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ABSTRACT.-

In this paper we describe the experimental apparatus exposed to the LNF-LEALE pion beam to measure the large angle pion-nucleus scattering. This 180° spectrometer consists in a streamer chamber filled with helium at atmosferic pressure, placed in a magnetic field, and used for identification of scattering events.

The required degree of localization and brightness of the tracks is obtained without using a Blumlein transmission line. Finally, the momentum resolution obtainable with this spectrometer has been evaluated by a Monte-Carlo technique.

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1. - INTRODUCTION. -

Very little is known about large angle pion-nucleus scattering, since experimental data are virtually non existent. A measurement of this type would greatly enhance our present understanding of the pion nucleus interaction mechanism. It is well known that differential cross sections can be calculated, through the scattering amplitudes, once that the corresponding phase shifts δ_l are known. Beiner and Huguenin[1] have shown that in the elastic scattering of 80 MeV π^- on C^{12}, theoretical differential cross sections obtained with different sets of phase shifts fit equally well the existing experimental data up to an angle of 120^o, while they become differing at larger angles: at 180^o this difference may reach two orders of magnitude.

Therefore, an accurate measurement of the large angle scattering should supplement the existing data and give some enlightenment on the models and the approximations used up to now for the description of pion-nucleus interaction.

Since with the usual experimental techniques it is not possible to measure differential cross sections at angles larger than 140^o[2], we proposed[3] to use a streamer chamber placed in a magnetic field for measuring the 180^o differential cross sections of elastic and inelastic $\pi^{\pm}$ scattering on nuclei.

In this paper we describe the experimental apparatus and we discuss the momentum resolution of this spectrometer, evaluated by means of a Monte-Carlo calculation, and compared with the results of preliminary measurements.

2. - THE EXPERIMENTAL APPARATUS. -

An outline of the experimental set-up is given in Fig. 1. A streamer chamber filled with helium at atmospheric pressure and

