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# Transmittance and Light Output Damage after 5.1 Mrad in Eight LYSO Samples

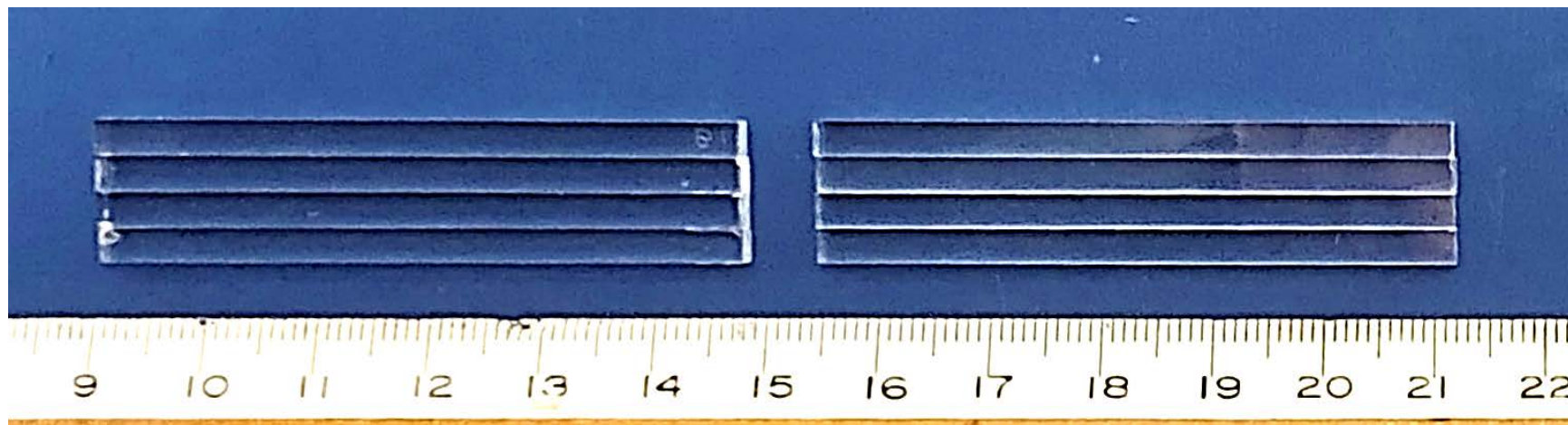
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# LYSO Bars from Eight Vendors



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

## Experiment

Longitudinal transmittance (LT), light output (LO) and decay time measured before/after (b/a) a TID of 5.1 Mrad by a Cs-137 source

LT/LO/Decay Time, RIN, and PL intensity/decay @ -30/-60 °C reported in BTL meetings on 1/22, 3/25 and 7/22 respectively



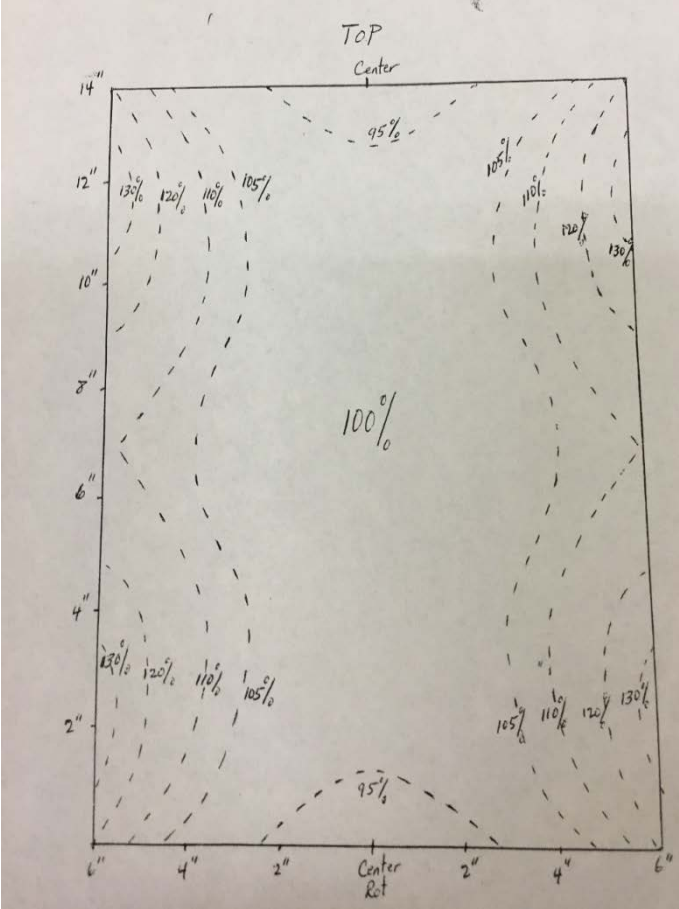
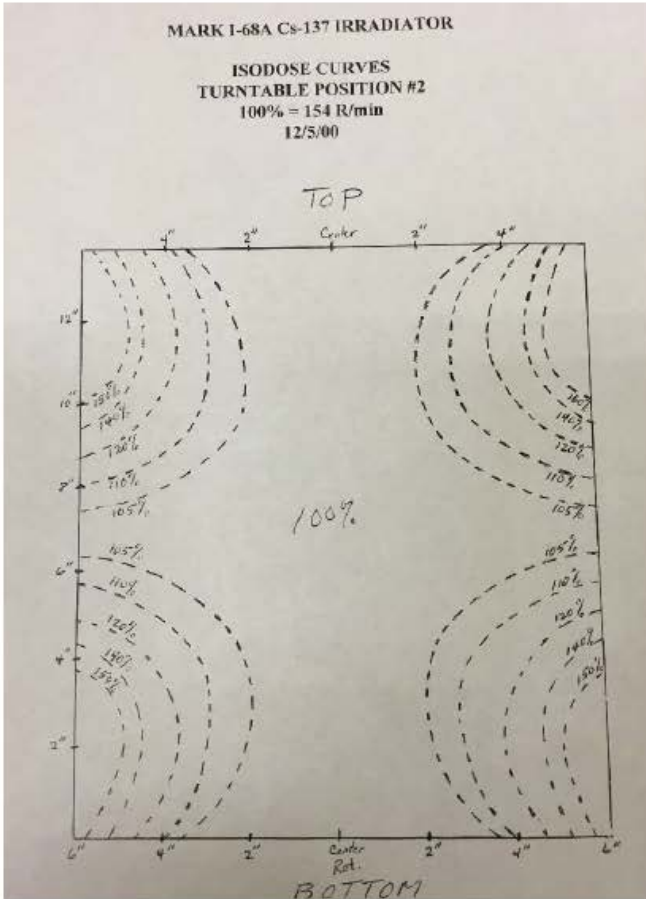
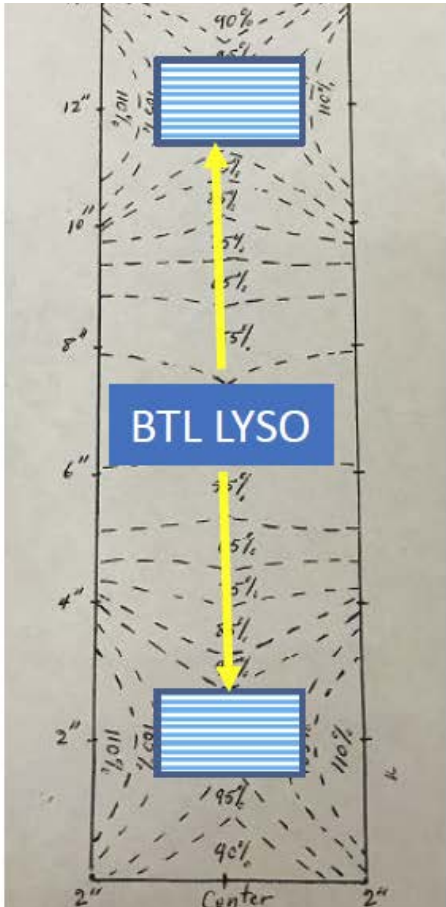
# Caltech Cs-137 Source for TID

