# ECal Material Radiation Hardness Summary

05/22/2025

Latest simulation gives for the Preshower:

30krad/month for PVDIS. Assuming 6 months of running (180 PAC days), this leads to 180 krad for each calendar year or for the total requested ~180 PAC days.

This presentation contains data from ATLAS, JLab (our data), and SDU (IMP, though incomplete and I have followed up with them)

Dave Mack's suggestion:
→ for large-angle, forget about preshower and pre-lead, just use Shower → bad idea?

ATLAS: NIMA 453 (2000) 255

Zhiwen's presentation on 02/12/2013

1Gy=100rad

100krad:
- Kuraray loss ~ 13% loss;
- Saint Gobain loss ~17% loss

700krad:
- Kuraray loss ~ 29%;
- Saint Gobain loss ~ 46%

some recovery after 10 days is observed but not large for BCF91A and Y11

vs. PVDIS 180 PAC days → 180 krad

Table 1
Optical properties of each type of WLS fibers before the irradiation. Average light output at 140 cm and RMS, average attenuation length ($L_{att}$) and RMS, for ten fibers of each type. The values are normalized to $I_{140}$ of the Y11(200)MSJ fibers

| Fiber type | $I_{140}$ | RMS (%) | $L_{att}$ (cm) | RMS (%) |
|---|---|---|---|---|
| BCF91A MC | 0.98 | 9.6 | 280 | 9.5 |
| Y11(200)MSJ | 1.00 | 1.8 | 280 | 1.6 |
| S250-100 | 0.81 | 5.7 | 230 | 5.6 |

Table 2
Relative light output at $x = 140$ cm, for total doses of 1.16 and 6.93 kGy

| Fiber type | $\frac{R(140)}{R(30)}$ for 1.16 kGy | | | $\frac{R(140)}{R(30)}$ for 6.93 kGy | | |
|---|---|---|---|---|---|---|
| | 0 days | 1 day | 10 days | 0 days | 1 day | 10 days |
| BCF91A MC | 0.83 | 0.86 | 0.85 | 0.54 | 0.56 | 0.56 |
| Y11(200)MSJ | 0.87 | 0.92 | 0.91 | 0.71 | 0.72 | 0.74 |
| S250-100 | 0.60 | 0.70 | 0.81 | 0.52 | 0.55 | 0.64 |

116krad 693krad

Our Preshower Irradiation test (Hall A, 2016)

[Vince's presentation on 01/02/2017]

A significant portion (~half) of the light loss seems to be from optical grease degrading

Y11(200) ?

# Irradiative Preshower Results

| Tile # | Radiation Dose | Before Radiation | With Old Grease | After Replacing Grease | After Replacing Fibers | After Replacing Tyvek Wrapping |
|---|---|---|---|---|---|---|
| Kedi 1 | 161-164 kRad | 87.1 | 56.6 | 74.4# | 73.3# | N/M |
| Kedi 2 | 185-189 kRad | 85.4 | 57.6 (fibers were kinked) | 67.3 | 68.0^ | 80.3 |
| Kedi 3 | 31-38 kRad | 87.0 | 66.0 | 69.7# | 77.3 | N/M |
| Kedi 4 | 9-17 kRad | 91.0 | 55-74*(?) (broken fiber replaced) | 86.5# | N/M | N/M |
| CNCS 1 | 156-172 kRad | 83.4 | 56.2 | 49.7^ | 70.0 | N/M |
| CNCS 2 | 43-53 kRad | 84.7 | 61.6 | 71.0 | 74.5 | N/M |
| CNCS 3 | 20-24 kRad | 81.8 | 62.5 | 69.3 | N/M | 80.2 |
| CNCS 4 | 230-286 kRad | 83.4 | 41.2 | 47.2 | 54.0 | 58.9 |

# These measurements were taken with PMT S/N 27587 and produced reliable results.
(N/M) no measurement was taken for these configurations. For CNCS 3, both the fibers and Tyvek wrapping were replaced at the same time.

