Maximum-rapidity-gap distribution at high energies

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The experimental maximum-rapidity-gap distributions in 50-GeV π^--N and 67- and 400-GeV p-N interactions have been examined in the light of the model of Jones and Snider. The number of events due to diffractive dissociation (Pomeron exchange) at 67 GeV is estimated to be 9% and with increasing shower-particle multiplicity (n_s), the number of such events appears to fall sharply.

I. INTRODUCTION

It is now believed that the hadronic inelastic cross section consists of two components, the short-range-order component or nondiffractive component and the diffractive component. This fact has been expressed in several models of multiparticle production, known as two-component models.[1] However, experimentally it is difficult to separate the events into the diffractive and the nondiffractive classes. Only a few attempts[2,3] have been made in the past to do this and to study the details of the diffractive events.

Jones and Snider[3] have proposed a method of determining the amount of diffractive dissociation (Pomeron exchange) in the data. It is based on the distribution of a parameter Δ which is defined to be the maximum value of the rapidity gap (in an event) between adjacent charged particles when ordered according to their rapidity values. The usefulness of Δ is revealed by the fact that the diffractive processes are expected to contribute mainly to large values of Δ, whereas the nondiffractive ones would contribute little to this region. Jones and Snider[3] obtained the distribution $d\sigma/d\Delta$ from a multiperipheral model by taking into account the exchange of Reggeons and Pomerons and found that for $\Delta \gtrsim 4$, the distribution is dominated by diffractive dissociation.

The aim of the present work is to study the experimental $d\sigma/d\Delta$ distribution for 50-GeV π^--N, and 67- and 400-Gev p-N interactions in emulsion in the light of the model of Jones and Snider.[3]

II. EXPERIMENTAL DETAILS

The data at 50 GeV (Ref. 4) consist of a line-scan sample of 182 π^--N interactions in emulsion, whereas those at 400 GeV (Refs. 5 and 6) consist of 168 p-N events (with number of shower particles, $n_s \geqslant 4$) collected by the method of area scanning. In view of the scanning biases, we have excluded the $n_s = 2$ and 3 events from the 400-GeV data. However, the rest of the data are in good agreement with the line-scan data.[5,6] At 67 GeV, we have a rather large line scan sample of 1070 p-N events in emulsion obtained by the AADCLMTUB collaboration.[7]

At such high energies, all the charged secondary particles cannot be identified and hence their true rapidities (y) cannot be calculated. We have, therefore, used the high-energy approximation ($p \approx E$) for the calculation of the rapidity, which gives

$$y \simeq \eta = -\ln \tan(\theta/2).$$

Here η is called the pseudorapidity of a particle emitted at a laboratory angle of emission θ with respect to the direction of the primary particle.

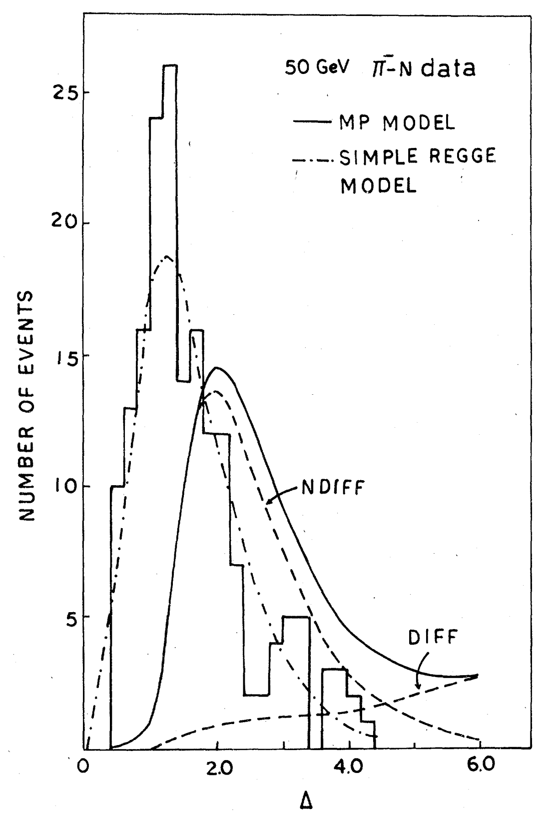

FIG. 1. The maximum-rapidity-gap (Δ) distribution for 50-GeV π^--N interactions.

