Clustering in ^{10}Be

S. Upadhyayula, G.V. Rogachev, E. Koshchiy, E. Uberseder, V.Z. Goldberg, J. Hooker,
H. Jayatissa, C. Hunt, and B. T. Roeder

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 generate 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. The scattering

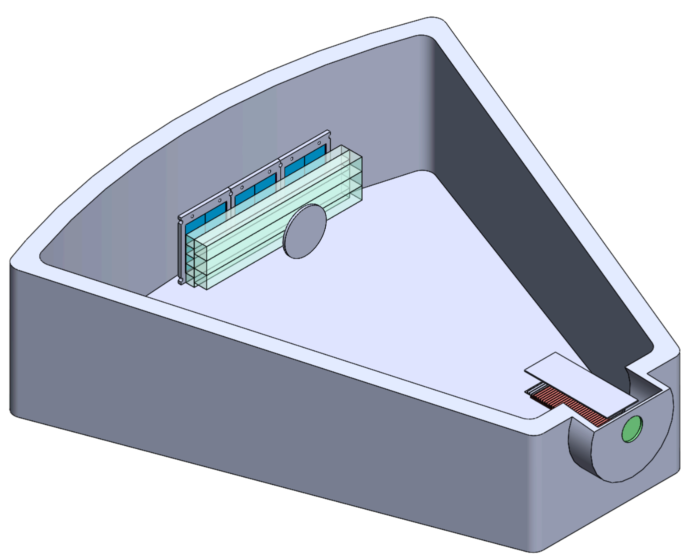

FIG. 1. Sketch of the experimental setup to measure the 6He+α excitation function around 13 MeV of ^{10}Be excitation energy.

chamber consisted of three forward silicon detectors to measure the total energy of the recoil α's. A position sensitive proportional counter located just before the silicon detectors and consisted of eight cells, in two layers, was used for particle identification and scattering angle reconstruction. A windowless ionization chamber for overall normalization and beam contaminant identification was installed at the entrance to the gas filled scattering chamber. There was a removable disk just before the proportional counter cells to avoid permanently damaging the silicon detector located on the beam axis and to reduce the trigger rate by stopping 95% of the ^{6}He ions not interacted with α particles. The setup was optimized to measure elastic and inelastic ^{6}He+α scattering at the lowest laboratory angles possible

