Irradiation Experiments at Caltech for BTL Radiation Study

Adi Bornheim, Chen Hu, Nan Lu, Maria Spiropulu, Jason Trevor, Liyuan Zhang and Ren-Yuan Zhu

California Institute of Technology

Jul 3, 2019

Presented in the CMS MTD Barrel Sensor Meeting at CERN

Introduction

A Question from the Fermilab Director's Review

"Effect on time resolution related to the instantaneous TID (rad/hour). From your 25 kGy after 10 years, we can derive 2.5 kGy per year i.e., 0.5 Gy/hour (50 rad/hour). Measurement of assembled BTL with MIP during irradiation should be performed before going to further. The noise induced from the scintillating tile can deteriorate the timing resolution."

Our Plan: Six Experiments of Two Types

- One total ionization dose (TID:ɣ) and two total neutron/proton fluence (TF:n/p) for BTL sensors from selected vendors.
- Three radiation induced photocurrent/readout noise (RIN) and coincidence timing resolution (CTR) under the expected dose rate and hadron (n/p) flux. These experiments follow R. Mao *et al.*, Paper N32-4 and N32-5, *IEEE NSS Conference Record* (2009).

Radiation Expected by CMS MTD

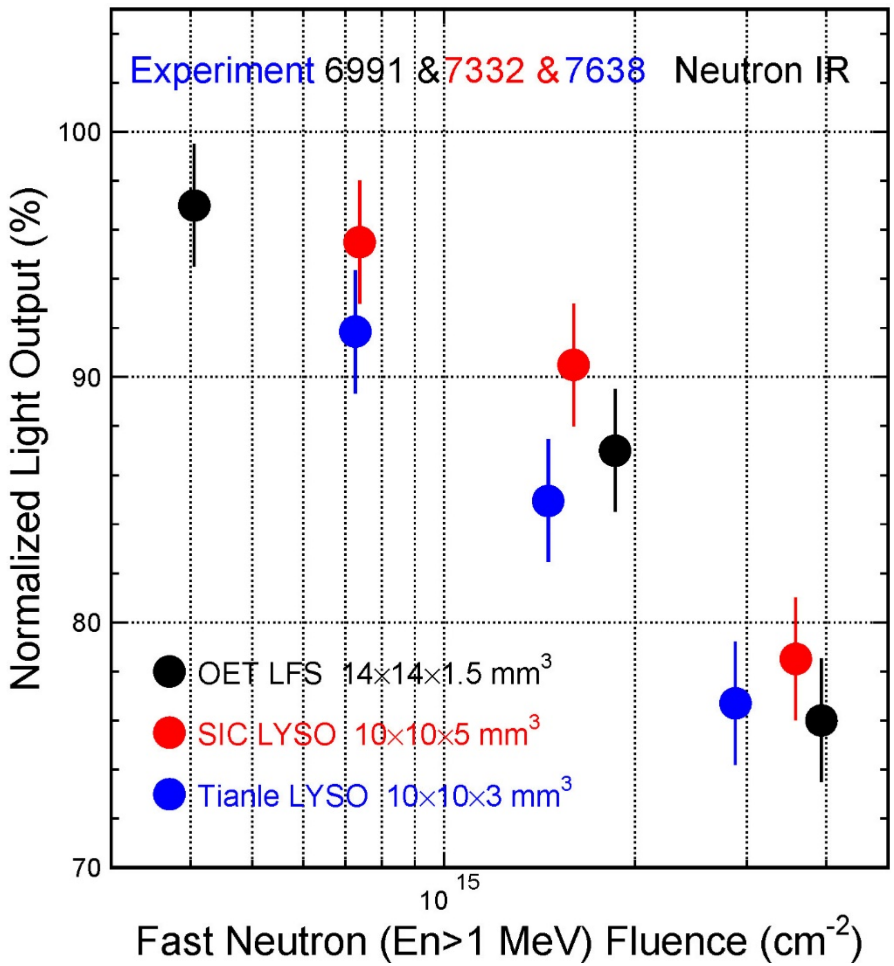
Data from MTD TDR, assuming 5×10^{34} $cm^{-2}s^{-1}$ and 3,000 fb^{-1}, and a safety factor of 2, a la. M. Lucchini, MTD Barrel Sensors Meeting, May 8, 2019