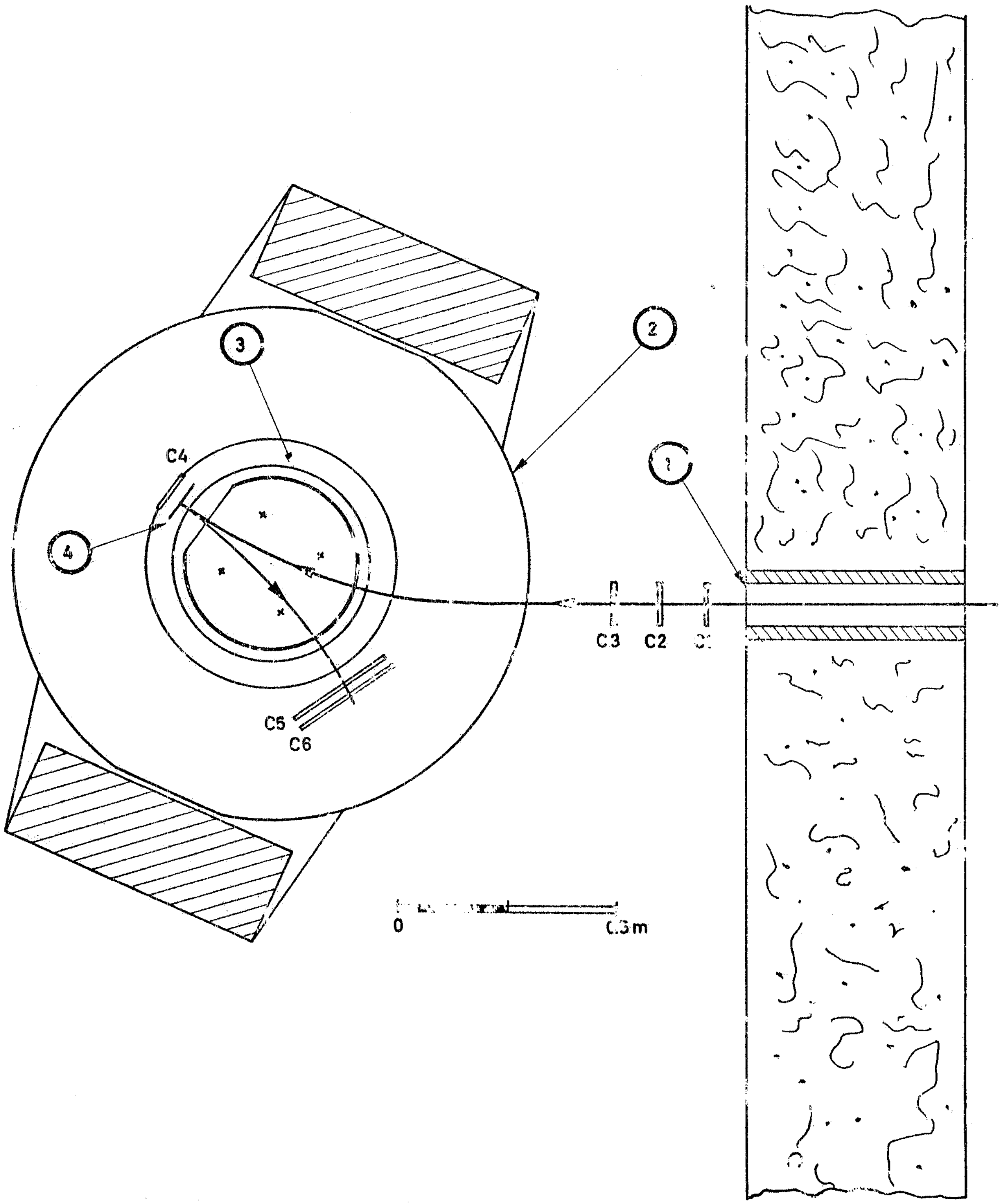

FIG. 1 - Layout of the experimental apparatus. 1 - Collimator $(10 \times 4)\ cm^2$; 2 - Magnet; 3 - Streamer Chamber; 4 - Target; C_1 to C_6 - Counters.

placed in a magnetic field has been exposed to the pion beam of the LNF-LEALE Laboratory. The hodoscope of thin scintillation counters $C_1C_2C_3C_4$ defines the geometry (100×40 mm^2) and the number of pions deflected by the magnet and impinging on the experimental target. In the first experiment[3] we used a Carbon target ($50 \times 100 \times 3$ mm^3) located 3 cm before the counter C_4. Pions scattered in the backward direction by thé target are deflected with an opposite curvature by the magnetic field and are counted by the coincidence $C_1C_2C_3\bar{C}_4C_5C_6$. The anticoincidence $\overline{C_4}$ excludes those particles which have interacted out of the target. The solid angle subtended by the target and by the counters C_5 and C_6 ($260 \times 120 \times 5$ mm^3) is about 0.1 sterad for accepting particles emitted between 170^o and 190^o. The coincidence triggers the high voltage pulse on the streamer chamber and the command circuits of the cameras, thus allowing to photograph the scattering event. The magnetic field is homogeneous along the height of the sensitive volume and within $\pm$ 0.5% along the radius[4].

3. - THE STREAMER CHAMBER. -

In this magnetic spectrometer the streamer chamber is used to identify the scattering events. The chamber is of the type described by Falomkin et al.[5] and later by Busso et al.[6]. In these papers it has been shown that the required degree of localization and brightness of the tracks in a streamer chamber filled with helium can be achieved by mixing small amounts of hydrocarbons or Krypton and Xenon to the gas and triggering the chamber with high voltage pulses a few hundreds of nanoseconds wide.

The streamer chamber is 39 cm in dia. and 12 cm high. The cylinder used for the chamber is made of 5 mm thick PVC, is closed on top and bottom by two optical glass plates 1 cm thick and its internal surface is painted with a black pigment solved in epoxy resin.

A window (200 x 120 mm^2), closed by a thin (0.07 mm) PVC foil, faces the target. The cylinder wall portion looking the incoming beam is 2 mm thick. The fiducial marks, engraved in the internal surface of the glass plates, are illuminated with grazing light. The upper electrode is transparent, in order to allow for the view of the chamber's interior, and is made up by an array of parallel conducting wires (Ni-Cr) 0.1 mm thick and 10 mm apart. The photographs are taken by two cameras equipped with objectives F.O.S. type Mir-1 (f/2.8 lens aperture; f = 37 mm focal lenght) and loaded with Ilford HP4, 35 mm, 27 ÷ 29 Din films. The base of the stereo cameras is 140 mm. The axes of the objectives are parallel to the direction of the magnetic and electric fields applied to the chamber. The distance between the centers of the objectives and the bottom of the chamber is 638 mm; the magnifying factor is 0.05714.

The chamber was evacuated and kept to a residual pressure of 10^{-2} torr for several hours before the filling. The filling system provided for adding to helium the requested amount of α-pinene-Nitrogen or Xenon-Nitrogen in order to obtain bright and well localized tracks in the presence of a magnetic field (see Fig. 2 and 3 respectively). The admixtures of α-pinene-Nitrogen or Xenon-Nitrogen give the best results when used in a percentage less than 0.5‰ (see Fig. 2 and 3: the distance between the fiducial marks is 16 cm). For higher percentages, tracks lose their vertical localization, as shown in Fig. 4. Nitrogen is always added since it turned out to be the best component for a good localization of tracks, while their brightness is improved by α-pinene and Xenon. Moreover we noticed that the amount of admixtures usually employed in this type of chambers in absence of a magnetic field[6, 7], gives rise to discharges between the electrodes along the particle's path when the magnetic field is present. Usually we exposed the chamber without refilling for some days.

