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# A PROPOSAL TO STUDY THE INCLUSIVE PARTICLE PRODUCTION AT VERY LOW $P_t$ AND $x = 0$

by

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## INTRODUCTION

We propose an experiment to study the yield of charged particles of very low transverse momenta at $x = 0$. The motivation for this is two-fold:

1. In the regions $p_t < 0.15$ GeV/c for $\pi^\pm$ and $K^\pm$ and $p_t < 0.35$ GeV/c for p there is as yet no data from the ISR. Data down to the limits quoted have been obtained by the British-Scandinavian collaboration.[1)] In their experiment the momentum limit is set by the finite range required in the detector and in the case of protons also by difficulties in making background subtractions because of multiple scattering in the apparatus and the lack of a large beam-beam monitor in coincidence.

2. Check the breakdown of scaling. Recent exciting results from the CERN-Rome[2] and the Pisa-Stony Brook[3] groups on the increasing total proton-proton cross section $\sigma_T$ indicate that in the region $\sqrt{s}$ = 22-52 GeV there may be some new physics of strong interactions to be explored. In particular, if we integrate the $\pi^\pm$ distribution $\frac{d^3p}{E} f(p_t)$ for $p+p\to\pi+\chi$, we have[4]

$$\int \frac{d^3p}{E} f(p_t) = \sigma_T \langle n \rangle$$

where $\langle n \rangle$ is the average multiplicity. Since both $\langle n \rangle$ and $\sigma_T$ increase with s this implies that $\frac{d^3p}{E} f(p_t)$ must increase with s faster than $\sigma_T$. Thus we have the breakdown of scaling.

The specific model of Cheng and Wu[4], which predicts an $(\ln s)^2$ increase of $\sigma_T$, predicts that with $p_{\parallel} = \frac{m_\pi E^{in}}{m_p C} \ll 1$ GeV and $p_t$ less than 300 Mev/c the $\pi$ distribution function increases as $\frac{d^3p}{E} f(p_t) F(s)$, where $F(s) = s^{\frac{C}{1+2C}} (\ln s)^{\frac{2C}{1+2C}}$, with C= 0.202

from fitting $\sigma_T$ data. In the $\sqrt{s}$ = 22 - 52 GeV region scaling should be violated by 30 % or more. Present data at larger $p_t$ (Fig. 1) do not allow any conclusions on the rise with s within the rather large normalization errors of 10 %.

Experimental Set Up

The proposed set-up is shown in Figs. 2a, 2b. A simple spectrometer with six counters, six small proportional chambers and a bending magnet will be used. It is essential to measure the momentum distribution as low as possible where the pionization is predicted to be energy dependent. The low momentum limit is set by the range of the particle in the wall of the vacuum chamber and in the counters of the spectrometer. The counters will be made very thin (appr. 1 mm, see App. I) and in addition we would like a window on the vacuum chamber. as thin as possible (e.g. 0.05 mm titanium and size 30 x 3 $cm^2$). The two proportional chambers in front enable narrow vertical limits on the beam-beam interaction region to be applied, thus minimizing the beam-wall background subtraction.

The magnet is used for the momentum analysis. This could be a permanent magnet shown in Figs. 3a, 3b. This magnet would give a 9.5 degree bend to a 200 MeV/c momentum particle (the pole piece is 15 x 50 $cm^2$ and the gap is 10 cm). A simple mechanical arrangement would be sufficient for the polarity reversal and also for the change in length of the spectrometer when going from one region of the momentum to another. The anticipated momentum range could be covered by only two settings. These mechanical complications could be avoided by using a powered magnet.

The trigger will be defined as the coincidence $C_1C_2C_3\bar{C}_5$ or $C_1C_2C_4\bar{C}_6$. Particles are identified using time of flight between the counters 1, 2 and (3 or 4). Counters 5 and 6 are used to veto events which decay into a μ of momentum > 300 MeV/c (with 155 grams per $cm^2$ of lead). The momentum is determined from the bend in the magnet with the proportional chambers 2,3,4 and (5 or 6). The bending is in the vertical plane. This allows the spectrometer to see only a small region along the beams and enables us to reduce beam-gas and beam-wall backgrounds.

In the non-bending plane all non-decaying particles essentially follow a straight line - decayed particles can be easily rejected ( < 5 % contamination).

The dimensions of the counters are foreseen to be:

| Counter # | C1 | C2 | C3,C4 | C5,C6 |
|---|---|---|---|---|
| Width (cm) | 30 | 10 | 30 | 35 |
| Height (cm) | 1 | 10 | 15 | 20 |
| Thickness (cm) | 0.1 | 0.1 | 0.5 | 0.5 |

The following table lists some of the parameters affecting the resolving power of the apparatus. We give the initial cms and laboratory momenta, $p_t$ and $p_1$, the range and then the mean measured value $p_2$ of the momentum, after energy loss in the walls of the vacuum tube and the first counter and proportional chambers. For the momentum $p_2$ we give the r.m.s. scattering angle $\theta_s$, in the equivalent of 2 mm of scintillator and the bending angle in the magnet of fig. 2, $\theta_b$. From these we calculate the momentum resolution (the error from the wire chamber resolution is negligible). The energy loss has an asymmetric Landau distribution, with a long tail. In the last two columns we list the momentum $p_3$ in the tail beyond which lies only the last 10% of the distribution, and the fractional difference between this and the most probable momentum at $C_2$.

