P-431

A Proposal to the Fermi National Accelerator Laboratory

350 GeV/c $\pi^- p$ Experiment in the 15 Foot Bubble Chamber

A. R. Erwin, E. H. Harvey, R. J. Loveless and M. A. Thompson

University of Wisconsin
Madison, Wisconsin 53706

A. Thorndike

Brookhaven National Laboratory
Upton, Long Island, New York 11973

August 29, 1975

Spokesman: M. A. Thompson
Physics Department
University of Wisconsin
1150 University Avenue
Madison, Wisconsin 53706
Phone: (608)-262-2486

Summary

We propose to take 50,000 exposures of hydrogen in the 15 foot bubble chamber with a beam of 350 GeV/c π^-. We intend to search the global data for coherent diffractive effects which may be made evident by the high momenta.

The film measurement will be done with semi-automatic machines with proven high accuracy such that fine structure may be detected.

Physics Justification

There have been a number of recent indications that high energy interactions show various diffractive phenomena.

(a) Data gathered by Hendry (Ref. 1).

(b) Preliminary data from the Argo experiment at BNL.

The origins of these phenomena are of great interest and recent suggested models include

(a) A Lorentz contracted disc of intrinsic radiators created at the interaction region.

(b) A pair of discs (formed from the beam and target particles) radiating as they move apart.

(c) A long cigar shaped fireball radiator.

Each of the suggestions is based on the assumption that the interaction region (or fireball) is large compared with the pion wavelength and so it should be possible, with high energy pions, to explore the interior structure with inelastic interactions.

Suggested methods of analysis include

(a) Seeking the Goldhaber effect (Ref. 2) of equal charge pions clumping in phase space due to being bosons.

(b) Looking for first order interference pattern about a collision axis.

(c) Looking for second order interference such as the Hanbury-Brown Twiss effect. This involves correlations between pions at all angles. The Hanbury-Brown Twiss effect has been used to measure stellar diameters since it was suggested in 1955 (Refs. 3, 4 and 5).

For example, taking one of the models, there is some evidence, some of which we will cite here, that nuclear matter may be regarded as a spatial distribution of intrinsic oscillators all radiating coherently in which the radiation quanta are mostly pions. In this model, some configurations of matter (such as the proton) are stable against radiation since the integral of the radiation from their oscillators is zero. It is easy to find the necessary boundary conditions for a spherical distribution to have no radiation.

The angular distribution of inclusive pions in the center of mass system has been found to follow something like

$$\frac{d\sigma}{d\Omega} \sim \frac{1}{\sin^2\theta}$$

This is compatible* with (and implied by) the suggested "flat" rapidity distribution. The rapidity $y \to -\log_e \tan(\frac{\theta}{2})$ if $y >> 0$

$$\theta^2 \to 4\ e^{-2y}$$

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d(\pi\theta^2)}$$

$$= \frac{1}{\pi}\frac{d\sigma}{dy}\frac{dy}{d(\theta^2)}$$

$$= \frac{1}{2\pi}\frac{d\sigma}{dy}\frac{1}{\theta^2}$$

---

*We were indebted to W. Selove for pointing out this connection.

If $d\sigma/dy$ is constant then

$$\frac{d\sigma}{d\Omega} = \frac{\text{constant}}{\theta^2}$$

We argue that diffraction effects alone are sufficient to produce such a flatness in rapidity. The magnitude of the momentum of pions radiating from volumes of nuclear size is such as to compel us to look for interference effects.

In this model the interaction region may be considered as the volume occupied simultaneously by two Lorentz contracted discs moving along a common axis in opposite directions. The volume may be regarded as a perturbed region and the boundary conditions which prevented radiation may no longer apply. If the interaction volume is shaped like a flat circular disc of radius R with its axis along the beam direction, then it will radiate with the same pattern as parallel light incident upon a circular aperture.

$$\frac{d\sigma}{d\Omega} \sim \left(\frac{J_1(kR\sin\theta)}{kR\sin\theta}\right)^2$$

If $kR\sin\theta$ is small (i.e. low energy pions)

$$\frac{d\sigma}{d\Omega} \sim \left(\frac{1}{2}\right)^2 = \text{constant}$$

If $kR\sin\theta$ is large, the Bessel function may be approximated:

$$\frac{d\sigma}{d\Omega} \sim \frac{\frac{2}{\pi kR\sin\theta}\cos^2\left(kR\sin\theta - \frac{\pi}{4}\right)}{(kR\sin\theta)^2}$$

$$\sim \frac{\cos^2\left(kR\sin\theta - \frac{\pi}{4}\right)}{\sin^3\theta}$$

At the momenta being proposed, the diffraction pattern will be formed from several kR values and so we might expect

(a) The fine structure of the cosine will be smoothed unless momenta are measured precisely and the various kR are separated.

