

SOME OBSERVATIONS ON THE FIRST EVENTS SEEN AT  
THE CERN PROTON-ANTIPROTON COLLIDER

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ABSTRACT

Track information from the central detector in the UA1 experiment at the CERN proton-antiproton Collider ( $\sqrt{s} = 540$  GeV) is used to determine the charged particle multiplicity distribution for the pseudorapidity range  $|\eta| < 1.3$ . The mean value for this multiplicity per unit of  $\eta$  is  $3.9 \pm 0.3$  for events having at least one track in this range. Data from the central electromagnetic and hadron calorimeters are used to examine the correlation between the transverse energy measured in the collisions and the multiplicity in the central region.

The UA1 detector [1] will be described in detail elsewhere. It is based on a dipole magnet which produces a field of 0.7 T over a volume of 7 m × 3.5 m × 3.5 m. This magnet contains the central detector, which is a 6 m long × 2.4 m diameter drift chamber (18 cm drift space). The image read-out on the 6200 wires yields space points at centimetre intervals on the detected tracks, giving a picture of the collision. The central detector is surrounded by electromagnetic calorimeters with fine sampling. The region  $25^\circ < \theta < 155^\circ$  is covered by 48 hemicylindrical detectors (24 on each side) containing 26 radiation lengths of interleaved 1.2 mm lead sheets and 1.5 mm scintillator sheets, approximately 4 m in arc, and 22 cm wide in the beam direction. Each end of the central detector,  $5^\circ < \theta < 25^\circ$ , is covered by 32 radial sectors of electromagnetic calorimeter, containing 27 radiation lengths of 4 mm lead sheets and 6 mm scintillator sheets. The attenuation length of the scintillator in this detector has been chosen to match the variation of  $\sin \theta$  over its angular range, and thus transverse energy<sup>\*)</sup> is measured directly. This central calorimetry,  $5^\circ < \theta < 175^\circ$ , is completed by a hadron calorimeter based on the laminated return yoke of the magnet (16 samplings each of 5 cm of iron and 1 cm of scintillator) with additional end caps (23 such samplings). The dipole magnet is surrounded by large chambers composed of 8 layers of aluminium drift tubes (drift length  $\pm 7.5$  cm) which provide muon detection.

The electromagnetic and hadronic calorimetry is extended into the forward regions,  $0.2^\circ < \theta < 5^\circ$ , by the combination of calorimetrized compensating magnets,  $0.7^\circ \leq \theta \leq 5^\circ$ , and small-angle calorimeters,  $0.2^\circ \leq \theta \leq 0.7^\circ$ . These forward regions are equipped with drift chambers with image read-out, which adds to the visual capability of the UA1 detector.

Scintillation counter hodoscopes exist in front of most of the electromagnetic calorimeters, and are used to generate a pretrigger for the experiment, with a signal from the proton directional coupler providing a strobe.

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\*) We define transverse energy in a calorimeter cell, as energy recorded multiplied by the mean value of the sine of the angle subtended by the cell.

In addition, in the extreme forward regions the detector has eight small drift chambers, four on each arm at  $\pm 22$  m from the collision point, which can enter the Super Proton Synchrotron (SPS) vacuum pipe vertically inside 'Roman pots'.

During the early runs in which the results reported here were obtained, the UA1 detector was not complete in its final form. The calorimetry was fully installed and operational; the central detector was equipped partially with read-out electronics, and the data were collected without the magnetic field in the dipole.

