Clustering in ^{10}Be

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There is a strong experimental evidence that some states in ^{10}Be exhibit molecular-like α:2n:α configuration [1,2,3]. Theoretically these exotic structures can be explored microscopically in the antisymmetrized molecular dynamics plus Hartree-Fock approach [4] or in Molecular Orbital model [5]. Based on these theoretical studies it appears that the 6.179 MeV 0^+ state in ^{10}Be has a pronounced α:2n:α configuration with 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. The 2^+ at 7.542 MeV in ^{10}Be is believed to be the next member of this rotational band [6]. The state at 10.2 MeV was identified as a 4^+ member [1, 3]. The algebraic model [7] predicts that a 6^+ state at around 13 MeV is the terminating member of this band. It would be of paramount importance to identify this 6^+ state experimentally and to conclusively establish the complete α:2n:α rotational band. This would become the most striking and well established case of molecular-like configurations in nuclei and an important step towards better understanding of clustering phenomena in atomic nuclei.

We performed an experiment to search for the 6^+ state in ^{10}Be at around 13 MeV excitation energy in the excitation function for ^{6}He+α scattering. The Cyclotron Institute Momentum Achromat Recoil Separator (MARS) facility was used to produce a secondary ^{6}He beam at 7.0 MeV/u from the production reaction of ^{7}Li(d,^{3}He). The sketch of the experimental setup is shown in Fig. 1. Modified thick target inverse kinematics approach [8] was used to measure the ^{6}He+α excitation function. Details of the experimental setup can be found in [9]. The energy of the ^{6}He beam was reduced down to 22 MeV by the thick scintillator foil located in front of the scattering chamber filled with Helium+CO_2 96:4 gas mixture at pressure of 1700 Torr.

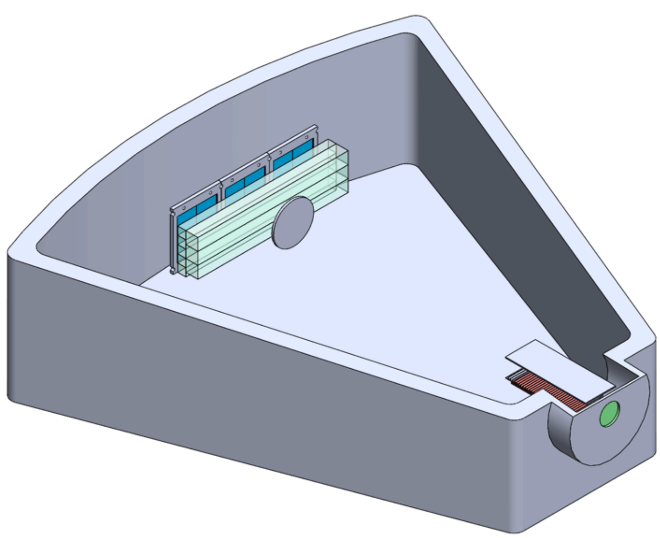

FIG. 1. Sketch of the experimental setup to measure the ^{6}He+α excitation function for resonance elastic scattering.

We have observed a distinct peak of α particles that could be a result of resonance in the ^{6}He+α excitation function which we were looking for (Fig. 2). It was verified that the peak in the α spectrum is associated with the incoming ^{6}He ions and not the other secondary beam components (the dominant of which is tritium). We expect that the highest energy α particles in the spectrum (from about 12 and 15 MeV) correspond to the pure elastic scattering. This is confirmed by sharp cut off in yield above 15 MeV (maximum energy of elastically scattered α particles). At lower energies admixtures from α particles due to inelastic scattering and breakup are possible. Based on the shape of the spectrum compared to Monte Carlo simulation (Fig. 3), the experimental yield and angular dependance of the cross section, we conclude that the α spectrum is dominated by the breakup of ^{6}He into α+2n at energies below 8 MeV.

