

# New Detectors for Gamma and Neutron Studies

## DOE SBIR Phase II

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# Outline

- **Requirements for Gamma Ray & Neutron Scintillators**
- **New elpasolite scintillators:**
  - $\text{Cs}_2\text{LiYCl}_6:\text{Ce}$  (CLYC),
  - $\text{Cs}_2\text{LiLaCl}_6:\text{Ce}$  (CLLC)
  - $\text{Cs}_2\text{LiLaBr}_6:\text{Ce}$  (CLLB)
- **RMD Corporate Background and Commercialization**

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# Requirements for Scintillators

## Gamma Ray

- High Energy Resolution
- High Timing Resolution
- High Light Yield
- High Proportionality
- High Efficiency for Gamma-Rays
- Fast Response
- Good Spectral Match with Optical Detectors
- Low Cost

## Neutron

- High Efficiency for Neutrons
- High Light Yield
- Good Gamma Rejection

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# Properties

	<b>Cs<sub>2</sub>LiLaCl<sub>6</sub>:Ce CLLC</b>	<b>Cs<sub>2</sub>LiLaBr<sub>6</sub>:Ce CLLB</b>	<b>Cs<sub>2</sub>LiYCl<sub>6</sub>:Ce CLYC</b>
<b>Density, g/cm<sup>3</sup></b>	<b>3.5</b>	<b>4.2</b>	<b>3.3</b>
<b>Emission, nm</b>	<b>290<sup>CVL</sup>, 400<sup>Ce3+</sup></b>	<b>410<sup>Ce3+</sup></b>	<b>290<sup>CVL</sup>, 390<sup>Ce3+</sup></b>
<b>Decay time, ns</b>	<b>1<sup>CVL</sup>, 60, ≥ 400</b>	<b>55, ≥270</b>	<b>1<sup>CVL</sup>, 50, ~1000</b>
<b>Max. light yield, ph/MeV</b>	<b>~ 35,000</b>	<b>~ 55,000</b>	<b>~ 20,000</b>
<b>Light yield, ph/n</b>	<b>~ 110,000</b>	<b>~ 180,000</b>	<b>~ 70,000</b>
<b>GEE, MeV</b>	<b>~3.1</b>	<b>3.2</b>	<b>~3.5</b>
<b>Best ER @662 keV</b>	<b>3.4%</b>	<b>2.9%</b>	<b>3.6%</b>
<b>PSD</b>	<b>Very Good</b>	<b>Possible</b>	<b>Excellent</b>

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# Performance Summary



CLYC



CLLC



CLLB

- High light yield
  - 70,000 to 180,000 ph/neutron;
  - 20,000 to 60,000 ph/MeV
- High gamma equivalent  $\geq 3$  MeV
- High energy resolution –  
as high as 3% FWHM @ 662 keV
- Pulse height discrimination
- Pulse shape discrimination
- Cubic structure

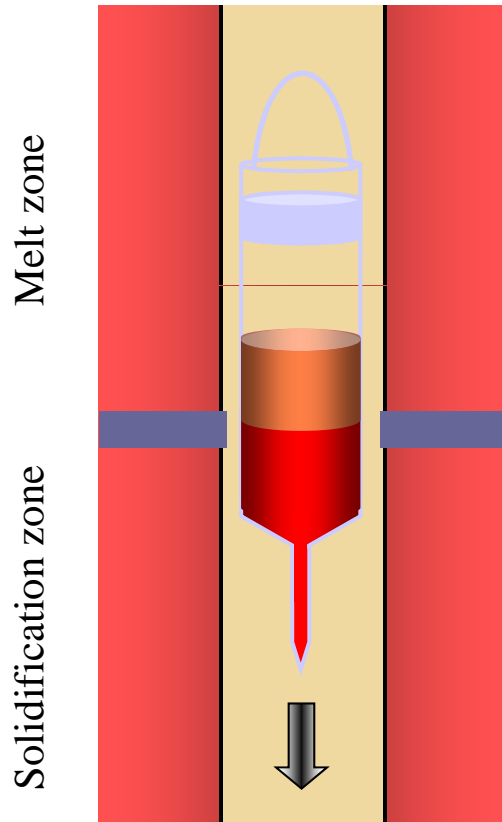
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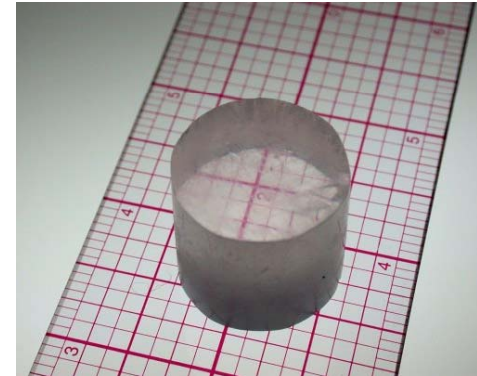
# Bridgman Grown Crystals



