Characterization of Sixty LYSO Bars from Three Vendors for Radiation Damage Tests

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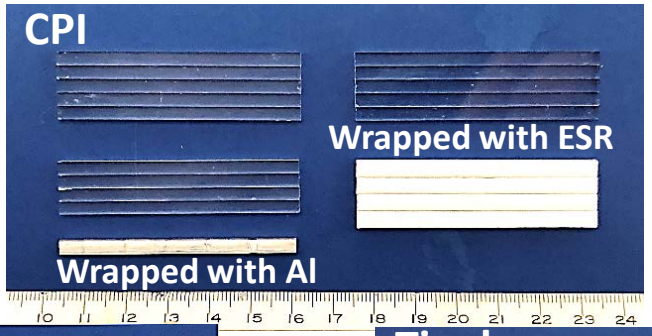
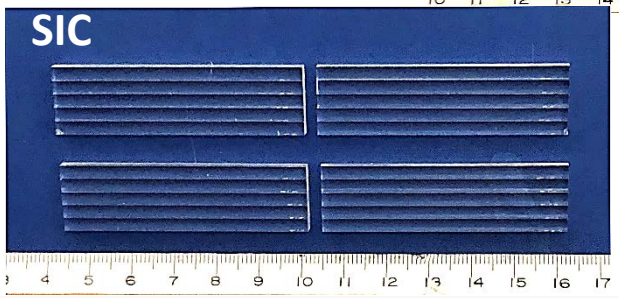
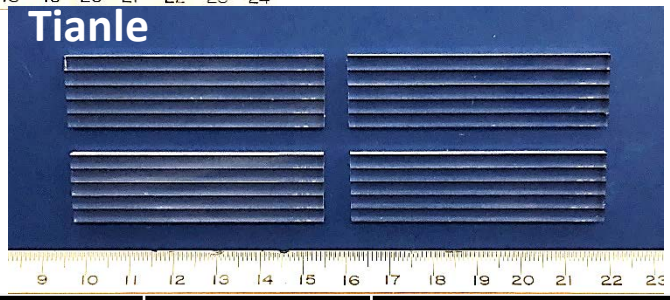
LYSO Bars from Three Vendors







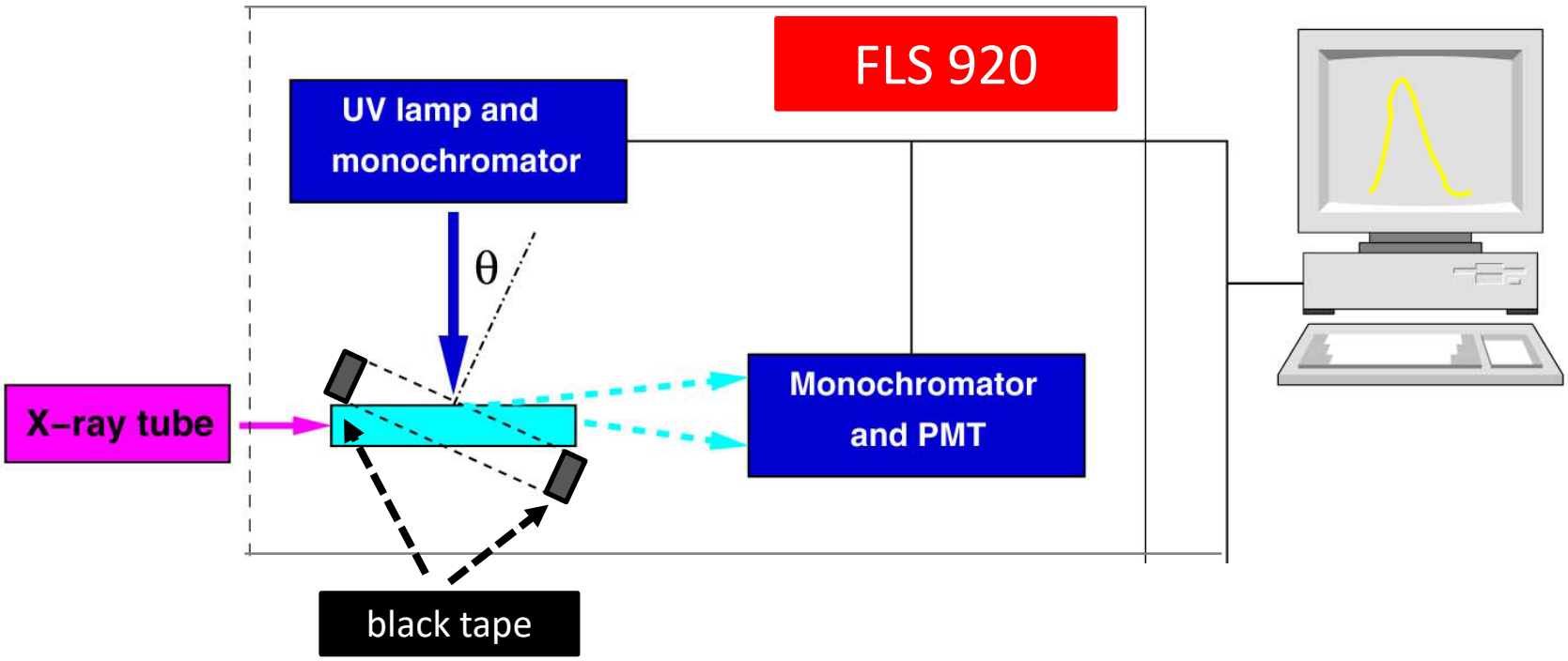
ID	Dimension (mm^3)	#	Polishing
CPI LYSO:Ce-1,19	3.12x3.12x57	19	All faces
SIC LYSO:Ce-1,20	3.12x3.12x57	20	All faces
Tianle LYSO:Ce-1,20	3.12x3.12x57	20	All faces
All samples received on Aug 5th, 2019 (Monday)			

Experiments

- Properties measured at room temperature : Transmittance, PHS, LO & Decay kinetics

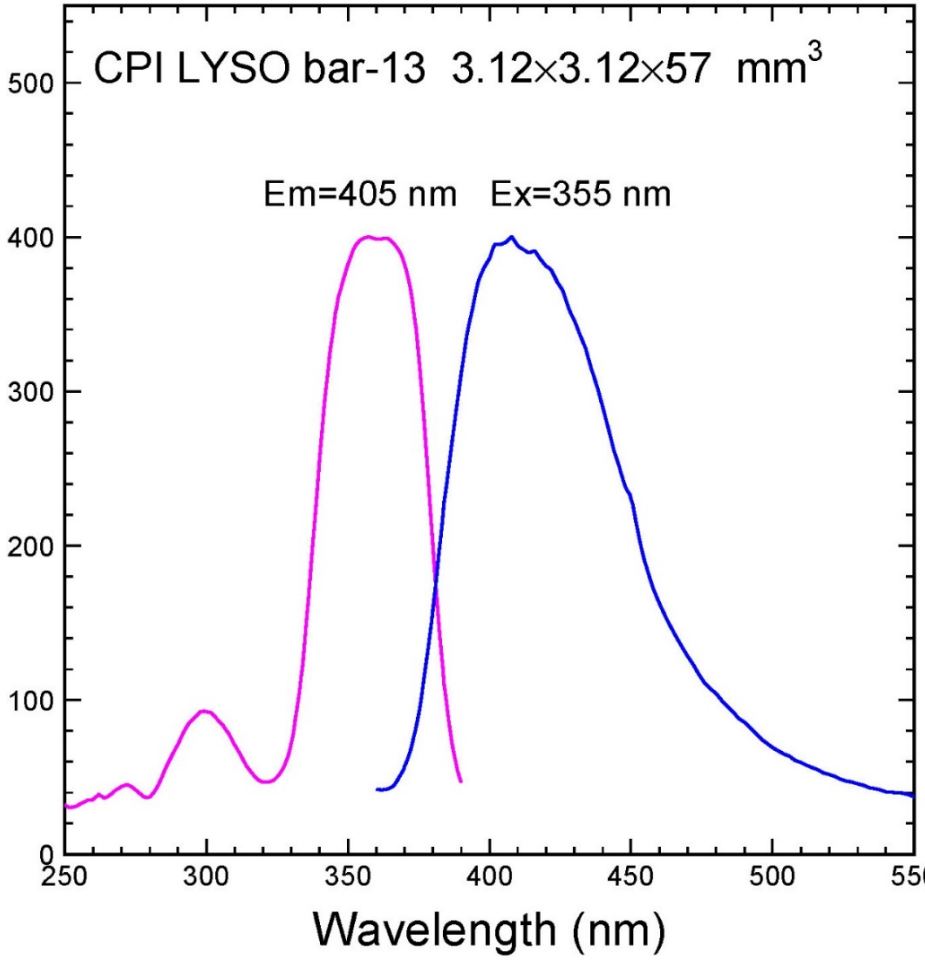
PL & XEL Measurement

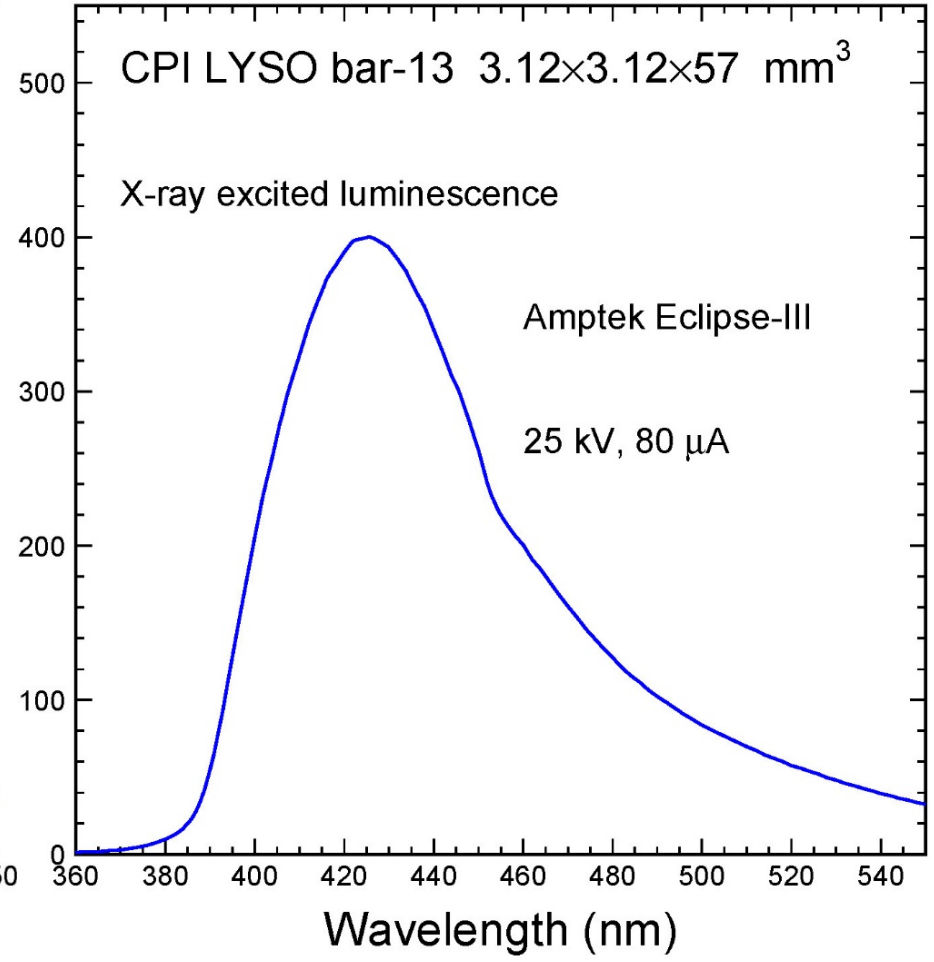
Photo-luminescence measured with θ = 10° without internal absorption, while XEL with internal absorption



