figure 5 shows a study of the integration of spaces and material for cables and cooling of the barrel calorimeters done within the ILD concept team.

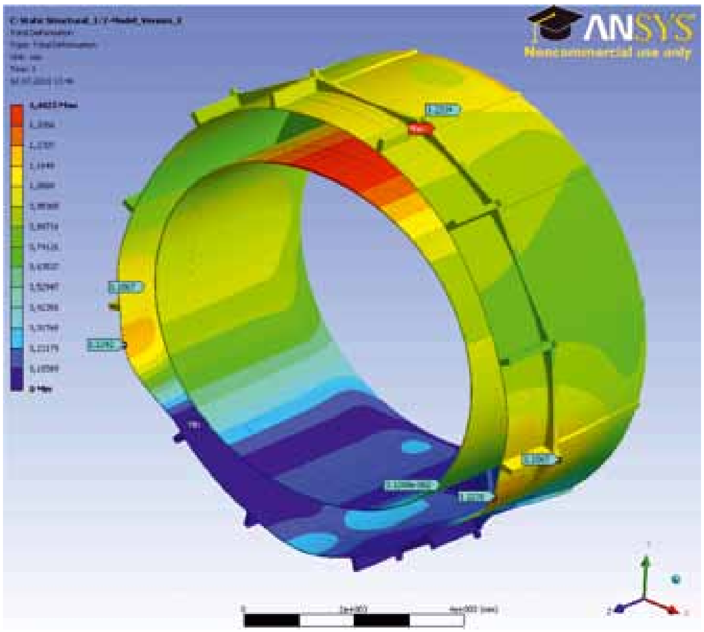


Figure 4

Deformation simulation of solenoid cryostat

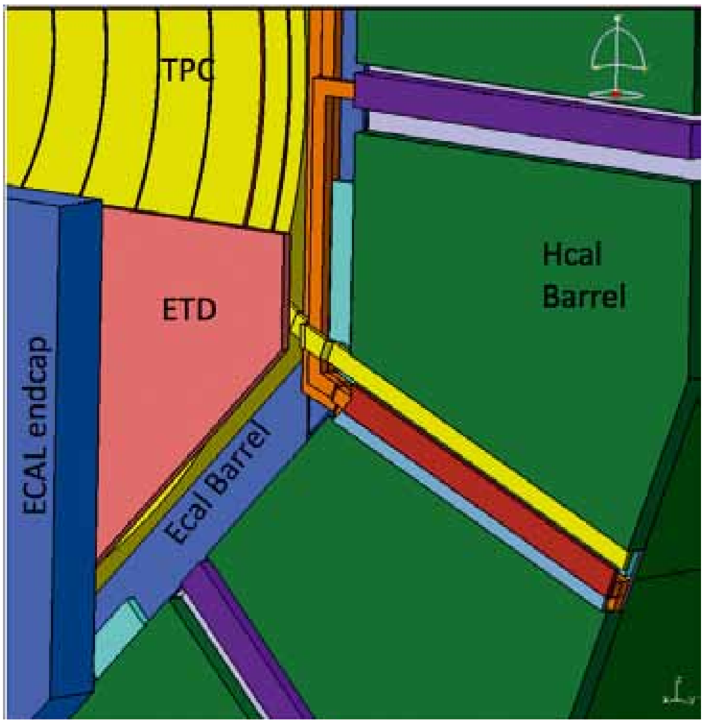


Figure 5

Integration of paths for cables and cooling in the inner detector (C. Clerc, “ILD Integration Studies”, IWLC10, Geneva, CH, 10/2010)

Contact:

Karsten Büßer, karsten.buesser@desy.de

Reference:

http://ilcild.org

Sharing vision.

Supporting simultaneous engineering in the design of the ILD detector

Years before even a decision is made whether a new detector will be built, scientists and engineers are already busy with its detailed design. The DESY Engineering Data Management System helps to share their ideas and keep their design work in synch.

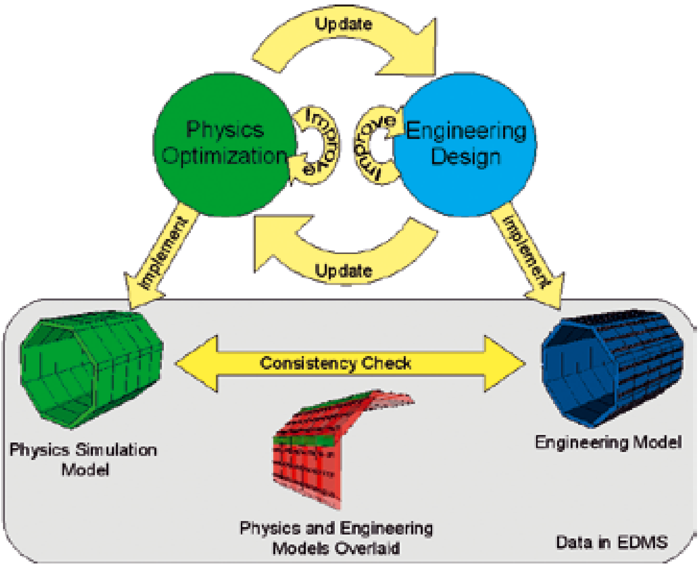


Figure 1

Detector models for physics simulation and detailed engineering models are developed in parallel and have to be kept synchronized.

Designing detectors for particle physics experiments at particle accelerators is one of the most demanding engineering tasks that can be imagined. Hundreds of physicists and engineers from dozens of institutes scattered around the world collaborate to come up with the best possible apparatus for their envisioned measurements.

Each particle detector is unique, and although dozens of detectors have been built and operated successfully over the last decades, every detector is an adventure of its own, striving for higher performance or operating under more demanding conditions than its predecessors. The International Large Detector (ILD) for the future International Linear Collider (ILC) is no exception to the rule. Weighing a staggering 14 000 tons, twice as much as the Eiffel tower, it will combine an unprecedented thin and precise pixel detector, a large time projection chamber with novel silicon readout and a fine-grained calorimeter capable of tracking the showers of individual particles. The inner detector is placed in a 4 Tesla magnetic field originating from a giant solenoid, and the entire detector is surrounded by an enormous flux return yoke which confines the magnetic field.

To satisfy the expectations, every new particle detector pushes the limits of technology further, and specialist groups around the world compete and collaborate to develop the best possible next generation of detector technology. But, large as a detector may be, space is at a premium, and in the inner region of the detector not a centimetre of space will be left empty. Thus it is important to coordinate the design work on the detector from the very beginning. The challenge is to coordinate space occupancy of the various detector components and make sure that everything will fit and work together immediately when parts that were designed and built by different groups thousands of kilometres apart arrive at a single place and are assembled for the first and only time.

The design process is a huge collaborative effort of many different specialist groups from institutes located all around the world. Particle physicists envision an overall detector layout of complementary detector components. They are aiming for an ideal combination of components with optimum coverage to achieve the best possible measurements of the particle collisions. Physicists who have specialized in the design of the various detector components are striving to come up with novel technologies with ever increasing precision and efficiency. Mechanical engineers are

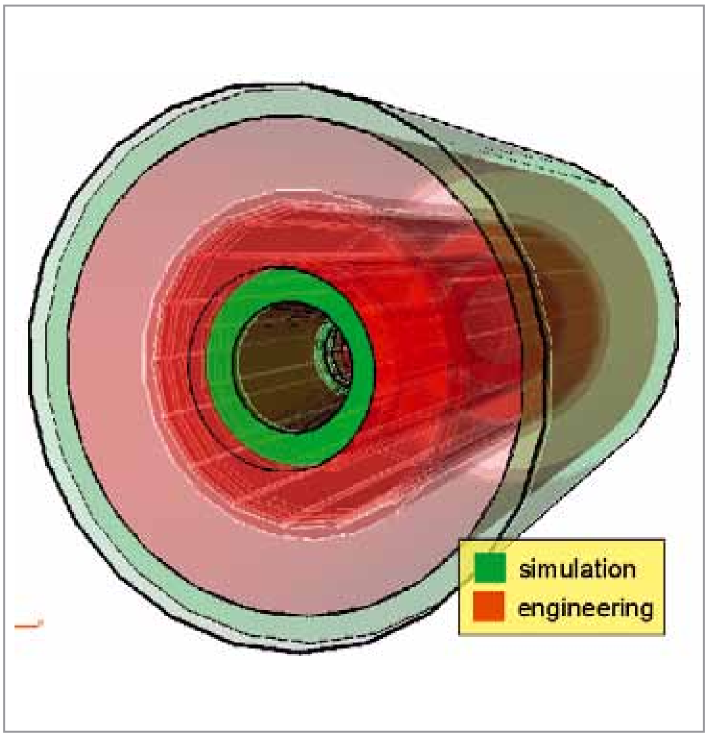


Figure 2

The simulation model of the vertex detector is already quite detailed.

challenged to develop support structures which are strong enough to carry the detector's weight, while at the same time being as light and thin as possible to minimize any shielding influence on the measurement. Amidst these activities, an integration office searches for ways of fiddling in supply lines and cables for detector powering and readout.

All the groups work in parallel. While they set out from an initial space allocation to the various groups, every improvement or new idea of one group may have impacts on the other groups. Consequently, the design activities must be closely monitored, and progress and changes must be regularly compared and checked for compatibility. This is easier said than done, as all the groups are using their own dedicated tools and models. Developing detector components requires highly detailed design models containing every nut and bolt. They are usually limited to single components, as those models tend to become huge and increasingly cumbersome. General layout on the other hand requires modeling the entire detector, though at a lower level of detail. Particle physicists develop their own 3D models in a program package called Geant4, which tracks particles through the detector, recording every subatomic collision and every signal that a particle leaves in the detector's electronics. Although these are also very detailed models of the detector, these simulation models serve a quite different purpose than the engineers' models, as they concentrate on the detected signals and on how the detector's "dead" structural material disturbs the measurement. Conversely, the physicists ignore more mundane problems, such as keeping 14 000 tons of material from crushing under its own weight, or preventing it from melting from the hundreds of kilowatts of power that are needed by the readout electronics. As compensation, they include detailed physical properties in their models, which describe the various active materials and gases, which may not be the primary focus of interest for structural engineers. In the end, the design is iterated many times, as scientists come up with ever better and more fancy – or more realistic – detector parts, or as engineers develop more detailed models of the necessary support structures, cabling and cooling schemes, and strive to find improved solutions to keep this dead material out of the way of the subatomic particles.

DESY's Engineering Data Management System (EDMS) makes it possible for the first time to overlay and compare the different models and keep track of their history throughout the entire development process, and thereby ensure that one hand knows what the other hand does. These comparisons may reveal large differences in material distribution or physical dimensions, or small details such as a different orientation of a part in the engineering and the simulation model. Once found, these differences can be reconciled and a better model of the detector emerges, until finally all the different models are consistent and compatible. Thus EDMS supports a design process where the parallel efforts to satisfy the complementary requirements of best possible physics performance and viable engineering solutions go hand in hand, with the goal to arrive at the optimal detector design.

The process was originally developed at DESY by the IPP group for the design of the European XFEL, where it was successfully implemented to coordinate accelerator development and civil construction. The same workflow is now also offered to and being adopted by the ILD detector community.

Contact:
Lars Hagge, lars.hagge@desy.de

Electronics for an ILC calorimeter.

Integration solutions for the electronics of an analogue hadron calorimeter

Electronics development for an analogue hadron calorimeter at the International Linear Collider (ILC) is challenging. The particle flow concept for the calorimeter asks for high granularity and energy resolution. In addition, a high integration level is essential, in order to reduce the non-interacting material in the active region. This has been achieved by the use of silicon photomultipliers for the readout of scintillating tiles and with a printed-circuit board design optimized for compactness. The electronics development of a prototype is accomplished within the CALICE collaboration with major contributions from DESY.

Within the CALICE collaboration, important steps towards a prototype of an analogue hadron calorimeter have been realized in 2010. The calorimeter follows the particle flow concept, which promises a major improvement of the energy resolution compared to more traditional approaches. This can be achieved by measuring details of the shower development and combining them with the data of the tracking chamber. The calorimeter and its electronics require high granularity and the integration of the electronics into the detector volume. Both requirements have been addressed by the use of 3 x 3 x 0.3 cm^3 scintillating tiles as active detector cells, which are read out by novel silicon photomultipliers (SiPMs).

The final analogue hadronic calorimeter (AHCAL) has a cylindrical structure that surrounds the interaction point. The electromagnetic calorimeter is placed inside the AHCAL, which is surrounded on the outside by the magnet. The circular structure of the AHCAL will be divided into

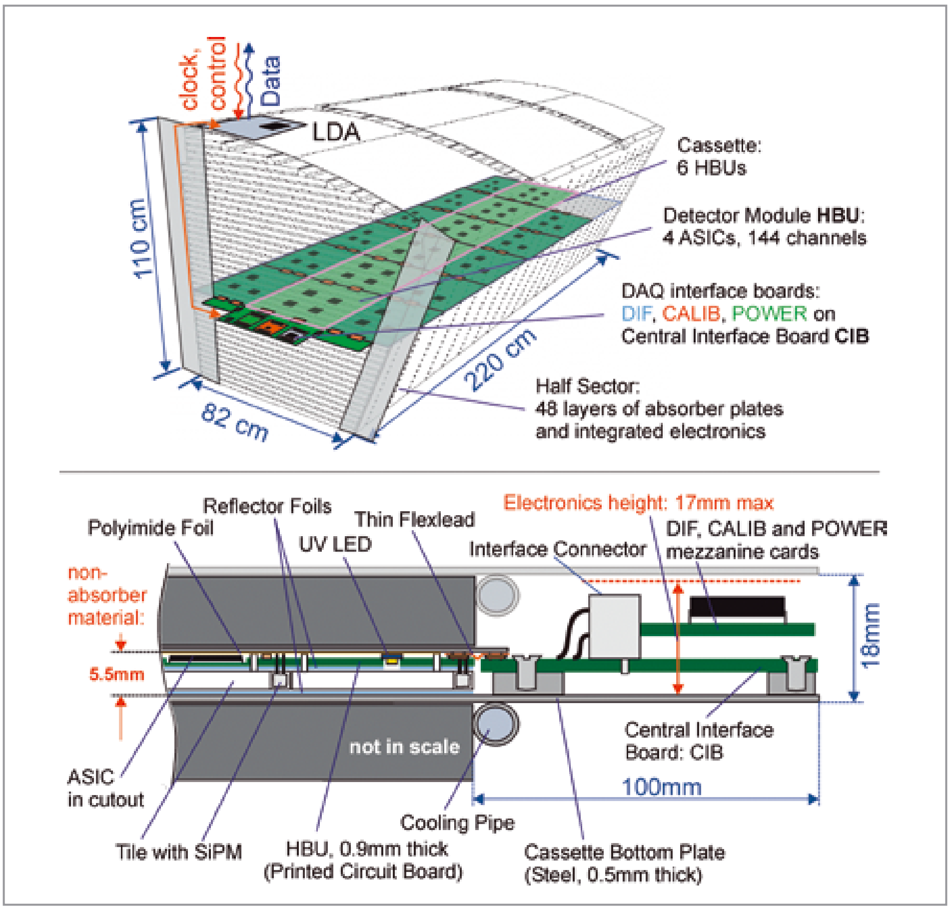


Figure 1

Half-Sector (1/16) of the calorimeter barrel with 48 layers (one shown equipped with electronics, top), and cross section of one calorimeter layer with the end-face interface electronics (bottom).

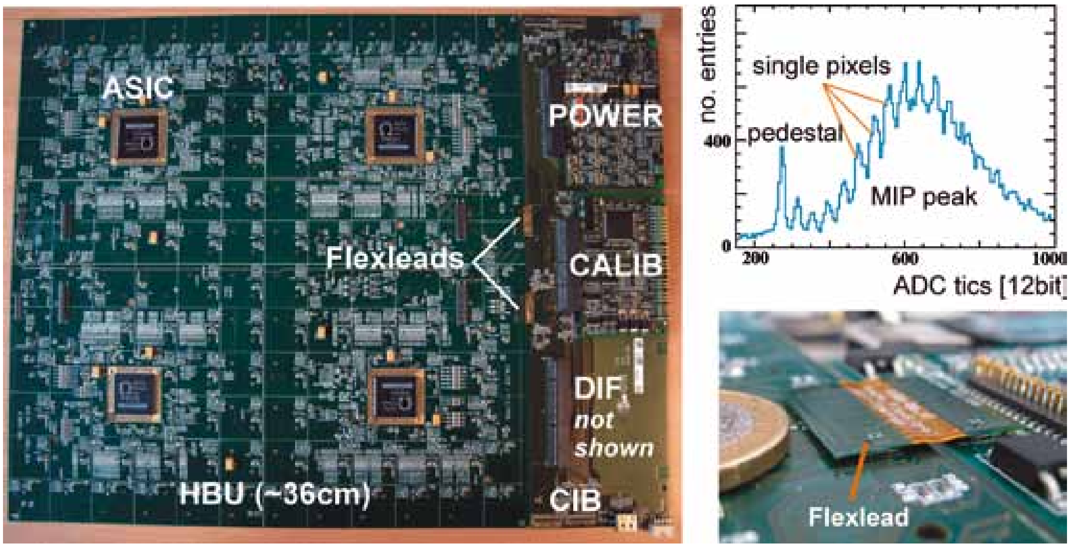


Figure 2

Photo of the realized prototype detector electronics (left), histogram achieved with the prototype at the DESY electron test beam facility (top right) and photo of the flexlead interconnection (bottom right).

16 segments (Fig. 1) and two parts along the beam axis. A segment consists of 48 layers of absorber plates and integrated electronics. The electronics of one layer will be subdivided into single units (HBUs) in order to keep the printed-circuit boards (PCBs) at reasonable sizes (36 x 36 cm^2) for production and assembly. At the end-face of the absorber structure the inner detector electronics communicates with the data acquisition (DAQ) interface boards. The cross section of one AHCAL layer with the integrated electronics and the interface electronics to the experiment's data acquisition at the end-face is shown in Fig. 1. The inner electronics will be placed in a cassette whose top and bottom covers are of the same material as the absorber plates, resulting in a height of non-absorbing material of 5.5 mm (with 3 mm scintillator) per layer. With almost 4 million detector channels in the AHCAL barrel structure, a reliable and simple concept for the assembly, commissioning and repair is required. This was taken into account for the developed electronics concept.

The realized prototype electronics is shown in Fig. 2. The HBU integrates 144 scintillator tiles with SiPMs that are mounted to the bottom side of the board with the readout ASICs and a light calibration system for the SiPMs. The calibration system is based on ultraviolet LEDs. In order to keep the sizes of the AHCAL surrounding magnet and of the showers within the AHCAL small, the height of the layer electronics must be limited as much as possible. For interconnection, ultrathin connectors with a stacking height of 0.8 mm from mobile-phone technologies were chosen. With the attached, newly designed flexible PCBs the interconnections require a total height of only 1.2 mm. Components thicker than the ASICs are placed into cut-outs of the HBU PCB. In 2011, new techniques for automatic assembly of components in cut-outs will be investigated.

Inside the detector, no active cooling for the electronics is foreseen. The electronics therefore has to operate with the smallest power dissipation (the aim is 40 µW/channel), which can only be achieved when the electronics is switched off during inactive gaps of the ILC bunch train structure. The main magnet around the calorimeter requires the electronics to be operational within a 3.5 Tesla magnetic field, which limited the number of usable components and materials. With a length of the inner detector electronics of more than 2 m, special care concerning signal integrity on the long traces was required. The prototype now takes into account all design aspects required by the intended operation at the ILC.

Fig. 2 shows the DAQ interface modules DIF, CALIB and POWER. These components will be placed in the narrow gap region between the barrel and end-cap detectors. The DIF forms the only interface between the global data acquisition and the front-end ASICs, e.g. for the data readout and all slow-control tasks like the detector configuration. Module CALIB is based on an ARM7 microcontroller that mainly controls the light calibration system. Module POWER provides all supply voltages, including the bias voltages for the SiPMs. It enables the power cycling of the inner-detector electronics in the ILC bunch train scheme.

The prototype has been extensively tested in 2010 in the laboratory and in the DESY electron test beam facility to demonstrate the performance and to gain experience for the next stage of development. Electrons between 2 GeV and 6 GeV were applied, which deposit energy within the scintillator as minimum ionizing particles (MIPs). An exemplary result for one channel is shown in Fig. 2.

In 2011, a redesign of the HBU with the newest generation of readout ASICs will be realized, and the preliminary Labview-based operating system will be replaced by the final CALICE data acquisition.

Contact:

Mathias Reinecke, mathias.reinecke@desy.de

Reference:

https://twiki.cern.ch/twiki/bin/view/CALICE/WebHome

R&D with silicon photomultipliers.

How a calorimeter can save your life

In collaboration with international partners, DESY has pioneered a novel technology for photon detection based on silicon photosensors called silicon photomultipliers (SiPM). The Helmholtz Young Investigators Group of E. Garutti investigates the various fields of application of this innovative technology, both in high-energy physics and in applied medical physics.

A prototype hadronic calorimeter for the ILC detector read out via about 8000 SiPMs serves as a proof of principle of the SiPM technology on a large scale. The calorimeter is used to collect hadronic shower data with unprecedented granularity for the validation of the particle flow approach, i.e. the separation of particles in a jet. The SiPM technology is also employed to read out detectors for positron emission tomography (PET), thereby improving the spatial resolution of these detectors.

An innovative design enabling extremely high segmentation of the active layers is necessary for calorimeters at future colliders like the ILC. This ansatz is driven by the particle flow approach, a new reconstruction technique to separate particles in a dense jet environment, which aims to improve the jet energy resolution utilizing the best suited detector component for the measurement of each individual particle. The key technological step is to design small calorimeter cells that are read out individually. One proposed solution (Fig. 1) is to use plastic scintillator tiles 3 cm x 3 cm in size and 3 mm thick. A wavelength-shifting fibre which collects the scintillation light and guides it to the SiPM is embedded in the tile. This design was produced, tested and assembled as the basic unit of the next calorimeter prototype. The group has played a central role in the commissioning and operation of the first-generation prototype. Five years of test beam and data analysis provided a deep understanding of the multi-channel operation of SiPMs. The second generation capitalizes on this experience, incorporating technological improvements developed within the group.

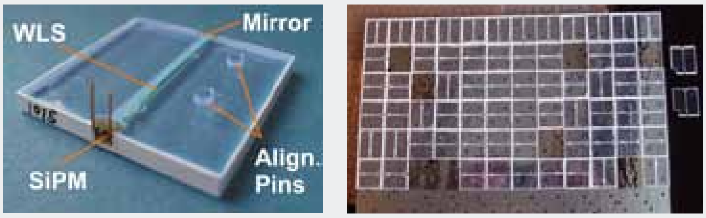


Figure 1

A scintillating tile with SiPM (left) and assembled tiles on a calorimeter readout layer (right)

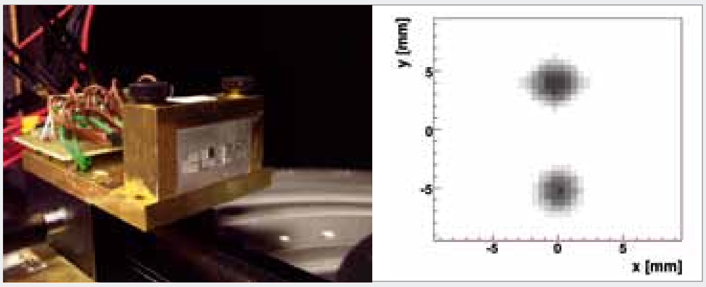


Figure 2

Left: One of the two PET detector modules of the test device realized at DESY, consisting of a matrix of LFS crystals with SiPM readout. Right: Reconstructed image of two point-like sources. The spatial resolution amounts to 2.5 mm FWHM.

Based on the experience of multi-channel SiPM operation the group initiated R&D activities in the medical field, proposing a solution for a PET detector with high granularity and time-of-flight information. A test device is operational and has demonstrated the feasibility of the design with a spatial resolution of 2.5 mm for a point-like ^{22}Na source. Since the beginning of 2011, additional funding from the European Union could be obtained to focus on the realization of an endoscopic PET system exploiting the miniaturization possibilities offered by the SiPM technology.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_206

HELMHOLTZ
I ASSOCIATION

Helmholtz Young Investigators Group
“R&D Studies for New Photo Detectors and their Integration in HEP Detectors” (VH-NG-206)

Contact:
Erika Garutti, erika.garutti@desy.de

Sensor images from electrons.

Mapping out detectors

The instrumentation of the very forward region of a future linear collider presents particular challenges. The FCAL R&D collaboration is meeting these challenges in dedicated developments and test experiments.

The FCAL collaboration is preparing technologies for special calorimeters at future colliders. For the first time, large-area prototypes were available in 2010, made of silicon and GaAs sensors interconnected to novel front-end readout chips. After amplification and shaping, signals were driven to Flash-ADCs in a VME crate. After successful tests in the laboratory, the assembled sensors were positioned in a 4.5 GeV electron beam at DESY. Scintillator counters triggered on beam particles, which hit the sensor under test while their tracks were precisely measured with three x/y planes of a silicon strip telescope, as shown in Fig. 1.

Within a few days, several million triggers were collected. Using the telescope the impact point of the beam particle on the sensor is predicted. Then, the signal of the pad hit by the particle is measured. In case it is above a defined threshold, a colour specific for this pad is assigned, and the impact point coordinates are fed into two-dimensional histograms, as shown in Fig. 2.

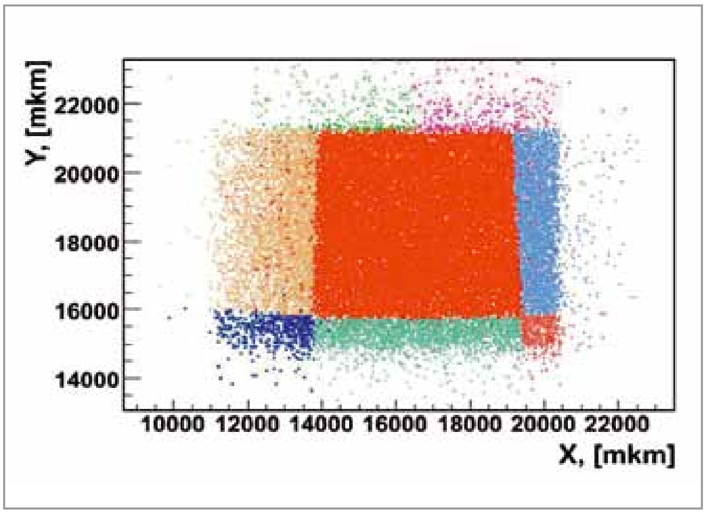


Figure 2

Image of a sensor pad as reconstructed from test beam data

The analysis of the data is still ongoing. We expect interesting results that will be important for possible improvements of the prototype. Furthermore, the prototype will be completed by an ADC ASIC. The results from the test beam experiment will be an important milestone to establish the performance of the detector system which will be included in the ILD detector baseline document, planned for 2012.

Figure 1

PhD students from Cracow, DESY and Minsk install the test beam setup at the DESY test beam facility.

Contact:

Wolfgang Lohmann, wolfgang.lohmann@desy.de

EUDET.

European detector connections

The EUDET project, which was funded by the European Union and coordinated by DESY, was completed in 2010 after five successful years. It united 29 institutes from 12 countries behind the common goal to develop infrastructures for detector research and development targeted at a future high-energy linear collider and other particle physics experiments.

Figure 1

The EUDET logo

The physics potential of a future linear collider represents a tremendous challenge for the performance of detectors, which is in most cases at odds with developments oriented towards experiments at the Large Hadron Collider (LHC). Rather than emphasizing radiation hardness and rate capability, the demands for precision and segmentation significantly exceed what is now state of the art. Vertex detectors should have 30 times smaller pixel size and be 30 times thinner, which is pushing the limits of sensor and electronics integration and lightweight precision mechanics at the same time. Large track detectors aim at 10-fold precision improvements while simultaneously requiring a reduction of the material budget by a factor of 6 at least, and the particle flow approach to calorimetry drives the design of highly compact and granular devices with a channel count more than two orders of magnitude above the finest segmented LHC detectors.

Such leaps in performance cannot be achieved by simple extrapolation known technologies, but only by entering new technological territory in detector R&D. Several new concepts for silicon sensor integration are being pursued for pixel devices, new micro-pattern gas amplification is explored for use in time projection chambers, and calorimeter developers are pioneering the application of new solid-state photo sensors for optical readout, to quote just some examples. While these new ideas have proven to be viable on desk-top scale or in typical test beam setups for proof-of-principle studies, the demonstration of integration feasibility at large scales still has to be done. The R&D enters a new stage, which brings new infrastructure needs with it.

EUDET was launched in 2005 to address these needs in a coordinated manner. The project was granted a total budget of 21.5 million euro, 7 million of which were contributed by the European Union (EU). The research towards improving sub-detector specific infrastructure was organized in three joint research activities (JRA), while the development of common frameworks was structured as networking activities.

JRA 1 aimed at improving the test beam infrastructure for the study of precision tracking devices. A superconducting magnet with a bore large enough to test real-size readout structures and a wall thin enough not to disrupt the incoming beam was refurbished, installed and precisely mapped. It is a sine qua non without which no time projection chamber can be operated. Since its commissioning, it has hosted a large number of research projects. The test beam infrastructure was complemented by a pixel telescope which defines the beam geometry to the precision adapted for the study of resolutions on the micrometre scale, embedded in a mechanical structure which holds devices under test precisely in place. The telescope has been operated quasi continuously for linear collider and LHC users at DESY and CERN over the past two years, and duplicates are now being fabricated to meet the ever-increasing demand.

JRA 2 addressed infrastructures for large tracking devices. A large electrostatic field cage adapted to the bore of the JRA 1 magnet was built. It provides the extremely homogenous electrical field required to transfer ionization charge to micro-pattern readout structures, for which various innovative technologies are being explored. Together with versatile mechanical interfaces and common readout electronics, it has enabled many groups from Germany and abroad to advance their developments. The project is a good example that demonstrates how the infrastructure theme strengthens the collaboration between institutes: small groups who could not afford magnets or field cages, could in this way contribute to the development of amplification structures and test them on realistic scales.

Figure 2

Calorimeter readout ASIC for 36 silicon photomultiplier channels, embedded in a printed circuit board optimized for compactness

The main themes of the calorimeter activity JRA3 are compactness and electronics integration. The immense channel density and the fine segmentation of particle flow calorimeters must be realized in very compact tungsten and steel structures and require high-level integrated mixed circuit microelectronics design respecting ultralow power dissipation limits. Making use of common building blocks, a microchip family has been developed and used to equip dense mechanical structures with versatile readout electronics, such that the novel sensor technologies can be tested and their functionality validated under these extreme but realistic conditions.

All sub-detectors need a common software framework long before a collider detector is being built: not only to avoid multiple developments, but also to exchange and combine results in the R&D phase, to analyse data from combined beam setups and to transfer the validated modeling of detector response into simulations. This is particularly true for the models of hadronic shower evolution, which acquired significant development momentum through EUDET and the close contact with test beam experimenters, and which is of relevance way beyond the linear collider community, namely also for the physics exploitation presently in full swing at the LHC.

EUDET was a good example of the high recognition of the linear collider by the EU, which was recently re-affirmed by the follow-up initiative AIDA, which again has a strong linear collider component, in conjunction with activities targeted at the LHC and at flavour factories. EUDET opened up a new funding source for particle physics and developed significant leverage in allowing many partners to acquire additional funds. It strengthened the community and was an excellent opportunity for DESY to contribute with its strengths in management, engineering and scientific integration. It had a huge impact at DESY itself and played a vital role in preparing detector contributions to the LHC experiments.

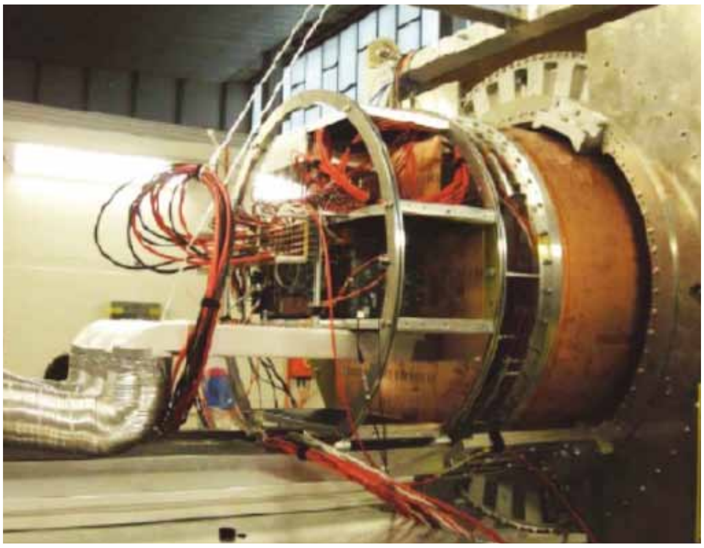


Figure 3

The TPC magnet with filed cage and readout electronics in the DESY test beam

Contact:
Felix Sefkow, felix.sefkow@desy.de

Reference:
www.eudet.org

EUDET telescope.

A versatile pixel beam telescope

A high-resolution pixel telescope has been developed at DESY as part of the EUDET consortium. The telescope consists of up to six planes of monolithic active pixel sensors, and is equipped with a versatile data acquisition environment. It was originally developed to be used at the DESY test beam facility, but in recent years there has been a growing number of requests for its use by groups at the CERN test beam. DESY is currently manufacturing two copies of the telescope to meet the increased demands for such a device.

The EUDET project, which was supported by the EU in the 6th Framework Programme, aimed to provide infrastructure for the R&D of detector technologies towards the International Linear Collider (ILC). The subproject JRA1 was dedicated to producing a high-resolution pixel telescope.

A beam telescope is used to define the track of a particle in a test beam to high precision. An important requirement of the beam telescope is to have a pointing resolution better than the expected intrinsic resolution of the device under test (DUT). Typically it is used for detailed studies of newly developed tracking detectors. One of the goals of the project was to design a tool which is very easy to use and which reduces the average time for test beam preparation and analysis significantly. The EUDET telescope was required to be portable and flexible, in order to allow DUTs to be tested using low-energy electrons at DESY as well as high-energy hadrons from the CERN SPS facility, under varying beam conditions. To be used for this range of conditions, the pixel telescope must have a good hit position resolution ($\sigma < 3\ \mu m$), a reasonably fast readout rate and a very low material budget to allow effective operation without high multiple scattering.

For the EUDET telescope, a two-stage approach was adopted: First, a “demonstrator telescope” was constructed quickly using well-established analog sensors. This telescope was available already 18 months after the start of the EUDET project in 2006. In late summer 2009, the telescope was upgraded with the new Mimosa26 sensor to form the final version. The sensor features 1152 columns of 576 pixels. The column (binary) outputs are processed through a zero-suppression circuitry integrated on the chip periphery.

The telescope, as shown in Fig. 1, consists of two arms, each equipped with three sensors kept at a stable temperature by a cooling system. The positions of the sensors along the beam axis can be adapted as necessary for a given

Figure 1

The EUDET telescope at the DESY test beam provides the exact position of the electrons.

application. Between the two arms, an optional mechanical x-y support stage is installed, which allows positioning of the DUT with a precision of a few micrometres.

The telescope has a flexible data acquisition software (EUDAQ) that was designed to be modular and portable. The software makes use of several independent programs (producers) connected with each other over the network. The hardware of the telescope and any connected DUTs is read out by separate producer tasks that are connected to the “run control” and “data collector” processes. The latter receives the data streams, builds the events and stores the data on the storage device.