Ø1 in CLLC



Ø1 in CLYC



Ø2 in CLYC



Ø1 in CLLB



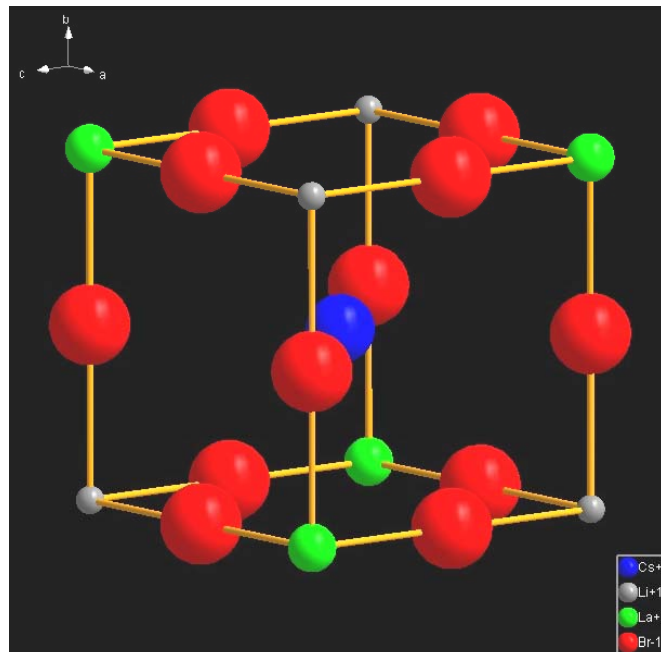
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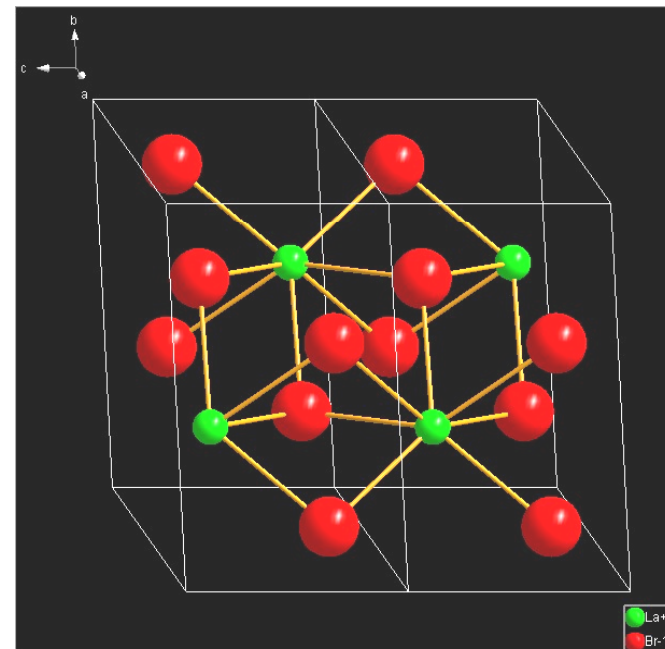
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# Cs<sub>2</sub>LiLaBr<sub>6</sub> (CLLB) vs. LaBr<sub>3</sub> Structure

