# Cryogenic setup for the characterization of wavelength-shifting materials for noble element radiation detectors

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ASTROCENT

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## Challenges in light collection for Dark Matter searches

Achieving high light collection efficiency in noble element detectors is critical as it crucially affects: **energy threshold**, **position** and **energy reconstruction**, **pulse shape discrimination** (essential for particle ID) and triggering. For efficient detection, vacuum UV (VUV) scintillation wavelengths of noble elements typically require wavelength shifters [1].

With currently available technologies, scaling up / enhancing light collection in large noble liquid detectors for dark matter or rare event searches poses a major challenge [2,3]. The presented setup provides a simple and robust way to test performance of wavelength shifters (and other approaches) in representative conditions.

**Main approaches**: optical [4] and electromagnetic lenses [5], reflective and wavelength-shifting passive coatings [1], wavelength-shifting using dissolved dopants or gas mixtures [4], some dedicated optical amplification structures (M-THGEM, G-THGEM, FAT-GEM) [6].

What strategy to follow?

- Identify **low background**, **radiopure** alternatives (improve PDE)
- **Scalable** and **stable** solution (compared to meshes/wires)
- **Wavelength-shift primary** and **secondary scintillation** (easier to readout),
- **Low-background, low-noise cryogenic amplification structures** and SiPMs,
- Improve the **electron extraction efficiency at the liquid-gas interface**

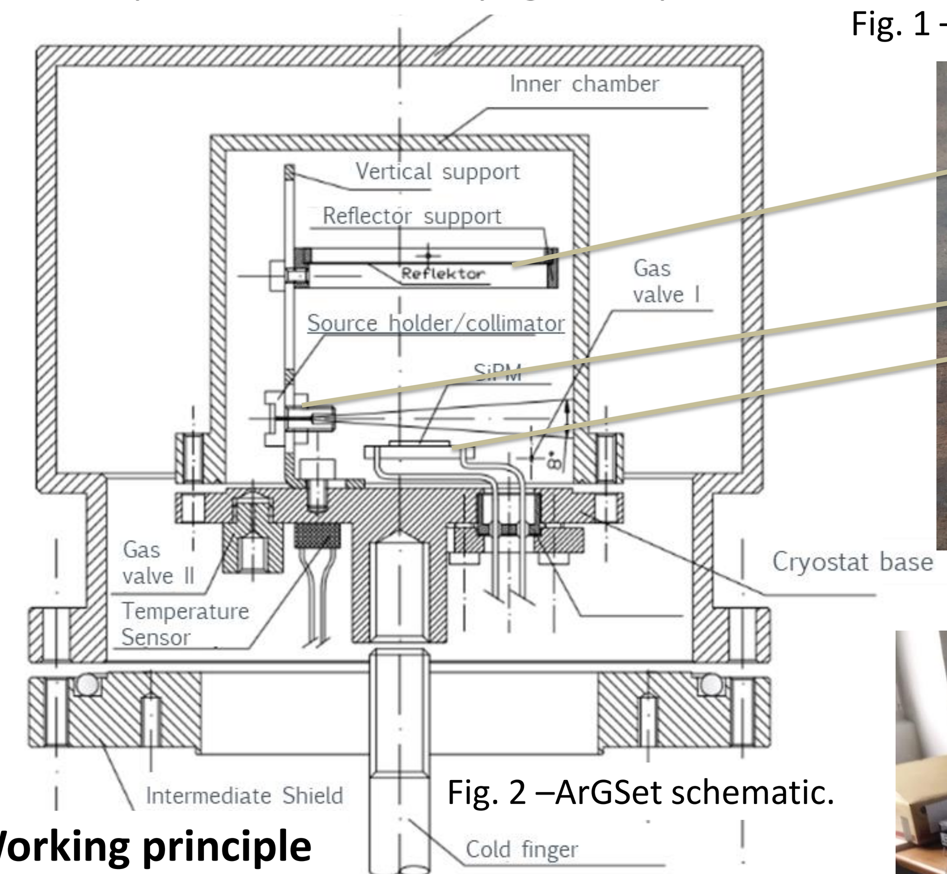
## ArGSet – A Cryogenic Setup for Argon wavelength-shifting testing at AstroCeNT

### Cryogenic Setup

To test the wavelength-shifting capabilities of new materials a dedicated cryogenic setup was recently commissioned and tested at AstroCeNT.

