DISAPPEARANCE OF ROTATIONAL FLOW AND REACTION PLANE DISPERSIONS IN Kr+Au COLLISIONS

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Recently, a new method has been proposed to extract single particle triple differential azimuthal distributions from two particles azimuthal correlation functions. In this article, we report the applications of this method to the ^{84}Kr + ^{197}Au reactions.

Measurements with ^{84}Kr ions at beam energies of E/A = 35, 55, and 70 MeV were performed with beams from the K1200 cyclotron of the National Superconducting Cyclotron Laboratory of Michigan State University (NSCL/MSU). Measurements at E/A = 100 MeV were performed at the Laboratoire National SATURNE at Saclay. The emitted charged particles were detected with the combined MSU Miniball/Washington University Miniwall 4π phoswich detector array. Unit charge resolution up to Z = 10 was routinely achieved for particles that transversed the fast plastic scintillator.

To avoid the complexities in determining the reaction planes, two particle correlations have been used to extract the energy where sideward or rotational flow disappears [1]. The azimuthal correlation function is defined as

$$C(\Delta\phi) = \frac{N_{corr}(\Delta\phi)}{N_{uncorr}(\Delta\phi)}, \qquad (1)$$

where $\Delta\phi$ is the relative azimuthal angle between the two particles; $N_{corr}(\Delta\phi)$ and $N_{uncorr}(\Delta\phi)$ are the distribution of the coincident fragment pairs and uncorrelated fragment pairs from different events, respectively.

In the past, the correlations have been fit with a Fourier series with the expression [2]

$$C(\Delta\phi) \propto 1 + \lambda_1\cos(\Delta\phi) + \lambda_2\cos(2\Delta\phi) \qquad (2)$$

where λ_1 and λ_2 can be treated as fit parameters to the data. The solid lines in Fig. 1 show the quality of the fit. In this expression, λ_2 represents the rotational flow in the reaction plane.

The left hand panels of Fig. 2 show the incident energy dependence of λ_2 for d-d, t-t and α-α azimuthal correlation functions. λ_2 decreases with incident energy and vanishes around E/A=100 MeV. A priori, one does not know the exact functional dependence of λ_2 on the incident energy. The data points seem to deviate from a simple linear function, shown by the dashed lines, which are the least square fits to the data. If linear fits are used on λ_2, the energy where rotational flow disappears, $E(\lambda_2 = 0)$ are : 104±5 MeV, 96±4 MeV and 93±10 MeV. If the two particles used in the azimuthal correlations are emitted independent of each other in the same event the correlation function, $C(\Delta\phi)$, can be described by the convolution of single particle azimuthal distributions, $P(\phi)$ [1,2]

$$C(\Delta\phi) = \int_0^{2\pi} P(\phi)P(\phi + \Delta\phi)d\phi \qquad (3)$$

Empirically, the single particle distribution $P(\phi)$ can be described by a function similar to Eq. 2 [3],

$$P(\phi) \propto 1 + a_1\cos(\phi) + a_2\cos(2\phi) \qquad (4)$$

Combining Eq. 2, 3 and 4, one obtains a relationship between a_i and λ_I:

