CERN/ISRC/69-13
CERN/D.Ph.II/EXP 69-2
12.3.1969

MEASUREMENT OF MULTIPARTICLE SPECTRA AT LARGE ANGLES AT THE ISR.

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1. Introduction

Two fields which can be considered as the first steps in the study of the general properties of pp interaction at a CM energy of 50 GeV are :

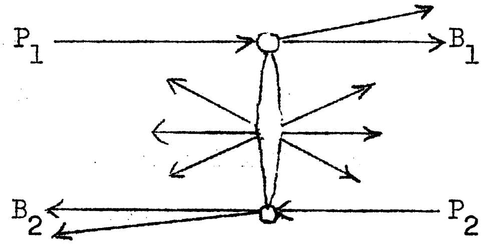
(i) the measurement of particle production spectra as function of the particle momentum and angle (proposed by : Scandinavian ISR collaboration, CERN/ISRC/69-2; Clegg et al, CERN/ISRC/69-5);

(ii) the study of correlations between the particles produced.

The present proposal concentrates on the second point. We intend to observe in the initial stage particles at large angles in a range of $90^\circ \pm 45^\circ$, depending on the available apparatus. From the experimental point of view this offers the advantages of a big accessible solid angle of $\sim 3\pi$, and no critical conditions on parameters like vacuum pipe, momentum bite, etc., are imposed. On the other hand we consider this study only as a first step towards the investigation of complete events, i.e.correlations between $\sim 0^\circ$ and $\sim 90^\circ$ particles.

2. Physics

From the physics point of view the concentration on the 90° region means something like the selection of the "central vertex" in a "double peripheral" graph :



It means the investigation of slow particles in a, more or less, isotropic distribution, which is believed not to contain the baryonic components. It is not clear, if particles emerging from this "vertex" show the same behaviour as those coming from the baryonic vertices ; more specifically, whether they have the same parameters concerning the distribution of transverse momentum, multiplicity, $\pi : K : N(\bar{N})$ ratio, if rules for stable mesons, such as π and K, continue to be valid for unstable particles, such as η, ρ etc..

The objectives of the present proposal are the following :

(a) Study of the multiplicity and, as a function of it, the angle and momentum distribution of charged secondaries. We do not try to identify the nature of the mesonic secondaries, but, considering all charged particles as pions, will obtain information on the kaon component from $K_s^0 \to \pi^+\pi^-$ decays ;

(b) Search for unstable mesons, i.e. meson $\to$ charged pions. In this sense this is a production experiment for unstable particles ;

(c) Search for events with nonperipheral baryons, especially baryon pairs and heavy mesons $\to p\bar{p}$ (+ pions) ;

(d) Search for events accompanied by a high energy particle, proton or pion, at large angle.

3. Apparatus

3.1 Magnet

The experiment requires a magnet with a field configuration that allows the detection and measurement of particles emerging at large angles with a good efficiency. Convenient parameters are :

magnetic field volume : $2 \times 2 \times 2$ meter^3
magnetic field : 10 kilo Gauss

3.2 Detector

We belive that, at least for part (a) of the proposed experiment, a visual detector with uniform efficiency, such as a streamer chamber, would be preferable. The final choice depends however on a satisfactory geometric configuration in a given magnet. A less restrictive alternative, as far as the magnet is concerned, would be a digital detector. This detector we split arbitrarily into a reconstruction part and an event identification part (or selection part). The reconstruction part should consist of four wire chamber setups of four planes each, with a total of ~ 30 000 wires, measuring the sagitta of particles over a distance of one metre in a 10 kilo Gauss magnetic field (fig. 1).

The identification part consists of several components :

(a) downstream hodoscopes in order to provide a loose trigger on beam-beam interactions ;

(b) proportional chambers around the vacuum tube in order to select events with a predetermined charge multiplicity at large angles ;

(c) a set of proportional chambers in order to identify nucleons. In this case the proportional chambers would have to be operated in such a way that the pulse height can be measured;

(d) small hodoscopes to be inserted between the wire chambers in order to preselect a preferred geometrical configuration, as for example fast particles with small sagitta.

