Calibration of the $^{40}Ca + ^{40}Ca$ data taken on NIMROD-ISiS array

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At low densities nuclear matter has the tendency to clusterize into α particles. Typically a Bose gas of α particles has the property of a condensate because the de Broglie wavelength of relative motion is much larger than the distance between two alpha particles. This indicates that α clusters could be a good candidate to observe the Bose Einstein Condensation (BEC). There are several suggestions [1] that one possible signature of this phenomenon is a strong fluctuation in the number of particles. Of course we have to assume that α particles exist inside particular nuclear states, but the Interactive Boson Model (IBM) and many experiments have proved that this assumption seems to be reasonable.

In order to investigate the properties of α clusters, an experiment was performed in August 2008 using the upgraded NIMROD-ISiS charged particle array [2], taking advantage of both its excellent isotopic resolution and the total angular coverage guaranteed by the 4π detectors. We chose to observe the α particles emitted by a ^{40}Ca projectile interacting with a ^{40}Ca target so as increase the probability of creating multiple α clusters. The system was studied at the three different energies of 35 MeV/u, 25 MeV/u and 10 MeV/u in order to understand changes in the characteristics of the α clustering as a function of excitation energy.

We have begun the calibration of the data set, starting with the particle identification (PID). We analyzed the spectra showing the CsI fast versus slow components, the Si versus CsI signals and, in the case of a Si – Si – CsI telescope, the ΔE -E plots of Si versus Si signals. For completeness, we also acquired signals collected from the back of the silicon detector wafers. PID is accomplished by setting gates around the linearized line of a particular element. Examples of the CsI fast vs. slow components and Si-CsI plots for the energy of 35 MeV/u are shown in Fig. 1 and Fig. 2.

We note that CsI detectors can resolve isotopes of elements with Z = 1 and Z = 2 and, for some crystals in the most forward rings, it is possible to see also lithium isotopes. On the other hand, the resolution of telescope arrays in many cases allows identification of isotopes of elements up to Z = 10.

Using the ΔE vs. E or fast vs. slow spectra a smooth line was drawn for each element along one isotope (usually the one with the highest intensity). Once the distance between the data points and the chosen line was computed, the data were displayed as function of the mass of each element. At this point, windows were placed around the centroid of each identified isotope.

The linearizations were examined run-by-run and all necessary adjustments were applied to compensate for small drift in gains.

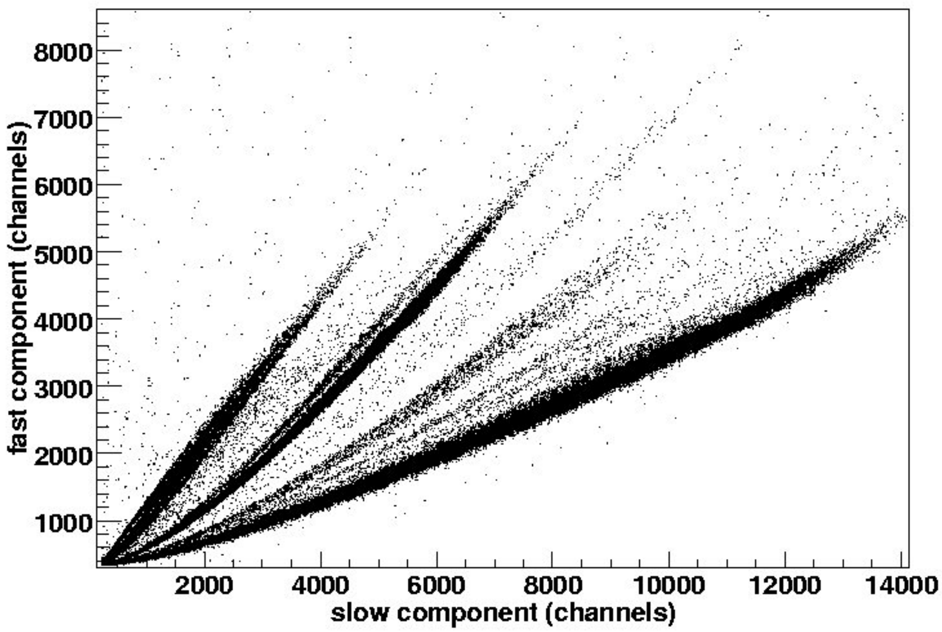

FIG. 1. Fast and slow components of CsI #4 are plotted. Hydrogen, Helium and Lithium isotopes are visible.