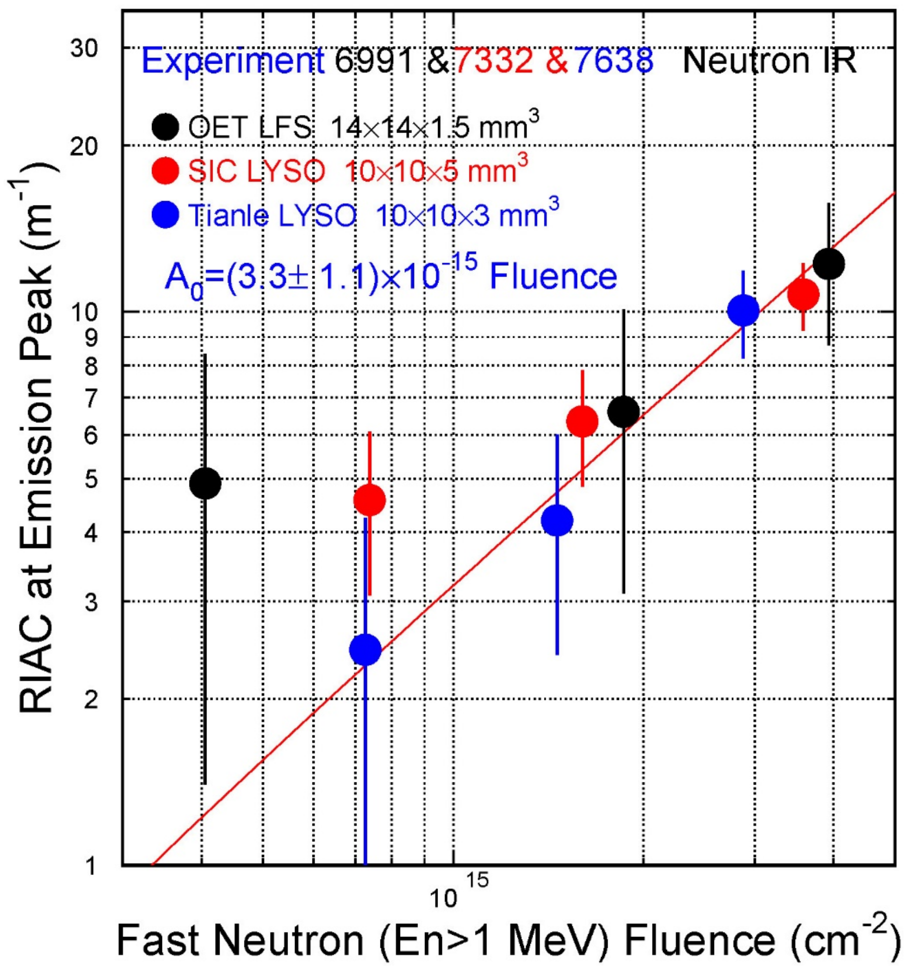
CMS MTD	η	n_{eq} (cm^{-2})	n_{eq} Flux ($cm^{-2}s^{-1}$)	Proton (cm^{-2})	p Flux ($cm^{-2}s^{-1}$)	Dose (Mrad)	Dose rate (rad/h)
Barrel	0.00	2.6E+14	3.2E+06	2.2E+13	2.7E+05	2.4	108
Barrel	1.15	2.9E+14	3.6E+06	2.4E+13	3.0E+05	3.2	142
Barrel	**1.45**	**3.0E+14**	**3.8E+06**	**2.5E+13**	**3.2E+05**	**3.7**	**165**
Endcap	1.60	1.7E+14	2.1E+06	1.4E+13	1.8E+05	3.8	169
Endcap	2.00	3.6E+14	4.5E+06	3.1E+13	3.8E+05	11.3	506
Endcap	2.50	9.9E+14	1.2E+07	8.4E+13	1.1E+06	39.0	1755
Endcap	3.00	2.6E+15	3.2E+07	2.2E+14	2.7E+06	103.5	4658

