CERN/ISRC/72-13 Add. 1

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

INTERSECTING STORAGE RINGS COMMITTEE

PROPOSAL FOR THE EXTENSION OF THE EXPERIMENT R 101

MEASUREMENT OF HIGH TRANSVERSE MOMENTUM CHARGED PARTICLES

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We would like to recall the experimental set-up of the experiment R 101 and the performance of this equipment; we will indicate the measurement that can be achieved with this apparatus. This will appear in chapter 1. In chapter 2, we will discuss the advantage of extending the apparatus of the experiment R 101 in a double arm spectrometer each on one side of the intersection region I_1. The performance of such an arrangement will appear in chapter 3.

I - Experimental set-up of the experiment R 101

This experiment is conceived essentially for the detection of high transverse momentum electrons and gamma rays at 90° of the intersecting beams. The momentum is determined by the deflection of the charged particles in a magnetic field (fig.1). The transverse momentum of the magnet used is 103 MeV/c (In other words, the deflection α in the field is given by $\Delta \sin \alpha = 103/p$ in MeV/c). A set of magnetostrictive wire spark chambers in front and in the back of the magnet determine the deflection α in the magnetic field.

The trigger is defined by a coincidence between the three hodoscope counters H_1, H_2, H_3. H_1 and H_2 in front of the magnet, H_3 is placed after the last magnetostrictive chamber. The selection of high speed particles is obtained by a Cerenkov counter situated in the magnet. The Cerenkov consists of 8 elliptical mirrors. The side view is indicated in (fig.2). The image of the intersection of the two beams is formed on 8 phototubes corresponding to the eight mirrors. Each mirror sees the intersecting region in a certain angular range, and therefore provides a correspondence between the track directions and the mirrors. At each trigger, the situation of the phototubes that triggered and the wire chamber informations are dumped on tape, and provide a very effective tool to reject in the analysis the wrong triggers. This apparatus has been used in two different ways :

a) Determination of particle spectra : A time of flight between H_1 and H_3 allows the separation of pions from protons until 1 GeV/c in the laboratory system. The center of mass of the two intersecting beams is moving away from the apparatus, and therefore transverse momenta of pions and protons have been obtained until 1.2 GeV/c [1]. Above 1.2 GeV/c, this set-up does not permit to separate between the different types of particles but does allow the determination of the spectrum of all particles above 1 GeV/c. The spectra we obtained are shown in fig.3 and 4 and we will discuss them in the next chapter.

b) Determination of the electrons'spectra : In this case, the Cerenkov signal is required in the trigger. The Cerenkov was usualy filled with isobutane and the threshold for pions detection was 2.7 GeV/c. One problem is the separation of the single electrons from the converted gamma rays in the vacuum pipe. Pulse height analysis in the hodoscope counters H_1 permits the discrimination between one and two particles in the same scintillator counter. Therefore it provides a separation between converted gamma rays and single charged particle. Fig.5 shows the pulse height spectrum obtained. Sometimes, the Cerenkov counter is triggered by a gamma ray converted inside, whereas the particle that traversed the apparatus was a pion. The first rejection of this type of event is to check if the right Cerenkov mirror has been hit. There remains an ambiguity if the pion is in the vicinity of the converted gamma ray. In this case, the electrons are recognized by pulse height in a shower counter. This shower counter is formed by a sandwich of scintillators and lead, there is a total of 2.5 R.L. In front of this counter there is 3 R.L. of shower chambers. The mean pulse height at 1 GeV/c electron is five times bigger than a minimum ionizing particle. The number of expected electrons being small, optical shower chambers are triggered if the pulse height in the sandwich counters goes beyong 3 minimum ionizations and will allow a vizualisation of the shower development . Fig.6 shows a transverse momentum spectrum of all particles taken in a 26 GeV x 26 GeV run.

The fast fall off below 2 GeV/c corresponds essentially to electrons coming from gamma rays conversion in the vacuum pipe. ~~Between 2 and 3 GeV/c there are no observed events~~. The events after 3 GeV/c correspond to pions above the Cerenkov threshold and have been recognized such by the pulse height in the sandwich detector. The cross section above 3 GeV/c is in 10^{-32} cm^2/st/GeV/c range.

It is clear that the experimental arrangement we have described is also a good set-up for the detection of transverse momenta pions above 3 GeV/c. It has the great advantage to avoid to trigger on the large flux of low momenta pions and consequently the trigger rate is low of the order of 2/s for 5A against 5 A. We will discuss in the next chapter, the interest of high transverse momenta charged particle measurement.

II - Interest in the study of high transverse momentum particles

The mean transverse momentum of particles produced in high energy collisions is of the order of 0.370 GeV/c. This mean transverse momentum correspond to the strong interaction length of the order of 1 fermi. The measurement of transverse momenta in the range of 3.7 GeV/c would probe in the interaction length of the order of 0.1 fermi. So if there are hard core constituant in the hadrons, they would manifest themselves by an abnormal high rate of emission of high transverse momenta hadrons. The deep inelastic e p scattering is interpreted by the existence of point like constituants (partons), and therefore suggests that such type of phenomena might exist. Calculation based on the partons hypothesis and one photon exchange [2] predicts cross section at 3 GeV/c in the 10^{-35} cm^2/st/GeV/c range an a dependence with P_T as $\frac{1}{P_T^4}$. This is the minimal cross section one would expect. If the partons interact strongly among themselves, cross section of several order of magnitude higher are expected. From the data we show on fig.3 and 4, the cross section at 3 GeV/c is of the order of 10^{-31} cm^2/st/GeV/c. The reason for this relatively high cross section is a slowdown in the exponential decrease in the transverse momentum spectrum. The slope change from 6 to 4 when the transverse momentum varies from 0.2 to 3 GeV/c. Therefore although the chance to see deep inelastic phenomena is small, the rate of events with transverse momenta above 3 GeV/c is relatively important, that a good measurement of their characteristics can be done at the I.S.R. Such high transverse momenta must be balanced by particles going in the opposite direction. One would expect if hardcore constituants exist in the nucleon to see high transverse momenta correlated or at least a high transverse momentum correlated with jets of particles going in the opposite direction. One could have an idea on this phenomena by measuring the correlation of particles emitted at 90° and see if the correlation function depends on the transverse momenta of the emitted particles. If f (p) is the single particle spectrum, F (p_1, p_2) the spectral function to observe p_1 and p_2, the ratio F (p_1, p_2) to f (p_1) f (p_2) indicates the amount of correlation. This correlation function has then to be measured for p_1 varying between 0.2 GeV/c up to 6 GeV/c.