To provide a simple and easy-to-use trigger system, a dedicated Trigger Logic Unit (TLU) was developed. The TLU was designed to be as flexible as possible, placing few restrictions on the user. It can generate any coincidence or anticoincidence of four trigger scintillators and also generates event numbers and time stamps. Six LVDS and two TTL interfaces are provided. It is connected by USB2.0 to a control PC running Linux that is in turn connected to the main DAQ PC through gigabit ethernet. The advantages of the TLU are that it allows changes in the trigger configuration to be made from the control room, and that it can be used to provide a centrally distributed trigger with time stamp for the telescope and several DUTs.

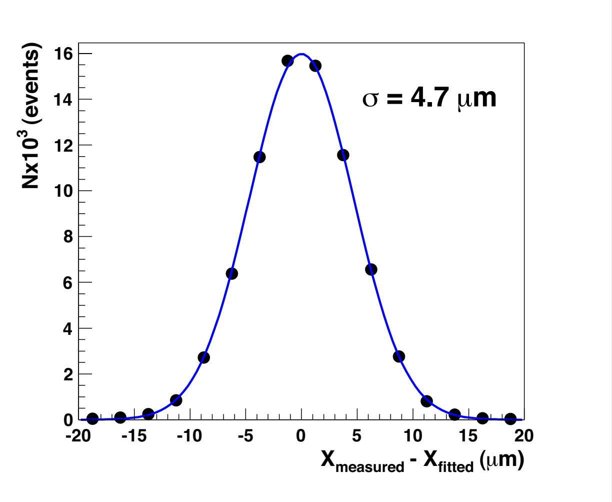


Figure 2

Distribution of track residuals for one of the telescope sensors.

The offline analysis software (EUTelescope) for the telescope data is based on Marlin and LCIO. The main goal of the EUTelescope software is to reconstruct raw data to high level objects like tracks crossing the telescope. Those tracks are used to characterize both the telescope itself and any DUT inserted into the telescope setup. Like the data aquisition, the structure of EUTelescope software is very modular; each process performs a specific task on an input collection, providing an output collection that can be used by other processes.

Fig. 2 shows the distribution of track residuals, i.e. distances between measured hit and fitted track position, for one of the telescope sensors. An overall pointing resolution of 2 μm for the full system was achieved, offering unique opportunities to study new detectors. The telescope has been extensively used by many groups, as was the initial intention for this project. The main DESY contributions were the coordination, the mechanics design and manufacturing, commissioning and running of the system, as well as the analysis software. DESY is also currently manufacturing two copies of the telescope to meet the high demand for such a device. Despite the EUDET programme concluding at the end of 2010, the telescope continues to be in heavy use, and will remain so for the forseeable future.

Contact:

Ingrid-Maria Gregor, ingrid.gregor@desy.de

Reference:

www.eudet.org

DESY II test beam.

A unique facility for detector R&D studies

DESY presently operates a test beam facility for detector studies. Thanks to its easy handling it is an excellent facility for prototype testing. In 2010 again, many groups from the international high-energy physics detector community used the facility for dedicated detector studies.

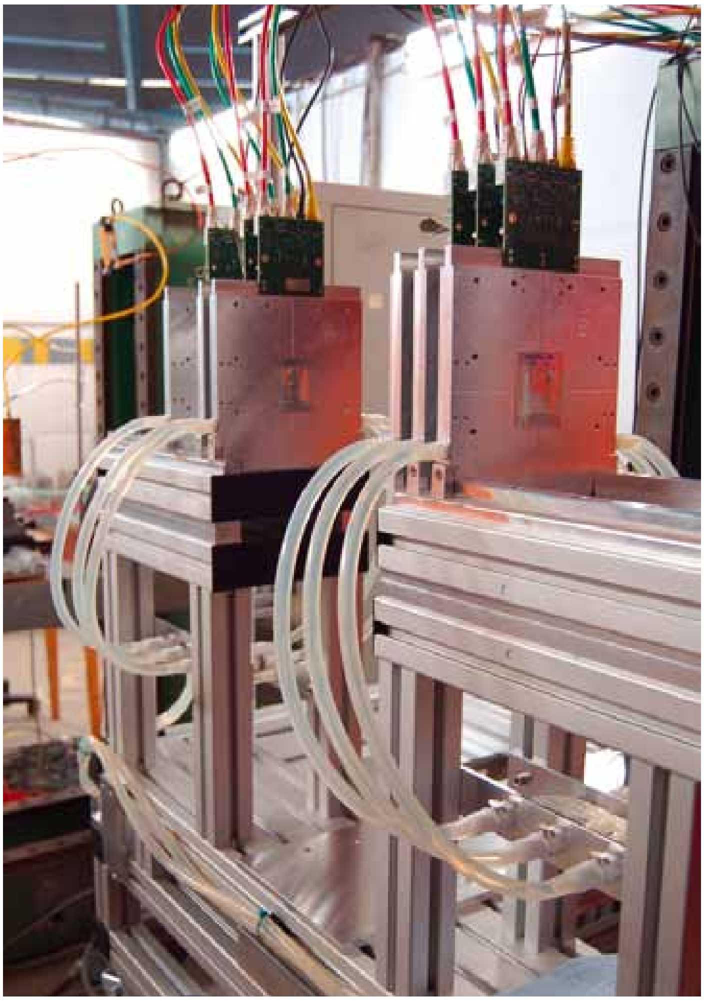


Figure 1

The EUDET telescope at the DESY test beam is a state-of-the-art device providing the exact position of the electron beam. It is in heavy demand by user groups. It also regularly travels to other test beam facilities, in particular to CERN.

DESY presently operates a test beam facility for detector studies in Hamburg. In parallel to its main duty as a pre-accelerator for DORIS and PETRA III, the DESY II synchrotron delivers electron or positron beams for three test beam areas using a fixed target. The operation of the DESY test beam and therefore access to the test beam area is under the control of the experimenter. Due to this easy handling, the DESY test beam is an excellent facility for prototype testing. DESY II provides electron or positron test beams with an energy between 1 GeV and 6 GeV, a small energy spread of about 5% and intensities of up to 5000 particles per cm^2 and second, depending on beamline and secondary target material.

Important infrastructure

In one of the three test areas, a high-precision multilayer pixel telescope was installed to measure the trajectories of the beam particles (Fig. 1). This tool is a typical device necessary for measuring tracking detector parameters such as efficiency and resolution. The CMOS sensors of the pixel telescope enable a pointing resolution of better than 3 μm even with the lower-momentum electrons at the DESY facility. A second telescope of medium precision (better than 10 μm) is also available at the test beam. Furthermore, a large-bore superconduction magnet with a field of about 1 Tesla was installed. Ideally suited for tracking studies in a magnetic field, it provides the perfect test bench for a light-weight time projection chamber (TPC, Fig. 2). The high-precision telescope and the large-bore magnet were installed within the EU-supported FP6 project EUDET.

This infrastructure makes the DESY II beam facility one of the few places in Europe where R&D for particle detectors can be rapidly performed. It has been extensively used in the past for the development of new detectors and prototype tests as well as for serial tests at the time the HERA experiments were

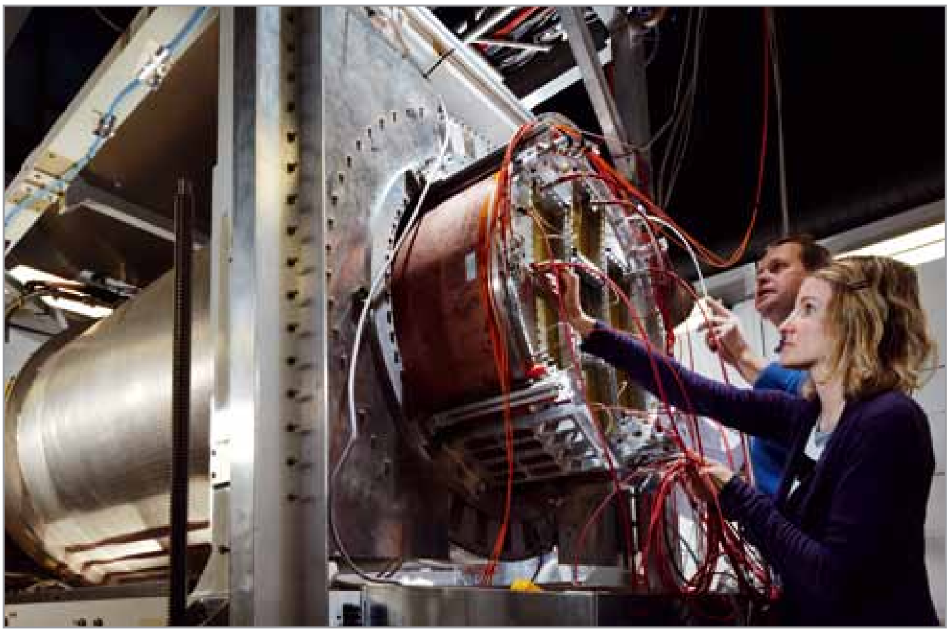


Figure 2

The TPC large prototype experiment at the test beam ran for extended periods in 2010 with different configurations. The prototype is seen here being re-configured for a new beam campaign.

built. In recent years, the DESY test beam played an important role for the linear collider detector R&D as well as for first studies within the LHC upgrade programme.

In 2010, a total of 13 groups with scientists from about 20 different countries utilized the DESY test beam facilities and conducted experiments with calorimeter prototypes, small pixel detectors and “TPC studies”. In the following, some highlights of such studies are briefly described.

Test beam studies in 2010

The SPiDeR collaboration measured the response to particles of the newly developed pixel sensors TPAC and FORTIS. For TPAC, the main goal was to study the response of the detector to electromagnetic showers. During this study, the amount of tungsten converter material added in front of the sensors was varied to obtain measurements of the shower density as a function of material depth. An energy scan from 1 to 5 GeV was performed, in which the EUDET telescope was used to provide an accurate shower centre; this was essential as the core shower density falls rapidly on the scale of 1 mm so that the centre needs to be known with high accuracy. For the FORTIS sensor, the efficiency of a four-transistor architecture was tested. Again the EUDET telescope provided accurate tracking information of the particle hitting the FORTIS sensor, making it the perfect tool to measure detection efficiency.

Luminosity monitor

A group from INFN-Rome/ISS tested a prototype of the tracking system for the Super BigBite Spectrometer, a new spectrometer being build for high-luminosity experiments in Hall A of the upgraded 12 GeV accelerator at Jefferson Laboratory. The new electronics for the GEM tracker is also a candidate readout electronics for the luminosity monitor detector of the OLYMPUS experiment, which will be carried out at the DORIS accelerator at DESY. The severe spatial constraints for the luminosity monitor inside OLYMPUS require small electronics.

This electronics can be used either for GEM or silicon strip detectors. In this campaign, the performance of the new readout and GEM modules were studied. The tests allowed the group to study detector and electronics performances and their dependence on several experimental conditions, as well to gain experience with continuous running under beam.

FCAL

The aim of the FCAL study was to measure the performance of the first fully assembled silicon and GaAs sensor planes prepared for special calorimeters in the very forward region of the ILD detector. Data was taken to study the response to MIPs as a function of the pad positions. Furthermore, effects of the sensor edges and non-metallized strips between the pads were investigated, as well as the cross-talk between neighbouring and non-neighbouring readout channels.

These examples are only a few of many studies performed in 2010. The test beam facility has already been booked by a number of groups for 2011 and detailed plans are under way to further improve the infrastructure.

Contact:

testbeam-coor@desy.de
Ingrid-Maria Gregor, ingrid.gregor@desy.de
Norbert Meyners, norbert.meyners@desy.de

Reference:

www.testbeam.desy.de

OLYMPUS.

Assembly of the detector

The goal of the OLYMPUS experiment is a precise measurement of the ratio of the unpolarized positron-proton and electron-proton elastic scattering cross sections to quantify the effect of two-photon exchange. The experiment will use intense beams of electrons and positrons stored in the DORIS ring, an unpolarized internal hydrogen target and the former BLAST detector from the MIT Bates Linear Accelerator Center. After the final approval in December 2009, the BLAST detector was disassembled at MIT, shipped to DESY and reassembled in the DORIS hall. The new target system was designed and built at MIT, shipped to DESY and recently installed during the winter shutdown.

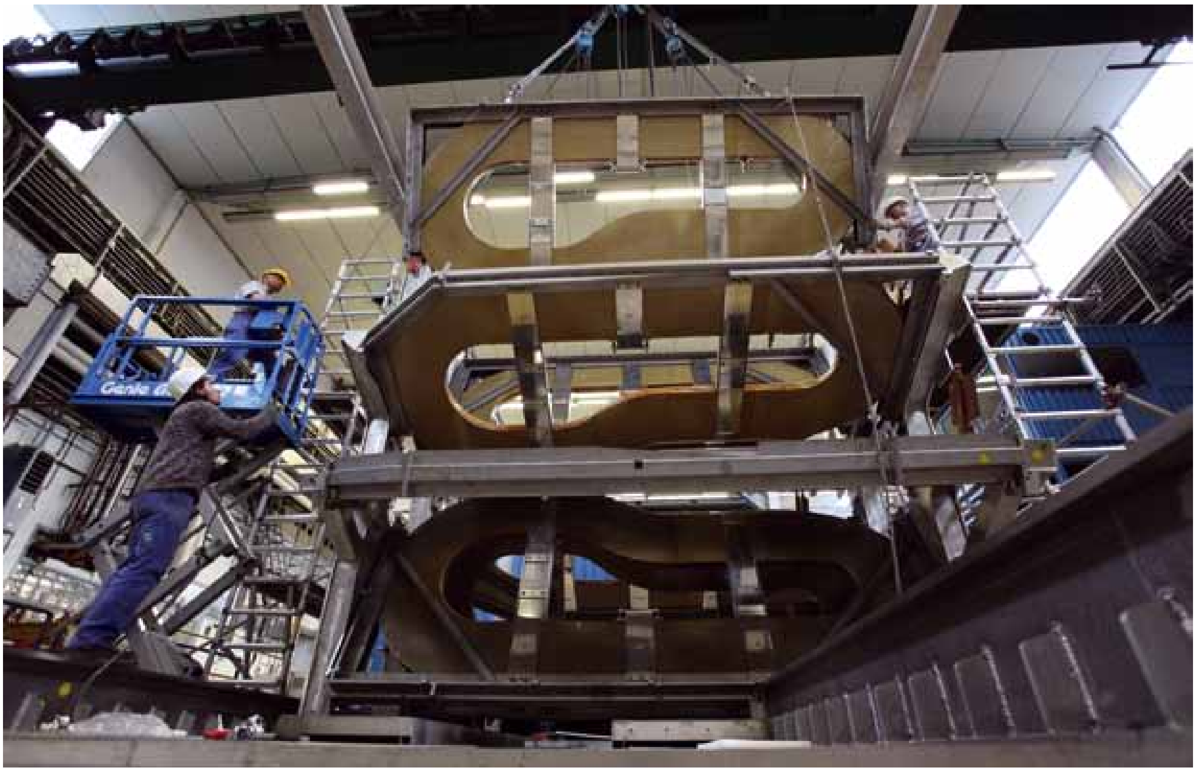


Figure 1

Installation of the final coil in September 2010

Recent determinations of the proton electric to magnetic form factor ratio from polarization transfer measurements at JLAB indicate an unexpected and dramatic discrepancy with the form factor ratio obtained using the Rosenbluth separation technique in unpolarized cross section measurements. This discrepancy may be explained as the effects of multiple photon exchange beyond the usual one-photon exchange approximation in the calculation of the elastic electron-proton scattering cross section. Since most of our understanding of the structure of the proton and atomic nuclei is based on lepton scattering analysed in terms of the single-photon approximation, it is essential to definitively verify the contribution of multiple photon exchange. This measurement is the aim of the OLYMPUS experiment. OLYMPUS will make use of the former MIT BLAST detector, which had to be transferred and reassembled at DESY.

After the final approval by the DESY Board of Directors in December 2009, the former BLAST detector was immediately dissembled at MIT and shipped to DESY. The shipment arrived in May 2010. The main support structures, outer and inner frames and the toroid magnet were assembled in the DORIS hall during the summer. The infrastructure (transformer, power supply, cabling and cooling) for providing 1.6 MW of power for the magnet was set up. The magnet was successfully commissioned. Three-dimensional magnetic field measurements along the nominal beam position and in the drift chamber region were done in December. The field along the beam position was minimized by readjusting the coil positions. The field limits set by the DORIS machine group were achieved.

Both drift chambers arrived at DESY in May 2010. Since the chambers had not been in operation for about five years, it was decided to remove all 10 000 wires and restring them in a cleanroom at DESY. This was accomplished within about 2 ½ months during the summer. All time-of-flight counters were checked and repaired as necessary. Preparation of the new detector components (luminosity detectors and improved tracking) is in progress.

The new vacuum system, including the target chamber, was designed and built at MIT. The complete system was installed into the DORIS beamline during the winter shutdown (December 2010 to February 2011). In addition, some detectors were installed for a test experiment. The goal is to commission the target system and the detectors, including their readout system, to do background measurements with positron and electron beam and carry out a first measurement of the target density.

In spring and early summer 2010, the remaining detector components will be installed and commissioned while OLYMPUS is still in the parking position. During the DORIS summer shutdown (July to August 2011), the whole detector will then be moved into the beam position.

Figure 2

Installation of the OLYMPUS vacuum system in the DORIS beamline during the winter shutdown

Contact:

Uwe Schneekloth, uwe.schneekloth@desy.de

Reference:

http://web.mit.edu/OLYMPUS/

LEXI second phase.

Prolongation of Cluster of Excellence "Connecting Particles with the Cosmos"

One of the main objectives of the cluster "Connecting Particles with the Cosmos" is to strengthen and further integrate the existing broad research spectrum at Hamburg University and DESY, which reaches from mathematics over theoretical and experimental particle and astroparticle physics to astronomy and cosmology. In the first 18 months after the launch of the Cluster of Excellence, several new groups took up their research activities and a number of new projects have successfully been started.

Figure 1

Vacuum tube for the prototype of the SHIPS helioscope (left), which will be installed on the Oskar-Lühning telescope at Hamburg observatory in Bergedorf (right).

The potential of future developments for the entire research field in Hamburg was discussed at several strategic LEXI (Landesexzellenzinitiative) workshops in 2010. Calls for new proposals were launched, resulting in the selection of several new and innovative projects that were granted some significant initial funding. Among these are detector projects within the common activities of the particle physics groups at Hamburg University and DESY at the LHC. In detail, this concerns infrastructure required for the replacement of the pixel detector that is foreseen for the phase-I upgrade of CMS, and the replacement of readout detectors of the HCAL-HO ring 0 scintillator system of CMS with silicon photomultipliers. Besides these experiments at the energy frontier, the cluster also supports local small-scale experimental activities searching for new phenomena at lower energies, which are at the interface between cosmology, astrophysics and particle physics.

The SHIPS (Solar Hidden Photon Search) experiment is being assembled together with the Hamburg observatory. It will search for hidden photons from the sun with a projected sensitivity to masses in the sub-eV range. Another experiment is being put together at DESY II with the help of LEXI funding. It will provide sensitivity to hidden photon masses in the 10-200 MeV range, which is particularly interesting since it might explain a number of anomalies observed in particle physics and cosmic-ray experiments. Furthermore, the cluster supports an experiment searching for possible deviations from Newton's law of gravity at very low values of acceleration. This experiment is testing alternative models of gravity that are surprisingly successful in explaining several astronomical observations which would otherwise require the presence of the up-to-now undetected dark matter.

Financial support for the cluster started in summer 2009 and was initially granted for a period of 18 months. In autumn 2010, an intermediate status report was submitted to the Hamburg science administration. It served as the basis for an evaluation by the newly established Hamburg research and science foundation. As a result, the funding of 1.2 million euro per year for the cluster was extended to the end of 2012.

Contact:

Carsten Niebuhr, carsten.niebuhr@desy.de

Reference:

http://lexi.desy.de

The ALPS experiment.

New lines of attack to reveal WISPs

"Light shining through a wall" experiments search for weakly interacting slim particles (WISPs). Long standing quests in particle physics and cosmology may find their solution in the discovery of this new species of particles. In 2009, the ALPS experiment at DESY achieved unprecedented sensitivities for WISP searches in the laboratory. The experience gained provides a firm foundation for future enterprises into unexplored parameter spaces: work towards an ALPS II experiment has started in the past year.

In general, the most stringent limits on the existence of WISPs originate from interpretations of astrophysics data. However, the interpretation of such observations is always hampered by the uncontrolled production mechanism of WISPs in stars and other environments. Hence only experimental efforts in the laboratory allow for robust WISP searches. The "light shining through a wall" (LSW) experiments have proven to be the most sensitive setups for WISP and especially axion-like particle (ALP) hunts in the laboratory [arXiv:1011.3741]. In the first part of such an experiment, WISPs are produced from intense laser light, either by interaction with a strong magnetic field or by kinetic mixing. This first part is separated by a light-tight wall from the second part. Only WISPs can traverse the wall due to their very low cross sections. Behind the wall, they could convert back into photons with exactly the same properties as the light generating the WISPs. This gives the impression of "light shining through a wall". In 2010, the ALPS collaboration published the most sensitive exclusion limits for WISP searches in laboratory experiments [K. Ehret et al., Phys. Lett. B689, 149-155 (2010)].

Based on these encouraging results, the ALPS collaboration, now reinforced by new members of Hamburg University, is progressing towards an ALPS II experiment with greatly increased sensitivity. All components of the experiment are to be improved:

- The optical system will provide much higher effective laser power in the resonator before the wall and include a second resonator in the regeneration part of the experiment to boost the reconversion of WISPs into photons.
- The applicability of a superconducting transition edge sensor (TES) to count single infrared photons in a nearly background-free environment is being tested with Italian partners.
- The usage of long strings of HERA dipole magnets is being explored.

It is planned to realize ALPS II, if the technical studies are successful, in a stepwise approach. First, the experiment will look for so-called hidden-sector photons. They couple via kinetic mixing to "normal" photons so that no magnetic field is required. Figure 1 shows the predicted sensitivity.

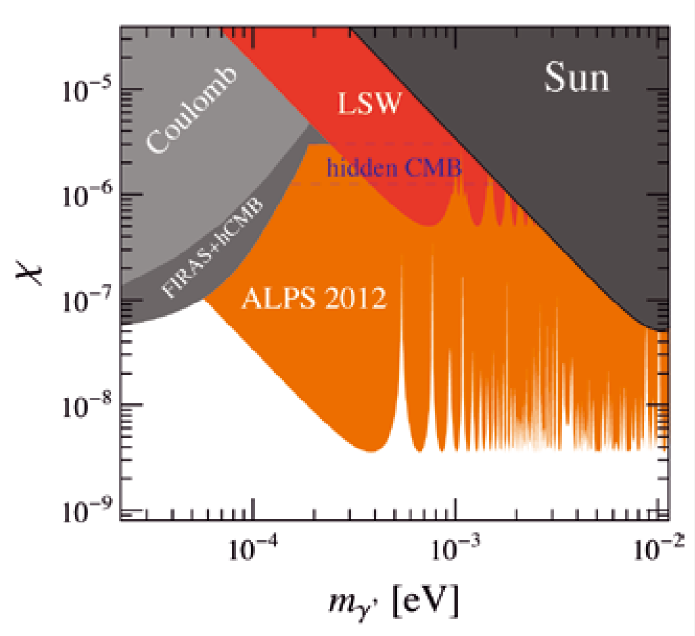


Figure 1

The estimated sensitivity for ALPS II ("ALPS 2012") in the search for so-called hidden photons in comparison to the present limits of ALPS (shown in red). Possible hints on the existence of a hidden cosmic microwave background radiation ("hidden CMB") could be tested.

In 2012, ALPS could search for hidden photons in a large parameter space not accessible to other approaches.

In a second stage, the techniques could be combined with strings of HERA dipole magnets (presumably in the HERA tunnel) to touch the parameter region for the existence of axion-like particles indicated by astrophysics phenomena. The technical studies are expected to be concluded with a technical design report in early 2012.

Contact:

Axel Lindner, axel.lindner@desy.de

Reference:

http://alps.desy.de

On to discoveries.

The neutrino observatory IceCube at the South Pole is completed

On 18 December 2010, the last string of the IceCube neutrino observatory was deployed. Each of the 86 strings carries 60 photomultipliers, buried in the south polar glacier at depths between 1.45 and 2.45 km. Thirty-three years after first concepts for underwater neutrino detectors with a cubic-kilometre volume were developed, we now have the cubic kilometre – and look forward to open a new window to the universe.

Figure 1

The last IceCube string is installed!

Half a century ago, Russian physicist Moishej Markov proposed using deep waters to detect neutrinos. Eighteen years later, a first cubic-kilometer underwater detector was conceived: the 1978 design of a Deep Underwater Muon And Neutrino Detector (DUMAND) close to Hawaii envisaged a total of 22 698 photomultipliers spread over 1.26 km^3 – clearly much beyond any technological and financial possibilities at the time. The first successful steps were done with much smaller detectors. In 1993, a first array of 36 photomultipliers on three strings was deployed in the Siberian Lake Baikal. Three strings mark the minimum needed for three-dimensional reconstruction of particle tracks. It took another three years before the first upward-going muon tracks from neutrino interactions were clearly identified, first in Lake Baikal, then in AMANDA, the Antarctic Muon And Neutrino Detection Array, in the deep south polar ice. DESY has played a substantial role in both pioneering projects.

At the end of the 1990s, it became clear that even an AMANDA-sized detector with 677 photomultipliers on 19 strings (enclosing a volume 500 m high and 200 m in diameter) might be too small to detect cosmic high-energy neutrinos. Therefore a follow-up project of AMANDA was prepared: IceCube. In January 2006, the first IceCube string with 60 photomultipliers was deployed; on 18 December 2010, the last of a total of 86 strings. We have the cubic kilometer! Now we are looking forward to discoveries.

DESY assembled 1250 optical modules and developed the front-end electronics at the surface which communicates with the detector deep in the ice. Meanwhile the focus is on analysis of the experimental data which have been taken since 2006, with the stepwise increasing detector. About 50 Terabyte per year are recorded, plus a much bigger amount of data from Monte Carlo mass simulation. Further

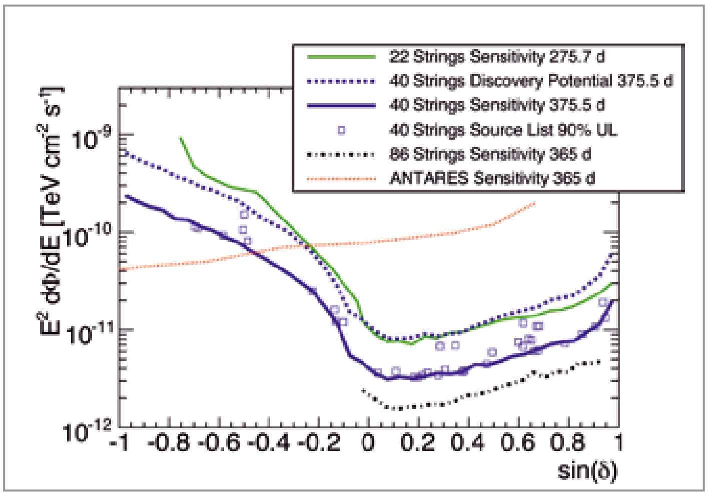


Figure 2

Upper limits on the flux from point sources

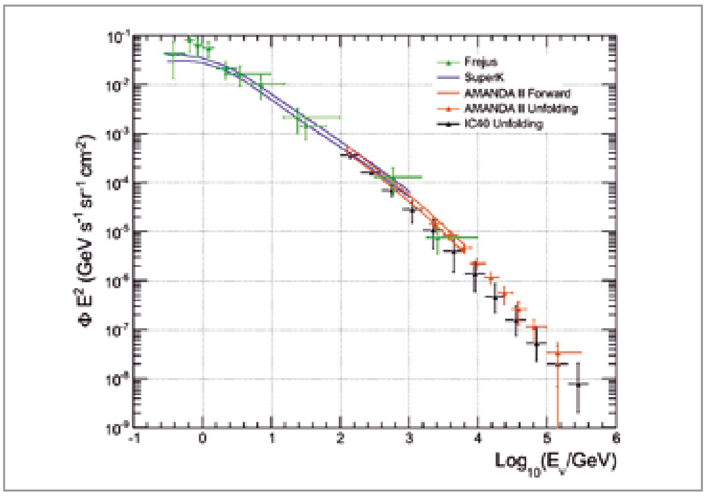


Figure 3

The spectrum of atmospheric neutrinos as measured with underground detectors, AMANDA and IceCube

DESY tasks include the development of online filters for the South Pole Data Acquisition System and the release management for reconstruction software.

High-energy neutrinos must be emitted as a by-product of collisions of charged cosmic rays with matter. Since they can escape much denser celestial bodies than light, they can be tracers of processes which stay hidden to traditional astronomy. Another source of cosmic neutrinos are annihilation reactions of dark matter particles which have accumulated over billions of years in dense celestial bodies like the Sun. IceCube has looked for both and – until now – did not find any statistically convincing excess of high-energy neutrinos, neither from acceleration processes nor from dark matter annihilation. A slight directional correlation of IceCube neutrino events with cosmic ray events observed with the Auger Observatory in Argentina was reported in the 2009 Annual Report. This correlation has weakened with more statistics from both Auger and IceCube. The various non-observations have led to record limits on the corresponding fluxes which are displayed in Fig. 2.

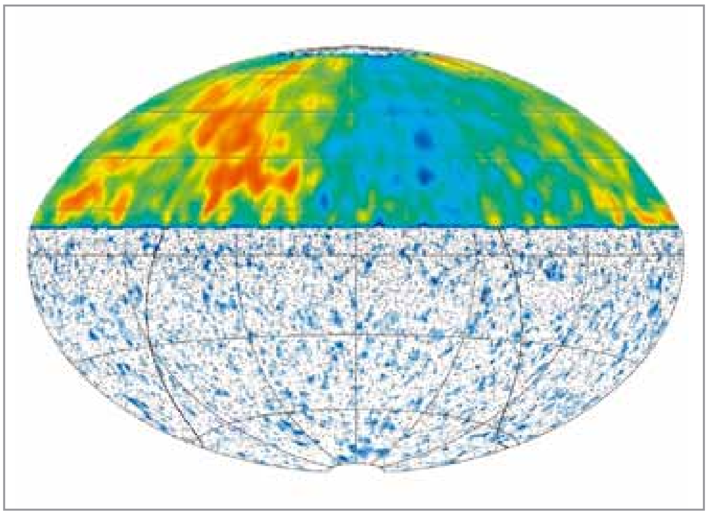


Figure 4

Combined sky map of ~20 000 neutrino candidates from below and around the horizon (bottom part of the map) and of ~1 billion downward moving muons (top part). Structures of the neutrino map are compatible with statistical fluctuations.

Nonetheless about fifty thousand neutrinos have been recorded. They are compatible with being most, or even all, produced in cosmic ray collisions in the Earth's atmosphere. The spectrum of these “atmospheric neutrinos” is displayed in Fig. 3. AMANDA and IceCube have extended the recorded spectrum by two orders of magnitudes compared to underground experiments. The 400 TeV maximum energy exceeds the energies of neutrinos generated at man-made accelerators by three orders of magnitude. These neutrinos are presently exploited as a tool for particle physics studies, like the search for the tiny effects of violation of Lorentz invariance and the test of other fundamental laws of physics.

Looking above the horizon and lowering the energy threshold down to the TeV range, one obtains a sky map of punch-through muons from air showers. The showers are caused by the interaction of cosmic rays which have entered the atmosphere from the Southern hemisphere. At these energies, punch-through muons outnumber muons from neutrino interaction by more than a factor of 10^5. Figure 4 shows a combination of the resulting sky map for particles with an average energy of 14 TeV and the sky map obtained from the neutrino analysis, both using data taken with the 40-string IceCube configuration from 2008. It convincingly confirms the large-scale anisotropy of downward-moving muons on the 0.1% level which has been reported previously.

Contact:

Christian Spiering, christian.spiering@desy.de

Reference:

http://icecube.wisc.edu

SPATS.

Detecting neutrino whispers at the South Pole?

The South Pole Acoustic Test Setup (SPATS) was built to measure the acoustic properties of ice as a function of depth. After more than three years of measurements its mission is nearly accomplished. In 2010, results were published for the sound speed, the acoustic attenuation length and the acoustic noise level at the Pole.

At ultrahigh energies above 10^{18} eV, neutrino interactions lead not only to the Cherenkov light which is normally used for their detection, but also to radio and acoustic signals (Fig. 1). It is expected that these signals can be detected at much larger distances than light. This would enable the construction of detectors some hundred cubic kilometres in size. The feasibility and the specific design of an acoustic sensor array as part of a large-volume ultrahigh-energy neutrino detector at the South Pole strongly depends on the acoustic properties and the noise conditions in the Antarctic ice. The South Pole Acoustic Test Setup (SPATS) was built to evaluate these parameters. Four strings, co-deployed in IceCube holes down to depths between 400 and 500 m, carry seven acoustic stations each. The three sensors of each station register sound signals produced in the ice or at the surface.

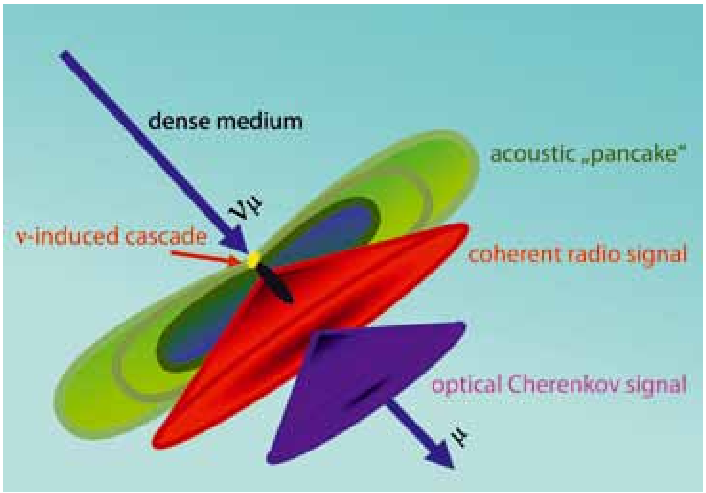


Figure 1

Schematic view of the propagation of signals emitted by muons and particle cascades in neutrino interactions (violet: Cherenkov light, red: radio waves, green: acoustic signals)

Using SPATS transmitters and receivers on two neighboring strings, with a horizontal distance of 125 m, the sound speed in ice was measured for pressure and shear waves at depths between 80 and 500 m. Below 200 m, it was found to be constant with values of $v_p = 3878 \pm 12$ m/s and $v_s = 1976 \pm 8$ m/s. Using data from a transmitter moving up and down in the water-filled IceCube holes (i.e. before re-freezing) at different locations, an attenuation length of 313 ± 57 m was determined. No significant dependences on depth or frequency were observed. In contrast to open sea or lake water, the acoustic noise in polar ice is stable and Gaussian. An in-situ calibration for the sensors in the ice at large depth and low temperature has not yet been possible. Using laboratory results, reasonable assumptions lead to a noise floor estimate of less than 20 mPa, including sensor self-noise.

Using a threshold trigger and five sensors out of twelve on three or four strings to record a sound signal from an identifiable source, data from SPATS allowed hearing noise produced by re-freezing IceCube holes and other sources that appeared due to the used drilling technology. An “acoustic image” of IceCube at the surface is shown in Fig. 3.

