Summary of MiB experience of the PDE measurements of the XA devices (SBND and Dune FD1)

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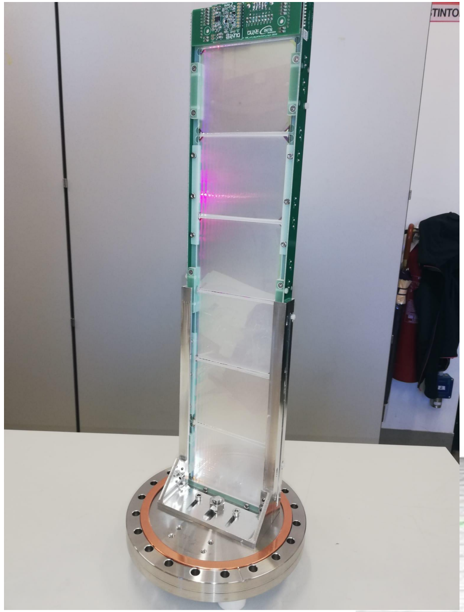
Setup to measure the XA-HD-SC PDE in LAr

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



The XA-SC installed in the test chamber (~10 l) to measure the PDE along its z-axis.

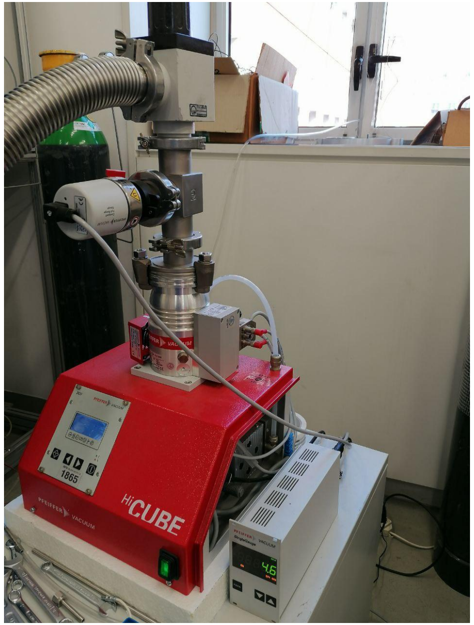
Supercell equipped with:

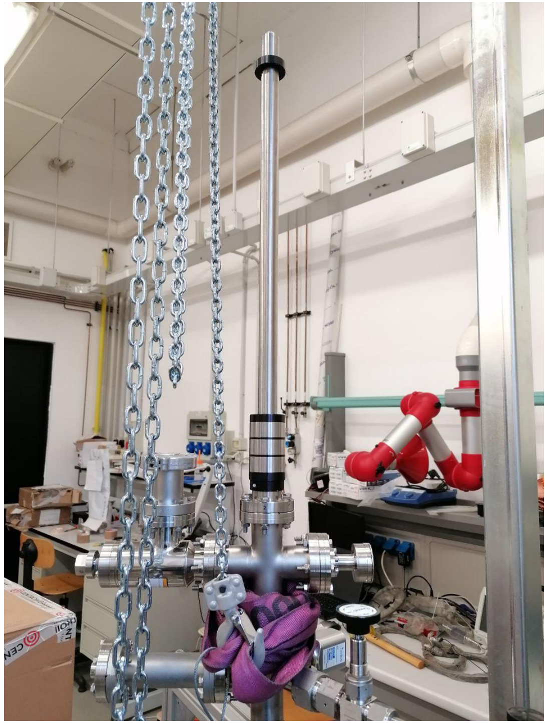
- PMMA WLS (G2P)
- dichroic filters

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

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

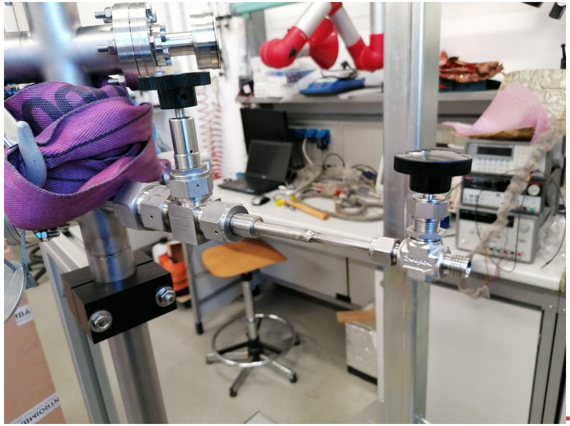
Chamber vacuum pumped to 10^{-4} - 10^{-5} mbar

