



3rd DUNE Near Detector Workshop

Light collection module for LAr TPC

Nikolay Anfimov on behalf of
UniBe and JINR groups

Argon Cube for the DUNE ND

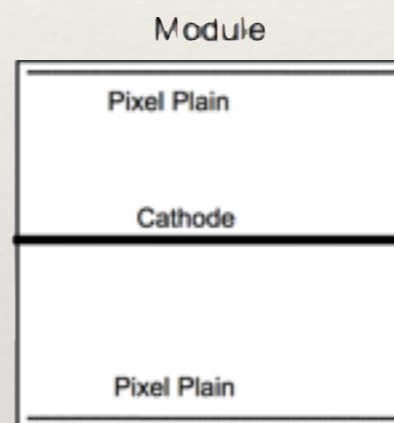
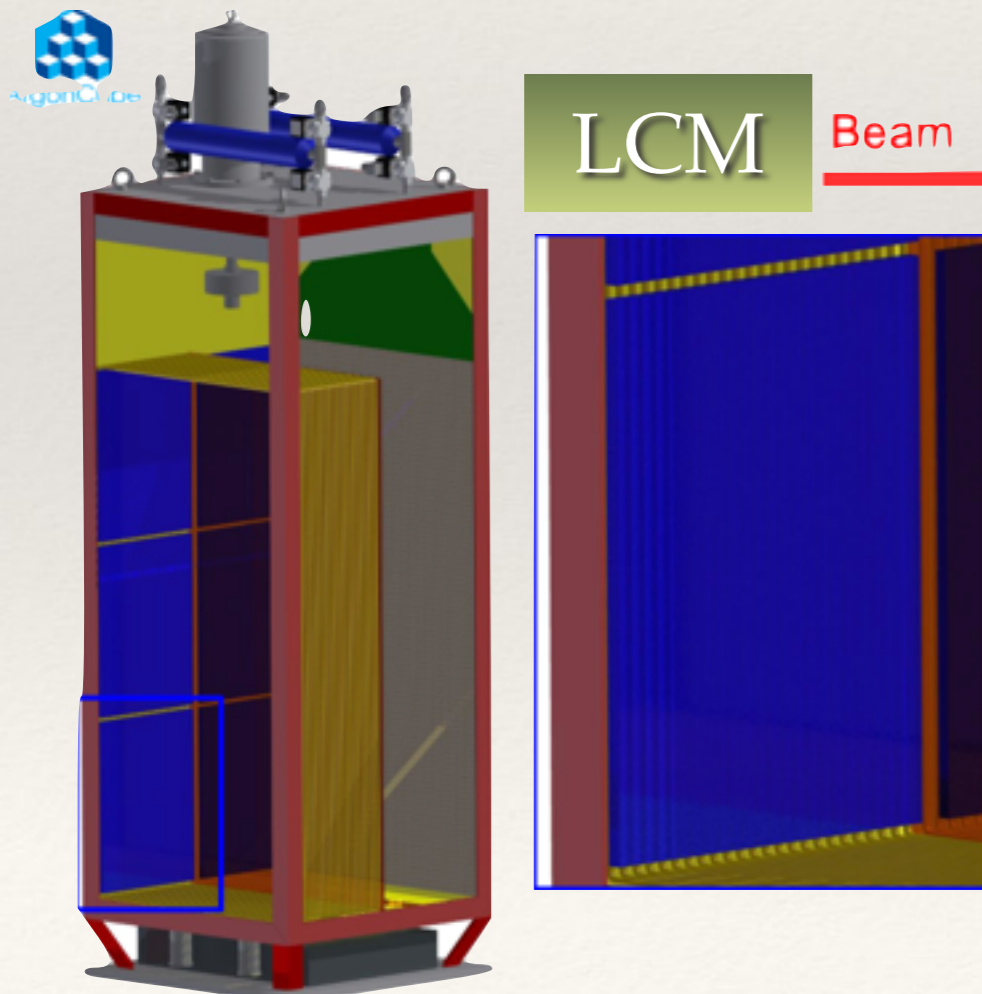
LBNL studies suggest **30 t** LAr TPC is sufficient

Proposed geometry is **3 x 5 modules** (longest in beam)

Each module: **1 x 1 x 2.5 m³** (50 cm drift, 50 kV)

Total detector: **7 x 5 x 4.5 m³** (inc. cryostat & ancillaries)

Active volume: ~ **5 x 3 x 2 m³**



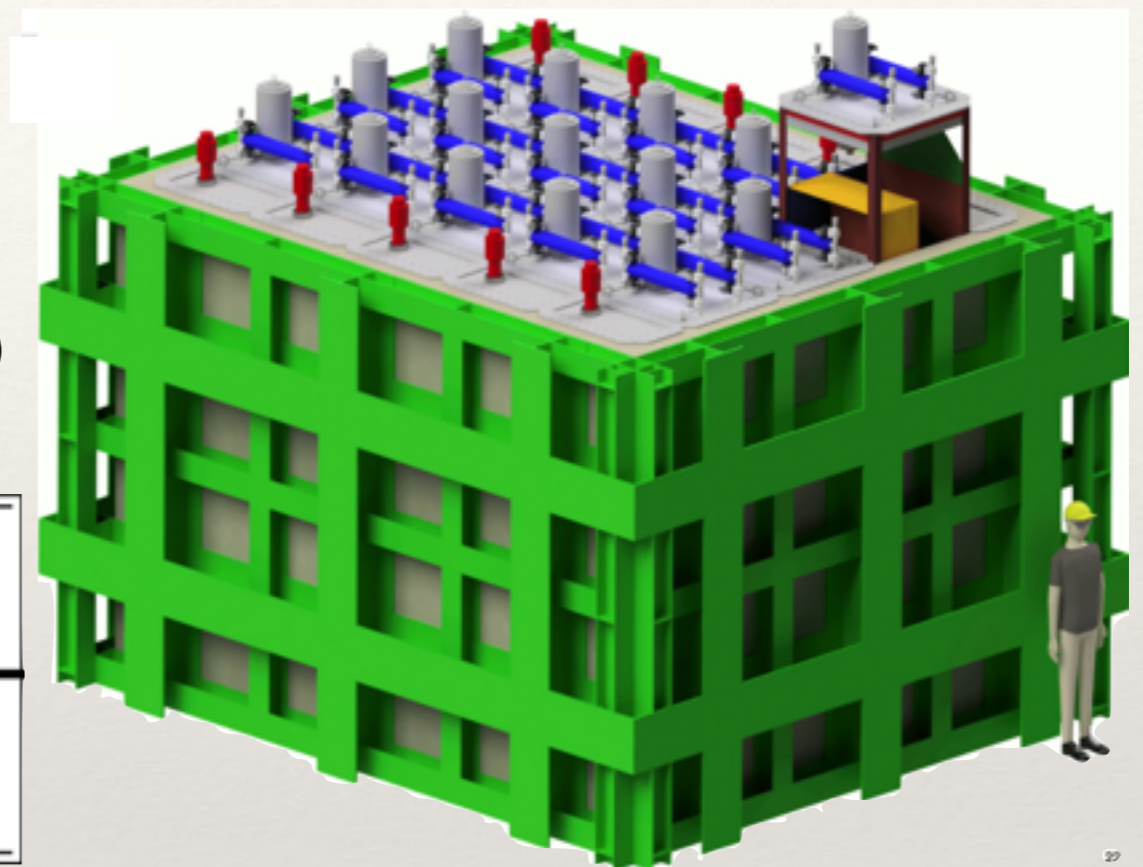
Light Collection Module:

Fixed directly into the readout PCB.

Supported on the field cage with custom hooks

Detecting **128 nm** scintillation light

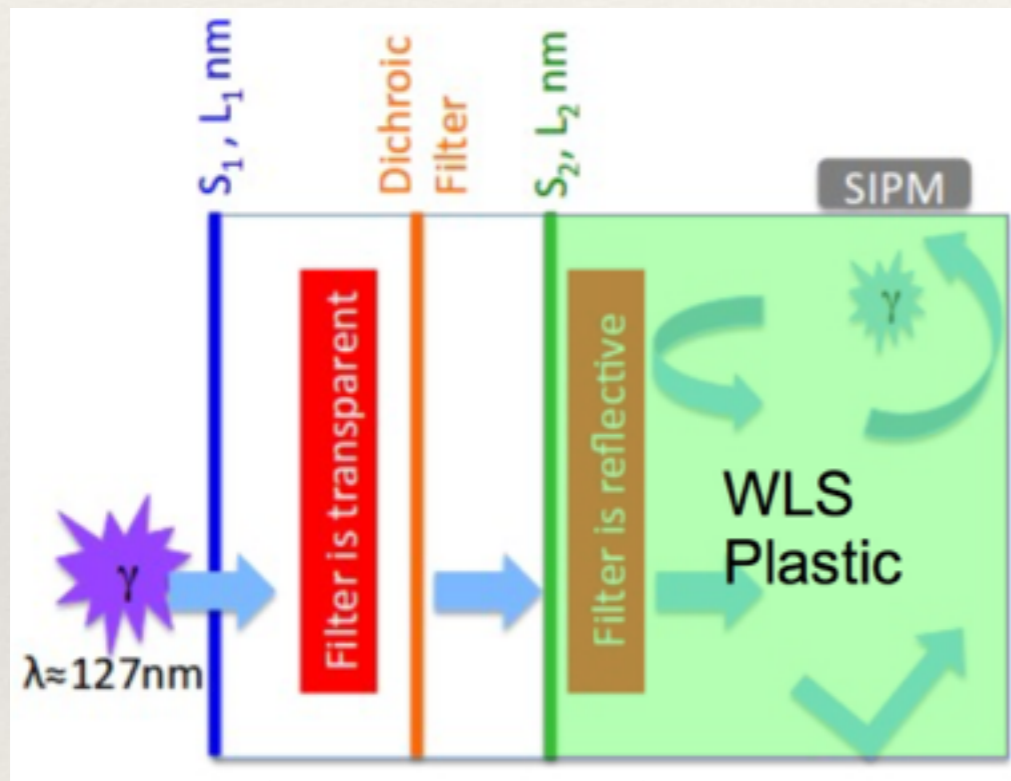
No metal (conductive) parts (only at zero potential)



Two approaches to detect UV-light

Both approaches are based on shifting UV light (128 nm) into visible (425 nm) by TPB

