Result of 18 2021 BTL LYSO Bars after Proton Irradiation at ITA

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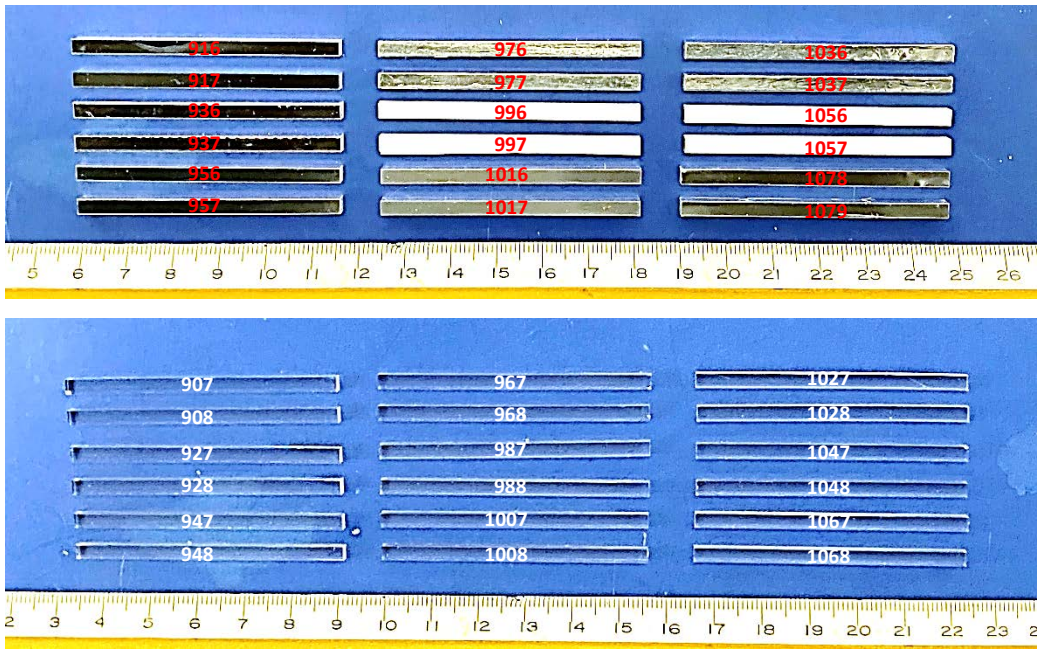
36 BTL LYSO Bars



ID	Dimension (mm^3)	#	Polishing
BTL LYSO-907~1079	3.00×3.12×56.3	36	All faces
All samples received on April 6th, 2021 (Tuesday)			
Sent to ITA: 4/30/20, $1.4/2.2\times10^{13}$ 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 $1.4/2.2\times10^{13}$ p/cm^2 for samples wo/w ESR

LYSO Bar Sample Cross Link

18 each with odd/even ID: proton/neutron irradiation at ITA/Lowell

Caltech ID	Barcode	Producer	Test
1	907	1	Proton
2	908	1	Neutron
3	927	8	Proton
4	928	8	Neutron
5	947	5	Proton
6	948	5	Neutron
7	967	10	Proton
8	968	10	Neutron
9	987	3	Proton
10	988	3	Neutron
11	1007	9	Proton
12	1008	9	Neutron
13	1027	6	Proton
14	1028	6	Neutron
15	1047	4	Proton
16	1048	4	Neutron
17	1067	2	Proton
18	1068	2	Neutron

Caltech ID	Barcode	Producer	Test
ESR 1	916	1	Proton
ESR 2	917	1	Neutron
ESR 3	936	8	Proton
ESR 4	937	8	Neutron
ESR 5	956	5	Proton
ESR 6	957	5	Neutron
ESR 7	976	10	Proton
ESR 8	977	10	Neutron
ESR 9	996	3	Proton
ESR 10	997	3	Neutron
ESR 11	1016	9	Proton
ESR 12	1017	9	Neutron
ESR 13	1036	6	Proton
ESR 14	1037	6	Neutron
ESR 15	1056	4	Proton
ESR 16	1057	4	Neutron
ESR 17	1078	2	Proton
ESR 18	1079	2	Neutron

Sample 11 without ESR broken to two pieces after irradiation

Error Weighted Average Fluence

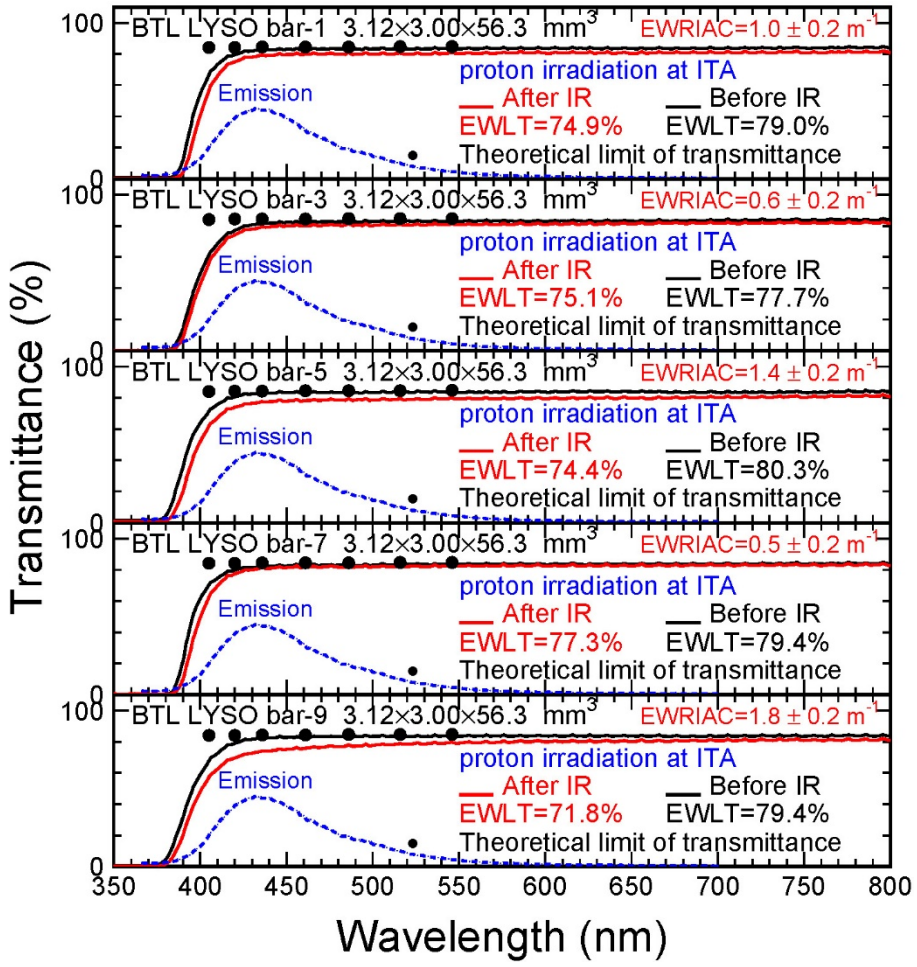
Fluence: error weighted average of Be-7 & Na-22 from activated Al foils
9 LYSO bars each with/without ESR were in G1/G2, Liyuan's 3/18/22 report

