Shell structure and evolution through spectroscopy of beryllium isotopes

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This project aims to develop the capacity to use the TEXas Active Target (TexAT) Time Projection Chamber (TPC) for transfer reaction studies [1]. We plan to accomplish this with a two-step experimental program, extracting spectroscopic factors to low-lying states in ^{11}Be and ^{12}Be with the ^{12}B(d,^{3}He)^{11}Be and ^{13}B(d,^{3}He)^{12}Be reactions, respectively. The first experiment aims to complement existing neutron-removal and neutron-addition spectroscopic data for ^{11}Be, studying the overlap between the ^{12}B ground state and low-lying excited states in ^{11}Be [2]. Because the ^{11}Be system is well studied, this experiment will also help to establish the validity of using an Active Target Time Projection Chamber (AT-TPC) for transfer reaction studies – with the eventual goal of coupling TexAT to the forthcoming TexNEUT p-Terphenyl neutron detector to study neutron-unbound states. Once the transfer-reaction experiment is verified to work in the ^{11}Be case, we will move to the less-studied ^{12}Be nucleus, where we will again investigate the overlap between ^{13}B$^{(gs)}$ and low-lying states in ^{12}Be.

Data for the ^{11}Be study was taken during May 2019 at the TAMU Cyclotron Institute using the K500 cyclotron and MARS [3]. Starting with a ^{14}C^{4+} beam at 30MeV/u, we used a 1 mm ^{9}Be target to produce 10^5 pps of ^{12}B at 259.5 MeV/u ± 4%. This beam was delivered to the TexAT experimental set-up where it was impinged on a 200 torr deuterated methane target composing the TexAT active volume. TexAT includes a MicroMeGAS pad plane which provides full momentum reconstruction in the gas target, which, as shown illustrated in Fig. 1, is accompanied by a wall of Si-CsI telescopes positioned perpendicular to the beam axis with a plastic scintillator at the 0^o position relative to the beam axis. The solid-state detectors are used to identify particles that do not stop in the gas volume.

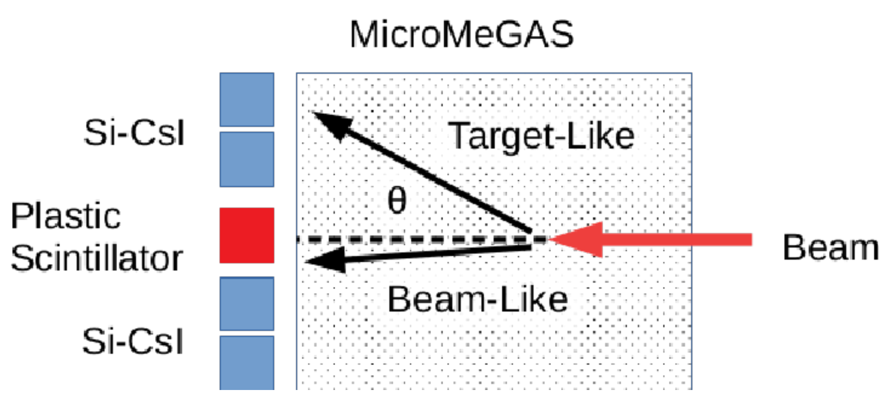

Fig. 1. Cartoon showing the arrangement of detectors inside the TexAT chamber with the target-like ejectile and beam-like ejectile of a beam induced event labeled.

Substantial progress towards establishing light-ion particle identification (PID) has been made during the past year. This is demonstrated in Fig. 2, which shows a spectrum of energy deposited in the Si detector vs. the mean energy loss in the gas (the ^{3}He ions of interest are not energetic enough to reach the CsI detectors, so gas vs. Si energies are required for PID). To construct this plot, we measure the energy loss in the MicroMeGAS by taking the average amplitude measured in the strips of one side of TexAT and plot that vs. the calibrated Silicon energy. Two distinct loci are evident in the plot, which are consistent with expected locations of Z=1 and Z=2 particles. It is important to note that the expected sharp upward slope for events below ~5 MeV Si energy deposition is not present. However, this may be accounted for by the dE averaging process, which, for low energy particles, will under report when used as a proxy for total energy loss. This under-reporting is due to the rapid changes in the stopping power that occur as the lower-energy particles traverse the gas. As such, we tentatively assign Z=2 to the band starting around 2500 channels on the y-axis.

