Construction of active target detector for experiments with rare isotope beams

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Over the last 20-30 years experiments with rare isotope beams (RIBs) developed from being exotic undertakings in select few laboratories into the main stream of nuclear science. RIBs provide a pathway to venture far beyond the constrains typically encountered in the experiments with stable beams. RIBs open up an opportunity to study very exotic nuclei using relatively simple and well understood reactions, such as elastic and inelastic scattering, one/two nucleon transfer, Coulomb excitation, etc. They allow to measure the key reaction rates that are relevant for explosive processes in astrophysics with radioactive nuclei. All these benefits come at a price. Typical intensity of RIBs is many orders of magnitude lower than intensity of stable beams. Therefore, efficiency of experimental setup becomes determining factor for RIBs experiments. One of the most efficient experimental approach that can be used with RIBs is active target detector. These detectors can be designed to have almost 4π solid angle coverage, and they naturally allow to use thick target without loss of energy resolution. Thick target also allows to measure reaction excitation functions without need to change the beam energy. The versatility of these devises for RIBs experiments has been recognized and many nuclear physics laboratories around the world are in the process of constructing and using these devices (TACTIC at U of York/TRIUMF [1], MAYA at GANIL/TRIUMF [2], AT-TPC at NSCL [3], ACTAR at GANIL/GSI [4], ANASEN at FSU/LSU/NSCL [5,6], and others). While the concept is similar for all active target detectors (the target material is spatially extended and "active" to allow for tracking of the reaction products), the specific implementation may be very different depending on the energy range, type and quality of RIBs characteristic for the particular facility.

We started design and construction of a general purpose active target detector (Texas Active Target, TexAT) for experiments with rare isotope beams produced by either MARS separator or the new reaccelerated beams facility at the Cyclotron Institute. TexAT will be used for wide variety of experiments to detect the charged products of nuclear reactions with rare isotope beams. Resonance elastic and inelastic scattering of protons and α-particles, (α,p) and (p,α) reactions, nucleon-transfer reactions, such as (d,p), (d,3He), (p,d), (p,t), (4He,t) and decay spectroscopy studies are the examples of the experiments that can be performed with TexAT.

The initial step is a construction of two prototype active target detectors that consist of Time Projection Chambers for tracking of the recoils and the segmented silicon detectors backed by CsI(Tl) scintillators for measuring total energy of the recoils and providing a trigger. The silicon part is identical for both prototypes. The prototype active target detectors (TexAT-P1 and TexAT-P2) are needed for testing and development on a smaller scale technologies that will be used for the TexAT. The prototype detectors will also be used for conducting experiments with rare isotope beams at the Cyclotron Institute before the completion of TexAT.

The TexAT-P1 (Fig. 1) is the early implementation of active target approach at the Cyclotron Institute. The conventional technologies are used for the Time Projection Chamber of TexAT-P1. The readout is performed by an array of position sensitive proportional counter wires located 6 cm below the reaction plane. The ionization electrons from the tracks of the recoils are projected onto the plane of readout wires by a set of field electrodes that are arranged to create a uniform electric field (the top “cathode“ electrode is shown transparent). The trigger is provided by the hit in the silicon array. All major components of the TexAT-P1 have been procured or already assembled. The first experimental campaign with TexAT-P1 is planned for summer of 2014.