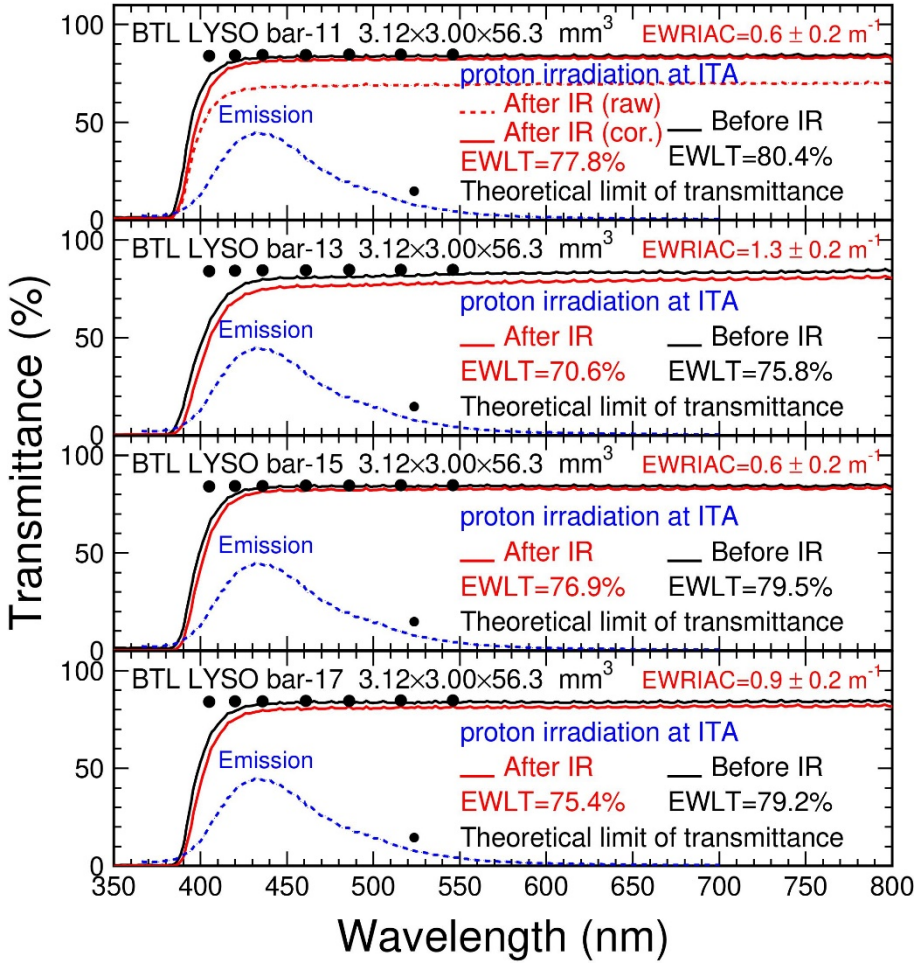
Group	Front EW Avg Fluence (cm^{-2})	± Error (cm^{-2})	Back EW Avg Fluence (cm^{-2})	± Error (cm^{-2})	Average Fluence (cm^{-2})	± Error (cm^{-2})
1	**2.16E+13**	7.2E+11	1.59E+13	6.9E+11	1.88E+13	5.0E+11
2	**1.43E+13**	6.8E+11	9.49E+12	7.1E+11	1.19E+13	4.9E+11
3	1.91E+13	7.6E+11	1.30E+13	7.5E+11	1.61E+13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

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

EWLT & EWLT: 9 2021 Bars w/o ESR

Radio-luminescence weighted longitudinal transmittance (EWLT)
Radiation induced absorption coefficient (EWRIAC)