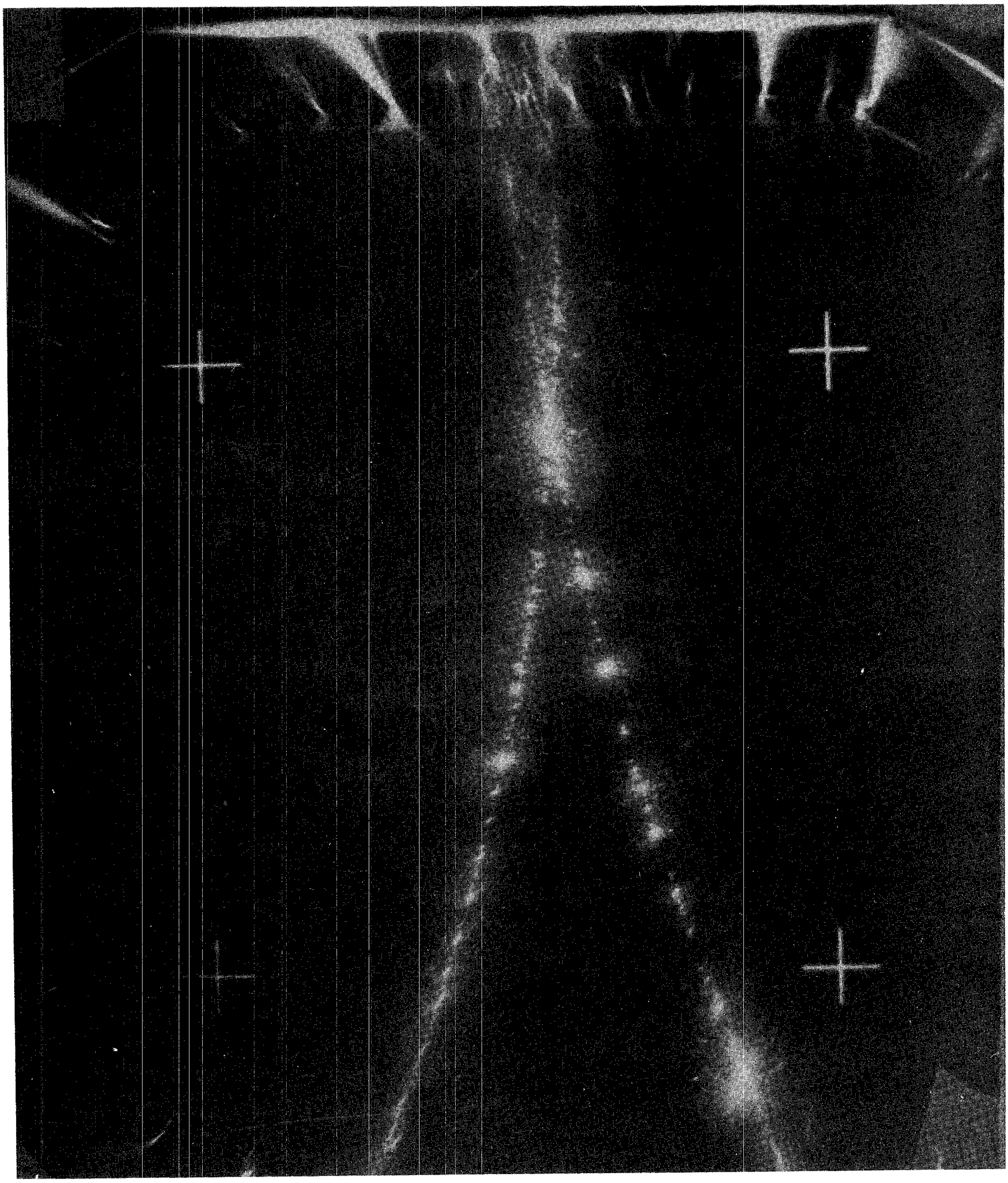

FIG. 2 - Typical event with α-pinene - Nitrogen admixture.

