

Assembly and test run of decay detector for ISGMR study

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1. ΔE - ΔE - E Plastic Scintillator Array Decay Detector

In order to study the Isoscalar Giant Monopole Resonance in unstable nuclei, we have designed and are in the process of building and testing a ΔE - ΔE - E decay detector composed of plastic scintillator arrays. The measurement of the ISGMR in unstable nuclei will be done using inverse kinematics, with a 40 MeV per nucleon beam of the unstable nucleus incident on a ${}^6\text{Li}$ target. Xinfeng Chen studied the viability of this approach, taking data for elastic scattering and inelastic scattering to low-lying states and giant resonances of 240 MeV ${}^6\text{Li}$ ions on ${}^{24}\text{Mg}$, ${}^{28}\text{Si}$, and ${}^{116}\text{Sn}$ [1]. Nuclei excited to the ISGMR region are particle unstable, and will decay by p, α or n decay shortly after excitation. To reconstruct the event it is necessary to measure the energy and angle of the decay particle (with the plastic scintillator array) and of the residual heavy ion (in the focal plane of the MDM spectrometer). In many lighter nuclei a few nucleons off stability, and in light proton rich nuclei, the neutron threshold is above the region of interest.

The decay detector (Figs. 1 and 2) is placed in the MDM target chamber and subtends 70° in $\Delta\theta$ and $\Delta\phi$. It is composed of 30 - 1 mm thick strips of BC408 plastic scintillator (14 horizontally aligned and 16 vertically aligned, forming the ΔE - ΔE arrays) and 5 blocks of BC408 plastic scintillator (E detector array). Placed back to back, the vertical and horizontal strips overlap to give 1 cm^2 pixels, providing an approximately $4^\circ \times 4^\circ$ angular resolution. Particle identification can be done using horizontal and vertical strips within the energy range (MeV/amu) $7 < E/A < 11$. For $11 < E/A < 75$, the strips (ΔE) and the block scintillator (E) can be used for particle identification.

Each strip is bonded to a bundle comprised of 19 optical fibers (1 mm diameter x 50 cm length) manufactured by Saint-Gobain. One end of the fiber bundle is cemented (optical cement BC600 Saint-Gobain) into a rectangular form, and the other end is cemented into an acrylic cylindrical sleeve. The rectangular end is then cemented to the 1 mm x 1 cm end of

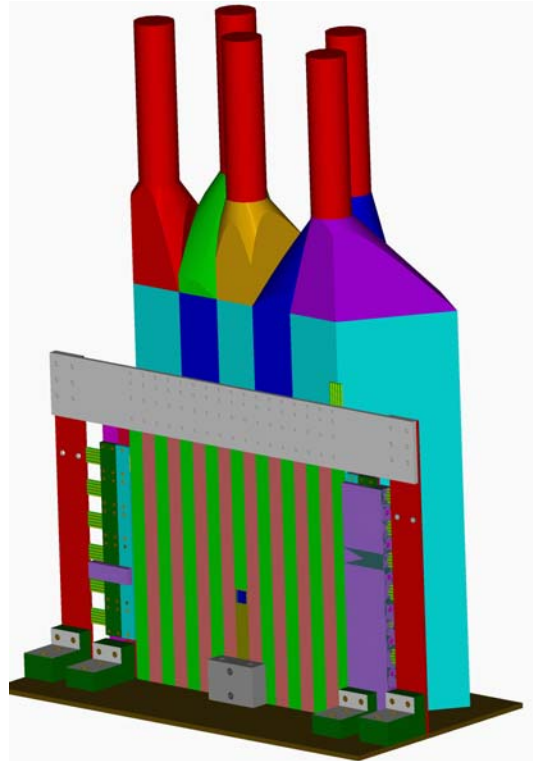
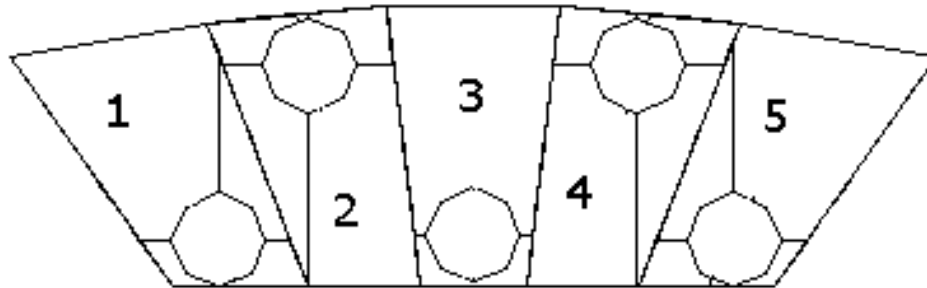


