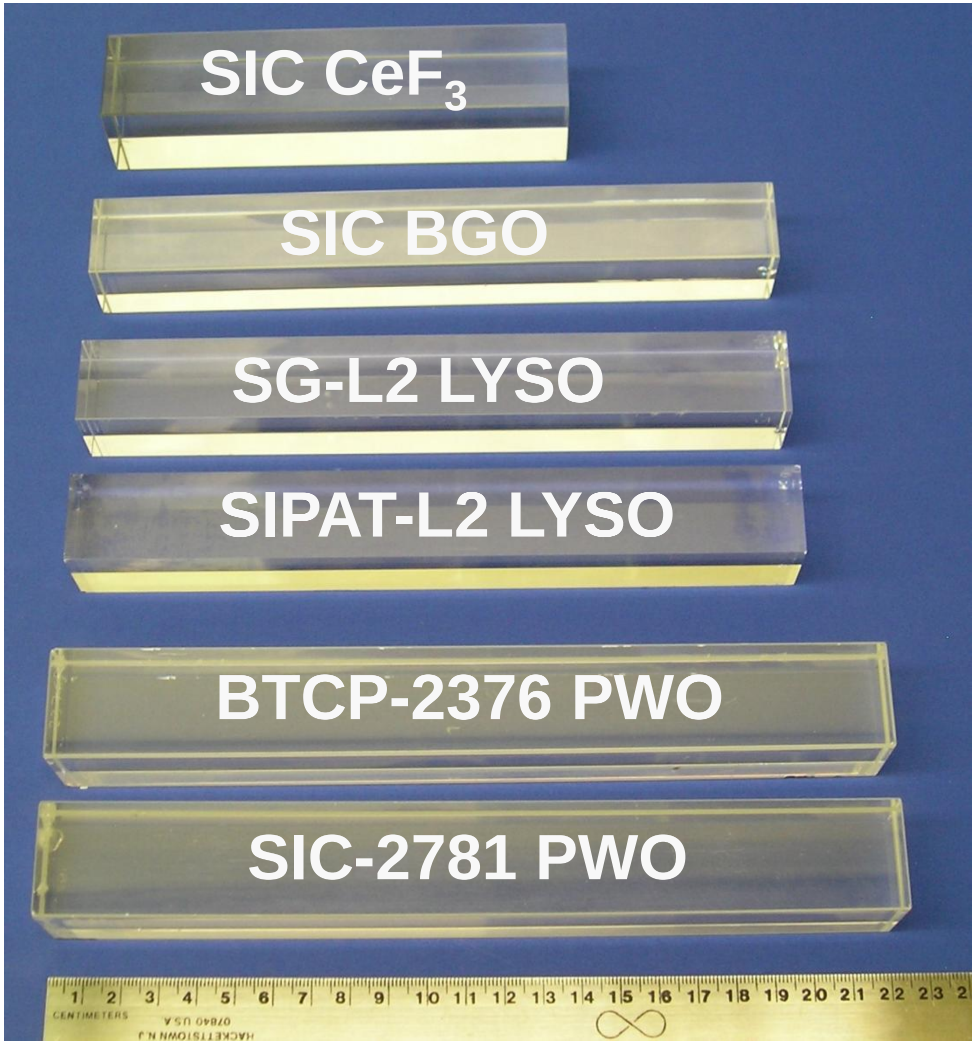
Effects of neutron irradiation in various crystal samples of large size for future crystal calorimeter

Liyuan Zhang, Rihua Mao, Ren-yuan Zhu

California Institute of Technology

Tested PWO, LYSO, BGO and CeF_3 Samples



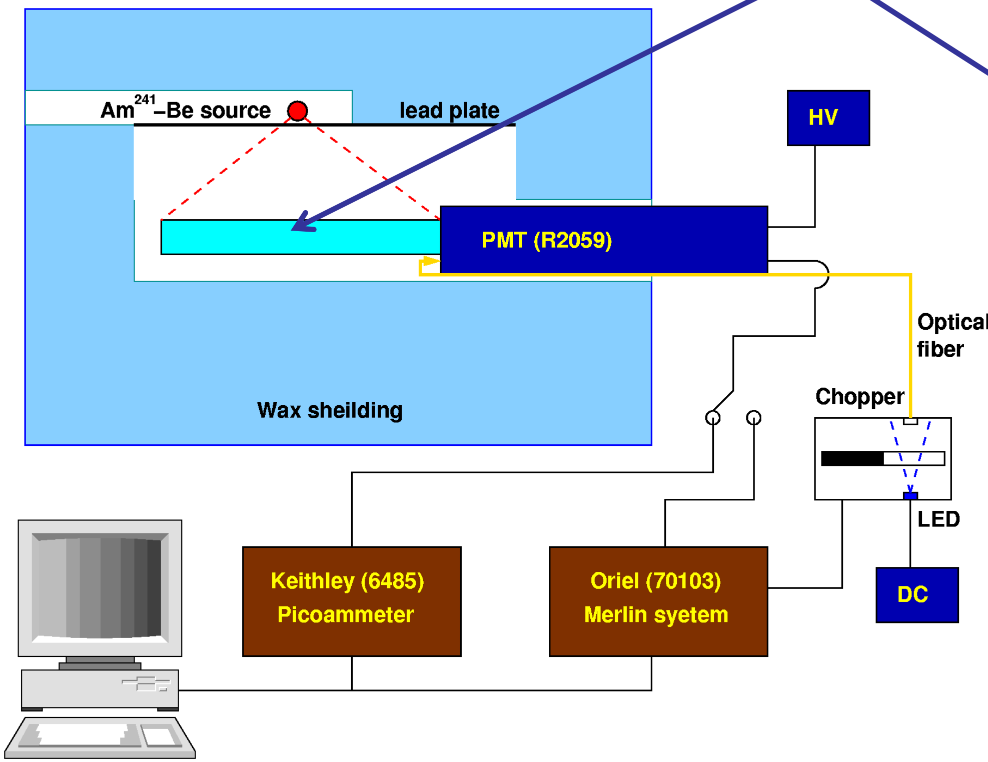
CeF_3:
$3.0 \times 14 \times 3.0$ cm^3

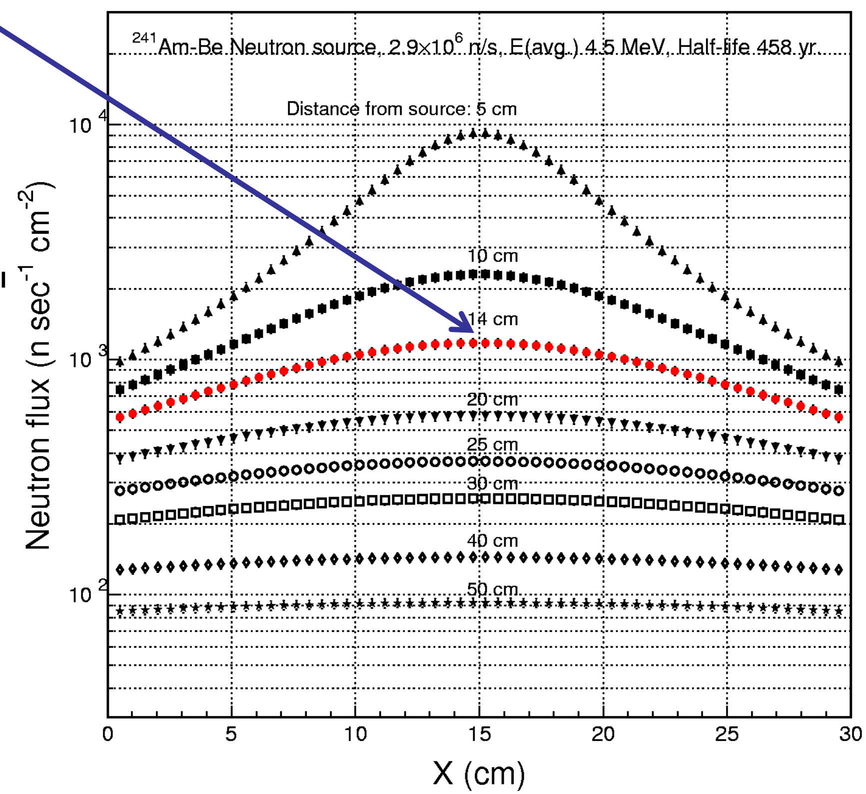
LYSO and BGO:
$2.5 \times 20 \times 2.5$ cm^3

