Results of LYSO Crystals from Eight Vendors

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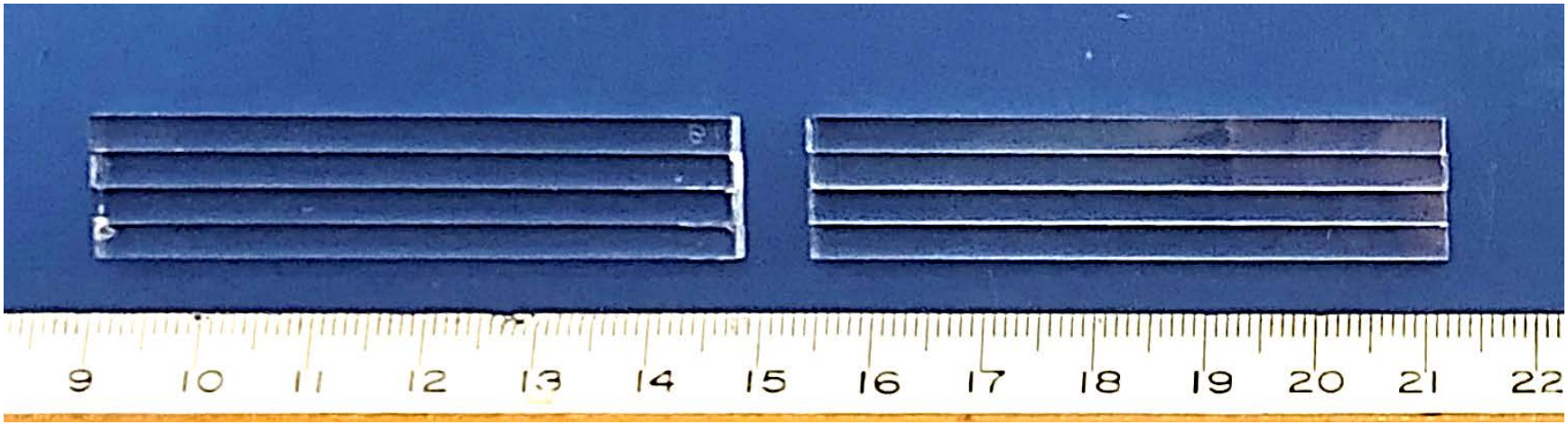
LYSO Bars from Eight Vendors



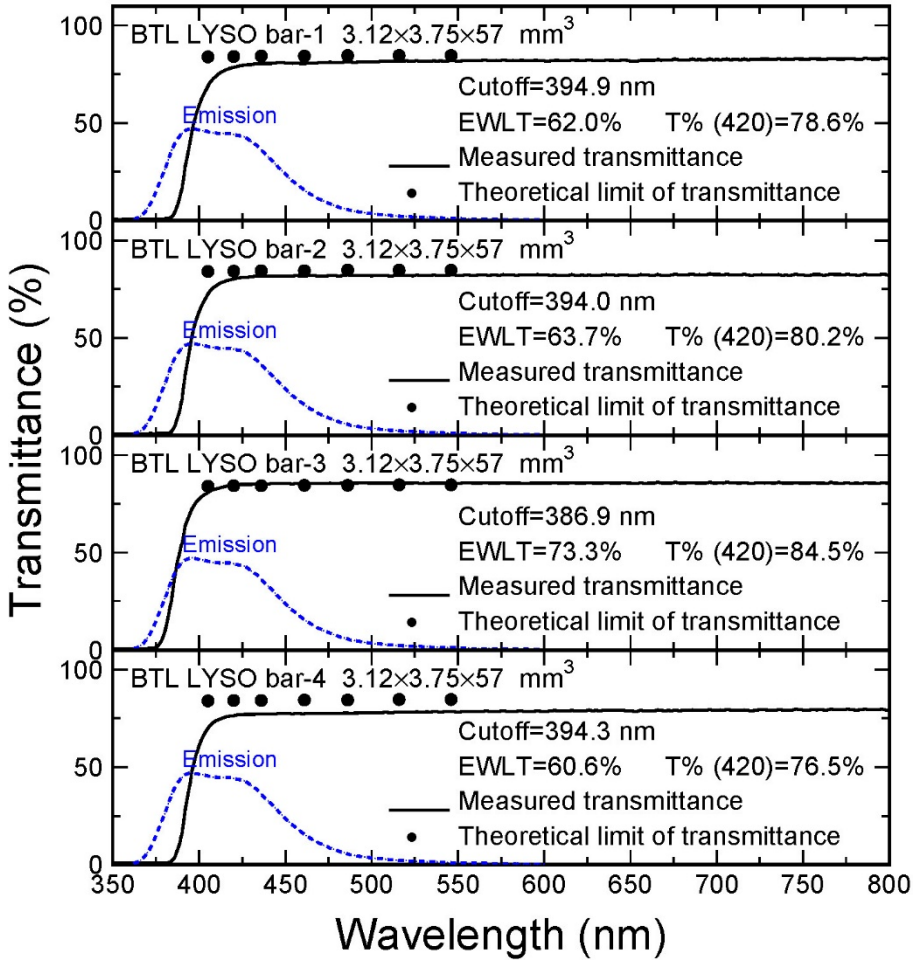
ID	Dimension (mm^3)	#	Polishing
BTL LYSO bar-1,8	3.12x3.75x57	8	All faces
Received on Dec 4th, 2019. Poor surface quality observed for some samples			

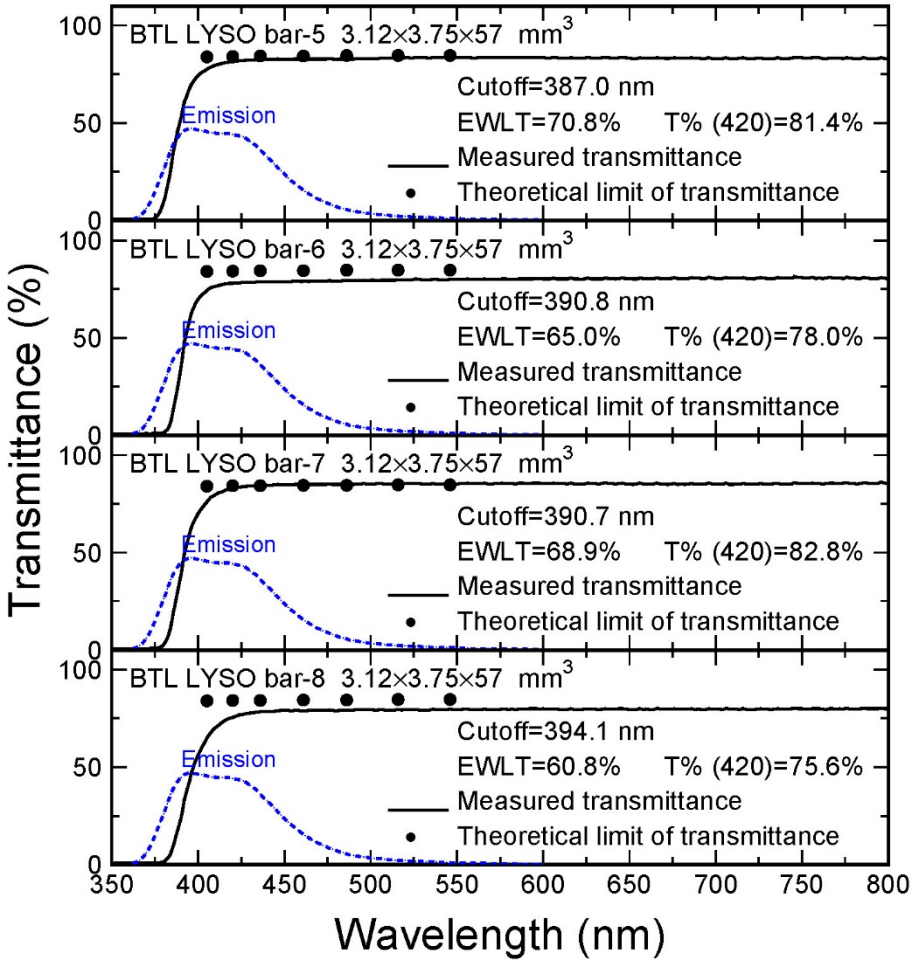
Experiments

- Properties measured at room temperature : LT, PHS, LO, ER, Decay time & CTR

Longitudinal Transmittance

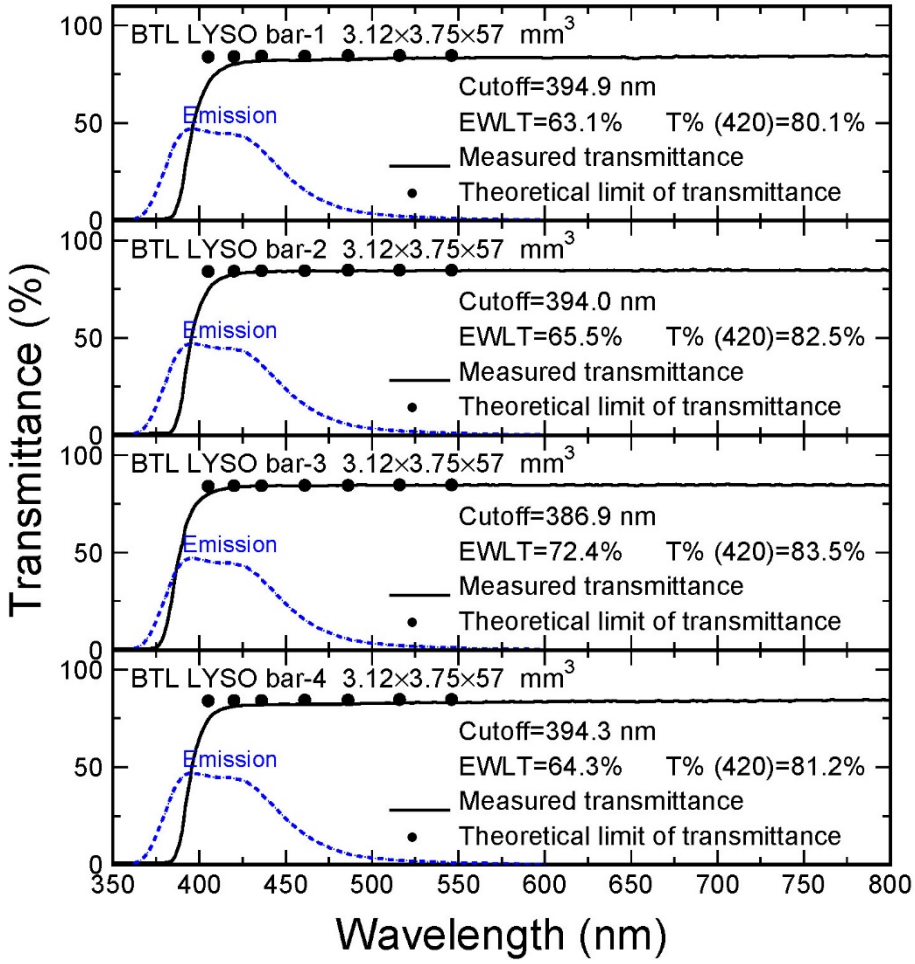
Transmittance affected by surface: correction using T @ 800 nm