FIG. 1. Schematic of decay detector. The front of the block scintillator array (E) is flat and lies parallel to the scintillator strips (ΔE). Each block covers $\Delta\theta \sim 14^\circ$ relative to the target.

the strip scintillator. The other end is mated with a 1 cm diameter Hamamatsu photomultiplier tube. The strips are wrapped in aluminum foil for light reflection and to eliminate cross-talk between scintillators.



**2.
Run**

FIG. 2. Drawing of scintillator block array. The lines inside each 4-sided block show how the corresponding light guides taper to 1 in. diameter

Test

A partial assembly of the decay detector shown in Fig. 3 was used for the purpose of testing and calibration. It consists of 7 strip scintillators (4 horizontal and 3 vertical), with the vertical strips aligned

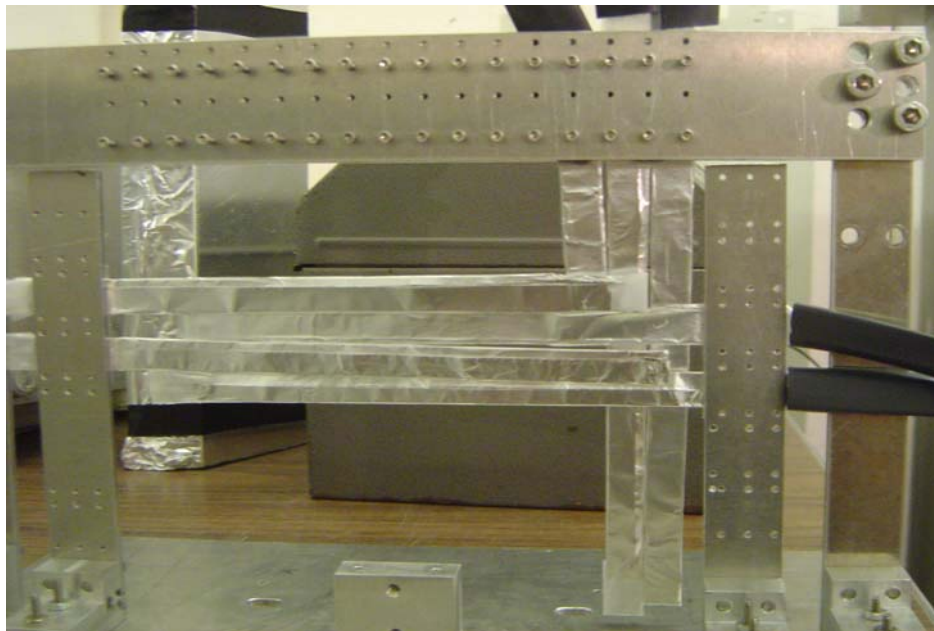


FIG. 3. Photo of partially assembled strip scintillator frame. The scintillators are wrapped in aluminum foil, and the fiber optic bundles are covered in black sheath (heat shrink tubing).

to the rightmost side relative to the beam. A single block scintillator (block 4 from Fig. 2) was used to obtain the E-signal. The block was rotated counter-clockwise so that the face nearest to the strip scintillators effectively overlapped the area of the vertically aligned strips (see Fig. 4).



FIG. 4. Photo of Single Block Scintillator, coupled to odd-shaped and cylindrical light guides by optical cement (BC600). 1.5 mm Aluminum plate is fixed to the ion accepting side of the block scintillator.

The test run was conducted to assess the suitability of methods employed for making the optical connections between strip scintillators and optical fiber bundles, between fiber bundles and small PMTs, between block scintillators and light guides, and between light guides and large PMTs. This assessment was made by examining and comparing signal strength output from each PMT in the detector array. The optical connection between strip scintillators and fiber bundles presented the greatest concern. Attempts to bond the two parts with optical cement by clamping proved very difficult because each has a small, thin surface area (1 mm x 1 cm), and the fiber bundles are not rigid objects, and plastic scintillators are very easily damaged when subjected to physical stress. As a result, a number of strip scintillators were rendered useless prior to or during the test run. Alternative methods for making this optical bond are being investigated.