Results of TF:n for LYSO

C. Hu *et al.*, *J. Phys.: Conference Series* **1162**, 012020 (2019)

Vendor	OET	SIC	Tianle
Dimension (mm^3)	14×14×1.5	10×10×5	10×10×3

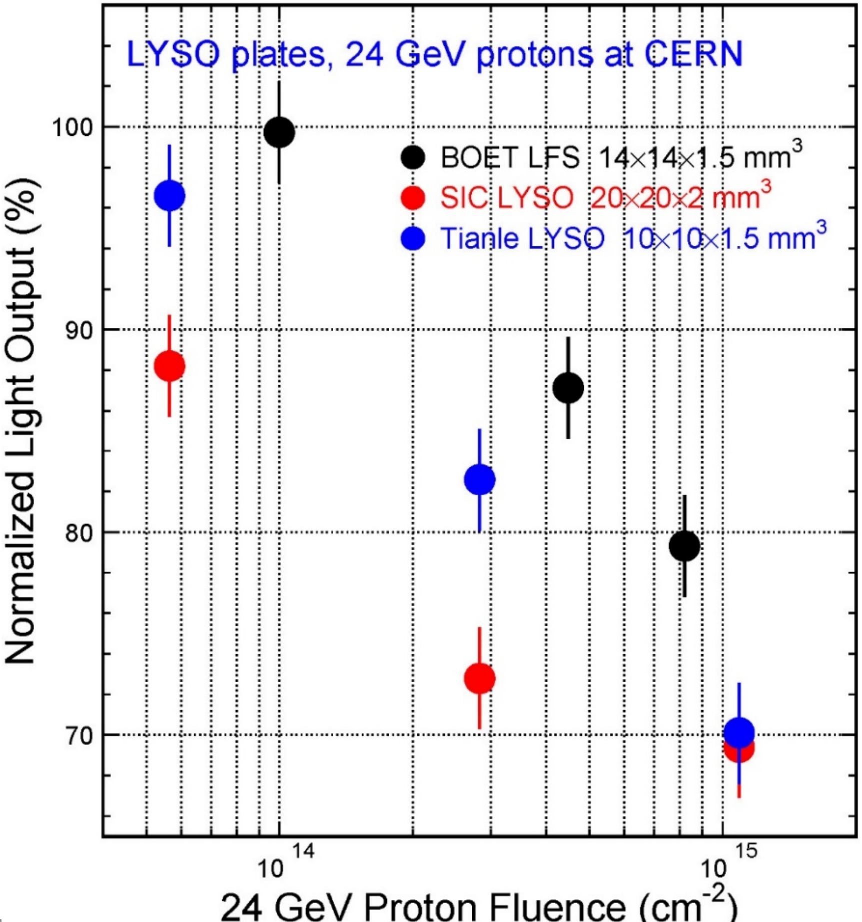


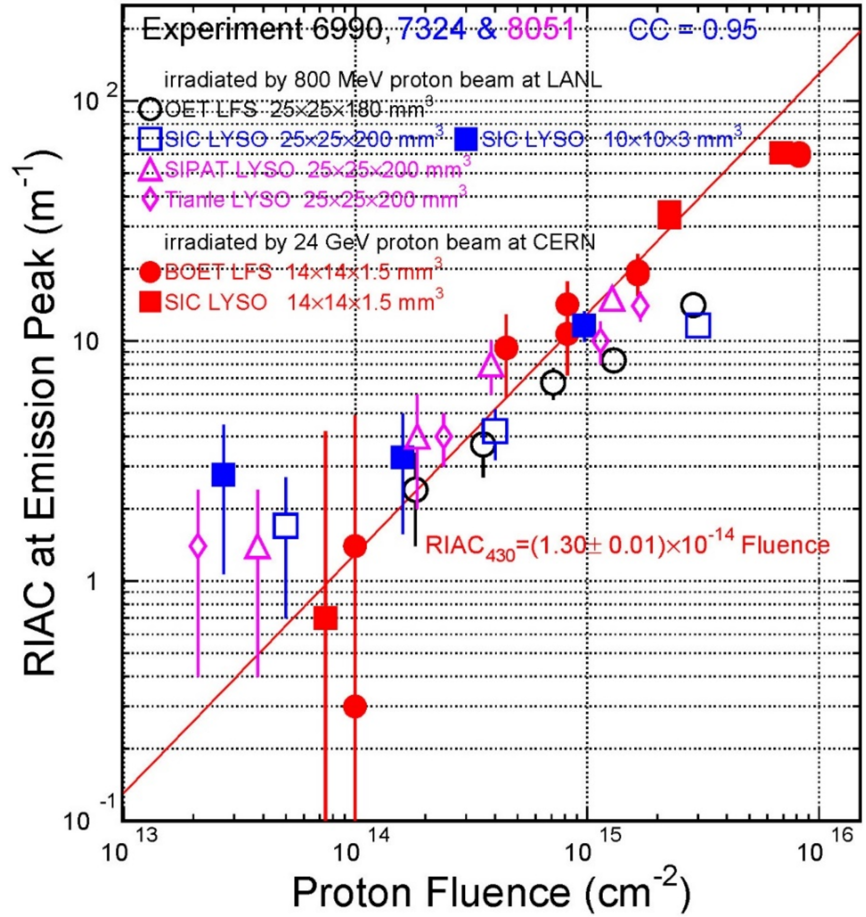


Results of TF:p for LYSO

F. Yang *et al.*, *IEEE Trans. Nucl. Sci.* **64**, pp. 665-672 (2017).
C. Hu *et al.*, *IEEE Trans. Nucl. Sci.* vol. **65**, pp. 1018-1024 (2018).

