Title
NEUTRON-GAMMA DISCRIMINATION USING NaI(T1) SCINTILLATORS WITH APPLICATION FOR MEASUREMENT OF THE GAMMA-RAY MULTIPLICITY DISTRIBUTION IN HEAVY-ION REACTIONS

Author
Richardson, L.W.

Publication Date
2012-02-17

LBL-10146
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Submitted to Nuclear Instruments and Methods

NEUTRON-GAMMA DISCRIMINATION USING NaI(Tl) SCINTILLATORS WITH APPLICATION FOR MEASUREMENT OF THE GAMMA-RAY MULTIPLICITY DISTRIBUTION IN HEAVY-ION REACTIONS

L. W. Richardson, G.J. Wozniak, M. R. Maier and L.G. Moretto

November 1979

Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

NEUTRON-GAMMA DISCRIMINATION USING NaI(Tl) SCINTILLATORS WITH APPLICATION FOR MEASUREMENT OF THE GAMMA-RAY MULTIPLICITY DISTRIBUTION IN HEAVY-ION REACTIONS

L. W. Richardson, G. J. Wozniak, M. R. Maier and L. G. Moretto

Nuclear Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Abstract

An intrinsic time resolution of 0.99 ± 0.08 ns FWHM has been measured for commercially available 7.6 cm x 7.6 cm NaI(Tl) scintillator detectors with fast photomultiplier tubes. This time resolution allows almost complete discrimination between neutrons and γ-rays over a short flight path. Application of this technique to the reaction 690 MeV ^{84}Kr + Ag is discussed.

There is presently a considerable interest in the measurement of the multiplicity distribution for heavy-ion continuum γ-ray spectra. Accurate measurements of the first and higher order moments of the multiplicity distribution are needed for studies of angular momentum transfer in deep-inelastic reactions[1]. Similar measurements are needed as well for studies of high spin states populated in compound-nucleus reactions[2].

One of the problems inherent in such measurements is the correction for neutron contamination of the γ-ray events[3]. A solution to the problem is to employ liquid scintillation detectors and pulse-shape discrimination to separate neutrons from γ-rays. This technique, however, may not always be desirable due to the poor energy resolution and low γ-detection effeciency of available liquid scintillators. An alternative approach is to employ thallium activated sodium iodide NaI(Tl) scintillator detectors and discriminate between neutrons and γ-rays by their flight times[4]. To be able to measure in a reasonable amount of time the γ-multiplicity distribution in coincidence with deep-inelastic fragments, it is important to use large scintillators with good timing characteristics so that the flight path necessary for adequate n-γ discrimination can be minimized to obtain a large particle-γ coincidence efficiency.

To determine the feasibility of using a time-of-flight discrimination technique over a short flight path with fairly large detectors and commercially available phototubes and electronics, we investigated the intrinsic time resolution of our NaI(Tl) scintillators which are coupled to fast photomultiplier tubes. Essentially the resolution was measured in a fast-slow coincidence experiment between two identical detectors as depicted in fig. 1. Each detector consisted of a single 7.6 cm x 7.6 cm polycrystalline NaI(Tl) scintillator* integrally mounted to a 6.8 cm diameter 12 stage head-on photomultiplier tube with a plano-concave window and semi-transparent bialkaline photocathode which was operated at a potential of -2.0 kV. These fast low-noise Amperex 2312B photomultipliers have an intrinsic risetime of 2.5 ns and when coupled to the scintillator give an anode signal for the 1332.5 keV ^{60}Co γ-ray photopeak with a risetime of less than 8.0 ns and a signal-to-noise ratio of 100/1 or better. The single-channel-analyzer (SCA) discriminators were set in the energy spectrum around the ^{60}Co photopeaks and a slow coincidence between the two SCA units was used to gate the time-to-amplitude converter (TAC) output for pulse-height analysis. The TAC was started by a signal from the constant-fraction-discriminator (CFD) of the first NaI(Tl) detector and stopped by a signal from the CFD of the second NaI(Tl) detector after being accurately delayed for a time calibration.