Data were taken using beams of 108 MeV α particles and 40 MeV protons on a ^{12}C target. Coincidences between 1 horizontal scintillator ($\Delta E1$) and the block (E), between 1 vertical scintillator ($\Delta E2$) and the block and triple coincidences between the horizontal and vertical strips and the block were

recorded. Also, singles were collected from the three signals ($\Delta E1$, $\Delta E2$, E). Data for accidental coincidences ($\Delta E1 + E$) were also collected.

During the test run, the $\Delta E1$ - E two-dimensional plot for the 40 MeV proton beam showed two overlapping regions of peak intensity along the E axis (Fig. 5), and the projections to ΔE and E axes are shown in Fig. 6. A 1.5 mm thick aluminum plate was subsequently fixed to the front of the block scintillator (Fig. 4) in order to shift these regions to the left along the E axis and yield additional information for the calibration and characterization of the scintillator light output (Table I). For NE-102, which is similar in composition to BC-408, light output is expected to be proportional to the ion range for the energies inside the range $0.5 \leq E/A \leq 15$ (MeV/amu) [4]. Protons entering the E scintillator have a minimum energy of 32 MeV. However, values obtained from this relationship are given in Table I and are in fair agreement with the data. This confirms that the two overlapping regions of peak intensity found in Fig. 5 are the result of protons passing through one ΔE strip and two ΔE strips respectively.

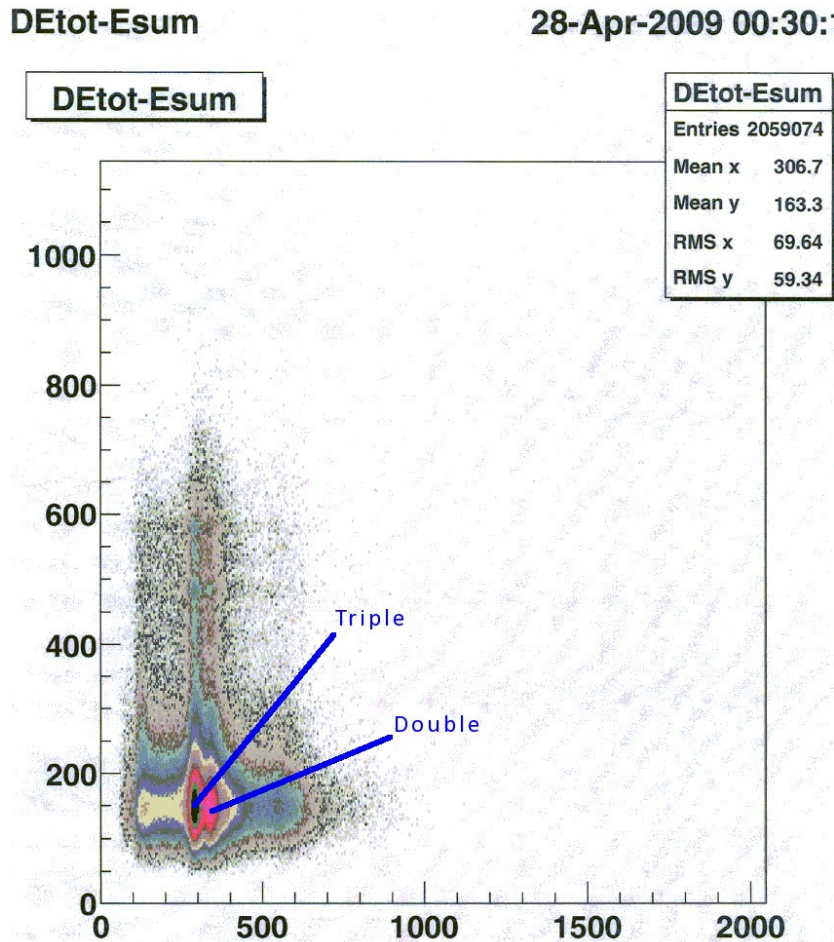


FIG. 5. Two-dimensional $\Delta E1$ vs. E plot (both axes in arbitrary units). Aluminum plate is fixed to E block scintillator. Data are collected with the requirement that signals from $\Delta E1$ and E coincide. “Triple” refers to region of peak intensity in plot believed to be due to protons passing through two strip scintillators before being absorbed by the block scintillator. “Double” refers to protons passing through one strip scintillator before being absorbed by the block scintillator.

