

Proton-Induced Radiation Damage in 20-cm Long LYSO:Ce and BaF₂:Y Crystals



Christina Wang, Liyuan Zhang, Chen Hu, Ren-yuan Zhu, (Caltech)

Kranti Gunthoti, Michael Mocko, Steve Wender and Zhehui Wang (LANL)

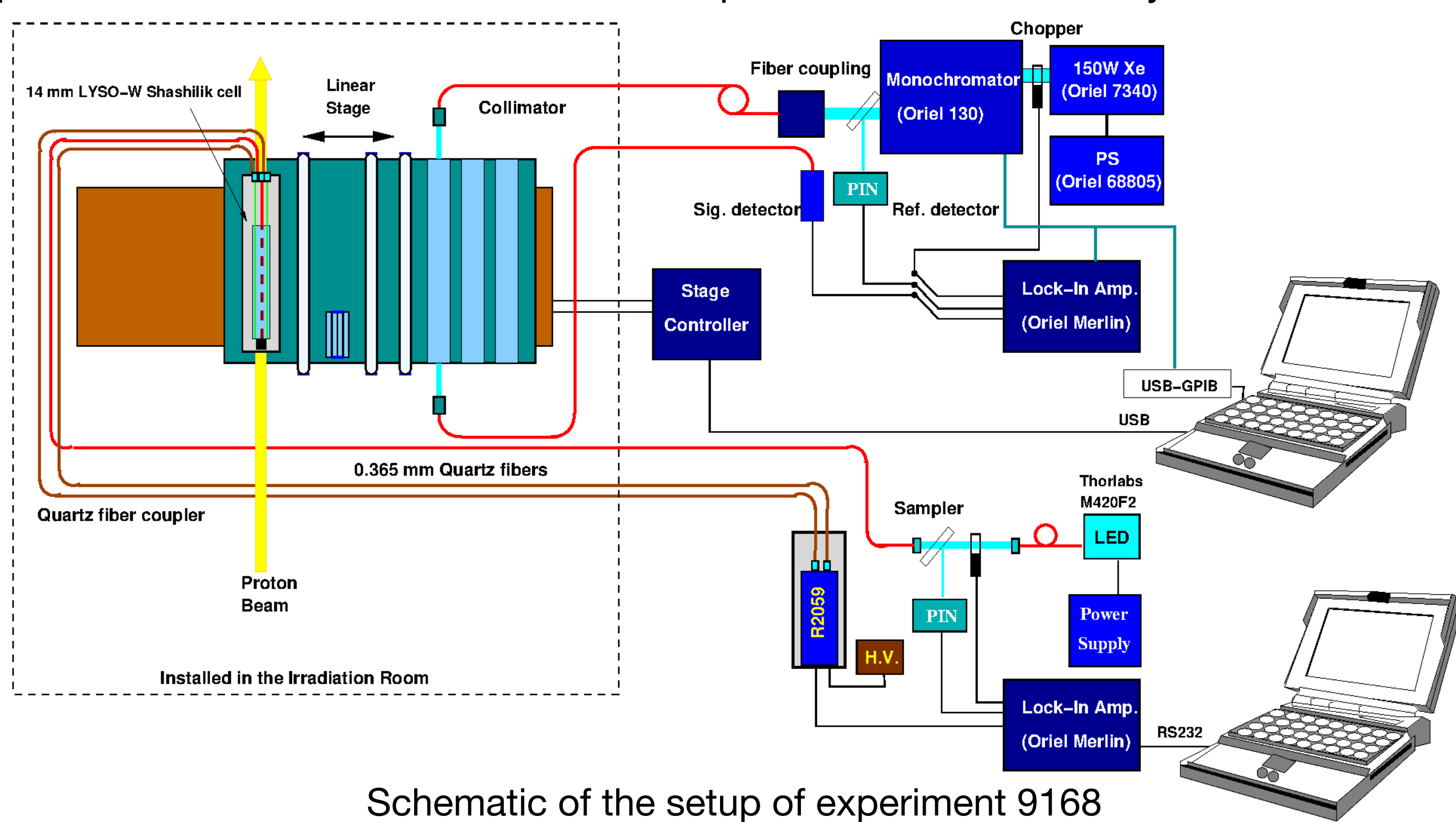


Introduction

- Inorganic scintillators are widely used in high-energy physics (HEP) experiments for precision photon and electron measurements
- Bright and fast LYSO:Ce crystals have been chosen to construct the CMS barrel timing layer detector at the HL-LHC
- BaF₂:Y crystal is a promising ultrafast scintillator for future time of flight and calorimeter applications at the energy and intensity frontiers.
- We study the optical properties of 20cm-long LYSO:Ce and BaF₂:Y crystals that were irradiated by 800 MeV proton beam up to 6.4×10^{15} p/cm² and by Co-60 gamma rays up to 100 Mrad