## Potentially Easier to Scale Up



**CLLB - cubic**



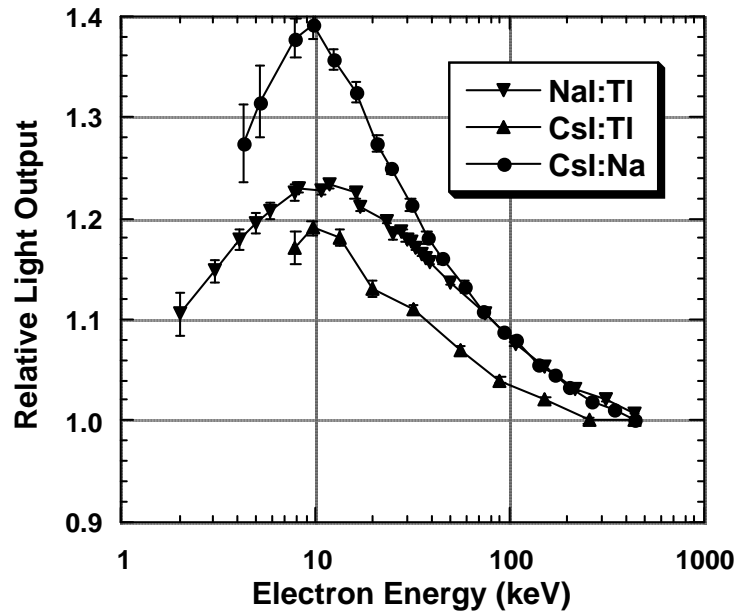
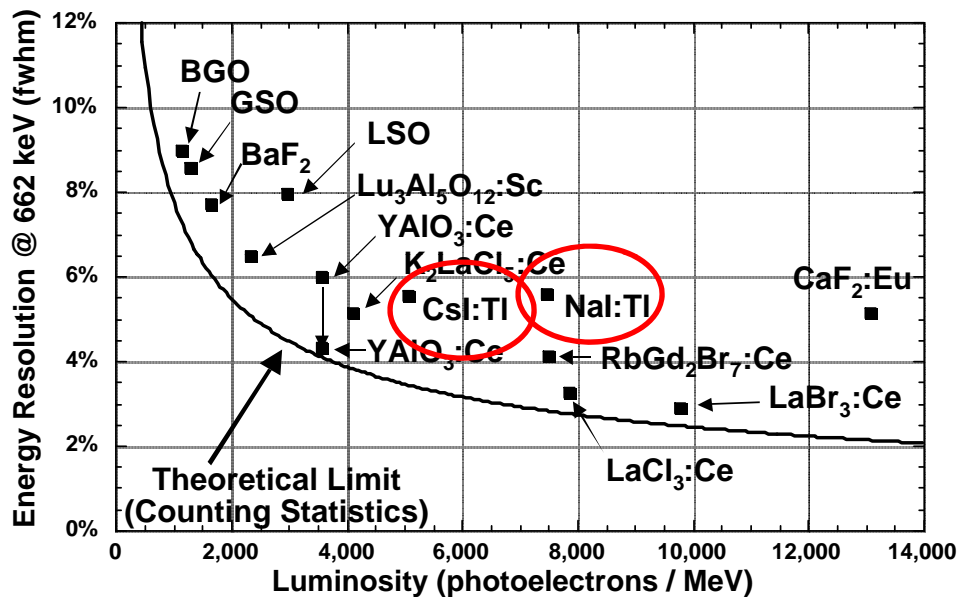
**LaBr<sub>3</sub> - hexagonal**

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# Proportionality and Its Implications



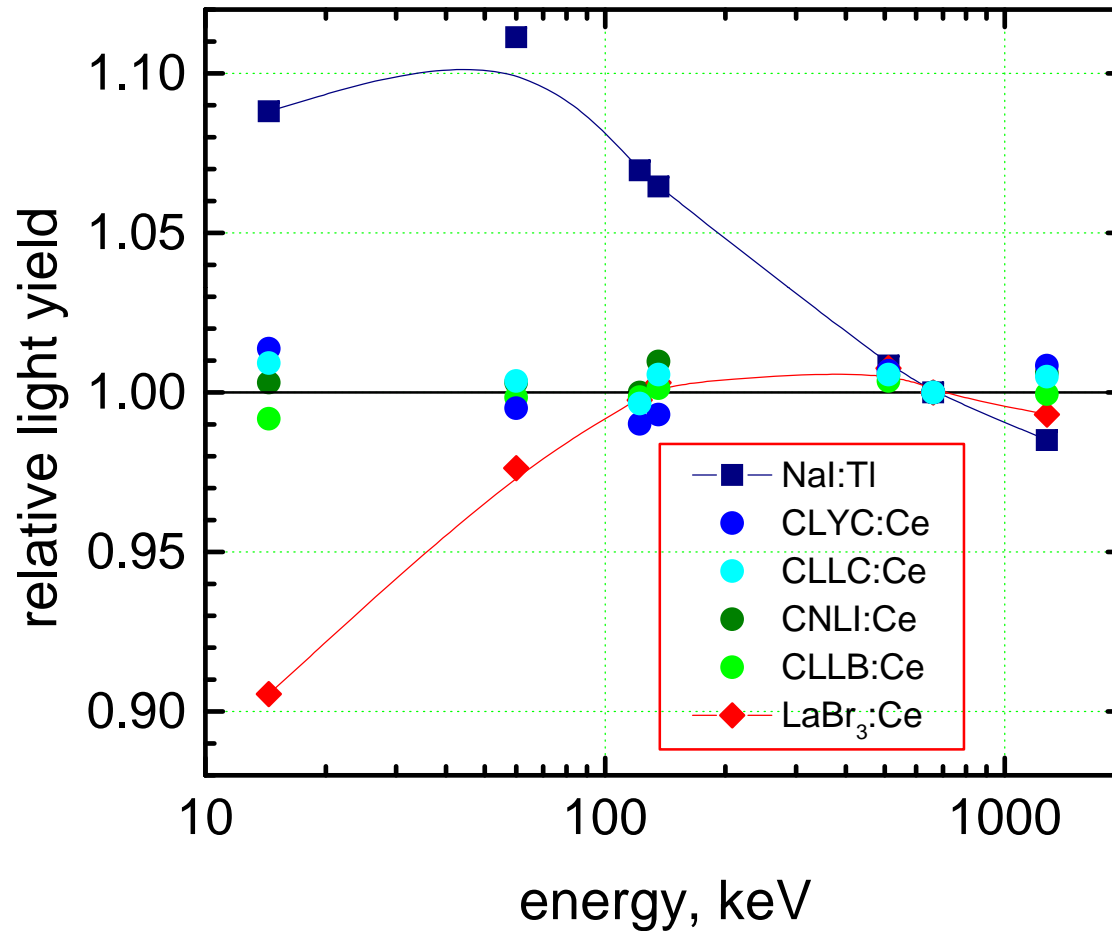
W.W. Moses, "Current trends in scintillator detector and materials", Nucl. Instr. and Meth. A 487 (2002) 123

