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25 Settembre 1979

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UVT-PMMA CERENKOV COUNTER PERFORMANCE TESTS.

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ABSTRACT.

UVT-PMMA Cerenkov detectors have been tested in a particle beam at the Frascati electron linear accelerator. The scintillation light is 1/45 of the Cerenkov light. These counters have good uniformity, in spite of the strong angular dependence of the Cerenkov light.

1. INTRODUCTION.

We have tested a prototype of the Cerenkov counters to be used in the Free Quark Search(1) experiment at the electron-positron colliding beam facility PEP (at SLAC-Stanford).

These counters are made of UVT-PMMA (ultra violet transparent poly-methyl-methacrylate) by Polivar(2).

The Cerenkov counter (Fig. 1a) we have used consists of a UVT-PMMA (refractive index n = 1.49) slab 300 cm long, 21 cm wide, 5 cm thick with a 30 cm light guide of the same material glued on each side. Each end of the counter is viewed by a 9618R 5" EMI photomultiplier. The coupling between the counter and the tube is realized by an UVT-PMMA cylinder, 11 cm long and with 5" base diameter.

We have measured:

A) the ligth attenuation lenght;

B) the number of the collected photoelectrons as a function of the incidence angle and the position in the counter;

C) the ratio between the Cerenkov and the scintillation light collected.

In this paper we summarize the results obtained and give a short description of the techniques used.

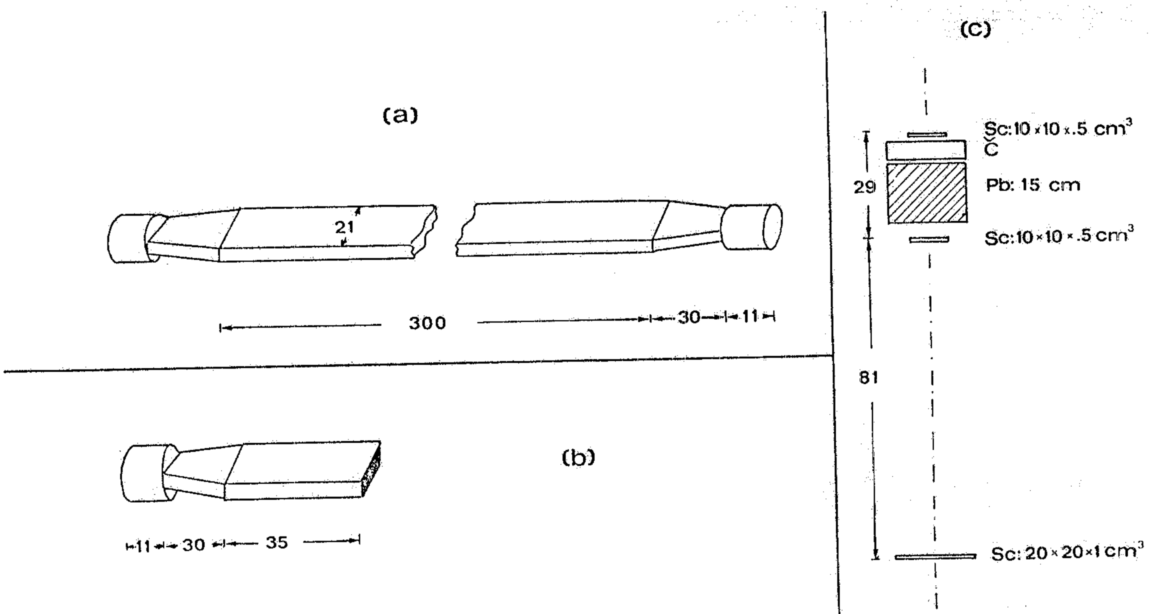

FIG. 1 a) Cerenkov prototype used in our tests with cosmic rays. The thickness is 5 cm. b) Cerenkov prototype used in our tests with pion beam. c) Telescope arrangement for our tests with cosmic rays.

