Light Response Uniformity of LYSO Crystals

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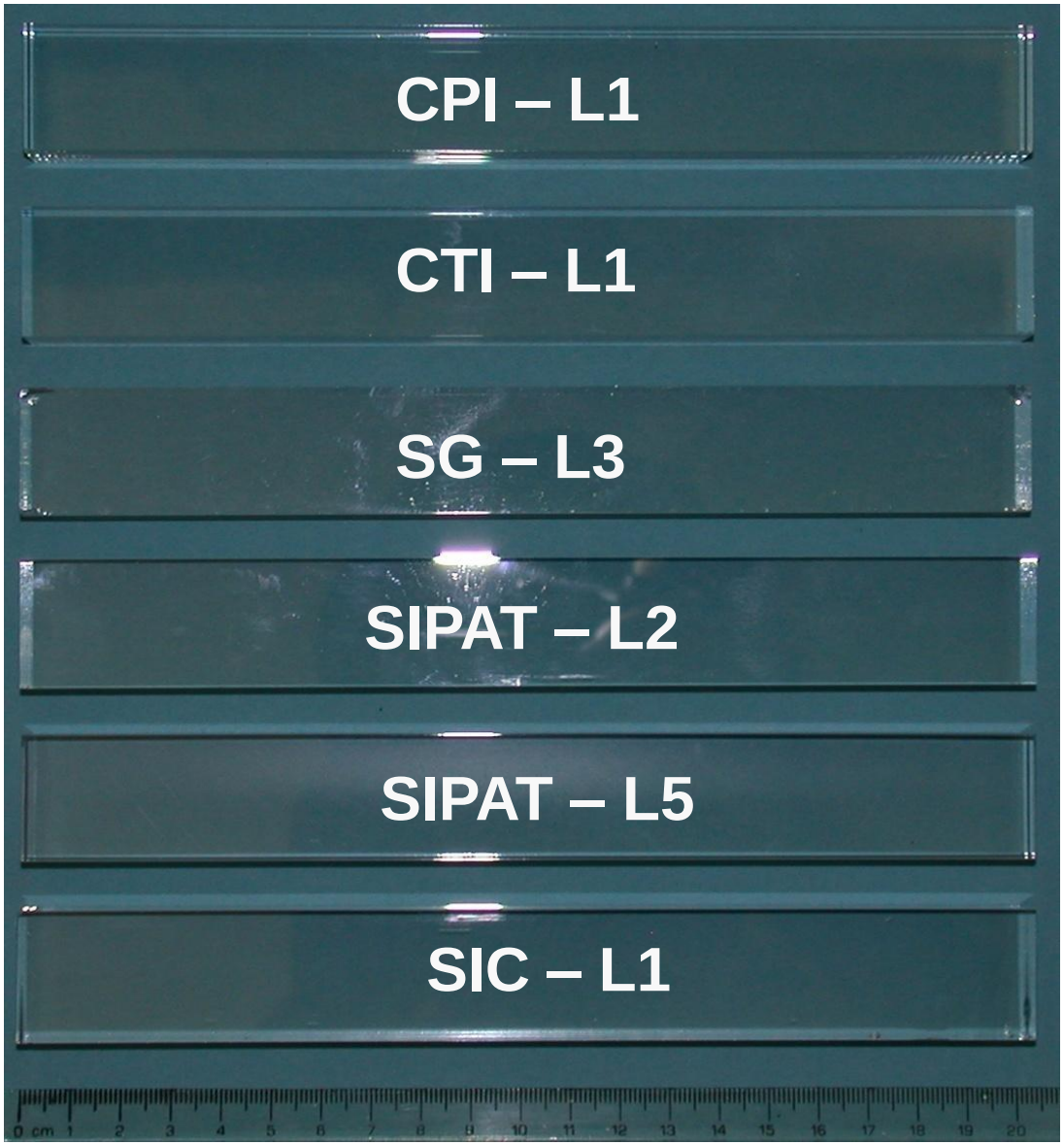
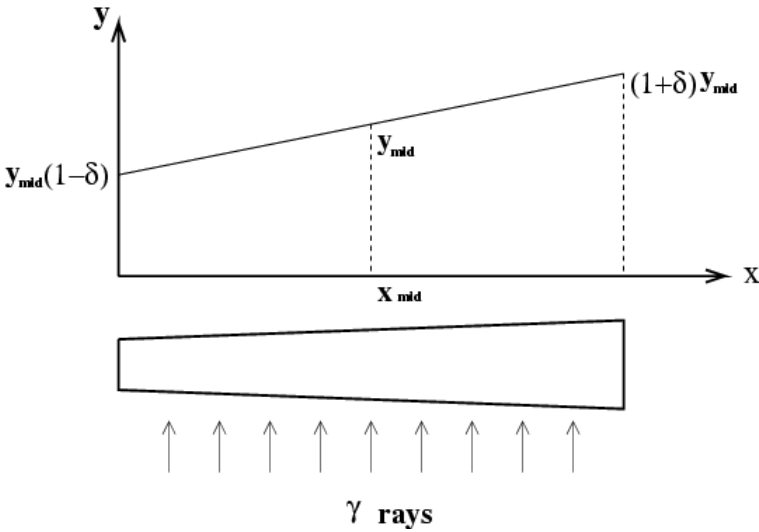
Light Response Uniformity



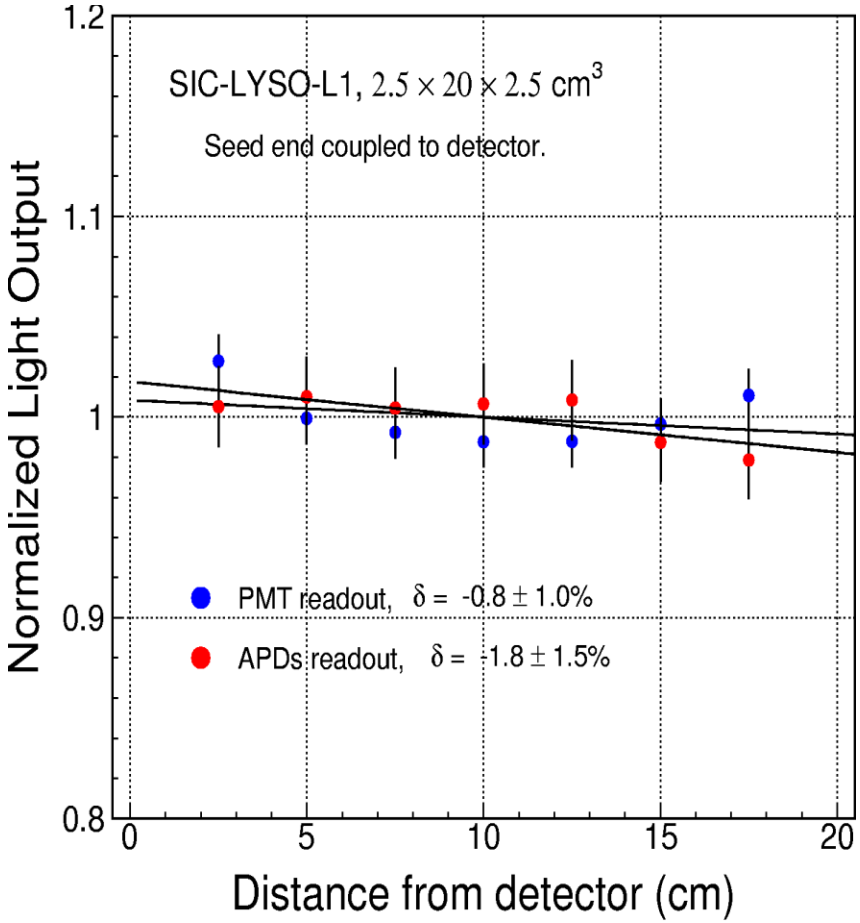
2.5 x 2.5 x 20 cm samples measured for their L.R.U. and fit to a linear function

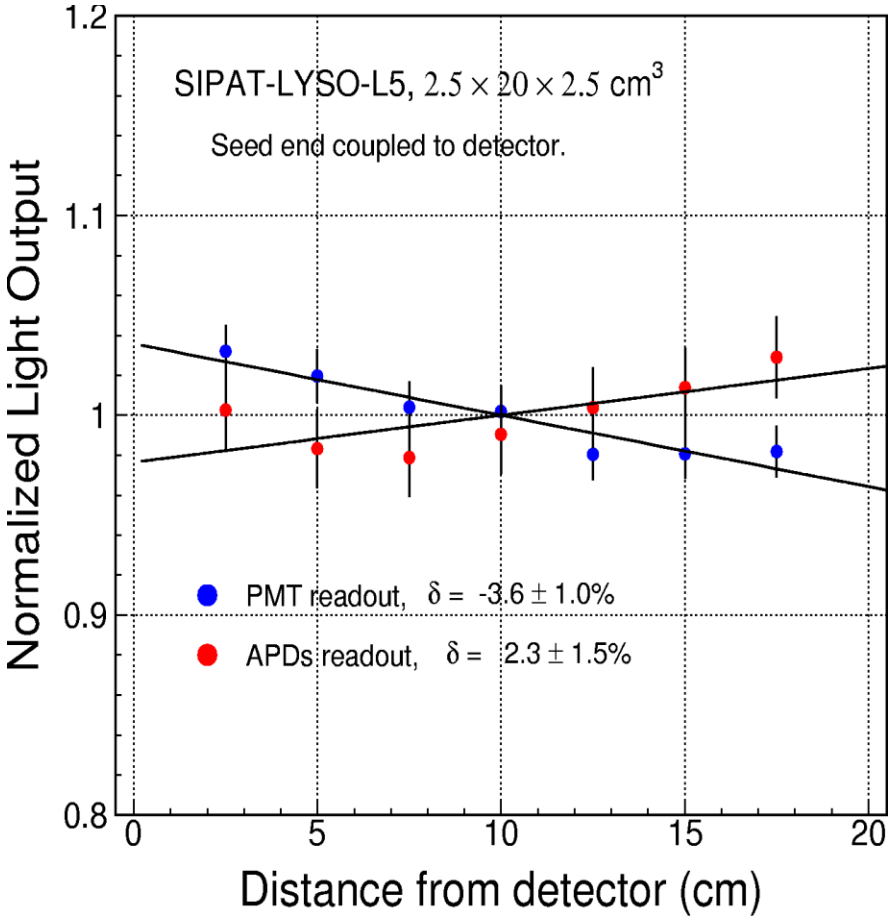
$$Y = Y_{mid}\,[1 + \delta(x/x_{mid} - 1)]$$