PL/XEL Spectra

PL/XEL peaked at 405/420 nm without/with internal absorption

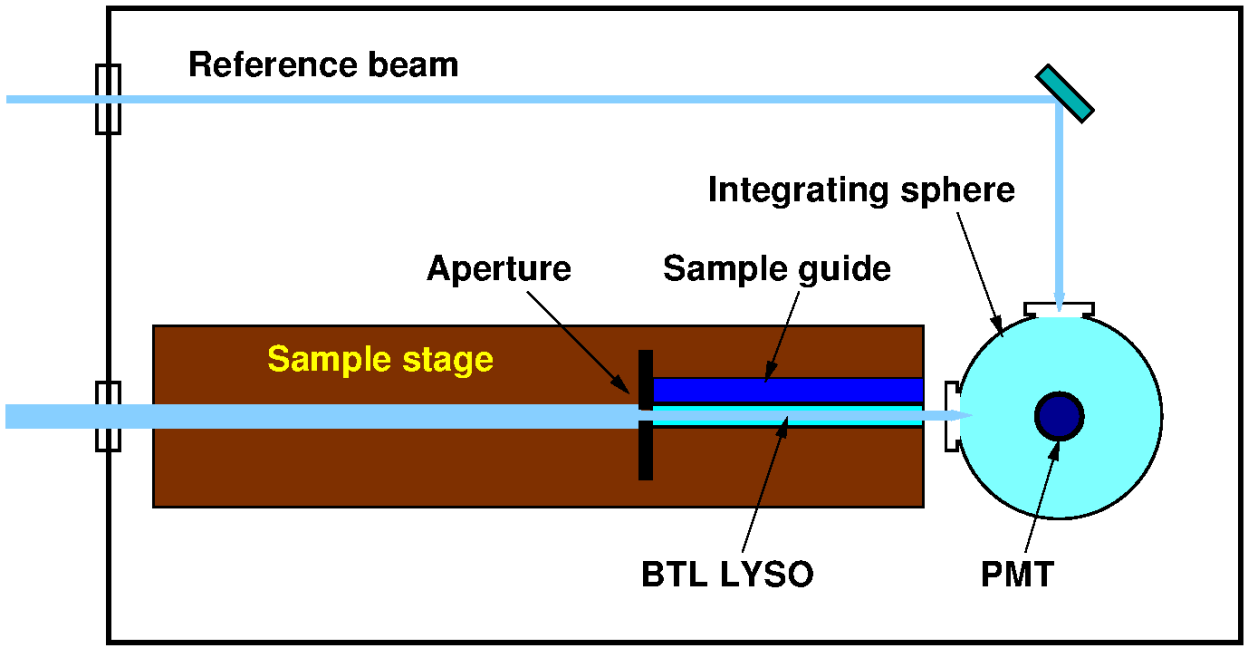




Transmittance Measurement

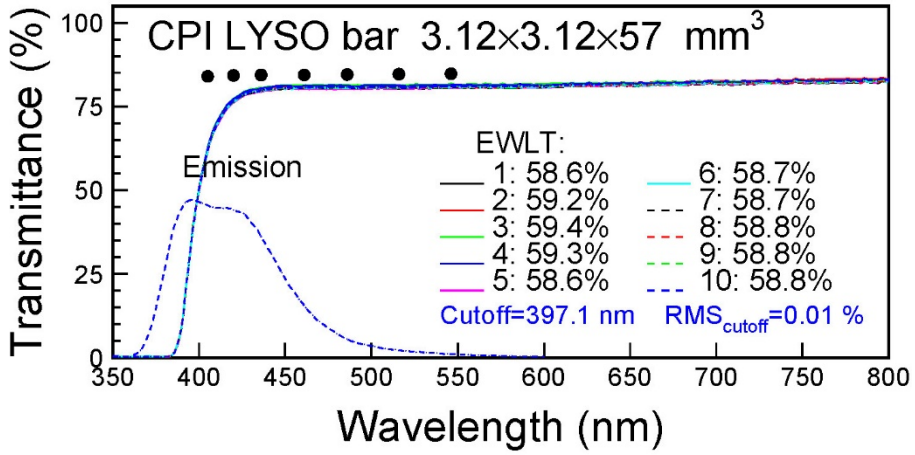
Longitudinal transmittance (LT) measured by a Hitachi U3210 spectrophotometer with a Φ2.8 mm aperture inserted in the light path. The systematic uncertainty is 0.5%.

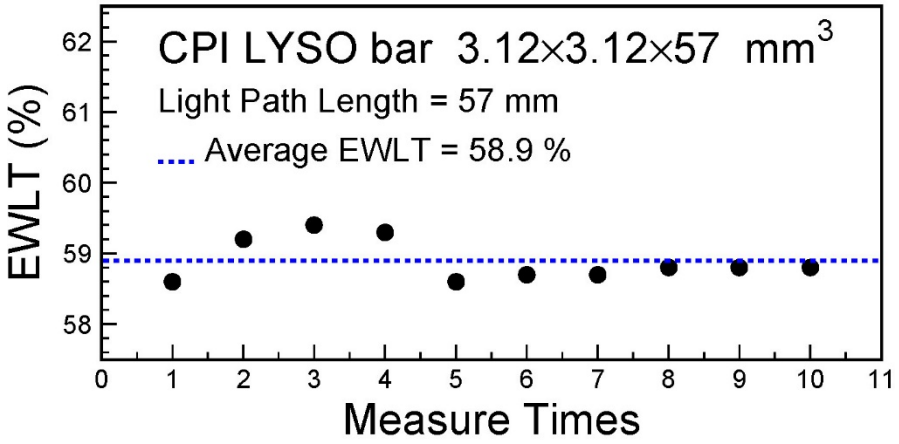
U3210 Large Sample Compartment

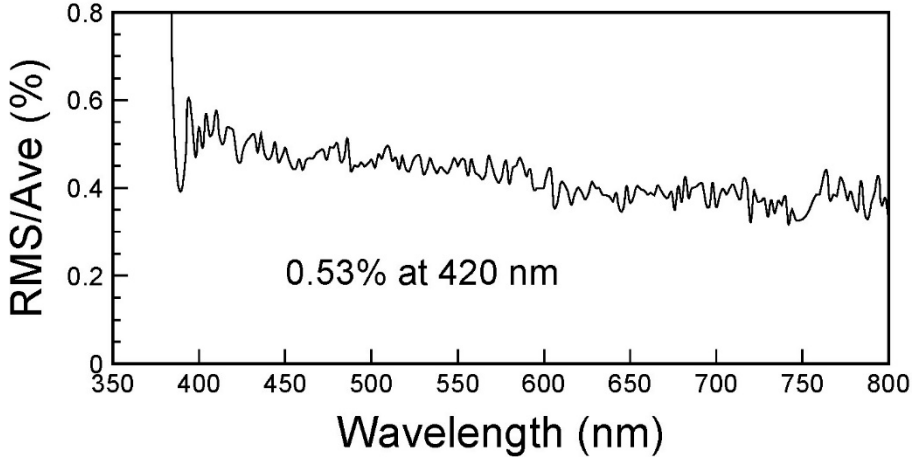


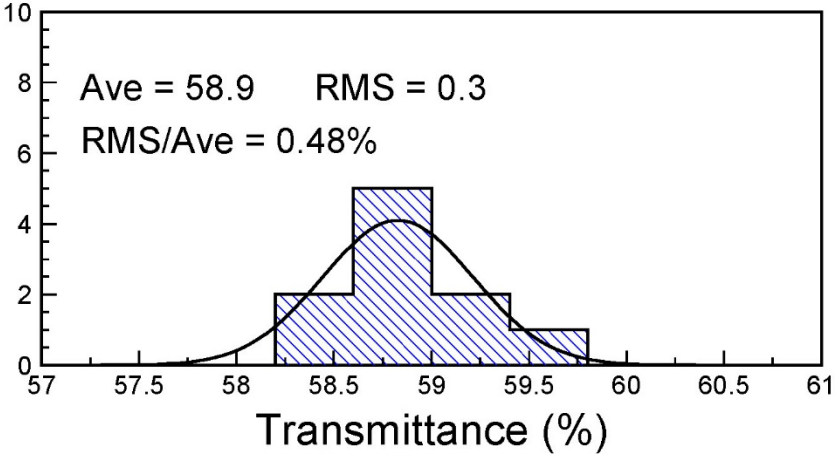
Sys. Uncertainties: EWLT & AC

The systematic uncertainty of EWLT is 0.5%, determined by the rms value of ten EWLT measurements, corresponding to 0.3 m^{-1} for absorption coefficient