| Particle | $p_t$ x) MeV/c | $p_1$ MeV/c | Range g/cm$^2$ | $p_2$ MeV/c | β | $\theta_s$ mr | $\theta_b$ mr | $\frac{dp}{p}$ % | $p_3$ (90%) MeV/c | $\frac{p_2-p_3}{p_2}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| π | 45.8 | 66.4 | 1.3 | 59.8 | .40 | ~50 | 564 | ~ 8.9 | 56.9 | .048 |
| π | 63.4 | 85.3 | 3.0 | 82.2 | .51 | ~30 | 411 | ~ 7.3 | 80.8 | .017 |
| p | 116 | 243 | 1.0 | 218 | .23 | ~25 | 155 | ~ 16 | 203 | .067 |
| p | 171 | 301 | 2.2 | 291 | .30 | ~15 | 166 | ~13 | 284 | .023 |

x) this assumes that the cms of the beams is moving towards the apparatus.

Fig. 4 gives the Monte Carlo results on acceptance in the vertical angle $\phi$ and momentum of the particle on the laboratory system. The lab. momentum accepted ranges from 65 to 450 MeV/c and the horizontal angular acceptance $\theta_\pi$ is 214 mr. The vertical angular acceptance is $\pm$50 mr.

Particle identification

In this experiment it is necessary to identify particles in the momentum range 45-450 MeV/c. The Table below summarizes some properties of 65, 200 and 450 MeV/c particles which have to be considered when discussing the detection system.

| Particle | Laboratory Momentum MeV/c | β | Time of flight* nsec | % decay |
|---|---|---|---|---|
| π | 65 | .4 | 10.8 | 35 |
| | 200 | .820 | 5.3 | 10.5 |
| | 450 | .955 | 4.55 | 5.0 |
| K | 200 | .375 | 11.5 | 42 |
| | 450 | .674 | 6.4 | 27 |
| P | 200 | .208 | 20.8 | - |
| | 450 | .432 | 10 | - |

*) An overall time-of-flight distance of 130 cm has been assumed

From the table we conclude that within the momentum range, 65 < p < 450 MeV/c, there is no problem in distinguishing

$\pi$, K and p by TOF. Using the fine spatial resolution of the proportional chambers one can reject all the decay particles with decay angles greater than 5 mr in the horizontal plane. Thus the only decay contamination will come from particles decaying before they reach the first proportional chamber. The decay probability is about 10% of the values listed in the above table and therefore is tolerable.

Background subtraction and monitoring

Recent analysis of the British-Scandinavian experiment of the background (beam-bas and beam-wall interaction subtraction) has shown that the pion and proton backgrounds go as $(p^2/E)\exp(-10\ p_t)$ and $(p^2/E)\exp(-8.5\ p_t)$ respectively, while the signal has a much less steep momentum dependence (slopes of -6 and -4.5 around $p_t = 0.5$ GeV/c). This means that the background subtraction becomes increasingly more severe at low momenta. For protons the subtraction in the British-Scandinavian experiment is typically 50% at $p_t \approx 0.35$ GeV/c. For pions the problem is less severe, the background being less than 10 % at $p_t \simeq 0.13$ GeV/c. One way to reduce this problem (beam-wall interaction) is to be able to apply very strict cuts on the beam height by reducing the multiple scattering in the front part of the apparatus ( i.e. mainly to have a thin window on the vacuum chamber) and thus being able to do an accurate extrapolation of the trajectory towards the source. Another way to circumvent this problem is to select off-line only events simultaneous with a beam-beam indication in the monitor. Since all monitors are finite in size events selected this way will however be biased. To minimize the possible bias one needs a monitor sensitive to all beam-beam events if possible. We therefore propose to add around the two downstream beam pipes ( if not already available) two large planes of counters rather close to the intersection and a smaller plane of counters further away. We hope to be capable of measuring beam luminosity by the Van der Meer method with the same accuracy as the CERN-Rome group, i.e. an absolute normalization of 2.5 % for all ISR energies.

Summary

The proposed experiment would give an important complement to the data on inclusive particle production at the ISR. We request 100 hours of running, at each energy, with narrow beams (Terwilliger or beam widths less than 25 mm). An even intersection region would therefore be preferred. For this case also the downstream monitor can be placed far away from the intersection thus intercepting most of the forward scattered particles. It is of course essential that the cms motion is towards the spectrometer. We require a modified vacuum chamber with a thin exit window at $90^{o}$. The apparatus can be ready about 6 months after the approval and could therefore be installed during the January 1974 shutdown. For some of us it is essential that the data-taking can take place during the first half of 1974.

## APPENDIX 1

### Scintillation Counter Hodoscopes

Many tests have been carried out at MIT to see how thin scintillation counter hodoscopes can be made while still 100 % efficient at the far end. The purpose of this is to ensure that as little scattering material is presented to the particles being detected as possible to reduce the effects of multiple scattering and hence improve the accuracy of vertex reconstruction.

The dimensions of the counter are shown in Fig. 5. The results presented refer to the case where an Amperex 56DVP photomultiplier together with a Nucletron Base were used.

The method of testing is shown in Fig. 6. A telescope of three scintillation counters (two above, one below) were used to measure the efficiency. The efficiency was then defined as the number of fourfolds versus the number of threefolds. In order to simulate the experimental conditions expected in our experiment, a Le Croy 321B discriminator with a nominal threshold of -50mv was used together with approximately 61 m of RG8 foam cable between the counter and the discriminator.