We propose to use our actual apparatus to detect the high transverse momentum pions as it was explained in chapter 1, and to add a similar magnet in the other side of intersection I_1. Details on the complete set-up will be given in the next chapter. We would like to emphasize that in same time we will be able to determine the amount of electrons produced in pp collisions. This will allow us to improve the upper limit of W production and reach a value for σB (σ is the W production cross section, B being the branching ratio for $W \rightarrow e \nu$) in the 10^{-35} cm^2 range. The detection of high transverse momenta pions and electrons occurs in the same runs. The addition of the second spectrometer for the reasons described previously permits also the scan for the existence of heavy bosons decaying in two pions. Fig 7 shows the invariant mass spectrum obtained by assuming that we detect in the two arms uncorrelated pions. This spectrum indicates the level of background involved in such a measurement.

The signal to noise ratio in such a search depends on the width of the hypothetical boson and on the apparatus resolution. For example, a boson of 10 GeV mass with negligeable width and a resolution of 10% would be detectable if the cross section production is higher that 10^{-40} cm^2. In this case, in fact we are limited by the luminosity of I.S.R., to cross section of 10^{-34} cm^2.

The performance of the apparatus can be checked by measuring the ρ^0 and the f^0 production. This will permit to test our resolution. It is to be remarked that the order of magnitude and the angular distribution of ρ^0 production compared to the production of π^+ and π^- at 90° is an interesting measurement in itself. It might help to determine the amount of π^+ and π^- in the inclusive spectra that are in fact ρ decay products.

III - Description of the complete set-up

Fig 8 shows the complete set-up. As we indicated previously it is a double arm spectrometer. The first arm is the same we had in experiment R 101. The second arm is composed by a magnet identical to the one we already used. A set of 10 magnetostrictive wire chambers, 5 in the front and 5 in the rear of this second magnet allows the measurement of the deflection in the magnetic field and therefore determines the momentum. Two hodoscope banks H_1' and H_2' provide by time of flight measurement a separation between pions and protons below 1.2 GeV/c. The solid angle of the first arm is 0.1 steradians. To collect the maximum number of events the second magnet will be closer to the intersecting beams. It will be at 1.2 m. The solid angle of the second spectrometer is going to be 0.25 steradians.

Our aim is to determine the correlation function in momentum between 0.2 GeV/c and 6 GeV/c. The momentum resolution of the apparatus depends on two factors, the multiple scattering in the spectrometer and the spatial resolution in the spark chambers. Fig.9 shows this resolution as a fonction of momentum. Between 0.2 GeV/c and 3 GeV/c, we plan to trigger on the first arm without making use of the Cerenkov signal. We know from experience that in this case, when the beam current is above 3A in each ring, the rate of data taking depends only on the speed we can trigger the chambers. The chambers will be able to fire at 20 per second.

In this conditions, a run of 100 hours per energy will provide 10^6 good events per energy. Assuming that there are no correlation between emitted particles, and using the value of 8 mb/st for the pion production cross section at 90°, there will be 80.000 events to determine the correlation function between 0.2 and 3 GeV/c. To measure the pion spectrum above 3 GeV/c it is absolutely necessary to use the Cerenkov signal in the trigger. In our previous run with 5A against 5A, the trigger rate was 2/second and can probably be reduced by a factor of 2. With such a trigger rate, the number of events depends only on luminosity. According to our spectrum at 26 GeV x 26 GeV, the cross section $\frac{1}{p}\frac{d^2\sigma}{d\Omega dp}$ at 3 GeV/c is 2×10^{-31} $cm^2/GeV^2/c^2/st$. With beam current of 10A in each ring, and assuming that the slope will remain constant after 3 GeV/c at a value of 0.33 $(GeV)^{-1}$ a run of 100 hours per energy will provide 5000 pions per energy above 3 GeV/c. This rate will probably be higher if the slowdown in the exponential decrease will continue. As we emphasize already such a run will permit to improve the upper limit on electrons detection, a run of 100 hours leads to a upper limit for σB on the W detection of $10^{-34} cm^2$.

IV - Conclusion

In summary, the spectrometer of the experiment R 101 is well adapted to the measurement of high transverse momentum electrons and pions. One can notice that the range of transverse momentum we propose to measure is above the kinematical limit of transverse momenta one can obtain at the P.S. The adjonction of a similar spectrometer in the other side of intersection region I_1 is a normal extension of the experiment R 101. In consequence, we would like that, when we start to rerun, the I.S.R.C. give us the permission to install our second magnet. The complete set-up will be ready on january 1973. This time corresponds to the PS shut-down and it seems to be a good period to install the complete set-up.

