DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 79/70
October 1979

SEARCH FOR NEW FLAVOUR PRODUCTION AT PETRA

by

JADE Collaboration

NOTKESTRASSE 85 · 2 HAMBURG 52

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Abstract:

The topological distribution of hadrons from the reaction $e^+e^- \rightarrow$ multi-hadrons has been studied at PETRA energies between $\sqrt{s}$ = 22 and 31.6 GeV. No evidence is seen for spherical events which would be expected if massive particles bearing new flavours were produced.

In a previous paper (1) we reported on measurements of the cross section for the reaction $e^+e^- \to$ multihadrons using the JADE detector at PETRA energies between 22 and 31.6 GeV. The R values, i.e. the hadron cross section in units of the theoretical $\mu^+\mu^-$ cross section, were found to be consistent with the production of the known quark-flavours (u,d,s,c,b) only. The energy dependence of the R value does not show any significant discontinuity, so that there is no apparent indication for a threshold of new flavour production in the energy range in question. However, the existence of a sixth quark, t (top), which would be the doublet partner of the b quark, has been conjectured in the standard SU(2) x U(1) model of quarks and leptons (2). The electric charge of the t quark is predicted to be 2/3 but its mass is essentially unknown.

In order to obtain a better sensitivity for new flavour detection, the topological distribution of final state hadrons has been studied as reported in this letter (3). The decays of heavy particles with new flavours are expected to result in a relatively wide angled hadron distribution in contrast to the narrow jet-like distributions from known low mass flavours. A comparison of the hadron measured distributions with the QCD predictions and evidence for 3-jet events will be presented in a subsequent letter.

The JADE detector has a solid angle of 97% and 90% of the full solid angle for detecting charged particles and photons respectively. The detector, the trigger conditions and the criteria for the selection of hadronic events have been described in ref. (1). The final multihadron sample for this analysis consists of 21, 81, 198 and 49 events at $\sqrt{s}$ = 22, 27.6, 30 and 31.6 GeV respectively with a residual background estimated to be less than 3 %.

For a detailed study of the event shape the sphericity tensor (4) was constructed and diagonalized for each event:

$$T_{\alpha\beta} = \sum_i P_{i\alpha} P_{i\beta} / \sum_i P_i^2$$

where $P_{i\alpha}$ is the α-component (α = x,y,z) of the momentum of the i-th particle. The sum runs over all charged particles and shower energy clusters. The resulting eigenvalues Q_1, Q_2, Q_3 ($Q_1 < Q_2 < Q_3$) correspond to the principal axes of the momentum ellipsoid and satisfy the constraint $Q_1 + Q_2 + Q_3 = 1$. Each event is then represented by a point in a Dalitz plot as shown in Fig. 1a). The perpendicular sides of the tirangle are Q_1 and $(Q_3 - Q_1)/\sqrt{3}$ so that the hypothenus is the shpericity $S = \frac{3}{2}(Q_1 + Q_2)$.

The plot shown in Fig. 1a) contains all events from the various C.M. energies. No significant accumulation of "spherical" events is observed in the upper part of the triangle.

In order to assess the significance of this observation we compare the data with model calculations. This model is based on virtual photon decays into a quark-antiquark pair $q\bar{q}$ (q = u,d,c,b,t) with a probability proportional to $(e_q)^2$, where e_q is the electric charge of the quark q. The primary quarks are then allowed to fragment into hadrons according to a cascade mechanism described in ref. (5). For the u,d,s quarks the fragmentation function $f(z) = 1-a+3a(1-z)^2$ with a = 0.77 was used, whereas f(z) = const. was used for the heavier quarks. Particles containing a t quark were assumed to decay[6] through the chain $t \rightarrow b \rightarrow c \rightarrow s$. To generate the final state particles we use the Monte Carlo Program of ref. (7) where the emission of hard photons by the initial electron and positron was taken into account. The final particles were then followed through the detector, taking into account decays and multiple scattering, conversion of photons and nuclear interaction in the detector material. We then calculate the quantities actually measured such as drift times and pulse heights, and bin them according to the resolution of the apparatus. These data were afterwards processed by the same chain of pattern recognition programs as our real data.

Fig. 1b) shows the results of this model calculation for a top meson mass of 14 GeV and a C.M. energy of 30 GeV. For quantitative comparion we list in Table 1 the number of observed and expected events inside the region $S > 0.55$ and $Q_1 > 0.075$ for three different values of the top meson mass. The normalization is based on the accumulated luminosity and an quark production cross section of $\sigma_{q\bar{q}} = 3 \cdot e_q^2 \cdot \sigma_{\mu^+\mu^-}$.

Monte Carlo simulation without top meson production yield no events in this region of the Dalitz plot.

Furthermore, if the top particles are allowed to decay according to an uniform invariant phase space distribution the same number of expected events is obtained to within 10 %.

In conclusion, no evidence has been observed for the production of heavy mesons with new flavour. Our data are inconsistent with the production of top mesons with masses between 11 and 14 GeV provided $\sigma_{t\bar{t}} \simeq 4/3 \cdot \sigma_{\mu^+\mu^-}$, although it should be remarked that the conclusion is based on the assumption of multihadron decays and a short life time of any hypothetical heavy particle. Similar deductions were made in ref. (8).