Figure 2

SPATS acoustic station

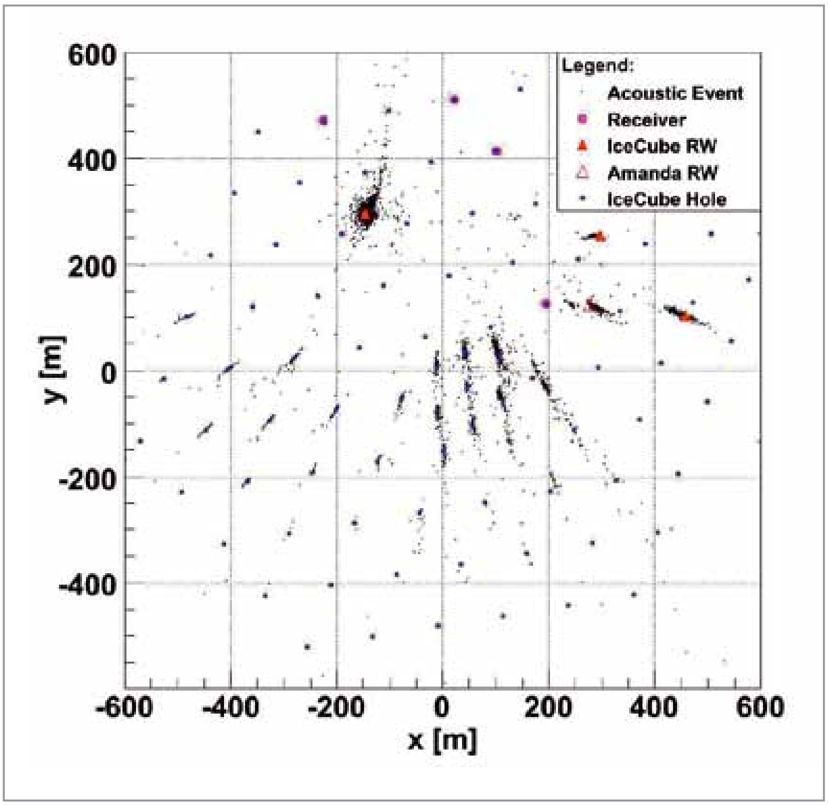


Figure 3

Plane view of the position of IceCube holes (blue circles) and wells used for drilling purposes (red triangles) in comparison to localized acoustic events (black dots).

The present SPATS results open up the possibility to build an acoustic component of a large hybrid detector at the South Pole on a 500 m grid scale with a lower energy threshold of about $10^{18.5}$ eV. Ongoing noise studies indicate that optimized sensors may allow a reduction of the minimum detectable energy. The efficiency of such a detector depends strongly on its geometry.

First Monte Carlo studies with corresponding realistic assumptions show that for about 10% of detectable events hybrid information will be available.

Whether such a concept will be realized at the South Pole is still under debate.

Contact:

Rolf Nahnhauer, rolf.nahnhauer@desy.de

CTA.

The Cherenkov Telescope Array

High-energy photons with energies above a few GeV trace enormous cosmic accelerators that are found in a variety of sources like supernova remnants, binary systems, active galactic nuclei or the enigmatic gamma-ray bursts. Gamma-ray observation is likely to be the key for understanding the origin of cosmic rays and the nature of dark matter. A huge detection area of several square kilometers is required to measure the very low fluxes of gamma rays. The Cherenkov Telescope Array (CTA), which is currently in the preparatory phase with strong participation of groups from DESY, will be such an instrument. CTA will offer a sensitivity improvement of one order of magnitude compared to current-generation instruments. The start of the construction is planned for 2014, research and development is now entering the decisive phase.

When a gamma ray interacts in the atmosphere, a cascade of high-energy particles produces a faint Cherenkov light flash which is collected by large telescopes on the ground and imaged onto a photomultiplier camera. Using arrays of these imaging atmospheric Cherenkov telescopes, scientists can image the shower development from several angles and reconstruct the direction, energy and type of the incoming high-energy photon. CTA will carry the field towards a new level of sensitivity through a much larger number of telescopes, improved optical properties, high-sensitive focal plane instrumentation and a sophisticated trigger concept.

For full sky coverage, CTA will be built in two arrays, one in each hemisphere. A CTA array will consist of telescopes of three types to obtain sensitivity over an unprecedented energy range:

- a few very large telescopes with more than 400 m^2 of mirror area to detect the faintest showers,
- 20 to 50 mid-size telescopes (100 m^2 mirror area) for high sensitivity in the mid-energy range from 200 GeV to 10 TeV and
- a large number of small telescopes with 6 to 7 m mirror diameter to obtain a high collection area at energies beyond 10 TeV.

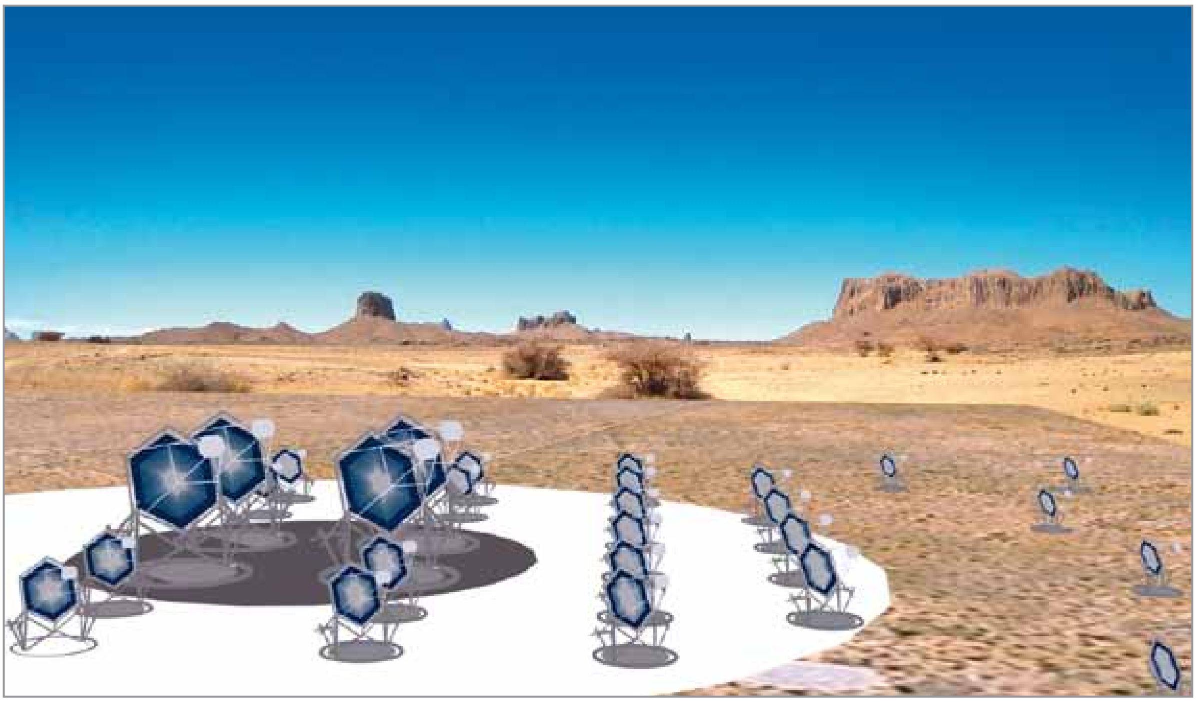


Figure 1

CTA telescope layout (artist's view)

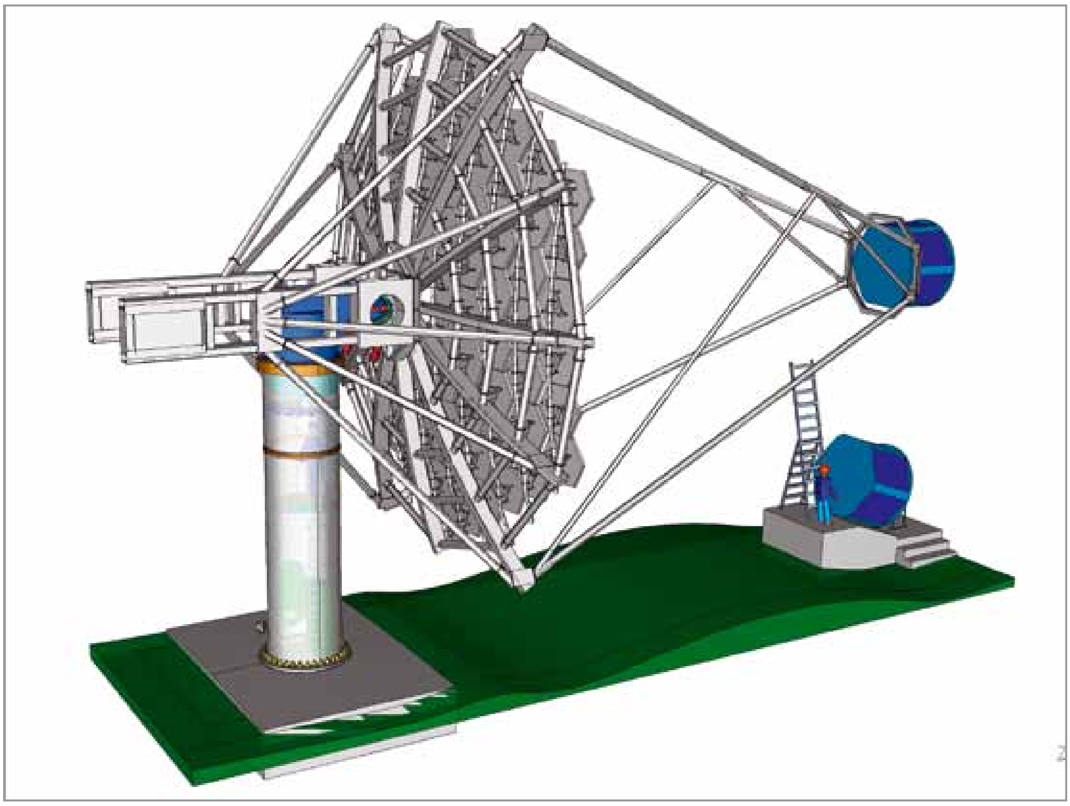


Figure 2

Design of a medium-size telescope

CTA is promoted by groups in Europe, Asia and America and supported by all groups currently participating in gamma-ray astronomy. CTA is on the list of projects on the roadmap of the European Strategy Forum for Research Infrastructures (ESFRI). ApPEC and ASTRONET, the European committees of the astroparticle and astronomy community, have given CTA top priorities. It is a project recommended by the Committee for a Decadal Survey of Astronomy and Astrophysics of the American National Research Council.

High-energy gamma-ray astronomy is an important component of DESY's multi-messenger programme. There are strong links between gamma-ray astronomy and the high-energy neutrino astronomy with IceCube, the newly established group for theoretical astrophysics at DESY and cosmic-ray projects at other Helmholtz centres.

The DESY CTA group is leading the development and mechanical construction of the mid-size telescopes with a dish diameter of 12 m. First prototypes for the structure and the drive system were built and are used as test facilities. A full telescope prototype will be built in Berlin in 2011 and will allow us to evaluate the performance of the construction and the production of the different parts by industrial partners. It will be used for detailed tests of the drive and safety system, the mirror mounting mechanics and procedure, a core calibration system and aspects of the telescope control. The group is developing a new type of digital trigger system that will allow a powerful suppression of the night sky background without significant loss of signal events. A HV system for the phototubes of CTA was designed and is being tested. The design of the telescope and the electronic development is accomplished in a close collaborative effort of physicists and engineers.

The reliable and safe control of the large number of telescopes and sub-systems in the field is a major challenge. It is being met by an array operation control system developed by DESY in collaboration with partners in Erlangen and Berlin, but also Annecy and Barcelona. The mechanical telescope prototype to be erected in Berlin will be a realistic testbed for these developments.

CTA will be an order of magnitude larger than current instruments and measure each event with much higher precision. New analysis methods are necessary to use the full potential of the instrument. The Helmholtz Young Investigators Group embedded into the CTA group in Zeuthen is developing such methods with emphasis on background suppression and low-energy reconstruction.

The installation of the first CTA array will start in 2014. It will take first data soon thereafter. The development of physics analysis and the training of young scientists is made possible by the group’s active participation in the science programmes of all three major instruments (H.E.S.S., MAGIC and VERITAS).

Contact:

Stefan Schlenstedt, stefan.schlenstedt@desy.de

Reference:

http://www.desy.de/cta

Towards the next-generation gamma-ray observatory.

Astrophysics with the Cherenkov Telescope Array

The universe is home to countless stunning and beautiful phenomena, some of which are almost inconceivably violent and energetic. Supermassive black holes and galactic binary systems are two examples of these marvels. They generate streams of matter and energy that move away from their accreting black holes with velocities close to the speed of light. These powerful flows, called jets, produce gamma rays, an extremely high-energy form of electromagnetic radiation, billions of times more energetic than visible light. What is happening in astrophysical jets to produce these high-energy radiation? How do black holes form jets? Where in these jet are particles accelerated to energies far beyond what is possible with Earth-based accelerators? These are the core questions addressed by the Helmholtz Young Investigators Group "Towards the Next-Generation Gamma-Ray Observatory: Astrophysics with CTA". The group is embedded into the Cherenkov Telescope Array (CTA) group at the Zeuthen site.

Figure 1

The VERITAS observatory in Southern Arizona, USA. CTA will consist of about 20 times more telescopes.

Astrophysical jets are most powerful at high energies. Very high-energy gamma-ray observation is likely to be the key to understanding the underlying physics of particle acceleration in jets, but current-generation instruments are probably not sensitive enough to answer these fundamental questions. The Cherenkov Telescope Array (CTA), a next-generation gamma-ray observatory being built by institutions in Europe, Asia and America, will be a unique tool for the Young Investigators Group to explore the high-energy nature of astrophysical jets. This telescope system will dwarf its predecessors, MAGIC, H.E.S.S. and VERITAS, in nearly all respects – sensitivity, angular resolution and energy coverage. DESY is a strong partner in the CTA consortium, contributing in several areas to the construction of CTA. CTA is expected to deliver first astrophysical data in 2014.

The Young Investigators Group is currently preparing for the science phase of CTA and helping to transfer the vast knowledge gained with present-day instruments. The current phase focuses on significantly improving the sensitivity of CTA over a wide energy range through implementation of sophisticated methods for background suppression at the telescope design, trigger and analysis level. In addition to extensive tests on Monte Carlo simulations, the participation in VERITAS, a state-of-the-art gamma-ray observatory in Arizona, allows the group to examine the power of these methods in realistic environments. The group is also developing innovative observation strategies to observe multiple sources simultaneously and most effectively.

Gamma-ray observatories like CTA or VERITAS are versatile instruments, which allow the exploration of many different science topics in astronomy and fundamental physics. The Young Investigators Group pursues a programme to search for evidence of gamma-ray annihilation signals of dark matter – the nature of dark matter being one of the most important questions of science in the 21st century. Of particular interest are the development of reconstruction methods for emission regions larger then the field of view of CTA and the improvement of the energy resolution. With these developments, CTA will have a realistic chance to detect signatures of dark-matter particles in the universe. A positive result would have unrivaled impact on astronomy and particle physics, and upper limits will be the most constraining available in this energy range.

The programme of the Young Investigators Group is carried out in close collaboration with experimental and theoretical groups at DESY, Humboldt University, University of Delaware and various member institutions of the VERITAS and CTA collaborations.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_602

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
"Towards the Next-Generation Gamma-Ray Observatory" (VH-NG-602)

Contact:
Gernot Maier, gernot.maier@desy.de

A MAGIC sky.

Gamma-ray astronomy with the MAGIC telescope

The Helmholtz Young Investigators Group “Multi-Messenger Astronomy” relates observations with the MAGIC gamma-ray telescope to neutrino events recorded with IceCube – and actively contributes to the recent MAGIC observations.

The MAGIC collaboration (Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes) includes 150 European physicists. It runs the largest telescopes for very high-energy gamma rays. The two 17 m diameter dishes on the Canary Island of La Palma, the first of which was commissioned in 2003, the second in 2009, are operated in stereo mode (MAGIC-II). The superior performance of MAGIC-II exceeds expectations and holds the promise of future milestone discoveries.

Within the first months of observation, MAGIC-II already discovered six new extragalactic emitters of energetic gamma rays, tracers of the highest-energy phenomena in the universe. The new sources are two galaxies located in the Perseus cluster of galaxies, a quasar, a super-massive black hole located at a distance of about 4.5 billion light years (one third of the radius of the universe) and thus belonging to the three most distant energetic sources ever found, the mysterious source J2001+435, the distance and nature of which are still uncertain, and two objects located at distances of 1.4 billion light years.

With the second telescope, MAGIC is bridging the observational gap between satellite- and ground-based gamma-ray telescopes. In this context, the DESY group has worked on simulations to compare and optimize different algorithms for energy reconstruction in order to make full use of the stereo mode capabilities. The group has demonstrated that a method based on look-up tables is optimal for energies below 300 GeV, whereas a second (Random Forest method) shows better performance for energies above 1 TeV – with comparable performance (15-20% resolution) in the mid-energy range.

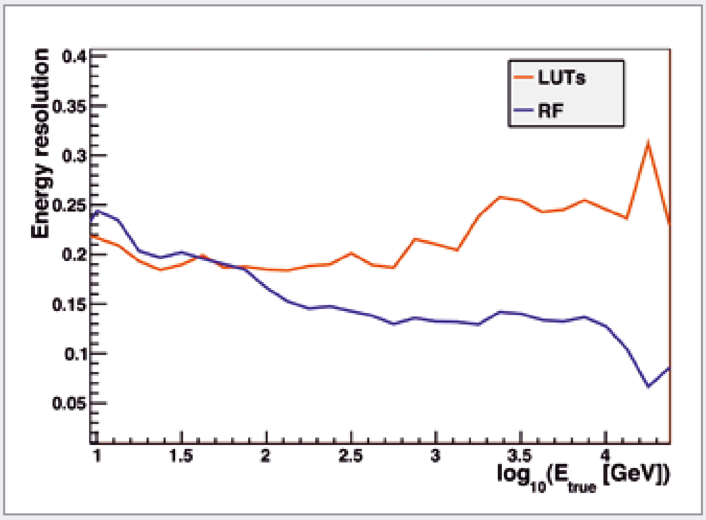


Figure 1

Energy resolution of the Look-up table method (LUT) and the Random Forest method (RF) as a function of gamma energy.

The Helmholtz Young Investigators Group continues its monitoring programme for bright blazars which is of utmost importance for any correlation studies between gamma-ray data and neutrino events. A large fraction of the data collected is part of multi-wavelength campaigns. Last but not least, an alert system in which MAGIC observations are triggered by neutrino event series taken with IceCube (Neutrino Target of Opportunity) was successfully taken into operation.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_205

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
“Multi-messenger studies of point sources of cosmic rays using data from IceCube” (VH-NG-205)

Contact:
Elisa Bernardini, elisa.bernardini@desy.de

Black holes and giant accelerators.

Theoretical astroparticle physics on the horizon

The Zeuthen lab has a long history in experimental astroparticle physics. This is now complemented with a theory effort that renders the lab well positioned to play a central role in the international research landscape.

Nearly a century ago, Austrian Scientist Viktor Hess conducted a series of balloon flights that demonstrated the existence of extraterrestrial particle radiation, later dubbed cosmic rays. The origin of Galactic cosmic rays and the mechanisms of their acceleration are among the most challenging problems in astroparticle physics and also among the oldest. Cosmic rays are energetically important in our understanding of the interstellar medium (ISM) because they contain at least as much energy as the other phases of the ISM. Along with interstellar dust, they also provide the only sample of ordinary matter from outside the heliosphere. Yet, more than 90 years after their discovery, the origin of cosmic rays in the Galaxy remains uncertain.

High-energy gamma rays are a unique probe of cosmic rays. Observations in the TeV band are a sensitive probe of the highest-energy physical processes occurring in a variety of astronomical objects, and they allow us to measure the properties of energetic particles anywhere in the universe, such as their number, composition and spectrum. DESY is involved in two currently operating experiments, MAGIC and VERITAS, and plays a central role in developing the future CTA observatory. From such measurements we know already that our Galaxy contains astrophysical systems capable of accelerating particles to energies beyond the reach of any accelerator built by humans. What drives these accelerators is a major question in physics and understanding these accelerators has broad implications.

The theory group at DESY investigates the natural physical processes through which particles can be accelerated to very high energies. We also study the propagation of cosmic rays and their impact on their environment. Finally, we are interested in identifying signatures of new physics in the cosmic-ray data, e.g. the decay or annihilation products of dark matter.

A likely class of sources of cosmic rays in the Galaxy are supernova remnants, at least up to energies of a few hundred TeV. Supernovae blast the outer envelope of the dying star into the ambient medium at a few percent of the speed of light. Ejecta and ambient material cannot mix because of magnetic fields, and therefore two shock waves develop, one in the

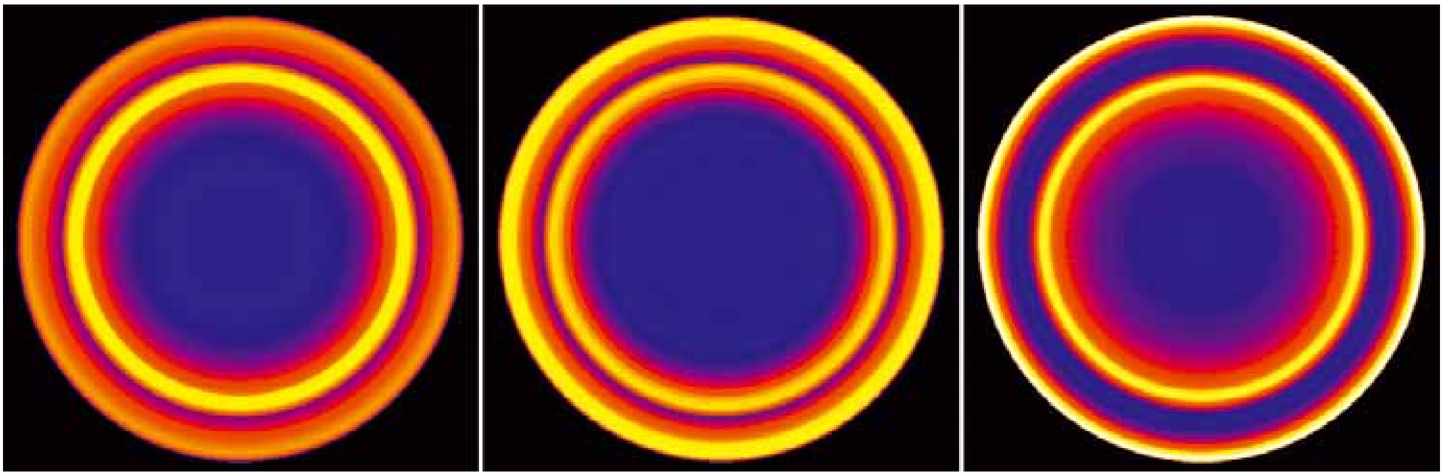


Figure 1

The brightness distribution of a supernova remnant at different energies. The left panel shows TeV-band emission, observable with, e.g., VERITAS, the middle panel is for GeV-band emission, and the right panel is X-ray synchrotron emission.

ambient gas and one in the ejected medium. Particles are accelerated through repeated adiabatic compression at the shocks, but they may be cooled by decompression in other places. We model the hydrodynamic evolution of these objects and calculate the particle transport in parallel. Care must be exercized, because electrons and ions evolve differently due to energy losses. Electrons are more radiative, though, and can be observed in the radio and X-ray band. Both electrons and ions radiate gamma rays, and it is unclear which dominate. Figure 1 shows calculated intensity distributions of the emitted radiation in different energy bands, which may be used to distinguish between electron and ion emission. To be noted in the figure are the ring-like structures at the location of the two shocks.

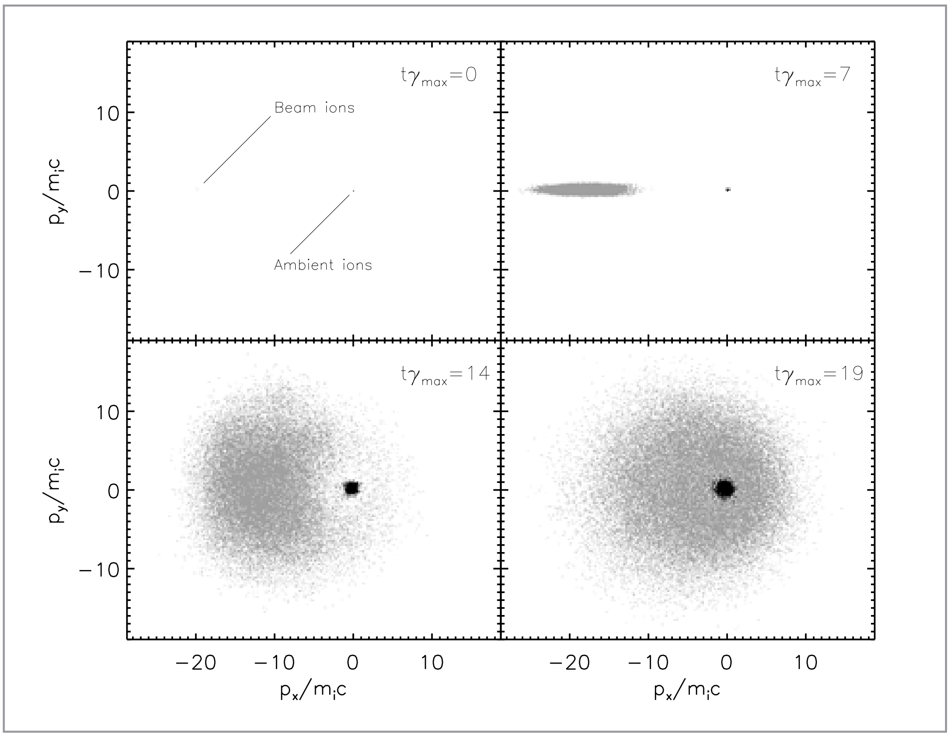


Figure 2

Phase-space distributions of the ions in the cosmic-ray beam (gray) and the ambient plasma (black) at t = 0, 7, 14, and 19 in units of the inverse linear growth rate for the run with cosmic-ray Lorentz factor 20 and Alfven velocity c/20 (taken from ApJ 709 (2010), 1148).

Kinetic simulations are required to study the detailed operation of shocks and the scattering of particles near them. We use particle-in-cell simulations to investigate the growth, saturation and back-reaction of magnetic turbulence caused by cosmic rays. A very important finding is that cosmic-ray scattering may be very efficient even if the wavelength of turbulence doesn't match the gyro-radius of the particles, in contrast to expectations based on quasi-linear gyro-resonance theory. Figure 2 demonstrates that a number of instabilities usually operate in parallel to build the electromagnetic environment near shocks in which scattering and hence particle acceleration is efficient.

At much higher energies close to 1 Joule per particle, extragalactic cosmic rays start dominating the spectrum. We have established that one class of cosmic-ray sources, the long gamma-ray bursts thought to arise from the collapse of a massive star into a black hole, cannot provide extragalactic cosmic rays on account of energetic considerations, but the same objects may dominate the galactic cosmic-ray production at 1 EeV, or 10^6 TeV. To what degree the observational limits on anisotropy can be satisfied is the subject of current research.

Cosmic-ray antiparticles can be messengers of dark matter, but do arise from ordinary cosmic-ray processes as well. Strong excess in the flux of high-energy positrons was recently observed, and we embarked on a study to investigate whether or not the decay of dark-matter particles into electron-positron pairs may be responsible for the measured positron excess. Both electrons and positrons would undergo inverse Compton scattering with the cosmological microwave background. The gamma-ray signal thus produced would appear as quasi-isotropic background radiation at a few hundred MeV, and the intensity is in conflict with recent measurements of the gamma-ray background performed with NASA's Fermi gamma-ray space telescope. The prediction is very robust because the dark-matter decay rate scales with density, or dark-matter mass, and therefore the cosmological measurements of the dark-matter content of the Universe can be used to very precisely predict the expected gamma-ray signal. Other groups have eliminated the possibility to ascribe the positron excess to dark-matter annihilation. The most likely explanation remains the leakage of electron-positron pairs from pulsars in the Galaxy, a process we investigated earlier.

The members of the theoretical astroparticle physics group at DESY in Zeuthen, look forward to a new year of studying the most violent and energetic processes in the universe.

Contact:
Martin Pohl, martin.pohl@desy.de

Small corrections to the greatest.

Quantum effects modify the cosmological expansion

In the ΛCDM model, the "standard model of cosmology", the influence of matter on the evolution of the universe – a curved space-time – is treated largely in classical terms. In particle physics, however, one models matter as a quantum field theory on flat space-time. One can therefore expect that an analysis of the cosmological evolution within quantum field theory on curved space-time can substantially boost our understanding of cosmological phenomena and reveal presently unknown quantum effects – it might even answer open questions of the classical standard model.

Investigating the history of the universe within cosmology is certainly one of the most exciting topics in modern physics. Whereas in the past astronomy was often viewed as being one of the most inaccurate areas of physics on the observational side, we can now profit from many instruments and experiments which measure the cosmos with an unprecedented accuracy.

A surprising consequence of recent observations is that 95% of the content of our universe is "dark", i.e. not interacting with electromagnetic radiation. The existence of the smaller part of the dark content was already predicted in the 1930s by Fritz Zwicky, who had observed that rotational velocities of stars in the external regions of galaxies imply that galaxies must contain more than just the luminous matter – "dark matter".

By now we know that dark matter must be cold in order to explain the observed large-scale structure in our universe. On small scales, however, the radial dependence of the dark matter density inferred from observations of dwarf galaxies resembles a so-called "core profile", which one would expect if dark matter were warm, rather than a "cusp profile", which one would expect if dark matter were cold. This problem and the question which particle physics model is the correct one to describe the constituents of dark matter are two of the most ardent issues in this field of physics.

While dark matter has in principle already been known for a long time, the largest part of our universe's content turned out to be of a completely unexpected form. In contrast to any known form of matter and to dark matter, this component of our cosmos is characterized by a negative pressure and can not build gravitationally bound local structures; consequently, it has been called "dark energy".

Shortly after the discovery of dark energy, it became clear that this phenomenon can be modeled to high accuracy by a cosmological constant, Λ, with constant energy density $\rho \sim 10^{-47}$ GeV^4 and pressure $p = -\rho$; consequently, the standard model of cosmology has been termed ΛCDM (Λ-cold-dark-matter).

A widely known potential explanation for the origin of the cosmological constant is the "vacuum energy" of a quantum field, but it is often argued that quantum field theory predicts a too large cosmological constant corresponding to an energy density of $\rho \sim 10^{74}$ GeV^4. However, at least since the works of groups in Chicago, Göttingen and our group in Hamburg, it has been known that any attempt to infer an absolute value of the cosmological constant from quantum field theory on curved space-time (QFTCST) is at variance with the principles of general relativity.

Namely, in contrast to accelerator experiments, where we measure relative energy densities, gravity is sensitive to absolute energy densities. But there is no unique way to define absolute energy densities within QFTCST. Instead, this ambiguity can be quantified by four free parameters of the theory, one of which is equivalent to a cosmological constant. Until we have a better understanding of quantum gravity and the limit in which it yields QFTCST, we can only fix these parameters by observations. Consequently, QFTCST is in perfect agreement with any measured value of the dark energy density.

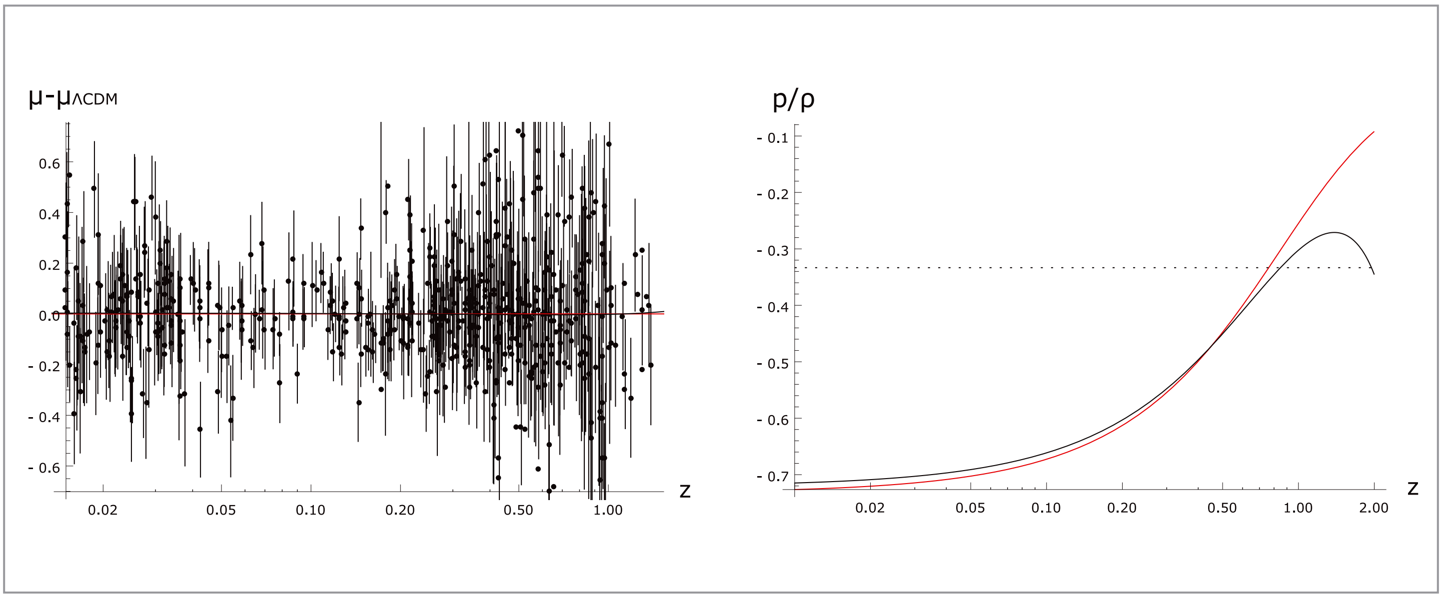


Figure 1

Comparison between ΛCDM (red line) and ΛCDM with relative quantum corrections to the energy density of ~ 1% (black line) as a function of the redshift z. Left panel: Deviations in the luminosity distance μ. The data points are taken from the Union2 supernova compilation. Right panel: Total pressure p divided by the total energy density ρ. Whereas the μ data are clearly insensitive to this amount of quantum corrections, we can infer from p/ρ that such large quantum corrections do not allow for a sufficiently long phase with $p/\rho > -\frac{1}{3}$ (dotted line), which is necessary for structure formation.

Motivated by this insight, we have investigated the question whether it is possible to model the recent cosmological evolution completely and from a more fundamental point of view within QFTCST. To this avail, we have modeled matter by free quantum fields, as interactions of dark matter and standard model fields are expected to have negligible influence on the late cosmological evolution. To incorporate the potential thermal origin of dark matter, we have required the massive quantum fields to be in a state which on the phenomenological side models the state of dark matter after the freeze-out of dark matter interactions in the very early universe. On the more technical side, we had to check that this state has the correct ultraviolet properties in order to assure that the theory can be regularized in a consistent manner [arXiv:1009.5179].

By fitting our model to recent observations of type Ia supernovae, we have found it to match the data as well as the ΛCDM model, although non-trivial potential deviations from ΛCDM appeared [arXiv:1007.5009]. Hence, we have found qualitative quantum corrections to the standard model of cosmology.

Quantitatively, these corrections are subject to the freedom of defining absolute energy densities within QFTCST and the data we have used is only capable of providing upper bounds for these corrections. To shed light on the open questions in dark matter physics, we have estimated the radial density profile of galactic dark matter which follows from the thermal quantum state in our model, and have found it to match the “core profile” which was previously believed to be in conflict with cold dark matter [arXiv:1007.5009]. Our results are very pleasing and promising. By taking more and better data into account, the unambiguous detection of quantum corrections to ΛCDM and the conclusive answer to open questions of the standard model seem to be merely a matter of time.

