Test of completed decay detector for ISGMR study

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Introduction

In order to study the Isoscalar Giant Monopole Resonance in unstable nuclei, we have designed and built a ΔE- ΔE - E decay detector composed of plastic scintillator arrays. The elements of this detector and its parameters are described in Ref. [1].

In Ref. [2], the design for the optical connection between strip scintillators and their respective fiber optic bundles was shown to be adequate. A complete array of vertically (ΔE1) and horizontally (ΔE2) aligned strips was constructed and assembled. A reference for the naming system used to define the overlapping, square-pixel areas from ΔE1 and ΔE2 is provided in Fig.1. A reference for the E-Block array geometry and naming system is provided in Fig.2.

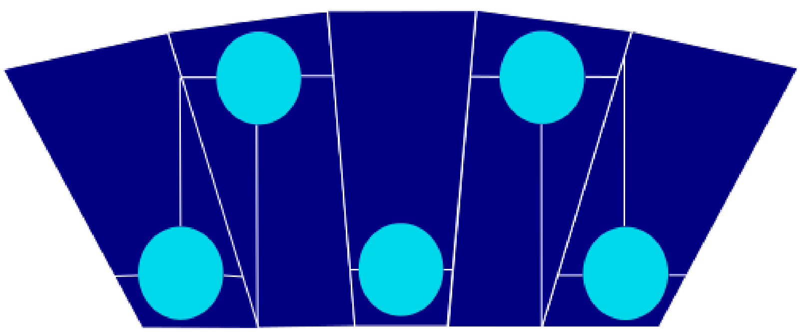

FIG. 2. Top view of E-block scintillators and light guides: The blocks are referred to as E1-E5 from left to right.

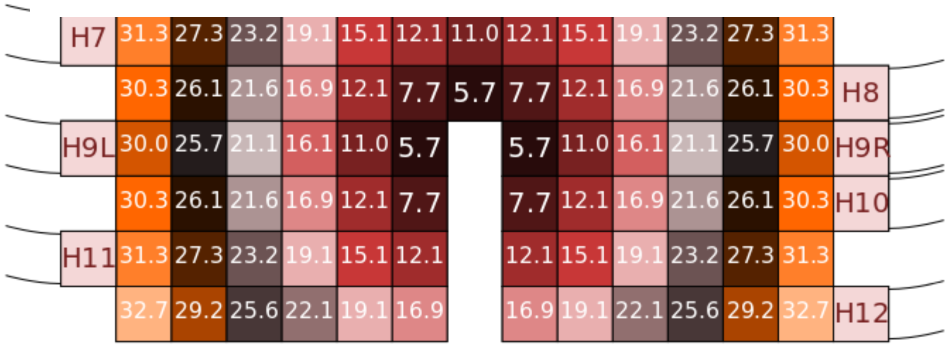

FIG. 1. Map of the ΔE1-ΔE2 Pixel Geometry: The median accepted azimuthal angle in degrees with respect to the beam direction is written on each color-coded pixel. The location of the strip label on the diagram (V1, H1, etc.) indicates the location of the optical connection of the strip scintillator with its fiber bundle. V7 and H9L&R are half-length strips. H10-12 are full length strips, but no signal should come from the center of those strips because there is no vertical strip in front.

In-beam testing has since been done using 30 MeV protons incident on a ^{12}C target. Analysis of the recorded data is still ongoing. Preliminary results show that the decay detector is operating well and that an effective method for energy calibration of the scintillator light response signals has been devised.

In-Beam Test and Preliminary Results

A test run of the completed decay detector was done using a beam of 30 MeV protons on a ^{12}C target. As in prior test runs described in Ref. 2, data collection was triggered by signals from the strip layer ΔE2. Since real proton events must also have a signal in E1, only events with both ΔE1 and ΔE2 signals were analyzed. Signals from all strip scintillators were amplified before being recorded by computer.

The ΔE2-E 2D-spectra (example shown in Fig. 3) show three distinct peaks due to protons of different energies from elastic scattering and excitation of the 4.4MeV (2+) and 9.6 MeV (3-) levels [3] in ^{12}C. To confirm this, ΔE2 and E 1D-spectra (Fig. 4) corresponding to each of the three peaks visible in the 2D-spectra were produced. Each peak in the resulting 1D-spectrum was fit with a Gaussian. The average peak position was then compared with the expected light response of the ΔE2 layer and E-Block (Tables I and II). The expected light response was calculated by first solving for the energies (corresponding to the spread in the azimuthal angle relative to the beam direction within the overlapping ΔE2-E area) of the incident proton on ΔE1 using relativistic kinematics. The energy deposited in each layer was found by using the SRIM tables [4]. The EDSE model [5] was used to calculate the expected light response (Figs. 5 and 6).

