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# Gamma-ray Induced Radiation Damage in 20 cm Long Y-11 & DSB WLS Fibers

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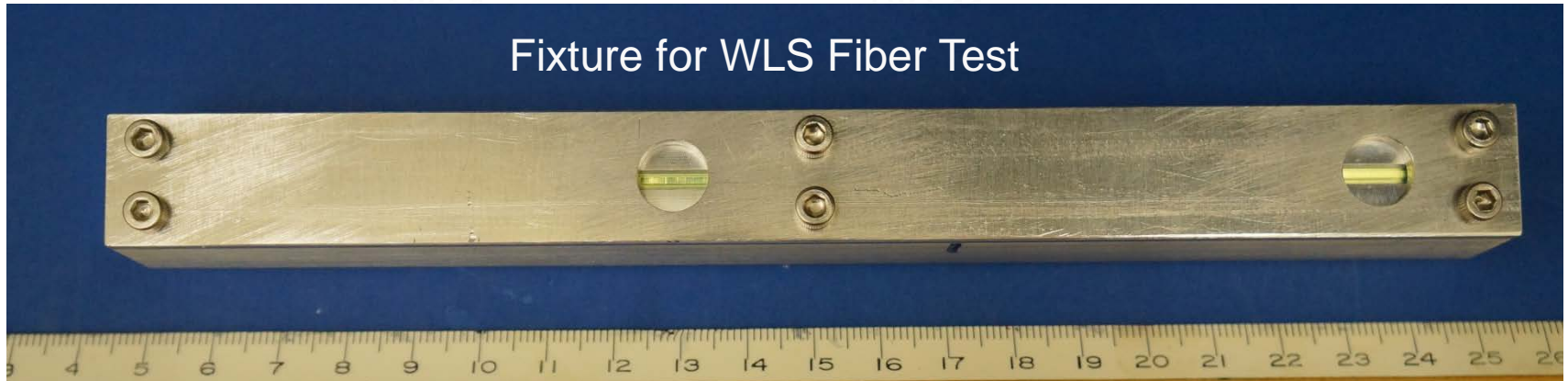
October 29, 2014

# Introduction

- LYSO crystals were irradiated by Co-60  $\gamma$ -rays up to 200 Mrad in the TAD facility of JPL with results showing that they are radiation hard up to the highest integrated dose expected by the Shashlik endcap ECAL at the HL-LHC.
- Radiation damage of the WLS medium is the other crucial issue for the Shashlik ECAL at the HL-LHC. While quartz capillary based WLS is being actively pursued it is also our interest to look the consequence of radiation damage effect in commercially available WLS fibers, such as Y-11 and DSB, for LYSO readout. This investigation makes sense since the length of the WLS fibers used for the LYSO/W Shashlik cell is as short as 12 cm.
- Y-11 and DSB fibers of 20 cm long were irradiated up to 100 Mrad under 1 Mrad/h, and up to 1.3 Mrad under 7 krad/h. The results indicate that 20 cm long Y-11 WLS fibers survive the 7 krad/h dose rate, so may be considered as a candidate backup solution for the quartz capillary.

# 20 cm Long Y-11 and DSB WLS Fibers

Fixture for WLS Fiber Test



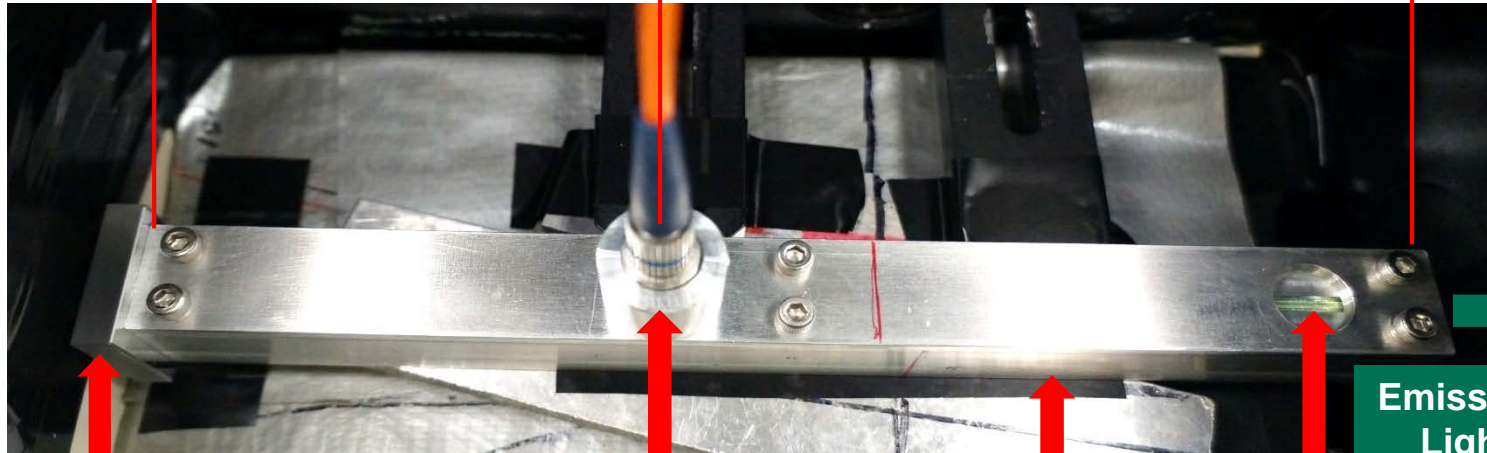
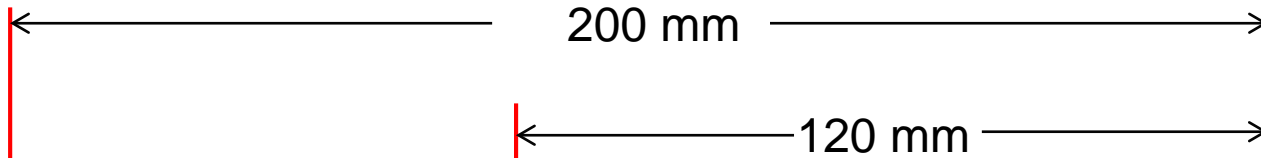
Sample ID	Length (mm)	Quantity
Y-11 No. 1 to No. 20	200	20
DSB No. 1 to No. 6	200	6

## Experiments

- Properties measured at room temperature: intensity of photo-luminescence excited by a blue LED of 420 nm.

# Measurement Setup

Light path in WLS fibers: Shashlik cell length of 12 cm



Hamamatsu R928 PMT in HITACHI F-4500 Spectrometer

Emission Light

Al Mirror (Thorlabs PFSQ10-03-G01)

Excitation Light from LED (Thorlabs M420L2 420 nm)