This setup can provide essential information on:

- Time response and efficiency of WLS materials;
- Temperature dependence of WLS materials;
- Compatibility of materials with cryogenic operation;
- SiPM performance in cryogenic operation;



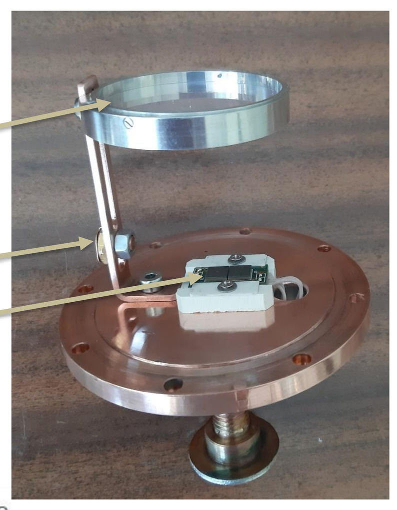



Fig. 1 – ArGSet internal structure.

Fig. 2 – ArGSet schematic.

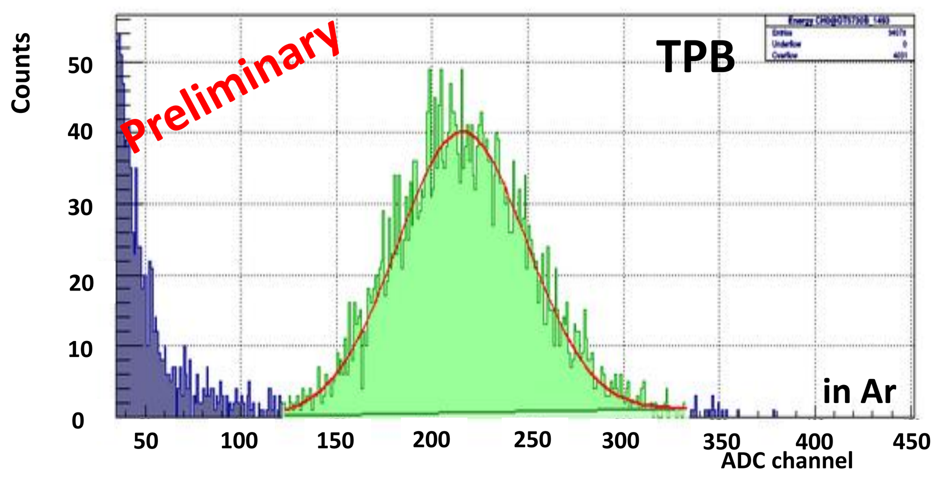
Fig. 3 – Experimental setup apparatus.

