A Study of Pseudo-Central Collision Events Observed in Pion-Nucleus Interactions

Tufail Ahmad* and Nazeer Ahmad
Department of Physics, Aligarh Muslim University, Aligarh 202 002, India

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The present study is based on the interactions caused by 340-GeV negative pions with emulsion nuclei. The main aim of this paper is to investigate some aspects of central collision events. Thus, the events in which the total number of charged shower particles is greater than or equal to twenty eight (\(N_s \geq 28\)) were chosen for the analysis. They are not exactly central collision events, but may be considered as pseudo-central collision events. The angular characteristics of relativistic charged secondaries have been studied in terms of pseudo-rapidity, and bimodality is found to be absent in the distributions. The mean pseudo-rapidity seems to be independent of grey and heavy particle multiplicities, which indicates its independence with number of collisions. Finally, the correlation between different particle multiplicities in this paper is discussed.

Keywords: Relativistic charged particles, Grey, Black and heavily ionizing particle multiplicity, Pseudo-rapidity
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I. INTRODUCTION

High-energy hadron-nucleus (hA) and nucleus-nucleus (AA) collisions have been investigated extensively by various workers [1–14] in the past. AA collisions may be explained as the superposition of many hA interactions which requires a detailed description of hadronic collisions. The interaction between elementary particles and nuclei is very important in order to get some insight into multiparticle production dynamics. The investigation of hA collisions is fundamental for studying the nature of the particles produced in such collisions. In high-energy multiparticle production, most of the work done is for inclusive interactions that are for all impact parameters, but fewer attempts have been made to study collisions with fewer impact parameters. Keeping this fact in mind, we chose to study events other than normal events. Therefore, we analyzed events beyond two standard deviations (\(\sigma\)) from the average value. In the case of inclusive data, the value of \(\sigma\) is equal to 6.48 ± 0.54 [7], and the mean value of relativistic charged particles, \(<N_s>\), is 14.18 ± 0.08 [7]. In this way, \(N_s \geq <N_s> + 2\sigma\), that is \(N_s \geq 28\). Thus, events with \(N_s \geq 28\) have been considered for the present study. We can say that these events are high multiplicity events. We cannot say that these events are exact central collision events, but may be considered as pseudo-central collision events.

We have analyzed the pseudo-central collision events observed in pion-nucleus collisions at the highest momentum of 340-GeV/c negative pions. For this purpose, the nuclear emulsion technique has been used. Nuclear emulsion is a detector that detects charged particles only. This technique for studying nuclear interactions has an advantage because it has high resolution. When a beam of high-energy particles is incident on an emulsion, secondary charged particles are produced, which is known as multiparticle production. The secondary particles leave behind tracks in the emulsion. Such tracks can be categorized as slow or relativistic charged particles. The slow particles are nothing, but target protons.

The results discussed are the rapidity distributions for inclusive data and pseudo-central events. The variation of the normalized pseudo-rapidity density with the pseudo-rapidity has been studied. The dependence of the mean pseudo-rapidity on the grey and the heavy ionizing particle multiplicity is presented. The correlations between different particle multiplicities have also been investigated.

II. EXPERIMENTAL DETAILS

For the present investigation, the data were collected using several Ilford G5 emulsion pellicles exposed to a negative pion beam of 340-GeV/c momentum at the European Organization for Nuclear Research (CERN) Super Proton Synchrotron (SPS). An interaction in the emulsion is called a star because of its very characteristic

*E-mail: tufailahmadphys@gmail.com
look. All the measurements were made under a 100X oil immersion objective on a compound microscope.

Fig. 1. Normalized single-particle pseudo-rapidity distribution of charged shower particles for events with \( N_s \geq 28 \) (- - -) and \( N_h \geq 0 \) (–).
A Study of Pseudo-Central Collision Events Observed in 

Fig. 3. Variation of the mean pseudo-rapidity with the number of grey and heavily ionizing particles.

Fig. 4. Variation of mean the pseudo-rapidity with the square root of the grey or the heavily ionizing particle multiplicities.

Figure 3 shows the variation of the mean pseudo-rapidity, \( <\eta> \), with the number of grey and heavy ionizing particles. In one of our earlier papers [8] on inclusive data for pion-nucleus collisions, we reported that the mean pseudo-rapidity changes its form after some value of the grey or the heavy particle multiplicity. However, we did not observe any such trend for pseudo-central collision data in this research. The following equations were obtained after performing least-square fits:

\[
<\eta> = (-0.08 \pm 0.04)N_h + (3.17 \pm 0.15), \quad (4)
\]

\[
<\eta> = (-0.13 \pm 0.05)N_g + (3.16 \pm 0.13). \quad (5)
\]

Thus, from Eqs. (4) – (7), we conclude that the mean pseudo-rapidity does not vary very much with the mean number of intranuclear collisions, \( <\nu> \), made by the incident hadron because the grey and the heavy particle multiplicities are regarded as measures of the numbers of collisions.

In order to study the correlation between different particle multiplicities, we plot the variations of \( <N_b> \), \( <N_h> \) and \( <N_s> \) with different number of grey particles in Fig. 5. From the figure, we note that the increase in the values of \( <N_b> \) and \( <N_h> \) are almost linear, but in the case of the variation of \( <N_s> \) with \( N_g \), a saturation effect is observed beyond \( N_g = 6 \), which is why a least-squares fit was performed up to \( N_g = 6 \) only, the following equations were obtained.

\[
<N_b> = (1.39 \pm 0.35)N_g + (2.02 \pm 1.55), \quad (8)
\]

\[
<N_h> = (2.16 \pm 0.22)N_g + (3.24 \pm 1.23). \quad (9)
\]

A similar result was observed for inclusive data [20]. As far as the variation in \( <N_s> \) with \( N_g \) is concerned, no such behavior is seen.

IV. CONCLUDING REMARKS

The conclusions that can be drawn from the study of pseudo-central collision events caused by 340-GeV negative pions are as follows:
(i) The double bump structure is found to be completely absent in the pseudo-rapidity distribution.
(ii) The normalized shower-particle pseudo-rapidity density, \( R(\eta) \), is observed to be very similar for inclusive data and pseudo-central collision events.
(iii) The mean pseudo-rapidity shows almost no dependence on the number of collisions.
(iv) Almost linear increase in the variations of \( <N_b> \) and \( <N_h> \) with number of grey particles are observed; however, \( <N_b> \) is found to become saturated beyond \( N_g = 6 \).

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