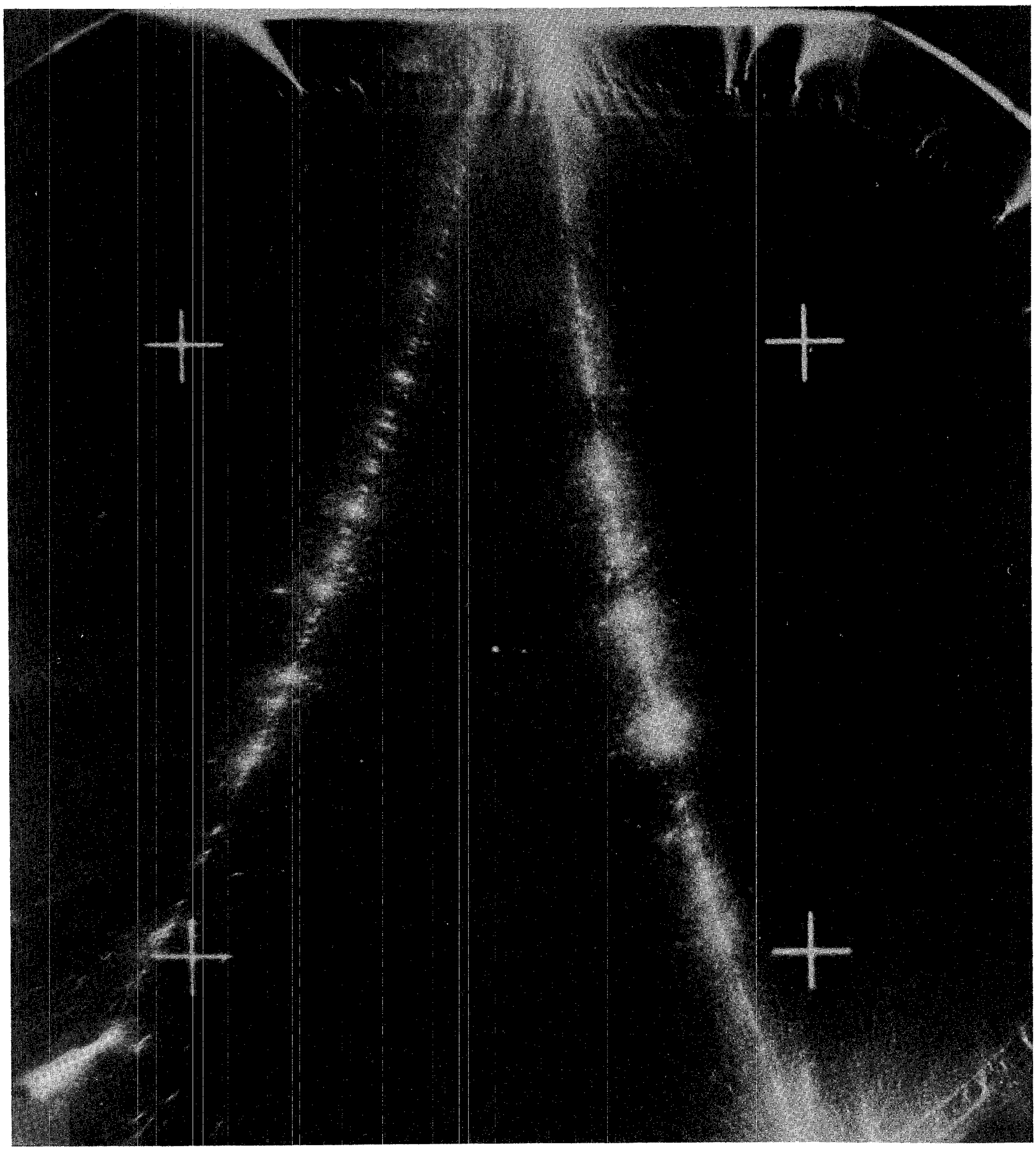

FIG. 3 - Typical event with Xenon-Nitrogen admixture.