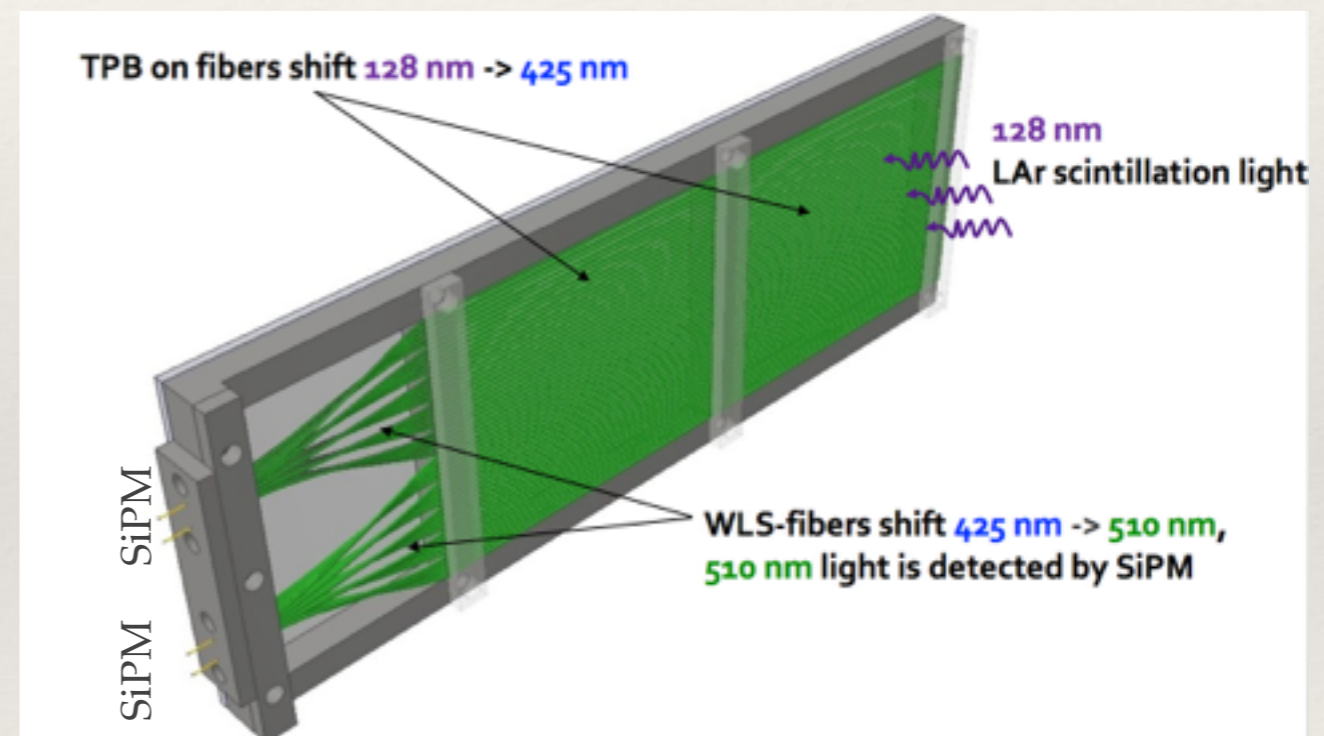
ARAPUCA-like design



Provides more rigid construction
More technological assembling
Zero dead area

loses PDE for scaling up

WLS-fibers design



Easy to scale -> Fibers have long attenuation
Doesn't lose efficiency (PDE) with scaling up

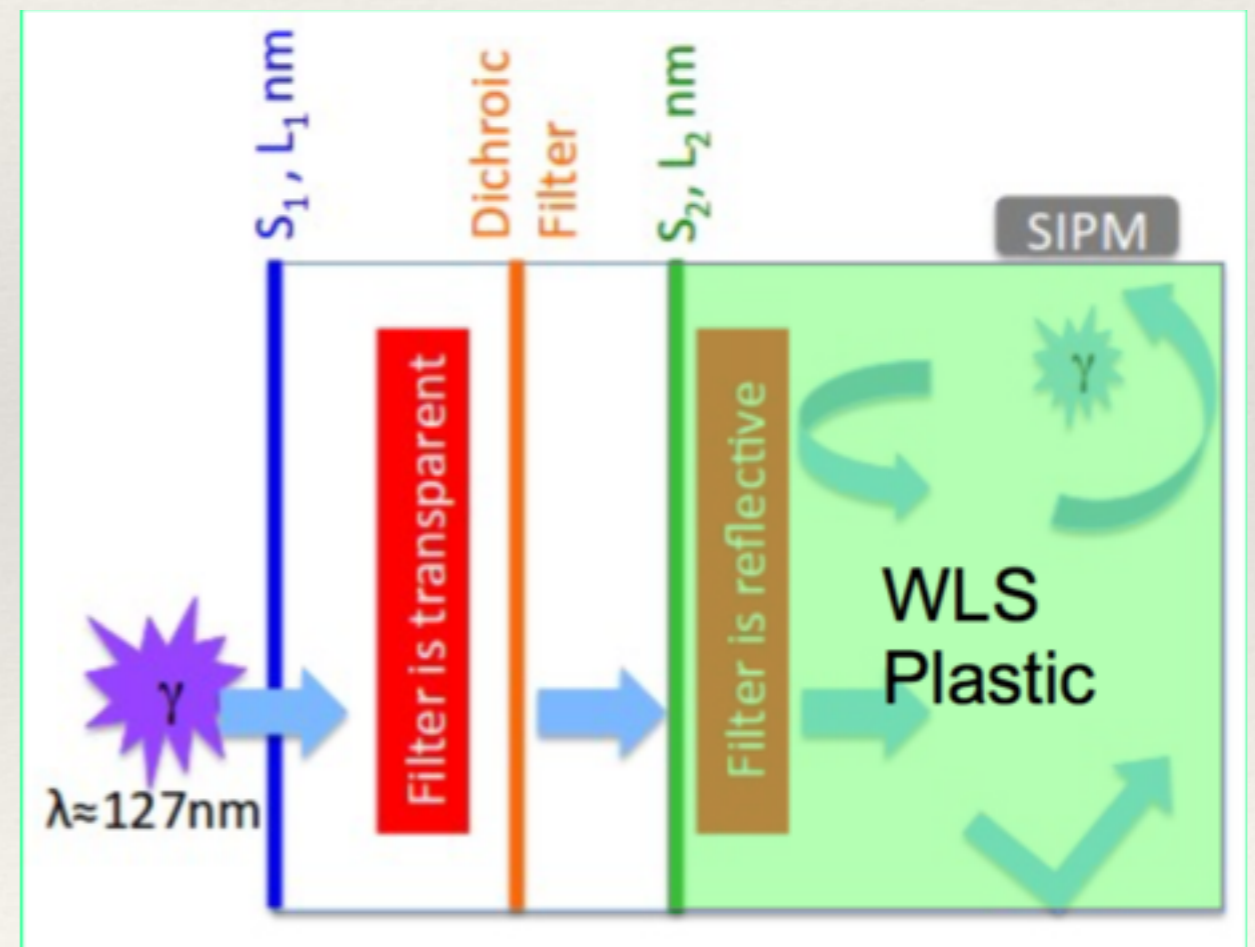
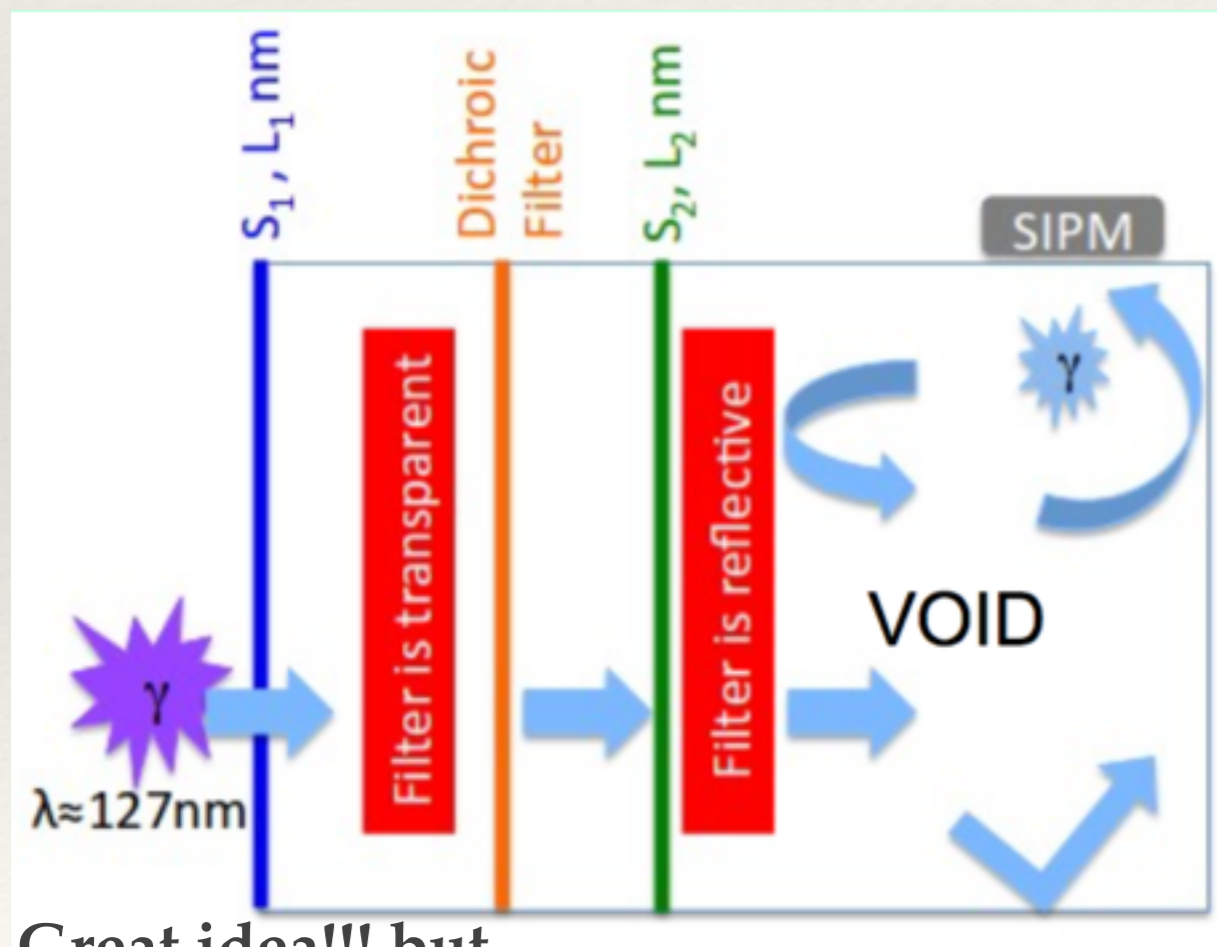
Hard to assembling

ArCLight design

ARAPUCA

ArCLight

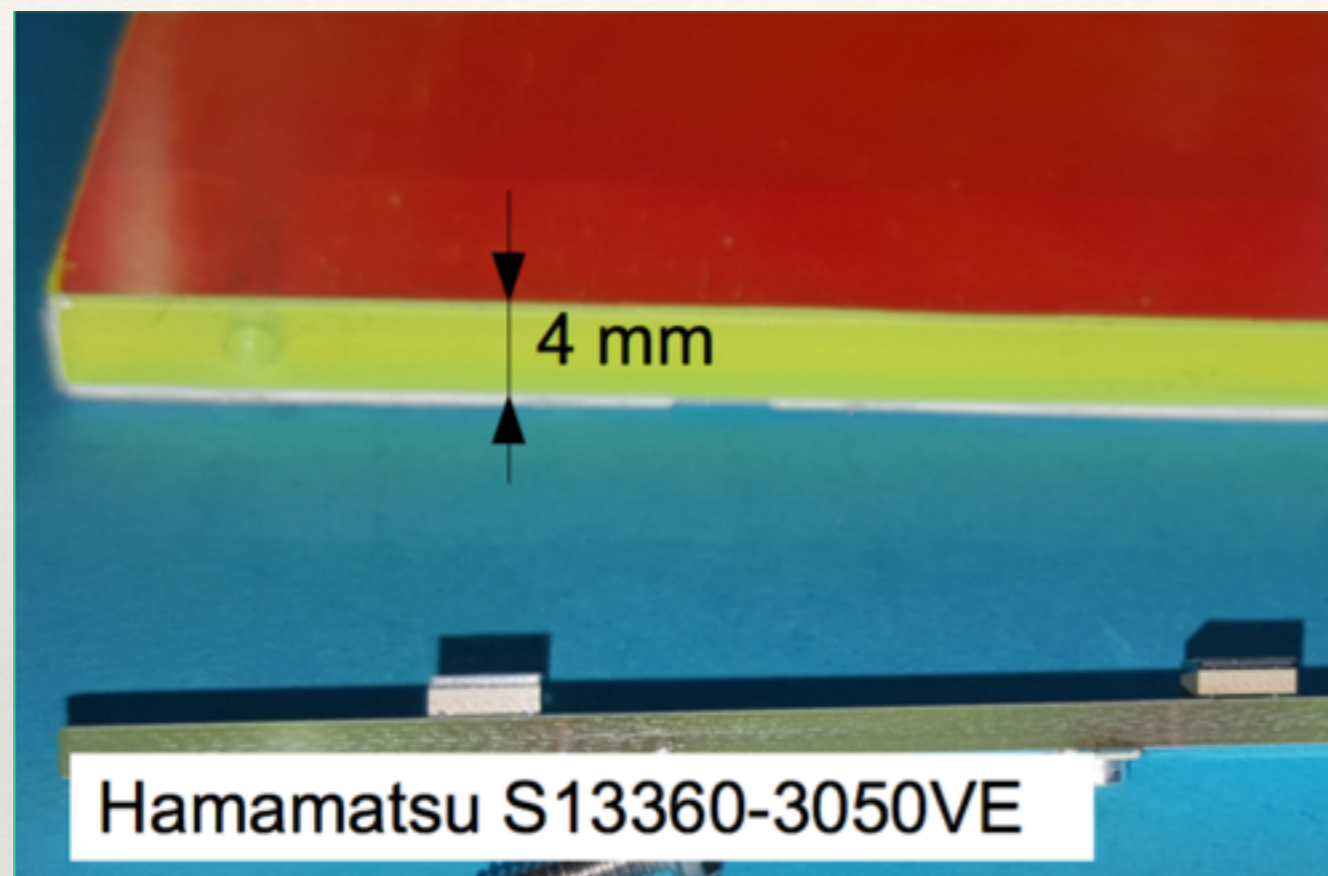
A.A. Machado and E. Segreto 2016 JINST 11 C02004



Great idea!!! but...

