Recent Activity for CalVision

Ren-Yuan Zhu

California Institute of Technology

April 6, 2023

Recent Activities

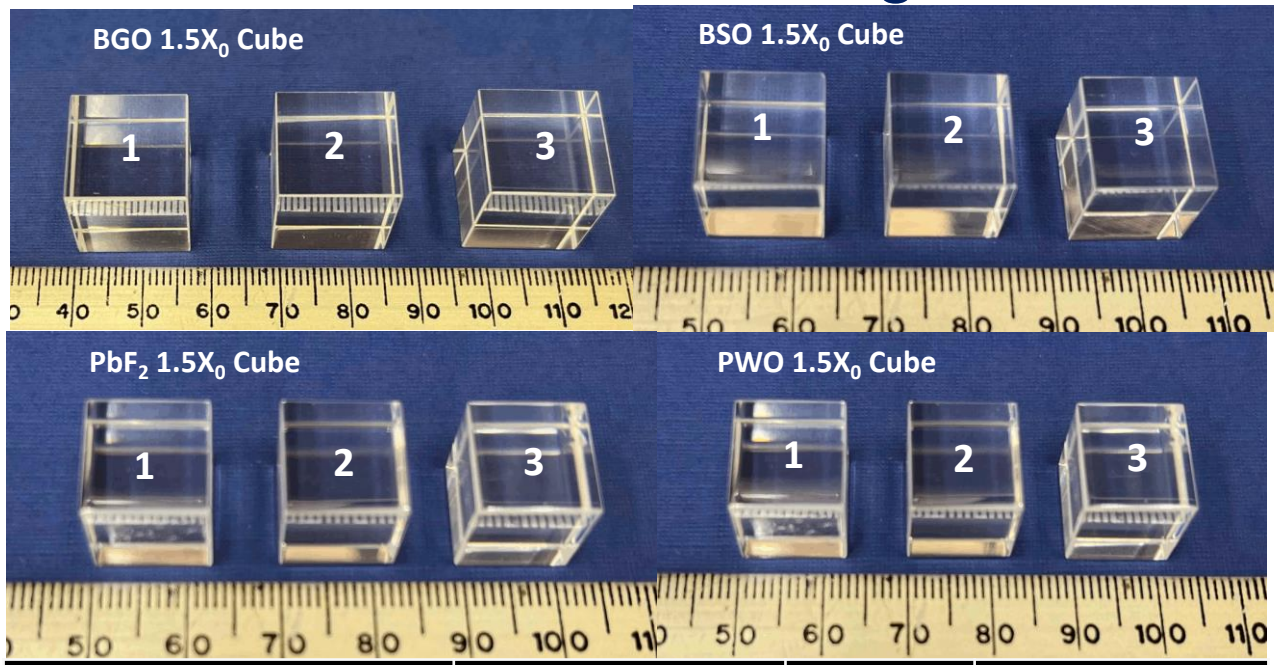
Characterized large BGO, PbF_2 and PWO samples last year by Chen and Liyuan. Received small samples from SIC. Characterized small LYSO:Ce crystals for beam test by Liyuan.

Our plan this year is to understand current status of inorganic scintillators relevant for the CalVision mission and to test scintillating glass samples from industry.

Blue Sky R&D: Several SBIR proposals for scintillating glass development from the US industry are now under review.

Worked on ECFA DRD proposals with European colleagues.

1.5 X_0 Samples



ID	Dimension (mm^3)	Qty.	Polishing
BGO-1.5X0-1,2,3	17×17×17	3	All faces
BSO-1.5X0-1,2,3	17×17×17	3	All faces
PbF_2-1.5X0-1,2,3	14×14×14	3	All faces
PWO-1.5X0-1,2,3	13×13×13	3	All faces
$1.5X_0$ crystal samples received from SIC on Oct. 24, 2022			

Measurement plan:

- X-ray excited luminescence (XEL)
- Transmittance (LT)
- Emission Weighted transmittance (EWLT)
- Pulse Height Spectra (PHS)
- Light Output (LO)
- Decay Time (τ)
- Light Yield with EWQE taken out

