Activities and status of the FD1 and FD2 PhCollectors

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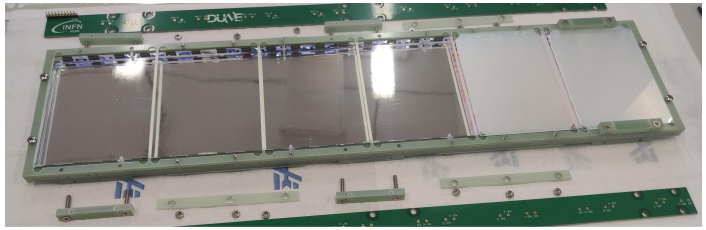
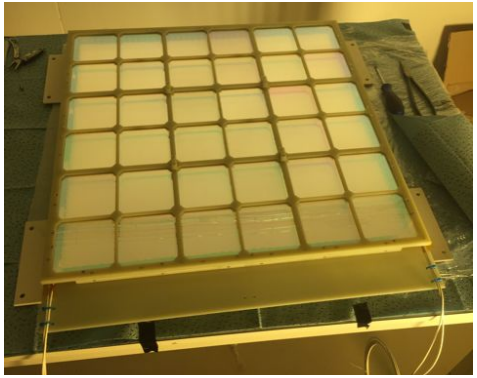
Summary



- FD1 & FD2 PhCollectors
- Contributions and activities
  - FD1
    - HW Contributions
    - Assembly and test of 47 XA units for pDUNE RunII
    - Main results
  - FD2
    - HW Contributions
    - Features of the Cold Box prototypes
- Preparation for Module-0
  - Mechanics
  - WLS lightguides
  - Dichroics
- Conclusions



An FD2 PDS Units

Features of the VD vs HD PDS Module

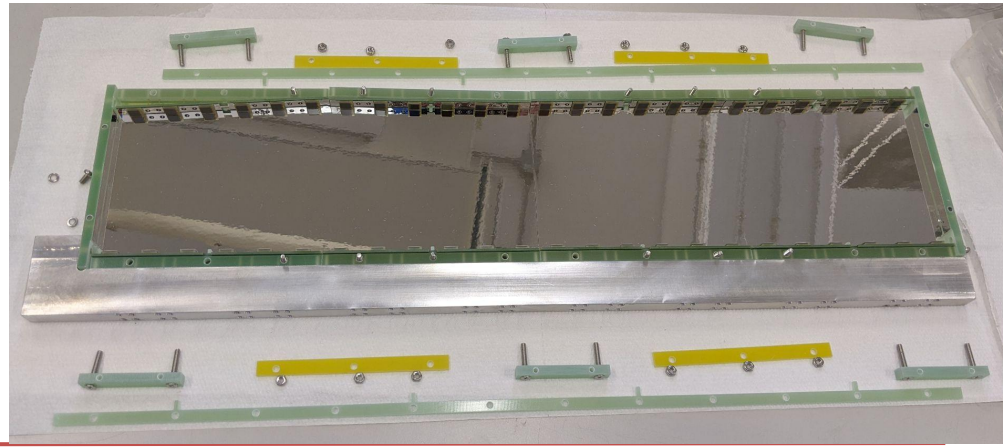
	HD PhCollector	VD PhCollector	VD/HD
Size of the WLS/Phcol	48 x 9.5 x 0.4 cm^3	62 x 62 x 0.4 cm^3	8.6
Number x Size of the dichroics	6 x (10 x 7.7) cm^2	36 x (9.7 x 9.7) cm^2	9
SiPM Coverage	3.9%	1.5%	0.4
SiPM boards Routing boards (RB)	Rigid FR4 integral to frame + RB	Kapton Flex integrate SiPM support & RB	-
SiPM contact to WLS at cold	Absent (~1 mm gap opens at cold)	Glue/ Springs compensated	

FD1: pDUNEII - SC Assembly and Test at Milano Bicocca

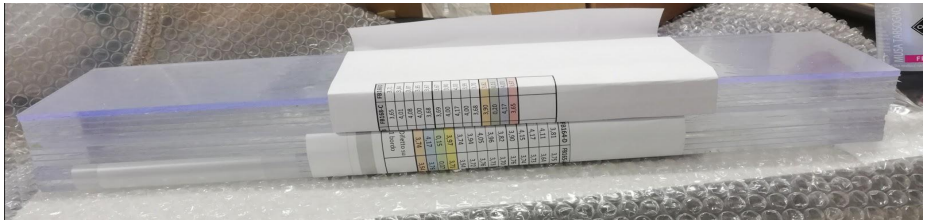
- From March to July 2022: Assembled and tested **47 Supercells (SC)** with **4 different configurations**. Timing driven by parts delivery (SiPMs, mech.frames).

WLS \ SIPM	_H: Hamamatsu	_F: FBK
_G: Glass to Power	_H_G: 17 units	_F_G: 12 units
_E: Eljen	_H_E: 6 units	_F_E: 12 units

- 2/3 people full time
  - C. Brizzolari
  - L. Meazza
- 3/4 people part time
  - C. Massari
  - M. Perego
  - C. M. Cattadori
  - A. Falcone



The WLS production for the HD



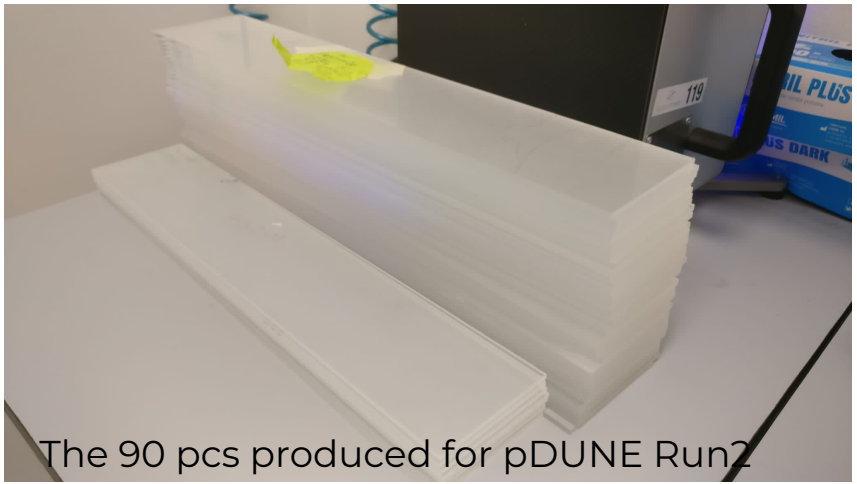
The 12 prototype HD-XA WLS produced in 2020-2021 by ScMat and tested at INFN-MiB. Funds from LEGEND

For HD, two manufacturers

- Eljen (PVT /PS based WLS)
- Glass to Power (PMMA based WLS)

Glass to Power (our industrial partner)

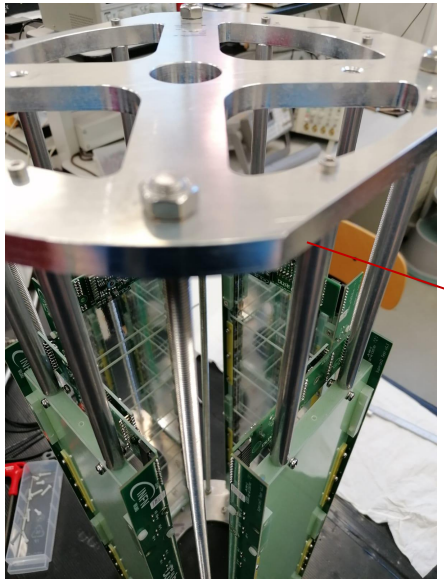
- July 2021: completed the production and late August delivered to UniCamp 90 pcs for the HD pDune Run2 in 2022.



