EC and SPD Updates

The SoLID EC Working Group

SoLID Collaboration Meeting

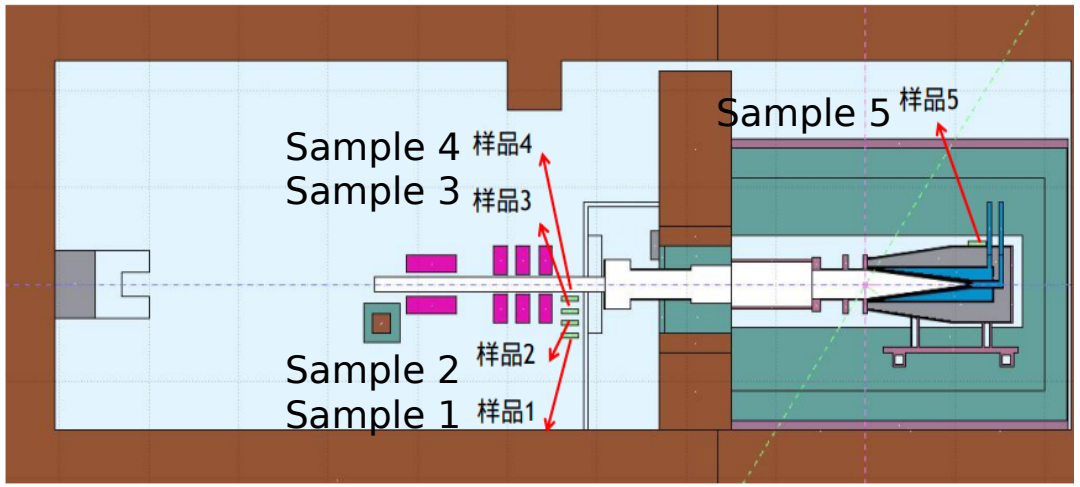
June 10-11, 2021

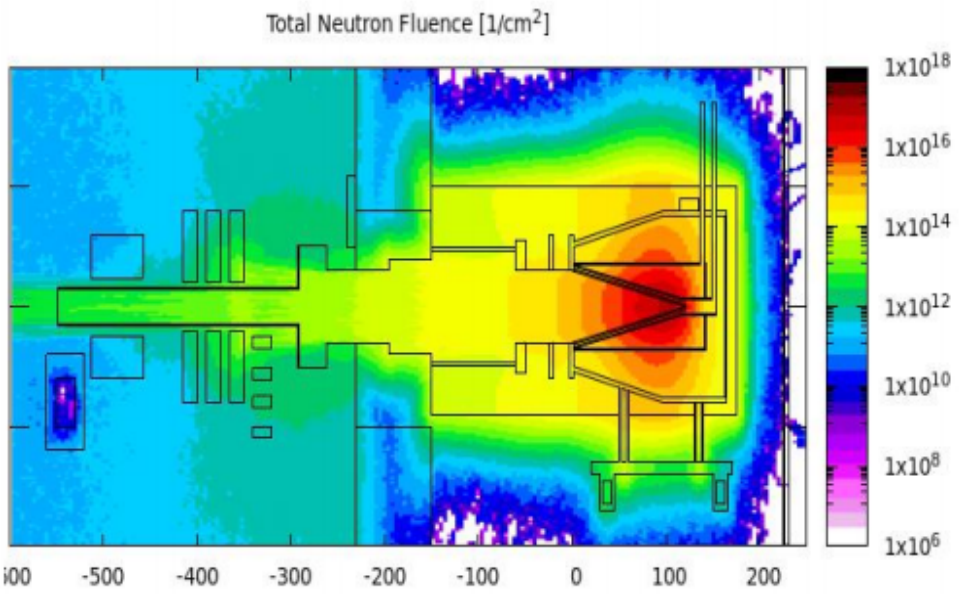
Outline

1. FTBF Test and Analysis → see previous talk
2. Radiation test results of scintillator and fibers (SDU/IMP)
3. Overview of ECal + SPD status
4. Plan and outlook

