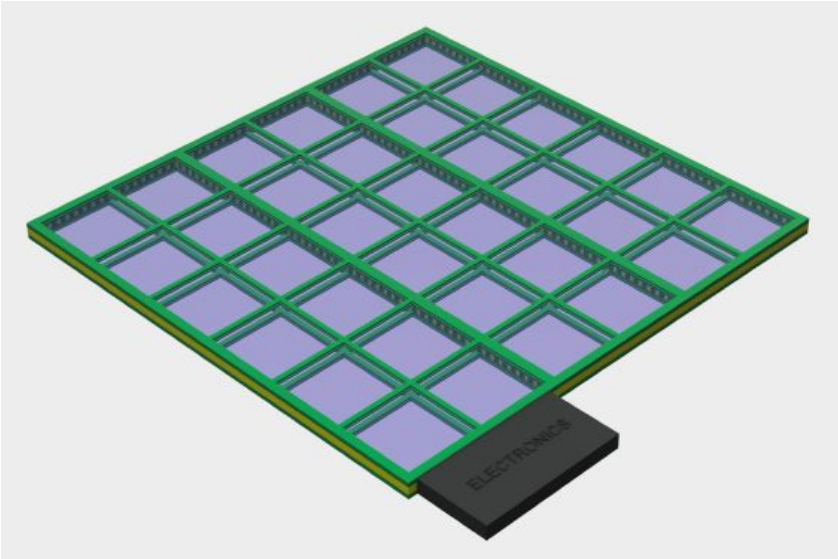
WLS Plates and SiPM mounting for VD PD



Workshop on the DUNE
Vertical Drift Photon Detector
26 July 2021

C.M. Cattadori

Photon Detection Efficiency of the XA device

- ➔ SN neutrino detection requires a LY of > 20 ph/MeV (ref. L.Paolucci Marinho talk)
- ➔ PDE of the XA device ~3.5% in VD (as in HD)

- ➔ Limits on the admissible power dissipated in LAr by the PoF technology requires at the same time
  - Increase of the surface of the XA (factor 8) in VD w.r.t. HD
  - Reduction of the number of SiPM/XA unit area

- ➔ Crucial to enhance the performances of each steps of the ph. conversion and ph. collection in the XA device

VD vs HD X-Arapuca: main facts

	Horizontal Drift	Vertical Drift	Ratio VD/HD
Size of the Ph. Collector	48 x 9.3 cm^2	60 x 60 cm^2	8.06
N. of SiPMs	48	160	3.3
N. of SiPM boards	8	8	-
Surface/SiPM	9.3 cm^2	23 cm^2	2.4
d (WLS center- closest SiPM)	4.6 cm	30 cm	~5

→ to match the VD XA PDE~3.5% while reducing a factor of 2.5 the n. of photosensors/unit area w.r.t. the HD → increase the conversion/detection efficiency in each step of the light conversion/detection process

Strategies to enhance the PDE of the VD XA

- Maximise the Ph Collector PDE by optimisation of the XA device
  - Dichroic filter with enhanced substrate and sharpest dichroic cuts (see A. Machado talk)
  - WLS PDE: in relative measurements performed with a two window XA cell (204 x 75 mm2) the G2P WLS performed 55% better than the EJ-286 baseline product
  - Light trapping of the WLS lightguide by applying reflector coating on the WLS slab edges (increase the ph. det. uniformity and the ph. det. efficiency)
  - Photosensor-to-WLS optical coupling

(204 x 75) mm^2 XA PDE: Final results

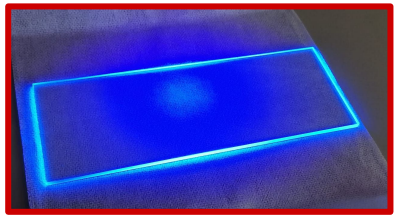
	EJ-286 w/o Vikuiti	EJ-286 w/ Vikuiti	G2P w. Viquiti
SPE Gain (ADC·ns)	1680 ± 80	1690 ± 80	1735 ± 90
En. res. (σ/μ)	6.3 ± 0.2 %	6.0 ± 0.2 %	3.6 ± 0.1 %
S/N	6.8 ± 0.3	7.3 ± 0.3	7.3 ± 0.3
ϵ_{raw}	2.1 ± 0.1 %	2.3 ± 0.1 %	3.5 ± 0.1 %
τ_T	1294 ± 35 ns		
LAr purity correction	+ (1.4 to 2.6) %		
Cross-talk correction	- (18 ± 1) %		
ϵ	1.8 ± 0.1%	1.9 ± 0.1%	2.9 ± 0.1%

