European Funds
Republic of Poland
FNP Foundation for Polish Science
European Union
NATIONAL SCIENCE CENTRE POLAND

The DarkSide-20k Experiment

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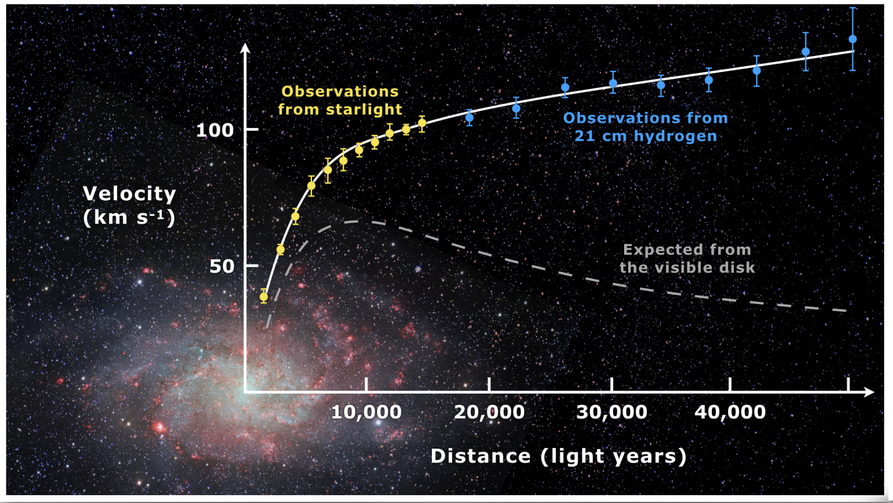
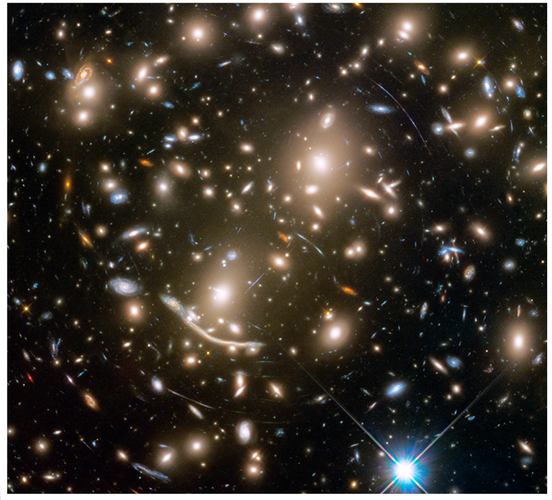
AstroCeNT, Warsaw

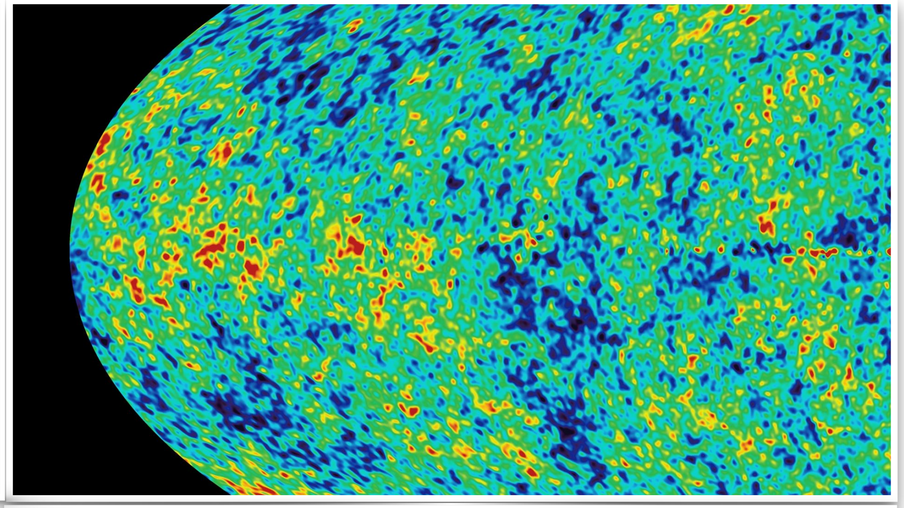
On behalf of the DarkSide-20k Collaboration
IDM-2024 workshop, L'Aquila