PWO:
$2.85 \times 22 \times 3.0$ cm^3

Am^{241}-Be Measurement Set-up

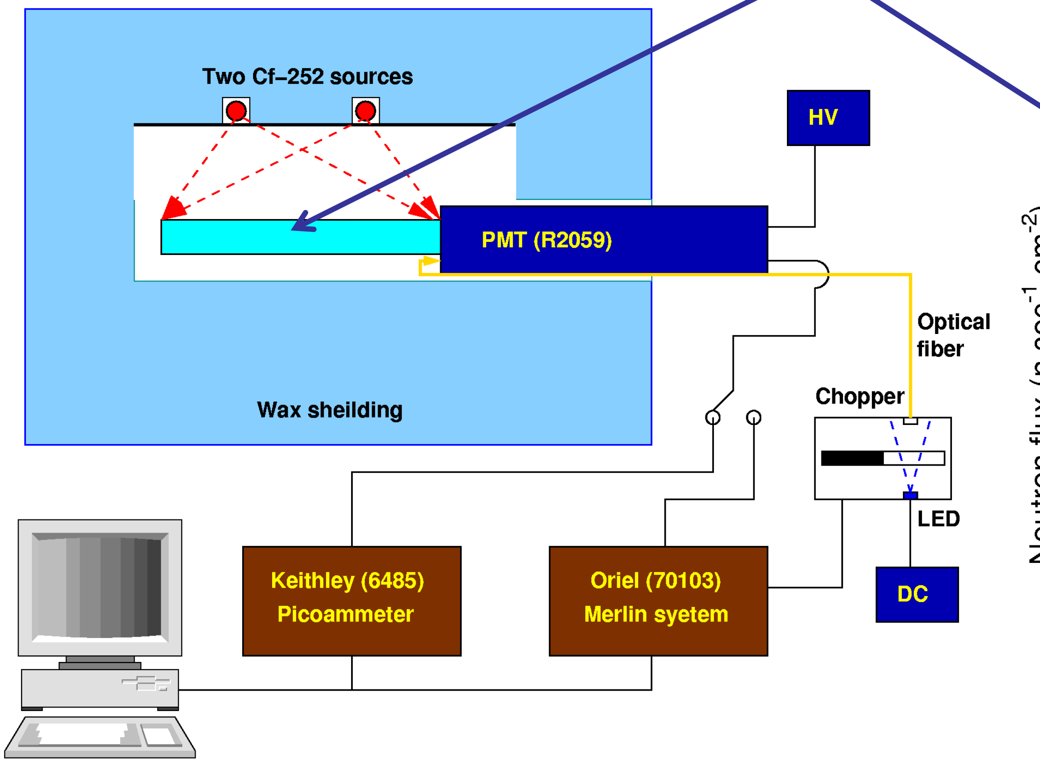
Placed at 14 cm from the source the fast neutron (4 MeV) flux at crystal surface is about 10^3 n s^{-1} cm^{-2} .

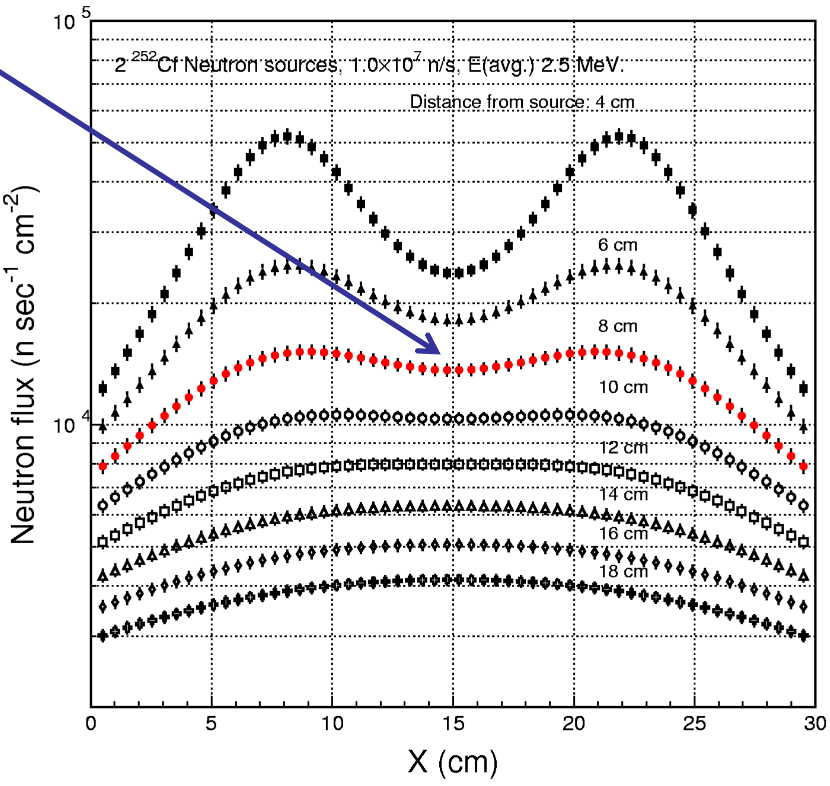




Cf^{252} Measurement Set-up

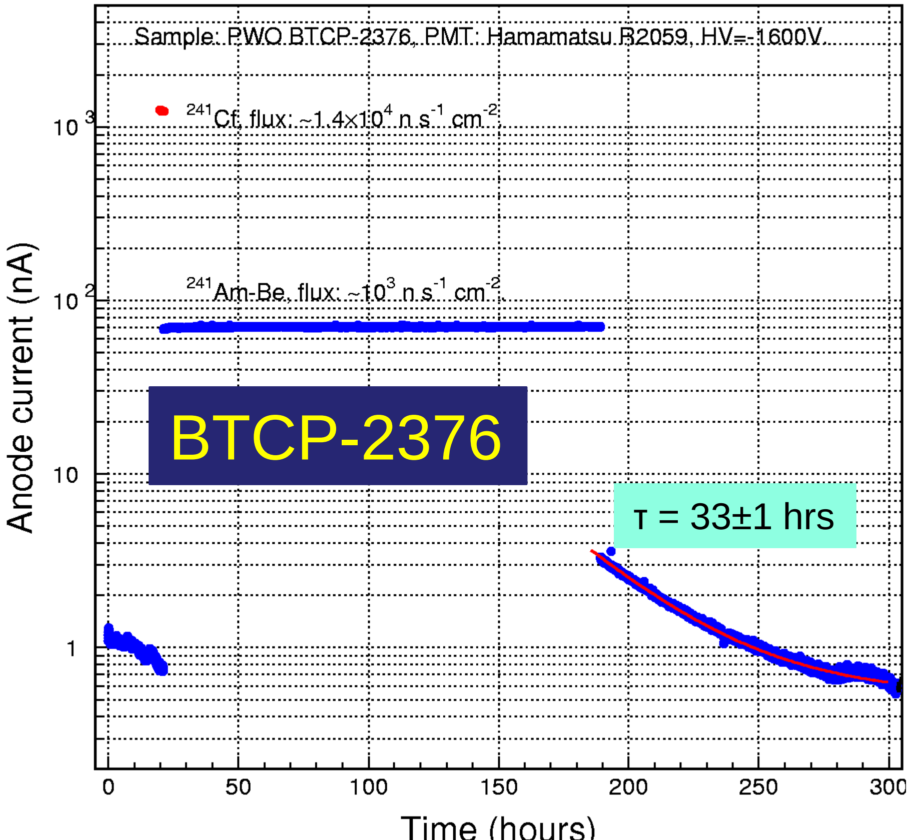
Placed at 8 cm from the two sources the fast neutron (2.5 MeV) flux at crystal surface is about 1.4×10^{4} n s^{-1} cm^{-2} .

