Characterization of Three LYSO Crystal Batches

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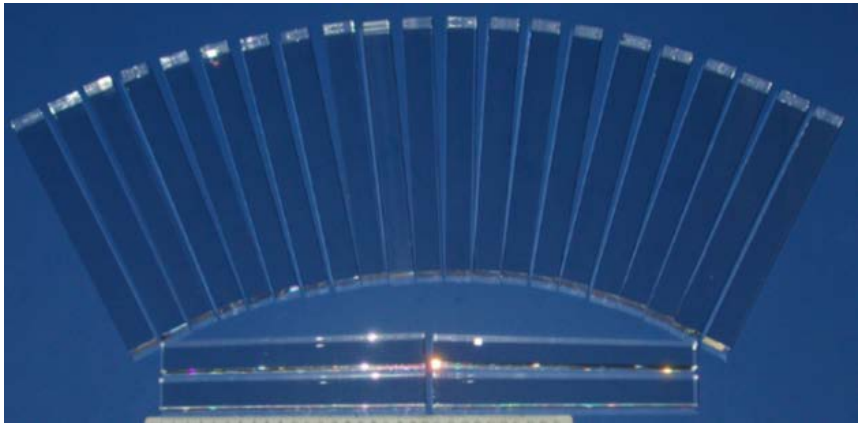
Introduction

- Three LYSO crystal batches were characterized at Caltech crystal laboratory for future HEP experiments:
  - Twelve 13 cm long crystals for the Mu2e experiment;
  - Twenty-five 20 cm long crystals for the SuperB experiment; and
  - 623 plates of 14 x 14 x 1.5 mm with five holes for the LYSO/W Shashlik beam test at Fermilab.
- Properties measured : Longitudinal Transmittance (LT), Light Output (LO), FWHM Energy Resolution (ER) and Light Response Uniformity (LRU).
- Correlations between optical and scintillation properties were investigated.

13/20 cm Long LYSO for Mu2e/SuperB

ID	Dimension (mm^3)	Polish	Amount
SIC-1 to 10	30 × 30 × 130	All faces	10
SIC-11,12	Hexagon 18.6× 130	All faces	2

Ten square & two hexagonal

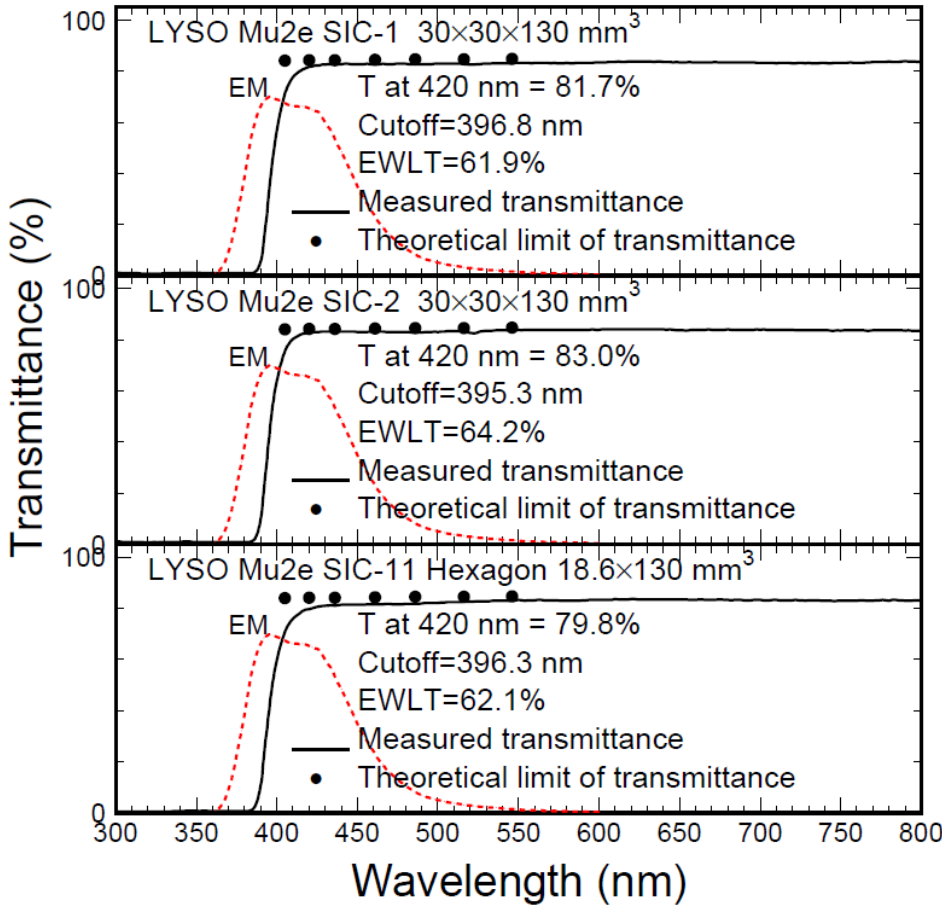


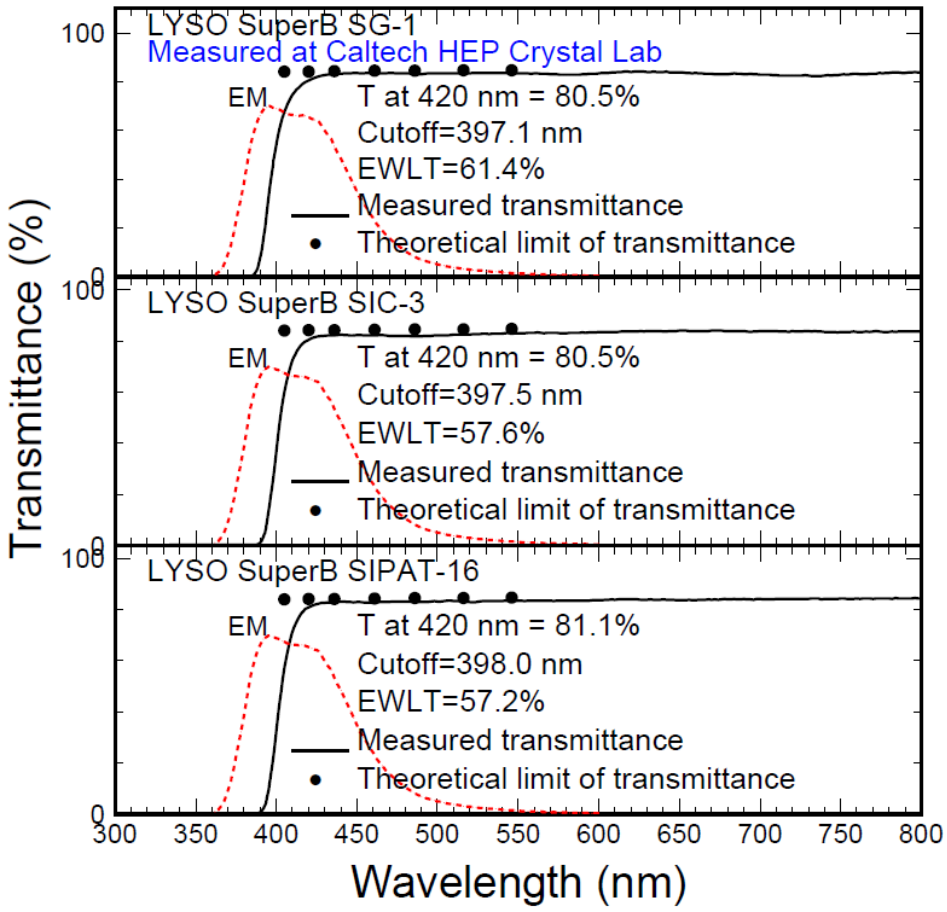
Vender	Dimension (mm^3)	Polished	Amount
Saint Gobain	$20^2 \times 23^2 \times 200$	All faces	12
SIC	$20^2 \times 23^2 \times 200$	All faces	3
SIPAT	$20^2 \times 23^2 \times 200$	All faces	10

LT and EWLT

EWLT (*emission weighted longitudinal transmittance*):

