CERN LIBRARIES, GENEVA

CM-P00100556

INSTITUTE OF HIGH-ENERGY PHYSICS, SERPUKHOV
Preprint IHEP 70-48

HIGH RESOLUTION DIFFERENTIAL ČERENKOV COUNTERS

Yu.P. Gorin, S.P. Denisov, S.V. Donskov, R.N. Krasnokutskij,
A.I. Petrukhin, Yu.D. Prokoshkin, D.A. Stoyanova, R.S. Shuvalov

Serpukhov 1970

Translated at CERN by R. Meunier
(Original: Russian)

(CERN Trans. 70-13)

Geneva
November 1970

1. INTRODUCTION

Differential Čerenkov counters of the DISC type, with a velocity resolution $\Delta\beta \sim 10^{-5}$, have been described[1,2] in which the chromatic dispersion of the Čerenkov light emitted at an angle of Θ = 44 mrad was compensated with a doublet of conical prisms (AXICONS) made of fused silica and NaCl crystal.

The domain of utilization of these counters in experiments on accelerators is limited by the divergence of the particles in the beam.

For $\Delta\beta = 10^{-5}$ the counters count only the particles whose trajectories make an angle with the axis of the counter of less than $\Delta\Theta_p \approx \frac{1}{2}\,\Delta\beta/\mathrm{tg}\,\Theta$ = = 0.1 mrad. It is possible to improve the velocity selection, without reducing $\Delta\Theta_p$ (or to increase $\Delta\Theta_p$ without worsening the resolution), only by reducing Θ.

We describe here two differential counters working with the Čerenkov light emitted at angles of 23 and 12 mrad. The small value of Θ permits the identification of particles having a Lorentz factor $\gamma \geq 50$ in the case where the gases used are He or Ne. (For greater values of Θ, or smaller values of γ, it is necessary to use rather high pressures of He or Ne, in order to obtain the required refractive index). The remarkable properties of He or Ne are that their dispersion coefficients are nearly twice smaller than those of other gases.

Therefore, the use of Ne or He as a radiator in differential Čerenkov counters offers the possibility of reaching high velocity resolution $\Delta\beta < 10^{-5}$, without compensation of the dispersion of the Čerenkov light.

A small value of Θ leads to a small intensity for the Čerenkov radiation. In order to obtain enough light for an efficient counting of the particles the length of the counters were chosen as 5 m (Θ = 23 mrad) and 10 m (Θ = 12 mrad). The effective range of wavelengths in the counters extends from 250 to 600 nm.

2. DESIGN OF COUNTERS

The counters were made of sections of steel tubing (Fig. 1). The internal surface was covered with flat black paint, and 16 diaphragms were used to reduce the background light produced by the scintillation of the gases used, and the Čerenkov radiation produced by the δ-rays. Čerenkov light emitted at the chosen angle Θ impinged on an annular diaphragm, placed in the focal plane of a spherical mirror. The reflection coefficient of the mirror is greater than 0.9 for wavelengths greater than 220 nm.

The light passed the diaphragm, went through an annular exit window of fused silica, and was directed by a collecting mirror onto 12 photomultipliers (PM) XP1023, disposed in a circle (Fig. 1). Signals from the PMs were processed by the standard electronic logic circuits of the IHEP, connected to give two-, three-, four- and sixfold coincidence signals between the PMs[2].*)

3. EXPERIMENTAL RESULTS

The characteristics of the counters were studied in the secondary beams of negative particles of the 70 GeV IHEP accelerator, of momenta 35, 40 and 45 GeV/c. The counters were placed in a parallel section of the beam, where the divergence of the particles did not exceed 0.5 mrad. The beam intensity M was monitored with a telescope of scintillation counters S_1-S_4 of 8 to 10 cm diameter, in fourfold coincidence. The counters S_1 and S_2 were in front of the Čerenkov counters, and S_3 and S_4 behind.

The signal $M = S_1S_2S_3S_4$ was put in coincidence with the signals D_i, i being the order of the coincidences between the PMs of the differential counters.

Simultaneously, the coincidences of order 2, 3, 4, and 6 were recorded. The value of $\varepsilon_i = D_iM/M$ as a function of the velocity gave the particle recording efficiency of the Čerenkov counters.

---

*) Translator's Note: The number of coincidences i = 2, 3, 4 or 6 has the following meaning: for example in twofold coincidence, i = 2, the outputs of six phototubes are added together and then put in coincidence with the six others. If $\bar{n}$ is the average number of photoelectrons per phototube the efficiency is:

$$\varepsilon_i = \left(1 - e^{-12\bar{n}/i}\right)^i$$

In the following i will be called the "number" of coincidences.

a) Characteristics of the 5 metre counter

The amplitude spectrum of the pulses of the 5 m counter is represented in Fig. 2. For a width $\Delta r = 10$ mm of the opening of the diaphragm, the mean particle registration efficiency for one PM was 0.83 corresponding to 1.8 photoelectrons emitted on an average by the Čerenkov radiation from the photocathode of XP1023 phototubes.