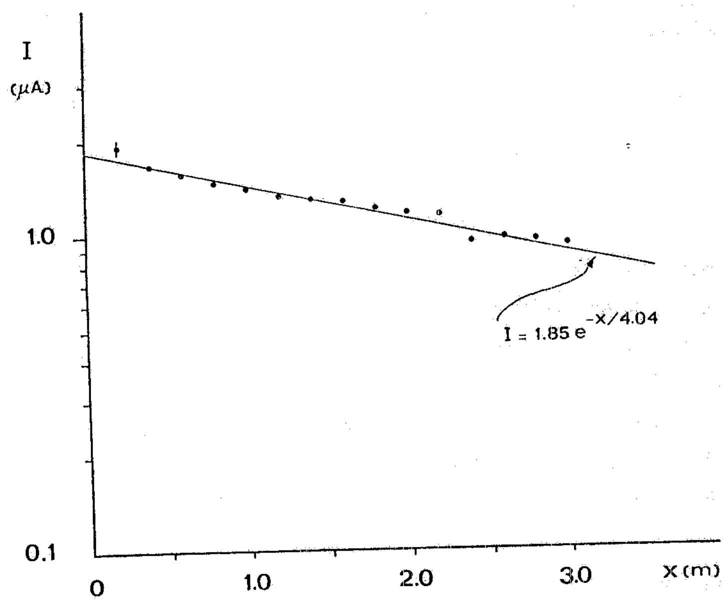

FIG. 2 Attenuation lenght measurement.

2.-ATTENUATION LENGTH MEASUREMENT.

For this measurement we have used a 5" EMI photomultiplier at one end of the counter while the opposite end was blackened. We have measured the anodic current of the tube versus the position of a CO^{60} source placed on the counter (Fig. 2). The attenuation length is found to be $\lambda = 4.04 + .40$ m (χ^2/DOF= 4.26/13) after correcting for the disuniformity of the counter's thickness (.5 cm over the all length). We notice that the attenuation lenght depends on the angle of the emitted light, which is isotropic in the case of a CO^{60} source. We than expect a somewhat lower value in the case of particles hitting the counter normally.

3. COSMIC RAY TESTS.

For this measurement we have used a telescope of scintillation counters detecting cosmic rays. Fig. 1c is a sketch of this set-up; a lead absorber of 15 cm thickness was inserted in order to accept only particles with $\beta > .9$. For this β value the Cerenkov angle is greater than the critical angle so that the light undergoes total internal reflection. In Fig. 3 we report the results obtained in terms of N_{PE}, the photoelectron number. We have

(1) $$N_{PE} = \alpha \mu$$

where μ is the mean of the pulse height distribution and α is a scale factor determined at an N_{PE} value such that the statistics can be regarded as gaussian[3]. For this test the Cerenkov was viewed by two EMI phototubes one at each end; the H.V. was adjusted in such a way that the anodic current was the same when a CO^{60} source was placed in the middle of the counter.

We have investigated the dependence of N_{PE} on the incidence angle (Fig. 3a): we have found that the total number of photoelectrons seen by the tubes in several angular conditions is enough to allow high detection efficiency ($1 - \exp(-10) \simeq 1 - 5 \times 10^{-5}$). We have also found that this number, in spite of the Cerenkov light directionality, does not show a strong dependence on the incidence angle and is about constant up to a distance of 1 m from the center of the counter (Fig. 3b).

4.-PION/ELECTRON TESTS.

In order to measure the ratio between the Cerenkov and the scintillation light collected in the counter we have used the LEALE pion beam facility at the LNF. The main parameters of the beam are: maximum kinetic energy T=170 MeV (corresponding to β =.9), momentum spread 1%, duty cycle 5×10^{-4}; the muon and electron contamination of the beam is the order of 10% at lower energy and decreases substantially with the energy.

Due to the large environmental background and the lack of space for a good shield we could not use the 3.6 m long counter for this measurement. We have then used a smaller prototype, of the same width and thickness but only 35 cm long, viewed by a phototube only at one end (Fig. 1b).