Irradiation test at Institute of Modern Physics, Lanzhou

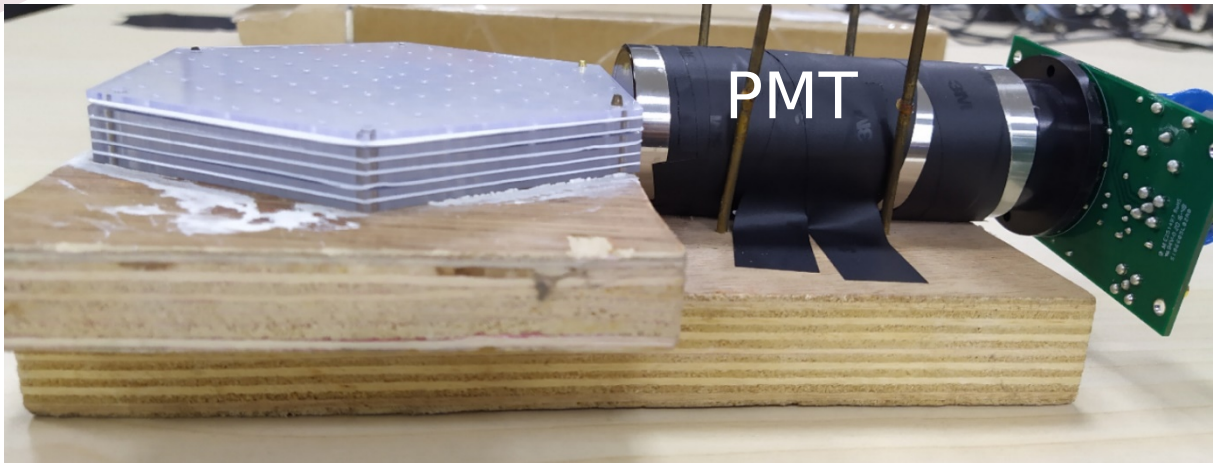
SDU/IMP group: Cunfeng Feng Dong Liu, Mengjiao Li, Ye Tian



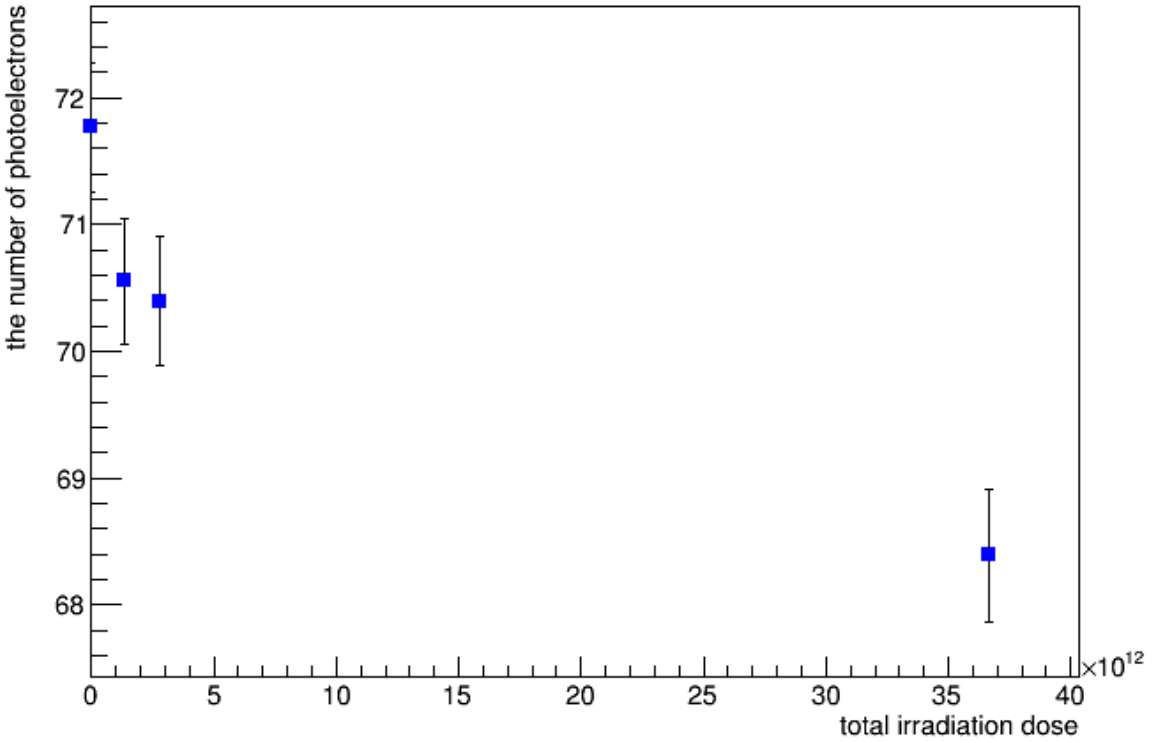


	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Total Irradiation （MeV/cm^2）	8.569E+11	1.360E+12	2.807E+12	3.665E+13	1.070E+14
Test material	BCF98-SC 3m*2 BCF98-SC 6m*1 PMMA 2m*3	BCF98-SC 3m*2 BCF98-SC 6m*1 PMMA 2m*3 BCF91A-MC*3 scintillator*1	BCF98-SC 3m*2 BCF98-SC 6m*1 PMMA 2m*3 BCF91A-MC*3 Scintillator*1	BCF98-SC 3m*2 BCF98-SC 6m*1 PMMA 2m*3 BCF91A-MC*3 Scintillator*1	BCF91A-MC*3 Scintillator*1

