Simulation of (d,p) reactions in inverse kinematics in Texas Active Target (TexAT) detector

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Direct nucleon transfer reactions have been used extensively in the past with stable beams to study structure of atomic nuclei. The angular distribution of the outgoing particles reflects the transferred angular momentum. In addition, since the cross-section is a measure of the overlap between the initial and final states, (d,p) transfer reactions are ideal for studies of nuclear structure and the main tool to probe single-particle structure in nuclei. These reactions are also important for the nuclear stewardship applications, where they can be used as surrogate reactions to constrain neutron capture (n,γ) reaction cross sections on neutron rich radioactive isotopes that are products of nuclear fission. The focus of this study is the implementation of the (d,p) reactions using the new active-target time projection chamber TexAT (Texas Active Target) [1] with the reaccelerated radioactive beams. The obvious advantage of the active target is that it provides a very thick target without loss of energy resolution, therefore opening up the possibility to study (d,p) reactions with the beam intensities as low as 1,000 pps.

The main goal of this study is to investigate the performance of the TexAT detector for the (d,p) reactions in inverse kinematics. We used the GEANT4 [2] based Monte Carlo simulations package developed for the TexAT detector and already tested for the elastic scattering reactions. The test reaction being studied here is ^{20}O(d,p) populating the ground state of ^{21}O. The beam energy was set to 8 MeV/u. The gas used inside the TPC is D_2 and CO_2 with 95/5 ratio respectively. The gas pressure was set to 350 Torr and the electric field setting in the drift region of TexAT was 150 V/cm to drift electrons towards the MicroMegas board.

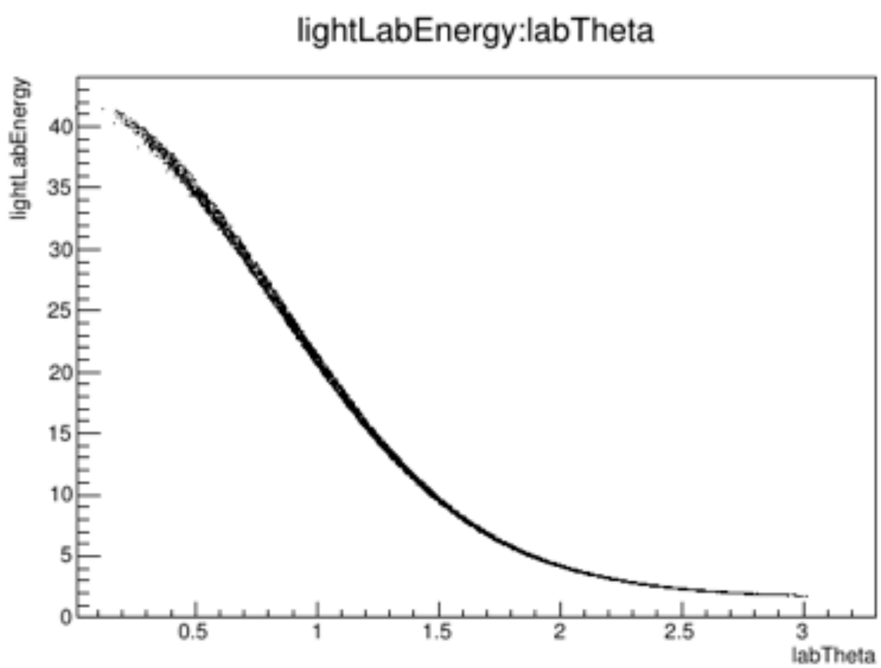

FIG. 1. Kinematics for the ^{20}O(d,p) reaction. Energy of protons (in MeV) is shown as a function of scattering angle (in rad.).

The track reconstruction algorithms for TexAT are generally based on time matching of the hits in the MicroMegas board. The MicroMegas board, located in the tracking volume, has three separate regions. The left and right regions consist of strips and chains, times for which are matched to determine the x-y coordinates of the discrete track point. The central region, located below the beam, determines the coordinates of the track by recording the electron count for each rectangular pad of a certain width. Fig. 1 shows the kinematics of the test transfer reaction. Fig. 2 shows the tracks generated for a (d,p) transfer reaction event. Fig. 3 demonstrates a reconstructed (d,p) event in TexAT detector.

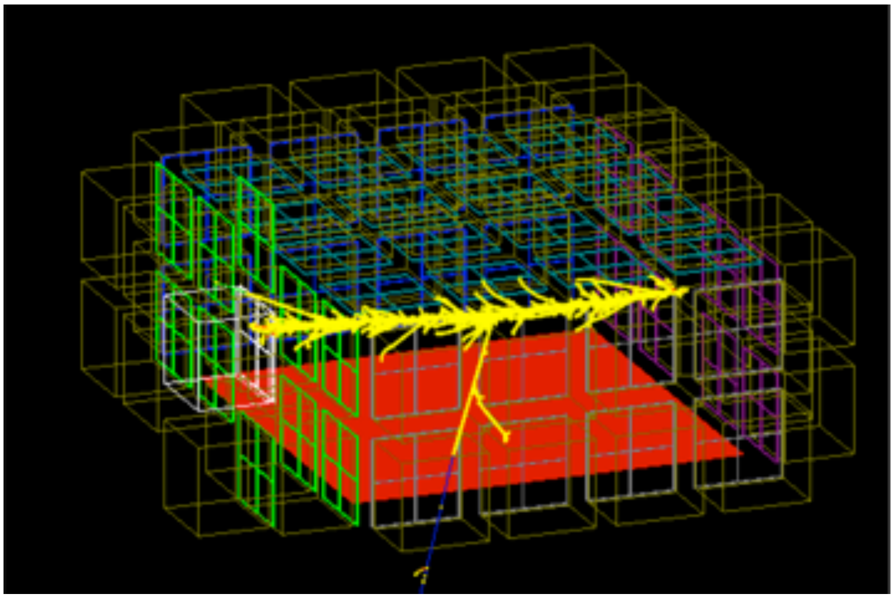

FIG. 2. GEANT4 simulation of the 20O(d,p) reaction in the TexAT detector. The beam comes in from the right. The proton hits the CsI-backed silicon detector on the left (with respect to the beam) plate. The heavy recoil continues through the front plate. The white colored detectors indicate that they have been removed.