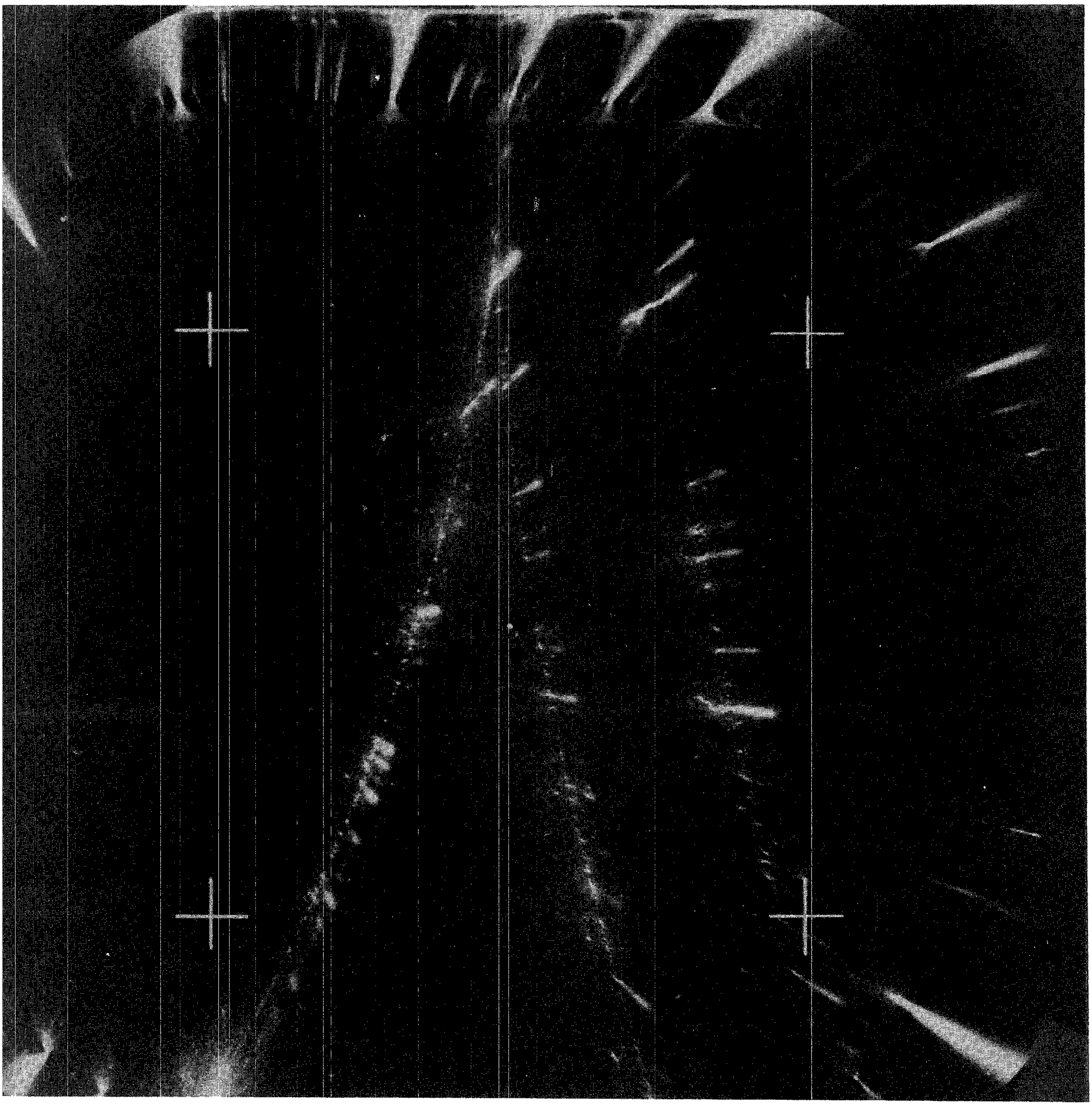

FIG. 4 - Typical event with α-pinene - Nitrogen admixture in exceeding percentage.

A fourteen-stage pulse generator of the Arkadiev-Marx type, as described in reference[6], was used for firing the high voltage pulse on the chamber. This generator is a bank of capacitors charged in parallel and switched in series by means of fast spark gaps. The first stage consists in a three electrode spark gap preionized by an ultraviolet flash produced by a fourth electrode on a $BaTiO_2$ tablet. Each of the following thirteen stages is a capacitor of 5000 pF and 20 kV maximum working voltage. All the gaps have adjustable distances and operate in Nitrogen at a pressure of up to 3 Atm. The high voltage pulse amplitude was around 200 kV and the total time delay from the passage of particles through the chamber was 250 ns. The general features of high voltage generator for streamer chambers of the type described in this paper are reported in detail in reference[8].

The effective dimensions of the bright points along the trajectory of a particle are about 2 mm in the direction of the electric field and about 1 mm in dia in the perpendicular direction. The average number of points in 1 cm of track in the presence of a magnetic field is about 2.

Measuring the two imaginies of every track with a semi-automatic plane digitizer, it turns out that the track points can be reconstructed with good approximation, i.e. within about $\pm$ 0.2 mm. This result is the same previously obtained in a streamer chamber with no applied magnetic field as quoted in reference[6].

Finally, we want to remark that in a streamer chamber pulsed through a Blumlein transmission line the points of the tracks have the same dimensions but a much poorer brightness.

4. - MOMENTUM RESOLUTION. -

Our purpose is to estimate the minimum track lenght to be measured in order to gain a prefixed momentum resolution. This goal can be easily reached with the help of a Monte-Carlo calculation, which proceeds through the following steps. For a given radius of curvature, R, the corresponding circumference has been traced and an arc of prefixed lenght has been choosen on it. Within this arc a number, n_p, of equidistant points has been selected and the respective coordinates has been slightly and randomly changed for taking in account the previously quoted precision of reconstruction of a track. These extracted coordinates have then been fitted with a new circumference. A repeated use of this procedure led us to a distribution of curvature radii around the starting one. The above calculation has been carried out for four values of R (0.5, 1, 1.5 and 2 m), four values of n_p (4, 8, 15 and 20) and taking only tracks 20 to 70 cm long, which assure them to lie in the region where the magnetic field is homogeneous. In Fig. 5 the momentum resolution corresponding to the calculated distribution of radii is plotted vs. the number of points n_p, for fixed track lengths L; the curves are labelled by different R values. All the momentum resolution curves can be seen to become independent from the number of points for $n_p \gtrsim 15$.

Fig. 6 presents the same data plotted vs. R, for fixed L's; the curves are labelled with n_p values. From these graphs, the curvature radii R corresponding to the requested energy resolution can be obtained for each L and for various n_p.

In Fig. 7 a solid line has been drawn through the available (L, R) pairs. In particular Fig. 7 shows the minimum track lenght to be measured for a given radius of curvature, to ensure a momentum of 1.1%. In our first experiment (E_{π^-} = 80 MeV, B = 5 kG), the hystogram of the curvature radius of a track portion (28 cm long) measured

40 times shows a percent standard deviation around 1.1% (see Fig. 8). This result is in very good agreement with the prediction of the Montecarlo calculation, as shown in Fig. 7.

