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P. Spillantini: CERENKOV LIGHT DETECTION FROM A LIQUID HYDROGEN COUNTER. -

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INTRODUCTION. -

In the multiparticle production experiments with the new accelerators at very high energy the problem of the π/K separation requires increasing attention. The very high total energy involved in the interactions and the high average multiplicity of the products do not generally allow for a π/K distinction by the complete kinematical reconstruction of the event, and one or more Cerenkov counters must be included in the set-up.

Different Cerenkov light radiators (solids, liquids or gases) can be used in different momentum ranges, depending on the value of their index of refraction (see Fig. 1). Solids and liquids can be used up to $\sim$ 0.7 GeV/c, whereas gases work satisfactorily from 4 GeV/c on up; some gases at moderately high pressures ($\lesssim$ 10 atm) can extend this range down to $\sim$ 1.5 GeV/c. In one of the most populated momentum intervals (0.7 ÷ 1.5 GeV/c) only liquified gases can be used as radiators, since the spread of the particles over the entire solid angle prevents the use of gaseous gases at very high pressures (tens to hundreds of atmospheres would be necessary depending on the nature of the gas). Therefore a system of liquified gas Cerenkov counters must be foreseen for any large solid angle device requiring π/K distinction. This is especially the case for experiments on multiparticle production with any type of storage ring in the range from $\sim$2 to $\sim$50 GeV total c. m. energy. The produced particles are expected to be spread on the entire solid angle with an average momentum in the range $\sim 0.5 \div 2.5$ GeV/c (i. e. exactly where liquified gases work) and the transverse momentum cut when protons are involved does not change this situation substantially.

LIQUIFIED GAS CERENKOV COUNTERS. -

Liquified gases that can be used as Cerenkov light radiators in the momentum interval where the other radiators do not work are very few.(1)

In practice liquid helium cannot be used, as it scintillates; air and nytrogen have an index of refraction near that of some liquid radiators (for example the liquid FC - 75 Fluorochemical) and do not improve substantially their range of π/K distinction. This leaves liquid hydrogen. It is a very efficient radiator: in fact it can emit (for $\beta = 1$) 85 photons/cm(4) integrated over the spectral response of a bialkali (type D) photocatode spectrum. A path length of 1 cm in liquid hydrogen can be sufficient for good π/K distinction provided the Cerenkov light collection is efficient.

Emission of Cerenkov light in liquid hydrogen has already been used in a number of sensitive liquid hydrogen targets(3, 4), in which the light is collected in a very efficient manner in the forward direction along the axis of the Cerenkov ligh cone. However this favorable scheme of light collection cannot be used for a liquid hydrogen Cerenkov counter system covering a wide solid angle. In fact it can hardly be located after the devices for momentum measurement becau se of the geometrical dimensions and the cryogenic difficulties, but it must be conceived as a very compact device surrounding the interaction point; as shown by the two schemes in Figs. 2 and 3, the Cerenkov light must be collected at a very large angle (on the average 90^{o}) with respect to the axis of the Cerenkov light cone.

LIGHT COLLECTION EXPERIMENT. -

An experiment has been carried out to measure this large angle light collection, using a geometry suitable for a proposed target, to be used in an experiment at the CERN SPS. The apparatus (Fig. 4) consisted of two small counters C_1 and C_2, placed 40 cm apart, defining a beam of electrons behind a pair spectrometer; between the two counters a liquid hydrogen counter (C_H) could be moved in the direction perpendicular to the electron beam. It consisted (Fig. 5) of a cylindrical (lightly conical) cell, placed with its axis perpendicular to the direction of the incident electron. The cell was viewed along its axis by a 56 DVP Phylips photomultiplier through a light pipe in vacuum and a perspex light pipe(5).

The efficiency of the C_H counter was measured as a function of its H. V. foı three geometrical different positions of the electron beam (see Fig. 5) it was in plateau above 2300 Volts (see Fig. 6), to whithin 97%(8). The empty counter background (1%), the delayed coincidence level of the C_1C_2 telescope (1%), the spurious rate of C_H(7) (1%) and e-γ and γ-e convertions in the entrance and exit of the cell ($\sim$0.5%) can explain the 3% lack of efficiency.