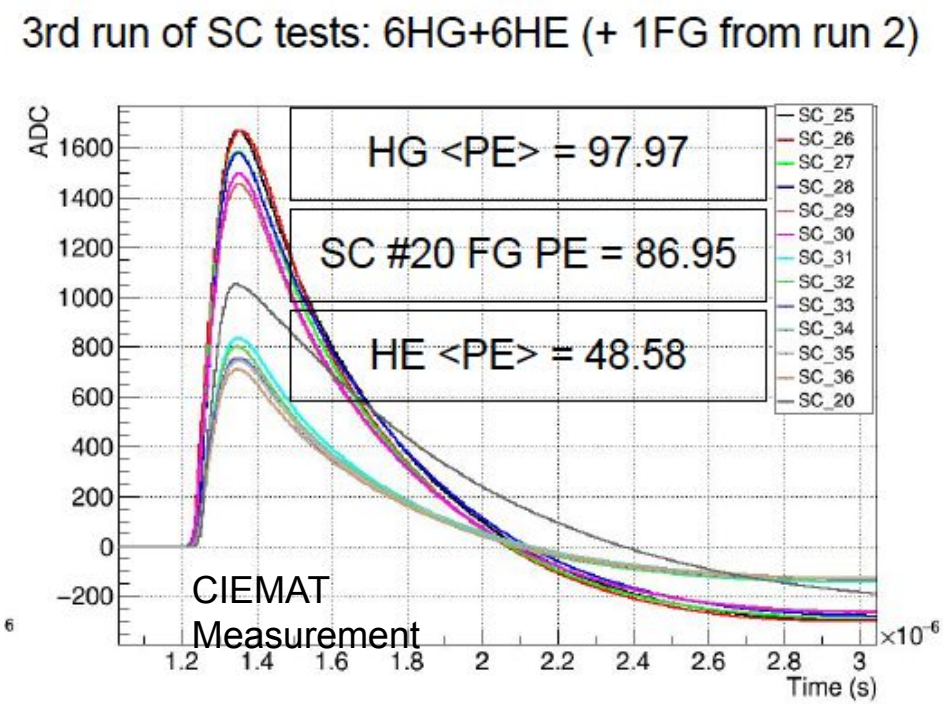
The 90 pcs produced for pDUNE Run2

FD1: Test of pDUNEII XA-SC

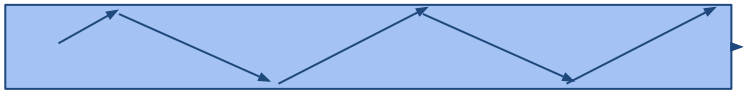
- 4 XAs measured at once inside a light tight dewar. LED source flashed. Operated in EMI shielded cabinet.
- Warm&Cold Electronics as in pDUNE
- SCs & Cold amplifiers submerged in LN2. Warm ampli x 4 SC
- DAQ: CAEN Single Ended, 4 ch digitizer (12bit, 250MHz)
- Measured Gain, SN,DCR @each SC
- Cooling/Measurements/Warming up cycle: 1-2 days (at regime). Warming in a glove box in Nitrogen flow
- Cleaning of parts: demi-water and isopropilic



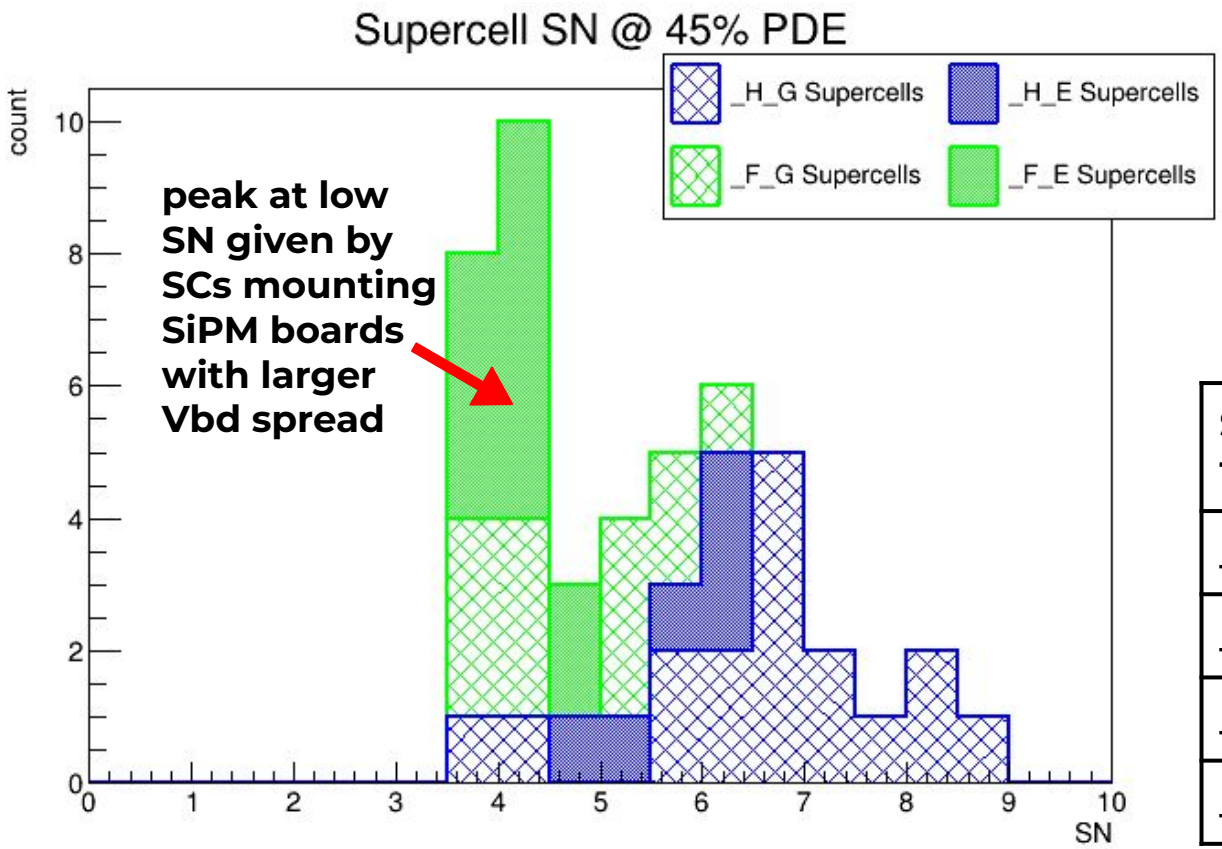
All the FD1-XA SC equipped with G2P WLS, showed ~ twice the light, when flashing the LED at several p.e.



- HG/HE~2 (LED@420nm)
- better flat surfaces driving the ph. to SiPMs



FD1: SN SuperCells distribution

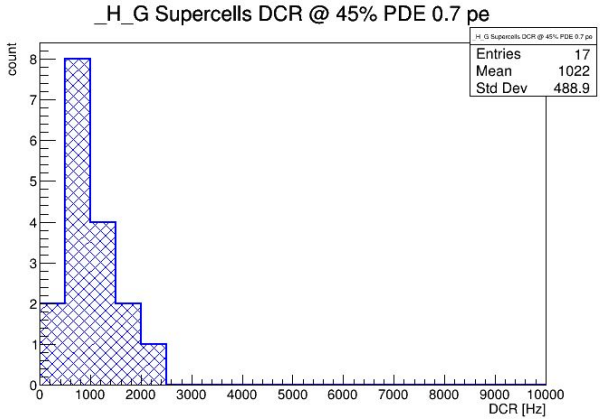


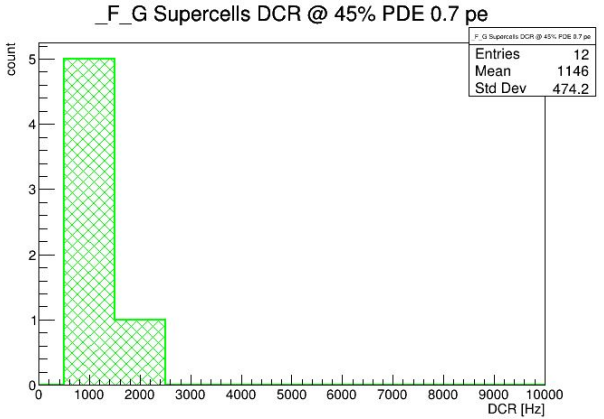
- SN1 > 3.5 for ~all SCs
- SN [HPK SCs] > SN [FBK SCs]
- observed large SN reduction in SCs having a large (or unknown) Vbd difference among SMBs

SC type	SN1 mean	SN1 std dev
_H_G	6.68	1.29
_H_E	5.76	0.56
_F_G	4.83	0.82
_F_E	4.21	0.35

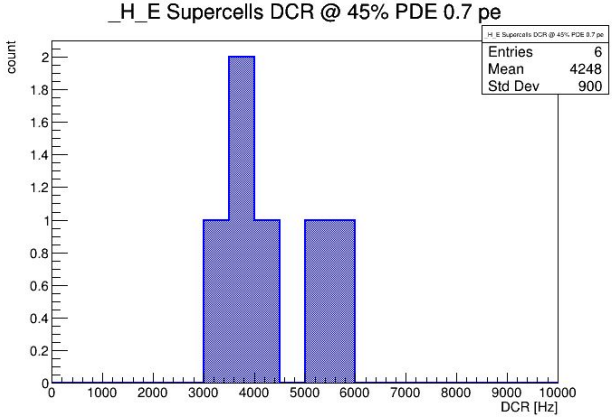
FD1: DCR SuperCells distribution

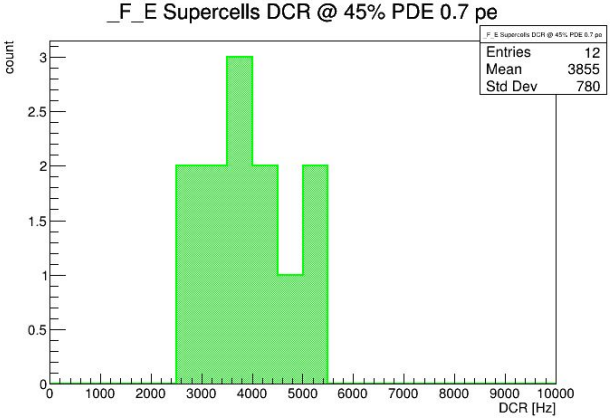
All the G2P SC satisfy the DCR requirement (~1kHz)