The results of the test are shown in Fig. 7 where the efficiency is plotted as a function of the applied voltage. It can be seen that the knee is about 1850 v so a safe working voltage for this counter would be 2100v.

REFERENCES

1) B. Alper et al., Proc. of the Vanderbilt International Conference on New Results from Experiments on High Energy Particle Collisions, Nashville, Tennessee, 1973.

2) U. Amaldi et al., CERN preprint 1973.

3) S.R. Amendolia et al., CERN preprint 1973.

4) Private communication with H. Cheng and T.T. Wu. To be published in Physics Letters.

FIGURE CAPTIONS

Fig. 1 s and $p_t$-dependence of the invariant cross section for $\pi^+$ at $x=0$ (Ref. 1).

Fig. 2 Experimental arrangement.

Fig. 3a Permanent magnet. All dimensions are in mm.

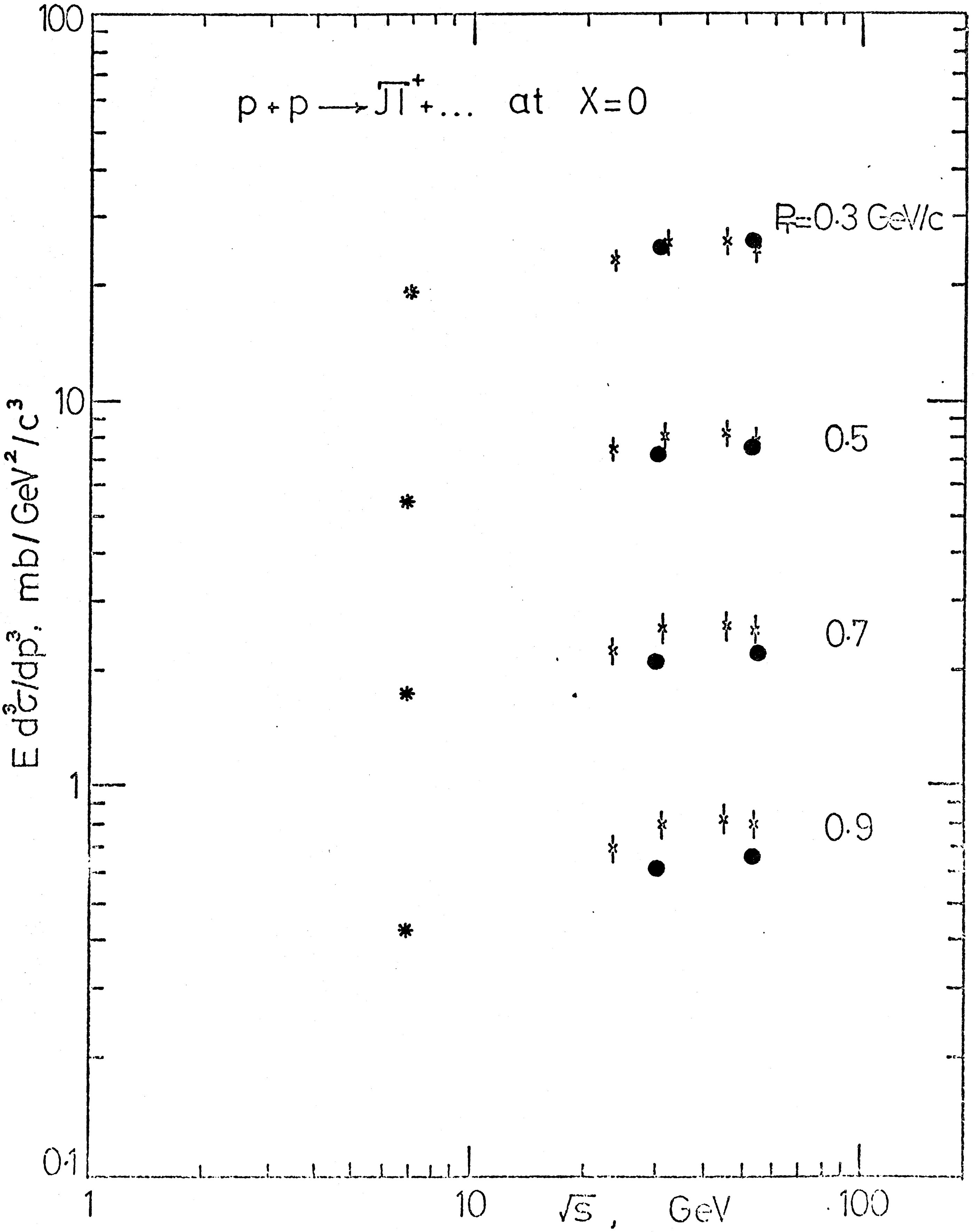
Fig. 3b Magnetic field distribution of the permanent magnet.

Fig. 4 Monte Carlo result on acceptance of the proposed arrangement.

Fig. 5 Arrangement for testing the efficiency of the thin counter.

Fig. 6 Efficiency of the thin counter as function of voltage.