Contact:

Klaus Fredenhagen, klaus.fredenhagen@desy.de

Matter-antimatter asymmetry and dark matter.

Implications for neutrino and superparticle masses

Leptogenesis provides an elegant explanation for the origin of matter in the universe. In its simplest version, the mechanism favours gravitinos as constituents of the observed dark matter. A consistent cosmological evolution imposes strong constraints on the masses of neutrinos and superparticles, which are currently tested at the Large Hadron Collider (LHC).

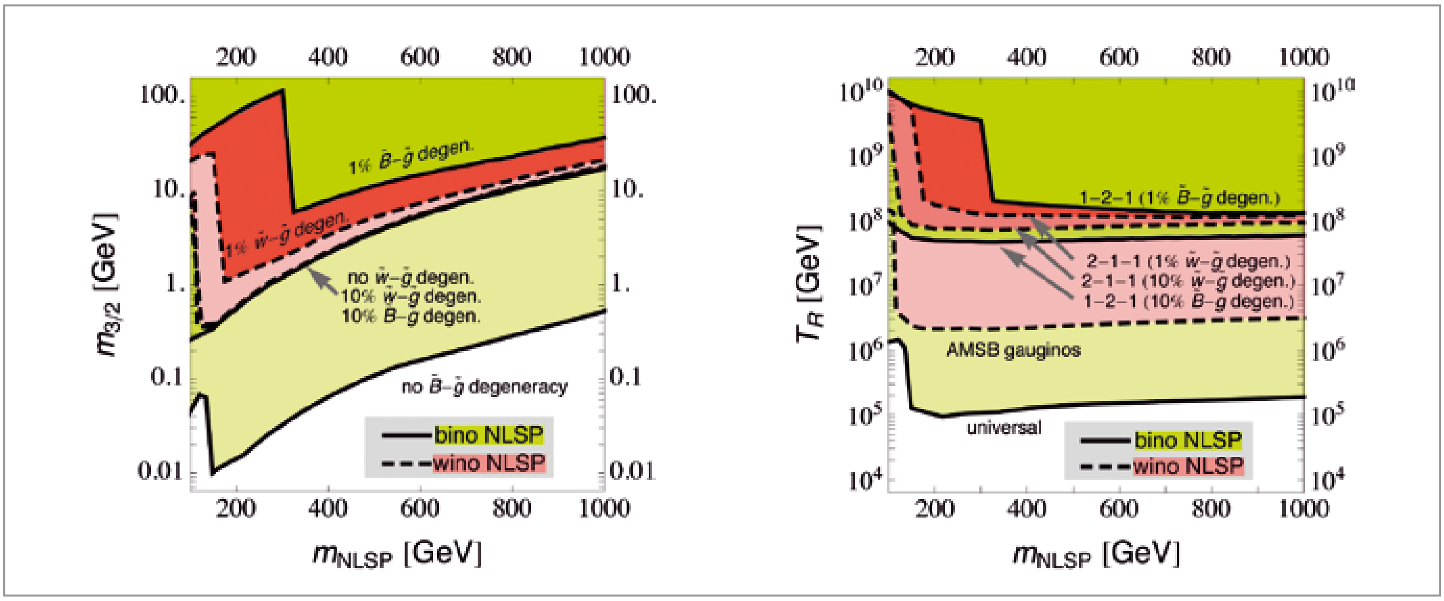


Figure 1

Upper bounds on the gravitino mass (left panel) and the reheating temperature (right panel) as a function of the next-to-lightest superparticle (NLSP) mass for different gaugino degeneracies

The standard model of cosmology succeeds in explaining a multitude of phenomena over a large range of time and distance scales, but still lacks the answers to several fundamental questions: What is the nature of dark matter? Why do we not observe antimatter in the cosmos, and how do we explain the present ratio of baryons to photons that exceeds by far the value one would expect if the universe had been matter-antimatter symmetric until the QCD phase transition?

An appealing and experimentally falsifiable solution to the last puzzle is offered by leptogenesis. It is a cosmological consequence of the seesaw extension of the standard model, which explains the smallness of the neutrino masses by their mixing with heavy Majorana neutrinos. Generically, out-of-equilibrium decays of these heavy neutrinos in the early universe generate a primordial lepton asymmetry, which is subsequently converted into a baryon asymmetry by electroweak sphaleron processes. The temperature at which leptogenesis takes place is determined by the heavy neutrino masses and is typically of the order of 10^{10} GeV.

Supersymmetric extensions of the standard model and Einstein's theory of gravity predict the existence of the gravitino, the superpartner of the graviton, which couples with gravitational strength to standard model particles. In the early universe, gravitinos are thermally produced. It is intriguing that for typical

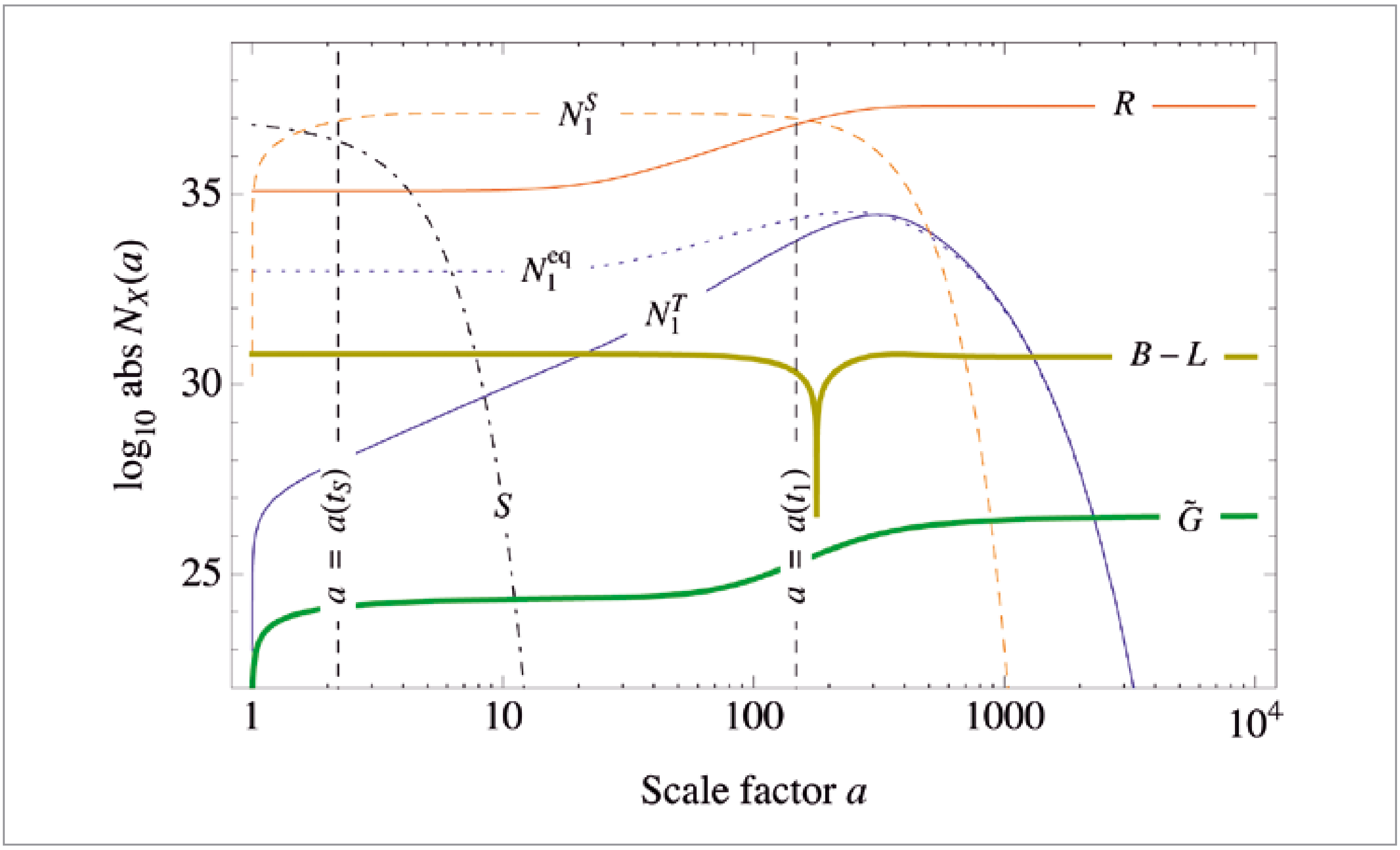


Figure 2

Generation of radiation (R), B – L charge and gravitino number ($\tilde{G}$) in a co-moving volume due to production and decays of heavy neutrinos. Increasing cosmic time corresponds to growing scale factor.

supergravity mass parameters and temperatures of the order of 10^{10} GeV, the predicted cosmological energy density of gravitinos is of the order of the observed amount of dark matter. A consistent cosmological evolution, including matter-antimatter asymmetry, dark matter and nucleosynthesis (BBN), strongly constrains the properties of neutrinos and superparticles. In particular, the next-to-lightest superparticle (NLSP), which may be a gaugino, the superpartner of the gluon or the electroweak bosons, has to decay sufficiently fast and have a low number density. This leads to upper bounds on the gravitino mass ($m_{3/2}$) and the temperature to which the universe is reheated after inflation (T_R) (Fig. 1) [arXiv:1009.3801]. Since leptogenesis needs large temperatures, gaugino masses below 300 GeV are predicted, a mass region which is currently probed at the Large Hadron Collider (LHC). Alternatively, entropy produced in the decay of a scalar particle may dilute the NLSP density at the time of BBN [arXiv:1008.1740], or the NLSP may decay into other light hidden-sector particles [arXiv:1004.4890] or into standard model particles if R-parity is slightly broken [arXiv:1007.5007, arXiv:1008.0398].

The fact that leptogenesis and gravitino dark matter point towards the same temperature scale suggests a possible common origin of the matter-antimatter asymmetry and dark matter. This is indeed the case if heavy neutrino decays produce not only the baryon asymmetry, but also all entropy of the hot early universe, which subsequently leads to thermal production of gravitinos [arXiv:1008.2355]. A particular realization of this scenario is “tachyonic preheating” in the course of false vacuum decay at the end of inflation. If the broken symmetry is identified with B – L, the difference of baryon and lepton number, preheating and (B – L) Higgs decay transfer the false vacuum energy density into heavy neutrinos whose decays produce entropy and baryon asymmetry. The evolution of the relevant number densities is shown in Fig. 2. The observed values of baryon-to-photon ratio and dark matter constrain the gravitino mass in terms of neutrino masses.

In the coming years, the possible connection between leptogenesis and gravitino dark matter will be tested by neutrino mass determinations in laboratory experiments and from cosmological observations, and by new results from the LHC.

Contact:

Wilfried Buchmüller, wilfried.buchmueller@desy.de

Non-perturbative phenomena in supersymmetric gauge theories.

From dreams to reality

During the last few years, some old ideas about the non-perturbative behaviour of gauge theories, such as the phenomenon of electric-magnetic duality, have been confirmed by detailed calculations in supersymmetric gauge theories. These advances became possible by an intricate blend of advanced methods of mathematical physics, some of which had their roots in rather different types of physical problems.

Since the 1970s, we have a very successful theory of the forces between the quarks, which are elementary constituents of matter. The theory of these forces, which has been tested with great success in particular at DESY, is called quantum chromodynamics (QCD). It explains the interactions between quarks by postulating new types of charges called colour, and describes the forces between coloured particles like the quarks by the exchange of a new type of particle, the gluon, which plays a role analogous to the photon in quantum electrodynamics (QED). Both QCD and QED fit into a common theoretical framework called gauge theory, the differences between the forces being related to the different types of charges that the respective forces couple to.

The description of QCD in terms of gluons works well when the processes under investigation can be described in terms of virtual gluon exchanges. This is indeed the case at high energies. The phenomenon called asymptotic freedom implies that the strength of the forces between quarks decreases when the energies involved in the process become large. Higher energies allow one to penetrate deeper into the cloud of virtual particles around a quark, which therefore contributes less to the effective strength of the interactions. Most of the success of QCD is based on this effect, which allows one to gain quantitative theoretical control over many interesting phenomena.

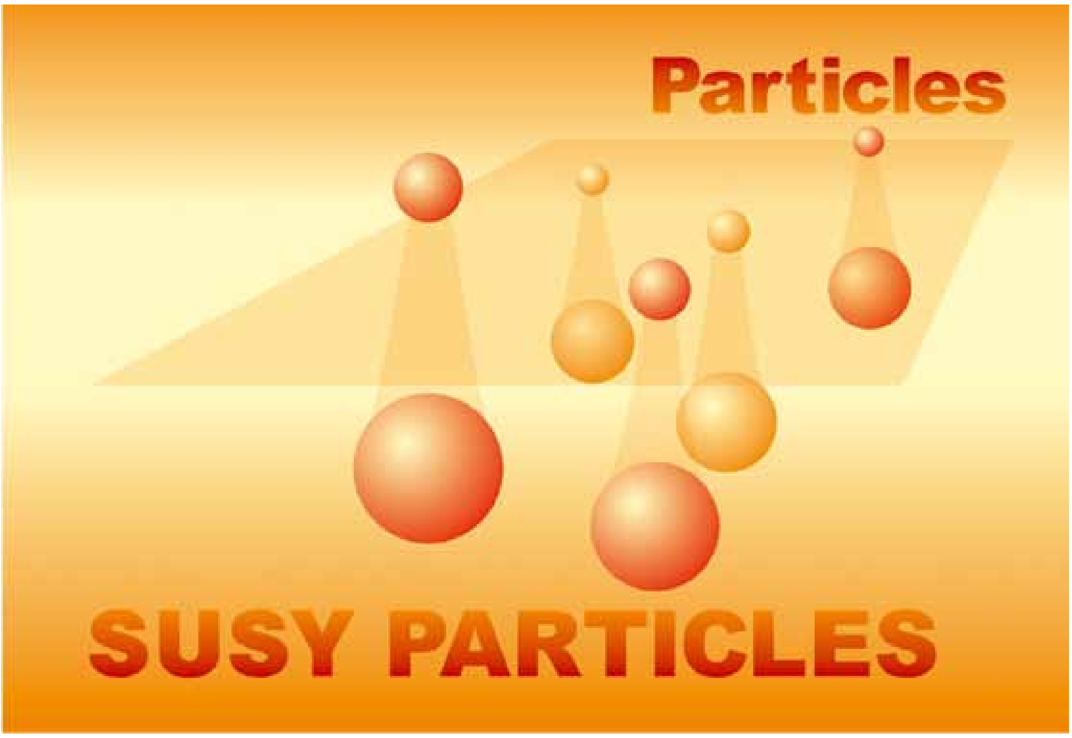


Figure 1

Supersymmetry postulates a supersymmetric partner for every particle.

The forces between quarks are much less well understood at low energies. They appear to be much stronger then, which prevents us from separating the quarks from each other and observing them in isolation. The quarks appear to be confined in bound states such as the neutrons and the protons formed by the effects of the strong interactions. It is a long-standing challenge for theoretical physics to develop efficient theoretical tools for the study of QCD in this regime in which the interactions are effectively strong.

It seems unlikely that the description of the forces in terms of gluons can still be useful in the low-energy regime where the forces become strong: too many virtual gluon exchanges would have to be taken into account. This has lead theoretical physicists like G. 't Hooft, A. Polyakov and S. Mandelstam to search for new theoretical tools. The question is: what are useful quantities that can be used to describe the behaviour of gauge theories at strong coupling? Analogs of the gluon field strength are not likely to be useful, as the description in terms of such quantities would be messed up by all kinds of effects.

One of the ideas put forward early on is often referred to as the electric-magnetic duality. This means, roughly speaking, that a useful description of the theory at strong coupling can be formulated with the help of new variables that are obtained from the variables used in the original formulation of QCD, like the gluon field by a non-local change of variables. If this or similar ideas are realized, they could become important parts of a future theory of phenomena like confinement. However, so far we do not seem to have sufficiently powerful tools for the analysis of gauge theories at strong coupling in general.

As often happens in such cases, it may help to study simplified examples which nevertheless capture some of the interesting qualitative features of realistic theories like QCD. The simplifications resulting from additional symmetries may help seeing through the “dust” of all the effects taking place in reality, the key effects responsible for a physical phenomenon of interest. Symmetries that have turned out to do this are called supersymmetries, their characteristic feature being relations between bosonic and fermionic particles in the theory. Even if supersymmetry is not realized in nature, it may be extremely useful as a theoretical tool to use for such investigations.

In the last few years, tremendous progress has been made in the study of supersymmetric gauge theories. This includes direct theoretical confirmations of phenomena such as the electric-magnetic dualities, together with quantitative predictions about the particle spectrum at low energies. The supersymmetry simplifies quantum effects due to virtual gluon exchanges, while keeping the so-called instanton corrections highly non-trivial. The analysis of the instanton corrections, which can be seen as quantum-field-theoretical analogs of quantum mechanical tunneling phenomena, is thereby becoming the key problem to solve to understand the strong-coupling physics of these gauge theories. This progress has one of its roots in the works of N. Seiberg and E. Witten. By using indirect arguments, these physicists were able to find exact results for a function called pre-potential, from which many physical quantities can be calculated. A direct method to derive the same results was subsequently developed by N. Nekrasov, based on a long series of works with other theoretical physicists in which sophisticated mathematical tools for the calculation of the instanton corrections had been developed.

With the help of these techniques it is has become possible to calculate the instanton corrections to the pre-potential and generalizations thereof to all orders in an expansion in powers of a parameter called Λ, related to the gauge coupling constant. However, in order to check the above-mentioned duality conjectures one would need to re-sum these expansions into expressions that are useful for calculating these quantities when Λ is large.

A breakthrough was achieved in the works of L. Alday, D. Gaiotto and Y. Tachikawa, who recognized that the series of instanton corrections coincide with objects known from a completely different direction of research, namely the correlation function of certain soluble models of statistical mechanics introduced for the study of critical phenomena. One of the main examples for the models related to gauge theory is the so-called Liouville theory, which was previously identified by Polyakov in 1981 as the main building block for interesting toy models of quantum gravity in two-dimensional space-time. Motivated by Polyakov’s discovery, the Liouville theory was intensively studied, leading to a precise understanding of its correlation functions.

The author’s work on the correlation functions of Liouville theory included a solution of the main problem arising in the gauge-theoretical context, namely finding re-summations of the instanton corrections which are useful for the investigation of gauge theories at strong coupling. By combining the observation of Alday, Gaiotto and Tachikawa with the author’s results about the correlation functions of Liouville theory, we obtain highly non-trivial quantitative confirmation of the electric-magnetic duality conjectures. These results can also be used to beautifully confirm the old ideas of Polyakov and others about the important role played by instanton corrections for the non-perturbative physics of gauge theories, and of ’t Hooft about the important role played by loop-localized observables as tools for the investigation of electric-magnetic duality phenomena in a theoretically well-controlled context.

Contact:

Jörg Teschner, joerg.teschner@desy.de

Reference:

Drukker, Gomis, Okuda, Teschner, JHEP 1002:057, 2010

Solving string theory on curved spaces.

Towards the solution of a supersymmetric gauge theory

The Young Investigators Group "Nonlinear Sigma Models in String Theory" of J. Teschner, funded by a Marie Curie Excellence Grant of the European Community, develops new techniques for quantitative calculations of the spectrum of string theory on curved spaces. In the context of the AdS-CFT correspondence, this is expected to lead to an exact solution of maximally supersymmetric gauge theory in the planar limit.

At present, we have a well-confirmed theory (quantum chromodynamics, QCD) of the strong interactions which bind the quarks into neutrons and protons. This theory fits into a larger class of quantum field theories called gauge theories. We also have a promising candidate for a unified theory of all matter and interactions – string theory. The main problem in the study of gauge theories is to understand what happens at strong coupling, where the qualitative behaviour is expected to be radically different from the well-understood situation at weak coupling. An important problem in our theoretical understanding of string theory is to understand what happens if space-time is strongly curved. This is the regime where string theory will differ drastically from any point-particle theory.

There is a growing number of hints that the two problems are often closely related. A class of conjectures of this type is referred to as the AdS-CFT correspondence. In an interesting particular case we even expect that both sides of the correspondence are exactly soluble. If this expectation, usually referred to as the integrability of the theories involved in this correspondence, is actually realized we could prove the AdS-CFT correspondence in this case. This would also allow us to quantitatively analyse both gauge theory and string theory in regimes which were believed to be inaccessible for theoretical studies until recently.

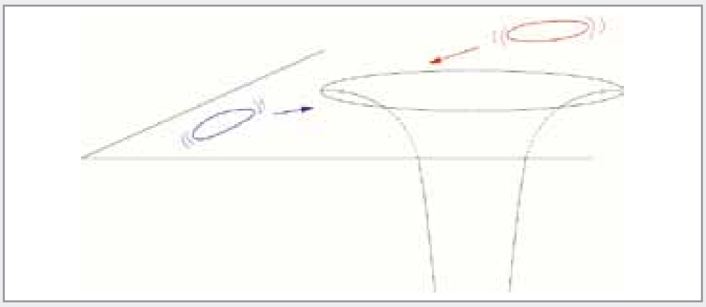


Figure 1

Strings on a curved space behave very differently from point particles.

However, despite much effort it has not yet been shown that the theories in question are integrable. The reason was a lack of sufficiently powerful mathematical tools for the analysis of such theories. The project at hand aimed at developing mathematical methods that would allow us to demonstrate that the string theory on certain Anti-deSitter (AdS) spaces is integrable.

We have made substantial progress towards this aim by developing a systematic mathematical procedure for regularizing large classes of quantum field theories in such a way that even the regularized version of the theory is integrable. The method has been successfully applied to first non-trivial examples relevant for string theory on curved spaces, demonstrating the integrability of these examples.

Even though we have not yet applied our techniques to the cases of three- and five-dimensional AdS spaces which motivate this line of research, we believe that our methods can be generalized to solve these cases too. Having developed the first systematic method for demonstrating the integrabilty of large classes of such theories is one of the main achievements of our project. No such method was known before. We believe that our work initiates a new line of research on the subject that will lead to the solution of the problems mentioned above.

Reference:
http://theory-hamburg.desy.de/e57813/e57817/e60458/index_eng.html

Marie Curie Young Investigators Group
"Nonlinear Sigma Models in String Theory"

Contact:
Jörg Teschner, joerg.teschner@desy.de

Computer algebra and higher orders in particle theory.

Precision phenomenology of physics processes at hadron colliders

Particle physics at high-energy collider experiments requires a quantitative understanding of strong and electroweak hard scattering processes to very high accuracy. The Helmholtz Young Investigators Group aims at this task of precision phenomenology by means of perturbative calculations to higher orders, where computer algebra is an indispensable tool for computations at the two- or three-loop level. The focus is on key observables for the current hadron colliders LHC and Tevatron as well as HERA.

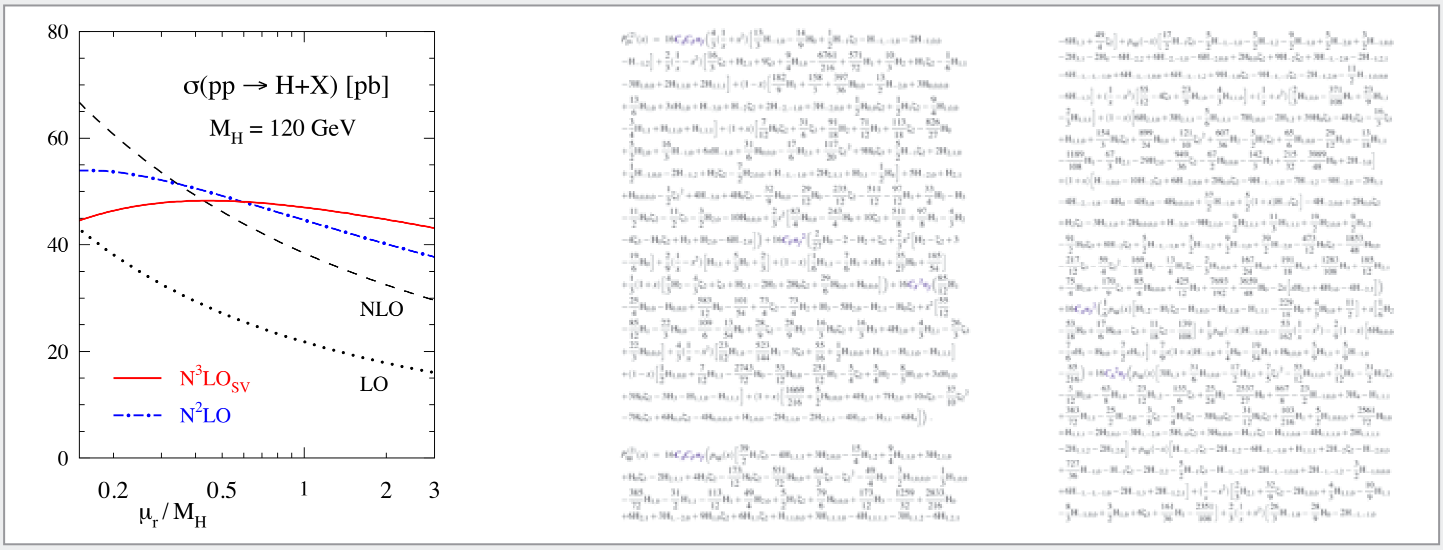


Figure 1

Precision QCD predictions of Higgs particle production at the LHC

Precision predictions for colliders are conducted in close contact to experiments. On the theory side, the computation of the radiative corrections, e.g. for the total cross section for Higgs boson production in gluon-gluon fusion at the LHC, no longer uses conventional technology. Instead it requires large-scale computer algebra, because the evaluation of the necessary Feynman diagrams leads to expression of the size of Gigabytes. Advanced mathematics and new algorithmic solutions for the complex problems arising at higher loop level in quantum field theory are also needed.

Today, forefront research in collider phenomenology is often pursued in small teams and in cooperation with international partners. This research group is integrated in actions funded by Deutsche Forschungsgemeinschaft (SFB/TR 9 “Computational Particle Physics”, Graduate school GK 1504 “Mass, spectrum, symmetry in the era of LHC”), the Initial Training Network “LHCPhenoNet” of the EU Marie Curie actions and, of course, in the Helmholtz Alliance “Physics at the Terascale”. Workshops allow for scientific discussions and the timely exchange of ideas. One example is the well-established conference series “Loops and Legs in Quantum Field Theory” at DESY in Zeuthen, which has been supported in the local organizing committee. Lectures at Humboldt Universität zu Berlin and the school on Computer Algebra and Particle Physics (CAPP) for graduate students bridge the gap to the even younger generation and provide training on state-of-the-art tools and technology.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_105

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
“Computer algebra and higher orders in particle theory” (VH-NG-105)

Contact:
Sven-Olaf Moch, sven-olaf.moch@desy.de

Precision phenomenology for the LHC.

Higgs and gauge boson production at TeV energies

The search for Higgs boson production as the last missing cornerstone of the Standard Model requires theoretical predictions at the best possible accuracy. For the important vector boson fusion channel, the accuracy of the cross section has recently been much improved through the computation of the next-to-next-to-leading order (NNLO) corrections in QCD. The production of electroweak gauge bosons as an important benchmark reaction needs to be considered at the same perturbative order to constrain the parton distribution functions (PDFs).

Higgs boson production in vector boson fusion (VBF) is the mechanism with the second largest rate and offers a clean experimental signature with the presence of at least two jets in the forward/backward rapidity region and a large variety of Higgs boson decay modes to be searched for (Fig 1). The VBF mode is a pure electroweak process at leading order and it acquires sizable corrections at next-to-leading order (NLO) in QCD as well as in the electroweak sector, leading to a typical accuracy for the total cross section in the 5-10 % range.

In [arXiv:1003.4451] [hep-ph], the NNLO QCD corrections for the VBF process have been completed in the so-called structure function approach, which builds on the approximate, although very accurate, factorization of the QCD corrections between the two quark lines. The inclusion of the NNLO corrections stabilizes the results at the 2% level against arbitrary variations of the renormalization (μ_R) and factorization (μ_F) scales, indicating an extremely well-behaved perturbative expansion (Fig. 2). PDF uncertainties are estimated at the 2% level as well, uniformerly

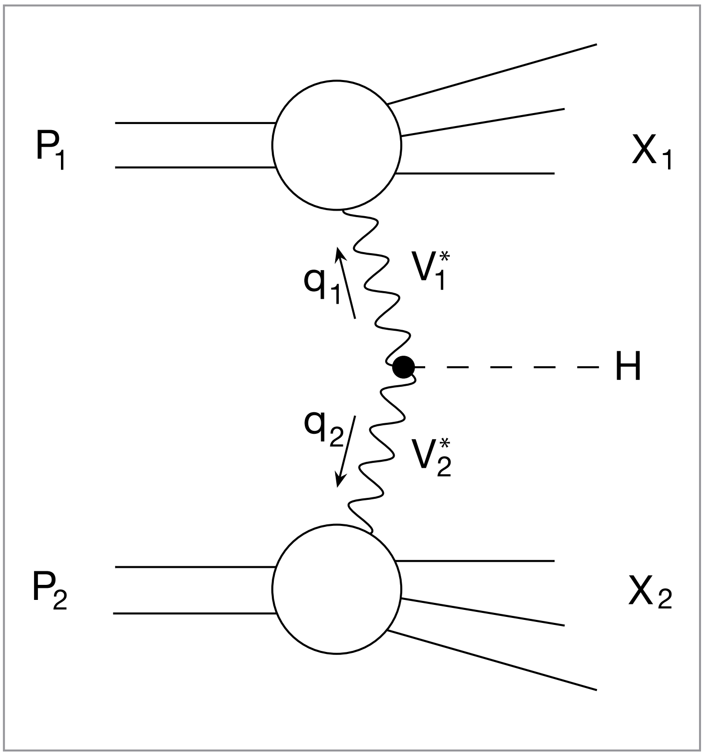


Figure 1

Higgs production via the VBF process

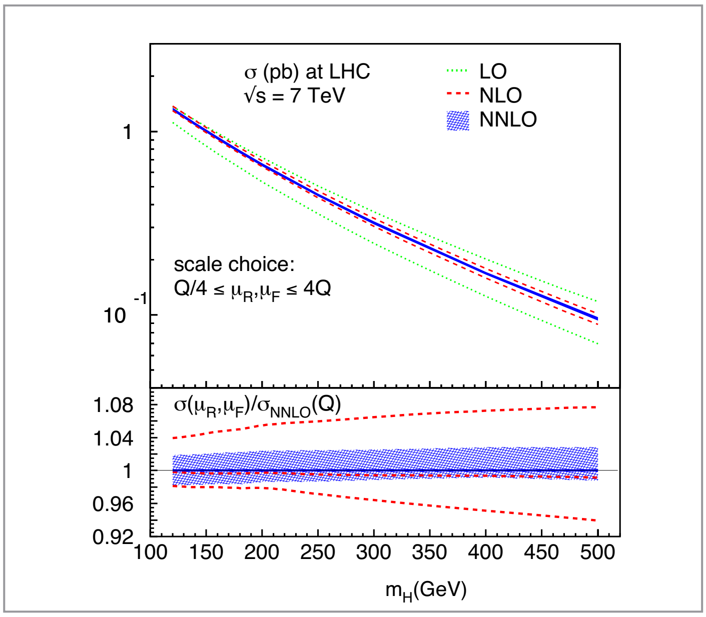


Figure 2

The total cross-section for Higgs production in VBF at LO, NLO and NNLO in QCD as a function of m_H for a $\sqrt{s} = 7$ TeV at the LHC with uncertainty bands due to scale variation. The lower inlay zooms in on the relative variations normalized to the NNLO cross section at μ_R, $\mu_F = Q$, so that the exceptionally good convergence of the perturbation series can be appreciated.

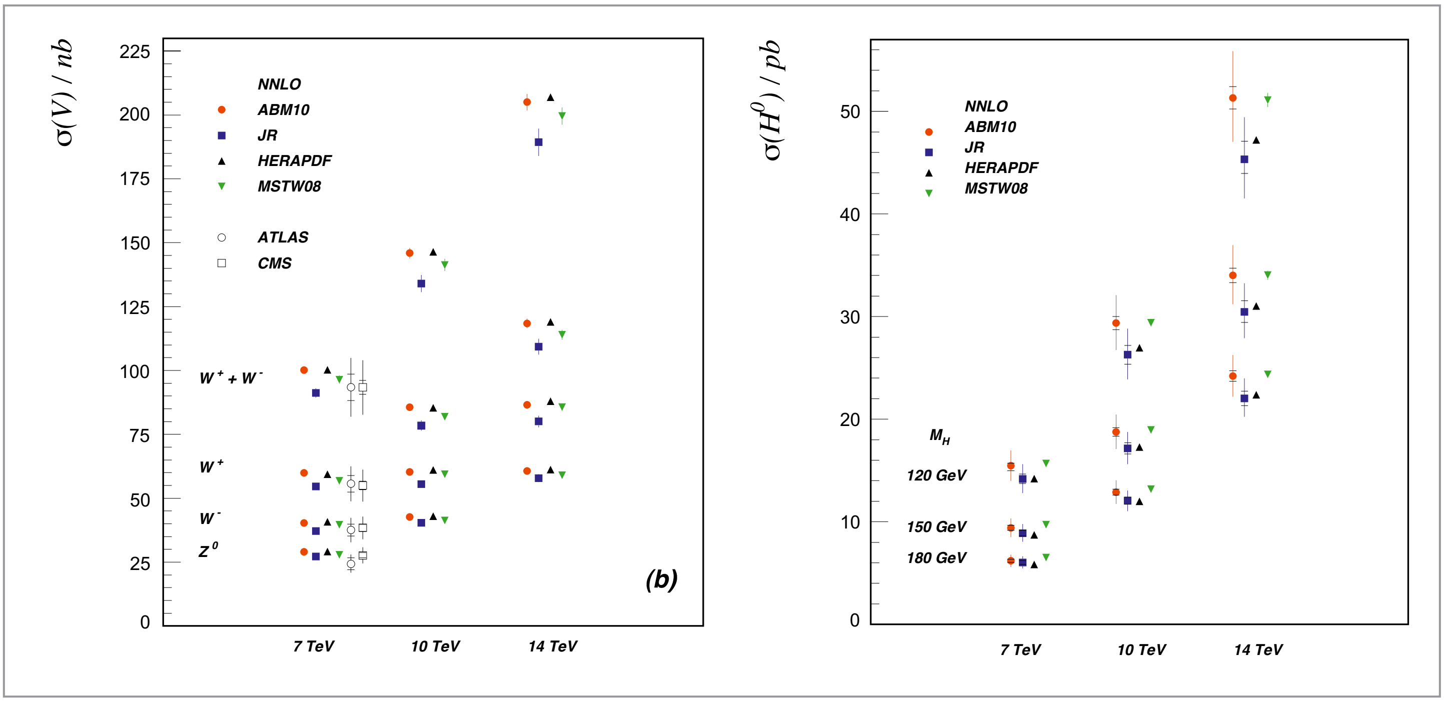


Figure 3

Left: Comparison of different NNLO predictions for the electroweak gauge boson production cross sections at different LHC energies based on PDFs of recent NNLO analyses (ABM10, JR, HERAPDF, MSTW08) and the corresponding experimental data. Inner error bars refer to $(\sigma_{\rm stat}^2+\sigma_{\rm syst}^2)^{1/2}$. The total error is obtained by adding the luminosity error in quadrature. Right: Predictions of the cross sections for Higgs-boson production in gluon-gluon fusion at NNLO for different LHC energies and the PDF sets ABM10, JR, HERAPDF, MSTW08. For the ABM10 and JR the scale variation in the range $M_H/2 \le \mu_F = \mu_R \le 2M_H$ is included. Inner error bars refer to the PDF errors only.

over a wide range of Higgs boson masses. This makes Higgs production in VBF currently the most accurately known process.

