WLS attenuation length.
&
Inconsistencies between DF T characteristics measurements

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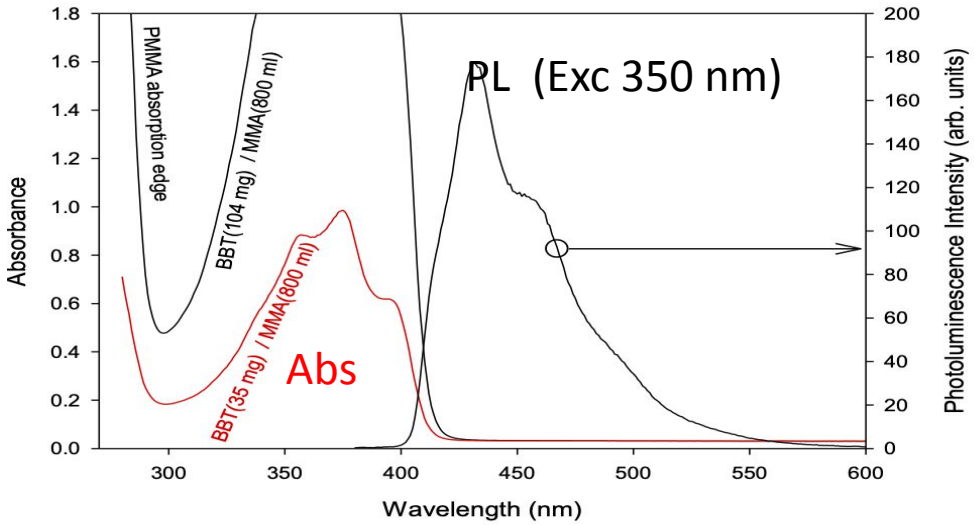
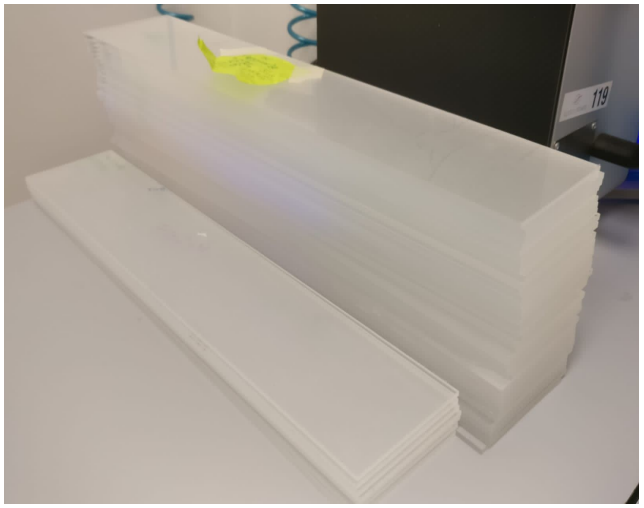
WLS for LAr detectors

- Requirements:
  - Cryoresilience
  - PMMA based (no scintillator, only Cerenkov emission)
  - High tolerances O(0.1 mm) on the as-cut tiles
  - Guiding surfaces: Optical grade
  - Edges: polished
  - Absorbption: 330-390 nm (tailored for pTP emission)
  - Emission: 420-500 nm to match the SiPM Q.E.
  - Optical Path O(1 m)



