Calibration of the Heracles Array

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The study of multifragmentation from heavy ion collisions requires a large multidetector setup composed of several detectors in order to gather information on the charge and energy of the many reaction products. The HERACLES (HEavy-ion Reaction Array for the Characterization of Light Excited Systems) array is such a multidetector and was used in experiments at the Texas A&M University (TAMU) cyclotron in a collaboration between Université Laval in Canada and members of the TAMU Cyclotron Institute.

HERACLES is composed of 120 detectors. The first five rings, covering angles from 1.3E to 24E are made of plastic phoswich detectors, each made of a thin "fast" plastic)E and a "slow" thicker E plastic scintillator. These detectors can identify particles with charges up to Z=30 with an energy threshold of ~10 MeV/nucleon. The following two rings, covering angles from 24E to 46E are made of CsI(Tl) scintillator crystals, which provide charge and isotopic resolution for elements up to Z=3, with a low energy threshold of ~2 MeV/nucleon. Three Si detectors were added to the setup in front of phoswich detectors at various angles to achieve isotopic resolution. A Correlation Array, mounted with a double-sided silicon strip detector was added at forward angles covering between 10E and 24E. Four Si-CsI telescopes and one Si-CsI telescope allow for isotopic resolution for higher charges over a range of central and backward angles.

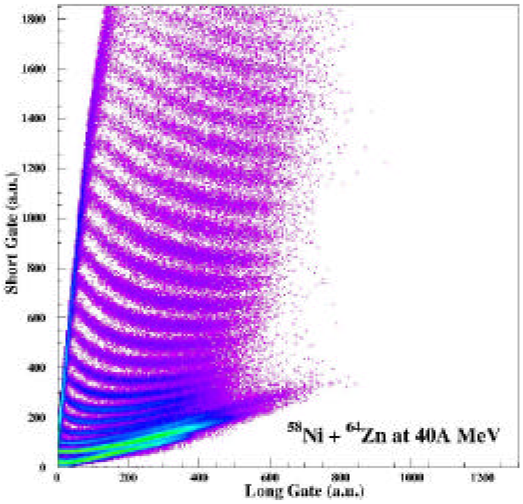

Figure 1: Plastic phoswich spectrum from the ^{58}Ni + ^{64}Zn at 40 MeV/nucleon experiment.

Recently four experiments designed to study the impact of isospin of the reaction partners on the exit channels were carried out at the TAMU Cyclotron Institute with the modified HERACLES array. It involved beams of 40 MeV/nucleon of ^{58}Ni, ^{64}Ni at 40 MeV/nucleon impinged on a ^{64}Zn target. Additionally, the ^{58}Ni beam was used with a ^{70}Zn and a ^{70}Zn beam was used with both Ni targets to permit the study of the reaction in reverse kinematics.

Figures 1 and 2 show typical plastic phoswich and “fast-slow” CsI(Tl) detector spectra, respectively, from one of those experiments.

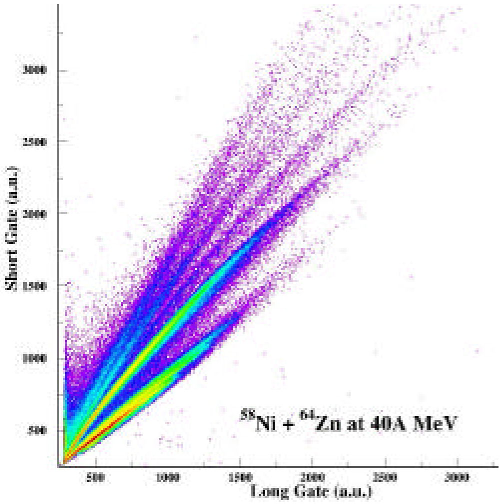

Figure 2: CsI(Tl) detector “Fast” versus “Slow” component spectrum from the ^{58}Ni + ^{64}Zn at 40 MeV/nucleon experiment.

Charge identification was obtained with a software mask applied to the spectra, delimiting the maximum of the distribution for each charge. The resulting particle identification (PID) spectra, where each charge covers one hundred bins for a typical phoswich detector is shown in Figure 3.

The energy calibration of the scintillator detectors involved production of secondary beams of many isotopes of known energy and charge, during the experiment. These beams, produced between the cyclotron and the reaction chamber, are selectively chosen by the magnetic rigidity of the remaining part of the beamline.