Kedi Scintillators



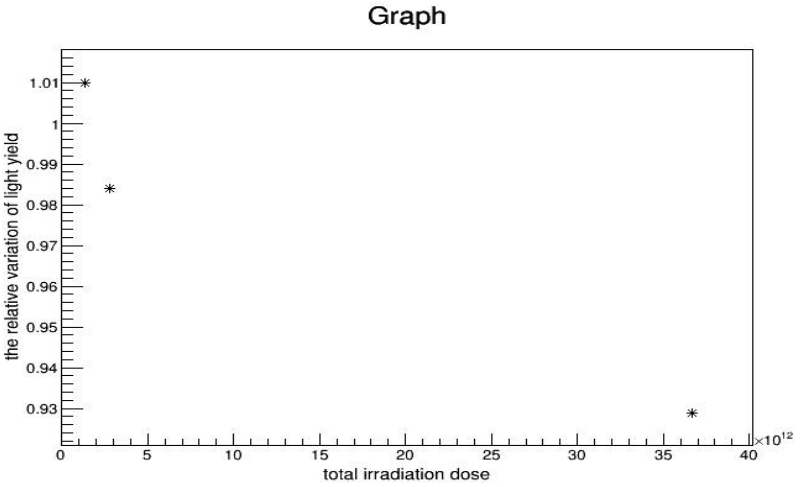
Scintillator test result (cosmic)

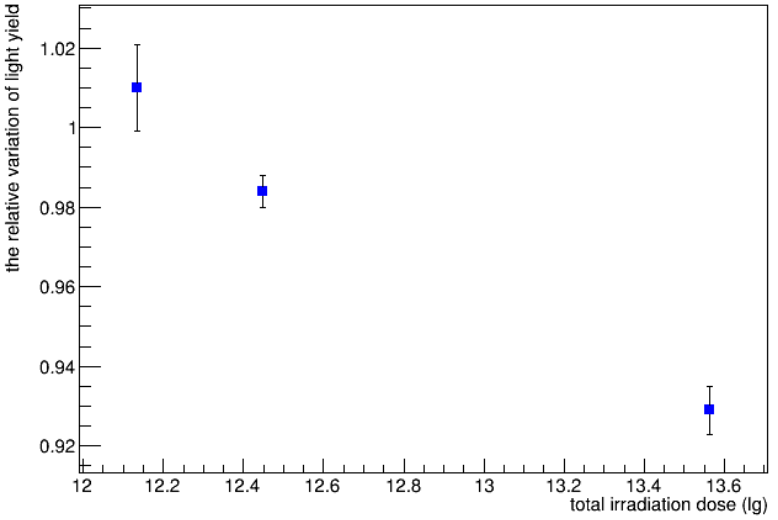


WLS fiber （BCF91A-MC） test result

	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





3m test result

$$\frac{I1}{I2} = \frac{I_0 * \exp(-\frac{x}{\lambda 1})}{I_0 * \exp(-\frac{x}{\lambda 2})} = \exp(-\frac{x}{\lambda 1} + \frac{x}{\lambda 2}) = \text{ratio}, \lambda 2 = 4.55\text{m}$$

BCF98-SC (3m)	Total radiation dose (MeV/cm^2)	After irradiation (ADC channel)	Relative light yield (ratio)	Attenuation length(λ1)
Sample 0	0 （without irradiation ）	991	1.000	4.55
Sample 1	8.569E+11	980	0.989	4.47
		961	0.970	4.35
Sample 2	1.360E+12	951	0.960	4.28
		958	0.967	4.33
Sample 3	2.807E+12	925	0.933	4.12
		935	0.943	4.18
Sample 4	3.665E+13	907	0.915	4.01
		889	0.897	3.91

6m test result

$$\frac{I1}{I2} = \frac{I_0 * \exp(-\frac{x}{\lambda 1})}{I_0 * \exp(-\frac{x}{\lambda 2})} = \exp(-\frac{x}{\lambda 1} + \frac{x}{\lambda 2}) = \text{ratio}, \lambda 2 = 4.55\text{m}$$

BCF98-SC (6m)	Total radiation dose （MeV/cm^2)	After irradiation (ADC channel)	Relative light yield(ratio)	Attenuation length(λ1)
Sample 0	0 （without irradiation ）	495	1.000	4.55
Sample 1	8.569E+11	484	0.978	4.47
Sample 2	1.360E+12	462	0.933	4.32
Sample 3	2.807E+12	455	0.919	4.28
Sample 4	3.665E+13	387	0.782	3.83

Relative light yield = After irradiation /No irradiation

PMMA(2m)	Total radiation dose (MeV/cm^2)	After irradiation (ADC channel)	Relative light yield (ratio)	Attenuation length (λ1)
Sample 0	0 （without irradiation ）	1692	0.998	17.24
		1699	1.002	
Sample 1	8.569E+11	1683	0.993	16.21
		1660	0.979	14.58
		1695	1.000	17.20
Sample 2	1.360E+12	1656	0.977	14.33
		1662	0.980	14.71
		1657	0.977	14.39
Sample 3	2.807E+12	1626	0.959	12.67
		1655	0.976	14.27
		1640	0.967	13.40
Sample 4	3.665E+13	1611	0.950	11.97
		1612	0.951	12.01
		1590	0.938	11.10

