Result of Eight 2019 BTL LYSO Bars after 5.1 Mrad, 3.2×10^{14} n_{eq}/cm^2, and 1.9×10^{13} p/cm^2

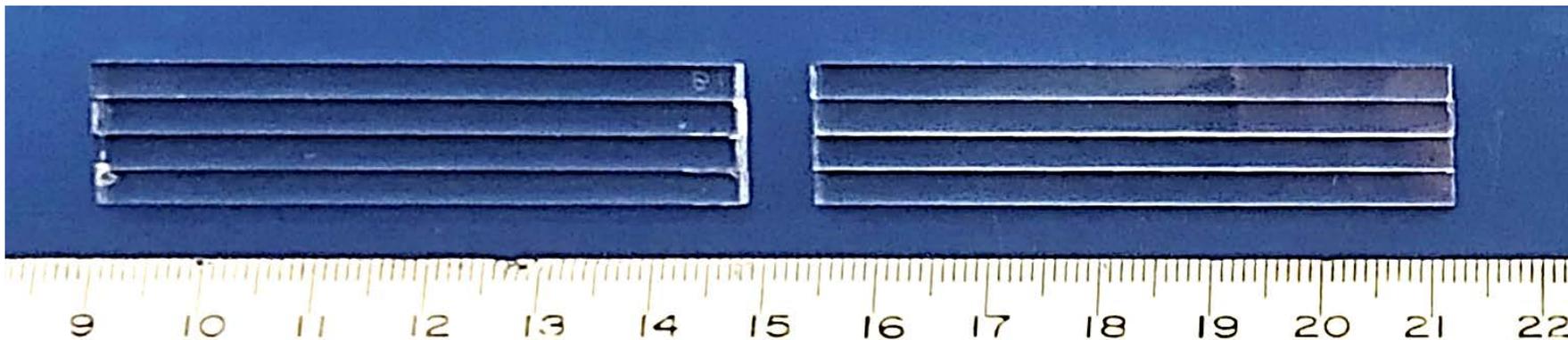Chen Hu[1], Liyuan Zhang[1], Ren-Yuan Zhu[1],
Adi Bornheim[1], Maria Spiropulu[1], Jason Trevor[1],
Evan D. Niner[2], Mandy Kiburg[2] and Jason St. John[2]

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BTL LYSO Bars from 8 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			
Sent to ITA: 4/30/20, 1.9×10^{13} p/cm^2: 6/16/21, back to Caltech: 7/22/21			

Experiments

Longitudinal transmittance (LT), light output (LO) and decay time (τ) measured before and after 5.1 Mrad, 3.2×10^{14} n$_{eq}$/cm^2 and 1.9×10^{13} p/cm^2

LT/LO/τ, RIN, PL@-35/-60 ^{o}C, 5.1 Mrad, 3.2×10^{14} n$_{eq}$/cm^2, and ITA reported on 1/22/20, 3/31/20, 7/22/20, 8/26/20, 5/19/21 and 7/7/21, respectively

Error Weighted Average Fluence

Fluence: error weighted average of Be-7 & Na-22 from activated Al foils
Eight 2019 BTL LYSO bars in the G3 group in Liyuan's report on 3/18/22

Group	Front EW Avg Fluence (cm^{-2})	± Error (cm^{-2})	Back EW Avg Fluence (cm^{-2})	± Error (cm^{-2})	Average Fluence (cm^{-2})	± Error (cm^{-2})
1	2.16E+13	7.2E+11	1.59E+13	6.9E+11	1.88E+13	5.0E+11
2	1.43E+13	6.8E+11	9.49E+12	7.1E+11	1.19E+13	4.9E+11
3	**1.91E+13**	7.6E+11	1.30E+13	7.5E+11	1.61E+13	5.3E+11

Fluence: 2.2, 1.4 and 1.9×10^{13} respectively for G1, G2 and G3

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Transmittance for 8 2019 Bars