Inorganic Scintillators for HHCAL

Snowmass 2022 White Paper: https://doi.org/10.48550/arXiv.2203.06788

	BGO	BSO	PWO	PbF_2	PbFCl	Sapphire :Ti	AFO Glass	DSB:Ce Glass[1]	BGS Glass[2]	ABS Glass[3]	DSB:Ce,Gd Glass[4,5]	HFG Glass[6]
Density (g/cm^3)	7.13	6.8	8.3	7.77	7.11	3.98	4.6	3.8	4.2	4.53	4.7 - 5.4[d]	5.95
Melting point (℃)	1050	1030	1123	824	608	2040	980[7]	1420[8]	1550	?	1420[8]	570
X_0 (cm)	1.12	1.15	0.89	0.94	1.05	7.02	2.96	3.36	2.62	2.41	2.14	1.74
R_M (cm)	2.23	2.33	2.00	2.18	2.33	2.88	2.90	3.52	3.33	3.09	2.56	2.45
λ_I (cm)	22.7	23.4	20.7	22.4	24.3	24.2	26.4	32.8	31.8	28.8	24.2	23.2
Z_{eff} value	71.5	73.8	73.6	76.7	74.7	11.1	41.4	42.9	49.6	51.9	47.2	55.7
dE/dX (MeV/cm)	8.99	8.59	10.1	9.42	8.68	6.75	6.84	5.56	5.90	6.42	7.68	8.24
Emission Peak[a] (nm)	480	470	425 420	\	420	300 750	365	440	430	396	440 460	325
Refractive Index[b]	2.15	2.68	2.20	1.82	2.15	1.76	\	\	\	\	\	1.50
LY (ph/MeV)[c]	7,500	1,500	130	\	150	7,900	450	~500	2,500	800	1,300	150
Decay Time[a] (ns)	300	100	30 10	\	3	300 3200	40	180 30	400 90	1200 260	120, 400 50	25 8
d(LY)/dT (%/°C)[c]	-0.9	?	-2.5	\	?	?	?	-0.04	0.3	?	?	-0.37
Cost ($/cc)	6.0	7.0	7.5	6.0	?	0.6	?	2.0	2.0	?	2.0	?

a. Top line: slow component, bottom line: fast component.
b. At the wavelength of the emission maximum.
c. At room temperature (20°C) with PMT QE taken out.
d. Gd loaded.

1. E. Auffray, et al., J. Phys. Conf. Ser. 587, 2015
2. V. Dormenev, et al., NIMA 1015, 2021
3. G. Tang, et al., Opt. Mater. 130, 2022
4. R. W. Novotny, et al., J. Phys. Conf. Ser. 928, 2017
5. V. Dormenev , et al., the ATTRACT Final Conference
6. E. Auffray, et al., CERN-PPE/96-35, 1996
7. R. A. McCauley et al., Trans. Br. Ceram. Soc., 67. 1968
8. I. G. Oehlschlegel, Glastech. Ber. 44, 1971

Raw Material Cost for Glasses

Weight ratio (%)	DSB Glass	DSB:Gd Glass	HFG Glass	Price/kg*
BaO	56.1	44.9	\	5
B_2O_3	\	\	\	3.4
SiO_2	43.9	35.1	\	0.57
Al_2O_3	\	\	\	1.5
Lu_2O_3	\	\	\	500
Gd_2O_3	\	20	\	10
BaF_2	\	\	28	0.95
AlF_3	\	\	2	0.8
YF_3	\	\	2	3
NaF	\	\	12	1
HfF_4	\	\	56	160
CeF_3	Unknown	Unknown	Unknown	10
Price/CC	0.01	0.02	0.54	

