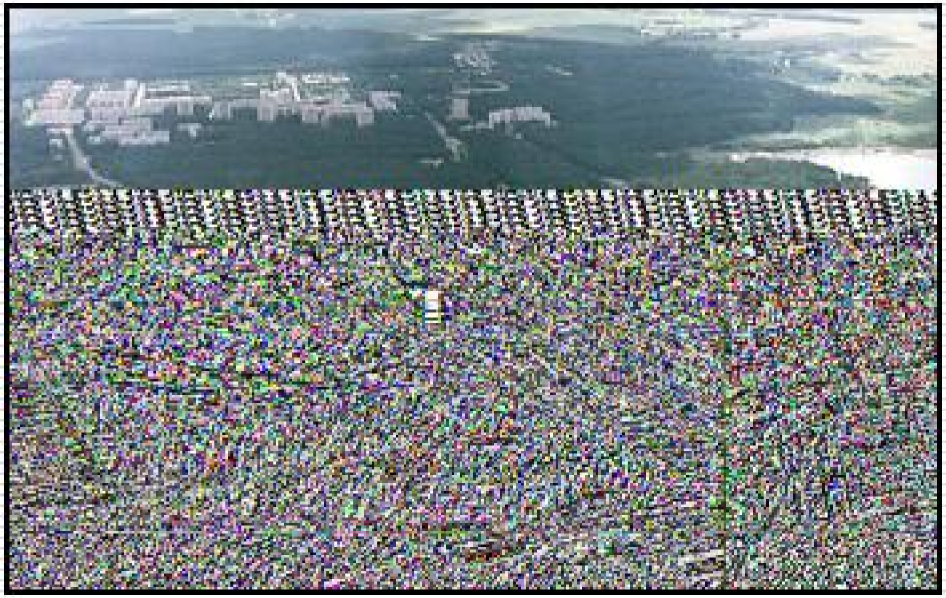
International Conference "P. A. Cherenkov and Modern Physics"

Cherenkov counters in experiments at IHEP



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Threshold and Differential Gas Cherenkov Counters for Particle Identification in High Energy Beams

$$\left.\begin{aligned} \Delta\beta_{12} &= \frac{1}{2}\frac{m_1^2 - m_2^2}{p^2} \\ p &= 20 \div 65\,\frac{GeV}{c} \end{aligned}\right\} \frac{\Delta\beta}{\beta} = 10^{-4} \div 10^{-5}$$

Threshold counters: $\beta > \beta_t = \frac{1}{n}$

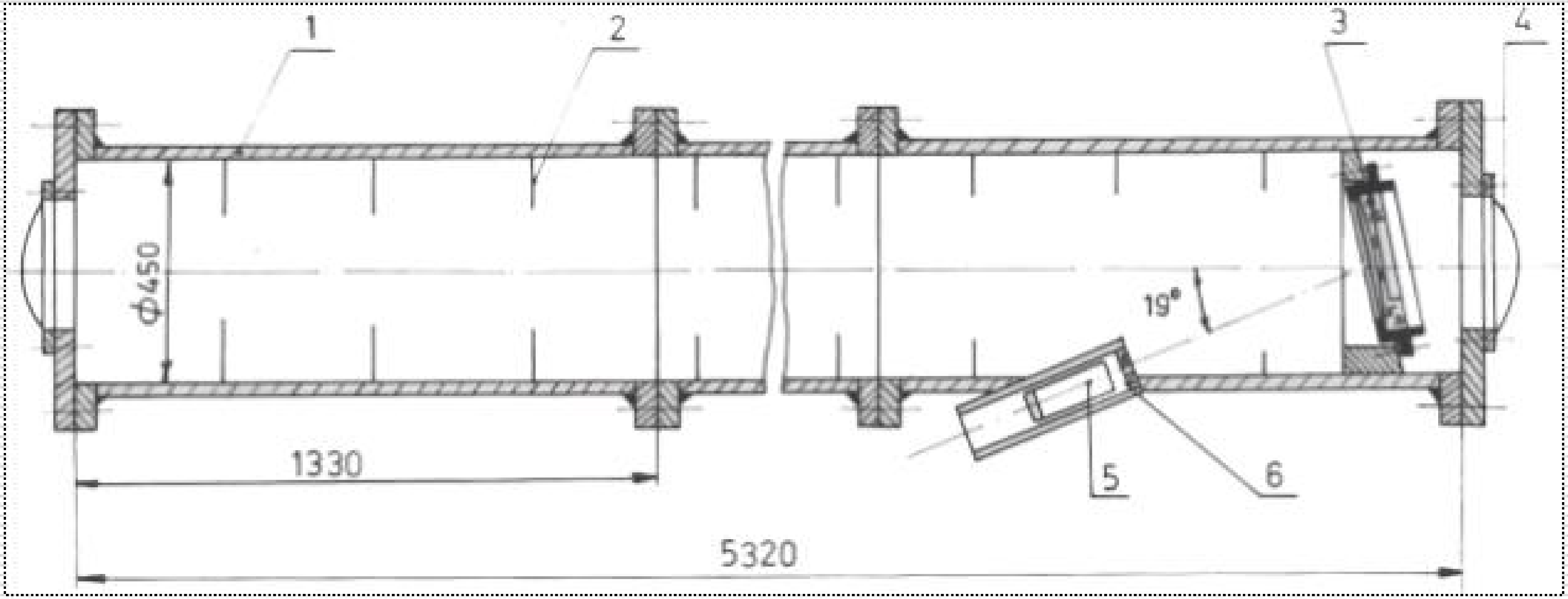


Fig. 1. Threshold Cherenkov Counter.

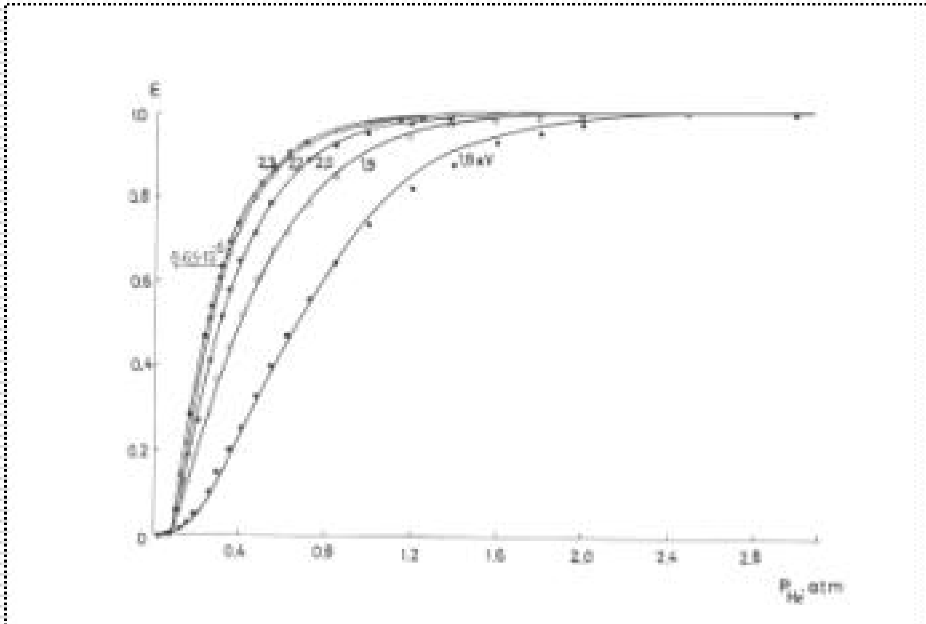


Fig. 2. Efficiency vs helium pressure (p=50Gev/c).

$$\varepsilon = 1 - e^{\frac{\beta-\beta_t}{\delta}};$$

$$\delta = 6.65 \cdot 10^{-6}, \ \ \varepsilon_p(\beta - \beta_t >> \delta) = 0.9999994$$

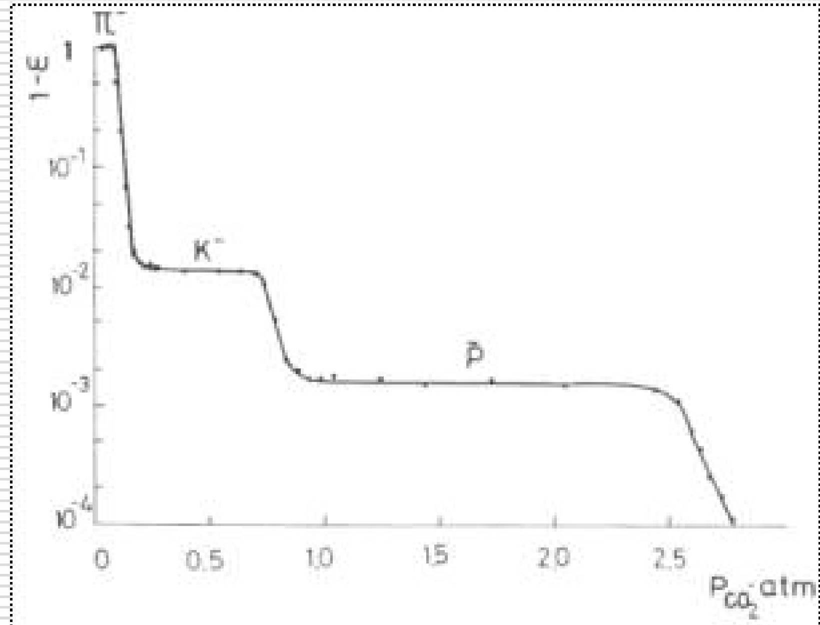
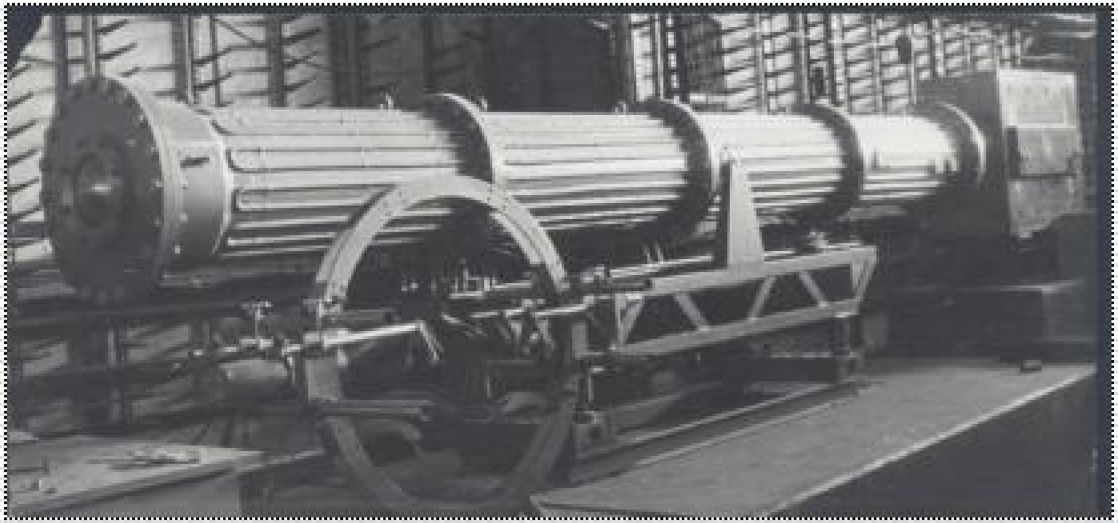


Fig. 3. Particle identification with the 5m threshold counter used in anticoincidence (p=20Gev/c).