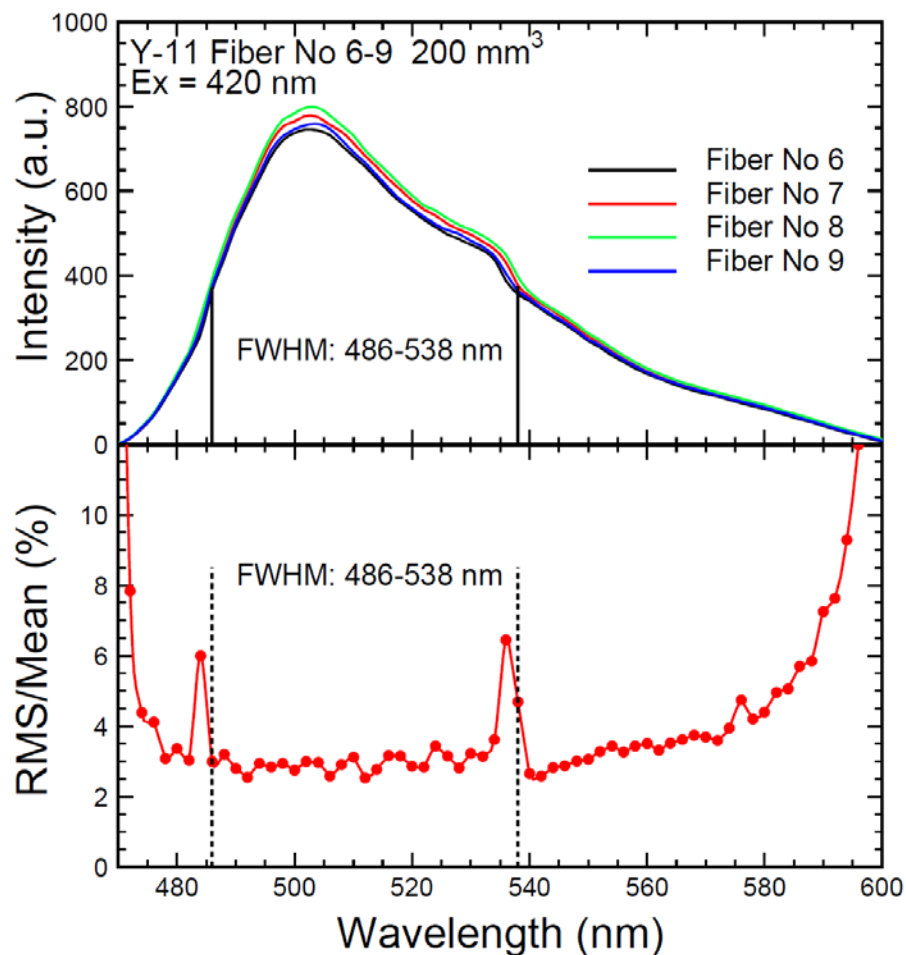
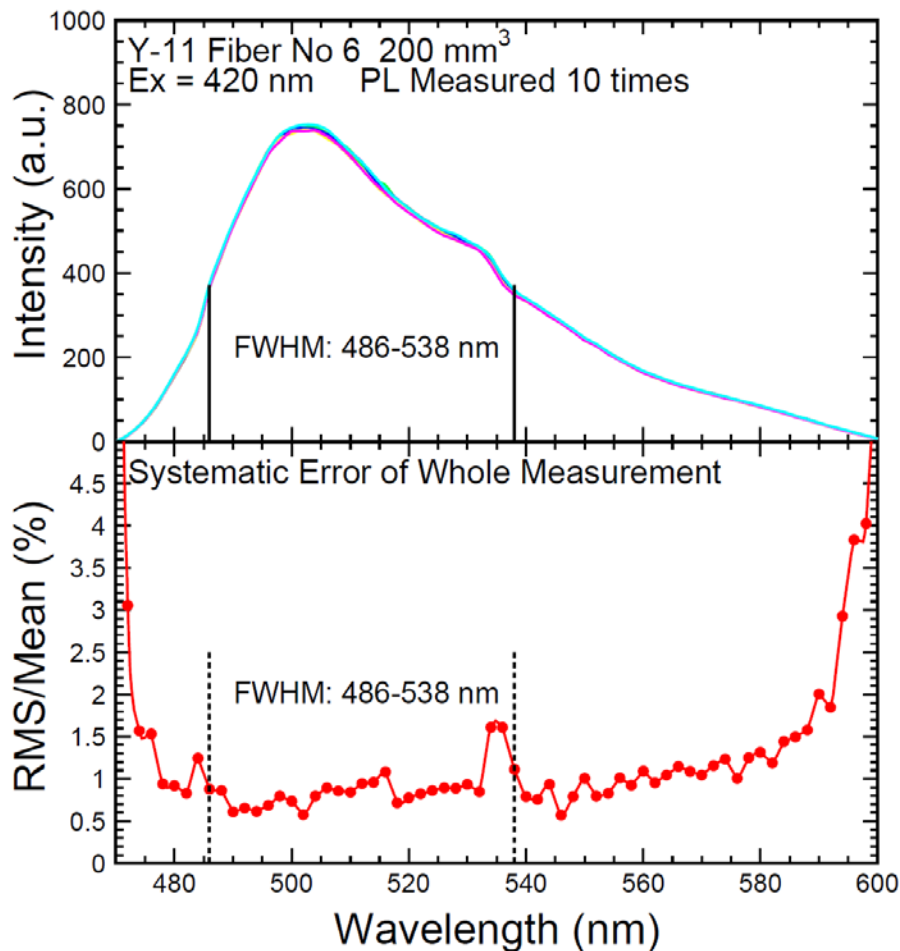
Fiber Fixture

WLS Fiber

PMT HV: 400 V; Emission slit width: 20 nm; Scan speed: 60 nm/min

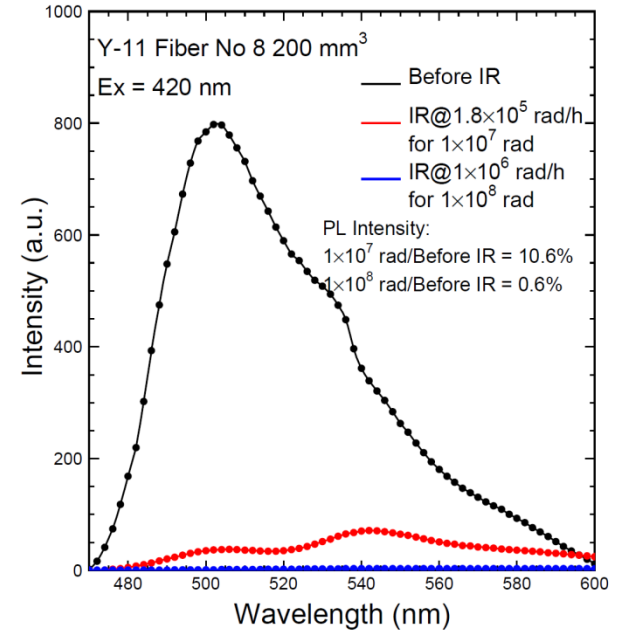
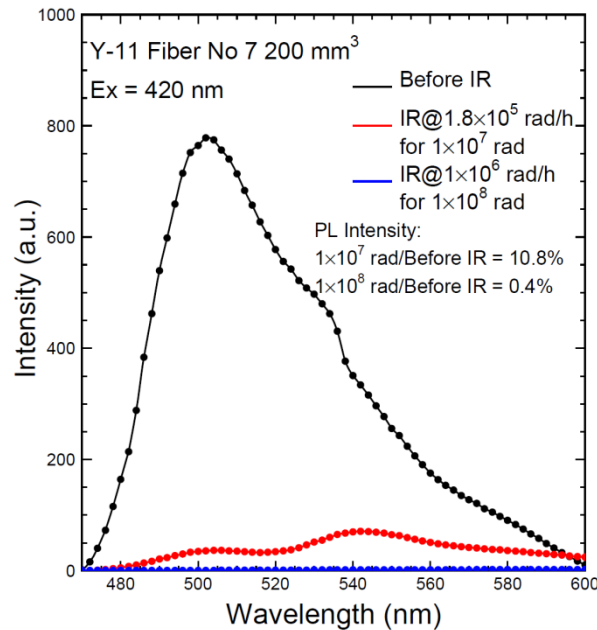
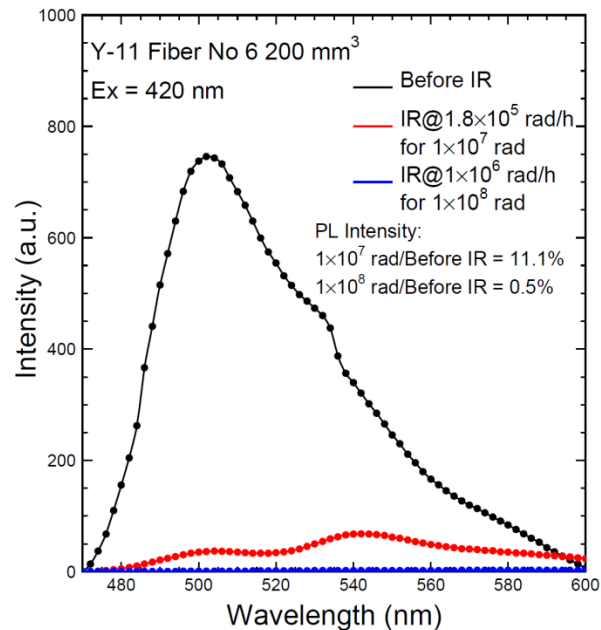
# Systematic Uncertainties