3.3 Vacuum chamber

The following requirements have to be met by the vacuum chamber :

(a) it should contain the additional beam displacement by the magnetic field ;

(b) the walls should be reasonably thin, for example 0.2 mm of stainless steel (The ISR division intends to supply a slightly corrugated stainless steel vacuum chamber of 0.15 mm wall thickness. Ref. E. Fischer) ;

(c) it should be equipped with flares in the downstream directions to minimize geometrical biases in trigger hodoscopes.

A vacuum chamber of suitable shape is shown in fig. 2.

4. Resolution and Efficiencies

Time resolution and geometrical resolution of the trigger counters appear to be standard requirements. So we discuss only

(a) angular and momentum resolution of the reconstruction chambers ;

(b) discrimination between pions and protons by proportional chambers.

To (a) : It seems at this moment that the angular resolution for individual tracks is limited by multiple scattering in the wall of the vacuum chamber. For 0.2 millimeter of stainless steel the r. m. s. scattering angle is

$$\langle \theta^2 \rangle^{\frac{1}{2}} \approx \left(\frac{2}{p\beta(\mathrm{MeV})}\right) [\mathrm{radian}]$$

Numerical values are displayed in fig. 3. The momentum resolution is given by the measurement of the particle trajectory in the magnetic field ; it can be expressed as :

$$\frac{\Delta p}{p} = \frac{1}{H}\left\{ \left(\frac{93.5\sigma_y p}{L^{5/2}\sqrt{N'}\cos^{3/2}\lambda} \right)^2 + \left(\frac{50}{\sqrt{LL_o}} \right)^2 \right\}^{1/2}$$

in units : cm, kG, MeV/c , and where :

H = magnetic field (10 kG) ;

σ_y = space resolution in the plane perpendicular to the magnetic field ; (σ_y = 0.05 cm ;)

p = particle momentum ;

L = length of measurable track in space (100 cm) ;

N' = number of measured sparks per cm of track (N' = 0.04 cm^{-1}) ;

λ = dip angle ;

L_o = radiation length [$L_o = 10^4$ cm for 1 metre of air and 0.1 gcm^{-2} of copper]

(reference : Ω-project, NP/68-11)

The result is for cos λ = 1 :

$$\frac{\Delta p}{p} = \left(0.0025 \ . \ p\,[\mathrm{GeV/c}\,]\,)^2 + (0.005)^2 \right)^{1/2}$$

Numerical values are displayed in fig. 3.

The mass resolution in the case of a mass M decaying into two secondaries 1 and 2 can be expressed as :

$$\Delta M = \frac{1}{M}\left\{ (E_2\beta_1 - p_2 \cos \theta)^2 \, \Delta p_1{}^2 + (E_1\beta_2 - p_1 \cos \theta)^2 \, \Delta p_2{}^2 + p_1{}^2 \, p_2{}^2 \sin^2 \theta \, \Delta\theta^2 \right\}^{1/2} = \left\{ (\Delta M)^2_{\Delta p} + (\Delta M)^2_{\Delta\theta} \right\}^{1/2}$$

where p_1, E_1, p_2, E_2 are the momenta and the energies of the two secondaries and θ is the angle between them.

(Reference : Ω Project, NP/68-11)

For a unstable meson at rest in the CM we find with $E_1 = E_2$, $\theta = \pi$ etc.

$$\Delta M = \frac{1}{M}\sqrt{2}p\,(1 + \cos^2 \theta)\Delta p.$$

This gives for example for $\rho \to \pi^+\pi^-$, $\Delta M_\rho \approx \sqrt{2}\ \Delta p = 12$ MeV and for $X_{2000} \to p\bar{p}$, $\Delta M_X = 0.5\ \Delta p = 1.5$ MeV.

To (b) : pion proton discrimination.