The resulting time spectrum is illustrated in fig. 2. An overall time resolution of 1.40 ± 0.08 ns at the full-width-half-maximum (FWHM) was measured indicating a FWHM resolution per detector of 0.99 ± 0.08 ns. The full-width-tenth-maximum (FWTM) resolution per detector was 2.32 ns. This result was obtained with LBL constant-fraction-discriminators[5)] where the zero-crossing of the discriminator

*Manufactured by the Bicron Corporation.

bipolar waveform was set at 20 percent of the input signal amplitude and with a short input delay time of 2.0 ns (25 percent of the anode signal risetime). This fraction and delay time were chosen to optimize the time resolution. The CFD thresholds were set at −350 mV corresponding to approximately 200 keV in the energy spectrum. With the above resolution one should be able to separate neutrons with energies up to the neutron binding energy from γ-rays over a short flight path.

To test the time-of-flight discrimination technique with our detection system, we measured the time spectrum for the NaI(Tl) scintillators in coincidence with heavy-fragment events detected in a silicon ΔE-E surface barrier detector telescope for the reaction 690 MeV ^{84}Kr + ^{nat}Ag at the Lawrence Berkeley Laboratory Super-HILAC. The detector array consisted of 8 fast NaI(Tl) scintillator detectors (previously described) located 24 cm from target, 45^{o} apart in the hemisphere above and at 45^{o} to the reaction plane. Each detector was shielded with 1.2 cm of lead to reduce Compton scattering into adjacent counters. The resulting Z-γ TAC spectrum gated on a crude window in energy and mass and without corrections for differences in the fragment velocities or walk in the electronics is shown in fig. 3 for a single NaI(Tl) detector. Even in this first order analysis a reasonable separation in time between γ-ray and neutron events in the scintillator is observed.

In conclusion we have investigated the timing characteristics of fairly large NaI(Tl) scintillators with fast photomultipliers. We find the time resolution sufficient to allow easy separation of neutrons from γ-rays by time-of-flight techniques.

This work was supported by the Nuclear Science Division of the U. S. Department of Energy under contract No. W-7405-ENG-48.

References

1. M. M. Aleonard, G. J. Wozniak, P. Glässel, M. A. Deleplanque, R. M. Diamond, L. G. Moretto, R. P. Schmitt and F. S. Stephens, Phys. Rev. Lett. 40 (1978) 622.

2. M. A. Deleplanque, I. Y. Lee, F. S. Stephens, R. M. Diamond and M. M. Aleonard, Phys. Rev. Lett. 40 (1978) 629.

3. A. Kerek, J. Kihlgren, Th. Lindblad, C. Pomar, J. Sztarkier, W. Walus, Ö. Skeppstedt, J. Białkowski, J. Kownacki, Z. Sujkowski and A. Zgliński, Nucl. Instr. and Meth. 150 (1978) 483.

4. C. Gerschel, M. A. Deleplanque, M. Ishihara, C. Ngô, N. Perrin, J. Péter, B. Tamain, L. Valentin, D. Paya, Y. Sugiyama, M. Berlanger and F. Hanappe, Nucl. Phys. A317 (1979) 473.

