Equation of state effects on nucleon transport

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The nuclear equation-of-state (EoS) has been well studied for symmetric nuclear matter at nuclear saturation densities. However, there are not strong constraints on the density dependence of the symmetry energy at sub-saturation densities. Nucleon transport, which includes isospin drift and diffusion, describes the interaction and movement of nucleons between projectile and target in a nuclear reaction. Isospin diffusion, the transport of nucleons due to differences in isospin content, can be used to further constrain the density dependence of the symmetry energy [1,2].

Experimental data was collected for the systems of 35 MeV/nucleon ^{70}Zn, ^{64}Ni+^{64}Zn and ^{64}Zn+^{70}Zn, ^{64}Ni in order to supplement the 35 MeV/nucleon ^{70}Zn+^{70}Zn, ^{64}Zn+^{64}Zn, and ^{64}Ni+^{64}Ni data collected by Z. Kohley [3]. All experimental data were measured using the NIMROD-ISiS array, briefly described below. 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 and nucleon transport 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 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 [4]. This Si-CsI combination allows for the identification of charged particles by energy deposited in the detectors via ΔE-E plots. A linearization 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 allowing for isotopic particle identification up to Z=20. Fast vs. Slow pulse-shape discrimination in the CsI crystals allows for high-resolution identification of light charged particles, up to ^{6}Li.

Identification of particle charge and mass and energy calibrations have been completed throughout the array. Silicon detectors are calibrated using the known threshold-corrected punch-through points (energy at which a particle passes through the Si detector but does not have enough energy to penetrate the CsI crystal) for specific isotopes. These punch-through points are then fit and compared to elastic scattering peaks from known calibration beams in order to get a linear calibration fit (Fig. 1a). The CsI crystals are calibrated by using elastic peaks from calibration beams and the use of a modified fitting function based on the Birks equation for light output of a CsI crystal [5,6]. A CsI calibration plot showing the results of this fit to the calibration points is shown in Fig. 1b. A preliminary calibration was completed previously allowing the examination of the resulting preliminary physics tapes. Figure 1c shows the Z=1 charged particle calibrated kinetic energy spectra for each ring of the NIMROD-ISiS array. Such plots are used to examine the energy calibration at each step through the process so that the quality of the calibration can be checked and assured. Complete energy calibrations will be finished in May 2014.

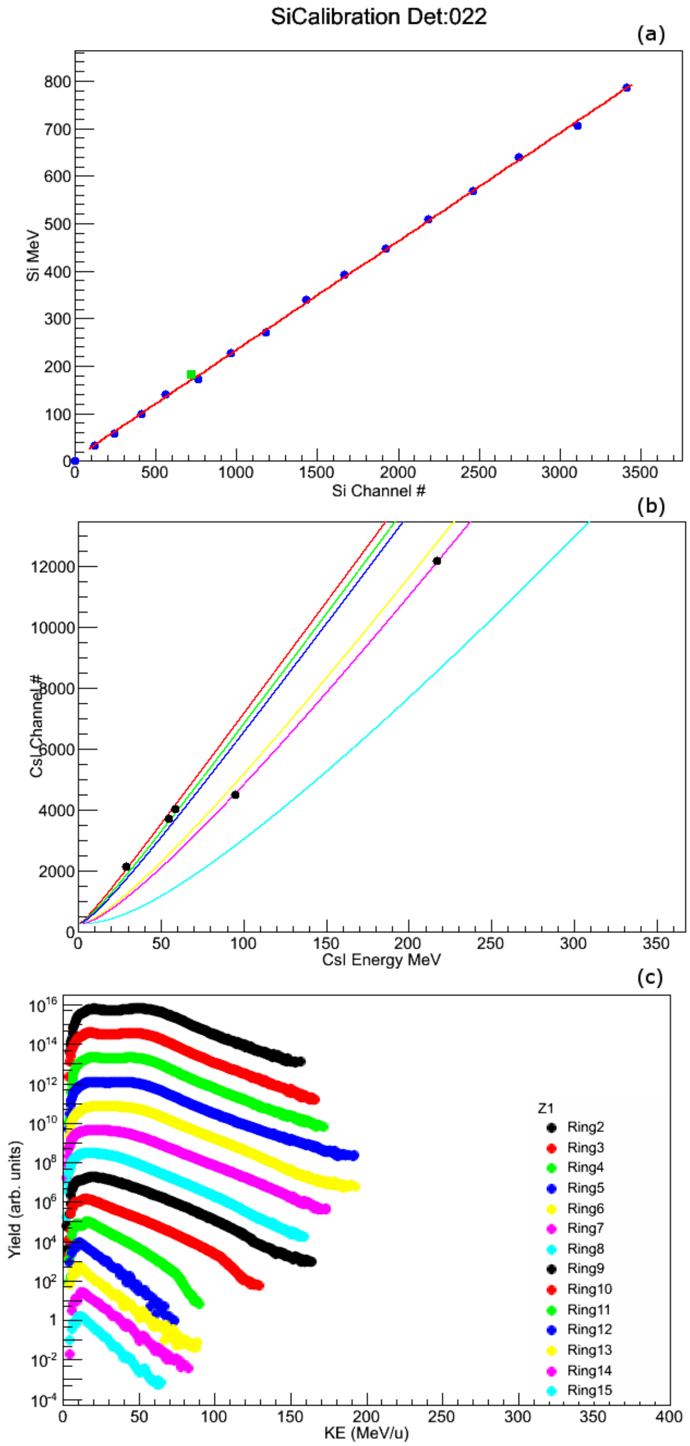

FIG. 1. (a)Si detector calibration plot: blue dots correspond to punch-through points, green dots are calibration beam points and red line is best-fit line used to extract calibration parameters. (b) CsI detector calibration plot: dots correspond to calibration beam points while colored lines are best-fit calibration parameters corresponding different isotopes (p,d,t,^{3}He,^{4}He,^{6}Li). c) Z=1 charged particle kinetic energy spectra as a function of theta (ring number) in NIMROD-ISiS array. Yield is given in arbitrary units and scaled so that curves are separated.

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