AN INVESTIGATION OF DIFRACTIVE DISSOCIATION
IN MULTI TeV HADRON-HADRON AND HADRON-NUCLEUS
INTERACTION

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ABSTRACT

This paper presents a first detailed investigation of diffractive process in hadron-hadron
and hadron-nucleus interaction at multi TeV cosmic ray energies using the method of the
maximum pseudorapidity gap distribution of charged particle in individual events. The
experimental distribution has been compared with the theoretical prediction of Jones and
Snider.

1. Introduction

Multi TeV hadron-hadron and hadron-nucleus interaction has been as subject of immense importance to the high ener-
gy physicist in recent time, since it is believed that multi TeV interactions might reveal some surprising phenomena.
Further it has been well recognized that the nuclei can offer a quite unique possibility of studying such properties
which can not be obtained by studying hadron-hadron interaction alone. Although considerable experimental and
theoretical works have been done to study the particle production off nuclei at acceleration energies still the dyna-
mics of production process in hadron-nucleus collision is less understood. In case of multi TeV range this type of
study is completely inadequate.

2. Method of Analysis

One of the important characteristics of the multi-
particle production which deserves special attention is the
maximum pseudorapidity gap distribution. The rapidity (Y)
of each charged secondary particle produced in an inelastic
interaction is defined as

\[ Y = -\frac{1}{2} \ln \frac{E + p_T}{E - p_T} \]  (1)
where $E$ and $p_{li}$ are the energy and longitudinal momentum of the secondary particle respectively. For $p_T^2 \gg m^2$ (where $p_T$ and $m$ denotes the transverse momentum and mass respectively), Eqn. 1 becomes

$$\gamma = -\ln \tan \frac{\theta}{2} = \eta$$

where $\theta$ is the spatial emission angle, $\eta$ is called the pseudorapidity of a particle. By ordering the pseudorapidity of each charged particle in an event as

$$\eta_1 < \eta_2 < \ldots < \eta_i < \ldots < \eta_n$$

where $n$ is the charged multiplicity in rapidity space, the maximum pseudorapidity gap ($\Delta_{\text{max}}$) is defined to be the maximum value of the pseudorapidity gap between adjacent charged particle in their pseudorapidity values i.e.

$$\Delta_{\text{max}} = \max[\eta_{i+1} - \eta_i]$$

From the study of $\Delta_{\text{max}}$ distribution one hopes to get information about the nature of particle production process. The diffractive processes are expected to contribute mainly to large values of $\Delta_{\text{max}}$ whereas the non-diffractive ones would contribute very little to that region of $\Delta_{\text{max}}$. Further Jones and Snider (1974) have suggested that the maximum rapidity gap distribution can be used as an energy-independent method of determining the amount of diffractive dissociation in the data. They have obtained distributions from a multiperipheral model by taking account the exchange of Reggeons and Pomerons and found that the $\Delta_{\text{max}}$ distribution is dominated by diffractive dissociation for $\Delta_{\text{max}} > 4$. A few works (Arya et al. 1980, Didenko et al. 1976) have been reported when study of $\Delta_{\text{max}}$ distribution has been made in case of hadron-hadron interaction. In a recent paper (Ghosh, 1982) we have a first investigation on the diffractive process in proton emulsion interaction in the entire machine energy range (22.6 - 400) GeV/c using the method of maximum pseudorapidity gap distribution. However no such study has been made so far in case of multi TeV cosmic ray energies. In view of this we have made a similar analyses for both hadron-hadron and hadron-nucleus interactions at the cosmic energy ($1 - 2600$) TeV, and compare the result with those obtained at machine energies.

3. Result and Discussion:

The experimental data have been taken from I.C.E.F. collaboration (Brisbout et al., 1963). Events were divided into two parts:

$N_h \leq 1$ to indicate hadron-hadron interaction and $N_h \geq 2$ to indicate hadron-nucleus interaction.
As mentioned earlier we actually calculate maximum pseudorapidity gap \( \Delta_{\max} = (\eta_{i+1} - \eta_i) \) in each event. The use of \( \eta \) instead of \( Y \) will not affect the resolution for obtaining the separation of the two regions-diffractive and non-diffractive since the energy concerned is enough high. The exponentially distribution of \( \Delta_{\max} \) for \( N_h \ll 1 \) and \( N_h \gg \) 2 events are shown in Fig. 1 and Fig. 2 respectively. The solid curve indicates the prediction according to Jones and Snider. The dashed curve (1) and (2) are the break up of the solid curve into diffractive and non-diffractive parts.

The following interesting features are revealed from the comparison of the experimental points and the theoretical curves:

1) For both hadron-hadron and hadron-nucleus interactions and there is a prominent peak in the small region due to non-diffractive production and the distribution fall off rapidity.

2) The experimental peak is shifted significantly with respect to the theoretical distribution towards the region of small \( \Delta_{\max} \) values. This shift can, however, be explained by the correlation of secondary particles.

3) In both the cases beyond \( \Delta_{\max} \gg 3.5 \) there is no event signifying no contribution due to diffractive dissociation.

4) As one goes from hadron-hadron to hadron-nucleus case the distribution of \( \Delta_{\max} \) has been observed.

It is extremely interesting to compare these observations with those at accelerator energies (22, 6 - 400) GeV/c. The observations (1), (2) and (4) are in agreement with the machine data whereas observation (3) disagrees. Some events were observed at each accelerator energy which are due to diffractive dissociation. Thus this analysis provides significant informations needed for the understanding of the particle production on nuclei at multi TeV energies.
Fig. 1. Experimental distribution of $\Delta_{\text{max}}$ for events with $N_h \leq 1$ along with the prediction of Jones and Snider.

Fig. 2. Experimental distribution of $\Delta_{\text{max}}$ for events with $N_h > 2$ along with the prediction of Jones and Snider.

References
Brisbout et al. (1963) Nuovo Cim. Suppl. 1039, 1