About 1% for the same fiber, and 3% for different fibers



# Three Y-11 Fibers Irradiated up to 100 Mrad

Degradation of 90% after 10 Mrad, and >99% after 100 Mrad



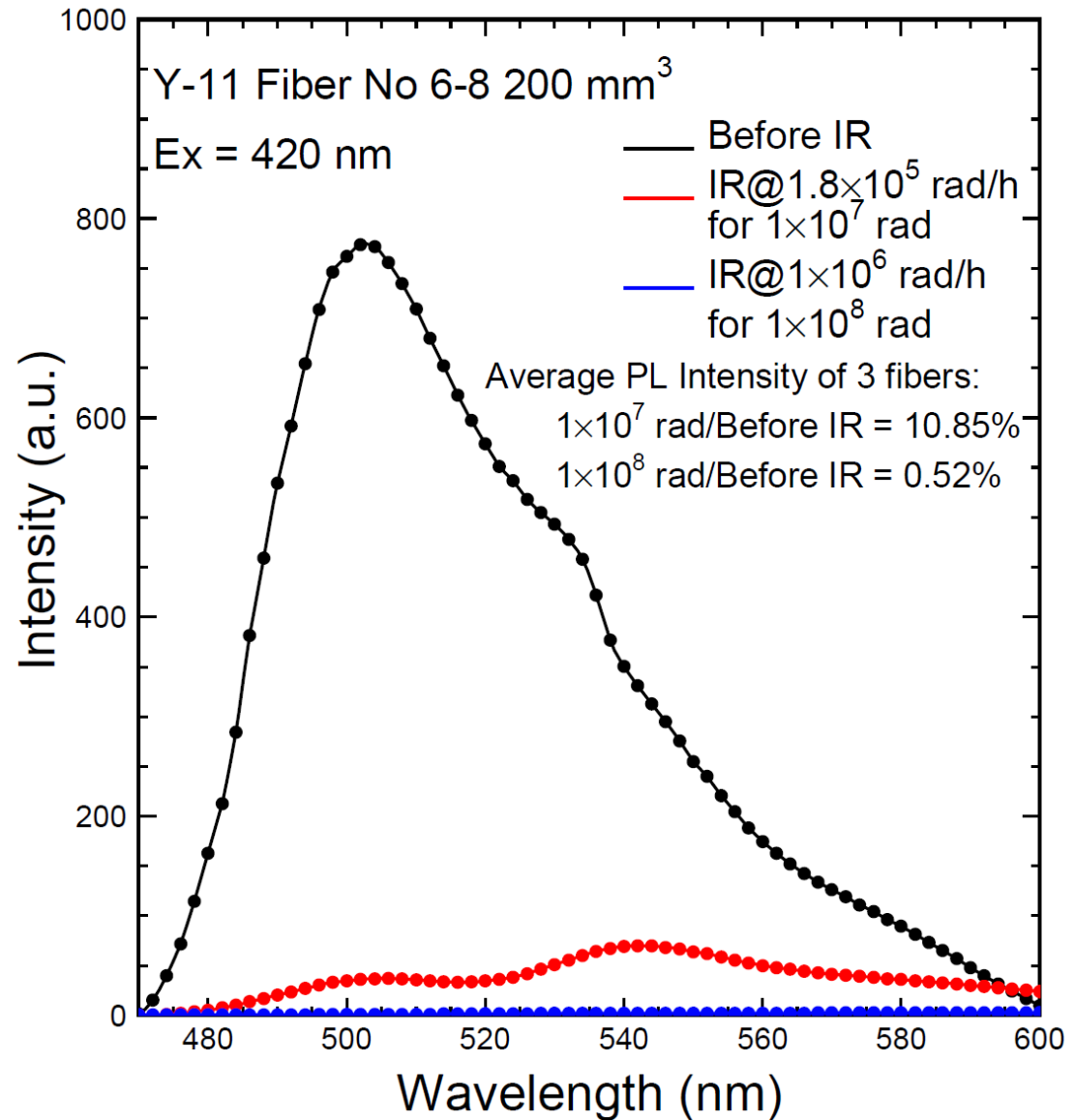
Dose rate of 180 krad/h for 10 Mrad and 1 Mrad/h for 100 Mrad  
Measurements carried out about one hour after the irradiation

# Average Degradation of three Y-11 Fibers

89% damage after  
10 Mrad at  
180 krad/h

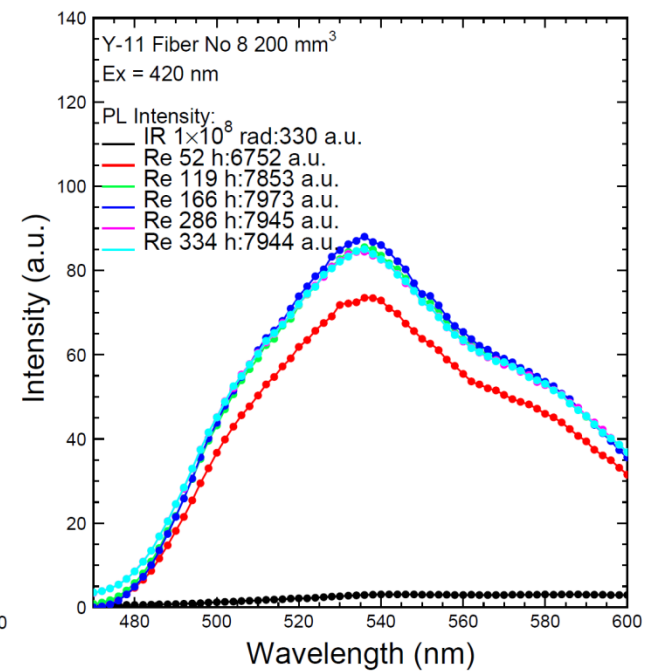
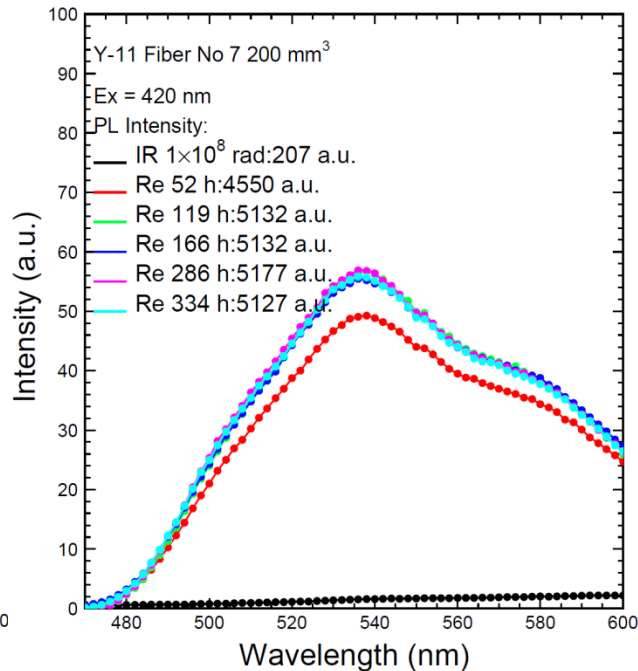
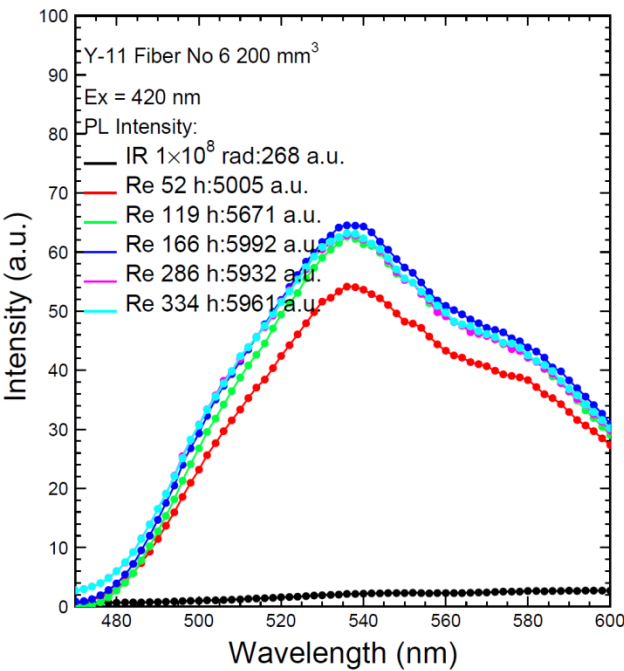
99.5% damage after  
100 Mrad at  
1 Mrad/h