Experiments: particle production, total cross-section measurements, search for antinuclei, studies of elastic scattering and many others.



In many cases threshold counters were used together differential counters to decrease the background by 2-3 orders of magnitude.

Differential counters: $\cos\theta = \frac{1}{\beta n}, \quad \frac{\Delta\beta}{\beta} = \Delta\theta \, tg\,\theta + \Delta n$

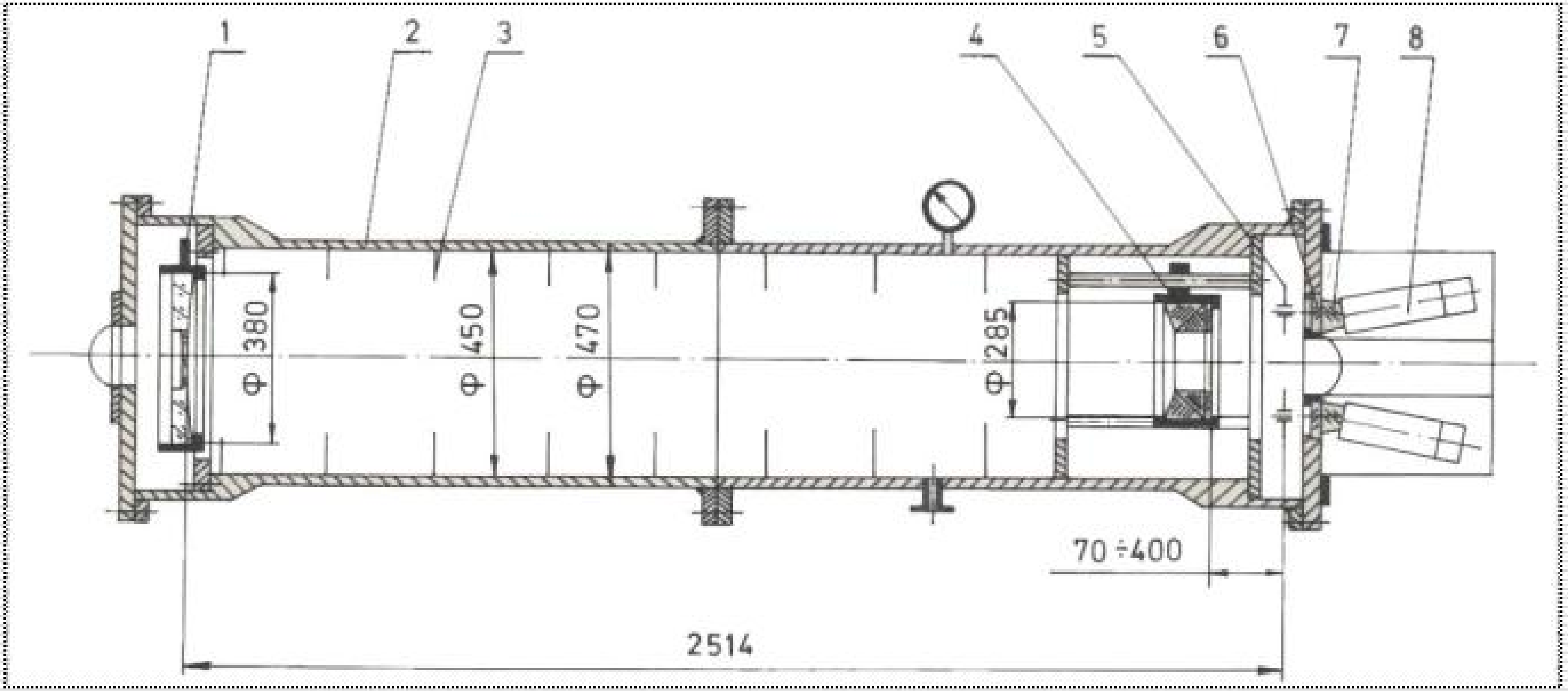
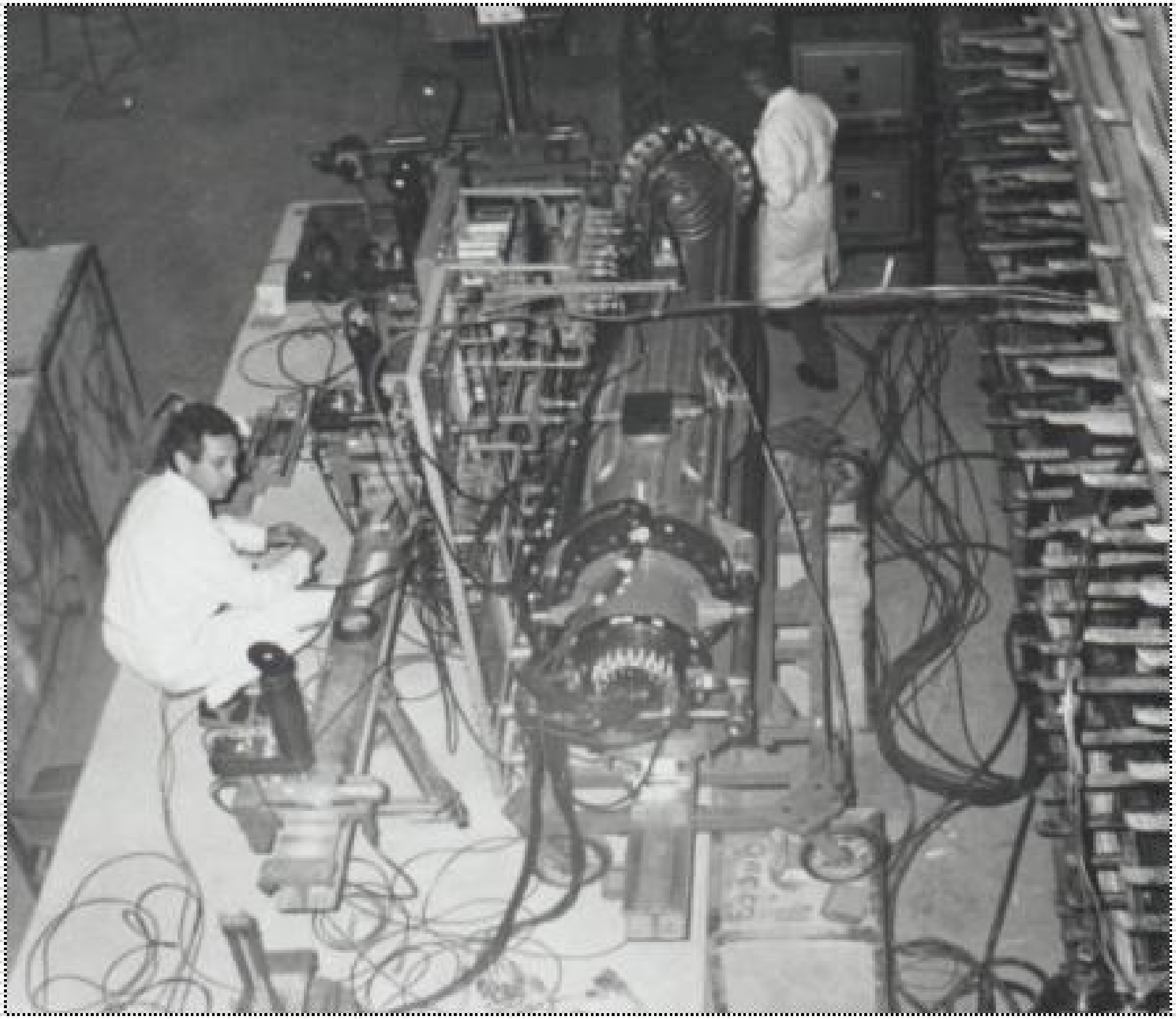


Fig. 4. Differential Cherenkov counter with optical correction of chromatism.



Optical correction of chromatism: P. Duteil et al. *High-resolution gas Cherenkov counter DISC (differential, isochronous, self-collimating).* Rev. Sci. Instrum. 1964. V. 35. P.1523.

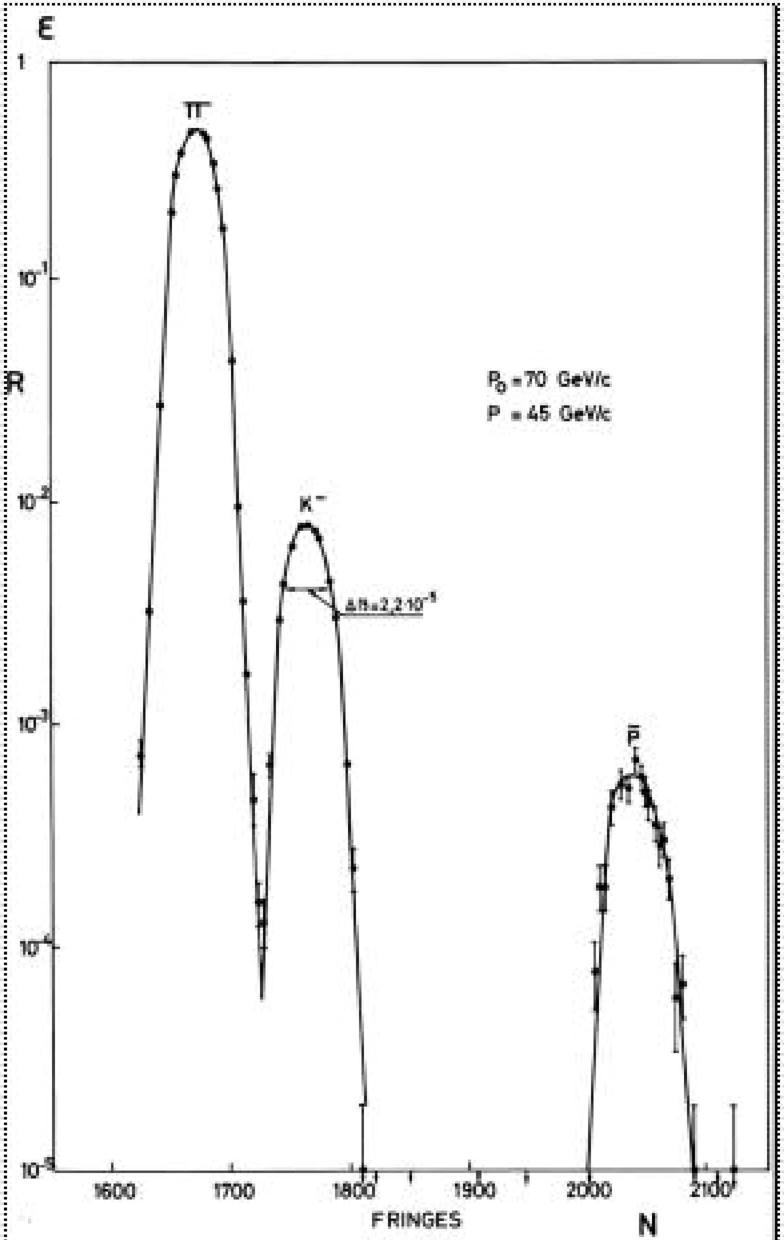
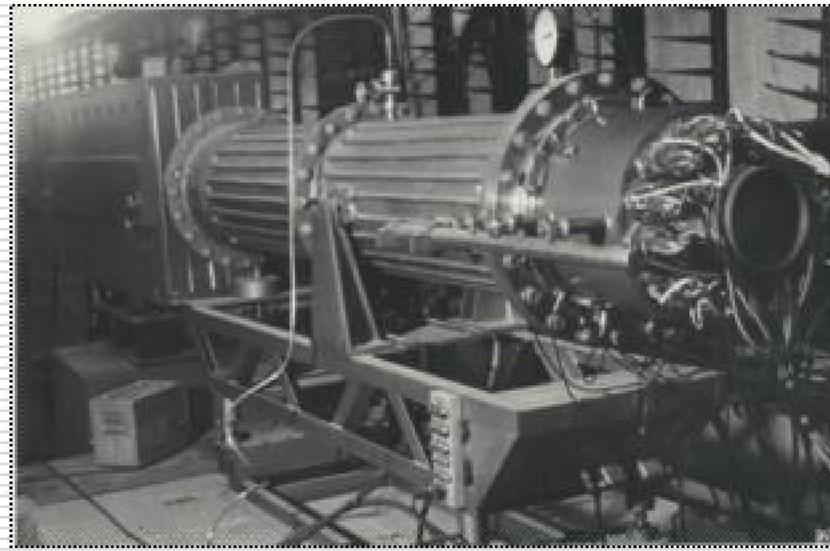


