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BEAM LINE FOR THE 84 cm HYDROGEN BUBBLE CHAMBER AT DESY

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Abstract

A photon beam for use with the 84 cm hydrogen bubble chamber at DESY has been built. The properties and operation of the beam together with the bubble chamber will be described.

Introduction

The properties of the photon beam required for the first experiments of the bubble chamber are the following: Fairly low, but easily and quickly adjustable intensity, a geometrical shape, such as to give a uniform distribution of events in the chamber, and a negligible contamination by other particles. The simplest possibility is to produce an electron or positron beam with a well defined momentum, and to use the bremsstrahlung of this beam from a thin target.

Set Up and Results

A photon beam coming from an internal accelerator target strikes a secondary target (T_1) at the point where the photon beam leaves the accelerator vacuum. Pair production in this target serves as a source of positrons and electrons. The following beam line is determined mainly by geometrical restrictions, namely the position of the bubble chamber and the shielding wall between the synchrotron and the experimental hall.

Fig. 1 shows the final arrangement of the beam consisting of three parts, first a doublet of quadrupoles (QB1, QB2) and a bending magnet MB1 which together produce a momentum analysed electron (positron) beam with $\frac{\Delta p}{p} \approx \pm 1\,\%$ at the collimator K 2. Secondly a doublet (QD1, QD2) and a bending magnet (MB2) are used to obtain the desired beam profile and to direct the beam into the bubble chamber. The electron (positron) beam strikes target T_2 to produce bremsstrahlung and is then swept away by magnet (MB3). The photon beam passes through a beam hardener inside a magnet (MA1) with $\simeq$ 9 kΓ (solid LiH, ∅ 10 cm, 0.6 - 0.8 radiation lengths), a collimator K 3 and a final cleaning magnet (MB4). This beam is completely symmetrical with respect to positrons and electrons.

The exact positions of the magnets, the magnitude and the sign of their currents have been calculated with the help of an analog computer. Polaroid pictures of the photon beam from the accelerator target (T_0) gave a rough estimate for the initial conditions

$$\begin{pmatrix} z \\ z' \end{pmatrix} = \begin{pmatrix} y \\ y' \end{pmatrix} = \begin{pmatrix} 1.0 \\ 1.0 \end{pmatrix} \begin{matrix} \text{cm} \\ \text{mrad} \end{matrix}$$

in the horizontal (z) and vertical (y) plane respectively. Fig. 2 shows a typical polaroid picture of the photon beam together with two lines produced by synchrotron radiation.

The final beam was required to have the form of a very flat upright standing ellipse following the form of the bubble chamber windows and to be as parallel as possible, at least with an angular divergence smaller than 3 mrad, because the direction of the photons should be known better than the measuring error on the bubble chamber pictures.

Fig. 3 and Fig. 4 show the calculated beam envelopes for the two perpendicular beam directions z (horizontal) and y (vertical). According to this calculation and taking into account multiple scattering of the electrons before making bremsstrahlung in the conversion target (T_2) one expects at the bubble chamber position

$$\begin{matrix} z \\ z' \end{matrix} = \begin{matrix} 1.8 \\ 2.5 \end{matrix} \quad \text{and} \quad \begin{matrix} y \\ y' \end{matrix} = \begin{matrix} 8.5 & \text{cm} \\ 1.2 & \text{mrad.} \end{matrix}$$

For comparison Fig. 5 shows the distribution of the origin of electron positron pairs in the bubble chamber, Fig. 6a and 6b the angular distributions of Dip and Phi, which are essentially the projected angles in the horizontal and vertical plane. Agreement with the calculated values is fairly good, but regarding the angular spread, no real conclusion can be drawn, because the width of the distributions (see Fig. 6a,b) is of the order of the measuring errors.

To determine the energy spectrum of the photon beam electron-positron-pairs were measured on the bubble chamber pictures. These measurements give a photon energy spectrum as shown in Fig. 7. The continuous curve represents a thin target bremsstrahlungs-spectrum. The deviations of the measured distribution from this curve show the influence of the beam hardener. The reason for using a beam hardener is to reduce the proportion of low energy photons. This gives a better ratio for nuclear events to electromagnetic background. Comparison of pictures with and without LiH shows a reduction of the number of Compton electrons by roughly a factor of two, so that the number of Compton electrons and electron positron pairs are approximately equal with LiH. Placing the LiH inside a magnetic field (MA1 in Fig. 1) leads to a further reduction of low energy photons in the beam[(1)], because secondary bremsstrahlung now has in most cases the wrong direction and will be absorbed in the collimator K 3 as is the case for Compton scattered photons.

This beam has been operated together with the 84 cm Hydrogen Bubble Chamber at DESY for approximately 1 ooo ooo pictures at beam momenta of 5.35 Gev/c and 5.8 Gev/c. In order to compensate for slow intensity variations of the accelerator, targets T_1 and T_2 can be changed by remote controll with a choice of six different target thicknesses. Furthermore the intensity shows a strong dependence on the width of the remotely controlled collimator K 1 which in most cases was used for intensity controll (Fig. 8).