Fig. 7 Efficiency of thin counter as function of voltage.



p + p ⟶ π⁺ + ... at X=0
P_T=0.3 GeV/c
0.5
0.7
0.9
E d³σ/dp³, mb/GeV²/c³
100
10
1
0.1
1
10
100
√s , GeV


Fig. 1

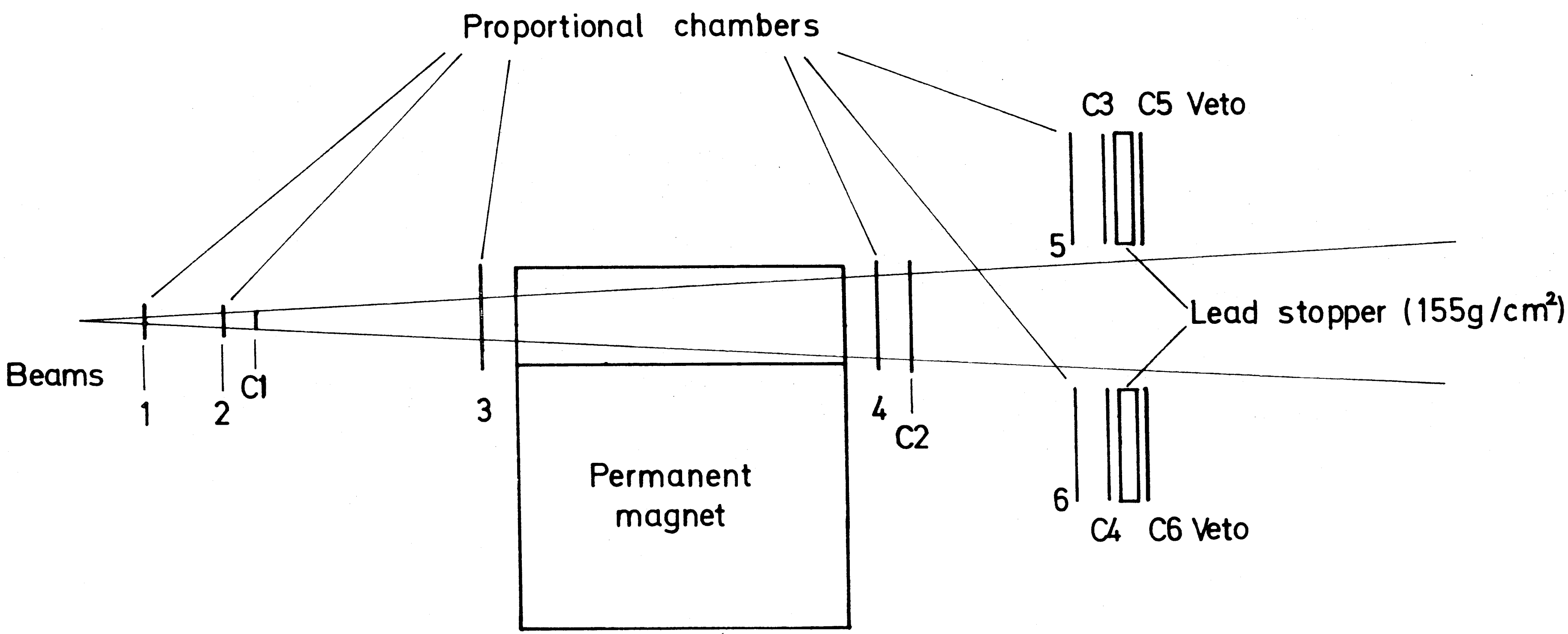



Fig. 2a
Side view of the detector. $C_i$ are counters.