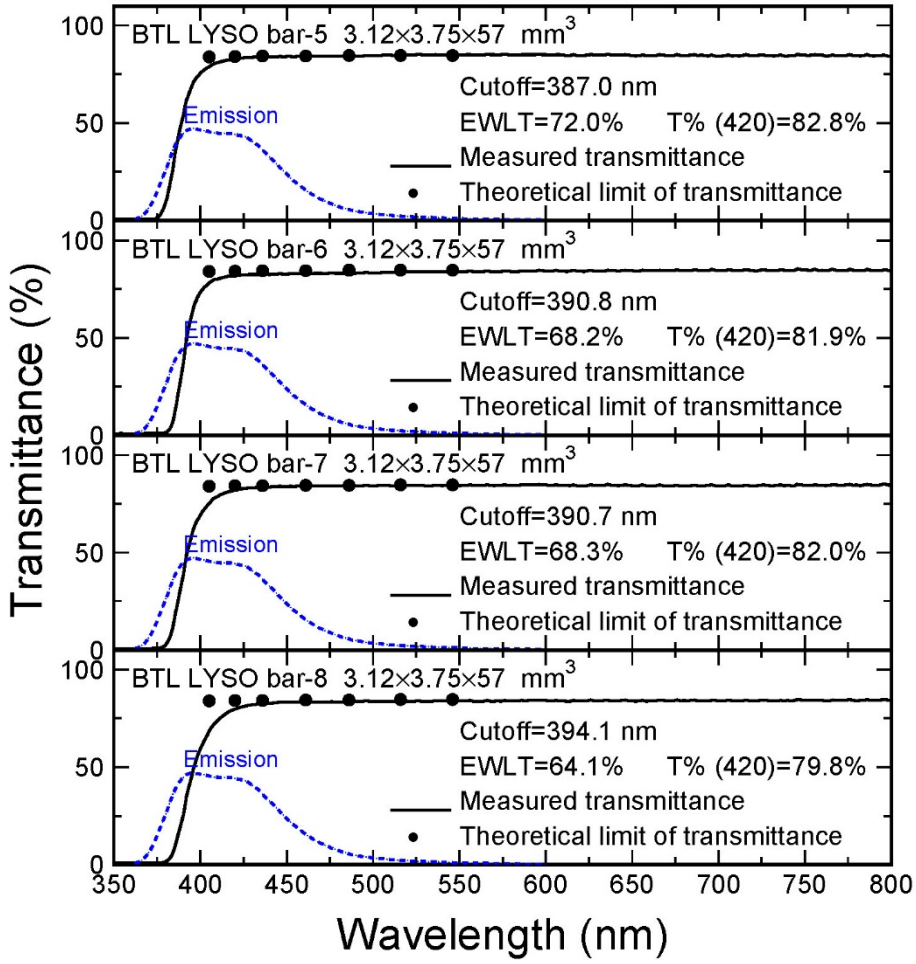




Transmittance after Correction

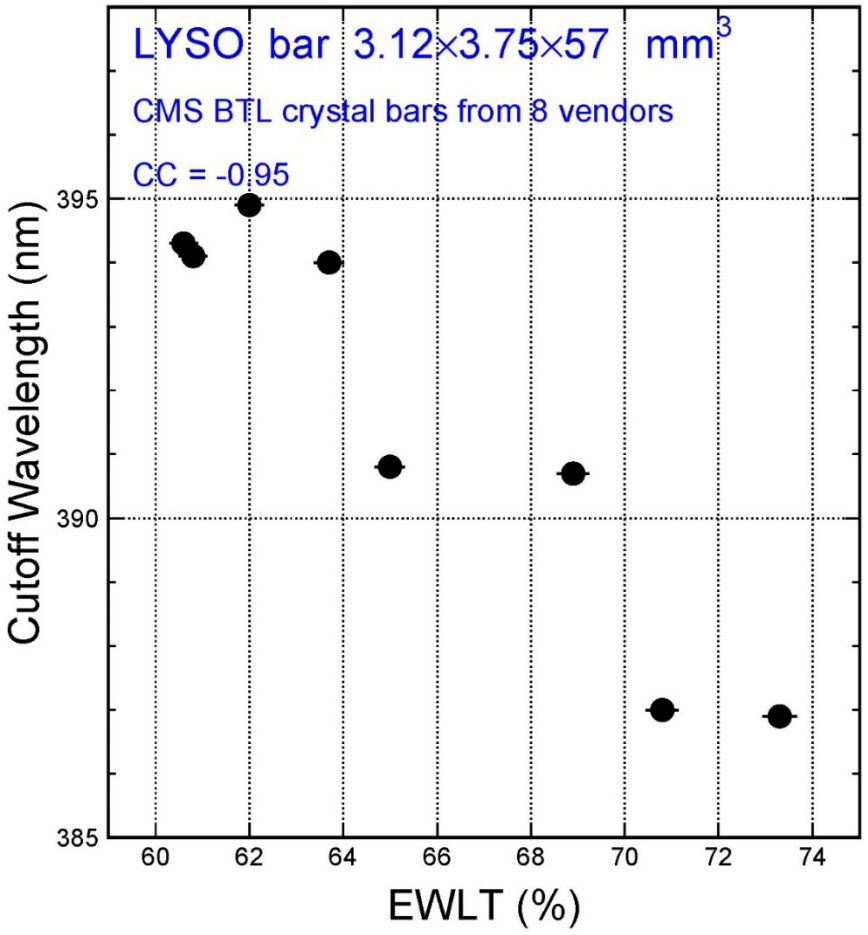
Sample 3 and 5 show the best transmittance
Sample 4 and 8 show the worst transmittance