For monitoring the number of particles in the beam, the output of a scintillation counter Z 2 placed in the deflected electron beam behind target T_2 was integrated and observed on an oscilloscope.

The flux of photons through the bubble chamber is limited by the number of pairs on the pictures which can be tolerated for reliable scanning and measuring of the nuclear events. This number is about 12 in a scanning volume of 47 cm length, and corresponds to about 70 equivalent photons for a maximum energy of 5.8 Gev. Taking into account the beam hardener of 0.6 radiation units and a target thickness at T_2 of $\frac{1}{15}$, the required number of electrons is $2 \cdot 10^3$ per

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pulse. This number has been reached for example for the following conditions:

Synchrotron energy	E_o	6.0 Gev
Beam energy	E	5.8 Gev
with	$\frac{\Delta E}{E}$	$\pm$ 0.5 %
Target	T_o	0.07 r.l.
	T_1	0.42 r.l.
	T_2	0.07 r.l.
Collimator	K 1	10 mm
	K 2	15 mm
	K 3	30 mm
Number of electrons in the synchrotron per pulse		10^{10}
Spill out time		20-50 μsec

To synchronize the bubble chamber with the accelerator an accelerator cycle clock giving two signals is used. The first signal starts the expansion system 3 cycles (60 msec, with an additional variable delay) before the beam pulse for the bubble chamber is produced. The second signal starts the flash of the bubble chamber shortly after the beam has passed through the bubble chamber. Fig. 9 illustrates these timing conditions.

Acknowledgments

We wish to thank the members of the Synchrotron group, the "Hallendienst", and the group M6 for their excellent service. We are particularly grateful to Mr. G. Knies for building the timing electronics. We also wish to thank Miss Borchardt for help with the analogue computer.

Figure Captions

Fig. 1 Arrangement of the beam elements

Fig. 2 Polaroid picture of a photon beam

Fig. 3, 4 Beam envelope in the horizontal and vertical direction respectively

Fig. 5 Distribution of the origin of electron positron pairs in the bubble chamber

Fig. 6a,b Angular distribution of the photon beam in the horizontal and vertical plane respectively

Fig. 7 Energy spectrum of the photon beam

Fig. 8 Relative intensity in the photon beam as a function of the collimator K 1

Fig. 9 Timing conditions between the synchrotron and the bubble chamber.

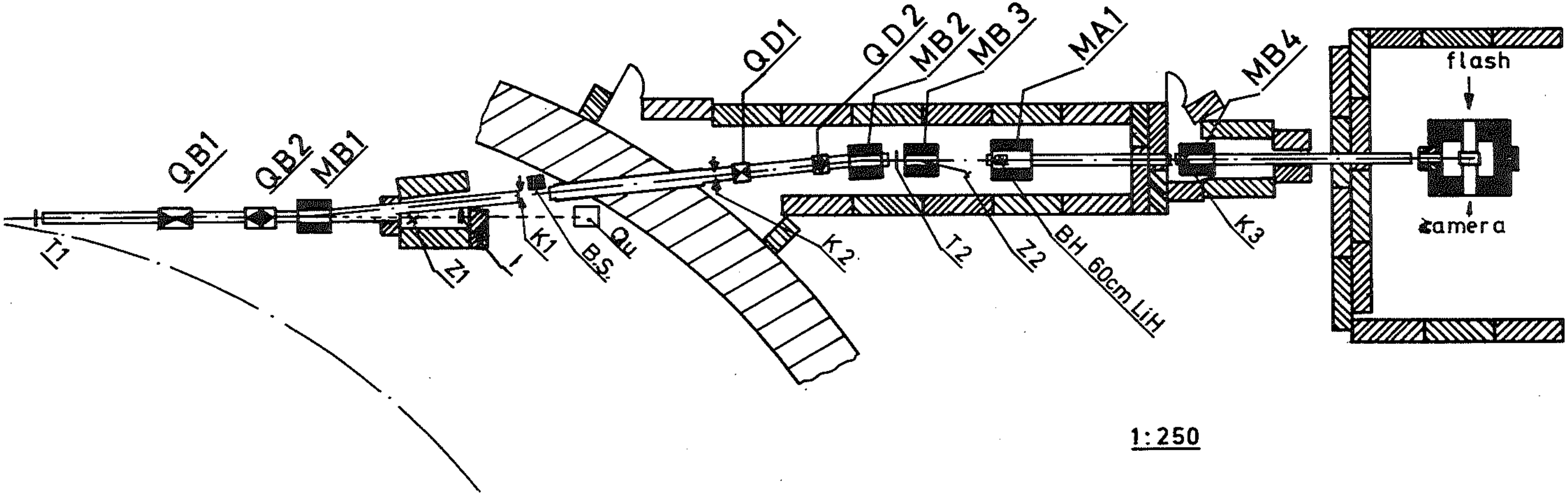
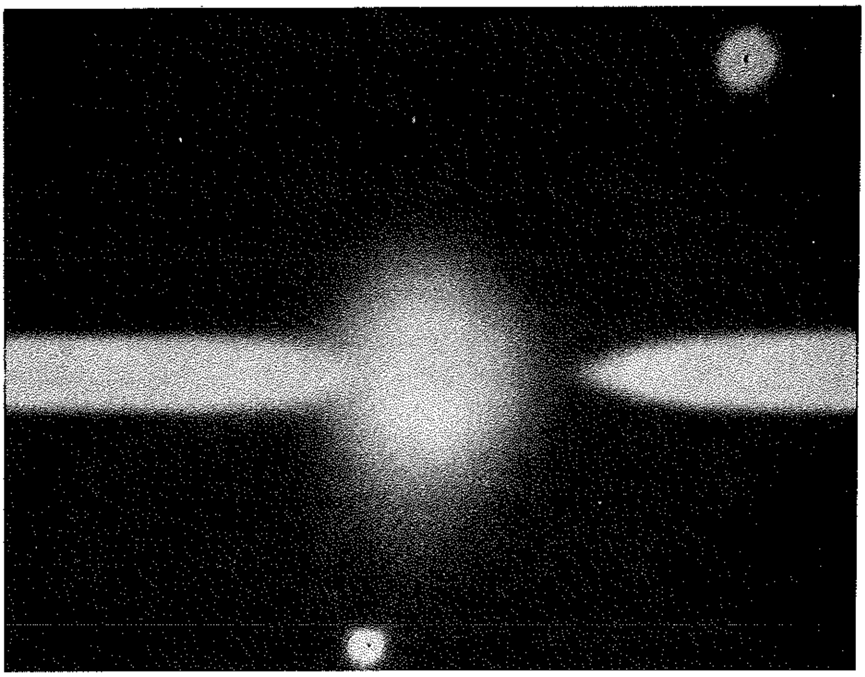