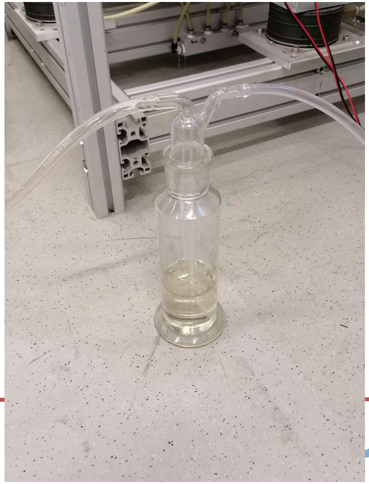




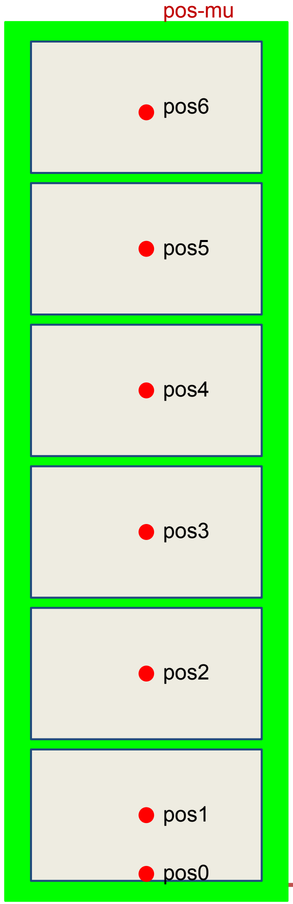
Cool down + Warm up procedures

- **Cool down**: ~1700 mbar of grade 6.0 GAr injected into vacuum chamber, external dewar filled with LAr
- GAr inlet is then opened again and left open until the filling is done, external LAr bath refilled as needed (consumed by the liquefaction of the internal GAr)
- Internal LAr level rises 3-4 mm per minute at the beginning, then slows down (condensation surface decreases)
- **Warm up**: chamber extracted from the dewar,
  - while the inner pressure ≫1100 mbar GAr →air open directly,
  - when inner pressure ≦ 1100 mbar a glycerin bubbler is added in series preventing the backflow of air.





Method & Data taking



Thanks to the magnetic manipulator → 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.
   Intermediate positions added as needed

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.

MC computed geometric acceptance

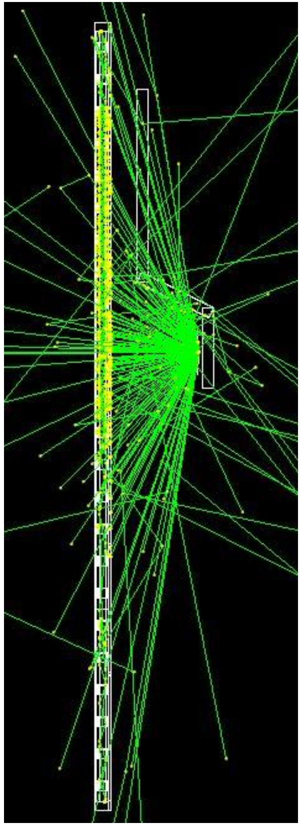
The knowledge of the solid angle is crucial for the PDE determination.

Solid angle computed via a geant4 simulation

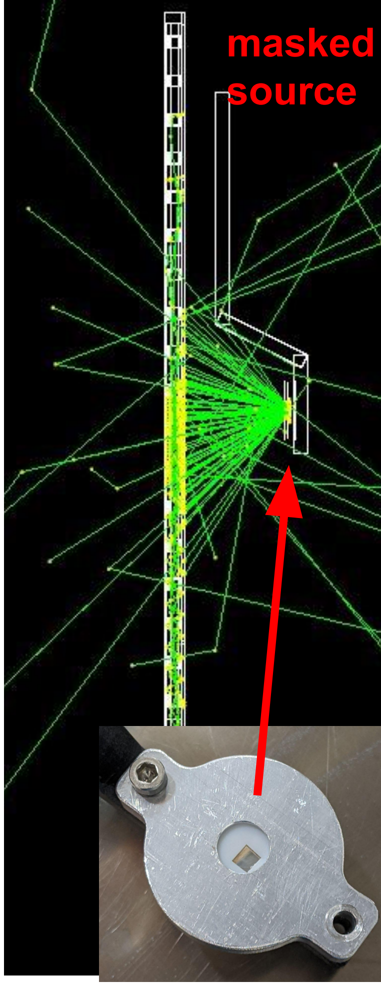
- geometry takes into account also the source holder, the source arm and the teflon mask (in the first analytical simulation only the source holder arm was modeled)

- solid angle obtained from the ratio of photons hitting the pTP deposit over the scintillation photons
  - $\Omega = (\gamma_{pTP}/\gamma_{scint})*4\pi$