The pion proton discrimination can be achieved by dE/dx measurement. A rejection of at least 10^3 is necessary at 500 MeV/c. The energy loss as a function of the particle velocity is given by

$$\frac{dE}{dx} = - \frac{4\pi Z^2 \lambda_o^2 m}{\beta^2} N \log\left(\frac{2m}{I(1-\beta^2)}^2 - \beta^2\right)$$

with Z = change of ionising particle

λ_o = classical electron radius = 2.8 10^{-13} cm

m = electron mass = 0.5 MeV

β = particle velocity $^v/c$

N = number of electrons/cm^3 $\approx 0.5 \cdot 10^{21}$ cm^3

I = ionisation energy = 240 eV for Argon

We obtain for Argon at atmospheric pressure

$$\frac{dE}{dx} \approx \frac{0.002}{\beta^2} \text{ MeV cm}^{-1}$$

The π - p separation obtained by Charpak and collaborators (Nucl. Instrum. and Methods 62, 262 (1968)) with a 1.5 cm Argon chamber for a particle momentum of 370 MeV/c is shown in fig. 4. Numerical integration of the curve gives a probability for a misinterpretation of a pion of about 0.05. By adding additional chambers the rejection can be increased in a multiplicative way. The variation of ionizing path length due to the particle's angle can be taken into account by the trajectory information.

5. Rates

Only very rough estimates can be made for the expected rates. As an event we define a process which yields :

(i) a charged particle in one downstream trigger ;

(ii) a charged particle in the other downstream trigger ;

(iii) one or more charged particles in the accepted region of the detector.

The probability for detecting an event is

$$P = \iiint P(\theta_1, \theta_2, \theta)\, d\Omega_1\, d\Omega_2\, d\Omega$$

where θ_1 and θ_2 represent the angles of the downstream particles and θ that of particles in the main detector. The expression for P contains correlations between the different particles, which are unknown. For lack of better knowledge we set the integral over $d\Omega_1$ and $d\Omega_2$ equal to unity. This is certainly optimistic, because we neglect forward neutrons and forward cones inside the vacuum tube ; we think however to be correct to an order of magnitude. Then

$$P = \int_{450}^{1350} \frac{d^2N}{d\Omega dp}\, d\Omega dp \approx \frac{dN}{d\Omega dp}\, \Delta\Omega\Delta p$$

From the calculation by Anderson and Daum with the thermodynamical model we find the yield in fig. 5 :

$$\frac{dN}{d\Omega dp} \approx 0.2\ (\pi^+ + \pi^-)\ /\ \text{Sterad} \cdot \text{GeV/c} \cdot \text{proton}$$

We obtain for a large angle multiplicity M a probability

$$P \approx \frac{2}{M}\ \pi^{\pm}\ /\ \text{intersecting proton}$$

in the solid angle mentioned above, integrated over all momenta.

Figure Captions

Fig. 1 Schematic layout of the detector, composed of

a) wire chambers for reconstruction ;

b) proportional chambers of multiplicity selection ;

c) proportional chambers for $\frac{dE}{dx}$ measurement.

Fig. 2 Schematic structure of the required vacuum chamber.

Fig. 3 Multiple scattering angle for pions and protons after passing 0.2 mm of stainless steel, and momentum resolution $\Delta p/_p$, separated for the effects of spatial resolution and multiple scattering in the wire chamber.

Fig. 4 Pion-proton separation at 370 MeV/c by a 1.5 cm Argon proportional chamber (from G. Charpak et al., Nucl. Instrum. and Methods, 62, 262 (1968)).

Fig. 5 Yields of $\pi^{\pm}$, K^{+}, p and $\bar{p}$ at angles of 1000-1500 mrad for pp collisions at 50 GeV CM energy (Calculation by Anderson and Daum).