QB1
QB2
MB1
QD1
QD2
MB2
MB3
MA1
MB4
flash
camera
T1
Z1
K1
B.S.
Qu
K2
T2
Z2
BH 60cm LiH
K3
1:250

FIG. 1

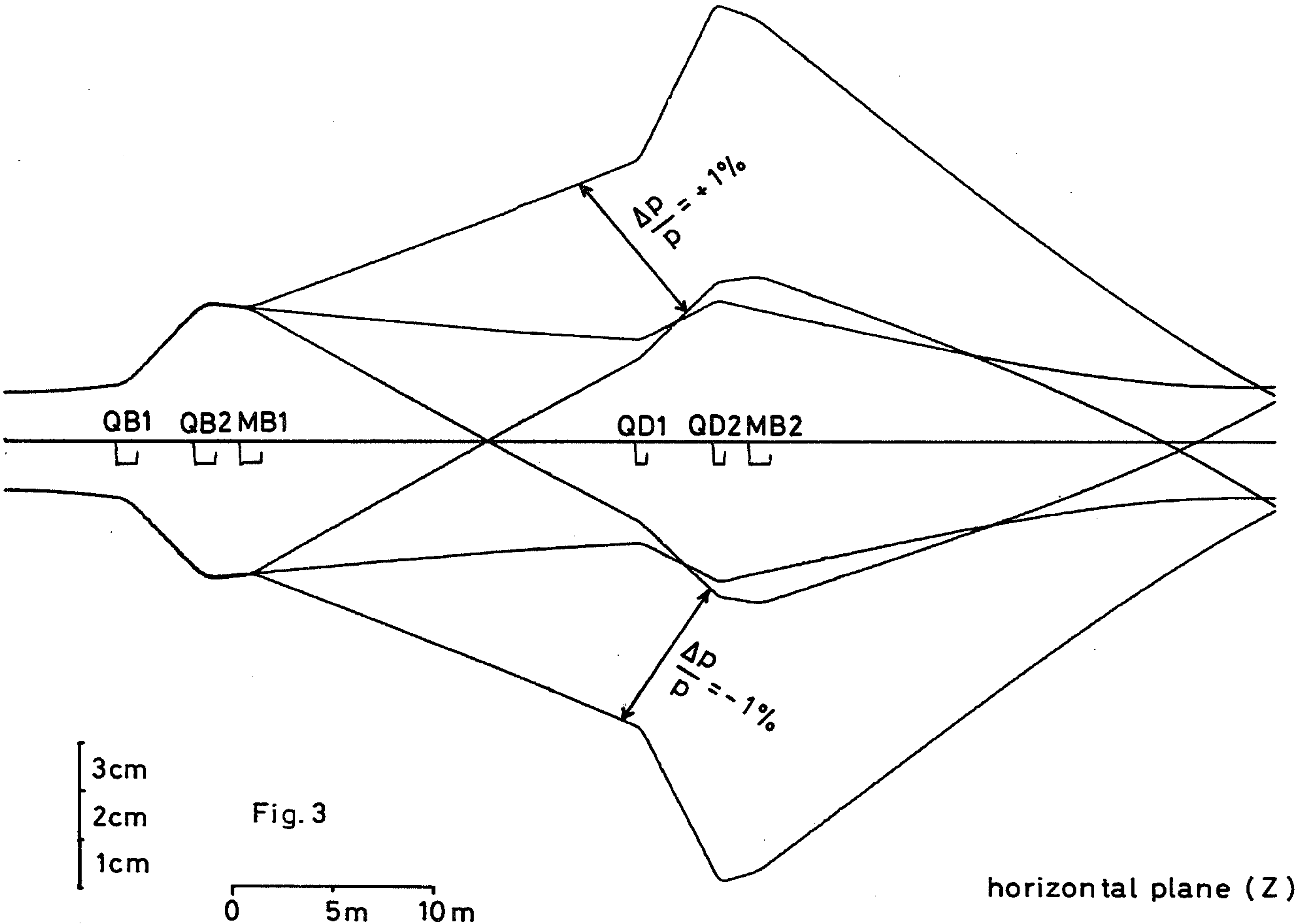
Fig. 2



Cross Section of a Photon Beam

11 meters downstream from the machine target T_o, at 3.6 Gev/c

The two lines at the right and left are produced by synchrotron radiation. The