Fig. 4 shows the experimental layout for this test and a flow chart of the electronics used.

The $\pi / \mu / e$ particle identification was obtained using time of flight measurements over a 6 m long path; typical T.O.F. distributions obtained are reported on Fig. 5. Fig. 6 shows some typical pulse-height distributions. In order to evaluate the background at each energy we collected also distributions with the gate signal delayed.

In order to determine the scale factor we have used the relation:

(2) $$N_{PE} = \ln(N_{TOT}/N_{PED})$$

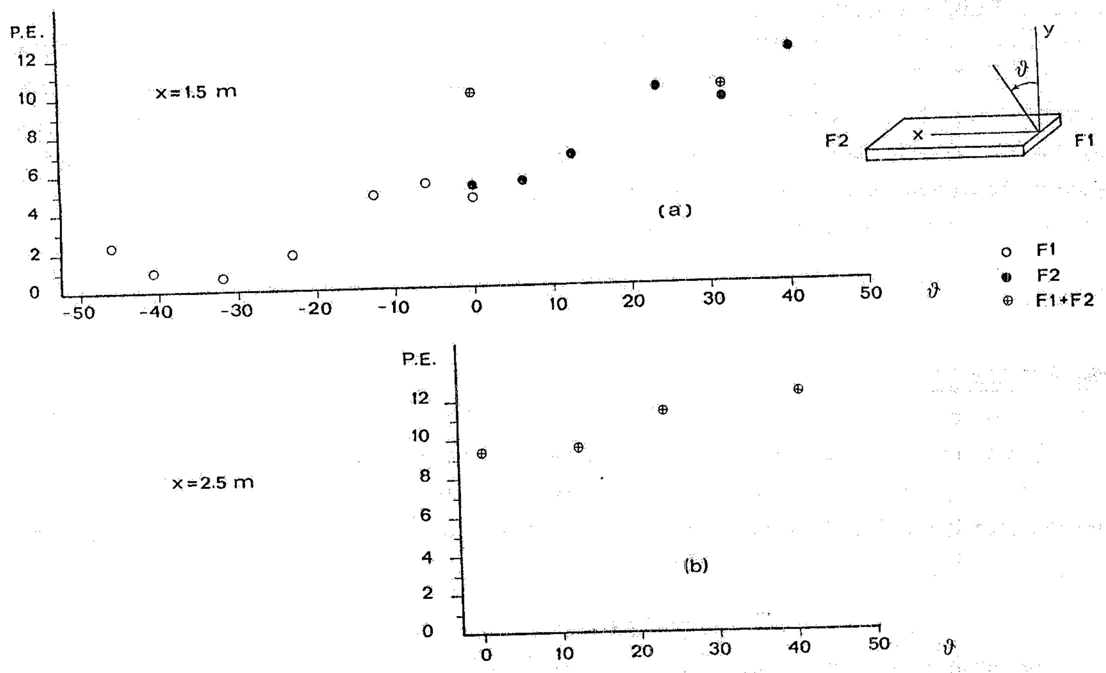

FIG. 3 Number of photoelectrons vs. the incidence angle ϑ . F1 and F2 are the two photomultipliers at the opposite ends of the counter. F1 + F2 refers to the sum of the photomultiplier signals. a) Telescope at center of the counter. b) Telescope placed 1 m from the center.

