A Further Study on Large Size LSO and LYSO Crystal Samples

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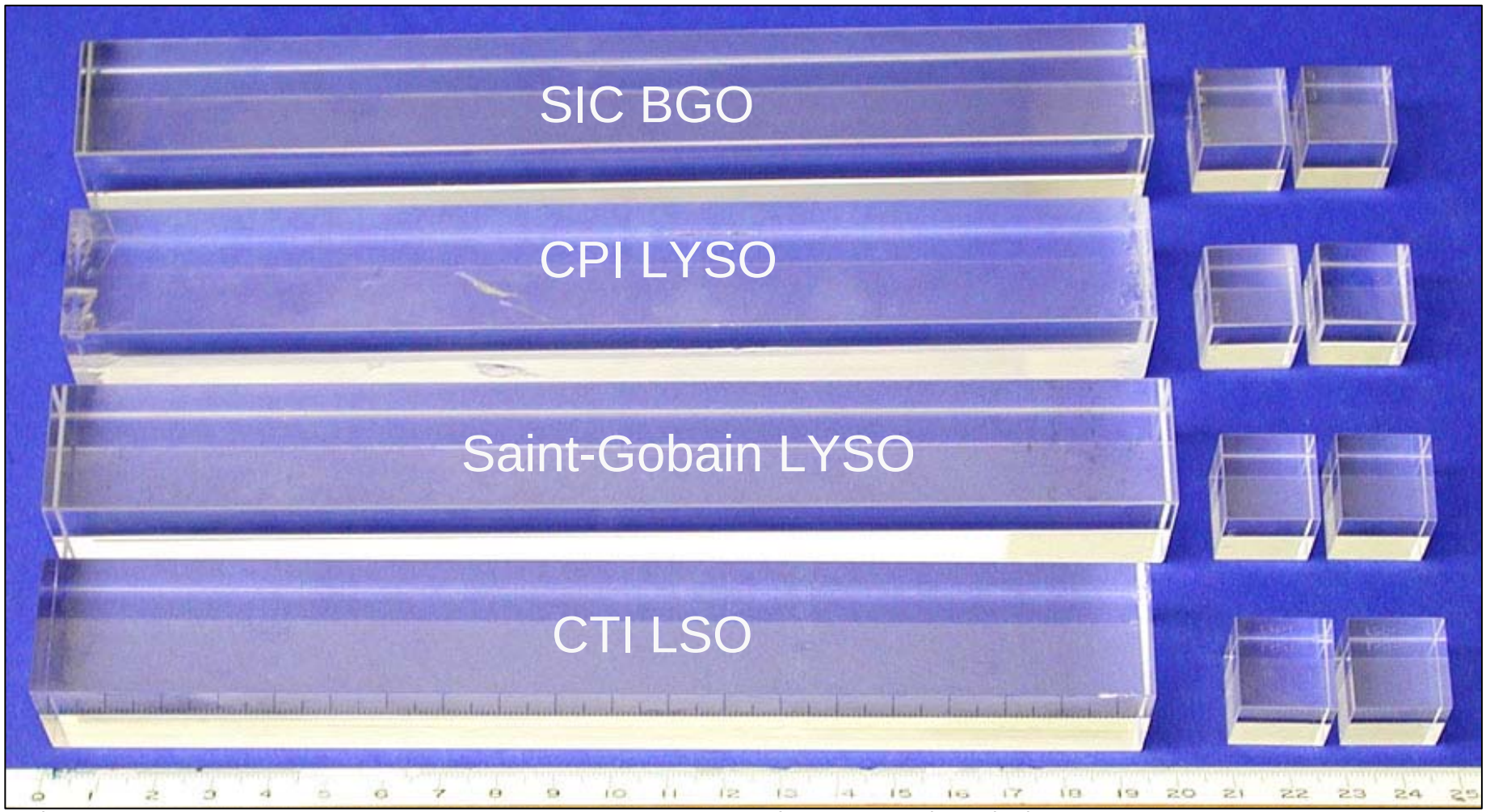
BGO, LSO & LYSO Samples

0.2--1% Ce in LSO/LYSO, 5--10% yttrium fraction in LYSO

Cube: 1.7 cm (1.5 X_0) , Bar: 2.5 x 2.5 x 20 cm (18 X_0)



Experiment

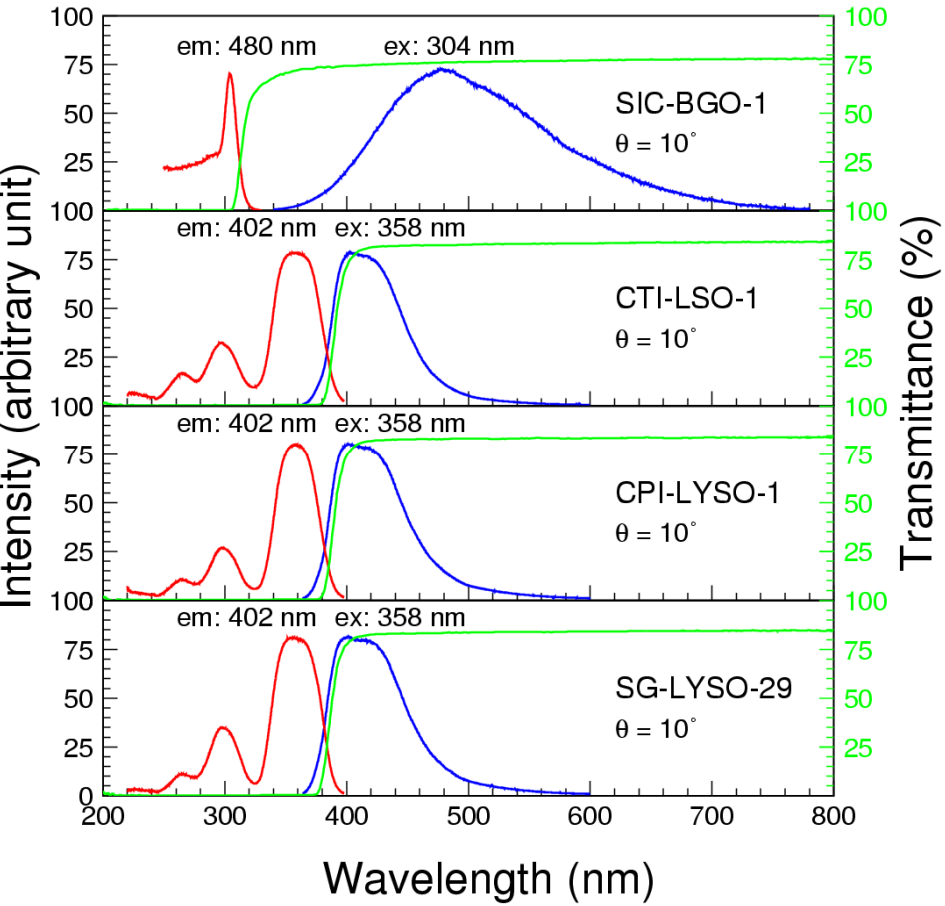
- Without any thermal treatment, all samples went through measurement for optical and scintillation properties.
- Optical properties measured: transmittance, emission and excitation spectra.
- Light output and light response uniformity were measured with PMT and Si APD readout.
- Radiation induced phosphorescence intensity was measured for two LYSO long samples under γ–ray irradiation, which was used to estimate readout noise with 100 ns gate.

Excitation, Emission & Transmittance

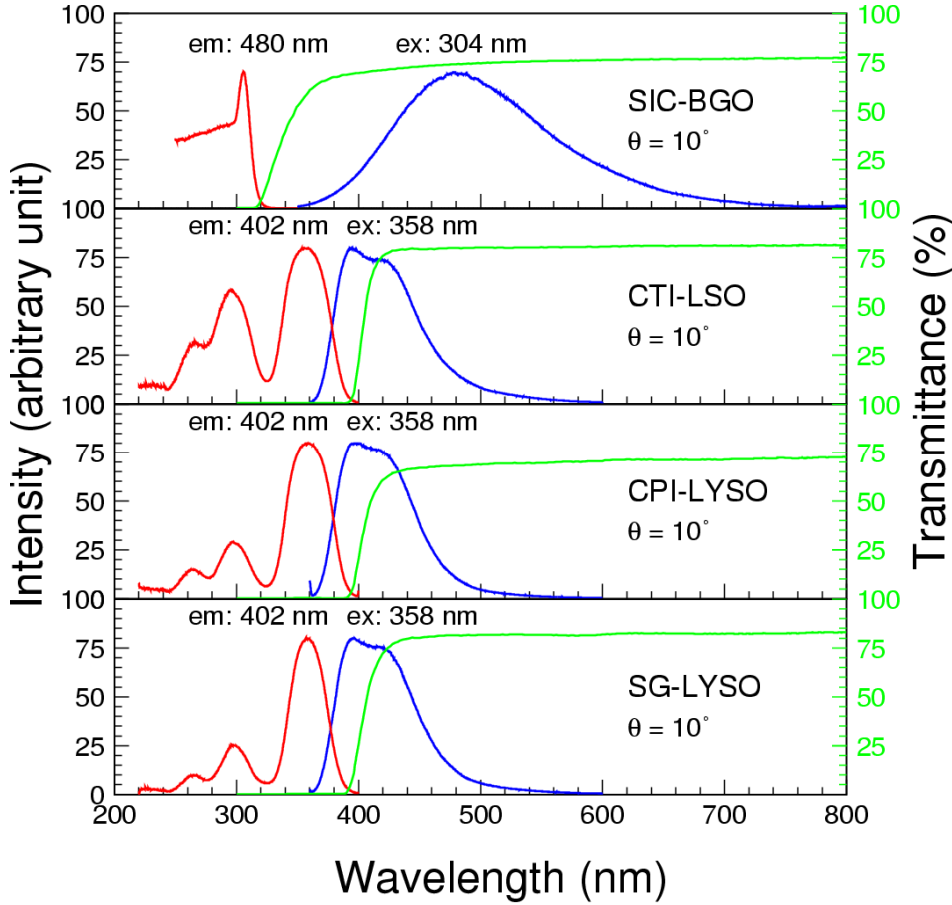
Identical transmittance, emission & excitation spectra