Pulse height spectra of the C_H photomultiplier were recorded. Their fractional FWHM (see Fig. 7) was ~65% over the whole H. V. plateau and for all the positions of the electron beam on the counter; it can be expressed by(6)

$$\mathrm{FWHM} = \frac{2.35}{\sqrt{N_{pe}}} \sqrt{1 + \frac{\beta\delta}{\Delta(\delta - 1)}} \, .$$

With the values of ref. (3) for the parameters ($\beta = 1.6$, $\Delta = 30$, $\delta = 5$) we find $N_{pe} \simeq 14$ photoelectrons at the first dynode of the photomultiplier.

From the relation

$$N_{pe} = \varepsilon_1 \times \eta_0 \times \varepsilon_2 \times N_p$$

where:

η_0 = quantum efficiency of the photocathode at the maximum of the spectral response (= 17% for our P. M.);

ε_2 = collection efficiency from the photocathode to the first dynode (assumed to be 90%);

N_p = number of photons integrated over the spectral response of the photocathode produced over a 3.5 cm path in liquid hydrogen ($\sim$ 300 photons),

we obtain a photon collection efficiency of the photocathode $\varepsilon_1 \simeq 0.33$.

CONCLUSIONS -

Given the unsophisticated construction of the C_H counter (made from a normal liquid hydrogen target by gluing aluminated mylar to the internal surface of the cell and the light pipe in vacuum) and the absence of any special geometrical shrewdness, the $\sim$30% measured value for light collection must be considered very good. This clearly indicates that very thin liquid hydrogen Cerenkov counters ($\gtrsim$ 2 cm) used in the threshold mode can distinguish efficiently between π's and K's in the 0.7 ÷ 1.5 GeV/c momentum range. Very small volumes of liquid hydrogen (of the order of an ordinary liquid hydrogen target) are sufficient to cover nearly the entire solid angle (as in Figs. 2 and 3): problems concerning hydrogen consumption(9), safety and thermal insulation are not serious.

The authors wishes to thank Prof. F. Scaramuzzi for his helpful advice and for the construction of the liquid hydrogen counter and Prof. A. Reale who has been very helpful during the experimentation.

REFERENCES AND NOTES -

(1) - The few liquid gases that can be used as Cerenkov light radiators in the 0.7 ÷ 1.5 GeV/c momentum interval are:

Air index of refraction n = 1.21(2) at 126°K
N_2 " " " n = 1.205(2) at 83°K
H_2 " " " n = 1.110(3) at 20°K
H_2 " " " n = 1.0206(2) at 4.22°K

(2) - W. Galbraith, High Energy and Nuclear Physics Data Handbook, (Rutherford High Energy Laboratory - Chilton), Sect. VI.

(3) - F. Sergiampietri, Use of Cerenkov light in liquid hydrogen targets, in Proc. 1973 Intern. Conf. on Instrumentation for High Energy Physics (Frascati, 1973), p. 430.

(4) - E. Bertolucci, I. Mannelli, F. Martorana, G. Pierazzini, A. Scribano, F. Sergiampietri and M. L. Vincelli, Nuclear Instr. and Meth. 69, 21 (1969).

(5) - The perspex light pipe allowed timing and calibration of the photomultiplier when the C_1C_2 telescope was moved in "test position" (Fig. 5).

(6) - G. A. Marton, H. M. Smith and H. R. Krall, Appl. Phys. Letters 13, 356 (1968); G. A. Marton, RCA Rev. 10, 525 (1949).

(7) - The spurious rate was obtained by moving the C_H counter out from the C_1C_2 telescope (position 4 in Fig. 5).

(8) - In position 3 the efficiency was a little less(95%) probably because of losses due to slight misalignement of the C_H counter on the C_1C_2 telescope.

(9) - For our liquid hydrogen cell the consumption was only 0.020 liters/hour although the cell was viewed over a 0.13 sterad solid angle (see Fig. 5) by the perspex light pipe at room temperature.

