Cerium and Yttrium Distributions in LSO crystals and their Influence to Optical and Scintillation Properties

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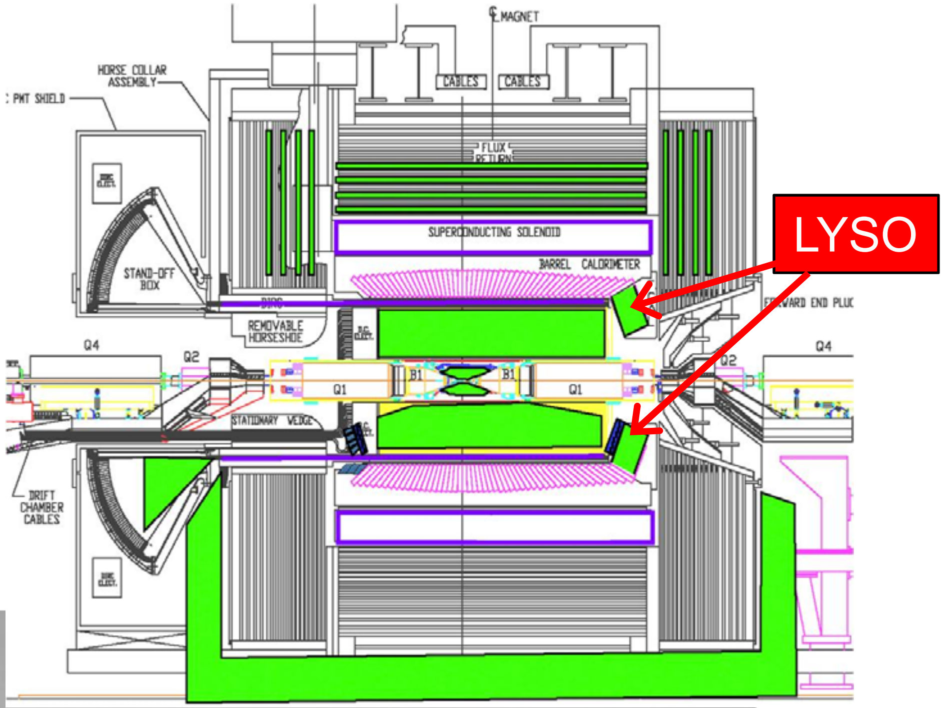
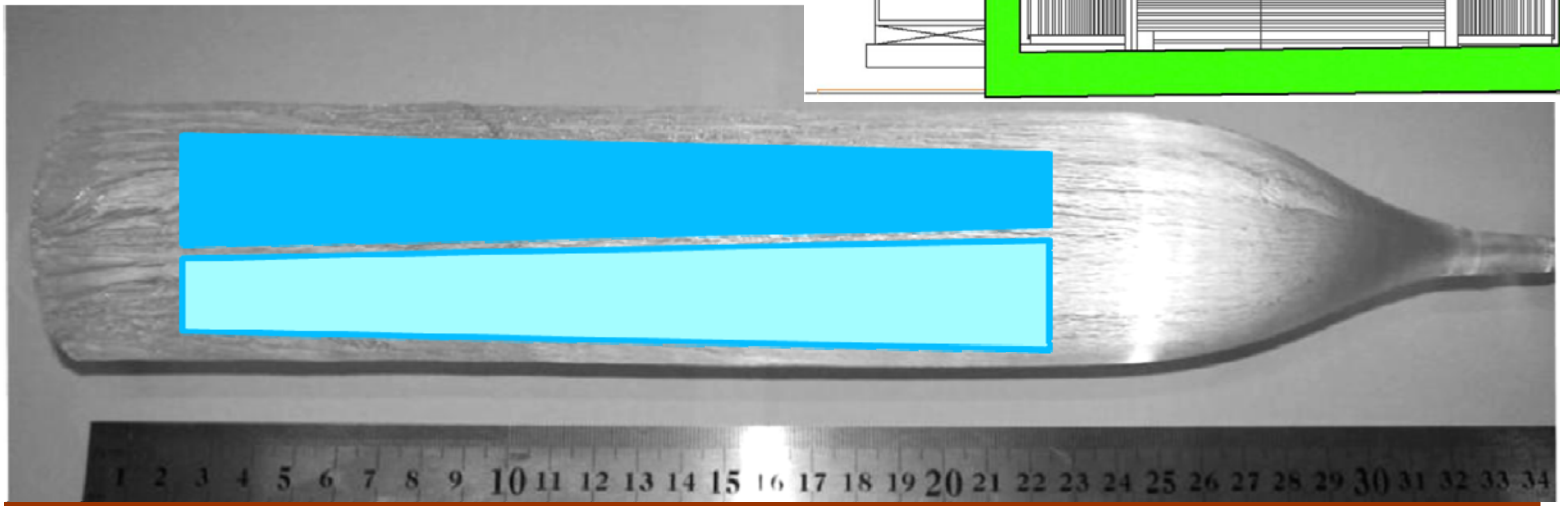
Motivation of this Work

- LYSO:Ce crystal is chosen for the forward electromagnetic calorimeter in the proposed *SuperB* experiment. See *SuperB* Conceptual Design Report, INFN/AE-07/2, March (2007).

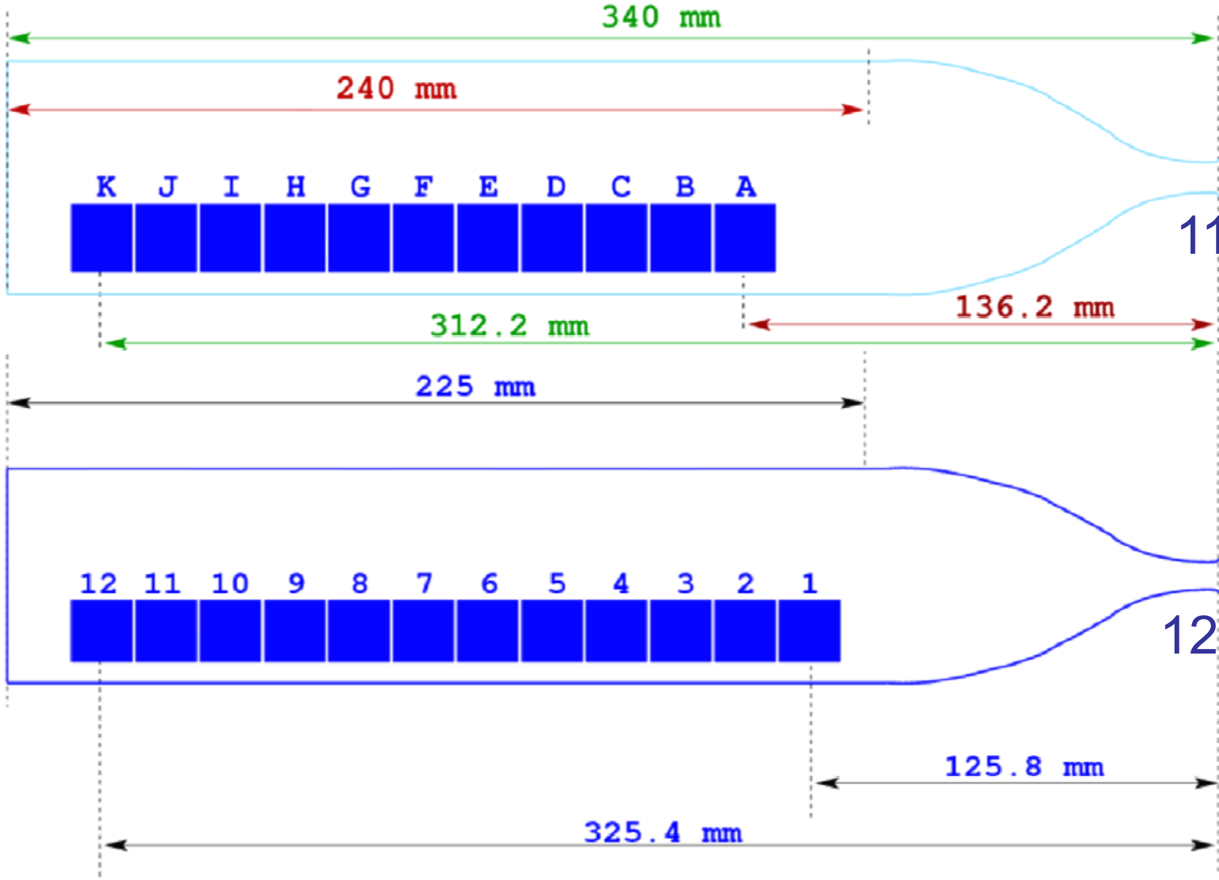
- This study aims at developing longitudinally uniform LYSO crystals for HEP applications.