Y-11 WLS fibers do  
not survive  
integrated dose  
delivered at very  
high dose rate



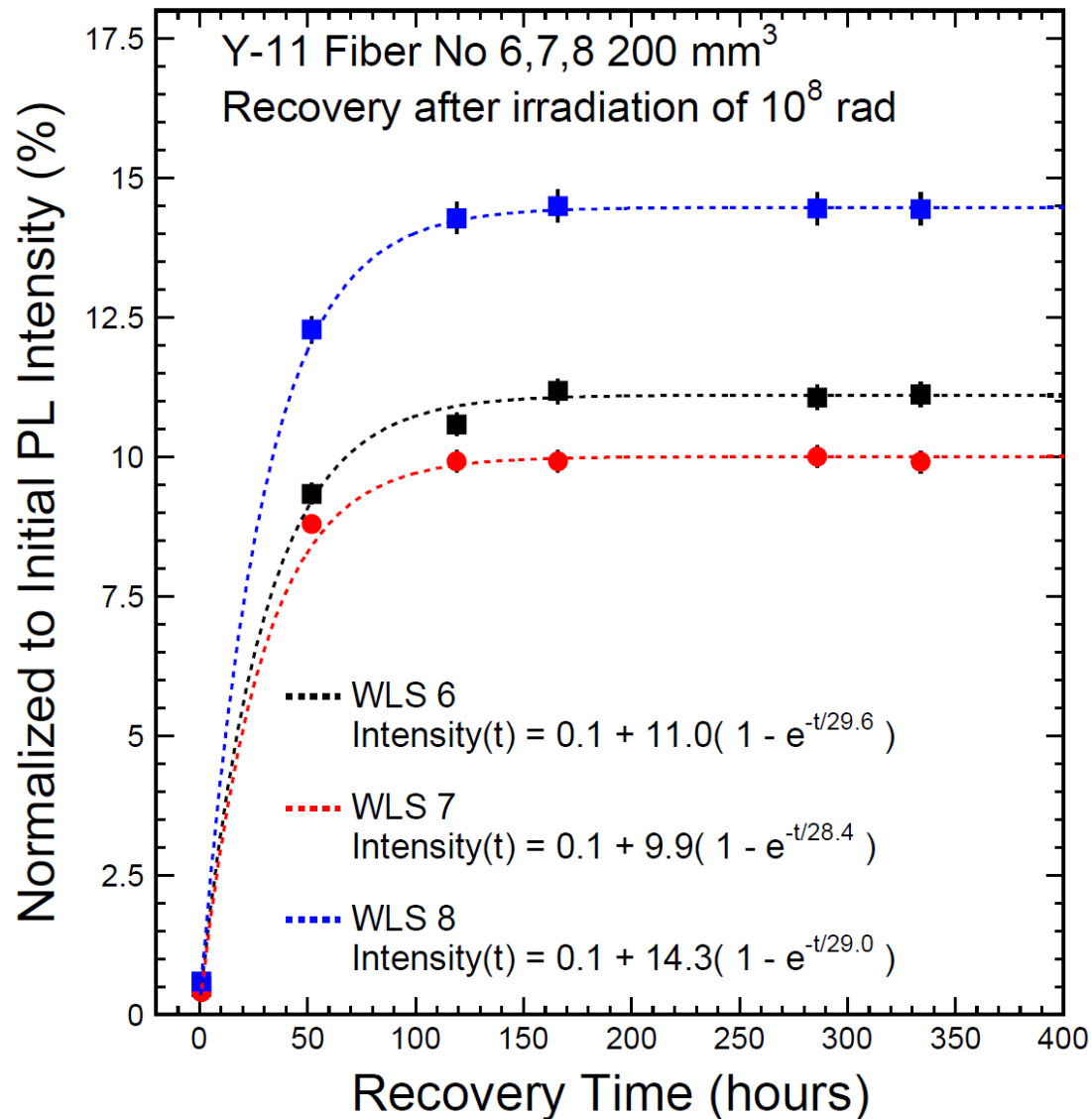
# Damage Recovery in Y-11 WLS Fibers

Significant recovery observed after 100 Mrad





# Consistent Recovery Time Constant: ~30 h

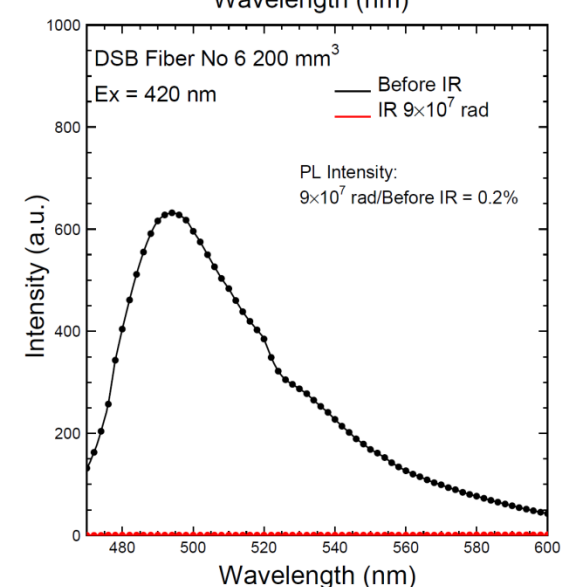
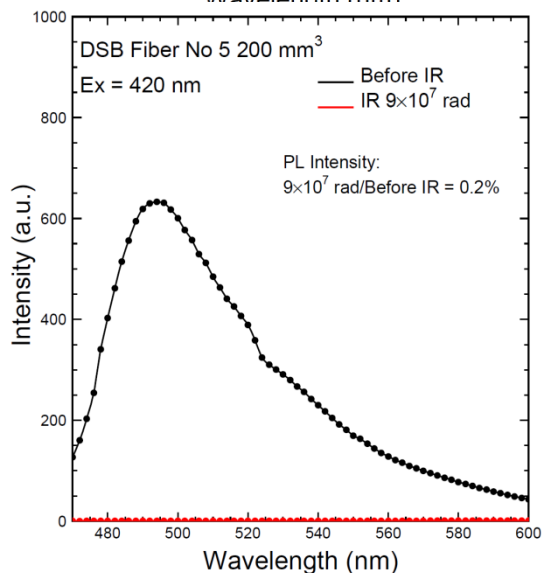
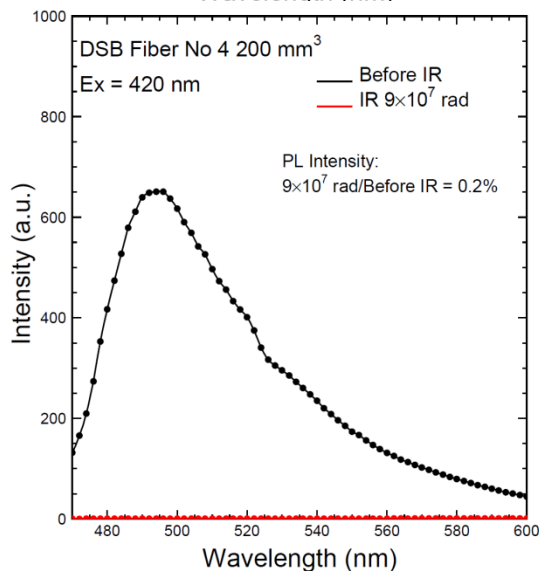