Transmittance: CPI and SIC

SIC LYSO shows a better EWLT with a poorer consistency

ID	CPI		SIC	
	EWLT (%)	T% @ 420 nm	EWLT (%)	T% @ 420 nm
1	58.8	76.5	60.1	72.6
2	60.0	77.9	65.7	80.6
3	57.1	74.6	65.9	79.2
4	58.2	75.7	66.8	80.5
5	55.2	71.8	65.1	78.5
6	59.7	78.2	68.0	82
7	58.6	76.6	64.4	79.2
8	59.2	77.1	66.3	80.8
9	56.7	73.8	65.5	79.9
10	60.0	78.2	61.6	75.1
11	59.8	77.9	66.9	81.8
12	57.1	74.4	65.1	79.7
13	57.7	75.0	64.1	78.0
14	58.6	76.5	65.7	79.7
15			66.1	80.4
16			65.3	80.1
17			63.3	77.1
18			66.2	80.6
19			65.2	80.1
20			67.0	81.8
Ave	**58.3**	**76.0**	**65.2**	**79.4**
RMS	**1.4**	**1.8**	**1.8**	**2.2**
RMS/Ave	**2.4%**	**2.4%**	**2.8%**	**2.8%**

wrapped samples

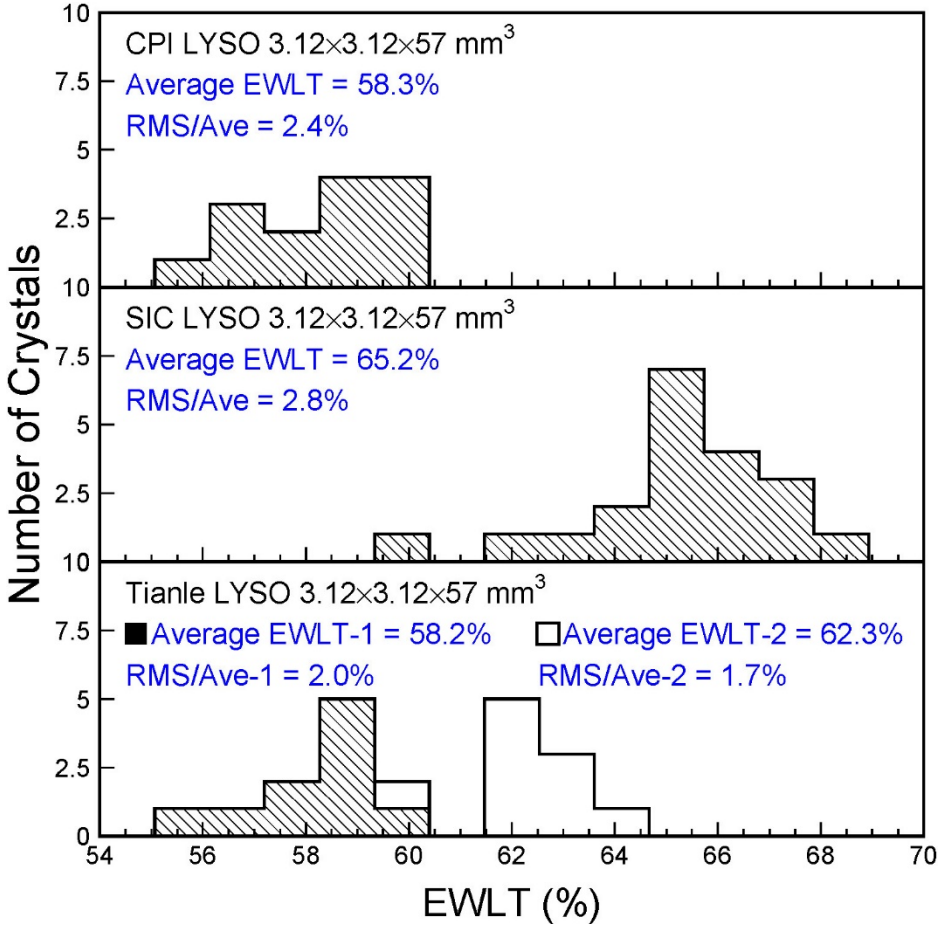
Transmittance: Tianle

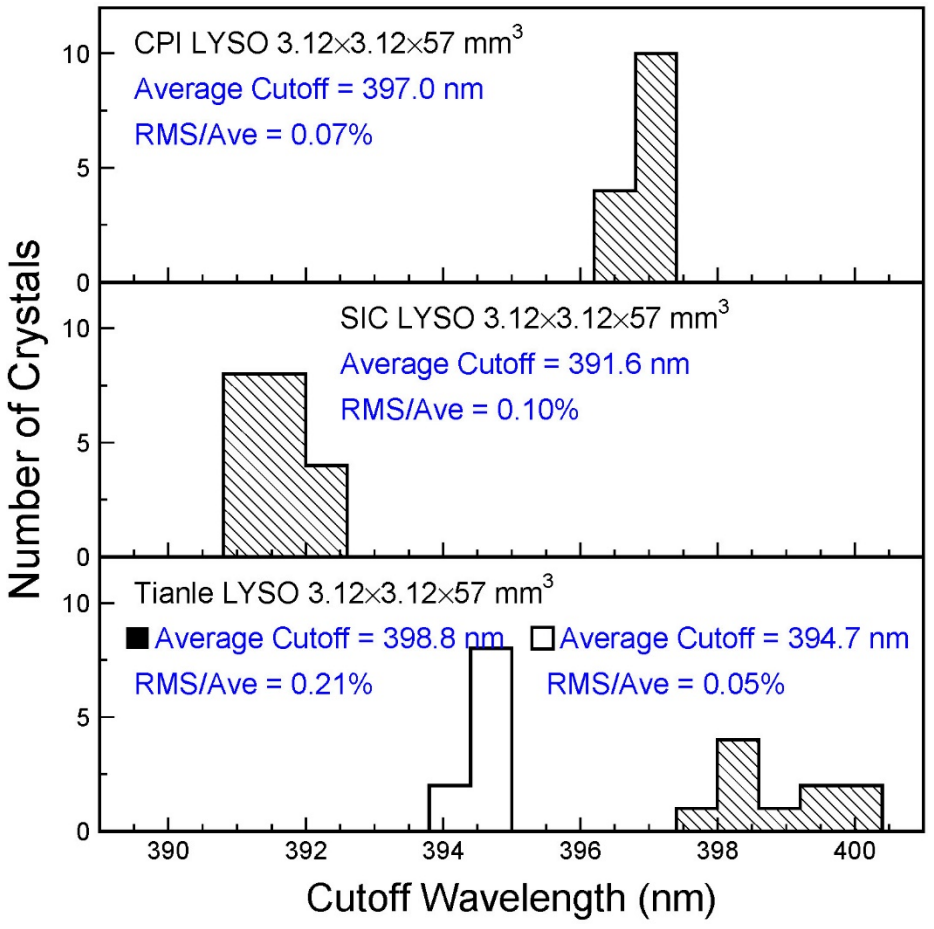
Two Tianle LYSO groups with different doping
The 2nd group shows a better consistency

ID	Tianle-1		ID	Tianle-2	
	EWLT (%)	T% @ 420 nm		EWLT (%)	T% @ 420 nm
1	56.1	72.5	11	62.7	79.4
2	56.3	72.8	12	61.6	77.8
3	58.6	75.9	13	61.9	78.2
4	58.5	75.7	14	62.4	78.4
5	59.8	77.3	15	63.5	80.0
6	58.1	74.9	16	59.9	75.6
7	59.2	76.4	17	62.3	78.6
8	57.8	74.9	18	64.0	80.6
9	58.7	76.0	19	62.3	78.8
10	59.3	76.4	20	62.7	79.2
Ave	**58.2**	**75.3**	**Ave**	**62.3**	**78.7**
RMS	**1.2**	**1.5**	**RMS**	**1.1**	**1.3**
RMS/Ave	**2.0%**	**2.0%**	**RMS/Ave**	**1.7%**	**1.6%**

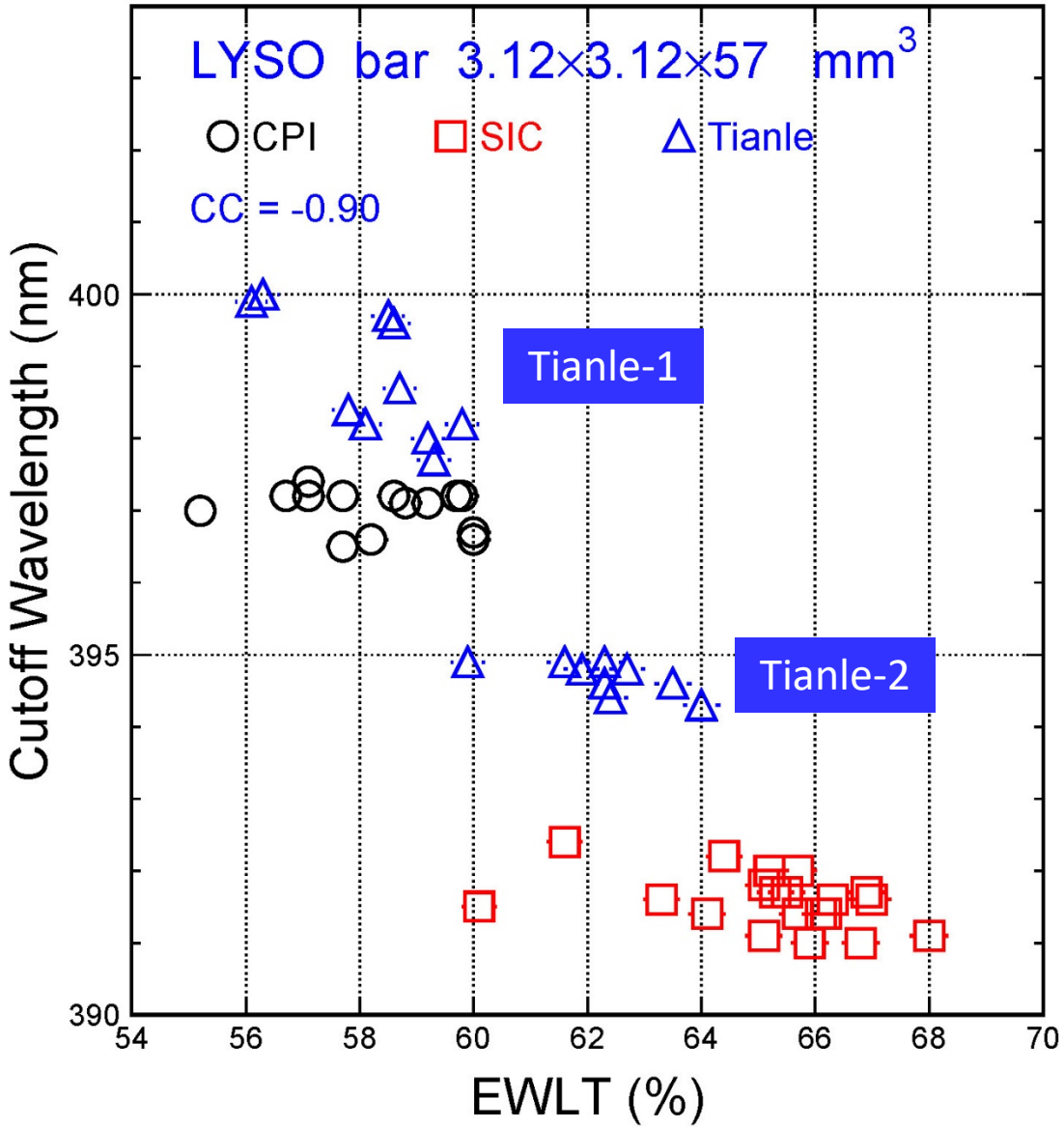
Summary: Transmittance

Cutoff wavelength is less affected by surface quality
The 2nd Tianle group shows the best consistency