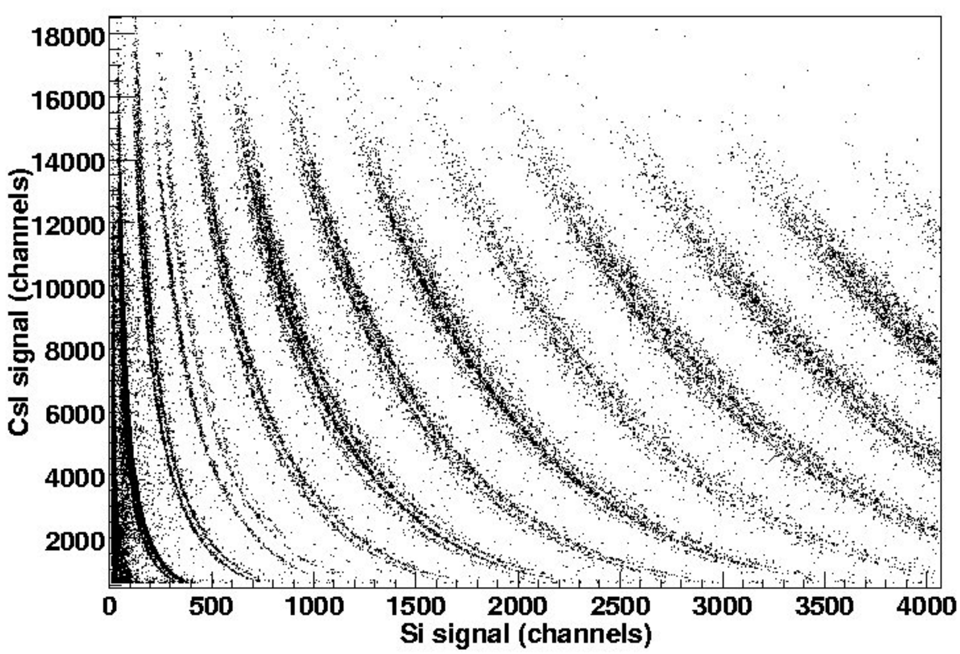

FIG. 2. Raw spectrum of a Si-CsI telescope in Ring 4.

The isotopic distribution obtained as a result of the linearization process is plotted in Figs. 3 to 5. In the CsI spectra elements with charge Z = 1, Z = 2 and Z =3 are shown. Elements with atomic number from 1 to 8 can be clearly resolved by the Si – CsI telescopes, whereas if we want to analyze heavier elements (up to Z = 14) we can look at the result of the linearization for Si – Si plots. Of course, both Si – CsI telescopes and Si – Si telescopes can also resolve lighter elements.

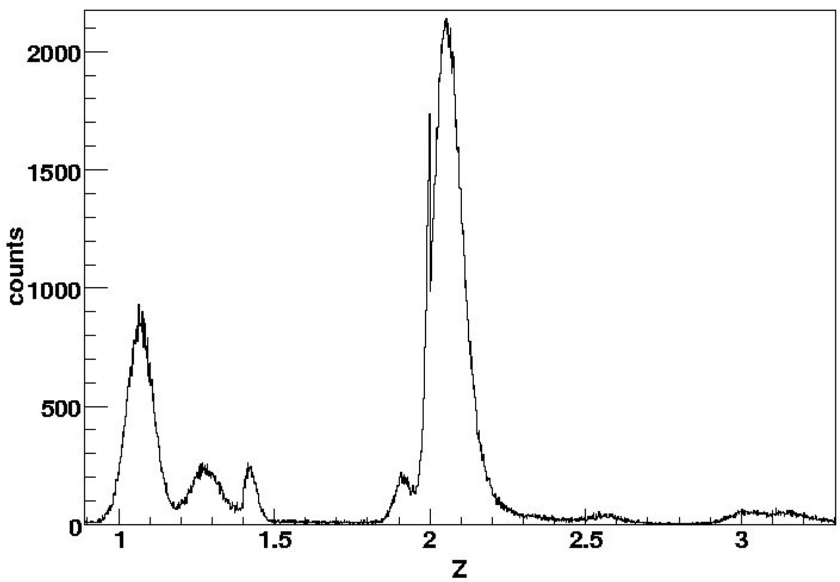

FIG. 3. Isotope distribution for a CsI detector in Ring 3.

