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Study of rapidity gap correlations in 400 GeV/c p-N interactions

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A study of the rapidity gap distribution from p-N interactions obtained from an emulsion stack exposed to 400 GeV/c proton beam at FNAL is reported. The data show that there is a correlation in rapidity gaps such that in general a small gap (≤ 0.1) occurs next to a small gap. This observation favours a two-channel Chew-Pignotti-type multiperipheral model. Our data also suggests that, an individual cluster should consist of more than two charged particles at our energy of 400 GeV.

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I. INTRODUCTION

The dynamics of multiparticle production in high energy hadron-hadron interactions is now understood in terms of a multiperipheral model. Several versions[1] of the model have been proposed to explain the experimental features. The rapidity gap[2] (r) distribution is one of the most successful methods of studying the mechanism of multiparticle production. Theoretical analyses[3,4] have shown that the rapidity gap distribution may give insight into the dynamics of interactions : especially the cluster formation.

In the present work, we report our experimental data on rapidity gap[5] correlation from p-N interactions at the highest available accelerator energy - 400 GeV, with a view to find out as to which of the multiperipheral model on cluster formation is supported by our data. In particular, we concentrate on two such models, one due to Snider[3] (Model-I) and the other due to Quigg et al.[4] (Model -II). These models differ in the following respects.

In Model-I, which is essentially a two-channel generalisation of Chew-Pignotti[6] model, all the charged particles are assumed to be produced singly from Regge exchanges. It uses as input two different Regge trajectories, one near J = 0.5 and another near J = -0.5. In Model-II, particles are supposed to be produced in clusters. They are emitted independently from a multiperipheral chain with $\alpha = 0.5$. The diagrams corresponding to Model-I and Model-II are shown in Figs. 1(a) and 1(b) respectively. The Model-II is also ascribed to the independent emission of clusters.[7] The Model-I predicts that next to a small (large) rapidity gap probably a small (large) gap occurs. But the Model-II predicts that the gaps tend to alternate. Thus in the first case one expects short-short or long-long correlations in rapidity gaps whereas in the second case short-long correlations are favoured. Another striking difference between the two models is the number of charged particles emitted per cluster. In Model-I, the average size of the cluster is expected to be more than two whereas Model-II predicts the average size of cluster as two.

II. EXPERIMENTAL DETAILS

The experiment was carried out by exposing a stack of 50 K5 nuclear emulsion pellicles each of size $16 \times 10 \times 0.06\ cm^3$ to a flux of $\simeq 5 \times 10^4$ particles per cm^2 from proton beam of momentum 400 GeV/c at FNAL. A total of 4020 interactions was collected by area-scan method. After applying the various selection criteria as detailed in our earlier paper,[8] we are left with 2488 interactions which are attributed to the primary interactions with emulsion nuclei.[9] For the present work we have selected a random sample of p-N interactions having $n_s \geq 4$.[10] The p-N like interactions were selected by applying the followi...

well-known criteria.

1) Event should have no black track associated with it, i.e., $N_b = 0$

2) Event should either have vo grey track ($N_g = 0$) or at the most one grey track ($N_g = 1$) associated with it. In the latter case, the grey track should lie only in the forward direction in the laboratory system.

3) Event should have no Auger election or recoil nucleus associated with it.

We finally obtain a sample of 168 p-N like interactions which contribute to a total of 1937 shower tracks for the present analysis.

III. RESULTS AND DISCUSSIONS

Following Snider[11] we now define a small gap as one having $r \leq 0.1$ and a large gap as one having $0.8 \leq r \leq 1.0$. In Fig. 2 we have shown a two dimensional plot of r_i versus r_{i+1} for our data on a logarithmic scale. It shows crowding of points along the line $r_i = r_{i+1}$, which indicates that our data favour short-short and long-long correlations. A better grasp of the short-short correlations may be had from the distribution of gaps next to a small gap. This distribution shown in Fig.3, indicates that in our data, next to a small gap, a small gap occures at least ten times more frequently than a large gap. We thus conclude that our data indeed favours short-short type correlations, thereby supporting Model-I.

It is believed that the decay products of a cluster are generally emitted close to each other in rapidity space[1]. Therefore, in view of our observed short-short type correlations, we expect at least two short gaps adjacent to each other. These can only be generated by three closely emitted charged particles. Thus the minimum number of charged particles constituting a cluster in our data should be three. This observation again supports the prediction of Model-I.