Part of emitted light is self-absorbed in long samples

1.7 cm Cube



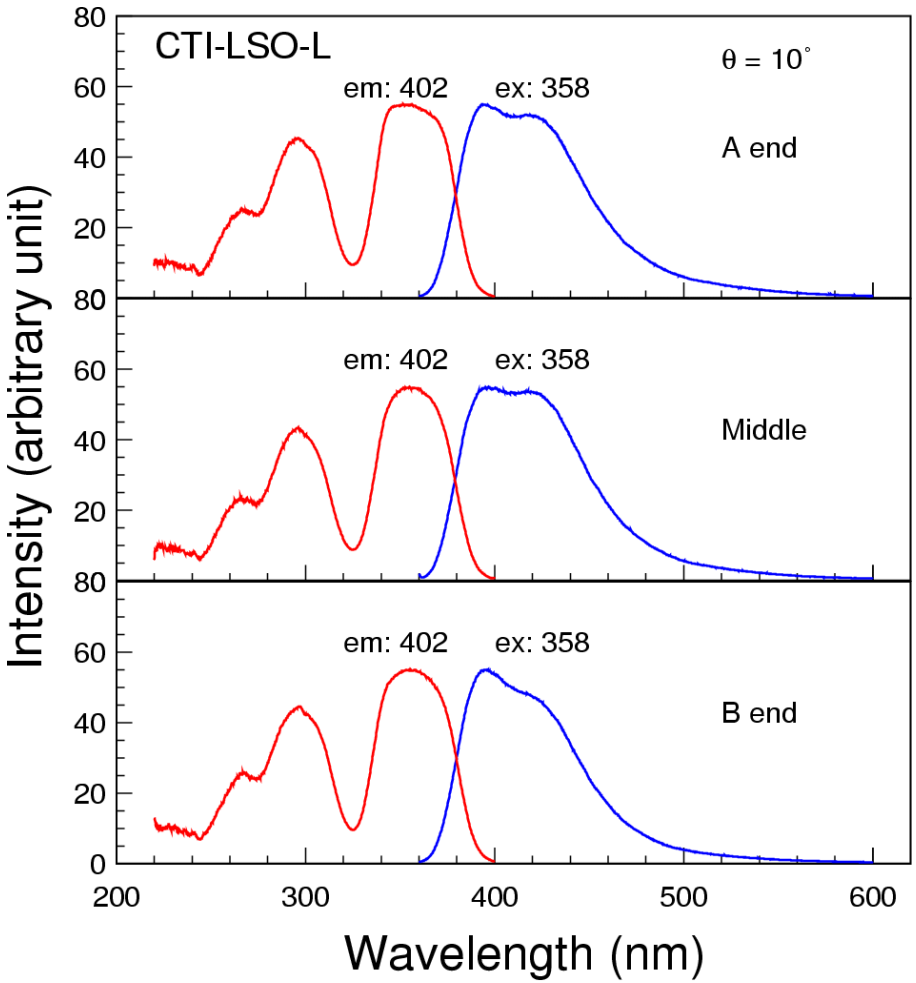
2.5 x 2.5 x 20 cm Bar

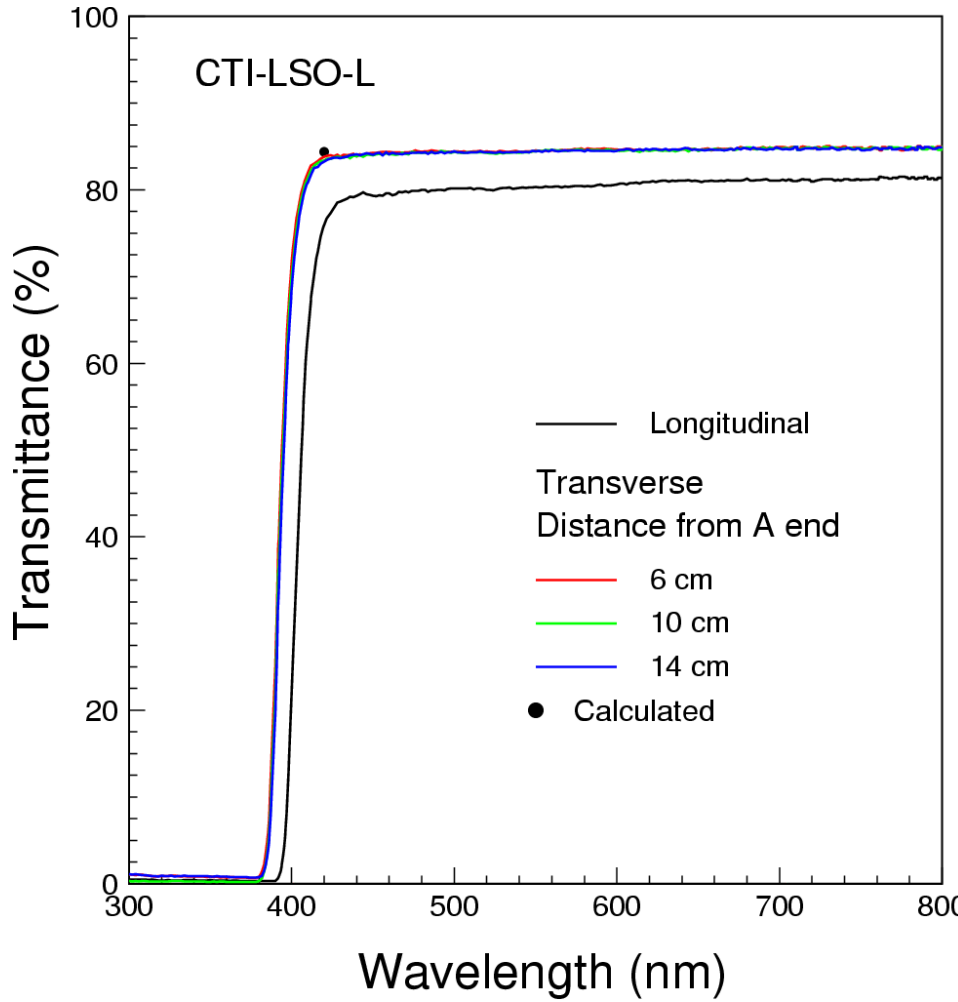


CTI LSO: longitudinal optical uniformity

No longitudinal variation in optical properties

Transverse transmittance approaches theoretical limit

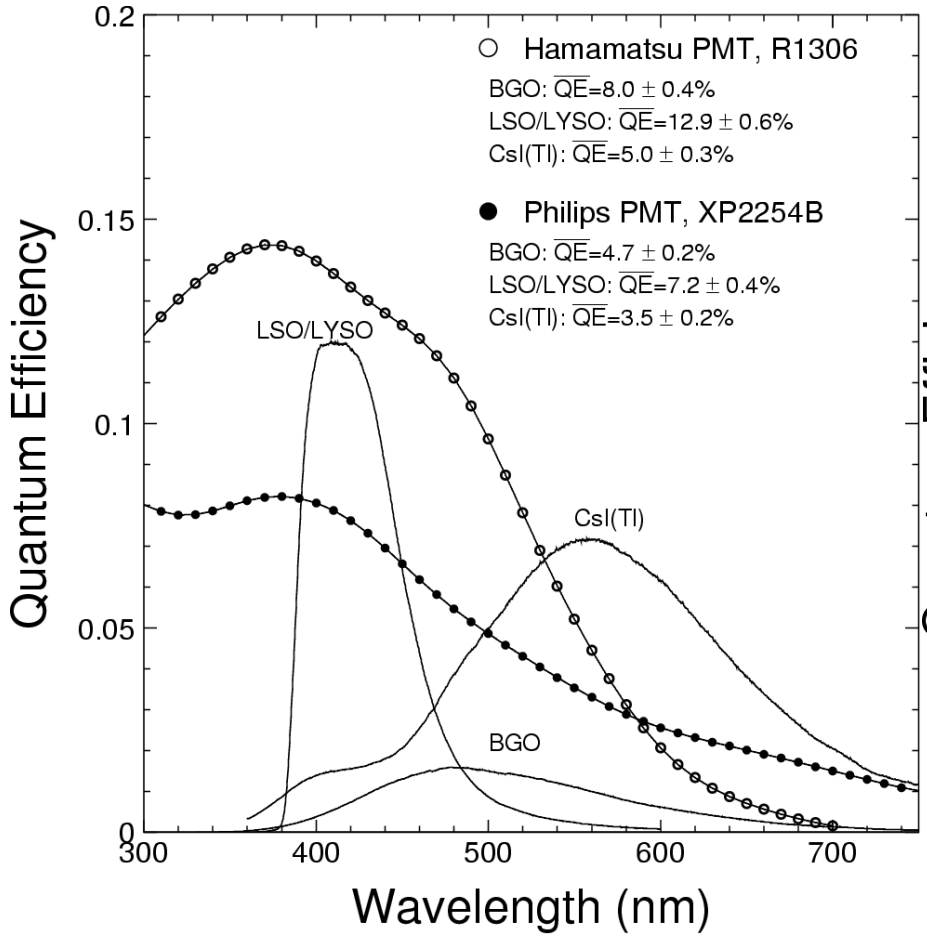