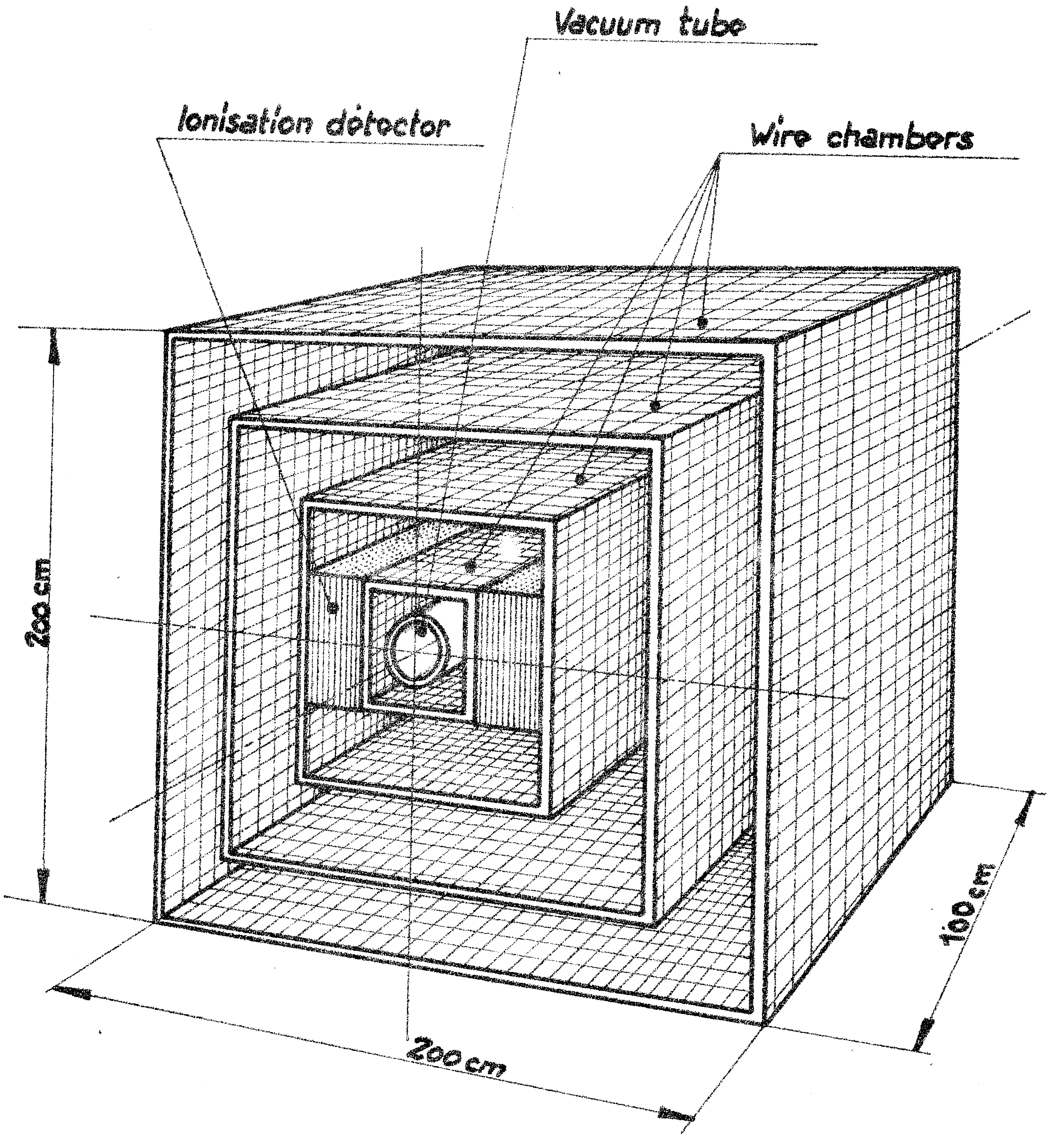
