

Preliminary Report on the Experiment 7324 with 800 MeV Protons at Los Alamos

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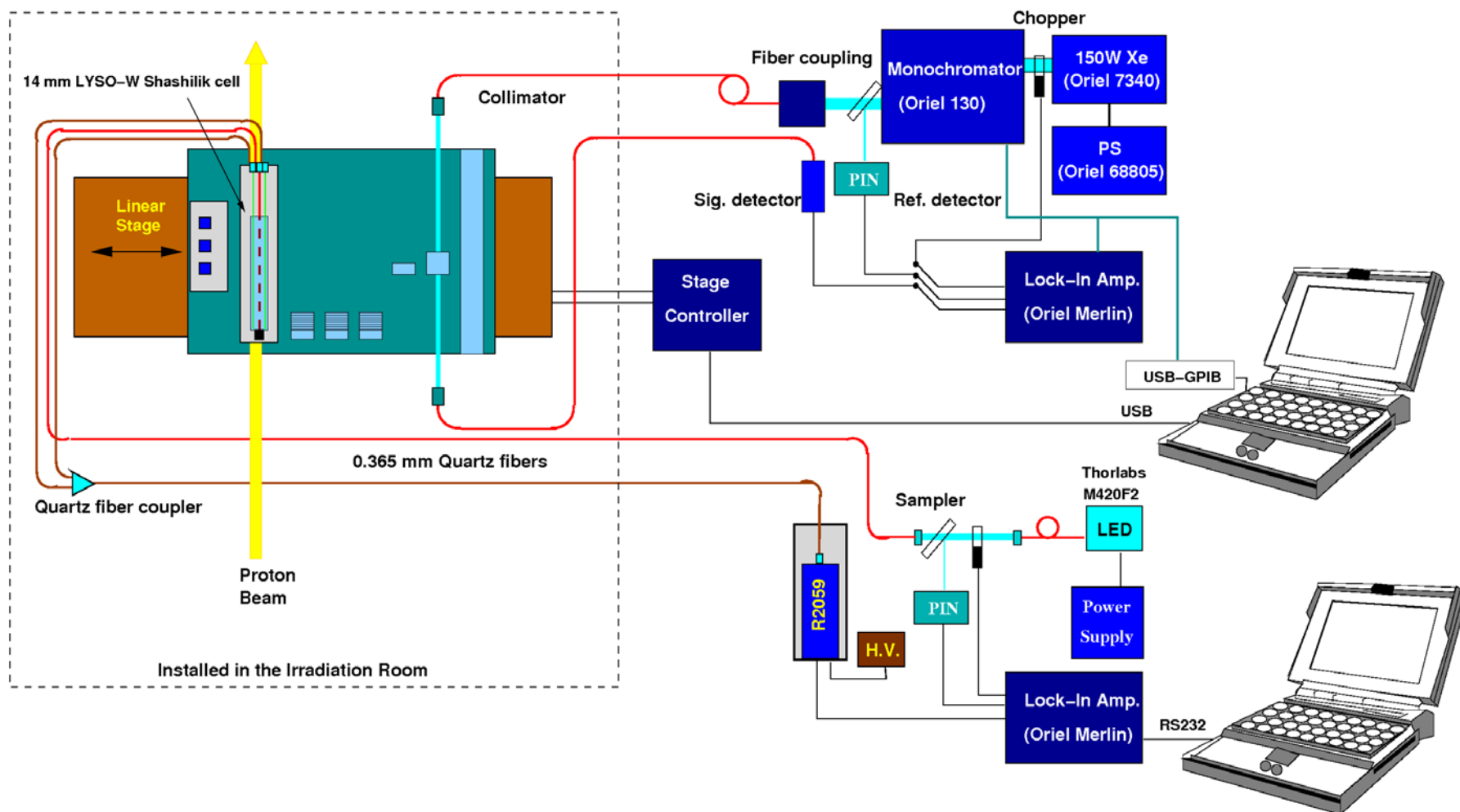
Introduction

- Following previous proton irradiation experiments at CERN and LANL, additional irradiations were carried out at LANL in Nov 2016. While samples irradiated are being cooled down, we report preliminary results for three crystals and a LYSO/W/Capillary Shashlik cell.
- The 800 MeV protons at the Weapons Neutron Research facility of Los Alamos Neutron Science Center (WNR of LANSCE) provide an ideal facility for investigations of charged hadron induced radiation damage.
- With excellent beam conditions the experiment 7324 was carried out in 34 hours between 4 PM, 11/16, to 2 AM, 11/18:
 - Three CLYC samples [1] from Los Alamos for low fluence;
 - Three diamond samples from BNL and Stony Brook;
 - One LFS/W/Capillary Shashlik cell with LED monitoring;
 - Three stacks of thin PWO, BaF2 and LYSO crystals;
 - Three crystals of PWO (5 mm), BaF2 (2 cm) and LYSO (20 cm).
- Measurements were carried out before, during and after irradiations *in situ* for PWO, BaF2 and LYSO crystals and the Shashlik cell with preliminary results presented in this report. Final results will be reported after samples are back to Caltech.

[1] <http://rmdinc.com/wp-content/uploads/2016/06/CLYC-Properties-5-10-16.pdf>

Experiment Setup for Exp-7324

A LYSO-W-Capillary Shashlik cell and three crystals were monitored by a 420 nm LED and a fiber based spectrophotometer (300 – 800 nm) respectively before, during and after irradiation



Instruments for On-line Monitoring

Most were shipped on 11/8/2016. The LYSO/W/Capillary Shashlik cell was shipped on 11/11/2016. Diamond and CLIC samples were installed on 11/16/16.



