Toward the understanding of the ^{10}Li system and the commissioning of the TexNeut array

D.P. Scriven,[1,2] G. Christian,[1-3] G.V. Rogachev,[1,2] C.E. Parker,[1] L. Sobotka,[4] S. Ahn,[1] S. Ota,[1]
E. Koshchiy,[1] E. Aboud,[3] J. Bishop,[1] N. Dronchi,[4] and A. Thomas[4]
[1]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843*
[2]*Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77843*
[3]*Department of Astronomy and Physics, Saint Mary's University, Halifax Nova Scotia, B3H 3C3, Canada*
[4]*Departments of Chemistry and Physics, Washington University, St. Louis, Missouri 63130*

Significant progress has been made in the last three years towards the construction of a state-of-the-art neutron detector at the Texas A&M University Cyclotron Institute (CI). The neutron detector array, TexNeut, will use novel neutron detector modules called pseudo-bars to reconstruct the kinetic energy of fast neutrons from experiments. These pseudo-bar modules are described and characterized in the works [1-3] and in this issue of *Progress in Research.* With a well-established understanding of the operating properties of these modules in the last year, we have started the construction of the TexNeut array.

For the commissioning run of TexNeut, we plan two experiments in conjunction with TexAT [4]. Using a ^{9}Li beam generated in MARS [5] we intend to populate states in the ^{10}Be system above the ^{9}Li + *p* and ^{9}Li + *n* thresholds. These states are expected to be T=2 isobaric analogue states (IAS) to the low-lying excited states of ^{10}Li. In the past, TexAT has been used for thick target inverse kinematics (TTIK) to populate IAS states of nuclear systems via proton elastic scattering. In our first experiment we use proton elastic scattering and TTIK to record the excitation function in the (*p*,*p*) channel. The second experiment uses TexAT with the addition of TexNeut outside of the target chamber to observe the excitation function in the (*p*,*n*) channel.

The IAS resonance corresponding to the s-wave ground state of ^{10}Li sits at 1.57 MeV center of mass (COM), and the first excited p-wave state is expected around 2.1 MeV COM. Shown in Fig. 1 are R-matrix predictions for the cross sections for both the (*p*,*p*) and (*p*,*n*) interactions around the COM energy regime of those T=2 states in ^{10}Be. One can see from these predictions that there is a strong reduction in the cross section in the resonance at 1.57 MeV in the (*p*,*p*) channel and a small enhancement expected at 2.1 MeV. The resonance at 2.1 MeV has a much stronger enhancement in the (*p*,*n*) channel. These features suggest that probing the ^{10}Li system will be aided by the addition of the TexNeut array.

The construction of TexNeut is ongoing with collaborators of the L. Sobotka group at Washington University in St. Louis. There, they are developing the data acquisition (DAQ) electronics which use ASIC chips [6] for signal processing and CFDs for accurate timing. We are currently benchmarking the DAQ to ensure the detector modules operate within nominal performance limits found during characterization using analog and digital DAQs. The Wash. U. group is also designing the structure for the detector which is carefully designed to be able to hold many detector modules in different arrangements that conform to experimental needs. In this way, TexNeut can be made thick or thin, wide or narrow, and sparse or dense.

