Probing clusterization in ^{40}Ca + ^{40}Ca reactions

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Given the high degree of alpha clustering which is expected for low mass alpha conjugate nuclei we previously initiated a search for evidence of cluster effects and possible Bose Condensates using the NIMROD array. Our experiments, carried out at the end of 2008 employed 10, 25, 35 MeV/u beams of ^{40}Ca and ^{28}Si incident on ^{40}Ca, ^{28}Si, ^{12}C and ^{180}Ta target. After completing the energy calibrations of the Si and CsI detectors we have initiated the physical analysis of the ^{40}Ca + ^{40}C reaction data at 35MeV/A in order to de-lineate the dominant reaction mechanisms present. We have also made comparisons with results of anti-symmetrized molecular dynamics (AMD) calculations. AMD calculations were performed up to 300 fm/c. The Gemini was employed as an afterburner to de-excite the fragments. All events were passed through an experimental acceptance filter. The goal of our analysis is to understand the mechanism of production of alpha conjugate products, similar to those shown in the Ikeda Diagram in Fig. 1.

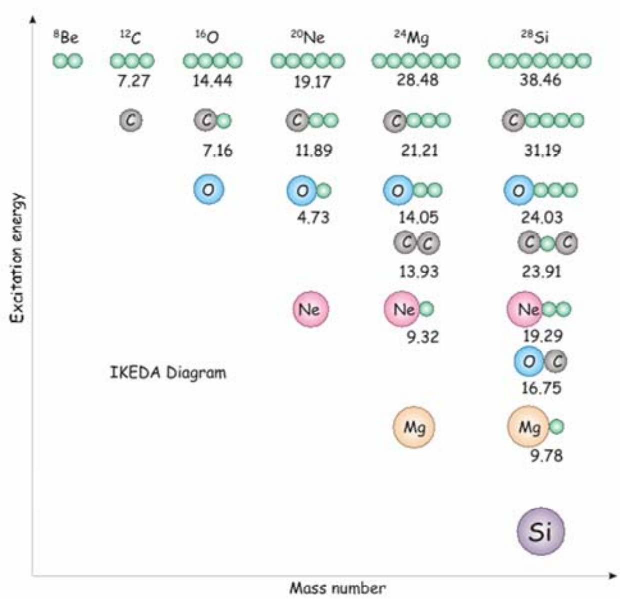

FIG. 1. Ikeda Diagram.

In order to find those various α-conjugate combinations it is necessary to define some observables. For each event we calculate the multiplicity of "α-like fragments" and the total mass of those fragments as defined below.

α-like mult = α mult + ^{12}C mult + ^{16}O mult +…+^{40}Ca mult
α-like mass = 4(α mult)+12(^{12}C mult)+ 16(^{16}O mult) +…+40(^{40}Ca mult)

We define similar observables for "d-like fragments" as well:

d-like mult = d mult + ^{6}Li mult + ^{10}B mult +…+^{22}Na mult
d-like mass = 2(d mult) + 6(^{6}Li mult) + 10(^{10}B mult) +…+30(^{30}P mult).

In Fig. 2 we show some preliminary results on the production of α (left) and d (right) conjugate fragments in the collisions of ^{40}Ca with ^{40}Ca at 35A MeV. The number of detected events with different multiplicities of α(d) conjugate nuclei is plotted against the total α(d) conjugate mass detected. No impact parameter selection is applied. A total mass as large as 85% of the entrance channel mass is observed. Given some detector inefficiency and energy thresholds this is a significant number. Also interesting is the limiting case, in which where all of the detected α(d) conjugate mass is in α-particles or deuterons. These are indicated by the large circles in Fig. 2.