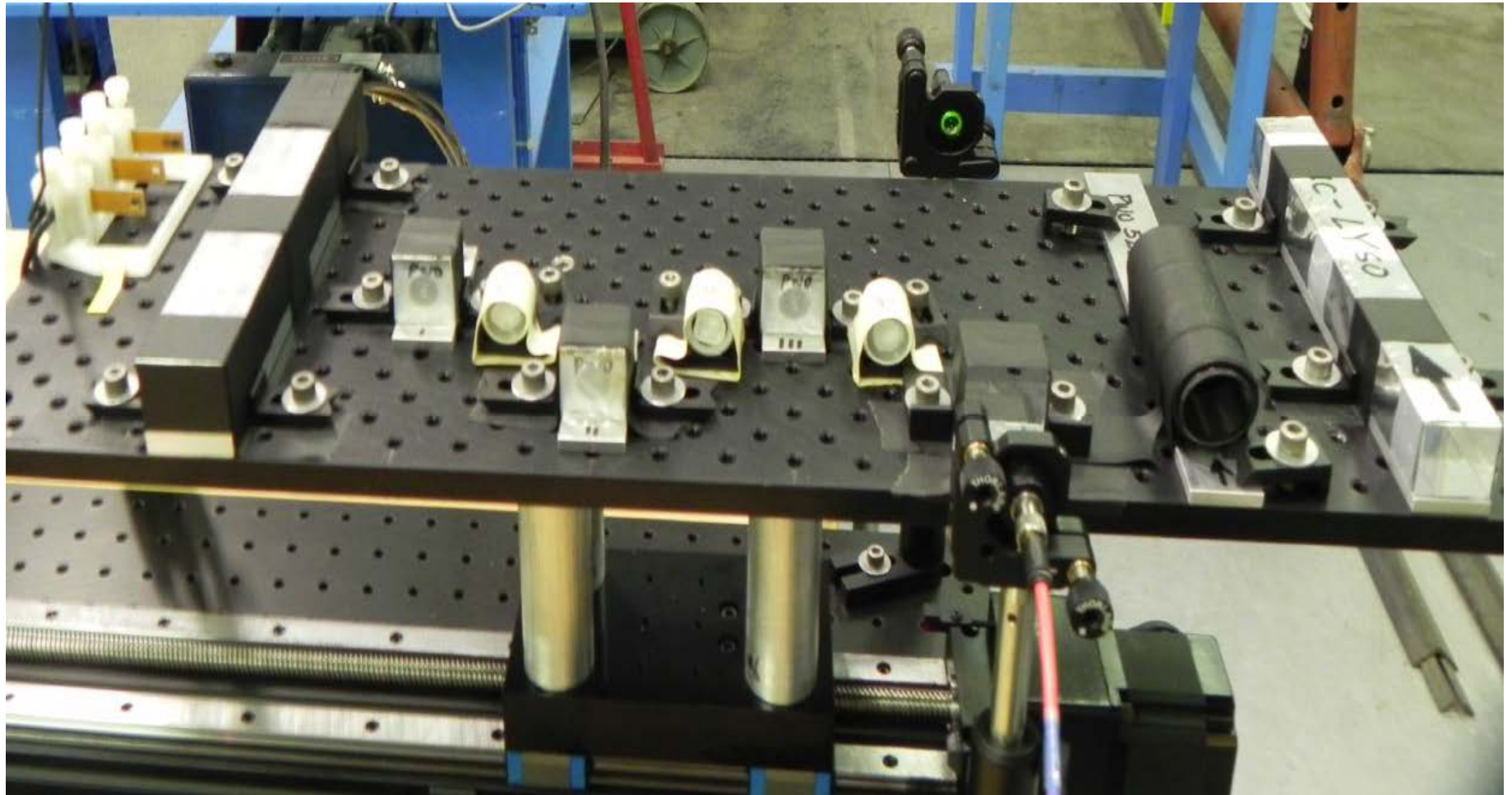
Samples on a Linear Stage

Setup in Corridor Out the Blue Room

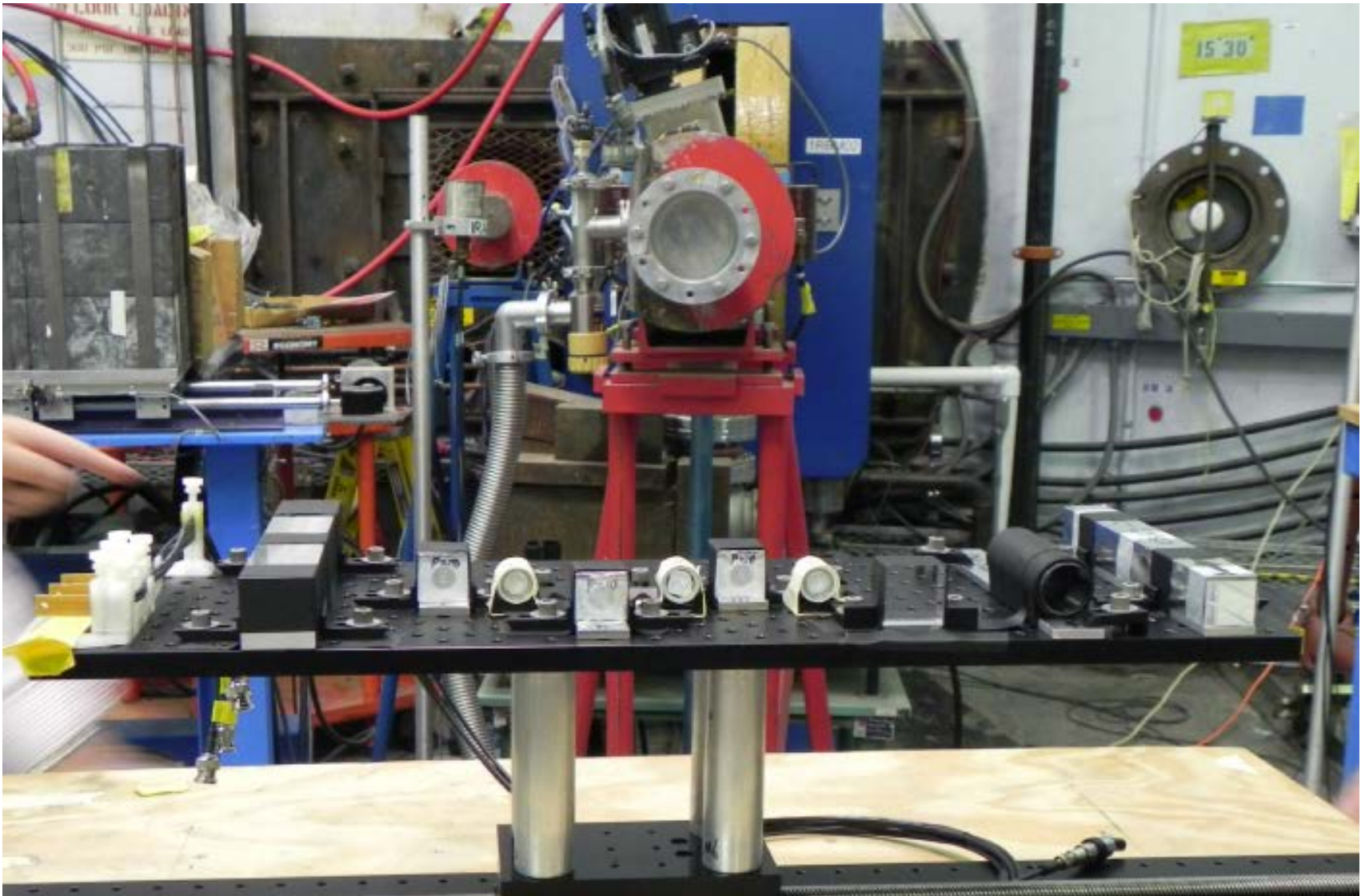


Samples for Experiment-7324