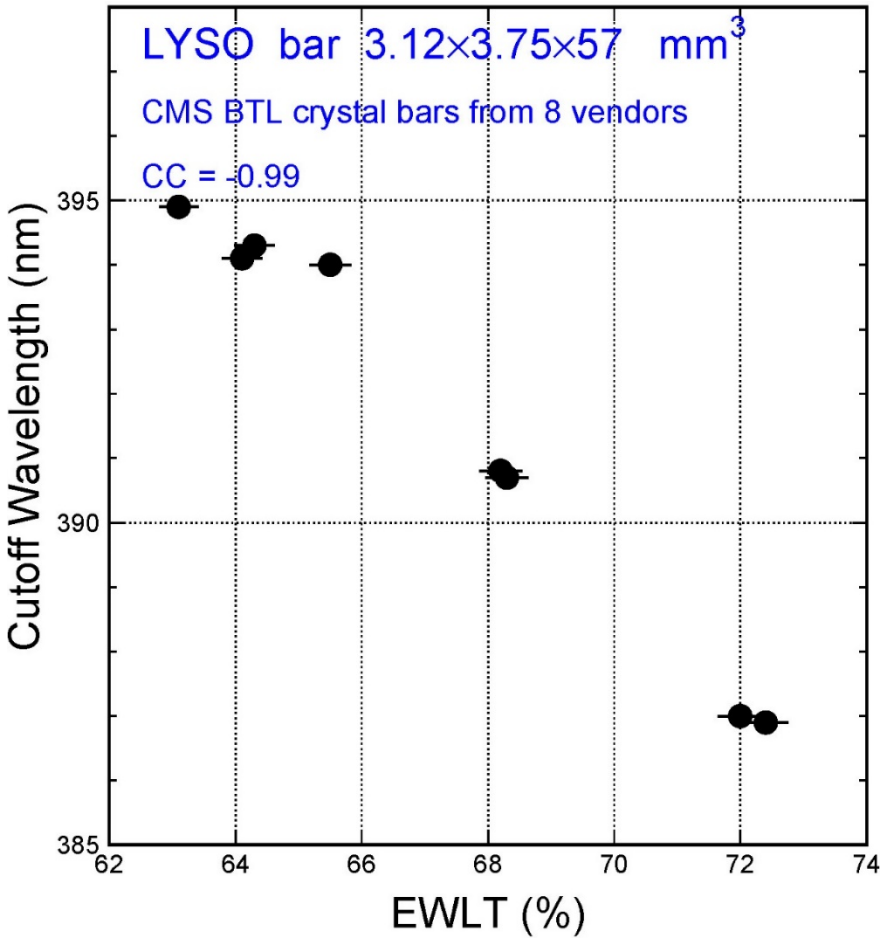


EWLT vs Cutoff Wavelength

A better correlation observed after correction via T @ 800 nm

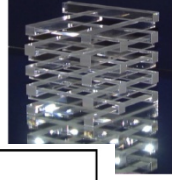


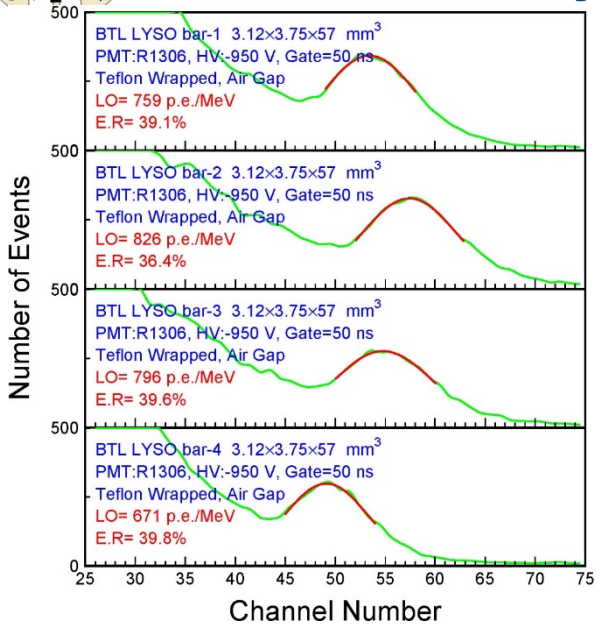
before correction

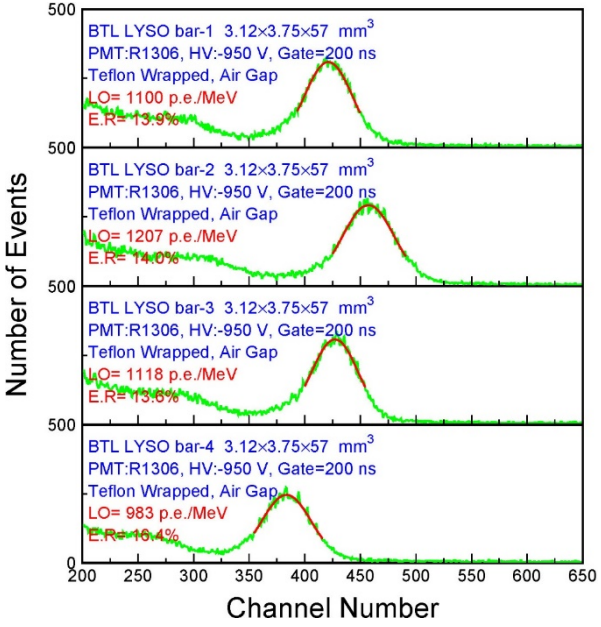


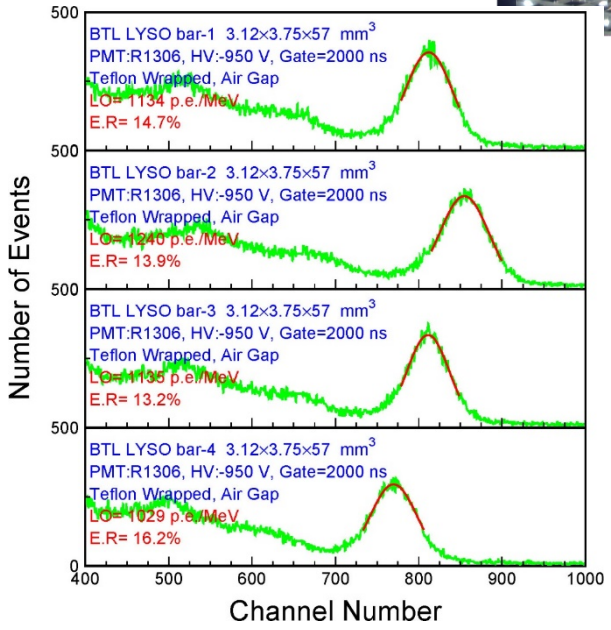
After correction

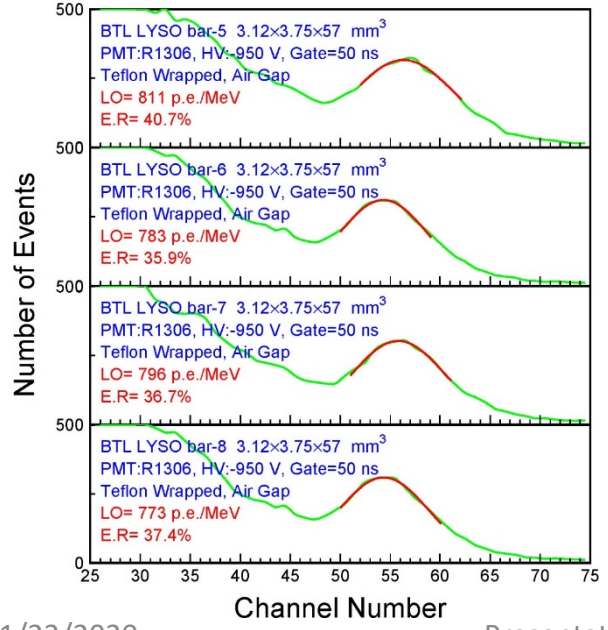
PHS: 50, 200 & 2,000 ns Gate

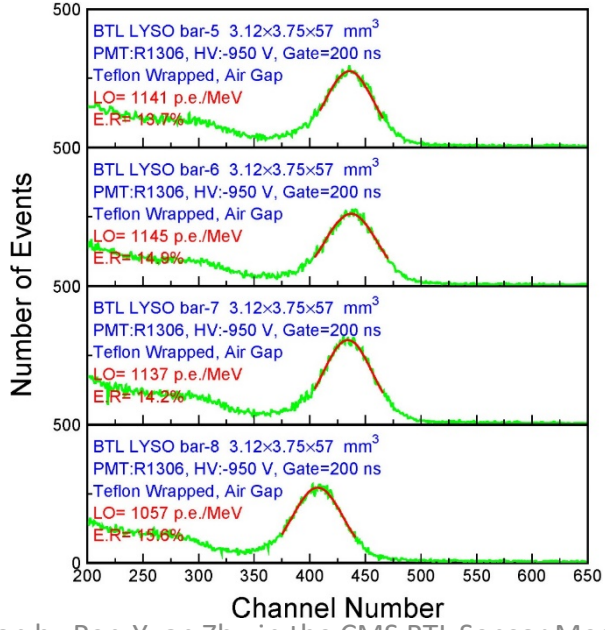


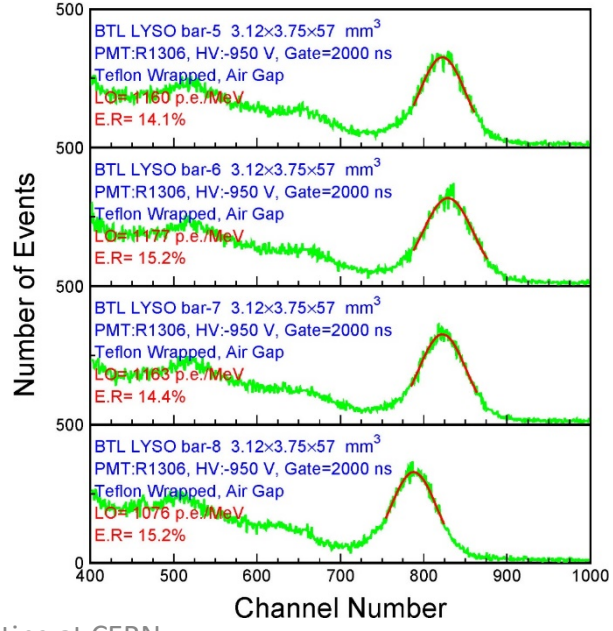






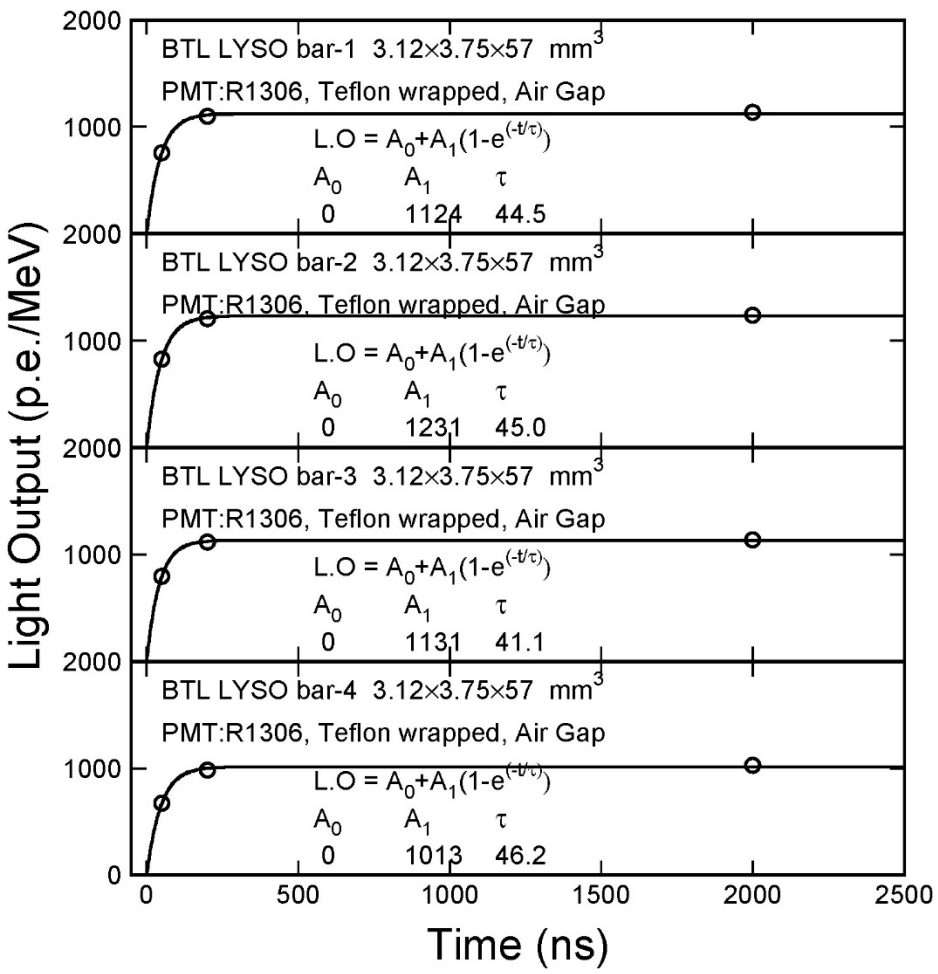


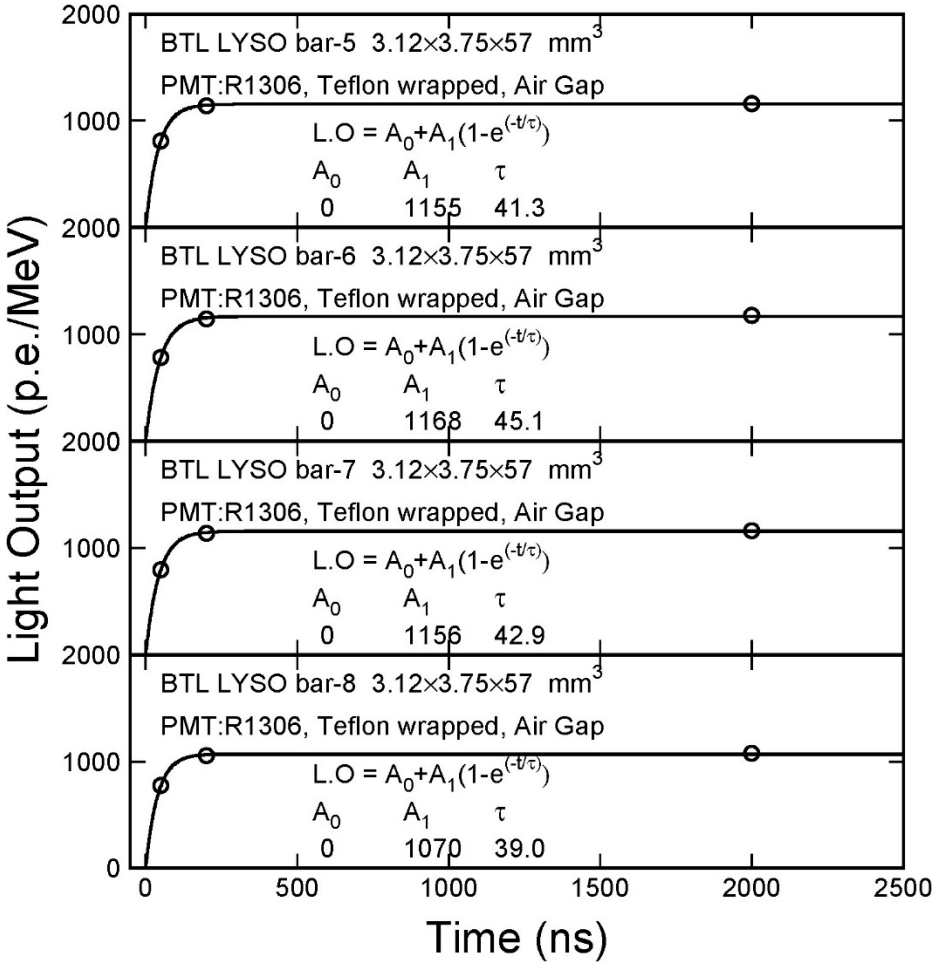




LO & Decay Time

τ determined by fitting LO as a function of integration time



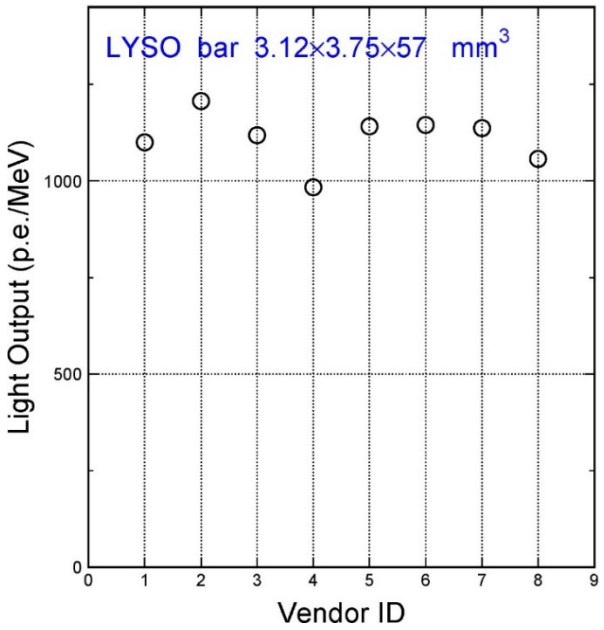


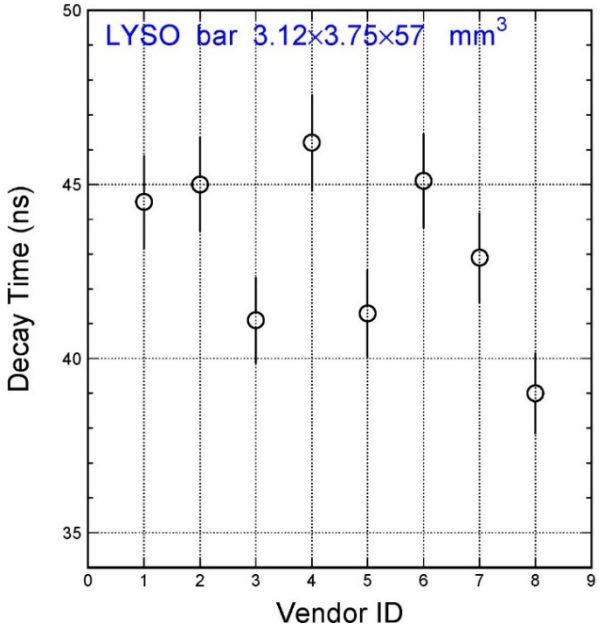
Summary: LT/LO/τ

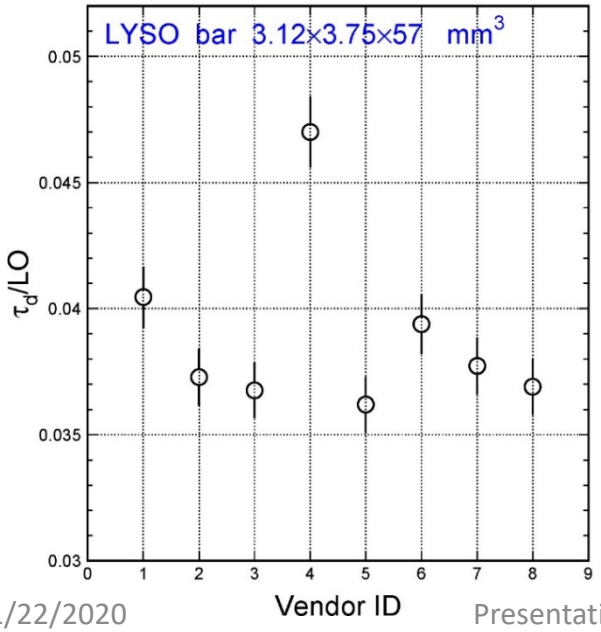
Light output measured with Teflon block wrapping and an air gap coupling to a PMT R1306 with triggers provided by a Na-22 source at the crystal center

