WP9: Light Readout at Milano Bicocca

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UniMiB & INFN Milano Bicocca

3rd AIDAINNOVA Annual Meeting 20/03/2024

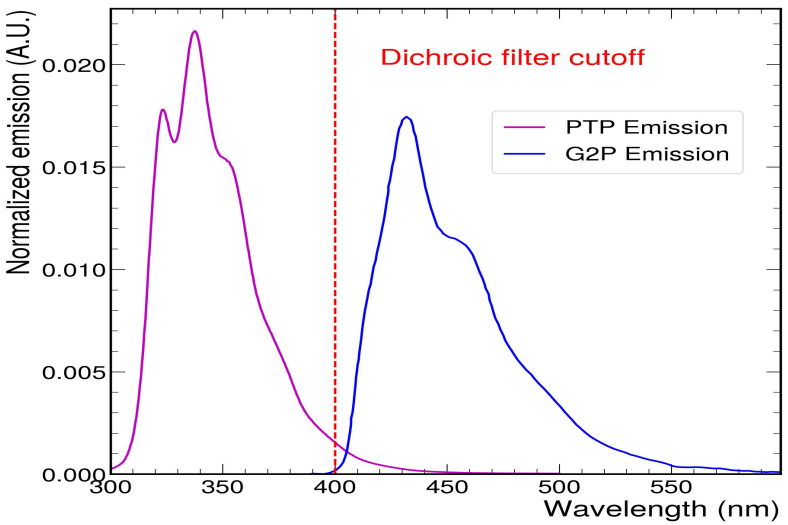
WP9: Activities at MiB (2023-2024)

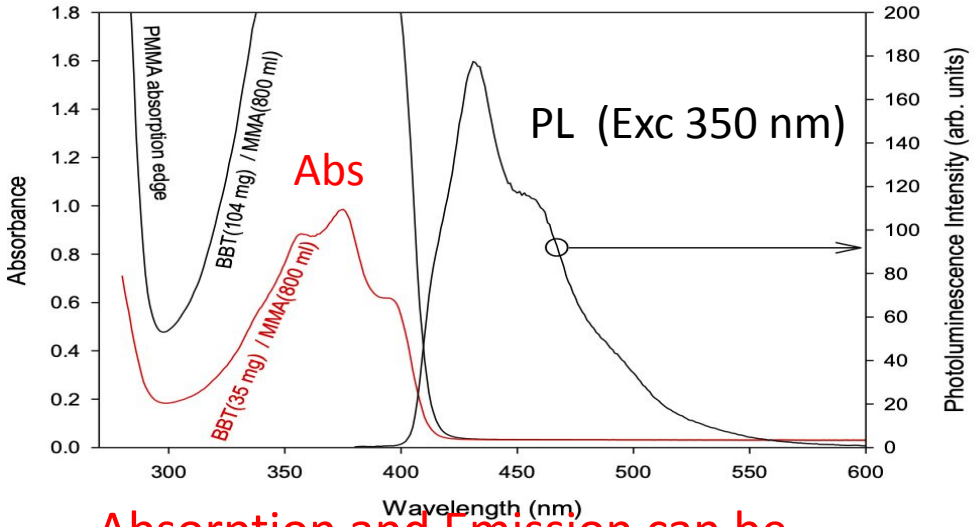
- Featuring the WLS (for SBND,DUNE,LEGEND)
  - Mass production (from casting to laser cut)
  - Attenuation length of WLS lightguides.
  - Assessment of the radiopurity budget.
  - Characterization at cryo-T of the abs, PL spectra of the main fluors (pTP, TPB,BBT) with VUV excitation radiation.
- Facilities to assess the Photon Detection Efficiency for
  - DUNE-PhDet System fundamental unit (X-Arapuca)
  - LEGEND LarATmVeto
- Modified XA Design allowing to double the Photon Detection Efficiency of the X-Arapuca.
- Assessment of the Dichoic Filters roles in the photon collection mechanics.
- WLS-LG bars and PMMA absorber for the LAr Atm Veto for LEGEND-1000

WLS for LAr detectors

Features:

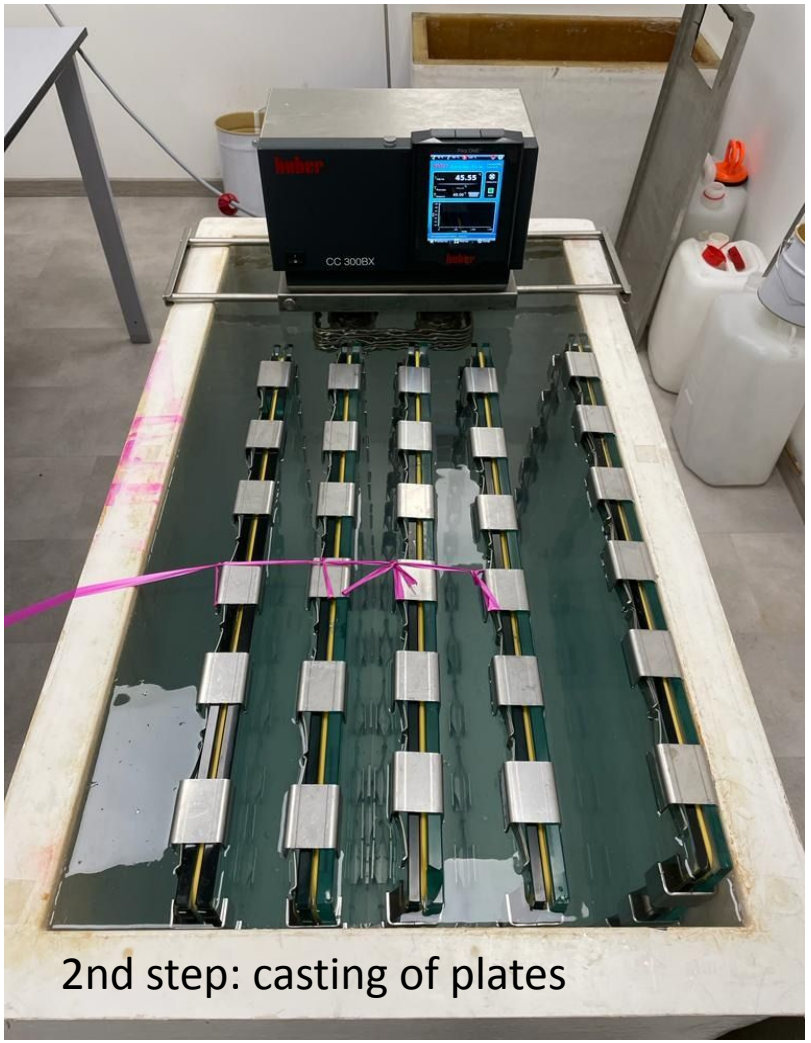
- Cryoresilience
- PMMA based (no scintillator, only Cerenkov emission)
- Absorbption: 330-390 nm (tailored for pTP emission)
- Emission: 420-500 nm to match the SiPM Q.E.
- Optical Path O(1 m)
- Very good tolerances O(0.1 mm) achieved in the laser cut process. Important when coupling photosensor w.o. glue





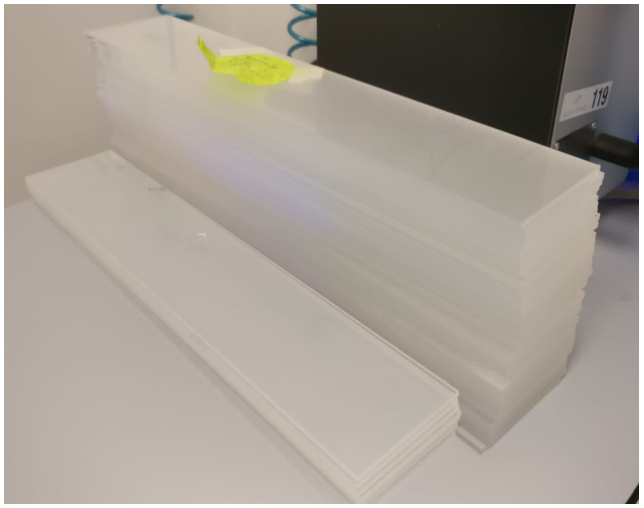
Absorption and Emission can be tailored on different wavelengths