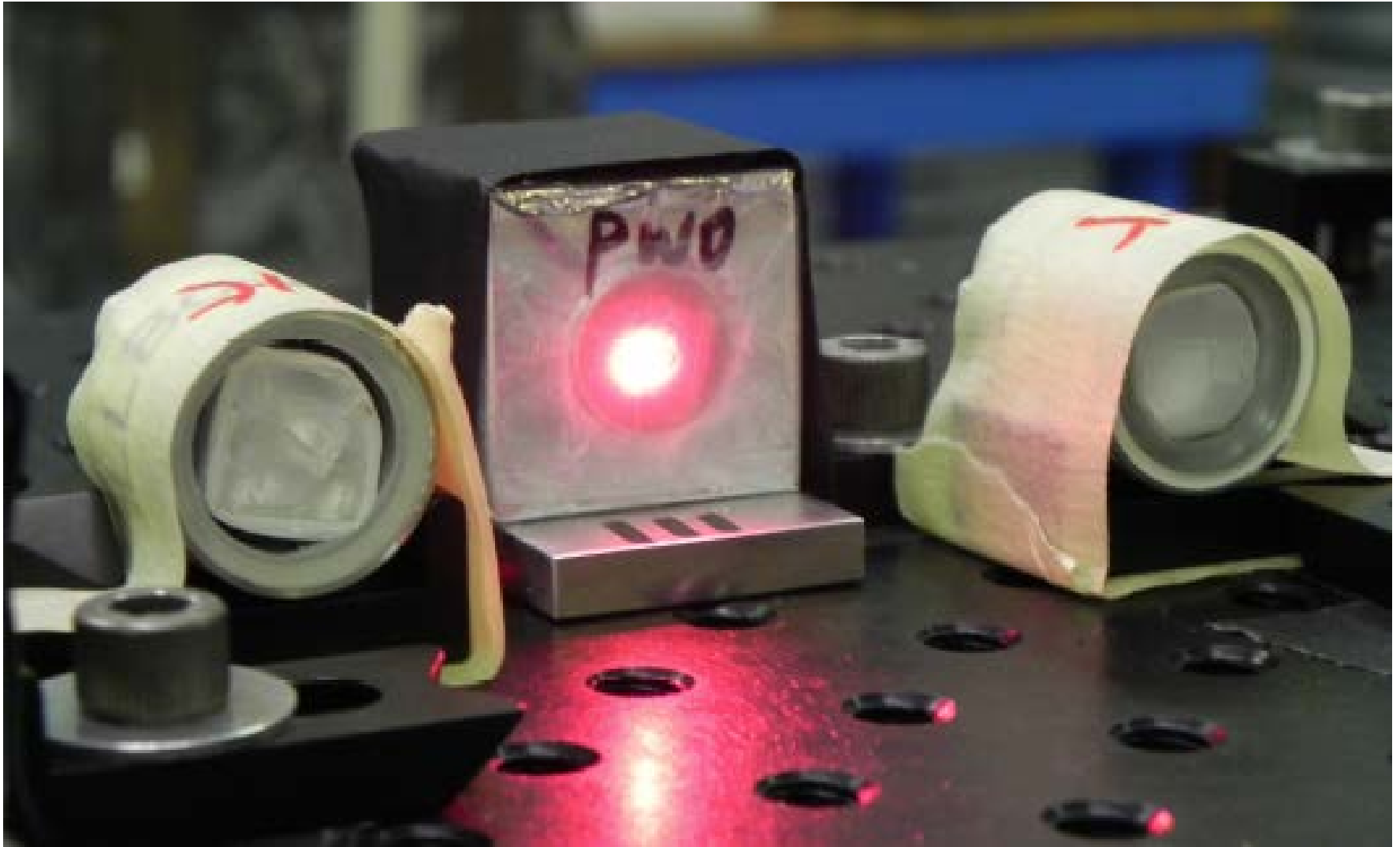
From left to right: Diamond, Shashlik, Crystal1, CLYC1, Crystal2, CLYC2, Crystal3, CYC3, BaF2, PWO and LYSO