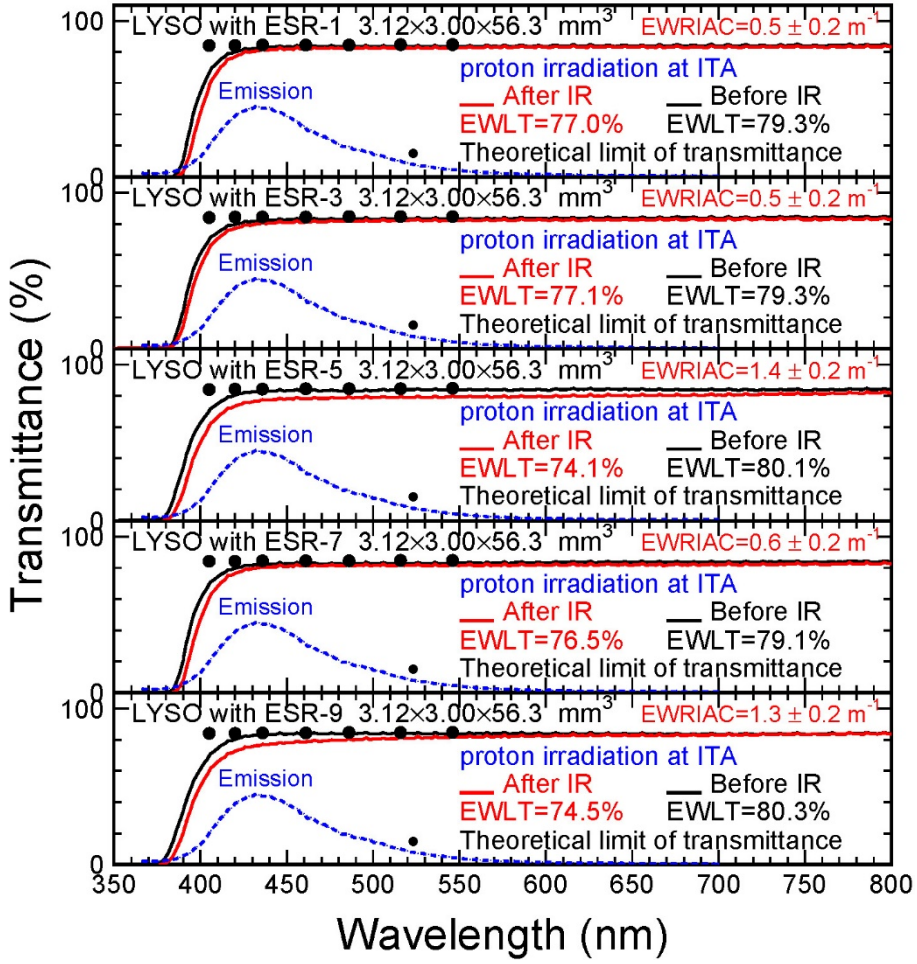


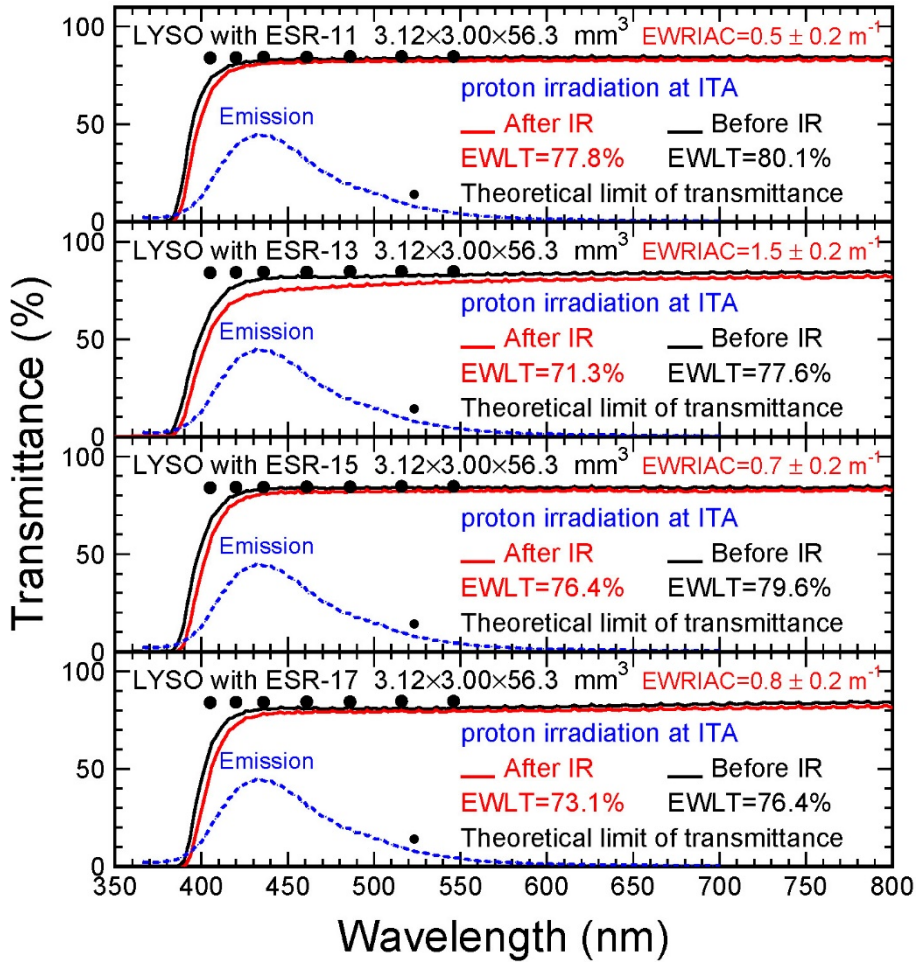


Transmittance of Sample 11 was corrected by additional bouncings at the boundary

EWLT & EWLT: 9 2021 Bars with ESR

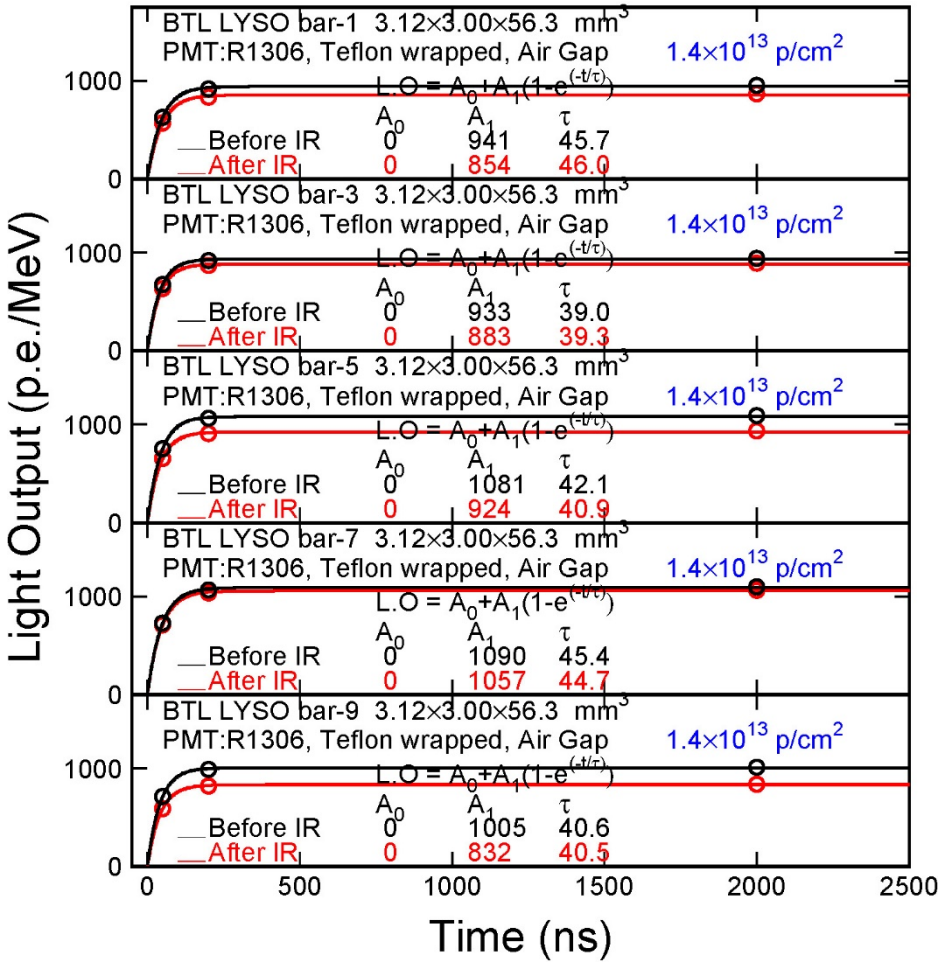
Radio-luminescence weighted longitudinal transmittance (EWLT)
Radiation induced absorption coefficient (EWRIAC)

