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Target Fragmentation at 4.5 a GeV/c in ^{24}Mg and ^{28}Si with Emulsion Interaction

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Abstract: The correlations between the multiplicity distributions and the projectile fragments, as well as the correlations between the black and grey fragments were given and the analysis of the projection of the transverse momentum, angular characteristics and azimuthal alignment were analyzed for the presence collective flow of nuclear matter in interactions of ^{24}Mg and ^{28}Si with AgBr emulsion nuclei at 4.5 AGeV/c.

Key words: Correlations between the multiplicity distributions, transverse momentum and azimuthal alignment

INTRODUCTION

In the last twenty years, with the availability of the monoenergetic beams of relativistic heavy ions at Brokhaven National Laboratory (BNL) the Alternating Gradient Synchrotron (AGS) and the CERN Super Proton Synchrotron (SPS), the fragmentation and multifragmentation of projectile spectator have been studied extensively, not only in experiments[1-6] but also within theories such as the bon-percolation prescription[7,8]. The interacting system in relativistic nucleus-nucleus collisions can be divided into three parts: a target spectator, a participant and a projectile spectator, according to the participant spectator model[9]. The overlapping part of the two colliding nuclei is called the participant and the other parts are called the target spectator and the projectile spectator, respectively. The velocity of the participant has a wide distribution from zero to the projectile velocity. The velocity of the target spectator in the laboratory reference frame is almost zero. The projectile spectator has almost the same velocity as that of the projectile. It is known that violent collisions happen in the participant and weak excitations and cascade collisions happen in the spectator. The authors of references[10-14] analyzed the azimuthal angles of secondary particles and the transverse momentum of projectile fragments. The aim of the present research is to perform a systematic analysis of target fragmentation in ^{24}Mg and ^{28}Si with emulsion at 4.5 A GeV/c. The second section describes the experimental materials. The correlations between the multiplicity distributions and the projectile fragments are given in the third. Transverse momentum distribution, the azimuthal alignment A (θ) and angular distribution of black particle from central collision, fourth, fifth and six sections respectively. The last section gives our conclusion.

EXPEERIMENTAL DETAILS

The present research was carried out using stacks of Br-2 nuclear emulsions exposed to 4.5 A GeV/c ^{24}Mg and ^{28}Si beams at the Dubna Synchrophastorn. The stacks have dimensions of 20×10cm×600 μm (undeveloped emulsions). The intensity of irradiation was ~ 10^4 particle cm^{-2} and the beam diameter was about 1 cm. Along the track double scanning was carried out, fast in the forward and slow in the backward direction. The scanned beam tracks were further examined by measuring the delta electron density on each of them to exclude the tracks having charge less than the beam particle charge Z_b. According to the range L in the emulsion and the relative ionization $I^* = I/I_0$ (where I is the particle track ionization and I_0 is the ionization of relativistic shower tracks in the narrow forwards cone of an opening angle of $\theta \leq 3°$) all charged secondary particles in the found interactions were classified into the following groups.

- Shower tracks producing particles s-particles having $I^* \leq 1.4$ tracks of such type with an emission angle $\theta \leq 3°$ were further subject to regular multiple scattering measurements for momentum determination
- Grey tracks producing particles g having relative ionization $I^* > 1.4$ and L > 3mm
- Black tracks producing particles b having L < 3mm
- The b and g particles tracks are called heavily ionizing tracks producing particles h

In each interaction we have taken the following measurements:

- The total charge of the projectile fragments $Z^* = \sum n_i z_i$ where n_i is the number of fragments of charge z_i in an event
- The polar angle θ of each tracks i.e. the space angle between the direction of the beam and that of the given tracks
- The azimuthal angle ψ of each track. i.e. the angle between the projection of the given tracks in the plane normal to the beam (the azimuthal plane) and the direction perpendicular to the beam, in this plane (in an anticlockwise direction)

CORRELATIONS BETWEEN MULTIPLICITY DISTRIBUTIONS AND PROJECTILE FRAGMENTS

The charges of the projectile fragments can be measured in a nuclear emulation, by the grain density and delta-ray counting methods[15] as well as the lacunarity technique[16]. The charge identification of relativistic fragment (of Z ≥ 2) has been made by measuring the gap length along the track which is associated with the energy loss. To identify the charge of a track by this method, one measures the frequency of the gaps with a length ≥ 2 μm in a distance of 2 cm along the track starting from the vertex. Thus, by counting the number of gaps of two tracks and knowing the charge of one, then the charge of the other can be determined from the inverse proportionality of gaps with charges. In this research, the charges of the projectile spectator were identified by means of the delta ray counting method. Let n_{Mg}, n_{Si} and n_z denote the experimental track delta ray densities of the incident ^{24}Mg, ^{28}Si nucleus and projectile fragment with charge respectively. In nuclear emulsion we can measure the charges of all projectile fragments.