Cutoff Wavelength vs. EWLT



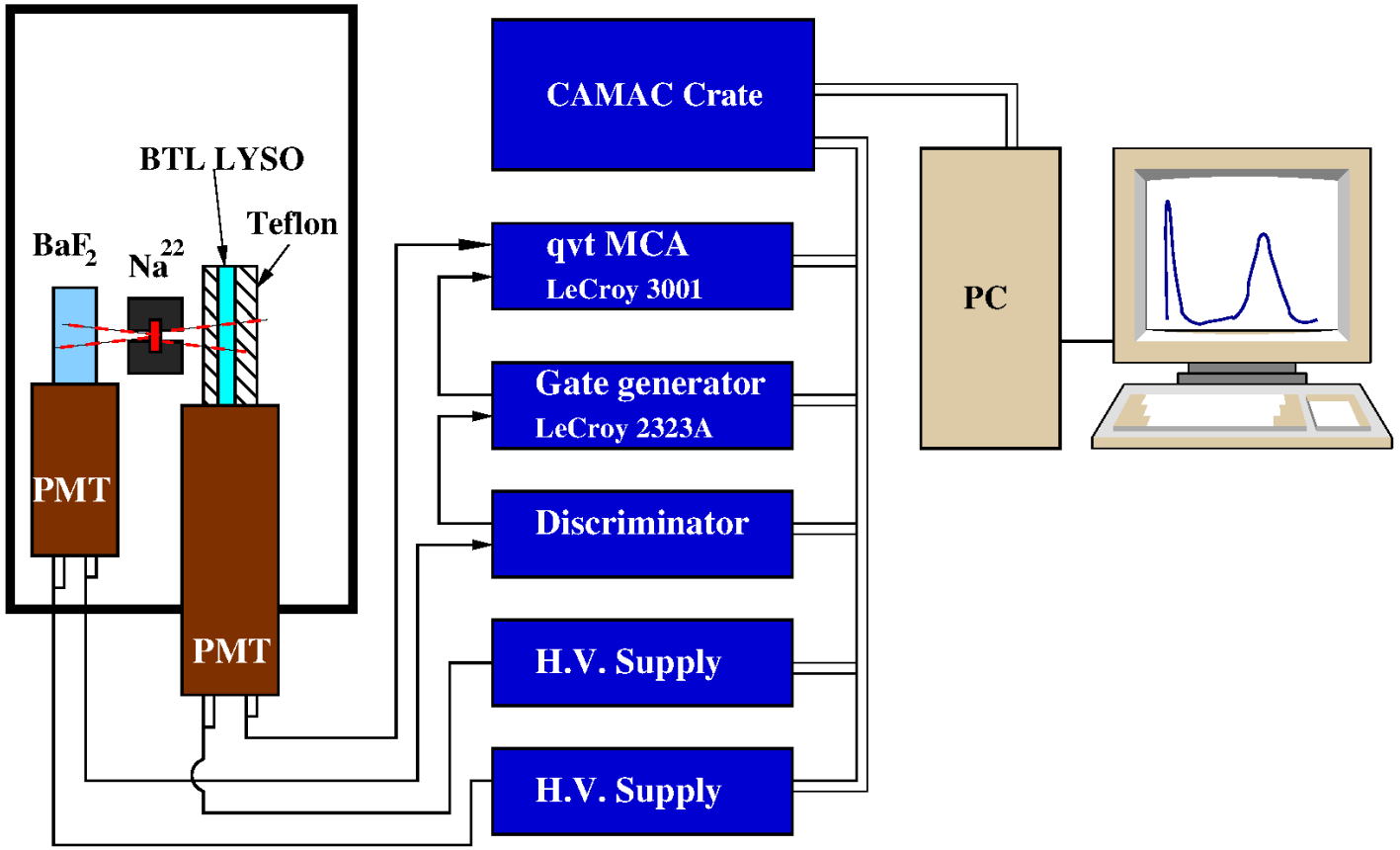
90% correlation between the cutoff wavelength and the EWLT values

Both affected by the Ce^{3+} doping level.

EWLT affected more by surface quality.

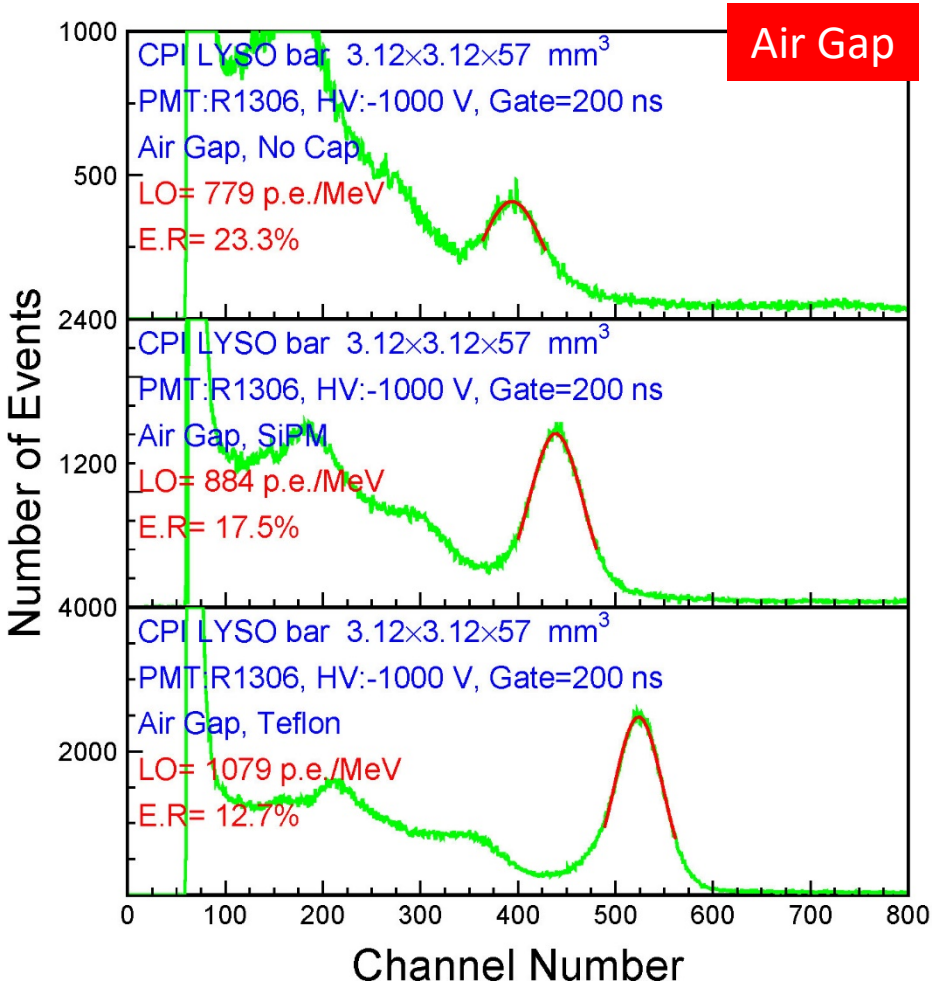
Light Output Measurement

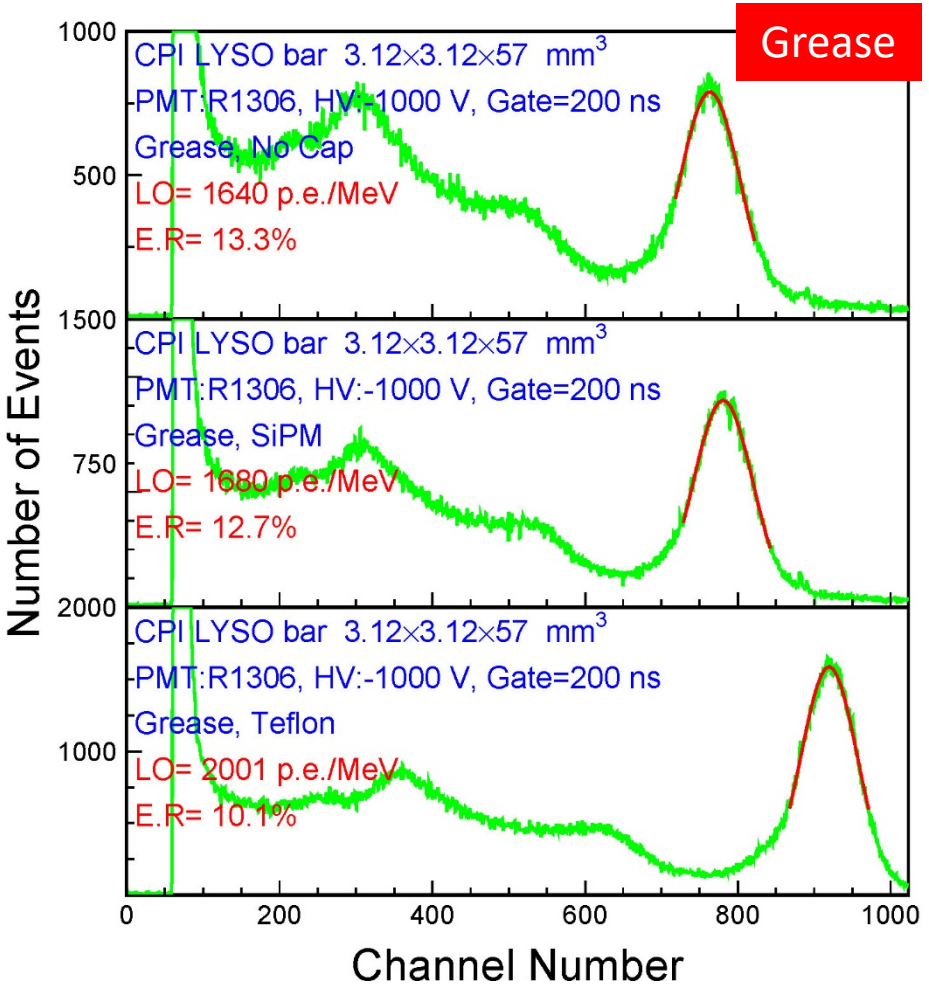
Light output measured by a Hamamatsu PMT R1306 and a LeCroy 3001 QVT MCA with coincidence triggers from a Na-22 source. LYSO bars surrounded by a Teflon block and coupled to PMT with an air-gap.



