DICHROIC FILTERS – FD2 AND FD1

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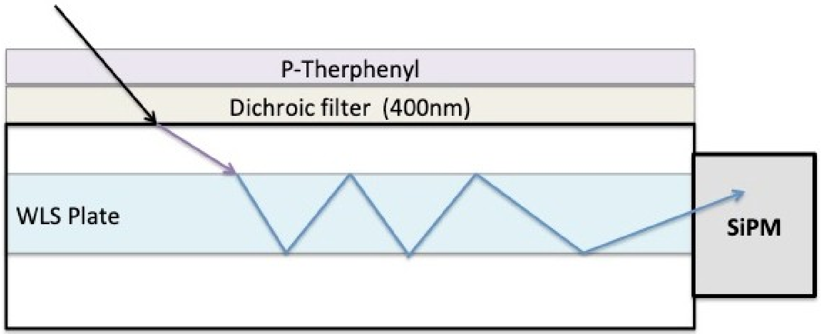
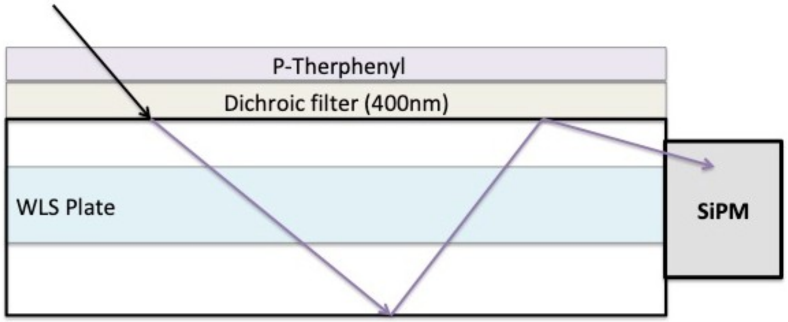
April 30^{th}, 2024

X-ARAPUCA concept

- X-ARAPUCA concept is based on **trapping as much as possible photons** inside a **WLS plate** and **in a reflective cavity** => *increase their detection probability by an array of SiPMs*

- Made of **few key components**:
  - a **WLS plate** installed in a reflective cavity;
  - observed by an **array of SiPM**;
  - A **dichroic filter** to trap the light in the cavity;
  - **PTP to shift the LAr scintillation**. Emission spectrum matched with absorption of WLS.





Two trapping mechanisms

- X-ARAPUCA implements ***two mechanisms for trapping light***. Both rely on a double shift of the light:

  - ***Total internal reflection inside the WLS:***
    - *Flatness of the surfaces;*
    - *Transparency to shifted light;*
    - *Light tightness at the edges*.

  - ***Dichroic filter reflections*:**
    - *Transmission of pTP shifted light;*
    - *Reflectivity of WLS shifted light;*
    - *Angular dependence of optical properties.*

X-ARAPUCA evolution

- Original studies based on ***Monte Carlo simulations*** and *tests with small scale prototypes in LAr and at room temperature with a VUV* Monochromator showed the *advantages of using the two mechanisms together;*

- In the last years there was an **impressive work made on WLS** (MiB) and **dichroic filters** (MiB, UNICAMP, Valencia)
  - *Optimization of WLS was more effective*
  - *Dichroic filter optimization more complicate and more expensive*

