Clustering in ^{10}Be

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Clustering phenomena clearly manifest themselves in light nuclei. It is well established that the low-lying states in ^{8}Be can be described as a two-center structure [1]. Recent *ab initio* GFMC calculations explicitly show how this structure emerges naturally for the ^{8}Be ground state [2]. The suggestion that this two-center structure may survive when "valence nucleons" are added to the system has been made in the early 1970s [1]. A semiquantitative discussion of this subject can be found in [3] where the two-center molecular states in ^{9}B, ^{9}Be, ^{10}Be, and ^{10}B nuclei were considered in the framework of a two-center shell model. An AMD plus Hartree-Fock (AMD+HF) approach was proposed in [4] as a theoretical tool to study the structure of low-lying levels in ^{9,10,11}Be isotopes. Deformation (distance between the two α's) for several low-lying states in Be isotopes has been calculated. Very large deformation (~0.8) for the 6.179 MeV 0^+ state in ^{10}Be was suggested, which corresponds to an α-α inter-distance of 3.55 fm. This is 1.8 times more than the corresponding value for the ^{10}Be ground state. A similar result was obtained in [5] where the spectrum of ^{10}Be was reasonably well reproduced using a Molecular Orbital model. The second 0^+ state in ^{10}Be has an enlarged α-α distance and the highly deformed rotational band with large moment of inertia built on that configuration emerges according to these calculations. The 0^+ at 6.179 MeV and the 2^+ at 7.542 MeV in ^{10}Be are believed to be associated with this rotational band. The 4^+ member was suggested at 10.2 MeV. However, contradicting spin-parity assignments (3- in [6] and 4^+ in [7,8]) have been made for this state. No experimental information on the possible next member of this band, the 6+ state, (predicted, for example, in [9]) is available. The goal of this study was observation of the state at 10.2 MeV and determination of its spin-parity, and search for the next, 6+, member of this highly deformed rotational band.

The excitation function for ^{6}He+α elastic scattering was measured using Array for Nuclear Astrophysics and Structure with Exotic Nuclei (ANASEN). Experiment was carried out using RESOLUT rare isotope beam facility at the John D. Fox superconducting linear accelerator facility at the Florida State University. ANASEN is an active target detector. Helium gas with 5% admixture of CO_2 was used as an active volume. ANASEN consist of an array of silicon double sided strip detectors and an array of position sensitive proportional counters that allow for reconstruction of the recoil tracks. The angle integrated (75^o-135^o) excitation function is shown in Fig. 1. The strong peak at 2.78 MeV c.m. energy corresponds to the 10.2 MeV excited state in ^{10}Be. The R-matrix fit to angular distributions in the area of the 10.2 MeV state were used to determine the spin-parity of this state unambiguously as 4^+. The angular distribution for 2.72 MeV excitation energy is shown in Fig. 2. The solid curve on Fig. 2 is an R-matrix fit with the 4^+ state at 2.78 MeV. No other spin-parity assignment is consistent with the data. This assignment is consistent with the results of earlier ^{6}He+α measurements [7,10].