WLS manufacturing capabilities



* Glass to Power Co.: Former start up of Uni MiB, now quoted at Eurostock: https://www.glasstopower.com/

WLS: Production of 90 FD1 and 20 FD2



- 90 x slabs for pDUNE FD1-PDS: 480 x 93 mm^2 x 4mm thick
- ~ 60 WLS SBND 202 x 77 mm2

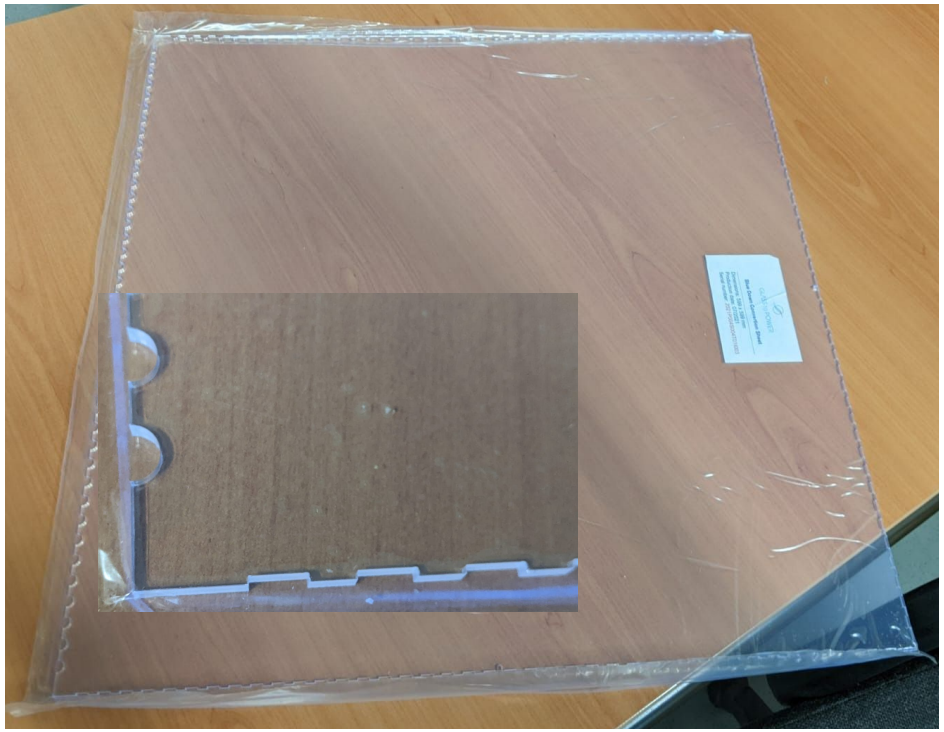
Laser cut (external industrial partner) and edge polishing procedures to cut out the casted plates in tiles defined and validated.

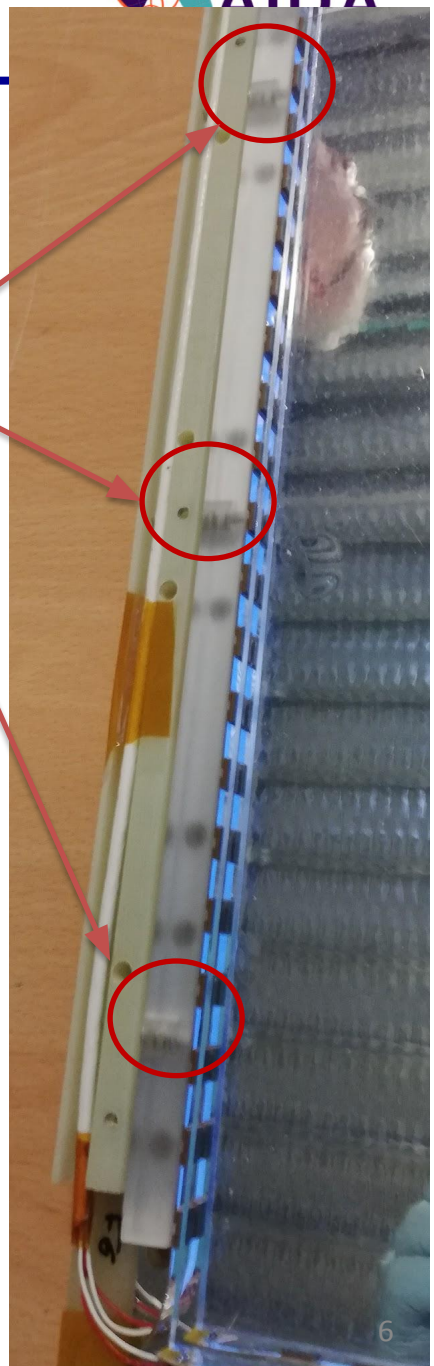
- **20** x slabs for the **Module-0** of **FD2-PDS**: 607 x 607 mm^2 x 4 mm thick casted in one week

- **10** x slabs in 2023 for the **Module-1** & PDE test stands 607 x 607 mm2 x 5.5 mm

SiPM to WLS coupling

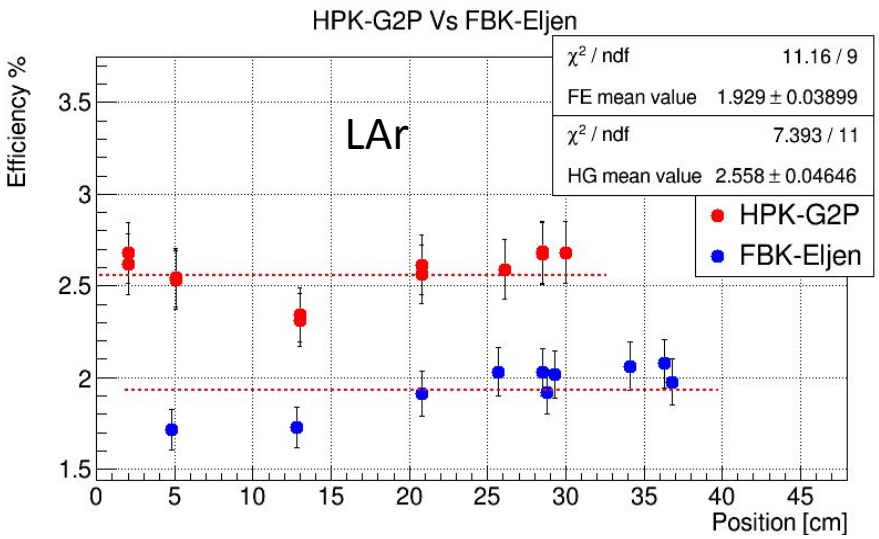
- Our WLS is now the BL for both FD1 &FD2: WLS with flat edges
- In LAr SiPMs are kept is in close contact to WLS thanks to flex circuits & spring loaded mechanism, to compensate the WLS shrinking (~1%. i.e. 6 mm)

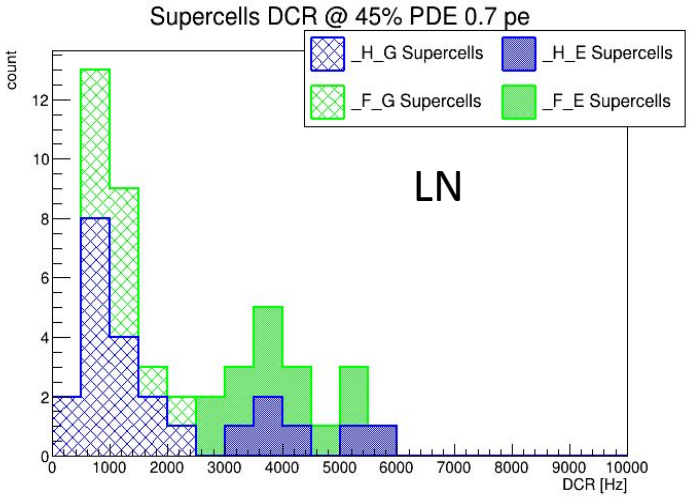




WLS features & Performances

- **Superior Cryoresilience**: No cracks or failures in cooling/warming cycle at rate of 3-4 mm/sec of the
  80 x FD1 pDUNE & 16 x FD2 Module-0 plates
- **Stress tests**: One prototype plate underwent 15-20 thermal cycles: no failures.
- **Superior light guiding surfaces as casted**
- **Superior LY and DCR of XA cells equipped with our PMMA based WLS**