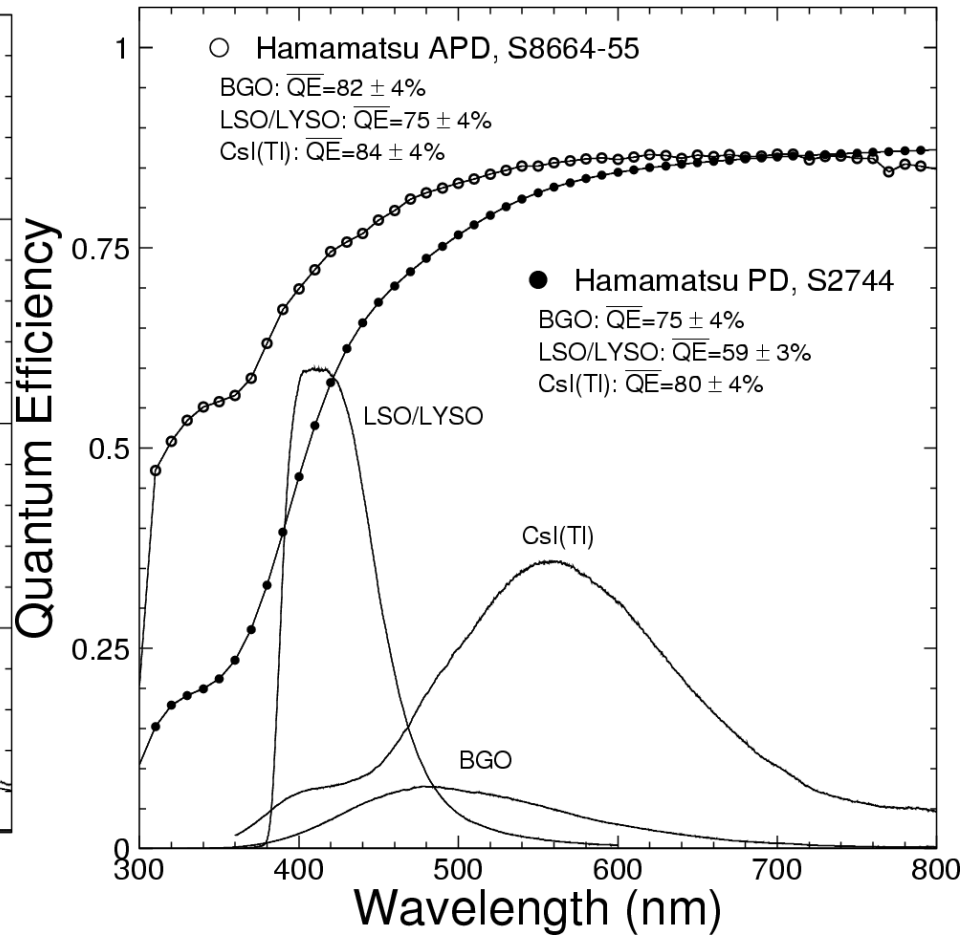


Emission Weighted Q.E.

Areas under emission spectra proportional to the LY

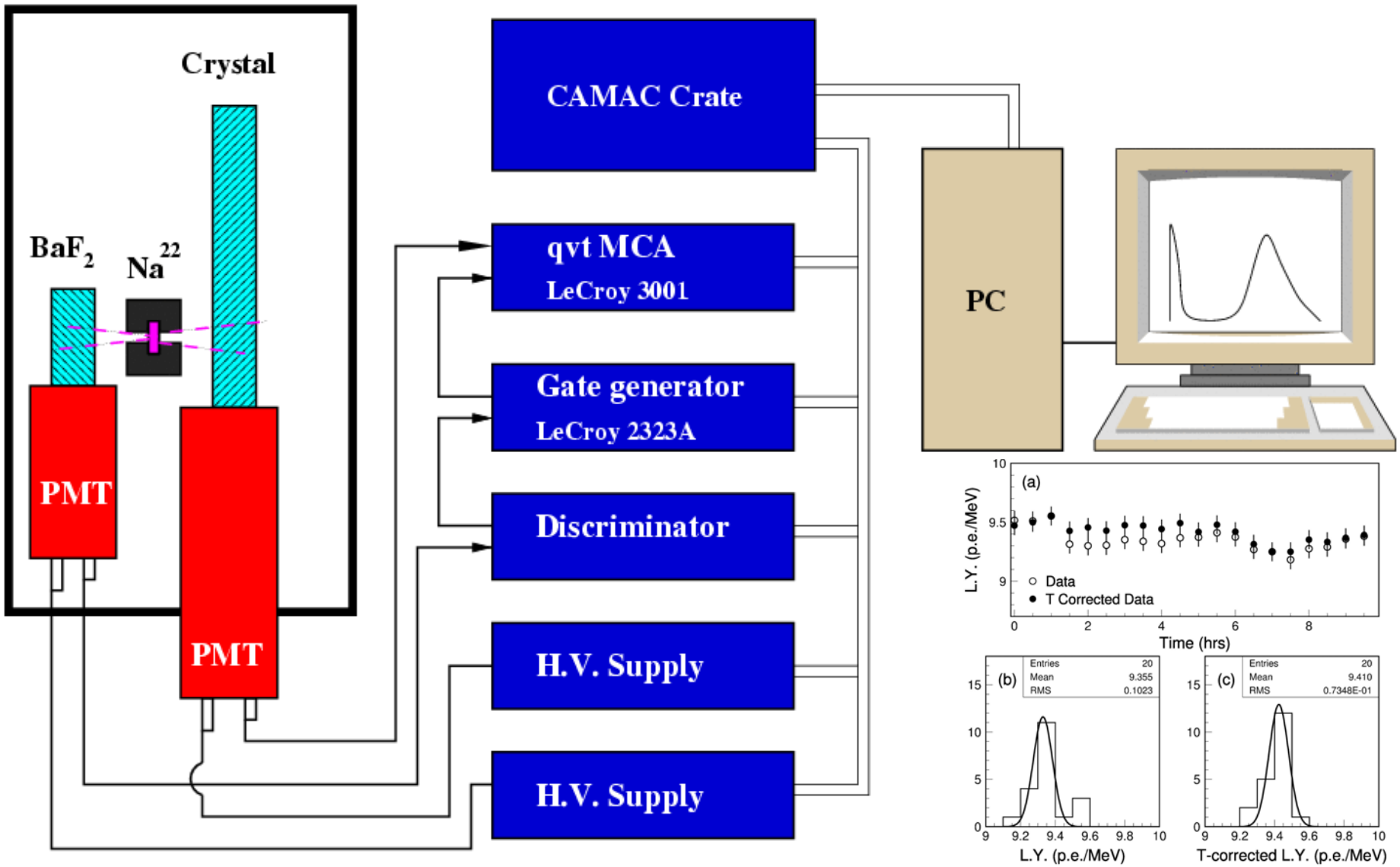
59%/75% QE for LSO/LYSO readout with Si PD/APD





PMT Based Readout with Coincidence

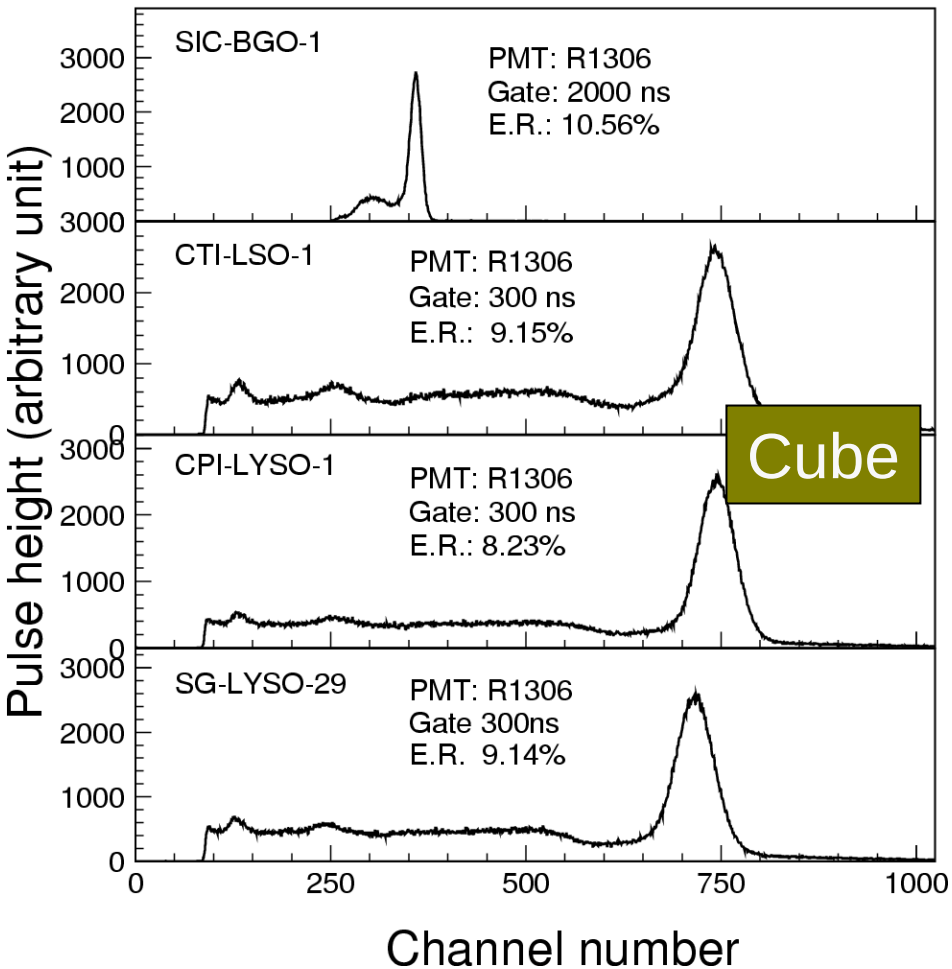
Systematic error with repeated mounts & measurements: **< 1%**

