



Result of Eight 2019 BTL LYSO Bars after 5.1 Mrad and $3.2 \times 10^{14} n_{eq}/cm^2$

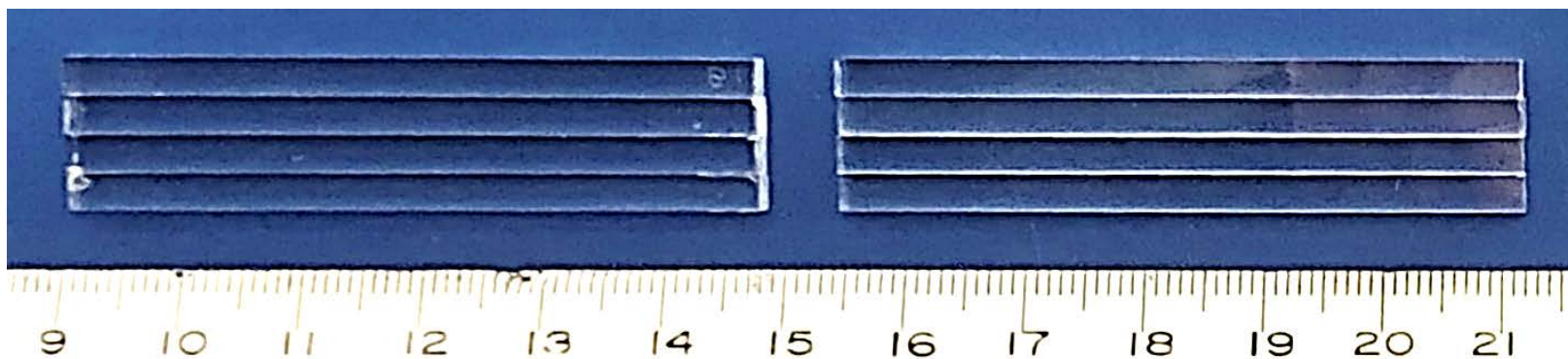
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LYSO Bars from Eight Vendors



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

Experiments

Longitudinal transmittance (LT), light output (LO) and decay time (τ) measured before and after 5.1 Mrad and $3.2 \times 10^{14} n_{eq}/cm^2$

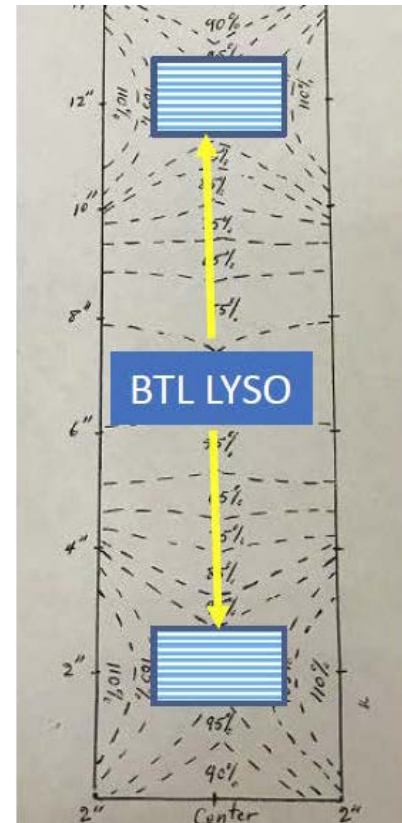
LT/LO/ τ , RIN, PL intensity/decay @ -35/-60 °C, and LT/LO/ τ after 5.1 Mrad were reported on 1/22/20, 3/25/20, 7/22/20, and 8/26/20, respectively