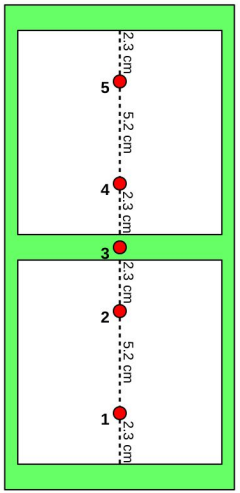
ϵ_{raw} , ϵ: Efficiency Prior (raw) and post corrections respectively

τ_T: measured Triplet half-life

Positions	G_ϵ
2,3,4	55 ± 5 %
5	50 ± 5 %
1	63 ± 6 %

G_ϵ: PDE ratio (G2P vs EJ bar)





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Enhancement of the X-Arapuca photon detection device for the DUNE experiment

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Abstract: In the Deep Underground Neutrino Experiment (DUNE), the VUV LAr luminescence is collected by light trap devices named X-Arapuca, sizing ~ (480 × 93) mm^2. Six thousand of these units will be deployed in the first DUNE ten kiloton far detector module. In this work we present the first characterisation of the photon detection efficiency of an X-Arapuca device sizing ~ (200 × 75) mm^2 via a complete and accurate set of measurements along the cell longitudinal axis with a movable ^{241}Am source. The MPPCs photosensors are readout by a cryogenic trans-impedance amplifier to enhance the single photoelectron sensitivity and improve the signal-to-noise while ganging 8 MPPC for a total surface of 288 mm^2. Moreover we developed a new photon downshifting polymeric material, by which the X-Arapuca photon detection efficiency was enhanced of about +50% with respect to the baseline off-shell product deployed in the standard device configuration. The achieved results are compared to previous measurements on a half size X-Arapuca device, with a fixed source facing the center, with no cold amplification stage, and discussed in view of the DUNE full size optical cell construction for both the horizontal and the vertical drift configurations of the DUNE TPC design and in view of liquid Argon doping by ppms of Xe. Other particle physics projects adopting Liquid Argon as target or active veto, as Dark Side and LEGEND or the DUNE Near Detector will take advantage of this novel wavelength shifting material.

[1] Corresponding author.

