EC and SPD Updates

The SoLID EC Working Group

SoLID Collaboration Meeting

October 8-9, 2020

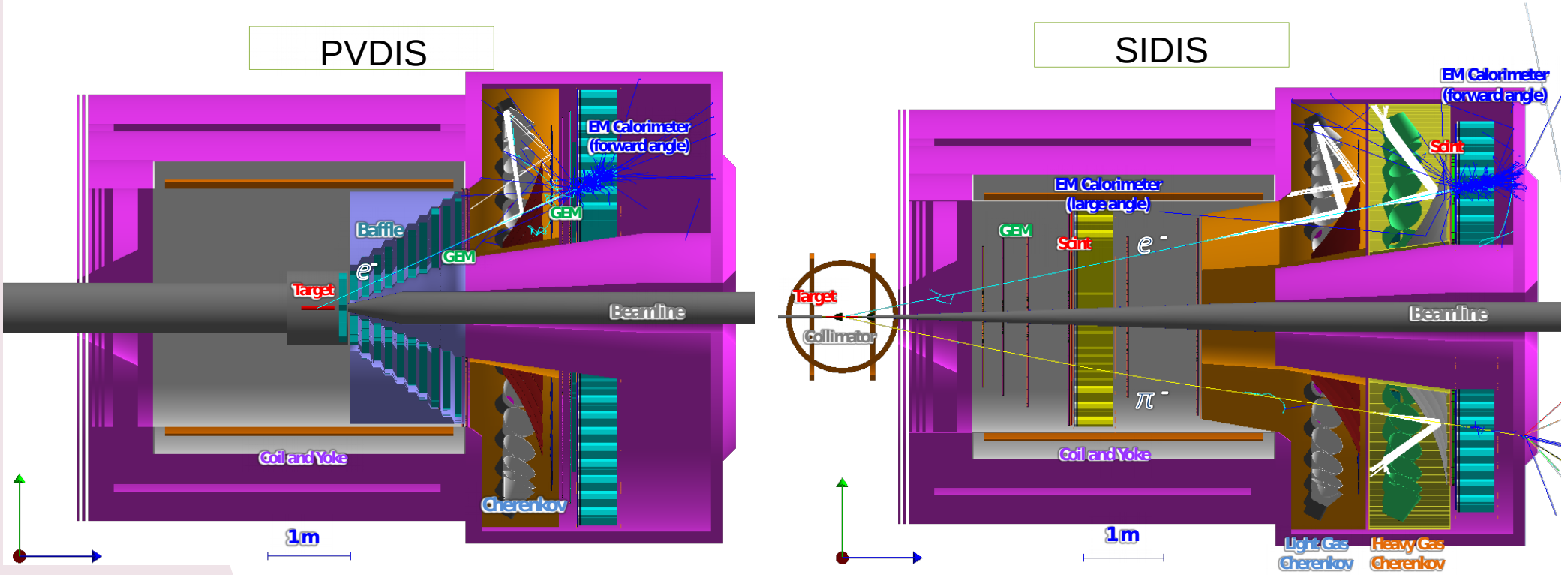
Outline

1. Overview of ECal and SPD status
2. Material testing progress since last meeting (June 2002)
3. Shashlyk prototype construction and testing status
4. FNAL beam test preparation
5. Support structure status
6. Discussions (?)

ECal and SPD Overview

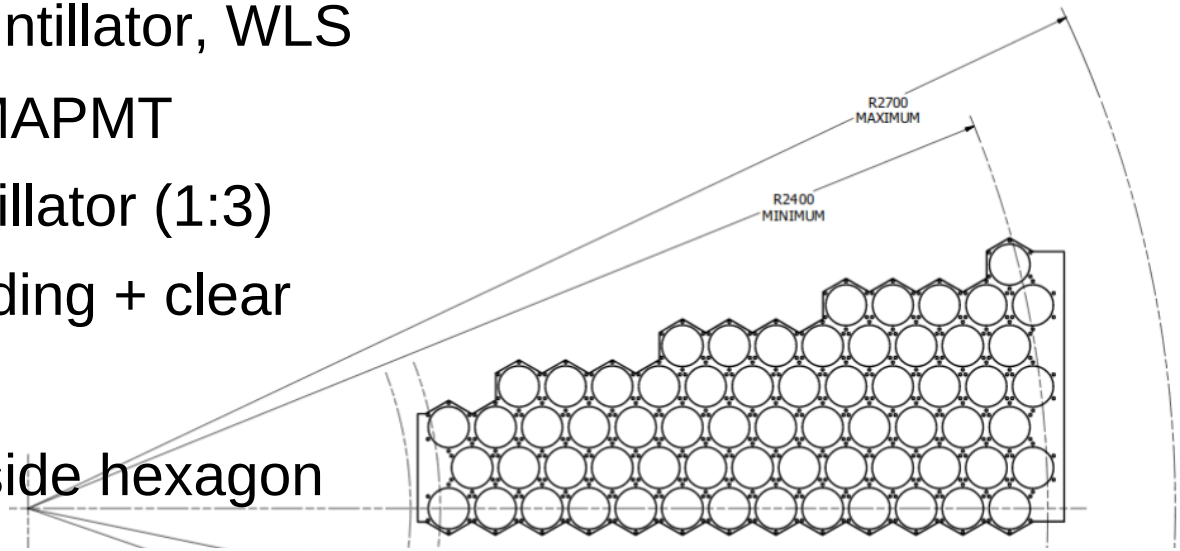
EM Calorimeter is used for PID, triggering, and background suppression. It is divided into large- and forward-angles in SIDIS configuration.

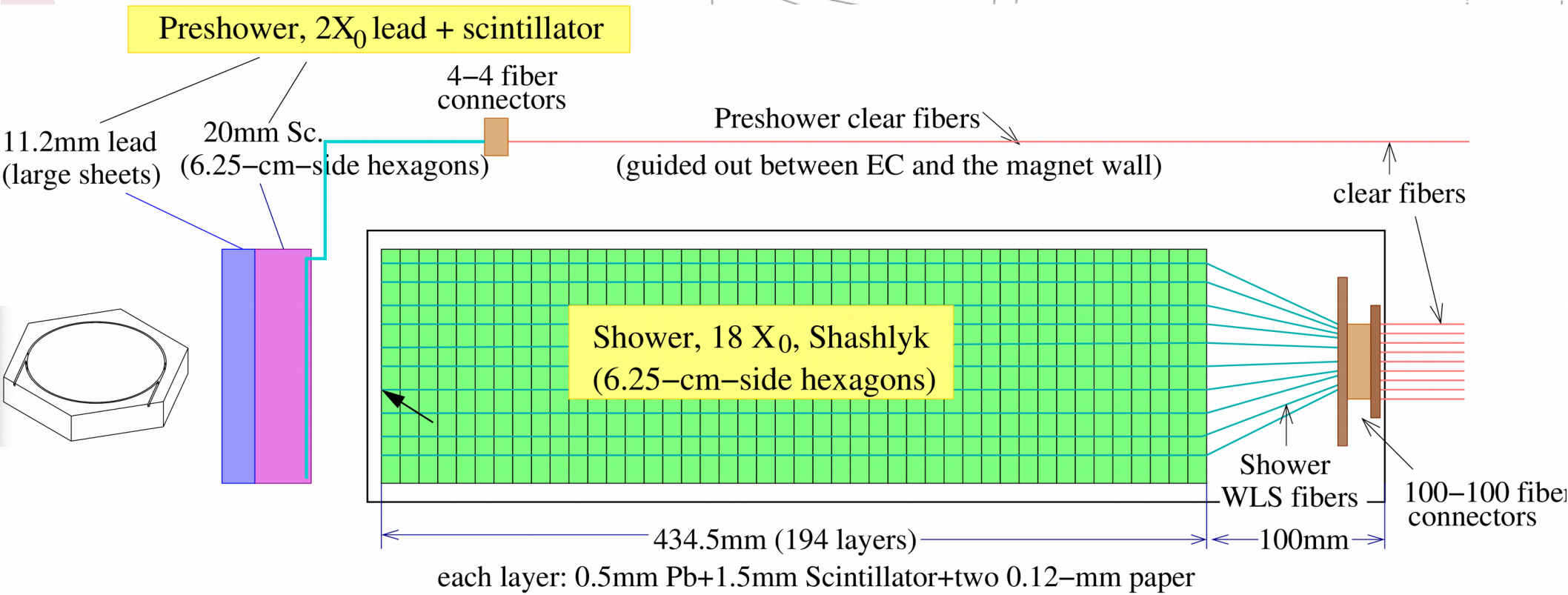
Scintillator Pad Detectors (SPDs) are used in SIDIS configuration to reject photons. It is divided into large- and forward-angles. The large angle SPD will also provide TOF.



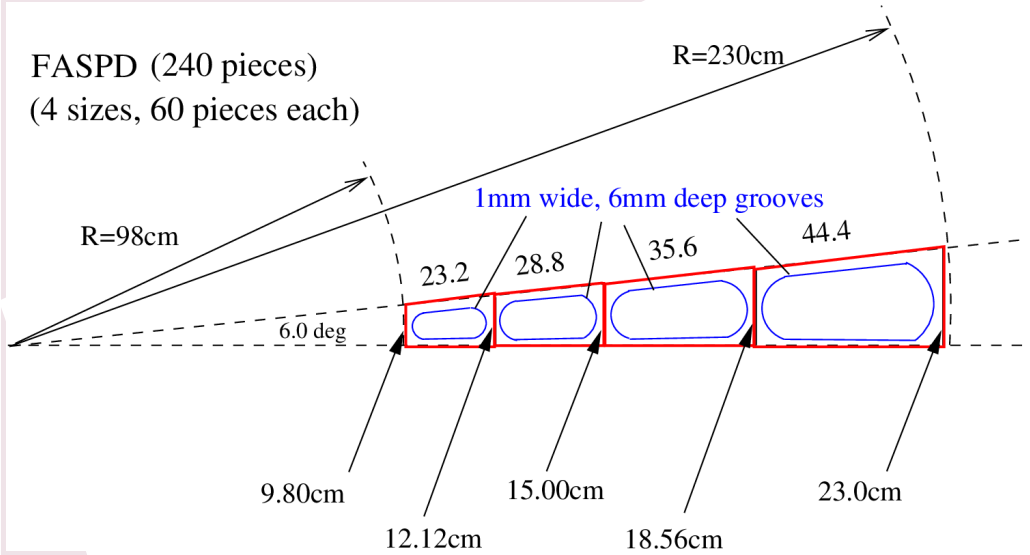
Shashlyk (Shower) design – size and sampling

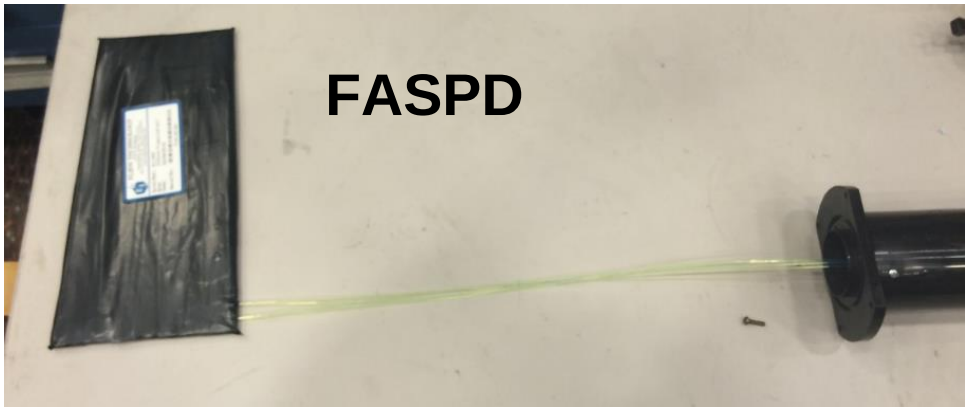
- Preshower: $2X_0$ lead + 20mm scintillator, WLS fiber embedding + clear fiber + MAPMT
- Shower: 0.5 mm Pb/1.5mm scintillator (1:3) sampling, $18X_0$, WLS fiber threading + clear fiber + PMT
- Lateral size: $100cm^2$ or 6.25cm-side hexagon



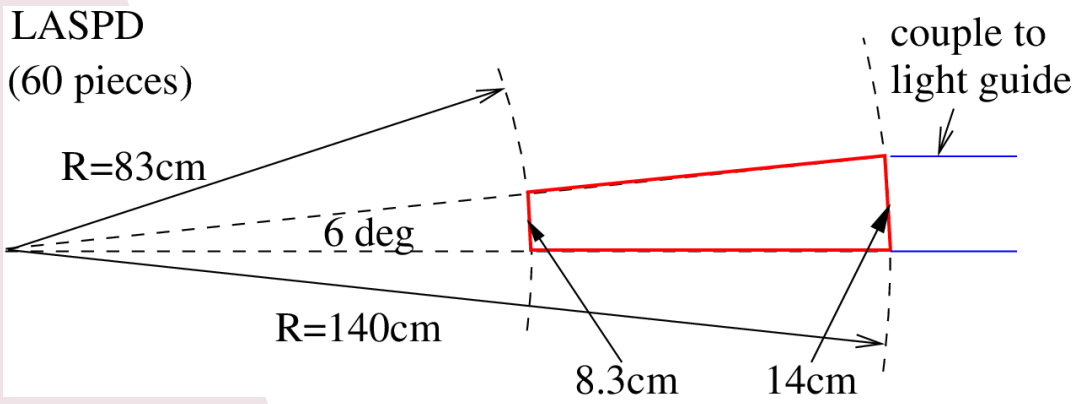


SPD Design and Prototyping





light yield: 9-11 p.e.