Different LRU for PMT & APD

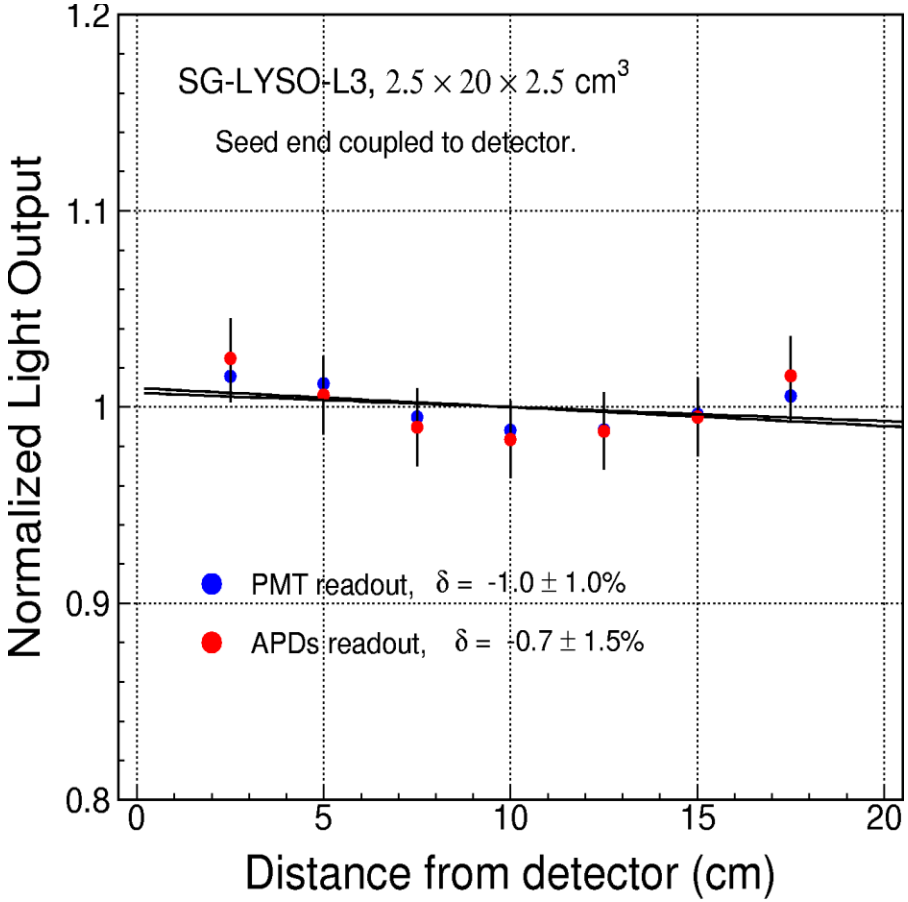
A large difference between LRU observed with PMT & APD in sample SIPAT-LYSO-L5

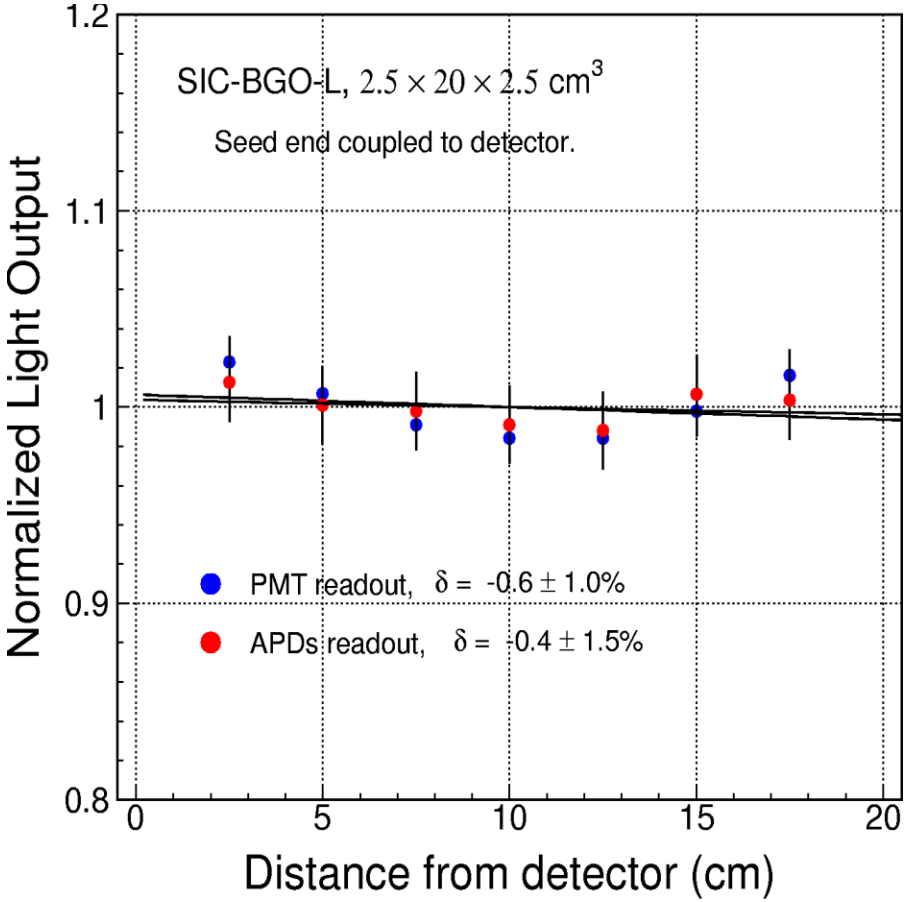




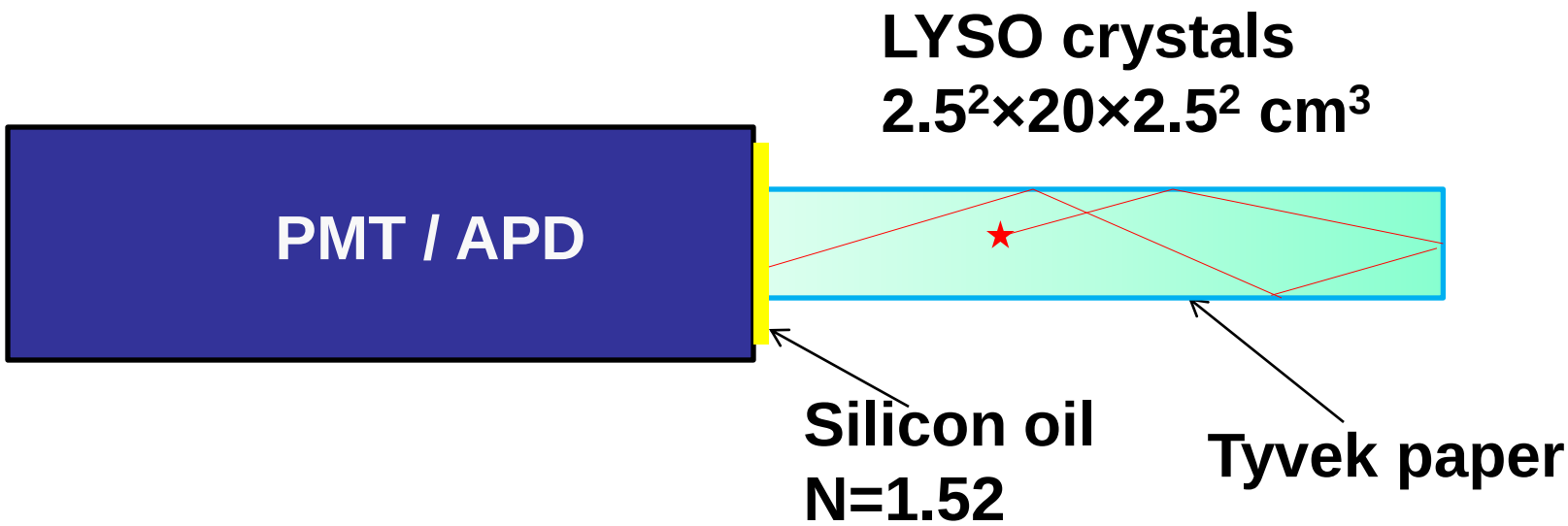
Different LRU for PMT & APD

Consistent LRU observed with PMT & APD readout in sample SG-LYSO-L3 & SIC-BGO



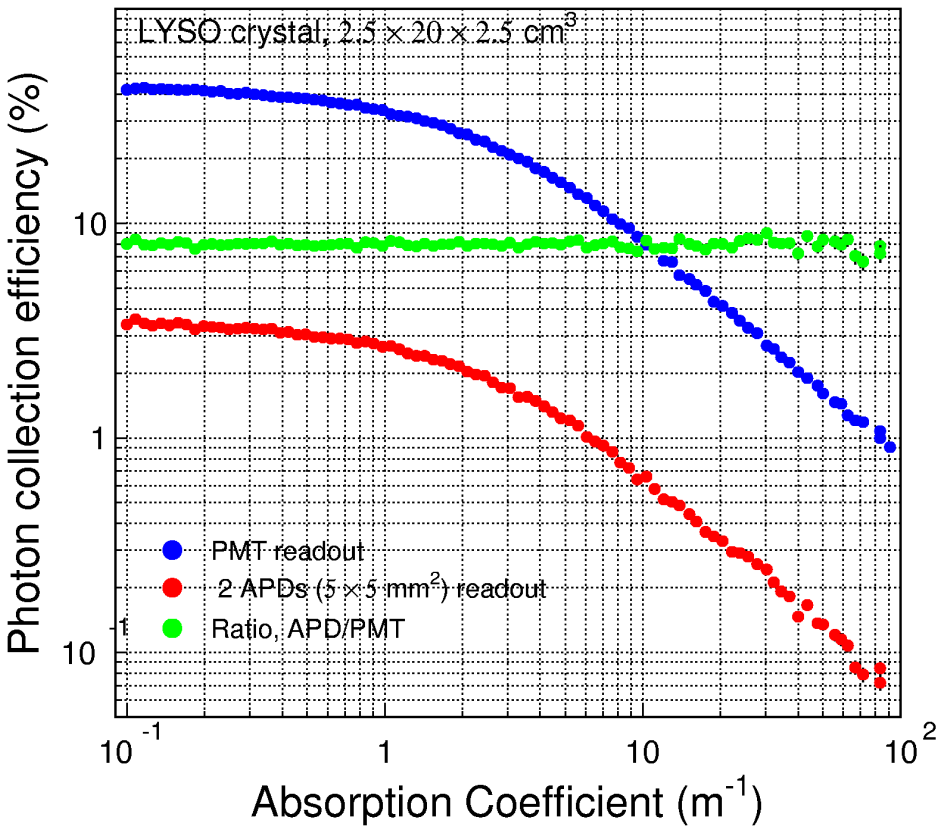


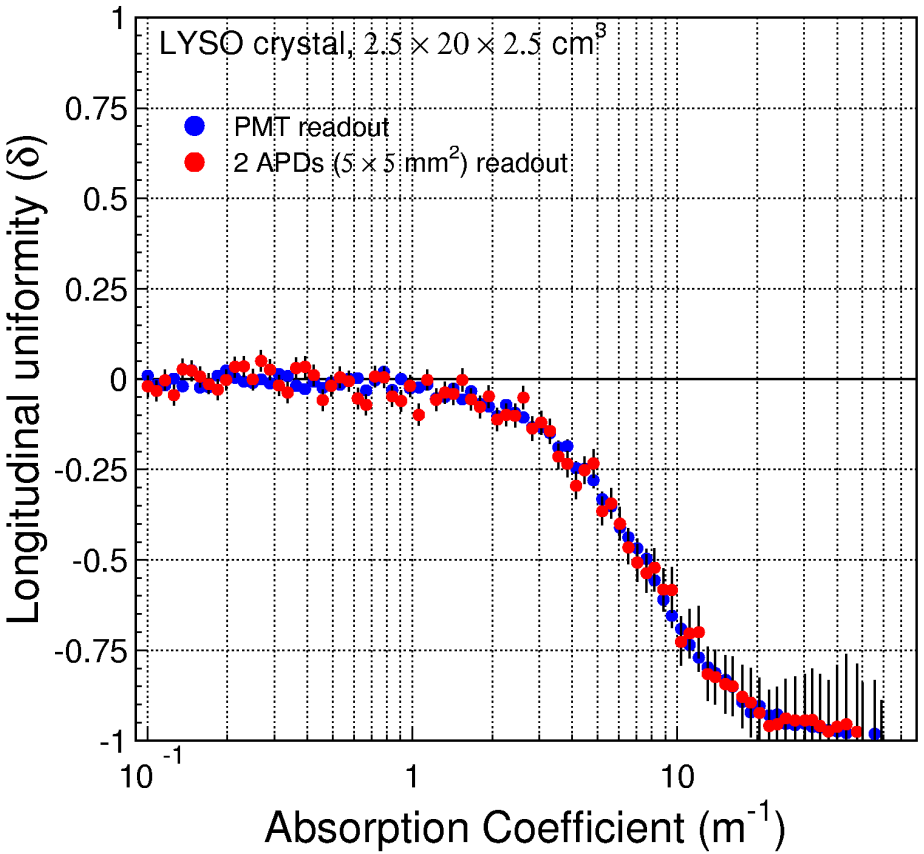
Ray-Tracing Simulation



Area Coverage Effect for PMT and APD

Different area coverage of PMT (2.5 ×2.5 cm^2) and APD (2×0.5×0.5 cm^2) determines the different light collection efficiencies, but has no effect on the L.R.U.

