CHARACTERISTICS OF 32-FOLD SEGMENTED GERMANIUM DETECTORS

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Coulomb excitation [1], nucleon knockout [5], and other gamma-ray emitting reactions are often used to study exotic nuclei. They facilitate the study of fast beams by inverse kinematics. The gamma-ray energy emitted depends on the emission angle. Reconstruction of the center-of-mass energy requires position-dependent detection of the gamma rays. In the past, detection of gamma rays at the NSCL has generally relied upon an array of NaI detectors [6]. To improve the energy resolution, a 32-fold segmented coaxial high-purity germanium detector was developed [3] and manufactured by Eurisys Mesures in 1999. Since then, the full array of 18 segmented germanium detectors has arrived at the NSCL and has been put through a battery of tests. The results assure quality and along with early in-beam trials, demonstrate improvement in energy resolution over non-segmented detectors [4].

The detection element consists of a single n-type high-purity germanium crystal, a diode capable of sustaining reverse high voltage at cryogenic temperatures. Thirty-two fold segmentation has been achieved by separation of the outer p-type ion-implanted contact into 8 transverse and 4 longitudinal segments. The lithium-diffused inner contact is biased with positive high voltage despite the n-type crystal. Within the crystal's aluminum housing, temperatures are sustained close to –177 °C by contact with a liquid nitrogen filled dewar. Average holding times are approximately 30 hours. A high voltage shut-down card protects the detector in case of accidental warm up. Thirty-three resistive feedback charge sensitive preamplifier cards integrate the gamma-ray induced current, producing a pulse with height proportional to the incident photon energy. DC-coupled preamplifiers give the position information from each segment while the full volume energy signal is collected by an AC-coupled preamp.The 32-fold segmentation provides a decrease in the uncertainty of the scattering angle and greater intrinsic position resolution of the detector. In tests following the IEEE standard (IEEE Std 325-1996), ^{60}Co and ^{152}Eu are used to measure the resolution of each of the segments and the central contact of the detectors. Typical energy resolution for the central contact of one detector is 2.7 keV for the 1332 keV peak of ^{60}Co (Fig. 1). This is a significant improvement over NaI scintillators (13% FWHM) [2]. Segment energy resolution is best along the sides of the detector as the field at the end of the crystal is distorted as expected. Typical segment resolutions are 2.7 keV for the side segments and 3.0 keV for the ends. The stability of the resolution is tested against changes in orientation of the detector, sound level and time. Timing of the detector is tested using a CsF reference detector and the same ^{60}Co source. The time resolutions are typically 10 ns FWHM.

The characteristics of the detectors have also undergone in-beam tests. The configuration of detectors in an array should allow for maximum exposure to the sides of the crystals, where resolution and efficiency are highest. One possibility places the crystals' longitudinal axes parallel to the beam line with the target positioned approximately in the middle of the array. Three successful experiments with this setup were performed at the ATLAS facility at Argonne National Laboratory (ANL 861X, ANL883, and ANL827) [4]. The target was located 6 cm from the crystals, giving an uncertainty in the scattering angle for the segments of 9.5¡ and an energy resolution of 1.5%. In comparison, the uncertainty for the whole crystal was 67¡ corresponding to an energy resolution of 6% without the segmentation.

The detectors may be used in a variety of configurations with support structures designed and built at the NSCL. The preamp cards and FETs are warm, reducing the overall size of the detector. This allows an ease of mobility as well as easy access for repair. Two annealing stations are in full operation at the NSCL as well.

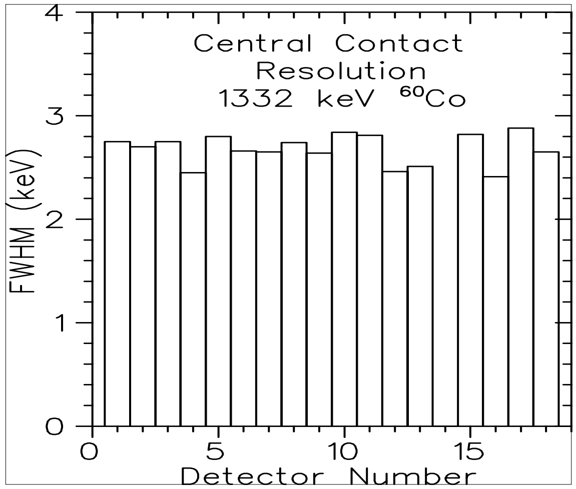

Fig 1. Central contact energy resolution for the 18 segmented germanium detectors. Detector number 14 is currently being tested.

References

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