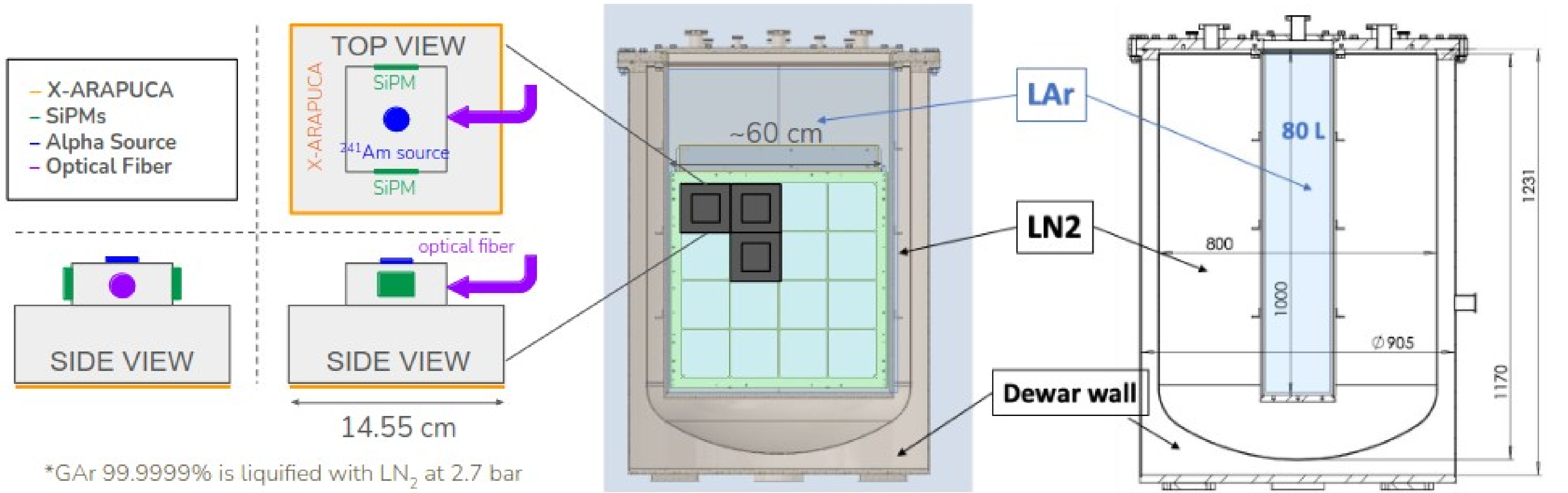
- An **impressive work done on detailed simulations** that benefited from *measurements of the optical properties of filters and WLS* plates. Helped to guide the optimization process and make predictions

- Simulations pointed out the the contribution of the **trapping mechanism through dichroic filters could be small with respect to the WLS**

- ***The Consortium reacted organizing a campaign of measurements (which is still ongoing) at CIEMAT, MiB and Naples***

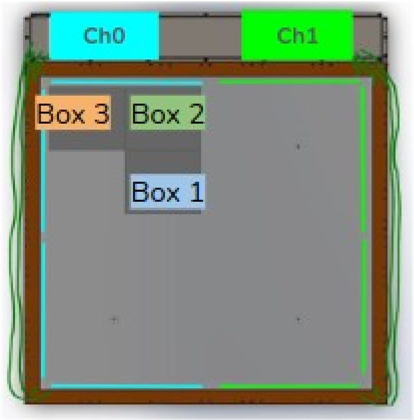
Megacell tests @ CIEMAT

- Measurement of the XA PDE in LAr using 2 ***reference VUV SiPMs*** facing each other triggering on scintillation light from an ^{241}Am alpha source in ***3 black calibration boxes*** *(at the only 3 not identical XA positions)*