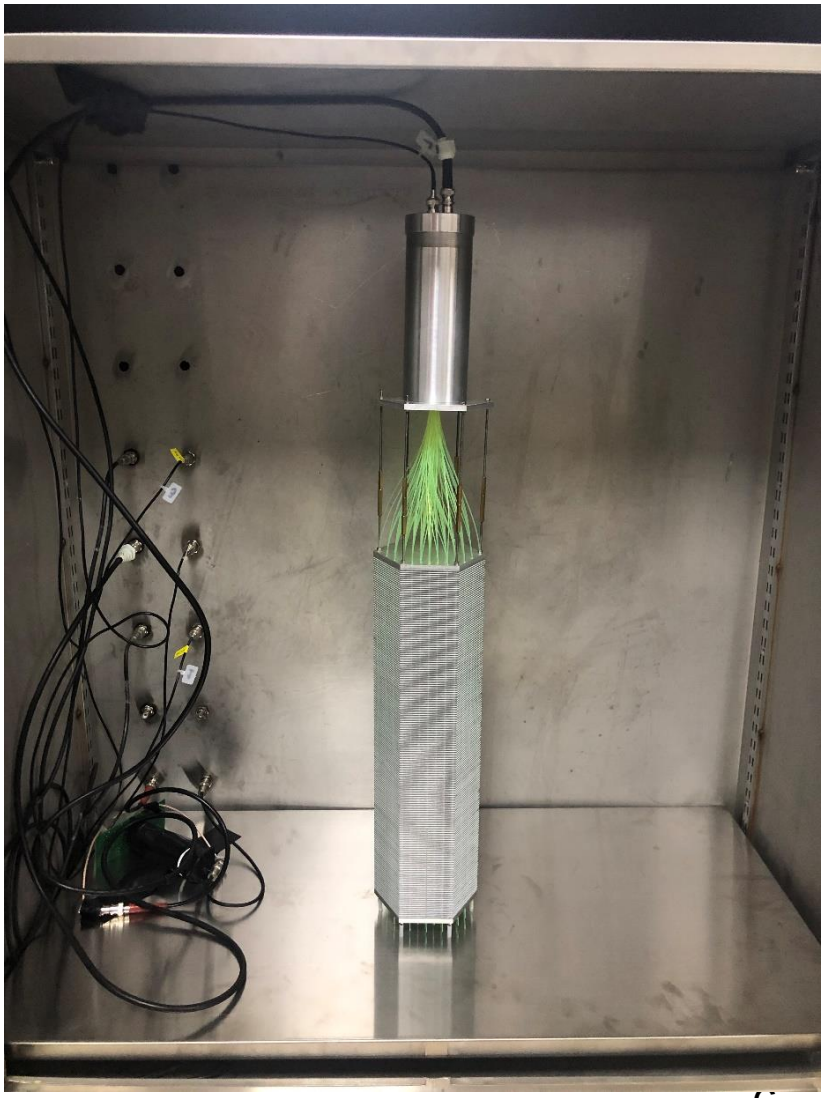


cosmic timing test: ~150ps single-side readout

Preshower design and prototyping status

Preshower light yield: 90 p.e. at best

Cosmic testing for Shashlyk modules (SDU, THU)



Shashlyk Prototype Modules (as of June 2020)

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→ TiO2	254	48	SPE/SDU
SDU2	Kedi new	Chn	printer paper	BCF91A (SC)	Chn silver-plating	Tyvek→ TiO2*	383	83	SPE/SDU
SDU3	Kedi new	US	printer paper	Y11(200) (MC)	Chn silver-plating	TiO2+glue (1/1)	450	108	SPE/SDU
SDU4	Kedi new	Chn	powder paint	BCF91A (SC)	ESR reflector	TiO2+glue +water	562		SPE/SDU
SDU5	Kedi new	US	Tyvek (0.145mm)	BCF91A (SC)	ESR reflector	TiO2+glue +water	398		SPE/SDU
SDU6	Kedi new	Chn							
THU1	Kedi original	Chn	mirror mylar (reflective)	Y11 (MC)	Italian silver shine	TiO2 (Kedi)	430-470	96	not measured
THU2	Kedi new	Chn	powder paint	BCF91A (SC)	Italian silver shine	Tyvek wrapping	748	90-103	SPE/IHEP
THU3	Kedi new	Chn	powder paint	BCF91A-MC					

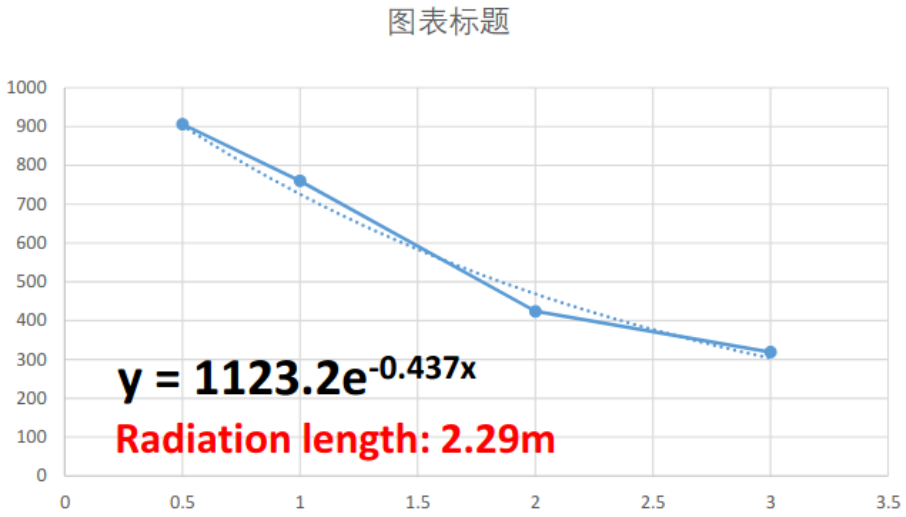
From June 2020 –

Clear fiber attenuation length test **(SDU)**

Test setup:

- LED light, transfer light from WLS fiber to clear fiber with connector
- Clear fibers are polished by polishing machine in SDU
- For long fibers, bend with same 15cm diameter

Fiber length	Bend circles(15cm diameter)	QDC channel
0.5m	0	906
1m	0	771/771(two tests)
1m	0.5	771/754(two tests)
2m	3	424
3m	5	319



Still get very bad attenuation length result…….

- These are for SG BCF98-SC fibers. Previously tested at THU (Apr 2018, ~2m). Results shown here still not so encouraging.
- Will do bending test first and separate bending from attenuation loss, (though previous test of Kuraray PSM fiber showed very small bending loss.)
- Will repeat for BCF98-MC

From June 2020 – Plan for material testing and more prototype construction

- UVA shipped BCF91A-MC and BCF98-MC (multicladding) fibers to China for building SDU6 and THU3;
- Because both THU and SDU have material for only one more module, we held off making new modules. And then this work was paused due to Covid-19.

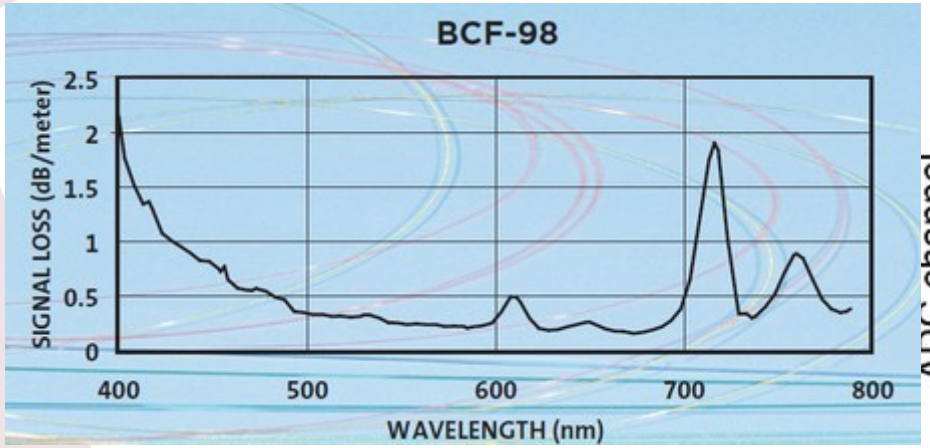
Once SDU and THU can start lab testing again, we will focus on:

- Measure bending loss of BCF98-SC and BCF98-MC and separate these from attentuation loss.
- Building THU3 and SDU6 using BCM91A-MC fibers, connect to 100x BCF98-MC fibers using 10x DDK connectors and compare light yield.

Fiber Attenuation Length Test Result for BCF98 (SDU)

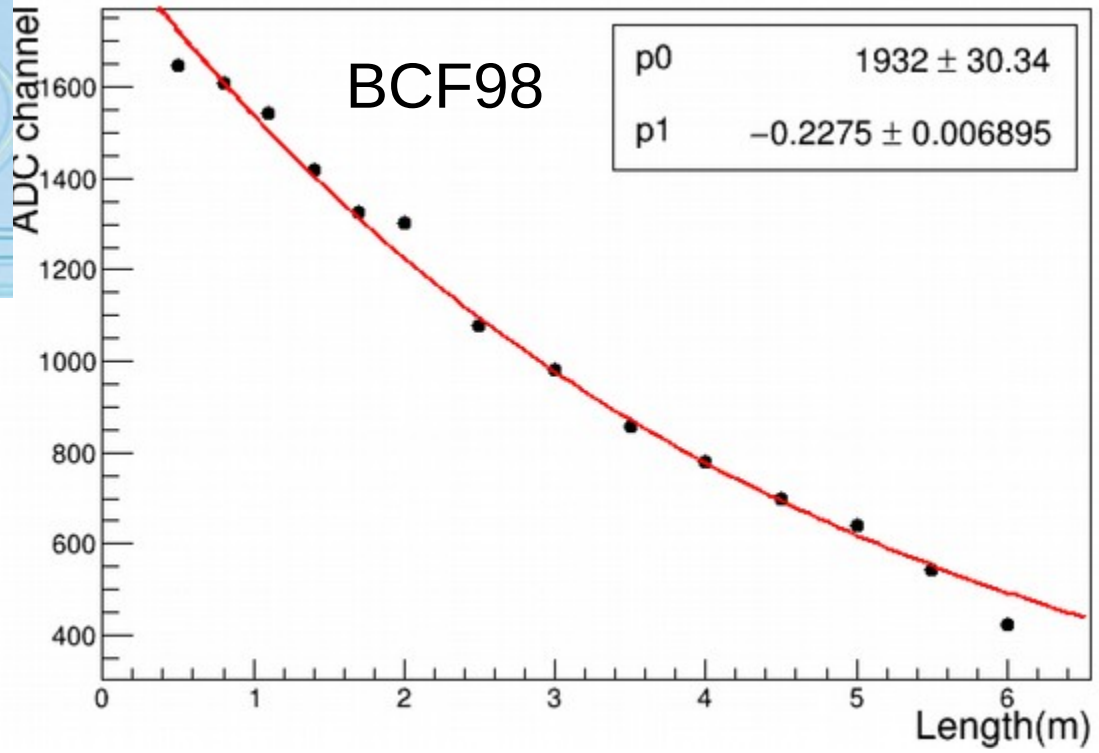
1. Fibers are bent with a bending diameter of 30-40cm to fit into the dark box. LED light used has 495 nm wavelength

$$A_{output} = A_{input}\, e^{-\frac{x}{L}}\, e^{\frac{-x}{Rf(R)}}$$



SG brochure: L ~ 9 m?