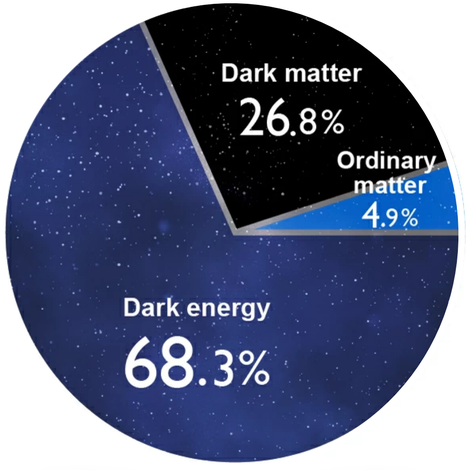
ASTROCENT
NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES
DARKSIDE

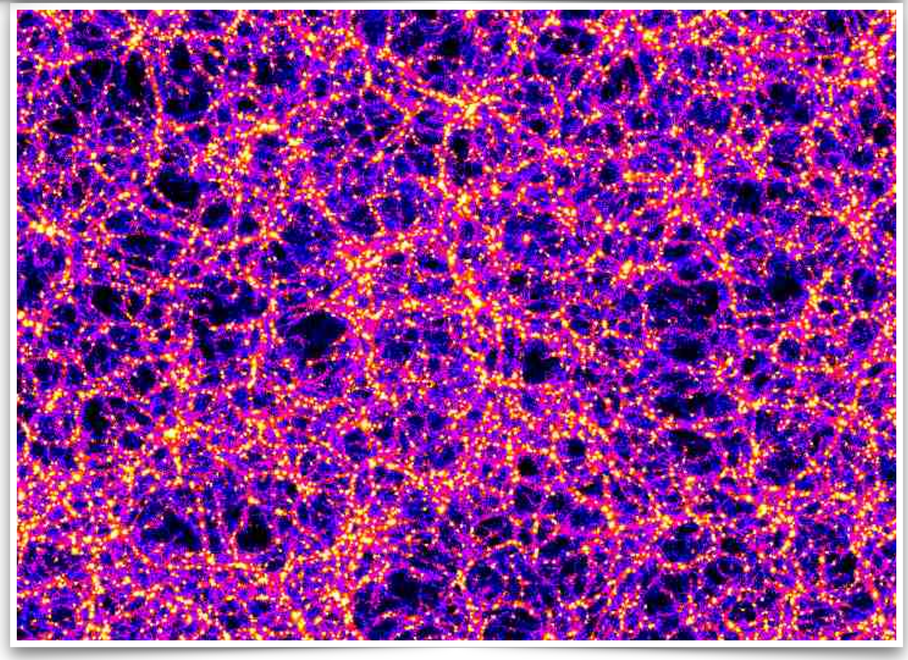
EVIDENCES FOR DARK MATTER





