Novel optical amplification structures for Dark Matter searches

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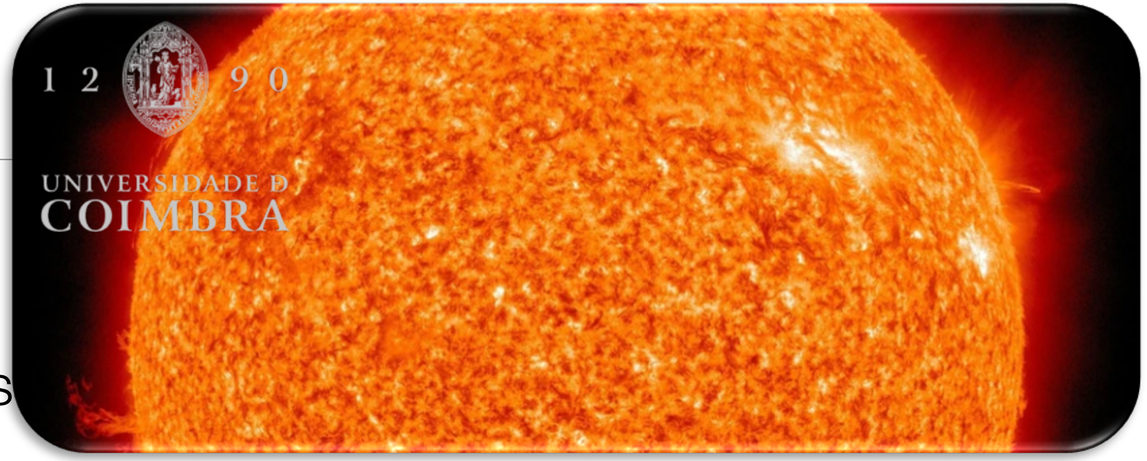
Dark Matter Coffee. AI generated image

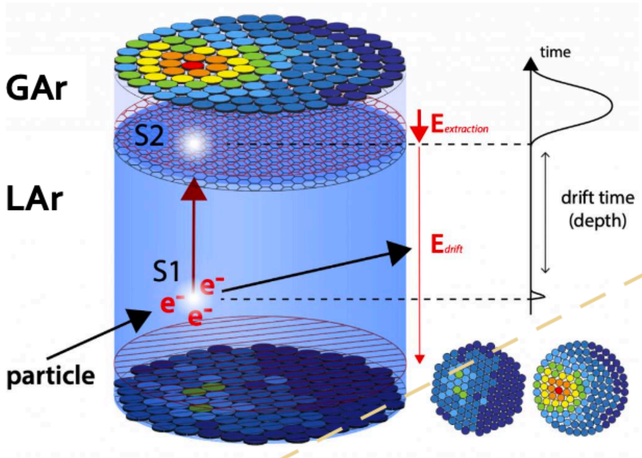
European Union
AstroCeNT
NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES
NATIONAL SCIENCE CENTRE POLAND
European Funds Smart Growth
Republic of Poland
FNP Foundation for Polish Science
European Union European Regional Development Fund

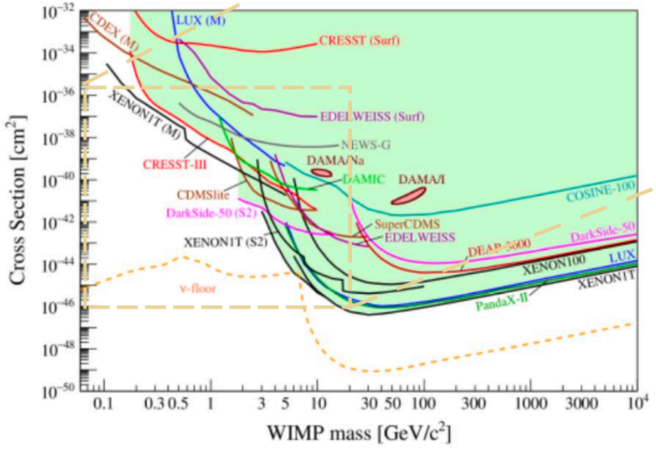
Outline



- Dark Matter and its challenges
- Developing novel optical amplification structures
- Current Activities
- Strenghtening Synergies within AstroCeNT
- Building an international network

Dark Matter and its challenges





How to explore low mass Dark Matter?