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# Proportionality of Elpasolites

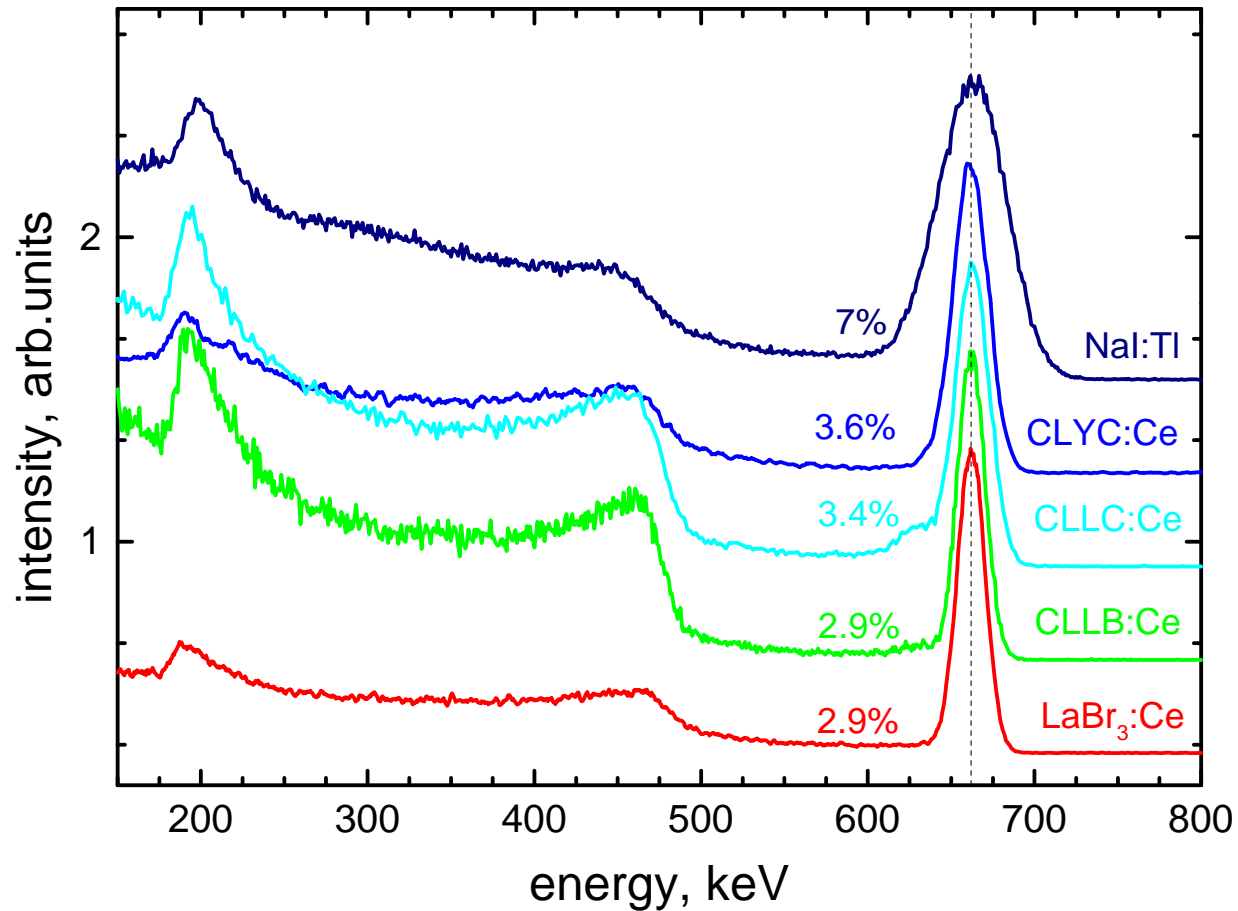


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# Energy Resolution of Elpasolites