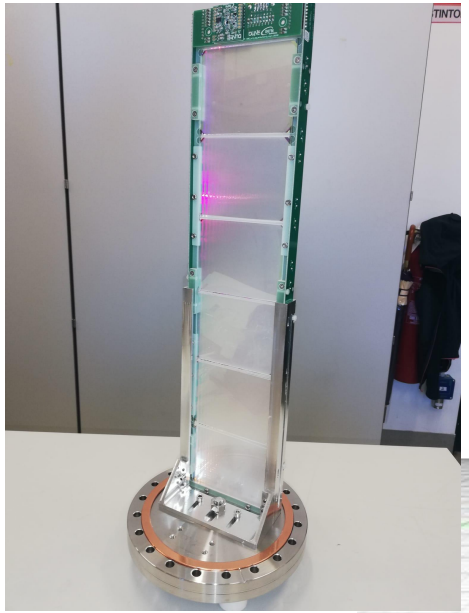
All the ELJIN SC (DCR~4KHz) do not satisfy the DCR requirement

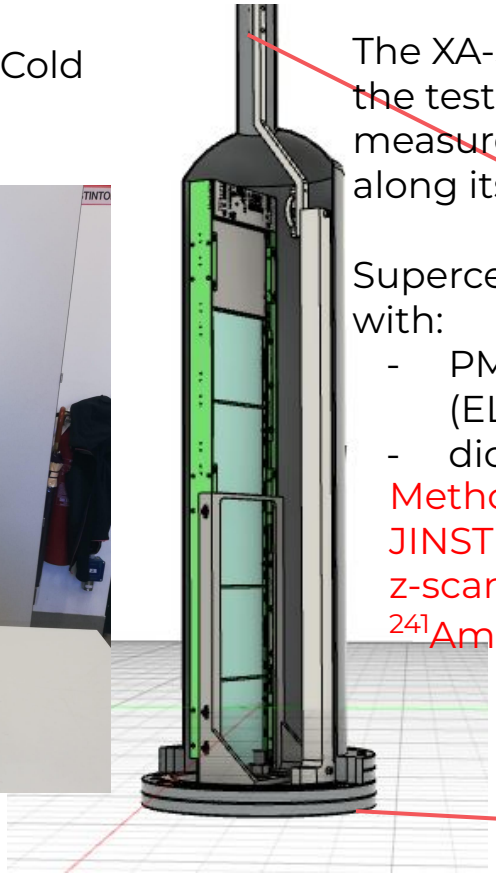




Setup to measure the XA-HD-SC PDE in LAr

The XA-HD-SC w. Cold FE circuit (top)





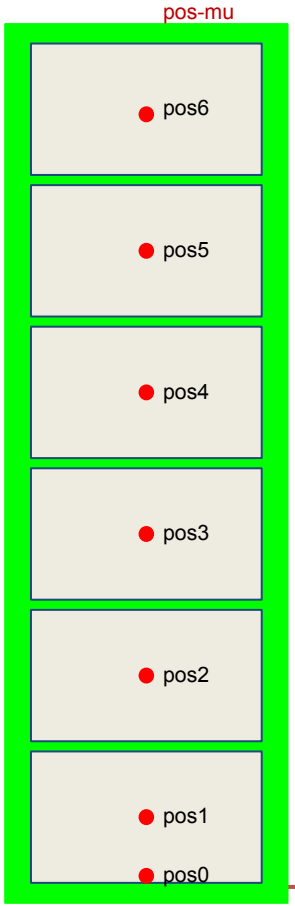
The XA-SC installed in the test chamber to measure the PDE along its z-axis.

Supercell equipped with:

- PMMA WLS (ELJ&G2P)
- dichroic filters

Method as published in JINST 16 (2021) 09027: z-scanning with an ^{241}Am exposed α source

Method & Data taking



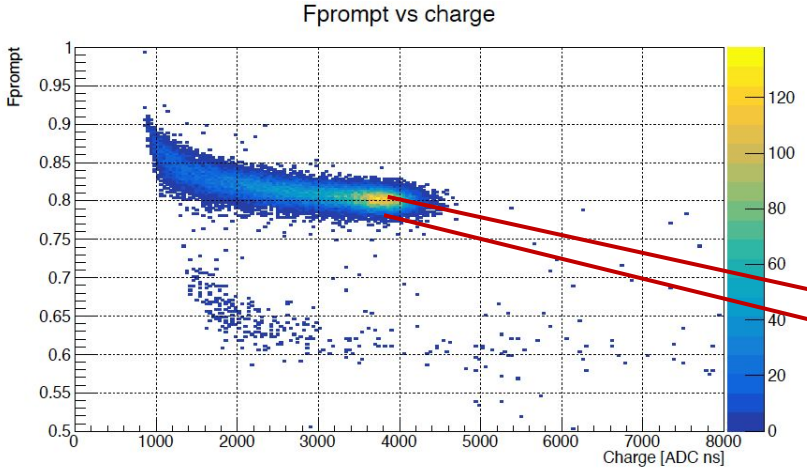
z-scanning of the SC with the ^{241}Am α (5.480 MeV) source at the following positions:

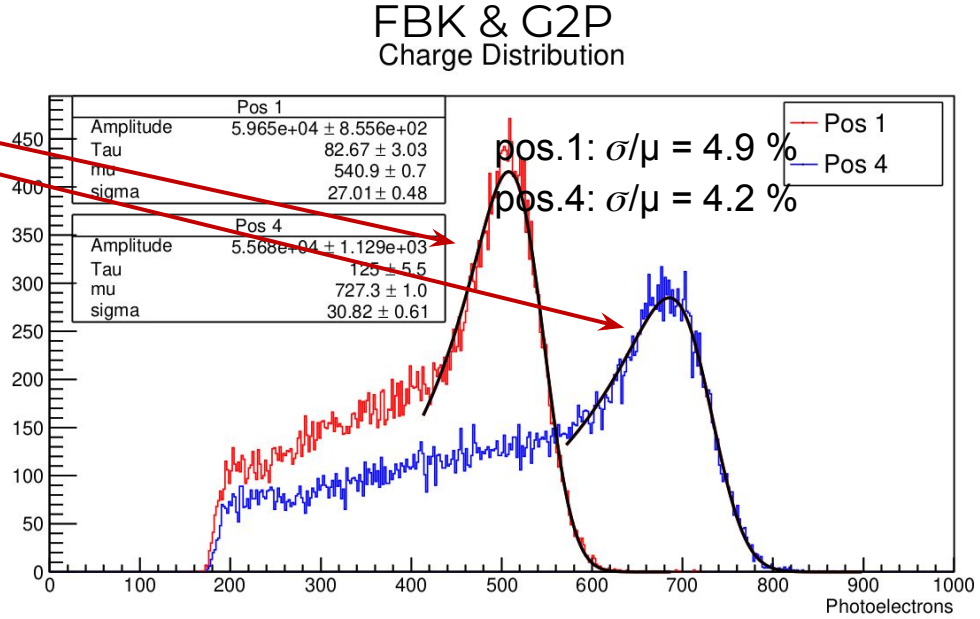
1. **pos0**: (the lowest possible): ~2 cm above the flange.
2. **pos1, 2, 3, 4, 5, 6**: the center of each dichroic filter.
   Acquired: 10^4 x 4 wfms; 20 μs length; ~5 μs pretrigger.

3. Source at the topmost position (~49 cm from the flange) and ~ out of LAr:
   - one **μ run** (10^4 x 4 events; 20 μs, 5 μs pretrigger)
   - one **s.ph.e. run** (10^4 x 8 events; 20 μs length; 1.6 μs pretrigger)

Source-to-dichroic filter distance: (55 +/- 1) mm.

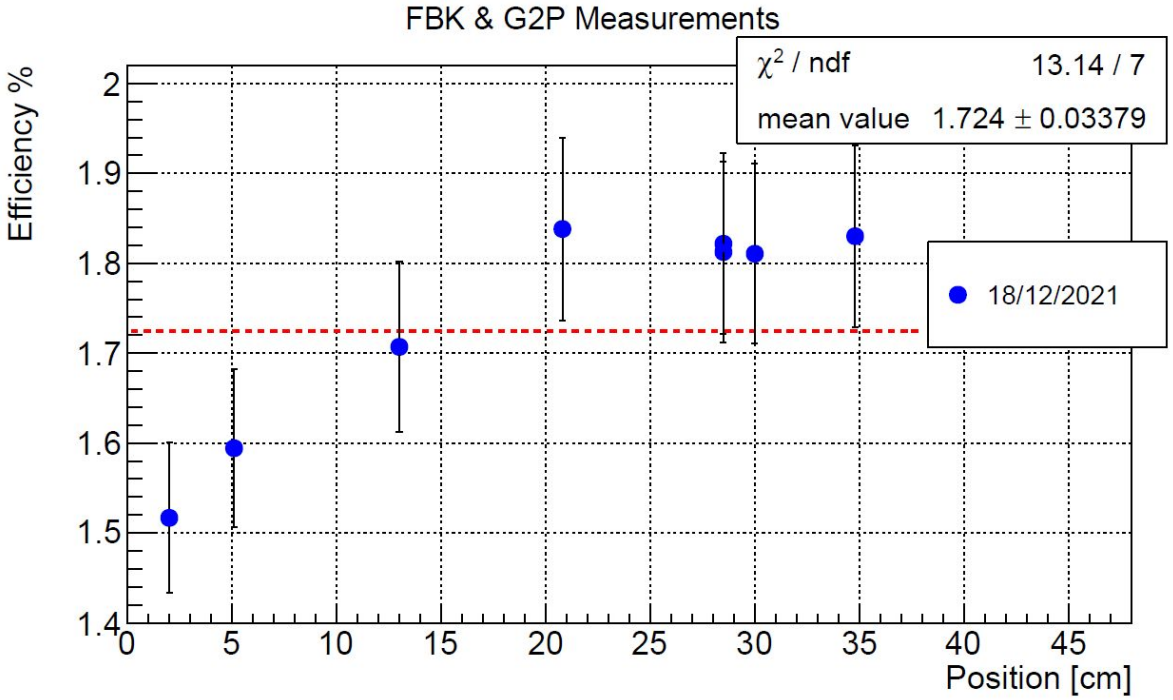
N. of detected PE from the calibrated alpha spectra





