

Bismuth-loaded plastic scintillator for nuclear security applications

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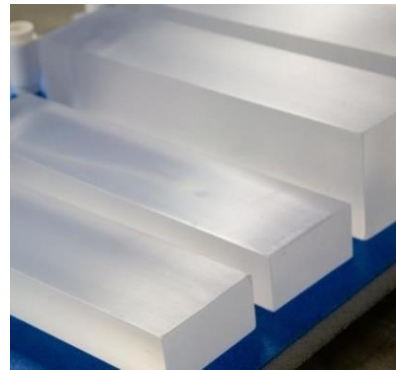
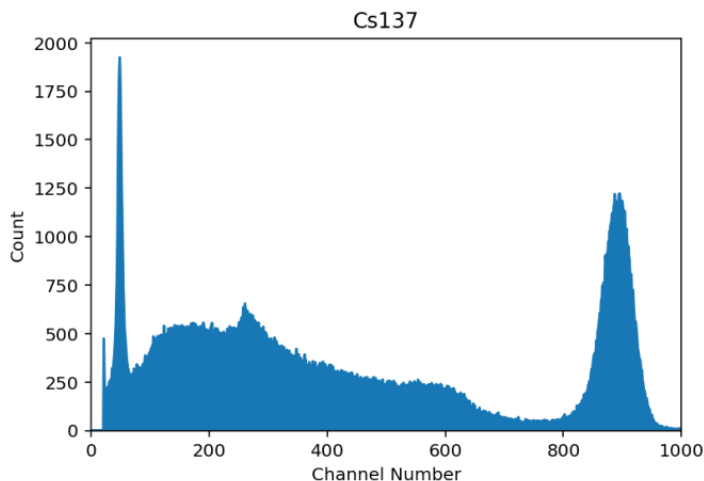
Metal-loaded plastics present advantages over current technologies

Deployment generally considers NaI(Tl) or PVT (other technologies are trust and cost prohibitive)[1]





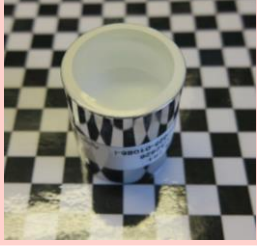
NaI(Tl) has acceptable energy resolution, but is hygroscopic, fragile, and limited in size (4"x4"x16")

PVT is cheap, robust but provides limited energy information

Metal-loading takes advantage of the ruggedity of plastic while introducing energy sensitivity