**Radio-luminescence weighted longitudinal transmittance (EWLT)
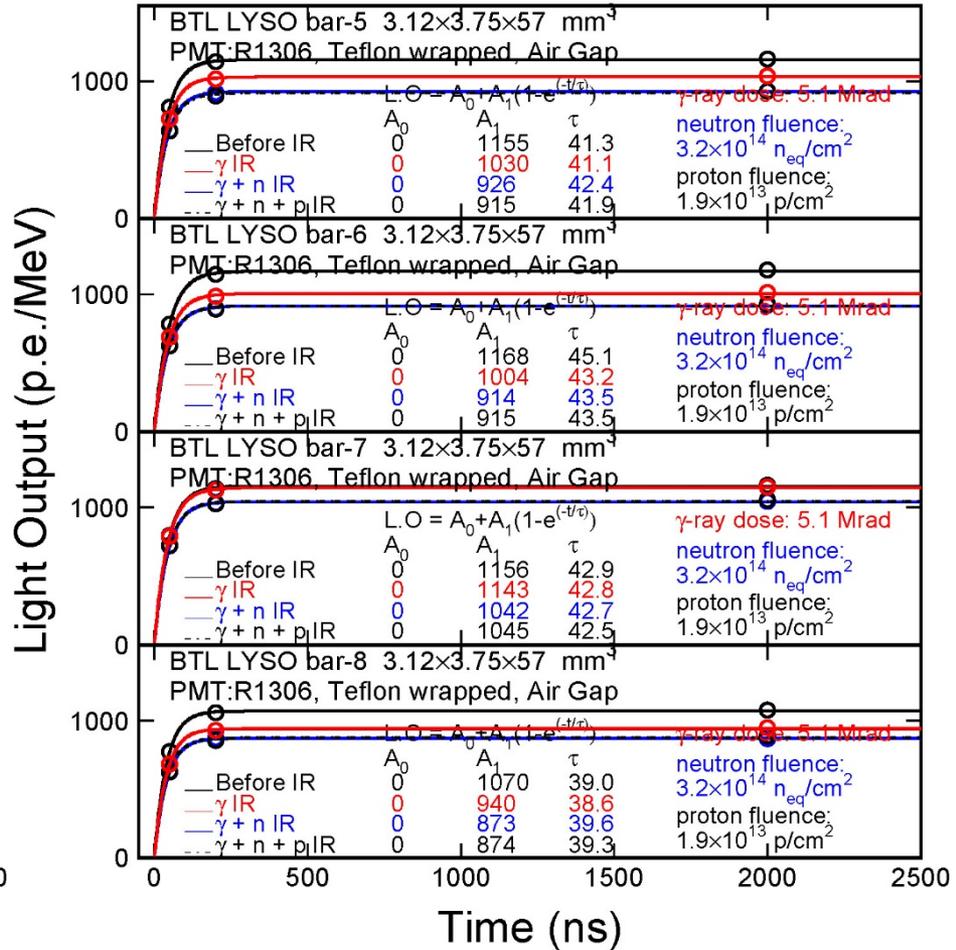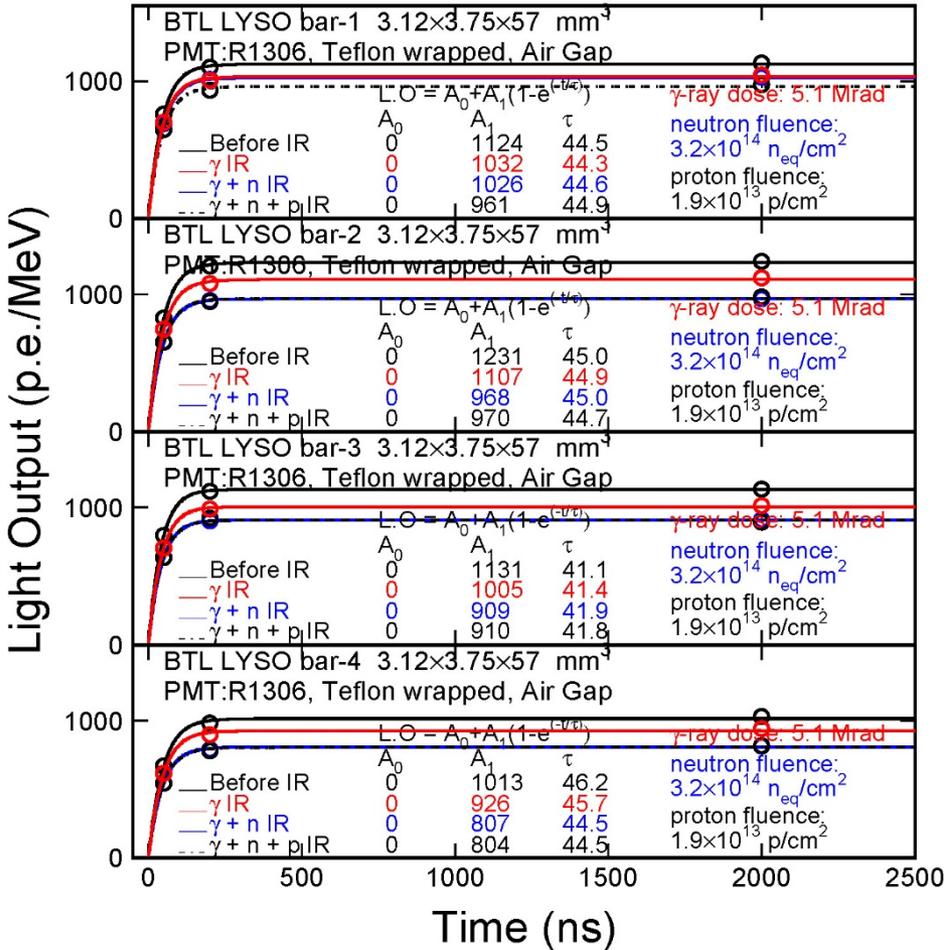Radiation