Neutron-proton equilibration in dynamically deformed nuclear systems: multifragmentation

A. Rodriguez Manso, A.B. McIntosh, J. Gauthier, L. Heilborn, A. Jedele,
A. Zarrella, and S.J. Yennello

Recently we have been studying neutron-proton equilibration between the largest two fragments produced when beams of ^{70}Zn, ^{64}Zn and ^{64}Ni are accelerated to *35* MeV per nucleon by the *K500* Cyclotron at Texas A&M University and focused onto thin foils of ^{70}Zn, ^{64}Zn and ^{64}Ni to obtain symmetric and asymmetric collisions [1,2]. The rotation angle has been used as a clock for the equilibration of the neutron-proton composition where the initially dissimilar fragments converge exponentially with consistent rate constants across a wide variety of reaction partners and systems, indicating that the equilibration follows first-order kinetics.

Of further interest is the investigation of neutron-proton equilibration between the three largest fragments coming from the excited Projectile-Like Fragment (PLF*) [3,4]. The physical idea is depicted in Fig. 1, where the (PLF*) breaks into a heavy fragment (HF), a light fragment (LF) and a third lighter fragment (3F).

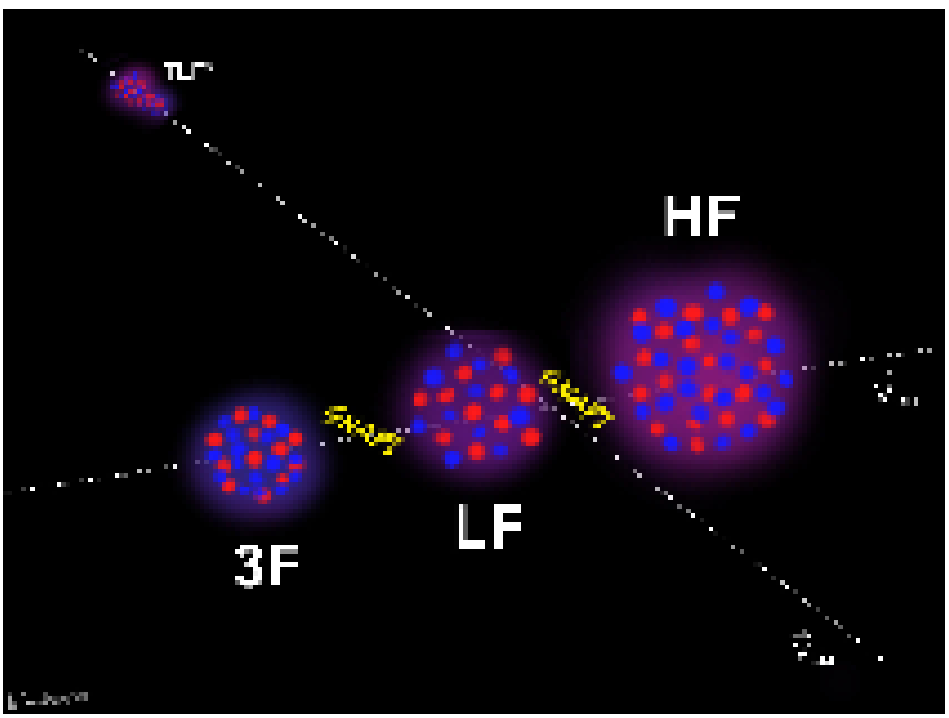

FIG. 1. Illustration of the last phase of dynamical deformation and decay after a heavy ion collision [5]. The excited PLF* and TLF* have broken apart and moved further away from each and the PLF* have subsequently separated into HF, LF and 3F.

The three body system's Z correlation can be studied using symmetrized Dalitz plots like the one shown in Fig. 2. The left panel of the figure is a cartoon that depicts how the events fill in the space of the triangle. The center of the triangle corresponds 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, if the vertices of the triangle are filled in, this hints to large cross sections for two small plus one large fragments. The right panel of Fig. 2, shows our data for all the *Z's* included in the analysis. The region where the data is peaked corresponds to one large and two smaller, equally sized fragments.