Fig. 5. Particle identification with the differential counter in 45 Gev/c beam.



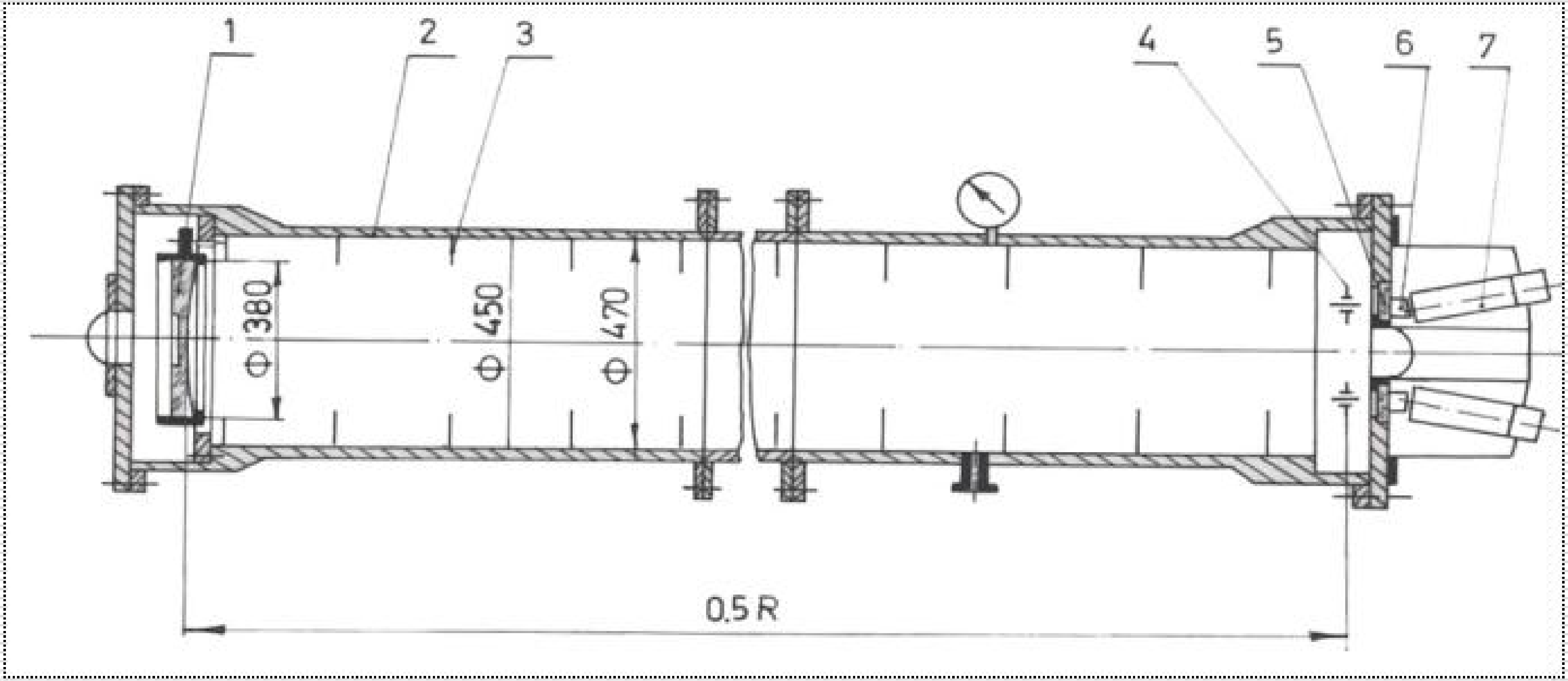
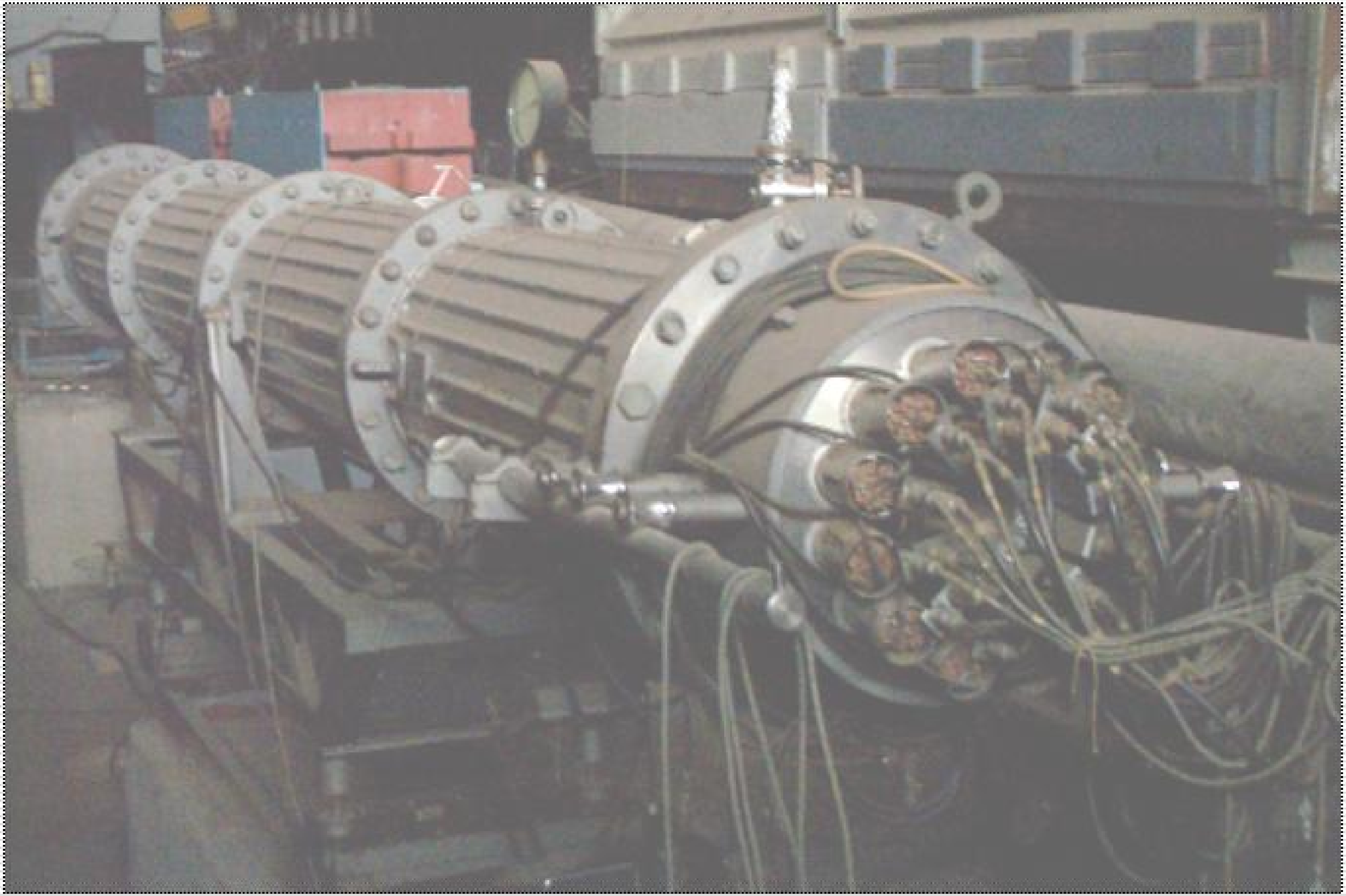


Fig. 6. 5m differential counter with θ = 23mrad.



