DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 75/16
July 1975

Scintillation in Gases Commonly Used as Cherenkov Radiators

by

S. Bertolucci, C. Bradaschia, P. Giromini, A. Mancuso,
T. McCorriston, C. Rippich, M. Rohde and S. Vaccaro

2 HAMBURG 52 · NOTKESTIEG 1

Scintillation in Gases Commonly Used as Cherenkov Radiators

by

S. Bertolucci, C. Bradaschia, P. Giromini, A. Mancuso,
T. McCorriston, C. Rippich, M. Rohde and S. Vaccaro
Deutsches Elektronen-Synchrotron DESY, Hamburg

Abstract

Data related to the scintillation of gases, commonly used as radiators in Cherenkov counters, are presented. Up to a factor of three differences in the scintillation yields of these gases is found.

Introduction

When ionizing particles traverse a gas volume, they lose their kinetic energy by electromagnetic interactions with the atomic electrons which results in the excitation and ionization of the atoms. In the deexcitation and recombination processes, immediately following, photons of visible light are emitted. One therefore expects to observe scintillation phenomena in gases due to passage of ionising particles.

The first successful observation of gas scintillation was reported by Grün and Schopper (1951). Further investigations have been always in the direction of finding the optimum condition for the design and the operation of noble gas scintillation detectors. On the contrary data related to scintillation yields of different gases are still practically nonexistent.

The data presented here are the byproduct of tests done for building a low background threshold Cherenkov counter to be used in a $\gamma p \rightarrow p + e^{+} + e^{-}$ experiment at DESY.

Experimental Arrangement and Results

The counter used for this test is shown in Fig.1. It is a 20 cm square box, painted black inside. The flat mirror is front coated with aluminum (the reflectivity was measured to be greater than 9o% for red light) and it is arranged to reflect scintillation light, emitted almost perpendicular to the particle trajectories, upwards at a 90^{o} angle, through a lucite window (.7 cm thick), onto a photomultiplier XP 2041.

The measurement was conducted with a Ru 106 β-source. The electron beam is defined by the coincidence ($s_1 \times s_2$) of the two plastic scintillators s_1 and s_2, each one 1. x 1. cm in size and 0.1 cm thick. A 0.2 cm thick Al absorber selects electrons with energy bigger than 1.5 MeV. The efficiency of the counter against $s_1 \times s_2$ was measured for Air, N_2, $N_2 + O_2$, A, $A + O_2$, CO_2, H_2, Freon 12 at atmospheric pressure.*

*Above this pressure the number of scintillation photons emitted by all of these gases upon passage of a minimum ionizing particle is almost constant (1).

Contribution to the observed efficiency can come neither from Cherenkov light, since ~ 3 MeV electrons are well below threshold, nor from δ-rays, since the photomultiplier does not see directly the beam trajectory. Bremsstrahlung of primary electrons can be evaluated by using (2) in the simplifying assumption of (3). Even considering the radiation intensity perpendicular to the plane of motion of the primary electron (in fact the average emission angle is (4) $\simeq m_e/E \simeq 22$ degrees which is too small an angle for reflection into the photomultiplier), one expects a number of photoelectrons per particle which is a factor ten smaller than that measured. Therefore bremsstrahlung from δ-rays is also negligible. In addition the measured efficencies do not show any Z^2 trend for different gases as expected for bremsstrahlung radiation.

On the assumption that single photoelectrons are detected, the measured efficency ε is related to the mean number of photoelectrons n by $\varepsilon = 1-e^{-n} \simeq n$ since ε is measured $<<1$. We checked the sensitivity of the apparatus to single photoelectrons by firing a light emitting diode mounted on the face of the photomultiplier to make sure that the counter efficency kept constant when the applied voltage was varied around the chosen operating voltage. This was indeed the case even when the l.e.d. intensity was such that the top efficency lay in the range 0.1 to 0.6.

Accidental coincidences were monitored by registering on a multichannel analyzer, for each event, the time of flight of the counter against $s_1 \times s_2$. A typical T.O.F. spectrum is shown in Fig.2. Accidentals were subtracted from the scintillation light peak using the measured flat background outside the peak.

In Table 1 are listed the numbers of photoelectrons from scintillation per unit path and unit solid angle for the analyzed gases. No correction is applied for reflectivity of the mirror, transmission through the lucite window and the spectral response of the photomultiplier.

Table 1

Measured scintillation yields in various gases at atmospheric pressure, for minimum ionizing particles.

Gases	photoelectron cm^{-1} $sterad^{-1}$
Air	1.36 10^{-3}
A	1.91 10^{-3}
95% A + 5% O_2	1.31 10^{-3}
90% A + 10% O_2	1.13 10^{-3}
80% A + 20% O_2	0.92 10^{-3}
N_2	3.08 10^{-3}
90% N_2 + 10% O_2	1.53 10^{-3}
80% N_2 + 20% O_2	1.5 10^{-3}
CO_2	1.23 10^{-3}
H_2	0.97 10^{-3}
Freon 12	1.13 10^{-3}

A possible systematic error ~ ± 10% is guessed for all the above values.

Acknowledgement

We thank P. Berges, K. Löffler, Ms. U. Rehder and H. Lenzen for assistance. Dr. D. Keßler, Dr. P. G. Schröter and Dr. F. Schwickert are especially thanked for their outstanding and continuous stimulation.

References:

1.) J. B. Birks; Scintillation Counters, Mc Graw-Hill (1953).