Ingots Grown at SIPAT

Ingots grown by Czochralski method at Sichuan Institute of Piezoelectric and Acousto-optic Technology (SIPAT), China.



1st ingot with high cerium

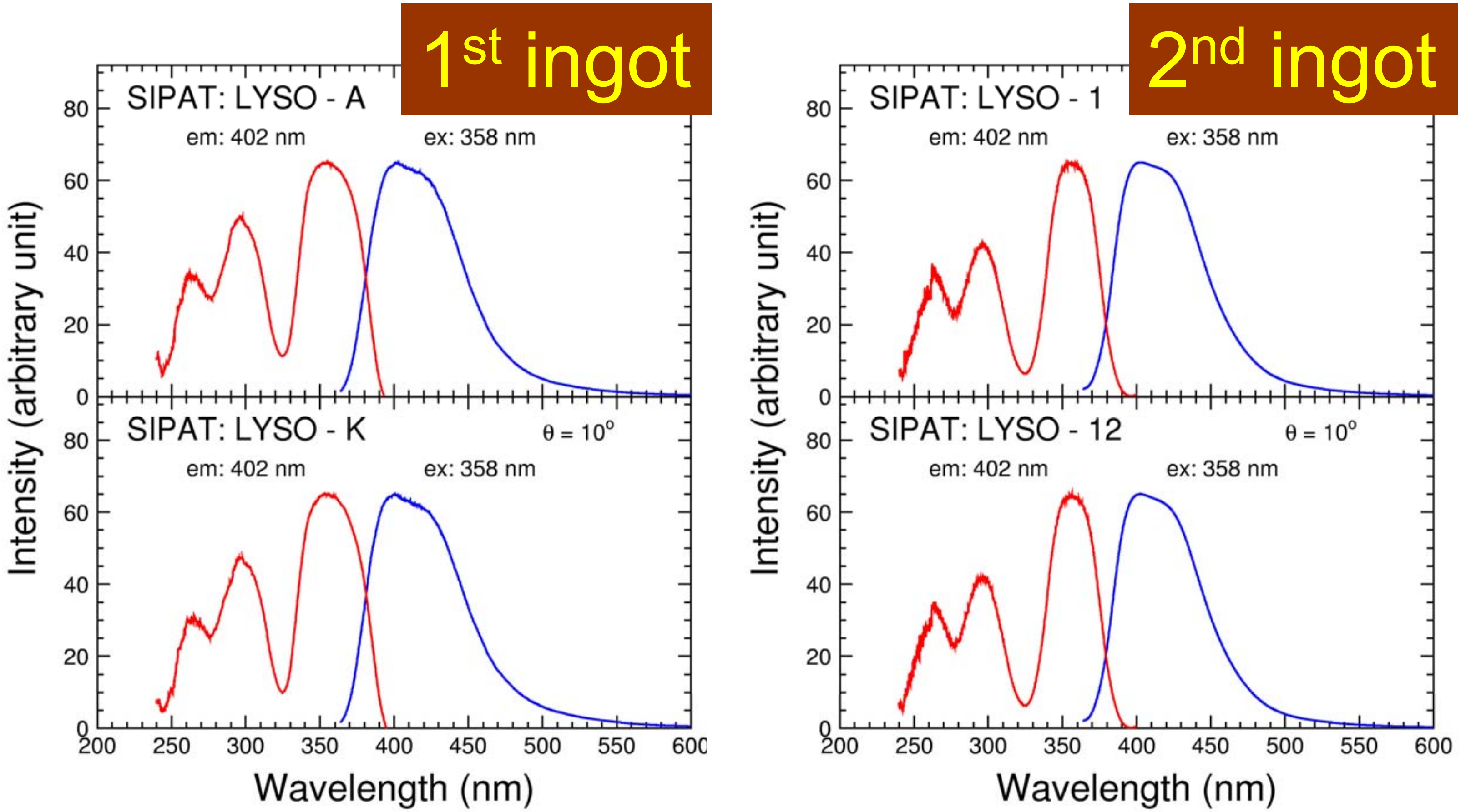
11 cubes of 17 (1.5 X_0) mm^3

2nd ingot with low cerium

12 cubes of 17 (1.5 X_0) mm^3

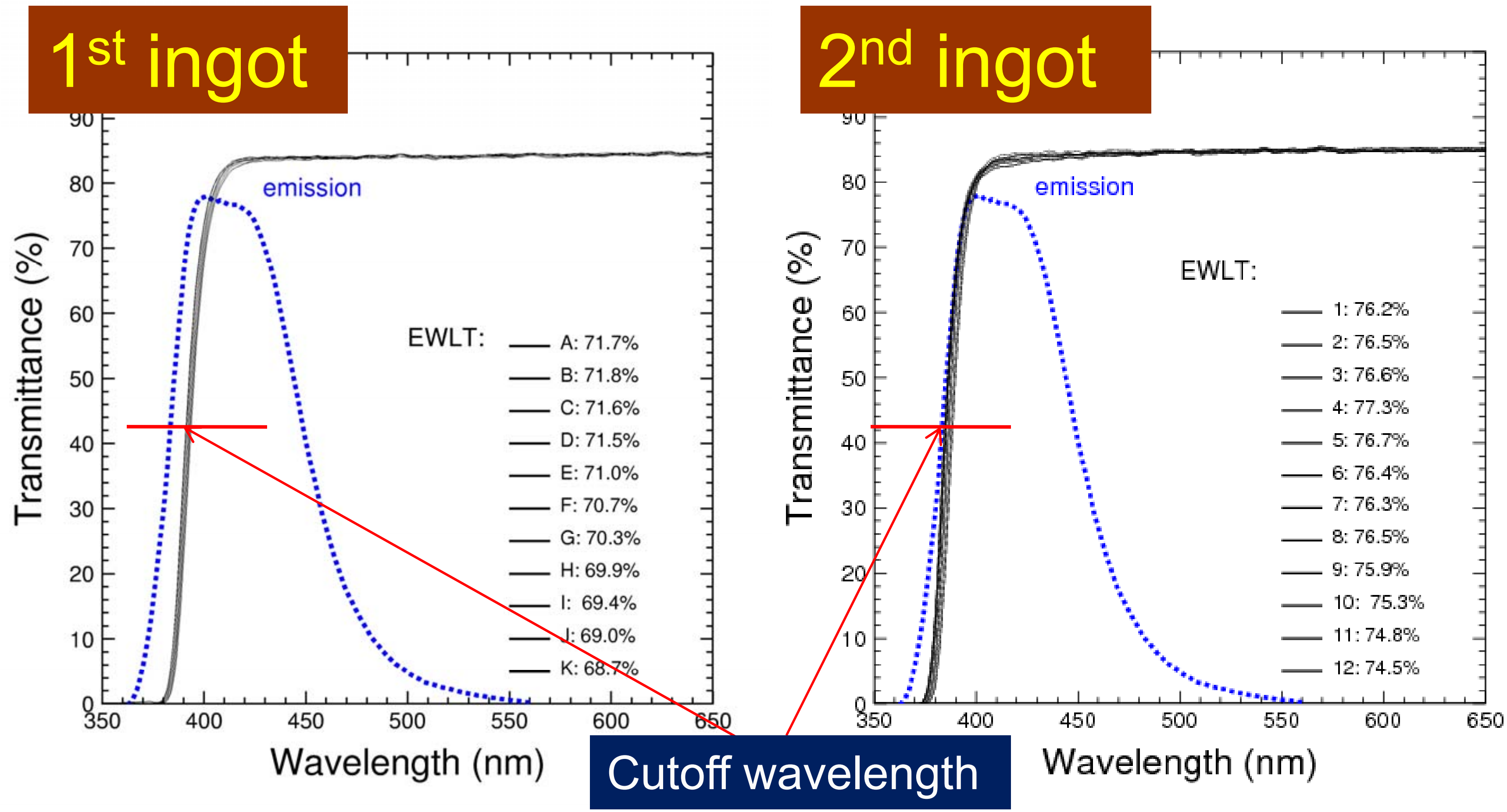
UV Excitation & Emission Spectra

Consistent excitation (red) and emission (blue) spectra observed from seed to tail for both ingots.