In Figs. 3 and 4 the dependence of ε_i on the helium pressure in the counter is shown for $\Delta r = 1.6$ and 3.2 mm. The velocity resolution obtained for the sixfold coincidence between the PMs is around 6.0×10^{-6} -- Fig. 3. The particle detection efficiency at the maximum of the curve $\varepsilon(P_{He})$ is basically determined by the actual dispersion of the particles in the beam*).

The dependence of the detection efficiency of π^- mesons as a function of the width of the circular diaphragm is shown in Fig. 5.

The level of the background of the counter was less than 10^{-5} for $i = 6$. The background consists for the main part of accidental coincidences, and is practically independent of Δr (Fig. 5). In a particular experiment the possibility of reducing the background through pulse height selection of the signals from the PMs was studied. For this purpose the output pulses from nine PMs were added linearly and were put in coincidence through a discriminator with the signal M giving the signal M_d. It was found that the amount of background in the coincidence $D_i M_d$ is nearly independent of the level of the discriminator for a number of coincidences $i \gtrsim 3$ so that for such values of i the amplitude spectra of registered particles and the background overlap (Fig. 6).

In Fig. 7 the dependence of the efficiency $\varepsilon_d = M_d/M$ is represented as a function of the helium pressure, which illustrates the possibility of particle identification by a differential counter, in which the light is collected by only one PM.

---

*) Translator's note: The efficiencies deduced from the curves are not consistent with the formula of the first footnote unless one accepts that the signal M exceeds by 5% the number of pions at the peak which can be counted at 100% efficiency by the differential counter.

b) Characteristics of the 10 metre counter

Figure 8 shows the dependence of the particle detection efficiency at the momentum 35 GeV/c, as a function of the helium pressure for a diaphragm opening width of 3.2 mm in the 10 m counter.

The velocity resolution of the counter for six- and fourfold coincidences obtained between the pulses of the PMs was around 2.0×10^{-6} and 2.5×10^{-6}, respectively. (The helium dispersion limits the resolution to $\Delta\beta \simeq 1.7 \times 10^{-6}$). Due to the high resolution it was possible to separate electrons and μ^- notwithstanding the fact that their velocity differences at the momentum of 3.5 GeV/c is only 4.5×10^{-6}. For a better enhancement of the μ^- meson peak, the signal of a scintillating counter S_μ was put in coincidence with the signal M.

This counter was placed behind a three metre thick iron absorber, which was installed after counter S_μ. The results of the measurement of the efficiency $\varepsilon_{i\mu} = MS_\mu D_i/M$ are shown in Fig. 8.

The particle detection efficiency at the maximum of the curves $\varepsilon(P_{He})$ is determined basically by the actual particle divergence in the beam.

By increasing the width of the slits of the diaphragm to 15 mm the maximum detection efficiency of π^- was

0.94 for twofold,
0.89 for threefold,
0.71 for fourfold, and
0.42 for sixfold coincidences*).

This corresponds to the emission of an average of 1 photoelectron from the photocathode of each PM.

Figure 9 illustrates the separation of π^- and K^- in a beam of particles of momentum 45 GeV/c. The background level between the peaks of pions and kaons is around 3×10^{-7} for ε_6 and 3×10^{-4} for ε_4.

---

*) Translator's note: These efficiencies are not consistent with the formula of the first footnote, unless one accepts that the signal M exceeds by 10% the number of pions on the peak which can be counted at 100% efficiency by the differential counter.

In our work it is shown that a 10 m differential Čerenkov counter can be used for the separation of pions and kaons in a beam of particles up to the momentum 200 GeV/c *).

The authors wish to thank I.A. Alikachkin, A.I. Kulechov, A.A. Mitin, V.N. Morozov and V.P. Saparov for their help in the construction of the counters and G.I. Nelipovitch for his presentation of the experimental data.

*) Translator's note: From the values obtained for the number of photoelectrons for phototube (which is not affected by the remarks about the value of the signal M) it can be deduced that $\overline{N} = AL\Theta^2$ with A = 82 for the 5 m counter and A = 84 for the 10 m counter, which is to be compared with figures given in the report CERN 68-14. The XP1023 is basically a 56 UVP S13 photocathode with improved collection efficiency.

REFERENCES

1) P. Duteil, L. Gilly, R. Meunier, J.P. Stroot and M. Spighel, Rev. Sci. Instrum. 35, 1523 (1964).

2) Yu.B. Bushnin, Yu.P. Gorin, S.P. Denisov, S.V. Donskov, A.I. Petrukhin, Yu.D. Prokoshkin, D.A. Stojanova and R.S. Shuvalov, Preprint IHEP 70-37, Serpukhov 1970.

