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Title: RESPONSE OF ALKALI HALIDE SCINTILLATORS TO NEUTRONS FROM 5 to 100 MeV

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Response of Alkali Halide Scintillators to Neutrons from 5 to 100 MeV

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ABSTRACT

The response of three alkali halide scintillators to neutrons in the range 5 to 100 MeV was investigated with the spallation neutron source at LAMPF/WNR. Scintillating crystals were NaI(Tl), KI(Tl) and CsI(Tl), each 2.5 cm in diameter and 1.2 cm thick. Pulse shapes that depend on particle type were observed for NaI(Tl) and CsI(Tl) but not for KI(Tl). Pulse height spectra for are reported as a function of neutron energy, and, where pulse shape discrimination was observed, for individual charged-particle groups.

I. INTRODUCTION

The response of scintillators to neutrons is needed in designing nuclear physics experiments, in nuclear technologies, in dosimetry applications, and in using the response to deduce reaction cross sections and charged-particle emission spectra. Both the pulse height spectra and possible pulse shape responses are needed for these applications. Previous works (for example, Refs. 1 - 10) have provided information on responses for single types of crystals or for individual incident neutron energies or for small neutron energy ranges. In this work, we perform a systematic study of three alkali halide scintillators, NaI(Tl), KI(Tl), and CsI(Tl), over a wide range of neutron energies from 5 to over 100 MeV. This work is part of a larger study, in progress, of the response of scintillators to fast neutrons.

II. EXPERIMENT

The LAMPF/WNR white neutron source[11] was used at a flight path of 41.39 meters and the scintillators were placed in the beam. To obtain reasonable counting rates, 35.6 cm of lead and 5 cm of polyethylene were inserted into the beam between the source and the detectors. This attenuation reduced the counting rate to a few events per macropulse (see Ref. 12) and eliminated "frame overlap," that is, events from neighboring micropulses. Because of the generally decreasing total cross section with neutron energy, however, lower energy neutrons were attenuated more than those of higher energy, and there were many events from neutrons above 100 MeV. Because many of these events are associated with energetic charged particles, most of which have ranges larger than the dimensions of the scintillators, data above 100 MeV were not analyzed but did contribute to dead-time of the electronics.

A fission counter was used to determine the flux spectrum with the unattenuated beam and corrections for attenuation by the lead and the polyethylene were made with well-known total cross sections.

The scintillators were typically 2.5 cm in diameter and 1.2 cm thick and were viewed by an RCA 8575 photomultiplier tube. The CsI(Tl) scintillator was new but the NaI(Tl) and KI(Tl) had been used in previous experiments.[5,10] The experimental arrangement is indicated in Fig. 1.

Standard electronics were used to analyze the signals. The pulse shape was characterized by a standard zero-crossing technique using a delay-line amplifier with 1 microsecond delay lines. Three parameters were recorded for each event: the time-of-flight to indicate the neutron energy, the pulse height, and the pulse shape. Data were acquired by the CAMAC-based acquisition system, XSYS.[13]

III. RESULTS

Pulse shape differences between electrons and heavy charged particles (protons, deuterons, and alpha particles) were observed in the NaI(Tl) and CsI(Tl) scintillators up to 100 MeV neutron energy but, in the KI(Tl) scintillator, no pulse shape discrimination was observed. In the first two, alpha particles could be distinguished from protons and deuterons, and, in CsI(Tl), there was further separation between protons and deuterons. Examples of pulse shape discrimination are shown in Fig. 2.

Pulse-height spectra were observed to increase as expected with increasing neutron energy. Representative spectra, with no cut on pulse shape, are shown in Fig. 3 for CsI(Tl). Pulse-height spectra for protons, deuterons and alpha particles in CsI(Tl) can be obtained due to the PSD characteristics of this material, in a manner similar to that reported by Bormann[3] over a narrow range of incident neutron energies.

A comparison of pulse height spectra for the three scintillators is given in Fig . 4. The deficit of pulses near channel 15 in CsI(Tl) reflects the Coulomb-barrier cutoff for charged particle spectra from (n,p) and (n,α) reactions.

IV. DISCUSSION

Pulse-shape discrimination is well known for NaI(Tl) and CsI(Tl) scintillators (e.g. Refs. 3 and 5). However only one group[9] has reported PSD for KI(Tl). Others have failed to observed PSD in this material. Thus our observation of PSD in NaI(Tl) and CsI(Tl) and not in KI(Tl) is consistent with most of the reported results. These PSD results are observed throughout this range of neutron energies, from 5 to 100 MeV.

As expected, the end points for pulse height spectra increase as the neutron energy increases throughout the region 5 to 100 MeV. The spectra in general show a decrease toward the endpoint. For pulse heights corresponding to charged-particle energies below the Coulomb barrier, a decrease in the spectra is observed.