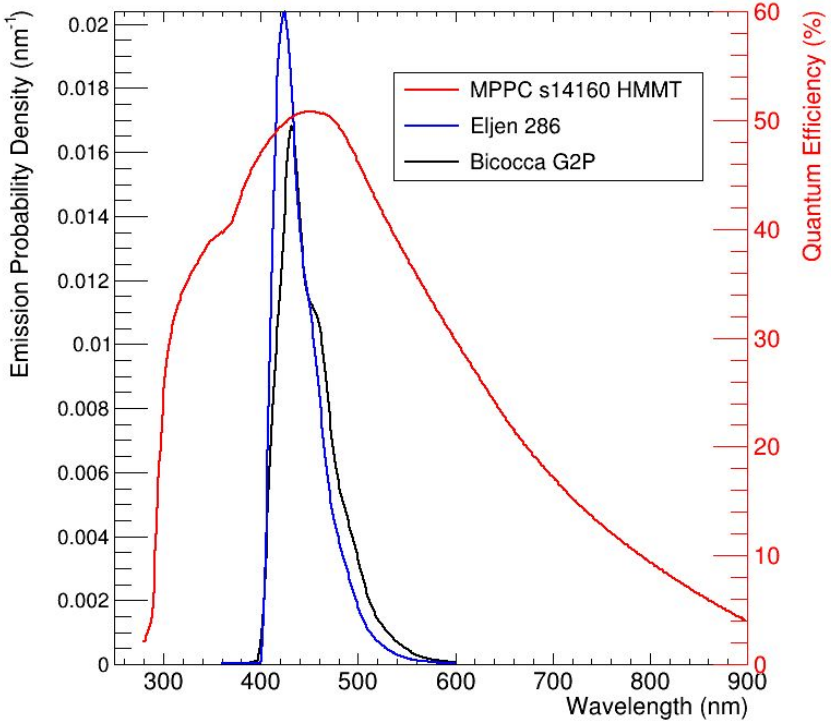
VD vs HD X-Arapuca features

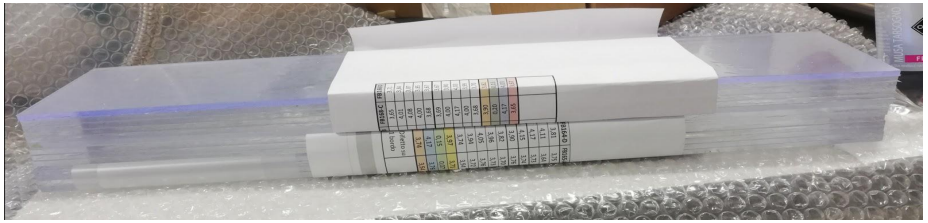
	Horizontal Drift	Vertical Drift
Ganging	Active x48	(Passive x 20) & (Active x 4)
Type of SiPMs boards	Rigid G10-FR4	Flex Kapton 200 um total thickness
SiPM boards fixed to	XA frame	WLS plate
SiPM-to WLS Optical contact	No	Epoxy glued

- The passive & active ganging is a new feature of the VD XA
- In the VD the SiPM boards are integral with the WLS lightguide and no longer w. the XA frame as in HD
- In HD a gap of few mm opens between SiPMs and WLS because of differential CTE of G10 w.r.t. PMMA/PVT

	CTE [ppM/K]
G10 FR4	1.4
Kapton	20
PMMA	70-77
epoxy	30-40
Cu	18

The WLS production for HD



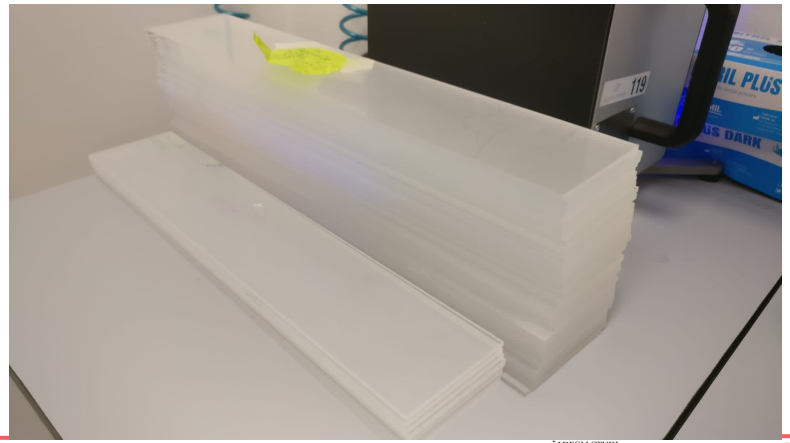


For HD two manufacturers

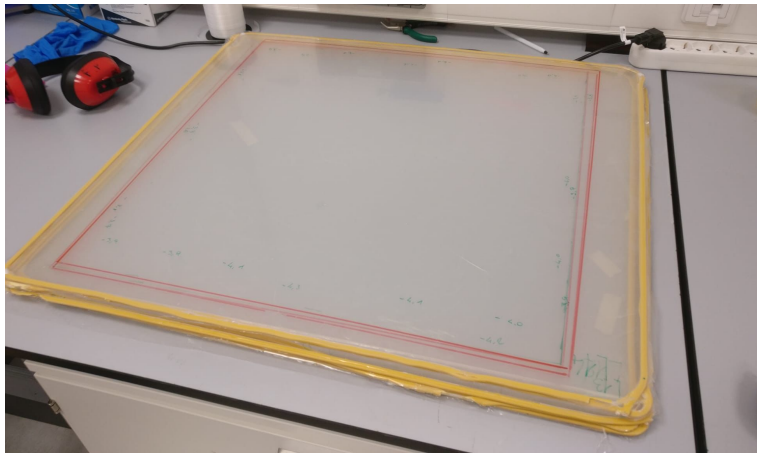
- Eljin (PVT /PS based WLS)
- Glass to Power (PMMA based WLS)

Glass to Power

- July 2021: completed the production of 90 pcs for the HD pDune Run2 in 2022.