Particle selection in the total cross-section measurements

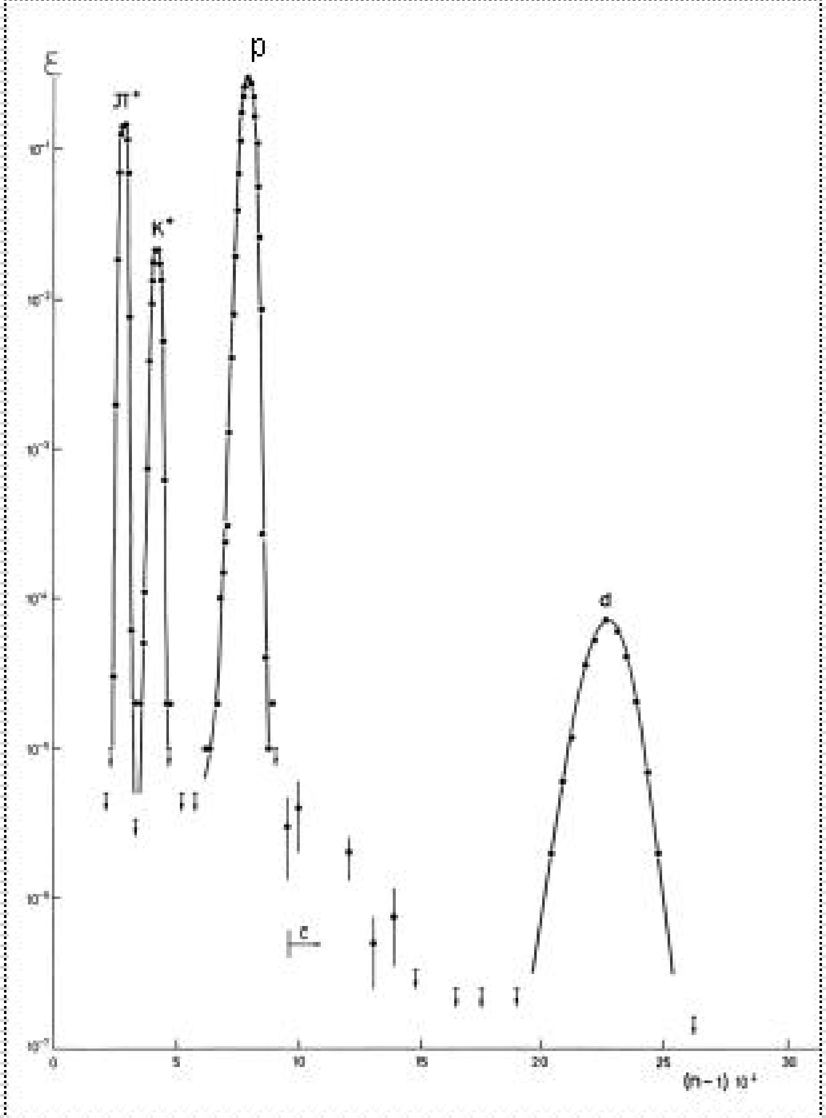
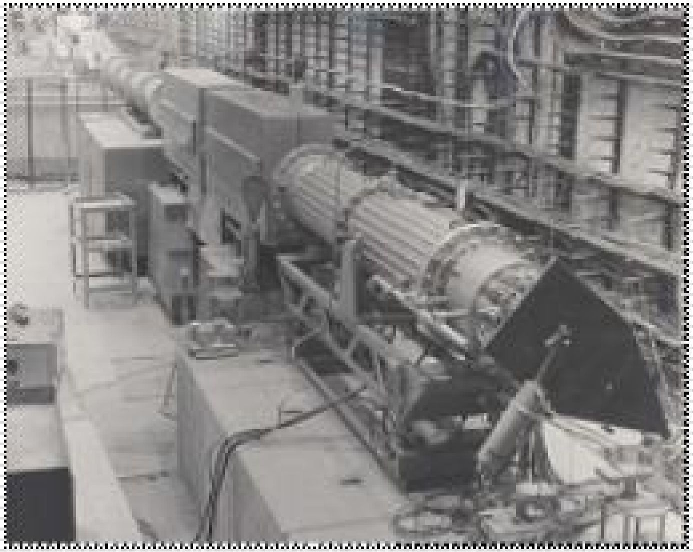


Fig. 7. Efficiency of 5m differential counter vs helium pressure.



First observation of σ_{tot} rising

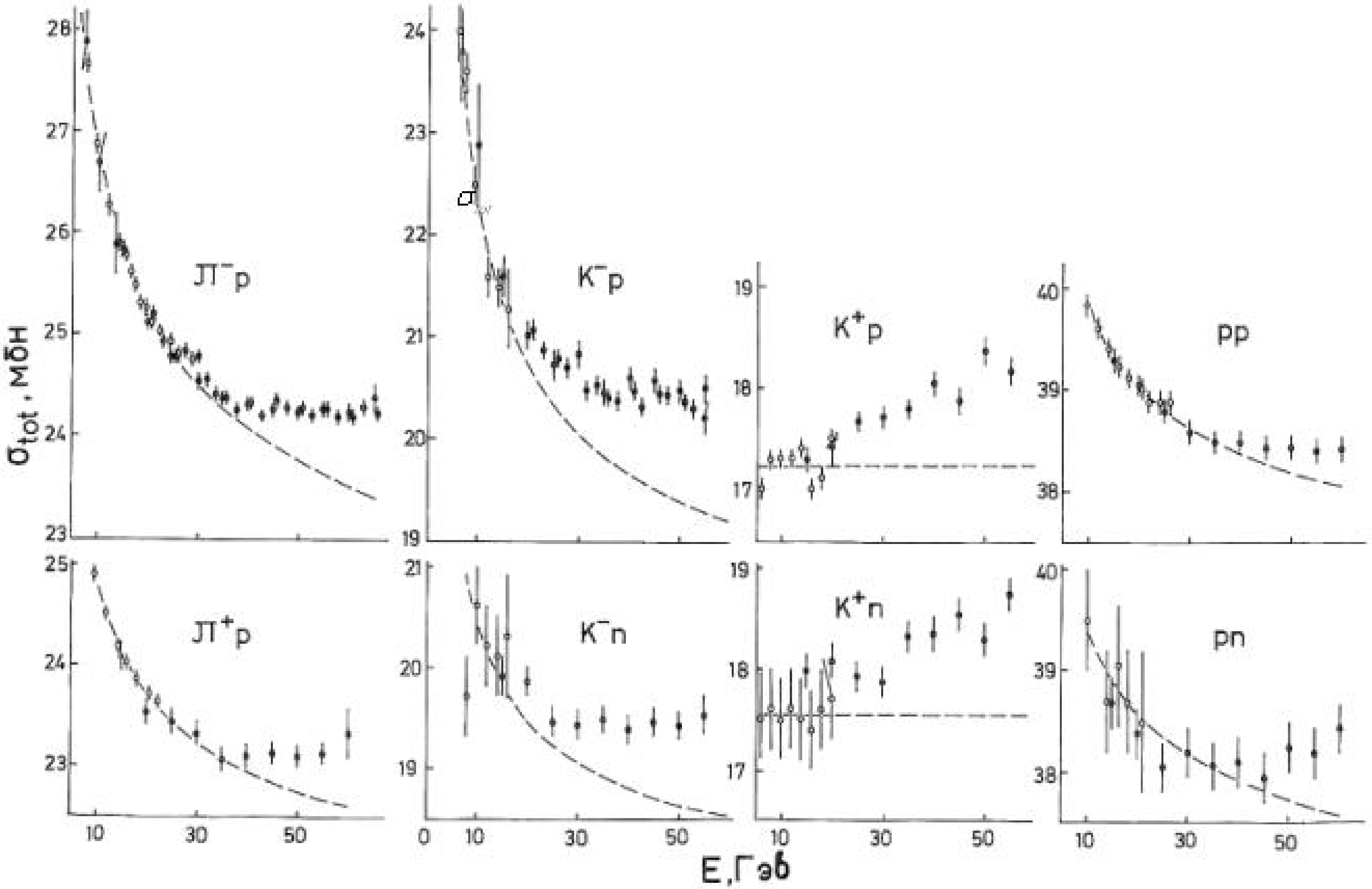


Fig. 8. σ_{tot} energy dependence.

$\overline{He}^3$ identification with threshold and differential counters

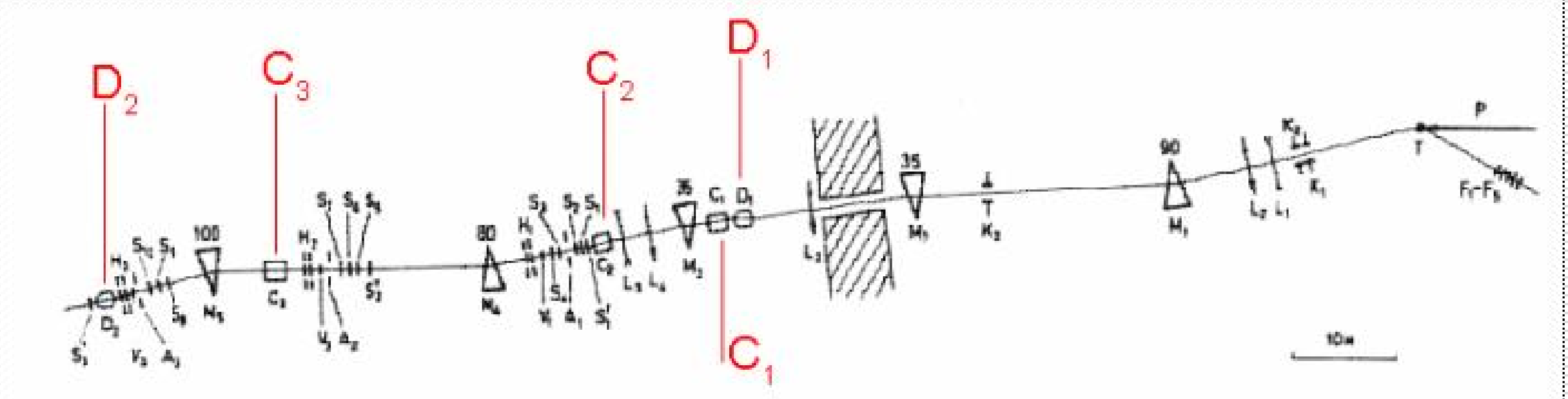


Fig. 9. Experimental layout.

3 threshold and 2 differential counters were used to reject the background of light particles with unit charge and to select $\overline{He}^3$ by measuring Cherenkov angle (local velocity), TOF (average velocity), and pulse height (Z).

Why differential counters for timing?

Due to isochronism of Cherenkov radiation all photons are collected onto PM photocathode within few ps.

Why pulse light measurements?

No Landau tail in the region of big pulse heights.

Important: Differential counters are blind for light particles.
So the measurements are not influenced by high
10^7 particle flux in the beam channel.

In total 5 $\overline{He}^3$ nuclei were selected of $3 \cdot 10^{11}$ particles passed through the channel. Four of them were detected by the differential counters.

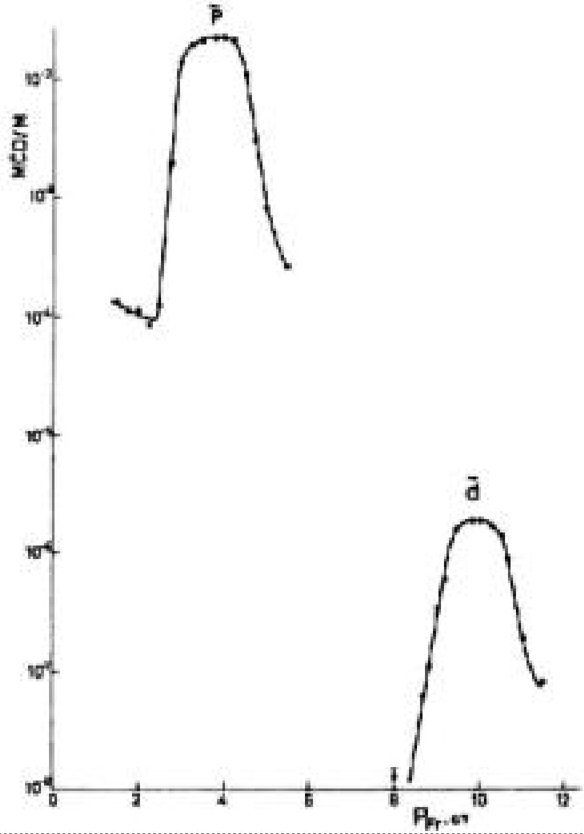


Fig. 10. The dependence of the counting rate of $\bar{p}$ and $\bar{d}$ with p=13,3 GeV/c upon the gas pressure in the differential Cherenkov counters. D – coincidences D_1D_2. Threshold counters C suppress registration of light particles. P – freon 13B1 pressure.