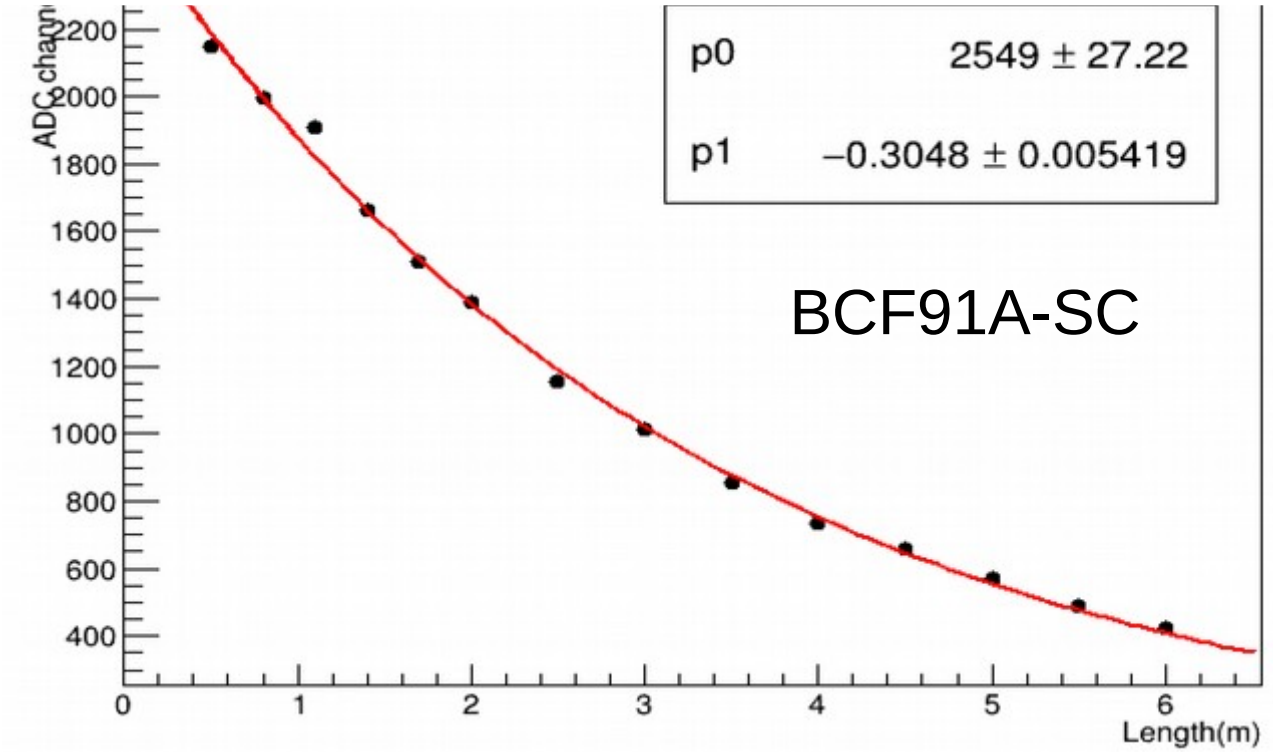
The short attenuation length is a big concern for the SoLID ECal project



Our latest result: L = 4.55 m

Fiber Attenuation Length Test Result for BCF91A (SDU)

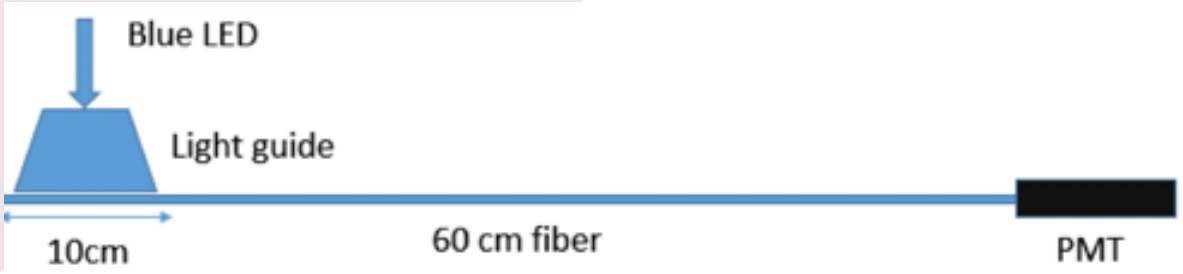
1. Fibers are bent with a bending diameter of 30-40cm to fit into the dark box. LED light used has 495 nm wavelength



SG brochure: L ~ 3.5m

Our latest result: L = 3.28 m

WLS Fiber light yield test (SDU)



Two 0.6-m length of fiber for each type are tested with LED and light output recorded.

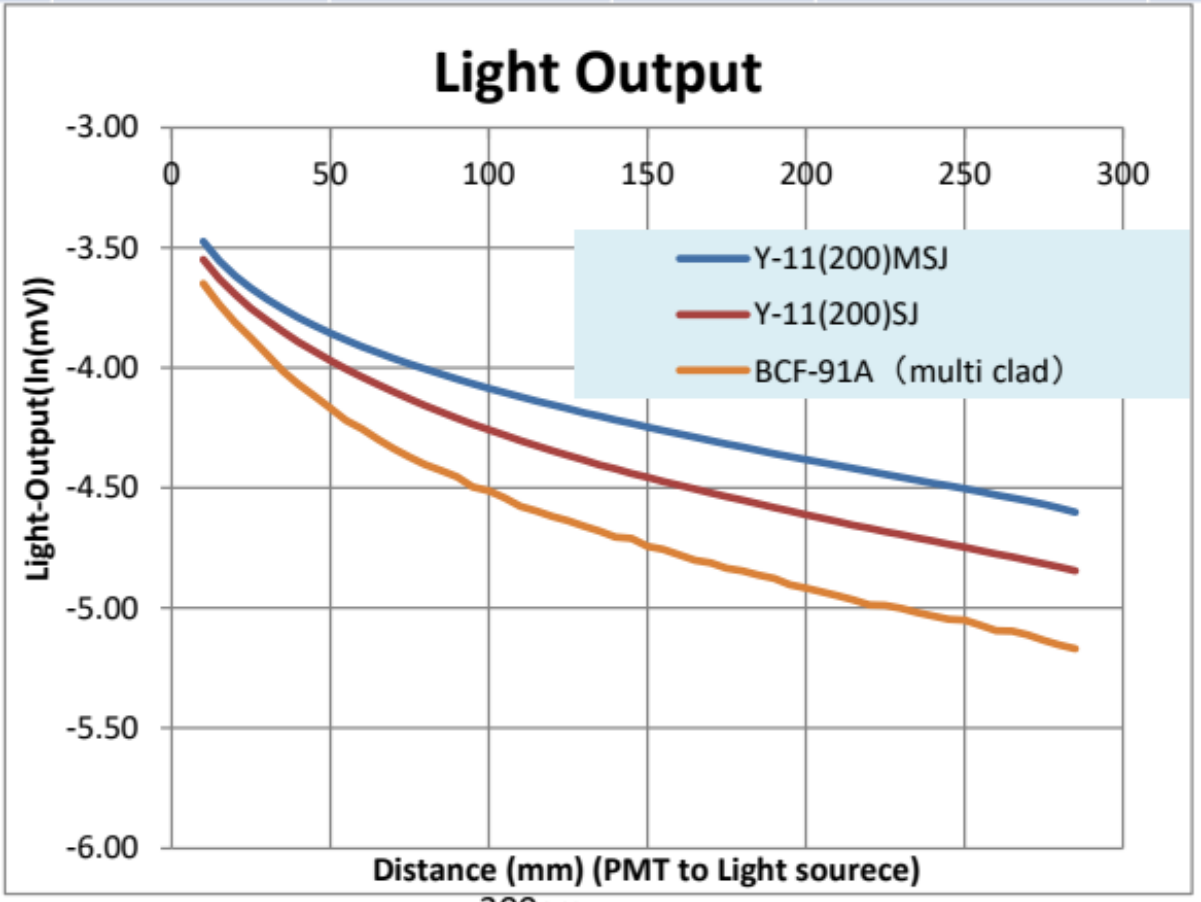
WLS fiber type	Fiber #	Output (ADC channel)	
BCF91A-SC	1	1337	← bought by SDU
BCF91A-SC	2	1326	
BCF91A-MC	1	1301	← bought by UVA
BCF91A-MC	2	1347	
Y11(200)-MC	1	1947	← bought by UVA
Y11(200)-MC	2	1898	

Something is not correct with BCF91A-MC bought by UVA

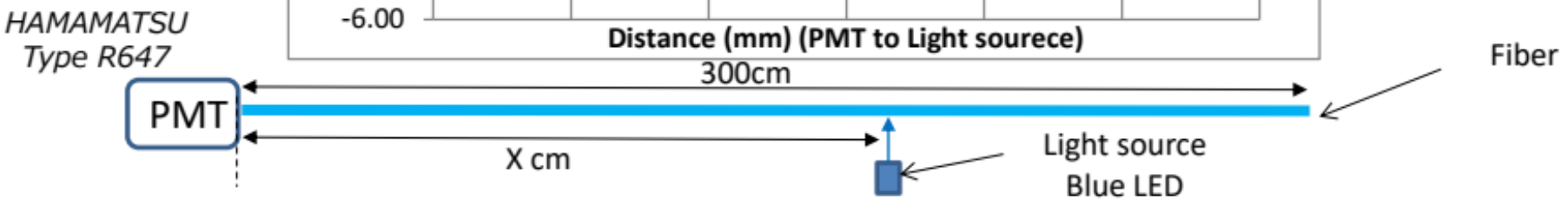
From Kuraray

Comparison Y-11 and BCF-91A

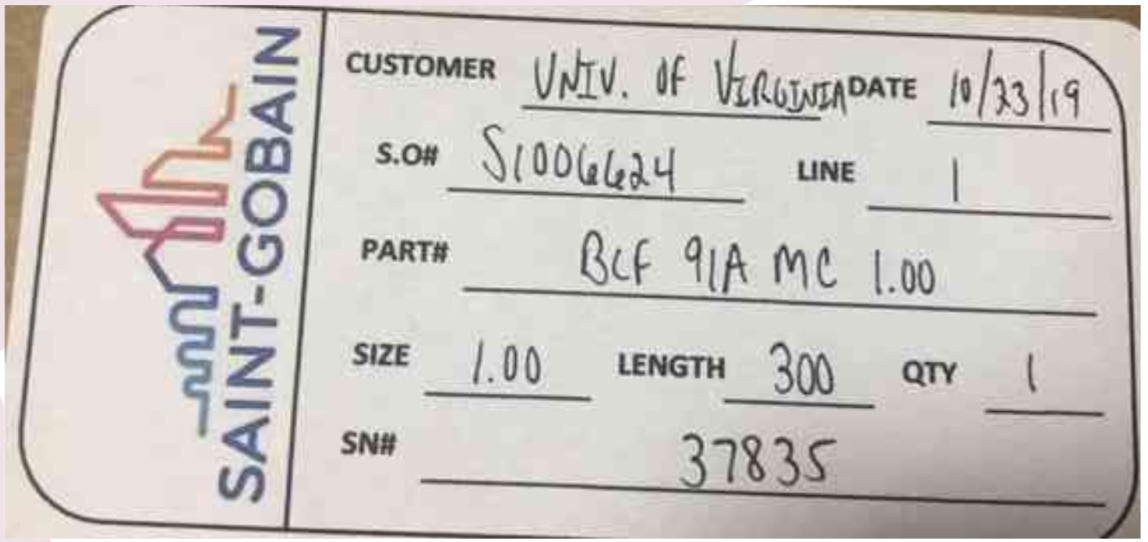
	Clad type	Diameter(mm)	ATT.L(cm)	V_10cm (mV)	V_285cm (mV)
Y-11(200)MSJ	Multi	1.0	373	30.9	10.0
Y-11(200)SJ	Single	1.0	328	28.7	7.9
BCF-91A	Multi	1.0	296	26.0	5.7

