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Study of Transverse momentum Distribution OF Charged Particles In 4.5 GeV/c Proton-Emulsion Interactions

S.S.Abdel-Aziz
Physics Department, Faculty of Science, Cairo University, Giza ,Egypt.
Sayed_saleh_ssa@yahoo.com

Abstract: The emission of charged particles in 4.5 GeV/c proton-emulsion interactions has been investigated. The emulsion plates have been irradiated at Dubna Synchrophastron. The experimental data were obtained at the Laboratory of High Energy Physics (LHEP) at Cairo University. The transverse momentum technique has been used to check the sideward flow of charged particles in the considered reactions. The reaction plane has been determined in each event and the transverse momentum (the momentum component in the azimuthal plane) was projected onto the reaction plane. The dependence of the average-oriented transverse momentum per charged particles, projected onto the reaction plane, on the pseudorapidity has been studied. The study has shown a significant sideward flow of charged particles in the region of large pseudorapidity i.e. small values of the space angle (forward cone). The side ward flow of nuclear matter seems to be a result of the interaction between any two composite particles. A correlation is seen between the direction of flow of the charged particles and the emitted heavy ionized target fragments.

1. Introduction

There is a variety of correlations observed in proton–proton or proton–antiproton interactions at high energies. In particular, it has been found that the average particle transverse momentum depends on the particle multiplicity in a given collision [1,2].These correlations should be also present in nucleus–nucleus (A–A) collisions if such a collision is a superposition of nucleon–nucleon(N–N).interactions. However, there is no straightforward method to observe them since the final state particles in A–A collisions originate from the various N–N interactions while the correlated particles come only from the same N–N interaction. The motivation of studying high energy nucleus-nucleus interaction is to learn about the space-time development of high-energy reactions within very small distances and short time from impact At very high energies, the projectile does not have a chance to terminate an interaction with a nucleon before it starts to reach with another. This should produce an intensive mixing of color degrees of freedom of nucleons forming a quark-gluon plasma (QGP) domain or clusters. The decolouring process needs certain time during which an intermediate system may be formed. This hadronic excited cluster may collect target nucleons in its way inside the nucleus, which leads to observation of baryonic clusters in the process of target nucleus destruction [2]. Many works have been devoted to the study of the collective sideward flow of the nuclear matter in nucleus-nucleus (A-A) interactions in the momentum range from a few hundreds MeV/c to a few GeV/c per incident nucleus-nucleus [1-9]. Nuclear emulsions and Ag/CI nuclear track detectors have been used for the first time to search for the collective sideward flow of nuclear matter in central 12C + 108 Ag collisions [2-3]. It has been shown that the angular distribution of alpha particle target fragments, emitted from these interactions, peaks at an angle predicted by the shock wave calculations [2]. A series of subsequent experiments has shown either less evidence for this peaking or its absence [3-5]. Signatures for a bounce off effect were observed, a few years later. Experimental results, concerning the collective sideward flow, have been obtained by the 4π plastic ball detectors [6-8] and by nuclear emulsion [9-14]. The collective sideward flow of the nuclear matter affects the emission of the projectile fragments, target fragments and pions [15-19]. Almost, all these experiments were restricted to the study of the projectile and / or target fragments, since these particles are easier to be measured. . The present paper deals with the. collective flow analysis for the produced shower particles in proton-emulsion collisions at 4.5 GeV/c. The transverse momentum technique was used to investigate such collisions. The significance of the determination of the reaction plane has been studied. The correlation], between the emitted shower particles and target figments ,has been investigated.

2.Results and discussion:

2.1 Transverse momentum calculations:

In the present analysis, the momentum per nucleon of the incident Proton is P_L = 4500 MeV/c. Assuming that the momentum per nucleon of a projectile fragment after collision is $\vec{P}_L$, then the transverse momentum per nucleon of the ith fragment $P_i = P_L \tan\vartheta_i$ where θ_i is the emission angle of the ith fragment.The direction of the vector P_i is the azimuthal direction of this fragment. The reaction plane is the plane, which lies between the direction of the incident nucleus and the vector R_μ is given by the formula [15].

$$R_\mu = \sum_{\substack{i=1 \\ i\neq 1}}^{N_f} w_i M_i P_i, \quad \mu = 1,2,3,......., N_f \; (1)$$

where $w_i = \begin{cases} 0 \; P_i > 240 MeV/c \\ 1 \; P_i \le 240 MeV/c \end{cases}$

The coefficient w_i is introduced to exclude fragments of very large transverse momentum. The quantity M_i is given by $M_i = \sum_K W_{i,k} A_{i,k}$,where $A_{i,k}$ is the mass number of the k th isotope and the i th fragment and $W_{i,k}$ is the corresponding fractional field of the isotope [18]. The projection P^*_μ of $\vec{P}_i$ on the vector $\vec{R}_\mu$ is given by :

$$P^*_\mu = \vec{P}_\mu \cdot \vec{R}_\mu / |\vec{R}_\mu|, \quad \mu = 1,2,.....,N_f \quad (2)$$

The mean transverse momentum per nucleon projected onto the reaction plane <P*>, can be obtained by averaging P^*_μ over all fragments and over all selected interactions.