Pulse Height Spectra

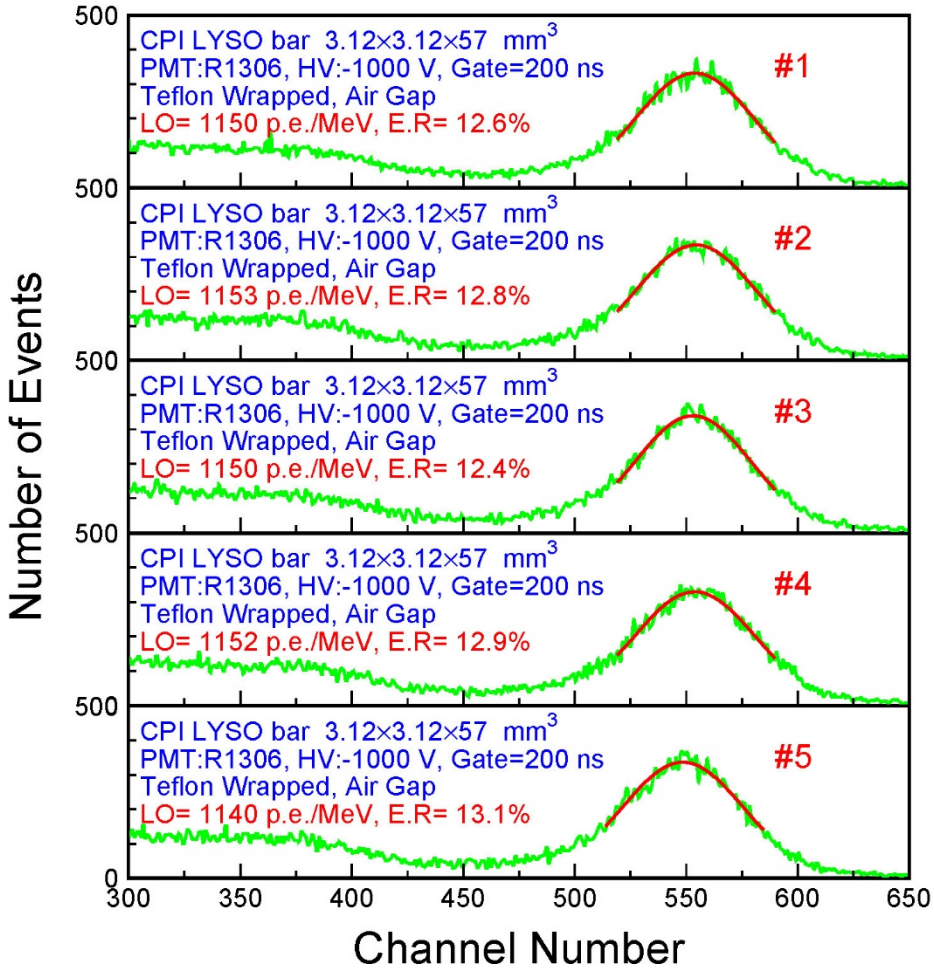
Teflon block/cap and air gap are chosen for stability

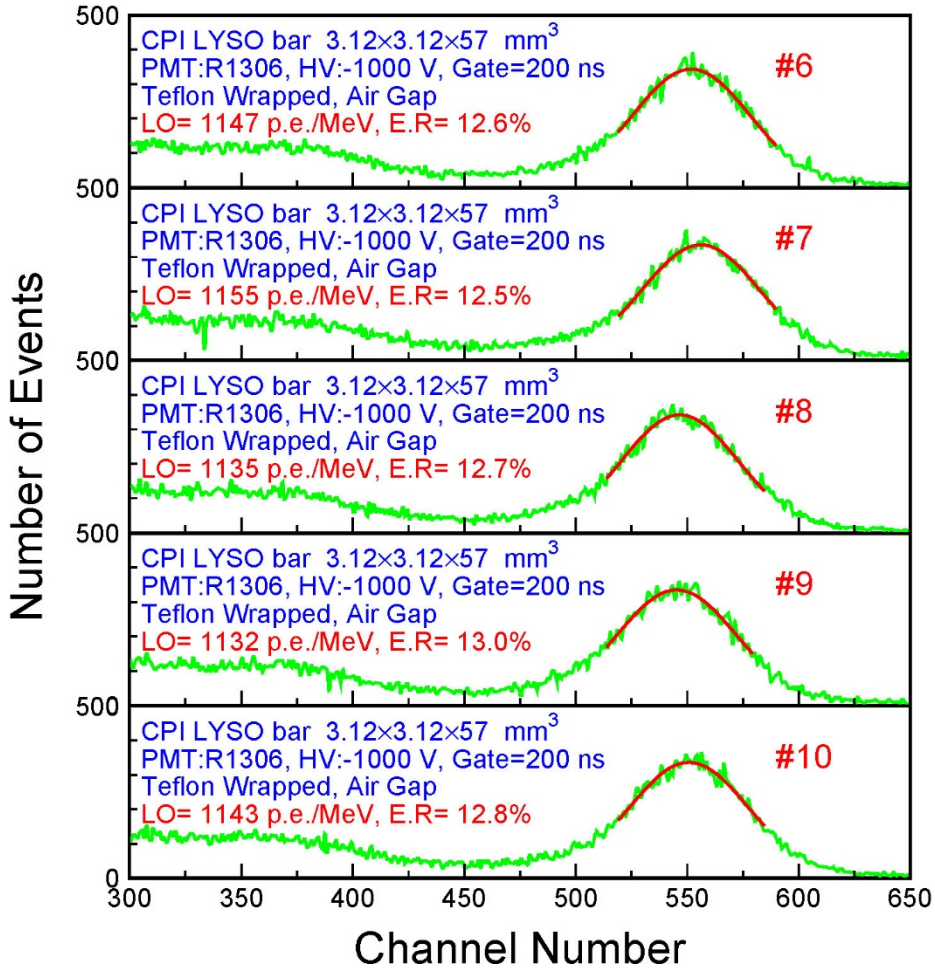




Systematic Uncertainty: LO

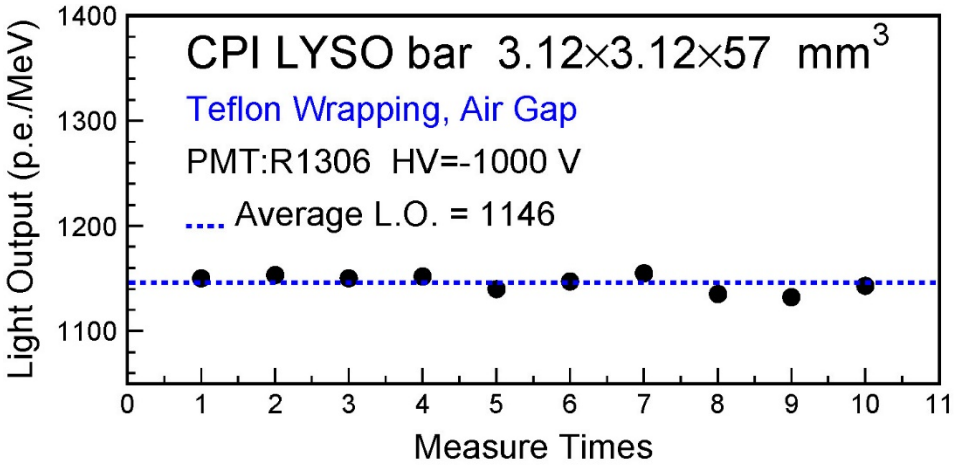
Systematic uncertainties determined for 200 ns gate