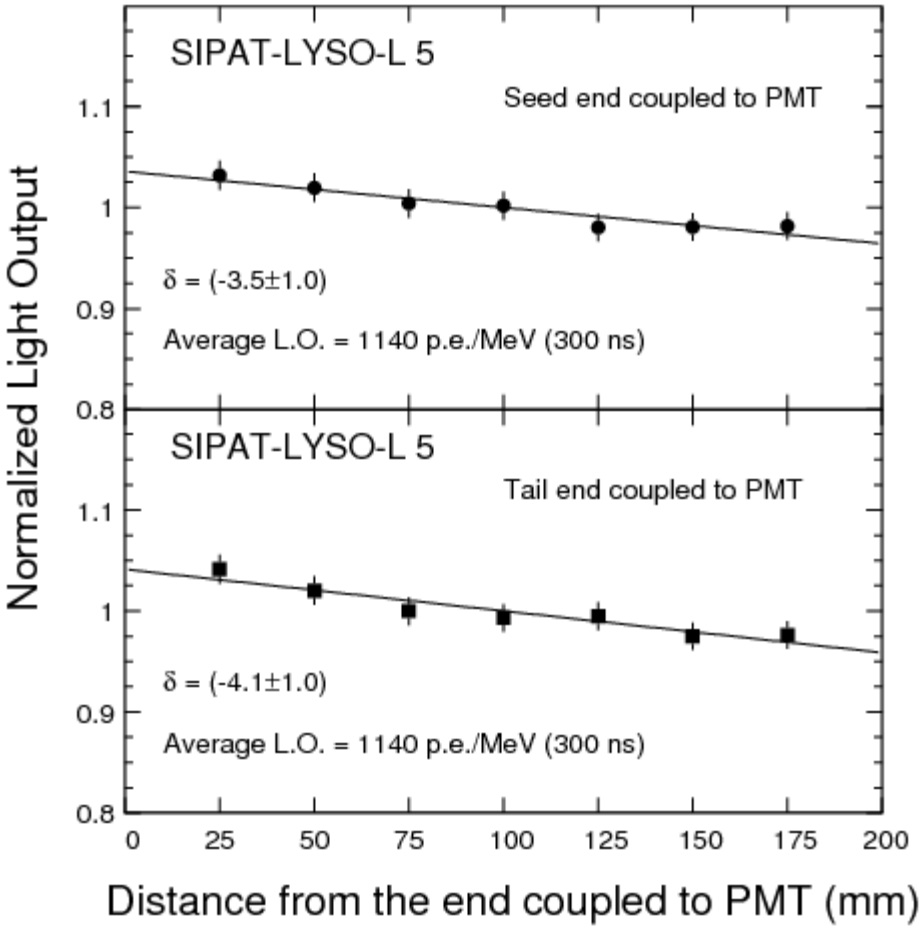




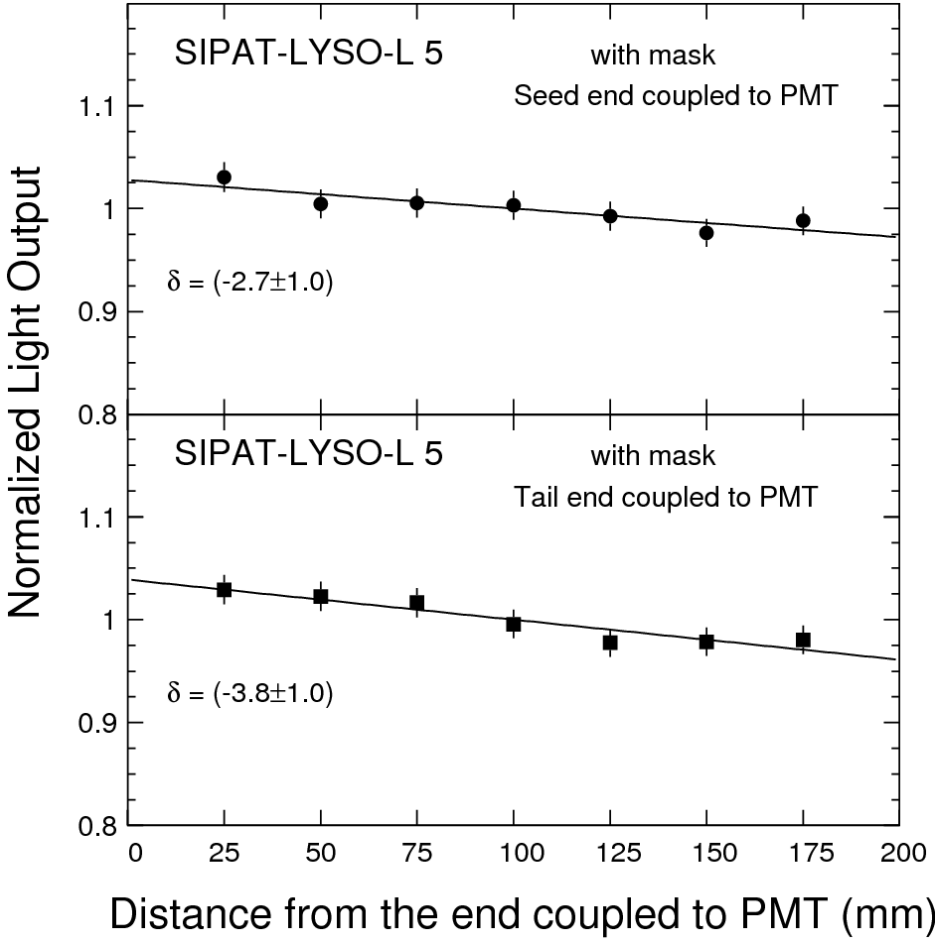
L.R.U. by PMT & Mask for SIPAT-LYSO-L5

Data confirm simulation: no geometry effect.