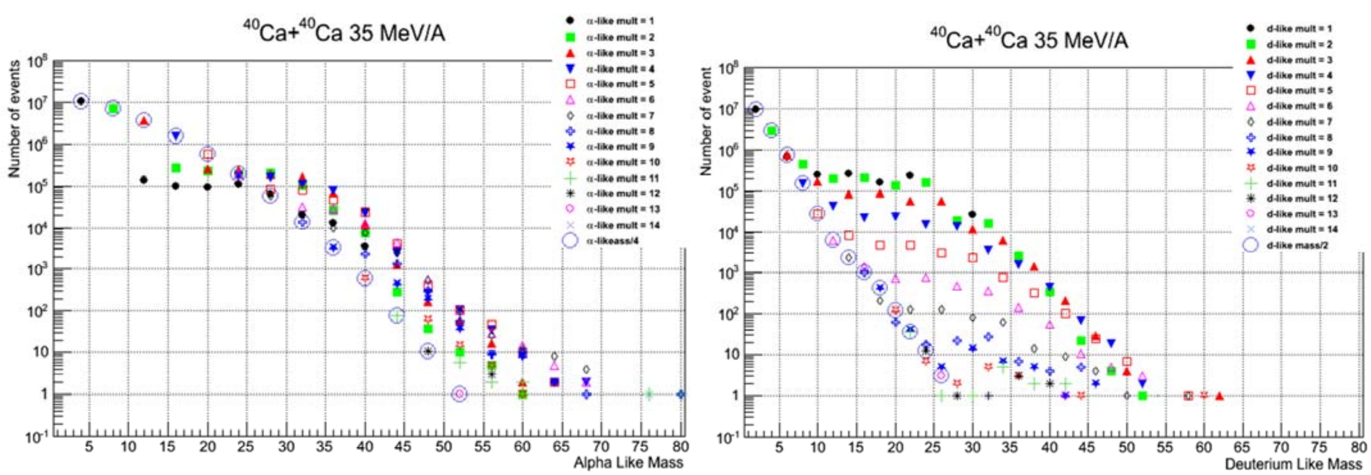

FIG. 2. α-like mass (left) and d-like mass (right) distribution for fixed α-like /d-like multiplicities.

Another interesting parameter, bj is defined as follows:

$$B_j = \frac{1}{M}\sum_{i=1}^{M}\frac{(-1)^{Z_i} + (-1)^{N_i}}{2}$$

this parameter ranges from -1 to 1. The negative value indicates more d-like fragments in the event whereas positive value means more α-like fragments.

Fig. 3 shows the comparison between the experimental data (blue line) and AMD theoretical results (red line) for the the A and Z distributions and for the observables defined above. The model underestimates the production of heavier fragments starting from Z=15. We observe good agreement in the distributions of α-like and d-like multiplicity and their total masses. The theoretical distribution for the bj parameter is narrower than that for the experiment, which might be due to the underestimate of heavier fragment production. It is also nearly symmetric, meaning that almost the same number of α-like and d-like fragments are predicted. The experimental distribution is weighted towards the positive values, which indicates that more α-like fragments have been created. The analysis is in progress and will explore source analyses, multiplicity fluctuations, multi-particle correlations and other observables.

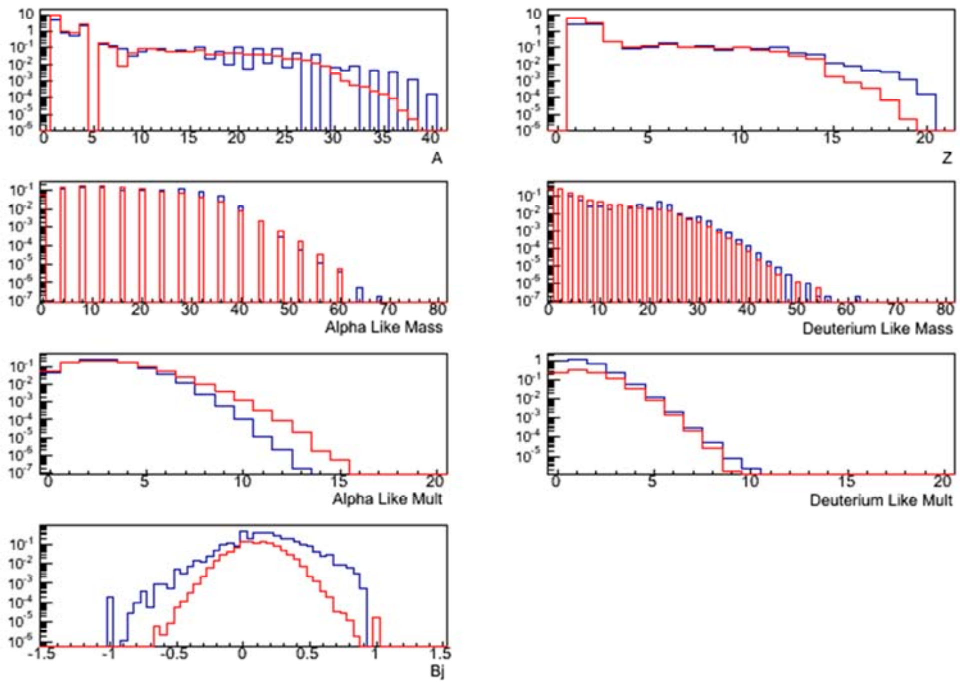

FIG. 3. A, Z, α-like mass, d-like mass, α-like multiplicity, d-like multiplicity, bj distributions. Blue line – experimental data, red line – AMD calculations.