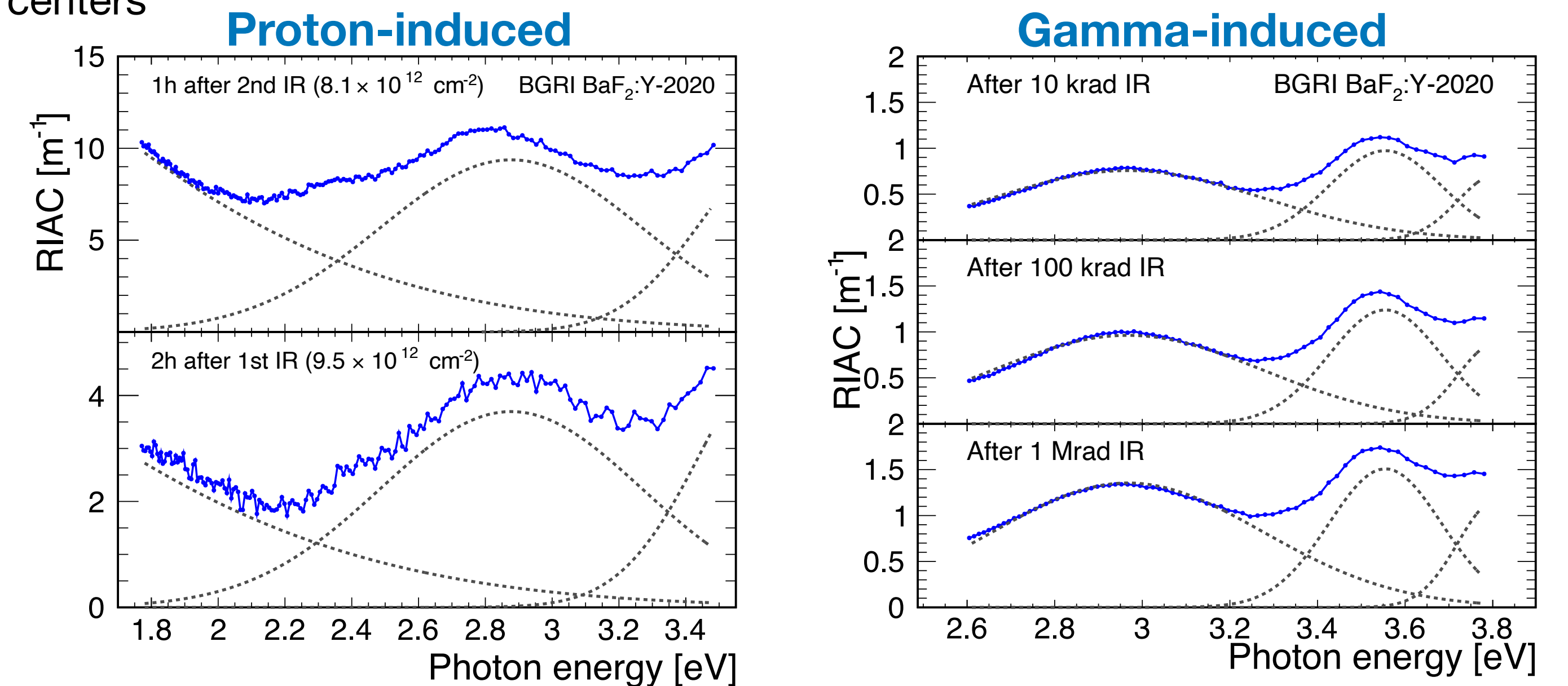
Proton Irradiation Experiment at LANCE

- Conducted proton irradiation experiment 9168 in October 2022 at the blue room of LANSCE by using 800 MeV proton beam
- Longitudinal transmittance (LT) was measured in situ, and used to extract radiation-induced absorption coefficient (RIAC) and radiation-induced color centers
- Proton fluence in the experiment was measured by integrating the beam current and applying a correction factor of 0.86 ± 0.15 measured from radioactivity of proton-induced Na22 in aluminum foils placed in front of the crystals