PMT without Mask

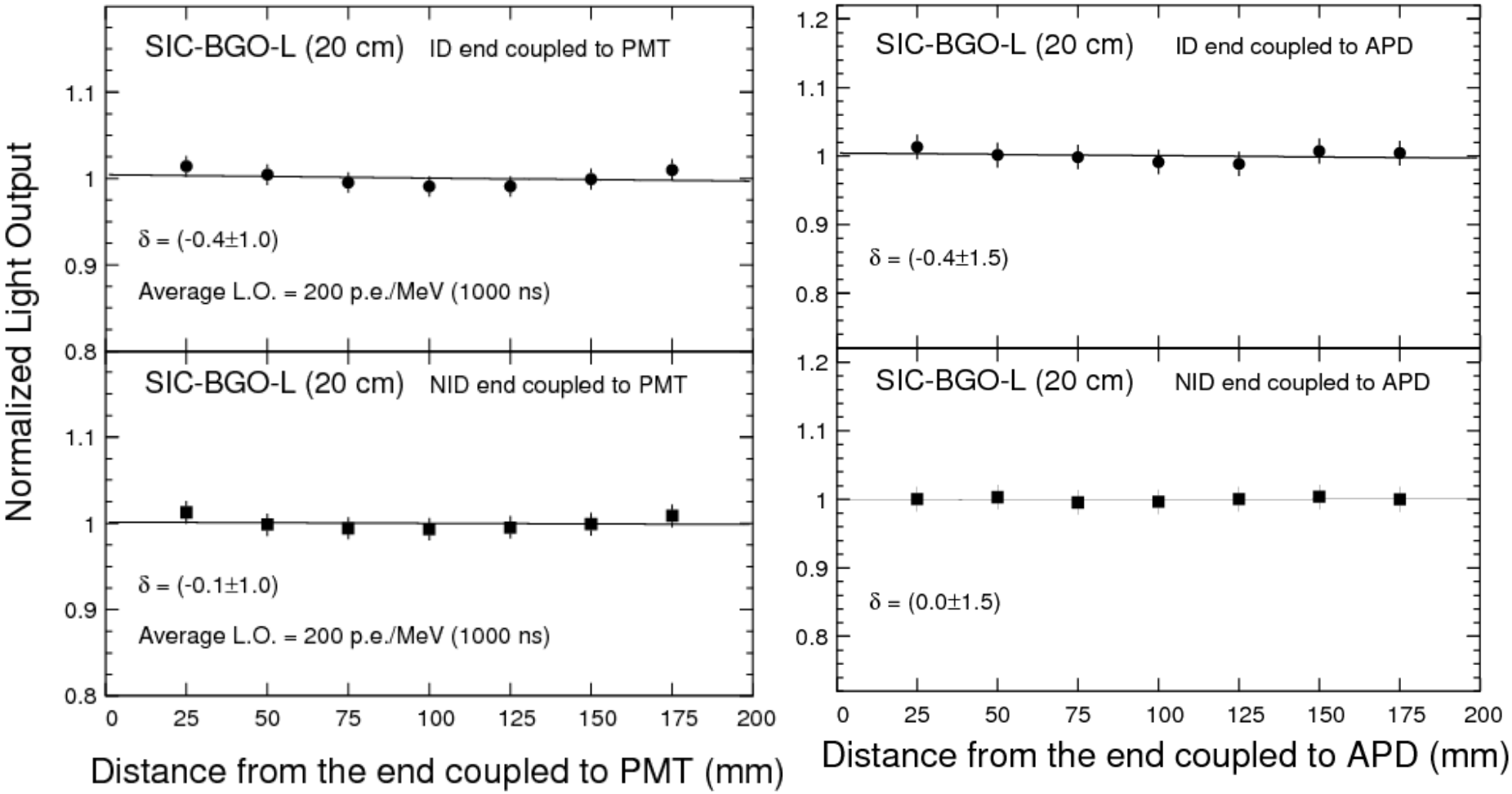


With a Mask of APD geometry



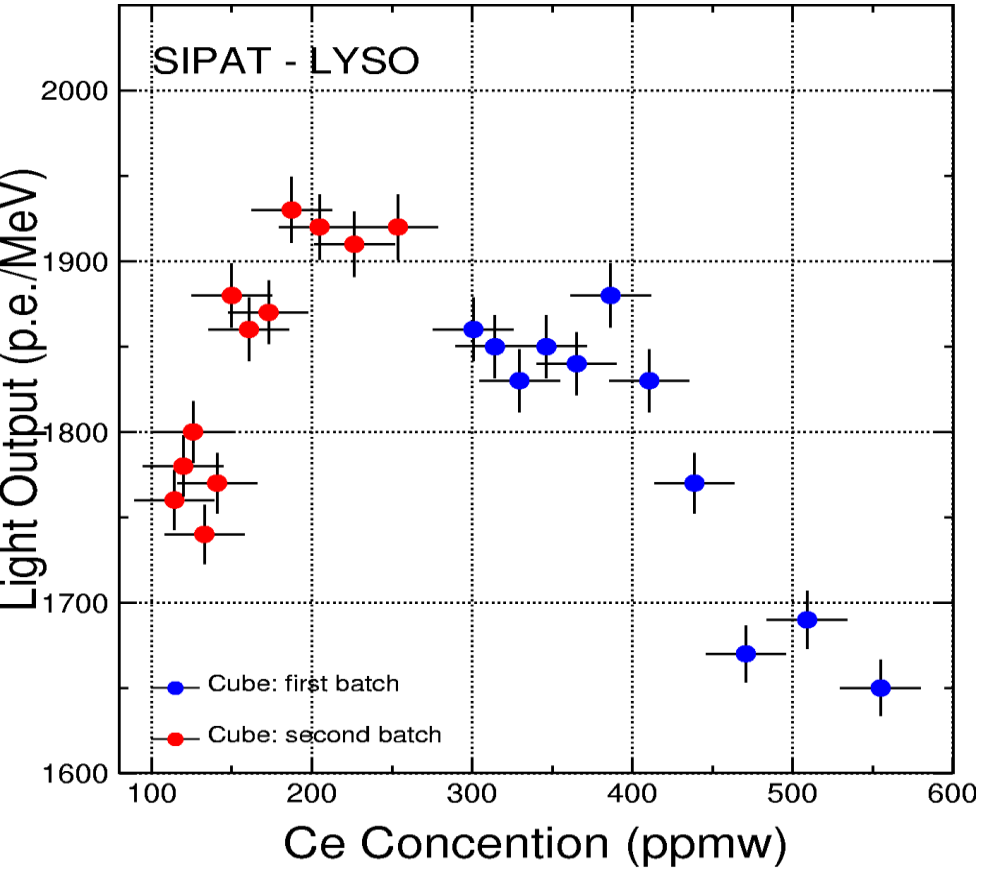
L.R.U. by PMT and APD for BGO

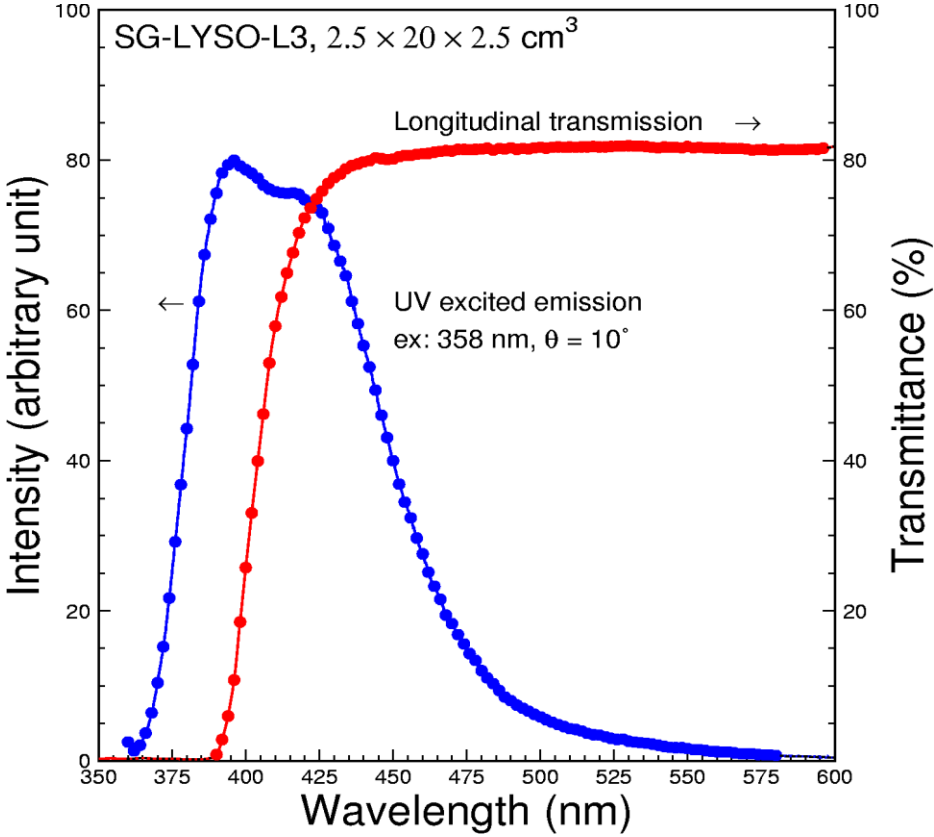
BGO data confirms ray-tracing simulation.
It seems a particular issue for LSO/LYSO.



Two Issues for LYSO:Ce

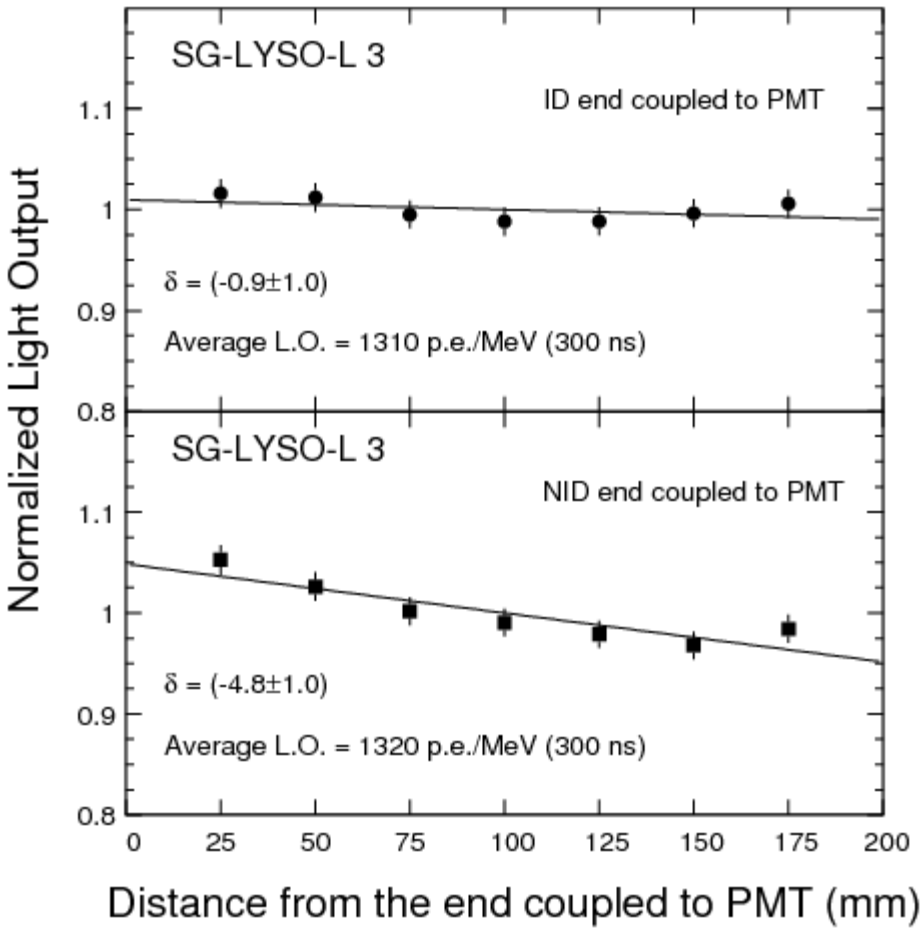
L.O. is a function of the Ce concentration, so depending on the longitudinal position. L.O. is also a result of the interplay between the transmittance and emission.

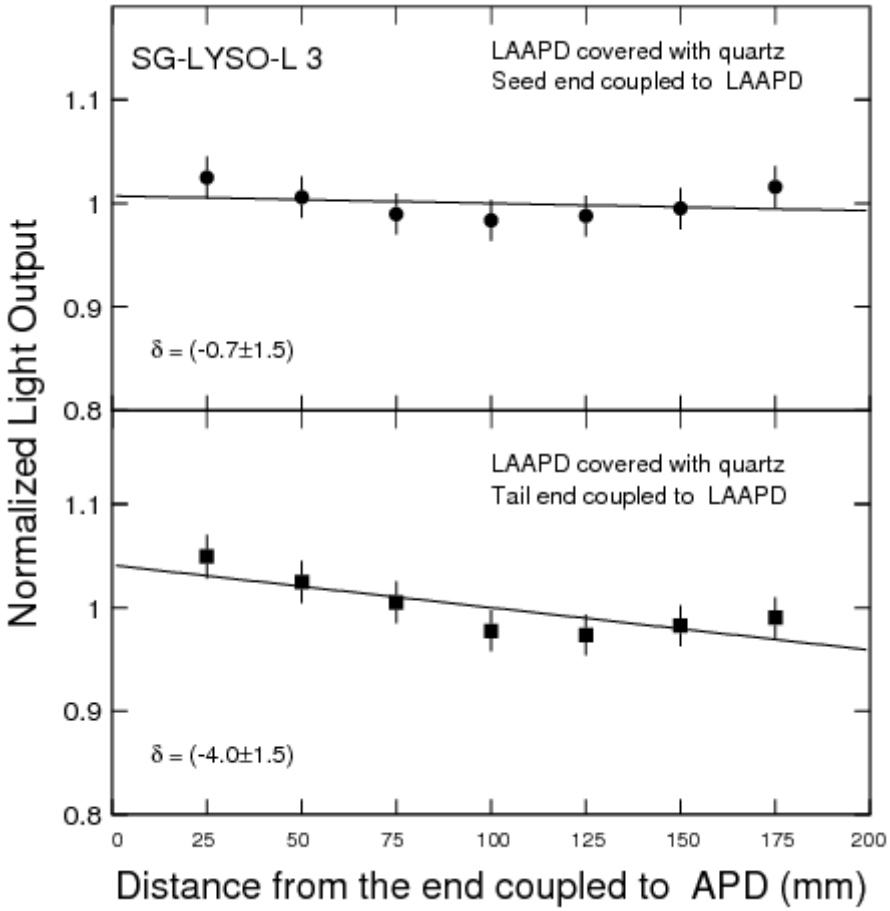




L.R.U. by PMT & LAAPD: SG-LYSO-L3

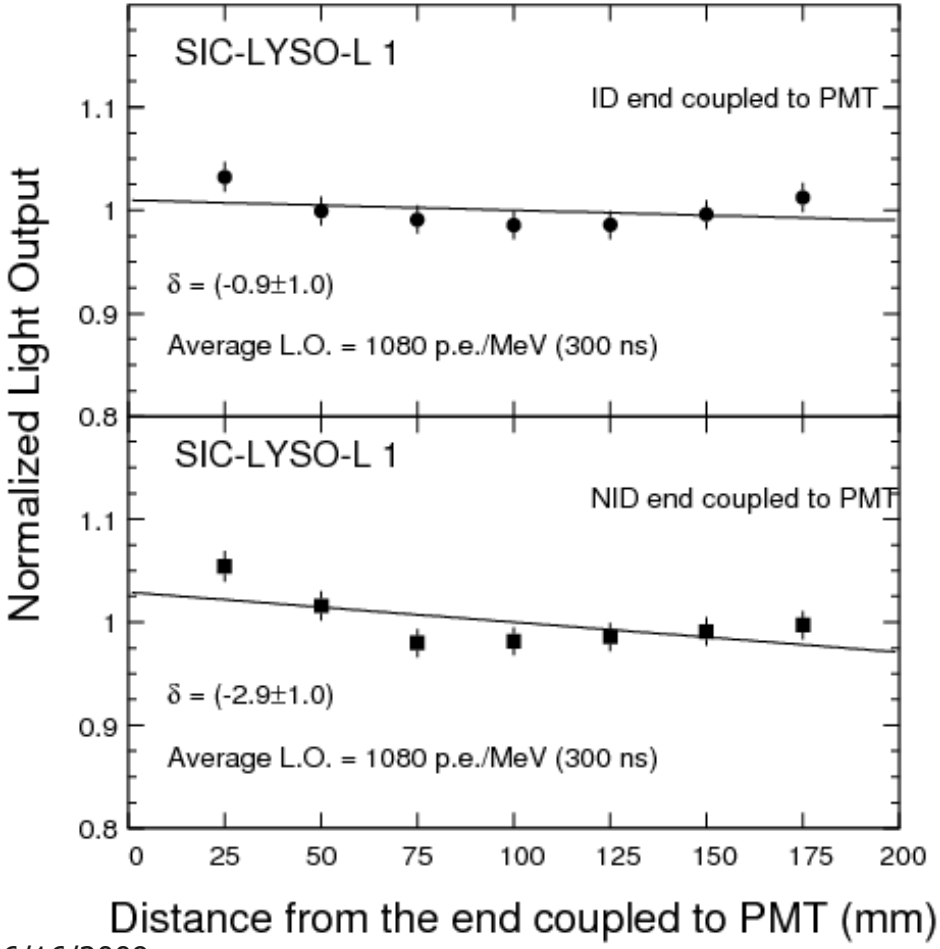
Consistent uniformities between PMT and APD
Some difference between two end-couplings.