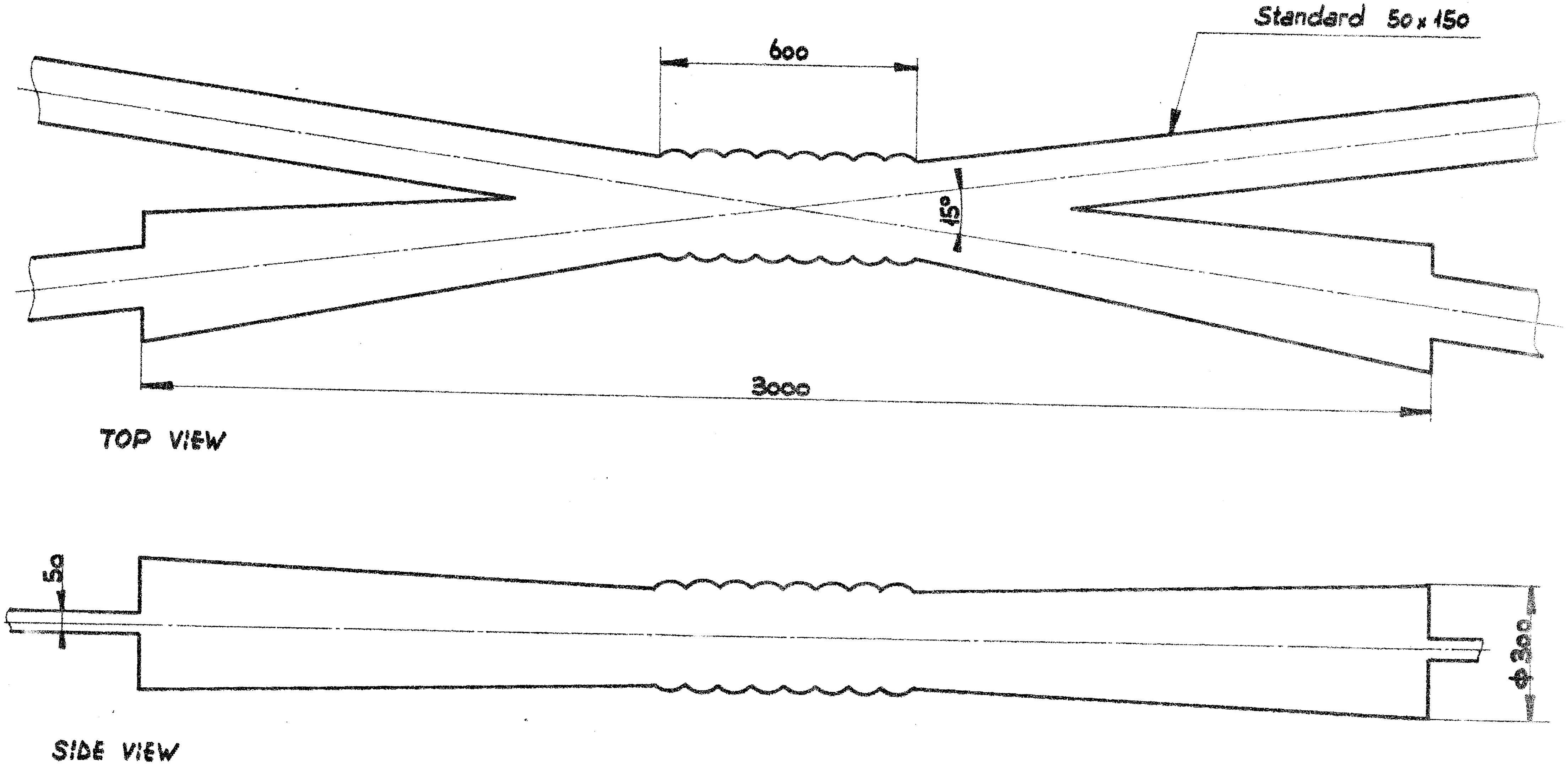