5.1 Mrad by Cs-137 at Caltech



8 LYSO bars irradiated under 21 krad/h to 5.1 Mrad

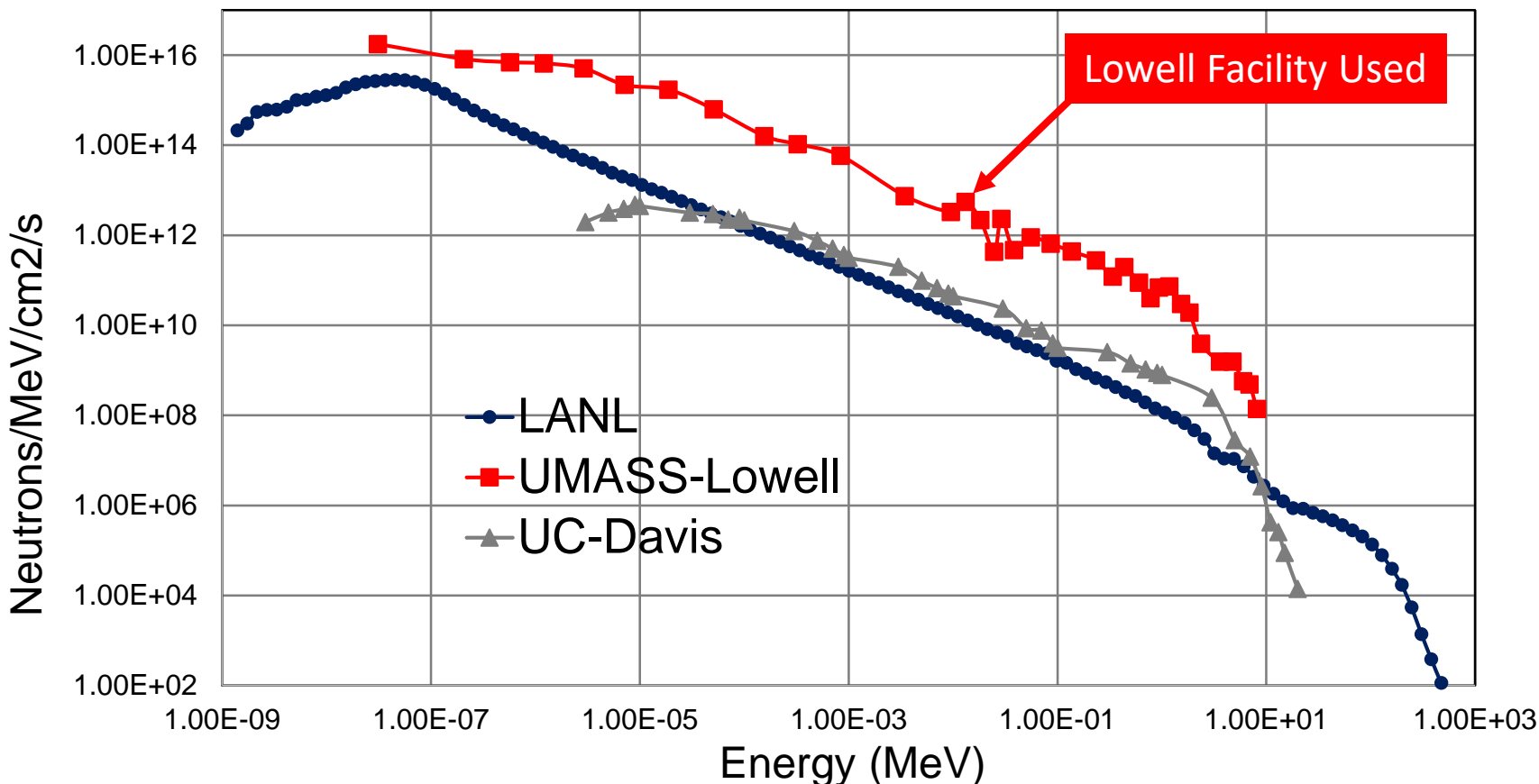




Neutron Spectra in 3 Facilities



$3.2 \times 10^{14} n_{eq}/cm^2$ @ $8.1 \times 10^{10} n_{eq}/cm^2/s$ and 42 krad background



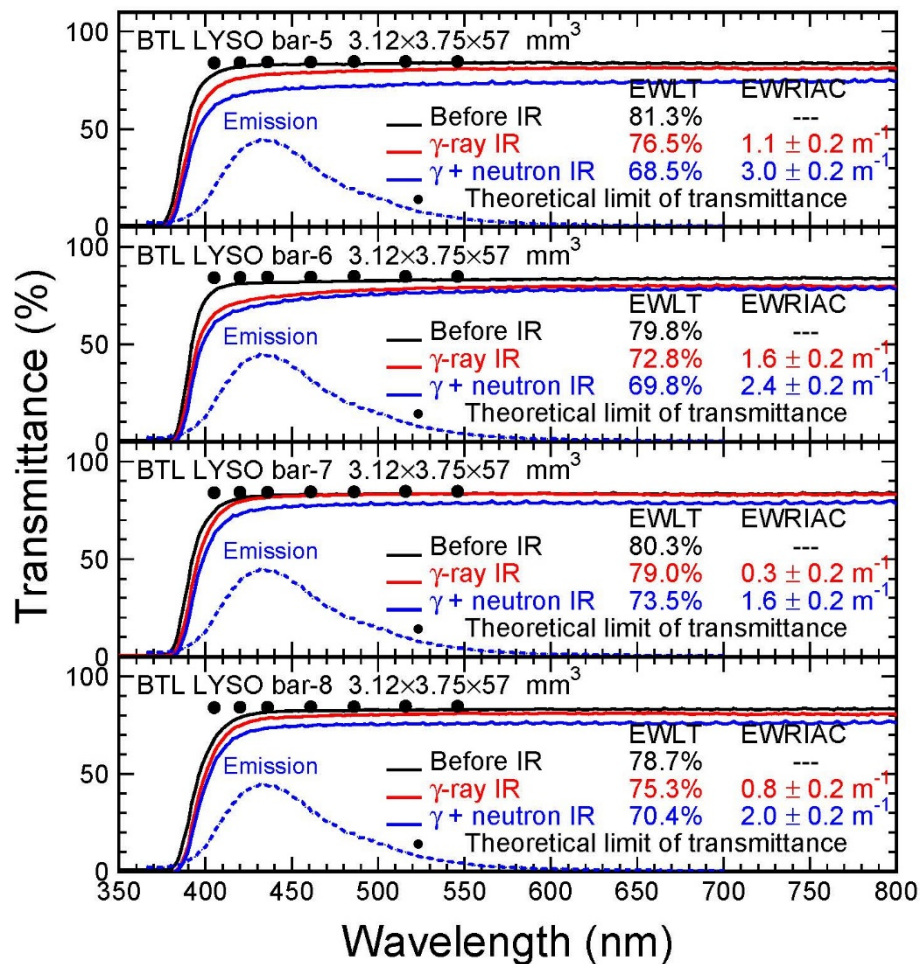
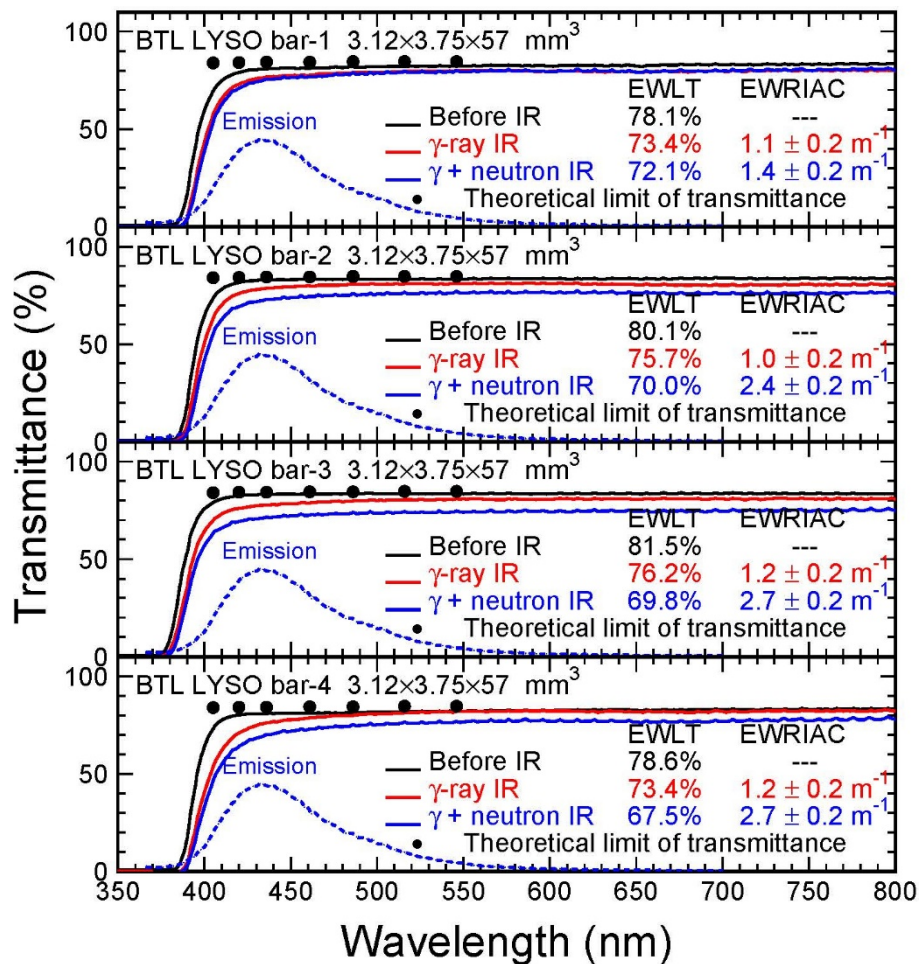
The neutron fluence for the Lowell irradiation was measured utilizing ASTM E-265 "Measuring Reaction Rates and Fast Neutron Fluence by Radioactivation of Sulfur-32" and correlated to the measured reactor power level. All irradiation conditions required under ASTM 722 were met, this includes: neutron fluence, distribution and uncertainty. The Average Integrated Neutron Fluence (1 MeV Si Eq.) reported in this document reflects these factors.