Samples in the Blue Room



Alignment for Crystal3 in Blue Room



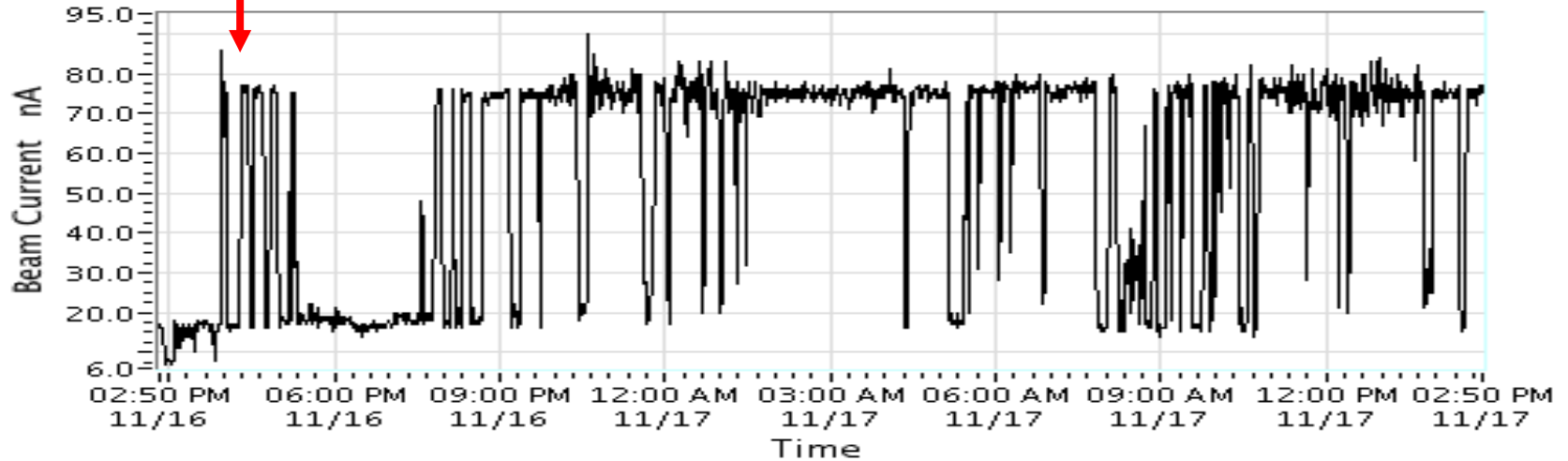
Samples & Fluence up to 3×10^{15} p/cm²

No.	Samples	Dimensions (mm ³)	In-situ Measurement	Fluence (p/cm ²)
1	Diamond Sensors			$\sim 2 \times 10^{14}$
2	Shashlik Cell	34x34x215	420 LED / Al	$2.9 \times 10^{13} - 1.9 \times 10^{15}$
3	2x PWOs	25x25x5	Al foil activation	2.7×10^{13}
	2x BaF ₂	25x25x5		
	3x LYSO (CPI,SIC, Tianle)	10x10x3		
4	2x PWOs	25x25x5	Al foil activation	1.6×10^{14}
	2x BaF ₂	25x25x5		
	3x LYSO (CPI,SIC, Tianle)	10x10x3		
5	2x PWOs	25x25x5	Al foil activation	9.7×10^{14}
	2x BaF ₂	25x25x5		
	3x LYSO (CPI,SIC, Tianle)	10x10x3		
6	PWO	25x25x5	LT (350-700 nm)	$1.6 \times 10^{13} - 1.2 \times 10^{15}$
7	BaF ₂	30x30x20	LT (350-700 nm)	$6.1 \times 10^{12} - 1.2 \times 10^{15}$
8	SIC LYSO	25x25x200	LT (350-700 nm)	$5.0 \times 10^{13} - 3.0 \times 10^{15}$