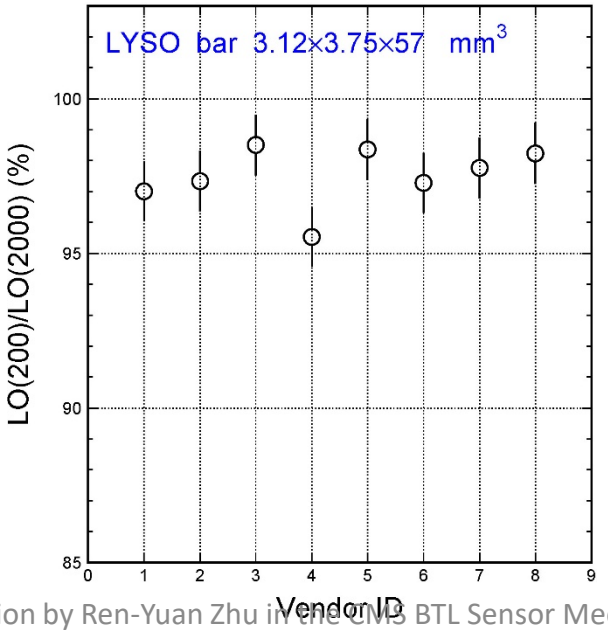
ID	EWLT (%)	T% @ 420 nm	200ns E.R. (%)	200ns L.O. (p.e./MeV)	2000ns L.O. (p.e./MeV)	LO(200) /LO(2000)	Decay Time (ns)	τ/LO(200)
1	62.0	78.6	13.9	1100	1134	97.0%	44.5	0.040
2	63.7	80.2	14.0	1207	1240	97.3%	45.0	0.037
3	73.3	84.5	13.6	1118	1135	98.5%	41.1	0.037
4	60.6	76.5	16.4	983	1029	95.5%	46.2	0.047
5	70.8	81.4	13.7	1141	1160	98.4%	41.3	0.036
6	65.0	78.0	14.9	1145	1177	97.3%	45.1	0.039
7	68.9	82.8	14.2	1137	1163	97.8%	42.9	0.038
8	60.8	75.6	15.6	1057	1076	98.2%	39.0	0.037
Ave	65.6	79.7	14.5	1111	1139	97.5%	43.1	0.039
RMS	6.9%	3.6%	6.5%	5.6%	5.3%	0.9%	5.4%	8.5%
Systematic Uncertainty	0.5%	0.5%	1.7%	0.7%	1.0%	1.0%	3%	3%

Vendor Comparison









Best & Worst

LO: #2 & #4

τ: #8 & #4

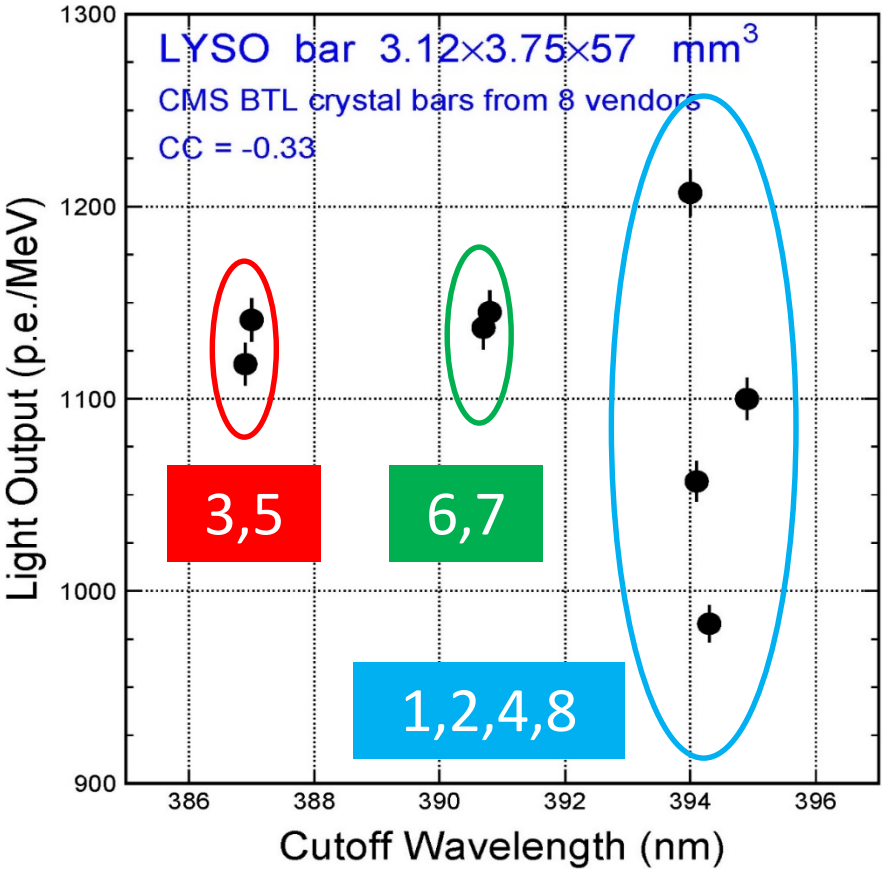
F/T: #3 & #4

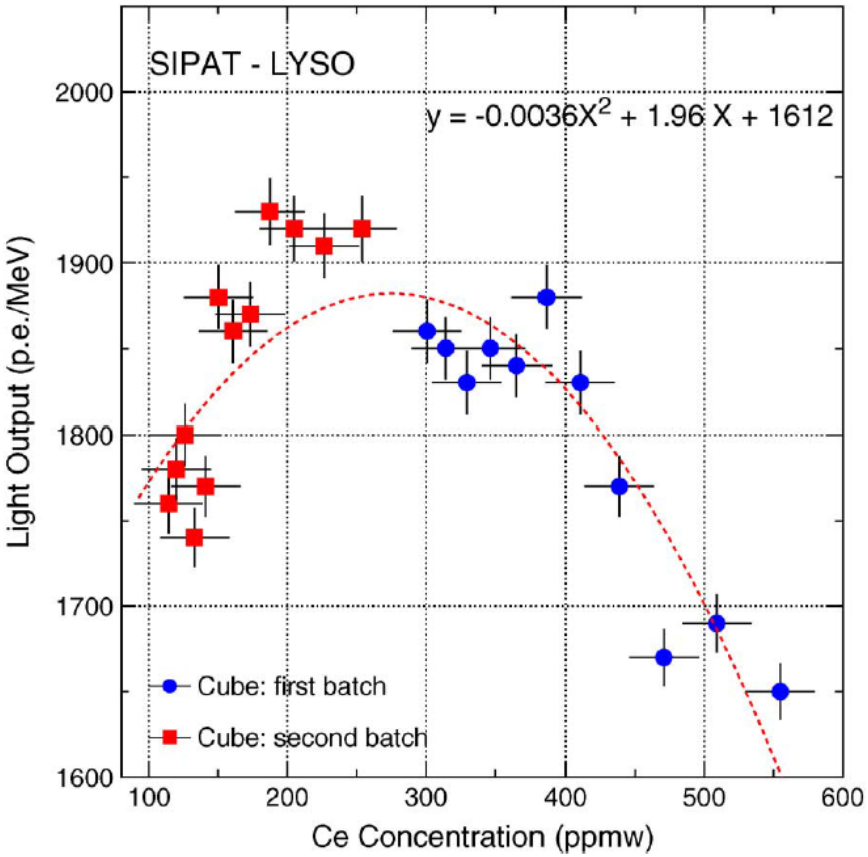
τ/LO: #5 & #4

More statistics required for judging vendors

Cutoff Wavelength vs LO

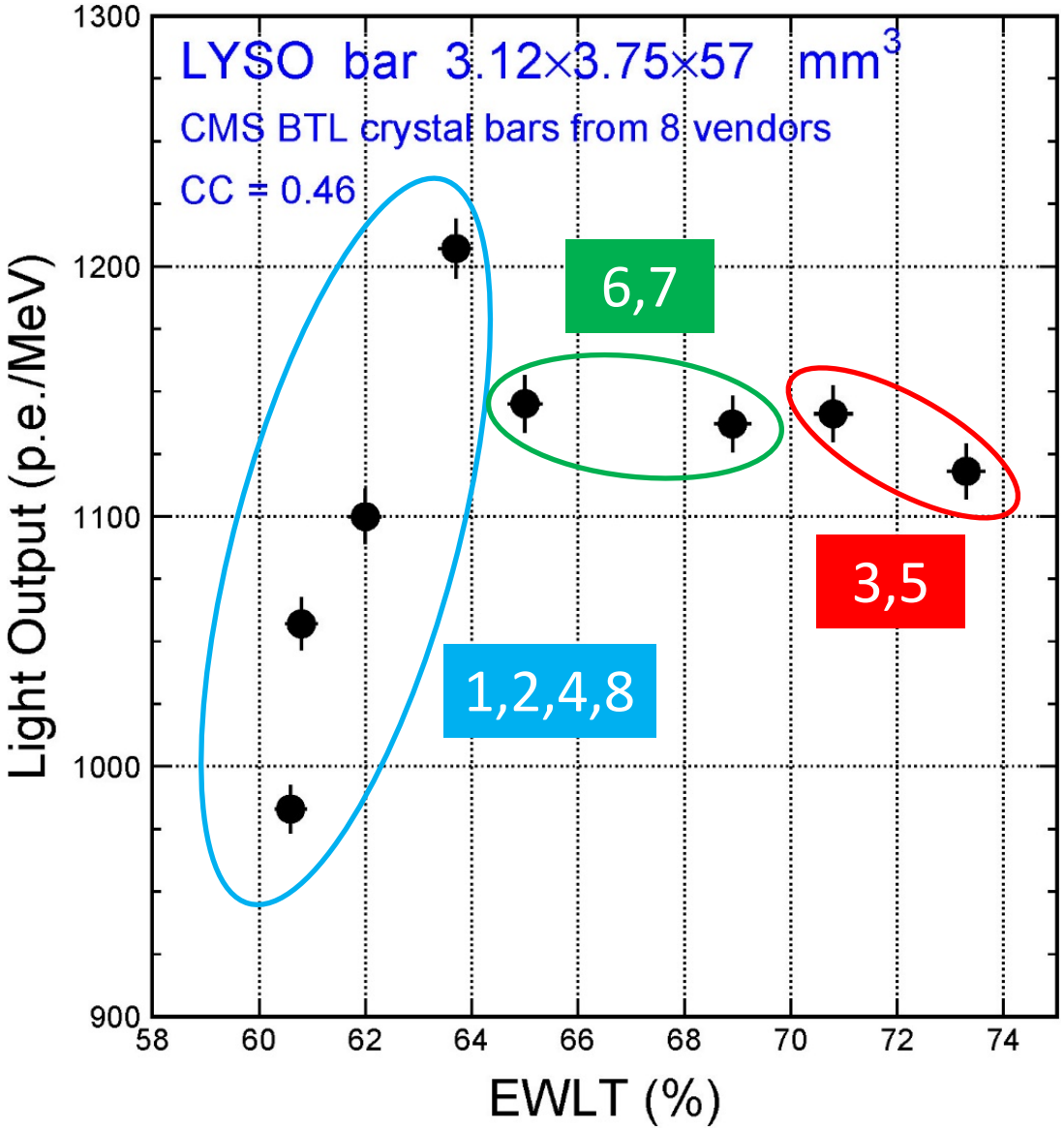
Three doping levels found for 8 vendors. The Ce concentration of samples 3,5,6,7 reach the plateau between 150 and 400 ppm





