Neutron-proton equilibration in dynamically deformed nuclear systems: multifragmentation

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We extend the study of neutron-proton (NZ) equilibration in dynamically deformed nuclear systems presented in [1,2] by investigating further the correlations between the three largest fragments coming from the excited Projectile-Like Fragment (PLF*) produced when beams of ^{70}Zn are accelerated to 35 MeV per nucleon by the K500 Cyclotron at Texas A&M University and focused onto thin foils of ^{70}Zn. Other studies on this topic can be found in [3,4] and the physical idea is depicted in Fig. 1.

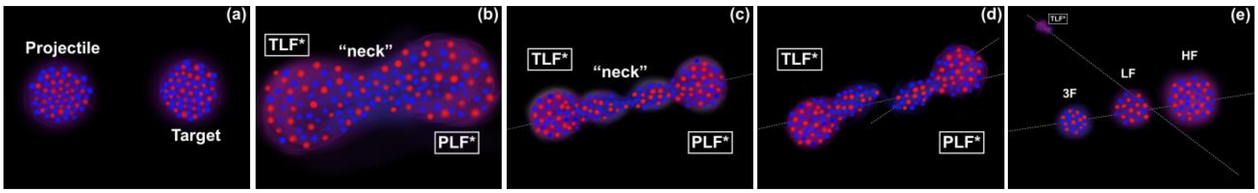

FIG. 1. Cartoon representation of the dynamical deformation and decay following a heavy-ion collision, by [5]. Panel (a): Projectile approaching target. Panel (b): Projectile rotated around target forming a low-density "neck" region. Panel (c): Excited PLF* and target like fragment (TLF*) moved further away from each other and stretched, with the smallest fragments forming out of the neck region. Panel (d): Nuclear system breaks and PLF* separates from TLF*. Panel (e): Subsequent separation of the PLF* into heavy fragment (HF), second heaviest fragment (LF) and third heaviest fragment(3F).

The fragments' velocity distributions in the direction of the beam, shown in Fig. 2, are used to establish the specific fragments that correspond to the PLF* daughters. The figure shows the normalized yield as a function of the velocity distributions of the symmetric ^{70}Zn+^{70}Zn system, for a representative combination of HF (in red), LF (in blue) and 3F (in green), (i.e. ZH = 12, ZL = 7, Z3 = 3). The dashed

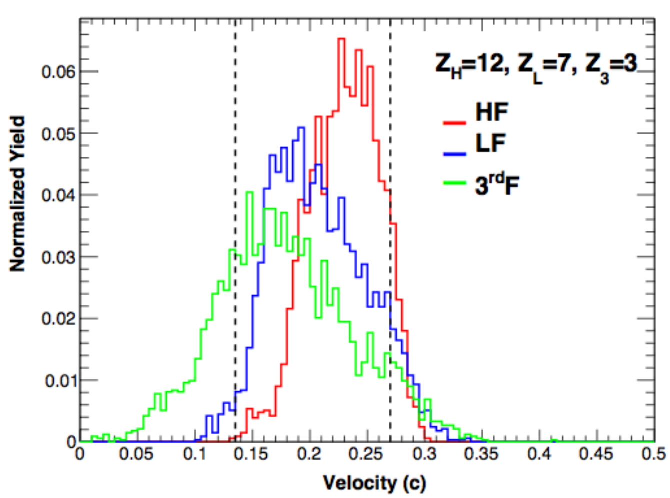

FIG. 2. Normalized velocity distributions for HF, LF and 3F in the direction of the beam.

lines (from right to left) correspond to the beam and half of the beam velocities. HF, LF and 3F are peaked above mid-velocity which indicates that the three of them likely originate from the PLF*. In addition to that, there seems to be a hierarchy in the velocity distributions that is strongly correlated to the charge sorting: the HF is, on average, the fastest one in the beam direction and appears to be forward with respect to the LF and 3F, while the LF is the second fastest fragment in the beam direction and appears to be forward with respect to 3F.

Symmetrized Dalitz plots, like the one shown in Fig. 3, could give information on the three body system's *Z* correlation. The center of the triangle would correspond to three approximately equal sized fragments. The edges of the triangle, between two vertices, corresponds to one small fragment and two large ones approximately equally sized. Finally, vertices of the triangle filled in hints to large cross sections for very asymmetric breaks. The region where the data in the figure is peaked corresponds to one large and two smaller, equally sized fragments.

