

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 -
Cs₂LiYCl₆:Ce (CLYC), Cs₂LiLaCl₆:Ce (CLLC)
& Cs₂LiLaBr₆:Ce (CLLB)**
- **RMD Corporate Background and Commercialization**

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Requirements for Gamma & Neutron Scintillators

- High Energy and Timing Resolution
- High Light Yield
- High Proportionality
- Fast Response
- Good Spectral Match with Optical Detectors
- Neutron-Gamma Pulse shape and/or Pulse Height Discrimination Capability
- High Efficiency for Gamma-Rays and Neutrons
- Low Cost

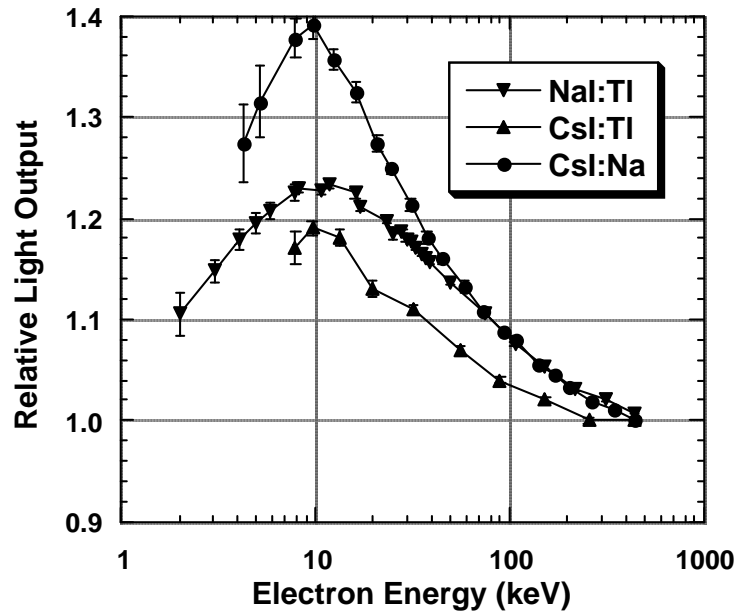
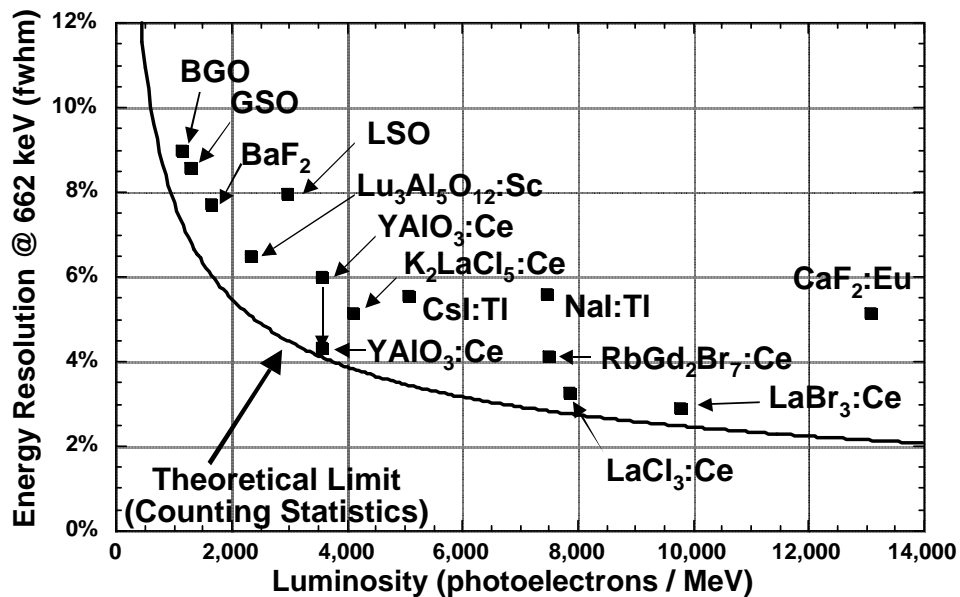
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Proportionality and Its Implications



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Gamma Scintillators

Material	Light Yield (Photons/MeV)	Emission (λ_{\max} , nm)	Energy resolution @662 keV (R, %)	Non-Proportionality (ΔL , %)	Principal Decay Time (s) (ns)
NaI:Tl	38,000	415	6-7	15	230
CsI:Tl	52,000	540	6-7	13	1000
LaBr ₃ :Ce	≥63,000	360	3	10	17
Cs₂LiYCl₆:Ce	20,000	370	4	2	1**, 50, ~1000
Cs₂LiLaCl₆:Ce	35,000	400	3.4	2	1**, 60, ≥400
Cs₂LiLaBr₆:Ce	60,000	410	3	2	~55, 270

