Understanding the Isotopic Fragmentation from a Nuclear Collision

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Isoscaling is performed by comparing the isotopic yields of fragments from two different systems, which differ in their source N/Z. In this experiment, rather than comparing systems, N/Z bins are compared so that the delta N/Z between the compared sources can be determined exactly. The equation for the yield ratio, \( R_{\Delta}(N/Z) \), is:

\[
Y_2(N,Z) = \frac{1}{A_2} \alpha \sum_{A_1} \frac{Y_1(A_1,N,Z)}{A_1} \]

where \( Y_2(N,Z) \) and \( Y_1(N,Z) \) are the yields of a specific isotope for the most neutron-rich source and the most neutron-poor source, respectively. The yield ratios exhibit an exponential dependence on the neutron and proton number of the chosen fragments. The isoscaling parameter, \( \alpha \), is associated with the symmetry energy coefficient by the formula:

\[
\alpha = 4C \left( \frac{Z^2}{T} \right) \frac{1}{A_2} = 4C \frac{\Delta}{T}
\]

The equation for the yield ratio, \( R_{\Delta}(N/Z) \), can be expressed in terms of the isoscaling parameter, \( \alpha \), as follows:

\[
\frac{Y_2(N,Z)}{Y_1(N,Z)} = \frac{1}{A_2} \alpha \sum_{A_1} \frac{Y_1(A_1,N,Z)}{A_1}
\]

Experimental Setup

Experimental data for 46,57Kr projectiles on 64,56Ni targets at 35 MeV/u was taken on the NIMROD-ISIS array, a neutron and ion multi-detector at Texas A&M University (TAMU). NIMROD-ISIS is a detector array that houses 228 detector modules arranged into 14 rings. The detector possess Si-CsI telescopes that provide excellent isotopic resolution. It is housed within the TAMU Neutron Ball which allows event-by-event event multiplicities to be measured.

NIMROD-ISIS

Theoretical Simulations

The Deep Inelastic Transfer code was coupled to the Statistical Multifragmentation Model to simulate the collision of 46,57Kr and 64,56Ni at 35 MeV/u.

Deep Inelastic Transfer (DIT): Theoretical code to simulate nuclear collisions in which nucleons are exchanged between the projectile and target. In peripheral collisions, quasi-projectile and quasi-target nuclei are formed in a highly excited state (E* between ~1-7 MeV/u). In this experiment, the quasi-projectile is then excited using the SMM code.

Statistical Multifragmentation Model (SMM): Attempts to describe the breakup pattern of any excited nuclei. As an excited nucleus expands, the density of the nuclear matter decreases, and a fragmentation process occurs. This is modeled in SMM by exploring all of the possible fragment distributions, or partitions. The simulation is carried out at a reduced density of ~1/6 p_0 in order to account for the expansion of the nucleus. The first stage of the SMM model provides a primary fragment distribution. Some of these primary fragments still have some excitation energy and can undergo a secondary decay. After SMM completes the secondary decay, one is provided with a final fragment distribution in which each fragment is characterized by its charge, mass, energy and angle of emission.

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