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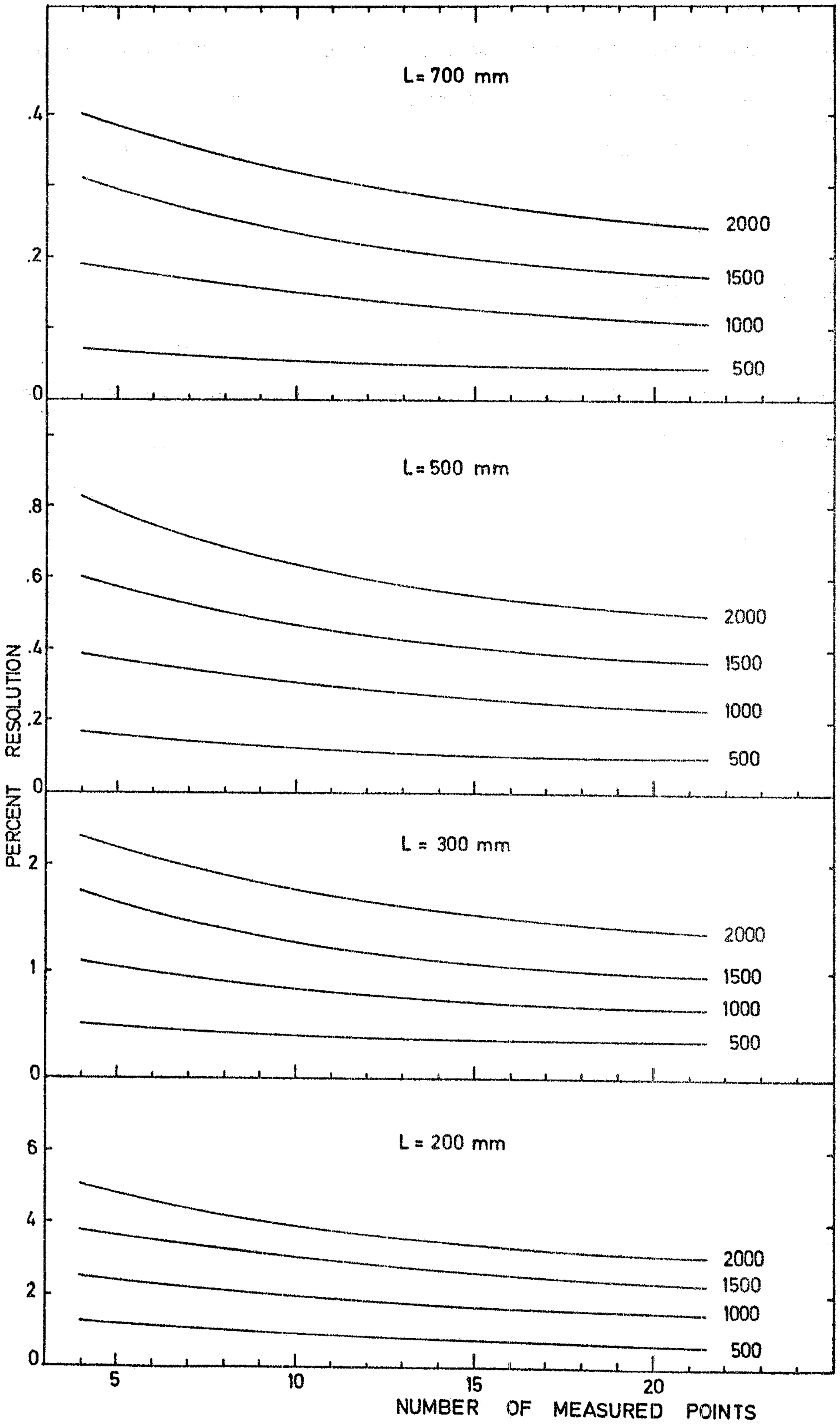

FIG. 5 - The momentum resolution vs. the number of points n_p, for various track lengths L. The curves are labelled by R-values.