REFERENCES

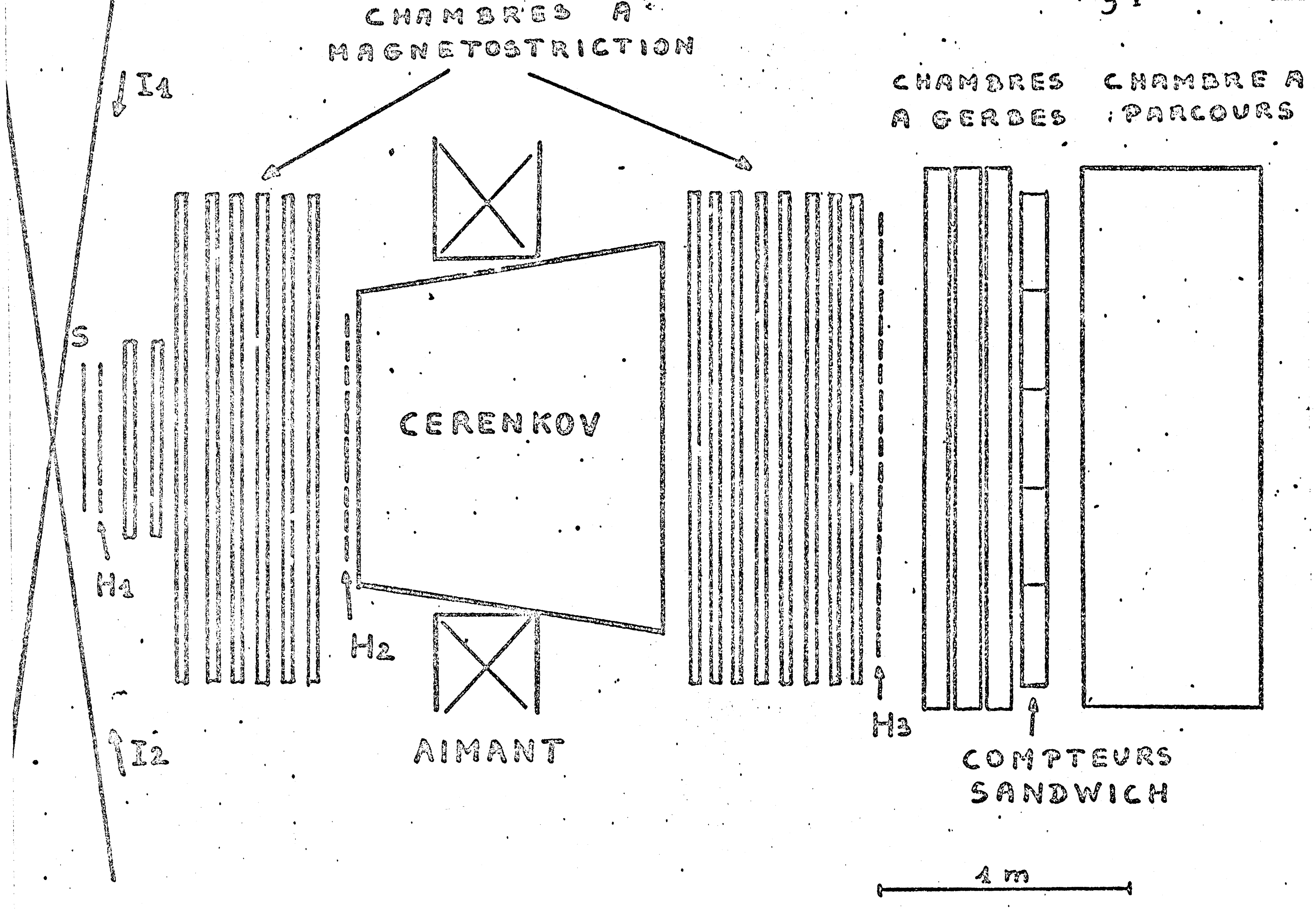
1 Results of experiments on inclusive reactions at the CERN intersecting storage rings.
J.C. SENS. Fourth international conference on high energy collisions, Oxford, U.K April 5-7, 1972.

2 Inclusive processes at high transverse momentum
S.M. BERMAN, J.D. BJORKEN, and J.B. KOGUT.
Physical review D4, 3388 (1971)

FIGURE CAPTIONS

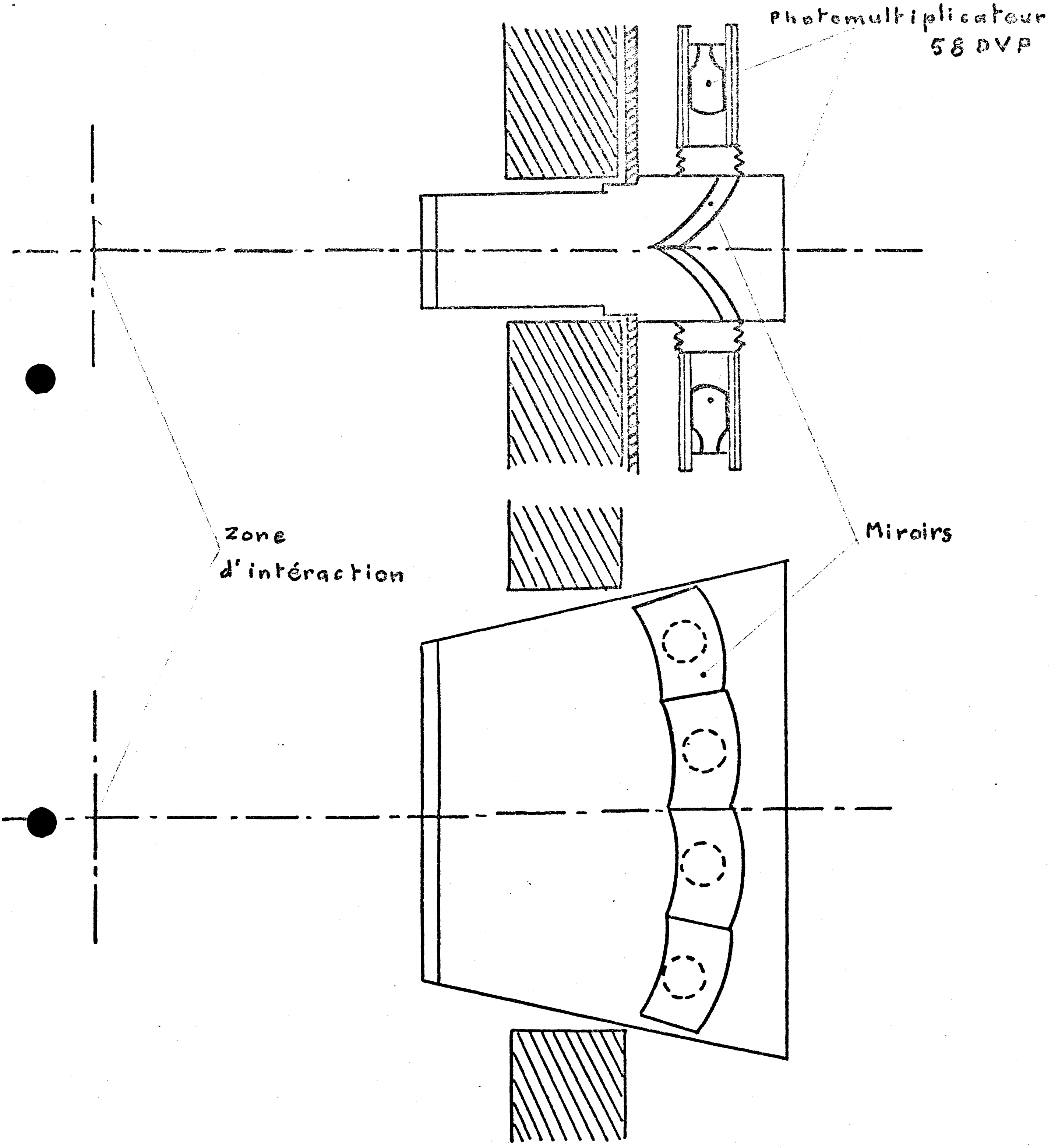
FIG 1	Design of the apparatus
FIG 2	Side view of the Cerenkov
FIG 3	Spectrum of all particles at 26 GeV
FIG 4	Spectrum of all particles at 11.7 GeV
FIG 5	Pulse height spectra in hodoscope H_1 for separation between electrons and γ rays
FIG 6	Transverse momentum spectrum of all particles (electrons and γ rays)
FIG 7	Invariant mass spectrum for uncorrelated pions
FIG 8	Resolution as a function of momentum of the spectrometer.