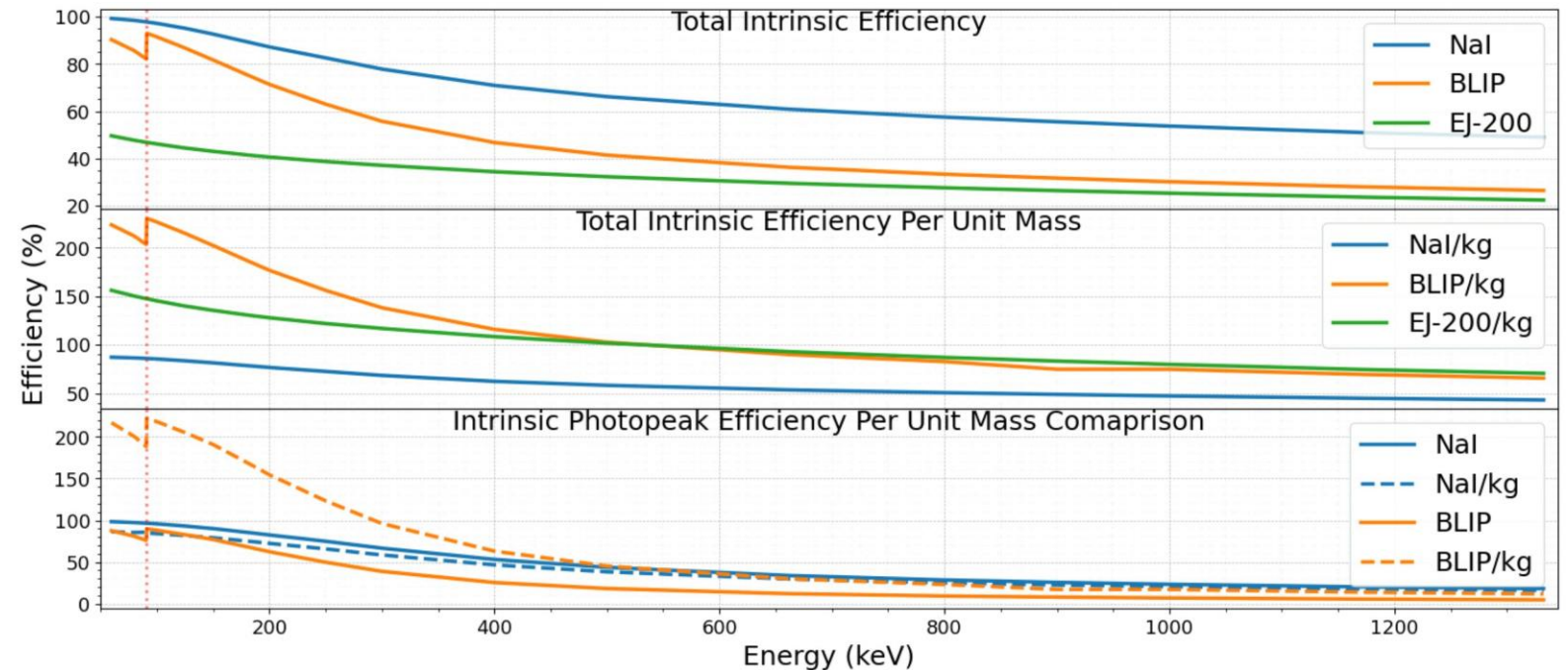


Bismuth loaded plastic performance

	PVT (Standard)	EJ256	Bi-PVT [1]	BLIP [2] (PVK + BiPh ₃ + Ir-fluor)	NaI(Tl) Single crystal
					
Metal loading (%)	N/A	5	8	21	N/A
Density (g/cm ³)	1.023	1.081	1.3	1.3	3.67
Light Yield (Ph/MeV)	10,000	5200	5000	30,000	38,000
Decay Time (ns)	2.1	2.1	10	1000	230
