Decay detector calibration and signal timing with oxford gas detector

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Introduction

The measurement of the GMR in unstable nuclei will be done using inverse kinematics, with a 40 MeV per nucleon beam of the unstable nucleus incident on a ^{6}Li target. Nuclei excited to the GMR region are particle unstable, and will decay by p, α or n decay shortly after excitation [1]. To reconstruct the event it is necessary to measure the energy and angle of the decay particle and of the residual heavy ion. In many lighter nuclei a few nucleons off stability, and in light proton rich nuclei, the neutron threshold is above the region of interest. There are 3 bodies in the final state (recoiling ^{6}Li, decay particle, and residual heavy ion). The recoiling ^{6}Li have low energy and for the most part will not get out of the target. Thus in order to experimentally determine the kinematics, we must measure at least three of the four quantities: decay particle energy and angle, and residual nucleus energy and angle. Thus a ΔE-ΔE-E decay detector composed of plastic scintillator arrays has been built and tested to measure the energy and angle of the light decay particle. The heavy ion will be measured using the Oxford detector in the MDM spectrometer. We have shown the viability of calibrating the decay detector components using the EDSE model for scintillator light output [2]. A hole in the decay detector with a horizontal and vertical opening of 4° allows the residual heavy-ion to enter the MDM spectrometer, which has a horizontal and vertical angular acceptance of ±2°. The heavy-ions energy and angle will be determined with the focal plane detector. The decay detector can measure decay particles within an angular range of 4° to 45° with respect to the beam direction.

In November 2013 run we used a 30 MeV proton beam on a 12C target to obtain an energy loss calibration for the decay detector. Also, we used a 12 MeV/u beam of 16O on 12C target looking at α particles in the decay detector and 12C ions in the gas detector to determine the timing between signals from the gas detector at the back of the MDM spectrometer and the decay detector which is in the target chamber.

Decay Detector Calibration

We have tested the decay detector with a beam of 30 MeV protons scattered from a ^{12}C target. From the elastic scattering and inelastic scattering exciting the 2^{+} (4.4 MeV) and 3^{-} (9.6 MeV) levels of ^{12}C, we were able to find a good set of EDSE fit parameters (ρ_q, A, F) [3] which are intrinsic to the type of plastic scintillator used in all three layers of the detector. The last parameter, the normalization constant C, differs between all the strips and varies slightly according to the attenuation behavior along the length of each strip. Therefore, it is necessary to find the normalization constant C for ΔE1, ΔE2, and E of all segments of the decay detector. Fig. 1 shows the behavior of C for one of the vertical strips for signals coincident with each horizontal strip. It also shows the change in this behavior from experiment to experiment. Fig. 2 shows a comparison of the expected light output calculated from the EDSE model with the measure light output.

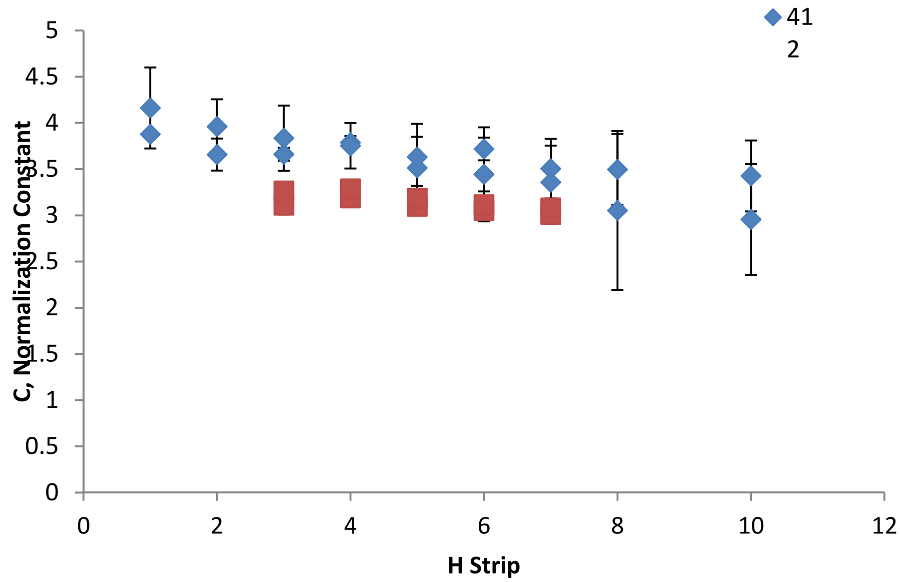

FIG. 1. Normalization constant for pixels on the V11 strip in coincidence with different horizontal strips (H Strip) for experiments done in April 2012 (412) and January 2013 (113).