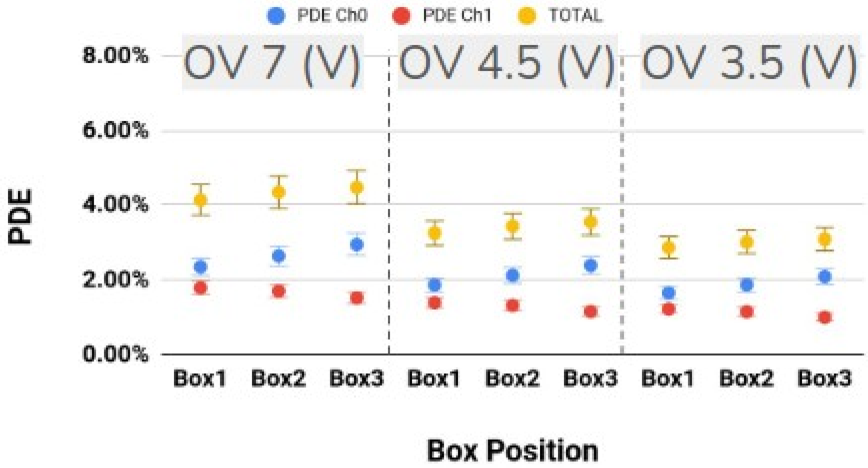


Megacell tests @ CIEMAT

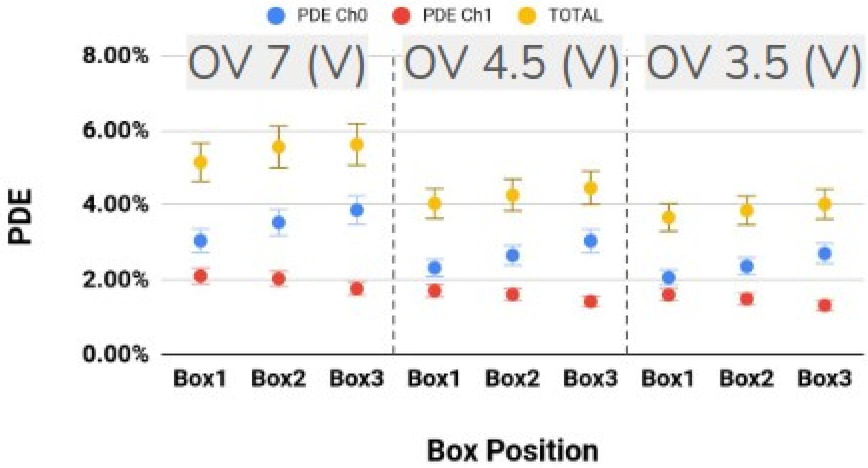
Preliminary results with a single sided Megacell show **an increase of performances without DF at the 30% level**