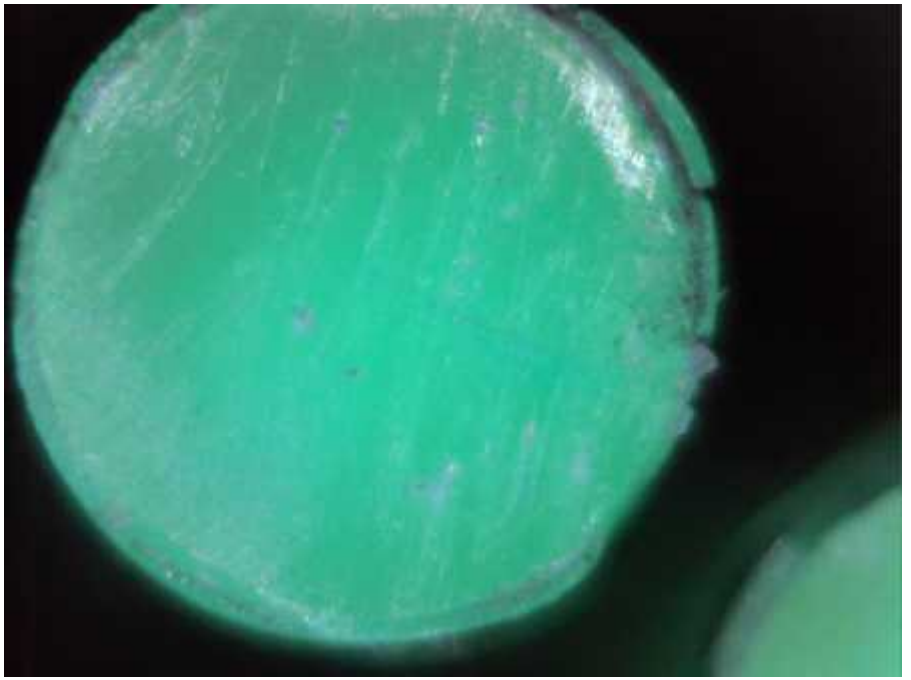


Data shown here also suggest BCF91A-MC to be higher than SDU's test result

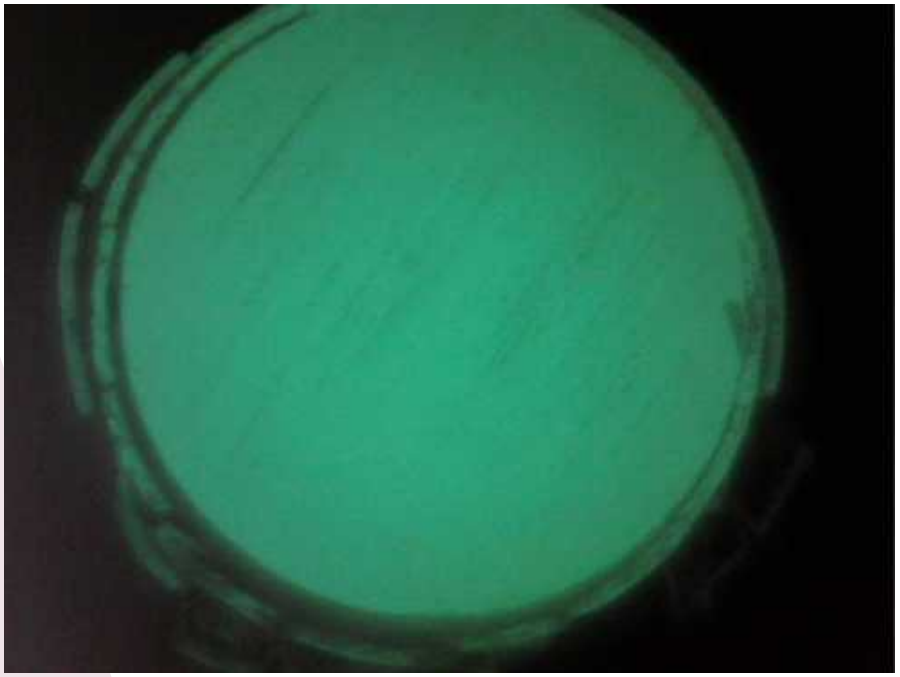


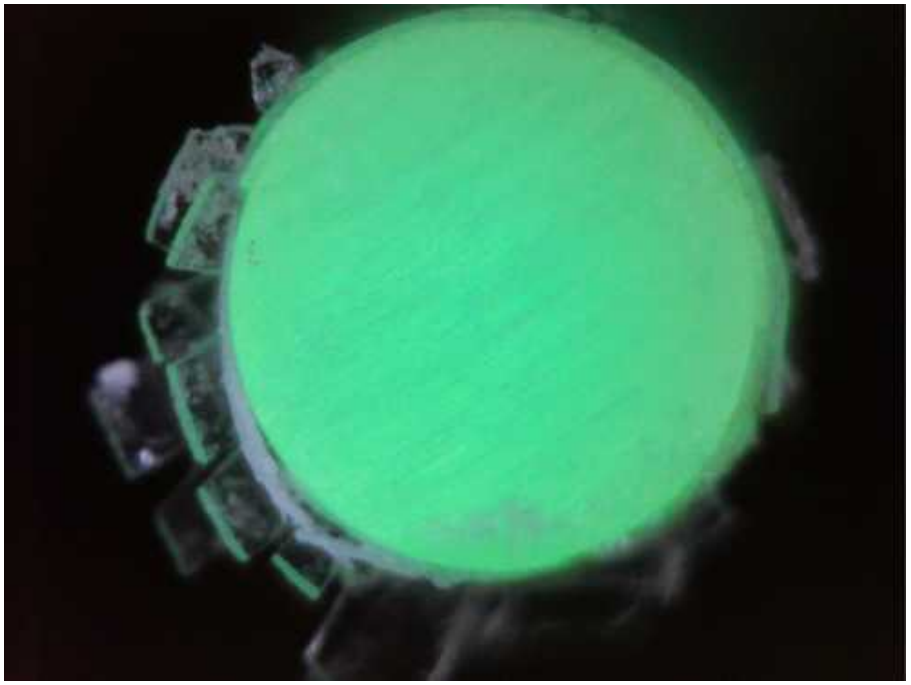
“Poorman’s test” of BCF91A-MC



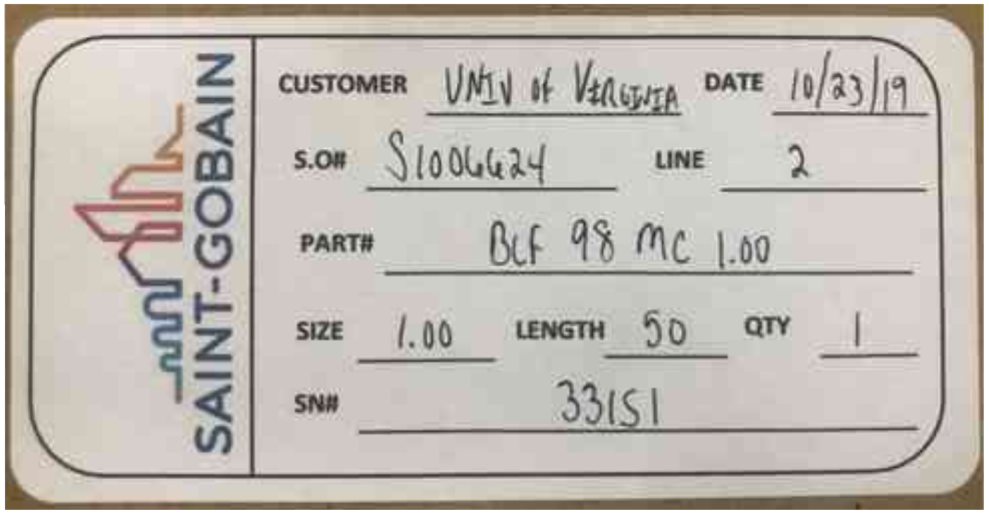


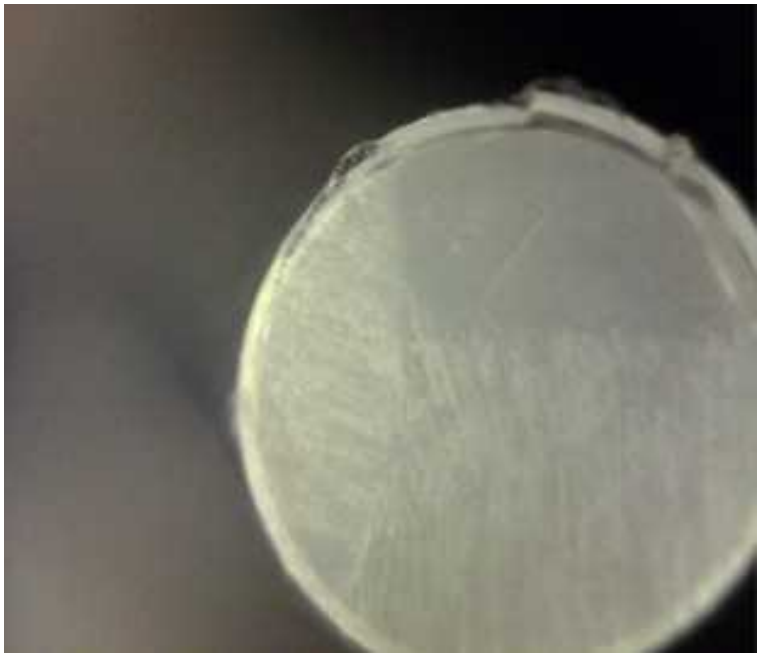
Below: similar picture for Y11-MC





Similar picture for BCF98-MC





Meeting with Saint Gobain Team on 8/19/2020

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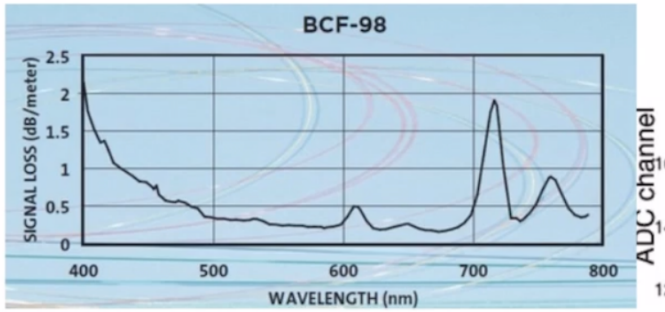