Vendor	BOET	OET	SIC	SIPAT	Tianle
Dimension (mm^3)	14×14×1.5	25×25×180	14×14×1.5, 20×20×2 10×10×3, 25×25×200	25×25×200	10×10×1.5 25×25×200

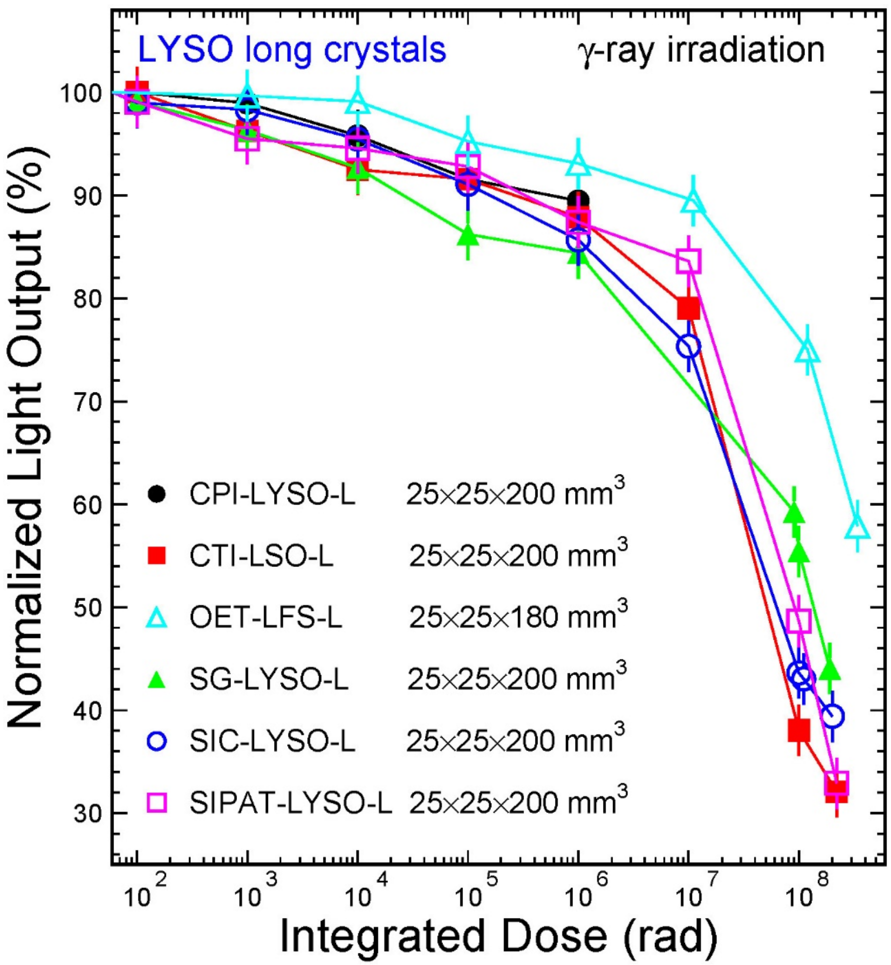


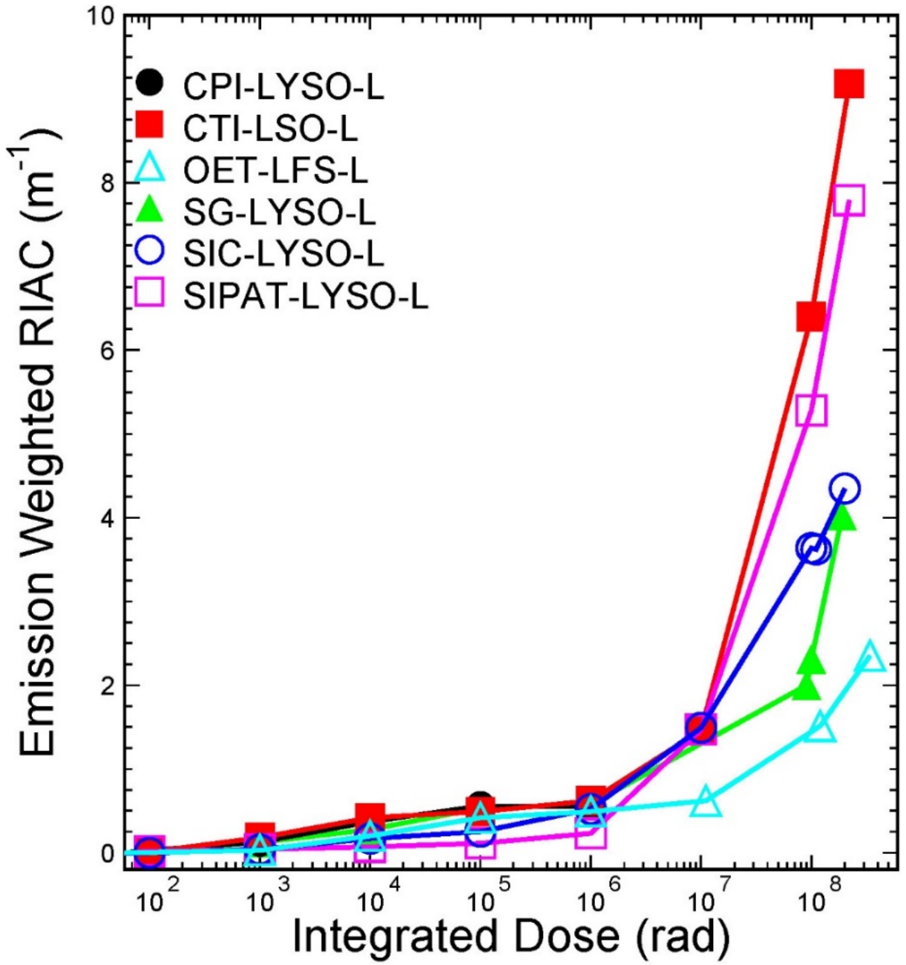


Results of TID:γ for LYSO

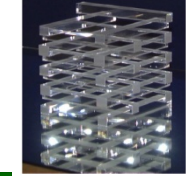
F. Yang *et al.*, *IEEE Trans. Nucl. Sci.* **63**, pp. 612-619 (2016)