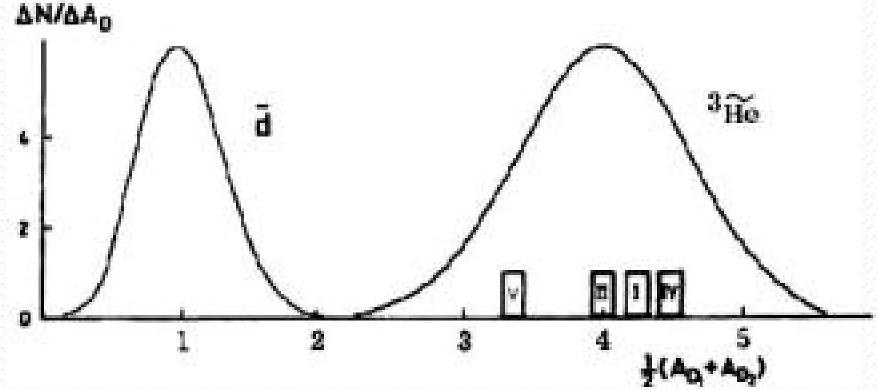
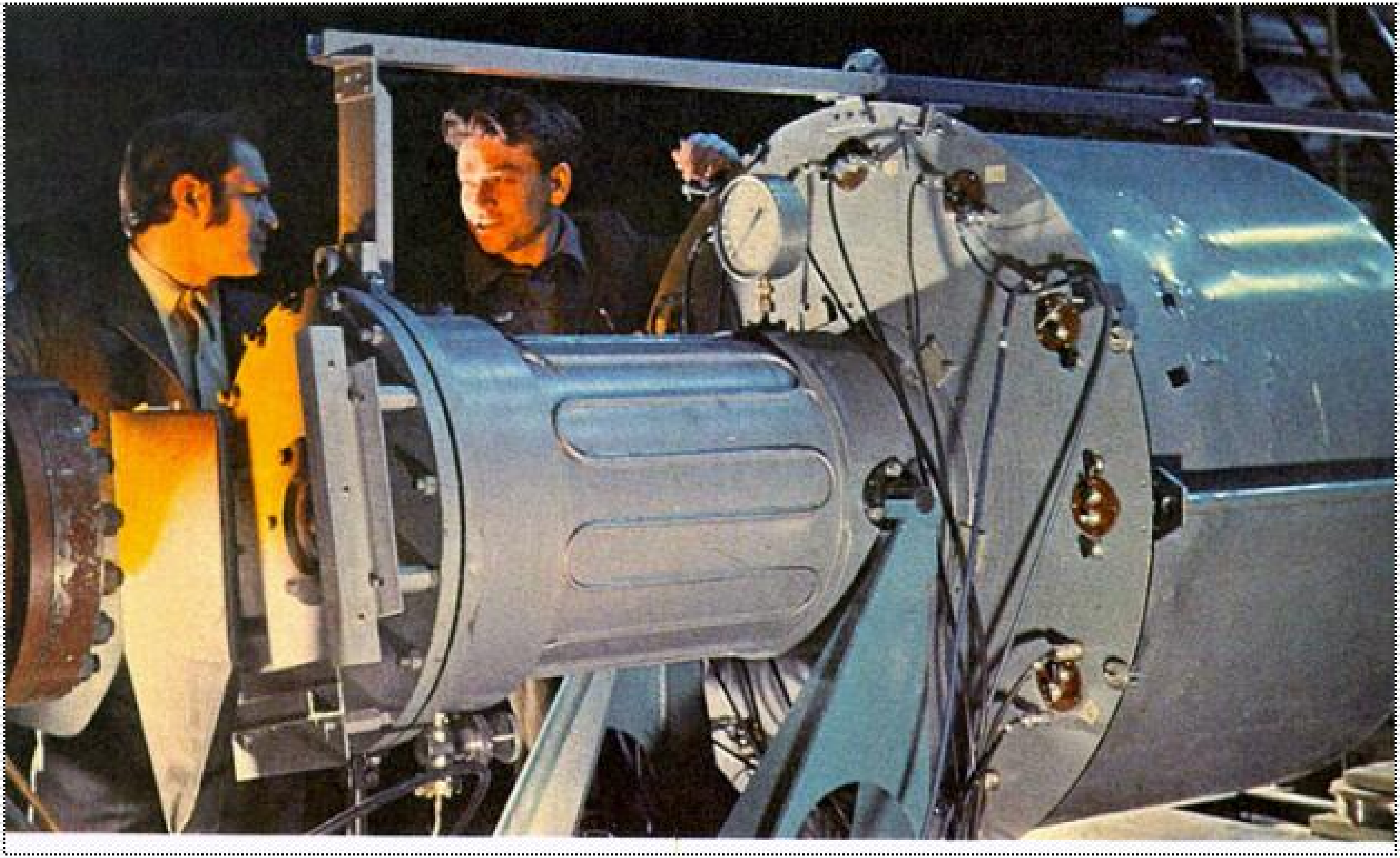


Fig. 11. The distribution of the events plotted against the halfsum of the pulse height in the D_1 and D_2 counters. The curves show the calibration spectrum, measured in the antideuteron beam with p=13,3 GeV/c and the calculated spectrum for $\overline{He}^3$ nuclei.



RICH counters

Measurement of the position of a Cherenkov ring imaging in the focal plane of the spherical mirror allows one to define not only the particle velocity but the angular coordinates θ_p, φ_p of its trajectory as well (see Fig.14).

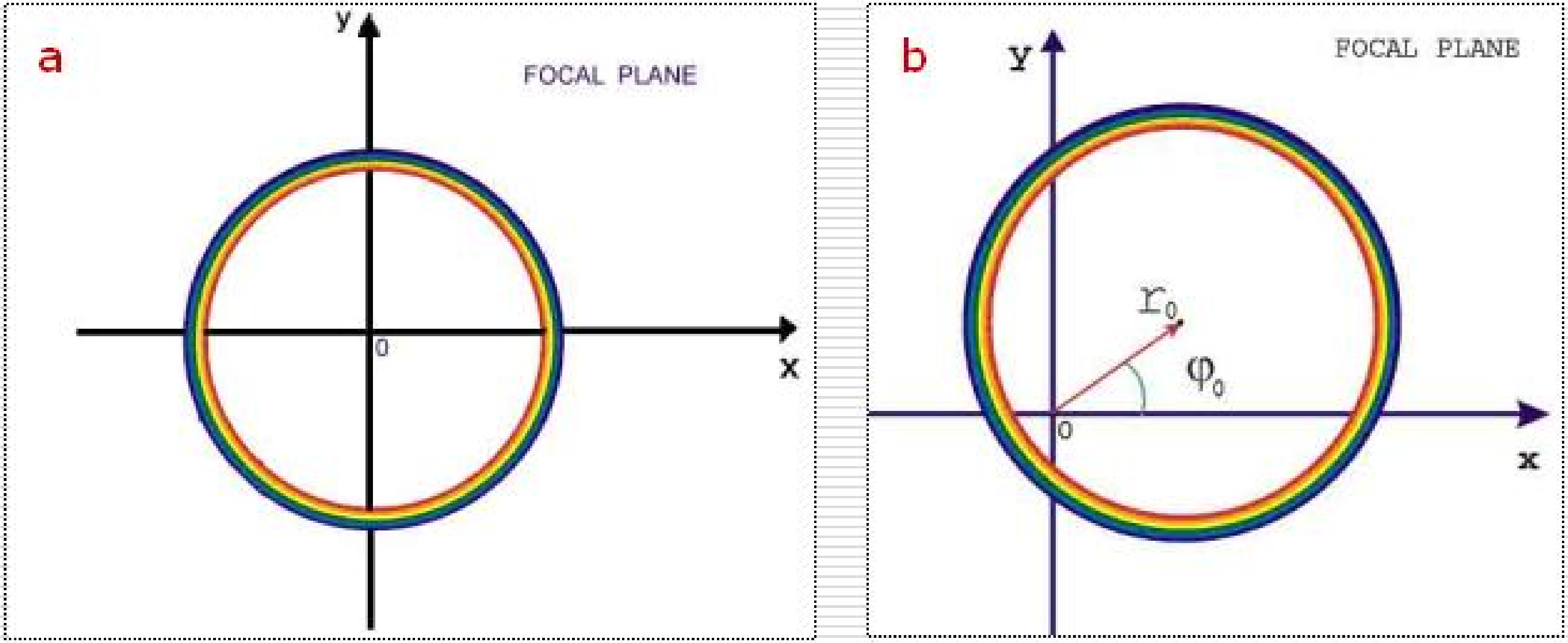


Fig. 12. Focal plane of the spherical mirror.

$$tg\theta_p = \frac{2r_0}{R} \qquad \varphi_p = \varphi_0$$

R- radius of the spherical mirror.

SCOCH Counter

The first RICH type counters named SCOCH was built in IHEP for experiments with the double arm spectrometer.

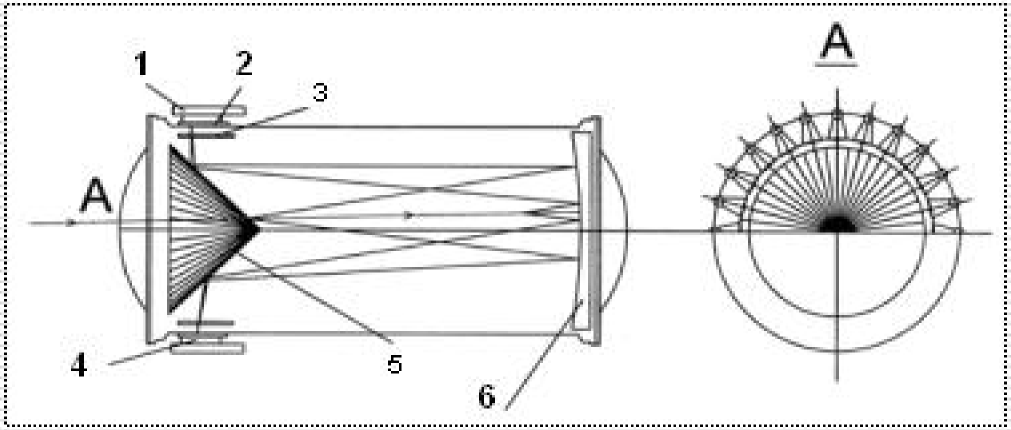


Fig. 13. SCOCH design: 1-HPMT, 2-window, 3-cylindrical lens, 4-mirror light guide, 5-conical mirror, 6-spherical mirror.