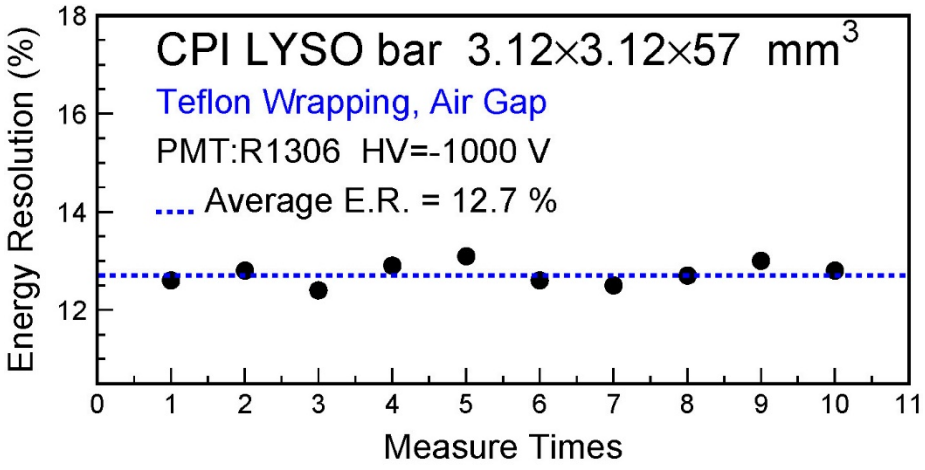


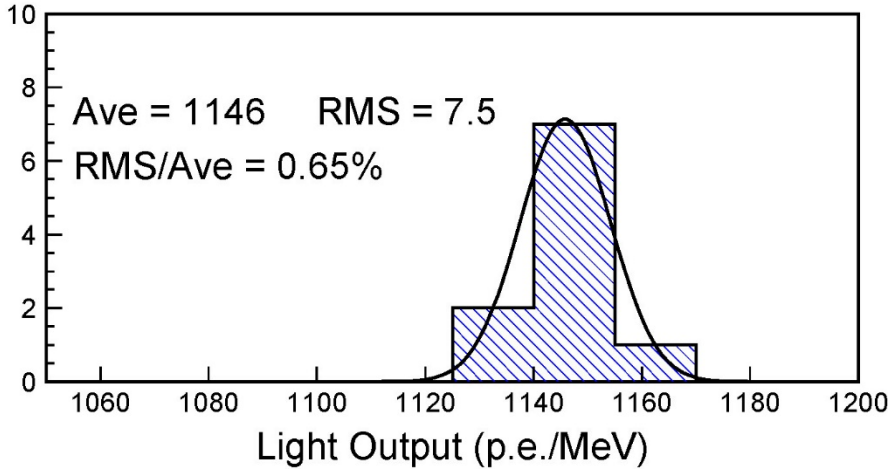


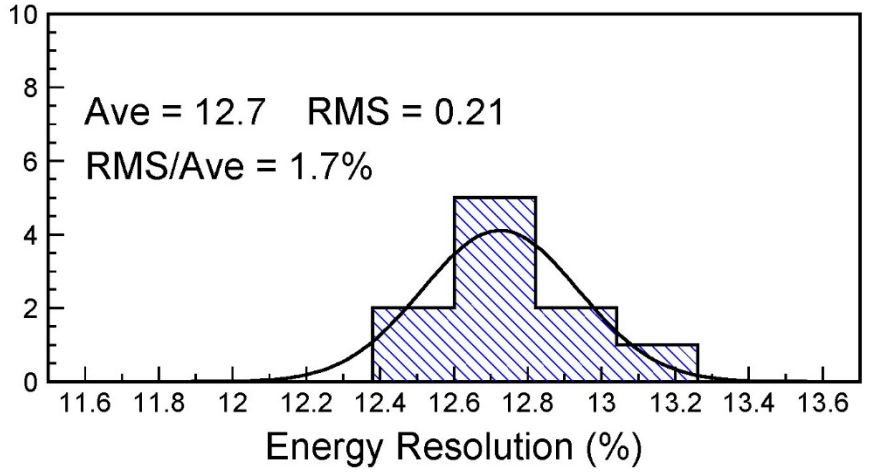
Sys. Uncertainties: LO & ER

0.7% and 1.7% respectively for LO and ER









LO, F/T & Decay Time: 15 CPI

ID	200ns E.R. (%)	50ns L.O. (p.e./MeV)	200ns L.O. (p.e./MeV)	2000ns L.O. (p.e./MeV)	LO (50) /LO (2000)	Decay Time (ns)	LO (50)/τ
1	12.6	804	1089	1104	73%	38	21.2
2	13.0	782	1103	1124	70%	42	18.6
3	13.7	779	1073	1089	72%	39	20.0
4	12.3	797	1106	1129	71%	40	19.9
5	12.8	789	1092	1115	71%	40	19.7
6	13.1	772	1057	1080	71%	39	19.8
7	12.3	784	1091	1111	71%	40	19.6
8	12.5	753	1068	1090	69%	42	17.9
9	12.7	788	1098	1108	71%	40	19.7
10	13.0	799	1111	1132	71%	40	20.0
11	12.2	799	1107	1124	71%	40	20.0
12	13.1	791	1084	1097	72%	39	20.3
13	12.7	757	1073	1098	69%	42	18.0
14	13.6	772	1058	1073	72%	39	19.8
15	13.5	756	1056	1076	70%	41	18.4
Ave	**12.9**	**781**	**1084**	**1103**	**71**	**40**	**19.5**
RMS	**0.5**	**16**	**18**	**19**	**1.1**	**1.1**	**0.9**
RMS/Ave	**3.5%**	**2.0%**	**1.7%**	**1.7%**	**1.5%**	**2.9%**	**4.4%**

LO, F/T & Decay Time: 20 SIC

ID	200ns E.R. (%)	50 ns L.O. (p.e./MeV)	200ns L.O. (p.e./MeV)	2000ns L.O. (p.e./MeV)	LO (50) /LO (2000)	Time Decay (ns)	LO (50)/τ
1	14.0	848	1194	1220	70%	42	20.2
2	13.4	802	1139	1156	69%	42	19.1
3	13.5	799	1136	1158	69%	42	19.0
4	13.6	786	1114	1133	69%	42	18.7
5	13.9	824	1146	1162	71%	40	20.6
6	13.8	797	1133	1154	69%	42	19.0
7	13.9	806	1105	1121	72%	39	20.7
8	12.7	901	1220	1234	73%	38	23.7
9	13.5	794	1070	1088	73%	38	20.9
10	13.5	875	1153	1171	75%	36	24.3
11	13.0	846	1195	1218	69%	42	20.1
12	12.9	806	1138	1159	70%	42	19.2
13	13.2	819	1132	1150	71%	40	20.5
14	13.1	865	1167	1184	73%	38	22.8
15	12.9	838	1118	1134	74%	37	22.6
16	13.2	793	1122	1142	69%	42	18.9
17	12.8	818	1138	1157	71%	40	20.5
18	14.1	826	1127	1143	72%	39	21.2
19	12.9	855	1153	1174	73%	38	22.5
20	12.9	837	1123	1141	73%	37	22.6
Ave	**13.3**	**827**	**1141**	**1160**	**71**	**40**	**20.9**
RMS	**0.4**	**30**	**33**	**34**	**1.8**	**2.0**	**1.7**
RMS/Ave	**3.2%**	**2.9%**	**2.9%**	**2.9%**	**2.6%**	**5.1%**	**8.0%**

LO, F/T & Decay Time: 10 Tianle-1

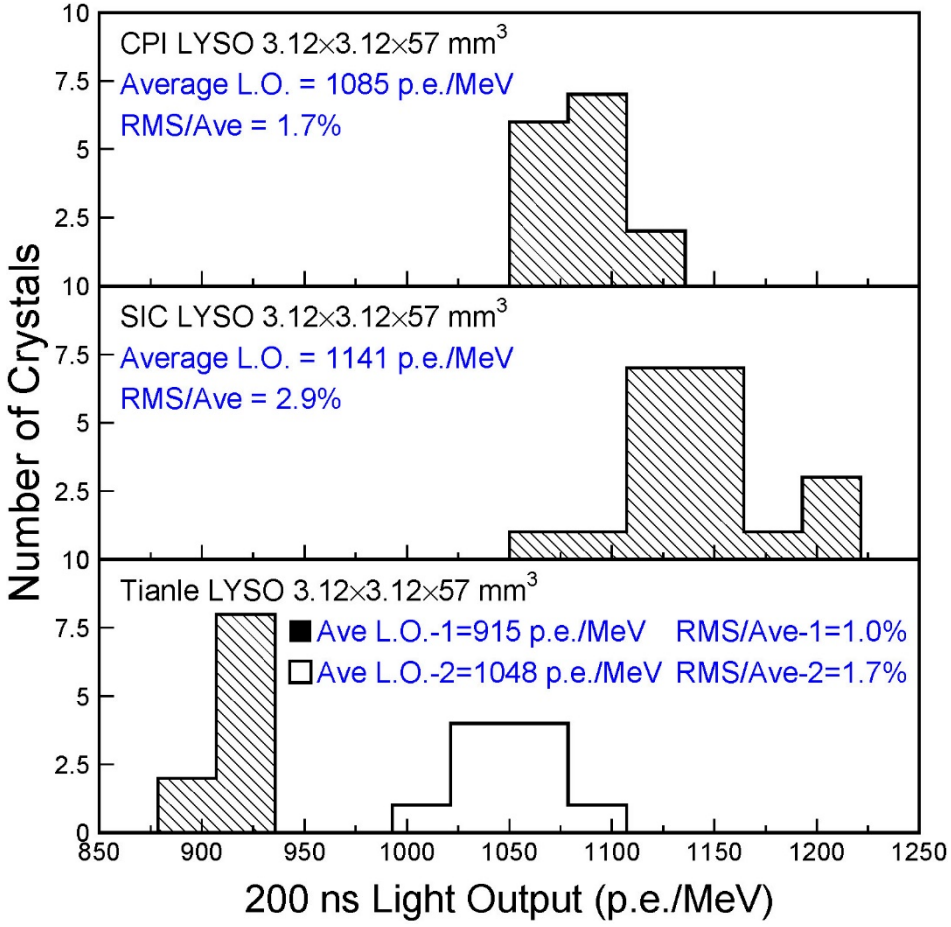
ID	200ns E.R. (%)	50 ns L.O. (p.e./MeV)	200ns L.O. (p.e./MeV)	2000ns L.O. (p.e./MeV)	LO (50) /LO (2000)	Decay Time (ns)	LO (50)/τ
1	13.5	719	932	946	76%	35	20.5
2	14.7	712	915	928	77%	34	20.9
3	14.2	705	915	931	76%	35	20.1
4	13.7	700	926	944	74%	36	19.4
5	14.1	713	902	913	78%	33	21.6
6	14.0	714	921	934	76%	34	21.0
7	13.4	693	908	922	75%	35	19.8
8	13.9	712	900	910	78%	32	22.3
9	14.3	704	913	923	76%	34	20.7
10	13.3	712	915	934	76%	34	20.9
Ave	**13.9**	**708**	**915**	**929**	**76**	**34**	**20.7**
RMS	**0.4**	**7.4**	**9.4**	**11**	**1.1**	**1.1**	**0.8**
RMS/Ave	**3.0%**	**1.0%**	**1.0%**	**1.2%**	**1.5%**	**3.1%**	**3.8%**