Dose rate calibrated with an ionization chamber

P1: 21.0 krad/h

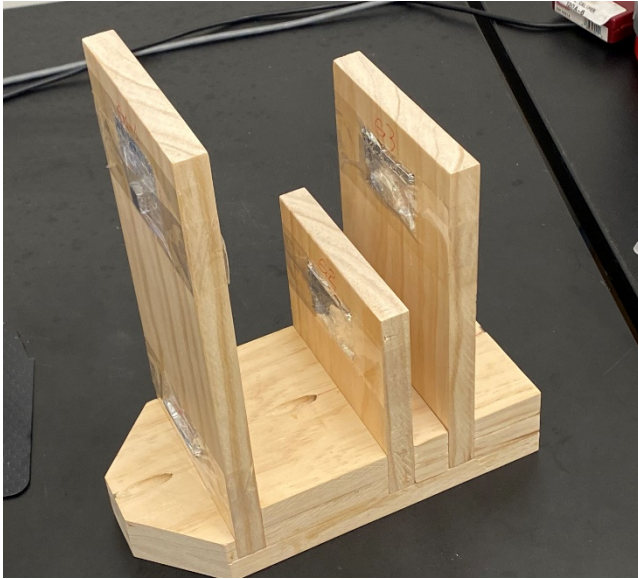
P2: 5.68 krad/h

P3: 4.16 krad/h





# Sample Holder: P1, P2 & P3



A total ionization dose of 5.1 Mrad was reached at P1



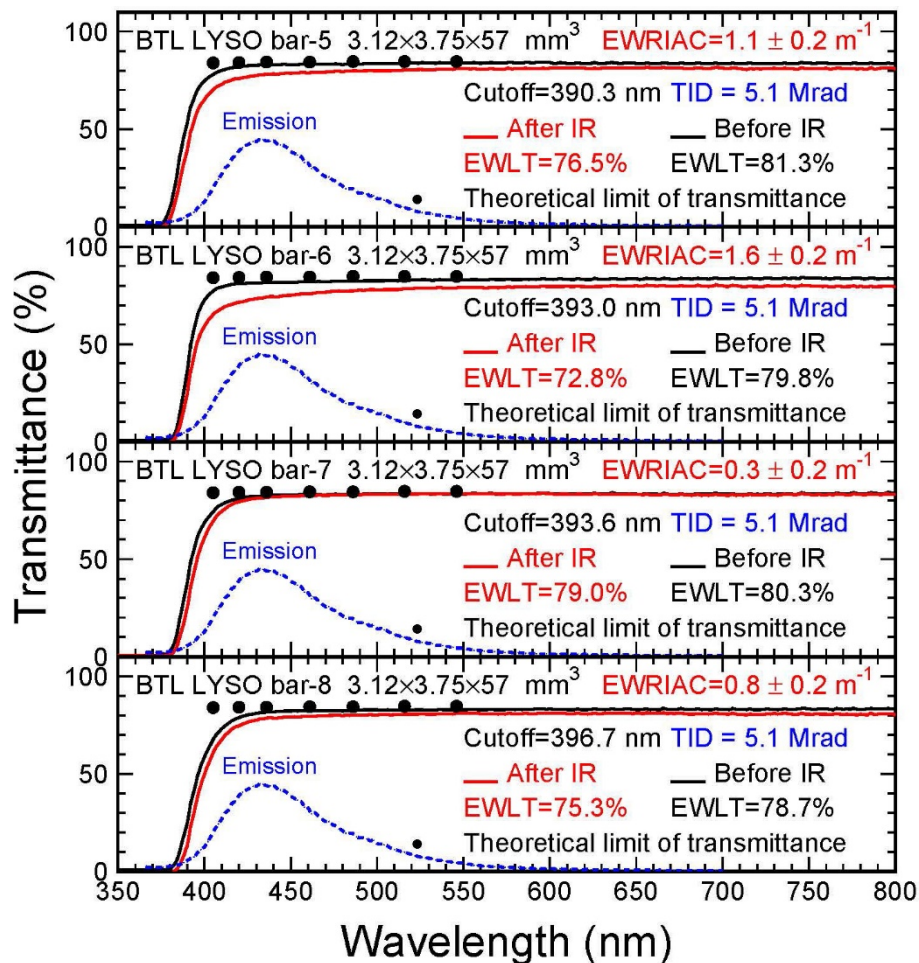
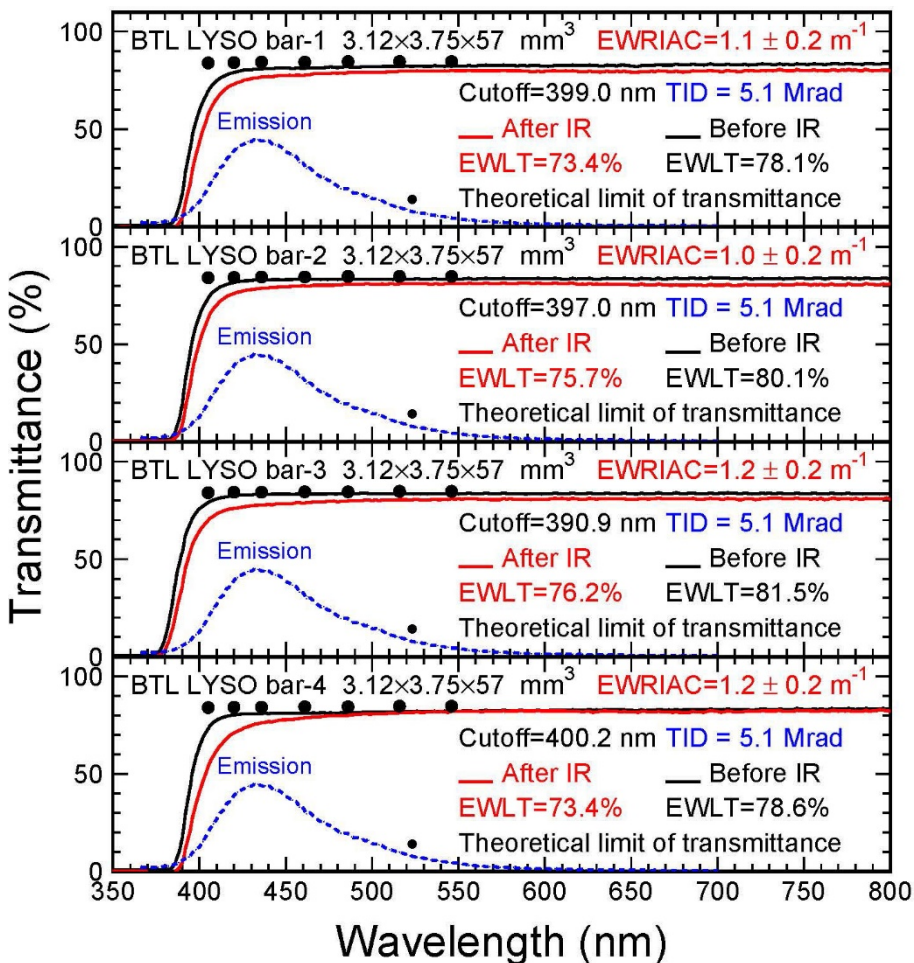




# Transmittance: b/a 5.1 Mrad



Emission weighted LT (EWLT) and emission weighted radiation induced absorption coefficient (EWRIAC) measured with a spectrophotometer