Absorption and Emission can be tailored on different wavelengths

WLS: Production of 90 FD1 and 20 FD2

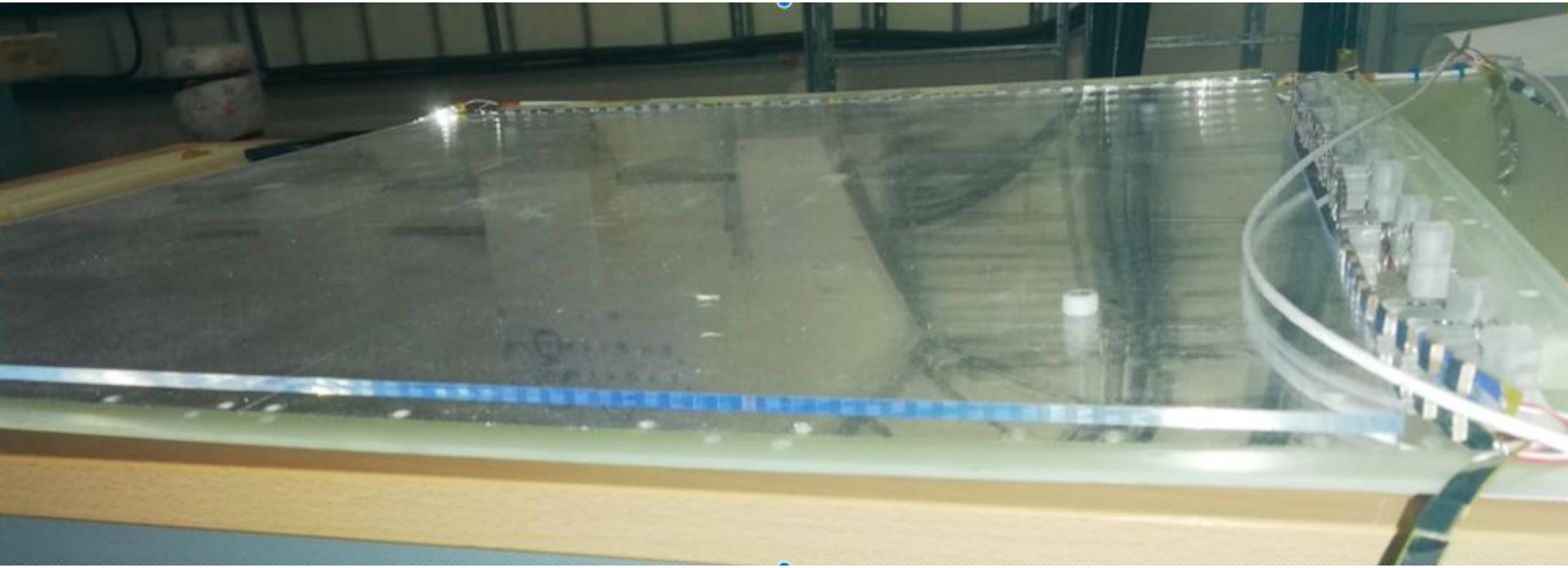


- 90 x WLS slabs for pDUNE
  FD1-PDS: 480 x 93 mm^2 x 4mm thick

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

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

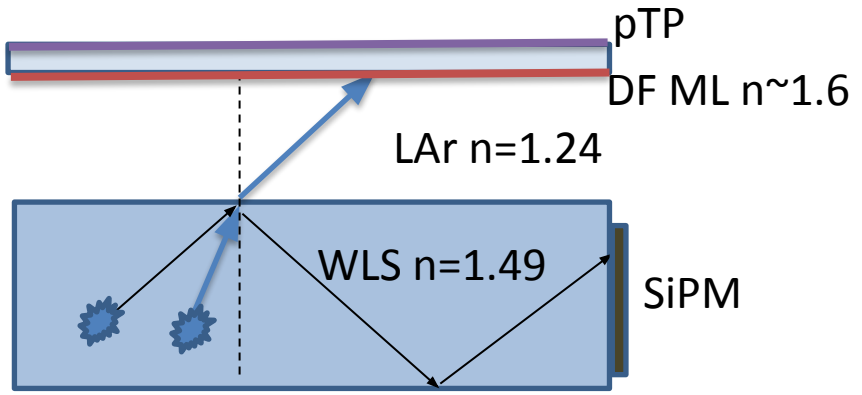
Large Area WLS



One 607 x 607 x 4 mm^3 slab is being assembled in one DUNE FD2 XA cell, together with SiPMs populated on flex circuits substrate.

WLS: Attenuation length (l_{att})

- In LAr the critical angle for Total Internal Reflection at the surfaces is $\theta_c = 56^o$.
- For $\theta > \theta_c$ photons are trapped and guided to SiPMs.
- For $\theta < \theta_c$ photons leave the lightguide and imping onto the DF
- Due to multiple reflections the optical path inside large size WLS (as for FD2 of DUNE) may reach a couple of meters.



The WLS attenuation length l_{att} is the leading parameter to maximize the photon transmission at the edges of a large area WLS-lightguide.

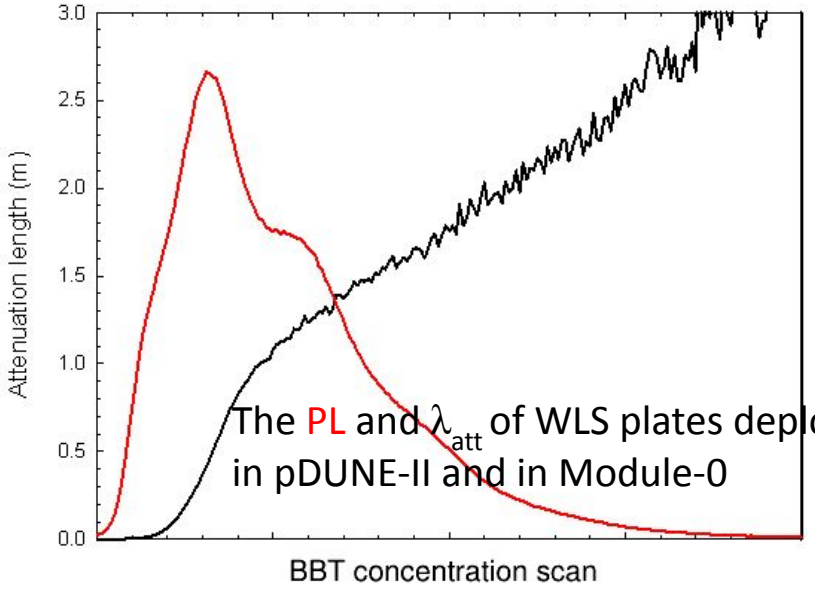
New measurements of G2P WLS lightguide

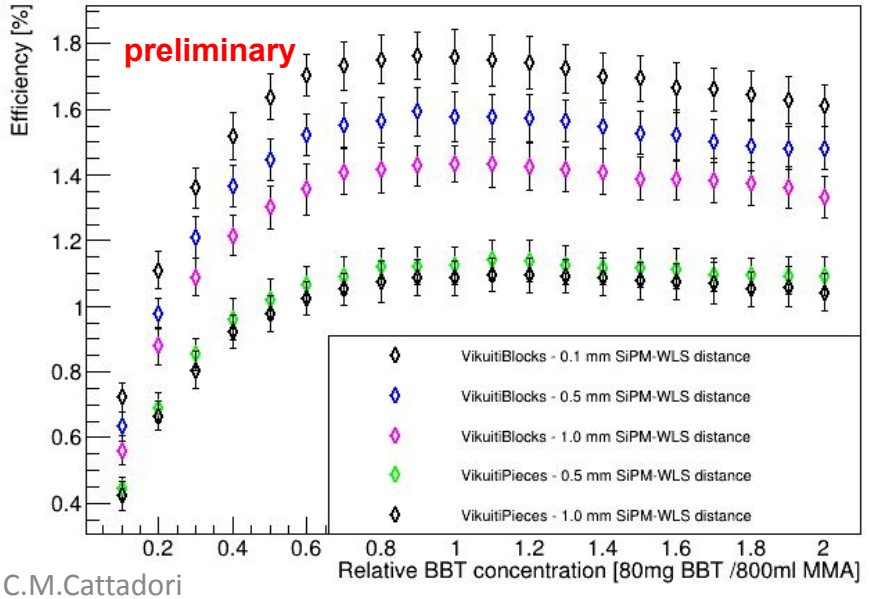
- T measurements at the spectrophotometer on 4 mm thick plates may suffer of systematics to infer att.length O(1 m)
- One 1 cm thick WLS plate has been casted
- T measurements have been performed with lasers at three λ 400<λ<450 nm. After subtraction of reflections effects at the entrance, these are used as reference.
- The T(λ) measured at the spectrophotometer are corrected (shifted)
- The Att.length (l_{att}) is derived (the method and the results will be published)

WLS for FD1: Attenuation length (l_{att})

The l_{att} of the DUNE - FD1:

- is 37 cm at 430 nm (maximum of WLS PL spectrum)
- The dye concentration has been tailored on the FD1 WLS shape.
- an optical simulation is employed to evaluate the impact of different variables on the light collection efficiency:
  - chromophore concentration
  - lightguide shape and size





WLS for FD2: Attenuation length (l_{att})

The *dye concentration* of the DUNE - FD2:

- must be tailored for the FD2 WLS size → optical path.
- Optimization (driven by sims)
- Given the WLS plate thickness (4 mm) the cromophore concentration must be tuned by the trade off of maximizing both the latt and the pTP ph. trapping efficiency