L. Zhang, *et al.*, IEEE TNS 61(1):483-488

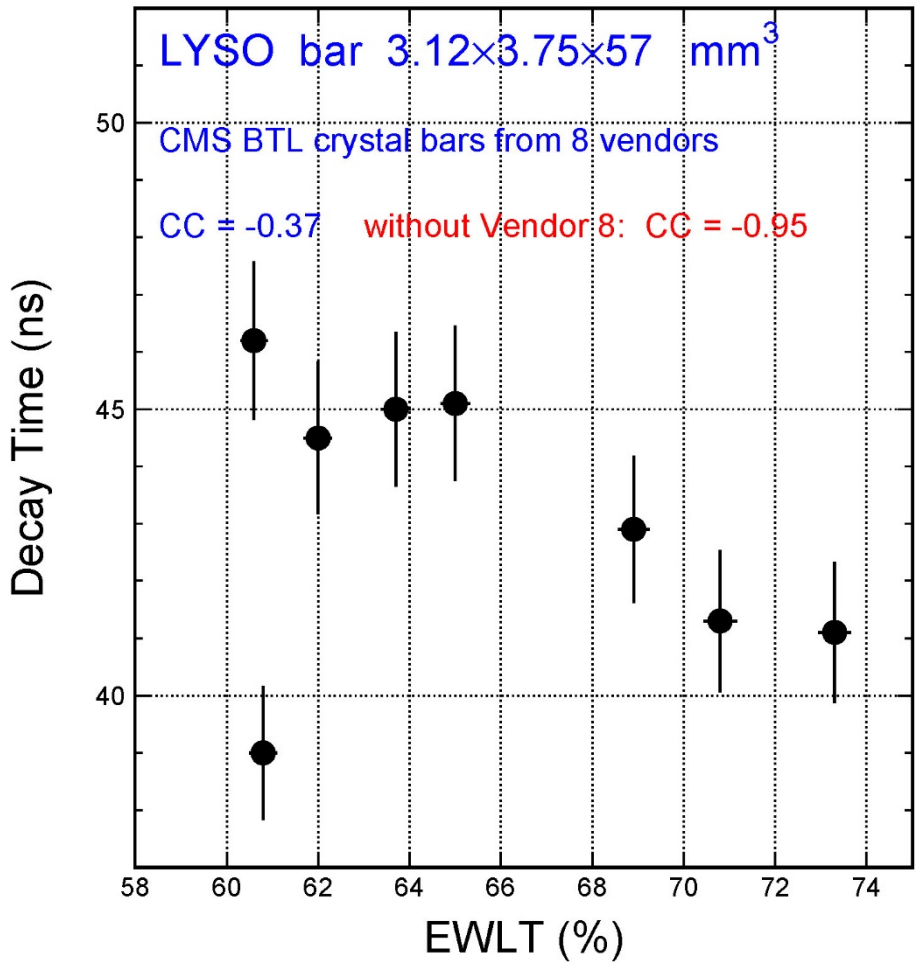
EWLT vs LO

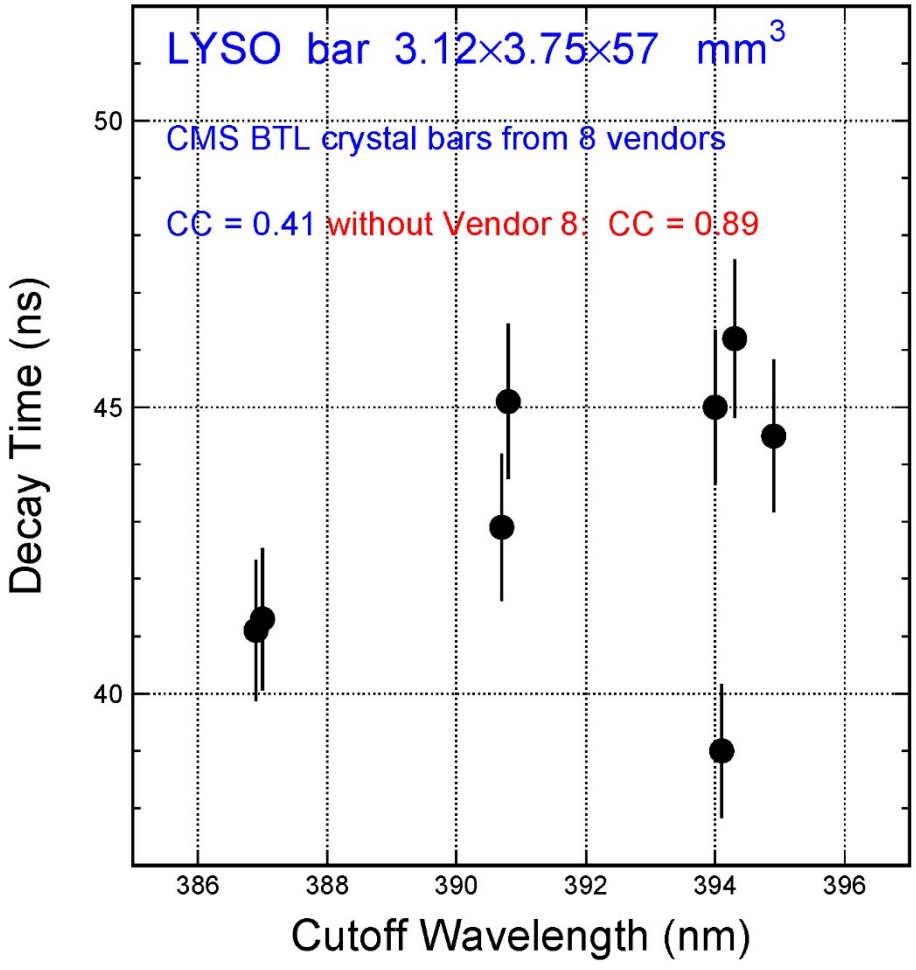


Some correlation observed between light output and optical quality for samples 1,2,4,8

EWLT/Cutoff vs Decay Time

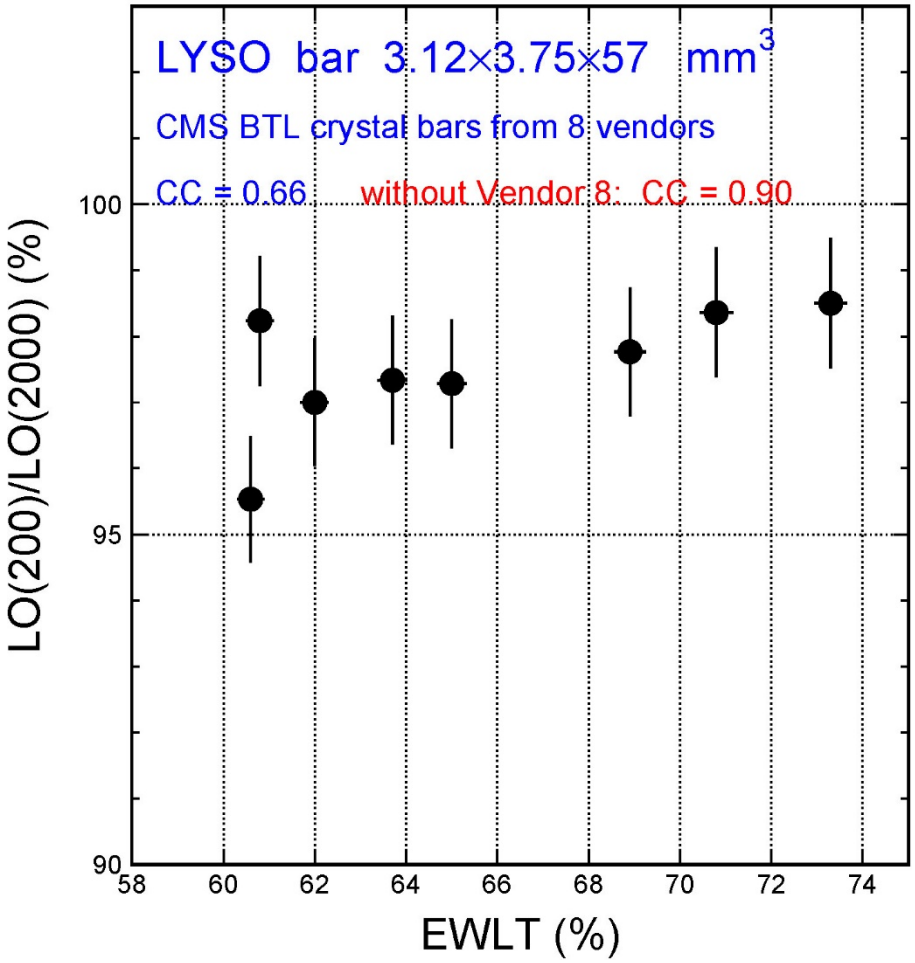
Decay time is affected by the Ce doping level

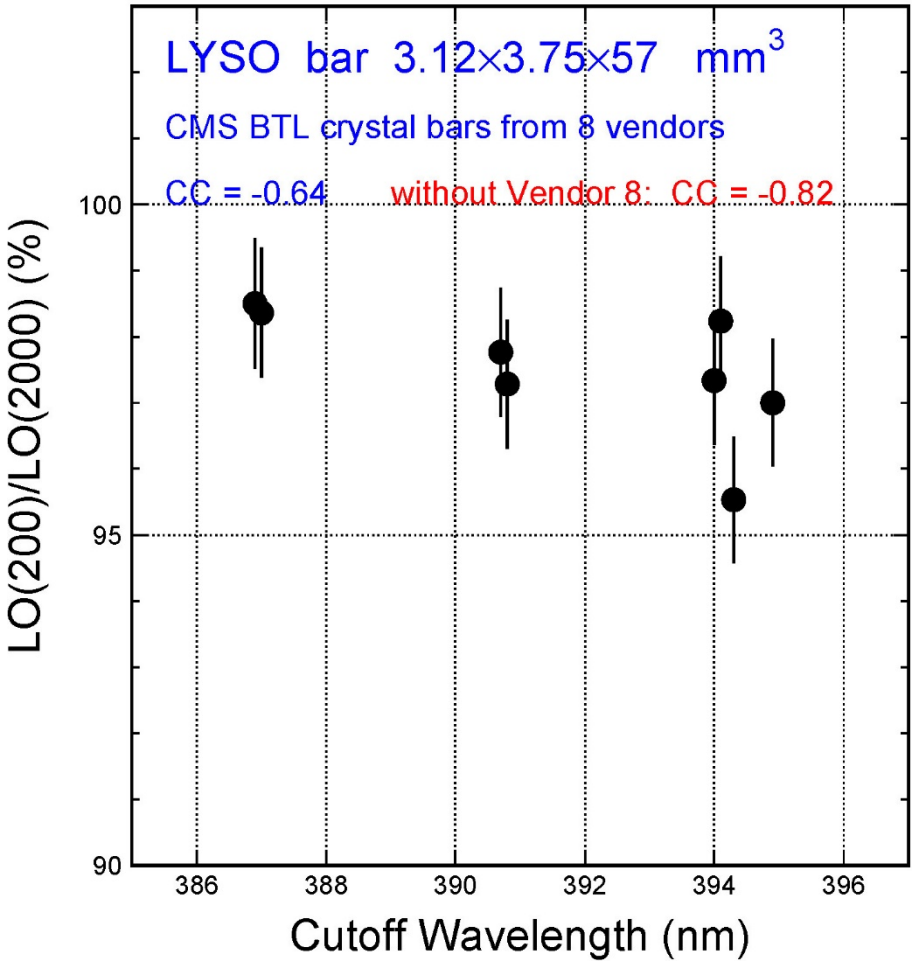




EWLT/Cutoff vs F/T

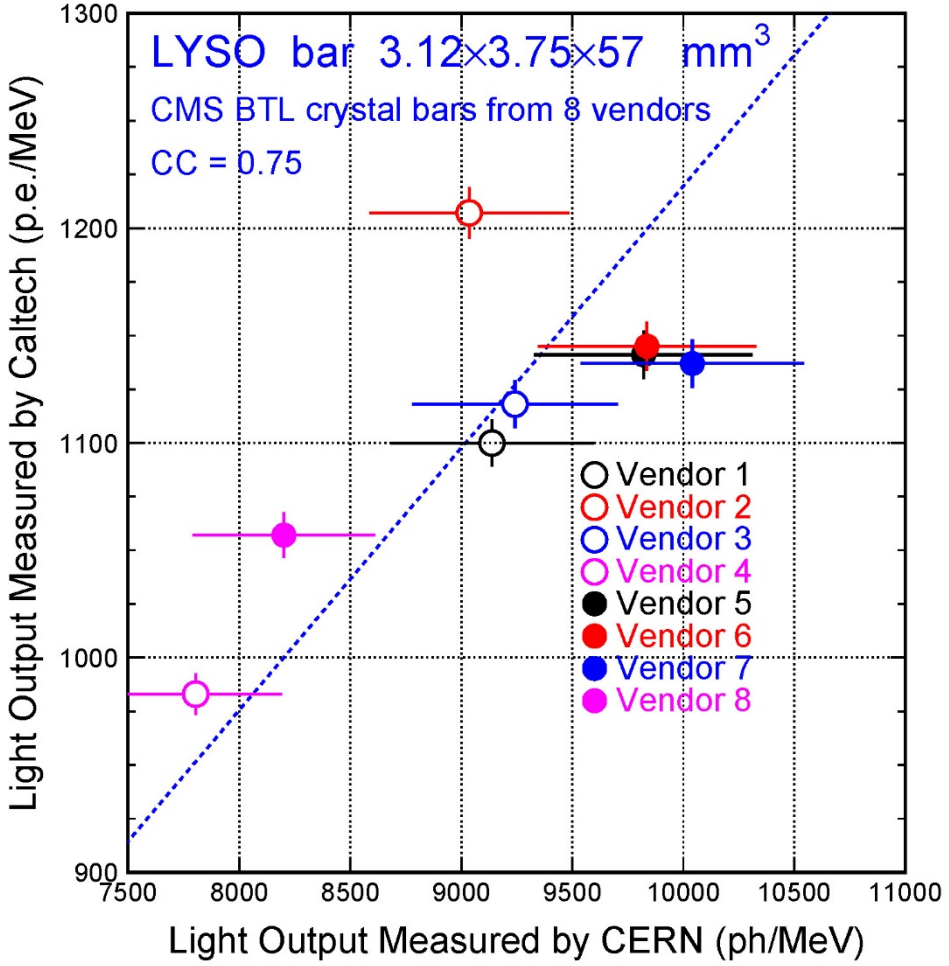
F/T is also affected by the Ce doping level