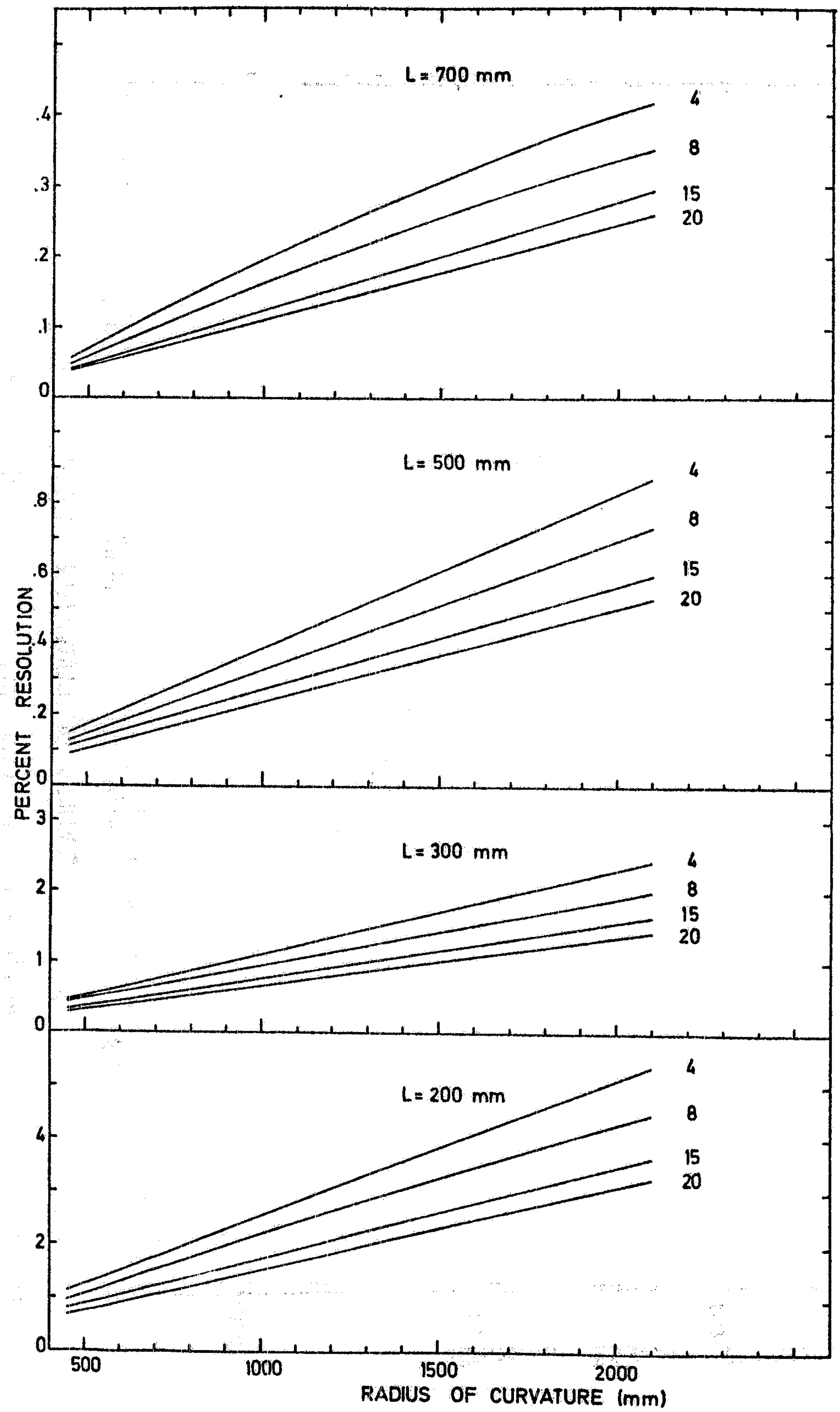

FIG. 6 - The momentum resolution vs. the curvature radius, for various track lengths L. The curves are labelled by n_p - values.