Fragile membrane, void inside, heavy frame, thermal deformations...

ArCLight Design



TPB

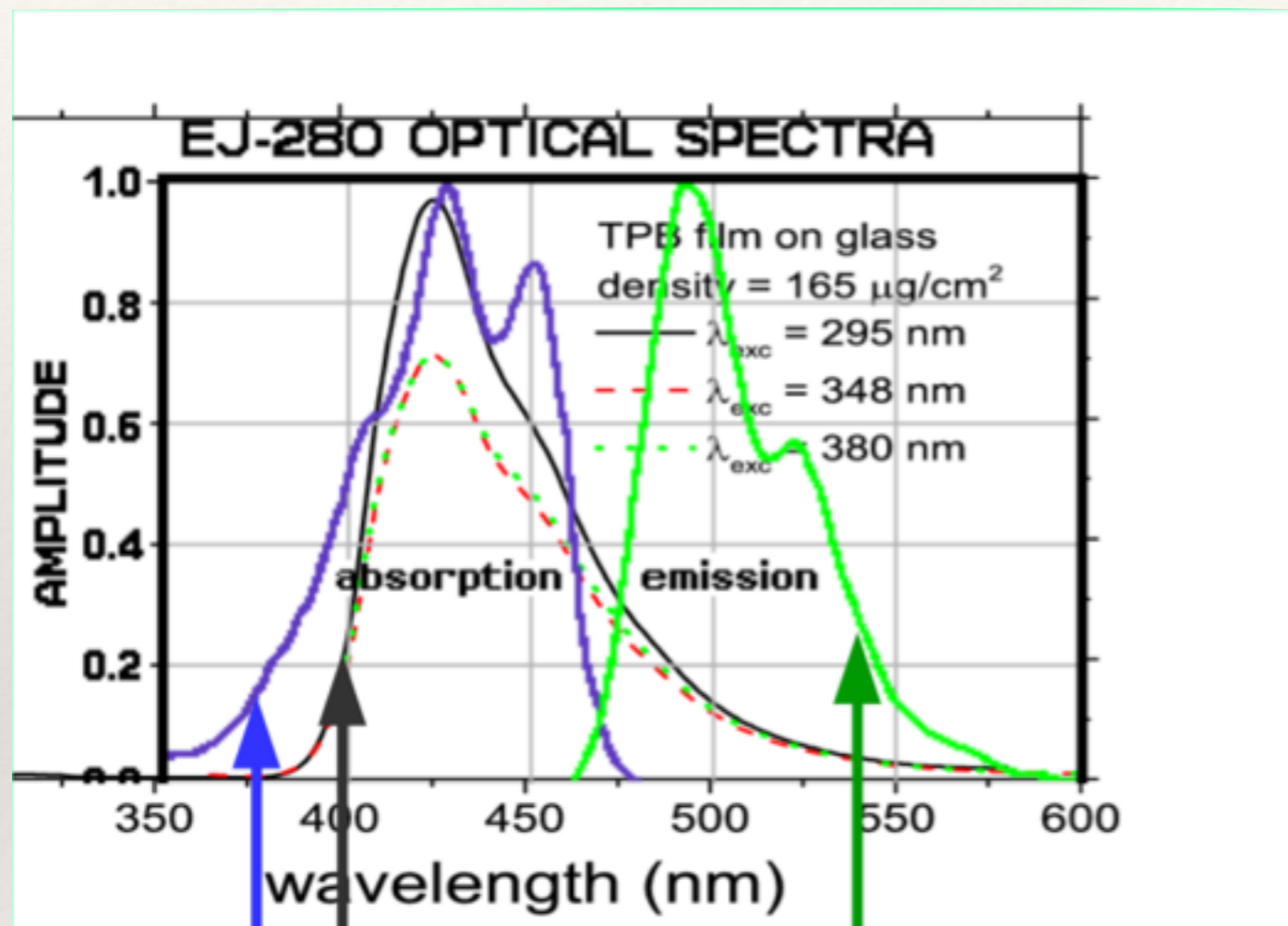
3M DF-PA Chill

EJ-280 Green WLS Plastic

3M Vikuiti ESR

Self-supporting
SiPM can be placed at one edge only
No frame — no deformations in cold

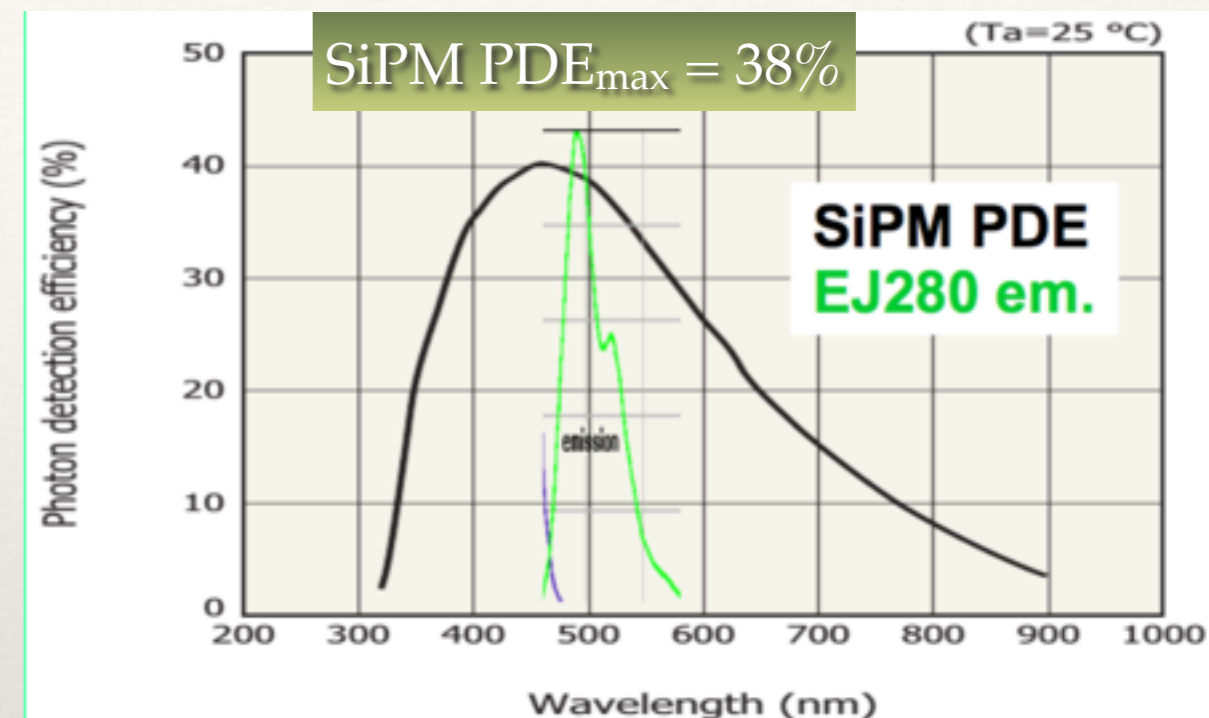
ArCLight Design



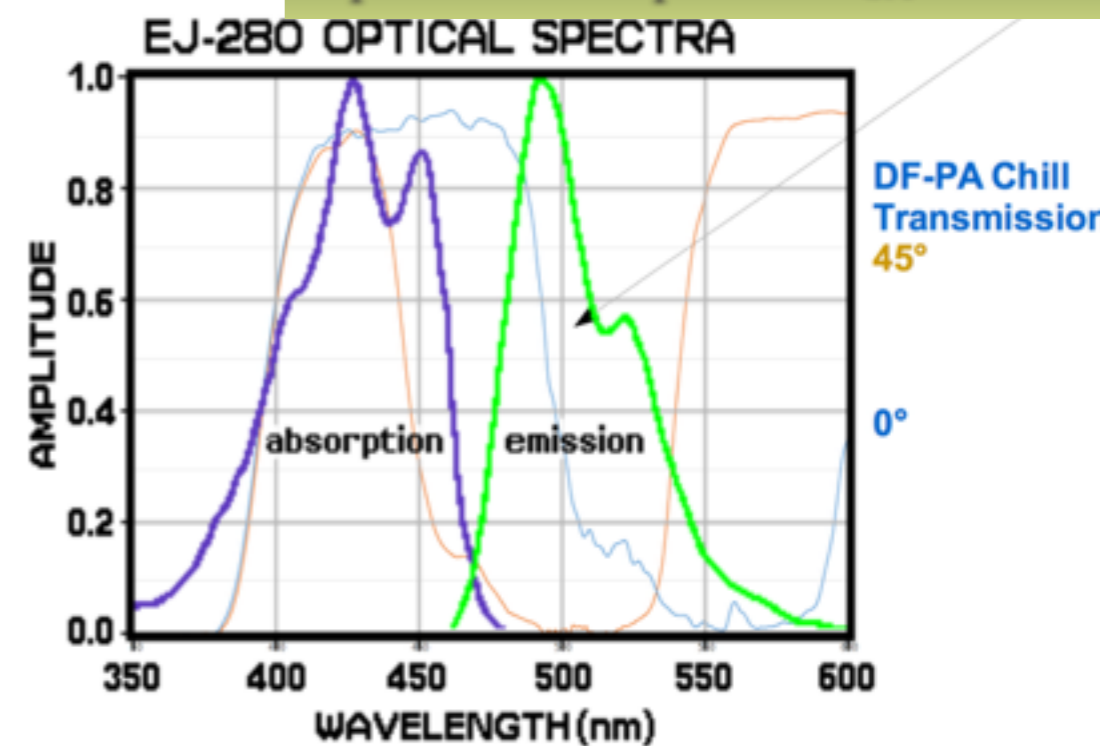
TPB Emission

EJ280 Emission

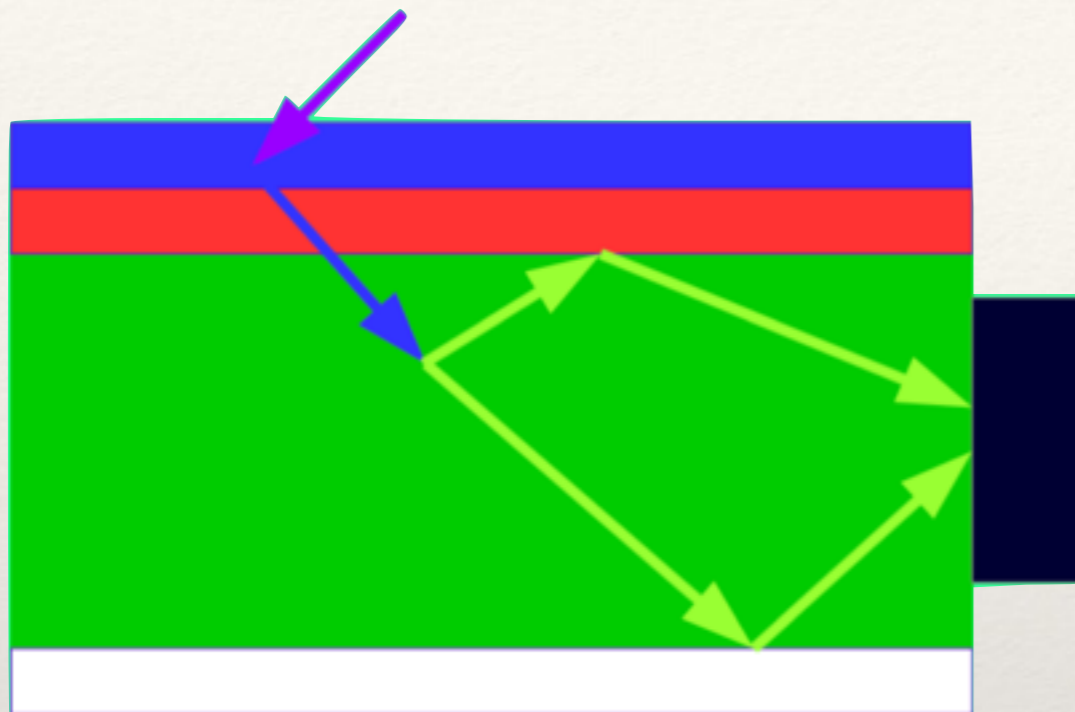
EJ280 Absorption



Spectral acceptance $\epsilon_{\text{SA}} \sim 70 \%$



Evaluation of PDE for ArCLight



$$\epsilon_{coll} = \frac{f}{1 - \langle R_{490} \rangle (1 - f)} = 0.077$$

TPB conv. efficiency $\epsilon_{tpb} = 1.3/2$

Dichroic transparency for blue $T_{430} = 0.87$ EJ-280
conv. efficiency $\epsilon_{WLS} = 0.86$