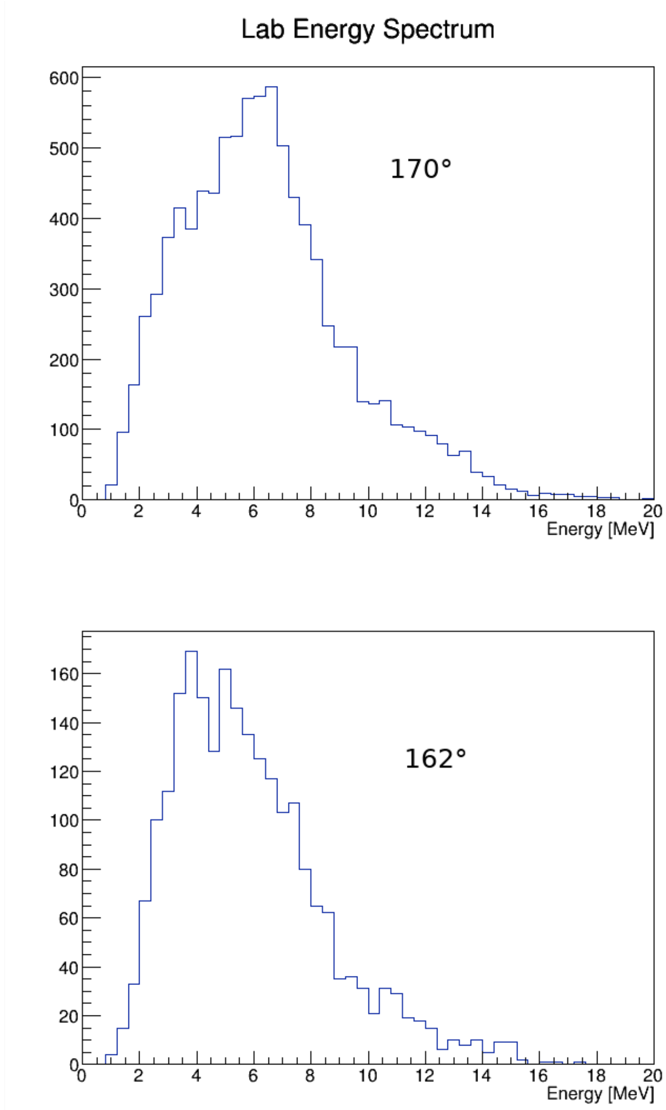

FIG. 2. Spectrum of α particles measured by the off-center Si detectors. The peak at 7 MeV is a result of ^{6}He decay into α + 2n (see text for details).

The peak in the α spectrum due to the hypothetical 6^+ state at 13.5 MeV [10] would appear in the vicinity of 10 MeV lab. energy of α-particles (Fig. 3). There is no indication for a resonance-like structure in our spectrum at that energy at any angle. The R-matrix calculations are being performed to put a qualitative limits on the existence of the hypothetical 6^+ resonance.

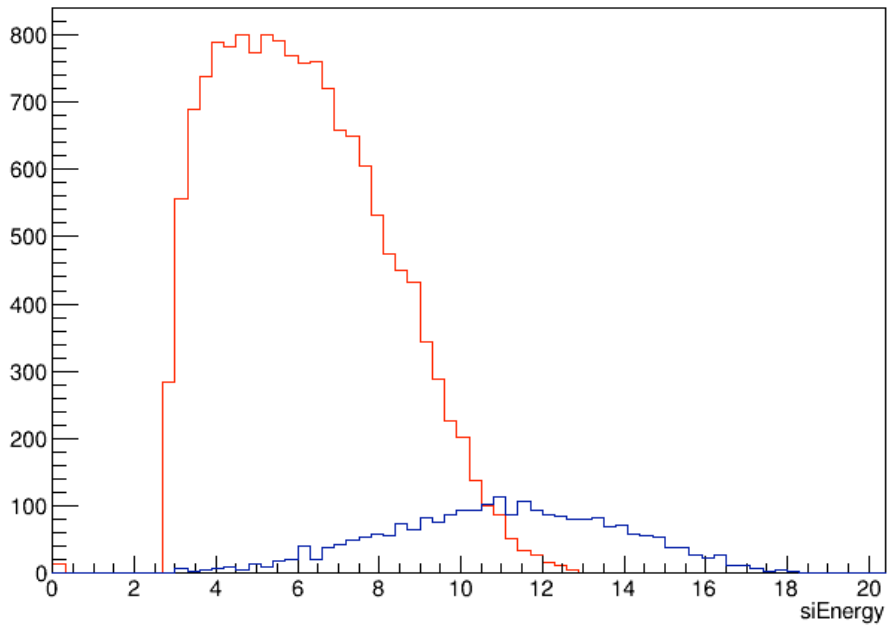

FIG. 3. Monte Carlo simulation of α particles spectrum due to breakup of ^{6}He. The (red) curve at lower energy shows α particles from ^{6}He decay. The (blue) curve at higher energy shows α particles due to inelastic scattering.

[1] M. Freer *et al.*, Phys. Rev. Lett. **96**, 042501 (2006).

[2] M. Milin *et al.*, Phys. At. Nucl. **69**, 1360 (2006).

[3] D. Suzuki *et al.*, Phys. Rev. C **87**, 054301 (2013).

[4] A. Doté, H. Horiuchi, and Y. Kanada-Enýo, Phys. Rev. C **56**, 1844 (1997).

[5] N. Itagaki and S. Okabe, Phys. Rev. C **61**, 044306 (2000).

[6] A.N. Kuchera *et al.*, Phys. Rev. C **88**, 054615 (2011).

[7] R. Wolsky *et al.*, Phys. At. Nucl. **73**, 1405 (2010).

[8] K. Artemov *et al.*, Sov. J. Nucl. Phys. **52** 408 (1990).

[9] S. Upadhyayula *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2015-2016), p.I-31.

[10] D. Dell'Aquila *et al.*, Phys. Rev. C **93** 024611 (2016).