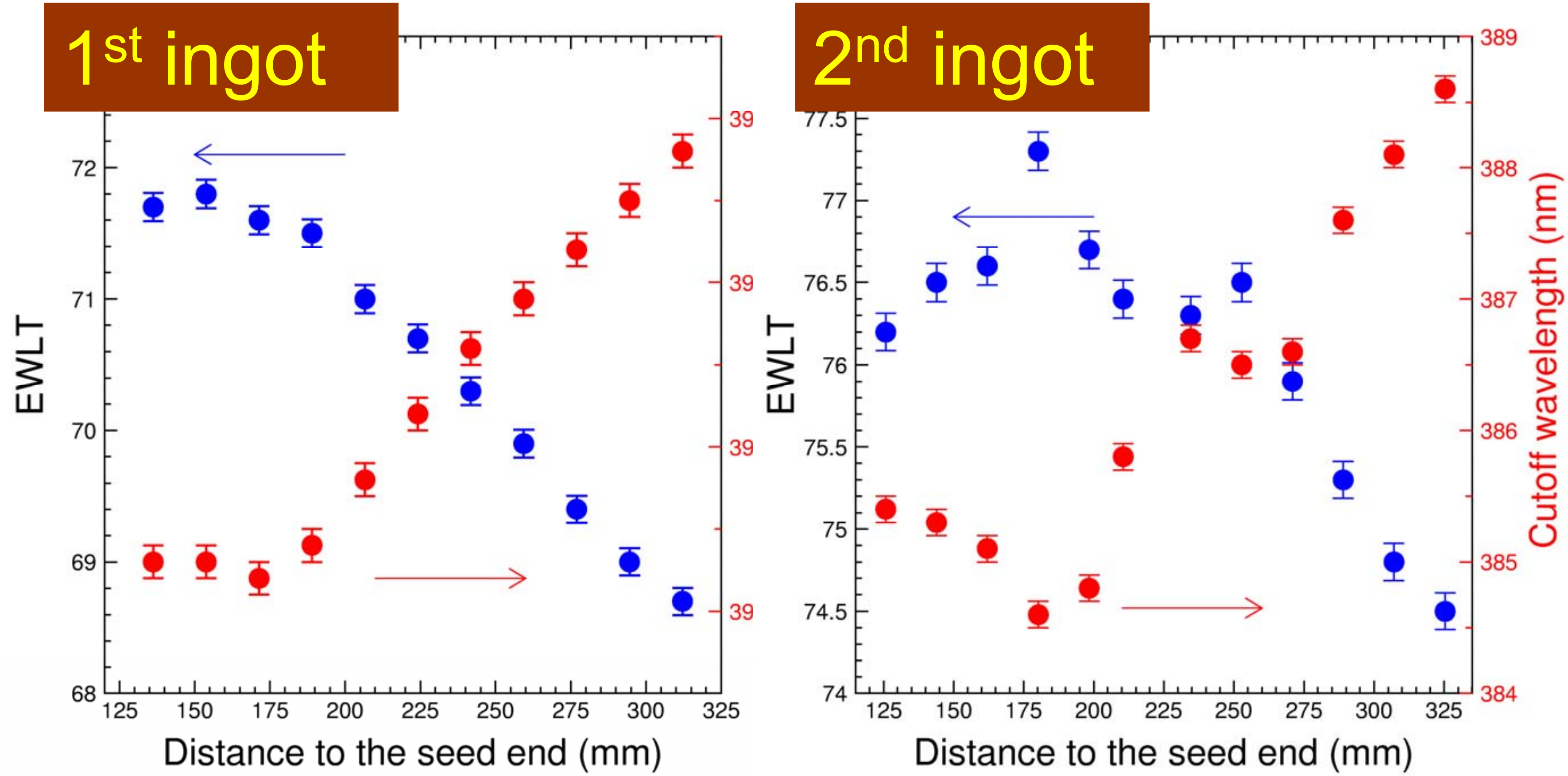
Transmission Spectra

Transmissions are position dependent: $EWLT = \frac{\int LT(\lambda)Em(\lambda)d\lambda}{\int Em(\lambda)d\lambda}$