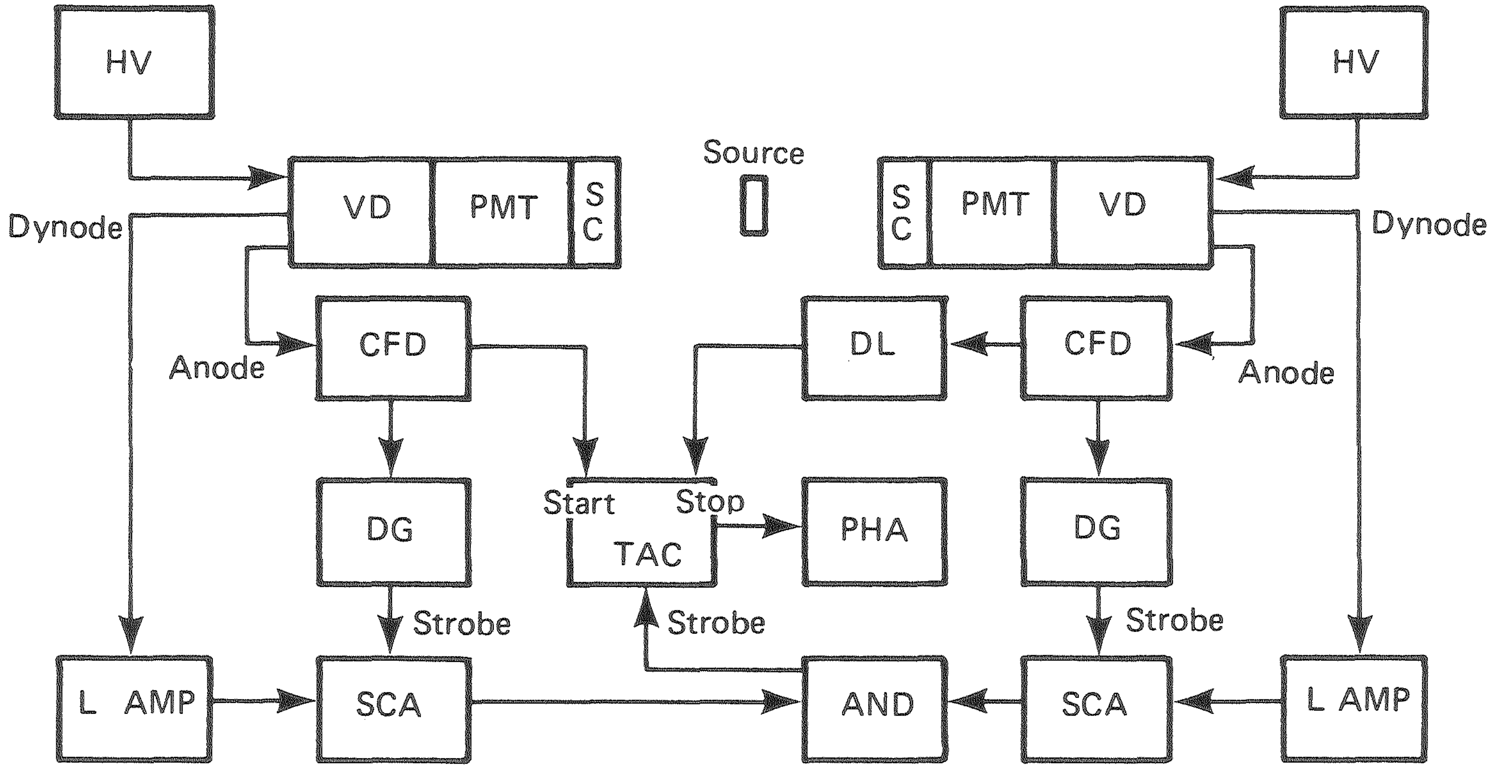
5. M. R. Maier and D. A. Landis, Nucl. Instr. and Meth. 117 (1974) 245.

Figure Captions

Fig. 1. Electronic setup for NaI(Tl) scintillator detector timing studies.

Fig. 2. Time spectrum for γ-γ coincidences detected in two NaI(Tl) scintillator detectors with fast photomultiplier tubes.