The large volume of data obtained in the present measurements will be presented elsewhere.[14]

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Figure Captions:

Fig. 1. Experimental setup for scintillator response tests. Each scintillator is 2.5 cm in diameter, and 1.2 cm thick.

Fig. 2. Pulse shape versus pulse height for the three scintillators investigated. Good pulse shape discrimination is observed for NaI(Tl) and CsI(Tl) but not for KI(Tl).

Fig. 3. Comparison of pulse height responses for neutrons of various energies on CsI(Tl) scintillator.

Fig. 4. Comparison of pulse height spectra for the three scintillators at $E_n = 30$ MeV. The gains were matched only approximately. Note the deficit of pulses for CsI(Tl) around channel 15, a consequence of the Coulomb barrier cut-off of (n,p) and (n,α) spectra.

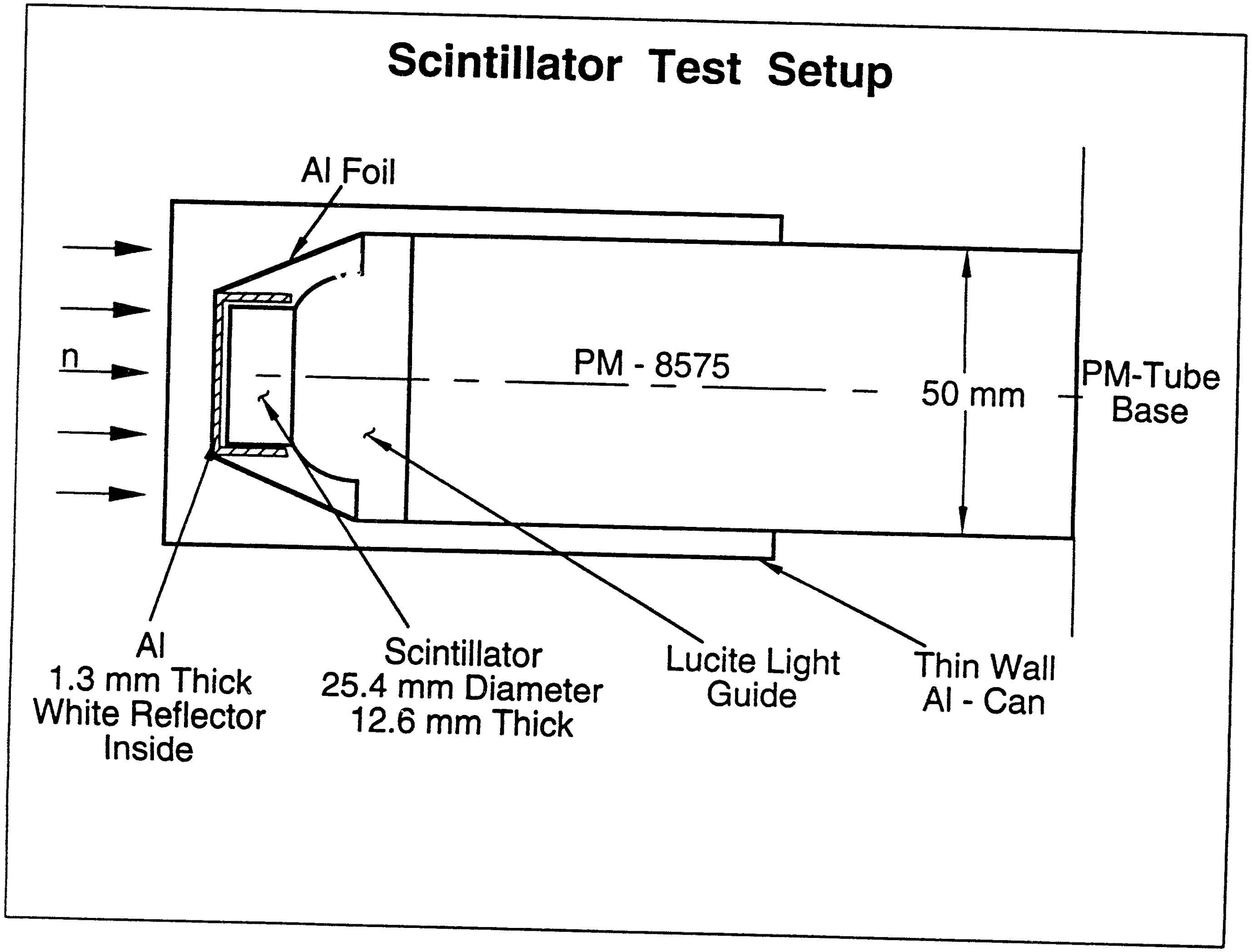
Scintillator Test Setup
Al Foil
n
PM - 8575
50 mm
PM-Tube Base
Al 1.3 mm Thick White Reflector Inside
Scintillator 25.4 mm Diameter 12.6 mm Thick
Lucite Light Guide
Thin Wall Al - Can