LT after 5.1 Mrad & $3.2 \times 10^{14} \text{ n}_{\text{eq}}/\text{cm}^2$



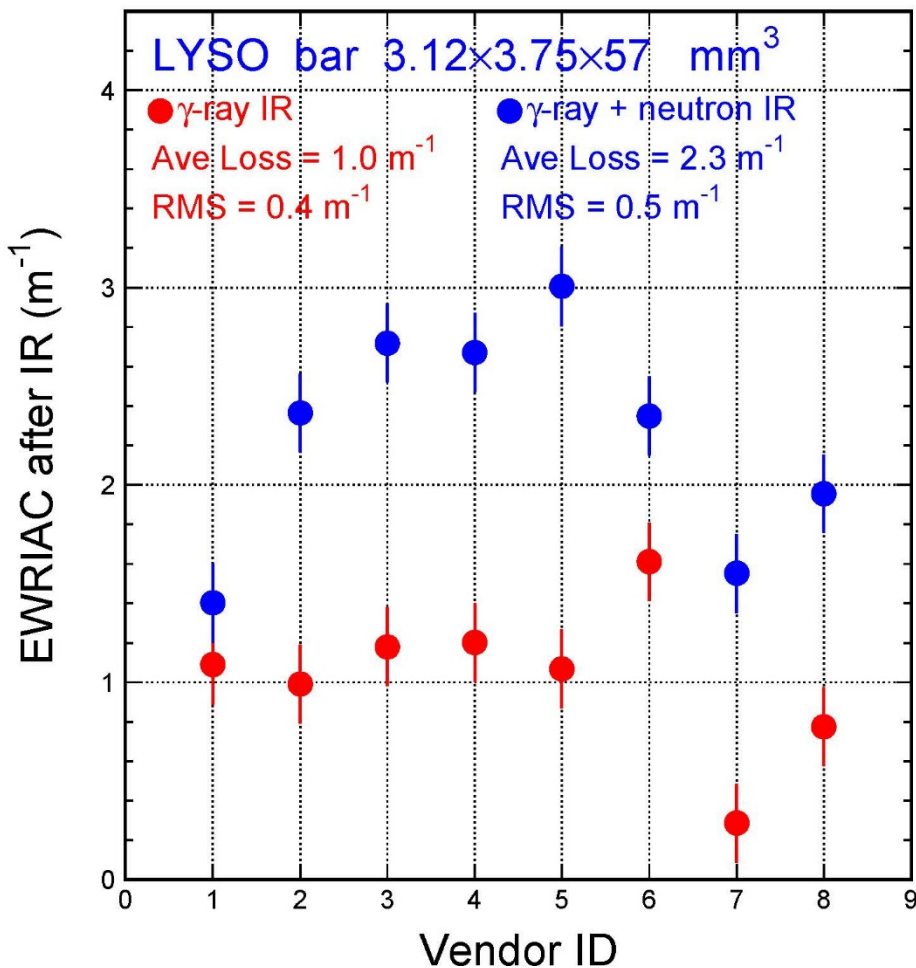
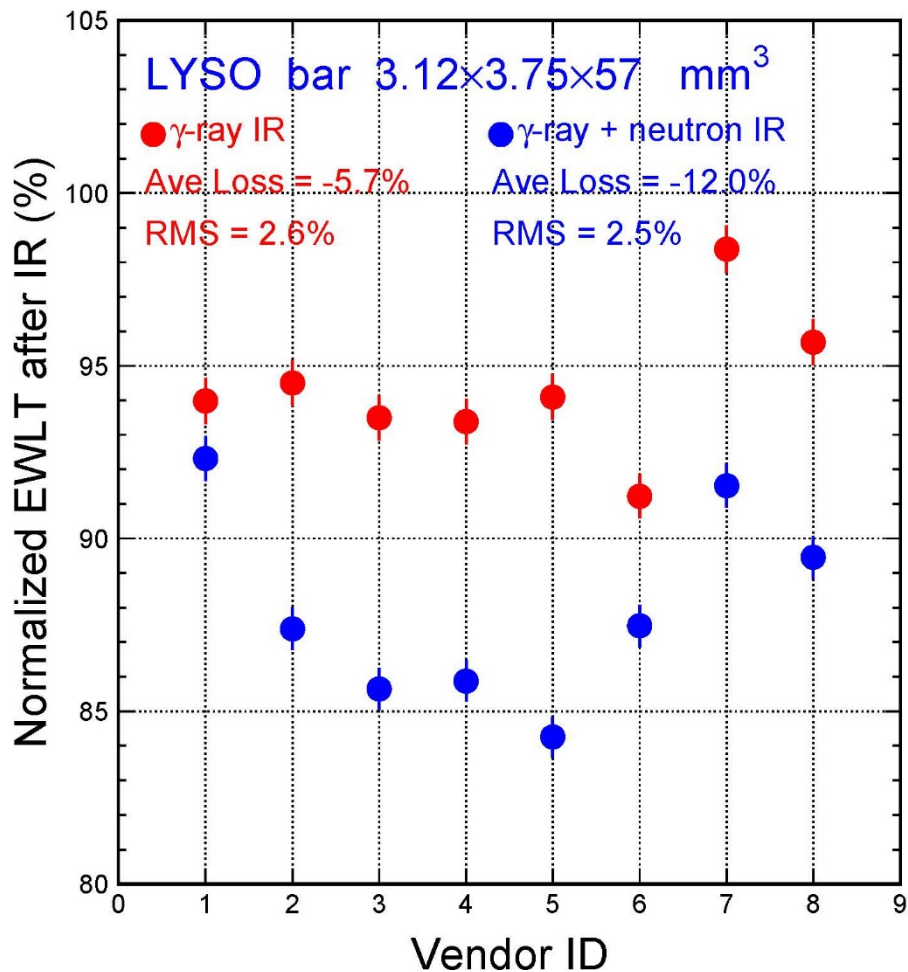
Radio-luminescence weighted LT (EWLT) and radiation induced absorption coefficient (EWRIAC) are measured with a spectrophotometer