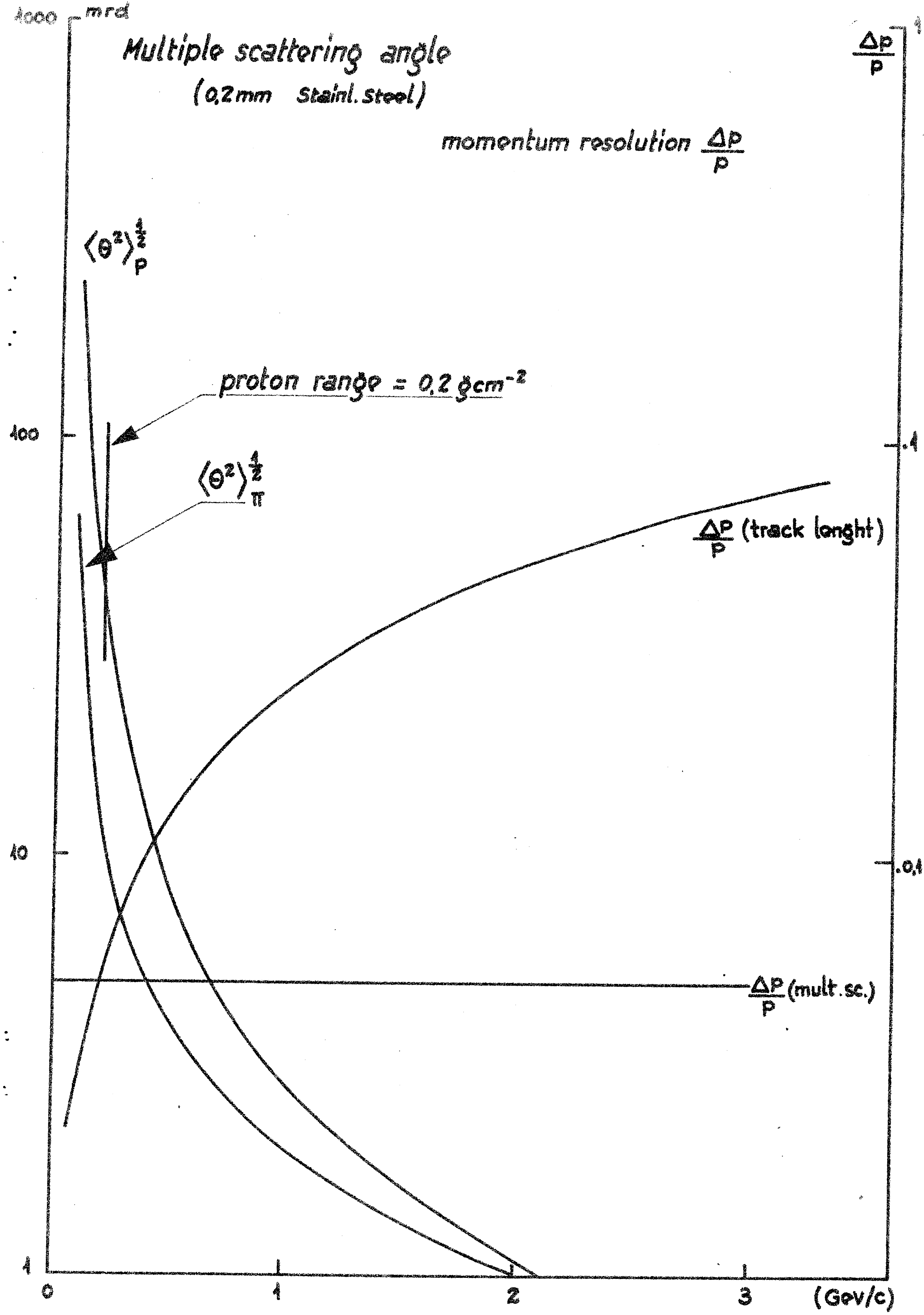