Dichroic reflectance for green $R_{490} = 0.98$

ESR reflectance for green $R_{490} = 0.98$

Total surface area $S_{tot} = 216 \text{ cm}^2$ SiPM
covered $S_{det} = 0.36 \text{ cm}^2$

$$f = S_{det}/S_{tot} = 0.0017$$

Absorption is neglected! ($\lambda \sim$ meters)

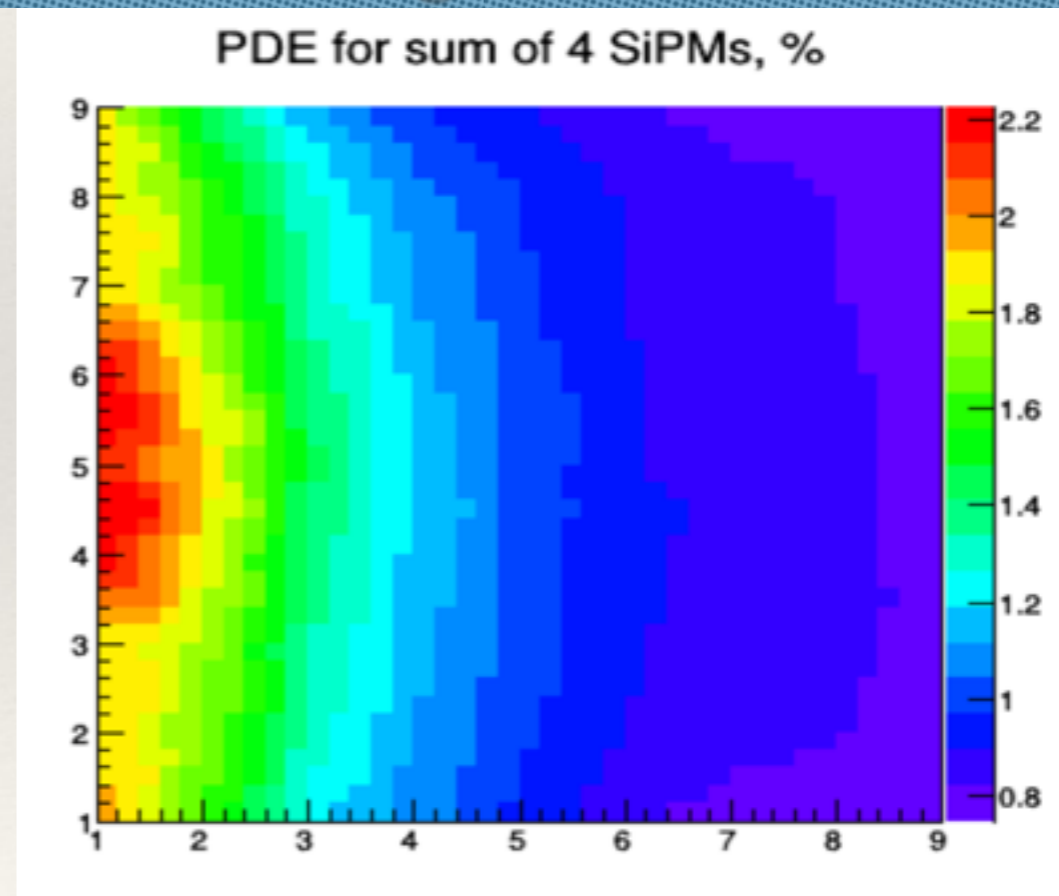
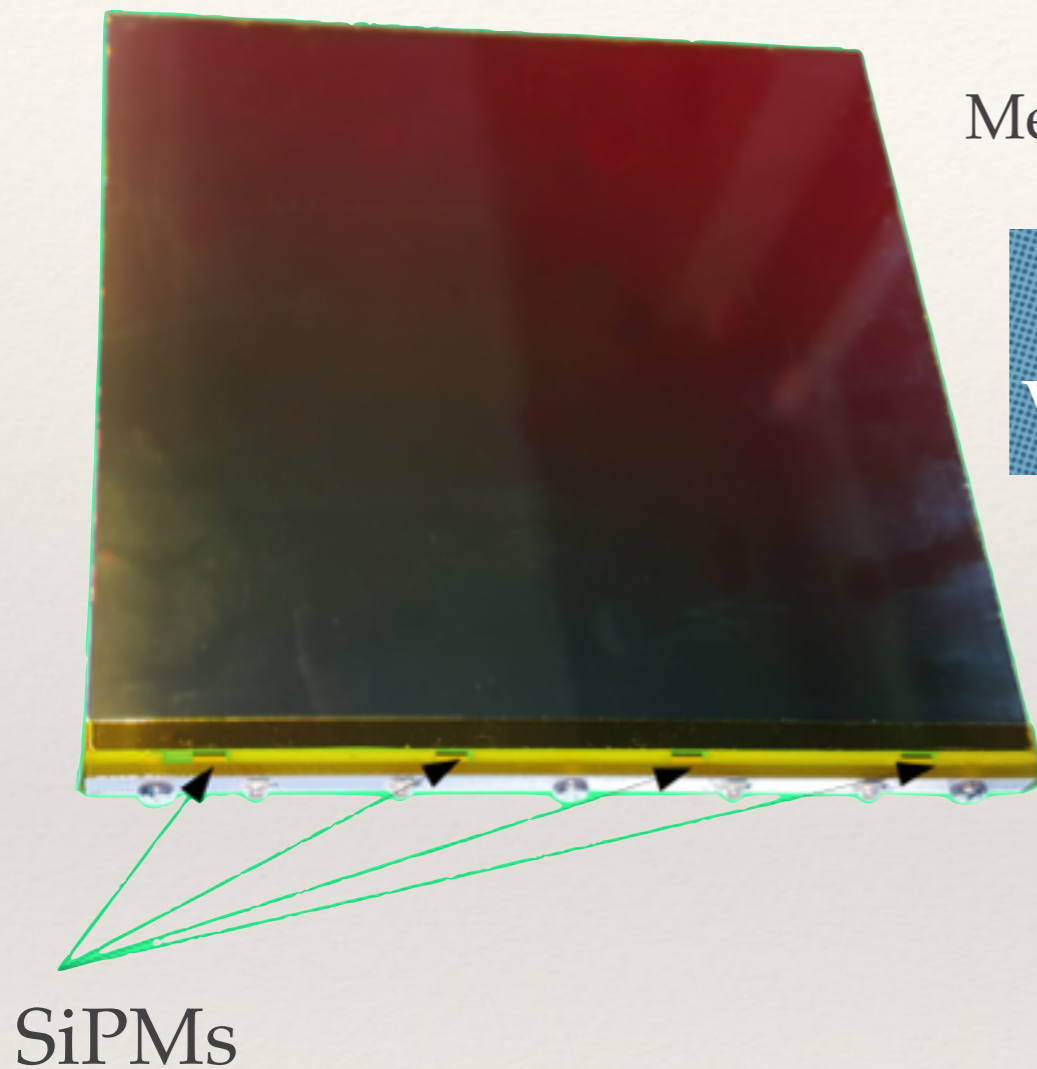
Putting it all together:

$$PDE = \epsilon_{tpb} \cdot T_{430} \cdot \epsilon_{WLS} \cdot \epsilon_{SA} \cdot \epsilon_{coll} \cdot \epsilon_{SiPM} = 0.01$$

ArCLight Prototypes w/o TPB

Measured PDE for 10x10 cm $\sim 1.5\%$

This is not for UV, but 425 nm!
Very well matching with calculations!



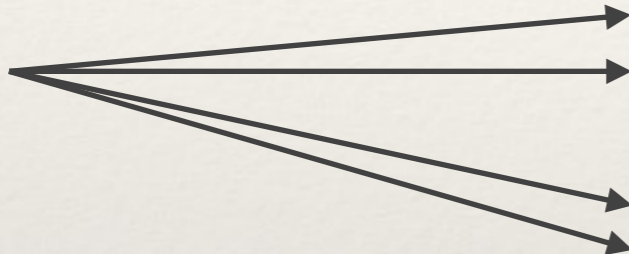
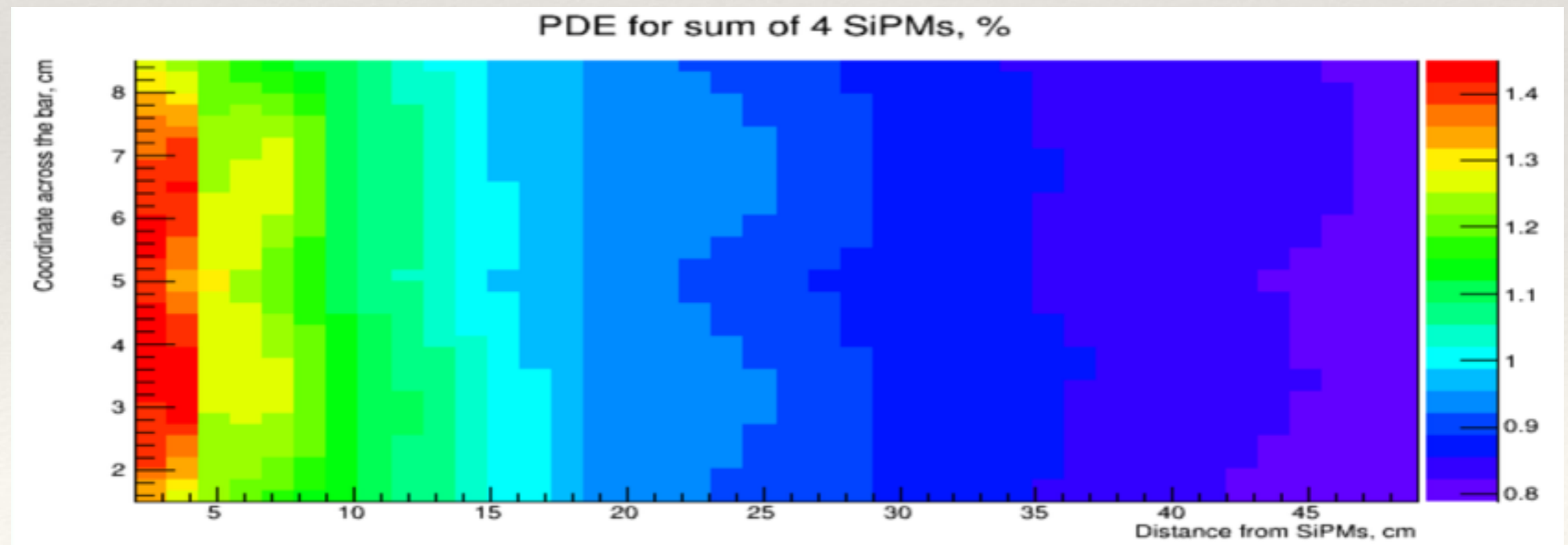
R/O electronics: Bern FEB (32-ch SiPM signal processor)