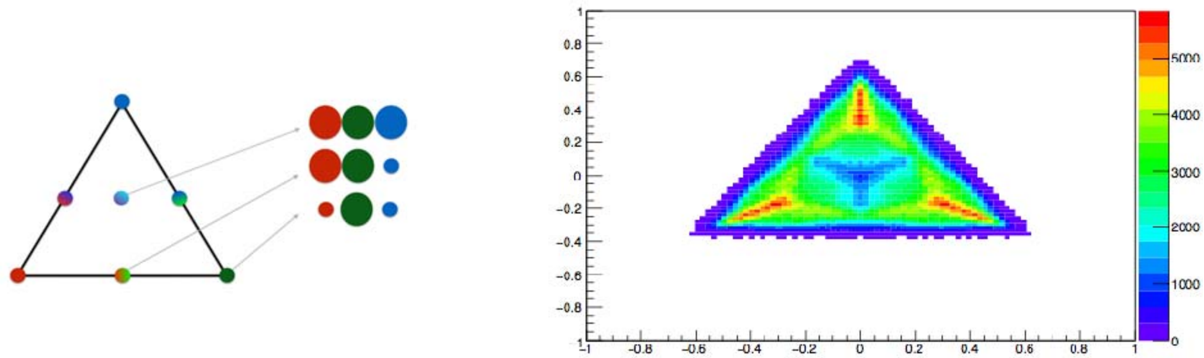

FIG. 2. *Z* correlation for the HF, LF and 3F studied using symmetrized Dalitz plots.

The fragments' velocity distributions in the direction of the beam are used to establish the specific fragments that correspond to the PLF* daughters. Fig. 3 illustrates the normalized yield as a function of the velocity distributions for the HF (in red), the LF (in blue) and the 3F (in green), in the direction of the beam. The distributions shown are from the symmetric $^{70}Zn+^{70}Zn$ system for three representative combinations of HF, LF and 3F: $Z_H = 14$, $Z_L = 5$, $Z_3 = 3$ (upper panel), $Z_H = 14$, $Z_L = 7$, $Z_3 = 3$ (middle panel), and $Z_H = 12$, $Z_L = 7$, $Z_3 = 3$ (lower panel). The dashed lines (from right to left) correspond to the beam velocity (i.e., $v = 0.27c$) and half of the beam velocity (i.e., $v = 0.13c$), respectively. The 3F is produced at velocities higher than mid-velocity and lower than both the LF and HF. The LF is produced at velocities higher than mid-velocity and lower than the HF, which is produced closer to the beam velocity. As the fragments get smaller, the velocity distribution broadens. HF, LF and 3F are peaked above mid-velocity which indicates that the three of them originate from the PLF*.

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 second heaviest (LF) is the second fastest fragment in the beam direction and appears to be forward with respect to 3F. The three body study is currently ongoing.

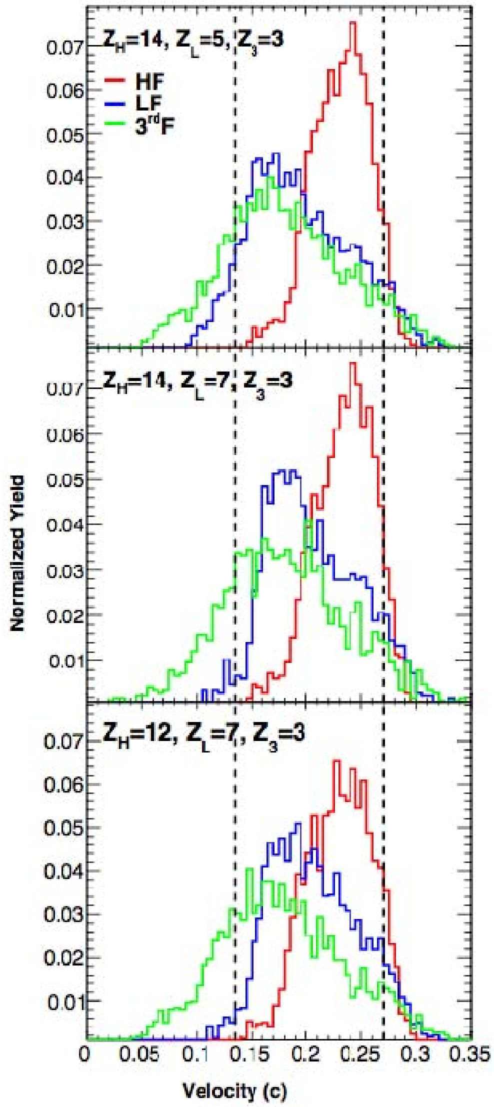

FIG. 3. Normalized velocity distributions for the HF, LF and the 3F in the direction of the beam. The HF is represented in red, the LF in blue and the 3F in green. The distributions correspond to the $^{70}Zn+^{70}Zn$ system for three representative combinations of HF, LF and 3F: Z_H = 14, Z_L = 5, Z_3 = 3 (upper panel), Z_H = 14, Z_L = 7, Z_3 = 3 (middle panel), and Z_H = 12, Z_L = 7, Z_3 = 3 (lower panel). The dashed lines (from right to left) correspond to the beam velocity (i.e., v = 0. 27c) and mid-velocity (i.e., v = 0.13c), respectively.

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