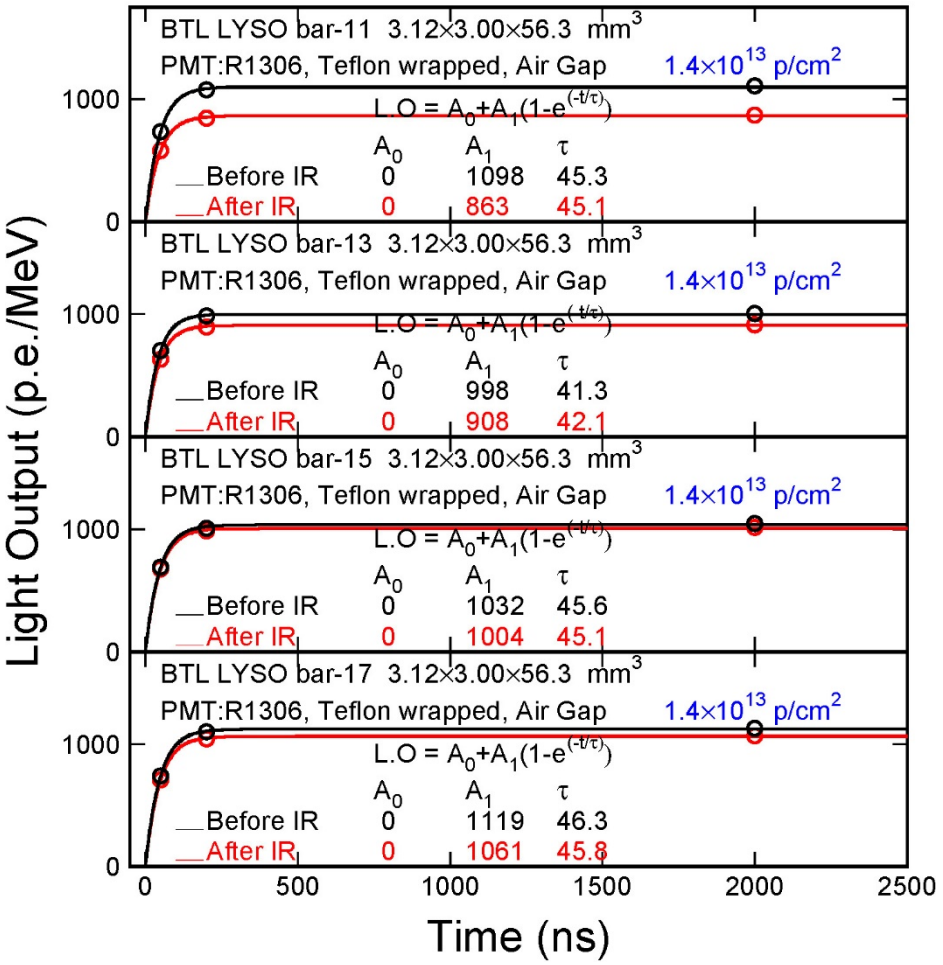




LO: Nine 2021 Bars w/o ESR

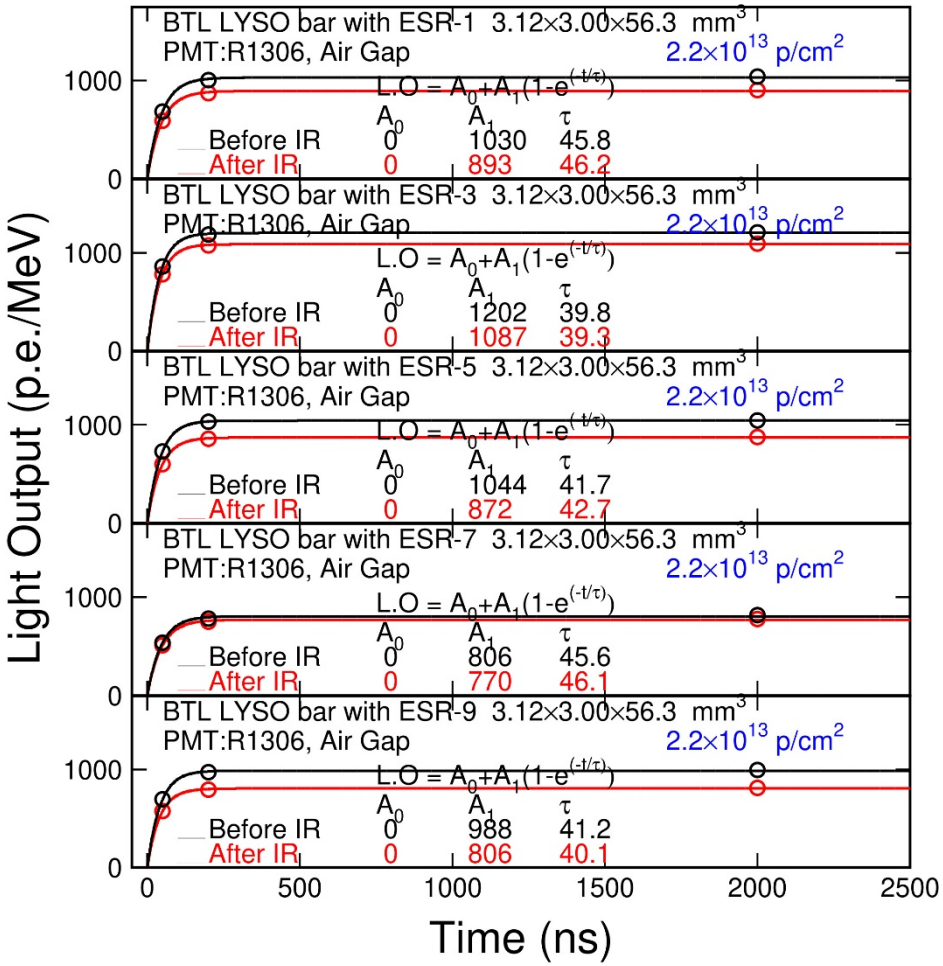
LYSO bars with Teflon block wrapping and an air gap coupling to an R1306 PMT triggered by a Na-22 source at the center