Then the number of interacting nucleons of the projectile nucleus is on average $n_{int} = A_p - 2Q$, since Q is the total charge. The relationship between N_i (i = g, b, h) with Q should be observed[17]. Figure 1 shows the correlations between N_i and Q at 4.5 A GeV/c (open circles) for ^{24}Mg and (solid circles) for ^{28}Si with emulsion collision. Figure 1a, b and c correspond to the correlation >N_i< with Q respectively. One can see that negative correlations between >N_i< and Q are obtained. The N_i distributions for events with different Q regions are shown in Fig. 2, 3 and 4 receptively. The dotted and solid histogram correspond to the experimental data for ^{24}Mg and ^{28}Si with emulsion collisions at 4.5 A GeV/c Fig. 1 a, b and c are the results for events with

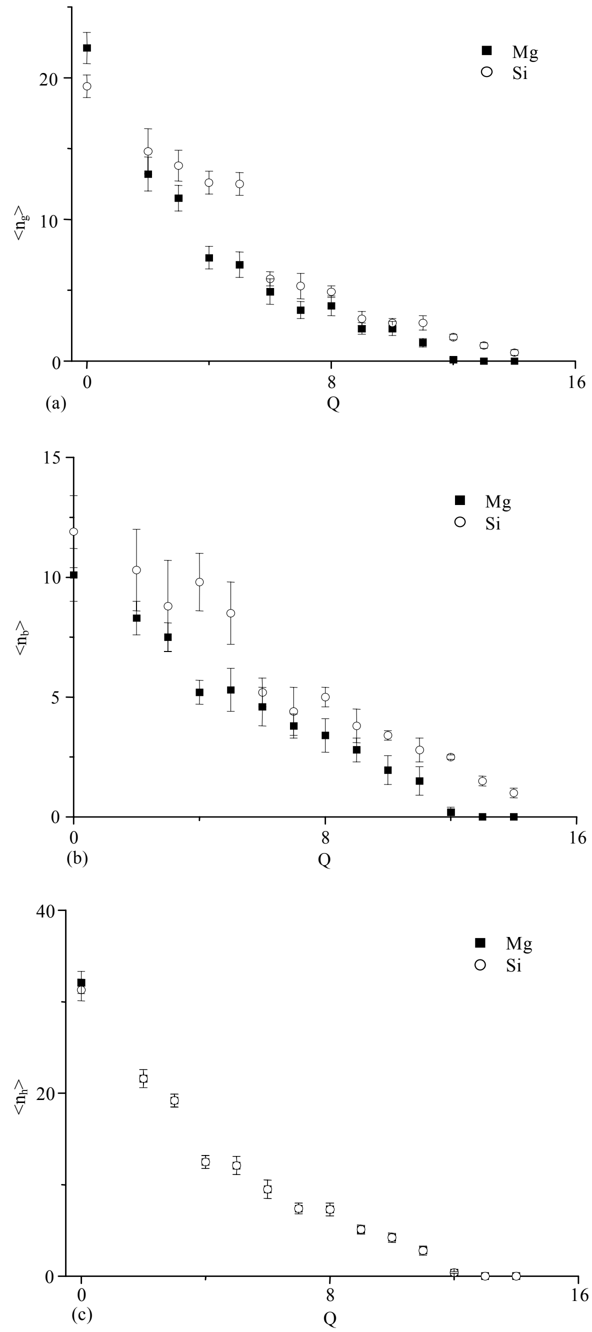

Fig. 1a-c: Correlations between the target fragment multiplicities and the system bound charge in ^{24}Mg and ^{28}Si with emulsion at 4.5 A GeV/c

Q = 0, Q = 2-6 and Q = 7-12 for ^{24}Mg and Q = 0, Q = 2-7 and Q = 8-14 for ^{28}Si. One can see that the multiplicity of fragments has a wide and even distribution at small Q. The number of events with low multiplicity increases and the number of events with