** - for gamma excitation only

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Neutron Scintillators

Material	Dopant	Emission nm	Light Yield ph/MeV	Light Yield ph/n	Decay ns	PSD
Li-Glass	Ce	395	4,000	6,000	75	N
LiI	Eu	470	12,000	50,000	1400	N
LiF/ZnS	Ag	450	75,000	160,000	1000,	N
CLYC	Ce	300*, 390	21,000	70,000	1*, 50, 1000	Y
CLLC	Ce	300*, 400	35,000	110,000	1*, 60, ≥400	Y
CLLB	Ce	410	60,000	180,000	55, ≥270	Y

* Core Valence Luminescence (CVL)

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Elpasolites



CLYC



CLLC



CLLB

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

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Summary of properties

	Cs₂LiLaCl₆:Ce CLLC	Cs₂LiLaBr₆:Ce CLLB	Cs₂LiYCl₆:Ce CLYC
Density, g/cm³	3.5	4.2	3.3
Emission, nm	290^{CVL}, 400^{Ce3+}	410^{Ce3+}	290^{CVL}, 390^{Ce3+}
Decay time, ns	1^{CVL}, 60, ≥ 400	55, ≥270	1^{CVL}, 50, ~1000
Max. light yield, ph/MeV	~ 35,000	~ 60,000	~ 20,000
Light yield ph/n	~ 110,000	~ 180,000	~ 70,000
GEE, MeV	~3.1	3.2	~3.1
Best ER @662 keV	3.4	2.9	3.9
PSD	Excellent	Possible	Excellent

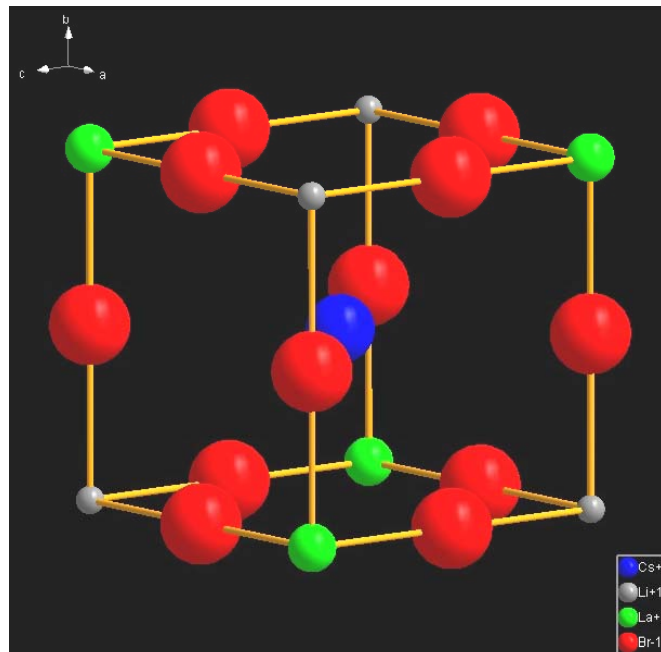
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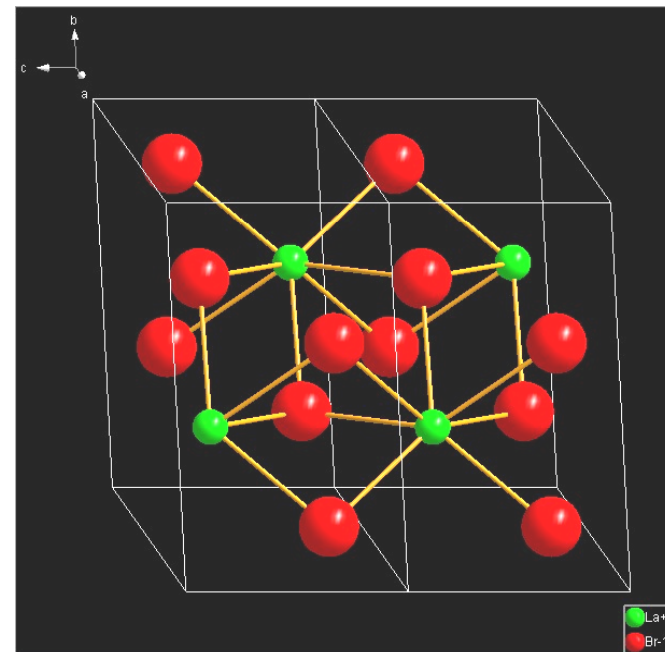


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$\text{Cs}_2\text{LiLaBr}_6$ (CLLB) vs LaBr_3 Structure