ArCLight Prototypes w/o TPB

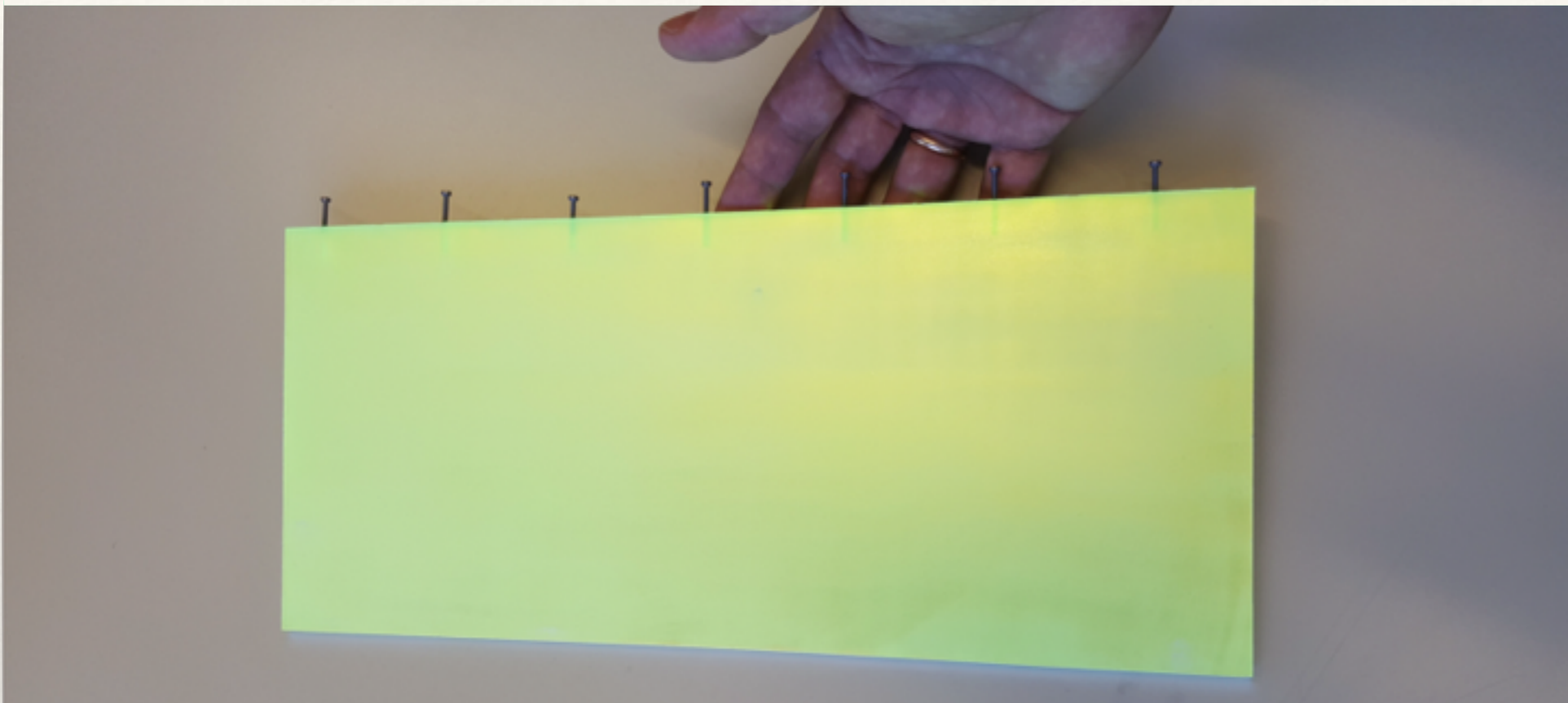
Measured PDE for 50x10 cm $\sim 1\%$
Improved mirror is used

Great and very promising result!

SiPMs

ArCLight Prototypes with TPB



Tile 43x15cm: total surface area $S_{\text{tot}} = 1336 \text{ cm}^2$

SiPM covered $S_{\text{det}} = 0.72 \text{ cm}^2$ $f = S_{\text{det}} / S_{\text{tot}} = 0.0005 \rightarrow$ **PDE=0.34%**

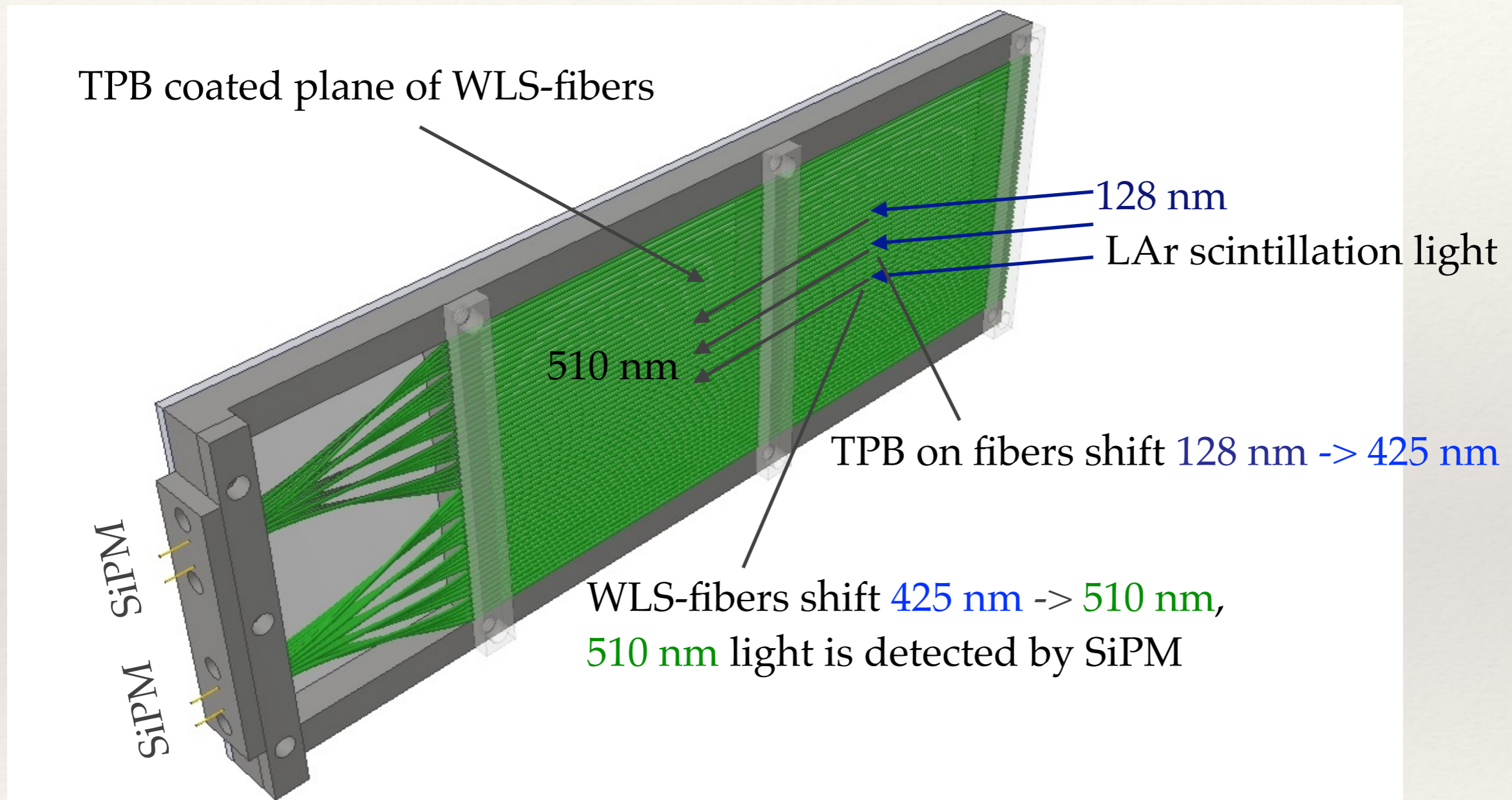
From 1 m away: solid angle $\Omega = 0.06$ (**worst case**)

LAr scintillation produces ~ 26000 photons/MeV @1kV/cm

1560 photons/tile $\rightarrow \sim$ **5.3 pe/MeV detected.**

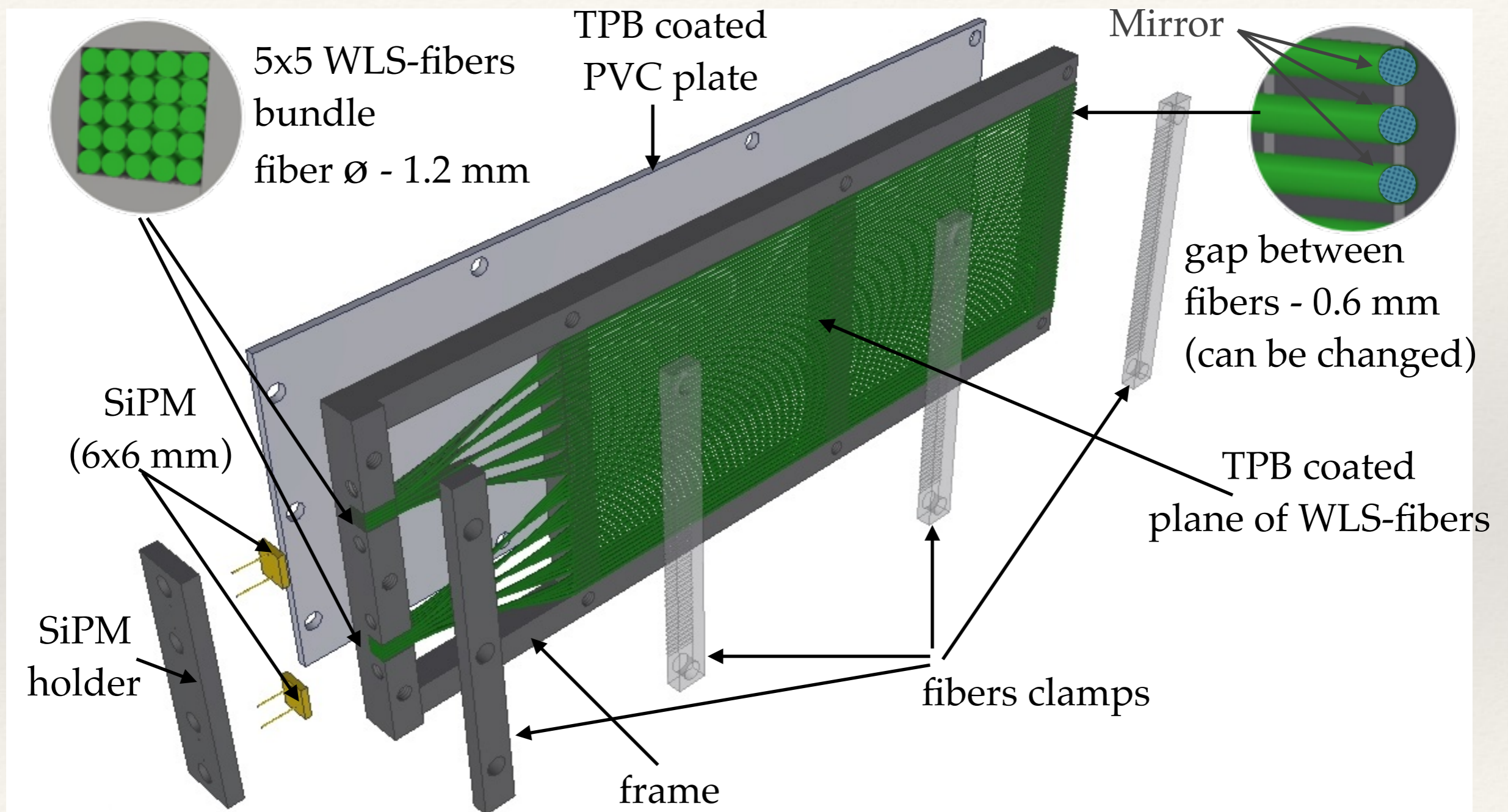
For **MIP 1 MeV \Rightarrow 5mm**, So we have **1 p.e. per mm of MIP track.**