Example of Efficiency results: FBK & G2P

$$\epsilon = \frac{4\pi \cdot \alpha \ \mathrm{peak(ADC)}}{\mathrm{s.ph.e.(ADC)} \cdot f_{int} \cdot \mathrm{LY_{LAr}} \cdot \mathrm{En}_{\alpha} \cdot \mathrm{q}_{\alpha} \cdot \Omega}$$



LY_{LAr} = 5.0 E+4
q_{α} = 0.7
En_{α} = 5.480 MeV
f_{int} = 0.86

No X-talk and LAr purity corrections

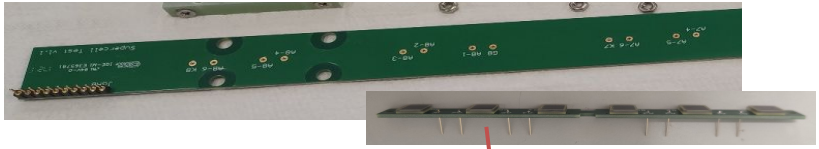
Efficiency: X-talk and P_{LAr} corrections

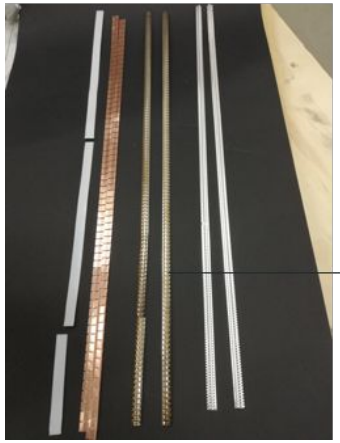
		OV	PDE	Uncorrected ε_{XA}	Measured Xtalk	P_{LAr}	Position systematic	Corrected $\varepsilon_{XA\ x\ talk\ only}$	Corrected $\varepsilon_{XA\ x\ talk\ and\ P\_LAr}$
this work	HPK** & G2P	3.0V	50%	1.94 (0.03)	6.62%	TBD	0.08	1.82 (0.08)	
	FBK*** & G2P	4.5V	45%	1.72 (0.03)	15.7%	1.06	0.10	1.49 (0.10)	1.58 (0.10)
	FBK*** & Eljen	4.5V	45%	1.50 (0.02)	15.7%	TBD	0.06	1.29 (0.07)	
JINST work	HPK commercial*	2.7V	45%	3.5 (0.1)	22%	1.02		2.9 (0.1)	

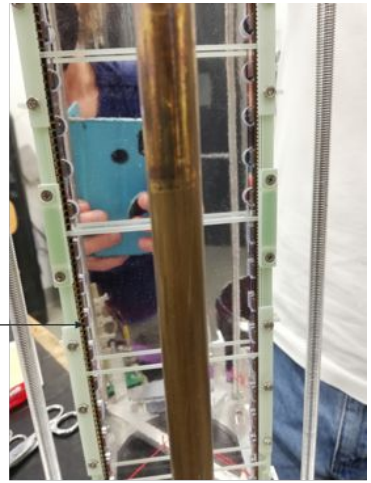
* S14160-6050HS (6 × 6) mm^2, 50 µm
** 75um-HQR
*** Triple Trench

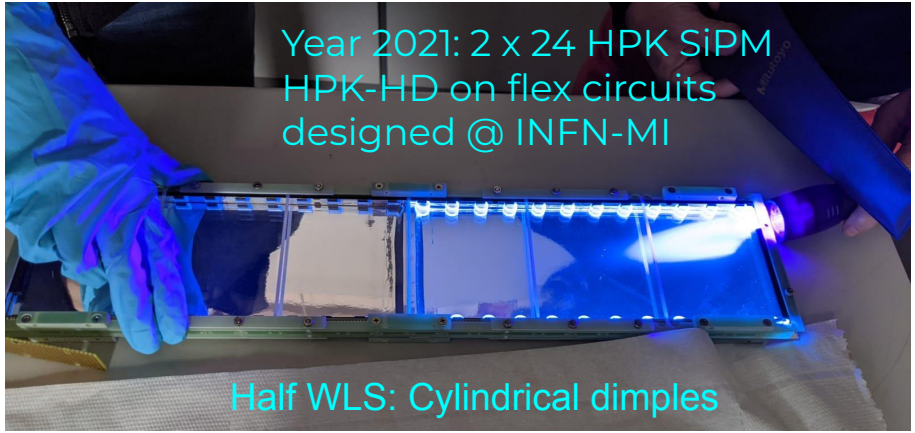
$$P_{\mathrm{LAr}} = \left(0.77 + 0.23 \times \frac{\tau_T}{1414\ \mathrm{ns}}\right)^{-1}$$

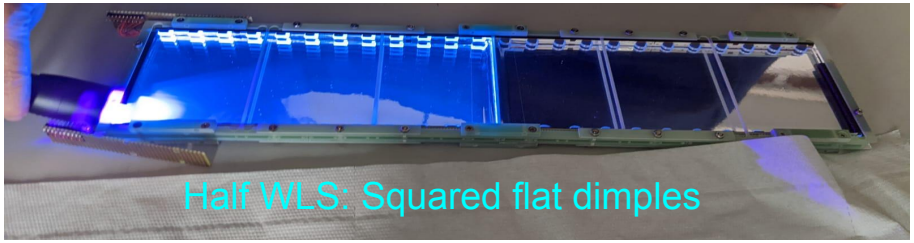
Optimization of the SiPMs-WLS Optical contact: SiPMs on flex, WLS with dimples, springs strips to compensate the WLS shrinking at cold