Relative light yield = After irradiation /No irradiation

Clear fiber test

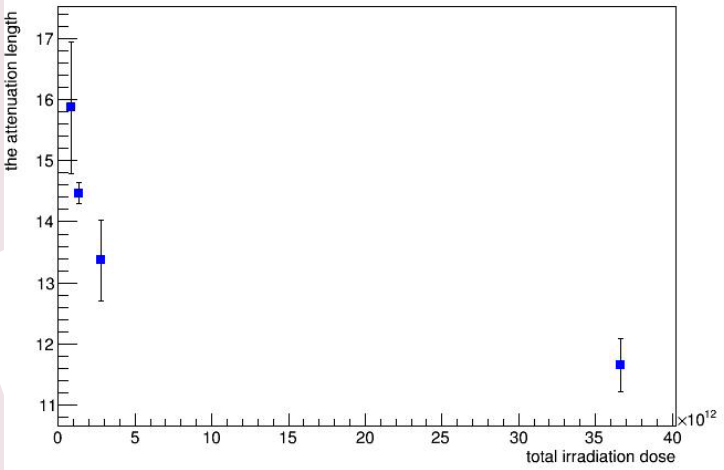
$I = I_0 * \exp(-x/\lambda)$, λ is the attenuation length of the medium

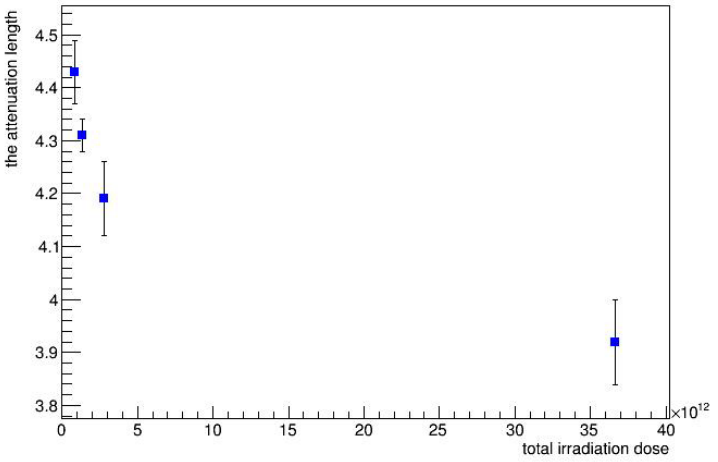
- Comparing the radiated fiber $I1$ with the non-radiated one $I2$:

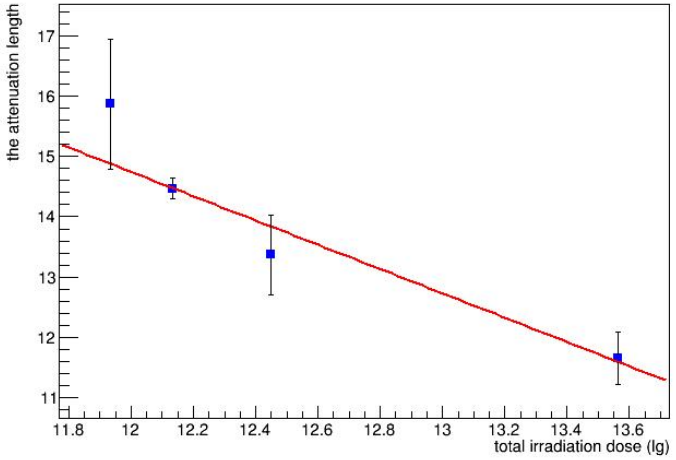
$$\frac{I1}{I2} = \frac{I_0 * \exp(-\frac{x}{\lambda 1})}{I_0 * \exp(-\frac{x}{\lambda 2})} = \exp(-\frac{x}{\lambda 1} + \frac{x}{\lambda 2}) = \text{ratio}$$

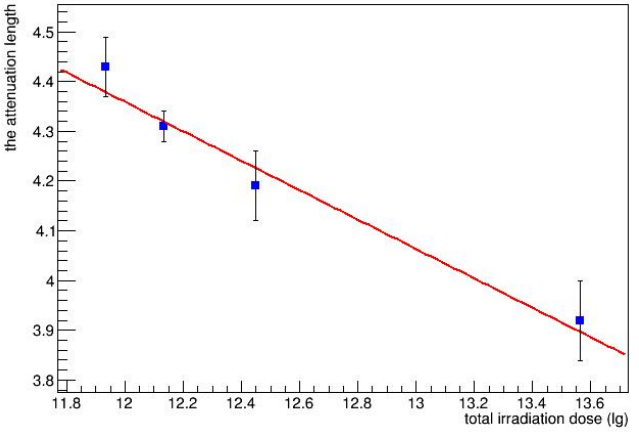
Where, x is the fiber length, $\lambda 1$ is the attenuation length of the irradiated fiber, $\lambda 2$ is the attenuation length of the clear fiber without irradiation.