unmasked source



masked source

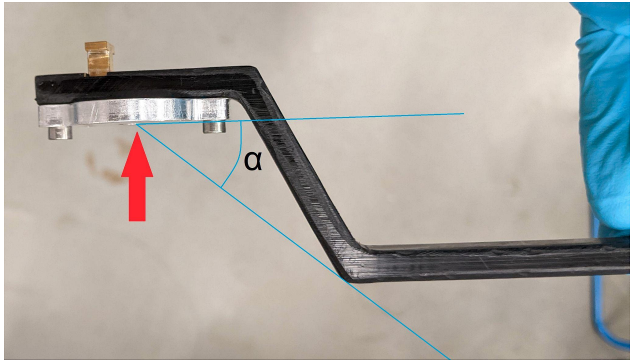


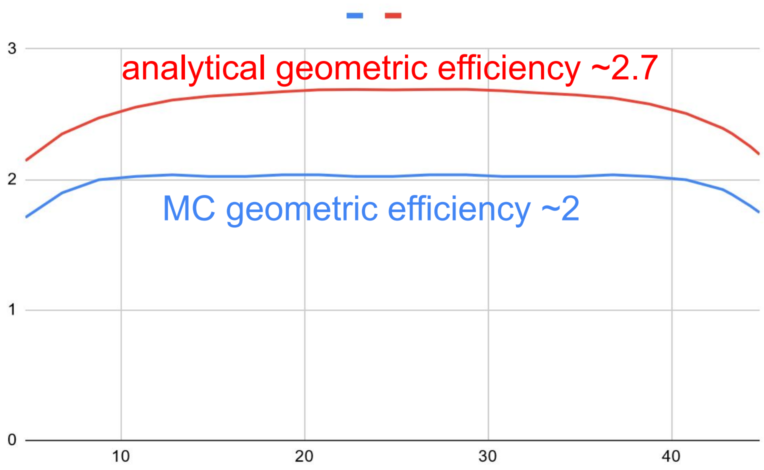
MC computed geometric acceptance

Adding the source geometry, (holder and teflon mask), the geometric acceptance decreases from a peak of **2.7** steradiants to **2**

- possible difference in the geometry
- effects from absorption and scattering in lAr

position	MC sim	analytical
4th dichroic	**2.43**	**2.69**





Solid angle computation: comments

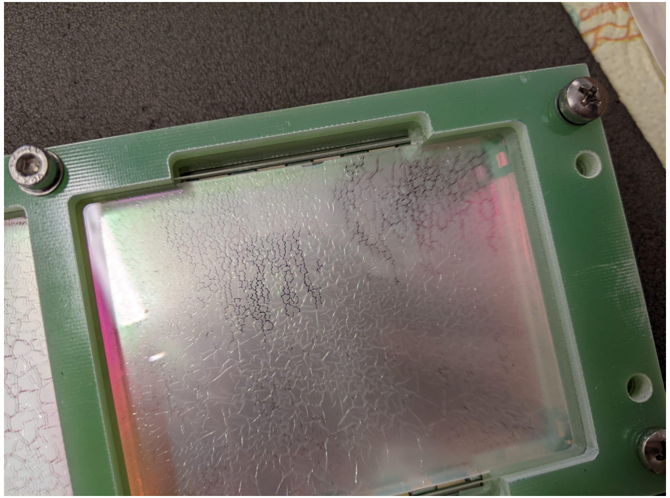
- In our setup, the source needed to be completely simulated, as the teflon mask impacts significantly the solid angle, especially for an object as extended as the Supercell (the effect was negligible for the 2 window X-Arapuca).

- For the Supercell, the impact of the mechanics (namely, the ribs between one dichroic and the other is minimal (~2 mm width). Nevertheless it was simulated

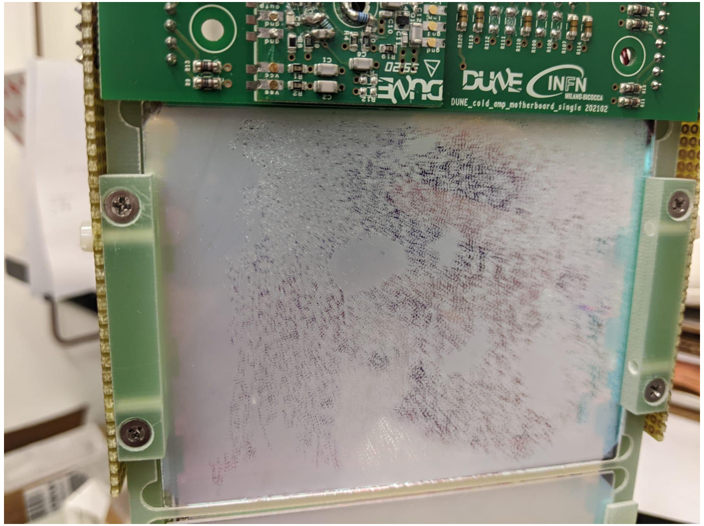
- For the Megacell (very large shape and size)
  - **the exact simulation of the DF frame geometry (ribs) is relevant.**
  - **Solid angle ≃ 1/source distance^2 ← must be carefully measured**
  - **measure both z and phi for both the megacell and the reference SiPMs (if deployed in the setup)**
  - **reference SiPM should be deployed at different positions**

Preservation of pTP coating of dichroic filter

In our setup, we never observed humidity-related damage on the pTP coating of the dichroic filter.
Flaking, however, does occur. After 10-15 thermal cycles it becomes severe enough in the topmost filter to impact the PDE of the Supercell in that position. We don't yet understand the mechanism