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

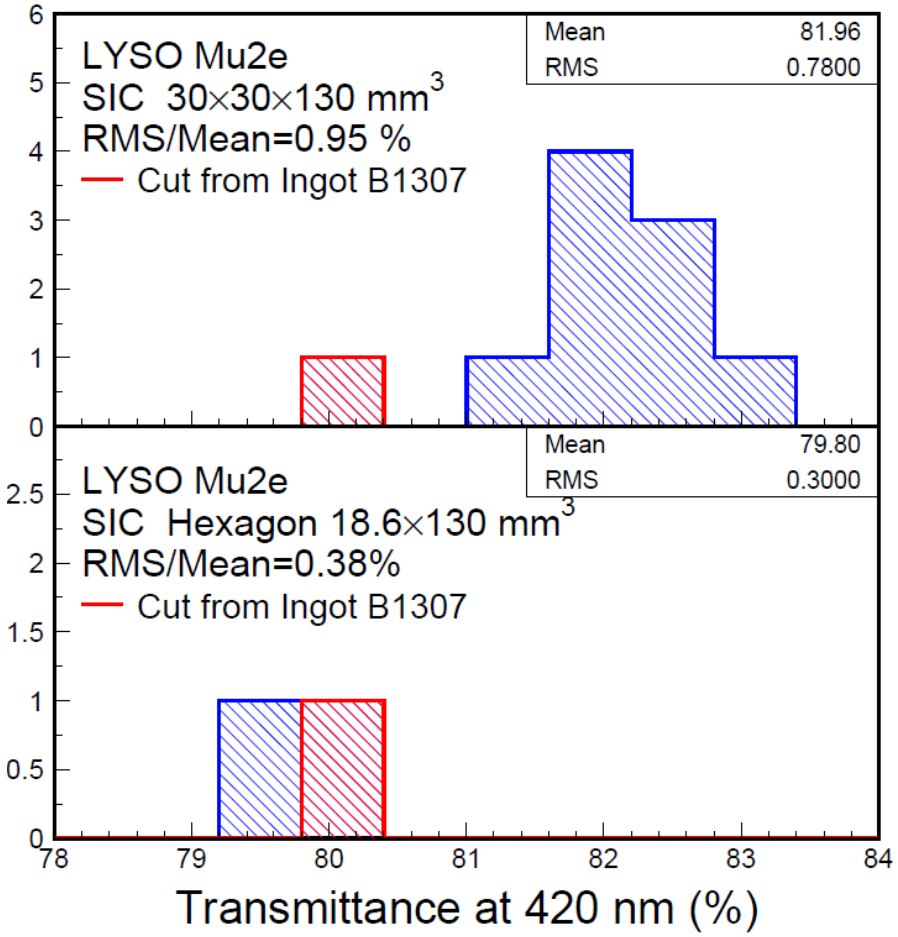


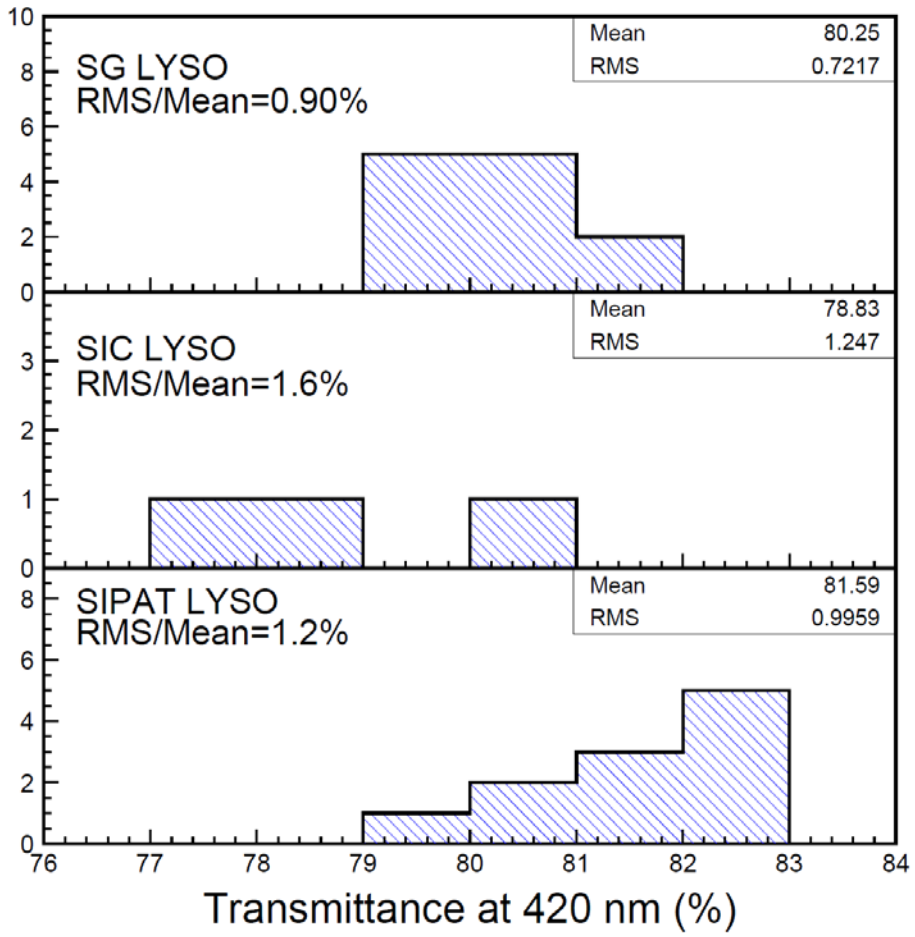


LT approaches the theoretical limit, indicating good optical quality

Summary of LT @ 420 nm

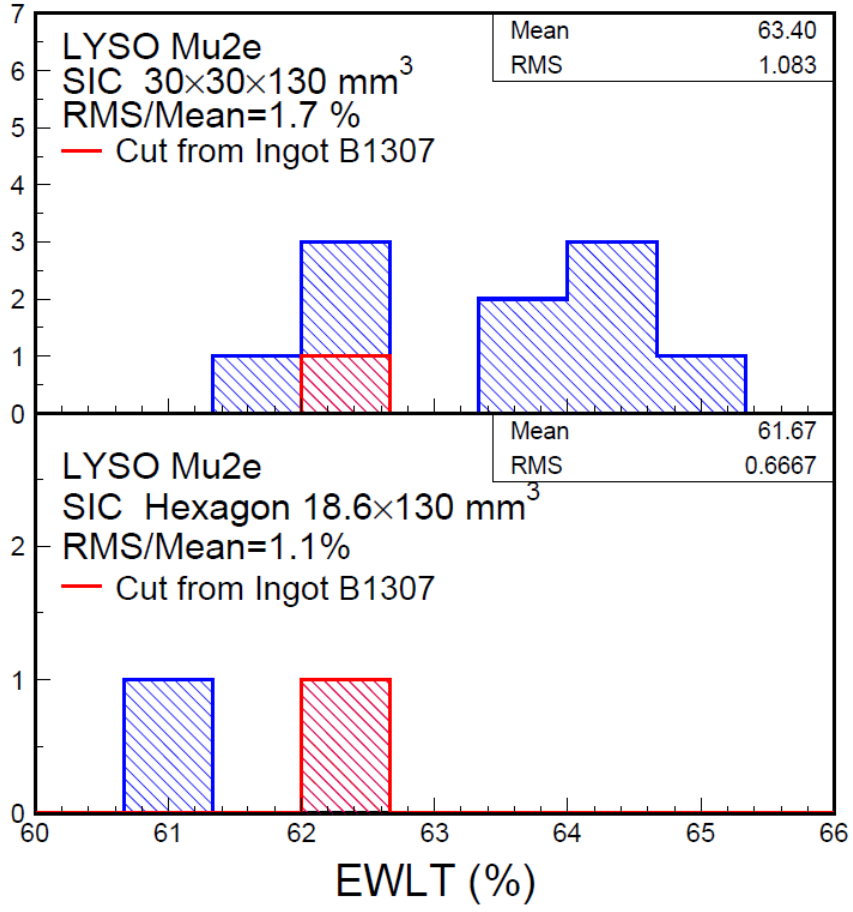
LT@ 420 nm better than 75% specification
Consistent LT between square and hexagon

