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# The **DarkSide-20k** Experiment

**Iftikhar Ahmad**

**AstroCeNT, Warsaw**

On behalf of the **DarkSide-20k Collaboration**  
IDM-2024 workshop, **L'Aquila**

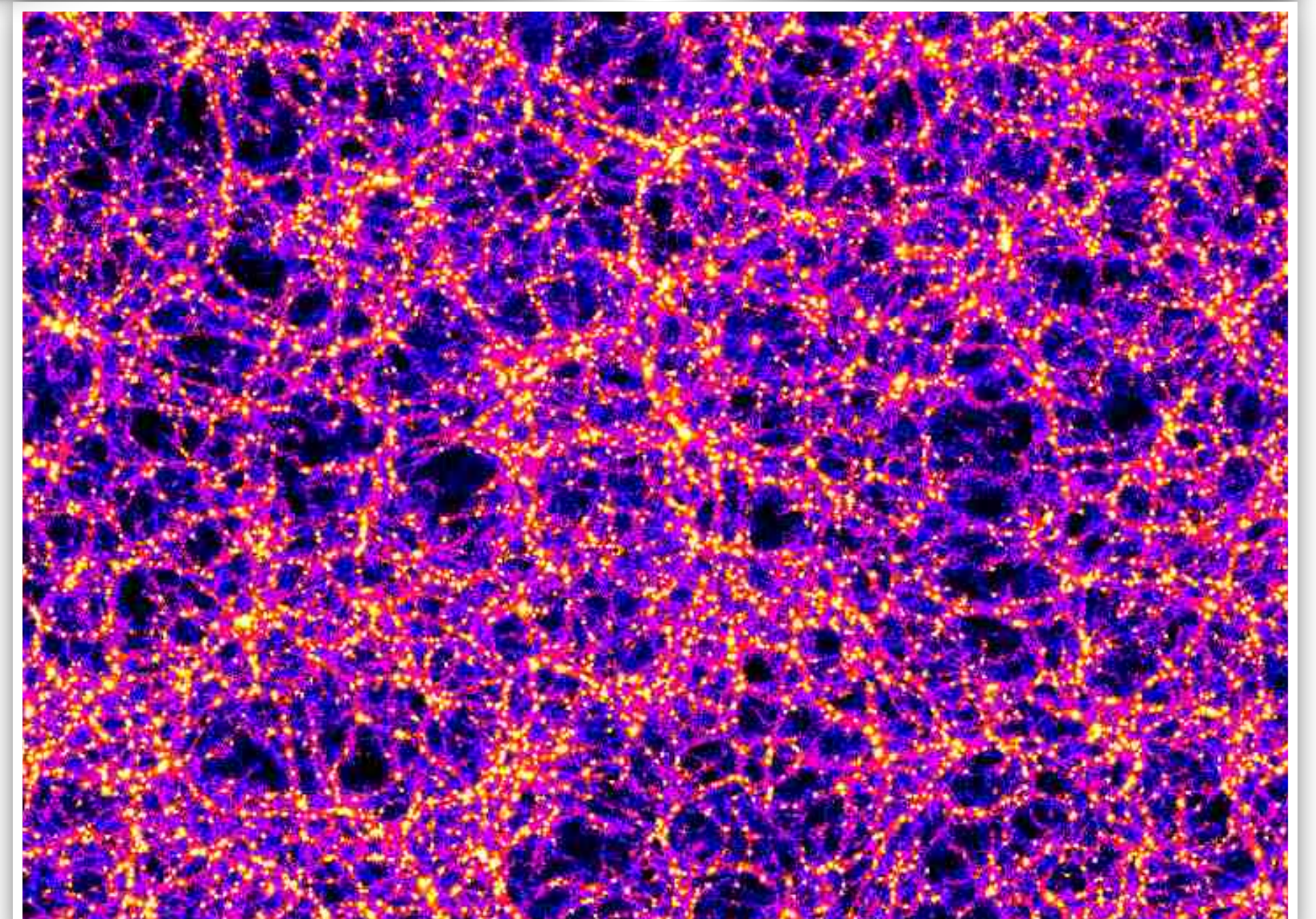
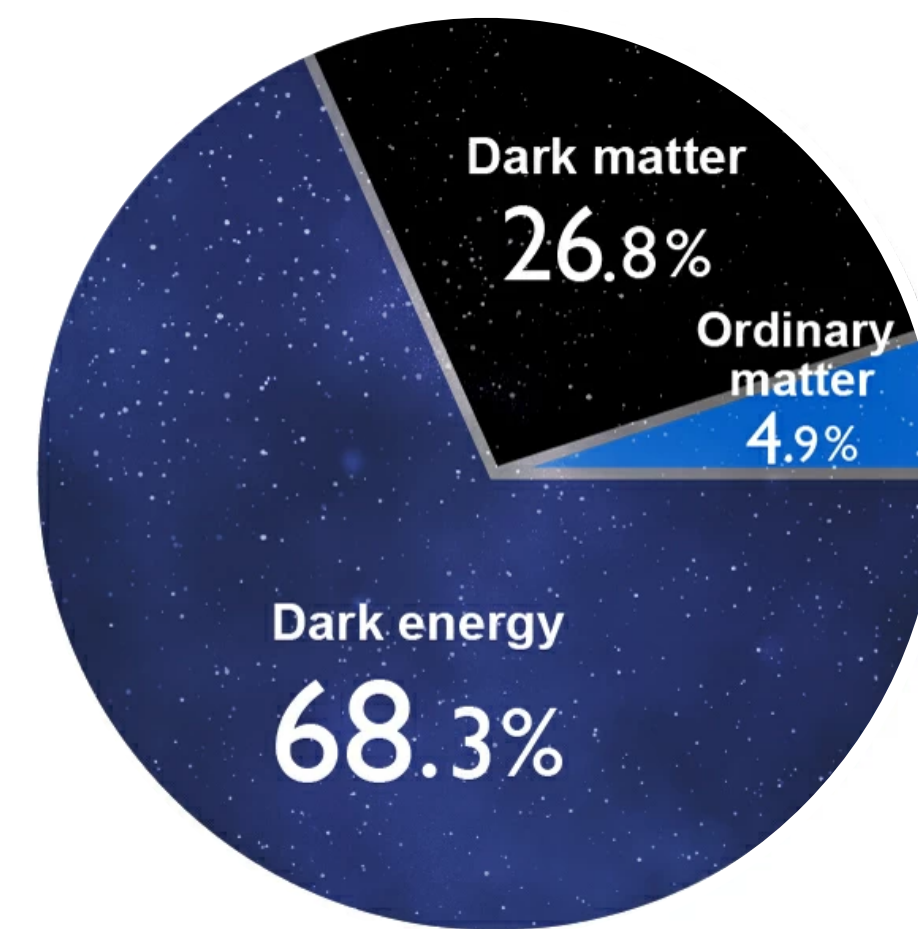
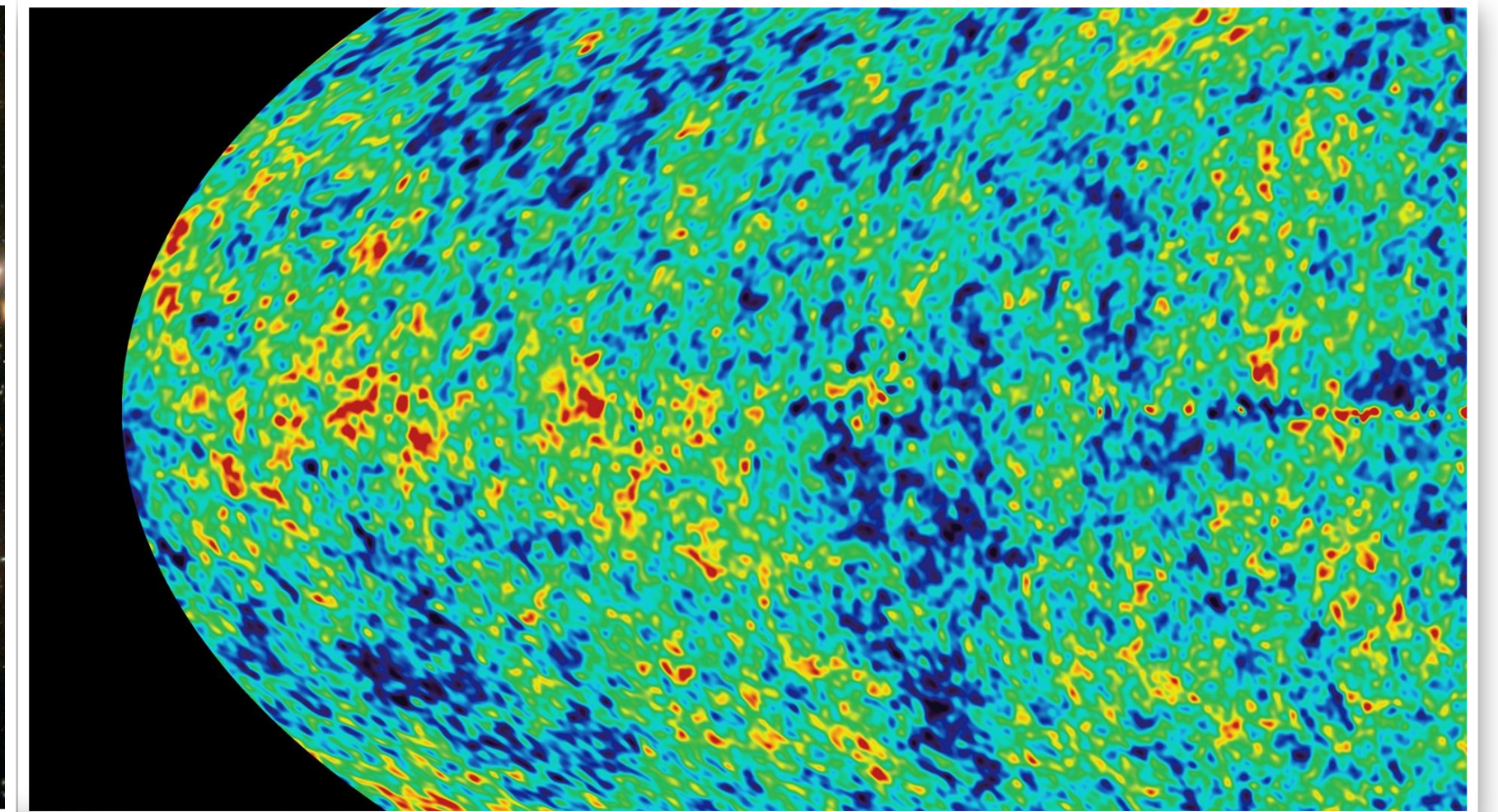
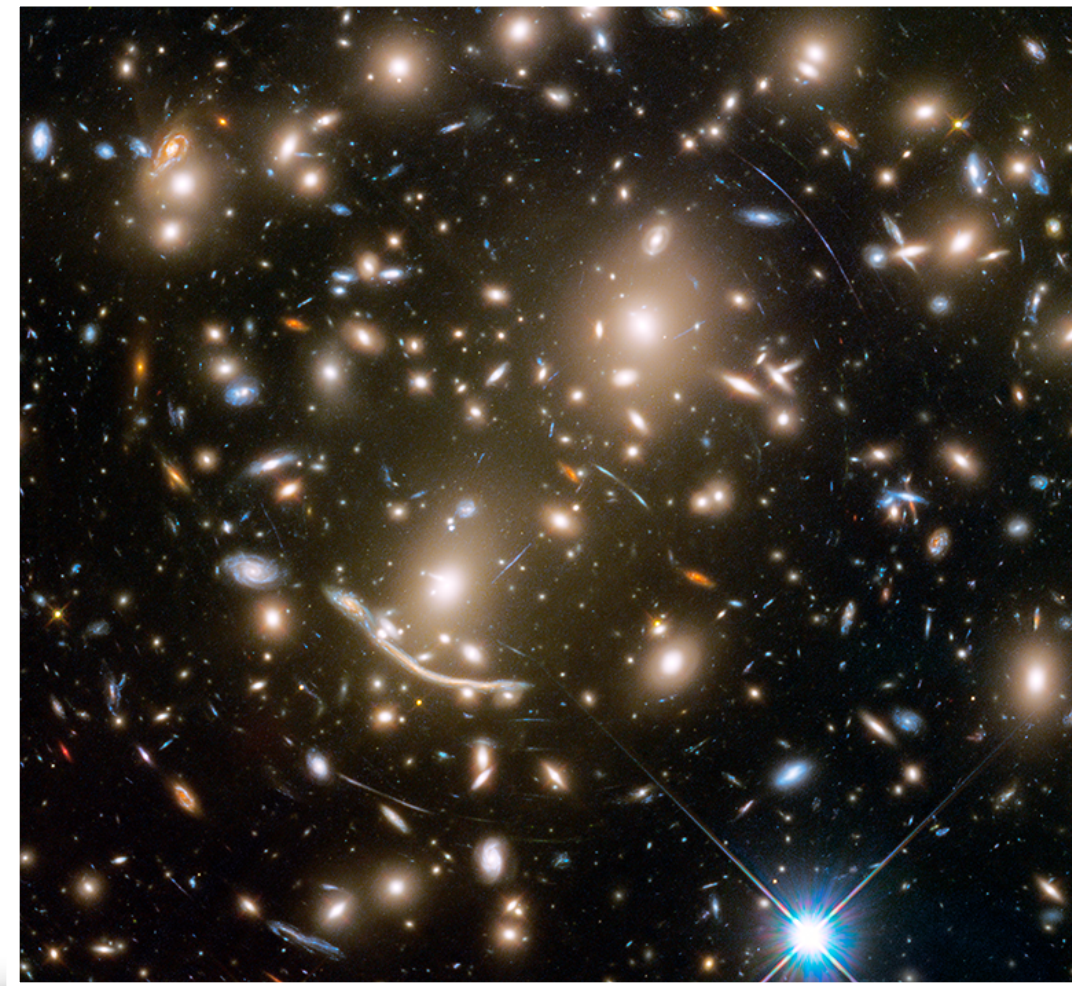
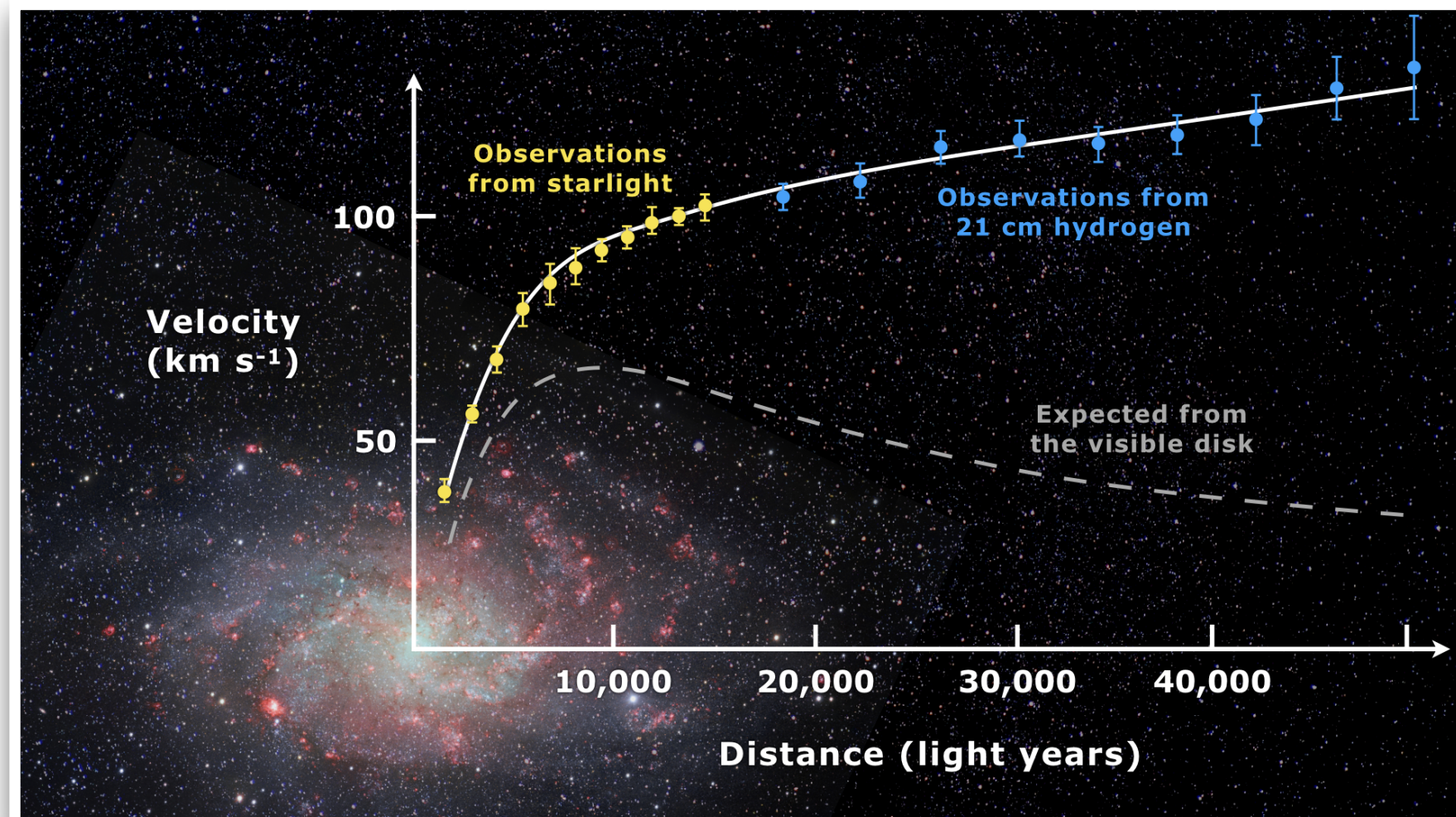
**ASTROCENT**