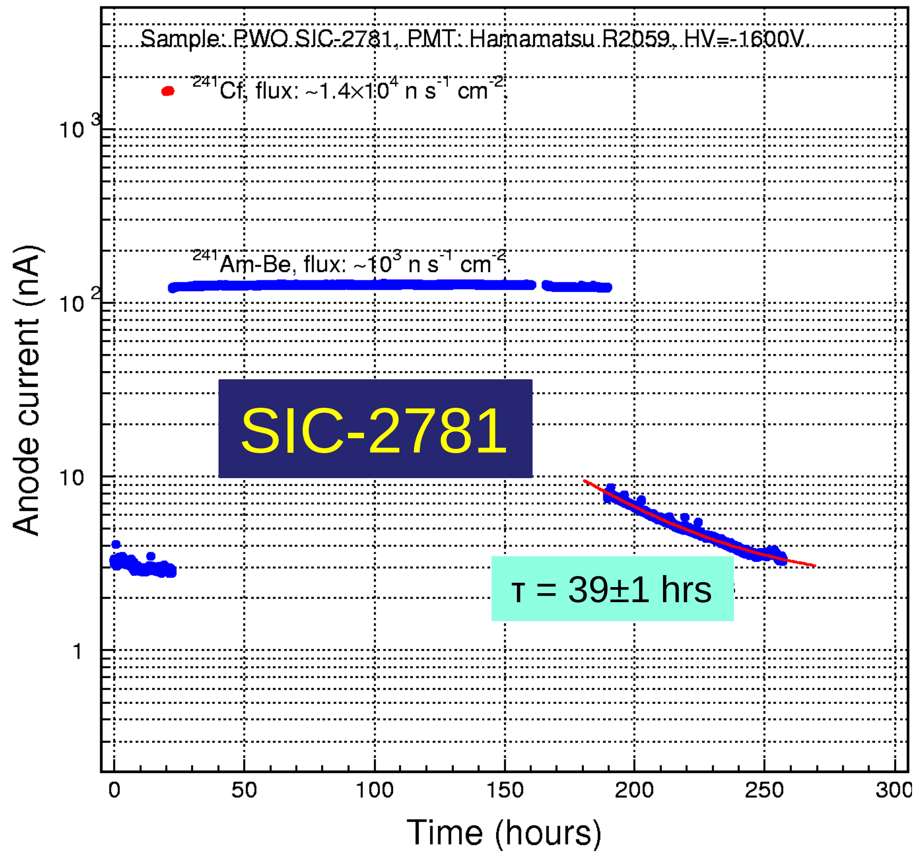




Neutron Induced Phosphorescence in PWO

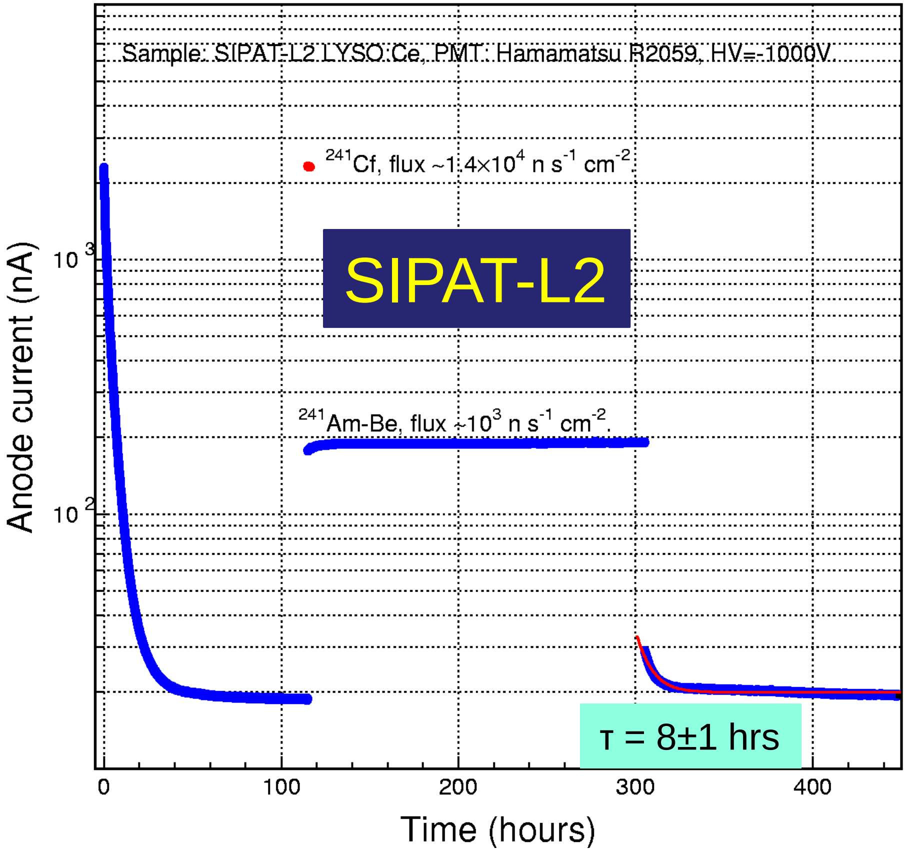
The measured anode current was stable during one week with an accumulated fluence of 6×10^8 n cm^{-2}, a cool-down time of 30~40 hours is observed.