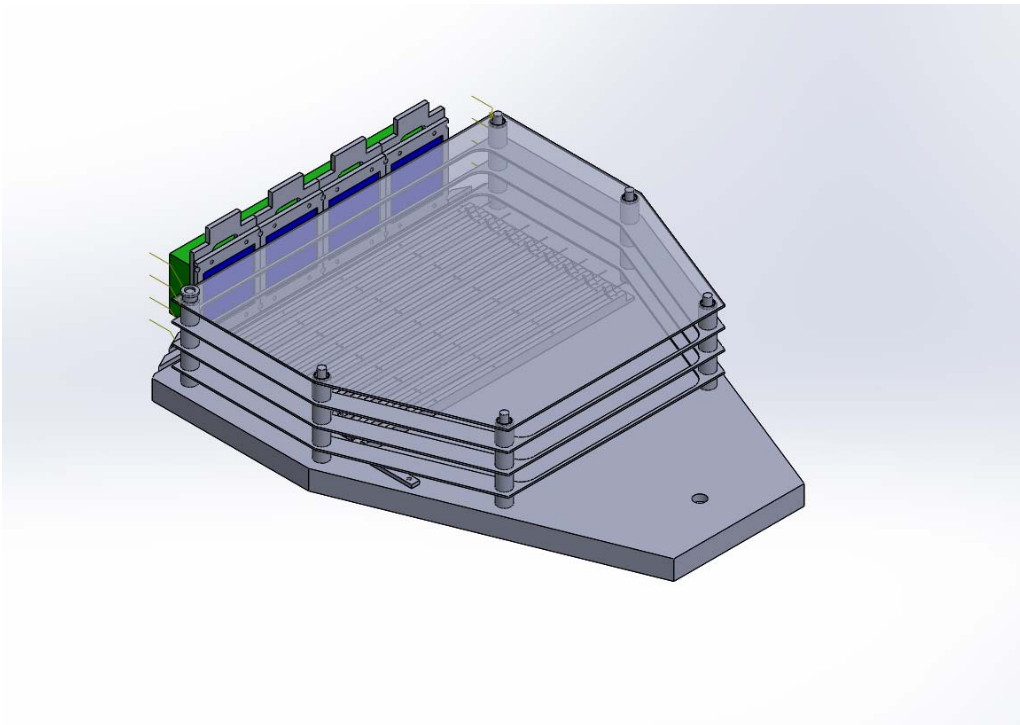

FIG. 1. Prototype of active target detector TexAT-P1.

The TexAT-P2 (Fig. 2) shares the silicon (shown in blue on both figures) and CsI(Tl) (shown in green) array with TexAT-P1 but will use different technology for the Time Projection Chamber (TPC). The wires will be replaced with the Micromegas [7] plate with 1024 independent channels (shown in red and yellow). This will improve tracking resolution and will enhance the performance of the prototype detector significantly, which will make the detector far more versatile. However, the number of readout channels required for this modification make it prohibitively expensive to use conventional electronics. Arrangements were made to procure a novel GET technology electronics [8] for the TexAT-P2. The components of GET electronics are the following. The AGET chips (64 independent channels each) provide preamplifier, shaper, TFA and CFD for each channel. They are placed on AsAd 2.1 PC boards that can accommodate 4 AGETs and provide the basic interface. Each AsAd board accommodates 256 channels. The CoBo card provides higher level interface between the AsAd and the MUTANT cards. The MUTANT card is used to produce a complex, hit pattern based trigger. The complete system of 1024 channels has a price tag of ~$80,000, compared to ~$1,000,000 for 1024 channels of conventional electronics. The channel density of microMegas plate will not be uniform, with highest density (768 channels) reserved for the beam axis area (shown in yellow in Fig. 2). Important advantage of the TexAT-P2 over the TexAT-P1 is a much higher data throughput and a possibility to organize complex, hit pattern specific trigger that could be independent of the silicon array hit. All components of the GET electronics have been procured. Delivery time varies, but we expect the complete system to be operational by the end of 2014 - beginning of 2015.

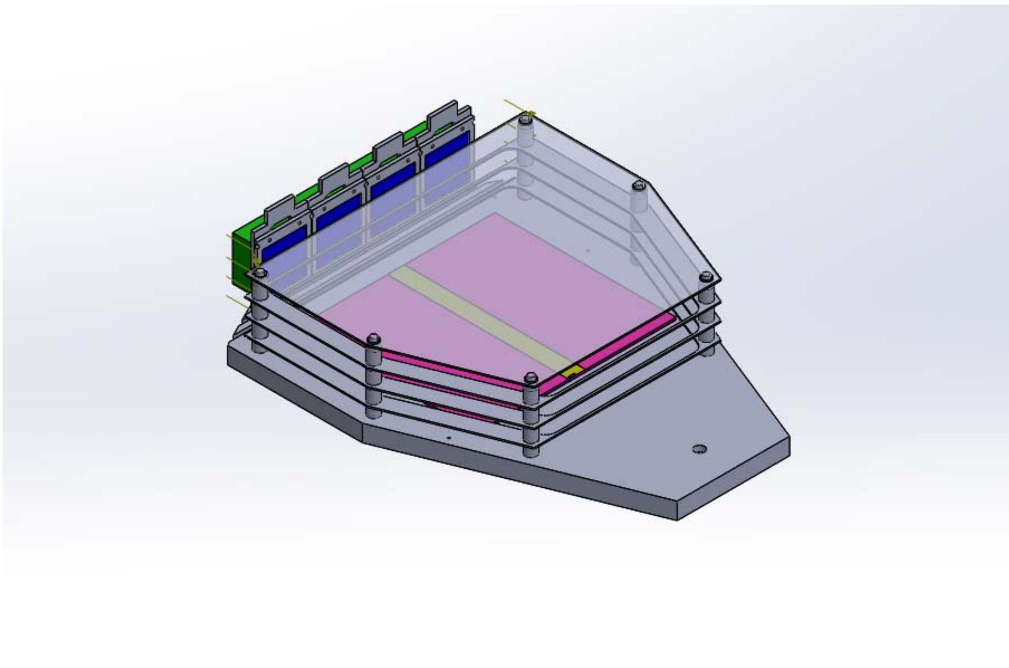

FIG. 2. Prototype of active target detector TexAT-P2.

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