Eres (662 keV)	N/A	N/A	13	16	6.7
Application			Drop-in portal replacement	γ-ray spectroscopy with plastic	

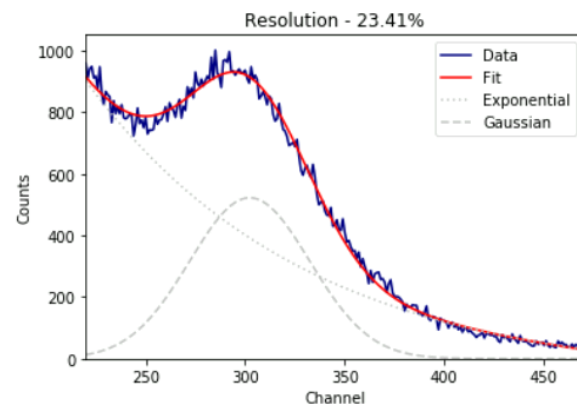
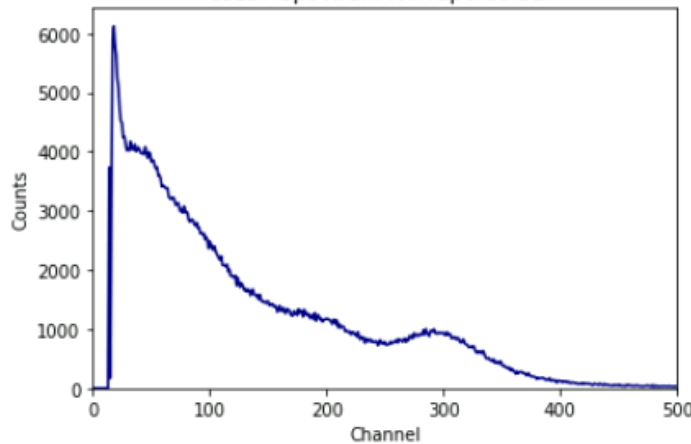
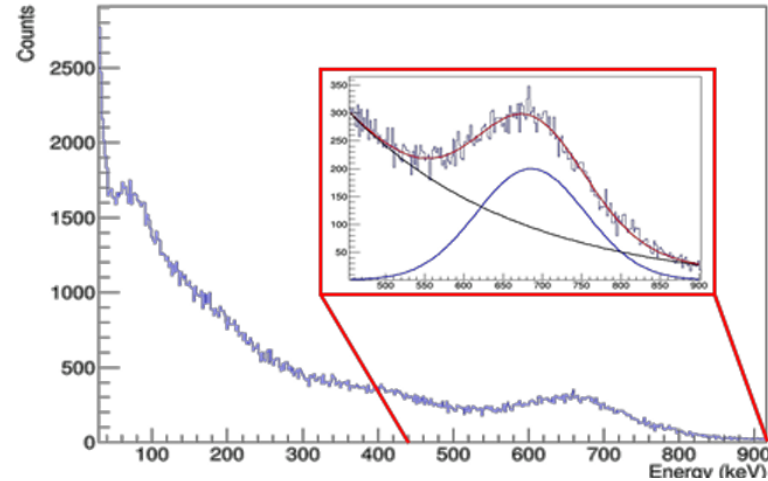
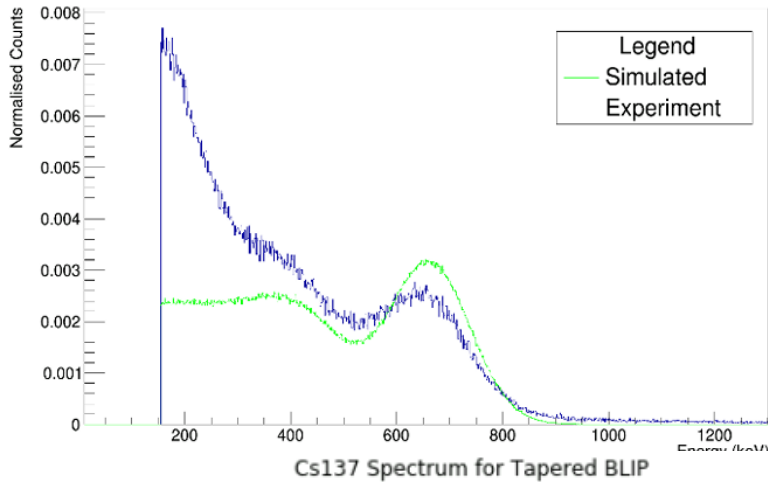
Bismuth-Loaded Iridium fluor Plastic - BLIP