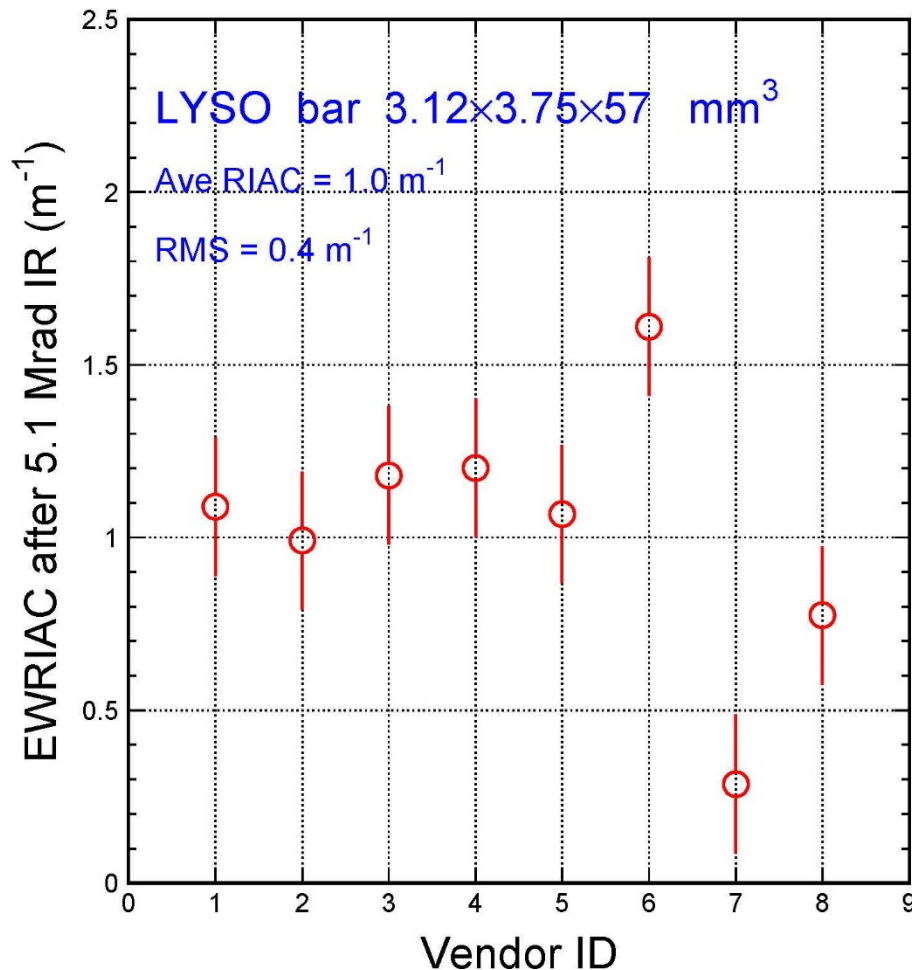
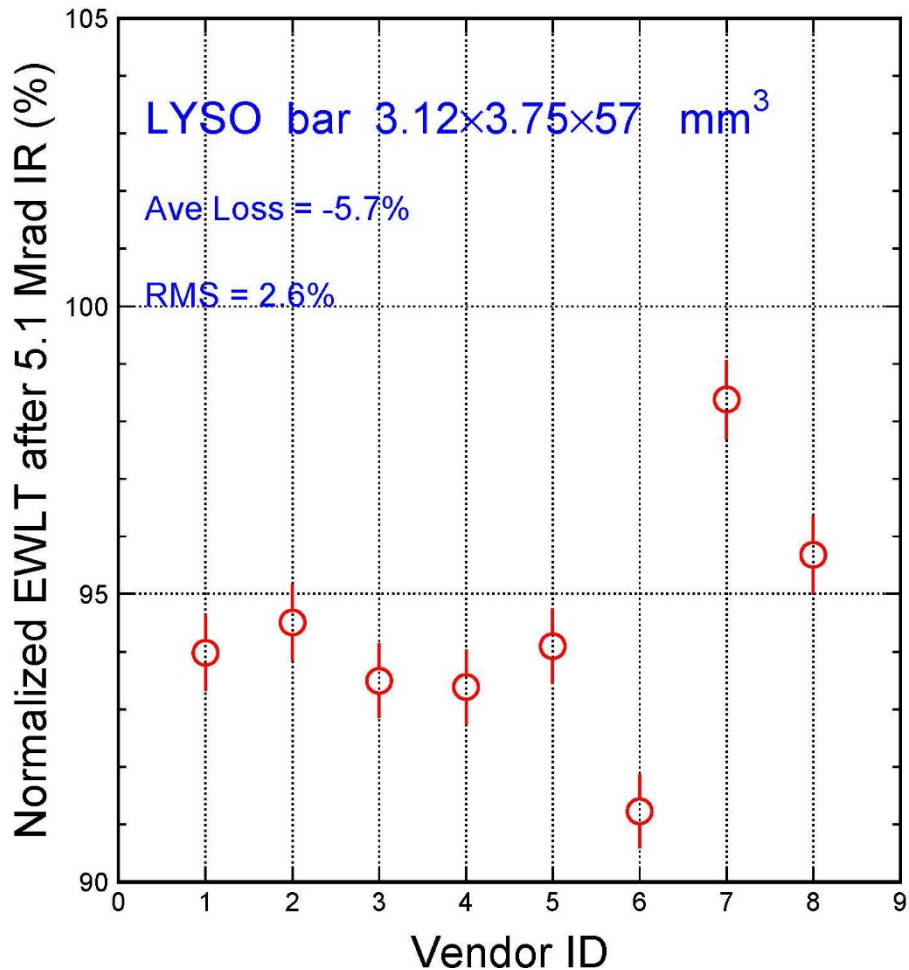