Normalized EWLT and EWRIAC



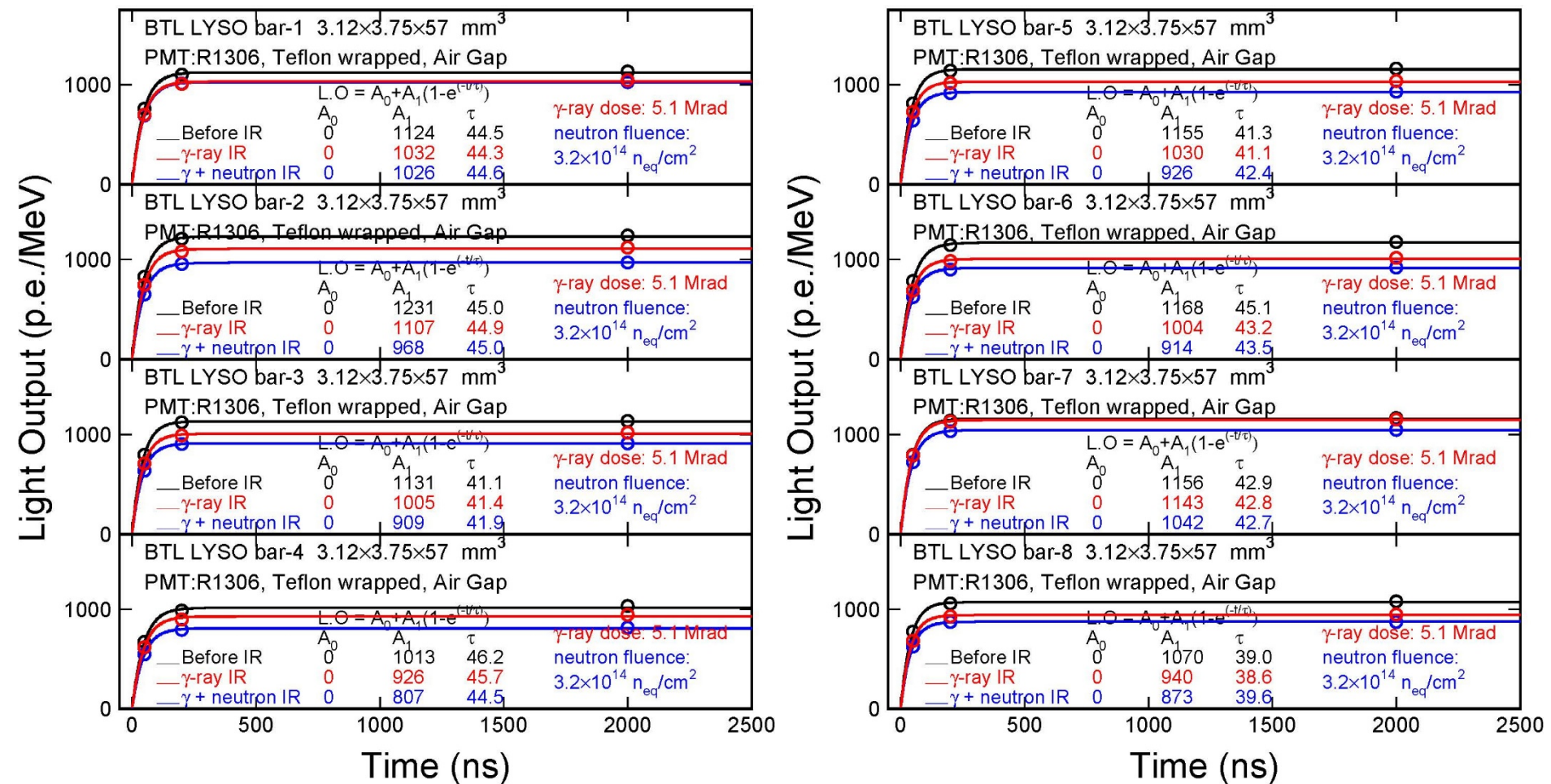
Average EWLT loss and EWRIAC: -5.7% and 1.0 m⁻¹ after 5.1 Mrad,
and -12.0% and 2.3 m⁻¹ after 5.1 Mrad plus 3.2×10¹⁴ n_{eq}/cm²