(b) The general dependence of the envelope on θ will lie between a constant and $1/\theta^3$. A dependence of $1/\theta^2$ would be reasonable.

The slight but definite difference in π^-p and pp collisions with respect to the forward-backward angular distributions makes the π^-p system more interesting to study since one may need to involve two disks - one for the excited pion and one for the excited proton.

At a beam momentum of 350 GeV/c, one has numerous secondary pions at $\sim$8 GeV/c in the center of mass system. This is sufficient to probe the shape of the radiator assembly to see structure of the order of 0.1 Fermi.

Figure 3 shows preliminary angular distributions of data obtained in 28.5 GeV/c pp interactions in the Argo spectrometer at BNL. The spectrometer was triggered electronically and so this data lacks the unbiased nature to make a simple diffraction interpretation. The data does, however, suggest some structure.

We would analyze the data from this experiment in a manner to best find the expected coherent effects. One might expect the radiator size and shape to vary with multiplicity. If so, some exclusive data with exact multiplicity (not just charged multiplicity) is needed.

This requires moderately good statistics, the best possible resolution in the forward direction as well as in the backward direction and an unbiased selection of events. The 15 foot bubble chamber seems to be the only device in the forseeable future which can provide these.

A bubble chamber provides the unbiased global data collection and the 15 foot chamber provides both significantly better momentum resolution and better π° detection than the 30 inch chamber.

We request the highest practical beam momentum (nominally 350 GeV/c) to probe the smallest structure. We would use an average of 8 beam tracks/exposure to give an average of 1 event/exposure in a fiducial volume of 40% of the chamber.

The film will be measured on flying spot scanners (HPDs at Wisconsin and BNL) which are able to use the full resolution of the bubble chamber optics and film. The HPD at Wisconsin ("SATR") is coupled with a 3-dimensional track recognition hardware system which combines the data from multiple films to recognize track elements in 3 dimensions. The controlling computer uses the hardware to follow track helices. The reconstruction resolution has been proven to be consistent and peaking at an RMS of [illegible]-3 microns on the film.

SATR has been used with both 30 inch and 15 foot chamber film and no serious changes are necessary. The tracks are reconstructed on-line and so TVGP is not needed.

Apparatus Needed

We do not expect to need any special apparatus. We would however prefer to take a few exposures with beam particles but without a magnetic field. This would greatly assist in our calibration and in our precise measurement of tracks with fast forward momenta.

Figures

Fig. 1(a), Fig. 1(b)

From Preprint of A. W. Hendry (Ref. 1)

Fixed angle differential cross-sections for (a) pp, (b) π^+p elastic scattering plotted against ℓns.

Fig. 2(a), Fig. 2(b)

From preprint of A. W. Hendry (Ref. 1)

Fixed angle differential cross-sections for (a) pp, (b) π^+ elastic scattering plotted against t.

Fig. 3 Preliminary angular distributions of π^+ at various momenta found in the Argo proton spectrometer.

Fig. 4

RMS errors of fits by TVGP of recent 30 inch HBC measurements made on the Wisconsin HPD ("SATR").