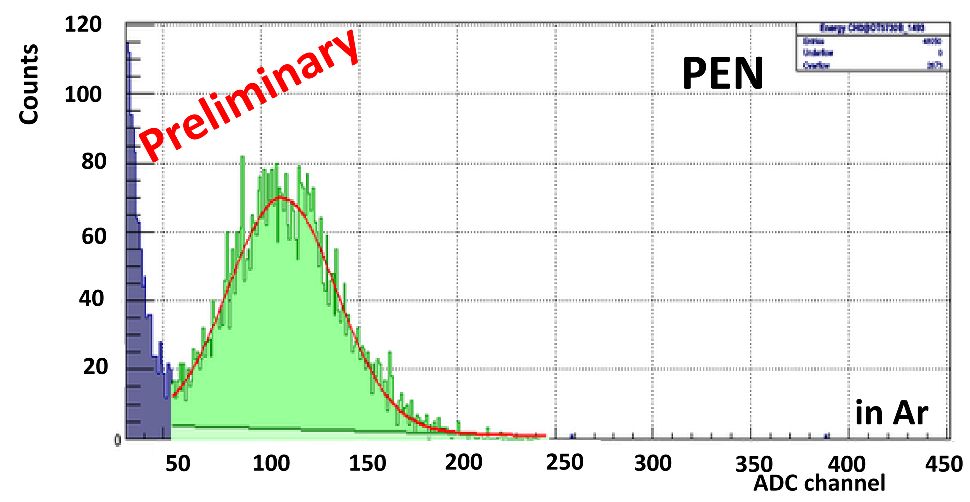
### Working principle

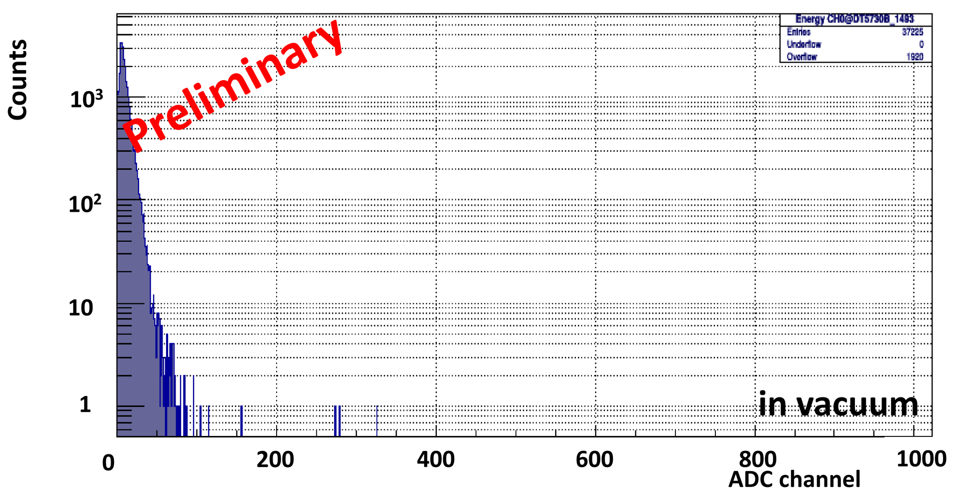
In order to enable **ns timing-resolution** for the **characterization of the WLS materials, primary scintillation (S1)** from **Ar** is **used as source**. To produce a measureable signal $^{241}$Am source is used (alpha particles). VUV photons will impinge on the sample material (WLS material to be tested). Resulting **WLS light** is then **detected** by a set of **2 independent SiPMs not sensitive** to the **VUV emission** spectra of **Ar.**

### Wavelength-shifter studies with ArGSet

The commissioning measurements revealed <5% reproducibility of the wavelength shifting efficiency measurement, with 50% efficiency of PEN relative to TPB -- consistent with independent result for the same PEN batch. Systematic uncertainties are being studied.



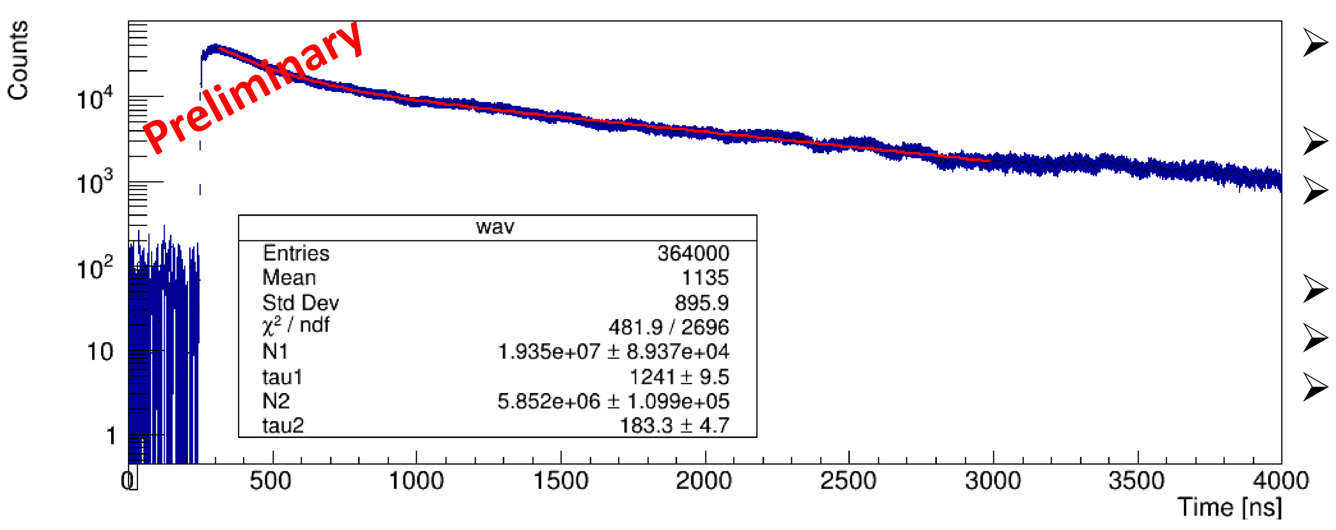




Table 1 – Comparison of the results obtained with ArGSet with previous works or litereature.