Use low-cost raw materials, such as Gd_2O_3 and BaF_2, would help

* https://www.alibaba.com/

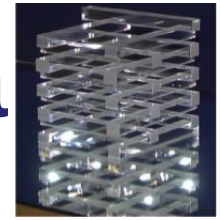
Summary

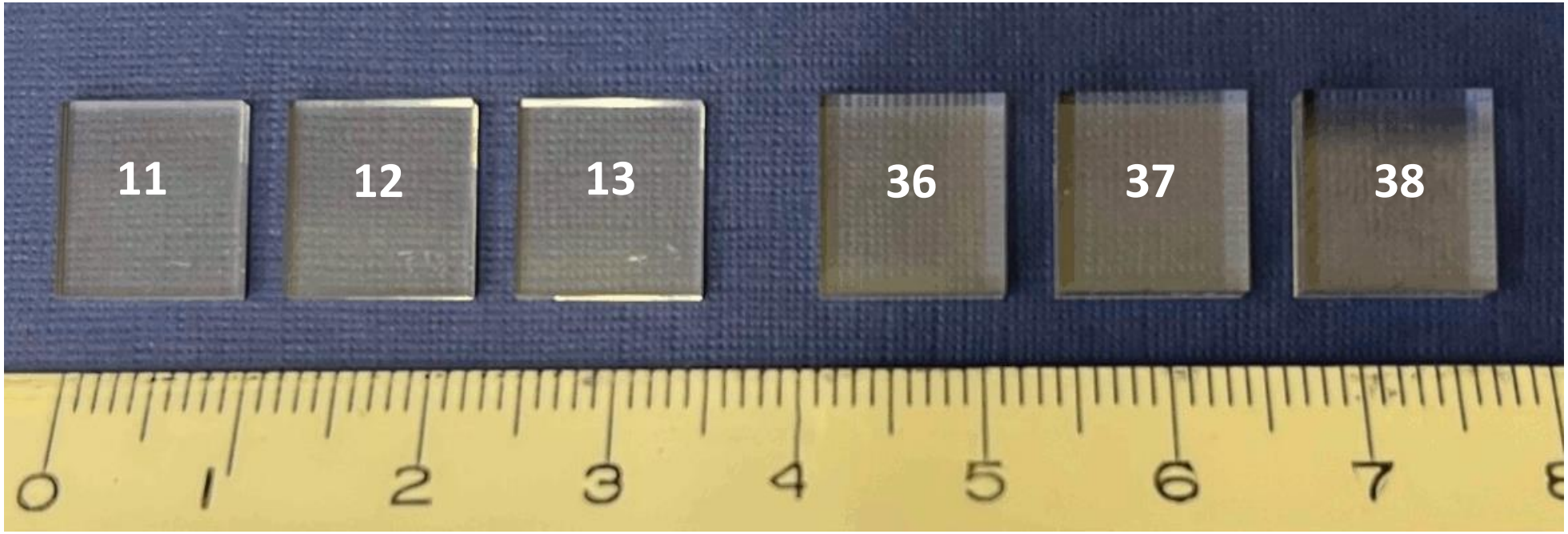
The **CalVision** mission is to build a longitudinally segmented crystal ECAL for the proposed Higgs factory by using heavy crystals, such as BGO or PWO.

The **HHCAL concept** promises the best jet mass resolution by total absorption. Crucial R&D is needed for cost-effective inorganic scintillators. This is very challenging for crystals. R&D is on-going by the US industry, Europe and China. The glass density, however, remains low as compared to crystals.

