Isospin diffusion and equilibration in heavy-ion reactions

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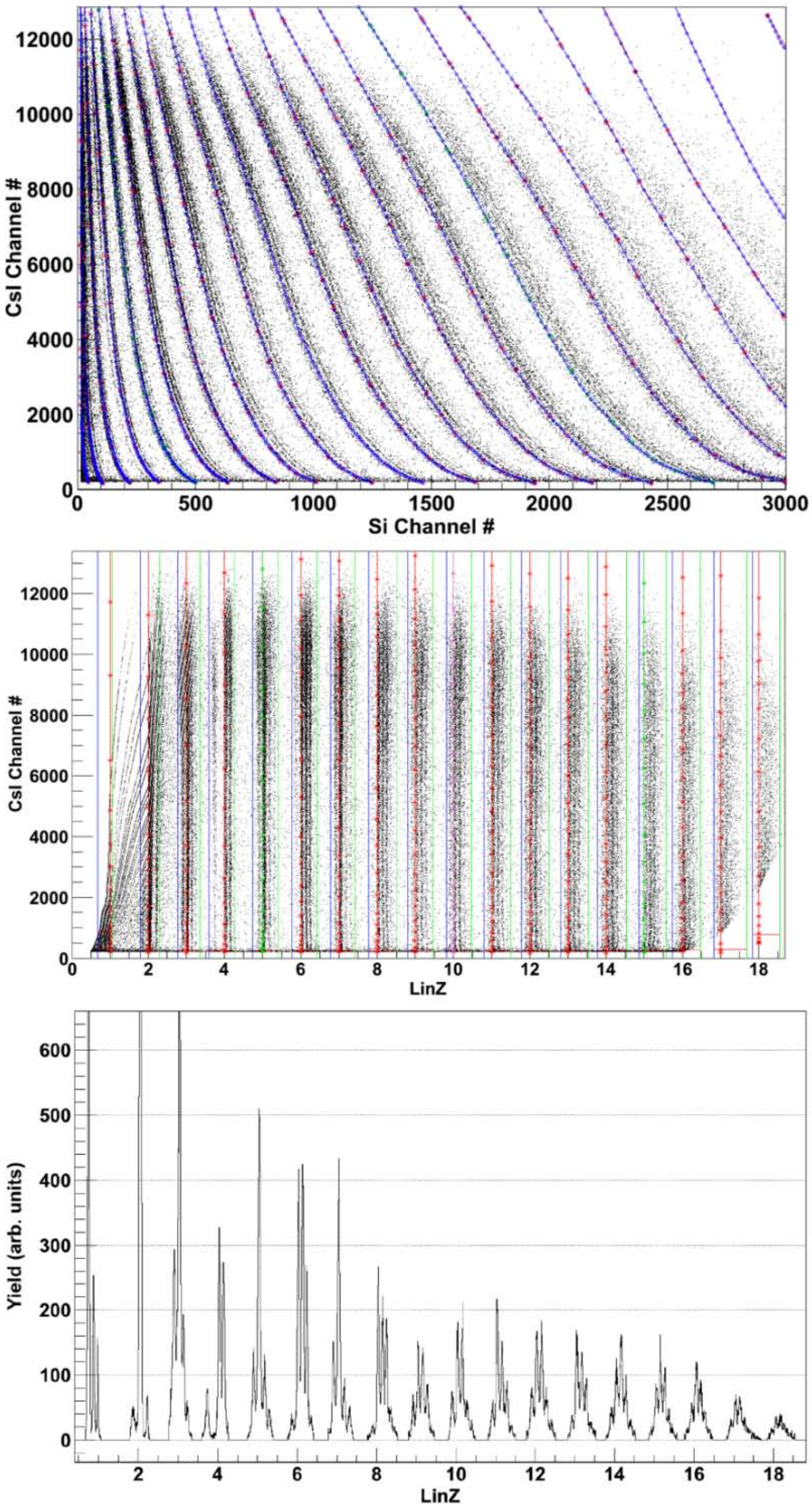
The nuclear Equation of State (EoS) is an important component to our understanding of astrophysical events like supernovae and neutron star composition as well as more terrestrial matters such as explaining the distribution of the elements and isotopes in the world resultant from the Big Bang. The nuclear symmetry energy, which describes the behavior of nuclear material as you move away from N=Z symmetric nuclear matter, is currently one of the least constrained portions of the nuclear EoS. Two suggested probes for this are isospin diffusion and isospin equilibration. Isospin diffusion is a driving force for the exchange of nucleons between projectile and target in a reaction where there is differential N/Z content and is defined as $D_q^I = -ct\left(\frac{\partial \mu_q}{\partial I}\right)_{\rho,T}$ where $I = \frac{\rho_n - \rho_p}{\rho_{Tot}} = \frac{N-Z}{A}$ and q can be either protons or neutrons. This isospin diffusion parameter, D in the equation above, describes the isospin dependent change in the chemical potential in nuclear matter and can be linked back to the symmetry energy. By looking at the nucleon transport between isospin asymmetric nuclei in Fermi energy heavy-ion collisions, using symmetric collisions as a reference, we can observe the un-equal mixing of N/Z content between nuclei in order to understand the diffusion that takes place in the reaction.

Isotopically identified fragments and neutron multiplicities were measured from the reactions of 35 MeV/nucleon ^{70}Zn,^{64}Ni+^{64}Zn and ^{64}Zn+^{70}Zn,^{64}Ni. These will be complimented by three previously obtained reactions on the same detector array: 35 MeV/nucleon ^{70}Zn+^{70}Zn, ^{64}Zn+^{64}Zn and ^{64}Ni+^{64}Ni. In addition, several reactions were collected for use in calibrating the detector. These calibration beams are 25 MeV/nucleon ^{4}He+^{197}Au, 30 MeV/nucleon p-d+^{197}Au, 35 MeV/nucleon ^{20}Ne+^{197}Au, 55 MeV/nucleon p-p, ^{4}He+^{197}Au, 35 MeV/nucleon ^{35}Cl+^{64}Zn and 35MeV/nucleon ^{70}Zn+^{70}Zn where the last system will be used to double check the energy calibrations against the symmetric systems from the previous campaign. With the addition of the previously acquired systems, a complete data set of 7 reaction systems will be formed and used to perform the isospin equilibration analysis.

The NIMROD-ISiS array is a 4π charged particle array that consists of 228 detector telescopes covering the complete solid-angle in φ and from 3.6°-167° in θ. Each telescope is composed of a silicon detector (150 or 300 μm thickness) followed by a CsI(Tl) crystal connected to a photomultiplier tube. This Si-CsI combination allows for the identification of charged particles by energy loss in the detectors via ΔE-E plots. A linearization, as shown in figure 1, is performed where lines are drawn to match the curves seen in the ΔE-E. These lines are then straightened and projected on the x-axis to give mass distributions of the particles detected. These distributions can then be fit with Gaussian curves to separate and identify particle charge and mass. Particle identification and energy calibration is underway.


CsI Channel #
Si Channel #
CsI Channel #
LinZ
Yield (arb. units)
LinZ