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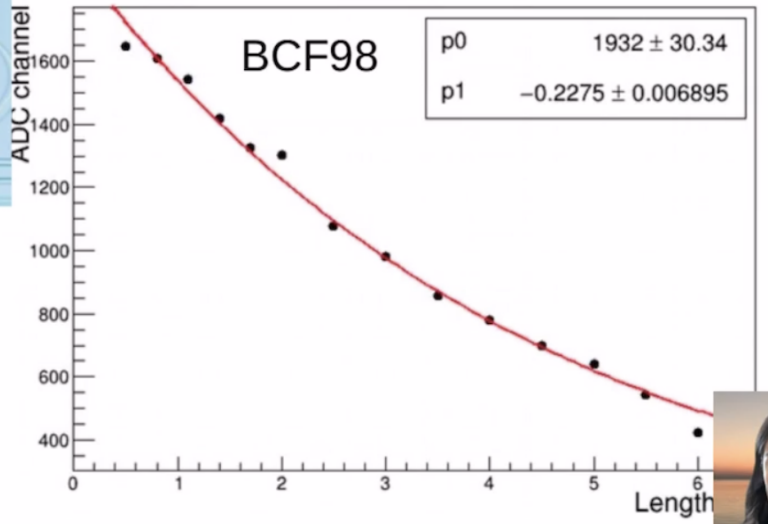

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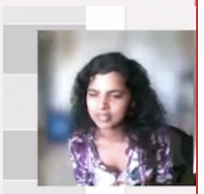

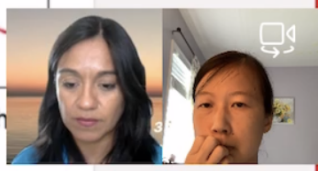

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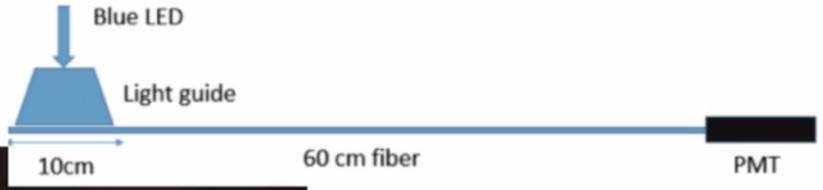
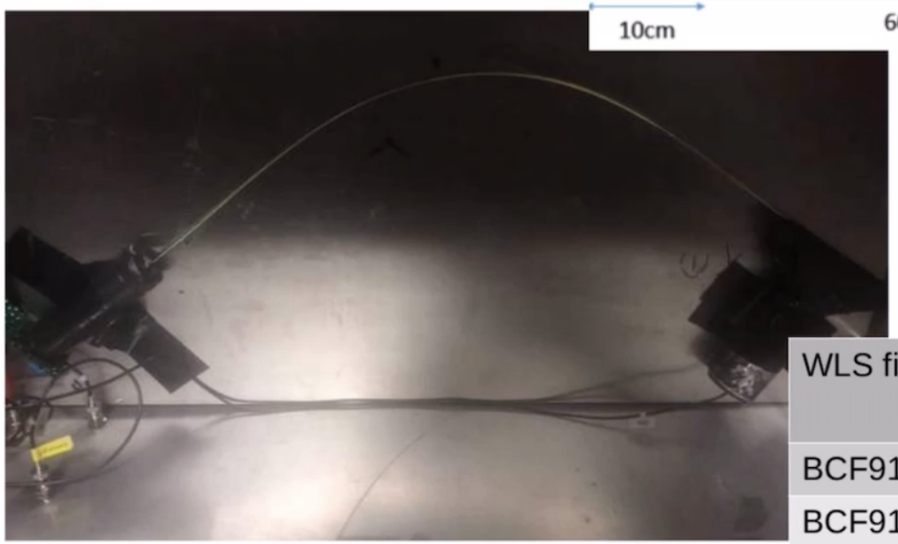
Meeting with Saint Gobain Team on 8/19/2020

WLS Fiber light yield test





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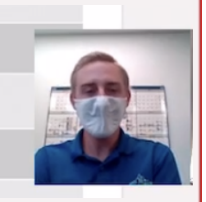

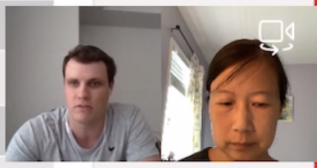

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Outcome of Meeting with S.G. Team on 8/19/2020

- Attentuation: S.G. brochure we have been using is outdated. Our 4.5-m result is as expected. (I checked, CMS HCal showed similar short length for BCF98)
- S.G. scientist team asked why we have not considered PMMA-core fibers → Looking into it.
- BCF91A-MC: manufactuering technique is different from Kuraray's, do not expect the two cladding to peel separately; checked manufacturering records and those shipped were MC fibers; However, found that particular batch "should not have passed quality control".
- Will ship replacement fibers once high quality can be guaranteed.
- Not able to provide comparison data Re BCF vs. Kuraray because "hard to get samples".
- "Can work with customer's budgetary limit".

Shashlyk prototyping

SDU6 fully assembled and tested

THU2 re-tested at SDU using SDU's PMT

(recall we had doubt about THU2's lightyield because the PMT gain was never fully understood)

Shashlyk Prototype Modules

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 → TiO2	254	48	SPE/SDU
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SDU3	Kedi new	US	printer paper	Y11(200) (MC)	Chn silver-plating	TiO2+glue (1/1)	450	108	SPE/SDU
SDU4	Kedi new	Chn	powder paint	BCF91A (SC)	ESR reflector	TiO2+glue +water	562		SPE/SDU
SDU5	Kedi new	US	Tyvek (0.145mm)	BCF91A (SC)	ESR reflector	TiO2+glue +water	398		SPE/SDU
SDU6	Kedi new	Chn	ESR	Y11(200)MC	ESR reflector (single)	TiO2+glue	813		SPE/SDU
THU1	Kedi original	Chn	mirror mylar (reflective)	Y11 (MC)	Italian silver shine	TiO2 (Kedi)	430-470	96	not measured
THU2	Kedi new	Chn	powder paint	BCF91A (SC)	Italian silver shine	Tyvek wrapping	748 → 570/580	90-103	SPE/IHEP
THU3	Kedi new	Chn	powder paint	BCF91A-MC					

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PMMA 塑料光缆规格表

品名	规格型号	直径/mm	光纤根数	光纤外径mm	护套材料	盘长/m
单芯缆	EL025/1	0.25	1	1	PE	1000
	EL050/1	0.5	1	1	PE	1000
	EL075/1	0.75	1	1.3	PE	2700
多芯缆	EL075/7	0.75	7	3.8	PE	300
	EL075/14	0.75	14	5.8	PE	250
	EL075/25	0.75	25	7	PE	100
	EL075/42	0.75	42	9	PE	100
	EL075/84	0.75	84	13	PE	100
单芯缆	EL100/1	1.0	1	2.2	PVC，PE。PA，L。	1500
双包层缆	EL100/1-	1.0	1	2.2/4	PE/PU	500
双芯缆	EL100/2	1	2	2.2*4.4	PE	500
单芯缆	EL150/1	1.5	1	3	PE	700
	EL200/1	2.0	1	3	PE	250
	EL250/1	2.5	1	4.5	PE	250
	EL300/1	3.0	1	4.5	PE	150

注：默认光缆护套材料为 PE 黑色，其它护套材料需加标记，如尼龙护套 EL100/1-PA；聚胺酯护套 EL100/1-PU；护套颜色红 R；黄 G；绿 B，黄绿 GB。如 PE 红缆 EL100/1R。L：阻燃低烟无卤缆

塑料光纤

OPTIC FIBER FIELD

主要技术参数：

芯材 PMMA　　皮材 氟树脂

透过率/%*m^{-1} ≥95（570nm）　　损耗/dB*km^{-1} ≤200（570nm）

芯折射率 1.49　　皮折射率 1.40

数值孔径 NA 0.5　　波长范围 420—680nm

入射角度 60　　弯曲半径 ≥8D

适用温度 -20℃～70℃

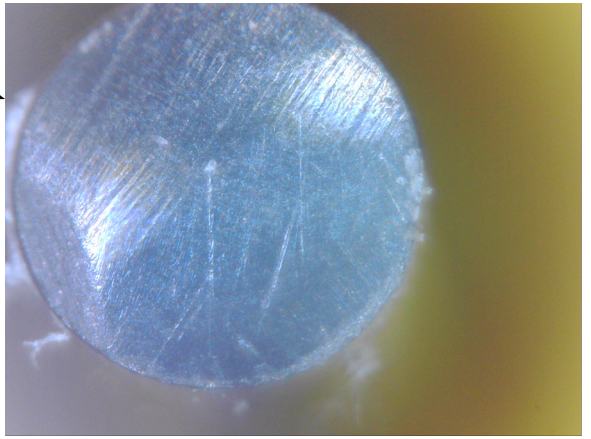
应用范围 数据传输，传感器，传像，刑侦，照明

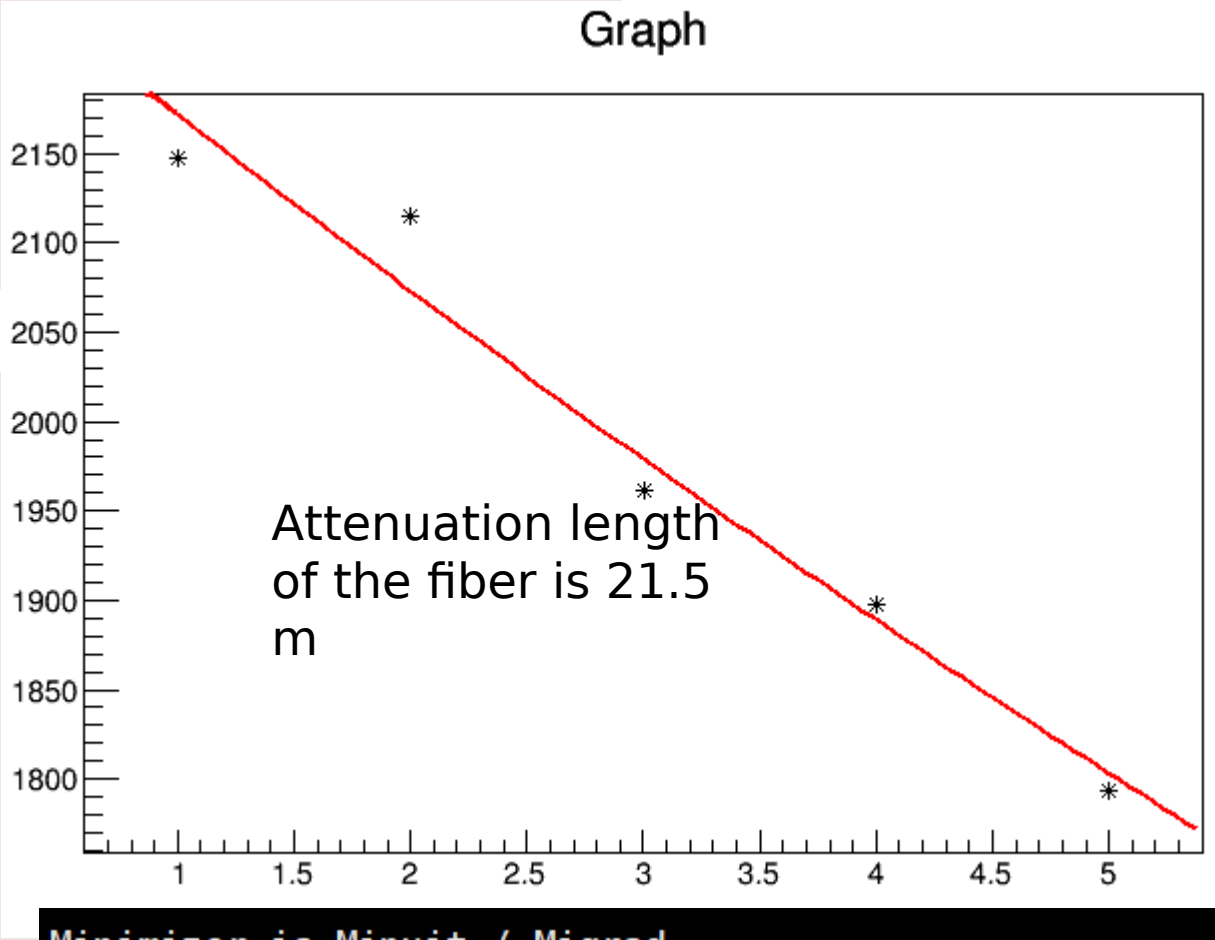
PMMA 塑料光纤规格表

规格型号	直径/mm	皮层厚度/um	盘长/m
EL2125	0.125	3	
EL225	0.25	5	12000
EL250	0.5	7	6000
EL275	0.75	7.5	2700
EL2100	1.0	10	1500
EL2150	1.5	15	700
EL2200	2.0	20	250

