CVT Workshop

*October 31 – November 1, 2018*

Further Advances in Modern Radioxenon Detector Design

*Steven A. Czyz, Abi T. Farsoni, Harish R. Gadey, Kacey D. McGee*

*Oregon State University*

*Date of presentation (11/01/2018)*
Introduction and Motivation

- Clandestine nuclear threats
  - Atmospheric radioxenon detection
  - 4 isotopes ($^{131m}\text{Xe}$, $^{133}\text{Xe}$, $^{133m}\text{Xe}$, $^{135}\text{Xe}$)
- International Monitoring System (IMS)
  - Beta-Gamma Coincidence
Mission Relevance

- Enhance US verification and monitoring capabilities
  - Nuclear detonations
- Improve the state-of-the-art
  - New technologies
    - Modern detectors/electronics
  - Reduces cost and complexity
  - High performance
- CVT Impact
PIPS-CZT & DPP8

- Four independent detecting bodies
  - Electron detection: PIPSBox
    - Two Passivated Implanted Planar Silicon (PIPS) wafers
  - Photon detection: 2 x Coplanar CZT
- Eight-Channel Digital Pulse Processor (DPP8)
  - Multiple independent channels
  - Field-Programmable Gate Array
  - Real-time coincidence identification
PIPS-CZT & DPP8

250 keV $\gamma \times$ 0-910 keV $\beta$

$^{135}$Xe

$^{133/133m}$Xe

81 keV $\gamma$ & 30 keV X-Ray $\times$ 0-346 keV $\beta$

30 keV X-Ray $\times$ 129 keV C.E.

30 keV X-Ray $\times$ 199 keV C.E.

Radiation | % FWHM | % FWHM (plastic)
---|---|---
129 keV C.E. | 12.5%-14.3% | 23.7%
199 keV C.E. | 8.8%-9.1% | 23.3%
30 keV X-Ray | 30%-35% | |
81 keV Gamma | 12.2% | |
250 keV Gamma | 5.1% | |
Memory Effect: 0.257% ± 0.034%
## PIPS-CZT & DPP8

<table>
<thead>
<tr>
<th>Detector</th>
<th>Tail/Total</th>
<th>Peak/Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIPS1</td>
<td>74.1%</td>
<td>25.9%</td>
</tr>
<tr>
<td>PIPS2</td>
<td>71.3%</td>
<td>28.7%</td>
</tr>
<tr>
<td>PIPS Summed</td>
<td>37.8%</td>
<td>62.2%</td>
</tr>
</tbody>
</table>

- Further backscatter reduction
  - Preamplifier
  - Statistical Methods (Sandia)
PIPS-CZT & DPP8

99.35% background rejection rate (single events/noise)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>MDC (simulated $\varepsilon_{\beta\gamma}$)</th>
<th>MDC (experimental $\varepsilon_{\beta\gamma}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{131m}$Xe</td>
<td>$0.443 \pm 0.100$</td>
<td>$1.678 \pm 0.457$</td>
</tr>
<tr>
<td>$^{133m}$Xe</td>
<td>$0.270 \pm 0.137$</td>
<td>$1.080 \pm 0.566$</td>
</tr>
<tr>
<td>$^{133}$Xe</td>
<td>$0.914 \pm 0.079$</td>
<td>$3.126 \pm 0.528$</td>
</tr>
<tr>
<td>$^{135}$Xe</td>
<td>$6.166 \pm 0.441$</td>
<td>$7.570 \pm 1.249$</td>
</tr>
</tbody>
</table>
Moving Forward -> Transitions

- PIPSBox + SrI₂(Eu) + SiPM
  - High resolution
  - Rapid response time
  - Higher efficiency
  - Testing (PNNL)

- CZT + Stilbene + SiPM
  - Better electron resolution
  - Low/no memory effect
Conclusion

• Deter/detect undeclared nuclear activities (CTBTO/IMS)
  • New technologies/methods for atmospheric radioxenon detection
• PIPS-CZT Prototype
  • Low (~0.25%) memory effect, high (99.4%) background rejection
  • High resolution (~9% for 199 keV electrons, 12.2% for 81 keV photons)
  • Backscatter, MDC, background counts, and noise
• DPP8
  • Real-time coincidence identification
• Future Efforts
  • Better backscatter reduction via hardware and algorithms
  • SrI₂(Eu) + SiPMs + PIPSBox, Stilbene + SiPMs + CZT
  • PNNL work
The Consortium for Verification Technology (CVT) would like to thank the NNSA and DOE for the continued support of these research activities.

This work was funded by the Consortium for Verification Technology under Department of Energy National Nuclear Security Administration award number DE-NA0002534