| | WLS efficiency (PEN/TPB) | Triplet lifetime constant |
|---|---|---|
| Current work | 50% | 1.24 μs |
| Literature* | 47.2±5.7% | 3.5 μs |

* For the WLS efficiency 2PAC results [7] and triplet lifetime constant the MiniCLEAN results [8].

**Next steps:**

- Study the influence of impurities on the triplet lifetime constant;
- Analysis of systematic uncertainties;
- Quality control of ~200 m² PEN batch for the DarkSide-20k veto;
- Survey of novel WLS materials;
- Measurement of Birks' constant of WLS;
- Operation with a nanosecond pulsed VUV light source;

## ArGSet – A tool for testing wavelength-shifting FAT-GEMs*

An extension to ArGSet's current design is ongoing. This extension will allow testing different configurations and manufacturing processes used in the development of wavelength-shifting FAT-GEMs [2,9] for their use in cryogenic environment.

**Features:**

- Modular structure made of cryogenic and radiopure materials (easy to change between WLS material studies and testing of FAT-GEMs);
- Independent biasing of all internal structures (cathode, FAT-GEM and induction gap mesh);
- Charge and light readout;
- Allow the performance of pressure (up to 5 bar) and temperature studies;
- Allow to vary the absorption/drift region from 5 mm up to 5 cm.

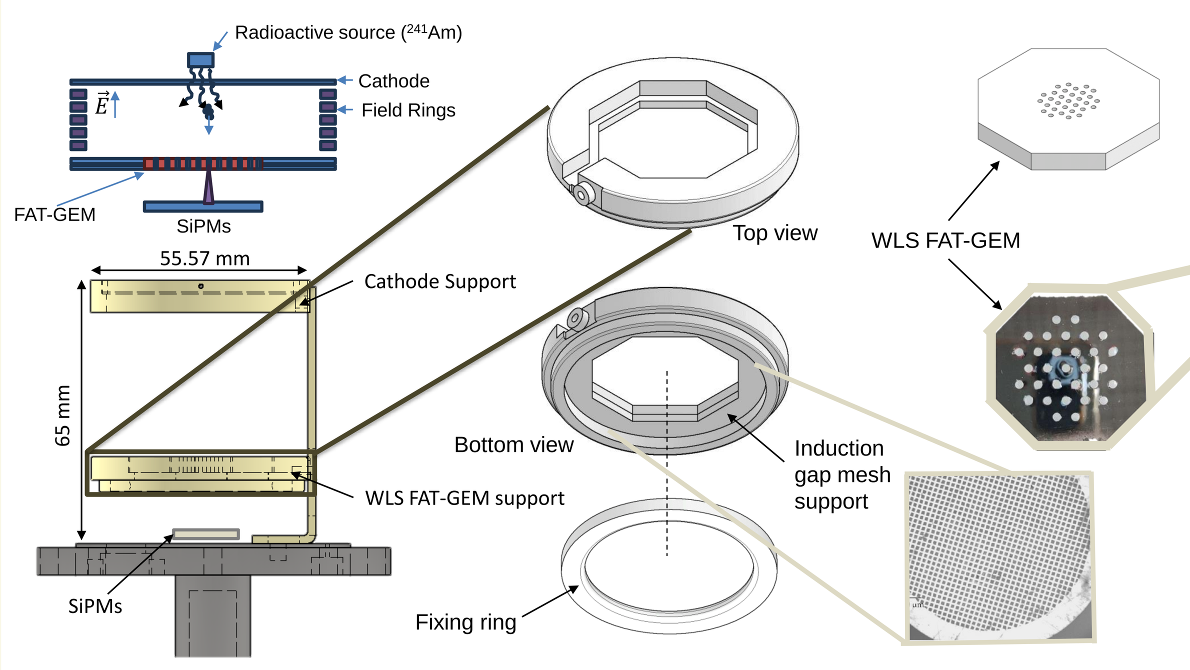



Fig. 1 – ArGSet extension to test wavelength-shifting FAT-GEMs.