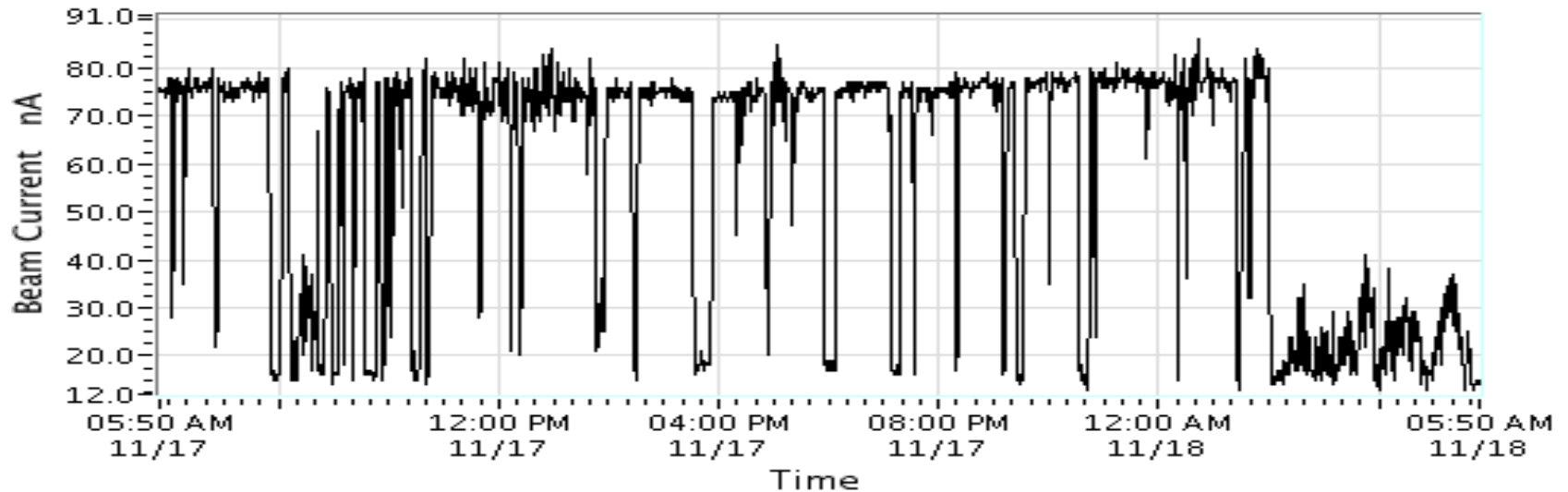
Proton Beam History

CLYC, Diamond

WNR Average Current
Peak: 90.00 nA Average: 55.82 nA

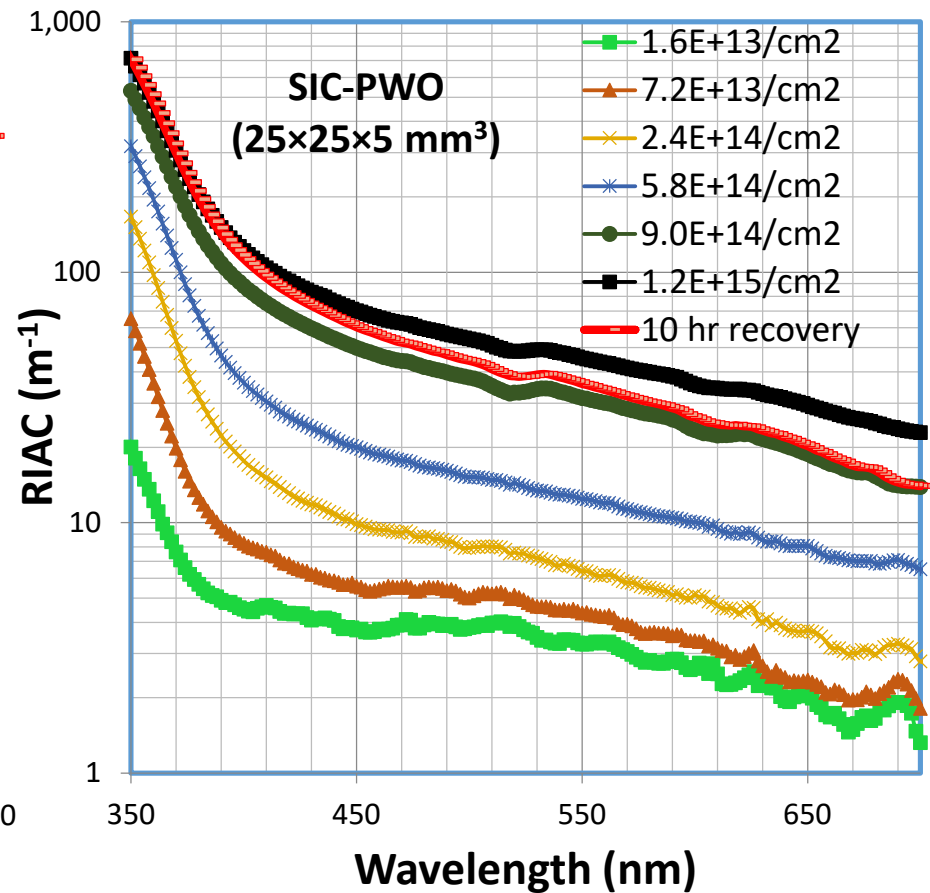
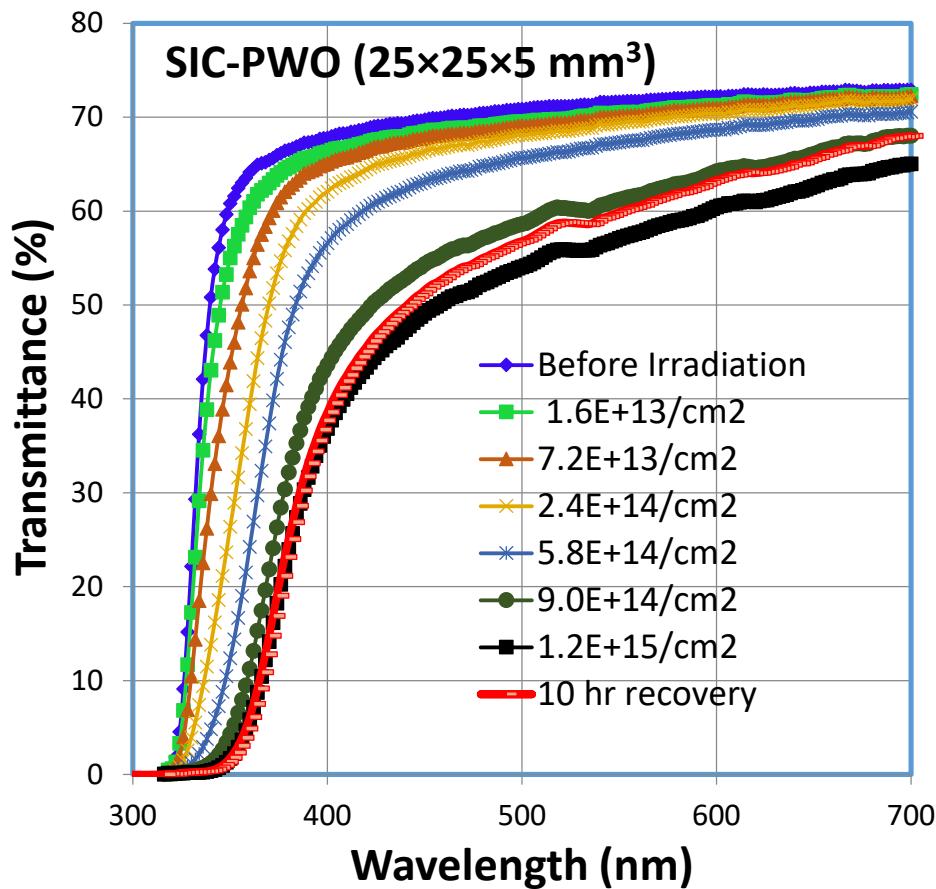