$$a_i = \sqrt{(2\lambda_I)} \tag{5}$$

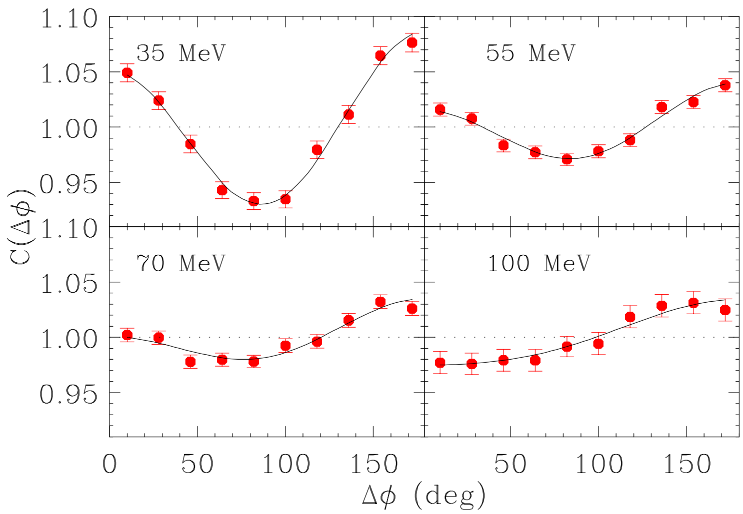

Fig.1. a-a azimuthal correlations for ^{84}Kr + ^{197}Au reactions at E/A = 35, 55, 70 and 100 MeV.

In the right panel of Figure 2, a_2^{true} from equation 5 are plotted as solid points. The data points at 100 MeV where the values of λ_2 are very small are not included since Coulomb forces between two alpha particles will always force λ_2 to be slightly positive even if the distribution is isotropic. If linear fits are applied to the extracted values of a_2^{true} (solid lines) at incident energies of E/A=35, 55 and 70 MeV, E(a_2^{true} = 0) are 98±5 MeV, 106±5 MeV and 96±4 MeV for d, t and α particles respectively.

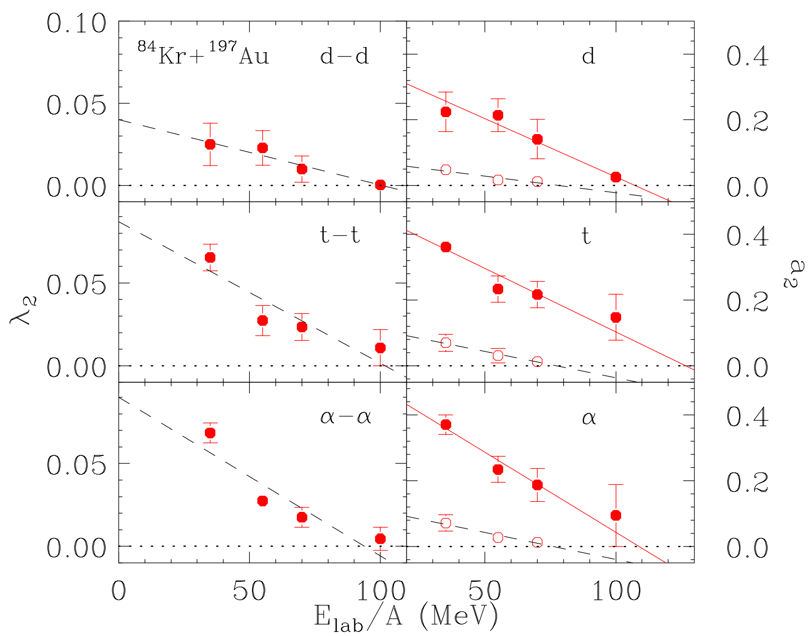

Fig.2. Left panels : Coefficients λ_2 of Eq. 2 plotted as a function of incident energies. Right panels: a_2^{expt} (open points) and a_2^{true} (solid circles) as function of incident energy for d, t and α particles.

From Eqs. 4 and 5, one can construct the triple differential cross-sections from the experimentally measured two-particle azimuthal correlation functions. The solid lines in Fig. 3 show the "true" single particle azimuthal distributions, $P(\phi) \propto 1+\sqrt{(2\lambda_2)}\cos(2\phi)$ for d, t and α particles at E/A=35, 55 and 70 MeV. The distributions are normalized to 1 at $\phi=0°$. For comparison, the experimental azimuthal distributions (open points) were obtained using the reaction planes constructed by the momentum tensor method described in ref. [3]. The same impact parameter and rapidity gates used in the two-particle correlation functions have been applied to these data. Data at E/A=100 MeV are not shown here due to problems associated with extracting the reaction planes at this energy. Study of Au+Au reactions suggests that squeezeout effects from repulsive nucleon-nucleon interactions start to dominate around E/A=100 MeV and the reaction planes determined from the momentum tensor method are not correct [4].