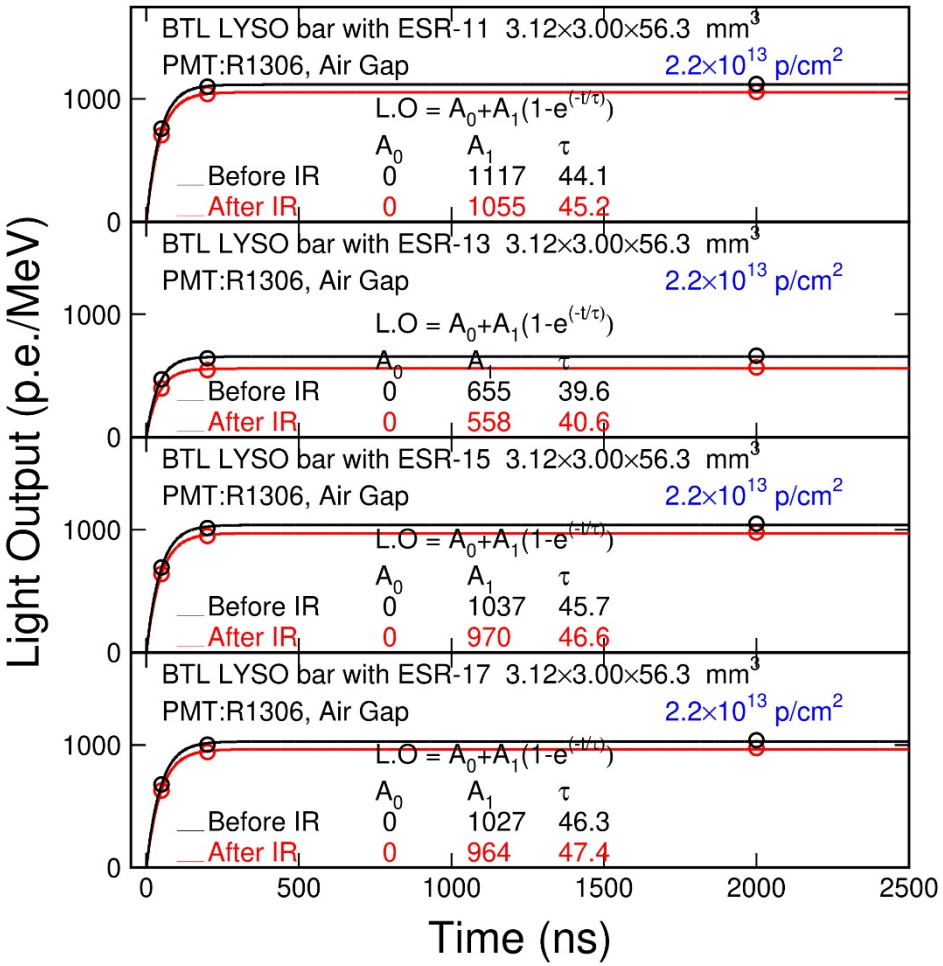




LO: Nine 2021 Samples with ESR

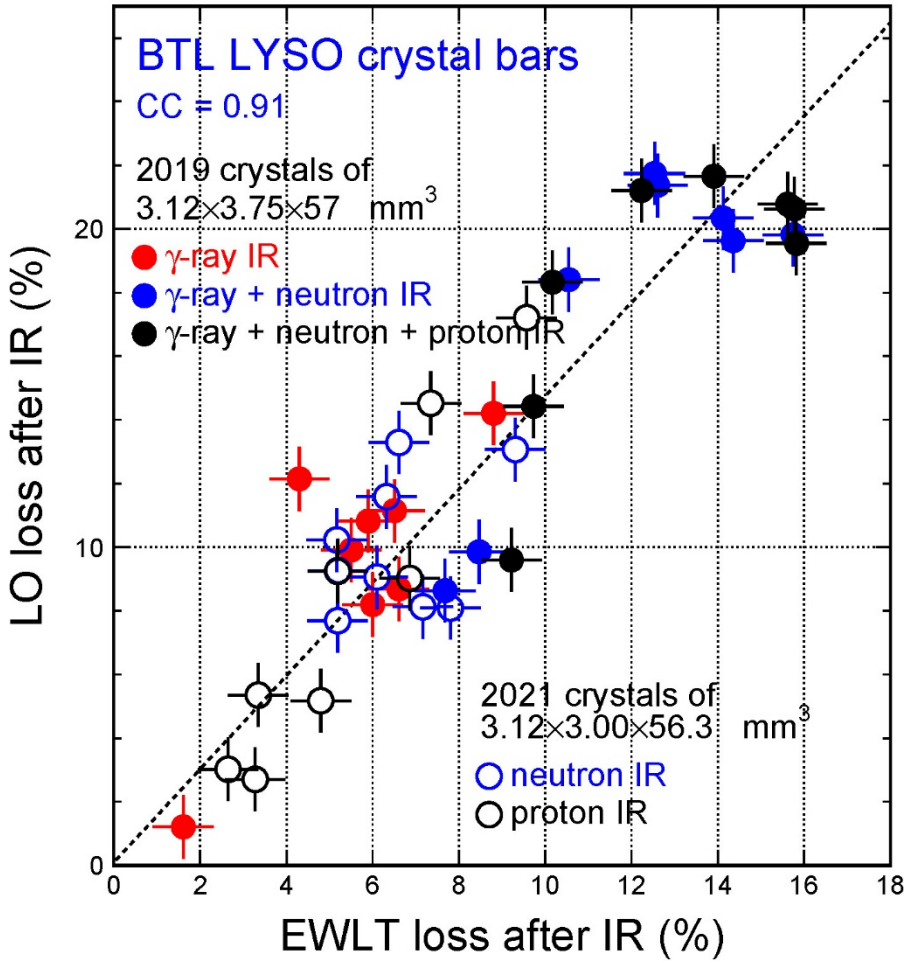
LYSO bars with ESR wrapping and an air gap coupling to an R1306 PMT triggered by a Na-22 source at the center

