The clusterization of alpha-conjugate nuclei

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We have discussed the analysis of an experiment probing the clusterization of alpha conjugate nuclei in several previous reports [1,2,3]. To recount, data on a number of systems that are composed of alpha conjugate nuclei was collected using the NIMROD-ISiS multidetector array. One experiment was performed using Ca beams of 35, 25 and 10 MeV/u and the other with at Si beams at 35 and 15 MeV/u. Data was collected with each of the beams using Ca, Si, C and Ta targets.

The previous report [3] showed results of an analysis of emission patterns for the various decay channels that lead to an alpha-like mass of 40 for all of the systems that were studied with the 35 MeV/u Ca beams and an alpha-like mass of 28 for all of the systems that were studied using the 35 MeV/u Si beams. The emission patterns indicate a neck like origin of the alpha in the reactions where the complete system is composed of alpha-like nuclei. This behavior appears to be inconsistent with statistical behavior. Indeed, recent studies [4] at higher energies have shown various behaviors associated with the breakup of alpha cluster nuclei to have a non-statistical origin.

In order to explore this possible non statistical behavior, we have performed statistical model calculations. These model calculations can indicate whether the observed behavior results from reaction mechanisms having a non statistical origin or whether a simple statistical explanation that includes detector biases might explain the observation.

The procedure used in [3] was to reconstruct the decaying source and plot the velocity spectra of the decaying products in the frame of the decaying source. The extension that we discuss in this work is similar in that the decaying source is reconstructed. The properties (mass, charge, excitation energy) of the reconstructed source are then used as input into the statistical model, GEMINI [5] on an even by event basis. The decays from GEMINI are performed event by event and are filtered through the experimental acceptance. The reaction products passing the filter are then analyzed in the same way as the experimental data.

Fig. 1 shows invariant velocity plots of the products that originate from events selected to have a total detected alpha-like mass of 40 for the systems with Ca beams and a total detected alpha-like mass of 28 for the systems with Si beams. We show the emission patterns for the various decay channels that lead to an alpha-like mass of 40 (28) for all of the systems with the Ca (Si) beam that were studied. The left side of the frame of each system shows the velocity distributions of the heavier alpha like fragments and the right side shows the velocity distributions of the alpha particles associated with those heavier fragments. The vertical lines indicate the location vz=0 which is the frame of the reconstructed decaying system. In contrast to the experimental data [3], this distribution shows a symmetric pattern of the alpha particle emission

relative to the rest frame of the emitting source. The emission pattern of the heavy partner also forms an oval around the rest frame of the emitting source as is expected from statistical behavior.

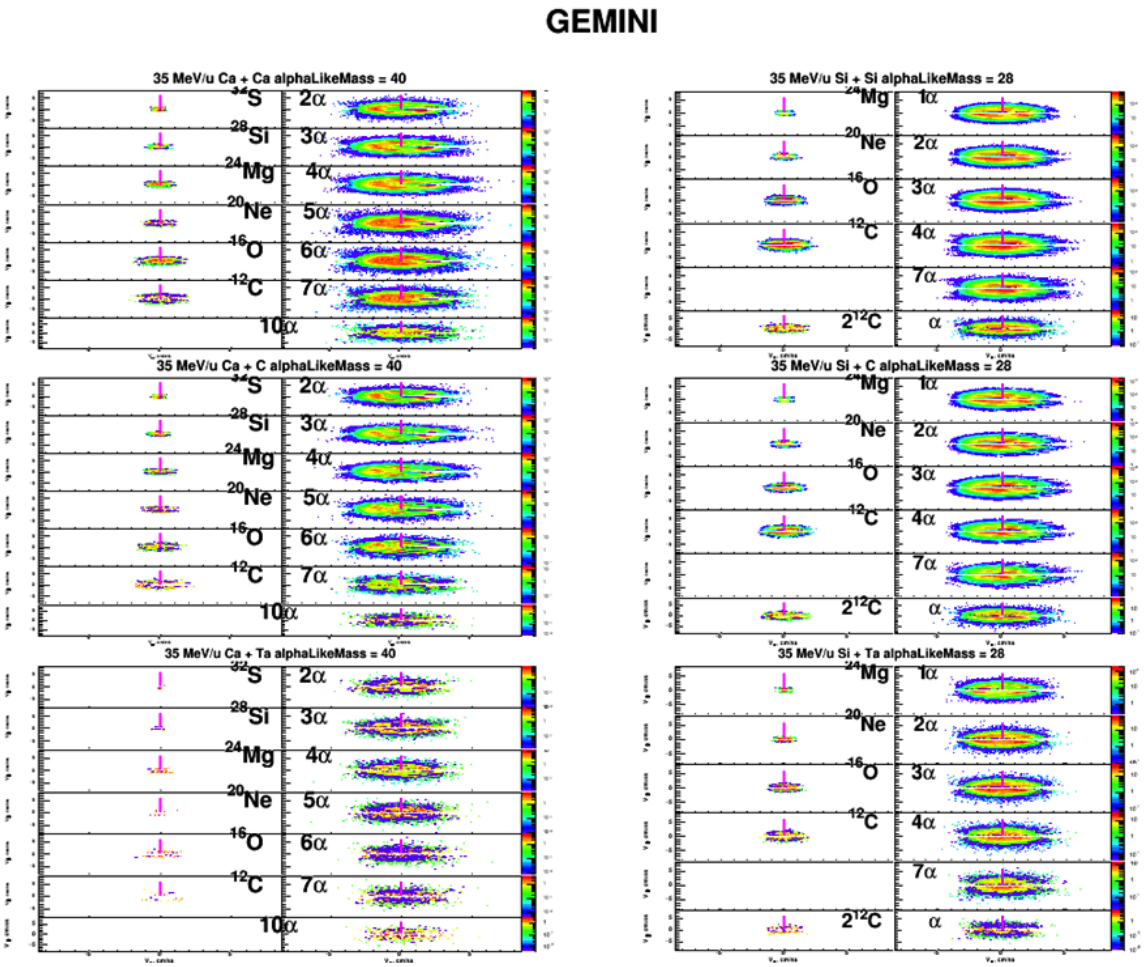

FIG. 1. Invariant velocity distributions of products predicted by GEMINI resulting from the various decay channels of a decaying source reconstructed in events having a detected alpha like mass of 40 for reactions with Ca beams and an alpha-like mass of 28 for the reactions with Si beams. The vertical lines indicate vz=0, the frame of the reconstructed source.

The emission patterns resulting from the model calculations and filtered through the experimental acceptance produce symmetric distributions, ie rings around the emitting source as expected from statistical decay, indicates that the observed behavior in the experimental data [3] is not the result of detector bias. As mentioned in the introduction, clear deviations from statistical behavior have been observed in the $^{12}C + ^{12}C$ alpha cluster reactions at higher energies. Branching ratios of multiple alpha particle emission were observed to be much larger than in the experimental data than the statistical would predict. The significant production of multiple alpha particle emission has been discussed in this work [3] and the emission patterns in the

experimental data compared to the statistical predictions are consistent with that non statistical behavior.

We are continuing the analysis of this large body of data. In particular, the calibrations of the same systems mentioned here at 10 and 15 MeV/u are in progress.

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[3] K. Schmidt *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2012-2013), p. II-9.
[4] G. Baiocco *et al.,* Phys. Rev. C **87**, 054614 (2013); L. Morelli *et al.,* J. Phys. G **41** 075108 (2014).
[5] R.J. Charity *et al.*, Nucl. Phys. **A483**, 371 (1988).