WLS-LG: Attenuation length (λ_{att})

- **Both the Absorbance of the pTP photons & the λ_{att} of the photons emitted by the secondary WLS depends on the WLS chromophore concentration**
  - The chromophore concentration & WLS-LG thickness are tuned to maximize the Photon Collection Efficiency (PCE)
- λ_{att} (400-500 nm) is the leading parameter for high PCE.
  - **Required: λ_{att} > Optical Path**

$A = \log_{10}(1/T)$

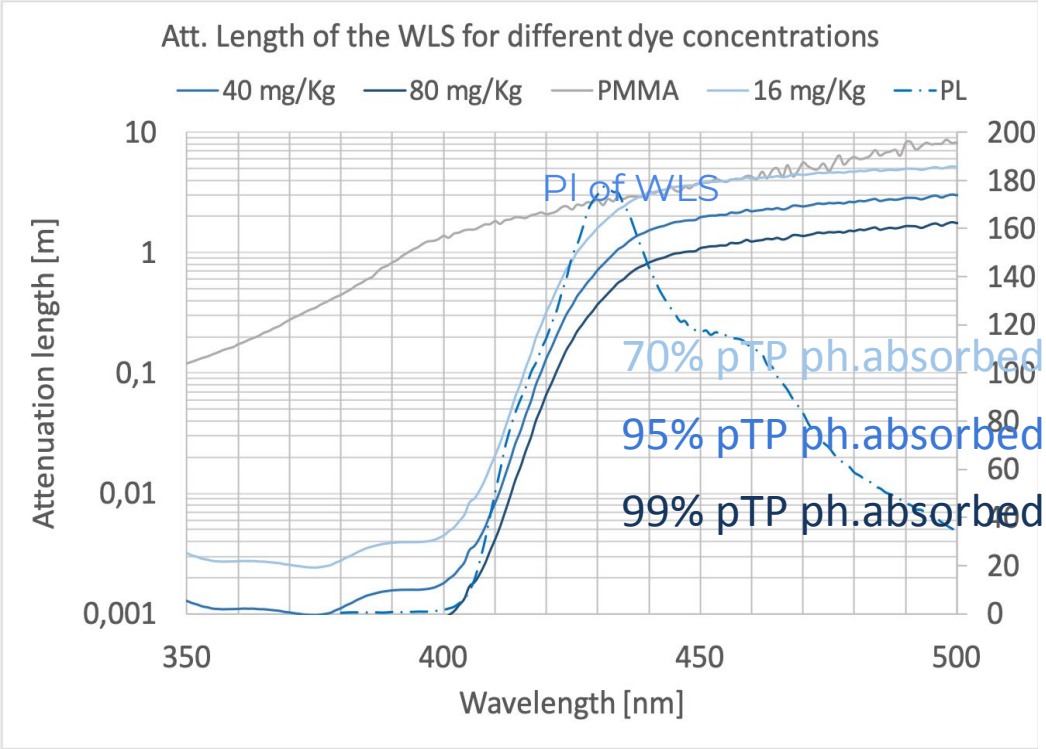
$T = I/I_o \exp(-d/\lambda_{att})$

$A = \varepsilon\, c\, d$

ε = molar extinction coeff.

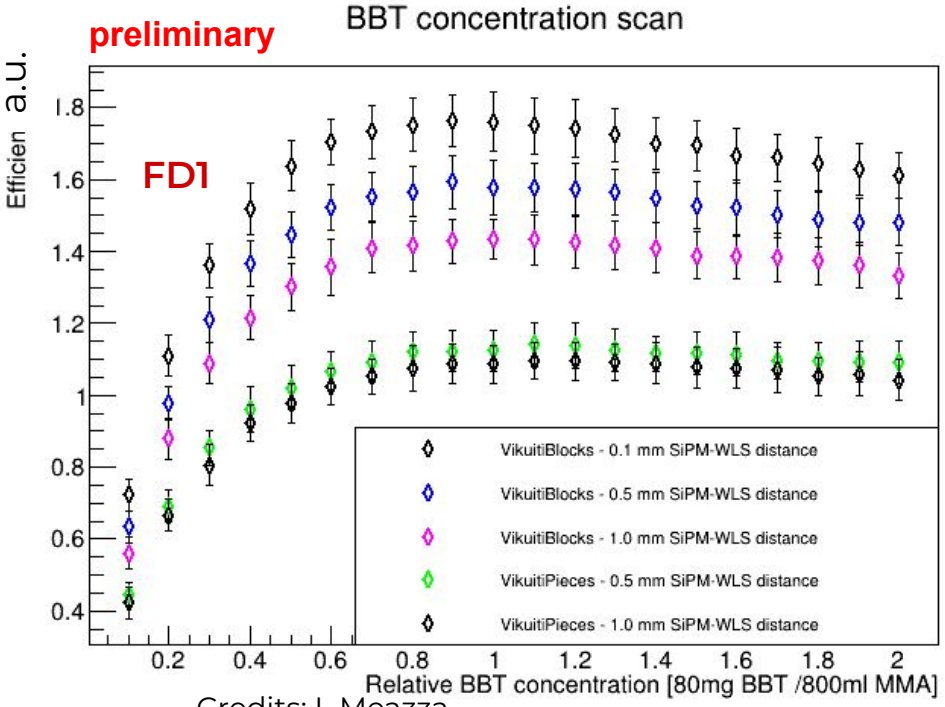
c = concentration

d = optical path



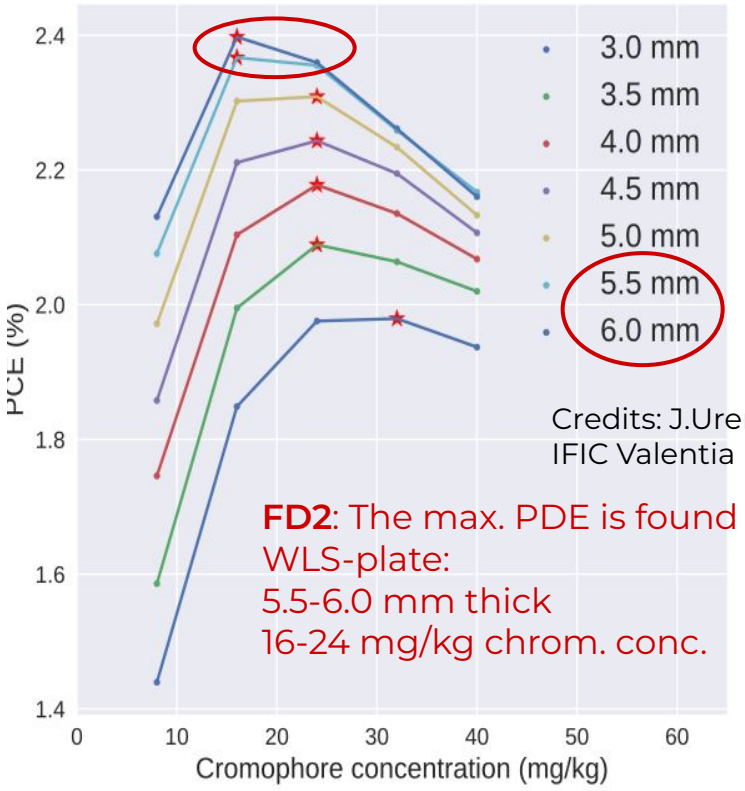
WLS- LG: chromophore concentration and thickness optimization for FD1 and FD2

OP ~ 10-100 cm; λ^{opt}_{att} =37 cm; thick=3.8mm



Credits: L.Meazza
UniMIB

OP ~ 60-200 cm; λ^{opt}_{att}~ 200 cm; thick = 5.5 mm

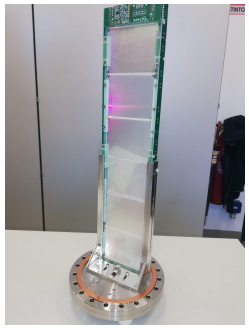


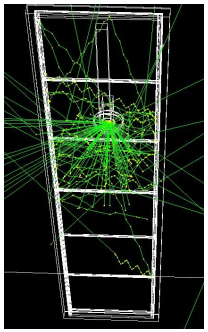
Credits: J.Urena
IFIC Valentia

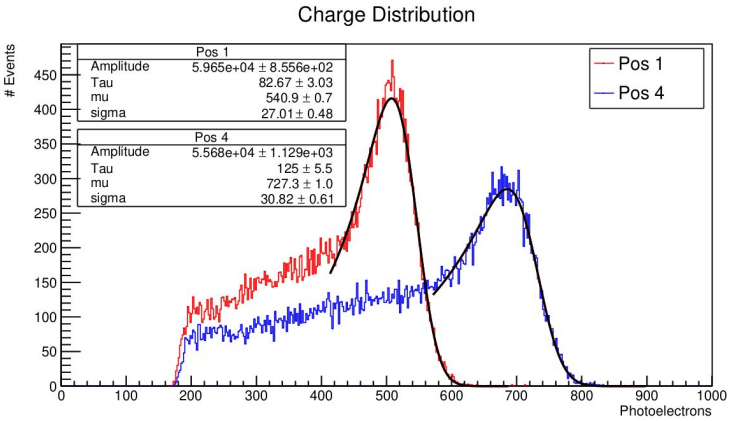
FD2: The max. PDE is found for WLS-plate:
5.5-6.0 mm thick
16-24 mg/kg chrom. conc.