The inclusive production cross sections for W^+, W^- and Z^0 bosons form important benchmarks for the physics at hadron colliders. In [arXiv:1011.6259] [hep-ph] a detailed comparison of the predictions for these standard candles based on recent NNLO PDFs has been presented (Fig. 3, left). The rates for gauge boson production at the LHC can be rather confidently predicted with an accuracy of better than about 10% at NNLO.

Detailed NNLO predictions have also been obtained for cross sections of Higgs boson production in gluon-gluon fusion for Tevatron and different LHC energies (Fig. 3, right). It has become obvious that currently the largest differences between the various predictions are due to the PDFs and the respective value of the strong coupling constant $\alpha_s(M_Z^2)$.

The cross sections for Higgs boson production in gluon-gluon fusion at the LHC are presently predicted with an accuracy of about 10-17 %. Including the NNLO contributions in QCD is mandatory in order to achieve such accuracies, since the total uncertainties are substantially larger at NLO. At NNLO accuracy [arXiv:1011.6259] [hep-ph] serves as the standard reference for inclusive $W^\pm$, Z^0 and Higgs-boson production for the analyses of the Tevatron and CERN experiments.
The differences due to different non-perturbative input (PDFs, value of $\alpha_s(M_Z^2)$, etc.) require more detailed theoretical and experimental investigations in the future.

Contact:

Sven-Olaf Moch, sven-olaf.moch@desy.de
Sergey Alekhin, sergey.alekhin@desy.de
Johannes Blümlein, johannes.bluemlein@desy.de

Lattice QCD analysis of B decays.

Precision tests of the Standard Model

Heavy-flavour physics provides many important tests of the Standard Model. They typically rely on lattice QCD simulations for an ab-initio computation of the required hadronic matrix elements. However, the large mass of the b-quark poses a severe difficulty for this approach. A new method based on non-perturbative heavy quark effective theory (HQET) allows to significantly improve lattice predictions for B physics.

The Standard Model (SM) is the basis for the description of the known phenomena of electroweak and strong interactions of fundamental particles. Comparison of high-precision experimental data and theoretical predictions yields strong tests of the SM or – in case of discrepancies – can provide indirect information on as yet completely unknown new physics. Heavy-flavour phenomenology is an important field for such tests, because particles with heavy quark flavours can decay through many different decay channels and these processes are sensitive to the structure and the fundamental parameters of the SM. Among these parameters is the CKM matrix, which describes the relative strengths of flavour-changing weak currents and may explain the observed violations of the CP symmetry in particle physics.

Theoretical predictions of the quantities studied in precision tests of the SM typically depend on two parts: one describing the effect of electroweak interactions of the fundamental quark fields at short distances, and one relating these processes to the hadrons which are actually observed. A typical example is the rare decay $B \to \tau\nu$ which has recently been measured by experiments [arXiv:1010.3746]. The theoretical prediction for the decay rate is proportional to the product $|V_{ub}|^2 f_B^2$, where the CKM element V_{ub} is a fundamental parameter of the SM and f_B is the so-called decay constant of the B meson. If f_B is known with sufficient precision, this decay can be used to test the SM by comparing the resulting value of V_{ub} with determinations from other processes, such as $B \to \pi\ell\nu$. Current data indicates a small tension at the level of 3σ [arXiv:1010.5089].

The “hadronic matrix elements”, such as f_B or form factors, represent the long-distance dynamics of the hadronic bound states which are formed through strong interactions. These

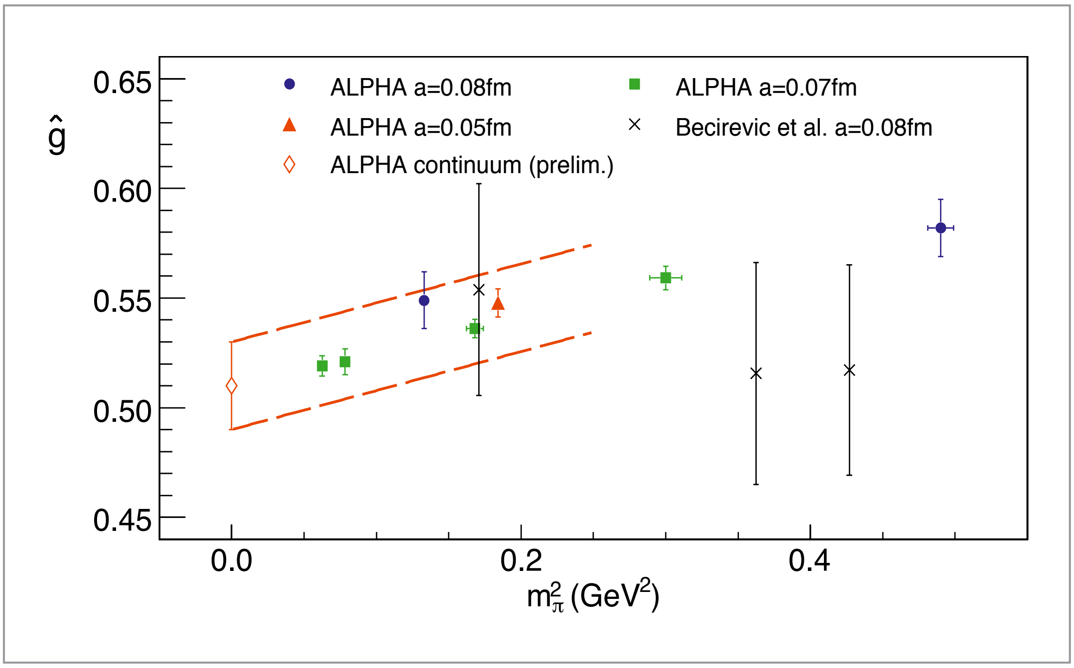
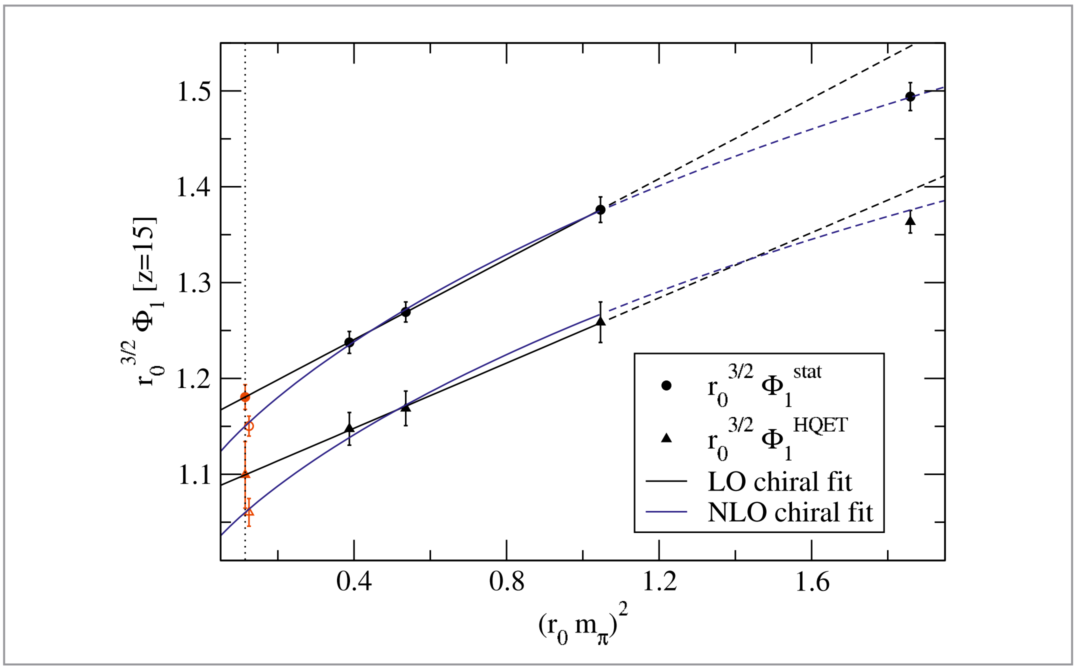


Figure 1

Lattice determination of the $B^*B\pi$ coupling, $\hat{g}$, which enters in the chiral extrapolation of various B physics hadronic matrix elements.

Figure 2

HQET matrix element to determine f_B in the static approximation and including $1/m_b$ terms. The figure shows the dependence on the light quark mass $m_q \sim m_\pi^2$ at a single lattice spacing $a = 0.07$ fm.



are assumed to be perfectly described within the SM by quantum chromodynamics (QCD), but their computation is difficult and requires non-perturbative methods, such as numerical simulations on the lattice (LQCD). A particular challenge for the application of LQCD to heavy-flavour physics is the adequate treatment of the propagation of the heavy b-quark. To keep discretization errors under control in direct simulations one would require very small lattice spacings which are far from being practical, even with today's most powerful computers and algorithms. To overcome this difficulty the b-quark needs to be treated using an effective theory.

The NIC group has developed and tested a non-perturbative lattice formulation of heavy quark effective theory (HQET). It takes into account all corrections at order $1/m_b$ of the expansion in the heavy quark mass m_b, and the continuum limit of physical quantities is well behaved because the parameters of the effective theory are determined by a non-perturbative matching with QCD. This new formulation of HQET on the lattice has been carefully tested in a simplified setup [arXiv:1001.4783], and is now being applied to the theory with two dynamical light quarks to compute f_B [arXiv:1012.1357] and other hadronic matrix elements relevant for heavy-flavour phenomenology.

To obtain precise and reliable results from lattice simulations, it is mandatory to have full control of all systematic effects, in particular those emerging from the extrapolation of results at finite lattice spacing to the continuum limit $a \to 0$, including non-perturbative renormalization, and the extrapolation in the mass of the light quarks, m_q, to the physical (or chiral) limit. This requires a combined analysis of data from many simulations at different lattice spacings and quark masses. These simulations are carried out within international collaborations, such as ALPHA and the Coordinated Lattice Simulations (CLS) effort, and use various high-performance computer systems, e.g. at NIC in Jülich, ZIB in Berlin, and DESY in Zeuthen.

The extrapolation in the light quark mass can be constrained by making use of chiral perturbation theory. It is based on general symmetry properties of QCD and allows to describe the m_q dependence of hadronic quantities in terms of a few effective parameters (low energy constants). For instance, the most important parameter entering in the chiral extrapolation of f_B is the effective $B^*B\pi$ coupling.

An improved lattice determination of this coupling [arXiv:1011.4393] is shown in Fig. 1. The significantly increased accuracy was achieved by using state-of-the-art techniques and analysis methods, such as variance reduction with stochastic estimators for all-to-all propagators. For the suppression of contaminations from excited states the generalized eigenvalue problem was solved in a way where fast convergence was proven recently by the NIC group [arXiv:0902.1265].

The chiral extrapolation of f_B at one lattice spacing is shown in Fig. 2. The analysis of further data from finer lattice spacings to perform a reliable continuum extrapolation of f_B is in progress.

In the next step, more difficult hadronic matrix elements, like the form factors for $B \to \pi$ decays, will be computed with high accuracy in the framework of HQET on the lattice. This will provide the theoretical input for an accurate determination of V_{ub} from $B \to \tau\nu$ and $B \to \pi\ell\nu$ decays, and thus to test the consistency of the SM or to find hints for new physics.

Contact:

Rainer Sommer, rainer.sommer@desy.de
Karl Jansen, karl.jansen@desy.de
Hubert Simma, hubert.simma@desy.de

Reference:

NIC Group http://nic.desy.de

Growing evidence for tetraquarks.

First tetraquark candidate in the bottom sector!

One of the basic question in hadron physics is: Are there additional structures beyond the $(q\bar{q})$ mesons and (qqq) baryons in nature? If not, why not? If so, where are they? We argue that the anomalously large production cross sections for $e^+e^- \to (\Upsilon(1S),\Upsilon(2S))\pi^+\pi^-$, measured near the $\Upsilon(5S)$ resonance by the Belle collaboration at KEK, can be explained in terms of a $[bq][\bar{b}\bar{q}]$ tetraquark called $Y_b(10890)$, which is a bound state of a diquark $[bq]$ and an antidiquark $[\bar{b}\bar{q}]$.

Hadrons with a valence quark content beyond $(q\bar{q})$ or (qqq) are called exotics. The ones which have $(qq\bar{q}\bar{q})$ valence quark content are called tetraquarks. Much of the discussion of tetraquark states involves the concept of diquarks as effective degrees of freedom in mesons. As concepts, diquarks are not new. They go back to theoretical suggestions some 40 years ago and were also discussed in contexts such as colour superconductivity, dense quark matter and, in particular, in explaining the $\Delta I = 1/2$ rule in kaon decays.

The scientific case for the existence of tetraquarks recently got a boost by the discovery of new hadronic states in the mass region of the charmonia. In the past several years, experiments at the two B-factories, BaBar and Belle, and at the Tevatron, CDF and D0, have discovered an impressive number of new hadronic states in this mass range. These states, generically labeled X, Y and Z, defy a conventional charmonium interpretation, and certainly not all of them can be accommodated in this picture. Also the perception about the light scalar mesons, such as $f_0(600)$ or σ and $f_0(980)$, has changed. They are now interpreted as being dominantly $[qq'][\bar{q}\bar{q}']$ states. The case of tetraquarks in the b-quark sector was provided by the analysis of the Belle and BaBar data [1,2] discussed below. To summarize all these experimental findings, it is fair to say that a theoretical consensus in favour of tetraquarks is slowly emerging.

From the phenomenological point of view, considering diquarks as building blocks is very attractive as it allows us to make specific predictions. For example, the production rates of tetraquarks with the spin-parity quantum numbers $J^{PC} = 1^{--}$ in e^+e^- annihilation experiments can be determined by extending the equivalent of the Van Royen-Weisskopf formula for the quarkonia to the tetraquark case, see Fig. 1. In the approximation that the photon coupling to Y_b is proportional to the charges of the diquarks, this formula has been derived in [1].

In [2], a dynamical model was developed to explain the Belle data for the process $e^+e^- \to (\Upsilon(1S),\Upsilon(2S))\pi^+\pi^-$ in terms of the production and decays of Y_b. The two puzzling features of these data are that the measured cross sections for these processes are anomalously larger by two orders of magnitude than the expectations from the conventional QCD formalism for dipionic transitions in bottomonium states, and the shape of the dipion invariant mass distributions are not in accord

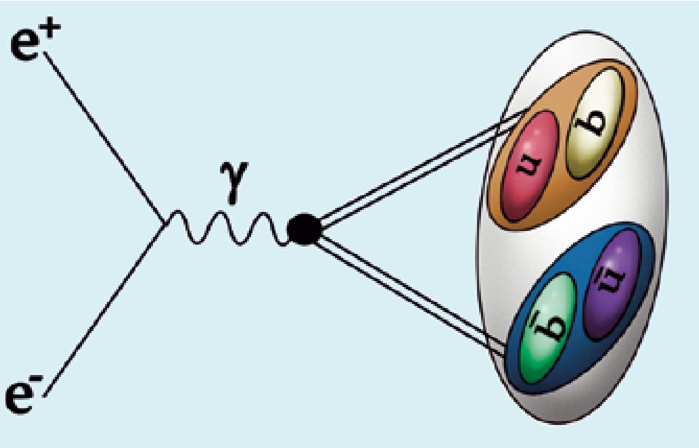


Figure 1

Diagram for calculating the Van Royen-Weisskopf leptonic width of $Y_b(10890)$

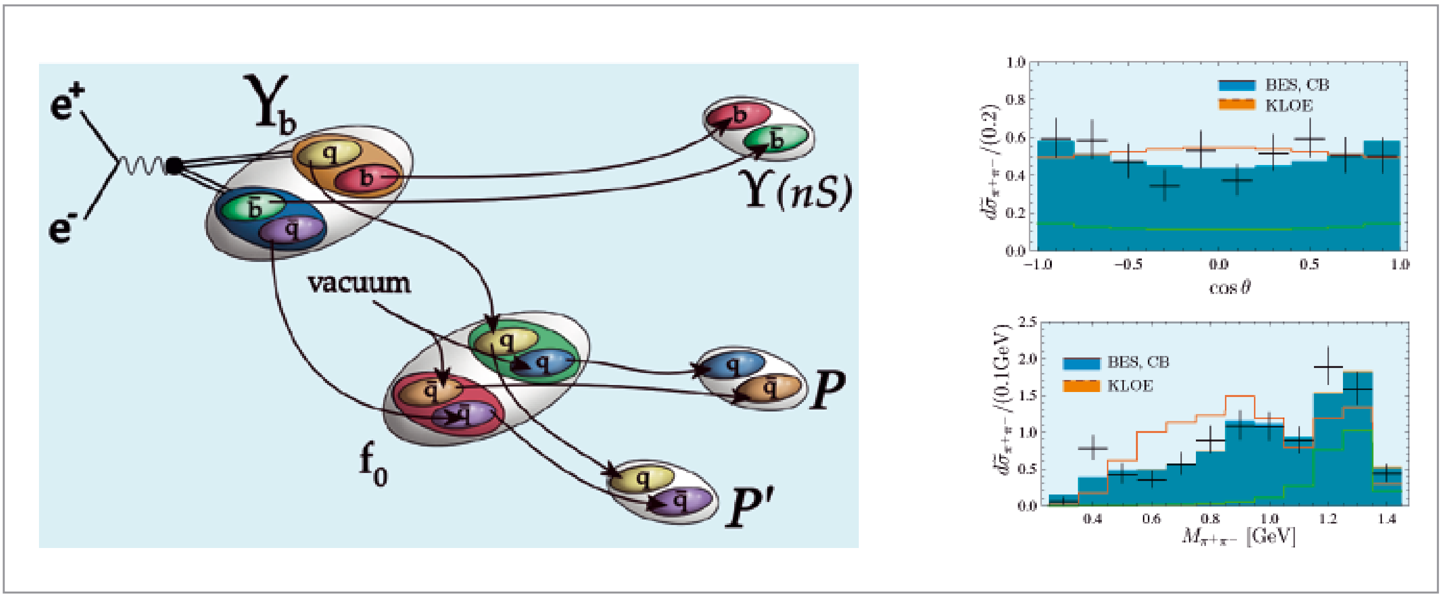


Figure 2

Left: Zweig-allowed quark rearrangement process for the interchange of a light scalar 0^{++} resonance. Right: measured spectra for the $\Upsilon(1S)\ \pi^+\ \pi^-$ channel (crosses are Belle data). The histograms represent the fits based on the tetraquark assumption [1].

with the QCD formalism either. These aspects are also at variance with similar dipionic transitions observed between the lower Υ resonances.

A key observation towards understanding the Belle data is that the final states in question are produced in the processes $e^+e^- \to Y_b(10890) \to (\Upsilon(1S), \Upsilon(2S))\pi^+\pi^-$, with Y_b being a $J^{PC}=1^{--}$ tetraquark, having a total decay width of about 30 MeV. Our model describes the measured distributions in the dipion invariant mass and helicity angle and offers an explanation of the rates in terms of the Zweig-allowed transitions, see Fig. 2 (left). In this model, the low-mass scalar 0^{++} hadrons σ or $f_0(600)$ and $f_0(980)$ and the $J^{PC}=2^{++}$ state $f_2(1270)$ provide the dominant resonant part of the amplitude for the process $e^+e^- \to Y_b \to \Upsilon(1S)\pi^+\pi^-$. The non-resonating continuum contributions are parametrized in terms of two a priori unknown constants, determined by the fits of the Belle data. The invariant mass $M_{\pi^+\pi^-}$ and the cos θ spectra are shown in Fig. 2 (right), where θ is the angle between the momentum of Y_b and π^+ in the dipion rest frame.

The tetraquark description was further developed in [1], in which in addition to the final states discussed above the final states $\Upsilon(1S)(K^+K^-, \eta\pi^0)$ were also theoretically worked out. The dimeson mass spectra in these states are dominated by the 0^{++} scalar mesons, where now the scalar meson $a_0(980)$ contributes too. Since these spectra are dominated by the scalars $f_0 + a_0$ and a_0, respectively, there is a strong correlation between the two cross sections. The predicted cross section for $\Upsilon(1S)K^+K^-$ is in agreement with the Belle measurement. The tetraquark model will be scrutinized as and when the cross section $\Upsilon(1S)\eta\pi^0$ is measured and the invariant mass spectra in K^+K^- and $\eta\pi^0$ become available. A further test of the tetraquark model is provided in terms of the cross sections in $e^+e^- \to \Upsilon(1S)K^+K^-$ and $e^+e^- \to \Upsilon(1S)K^0\bar{K}^0$, as they are predicted in this model with a ratio of 1:4. These tests will be performed in the near future in experiments at the B-factories. If confirmed by future experiments, our work in [1] and [2] will be the first convincing model in support of tetraquarks in the bottom sector.

Contact:

Ahmed Ali, ahmed.ali@desy.de

References:

[1] Phys. Rev. Lett. 106, 092002 (2011)
[2] Phys. Rev. Lett. , 162001 (2010)

Testing string theory in cosmology.

How string theory may become visible in the sky

Observational cosmology points towards a very early phase of cosmological inflation prior to the hot big bang. Future observations like those of the PLANCK satellite may detect primordial gravitational waves generated during inflation. If they are seen, then the energy scale of inflation is so high that string theory as a candidate quantum gravity may modify the inflationary predictions and become testable.

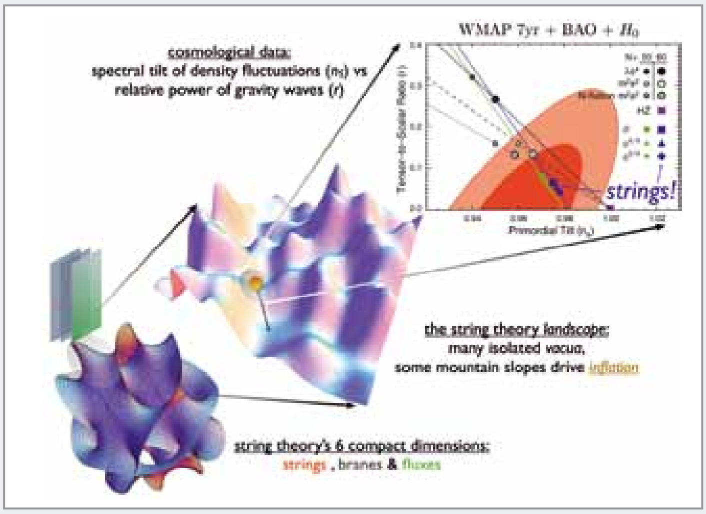


Figure 1

String theory produces a landscape of vacua, some of them contain inflationary slopes. High enough slopes produce gravity waves detectable by PLANCK. Their stringy origin 'deforms' the shape of the slopes and their inflationary predictions, compared to naive field theory.

Recent years have seen the emergence of a concordance model of cosmology furnished by high-precision measurements of distant supernovae and the cosmic microwave background (CMB) radiation, e.g. from the recent seven-year-data of the Wilkinson Microwave Anisotropy Probe (WMAP) collaboration: a spatially flat universe composed of 4% ordinary matter, 22% dark matter, and 74% dark energy. The initial conditions of the hot big bang, including the nearly scale-invariant spectrum of primordial density fluctuations, agree beautifully with a very early phase of cosmological inflation.

Inflation denotes a form of quasi-exponential expansion of the very early universe driven by the potential energy density of a slowly rolling scalar field. Beyond the primordial density fluctuations responsible for all visible structure of the universe today, inflation also produces a scale-invariant spectrum of primordial gravitational waves. Their amount relative to the amount of density fluctuations depends on the energy scale of inflation. If future observations such as those of the PLANCK satellite detect these gravitational waves, then the energy scale of inflation is so high that string theory as a candidate quantum gravity may modify the inflationary predictions and become testable.

Recently, string theorists have learned [arXiv:hep-th/0301240, hep-th/0308055] how to construct stabilized four-dimensional string vacua, which are cosmologically viable and devoid of unwanted additional light scalar fields, a prerequisite for inflation. This led to the realization that string theory generates a whole 'landscape' of vacua, that is, (meta)stable solutions of string theory [arXiv:hep-th/0302219]. They can be pictured as the local valleys in a mountainous landscape of potential energy, and their number possibly exceeds scales like 10^{500}. Here, inflation corresponds to e.g. a scalar field slowly rolling off some shallow slope of a particular mountain into the nearest valley.

Recent work of members of our group [arXiv:0803.3085, 0808.0706] has succeeded in constructing controlled models of inflation in string theory where the energy scale of inflation is close enough to the fundamental string/Planck scale of 10^{18} GeV that they produce primordial gravitational waves visible with PLANCK. Moreover, there seems to be a generic tendency in the string landscape to 'flatten' away the properties of gravity waves from naive field theory expectation in those string inflation models which generate detectable amounts of gravity waves [arXiv:1011.4521]. These developments may enable us to confront string theory with observational data at energy scales far beyond any particle accelerator.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_603

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group
"Strings and Cosmology - an Interface for Testing fundamental Theories Gamma-Ray Observatory" (VH-NG-603)

Contact:
Alexander Westphal, alexander.westphal@desy.de

Particles, strings and the early universe.

Collaboration to unravel the structure of matter and space-time continues

In 2010, the German Research Foundation (DFG) approved the second four-year funding period of the Collaborative Research Centre (SFB) 676, whose research programme is centred at the interface of particle physics, string theory and cosmology, and carried out by researchers from various institutes in the Physics Department and the Department of Mathematics of the University of Hamburg, as well as from DESY.

Figure 1
The members of the Collaborative Research Centre 676

Significant advances are expected in particle physics and cosmology in the course of the next decade. Experiments at the Large Hadron Collider (LHC) will elucidate the nature of the elementary building blocks of matter, uncover the mechanism responsible for their mass generation and discover or severely constrain physical phenomena which go beyond the Standard Model of particle physics. Similarly, cosmological observations will improve the understanding of dark matter and dark energy and will further establish the history of the very early universe. Particle physics and cosmology are expected to be unified within string theory.

In order to benefit from the fruitful interplay between these different fields, the SFB 676 includes researchers from many different groups at the University of Hamburg and DESY. Eliminating the traditional borders between these subjects has proven to be inspirational and has led to interesting interdisciplinary research projects.

Various research groups participating in the SFB are involved in LHC experiments and in aspects of upcoming cosmological observations. In parallel, theoretical and mathematical investigations are carried out. (Supersymmetric) extensions of the Standard Model are a particular focus of interest. Such theories lead to interesting predictions for new particles within the discovery reach of the LHC, and they also suggest a promising explanation of dark matter. The physics of axions and other very weakly interacting slim particles, questions concerning the origin of cosmic rays and cosmic leptogenesis are further research projects of the SFB. The mathematical development of string theory and its application in particle physics and cosmology form another central research topic of the SFB.

Last year, the SFB, which was originally installed in 2006, successfully applied for a second funding period. The funding approved by the DFG amounts to about 2 million euro per year, from mid-2010 to mid-2014.

Contact:
Andreas Ringwald, andreas.ringwald@desy.de

Reference:
http://wwwiexp.desy.de/sfb676/

FATER.

Instant access to more than 15 million scientific documents

The FATER (Fast Access To Electronic Resources) application, which was developed by the DESY library and is now used by eight libraries throughout the Helmholtz Association of National Research Centres, enables instant access for all DESY users to more than 15 million scientific documents, either by seamless pay-per-view or fast interlibrary loan.

Scientists need access to a broad spectrum of scientific literature. With subscriptions to more than 700 electronic journals, close to 300 printed journals and approximately 30 000 books, the DESY library provides direct access to a majority of this information. Recent access statistics at DESY and at Forschungszentrum Jülich (FZJ) clearly show that the more interdisciplinary the research, the broader the required journal spectrum. This results in various but widely spread full-text requests in non-subscribed journals outside the main research area. At DESY, requests to nearly 40 of these journals were observed, while at FZJ requests to non-subscribed journals covered more than 360 titles. In fact, in more than two out of three cases there were less than two full-text requests for each of those journal titles during half a year. Obviously to provide access to all these journals through subscription is no sensible option, so libraries use interlibrary loan (ILL) services (e.g. SUBITO) to obtain non-subscribed content. With standard ILL, the content is provided usually within one day during working hours. To offer a much faster service with an extended availability of 24/7, the DESY library developed FATER. This unique open source web application developed in PERL (see Fig. 1) allows automatic, seamless pay-per-view access to unsubscribed contents for the major scientific publishers (e.g. Elsevier, IOP, Nature, Springer, Taylor & Francis, Wiley and World Scientific) and fast ILL with selected partners through secure electronic fax transmission. It thus gives all DESY scientists almost instant access to more than 15 million documents and to all DESY scientists and allowed the DESY library to adjust its journal portfolio to its users' needs.

LIBRARIES PDF >>

When requesting a document, the FATER server tries to find the corresponding full text first through the publisher's web site. If this fails, the partners are asked for a copy through fast ILL. Finally the web is searched for an open access version. If none is found, either – for selected publishers – the additional option to use the fast, but more expensive seamless pay-per-view option is presented to the user, or the user may order the article through standard ILL. In the latter case, the resulting ILL request is fulfilled manually by the library staff.

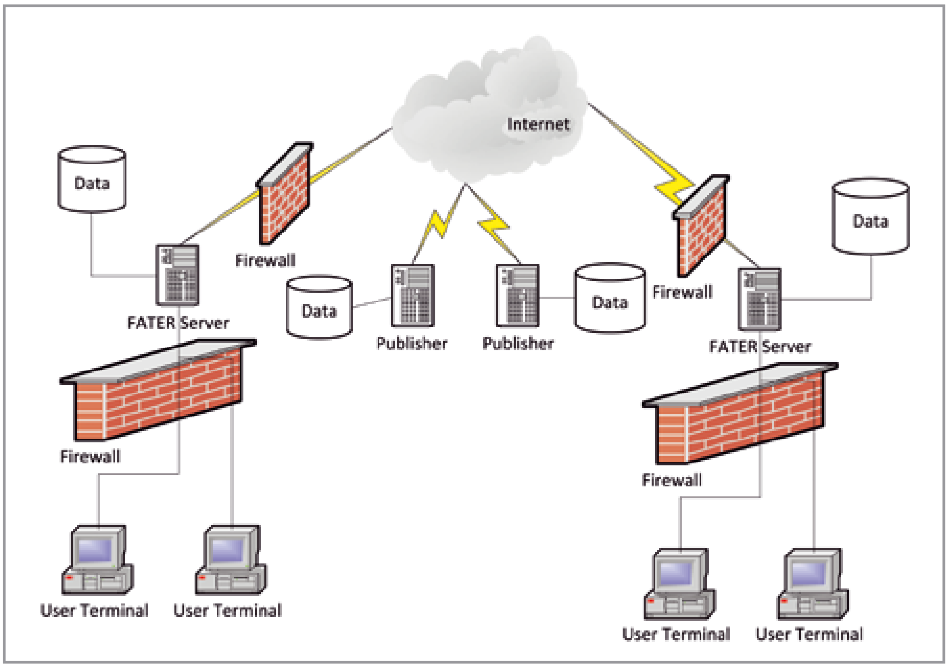


Figure 1

FATER architecture

Figure 3

Some journals available at the DESY libraries

FATER allows an individual branding (see Fig. 2 and 3) and can thus be used at other research facilities as well. In 2010, seven HGF centres beside DESY used the software. FATER is maintained and deployed in tight collaboration with FZJ. It is openurl-compliant and can be integrates seamlessly into access portals of publishers (e.g. Elsevier, Springer) as well as into commercial databases like Web Of Science (Thomson) or SCOPUS (Elsevier). When using these systems, obtaining the full text of a document through either fast ILL or seamless pay-per-view is just one click away.

It is very interesting to note that at DESY, users order only 20 % of all articles FATER cannot deliver immediately through standard ILL. Pay-per-view is used even more rarely. From every 100 articles the system could buy, only seven were actually bought by the users. For the remaining 93 articles, the users either abdicated the full text or they ordered the article through standard ILL.

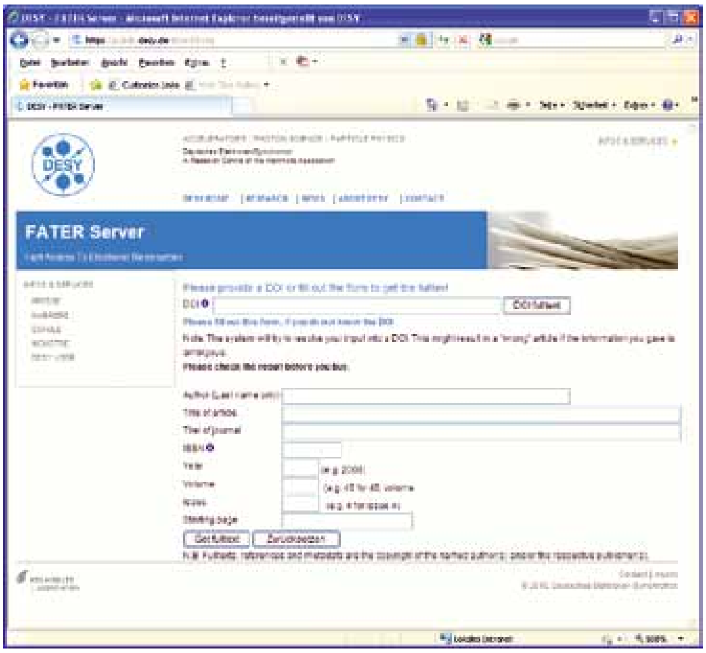


Figure 2

FATER server (DESY branding)

Contact:

Martin Köhler, martin.koehler@desy.de

References.

Committees.