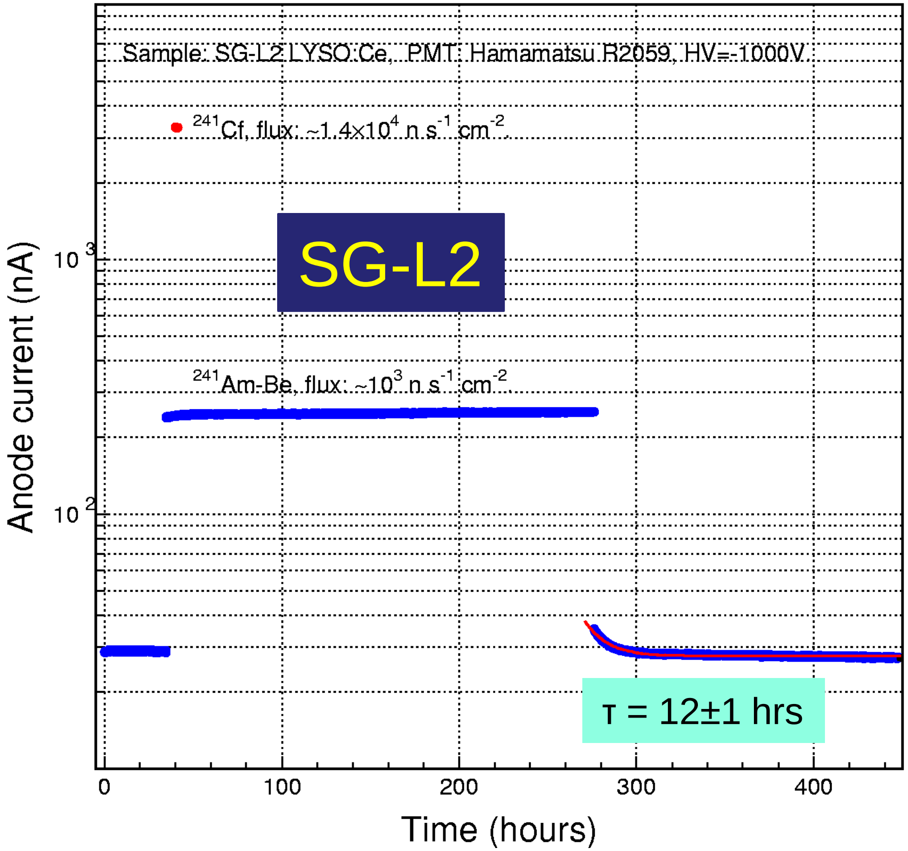




Neutron Induced Phosphorescence in LYSO

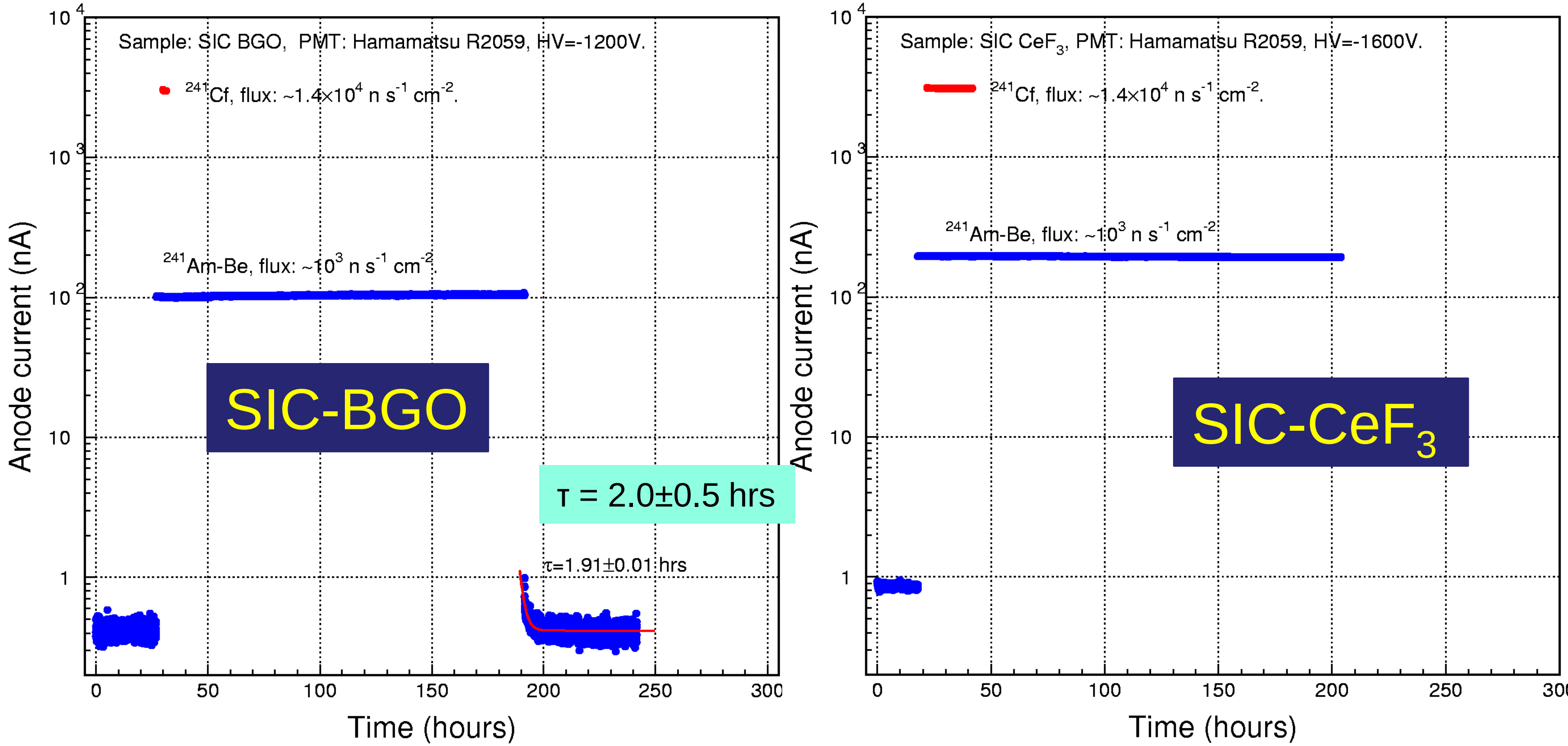
- The cool-down time is about 10 hrs.
- The room light induced phosphorescence needs two days to relax.





Neutron Induced Phosphorescence in BGO and CeF_3

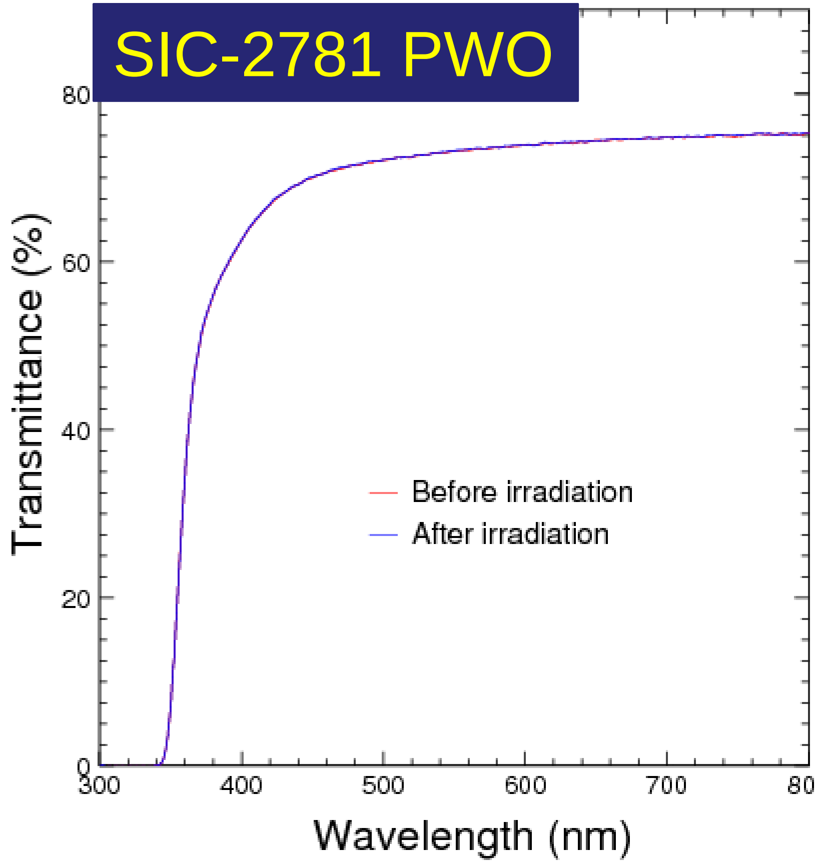
- The BGO shows a cool-down time of about 2 hrs.
- A long term test of CeF_3 under Cf-252 sources is on going.