A more straight forward prediction of Model-I is the rapidity gap distribution of the form :

$$dn/dr = 0.2\, e^{-0.9r} + 2.4\, e^{-3.1r} \quad . \qquad (1)$$

In Fig. 4 we have shown the rapidity gap distribution for our data at 400 GeV/c. The solid curve corresponds to the fit ($\chi^2/NDF = 1.2$) :

$$dn/dr = 0.18\, e^{-0.7r} + 2.98\, e^{-3.9r} \qquad (2)$$

The form of the fit seems to agree well with the prediction of Model -I.

Another feature of Model-I is the expectation of a dip in the rapidity gap distribution at $r \approx 0.0$. No such dip is seen in our experimental data as is evident from Fig.4. When

When we divide our data of first bin of 0.0 - 0.04 into two bins: 0.0 - 0.02 and 0.02 - 0.04, the number of gaps comes out to be 104 and 65 respectively. Thus the trend still remains the same and in no way a dip can be created around $r \approx 0.0$. This result is ~~pen~~ consistent with the observation in 205 GeV/c bubble chamber data.[3] It may however be mentioned that a better resolution in angles can be achieved in nuclear emulsion than in bubble chamber. The experimental resolution in our data is at least 0.02 rapidity gap unit. The absence of dip may thus indicate that complex poles are probably not important in non-diffractive cross-section as suggested by Snider.[3]

It may be concluded that the multiperipheral model of Snider[3] seems to describe the experimental features of rapidity gap distribution at 400 GeV/c. Also as suggested by Model-I, an individual cluster should consist of more than two charged particles at our energy - 400 GeV.

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1. I.M.Dremin and A.M.Dunaevskii, Phys. Rep. 18C, 159 (1975); I.M. Dremin, A.M.Orlov and E.I. Volkev, P.N.Lebedev Physical Institute Preprint, N. 120 (1978).

2. A rapidity gap, r, is defined as the difference in rapidity between neighbouring final state particles (ordered in rapidity) with the exception of leading and target particles. Thus one considers the secondary particles in the central region only and the two particles on each side of the rapidity space are neglected. In this way, an event with n_s charged particles contributes to the rapidity gap distribution $n_s - 3$ times with contribution coming only from events having $n_s \geq 4$.

3. D.R. Snider, Phys. Rev. D 11, 140 (1975).

4. C. Quigg, P. Pirila and G.H. Thomas, Phys. Rev. Lett. 34, 290 (1975).

5. In the present experiment, the rapidity gap, r, is determined by using pseudo-rapidity $\eta = -\ln \tan(\theta_{lab}/2)$, instead of rapidity, $y = -\frac{1}{2} \ln [(E - p_L)/(E + p_L)]$ (see for example, B. Singer et al., Phys. Lett. 49B, 481 (1974)). This is because it is not generally possible to measure the momenta of high energy ($p \geq 15$ GeV/c) shower particles with a desired accuracy. However, this is not a serious limitation since the value of r calculated either by using η or y remains practically the same.

6. G.F. Chew and A. Pignotti, Phys. Rev. 176, 2112 (1968).

7. A.W. Chao and C. Quigg, Phys. Rev. D 9, 2016 (1974).

8. M.M.Aggarwal et. al., Nucl. Phys. B131, 61 (1977).

9. It may be mentioned that the number of events with $N_h \leq 1$ in our data (ref. 8) and in the line-scan data of Tsai-Chu et. al. (see Tsai-Chu et. al, Nuovo Cimento Lett. 20, 257 (1977)) are $(23.6 \pm 0.5)\%$ and $(26.3 \pm 1.5)\%$ respectively. Thus we believe that there is no appreciable loss of events with $N_h \leq 1$ in our area-scan data.

10. Events with $n_s < 4$ do not contribute to our rapidity gap distribution for reason mentioned in ref. 2.

11. D.R. Snider, University of Illinois Preprint No. ILL (TH) - 75-5.

LIST OF FIGURES

Fig. 1. Typical diagram corresponding to (a) Model-I and (b) Model-II for the production of 12 charged particles. The horizontal scale may be assumed to be about 8 units in rapidity.