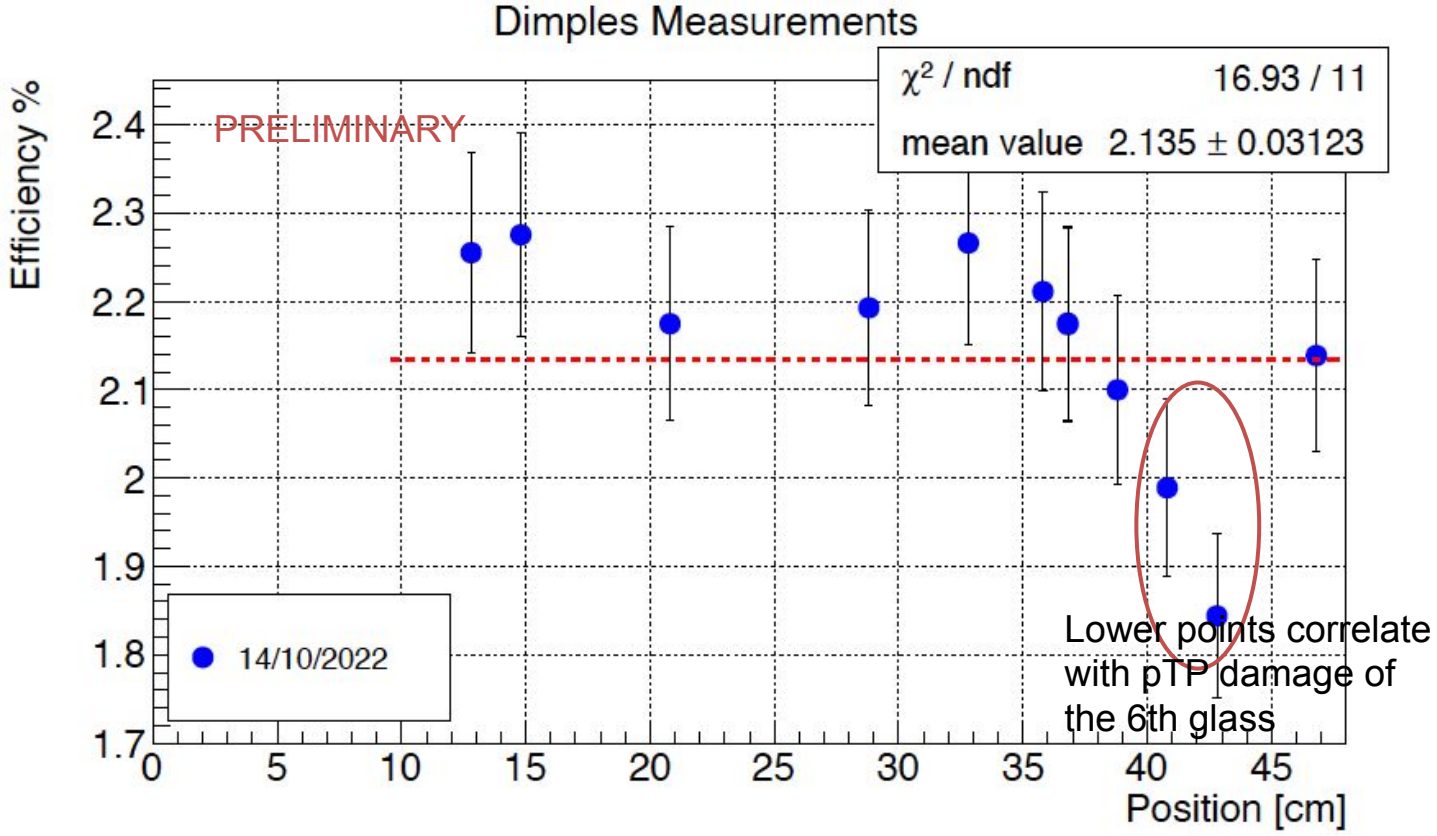




FD1: PDE per XA con SiPMs on flex and springs back-contacts

→PDE enhancement: wrt rigid boards-no dimples ~10%

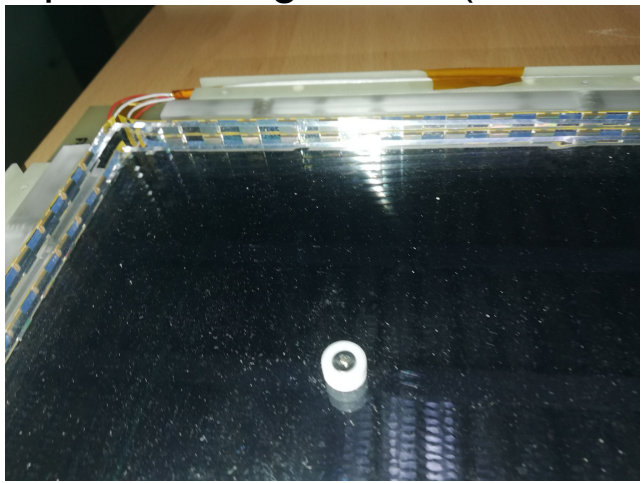
→ no difference between flat and cyl dimples

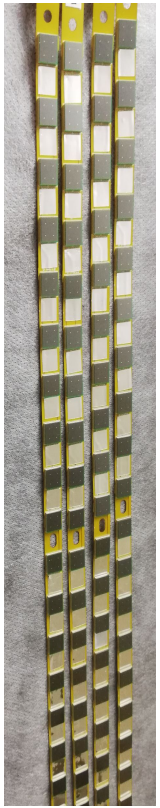


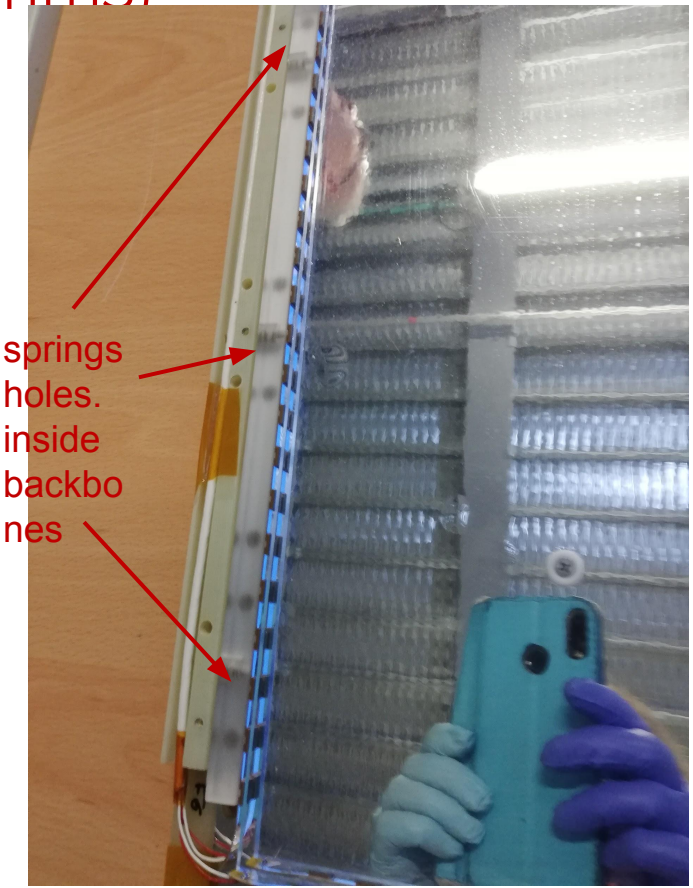
FD2: The five prototypes

FD2: The Mega XA Cell (600 x 600 x 4 mm3)

- Mechanics: US (CSU,Iowa, NIU)
- WLS: Italy (G2P): 5 large tiles
- SiPMs: US, (Italy, Spain)
- Flex circuits: US
- Dichroics: Italy, Spain
- pTP coating: Brazil (UniCAMP)







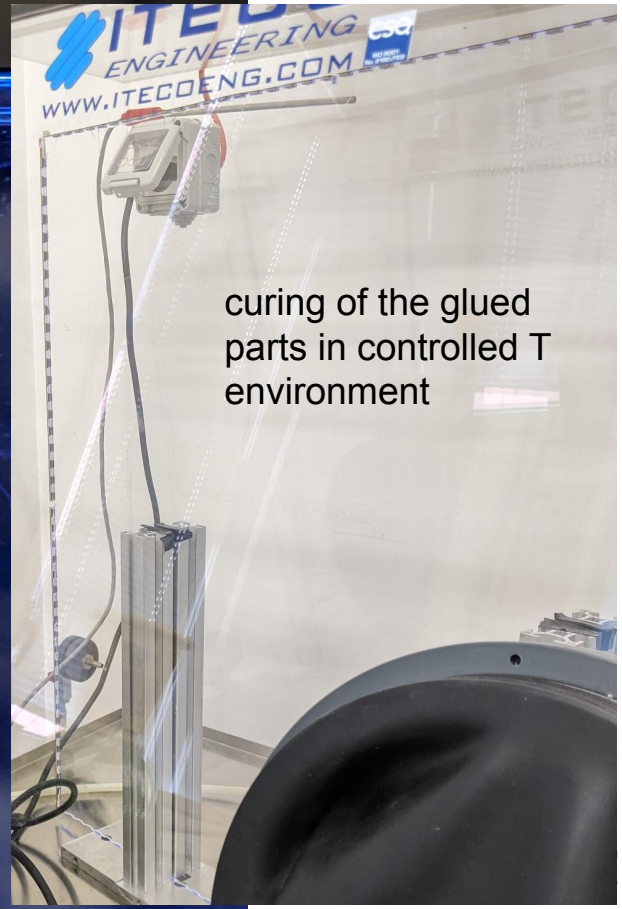
The PhCollectors for the ColdBox prototypes

- In 2022 an intense CB program aiming to integrate all the detector parts and CE (PoF bias, and SoF Readout)

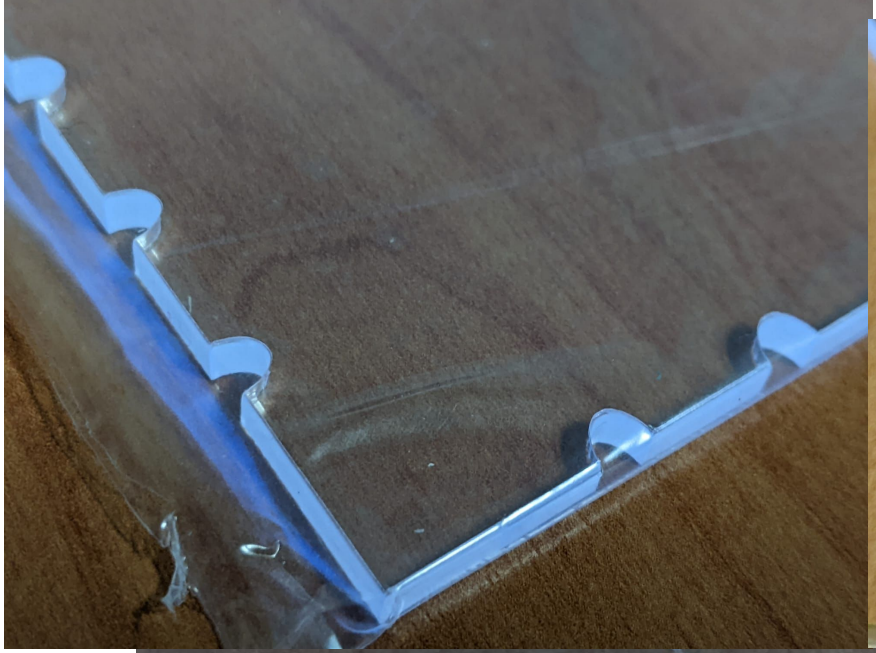
- No PDE info can be extracted from these tests: PDE will be measured in Naples (see N. Canci talk)