CLLB - cubic



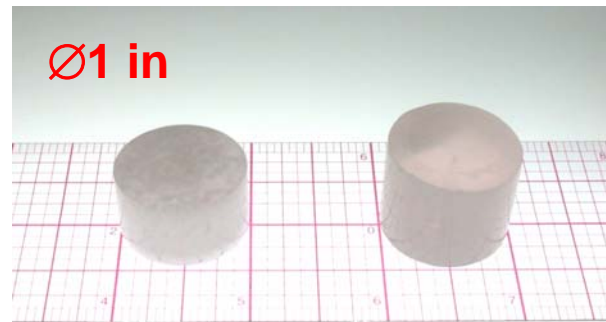
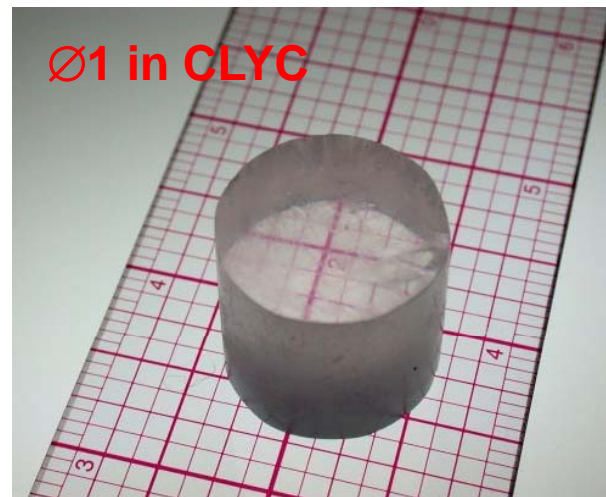
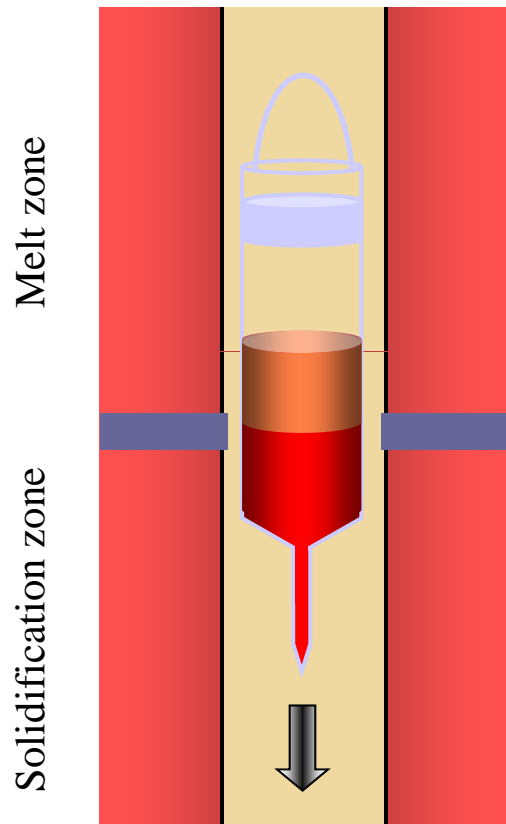
LaBr_3 - hexagonal

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Bridgman Grown Crystals



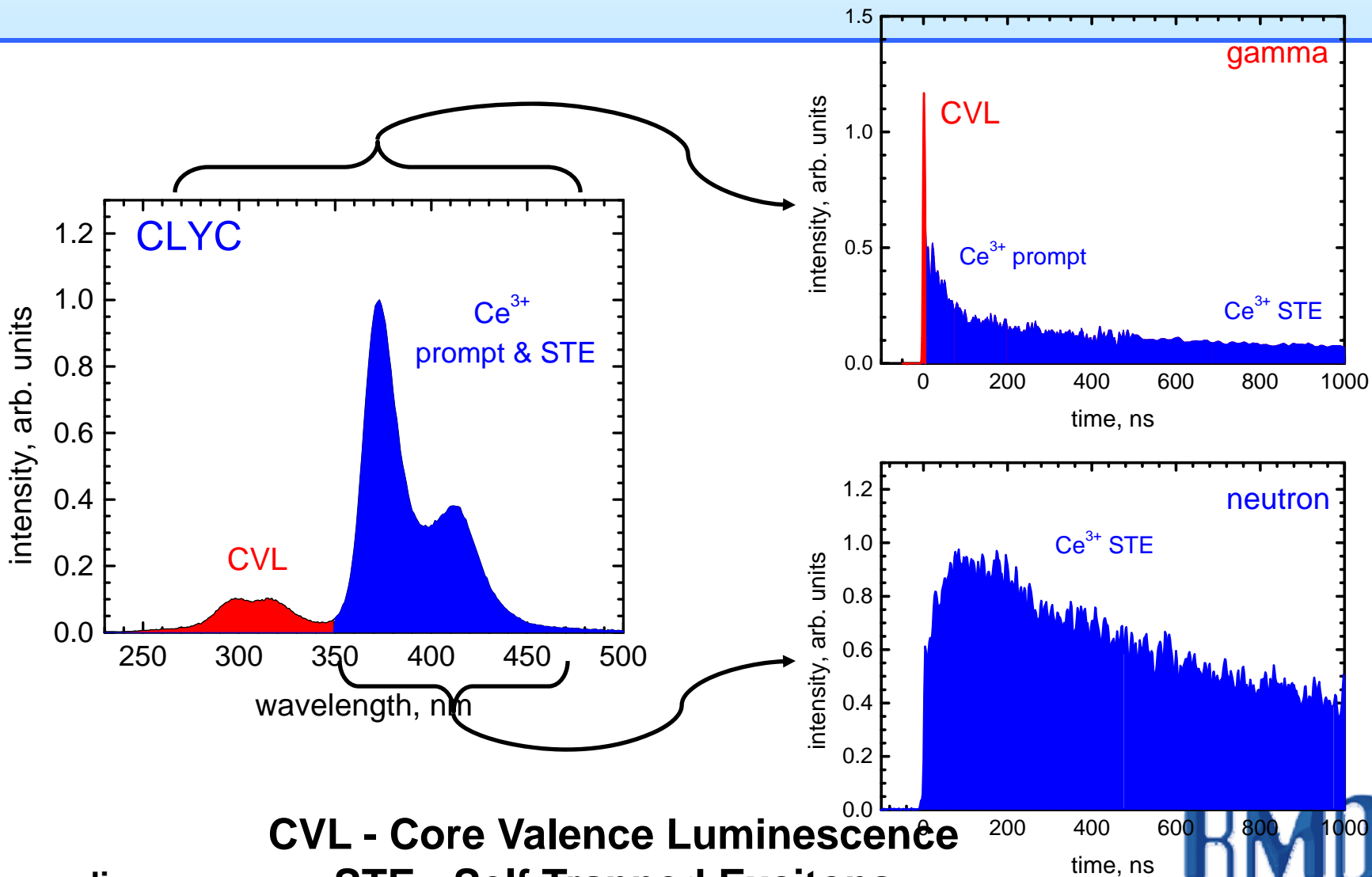
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Scintillation Characteristics