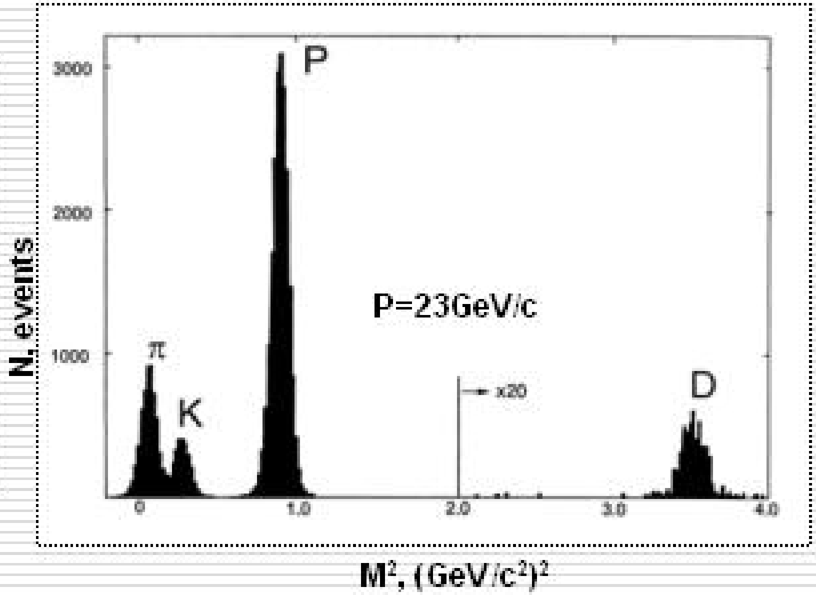


Fig. 14. Particle identification.

RICH counter for the SPHINKS facility

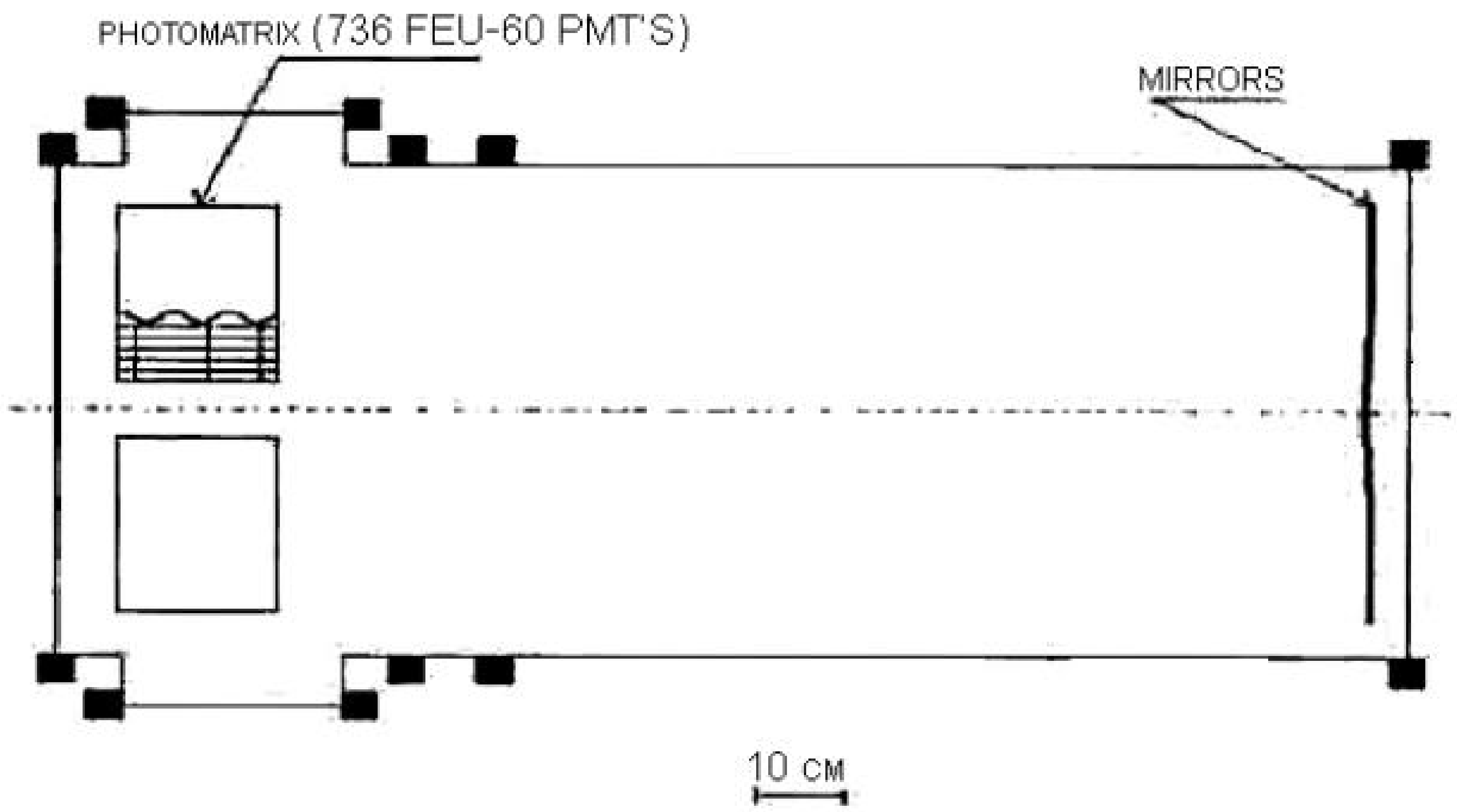


Fig. 15. RICH counter design.

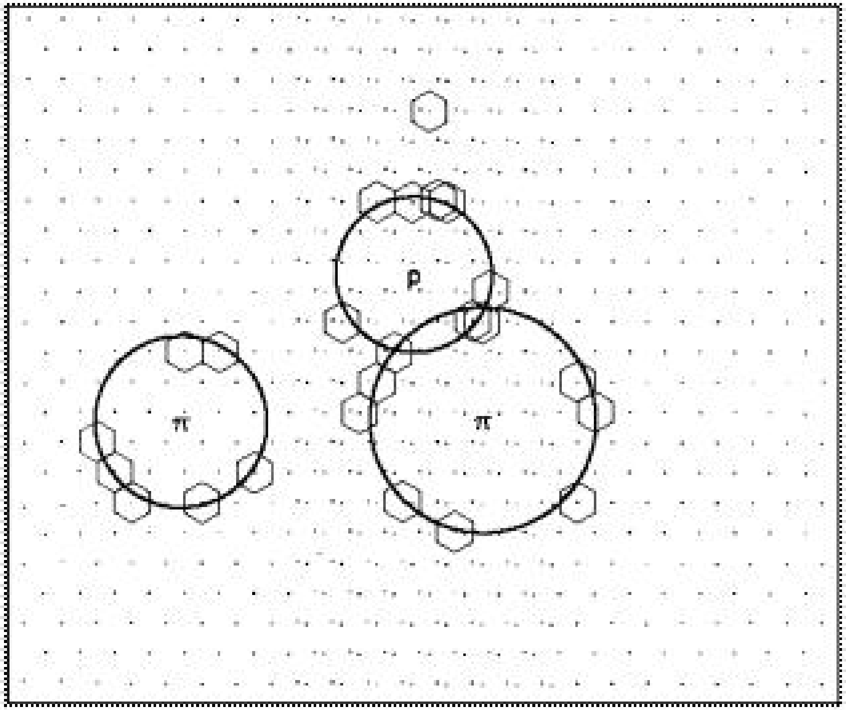


Fig. 16. Particle identification.

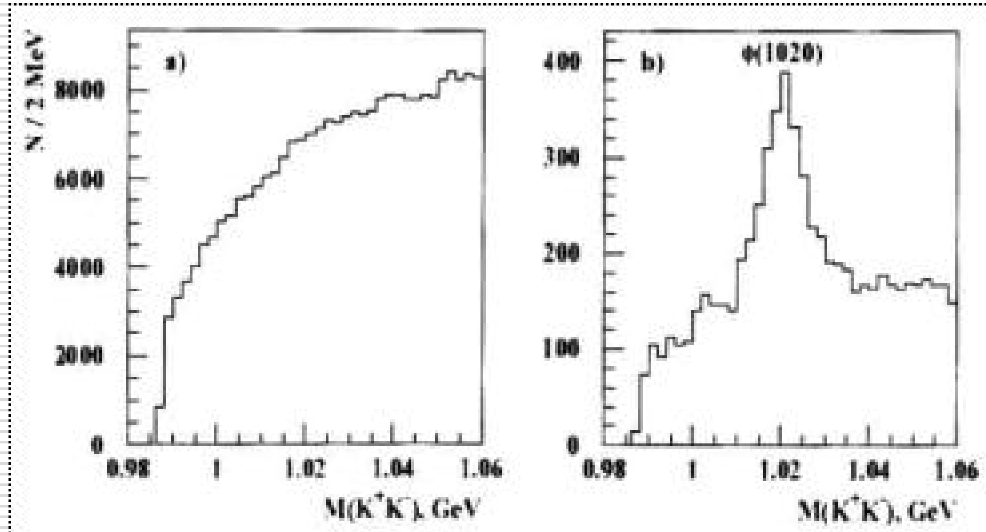


Fig. 17. $K^+ K^-$ mass spectra without (a) and with (b) kaon identification by the RICH counter.

Search for the Dirac Monopole using Cherenkov radiation

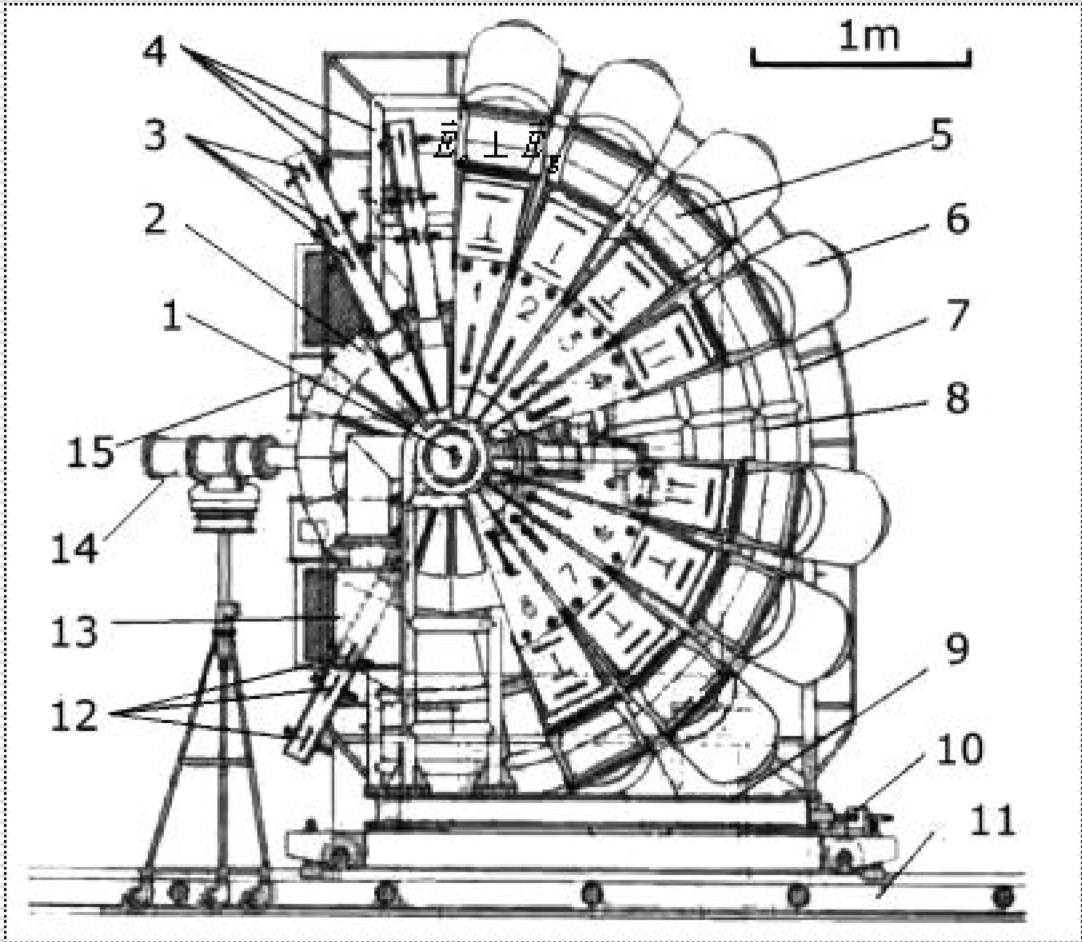
(V. Zrelov et al, JINR, Dubna)