Facility @INFN-MiB to assess & improve the PDE of the FD1-XA & Components qualification

Update 2023

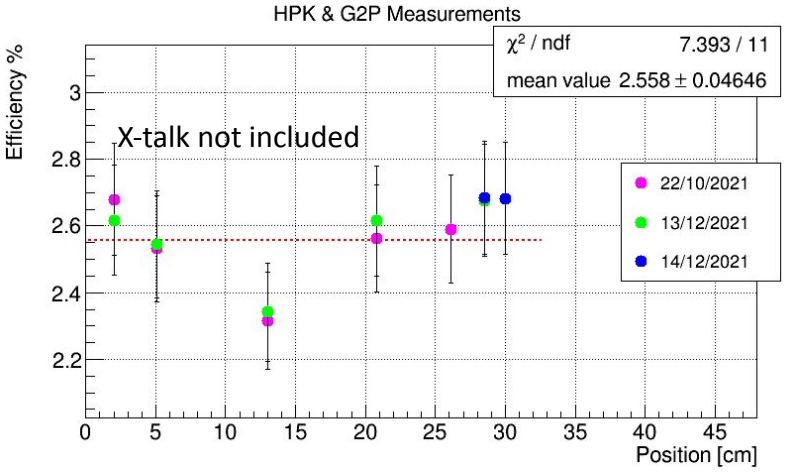






Method: z-scanning of the whole cell (~2 Sr) with an ^{241}Am exposed α source (JINST 16 (2021)09027) +SBND PDE determination

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



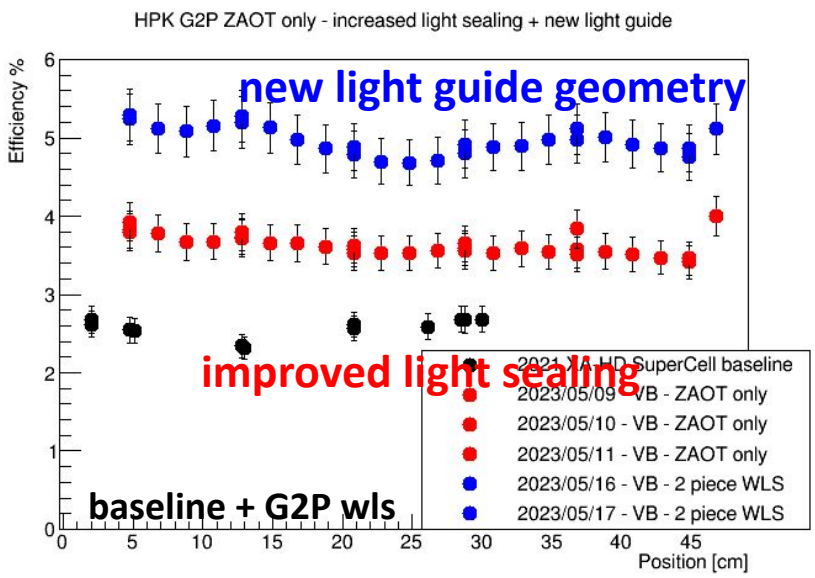
No correction for LAr purity applied.
Expected: < 8%

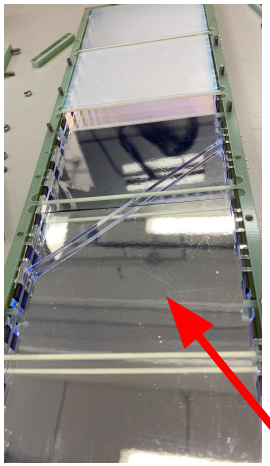
	SiPM PDE	XA PDE MiB Xtalk corr.	XA PDE CIEMAT Xtalk corr.
HPK & G2P	50%	**2.49** (0.15)	**2.51** (0.21)
FBK & G2P	45%	**2.1** (0.23)	1.87 (0.15)
FBK & Eljen	45%	**1.8** (0.18)	**1.56** (0.12)

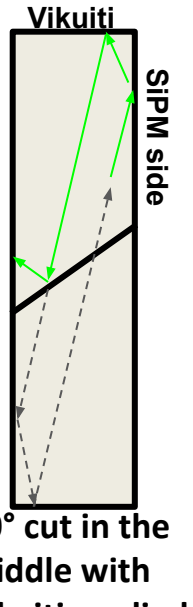
FD1: The improved WLS-LG geometry doubles the PDE

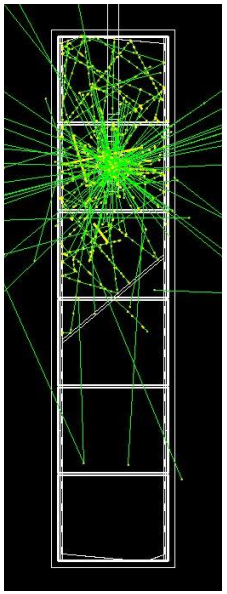
Major improvement of the FD1 XA PDE cutting the WLS-LG in two parts by a 40° cut and improved LG light-sealing