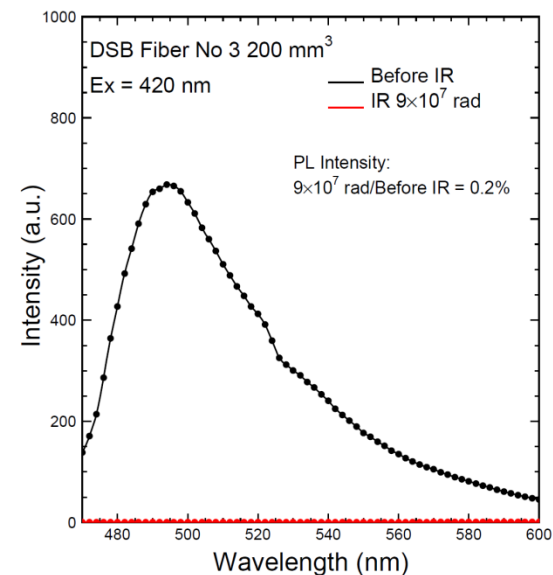
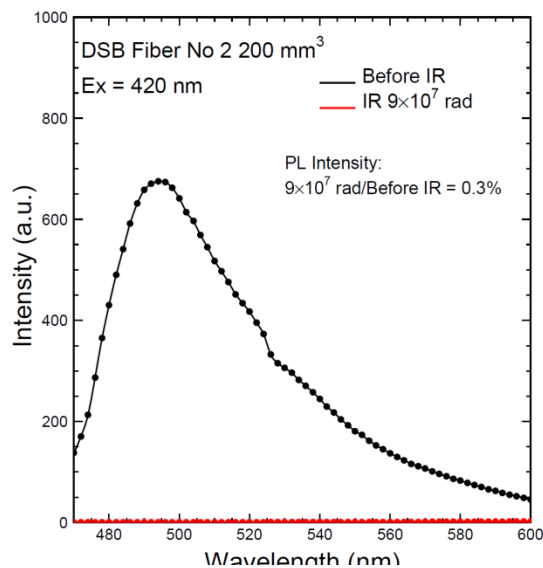
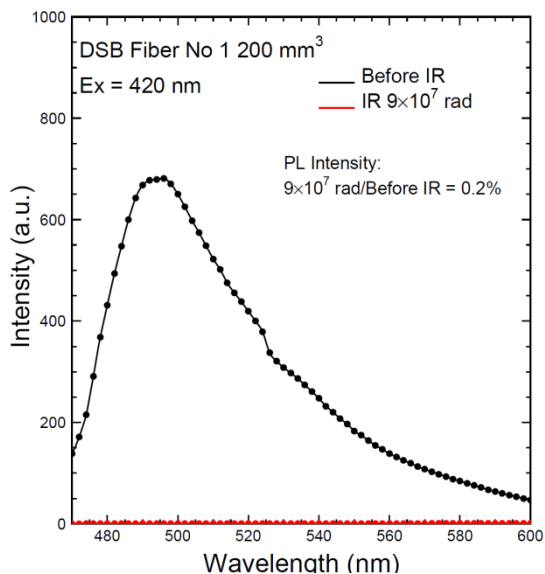


Recovery indicates a dose rate dependent damage, similar to PWO crystals

It is important to study dose rate dependence of the damage in Y-11 WLS fibers

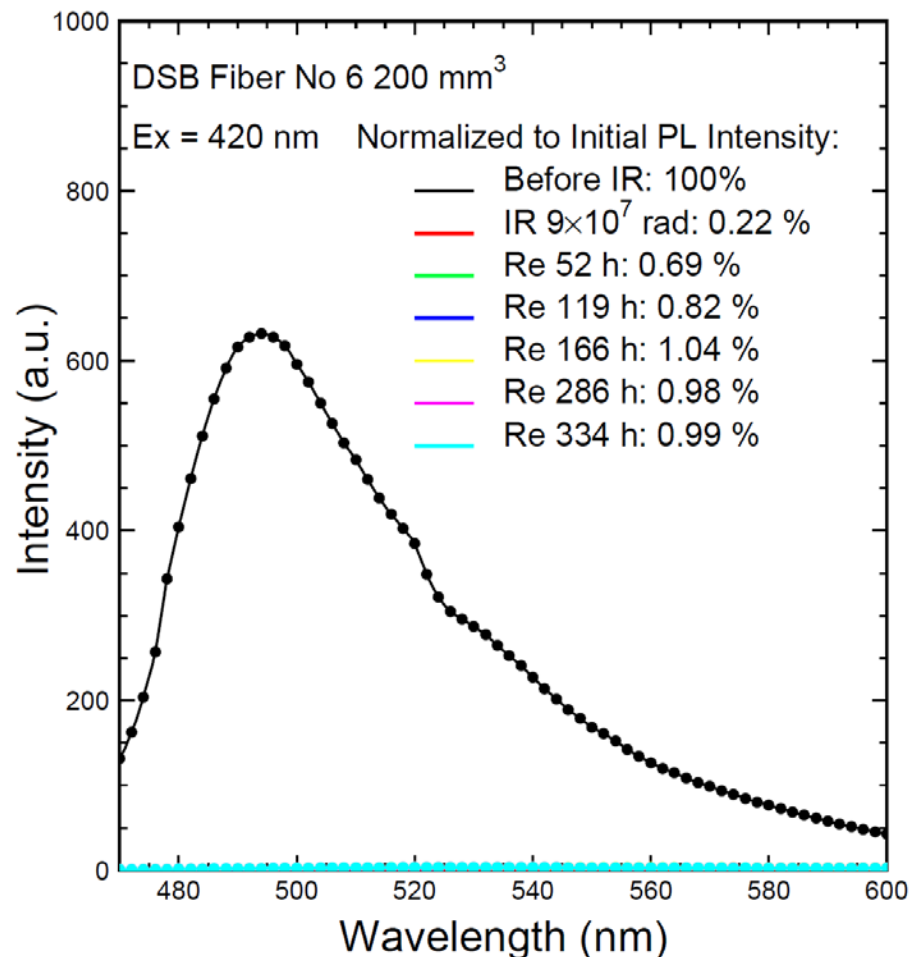
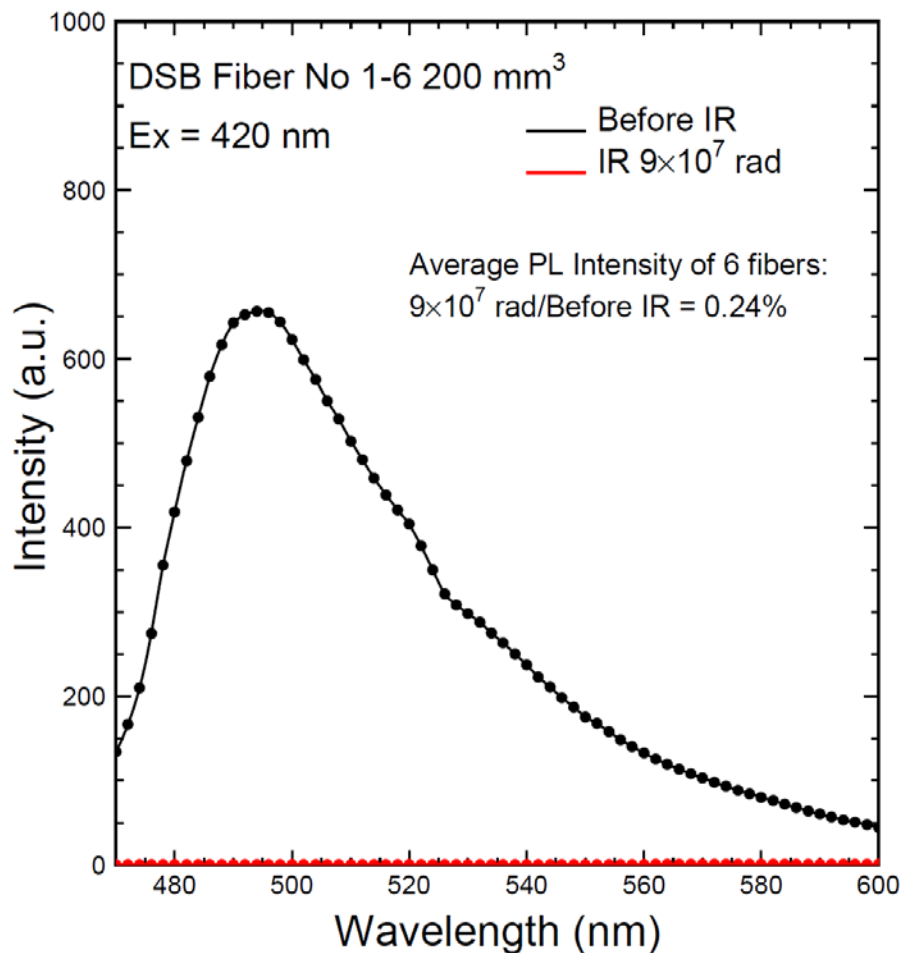
# Six DSB Fibers Irradiated to 90 Mrad @ 1 Mrad/h