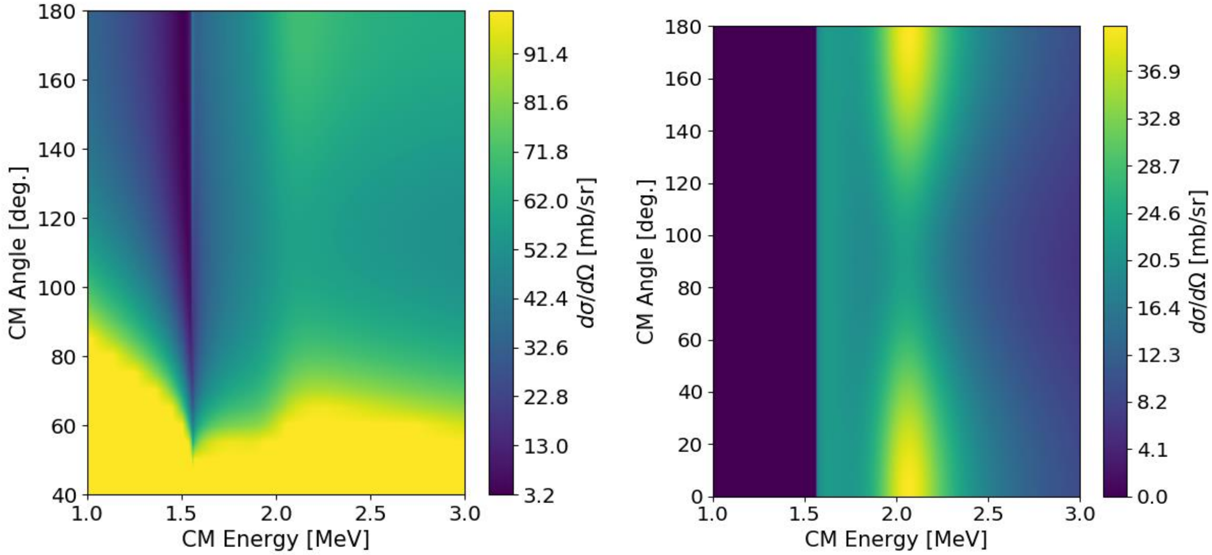

Fig. 1. Predicted cross sections for the ^{9}Li + p (left) and ^{9}Li(p,n)^{9}Be reaction (right) channels. Data is truncated on the left due to obscene enhancement in the cross section at low angles due to Rutherford scattering. The hard cutoff in the (p,n) channel is from the ^{9}Li(p,n)^{9}Be Q-value.

Some initial calculations and Geant4 simulations were performed to optimize the array arrangement for the ^{9}Li(*p,n*)^{9}Be experiment. The commissioning run will use a smaller prototype version of the TexNeut array that uses 48 detector modules rather than the 120 modules of the full array. The interlayer time-of-flight was calculated for neutrons with kinetic energies 0.5-5.0 MeV, which are

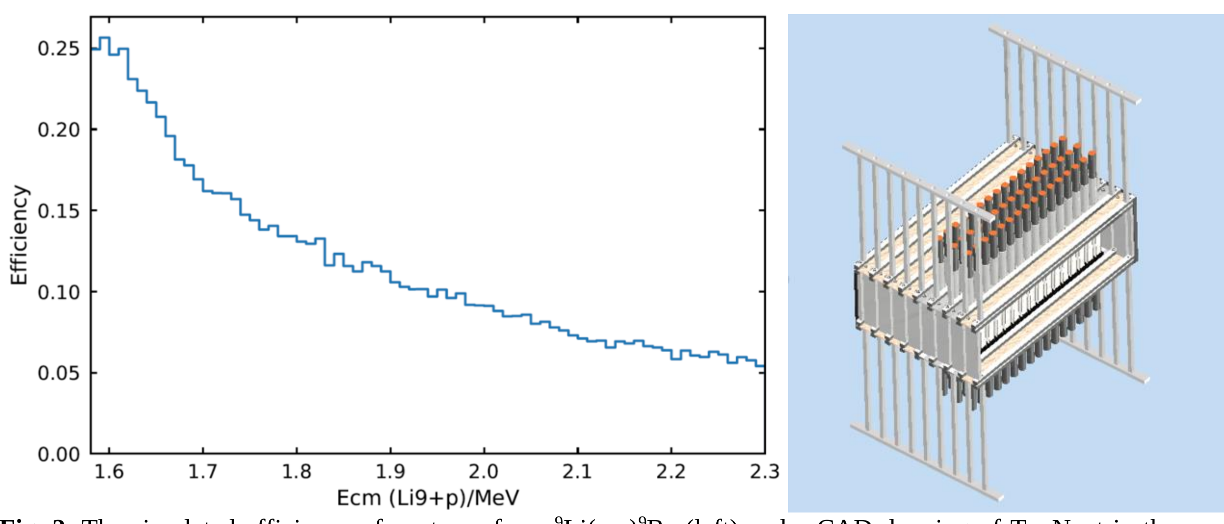

Fig. 2. The simulated efficiency of neutrons from ^{9}Li(p,n)^{9}Be (left) and a CAD drawing of TexNeut in the same configuration that was simulated and that is planned for deployment.