Acknowledgements: DOE HEP Award DE-SC0011925

Report on Six LYSO:Ce Plates for Virginia



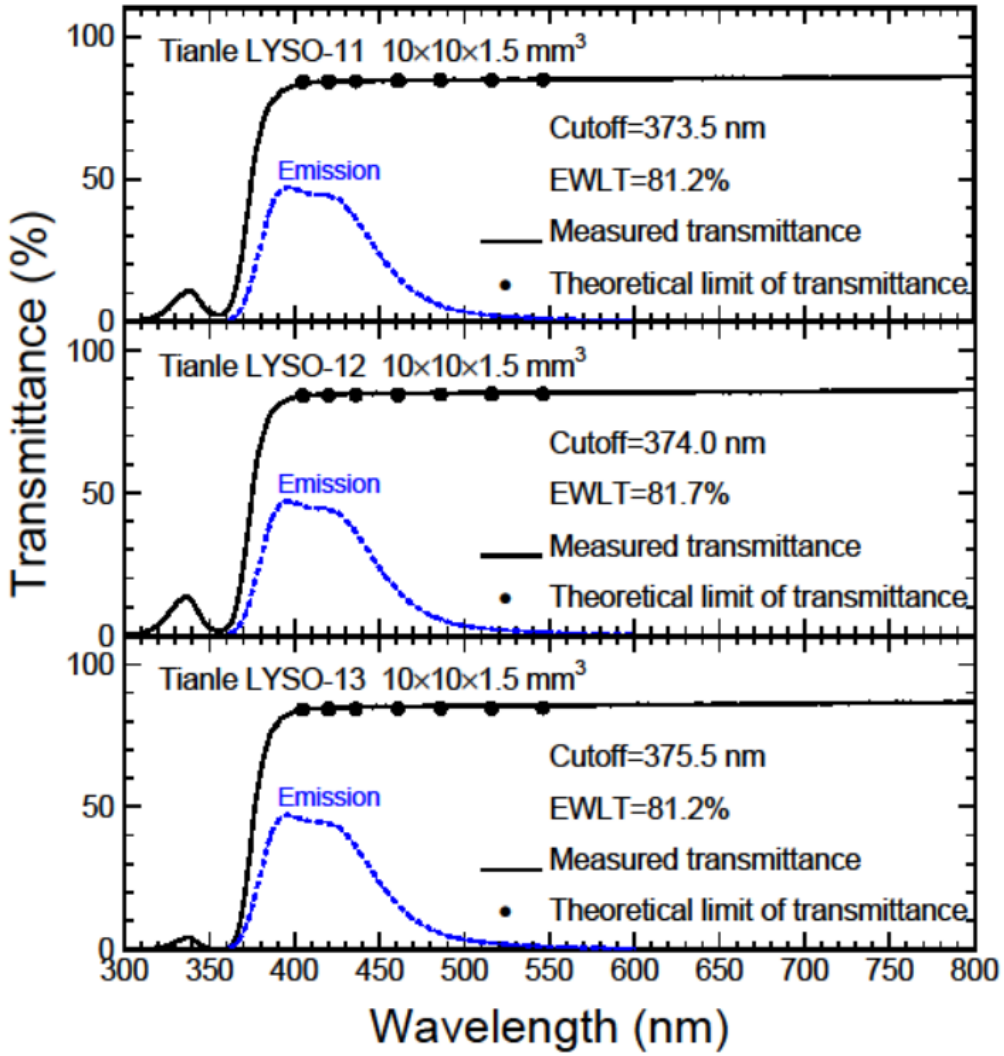


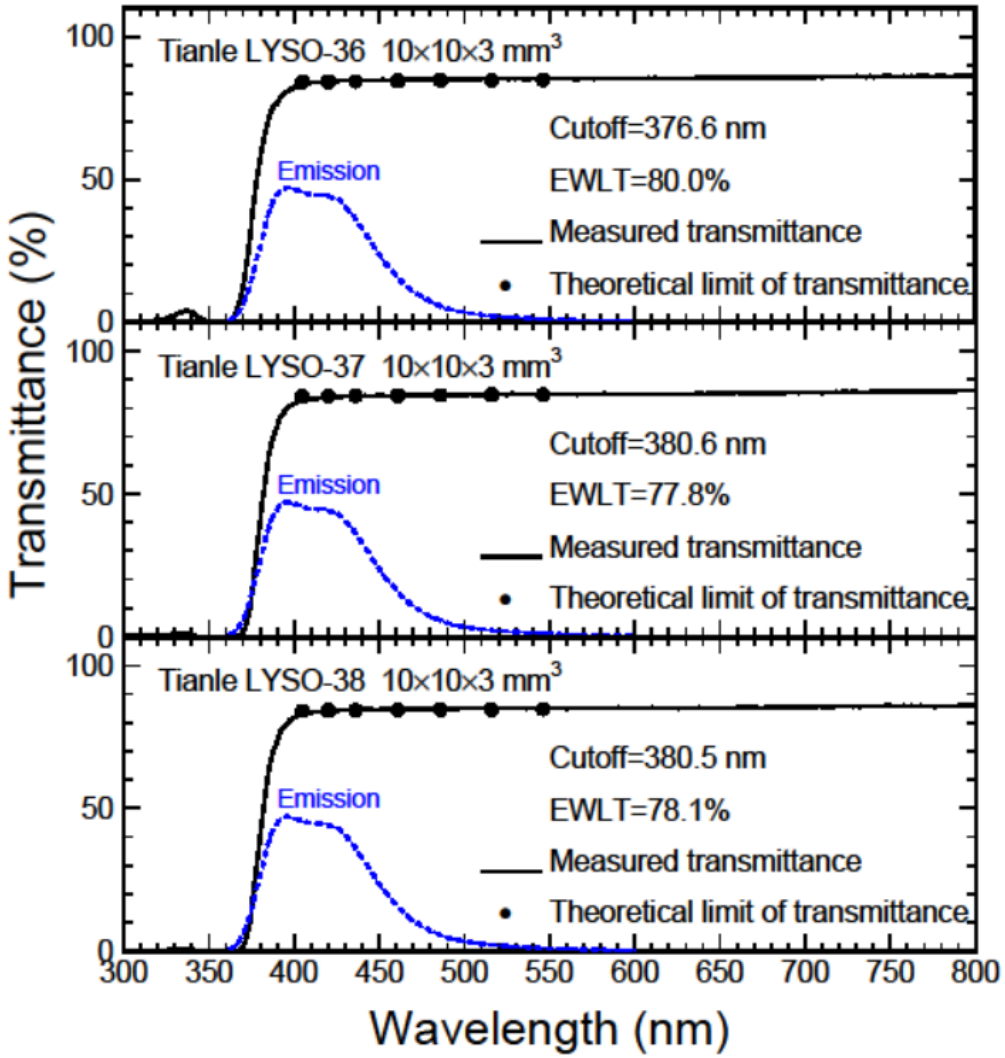
ID	Samples #	Dimension (mm^3)	Polishing
Tianle LYSO-11, 12, 13	3	10×10×1.5	All faces
Tianle LYSO-36, 37, 38	3	10×10×3	All faces