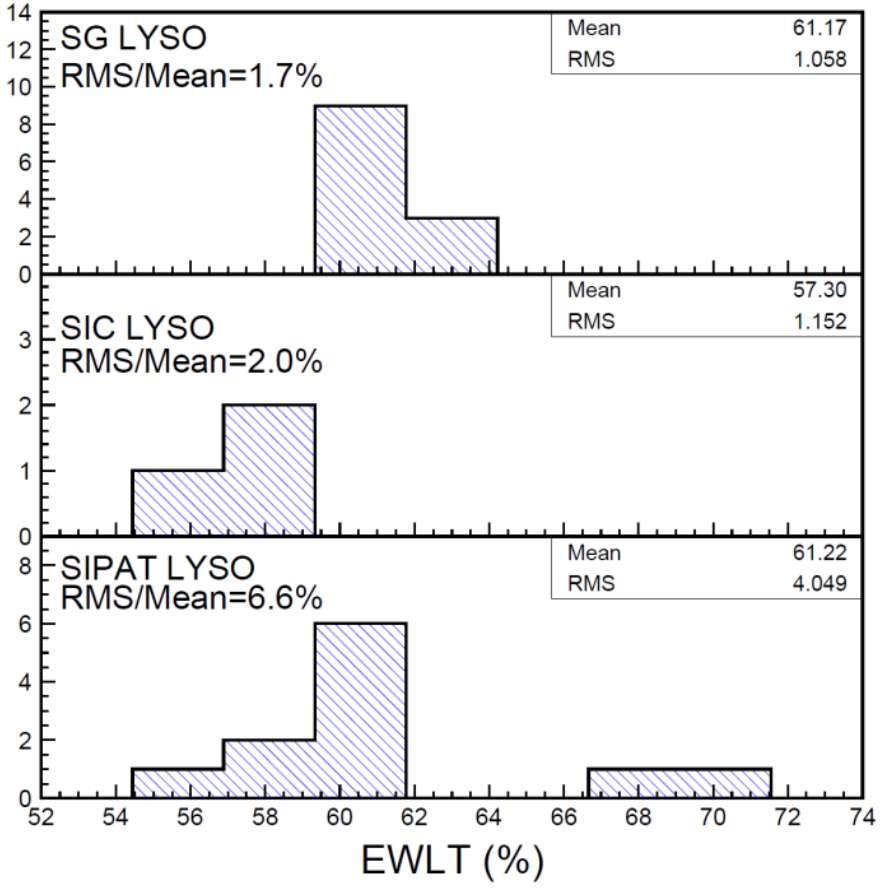




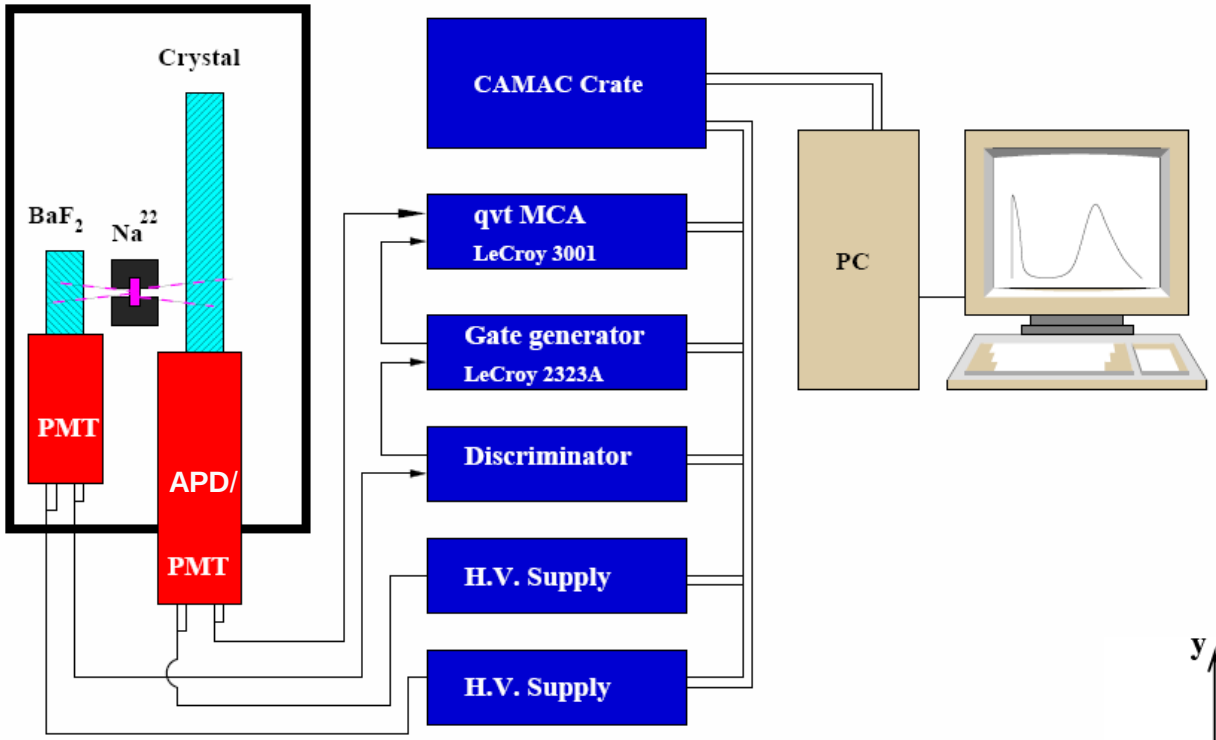
Summary of EWLT

Consistent EWLT of square and hexagonal crystals





LO & FWHM: by R1306 PMT



Sample wrapped by two layers of Tyvek paper

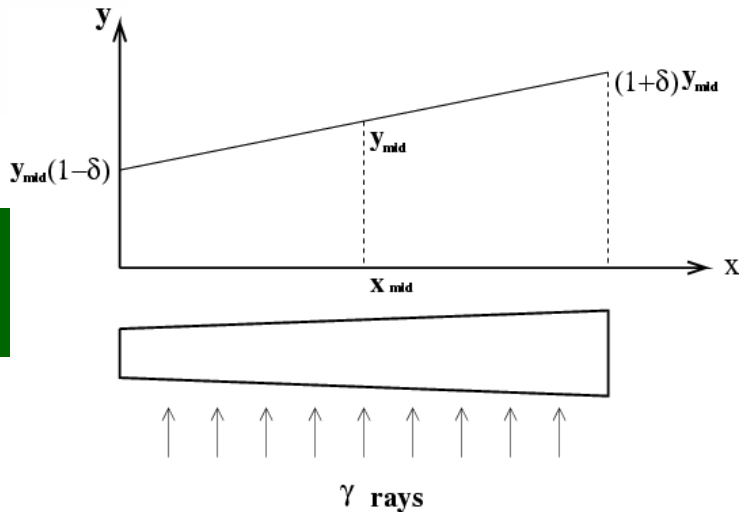
One end coupled to

Hamamatsu R1306 PMT or
2 x Hamamatsu S8664-55 APD

With DC-200 grease coupling

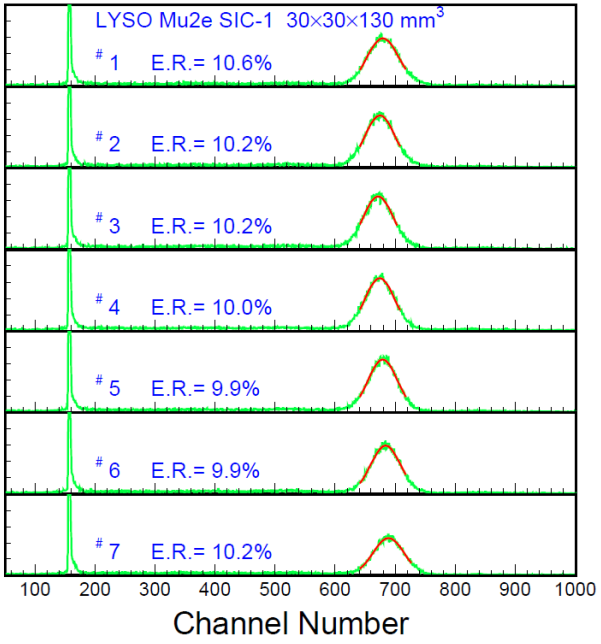
200 ns integration gate
Coincidence trigger from
a Na-22 source