Peak: 86.00 nA Average: 58.54 nA



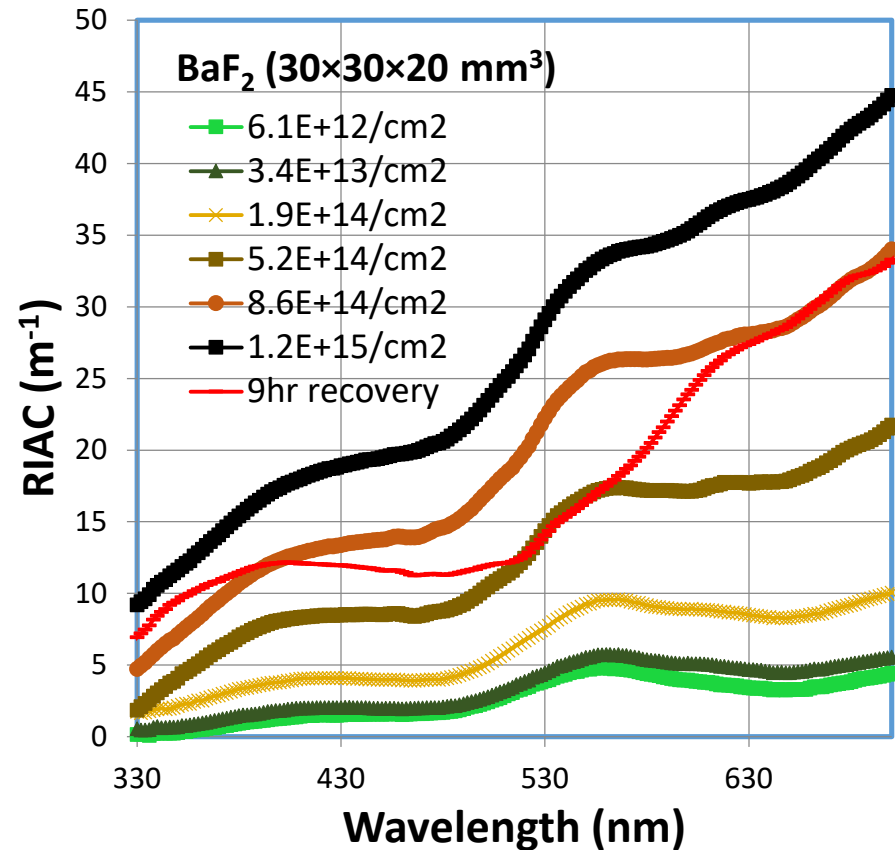
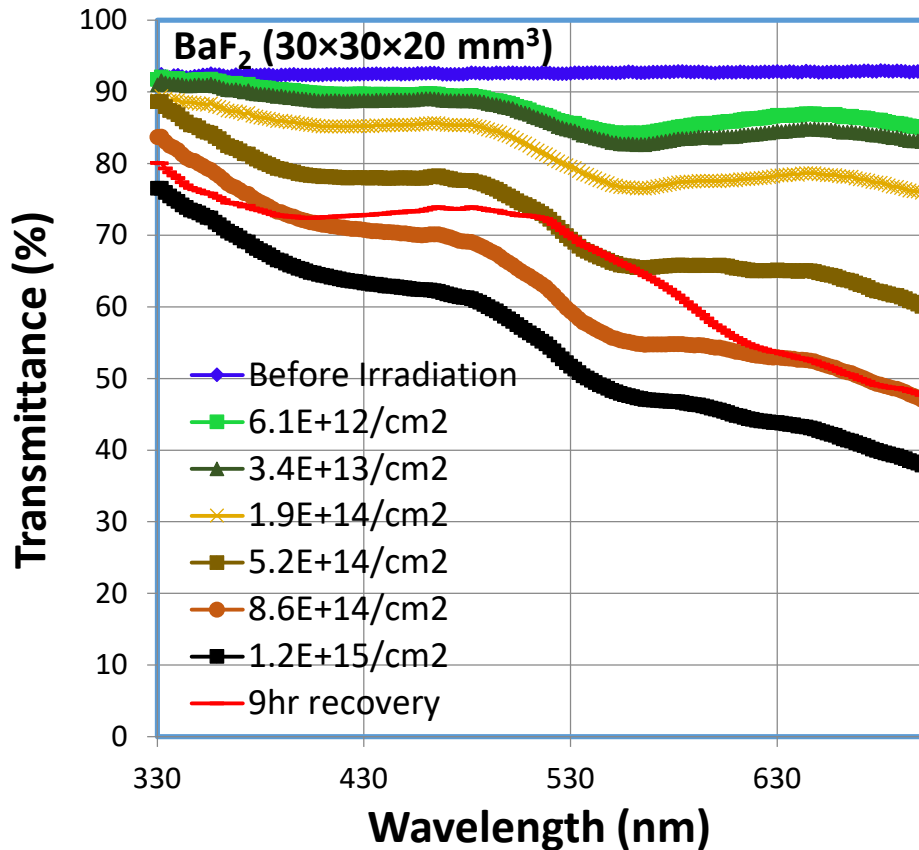
SIC-PWO: LT Damage and RIAC