Measurements: Transmittance and Light Output

Transmittance

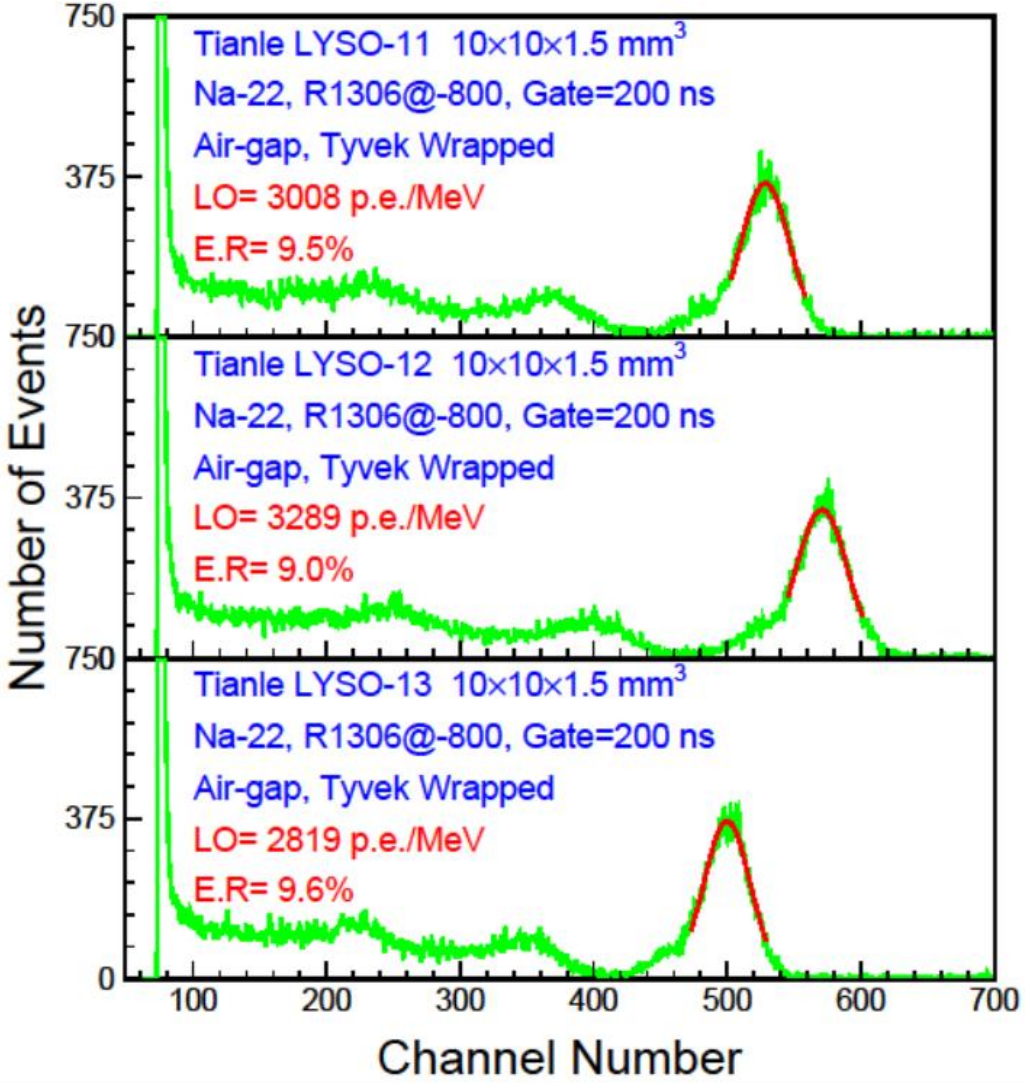
Six LYSO plates showed consistent transmittance

