MICHIGAN STATE UNIVERSITY

CYCLOTRON LABORATORY

FAST TIMING WITH BISMUTH GERMANATE

D. J. MORRISSEY, S. H. WERNIG and R. A. BLUE

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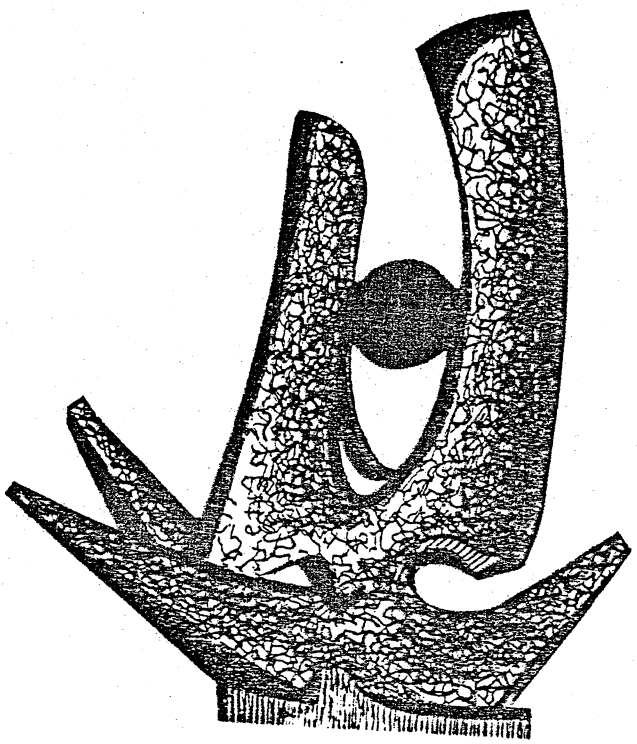

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Fast Timing with Bismuth Germanate

D. J. Morrissey and S. H. Wernig

National Superconducting Cyclotron Laboratory
and Department of Chemistry
Michigan State University
East Lansing, MI 48824-1321

R. A. Blue

National Superconducting Cyclotron Laboratory
Michigan State University
East Lansing, MI 48824-1321

The coupling of an Amperex 2312 photomultiplier to a 7.6 x 7.6 cm Bismuth Germanate (BGO) detector has yielded excellent time resolution for 0.5 MeV gamma-rays (1.40 +/- 0.05 nsec). Along with the excellent timing this photomultiplier has an energy resolution which is as good as that obtained slower tubes.

An important area of heavy-ion nuclear physics research is that of continuum gamma-ray spectroscopy. Such studies have used large volume NaI(Tl) detectors to measure the number and total energy of the unresolvable gamma-rays emitted in these reactions [1]. With the recent appearance of Bismuth Germanate (BGO) scintillators many researchers have begun to think about replacing NaI(Tl) with BGO. An important reason for considering this replacement is that the relative fraction of gamma-ray interactions that lie in the full energy peak is far larger for a BGO detector than for a NaI(Tl) detector of the same volume as pointed out by Evans [2]. However, the timing characteristics of any gamma-ray detector are just as important in determining its usefulness in heavy-ion reaction studies [3]. The primary products from essentially all heavy-ion induced reactions emit neutrons as well as gamma-rays, and the best method to discriminate between the neutrons and the gamma-rays is to measure the difference in their times of flight (over a constant flight path). Because BGO detectors are approximately as sensitive to fast neutrons as NaI(Tl) detectors per unit volume [4], the timing properties of BGO need to be approximately as good as those of NaI(Tl). Poorer time resolution would necessitate the use of longer flight paths for BGO detectors to achieve the same neutron-gamma separation as with NaI(Tl). Such longer flight paths would increase the size and cost of the BGO detector and limit their usefulness.

The properties of BGO detectors that influence the timing are mostly beyond the control of the experimenters as they are determined by light collection and depend on the purity of the

BGO material, indices of refraction, and surface effects. However, the optimization of the photomultiplier tube (PMT) is in the realm of control. Up to the present a wide range of PMT's have been used in order to obtain the optimum time resolution with BGO crystals in a variety of sizes [5-8]. Commonly two different PMT's have been used with smaller diameter BGO crystals, one optimized for timing (e.g. Hamamatsu R-329-2), and another optimized for energy resolution (e.g. Hamamatsu R-1306) [e.g. 7]. A PMT which can provide both a fast fise time and good linearity for the largest diameter BGO crystals presently available (7.6 cm) is the Amperex-2312.

A 7.6 x 7.6 cm right cylindrical BGO detector coupled to an Amperex-2312B PMT was obtained from the Harshaw Chemical Company. The energy resolution and photopeak to total response was measured with gamma-rays from monoenergetic sources (e.g. 137-Cs), monoenergetic gamma-rays from cascade sources triggered by a fast-slow coincidence with an intrinsic germanium detector (e.g. 60-Co), and the 4.44 MeV gamma-ray from a Pu-Be source triggered by a fast-slow coincidence with a neutron detected in a NE-213 liquid scintillator with pulse shape discrimination. The results of these measurements are shown in figure 1 along with similar measurements of a 7.6 x 7.6 cm NaI(Tl) detector. The BGO detector was found to have 15% (FWHM) resolution at 662 keV. This is an indication that the large BGO volume is an excellent quality crystal .