3) Yu.B. Bushnin, A.F. Dunajtsev and V.A. Senko, Preprint IHEP 67-36 K, Serpukhov 1967; Preprint IHEP 69-57, Serpukhov 1969.

4) I.A. Aleksandrov, M.I. Grachev, K.I. Gubrienko, E.V. Eremenko, V.I. Kotov, A.N. Nekrasov, A.A. Prilepin, V.A. Pichugin, R.A. Rzaev, A.V. Samojlov, V.S. Seleznev, B.A. Serebryakov, A.E. Khanamiryan and Yu.S. Khodyrev, Preprint IHEP 69-36, Serpukhov 1969.

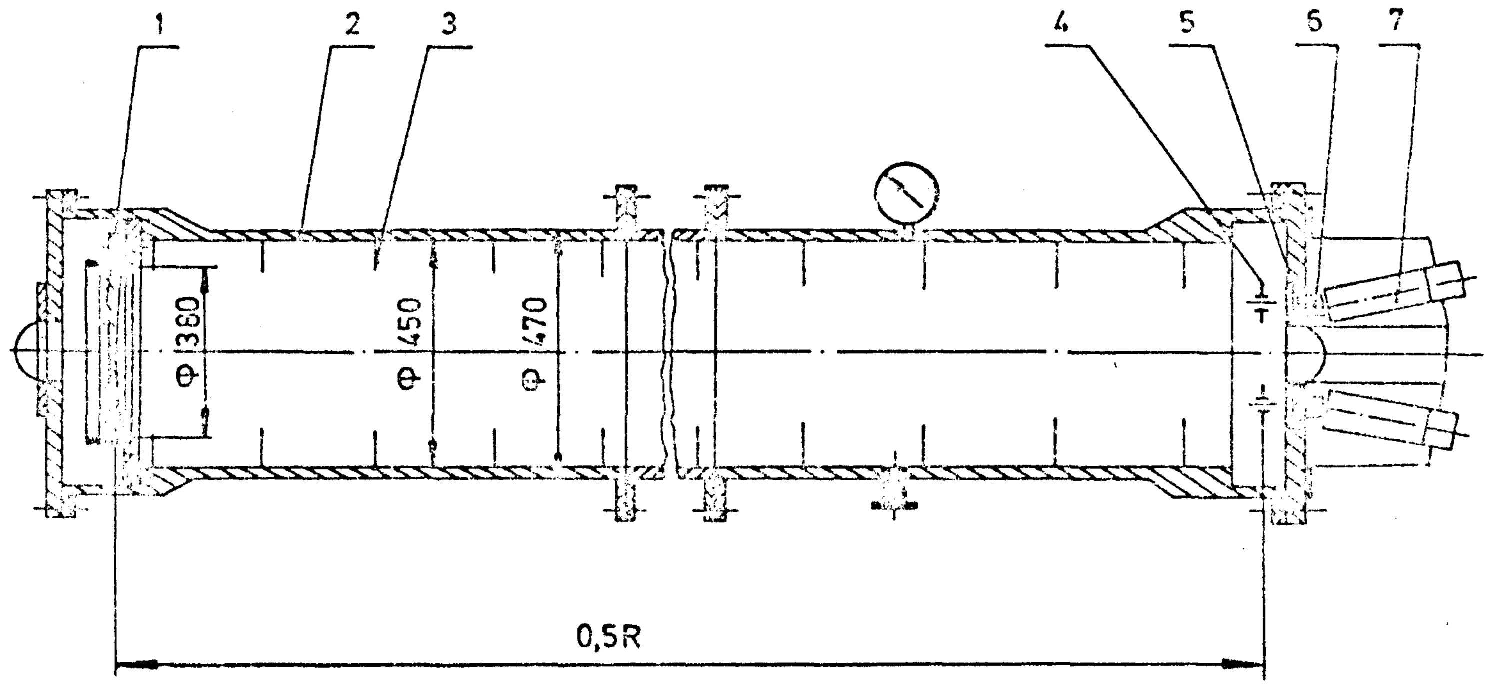

Fig. 1 : Design of the differential counter.
1) Spherical mirror (radius of curvature of the mirror = R = 10286 mm for Θ = 23 mrad, and R = 20140 for Θ = 12 mrad. 2) Steel tubing. 3) Diaphragm. 4) Annular diaphragm. 5) Fused silica exit window. 6) Collecting mirror. 7) Photomultiplier XP 1023.