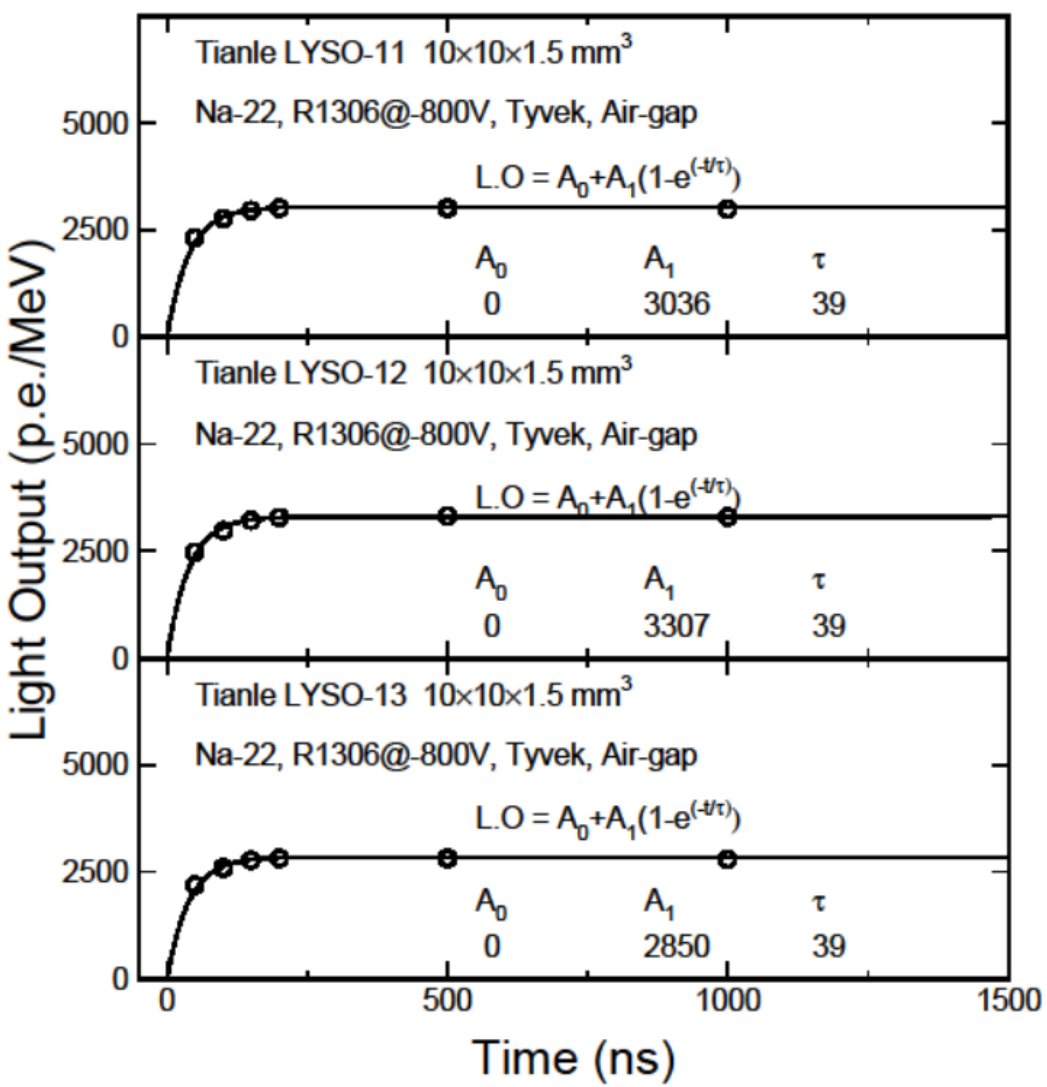




Light Output and Decay (1.5 mm)