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

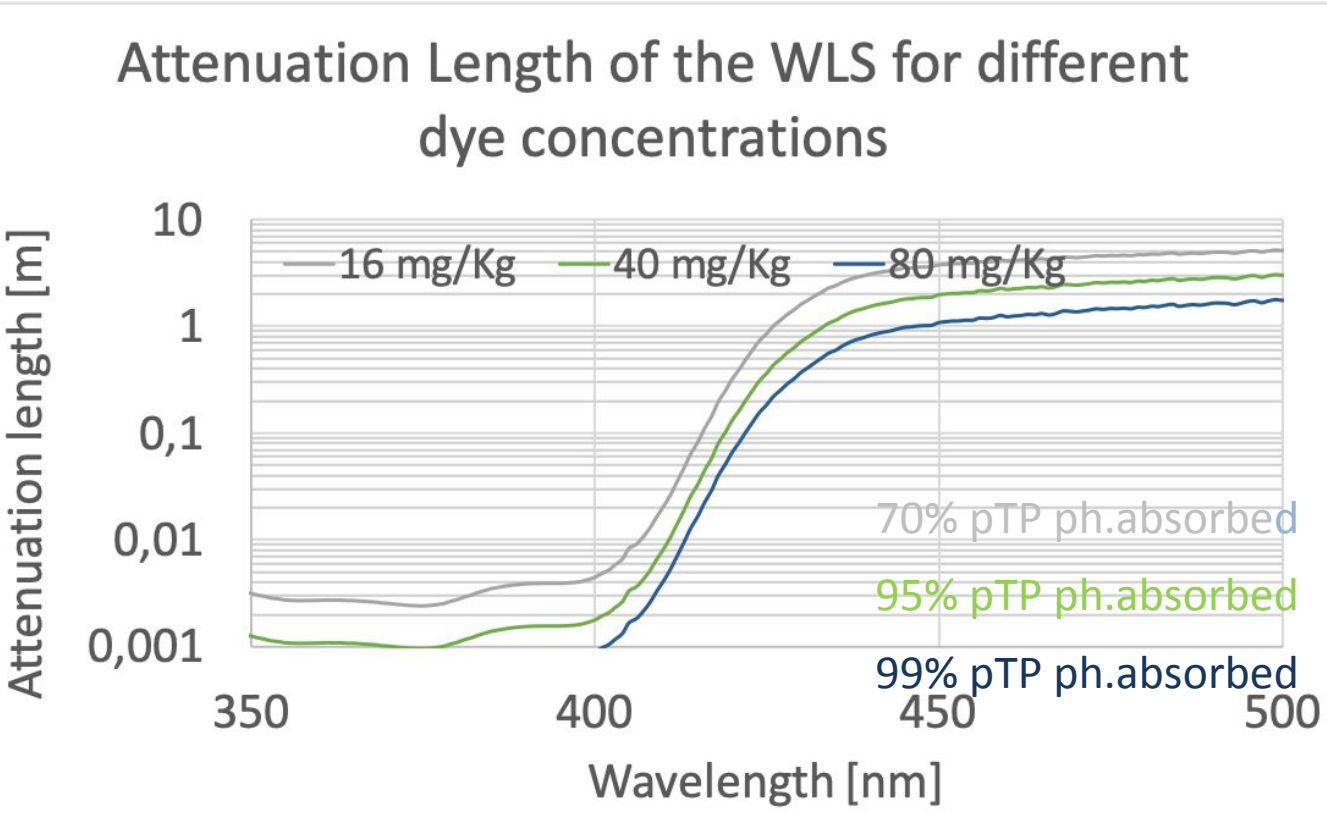
$T = I/I_o \exp(-d/l_{att})$

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

ε = molar extintion coeff.

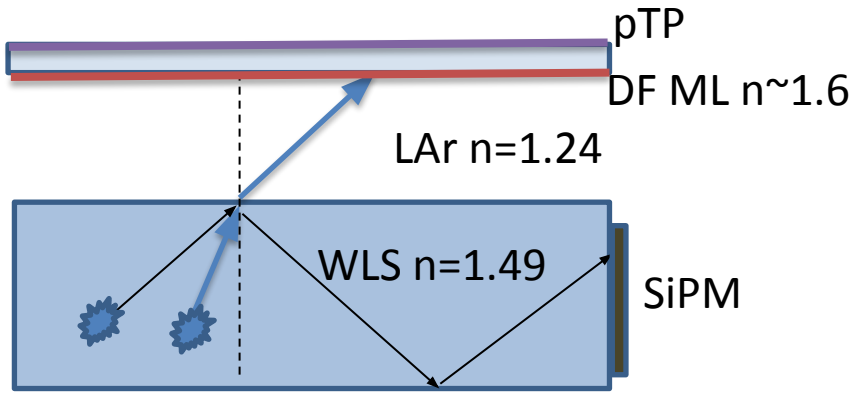
c = concentration

d = optical path



Dichroic Filters

- Dichroics Filter (DF) are made of thin film multilayer coatings on a glass/fused silica substrate. They act as Fabry-Perot interferometer to slectively transmit/reflect light.
- For Large volume LAr detectors => Large area DF
- The glass window is coated with a primary WLS (pTP) to downshift the 128 nm light to ~350 nm