FIGURE CAPTIONS:-

FIG. 1 - Ranges of momentum where different Cerenkov light radiators can be used to distinguish between π's and K's. The abscissa gives the momentum of the particle. The ordinate gives the n-1 (n = = index of refraction) of the substance (left scale) and the number of photons/cm emitted by the substance at a bialkali (type D) photocatode for a particle with $\beta = 1$. The arrows indicate for each substance useful momentum range for π/K distinction discriminating the electrical pulse to 1/2 of the pulse for $\beta = 1$. Solid curves indicate the envelope formed by the tips of the arrows. Dashed curves are Cerenkov effect thresholds for π's (left curve) and K's (right curve).

FIG. 2 - Drawing of a system of liquid hydrogen Cerenkov counters surrounding a liquid hydrogen target in a high energy beam.
1 - liquid H_2 target (10 cm x $\emptyset$ 2 cm); 2 - liquid H_2 cells (12 cells of 25 x 3 x 3 cm^3 each); 3 - thin mirrors (at liquid H_2 temperature); 4 - mirrors (at liquid N_2 temperature); 5 - vacuum tank; 6 - mylar windows; 7 - liquid H_2 filling; 8 - perspex light pipes; 9 - photomultipliers; 10 - vacuum flanges supporting the photomultipliers.

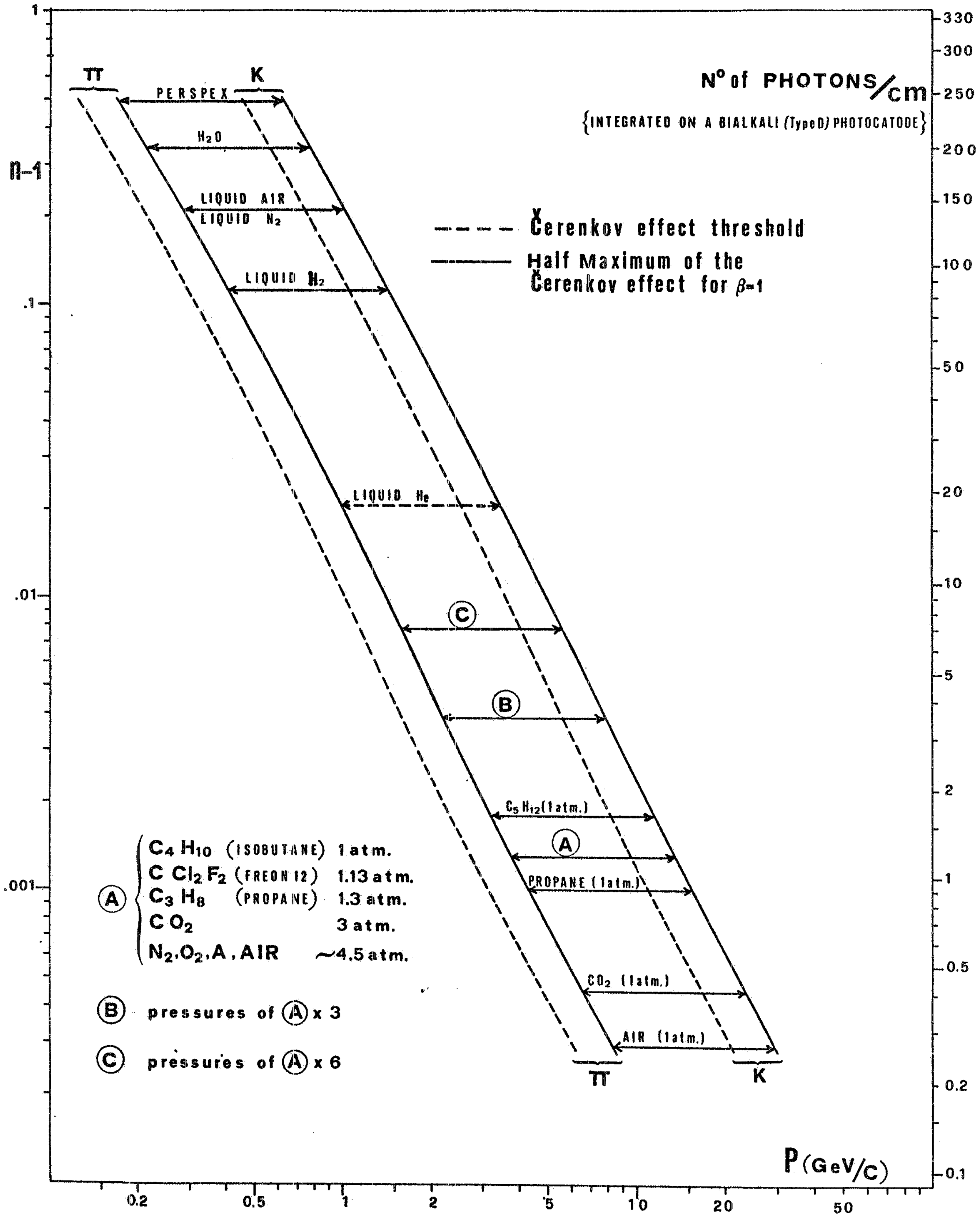
FIG. 3 - Drawing of a system of liquid hydrogen Cerenkov counters surrounding the interaction region of a storage ring.
1 - interaction point; 2 - liquid H_2 cells (12 cells of $\sim$ 30 x 2.5 x 3 cm^3 each); 3 - thin mirrors (at liquid H_2 temperature); 4 - mylar windows; 5 - vacuum tank; 6 - perspex light pipes; 7 - photomultiplier; 8 - vacuum flanges supporting the photomultipliers; 9 - vacuum pipe of the storage ring.