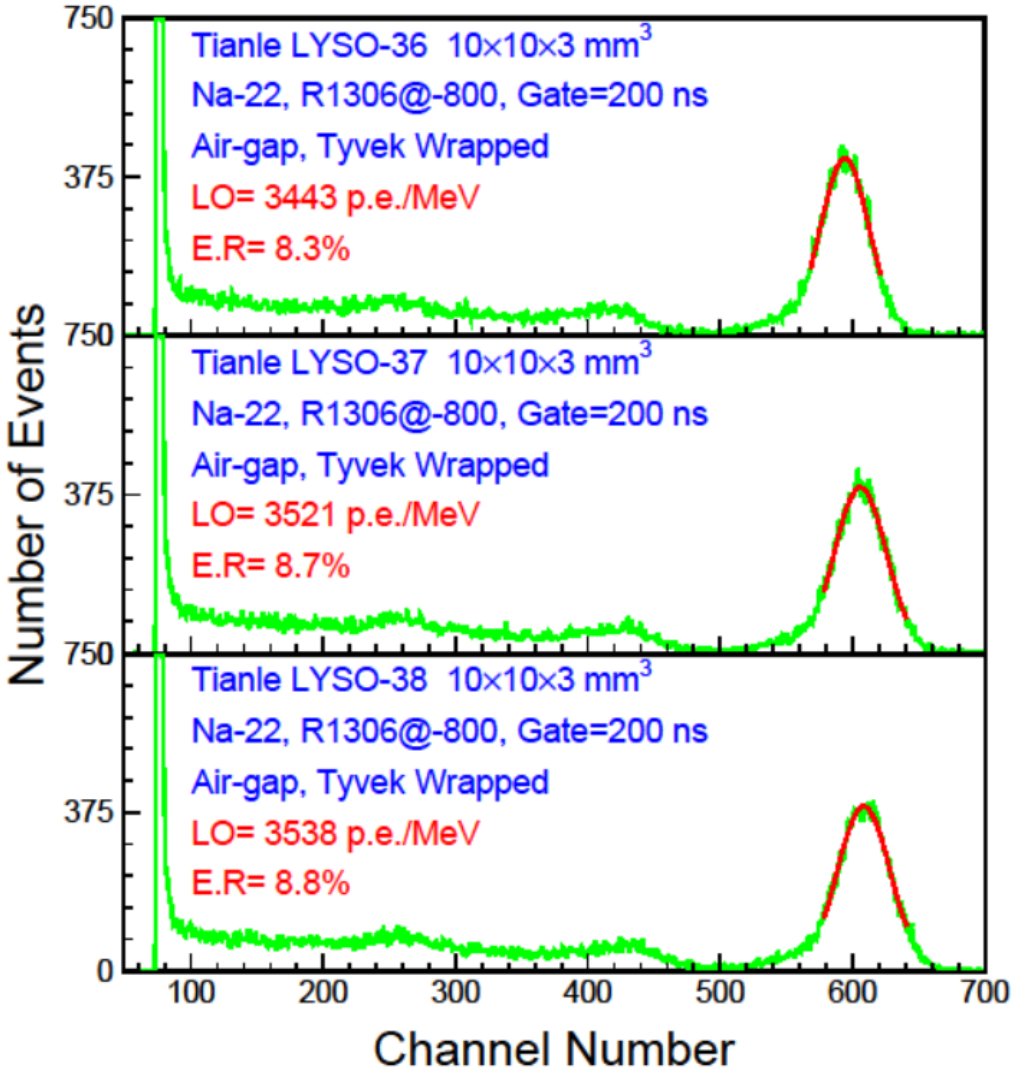
Three 1.5 mm LYSO plates show consistent decay time of ~39 ns