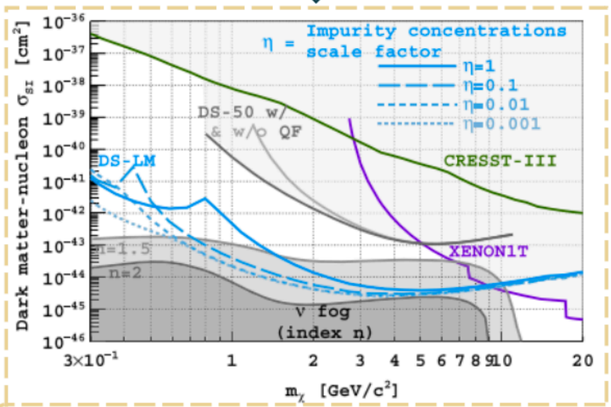
- Exposure (time and target mass) ➡ Typical approach low atomic mass target materials (CYGNO Experiment)
- Reduce/control background
- Improve energy threshold

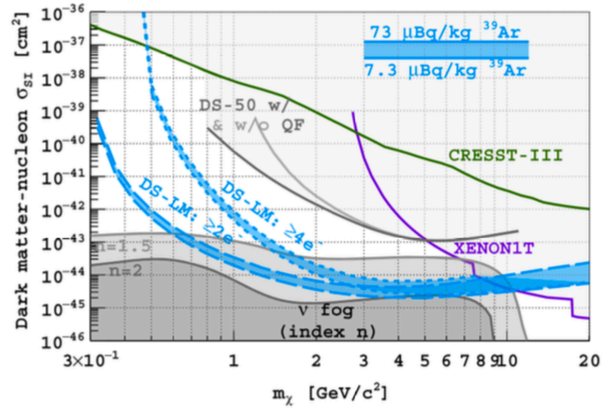
S2-only analyses allowing an increase in the sensitivity for low mass candidates ➡

- particle discrimination
- z-coordinate information

Lost

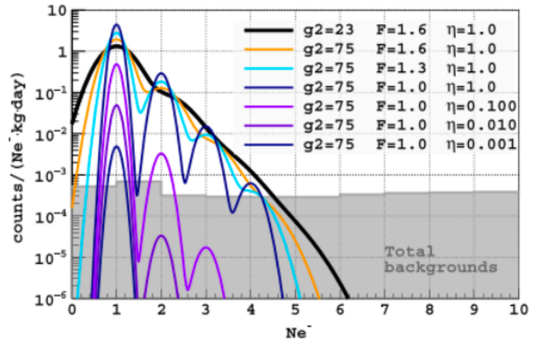
(S1 fall under energy threshold)





Low-energy sensitivity improves, many detectors start to see a large number of not-well-identified low-energy events (excess of events).

SEs dominate signals below 4 e–.



Problem: Poor background understanding at these energies.

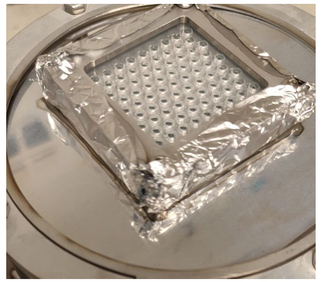
Developing novel optical amplification structures - WLS FAT-GEM

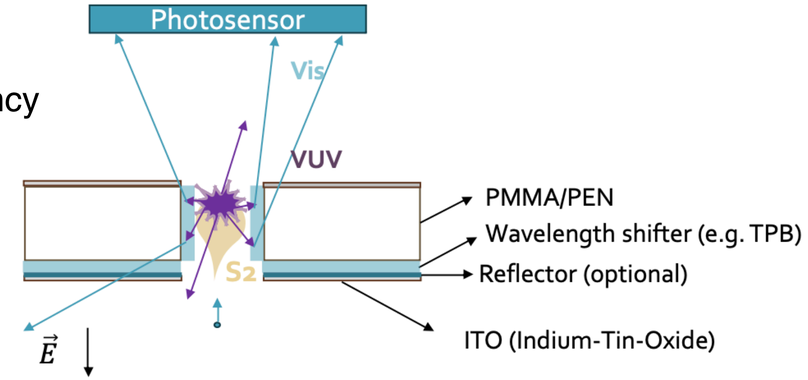
R&D on novel amplification structures

Wavelength-Shifting Field-Assisted Gas Electroluminescence Multiplier (WLS FAT-GEM)