induced absorption coefficient (EWRIAC)**
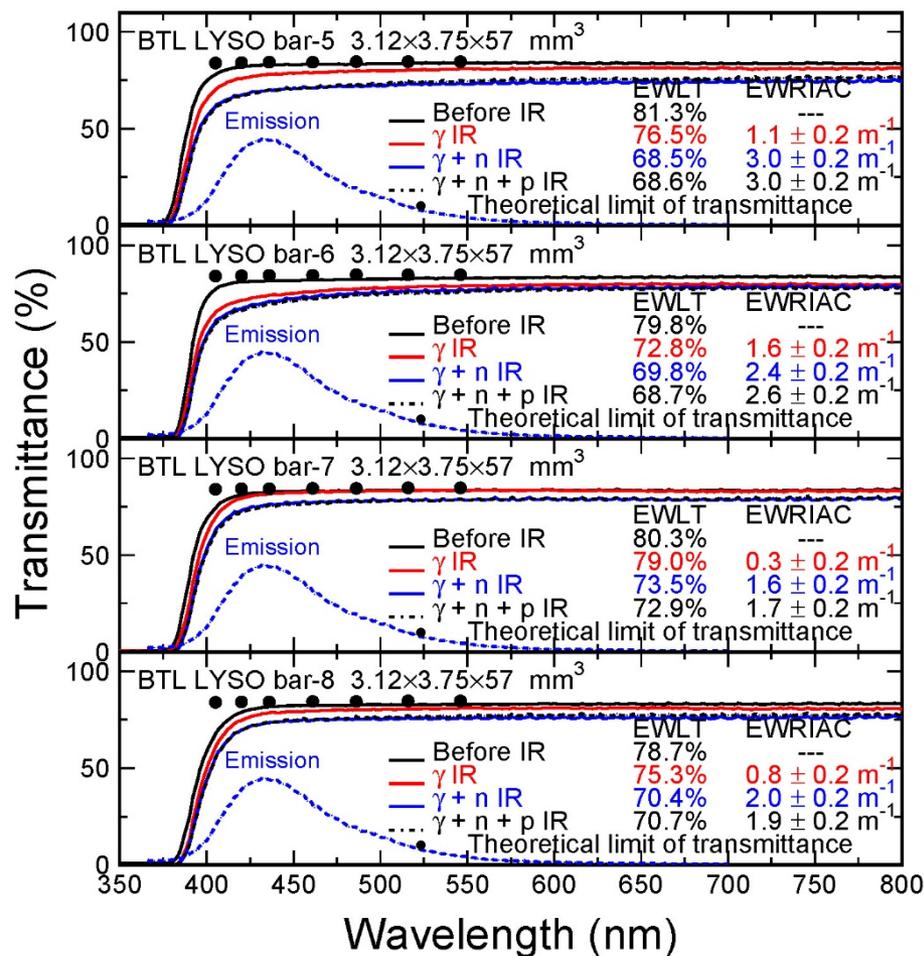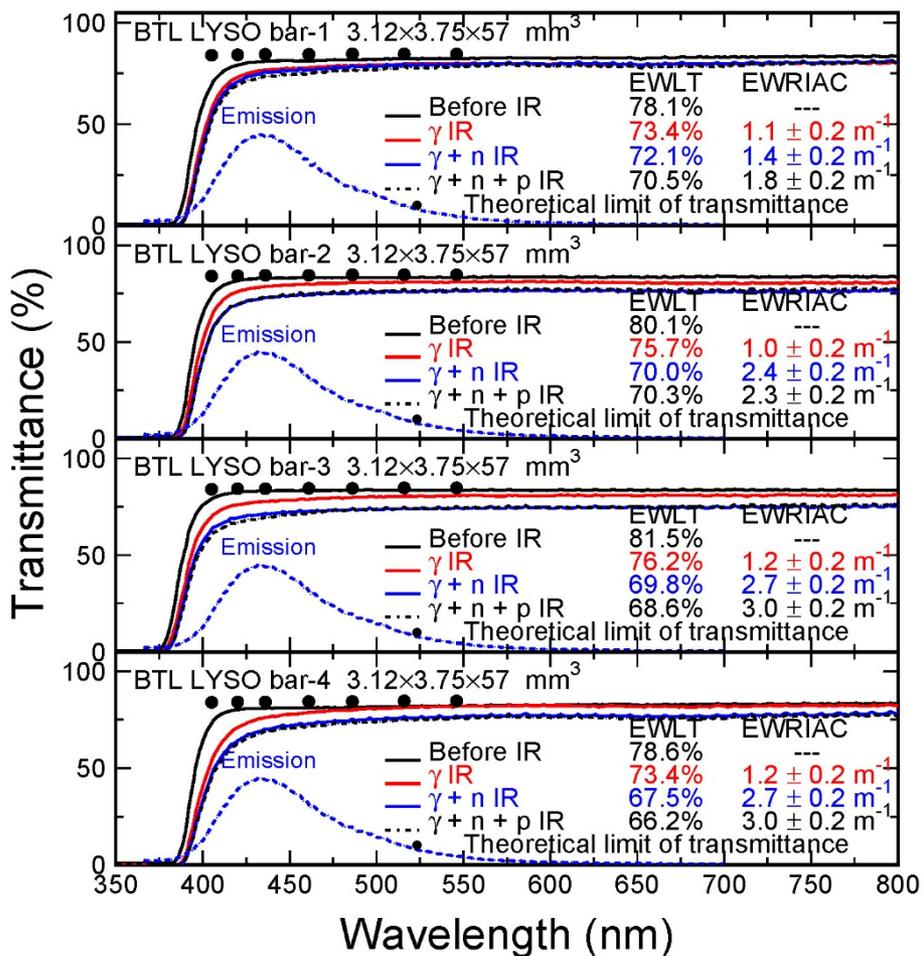
Light Output for 8 2019 Samples