- Three samples of BLIP have been provided by LLNL: $\text{Ø}2.3'' \times 3.5''$ (0.24I), $\text{Ø}3'' \times 2.68''$ (0.31I), and a $\text{Ø}2'' \times 4.25''$ (tapered, 0.2I)
- Hamamatsu R6231-100 PMT



Bismuth-Loaded Iridium fluor Plastic - BLIP

- Well-defined photopeaks clearly visible in all tested samples
- Ø2.3" x 3.5" (Top), and tapered (Bottom)
- Tapering provides improved light collection
 $E_{res}(662) = 23.41\%$ c.f. 27.97%
- Greater understanding of the underlying background is expected to allow our fitting algorithm to improve this further



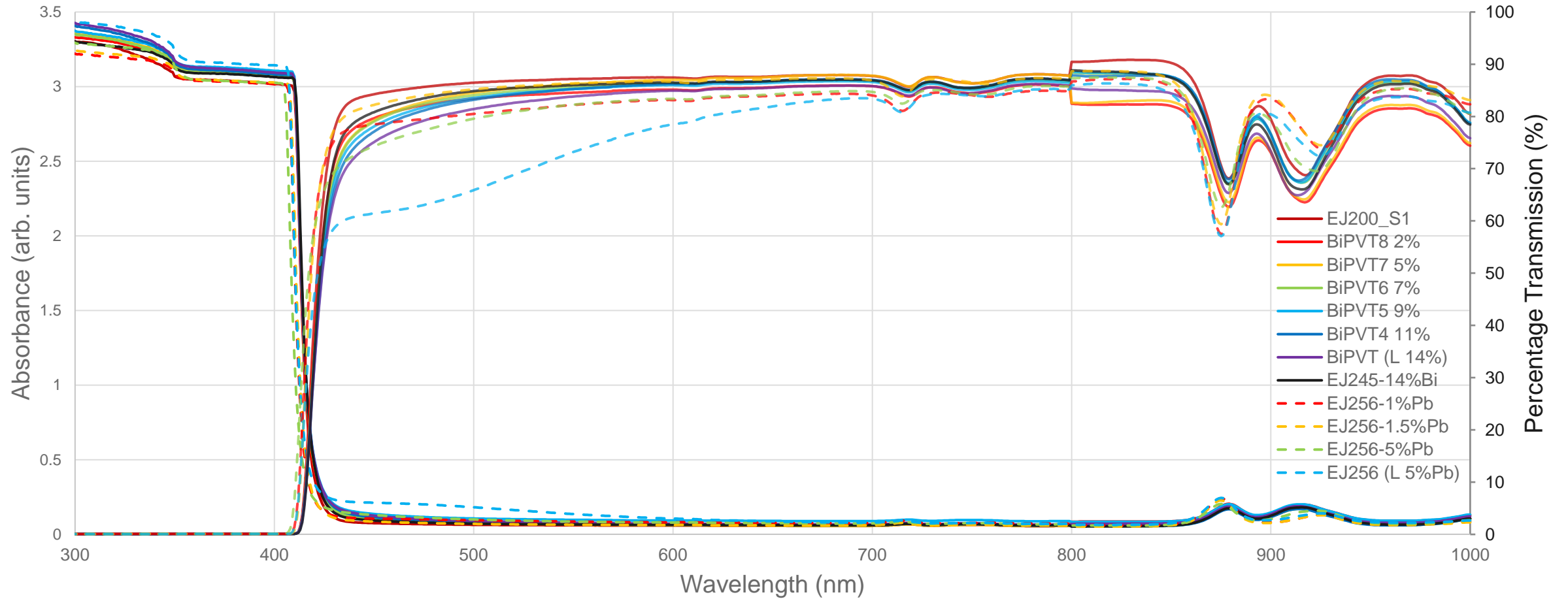
GMS595 Upgrade – an implementation of Bi-loaded plastic

- GMS595 designed by RI&C and commercialised by JCS Nuclear Solutions
- Currently uses a 2” cylinder of EJ256 1.5% Pb-loading
- LLNL have provided samples of Bi-PVT at 2-14% Bi loading
- Additional test materials: “commercial” grade Bi-PVT (EJ245), and EJ256 1, 1.5, and 5% Pb loading