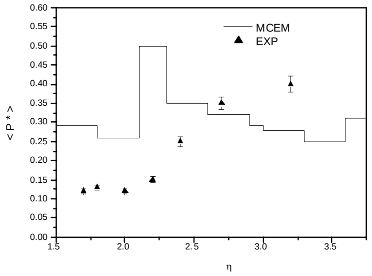

Fig.1: shows the relation between <P*> and the pseudorapidity, (η) , of the shower produced particles in proton-emulsion collisions at 4.5GeV/c.

Fig.1 shows the relation between < <P*> and the pseudorapidity, (η) of the shower produced particles in proton-emulsion collisions at 4.5 GeV/c. The dots with error bars, are the experimental points and the histogram represents the Monte-Carlo simulation of events from the experimental tracks which were randomized before the simulation. The experimental data shown

Fig. 1 reveals that $<P^*>$, differs significantly from zero. To investigate whether such observation is a true significant effect or just a statistical fluctuation., a Monte-Carlo (MCEM) program was designed to regenerate events of the same multiplicity from a randomized sample of produced showers in the experiment (i.e., all the shower produced were raffled and . MC events were generated randomly £Tom them). The histogram represents the relation between $<P^*>$, and the pseudorapidity, (η) , assuming a random distribution of the produced showers. A significant difference between the experimental and simulated data is seen in Fig. I, especially in the region of large (η) .This observation displays the sideward flow of the produced showers in p-Emulsion collisions at 4.5 GeV/c. The resultant vector R together with the direction of the incident particle reconstruct the' geometry of the collision and determine the reaction plane with a certain accuracy. The uncertainty in the determination of the reaction plane can be estimated by studying the difference between the reaction planes found for single events using different sets of particles if the difference between two reaction planes for the same event is small, either of these two planes can be viewed as being well determined. Thus, it has been proved that a good accuracy, for the method used in the present work for the reaction plane determination, has been achieved. The reaction plane is important for the analysis of-high energy nuclear reactions.

Figure (2) and figure (3) show the angular distribution of the black and grey particles relative to the reaction plane. It can be seen that, for black particles, in the region of cos (θ) greater than 0.2, there is an enhancement in the angular distribution. This may indicate a collective sideward flow of slow target fragments (black-particles). Such signature is difficult to be observed in the angular distribution of black particles relative to the microscope coordinates.

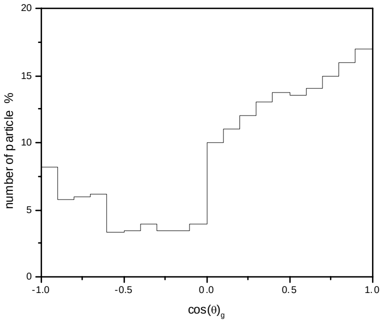

Fig.2 The angular distribution of g- particle relative to the reaction plane

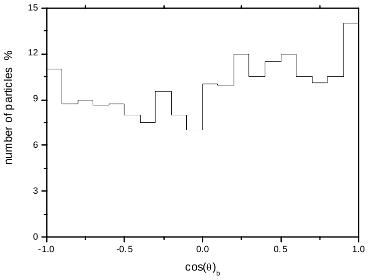

Fig.3The angular distribution of b-particle relative to the reaction plane.

Correlation Between The Produced Shower Particles And Target fragments:

A unit vector was assumed along the projection of the direction of flight of each particle onto the azimuthal plane. Then, the unit vectors for the produced shower particles and for the emitted target fragments, in each events, were. summed separately to find the resultant vectors of the produced shower particles and the emitted target fragments . A peak is observed at an angle ϕ_{sh} = 180□.This shows that the produced shower particles and target fragments indicate a back-to-back emission. This observation agrees with the sideward flow of the nuclear matter .In Figure(4) the azimuthal angle between the resultant vectors of the shower particles and the heavy target fragments .

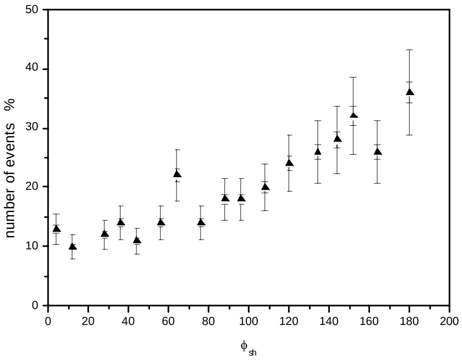

Fig.4: Presents the distribution of the angle (ϕ_{sh})

Conclusions:

The sideward flow of the produced shower particles has been observed in proton-emulsion collisions at 4.5 GeV/c. A back-to-back emission has been seen for the produced shower particles and emitted target fragments.

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