The time resolution of the BGO detector was obtained in two coincidence measurements triggered by either a NE-102 plastic scintillator using a 60-Co source or a Si surface barrier

detector in-beam. In the measurement with the source the anode signals from the BGO and plastic (RCA 8575 PMT) were passed in paralllel through a LeCroy 612AM fast amplifier and Canberra 1428 constant fraction discriminator into a TAC. No selection was made on gamma-ray energy in order to be representative of the continuum gamma-ray spectra found in-beam. The time resolution was found to be 1.58 +/- 0.03 ns in this system. These reults are shown by the dotted curve in figure 2. The time resolution was also measured in a fast-slow coincidence between reaction products detected in a Si surface barrier telescope and continuum gamma-rays emitted at 120 degrees from the beam at the MSU K500 Superconducting Cclotron. The time resolution obtained in this experiment was 1.40 +/- 0.05 s and is shown in figure 2 by the solid curve. The gamma-ray spectrum was dominated by the 477 keV line from 7-Li and was cut off below 150 keV. In both measurements the time spectrum tails toward longer separation between trigger and BGO signal. This tailing is possibly due to the presence of two decay components in the BGO scintillation [9].

We can summarize our results as showing excellent timing and energy resolution can be obtained with an Amperex 2312 PMT coupled to a BGO crystal. We have obtained the best timing to date with a large volume BGO crystal and low energy photons. This indicates that BGO can be a favourable replacement for NaI(Tl) in continuum gamma-ray studies. This work was supported by the National Science Foundation under Grant No. PHY 80-17605.

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Figure captions

1. Calibration results for the 7.6 x 7.6 cm BGO detector used in this study. Typical results obtained with an off-the-shelf NaI(Tl) detector of the same volume are also shown for comparison. In part (a) the peak-to-total ratios (in percent) are compared. And in part (b) the energy resolution of the full energy peaks are compared (also in percent).

2. The results from timing tests of a 7.6 x 7.6 cm BGO detector coupled to an Amperex 2312B photomultiplier tube are shown. The points were obtained with a 60-Co source and the solid curve was obtained in-beam.

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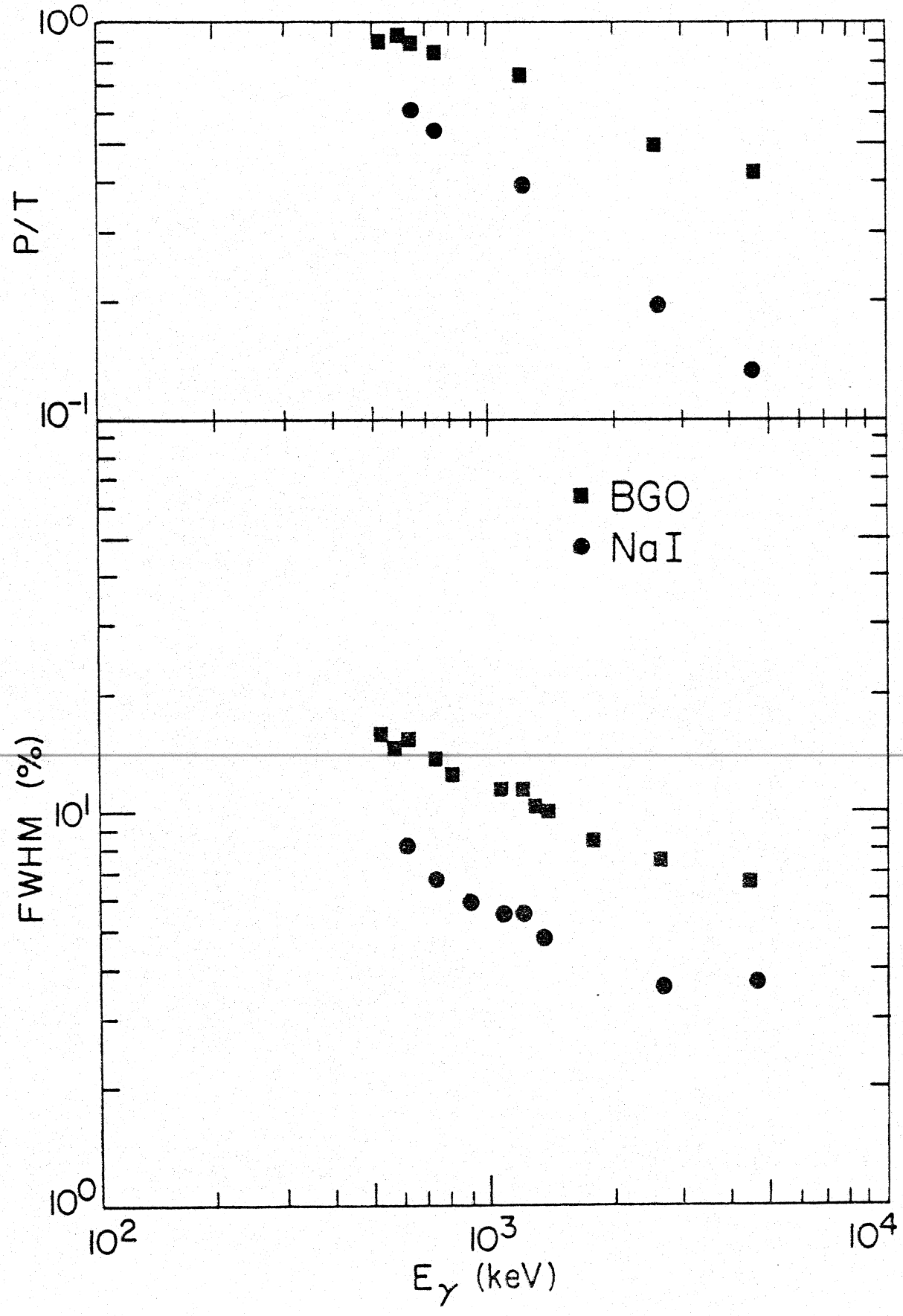

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