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

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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.
Experiments

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

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

- Al Mirror (Thorlabs PFSQ10-03-G01)
- Excitation Light from LED (Thorlabs M420L2 420 nm)
- Fiber Fixture
- WLS Fiber

Hamamatsu R928 PMT in HITACHI F-4500 Spectrometer

Emission Light

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

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Caltech HEP Crystal Laboratory
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: \( \sim 30 \text{ h} \)

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.

Measurements carried out about 20 minutes after the irradiation.

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

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

Measurements carried out about 20 minutes after the irradiation

11 krad @ 175 rad/h, and 1.3 Mrad @ 7 krad/h

Measurements carried out about 20 minutes after the irradiation

Ex = 420 nm

Y-11 Fiber No 11 200 mm³

Relative PL Intensity:
- Before IR = 100 %
- IR@175 rad/h for 21 h = 99±1 %
- IR@175 rad/h for 65 h = 98±1 %
- IR@7062 rad/h for 62 h = 94±1 %
- IR@7062 rad/h for 124 h = 96±1 %
- Re 80 h = 97±1 %
- IR@7062 rad/h for 185 h = 95±1 %

Ex = 420 nm

Y-11 Fiber No 12 200 mm³

Relative PL Intensity:
- Before IR = 100 %
- IR@175 rad/h for 21 h = 103±1 %
- IR@175 rad/h for 65 h = 101±1 %
- IR@7062 rad/h for 62 h = 94±1 %
- IR@7062 rad/h for 124 h = 95±1 %
- Re 80 h = 97±1 %
- IR@7062 rad/h for 185 h = 94±1 %
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


A total of 693 krad under 1.4 krad/h

Kuraray Y11(200) MSJ

Our observation: ~5% under 7 krad/h
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 ~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 γ-rays, fast neutrons and charged hadrons.