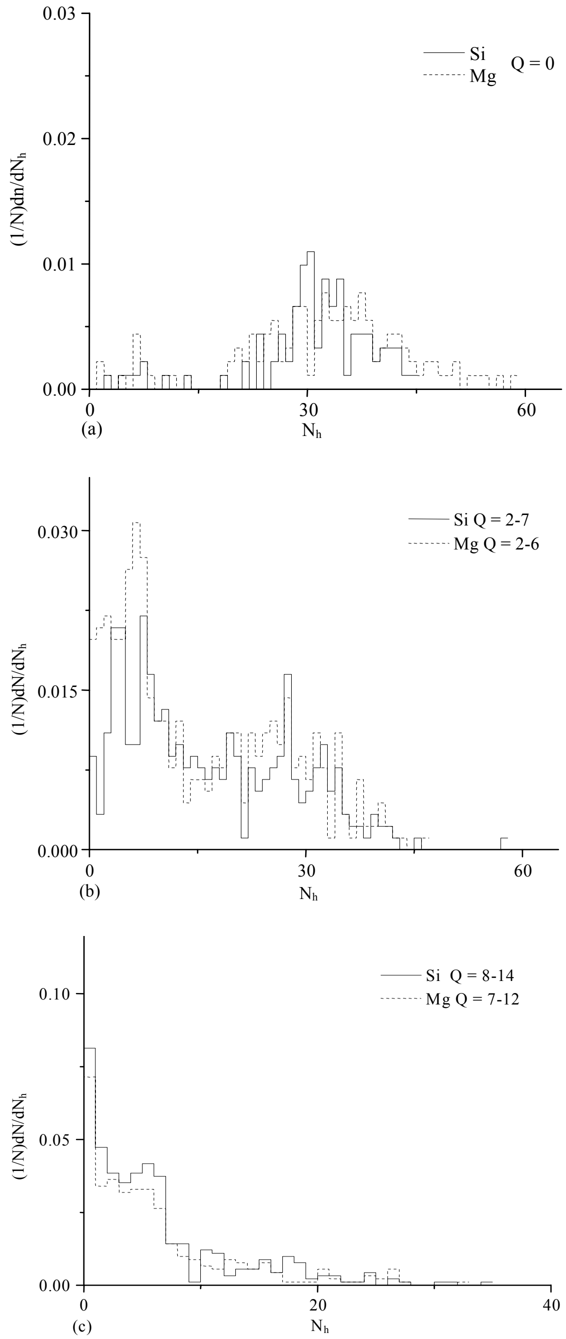

Fig. 2: The N_h distributions for events with different Q values in emulsion collisions at 4.5 A Gev/c. The N_h distributions for Q = 0, 2-6 and 7-12 (dotted histogram) for ^{24}Mgand Q = 0, 2-7 and 8-14 (solid histogram) for ^{28}Si