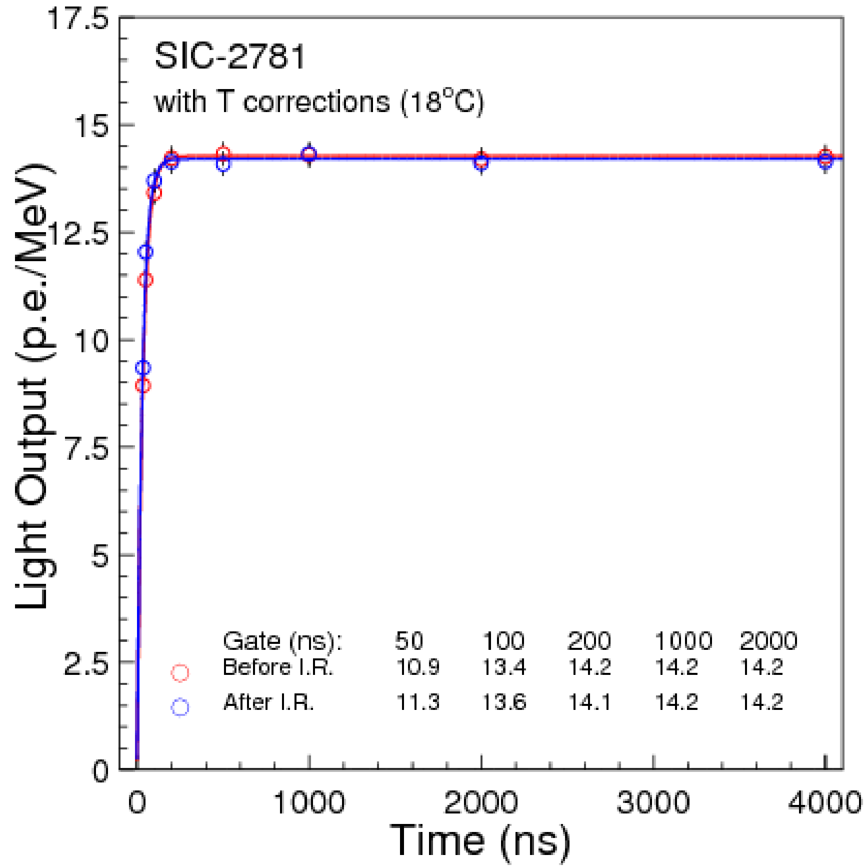


Effect of Neutron Irradiation on T and LO

After 7 days exposure (total 6×10^{8} n/cm^{2}), no evident change was observed in both longitudinal transmission and light output

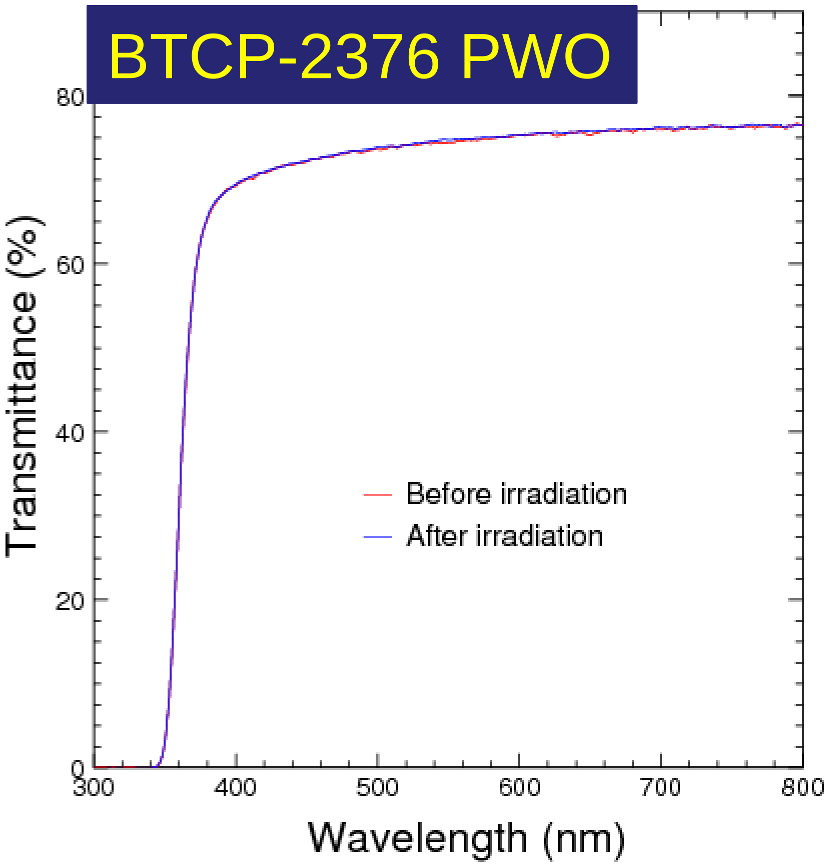
SIC-2781 PWO

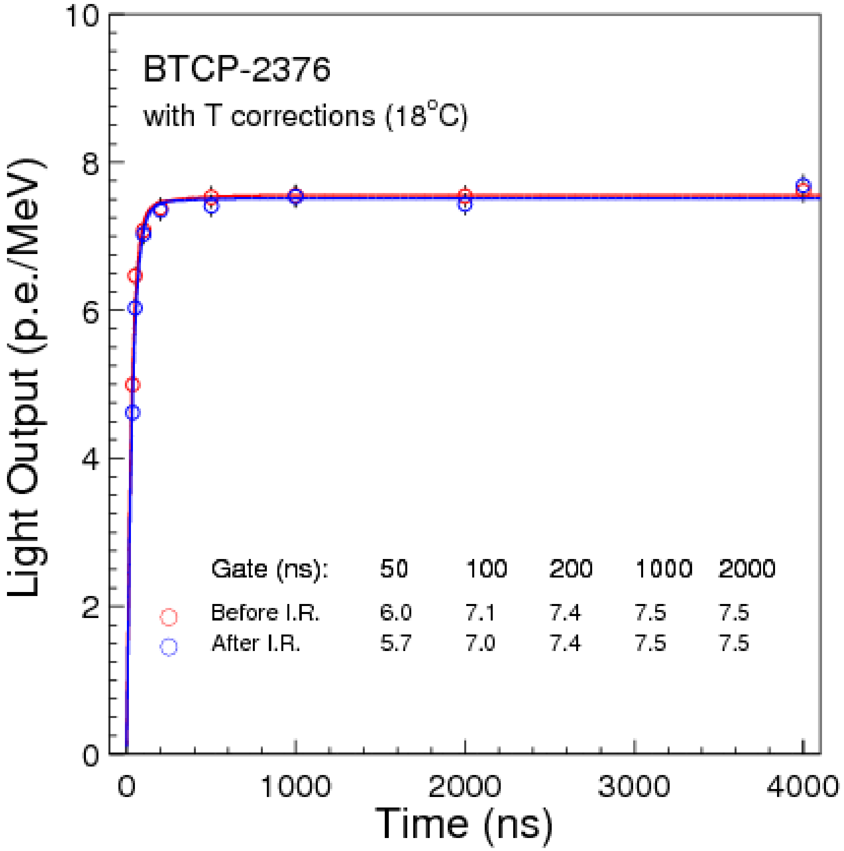




Effect of Fast Neutrons on LT and LO

Same results as in SIC PWO sample.