Vendor	CPI	CTI	OET	SG	SIC	SIPAT
Dimension (mm^3)	25×25×200	25×25×200	25×25×180	25×25×200	25×25×200	25×25×200





BTL Sensor Radiation Tests

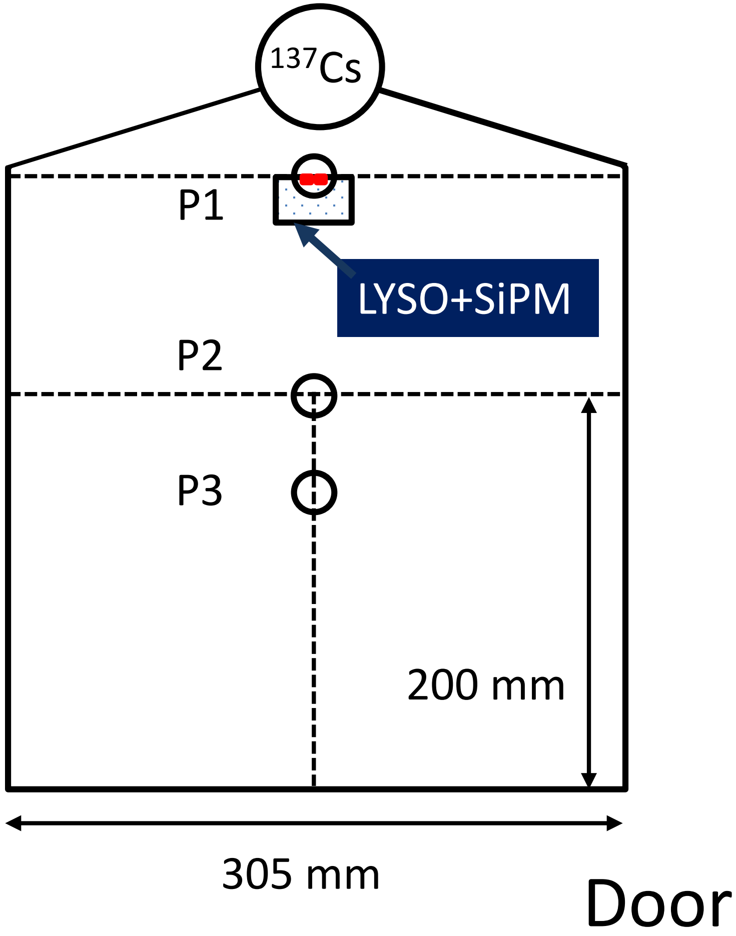


LO and CTR: before/after the total ionization dose and neutron/proton fluence
Radiation induced current (noise) under the expected dose rate, and n/p flux
Caltech sources: 3.7 Mrad TID, 165 rad/h dose rate, and 1.5×10^{6} n/cm^2/s flux

Radiation	Measurement	Laboratory
Total Ionization Dose: 3.7 Mrad	LO and CTR, before/after	**Caltech Cs-137: 3.7 Mrad**
Neutron fluence: 3×10^{14} n/cm^2	LO and CTR, before/after	**LANSCE East Port, or ORNL**
Proton fluence: 2.5×10^{13} p/cm^2	LO and CTR, before/after	**LANSCE Blue Room**
Gamma Dose Rate: 165 rad/hr	RIN *in-situ*	**Caltech Co-60: 165 rad/h**
Neutron flux: 3.8×10^{6} n/cm^2/s	RIN *in-situ*	**Caltech Cf-252: 1.5×10^{6} n/cm^2/s**
Proton flux: 3.2×10^{5} n/cm^2/s	RIN *in-situ*	**LANSCE Blue Room**