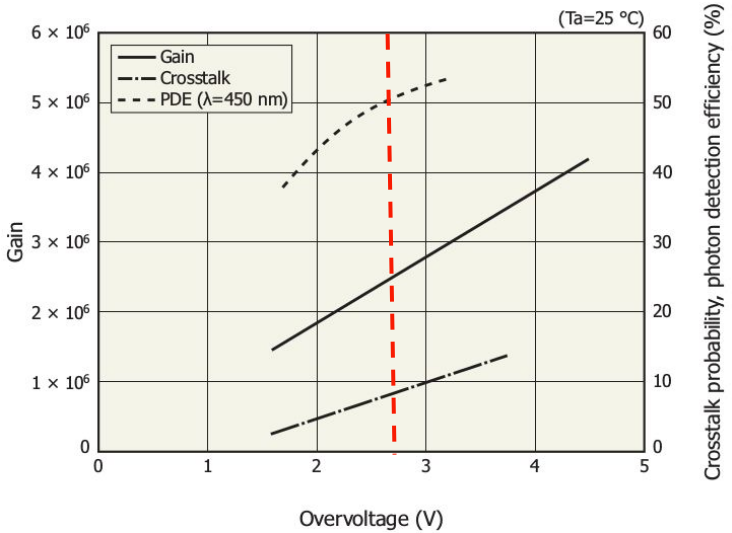
The 5 VD WLS slabs for the two VD Prototypes for 2021 CERN coldbox test

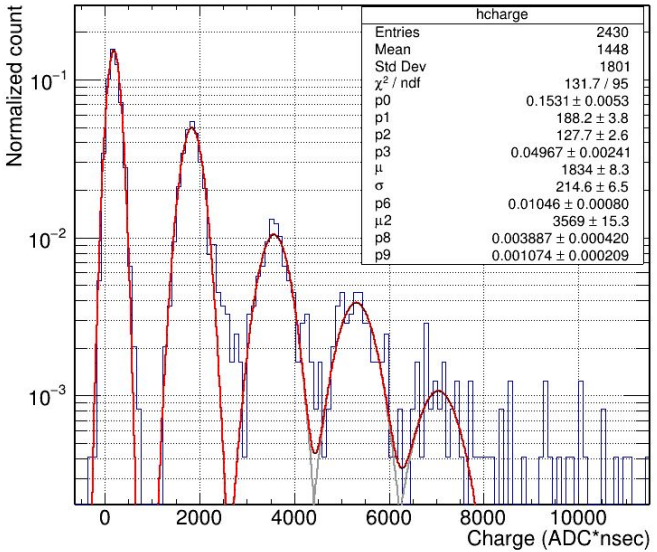


- July 2021: G2P completed the production of 5 pcs for the VD x (600 x 600 x 4) mm.
- Measurements of the attenuation length of the SC WLS ongoing: preliminar results ≥ 1 m).
- Possible R&D to further optimize the chromophore concentration for further tests
- Possible R&D to change both the substrate and the chromophore to optimize the detection of the light emitted by LAr-Xe mixtures