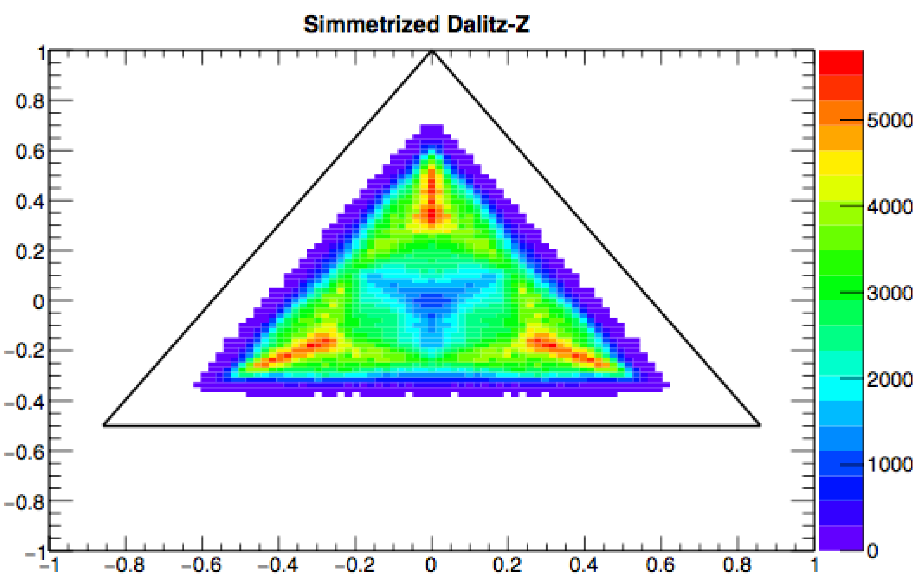

FIG. 3. *Z* correlation for the HF, LF and 3F studied using symmetrized Dalitz plots.

Two other interesting Dalitz plots one could look at when studying a three body system are shown in Fig. 4. The interpretation of both will be combined shortly. The left panel of the figure illustrates the angular correlation between the projections of the HF, LF and 3F velocities in a plane perpendicular to Vcm, while the right panel depicts the correlations between the angles of the HF, LF and 3F relatives velocities in the plane formed by the three fragments.

Looking at the left panel of the figure, each vertex of the total triangle being filled in would correspond with only one angle being 360°, that is not possible which is why the vertices of the plot are not filled in. The sides of the triangle being hot, represent two fragments having big angles while another one having a small one, resulting in two fragments seemingly closer to each other and apart from the third one (e.g. majority of events populating combinations of 180°,0° and180°). From the right panel of

Fig. 4 it looks like the three angles are somehow similar with a slight preference to the lower vertices being bigger compared to the top vertex.

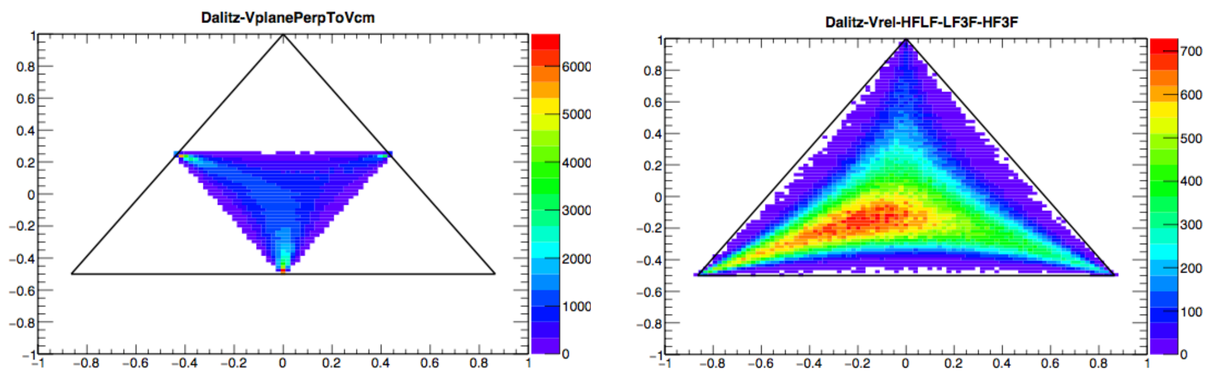

FIG. 4. The left panel illustrates the angular correlation between the projections of the HF, LF and 3F velocities in a plane perpendicular to Vcm, while the right panel depicts the correlations between the angles between the relatives velocities of the HF, LF and 3F in the plane form by the three fragments.