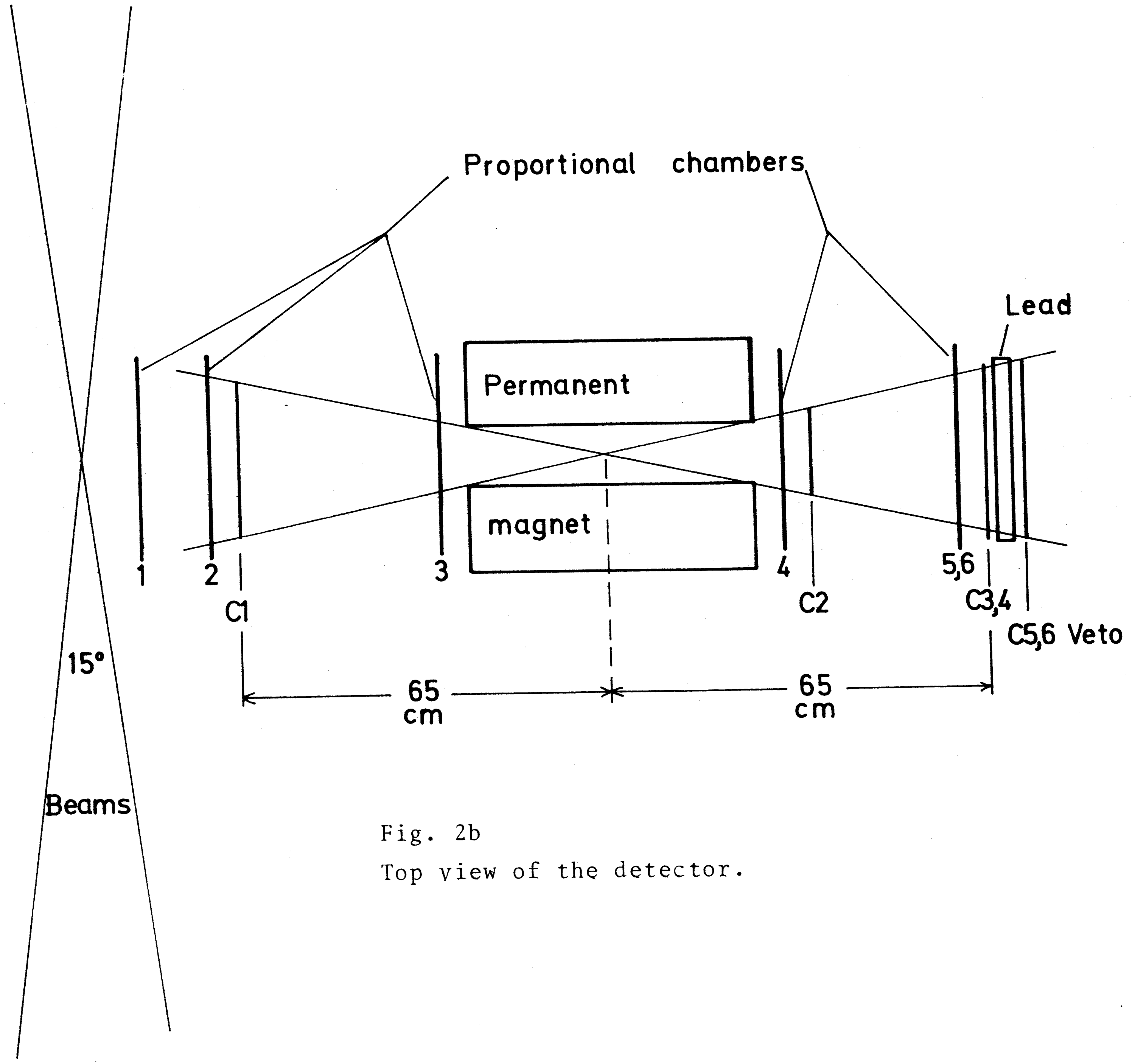
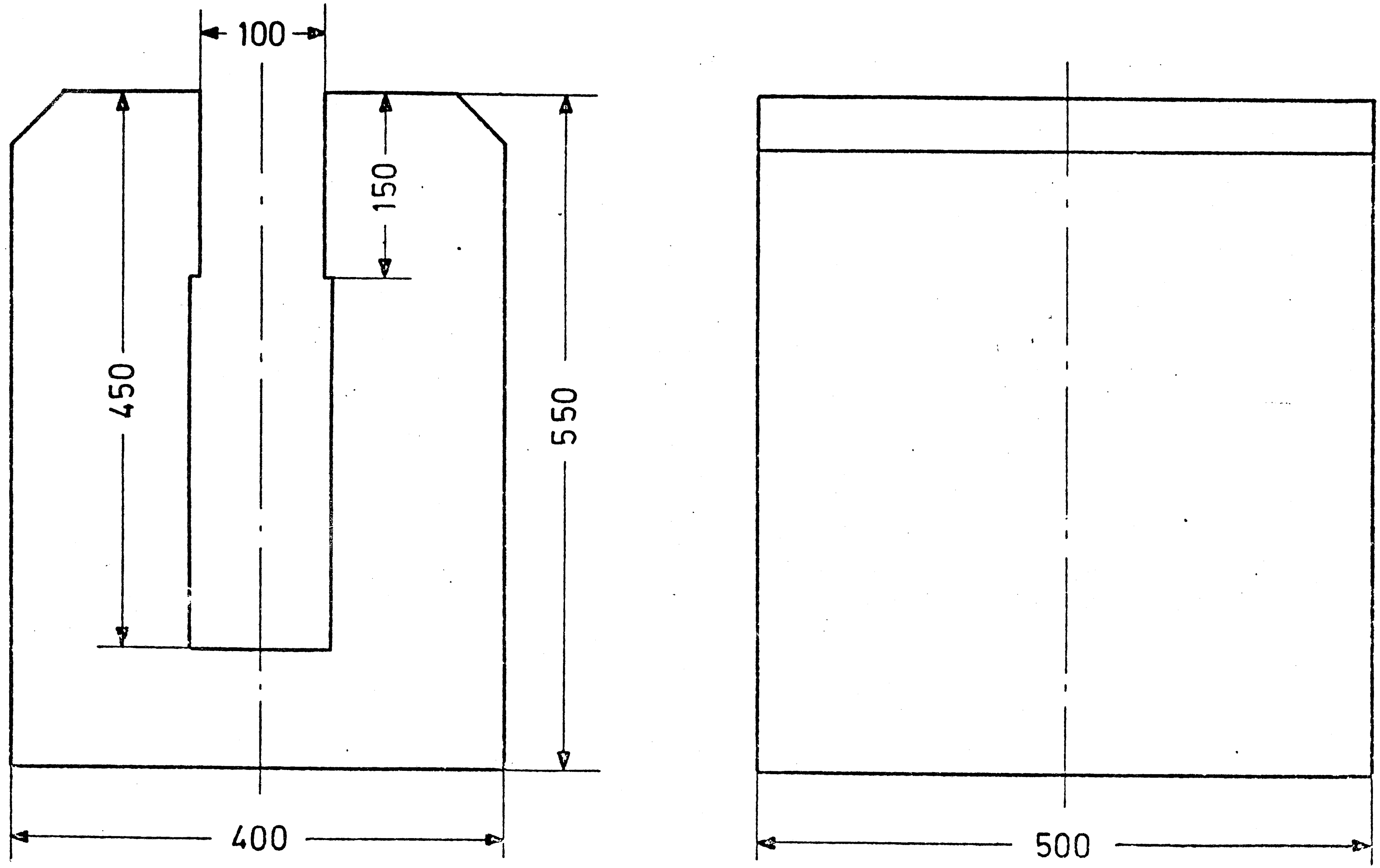



Fig. 2b
Top view of the detector.