ZAOT (our industrial partner) substrate

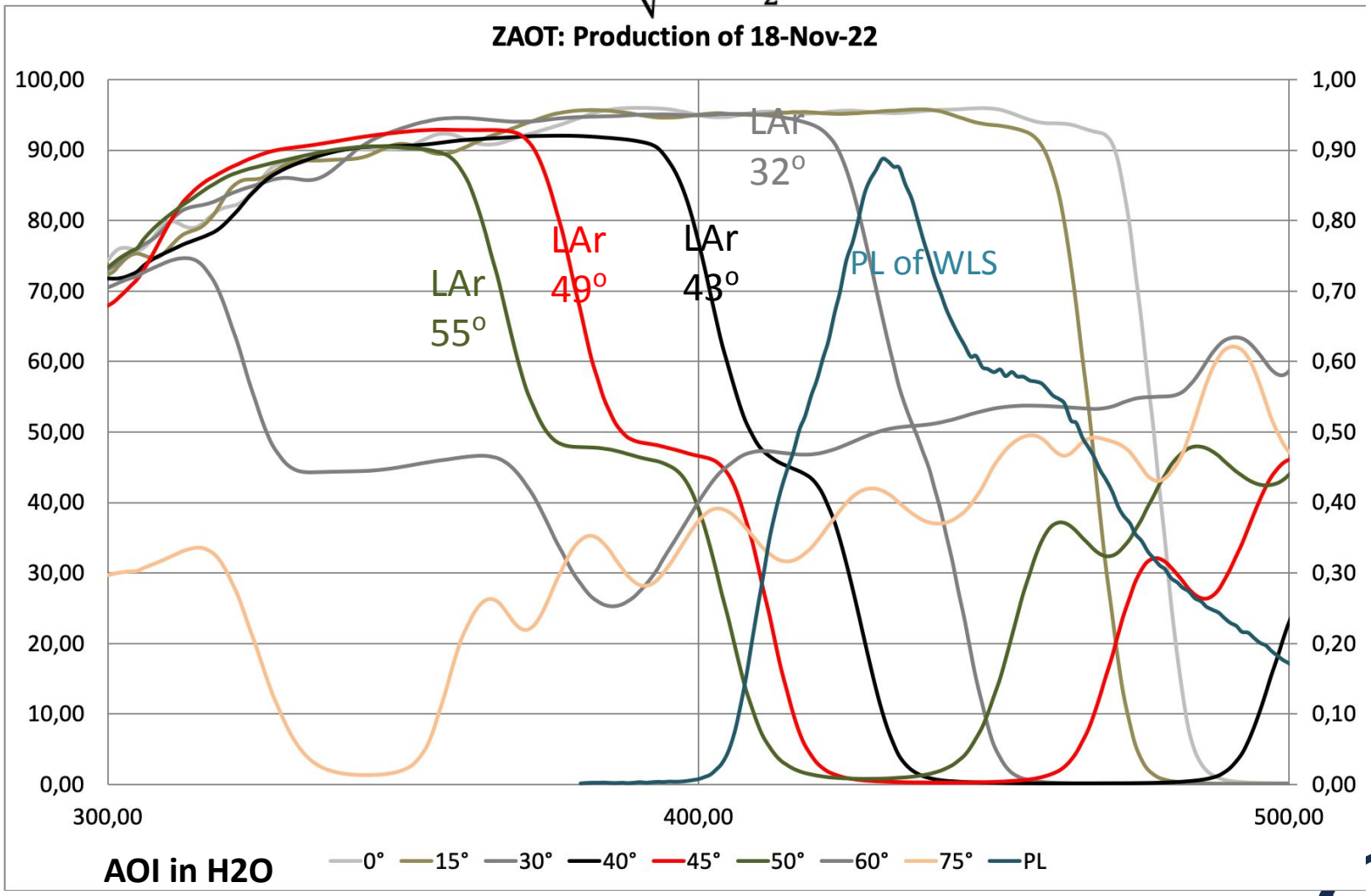
- Borofloat 33 Optical Glass

OPTO (BL component) Substrate

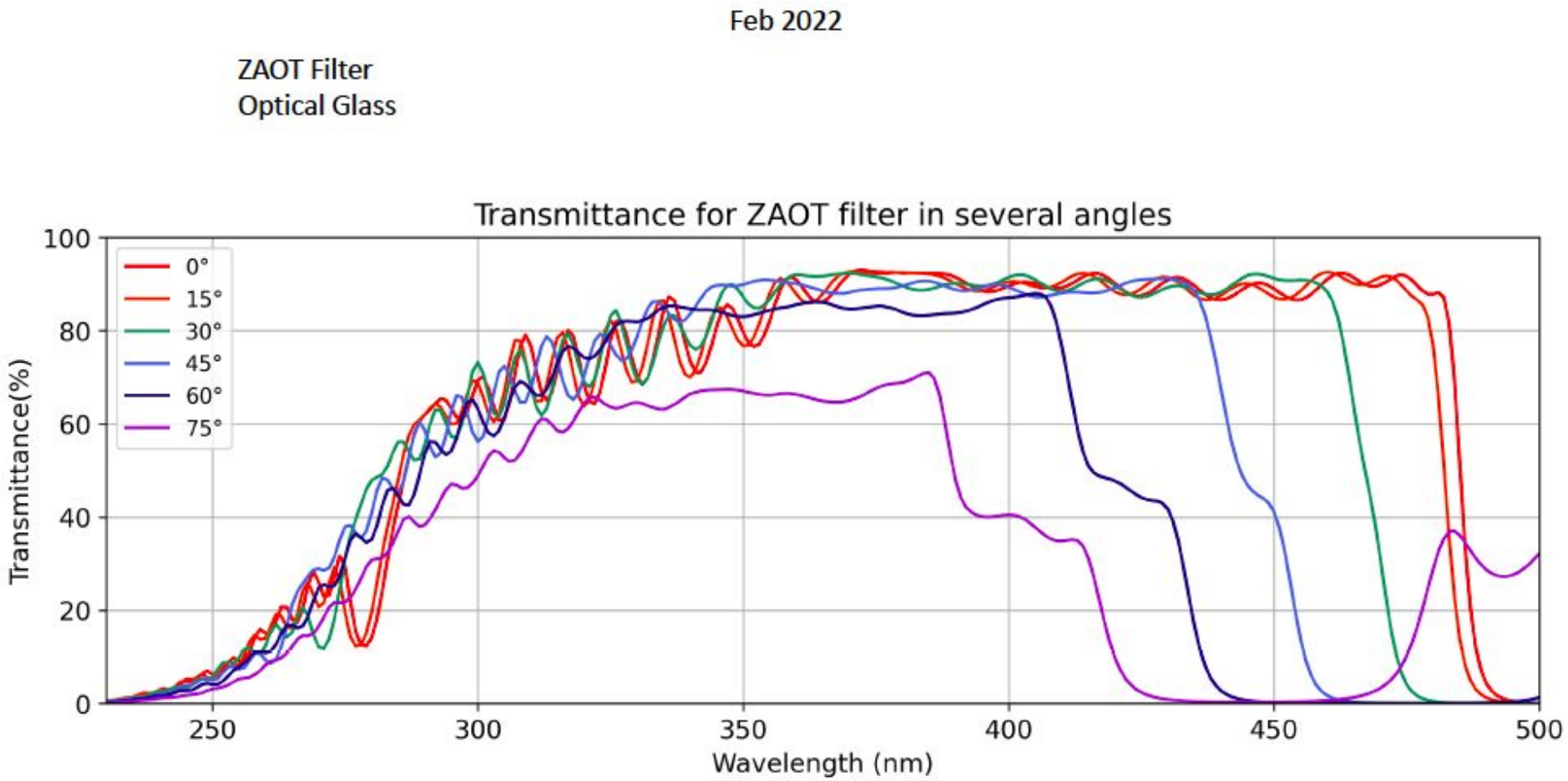