LO & τ after 5.1 Mrad & $3.2 \times 10^{14} n_{eq}/cm^2$



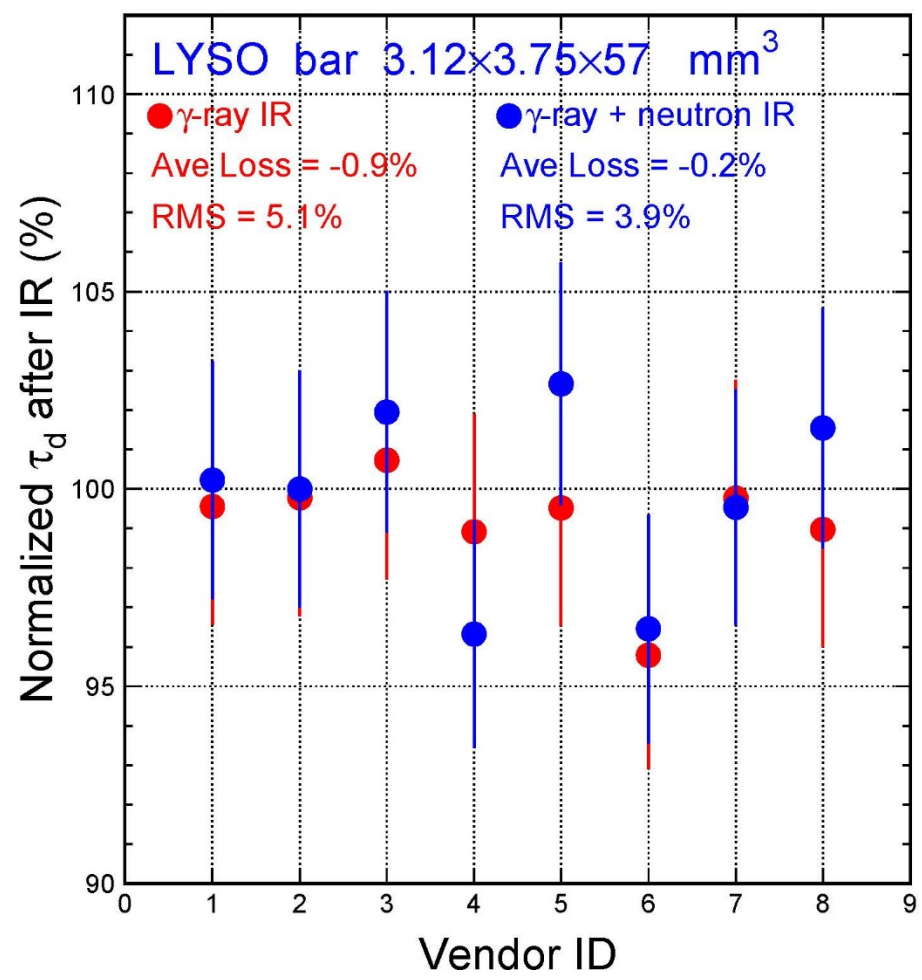
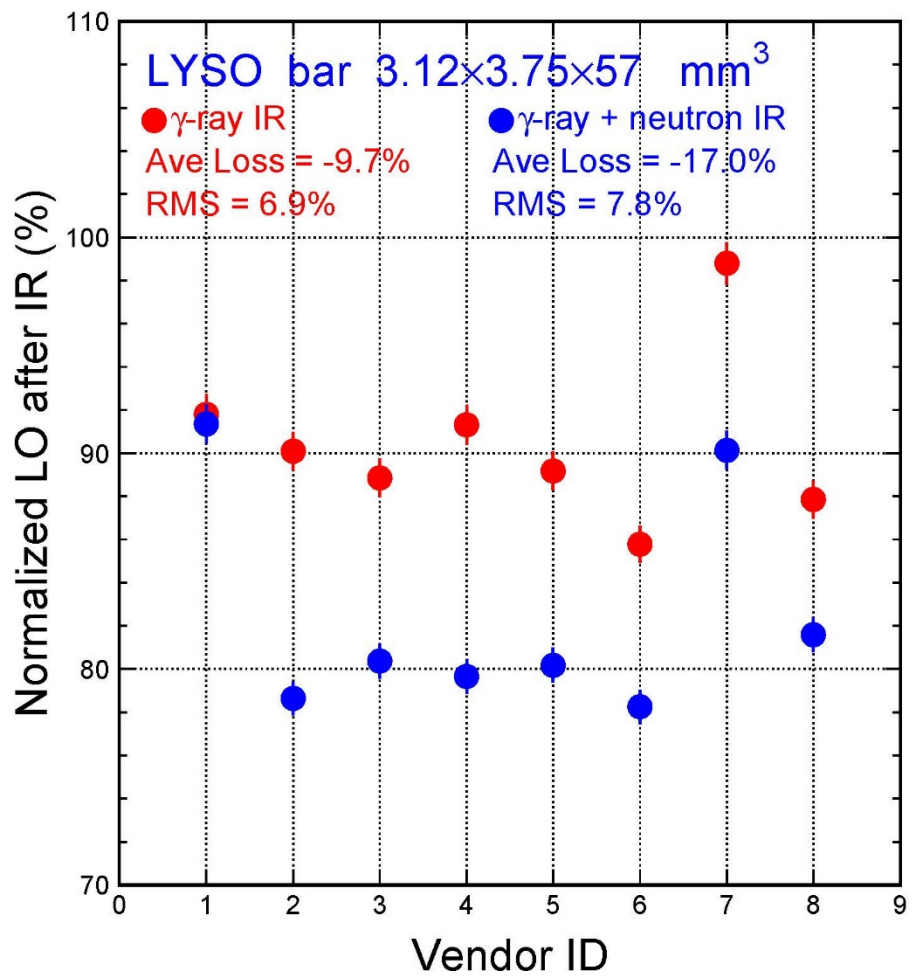
LYSO bars in Teflon block and with an air gap coupling to R1306 PMT triggered by a Na-22 source at the crystal center



