LYSO Crystal Progress

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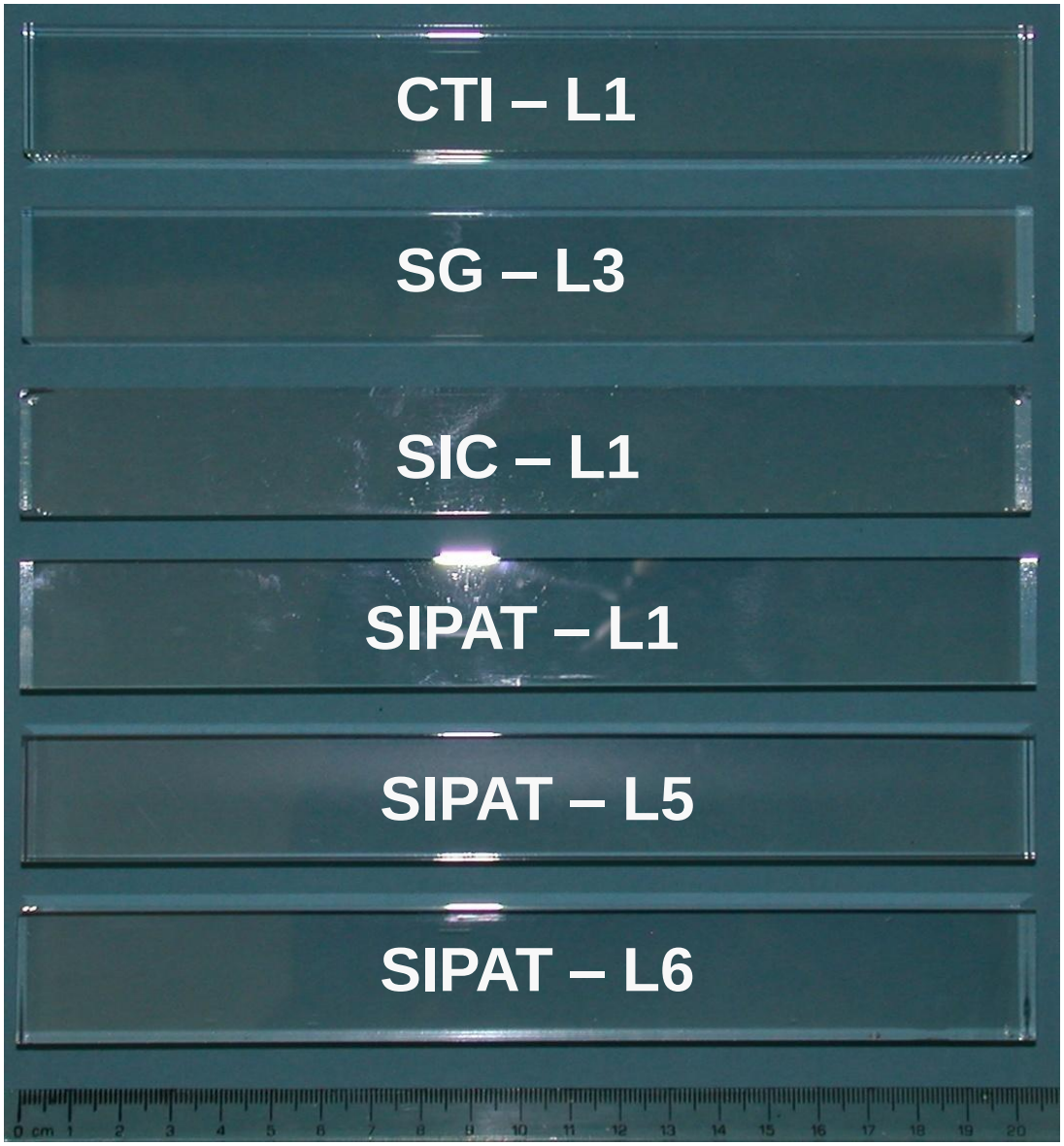
Outline

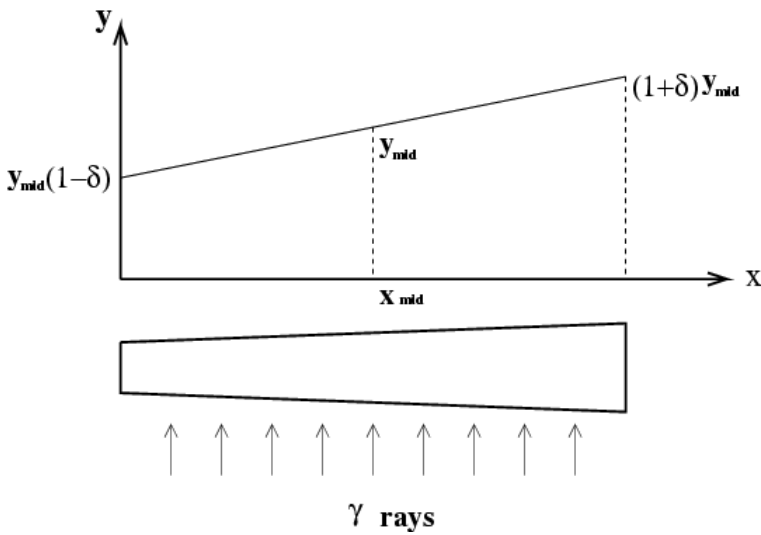
- Understanding the light response uniformity: a new sample SIPAT-LYSO-L6 received in July.
- Discussion about crystal specifications.
- Ce and Y segregation coefficients and calculated [Ce] from the growth parameter or cut-off wavelength.
- Progress at SIPAT and SIC.

Light Response Uniformity



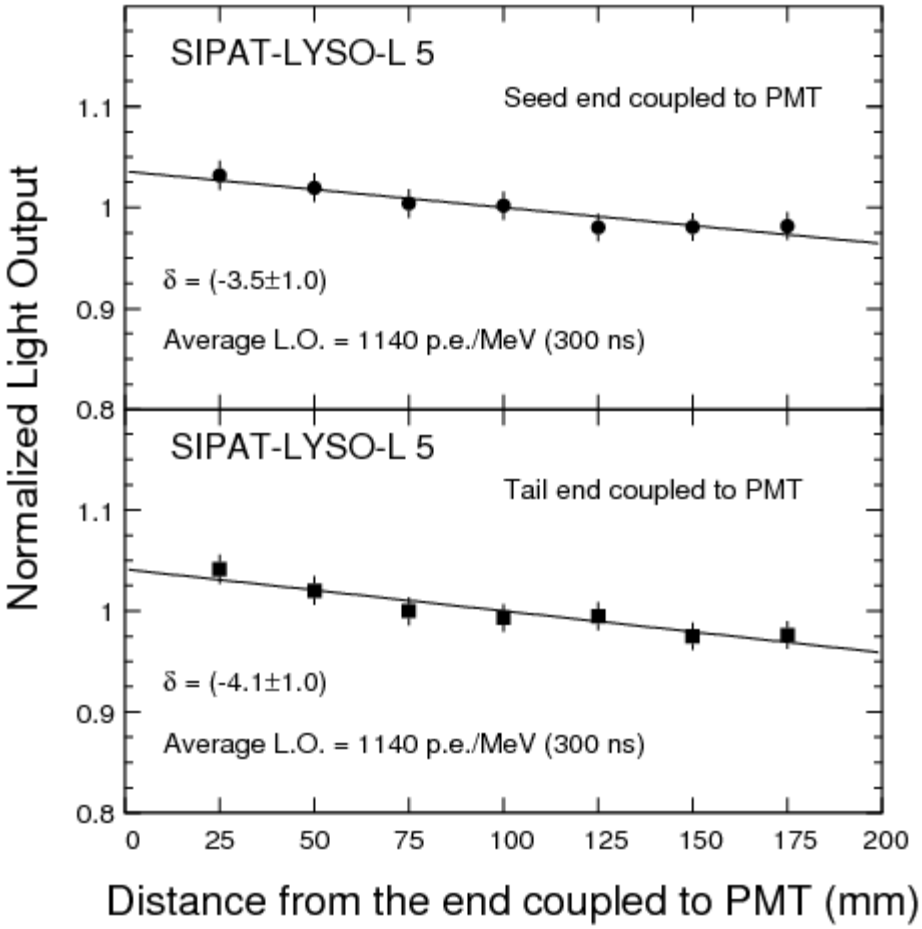
25 x 25 x 200 mm samples measured for their L.R.U. and fit to a linear function

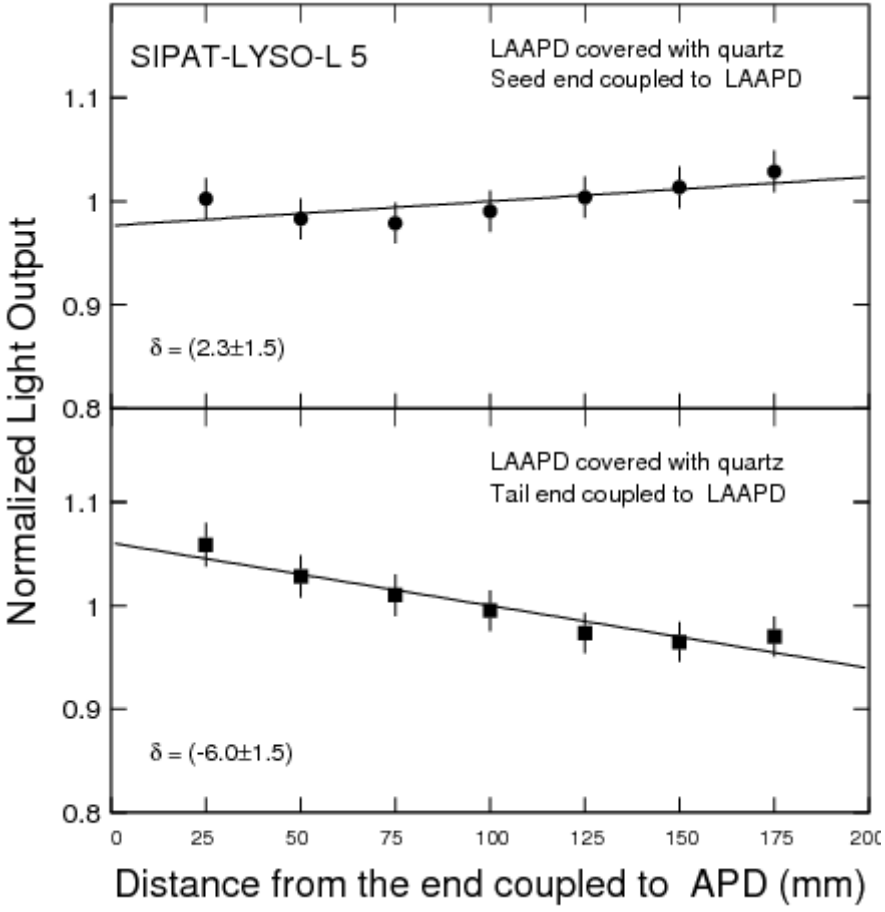
$$Y = Y_{mid}\,[1 + \delta(x/x_{mid} - 1)]$$



L.R.U. by PMT & LAAPD: SIPAT-LYSO-L5

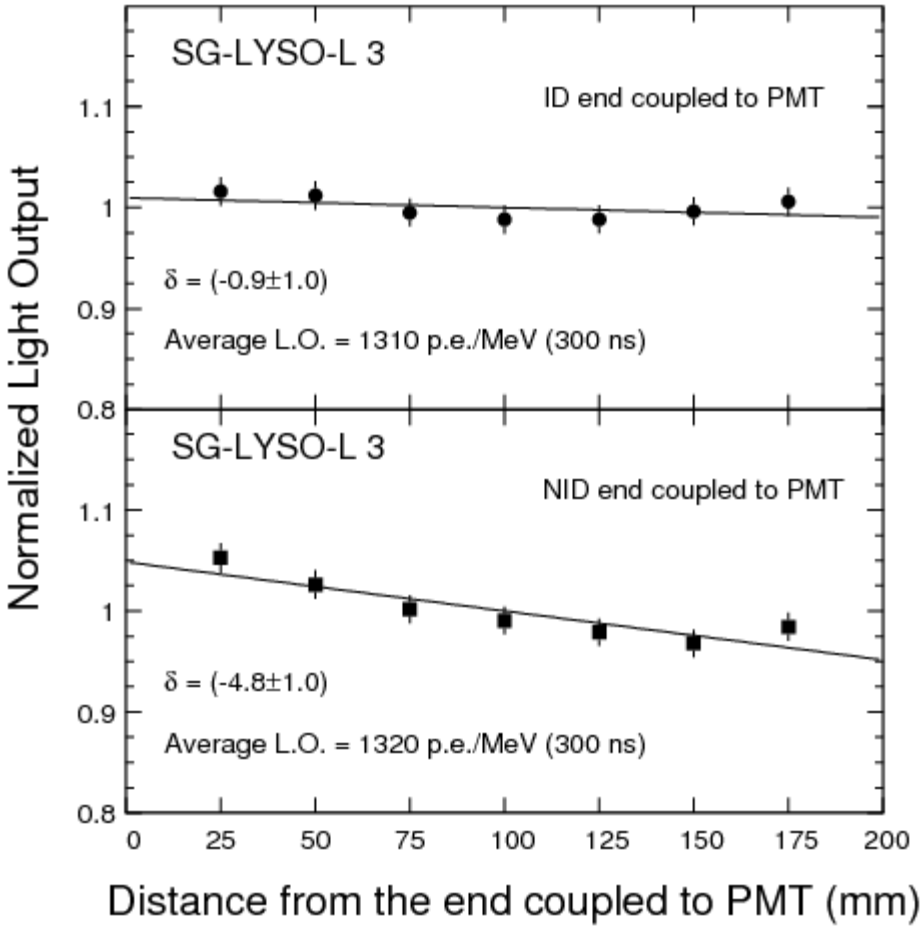
Issue: Ce doping was optimized for the uniformities measured by PMT with two end-couplings, but a large difference observed between the PMT & APD readouts.