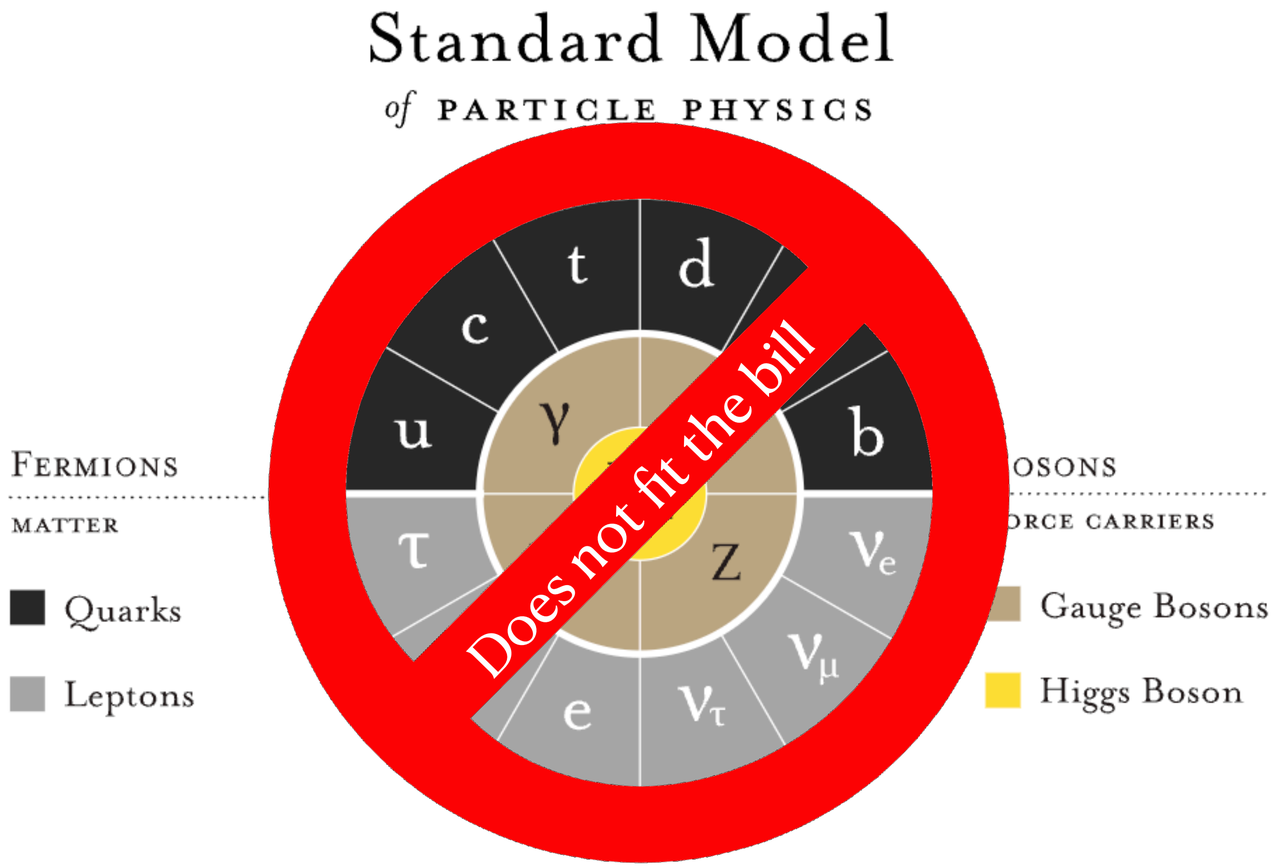






PROPERTIES OF DARK MATTER

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

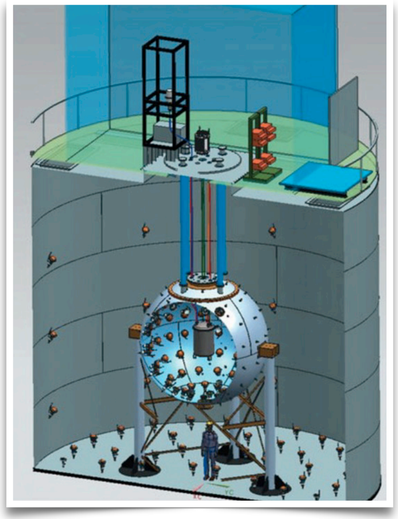


New Physics Beyond Standard Model!!