Radiation-Induced Color Centers (BGRI BaF₂:Y)

- Both proton and gamma-induced RIACs can be well described by combined fits with **three color centers of Gaussian shape**
- The proton-induced color centers have photon energy of 3, 3.6, and 3.8 eV, while gamma-induced color centers are at 1.2, 2.8, and 3.7 eV
- Two proton-induced color centers are slightly (0.1 eV) shifted from gamma-induced centers

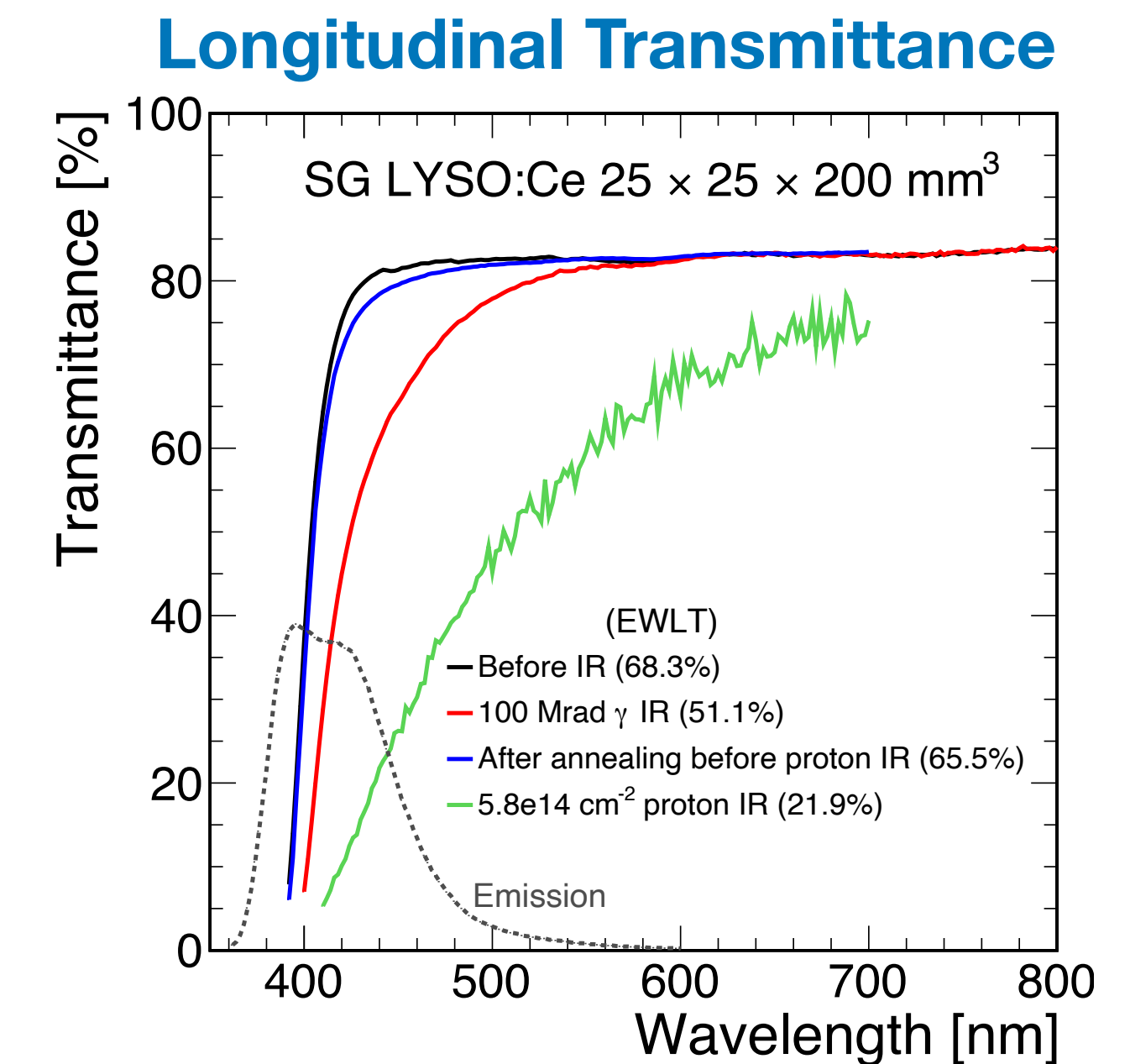


Summary of proton and gamma-induced color centers, where E, A, and σ are the energy, width and amplitude of the fits