TABLE I. Relative pulse height output for the E block scintillator, with and without the 1.5 mm thick aluminum plate attached, for 40 MeV protons. The expected light output is calculated by taking the light output to be proportional to the ion range in BC-408. Range data was taken from the SRIM tables[3].

| 40 MeV proton in E block Scintillator | Energy absorbed by block scintillator (MeV) | Ion range in BC-408 for proton energy absorbed by block scintillator | Expected relative light output difference (± 11) | Measured relative pulse height difference (± 5) |
|---|--|---|--|--|
| Double, No Plate | 38 | 1.32 | +36% | +45% |
| Triple, No Plate | 36 | 1.20 | +23% | +23% |
| Double, w/ Plate | 34 | 1.08 | +11% | +15% |
| Triple, w/ Plate | 32 | .97 | 0 | 0 |

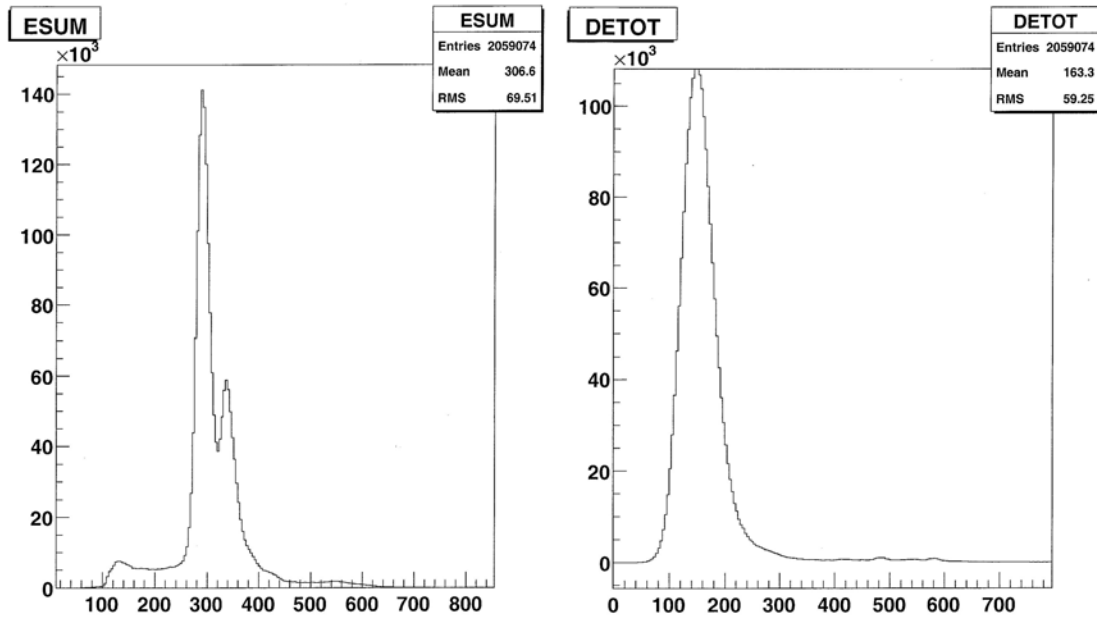


FIG. 6. The number of counts vs. light output for the block scintillator(left) and a strip scintillator (right) for 40 MeV protons incident on the detector.

3. Results

The test run demonstrated that the optical connections used to transmit light produced by the scintillator strips and block to the photomultiplier tubes are adequate. In order to complete construction of the detector array, significant improvements in the optical cement joint between the fiber bundles and strip scintillators are required.

Data analysis is ongoing and efforts are underway to make calculations of the expected light output of the scintillator detector array for incident ions of varying Z , A , and energy. Two methods for the calculation of relative light output of plastic scintillator when ions of a particular energy pass through or are stopped in the scintillator will be compared for suitability in calibrating light output from the experimental setup. An empirical relationship such as the Birks formula [2], which relates light output to the stopping power directly, is a convenient method because stopping power tables for energetic ions passing through matter [3] are widely available and stopping power may also be calculated directly by the Bethe-Bloch formula [5]. However, the Birks formula becomes a hindrance when the experiment involves many ion types, since the parameters L_0 and K will vary by ion type. For this situation, models with a specific Z dependence have been proposed. One such model (Energy Deposition by Secondary Electrons) relates light output dL/dx to the number of energy carriers created due to energy loss of the ion in the scintillating material [6].

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