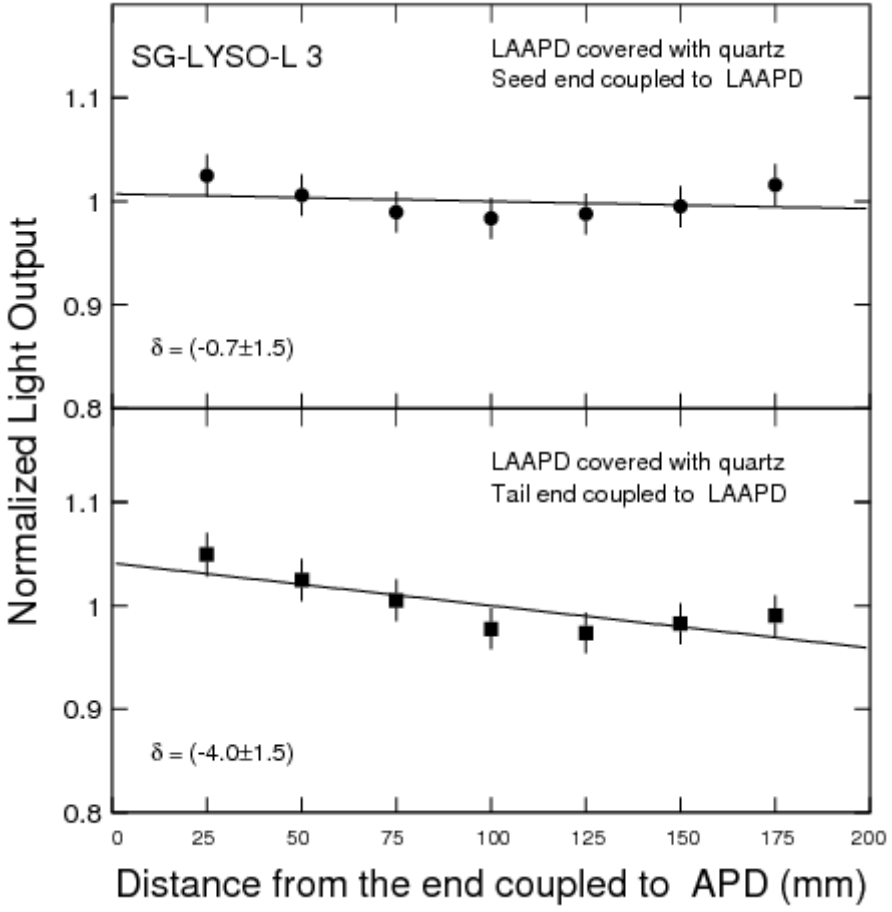




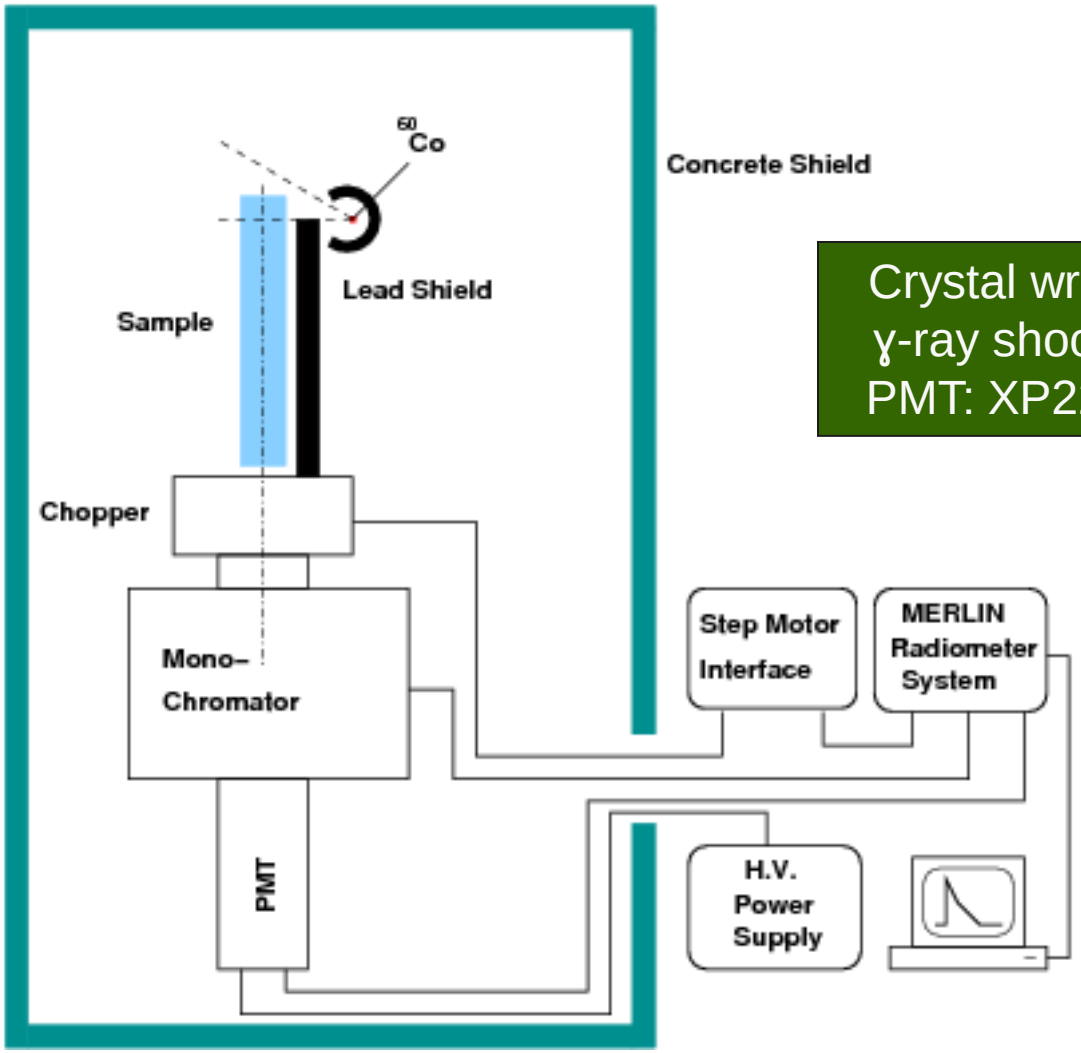
L.R.U. by PMT & LAAPD: SG-LYSO-L3

Consistent uniformities between PMT and APD
Some difference between two end-couplings





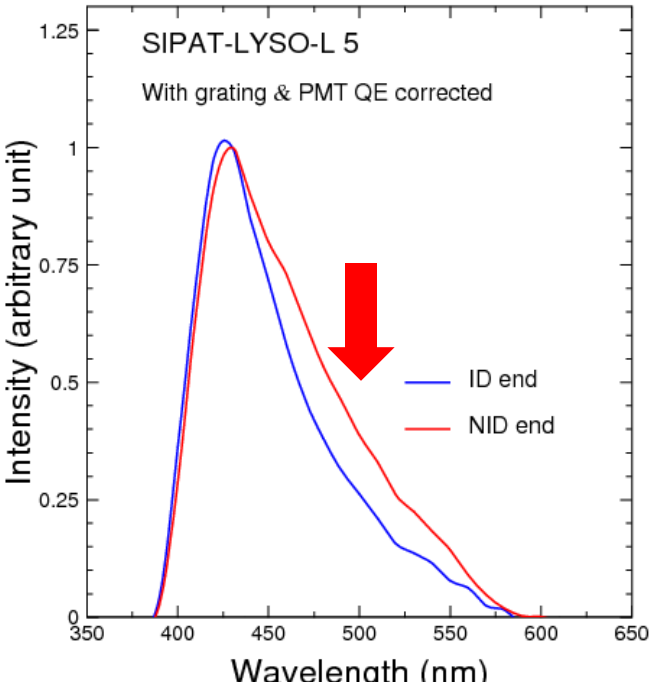
Radio-luminescence for LSO/LYSO

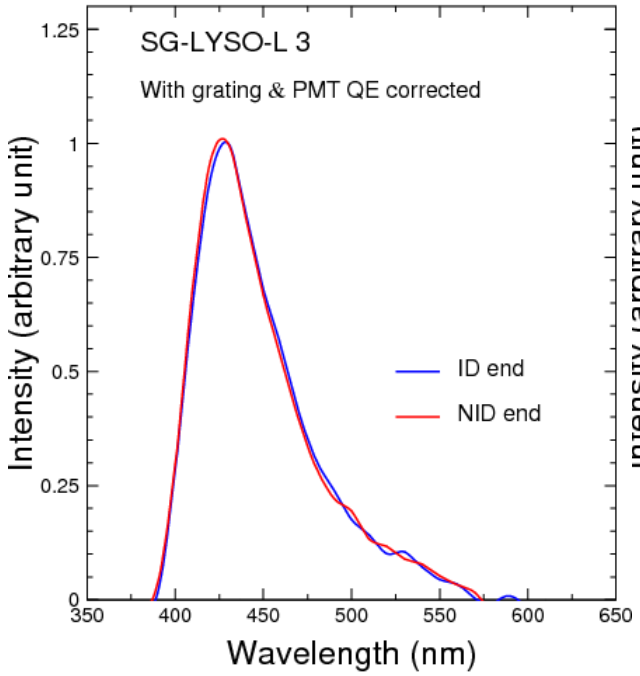


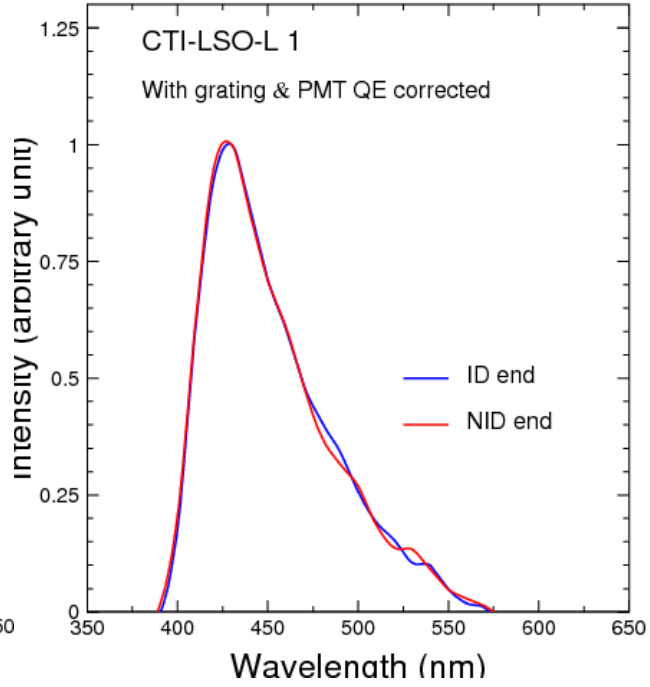
Crystal wrapped with Tyvek paper;
ɣ-ray shooting at two ends (1 cm);
PMT: XP2254B running @ -1800V.

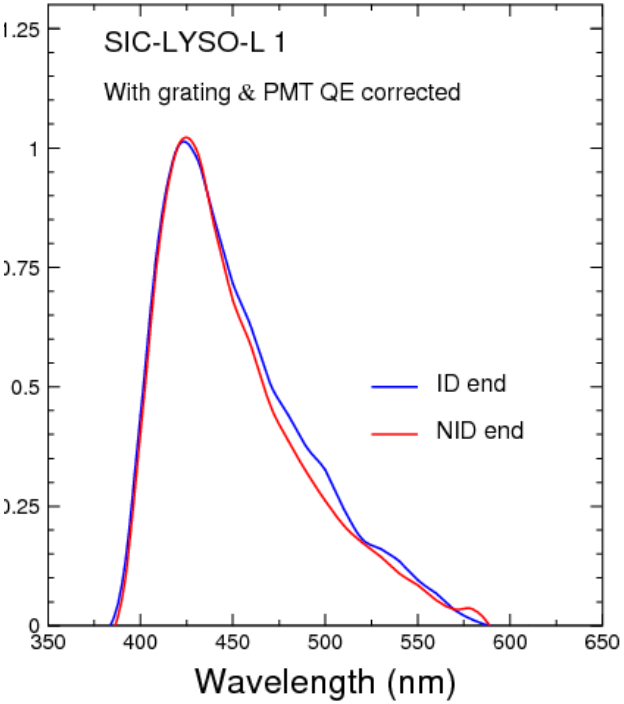
Radio-luminescence

Found: SIPAT-LYSO-L5 has an extra green emission component at the tail end, which does not show in other samples. This may explain the large difference observed in uniformities measured by PMT and APD.