DESY Administrative Council

Representatives of the Federal Republic of Germany:

Dr.-Ing. **B. Vierkorn-Rudolph** (Chair)
(Federal Ministry of Education and Research)

MinR'in **O. Keppler**
(Federal Ministry of Education and Research)

MinR **H. J. Hardt**
(Federal Ministry of Finance)

Representatives of the Free and Hanseatic City of Hamburg:

LRD Dr. **R. Greve**
(Ministry of Education and Research)

ORR Dr. **M. Brüser**
(Ministry of Finance)

Representatives of the Federal State of Brandenburg:

MinDirig Dr. **J. Glombik**
(Ministry of Science, Research and Culture)

Dr. **C. Menzel**
(Ministry of Finance)

DESY Board of Directors

Dr. **R. Brinkmann**
(Accelerator division)

Prof. Dr. **H. Dosch**
(Chairman of the DESY Board of Directors)

Prof. Dr. **J. Mnich**
(High energy physics and astroparticle physics)

C. Scherf
(Administrative division)

Prof. Dr. **E. Weckert**
(Photon science division)

Dr. **U. Gensch**
(Representative of the directorate in Zeuthen)

DESY Scientific Council

Dr. **U. Bassler**
CEA-DSM Gif sur Yvette (FR)

Prof. Dr. **S. Chattopadhyay**
Daresbury Laboratory (UK)

Prof. Dr. **M. Danilov**
ITEP, Moscow (RU)

Dr. J.-P. **Delahaye**
CERN, Geneva (CH)

Prof. Dr. **B. Foster**
University of Oxford (UK)

Prof. **J. Hastings**
Stanford Linear Accelerator Center (USA)

Dr. **N. Holtkamp**
ITER International Team, St. Paul lez Durance (FR)

Prof. **E. Iarocci**
INFN Frascati (IT)

Prof. Dr. **J. Kirz**
Lawrence Berkeley National Lab (USA)

Dr. **G. Long**
Argonne National Laboratory (USA)

Prof. Dr. **J. Nordgren**
University of Uppsala (SE)

Prof. Dr. **H. Ott**
Laboratorium für Festkörperphysik, Zürich (CH)

Prof. Dr. **M. Tolan** (Chair)
Universität Dortmund

Dr. **P. Wells**
CERN, Geneva (CH)

Prof. **G. Wormser**
LAL, Orsay (FR)

and the chairs of:

ECFA: Prof. Dr. **T. Nakada**
(EPFL, Lausanne, CH & CERN, Genf, CH)

MAC: Dr. **L. Rivkin**
(Paul Scherrer Institut, Villigen, CH)

PRC: Prof. Dr. **T. Lohse**
(Humboldt Universität Berlin)

PSC: Prof. Dr. **C. Norris**
(DIAMOND, CCLRC Rutherford Appleton Laboratory, USA)

WA: Dr. **T. Behnke**
(DESY, Hamburg)

European XFEL: Prof. **M. Altarelli**
(DESY, Hamburg)

DESY Scientific Board

K. Balewski (DESY)
F. Beckmann (GKSS)
T. Behnke (DESY) (Chair)
M. Bieler (DESY)
K. Borras (DESY)
W. Buchmüller (DESY)
W. Drube (DESY)
G. Eckerlin (DESY)
E. Elsen (DESY)
T. Finnern (DESY)
K. Flöttmann (DESY)
H. Franz (DESY)
H. Graafsma (DESY)
I.-M. Gregor (DESY)
G. Grübel (DESY)
V. Gülzow (DESY)
J. Haller (Univ. Hamburg)
A. Hayrapetyan (Univ. Gießen)
K. Honkavaara (DESY)
J. Jung (DESY)
J. Kaminski (Univ. Bonn)
M. Kasemann (DESY)
O. Kind (Humboldt-Univ. Berlin)
K. Krüger (Univ. Heidelberg)
M. Martins (Univ. Hamburg)
K. Mönig (DESY)
T. Naumann (DESY)
D. Nölle (DESY)
K. Rehlich (DESY)
B. Reisert (MPI München)
A. Ringwald (DESY)
K. Rith (Univ. Erlangen-Nürnberg)
M. Roessle (EMBL)
R. Santra (DESY)
F.-P. Schilling (Univ. Karlsruhe)
S. Schlenstedt (DESY)
M. Schmitz (DESY)
V. Schomerus (DESY)
S. Schreiber (DESY)
H. Schulte-Schrepping (DESY)
A. Schwarz (DESY)
J. Spengler (DESY)
M. Tischer (DESY)
T. Tschentscher (European XFEL)
U. Vainio (DESY)
J. Viefhaus (DESY)
M. Vogt (DESY)
D. Wegener (Univ. Dortmund)
P. Wegner (DESY)
G. Weiglein (DESY)
H. Weise (DESY)
K. Wittenburg (DESY)

Machine Advisory Committee (MAC)

Dr. **H. Braun** (PSI, CH)
Dr. **M. Eriksson** (Univ. Lund, SE)
Dr. **J. Filhol** (Soleil, FR)
Dr. **K. Oide** (KEK, JP)
Dr. **L. Rivkin** (PSI, CH) (Chair)
Dr. **M. Ross** (FNAL, USA)
Dr. **R. Schmidt** (CERN, CH)
Dr. **R. Walker** (Diamond, UK)

Physics Research Committee (PRC)

Prof. Dr. **G. Anton** (Univ. Erlangen)
Dr. **E. Aschenauer** (BNL, USA)
Prof. Dr. **M. Beneke** (RWTH Achen)
Prof. Dr. **P. Buchholz** (Univ. Siegen)
Dr. **M. Carena** (Fermilab, USA)
Prof. Dr. **T. Lohse** (HU Berlin) (Chair)
Dr. **E. Perez** (CERN, CH)
Prof. Dr. **G. Quast** (Univ. Karlsruhe)
Prof. Dr. **N. Saito** (Univ. Kyoto, JP)
Dr. **J. Timmermans** (NIKHEF / CERN)
Dr. **A. White** (Univ. Texas, USA)
Dr. **R. Yoshida** (ANL, USA)

Photon Science Committee (PSC)

Prof. Dr. **M. Fröba** (Univ. Hamburg)
Dr. **R. Horisberger** (PSI Villigen, CH)
Prof. Dr. **K. Janssens** (Univ. Antwerpen, BE)
Prof. Dr. **C. Norris** (Diamond, UK) (Chair)
Prof. Dr. **F. Pfeiffer** (TU München)
Dr. **H. Reichert** (MPI Stuttgart)
Prof. Dr. **J.-P. Samama** (Soleil, FR)
Dr. **P. Siddons** (BNL, Upton, USA)
Dr. **S. Techert** (MPI Göttingen)
Prof. Dr. **E. Weckert** (DESY)
Prof. Dr. **P. Withers** (Univ. Manchester, UK)

Landesexzellenzinitiative Hamburg, Research Board

Connecting Particles with the Cosmos

T. Behnke (DESY)
K. Borras (DESY)
W. Buchmüller (DESY)
L. Covi (DESY)
E. Elsen (DESY)
C. Hagner (Univ. Hamburg)
P. Hauschildt (Univ. Hamburg)
T. Kneiske (Univ. Hamburg)
B. Andreas Kniehl (Univ. Hamburg)
J. Louis (Univ. Hamburg)
J. Mnich (DESY)
C. Niebuhr (DESY)
A. Ringwald (DESY)
P. Schleper (Univ. Hamburg) (Chair)
V. Schomerus (DESY)
C. Schweigert (Univ. Hamburg)
F. Sefkow (DESY)
G. Sigl (Univ. Hamburg)
G. Weiglein (DESY)
H. Weise (DESY)
G. Wiedemann (Univ. Hamburg)

Helmholtz Alliance International Advisory Board

Physics at the Terascale

Dr. **K. Bos** (Nikhef, Netherlands)
Dr. **J. Brau** (Univ. of Oregon, USA)
Prof. Dr. **B. Foster** (Bristol Univ., UK)
Dr. **P. Jenni** (CERN, CH)
Dr. **D. Schlatter** (CERN, CH)
Prof. Dr. **B. Spaan** (Univ. Dortmund)
Prof. Dr. **J. Stirling** (Univ. of Cambridge, UK)
Prof. Dr. **T. Virdee** (Imperial College, London, UK)
Prof. Dr. **S. Yamada** (Univ. of Tokyo, Japan)

German Committee for Particle Physics (KET)

Prof. Dr. **S. Bethke** (MPI München)
Prof. Dr. **K. Desch** (Univ. Bonn)
Prof. Dr. **S. Dittmaier** (MPI München)
Dr. **M. Hauschild** (CERN, CH)
Prof. Dr. **W. Hollik** (MPI München)
Prof. Dr. **K. Jakobs** (Univ. Freiburg)
Prof. Dr. **T. Lohse** (HU Berlin)
Prof. Dr. **T. Mannel** (Univ. Siegen)
Prof. Dr. **J. Mnich** (DESY)
Prof. Dr. **K. Mönig** (DESY)
Prof. Dr. **T. Müller** (KIT, Karlsruhe)
Prof. Dr. **R. Rückl** (Univ. Würzburg)
Prof. Dr. **D. Schaile** (LMU München)
Prof. Dr. **B. Spaan** (TU Dortmund) (Chair)
Prof. Dr. **U. Uwer** (Univ. Heidelberg)

John von Neumann Institute for Computing (NIC): Scientific Council

Prof. Dr. **K. Albe** (TU – Darmstadt)
Prof. Dr. **K. Binder** (Univ. Mainz)
Prof. Dr. **S. Blügel** (IFF, FZJ)
Dr. **St. Güsken** (Postbank Systems AG)
Dr. **K. Jansen** (DESY)
Prof. Dr. **J. Kertesz** (Univ. of Budapest)
Prof. Dr. **E. Laermann** (Univ. Bielefeld)
Prof. Dr. **R. Lasser** (GSF, Helmholtz Zentrum München)
Prof. Dr. **G. Münster** (Univ. Münster) (Chair)
Prof. Dr. **P. Nielaba** (Univ. Konstanz)
Prof. Dr. **G. U. Nienhaus** (KIT, Karlsruhe)
Prof. Dr. **H. Rollnik** (Univ. Bonn)
Prof. Dr. **J. Wambach** (GSI, Darmstadt)
Dr. **H. Weiß** (BASF AG)
Prof. Dr. **D. E. Wolf** (Univ. Duisburg)

Memberships.

Akademie der Wissenschaften Hamburg
Wilfried Buchmüller

Astroparticle Physics European Coordination (ApPEC), PRC
Christian Spiering (Chair)

ATLAS-Canada Review Committee of NSERC, Canada
Eckhard Elsen

BMBF, Gutachterausschuss Hadronen und Kernphysik
Hans Weise

BMBF, Gutachterausschuss Teilchenphysik
Ties Behnke

CALICE Steering board
Felix Sefkow (spokesperson)

CERN Machine Advisory Committee
Reinhard Brinkmann

CERN Science Policy Committee
Christian Spiering

CLIC Advisory Committee
Markus Hüning

CMS Collaboration Board, Executive Board und Management Board
Matthias Kasemann

CMS Finance Board
Kerstin Borras

Common Task Group Detector R&D
Wolfgang Lohmann

Computer Applications in Nuclear and Plasma Sciences (CANPS), Technical Committee
Günter Eckerlin

Computing Resource Review Board, CERN
Volker Gülzow

Data Preservation and Long Term Analysis in High Energy Physics (DPHEP) Intenational Steering Committee
Zaven Akopov, Cristinel Diaconu, Achim Geiser,
Volker Gülzow, David South

Deutsches Komitee für Astroteilchenphysik (KAT)
Christian Spiering

DFG Allianz “Digitale Information”
Martin Köhler

DKE Deutsche Kommission Elektrotechnik, Elektronik und Informationstechnik im DIN und VDE, Kommission K967
Peter Göttlicher

DPG Vorstandsrat
Thomas Naumann

DPG, Beirat der Sektion Teilchenphysik
Ties Behnke

DPG, Wissenschaftlicher Beirat des Physikzentrum
Wilfried Buchmüller

EUDET, steering committe
Felix Sefkow (Chair)

European Committee for Future Accelerators (ECFA)
Eckhard Elsen, Joachim Mnich, Klaus Mönig

European Particle Physics Communication Network (EPPCN)
Thomas Naumann

European Physics Journal C
Georg Weiglein (Editor in Chief)

European Strategy Group for Accelerator R&D (ESGARD)
Eckhard Elsen

European Studies on Norms for Electronics (ESONE)
Dieter Notz

FAIR, Machine Advisory Committee
Kay Wittenburg

FP7-health EndoTOFPET-US work package
Erika Garutti (leader)

FZ Karlsruhe, Nachwuchsbeirat
Rolf Nahnhauer

Gauss Mitgliederversammlung und Grid-Koordinationsausschuss
Volker Gülzow

German Executive LHC Outreach Group (GELOG)
Ulrike Behrens, Klaus Ehret, Gerrit Hoerentrup,
Matthias Kasemann, Christian Mrotzek, Thomas Naumann,
Thomas Zoufal

Global Design Effort (GDE)
Nicholas John Walker (Projekct Manager)

GridKa, Technical advisory board
Martin Gasthuber, Knut Woller

Helmholtz Alliance, Institute Assembly
Ingrid Gregor, Sven Moch

Helmholtz Alliance, Management Board
Ties Behnke (Scientific Coordinator), Karsten Büßer,
Eckhard Elsen, Matthias Kasemann, Joachim Mnich,
Thomas Schörner-Sadenius

Helmholtz Alliance, Project Boards
Doris Eckstein, Eckhard Elsen, Volker Gülzow,
Matthias Kasemann, Klaus Mönig, Thomas Schörner-Sadenius, Felix Sefkow, Georg Weiglein

Helmholtz-Programmsprecher für Elementarteilchenphysik
Joachim Mnich

HGF, Arbeitskreis Bibliotheks- und Informationsmanagement
Martin Köhler

HGF, Versammlung der wissenschaftlich-technischen Räte
Ties Behnke

Helsinki Physics Institute, Scientific Advisory Board
Wilfried Buchmüller

ILC Accelerator Advisory Panel (AAP) und International Detector Advisory Group (IDAG)
Eckhard Elsen

ILC and High Gradient Superconducting RF-Cavities (ILC-HiGrade)
Eckhard Elsen (Project Coordinator)

ILC CLIC Physics and Detector Working Group
Felix Sefkow

ILC MDI Common Task Group
Karsten Büßer (Chair)

ILC Physics and Experiment Board
Ties Behnke, Karsten Büßer

ILC Steering Committee (ILCSC)
Joachim Mnich

ILC Top Level Change Control Evaluation Panel
Karsten Büßer

ILD Executive Board
Ties Behnke, Karsten Büßer, Wolfgang Lohmann, Felix Sefkow

ILD steering boards
Felix Sefkow, Ties Behnke

INSPIRE Steuerungsgremium
Kirsten Sachs

International Committee for Future Accelerators (ICFA)
Joachim Mnich

International Committee for Future Accelerators (ICFA), Panel on Advanced and Novel Accelerators
Siegfried Schreiber, Rainer Wanzenberg

International Lattice Data Grid
Karl Jansen

John von Neumann Institute for Computing NIC, Director
Joachim Mnich

John von Neumann Institute for Computing NIC, Peer Review Board und Scientific Council
Rainer Sommer

Joint Institute of Nuclear Research JINR, Physics Advisory Committee
Joachim Mnich

KEKB2/BELLE2 Advisory Board
Wulfrin Bartel

KIT Center Elementary Particle and Astroparticle Physics (KCETA), Advisory Board
Joachim Mnich

Komitee für Elementarteilchenphysik (KET)
Joachim Mnich, Klaus Mönig

Laboratoire Souterraine Modane, Advisory Board
Christian Spiering

L'Agence d'Evaluation de la Recherche et de l'Enseignement Superieur (AERES)
Eckhard Elsen

Landesexzellenzinitiative Connecting Particles with the Cosmos, Research Board
Ties Behnke, Kerstin Borras, Wilfried Buchmüller, Eckhard Elsen, Joachim Mnich, Carsten Niebuhr (Vorstandsmitglied), Andreas Ringwald, Volker Schomerus, Felix Sefkow, Georg Weiglein, Hans Weise

Large Hadron Electron Collider (LHeC), SAC
Joachim Mnich

LHC computing resource scrutiny group
Martin Gasthuber

LHC Experiments Committee (LHCC)
Eckhard Elsen, Daniel Pitzl

LHC Resources Review Boards (LHC-RRB)
Manfred Fleischer

LHC-RRB, Scrutiny Group
Bernd Löhr (chair)

LHC-US Accelerator Research Program Advisory Committee
Kay Wittenburg

MPI-München, Scientific Advisory Board
Joachim Mnich (Chair)

OECD Global Science Forum
Christian Spiering

Particle Data Group
Klaus Mönig, Georg Weiglein

Particle Physics Grants Panel (PPGP) STFC, UK
Georg Weiglein

Peta QCD Scientific Advisor
Karl Jansen

Rat Deutscher Sternwarten
Martin Pohl

SFB676 Vorstand
Jenny List

Spanisch Evaluation Panel for Particle Physics
Joachim Mnich

Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP^3)
Florian Schwennsen

The Cluster of Excellence for Fundamental Physics, Munich, Scientific Advisory Committee
Wilfried Buchmüller (Chair)

TTC Technical Board
Wolf-Dietrich Möller, Detlef Reschke

Collaborations.

H1

I. Physikalisches Institut, RWTH Aachen

Universiteit Antwerpen (BE)

VINCA Institute of Nuclear Sciences, Belgrade (CS)

School of Physics and Space Research,
University of Birmingham (GB)

Inter-University Institute for High Energies ULB-VUB,
Brussels (BE)

National Institute for Physics and Nuclear Engineering,
Bucharest (RO)

Rutherford Appleton Laboratory, Chilton, Didcot (GB)

The Hendryk Niewodniczanski Institute of Nuclear Physics,
Cracow (PL)

Institut für Physik, Technische Universität Dortmund

Joint Institute for Nuclear Research (JINR), Dubna (RU)

CEA, DSM-DAPNIA, CE Saclay, Gif-sur-Yvette (FR)

Deutsches Elektronen-Synchrotron DESY

Institut für Experimentalphysik, Universität Hamburg

Max-Planck-Institut für Kernphysik, Heidelberg

Kirchhoff Institut für Physik, Universität Heidelberg

Physikalisches Institut, Universität Heidelberg

Institute of Experimental Physics,
Slovak Academy of Sciences, Košice (SK)

School of Physics and Chemistry,
University of Lancaster (GB)

Oliver Lodge Laboratory, University of Liverpool (GB)

Queen Mary and Westfield College, London (GB)

Physics Department, University of Lund (SE)

Physics Department, University of Manchester (GB)

CPPM, Université de la Méditerranée,
IN2P3-CNRS, Marseille (FR)

Departamento de Fisica Aplicada, CINVESTAV, Mérida (MX)

Departamento de Fisica, CINVESTAV, México (MX)

Institute for Theoretical and Experimental Physics (ITEP),
Moscow (RU)

Russian Academy of Sciences, Lebedev Physical Institute,
Moscow (RU)

Max-Planck-Institut für Physik,Werner-Heisenberg-Institut,
München

LAL, Université Paris-Sud, IN2P3-CNRS, Orsay (FR)

Laboratoire Louis Leprince Ringuet, LLR,
IN2P3-CNRS, Palaiseau (FR)

LPNHE, Université Paris VI et VII, IN2P3-CNRS, Paris (FR)

Faculty of Natural Sciences and Mathematics,
University of Montenegro, Podgorica (YU)

Institute of Physics, Academy of Sciences of the Czech
Republic, Prague (CZ)

Institute of Particle and Nuclear Physics,
Charles University, Prague (CZ)

Dipartimento di Fisica, Università Roma 3 and INFN Roma 3,
Rome (IT)

Institute for Nuclear Research and Nuclear Energy, Sofia (BG)

Institute of Physics and Technology,
Mongolian Academy of Sciences, Ulaanbaatar (MN)

Paul Scherrer Institut, Villigen (CH)

Fachbereich Physik, Bergische Universität-GH Wuppertal

Yerevan Physics Institute, Yerevan (AM)

Institut für Teilchenphysik, ETH Zürich (CH)

Physik Institut, Universität Zürich (CH)

ZEUS

Department of Engineering in Management and Finance, University of the Aegean (GR)

Institute of Physics and Technology, Ministry of Education and Science of Kazakhstan, Almaty (KZ)

National Institute for Nuclear and High Energy Physics (NIKHEF), Amsterdam (NL)

Argonne National Laboratory (ANL), Argonne IL (USA)

Andrews University, Berrien Springs MI (USA)

University and INFN, Bologna (IT)

Physikalisches Institut, Universität Bonn

H.H. Wills Physics Laboratory, University of Bristol (GB)

Panjab University, Chandigarh (IN)

Rutherford Appleton Laboratory, Chilton, Didcot (GB)

Physics Department, Ohio State University, Columbus OH (USA)

Physics Department, Calabria University and INFN, Cosenza (IT)

The Henryk Niewodniczanski Institute of Nuclear Physics, Cracow (PL)

Department of Physics, Jagellonian University, Cracow (PL)

Faculty of Physics and Nuclear Techniques, AGH-University of Science and Technology, Cracow (PL)

University and INFN, Florence (IT)

Fakultät für Physik, Universität Freiburg

Department of Physics and Astronomy, University of Glasgow (GB)

Deutsches Elektronen-Synchrotron DESY

Institut für Experimentalphysik, Universität Hamburg

Nevis Laboratories, Columbia University, Irvington on Hudson NY (USA)

Institute for Nuclear Research, National Academy of Science and Kiew National University, Kiew (UA)

Department of Physics, Malaya University, Kuala Lumpur (MY)

Department of Physics, Chonnam National University, Kwangju (KR)

High Energy Nuclear Physics Group, Imperial College, London (GB)

Physics and Astronomy Department, University College, London (GB)

Institute de Physique Nucléaire, Université Catholique de Louvain, Louvain-la-Neuve (BE)

Department of Physics, University of Wisconsin, Madison WI (USA)

Departamento de Fisica Teórica, Universidad Autónoma Madrid (ES)

Department of Physics, McGill University, Montreal (CA)

Moskau Engineering und Physics Institute, Moskau (RU)

Institute of Nuclear Physics, Moskau State University, Moskau (RU)

Max-Planck Institut für Physik, München

Department of Physics, York University, North York (CA)

Department of Physics, University of Oxford (GB)

Dipartimento di Fisica, University and INFN, Padova (IT)

Department of Particle Physics, Weizmann Institute, Rehovot (IL)

Dipartimento di Fisica, Università La Sapienza and INFN, Roma (IT)

Polytechnic University, Sagamihara (JP)

Kyungpook National University, Taegu (KR)

School of Physics, University of Tel Aviv (IL)

Department of Physics, Tokyo Institute of Technology, Tokyo (JP)

Department of Physics, Tokyo Metropolitan University, Tokyo (JP)

Department of Physics, University of Tokyo (JP)

Università di and INFN, Torino (IT)

Università del Piemonte Orientale, Novara and INFN, Torino (IT)

Department of Physics, University of Toronto (CA)

Institute for Particle and Nuclear Study, KEK, Tsukuba (JP)

Department of Physics, Pennsylvania State University, University Park PA (USA)

Institute for Nuclear Studies, Warschau (PL)

Institut of Experimental Physics, University of Warschau (PL)

Faculty of General Education, Meiji Gakuin University, Yokohama (JP)

HERMES

National Institute for Subatomic Physics (NIKHEF), Amsterdam (NL)
Department of Physics and Astronomy, Vrije Universiteit, Amsterdam (NL)
Randall Laboratory of Physics, University of Michigan, Ann Arbor MI (USA)
Physics Division, Argonne National Laboratory, Argonne IL (USA)
Dipartimento di Fisica dell'Università and INFN, Bari (IT)
School of Physics, Peking University, Beijing (CN)
Nuclear Physics Laboratory, University of Colorado, Boulder CO (USA)
Joint Institute for Nuclear Research (JINR), Dubna (RU)
Physikalisches Institut, Universität Erlangen-Nürnberg
Dipartimento di Fisica dell'Università and INFN, Ferrara (IT)
Laboratori Nazionali di Frascati, INFN, Frascati (IT)
Petersburg Nuclear Physics Institute (PNPI), Gatchina (RU)
Department of Subatomic and Radiation Physics, University of Gent (BE)
Physikalisches Institut, Universität Gießen
School of Physics and Astronomy (SUPA), University of Glasgow (GB)
Deutsches Elektronen-Synchrotron DESY
P. N. Lebedev Physical Institute, Moscow (RU)
Institute for High Energy Physics (IHEP), Protvino (RU)
Institut für Theoretische Physik, Universität Regensburg
Gruppo Sanità, INFN and Physics Laboratory, Istituto Superiore di Sanità, Rome (IT)
Department of Physics, Tokyo Institute of Technology, Tokyo (JP)
Department of Physics, University of Illinois, Urbana IL (USA)
TRIUMF, Vancouver (CA)
Andrzeij Soltan Institute for Nuclear Studies, Warsaw (PL)
Yerevan Physics Institute, Yerevan (AM)

OLYMPUS

INFN, Bari (IT)
Universität Bonn
University of Colorado, Boulder (USA)
Massachusetts Institute of Technology, Cambridge (USA)
University of New Hampshire, Durham (USA)
INFN, Ferrara (IT)
Petersburg Nuclear Physics Institute, Gatchina (RU)
University of Glasgow (UK)
Deutsches Elektronen-Synchrotron DESY
Hampton University, Hampton (USA)
Universität Mainz
MIT-Bates Linear Accelerator Center, Middleton (MA)
INFN, Rome (IT)
Arizona State University, Tempe (USA)
Yerevan Physics Institute, Yerevan (AM)

TESLA Technology Collaboration

Argonne National Laboratory (ANL), Argonne IL (USA)

Fermi National Accelerator Laboratory (FNAL), Batavia Il (USA)

Beijing University, Beijing (CN)

Institute for High Energy Physics (IHEP), Academia Sinica, Beijing (CN)

Tsinghua University, Beijing (CN)

Lawrence Berkeley National Lab, Berkeley (USA)

BESSY Berlin

Hahn-Meitner Institut Berlin

AGH-University of Science and Technology, Cracow (PL)

Henryk Niewodnizanski Institute of Nuclear Physics, Polish Academy of Science, Cracow (PL)

Technische Universität Darmstadt

CCLRC, Daresbury & Rutherford Appleton Laboratory, Chilton, Didcot (GB)

Forschungszentrum Rossendorf, Dresden

Joint Institute for Nuclear Research (JINR), Dubna (RU)

Universität Frankfurt/Main

Laboratori Nazionali di Frascati, INFN, Frascati (IT)

GKSS-Forschungszentrum Geesthacht

CERN, Geneva (CH)

CEA/DSM DAPNIA, CE-Saclay, Gif-sur-Yvette (FR)

Deutsches Elektronen-Synchrotron DESY

Universität Hamburg

Raja Ramanna Centre of Advanced Technology (RRCAT), Indore (IN)

Cornell University, Ithaca NY (USA)

Variable Energy Cyclotron Centre VECC, Kolkata (IN)

Istituto Nazionale di Fisica Nucleare (INFN), Legnaro (IT)

Technical University of Lodz (PL)

Royal Holloway University of London (RHUL/JAI), London (GB)

University College London (UCL), London (GB)

Stanford Linear Accelerator Center (SLAC), Menlo Park CA (USA)

Istituto Nazionale di Fisica Nculeare (INFN), Milan (IT)

Institute for Nuclear Research (INR), Moscow (RU)

Moscow Engineering and Physics Institute (MEPhI), Moscow (RU)

Bhabha Atomic Research Centre (BARC), Mumbai (IN)

Jefferson Lab, Newport News VA (USA)

Budker Institute for Nuclear Physics (BINP), Novosibirsk (RU)

LAL, Université Paris-Sud, IN2P3-CNRS, Orsay (FR)

The Andrzej Soltan Institute for Nuclear Studies, Otwock-Swierk (PL)

University of Oxford (JAI), Oxford (GB)

Institute for High Energy Physics (IHEP), Protvino (RU)

Istituto Nazionale di Fisica Nucleare (INFN), Rome II (IT)

Universität Rostock

Sincrotrone Trieste (IT)

Institute for Particle and Nuclear Study, KEK, Tsukuba (JP)

Canada's National Laboratory for Particle and Nuclear Physics (TRIUMF), Vancouver (CA)

Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw (PL)

Warsaw University of Technology (WUT), Warsaw (PL)

Warsaw University, Department of Physics, Warsaw (PL)

Bergische Universität-GH Wuppertal

CANDLE, Yerevan (AM)

Yerevan Physics Institute, Yerevan (AM)

Physics at the Terascale, Helmholtz Alliance

Rheinisch-Westfälische Technische Hochschule Aachen
Humboldt-Universität zu Berlin
Rheinische Friedrich-Wilhelms-Universität Bonn
Deutsches Elektronen-Synchrotron DESY
Universität Dortmund
Technische Universität Dresden
Albert-Ludwigs-Universität Freiburg
Justus-Liebig-Universität Giessen
Georg-August-Universität Göttingen
Universität Hamburg
Ruprecht-Karls-Universität Heidelberg
Karlsruher Institut für Technologie - Großforschungsbereich
Karlsruher Institut für Technologie - Universitätsbereich
Johannes Gutenberg-Universität Mainz
Ludwig-Maximilians-Universität München
Max-Planck Institut für Physik München
Universität Rostock
Universität Siegen
Julius-Maximilians-Universität Würzburg
Bergische Universität Wuppertal

Adjunct Partner
Universität Regensburg

ALPS

Deutsches Elektronen-Synchrotron DESY
Universität Hamburg
Albert Einstein Institut Hannover
Laser Zentrum Hannover

Publications.

HERA

C. Diaconu, T. Haas, M. Medinnis, K. Rith, A. Wagner
Physics Accomplishments of HERA.
Ann. Rev. Nucl. Part. Sci. 60 (2010) 101
`http://dx.doi.org/10.1146/annurev.nucl.012809.104458`

H1- and ZEUS-Experiments (combined)

H1 and ZEUS Collaborations,
F.D. Aaron et al., H. Abramowicz et al.
Combined Measurement and QCD Analysis of the Inclusive $e^{\pm}p$ Cross Sections at HERA.
JHEP 2010 (2010) 1 and DESY 09-158; arXiv:0911.0884
`http://dx.doi.org/10.1007/JHEP01(2010)109`

Events with an Isolated Lepton and Missing Transverse Momentum and Measurement of W Production at HERA.
JHEP 1003 (2010) 035 and DESY 09-140; arXiv:0911.0858
`http://dx.doi.org/10.1007/JHEP03(2010)035`

H1-Experiment

H1 Collaboration, F.D. Aaron et al.
Measurement of the Charm and Beauty Structure Functions Using the H1 Vertex Detector at HERA.
Eur. Phys. J. C 65 (2010) 89 and DESY 09 096;
arXiv:0907.2643

Jet Production in ep Collisions at High Q^2 and Determination of α_s.
Eur. Phys. J. C 65 (2010) 363 and DESY 09-032;
arXiv:0904.3870
`http://dx.doi.org/10.1140/epjc/s10052-009-1208-7`

Measurement of the $D^{*\pm}$ Meson Production Cross Section and $F_2^{c\bar{c}}$ at High Q^2 in *ep* Scattering at HERA.
Phys. Lett. B 686 (2010) 91 and DESY 09-165;
arXiv:0911.3989

Prompt Photons in Photoproduction at HERA.
Eur. Phys. J. C 66 (2010) 17 and DESY 09-135;
arXiv:0910.5631

Diffractive Electroproduction of ρ and ϕ Mesons at HERA.
JHEP 1005 (2010) 032 and DESY 09-093

Jet Production in *ep* Collisions at Low Q^2 and Determination of α_s.
Eur. Phys. J. C 67 (2010) 1 and DESY 09-162
`http://lanl.arxiv.org/abs/0911.5678`

Measurement of Leading Neutron Production in Deep-Inelastic Scattering at HERA.
Eur. Phys. J. C 68 (2010) 381 and DESY 09-185

Inelastic Production of J/ψ Mesons in Photoproduction and Deep Inelastic Scattering at HERA.
Eur. Phys. J. C 68 (2010) 401 and DESY 09-225

Diffractive Dijet Photoproduction in *ep* Collisions at HERA.
Eur. Phys. J. C 70 (2010) 15 and DESY 10-043;
arXiv:1006.0946

A. Bacchetta, H. Jung, A. Knutsson, K. Kutak,
F. v. Samson-Himmelstjerna
A Method for Tuning Parameters of Monte Carlo Generators and its Application to the Determination of the Unintegrated Gluon Density.
Eur. Phys. J. C 70 (2010) 503 and DESY 10-013;
arXiv:1001.4675
`http://dx.doi.org/10.1140/epjc/s10052-010-1464-6`

S. Baudrand et al.
A High Precision Fabry-Perot Cavity Polarimeter at HERA.
J. Instrum. 5 (2010) P06005 and LAL 10-43
`http://dx.doi.org/10.1088/1748-0221/5/06/P06005`

V. Brisson, R. Chiche, M. Jacquet, C. Pascaud, V. Soskov, Z. Zhang, F. Zomer, M. Beckingham, N. Coppola
Per Mill Level Control of the Circular Polarisation of the Laser Beam for a Fabry-Perot Cavity Polarimeter at HERA.
J. Instrum. 5 (2010) 6006 and arXiv:1005.2742
`http://dx.doi.org/10.1088/1748-0221/5/06/P06006`

A. Glazov, N. Raiĉević, A. Zhokin
Fast Simulation of Showers in the H1 Calorimeter.
Comput. Phys. Commun. 181 (2010) 1008
`http://dx.doi.org/10.1016/j.cpc.2010.02.004`

K. Müller
Precision Measurements with Jets and Particles at HERA.
Nucl. Phys. B, Proc. Suppl. 207-208 (2010) 17

A. Petrukhin
Measurements of the Proton Structure at HERA and their Impact for LHC.
Nucl. Phys. B, Proc. Suppl. 207-208 (2010) 45

N. Raičević
HERA Results and Their Impact for LHC.
Nucl. Phys. B, Proc. Suppl. 198 (2010) 75

Measurements at High Q^2 and Searches at the *ep* Energy Frontier.
Nucl. Phys. B, Proc. Suppl. 207-208 (2010) 125

D. Traynor
QCD Studies at HERA.
Il Nuovo Cimento B 32 (2010) 159
`http://dx.doi.org/10.1393/ncc/i2010-10529-9`

A. Valkárová
Factorisation in Diffraction.
Nucl. Phys. B, Proc. Suppl. 198 (2010) 25

ZEUS-Experiment

ZEUS Collaboration, H. Abramowicz et al.
Measurement of dijet photoproduction for events with a leading neutron at HERA.
Nucl. Phys. B 827 (2010) 1 and DESY 09-139;
arXiv:0909.3032
`http://dx.doi.org/10.1016/j.nuclphysb.2009.10.002`

Measurement of Charm and Beauty Production in Deep Inelastic ep Scattering from Decays into Muons at HERA.
Eur. Phys. J. C 65 (2010) 65 and DESY 09-056;
arXiv:0904.3487
`http://dx.doi.org/10.1140/epjc/s10052-009-1193-x`

A QCD Analysis of ZEUS Diffractive Data.
Nucl. Phys. B 831 (2010) 1 and DESY 09-191;
arXiv:0911.4119
`http://dx.doi.org/10.1016/j.nuclphysb.2010.01.014`

Measurement of isolated photon production in deep inelastic ep scattering.
Phys. Lett. B 687 (2010) 16 and DESY 09-142;
arXiv:0909.4223
`http://dx.doi.org/10.1016/j.physletb.2010.02.045`

Inclusive-Jet Cross Sections in NC DIS at HERA and a Comparison of the κ_T, anti-κ_T and SIScone Jet Algorithms.
Phys. Lett. B 691 (2010) 127 and DESY 10-034,
arXiv:1003.2923
`http://dx.doi.org/10.1016/j.physletb.2010.06.015`

Measurement of J/ψ photoproduction at large momentum transfer at HERA.
JHEP 5 (2010) 1 and DESY 09-137; arXiv:0910.1235
`http://dx.doi.org/10.1007/JHEP05(2010)085`

Inclusive dijet cross sections in neutral current deep inelastic scattering at HERA.
Eur. Phys. J. C 79 (2010) 945 and DESY 10-170 ;
arXiv:1010.6167
`http://dx.doi.org/10.1140/epjc/s10052-010-1504-2`

Measurement of high-Q^2 charged current deep inelastic scattering cross sections with a longitudinally polarised positron beam at HERA.
Eur. Phys. J. C 70 (2010) 965 and DESY 10-129;
arXiv:1008.3493
`http://dx.doi.org/10.1140/epjc/s10052-010-1498-9`

Measurement of D^+ and Λ_c^+ production in deep inelastic scattering at HERA.
JHEP 2010 (2010) 1 and DESY-10-064; arXiv:1007:1945
`http://dx.doi.org/10.1007/JHEP11(2010)009`

Measurement of Beauty Production in DIS and $F_2^{b\bar{b}}$ Extraction at ZEUS.
Eur. Phys. J. C 69 (2010) 347 and DESY 10-047;
arXiv:1005.3396
`http://dx.doi.org/10.1140/epjc/s10052-010-1423-2`

Scaled Momentum Spectra in deep inelastic Scattering at HERA.
JHEP 06 (2010) 1 and DESY-09-229; arXiv:1001.4026
`http://dx.doi.org/10.1007/JHEP06(2010)009`

Forward instrumentation for ILC detectors.
J. Instrum. 5 (2010) 12002 and DESY 10-142;
arXiv:1009.2433
`http://dx.doi.org/10.1088/1748-0221/5/12/P12002`