Figure 1

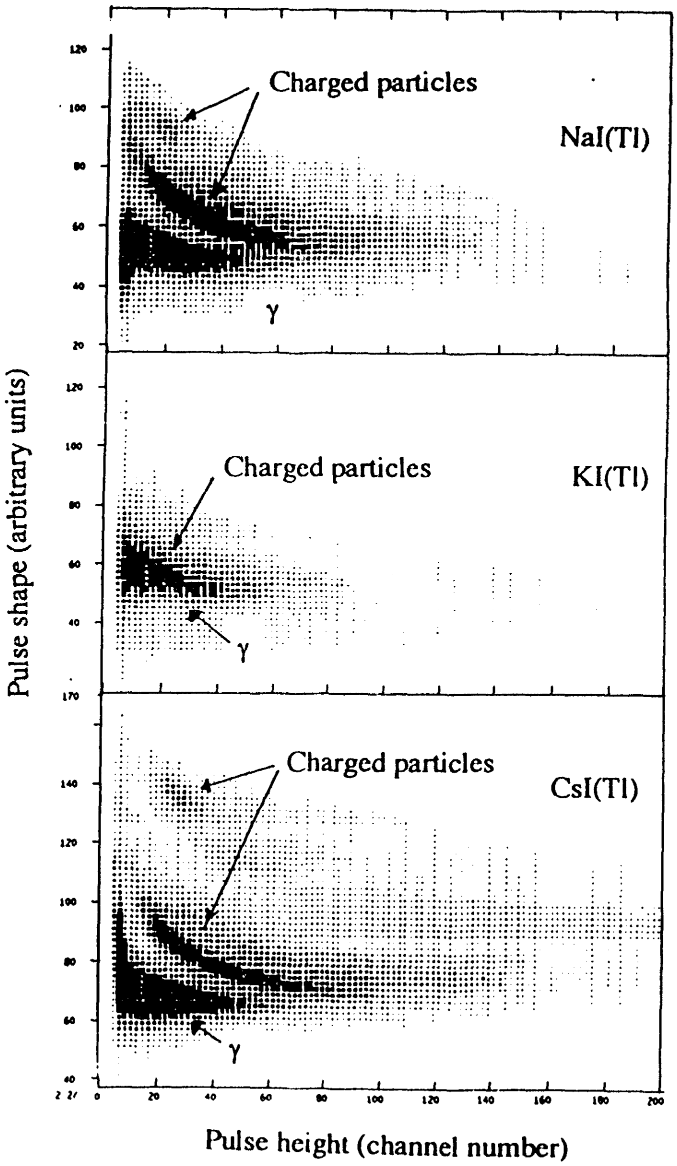
Charged particles
NaI(Tl)
γ
Charged particles
KI(Tl)
γ
Charged particles
CsI(Tl)
γ
Pulse shape (arbitrary units)
Pulse height (channel number)