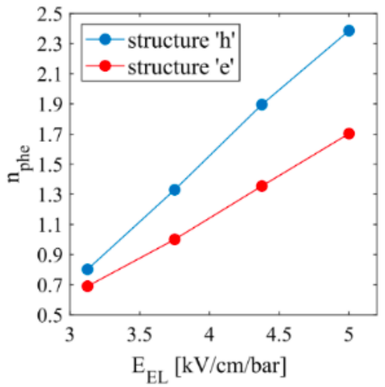
New structure developed at ASTROCENT and IGFAE (Instituto Galego de Física de Altas Enerxías)

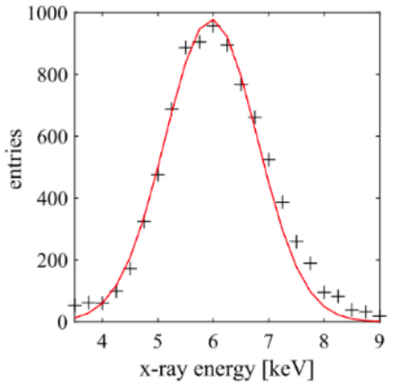
- Scalable solution (tileable)
- Increase both EL yield and light collection efficiency
- Wavelength-Shift VUV to Vis (S1 and S2)



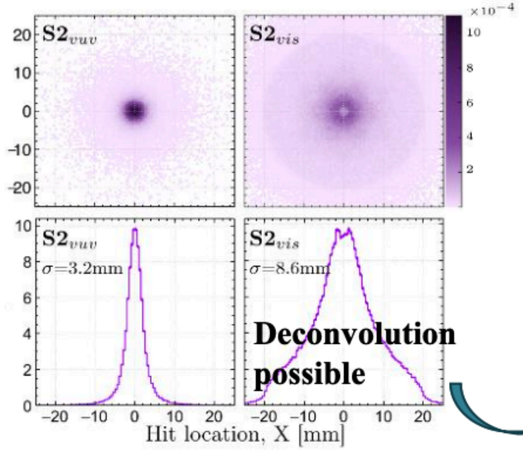


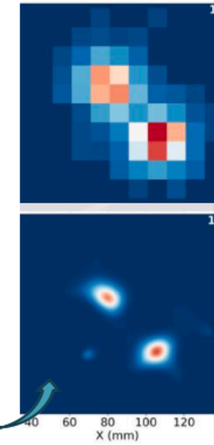
S1



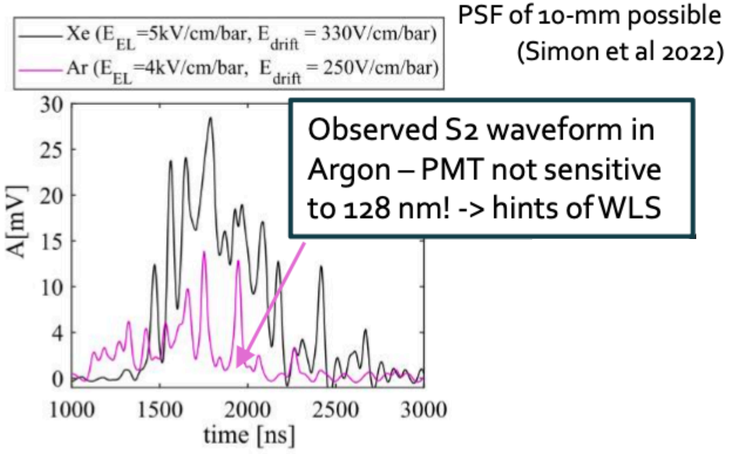


Simulation:





PSF of 10-mm possible (Simon et al 2022)



Observed S2 waveform in Argon – PMT not sensitive to 128 nm! -> hints of WLS

Preliminary results:

Comparison with a TPC supplied with wire mesh electrodes, shows:

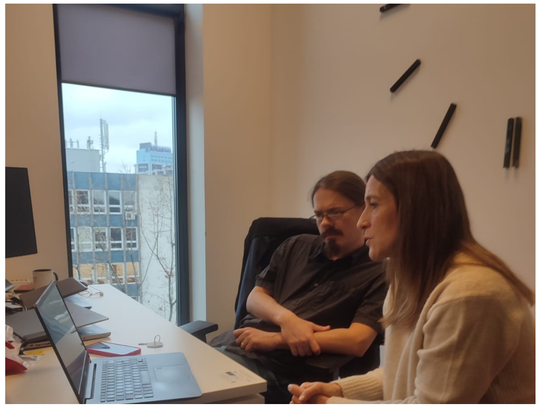
- Similar S1 light collection yield (up to 75%);
- Up to 2-3 times higher S2;

Current Activities

AstroCeNT facilities

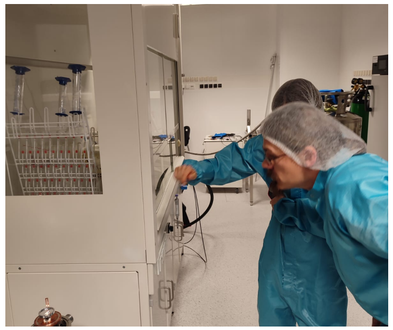
AstroCeNT

Office space plus electronics and workshop.



CEZAMAT

Lab space - production and testing of new materials and structures.

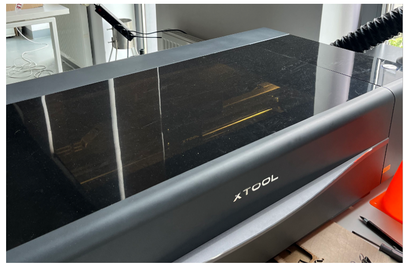


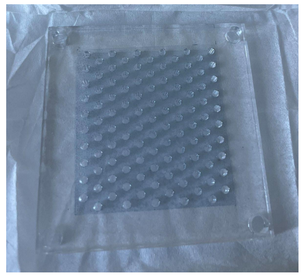
Current Activities

Production at AstroCeNT

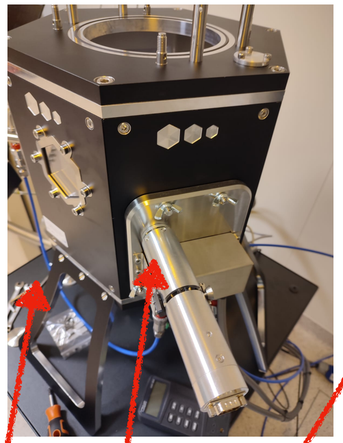
Important Milestones:
- Production of the first batch at AstroCeNT (to be tested soon);
- Innovative technique to produce using laser cutting techniques;