gap in the radiation as shown on this picture is caused by reduced emission in the region of the fringing field of the magnets.



$\Delta p / p = +1\%$
QB1
QB2
MB1
QD1
QD2
MB2
$\Delta p / p = -1\%$
3cm
2cm
1cm
0
5m
10m
horizontal plane (Z)

Fig. 3

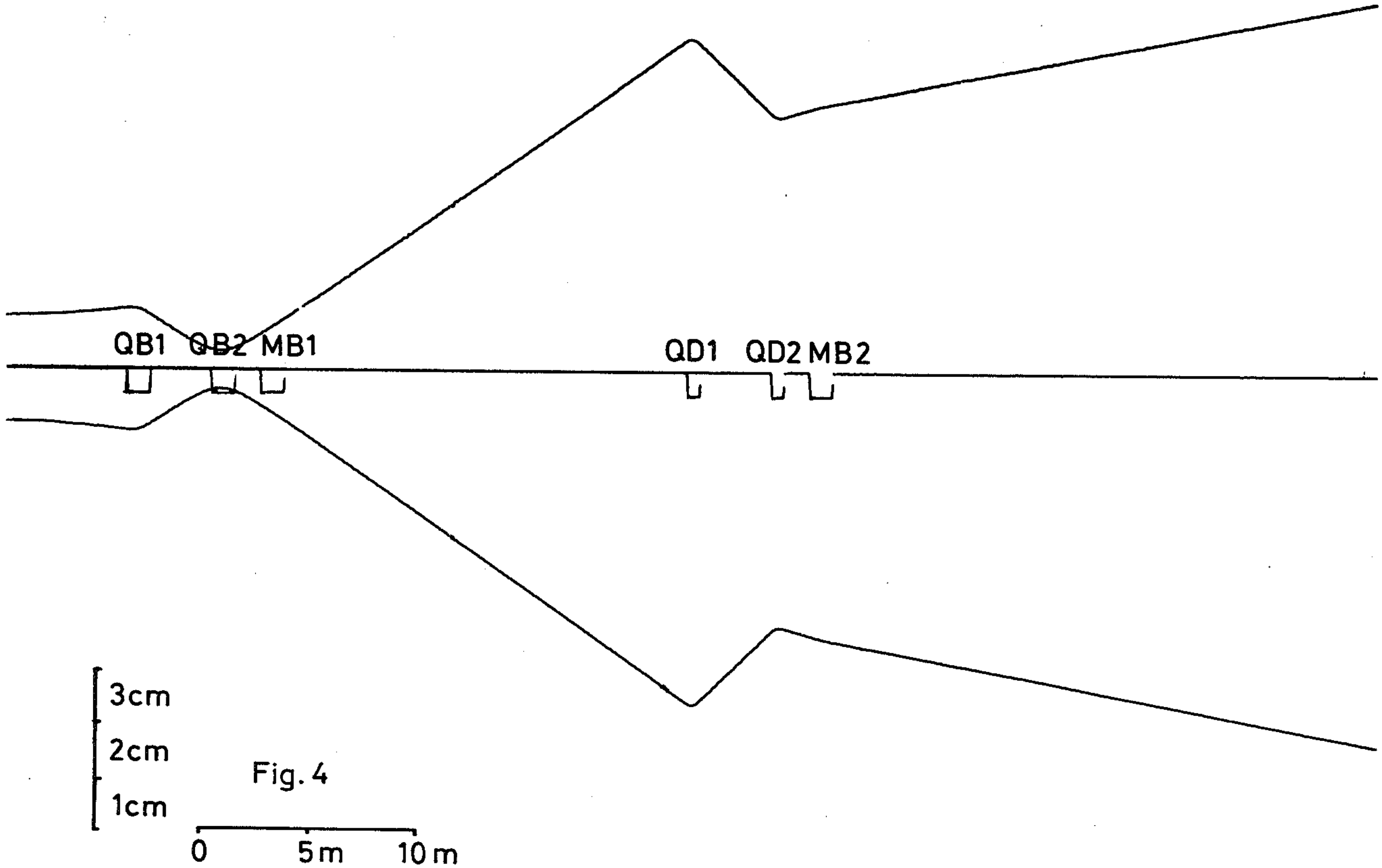


Fig. 4

vertical plane (Y)