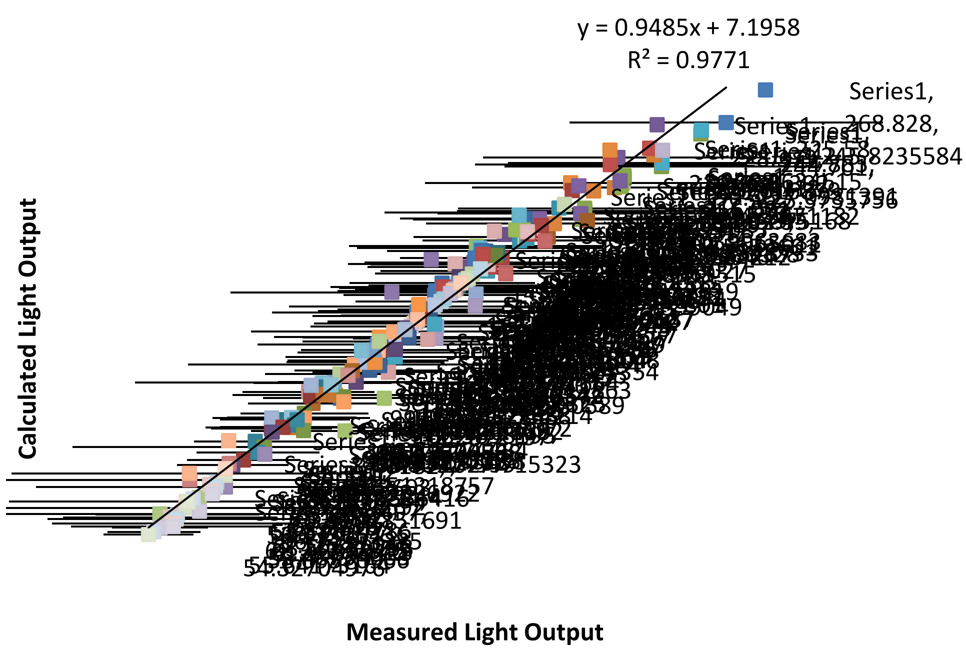

FIG. 2. Example of measured and calculated light outputs for all pixels along vertical strips due to incident protons. A linear fit shows that the measured and calculated light outputs are in good agreement. The parameters obtained by chi-square fits have the values ρ_q = 663.1 MeV/nm, F = .990, and A = 4.6x10^{-6}.

A full calibration before each production run will use proton and alpha energies near the top and bottom of the required range, such as 20 and 60 MeV for protons and 60 and 100 MeV for alphas.

Timing between Coincident Events

Using a 12 MeV/u beam of ^{16}O on a ^{12}C target, we wanted to establish a working method for identifying coincident events due to some proton or alpha decay in both the decay detector and the gas detector.

In the electronics setup, we use the ΔE2 layer as a trigger for the decay detector. And for the gas detector, the plastic scintillator in back is used as a trigger (Fig. 3). The time of flight of the heavy ion through the MDM spectrometer is approximately 250 nanoseconds.

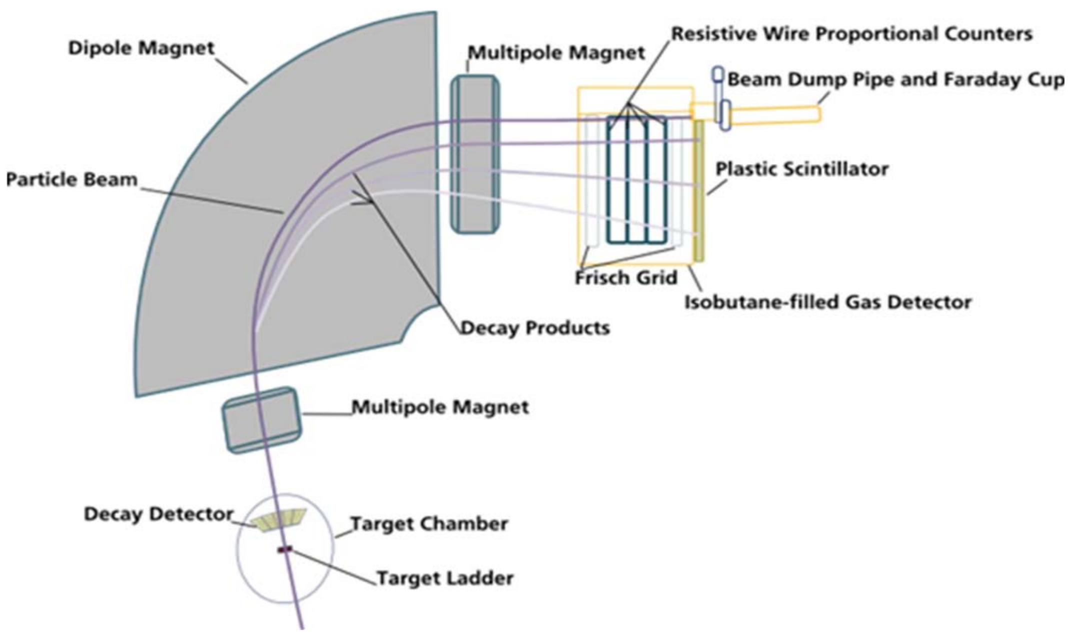

FIG. 3. Diagram of the experimental layout. The deltaE2 layer of the decay detector in the target chamber is used as a trigger to gate events from the decay detector and gas detector.