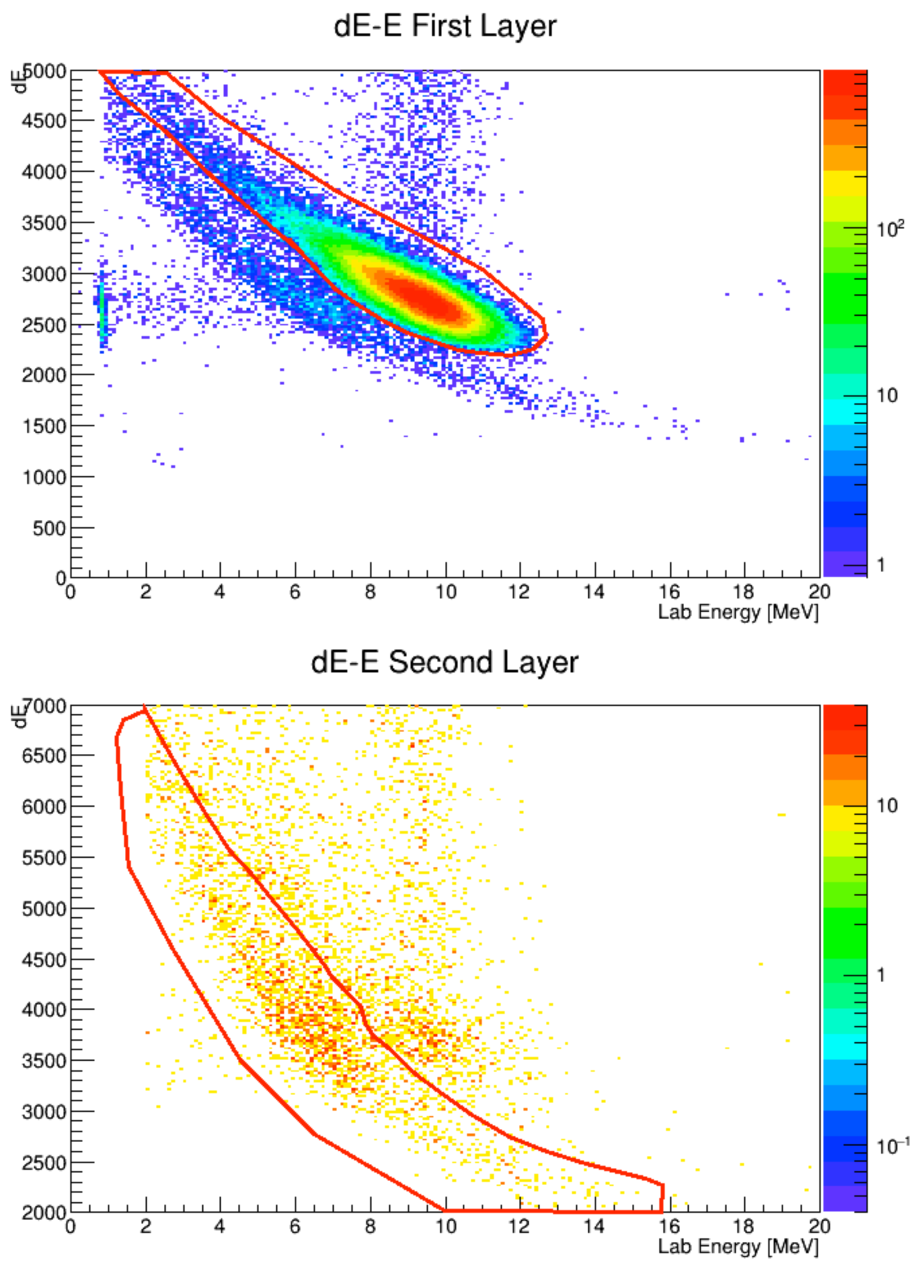

FIG. 2. dE-E spectrum for the first and second layers of the position sensitive proportional counter and an off-center silicon detector.

(closest to 180^o in c.m.) where the 6^+ state has maximum cross section (but decreases sharply for smaller c.m. angles). A mixture of 95% Helium gas with 5% CO_2 was used as a target. We also used a scintillator placed before the entrance window to degrade the beam energy to achieve the desired energy range. This was used in conjunction with the ionization chamber for particle identification of the secondary beam.

The scattering of ^{6}He+α was measured over a few angles close to 180^0 c.m. to search for the 6^+ state of the highly deformed cluster band in ^{10}Be. Using the proportional counter, we were able to achieve good particle separation and select for the recoil α particles in spite of a significant background from the ^{6}He ions. We have achieved strong background reduction by gating on the alpha-particles in the dE-E 2D spectrum in the second layer of wires after it was anti-gated on the ^{6}He in the first layer of the wires, as shown in Fig. 2. A distinct peak of α particles is clearly visible in Fig. 3 and could be a result of a resonance in the ^{6}He+α excitation function which we were looking for! Moreover, the energy of this peak corresponds to the excitation energy close to 13 MeV under the assumption that alpha decay of this state predominantly populates the first excited state in ^{6}He, the 2^+ at 1.8 MeV. Further analysis is now under way in order to investigate if any source other than the ^{6}He+α inelastic scattering can result in similar spectrum.

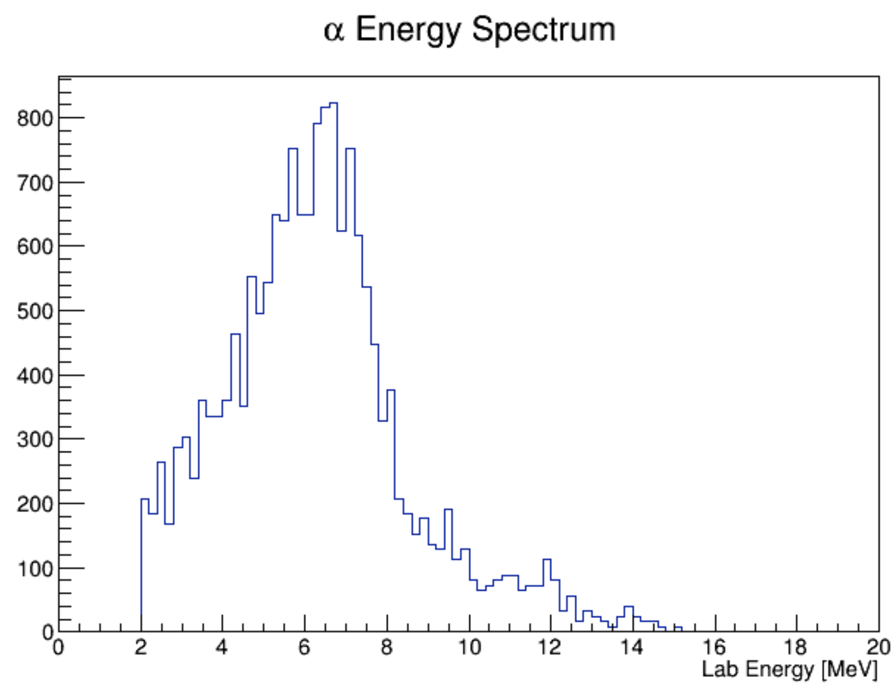

FIG. 3. Spectrum of α particles measured by the off-center Si detectors. The peak at 7 MeV may be a result of a resonance in the 6He+α inelastic scattering, or alternatively a result of random coincidence with the α+t events (see text for details).

[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).