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

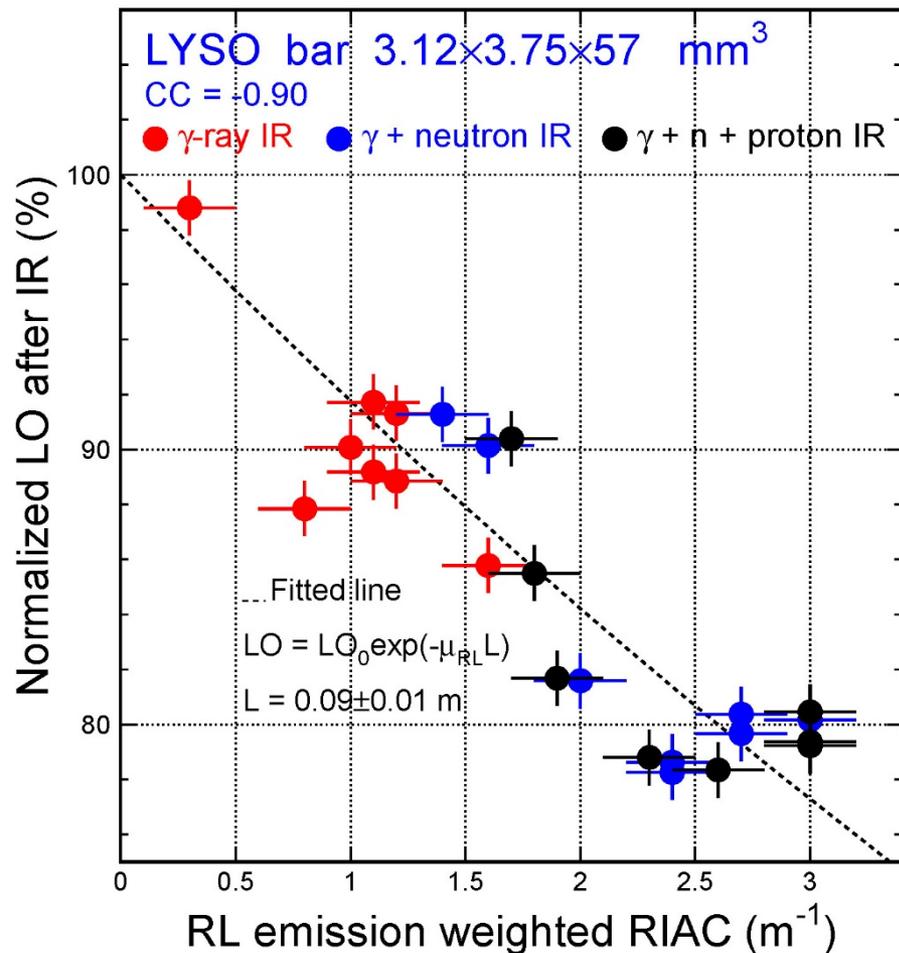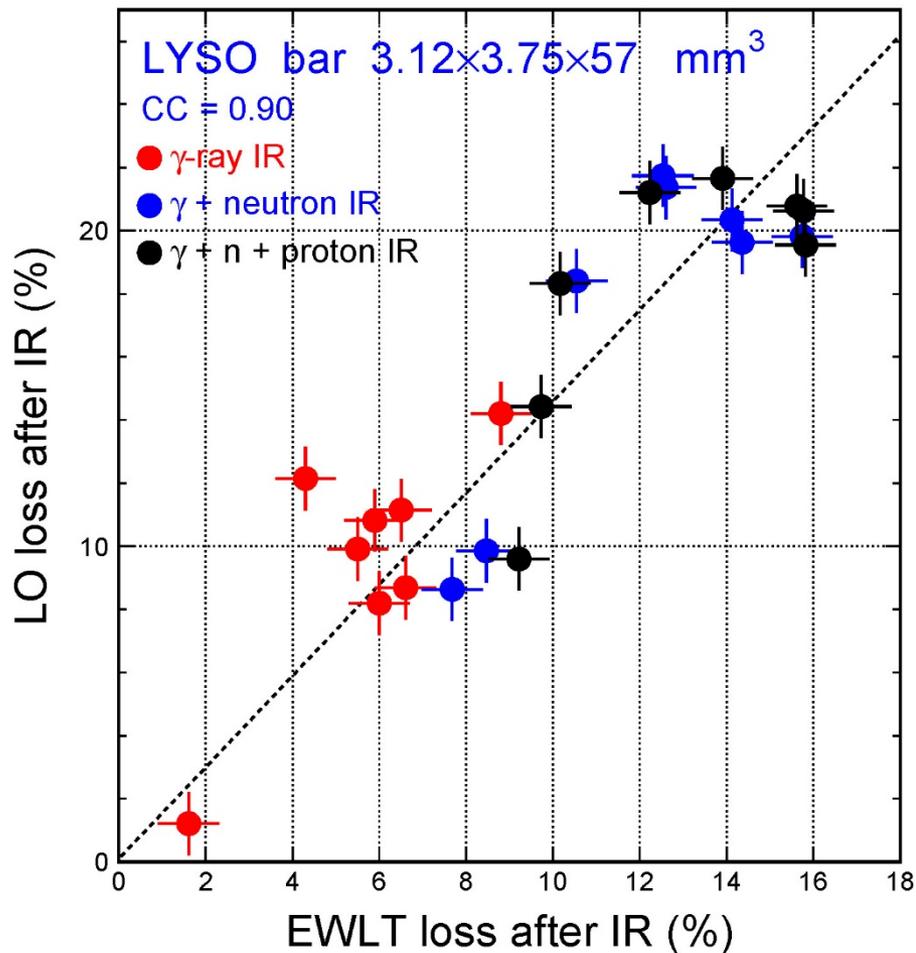Presentation by Chen Hu of Caltech in CMS BTL General Meeting