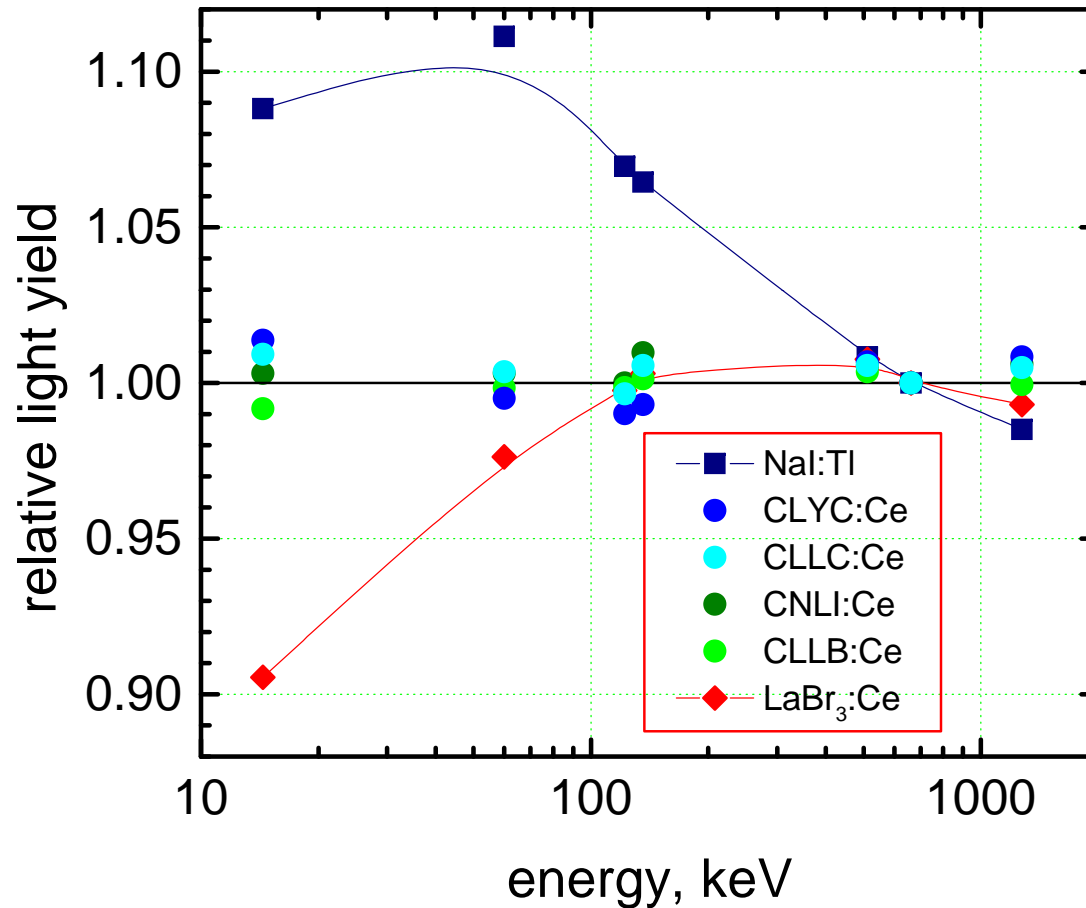
CVL - Core Valence Luminescence
STE - Self Trapped Excitons