The SiPMs for the VD Prototypes

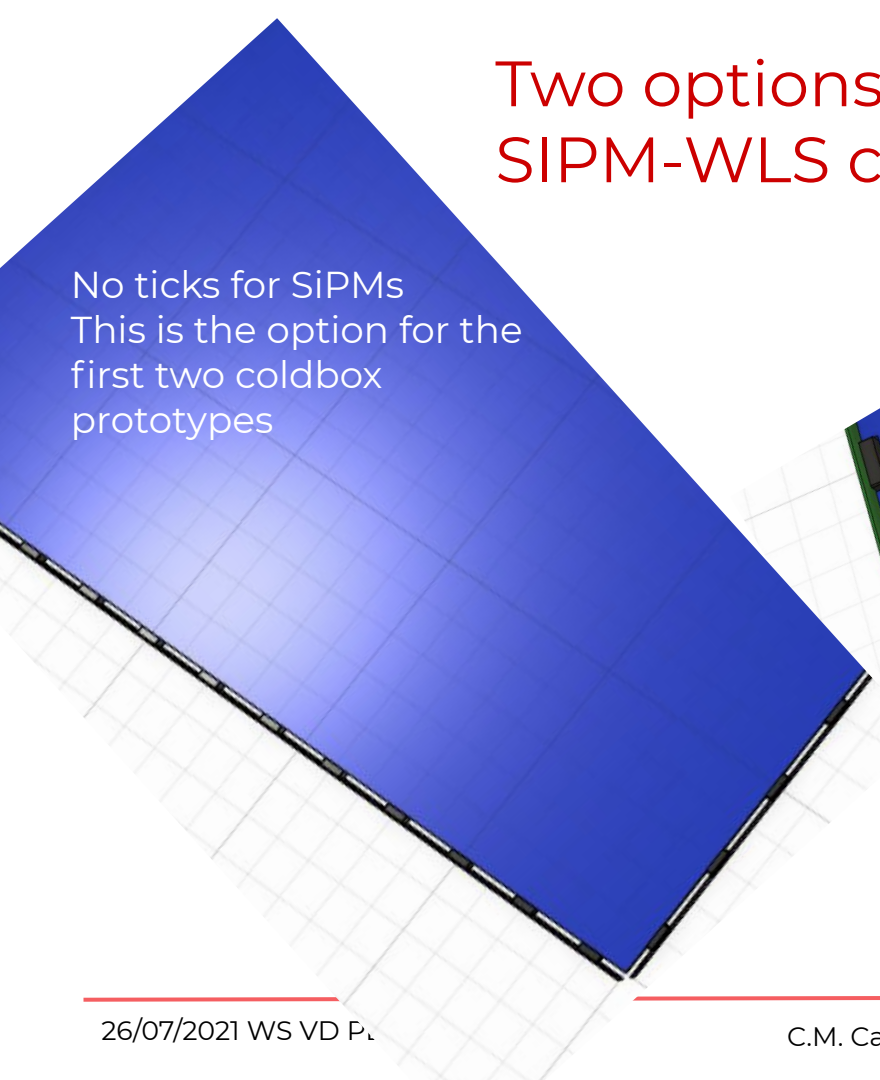
DUNE custom production of HPK SiPMS doesn't match the MC prototyping schedule → adopt the **S14160-6050HS:** 16 pcs have been succesfully used in the X-Arapuca (200 x 75 mm^2) characterization at MiB with cold amplifier and satisfactory S/N. Available 500 pcs purchased by FNAL