2.) B. Rossi; High Energy Particles, Prentice Hall (1952).

3.) A. S. Vovenko et al., USP. FIZ. NAUK. 81, 435 (1963).

4.) Heitler; The Quantum Theory of Radiation, Oxford (1960).

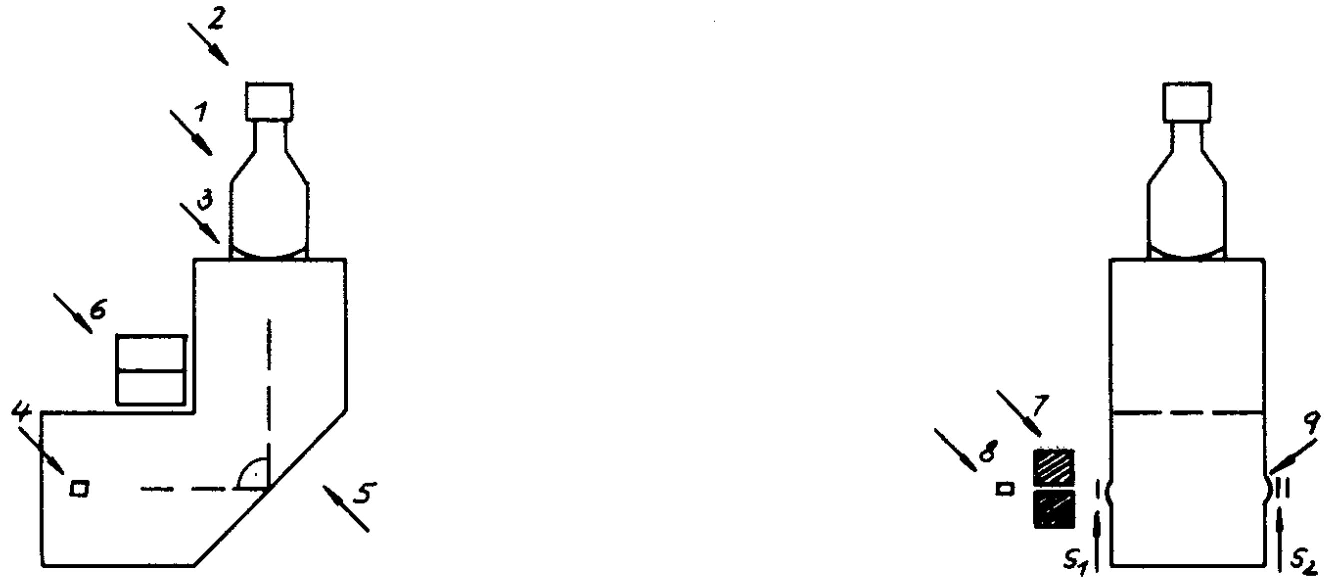

Fig 1: Test counter

1: Photomultiplier · 2: Photomultiplier base · 3: Lucite window · 4: Thin mylar windows · 5: aluminized flat mirror · 6: Lead bricks to stop δ-rays · 7: Collimator · 8: β-source · 9: 2 mm thick aluminium foil · s_1, s_2: plastic scintillation counters used in the test (see text).

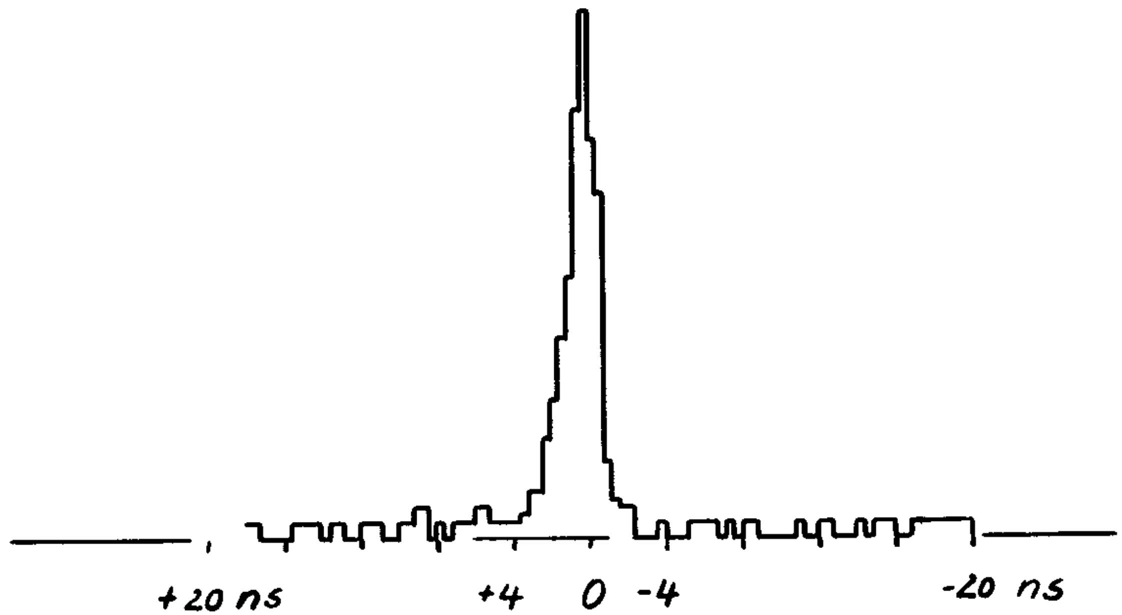

Fig 2