Light output and FWHM energy resolution are measurement at seven points

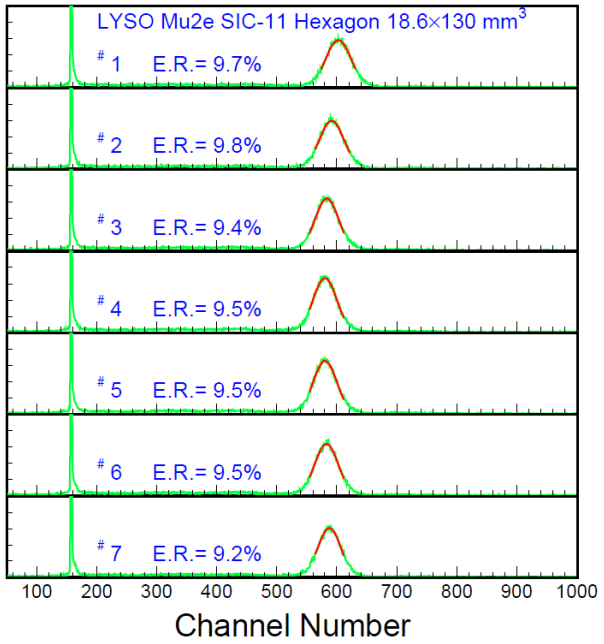


Pulse Height Spectra

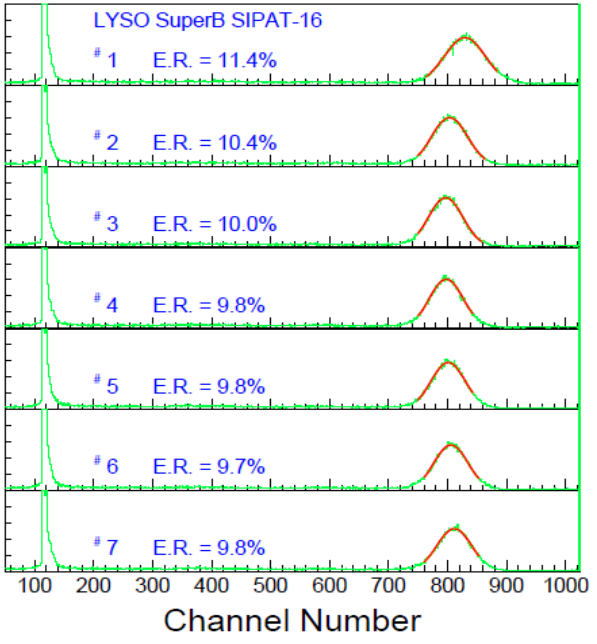
Average ER = 10.1 %



Average ER = 9.5 %



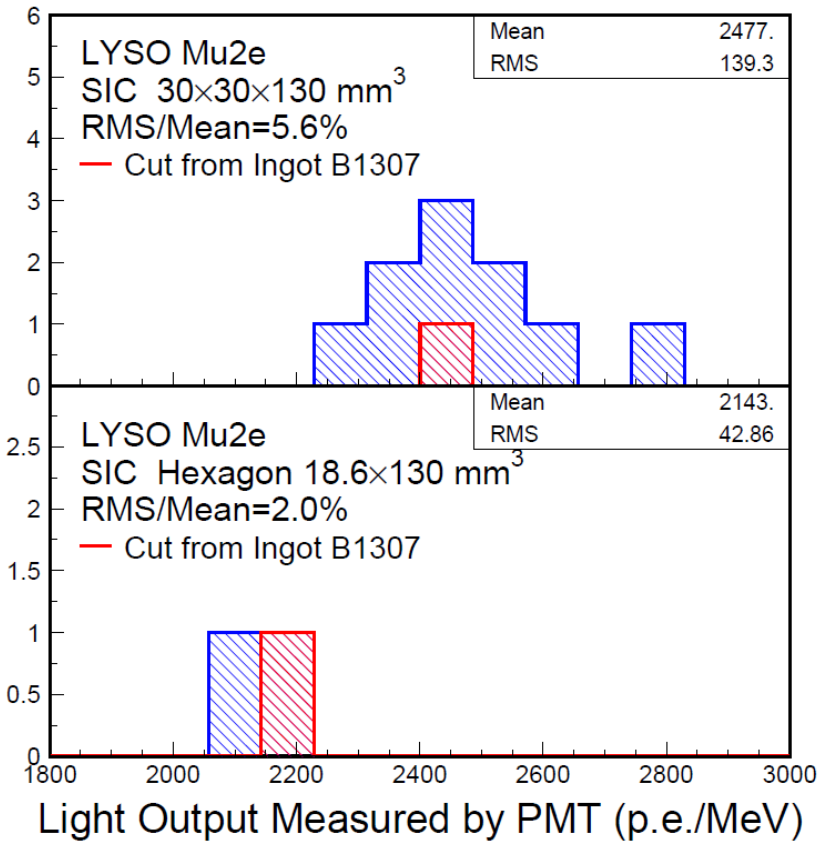
Average ER = 10.1 %

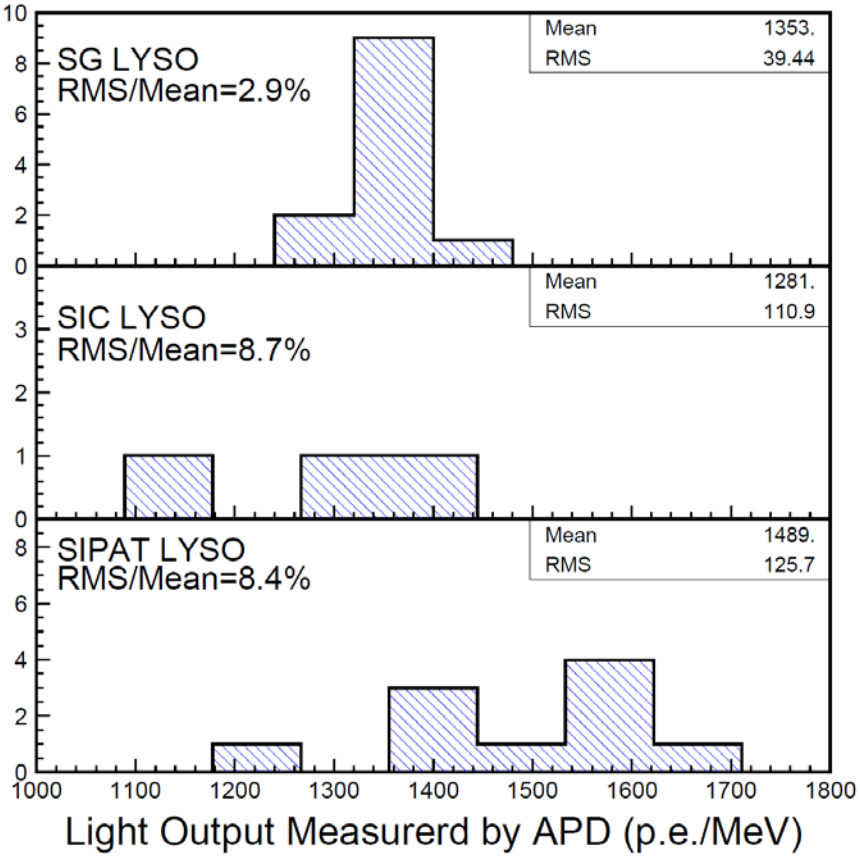


FWHM resolution better than 12.5% specification

Summary of Light Output

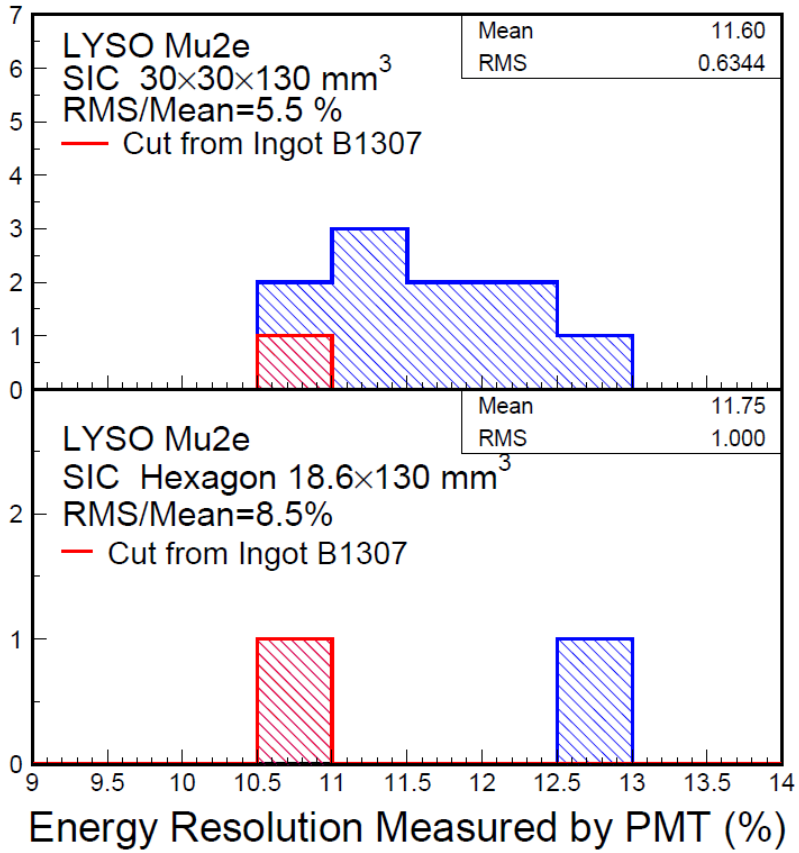
Divergence of LO < 6% observed. Saint-Gobain crystals have the best consistency at 3%. Square samples seem having higher LO than hexagonal ones, which is to be further investigated.