$p + N \rightarrow p' + N' + g + \bar{g}$

Intensity: $\frac{W_g}{W_e} = n^2 \cdot \frac{g^2}{e^2} \approx 10^4$

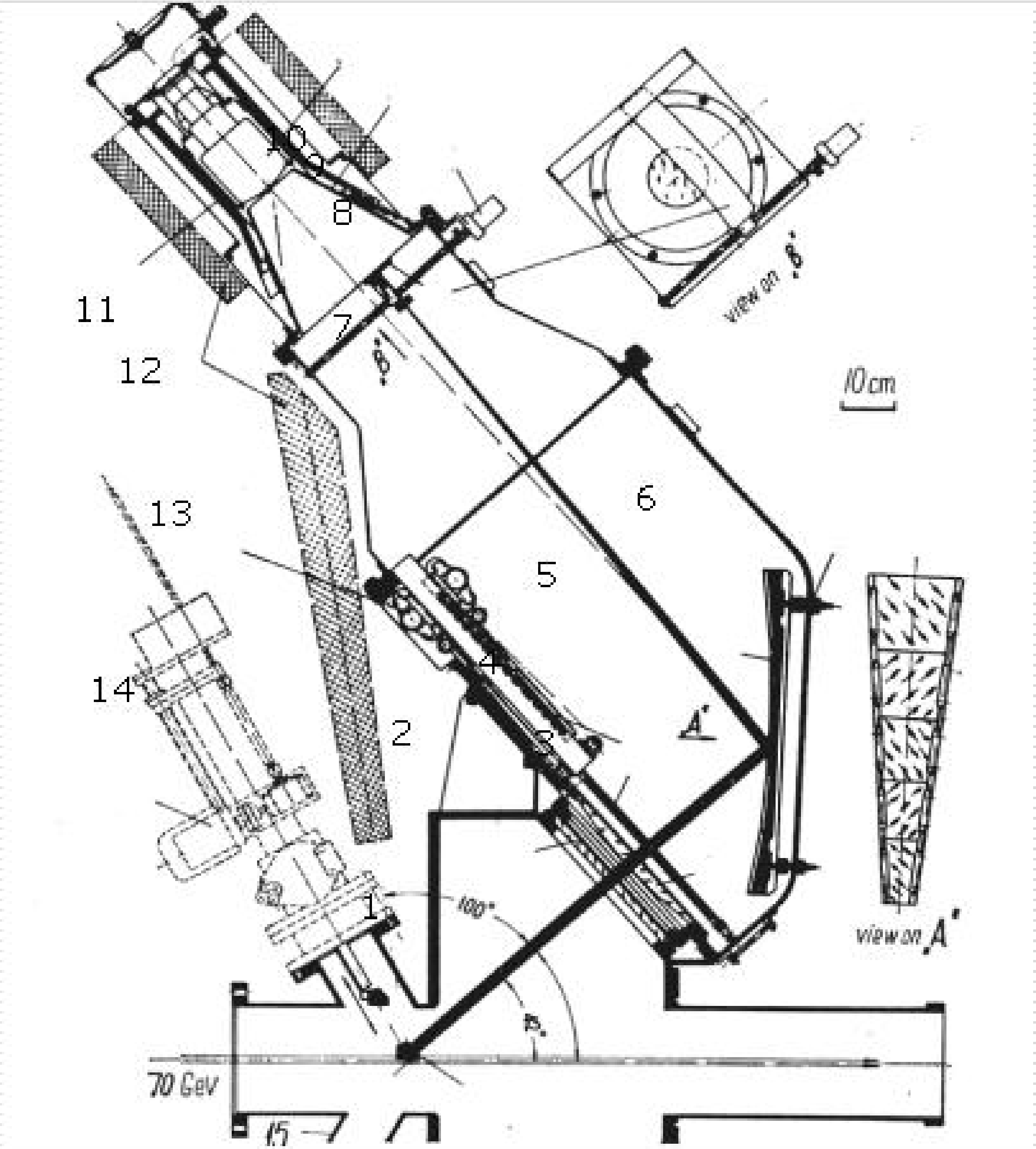
$m_g = 3 \div 5.5 Gev/c^2, g = 68.5e$

Polarization: $\vec{E}_e \perp \vec{E}_g$



General view of the device for the Dirac monopole by means of Vavilov-Cherenkov radiation radiation (view against the 70Gev proton beam).

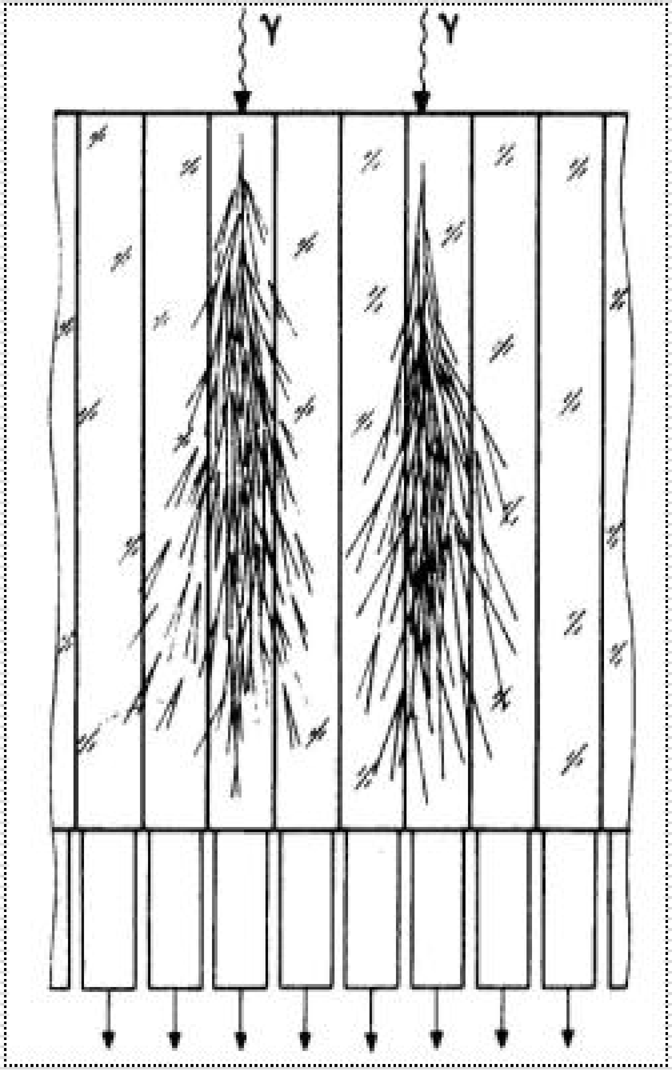
1 – Target Radiator,
2 – vacuum chamber,
3,4,12 – monitor counters for control of proton intensity and "feedback" counter,
5 – Cherenkov counter (total of eight pieces),
6 – lead shielding,
7 – truss support,
8 – mechanism for target introducing,
9 - adjusting-turning plate,
10 – base-plate,
11 – rails,
12 – the additional titanium pump,
14 – television camera PTU-101,
15-45-th magnet of ring of the IHEP proton synchrotron.



7.7·10[15] protons passed through the target – radiator (quartz). The cross-section upper limit for monopole production by 70 GeV protons : $\sigma(95\%) \leq 10^{-40} cm^2$.

Fig.18. Schematic view of the Cherenkov counter. 1-target radiator, 2- outlet window of the vacuum chamber, 3-focusing lens, 4-polariods(‖ and ⊥), 5-set of plane mirrors, 6-control screw, 7,8-remote-controlled screen, 9-cone mirror, 10- 58 AVP photomultiplier, 11- photomultiplier magnetic shielding,13-mechanism of polaroid motion, 14-mechanism for target introducity.