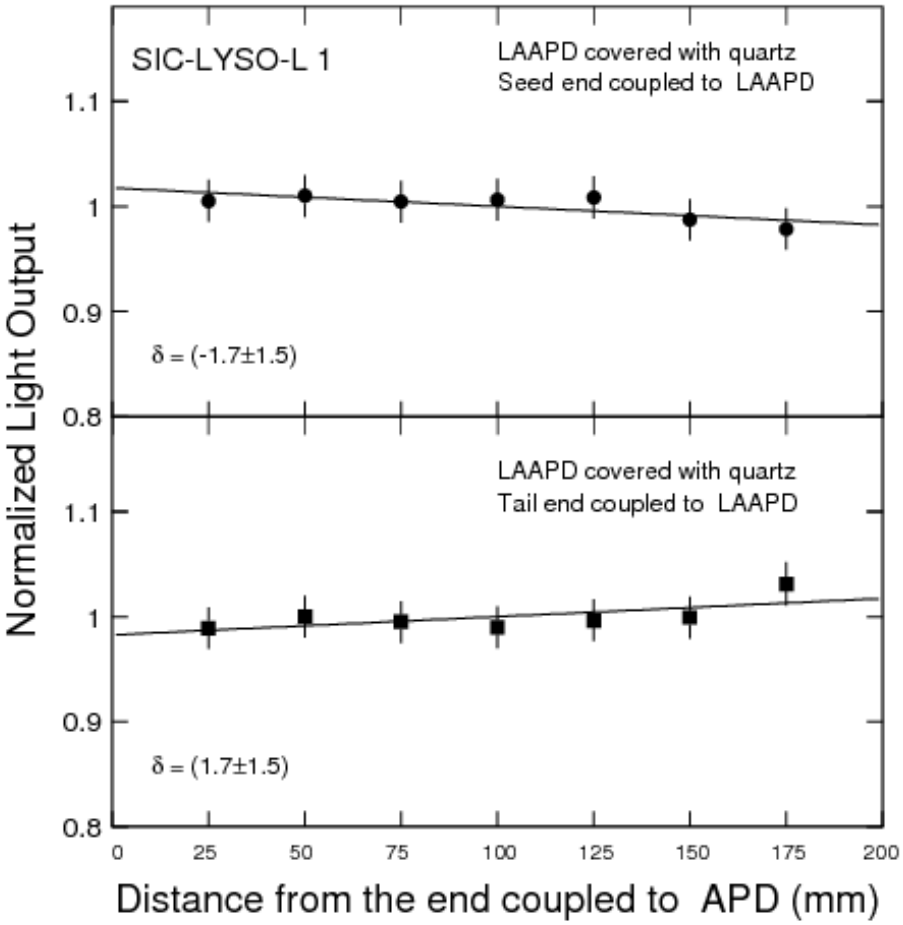




L.R.U. by PMT & LAAPD: SIC-LYSO-L1

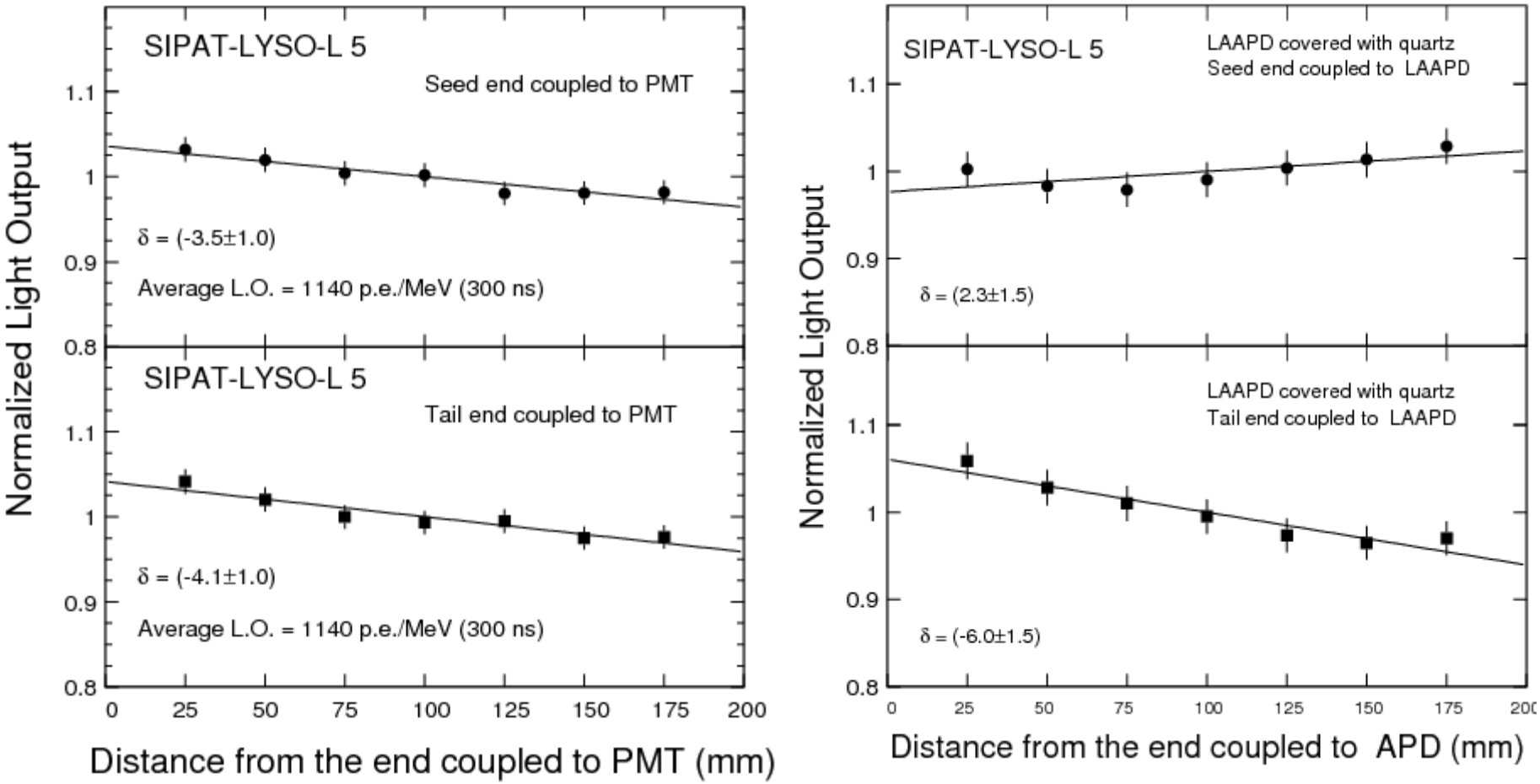
Consistent uniformities between PMT and APD for one end coupling. A large difference for the other end-coupling seems caused by not optimized Ce concentration.





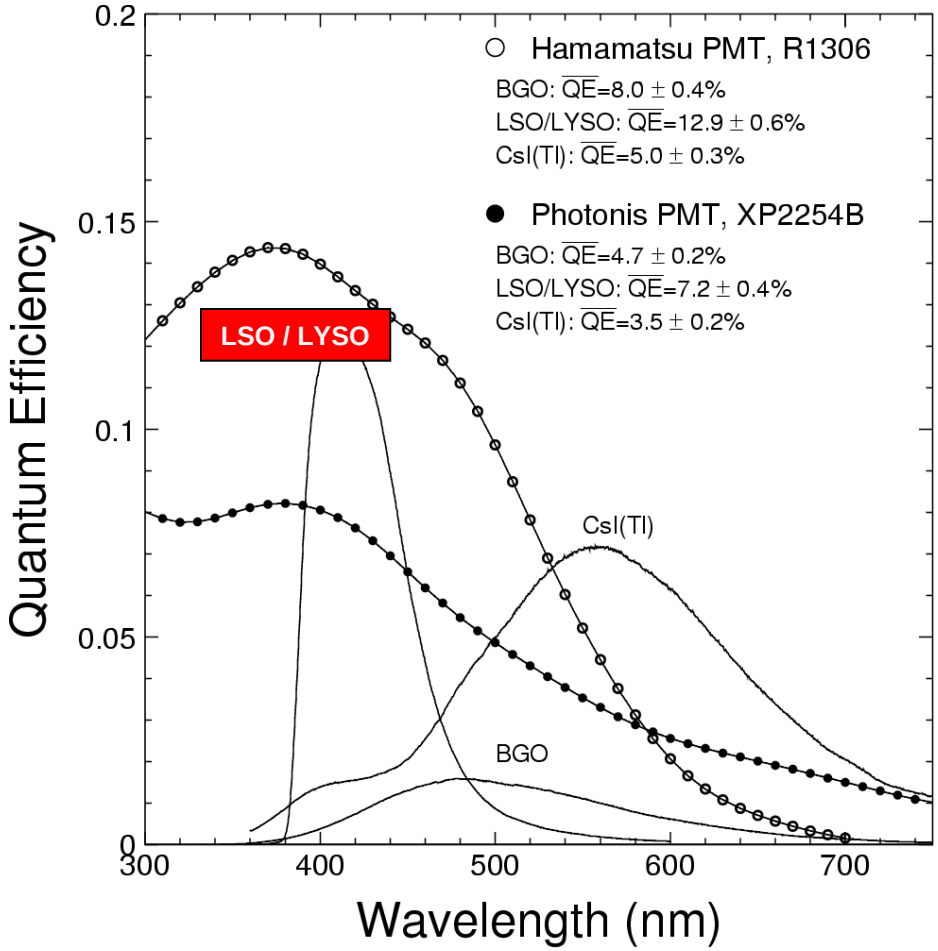
L.R.U. by PMT & LAAPD: SIPAT-LYSO-L5

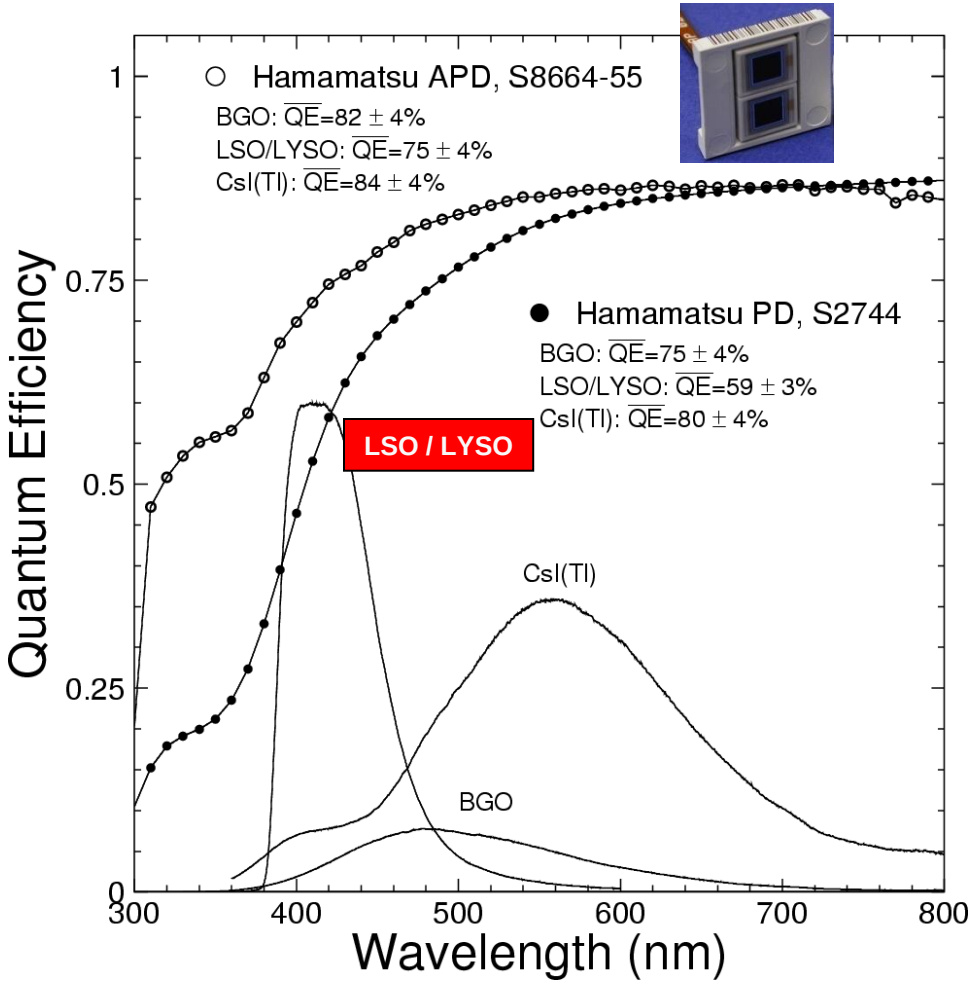
Ce doping was optimized for the uniformities measured by PMT with two end-couplings. A large difference observed between the PMT & APD readouts.