Damage observed much larger than 99.7%



# Average Damage of 6 DSB Fibers and Recovery

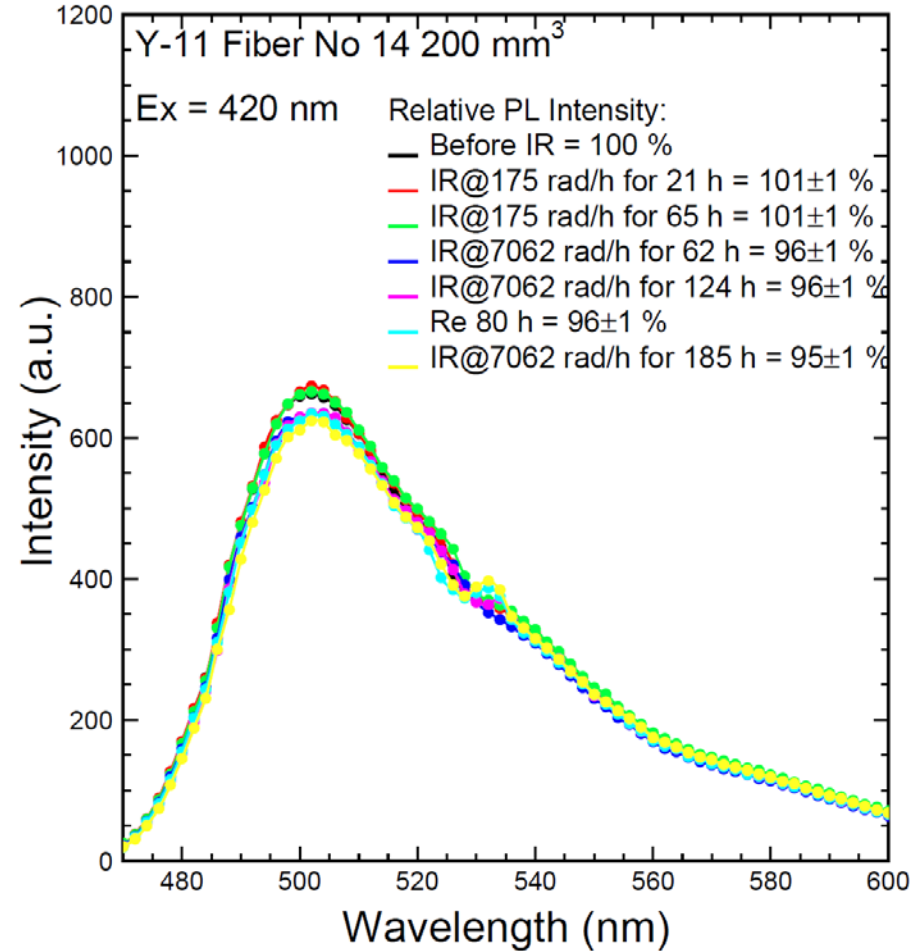
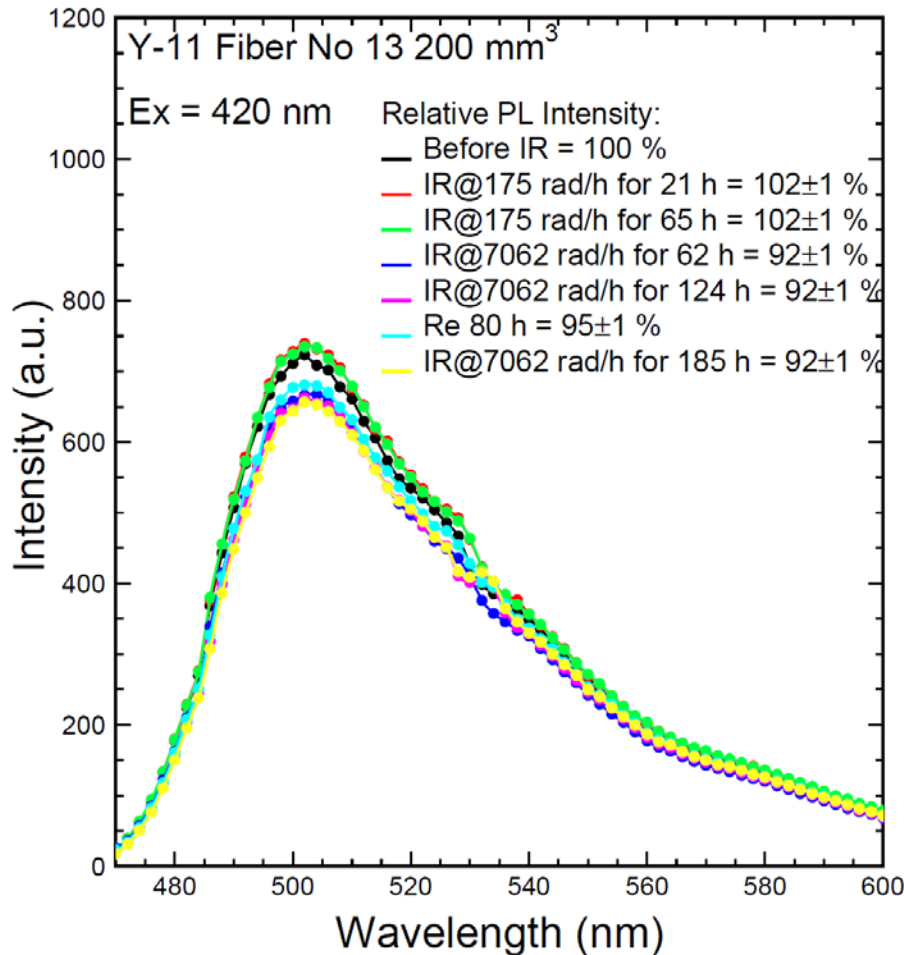
99.8% damage after 90 Mrad @ 1 Mrad/h