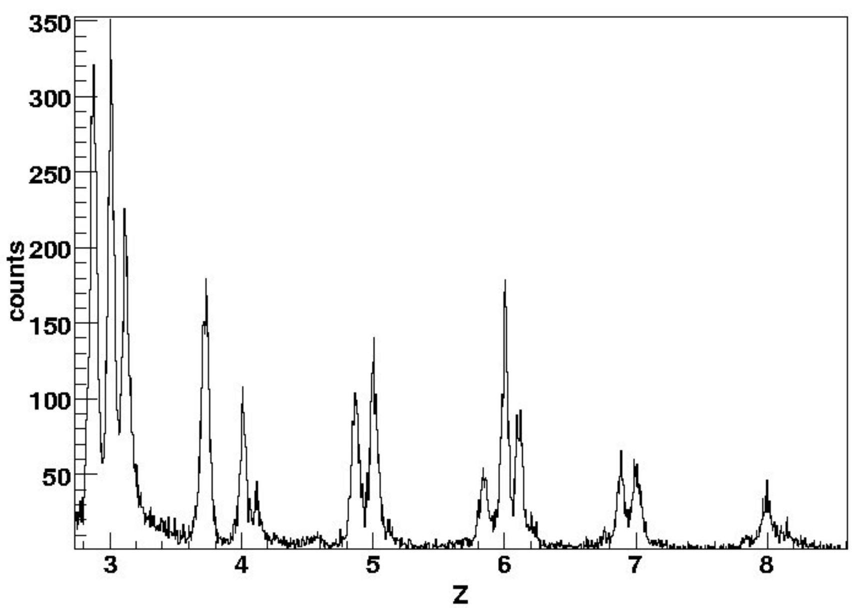

FIG. 4. Result of the linearization process for one Si -CsI telescope in Ring 2. Isotope identification of elements with charge up to Z = 8 is possible.

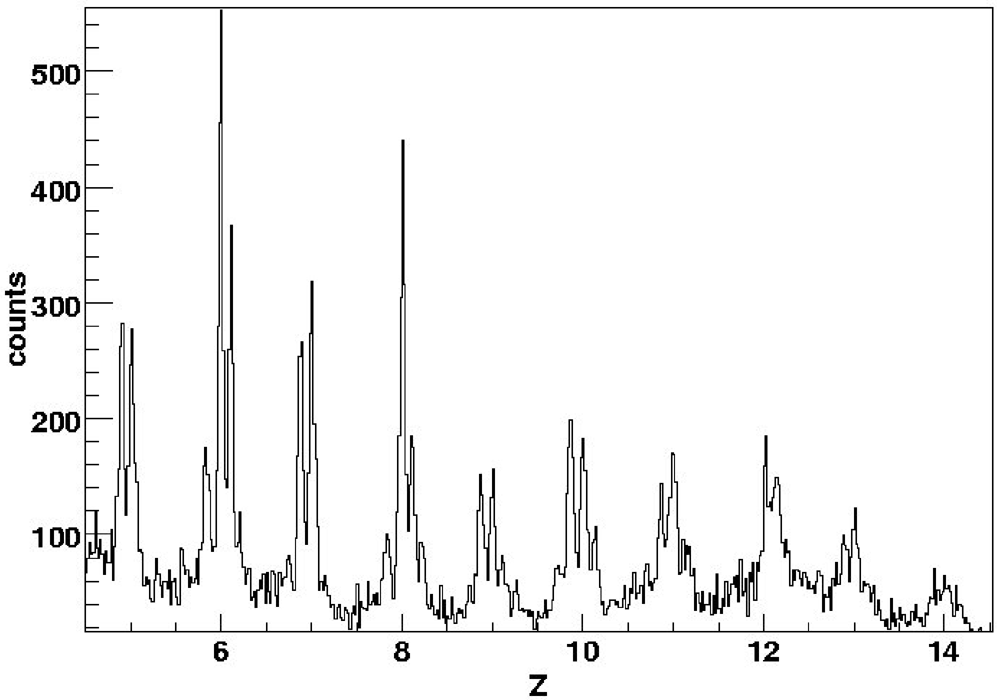

FIG.5. Result of the linearization process for a Si – Si – CsI telescope in Ring 4.

The linearization process is now complete. It was important to be able to identify isotopes of elements heavier than Helium because we could find, even though with low probability, 3-α systems collapsing to ^{12}C or 4-α systems collapsing to ^{16}O.

At the moment our next step will be the calibration in energy of the spectra that have been linearized. We foresee that in the next few weeks we will be able to proceed with the data analysis.

[1] S. Wuenschel *et al.*, Nucl. Instrum. Methods Phys. Res.. **A604**, 578 (2009)
[2] V. V. Begun and M. I. Gorenstein, Phys. Lett. B **653**, 190 (2007).