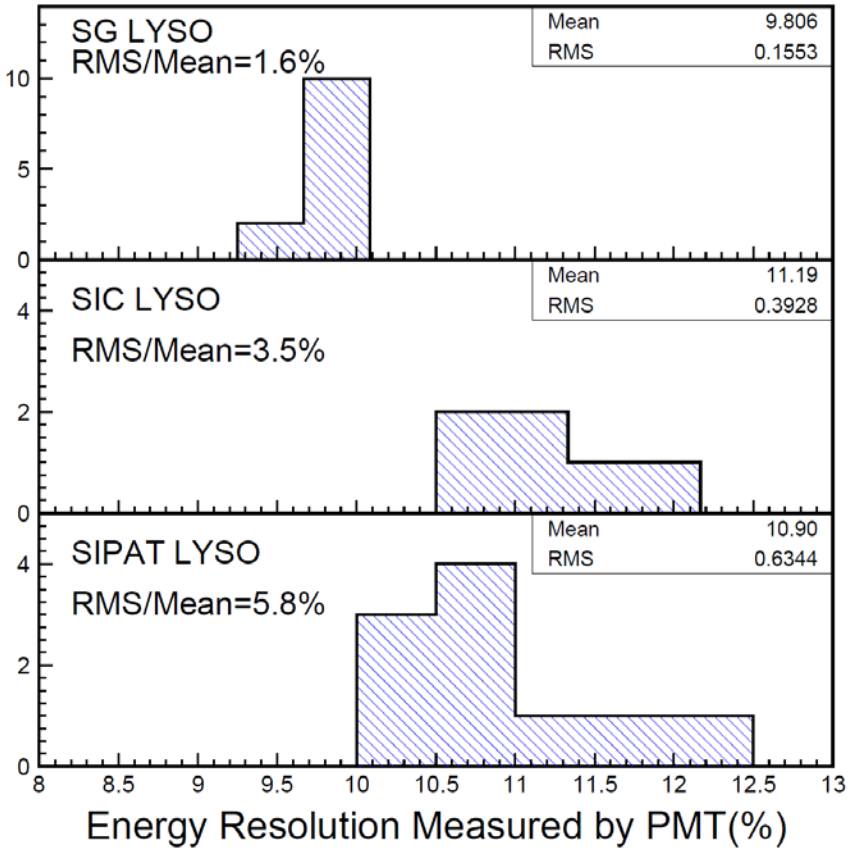




Summary of FWHM Resolution

Saint-Gobain crystals have the best resolution & consistency

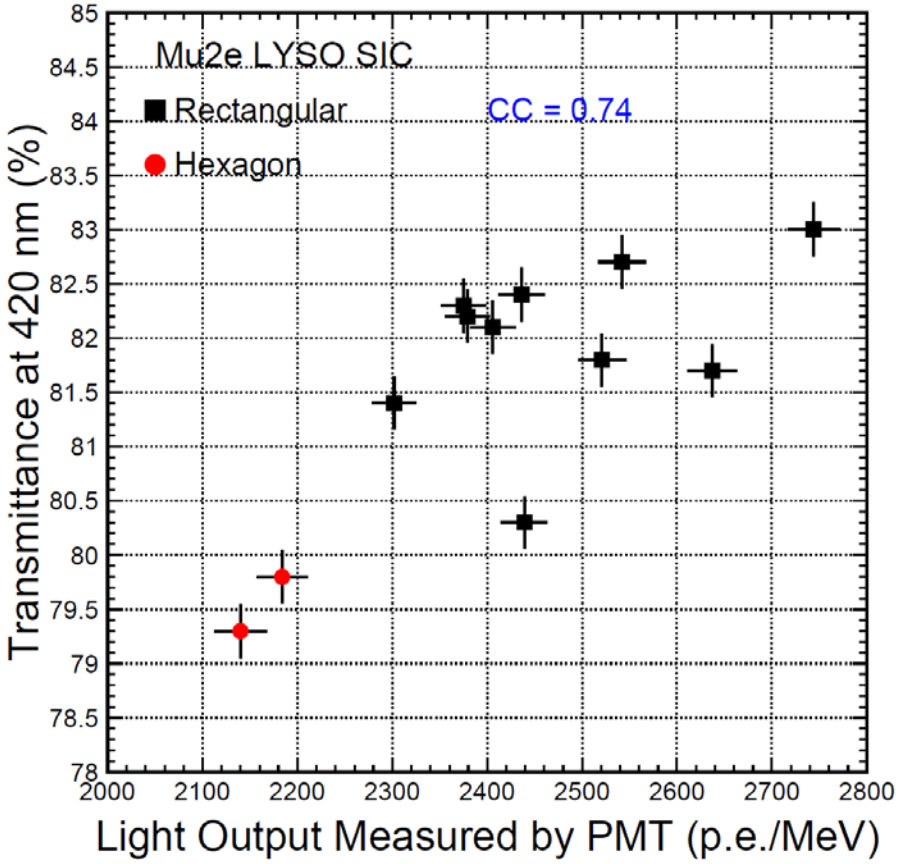


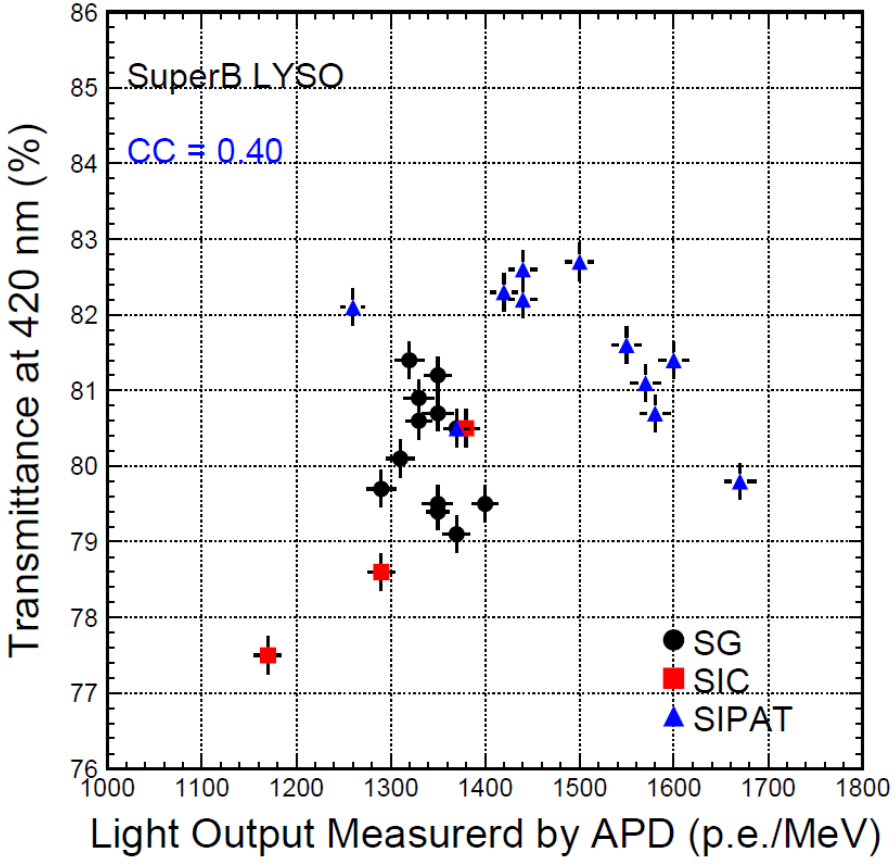


Correlation: T @ 420 nm versus LO

CC, *correlation coefficient*, is a measure of the correlation and defined by: $$CC = \frac{\sum(x-\overline{x})(y-\overline{y})}{\sqrt{\sum(x-\overline{x})^2 \sum(y-\overline{y})^2}}$$

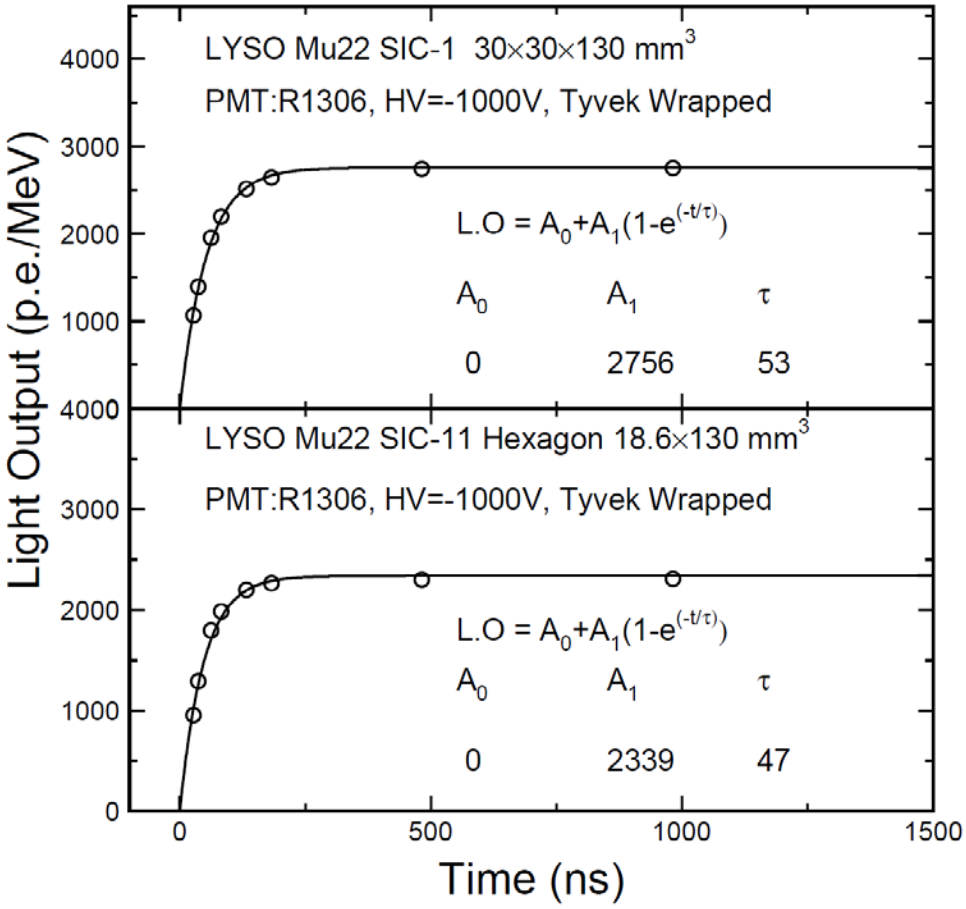
Correlation observed between T @ 420 nm and LO