With DF

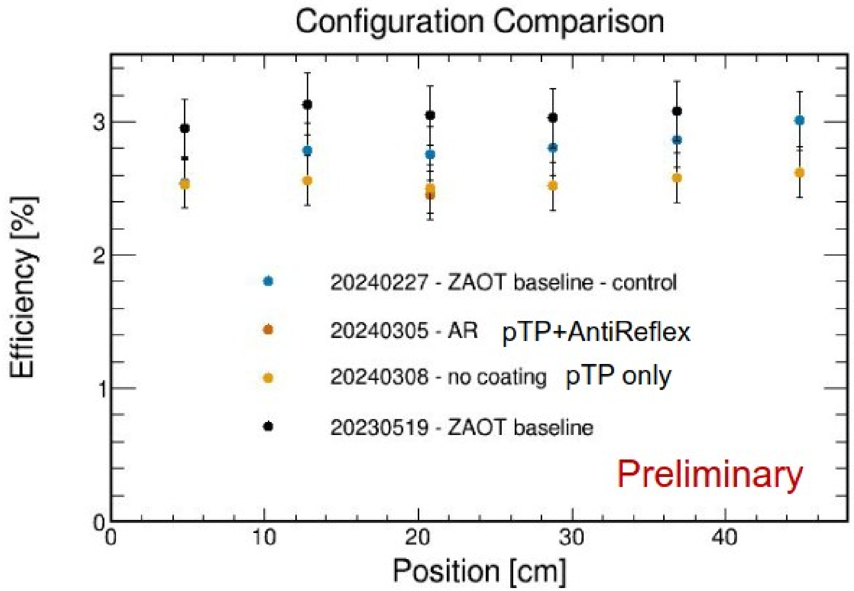


Without DF

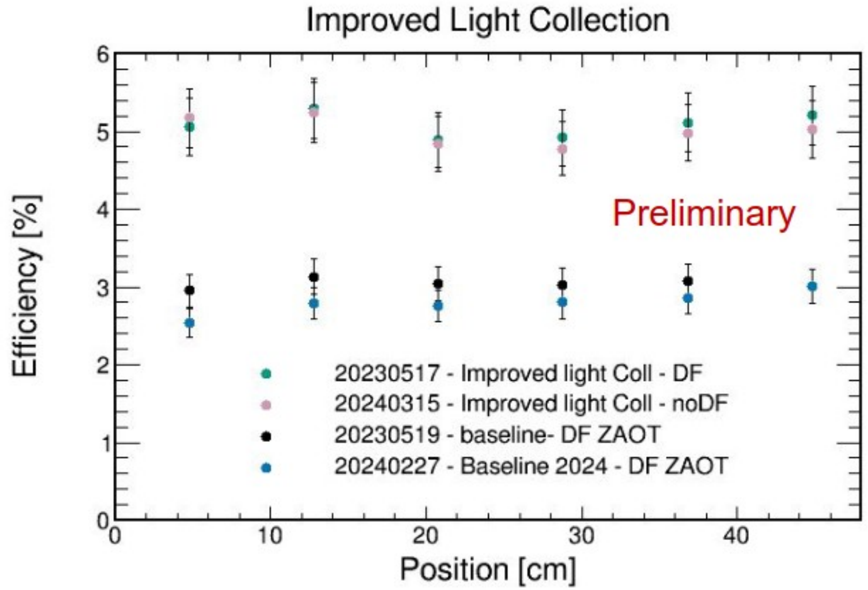


Supercell tests @ MiB

- For the *current baseline configuration*, the **use of dichroic filters improves the detection efficiency of 15-20%**.



- For the *improved configuration* (40^{o} cut and enhanced sealing of WLS with reflector) **there is no apparent gain in using dichroic filters.**



Interpretation of the results

Assuming that **half of the photons** is initially trapped inside the WLS by total internal reflection and the other half escapes the WLS:

$$\varepsilon = \frac{\varepsilon_{pTP}}{2} \times \varepsilon_{WLS} \times PDE_{SiPM} \times T_{w} \times \left(\frac{g_{WLS}}{2} + \frac{g_{DF}}{2} \right)$$

Where:

ε_{pTP} *is the conversion efficiency of pTP*

ε_{WLS} *is the conversion efficiency of WLS*

T_w *is the transmissivity of the acceptance window*

g_{WLS} *is the collection efficiency through the WLS*

g_{DF} *is the collection efficiency through the DF*

Making the **simplifying assumptions** that $\varepsilon_{pTP} = 1$, $\varepsilon_{WLS} = 1$, and $PDE_{SiPM} = 0.5$

$$\varepsilon \simeq \frac{T_w}{8} \times (g_{WLS} + g_{DF})$$

Interpretation of the results

- The measurements with the Megacell indicate that probably, *with this geometry*, ***the collection efficiency through the DF is small*** compared to the one through the WLS. This can be due to the large area of the Megacell and to *the number of reflections on the DF that a photon should undergo for being detected*. This allows to make an estimation for ***T_w => 30% less for the DF;***

- The measurement with the Supercell returns the **same efficiency with or without DF**. This means that *the trapping through DF is effective*, **since what is lost in the transmission of the photons is re-gained through the trapping;**

- Using the measurements *without DF* and assuming $T_w = 1$ for no-DF case and taking the improved configuration which gives $\varepsilon = 0.05$ => **g_{WLS} = 40%** (g_{DF} is set to zero in this case);

- Using the measurements with DF and assuming $T_w = 0.7$ and g_{WLS} = 40% => **g_{DF} = 20%.**

Plans

Megacell:

- The trapping mechanism through the DF does not seem to be effective;
- We need to consider the possibility of changing the Megacell design and not using DF;
- Measurements are ongoing at CIEMAT on double sided Megacell with and without DF;
- Two/three Megacell without DF will be installed in protoDUNE VD;
- Based on the results of this testing campaign we will decide wether to use DF or not.

Supercell:

- The trapping mechanism seems to work but with a collection efficiency lower w.r.t WLS and the reduced transmissivity of the filter does not allow to see a net increase in detection efficiency;
- DF can be slightly improved to have better optical properties (sharper cutoff, reduced angular dependence and increased transmissivity) without impacting the overall costs (OPTO is working on it);
- Double sided Supercell need to be tested with and without DF;
- Based on these additional information the Consortium will decide wether to use DF or not or partially (just single sided or double sided supercells).

The detection efficiency of both Supercell and Megacell are about a factor two higher than our requirements