- optimization via optical sims
- measurements with MiB setup

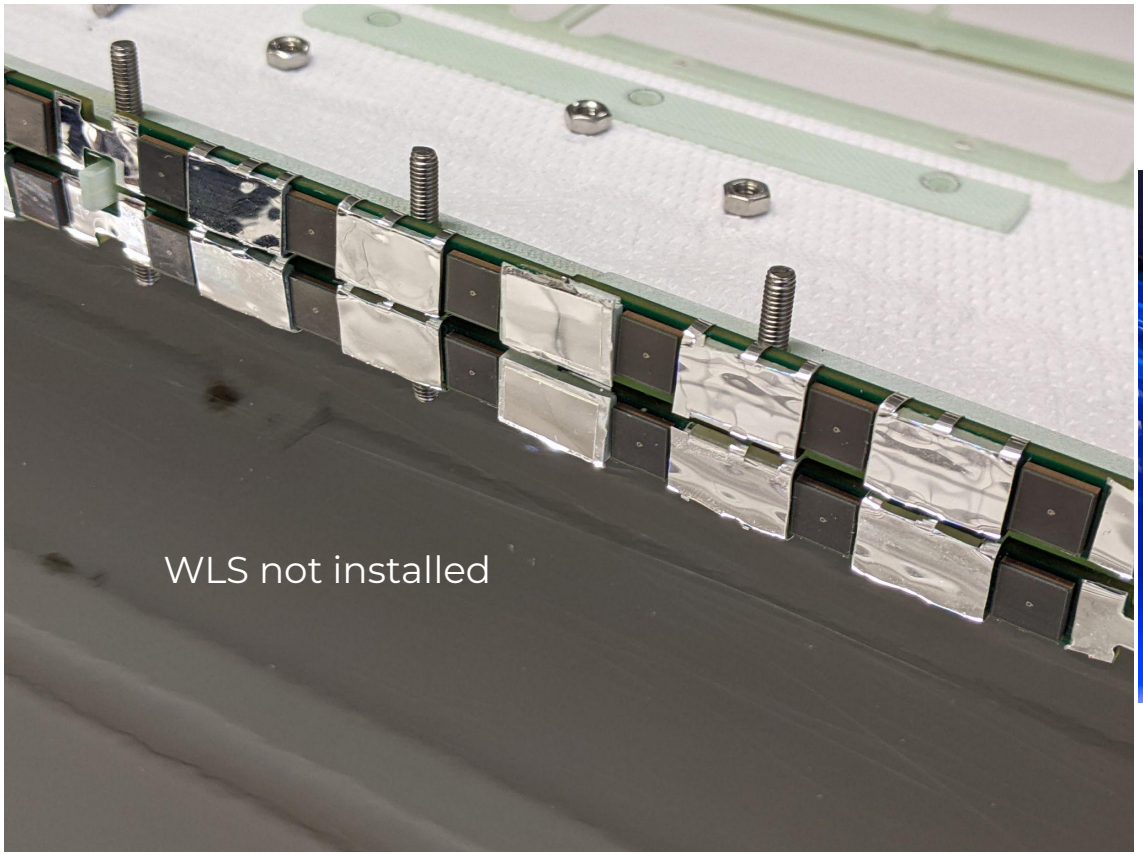








Improved Optical Sealing of the WLS lightguide

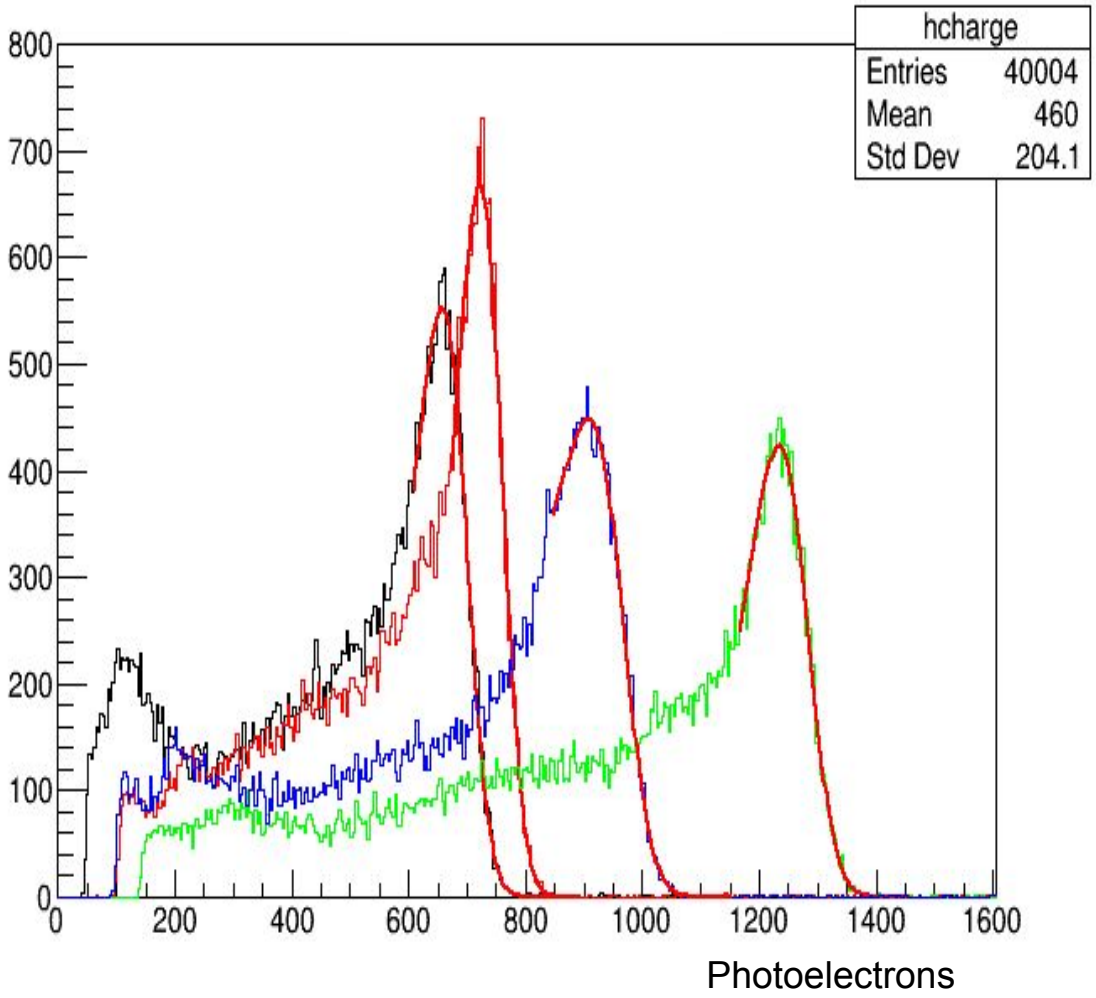


Alpha Spectra resolution, p.e. calibrated

— baseline
— p-DUNE WLS, NO G10 blocks, ZAOT
— p-DUNE WLS, G10 blocks, ZAOT
— WLS with cut, G10 blocks, ZAOT

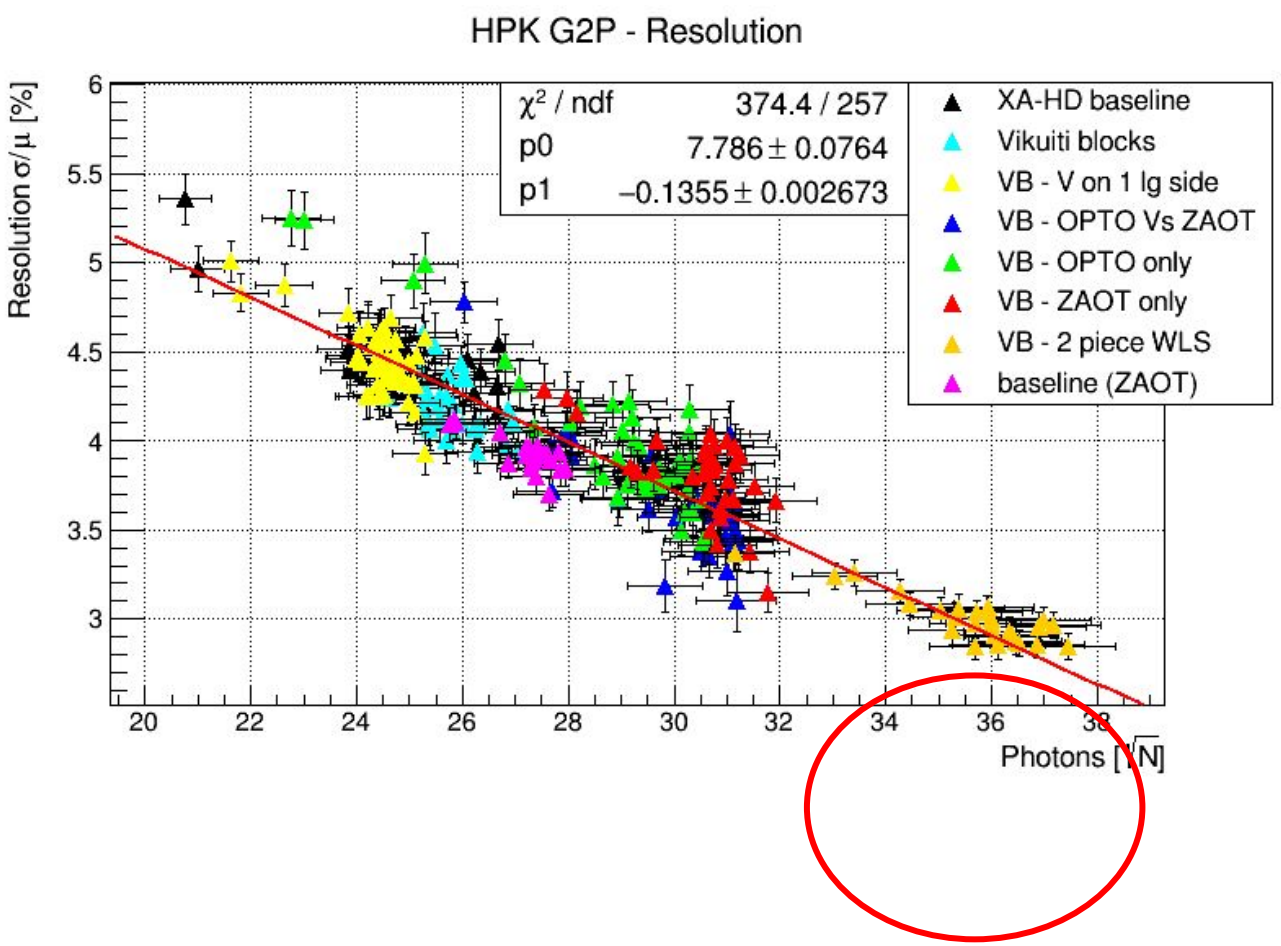
All taken in the middle of the 3rd dichroic filter

mu = 692.704 sigma = 31.4929
mu = 749.976 sigma = 30.3693
mu = 962.185 sigma = 38.2959
mu = 1272.26 sigma = 38.0256