Combining the observations from both panels one could conclude that the physics of the three body system is dominated by the angular momentum, as in [1,2]). The angular momentum seems to be controlling the rupture of the three fragments, because it is occurring in preferential planes. In addition to that, the three fragments don't seem to be aligned.

In Fig. 5 we have a cartoon representation of both the plane perpendicular to V_{cm} and the plane formed by the three fragments. To cause such asymmetric angular projection in the plane perpendicular

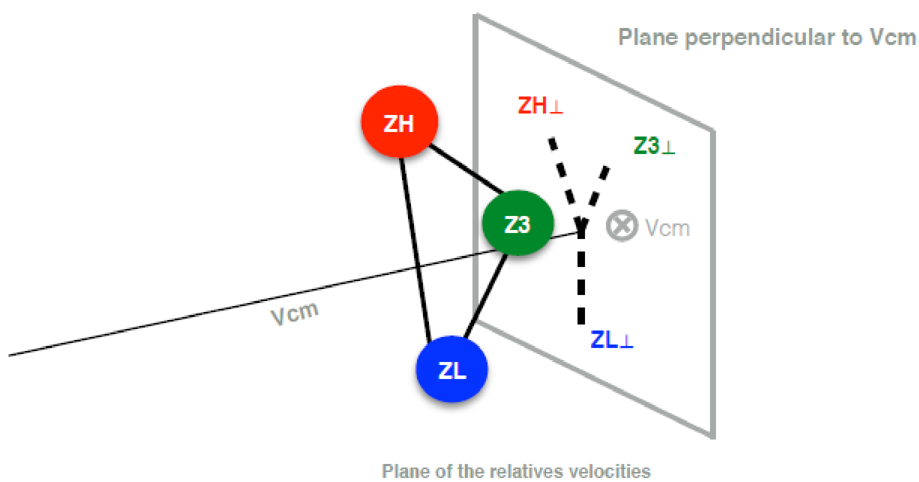

FIG. 5. Cartoon of a plane perpendicular to V_{cm} and a plane form by the three fragments.

to V_{cm}, while having very symmetric angle values for the relatives velocity plane of the three fragments, would mean the latter is oblique to the V_{cm} vector and the three fragments are not aligned.

If one imagines the rupture as being spontaneous (i.e. the three fragments separate simultaneously), we wouldn't have a preference in the direction of the movement. On the other hand, if the system breaks due to rotation and in a double rupture scenario, the plane of the relative velocities is the plane perpendicular to the angular momentum, and almost the same as V_{cm}, or very oblique to V_{cm}. We calculated this angle demonstrating is indeed oblique to V_{cm}, and it is shown in Fig. 6. The three body study is currently ongoing

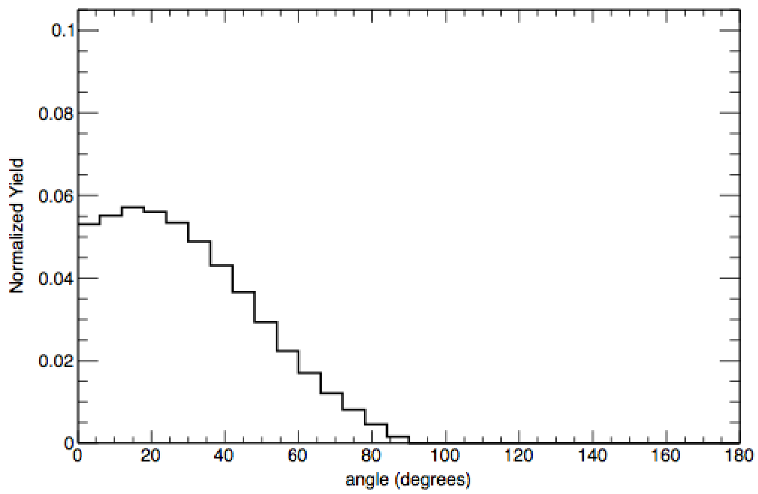

FIG. 6. Oblique angle between the plane that contains the relatives velocities of the three fragments and the V_{cm} vector.

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