Operation of WLS-fiber LCM



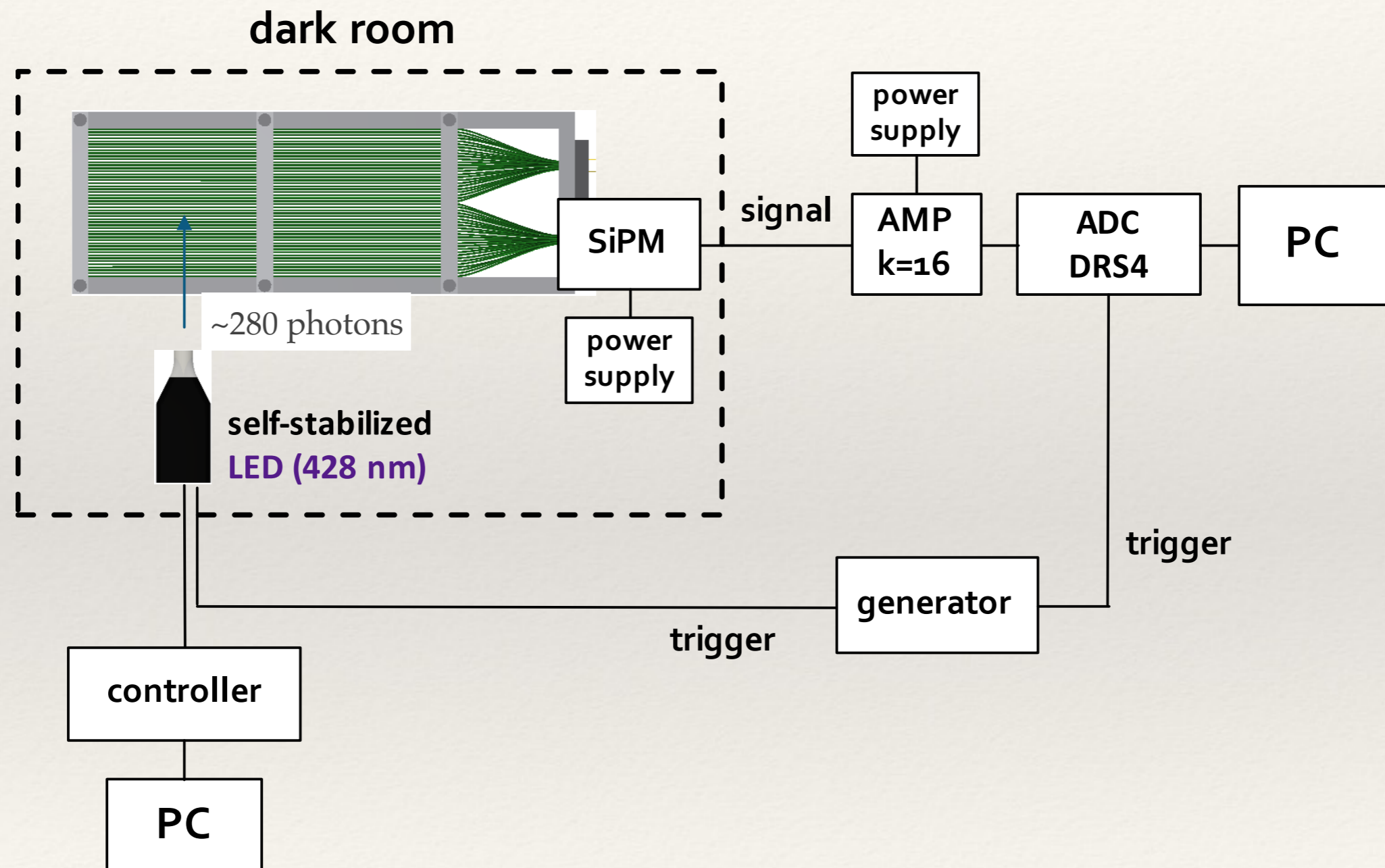
Fibers provide trapping efficiency at level of 5-7%

WLS-fibers LCM Design

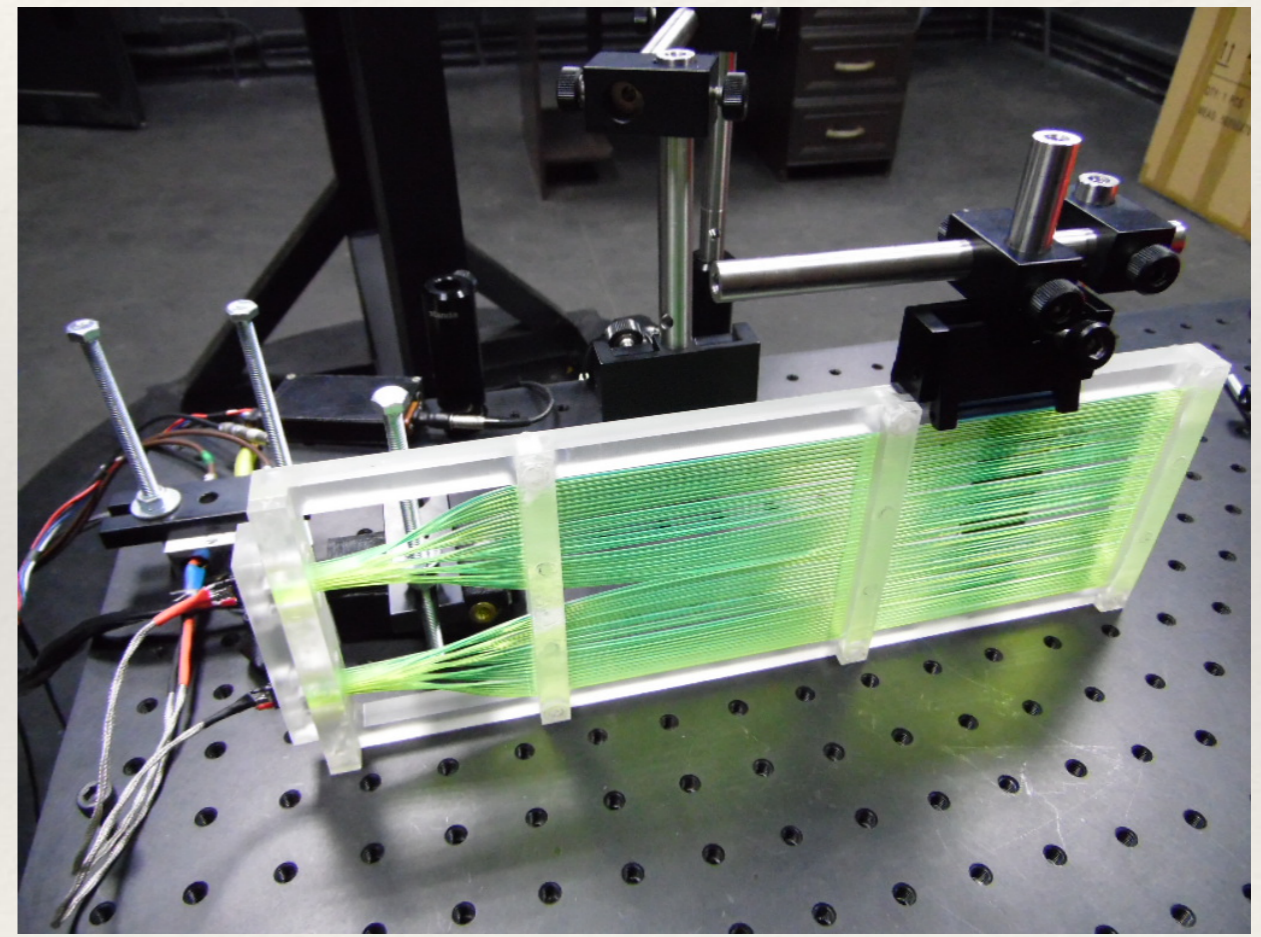
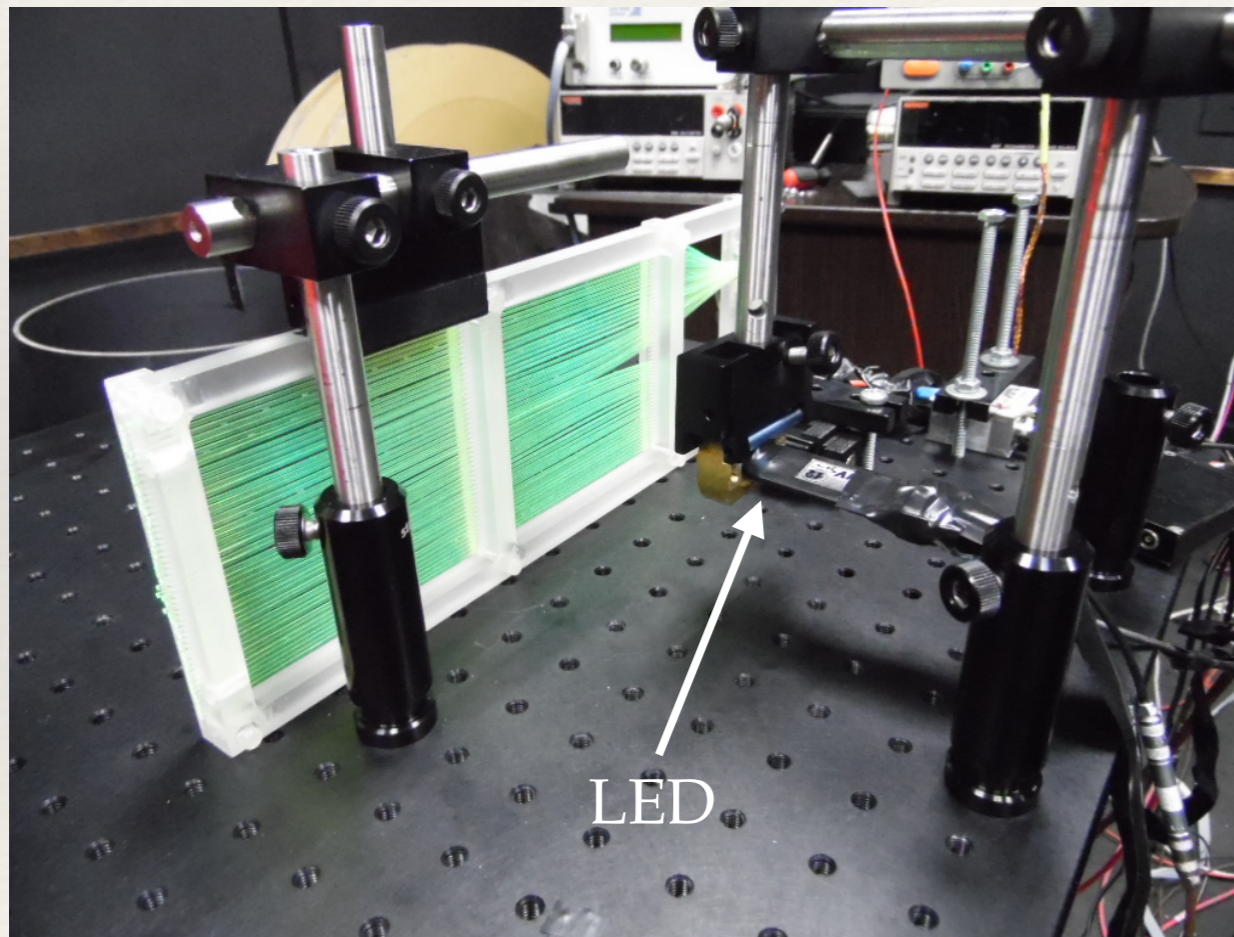


module size can be scaled easily
(for the first tests it has 30 cm length and 11 cm width)