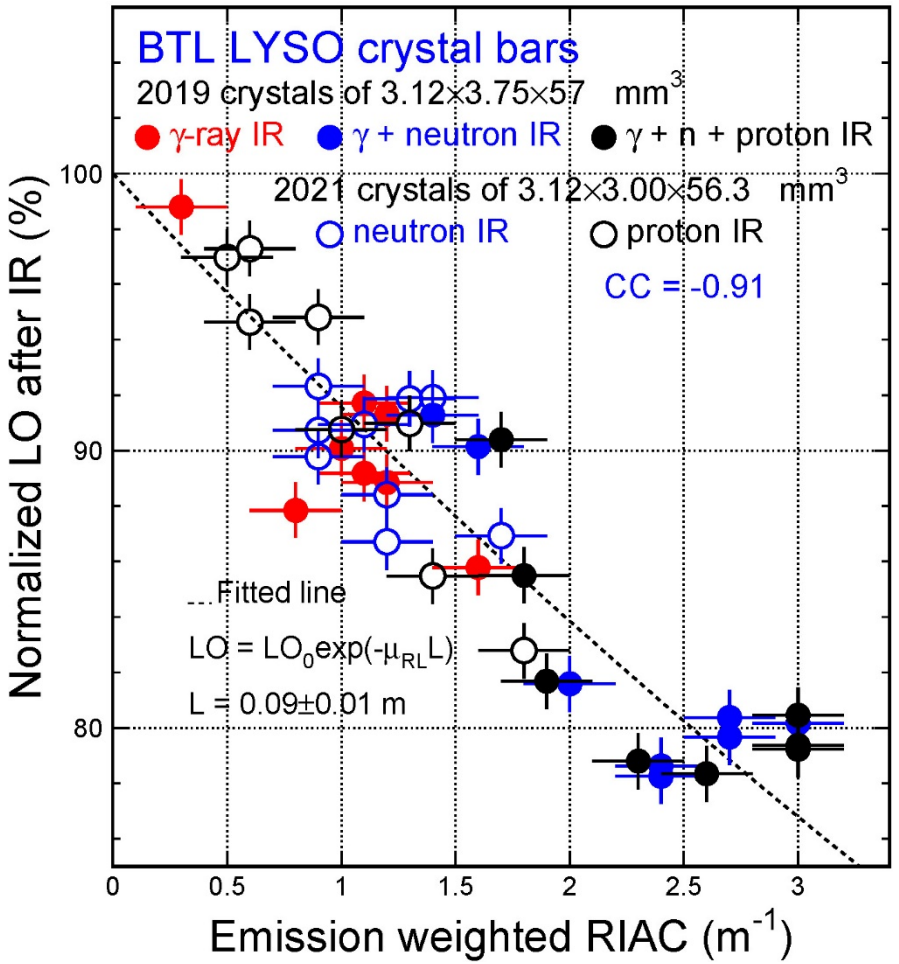




Light Output vs EWLT & EWRIAC

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

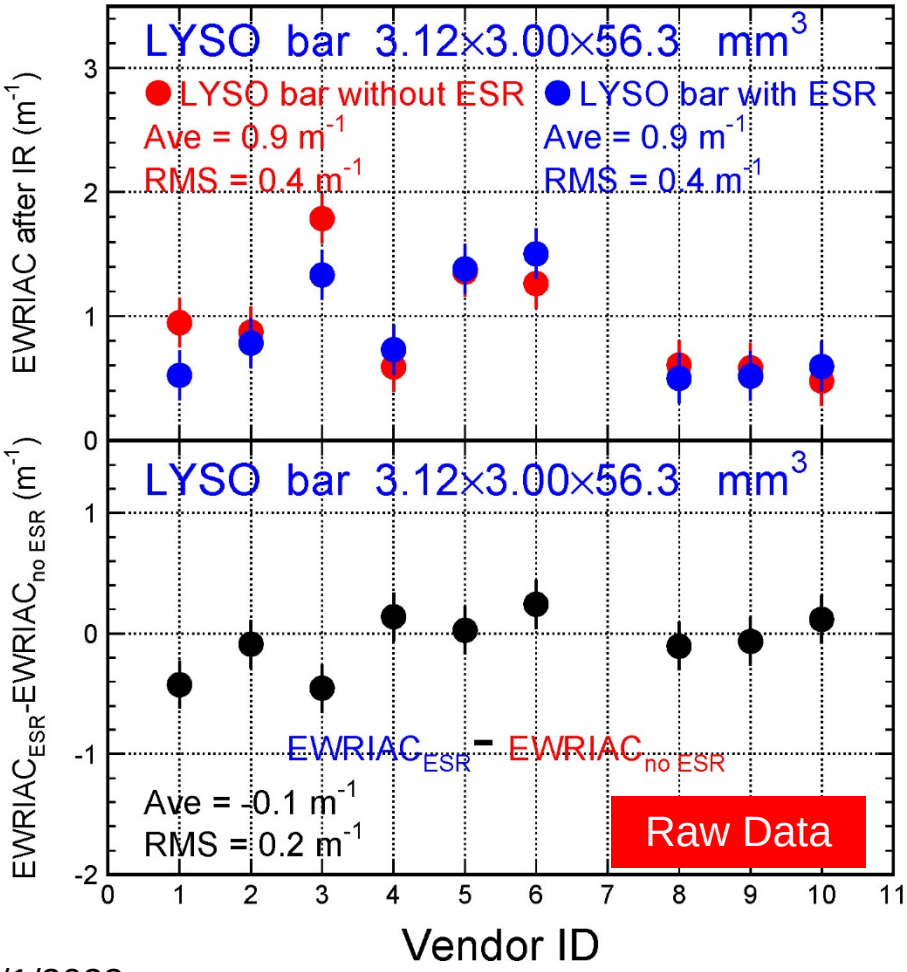


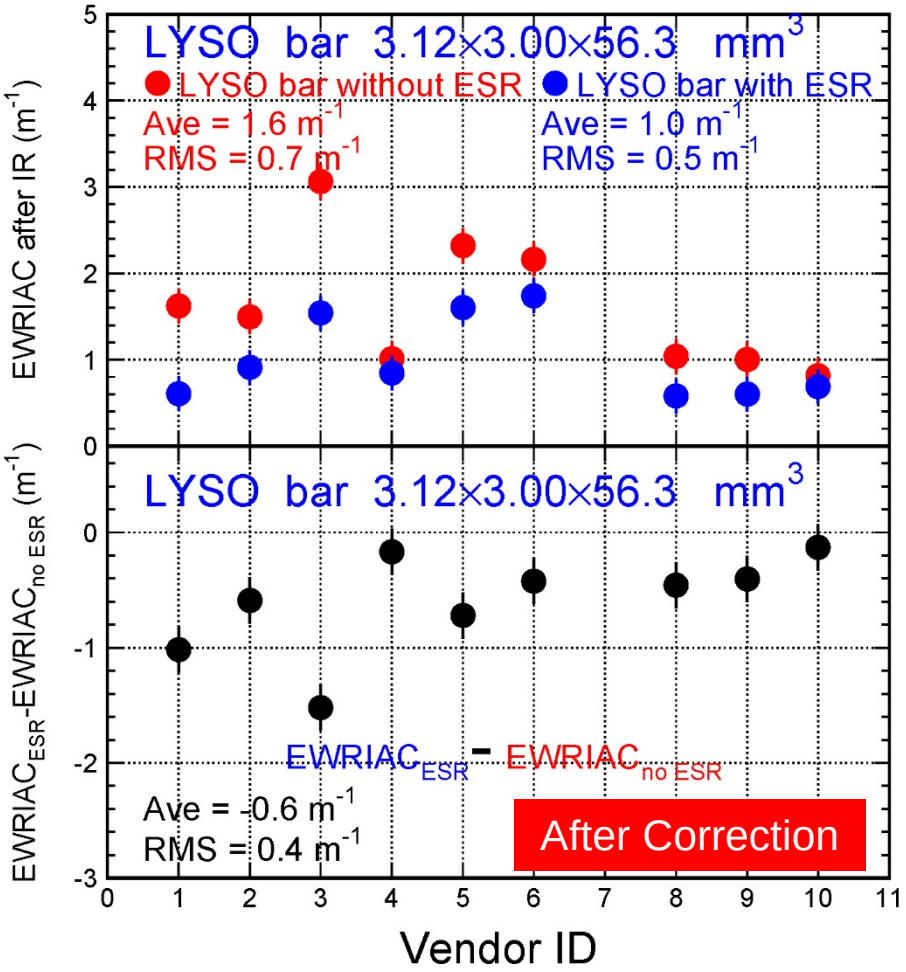


EWRIAC scaled to 2.5×10^{13} p/cm^2

$RIAC \propto$ Fluence

1.6 m^{-1} & 1.0 m^{-1} for without & with ESR after 2.5×10^{13} p/cm^2
Average ESR effect is -0.6 m^{-1}: ESR induced damage is negligible