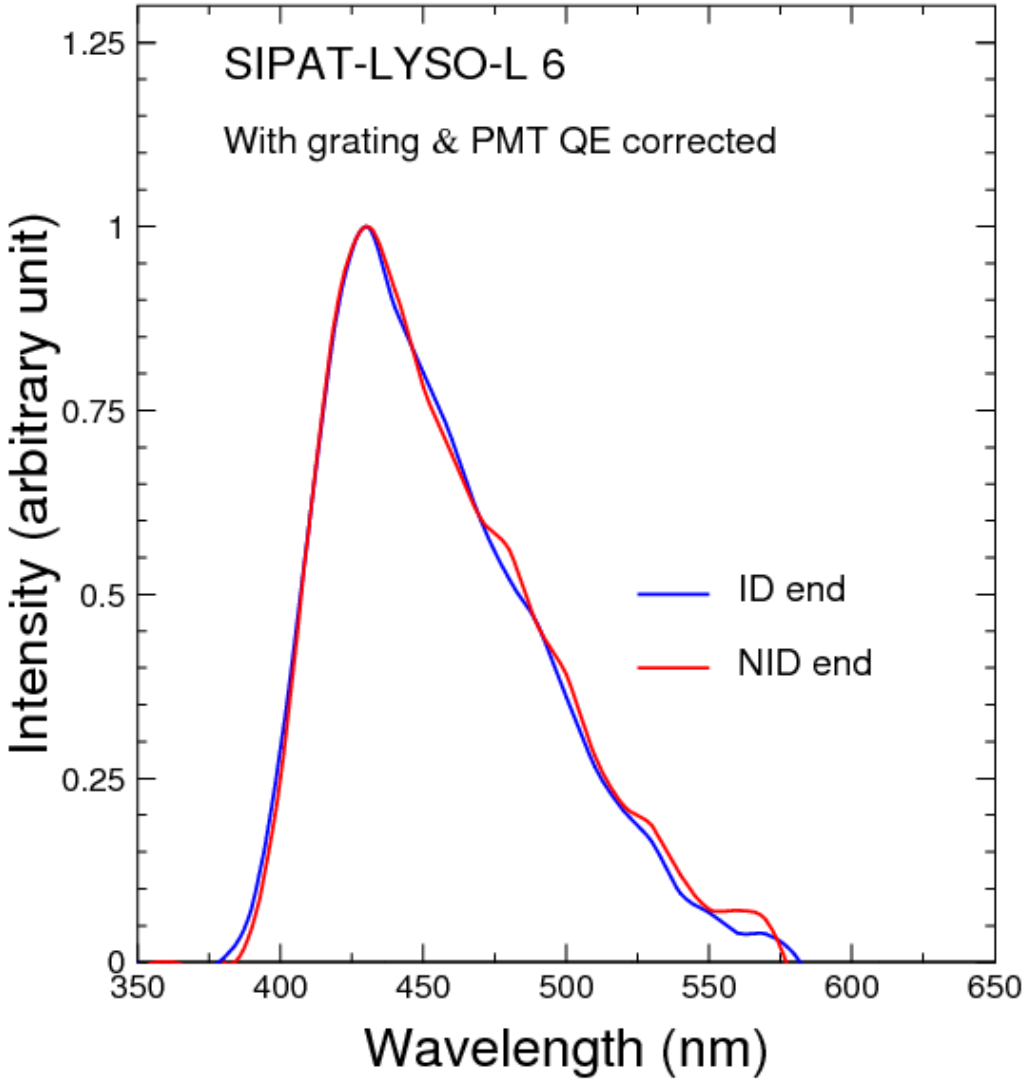






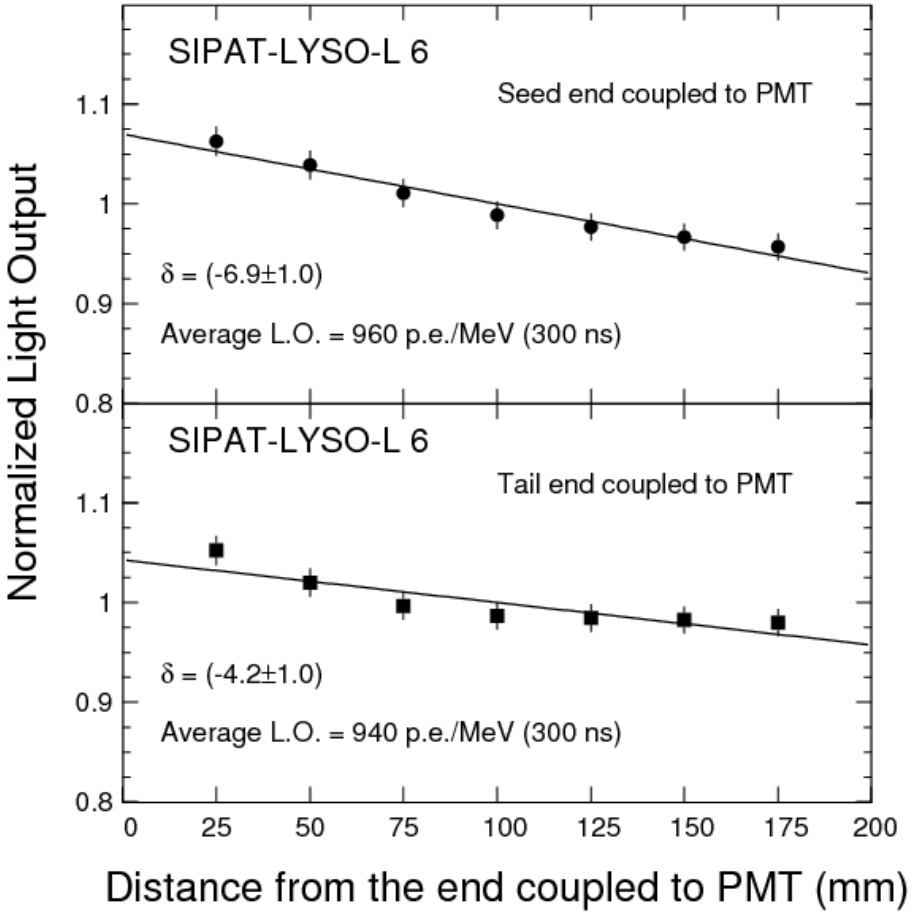
SIPAT-L6: Consistent Emission at two ends

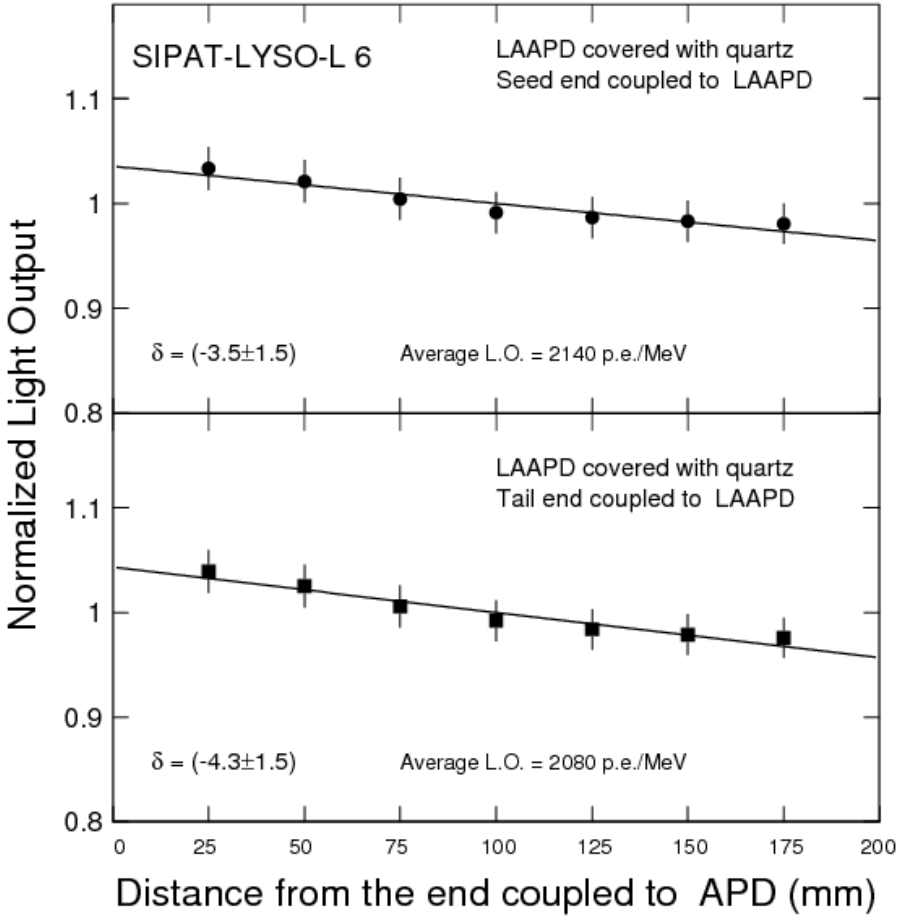
Extra green component at the tail end eliminated



SIPAT-L6: LRU with PMT and APD Readout

Slopes are more or less consistent for both PMT and APD. They may be compensated by the optical focusing effect.





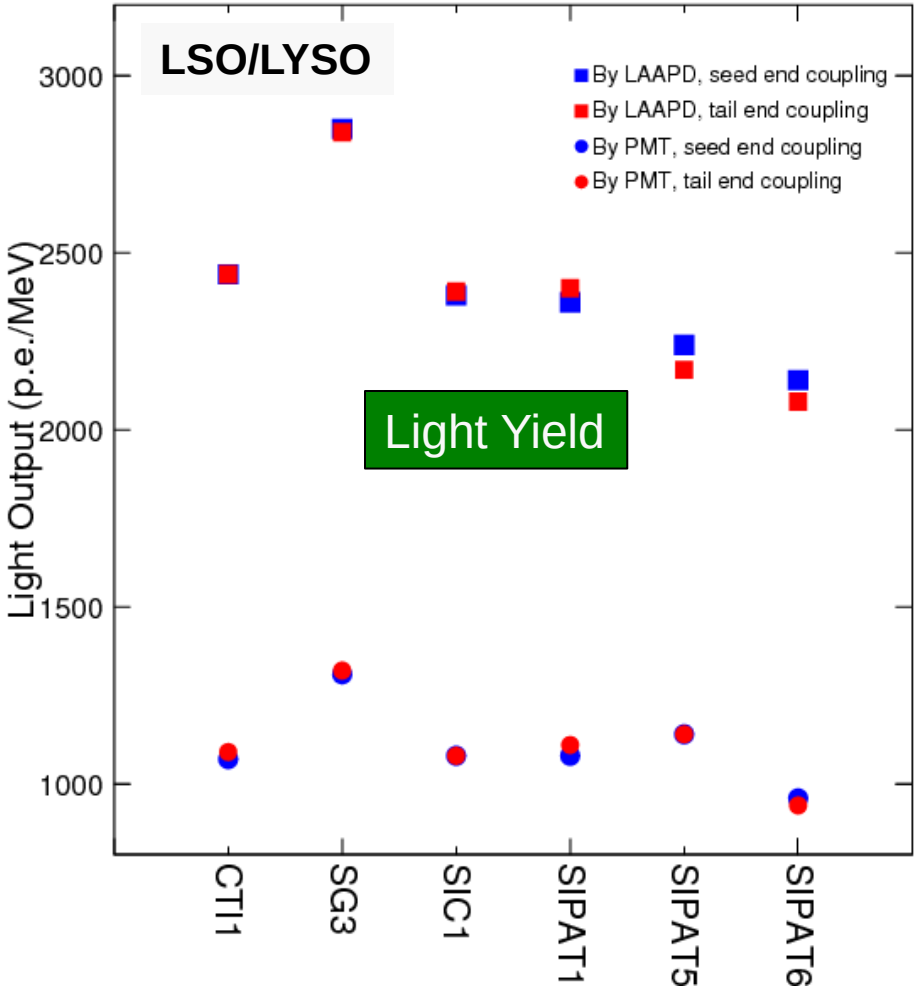
LYSO Uniformity

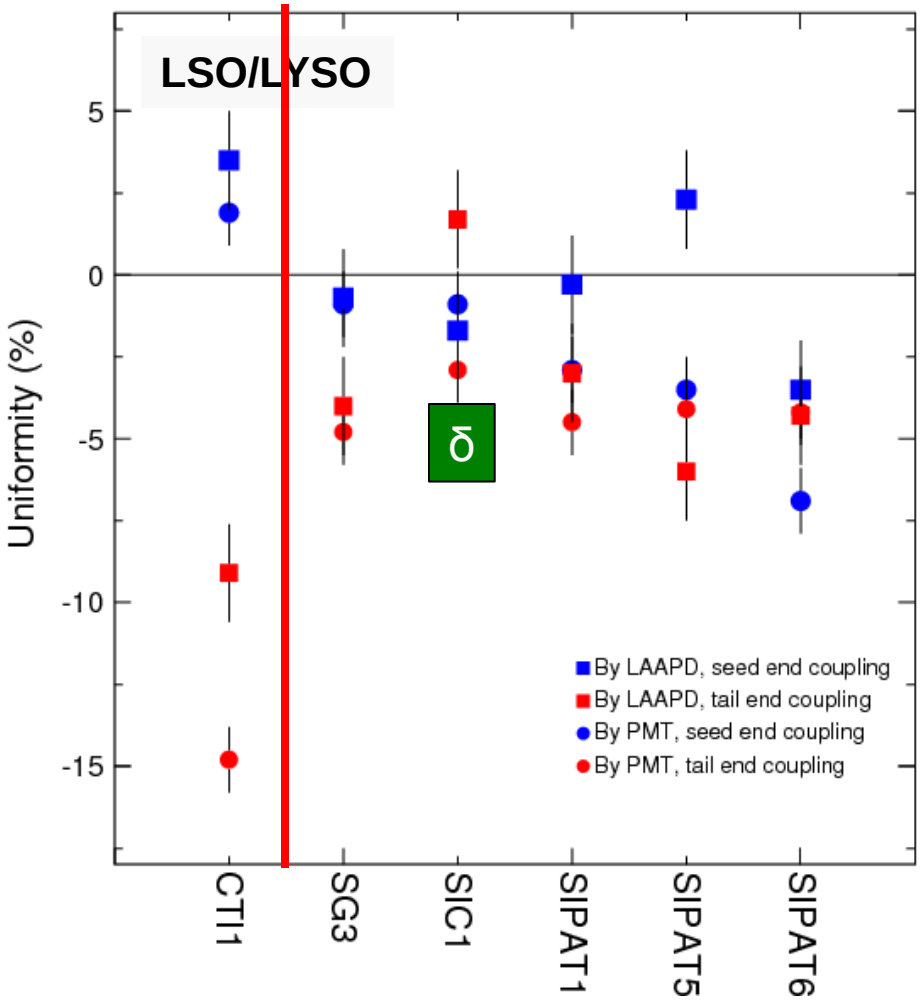
Slope δ is defined in slide 3, r.m.s. is for 14 measurements

ID	δ (%)				r.m.s. (%)	
	PMT Seed (±1)	PMT Tail (±1)	LAAPD Seed (±1.5)	LAAPD Tail (±1.5)	PMT	LAAPD
CTI-L1	1.9	-14.8	3.5	-9.1	6.8	4.2
SG-L3	- 0.9	- 4.8	- 0.7	- 4.0	2.3	2.3
SIC-L1	- 0.9	- 2.9	- 1.7	1.7	3.8	2.3
SIPAT-L1	-2.9	-4.5	-0.3	-3.0	2.7	1.8
SIPAT-L5	-3.5	-4.1	2.3	-6.0	4.7	3.9
SIPAT-L6	-6.9	-4.8	-3.5	-4.3	4.9	3.6