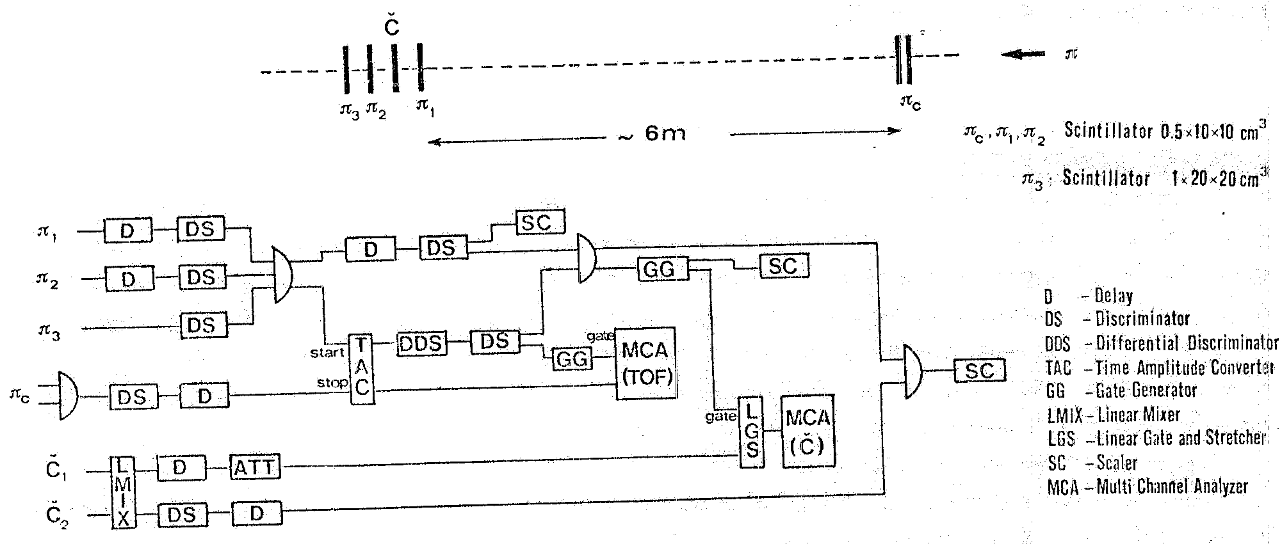

FIG. 4 Counter arrangement and logic for tests with pion beam.

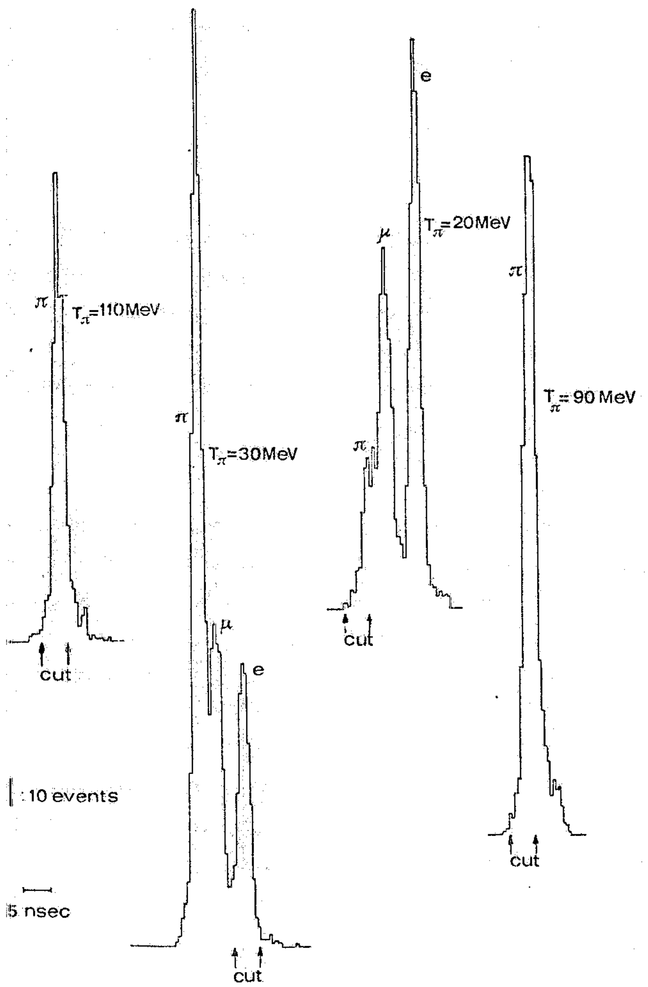

FIG. 5 Time of flight spectra; the sensitivity is 2 chs/nsec, T is the kinetic energy of a pion at the exit from the Cerenkov counter; the cuts used to select different particles are also shown.

