Isotopic scaling of Z=1-17 fragments

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Projectile fragmentation sources were identified from reactions of $^{86,78}Kr+^{64,58}Ni$ at 35 MeV/A collected with the upgraded NIMROD-ISiS array [1,2]. This data has been calibrated, particle identified, and analyzed to isolate the quasi-projectile source [3,4].

In heavy-ion collisions, fragment yield ratios $R_{21}(N,Z)$, obtained from two sources differing only in N/Z, have been shown to exhibit an exponential dependence on the neutron (N) and proton (Z) numbers of the fragments. This relationship is parameterized in (1) where the ratio of an isotope's yield from two fragments is linked to an exponential function. The α and β in the exponential portion of (1) are related to the chemical potentials and through these the coefficient of the asymmetric portion of the nuclear equation of state (C_{sym}). The relationship between α and C_{sym} given in (2) is well established and has been utilized in experimental investigations of the nuclear symmetry energy[5-9].

$$R_{21}(N,Z) = \frac{Y_2(N,Z)}{Y_1(N,Z)} = Ce^{(N\alpha + Z\beta)} \tag{1}$$

$$\frac{\alpha}{\Delta} = \frac{4C_{sym}}{T} \quad where \Delta = \left(\frac{Z}{A}\right)_1^2 - \left(\frac{Z}{A}\right)_2^2 \tag{2}$$

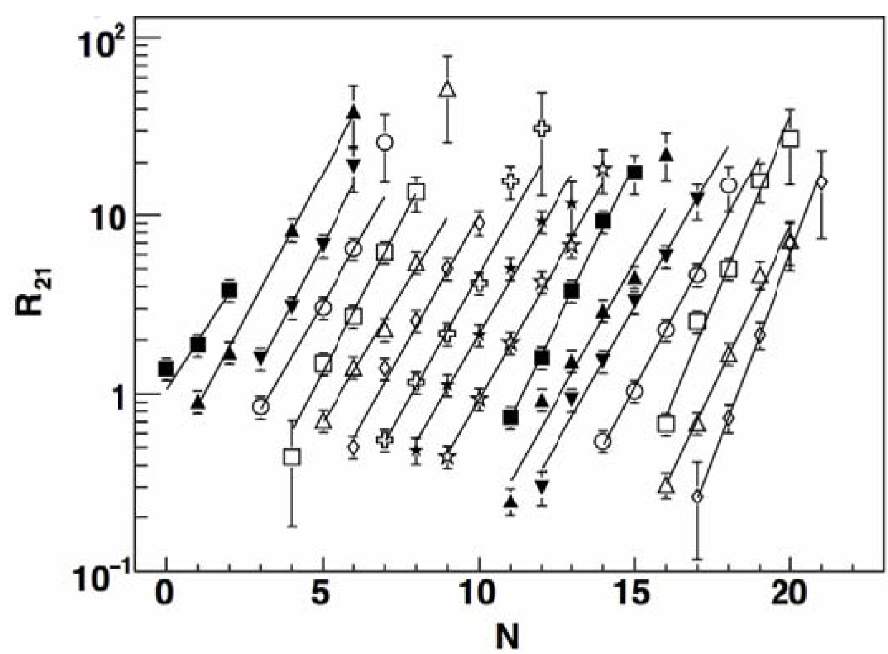

FIG. 1. Isoscaling of Z=1-17 isotopes.

The reconstructed quasi-projectiles from this data set were divided based on the experimentally determined N/Z ratio. The neutron number was obtained event by event from the sum of neutrons bound in charged particles with experimental neutrons obtained from the Neutron Ball [10]. The Z was defined as the sum of protons detected in an event. Two windows in N/Z were taken for the neutron rich and neutron poor sources for isoscaling.

The isoscaling results for Z=1-17 isotopes is plotted in Fig. 1. The lines are individual fits to the isotopic ratios of each element. These fits are parallel and evenly spaced across the range of elements shown in this figure.

The reconstructed quasi-projectiles in this data have been assigned excitation energies through calorimetry [4]. Thus, C_{sym} was studied as a function of E*/A through isoscaling of the data divided into bins of source E*/A.

The same two bins in N/Z used for Figure 1 were used for isoscaling as a function of the source E*/A. The evolution of the isocaling parameter α normalized to the asymmetry of the two source as a function of E*/A is plotted in Fig. 2. The significant decrease in α/Δ seen in this figure may indicate that C_{sym} is decreasing with increasing source excitation energy.