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Proportionality of Elpasolites

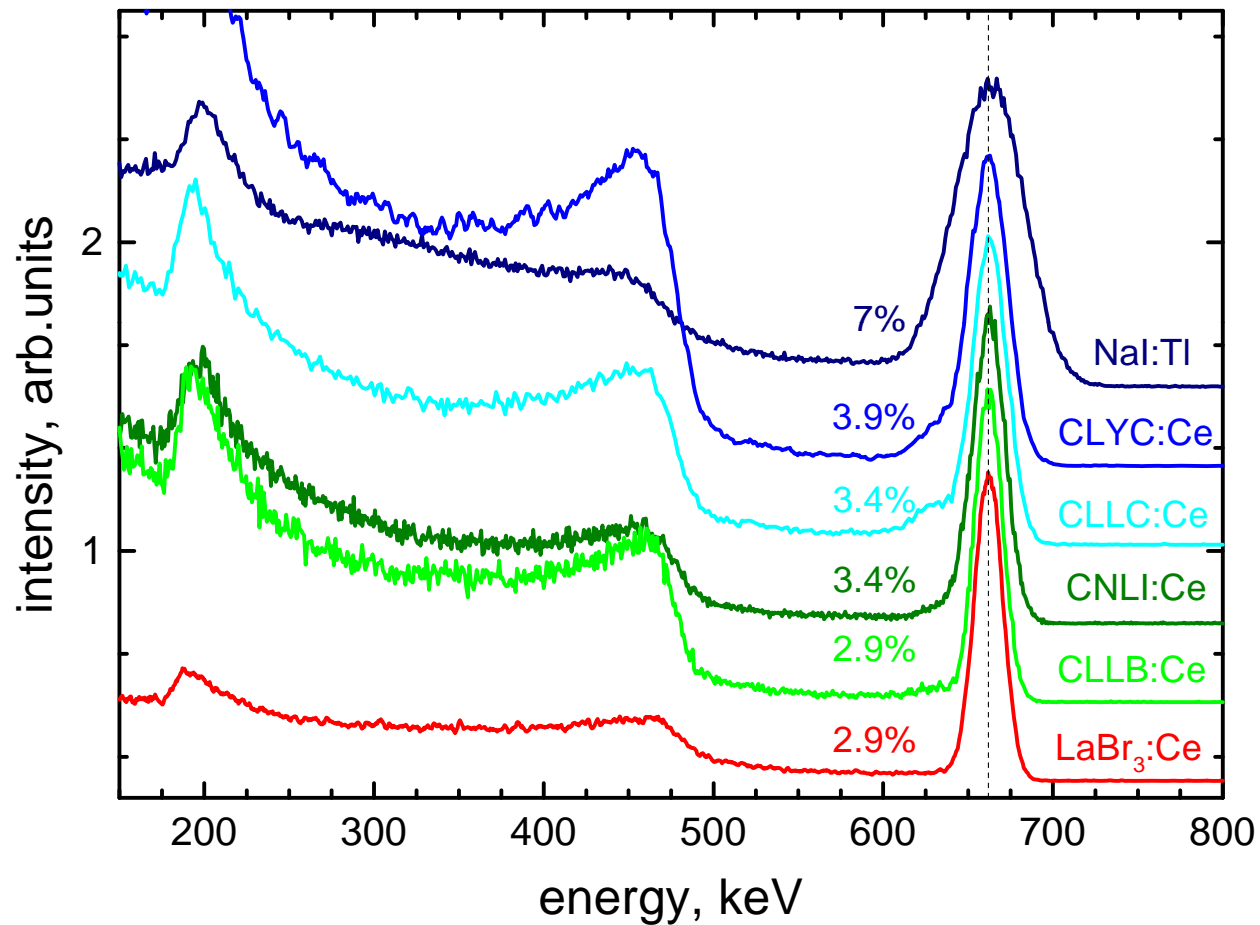


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Energy Resolution of Elpasolites