PERMANENT MAGNET

Fig. 3a

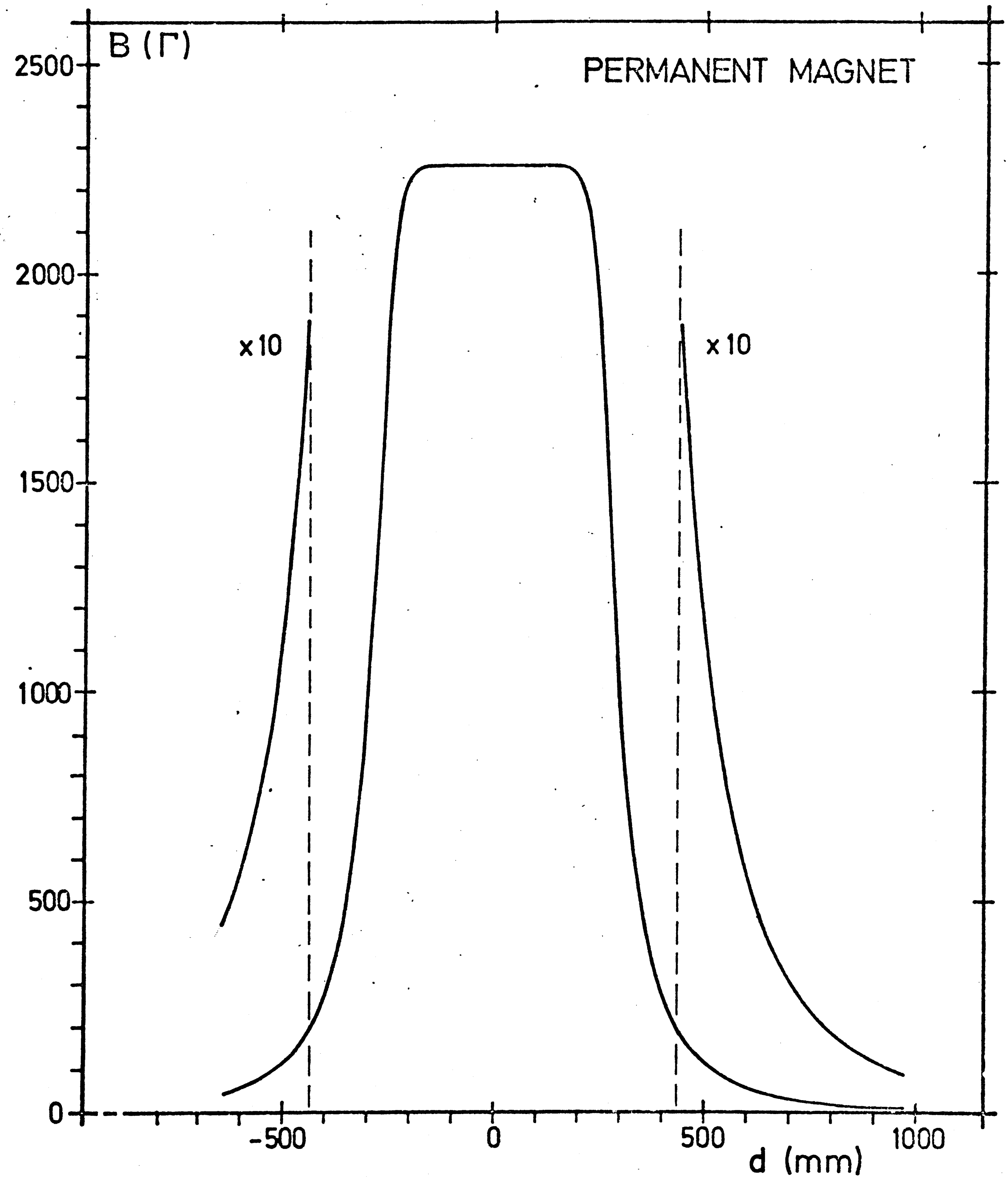

B (Γ)
PERMANENT MAGNET
2500
2000
1500
1000
500
0
x10
x10
-500
0
500
1000
d (mm)