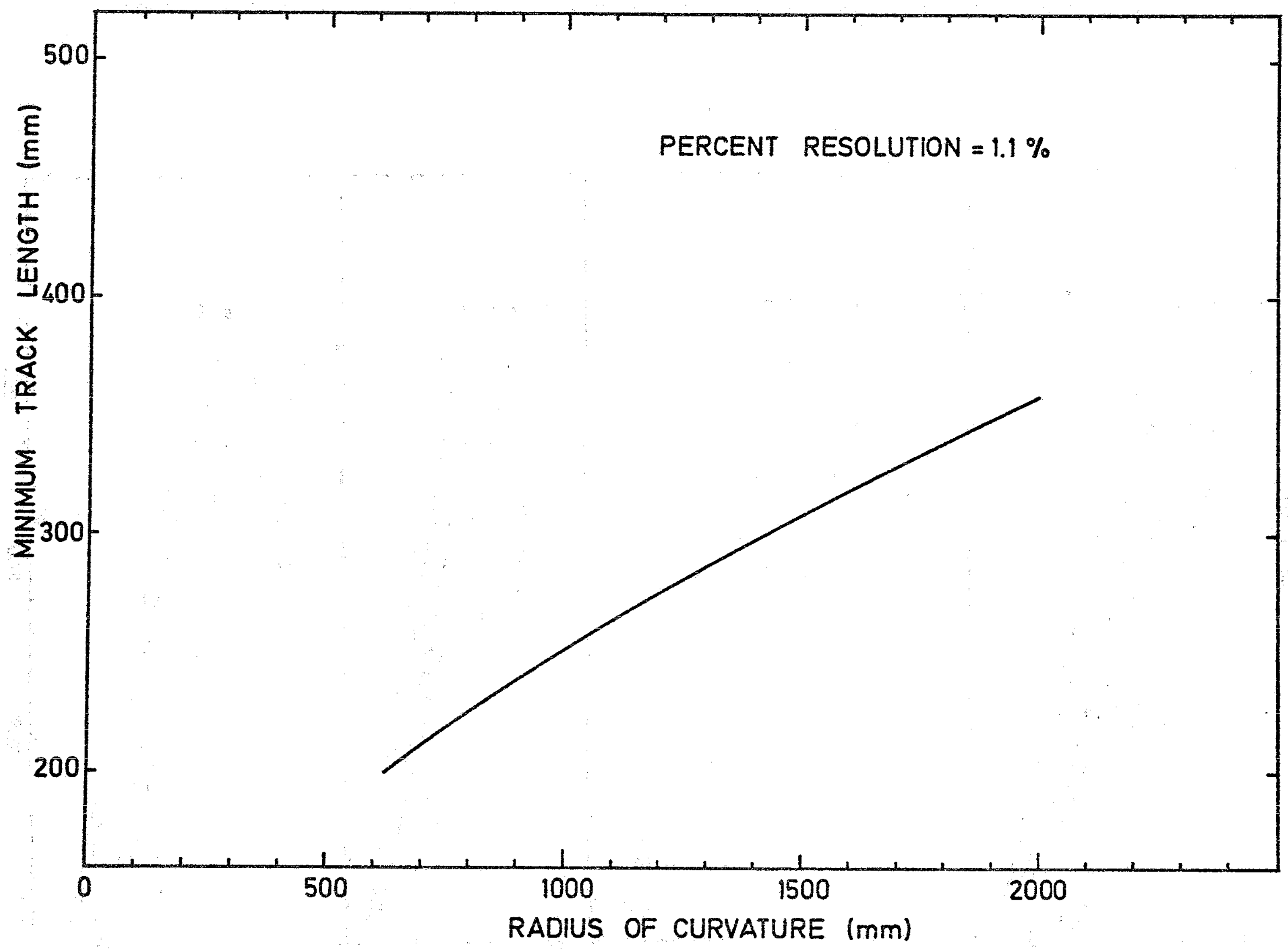

FIG. 7 - The minimum track length to be measured vs. the curvature radius, for $n_p = 15$, to ensure a momentum resolution of 1.1%.

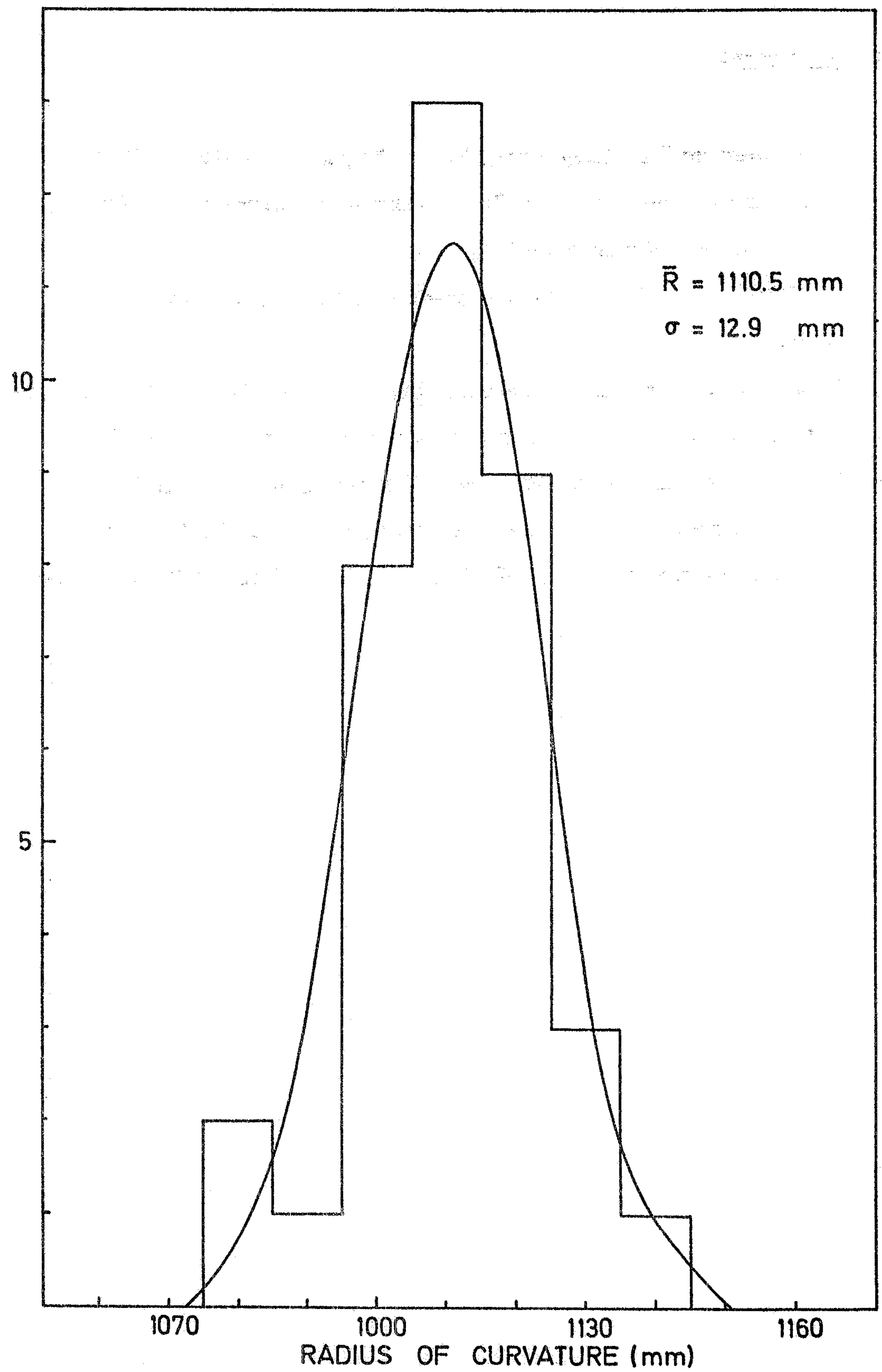

FIG. 8 - The hystogram of the curvature radius of the same track measured 40 times.

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