Data were recorded during two short accelerator development periods in October and November 1981 when collisions were achieved between protons and antiprotons, each having 270 GeV energy, for periods of hours, with a maximum luminosity of  $\sim 2 \times 10^{25} \text{ cm}^{-2} \text{ s}^{-1}$ . Triggers were collected in a  $\pm 20$  ns coincidence, centred around the crossing time, between hodoscopes placed  $\pm 6.2$  m on the proton and antiproton arms. Approximately 90% of these triggers are antiproton-proton collisions. The 10% contamination of beam-gas events is consistent with the randoms rate measured between one arm and the other delayed by precisely one machine revolution period (23.04  $\mu\text{s}$ ). Because of timing problems with the antiproton injection, the position of the crossing point varied from run to run but remained constant within a particular run with a standard deviation of about 11 cm. Figure 1 shows such a vertex distribution reconstructed from tracks in the central detector.

Results from measurements at the CERN Intersecting Storage Rings (ISR) have shown that the mean charged particle multiplicity in the central rapidity plateau [2] (pseudorapidity  $|\eta| < 1.5$ ) and the cross-section  $(d\sigma/dy)_{y=0}$  [3] increase by about 40% over the ISR energy range ( $\sqrt{s} = 24\text{--}63$  GeV). It is therefore interesting to study whether this substantial violation of Feynman scaling [4] persists up to the energy of the proton-antiproton collider.

The present analysis has been concentrated on the central region, where corrections to the raw data are small and where a direct comparison with the ISR data is possible. The trigger hodoscope subtends a minimum angle of  $\sim 12$  mrad and a

maximum of  $\sim 56$  mrad. Hence most single diffraction events are excluded from the sample. However, these events should not populate the region of  $|\eta| \leq 1.3$ , and their loss should not affect a plot of mean charge multiplicity against  $\sqrt{s}$  for events with at least one track in this interval. Tight cuts on the individual time-of-flight spectra in the proton and antiproton arms have been used to select genuine interactions, and beam-gas background was further reduced by demanding at least 100 GeV energy deposited in the calorimeters with a correct indication of energy flow.

A measurement of track multiplicity was made using over 700 events from the November run which passed the above criteria. The events were scanned by physicists on a Megatek display. Tracks from the vertex were counted within a fiducial region which required them to reach a plane 40 cm above or below the beam axis and to have projected angles in the vertical plane between  $30^\circ$  and  $150^\circ$ . A subsample of these events were examined independently by all physicists who participated in the scanning. The combined effect of scanner variations and counting statistics showed a standard deviation of about 5% on the mean track number. The fiducial cuts give a flat acceptance of 0.76 at  $\eta = 0$  falling to zero at  $|\eta| = \pm 1.3$ , for a uniform track density per unit of  $\eta$ . Assuming the track density as a function of  $\eta$  has the shape shown in Fig. 4, a correction of  $(1.5\% \pm 1.5\%)$  has been applied to the integrated acceptance. To obtain the mean charged particle multiplicity, corrections were applied for electrons from Dalitz decay and conversion in the beam pipe and surrounding material ( $-6\% \pm 2\%$ ) and for nuclear interactions in the same material ( $1.5\% \pm 1\%$ ). No correction was applied for  $K_S^0$  or  $\Lambda^0$  charged decays. These would normally be counted as two charged tracks in our scan. We obtain a mean charged particle multiplicity of  $3.9 \pm 0.3$  per unit of  $\eta$  at  $|\eta| < 1.3$ . The quoted error includes an allowance for the uncertainties in the correction terms. In order to compare our data with those from Thomé et al. [2] (Fig. 9) we have included only events having at least one track in our fiducial region. If events with zero central tracks are included our quoted number is reduced by  $\sim 6\%$  to  $3.6 \pm 0.3$ . Figure 2 shows our result together with data from the ISR and results

from two cosmic ray experiments [5, 6]. These cosmic ray results, from balloon experiments with nuclear emulsions, are the highest in energy to yield information on single charged hadrons, and can thus be compared with accelerator experiments.

The multiplicity distribution of charged particles detected within our fiducial volume is shown in Fig. 3, using the coordinates suggested by the idea of KNO scaling [7]. This distribution agrees well with the one measured for pp collisions at the ISR [2] over about the same rapidity interval. The deviation from a Poisson distribution indicates the existence of multiparticle correlations.