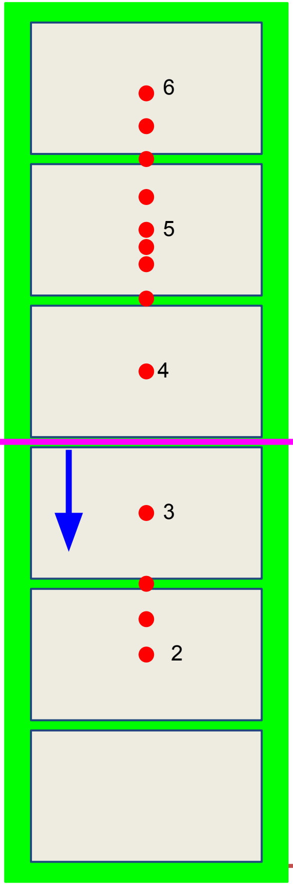


SBND XA: XA extracted from pDUNE-I after Xe doping exp..Humidity-related damage at the extraction



Flaking of pTP: the DF was from the FD1 coldbox 1

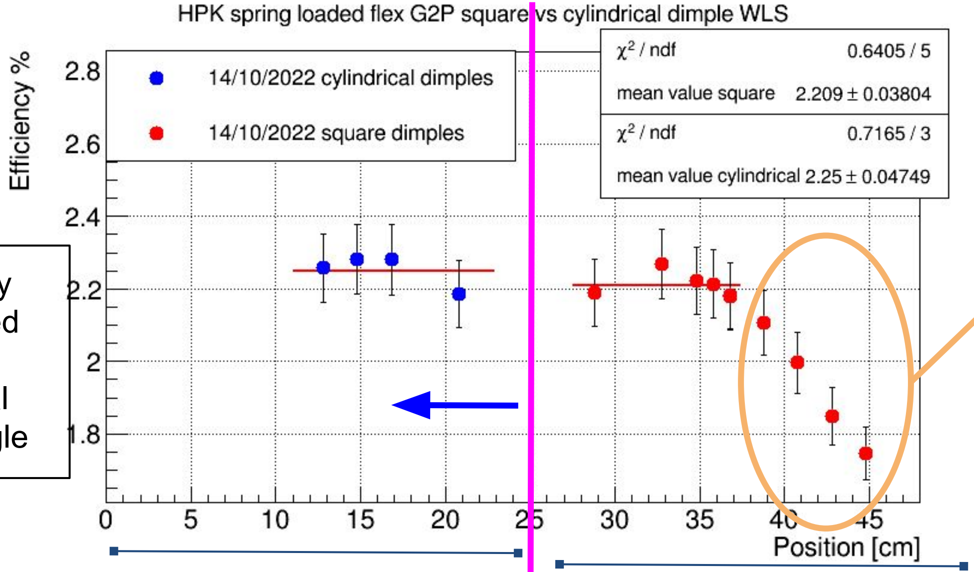
Effect of damaged pTP on the PDE



Square dimples

Cylindrical dimples

Efficiency calculated with analytical solid angle



Cylindrical dimples

Square dimples

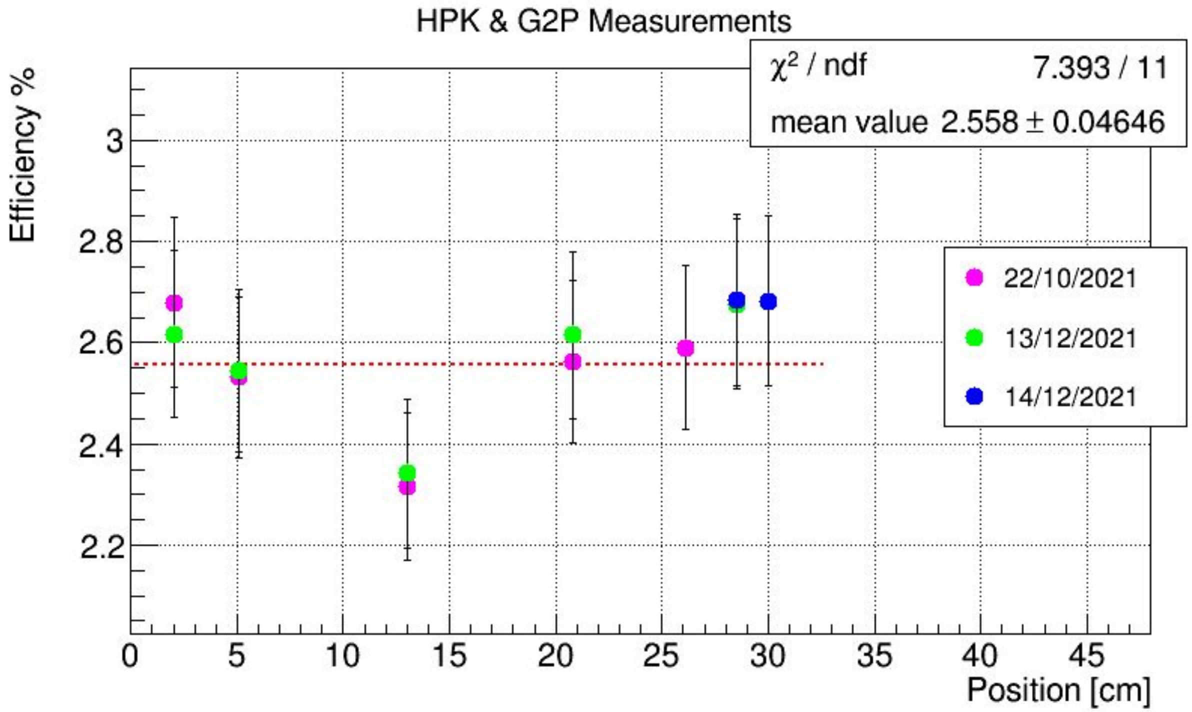
Lower positions inaccessible due to stuck cable

LAr surface well above 6th dichroic

Reproducibility of the measurements

Measurements taken months apart of the same SC configuration are consistent.