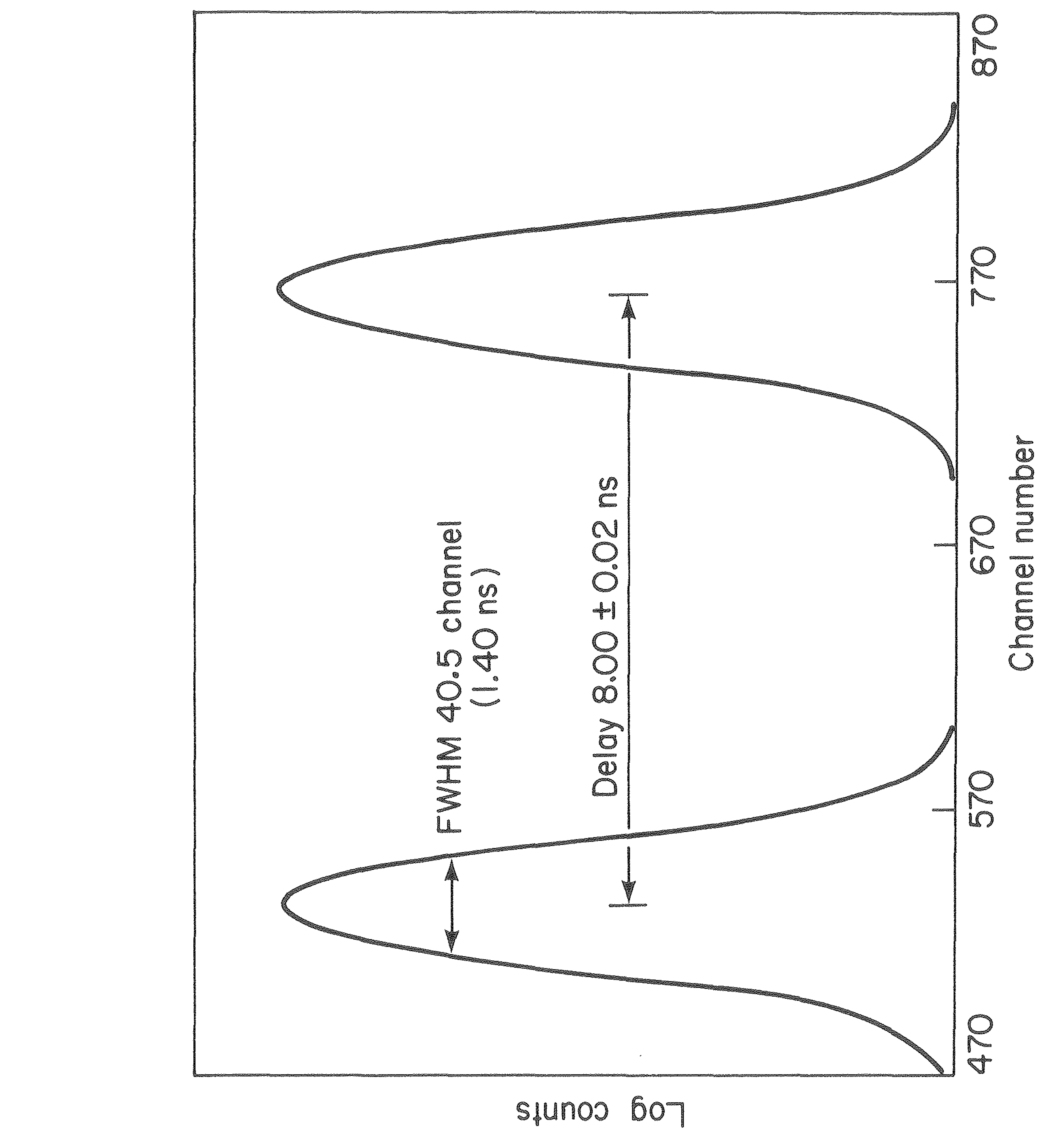
Fig. 3. Gated Z-γ TAC spectrum for 690 MeV ^{84}Kr + Ag reaction showing n-γ separation by time-of-flight with a 24 cm flight path.