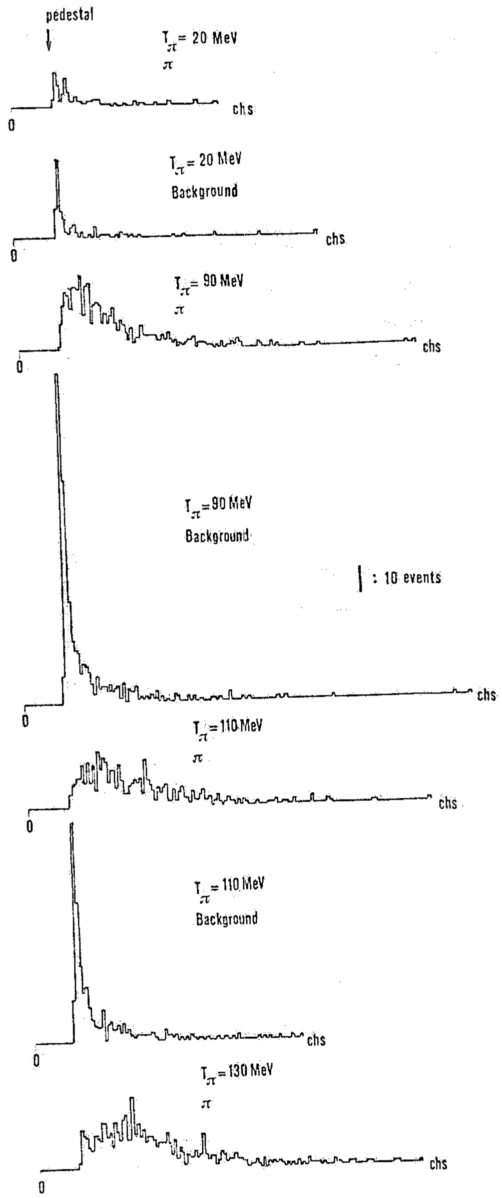

FIG. 6 Pulse-height spectra: "π" refers to spectra collected with gate intime and "background" to spectra with gate out-of-time.

where N_{TOT} is the total number of events and N_{PED} is the number of events in the pedestal channel. We have measured N_{PE} for electrons and found N_{PE}=5.8 + .8. N_{PE} can also be determined using the mean value and the variance of the distribution[3,4]

(3) $$N_{PE}=(M^2/V)$$

In order to determine M and V we have fitted our experimental distribution with a gaussian (χ^2/DOF=94/74) and a poissonian with a continuous approximation for the factorial function (χ^2/DOF = 49/40) (Fig. 7). We have obtained respectively N_{PE}=5.3 + .8 and N_{PE}=5.75 + .75. The results from the two techniques are in very good agreement; the value of the scale factor (see eq. 1) that we derive is α =8.7 channels x PE.

When the number of photoelectrons is very small eq. (2) can not be used because the position of the pedestal can hardly determined with high accuracy due to the high level background, so we have used the equation

(1') $$N = \alpha (\mu - \mu_{BG})$$

where μ and μ_{BG} are the mean values of the spectra respectively with the gate in time and out. Fig. 8 shows the results in function of beta. The ratio $N_{PE}(\beta=1)/N_{PE}$ ($\beta <$ Cerenkov threshold) is found to be 45. This result agrees with that obtained by Sacharidis[5] in 1972, altough there is some difference between Sacharidis curve and our results in the region of the critical angle where the geometrical effects are important.

Consistence has also been found between our experimental data and the results of a Montecarlo simulation of the counter (GUIDE7[6]). The results, plotted also in Fig. (8), have been normalized for β = 1; for beta below the value that gives total internal reflection, the reflection coefficient has been assumed to be .9.