# Normalized EWLT and EWRIAC

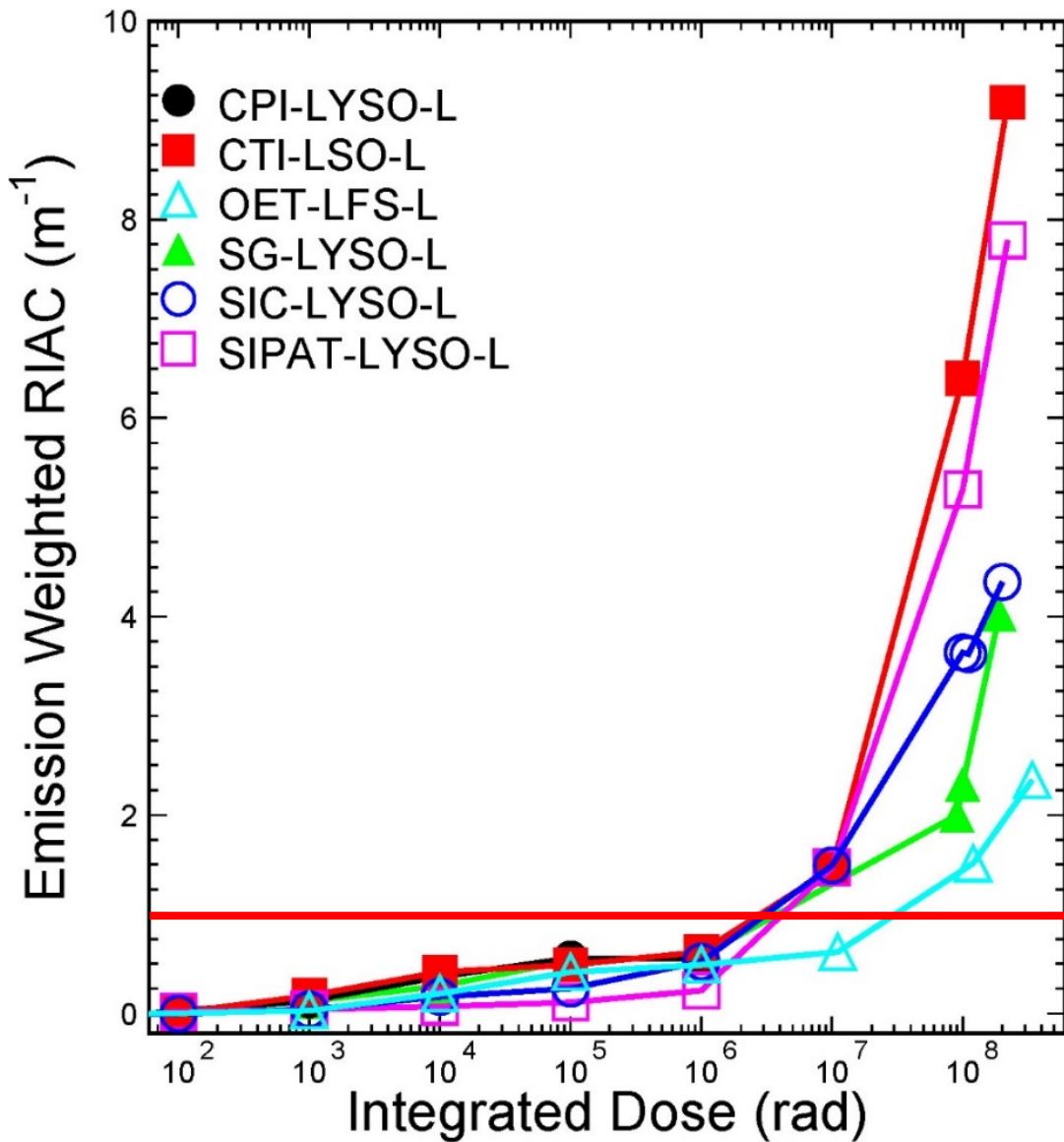


Average EWLT loss: -5.7%; Average EWRIAC: 1.0 m<sup>-1</sup>





# EWRIAC for 20 cm Long LYSO

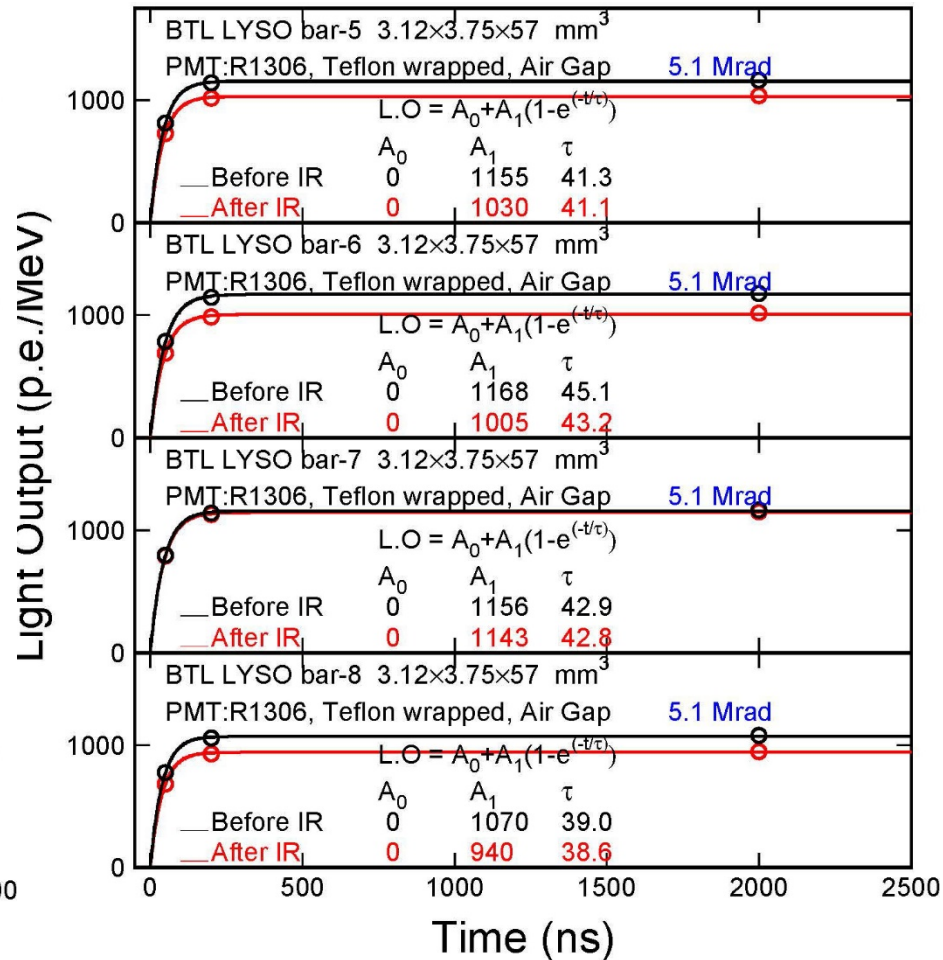
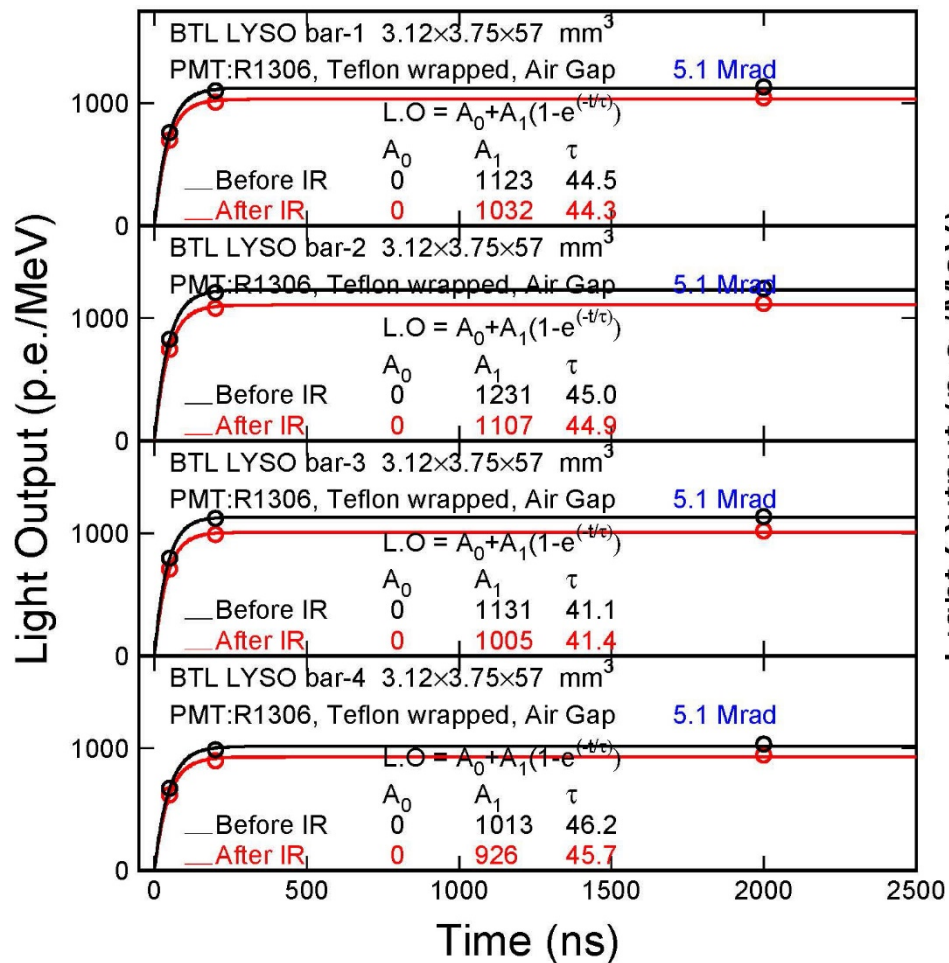


The observed average EWRIAC of 1 m<sup>-1</sup> after 5.1 Mrad is consistent with data measured for 20 cm long LYSO samples published in IEEE TNS 63 (2016) 612-619

# LO and $\tau$ : b/a 5.1 Mrad



LYSO with Teflon block wrapping and air gap coupling to R1306 PMT triggered by a Na-22 source at crystal center