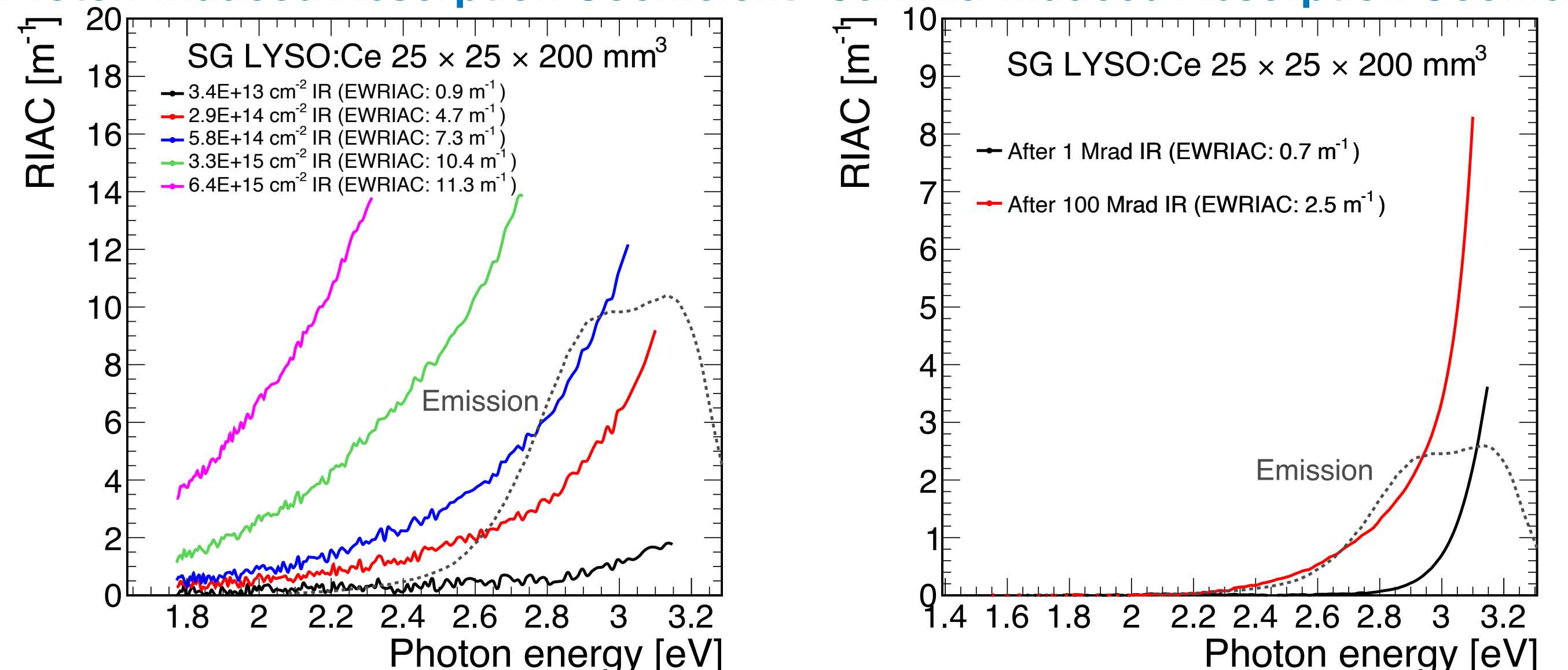
E/ σ [eV]	Gamma-induced			Proton-induced		
	A (10 krad) [m ⁻¹]	A (100 krad) [m ⁻¹]	A (1 Mrad) [m ⁻¹]	E/ σ [eV]	A (2h) [m ⁻¹]	A (1h) [m ⁻¹]
3.0/0.3	0.8	1.0	1.4	1.2/1.1	4.9	10.0
3.6/0.1	1.0	1.2	1.5	2.9/0.4	3.7	9.4
3.8/0.1	0.7	0.9	1.2	3.7/0.2	9.2	33