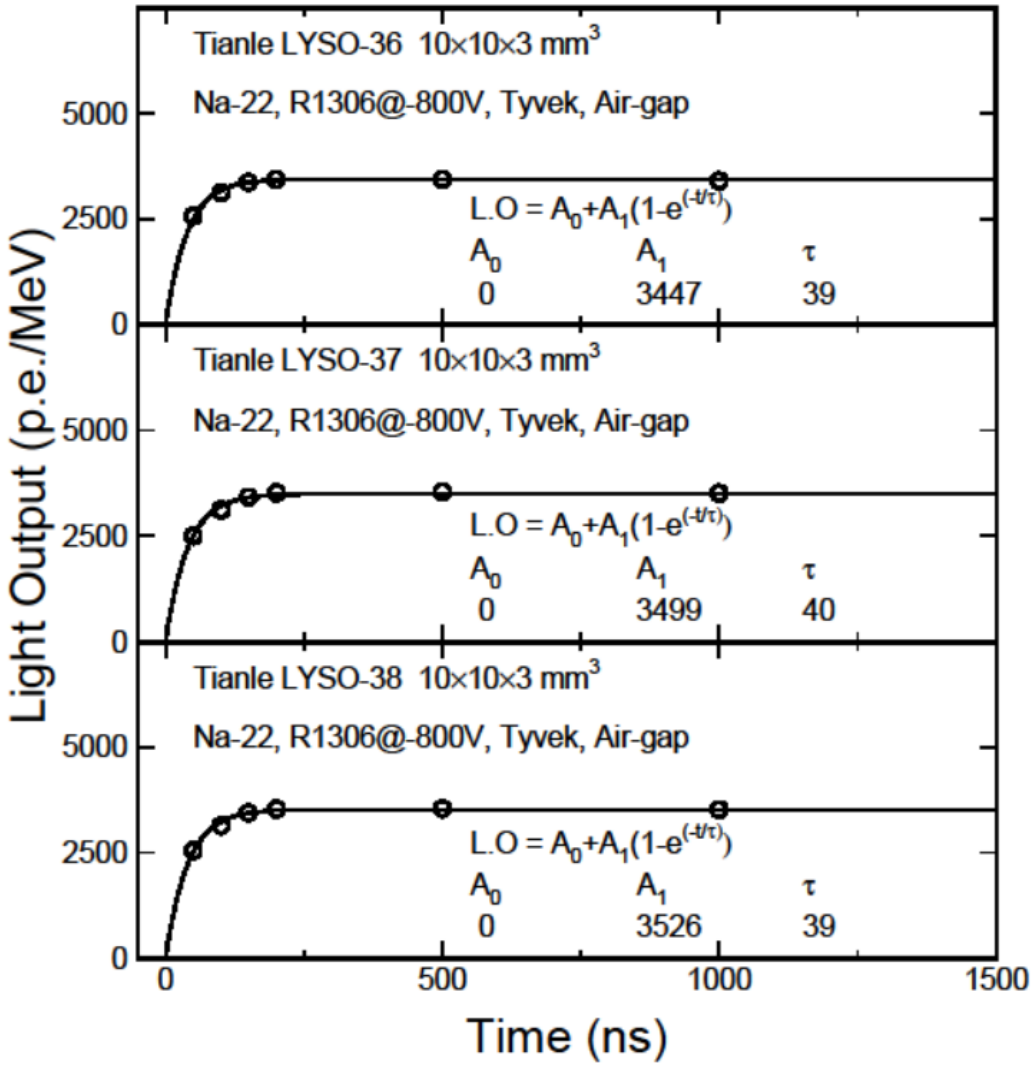




Light Output and Decay (3 mm)

Three 3 mm LYSO plates show consistent decay time of ~39 ns





Summary

Light output of 1.5 mm plates is ~13% lower than that of 3 mm plates due to a loose Tyvek wrapping

ID	Dimensions (mm^3)	EWLT (%)	ER (%)	200 ns LO (p.e./MeV)	Fit LO (p.e./MeV)	Decay Time (ns)
11	10×10×1.5	81.2	9.5	3008	3036	39
12	10×10×1.5	81.7	9.0	3289	3307	39
13	10×10×1.5	81.2	9.6	2819	2850	39
	Avg.	81.4	9.4	3039	3064	39
	RMS/Avg (%)	0.4	3.4	7.8	7.5	0.0
36	10×10×3	80.0	8.3	3443	3447	39
37	10×10×3	77.8	8.7	3521	3499	40
38	10×10×3	78.1	8.8	3538	3526	39
	Avg.	78.6	8.6	3501	3491	39
	RMS/Avg (%)	1.5	3.1	1.4	1.2	1.5