Tests of LCM under room temperature conditions

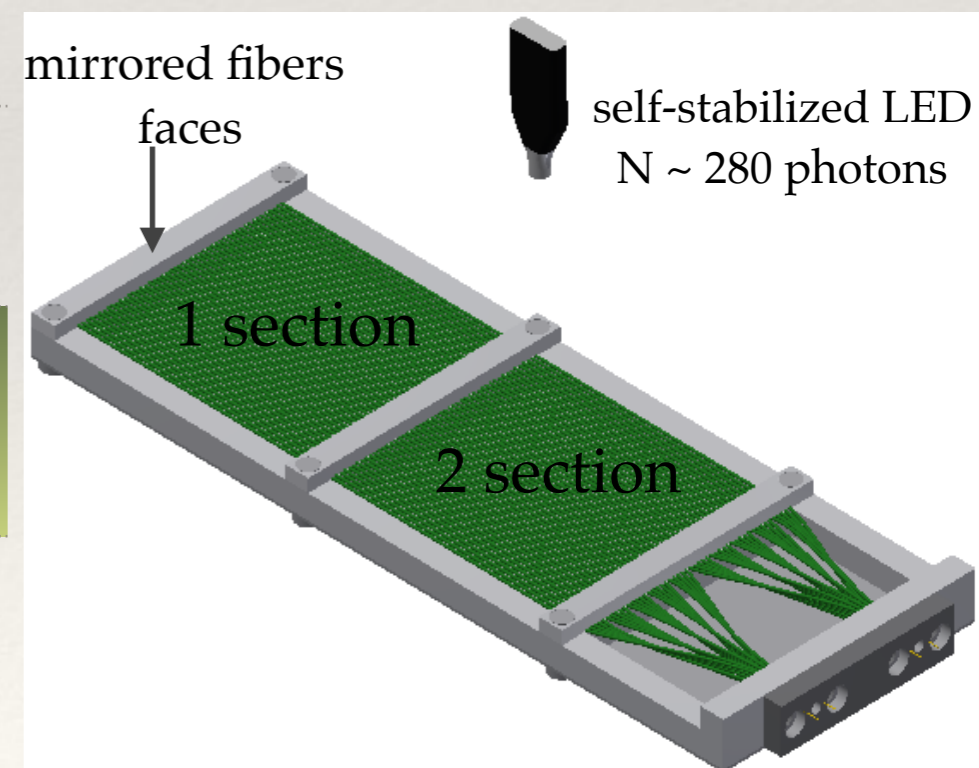
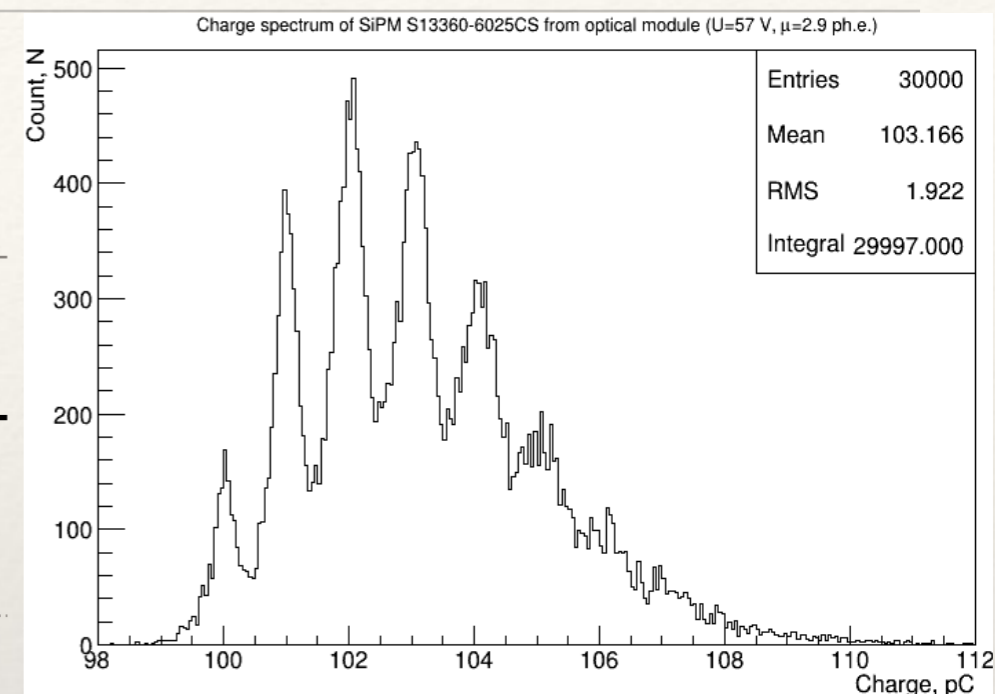


Tests of LCM under room temperature conditions



Performance of LCM under room temperature conditions

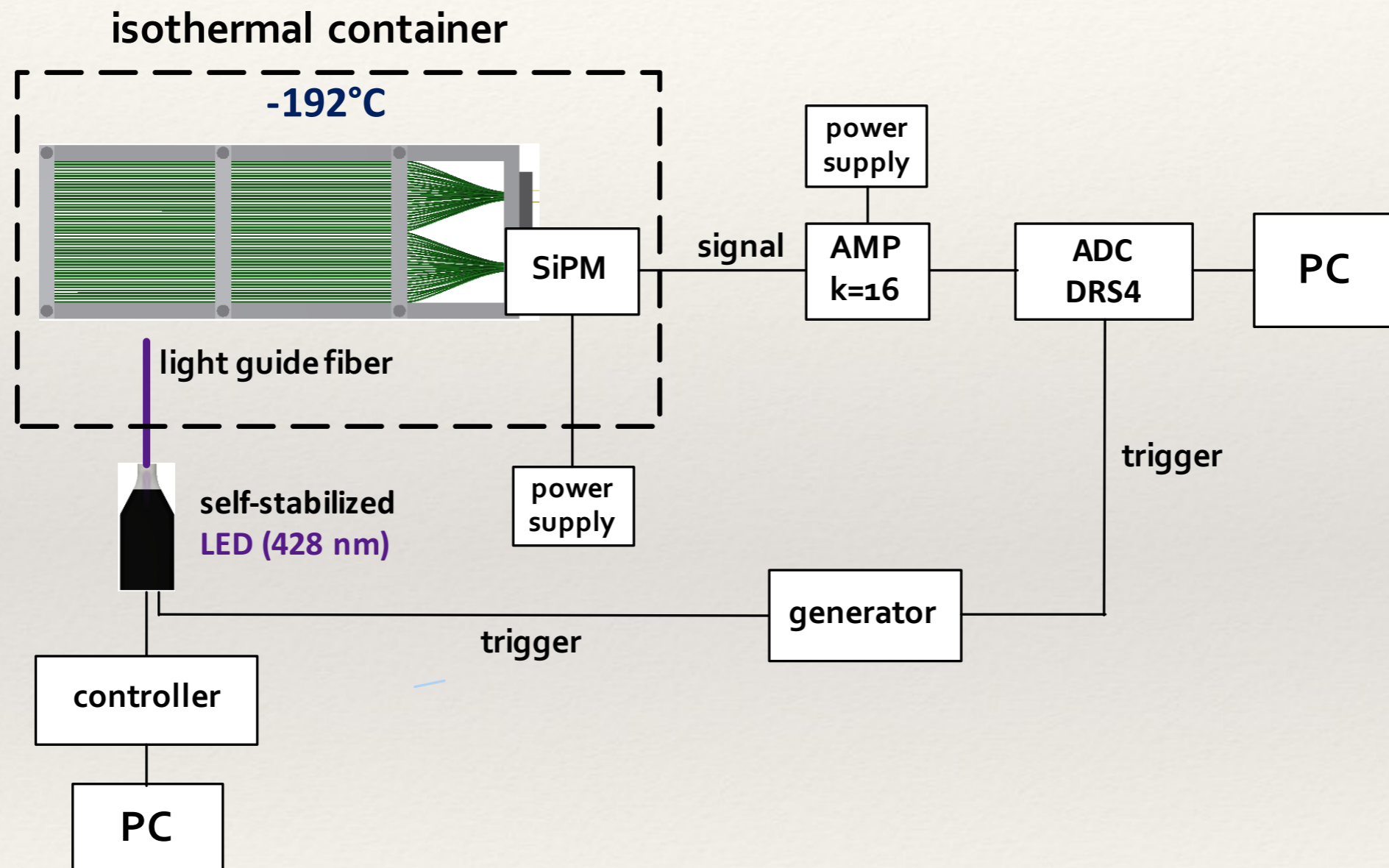
	1st section illuminated by LED		2nd section illuminated by LED	
	μ	LCM PDE, %	μ	LCM PDE, %
frame with fibers	2.07	0.74	2.36	0.84
frame with fibers + white PVC plate	2.85	1.02	3.14	1.12
frame with fibers + mirrored faces	3.45	1.22	3.55	1.26
frame with fibers + white PVC plate + mirrored faces	4.84	1.72	4.94	1.76
frame with fibers + mirrored faces + TPB	3.18	1.48	3.5	1.62