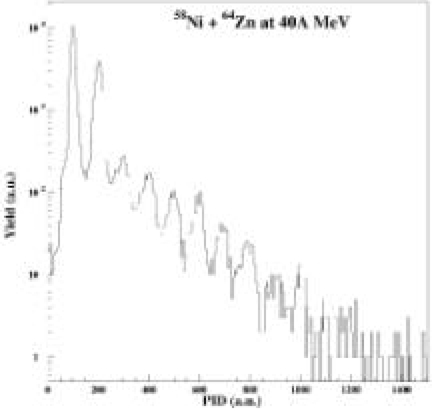

Figure 3: Particle identification (PID) spectrum for a phoswich detector at 20° in the laboratory frame, from the ^{58}Ni + ^{64}Zn at 40 MeV/nucleon experiment.

The resulting spectra were then analyzed to obtain many different calibration points. These points, of known energy, are then fitted to the scintillation registered during the experiment via a parameterization, in order to obtain an energy calibration.

For this calibration, a formula by Cebra *et al.* [1] was used for the phoswich detector:

$$L(E,A,Z)= kA^{"}Z^{\$}/E^{(} \qquad (1)$$

where A, Z are the mass and charge of the particle and k a constant related to the electronic gain. For the CsI(Tl) detector, a different parameterization from Larochelle *et al.* [2] was used. It relates the energy to the scintillation light as follows:

$$E(L,Z,A) = aAZ^{2}L + (b + cAZ^{2})L^{1-d\sqrt{AZ^{2}}}, \qquad (2)$$

where *a,b,c,d* are determined by fitting experimental points. The parameters *a,b,c* depend on the electronic gain and scintillation efficiency. A resulting energy spectra for Z=2 particles detected in CsI(Tl) scintillators at 30E is shown in Figure 4.

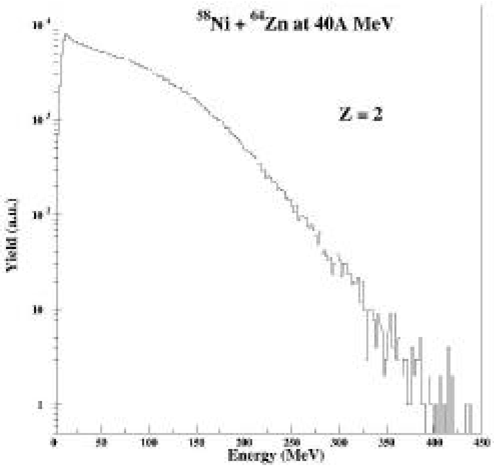

Figure 4: Energy spectrum for Z=2 particles identified in CsI(Tl) detectors at 30E in the laboratory frame, from the reaction ^{58}Ni + ^{64}Zn at 40 MeV/nucleon.

The Si detectors in the additional telescopes have been calibrated using a $^{228/230}$Th alpha source and by calculating the energy values of the punch through points for the Si-Si 2-D spectra. The CsI behind the Si detectors have been calibrated using the energy loss in the Si detectors and selected points on the 2-D Si-CsI spectra. Figure 5 shows a typical Si-Si detector spectrum from one of the experiments.

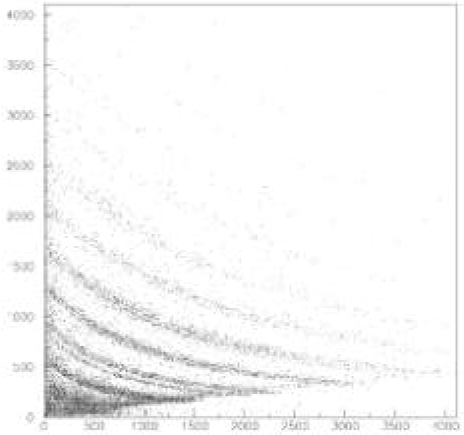

Figure 5: Si-Si 2-D for a Si-Si-CsI detector telescope at 40° in the laboratory frame, from the ^{58}Ni + ^{70}Zn at 40 MeV/nucleon experiment.

With the calibration done, the next step in the analysis involves comparison of particle energy and velocity distributions and global observables to simulations from statistical and dynamical simulations for the different projectile-target combinations. New insights on the nuclear equation of state and/or the dynamical effects arising in nuclear collision in the intermediate energy range might hence be gained.

Acknowledgments

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Reference

[1] D. Cebra *et al.*, Nucl. Instr. and Meth. in Phys. Res. **A313**, 367 (1992).
[2] Y. Larochelle *et al.*, Nucl. Instr. and Meth. in Phys. Res. **A348**, 167 (1994).