FIG. 4 - Experimental set-up.

FIG. 5 - Liquid hydrogen Cerenkov counter C_H.

FIG. 6 - Efficiency of the liquid hydrogen Cerenkov counter C_H as a function of the H.V. applied and for different positions (see in Fig. 5) of the electron beam in the counter.

FIG. 7 - Pulse height spectra of the liquid hydrogen Cerenkov counter C_H for different positions (see in Fig. 5) of the electron beam in the counter.



1
.1
.01
.001
n-1
π
K
PERSPEX
H_2O
LIQUID AIR
LIQUID N_2
LIQUID H_2
LIQUID He
Ⓒ
Ⓑ
C_5H_{12} (1atm.)
Ⓐ
PROPANE (1atm.)
CO_2 (1atm.)
AIR (1atm.)
π
K
N° of PHOTONS/cm
{INTEGRATED ON A BIALKALI (TypeD) PHOTOCATODE}
- - - - Čerenkov effect threshold
——— Half Maximum of the Čerenkov effect for β=1
Ⓐ C_4H_{10} (ISOBUTANE) 1 atm.
CCl_2F_2 (FREON 12) 1.13 atm.
C_3H_8 (PROPANE) 1.3 atm.
CO_2 3 atm.
N_2, O_2, A, AIR ~4.5 atm.
Ⓑ pressures of Ⓐ x 3
Ⓒ pressures of Ⓐ x 6
330
300
250
200
150
100
50
20
10
5
2
1
0.5
0.2
0.1
P (GeV/c)
0.2
0.5
1
2
5
10
20
50