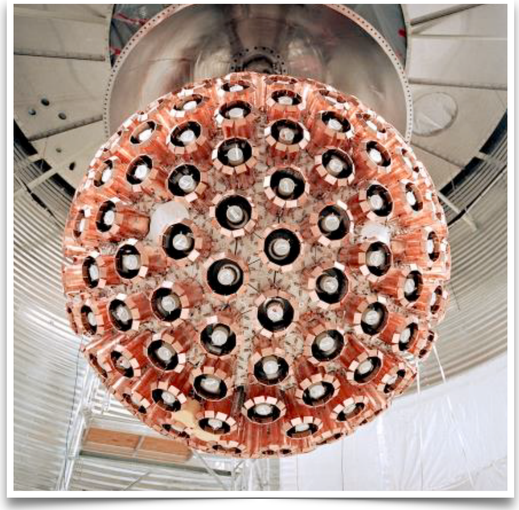
One of the candidates is WIMPs.

THE GLOBAL ARGON DARK MATTER COLLABORATION

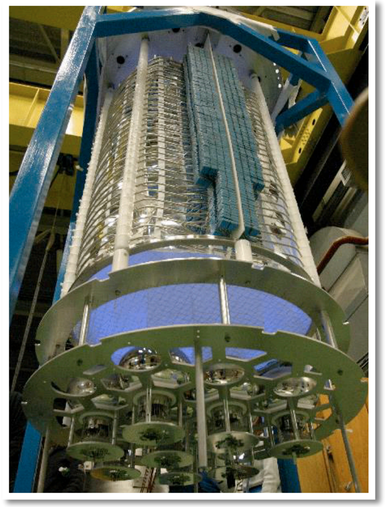
MiniCLEAN @Snolab



DarkSide-50 @LNGS



DEAP @Snolab



ArDM @Canfranc

GOAL

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

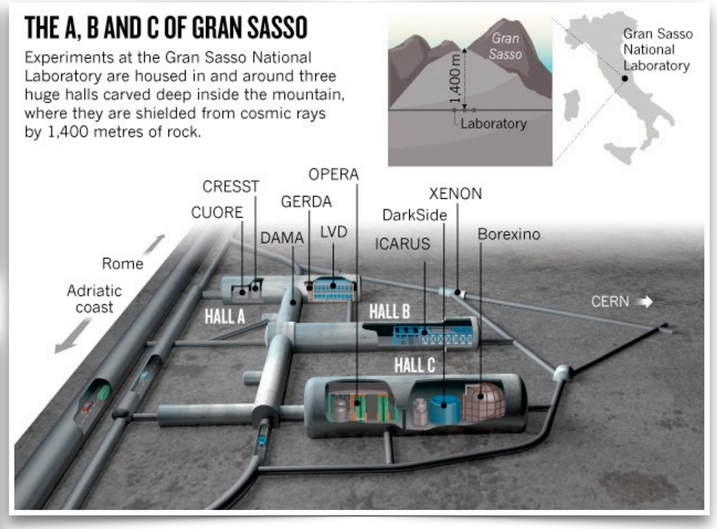
DARKSIDE-20K EXPERIMENT

DarkSide-20k:

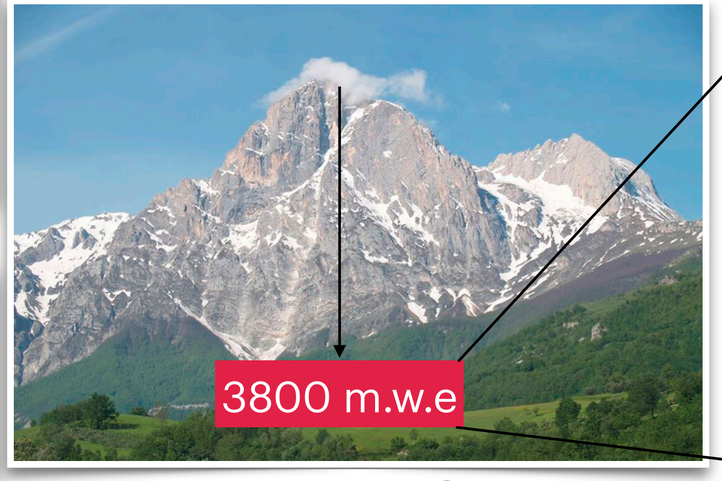
- LAr dual-phase TPC experiment designed to detect WIMP scattering interactions from the dark matter halo.
- Commissioning expected by the end of **2026**.