SDU fiber and scintillator irradiation test (IMP, Lanzhou)

Dong Liu and Mengjiao Li's presentation on 05/20/2021

| | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|
| Total Irradiation (MeV/cm^2) | 8.569E+11<br>$10^{11.94}$ | 1.360E+12<br>$10^{12.13}$ | 2.807E+12<br>$10^{12.45}$ | 3.665E+13<br>$10^{13.56}$ | 1.070E+14<br>$10^{14.03}$ |
| Test material | BCF98-SC 3m*2<br>BCF98-SC 6m*1<br>PMMA 2m*3 | BCF98-SC 3m*2<br>BCF98-SC 6m*1<br>PMMA 2m*3<br>BCF91A-MC*3<br>scintillator*1 | BCF98-SC 3m*2<br>BCF98-SC 6m*1<br>PMMA 2m*3<br>BCF91A-MC*3<br>Scintillator*1 | BCF98-SC 3m*2<br>BCF98-SC 6m*1<br>PMMA 2m*3<br>BCF91A-MC*3<br>Scintillator*1 | BCF91A-MC*3<br>Scintillator*1 |
| | 2.83 krad | 4.49 krad | 9.26 krad | 120.9 krad | 353 krad |

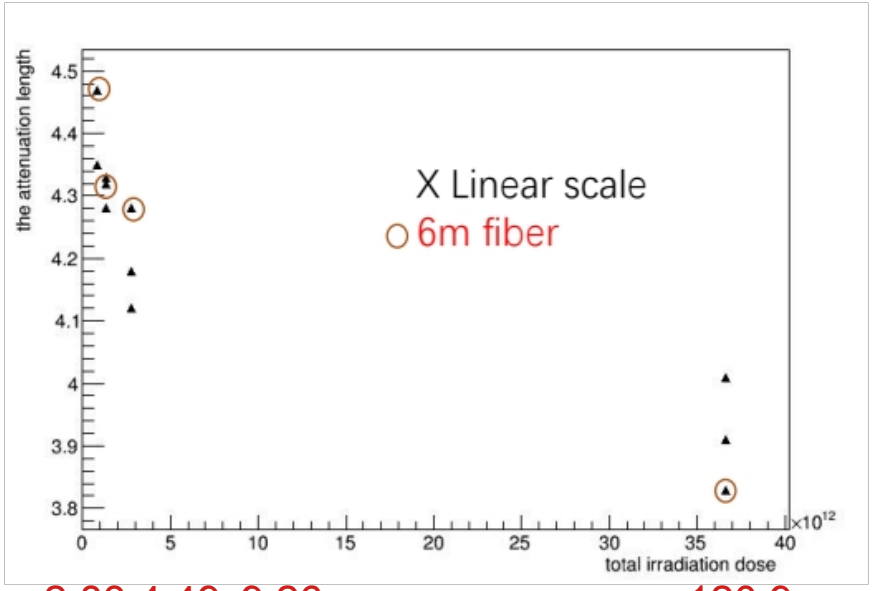
2.12E+14
$10^{14.33}$

700 krad

Note: 1-n-MeV/cm2 approx= 3.3E-11 Gy and 1Gy=100rad, see Lorenzo's talk at ? …
Did not observe color change or degradation of mechanical property of fibers for samples 1-4