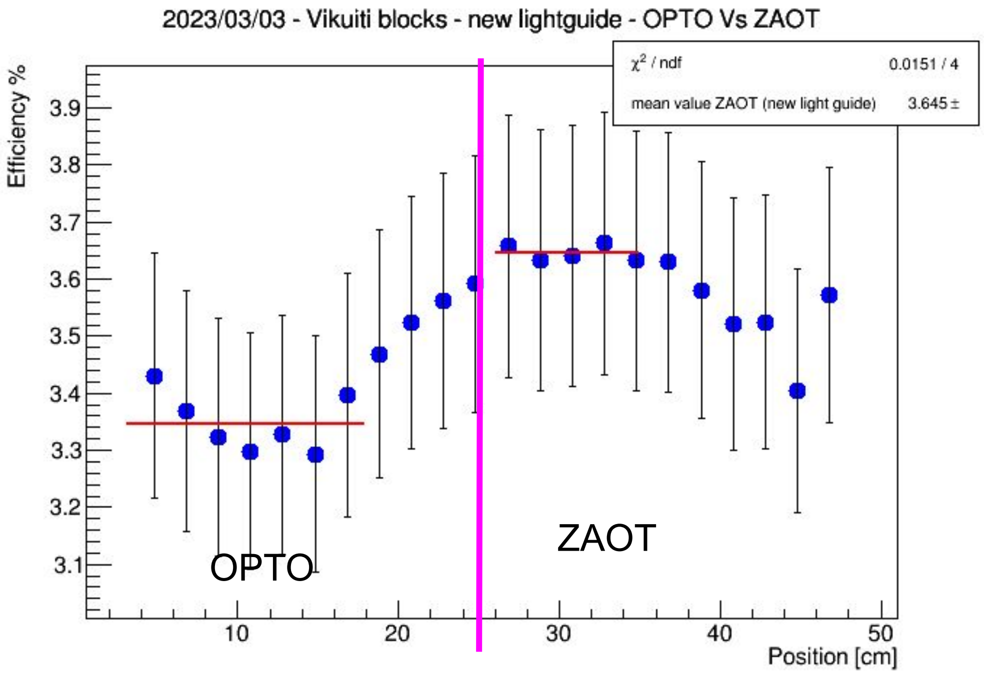
Our procedure ensures the preservation of the GAr quality.

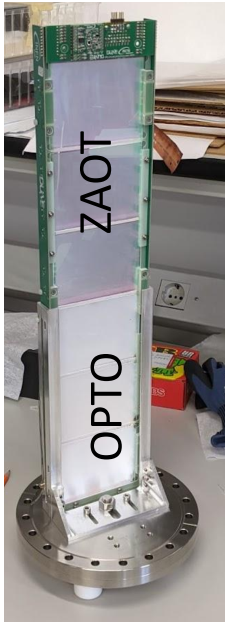


Sensitivity of the setup: some examples

ZAOT DF: November 2022 production for Module-0 of VD. pTP coated in Campinas in Dec '22