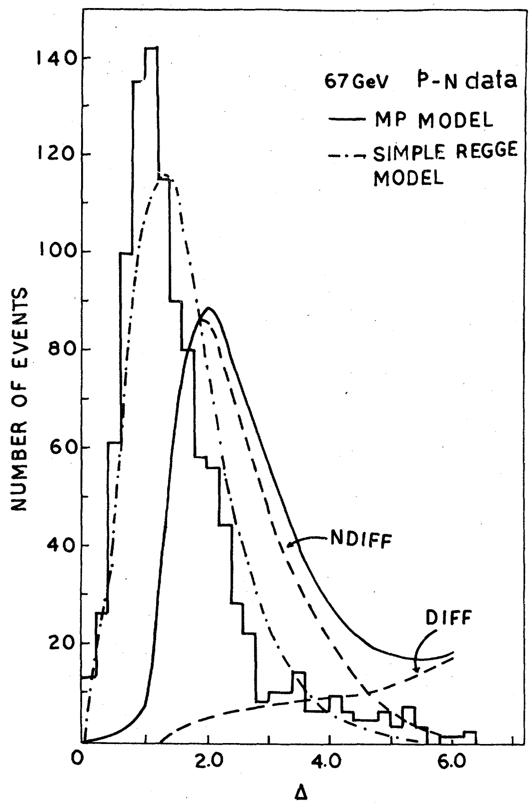

FIG. 2. The maximum-rapidity-gap (Δ) distribution for 67-GeV p-N interactions.

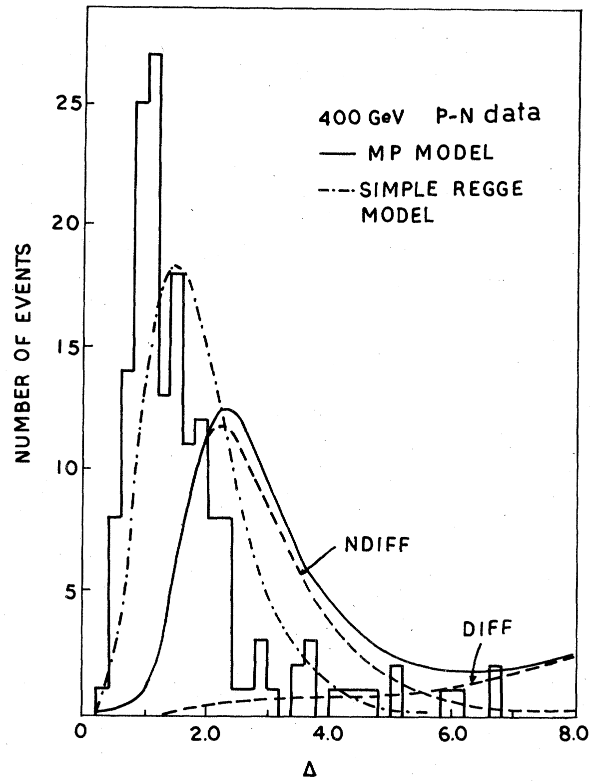

FIG. 3. The maximum-rapidity-gap (Δ) distribution for 400-GeV p-N interactions.

In the present work, the calculation of Δ is based on η instead of y.