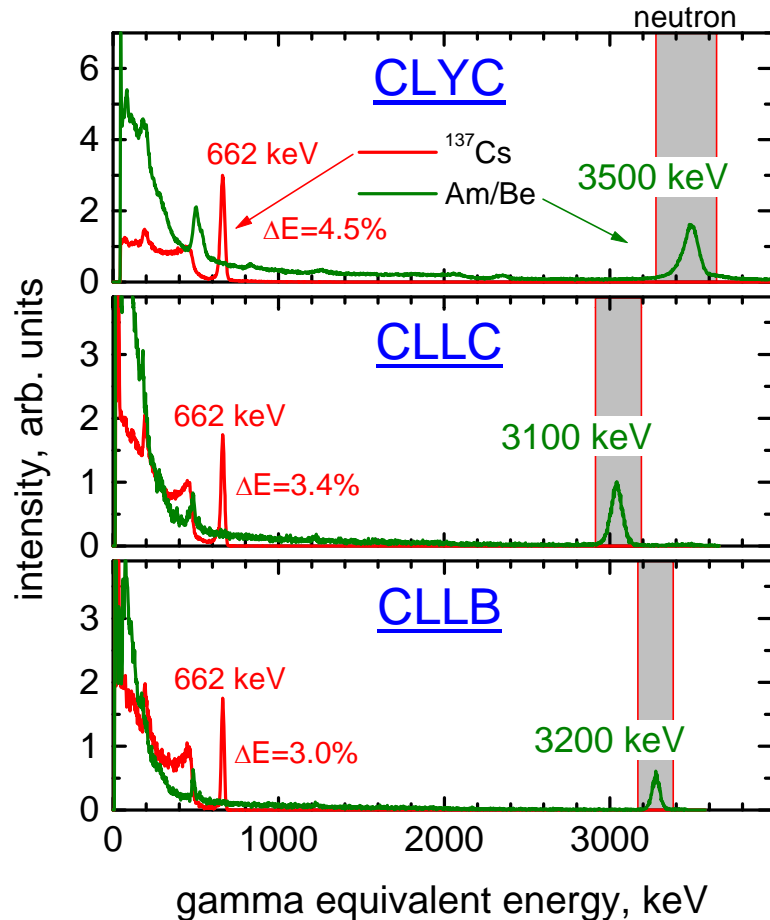
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Thermal Neutron Detection



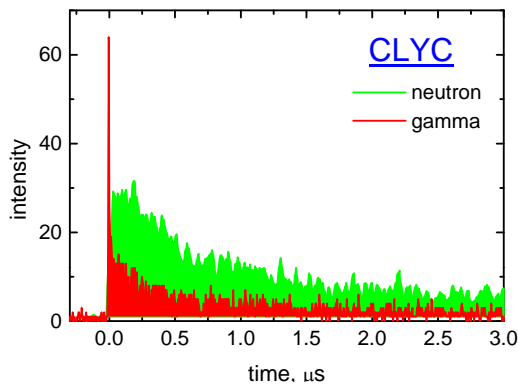
- High Gamma EE
- High energy resolution
- Single full energy peak
- PHD

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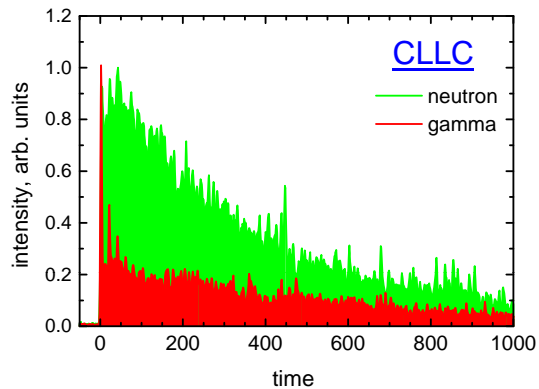
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Pulse Shape Discrimination – overview

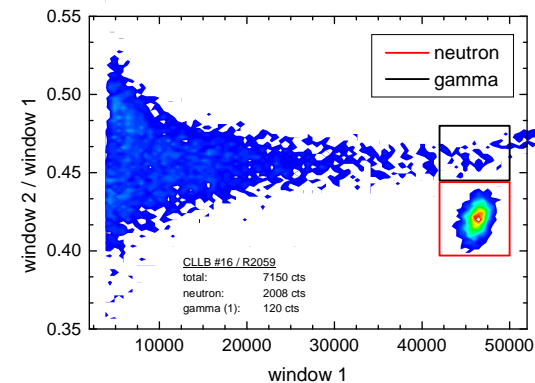
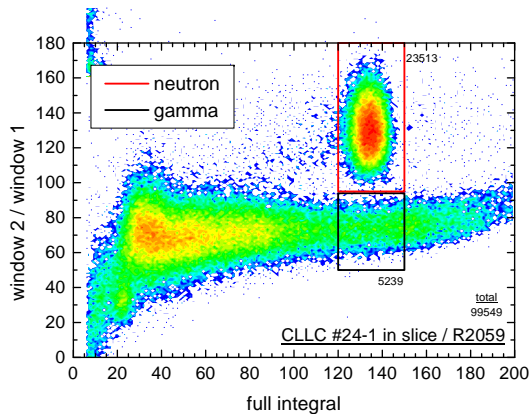
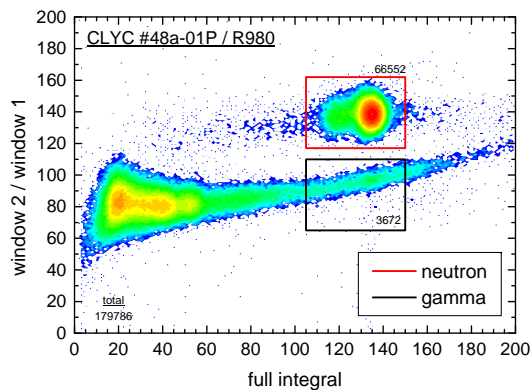
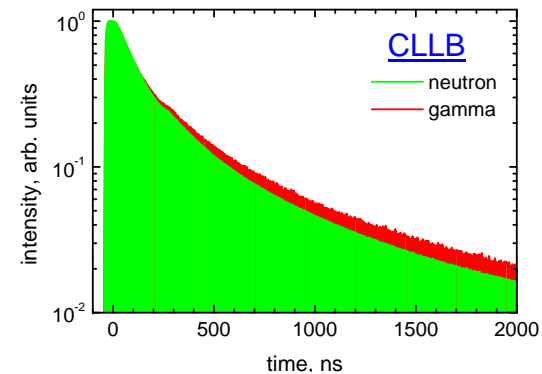
CLYC