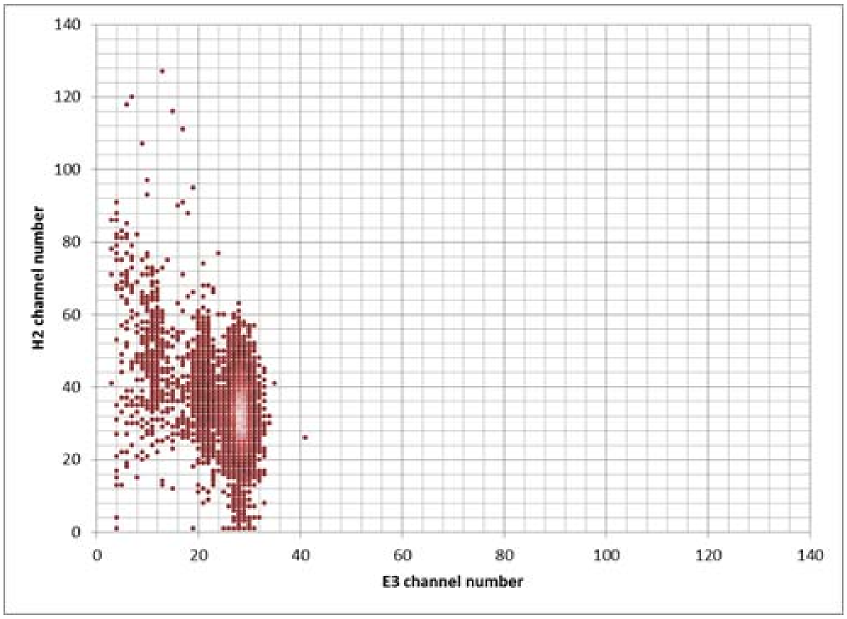

FIG. 3. Example ΔE2-E 2D-spectrum: Lighter shades of red are used to indicate greater numbers of counts.

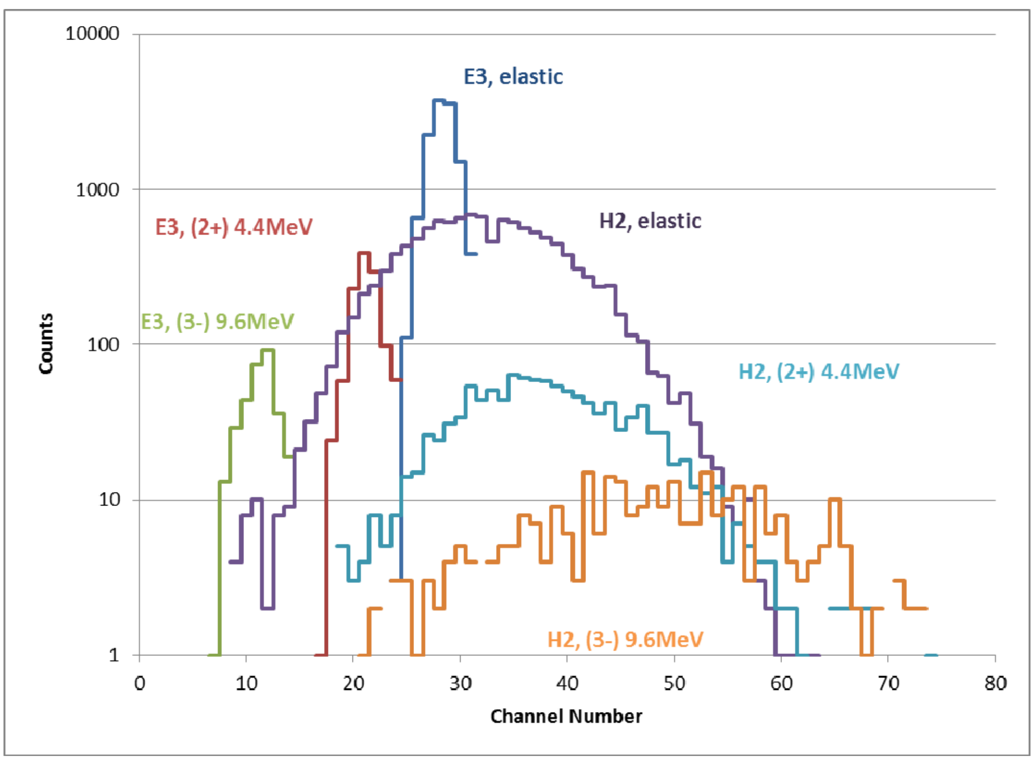

FIG. 4. Example 1D-spectra resulting from gates on peaks in the ΔE2-E 2D-spectra (**Error! Reference source not found.**): Each peak is fit with a Gaussian. The extracted average peak positions are then compared to the expected light response calculated from the EDSE model.