Fig. 2. Scatter plot of rapidity gap r_i versus next gap r_{i+1}. The dashed line corresponds to $r_i = r_{i+1}$.

Fig. 3. Distribution of rapidity gap r_{i+1} next to a small rapidity gap r_i (≤ 0.1).

Fig. 4. Rapidity gap r distribution at 400 GeV/C. The solid curve represents a fit due to Eq.(2) as in the text. The dashed lines represent the contributions of the two exponential terms individually.

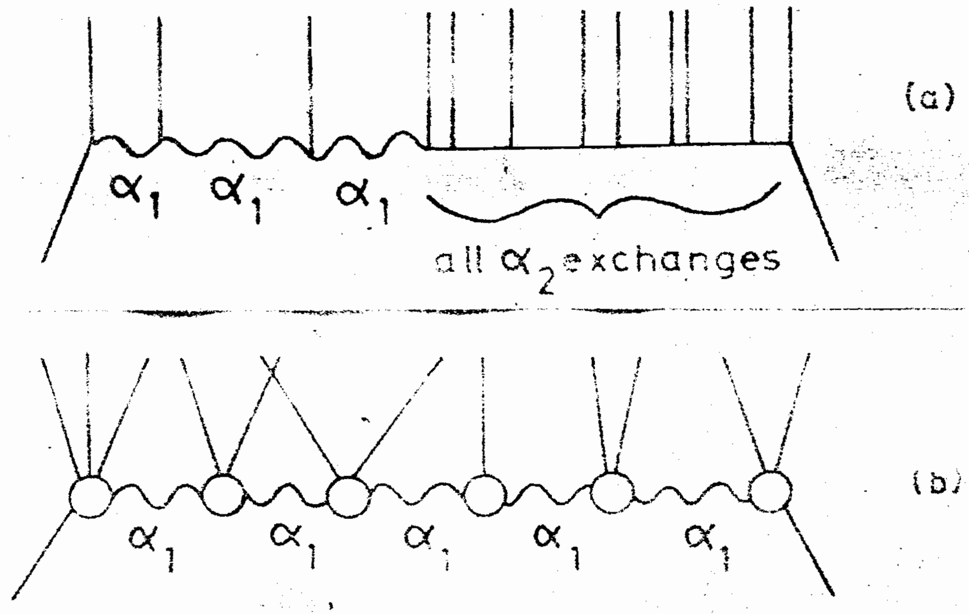
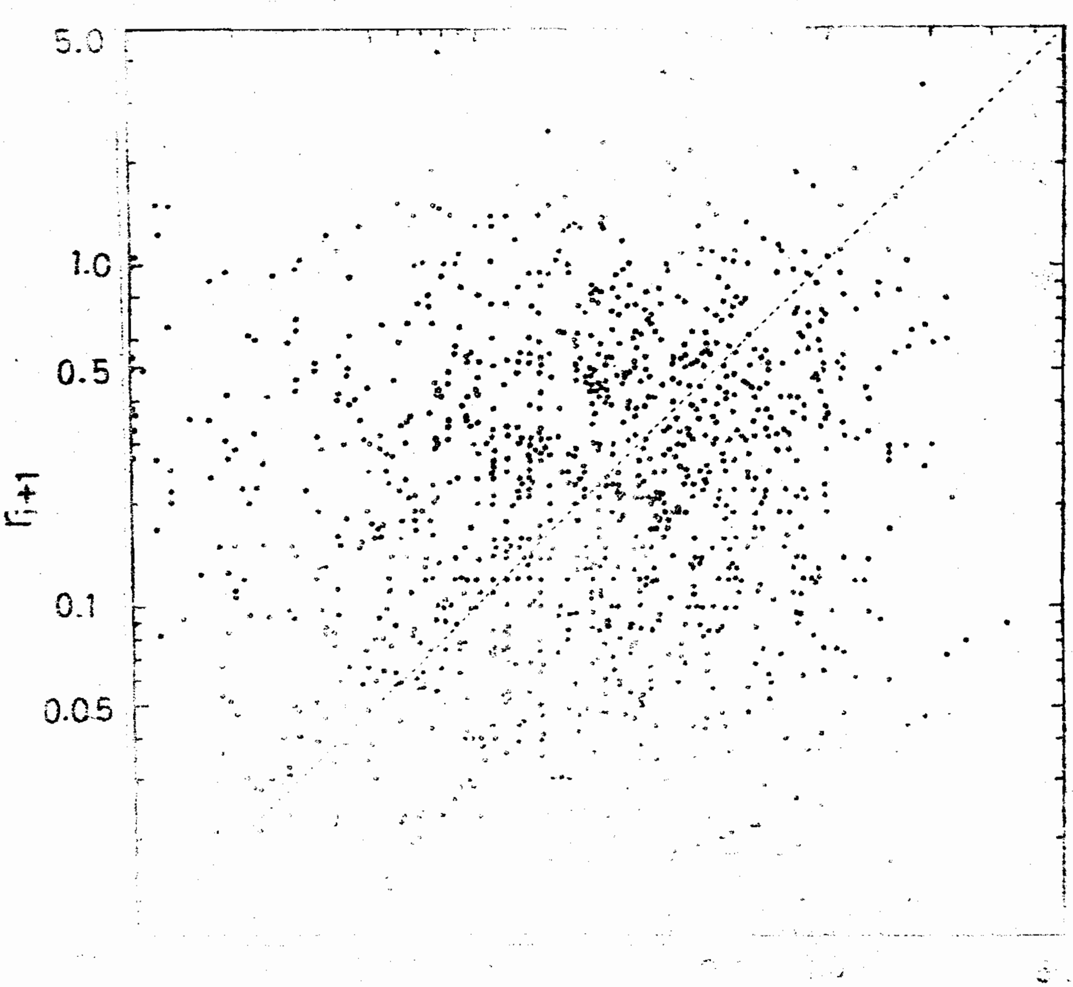

