Characterization of the Anisotropic Scintillation Response of Stilbene to Neutrons

R. A. Weldon, J. M. Mueller, J. K. Mattingly
Department of Nuclear Engineering, North Carolina State University
PI: Prof. John Mattingly, email: john_mattingly@ncsu.edu
Consortium for Verification Technology (CVT)

Introduction

• New crystal growth techniques have expanded the use of stilbene for radiation detection applications
  • Crystalline organic scintillator
  • Excellent PSD characteristics
• Stilbene has an anisotropic scintillation response to neutrons dependent on the proton recoil direction w.r.t. the crystalline axis
• Research goals:
  • Obtain a high precision light output characterization over a wide energy range (500 keV – 10 MeV)
  • Measure proton recoils over a full hemisphere of the crystal over this range
  • This will expand the current response characterization for stilbene from 2 energies to over 10 energies
• Measurements presented here: ratios of maximum to minimum light outputs at 6 distinct energies between 1.3 MeV and 10 MeV

Experiment Setup

• Measure proton energy deposition in the stilbene using known neutron beam energies and n-p scatter kinematics:
  \[ E_p = E_n \sin^2 \theta \]
  • Identify neutron scatter angle \(\theta\) by backing detector that is triggered in coincidence with the stilbene
• 14 EJ-309 backing detectors
• Neutron beam: d(d,n) reaction using the tandem accelerator at TUNL
• Protons recoil at 90° relative to the scatter direction of the neutron (e.g. \(\theta_n = \theta_p = 45°\), \(\theta_n + \theta_p = 90°\))
• Rotate stilbene on rotational stage to change the direction of the proton recoils relative to the crystalline axes

Measurements

• Goal: measure light output along major axes (a, b, c’)
• 11.33 MeV neutron beam
• Proton recoil energy range: 1.3 MeV– 10 MeV
• Measured 3 separate 1cc stilbene crystals:
  (1) c’ vertical, measurements in a-b plane
  (2) b vertical, measurements in a-c’ plane
  (3) a vertical, measurements in b-c’ plane
• Ratio of maximum light output to minimum light output for the b vertical crystal are presented here

Results

• Plot: ratio of maximum light output to minimum light output vs proton recoil energy (\(A_L = \) maximum light output / minimum light output)
• Red points are the result of our measurement, blue points were measured by Brooks\(^1\), green points were measured by Schuster\(^2\)

<table>
<thead>
<tr>
<th>Proton recoil energy (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3 MeV</td>
</tr>
<tr>
<td>2.2 MeV</td>
</tr>
<tr>
<td>3.3 MeV</td>
</tr>
<tr>
<td>4.4 MeV</td>
</tr>
<tr>
<td>5.5 MeV</td>
</tr>
<tr>
<td>6.6 MeV</td>
</tr>
<tr>
<td>7.7 MeV</td>
</tr>
<tr>
<td>8.8 MeV</td>
</tr>
<tr>
<td>9.9 MeV</td>
</tr>
<tr>
<td>10.0 MeV</td>
</tr>
</tbody>
</table>

Conclusions and Future Work

• Measured the light output in the major axes planes using 3 stilbene crystals at 6 proton recoil energies
• Ratios of maximum to minimum light output are consistent with results published by previous authors
• Future work:
  • Compare light output between crystals (different crystals and different PMTs)
  • Return to TUNL and measure the scintillation response over a full hemisphere

References