In order to evaluate the fraction of particles with beta below the Cerenkov threshold that gives a pulse-height in the counter above a fixed value we must first subtract from the β = .62 pion distribution with gate in time and out respectively. The subtraction of the background was carried out using the equation

(4) $$G(j) = \left[F(j)/D - \sum_{i=0}^{j-1} G(i)\, H(j-i) \right] / H(0)$$

where i and j are bin indexes, 0 is the pedestal channel, D the bin width, H and F are the normalized distributions corresponding to the spectra of Fig. 9. After this background subtraction the PE number at β = .62 calculated from (3) is .12 (to be compared to .13 calculated from (1')). Fig. 10 shows G(j), as function of N_{PE}, compared to the normalized distribution of the β =1 particles.

The comparison of these two distributions shows that a suitable cut is at N_{PE}=1: with this cut a β=.62 particle has a probability close to zero to be detected while the tagging efficiency for β = 1 particles is about 98%.

5. CONCLUSIONS

Main features of the counter we have tested are: very easy to be built, low cost if compared with counters with wave-shifter and quencher good attenuation lenght, good angular uniformity. The angular dependence of the light seen by one phototube is well compensated when the signals of both are summed. Scintillation light is rather low in comparison with counters of different kind[8]. The tagging efficiency when a cut at 1 photoelectron is applied is greater than 99% (extrapolating our result with one photomultiplier to the case of two).

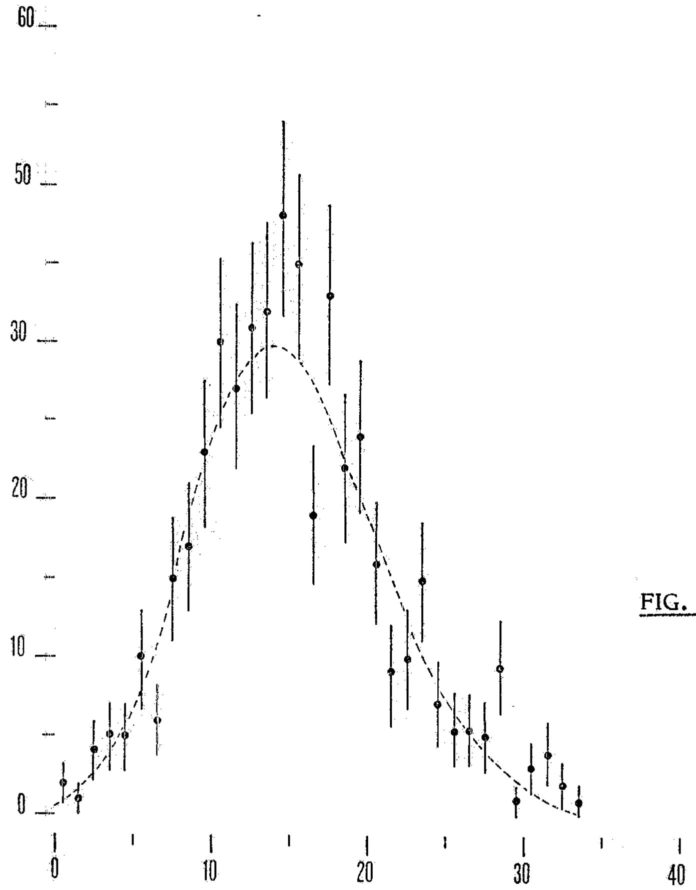

FIG. 7 Electron spectrum; the dotted line refers to a fit with an empirical distribution derived from the poissonian with a continuous formula for the factorial.