Light Output vs EWLT & 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
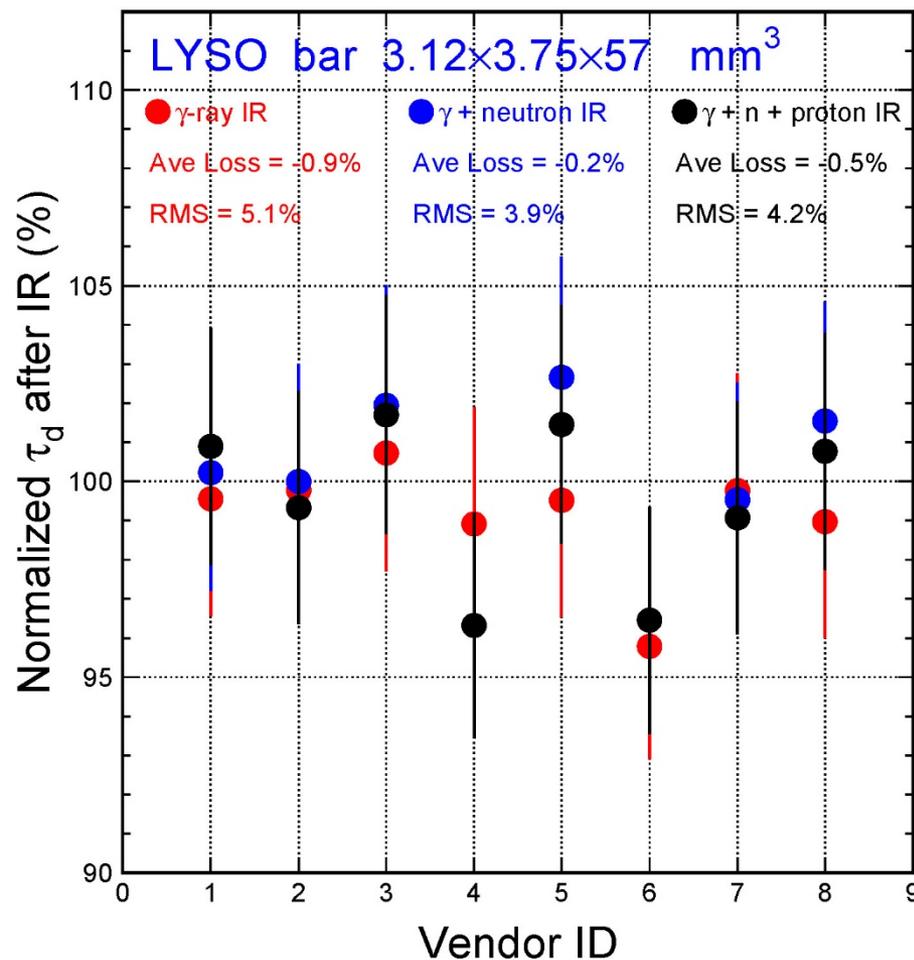

LYSO bar 3.12×3.75×57 mm^3
CC = 0.90
● γ-ray IR
● γ + neutron IR
● γ + n + proton IR