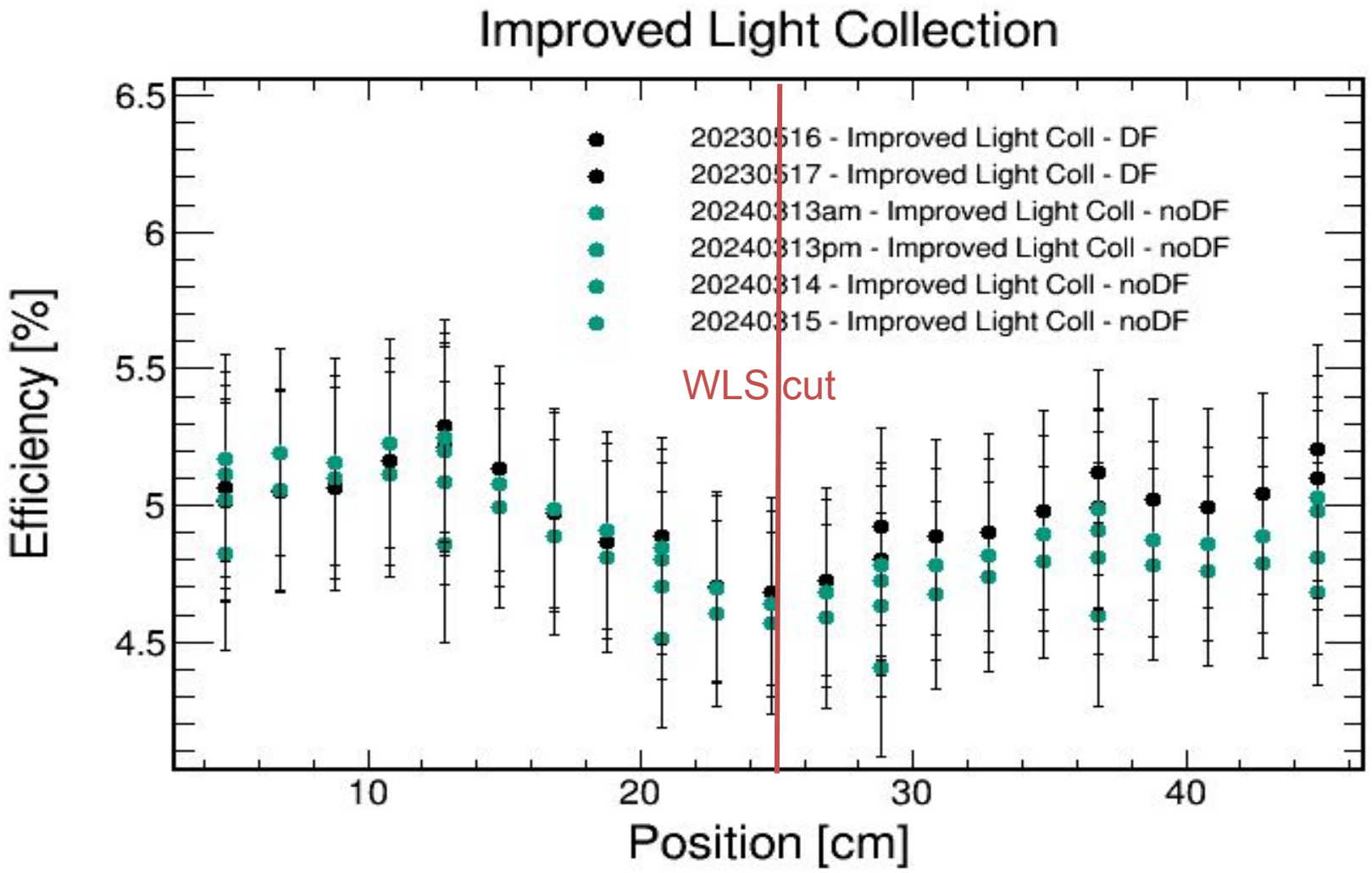


Alpha Spectra resolution

- The 2 pieces WLS lg improves coherently with the number of detected photons the energy resolution w.r.t. all the other configurations



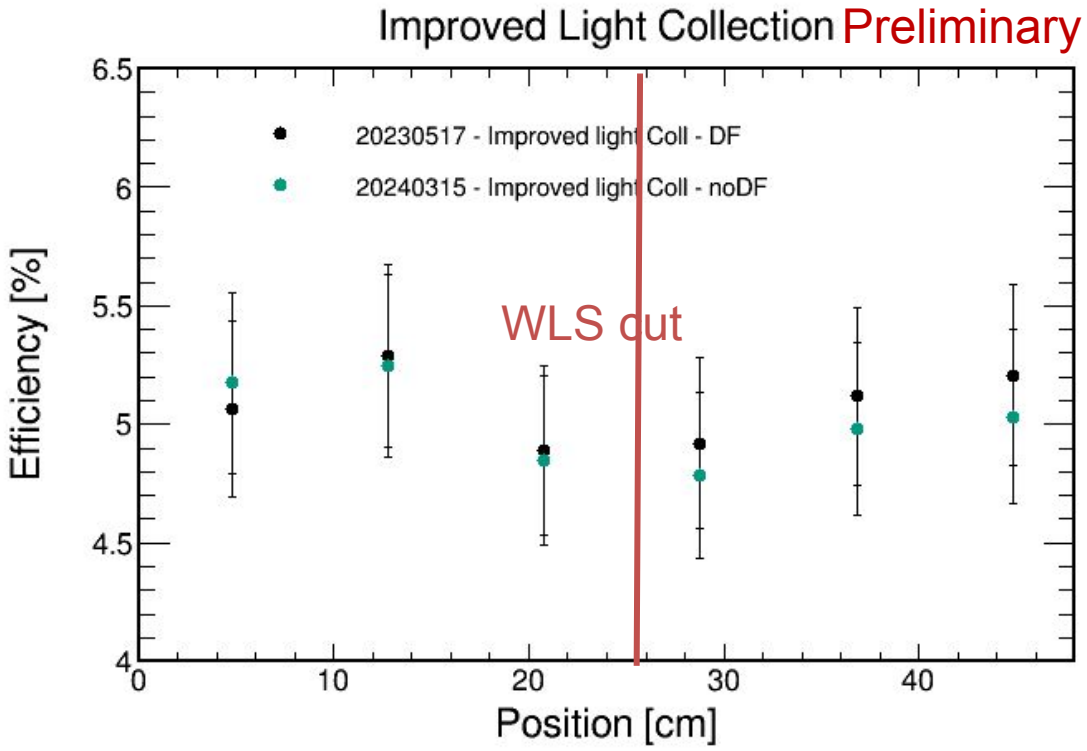
Long term study of the upgraded XA PDE and components