Fig 1


CHAMBRES A MAGNETOSTRICTION
I1
S
H1
H2
CERENKOV
AIMANT
I2
H3
CHAMBRES A GERBES
CHAMBRE A PARCOURS
COMPTEURS SANDWICH
1 m

SIDE VIEW

Fig 2



COMPTEUR CERENKOV

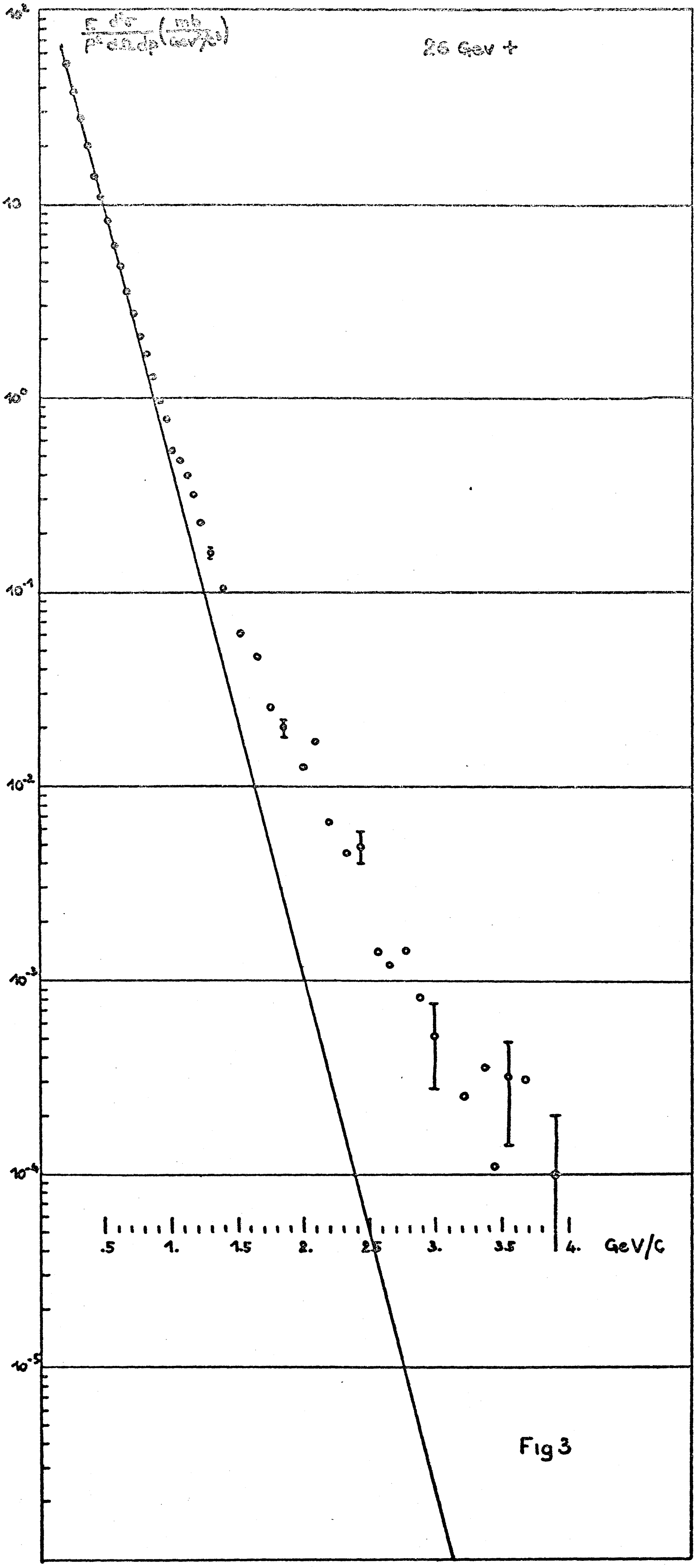

$\frac{E}{p^2}\frac{d^2\sigma}{d\Omega dp}\left(\frac{mb}{(GeV/c)^3}\right)$
26 Gev +
10^2
10
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
.5
1.
1.5
2.
2.5
3.
3.5
4.
GeV/c