LT and RIAC of LYSO:Ce

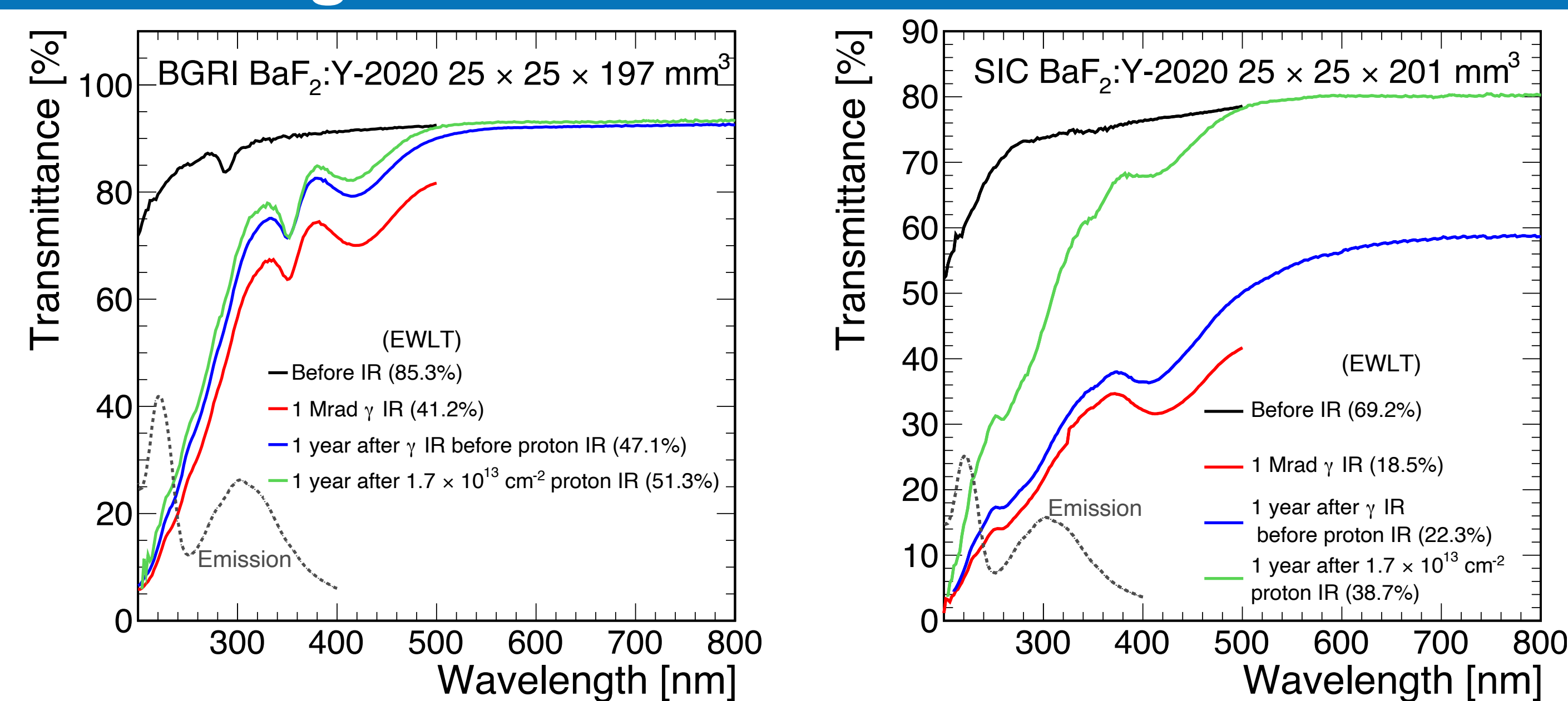
- This LYSO:Ce sample shows an EWRIAC value of 2.5 m⁻¹ after 100 Mrad and 0.9 m⁻¹ after 3.4E13 p/cm², which is much better than the CMS BTL specification: < 3 m⁻¹ after 2.5 Mrad and 1.7E13 p/cm² protons
- No color centers were identified in LYSO:Ce