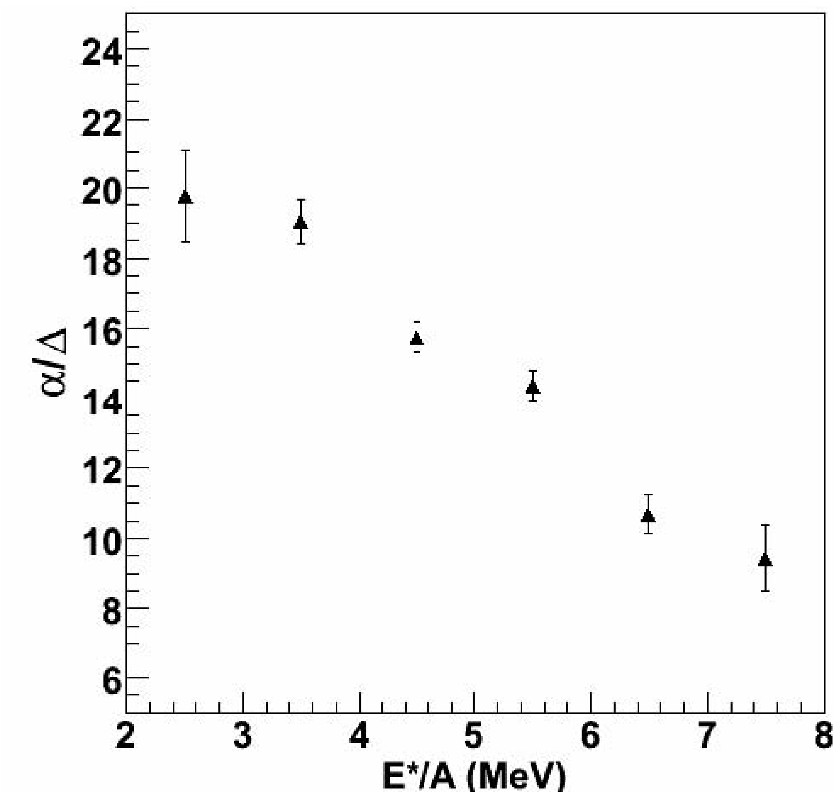

FIG. 2. Isoscaling α/Δ plotted as a function of the E*/A of the reconstructed quasi-projectile sources.

The connection of α/Δ to C_{sym} was made through Eq. 2 with the temperature obtained from the proton momentum fluctuation thermometer [4]. The evolution of C_{sym} with E*/A is plotted in Figure 3 for constant and evolving temperature. It is clear from this plot that C_{sym} is indeed decreasing as a function of the source E*/A.

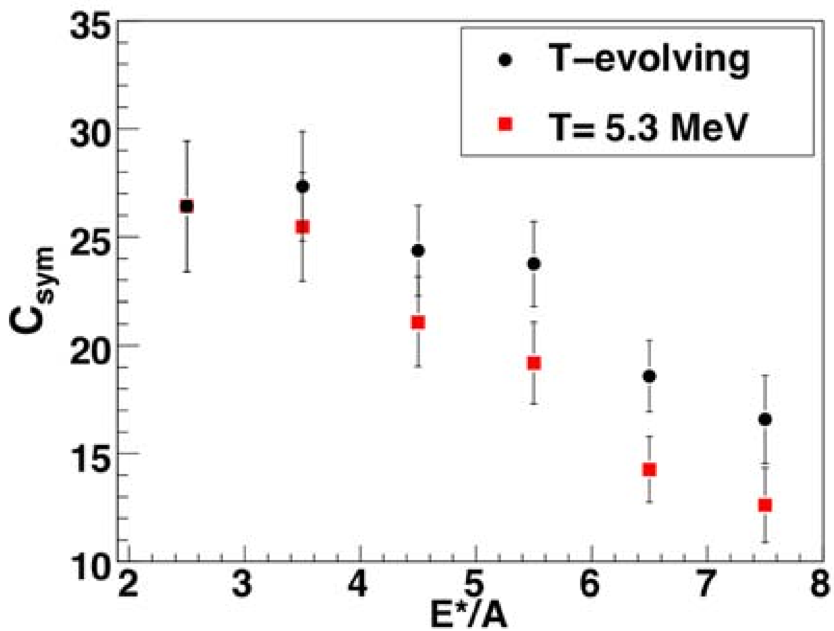

FIG. 3. Csym as a function of the source E*/A. Temperature for this plot was measured using the proton momentum fluctuation thermometer[4].

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