References

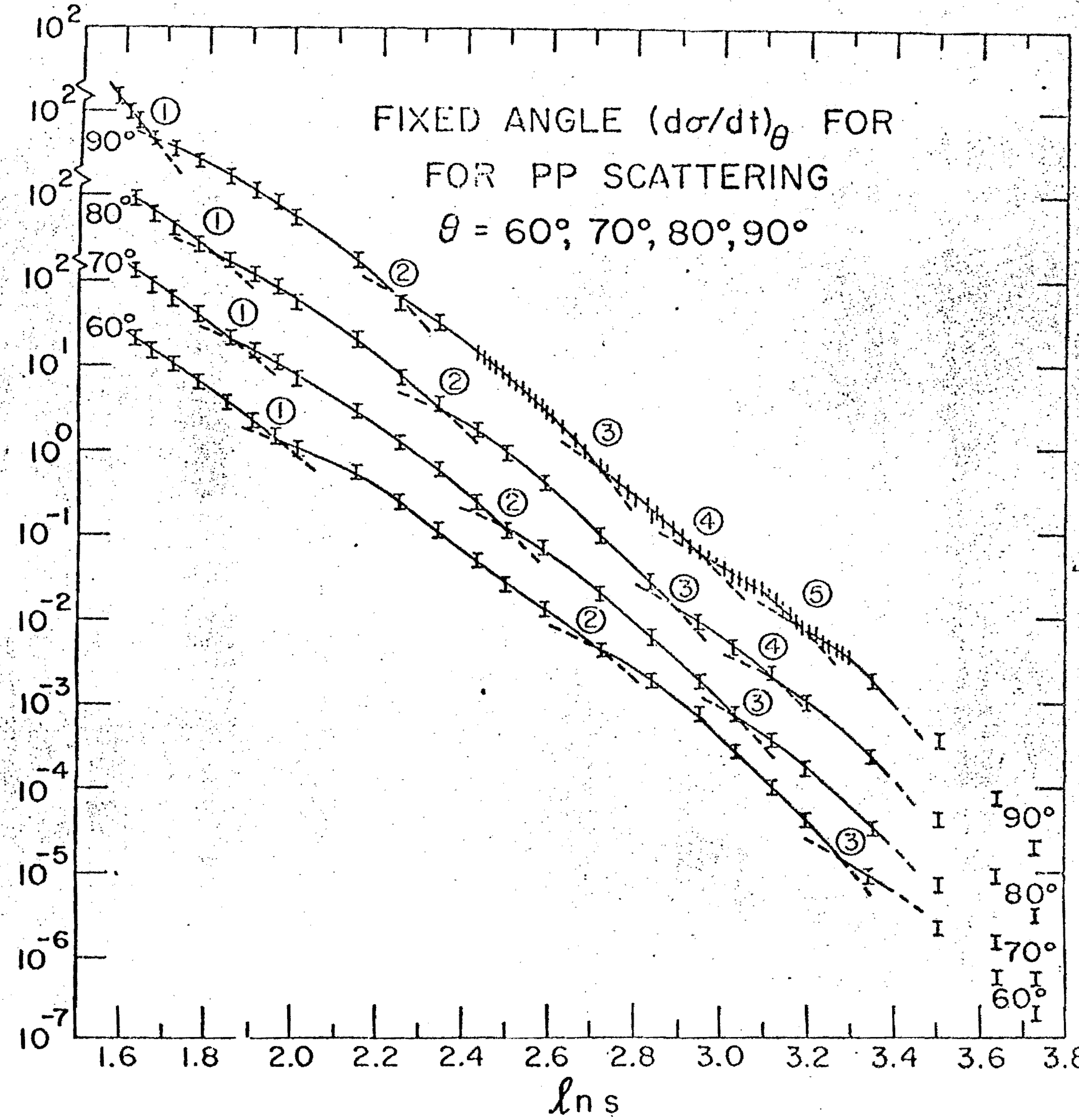
1. A. W. Hendry, "Evidence for Coherent Effects in Large Angle Hadron-Hadron Scattering", preprint (March 1974).

