THIRTY-TWO-FOLD SEGMENTED GERMANIUM DETECTORS TO IDENTIFY γ RAYS FROM INTERMEDIATE-ENERGY EXOTIC BEAMS

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With the impending completion of the upgrade of the NSCL upgrade comes the prospect of producing neutron-rich nuclei farther from stability than previously achieved. In addition to these improvements in isotope production, it is vitally important that the detectors that measure the properties of these rare nuclei also be continually updated. As part of this equipment upgrade, a new segmented germanium array is being developed to supplement the existing γ-ray detector array at the NSCL.

Significant information about the structure of nuclei can be obtained from the identification of their γ-ray decay. In particular, γ rays that result immediately following a reaction. Consequently, these photons must be detected in-flight. This results in a large doppler broadening when these γ rays are detected in the laboratory frame. Such experiments at the NSCL involve the production of a radioactive beam by fragmentation of a projectile at energies of 10-300 MeV/nucleon ($v/c \approx 0.15$ to 0.65). These exotic beams of nuclei are subsequently studied by their Coulomb excitation [1,2,3], nucleon knockout [4,5] in a secondary target.

The success of these experiments stemmed from the use of a position-sensitive NaI(Tl) array [6] to detect the in-flight γ-ray decays. The use of this array is detailed in other articles of this report as well as in previous reports. A limitation of this array, however, is that the intrinsic resolution of NaI(Tl) is very poor compared to solid-state germanium detectors. The instrisic resolution of the MSU NaI(Tl) array is 8% for 1.3 MeV γ ray, while a typical germanium detector has <0.2% resolution at this energy. For detailed spectroscopy of nuclei, it is necessary to have the resolution of germanium detectors. The major limitations of germanium detectors, however, is their expense and detection efficiency. Thus these detectors should be placed close to the re-excitation target, and thus present a large opening angle. Consequently, the gain in intrinsic energy resolution is lost due to the uncertainty in the Doppler-reconstructed energy created by the opening angle of the detector.

Recent developements in the electronic segmentation of germanium crystals (see Refs. [7,8,9,10]) has opened up the possibility of localizing the interaction of a γ ray within a detector and consequently reducing the effective opening angle of a detector [11,12]. This allows the detectors to be placed closer to the target for greater efficiency while minimizing the effect of the detector opening angle on the final energy resolution. To take advantage of these new developments the NSCL in cooperation with Eurisys Mesures corporation have initiated a program to develop an array 32-fold segmented germanium detectors for use in Coulomb excitation studies.

In addition to the array at MSU, there are several other programs for developing arrays of highly-segmented germanium detectors, e.g. GRETA [11,12], MINIBALL [7,8], and EXOGAM [13]. In these arrays the germanium detectors are being designed so that the axis-of-symmetry of the detectors points toward the target point (i.e. similar to detectors in GAMMASPHERE or EUROBALL). A different approach was used for the development of the detectors at the NSCL. Rather than aligning the detectors with the axis-of-symmetry toward the source, the detectors will be aligned with the axis-of-symmetry perpendicular to the source and parallel with the azimuthal spherical angle (θ).

The active part of an MSU detector is a hyper-pure n-type coaxial germanium crystal of approximately 75% efficiency relative to a 3 in $\times$ 3 in NaI(Tl) counter. The boron-implanted outer layer divided into eight 10 mm wide disks in the lateral direction, and four-fold radial segmentation for a total of 32 segments. This segmentation is shown schematically in Fig. 1. Also shown in this figure is scheme for placing one of the detector detector relative to the target, and how the lateral segmentation will be dramatically reduce the measureable opening angle for a γ ray interaction.

Because of the atypical configuration for operating these detectors, the cryostat of the detector is mounted at a 45° angle relative to the crystal axis. This allows the crystals to be placed in a more compact configuration without having interference from the cyrostats of other detectors.

As of this report, eight detectors from the total of eighteen ordered have been delivered from the manufacturer to the NSCL. A photograph of one of these detectors is shown in Fig. 2. A detailed description of the operating characteristics of these detectors can be found in Ref. [14]. At present, the delivered detectors are being tested for reliability as well as their response to multiply-scattered γ rays. An array of six segmented detectors including all the required electronics and mounting frames will be operational this summer. Since the NSCL cyclotrons are currently offline as part of their upgrade, it is planned to use the segmented germanium array in low-energy experiments at the ATLAS facility at Argonne National Laboratory during the Autumn of this year. At these experiments, the MSU germanium array will be the most highly-segmented germanium detectors to be used in an in-beam experiment.

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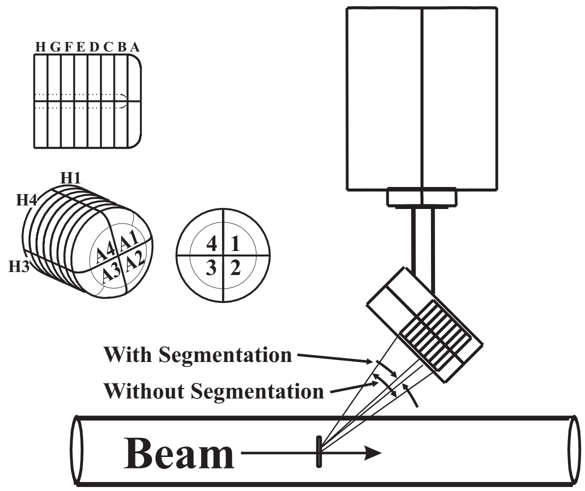

Figure 1: Schematic diagrams of the segmented germanium crystal. The letters label the lateral disk divisions, and the numbers label the radial quadrant. Also shown is a possible configuration for one of the segmented detectors with respect to the target.

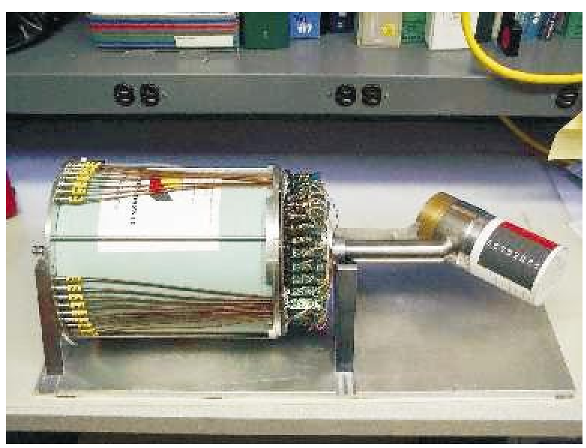

Figure 2: Photograph of an MSU 32-fold segmented germanium detector. The preamplifier housing has been removed to allow viewing of a portion of the preamplifiers.