Fig 3

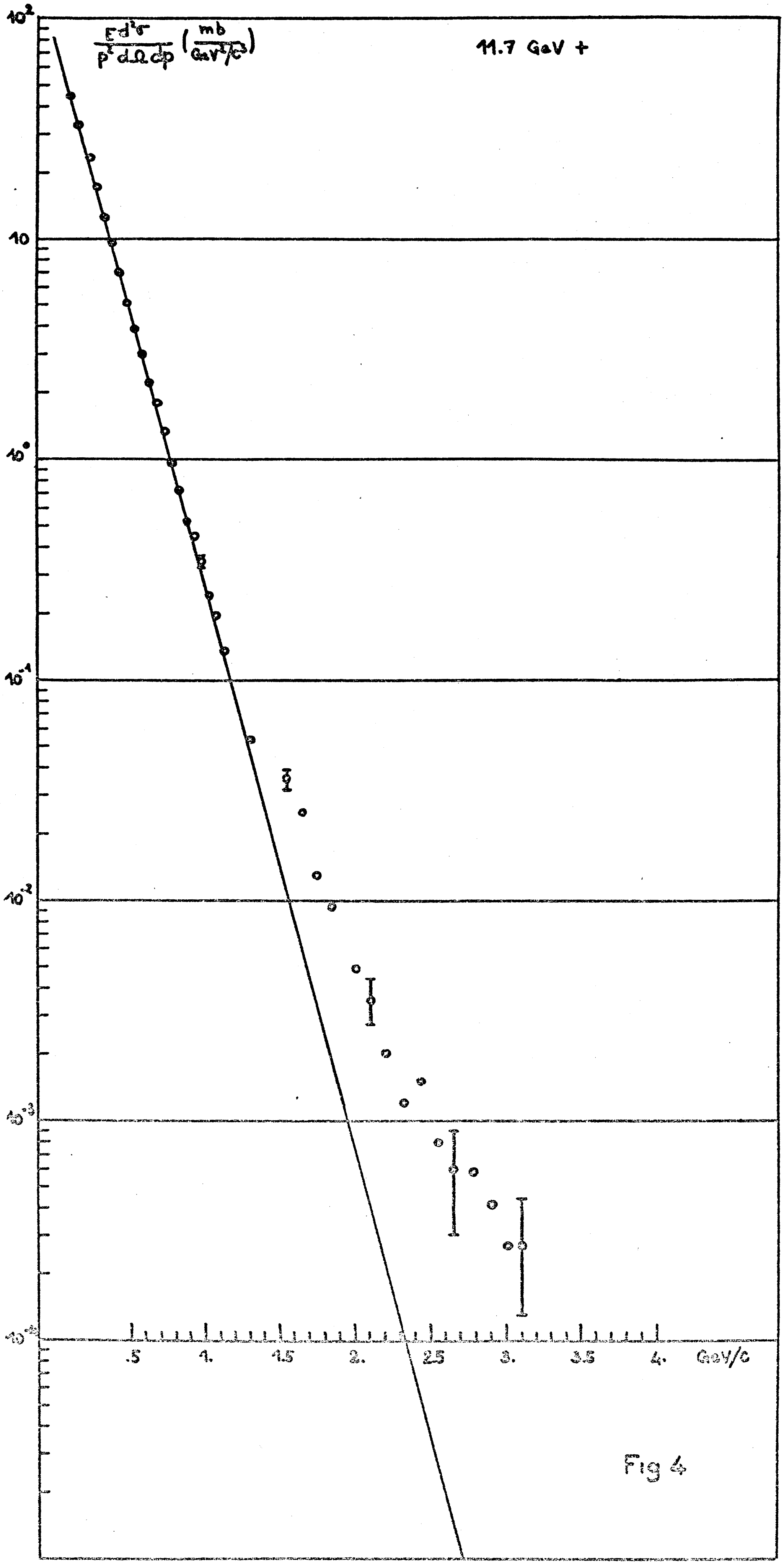