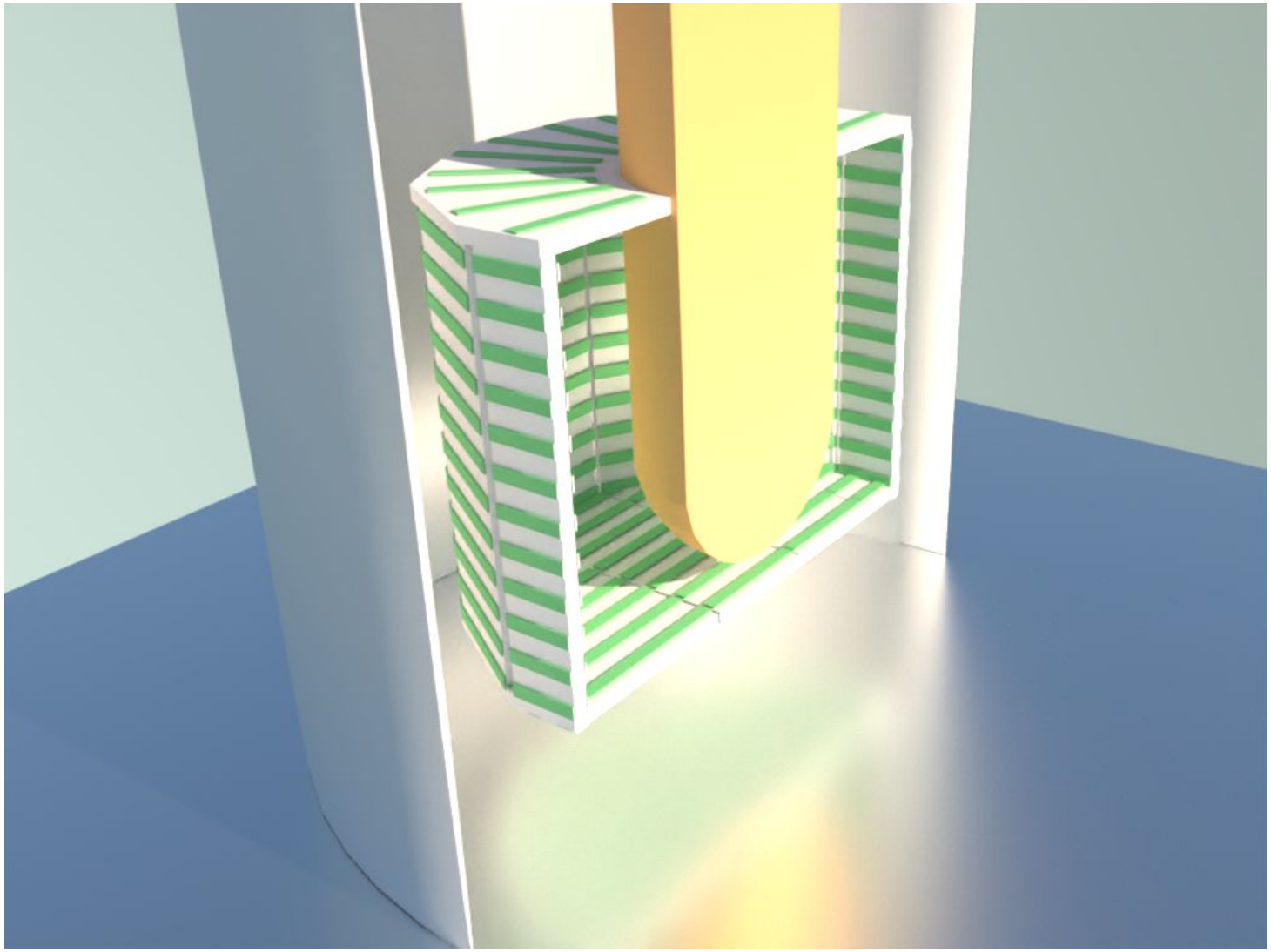
Impact of Dichroic Filters is marginal with the improved light collection configuration

Lightguide (LG) from the pDUNE-HD batch.

Improved light collection
1. LG with 40º cut
2. LG & SiPMs sides optically sealed by Vikuiti lined blocks



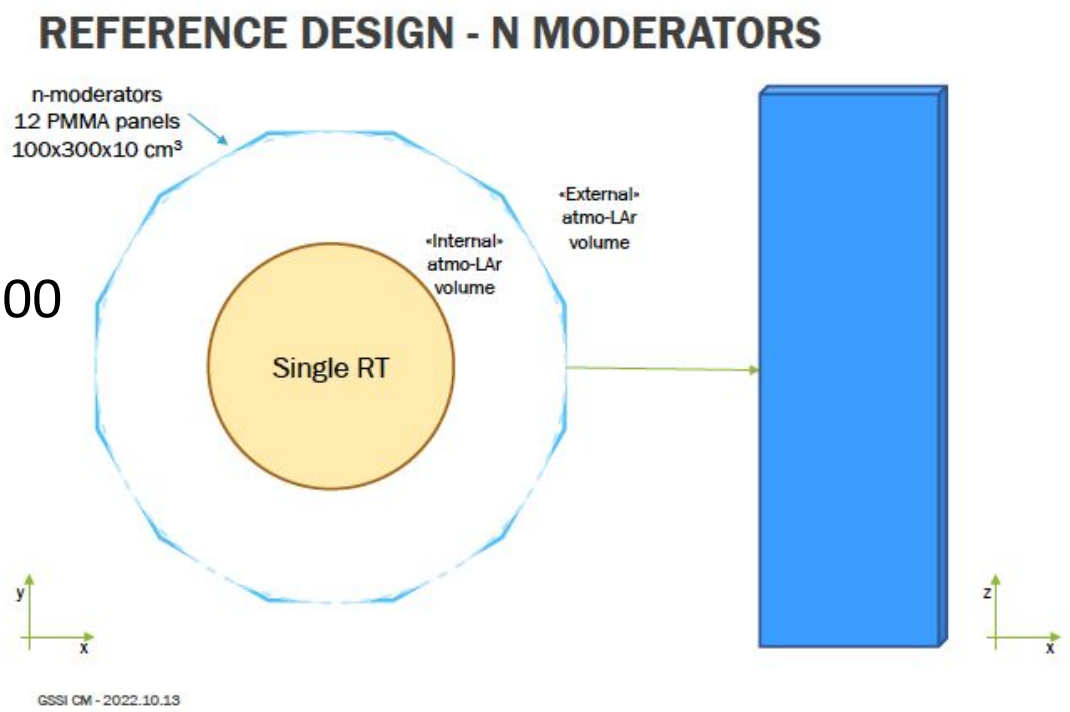
The L1000 PMMA n moderator shield: a pictorial view



