Probing the density dependence of the symmetry energy with the binary breakup of a projectile

The EOS is a fundamental description of nuclear matter. For isospin asymmetric matter the symmetry energy term is of prime importance. The density dependence of the symmetry energy impacts:

- Neutron star properties
- The existence of exotic nuclei
- Nuclear reactions (e.g. equilibration)

Transport model calculations (BUU) demonstrate that neutron and proton exchange (N/Z equilibration) in a peripheral heavy-ion collision is sensitive to the density dependence of the symmetry energy.

However, the brief projectile-target interaction limits the equilibration process to a relatively short interaction time, ~100 fm/c.

A long-lived system such as a dinuclear projectile-like fragment may provide access to longer equilibration timescales.

The initial N/Z gradient in the dinuclear system is induced by the collision dynamics.
Present Status on Binary Breakup of a Projectile

- Decrease of the $<N>/Z$ of the light fragment with rotation of the binary system (time)
- Clear target dependence of $<N>/Z$ (both initial value and equilibration rate)
- $<N>/Z$ continues to evolve up to $\sim 800$ fm/c

• Constrained Molecular Dynamics (CoMD) calculations show:
  • $N/Z$ equilibration persists for long times, 800 fm/c.
  • The rate of $N/Z$ equilibration depends on the density dependence of the symmetry energy

Brown, PRC87, 061601 (2013); Stiefel, in preparation (2014)
Future Plans and Challenges

Radioactive beams provide the opportunity to access larger gradients in N/Z and explore N/Z equilibration for different size (A) systems.

With intermediate energy (E/A ~ 50 MeV) radioactive ion beams:

Measure binary breakup of PLF* with isotopic resolution of both products (verify experimentally that exchange dominates changes in N/Z)

Need: Spectrometer in coincidence with a silicon array. Good measurement of Z,A,E,θ, and φ is required for both particles.

With low energy (E/A = 5-10 MeV) radioactive ion beams:

Explore whether long timescale N/Z equilibration in other di-nuclear systems (e.g. damped reactions between projectile and target at energies near the Coulomb barrier) can provide a sensitive probe of the density dependence of the symmetry energy?

To understand this phenomenon better and extract the density dependence of the symmetry energy, theoretical support at both the phenomenological and fundamental levels is needed.