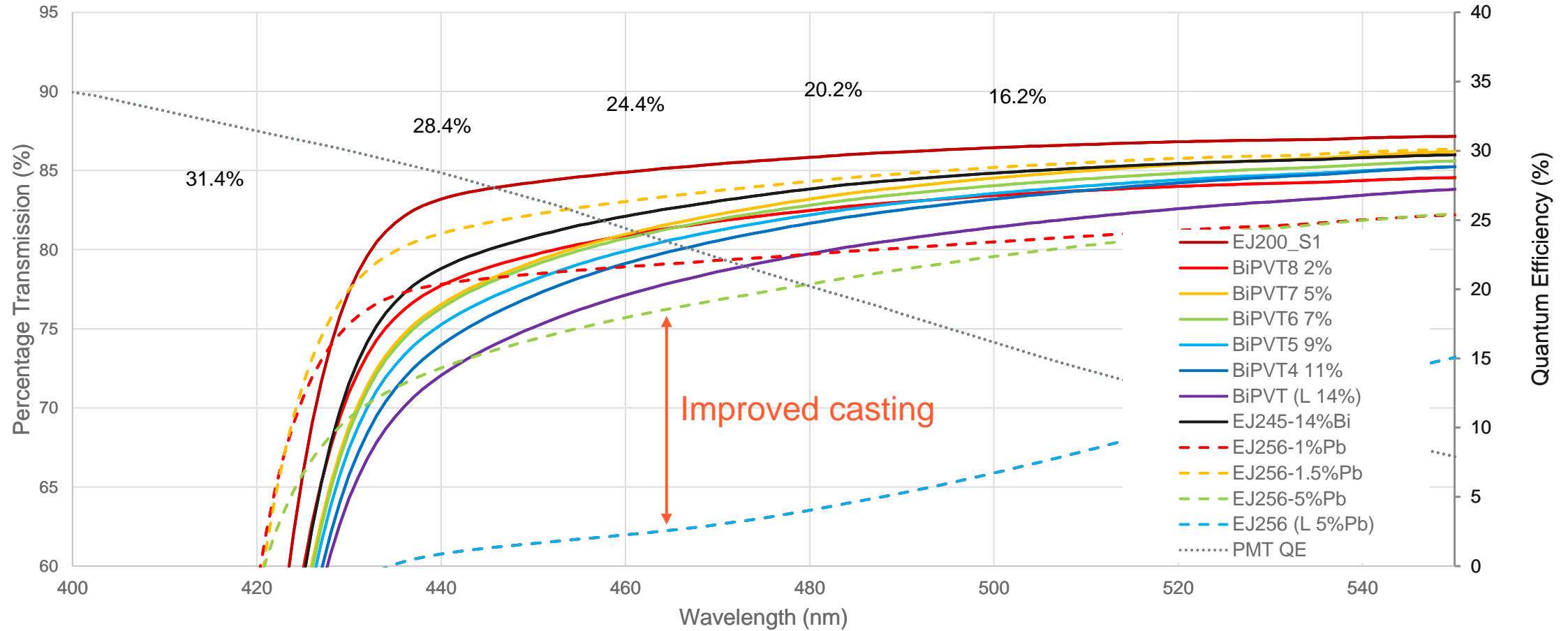


Does a “better” scintillator improve the performance of the detector?

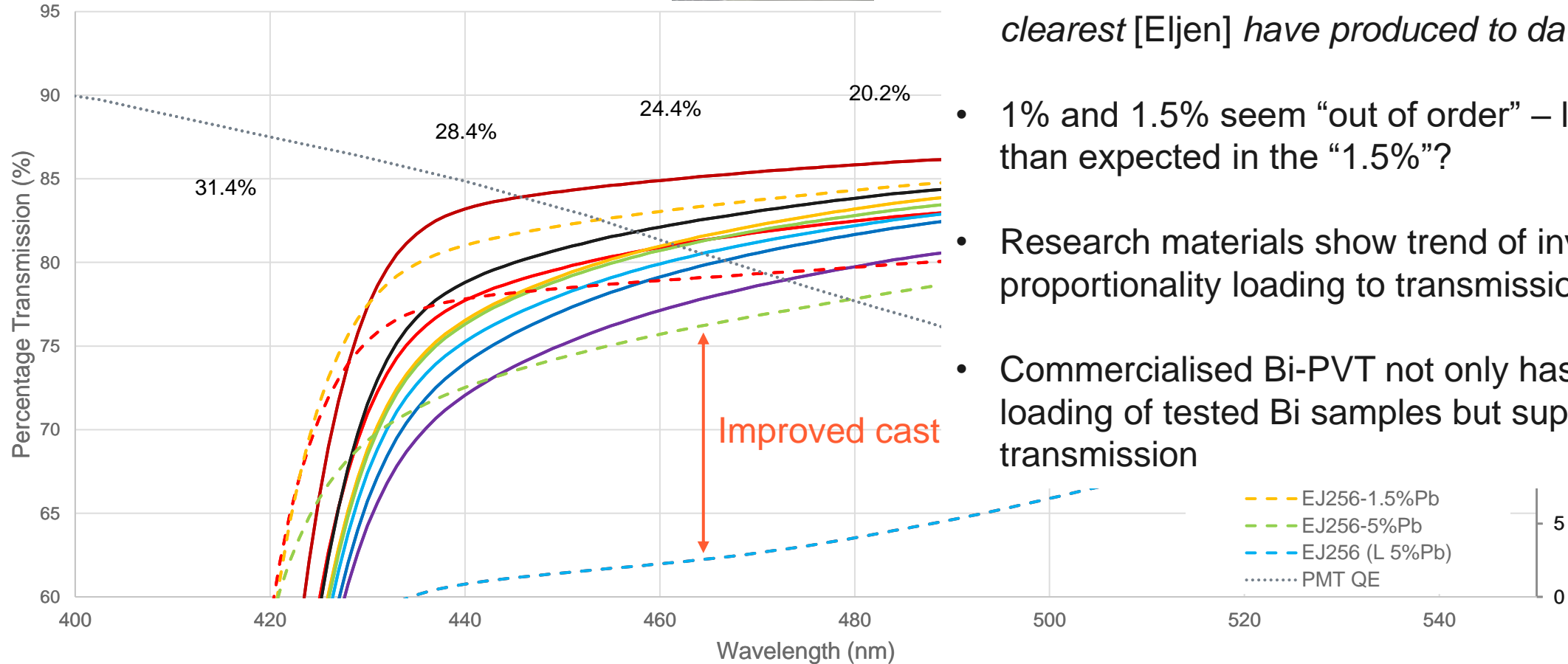
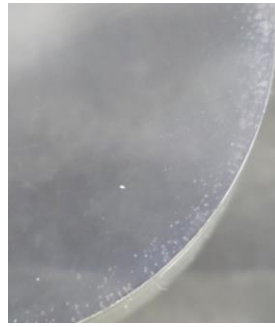
Transmission and Absorbance Measurements