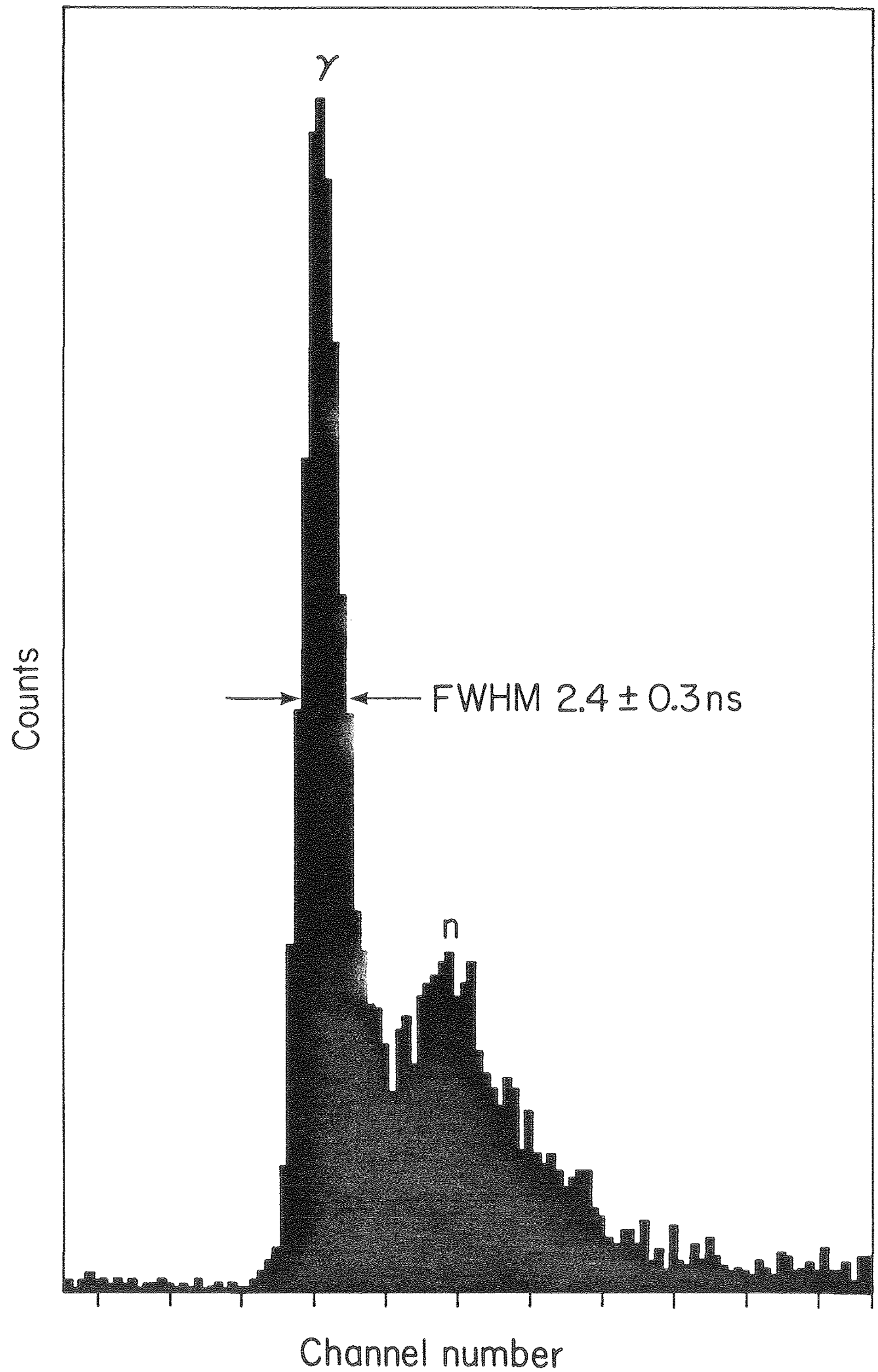
HV = High voltage
SC = NaI Scintillator
PMT = fast photomultiplier tube
VD = voltage divider
L AMP = linear amplifier
CFD = constant fraction discriminator

DL = delay
DG = delay gate
SCA = single channel analyzer
TAC = time - to - amplitude converter
AND = logic
PHA = pulse height analyzer

XBL 798 - 2408


FWHM 40.5 channel
(1.40 ns)
Delay 8.00 ± 0.02 ns
Log counts
470
570
670
770
870
Channel number

XBL 798 - 2409



XBL 798 - 2410