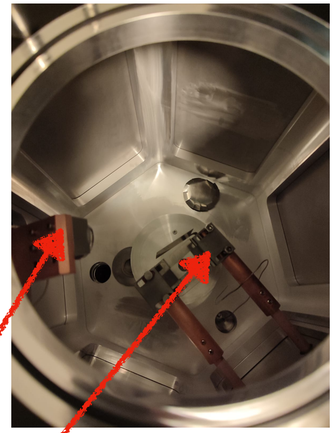
Laser cutting

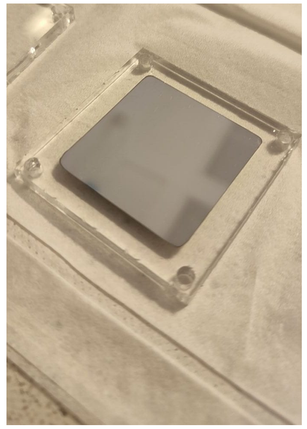




Evaporation







View port

Movement feedthrough

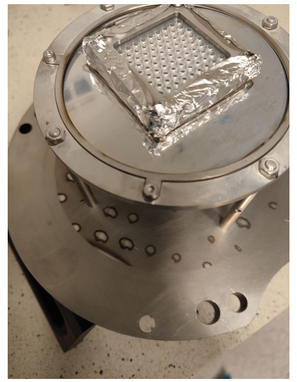
Thin film thickness monitor

Evaporation boat

Spray coating

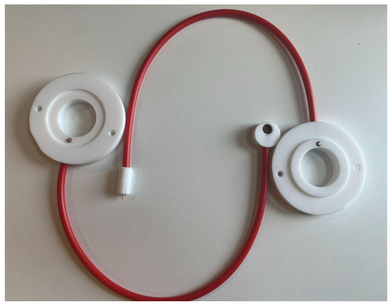
Thermal curing and annealing

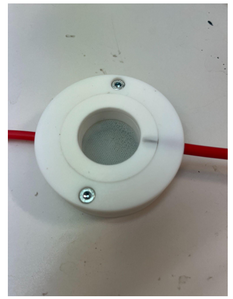
WLS Evaporation



Testing

- Electrical insulation
- Operation stability



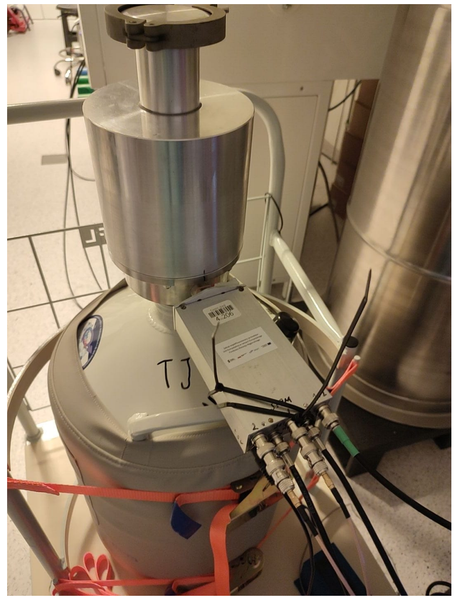


Current Activities

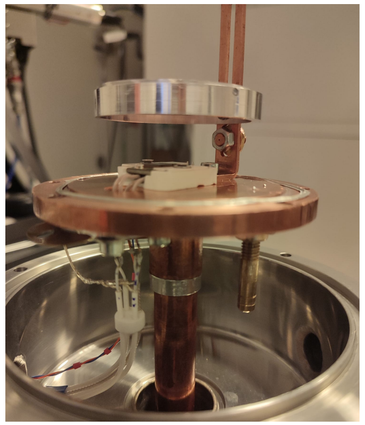
Development of Infrastructures to Study WLS and WLS Structures at Astrocent

ArGSet

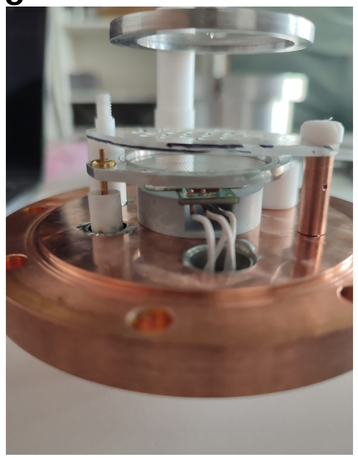
- Modular structure (for both WLS materials or WLS FAT-GEMs);
- Charge and light readout;
- Independent biasing;
- Pressure and temperature studies;