Comparison of Light Yield and Uniformity

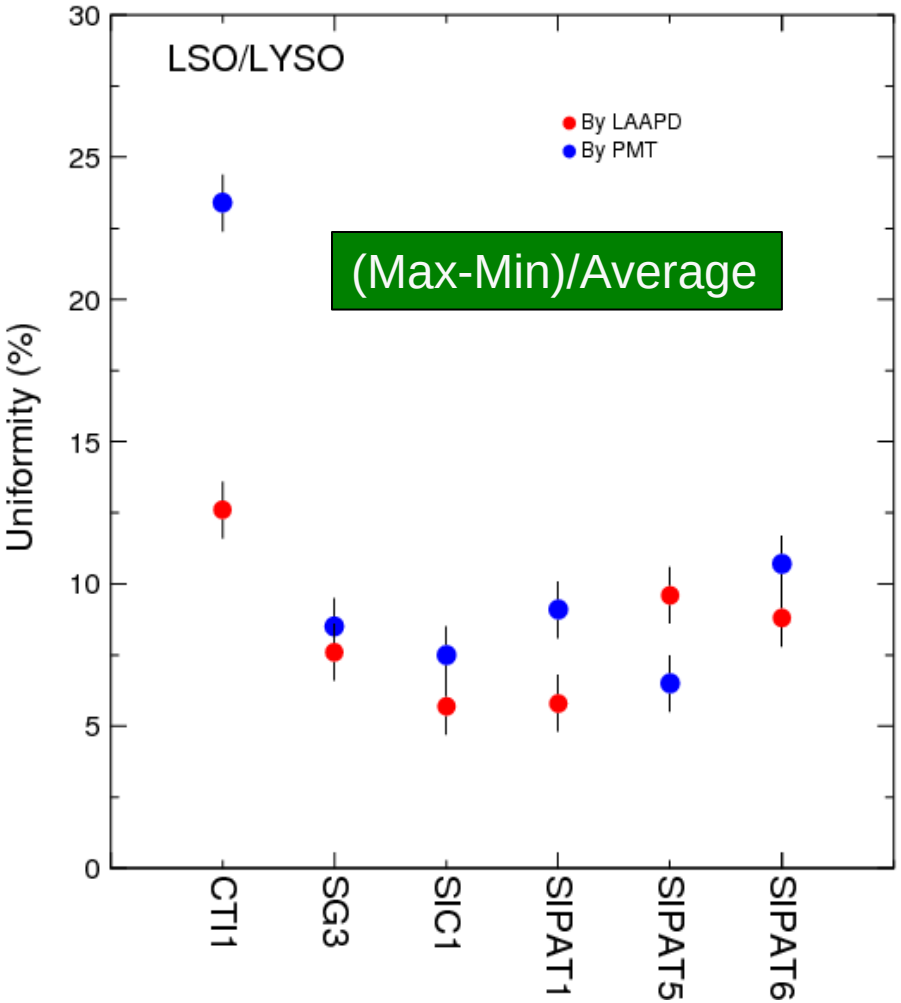
SG-L3 has high light yield. LYSO more uniform than LSO

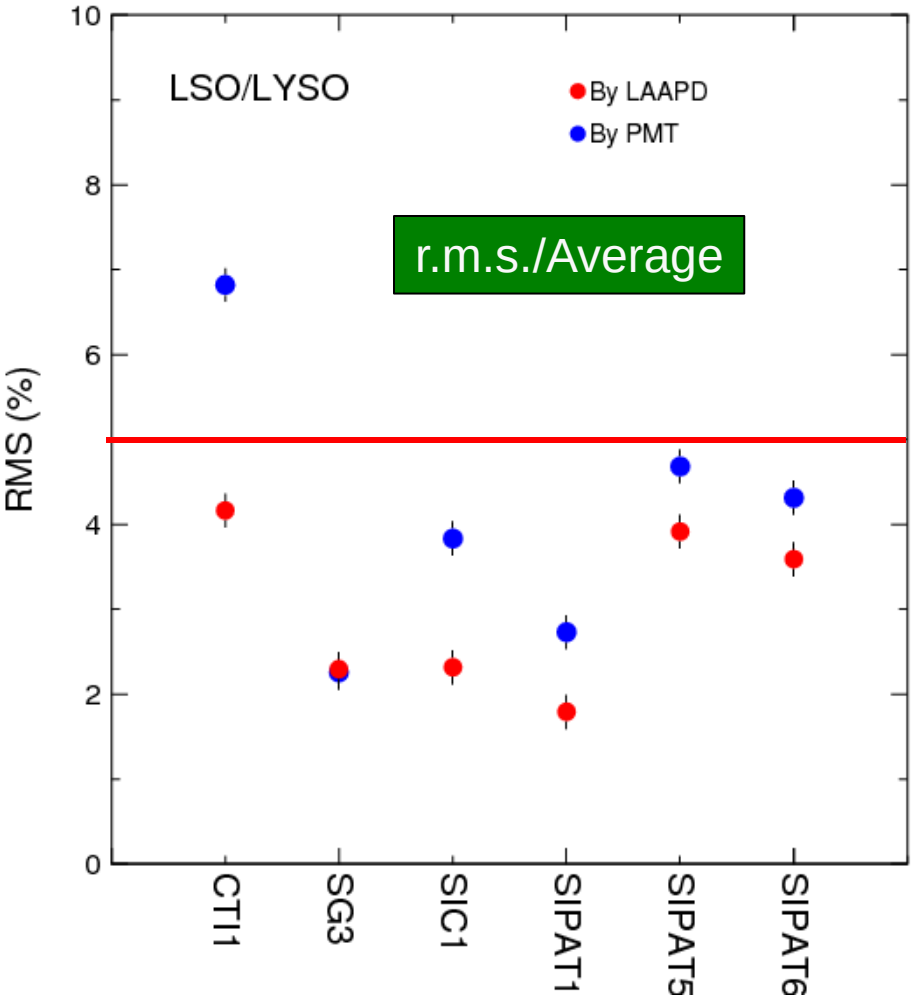




Comparison of Uniformity

All LYSO samples with r.m.s. less than 5%
SG-3 has the best uniformity



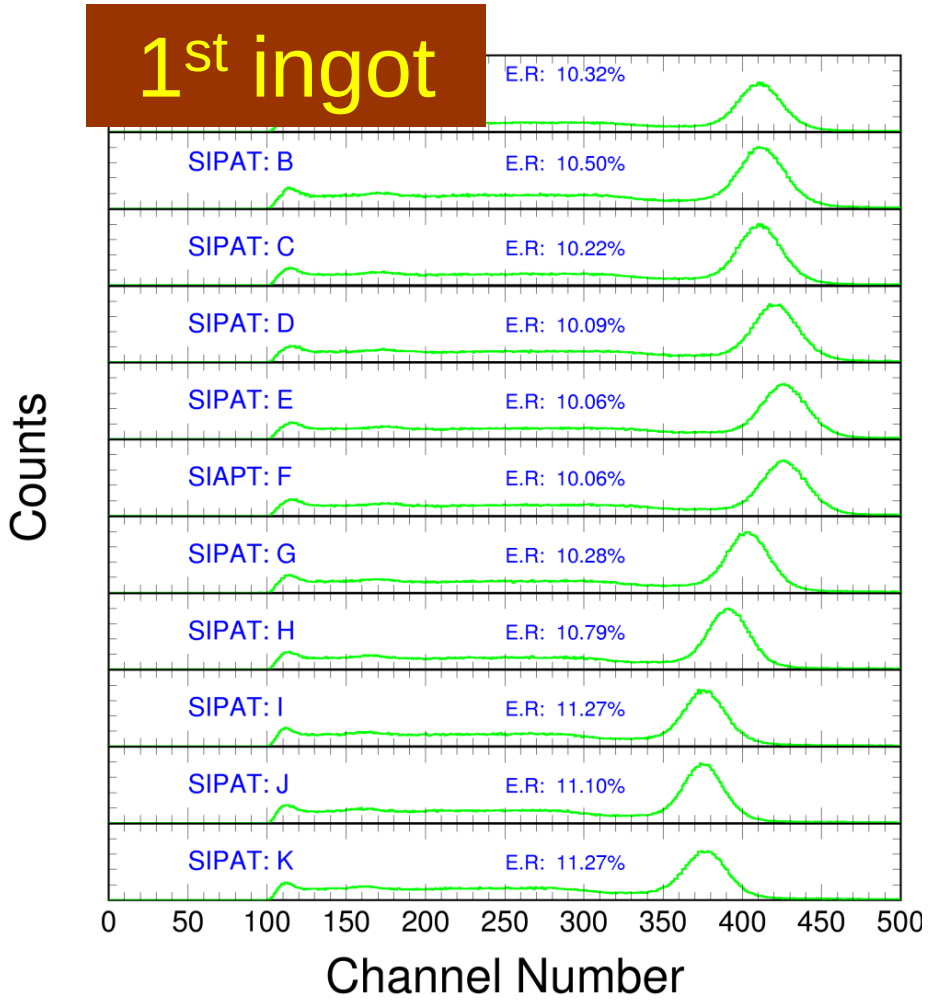


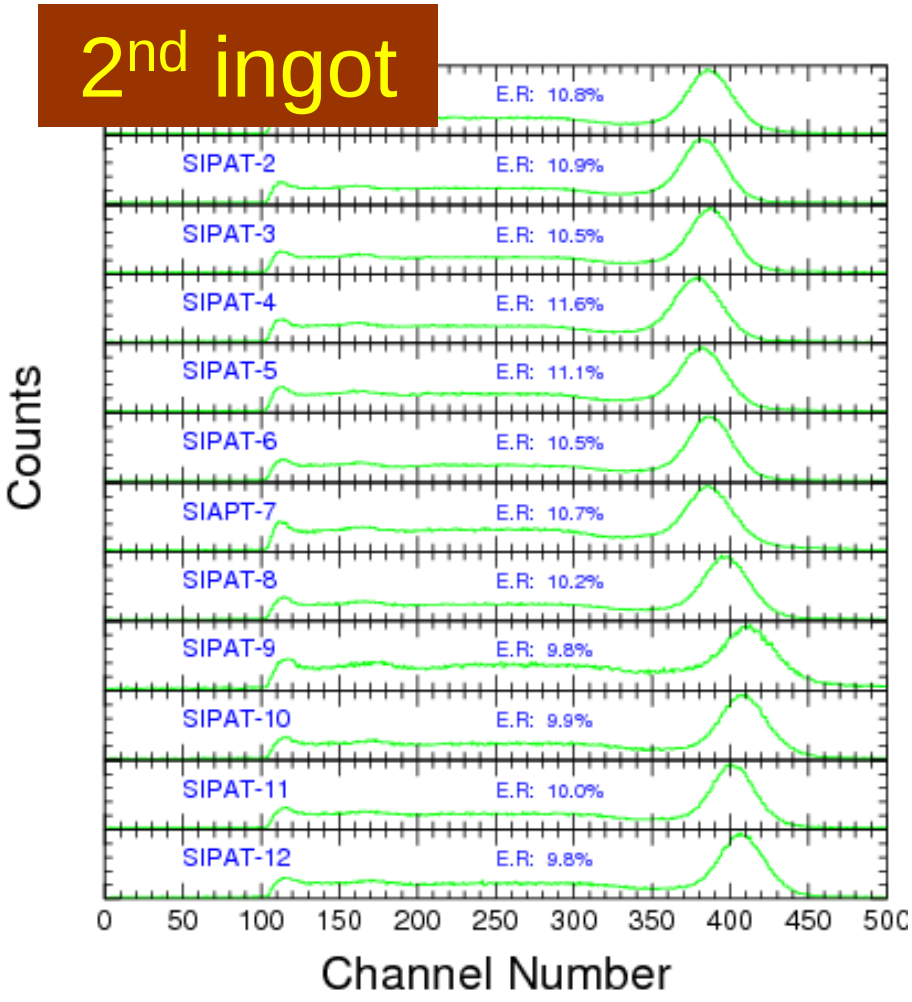
Crystal Specifications?

- Define the required light yield: relative to a small candle with PMT and air gap.
- It may be important to define pulse FWHM resolution, which has an intrinsic contribution.
- Define the required light response uniformity profile by GEANT simulation.
- Check consistency of transmittance and emission.

FWHM Resolution: <12.5% for ^{137}Cs

Energy resolutions are position dependent, indicating possible correlation with the cerium concentration.