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OF THE POLISH ACADEMY OF SCIENCES

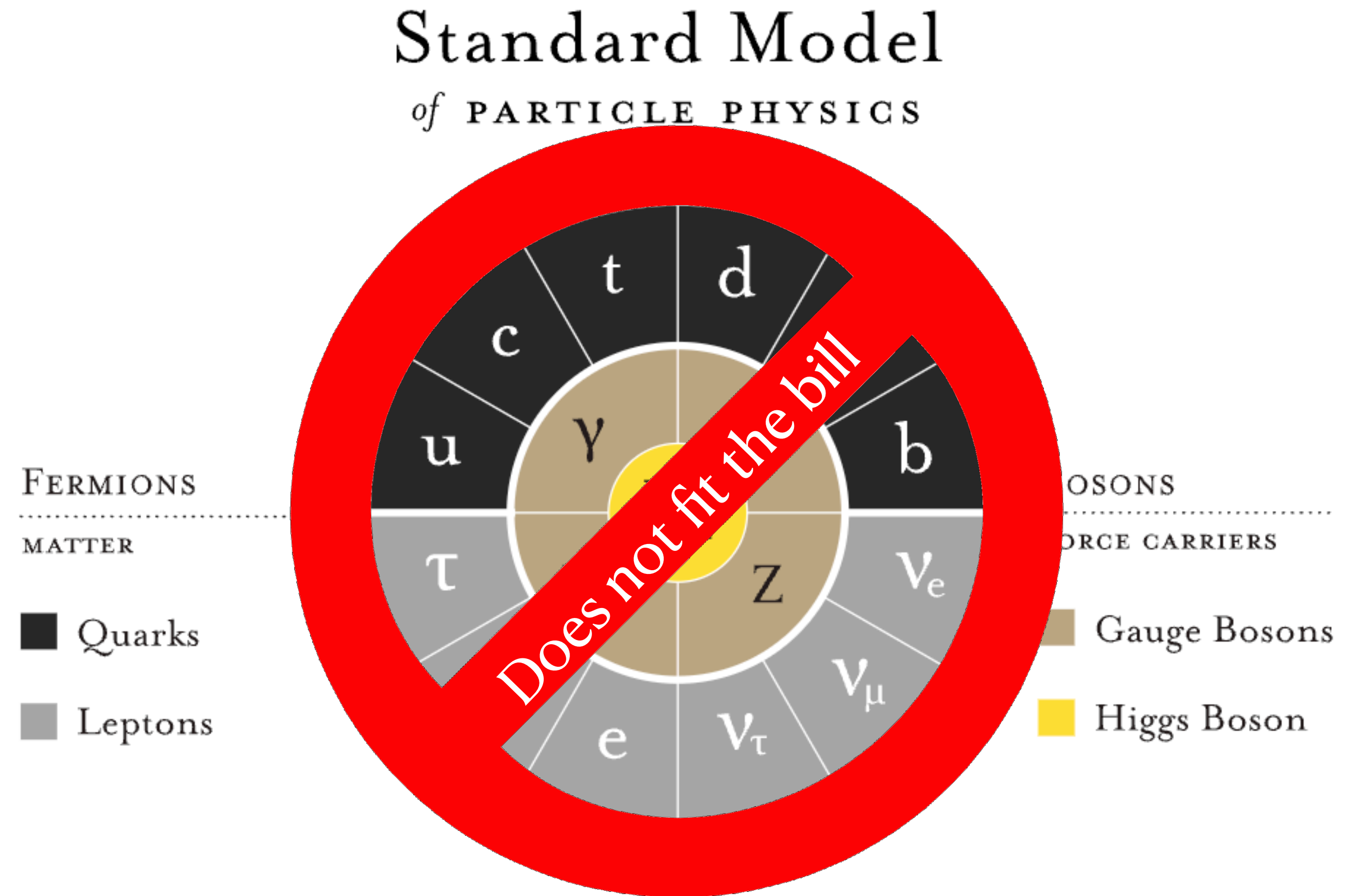


# EVIDENCES FOR DARK MATTER



# PROPERTIES OF DARK MATTER

- ▶ Gravitationally interacting
- ▶ Stable particle
- ▶ Not Hot (Heavy)
- ▶ Not Baryon



**New Physics Beyond Standard Model!!**

One of the candidates is **WIMPs**.

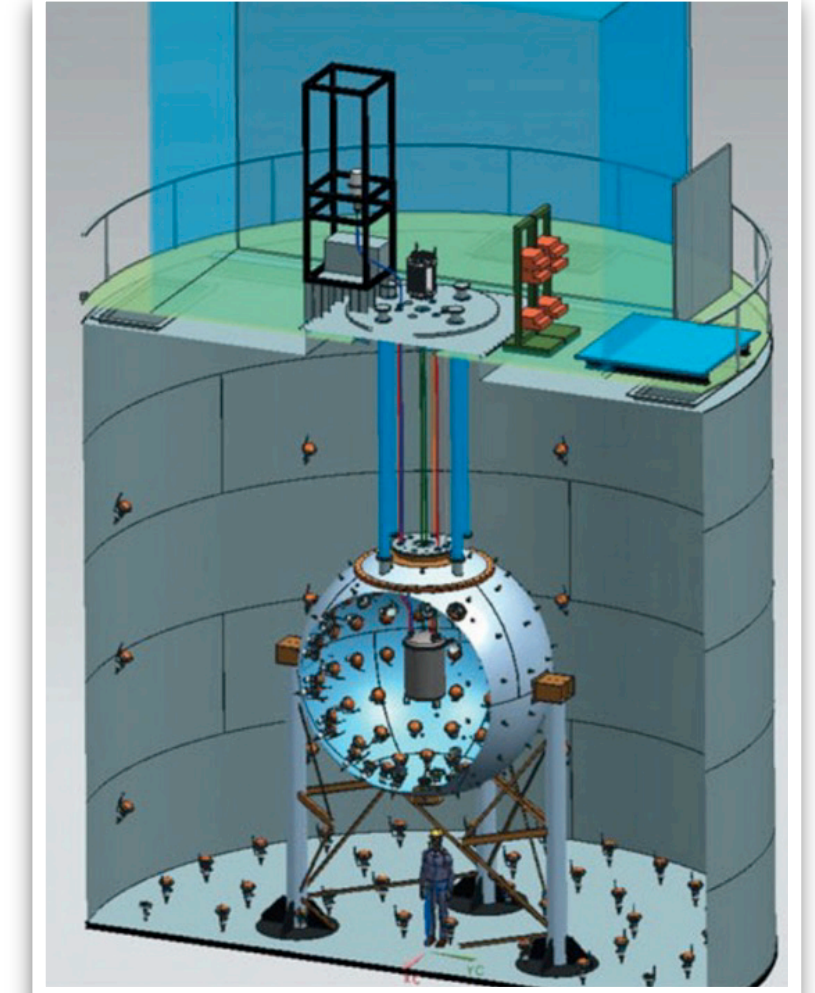
# THE GLOBAL ARGON DARK MATTER COLLABORATION



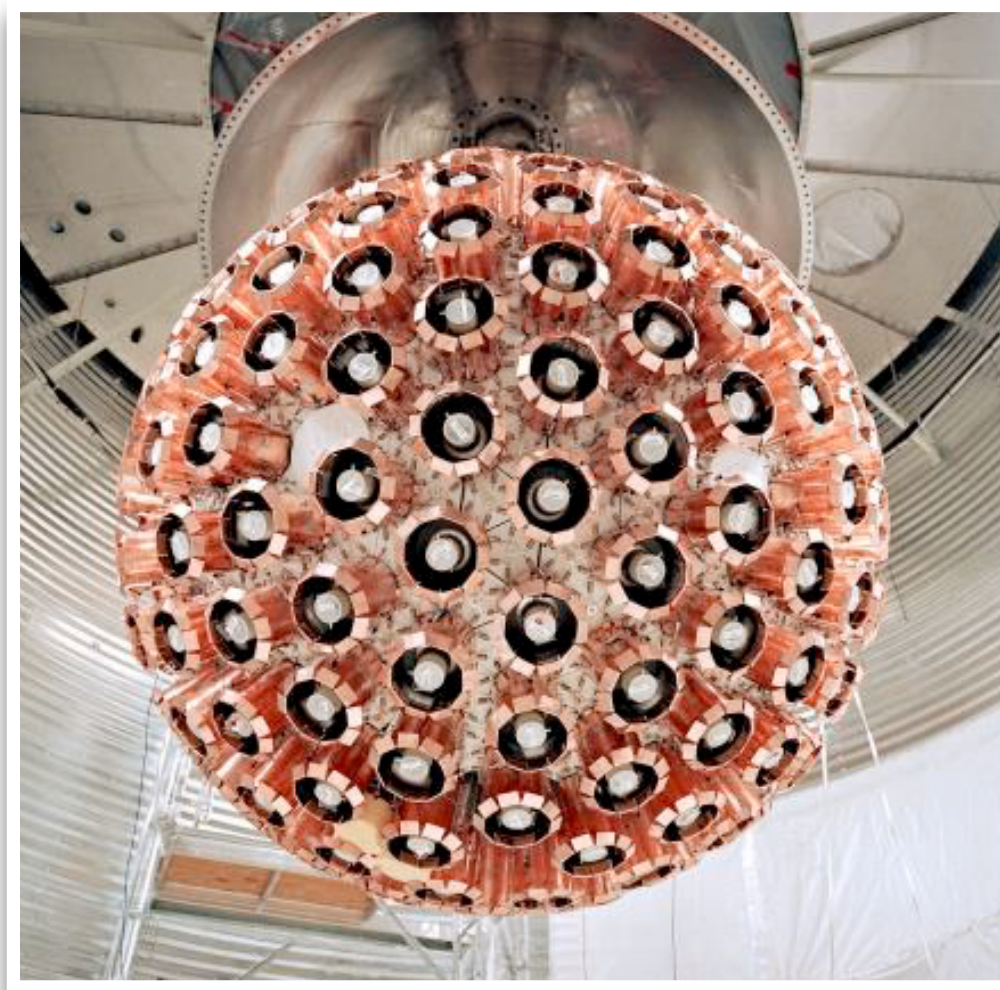
MiniCLEAN @Snolab



- Combined expertise from 4 LAr experiments
- Over 400 collaborators from 100 different institutes



DarkSide-50 @LNGS



DEAP @Snolab



## GOAL

To explore heavy dark matter to the **neutrino floor** and beyond with extremely **low instrumental background**