At low energies, the experimental azimuthal distributions show a fairly small anisotropy while the true azimuthal distributions are relatively sharp. The difference between experimental (open circles) and true azimuthal distributions (solid lines) shown in Fig. 3 are so large that the reaction plane dispersions can not be neglected. To quantify the reaction plane dispersions, the dashed lines are the fits of Eq. 4 to the data. The fit values of a_2^{expt} for d, t, and α particles are plotted as open points in the right panel of Figure 2. If the experimental determined reaction plane is close to the true reaction plane as in the case of low energy fission reactions , then $a_2^{expt} \approx a_2^{true}$. However, for the present study, a_2^{true} (solid circles) are much larger than a_2^{expt} . If linear fits are applied to the extracted values of a_2^{expt} (dashed lines), $E(a_2^{expt}=0)$ are 82±5 MeV, 78±5 MeV and 76±4 MeV for d, t and α particles respectively, about 20 MeV lower than $E(a_2^{true}=0)$ for light charged particles. As $E(a_2^{expt}=0)$ and $E(a_2^{true}=0)$ should be the same. The 20 MeV discrepancies indicate that the errors associated with the reaction plane dispersions when extracting the energy where rotational flow disappears are large possibly because the linear functional form used to extract $E(a_2^{expt}=0)$ is wrong.

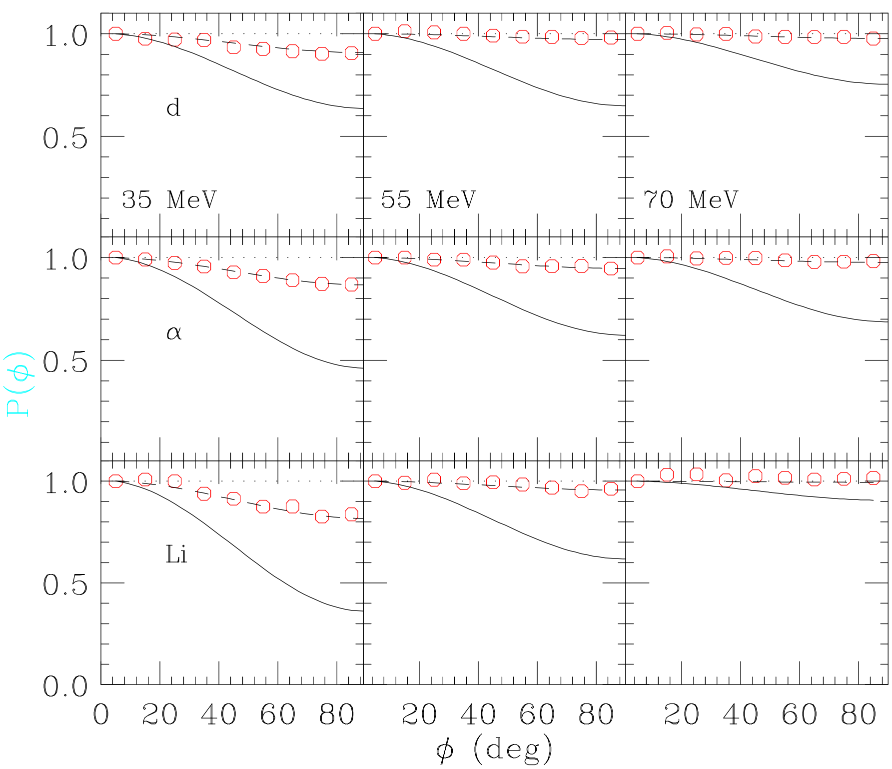

Fig.3. Single particle azimuthal distributions: Solid points are the data; dashed lines are fits to data according to Eq. 4 and solid lines are true azimuthal distributions from Eq. 2 and 4.

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