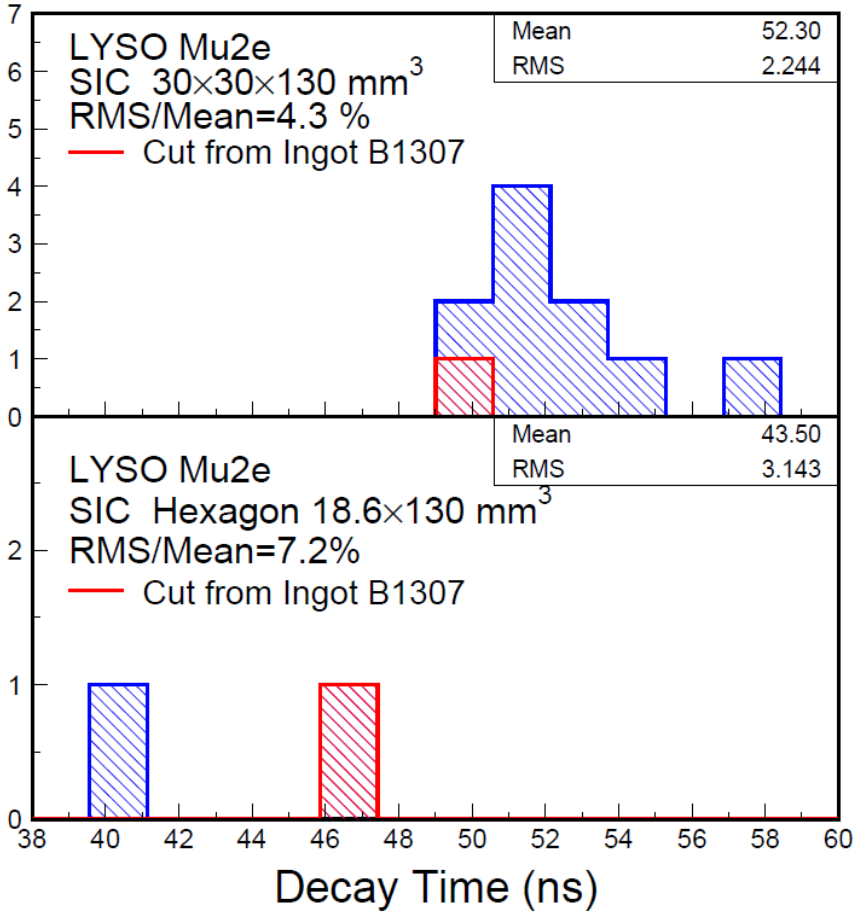




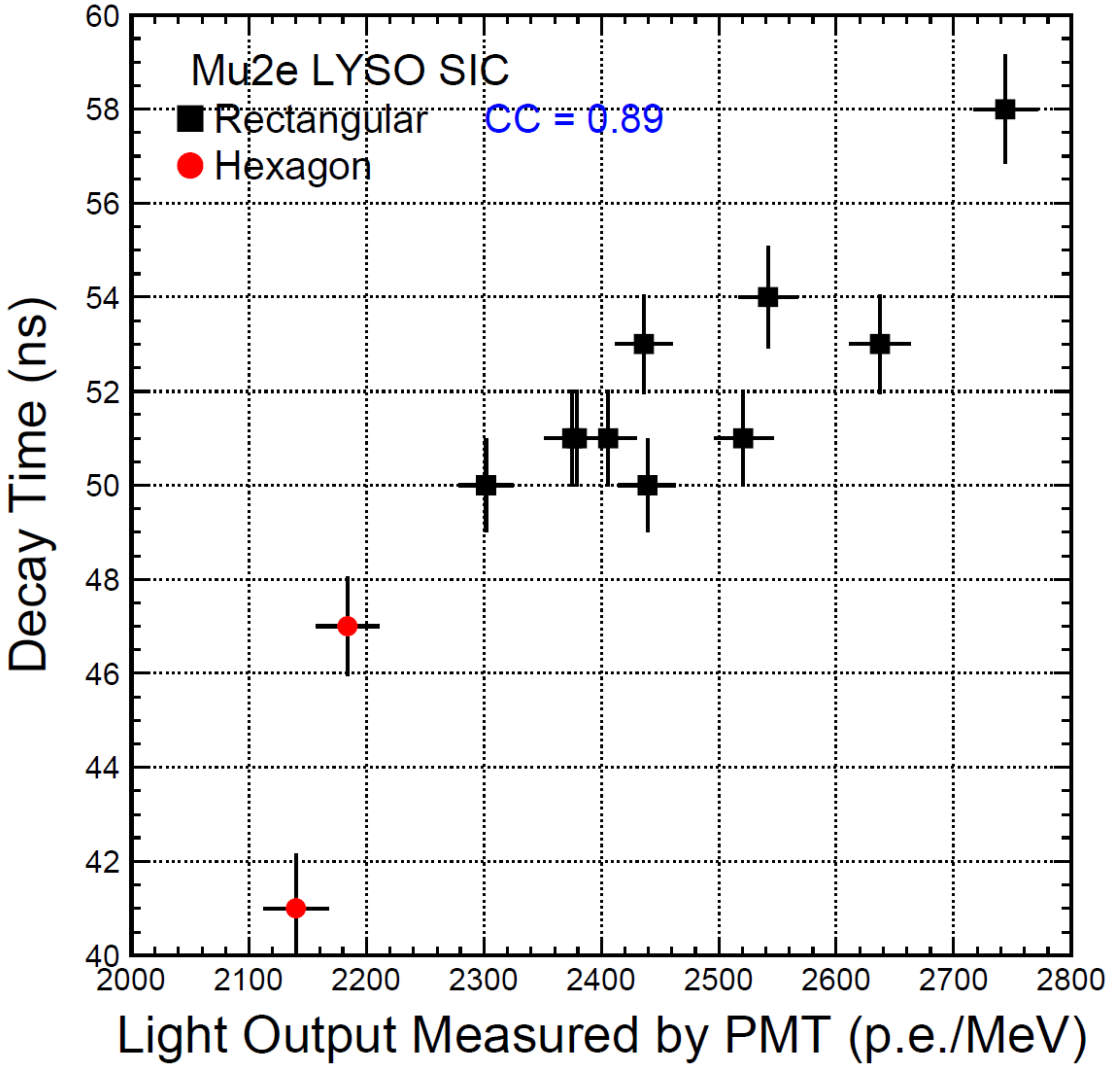
Decay Time

Hexagonal samples have shorter decay time because of less bouncing



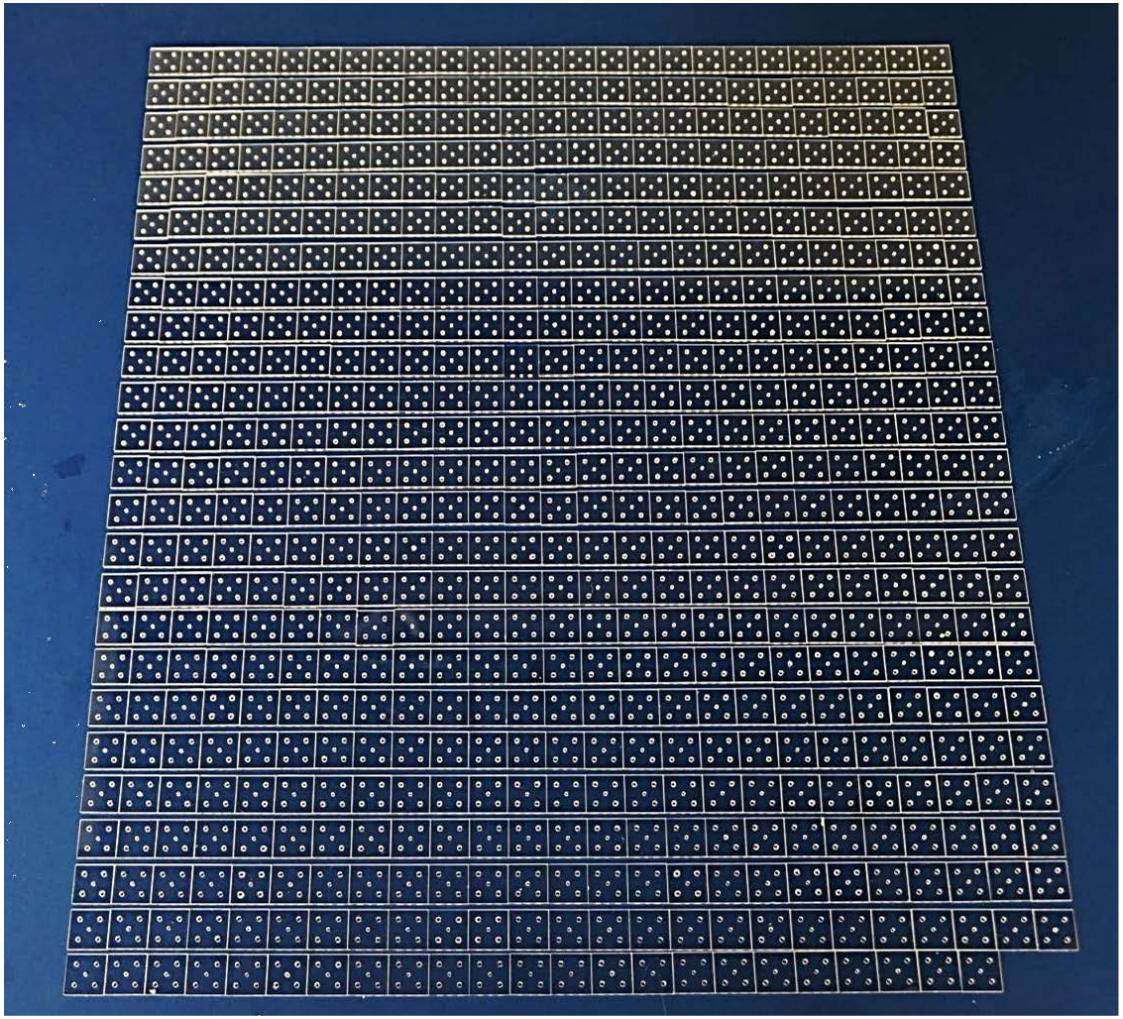


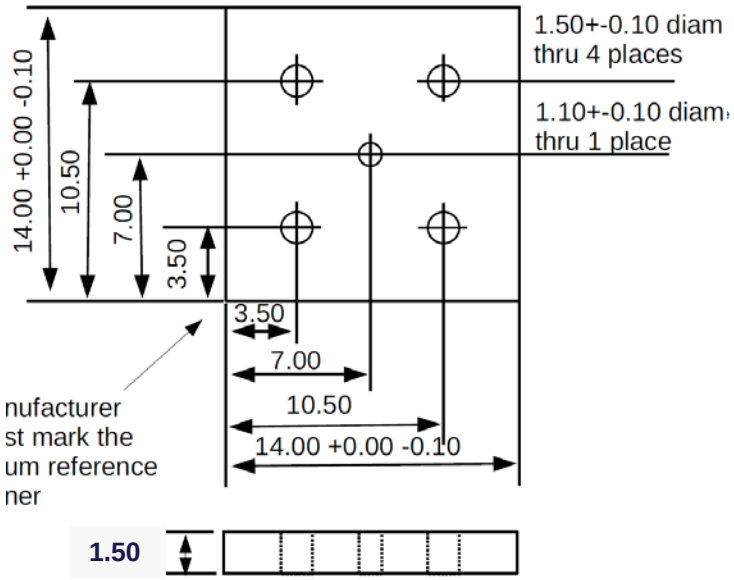
Correlation: Decay Time versus LO



Correlation between LO and decay time because of light propagation

623 Plates of 14 x 14 x 1.5 mm with 5 Holes

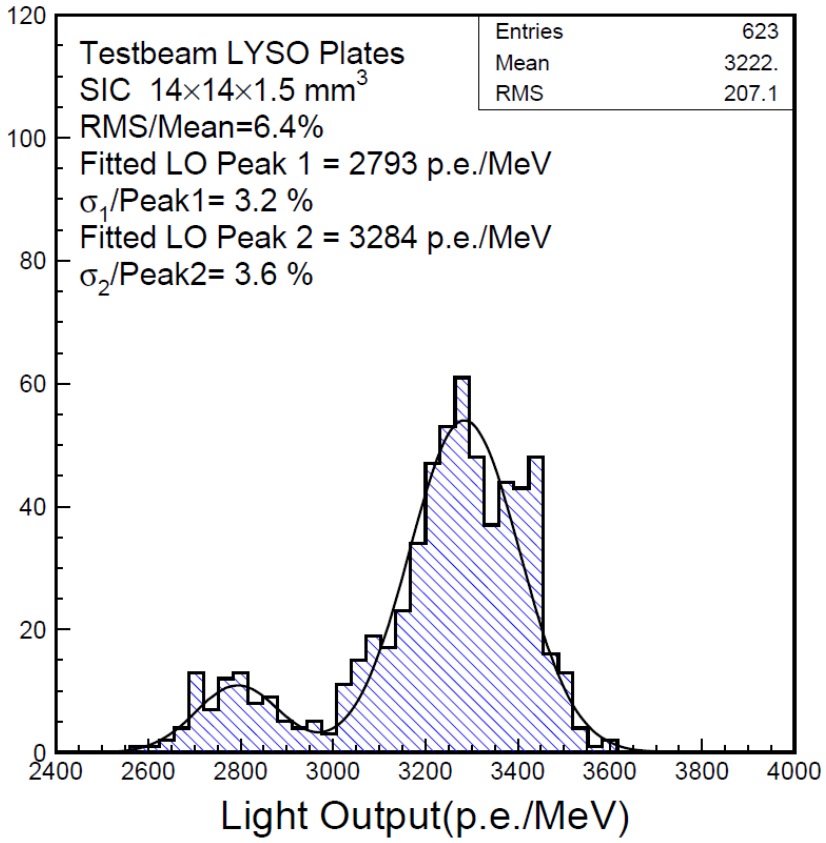


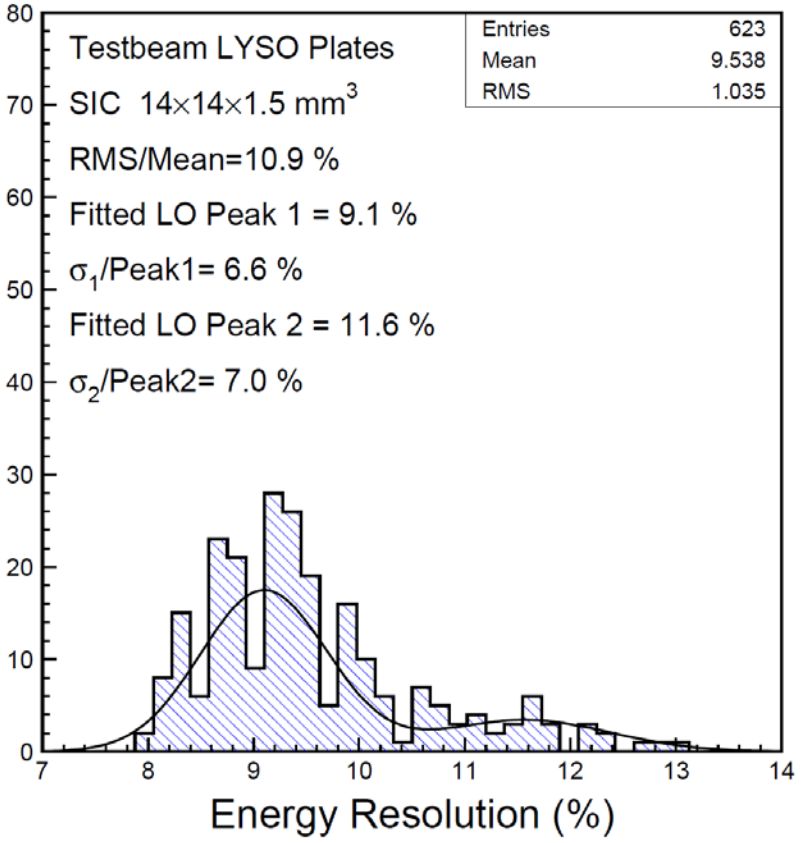


ID	Dimension (mm^3)	Received date	Polished	Amount
LYSO SIC	**14×14×1.5**	2/26/2014	All faces	623