Vacuum tube
Ionisation detector
Wire chambers
200 cm
200 cm
100 cm

FIG 1



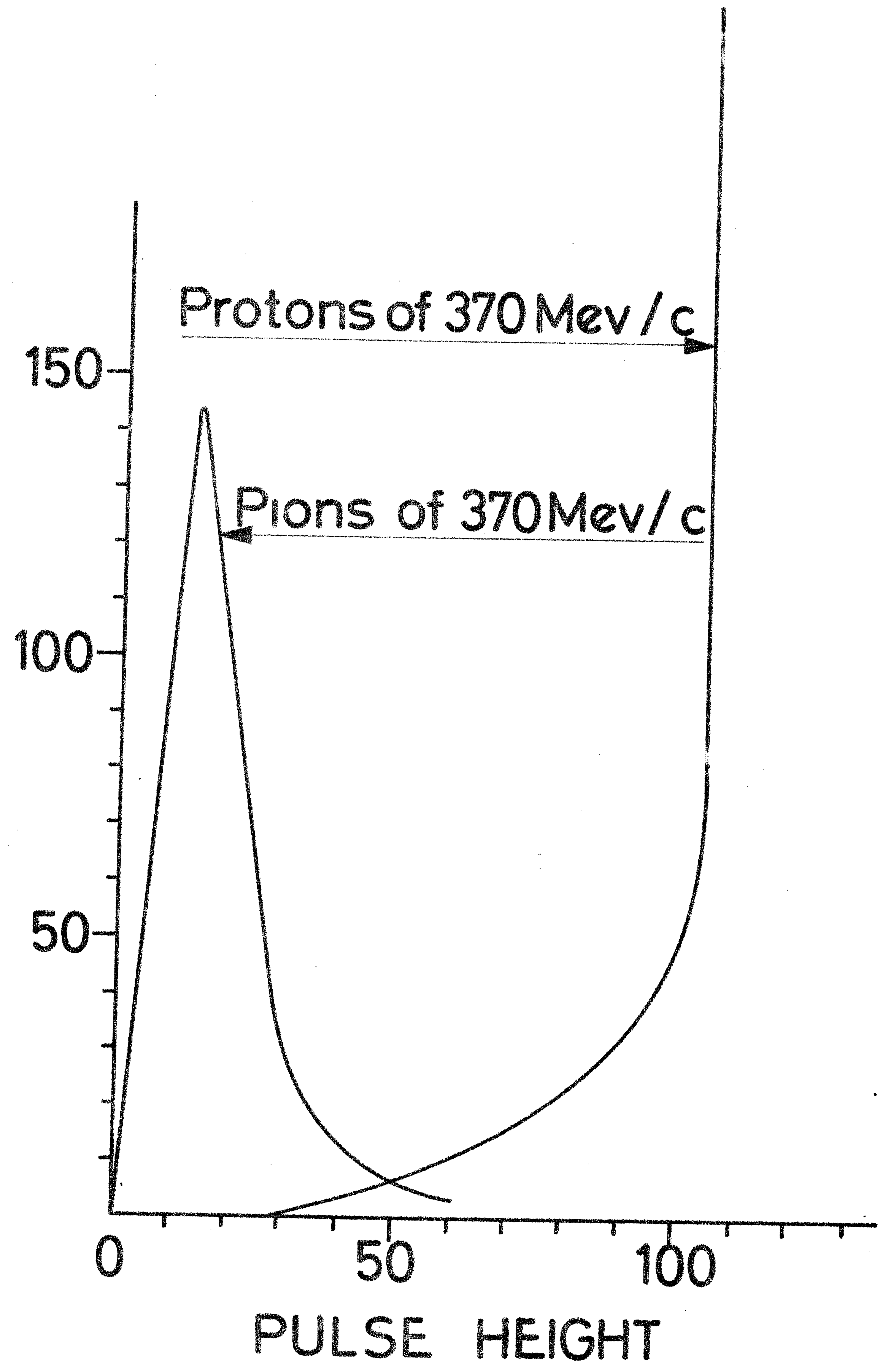
VACUUM CHAMBER (Schematic)

FIG 2



1000
mrd
Multiple scattering angle
(0,2 mm Stainl. steel)
momentum resolution $\frac{\Delta p}{p}$
$\frac{\Delta p}{p}$
1
$\langle\theta^2\rangle_p^{\frac{1}{2}}$
proton range = 0,2 gcm^{-2}
100
.1
$\langle\theta^2\rangle_\pi^{\frac{1}{2}}$
$\frac{\Delta p}{p}$ (track lenght)
10
.01
$\frac{\Delta p}{p}$ (mult. sc.)
1
0
1
2
3
(Gev/c)

