R&D on CsI(Tl) crystals + LAAPD at USC
Activities report

Martín Gascón

GENP - Grupo Experimental de Núcleos y Partículas
Departamento de Física de Partículas
Universidade de Santiago de Compostela

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1. Testing the electronic setup
2. Temperature and voltage dependence of LAAPDs
3. Comparison between APDs and PIN Diodes
4. Non-Uniformity measurements
Test on the electronic setup
Electronic chain dependence

Crystal + LAAPD
- CsI(Tl) crystals of 1 cm² cross-section from Saint Gobain
- LAAPD S8664-1010 from Hamamatsu

Best results after optimising electronic parameters (Cs-137 @ 662 keV)

<table>
<thead>
<tr>
<th>Place</th>
<th>Preamplifier</th>
<th>Amplifier</th>
<th>shap. Time</th>
<th>1 cm</th>
<th>10 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santiago</td>
<td>Ortec 142</td>
<td>Canberra 2022</td>
<td>4 μs</td>
<td>4.57 ± 0.12</td>
<td>4.84 ± 0.12</td>
</tr>
<tr>
<td>GSI (Jul-Aug)</td>
<td>Canberra 2001</td>
<td>Ortec 572</td>
<td>6 μs</td>
<td>4.55 ± 0.09</td>
<td>4.87 ± 0.08</td>
</tr>
<tr>
<td>bibliography</td>
<td>-</td>
<td>-</td>
<td>6 μs</td>
<td>4.8</td>
<td>-</td>
</tr>
</tbody>
</table>

- presented in the IEEE - 9th. International congress on Inorganic Scintillators and Their Applications in Winston-Salem (USA) during June 2007 and accepted for publication
Temperature dependence of LAAPDs on CsI(Tl) crystals

Experimental setup

Features

- The detector is electrically isolated by a grounded Faraday box
- The detector and Preamplifier are placed in a metallic box with a humidity control system
- The system is temperature monitorised
Gain dependences on temperature and voltage for Crystal and LAAPD

### Remarks

- CsI(Tl) works at room temperature (cryostat not required!)
- \((dG/dV)_{APD} = 3\% / V\) (from Hamamatsu @ G=50)
- \((dG/dT)_{APD} = -2\% / ^\circ C\) (from Hamamatsu @ G=50)
Gain dependences on temperature and voltage
for Crystal and LAAPD

Preliminary results obtained with 1 cm$^3$ CsI(Tl) + S8664-1010

- $(dG/dV)_{APD+Crystal} \sim 2.37\% / V$
- $(dG/dT)_{APD+Crystal} \sim -1\% / ^\circ C$
- A locally linear gain function, related to both T and V, can be obtained
- Temperature drifts are very slow
- Conclusion: Temperature monitorisation will allow gain corrections

\[
\begin{align*}
\chi^2 / ndf & \quad 2008 / 3 \\
p_0 & \quad -4.599e+04 + 121.1 \\
p_1 & \quad 136.3 \pm 0.3741
\end{align*}
\]

\[
\begin{align*}
\chi^2 / ndf & \quad 557 / 23 \\
p_0 & \quad 479 \pm 7.346 \\
p_1 & \quad -36.4 \pm 0.3008
\end{align*}
\]
Comparison between APDs and PIN Diodes

Shaping Time and Energy Resolution

3 µs and 6 µs are good compromise in both cases

Pin Diode has worse energy resolution, but similar trend for energies above 500 keV

Energy resolution with LAAPD is 40 % better than with Pin Diodes

We got a noise level for Pin Diodes around 300-400 keV
Non-Uniformity measurements

Non-Uniformity definitions

Non Uniformity in the Ligth Output

- is one of the factors worsening the energy resolution
- at least, two methods are commonly used to characterise it: G and $\delta$

Definition of $G$

$$G = \frac{LO_{\text{max}} - LO_{\text{min}}}{LO_{\text{med}}}$$  \hfill (1)

$LO = $ Light Output (Photopeak channel)

Definition of $\delta$

$$\frac{LO}{LO_{\text{med}}} = 1 + \delta \left( \frac{x - x_{\text{med}}}{x_{\text{med}}} \right)$$  \hfill (2)

$x = $ measured position of the crystal

Notes

- $\delta$-value is independent of the number of measured points, but G is not
- infinite number of measured points means $G = 2 \cdot \delta$
- Example:
  - For a 10 cm length crystal, measuring 9 points every 1 cm, one gets $G = 1.6 \cdot \delta$

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Non-Uniformity measurements

Experimental setup

Features

- 5 cm thick lead blocks were used as collimator, 5 cm apart from the crystal.
- 10 cm length crystal coupled to a PMT and also an APD
- 1.33 MeV photopeak from a Co-60 source used for the test
Non-Uniformity measurements
10 cm CsI(Tl) + APD + PMT

Results
- G = 16.7 %; \( \delta = 9.28\% \) for 10 cm CsI(Tl) + HAMA
- G = 9.6 %; \( \delta = 5.33\% \) for 10 cm CsI(Tl) + XP1918

S8664 -1010 Hamamatsu
PMT XP1918 Photonis
Non-Uniformity measurements
10 cm CsI(Tl) + APD + PMT

Remarks

- Comparing the APD with a normalised PMT curve (left plot)
- Half-summing the response of both (right plot)
- The behaviour of APD and PMT is not symmetrical for gammas impinging close to the entrance windows
Energy resolutions below 5 % at 662 keV for CsI(Tl) (1x1x10 cm + LAAPD) are obtained with different electronic setups

- Optimum temperature operation for CsI(Tl) crystals is 20-40°C (cryostat not required!)

- Keeping the temperature stable within ± 2 °C and the bias voltage within ± 1.5 V, the gain drifts can be off-line corrected provided that the temperature and the voltage are continuously monitorised.

- Pin Diodes work at lower bias voltage but their noise level is very high! ⇒ there is a limitation for the events hitting several crystals (add-back)

- Pin Diodes present lower energy resolution than APDs (∼ 7 % @ 662 keV)
Conclusions

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H. Alvarez−Pol et al. A first proposal for the geometry of the Total Absorption Calorimeter design at R3B. Internal Note: R3B_CAL_01/05. http://www.usc.es/genp/


Hamamatsu Photonics: Photomultiplier Tubes and Related Products