Summary of LO & Resolution

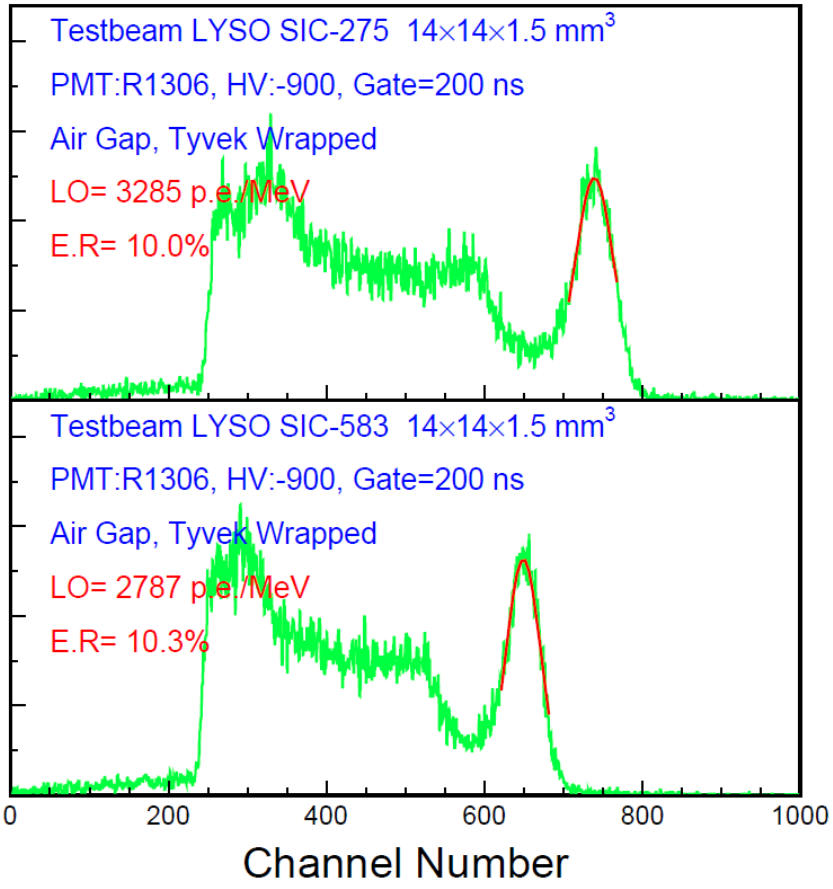
Two groups with 15% difference in LO and about 3.4% spread observed
The average LO/resolution is 3,284/9.1% and 2,793 /11.6%

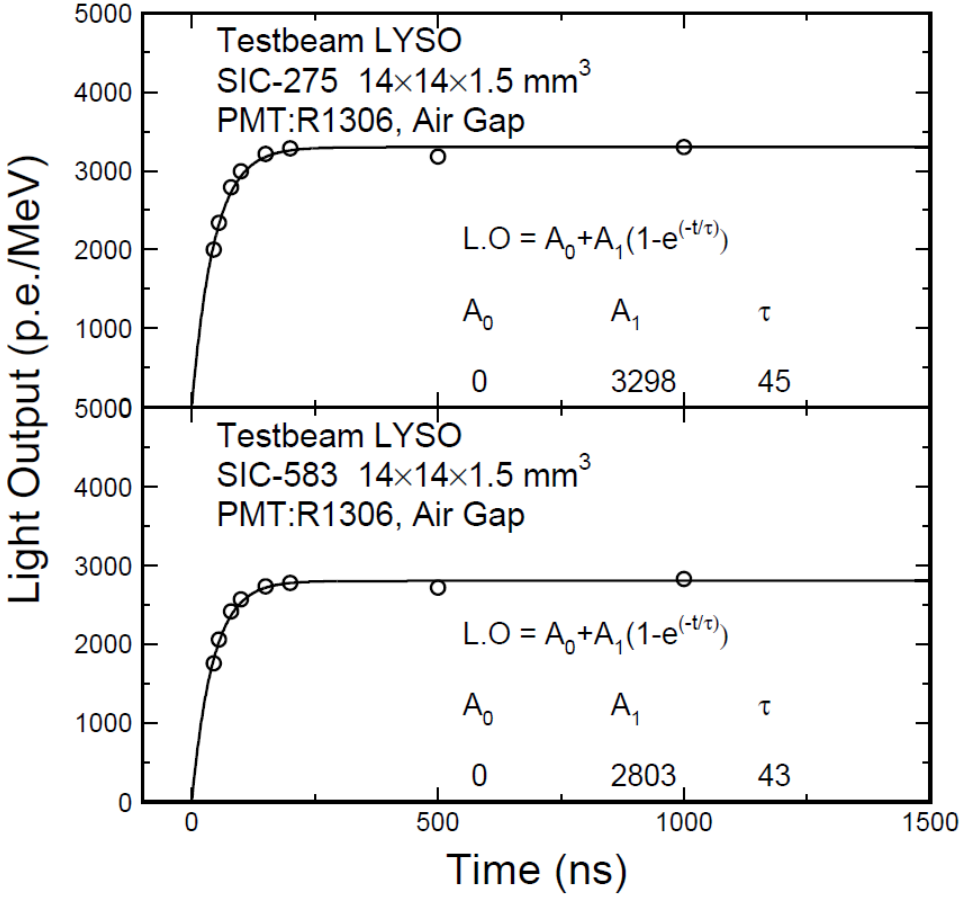




PHS & Decay Kinetics

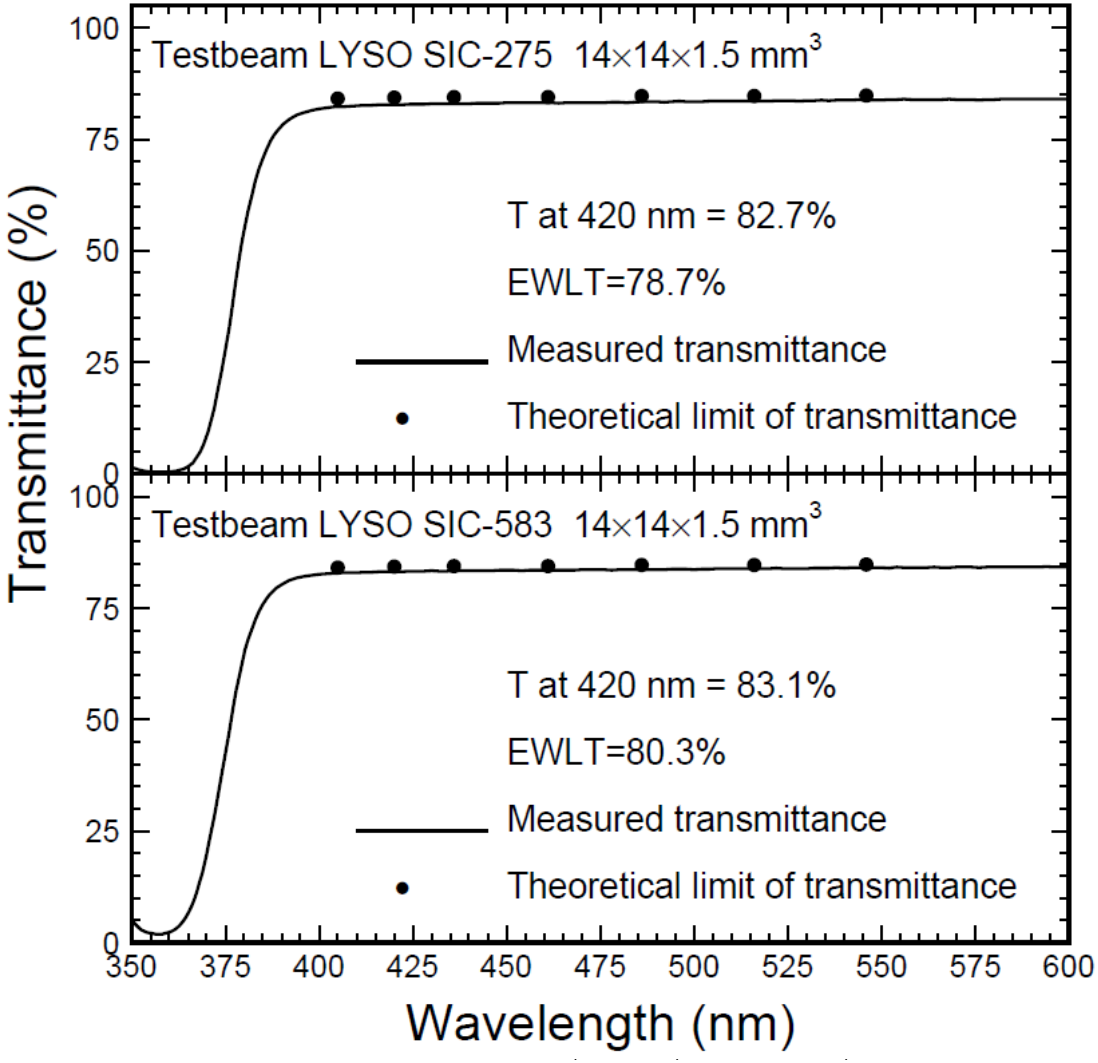
Consistent resolution (10%) decay time (40 ns) observed