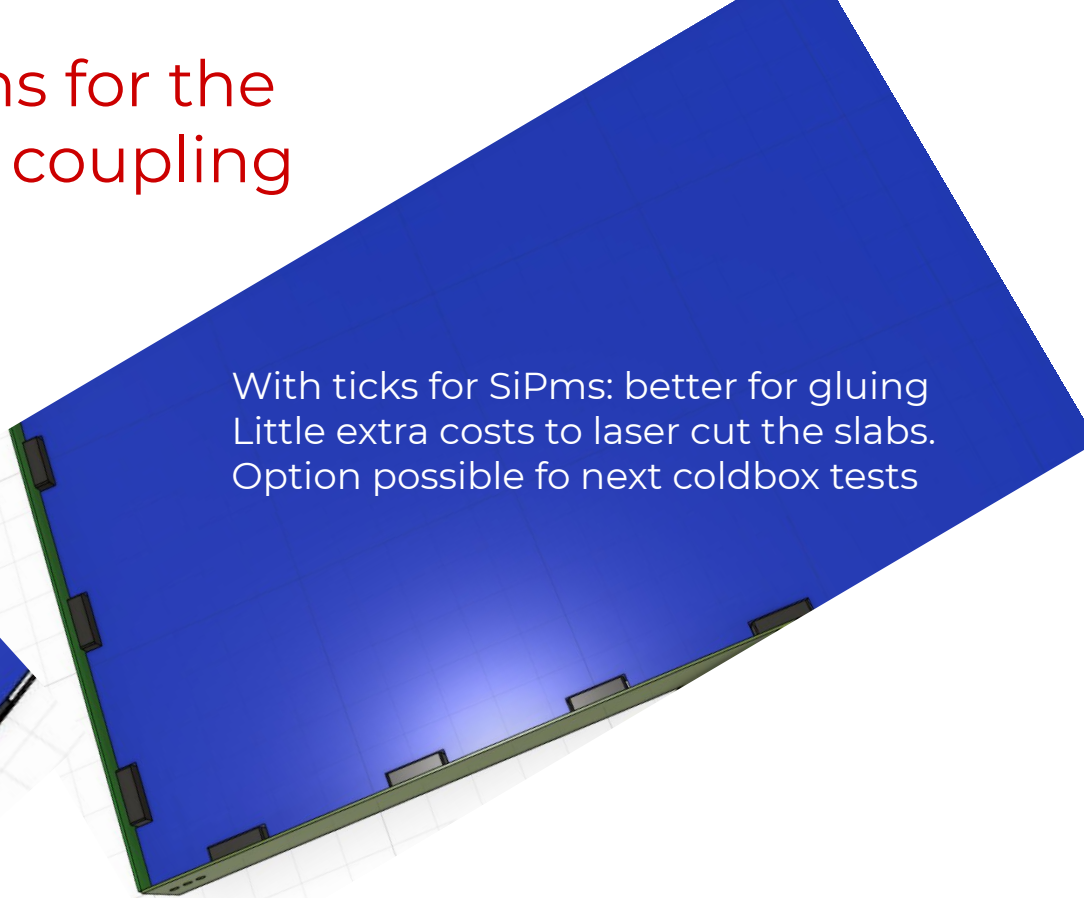


Two options for the SIPM-WLS coupling

No ticks for SiPMs
This is the option for the first two coldbox prototypes



With ticks for SiPms: better for gluing
Little extra costs to laser cut the slabs.
Option possible fo next coldbox tests

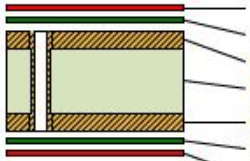


Flex SiPMs boards for VD prototypes

- In VD the flex board integrates two functions: SiPM boards & the Signal Routing Boards (they are two independent pieces to be assembled by pins in HD XA)

- Flex PCB w. Passive ganging designed by D. Totani & G. Cancelo
- 150 um kapton DuPont
- 17 um (35 um) Cu
- Total thickness 220 um
- Order issued from CSU
- Production & SiPM population ongoing both in the US and in Italy