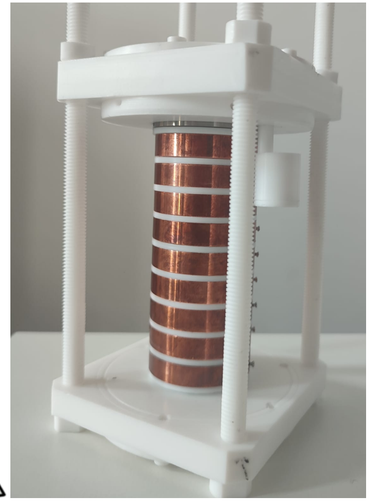


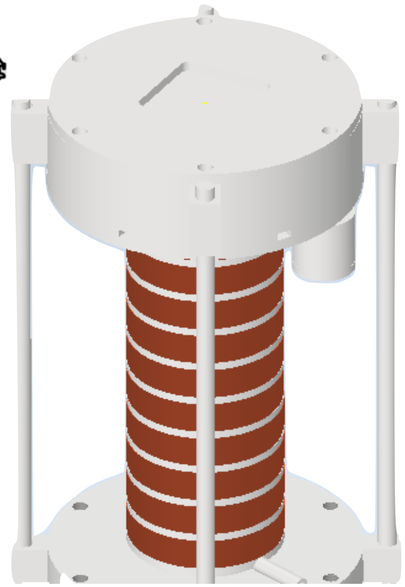
Config. 1 WLS Material testing



Config. 2 WLS Structures testing





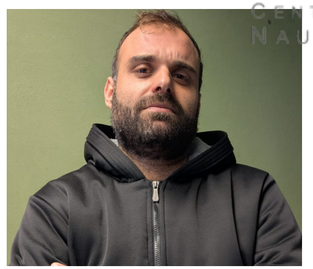


Dual-Phase TPC under construction at Astrocent (SONATA BIS)

- Modular structure
- Allows to easily compare mesh and WLS FAT-GEMs
- Optical readout

Strengthening Synergies within AstroCeNT

Towards establishing an independent research line



Team:

André Cortez (Leader)

Pedro Costa e Silva (Postdoc) - from August 2025

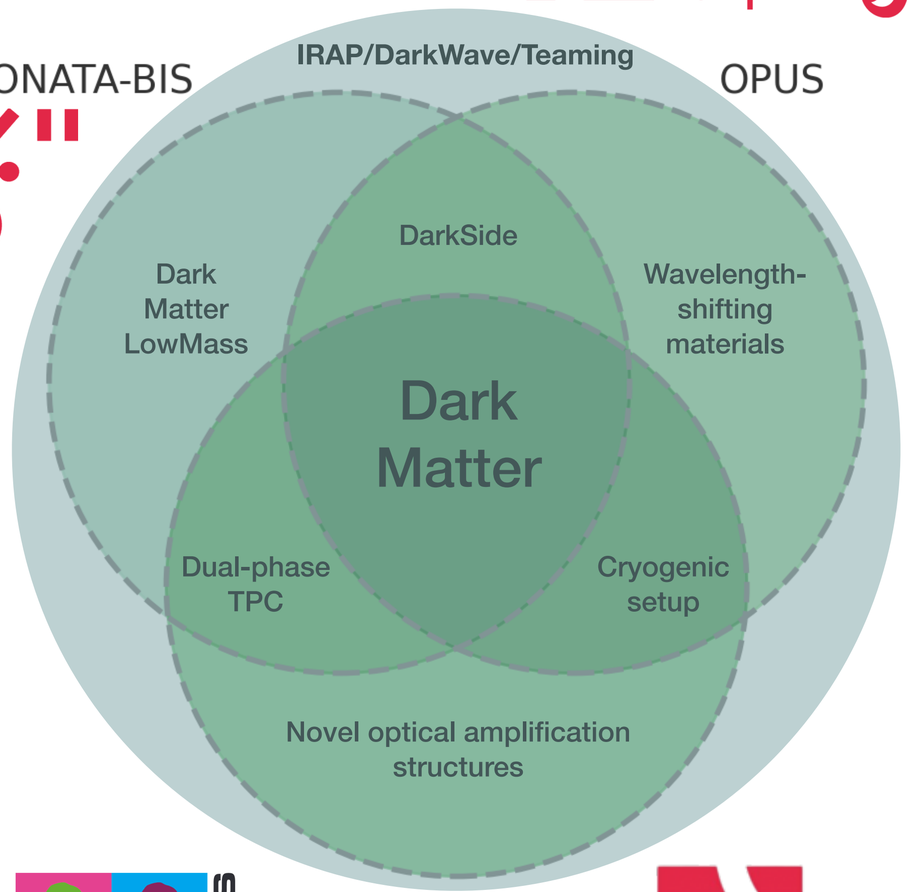
Diego Rodas Rodriguez (PhD student) - From March 2025

Aleksander Gnat (Technician)

Advisors:

Marcin Kuźniak and Masayuki Wada

Another Postdoc expected to join our team sometime in 2025/2026



MSCA Postdoctoral Fellowship

NATIONAL SCIENCE CENTRE POLAND

Funded by the European Union

Strengthening Synergies within AstroCeNT

Papers

- **Papers published: 4**

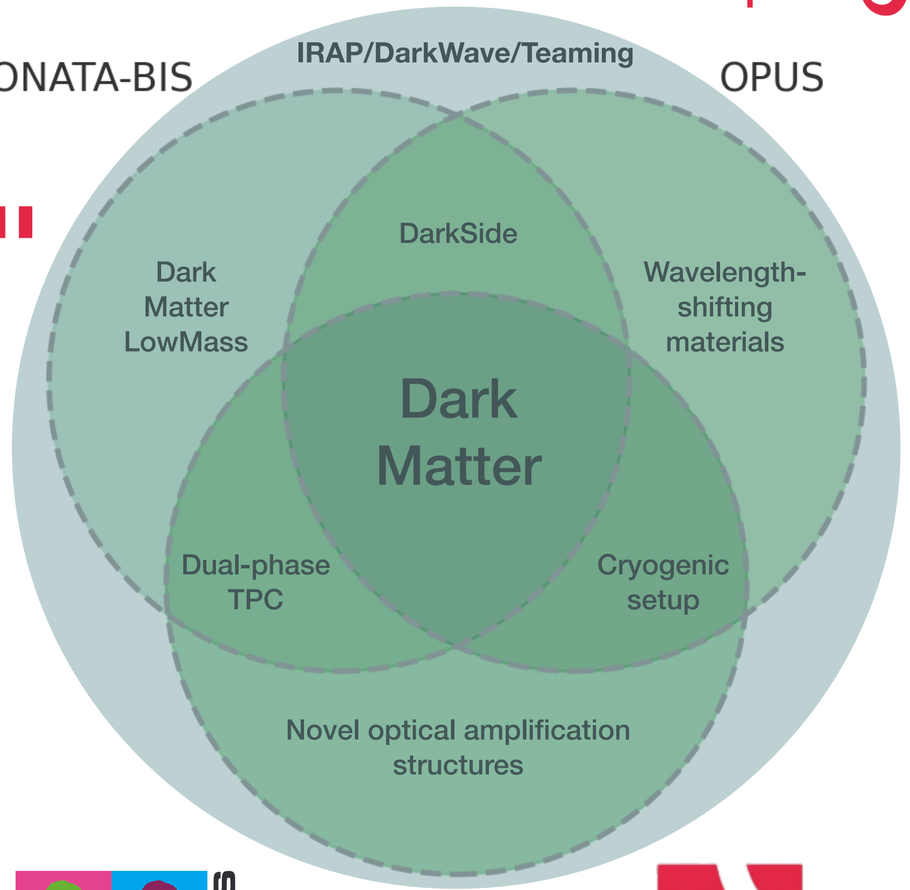
  2 proceedings from our participation at LIDINE2023
  1 paper related with the development of FAT-GEM structures
  1 paper from the **DUNE collaboration** where it is mentioned the WLS FAT-GEM technology with potential to be explored for the far detector unit

- **Papers submitted: 3** (under review)

Invited seminars and Conferences

- International Conferences: 1 iWoriD 2024, Lisbon (Portugal)
- Invited seminar - LIP Seminar (Oct 24 -Coimbra, Portugal)
  - IEEE Seminar (Dec 24 - Prague, Czech Republic)
- Initiated the discussion of the possibility of signing a MoU between Astrocent/CAMK and LIP (Portugal)

Funding



MSCA Postdoctoral Fellowship 2023	600k PLN (about 150k euro) - 2 years (EU)
NCN SONATA-19	1.2M PLN (about 300k euro) - 3 years (NCN)

This will ensure we have the funds to cover activities for the next **3 years**.

MSCA Postdoctoral Fellowship

National Science Centre Poland

Funded by the European Union

Building an international network

Working towards establishing an international network

- WLS FAT-GEM collaboration (**leading effort**);
- DRD1/CERN collaboration (**CB member**);
- DarkSide (since November 2024) where I will be involved in the vPDU tests;
- Steering/Cooperation Committee NÜRDAM/Bolu University (Turkey) - Since 2023

Developing some new ideas..