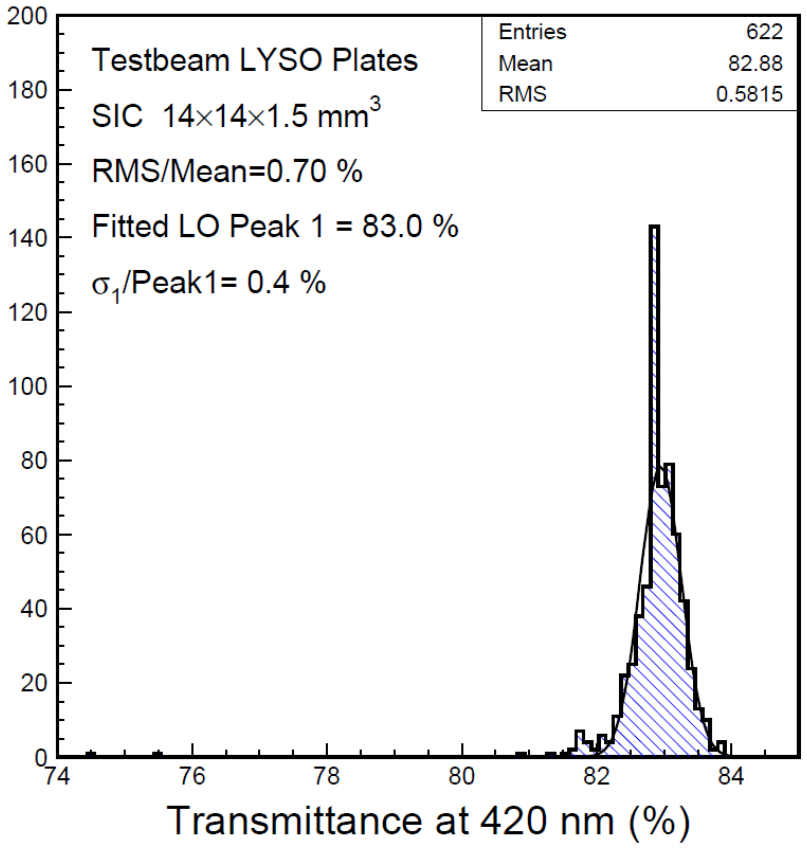
Transmittance

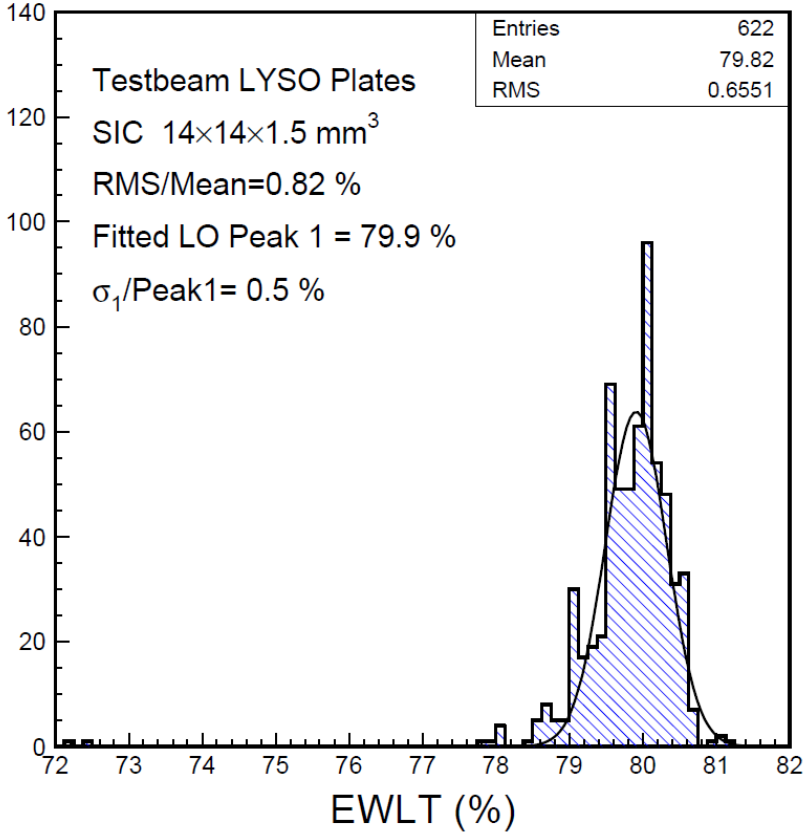
Good transmittance approaches the theoretical limit



Summary of T@420 nm & EWLT

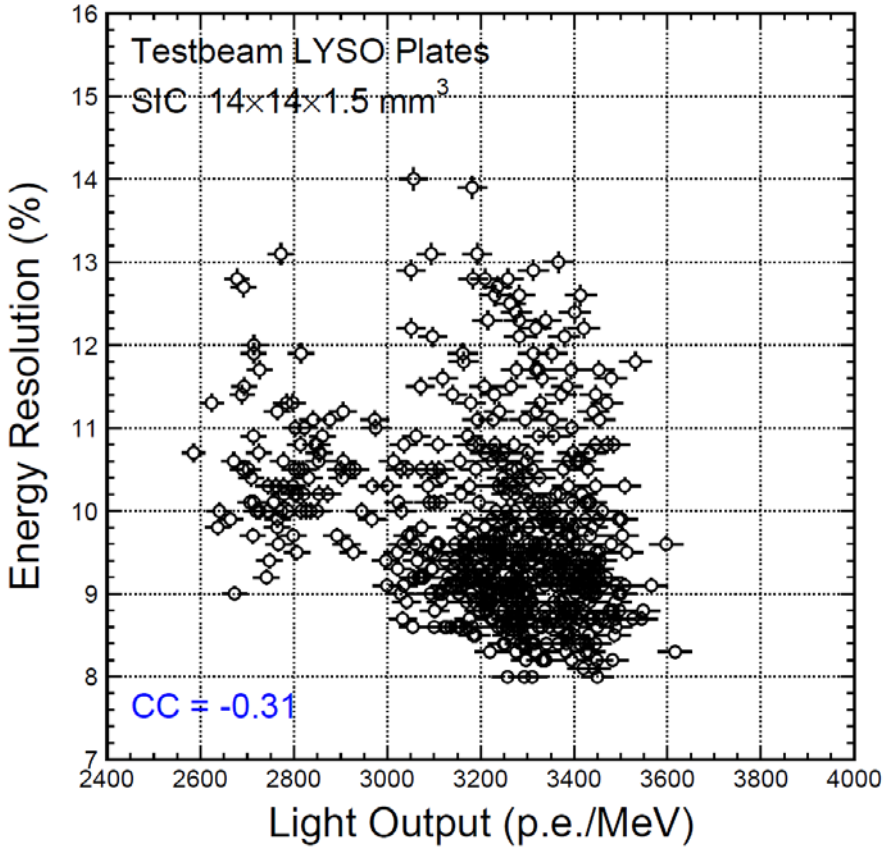
Most plates have consistent T@420 nm (83%) and EWLT (80%)

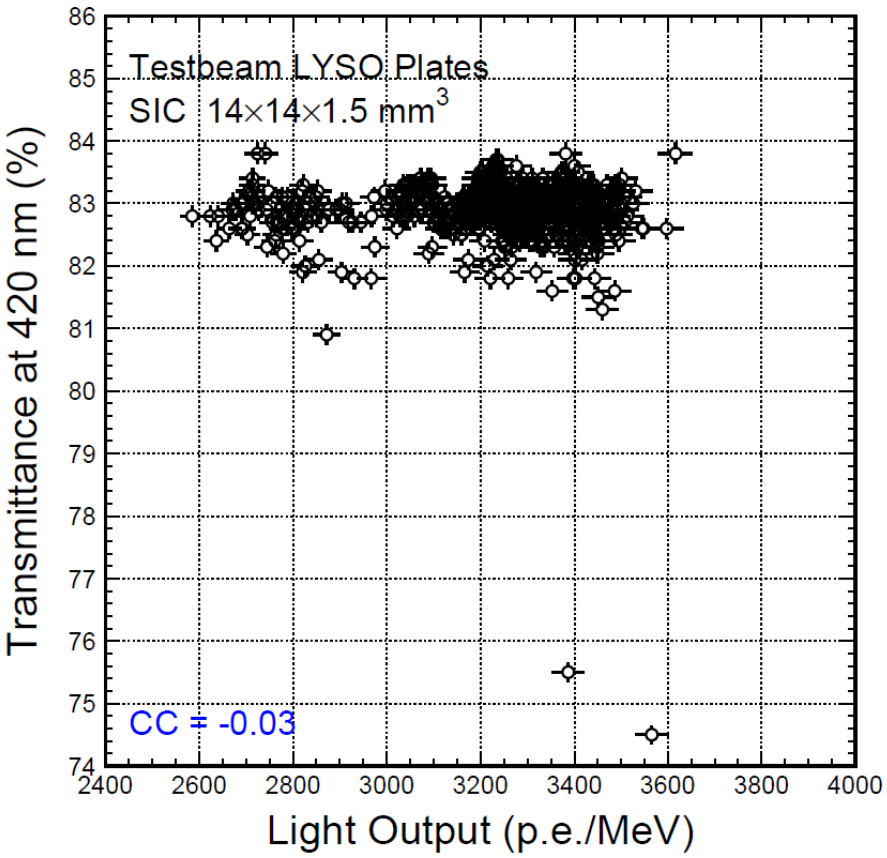




Correlations: Resolution & T@420 nm versus LO

Plates with low LO show poor resolution





No correlation between LO and transmittance because of short light path

Conclusion

- LYSO crystals produced in industry show good transmittance exceeding 75% specification @ 420 nm and good FWHM energy resolution better than 12.5% specification @ 511 keV.
- Typical LO spread is at a level of 6%, which may be reduced to about 3% in mass production.
- Correlations are observed between LO and LT @ 420 nm as well as between LO and decay time for long LYSO crystals.
- A slight anti-correlation observed between LO and energy resolution for 14 x 14 x 15 mm LYSO plates.
- Results of these investigations indicate that the quality LYSO crystals grown in industry is adequate for future HEP calorimeters at both the energy and intensity frontiers.