CLLC



CLLB



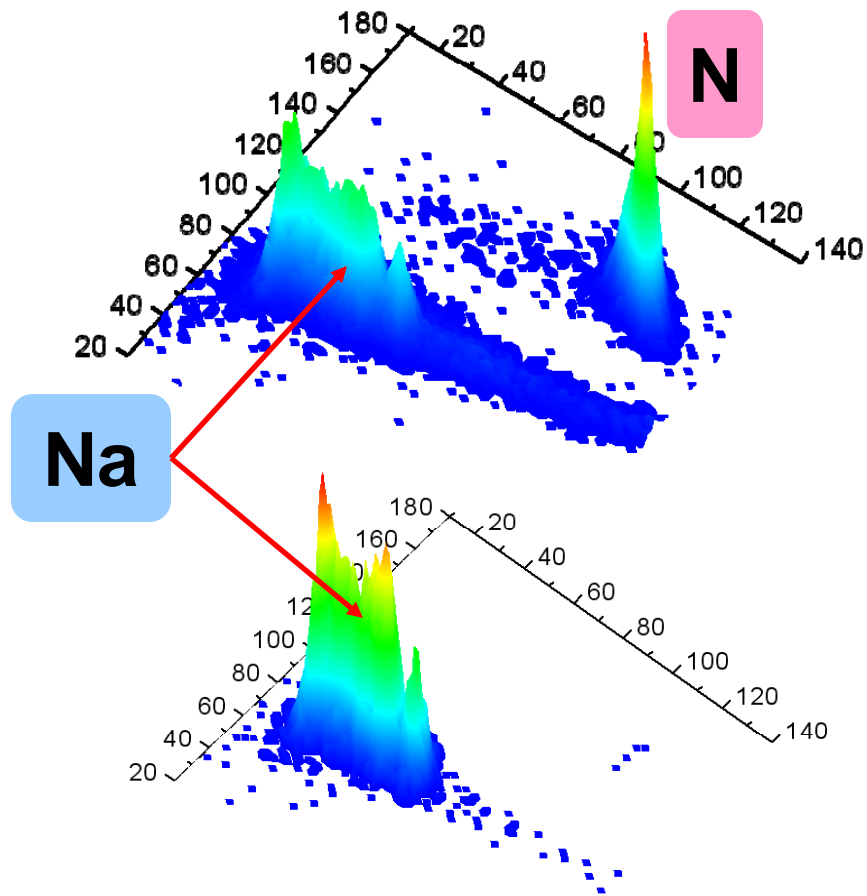
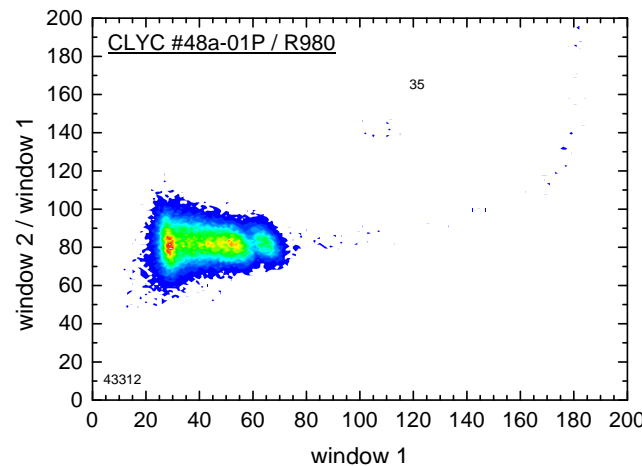
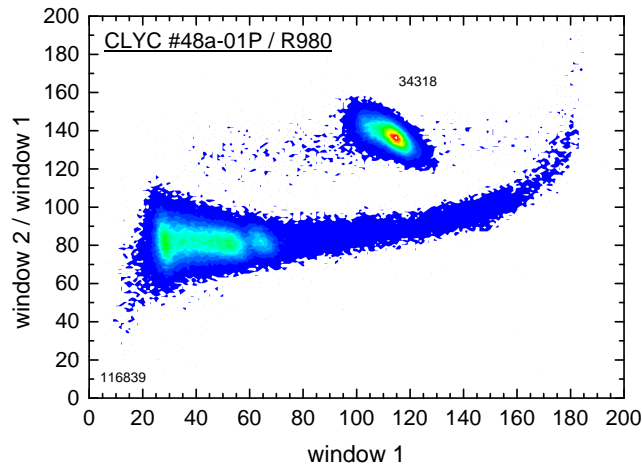
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PSD, CLYC