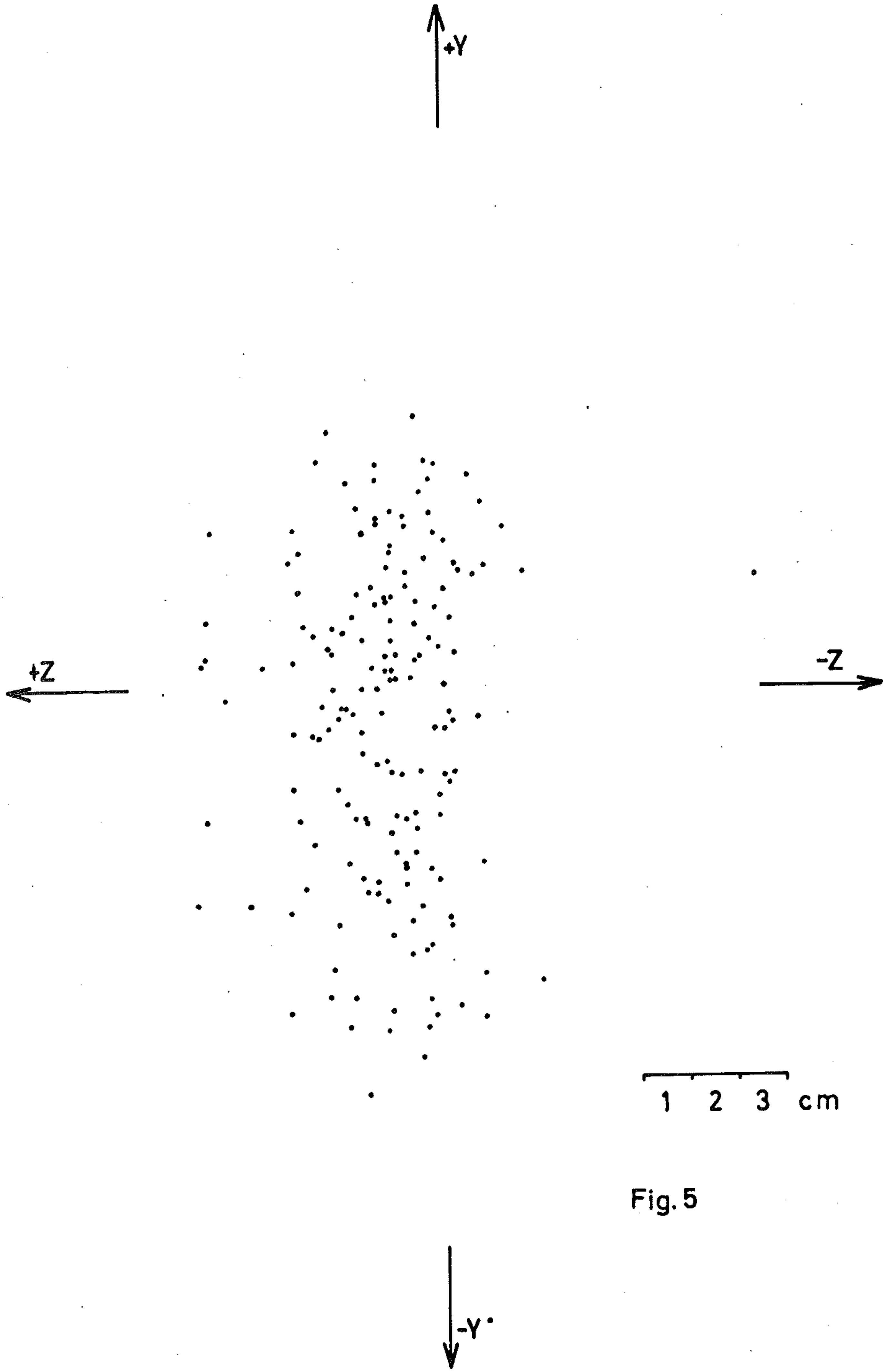


Fig. 5

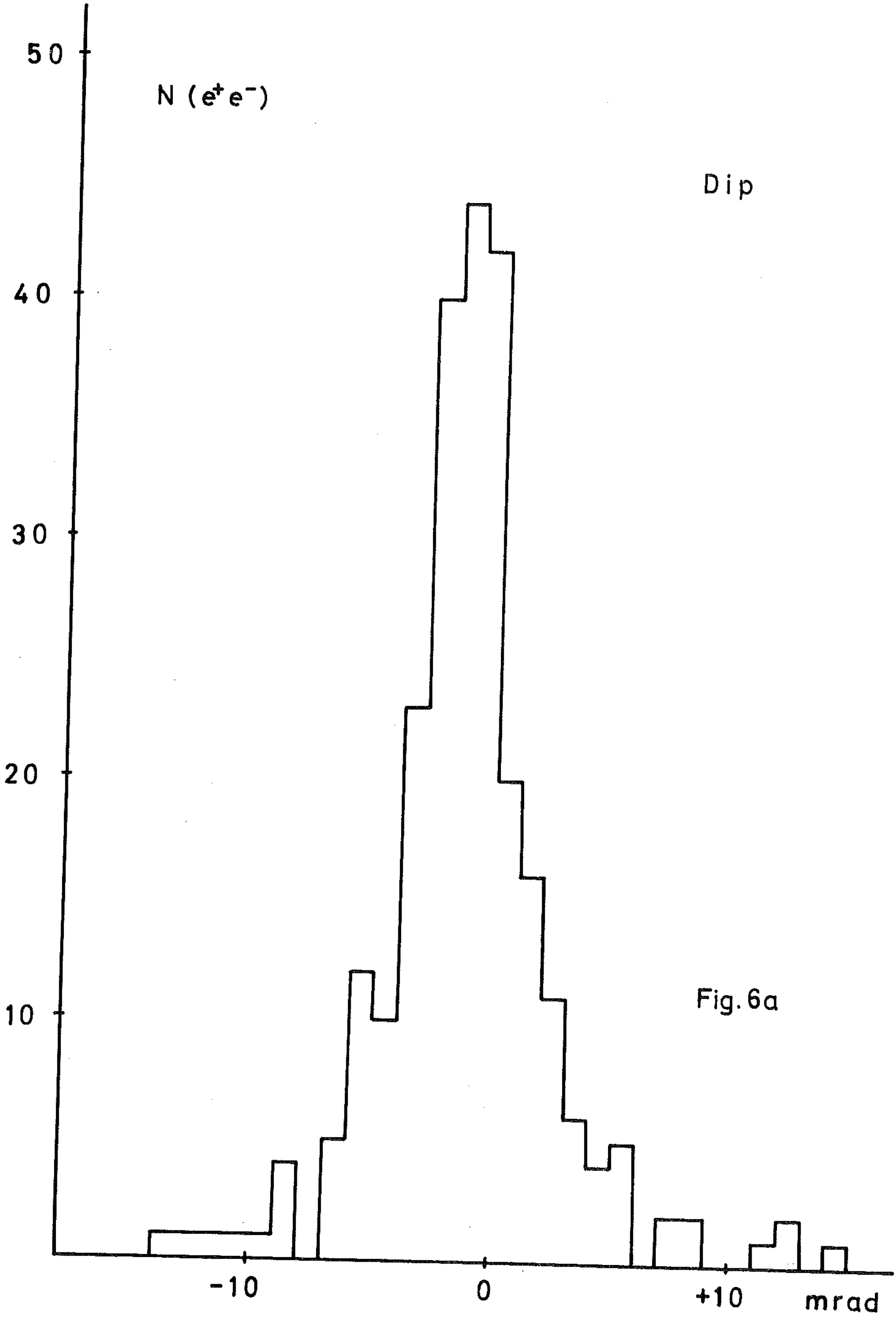