Proton-induced Absorption Coefficient Gamma-induced Absorption Coefficient

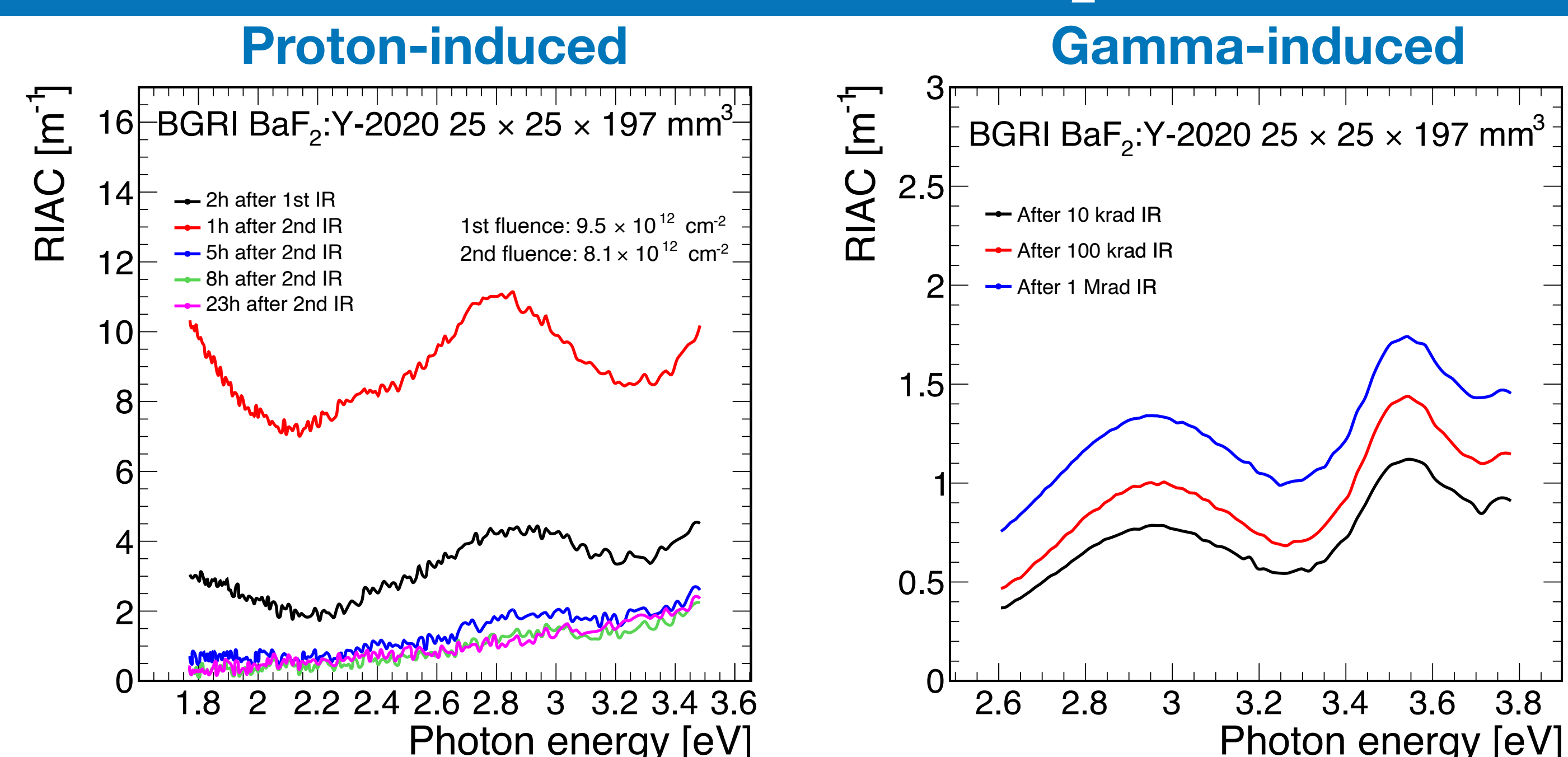


Longitudinal Transmittance of BaF₂:Y



- Longitudinal transmittance of 20cm-long BaF₂:Y crystals grown at BGRI and SIC
- Long term recovery of transmittance was observed a year after 1 Mrad ionization, and a year after 1.7E13 p/cm² as seen in EWLT

RIAC of BGRI BaF₂:Y



- RIAC values are calculated by using the LT data > 5% to reduce systematic uncertainties
- A fast recovery may be attributed to thermal relaxation

Summary

- We presented the optical properties of proton and gamma-irradiated 20cm-long LYSO:Ce and BaF₂:Y crystals
- BaF₂:Y samples were irradiated by gamma rays up to 1 Mrad, and by protons up to 1.7×10^{13} p/cm². Fast recovery was observed in several hours after the proton irradiation.
- Radiation-induced color centers for BaF₂:Y were analyzed with distinct color centers for proton and gamma irradiation with photon energy between 1 and 4 eV
- This LYSO:Ce sample shows excellent radiation hardness against gamma-rays and protons, consistent with our previous publications

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Corresponding author: Ren-Yuan Zhu (zhu@caltech.edu)