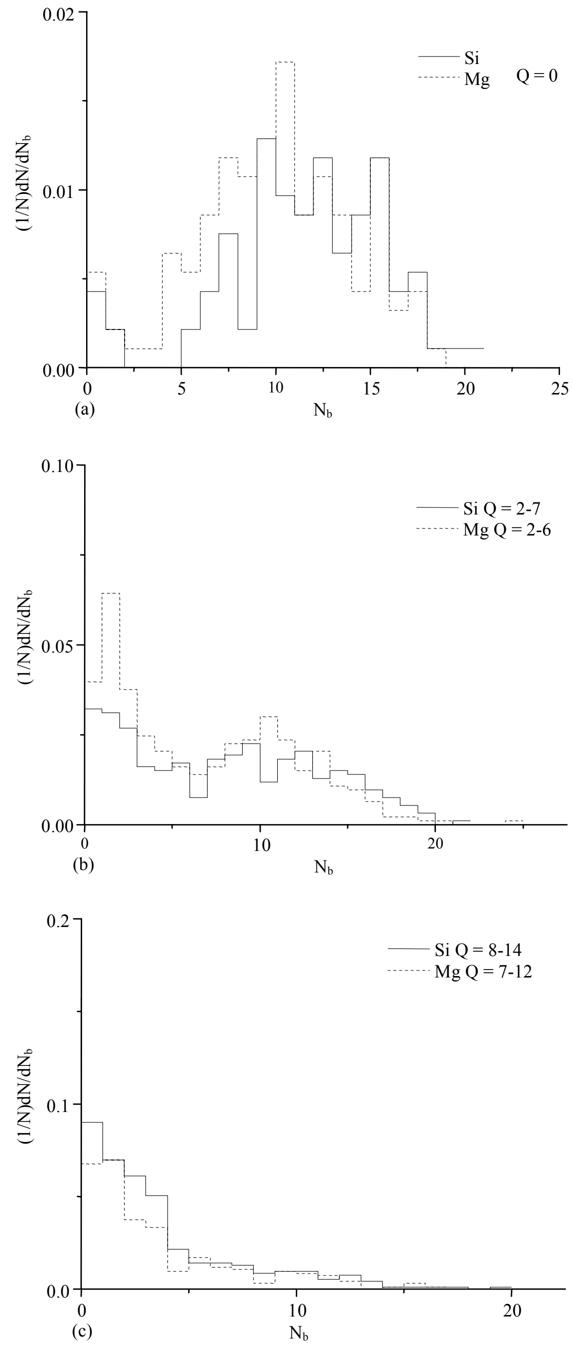

Fig. 3: As for Fig. 2 but showing the result of N_b distributions

high multiplicity decreases with increasing value of Q. The multiplicity distribution becomes narrow at great Q.

The mean multiplicities of events with different Q are shown in Table 1. One can see that the mean multiplicities decrease with increasing value of Q. The negative correlation between N_i and Q is determined by the nuclear geometry.

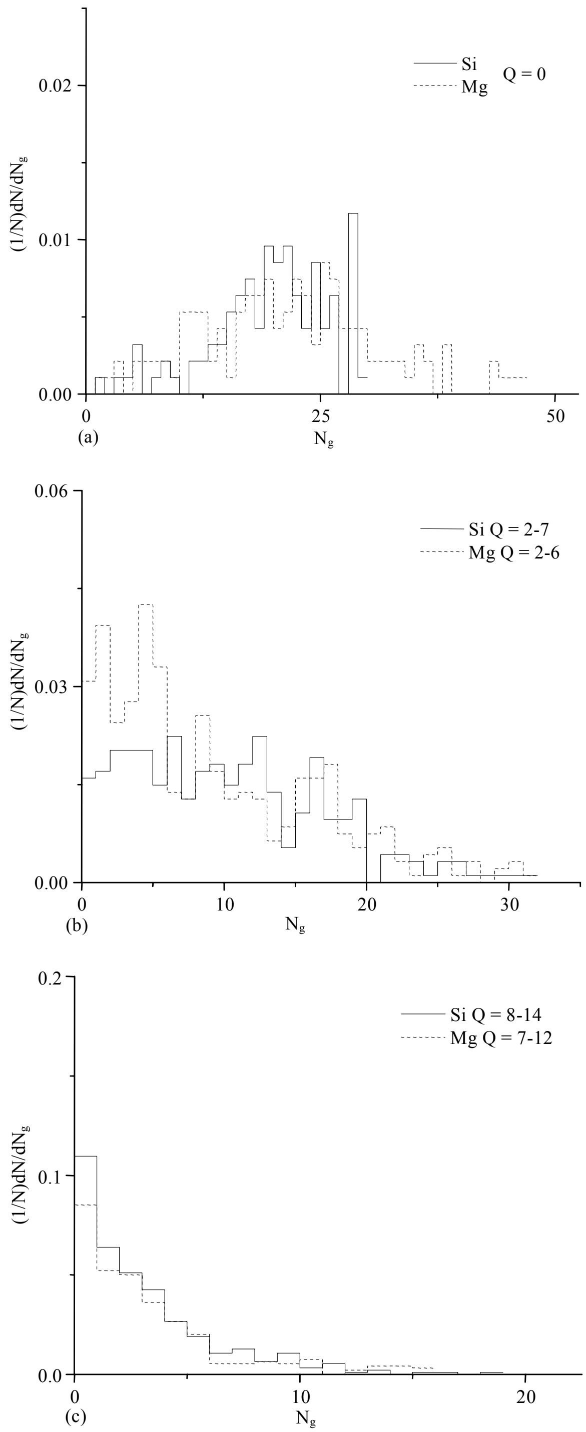

Fig. 4: As for Fig. 2 but showing the results of Ng distributions

For a projectile and target, N_i increases with decreasing the impact parameter. For N_b, there is a saturation effect appearing if the impact parameter is small enough i.e., N_b does not decrease. But the projectile spectator, the value of Q decreases with increasing the impact parameter.