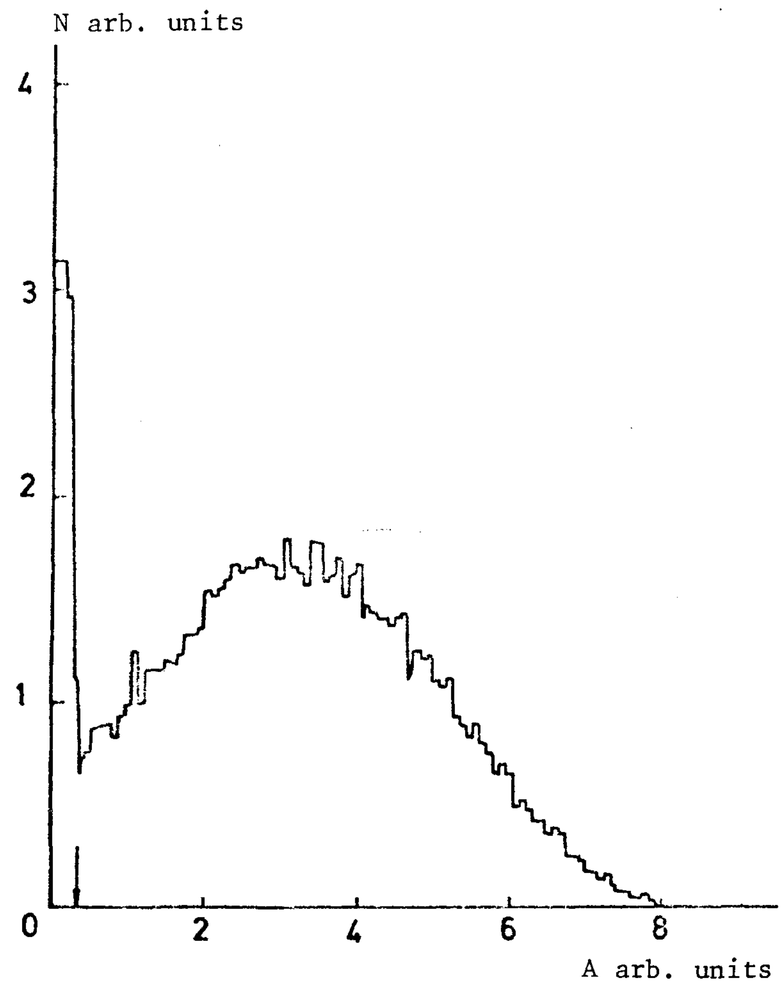

Fig. 2 : Pulse height spectrum of a PM in the 5 m counter, set to count π^- of 40 GeV/c momentum. (P_{He} = 8.06 atm.) Width of the slits of the diaphragm = 2.4 mm. The arrow shows the detection threshold of the electronics.