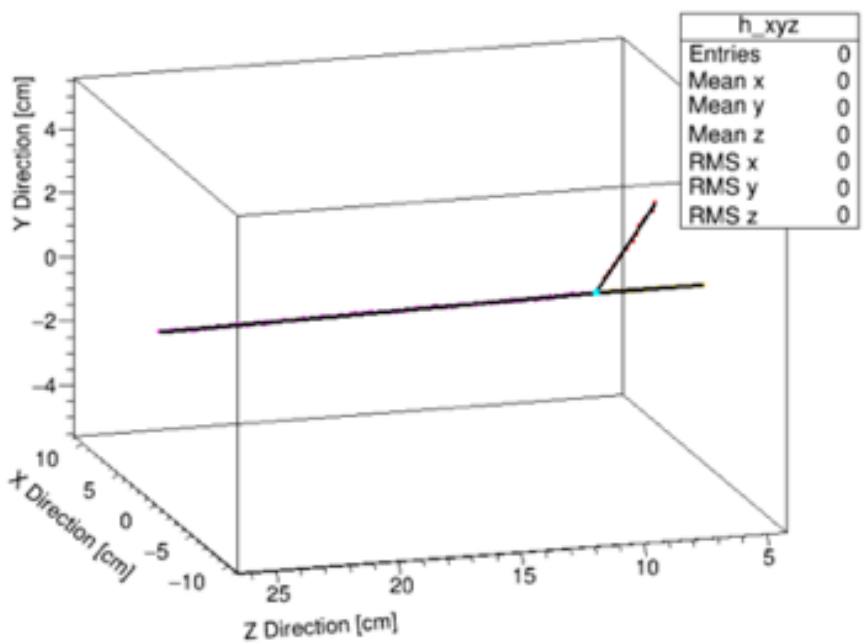

FIG. 3. Reconstructed (d,p) reaction event.

Testing of the track reconstruction is underway. Fig. 4 shows a comparison of the generated light product angle (blue) and the reconstruction of that angle (red). If the reconstruction fails, the value is set to zero. The dip in the middle of the red plot corresponds to a lab angle of 90 degrees. Reconstruction at this angle fails due to improper matching of times between the strips and chains in the MicroMegas detector. Algorithm that allows to mitigate that problem is being developed. The energy and angular resolution will be determined after this problem is resolved.

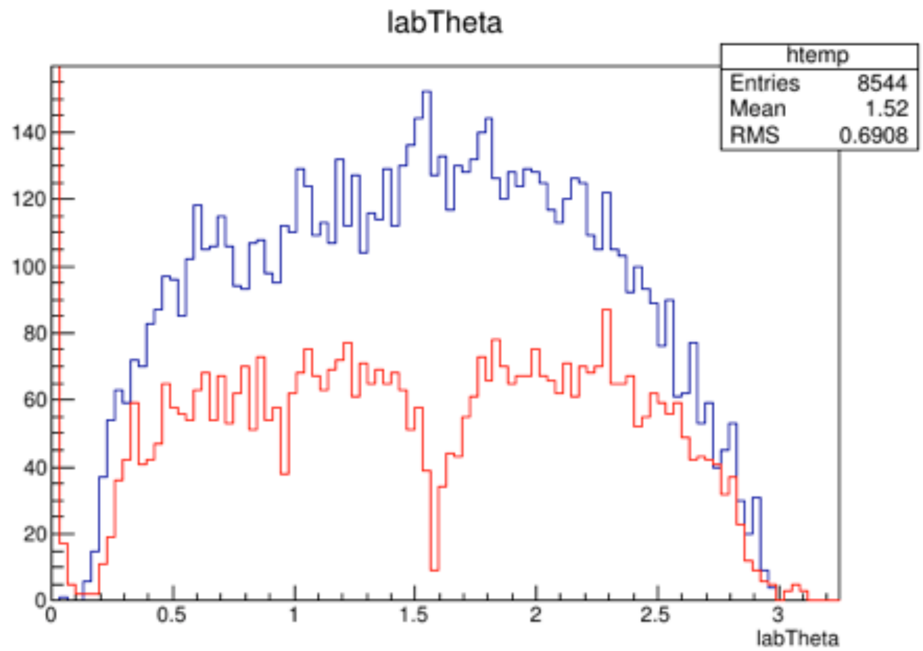

FIG. 4. Plot of the simulated light product lab angle (blue) versus the reconstructed light product lab angle (red).

In summary, Monte Carlo simulations of the TexAT detector are currently being developed to incorporate (d,p) reactions. The track reconstruction for the (d,p) events work well for most angles, except for angular region around 90° in the Lab. frame.

[1] E. Koshchiy *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. IV-42; E. Uberseder *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. IV-47; E. Uberseder *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. IV-51.

[2] S. Agostinelli *et al.*, Nucl. Instrum. Methods Phys. Res. **A506**, 250 (2003).