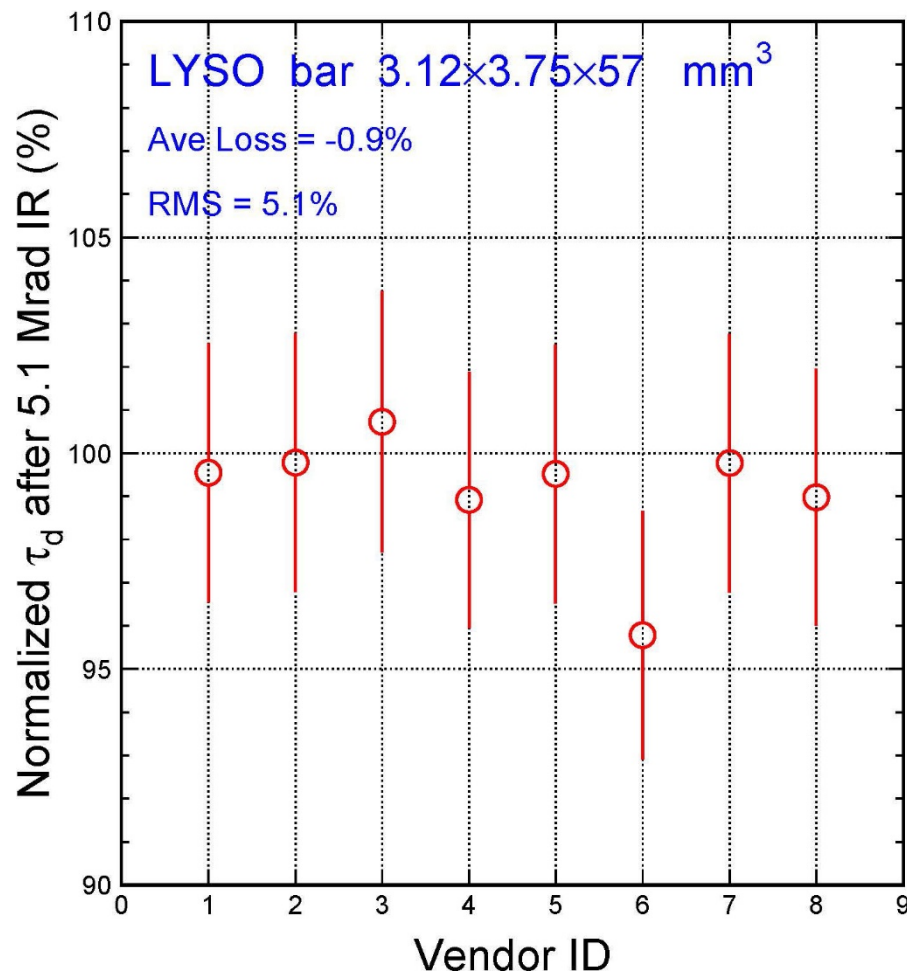
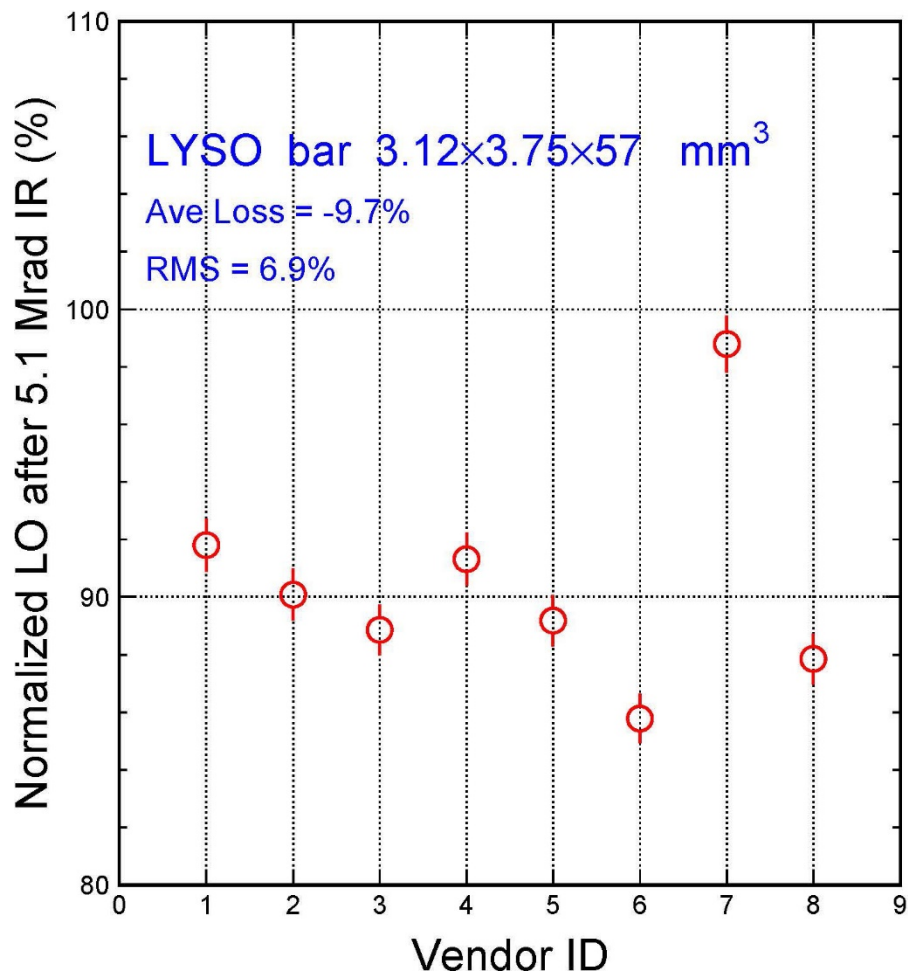




# Normalized LO and $\tau$



Average  $\delta LO/LO = -9.7\%$  Average  $\delta\tau/\tau = -0.9\%$



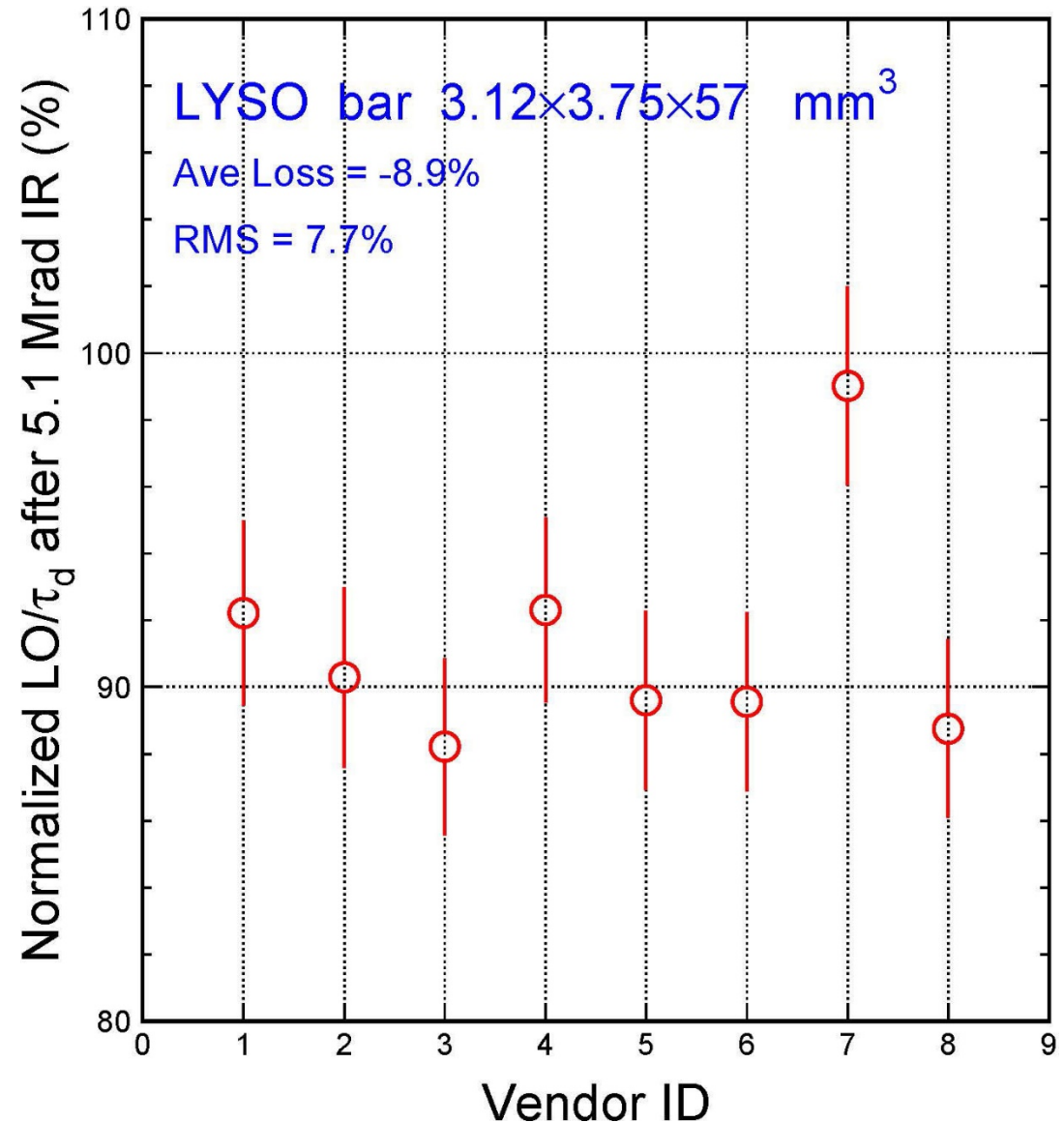


# Average $LO/\tau$ for Timing



Average  $LO/\tau$  degrades by 8.9%, indicating a less than 5% degradation in timing resolution

All samples are consistent, except sample 7 showing a smaller degradation than others





# Summary



Average variations are -5.7%, -9.7%, -0.9% and -8.9% for LT, LO,  $\tau$  and LO/ $\tau$  with divergence of 2.6%, 6.9%, 5.1% and 7.7%