OPTO: from Campinas, pTP deposit in good condition

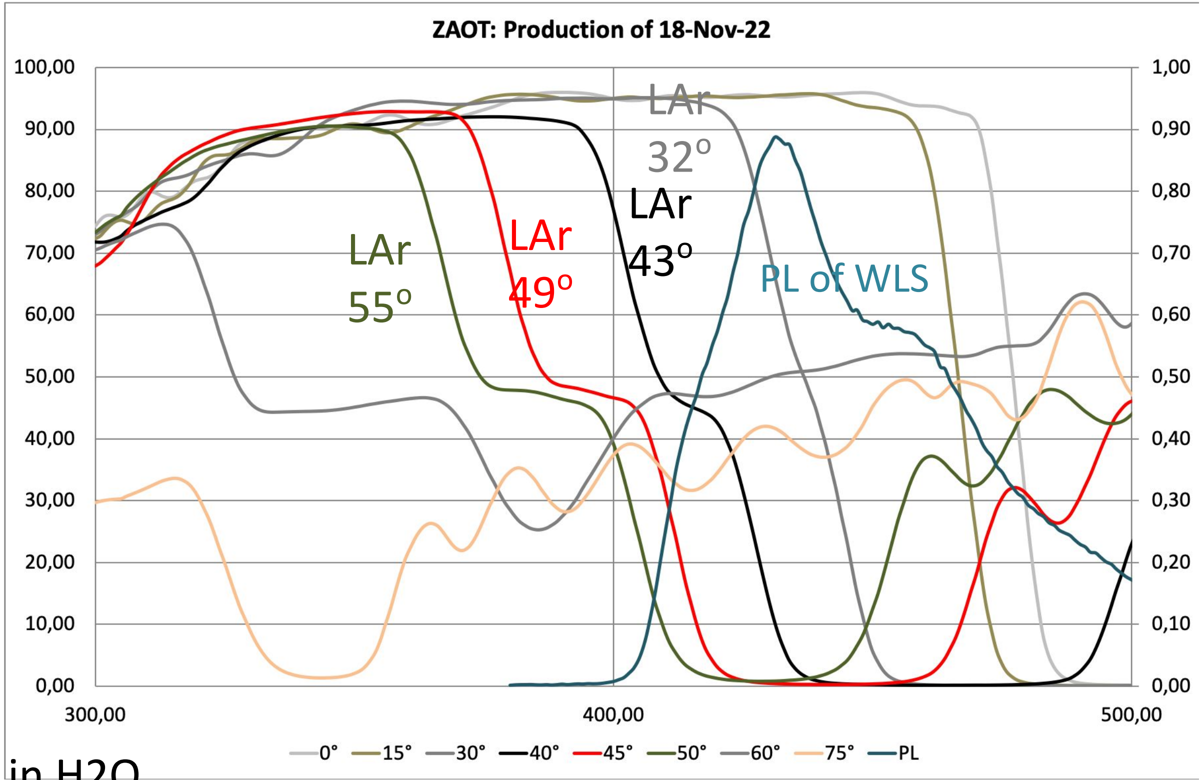




Sensitivity of the setup

Cutoff change vs n□

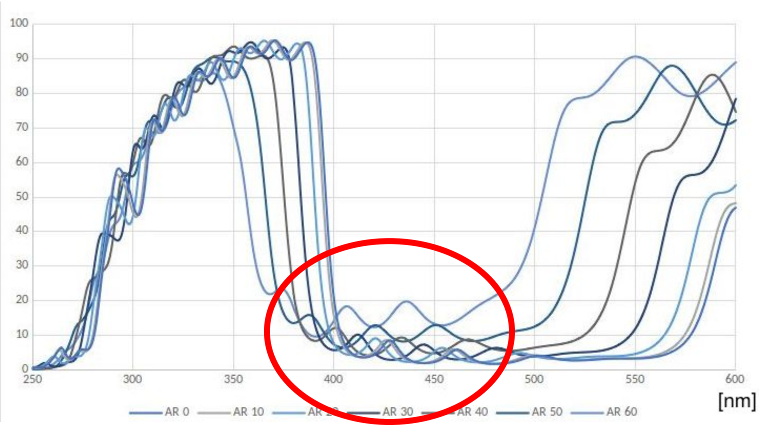
$$\lambda = \lambda_0 \sqrt{1 - \frac{n_1^2}{n_2^2}\sin^2\theta}$$