http://www.china-light-guides.com/product/17.html

ChunHui PMMA-core clear fiber





BCF98

```
Minimizer is Minuit / Migrad
Chi2                      =      2806.71
NDf                       =            3
Edm                       =  1.49435e-08
NCalls                    =           77
p0                        =      2275.11   +/-   34.9761
p1                        =   -0.0464945   +/-   0.00488425
root [2]
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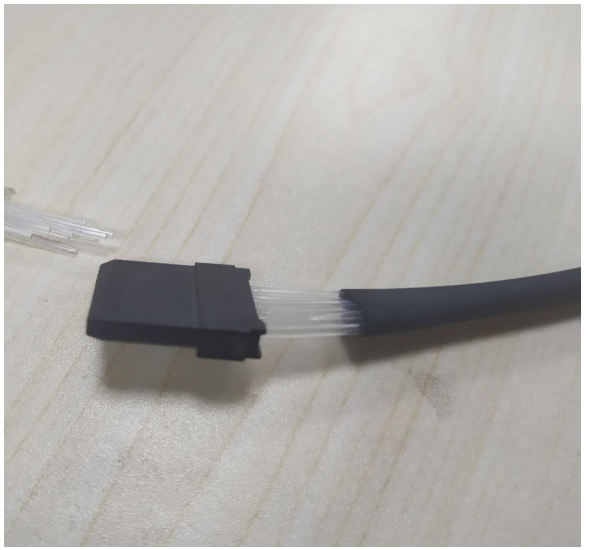
Fiber Connector Test

DDK connector with optical grease: (24-32)% loss.

Note: UVA testand Minerva published data showed <20% loss but both used optical cement

ChunHui commercial connector shows 25% loss.



Shashlyk Material Test and Light Yield Status

- With extensive material testing, the best combination seems to be: Kedi new scintillator; ESR reflective layers, ESR reflective tape at fiber end, and TiO2+glue mixture on module sides.
- The higher yield of THU2 module is due to PMT gain determination and was never fully understood. Most recent testing results of THU2 at SDU lab showed comparable light yield as SDU modules.
- Using the highest MIP light yield of 800 p.e./200 layers 1.5mm layers (at 0.3MeV MIP energy per layer or 60 MeV MIP energy total), scale up to 1 GeV electron (20% sampling factor or 200MeV energy deposit in the scintillators), we obtain (800/60*200=2666 p.e.) for 1 GeV electrons. This is 2.67 p.e./MeV, comparable to LHCb 2.6-3.5 p.e./MeV, but below ALICE 4-4.4 p.e./MeV, and KOPIO 53 p.e./MeV (with APD). We still need to assemble a prototype with BCF91A-MC (could be 30% lower than Y11-MC).
- With 2666 (previously 500 Npe for MIP or 1666 p.e./GeV electron), the energy resolution due to photon statistics will be 2.7% (previously 3.5%) if also considering factor 2 light loss of fiber connector and clear fibers. This is okay considering the intrinsic resolution is (5-6)%, although ideally we would like to see the effect of photoelectron statistics to be negligible.
- Fiber bending and attenuation loss ongoing – will focus on PMAA bending

FNAL Beam Test

- Previously (June 2020): We are now back at studying the feasibility of testing these modules at FNAL's test facility. Beam request was sent last week. Earliest possible time would be early 2021 (if we can piggyback on some other tests). We will need to bring our DAQ, and borrow logic modules from FNAL to integrate with the DAQ of their test facility.