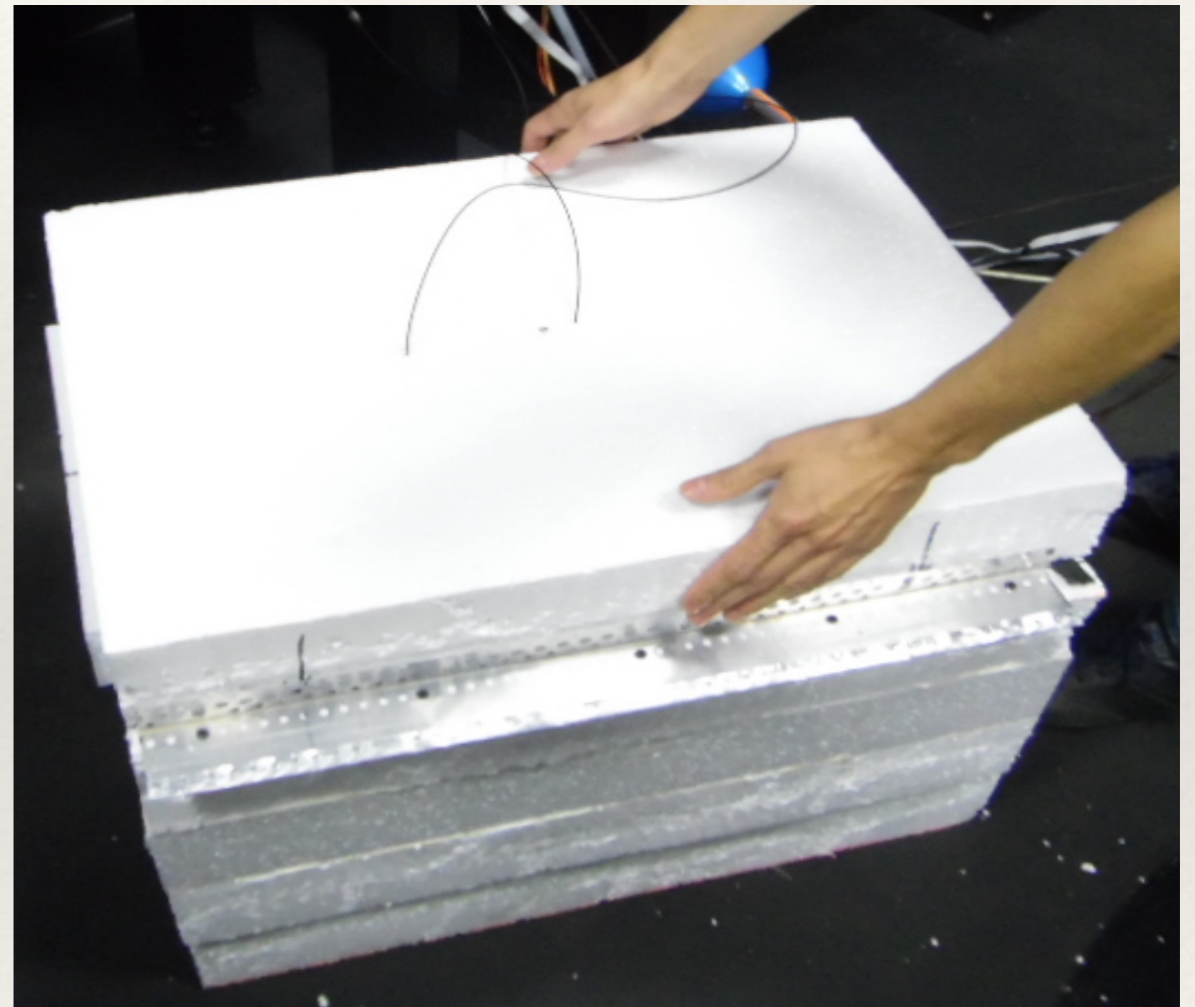
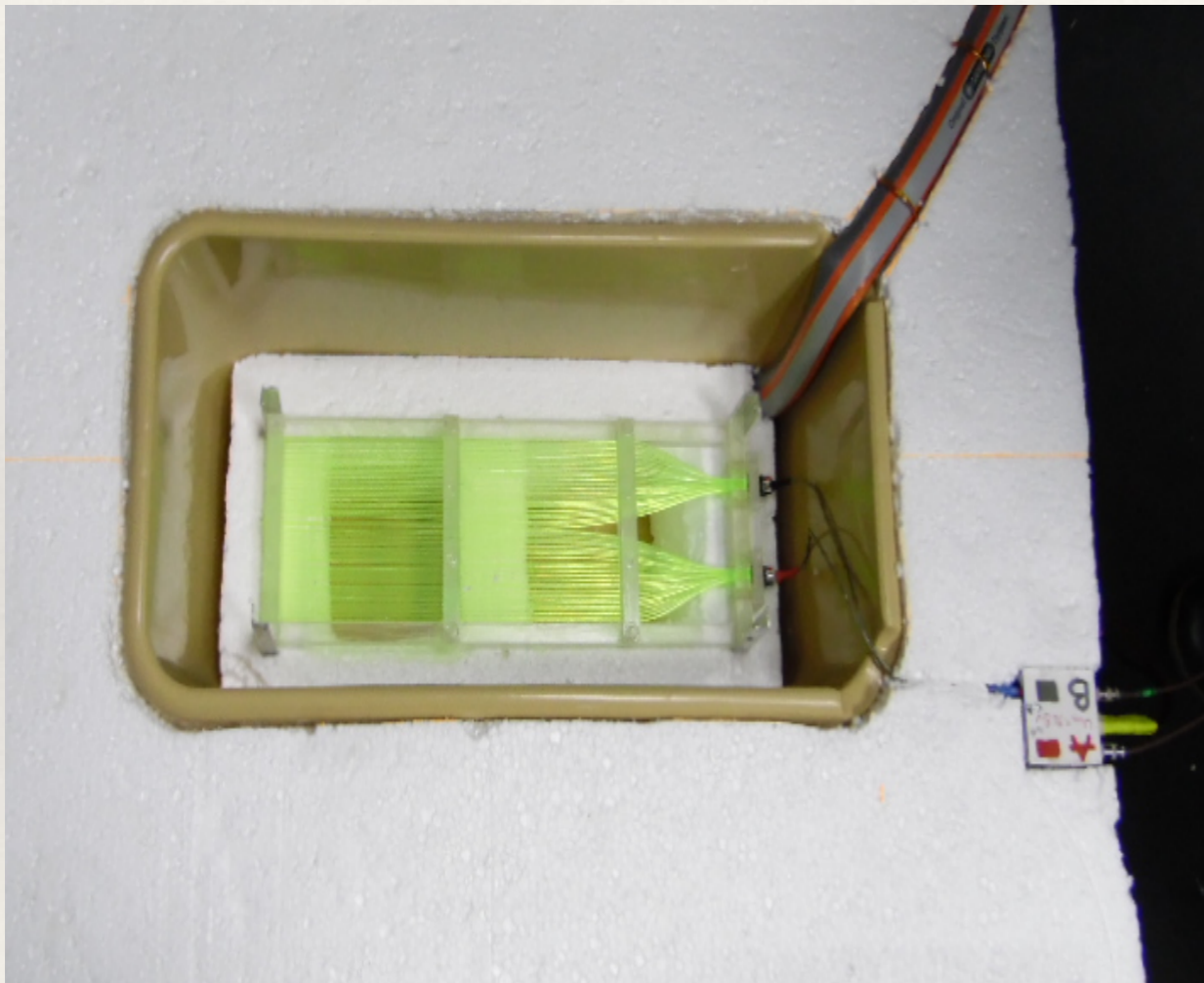
PDEMPPC = 24 %

15 If we use **PDE_{SiPM}=38%** then **PDE_{LCM}=2.8%**

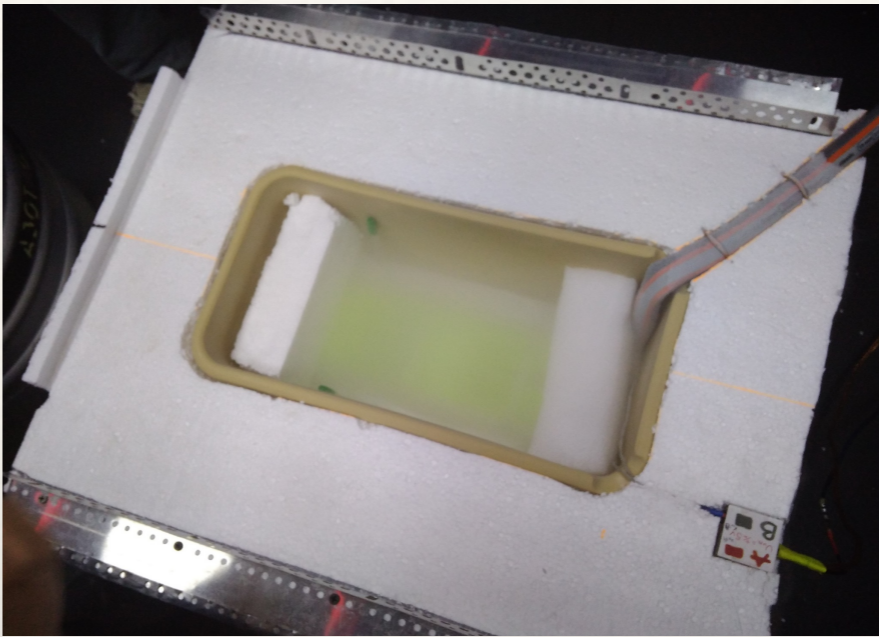
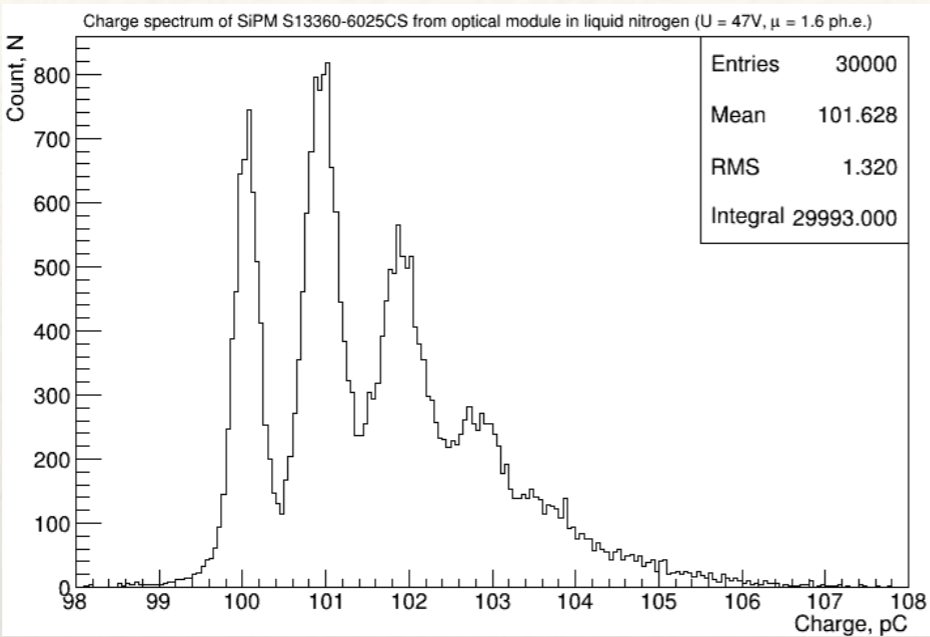
Tests of LCM under LN temperature conditions



Thermostat for LN-tests



Performance of LCM under LN conditions



$PDE_{MPPC} = 24 \%$ $PDE_{MPPC} = 38 \%$

	U, V	μ , p.e.	LCM PDE, % @425nm
frame with fibers + mirrored faces + TPB	46	5.57	1.99
	46.5	5.9	2.09
	47	6.16	2.19
	47.5	6.38	2.26
	48	6.58	2.34

LCM PDE, % @425 nm
3.15
3.31
3.47
3.58
3.71

$\epsilon_{tpb} = 0.7$

$PDE_{MPPC}(75\mu m) = 48 \%$
(MAX)

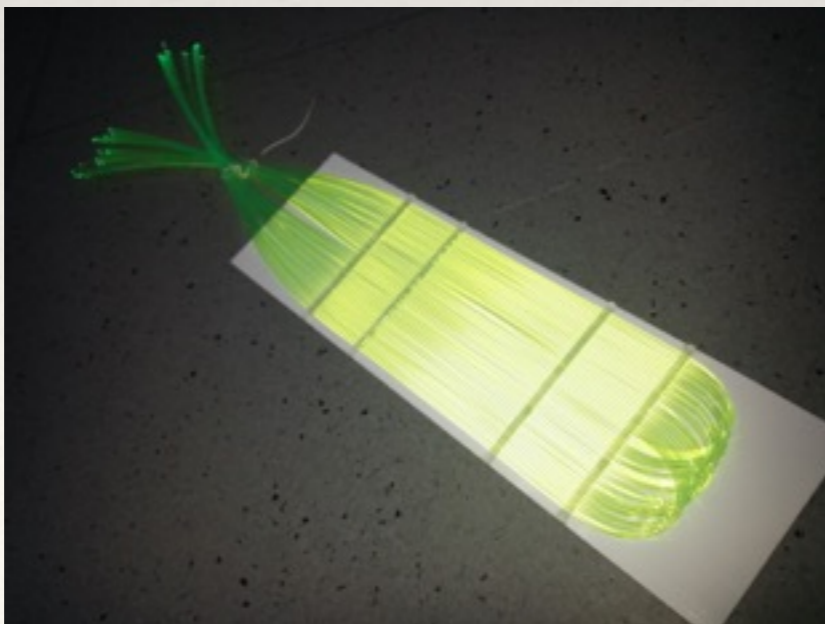
$PDE_{LCM} \sim 3 \%$ @ 128 nm
is achievable

18 So we can have > 5 p.e./mm of MIP track.

Conclusions & Plans

- ❖ ArCLight: more rigid, easy to assemble, compact, but less efficient (PDE) for large dimensions
- ❖ WLS-Fiber: easy to scale, higher efficiency, daedal design -> complex to produce, *compact solution?*
- ❖ Two prototypes have advantages and disadvantages -> combining might be an optimal solution
- ❖ Tests in Liquid Argon:
 - ArcLight - ongoing at LArIAT at FNAL
 - WLS-Fiber LCM at UniBe next days

Slim prototype of WLS-fibers LCM



ArCLight on pixel R/O plane in LArIAT

