Development of a YAP-CsI phoswich for use with TexAT-TPC

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Transfer reaction measurements performed in inverse kinematics are a key tool for exploring the nuclear landscape. Several such measurements - to be performed using the Texas Active Target (TexAT) Time Projection Chamber (TPC) [KOS20] have been proposed at the Texas A&M University Cyclotron Institute. The reactions of interest for these measurements are ^{12}B(d,^{3}He)^{11}Be, ^{13}B(d,^{3}He)^{12}Be, and ^{14}B(d,3He)^{13}Be. The latter will be coupled to the TexNeut neutron detector array.

One of the foremost challenges to the success of transfer measurements in active target TPCs is that of reliable reaction ID. Due to the various energy scales and stopping powers of the involved particles, it is difficult to identify both the beam-like and target-like reaction products using the TPC alone. However this can be remedied by coupling the TPC system to a solid-state detector array as is done in the TexAT system. This work aims to develop a heavy recoil identification detector capable of separating unreacted beam and beam contaminants from the reacted beam of interest. This detector would need to, at minimum, separate Z=3,4 and 5, have a radiation hardness sufficient to survive the dose from multiple experiments and fit into the TexAT footprint.

The TexAT set-up would typically use a Silicon-Cesium-Iodide (Si-CsI) telescope, but due to the desired radiation hardness constraints, this is suboptimal. Because scintillators are simple to source and can be designed with exceptional radiation hardness, a phosphor sandwich or phoswich could satisfy the above requirements. A phoswich is a scintillator detector composed of two different crystals with different timing properties. A pulse shape analysis can then be used to extract the energy deposited in each layer of the sandwich; this then can be used as PID through the standard dE-E method.

A phoswich composed of 100-µm-thick cerium doped yttrium aluminium perovskite (YAP:Ce) and a 2-cm-thick CsI was designed and tested at the TAMU-CI. A schematic of the design and a model of the relative pulse shape is shown in Fig. 1. As care had to be taken to ensure the timing resolution and

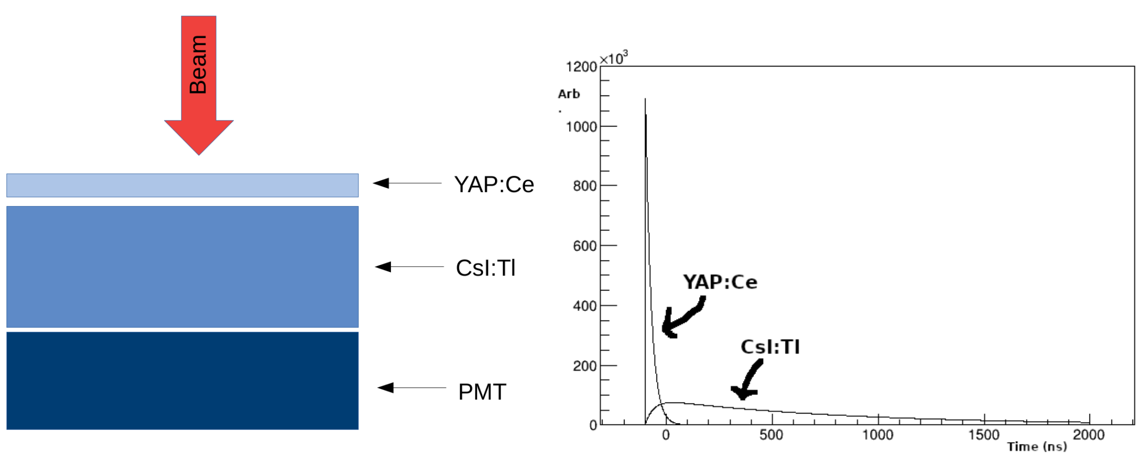

Fig. 1. (Left) A cartoon demonstrating the design of the detector. (Right) modeled pulse shape from the reported brightness, rise and decay times of each scintillator.

light collection efficiency would not destroy the pulse shape information; a Hamamatsu R12699-406-M4 PMT was determined to be a good candidate.

A ^{14}N beam at 15MeV/u was impinged on 100 μg/ cm^2 gold and 1 mg/cm^2 carbon during a beam test in April 2022. Plots of the short integration against the total integration gate from that test are shown in Fig. 2. This gate pairing corresponds to energy loss in the YAP(Ce) vs Total energy and is analogous to a typical dE-E plot used for charged particle identification. When using the gold target, we can see a distinct grouping of events that correspond to elastically scattered ^{14}N and a characteristic energy dependence of the short component (ΔE) on energy. Analysis of the data on the carbon target was complicated by the experimental noise issues and it may be necessary to repeat this test run to demonstrate efficacy of the phoswich detector system for recoil ID.

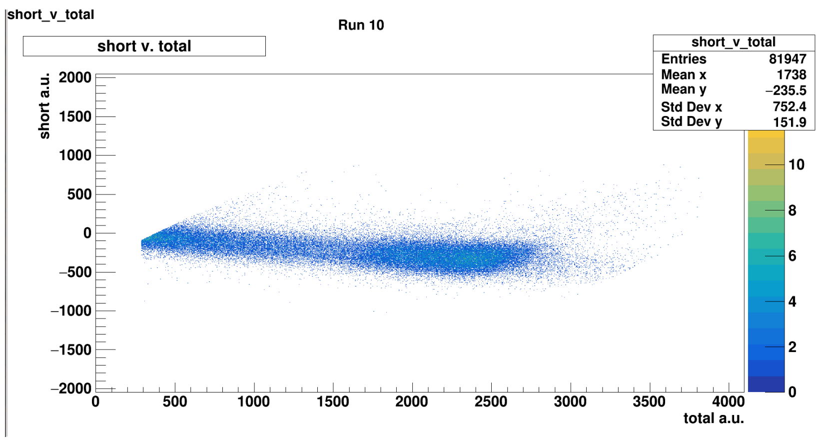

Fig. 2. Short Gate v. Total Integration is plotted for 15Mev/u 14N on Gold (Left) and 15Mev/u 14N on Carbon (Right). See text for discussion.

[1] E. Koshchiy *et al.*, Nucl. Instrum. Methods Phys. Res. **A957**, 163398 (2020).