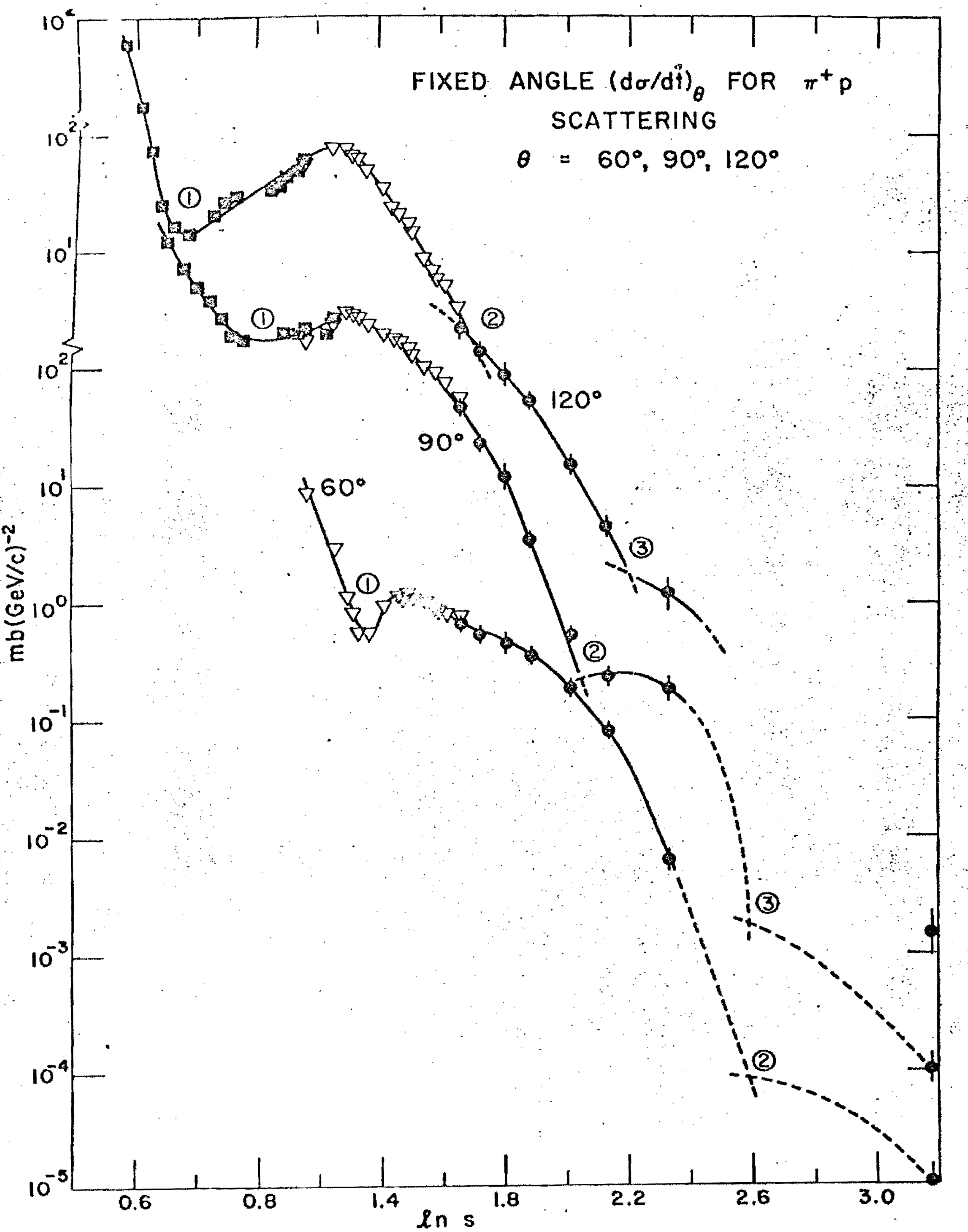
2. G. Goldhaber, S. Goldhaber, W. Lee and A. Pais, "Influence of Bose-Einstein Statistics on the Antiproton-Proton Annihilation Process", Phys. Rev. 120, 300 (1960).