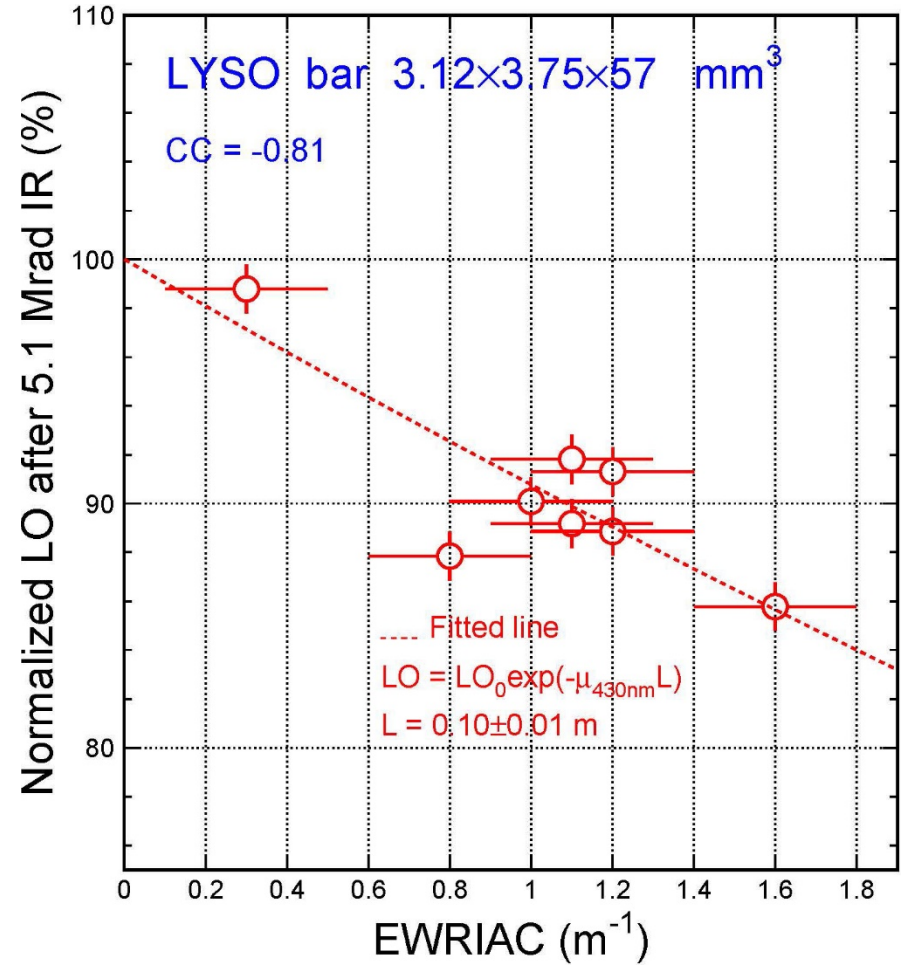
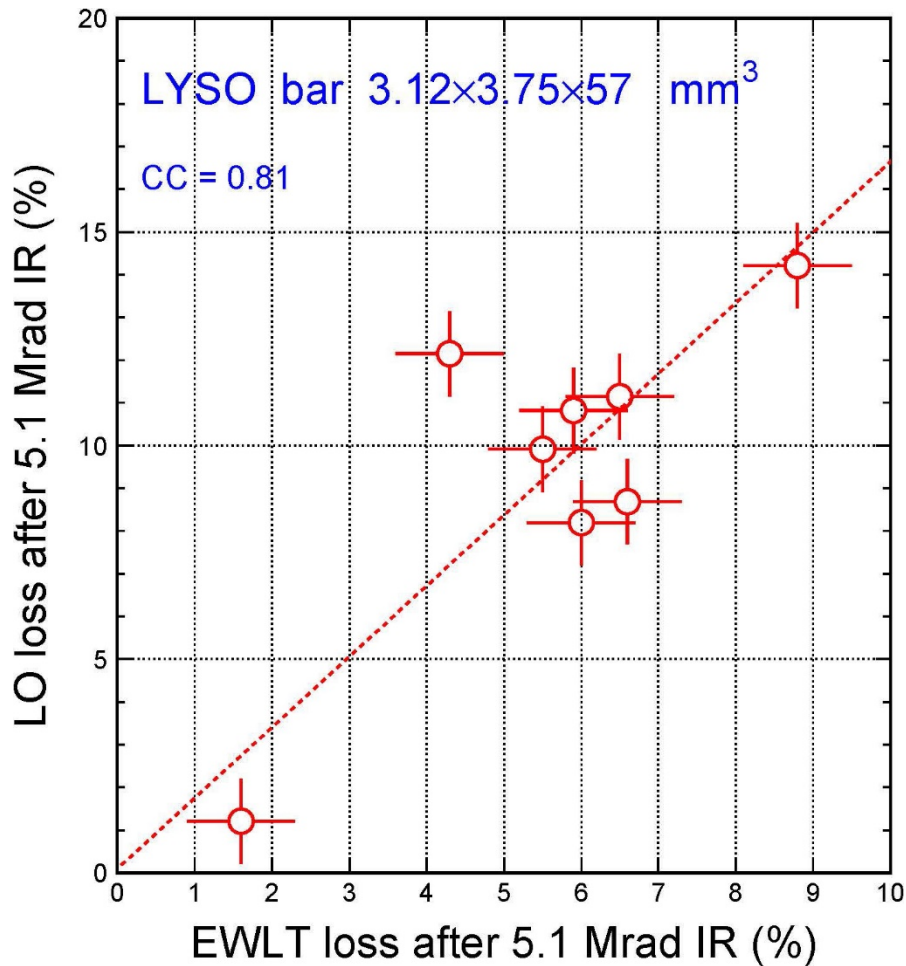
ID	Dose (Mrad)	EWLT (%)	200ns L.O. (p.e./MeV)	2000ns L.O. (p.e./MeV)	LO(200)/LO(2000)	Decay Time (ns)	LO(200)/ $\tau$
1	Before IR	78.1	1100	1134	97.0%	44.5	24.7
	5.1	73.4 (-6.0%)	1008 (-8.4%)	1045 (-7.8%)	96.5% (-0.5%)	44.3 (-0.4%)	22.8 (-7.9%)
2	Before IR	80.1	1207	1240	97.3%	45.0	26.8
	5.1	75.7 (-5.5%)	1080 (-10.5%)	1120 (-9.7%)	96.4% (-0.9%)	44.9 (-0.2%)	24.1 (-10.3%)
3	Before IR	81.5	1118	1135	98.5%	41.1	27.2
	5.1	76.2 (-6.5%)	988 (-11.6%)	1015 (-10.6%)	97.3% (-1.2%)	41.4 (+0.7%)	23.9 (-12.3%)
4	Before IR	78.6	983	1029	95.5%	46.2	21.3
	5.1	73.4 (-6.6%)	897 (-8.7%)	942 (-8.5%)	95.2% (-0.3%)	45.7 (-1.1%)	19.6 (-7.8%)
5	Before IR	81.3	1141	1160	98.4%	41.3	27.6
	5.1	76.5 (-5.9%)	1015 (-11.0%)	1037 (-10.6%)	97.9% (-0.5%)	41.1 (-0.5%)	24.7 (-10.6%)
6	Before IR	79.8	1145	1177	97.3%	45.1	25.4
	5.1	72.8 (-8.8%)	984 (-14.1%)	1015 (-13.8%)	96.9% (-0.4%)	43.2 (-4.2%)	22.8 (-10.3%)
7	Before IR	80.3	1137	1163	97.8%	42.9	26.5
	5.1	79.0 (-1.6%)	1127 (-0.9%)	1149 (-1.2%)	98.1% (0.3%)	42.8 (-0.2%)	26.3 (-0.6%)
8	Before IR	78.7	1057	1076	98.2%	39.0	27.1
	5.1	75.3 (-4.3%)	929 (-12.1%)	947 (-12.0%)	98.1% (-0.1%)	38.6 (-1.0%)	24.1 (-11.2%)
Ave	Before IR	79.8	1111	1139	97.5%	43.1	25.8
	5.1	<b>75.3 (-5.7%)</b>	<b>1004 (-9.7%)</b>	<b>1034 (-9.3%)</b>	<b>97.1% (-0.5%)</b>	<b>42.8 (-0.9%)</b>	<b>23.5 (-8.9%)</b>
RMS	Before IR	1.5%	5.6%	5.3%	0.9%	5.4%	7.5%
	5.1	2.6%	6.9%	6.6%	1.0%	5.1%	7.7%
Sys. Uncertainty		0.5%	0.7%	0.7%	1.0%	3%	3%



# LO vs. EWLT and EWRIAC



Good correlations between LO, EWLT and EWRIAC  
Average light path length: 10 cm for 5.7 cm bars