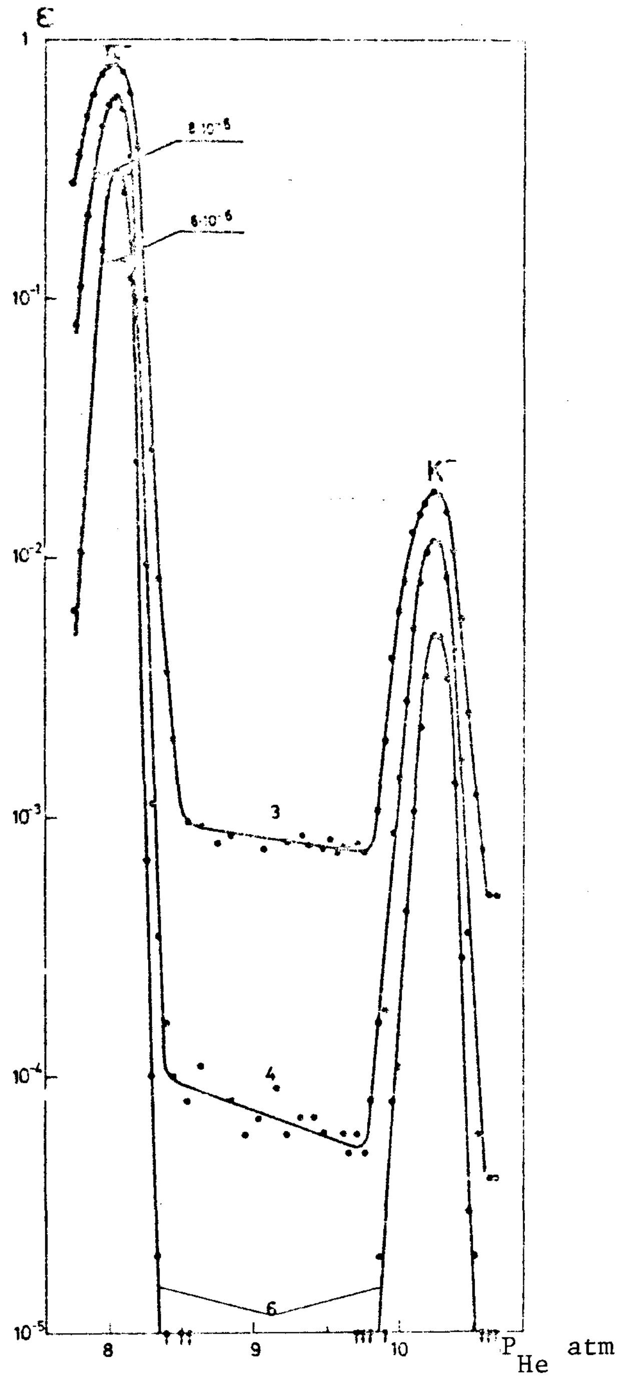

Fig. 3 : Detection efficiency of the 5 m counter versus helium pressure for a width of the slits of the annular diaphragm of 1.6 mm. Beam momentum = 40 GeV/c. The numbers on the curves indicate the number of the coincidences between the PMs of the differential counters. Level of background for sixfold coincidence < 10^{-5}.

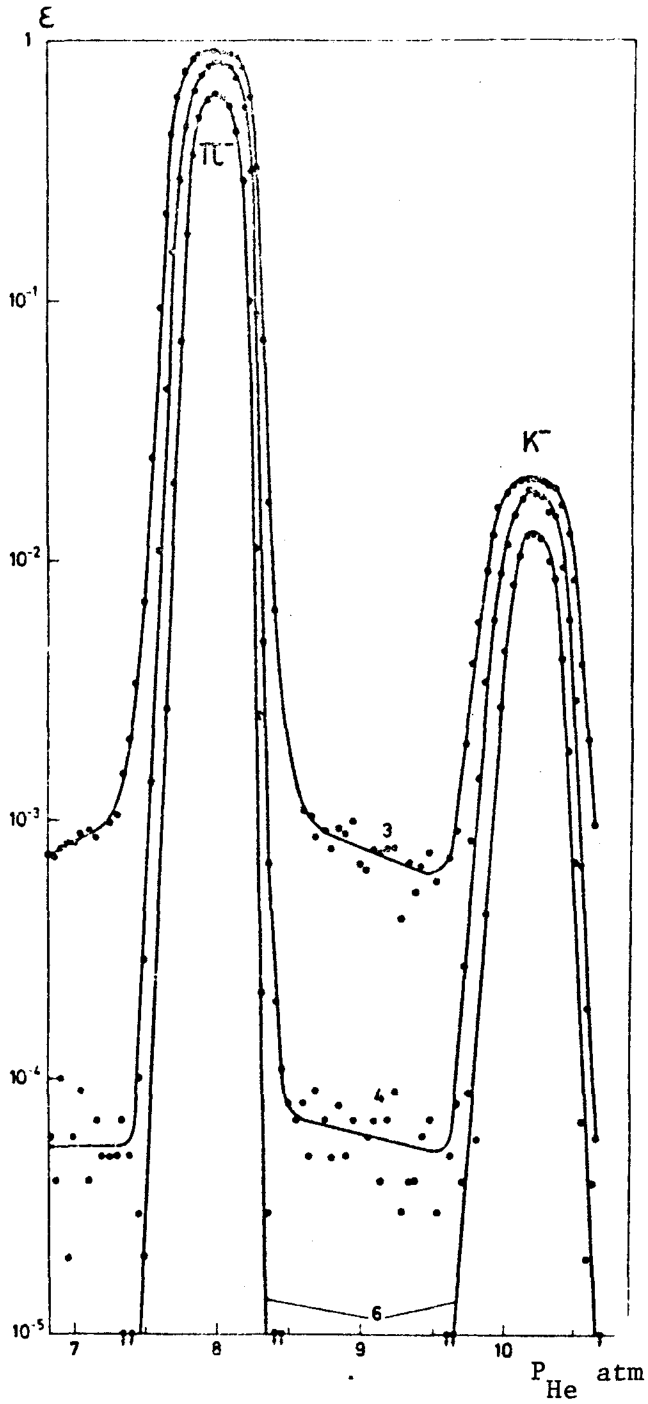

Fig. 4 : Detection efficiency of the 5 m counter versus helium pressure for a width of the slits of the annular diaphragm of 3.2 mm. Beam momentum = 40 GeV/c. The numbers on the curves indicate the number of the coincidences between the PMs of the differential counters. Level of background for sixfold coincidence < 10^{-5}.