Figure 2

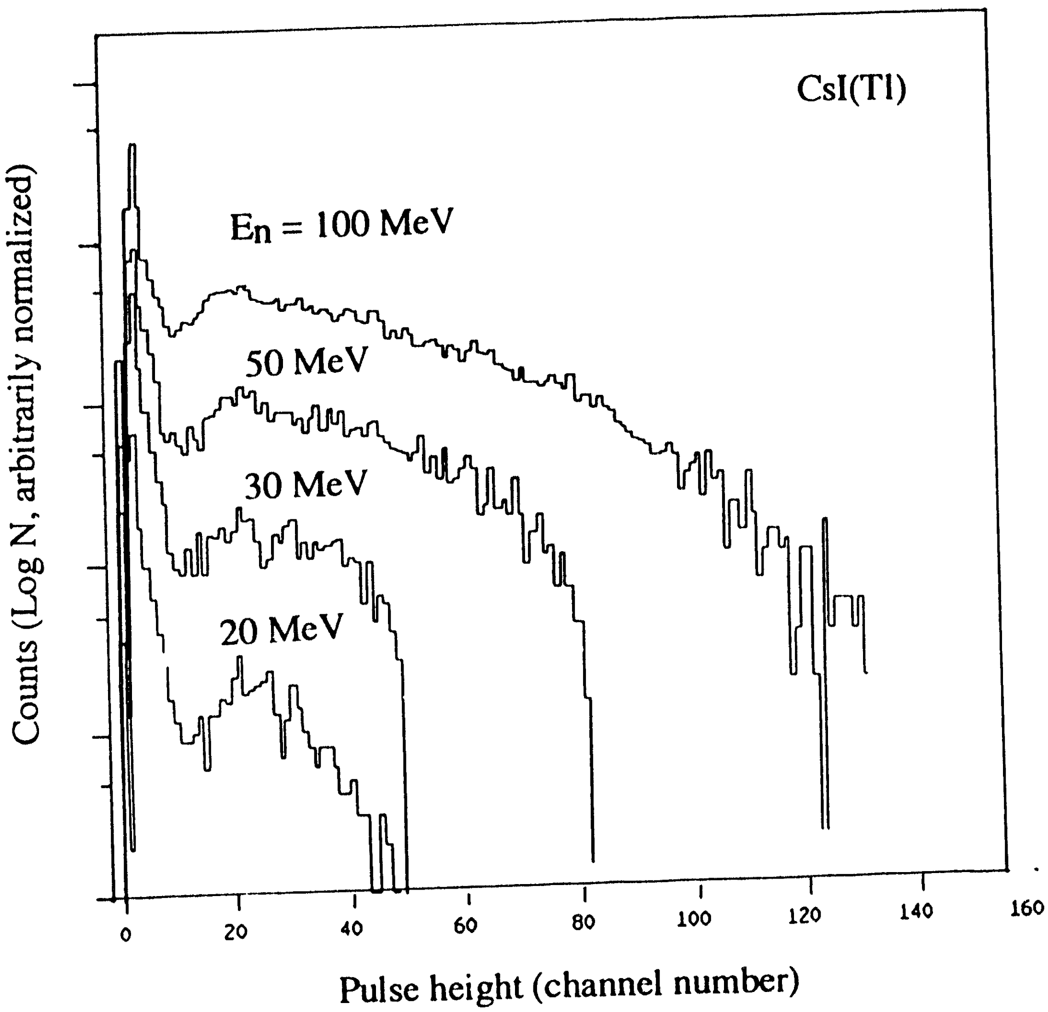
CsI(Tl)
En = 100 MeV
50 MeV
30 MeV
20 MeV
0
20
40
60
80
100
120
140
160
Pulse height (channel number)
Counts (Log N, arbitrarily normalized)

Figure 3

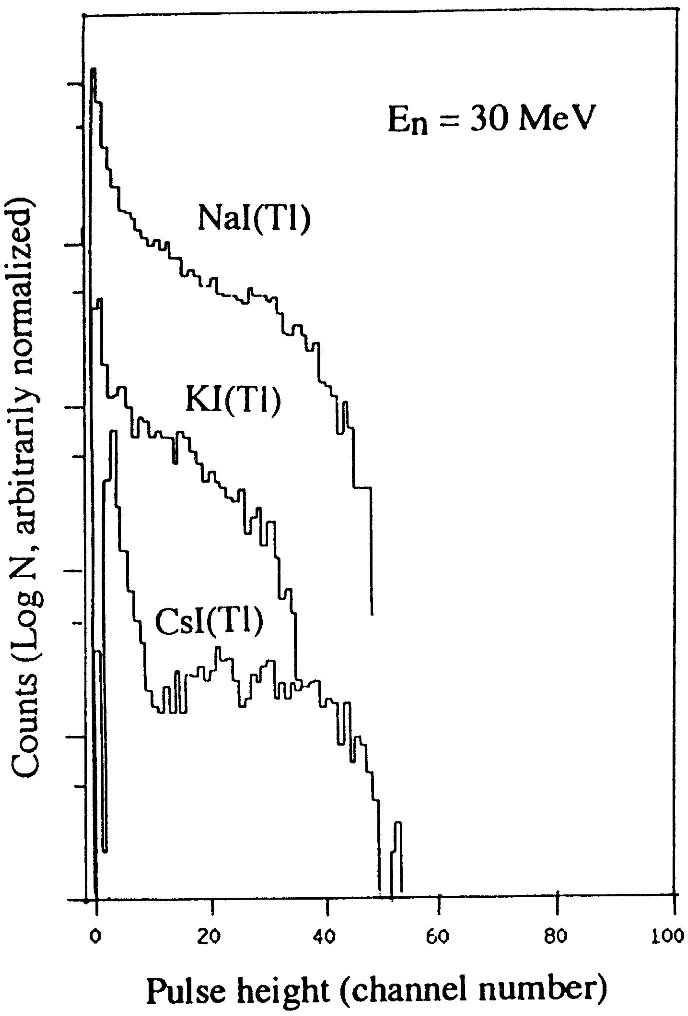
En = 30 MeV
NaI(Tl)
KI(Tl)
CsI(Tl)
Counts (Log N, arbitrarily normalized)
0
20
40
60
80
100
Pulse height (channel number)

Figure 4

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