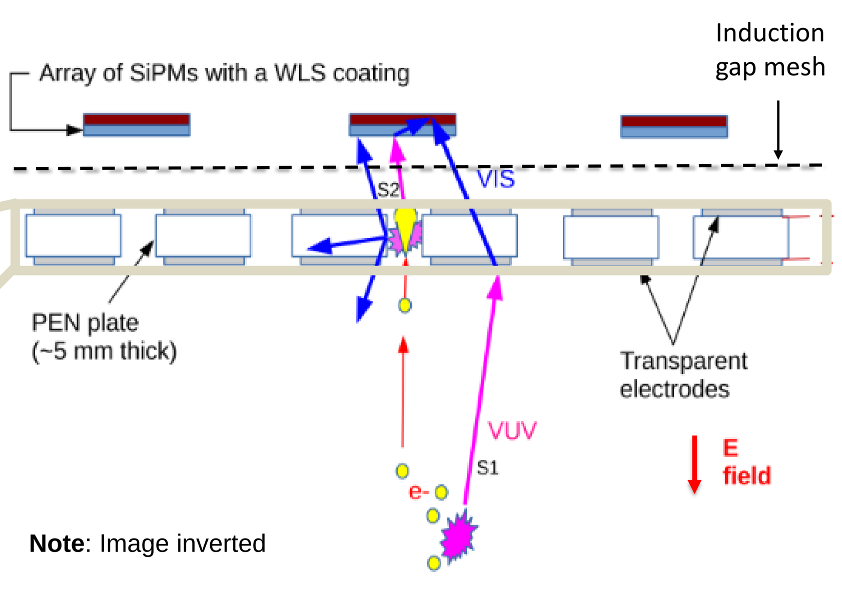



Fig. 2 – Working principle of WLS FAT-GEMs.

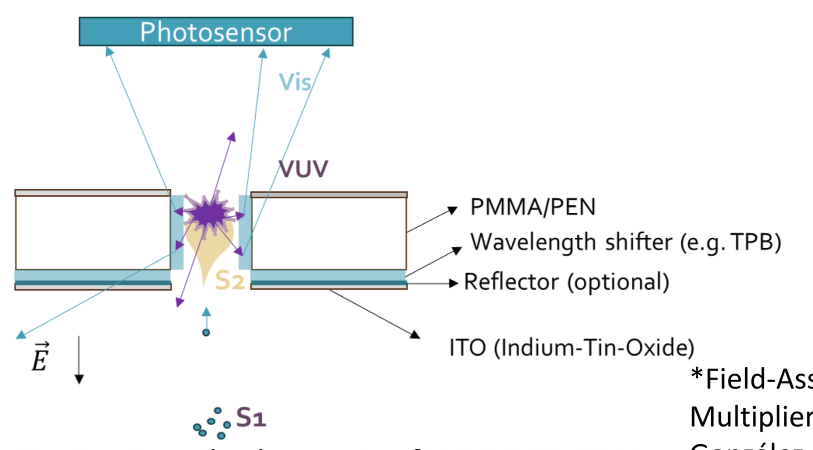



Fig. 3 – Detail schematic of WLS FAT-GEMs.

*Field-Assisted Transparent Gas Electroluminescence Multipliers (FAT-GEM) were introduced by Diego González-Diaz (IGFAE) [10].

## Conclusions and Future work

A cryogenic setup (ArGSet) to study the wavelength-shifting performance of potential interesting materials for the development of novel WLS FAT-GEMs was commissioned and successfully tested at Astrocent. This setup allows to:

- Study the time response of WLS materials;
- Temperature and pressure dependence of WLS materials performance;
- Test new materials in cryogenic operation;
- Test SiPMs performance.

ArGSet will allow the testing of promising radiopure, and scalable structures recently developed by Astrocent and IGFAE, such as the WLS FAT-GEM.

ArGSet extension will open the possibility to have more detailed understanding of these structures under cryogenic operation.

**References**

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