ArDM @Canfranc

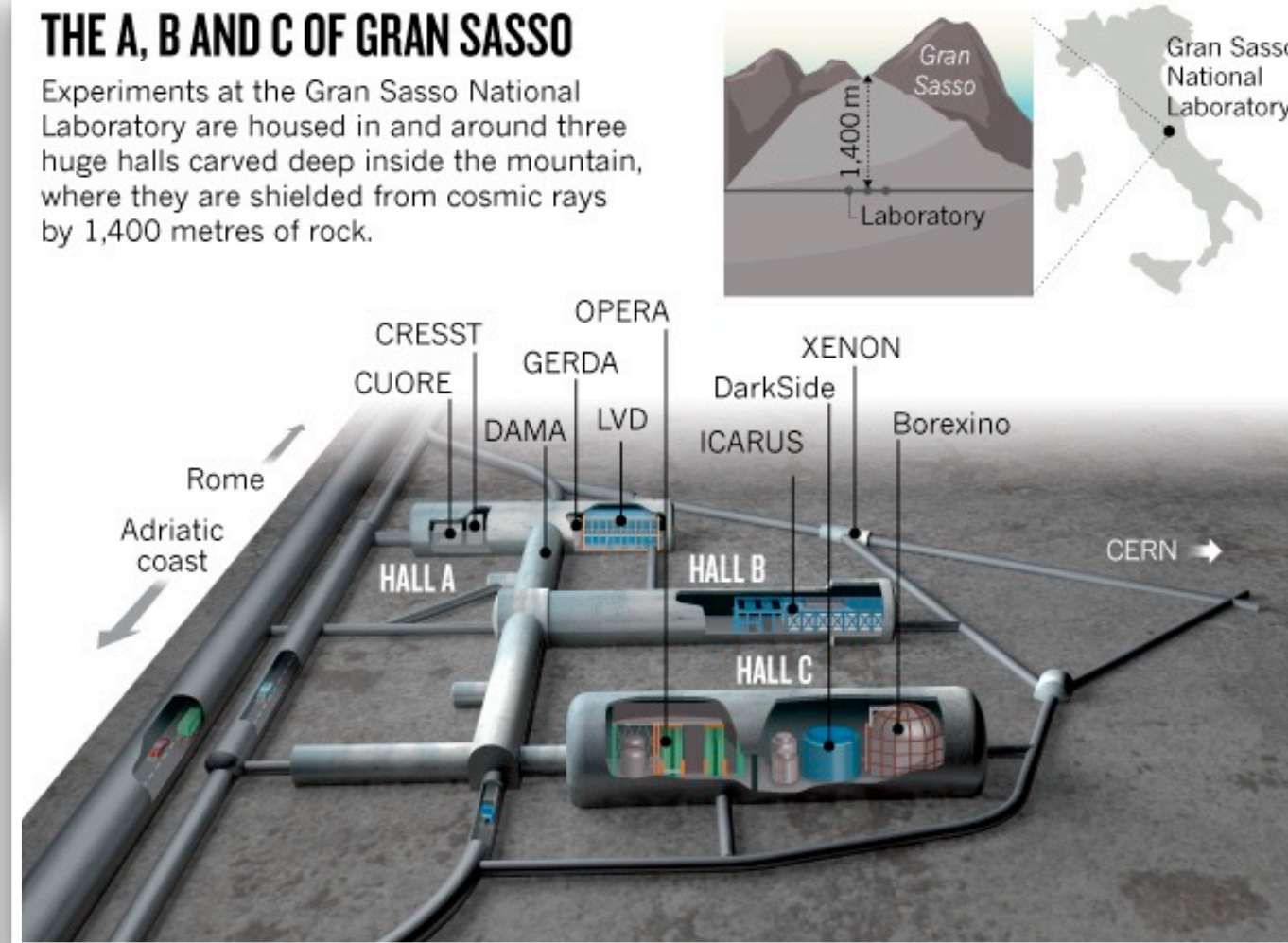
# DARKSIDE-20K EXPERIMENT

## DarkSide-20k:

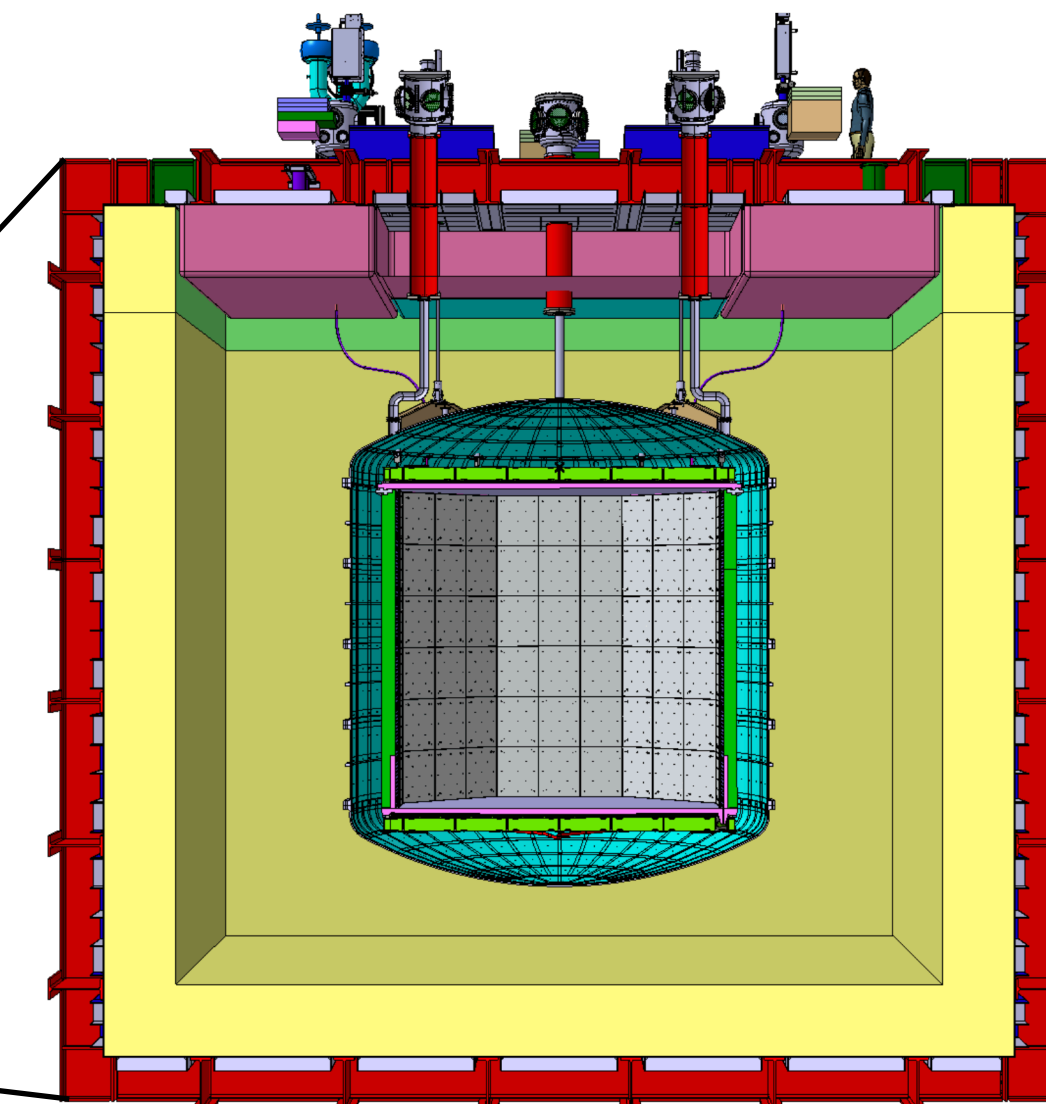
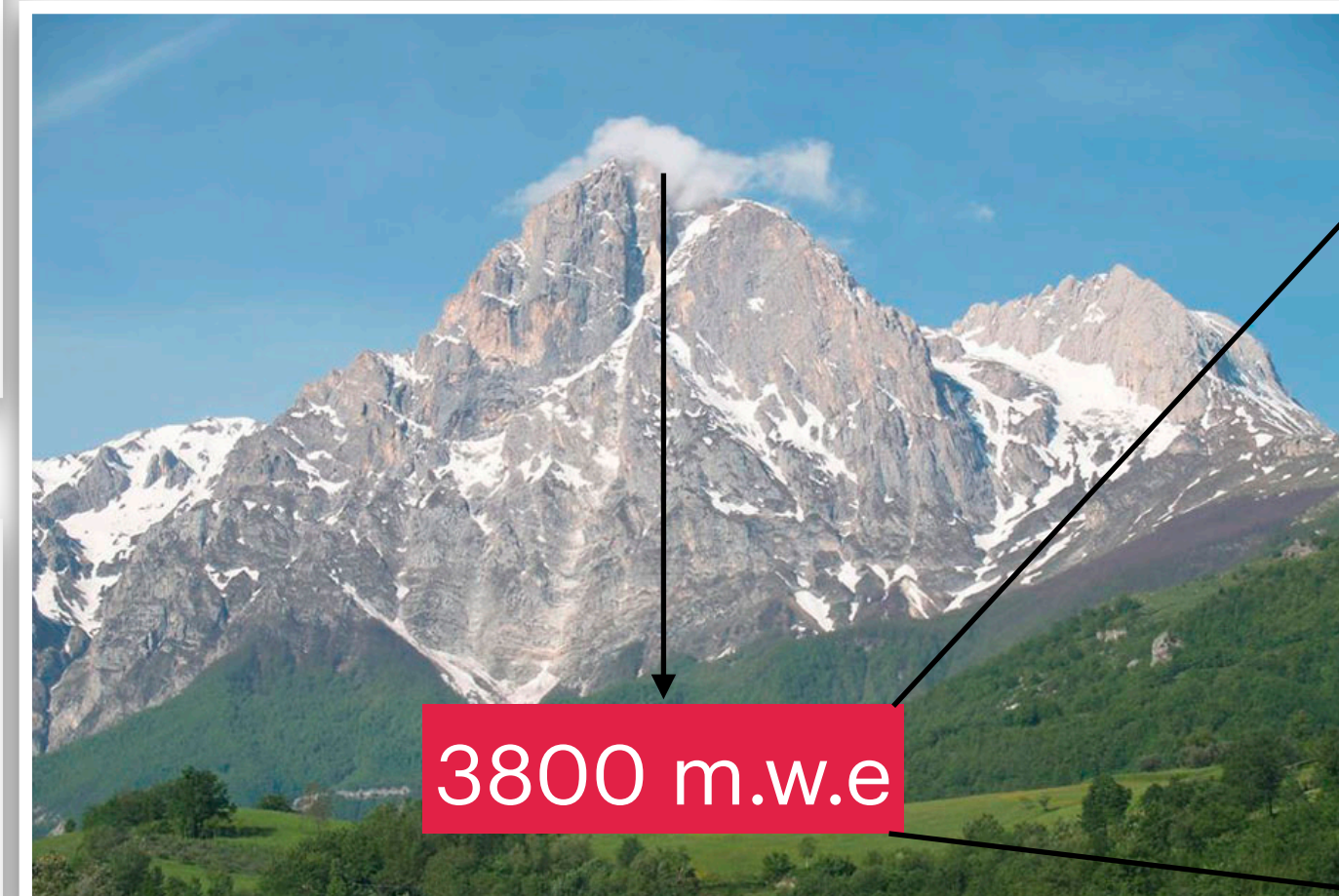
- LAr dual-phase TPC experiment designed to detect WIMP scattering interactions from the dark matter halo.
- Commissioning expected by the end of **2026**.

- Located at LNGS (Italy), **1400m** underground.
- $\mu$  flux reduction by  **$10^6$** .
- TPC circumscribed by acrylic panels (**PMMA**).
- Utilises **UAr**.
- Light Readout: large array of cryogenic low-noise **SiPMs**.
- Sensitivity to WIMP-nucleon cross sections of  $\sim 10^{-24}$  barns @mass of 1 TeV.

- Primarily optimised for heavy ( **$\sim 1$  TeV**) WIMP-like candidates.
- Also sensitive to light ( $\sim 1-10$  GeV) WIMP-like candidates.
- Neutrino interactions via coherent scattering (**CEvNS**).



**12-June-2024**



DarkSide-20k under construction at LNGS.

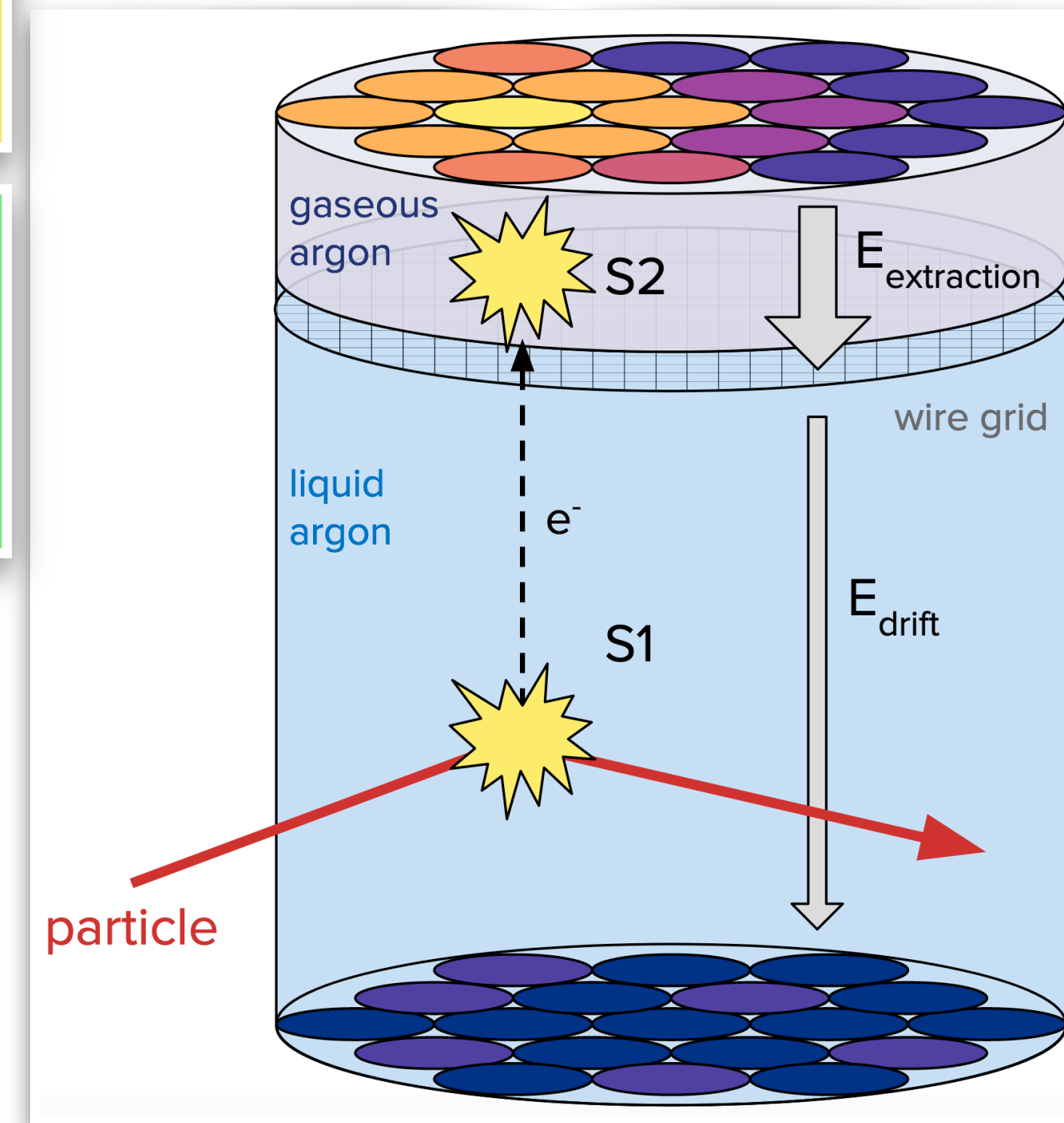
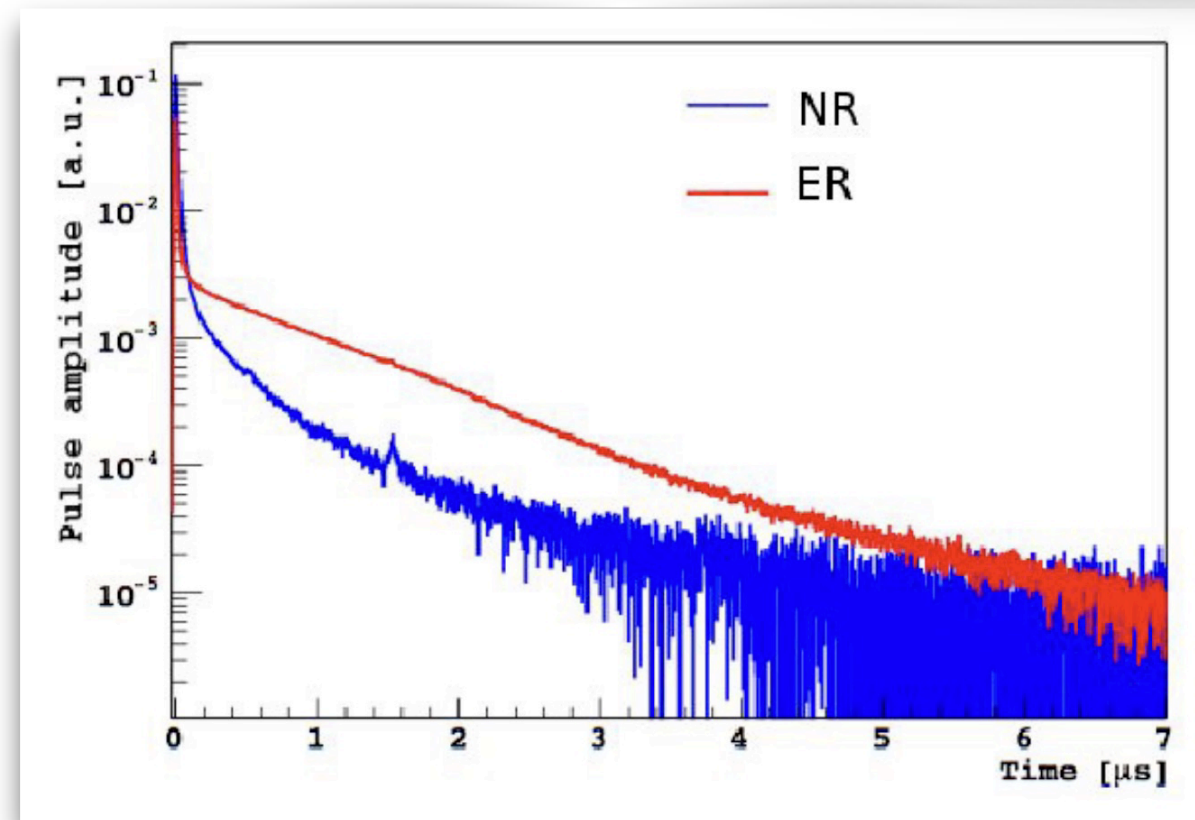
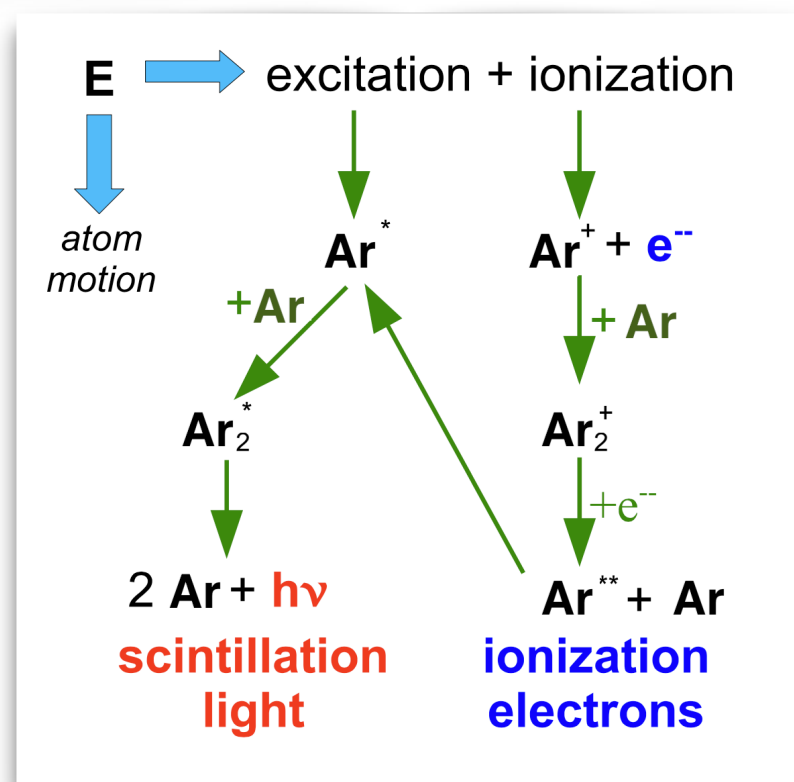
# TIME PROJECTION CHAMBER