III. RESULTS AND DISCUSSIONS

The distributions of the maximum rapidity gap Δ at 50, 67, and 400 GeV are shown in Figs. 1, 2, and 3 respectively. The solid curves are the predictions of the multiperipheral (MP) model of Jones and Snider.[3] The dotted curves are the breakup of the solid curves into diffractive (DIFF) and nondiffractive (NDIFF) parts. The curves drawn by dots and dashes are the predictions of a simple Regge model (as discussed by Jones and Snider[3]) for the nondiffractive component of the $d\sigma/d\Delta$ distribution. The histograms in Figs. 1, 2, and 3 indicate that after their prominent peaks the distributions fall sharply, and beyond $\Delta \sim 3.0$ they tend to be flat. Therefore we have identified the two regions having $\Delta < 3.0$ and $\Delta \geq 3.0$ as being mainly due to nondiffractive and diffractive components respectively. Keeping this in mind, the curves drawn by dots and dashes, which represent only the nondiffractive part, have been normalized with the experimental distributions only up to $\Delta = 3.0$. On the other hand, Jones and Snider[3] have suggested $\Delta \simeq 4.0$ as the separation point for the two components. It is quite possible that the experimental distributions obtained at energies higher than 400 GeV may display this demarcation at $\Delta \sim 4.0$.

The following features emerge from an examination of the distributions shown in Figs. 1, 2, and 3:

(1) In the low-Δ region, there exists a peak (presumably due to the nondiffractive component) which falls off rapidly. The peaks in the experimental distributions of 50-, 67-, and 400-GeV

TABLE I. The number of diffractive events (%) and the values of their $\langle\Delta\rangle$ as a function of multiplicity for 67-GeV p-N interactions.

n_s	Diffractive events (%)	$\langle\Delta\rangle$
2	48	4.3
3	5	3.9
4	18	3.7
5	3	3.3
6	4	3.8
7	2	3.3
≥ 8	0	
All	8.6	4.03

