Collective flow in nucleus-nucleus collisions

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In a typical high-energy nucleus-nucleus collision the final state particles projected onto the transverse plane are found to be correlated with the orientation of the impact factor. This directed fluid like behaviour of the nuclear matter is referred to as the "collective flow". Accurate measurement of the flow parameters enables us to find out the nuclear matter compressibility, that can subsequently be used to determine the nuclear equation of state under extreme conditions [1]. Here we present some results on the collective flow analysis on two sets of data: (i) ^{84}Kr-Ag/Br interaction at 1.52A GeV (Bevalac, LBL) and (ii) ^{28}Si-Ag/Br interaction at 14.5A GeV (AGS, BNL). Here we adopt the technique of reaction plane (RP) determination as suggested in [2]. Accordingly, the RP of an event is defined by the beam direction and a plane (flow) vector $\boldsymbol{Q}$. For an arbitrary ith projectile fragment (pf) of an event the flow vector is defined as:

$$\boldsymbol{Q}_i = \sum_{j=1, j\neq i} \omega_j A_j \boldsymbol{P}_{t,j}, \tag{1}$$

where A_j is the mass number of the jth pf having transverse momentum/nucleon $\boldsymbol{P}_{t,j}$ and $\omega_j = 1$. Moreover, we take $P_{t,j} = P_l \tan\theta_j$, where P_l is the beam momentum and θ_j is the polar angle of the fragment j.

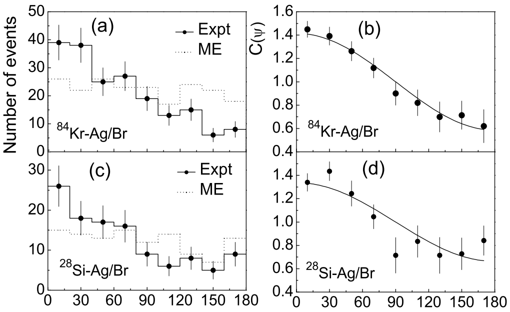

FIG. 1: Left: Distributions of the azimuthal angle differences between two constructed subgroups in one event. Right: Azimuthal correlation function.

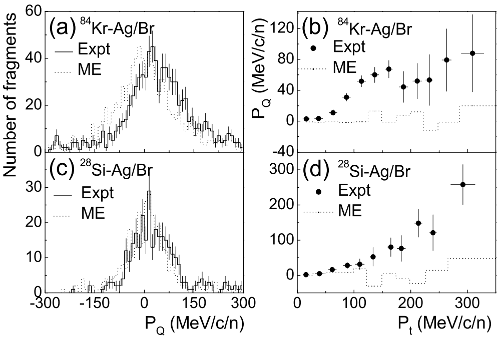

FIG. 2: Left: Distributions of the projected transverse momenta P_Q. Right: P_Q as a function of P_t.

To estimate the particle correlation in the RP, we randomly divide an event into two subevents and determine the corresponding flow vectors. Then the difference between the azimuthal angles of these vectors ($\Delta\Psi$) is calculated on an event-by-event basis. Distributions of $\Delta\Psi$ for the event samples used are given in FIG. 1(Left). The forward peaked distributions indicate a collective behaviour in the real events (experiment), which is absent in the mixed event (ME) sample. The effect can also be studied by the so-called "azimuthal correlation function" [3]:

$$C(\psi) = P_{\text{corr}}(\psi)/P_{\text{uncorr}}(\psi), \tag{2}$$

where $P(\psi)$ is the probability distribution of the azimuthal angle between two fragments.

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TABLE I: Values of the flow parameters.

Interaction	Particle type	v_1	v_2	χ^2(dof)
	Projectile fragments	0.275±0.027	0.064±0.026	39.65(33)
^{84}Kr-Ag(Br)	-s particles ($\lvert\eta_{rel}\rvert < 0.6$)	0.014±0.015	0.005±0.015	46.54(33)
at 1.52A GeV	s-particles ($0.6 \le \eta_{rel} < 1.73$)	0.132±0.019	0.017±0.019	49.52(33)
	Projectile fragments	0.240±0.029	0.136±0.028	16.92(33)
^{28}Si-Ag(Br)	s-particles ($\lvert\eta_{rel}\rvert < 0.3$)	0.046±0.023	-0.076±0.024	38.41(33)
at 14.5A GeV	s-particles ($0.3 \le \eta_{rel} < 1.7$)	0.048±0.022	-0.003±0.022	41.08(33)

Here $P_{\text{corr}}(P_{\text{uncorr}})$ refers to the experiment (ME). Plots of the $C(\psi)$-function are shown in FIG. 1(Right). $C(\psi) > 1$ in the low-ψ region is an indication of collective flow.

Bounceoff or sideward flow of the PFs can be investigated in terms of their transverse momenta projected onto their RPs: $P_Q = \boldsymbol{P}_t \cdot \boldsymbol{Q}/Q$. The P_Q distributions and their p_t dependences are shown in FIG. 2 along with the corresponding ME predictions. The estimated mean values of the P_Q-distributions ($\langle P_Q \rangle$) in MeV/c/n for the ^{84}Kr data are 37.62 ± 2.54 (Expt) and 0.99 ± 3.64 (ME), and for the ^{28}Si data they are 19.41 ± 2.91 (Expt) and 2.26 ± 4.09 (ME). For an uncorrelated sample $\langle P_Q \rangle \approx 0$. The significant deviations between the experimental $\langle P_Q \rangle$ values and the corresponding ME values are consistent with the flow angle analysis, and are indicative of a bounce-off effect of the PFs. The same effect is also observed in the P_Q *vs.* P_t plots.

The observed flow effect can also be characterized in terms of the flow parameters v_1 (direct) and v_2 (elliptic) which are determined from the Fourier decomposition of the azimuthal distribution [4]:

$$F(\varphi) = \frac{N}{2\pi}\left(1 + 2v_1 \cos\varphi + 2v_2 \cos 2\varphi\right). \quad (3)$$

We study the azimuthal angle distribution of the PFs along with the singly charge produced (also called s-) particles. The results are shown in FIG. 3 only for the singly charged produced particles (s-tracks) at two different values of the relative pseudorapidity $\eta_{rel} = (\eta - \eta_c)/\eta_c$ cuts, as quoted in the caption, where η_c is the central η value of the s-track distribution. The distributions are fitted to Eq. (3) which yield the flow parameters given in TABLE 1. It is seen that for both interactions the pfs and the s-tracks posses noticeable direct flow, but the elliptic flow is negligibly small.

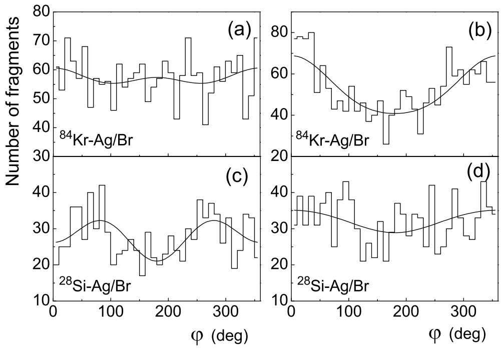

FIG. 3: Distributions of the azimuthal angles of s-particles for (a) $\lvert\eta_{rel}\rvert < 0.6$, (b) $0.6 < \eta_{rel} < 1.73$, (c) $\lvert\eta_{rel}\rvert < 0.3$ and (d) $0.3 < \eta_{rel} < 1.7$.

Acknowledgments

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