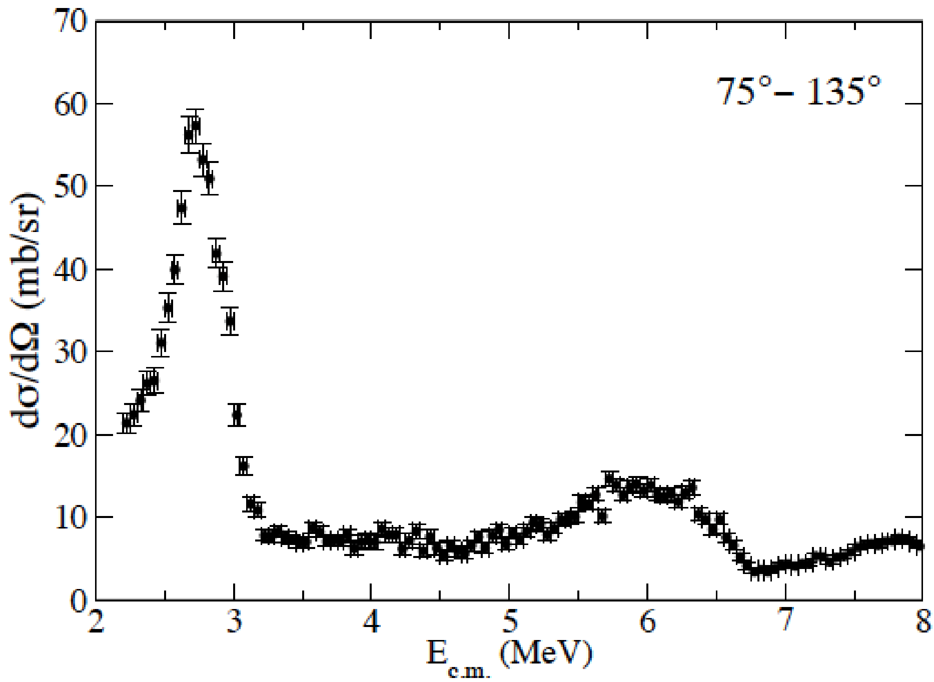

FIG. 1. Angle integrated (75^o - 135^o) excitation function for the ^{6}He+α elastic scattering measured using the Array for Nuclear Astrophysics and Structure with Exotic Nuclei (ANASEN).

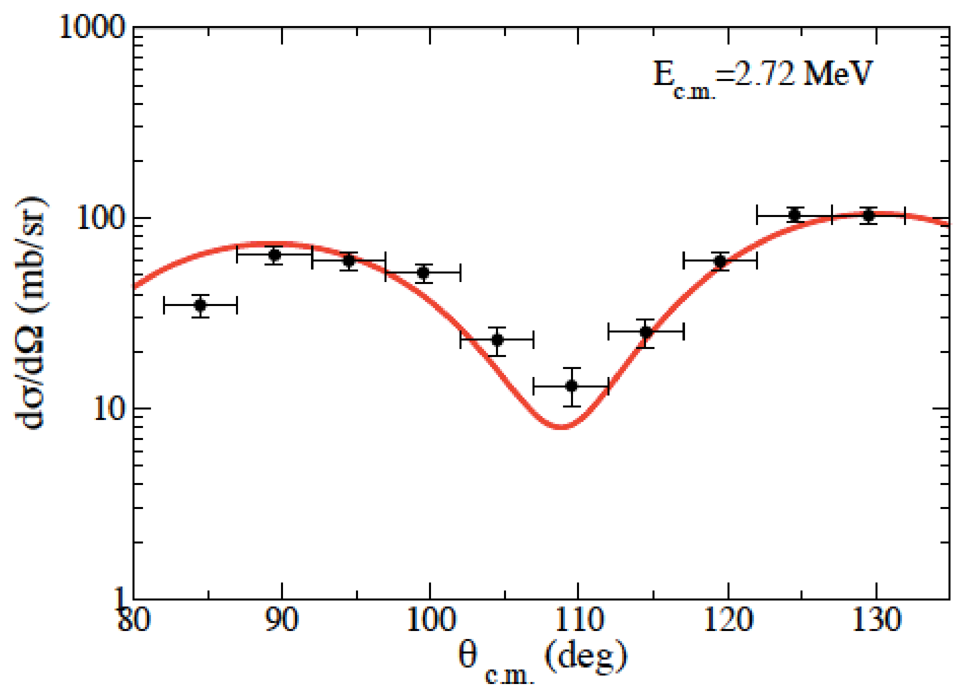

FIG. 2. Angular distribution for the ^{6}He+α elastic scattering at 2.72 MeV c.m. energy. The red solid curve is an R-matrix fit with a 4^+ state at 2.78 MeV.