- PMMA : $\lambda 2 = 17.24$
- BCF98-SC : $\lambda 2 = 4.55$







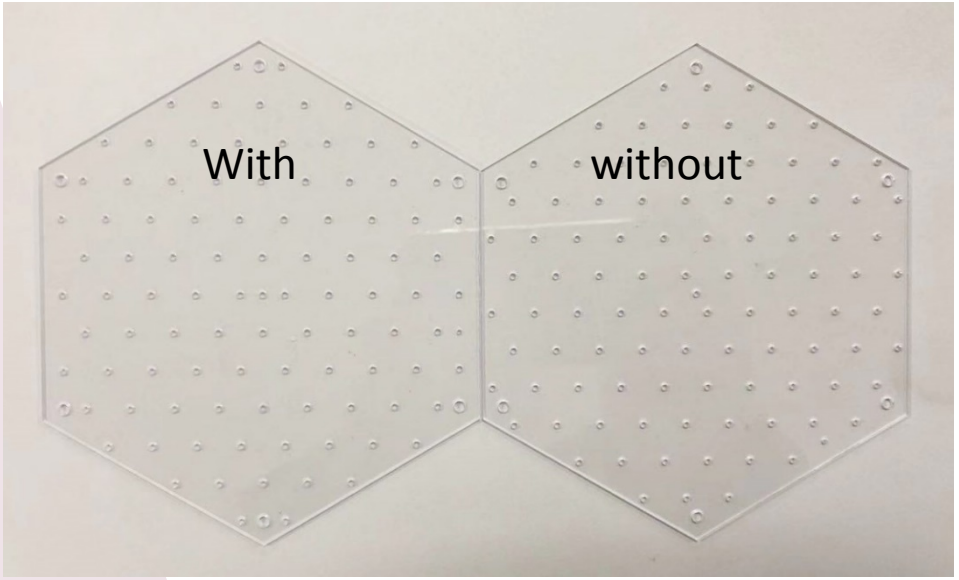


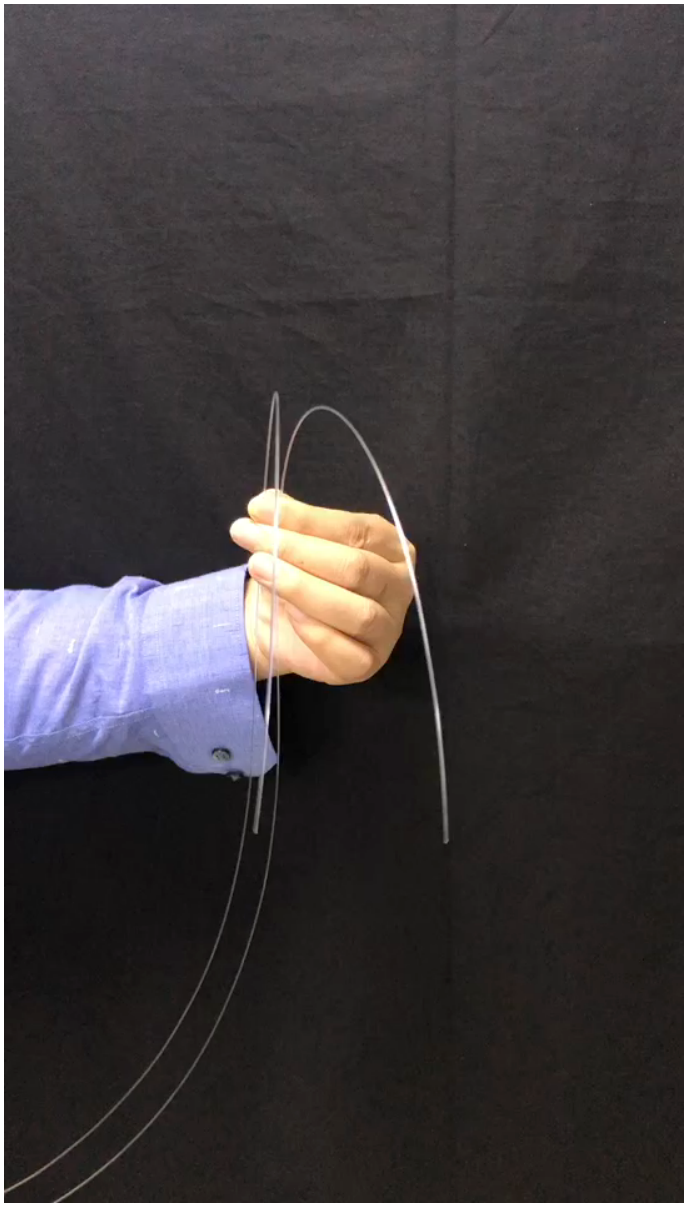

```
Minimizer is Linear
Chi2                      =       1.377
NDf                       =           2
p0                        =     38.9083   +/-   3.95418
p1                        =    -2.01374   +/-   0.320566
```

```
Minimizer is Linear
Chi2                      =      1.1839
NDf                       =           2
p0                        =      7.9057   +/-   0.685947
p1                        =   -0.295561   +/-   0.0558866
```