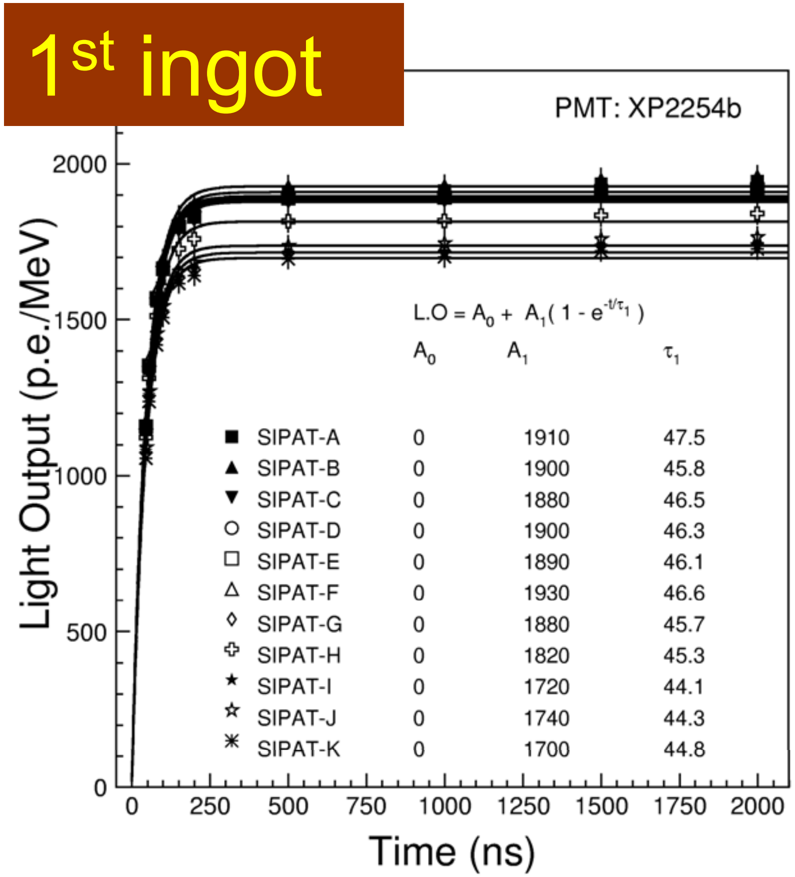
EWLT and **Cut-off** versus Position

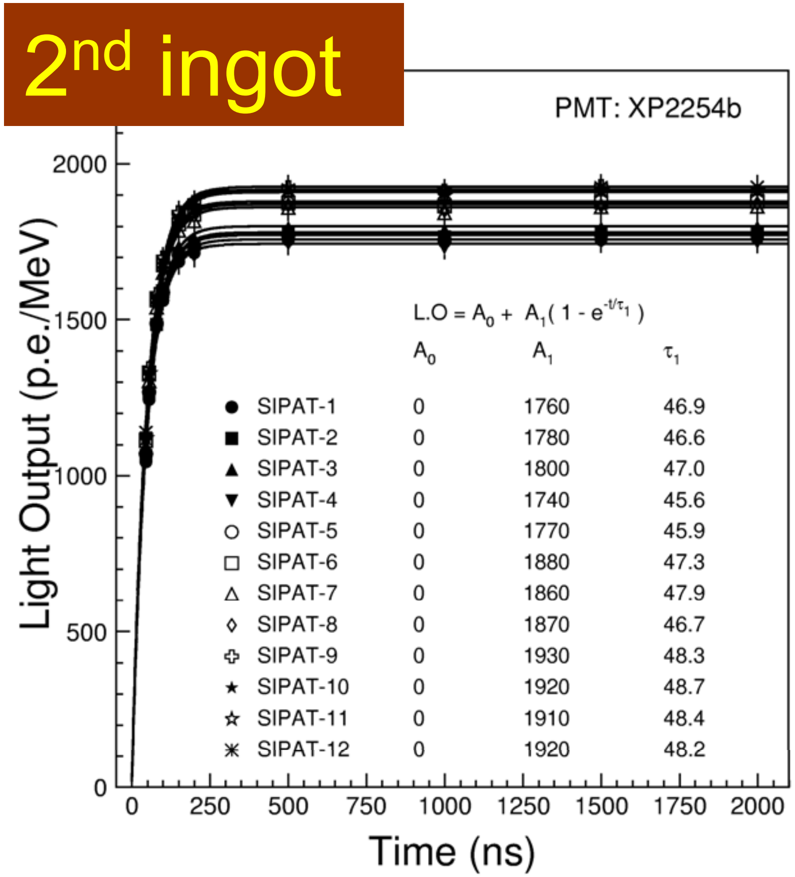
Correlations exist between EWLT/cut-off and cube position, indicating possible correlation with dopant concentrations.



Light Output

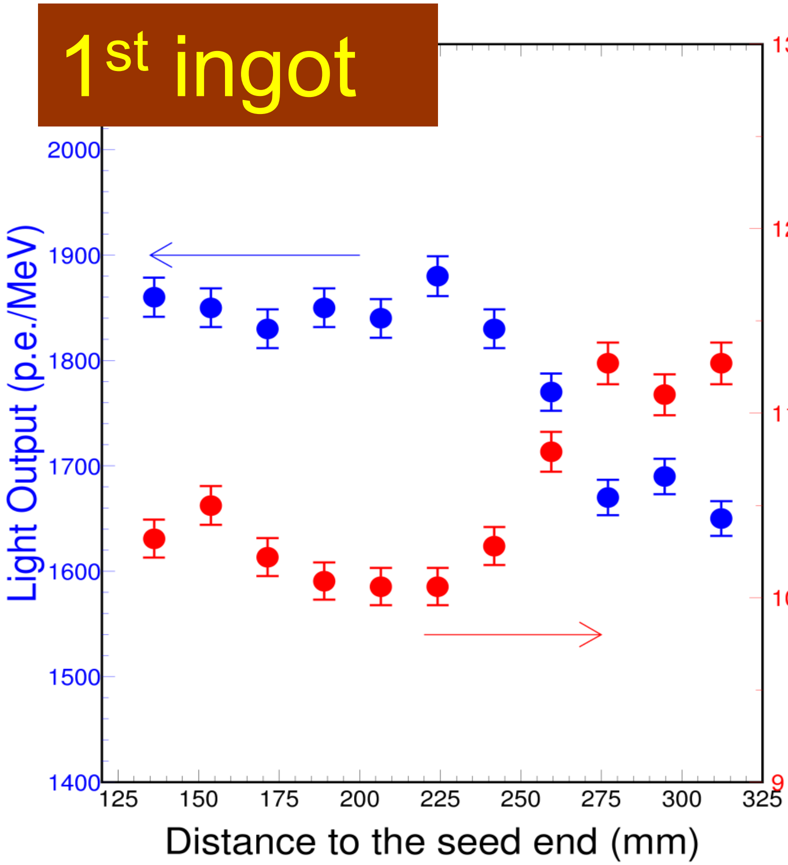
Light Outputs are position dependent, indicating possible correlation with dopant concentrations.

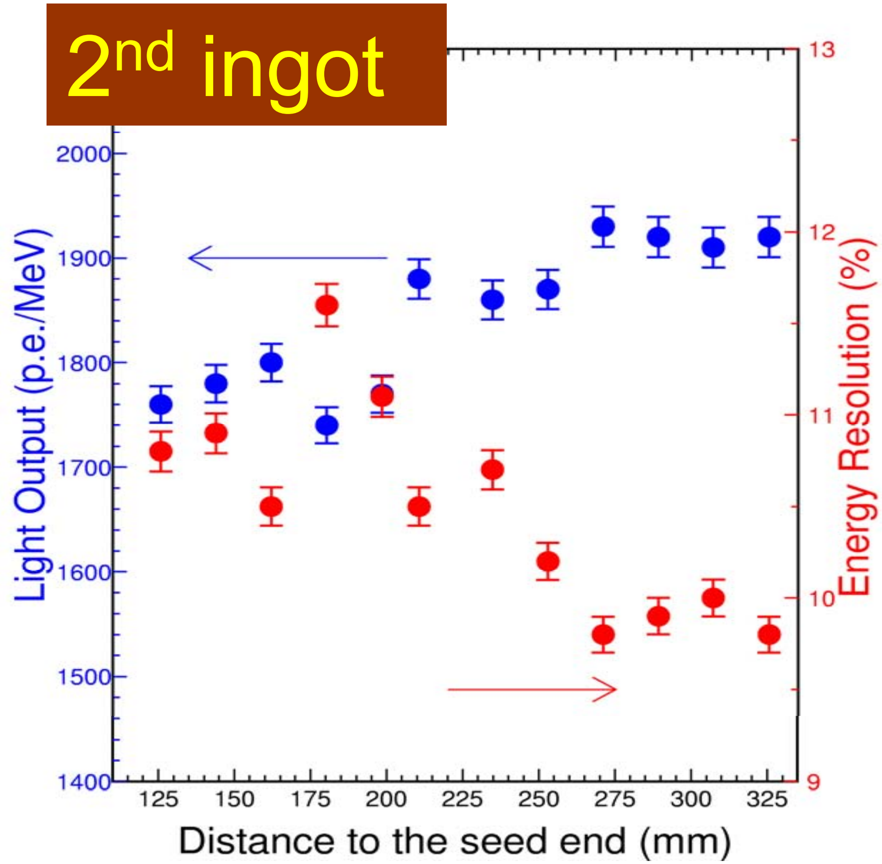




L.O. and E.R. versus Position

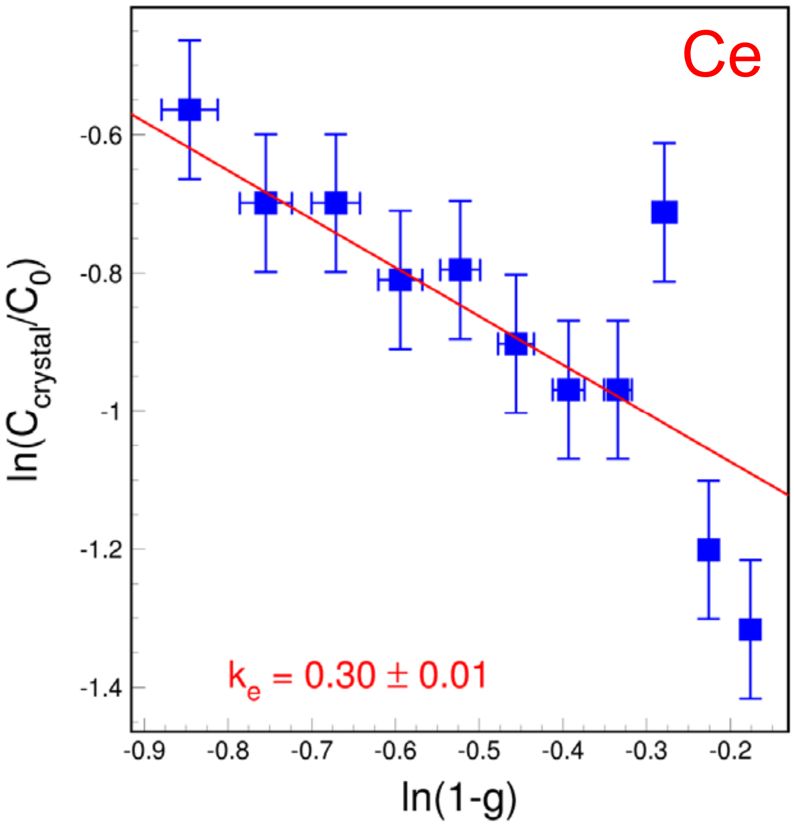
Correlations exist between L.O./E.R. and cube position