Acknowledgements:

We acknowledge the efforts of the PETRA machine group, who provide us with the opportunity of doing this experiment, and also the efforts of the technical support groups of the participating institutes in the construction and maintenance of our apparatus. This experiment was supported by the Bundesministerium für Forschung und Technologie, by the Education Ministry of Japan and by the U.K. Science Research Council through the Rutherford Laboratory. The visiting groups at DESY wish to thank the DESY directorate for their hospitality.

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(4) Our definition of $T_{\alpha\beta}$ is slightly different from but equivalent to the one proposed in
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(8) See contributions by the Mark J, Pluto and Tasso collaborations to the 1979 International Symposium on Lepton and Photon Interactions (2) and D.P. Barber et al., Phys. Lett. 85B (1979) 463; Ch. Berger et al., DESY 79/56

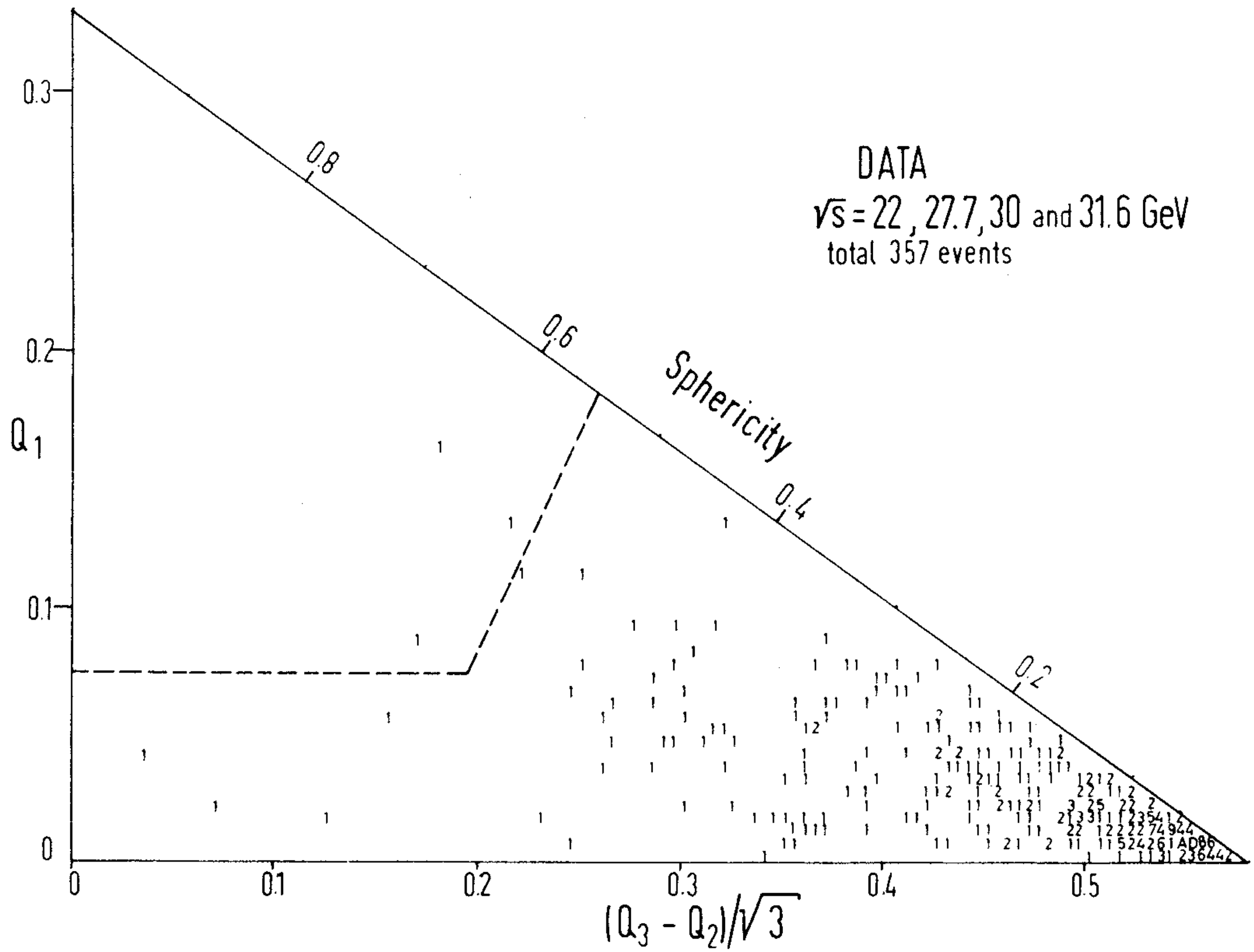
Figure captions:

Fig. 1: The distribution of eigenvalues Q_1, Q_2, Q_3 of the sphericity tensor T described in the text.
Q_1 is plotted versus $(Q_3 - Q_1)/\sqrt{3}$.
a) Data from all energies combined and
b) model prediction at $\sqrt{s}$ = 30 GeV including top-meson (m_t = 14 GeV) production.
The cuts $Q_1 > 0.075$ and sphericity > 0.55 are indicated.

	m_t (GeV)	$\sqrt{s}$ (GeV)			
		22	27.7	30	31.6
number of events expected	8	4	3	2	0
	11	-	15	22	4
	14	-	-	25	5
number of events observed	-	0	1	1	1

Table 1:

The observed numbers of events with $Q_1 > 0.075$ and sphericity > 0.55 and the numbers expected from top-meson production for assumed top-meson masses of 8, 11 and 14 GeV.