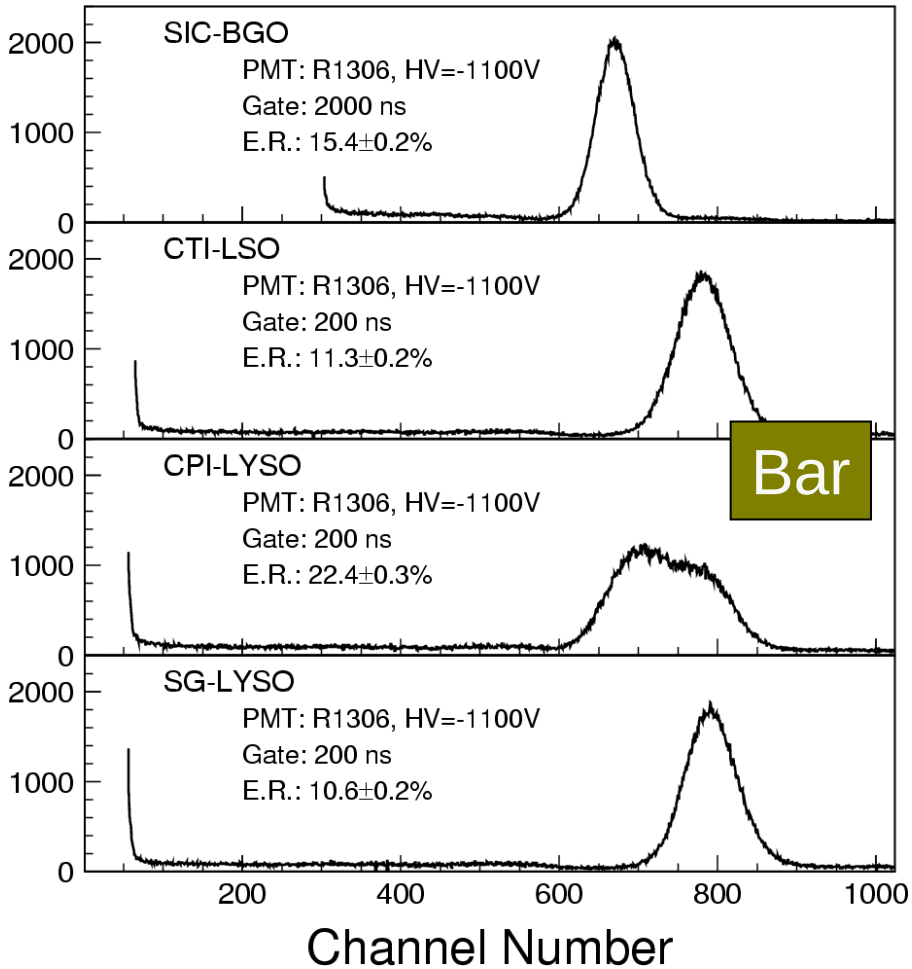


^{137}Cs & ^{22}Na Pulse Height Spectra

Cube and bar samples have 8% and 10% FWHM resolution respectively for ^{137}Cs (0.66 MeV) and ^{22}Na source (0.51 MeV)