- B270

ZAOT - T curves

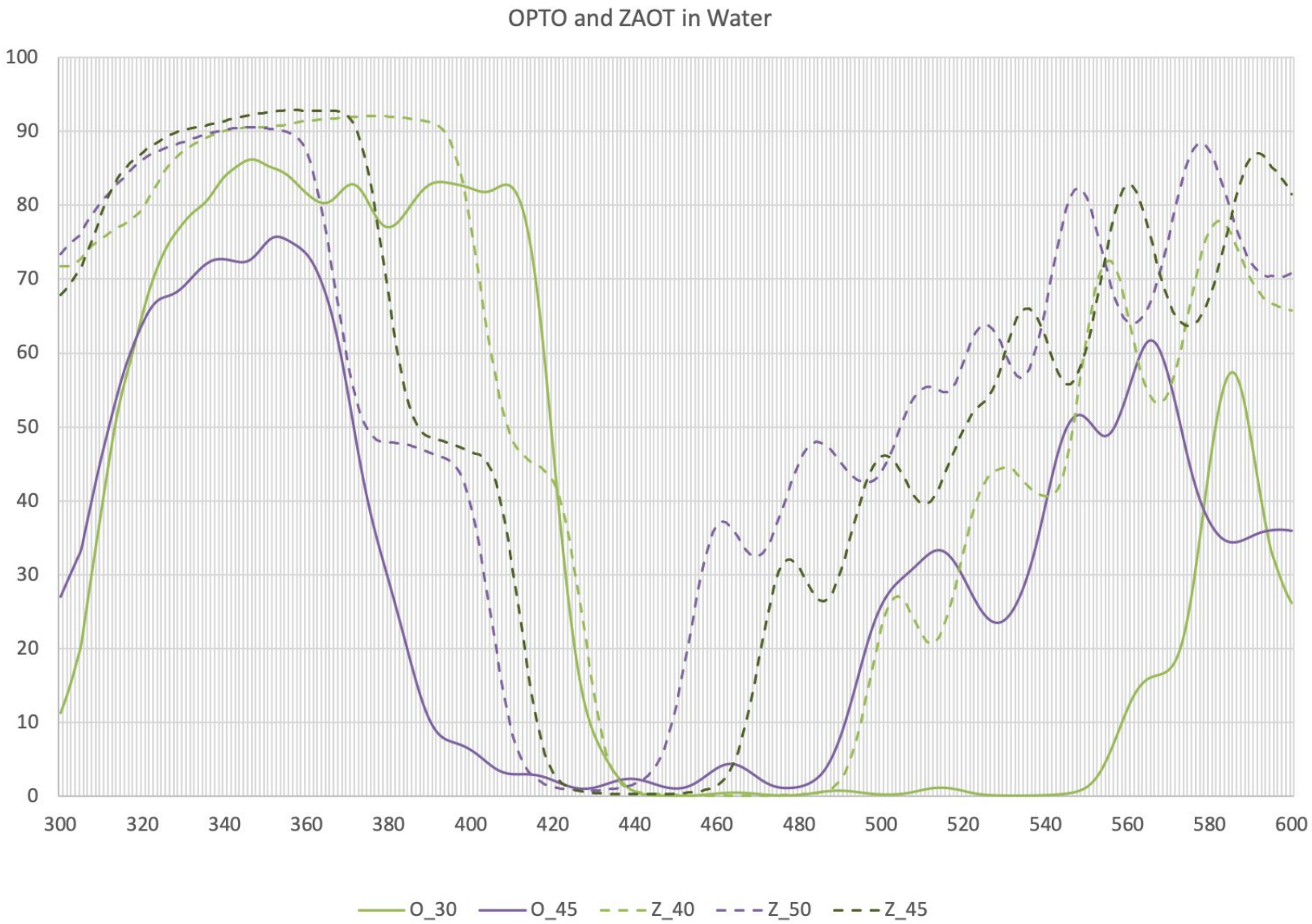
Cutoff change vs n => $\lambda = \lambda_0 \sqrt{1 - \frac{n_1^2}{n_2^2} \sin^2 \theta}$