Table 1: Average multiplicities of target fragments in ^{24}Mg and ^{28}Si with emulsion collisions at 4.5 A GeV/c

Projectile	Q (region)	$>N_h<$	$>N_b<$	$>N_g<$
^{24}Mg	Q = 0	32.1±1.2	10.1±1.1	22.1±1.1
	Q = 2-6	14.8±0.9	6.20±0.7	08.8±0.9
	Q = 7-12	2.40±0.3	2.30±0.5	02.2±0.4
^{28}Si	Q = 0	31.3±1.0	11.9±1.5	19.4±0.8
	Q = 2-7	18.8±1.2	7.90±1.3	10.8±0.9
	Q = 8-14	5.50±0.7	2.80±0.3	2.40±0.3

DETERMINATION OF THE REACTION PLANE AND THE AZIMUTHAL FLOW

The method of analysis is based on the famous technique of transverses momentum analysis[18]. In each event of the chosen ones and for each black particle track we define the azimuthal angle ψ. Then we define a unit vector $\vec{P}_i = Z_i \hat{k} + Y_i \hat{j}$, where $Z_i = \sin \psi_i$, $Y_i = \cos \psi_i$, $\hat{k}$ is the unit vector in the z-direction and $\hat{j}$ is the unit vector in the y-direction. The vector $\vec{P}_i$ points in the azimuthal direction of the emitted black particle. The reaction planes are defined by the direction of the incident nucleus and the vector $\vec{R}_\mu$ which are given by:

$$\vec{R}_\mu = \sum_{i \neq \mu}^{nb} P_i \quad (\mu = 1, 2...... n_b) \tag{1}$$

The projection P^*_μ of a vector $\vec{P}_\mu$ on the direction of $\vec{R}_\mu$ is given by:

$$\vec{P}_\mu = \vec{P}_\mu \vec{R}_\mu / \left| R_\mu \right| \quad (\mu = 1, 2..... n_b) \tag{2}$$

The mean values of P^* projected onto the reaction plane $>P<^*$ is obtained by averaging P^*_μ over all black particles and over all the events.

The $>P^*<$ would have been equal to zero if $\vec{P}_i$ is randomly distributed in the azimuthal plane and it will be different zero angle direction i.e., if the side-splach of target fragments takes place. Figure 5 shows the dependence of $> P^*<$ on the emission angle cos (θ) of the target fragment in central collisions of ^{24}Mg+AgBr and ^{28}Si+AgBr at 4.5 A GeV/c in the reaction plane. From the present analysis we see that the reflections of side splach on the transverse momentum of target fragments are better seen if the reaction plane is considered. Also, from the present analysis we see that