If it is assumed that the total multiplicity is made up from  $\frac{2}{3}$  charged and  $\frac{1}{3}$  neutrals, and also that each gamma from the decay of  $\pi^0$  is counted separately, then we predict an average of about 50 particles entering the central electromagnetic calorimeters ( $5^\circ < \theta < 175^\circ$ ). We in fact measure an average of 55 calorimeter cells with a signal above threshold, which is an independent indication of the observed high multiplicity seen in the collisions.

The electromagnetic and hadron calorimeters have been used to study the transverse energy distribution in the central region of the events selected by our trigger. Figure 4 shows the plot of the transverse energy density as a function of pseudorapidity; the bin size is determined by the granularity of the calorimeter. The distribution is fairly flat, and the shallow dip which is also seen at the ISR [2] is consistent with the kinematic transformation into pseudorapidity of a uniform rapidity distribution. The left-hand vertical scale shows the visible energy measured in the electromagnetic and hadron calorimeters. The right-hand scale has been corrected by a factor 1.35 to take account of the lower response to hadrons of the electromagnetic calorimeter. An absolute scale uncertainty of  $\pm 20\%$  still remains, as a precise application of this factor requires a knowledge of the momentum of the incident hadrons. The level of the plateau suggests an average  $E_T$  per secondary particle of 0.50 GeV.

It has been suggested by Lattes et al. [8] that the C-jet events of the Chacaltaya experiment, with an average incident energy of  $\sim 130$  TeV, show a significant difference from the extrapolation of accelerator events both in their

multiplicity and their transverse energy ( $E_T$ ). They propose a correlation between  $E_T$  and multiplicity, suggesting that events fall into different classes. One such class has a low value of average  $E_T$  per secondary particle (gamma rays in their case) and a low average number of gamma rays per unit of rapidity. Another class has a high average value of  $E_T$  per secondary and also a high multiplicity. The SPS collider at  $\sqrt{s} = 540$  GeV has a laboratory equivalent energy of  $\sim 155$  TeV for fixed target collisions and so it is meaningful to examine the data for these effects.

The calorimeter data have been used in conjunction with the track information from the central detector. Figure 5 shows the deposited transverse energy as a function of observed charged track multiplicity. The average value of the transverse energy per event divided by the charged particle multiplicity seen in the central detector does not appear to depend on the multiplicity for these events.

In conclusion we make the following observations on the first events seen at the SPS proton-antiproton collider:

- i) The average charged particle multiplicity per unit of  $\eta$  for  $|\eta| < 1.3$  is  $3.9 \pm 0.3$ .
- ii) There is a flat central plateau in rapidity.
- iii) The charged particle multiplicity distribution, in coordinates suggested by KNO scaling, is the same as at ISR energies.
- iv) For the events examined, high transverse energy is built up from a large number of particles each having a rather small value of transverse energy.

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Figure captions

- Fig. 1 : A vertex distribution reconstructed from the tracks in the central detector.
- Fig. 2 : The mean charged particle multiplicity per unit of  $\eta$  for  $|\eta| < 1.5$  as a function of centre-of-mass energy for events with at least one charged particle in the fiducial region. The line is the linear fit of Thomé et al. to their data.
- Fig. 3 : The charged particle multiplicity  $n_{\pm}$  in our fiducial region.  $T_n$  is the probability for the observation of  $n$  tracks and  $\langle n \rangle_{\pm} = 6.57$  is the mean number per event.
- Fig. 4 : Deposited transverse energy as a function of pseudorapidity (see text for comments about the energy scale).
- Fig. 5 : Deposited transverse energy as a function of observed charged particle multiplicity (see text for comments about the energy scale).