Normalized LO and τ



Average $\delta LO/LO$ and $\delta\tau/\tau$: -9.7% and -0.9% after 5.1 Mrad,
and -17.0% and -0.2% after 5.1 Mrad plus $3.2 \times 10^{14} n_{eq}/cm^2$



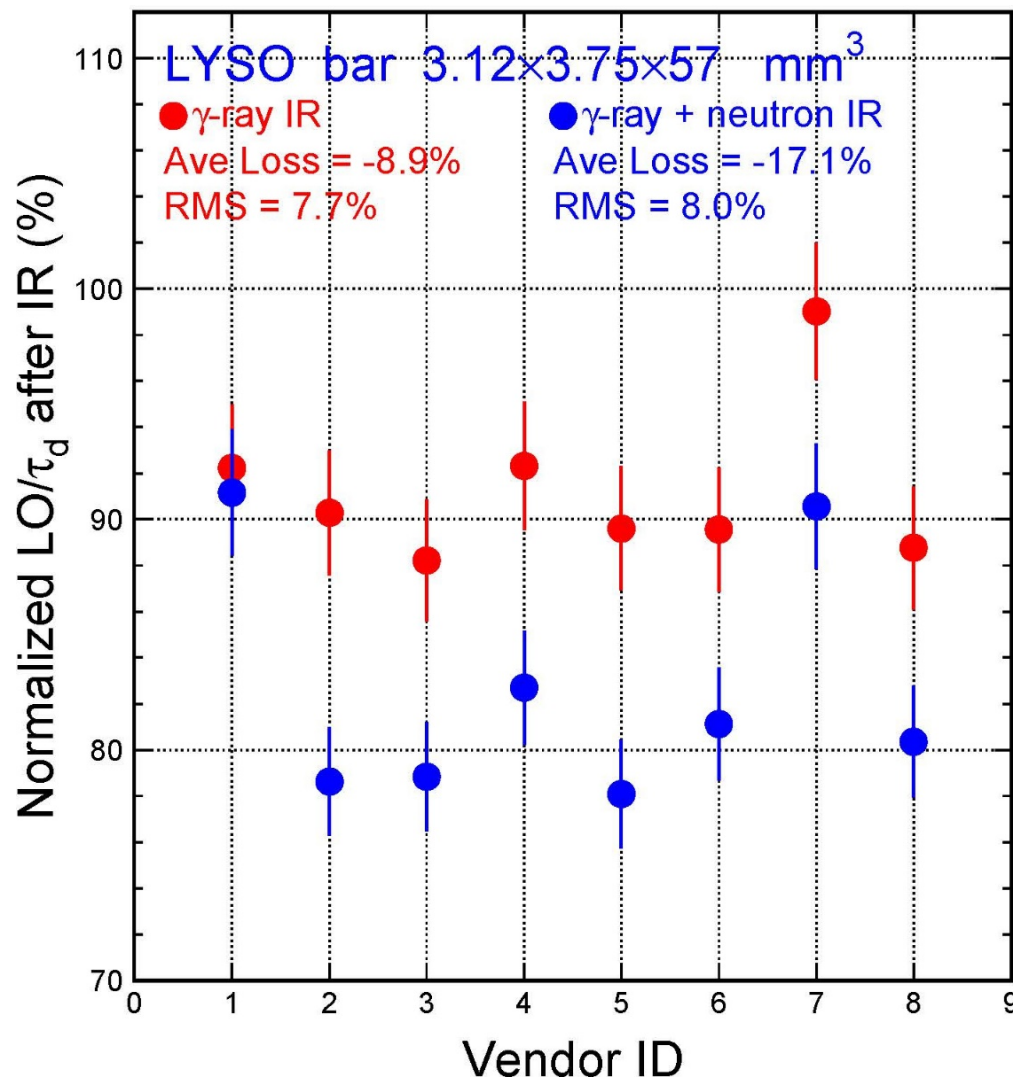


LO/ τ after 5.1 Mrad & 3.2×10^{14} n_{eq}/cm^2



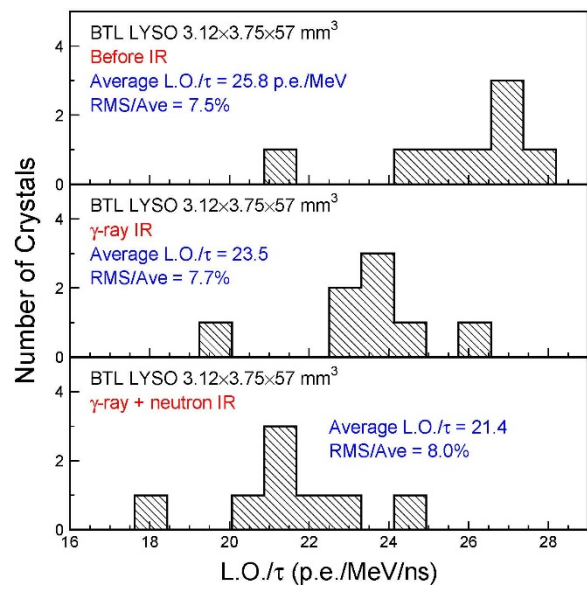
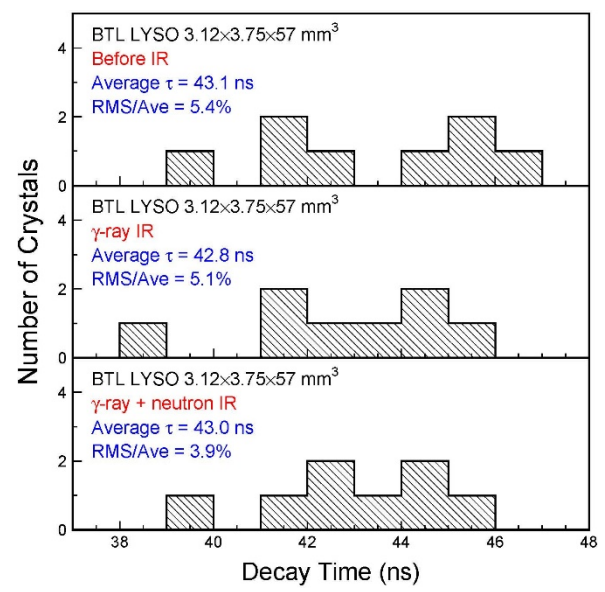
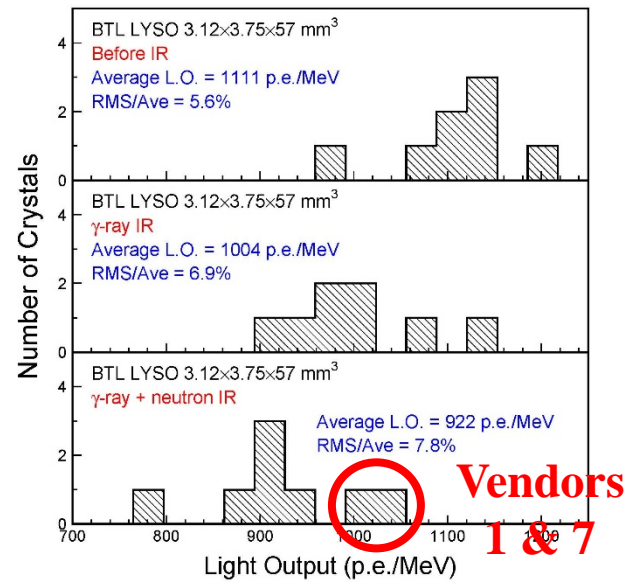
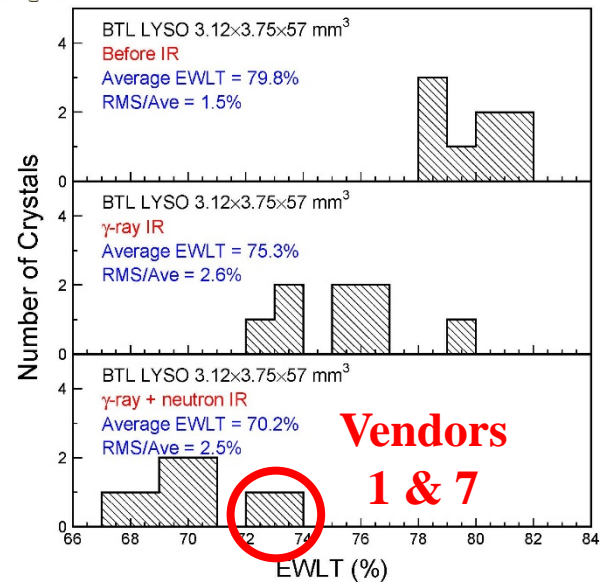
Average LO/ τ changes by -8.9%/-17% after 5.1 Mrad plus 3.2×10^{14} n_{eq}/cm^2 , indicating a less than 5%/9% degradation in timing resolution

All samples are consistent, except samples 1 and 7 showing a smaller degradation than others