Table I. Comparison of the light response in block E3 in coincidence with horizontal strip H2 at 3 different proton energies: The decay detector area corresponding to the overlap of E3 and H2 is at an azimuthal angle relative to the beam direction of 33±2°. The uncertainty in the energy incident on ΔE1 is due to the uncertainty of the proton angle. The energy deposited in E3 is found by consulting the SRIM tables [4].

	Energy incident on ΔE1 MeV	Energy Deposited in E3 MeV	Exp. L.O. E3 (Ch. Number)	Relative Exp. L.O. E3	EDSE L.O. E3 (Arb. Unit)	Relative EDSE L.O. E3
Elastic	29±1	25±1	28.0 ± 2.0	1.0	660±4	1.0
2+ (4.4MeV)	24±1	20±1	21.1 ±0.1	0.8±0.1	498±5	0.8±0.1
3- (9.6 MeV)	19±1	13±1	12.0 ±3.0	0.4±0.1	279±4	0.4±0.1

Table II. Comparison of the light response in strip H2 in coincidence with E-block E3 at 3 different proton energies: The decay detector area corresponding to the overlap of E3 and H2 is at an azimuthal angle relative to the beam direction of 33+/-2°. The uncertainty in the energy incident on ΔE1 is due to the uncertainty of the proton angle. The energy deposited in ΔE2 is found by consulting the SRIM tables [4].

	Energy Deposited in ΔE2 MeV	Exp. L.O. H2 (Ch. Number)	Relative Exp. L.O. H2	EDSE L.O. H2 (Arb. Unit)	Relative EDSE L.O. H2
Elastic	2.0±1.0	32 ±5	1.0	76±3	1.0
2+ (4.4MeV)	2.5±1.0	38 ±4	1.2±0.3	93±4	1.2±0.1
3- (9.6MeV)	3.5±1.0	49 ±6	1.6±0.3	122±6	1.6±0.1

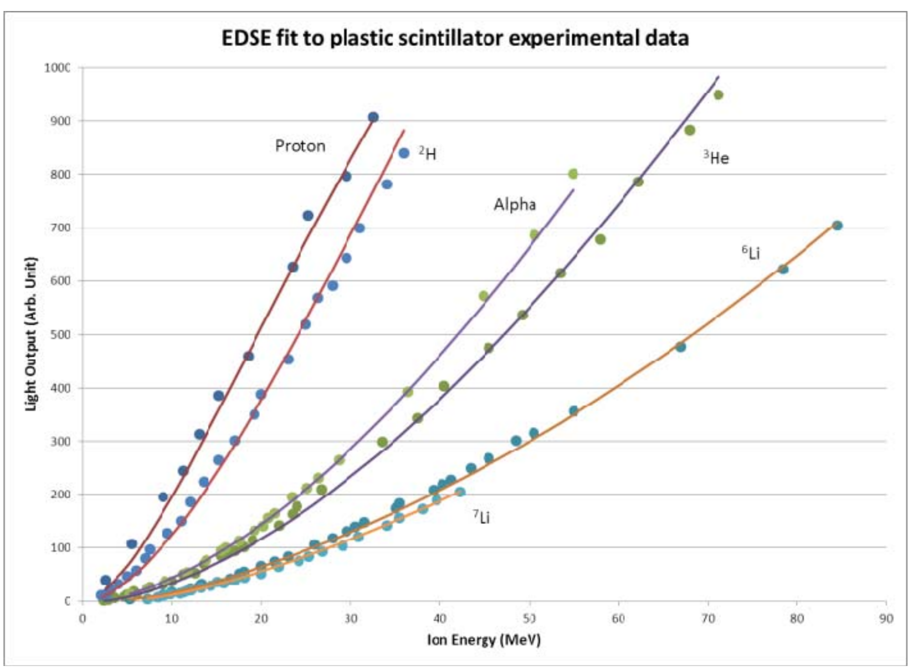

FIG. 5. Fit to published experimental data of the light response by plastic scintillator [6]: The parameters obtained by chi-square fit have the values ρ_q = 99.7 MeV/nm, F = .998, A = 1E-4, C_{proton} = 1.14, C_α = 1.96, and C_{6Li} = 2.90.