Effect of Fast Neutrons on T and LO

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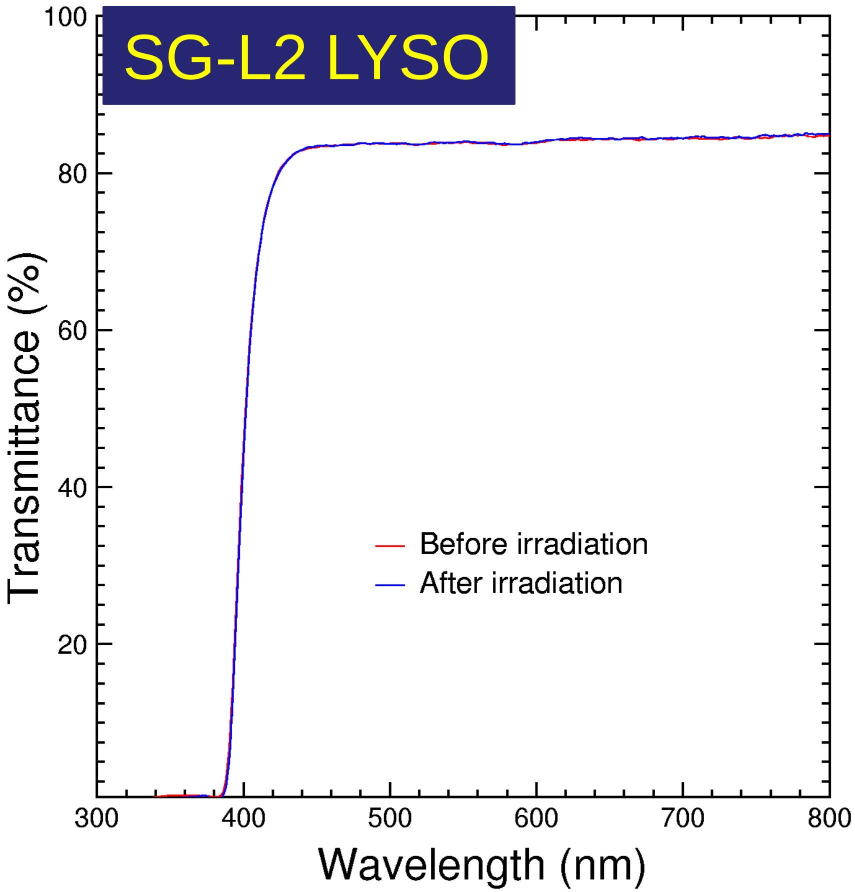
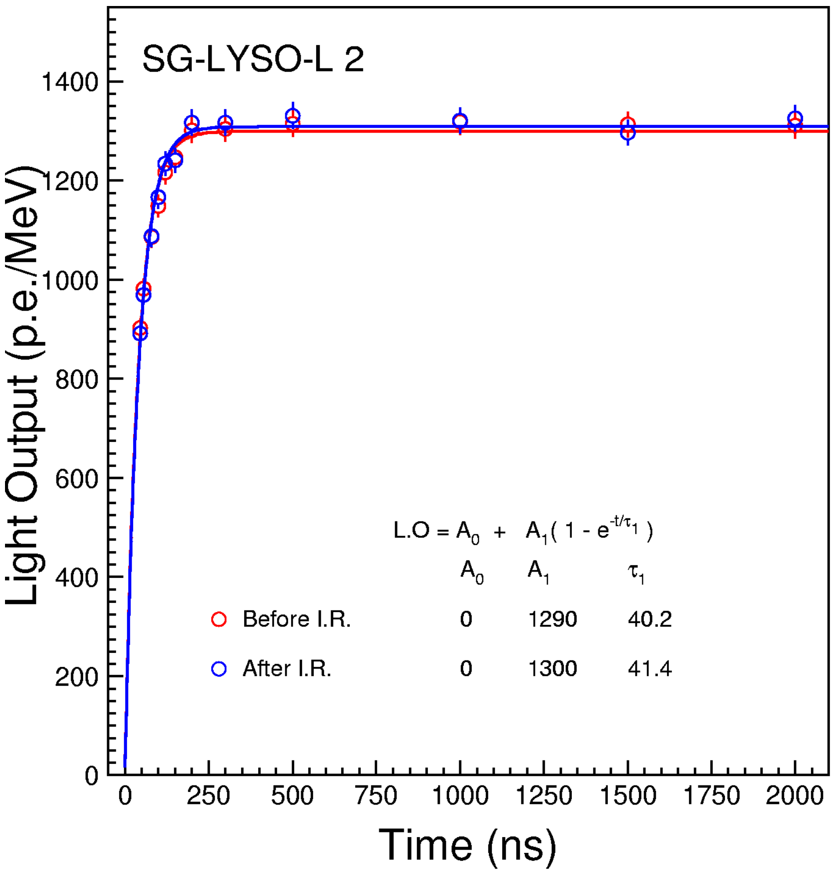
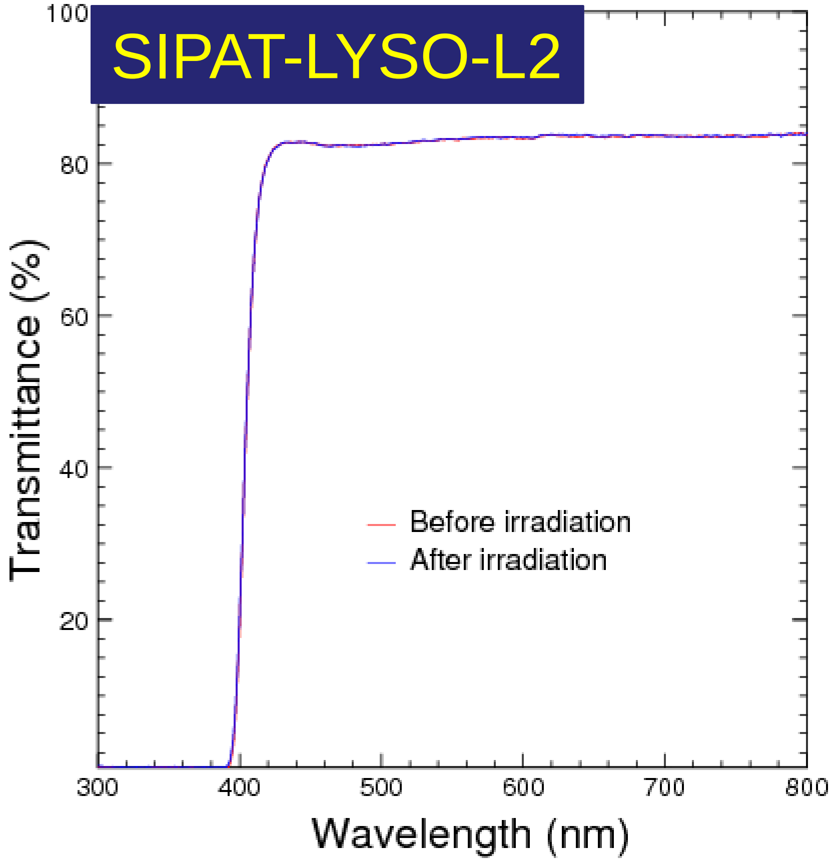
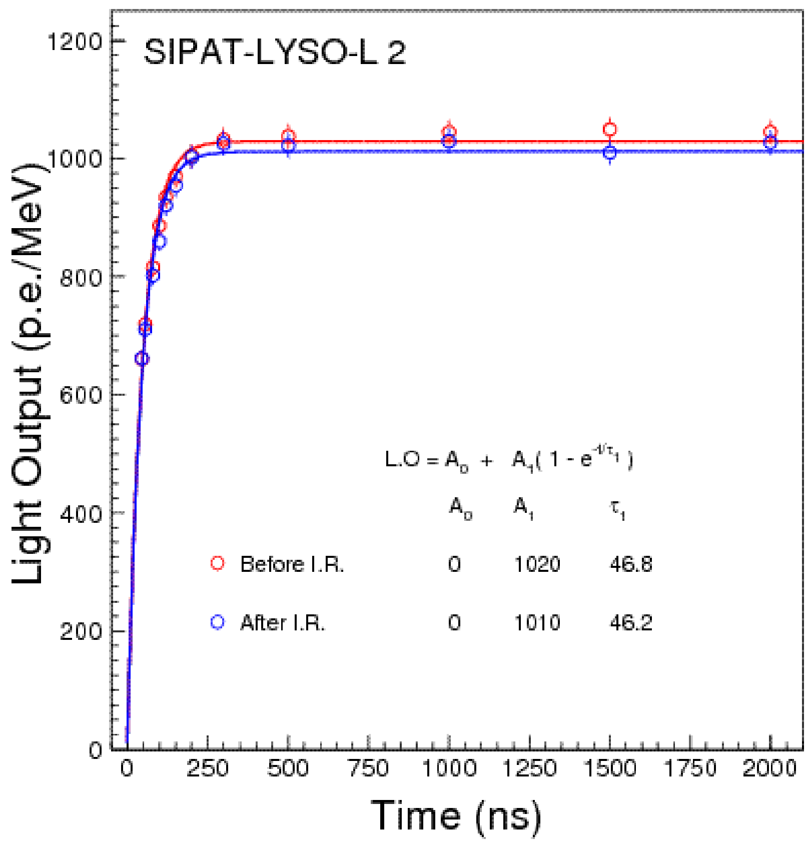




