A Study of Phoswich Detectors for Dosimetry Measurements

Esther M. Dönsdorf, S. Burmeister, B. Heber, C. Martin, D. Sie

University of Kiel/IEAP, 24098 Kiel, Germany
Outline

• Motivation

• Theoretical background
  • Detector principles
  • Scintillators
  • Photomultiplier (PMT)

• First preliminary results

• Future work
  • Electronics
Motivation

• Importance for Dosimetry

• Neutrons have a high impact on biological cells
  • There is a significant production of high energy secondary neutrons in the space craft material
  • These neutrons add a great amount to the dose equivalent

→ discrimination of neutrons and γ is needed

• Not possible with silicon telescope → underestimation of neutrons

• With phoswich: relatively easy discrimination between neutrons and γ is possible

• So far mostly liquid scintillators have been used to measure neutrons
Phoswich Detectors

• Two or more dissimilar scintillators are optically coupled to one photomultiplier

• By pulse shape discrimination the pulses from the two scintillators are separated
Scintillators

- **BC-400**
  - based on polyvinyltoluene, density: 1.032 g/cc
  - decay time: 2.4 ns
  - wavelength of max. emission: 423 nm

- **CsI(Na)**
  - high density (4.51 g/cm²) and high atomic number → high γ stopping power
  - decay time: 630 ns
  - Wavelength of max. emission: 420 nm
The Scintillators

- Crystals are wrapped in millipore and teflon tape
- To attach scintillator to window of PMT optical grease (BC-630) is used

Dimensions:
- CsI(Na) : 50 mm x 17 mm
- BC400 : 50 mm x 10 mm
Photomultiplier

- **test setup**: PMT R1924-01 (Hamamatsu)
  - Wavelength of maximum response: 420 nm ± 50 nm
  - Window diameter: 2.4 cm
  - Bias voltage: positive up to 2.5 kV
Electronics

- Socket contains resistor divider and preamplifier: output rise time $\leq 50$ ns
Experimental Setup

- The output pulse of the preamplifier is measured with an oscilloscope
Measurement with CsI(Na)

- Source: Cs137 \( \gamma \) with energy of 662 keV
Measurement with CsI(Na)

- Red: cosmic $\mu$
- Black: $\alpha$ from Am241
- Blue: $\gamma$ from Cs137

Volts vs. time / $\mu$s
Measurements with BC400

- Red: cosmic $\mu$
- Black: $\alpha$ from Am241
- Blue: $\gamma$ from Cs137

Volts vs. time / ns
Measurements with BC400

- Red: cosmic µ
- Black: α from Am241
- Blue: γ from Cs137

Volts

time / ns
Quenching in Plastic Scintillators

- de-excitation within the scintillator is non-radiative
- Instead of the production of light for example heat is generated

→ the light output of the crystal is not equivalent to the energy of the incident particle anymore

(Muga and Bridges, 1976)
### Slew rates of single pulses

- **Slew rates**
  - Pulses from BC400 much faster than CsI(Na)
  - For both scintillators
    - Smallest slew rate for γ
    - Largest slew rate for μ

<table>
<thead>
<tr>
<th>scintillator</th>
<th>CsI(Na) [mV/µs]</th>
<th>BC400 [mV/µs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ</td>
<td>10.7</td>
<td>167.2</td>
</tr>
<tr>
<td>α</td>
<td>34.86</td>
<td>332.2</td>
</tr>
<tr>
<td>μ</td>
<td>352.7</td>
<td>1646</td>
</tr>
</tbody>
</table>
**Future Work**

- Need to use faster preamplifier to read out the plastic scintillator properly (maybe from Ortec)

- look at the signal from the anode directly $\rightarrow$ no alteration of the signal by the preamplifier

  $\rightarrow$ linear or integrating preamplifier

- study other scintillator materials

- look at two scintillators together with one PMT
Electronics

PMT

HV

preamplifier

amplifier

BC400

CsI(Na)

Fast gate

Slow gate

Volts

time

ADC

Slow gate

Fast gate

ADC
Summary

• It is possible to distinguish between neutrons and $\gamma$ using a phoswich detector

• preliminary results
  • pulses from BC400 and CsI(Na) can be separated because of their different decay times
  • in both scintillators: $\mu$ pulses are the fastest and $\gamma$ pulses are the slowest

• significant quenching in plastic scintillator

• goal: build a phoswich detector which is capable of measuring charged as well as neutral particles plus distinguish between neutrons and $\gamma$