A COMPARATIVE STUDY ON THE FOUR-MOMENTUM TRANSFER BETWEEN FIREBALLS PRODUCED IN HADRON-NUCLEUS AND NUCLEUS-NUCLEUS INTERACTION

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ABSTRACT

In this work we have made a comparative study of the lower limit of the four-momentum transferred between groups of secondary particles in jets produced by proton at 400 GeV/c and oxygen 16 at 2.1 GeV/nucleon. The multiplicity dependence in both cases has been investigated. A comparison is made by estimating the longitudinal component of the four-momentum transfer per elementary NN interaction inside the target nucleus. Also a deviation in the peak position in the distribution of four-momentum in two cases were observed and the possible significance discussed.

1. Introduction

In recent years there has been tremendous activity in studying hadron-nucleus and relativistic heavy ion interaction. The prime interest lies in the fact that such study might provide much more information about the elementary nucleon-nucleon process.

The dynamics of hadron-nucleus and heavy-ion interaction can be understood using the concept of fireball models. One of the important characteristics is the four-momentum transfer between fireballs which is a quantity invariant under Lorentz transformation. In view of above we present in this paper a comparative investigation on the lower limit of the four-momentum transfers between fireballs produced in the interaction of $^{16}$O with nuclei of photoemulsion at
2.1 GeV/n and in the interaction of 400 GeV proton with nuclei of photoemulsion.

2. Method of Analysis

The four-momentum transfer between the fireballs is given by

\[ \Delta \vec{z} = (\vec{p}_1 - \vec{p}_2) \times (\vec{E}_1 - \vec{E}_2) \times \]  

where \( P \) and \( E \) refer to momentum and energy of fireballs. Neglecting the terms of higher order in the transverse momentum and masses in the relativistic approximation the longitudinal component of the four-momentum transfer between the fireballs can be expressed as \[ \sum_{\text{Fujikai et al 1963}} \]

\[ \Delta \hat{z} = (i \cdot \delta \sum p_{\perp} \sum \tan \theta_i \sum \cot \theta_j \]  

where \( \theta_i \) and \( \theta_j \) denote the space angle of the particles produced from the decay of the fireballs, \( p_{\perp} \) is the average transverse momentum of the particles produced, the factor account for the neutral pion.

Thus we can estimate \( \Delta \hat{z} \) only from the emission angles of the particles and the average transfer momentum.

To calculate in such event the shower particles are divided into two groups with indices \( i \) and \( j \) the first of which contains particles emitted at an angle smaller than a certain definite value of \( \theta_i \) in the laboratory system and the second all the remaining particles. The value of \( \Delta \hat{z} \) can then be calculated using formula (2) for all possible values of \( i \) from \( 1(j = n_s - 1) \) to \( n_s - 1 \) \((j = 1)\).

3. Experimental details

Data from a set of photoemulsion Illford K2 plates exposed to 2.1 GeV/\( \mu \)n \( ^{16} \)O beam and 400 GeV proton beam in the present investigation. The scanning of the plates was performed on a Leitz-Ortholux microscope provided with a Brower travelling stage. Plates were scanned using an oil immersion 53.1 x objective in conjunction with a 16.8 x ocular. The events were chosen utilizing the following criteria i) the beam track must be \( 1^\circ \) to the mean beam direction in the pellicle ii) interaction should not be within the top or bottom 20 um thickness of the pellicle. Further all primary beam tracks were followed back to be sure that the events chosen did not include interactions from the secondary tracks of other interactions. The primaries originated from other interactions were observed and the corresponding events were removed from the sample. With these criteria a sample of 380 events were selected for analysis. The shower tracks are selected according to the
criterion $b^*$ 1.4 where $b^*$ is the normalised blob density. The spatial emission angles of all shower particles in an event were obtained by measuring $x$, $y$ and $z$ coordinates of the interaction vertex, three points on the beam track and three points on the shower track and hence the rapidity (actually pseudorapidity) $Y = -\ln (\tan \theta/2)$ were calculated for all showers.

4. Results and Discussions

We calculated $\Delta_\|$, for each event following the procedure described in section II. The obtained $n_\|$ values of $\Delta_\|$ were plotted against the corresponding values of angle $\theta$ in $\log_2 \tan \theta$ scale. The typical examples of the results thus obtained are shown in Fig. 1 and 2 for 0.16 and 400 GeV events respectively. The lower part of the plot show the spectrum of the emission angle of the particle in $\log_2 \tan \theta$ scale. It is interesting to observe that in the most of the cases there is a pronounced maxima. The distribution taking all values obtained as above is shown in Fig. 3 and 4. It is observed that the peak occurs at 1.6 GeV in the case of 0.16 and 1.4 GeV in the case of 400 GeV proton. To study the correlation between the multiplicity and the momentum transfer we plot $\Delta_\|$ against $n_\|$ in Fig. 5 and 6. It is interesting to observe that in each case $\Delta_\|$ increases with increase of $n_\|$. By a least square fit the following relation between $\Delta_\|$ and $n_\|$ has been obtained

$$\langle \Delta_\| \rangle = n_\|^2.3$$ for 0.16 and

$$\langle \Delta_\| \rangle = n_\|^2$$ for 400 GeV proton. It may be remarked that $\langle \Delta_\| \rangle$ is expected to be an increasing function of the multiplicity $n_\|$ since the reciprocal of $\langle \Delta_\| \rangle$ is regarded as a measure of the impact parameter in a collision and $n$ will be more in centre collision than in peripheral one.

The longitudinal component of the four-momentum transfer per elementary NN interaction inside the target nucleus has been found to be 1.39 GeV for 400 GeV proton and 1.30 GeV for 2.1 GeV/n 0.16
Fig. 1: Plot of $\langle \Delta n \rangle$ against $\log_{10} \tan \theta_L$ (2.1 GeV/n, 0°)

Fig. 2: Plot of $\langle \Delta n \rangle$ against $\log_{10} \tan \theta_L$ (400 GeV P)

Fig. 3: $\sqrt{\Delta n}$ distribution (2.1 GeV/n, 0°)

Fig. 4: $\sqrt{\Delta n}$ distribution (400 GeV/c P)

Fig. 5: Plot of $\langle \Delta n \rangle$ against multiplicity (2.1 GeV/n, 0°)

Fig. 6: Plot of $\langle \Delta n \rangle$ against multiplicity (400 GeV/c P)

Reference