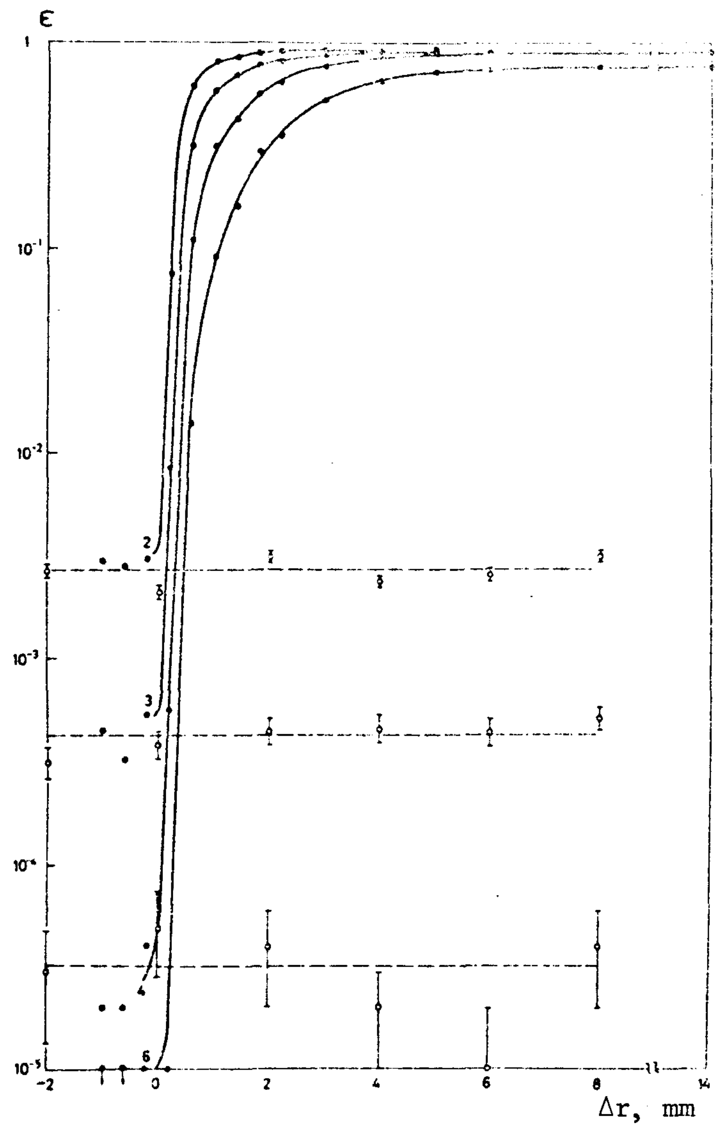

Fig. 5 : Detection efficiency for π^- (plain line, black dots) and level of background (interrupted line, circles) versus width of the slits of the annular diaphragm for the 5 m counter. Δr = distance between the external and internal radius of the slit of the diaphragm. The detection efficiency of π^- was measured at P_{He} = 8.06 atm. The level of background at P_{He} = 7.2 atm. The numbers on the curves show the numbers of coincidences between the PMs of the counters. The level of background for sixfold coincidence < 10^{-5}.

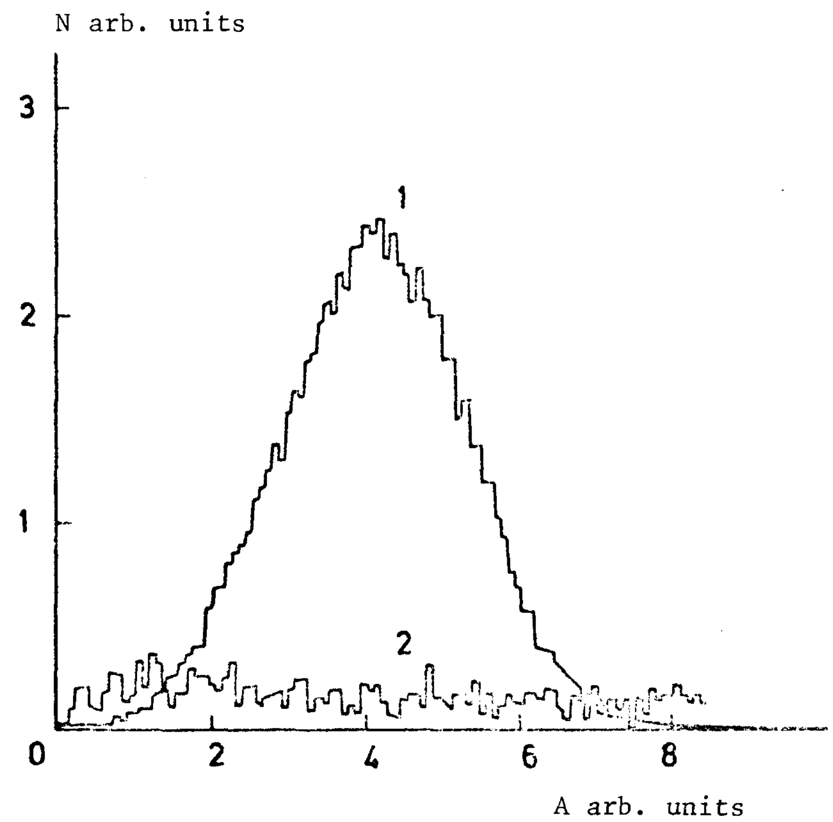

Fig. 6 : Amplitude spectrum of the pulse obtained after linear addition of the signals from nine PMs of the 5 m counter. The spectrum was triggered by the fourfold coincidence MD_4. Spectrum 1 obtained at P_{He} = 8.06 atm (π^- peak), Spectrum 2 at 9.2 atm (background). Width of the slits of the diaphragm: 2.4 mm.