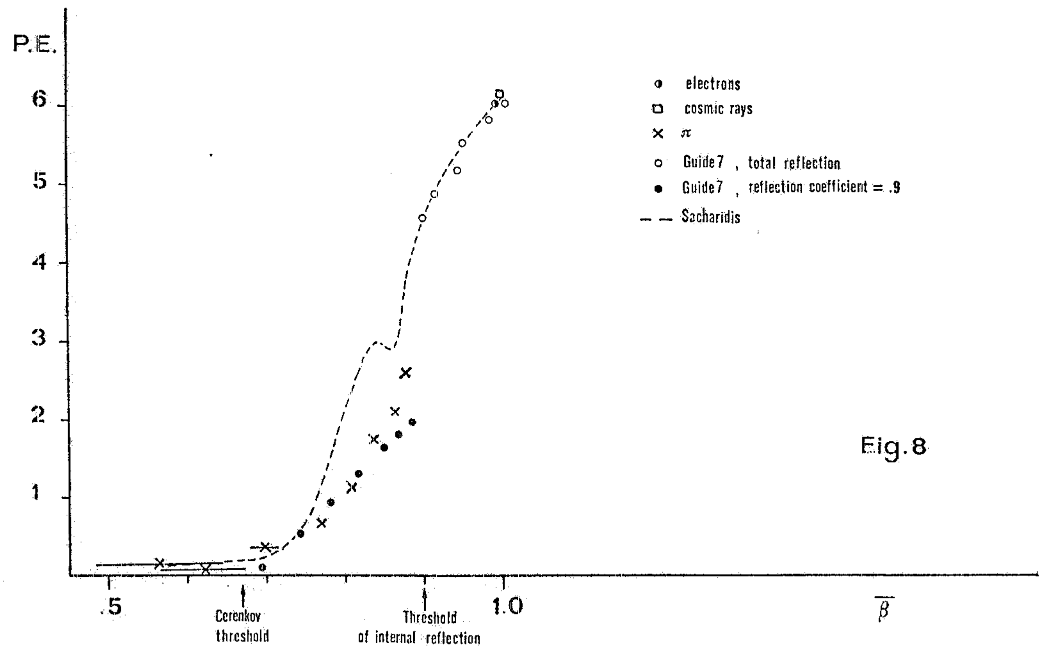

FIG. 8 Photoelectron number vs. beta.