Layer Stack Legend

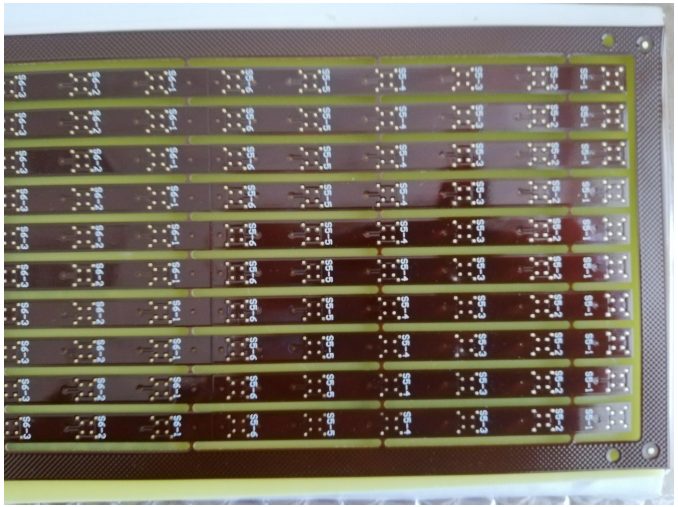


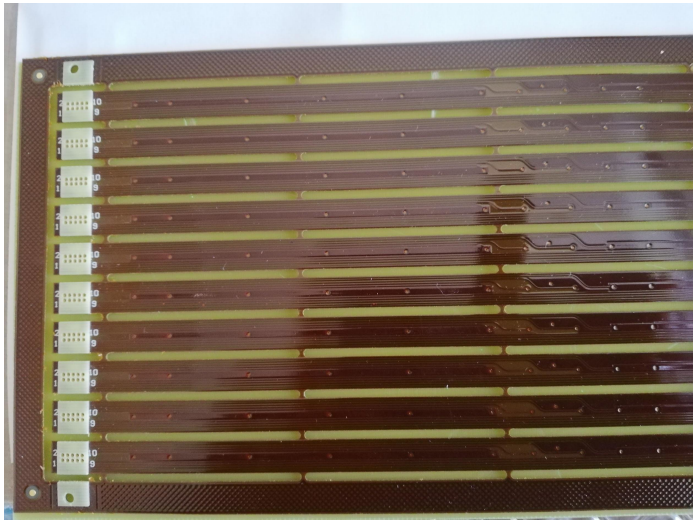
Material	Layer	Thickness	Dielectric Material	Type	Gerber
	Top Overlay			Legend	GTO
Surface Material	Top Solder	0.40mil	Solder Resist	Solder Mask	GTS
Copper	**Top Layer**	**1.40mil**		**Signal**	**GTL**
Core		*5.00mil*	*Core-016*	*Dielectric*	
Copper	**Bottom Layer**	**1.40mil**		**Signal**	**GBL**
Surface Material	Bottom Solder	0.40mil	Solder Resist	Solder Mask	GBS
	Bottom Overlay			Legend	GBO

Total thickness: 8.60mil

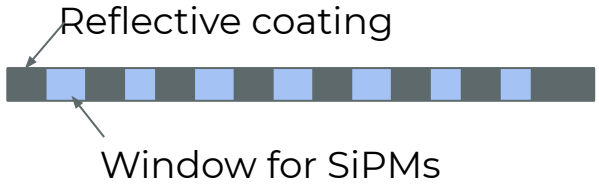
Flex SiPM boards: test with the HD cell

- Test at MiB in the framework of the HD XA tests
- No passive ganging
- Each flex hosts 24 SiPM to comply to the HD cell SiPM coverage





Plans for optimization of the light trapping in the WLS slab & simplify XA assembly procedure



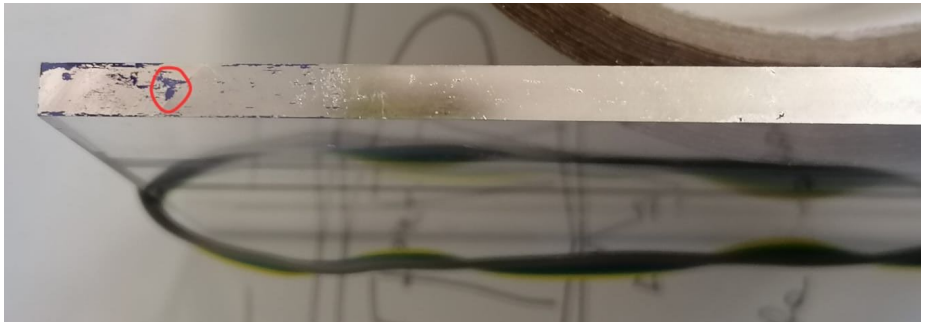
Aluminium coating of the WLS slab edges

- ✓ Define adequate coating technology (ongoing) to replace Viquiti sticks on edges
- ✓ Coat the slab edges (~1.5 spaces between SiPMs)
- ✓ Cold Test and thermal cycles

First results of Aluminium coating of the WLS edges

First Al coating process on edges: exfoliation observed

To be optimized



Optimization of the light trapping/extraction from the WLS

SiPms optical bonding

- ✓ Two optical cryoresilient epoxy resins have been selected.
- ✓ First bond individual SiPMs on small WLS plates + LAr cycles
- ✓ Next glue and Lar tests of SiPMs populated on boards
- ✓ This task needs manpower and R&D

Conclusions

To maximise the XA PDE for the VD PD several optimisations have been envisaged. The flag color code provides the R&D status

- ✓ Dichroic filter with enhanced substrate and sharpest dichroic cuts (see A. Machado talk)
- ✓ WLS PDE: in relative measurements performed with a two window XA cell (204 x 75 mm2) the G2P WLS performed 55% better than the HD (EJ-286) baseline product
- ✓ Light trapping of the WLS lightguide by applying reflector coating on the WLS slab edges (increase the ph. det. uniformity and the ph. det. efficiency)
- ✓ Photosensor-to-WLS optical coupling
- ✓ New design of the WLS for the Xe-doping