## Why Argon?

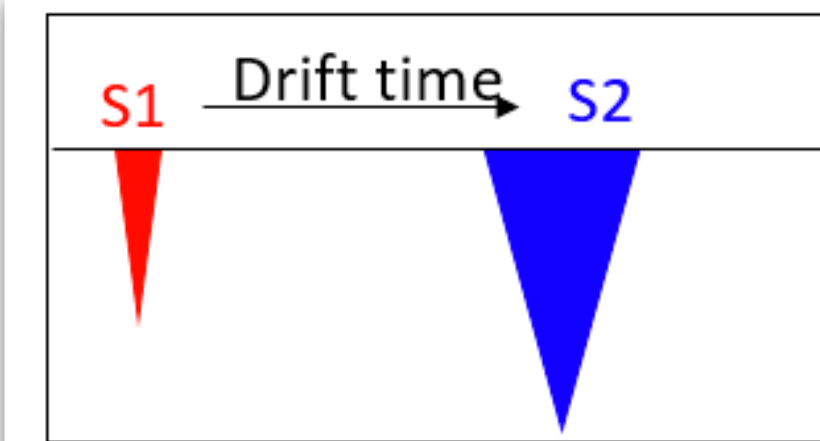
- Easy to purify and scalable
- High ionisation, good scintillator - transparent to own scintillation
- Strong **electron recoil (ER)** discrimination via pulse shape (**PSD**)

**S1:** primary scintillation in LAr (energy information and pulse shape discrimination)

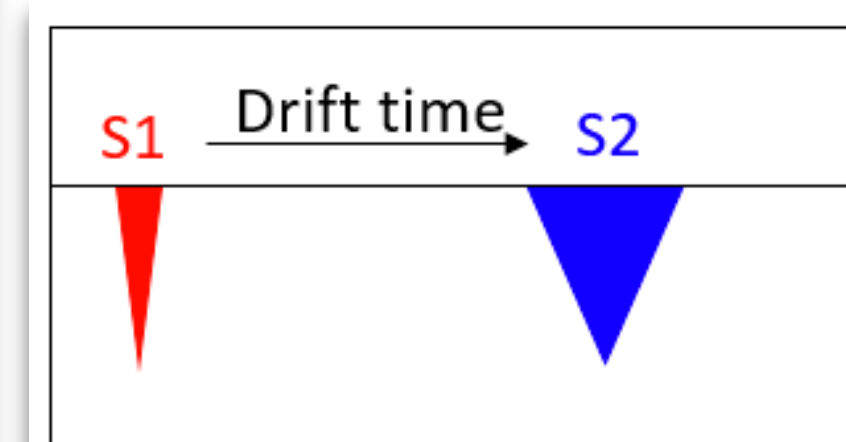
**S2:** secondary scintillation from electroluminescence of electrons in gas pocket (energy information and position reconstruction)



$\gamma$  background: electron recoil (ER)



Dark matter: nuclear recoil (NR)



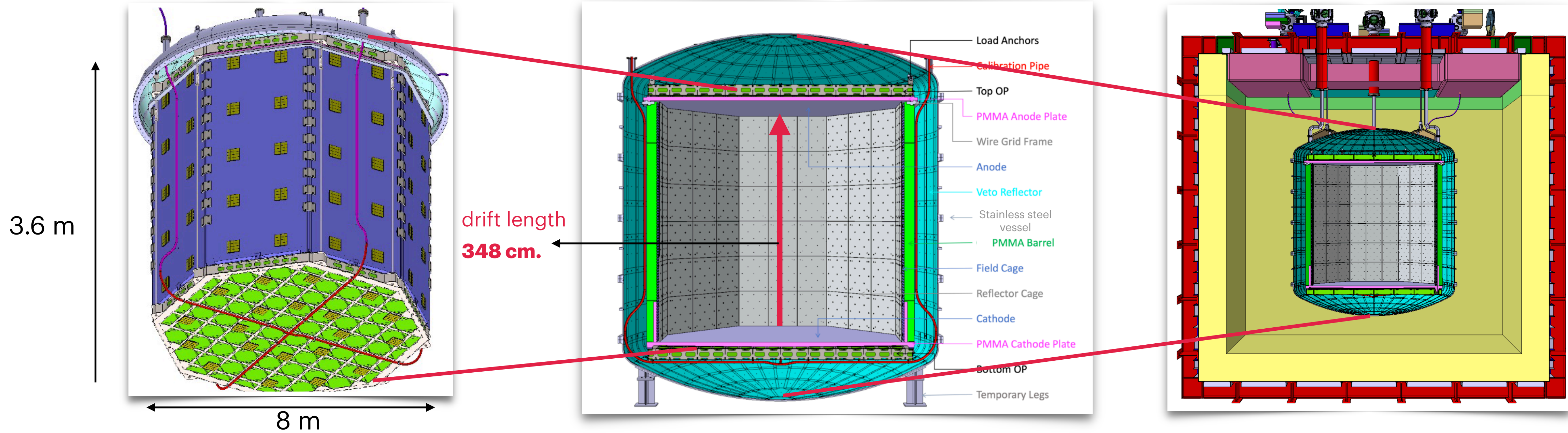
$$(S2/S1)_{NR} \ll (S2/S1)_{ER}$$

F90: fraction of light detected in the first 90 ns. (Singlet  $\sim 7$  ns ; Triplet  $\sim 1.5$   $\mu\text{s}$ )

- **S2/S1** ratio and **PSD**

- WIMPs generates nuclear recoils (NRs)

# DARKSIDE-20K DESIGN



**Dual phase LAr TPC:**

- Active UAr mass: 50 tons (**20 t fiducial**).
- The TPC walls (**15 cm thickness**) are made from **PMMA**.
- Two optical planes, total SiPM coverage of **21m<sup>2</sup> (top + bottom)**.

**Neutron Veto:**

- Active UAr mass: **32 tons**.
- Equipped with **120 vPDUs** covering **5m<sup>2</sup>**.
- **40 cm** space between the stainless-steel vessel and PMMA.
- Covered with **WLS and ESR reflectors**.

**Outer cosmic Veto:**

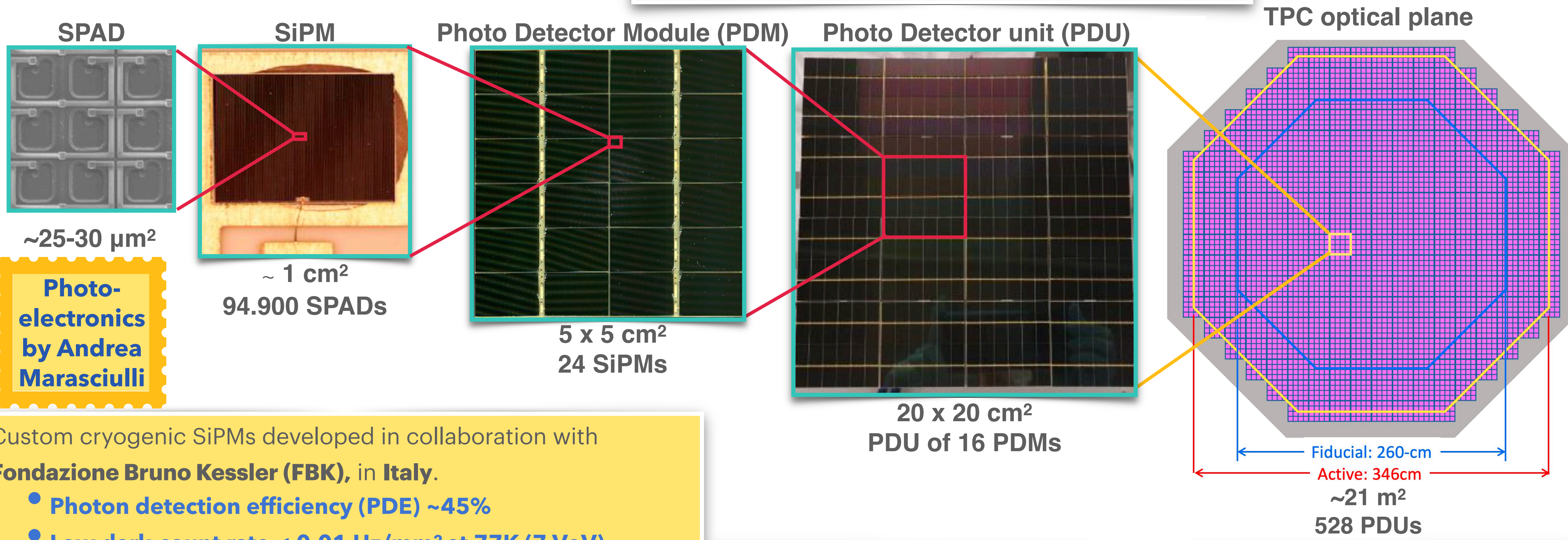
- Active **A**Ar mass: **650 tons**.
- Membrane "**ProtoDUNE-like**" cryostat **8x8x8 m<sup>3</sup>**.
- Outer veto will consist of **SiPM arrays** near the cryostat walls.



**Material assay campaign of the DarkSide-20k experiment by Roberto Santorelli (Thu 17:30 P1)**

# LARGE AREA CRYOGENIC SiPM LIGHT DETECTORS

4 PDMs are summed and read as a single channel.  
**Largest SiPM array!**



**Photo-electronics by Andrea Marasciulli**

Custom cryogenic SiPMs developed in collaboration with **Fondazione Bruno Kessler (FBK)**, in **Italy**.

- Photon detection efficiency (PDE) ~45%
- Low dark-count rate < 0.01 Hz/mm<sup>2</sup> at 77K (7 VoV)
- Timing resolution ~ 10 ns
- SNR>8 for 10x10cm<sup>2</sup>

Mass production of the raw wafers at **LFoundry (Italy)**

- SiPM testing and assembling facility at **NOA (Nuova officina Assergi)**.