Lead glass spectrometer GAMS



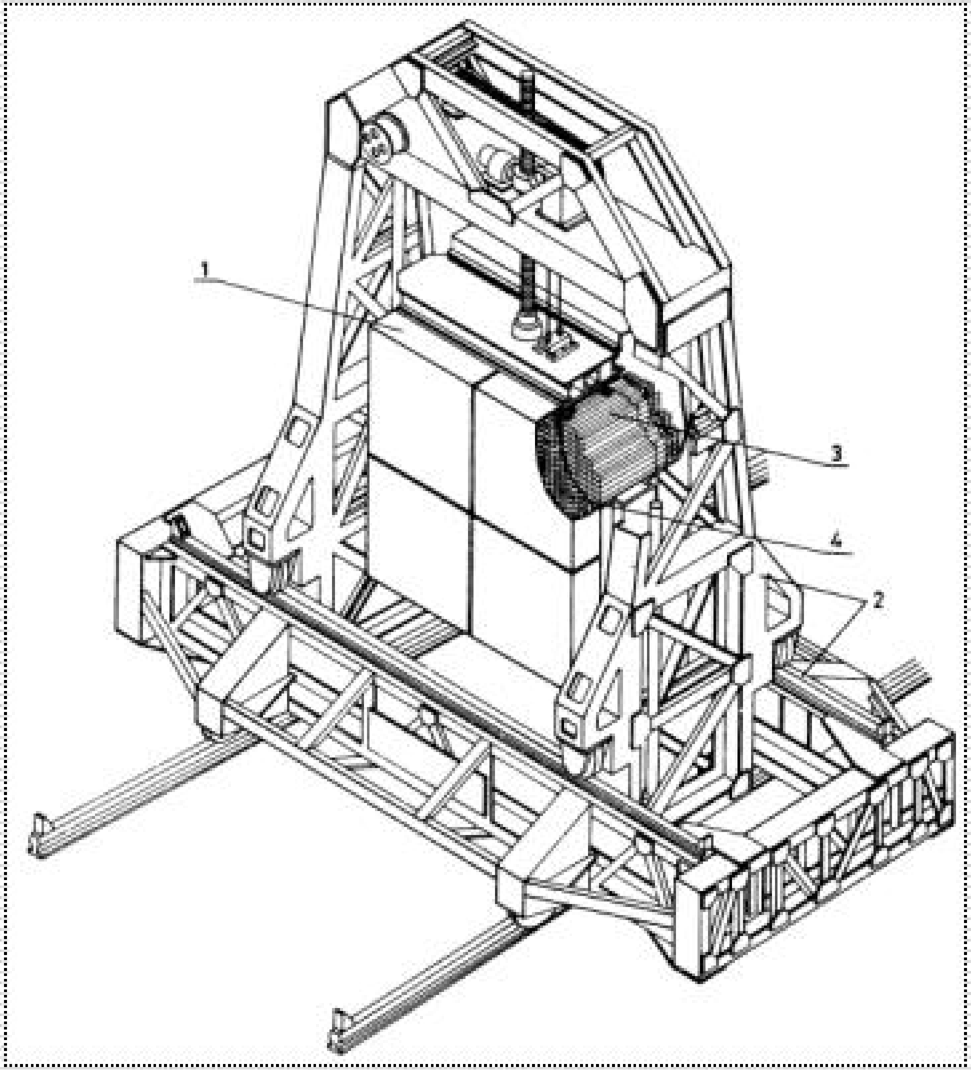
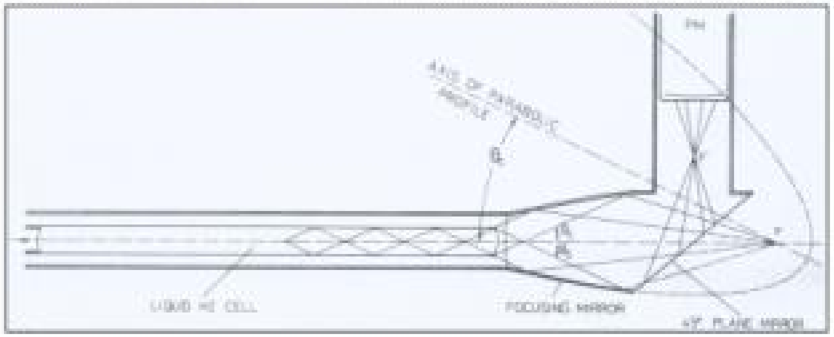
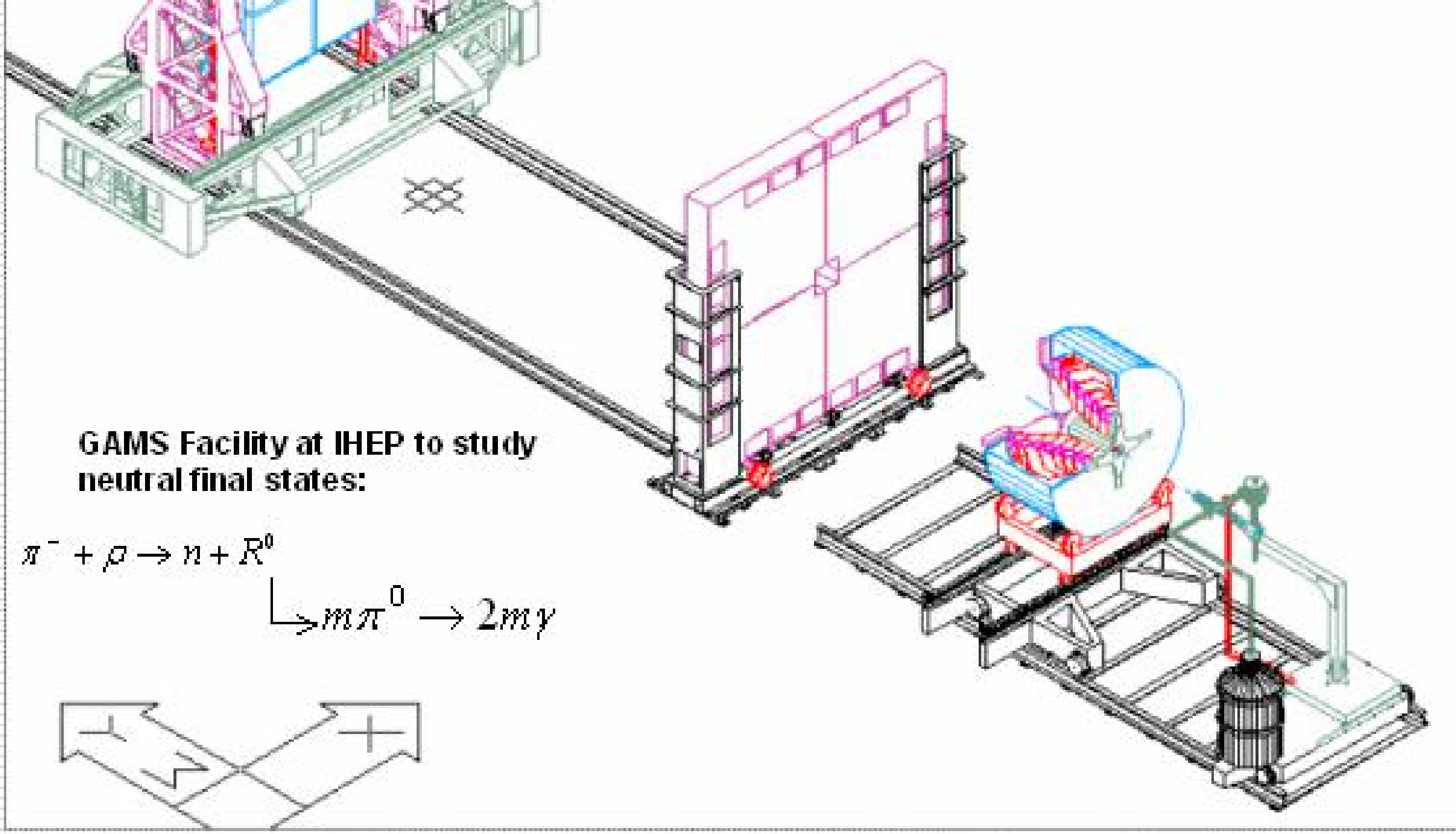


Fig. 19. GAMS-2000 for the experiments in IHEP.

$\sigma_E \approx 1\%$ and $\sigma_x \approx 1mm$ at E=25 GeV





GAMS Facility at IHEP to study neutral final states:

$$\pi^- + p \rightarrow n + R^0$$

$$\hookrightarrow m\pi^0 \rightarrow 2m\gamma$$

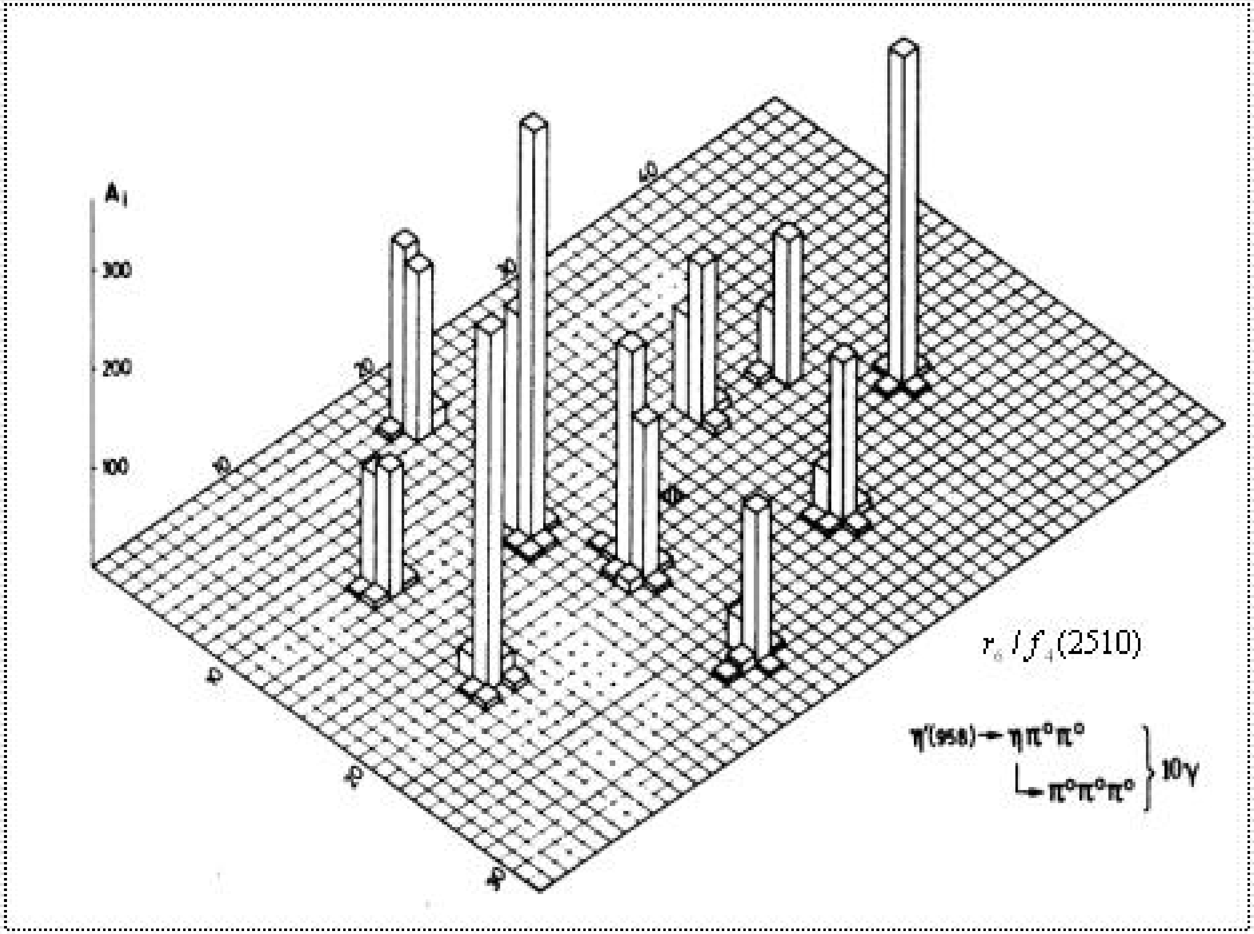


Fig. 20. Multiphoton event detected in the GAMS-2000.

GAMS spectrometers were used in many experiments at IHEP, CERN, Fermilab, BNL, JLAB which brought a lot of fundamental results. In particular, a new $r_6/f_4(2510)$ meson state with S=6 was discovered in IHEP.

Conclusion

Cherenkov counters have played a crucial role in numerous experiments carried out at the IHEP accelerator. All unique features of Cherenkov radiation were used:

- its angular direction;
- its dependence on particle charge and radiator length;
- its isochronism and polarization.

The application of Cherenkov counters permitted to discover the total cross-section growth (rise) for hadron interactions; scale invariance in hadron production as well as antihelium-3, antitritium and r/f6-meson.

It goes without saying that Cherenkov counters were used and are being used at all accelerators in the world. One can hardly overestimate the significance of Cherenkov counters for high energy physics.