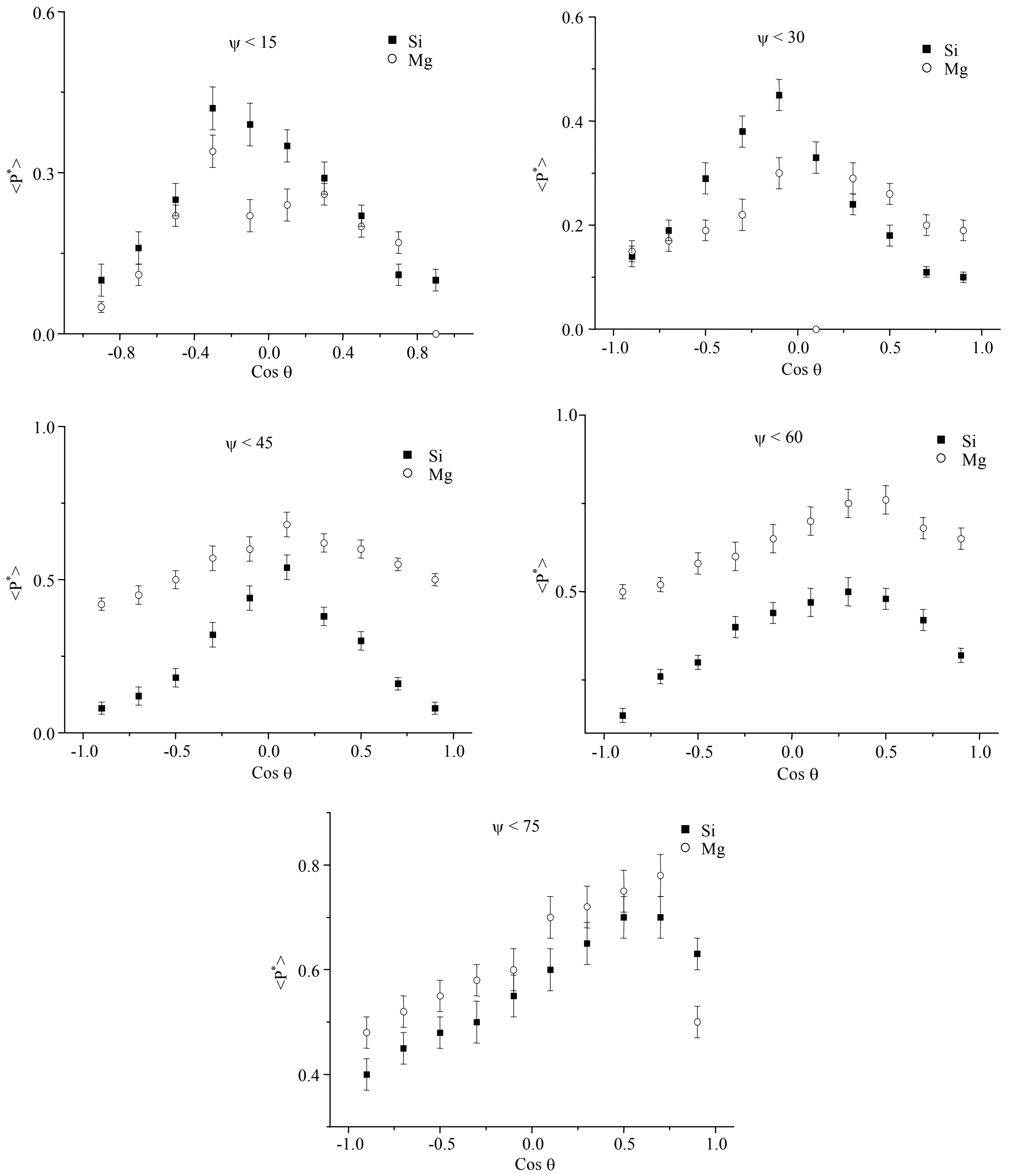

Fig. 5: Transverse momentum distribution of b-particle from central collision with $N_h \geq 28$ in the reaction plane of ^{24}Mg+Ag Br (0) and ^{28}Si+ Ag Br (0) at 4.5 A GeV/c

Have is a clear transverse momentum of target fragments. Also the position of the maximum of >P*< shifts to higher values of the azimuthal angle ψ with respect to the vector $\vec{R}$ of the reaction plane.

ALIGNMENT OF TARGET FRAGMENTS

A better parameter to measure the sideward flow is the azimuthal alignment which is defined here as:

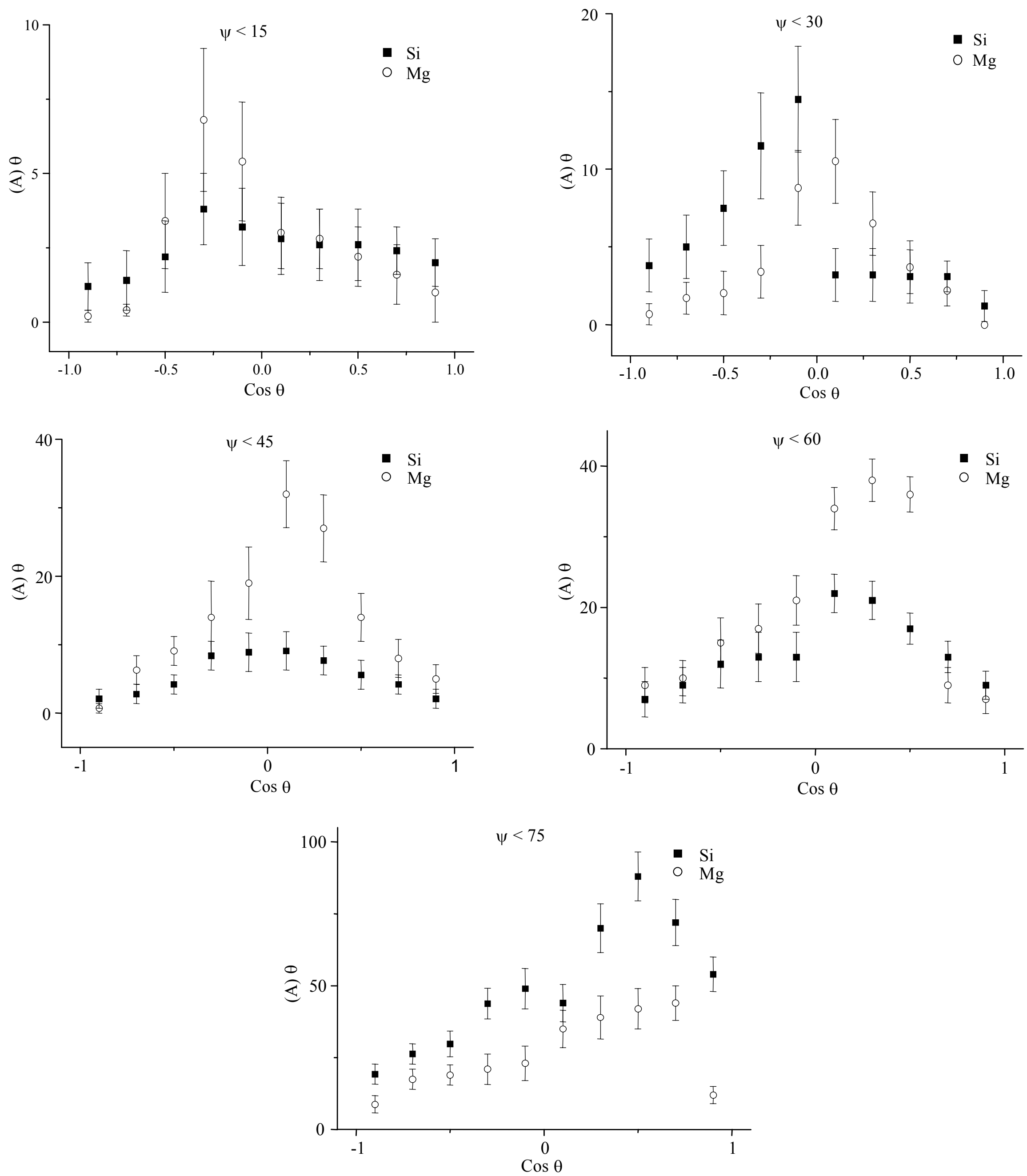

Fig. 6: The azimuthal alignment A (θ) as a function of cos (θ) for $N_h \geq 28$ in the reaction plane of ^{24}Mg +Ag Br (0) and ^{28}Si + AgBr (0)at 4.5 A GeV/c

$$A(\theta) = N_{\theta} > P^{*} <_{\theta} \ldots\ldots \quad (3)$$

Where, N_θ is the number of black particles in the θ-interval. Figure 6 show the azimuthal alignment as a function of cos (θ) for experimental events in the reaction plane. From the present analysis we can see that there is no significant flow in the azimuthal plane and show the obtained effect is not accidental but it reflects real physical correlation among the emitted particles. Also, we can see that the azimuthal alignment A(θ) have a tendency to increase with increasing of the azimuthal angle ψ with respect to the reaction plane.

ANGULAR CHARACTERISTIC OF TARGET FRAGMENT IN THE REACTION PLANE

The purpose of such investigation is to test the existence of the collective flow of nuclear matter in the studied events. The study for ^{24}Mg and ^{28}Si with emulsion inelastic interactions at 4.5 A GeV/c at used events $N_h \leq 28$. Figure 7 show the angular distribution in the reaction plane of black particle tracks. It is seen that there is a tendency for peaking in the angular distribution and the position of the maximum of this peaking shifts to higher values of the azimuthal angle with respect to the reaction plane. Usually the angular distribution of black particle tracks is isotropic and no deviation from this isotropy was reported as a clear