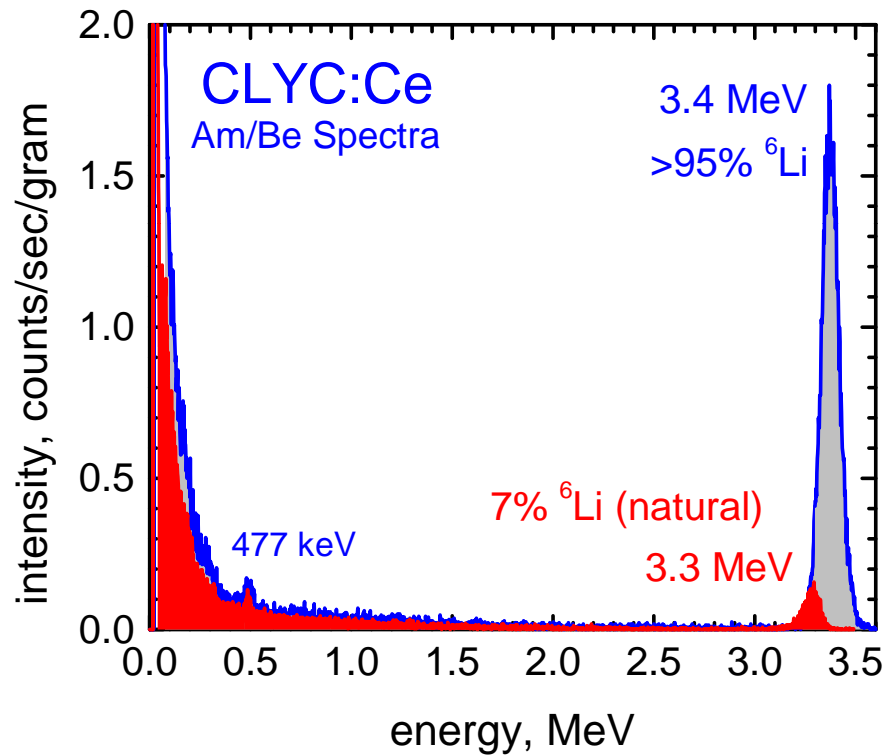
Ø1 inch x 15 mm sample, 95% ⁶Li



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CLYC: ^6Li vs. natLi



Enrichment significantly improves detection of thermal neutrons.

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Potential Applications

- **Nuclear & particle physics research**
- **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 ft² lab & manufacturing space*
- *Clean rooms*
- *Full digital machine shop*
- *In-house prototyping & production*

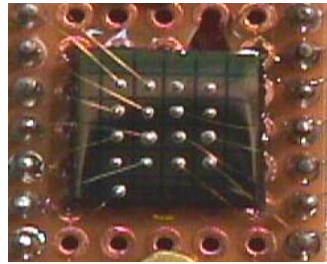
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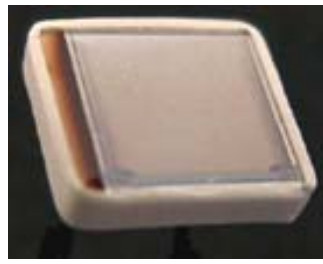


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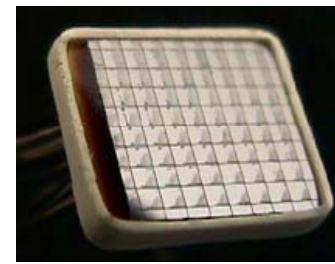
RMD - Products Overview



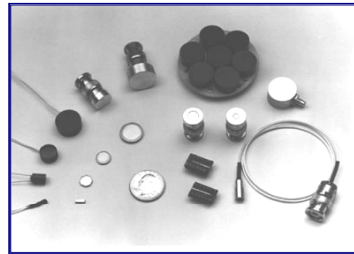
CZT Arrays



13mm x 13mm Si APD



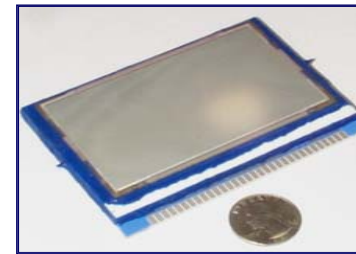
64-element APD Array



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

- Varied strategies employed for commercialization of scintillators funded by DOE SBIR NP Program.
 - CeBr_3 , a licensing agreement has been executed with a large company, production is expected to begin next year
 - CLYC and related compositions, RMD is establishing a pilot-line in a Phase III program.
 - Dynasil recently acquired Hilger Crystals with a specific aim of commercializing RMD's very active scintillator research. Hilger has been commercializing scintillators over several decades.



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Acknowledgements

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