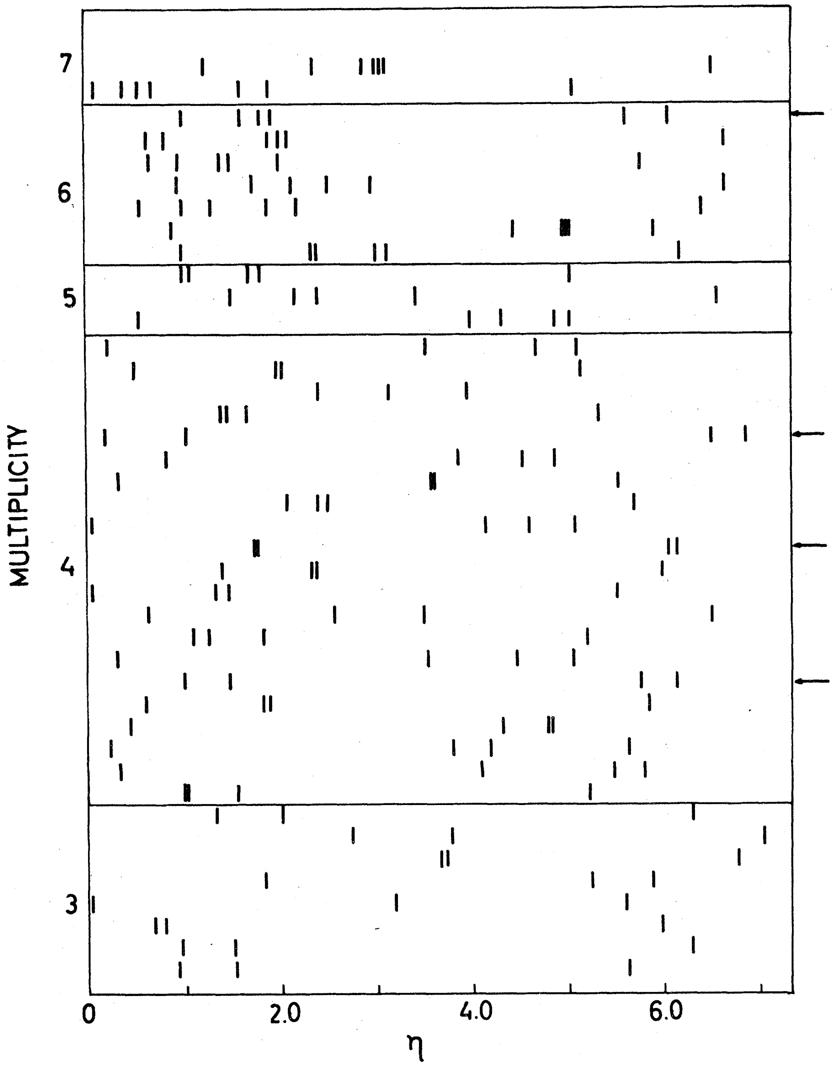

FIG. 4. The pseudorapidity (η) distribution of diffractive events (having $\Delta \geq 3.0$) from 67-GeV p-N interactions. The events marked with arrows are those having their Δ falling in the central region of rapidity.

data fall in the Δ regions 1.2–1.4, 1.0–1.2, and 1.0–1.2 respectively. From theory,[3] we expect the peaks to fall at $\eta_{max}/\langle n\rangle$, where $\langle n\rangle$ is the average number of charged particles, and $\eta_{max} = \ln(s/m_\pi)$ is the maximum value of η at c. m. energy $\sqrt{s}$. Thus theory predicts the diffractive peaks at $\Delta = 1.1$, 1.2, and 1.0 for the 50-, 67-, and 400-GeV data respectively.

(2) Comparison of the solid curves with the experimental distributions indicates that events exist, although in smaller number than predicted by theory, which are due to Pomeron exchange, i.e., due to diffractive dissociation of the colliding particles. However, there is no indication of a pure diffraction peak at large values of Δ as expected from theory.[3] It may be remarked that in the 400-GeV data some events due to the diffractive component might have been removed by the cut $n_s > 3$. It is expected that inclusion of these events may improve the agreement between theory and experiment in the diffractive region. It is difficult to estimate the number of such events in our experiment[6]; however, we note that in the 50- and 67-GeV data, where no cut on n_s has been imposed, the disagreement between theory and experiment does exist.

(3) Neither the simple Regge model[3] (dot-dash curves) nor the multiperipheral model[3] (solid curves) agrees with the experimental distribution. However, the former model of nondiffractive production depicts well the trend of variation of the $d\sigma/d\Delta$ distribution in the nondiffractive region ($\Delta < 3$) at all three energies. The marked discrepancy of the complete model (solid curve) with

the experiment may be due to the existence of two-particle correlations[5] among the secondary particles. Such observations have been made at 200 GeV also.[2]

In order to determine the gross characteristics of diffractive events, we assume that all events for which $\Delta \geq 3.0$ are due to the Pomeron exchange mechanism. Further, since statistics at 67 GeV are rather good as compared to those at other energies considered here, we give these features only for 67-GeV p-N interactions.

The number of diffractive events, i.e., those having $\Delta \geq 3.0$ in the whole sample, is 92, which constitutes about 9% of the total number of events. The percentage of diffractive events and the average value of Δ at each multiplicity have been shown in Table I. It is observed that the number of diffractive events drops sharply with multiplicity, and for high-multiplicity events ($n_s \geq 8$) no diffractive dissociation occurs.

In Fig. 4, the distributions of the secondary charged particles in rapidity space for each diffractive event are shown. An interesting feature which can be immediately seen is that the maximum gap Δ occurs generally at the end, either near the target or near the projectile region. Only in four events (see Fig. 4) do we find that Δ occurs as a central gap. Thus the diffractive production seems to occur predominantly through a process in which either the projectile or the target is excited to a higher mass state, which subsequently decays, producing the fragmentation products. A double-diffractive dissociation mechanism where both target and projectile are excited would lead to the occurrence of Δ in the central region of rapidity. The probability of this process occurring seems to be quite small, as we find only 4 such events in our data.

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