FIG 3



Protons of 370 Mev / c
Pions of 370 Mev / c
150
100
50
0
50
100
PULSE HEIGHT

FIG 4

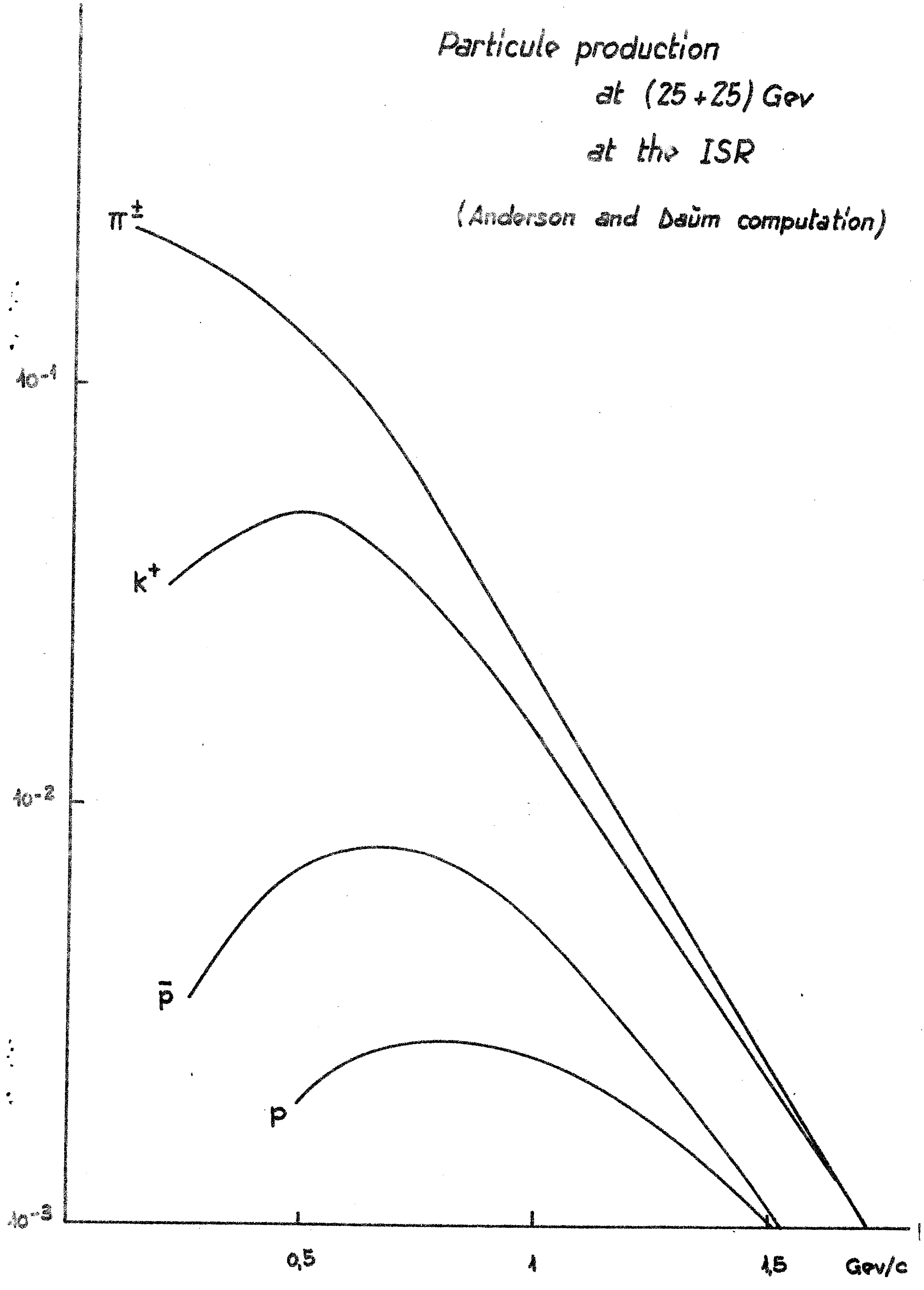

Particule production
at (25 + 25) Gev
at the ISR
(Anderson and Daüm computation)
π±
k+
p̄
p
10-1
10-2
10-3
0,5
1
1,5
Gev/c

FIG 5