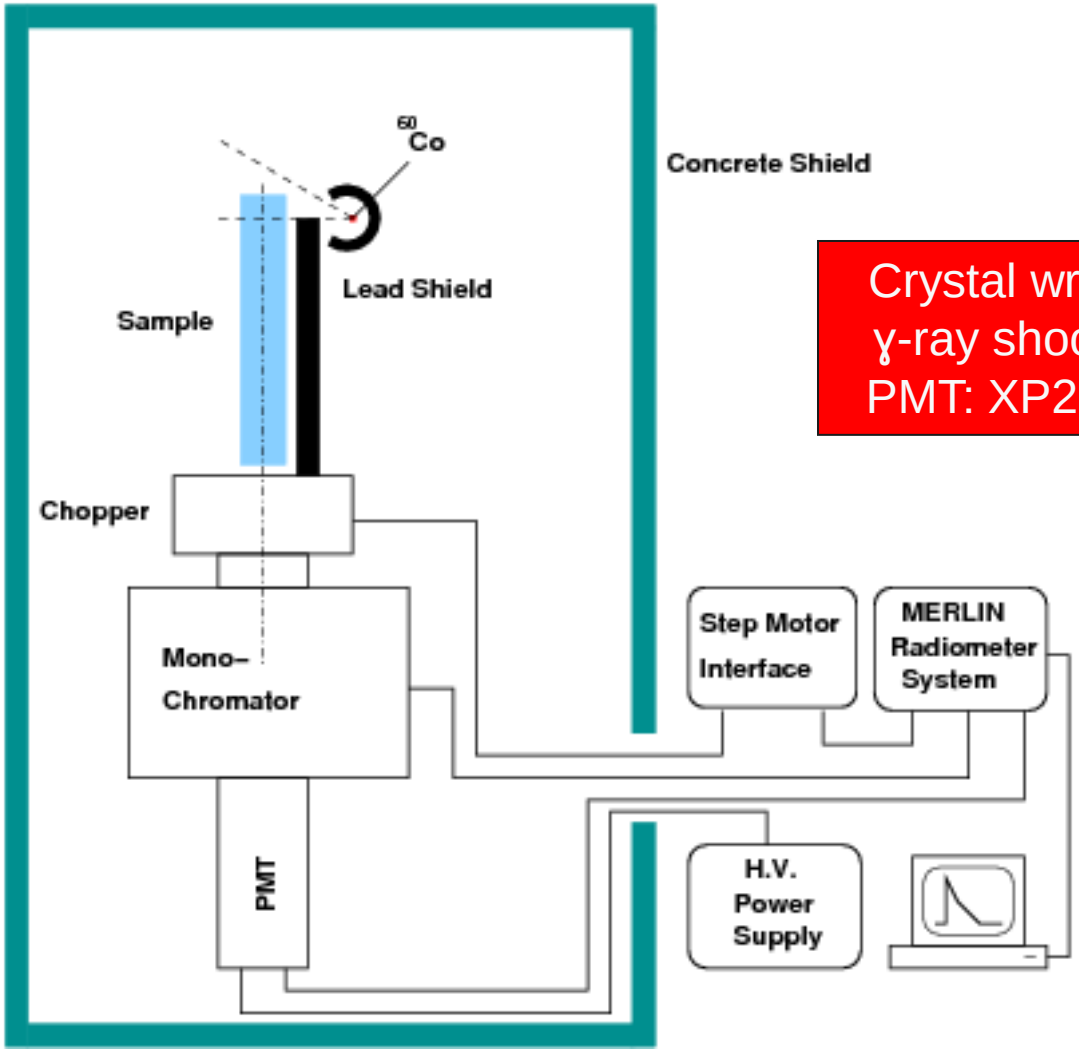
Another Possibility

Variation of radio-luminescence the along crystal length and QE difference between PMT and APD





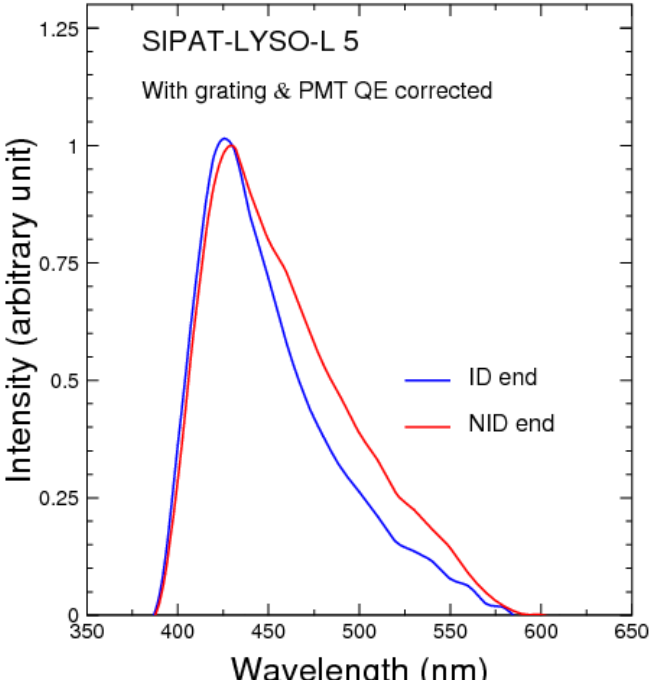
Radio-luminescence for LSO/LYSO

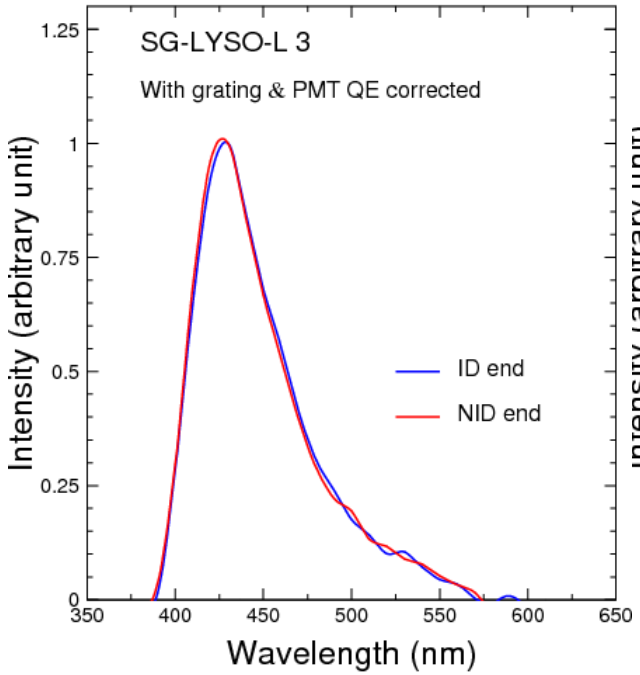


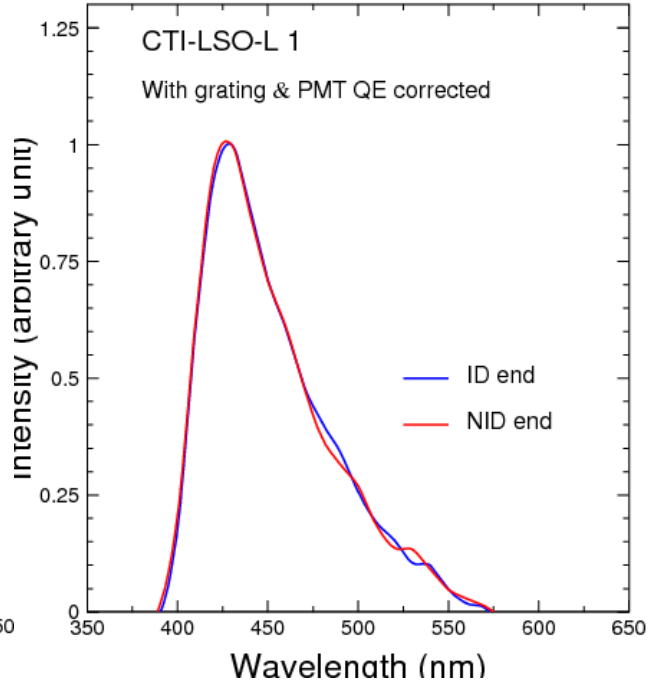
Crystal wrapped with Tyvek paper;
γ-ray shooting at two ends (1 cm);
PMT: XP2254B running @ -1800V.

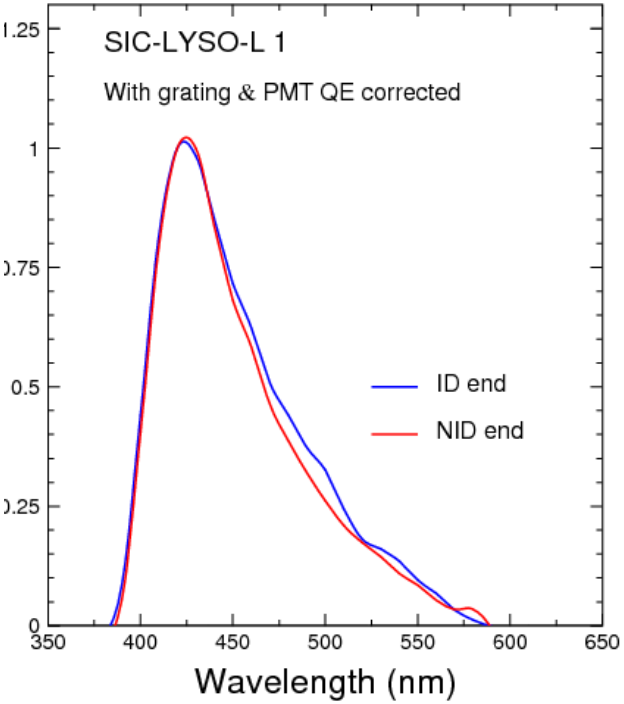
Radio-luminescence

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.