No recovery, so damage is not dose rate dependent

# Radiation Damage under 175 & 7k Rad/h

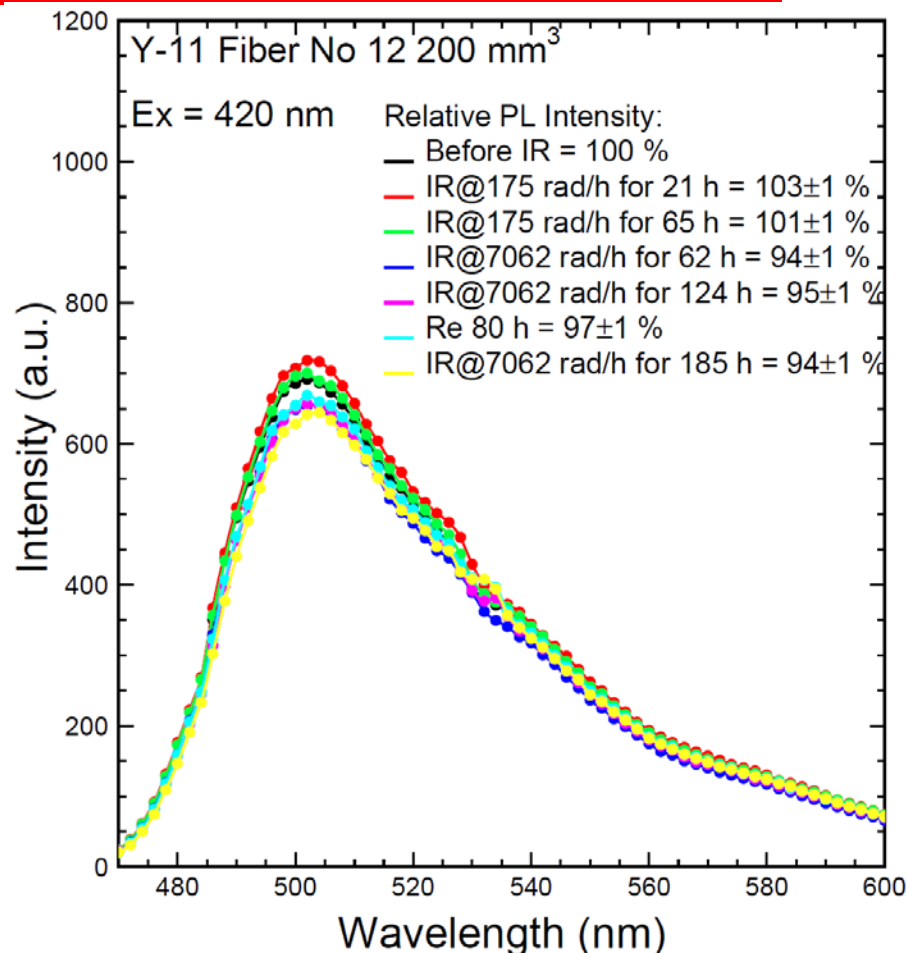
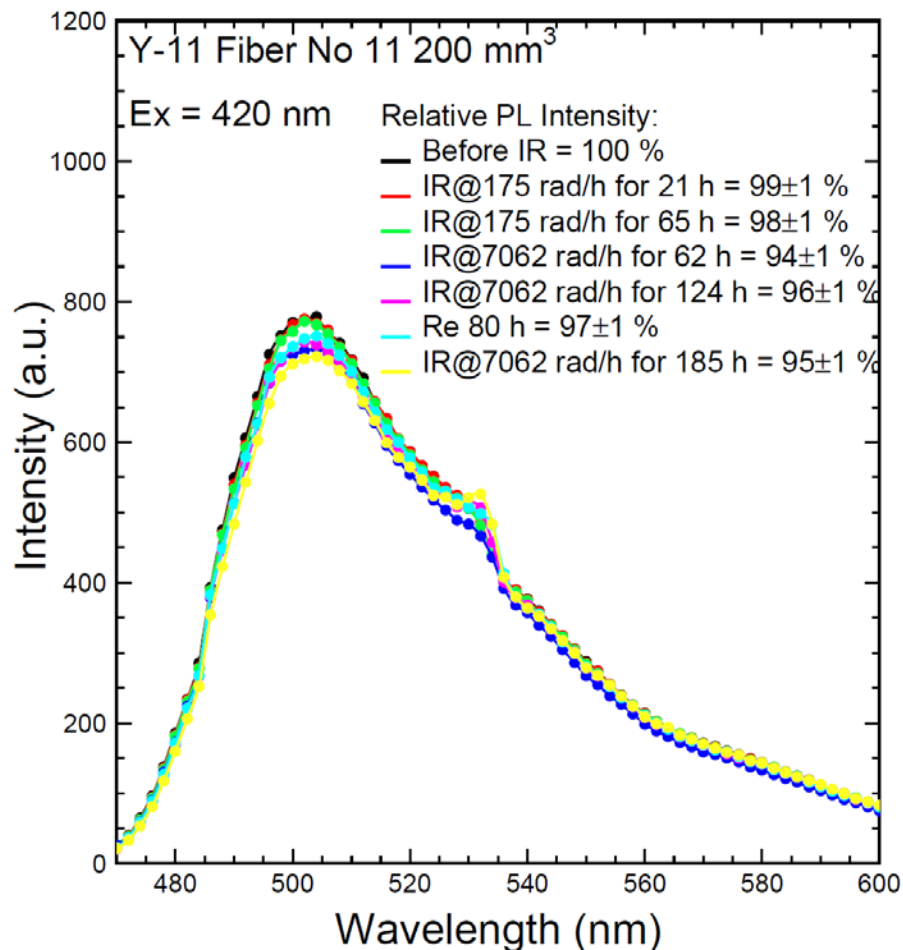
Very small damage observed under 175 rad/h, and ~5% under 7 krad/h



11 krad @ 175 rad/h, and 1.3 Mrad @ 7 krad/h  
Measurements carried out about 20 minutes after the irradiation

# Radiation Damage under 175 & 7k Rad/h

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11 krad @ 175 rad/h, and 1.3 Mrad @ 7 krad/h  
Measurements carried out about 20 minutes after the irradiation