A Week to Reach 3.7 Mrad TID

Front surface of LYSO+SiPM package at the center of each mark

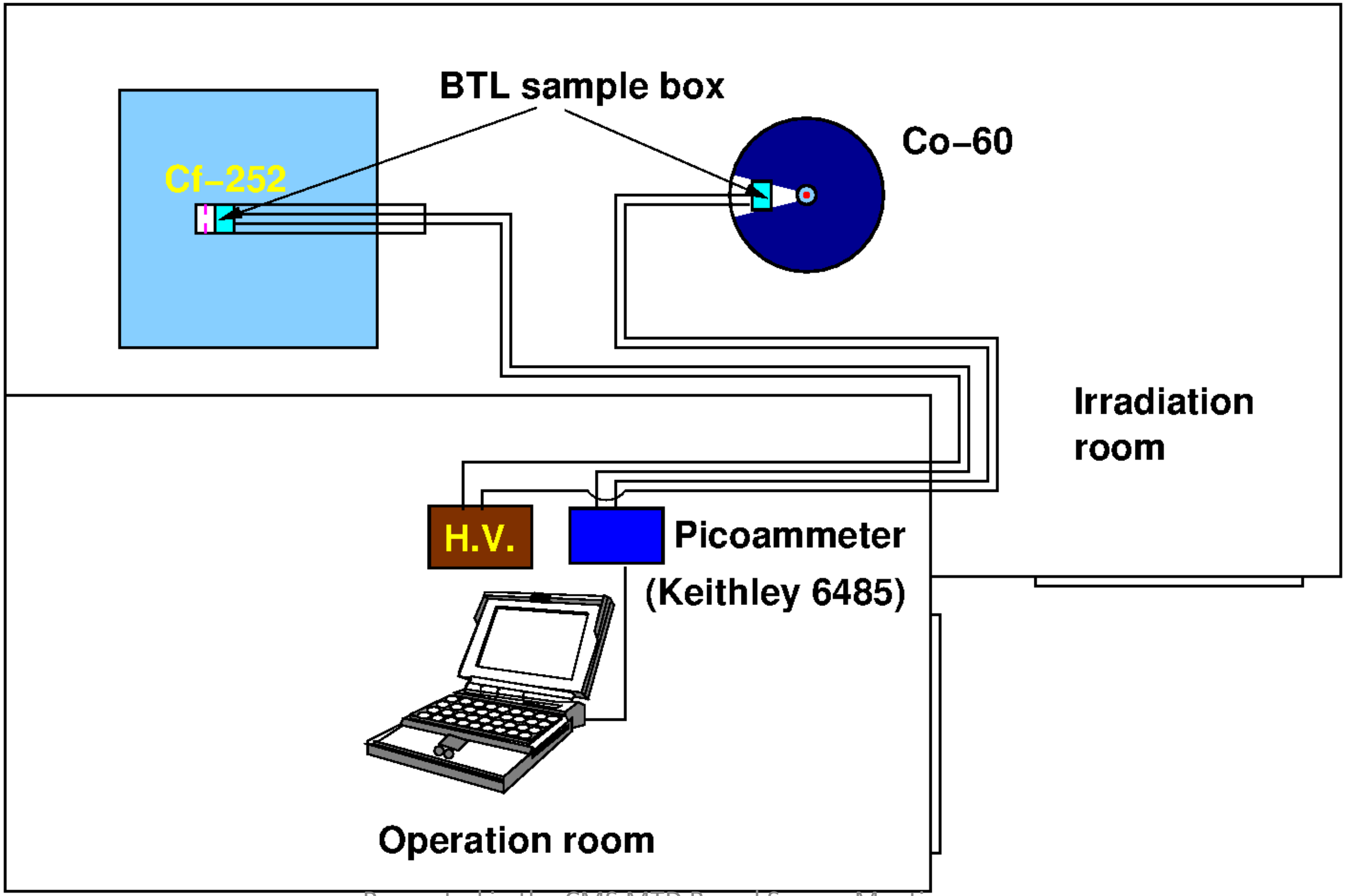


Position	Dose Rate (krad/h)	Time for 3.7 Mrad (days)
P1	21.1	**7.3**
P2	5.3	30
P3	4.0	38