Materials with/without irradiation

- For both fibers and scintillators: didn't see any difference in appearance and mechanical properties;
- Same color/elasticity after irradiation;
- Can test more material (optical glue, grease, etc) after IMP facility comes back online after summer





Backup Slides

Ongoing studies with fibers and light yield

- Saint Gobain's BCF98 has too short attenuation length
- CERN tested Kuraray PSM clear fiber to have 8m attenuation (vs. BCF98's 4.5m), but more expensive
- Chunhui's PMMA-core clear fiber is promising in attenuation length and radiation hardness, but single-cladding only → we could consider Y11(200)SC, existing data show higher light yield than BCF91A-MC
- The above may be particularly useful for SPDs (FASPD has very low light yield) and preshower.
- Prototyping with 3m long clear fiber readout would be useful.

- Connector of fiber → PMTs
- MAPMT use for Preshower and FASPDs (purchased two MAPMT assemblies from Hamamatsu) → will be useful to test out MAPMTs

Bucket list for R&D

- Support structure design;
  - need a practical shashlyk module support,
  - need design for Preshower and SPD mounting/suppport system;
  - need integrating all to SoLID structure.
- need design for LED monitoring system → SDU group;
- Full simulation ending with digitization → student from Zhenyu's group;
- need MAPMT and PMT base design, prototyping, and tests - can start after Science review (CD0);
- need to develop calibration procedure;
- need to ramp up beam test for realistic SoLID running (?)

Backup Slides

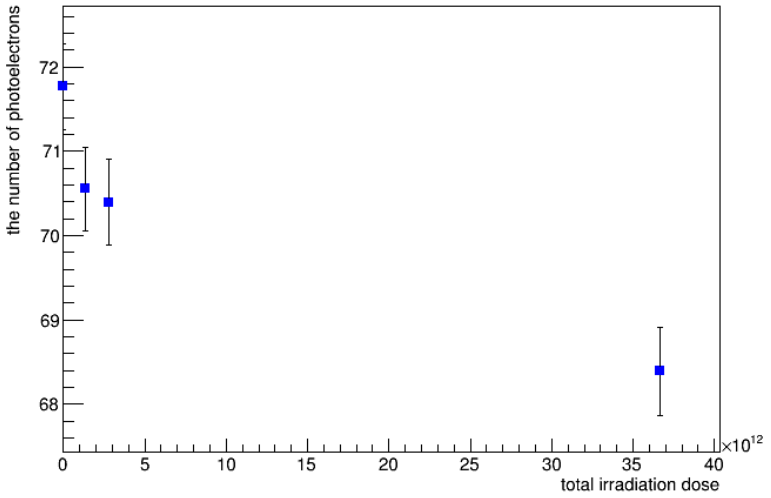
Scintillator test result

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

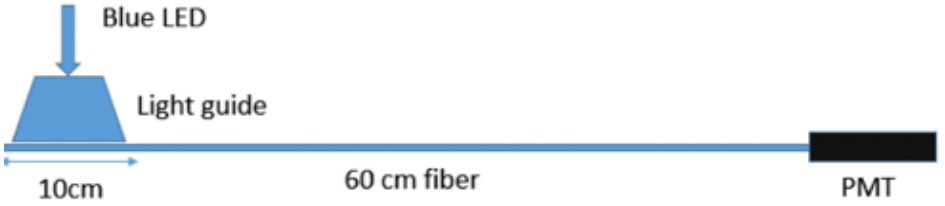
	Number of photoelectrons
1	71.52±0.51
2	72.77±0.53
3	71.02±0.51
average	71.77



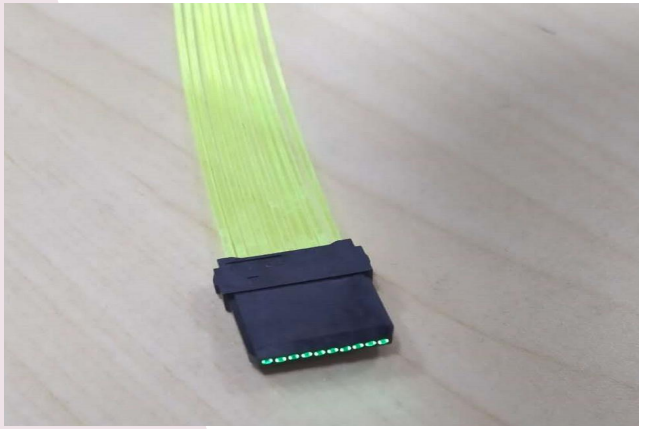
Fiber Status

- In August, met with Saint-Gobain to discuss WLS and clear fiber issues.
- "faulty" BCF91A-MC fiber has been replaced and tested by SDU, now showing 25% higher light yield than BCF91A-SC as expected (note: Y11-MC is 46% higher). Fiber diameter is 1.06mm (vs. 1.00m of SC fibers), but should not be a problem for assembling.