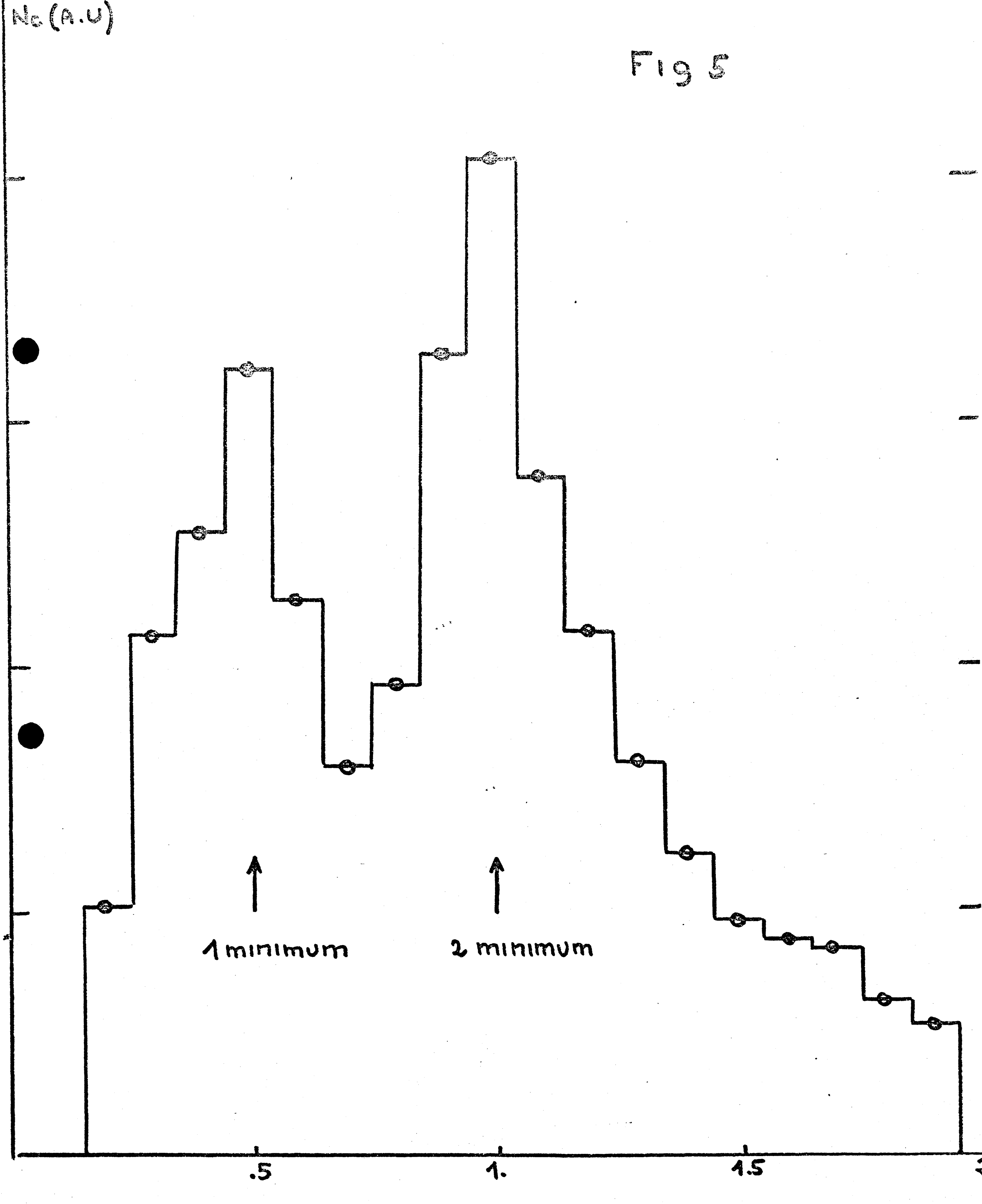
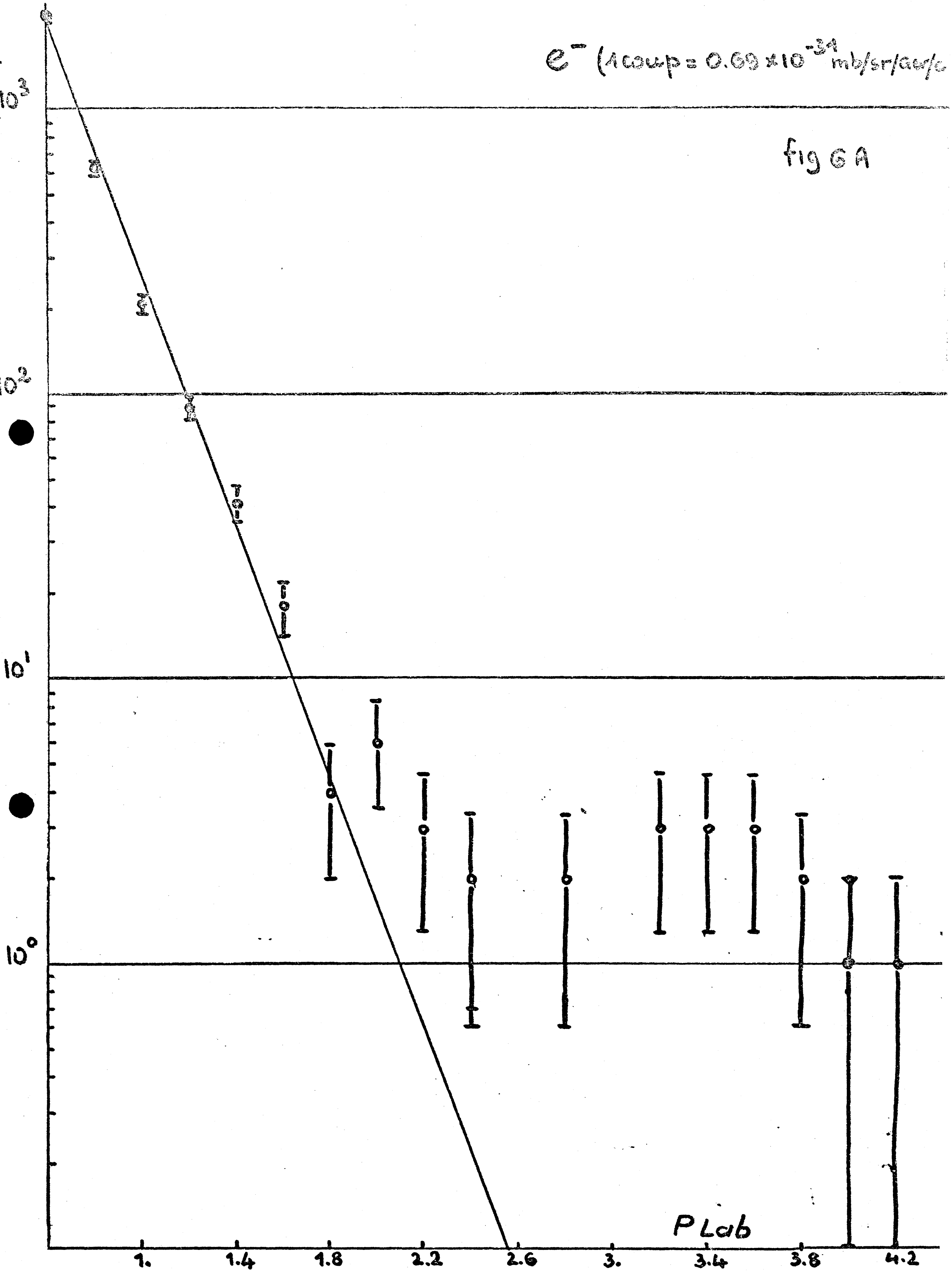