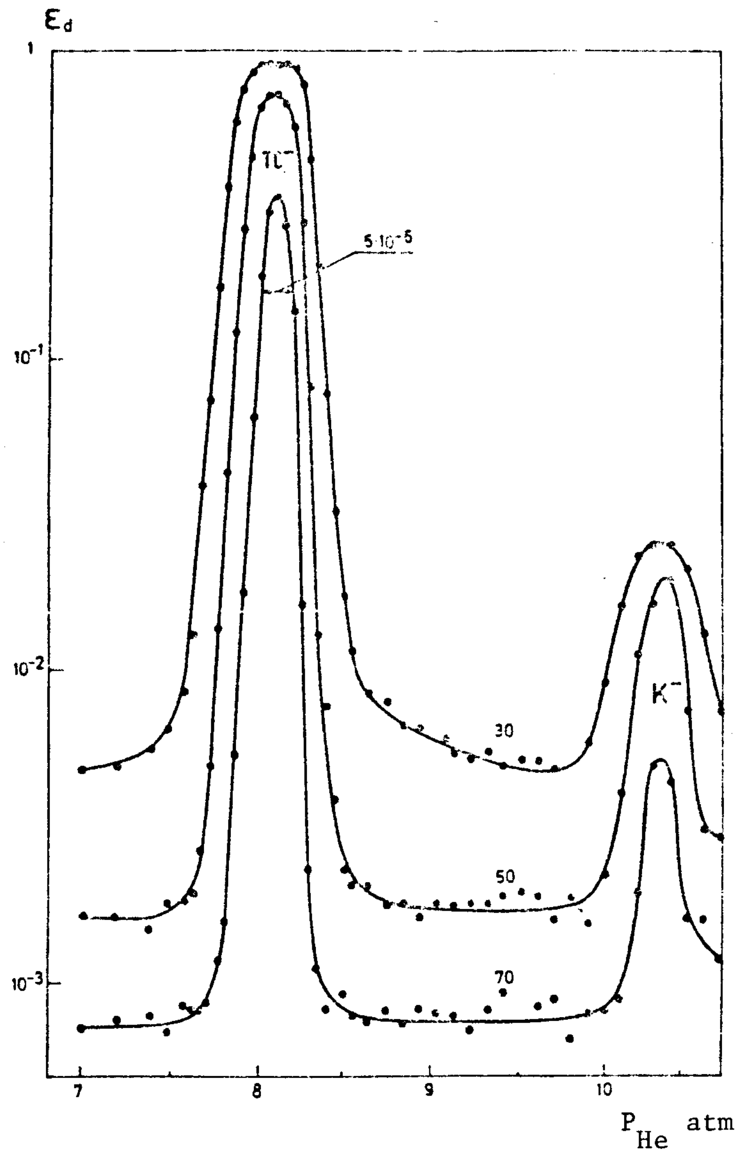

Fig. 7 : Detection efficiency of particles of 40 GeV/c momentum versus helium pressure in the 5 m counter, for different values of the discriminator (numbers on the curves). $\varepsilon_d = M_d/M$. Width of the slits of the diaphragm: 2.4 mm.