DATA
√s = 22, 27.7, 30 and 31.6 GeV
total 357 events
Sphericity
0.8
0.6
0.4
0.2
Q1
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
(Q3 - Q2)/√3

Fig. 1a)

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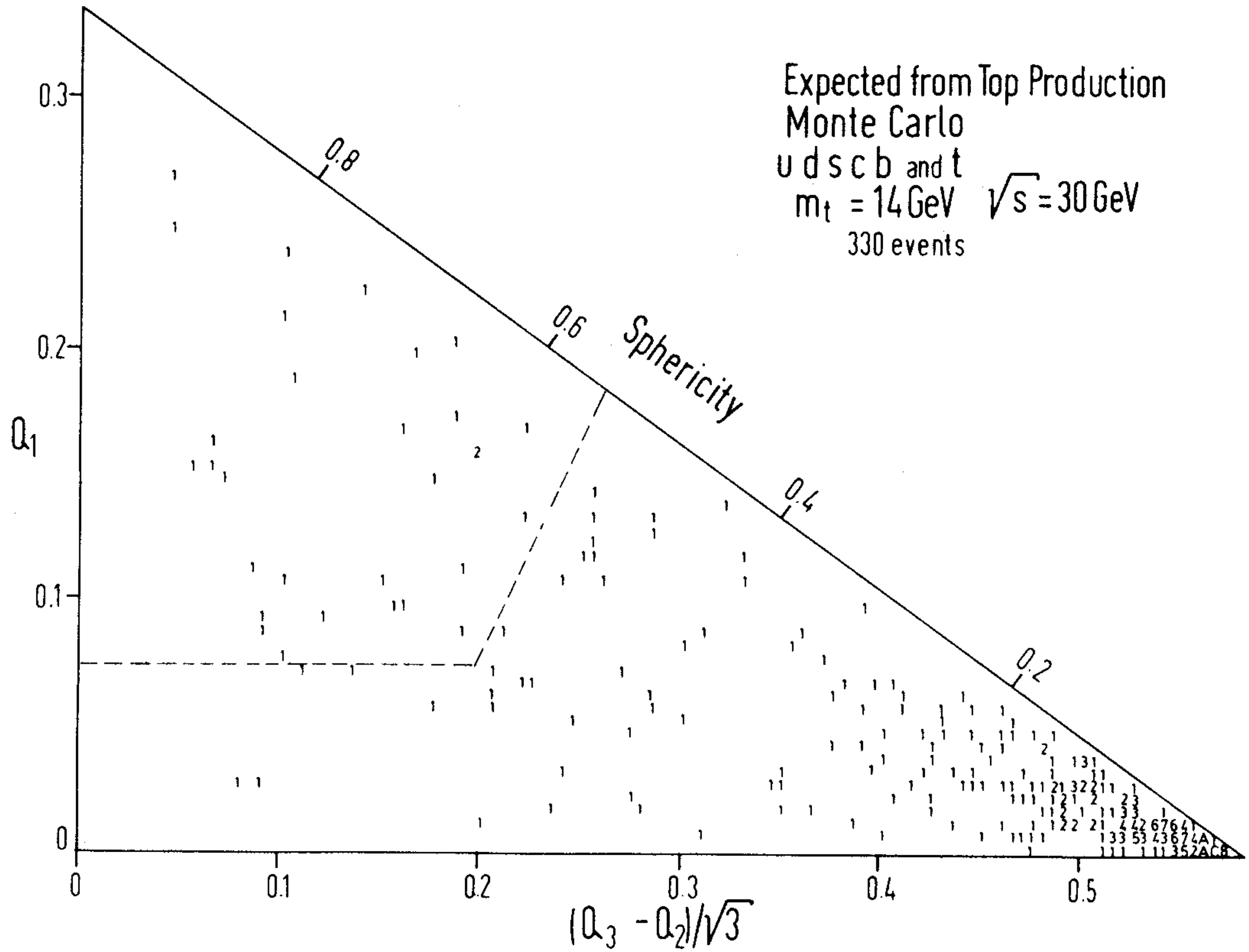
Expected from Top Production
Monte Carlo
u d s c b and t
m_t = 14 GeV $\sqrt{s}$ = 30 GeV
330 events
Sphericity
0.8
0.6
0.4
0.2
Q_1
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
$(Q_3 - Q_2)/\sqrt{3}$

Fig. 1 b)