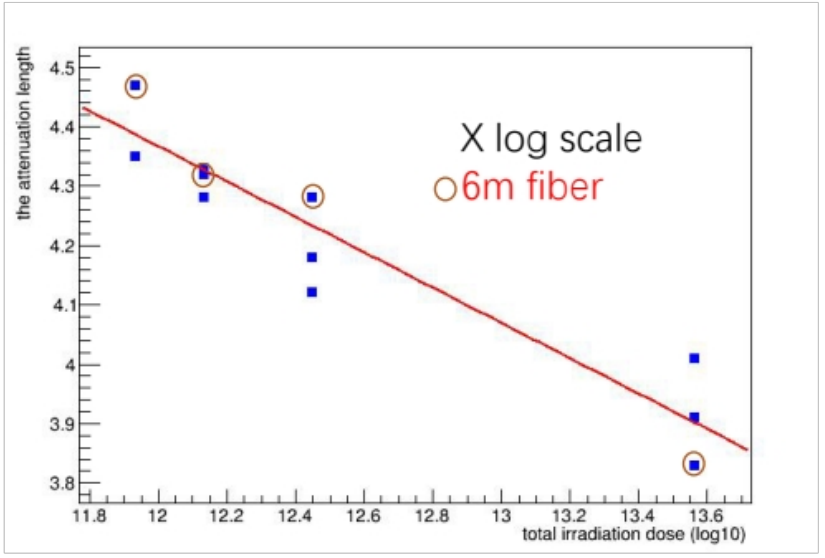
# BCF98-SC

# Attenuation length(λ1) vs Total radiation dose




2.83 krad 4.49 krad 9.26 krad

120.9 krad



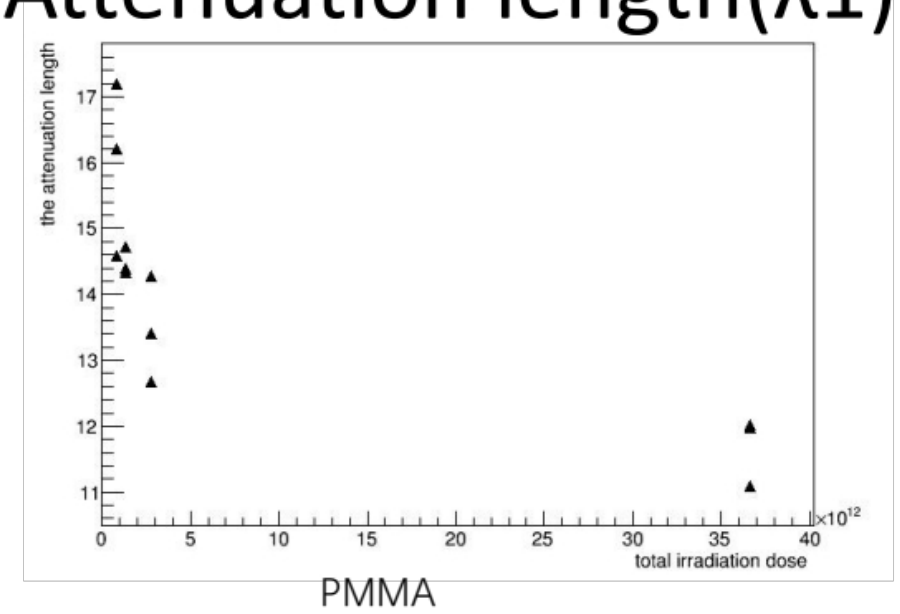

```
Minimizer is Linear
Chi2                      =     0.0523427
NDf                       =            10
p0                        =       7.93826   +/-   0.415426
p1                        =      -0.297591  +/-   0.0331397
```