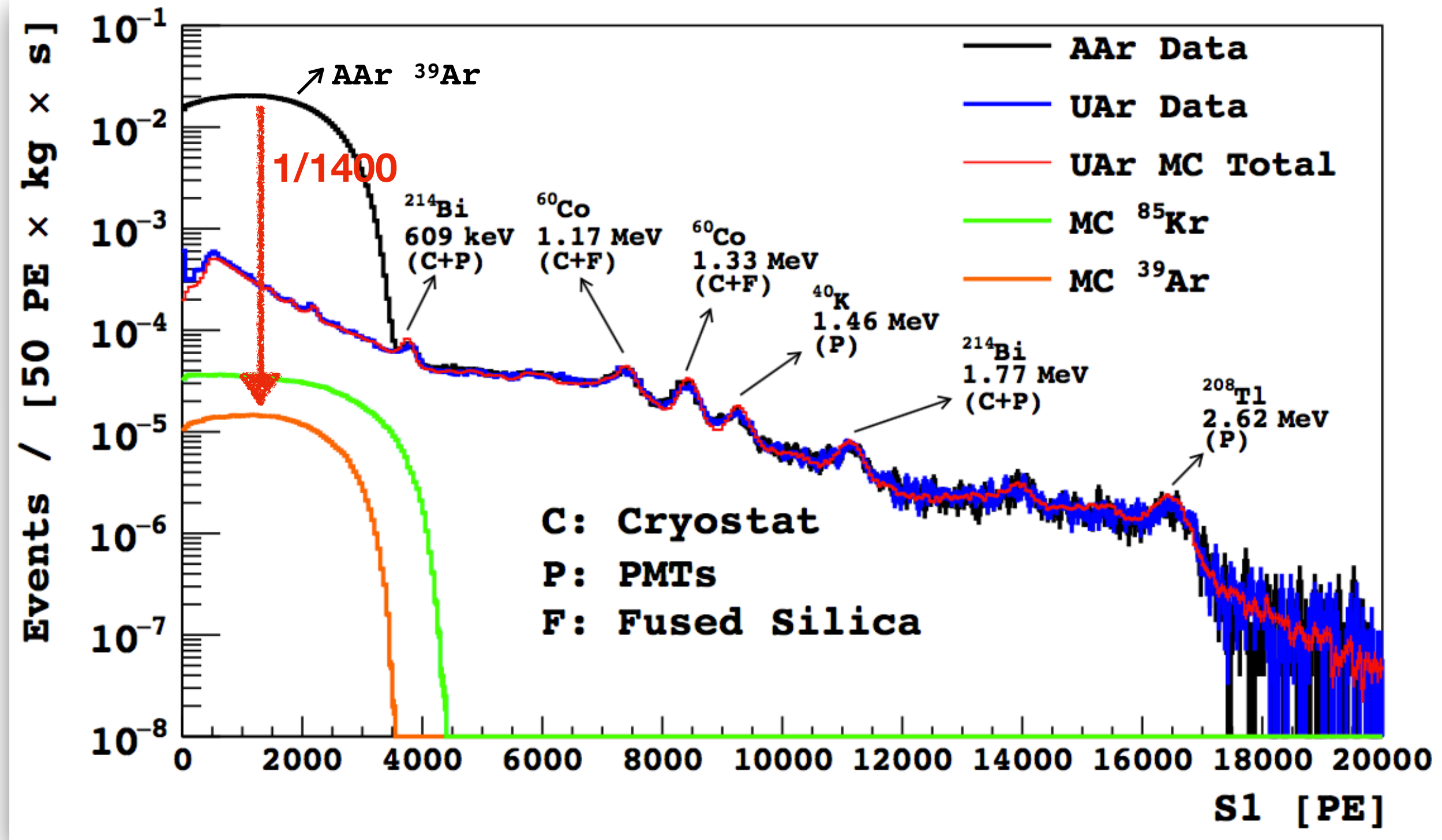


# UNDERGROUND ARGON

$\beta$  &  $\gamma$   
Rejection

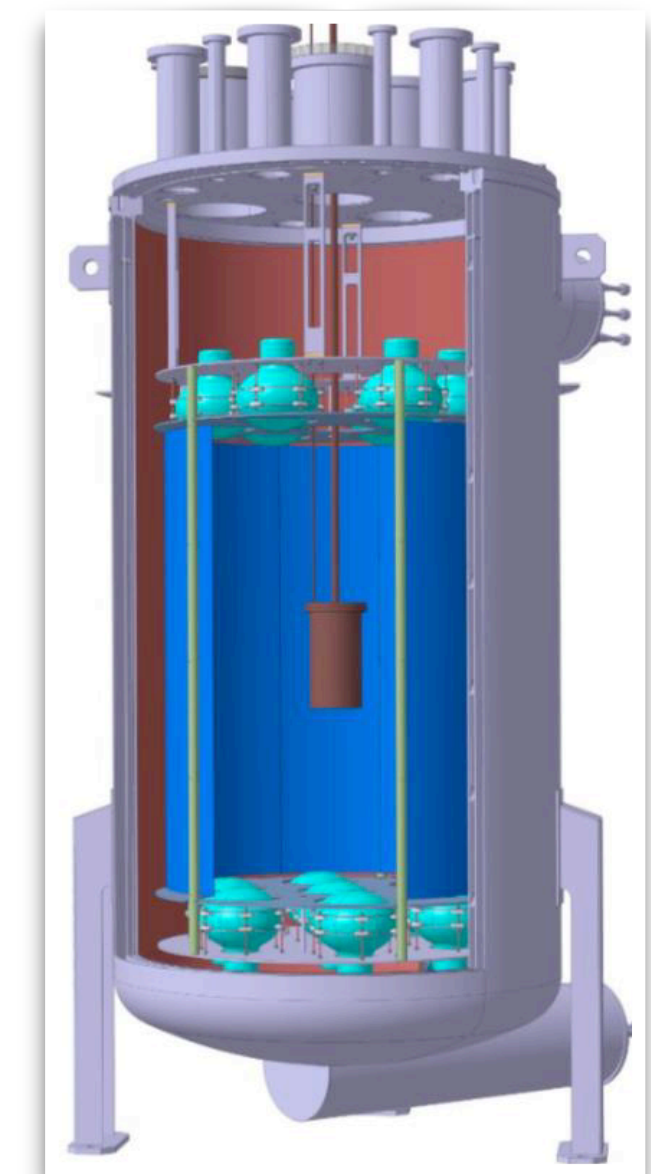
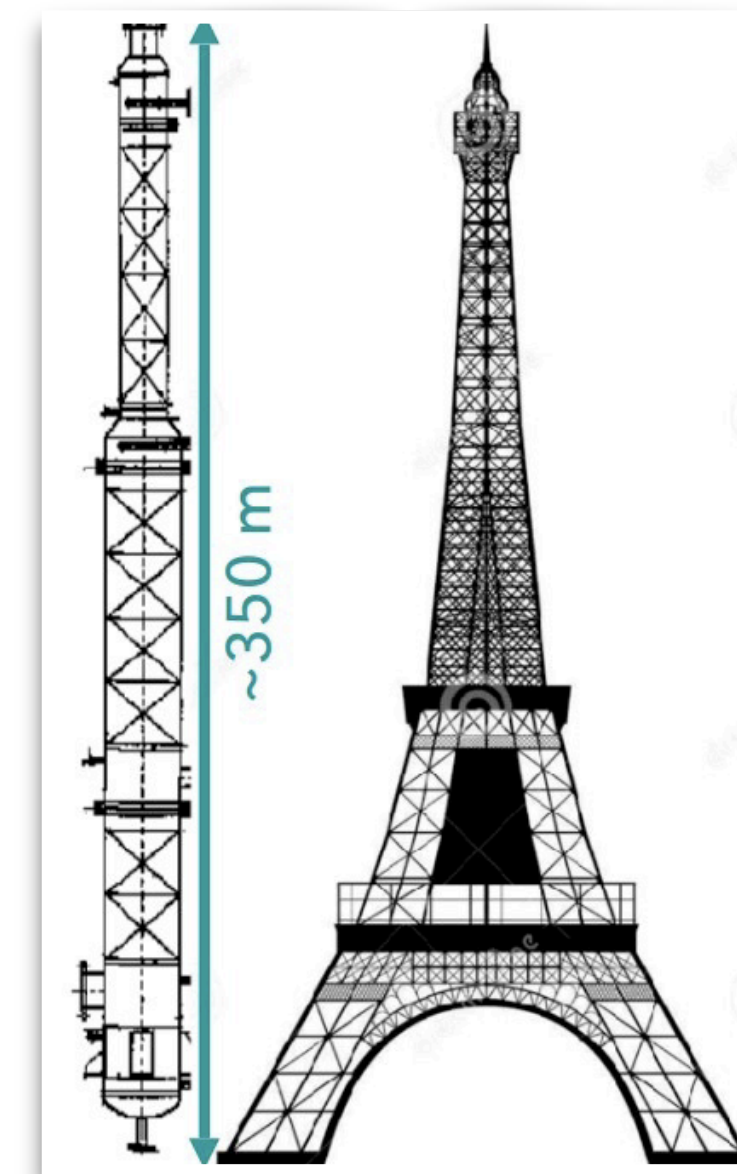
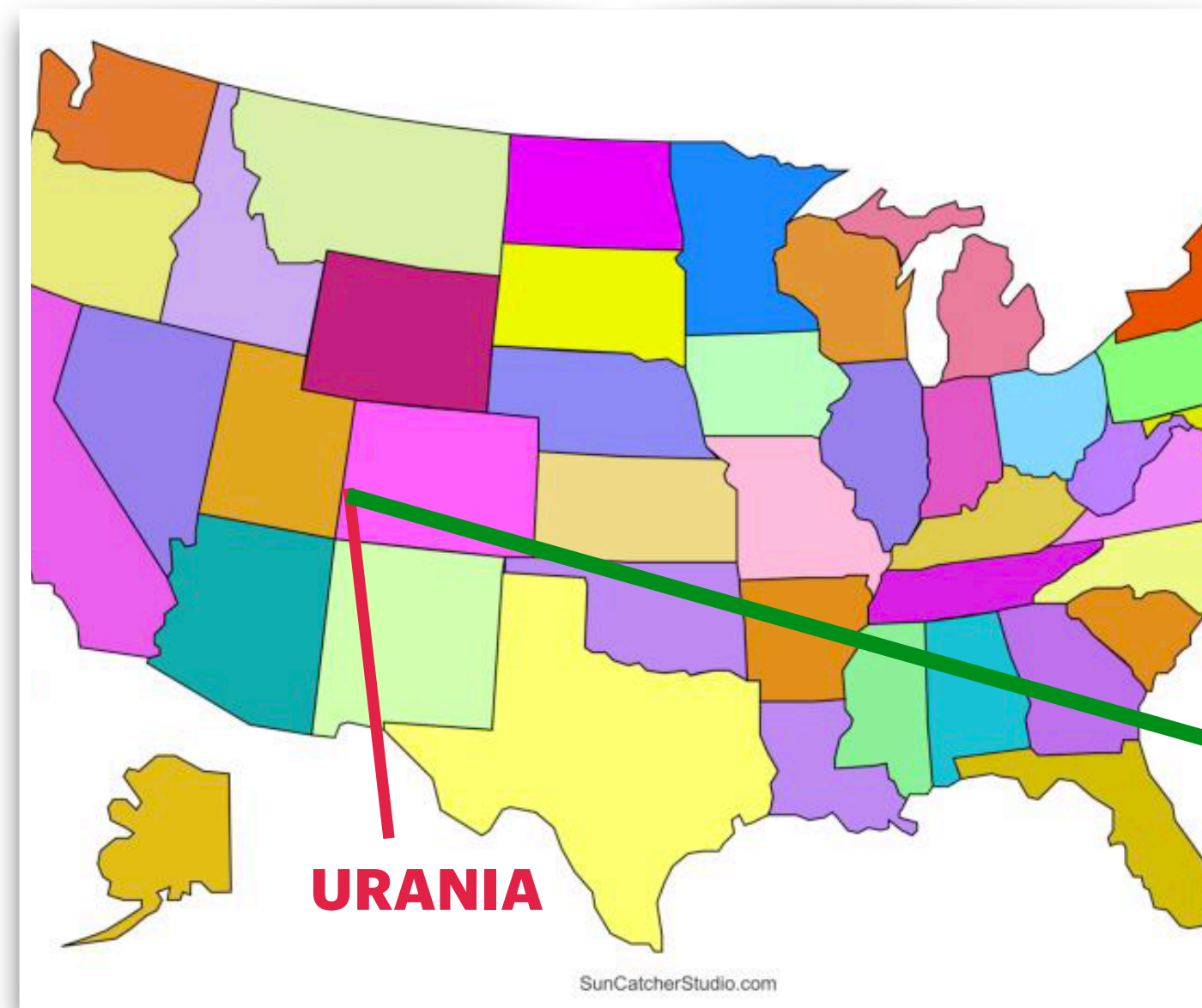
- **Intrinsic  $^{39}\text{Ar}$**  radioactivity in atmospheric argon is the primary background for argon-based detectors.
- $^{39}\text{Ar}$  activity sets the dark matter detection threshold at **low energies** (where PSD is less effective).

- $^{39}\text{Ar}$  is a cosmogenic isotope, and the activity in argon from underground sources can be significantly lower compared to AAr.
- $^{39}\text{Ar}$  activity in **AAr: 1 Bq/kg** while for **UAr: 0.73 mBq/kg**
- **157 kg** of UAr deployed in DarkSide-50 in 2015.
- $^{39}\text{Ar}$  reduction factor of **~1400!**



**Low-radioactivity argon for dark matter searches and beyond by R. Stefanizzi (Mon-17:50 P1)**

# DEPLETION AND PURIFICATION



**Urania** (Extraction):

- UAr extraction plant in Colorado, USA.
- Expansion of the argon extraction plant, to reach capacity of **330 kg/day** of UAr.

**Aria** (Isotope separation):

- A **~350m** tall column in the Seruci mine in Sardinia, Italy, for **high-volume chemical** and isotopic purification of UAr.
- **A factor 10 reduction of  $^{39}\text{Ar}$**  per pass is expected with ~10 kg/day.