LO loss after IR (%) vs EWLT loss after IR (%)

LYSO bar 3.12×3.75×57 mm^3
CC = -0.90
● γ-ray IR   ● γ + neutron IR   ● γ + n + proton IR

Fitted line
$LO = LO_0 exp(-\mu_{RL}L)$
$L = 0.09 \pm 0.01$ m

Normalized LO after IR (%) vs RL emission weighted RIAC (m^{-1})

Normalized EWLT and EWRIAC
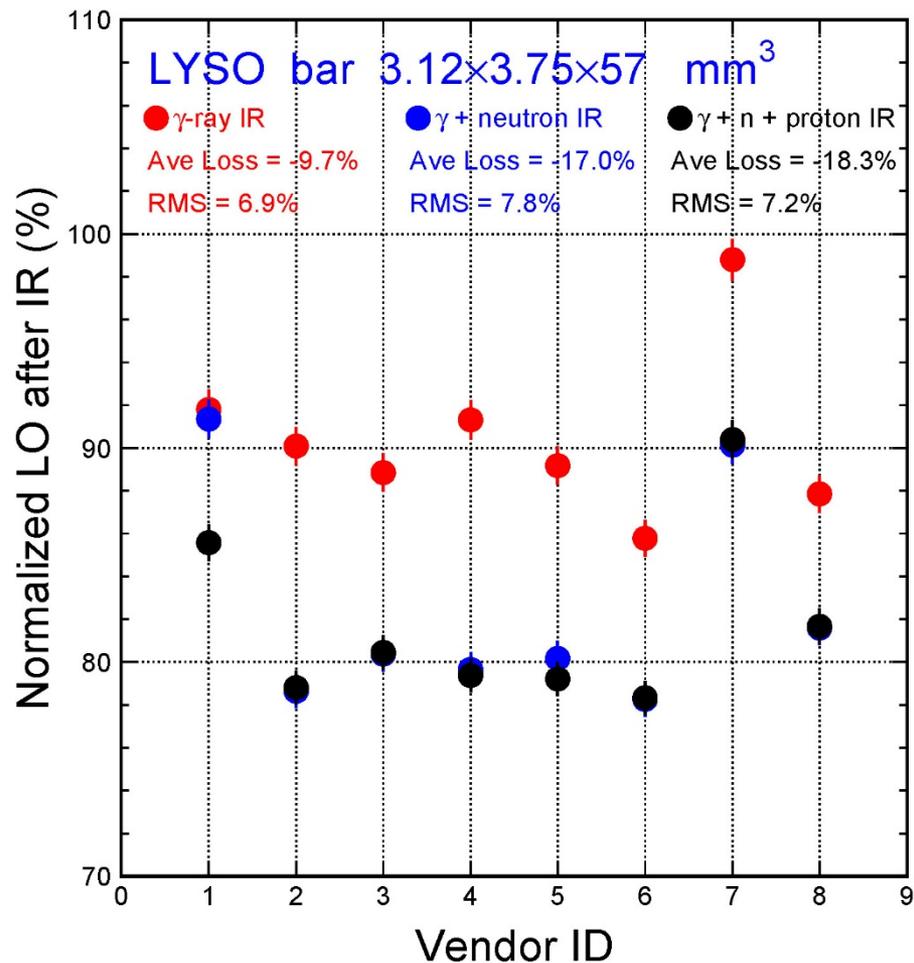