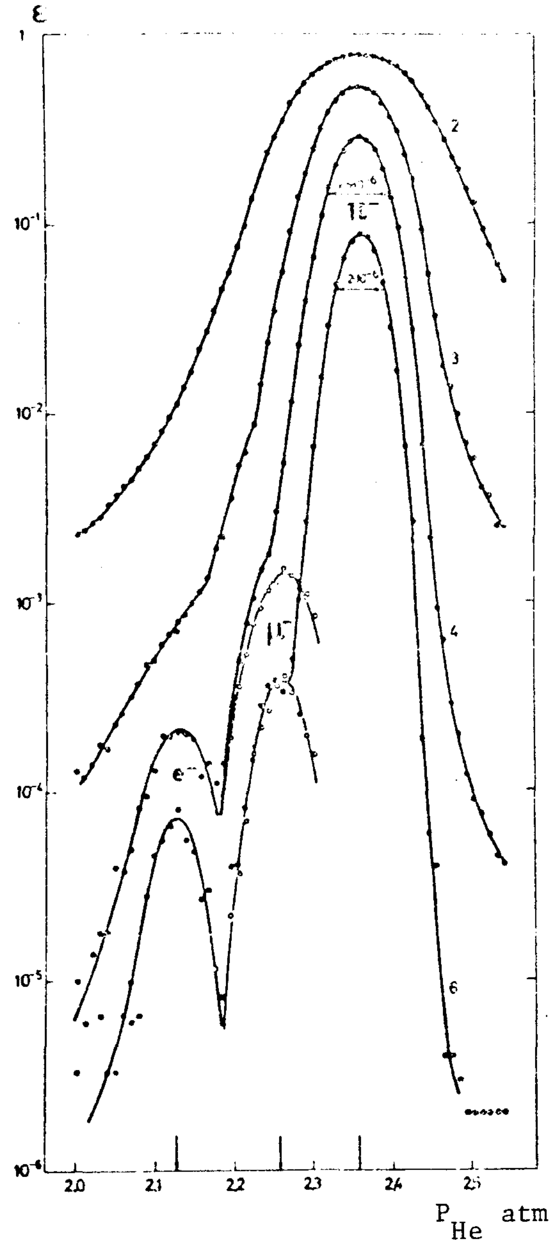

Fig. 8 : Detection efficiencies of the 10 m counter versus helium pressure. $\varepsilon_i = MD_i/M$ (plain line), $\varepsilon_{i\mu} = MD_iS_\mu/M$ (open dots). Beam momentum: 35 GeV/c. The numbers on the curves represent the number of coincidences between PMs. The arrows show the calculated position of the maxima of ε for electrons, muons and pions. Width of the slit of diaphragm: 3.2 mm.

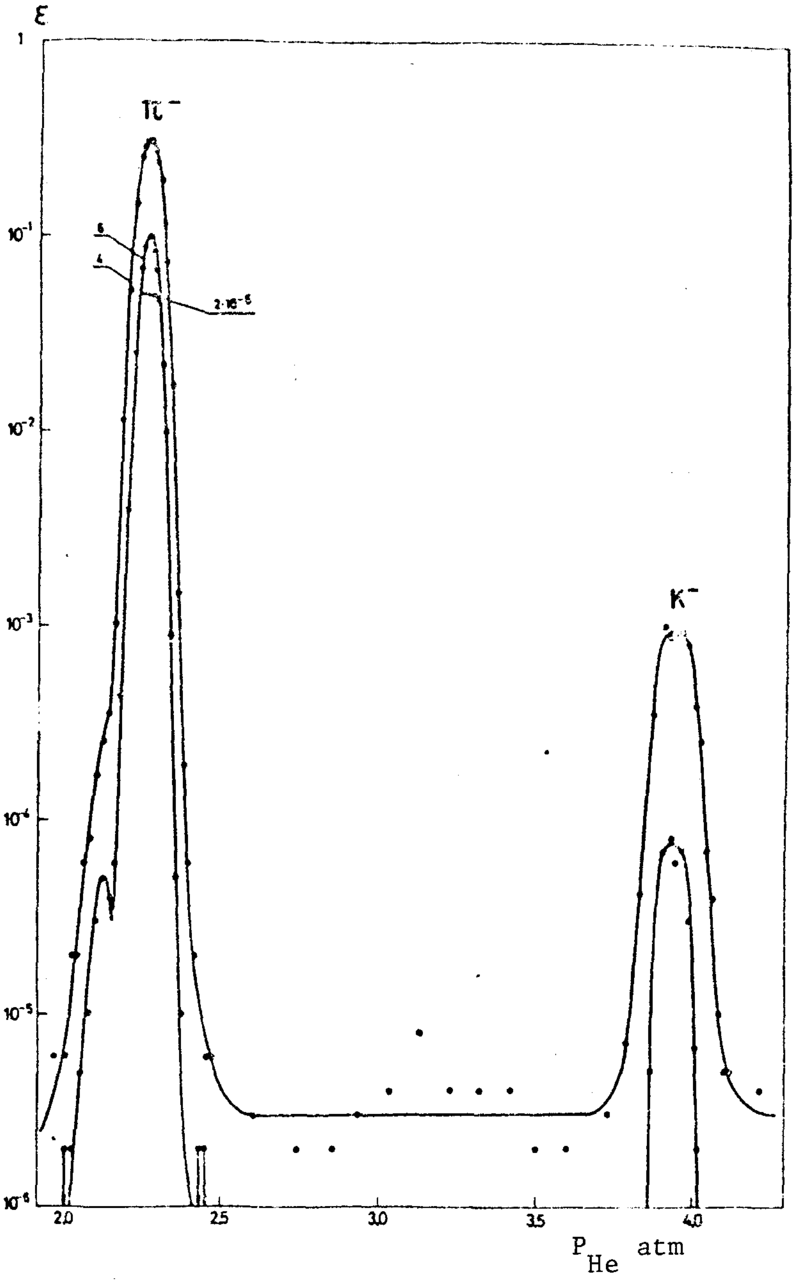

Fig. 9 : Separation between π^- and K^- in a beam of 45 GeV/c momentum. The numbers on the curves represent the number of coincidences between PMs of the 10 m counter. The level of the background for sixfold coincidences is 3×10^{-7}. Width of the slit of the diaphragm: 3 mm.