ZAOT: T measurements at UniCamp

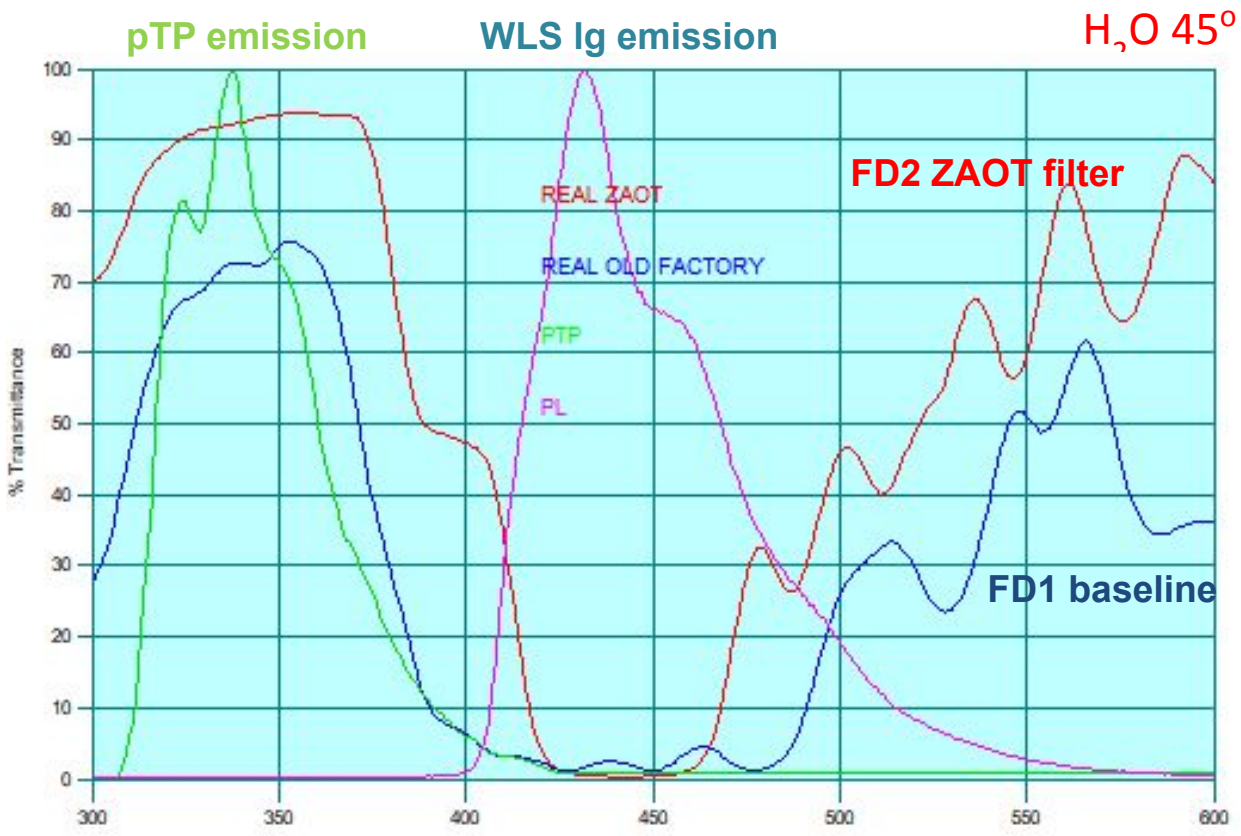


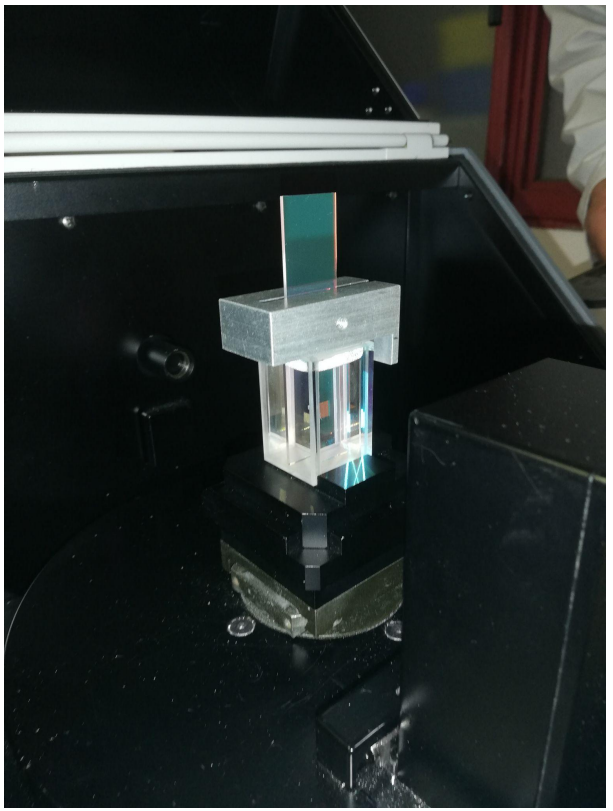
ZAOT vs OPTO: T measurements @ MiB



ZAOT vs OPTO: T meas. at ZAOT company

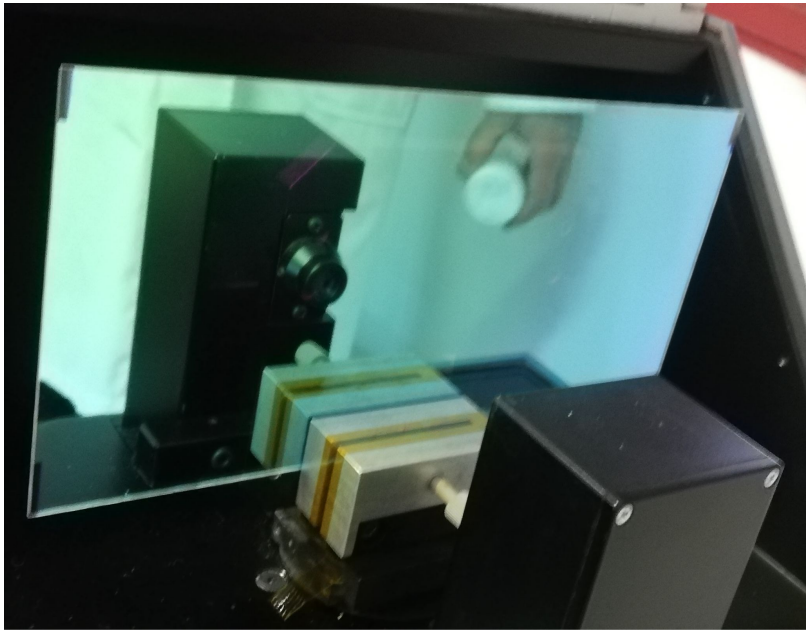
- Filters have been optimized to operate in lAr (@45°)
  - **Higher transmittance in the pTP emission range**
  - **Higher reflectivity in the light gude WLS chromofore emission range**
  - **But narrower refectivity window**