Dimension of LYSO+SiPM package
3.2 x 4.3 x 60 mm plus cables

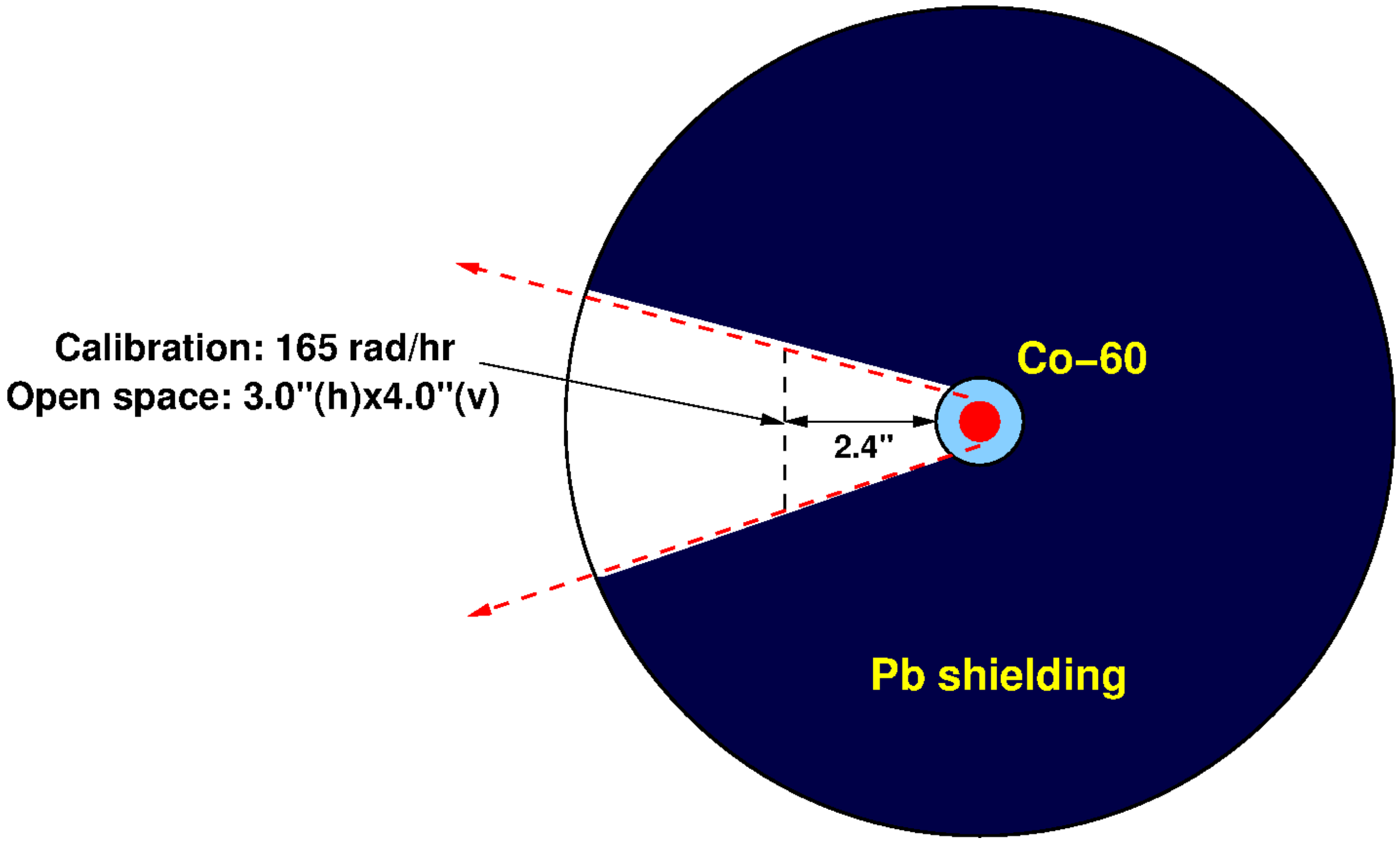
RIN Experiment at Isotope Lab

Radiation photocurrent/noise induced by ionization dose and neutrons can be measured using the Co-60 ɣ-ray and Cf-252 neutron sources, respectively