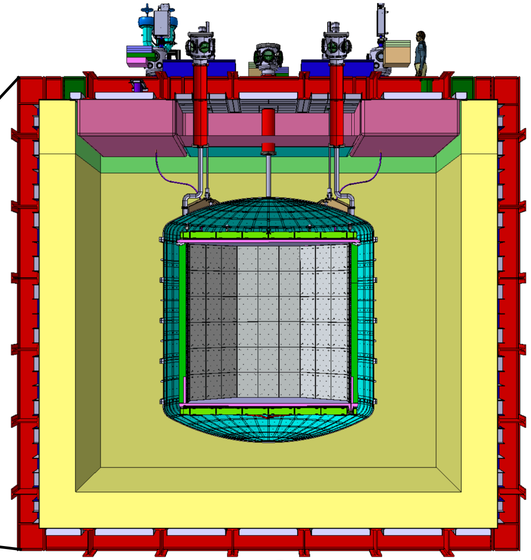
- Located at LNGS (Italy), **1400m** underground.
- μ flux reduction by **10^6**.
- TPC circumscribed by acrylic panels (**PMMA**).
- Utilises Underground Argon (**UAr).**
- Light Readout: large array of cryogenic low-noise **SiPMs**.
- Sensitivity to WIMP-nucleon cross sections of ~10^{-24} barns @mass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

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



12-June-2024



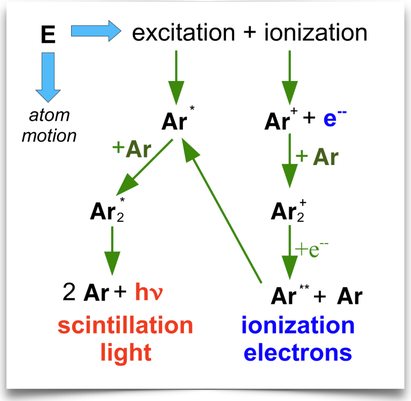


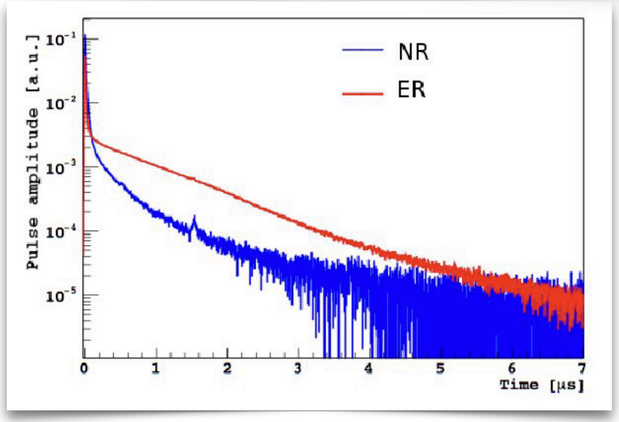
DarkSide-20k under construction at LNGS.

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**)

