Isospin Non-equilibration

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The question of whether or not an excited nuclear system reaches equilibrium before decaying is of importance when trying to determine the events that occur in hot nuclear matter just prior to fragment emission. Isospin equilibrium is one type of equilibrium that excited nuclear matter can achieve.

We examine the reactions of 35 and 45 MeV/nucleon ^{54,58}Fe and ^{58,64}Ni on ^{54,58}Fe and ^{58,64}Ni in order to study isospin equilibration. The data were taken using NIMROD, the Neutron Ion Multidetector for Reaction Oriented Dynamics, at the Cyclotron Institute. NIMROD incorporates the outer shell of the 4B Neutron Ball [1], the backward half of the CsI Ball [2], and a newly fabricated set of forward rings. Ionization chambers built in-house at the Cyclotron and neutron energy detectors from the DEMON [3] collaboration are part of NIMROD, as well. With the use of the NIMROD apparatus [4], the most detailed and extensive isotopic information, to our best knowledge, can be obtained for analysis.

In the data analysis, the N/Z tracer method, as cited in ref. [5] will be used to gauge the amount of isospin equilibration that had occurred in the system prior to fragment emission, but this time at a more intermediate energy than in ref. [5]. Also, isobaric ratios [6] will be used to test whether or not isospin equilibrium has been reached. The mixed isospin, same-mass systems will provide mass independent data concerning isotopic equilibration. The neutron-poor ^{54}Fe beams and targets as well as the neutron rich beams and targets of ^{64}Ni could lend some interesting insight into nucleon flow between target and projectile during the isospin equilibration process.

The calibration of NIMROD data involves the automation of line and gate drawing on silicon versus silicon spectra as well as silicon versus cesium iodide spectra. Fig. 1 shows an example of gates being drawn over helium isotopes on a silicon versus silicon spectra.

The super telescopes that include two silicons and a cesium iodide detector are to be calibrated first, followed by the detectors that include only one silicon and a cesium iodide detector. Lastly, the detectors with only the cesium iodide will be calibrated. The automation of the calibration process has met

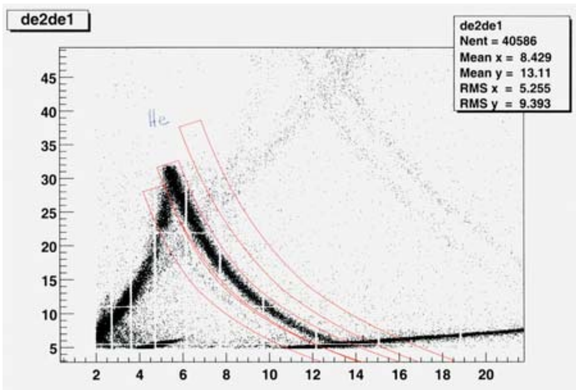

Figure 1: Gates drawn over helium isotopes in a silicon versus silicon spectra using the automated calibration code are shown.

with some obstacles such as gains not being matched among detectors in each ring, as well as cesium iodide spectra that show non-linear isotope lines. Each of these issues must be addressed separately from the automated group.

Preliminary experimental results in the form of energy spectra from one detector centered at 6^o in the lab frame are shown for 35 MeV/nucleon ^{58}Fe on ^{58}Fe in Fig. 2. Shown are the yields of all particles with Z=2 through 6 as a function of their energy in MeV. The lines are separated by orders of magnitude to enable clear viewing of the separate slopes. The slopes of the fragment lines are very similar, with the exception of the helium line. The helium fragment line's increased slope at low energy may be a signature of the evaporation of alpha particles. Calibrations are near completion on the NIMROD data, taken in March 2000. Extracation of experimental observables is expected by early summer 2002.

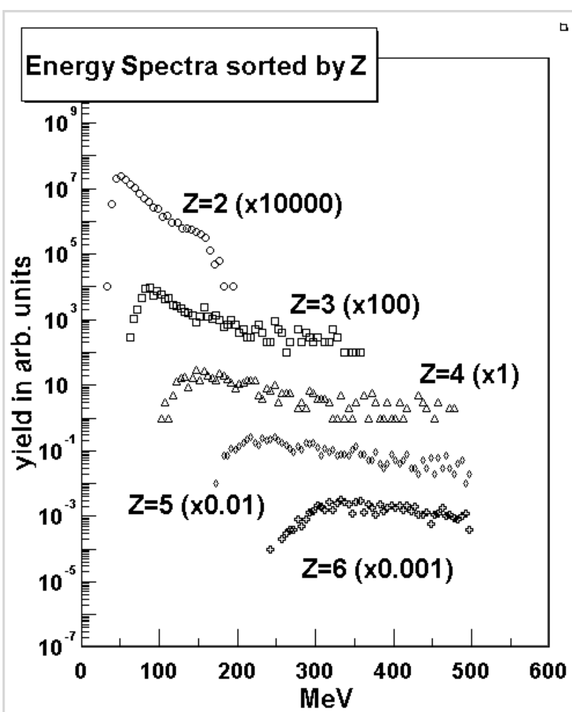

Figure 2: Energy spectra for 35 MeV/nucleon ^{58}Fe on ^{58}Fe plotted as the yield of fragments in arbitrary units broken down by the Z versus the energy of the fragment in MeV.

References

[1] R. P. Schmitt, *et al.*, Nucl. Instrum. Meth. Phys. Res. A **354**, 487 (1995).

[2] I. Tilquin, *et al.*, Nucl. Instrum. Meth. Phys. Res. **A359**, 530 (1995).

[3] K. Hagel, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (1999-2000); T. Keutgen, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (1999-2000).

[4] F. Rami, *et al.*, Phys. Rev. Lett. **84**, 1120 (2000).

[5] H. Johnston, *et al.*, Phys. Lett. **B371**, 186; (1996), H. Johnston, *et al.*, Phys. Rev. C **56**, 1972 (1997).

[6] K. Hagel, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (1999-2000); T. Keutgen, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (1999-2000).