Progress in the search for an excited state in tritium via the ^{6}He(p,t)α reaction

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Although the ^{3}H nucleus, or triton, is a well-studied system there remains uncertainty as to whether an excited state (t*) exists. To help address this open question, an experiment using the Texas Active Target Time Projection Chamber (TexAT TPC) to measure the ^{6}He(p,t)α reaction has been performed. Further details on the physics motivation, experimental setup, and analysis technique can be found in the previous year's Progress in Research report [1].

Events corresponding to the ^{6}He(p,t) ground state Q-value of 7.5 MeV have been identified and reconstructed, however the next challenge is to eliminate those easier-to-identify events and focus on potential t* events. For the beam energies of the current measurement, the t* signature will decay via d+n; the three-body decay to p+n+n is not possible. Following a similar process for the ground state analysis, the first step in reconstructing potential t* events is by identifying a Z=2 hit in a silicon detector for a minimum detected energy of about 2 MeV. This detector hit would also have a corresponding α-particle track in the Micromegas (MM) portion of the detector.

It is then assumed based on the dE/dx in the isobutane that the other particle is a deuteron, with track length >50 mm; shorter track lengths are likely from interactions with ^{12}C in the target gas, and therefore are not of interest. Fig. 1 shows the reconstructed vertex α-particle energy versus α-particle angle for a subset of the silicon detectors compared with the expected kinematics for the ^{6}He(p,t) ground state and potential excited state for two possible beam energy slices in the MM region. An anti-gate for the MM versus silicon energy has been implemented as an additional check to make sure the second track is either from a triton or deuteron (t*) event. As expected, there is separation between the ground state and the potential t* events.

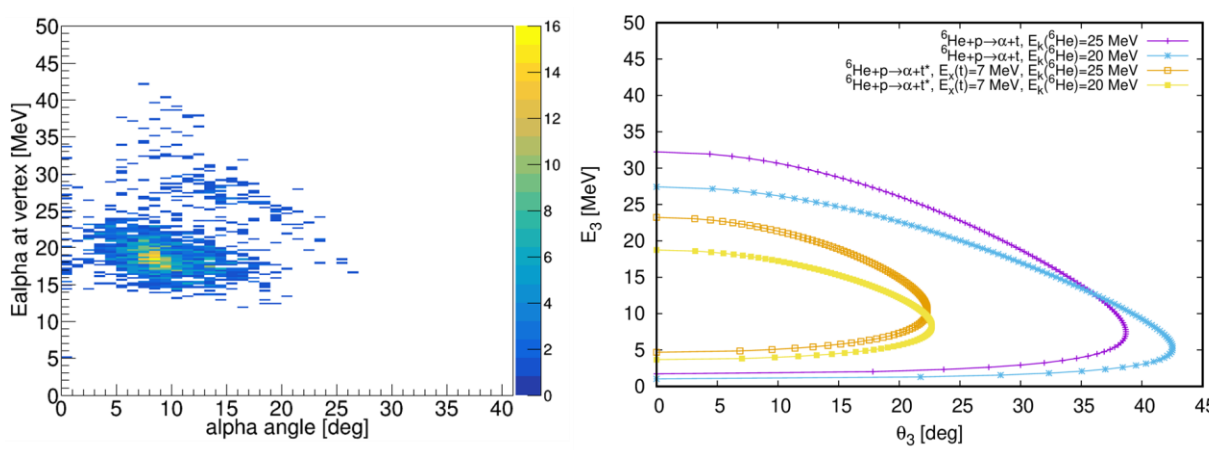

Fig. 1. Reconstructed α-particle energy versus angle (left) for small-angle detectors from fitted track data and (right) for expected kinematics for the ground state and a 7 MeV excitation in the triton.

The resulting Q-value reconstruction for these possible t* events is shown in Fig. 2. Included with the potential t* events, multiple background reaction channels are likely present. The bulk of the $^{6}He(^{12}C,X)$ events have likely been removed due to the length requirement of the particle tracks. However, α-particles can result from other reactions such as $^{6}He(p,d)^{5}He$ where the unbound ^{5}He breaks up into α+n. This process will not result in a single Q-value peak, therefore modifying the TexAT GEANT4 simulation tools is needed to help model the expected breakup lineshape. Another possible source of background would be $^{6}He(p,p')^{6}He(2^{+})$ where it is important to differentiate the proton versus deuteron via energy loss in the TPC. The contribution of misidentifying proton tracks as deuterons tracks is another ongoing simulation task.

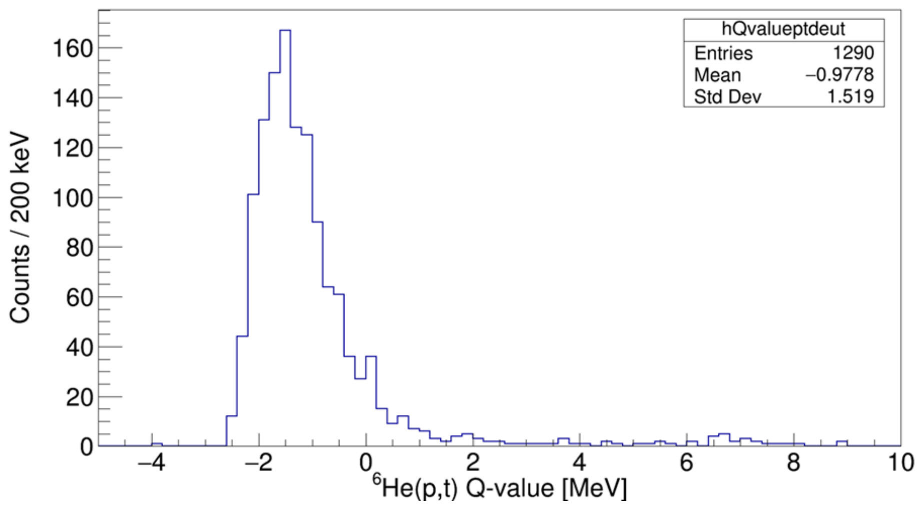

Fig. 2. Q-value reconstruction for possible $^{6}He(p,t^{*})$ events and background reaction channels; the events of interest at this energy will mainly be t*→ d+n rather than t*→p+n+n.

In addition to the simulation work, future data analysis will include grouping the silicon detector hits into smaller vertical zones of fixed laboratory angle to check the energy dependence of the reconstruction. Further refinements of the track reconstruction within the MM region can also be considered, as that will impact the calculated Q-values. An additional refinement could be to implement track reconstruction for interactions that occur prior to the MM region to help extend the range of beam energies covered in the Q-value reconstruction.

[1] C.E. Parker et al., *Progress in Research*, Cyclotron Institute, Texas A&M University (2020-2021), p. IV-8.