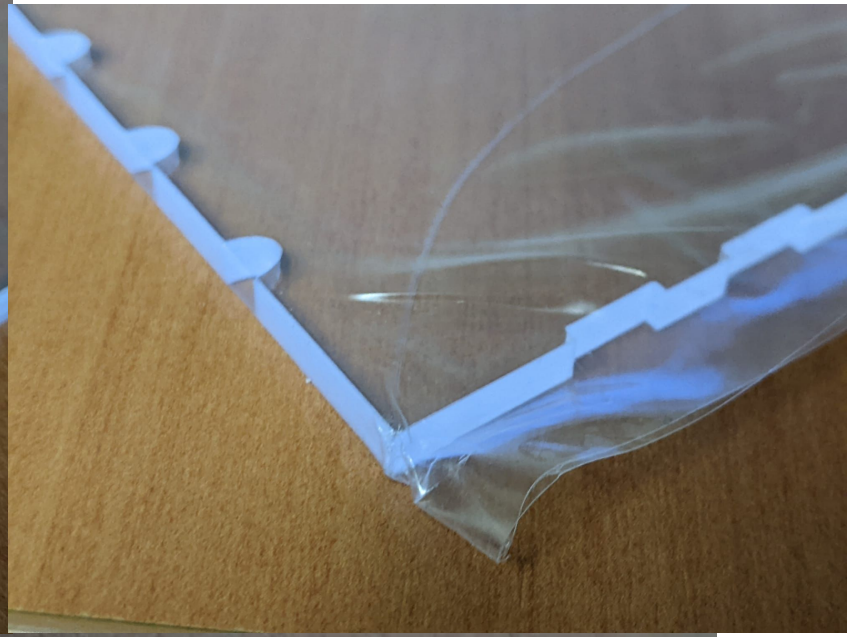
- All the prototypes compensate the WLS shrinking at cold (~6 mm) with SiPMs on flexes and springs back-pushing the flexes
  - v1 deployed in summer 2021, (WLS flat, SiPms on flexes, Springs)
  - v2, v3 deployed in summer 2022 (WLS flat dimples, SiPMs glued/springs)
  - v4,v5 deployed in October/November 2022 (WLS flat/cyl dimples, SiPMs on flex, springs)
  - mechanics for Module-0 defined

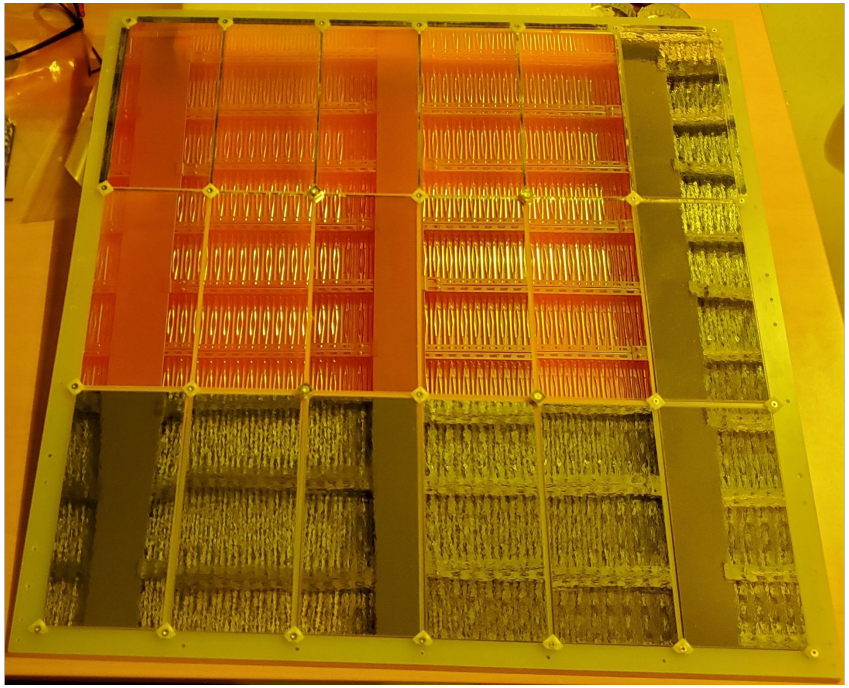
v3: 4 SiPMs glued (with some imperfections)

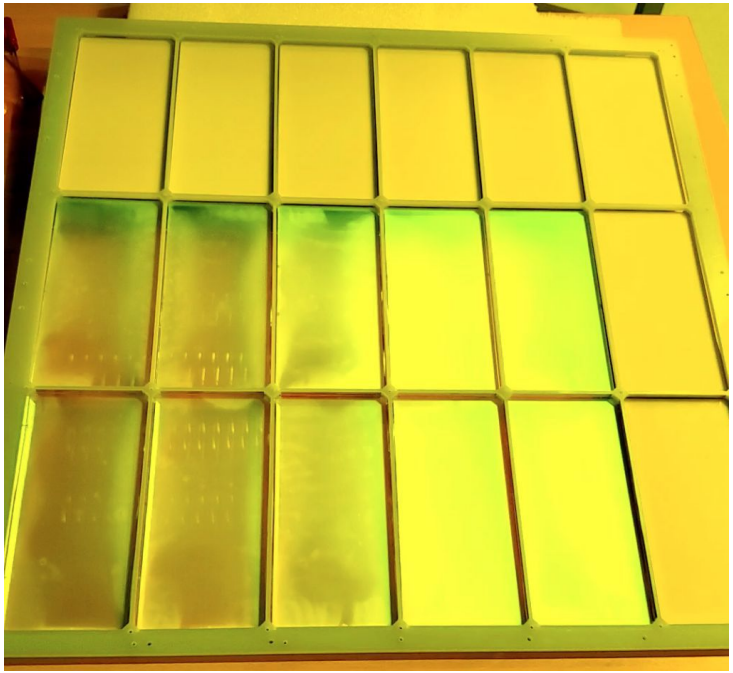


curing of the glued parts in controlled T environment









Ph Collectors for Module-0

- Module-0:
  - 16 XA Units (8 on Cathode, 8 on Membrane)
    - 2 membrane upstream units December 2022
    - 4 cathode units in January 2023
    - 2 membrane downstream January-February 2023
    - 4 cathode downstream units January-February 2023
    - 4 bottom membrane (temporary re-use of CB materials) March 2023
- INFN Contributions
  - 16 + spares WLS tiles 607 x 607 x 4 mm3 will be delivered in one batch (end November 2022)
  - 230 dichroics (202 x 97.5 & 143 x 143 mm2) will be delivered in two/three batches

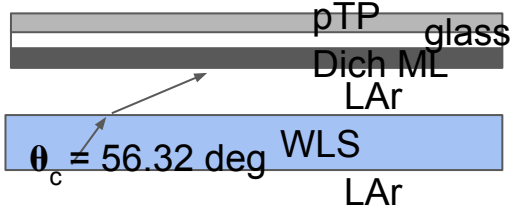
The structure of a Dichroics filter based on Dielectric Multi Layer (DML)

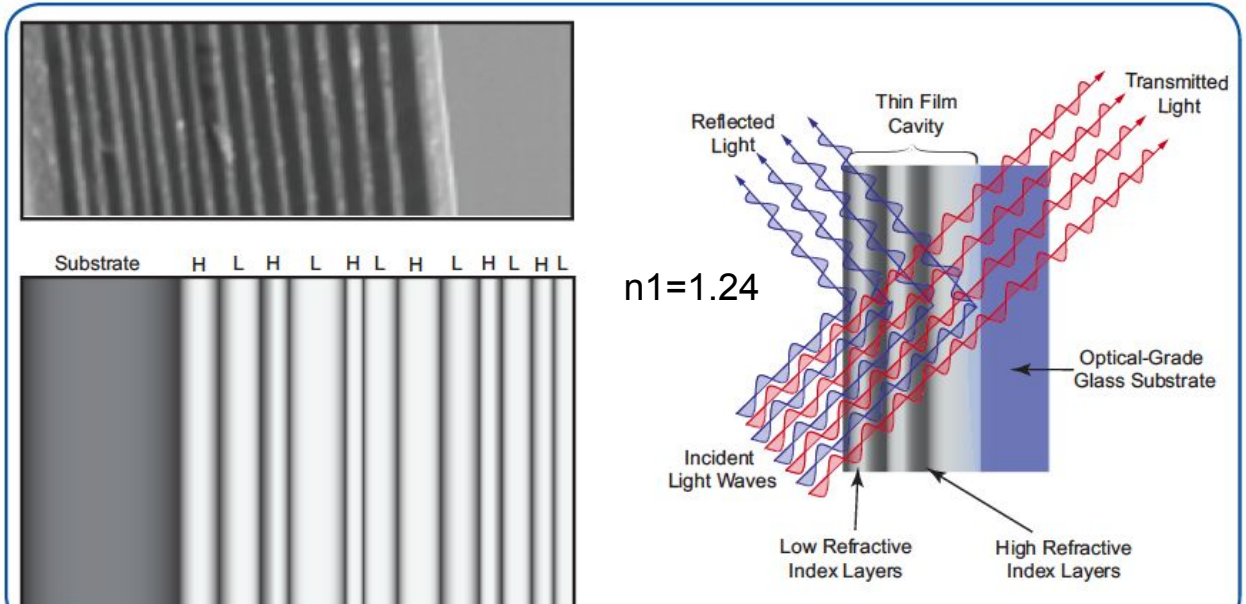
- $Reflectivity: \varrho^2 = \left|\frac{n_1 - n_2}{n_1 + n_2}\right|^2$