After 5.1 Mrad & 3.2×10^{14} n_{eq}/cm^2

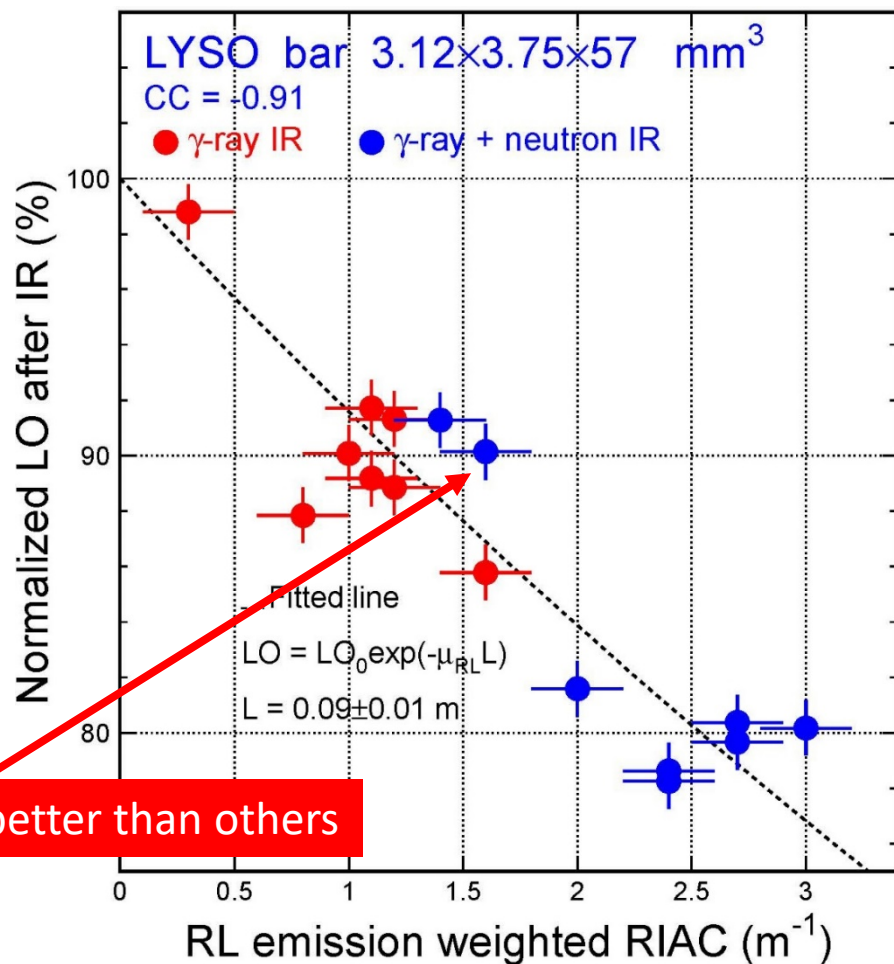
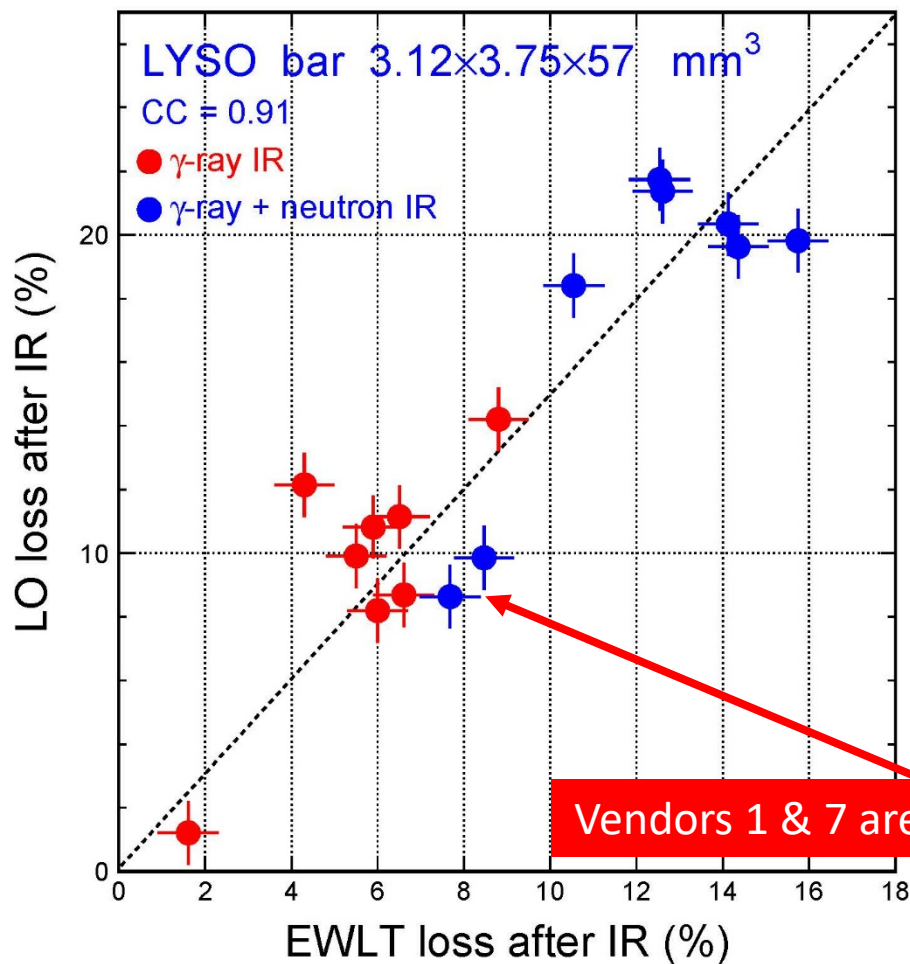


Average variations are -12%, -17%, -0.2%, and -17% for LT, LO, τ and LO/τ with divergence of 2.5%, 7.8%, 3.9% and 8.0% for 8 samples

LO vs. EWLT and EWRIAC



Good correlations between LO, EWLT and EWRIAC indicate that LO loss is due to radiation induced absorption with a mean light path of 9 cm



Vendors 1 & 7 are better than others



Summary



LT, LO and τ were measured for the 2019 LYSO bars from 8 vendors after 5.1 Mrad and $3.2 \times 10^{14} n_{eq}/cm^2$.

The average degradation of LT, LO, τ and LO/ τ for 8 samples after 5.1 Mrad and $3.2 \times 10^{14} n_{eq}/cm^2$ is 12%, 17%, 0.2% and 17%, respectively. The timing resolution is expected to degrade by 9% with a divergence of 4% among 8 vendors. Vendors 1 & 7 are better than others.

γ -ray and neutron induced LO loss is due to induced absorption with a mean path of 9 cm in BTL LYSO bars.

These eight 2019 samples were shipped to Fermilab ITA on April 30 for a 400 MeV proton irradiation to $2.5 \times 10^{13} p/cm^2$ together with eighteen 2021 LYSO bars of 9 each with and without ESR wrapping.

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