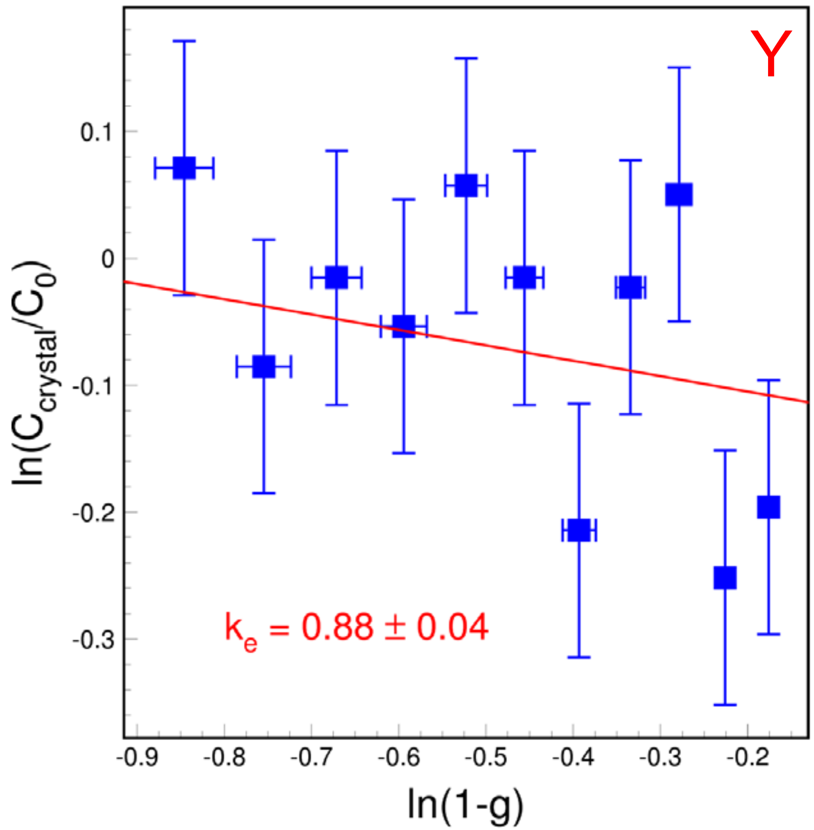




Cerium & Yttrium Segregation Coefficient

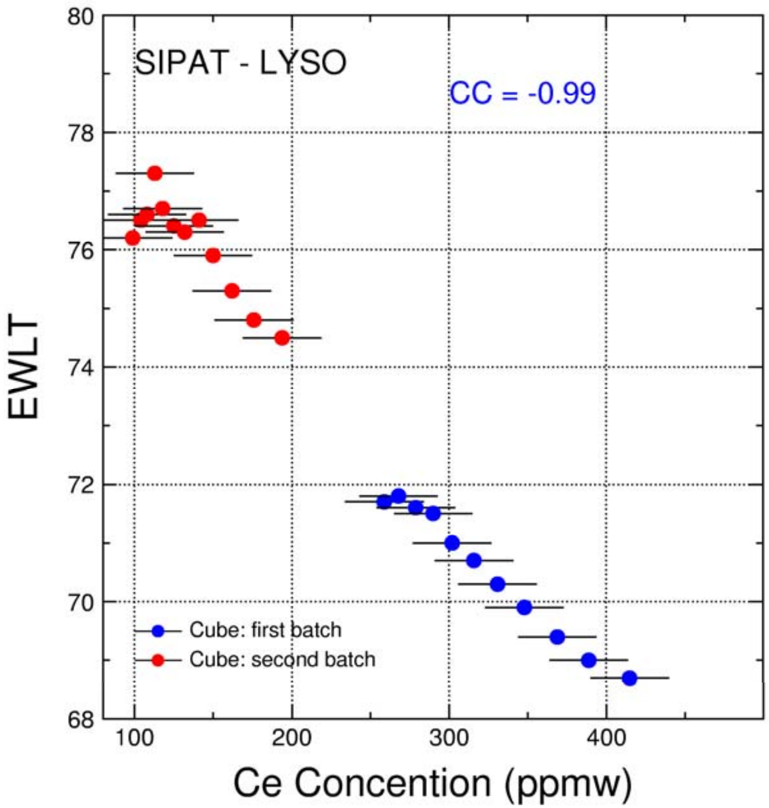
- Concentrations of cerium and yttrium were measured by using Glow Discharge Mass Spectrometry (GDMS) analysis.
- Segregation coefficients of cerium and yttrium in LSO were fitted to be 0.30 and 0.88 respectively: $ln\frac{C_{Crystal}}{C_0} = lnk_e + (k_e - 1)\ln(1-g)$