γ-rays: Average EWLT: -5.7%; Average EWRIAC: 1.0 m^{-1}
γ-ray + neutrons: Average EWLT: -12.0%; Average EWRIAC: 2.3 m^{-1}
γ + n + protons: Average EWLT: -12.8%; Average EWRIAC: 2.4 m^{-1}
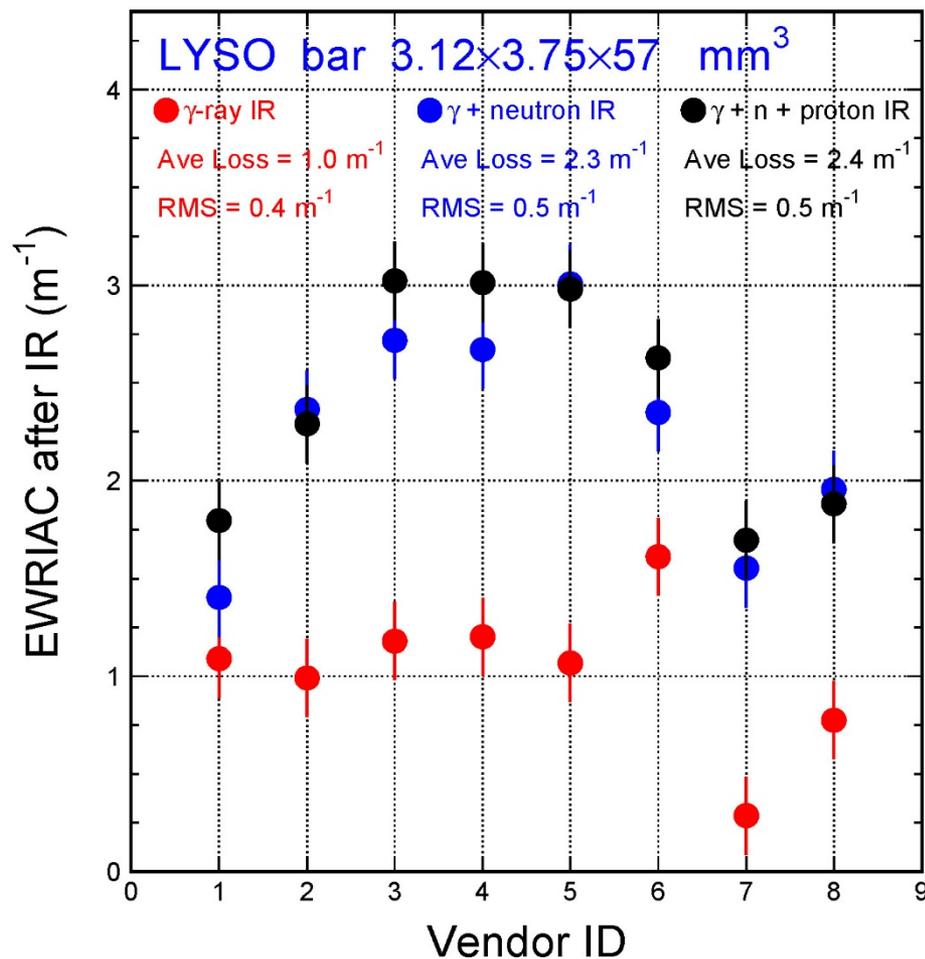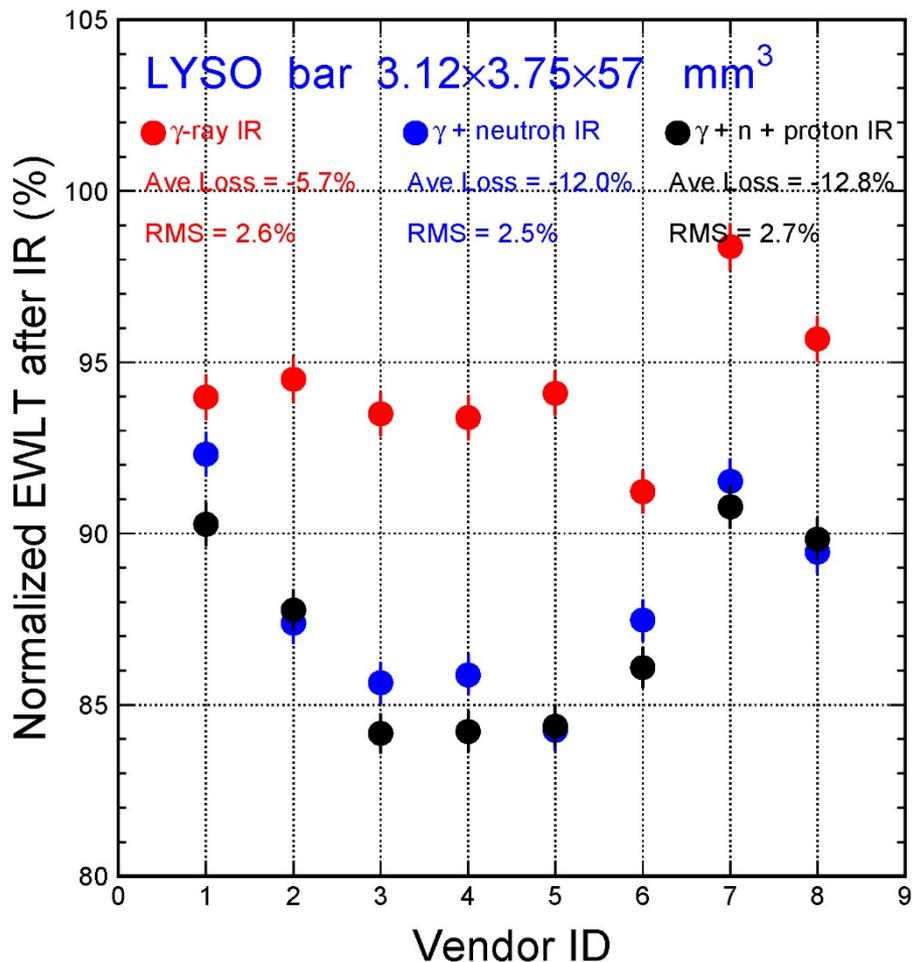
Normalized Light Output and τ