Effect of Fast Neutrons on T and LO

Unlike the SG LYSO sample, there is a slightly decrease of the LO after the neutron irradiation which is within 1σ of the systematic error.





Effect of Fast Neutrons on T and LO

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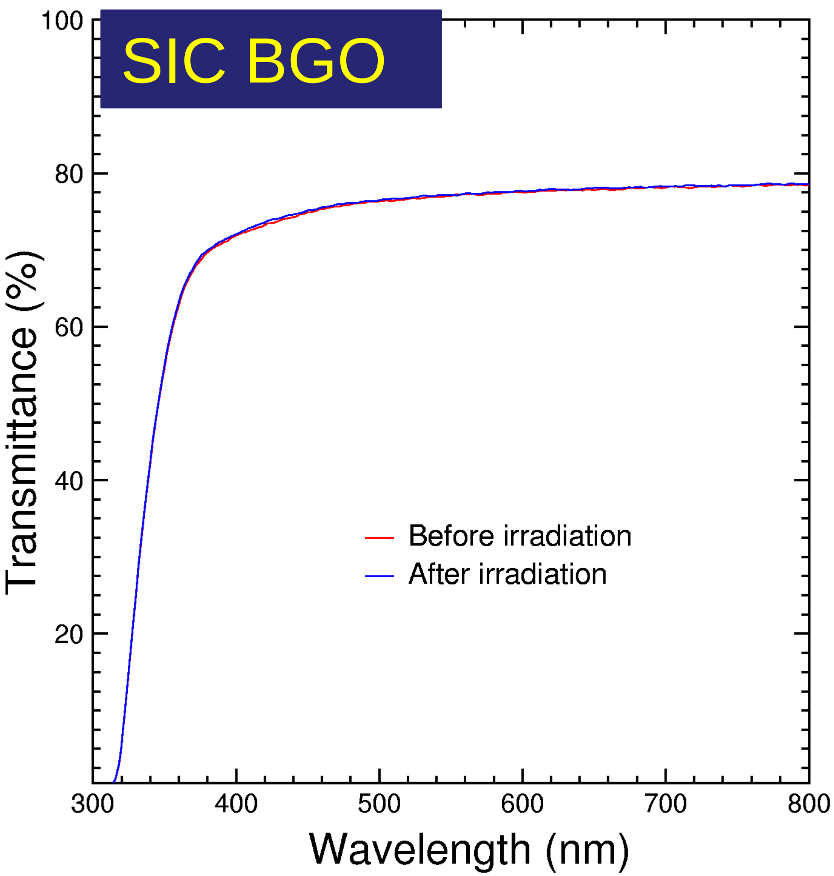