Fig. 6a

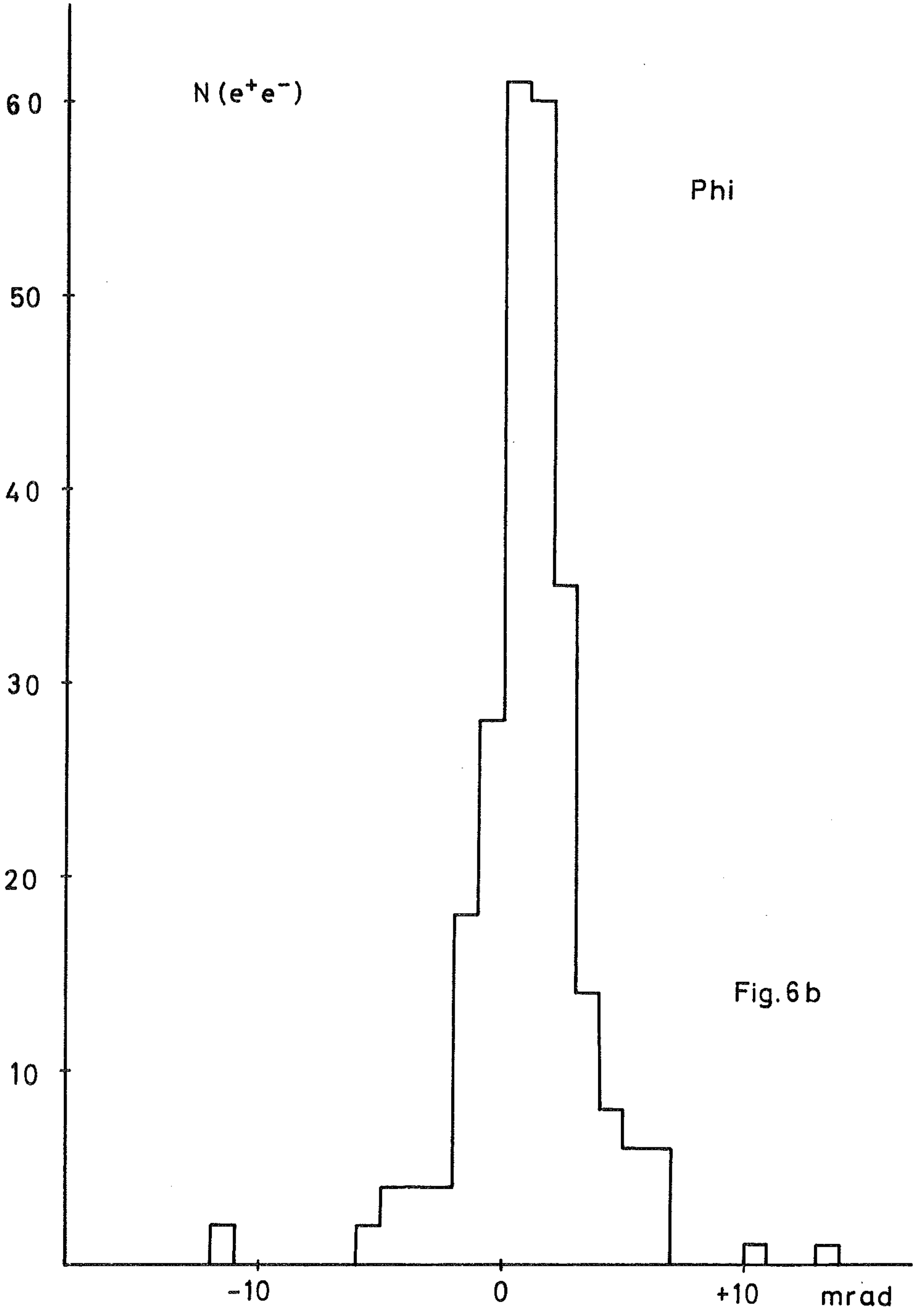


Fig. 6 b

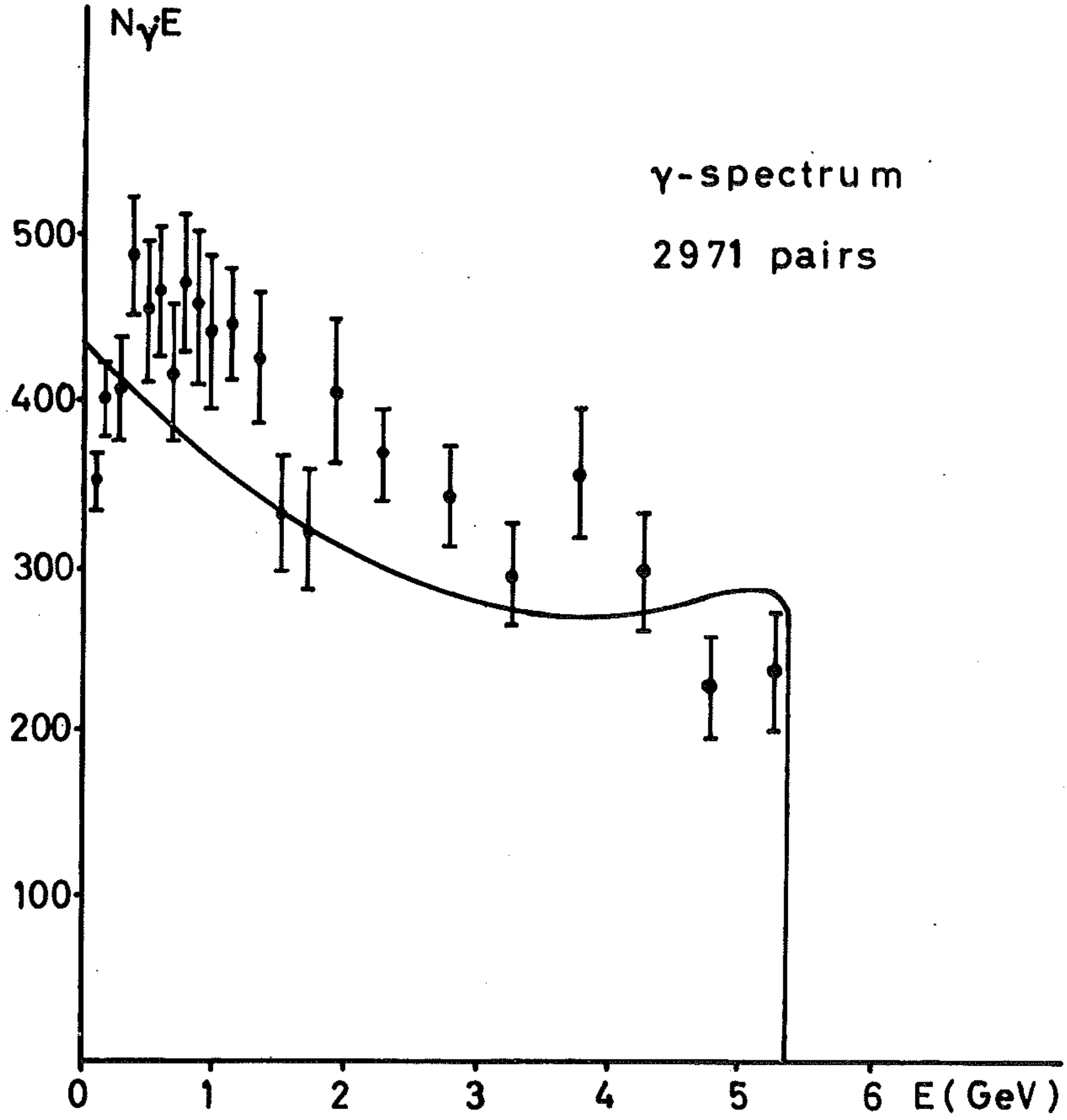