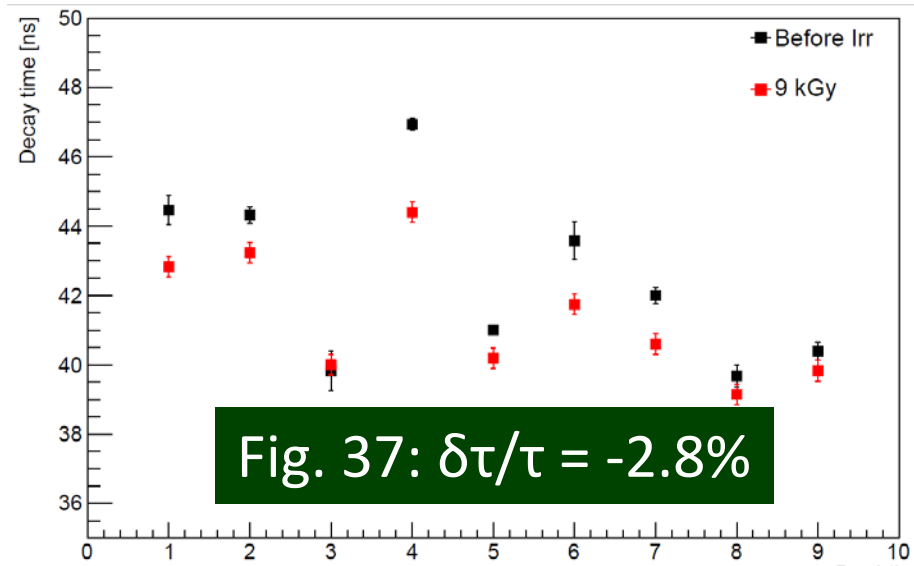
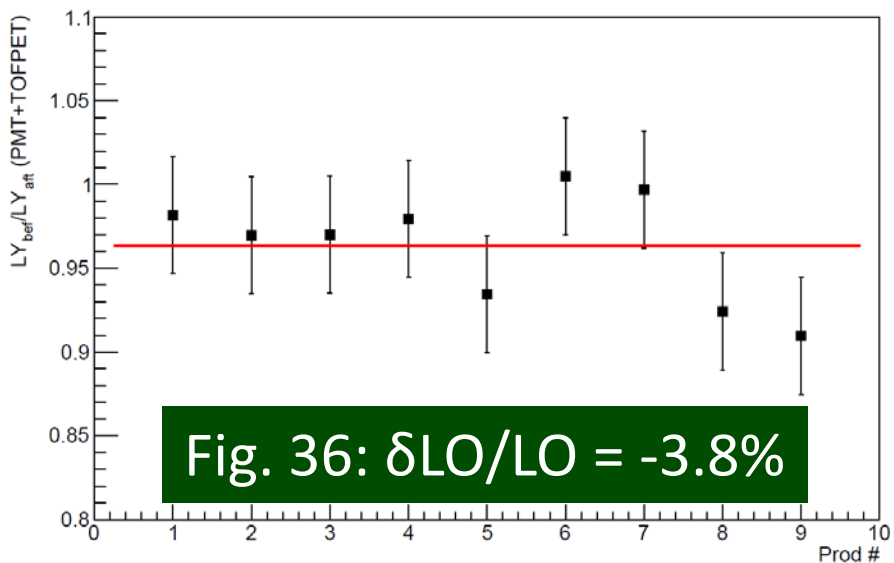




# Rome Data in CMS DN-2020/010



Following Marco's advice a one on one comparison between Caltech 5.1 Mrad data and Rome 0.9 Mrad data was made



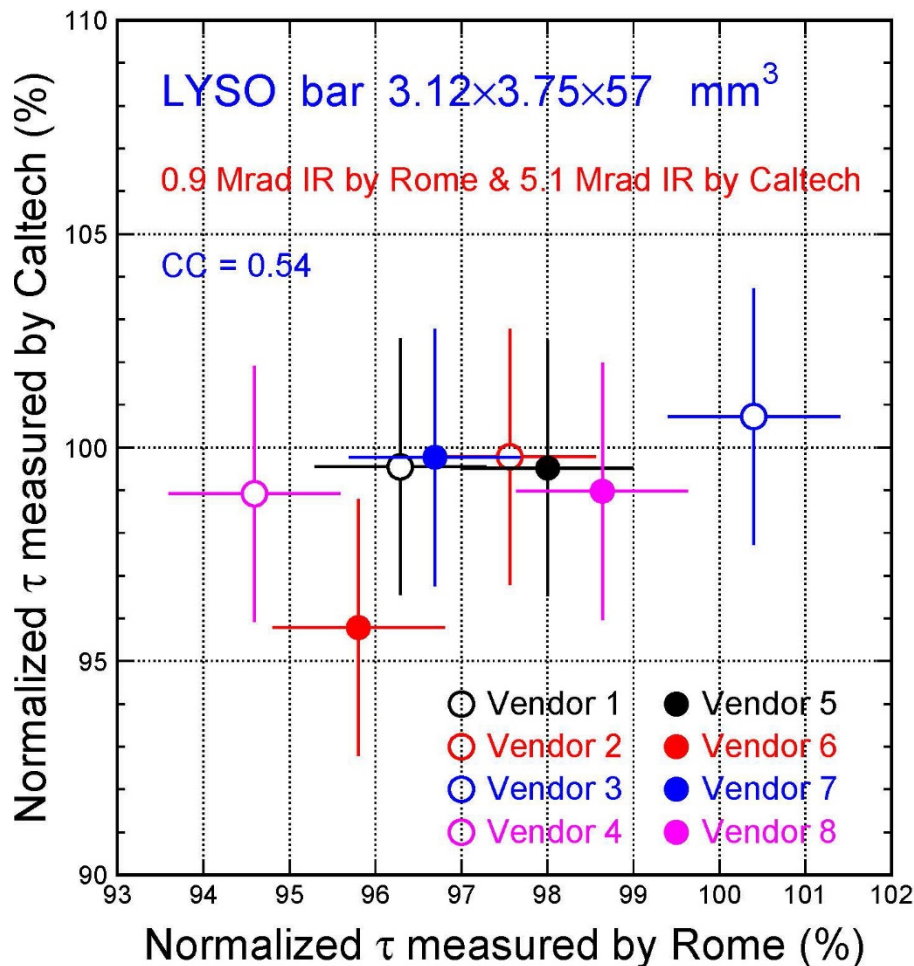
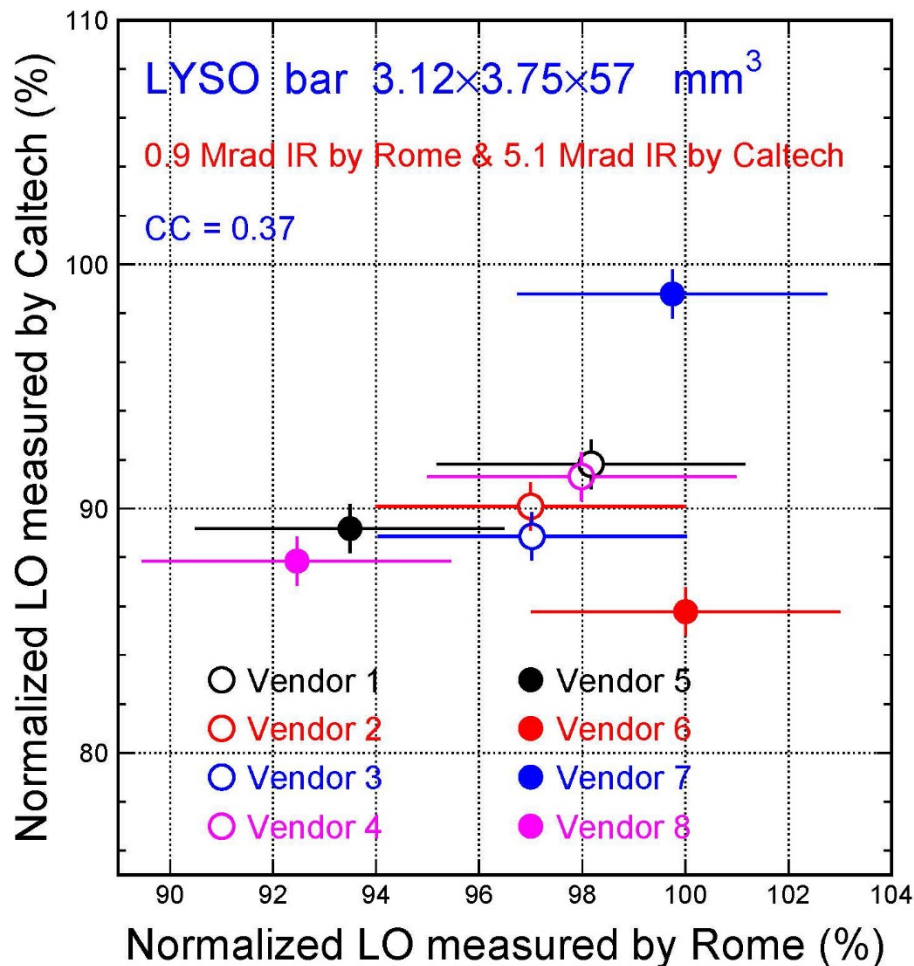
The average  $\delta LO/LO$  and  $\delta \tau/\tau$  are -3.8% -2.8% after 0.9 Mrad of Rome data are consistent with -9.7% and -0.9% after 5.1 Mrad of Caltech data. Note: Caltech data are for single samples, Rome data are the averages of multiple samples.