CPI LYSO bar has double peak because of poor annealing

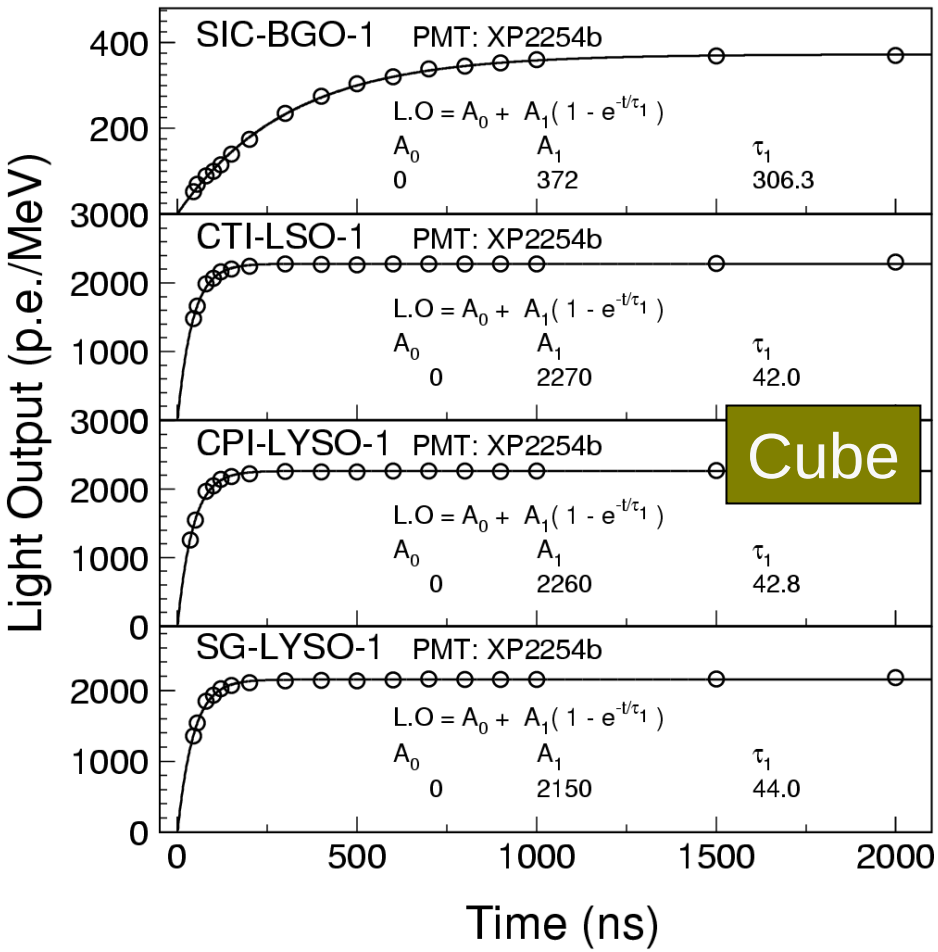


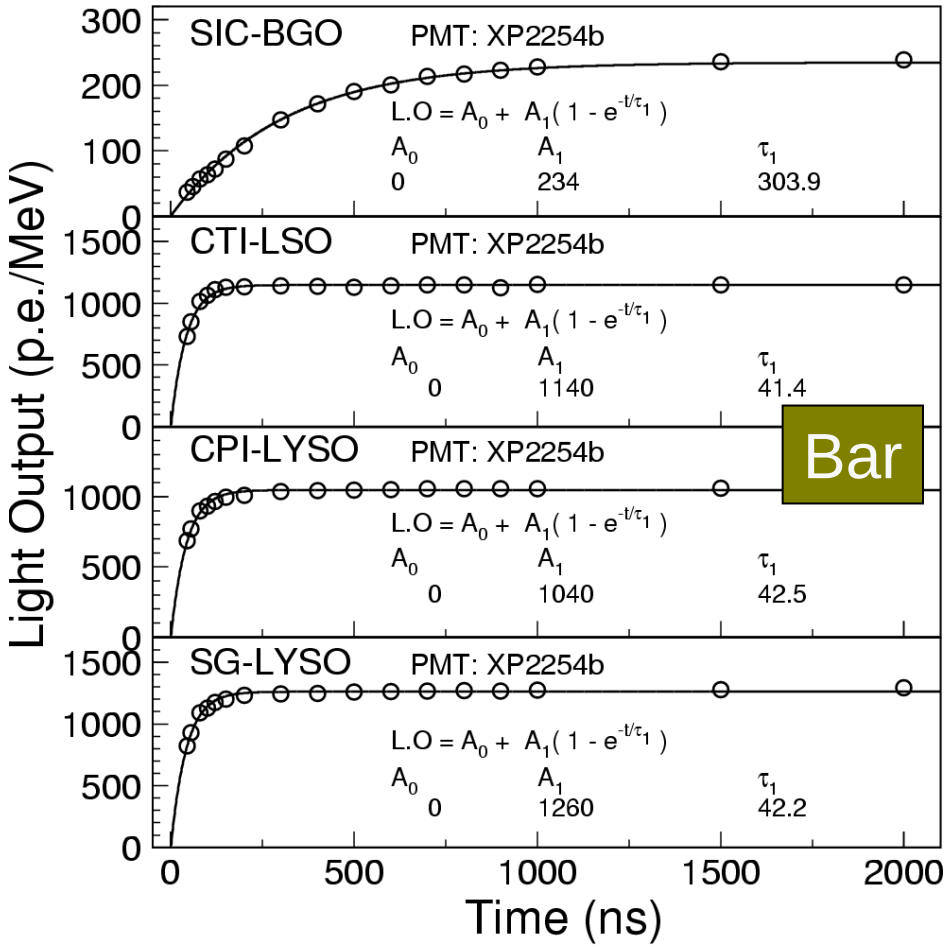


Light Output & Decay Time

LSO/LYSO Light yield: a factor of 4/100 of BGO/PWO

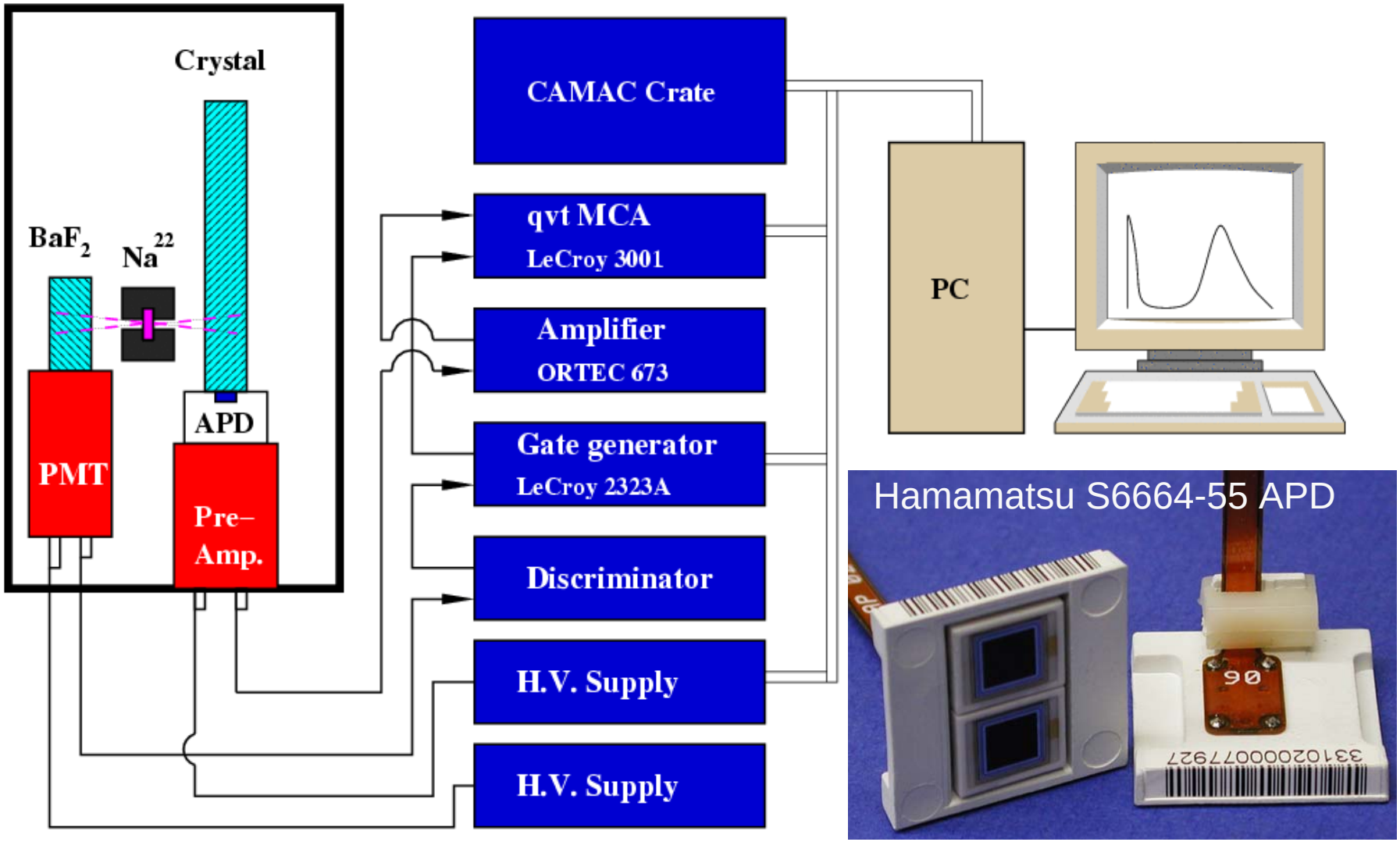
LSO/LYSO decay time: 42 ns compared to 300 ns of BGO





APD Based Readout with Coincidence

Two Hamamatsu S6664-55 APD, Canberra 2003 BT preamplifier and ORTEC 673 shaping amplifier with shaping time 250 ns

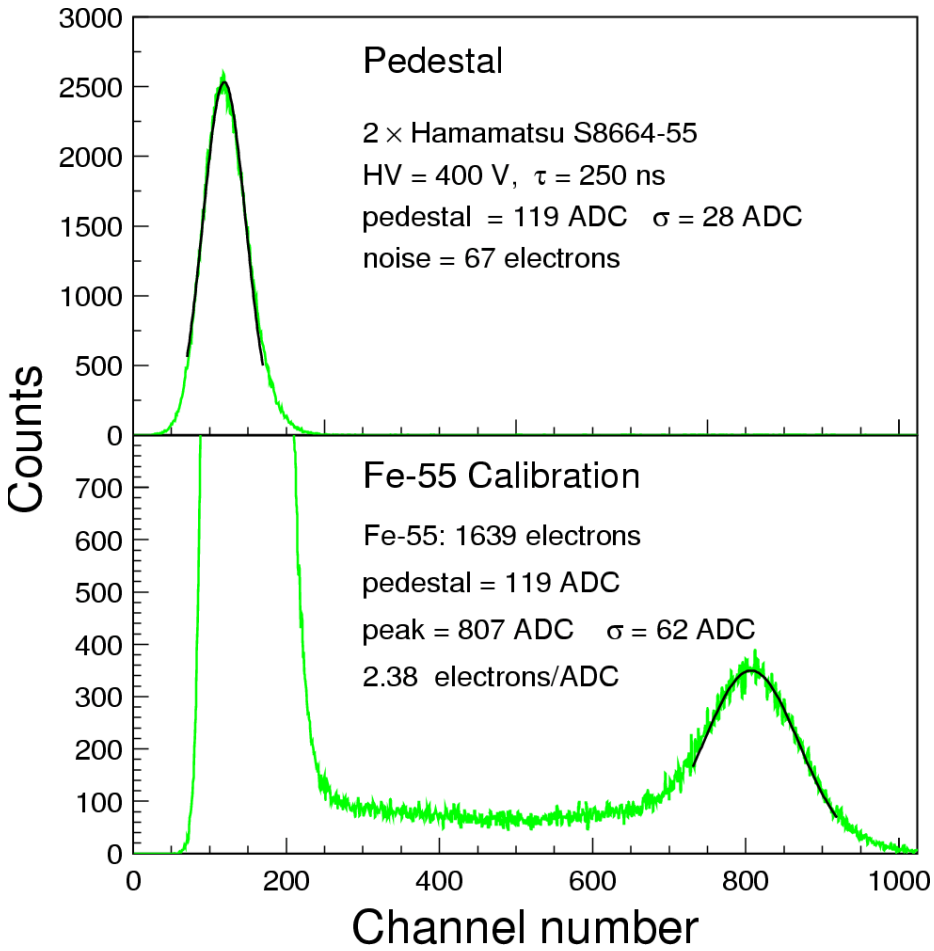


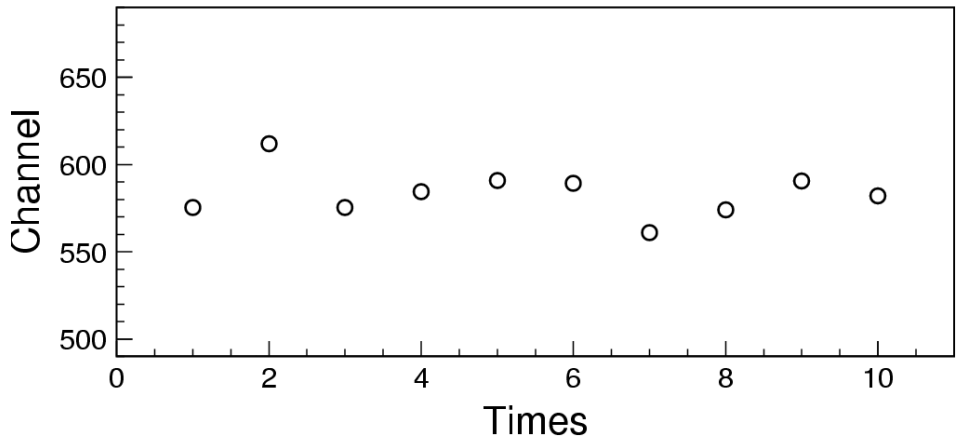
APD Readout Calibration

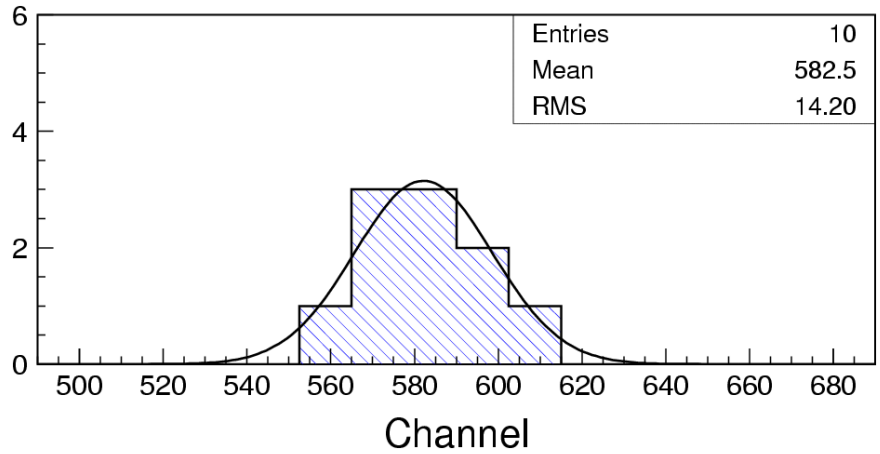
Readout noise: **67 electrons** for 2 APD with 250 ns shaping