# History of Dose Rate Dependent Damage

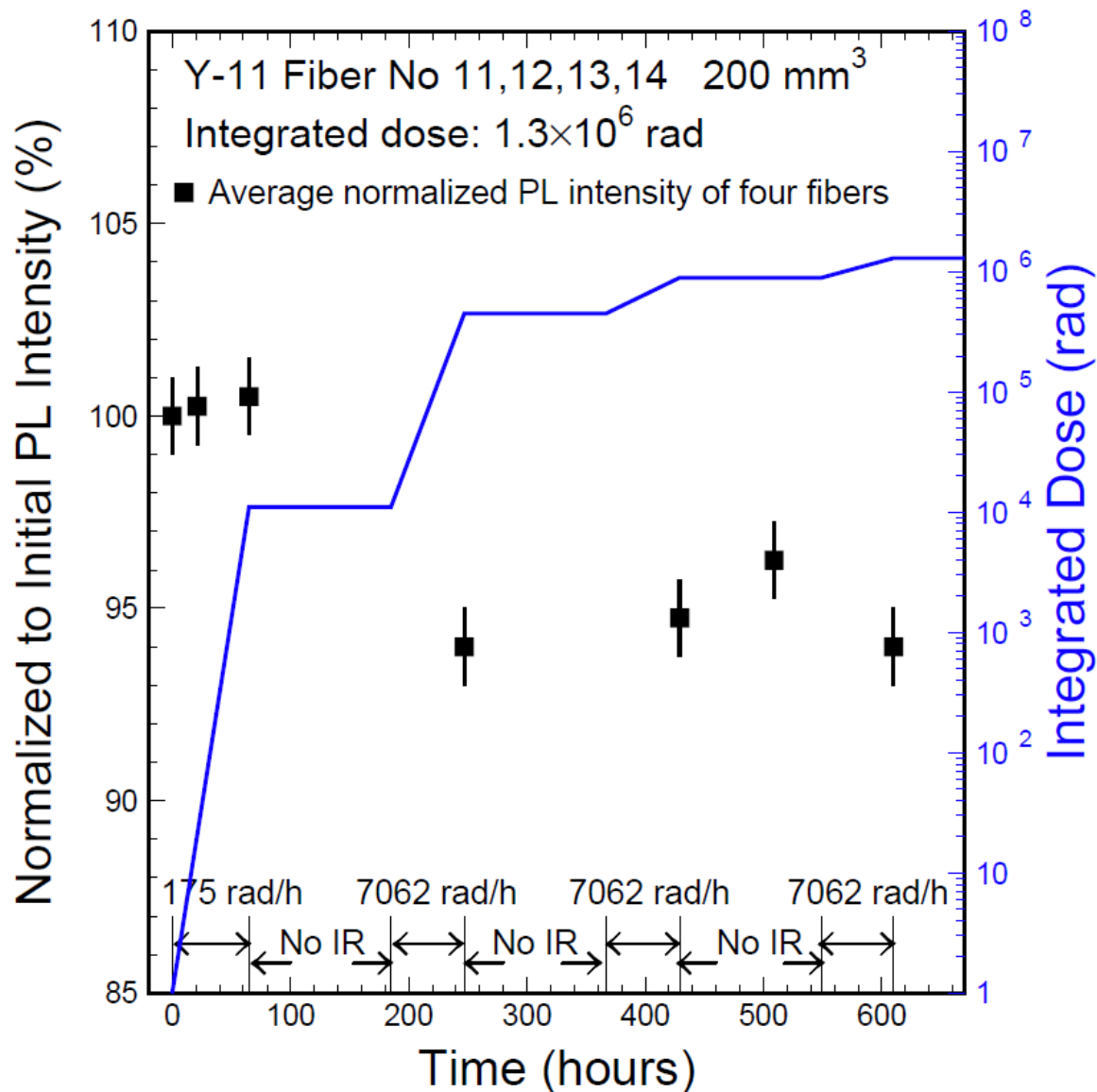
Average damage of four Y-11 fibers:

Almost no damage under 175 rad/h

About 5% damage under 7 krad/h, which will be less for 12 cm long fibers.

Recovery at % level observed after 80 h.

Y-11 WLS fibers survive the maximum dose rate expected by the endcap ECAL at the HL-LHC



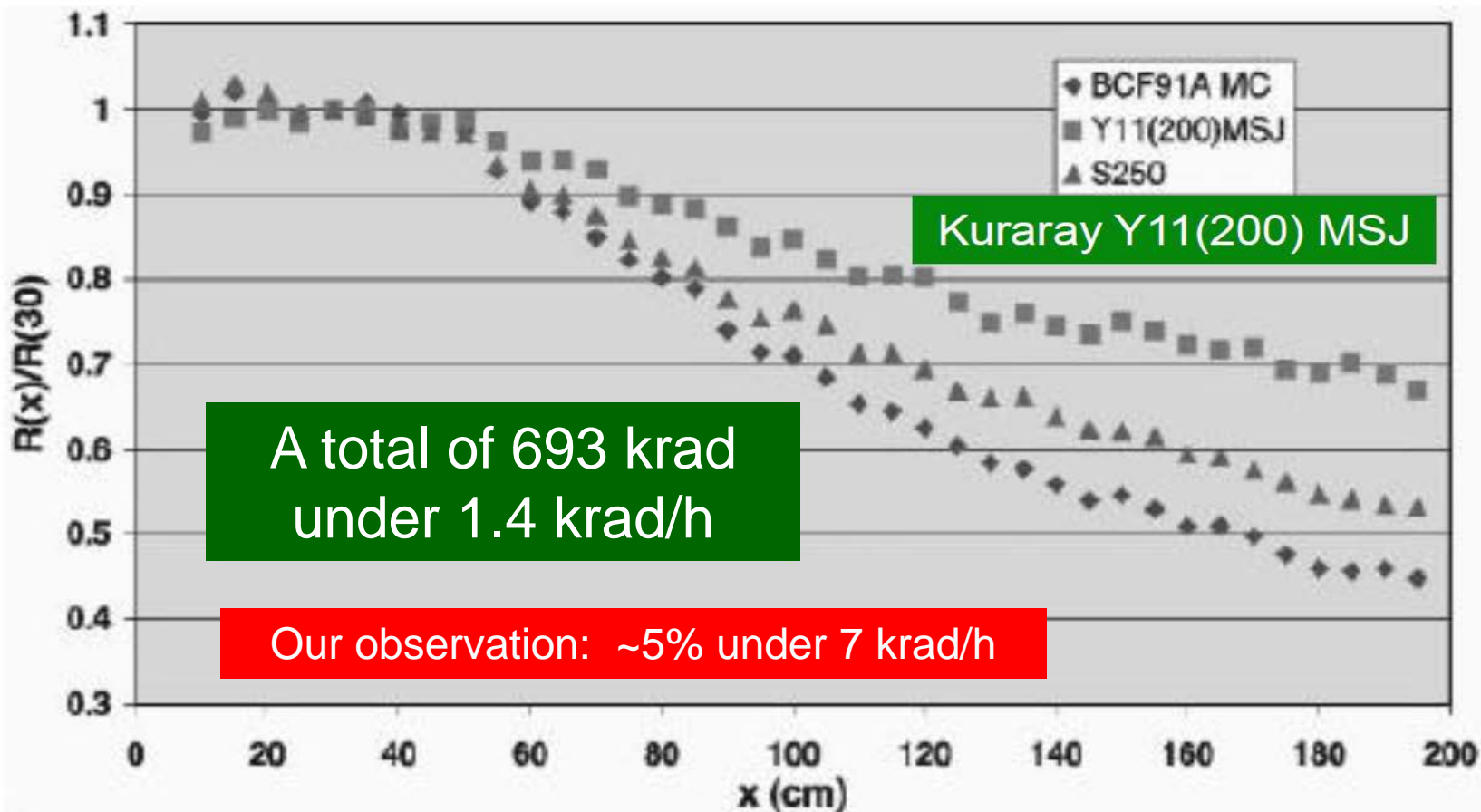
# Consistent with Previous Publication



## Radiation Hardness of WLS Fibers



M. David, A. Gomes, A. Maio, NIM A453 (2000) 255.





# Summary

- Gamma-ray induced radiation damage was measured for 20 cm long Y-11 and DSB WLS fibers. Both fibers show almost no light after 100 Mrad irradiation at a dose rate of 1 Mrad/h.
- Significant recovery was found in the Y-11 fibers after 1 Mrad/h irradiation with a time constant of  $\sim 30$  h, while almost no recovery in the DSB fibers.
- Following our experience in crystal radiation damage study, Y-11 fibers were irradiated under low dose rates. No damage was found under 175 rad/h, and about 5% damage was found under 7 krad/h, confirming dose rate dependent damage in Y-11 WLS fibers. The recovery observed 80 h after the 7 krad/h irradiation is at percent level.
- Since 7 krad/h is the maximum dose rate expected by the endcap ECAL at the largest rapidity, this result indicates that 20 cm long Y-11 WLS fibers survive the HL-LHC.
- The result is consistent with previous publications.
- Work is needed to further our understanding on radiation damage in WLS fibers, and the difference between Y-11 and DSB fibers. LYSO/W/Y-11 cells will be irradiated under  $\gamma$ -rays, fast neutrons and charged hadrons .