A close up of the transmission data

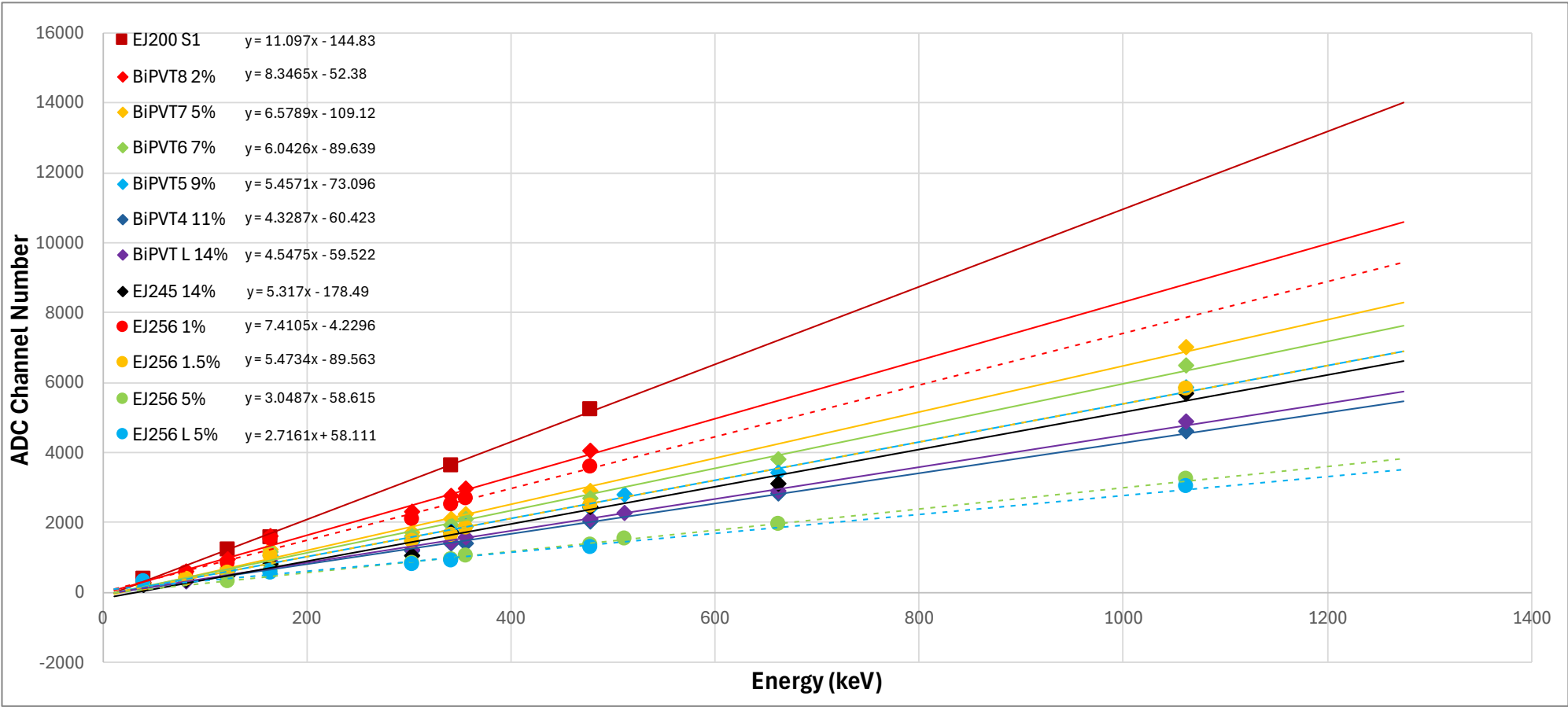


Interesting Points

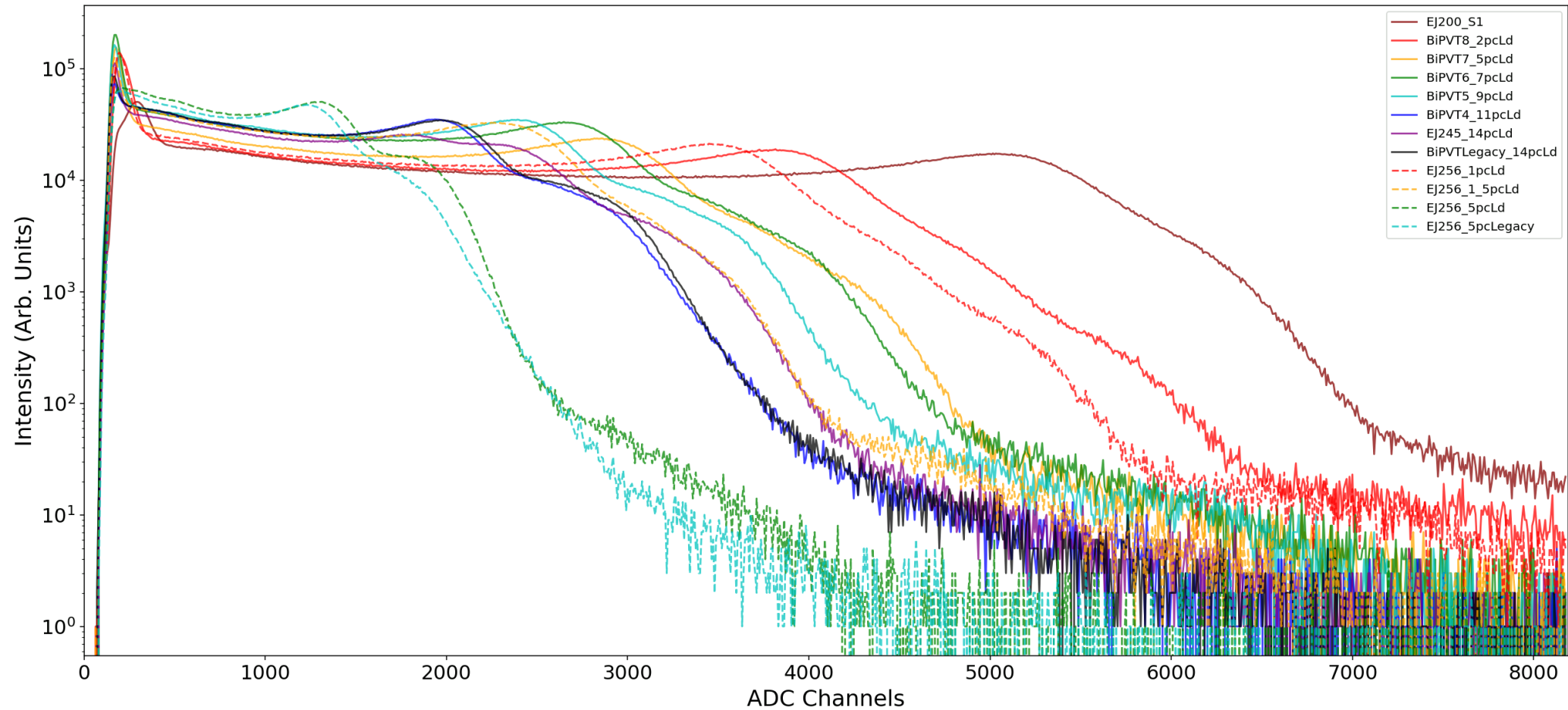


- The transmission of EJ256 (5%) has improved by 12-15% from 2021 to 2025
- Two samples (EJ256-5% and -1.5%) contained “fallout” but were “*some of the clearest [E]ijen have produced to date*”
- 1% and 1.5% seem “out of order” – less Pb than expected in the “1.5%”?
- Research materials show trend of inverse proportionality loading to transmission
- Commercialised Bi-PVT not only has highest loading of tested Bi samples but superior transmission

How does Bi-PVT compare as a γ -ray detector?