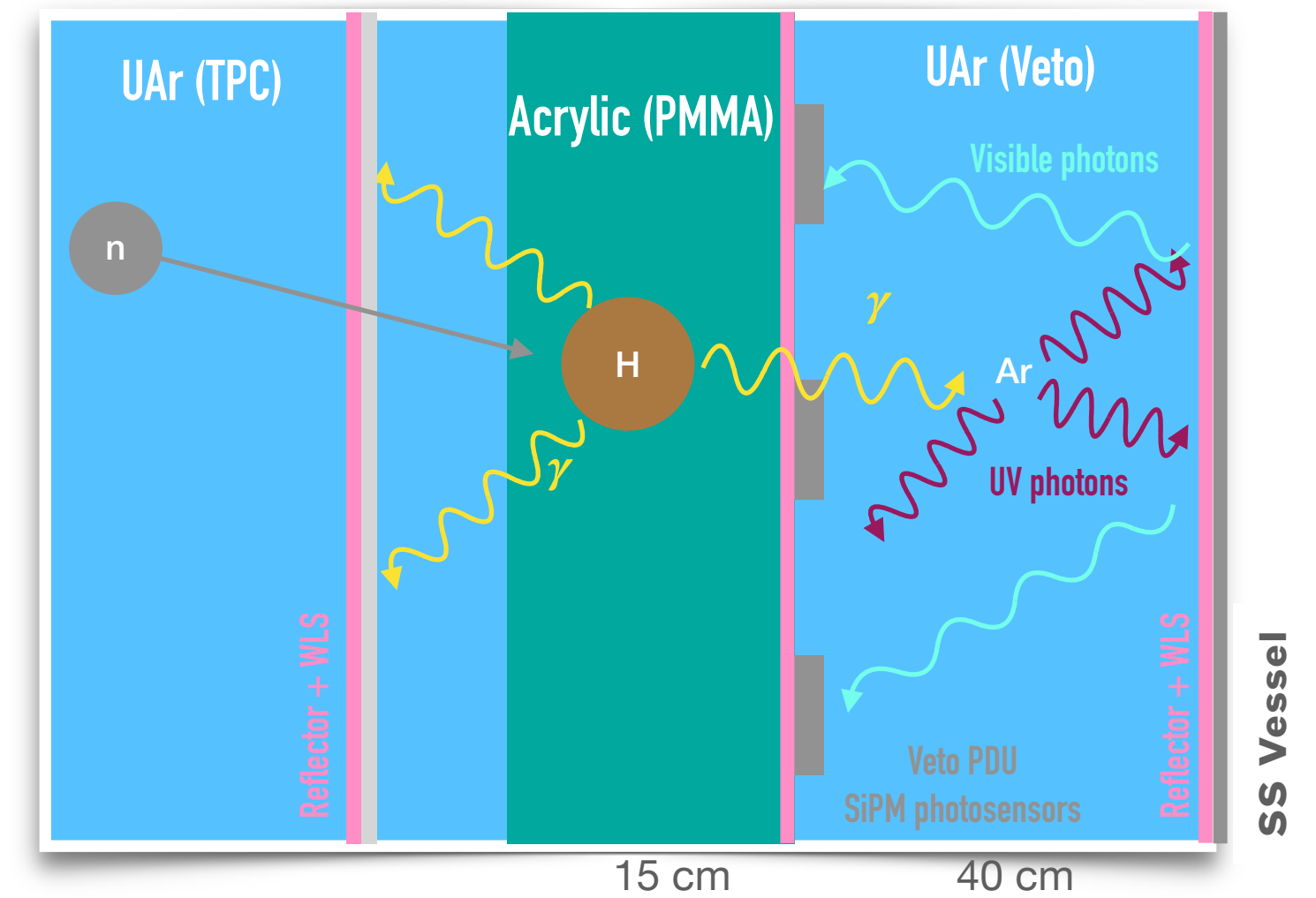
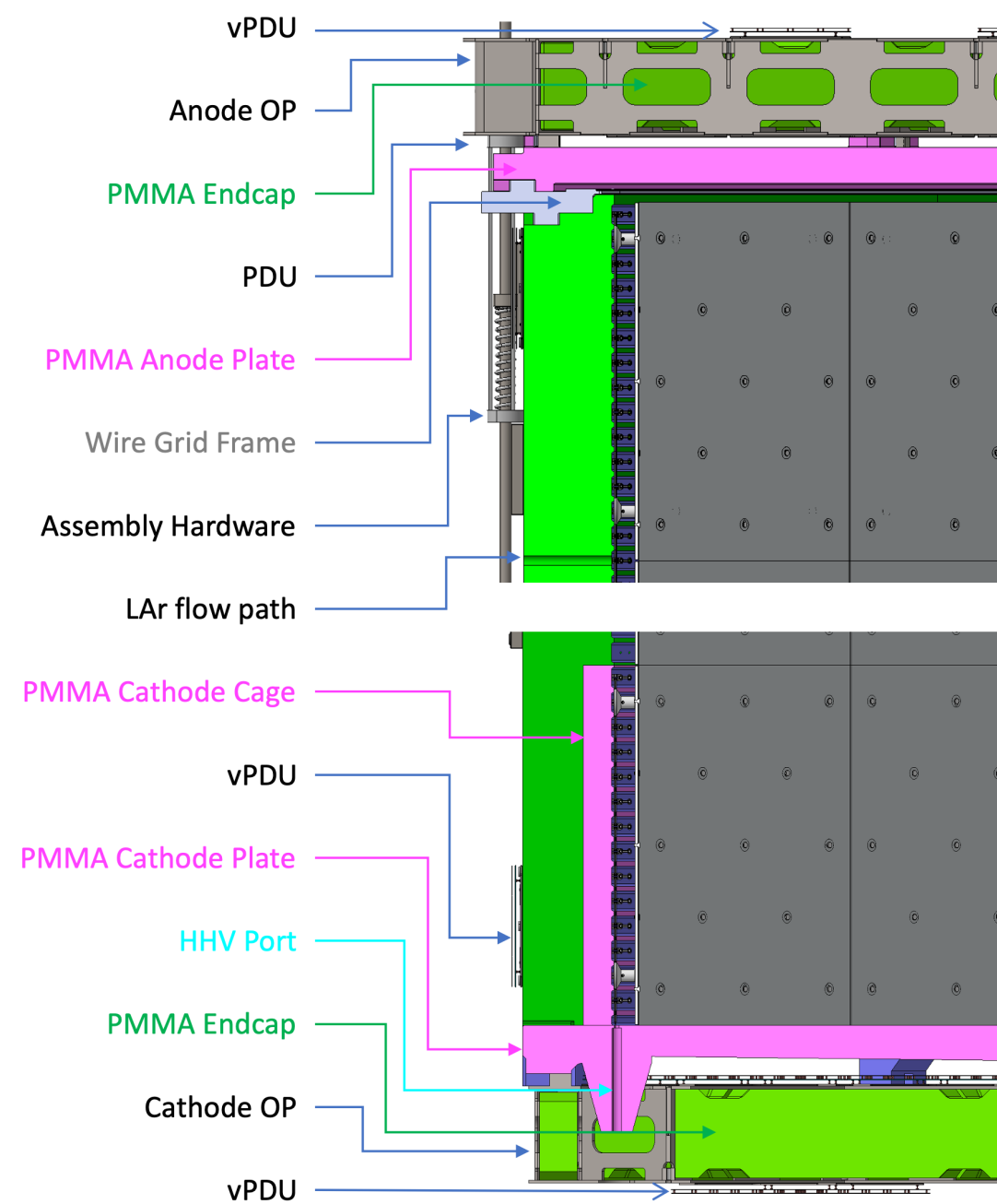
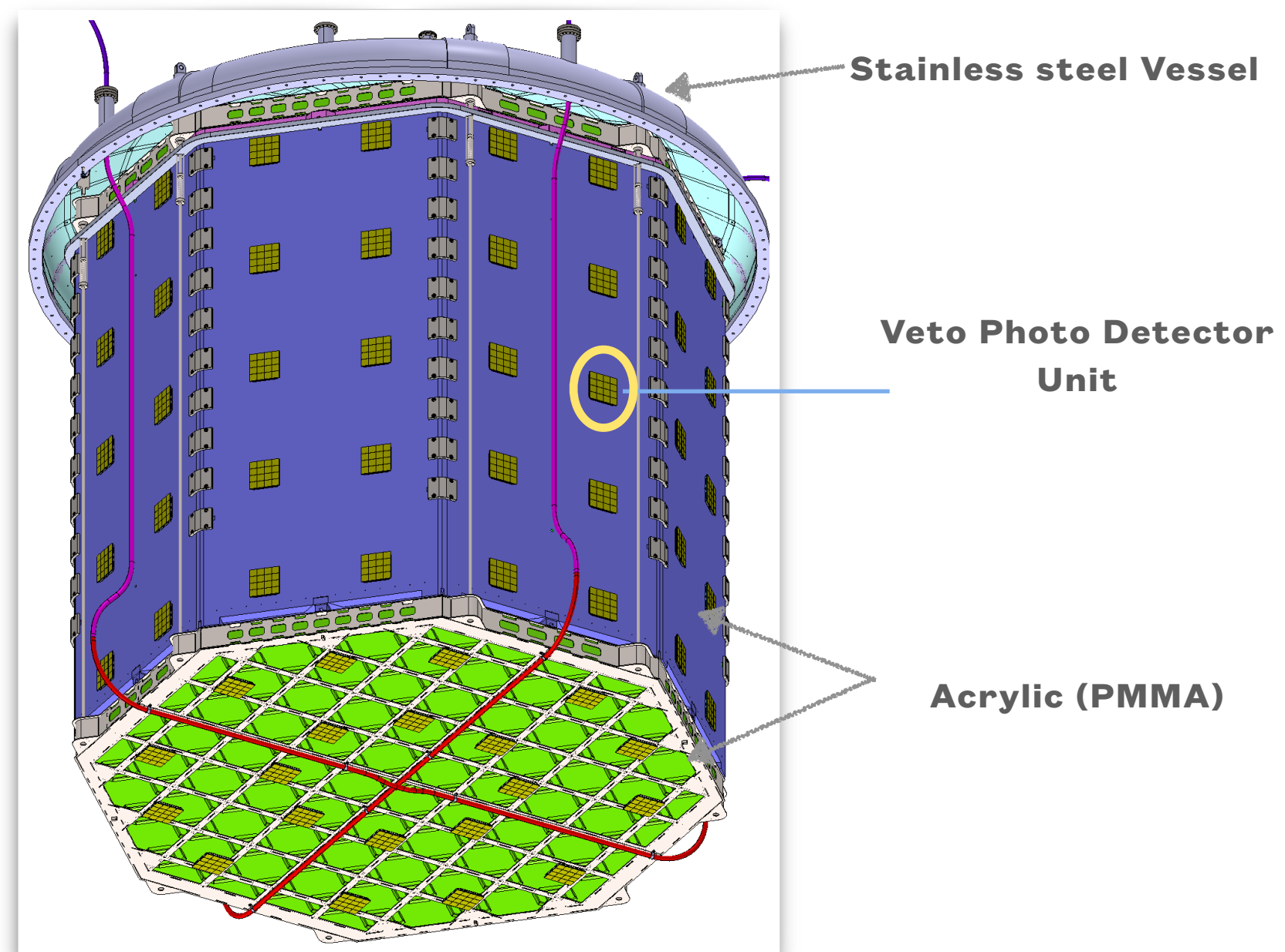
**DArT** (assay):

- A single phase low-background detector to measure the  $^{39}\text{Ar}$  depletion factor of different UAr batches.
- Located in **ArDM experiment** at Canfranc lab, **~2500 m.w.e.**



**Status and short term prospects of DArT, the Underground Ar measurement at Canfranc by Vicente Pesudo (Mon-18:10 P1)**

# NEUTRON VETO DETECTOR



- Neutrons can mimic WIMP signal. **PSD** is useless against neutron events.
- The UAr volume between the SS vessel and **PMMA** serves as a veto volume with **~40 cm thickness**.

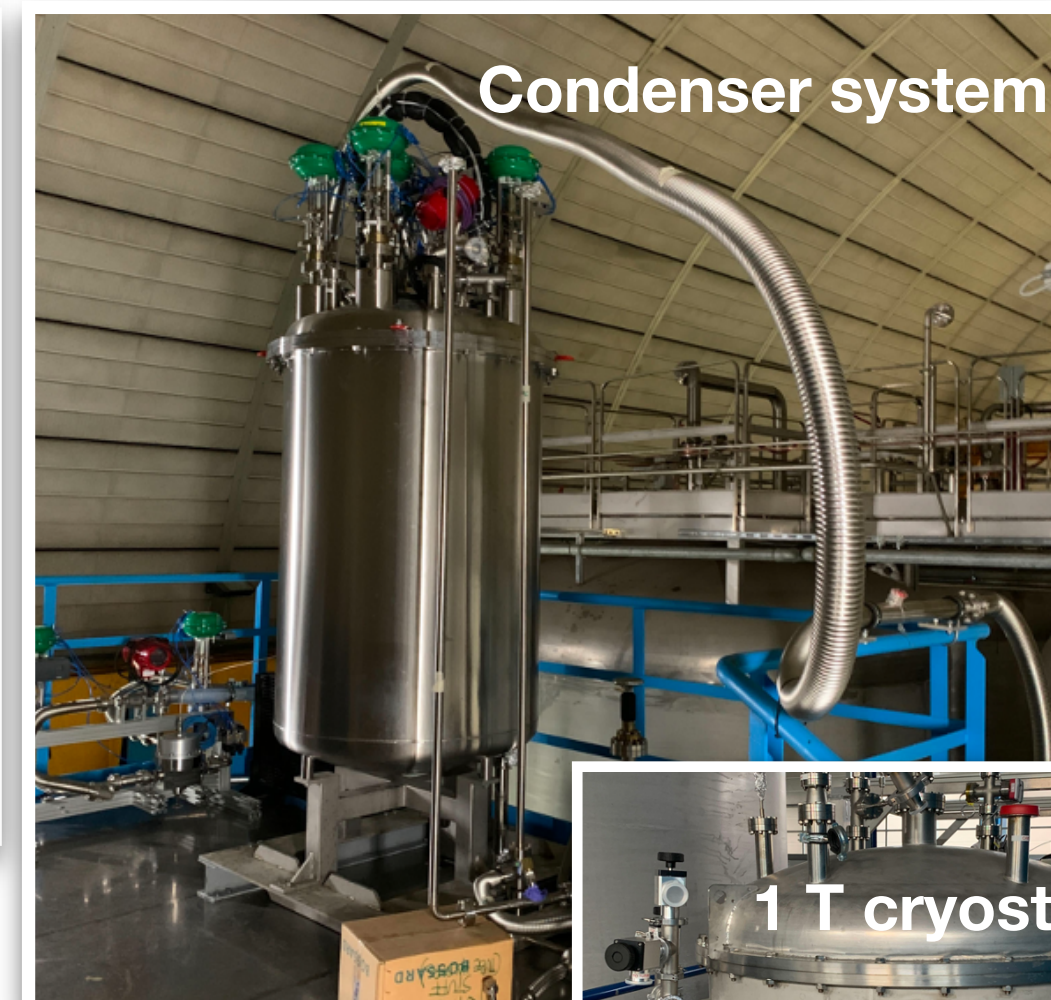
## Veto Working Principle

- Neutrons are moderated in the acrylic shell and then captured by **Hydrogen**.
- H emits  $\gamma$ -rays **2.2 MeV**.
- $\gamma$ -rays interact in the liquid argon buffers.
- LAr scintillation light is wavelength shifted and detected by **~1920 SiPM-based photosensors**.

# CRYOGENIC SYSTEM FOR TPC

- Integrated test of the **UAr cryogenics** is ongoing at **CERN**.
- Up to **10 kW** (latent heat + heat exchanging) adjustable condenser box.
- **1000 SLM** circulation speed with two homemade pumps in parallel.
- The first test was taken in **July 2021**.
- More tests are planned later this year.

- Fabrication, construction, commissioning.
- First **efficiency & recirculation** tests.
- Mock-up detector at **LNGS** check TPC **mechanical assembly** and **characterisation** of the **cryogenic system**.
- **Mockup TPC** will be installed in Summer **2024!**



Condenser system

Credit: P. Salomone



1 T cryostat



Condenser Heat Exchanger system



Heat Exchangers

**UAr cryogenics by Kevin Thieme**



Circulation Pump

Nitrogen Supply & Phase Separator

Valve Control Panel & Monitor

Cold Gas Ar

Cooling control loop

LAr lines

Test Cryostat

TPC Cryogenic system (test installation) at CERN



In-house fabrication of the gas handling system



Fully instrumented condenser system

Mockup at LNGS

# NUOVA OFFICINA ASSERGI (NOA)

- **ISO-6** clean room at LNGS completed in 2023
- Made for **large-area silicon photodetectors production** and part of the **detector assembly**.

- Start-up of activities, characterisation of **silicon wafers** procured for the in-house production of the **PhotoDetector Units (PDUs)**.

## Database to store information on production

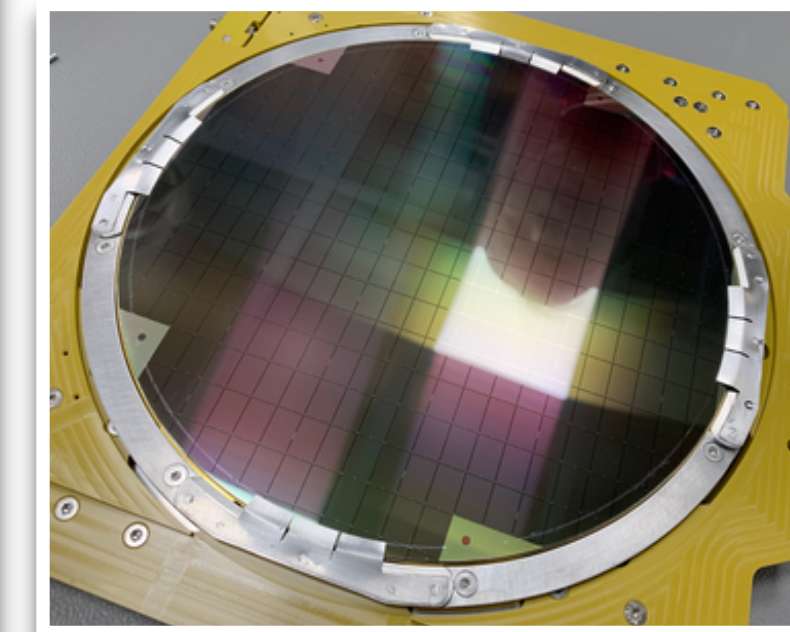
- **Software developed** to update database during production.
- Online webpage to **visualise database**.
- Status of different objects.
- Different test results.