S. Fang
Recent results on strangeness, charm and beauty production at HERA.
Chin. Phys. C 34 (2010) 757
`http://dx.doi.org/10.1088/1674-1137/34/6/025`

I. Korzhavina
Diffractive Structure Functions from the H1 and ZEUS Experiments at HERA.
Nucl. Phys. B, Proc. Suppl. 207-208 (2010) 21

H. Kowalski, L.N. Lipatov, D.A. Ross, G. Watt
Using HERA Data to Determine the Infrared Behaviour of the BFKL Amplitude.
Eur. Phys. J. C 70 (2010) 983 and DESY 10-061,
SHEP-10-04, CERN-PH-TH/2010-091, arXiv:1005.0355
`http://dx.doi.org/10.1140/epjc/s10052-010-1500-6`

H. Kowalski
Investigating the gluonic structure of nuclei via J/ψ scattering.
Phys. Rev. C 81 (2010) 17
`http://dx.doi.org/10.1103/PhysRevC.81.025203`

Y. Onishchuk
Production of heavy flavours at HERA.
Nucl. Phys. B, Proc. Suppl. 207-208 (2010) 383

G. Wolf
Review of High Energy Diffraction in Real and Virtual Photon-Proton Scattering at HERA.
Rep. Prog. Phys. 73 (2010) 11602 and DESY 09-098;
arXiv:0907.1217
`http://dx.doi.org/10.1088/0034-4885/73/11/116202`

HERMES-Experiment

HERMES Collaboration, A. Airapetian et al.
Search for a Two-Photon Exchange Contribution to Inclusive Deep-Inelastic Scattering.
Phys. Lett. B 682 (2010) 351 and DESY 09-117,
arXiv:0907.5369

Single-spin azimuthal asymmetry in exclusive electroproduction of π^+ mesons on transversely polarized protons.
Phys. Lett. B 682 (2010) 345 and DESY 09-106;
arXiv:0907.2596

Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on an unpolarized deuterium target.
Nucl. Phys. B 829 (2010) 1 and DESY 09-189,
arXiv:0911.0095

Transverse momentum broadening of hadrons produced in semi-inclusive deep-inelastic scattering on nuclei.
Phys. Lett. B 684 (2010) 114 and DESY 09-082;
arXiv:0906.2478

Exclusive Leptoproduction of Real Photons on a Longitudinally Polarised Hydrogen Target.
JHEP 06 (2010) 019 and DESY 10-046, arXiv:1004.0177

Effects of transversity in deep-inelastic scattering by polarized protons.
Phys. Lett. B 693 (2010) 11 and DESY 10-087;
arXiv:1006.4221
`http://dx.doi.org/10.1016/j.physletb.2010.08.012`

Separation of contributions from deeply virtual Compton scattering and its interference with the Bethe-Heitler process in measurements on a hydrogen target.
JHEP 11 (2009) 083 and DESY 09-143; arXiv:0909.3587
`http://dx.doi.org/10.1088/1126-6708/2009/11/083`

Leading-Order Determination of the Gluon Polarization from high-PT Hadron Electroproduction.
JHEP 08 (2010) 130 and DESY 10-21; arXiv:1002.3921
`http://dx.doi.org/10.1007/JHEP08(2010)130`

Nuclear-mass dependence of azimuthal beam-helicity and beam-charge asymmetries in deeply virtual Compton scattering.
Phys. Rev. C 81 (2010) 035202 and DESY 09-190; arXiv:0911.0091

N. Akopov, L. Grigoryan, Z. Akopov
Study of the hadronization process in cold nuclear medium.
Eur. Phys. J. C 70 (2010) 5
`http://dx.doi.org/10.1140/epjc/s10052-010-1451-y`

E. Avetisyan
Exclusive meson production at HERMES.
Chinese Physics 34 (2010) 1472

M. Burkardt, A. Miller, W.-D. Nowak
Spin-polarized high-energy scattering of charged leptons on nucleons.
Rep. Prog. Phys. 73 (2010) 016201 and DESY-08-162; JLAB-THY-08-913; arXiv:0812.2208
`http://dx.doi.org/:10.1088/0034-4885/73/1/016201`

Ch. Van Hulse
The HERMES Recoil Detector.
Nucl. Instrum. Methods A 623 (2010) 359

ATLAS-Experiment

ATLAS Collaboration
Drift Time Measurement in the ATLAS Liquid Argon Electromagnetic Calorimeter using Cosmic Muons.
Eur. Phys. J. C 70 (2010) 755 and arXiv:1002.4189
`http://dx.doi.org/10.1140/epjc/s10052-010-1403-6`

Charged-particle multiplicities in pp interactions at $\sqrt{s} = 900$ GeV measured with the ATLAS detector at the LHC.
Phys. Lett. B 688 (2010) 21 and arXiv:1003.3124
`http://dx.doi.org/10.1016/j.physletb.2010.03.064`

The ATLAS Inner Detector commissioning and calibration.
Eur. Phys. J. C 70 (2010) 787 and arXiv:1004.5293
`http://dx.doi.org/10.1140/epjc/s10052-010-1366-7`

The ATLAS Simulation Infrastructure.
Eur. Phys. J. C 70 (2010) 823 and arXiv:1005.4568
`http://dx.doi.org/10.1140/epjc/s10052-010-1429-9`

Performance of the ATLAS Detector using First Collision Data.
JHEP 1009:056 (2010) and arXiv:1005.5254
`http://dx.doi.org/10.1007/JHEP09(2010)056`

Commissioning of the ATLAS Muon Spectrometer with Cosmic Rays.
Eur. Phys. J. C 70 (2010) 875 and arXiv:1006.4384
`http://dx.doi.org/10.1140/epjc/s10052-010-1415-2`

Readiness of the ATLAS Tile Calorimeter for LHC collisions.
Eur. Phys. J. C 70 (2010) 1193 and arXiv:1007.5423
`http://dx.doi.org/10.1140/epjc/s10052-010-1508-y`

Search for New Particles in Two-Jet Final States in 7 TeV Proton-Proton Collisions with the ATLAS Detector at the LHC.
Phys. Rev. Lett. 105 (2010) 161801 and arXiv:1008.2461
`http://dx.doi.org/10.1103/PhysRevLett.105.161801`

Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS Detector at the LHC.
Phys. Rev. Lett. 105,252303 (2010) and arXiv:1011.6182
`http://dx.doi.org/10.1103/PhysRevLett.105.252303`

Readiness of the ATLAS Liquid Argon Calorimeter for LHC Collisions.
Eur. Phys. J. C 70 (2010) 723 and arXiv:0912.2642
`http://dx.doi.org/10.1140/epjc/s10052-010-1354-y`

C. Ay, S. Johnert, J. Katzy, Z. Qin
HepMCAnalyser: A tool for Monte Carlo generator validation.
J. Phys., Conf. Ser. 219 (2010) 032029
`http://dx.doi.org/10.1088/1742-6596/219/3/032029`

U. Husemann, J. Mechnich, A. Salzburger
Simulation strategies using FATRAS and Geant4 for a future upgrade of the ATLAS tracking detectors.
J. Phys., Conf. Ser. 219 (2010) 032021
`http://dx.doi.org/10.1088/1742-6596/219/3/032021`

CMS-Experiment

CMS Collaboration
Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{(s)} = 0.9$ and 2.36 TeV.
JHEP 1002 (2010) 041 and CMS-QCD-09-010, CERN-PH-EP-2010-003
`http://dx.doi.org/10.1007/JHEP02(2010)041`

Measurement of the muon stopping power in lead tungstate.
J. Instrum. 5 (2010) P03007 and CMS-CFT-09-005
`http://dx.doi.org/10.1088/1748-0221/5/03/P03007`

Performance of the CMS Level-1 trigger during commissioning with cosmic ray muons and LHC beams.
J. Instrum. 5 (2010) T03002 and CMS-CFT-09-013
`http://dx.doi.org/10.1088/1748-0221/5/03/T03002`

Performance of CMS muon reconstruction in cosmic-ray events.
J. Instrum. 5 (2010) T03022 and CMS-CFT-09-014
`http://dx.doi.org/10.1088/1748-0221/5/03/T03022`

Performance of the CMS cathode strip chambers with cosmic rays.
J. Instrum. 5 (2010) T03018
`http://dx.doi.org/10.1088/1748-0221/5/03/T03018`

Performance of the CMS hadron calorimeter with cosmic ray muons and LHC beam data.
J. Instrum. 5 (2010) T03012 and CMS-CFT-09-009; arXiv:0911.4991
`http://dx.doi.org/10.1088/1748-0221/5/03/T03012`

CMS data processing workflows during an extended cosmic ray run.
J. Instrum. 5 (2010) T03006 and CMS-CFT-09-007; arXiv:0911.4842
`http://dx.doi.org/10.1088/1748-0221/5/03/T03006`

Performance of the CMS drift tube chambers with cosmic rays.
J. Instrum. 5 (2010) T03015
http://dx.doi.org/10.1088/1748-0221/5/03/T03015

Calibration of the CMS drift tube chambers and measurement of the drift velocity with cosmic rays.
J. Instrum. 5 (2010) T03016 and CMS-CFT-09-023; arXiv:0911.4895
http://dx.doi.org/10.1088/1748-0221/5/03/T03016

Commissioning of the CMS experiment and the cosmic run at four Tesla.
J. Instrum. 5 (2010) T03001 and CMS-CFT-09-008
http://dx.doi.org/10.1088/1748-0221/5/03/T03001

Identification and Filtering of Uncharacteristic Noise in the CMS Hadron Calorimeter.
J. Instrum. 5 (2010) T03014
http://dx.doi.org/10.1088/1748-0221/5/03/T03014

Commissioning of the CMS High-Level Trigger with cosmic rays.
J. Instrum. 5 (2010) T03005
http://dx.doi.org/10.1088/1748-0221/5/03/T03005

Aligning the CMS muon chambers with the muon alignment system during an extended cosmic ray run.
J. Instrum. 5 (2010) T03019 and CMS-CFT-09-017; arXiv:0911.4770
http://dx.doi.org/10.1088/1748-0221/5/03/T03019

Performance of the CMS drift-tube chamber local trigger with cosmic rays.
J. Instrum. 5 (2010) T03003
http://dx.doi.org/10.1088/1748-0221/5/03/T03003

Fine synchronization of the CMS muon drift-tube local trigger using cosmic rays.
J. Instrum. 5 (2010) T03004
http://dx.doi.org/10.1088/1748-0221/5/03/T03004

Performance of CMS Hadron Calorimeter Timing and Synchronization using Test Beam, Cosmic Ray, and LHC Beam Data.
J. Instrum. 5 (2010) T03013
http://dx.doi.org/10.1088/1748-0221/5/03/T03013

Commissioning and Performance of the CMS Silicon Strip Tracker with Cosmic Ray Muons.
J. Instrum. 5 (2010) T03008
http://dx.doi.org/10.1088/1748-0221/5/03/T03008

Performance of the CMS Strip Chambers with Cosmic Rays.
J. Instrum. 5 (2010) T03018
http://dx.doi.org/10.1088/1748-0221/5/03/T03018

Search for Quark Compositeness with Dijet Centrality Ratio in pp Collisions at $\sqrt{(\mathrm{s})} = 7$ TeV.
Phys. Rev. Lett. 105 (2010) 262001 and arXiv:1010.4439

Search for Dijet resonances in 7 TeV pp Collisions at CMS.
Phys. Rev. Lett. 105 (2010) 211801 and arXiv:1010.0203; CMS-EXO-10-010; CERN-PH-EP/2010-035
http://dx.doi.org/10.1103/PhysRevLett.105.211801

Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions at LHC.
JHEP 1009 (2010) 091 and arXiv:1009.4122; CERN-PH-EP/2010-031
http://dx.doi.org/10.1007/JHEP09(2010)091

CMS Tracking Performance Results from early LHC Operation.
Eur. Phys. J. C70 (2010) 1165 and arXiv:1007.1988
http://dx.doi.org/10.1140/epjc/s10052-010-1491-3

First Measurement of the Underlying Event Activity at the LHC with $\sqrt{(\mathrm{s})} = 0.9$ TeV.
Eur. Phys. J. C70 (2010) 555 and arXiv:1006.2083
http://dx.doi.org/10.1140/epjc/s10052-010-1453-9

Measurement of the charge ratio of atmospheric muons with the CMS detector.
Phys. Lett. B 692 (2010) 83 and arXiv:1005.5332; CERN-PH-EP-2010-011
http://dx.doi.org/10.1016/j.physletb.2010.07.033

Measurement of Bose-Einstein correlations with first CMS data.
Phys. Rev. Lett. 105 (2010) 032001 and arXiv:1005.3294; CERN-PH-EP-2010-010
http://dx.doi.org/10.1103/PhysRevLett.105.032001

Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{(\mathrm{s})} = 7$ TeV.
Phys. Rev. Lett. 105 (2010) 022002 and arXiv:1005.3299; CSM-QCD-10-006, CERN-PH-EP/2010-009

Performance Study of the CMS Barrel Resistive Plate Chambers with Cosmic Rays.
J. Instrum. 5 (2010) 703017 and arXiv:0911.4045; CMS-CFT-09-010; FERMILAB-PUB-10-161-CMS
http://dx.doi.org/10.1088/1748-0221/5/03/T03017

Time Reconstruction and Performance of the CMS Electromagnetic Calorimeter.
J. Instrum. 5 (2010) T03011 and arXiv:0911.4044; CMS-CFT-09-006; FERMILAB-PUB-10-162-CMS

Precise Mapping of the Magnetic Field in the CMS Barrel Yoke using Cosmic Rays.
J. Instrum. 5 (2010) T03021 and arXiv:0910.5530; CMS-CFT-09-015; FERMILAB-PUB-10-164-CMS
http://dx.doi.org/10.1088/1748-0221/5/03/T03021

V. Andreev et al.
Performance studies of a full-length prototype for the CASTOR forward calorimeter at the CMS experiment.
Eur. Phys. J. C C67 (2010) 601

S. Basegmez, D. d'Enterria, L. Gouskos, I. Katkov, P. Katsas, L. Khein
Performance studies for the prototype III of CASTOR forward calorimeter at the CMS experiment.
Indian. J. Phys. 84 (2010) 1689 and CERN-CMS-CR-2008-039.

G. Bauer et al.
Dynamic configuration of the CMS data Acquisition cluster.
J. Phys., Conf. Ser. 219 (2010) 022002

The CMS data acquisition system software.
J. Phys., Conf. Ser. 219 (2010) 022011

The CMS event builder and storage system.
J. Phys., Conf. Ser. 219 (2010) 022038

Monitoring the CMS data acquisition system.
J. Phys., Conf. Ser. 219 (2010) 022042

A. Bell et al.
Fast beam conditions monitor BCM1F for the CMS experiment.
Nucl. Instrum. Methods A 614 (2010) 433 and arXiv:0911.2480; DESY 09-178

O. Buchmuller, D. Bonacorsi, F. Fanzago, S. Gowdy, P. Kreuzer, L. Malgeri, R. Mankel, S. Metson, B. Panzer-Steindel, J. Afonso Sanches
The CMS CERN Analysis Facility (CAF).
J. Phys., Conf. Ser. 219 (2010) 052022

D. Futyan, R. Mankel, C. Paus
The CMS computing, software and analysis challenge.
J. Phys., Conf. Ser. 219 (2010) 032008

P. Goettlicher
Design and test beam studies for the CASTOR calorimeter of the CMS experiment.
Nucl. Instrum. Methods A 623 (2010) 225
`http://dx.doi.org/10.1016/j.nima.2010.02.203`

R.S. Schmidt et al.
Performance of the Fast Beam Conditions Monitor BCM1F of CMS in the first running periods of LHC.
J. Instrum. 6 (2010) C01004 and DESY 10-208

L. Tuura, A. Meyer, I. Segoni, G. Della Ricca
CMS data quality monitoring: Systems and expierences.
J. Phys., Conf. Ser. 219 (2010) 072020
`http://dx.doi.org/10.1088/1742-6596/219/7/072020`

L. Tuura, G. Eulisse, A. Meyer
CMS data quality monitoring web service.
J. Phys., Conf. Ser. 209 (2010) 072055
`http://dx.doi.org/10.1088/1742-6596/219/7/072055`

ALPS-Experiment

K. Ehret et al.
New ALPS results on hidden-sector lightweights.
Phys. Lett. B 689 (2010) 149 and DESY 10-030
`http://dx.doi.org/10.1016/j.physletb.2010.04.066`

Other Particle Physics

O. Adriani et al.
Observation of a VHE cosmic-ray flare-signal with the L3+C muon spectrometer.
Astropart. Phys. 33 (2010) 24
`http://dx.doi.org/10.1016/j.astropartphys.2009.11.001`

S. Ask, I.V. Akin, L. Benucci, A. de Roeck, M. Goebel, J. Haller
Real emission and virtual exchange of gravitons and unparticles in PYTHIA8.
Comput. Phys. Commun. 181 (2010) 1593
`http://dx.doi.org/10.1016/j.cpc.2010.05.013`

S. Riemann
Precision electroweak physics at high energies.
Rep. Prog. Phys. 73 (2010) 126201
`http://dx.doi.org/10.1088/0034-4885/73/12/126201`

P. Söding
On the discovery of the gluon.
Eur. Phys. J. H. 35 (2010) 205
`http://dx.doi.org/10.1140/epjh/e2010-00002-5`

Astroparticle Physics

ANTARES Collaboration
Zenith distribution and flux of atmospheric muons measured with the 5-line ANTARES detector.
Astropart. Phys. 34 (2010) 179
`http://dx.doi.org/10.1016/j.astropartphys.2010.07.001`

Measurement of the atmospheric muon flux with a 4 GeV threshold in the ANTARES neutrino telescope.
Astropart. Phys. 33 (2010) 86
`http://dx.doi.org/10.1016/j.astropartphys.2009.12.002`

BAIKAL Collaboration
The Baikal Experiment: from Megaton to Gigaton.
J. Phys., Conf. Ser. 203 (2010) 012123
`http://dx.doi.org/10.1088/1742-6596/203/1/012123`

BAIKAL Neutrino Project: History and Prospects.
Russ. Phys. J. 53 (2010) 601
`http://dx.doi.org/1064-8887/10/5306-0601`

D. Blaschke, J. Berdermann
Neutrinos in dense quark matter and cooling of compact stars.
Progress in Particle and Nuclear Physics 64 (2010) 432 and arXiv:0912.3075
`http://dx.doi.org/10.1016/j.ppnp.2009.12.068`

D. Blaschke, J. Berdermann, R. Lastowiecki
Hybrid neutron stars based on a modified PNJL model.
Prog. Theor. Phys. 186 (2010) 81 and arXiv:1009.1181
`http://dx.doi.org/10.1143/PTPS.186.81`

D. Eichler, D. Guetta, M. Pohl
The high energy budget allocations in shocks and gamma ray bursts.
Astrophys. J. 722 (2010) 543
`http://dx.doi.org/10.1088/0004-637X/722/1/543`

A.D. Falcone, J. Grube, J. Hinton, J. Holder, G. Maier, R. Mukherjee, J. Skilton, M. Stroh
Probing the Nature of the Unidentified TeV Gamma-Ray Source Hess J0632+057 with Swift.
Astrophys. J. Lett. 708 (2010) L52-L56
`http://dx.doi.org/10.1088/2041-8205/708/1/L52`

Fermi-LAT Collaboration
Fermi-lat discovery of GeV gamma-ray emission from the young supernova remnant Cassiopeia A.
Astrophys. J. Lett. 710 (2010) L92
`http://dx.doi.org/10.1088/2041-8205/710/1/L92`

L. Gargate, R.A. Fonseca, J. Niemiec, M. Pohl, R. Bingham, L.O. Silva
The nonlinear saturation of the non-resonant kinetically driven streaming instability.
Astrophys. J. Lett. 711 (2010) L127
`http://dx.doi.org/10.1088/2041-8205/711/2/L127`

IceCube Collaboration
Search for muon neutrinos from Gamma-Ray Bursts with the IceCube neutrino telescope.
Astrophys. J. 710 (2010) 346 and arXiv:0907.2227
`http://dx.doi.org/10.1088/0004-637X/710/1/346`

Limits on a muon flux from Kaluza-Klein dark matter annihilations in the Sun from the IceCube 22-string detector.
Phys. Rev. D 81 (2010) 057101 and arXiv:0910.4480
`http://dx.doi.org/:10.1103/PhysRevD.81.057101`

Measurement of sound speed vs. depth in South Pole ice for neutrino astronomy.
Astropart. Phys. 33 (2010) 277 and arXiv:0909.2629
`http://dx.doi.org/10.1016/j.astropartphys.2010.01.012`

Calibration and Characterization of the IceCube Photomultiplier Tube.
Nucl. Instrum. Methods A 618 (2010) 139 and arXiv:1002.2442
`http://dx.doi.org/10.1016/j.nima.2010.03.102`

Measurement of the Anisotropy of Cosmic Ray Arrival Directions with IceCube.
Astrophys. J. Lett. 718 (2010) L194-L198 and arXiv:1005.2960
`http://dx.doi.org/10.1088/2041-8205/718/2/L194`

The Energy Spectrum of Atmospheric Neutrinos between 2 and 200 TeV with the AMANDA-II Detector.
Astropart. Phys. 34 (2010) 48 and arXiv:1004.2357
`http://dx.doi.org/10.1016/j.astropartphys.2010.05.001`

The first search for extremely-high energy cosmogenic neutrinos with the IceCube Neutrino Observatory.
Phys. Rev. D 82 (2010) 072003 and arXiv:1009.1442
`http://dx.doi.org/DOI:10.1103/PhysRevD.82.072003`

Search for relativistic magnetic monopoles with the AMANDA-II neutrino telescope.
Eur. Phys. J. C 69 (2010) 361
`http://dx.doi.org/DOI10.1140/epjc/s10052-010-1411-6`

Search for a Lorentz-violating sidereal signal with atmospheric neutrinos in IceCube.
Phys. Rev. D 82 (2010) 112003 and arXiv:1010.4096
`http://dx.doi.org/10.1103/PhysRevD.82.112003`

MAGIC Collaboration
Detection of very high energy gamma-ray emission from the Perseus cluster head-tail galaxy IC 310 by the magic telescopes.
Astrophys. J. Lett. 723 (2010) L207
`http://dx.doi.org/10.1088/2041-8205/723/2/L207`

MAGIC upper limits for two Milagro-detected bright Fermi sources in the region of SNR G65.1+0.6.
Astrophys. J. 725 (2010) 1629
`http://dx.doi.org/10.1088/0004-637X/725/2/1629`

MAGIC constraints on gamma-ray emission from Cygnus $\mathrm{X}-3$.
Astrophys. J. 721 (2010) 843
`http://dx.doi.org/10.1088/0004-637X/721/1/843`

Simultaneous multi-frequency observation of the unknown redshift blazar PG1553+113 in March-April 2008.
Astron. Astrophys. 515 (2010) A76
`http://dx.doi.org/10.1051/0004-6361/200913607`

Search for very high energy gamma-ray emission from pulsar-pulsar wind nebula systems with the MAGIC telescope.
Astrophys. J. 710 (2010) 828
`http://dx.doi.org/10.1088/0004-637X/710/1/828`

MAGIC TeV gamma-ray observations of Markarian 421 during multiwavelength campaigns in 2006.
Astron. Astrophys. 519 (2010) A32
`http://dx.doi.org/10.1051/0004-6361/200913945`

MAGIC observation of the GRB 080430 afterglow.
Astron. Astrophys. 517 (2010) A5
`http://dx.doi.org/10.1051/0004-6361/200913461`

Search for an extended VHE gamma-ray emission from Mrk 421 and Mrk 501 with the MAGIC Telescope.
Astron. Astrophys. 524 (2010) A77
`http://dx.doi.org/10.1051/0004-6361/201014747`

J. Niemiec, M. Pohl, A. Bret, T. Stroman
Aperiodic magnetic turbulence produced by relativistic ion beams.
Astrophys. J. 709 (2010) 1148
`http://dx.doi.org/10.1088/0004-637X/709/2/1148`

M. Pohl, D. Eichler
Fermi constrains dark-matter origin of high-energy positron anomaly.
Astrophys. J. Lett. 712 (2010) L53
`http://dx.doi.org/10.1088/2041-8205/712/1/L53`

I. Telezhinsky, D. Eckert, V. Savchenko, A. Neronov, N. Produit, T.J.-L. Courvoisier
The catalog of variable sources detected by INTEGRAL - I. Catalog and techniques.
Astron. Astrophys. 522 (2010) A68
`http://dx.doi.org/10.1051/0004-6361/200912216`

The High Resolution Flys Eye Collaboration
Analysis of large-scale anisotropy of ultra-high energy cosmic rays in HiRes data.
Astrophys. J. Lett. 713 (2010) L64-L68
`http://dx.doi.org/10.1088/2041-8205/713/1/L64`

Indications of Proton-Dominated Cosmic-Ray Composition above 1.6 EeV.
Phys. Rev. Lett. 104 (2010) 161101
`http://dx.doi.org/10.1103/PhysRevLett.104.161101`

M. Tluczykont, E. Bernardini, K. Satalecka, R. Clavero, M. Shayduk, O. Kalekin
Long-term lightcurves from combined unified very high energy gamma-ray data.
Astron. Astrophys. 524 (2010) A48
`http://dx.doi.org/10.1051/0004-6361/201015193`

VERITAS Collaboration, V.A. Acciari et al.
VERITAS search for VHE gamma-ray emission from dwarf spheroidal galaxies.
Astrophys. J. 720 (2010) 1174
`http://dx.doi.org/10.1088/0004-637X/720/2/1174`

VERITAS 2008-2009 monitoring of the variable gamma-ray source M87.
Astrophys. J. 716 (2010) 819
`http://dx.doi.org/10.1088/0004-637X/716/1/819`

Observations of the shell-type supernova remnant Cassiopeia A at TeV energies with VERITAS.
Astrophys. J. 714 (2010) 163
`http://dx.doi.org/10.1088/0004-637X/714/1/163`

Discovery of very high energy gamma-ray emission from the SNR G54.1+0.3.
Astrophys. J. Lett. 719 (2010) L69
http://dx.doi.org/10.1088/2041-8205/719/1/L69

The discovery of gamma-ray emission from the Blazar RGB J0710+591.
Astrophys. J. Lett. 715 (2010) L49
http://dx.doi.org/10.1088/2041-8205/715/1/L49

Discovery of variability in the very high energy gamma-ray emission of 1ES 1218+304 with VERITAS.
Astrophys. J. Lett. 709 (2010) L163
http://dx.doi.org/10.1088/2041-8205/709/2/L163

Discovery of very high energy gamma rays from PKS 1424+240 and multiwavelength constraints on its redshift.
Astrophys. J. Lett. 708 (2010) L100
http://dx.doi.org/10.1088/2041-8205/708/2/L100

Theory

J. Ablinger, I. Bierenbaum, J. Blümlein, A. Hasselhuhn, S. Klein, C. Schneider, F. Wissbrock
Heavy Flavor DIS Wilson coefficients in the asymptotic regime.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 242 and arXiv:1007.0375
http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.050

J. Ablinger, J. Blümlein, S. Klein, C. Schneider
Modern Summation Methods and the Computation of 2- and 3-loop Feynman Diagrams.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 110 and arXiv:1006.4797
http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.028

S. Alekhin
Parton Distributions for LHC.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 205 and arXiv:1008.3988
http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.048

A. Al-haydari, A. Ali Khan, V.M. Braun, S. Collins, M. Gockeler, G.N. Lacagnina, M. Panero, A. Schafer, G. Schierholz
Semileptonic form factors $D \to \mathrm{pi}, K$ and $B \to \mathrm{pi}, K$ from a fine lattice.
Eur. Phys. J. A A43 (2010) 107 and DESY 09-029

A. Ali, F. Barreiro, T. Lagouri
Prospects of measuring the CKM matrix element $|V_{ts}|$ at the LHC.
Phys. Lett. B 693 (2010) 44 and DESY 10-045

A. Ali, C. Hambrock, M.J. Aslam
A tetraquark interpretation of the BELLE data on the anomalous $\Upsilon(1S)\pi^+\pi^-$ and $\Upsilon(2S)\pi^+\pi^-$ production near the $\Upsilon(5S)$ resonance.
Phys. Rev. Lett. 104 (2010) 162001 and DESY 09-222
http://dx.doi.org/10.1103/PhysRevLett.104.162001

A. Ali, E.A. Kuraev, Y.M. Bystritskiy
Radiatively corrected lepton energy distributions in top quark decays $t \to bW^+ \to b(\ell^+\nu_\ell)$ and $t \to bH^+ \to b(\tau^+\nu_\tau)$ and single charged prong energy distributions from subsequent τ^+ decays.
Eur. Phys. J. C 67 (2010) 377 and DESY 09-115
http://dx.doi.org/10.11140/epjc/s10052-010-1300-z

A. Ali, C. Hambrock, I. Ahmed, M.J. Aslam
A case for hidden $b\bar{b}$ tetraquarks based on $e^+e^- \to b\bar{b}$ cross section between $\sqrt{s} = 10.54$ and 11.20 GeV.
Phys. Lett. B 684 (2010) 28 and DESY 09-192
http://dx.doi.org/10.1016/j.physletb.2009.12.053

A. Ali, A.V. Borisov, D.V. Zhuridov
Mechanisms of Neutrinoless Double-Beta Decay: A Comparative Analysis of Several Nuclei.
Phys. At. Nucl. 73 (2010) 2083

S. Alioli, P. Nason, C. Oleari, E. Re
A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX.
JHEP 1006 (2010) 043 and DESY-10-018; SFB-CPP-10-22; IPPP-10-11; DCPT-10-22; arXiv:1002.2581
http://dx.doi.org/:10.1007/JHEP06(2010)043

R. Alvarez Banos et al.
Static versus Dynamic Heterogeneities in the D=3 Edwards-Anderson-Ising Spin Glass.
Phys. Rev. Lett. 105 (2010) 177202
http://dx.doi.org/10.1103/PhysRevLett.105.177202

S. Andreas, O. Lebedev, S. Ramos-Sanchez, A. Ringwald
Constraints on a very light CP-odd Higgs of the NMSSM and other axion-like particles.
JHEP 08 (2010) 003 and DESY 10-069; arXiv:1005.3978

A. Anisimov, W. Buchmuller, M. Drewes, S. Mendizabal
Leptogenesis from Quantum Interference in a Thermal Bath.
Phys. Rev. Lett. 104 (2010) 1 and DESY 09-223

P. Arias, J. Jaeckel, J. Redondo, A. Ringwald
Optimizing light-shining-through-a-wall experiments for axion and other weakly interacting slim particle searches.
Phys. Rev. D 82 (2010) 115018 and DESY 10-147

C. Arina, T. Hambye, A. Ibarra, C. Weniger
Intense Gamma-Ray Lines from Hidden Vector Dark Matter Decay.
JCAP 1003 (2010) 024 and DESY 09-221; arxiv:0912.4496
http://dx.doi.org/10.1088/1475-7516/2010/03/024

J. Baacke, L. Covi, N. Kevlishvili
Coupled scalar fields in a flat FRW universe: Renormalisation.
JCAP 1008 (2010) 026 and DESY 10-079

J. Baacke, N. Kevlishvili
Initial time singularities and admissible initial states for a system of coupled scalar fields.
Phys. Rev. D D81 (2010) 023509 and DESY-09-161

S. Badger, E.W.N. Glover, P. Mastrolia, C. Williams
One-loop Higgs plus four gluon amplitudes: Full analytic results.
JHEP 01 (2010) 036 and IPPP/09/58; CERN-PH-TH/2009-163; DESY 09-138; arXiv:0909.4475
http://dx.doi.org/10.1007/JHEP01(2010)036

S. Badger, R. Sattler, V. Yundin
Analytic computations of massive one-loop amplitudes.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 61 and arXiv:1006.5011
http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.020

S. Badger, J. Henn
Compact QED Tree-Level Amplitudes From Dressed BCFW Recursion Relations.
Phys. Lett. B 692 (2010) 143 and DESY-10-074
http://dx.doi.org/:10.1016/j.physletb.2010.07.021

H. Baier et al.
QPACE: power-efficient parallel architecture based on IBM PowerXCell 8i.
Comp. Sci. Res. Develop. 25 (2010) 149
`http://dx.doi.org/10.1007/s00450-010-0122-4`

R. Baron et al.
Light hadrons from lattice QCD with light (u,d), strange and charm dynamical quarks.
JHEP 6 (2010) 111 and DESY 10-054; HU-EP-10/18; IFIC/10-11; SFB/CPP-10-29; LPT-Orsay 10-28; LTH873; LPSC1042; MS-TP-10-09; ROM2F/2010/08; arXiv:1004.5284
`http://dx.doi.org/10.1007/JHEP06(2010)111`

Computing K and D meson masses with $N_f = 2+1+1$ twisted mass lattice QCD.
Comput. Phys. Commun. 182 (2010) 299
`http://dx.doi.org/10.1016/j.cpc.2010.10.004`

Light hadrons from lattice QCD with light (u, d), strange and charm dynamical quarks.
JHEP 06 (2010) 111
`http://dx.doi.org/10.1007/JHEP06(2010)111OpenAccess`

J. Bartels, J. Kotanski, A.-M. Mischler, V. Schomerus
Regge limit of R-current correlators in AdS Supergravity.
Nucl. Phys. B 830 (2010) 153 and DESY 09-118

R-current six-point correlators in AdS(5) Supergravity.
Nucl. Phys. B B832 (2010) 382 and DESY 09-217

K. Benakli, M.D. Goodsell
Dirac Gauginos, Gauge Mediation and Unification.
Nucl. Phys. B 840 (2010) 1 and DESY 10-044
`http://dx.doi.org/10.1016/j.nuclphysb.2010.06.018`

W. Bietenholz, M. Gockeler, R. Horsley, Y. Nakamura, D. Pleiter, P.E.L. Rakow, G. Schierholz, J.M. Zanotti
Pion in a Box.
Phys. Lett. B B687 (2010) 410 and DESY 10-014

L. Biferale, F. Mantovani, M. Sbragaglia, A. Scagliarini, F. Toschi, R. Tripiccione
High resolution numerical study of Rayleigh-Taylor turbulence using a thermal lattice Boltzmann scheme.
Phys. Fluids 22 (2010) 115112
`http://dx.doi.org/10.1063/1.3517295`

L. Biferale, F. Mantovani, M. Pivanti, M. Sbragaglia, A. Scagliarini, S.F. Schifano, F. Toschi, R. Tripiccione
Lattice Boltzmann fluid-dynamics on the QPACE supercomputer.
Proc. Comp. Sci. 1 (2010) 1069
`http://dx.doi.org/10.1016/j.procs.2010.04.119`

B. Blossier, M. Della Morte, N. Garron, G. von Hippel, T. Mendes, H. Simma, R. Sommer
HQET at order 1/m: II. Spectroscopy in the quenched approximation.
JHEP 1005 (2010) 074 and DESY 09-154; SFB/CPP-10-02; Edinburgh 2010/07; MKPH-T-10-05; LPT-Orsay/10-09; arXiv:1004.2661
`http://dx.doi.org/10.1007/JHEP05(2010)074OpenAccess`

B. Blossier, M. Della Morte, N. Garron, R. Sommer
HQET at order 1/m: I. Non-perturbative parameters in the quenched approximation.
JHEP 1006 (2010) 002 and arXiv:1001.4783; DESY 09-153
`http://dx.doi.org/10.1007/JHEP06(2010)002OpenAccess`

B. Blossier, G. von Hippel, N. Garron, T. Mendes
Nonperturbative HQET at order 1/m.
Int. J. Mod. Phys. D 19 (2010) 1661
`http://dx.doi.org/10.1142/S0218271810017858`