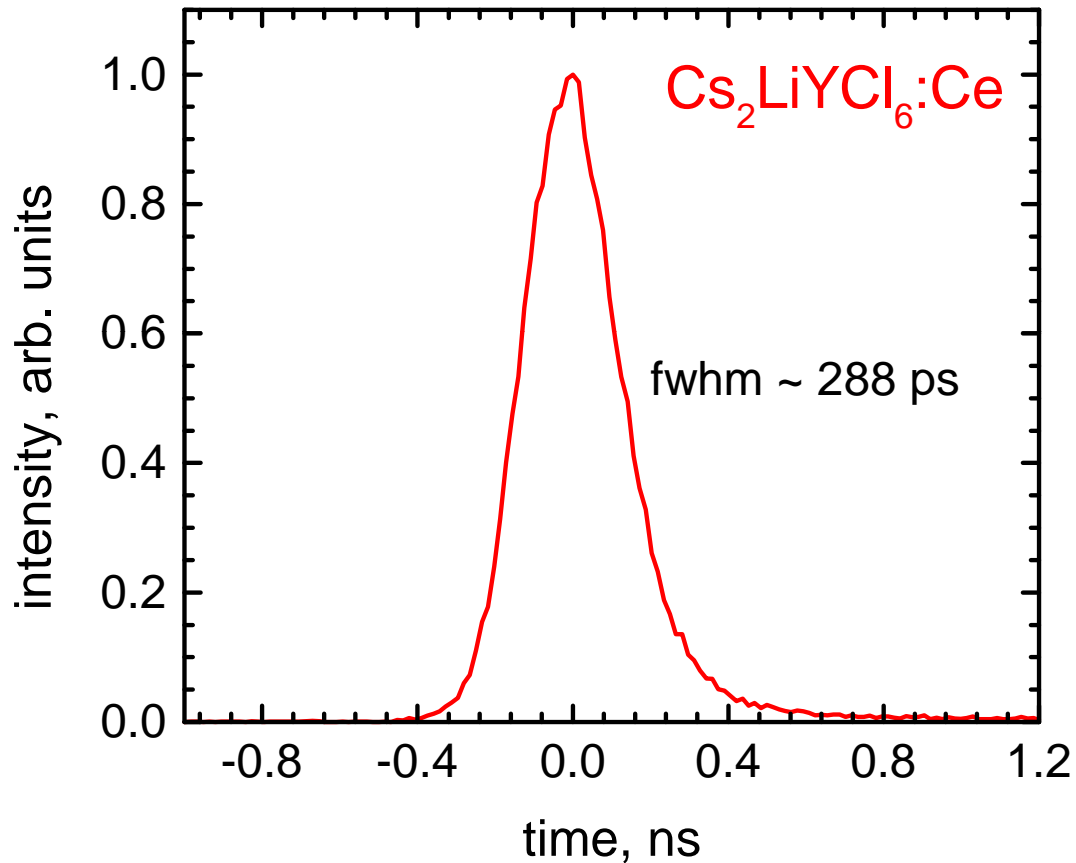


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# Timing Resolution



**CLYC - BaF<sub>2</sub>**

**511 keV**

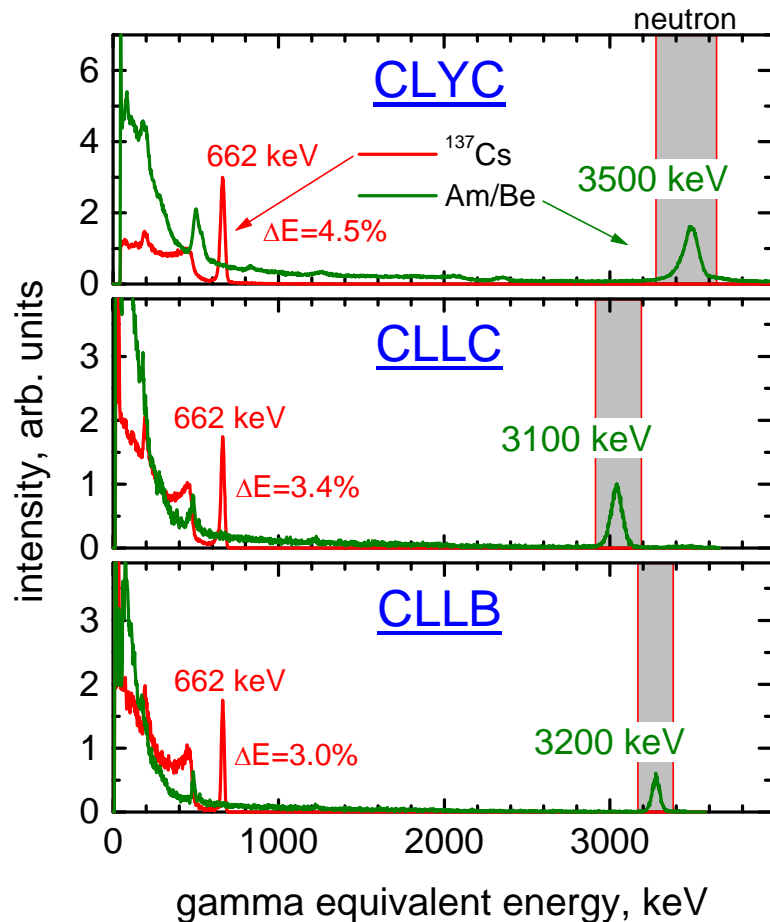
**Courtesy of UMass, Lowell**

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# Thermal Neutron Detection