A 5 mm thick SIC PWO plate was irradiated from 1.6×10^{13} to 1.2×10^{15} p/cm² with transmittance (300-700 nm) measured *in-situ*. The RIAC at 420 nm was measured to be 13.1 / 92.2 cm⁻¹ after 2.4×10^{14} / 1.2×10^{15} p/cm².



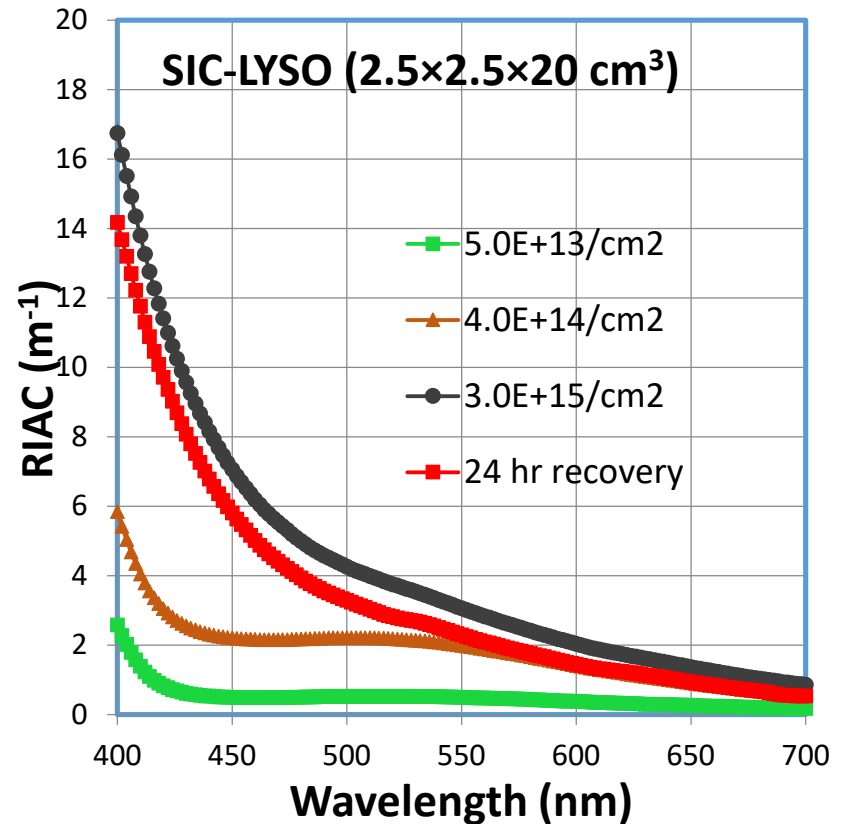
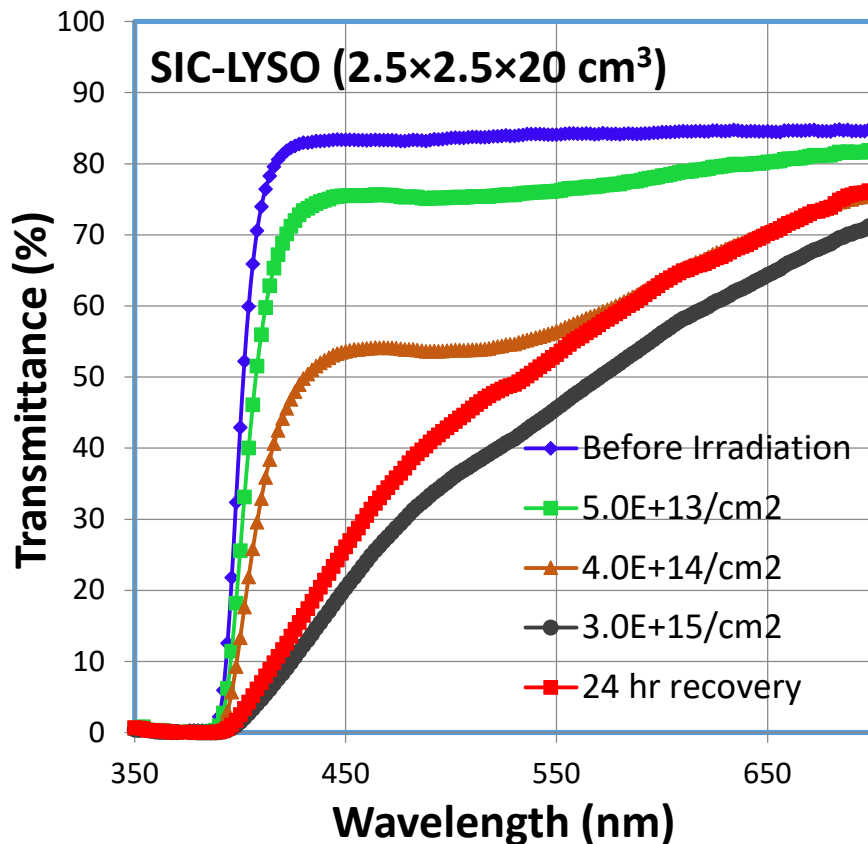
Helma-BaF₂: LT Damage and RIAC

A Helma BaF₂ of 2 cm was irradiated from 6.1×10^{12} to 1.2×10^{15} p/cm² in six steps with transmittance (330-650 nm) measured *in-situ*. The sample will be measured at Caltech for 200 – 650 nm.