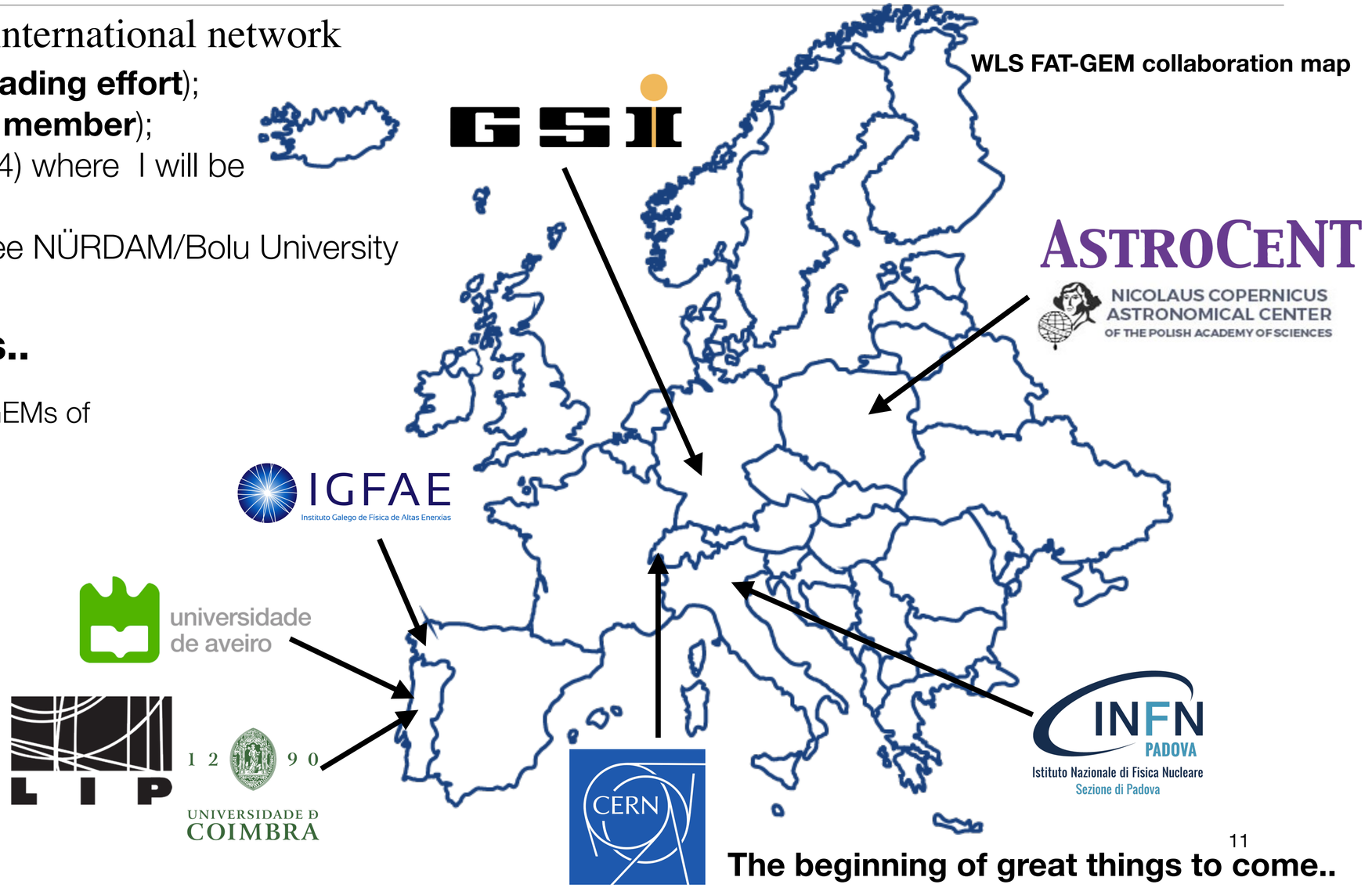
Radon trapping system using WLS FAT-GEMs of potential interest to rare event experiments;

Interested partners:

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

IEAP/CTU Prague (Czech Republic)

Institute of Physics Jagiellonian University (Poland)



The beginning of great things to come..

Thank you!

Dark Matter Coffee. AI generated image

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