BCF98-SC

for 343 krad, L=7.938-0.297*14.03=3.77 m

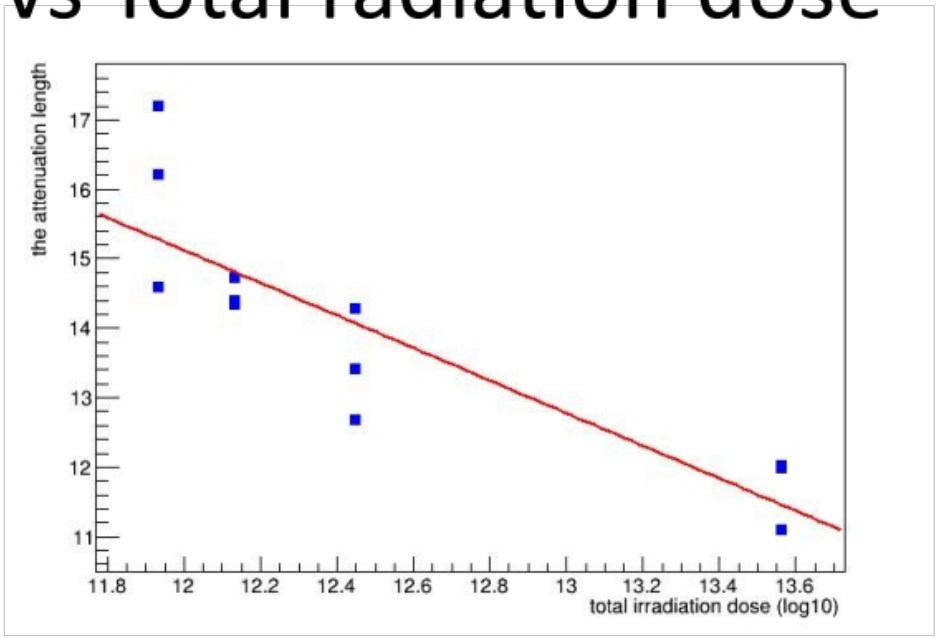
# PMMA

# Attenuation length(λ1) vs Total radiation dose




PMMA

2.83 4.49 9.26
krad krad krad




120.9
krad

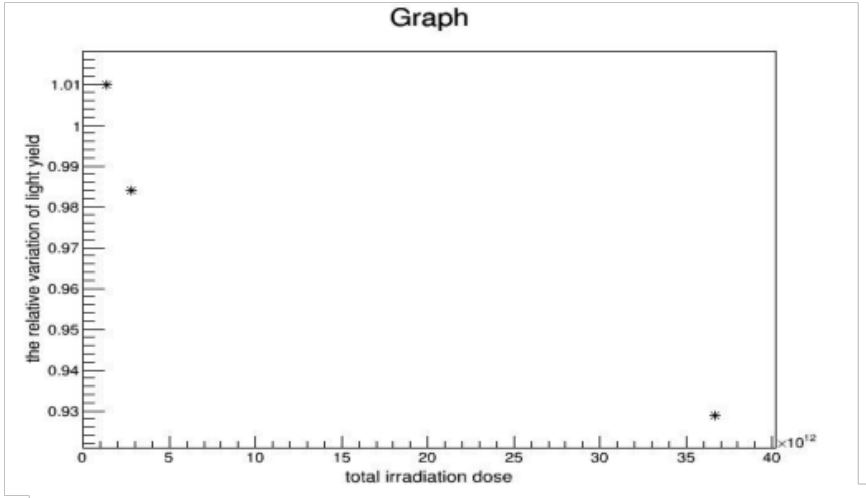
```
Minimizer is Linear
Chi2                      =      8.61186
NDf                       =           10
p0                        =      43.2542   +/-   5.32861
p1                        =     -2.34436   +/-   0.425078
```

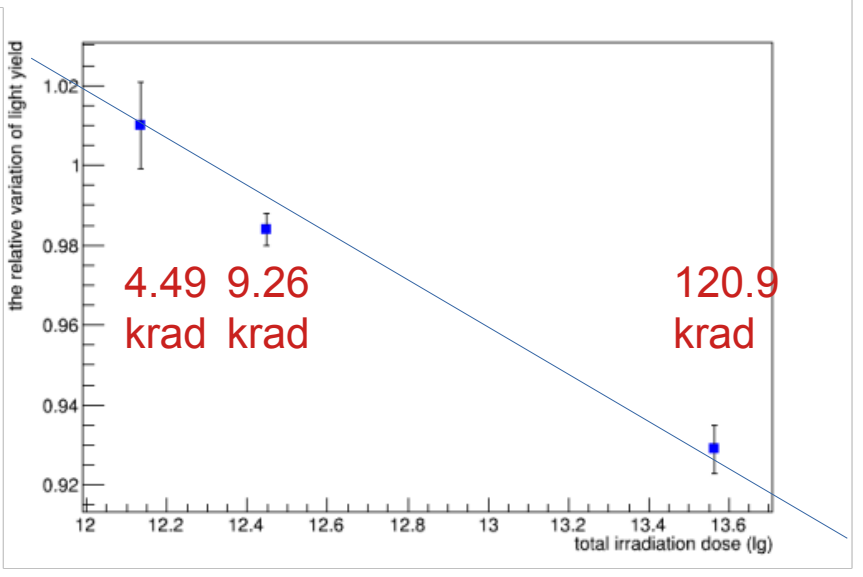
for 343 krad, L=43.25-2.344*14.03=10.365 m