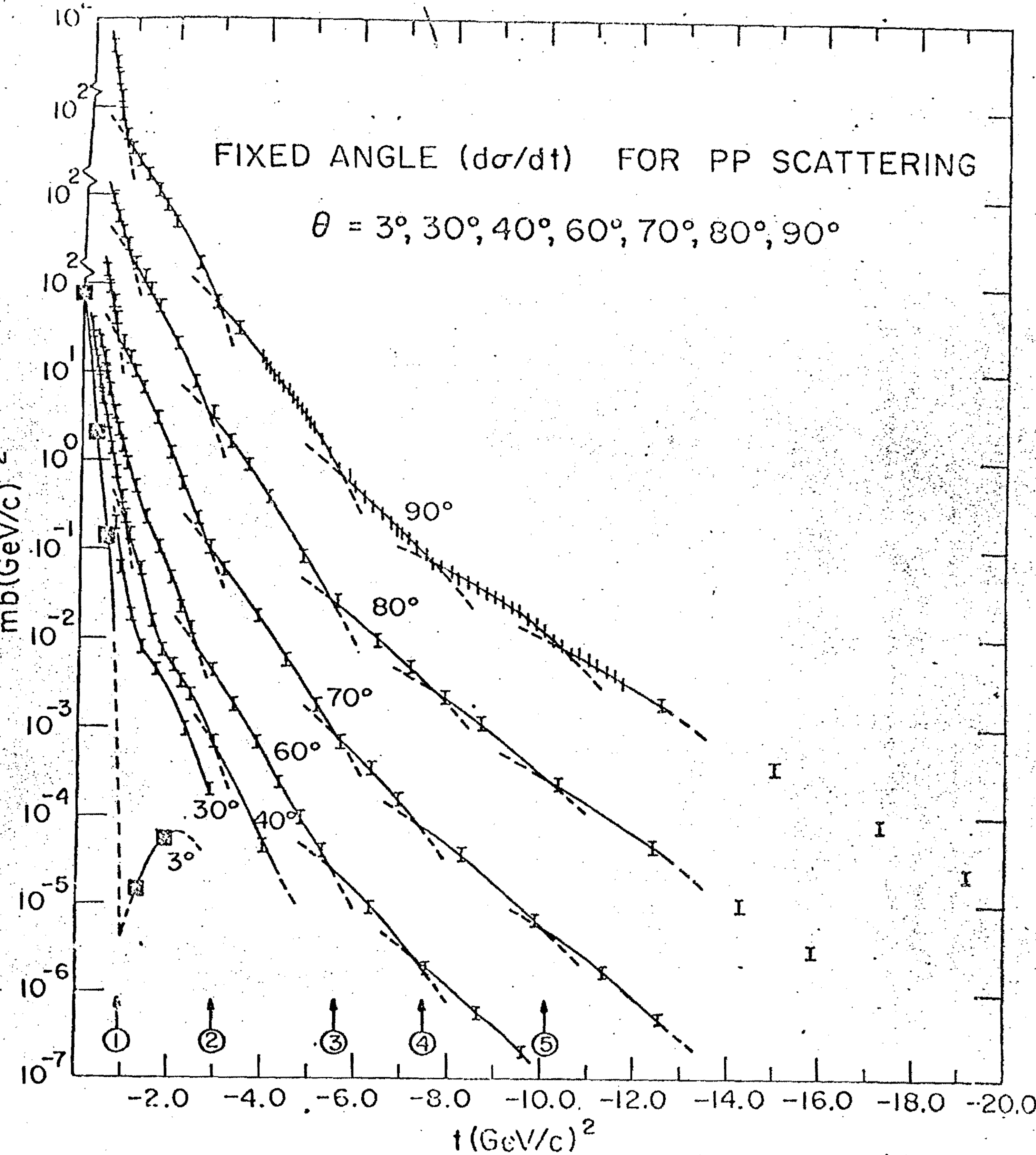
3. E. V. Shuryak, "The Correlations of Identical Pions in Multibody Production", Phys. Letters 44B, 387 (1973).