- High Gamma Equivalent Energy
- High energy resolution
- Single full energy peak
- Pulse Height Discrimination



Q-value = 4.8 MeV

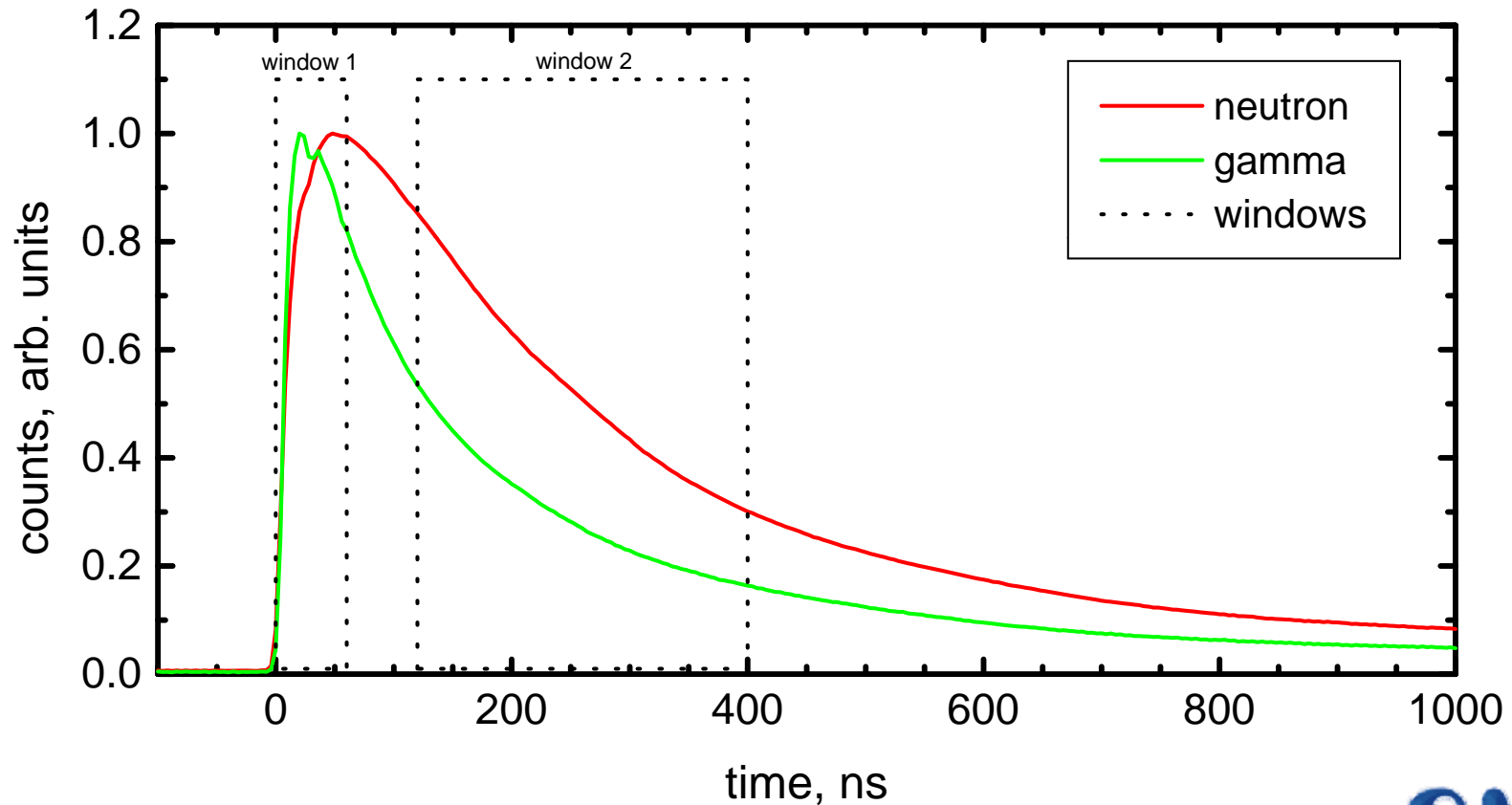
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# Pulse Shape Discrimination (PSD)