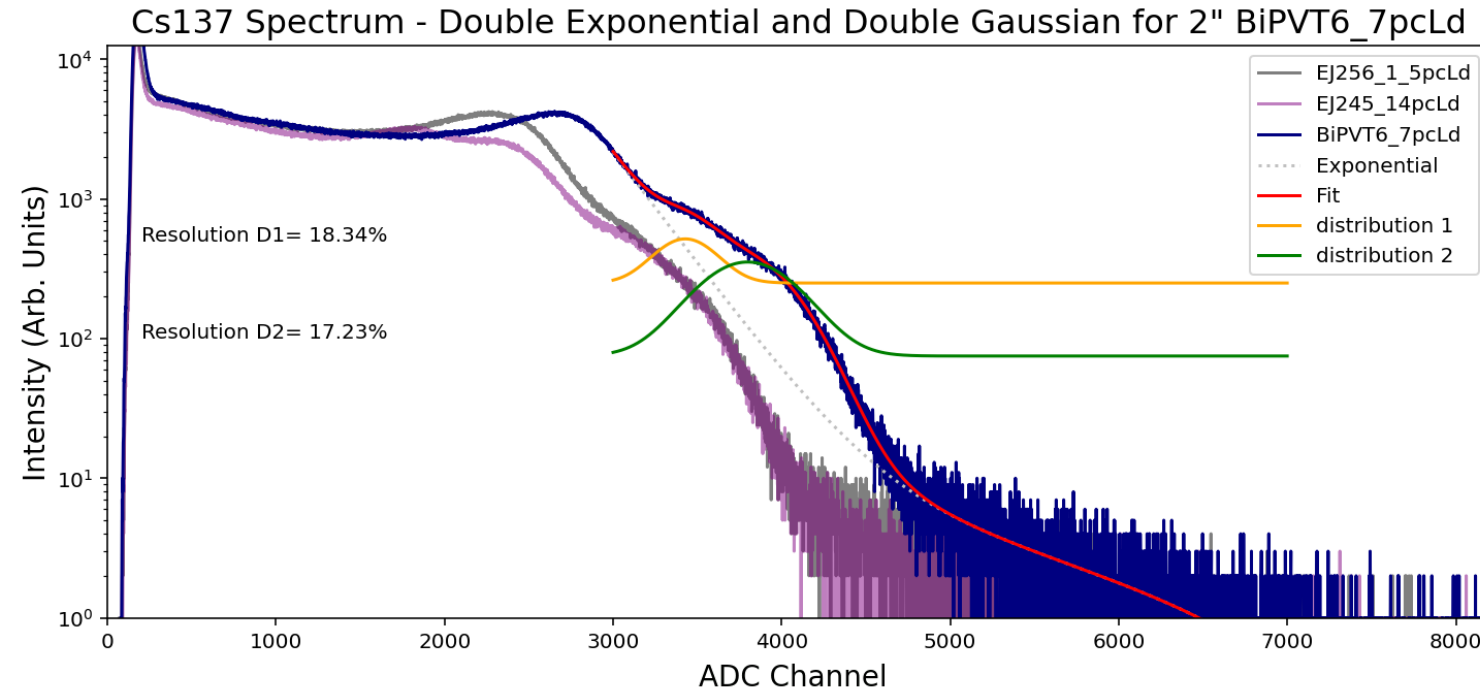


137Cs Spectra



Scintillator Performance

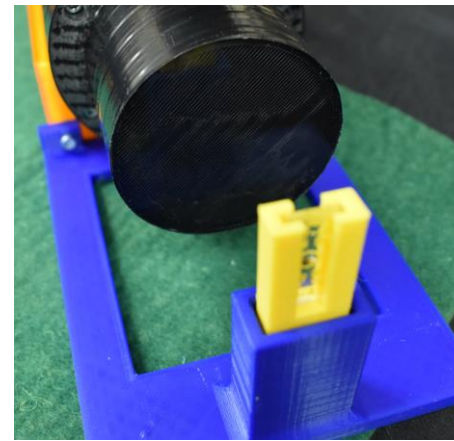
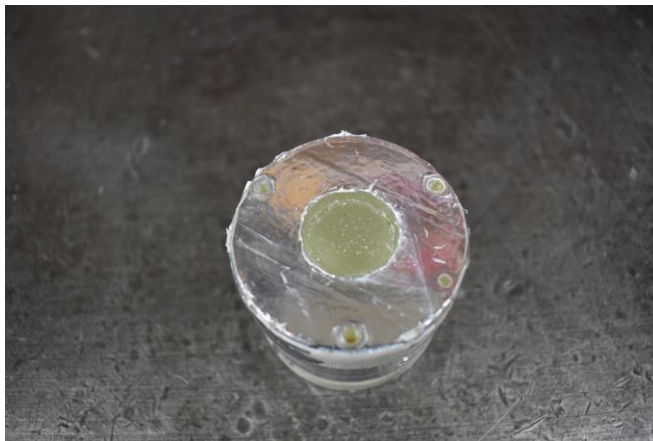
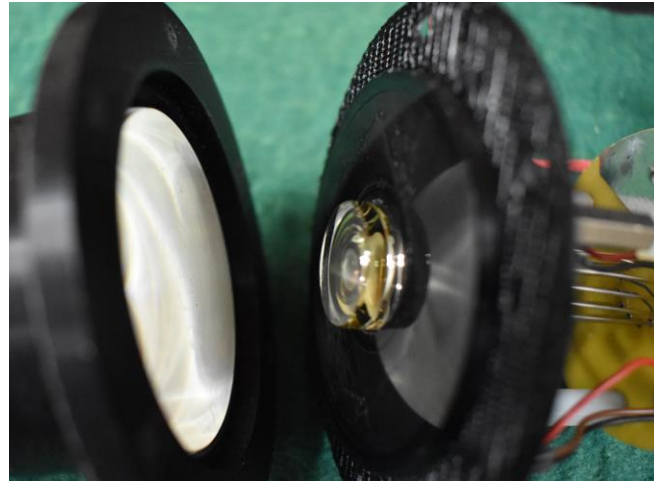
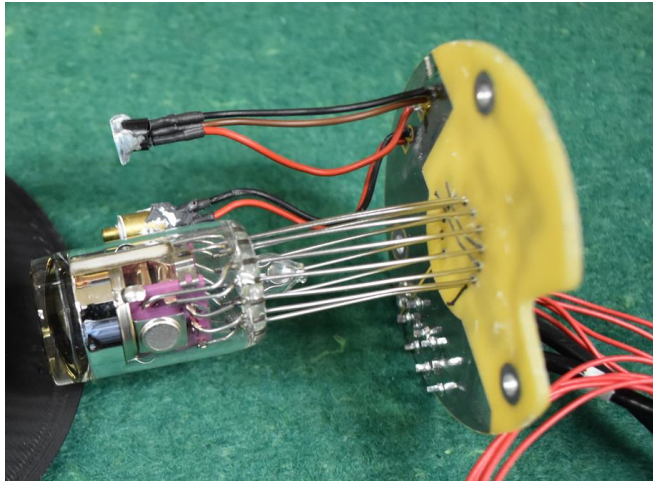
- We fit a double exponential and double Gaussian to the region of interest
- Higher loading samples can deconvolve photopeak and escape peak from the data
- Not possible with any Pb-loaded PVT