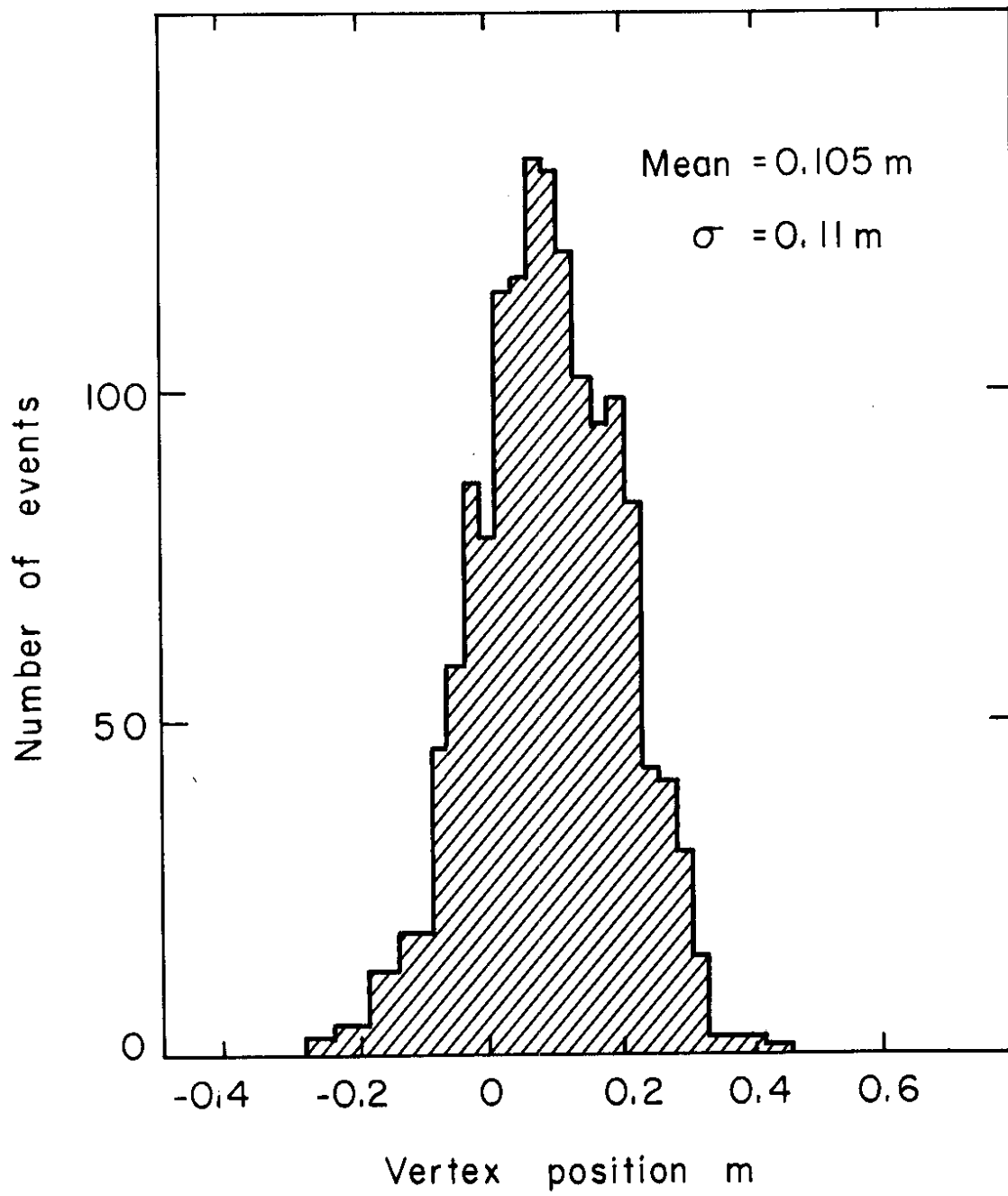


Fig. 1