Decay traces for a 1 in dia. x 1.5 cm tall CLYC



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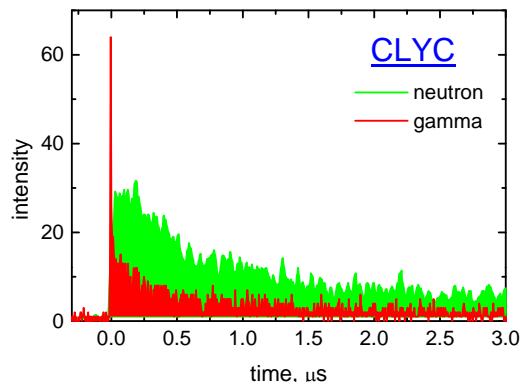
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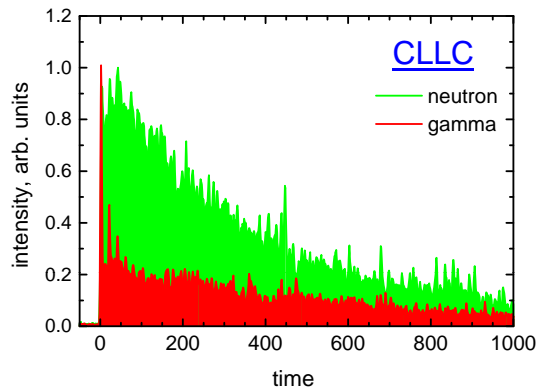
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# Pulse Shape Discrimination – overview

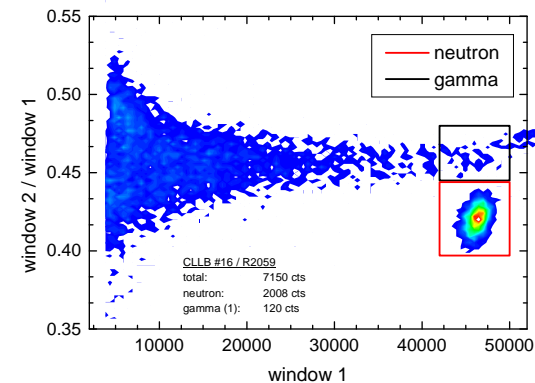
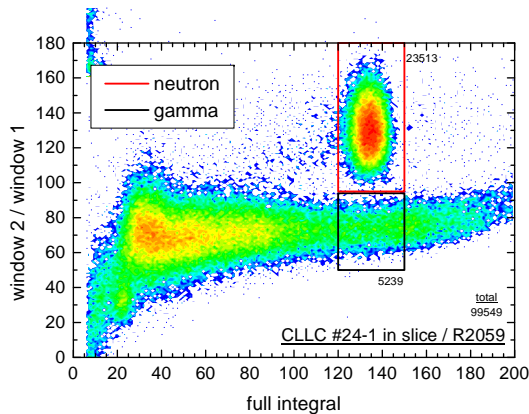
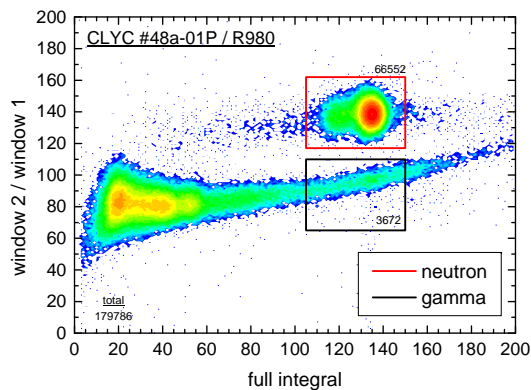
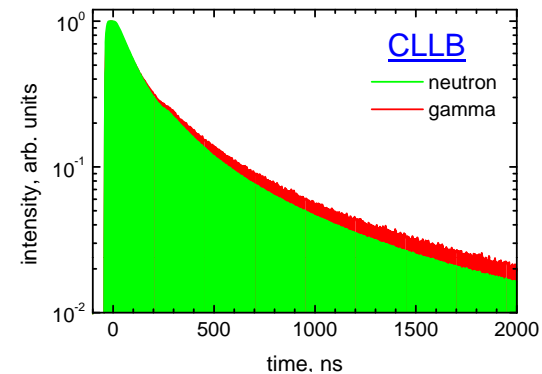
CLYC