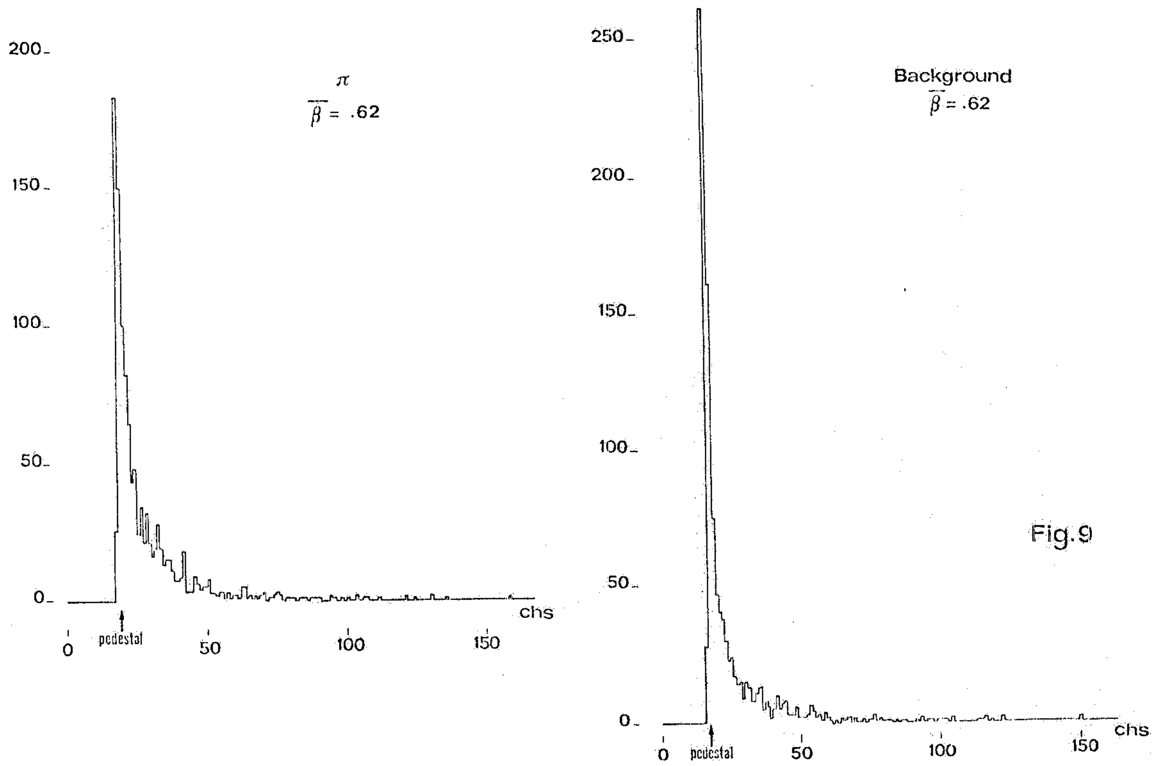

FIG. 9 Pion and background pulse-height spectra at β =.62.

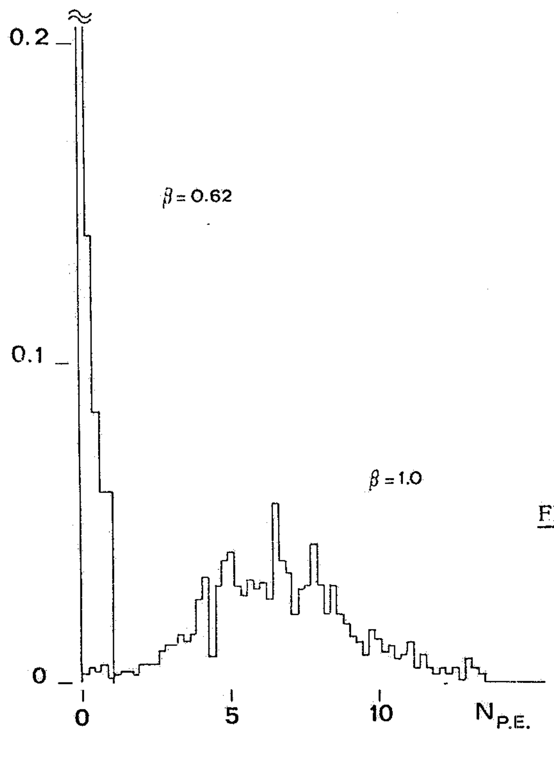

FIG. 10 Normalized pulse-height distribution for β =.62 pions with the subtraction of the background and normalized pulse-height distribution for = 1 particles.

We are grateful to Prof. C.Guaraldo, Dr. A.Maggiora and the whole staff of the LEALE group for their support during the test runs.

REFERENCES AND FOOTNOTES.

(1) T.Pun et al., PEP Proposal PEP 14.

(2) POLIVAR S.p.A., Via Naro, 72, P.O.BOX 111, 00040 Pomezia (Roma).

(3) The exact relation is[4]:

$$N_{PE} = (M^2/V)(\delta/(\delta-1))$$

where δ is the secondary emission rate of the photomultiplier. The correction due to δ ($\simeq$ 20%) and other effects as the cathodic quantum efficiency have been disregarded since we are interested in relative measurements.

(4) E. Breitenberger, Prog. Nucl. Phys., 4, 56 (1961).

(5) E. J. Sacharidis, Nucl. Instr. and Meth., 101, 327 (1972).

(6) T. Massam, CERN 76-21 (1976).

(7) Let F(x), G(y), H(z) the distribution functions of x,y,z with the constraint x=y+z. We assume F and H known and G unknown. Then

(I) $$F(x)=\int G(y)\, H(x-y)\, dy$$

If all the previous distributions are 0 for negative arguments, an approximation for (I) is

(II) $$F(i) = \sum_{j=0}^{i} G(j)\, H(i-j)\, D$$

where D is the integration step. By inverting (II) it is possible to obtain (4).

(8) R. Bernabei et al., Nucl. Instr. and Meth. 155, 407 (1978).