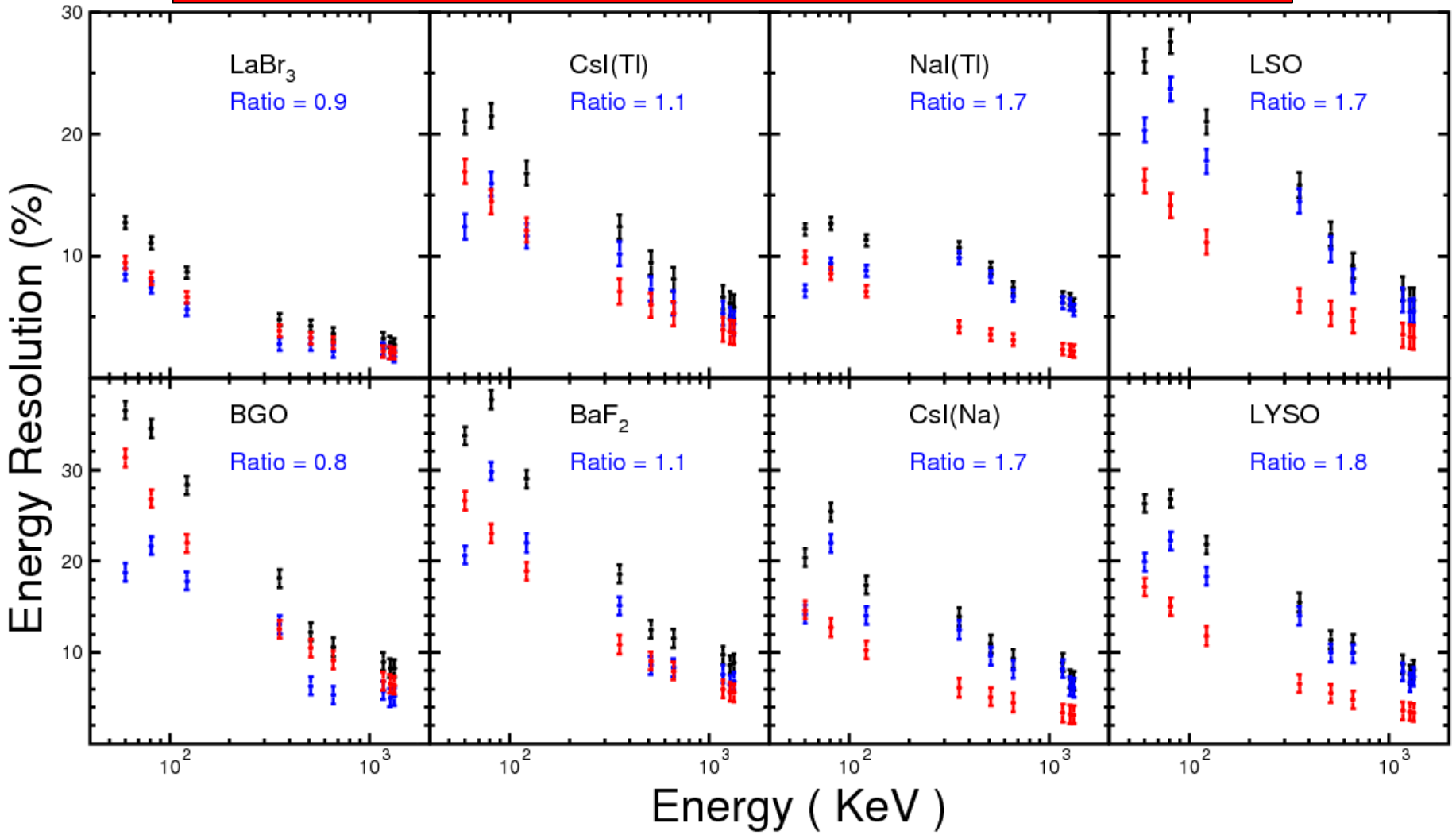




Statistical & Intrinsic Resolutions

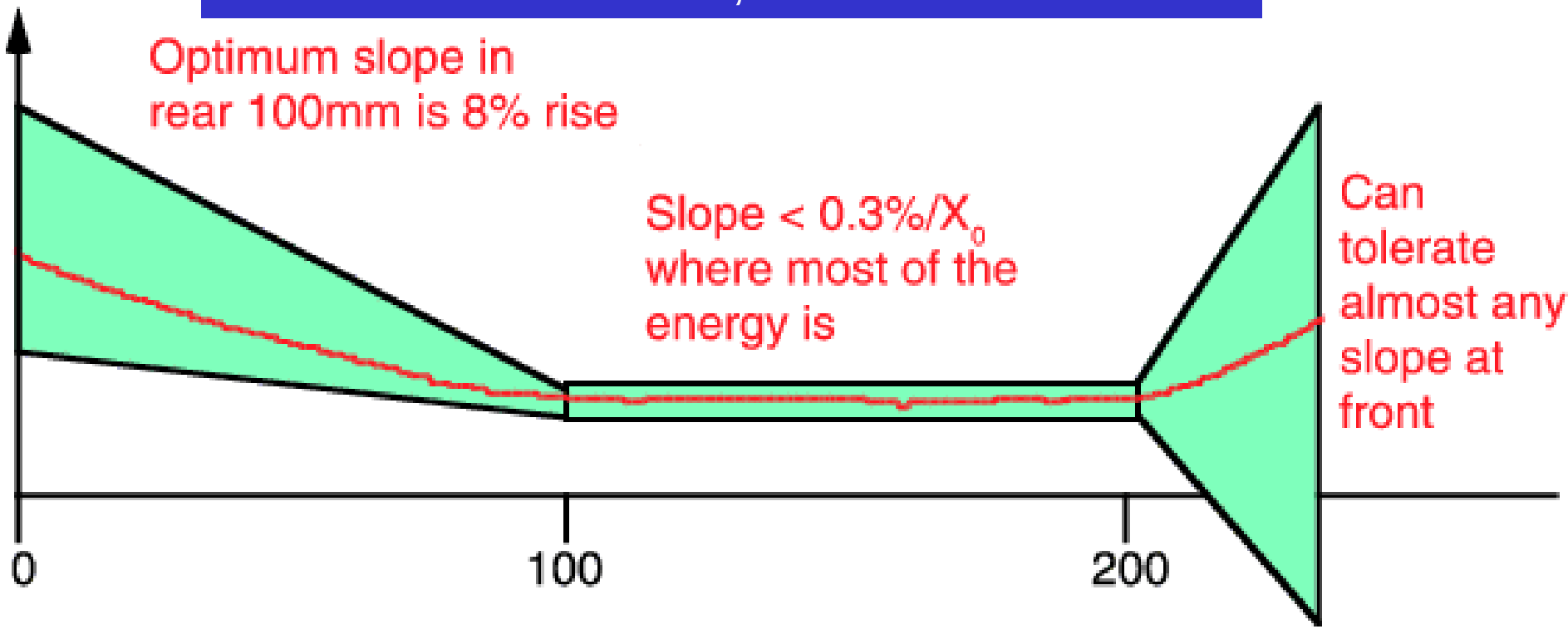
$\sigma^2 = \sigma^2_{intrinsic} + \sigma^2_{statistical}$, ratio = $\sigma_{intrinsic} / \sigma_{statistical}$