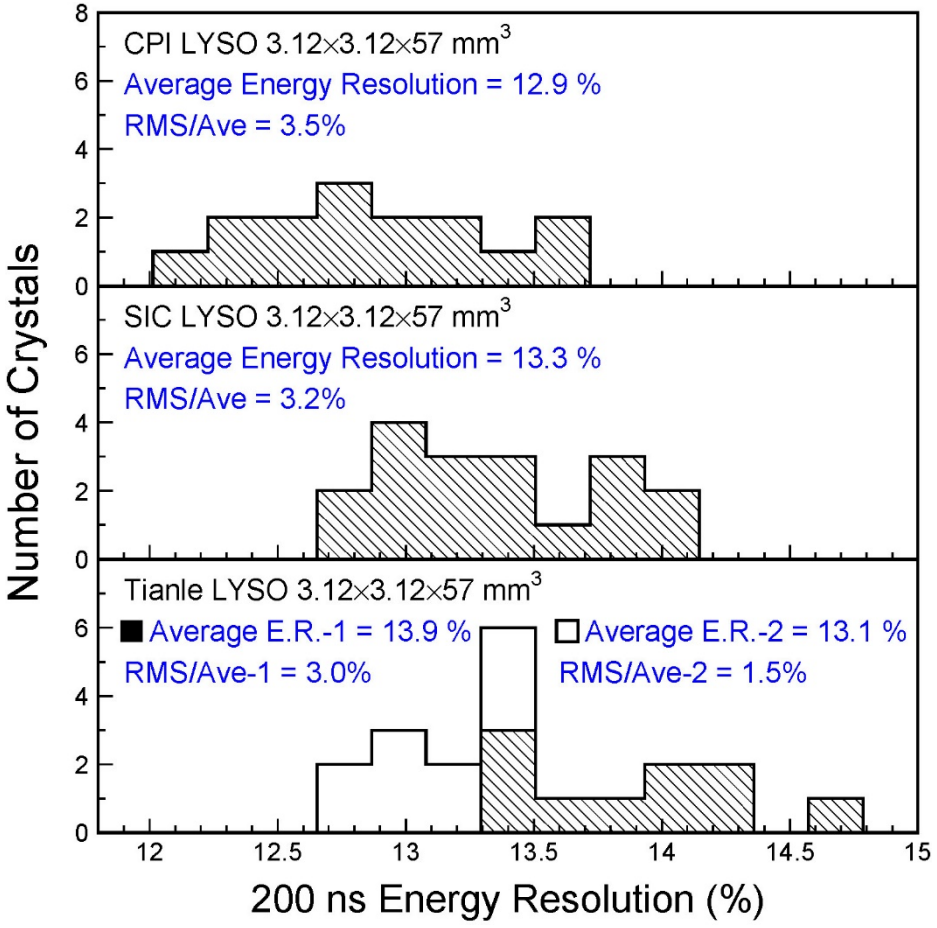
LO, F/T & Decay Time: 10 Tianle-2

ID	200ns E.R. (%)	50 ns L.O. (p.e./MeV)	200ns L.O. (p.e./MeV)	2000ns L.O. (p.e./MeV)	LO (50) /LO (2000)	Decay Time (ns)	LO (50)/τ
11	12.9	764	1053	1083	71%	40	19.1
12	13.3	755	1033	1063	71%	40	18.9
13	12.8	771	1053	1079	71%	39	19.8
14	13.2	751	1061	1098	68%	42	17.9
15	13.3	733	1029	1058	69%	42	17.5
16	13.0	746	1044	1072	70%	41	18.2
17	13.3	744	1044	1076	69%	42	17.7
18	12.9	765	1090	1121	68%	43	17.8
19	12.8	743	1021	1051	71%	40	18.6
20	13.1	763	1050	1077	71%	40	19.1
Ave	**13.1**	**754**	**1048**	**1078**	**70**	**41**	**18.4**
RMS	**0.2**	**12**	**18**	**19**	**1.1**	**1.2**	**0.7**
RMS/Ave	**1.5%**	**1.5%**	**1.7%**	**1.8%**	**1.5%**	**3.0%**	**3.9%**

Summary: LO and ER

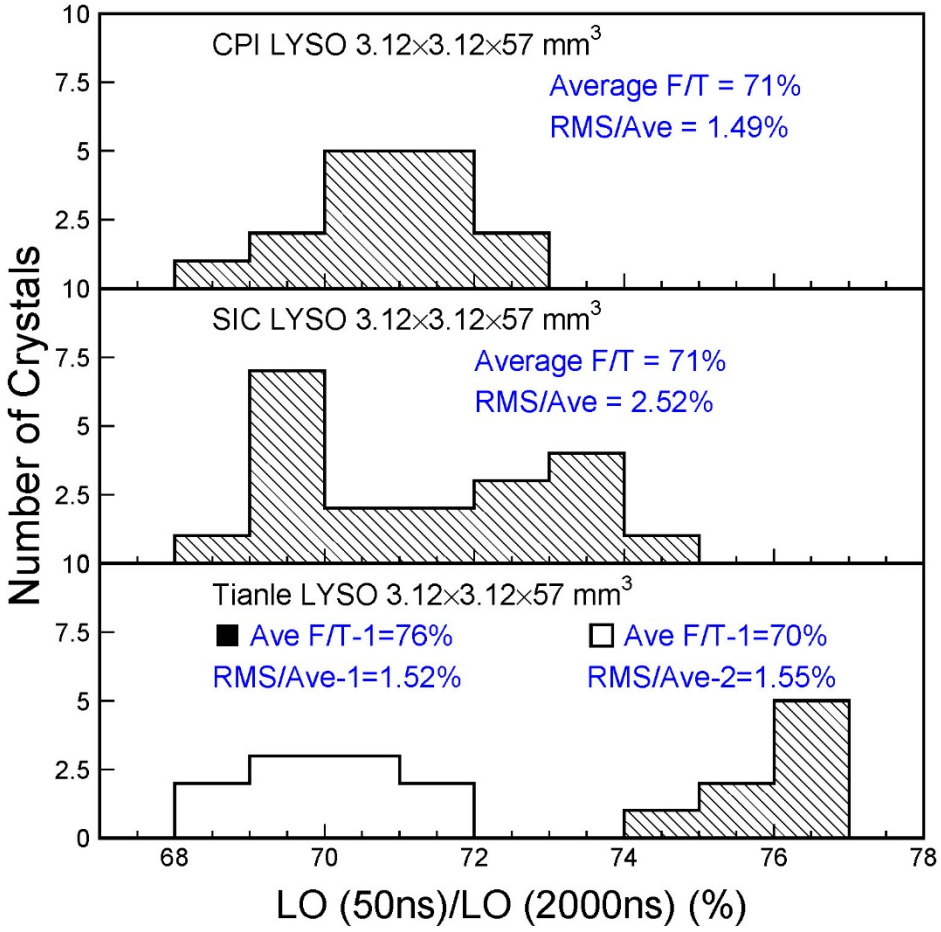
SIC crystals show the highest LO but the poorest rms

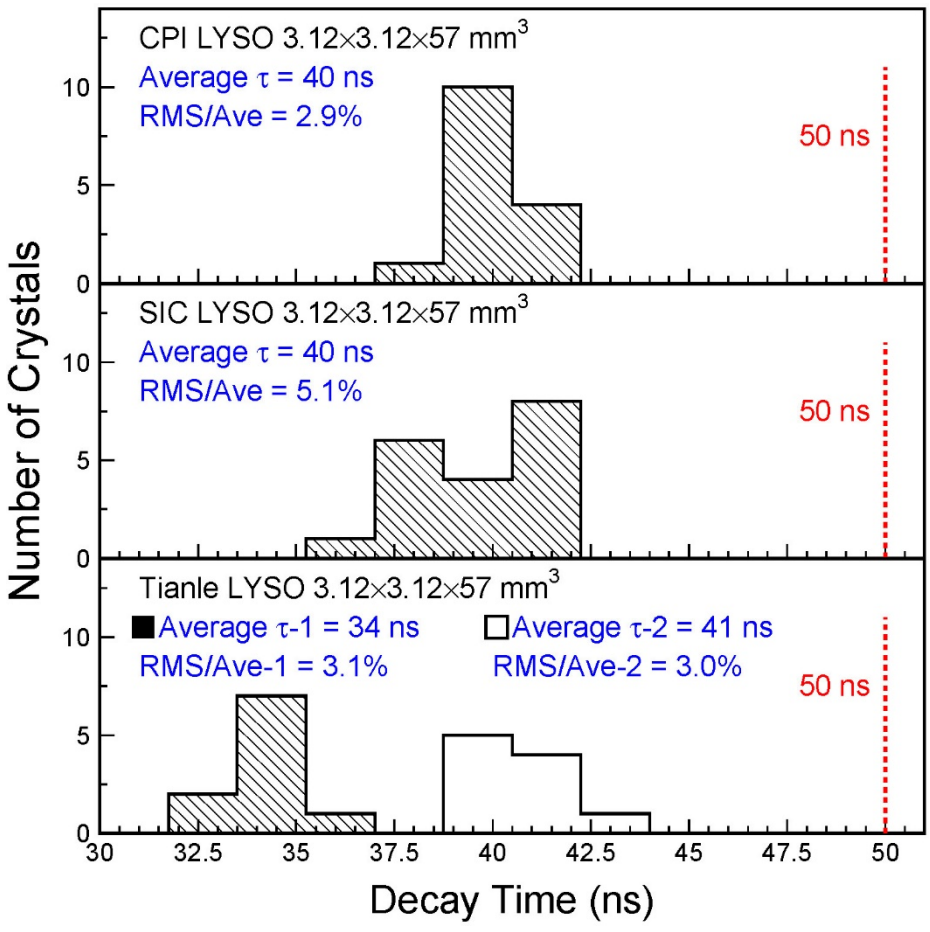




F/T:LO(50 ns)/LO(2000 ns) & Decay Time

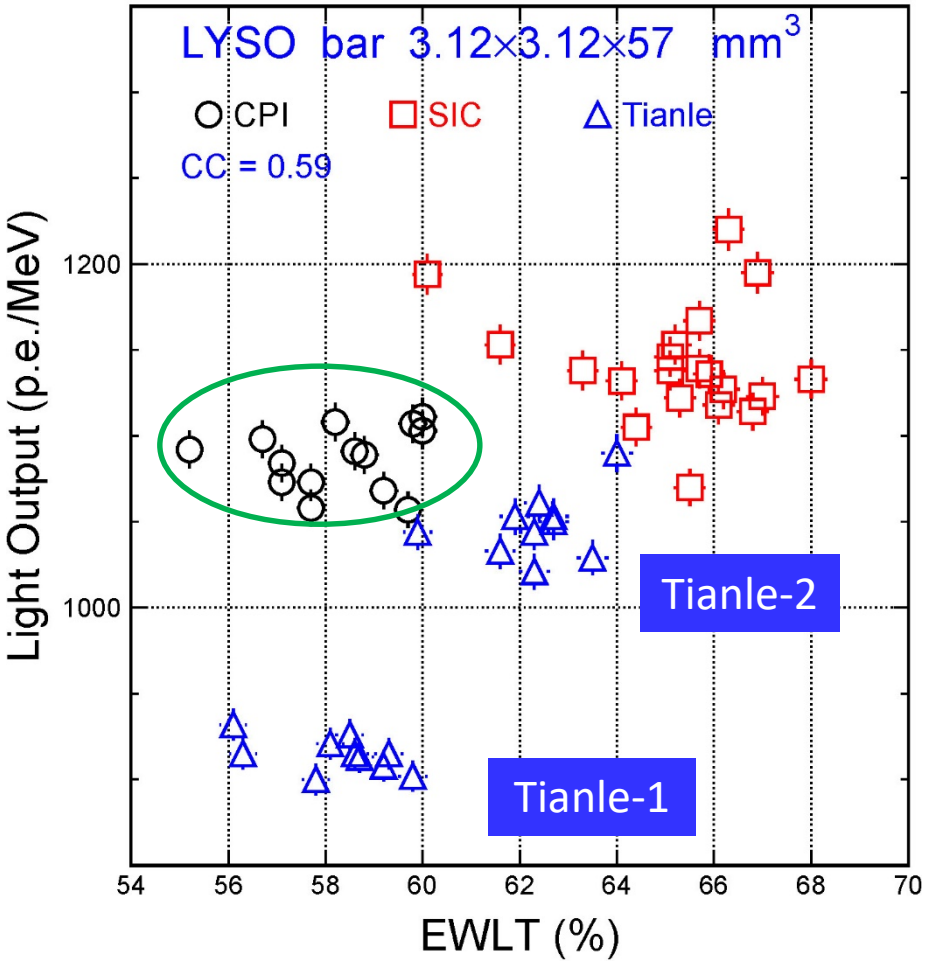
Tianle-1: F/T ratio = 76% and decay time = 34 ns
CPI, SIC, and Tianle -2: F/T ratio = 71% and decay time = 40 ns