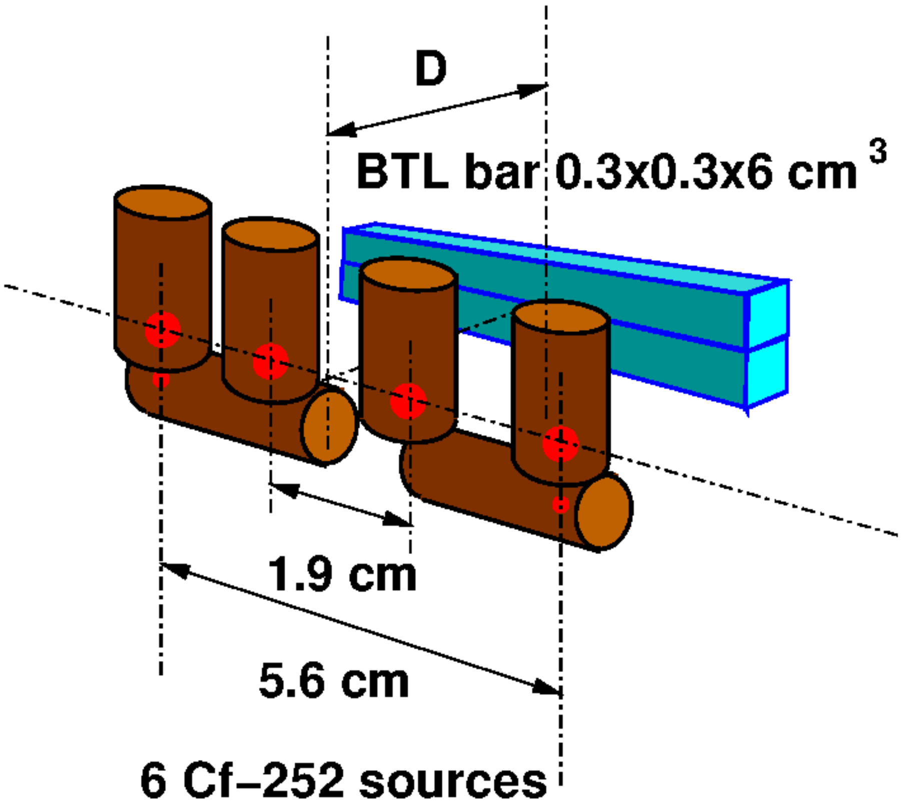
Dose Rate: A Co-60 Source

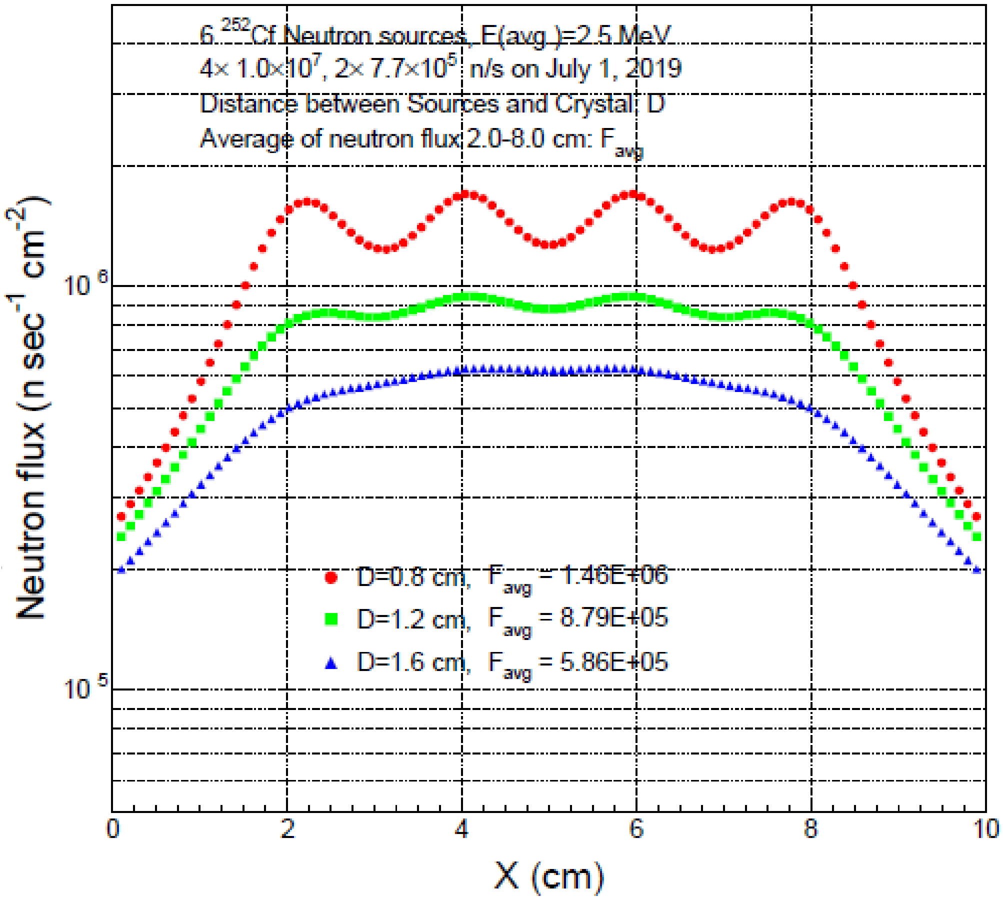
Dose rate at 2.4” from the Co-60 source is 165 rad/h
Open space: large enough for a few LYSO+SiPM packages



Neutron Flux: Three Cf-252 Pairs

Neutron flux @ 0.8 cm
1.5×10^6 n or 1.7×10^6 $n_{eq}/cm^2/s$, lower than 3.8×10^6 $n_{eq}/cm^2/s$





Summary

- One TID:ɣ and two RIN:ɣ/n experiments will be carried this Summer at Caltech for BTL sensors, including LYSO, SiPM, wrapping and glue. Light output and CTR will be measured before/after TID:ɣ irradiation. Results of the radiation induced noise and CTR measured during irradiation are expected in Fall.
- For the TID:ɣ experiment, 3.7 Mrad can be reached in about a week by using the Cs-137 source.
- For the RIN:ɣ experiment, 165 rad/h can be reached by placing samples at 2.4” from the Co-60 source.
- For the RIN:n experiment, 1.7×10^6 $n_{eq}/cm^2/s$ can be reached at 0.8 cm from 3 pairs of Cf-252 source, which is a factor of 2.2 less of the 3.8×10^6 $n_{eq}/cm^2/s$ required.
- Experiments 8351 (TF:n) and 8362(TF:p and RIN:p) are to be carried out at LANSCE late 2019 in the East Port and Blue Room, respectively. The results are expected to be available next year, pending on the repair of the LANSCE accelerator.