Systematic error with repeated mountings & measurements: **2.4%**

Calibration with Fe-55 source: 2.38 electrons/ADC Channel

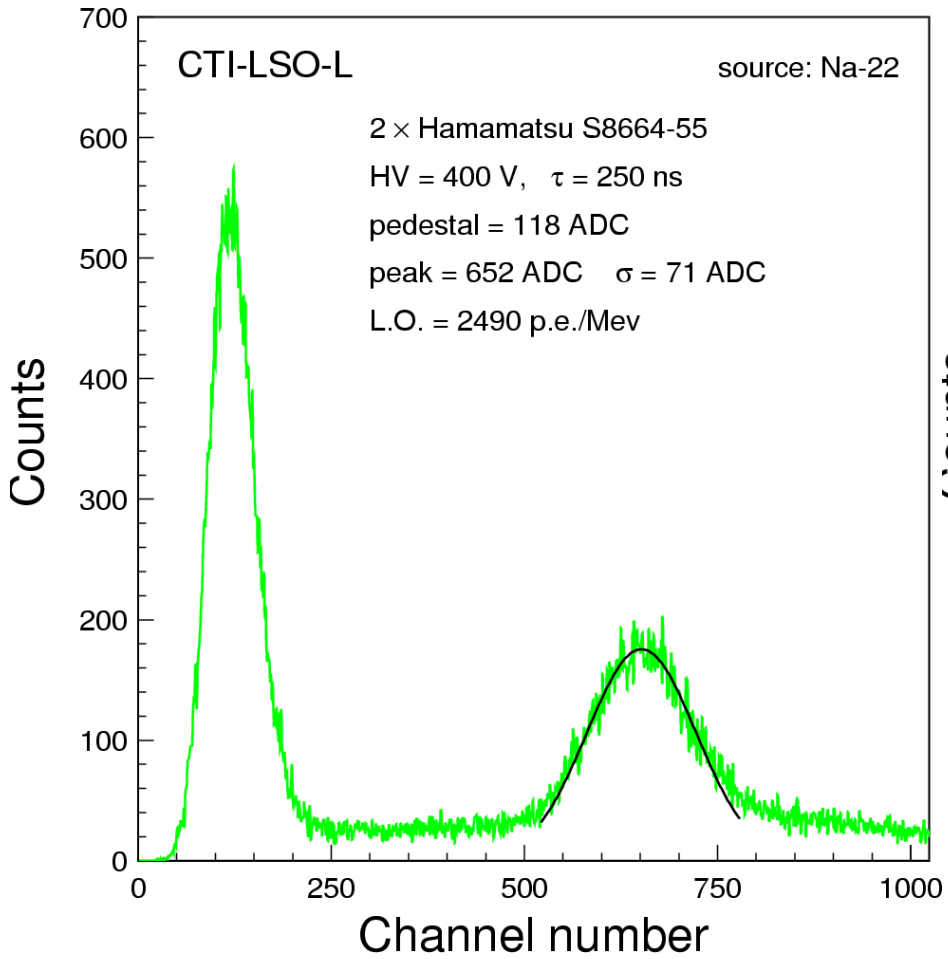


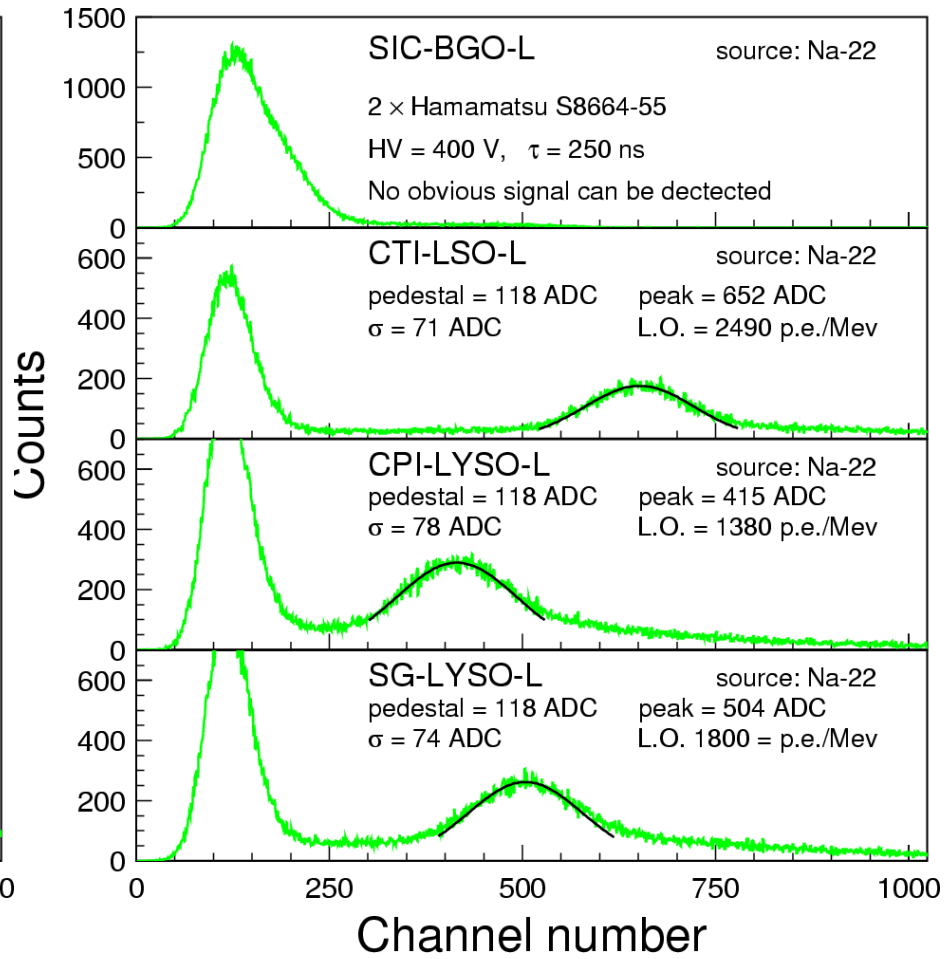




Pulse Height & Light Yield with APDs

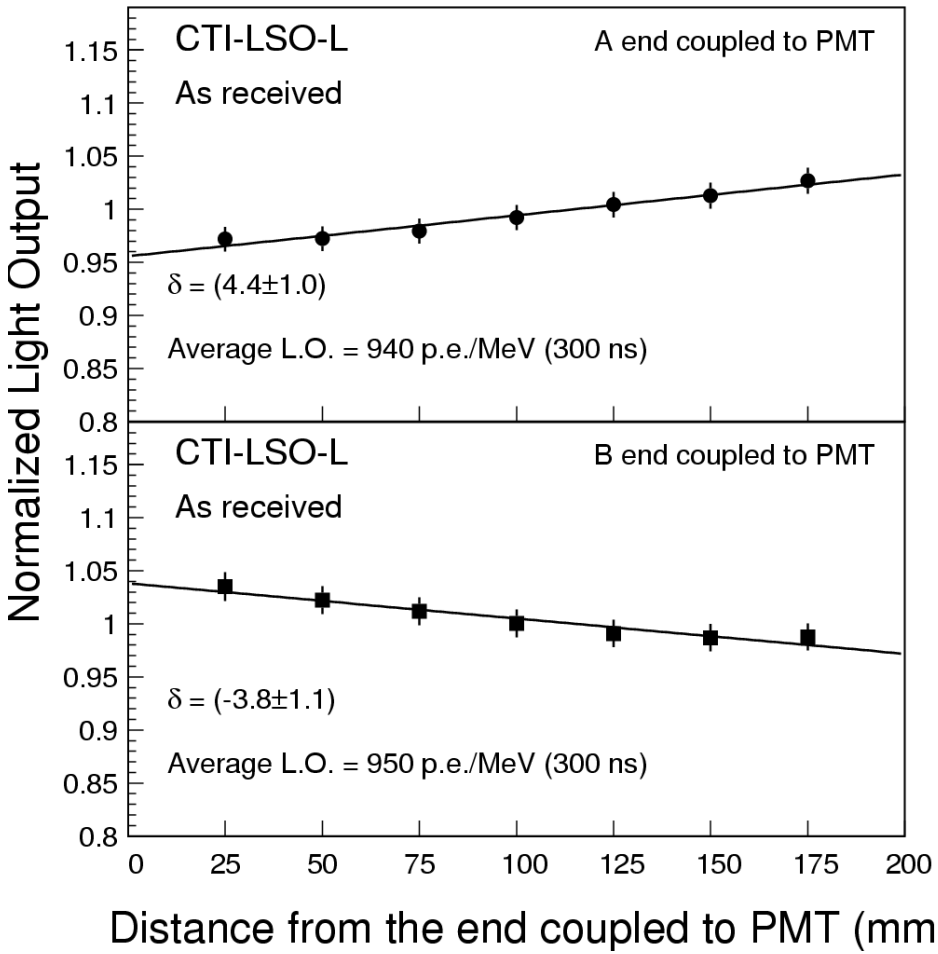
Na-22 annihilation peak (510 keV) well measured
CTI LSO sample has significantly higher LO