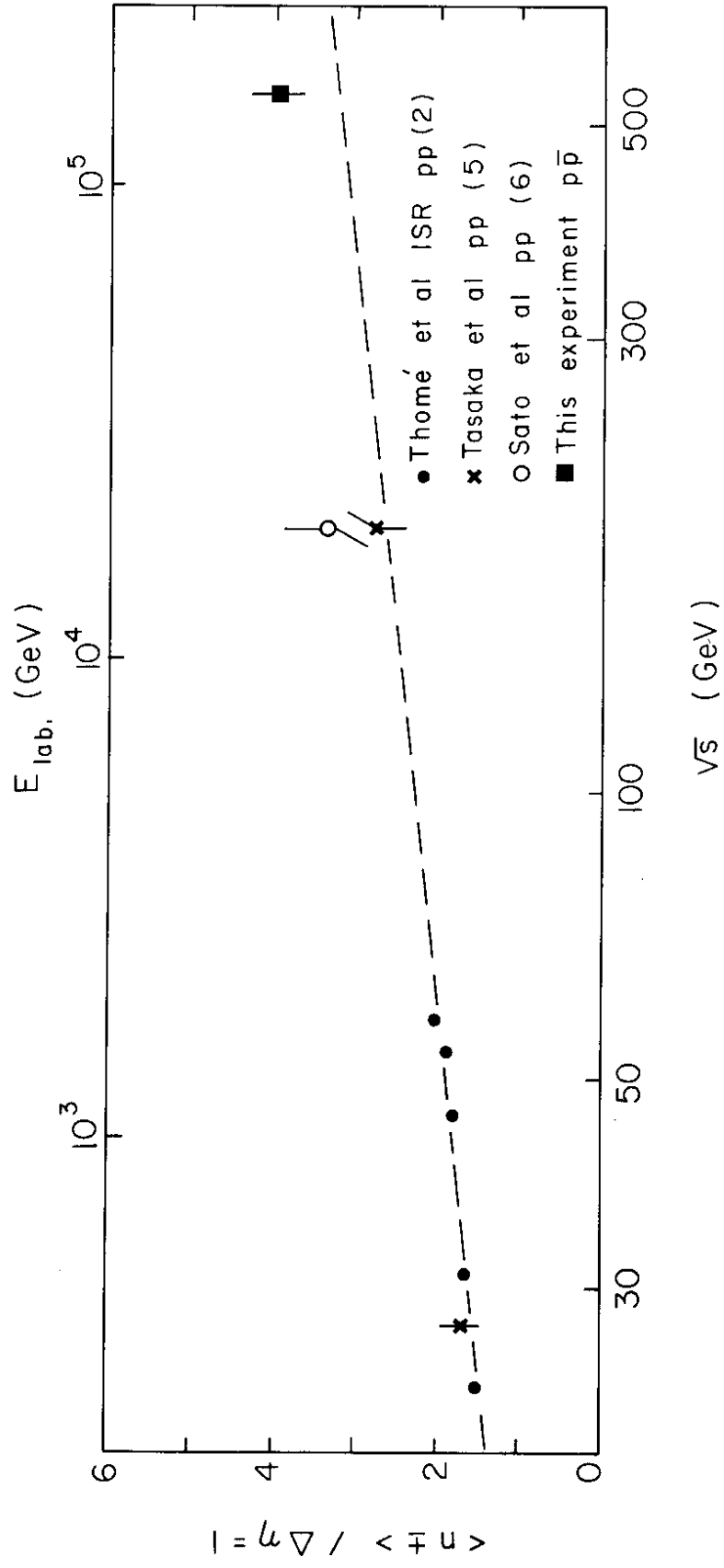


Fig. 2