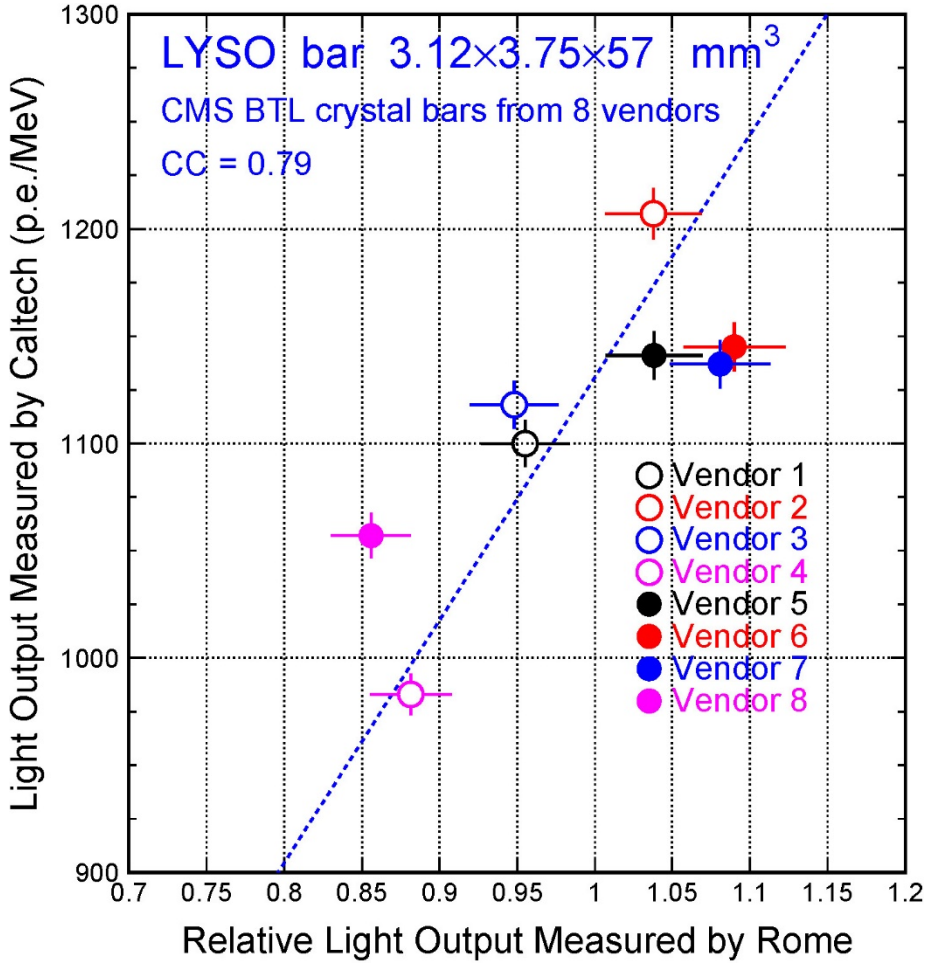


Between Lab Comparison: LO

Caltech vs. CERN

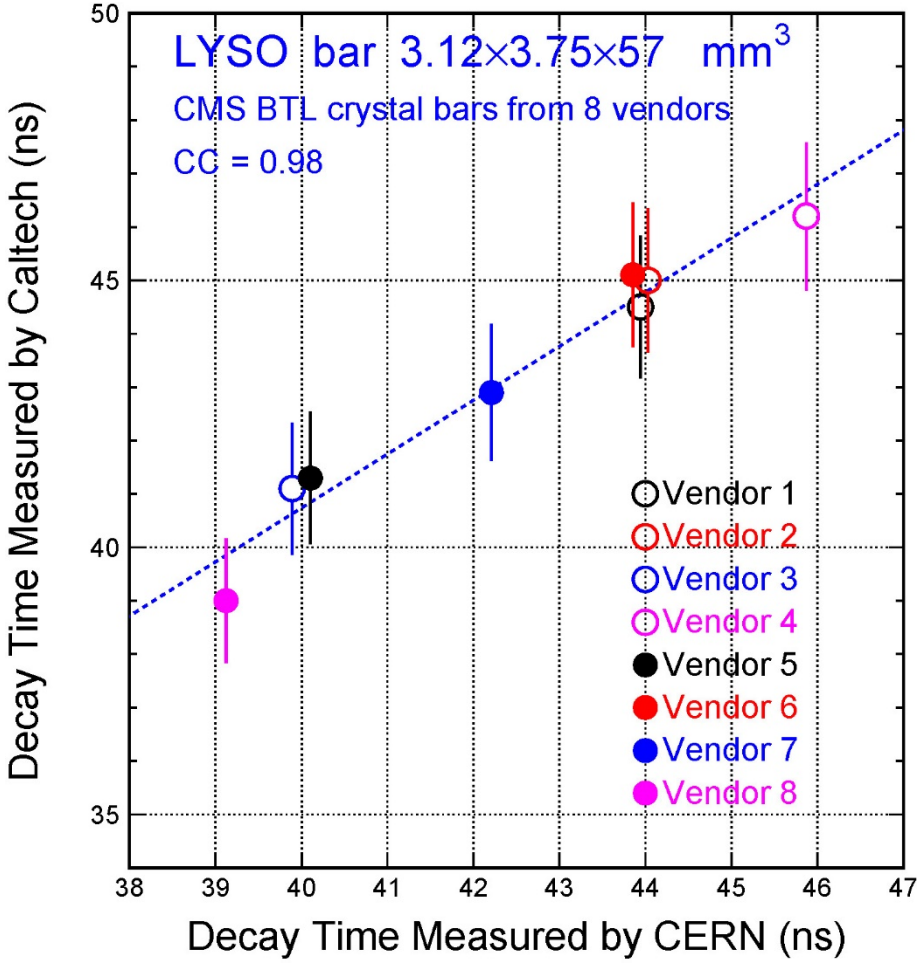


Caltech vs. Rome

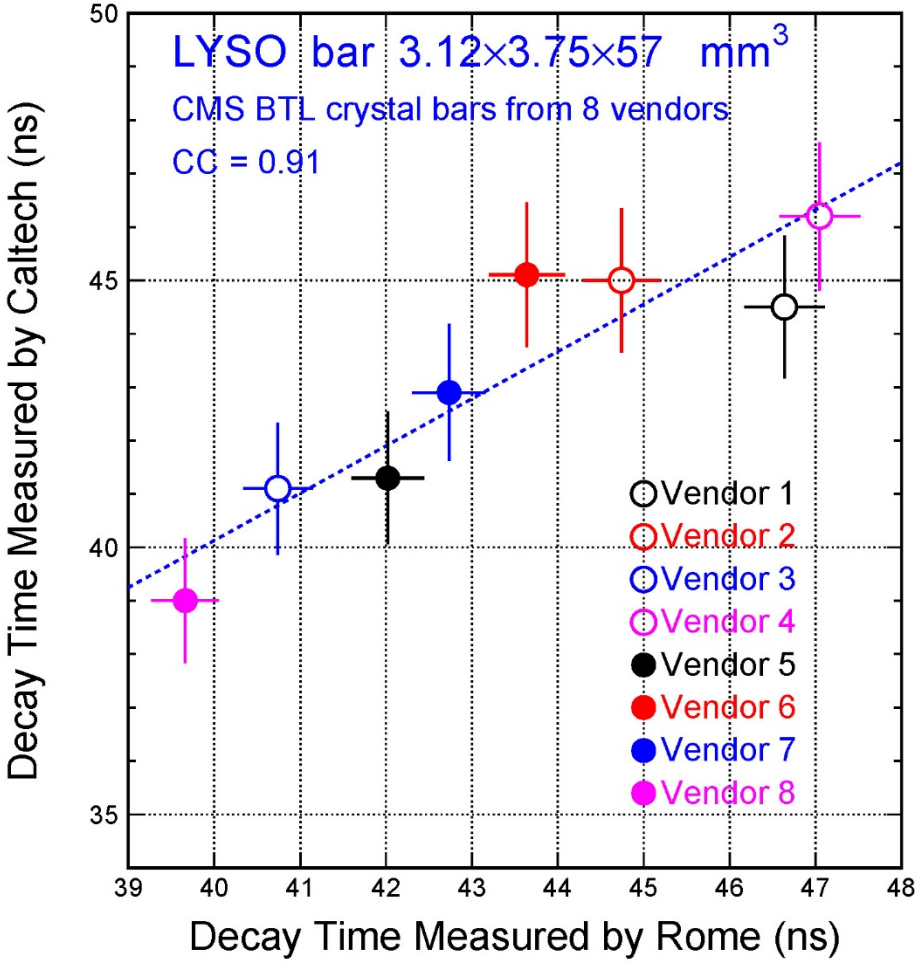


Between Lab Comparison: Decay

Caltech vs. CERN

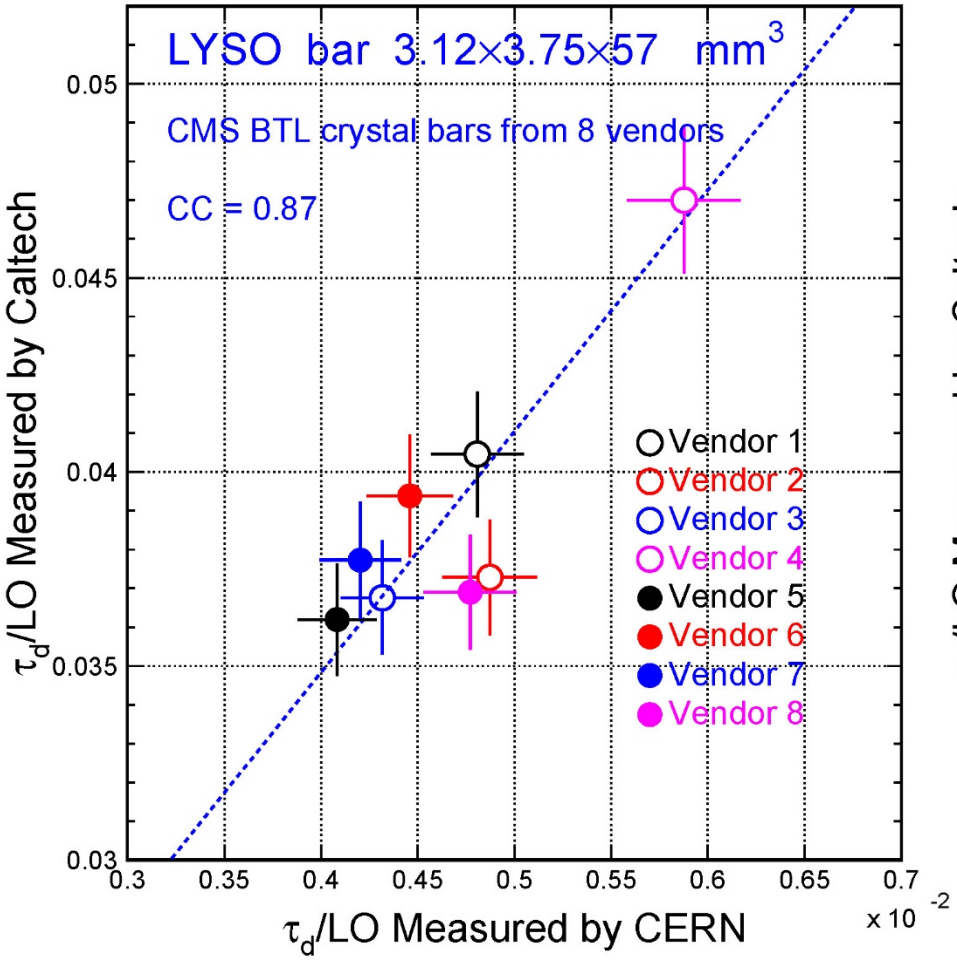


Caltech vs. Rome

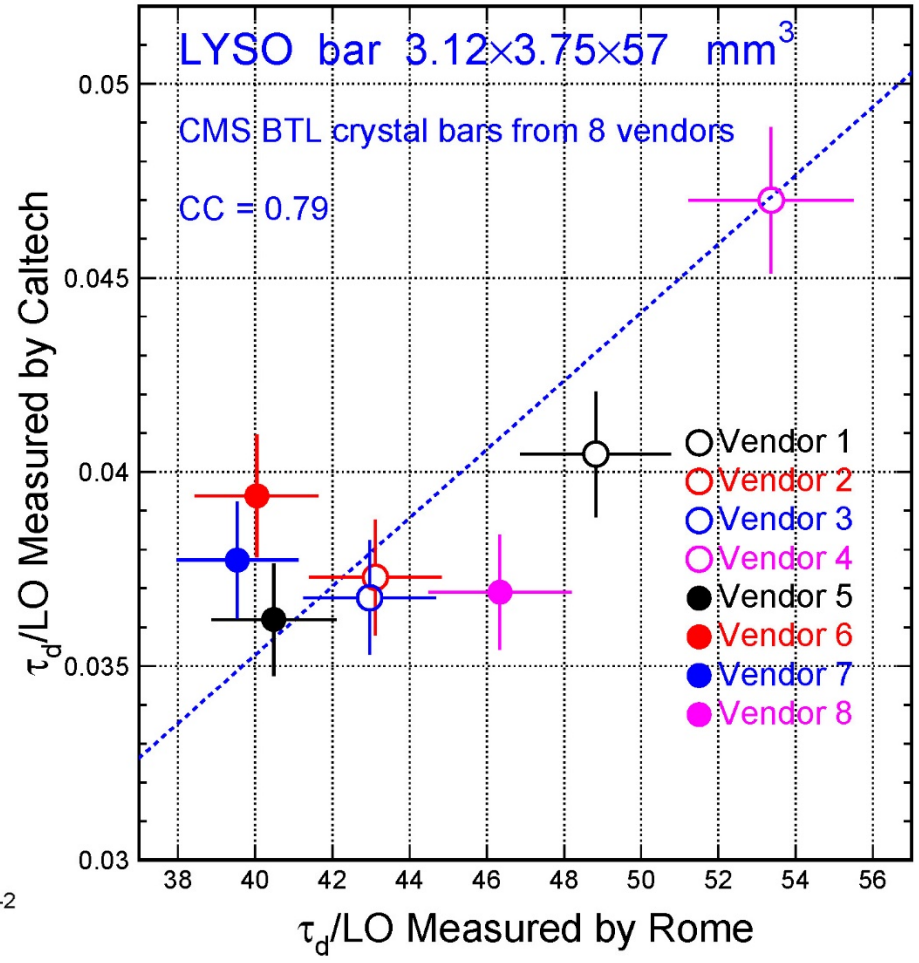


Between Lab Comparison: τ_d/LO

Caltech vs. CERN

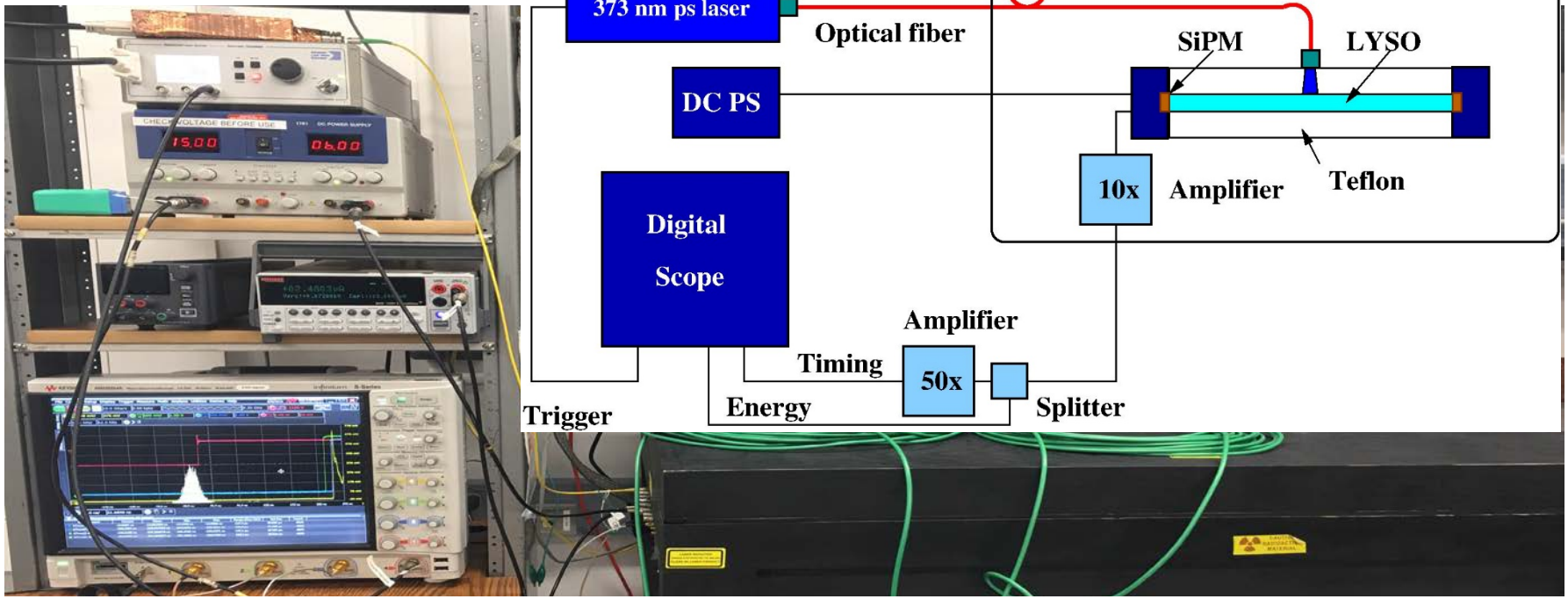


