Shell structure and evolution through spectroscopy of ^{11}Be

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As the canonical example of shell-breaking in a neutron-rich nucleus ^{11}Be has been a focus for *ab-initio* calculations [1]. The largest component of its ground state, $\nu 1s_{1/2}$, is an inversion from the naive shell model's prediction and lacks a centrifugal barrier, producing ^{11}Be's famous one neutron halo. These studies will benefit from detailed spectroscopic information of ^{11}Be's low-lying states, some of which have been probed with neutron transfer studies [2]. We intend to provide a complementary measurement to neutron transfer studies with the proton pickup reaction (d, ^{3}He). Proton removal from ^{12}B will selectively populate p-wave states, making us particularly sensitive to the excited and unbound states of ^{11}Be.

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 [3]. We will extract differential cross sections from ^{12}B(d,^{3}He)^{11}Be in inverse kinematics to determine the spectroscopic factors of, and thus p-wave contributions to, low-lying states in ^{11}Be. Once the method is verified to work in the ^{11}Be case, we will extend it to the less-studied ^{12}Be system, where we will investigate occupancy of intruder shells in its low-lying states. The beam for this second experiment has already been developed – we expect 1.5×10^{4} pps of incident ^{13}B.

Data for the ^{11}Be study was taken during May of last year (2019) at the TAMU Cyclotron Institute using the K500 cyclotron and MARS [4]. Starting with a $^{14}C^{4+}$ beam at 30 MeV/u, we used the 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. TexAT includes a MicroMeGAS pad plane which provides full momentum reconstruction in the gas target, accompanied by

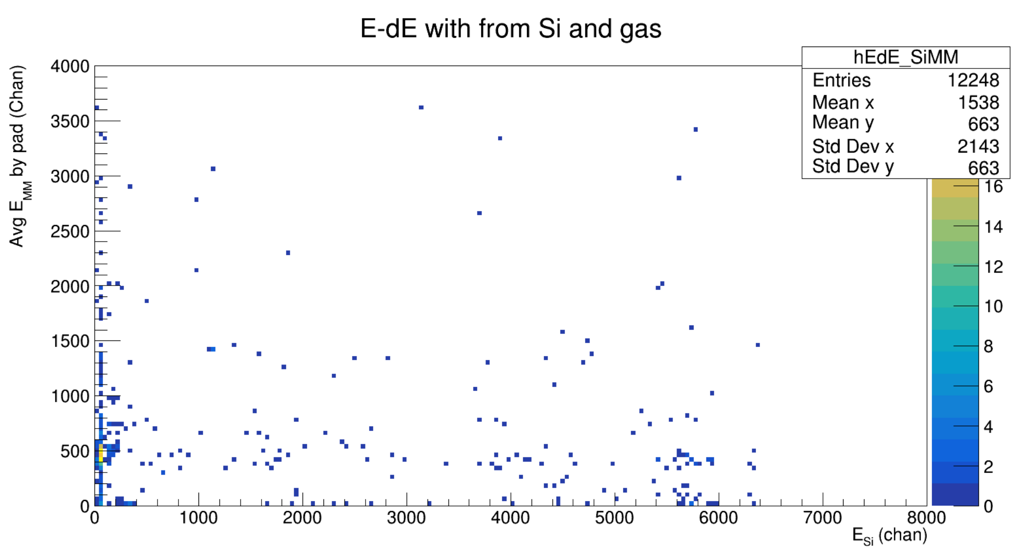

Fig. 1. Average energy loss in the gas(Arb) is plotted against remaining energy(Arb) measured in the silicon detectors for a small subset (<1%) of available data.

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, and thus events, that are not contained within the active volume.

At present, the project is in the analysis process; with focus on establishing reliable particle identification (PID). We optimistically plan to be able to identify protons, deutrons, tritons and alpha particles in addition to the ^{3}He of interest. We plan to use a traditional E-ΔE method (Fig. 1), in conjunction with a kinematics plot (Fig. 2) to separate the different particles.

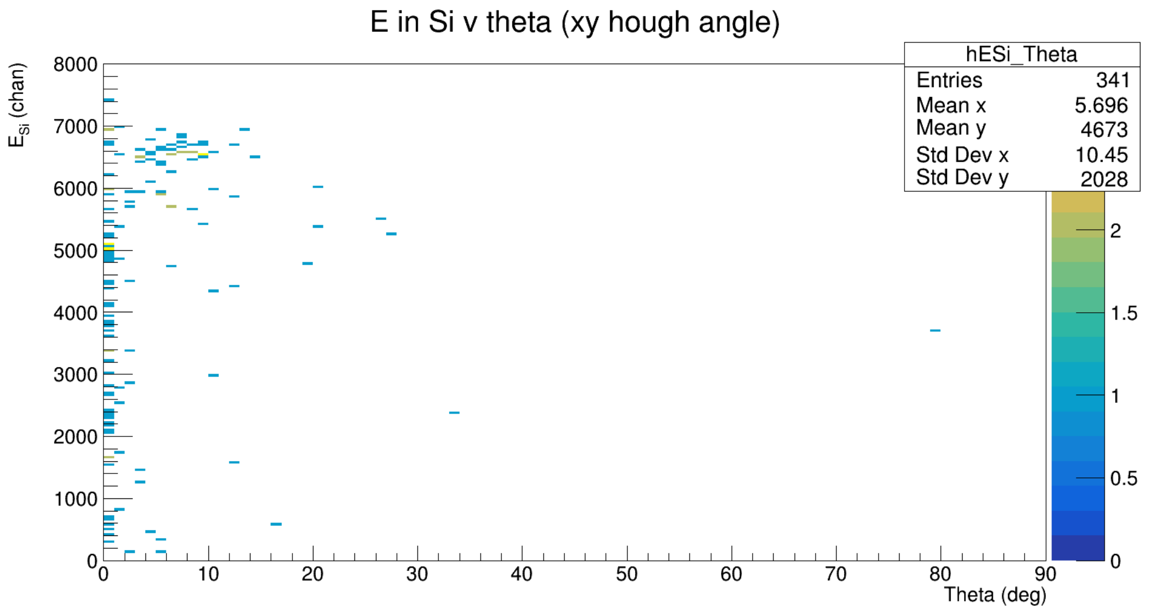

Fig. 2. Energy from the silicon detectors plotted against reconstructed angle for a small subset (<1%) of available data. ^{3}He will only be found with θ< 45^{o} .

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