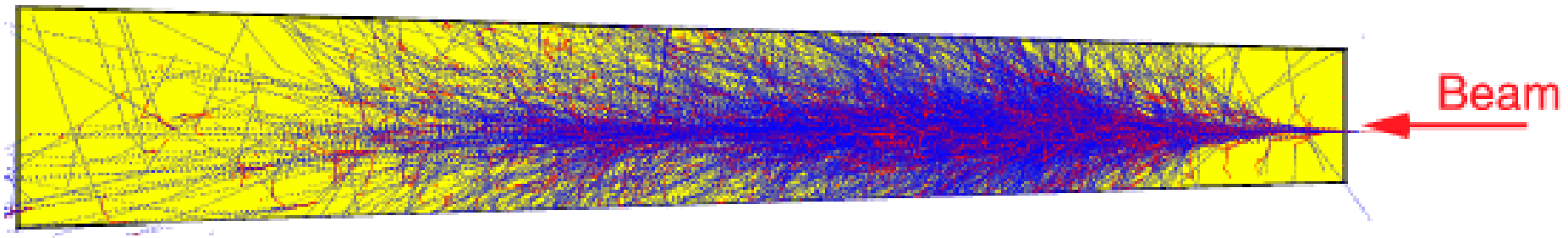
Good crystals: BGO and $LaBr_3$



CMS Specification for LRU

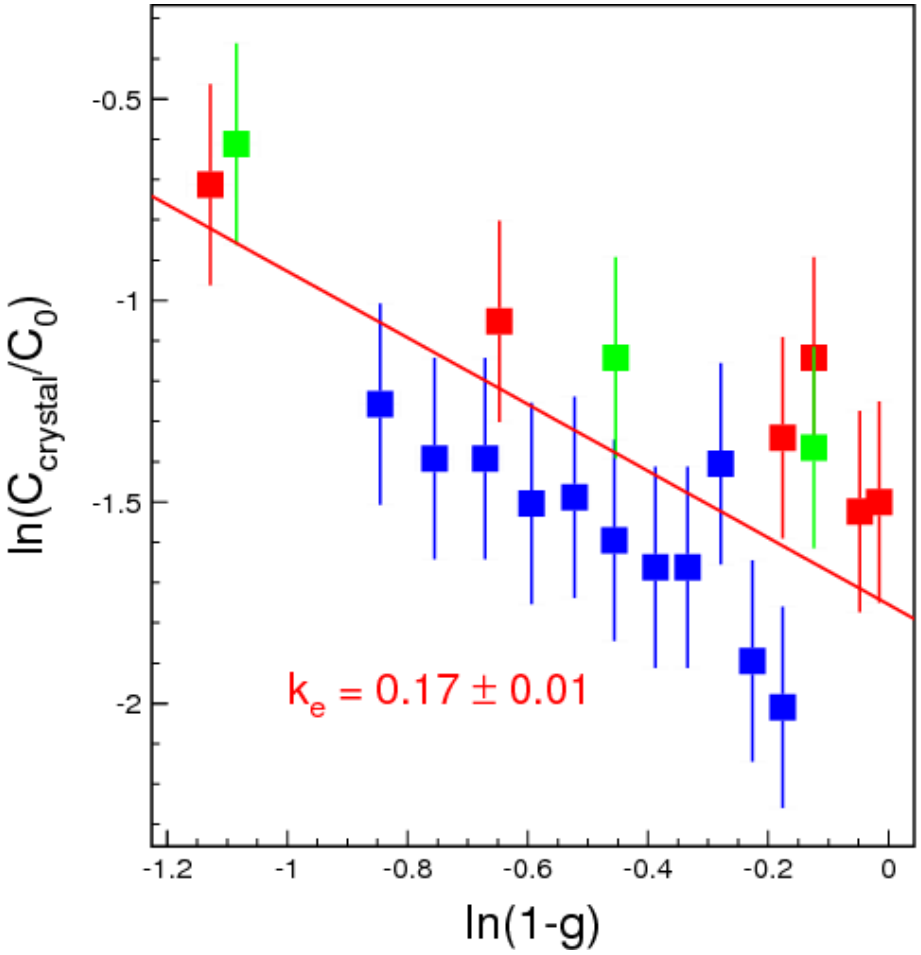
D. Graham & C. Seez, CMS Note 1996-002

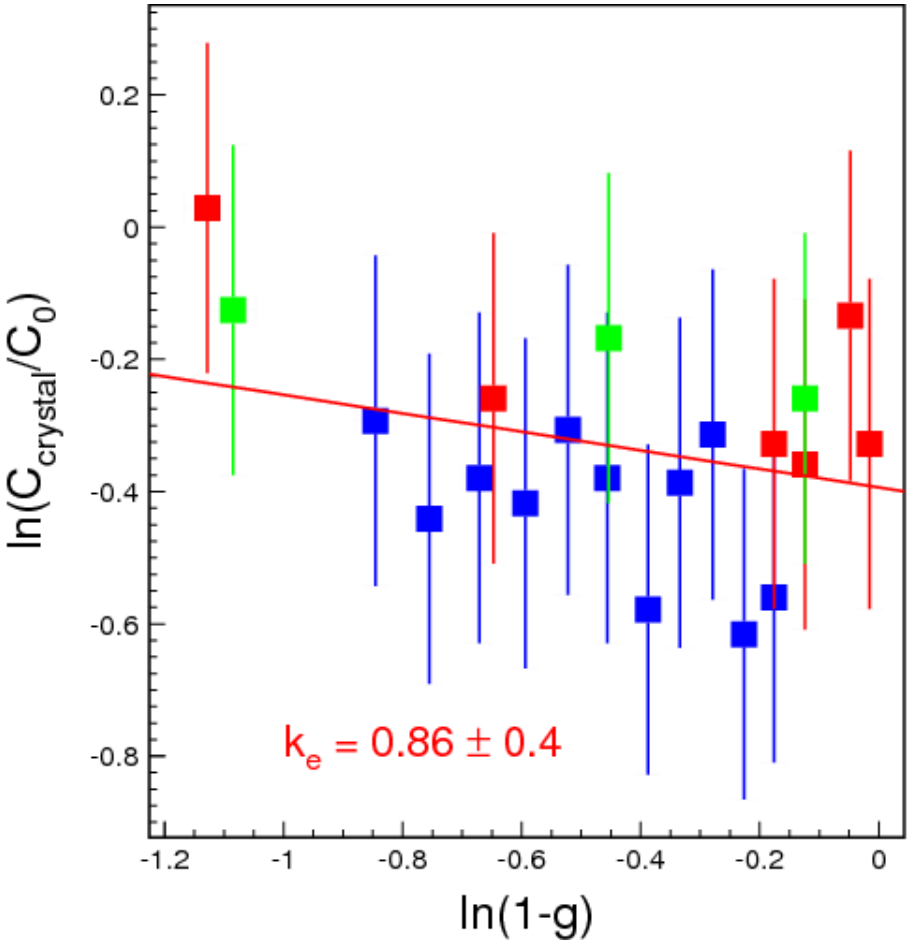




Ce & Y Segregation Coefficients

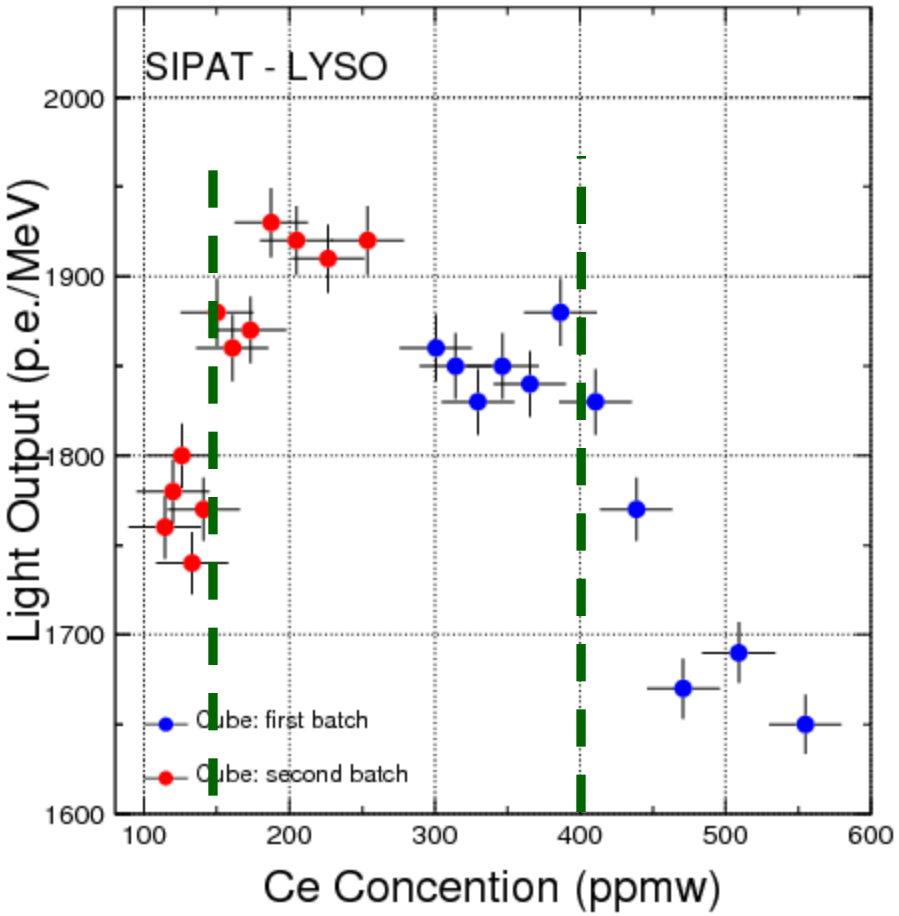
Extracted from two sets of GDMS data

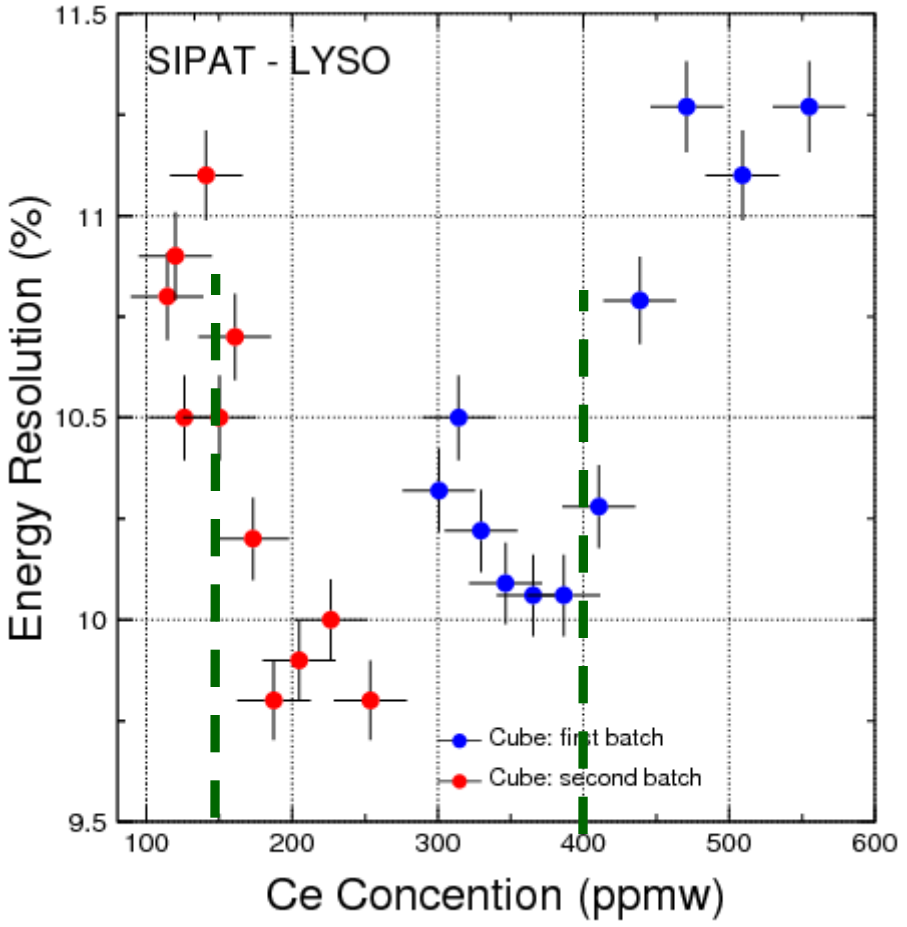




Relation between Light Output and FWHM Resolution versus [Ce]

Optimum [Ce]: 150 to 400 ppmw



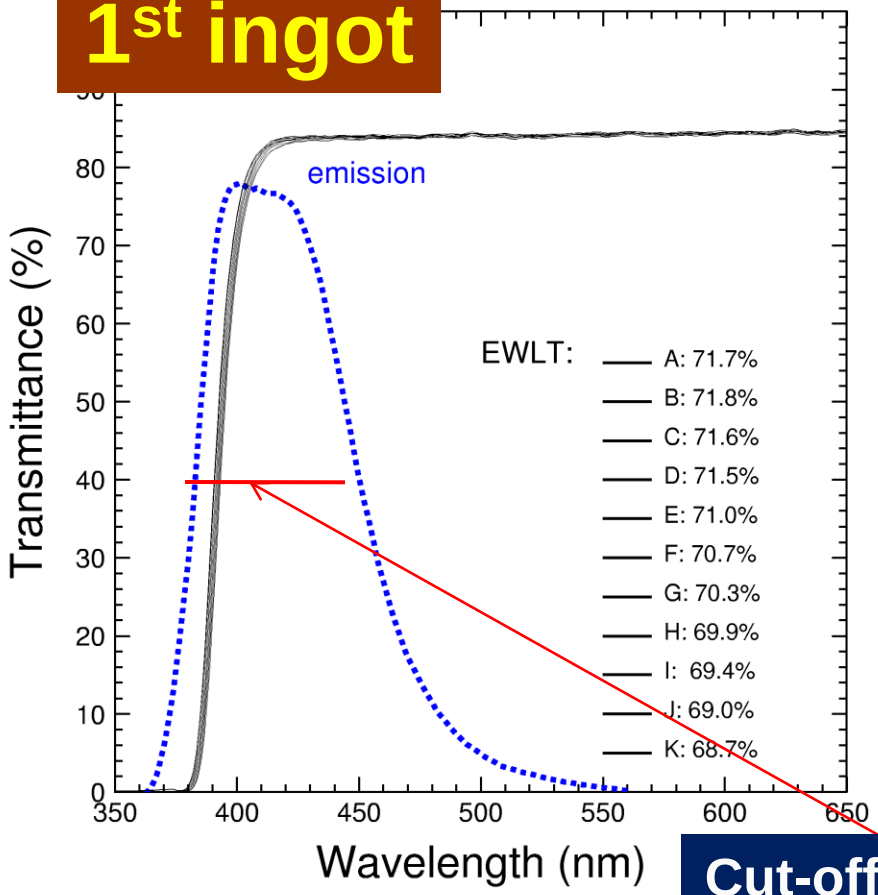


Transmission Spectra

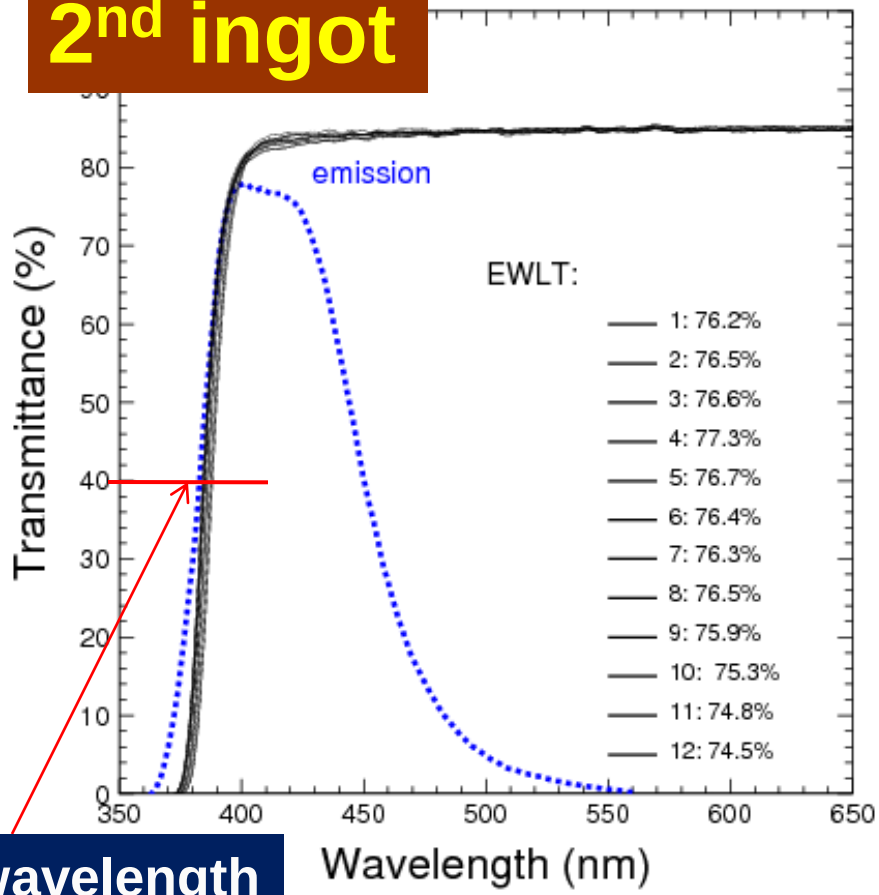
Transmissions are position dependent:

$$EWLT = \frac{\int LT(\lambda)Em(\lambda)d\lambda}{\int Em(\lambda)d\lambda}$$

1st ingot



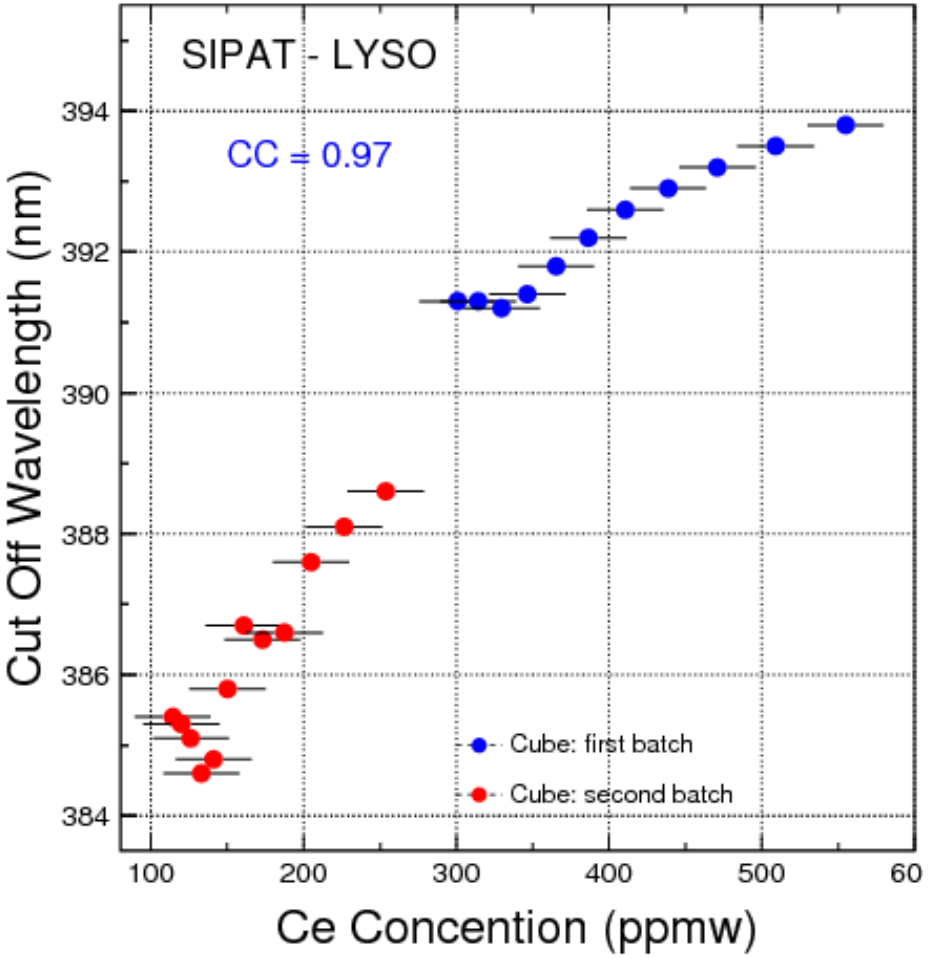
2nd ingot

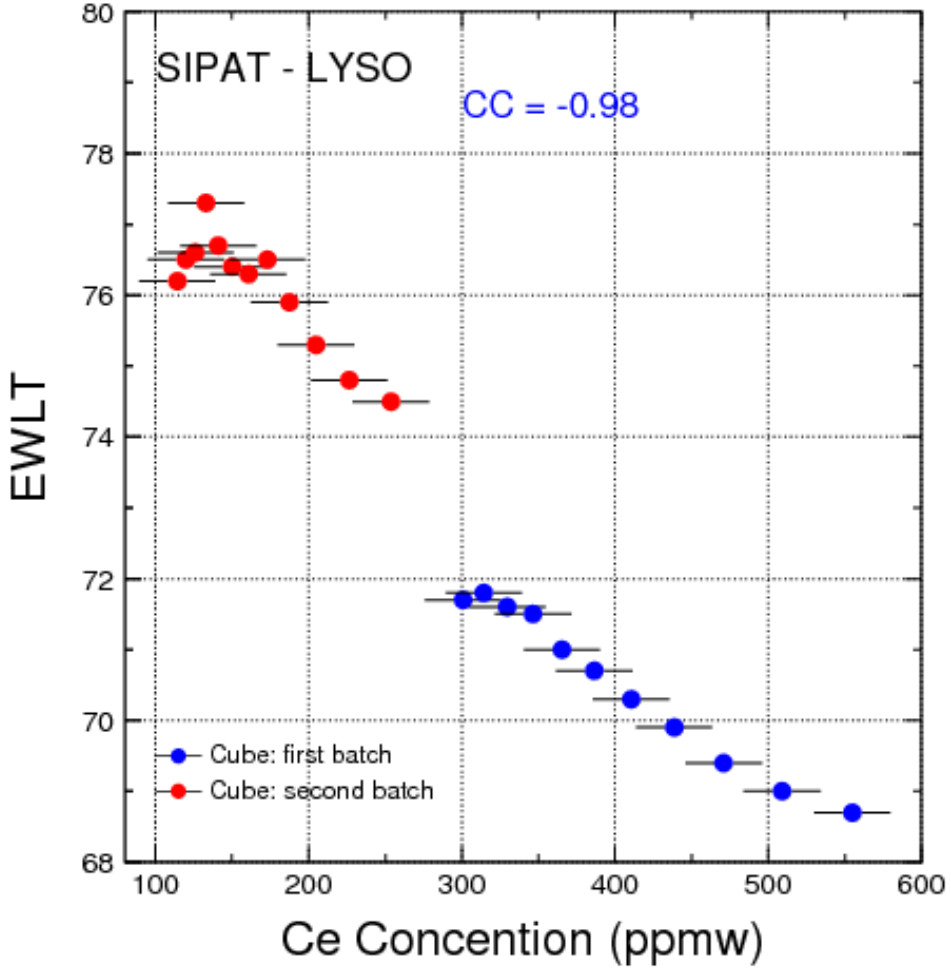


Cut-off wavelength

Correlations: T (17 mm) versus [Ce]