CLLC



CLLB

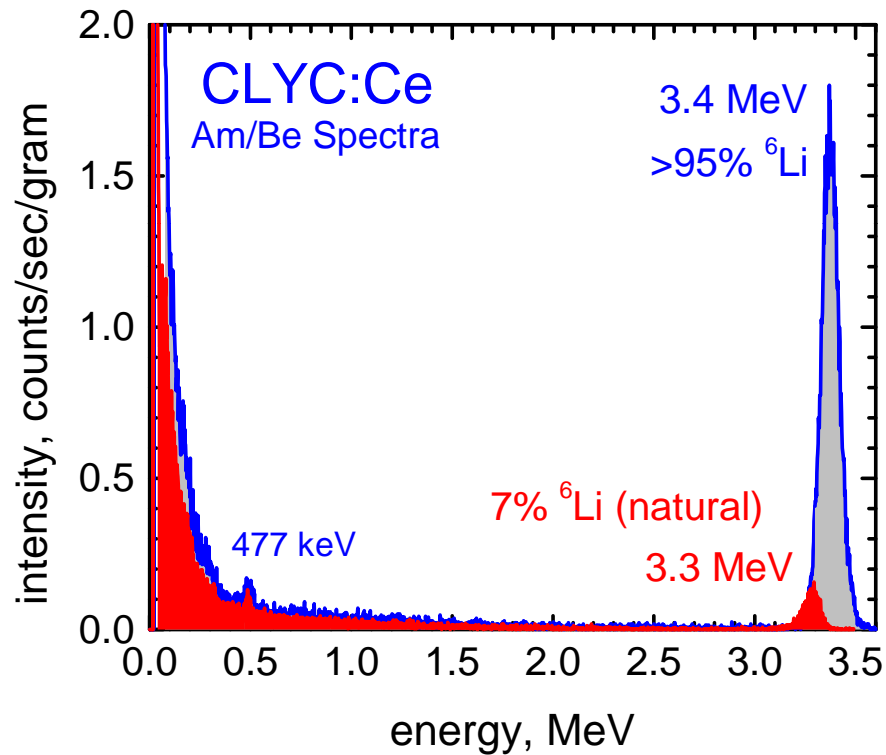


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# CLYC Detection Efficiency: $^6\text{Li}$ vs. $^{\text{nat}}\text{Li}$



Enrichment significantly improves detection of thermal neutrons.

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# Potential NS Applications

- **Nuclear & particle physics research**
  - Nuclear Spectroscopy
  - Accelerator Control
  - Neutron Detection Studies

## Other Potential Applications

- **Homeland security**
- **Neutron diffraction**
- **Oil well logging**
- **Nuclear waste characterization**

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# RMD Corporate Background & Commercialization History

- **Founded in 1974, now part of Dynasil Family**
- **80 Research Staff**
- **40 Ph.D. & 11 M.S.**
- **45,000 ft<sup>2</sup> lab & manufacturing space**
- **Clean rooms**
- **Full digital machine shop**
- **In-house prototyping & production**

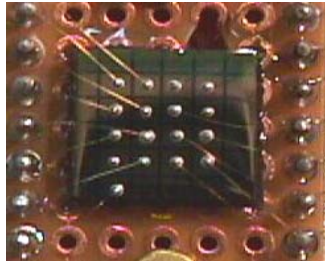
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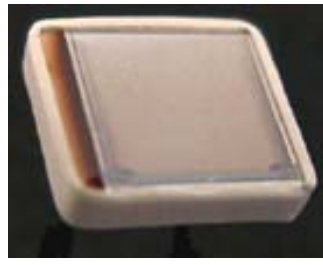


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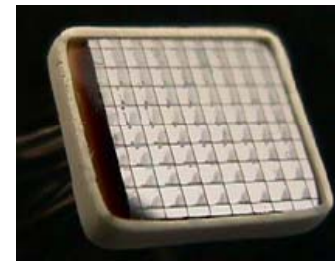
# RMD - Products Overview



CZT Arrays



13mm x 13mm Si APD



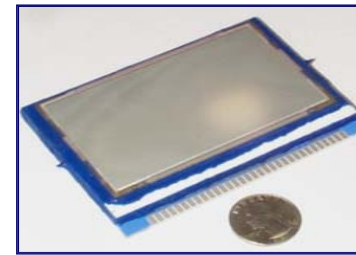
64-element APD Array



CdTe Detectors



LPA-1 Lead-in-Paint Analyzer



CsI Imaging Screens



Navigator™ Surgical Probe



RadCam 2000™ Portable  
Gamma/Video Imager



RadCam 2000™ Image

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# Dynasil/RMD Scintillator Commercialization

## CLYC & related compositions

A pilot-line in a Phase III program.

Dynasil board recently acquired Hilger Crystals that has been commercializing scintillators over several decades.



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# Acknowledgements

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