SIC-LYSO: LT Damage and RIAC

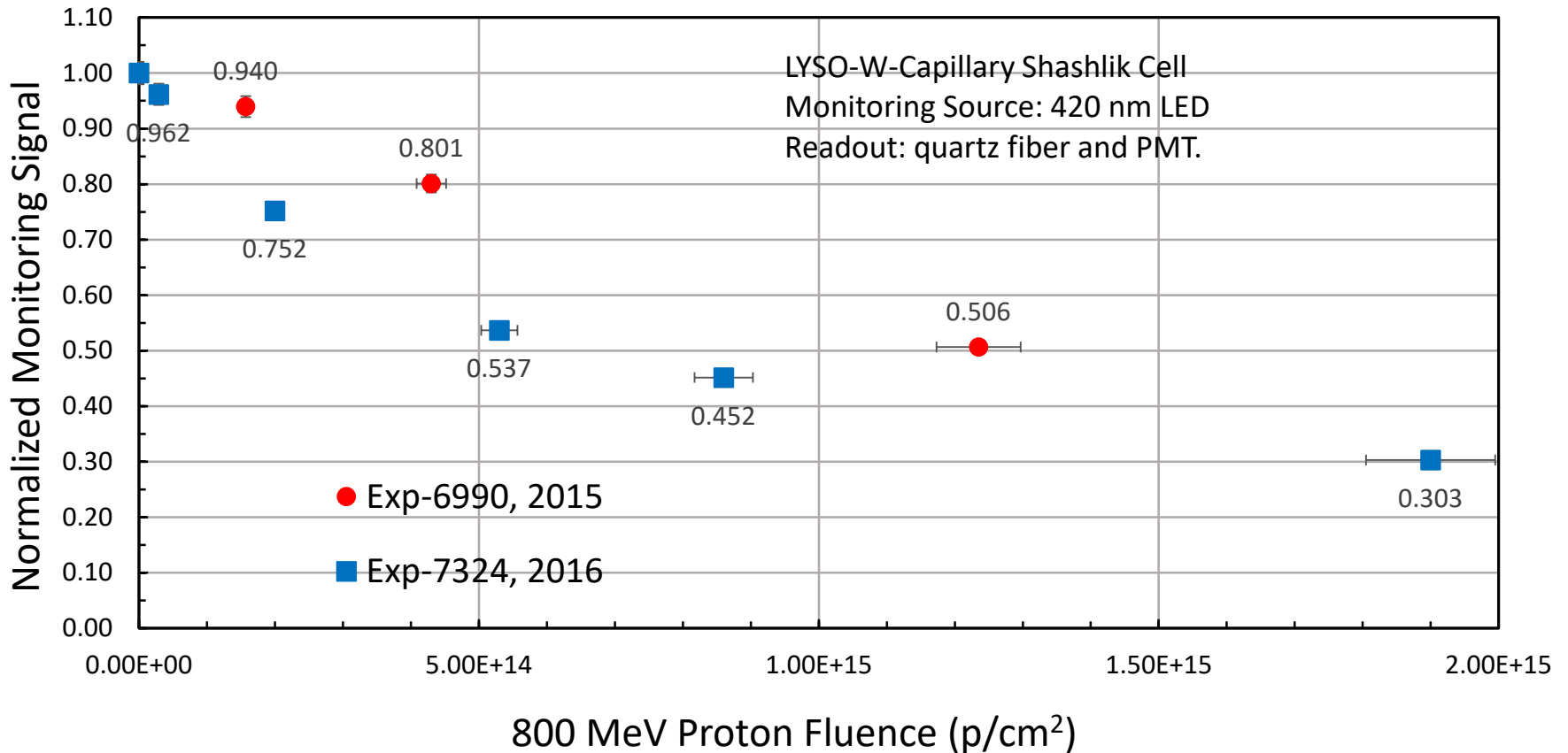
The 20 cm SIC-LYSO crystal irradiated from 5×10^{13} to 3×10^{15} p/cm² in three steps with the RIAC values consistent with previous experiments: 6501 and 6990.



Result consistent with previous publication in <http://dx.doi.org/10.1016/j.nima.2015.11.100>

LFS/W/Capillary Shashlik Cell

The Shashlik cell irradiated from 2.9×10^{13} to 1.9×10^{15} p/cm² in five steps with degradation of 30%/70% after 3×10^{14} / 1.9×10^{15} p/cm²



It is rad hard against hadrons, but slightly worse than that in Exp-6990

Summary

- Experiment 7324 measures crystal's transmittance and Shashlik response during proton irradiation at Los Alamos.
- Irradiation was carried out up to 3×10^{15} p/cm² for LYSO.
- Damage in a 5 mm PWO sample is consistent with 1 cm samples irradiated in 2015. A 2 cm BaF₂ sample shows good radiation hardness against protons..
- A LFS/W/Capillary Shashlik cell was irradiated to 1.9×10^{15} p/cm² in five steps with degradation of 30%/70% after 3×10^{14} p/cm² / 1.9×10^{15} p/cm², showing excellent radiation hardness against protons, but slightly worse than last year.
- Investigations are planned to further understand hadron induced radiation damage in crystals and their monitoring.
- Acknowledgements: US Department of Energy Grants DE-SC0011925 and DE-AC52-06NA25396.