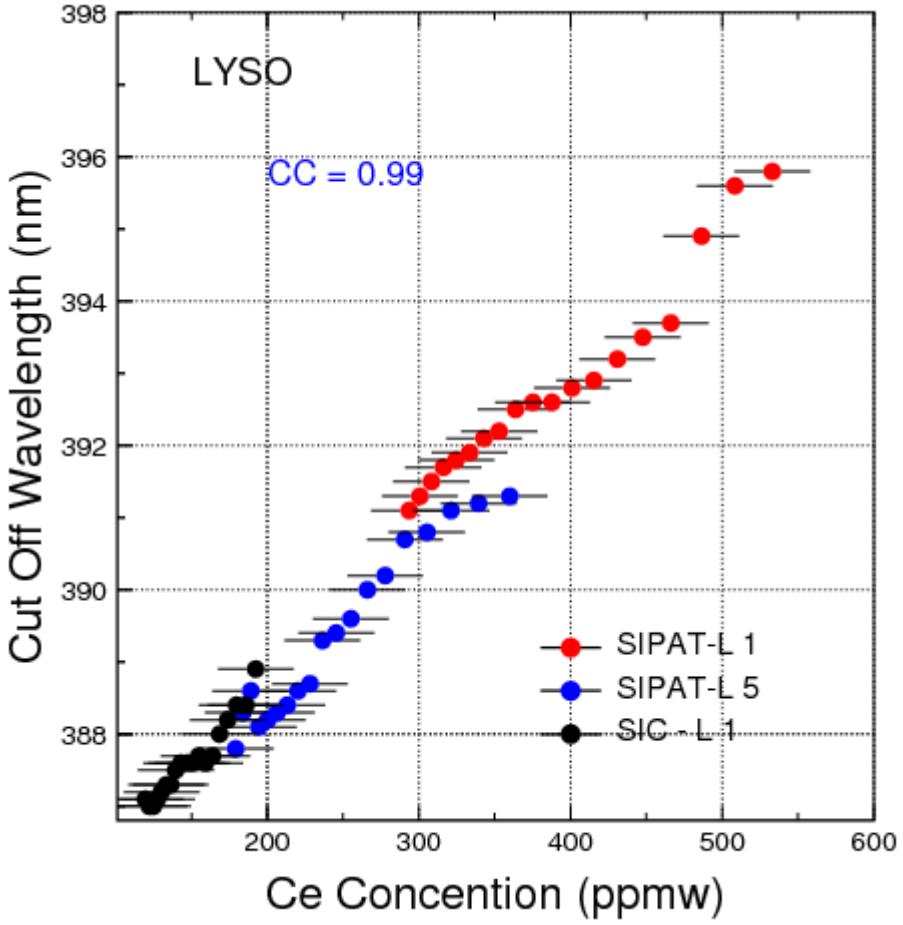
Transverse transmittance (17 mm path length)

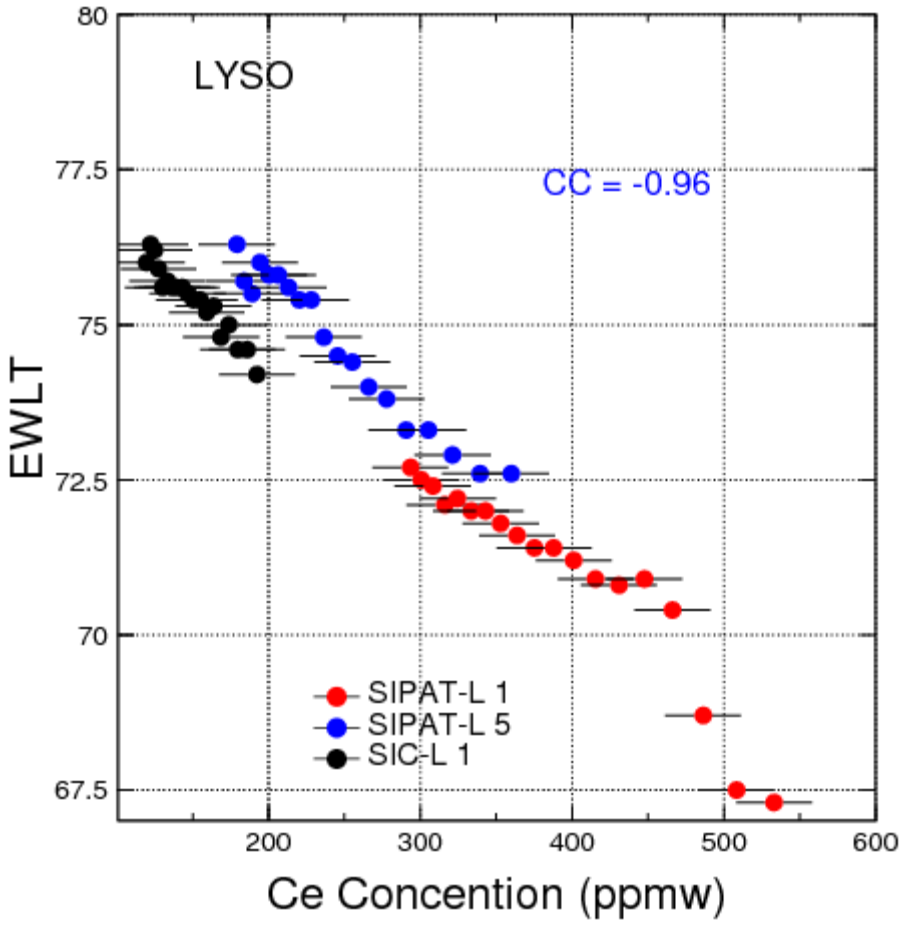




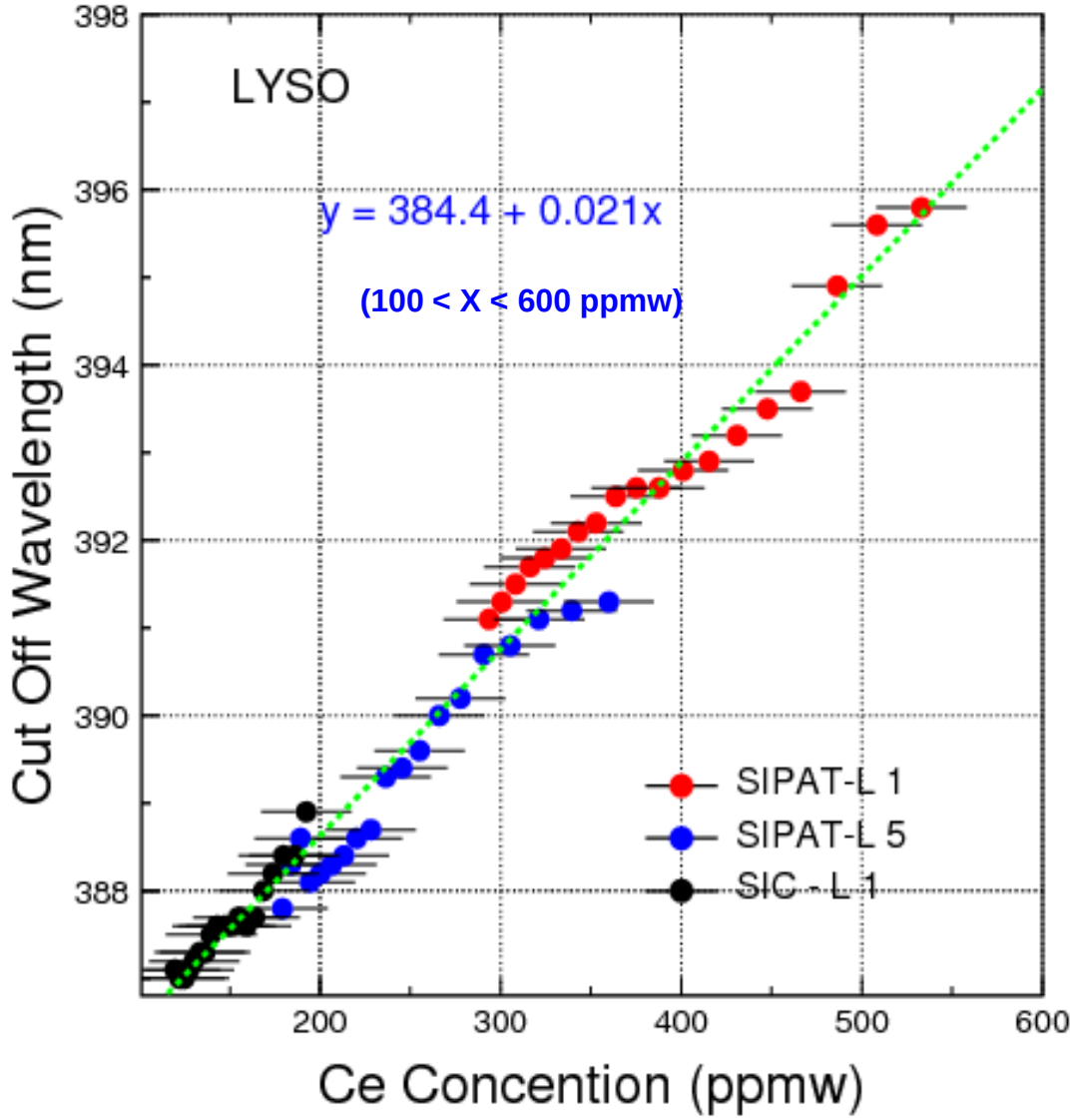
Correlations: T (25 mm) versus [Ce]

Transverse transmittance (25 mm path length)