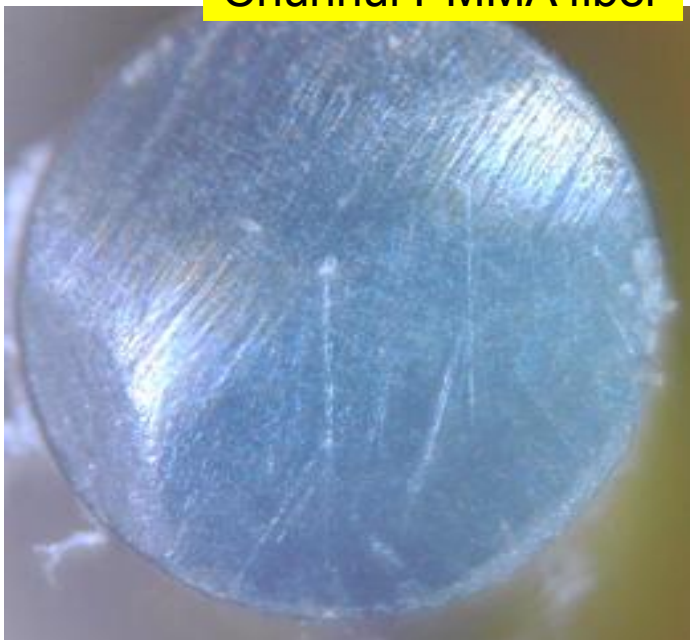
Fiber type	ADC channel
BCF91A-SC	2588
BCF91A-MC faulty	2577
BCF91A-MC new	3219



- Chunhui PMMA fiber tested by SDU with attenuation length ~20m, but **radiation hardness is questionable.**
- DDK fibre connectors tested by SDU repeatedly, ~22% light loss, small variation depending on polishing quality.