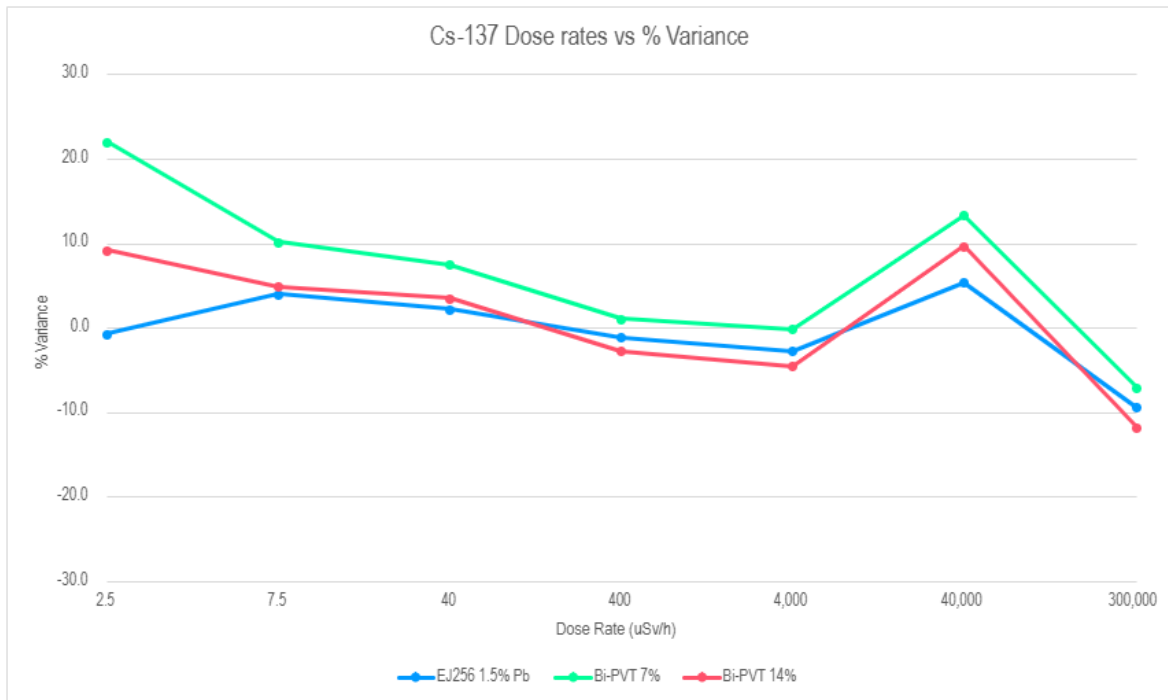
Bi loading	¹³⁷ Cs Resolution
2	Unable to Fit
5	Unable to Fit
7	17.23%
9	17.94%
11	17.64%
14 (Legacy)	15.70%

Detector (Re-)construction

- Tests performed on a rebuilt GMS595 taken from spares
- Removal of some user experience functionality
- Replacement 3D-printed End Cap
- Standard GMS595 uses machined 2" cylinders



Gamma Calibration Testing



- Down-selected samples tested (control EJ256-1.5%, Bi-PVT 7%, and Bi-PVT 14%)
- ^{137}Cs 2.5 – 300,000 $\mu\text{Sv/hr}$, ^{241}Am 100 $\mu\text{Sv/hr}$
- All samples pass Cs testing
- Bi-PVT over-reports at low energies
- Bi-PVT “fails” Am tests (outside of established parameter for EJ256)
- Increased sensitivity at the low end could be advantageous for some deployment scenarios

References

- [1] S. O'Neal, N. Cherepy, S. Hok and S. Payne, “Performance of High Stopping Power Bismuth-Loaded Plastic Scintillators for Radiation Portal Monitors,” IEEE Transactions of Nuclear Science, vol. 67, no. 4, p. 746, 2020.
- [2] S. O'Neal, Light Weight, Modular Gamma Spectrometer Using Bismuth-Loaded Iridium-flour Plastic (BLIP), Aldermaston, 2023.

We thank our collaborators at LLNL for providing the materials, and you for listening.

Any Questions?

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