FIG. 1

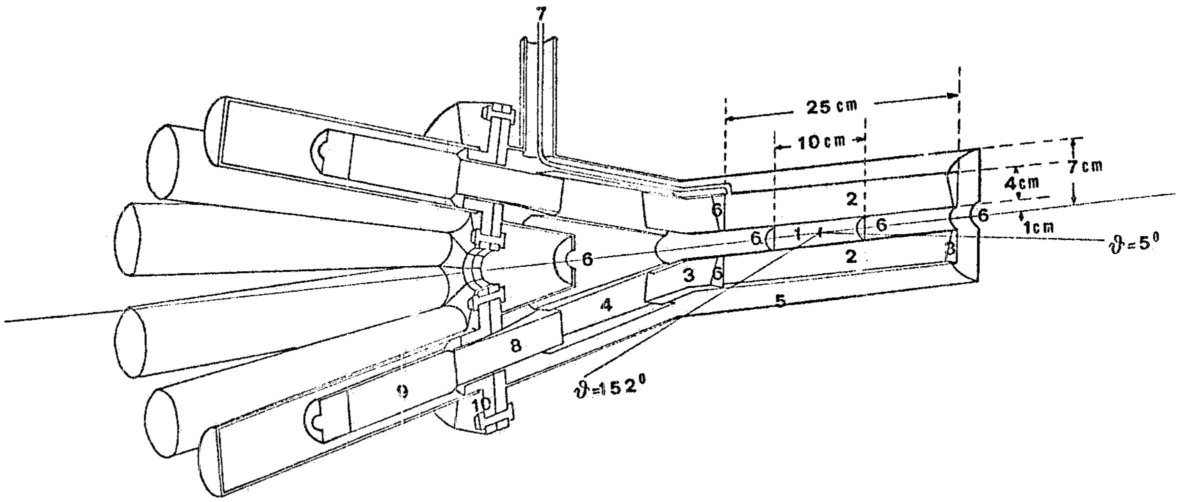

7
25 cm
10 cm
7cm
4cm
1cm
2
6
6
1
6
6
2
3
ϑ=5°
6
3
6
4
5
8
9
10
ϑ=152°

FIG. 2

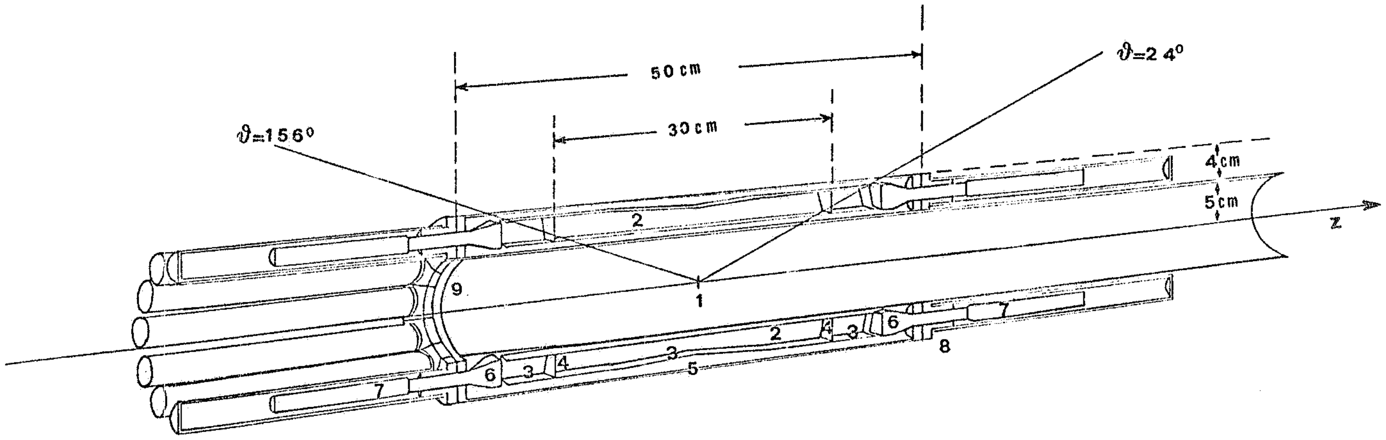

50 cm
30 cm
ϑ=24°
ϑ=156°
4cm
5cm
z
2
9
1
2
4
3
6
7
8
7
6
3
4
3
5

FIG. 3

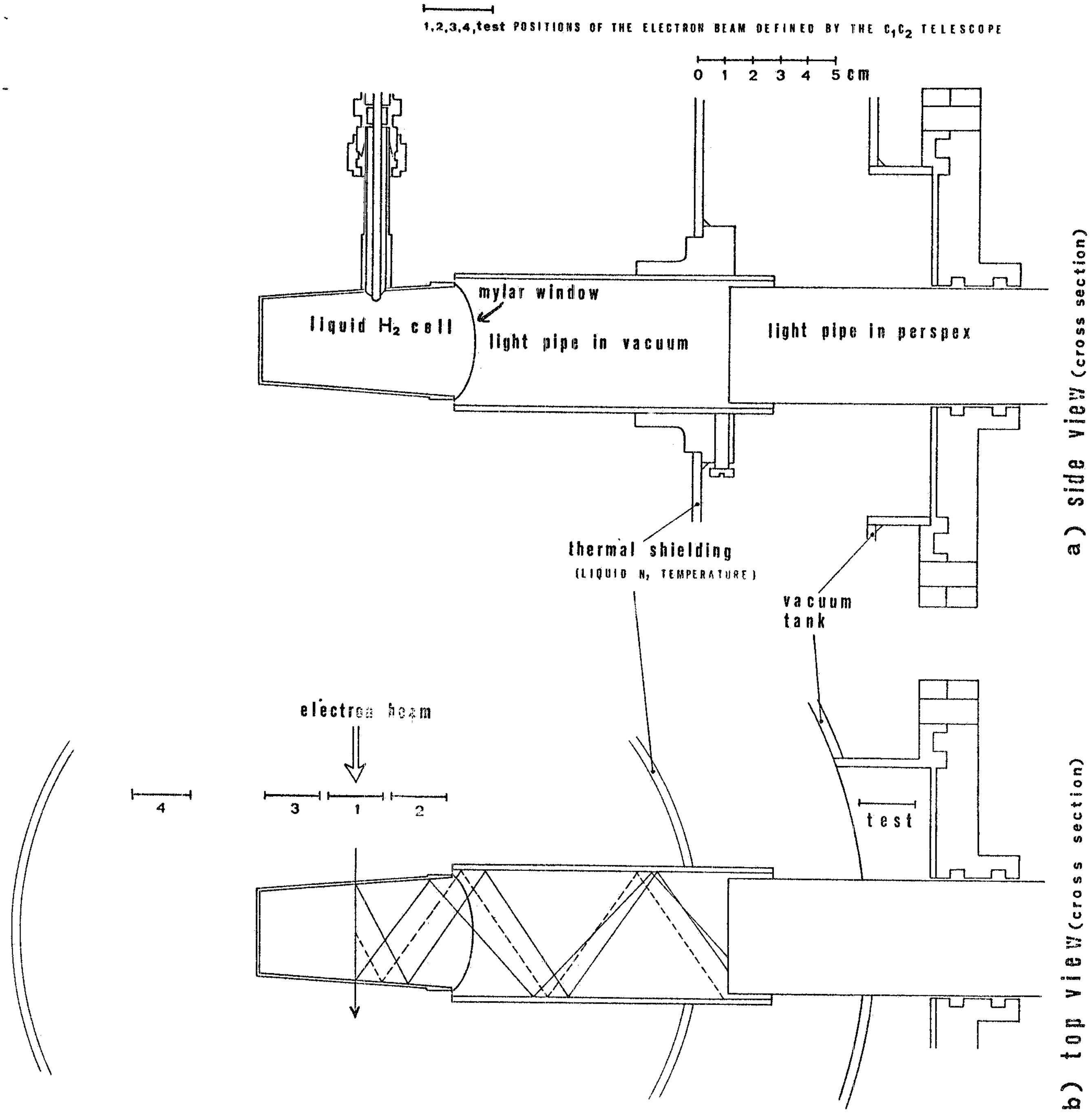

1,2,3,4,test POSITIONS OF THE ELECTRON BEAM DEFINED BY THE C_1C_2 TELESCOPE
0 1 2 3 4 5 cm
mylar window
liquid H_2 cell
light pipe in vacuum
light pipe in perspex
thermal shielding
(LIQUID N_2 TEMPERATURE)
vacuum tank
a) side view (cross section)
electron beam
4
3
1
2
test
b) top view (cross section)