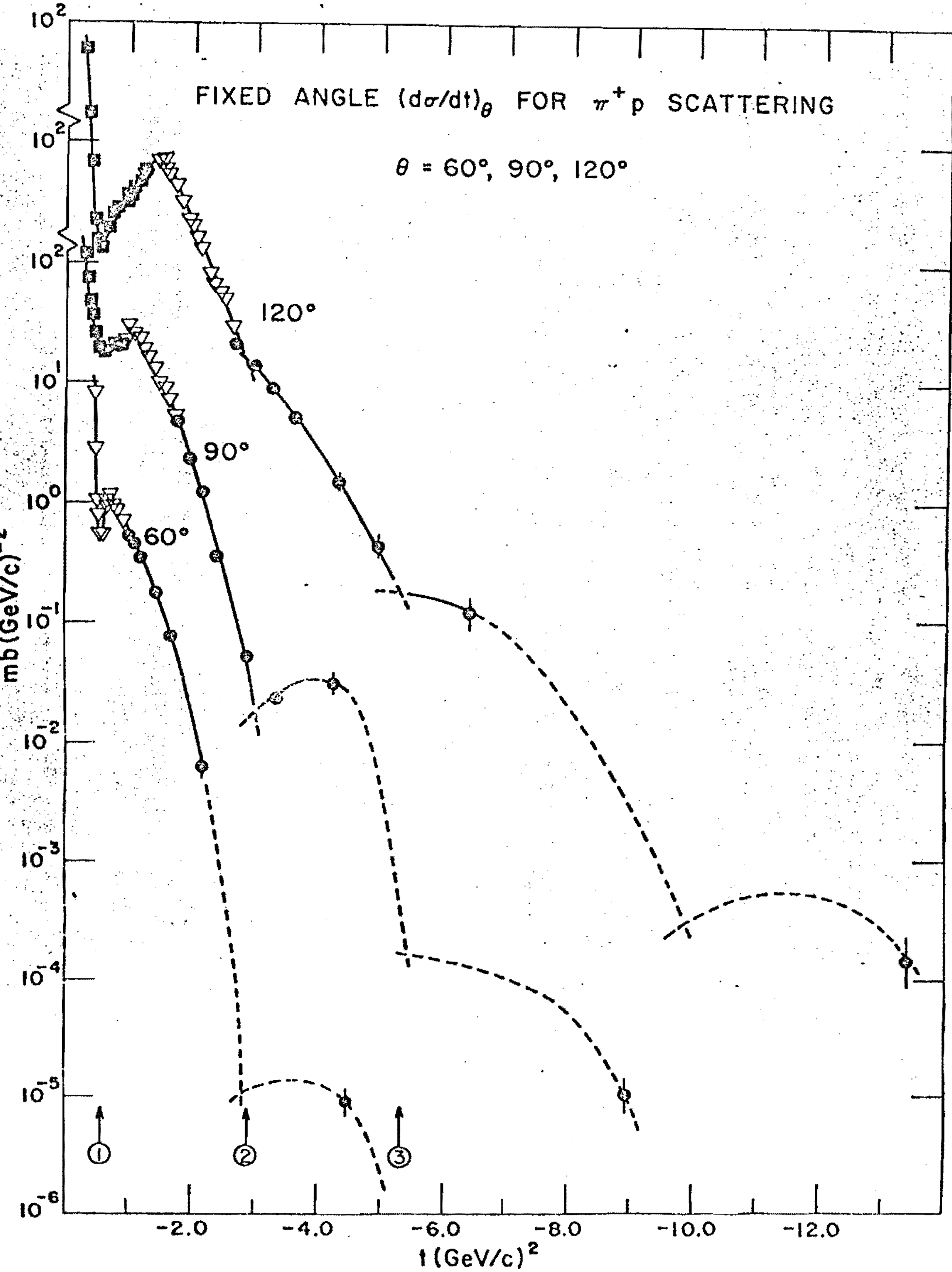
4. G. Cocconi, "Second-Order Interference as a Tool for the Determination of Hadron Fireball Dimensions", Phys. Letters 49B, 459 (1974).

5. G. I. Kopylov, "Like Particle Correlations as a Tool to Study the Multiple Production Mechanism", Phys. Letters 50B, 472 (1974).