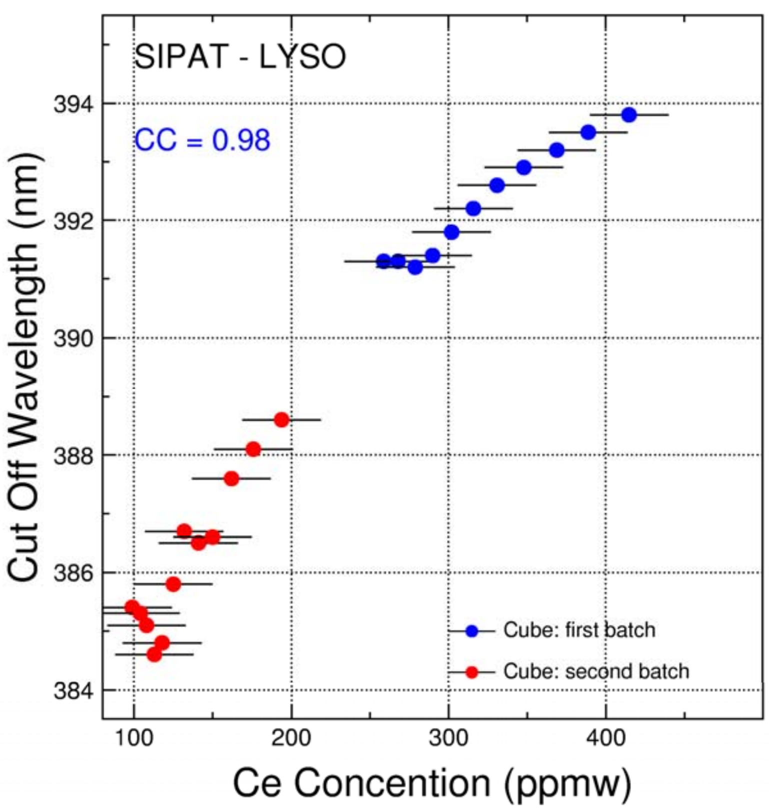




EWLT & Cut-off vs. Ce Concentration

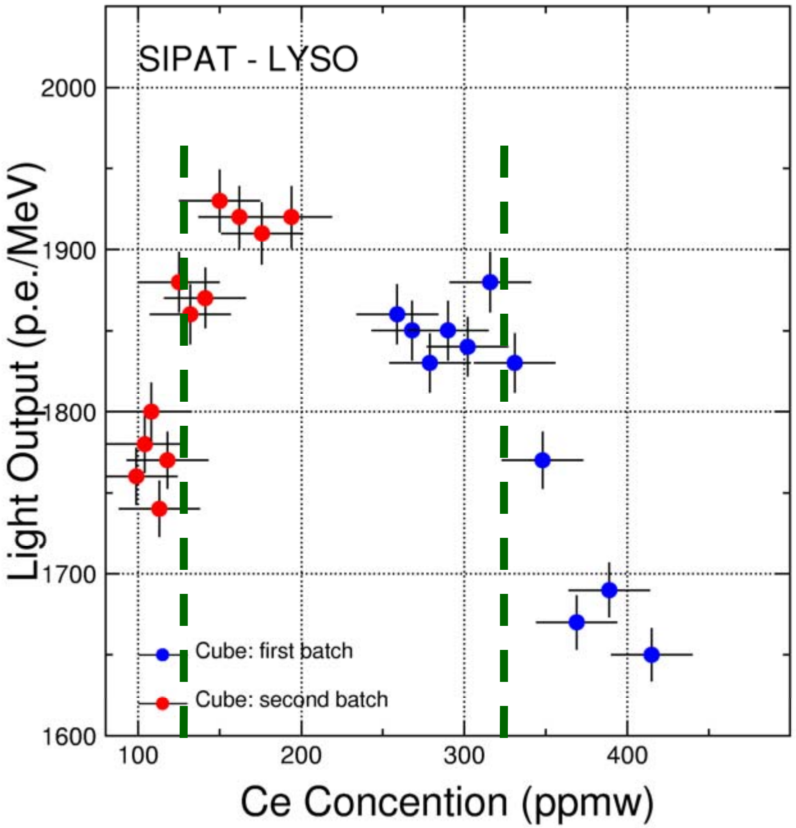
Strong correlations observed between EWLT and the cut-off wavelength versus the Ce concentration.

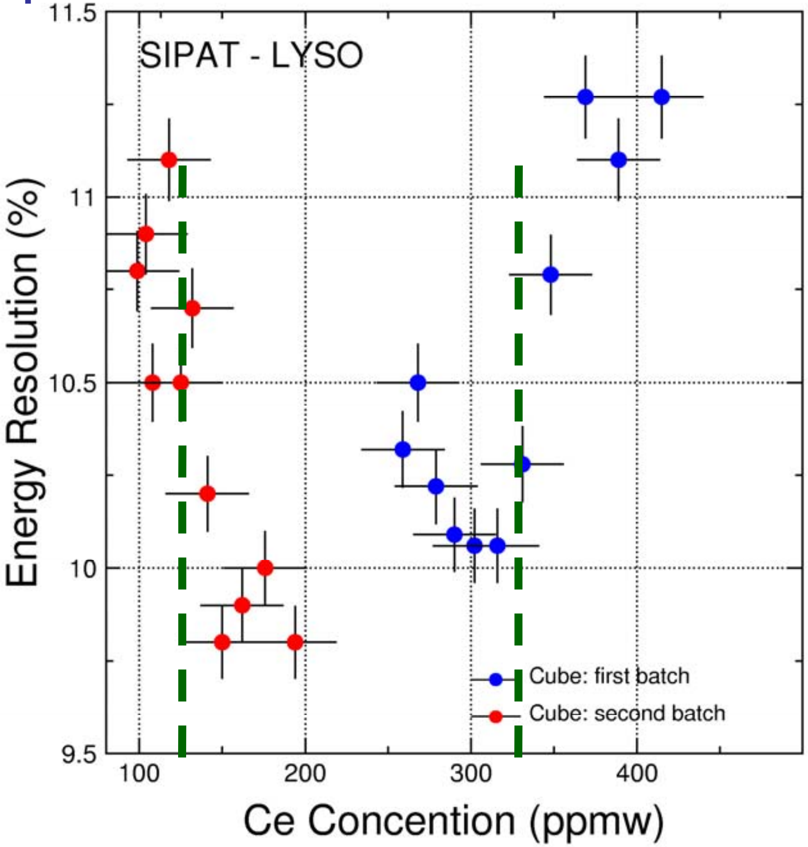




L.O. and E.R. versus Ce Concentration

A ‘plateau’ observed between 125 ~ 325 ppm, indicating a possibility to grow uniform crystal with optimized Ce doping. This observation consists with private data from C. Melcher.

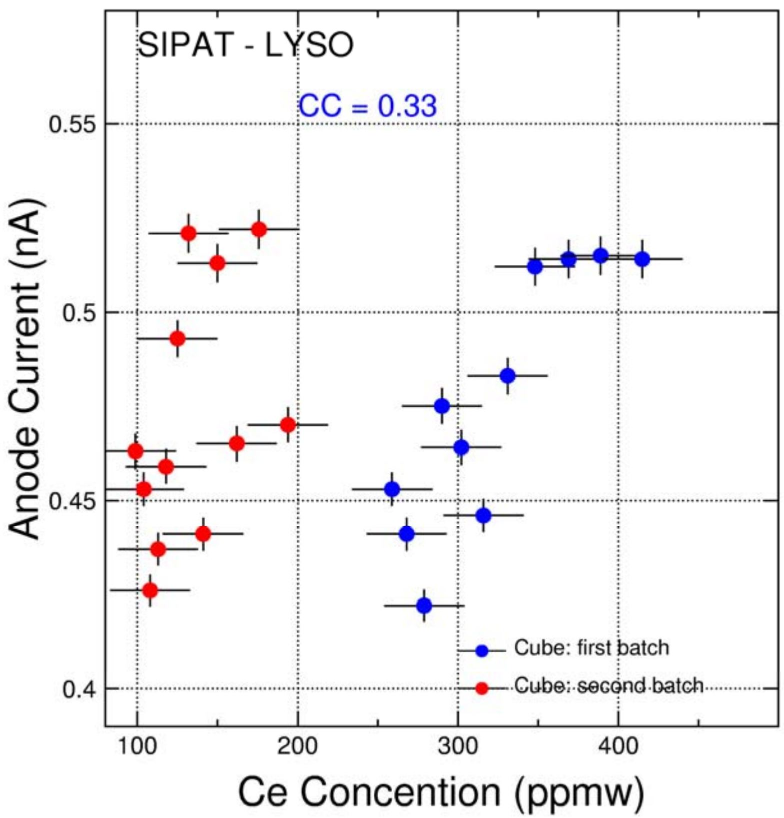




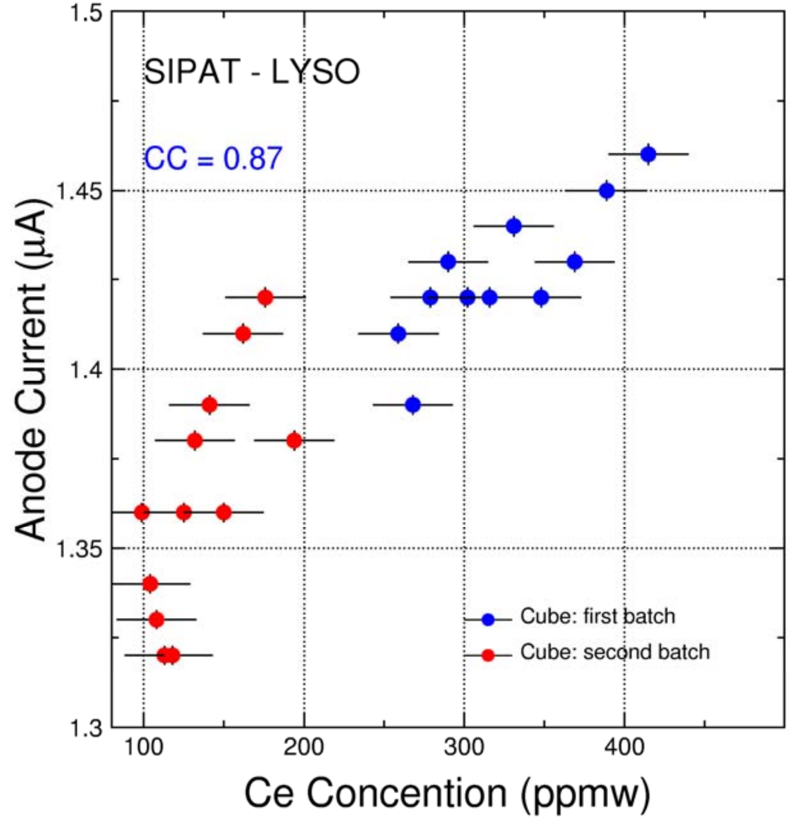
Phosphorescence vs. Ce Concentration

Correlation observed between radiation induced phosphorescence and the Ce concentration, but not before gamma-ray irradiation.