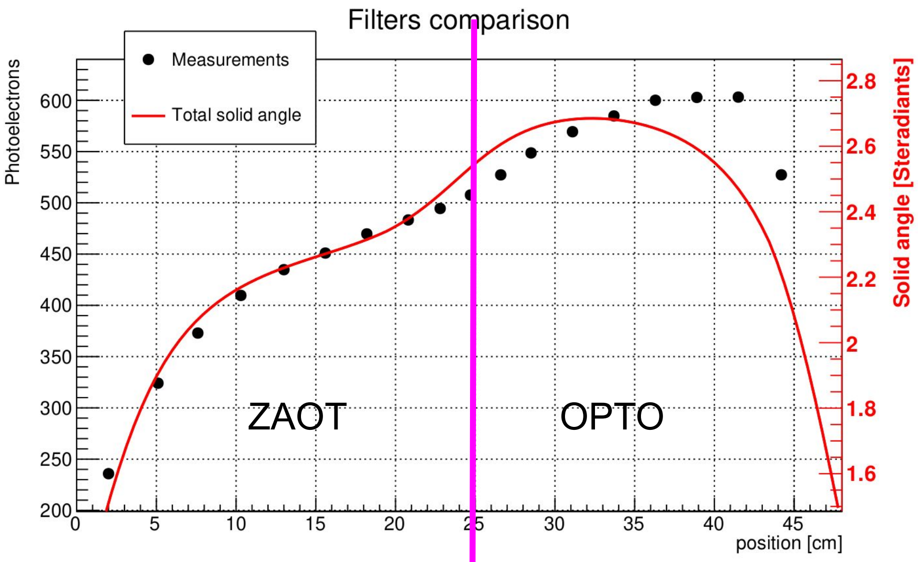


AOI in H2O

Sensitivity of the setup: some examples

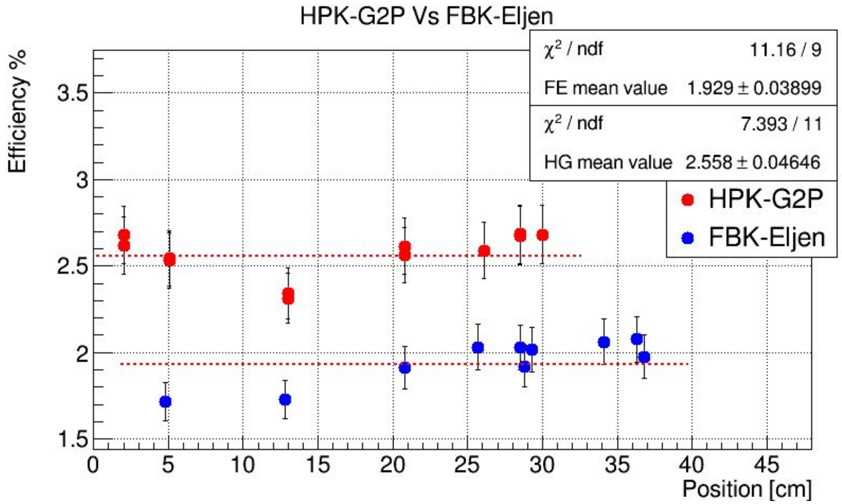
- damaged pTP (see slide 11)
- ZAOT filters: first production (end of 2021), Poor optical density at AOI = 45°





Results for the FD1 XA baseline configuration

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



	SiPM PDE	XA PDE MiB Xtalk corr.	XA PDE CIEMAT Xtalk corr.
HPK & G2P	50%	**2.2** (0.15)	**2.51** (0.21)
FBK & G2P	50%	**1.9** (0.14)	
FBK & Eljen	50%	**1.7** (0.14)	**1.56** (0.12)

To recap:

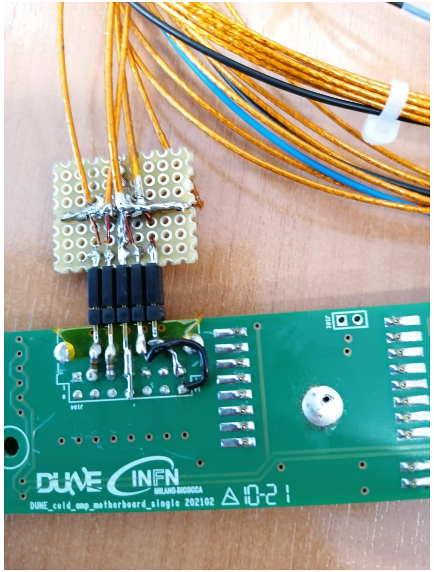
- With a well tuned setup and consolidated procedure
  - achieved high sensitivity of the PDE. This allow to assess the quality of the components (status of the pTP, DF, WLS, XA configuration)
  - The PDE measurements are consistent with the simulation and measurements performed with independent instruments (e.g. DF characteristic curves)

BACKUP

Features of the XA HD Supercell under tests

Size/type of the WLS slab Dichoics (sipm/WLS) area	**G2P** 480 x 93 mm^2, EJ- 6 x dichroics (Opto-Campinas) 3.9%
SIPMs	HPK DUNE-75um-HQR, +3V OV (50% PDE) FBK TT, +4.5V OV (45% PDE)
Ganging	x 48 SiPMs by MiB cold Amplifier
# electronic channels	1
SiPMs -Cold Amp. Cold Amp dyn. range	AC 2000 ph.e.
s.ph.e. (50 Ω, 45 V)	~ 2.0 mV on 50 Ω for both HPK and FBK
Chamber volume	~ 10 l
Digitizer	CAEN 14-bit 250 MS/sec, 4 ns/sample

Hardware

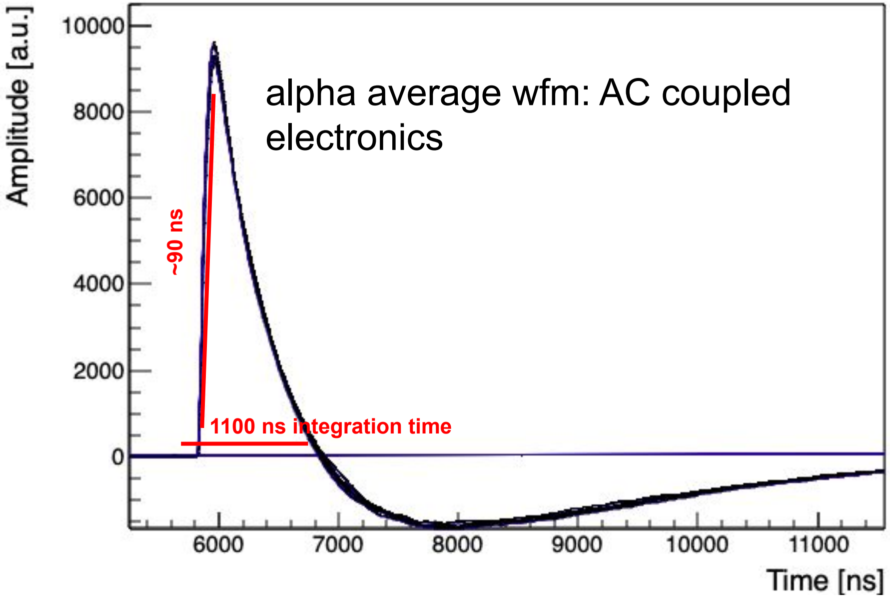


- Cold cables: a bundle of five Kapton RG178 coaxial cables. No DUNE blue cable & Hirose connector due to mechanical (dimension, stiffness) constraints of the setup