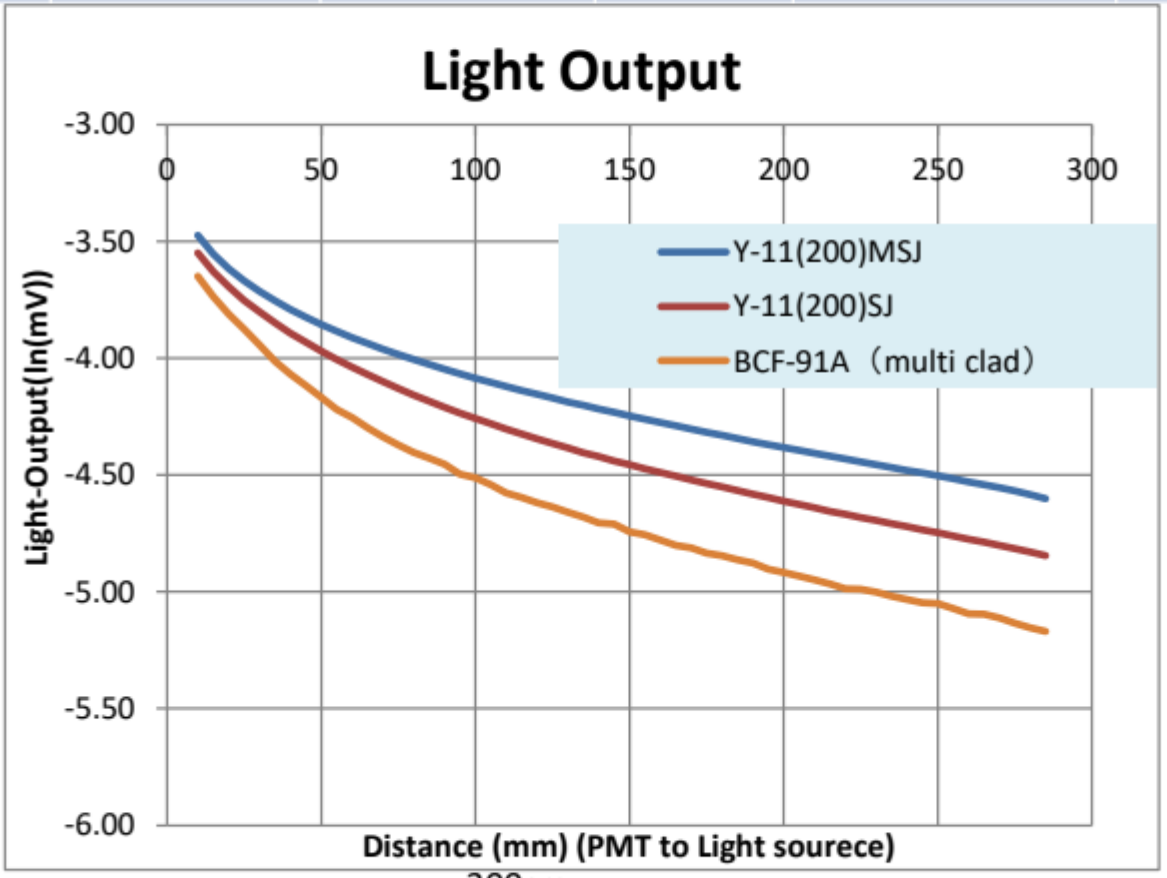


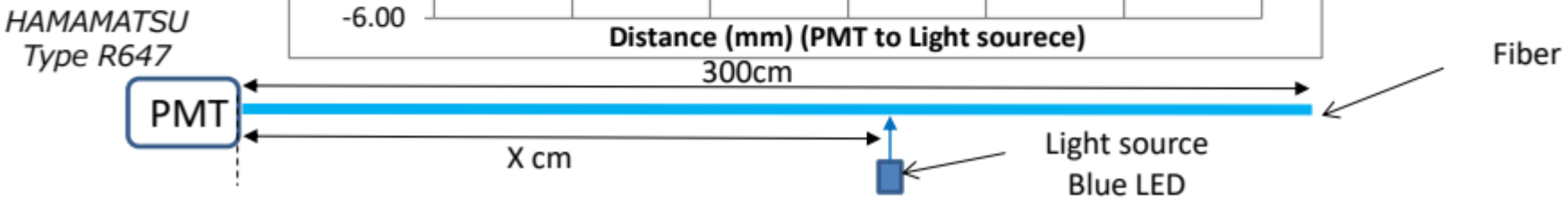
Chunhui PMMA fiber



Comparison Y-11 and BCF-91A

	Clad type	Diameter(mm)	ATT.L(cm)	V_10cm (mV)	V_285cm (mV)
Y-11(200)MSJ	Multi	1.0	373	30.9	10.0
Y-11(200)SJ	Single	1.0	328	28.7	7.9
BCF-91A	Multi	1.0	296	26.0	5.7





FTBF test

Shashlyk prototype and light yield overview

Proto-type	scintillator	lead	reflective layer	WLS fiber	WLS fiber end	module side	cosmic vertical test Npe	cosmic horizontal test Npe	PMT gain method
SDU1	Kedi original	US	printer paper	BCF91A (SC)	none	Tyvek→ TiO_2	254	48	SPE/SDU
SDU2	Kedi new	Chn	printer paper	BCF91A (SC)	Chn silver-plating	Tyvek→ TiO_2	383	83	SPE/SDU
SDU3	Kedi new	US	printer paper	Y11(200) (MC)	Chn silver-plating	TiO_2+glue (1/1)	450	108	SPE/SDU
SDU4	Kedi new	Chn	Powder paint	BCF91A (SC)	ESR	TiO_2+glue+ water	562		SPE/SDU
SDU5	Kedi new	US	Tyvek (0.145mm)	BCF91A (SC)	ESR	BCF91A (SC)	398		SPE/SDU
SDU6	Kedi new	Chn	ESR	Y11(200) MC	ESR (individual)	TiO_2+glue	813		SPE/SDU
THU1	Kedi original	Chn	mirror mylar (reflective)	Y11(200) MC	Italian silver shine	TiO2 (Kedi)	430-470	96	not measured
THU2	Kedi new	Chn	powder paint (diffusive)	BCF91A-SC	Italian silver shine	Tyvek wrapping	748 → 570*	90-103	SPE/IHEP
THU3	Kedi new	Chn	Powder paint	BCF91A-MC					

*re-tested at SDU with better-understood PMT gain

Irradiated Preshower Results

1. Students: Margaret Doyle, Sam Blum
2. Optical grease is from 2014, expired. We tested the preshower "as is", after replacing grease, and after replacing the fiber. All NPE lower than before radiation but could be partly due to mechanical (not radiational) damage to fiber

Tile #	location in Hall A	Before Radiation	Radiation Dose (krad)	With Old Grease "as is"	After replacing grease	After replacing fiber
Kedi 1	Beam Right lumis	87.1	161-164	56.6	74.4	73.3
Kedi 2	Upstream of scattering chamber	85.4	185-189	57.6 (fiber had a kink)	67.3	68.0
Kedi 3	Beamline grider	87	31-38	66	69.7	77.3
Kedi 4	Compton chicane	91	9-17	55(?)*-74 (fiber broken)	86.5	
CNCS 1	beam left lumis	83.4	156-172	56.2	49.7	70.0
CNCS 2	Beam Right scattering chamber	84.7	43-53	61.6	71.0	74.5
CNCS 3	Beam Left scattering chamber	81.8	20-24	62.5	69.3	
CNCS 4	Hall A dump	83.4	230-286	41.2	47.2	54.0

Green numbers are updated results after replacing a loose-wire PMT
Red numbers were performed with a PMT that behaved inconsistently.

http://hallaweb.jlab.org/experiment/PVDIS/SoLID/EC/meetings/2014-test/2016-test/Documents/PSH_rad_tests_02Jan2017.pdf