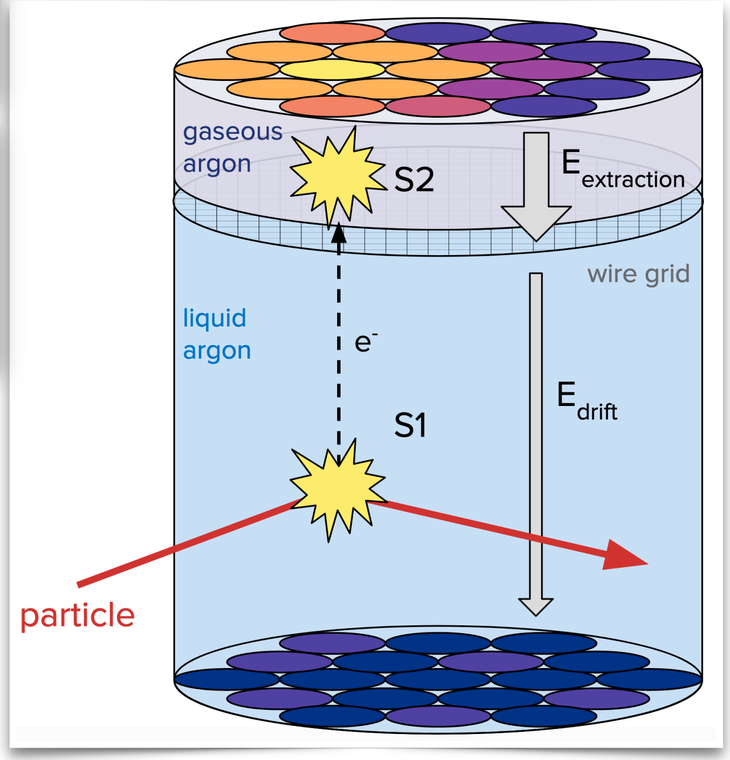
S1: primary scintillation in LAr (energy information and pulse shape discrimination)
S2: secondary scintillation from electroluminescence of electrons in gas pocket (energy information and position reconstruction)



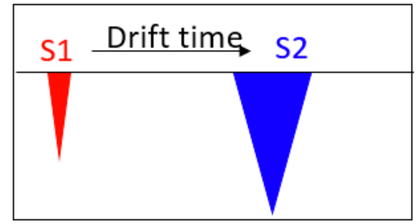


F90: fraction of light detected in the first 90 ns. (Singlet ~7 ns ; Triplet ~1.5 μs)

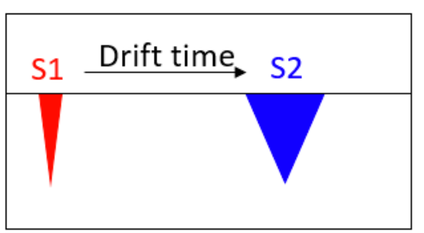
- **S2/S1 ratio** and **PSD**
- WIMPs generates nuclear recoils (NRs)



γ background: electron recoil (ER)

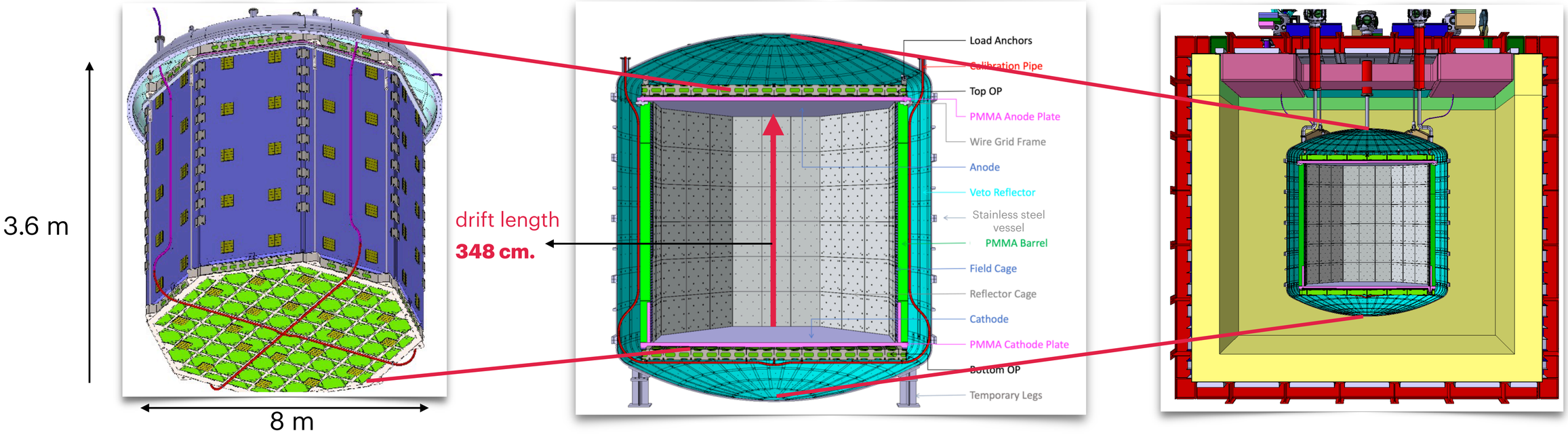


Dark matter: nuclear recoil (NR)