- Warm cables: 2.5 m, 50 Ω LEMO cables

- Cold-to-warm flange: 10 contacts vacuum/pressure connector mounted on a CF40 flange - No Hirose:
  - **the chamber and its payload are pumped down to 10^{-4} mbar prior filling →**
  - **high LAr purity achieved with high reproducibility**
  - **the purity is maintained w.o. any recirculation along several days from filling**

Alpha pulse shape



- The wfm shows a long undershoot due to 1) the SiPMs AC and 2) cold-to-warm stage couplings. This is not fully cared by simple sphe deconvolution **CONTROLLO**

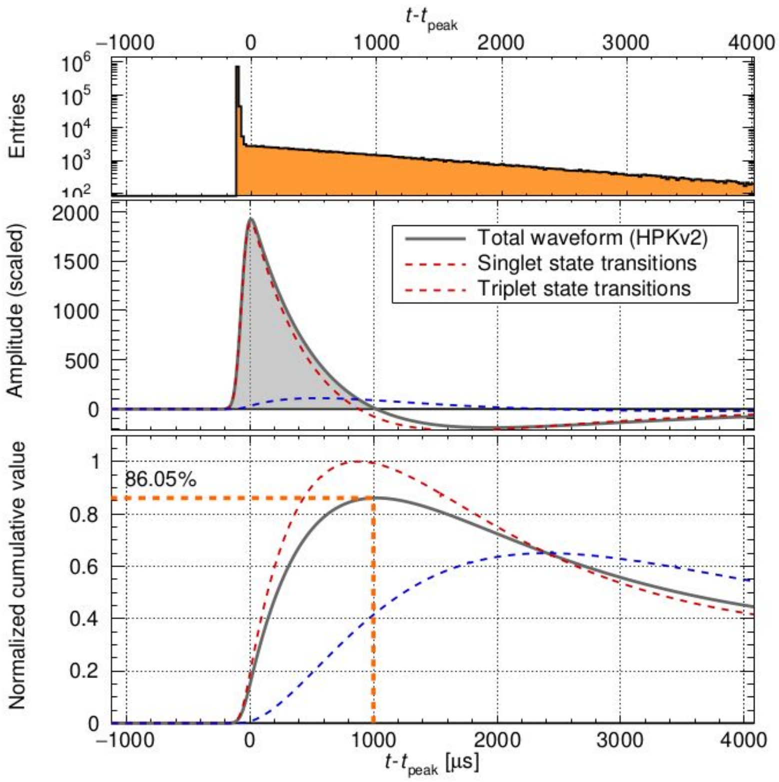
- Hence we integrate for 1100 nsec (1000 ns from peak), to avoid the negative lobe **CONTROLLO**

- Determine the integrated fraction of singlet/triplet light

Fraction of integrated light

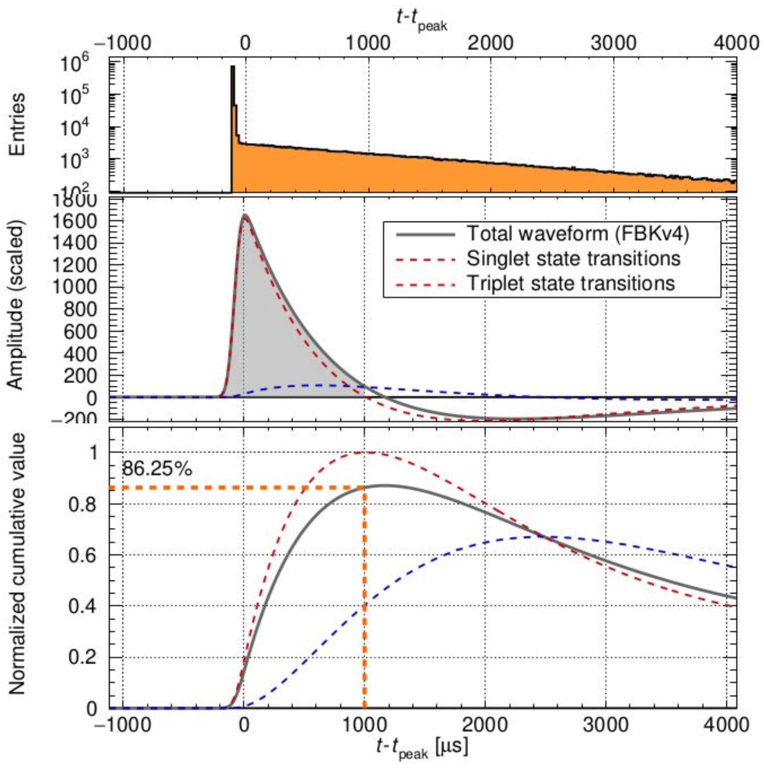
Synthetic wfms: SPHE ⊛ LAr profile (A_s=0.77; τ_s=7ns A_t=0.23; τ_t=1400 ns)

Fraction of Integrated light



HPK SPHE wfm

Fraction of Integrated light



FBK SPHE wfm

Analytical solid angle

- Analytical computatiotion, take into account the source-arm shadowing
- it does not take into account the teflon mask reduction of the solid angle