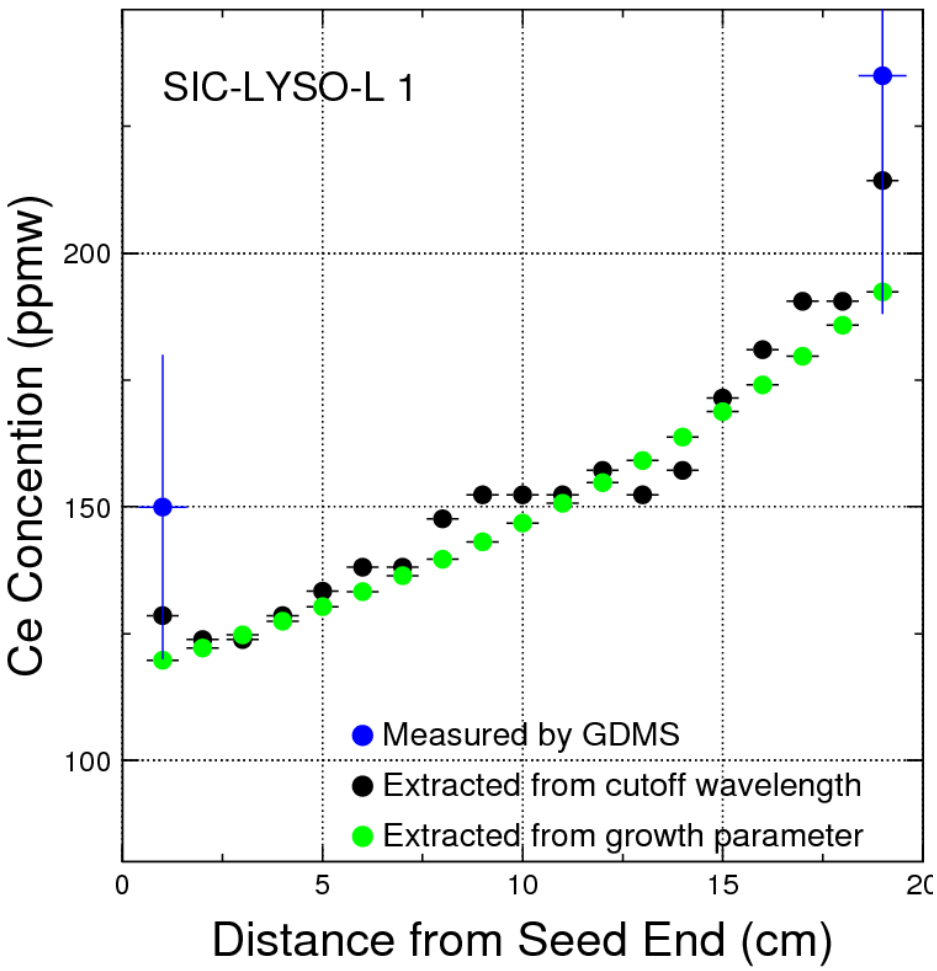


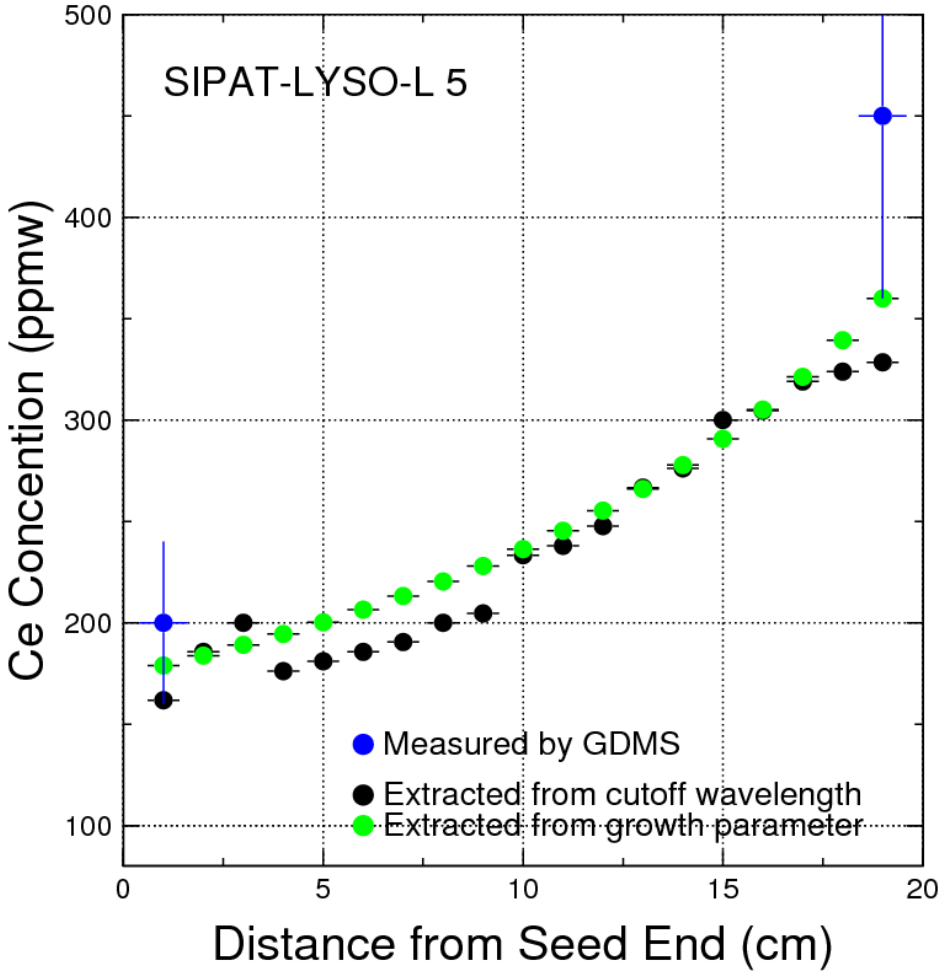


[Ce] may be Extracted by Cutoff Wavelength

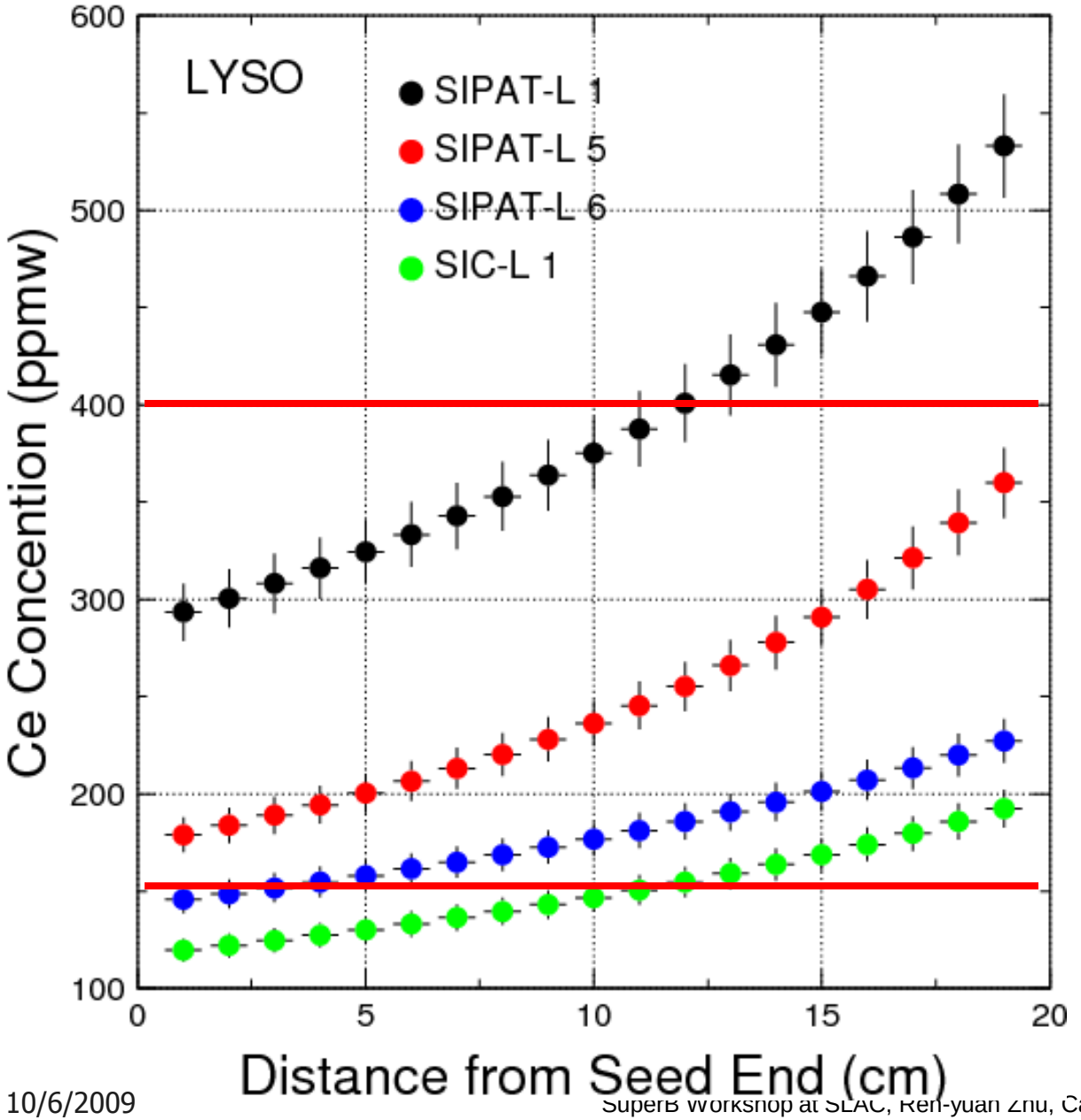


[Ce] extracted using transmittance cut-off compared to calculated/measured values





[Ce] Calculated using Growth Parameters



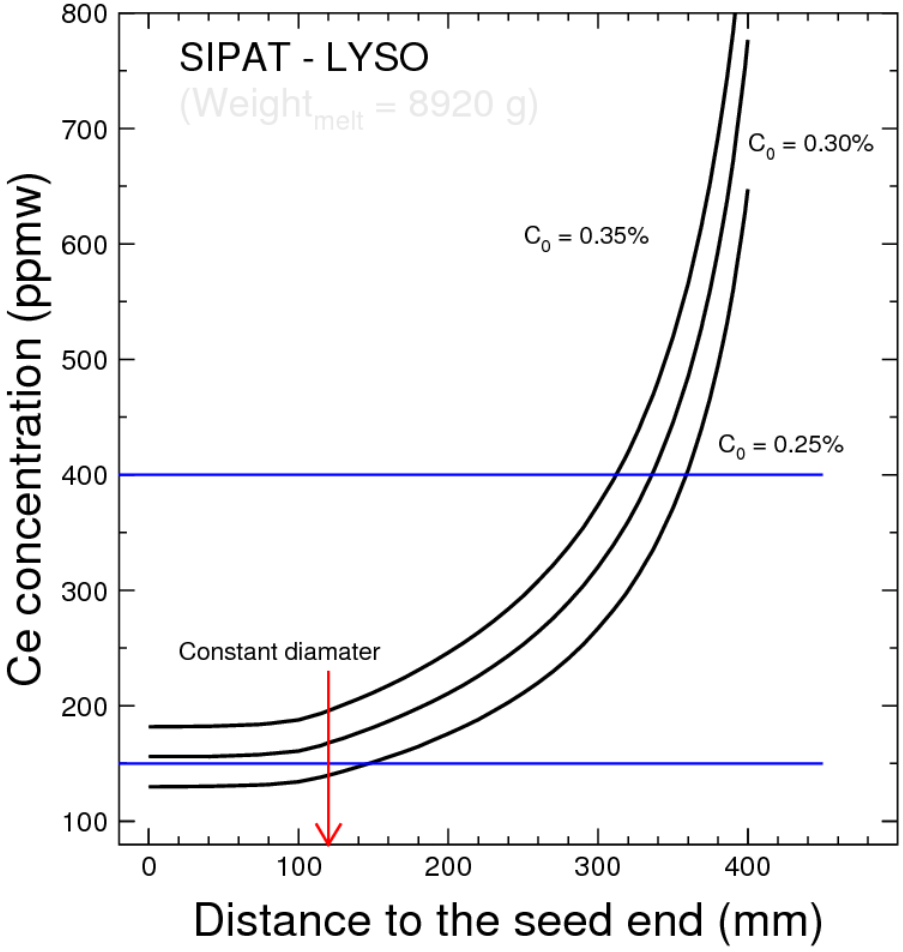
[Ce] in both SIPAT and SIC samples needs to be further optimized.

This is an expansive exercise.

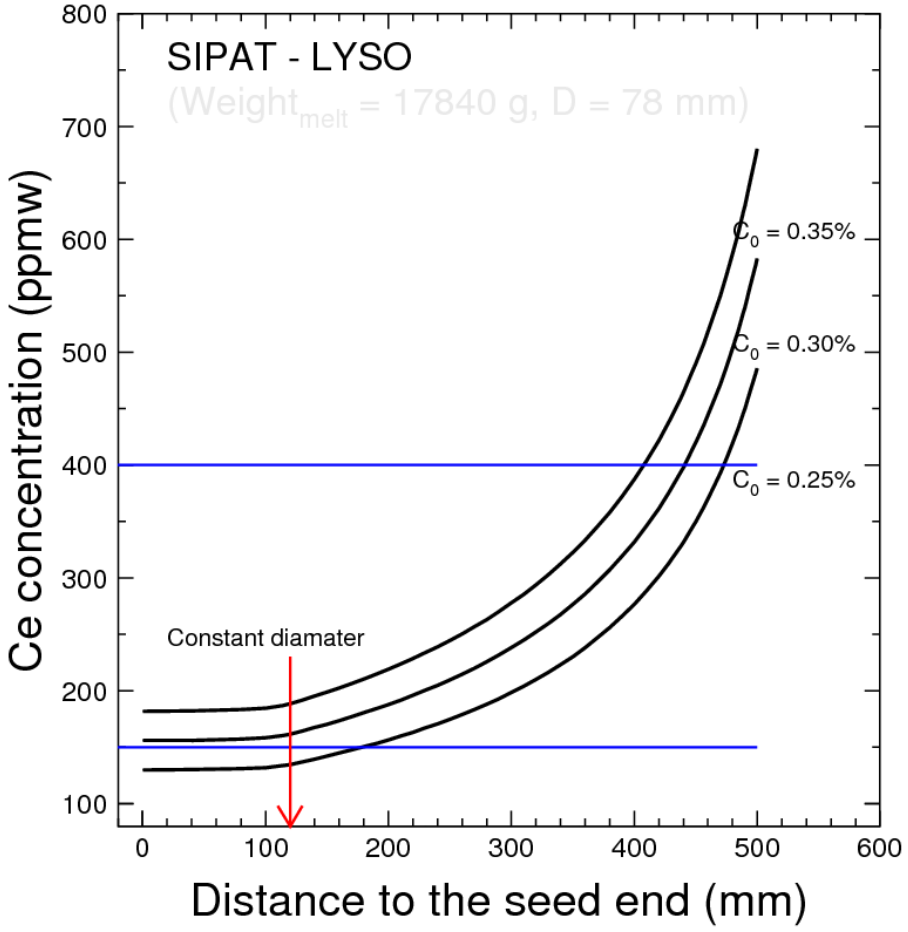
Calculate [Ce] in Long LYSO Ingot

0.30% mol, or 0.15% atomic [Ce] in melt seems the best

Raw material: 8920g, Φ= 65 mm

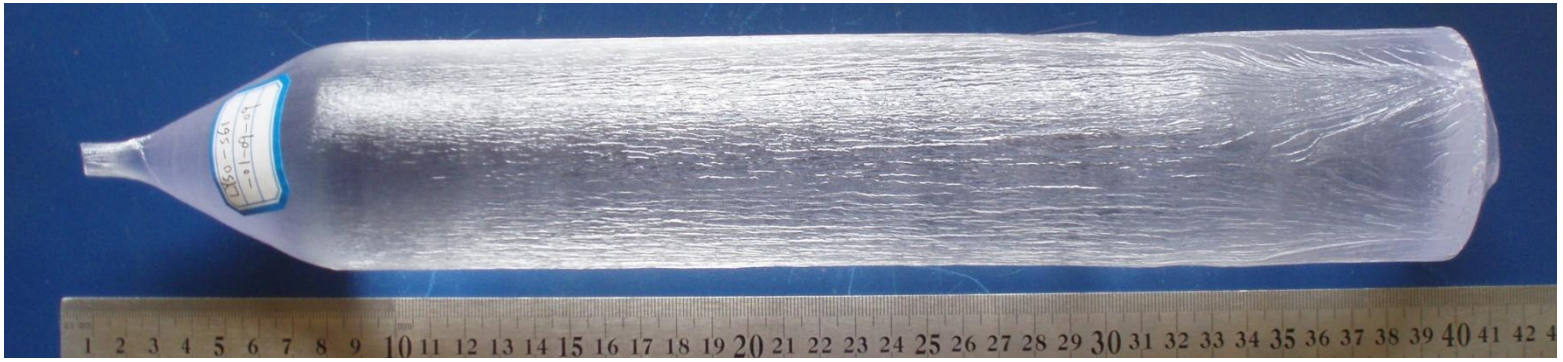


Raw material: 17840g, Φ= 78 mm



LYSO Progress at SIPAT

- Six furnaces for LYSO ingots of Φ61-68 x 210-230 mm.
- Average yield better than 90%.
- Uniformity of light yield is about 5%.
- 1st Φ61x 300 mm Ingot produced in August for 25 X_0 crystal sample.



LYSO Progress at SIC

- Two furnaces for LYSO ingots of Φ60 x 210 mm are in construction.
- 1st 25 x 25 x 200 mm sample delivered last September has good uniformity.
- It is important to keep SICCAS in the game so that the crystal cost is under control.

Summary

- The difference between the L.R.U. measured by PMT and APD readouts is understood. Consistent uniformity is achieved by eliminating the excess green component in the radio-luminescence spectrum at the tail end. The latest sample SIPAT-LYSO-L6 has good uniformity.
- Two sets of GDMS data allow extraction of segregation coefficients for cerium and yttrium. The optimum of cerium doping level is between 150 and 400 ppmw.
- The cerium concentration may be extracted by using the transverse transmittance data.
- Progress has been made in China for LYSO crystals production. It is time to define specifications and order crystals in batch so that the quality can be further improved.