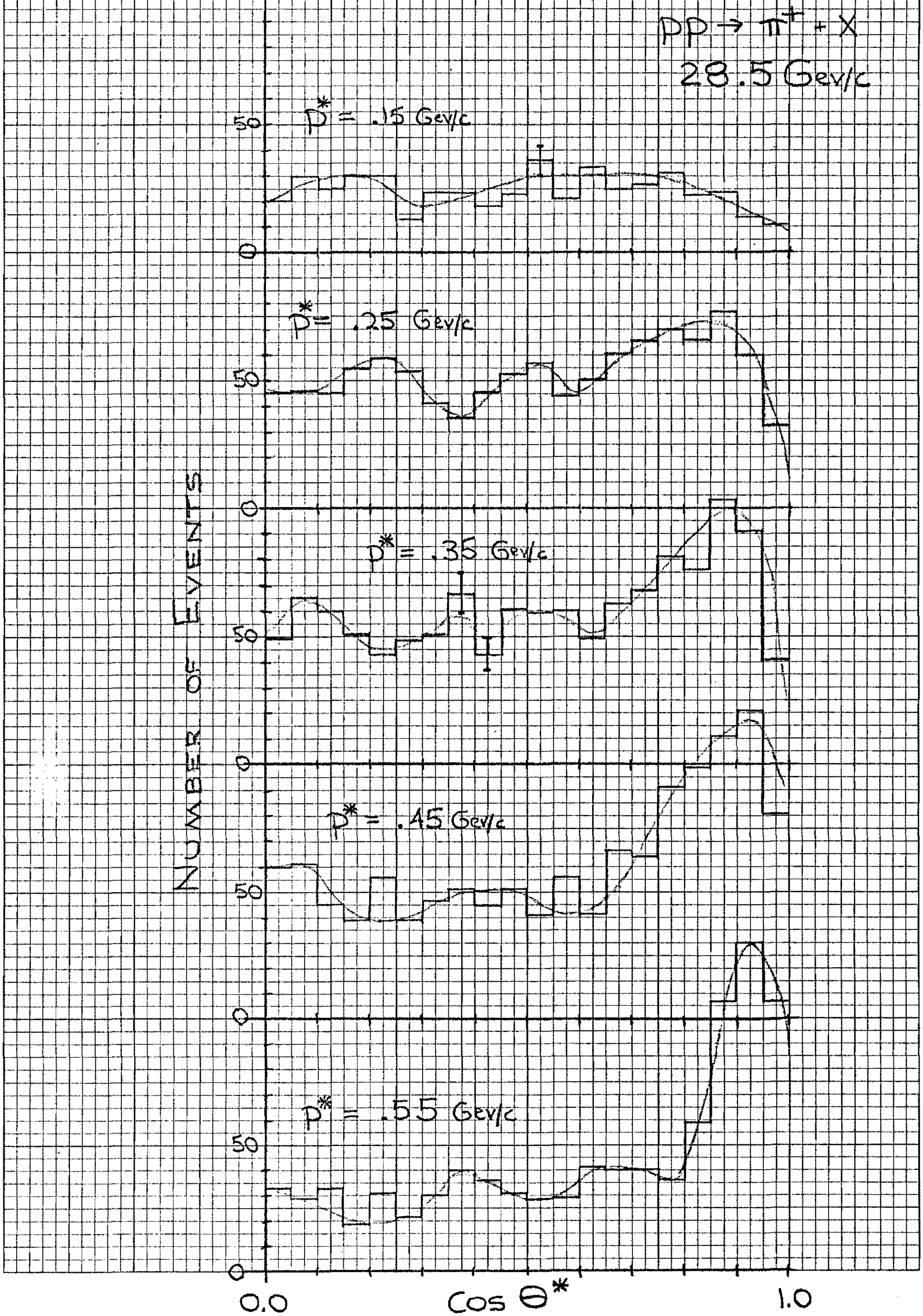

FIXED ANGLE $(d\sigma/dt)_\theta$ FOR
FOR PP SCATTERING
θ = 60°, 70°, 80°, 90°
90°
80°
70°
60°
mb(GeV/c)$^{-2}$
ℓn s
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8


FIXED ANGLE (dσ/dt)θ FOR π+ p
SCATTERING
θ = 60°, 90°, 120°
120°
90°
60°
①
②
③
mb(GeV/c)-2
ln s
0.6
0.8
1.4
1.8
2.2
2.6
3.0
10^0
10^-1
10^-2
10^-3
10^-4
10^-5


FIXED ANGLE (dσ/dt) FOR PP SCATTERING
θ = 3°, 30°, 40°, 60°, 70°, 80°, 90°
90°
80°
70°
60°
30°
40°
3°
1
2
3
4
5
mb(GeV/c)$^{-2}$
t (GeV/c)^2
10^2
10^2
10^2
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0


FIXED ANGLE $(d\sigma/dt)_\theta$ FOR $\pi^+ p$ SCATTERING
θ = 60°, 90°, 120°
120°
90°
60°
mb(GeV/c)$^{-2}$
t (GeV/c)^2
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
①
②
③