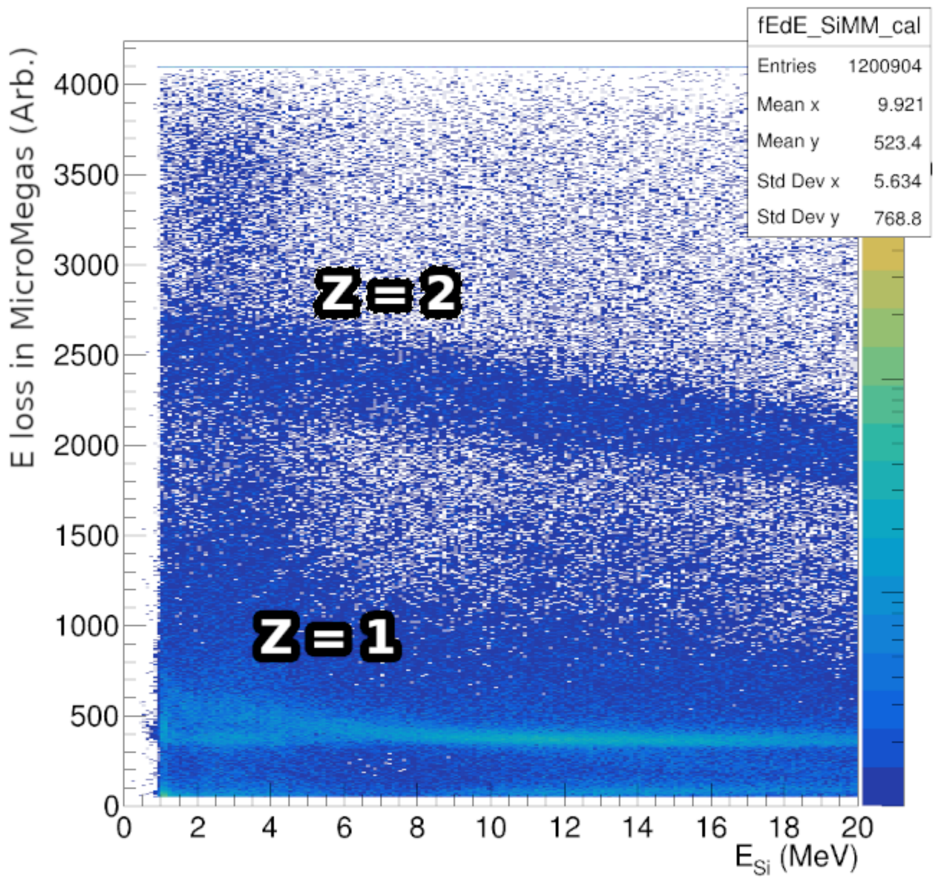

Fig. 2. The measured energy loss in the MicroMeGAS in arbitrary units versus measured Silicon energy

The PID component of this analysis is pending validation. We plan on using kinematics from the reconstructed tracks from the MicroMeGAS in conjunction with the PID shown above to establish more precise light-ion identification.

The beam has already been developed for the ^{12}Be run and we can expect 1.5 x 10^4 pps of incident ^{13}B. We are, however, waiting until the analysis of the first experiment is completed before moving on.

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[2] K.T. Schmitt *et al.*, Phys. Rev. Lett. **108**, 192701 (2012).

[3] R.E. Tribble *et al.,* Nucl. Instrum. Methods Phys. Res. **A285**, 441 (1989).