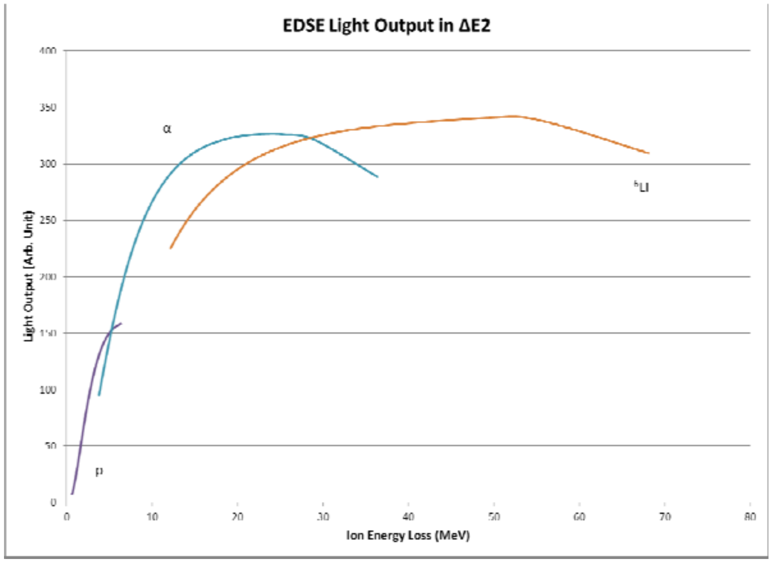

FIG. 6. Light response of the decay detector as a function of the energy deposited by various ions.

Conclusion

Comparison of the light output in the E3 and H2 scintillators for protons from the three groups shows good agreement between the expected and experimental relative values. This method of comparison could be extended by applying a similar procedure to the 2D-spectra generated by coincidences between the ΔE1 and the E-Block layer. This would give an energy calibration for all scintillator signals.

The poorer resolution in the strip scintillators is probably due largely to energy straggling in the thin strips. Because of this, the three peaks are not resolved in the ΔE1-ΔE2 2D-spectra (Fig. 7).

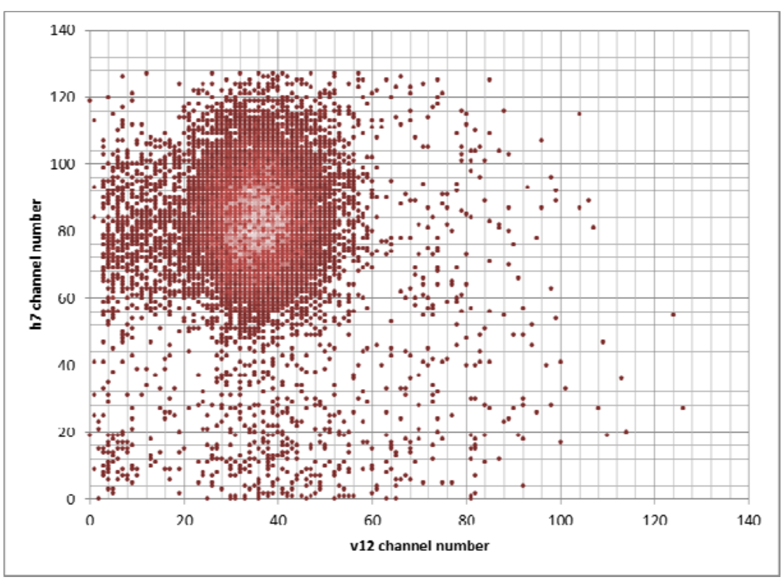

FIG. 7. An example ΔE1-ΔE2 2D-spectrum: The three peaks visible in the ΔE2-E 2D-spectra are not visible here due to the poorer energy resolution of the strip scintillators compared to that of the block scintillators.

[1] J. Button, R. Polis et al., Progress in Research, Cyclotron Institute Texas A&M University (2008-2009), p.V-30.
[2] J. Button, R. Polis et al., Progress in Research, Cyclotron Institute Texas A&M University (2010-2011), p.V-55.
[3] National Nuclear Data Center, information extracted from the Chart of Nuclides database, http://www.nndc.bnl.gov/chart/
[4] J.F. Ziegler, M.D. Ziegler and J.P. Biersack, Nucl. Instrum. Methods Phys. Res. **B268**, 1818 (2010).
[5] K. Michaelian, A. Menchaca-Rocha, and E. Belmont-Moreno, Nucl. Instrum. Methods Phys. Res. **A356**, 297 (1995).
[6] F.D. Becchetti, C.E. Thorn and M.J. Levine Nucl. Instrum. Methods **138**, 93 (1976).