HIPSE calculations of alpha conjugate systems in the reactions of 35 MeV/u Si + C and implications in the search for toroidal configurations

X.G. Cao, K. Schmidt, K. Hagel, S. Wuenschel, E.J. Kim, M. Barbui, J.B. Natowitz, H. Zheng, N. Blando, A. Bonasera, G. Giuliani, M. Rodrigues, R. Wada, M. Huang, C. Botosso, G. Liu, G. Viesti, S. Moretto, G. Prete, S. Pesente, D. Fabris, Y. El Masri, T. Keutgen, S. Kowalski, Z. Kohley, and A. Kumar

We have continued the analysis of the alpha conjugate systems that were studied with NIMROD and reported previously [1-6]. In a previous report we discussed the idea that heavy ion collisions induced by light α-conjugate nuclei may provide conditions to access toroidal isomers with high excitation energies and angular momentum [7]. Peaks in the excitation energy distributions near those predicted by Staszczak, and Wong [8] for high spin isomers of the different decay channels led us to the idea that the decay of toroidal isomers might be a component of those excitation energy distributions.

In order to ascertain whether peaks in excitation energy distributions may result from toroidal configurations predicted by Staszczak, and Wong [8], we have compared events generated by HIPSE [9] calculations to the experimental data. The HIPSE (heavy-ion phase-space exploration) calculation proceeds first by describing the approaching phase of the collision, then the partition formation phase and finally the exit channel and after-burner phase. The first two phases are performed with the HIPSE code and the last phase is accomplished using the evaporation code GEMINI [10]. In particular, HIPSE with an afterburner has been shown to provide a good simulation of the energy and particle distributions in intermediate heavy-ion reactions [9]. It does not have a component of the decay of high spin toroidal isomers, so comparisons of the model calculations to the experimental data can show whether observed peaks are the result of experimental acceptance or perhaps phenomena not included in the calculation.

In Fig. 1 we show excitation energy distributions of events where 7 alpha particles are detected and the detected alpha like mass (Almass) is 28, ie a ^{28}Si nucleus. The solid points in figure 1 show the excitation energy distributions of 7α events with cuts in delta and distance, d, as described in [7]. The red arrow shows the position of 143 MeV, the excitation energy predicted for a toroidal configuration of ^{28}Si. As noted in [7], we observe an enhancement in the data in the region of this prediction.

We have performed calculations using the HIPSE code. HIPSE was used to generate the primary distributions as described briefly above and in [9] and GEMINI [10] was used as an afterburner in order to compare the calculations to the experimental data. The events in which the products had and alpha-like mass (Almass) = 28 before being filtered are shown as the red histogram in Fig. 1. It is clear that HIPSE does not generate the peaks at 143 MeV that are observed in the experiment.

As we note that HIPSE does not generate a peak observed at 143 MeV for the 7α events, we are in the process of filtering the HIPSE-GEMINI events to ensure that the acceptance of the detector does not “manufacture” such events. Simple simulations with a “toy model” suggest that the excitation energy reconstructed after filtering should track with the primary excitation energy, but a definitive answer requires the filtering and analysis performed in the same way as the data. These investigations are underway.

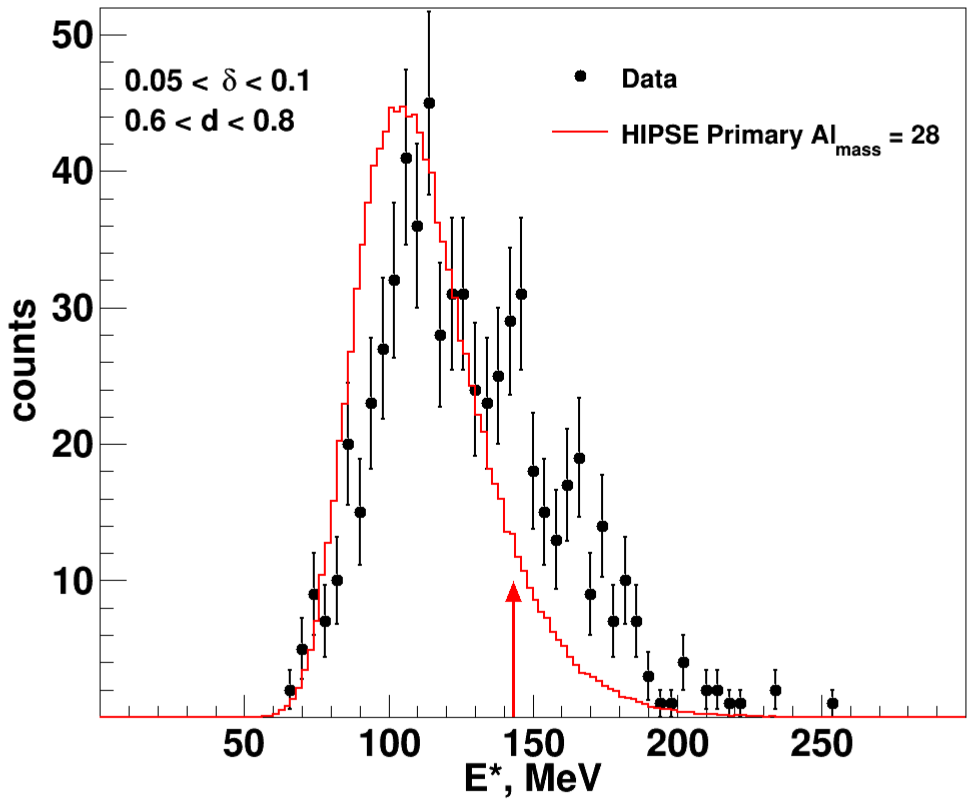

FIG. 1. Excitation energy distributions for 7α events where Almass = 28. The solid points represent the data. The red histogram shows the prediction of HIPSE events where the products produced by HIPSE have Almass = 28 after the GEMINI afterburner, but before filtering. The arrow at E*=143 MeV indicates the position of the prediction of [8] for a toroidal configuration of ^{28}Si.

[1] K. Schmidt *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2011-2012), p. II-9.

[2] K. Schmidt *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2012-2013), p. II-20.

[3] K. Schmidt *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2012-2013), p. II-9.

[4] K. Schmidt *et al.,* J. Phys. Conference Series **420**, 012088 (2013).

[5] K. Schmidt *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2013-2014), p. II-18.

[6] K. Schmidt *et al.*, Eur. Phys. J. Web of Conferences **88**, 24 (2015).

[7] X. G. Cao *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2015-2016), p. II-16.

[8] A. Staszczak and C.Y. Wong, Phys. Lett. B **738**, 401 (2014).

[9] D. Lacroix, A.V. Lauwe, and D. Durand, Phys. Rev. C **69**, 054604 (2004).

[10] R.J. Charity *et al.*, Nucl. Phys. **A483**, 371 (1988).