## DarkSide-20K Database

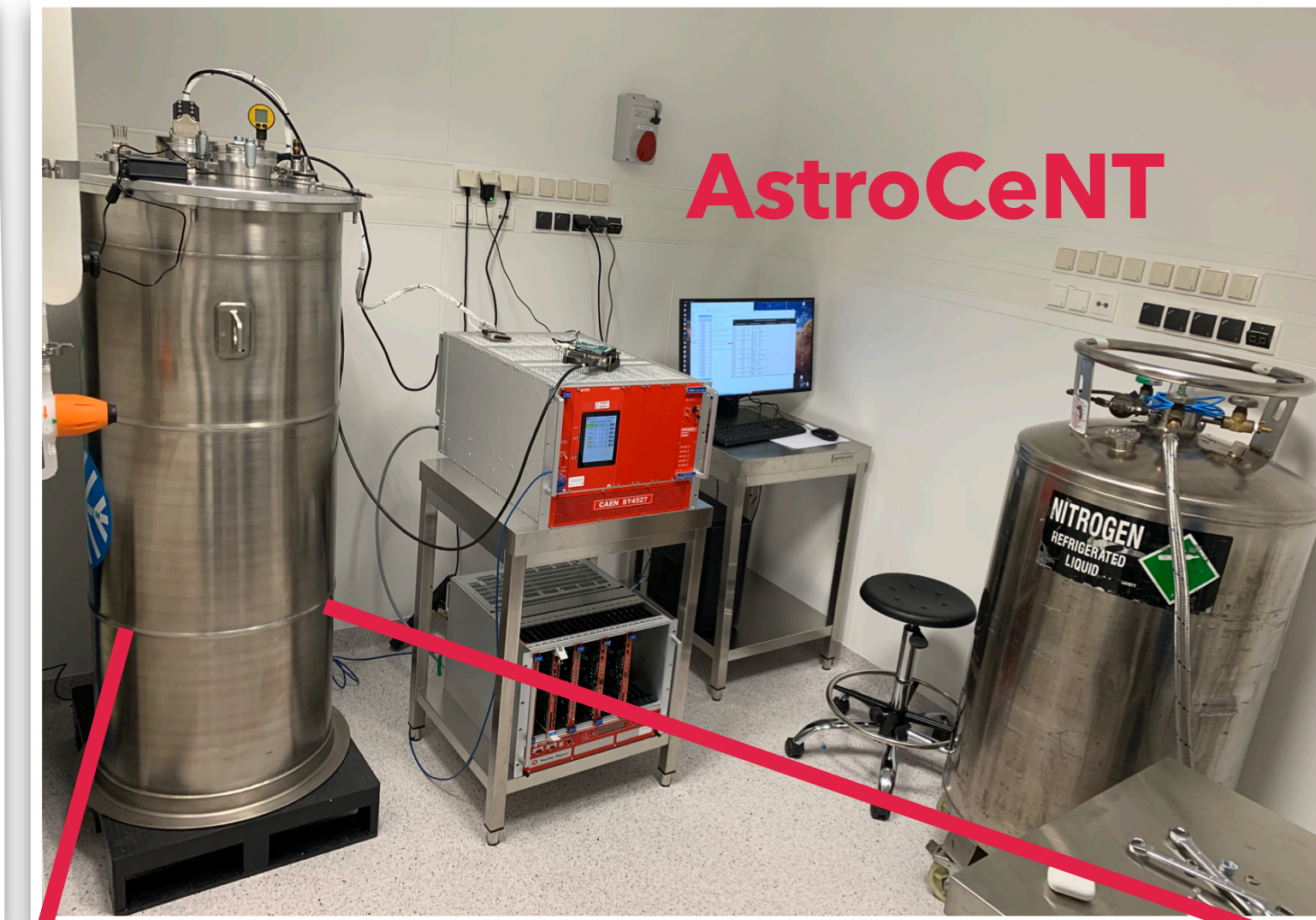
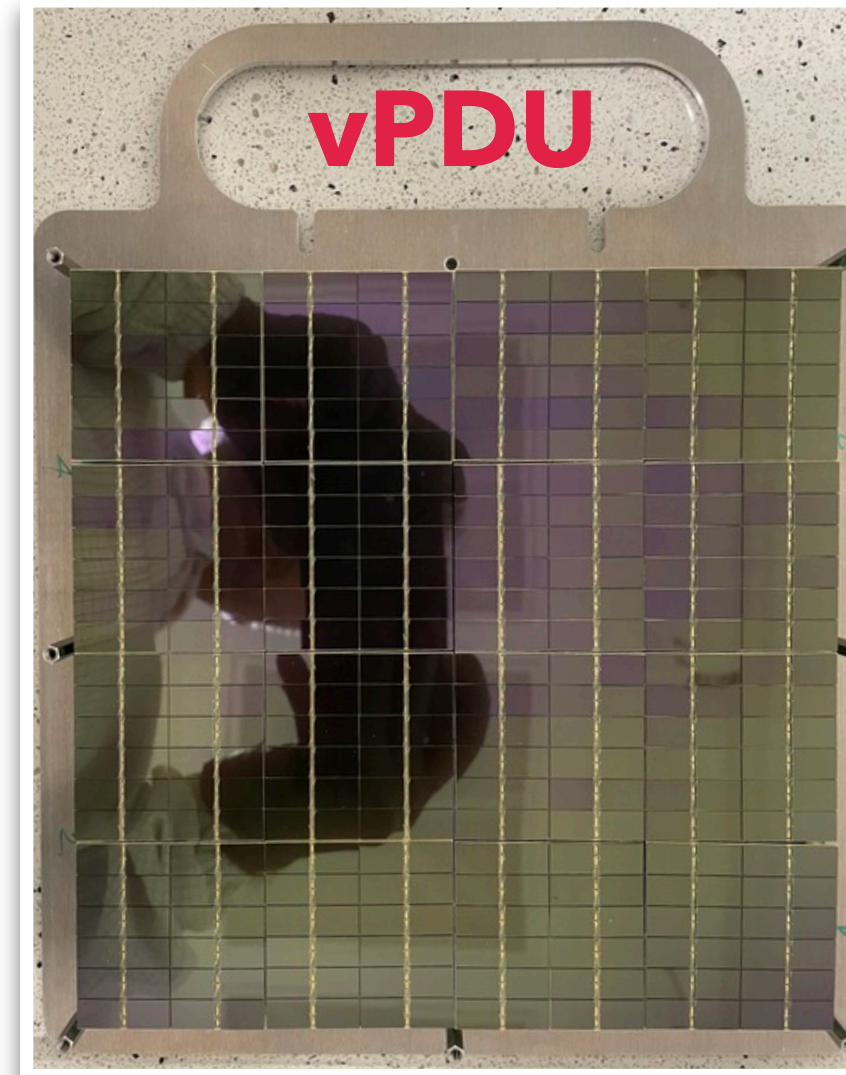
### Available apps