Fig. 3b

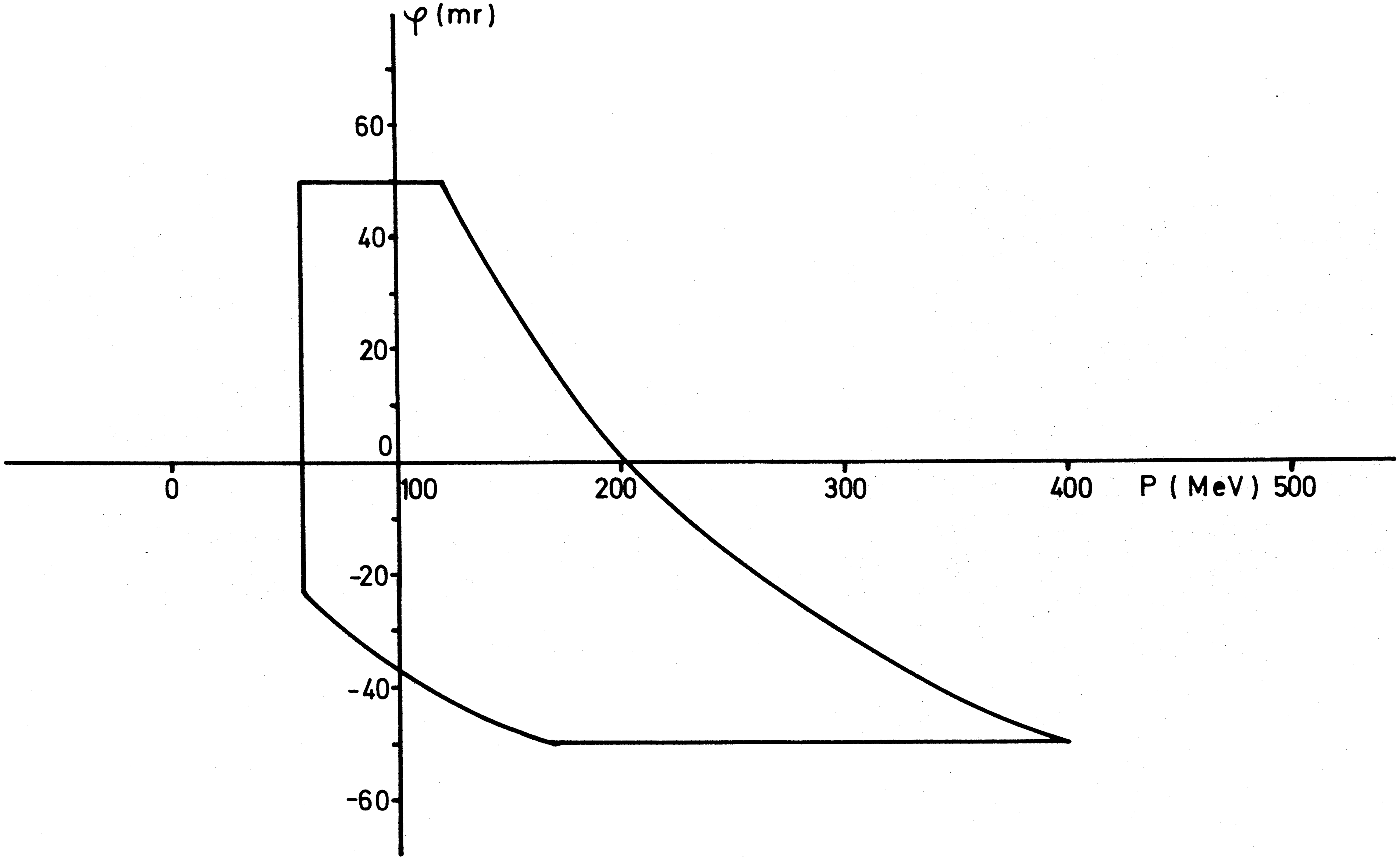



Fig. 4
Acceptance window (P~φ)

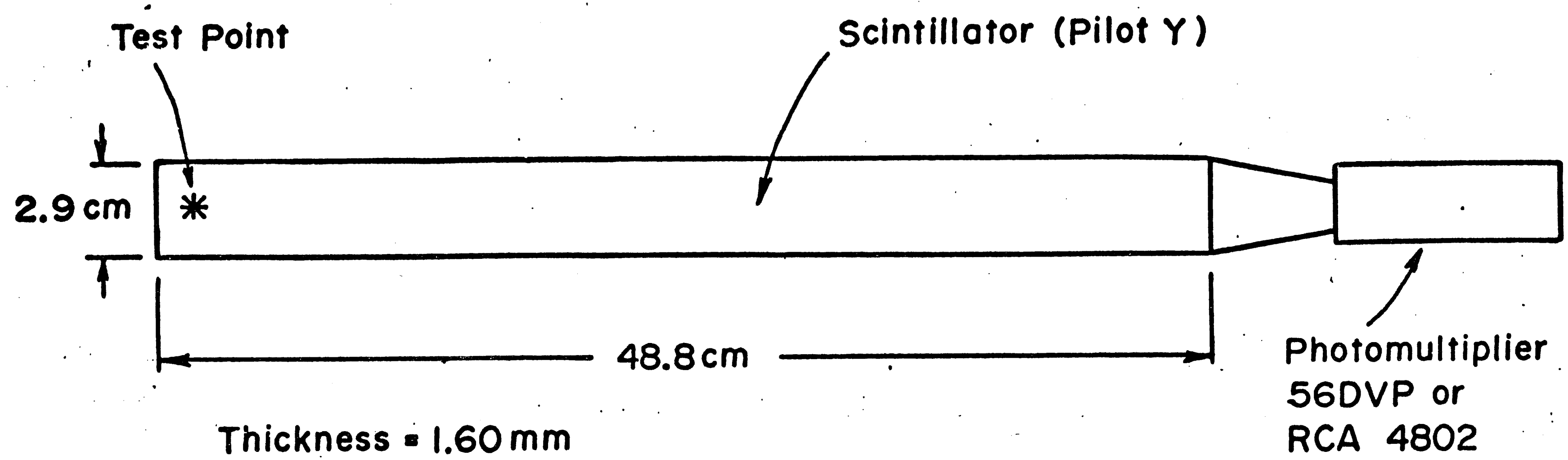
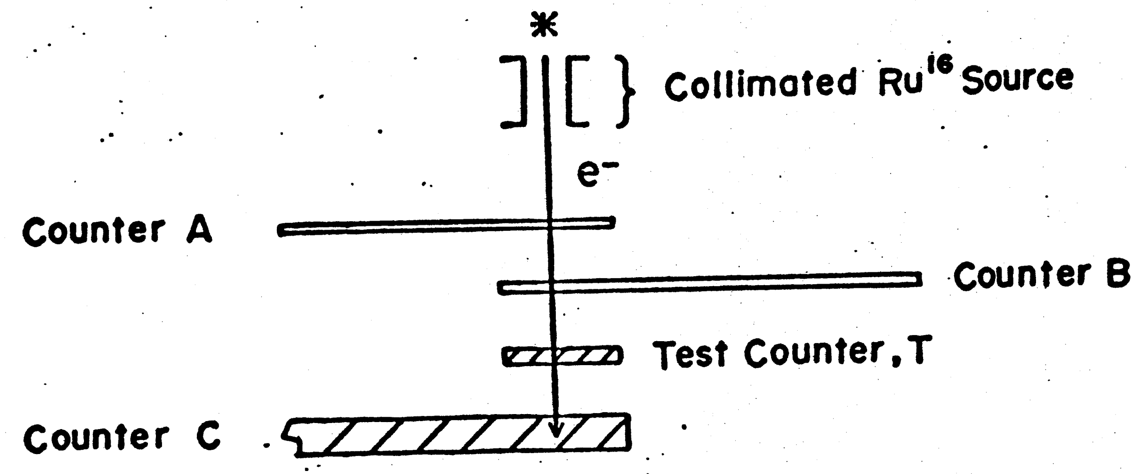