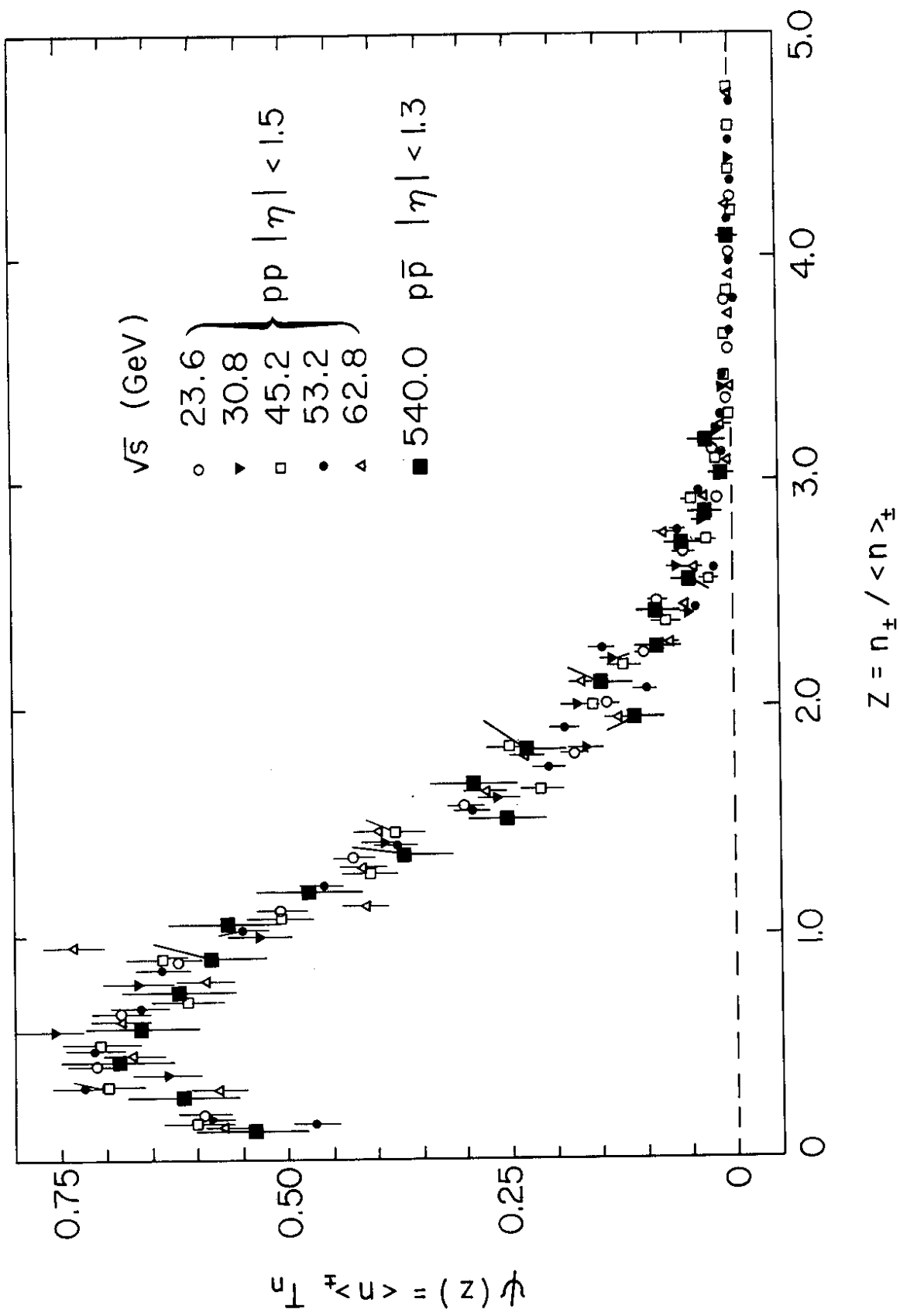


Fig. 3

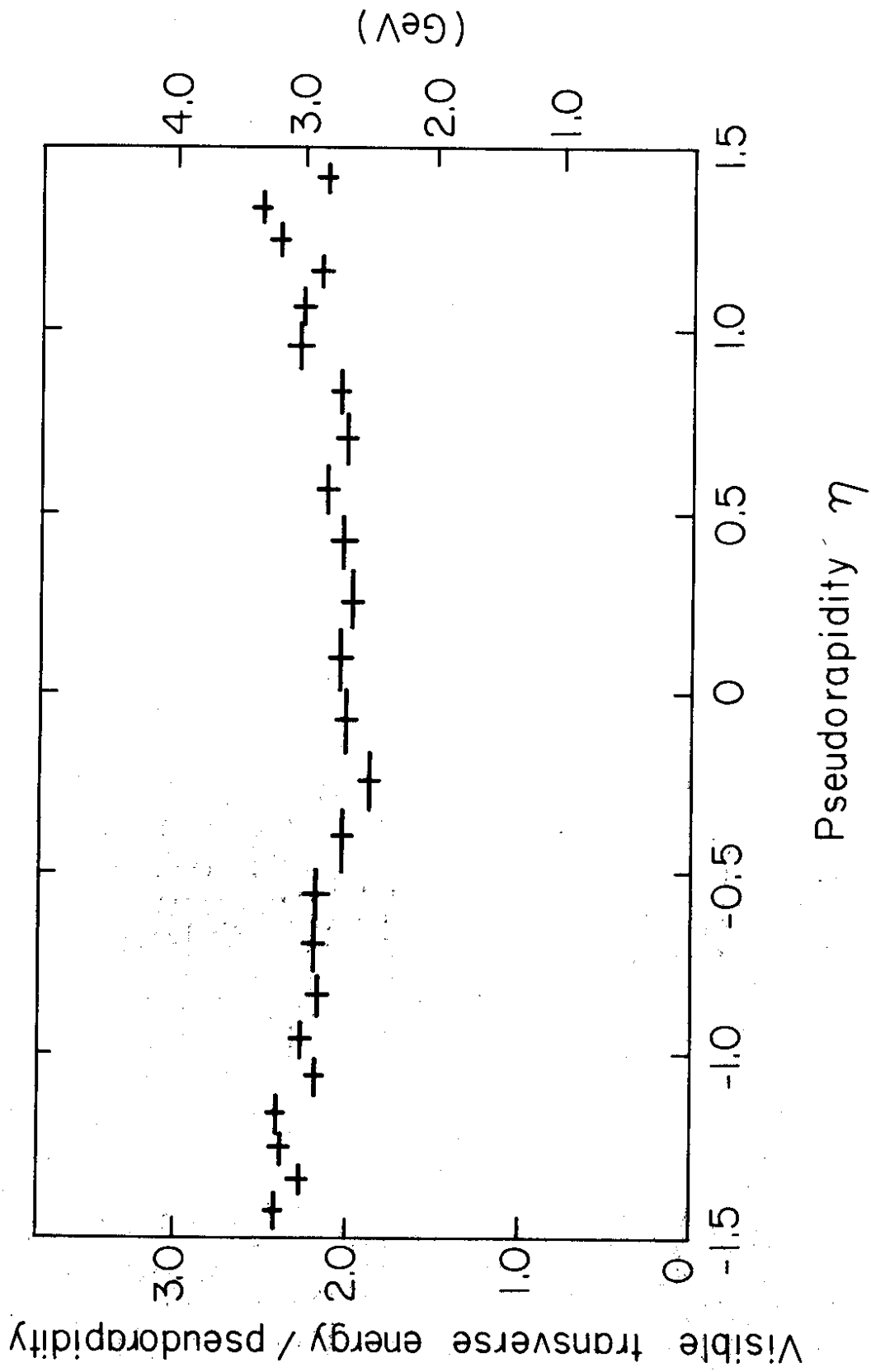