Starting with the trigger from the decay detector and stopping with the trigger from the gas detector, the time difference between the two triggers is measured by a Time-to-Amplitude Convertor (TAC) and is shown in Fig. 4. Peaks of equal height seemed to be spaced evenly at roughly 50 ns and to be coincident with the cyclotron RF. The primary peak at 300 ns corresponds with the calculated delay between the two triggers and is interpreted to be the true coincident events. To illustrate this, the two-dimensional E vs. ΔE spectrum (Fig. 5) from the gas detector is shown for all gated events (blue) and events coincident with the primary peak around 300 ns from the TAC spectrum (red).

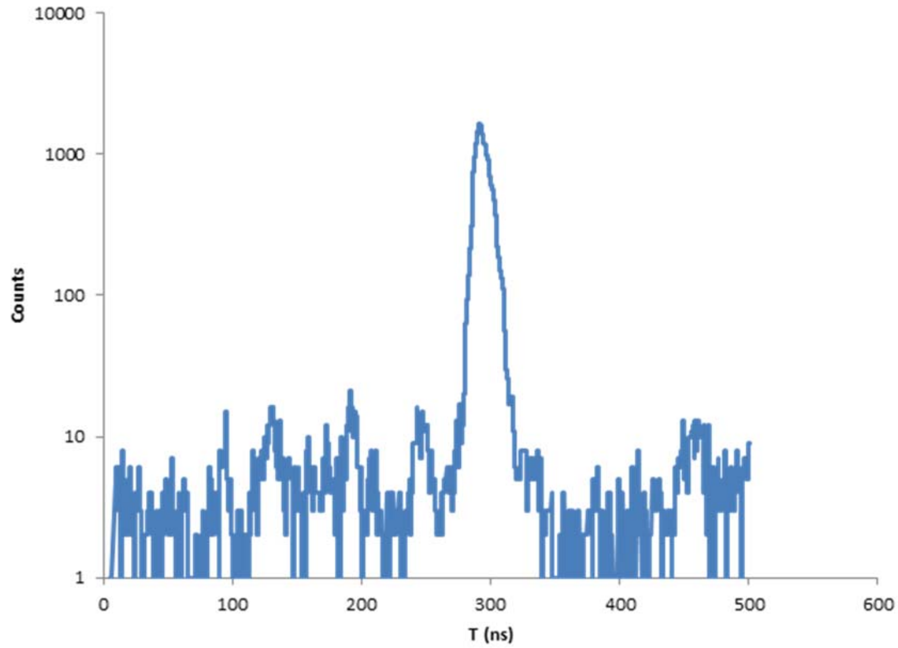

FIG. 4. TAC spectrum for timing between signals from the decay detector and the gas detector. The ΔE2 layer from the decay detector starts the TAC, and the plastic scintillator at the back of the gas detector stops it.

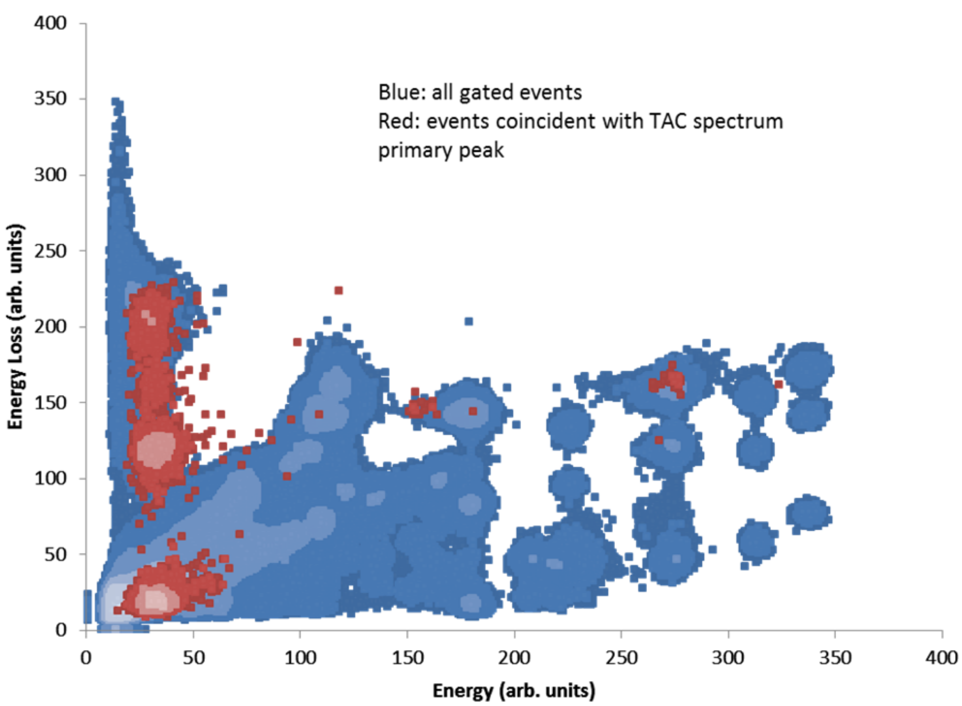

FIG. 5. Energy vs. Energy Loss signal from Oxford gas detector for all gated events (blue) and events coincident with primary peak from the TAC spectrum (red).

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