Test Point
Scintillator (Pilot Y)
2.9 cm
48.8 cm
Thickness = 1.60 mm
Photomultiplier
56DVP or
RCA 4802

Fig. 5




$$\text{Efficiency of Test Counter} = \frac{A \cdot B \cdot C \cdot T}{A \cdot B \cdot C}$$

Fig. 6

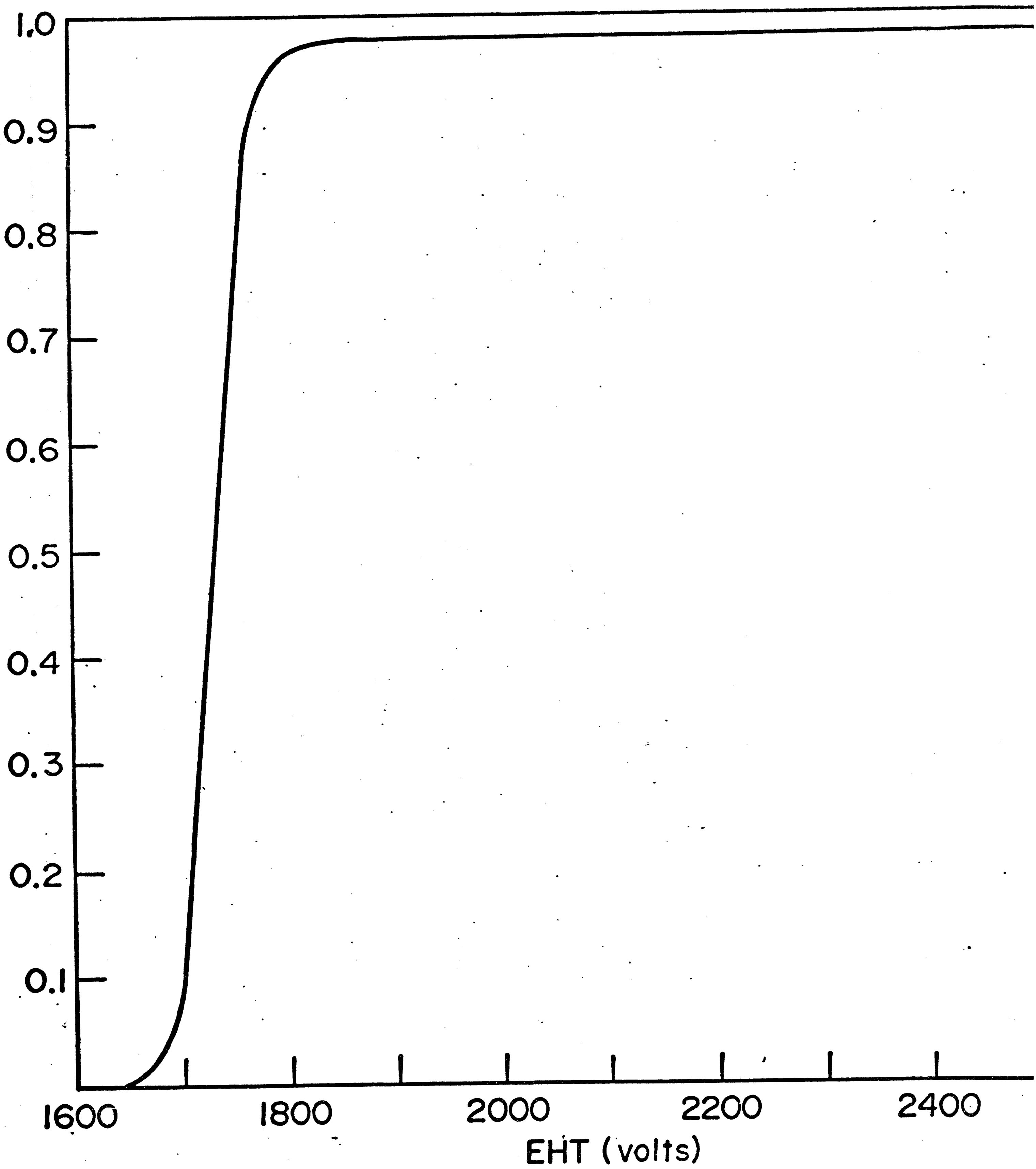



Fig. 7