Caltech vs. Rome



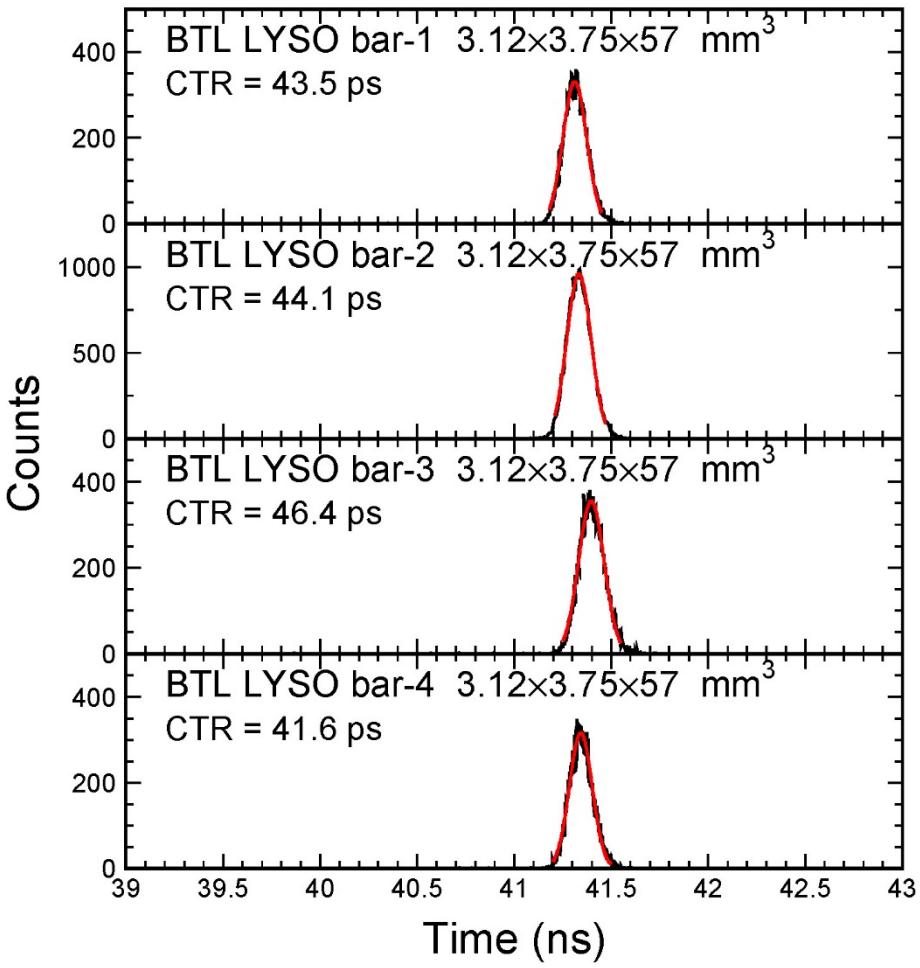
CTR Measurement

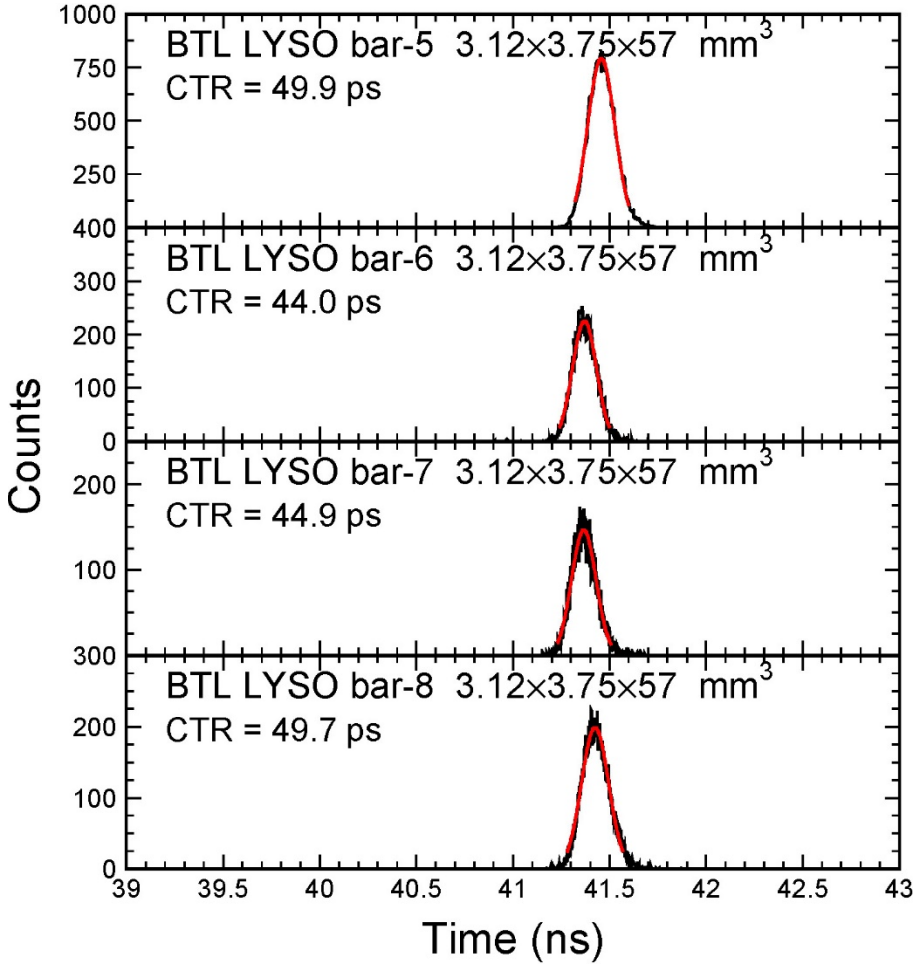
CTR measured in the Caltech CPT lab. LYSO bars wrapped with a Teflon block, and coupled to Hamamatsu SiPM S14160-3015PS at two ends via air-gap. Timing and energy were measured with a single SiPM through two amplifies and a splitter, with crystals excited by a 373 nm ps laser with ~4 MeV energy at the center.