- $Cutoff\ dependency\ from\ refraction\ index$

$$\lambda = \lambda_0 \sqrt{1 - \frac{n_1^2}{n_2^2} \sin\theta^2}$$

Dichroics role is to bounce back the photons escaping the WLS, that due to the difference in n_{refr} are refracted at larger angles

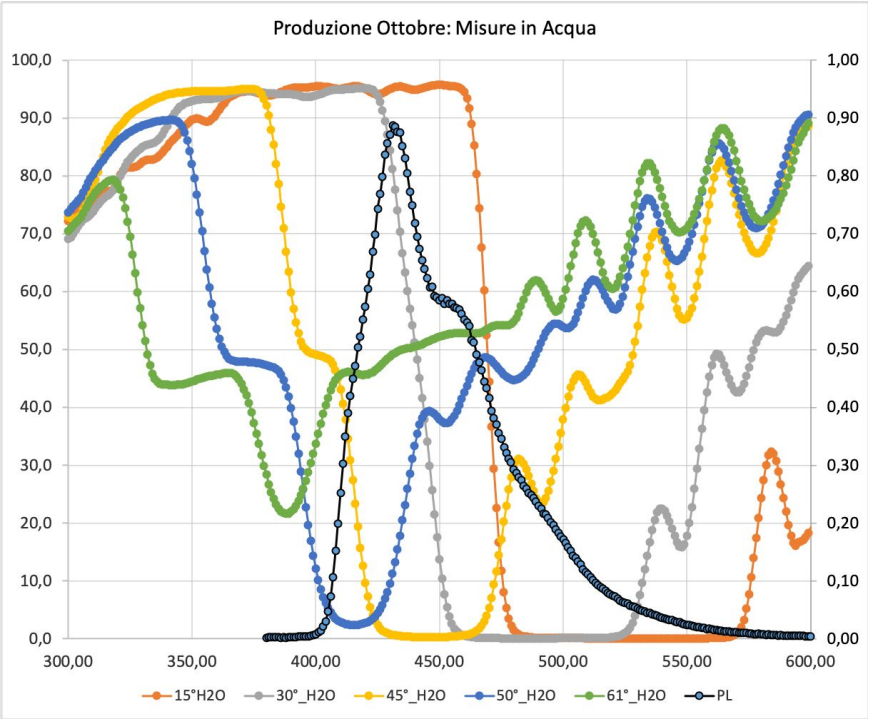


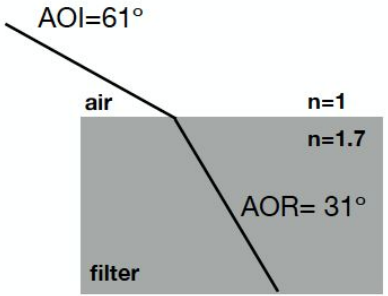


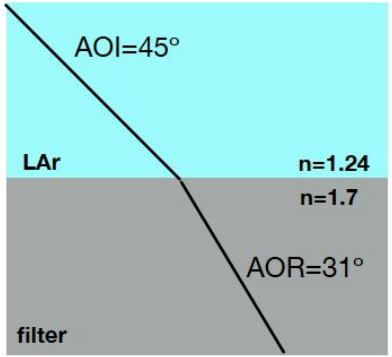
Dichroics

ML design must be optimized for

- the LAr medium and
- the most probable escape angle from the WLS

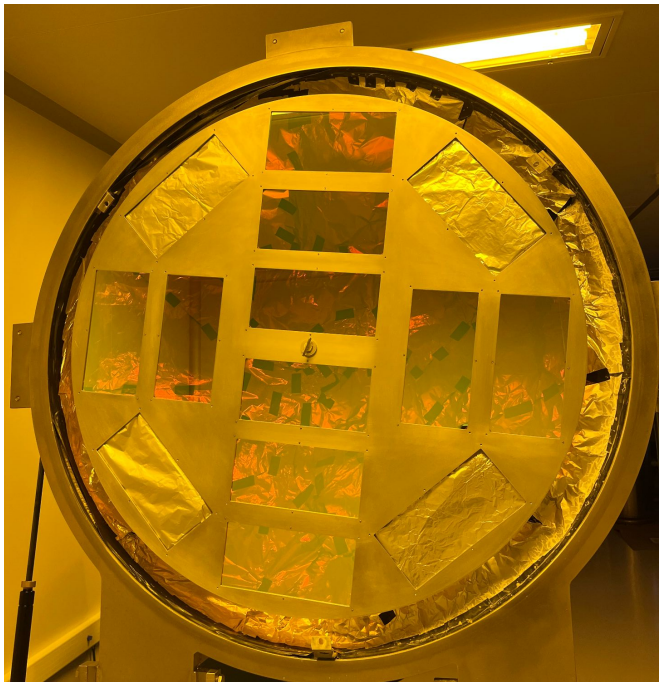


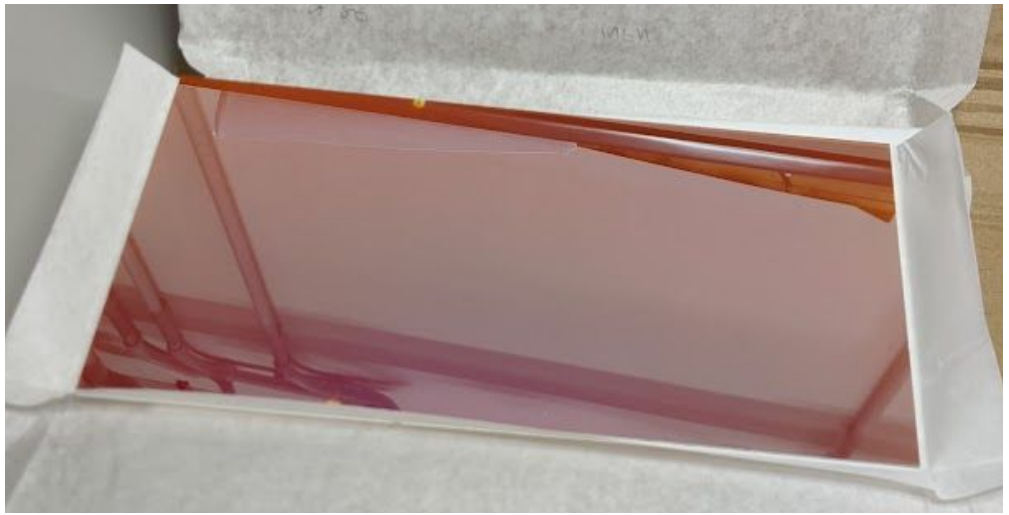




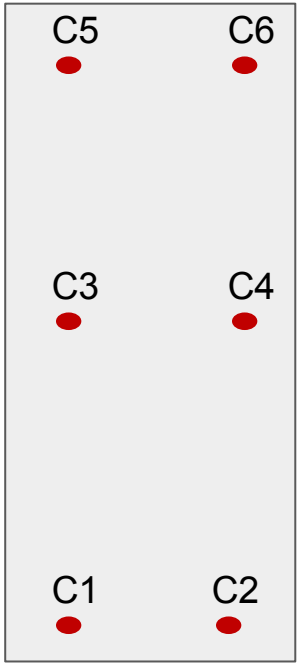
The 20 x 202 x 97.5 mm filters (ZAOT (Italy))