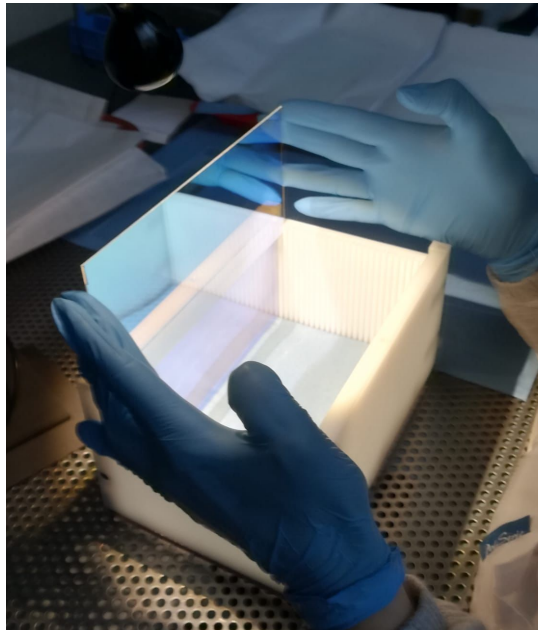




Dichroic filters production

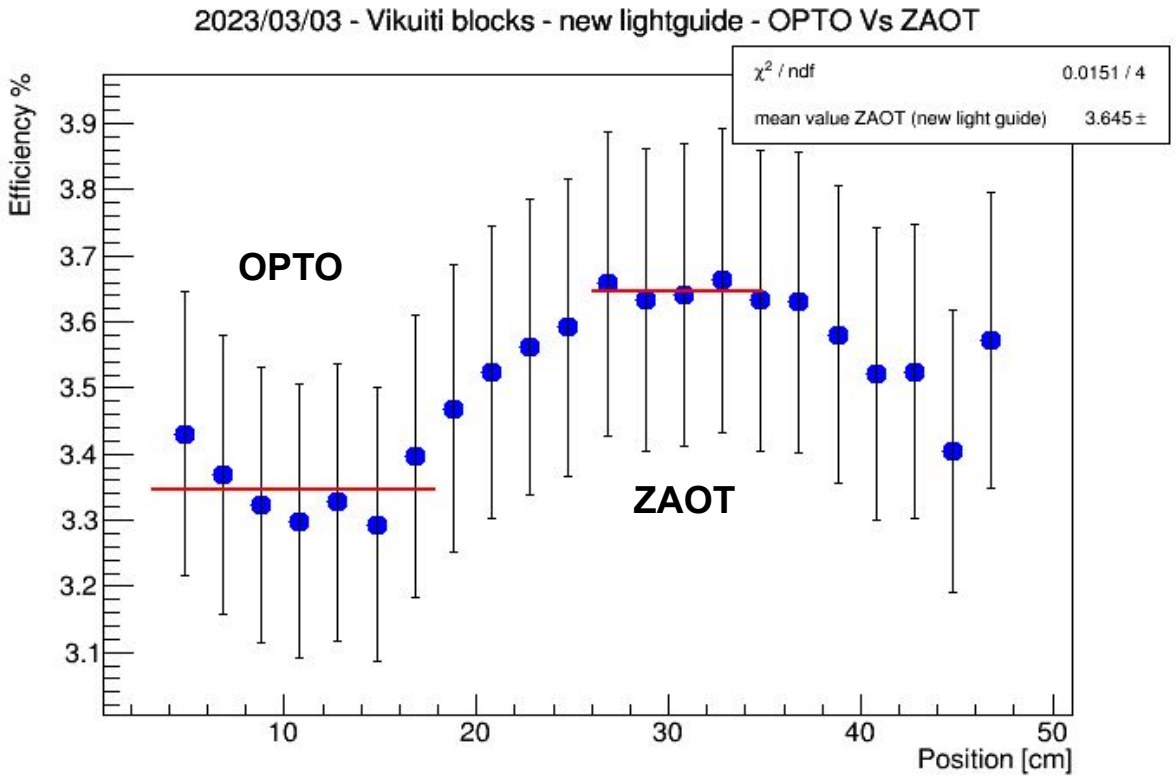
- ZAOT produced large area (150 x 150 mm^2):
  - 265 DF for the Module-0 of the DUNE-FD2 for 10 XA Megacells (4 membrane + 6 cathode)
  - 54 DF for PDE Production capabilities of both vendors: > **120 DF in 5 w.d.**

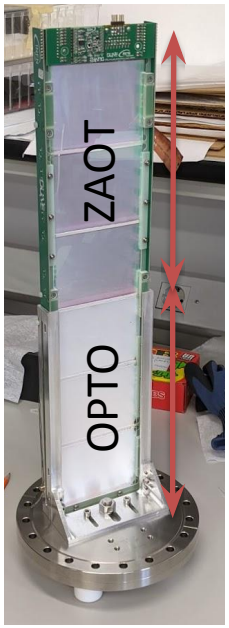




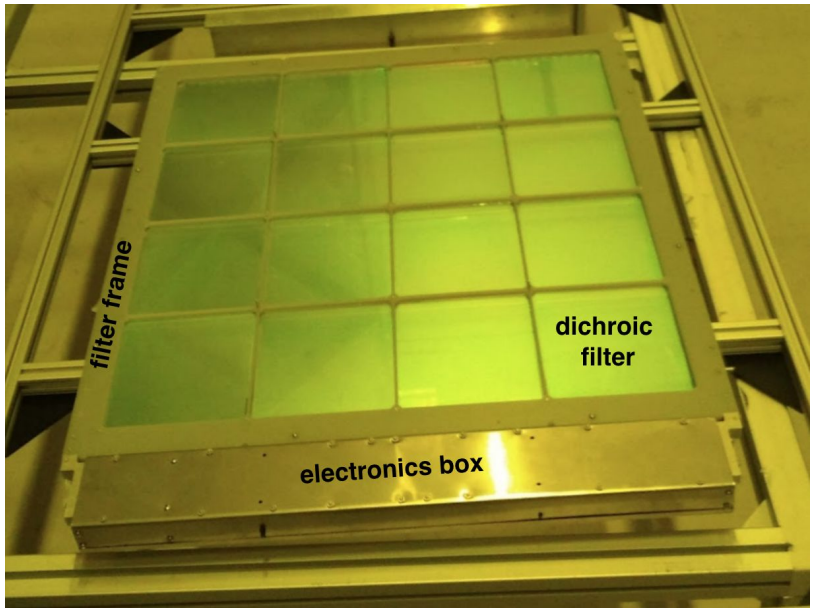
Assessment of ZAOT DFs performances in LAr

- Measurements of the PDE in LAr of one FD1-XA equipped with
  - three OPTO (0 < position< 24 cm)
  - three ZAOT (24 < position< 48 cm)
- Effect foreseen by GEANT based Simulations