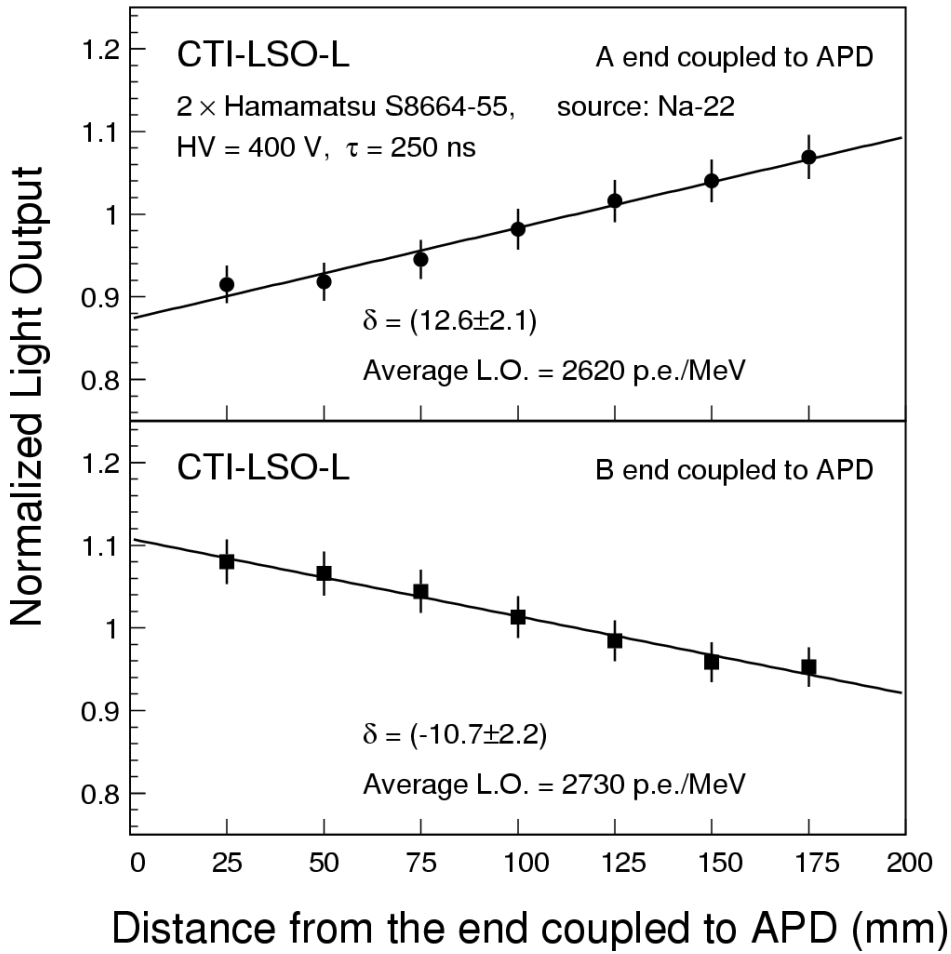




LSO Light Response Uniformity

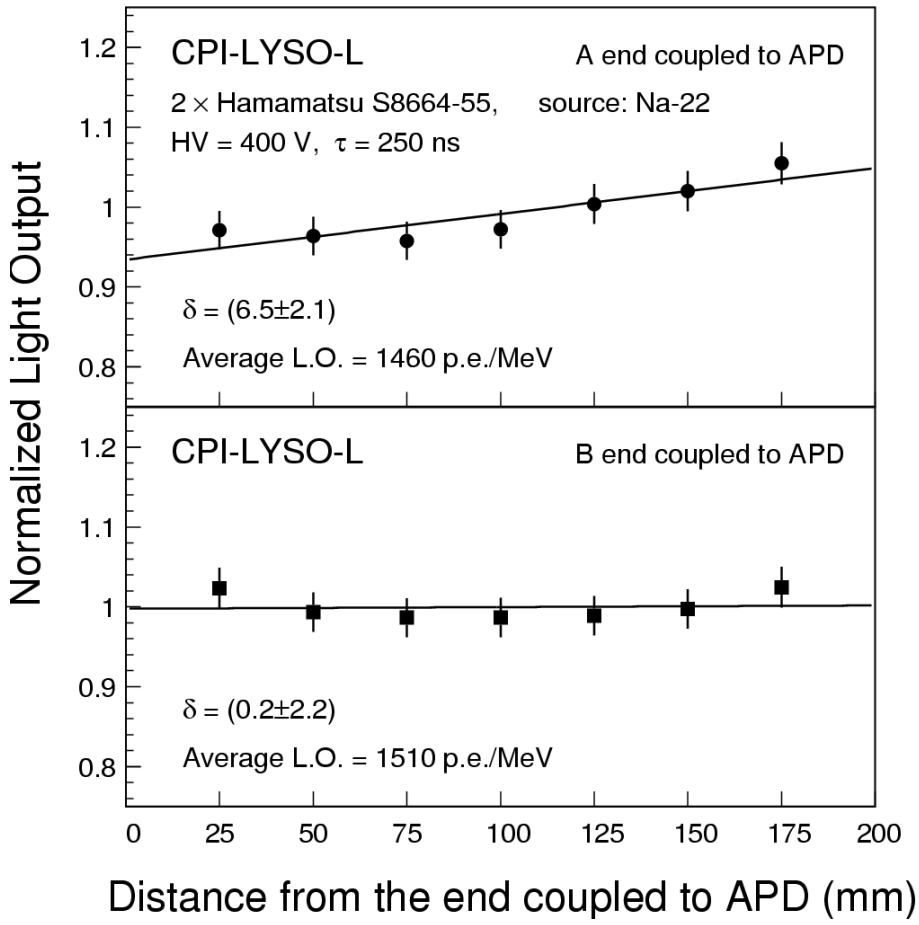
Uniformity depends on end coupled to the PMT/APD, indicating a not uniform light yield along crystal

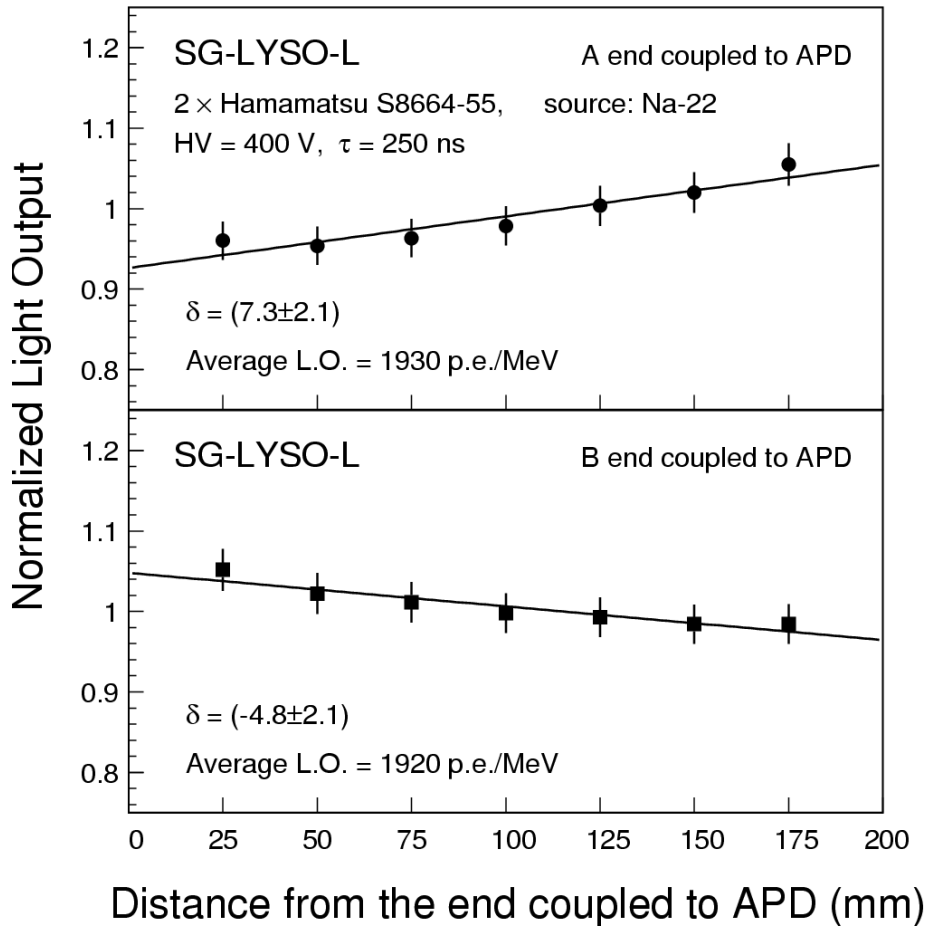




LYSO LRU Measured with APD

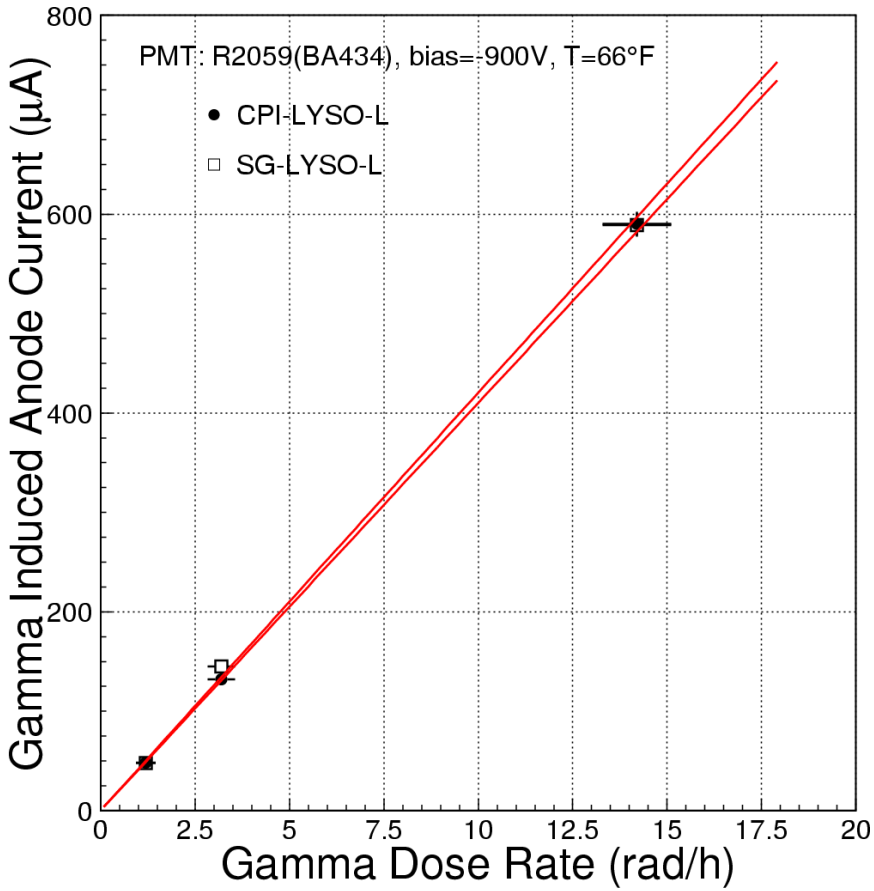
Uniformity depends on which end coupled to the APD, indicating a not uniform light yield along crystal