FIG. 5

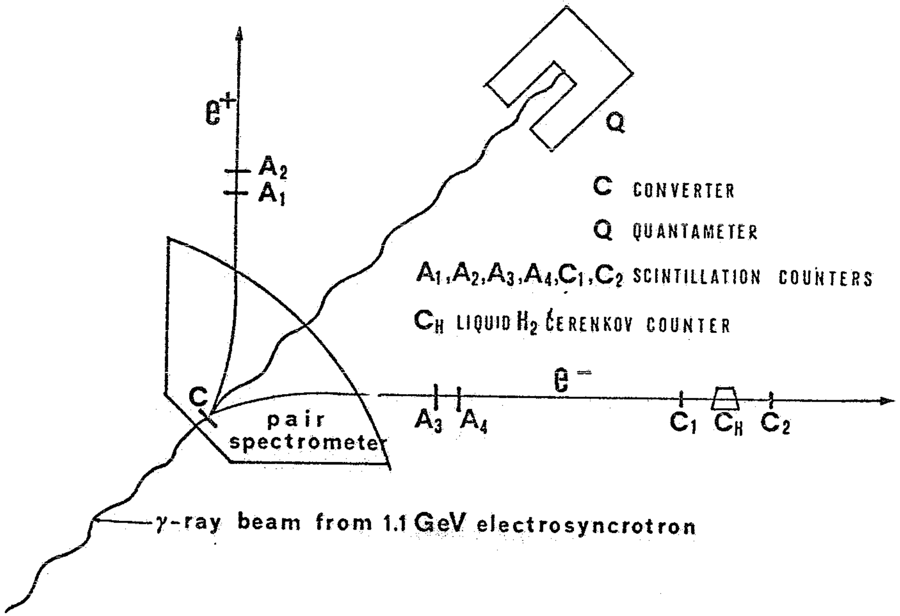


FIG. 4

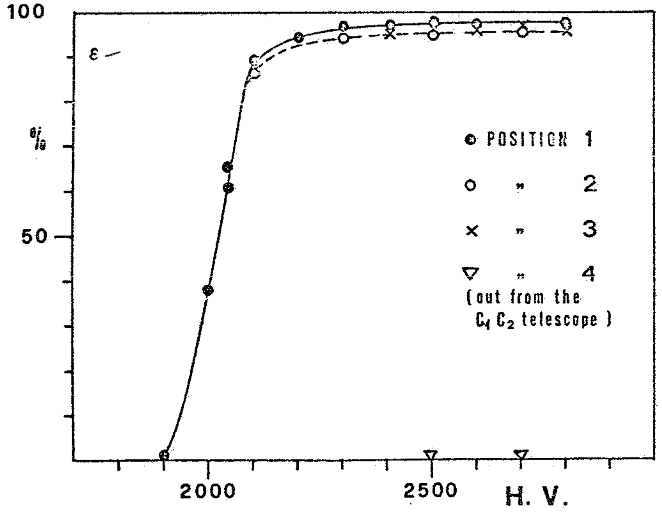


FIG. 6

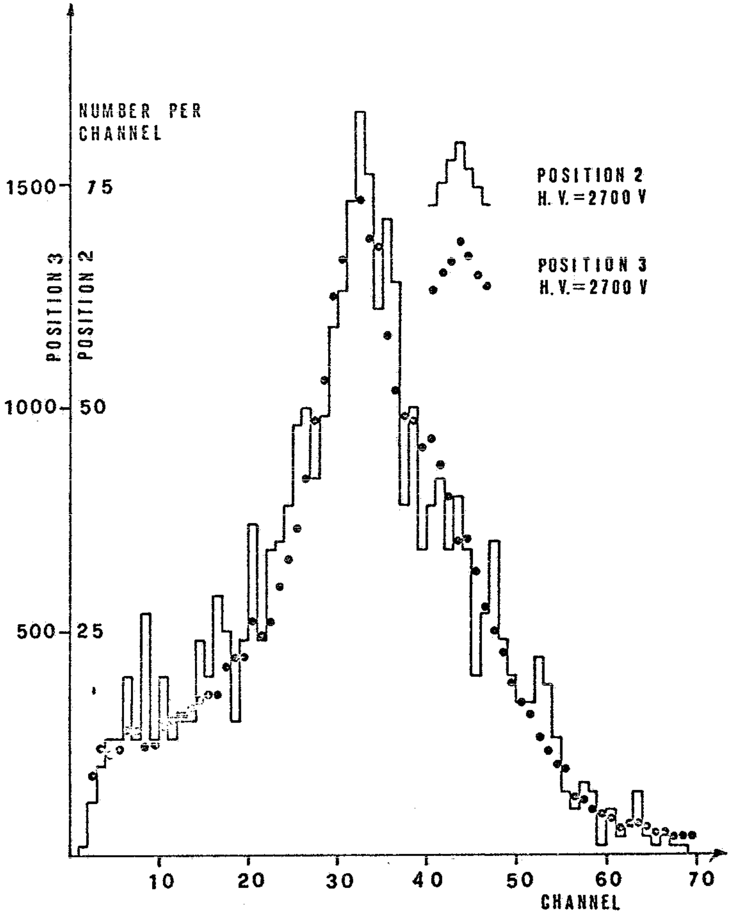


FIG. 7