# Comparison: Normalized LO and $\tau$

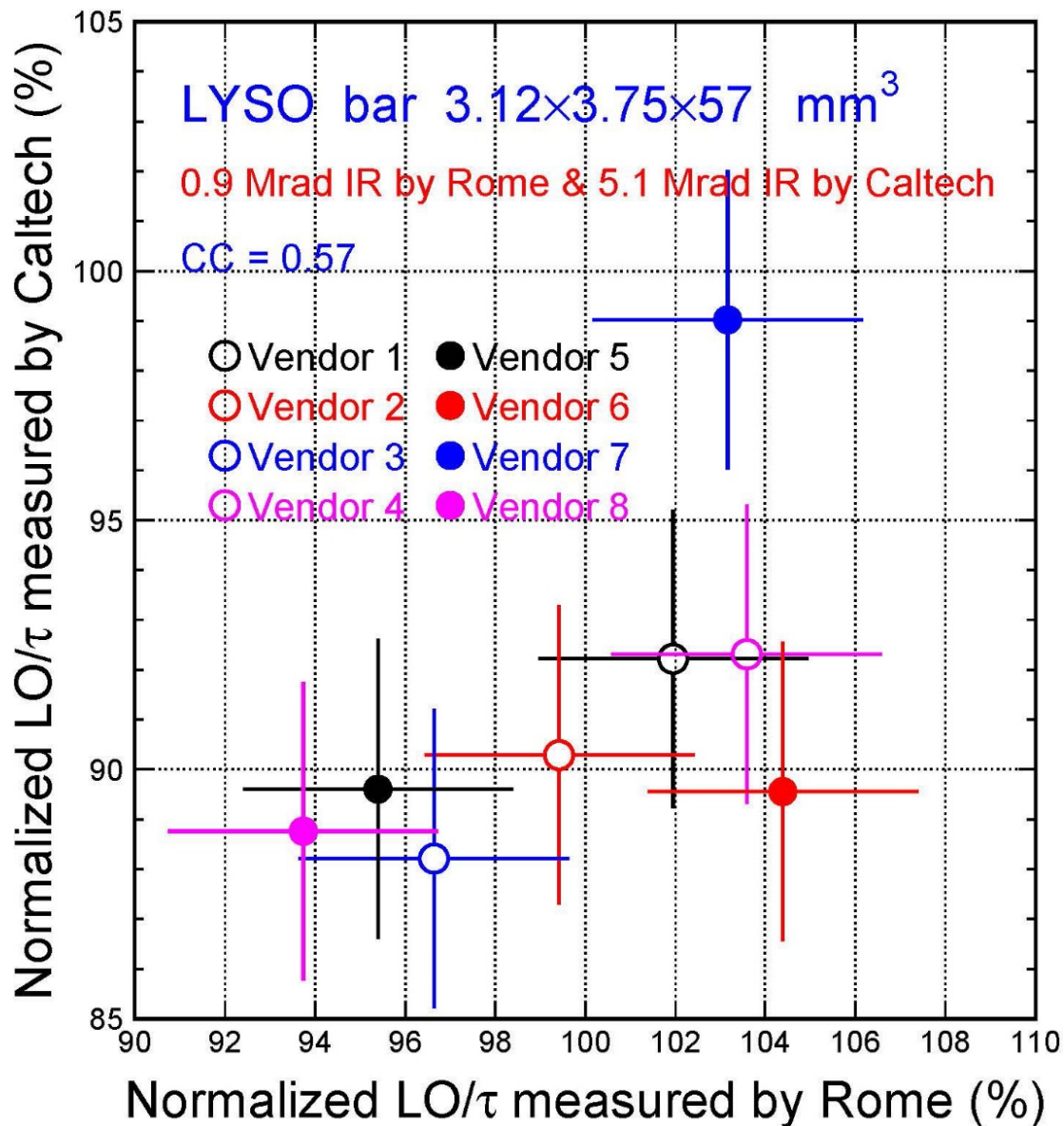


37%/54% correlations are less good compared to 79%/90% reported on 1/22 for the same samples measured in two labs





# Comparison: $LO/\tau$



57% correlation is also less good as compared to 79% reported on 1/22/20 for the same sample batch measured in two labs before irradiation



# Summary

- LT, LO and decay time were measured for LYSO samples from 8 vendors after 5.1 Mrad by Cs-137  $\gamma$ -rays.
- Average EWRIAC after 5.1 Mrad is  $1 \text{ m}^{-1}$  for LYSO bars from 8 vendors, which is consistent with published data from 20 cm samples. The light path length in BTL LYSO bars is about 10 cm.
- Average variation of LT, LO,  $\tau$  and LO/ $\tau$  is -5.7, -9.7, -0.9 and -8.9% respectively. The timing resolution after 5.1 Mrad is expected to degrade by 4.5% with a divergence of 7.7% for 8 vendors.
- Sample 7 shows less degradation in LO/ $\tau$  than others, maybe worth a further investigation.
- Overall variations in LO and  $\tau$  are consistent between Caltech (5.1 Mrad) and Rome (0.9 Mrad) data. Vendor correlations are not as good as the 1/22/20 report for the same samples.
- While not final, TF:n and TF:p seem not possible at LANSCE this year. Alternative facilities are under investigation.

Acknowledgements: DOE HEP Award DE-SC0011925



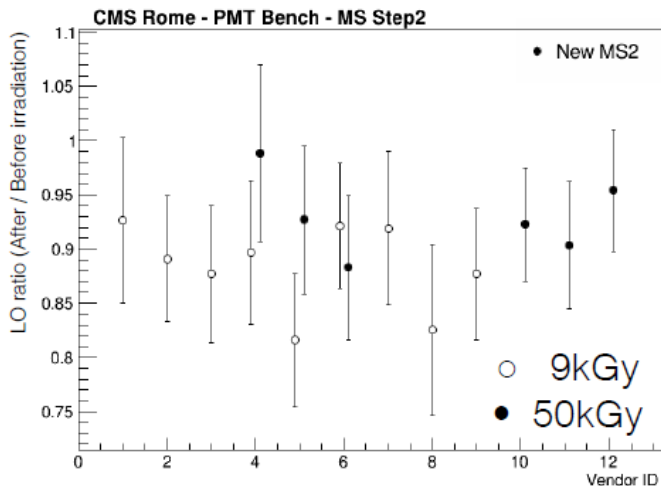
# Rome Data (7/31/20)



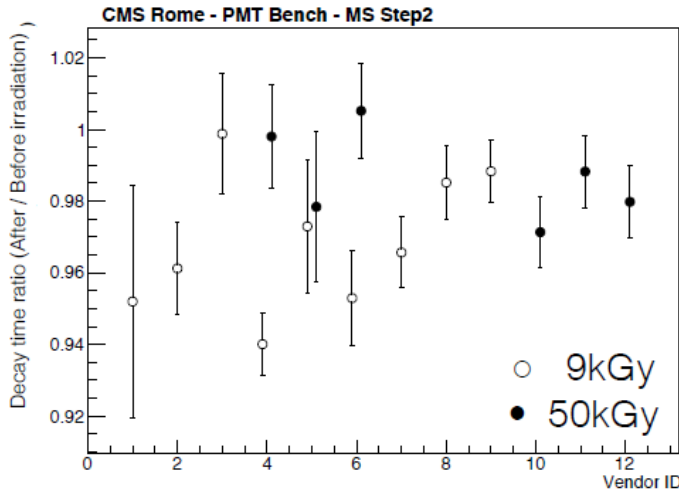
## Bars: effects of irradiation

- Light output loss after irr. at  $\approx 10\%$  level for all vendors It is about 1~2%
- Decay time reduces for almost all producers (reduction up to  $\approx 5\%$ )

Light output (LO) ratio (After/Before Irr.)



Decay time ratio (After/Before Irr.)



\* only 1 or 2 crystal bars per vendor in these plots (1 or 2 measurements per point)