Before irradiation

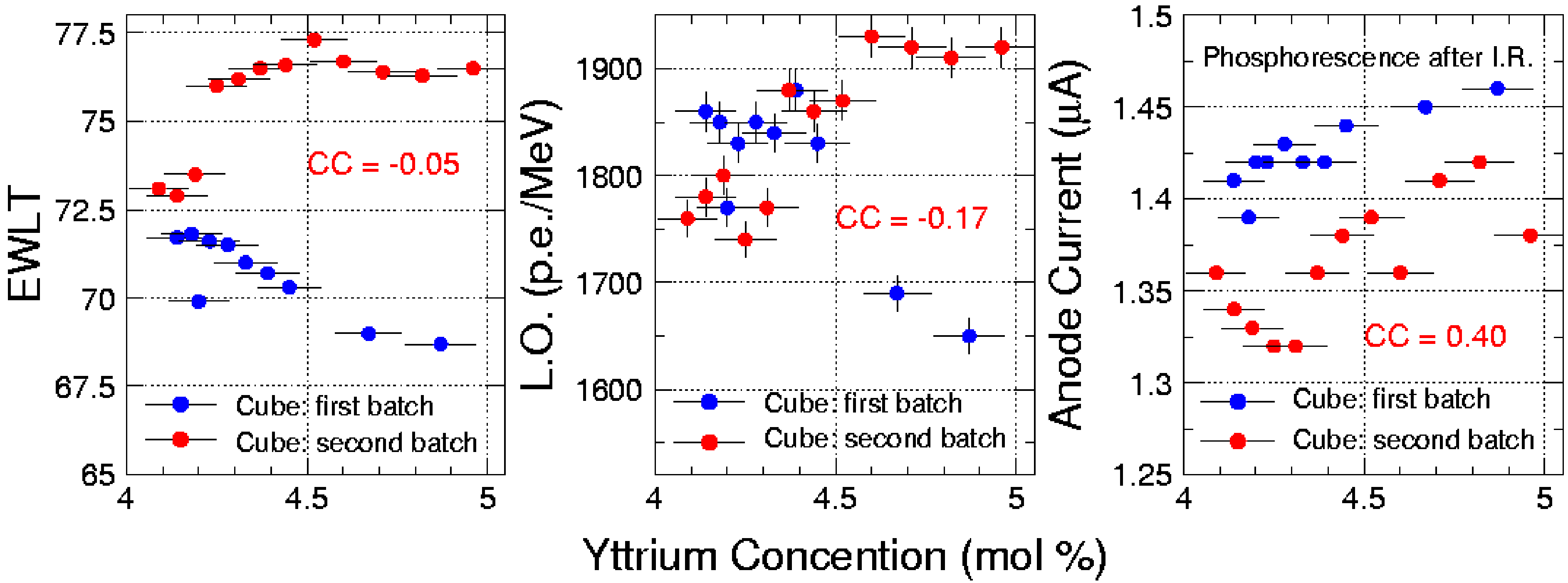


After irradiation

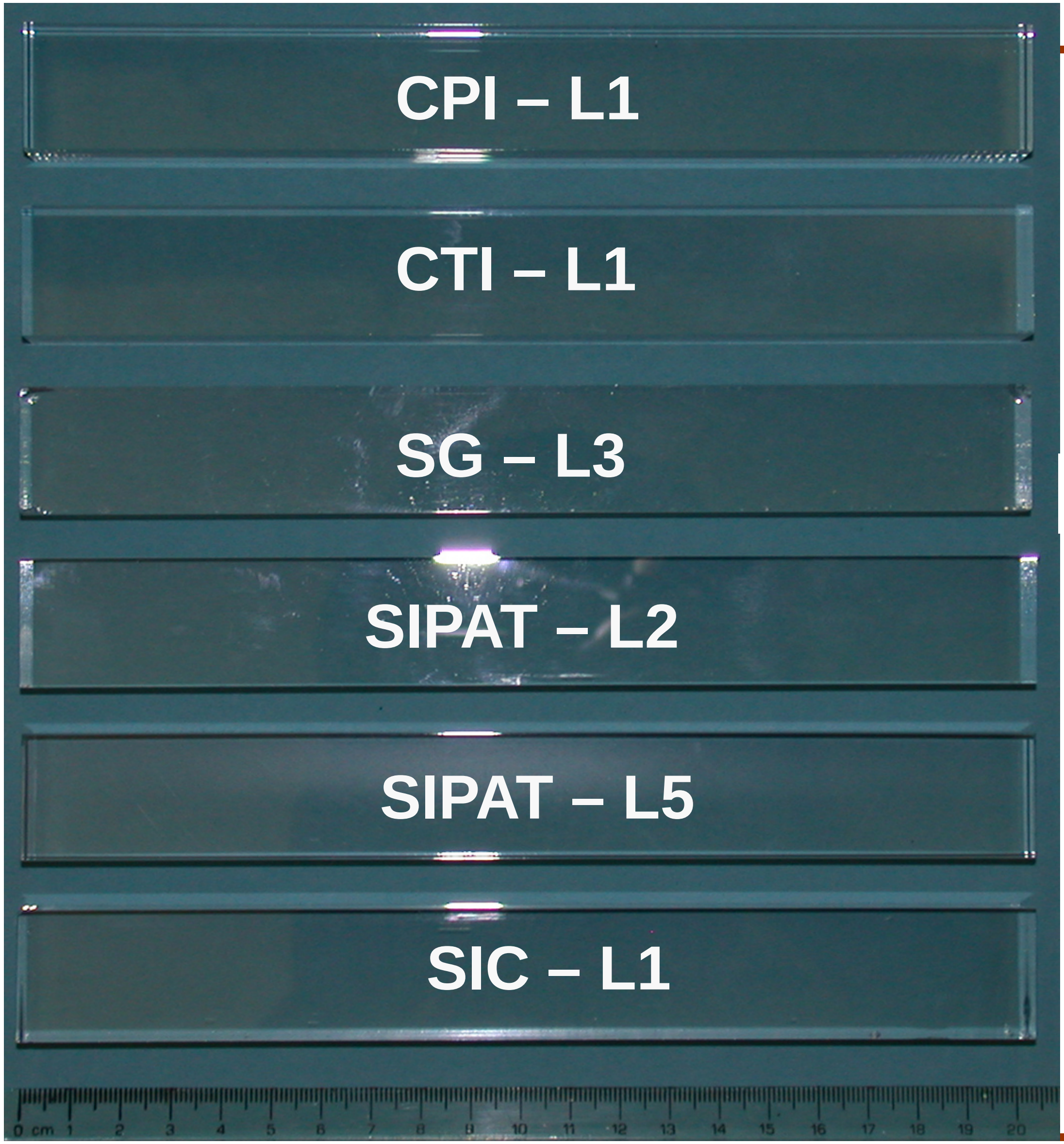


EWLT, L.O. and Phosphorescence after irradiation vs. the Yttrium Concentration

No correlations were observed between the yttrium concentrations and EWLT, the light output and the intensity of phosphorescence after gamma-ray irradiations.