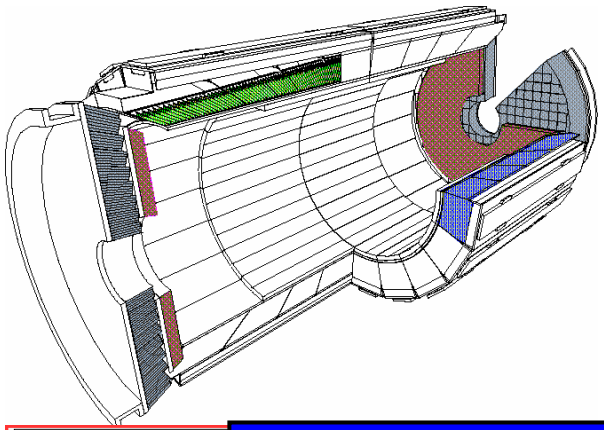
γ–ray Induced Readout Noise

Sample ID	L.Y. p.e./MeV	F μ A/rad/h	$Q_{15\ rad/h}$ p.e.	$Q_{500\ rad/h}$ p.e.	$\sigma_{15\ rad/h}$ MeV	$\sigma_{500\ rad/h}$ MeV
CPI	1,480	41	$6.98x10^4$	$2.33x10^6$	0.18	1.03
SG	1,580	42	$7.15x10^4$	$2.38x10^6$	0.17	0.97

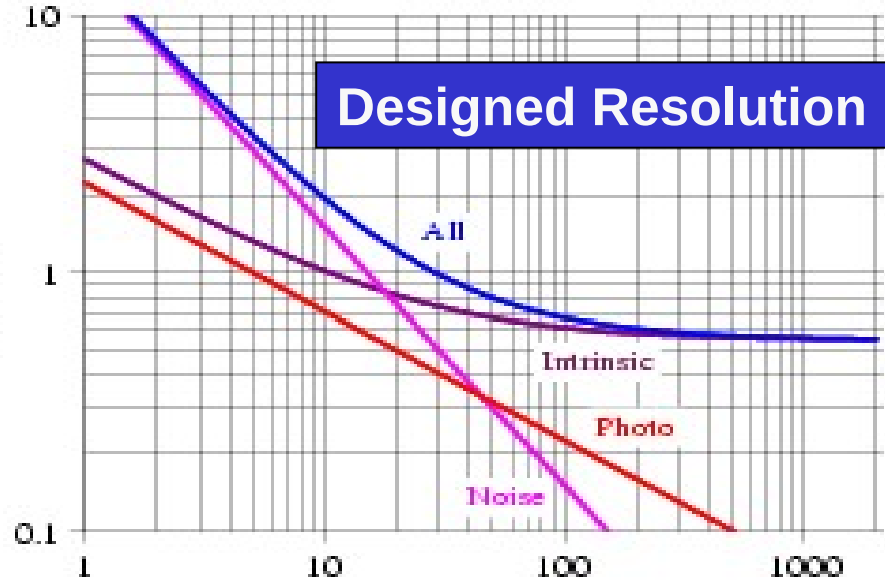


γ–ray induced PMT anode current can be converted to the photoelectron numbers (Q) integrated in 100 ns gate. Its statistical fluctuation contributes to the readout noise (σ).

CMS PWO Resolution



77k PWO

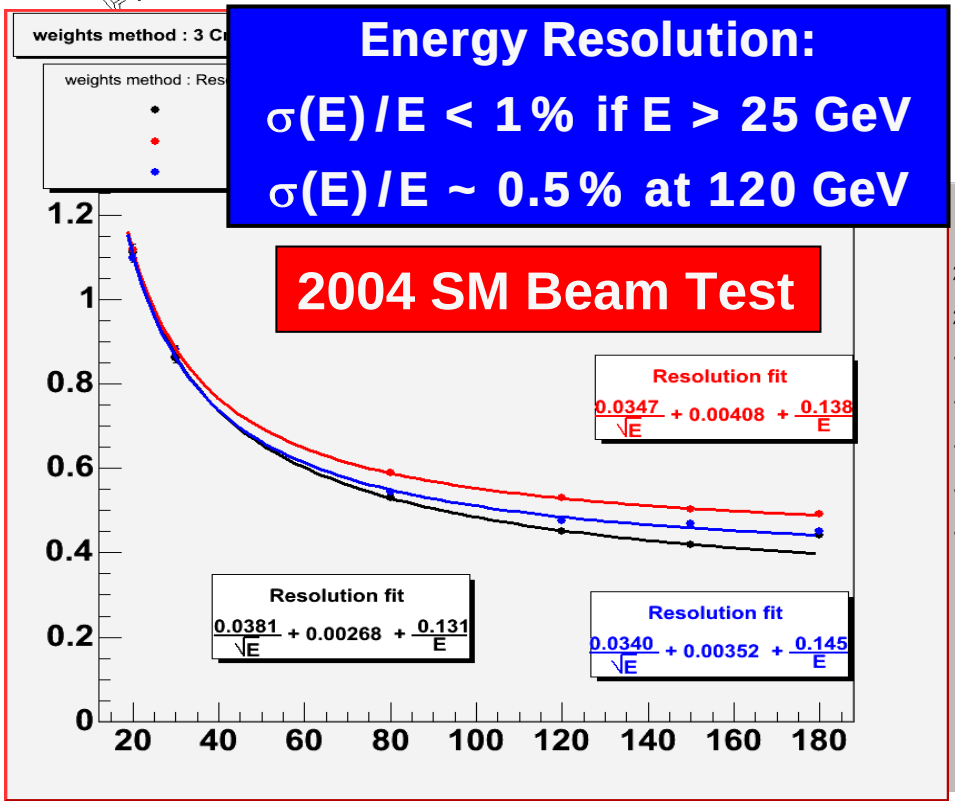


Energy Resolution:

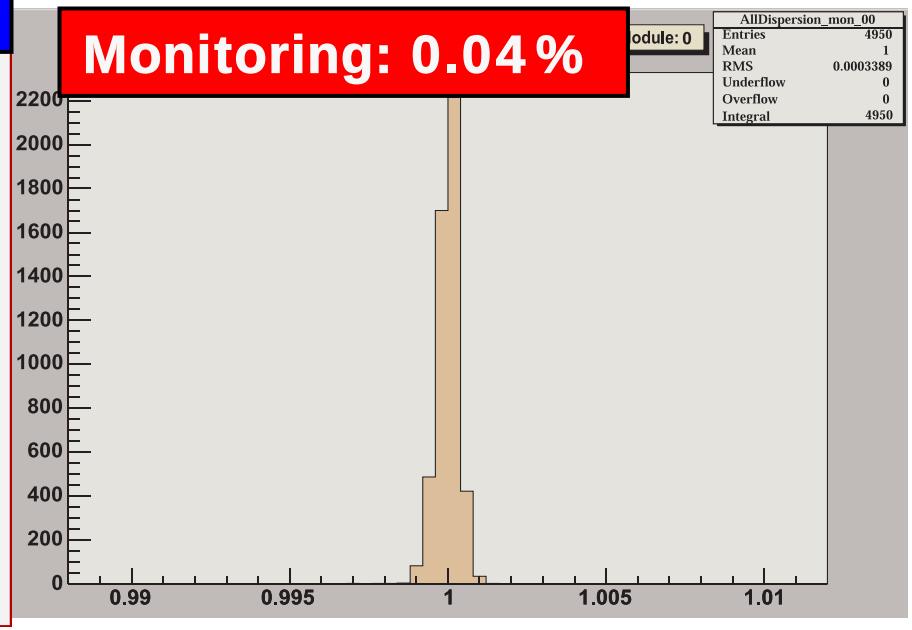
σ(E)/E < 1% if E > 25 GeV

σ(E)/E ~ 0.5% at 120 GeV

2004 SM Beam Test



Monitoring: 0.04%



LSO/LYSO ECAL Performance

- Less demanding to the environment because of small temperature coefficient.
- Radiation damage is less an issue as compared to the CMS PWO ECAL.
- A better energy resolution, $\sigma(E)/E$, at low energies than L3 BGO and CMS PWO because of its high light output and low readout noise:

$$2.0\%/\sqrt{E} \oplus 0.5\% \oplus .002/E$$

Summary

- Ce doped LSO & LYSO crystals have fast (42 ns) and high (4 X BGO) light output.
- The light output of 2.5 x 2.5 x 20 cm LSO and LYSO samples, excited by 0.51 MeV γ–ray, can be readout by Hamamatsu S8864-55 APD (2 x 0.25 cm^2) with electronic noise of 70 electrons (< 35 keV).
- Longitudinal light response uniformity of long LSO/LYSO samples seems affected by Ce distribution along crystal.
- The radiation induced phosphorescence in 2.5 x 2.5 x 20 cm LYSO causes ~0.2 MeV noise @ 15 rad/h.
- An LSO/LYSO crystal calorimeter would provide very good energy resolution down to MeV range for future HEP experiments.
- To be understood: why LSO long sample has higher LO as compared to long LYSO samples with APD readout.

Possible Origin of Non Uniformity

C. Melcher: LO in LSO is a function of Ce concentration

B. Chai: LO in LYSO is a function of atomic fraction of Yttrium