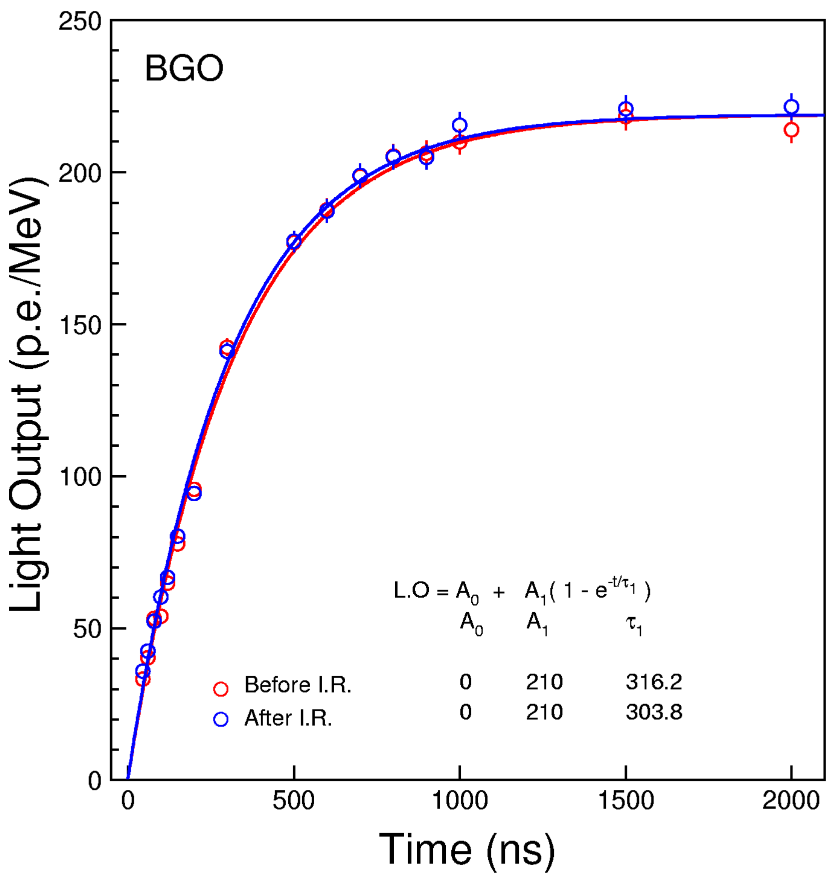

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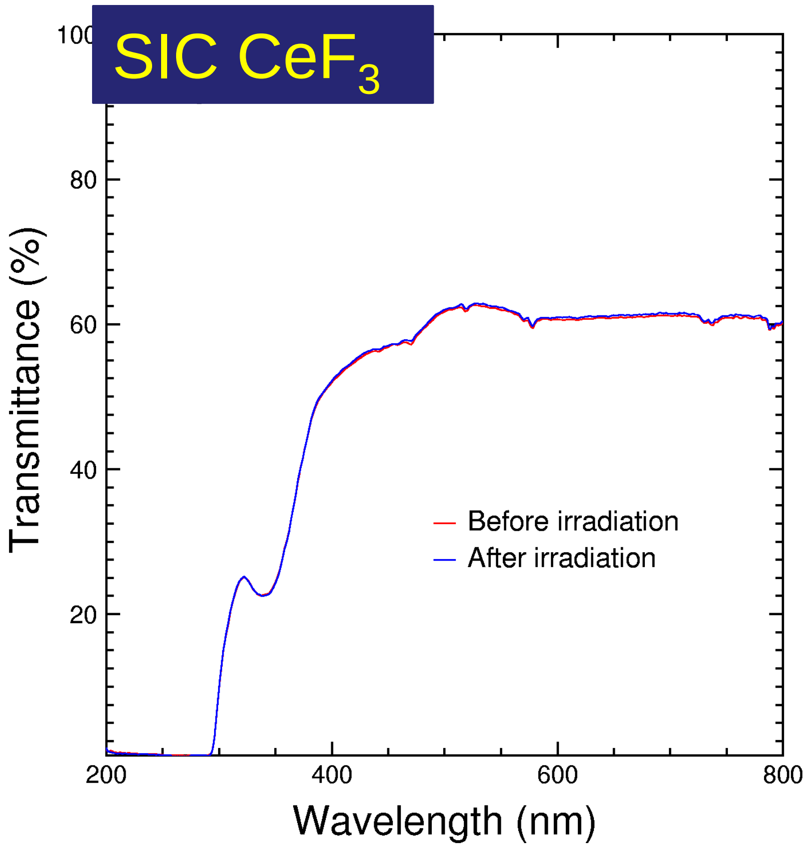

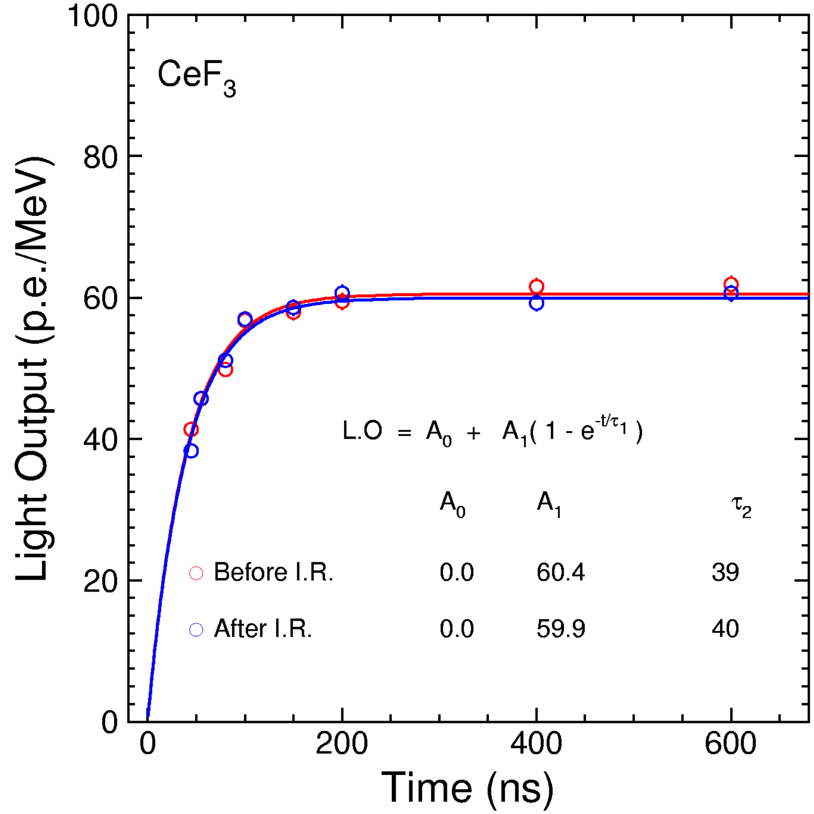

Neutron Induced Photoelectron Current Coefficient

F is defined as the neutron induced photoelectron number under unit neutron flux, which can be determined by using the measured anode current:

$$F = \frac{\dfrac{Photocurrent}{Charge_{electron} \times Gain_{PMT}}}{Flux_{crystal}} \qquad (\text{p.e. } n^{-1}\ cm^{2})$$

Since it's not easy to properly subtract the contribution of gamma components of the radioactive source from the measured photocurrent, we have to consider F and all other inferred numbers from here as a upper limit.

Extrapolation to Readout Noise at a Severe Radiation Environment

Accumulated neutron fluences at LHC are estimated to be up to 5.3×10^{13} n/cm^2 and 1.7×10^{15} n/cm^2 for barrel and endcap respectively (CMS NOTE, 2008/000), we assume an environment with 10 times higher neutron fluences.

The photoelectron number in the readout gate can be extrapolated as following:

$$Q = \frac{10 \times Fluence_{10yr} \times Gate_{readout} \times F}{5.0\ \times 10^{7}\ (s)} \quad \text{(p.e.)}$$

and the energy equivalent noise is derived as the standard deviation of photoelectron number :

$$\sigma = \frac{\sqrt{Q}}{LO} \quad \text{(MeV)}$$

Readout Noise Summary

- The readout gates of 100 ns, 200 ns and 1μs are used for PWO, LYSO and CeF, and BGO respectively.
- The LYSO crystal shows the smallest neutron induced readout noise.

Sample	Dimension cm^3	L.Y. p.e./MeV	F $p.e.n^{-1}cm^2$	F $p.e.n^{-1}cm^2$	σ_{bar} MeV	σ_{bar} MeV	σ_{end} MeV	σ_{end} MeV
SIC-2781 PWO	2.8×22×3.0	14.2	1.7×10^3	1.6×10^3	2.5	2.4	26.3	25.5
BTCP-2376 PWO	2.8×22×3.0	7.5	1.0×10^3	1.2×10^3	4.1	4.5	37.0	40.5
SIPAT-L2 LYSO	2.5×20×2.5	1940	2.6×10^5	2.3×10^5	0.3	0.3	3.4	3.2
SG-L2 LYSO	2.5×20×2.5	2480	3.4×10^5	3.2×10^5	0.3	0.3	2.9	2.8
SIC BGO	2.5×20×2.5	340	2.0×10^4	4.1×10^4	1.4	1.9	11.7	16.3
SIC-CeF_3	3.0×14×3.0	60	2.6×10^3	3.0×10^3	0.4	0.4	2. 2	2. 4

Am^{241}-Be	Cf^{252}

Summary

➢ Neutron induced effects are investigated for large size PWO, LYSO, BGO and CeF_3 scintillation crystals, no evident change was observed in optical and scintillation properties during one week irradiation with accumulated fluence of 6×10^8 n cm^{-2}.

➢ The neutron induced photocurrent during irradiation was measured and used to estimate the readout noise in a severe environment, the results show that the LYSO has the smallest neutron induced readout noise.

➢ Testing these samples under higher neutron fluence is underway.