Another interesting feature of the measured ^{6}He+α excitation function is a broad peak at 6 MeV c.m. energy (13 MeV excitation energy of ^{10}Be). It is clearly visible in the 90°+/-5° excitation function (see Fig. 3), but it is not obvious at any other angle. This may indicate a high spin, positive parity state. The R-matrix fit to the 90° excitation function shown in Fig. 3 includes a highly clustered 6^+ state at 6.0 MeV. It is a good candidate for next, 6^+, member of the highly deformed rotational band mentioned above. However, the angular distribution over the wider angular range differ from the R-matrix prediction for the 6^+. This is probably due to the fact that lower orbital angular moment partial waves contribute (0^+ and 2^+, predominantly) and it is difficult to fix the corresponding phase shifts for this largely flat excitation function using only limited set of angles. Future measurement of the ^{6}He+α excitation function at angles close to 180° (where the 6^+ state has a strong maximum) is essential to decide if the peak at 6 MeV is indeed a 6^+.

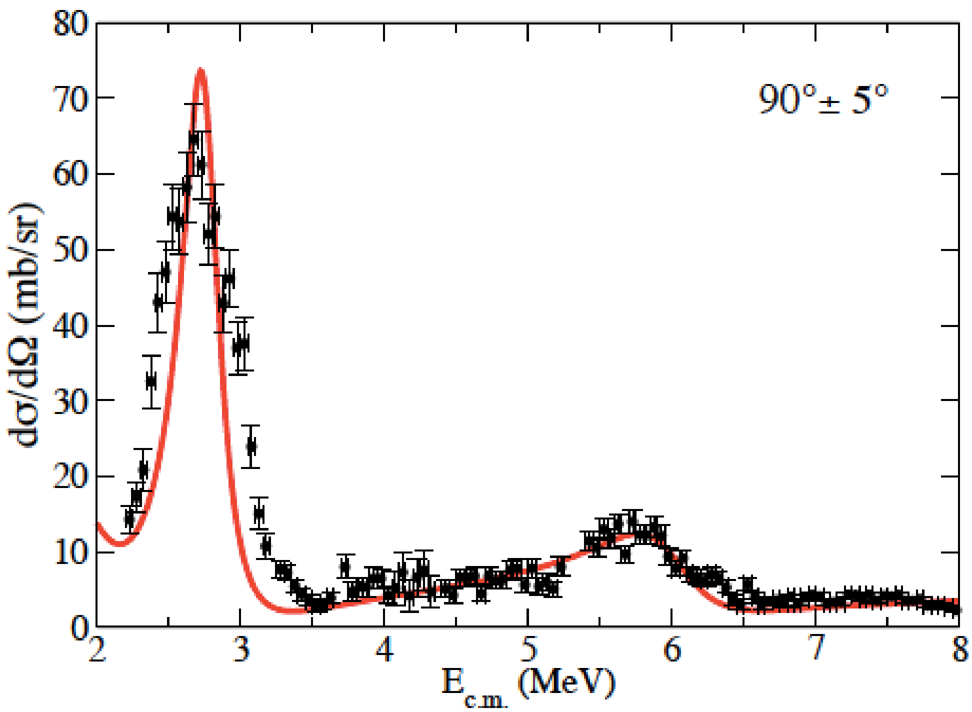

FIG. 3. Excitation function for the ^{6}He+α elastic scattering at 90° in c.m. Solid curve is an R-matrix fit with 4^+ and 6^+ states at 2.78 MeV and 6.0 MeV respectively.

In summary, the excitation function for ^{6}He+α was measured in the broad energy range from 2.0 to 8.0 MeV and angular range of 75° to 135°. The strong state at 10.2 MeV is observed. We confirm the results of the previous ^{6}He+α measurements [7,10] that indicate that the state at 10.2 MeV is a highly clustered 4^+ state. The dimensionless reduced α-width for this state is ~1.5. We observed a peak at 6.0 MeV that may be assigned spin-parity 6^+, but this assignment is tentative. If this state is indeed 6+ then it has dimensionless reduced α-width close to unity and can be assigned to the highly deformed cluster band in ^{10}Be, that has a 0^+ band head at 6.18 MeV, 2^+ member at 7.54 MeV, 4^+ at 10.2 MeV and a tentative 6^+ at 13.5 MeV. This band has moment of inertia that is a factor of three larger than the moment of inertia of the ground state band.

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