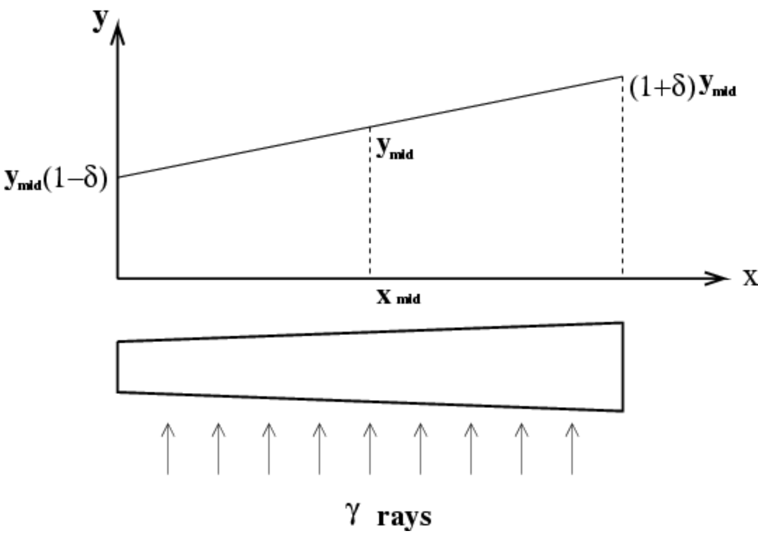


Light Response Uniformity



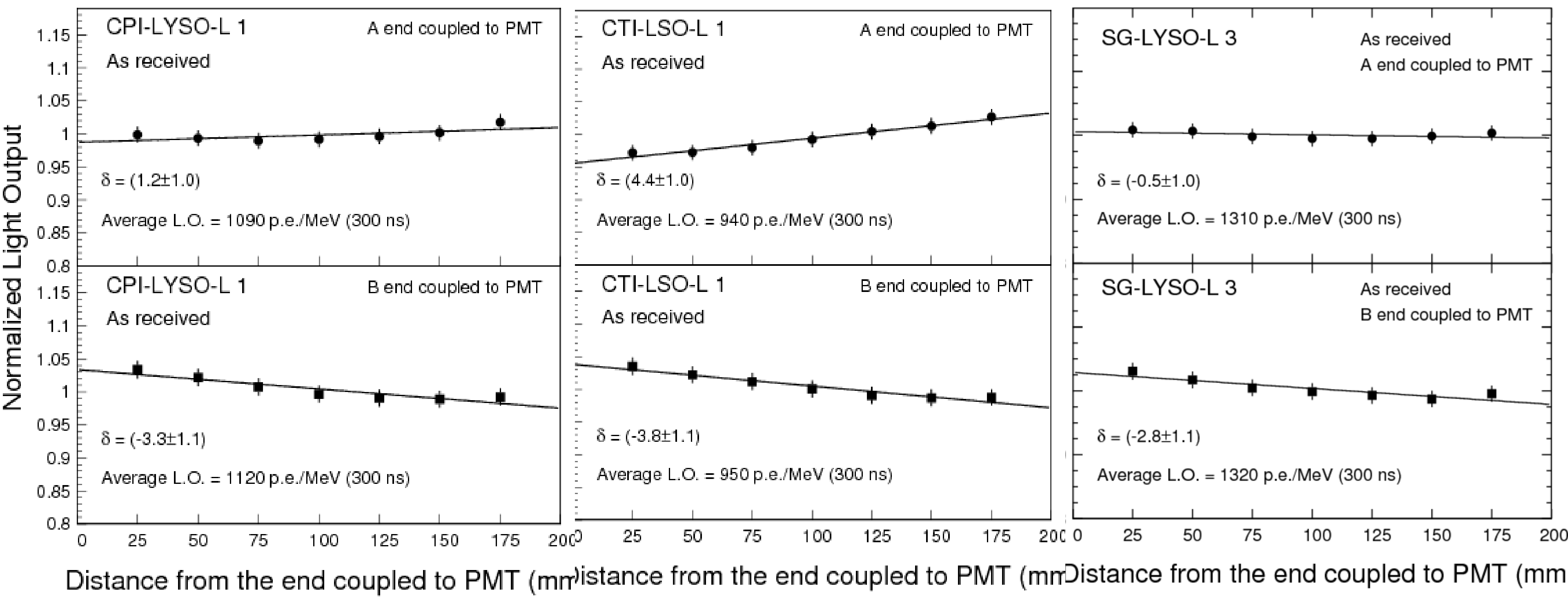
2.5 x 2.5 x 20 cm Samples tested for their light response uniformity

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



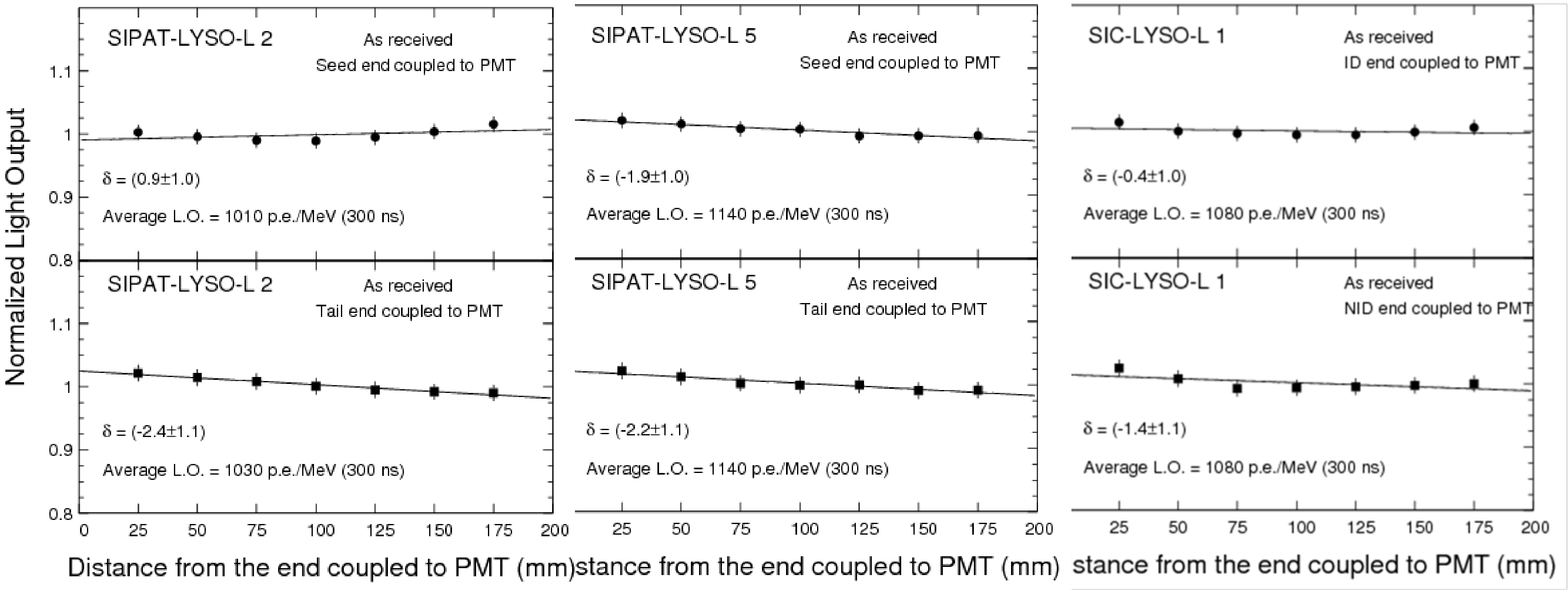
L.R.U. of Long LYSO:Ce Crystals

Crystals in market have diverse light response uniformity with δ = 1.2/-3.3, 4.4/-3.9, -0.5/-2.8 for CPI, CTI & SG respectively



Progress Achieved in L.R.U.

This optimization improves the L.R.U. of SIPAT samples from 0.9/-2.4 to -1.9/-2.2. The 1st SIC samples show quite good L.R.U.: -0.4/-1.4



Before Optimization | After Optimization | 1st SIC Sample

Summary

- Two LYSO:Ce ingots grown by Czochralski method at SIPAT were cut into cubes of 17 mm (1.5 X_0), of which the optical and scintillation properties were characterized.
- By using GDMS analysis the segregation coefficients of cerium and yttrium were determined as 0.30 ± 0.01 and 0.88 ± 0.04 respectively.
- Correlations are observed between the EWLT, the cut-off wavelength in transmission, the light output, the energy resolution and the radiation-induced phosphorescence versus the cerium concentration, but not the yttrium concentration.
- The optimized cerium concentration in LYSO was found to be between 125 and 325 ppmw. An optimized SIPAT sample shows very good light response uniformity, making possible to cut one ingot into two tapered crystals for HEP applications. The 1st SIC LYSO sample also shows quite good uniformity.