- Now: we are tentatively scheduled for one week of day-time beam time in early Dec, 2020. Working on FSW.

- Plan: move test DAQ from hall C to test lab, set up cosmic test with 3 shashlyks, 3 preshowers, trigger scintillator (from Nilanga), lead sheets; Then drive to FNAL. We are given one week for setup.

- Team: Jixie Zhang (UVA), Xinzhan Bai (UVA, pending), David Flay (JLab, if local), local ANL group

- (Purchased 2x 16-ch MAPMTs from Hamamatsu, will test out Preshower readout opportunistically).

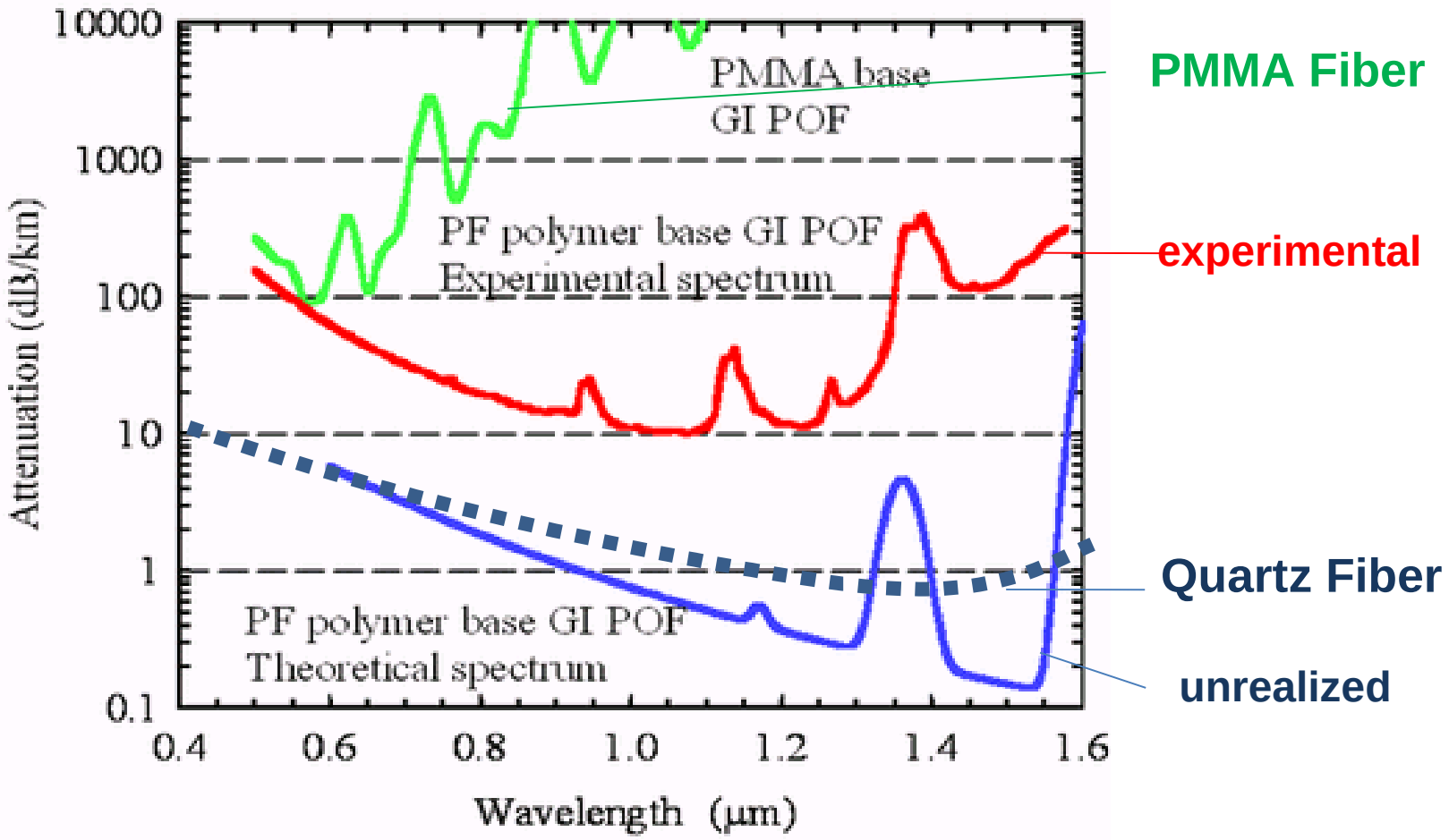
ECal Support

- Design transferred from Vic (ANL Engineering) to ANL MEP (Paul Reimer). Plan to move forward “in-(MEP)house”.
- Module front and back plate design must be integrated with support design, will affect how modules are assembled.
- No design is done yet for preshower, lead and SPD support/mounting. Need to integrate mounting/fixture of WLS fiber with design. LED test structure can be integrated at this stage.

Summary

- Material Test/prototyping continues, need a module with BCF-91A-MC
- Studying PMMA-core clear fiber (strengh? durability? Why CMS and Minerva used BCF-98 and Kuraray's clear fiber, both polysterene-based? Note BC fibers all have polysterene core and PMMA cladding)
- Plan to test at FNAL Test Beam Facility in Dec 2020 or early 2021.
- Support structure design moved in-house at ANL/MEP.
- Revisited (briefly) SiPM readout. Neutron background behind ECal is 10 times higher than any existing SiPM data (which shows cooling is neededto reduce dark current)
- Additional info: THU group received China MOST funding for building shashlyk calorimeter at NICA. (slightly higher sampling, shorter, much smaller lateral size, low radiation+SiPM readout).

Backup Slides



Attenuation Length can be calculated from Transmission Loss

$$A(\lambda)=\frac{10\,x}{\alpha X \ln 10}=\frac{4343}{\alpha}\ \text{in meters}$$

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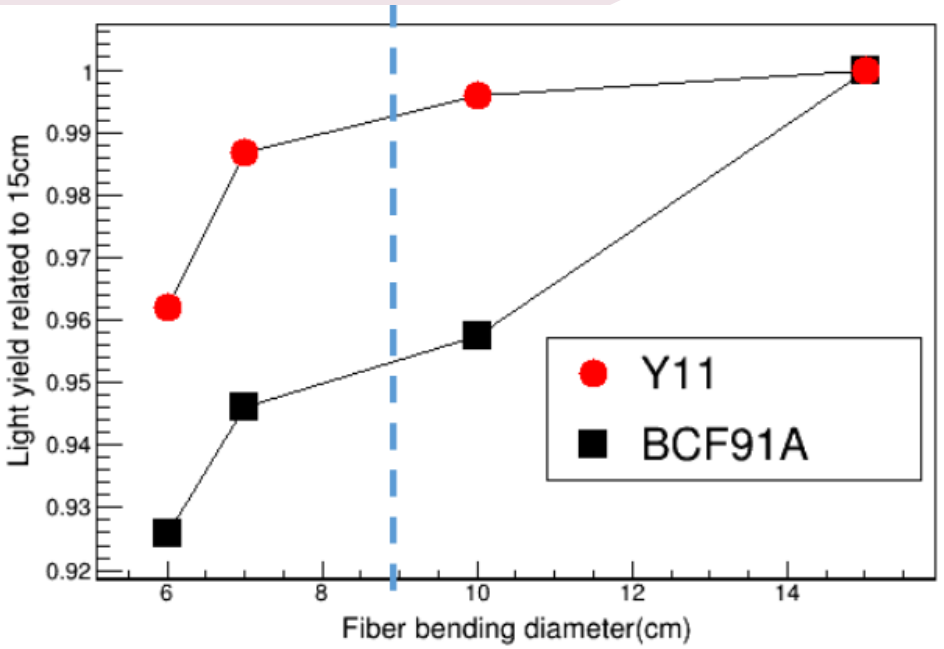
Fiber Bending Light Loss (SDU)



BCF91A lose more light than Y11 with same bending diameter, but the difference is not too much.

bend diameter (result in channel)		15cm	10cm	7cm	6cm
BCF91A (SC)	#1 (1m)	447	428	423	414
	#2 (1m)	326	313	402	402
Y11 (MC)	#1 (1m)		524	519	506
	#2 (1m)	767	760	751	758

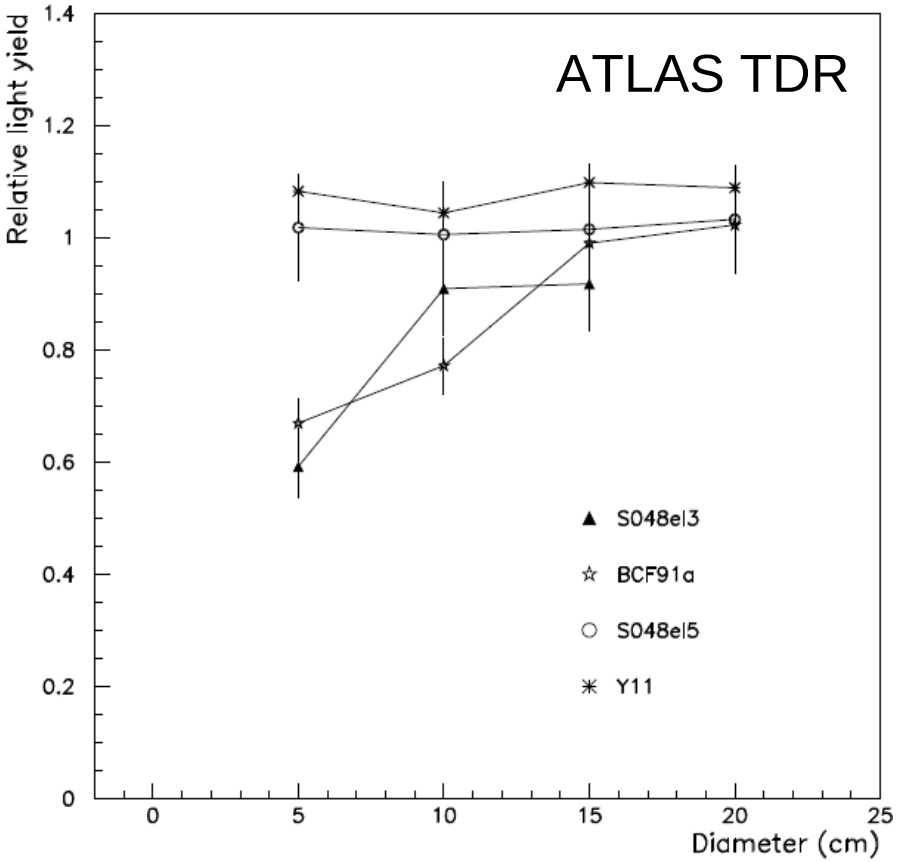


