Timing and Energy Response of Six Prototype Scintillators

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Motivation (1)

- Standard PET uses line-of-response (LOR) to determine activity distribution
- The use of time of flight (TOF) information reduces correlations
- TOF reconstruction algorithms take advantage of local positioning to improve sensitivity
Clinical Advantage of TOF-PET

Example: Colon cancer images for a heavy weight patient

Improvement in lesion detectability with TOF

Improving timing capabilities will extend TOF benefits to all patients
Motivation (2)

- New scintillators are interesting for future TOF-PET scanners
- Understanding differences between benchtop measurements and scanner performance
- Energy and timing measurements are necessary for the planning of future scanners
Scintillator Samples from RMD

- YI$_3$ (2% Ce)
- LuGdI$_3$ (2% Ce)
- LuI$_3$ (2, 5, 10% Ce)
- CeBrCl$_3$
- Samples are hygroscopic, and packaged inside glass window
- Variations in packing affect light output
- LaBr$_3$ (5% Ce) crystal from Saint-Gobain used as reference
## Timing and Energy Comparison

<table>
<thead>
<tr>
<th>Sample</th>
<th>Resp (%)</th>
<th>$E_{FWHM}$ (%)</th>
<th>$T_{FWHM}$ (ps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LaBr$_3$ (5% Ce)</td>
<td>100</td>
<td>4.4</td>
<td>160</td>
</tr>
<tr>
<td>LuI$_3$ (2% Ce)</td>
<td>65</td>
<td>8</td>
<td>178</td>
</tr>
<tr>
<td>CeBrCl$_3$</td>
<td>58</td>
<td>10</td>
<td>159</td>
</tr>
<tr>
<td>LuGdI$_3$ (2% Ce)</td>
<td>52</td>
<td>54</td>
<td>253</td>
</tr>
<tr>
<td>YI$_3$ (2% Ce)</td>
<td>49</td>
<td>18</td>
<td>201</td>
</tr>
<tr>
<td>LuI$_3$ (5% Ce)</td>
<td>40</td>
<td>19</td>
<td>204</td>
</tr>
<tr>
<td>LuI$_3$ (10% Ce)</td>
<td>35</td>
<td>21</td>
<td>203</td>
</tr>
</tbody>
</table>
Energy Linearity Setup

Also test $^{133}$Ba, $^{137}$Cs, and $^{57}$Co

22Na sample

H4968

ADC
Gate
CAMAC

PC

CFD
Fitting Multiple $^{133}\text{Ba}$ Peaks

- Requires good energy resolution
- Easy with LaBr$_3$ ($4.4\%$ FWHM), very difficult beyond $10\%$ $E_{\text{res}}$
- If peaks are not distinguishable used $\sim 294$ and $356\text{keV}$
LaBr₃ Energy Proportionality

- Eight energy points used in fit
- Data agrees with a linear fit within uncertainties, but the intercept is not at zero
Energy Proportionality

- Uncertainty due to changes in pedestal, larger fraction at lower ADC values
- LaBr$_3$ is proportional in the range studied
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Further Considerations for TOF-PET

The image quality, lesion detectability, and quantification possible on a clinical scanner are dependent upon each of these properties.
Summary

• LuI$_3$ and CeBrCl$_3$ are already interesting possibilities for future TOF-PET scanners
  – LuI$_3$ has a higher stopping power than LaBr$_3$
  – The PMT used in this study was not well matched to the frequency spectrum of LuI$_3$. A better match would lead to increased light detection/energy resolution

• Crystal development and testing continues
  – Multiple samples and long crystals
  – Development of detector arrays