CTR Result for Eight Vendors

Measured σ_t converted to CTR for 2 SiPMs by x 1/√2





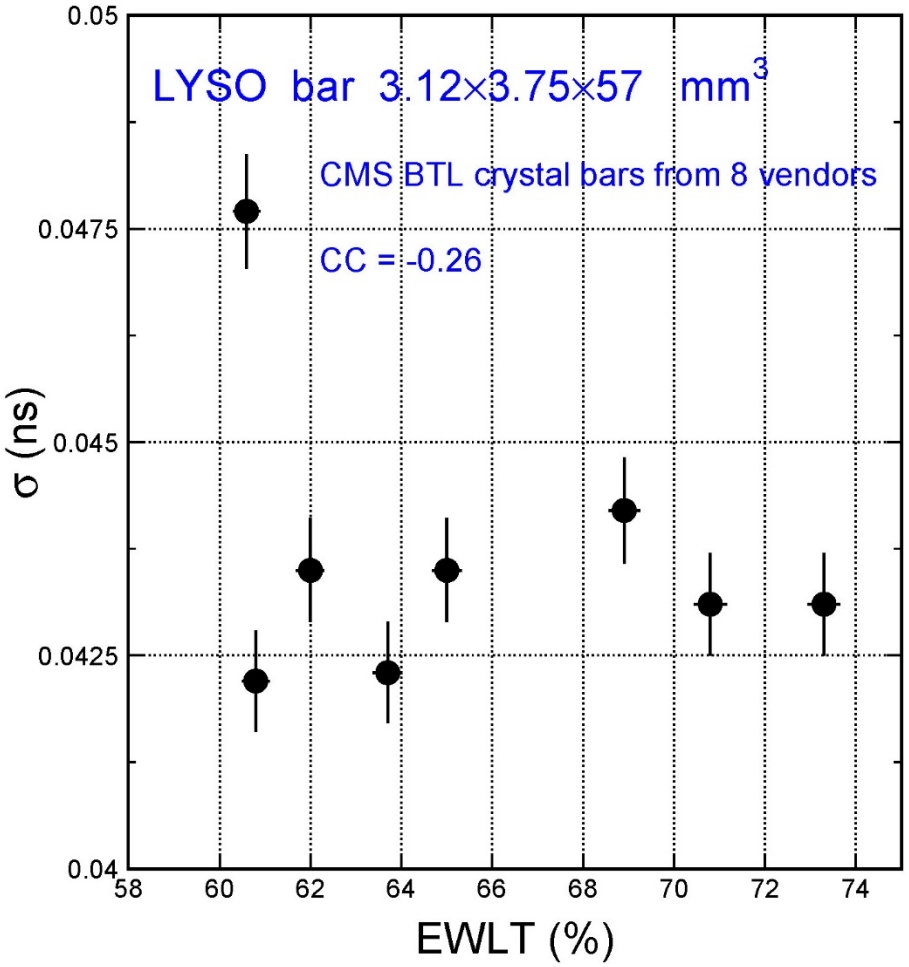
Corrected CTR

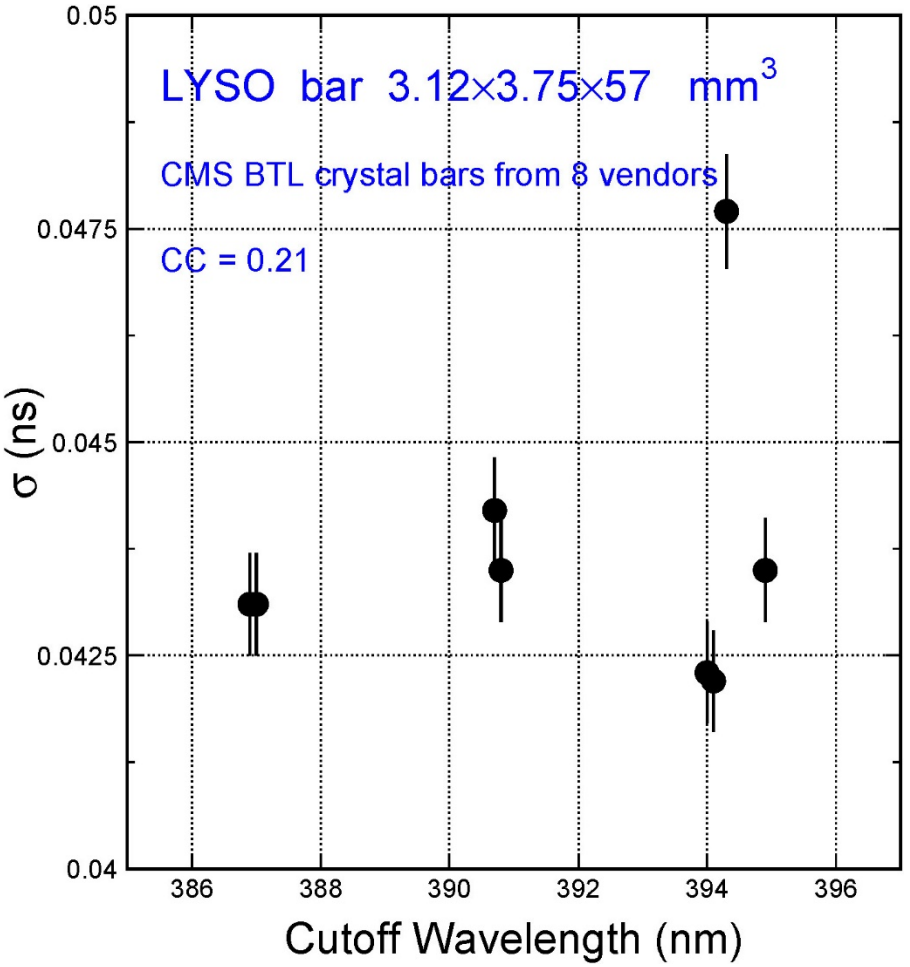
CTR corrected by scaling laser pulse energy to 4 MeV MIP signal

ID	CTR (ps)	Relative Laser LO	200ns LO by PMT	Corrected Relative Laser Power	Corrected CTR (ps)	τ/LO(200)
1	43.5	1.20	1100	1.00	**43.5**	0.040
2	44.1	1.21	1207	0.92	**42.3**	0.037
3	46.4	1.05	1118	0.86	**43.1**	0.037
4	41.6	1.41	983	1.31	**47.7**	0.047
5	49.9	0.93	1141	0.75	**43.1**	0.036
6	44.0	1.22	1145	0.98	**43.5**	0.039
7	44.9	1.20	1137	0.97	**44.2**	0.038
8	49.7	0.83	1057	0.72	**42.2**	0.037
Ave	45.5	1.13	1111	0.94	**43.7**	0.039
RMS	6.1%	15.3%	5.6%	18.2%	**3.7%**	8.5%
Systematic Uncertainty	1.4%	\	0.7%	\	**1.4%**	3%

EWLT/Cutoff vs CTR

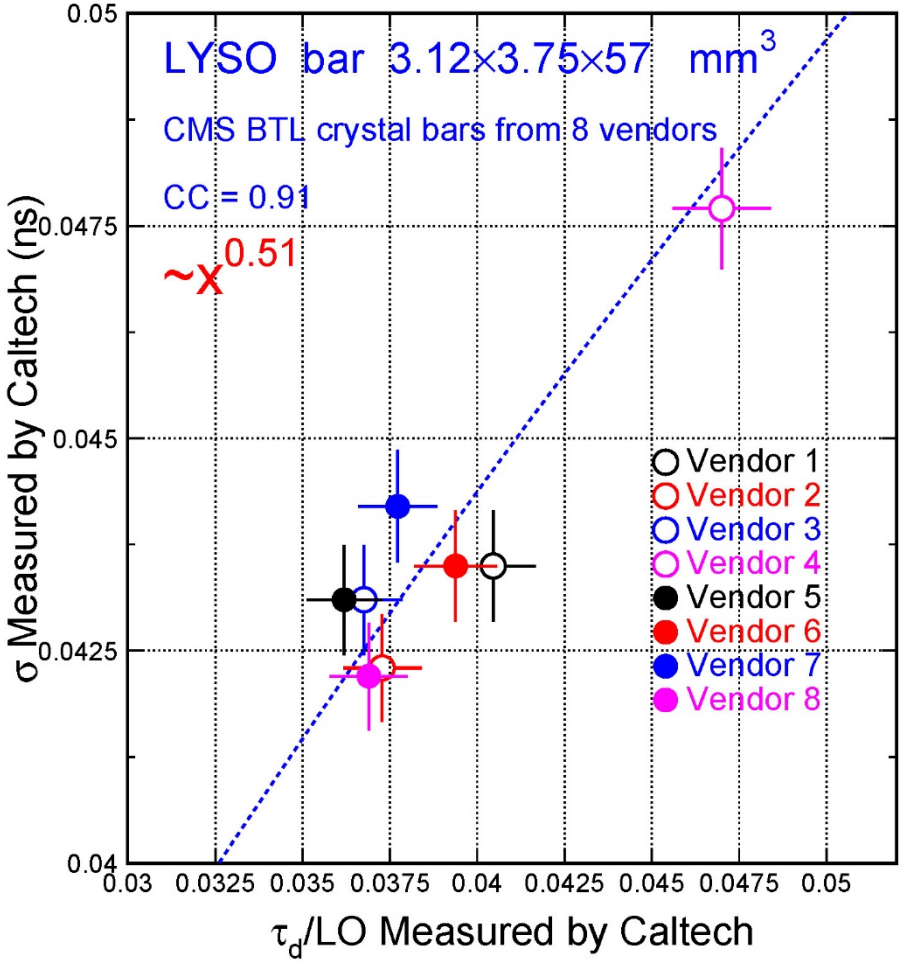
CTR seems not affected by Ce doping level

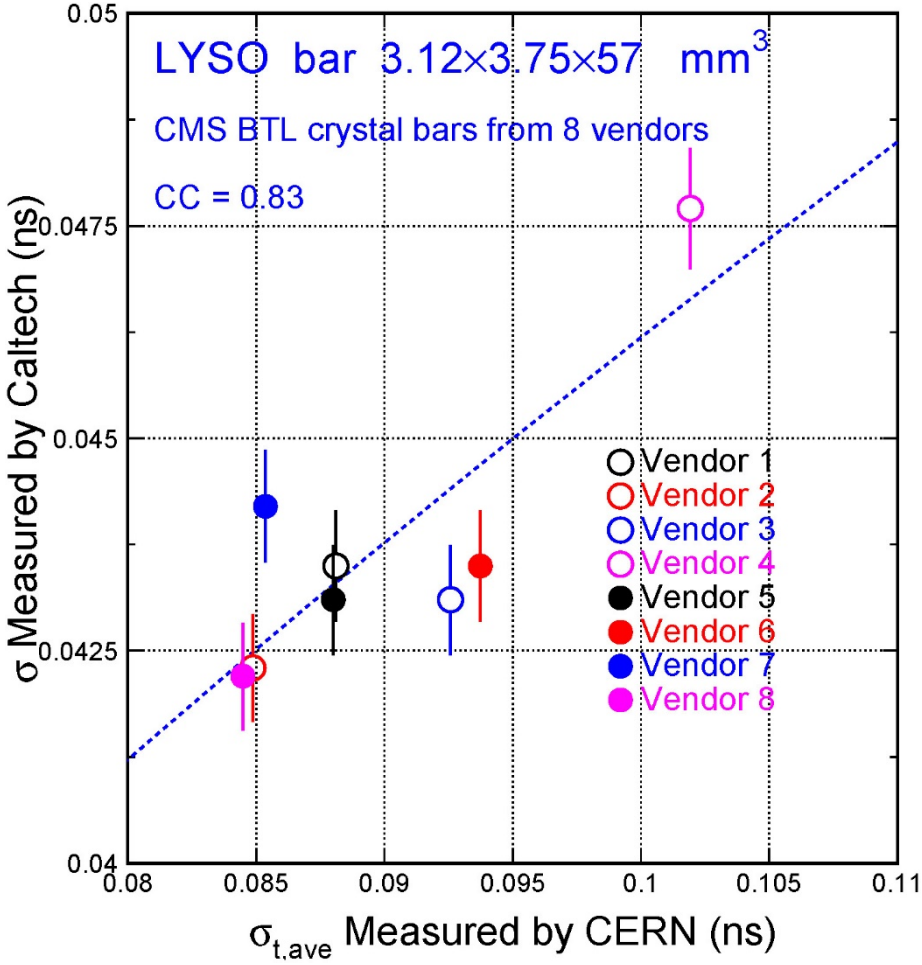




CTR Comparison

CTR follows $\sqrt{\tau_d}$/LO, and correlates with CERN data well





Summary

- Longitudinal transmittance, light output, decay time and CTR were measured for eight LYSO bars from eight vendors.
- Excellent correlations are observed between the EWLT and the cutoff wavelength, but not with their light output. This is presumably due to different cerium doping levels as well as different growth and annealing conditions.
- A higher [Ce] leads to a longer cutoff, a lower EWLT, a larger τ and a smaller F/T, but not LO and CTR.
- While one sample per vendor does not allow vendor judgement, sample #4 shows the worst CTR and LO/τ.
- Although different labs measured samples under very different conditions, good consistency is observed for LO, τ and CTR.
- Plan to do radiation damage tests for these eight samples to see any significant difference between vendors: RIN:ɣ, RIN:n, TID:ɣ and TF:n. Will also do RIN:p and TF:p in Fall if proton beam is available at LANSCE.