Fig. 7

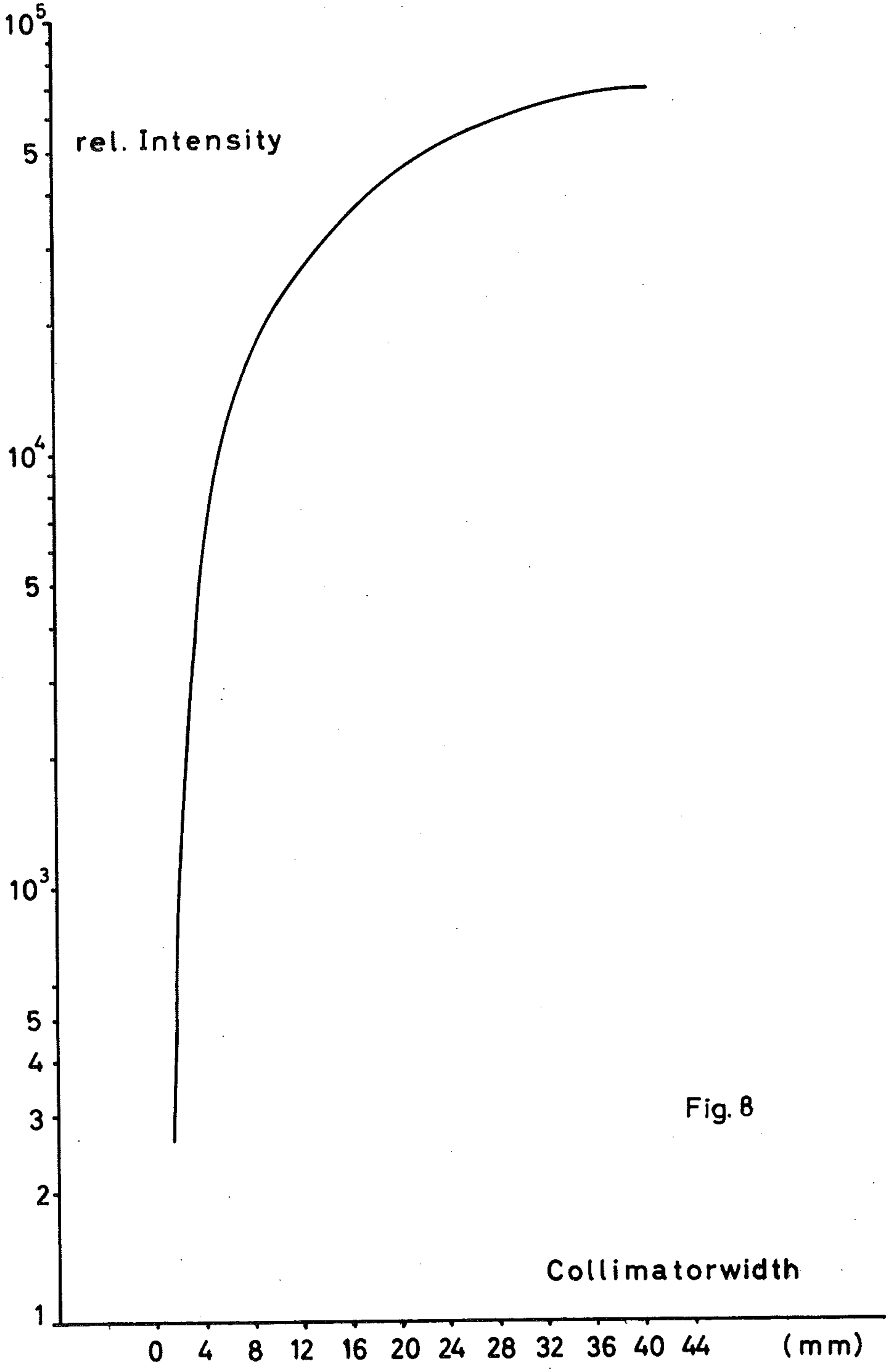

rel. Intensity
10^5
5
10^4
5
10^3
5
4
3
2
1
Collimatorwidth
0 4 8 12 16 20 24 28 32 36 40 44
(mm)

Fig. 8