(a)
α_1 α_1 α_1
all α_2 exchanges
(b)
α_1 α_1 α_1 α_1 α_1

FIG. 1


5.0
1.0
0.5
0.1
0.05
r_{i+1}

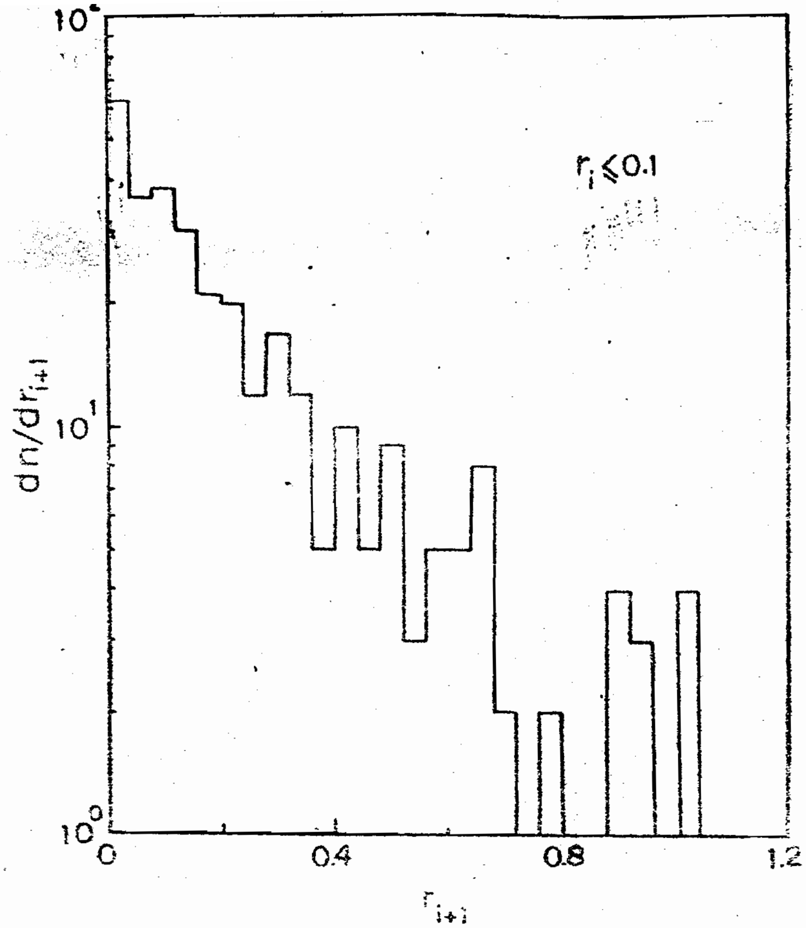


FIG. 3