γ-rays: Average δLO/LO = -9.7%; Average δτ/τ = -0.9%
γ-ray + neutrons: Average δLO/LO = -17.0%; Average δτ/τ = -0.2%
γ + n + protons: Average δLO/LO = -18.3%; Average δτ/τ = -0.5%
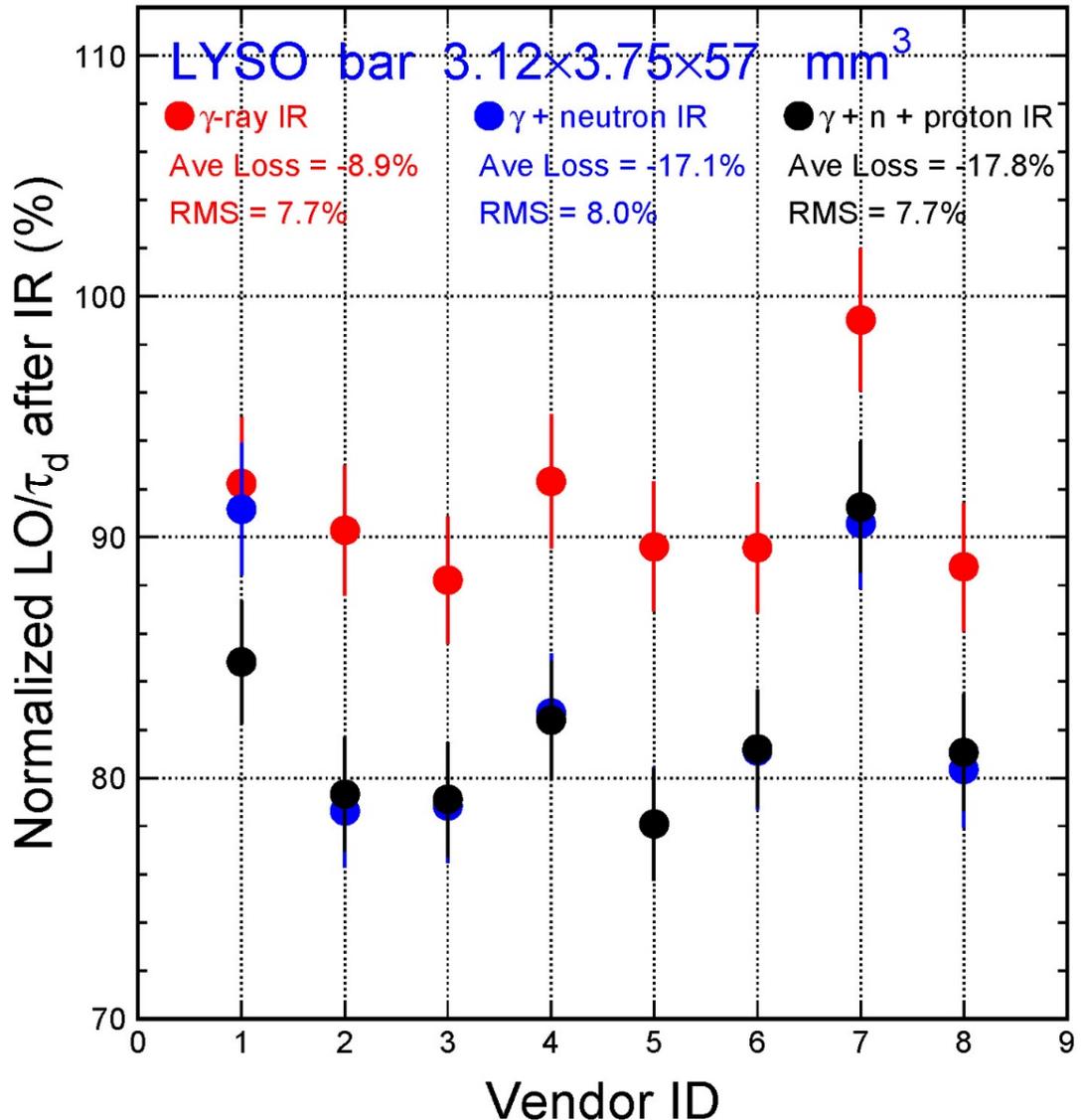
Average LO/τ for Timing

Average LO/τ degrades by 8.9/17.1/17.8 % after γ/γ+n/γ+n+p, indicating a less than 5/10/10 % degradation in timing resolution

Summary

LT, EWRIAC, LO and τ were measured for eight 2019 LYSO bars from different vendors after 5.1 Mrad at Caltech, 3.2×10^{14} n_{eq}/cm^2 at Lowell, and 1.9×10^{13} p/cm^2 at Fermilab ITA.

Proton induced LO loss is due to induced absorption with 9 cm path length, consistent with γ-ray and neutron data.

The average variation of EWRIAC, LO and LO/τ after γ + neutron + proton irradiation is 2.4 m^{-1}, -18.3% and -17.8% respectively for 8 vendors. The overall degradation in timing resolution is 9.3% with a divergence of 8% for eight LYSO vendors.

Additional proton irradiation is planned at LANSCE with 800 MeV proton beam.

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