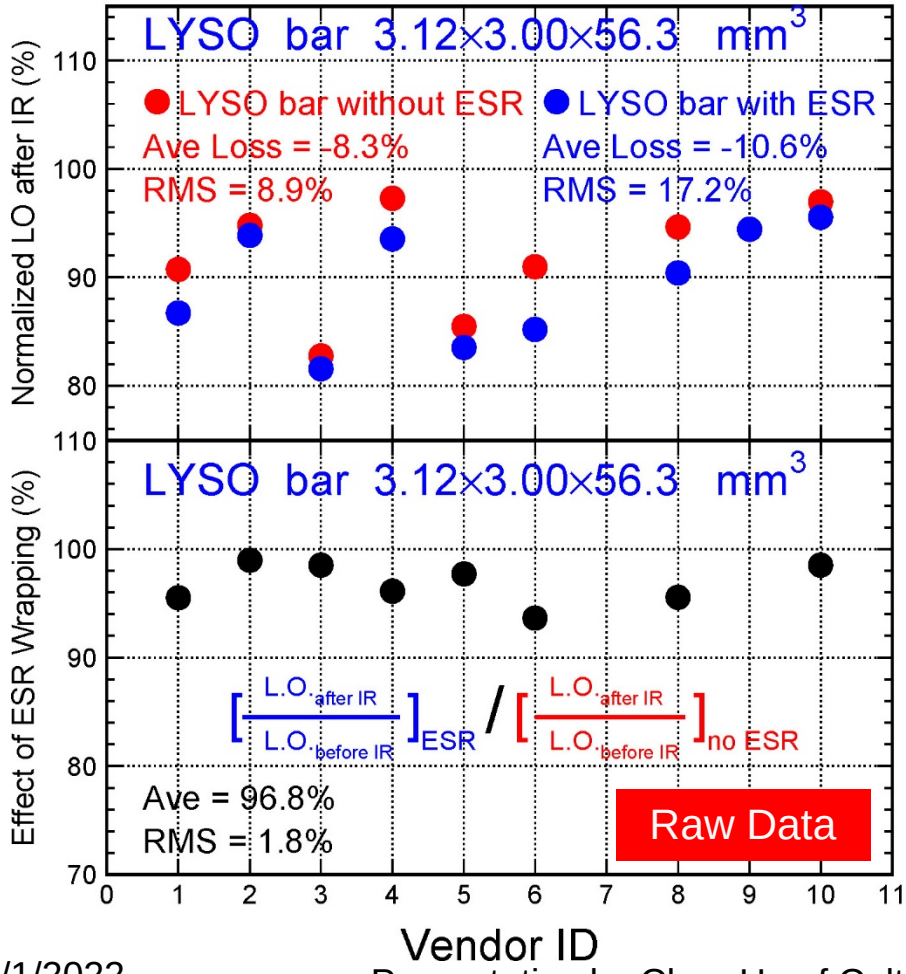


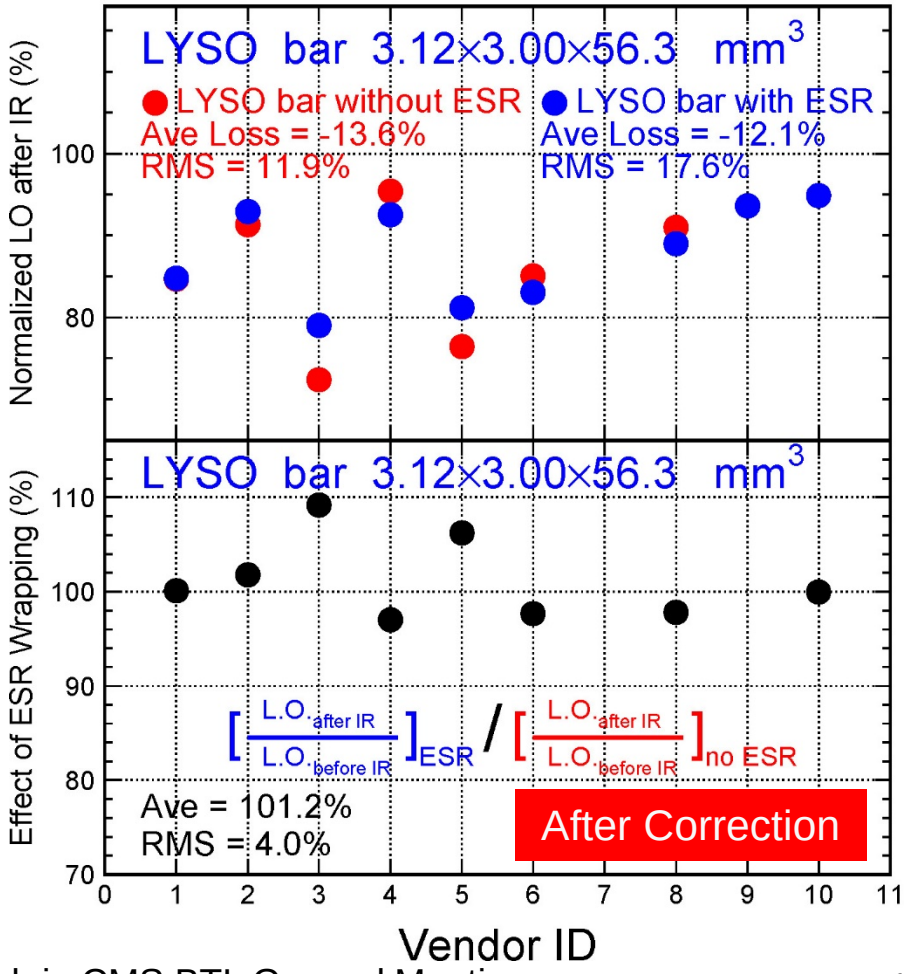


Light Output scaled to 2.5×10^{13} p/cm^2

$$LO = LO_0 \exp(-RIAC \times L)$$

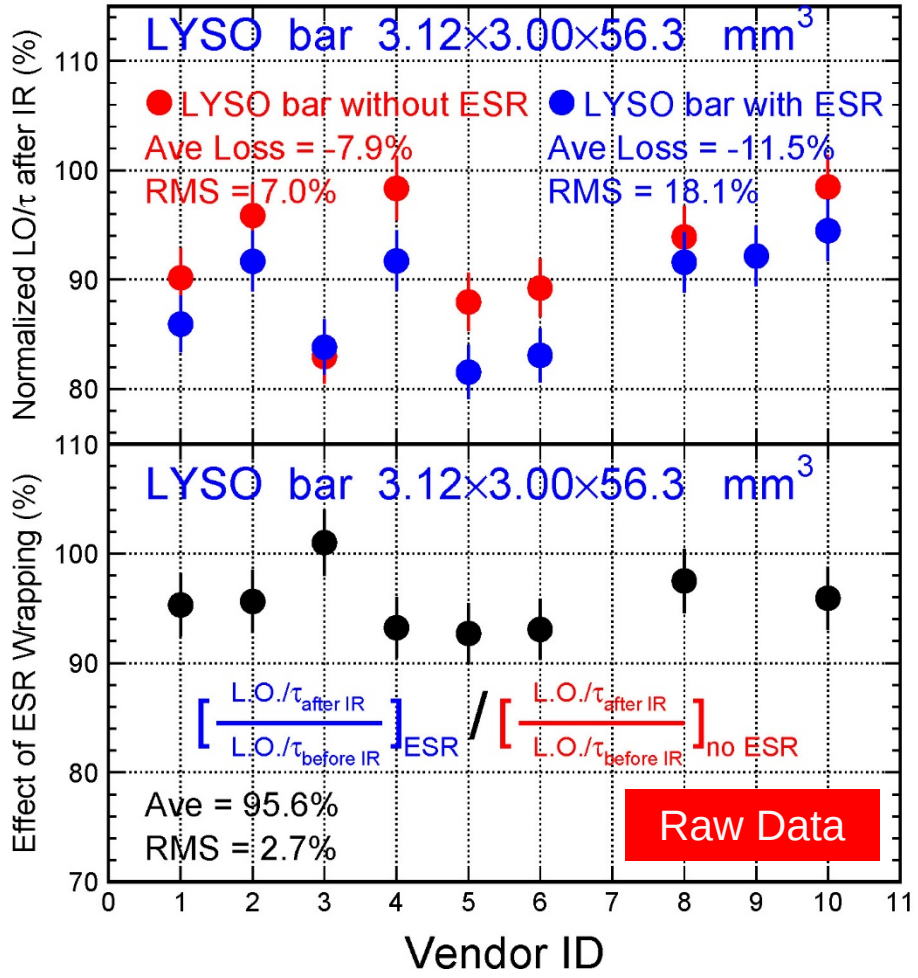
-13.6% & -12.1% for without & with ESR after 2.5×10^{13} p/cm^2
Average ESR effect is 1.2%: ESR induced damage is negligible

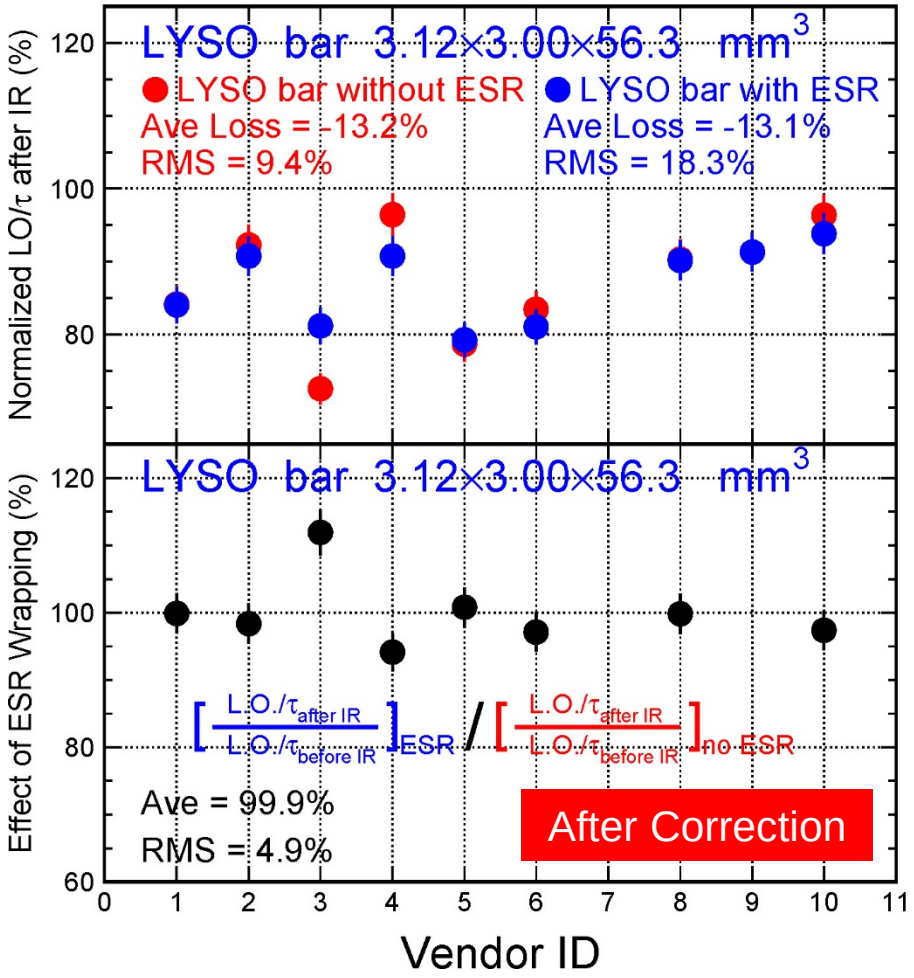




LO/τ scaled to 2.5×10^{13} p/cm^2

-13.2% & -13.1% for bars without & with ESR after 2.5×10^{13} p/cm^2
Average ESR effect is <1%: ESR induced damage is negligible





Summary

LT, EWRIAC, LO and τ were measured for 18 BTL LYSO bars without and with ESR wrapping after 1.4 & 2.2×10^{13} p/cm^2 at Fermilab ITA.

Proton induced LO loss is due to induced absorption with 9 cm path length, consistent with ɣ-ray & neutron induced damage.

LYSO bars from nine vendors show good consistency. The average variation of EWRIAC, LO and LO/τ scaled to 2.5×10^{13} p/cm^2 is 1.6/1.0 m^{-1}, -13.6/-12.1 % and -13.2/-13.1 % respectively for 9 LYSO bars each without/with ESR with an overall consistency of 0.7/0.5 m^{-1}, 11.9/17.6% and 9.4/18.3%.

Proton-induced damage in time resolution is ~7% for LYSO bars with and w/o ESR, indicating a negligible ESR effect. A larger divergence was observed for LYSO bars with ESR as compared to without ESR. A uniformized ESR wrapping would help.

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