$\frac{E d^2\sigma}{p^2 d\Omega dp} \left(\frac{mb}{GeV^2/c^3}\right)$
11.7 GeV +
10^2
10
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
.5
1.
1.5
2.
2.5
3.
3.5
4.
GeV/c

Fig 4

Pulse hight spectra for 1 and 2 particles in H1

Fig 5





e^- (1coup = 0.69 x 10^{-34} mb/sr/Gev/c
10^3
10^2
10^1
10^0
P Lab
1.
1.4
1.8
2.2
2.6
3.
3.4
3.8
4.2

fig 6A

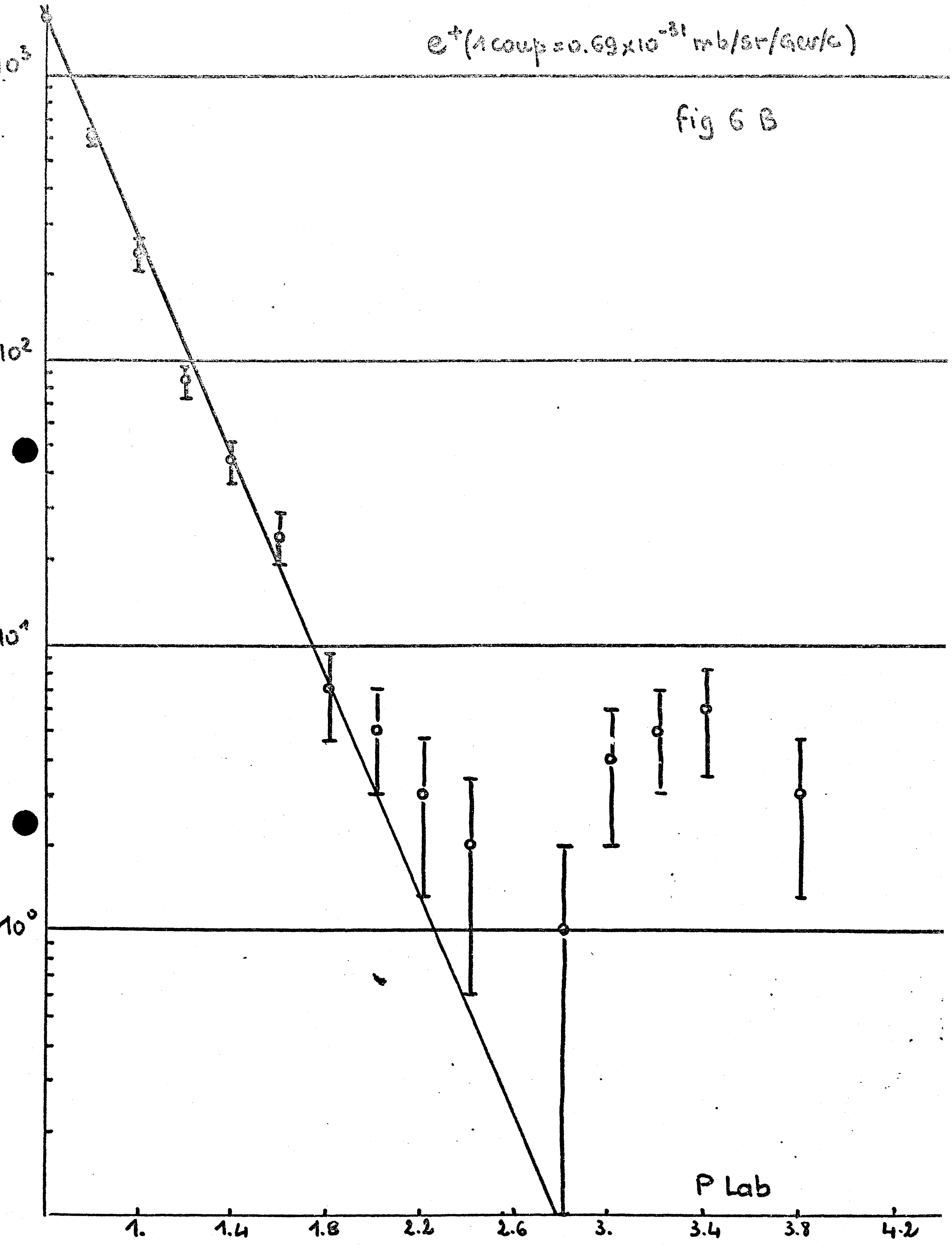
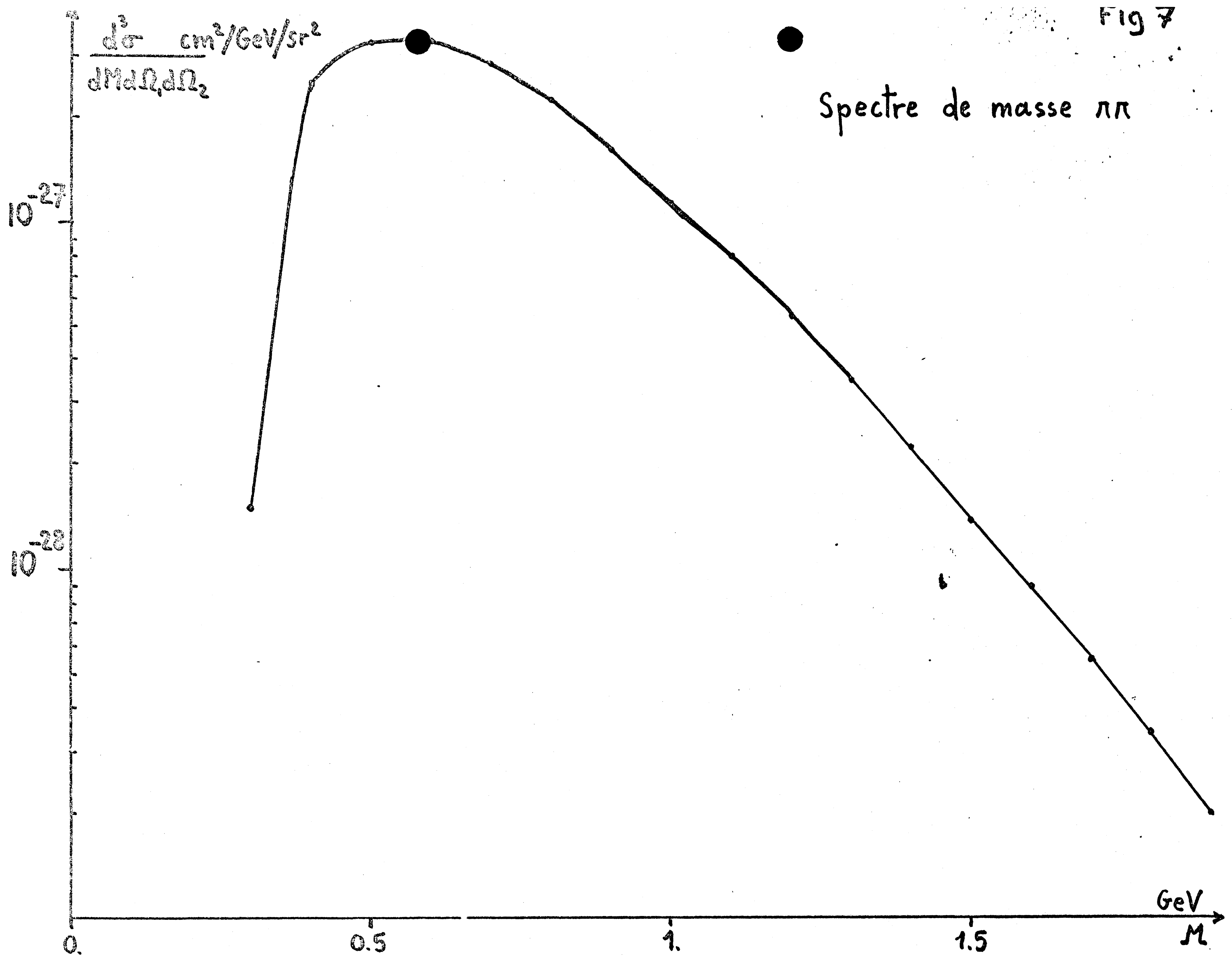