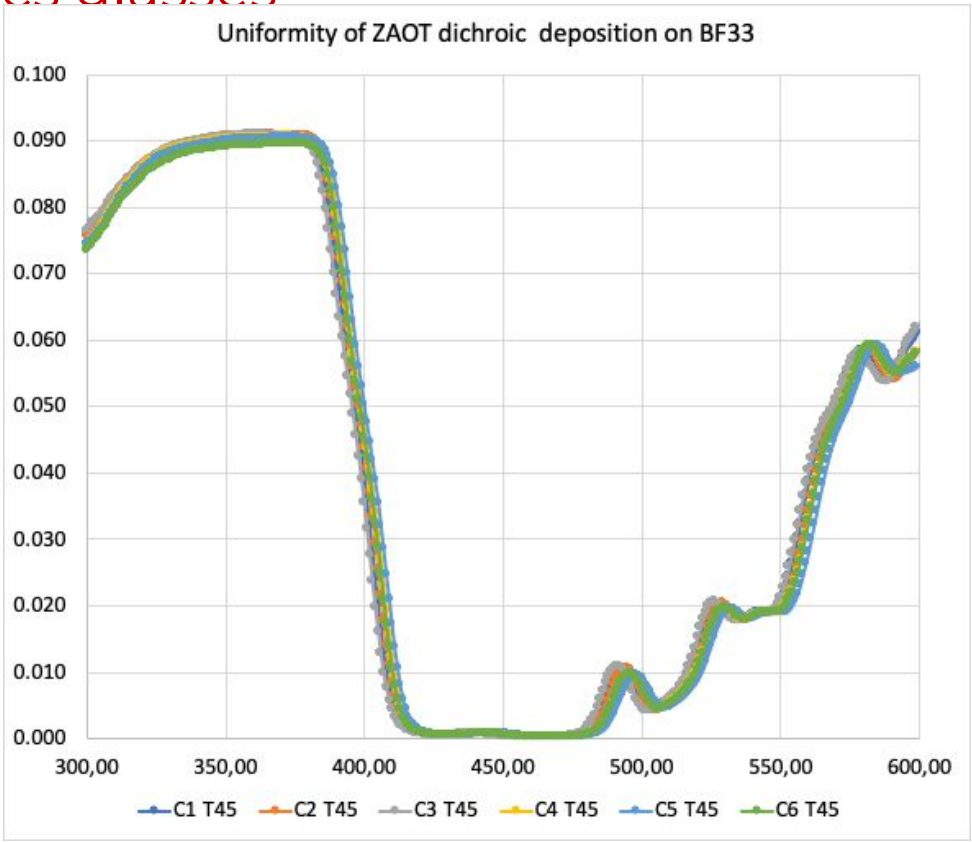
- Larger surface improves the PDE (minimize the surface of the frame passive parts)
- We moved the size freom 97 x 97 mm2 to 202 x 97.5 mm2
- pTP Coating uniquely in Campinas (the unique coating facility in the collaboration)





Uniformity of T vs wavelength at 45deg in air for large size (202 x 97.5 mm) ZAOT dichroics glasses



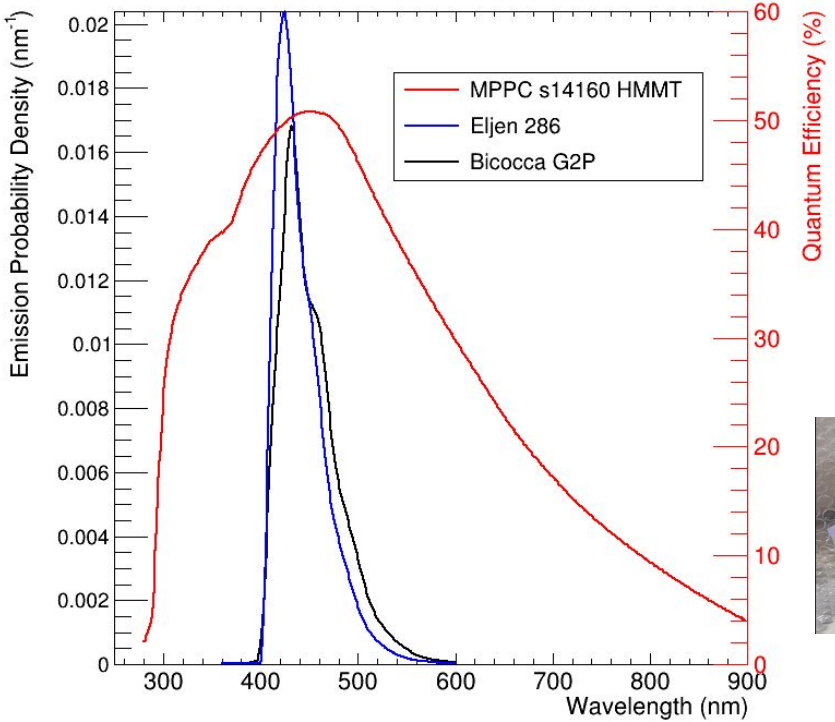


Conclusioni

- The WLS developed at INFN-MiB and ScMat Unimib proved to be perform much better than the Eljin baseline product. It is
  - compliant to DCR requirements (1 kHz)
  - has been produced in several size and shapes up to 600 x 600 mm for VD
  - it is the only product available for the VD PDS
- A precise method to measure the XA-FD1-SC has been developed and published (JINST 16 (2021) 09027) and allowed to measure the PDE: 1.2%-1.9%....much lower than measured on a two window XA device (2.9%)
- R&D to enhance the PDE ongoing
- 47 XA-FD1-SC have been fully characterized (Gain, SN,DCR)
- Five CB prototypes have been deployed equipped with the WLS
- Two Dichroic Filter manufacturer alternative to the Brasilian OPTO have been selected : ZAOT (Italy)that did already 3 pilot production and PhotoExpert (Spain)
- Italy and Spain will produce the dichroics in x2-3 sizes of the BL OPTO design

Extra slides

The WLS production for the HD

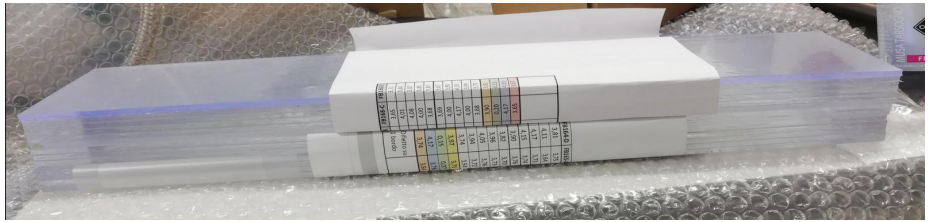


For HD, two manufacturers

- Eljin (PVT /PS based WLS)
- Glass to Power (PMMA based WLS)

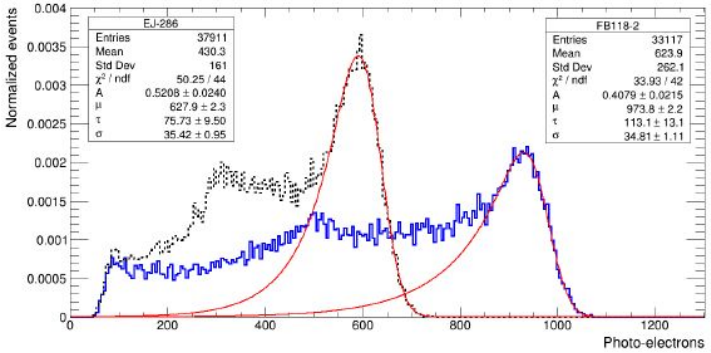
Glass to Power

- July 2021: completed the production and delivered to UniCamp 90 pcs for the HD pDune Run2 in 2022.

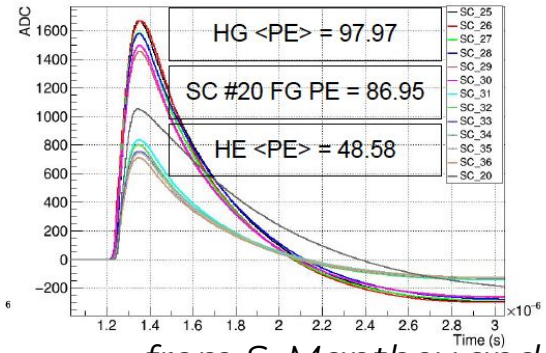


The WLS production for the VD

JINST 16(2021) 09027



3rd run of SC tests: 6HG+6HE (+ 1FG from run 2)

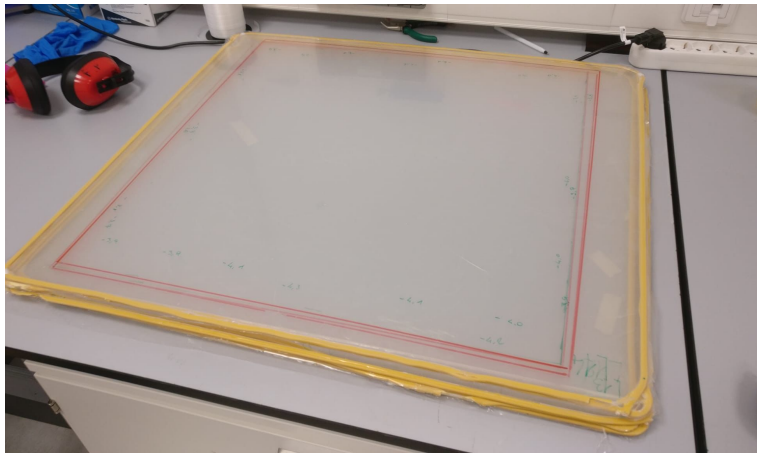


For VD only Glass to Power provided technical & economical offer for 600 x 600 mm WLS lightguides

- From HD-SCs PDE & massive test
  - PDE (G2P) is 20-30% > PDE(Eljin)
  - DCR (G2P) < 2kHz in specs for HD
  - DCR (Eljin) ~ 5 kHz not in specs for DUNE

from S. Manthey and L. Meazza presentation PhDet Consortium Parallel

5 VD WLS slabs for the two VD Prototypes for 2021-2022 CERN coldbox test



- July 2021: 5 month tuning of the casting reactor . Then G2P successfully produced 5 pcs for the VD x (600 x 600 x 4) mm.
- Measured attenuation length: ≥ 1 m.
- Tuned the casting process and casting reactor to match the thickness tolerances
- Tuned the laser cut + edge polishing processes to cut plates at their required size.