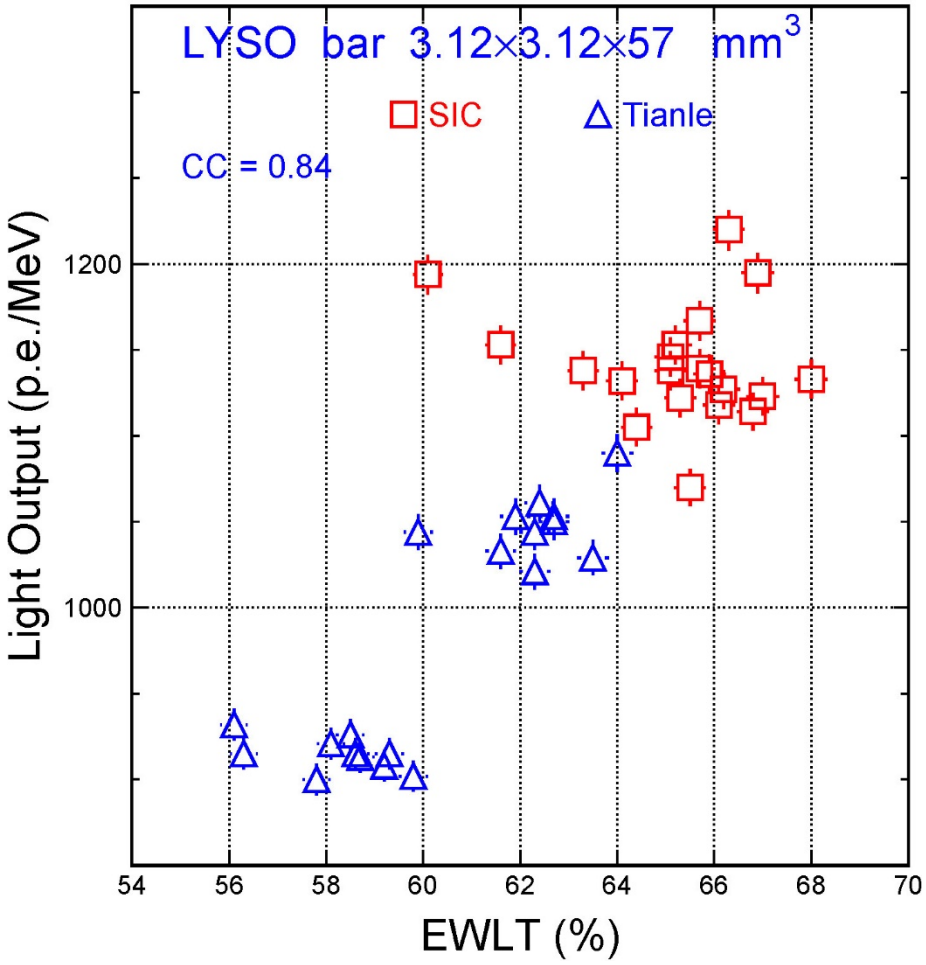




Correlations: LO vs. EWLT

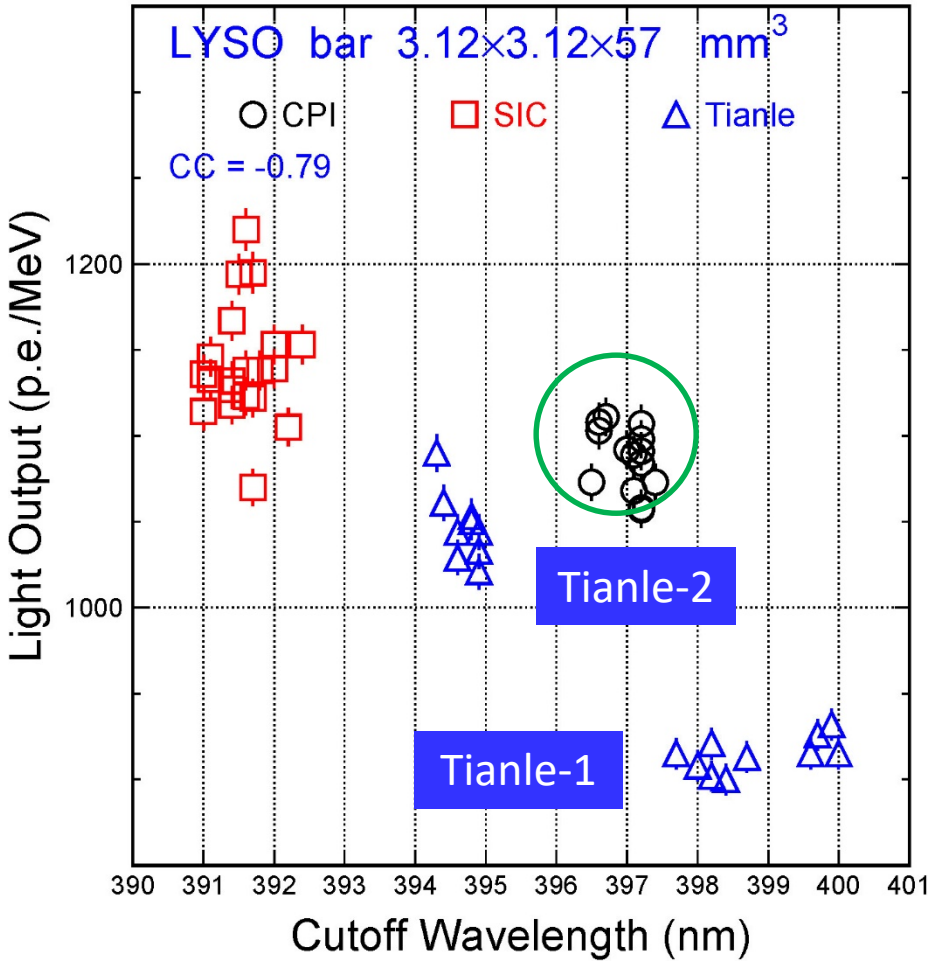
A better correlation after removing CPI samples

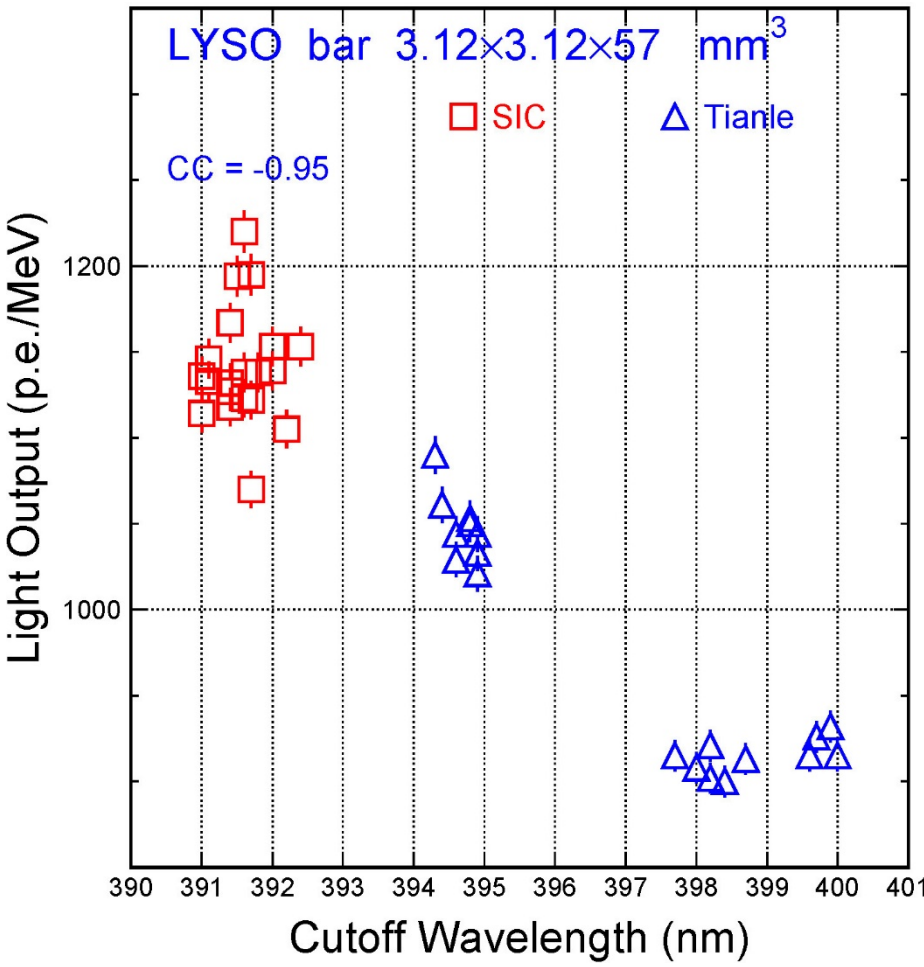




LO vs. Cutoff Wavelength

Cutoff wavelength better than EWLT because of less surface dependence





Summary

- Emission, transmittance, light output and decay kinetics of LYSO bars of 3.12x3.12x57 mm^3 from three vendors were measured. Systematic uncertainties of 0.5%, 0.3 m^{-1}, 0.7%, 1.7%, 1.5%, 3% and 4% were determined for EWLT, AC, LO, ER, F/T, decay time (τ) and LO(50ns)/τ, respectively.
- While crystals from different vendors show slightly different performance, the overall consistency is good for each vendor and each growth recipe. The Tinle-1 samples show the shortest decay time (34 ns) and the highest LO(50 ns)/τ (76) ratio although the lowest LO(50 ns).
- Correlations are observed between EWLT, cut-off wavelength and light output. The cut-off wavelength is found to be affected less by the crystal surface quality.
- The data presented will be used in the radiation damage tests for RIN:ɣ, RIN:n, TID:ɣ, TF:n, RIN:p and TF:p.