Extract data   Veto Production   TPC Production   Wafers

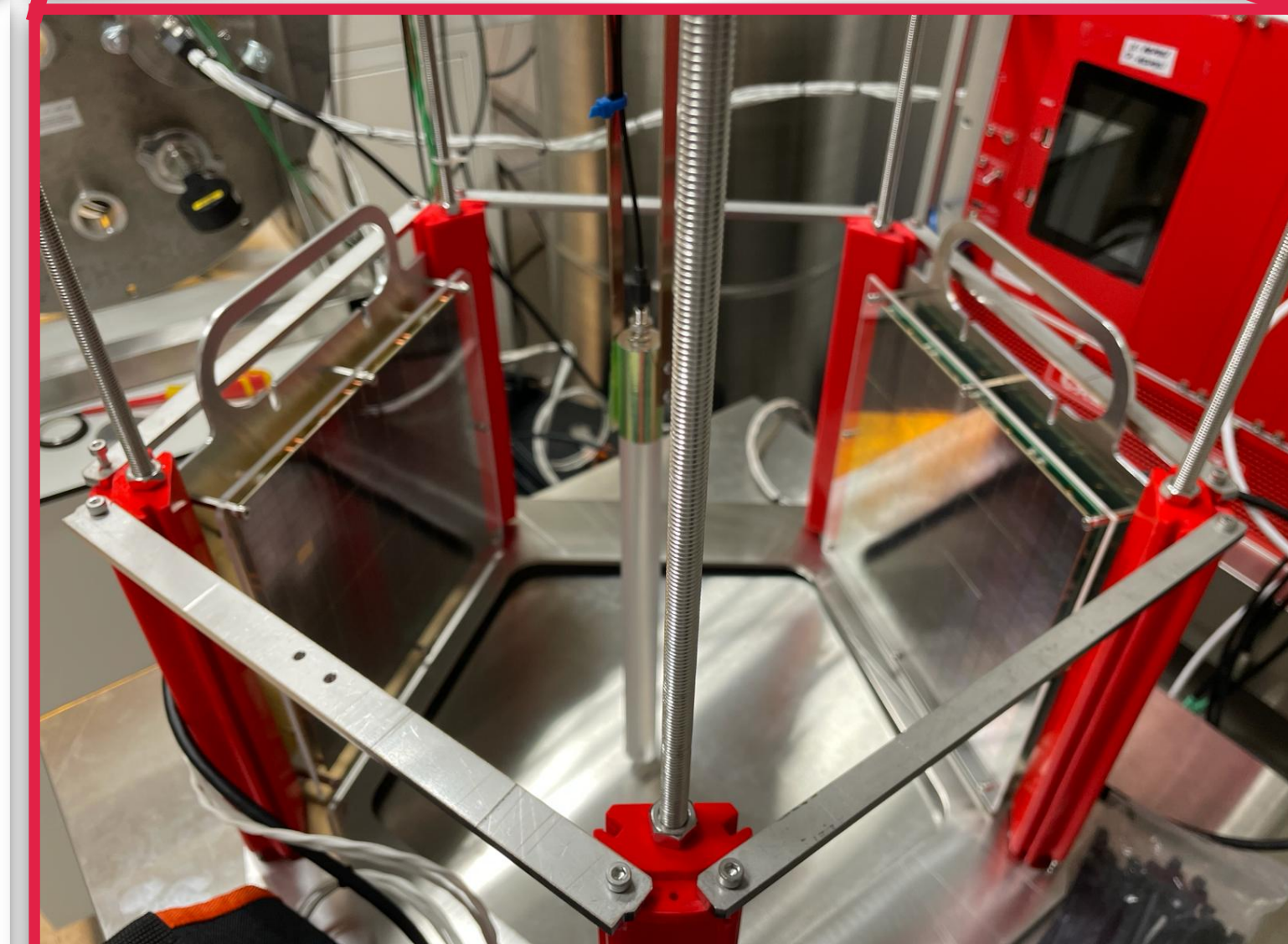


# VETO PDU FACILITIES

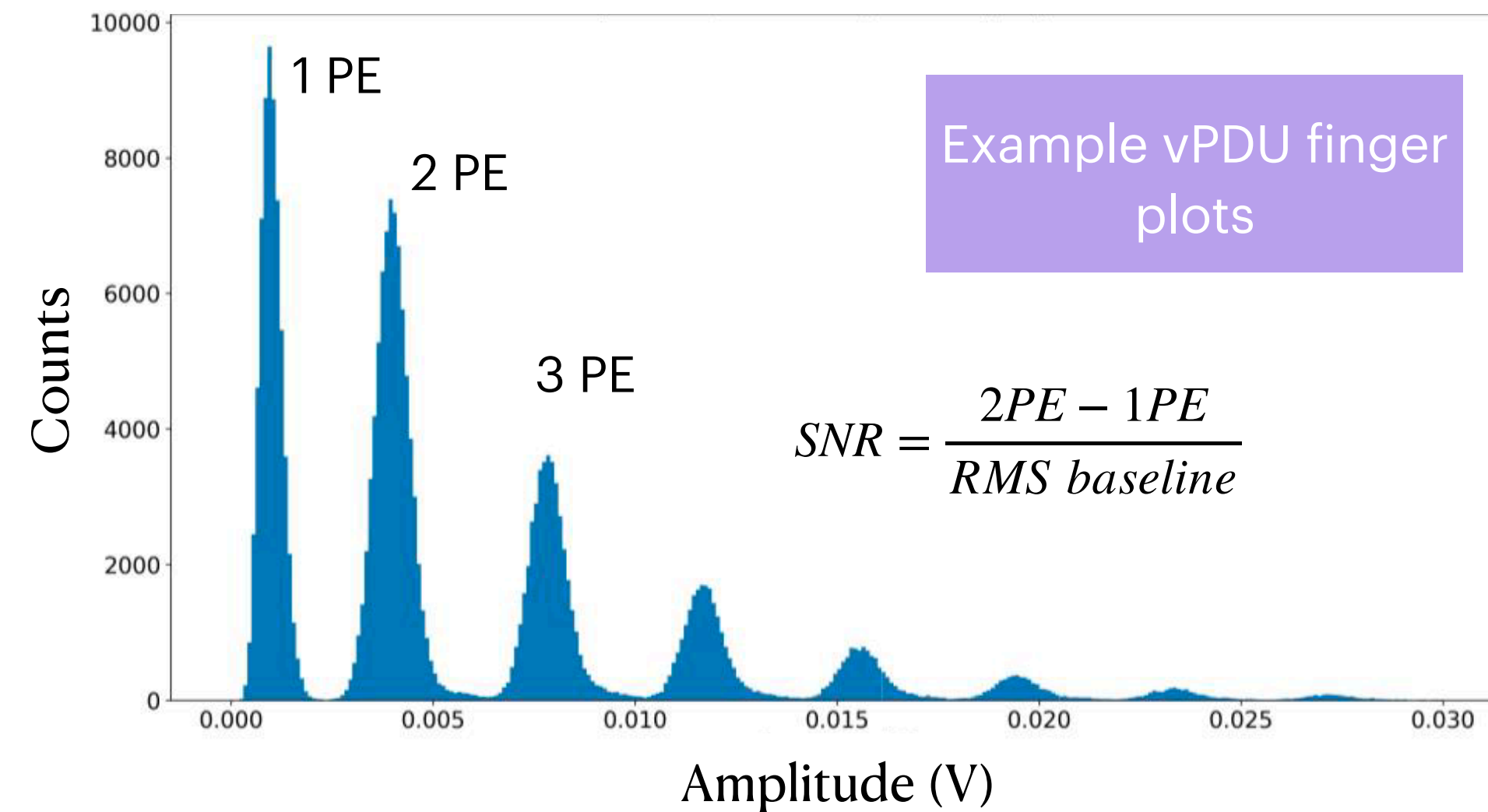
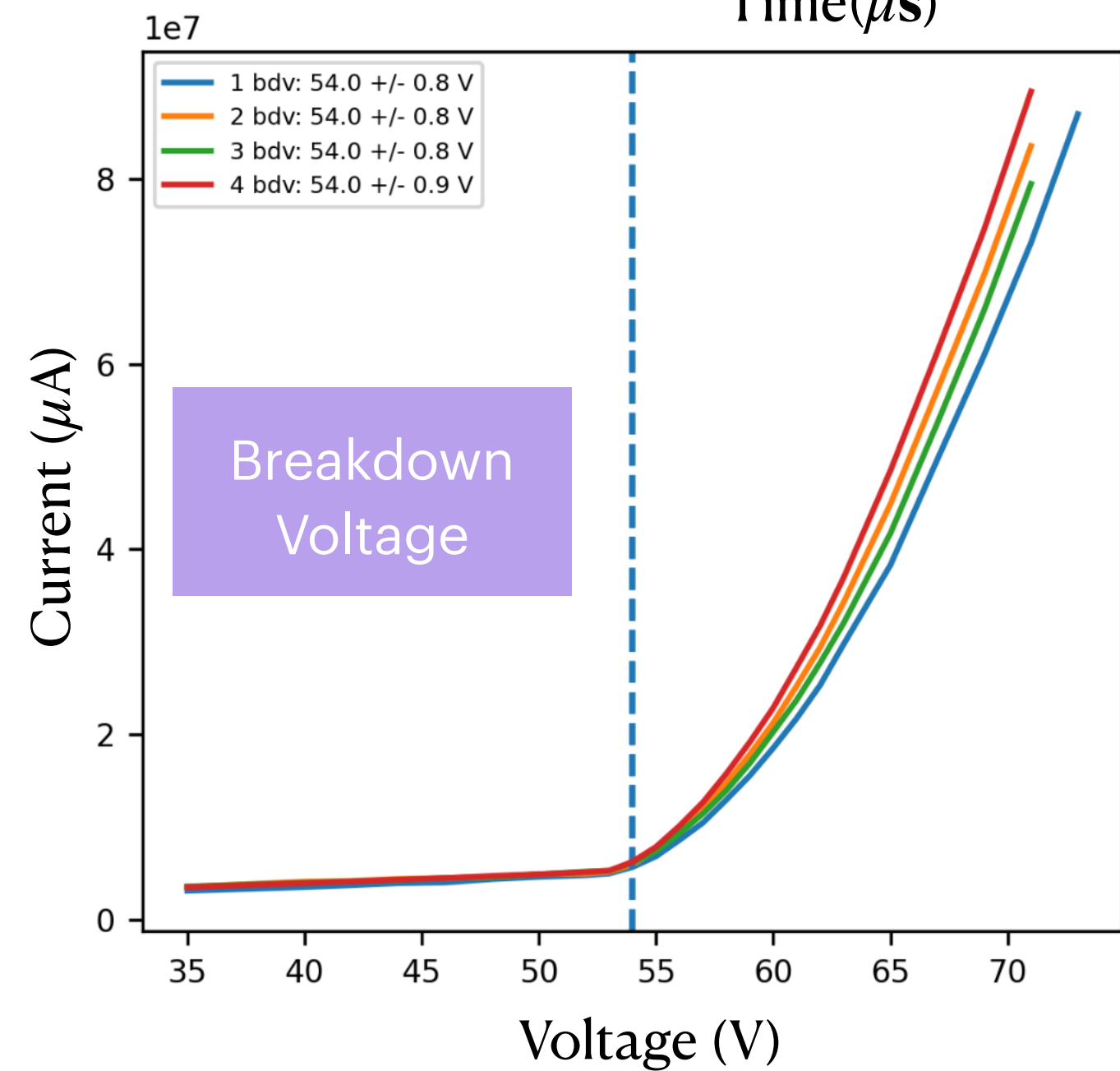
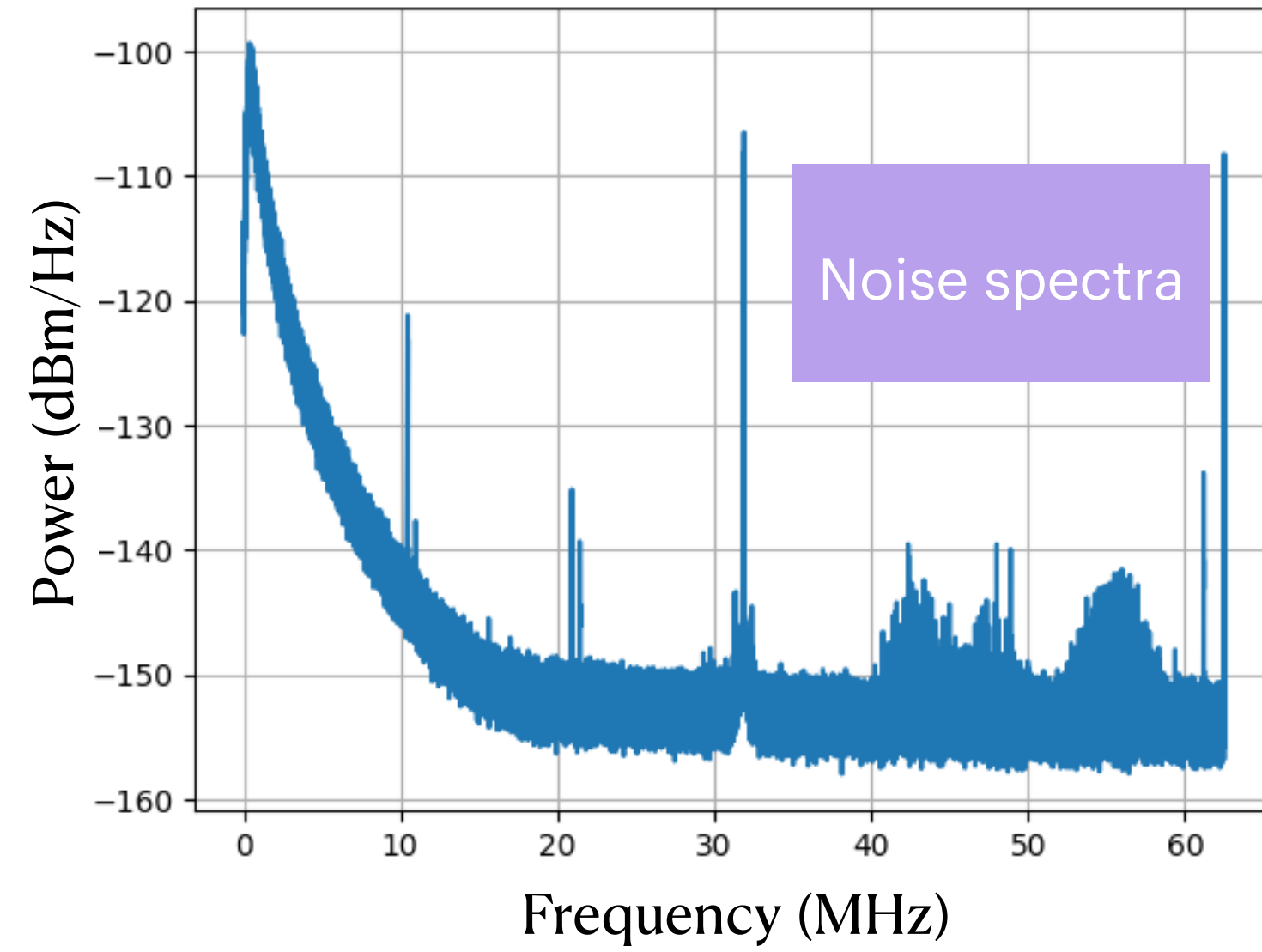
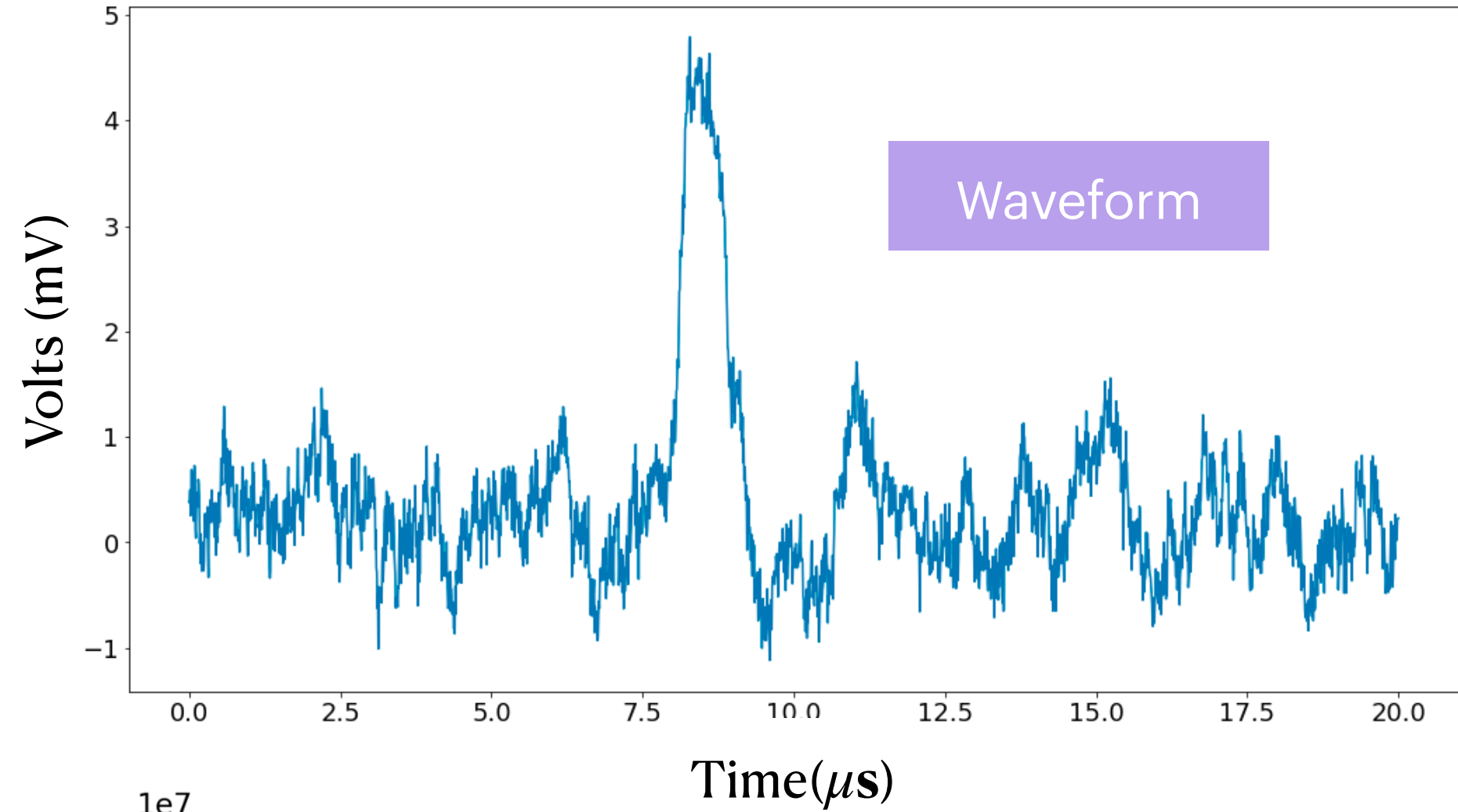
- ASIC amplifier designed by INFN Torino.
- **120** Veto Photon Detector Units (**vPDUs**).
- SiPM are produced by **NOA** and Production of vPDU is in **Birmingham, STFC interconnect, Manchester, and Liverpool.**
- Testing at 3 sites: **AstroCeNT, Edinburgh, and Liverpool.**
- All facilities are **ready** for production and testing.



PDU  
production  
by Paolo  
Salomone



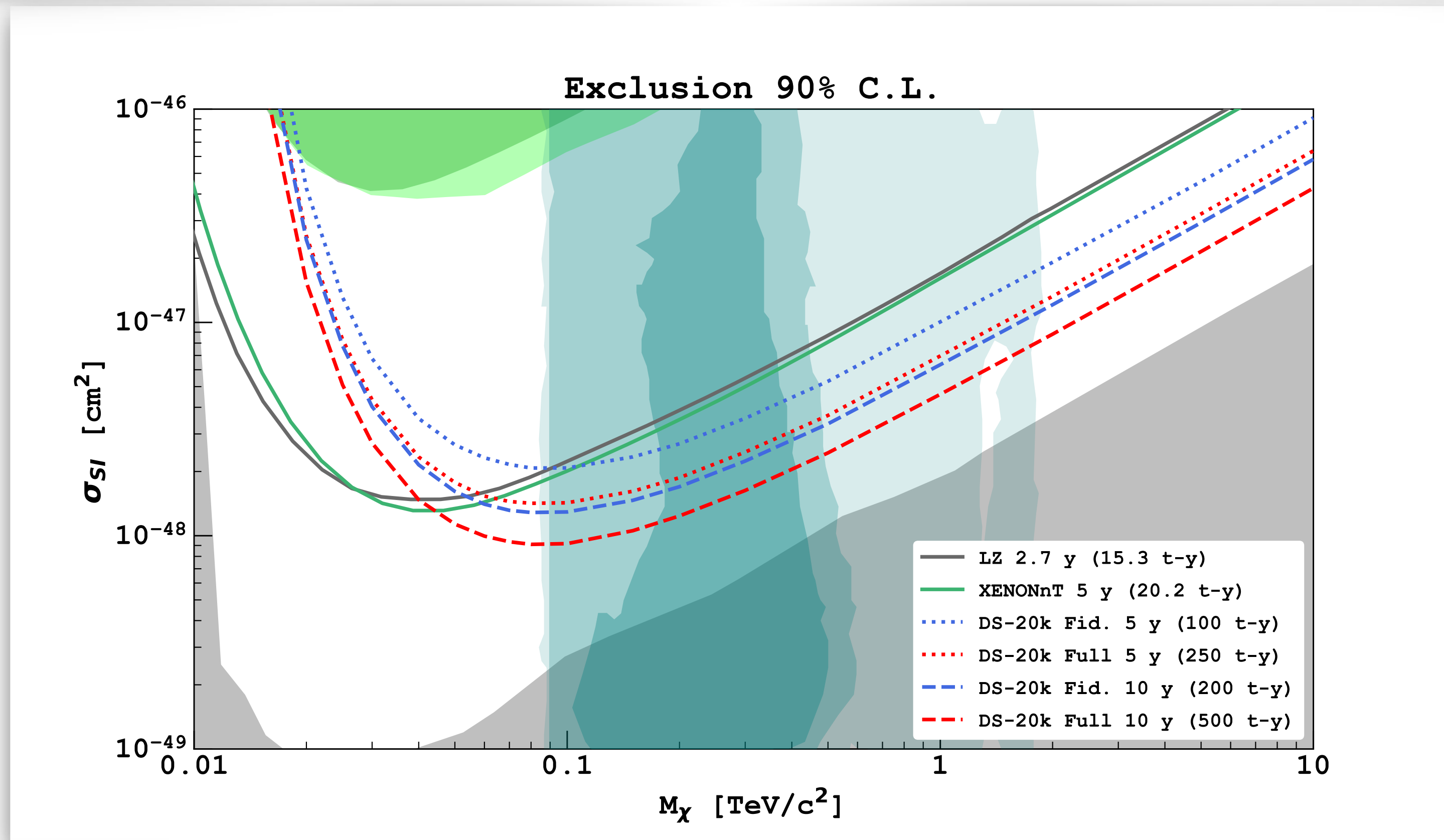
# VETO PDU FACILITIES (ANALYSIS)



- Quality control Criteria**
- SNR > 5
  - Distinct PE spectra
  - Nominal breakdown voltage ~55 V

# EXPECTED SENSITIVITY

The sensitivity of DS-20k to spin independent WIMPs for different lengths of runs, with the **full exposure** and with the **fiducial cuts** applied, compared to **LZ** and **XENONnT**.



Prospects for DarkSide-20k sensitivity to light dark matter particles by Marie van Uffelen (Thu-15:40 P3)

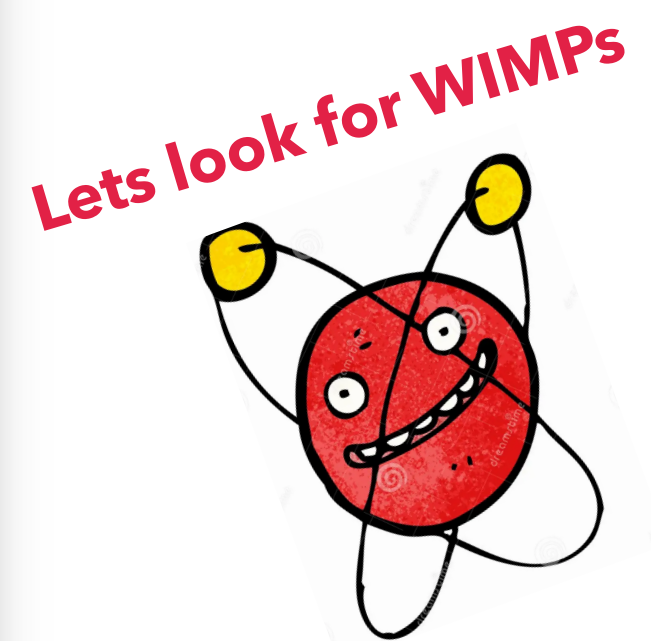
Boosted sub-GeV Dark Matter from Primordial Black Holes in DarkSide-50 (Wed-15:20 P1)

The present projection - based on a **10 yr run**, giving a fiducial volume exposure of **200 t yr** - is  **$6.3 \times 10^{-48}$  cm<sup>2</sup>** for **1 TeV/c<sup>2</sup>** WIMP for the 90% C.L. exclusion.



# SUMMARY AND OUTLOOK

- DarkSide-20k **photosensors** represent a real technical challenge and are a key point for the search of WIMPs.
- DarkSide-20k utilises many **state-of-the-art technologies**:
  - **Novel cryogenic large area SiPM arrays**
  - **Underground Ar**
  - **PMMA**
- The PDU will be produced at **NOA**. Right now still on **preproduction phase**.
- Procedures for **production and test** of PDUs are in place.
- DarkSide-20k will start data taking in the end of **2026 for 10 years**.
- A joint effort from all the **collaboration**.



# Thank you

Photo-  
electronics  
by Andrea  
Marasciulli

 Low-radioactivity argon for dark matter searches and beyond by R. Stefanizzi (Mon-17:50 P1)

UAr  
cryogenics  
by Kevin  
Thieme

 Status and short term prospects of DArT, the Underground Ar measurement at Canfranc by V. Pesudo (Mon-18:10 P1)

 Boosted sub-GeV Dark Matter from Primordial Black Holes in DarkSide-50 by R. Calabrese (Wed-15:20 P1)

PDU  
production  
by Paolo  
Salomone

 Prospects for DarkSide-20k sensitivity to light dark matter particles by M. Van Uffelen (Thu-15:40 P3)

 Material assay campaign of the DarkSide-20k experiment by R. Santorelli (Thu-17:30 P1)

 Characterisation of Low-Energy Argon Recoils with RED and RED+ by L. Pandola (Thu-17:50 P1)

ReD with  
ML by  
Noemi  
Pino

 Status of the DEAP-3600 experiment by P. Adhikari (Mon-16:30 P1)