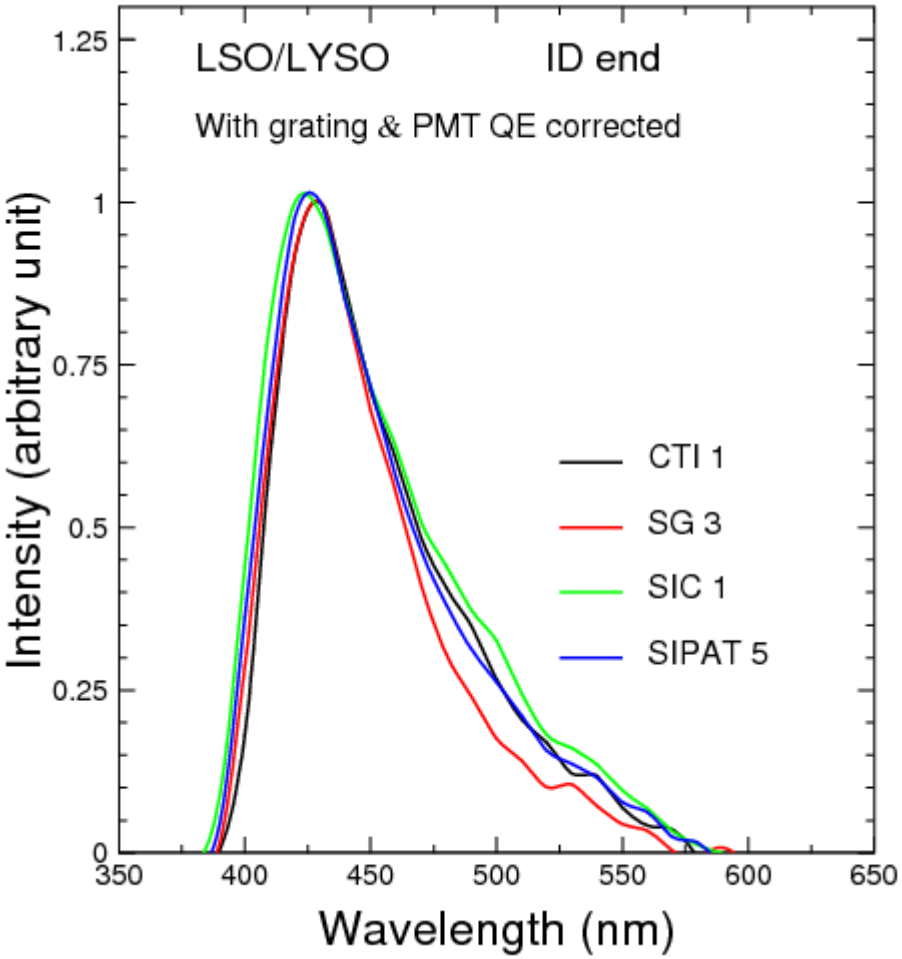


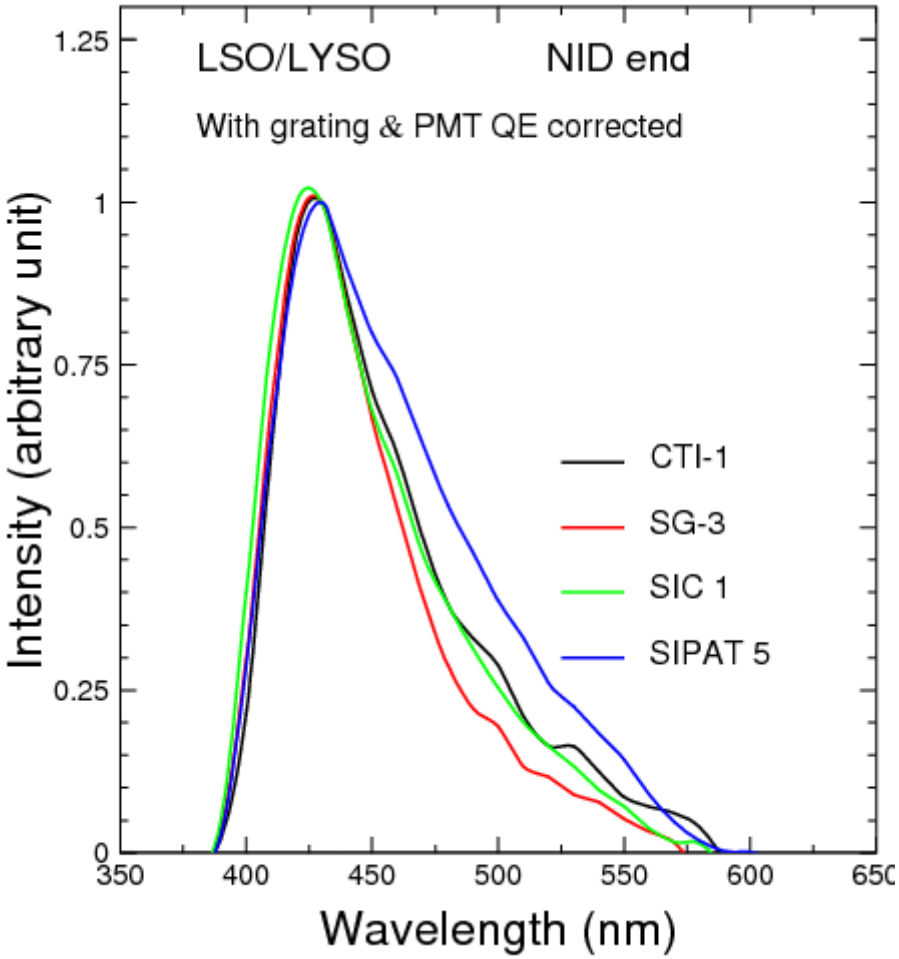




Radio-luminescence Comparison

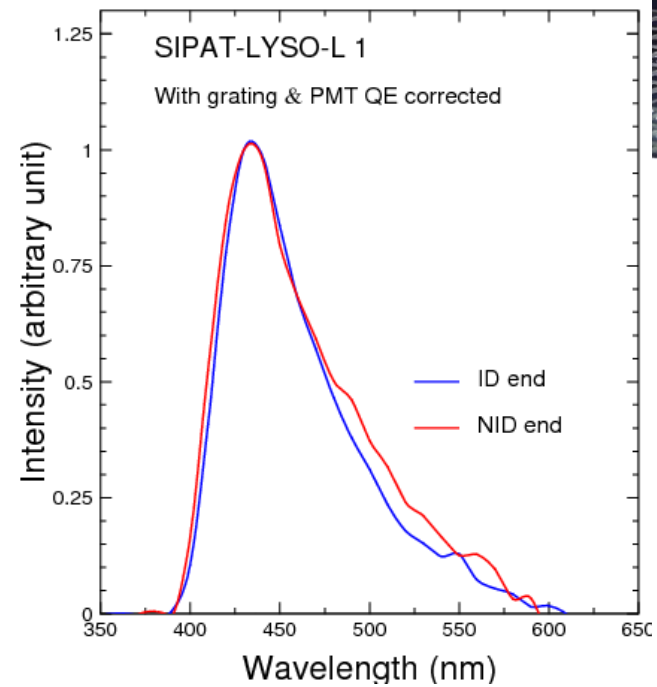
SIPAT-5: extra green component at the tail end

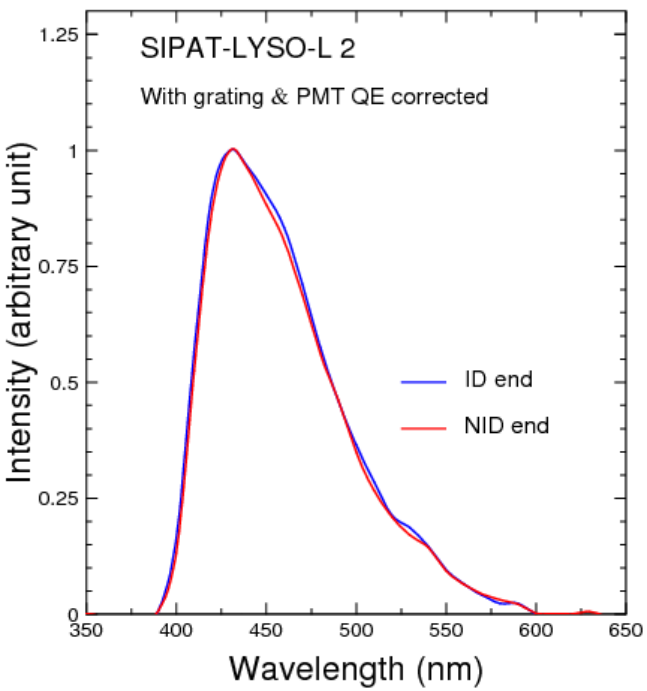


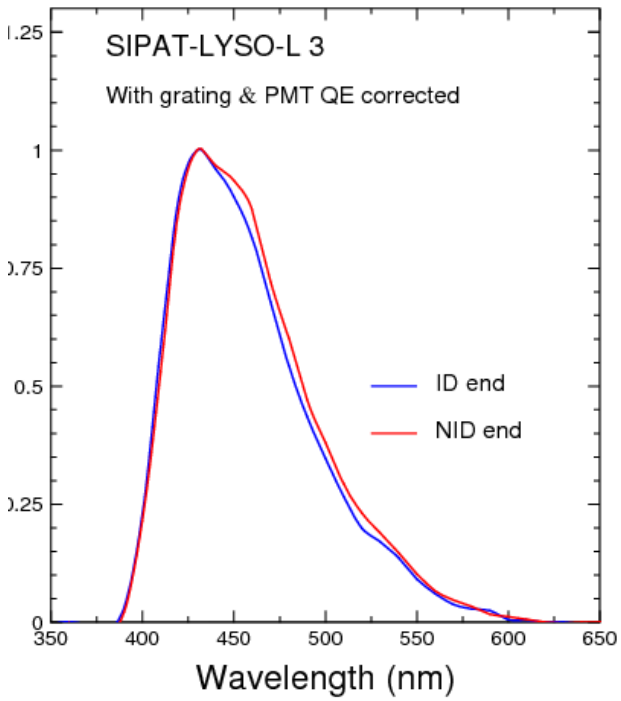


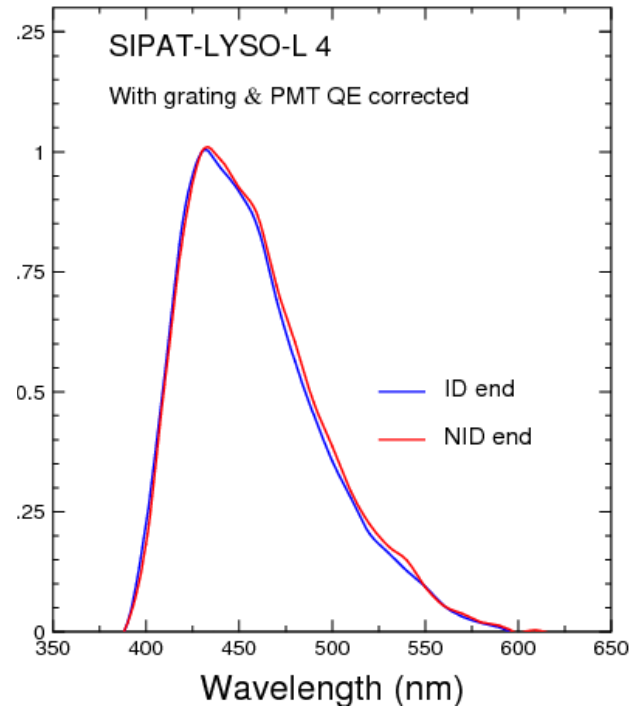
Radio-luminescence

SIPAT-LYSO-L1 also has more green component at the tail end, but not SIPAT-LYSO-L2, L3 and L4, indicating possible variations in the crystal growth processes.