expected from the reaction kinematics. Based on the timing resolution of the detectors, individual layers should be separated by about 4 cm center-to-center to give time-resolved layer ID for causality cuts. Taking into account the predicted R-matrix scattering cross sections shown in Fig. 1, layer spacing, and detector thresholds of [1-3], Geant4 simulations showed that the best use of the 48 modules was to arrange them in 3 layers, with 16 modules each. The simulated efficiency of this configuration is shown in Fig. 2 along with the most recent CAD drawing.

In October 2020, beam time was allocated to perform the ^{9}Li(*p,p*)^{9}Li study. This allowed us to spend time tuning MARS for optimal production of ^{9}Li and also to optimize many of the running parameters of the TexAT detector. It also allowed the (*p,p*) channel to be studied with TexAT optimized for the proton detection (in the (*p,n*) experiment, TexAT will be optimized for detecting breakup products of ^{9}Li$^{(gs)}$ isobaric analog). We are currently working to analyze this data. During this run several different nuclear species were produced in MARS with the same magnetic rigidity, $B\rho$ = 1.113 Tm. The primary beam constituents were ^{3}H, ^{6}He, and ^{9}Li. In our analysis we are able to successfully identify the beam particles based on their energy loss using the micromegas Detectors of TexAT. After calibration of the TexAT silicon array, we have start looking for the relevant ^{9}Li + *p* scattering events using coincidences with ^{9}Li beam, silicon detector energies, and energy loss found in the tracks of scattered particles. Micromegas tracks from one suspected ^{9}Li + *p* event can be seen in Fig. 3. Continued analysis is ongoing to produce the (*p,p*) excitation function. Completion of TexNeut is expected during 2021 with the commissioning run following by the end of the year.

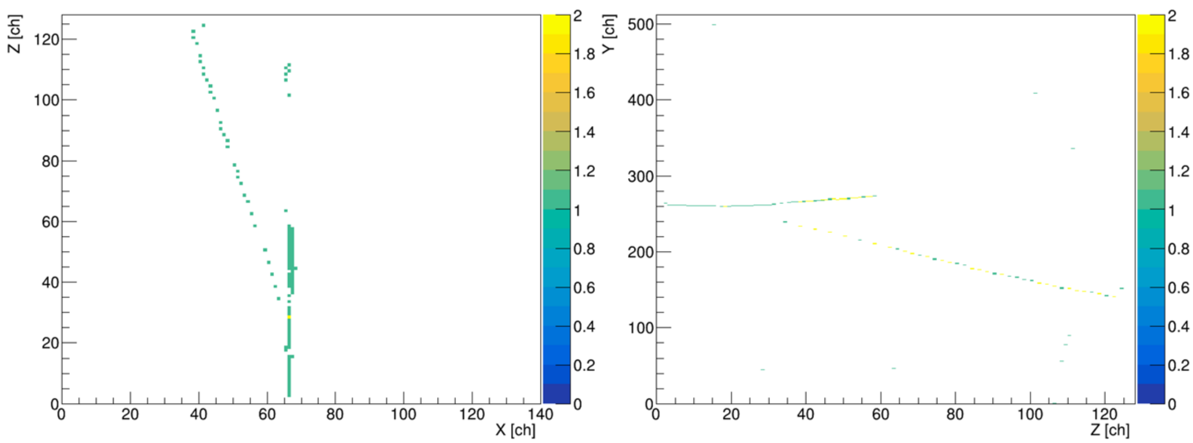

Fig. 3. Tracks recorded by the micromegas detectors in TexAT of a suspected ^{9}Li + p event. This event was selected by gating on the ^{9}Li beam events and on silicon events within the kinematically allowed energy. These are the X-Z (left) and the Z-Y (right) projections.

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