ARGO SPECTROMETER



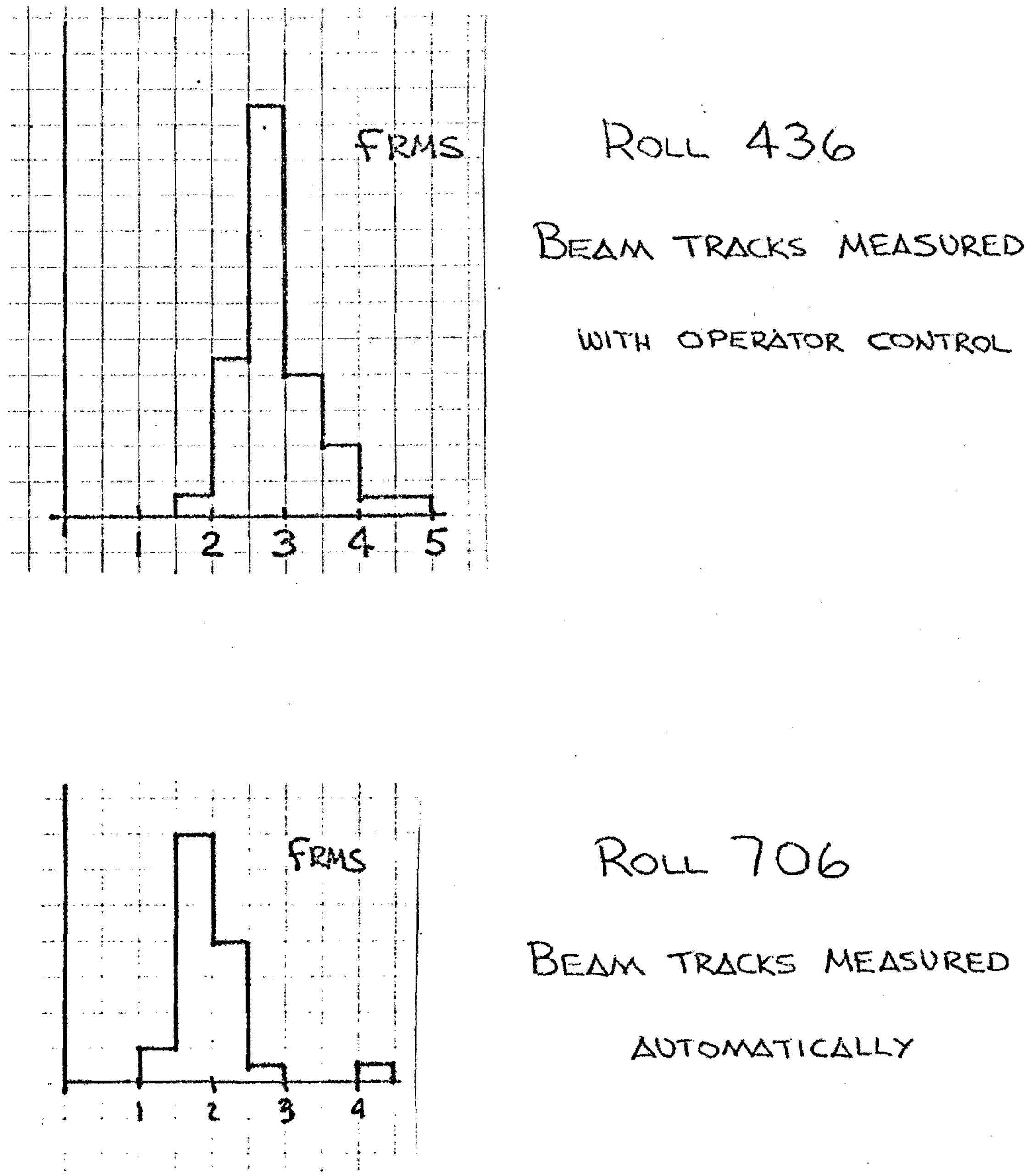


Fig. 4

RMS errors of fits by TVGP of recent 30 inch HBC measurements made on the Wisconsin HPD ("SATR").