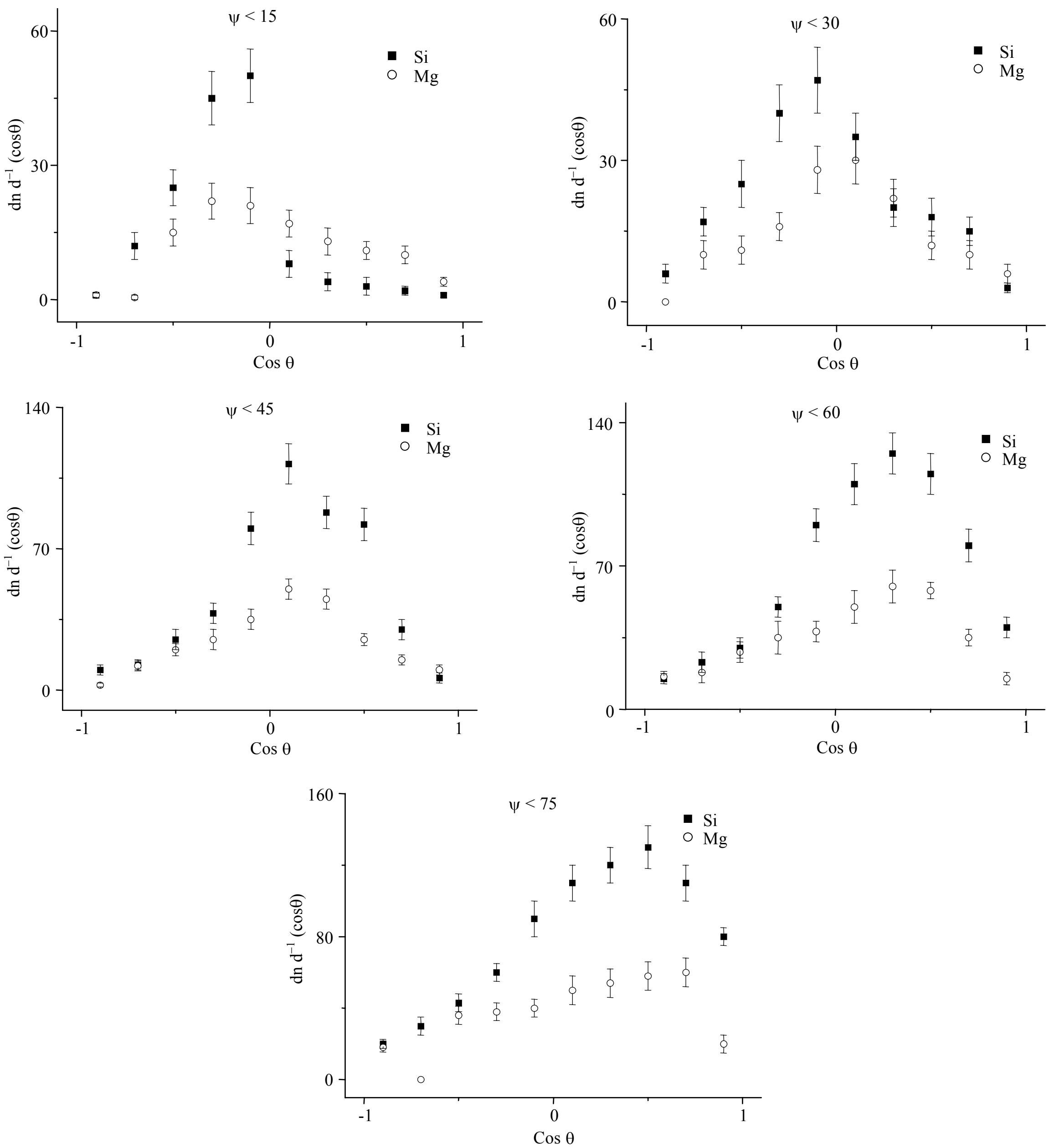

Fig. 7: Angular distribution of b particles from central collision with $N_h \geq 28$ in the reaction plane of ^{24}Mg +Ag Br (0) and ^{28}Si + Ag Br (0) at 4.5 A GeV/c

effect. From the analysis we can conclude that angular distribution of black particles tracks in the reaction plane is anisotropic and a tendency to increase with the increasing of the azimuthal angle with respect to the reaction plane. Also, we can see that the average value of >dn/dcosθ< increases with the increase of the mass number of the projectile.

CONCLUSION

From the investigation of particles emitted from ^{24}Mg and ^{28}Si with emulsion collisions, we can make the following conclusions:

- Correlation between multiplicity distributions and projectile fragments, we can see that negative correlations between $<N_i>$ and Q, the number of events with high multiplicity decreases with increasing value of Q and the multiplicity distribution becomes narrow at great Q
- We see that the reflections of side splach on the transverse momentum of target fragments are better seen if the reaction plane is considered
- It is seen that there is a tendency for peaking in the angular distribution and the position of the maximum of this peaking shifts to higher values of the azimuthal angle with respect to the reaction plane

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