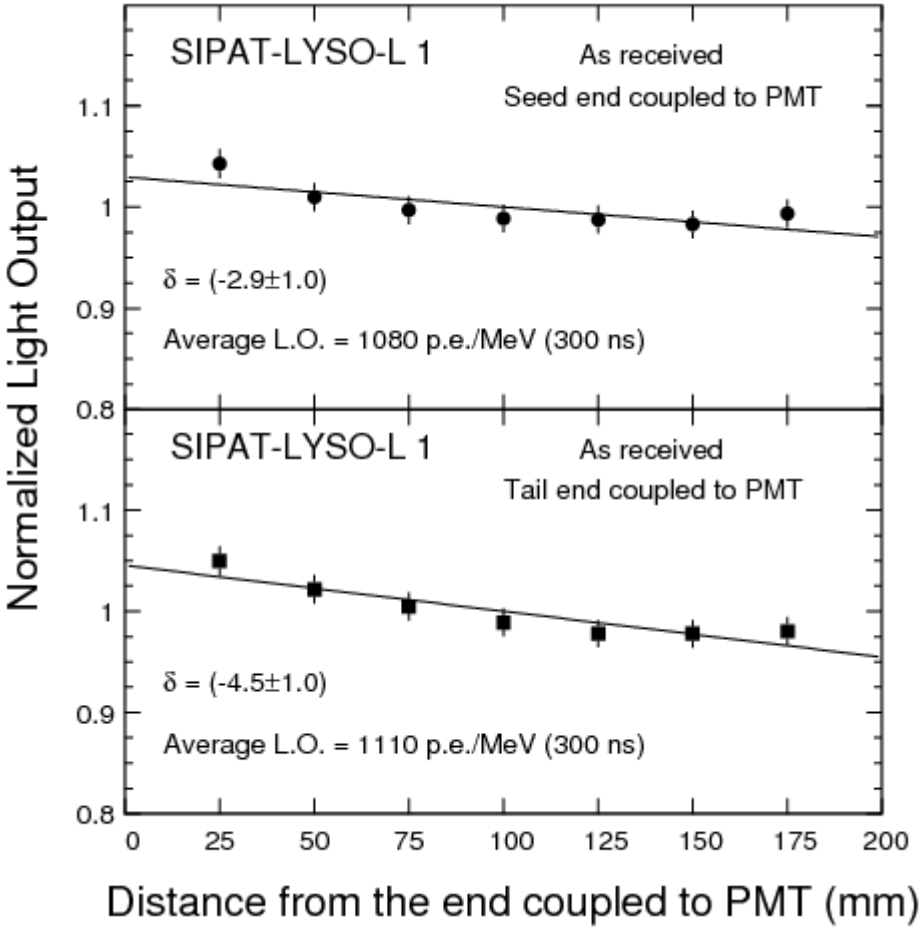


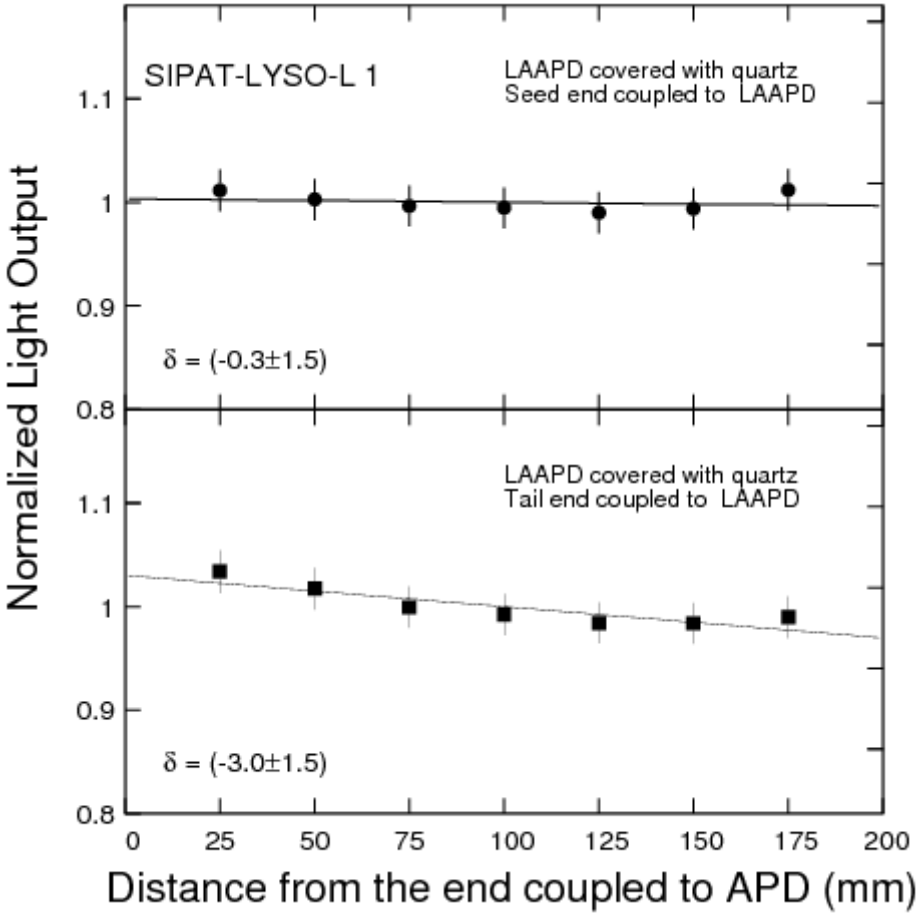




L.R.U. by PMT & LAAPD: SIPAT-LYSO-L1

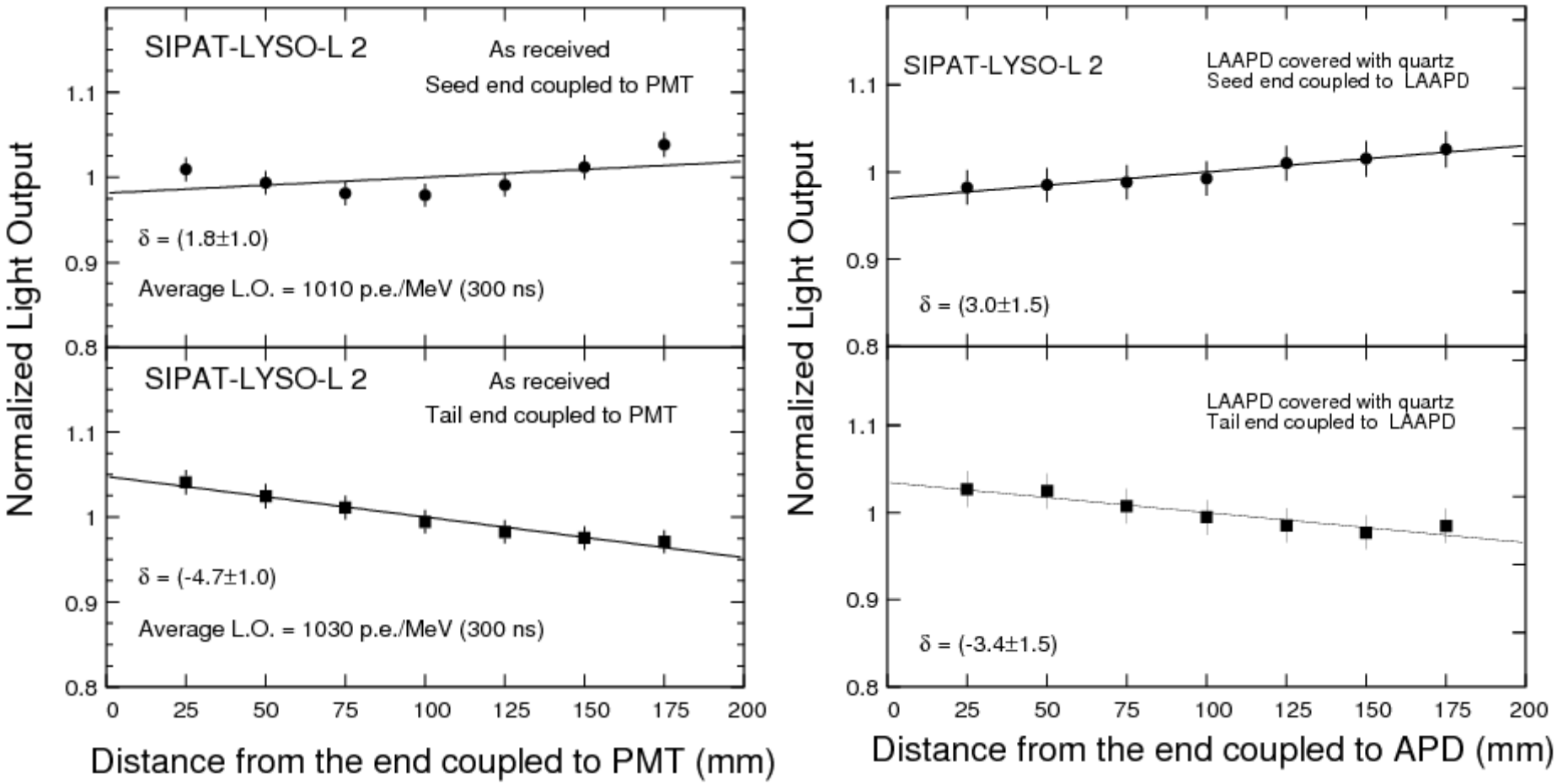
Difference observed between PMT & APD





L.R.U. by PMT & LAAPD: SIPAT-LYSO-L2

Consistent uniformities between PMT and APD
Some difference between two ends coupling



Summary of L.R.U. Data

Largest differences between PMT and APD readouts observed in SIPAT-LYSO-L5 and L1. This result consists with the RL deviation.

Sample	δ % (ID end coupling)		δ % (NID coupling)	
	PMT (±1)	APD (±1.5)	PMT (±1)	APD (±1.5)
SIPAT-1	-2.9	-0.3	-4.5	-3.0
SIPAT-2	1.8	3.0	-4.7	-3.4
SIPAT-5	-3.5	2.3	-4.1	-6.0
SIC-1	-0.9	-1.7	-2.9	1.7
SG-3	-0.9	-0.7	-4.8	-4.0
BGO	-0.4	-0.4	-0.1	0.0
SIPAT-5 (Mask)	-2.7	-	-3.8	-

GDMS Results for SIPAT-5 & SIC-1

No obvious contamination found in both SIC-1 and SIPAT-5
The sum of impurities seems larger for SIPAT-5

ID	Na*	Mg*	Al*	P*	S*	Cl*	K*	Ca*	Fe*	Yb*	Re#	Tm$	Other&
SIC-1(seed)	1.3	2.4	2.0	0.6	4.0	12	2.8	12	2.3	3.7	3.9	3.8	35.2
SIC-1(tail)	1.1	0.7	3.5	1.1	3.0	8.0	2.8	17	2.1	4.3	4.6	5.0	37.3
SIPAT-5(seed)	6.8	1.0	6.0	0.8	5.5	20	3.3	6.0	1.2	3.0	4.2	3.1	49.5
SIPAT-5(Tail)	4.5	0.8	7.6	1.5	10	15	2.0	8.0	1.0	3.0	4.1	2.6	49.5
Cubic-A	4.9	13	20	0.7	10	13	1.6	4.5	0.9	11	13.4	2.7	67.8
Cubic-6	3.5	1.3	8.5	0.7	12	16	2.5	5.5	1.8	3.5	6.5	3.8	50.1
SG-29	0.7	0.2	1.2	2.0	1.3	5.5	0.7	11	0.8	11	12.2	1.8	22.7

***: with concentration higher than 1 ppmw;**
 # :Sum of earth elements;
$: Sum of transition metals;
&: Sum of elements except Re, Tm, matrix and doping.

Summary

- A difference between the L.R.U. measured by PMT and APD readouts was found for the sample SIPAT-LYSO-L5, which is not caused by detector coverage, cerium segregation or self-absorption.
- An excess green component was observed in the radio-luminescence spectrum at the tail end of SIPAT-LYSO-L5 and L1, which affects the L.R.U.
- The result of GDMS analysis is not conclusive in identifying any particular responsible impurity. The issue seems growth process dependent.
- Further investigation is under way to optimize LYSO crystals produced in China.