# WLS fiber （BCF91A-MC） test result

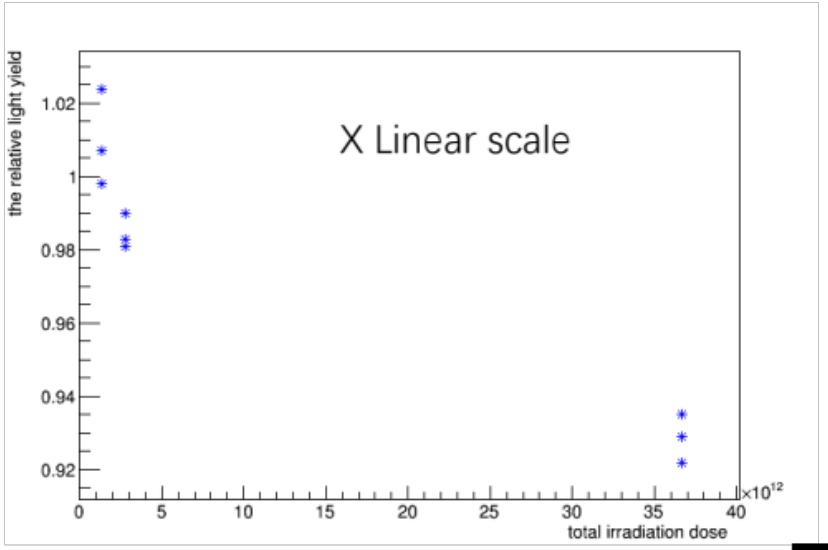
| | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|
| Total irradiation dose (MeV/cm^2) | 1.360E+12 | 2.807E+12 | 3.665E+13 |
| BCF91A-MC | 0.998 | 0.990 | 0.935 |
| | 1.024 | 0.983 | 0.929 |
| | 1.007 | 0.981 | 0.922 |
| Average | 1.010±0.011 | 0.984±0.004 | 0.929±0.006 |

Standard deviation of the test results for the three fibers

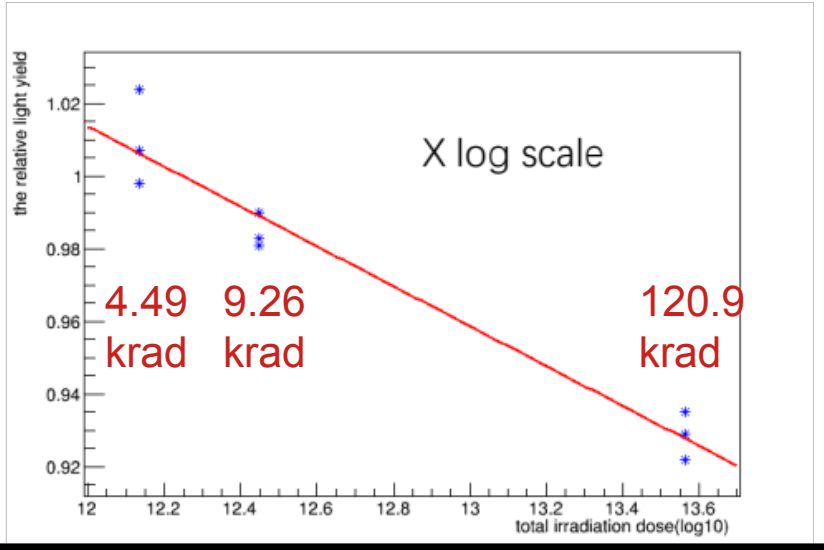


# WLS fiber （BCF91A-MC)
# Relative light yield vs Total radiation dose




BCF91A-MC




```
Minimizer is Linear
Chi2                      =  0.000572206
NDf                       =              7
p0                        =        1.67286   +/-   0.0625212

p1                        =     -0.0549362   +/-   0.00491128
```

for 343 krad, 1.57-0.0549*14.03 ~ 80%
for 700 krad, 1.57-0.0549*14.33 ~ 78%

# Scintillator test result

| scintillator | Total radiation dose (MeV/cm^2) | Number of photoelectrons |
|---|---|---|
| Sample 2 | 1.360E+12 | 70.55±0.50 |
| Sample 3 | 2.807E+12 | 70.39±0.51 |
| Sample 4 | 3.665E+13 | 68.39±0.52 |

landau fitting error

scintillator without irradiation for reference

| | Number of photoelectrons |
|---|---|
| 1 | 71.52±0.51 |
| 2 | 72.77±0.53 |
| 3 | 71.02±0.51 |
| average | 71.77 |