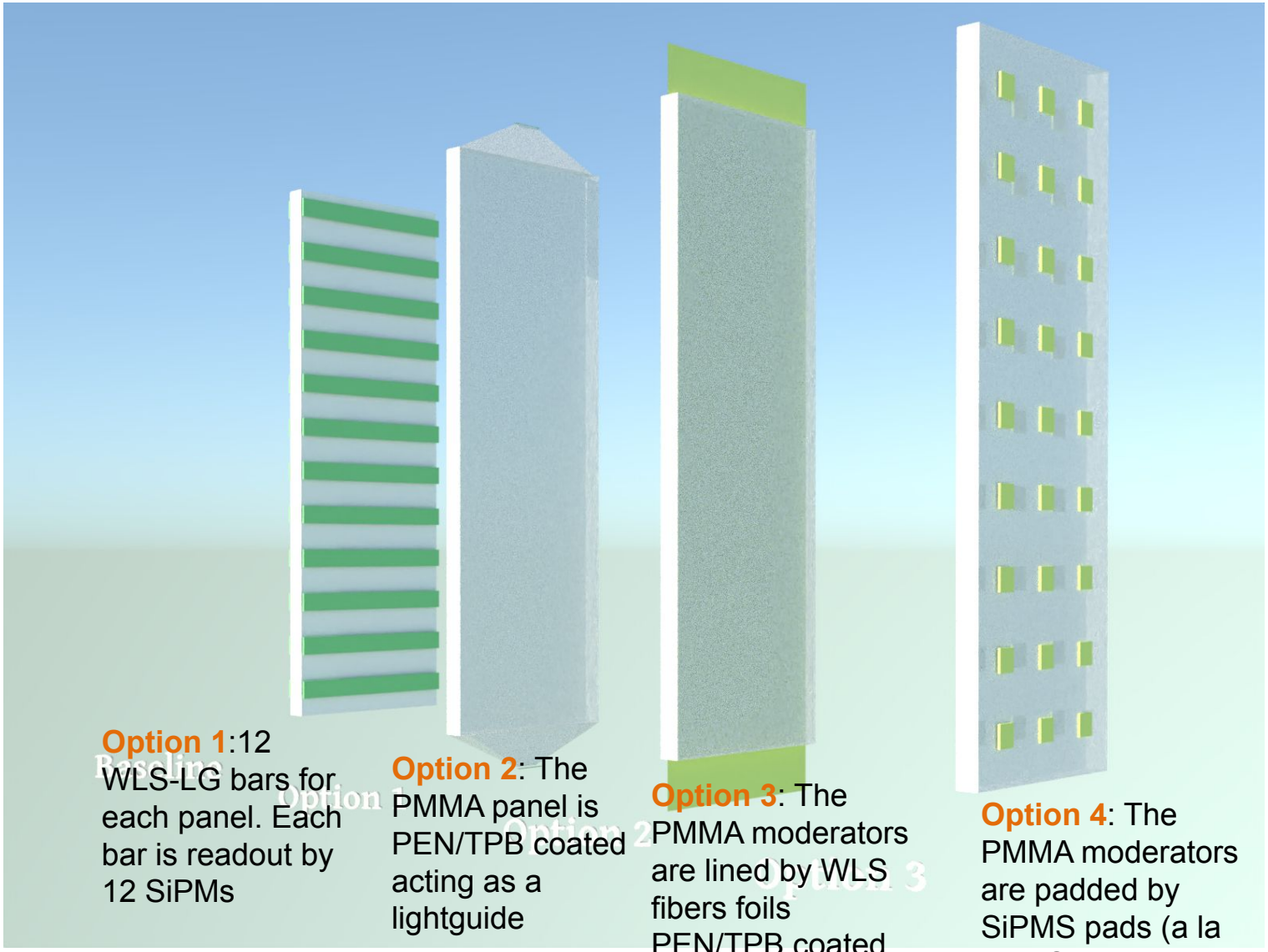
The L1000 n moderator shield

PMMA Moderator Shield

- 4 m diam
- 3 m height
- 10 cm thickness
- 12 x panels sizing: 300 x 100 x 10 cm^3 = 540 kg
- Top&bottom lids
- Defines two LAr volumes
  - External
  - Internal
- Require PMMA high radiopurity – JUNO grade
  - Optional: 0.5%-1% Gd to enhance n_{th} capture rate



The LarATm Veto readout Options



Option 1:12 WLS-LG bars for each panel. Each bar is readout by 12 SiPMs

Option 2: The PMMA panel is PEN/TPB coated acting as a lightguide

Option 3: The PMMA moderators are lined by WLS fibers foils PEN/TPB coated

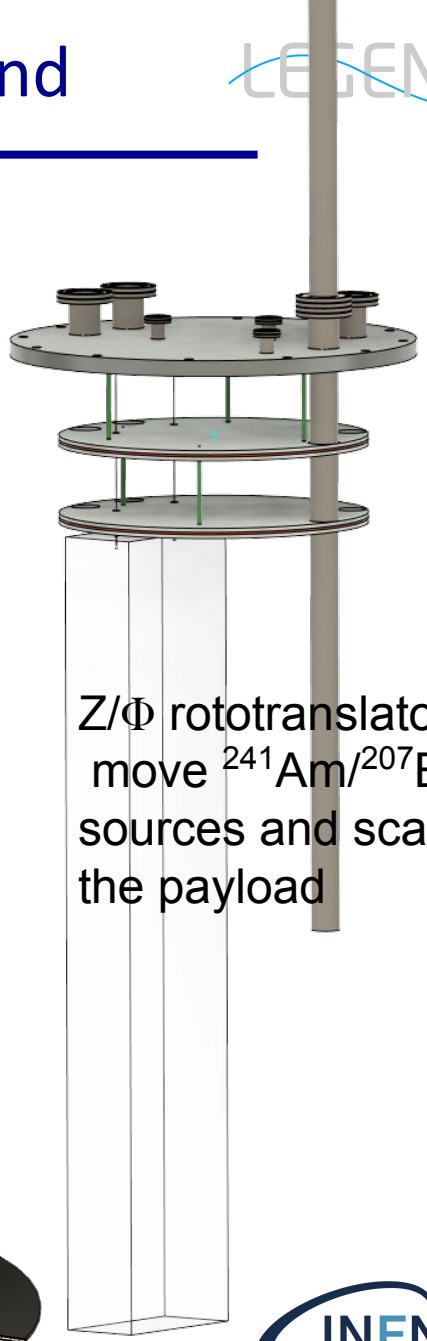
Option 4: The PMMA moderators are padded by SiPMS pads (a la DarkSide)

Summary of PMMA screening

- Found two italian vendors alternative to Donchamp
  - γ-screening on 14.5 kg sample: Ra-226 & Th- 232radiopure O(ppT).
  - ICPMS shows U-238 O(15-20 ppT) for both Clax & Donchamp.
  - Both vendors cast their plates from the syrup, hence the U-238 found by ICPMS is probably related to the initiator (see blue circle). We are searching for a cleaner initiator
- One has production capability for 10 cm thick plates & optical grade PMMA
- The second has production capability of plate thickness <=3 cm & optical grade

The INFN-MiB & LNGS test stand

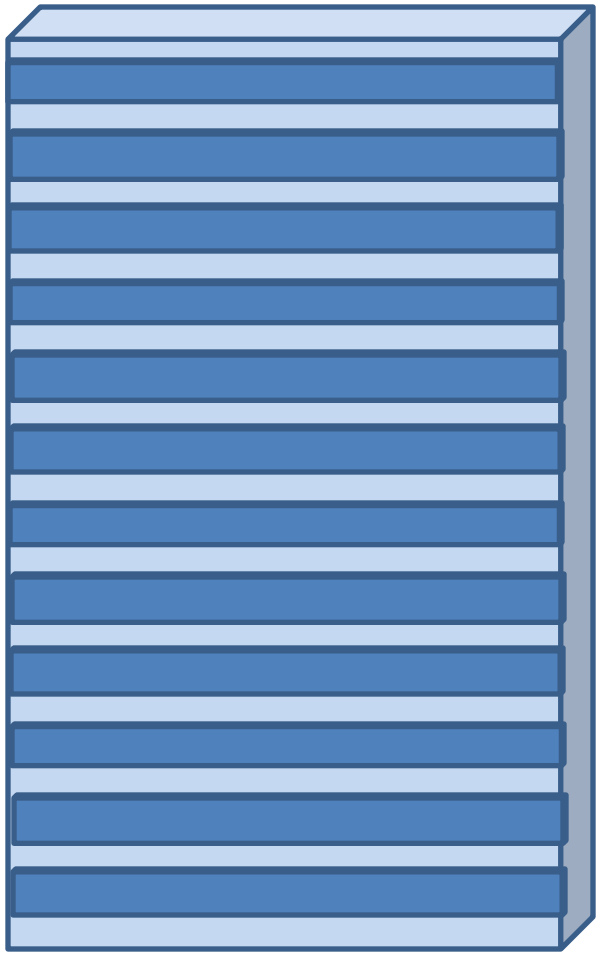
- DN 400
- Height:1350 mm-
- Will enable test of different readout options
- Will enable the test of PMMA absorber & PMMA-LG and/or WLS fibers ribbons



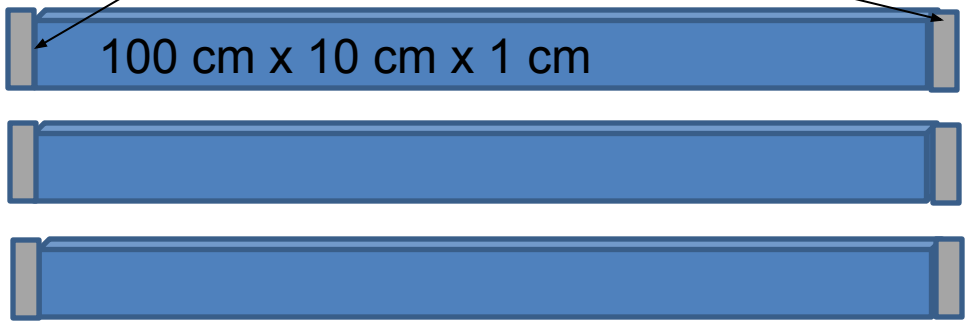
Z/Φ rototranslator to move ^{241}Am/^{207}Bi sources and scan the payload

Possible BL readout scheme: two electronic channels/PMMA panel

WLS-LG bars lined with PEN. Test of PEN lamination on PMMA ongoing



SiPMs boards: 6x (6x6 mm2)



6 SiPMs X 12 WLS-LG bars= Total 72 SiPMs/side of PMMA panel

One electronic channel/PMMA moderator side