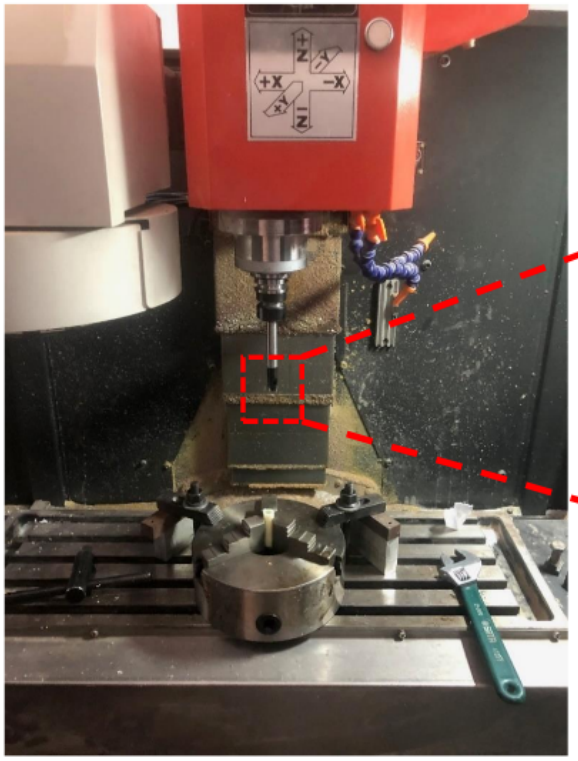
Figure 5-24 Relative light output for some fibres as a function of bending diameter.

Results encouraging;

Will repeat for BCF91A-MC

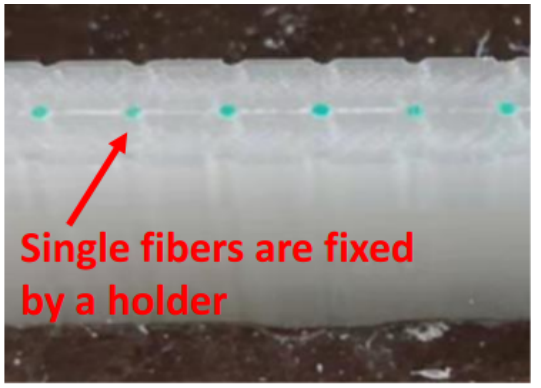
Fiber polishing in SDU

Fiber is polished in bundle or as single by a diamond milling cutter in SDU. This method shows good efficiency and quality.

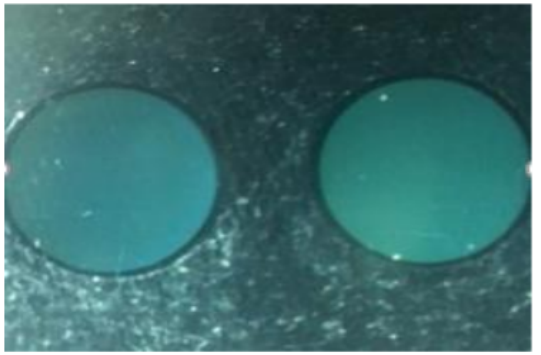


Polishing Machine tool

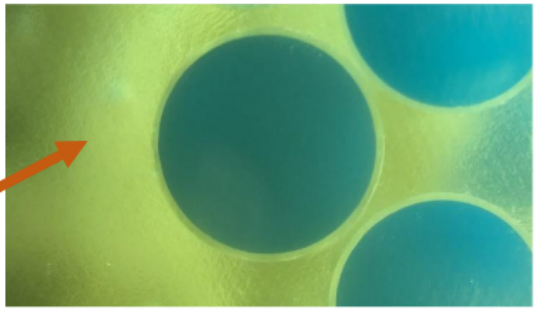
Diamond milling cutter



Loose single fiber (unglued)



Single fiber in connector

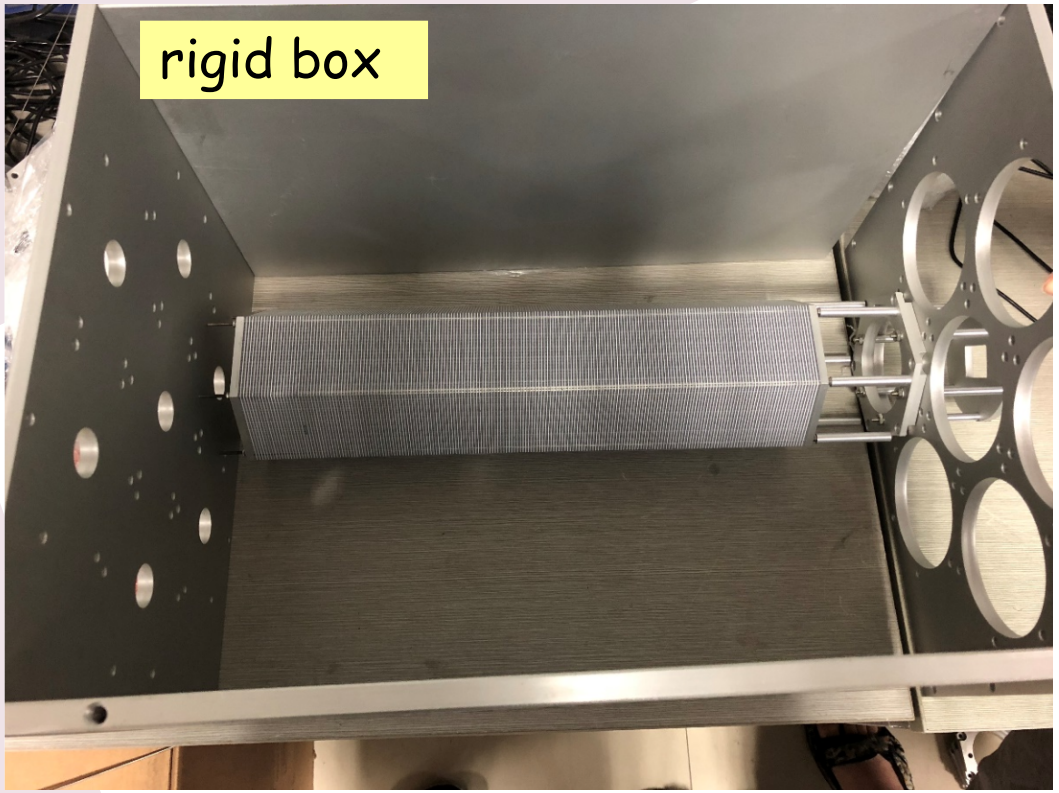


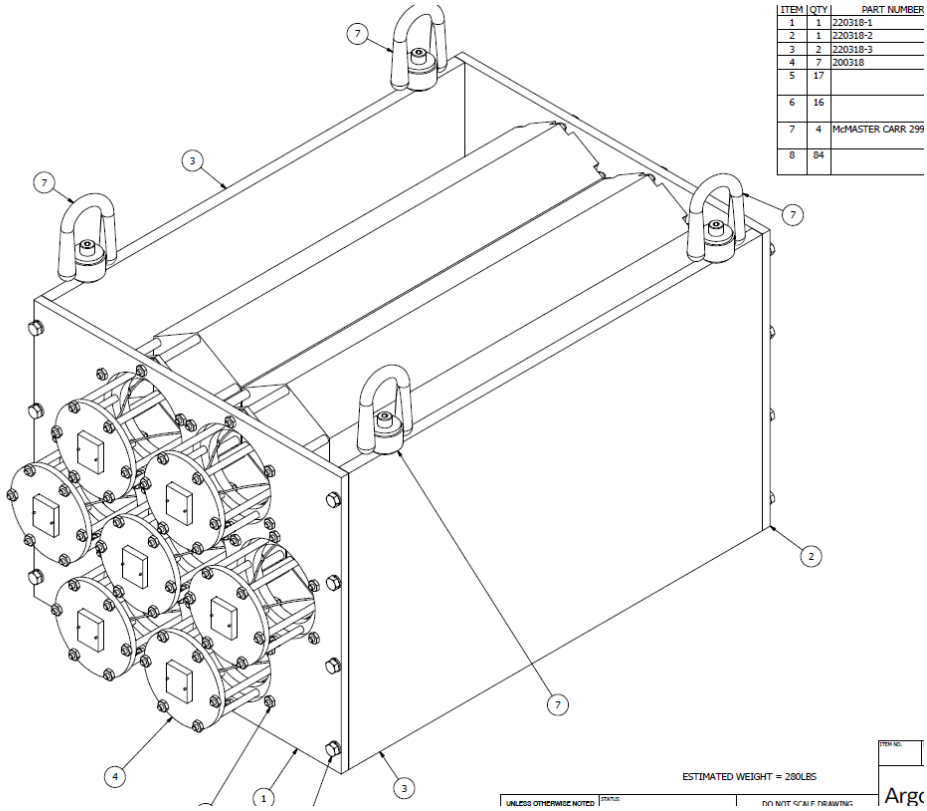
Fiber in bundle

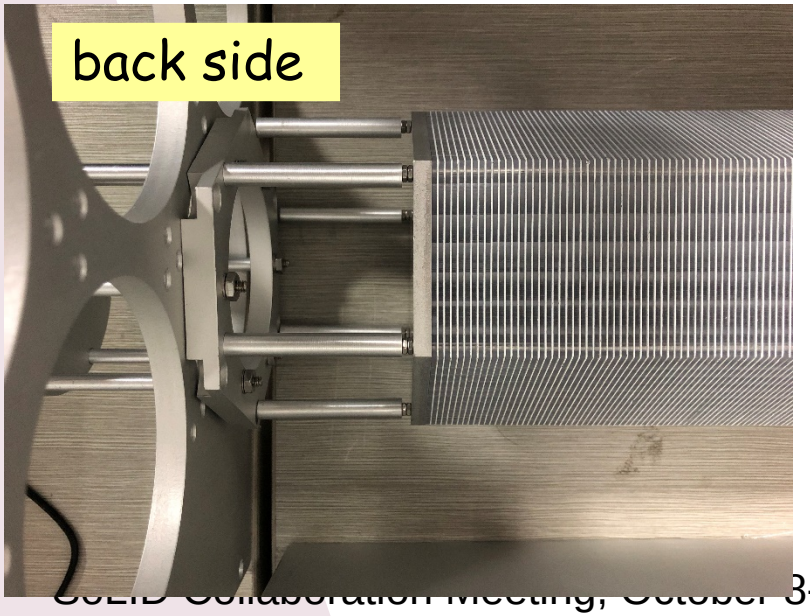
To Do Items Related to Director's Review Outcome

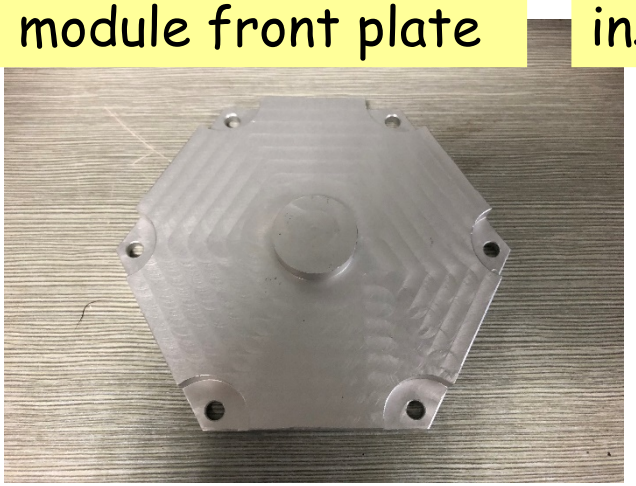
- "A complete pre-conceptual design of the detectors, their supports and installation including assembly and installation tooling would help the SoLID project with the cost and schedule analysis to develop a pre-conceptual cost."
- "The risks for the project are not yet complete and focus on technical risks. currency fluctuations, VAT and tariffs, risks related to university contribututors underperforming (or become impossible?), EH&S associated to lead heandling, hoisting and rigging etc."

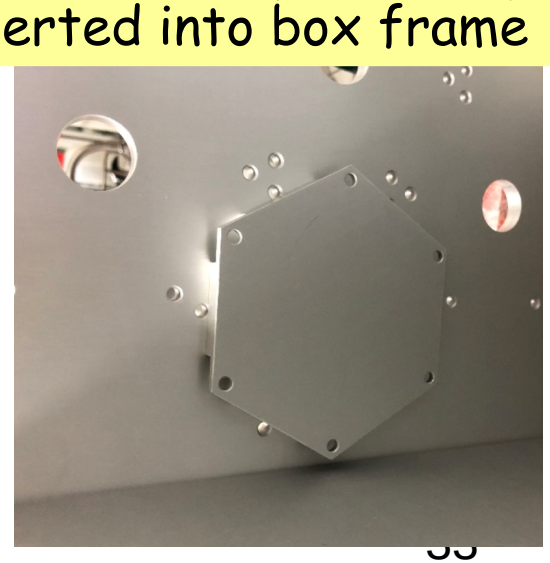
ECal Support





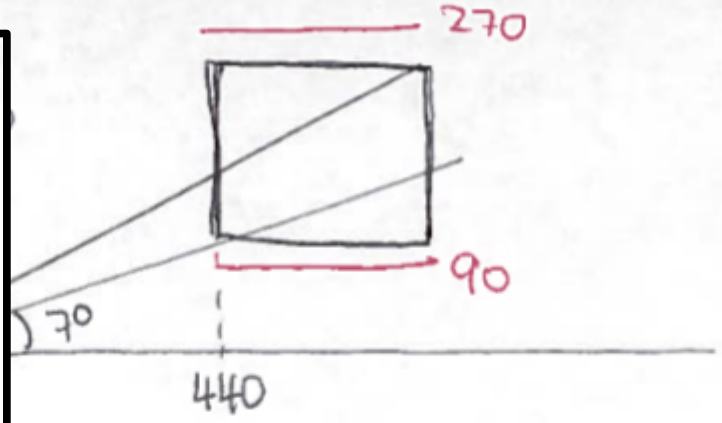






ECal Layout

SIDIS FAEC
+J/ψ



$R_{in} = (440+350)\tan 7^\circ =$

$= 790 \times \tan 7^\circ$

$= 97.0\,cm$

① needs full coverage from 97 to 240cm

② hard Limits at 90cm and 270cm.

PVDIS EC coverage : (calculations)

$(325-10) \times \tan 21^\circ = 120.9\,cm$

$(325+\underbrace{50}_{\text{EC length}}-10) \times \tan(34.6^\circ) = 251.8\,cm$

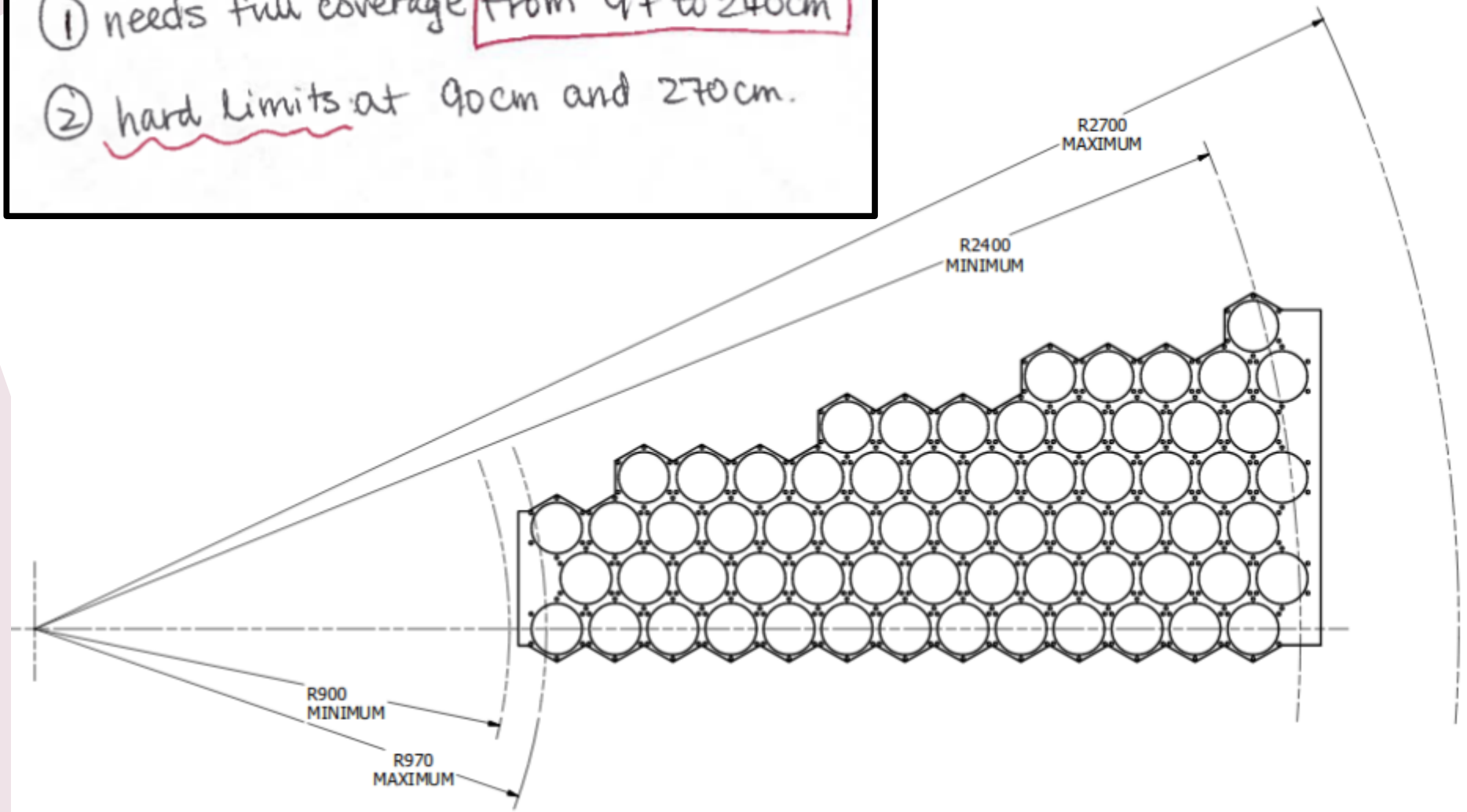
(2cm PS
2cm support
45-46cm shower module)

need full coverage from 120.9 cm to 251.8cm.

From Vic, ~August 2018 (SIDIS FAEC)

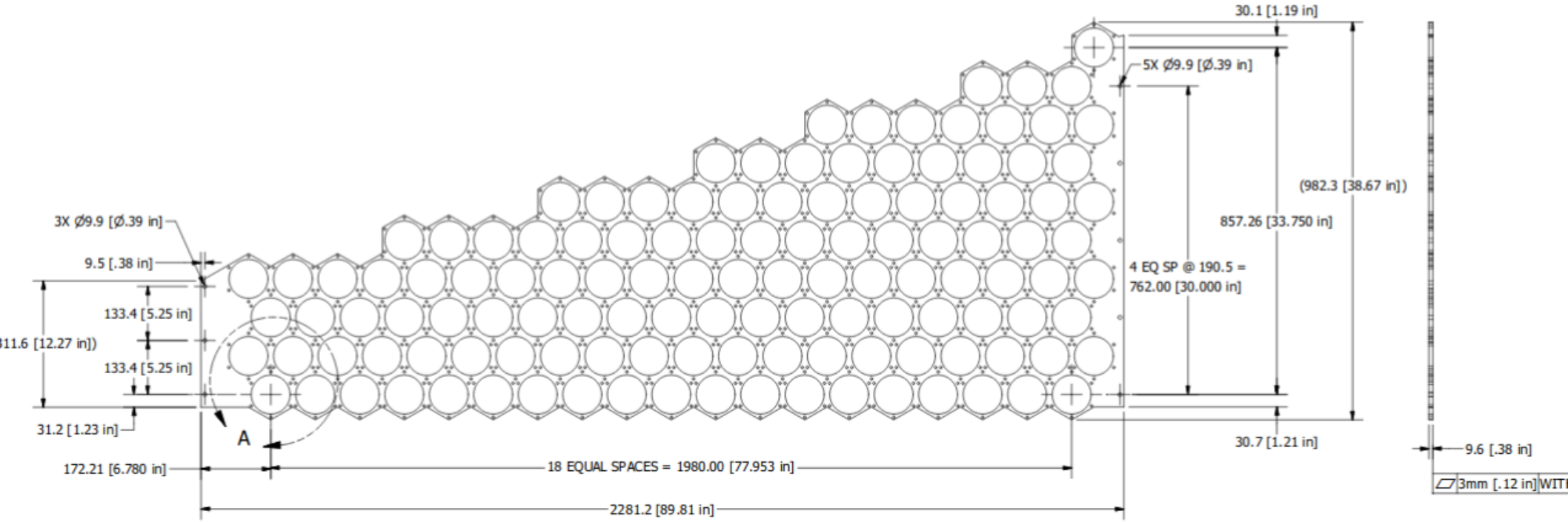
① needs full coverage from 97 to 240cm

② hard Limits at 90cm and 270cm.



ECal Layout

However, in July 2018 also received from Vic the support plate design with quote. Coverage doesn't seem correct, not sure where this one comes from.



To do:

- Lots of uncertainties in how to mount modules. In-person discussion seems mandatory;
- Continue to PVDIS and SIDIS/LAEC layout.
- Figure out where the layout for the July 31st support plate design comes from, and revise.