J. Blümlein, D.J. Broadhurst, J.A.M. Vermaseren
The Multiple Zeta Value data mine.
Comput. Phys. Commun. 181 (2010) 582 and DESY 09-003; SFB-CPP/09-065

J. Blümlein, S.-O. Moch, T. Riemann
Loops and legs in quantum field theory.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 1

J. Blümlein, H. Böttcher
QCD Analysis of Polarized Deep Inelastic Scattering Data.
Nucl. Phys. B 841 (2010) 205 and DESY-09-131; SFB-CPP-10-032; arXiv:1005.3113
`http://dx.doi.org/:10.1016/j.nuclphysb.2010.08.005`

S. Bobrovskyi, W. Buchmuller, J. Hajer, J. Schmidt
Broken R-Parity in the Sky and at the LHC.
JHEP 1010 (2010) 061 and DESY 10-068
`http://dx.doi.org/10.1007/JHEP10(2010)061`

P. Bolzoni, F. Maltoni, S. Moch, M. Zaro
Higgs production at NNLO in QCD: the VBF channel.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 314 and arXiv:1006.2323
`http://dx.doi.org/10.1016/j.nuclphysbps.2010.09.012`

Higgs production via vector-boson fusion at NNLO in QCD.
Phys. Rev. Lett. 105 (2010) 011801
`http://dx.doi.org/10.1103/PhysRevLett.105.011801`

V.V. Braguta, P.V. Buividovich, T. Kalaydzhyan, S.V. Kuznetsov, M.I. Polikarpov
The Chiral Magnetic Effect and symmetry breaking in SU(3) quenched theory.
PoS LAT2010 (2010) 190 and DESY 10-171

P. Brax, C. Burrage, A.-C. Davis, D. Seery, A. Weltman
Higgs production as a probe of Chameleon Dark Energy.
Phys. Rev. D D81 (2010) 103524 and DESY 09-163

T.W. Brown
Cut-and-join operators and N=4 super Yang-Mills.
JHEP 1005 (2010) and DESY 10-020
`http://dx.doi.org/10.1007/JHEP05(2010)058`

F. Bruckmann, F. Gruber, K. Jansen, M. Marinkovic, C. Urbach, M. Wagner
Comparing topological charge definitions using topology fixing actions.
Eur. Phys. J. A 43 (2010) 303
`http://dx.doi.org/10.1140/epja/i2010-10915-1`

M. Bruhnke, B. Herrmann, W. Porod
Signatures of bosonic squark decays in non-minimally flavour-violating supersymmetry.
JHEP 09 (2010) 1 and DESY 10-060
`http://dx.doi.org/10.1007/JHEP09(2010)006`

O. Buchmueller, R. Cavanaugh, A. De Roeck, J.R. Ellis, H. Flacher, S. Heinemeyer, G. Isidori, K.A. Olive, F.J. Ronga, G. Weiglein
Predictions for m(t) and M(W) in Minimal Supersymmetric Models.
Phys. Rev. D 81 (2010) 035009 and DESY 09-207

W. Buchmuller, J. Moller, J. Schmidt
Light Moduli in Almost No-Scale Models.
Nucl. Phys. B 826 (2010) 365 and DESY 09-026
`http://dx.doi.org/10.1016/j.nuclphysb.2009.10.024`

W. Buchmuller, K. Schmitz, G. Vertongen
Matter and Dark Matter from False Vacuum Decay.
Phys. Lett. B 693 (2010) 421 and DESY 10-128
`http://dx.doi.org/10.1016/j.physletb.2010.09.004`

P.V. Buividovich, M.N. Chernodub, D.E. Kharzeev, T. Kalaydzhyan, E.V. Luschevskaya, M.I. Polikarpov
Magnetic-field-induced insulator-conductor transition in $\mathrm{SU}(2)$ quenched lattice gauge theory.
Phys. Rev. Lett. 105 (2010) 132001
`http://dx.doi.org/10.1103/PhysRevLett.105.132001`

P.V. Buividovich, M.N. Chernodub, T. Kalaydzhyan, D.E. Kharzeev, E.V. Luschevskaya, M.I. Polikarpov
Magnetic-Field-Induced insulator-conductor transition in quenched lattice gauge theory.
PoS LAT2010 (2010) 076

J. Bulava, R.G. Edwards, E. Engelson, B. Joo, H.-W. Lin, C. Morningstar, D.G. Richards, S.J. Wallace
Nucleon, Δ and Ω excited states in $\mathrm{N_f} = 2+1$ lattice QCD.
Phys. Rev. D 82 (2010) 014507 and UMD-DOE-40762-472; JLAB-THY-10-1170; DESY 10-057; arXiv:1004.5072
`http://dx.doi.org/10.1103/PhysRevD.82.014507`

C. Candu, T. Creutzig, V. Mitev, V. Schomerus
Cohomological Reduction of Sigma Models.
JHEP 1005 (2010) 047 and DESY 10-003
`http://dx.doi.org/10.1007/JHEP05(2010)047`

C. Candu, V. Mitev, T. Quella, H. Saleur, V. Schomerus
The Sigma Model on Complex Projective Superspaces.
JHEP 1002 (2010) 015 and DESY 09-120

C. Candu, J.L. Jacobsen, N. Read, H. Saleur
Universality classes of dense polymers and conformal sigma models.
J. Phys. A 43 (2010) 142001

J.P. Conlon, M. Goodsell, E. Palti
One-loop Yukawa Couplings in Local Models.
JHEP 2010 (2010) 1 and DESY-10-115
`http://dx.doi.org/10.1007/JHEP11(2010)087`

Anomaly Mediation in Superstring Theory.
Prog. Phys. 59 (2010) 5 and DESY 10-135
`http://dx.doi.org/10.1002/prop.201000087`

M. Constantinou et al.
Non-perturbative renormalization of quark bilinear operators with $\mathrm{N_f} = 2$ (tmQCD) Wilson fermions and the tree-level improved gauge action.
JHEP 04 (2010) 068 and DESY 10-037; RM3-TH/10-6; ROME1/1468; ROM2F/2010/06; arXiv:1004.1115
`http://dx.doi.org/10.1007/JHEP08(2010)068`

L. Covi, M. Grefe, A. Ibarra, D. Tran
Neutrino Signals from Dark Matter Decay.
JCAP 1004 (2010) 017 and DESY 09-164; TUM-HEP-743-09
`http://dx.doi.org/10.1088/1475-7516/2010/04/017`

T. Creutzig, P.B. Ronne
From world-sheet supersymmetry to super target spaces.
JHEP 1011 (2010) 021 and DESY 10-098

A. Cucchieri, T. Mendes
Landau-gauge propagators in Yang-Mills theories at beta=0: Massive solution versus conformal scaling.
Phys. Rev. D 81 (2010) 016005
`http://dx.doi.org/10.1103/PhysRevD.81.016005`

K. Demmouche, F. Farchioni, A. Ferling, I. Montvay, G. Münster, E.E. Scholz, J. Wuilloud
Simulation of 4d N=1 supersymmetric Yang Mills theory with Symanzik improved gauge action and stout smearing.
Eur. Phys. J. C 69 (2010) 147

A. De Simone, M. Garny, A. Ibarra, C. Weniger
Supersymmetric leptogenesis with a light hidden sector.
JCAP 07 (2010) 017 and DESY 10-056
`http://dx.doi.org/10.1088/1475-7516/2010/07/017`

T. Diakonidis, J. Fleischer, T. Riemann, J.B. Tausk
A recursive reduction of tensor Feynman integrals.
Phys. Lett. B 683 (2010) 69 and DESY 09-101; BI-TP 2009/15; HEPTOOLS 09-020; SFB/CPP-09-63; arXiv:0907.2115
`http://dx.doi.org/10.1016/j.physletb.2009.11.049`

T. Diakonidis, B. Tausk
Calculating one-loop multileg processes.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 86 and DESY-10-067; SFB-CPP-10-40; HEPTOOLS-10-018; arXiv:1005.5256

G. Di Bernardo, C. Evoli, D. Gaggero, D. Grasso, L. Maccione
Unified interpretation of cosmic ray nuclei and antiproton recent measurements.
Astropart. Phys. 34 (2010) 9 and DESY 09-148
`http://dx.doi.org/10.1016/j.astropartphys.2010.08.006`

M. Diehl, P. Kroll
Two-photon annihilation into octet meson pairs: symmetry relations in the handbag approach.
Phys. Lett. B 683 (2010) 165 and DESY 09-204
`http://dx.doi.org/10.1016/j.physletb.2009.12.009`

M. Diehl, L. Szymanowski
The transverse spin structure of the pion at short distances.
Phys. Lett. B 690 (2010) 149 and DESY 10-041
`http://dx.doi.org/10.1016/j.physletb.2010.05.014`

M. Diehl
Multiple interactions and generalized parton distributions.
PoS DIS2010 (2010) 223 and DESY 10-120

N. Drukker, J. Gomis, T. Okuda, J. Teschner
Gauge Theory Loop Operators and Liouville Theory.
JHEP 1002 (2010) 057

X. Feng, K. Jansen, D. Renner
The pi+ pi+ scattering length from maximally twisted mass lattice QCD.
Phys. Lett. B 684 (2010) 268
`http://dx.doi.org/10.1016/j.physletb.2010.01.018`

S. Forste, H.P. Nilles, S. Ramos-Sanchez, P.K.S. Vaudrevange
Proton Hexality in Local Grand Unification.
Phys. Lett. B 693 (2010) 386 and DESY 10-111

P. Gerhold, K. Jansen
Upper Higgs boson mass bounds from a chirally invariant lattice Higgs-Yukawa model.
JHEP 04 (2010) 094 and HU-EP-10/08; DESY 10-022; arXiv:1002.4336
`http://dx.doi.org/10.1007/JHEP04(2010)094`

S. Gerigk, I. Kirsch
On the Relation between Hybrid and Pure Spinor String Theory.
JHEP 1003 (2010) 106 and DESY 09-216

J. Gluza, K. Kajda, T. Riemann, V. Yundin
News on Ambre and CSectors.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 147 and arXiv:1006.4728
`http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.034`

M. Göckeler et al.
Perturbative and nonperturbative renormalization in lattice QCD.
Phys. Rev. D 82 (2010) 114511
`http://dx.doi.org/10.1103/PhysRevD.82.114511`

M. Goodsell, A. Ringwald
Light hidden-sector U(1)s in string compactifications.
Prog. Phys. 58 (2010) 716 and DESY 10-015

N. Gromov, V. Kazakov, Z. Tsuboi
PSU(2,2—4) Character of Quasiclassical AdS/CFT.
JHEP 1007 (2010) 097 and OIQP-09-14

N. Gromov, F. Levkovich-maslyuk
Y-system, TBA and Quasi-Classical strings in AdS(4) x CP3.
JHEP 1006 (2010) 088

N. Gromov
Y-system and Quasi-Classical Strings.
JHEP 1001 (2010) 112 and DESY 09-209

T. Hahn, S. Heinemeyer, W. Hollik, H. Rzehak, G. Weiglein
FeynHiggs 2.7.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 152 and DESY 10-100
`http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.035`

K. Hasegawa, S. Moch, P. Uwer
AutoDipole - Automated generation of dipole subtraction terms.
Comput. Phys. Commun. 181 (2010) 1802
`http://dx.doi.org/10.1016/j.cpc.2010.06.044`

S. Heinemeyer, G. Weiglein
Predicting Supersymmetry.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 283 and DESY 10-099
`http://dx.doi.org/10.1016/j.nuclphysbps.2010.09.007`

K. Hsieh, K. Schmitz, J. Yu, C.-P. Yuan
Global analysis of general SU(2) X SU(2) X U(1) models with precision data.
Phys. Rev. D 82 (2010) 26
`http://dx.doi.org/10.1103/PhysRevD.82.035011`

A. Ibarra, D. Tran, C. Weniger
Decaying dark matter in light of the PAMELA and Fermi LAT data.
JCAP 1001 (2010) 009 and DESY 09-083
`http://dx.doi.org/10.1088/1475-7516/2010/01/009`

Detecting Gamma-Ray Anisotropies from Decaying Dark Matter: Prospects for Fermi LAT.
Phys. Rev. D 81 (2010) 023529 and DESY 09-134
`http://dx.doi.org/10.1103/PhysRevD.81.023529`

J. Jaeckel, A. Ringwald
The Low-Energy Frontier of Particle Physics.
Ann. Rev. Nucl. Part. Sci. 60 (2010) 405 and DESY 10-016

K. Jansen
The Quest for Solving QCD: Simulations at Light Quark Masses.
Phys. Part. Nucl. 41 (2010) 857
`http://dx.doi.org/10.1134/S1063779610060079`

Results from the ETM Collaboration at Light Dynamical Quark Masses.
Int. J. Mod. Phys. D 19 (2010) 1619
`http://dx.doi.org/10.1142/S0218271810017640`

K. Jansen, C. McNeile, C. Michael, C. Urbach
A lattice QCD calculation of the transverse decay constant of the b(1)(1235) meson.
Phys. Lett. B 690 (2010) 491
`http://dx.doi.org/10.1016/j.physletb.2010.05.074`

P. Ko, Jh. Park
Addendum to: Implications of the measurements of B_s–$\overline{B_s}$ mixing on SUSY models.
Phys. Rev. D 82 (2010) 117701 and DESY 10-097
`http://dx.doi.org/10.1103/PhysRevD.82.117701`

O. Lebedev, S. Ramos-Sanchez
The NMSSM and String Theory.
Phys. Lett. B 684 (2010) 48 and DESY 09-213
`http://dx.doi.org/10.1016/j.physletb.2009.12.058`

O. Lebedev, C. Papineau, M. Postma
On Inflation in the Presence of a Gaugino Condensate.
Phys. Lett. B 684 (2010) 154 and DESY 09-116

A.V. Lipatov, N.P. Zotov
Study of non-collinear parton dynamics in the prompt photon photoproduction at HERA.
Phys. Rev. D 81 (2010) 094027 and DESY 10-052; arXiv:0907.3303

L. Maccione, S. Liberati, G. Sigl
Ultrahigh-Energy Photons as Probes of Lorentz Symmetry Violations in Stringy Space-Time Foam Models.
Phys. Rev. Lett. 105 (2010) 021101 and DESY 10-039
`http://dx.doi.org/10.1103/PhysRevLett.105.021101`

P. Nath et al.
The Hunt for New Physics at the Large Hadron Collider.
Nucl. Phys. B, Proc. Suppl. 200-202 (2010) 185

G. Niccoli, J. Teschner
The Sine-Gordon model revisited I.
J. Stat. Mech.: Theory and Experiment 2010 (2010) 09014 and arXiv:0910.3173
`http://dx.doi.org/10.1088/1742-5468/2010/09/P09014`

G. Niccoli
Reconstruction of Baxter Q-operator from Sklyanin SOV for cyclic representations of integrable quantum models.
Nucl. Phys. B 835 (2010) 263 and DESY 09-227

H.P. Nilles, S. Ramos-Sanchez, P. Vaudrevange
Local Grand Unification and String Theory.
AIP Conf. Proc. 1200 (2010) 226 and DESY 09-147; LMU-ASC 40/09

C. Papineau, M. Postma, S. Ramos-Sanchez
Dynamics of moduli and gaugino condensates in an expanding universe.
JCAP 02 (2010) 017 and DESY 09-126; NIKHEF/2009-017
`http://dx.doi.org/10.1088/1475-7516/2010/02/017`

S. Ramos-Sanchez
The mu-problem, the NMSSM and string theory.
Prog. Phys. 58 (2010) 748 and DESY 10-028

J. Schmidt
Local Grand Unification in the Heterotic Landscape.
Prog. Phys. 58 (2010) 3 and DESY-THESIS-2009-020
`http://dx.doi.org/10.1002/prop.200900079`

J. Schmidt, C. Weniger, T.T. Yanagida
Dynamical Matter-Parity Breaking and Gravitino Dark Matter.
Phys. Rev. D D82 (2010) 103517 and DESY 10-058

V. Schomerus
Integrable Conformal Field Theory - A case study.
AIP Conf. Proc. 1243 (2010) 3
`http://dx.doi.org/10.1063/1.3460178`

G. Somogyi, P. Bolzoni, Z. Trocsanyi
NNLO jet cross sections by subtraction.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 42 and DESY 10-096; arXiv:1007.4067
`http://dx.doi.org/10.1016/j.nuclphysbps.2010.08.017`

G. Somogyi, R.E. Smith
Cosmological perturbation theory for baryons and dark matter: One-loop corrections in the renormalized perturbation theory framework.
Phys. Rev. D 81 (2010) 023524
`http://dx.doi.org/10.1103/PhysRevD.81.023524`

F. Staub, W. Porod, B. Herrmann
The electroweak sector of the NMSSM at the one-loop level.
JHEP 2010 (2010) 1 and DESY 10-106
`http://dx.doi.org/10.1007/JHEP10(2010)040`

F. Tekin, R. Sommer, U. Wolff
Symanzik improvement of lattice QCD with four flavors of Wilson quarks.
Phys. Lett. B 683 (2010) 75 and arXiv:0911.4043
`http://dx.doi.org/10.1016/j.physletb.2009.11.055`

The running coupling of QCD with four flavors.
Nucl. Phys. B 840 (2010) 114 and arXiv:1006.0672; HU-EP-10/26; SFB/CPP-10-38; DESY 10-075
`http://dx.doi.org/10.1016/j.nuclphysb.2010.07.002`

A. Vogt, G. Soar, S. Moch, J.A.M. Vermaseren
On higher-order flavour-singlet splitting and coefficient functions at large x.
Nucl. Phys. B, Proc. Suppl. 205-206 (2010) 250

Working Group on Radiative Corrections and Monte Carlo Generators for Low Energies Collaboration, S. Actis, T. Riemann
Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data.
Eur. Phys. J. C 66 (2010) 585 and BIHEP-TH-2009-005; BU-HEPP-09-08; CERN-PH-TH-2009-201; FNT-T-2009-03; FREIBURG-PHENO-09-07; HEPTOOLS-09-018; IEKP-KA-2009-33; LNF-09-14-P; LPSC-09-157; LPT-ORSAY-09-95; LTH-851; MZ-TH-09-38; PITHA-09-14; arXiv:0912.0749
`http://dx.doi.org/10.1140/epjc/s10052-010-1251-4`

L. Zhang, C. Weniger, L. Maccione, J. Redondo, G. Sigl
Constraining decaying dark matter with Fermi LAT gamma-rays.
JCAP 06 (2010) 027 and DESY 09-220
`http://dx.doi.org/10.1088/1475-7516/2010/06/027`

Linear Accelerator Technologies

P. Bambade et al.
Present status and first results of the final focus beam line at the KEK Accelerator Test Facility.
Phys. Rev. STAB 13 (2010) 042801
`http://dx.doi.org/10.1103/PhysRevSTAB.13.042801`

F. Löhl et al.
Electron Bunch Timing with Femtosecond Precision in a Superconducting Free-Electron Laser.
Phys. Rev. Lett. 104 (2010) 4
`http://dx.doi.org/10.1103/PhysRevLett.104.144801`

International Linear Collider

H. Abramowicz et al.
Forward instrumentation for ILC detectors.
J. Instrum. 5 (2010) 12002 and DESY 10-142; arXiv:1009.2433
`http://dx.doi.org/10.1088/1748-0221/5/12/P12002`

C. Adloff et al.
Study of the interactions of pions in the CALICE silicon-tungsten calorimeter prototype.
J. Instrum. 5 (2010) P05007

Construction and Commissioning of the CALICE Analog Hadron Calorimeter Prototype.
J. Instrum. 5 (2010) P05004 and DESY-10-032

C. Bartels, A. Hartin, C. Helebrant, D. Käfer, J. List
Precision Polarimetry at the ILC: Concepts, Simulations and experiments.
Nucl. Instrum. Methods A 623 (2010) 570

S. Baudrand et al.
A High Precision Fabry-Perot Cavity Polarimeter at HERA.
J. Instrum. 5 (2010) P06005 and LAL 10-43
`http://dx.doi.org/10.1088/1748-0221/5/06/P06005`

P. Bechtle, M. Berggren, J. List, P. Schade, O. Stempel
Prospects for the study of the $\tilde{\tau}$-system in SPS1a' at the ILC.
Phys. Rev. D 82 (2010) 055016 and DESY-09-124
`http://dx.doi.org/10.1103/PhysRevD.82.055016`

M. Beckmann, B. List, J. List
Treatment of Photon Radiation in Kinematic Fits at Future e^+e^- Colliders.
Nucl. Instrum. Methods A 624 (2010) 184 and DESY-10-078
`http://dx.doi.org/10.1016/j.nima.2010.08.107`

T. Behnke
The International Linear Collider.
Prog. Phys. 58 (2010) 622
`http://dx.doi.org/10.1002/prop.201000033`

T. Behnke, K. Dehmelt, R. Diener, L. Steder, T. Matsuda, V. Prahl, P. Schade
A Lightweight Field Cage for a Large TPC Prototype for the ILC.
J. Instrum. 5 (2010) 1
`http://dx.doi.org/10.1088/1748-0221/5/10/P10011`

E. Berdermann et al.
Diamond detectors for hadron physics research.
Diam. Relat. Mater. 19 (2010) 358

S. Boogert et al.
Polarimeters and energy spectrometers for the ILC Beam Delivery System.
J. Instrum. 4 (2009) P10015

T. Buanes, M. Danilov, G. Eigen, P. Goettlicher, O. Markin, M. Reinecke, E. Tarkovsky
The CALICE hadron scintillator tile calorimeter prototype.
Nucl. Instrum. Methods A 623 (2010) 342
`http://dx.doi.org/10.1016/j.mima.02.242`

C. Coca, W. Lohmann, M. Orlandea, A. Sapronov, E. Teodorescu
Expected Electromagnetic and Neutron Doses for the BeamCal at ILD.
Romanian Journal of Physics 55 (2010) 687

A. De Roeck et al.
From the LHC to Future Colliders.
Eur. Phys. J. C C66 (2010) 525 and CERN-PH-TH-2009-166

M. Gottlich, E. Garutti, A. Tadday, H.-C. Schultz-Coulon
Application of silicon photomultipliers to calorimetry and positron emission tomography.
Compos. Int. PD09 (2010) 009

G. Moortgat-Pick, K. Rolbiecki, J. Tattersall, P. Wienemann
Probing CP Violation with and without Momentum Reconstruction at the LHC.
JHEP 1001 (2010) 001

CP Violation in SUSY Cascade Decay Chains at the LHC.
AIP Conf. Proc. 1200 (2010) 337

K. Rolbiecki, G. Moortgat-Pick, J. Tattersall, P. Wienemann
Probing CP Violation with Kinematic Reconstruction at the LHC.
Prog. Phys. 58 (2010) 699

F. Sefkow, A. Lucaci-Timoce
Monte Carlo Studies of the CALICE AHCAL Tiles Gaps and Non-uniformities.
J. Phys., Conf. Ser. 3 (2010) 1

A. Tadday et al.
Characterisation studies of silicon photomultipliers for a calorimeter for the ILC.
PoS PD09 (2010) 021

Theses.

Habilitation

J.E. Ruiz Tabasco
K^0_S Production at High Q^2 in Deep Inelastic ep Scattering at H1.
Univ. Mérida, Yucatán, México (2010)
DESY-THESIS-2010-050

PhD theses

J.L. Bazo Alba
Search for steady and flaring astrophysical neutrino point sources with the IceCube detector.
Humboldt Universität Berlin (2010)

J. Becker
Signal development in silicon sensors used for radiation detection.
Univ. Hamburg (2010)
DESY-THESIS-2010-033

J. Behr
Jets at High Q^2 at HERA and Test Beam Measurements with EUDET Pixel Telescope.
Univ. Hamburg (2010)
DESY-THESIS-2010-038

S. Boutle
Beauty in photoproduction at HERA II with the ZEUS detector.
University College London (2010)
DESY-THESIS-2010-005

M. Brinkmann
Measurement of the $D^{*\pm}$ Meson Production Cross Section and $F_2^{c\bar{c}}$ at High Q^2 in ep Scattering at HERA.
Univ. Hamburg (2010)
DESY-THESIS-2010-016; h1th-523

B. Brzozowska
Scaled momentum spectra in deep inelastic scattering at HERA.
Univ. Warsaw (2010)

J. Burns
Deeply Virtual Compton Scattering off an Unpolarised Hydrogen Target at HERMES.
Univ. Glasgow (2010)
DESY-THESIS-2010-036

T. Danckaert
Type IIA orientifolds on SU(2)-structure manifolds.
Univ. Hamburg (2010)
DESY-THESIS-2010-046

M. Deák
Transversal Momentum of the Electroweak Gauge Boson and Forward Jets in High Energy Factorisation at the LHC.
Univ. Hamburg (2010)
DESY-THESIS-2010-025

J. Delvax
Etude de la Production de Jets en Diffraction à HERA, à l'aide du Spectométre à Protons VFPS.
Universite libre de Bruxelles (2010)
DESY-THESIS-2010-045; h1th-544

M. Diefenthaler
Signals for transversity and transverse-momentum-dependent quark distribution functions studied at the HERMES experiment.
Univ. Erlangen-Nürnberg (2010)
DESY-THESIS-2010-032

B.R. Grell
Jet Shapes in Charm Photoproduction and Deeply Inelastic Scattering at HERA.
Univ. Hamburg (2010)
DESY-THESIS-2010-039; h1th-526

J. Grossehelweg
Semiclassical versus exact quantization of the Sinh-Gordon model.
Univ. Hamburg (2010)
DESY-THESIS-2009-048

T.-P. Hack
On the Backreaction of Scalar and Spinor Quantum Fields in Curved Spacetimes.
Univ. Hamburg (2010)
DESY-THESIS-2010-042

K. Hacker
Measuring the Electron Beam Energy in a Magnetic Bunch Compressor.
Univ. Hamburg (2010)
DESY-THESIS-2010-037

L. Hallermann
Analysis of GEM Properties and Development of a GEM Support Structure for the ILD Time Projection Chamber.
Univ. Hamburg (2010)
DESY-THESIS-2010-015

M. Jüngst
Measurement of beauty and charm cross sections in photoproduction using decays into electrons with ZEUS at HERA.
Univ. Bonn (2010)

S. Kama
Automatic Monte-Carlo Tuning for Minimum Bias Events at the LHC.
Humboldt Universität Berlin (2010)

K.J. Keller
Dimensional Regularization in Position Space and a Forest Formula for Regularized Epstein-Glaser Renormalization.
Univ. Hamburg (2010)
DESY-THESIS-2010-012

T. Kneesch
Charmed-meson fragmentation functions with finite-mass corrections and their application in various processes.
Univ. Hamburg (2010)
DESY-THESIS-2010-049

K. Korcsák-Gorzó
High P_T Leptons and Single W Boson Production at HERA.
Univ. Oxford (2010)
DESY-THESIS-2010-053, December 2010

P. Kravchenko
The final inclusive and semi-inclusive longitudinal double-spin asymmetries at HERMES. Extraction of quark helicity distributions of the nucleon from deep-inelastic scattering.
Univ. Erlangen-Nürnberg (2010)
DESY-THESIS-2010-043

R. Lamb
The Boer-Mulders and Cahn effects: Azimuthal modulations in the spin-independent SIDIS cross section at HERMES.
University of Illinois at Urbana-Champaign (2010)
DESY-THESIS-2010-035

R.J. Lauer
Extending the search for cosmic point sources of neutrinos with IceCube beyond PeV energies and above the horizon.
Humboldt Universität Berlin (2010)

L.A. Linden Levy
On Extracting Hadron Multiplicities and Unpolarized Nucleon Structure Ratios from Sidis Data at the HERMES Experiment.
University of Illinois at Urbana-Champaign (2008)

B. Lutz
Hadron Showers in a Highly Granular Calorimeter.
Univ. Hamburg (2010)
DESY-THESIS-2010-048

D.F. Mahon
Deeply Virtual Compton Scattering off Longitudinally Polarised Protons at HERMES.
Univ. Glasgow (2010)
DESY-THESIS-2010-023

S. Mehlhase
Development of a Data-Driven Algorithm to Determine the W+Jets Background in ttbar Events in ATLAS.
Humboldt Universität Berlin (2010)

S. Mendizabal Cofre
Quantum mechanics of leptogenesis.
Univ. Hamburg (2010)
DESY-THESIS-2010-029

V. Mitev
Sigma Models on Supercosets.
Univ. Hamburg (2010)
DESY-THESIS-2010-034

K. Nowak
Prompt Photon Production in Photoproduction at HERA.
Univ. Zürich (2010)
DESY-THESIS-2010-011; h1th-520

R. Perez-Benito
Exclusive ρ^0 Production measured with the Hermes Recoil Detector.
Univ. Giessen (2010)
DESY-THESIS-2010-052

S. Piec
Measurement of the Proton Structure Function FL(x,Q2) with the H1 Detector at HERA.
Humboldt Universität Berlin (2009)
DESY-THESIS-2010-051

E. Ron
Measurements of the internal structure of jets using subjets in NC DIS at HERA.
Universidad Autonoma de Madrid (2010)

K. Satalecka
Multimessenger Studies of Point-Sources Using the IceCube Neutrino Telescope and the MAGIC Gamma-Ray Telescope.
Humboldt Universität Berlin (2010)

V. Schönberg
Measurement of beauty and charm photoproduction using inclusive secondary vertexing with the ZEUS detector at HERA.
Univ. Bonn (2010)

T. Toll
MC@NLO for Heavy Flavour Photoproduction at HERA.
Univ. Hamburg (2010)
DESY-THESIS-2010-004; h1th-519

D. Tosi
Measurement of Acoustic Attenuation in South Pole Ice with a Retrievable Transmitter.
Humboldt Universität Berlin (2010)

Ch. Van Hulse
The HERMES recoil photon detector and the study of deeply virtual Compton scattering.
Univ. Gent (2010)

S. Vinokurova
Diffractive D*-Mesons Production in DIS at HERA.
Univ. Hamburg (2008)
DESY-THESIS-2010-020; h1th-524

M. Viti
Precise and Fast Beam Energy Measurement at the International Linear Collider.
Humboldt Universität Berlin (2010)
DESY-THESIS-2010-007

N. Wattimena
Calorimetry at the International Linear Collider - From Simulation to Reality.
Univ. Hamburg (2010)
DESY-THESIS-2010-006

C. Weniger
From superWIMPs to decaying dark matter: Models, bounds and indirect searches.
Univ. Hamburg (2010)
DESY-THESIS-2010-024

L. Zhang
A Holistic View of Unstable Dark Matter: Spectral and Anisotropy Signatures in Astrophysical Backgrounds.
Univ. Hamburg (2010)
DESY-THESIS-2010-047

Diploma theses

C. Behrens
Detection and Spectral Measurements of Coherent Synchrotron Radiation at FLASH.
Univ. Hamburg (2010)
DESY-THESIS-2010-002; TESLA-FEL 2010-03

M. Dornberger
Studien zur Simulation von Minimum-Bias-Ereignissen für den ATLAS Detektor mit verschiedenen Monte-Carlo-Generatoren.
Humboldt Universität Berlin (2010)

J. Franck
Experimental Study of the Higgs-b/c Couplings in Photon-Proton Collisions.
Univ. Hamburg (2010)

C. Friedrich
Alternative Spannungsversorgungskonzepte für zukünftige Silizium-Pixel- und Streifendetektoren.
Humboldt Universität Berlin (2010)

J. Hajer
Gravitino and Scalar τ-Lepton Decays in Supersymmetric Models with Broken R-Parity.
Univ. Hamburg (2010)

F. Huber
Elastic J/ψ Production at low Q^2 at HERA.
ETH Zürich (2010)
DESY-Thesis-2010-018

S. Mergelmeyer
D*-Photoproduktion mit assoziierten Jets und Vertices bei ZEUS.
Univ. Bonn (2010)

J. Moeller
GUT scale extra dimensions and light moduli in supergravity and cosmology.
Univ. Hamburg (2010)
DESY-THESIS-2010-017

T. Pöhlsen
Charge Collection and Space Charge Distribution in Neutron-Irradiated Epitaxial Silicon Detectors.
Univ. Hamburg (2010)
DESY-THESIS-2010-013

A. Stössl
Estimating the performance of cascade reconstruction algorithms with artificial light sources in IceCube.
Univ. Tübingen (2010)

C. Wasicki
Monte-Carlo-Simulation von Top-Paaren in nächstführender Ordnung am ATLAS-Experiment.
Freie Universität Berlin (2010)

Bachelor theses

P. Birr
Analysis of signals ion the IceTop detector to identify muons.
Humboldt Universität Berlin (2010)

E. Etzelmüller
Messung diffraktiver Φ-Produktion mit dem HERMES Rückstossdetektor.
Univ. Giessen (2010)

O. Gogota
Study of the D0 photoproduction at HERA.
National University Kiev (2010)

M. Hoffmann
Studie zum Entdeckungspotential von GMSB Modellen mit Tau Endzuständen mit Hilfe des ATLAS-Detektors.
Univ. Hamburg (2010)

I. Korol
D+ mesons differencial cross sections in PHP at HERA.
National University Kiev (2010)

T. Murach
Vergleich von simulierten und gemessenen Daten beim ATLAS-Experiment anhand von grundlegenden kinematischen Variablen.
Humboldt Universität Berlin (2010)

T. Nobe
Search for Z0 production at HERA.
Tokyo Institute of Technology (2010)

R. Riemann
Diskriminierung von Top-Ereignissen aus dem W+Jets-Untergrund mittels Shape-Variablen bei ATLAS.
Humboldt Universität Berlin (2010)

R. Schichte
Experimental determination of the influence of snow on the signal in IceTop detectors.
Humboldt Universität Berlin (2010)

M. Stahl
Verfeinerung der Θ^+-Analyse beim HERMES-Experiment.
Univ. Giessen (2010)

O. Viazlo
Charm and beauty in DIS with inclusive secondary vertexing.
National University Kiev (2010)

Photographs and graphics
American Institute of Physics
CERN
DESY
Lars Berg, Münster
Hans-Peter Hildebrandt, Pinneberg
Heiner Müller-Elsner, Agentur-Focus.de
Rüdiger Nehmzow, Düsseldorf
Manfred Schulze-Alex, Hamburg

The figures were reproduced by permission of authors or journals.

Acknowledgement

We would like to thank all authors and everyone who helped in the creation of this annual report. ●

Imprint

Publishing and contact
Deutsches Elektronen-Synchrotron DESY
A Research Centre of the Helmholtz Association

Hamburg location:
Notkestr. 85, 22607 Hamburg, Germany
Tel.: +49 40 8998-0, Fax: +49 40 8998-3282
desyinfo@desy.de

Zeuthen location:
Platanenallee 6, 15738 Zeuthen, Germany
Tel.: +49 33762 7-70, Fax: +49 33762 7-7413
desyinfo.zeuthen@desy.de

www.desy.de
ISBN 978-3-935702-54-6

Editing
Manfred Fleischer, Matthias Kasemann

Layout
Heike Becker, Britta Liebaug

Printing
Heigener Europrint GmbH, Hamburg

Copy deadline
20 April 2011

Editorial Note
The authors of the individual scientific contributions published in this report are fully responsible for the contents.

HELMHOLTZ
ASSOCIATION

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

The Helmholtz Association is a community of 17 scientific-technical and biological-medical research centres. These centres have been commissioned with pursuing long-term research goals on behalf of the state and society.

The Association strives to gain insights and knowledge so that it can help to preserve and improve the foundations of human life. It does this by identifying and working on the grand challenges faced by society, science and industry. Helmholtz Centres perform top-class research in strategic programmes in six core fields: Energy, Earth and Environment, Health, Key Technologies, Structure of Matter, Aeronautics, Space and Transport.

www.helmholtz.de