fig 6 B
e^+(1 coup = 0.69 x 10^{-31} mb/sr/GeV/c)
10^3
10^2
10^1
10^0
P Lab
1.
1.4
1.8
2.2
2.6
3.
3.4
3.8
4.2

Fig 7



Spectre de masse ππ

Fig 8.

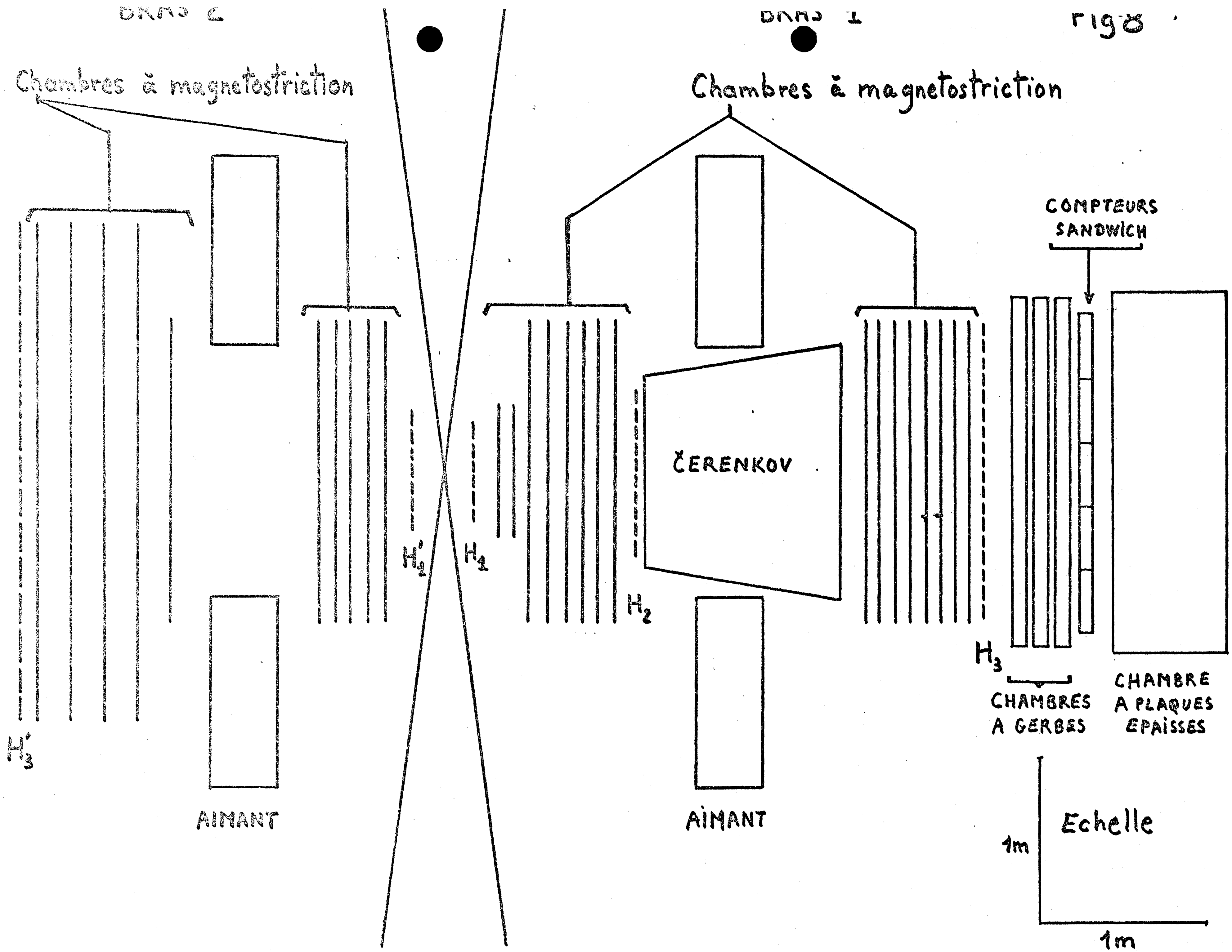

BRAS 2
BRAS 1
Chambres à magnetostriction
Chambres à magnetostriction
COMPTEURS SANDWICH
ČERENKOV
H_1'
H_1
H_2
H_3
H_3'
CHAMBRES A GERBES
CHAMBRE A PLAQUES EPAISSES
AIMANT
AIMANT
Echelle
1m
1m

Fig 9