Large area XA configuartions



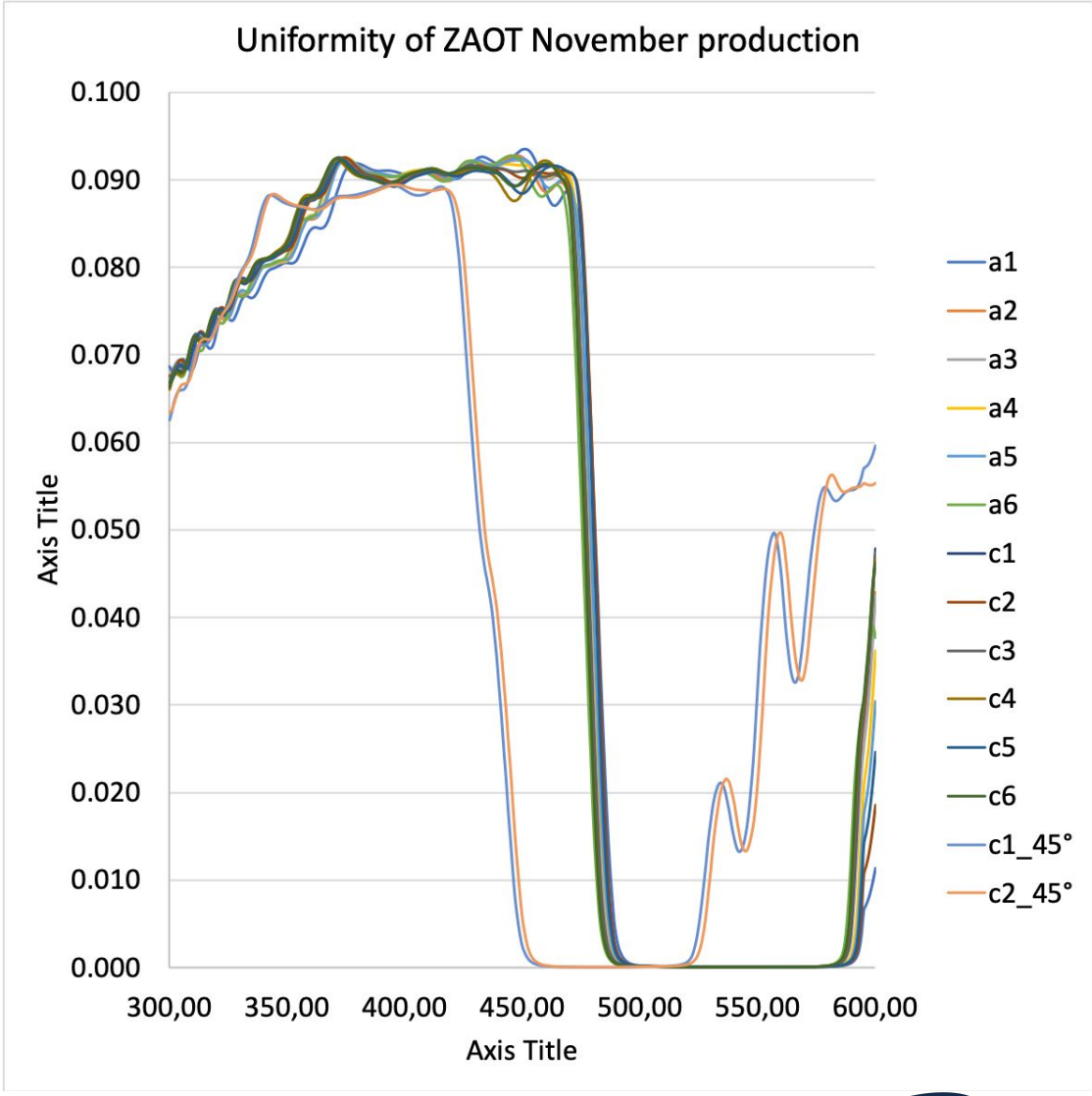
	WLS dimples	DF size (mm^2)	DF	SiPM	PoF	SoF	shared elec. box
M1		100x200	ZAOT	HPK			x
M2		100x200	ZAOT	HPK			x
M3	x	100x200	ZAOT	HPK			x
M4	x	100x200	ZAOT	HPK			x
M5	x	150x150	PE	FBK		x	
M6	x	150x150	PE	HPK			
M7	x	150x150	PE	HPK			
M8	x	150x150	PE	FBK			
C1		100x200	ZAOT	HPK	x	x	
C2		100x200	ZAOT	HPK	x	x	
C3		150x150	PE	FBK	x	x	
C4	x	150x150	PE	HPK	x	x	
C5	x	150x150	ZAOT	HPK	x	x	
C6	x	150x150	ZAOT	HPK	x	x	
C7	x	150x150	ZAOT	FBK	x	x	
C8	x	150x150	ZAOT	HPK	x	x	

- PDE measurements of the large area XArapuca will be performed at different sites:
  - INFN Naples
  - CIEMAT (Madrid)

Thank you!

DF coating uniformity

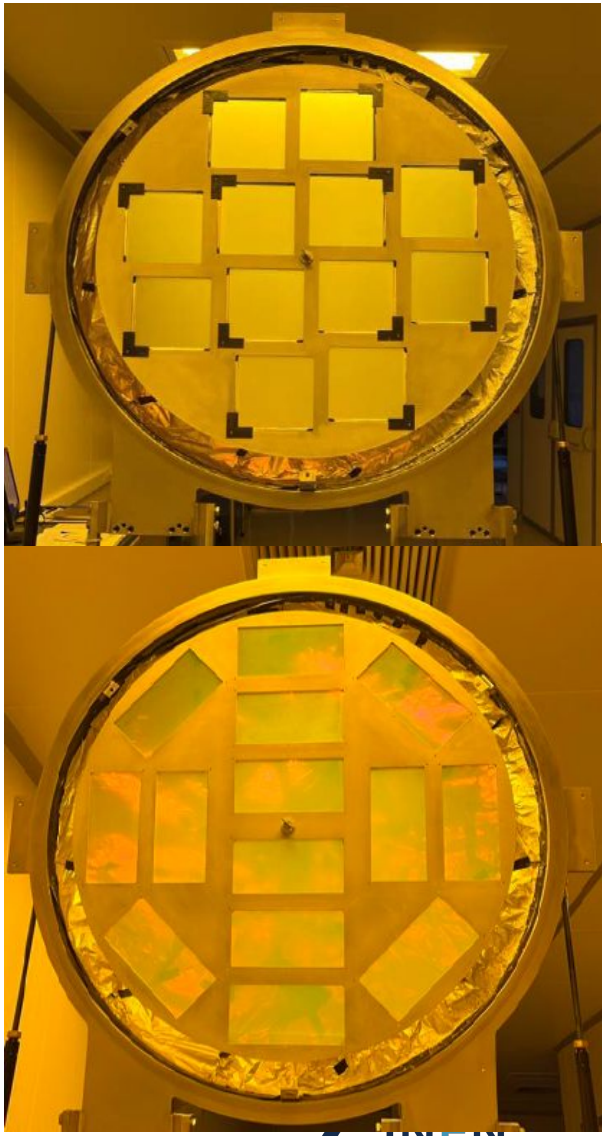
- two extreme positions (a and c) of the ML coating disk tested
- each of the two DF tested at 6 different points



pTP coating

The coating report from UniCAMP

Date	Size	Disc position	Mass before	Mass after
26/01/23	143.75x143.75	Central (01)	66,62698 g	66,72385 g
26/01/23	143.75x143.75	External (07)	66,17028 g	66,22962 g
N. filters = 12		pTP = 4,000 g		Pc=2,2*10-5 mbar



Main pTP coating site: UNICAMP

Coating capabilities: 2 batches/day => 24/day

- Evaporation of ~400 ug/cm2
- Thickness: 3.2 um

Twin facility will participate at the FD2 pTP coating efforts at INFN Napoli starting from spring 2024