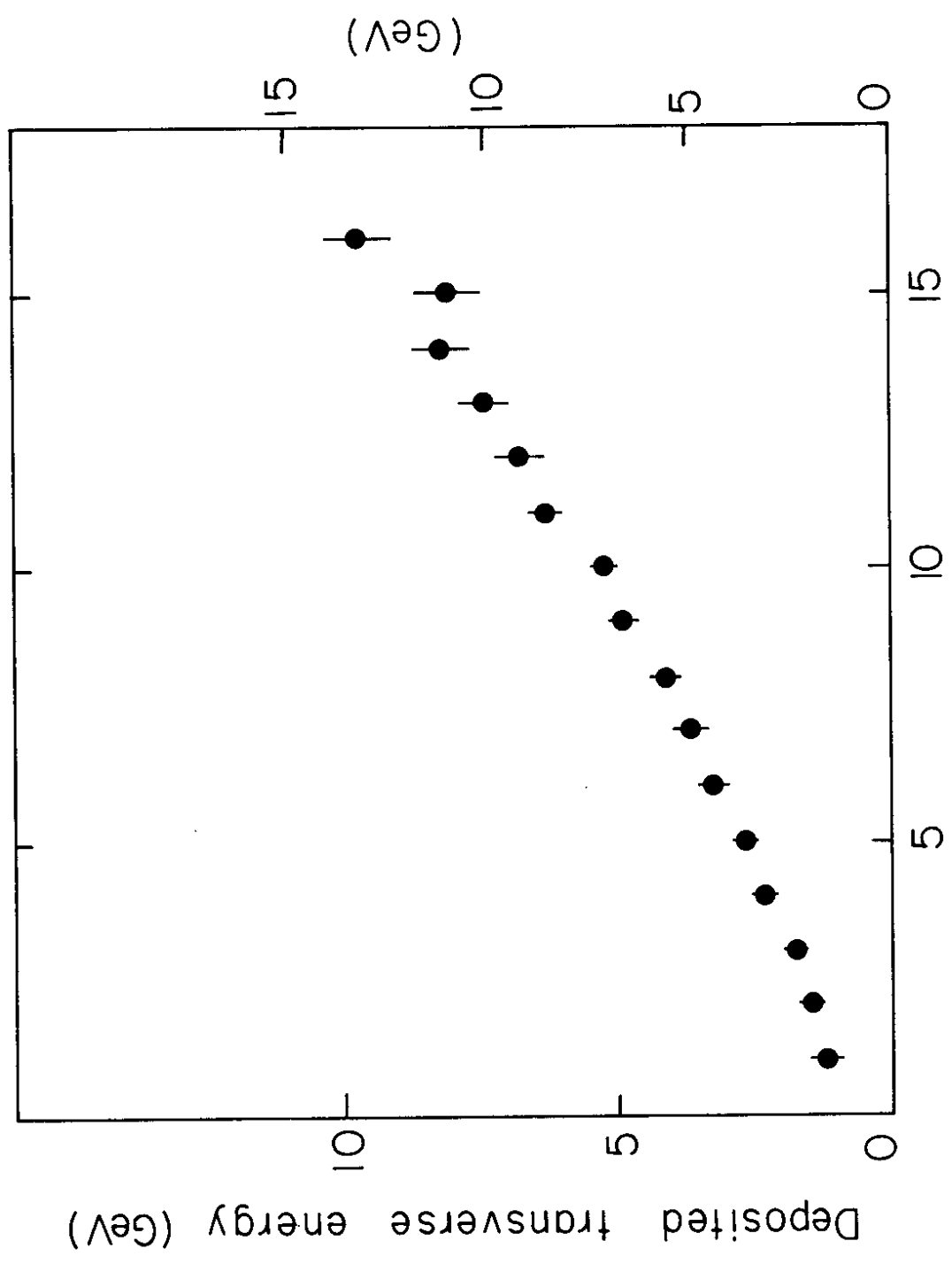


Fig. 4



Observed charged track multiplicity

Fig. 5