$(S2/S1)_{NR} << (S2/S1)_{ER}$

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 **21m² (top + bottom).**

Neutron Veto:

- Active UAr mass: **32 tons.**
- Equipped with **120 vPDUs** covering **5m².**
- **40 cm** space between the stainless-steel vessel and PMMA.
- Covered with **WLS and ESR reflectors**.

Outer cosmic Veto:

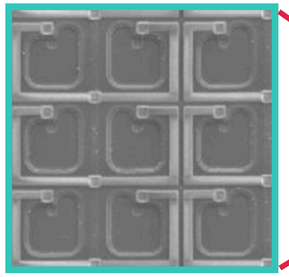
- Active Atmospheric Argon (**AAr)** mass: **650 tons.**
- Membrane "**ProtoDUNE-like**" cryostat **8x8x8 m³**.
- Outer veto will consist of **SiPM arrays** near the cryostat walls.

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

LARGE AREA CRYOGENIC SIPM LIGHT DETECTORS

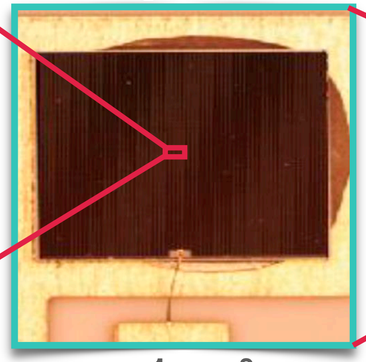
4 PDMs are summed and read as a single channel.
Largest SiPM array!

SPAD



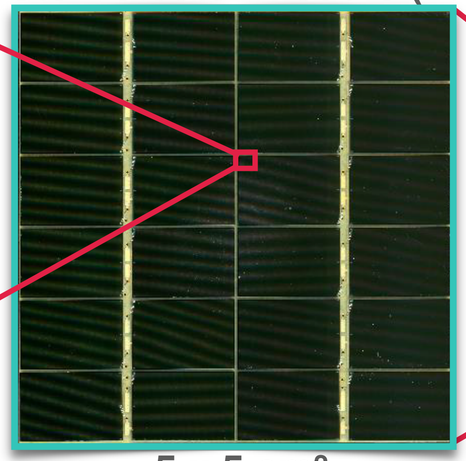
~25-30 μm²

SiPM



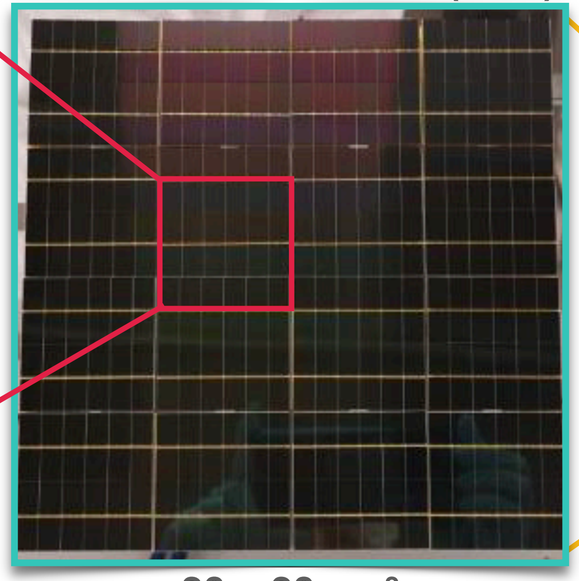
~ 1 cm²
94.900 SPADs

Photo Detector Module (PDM)



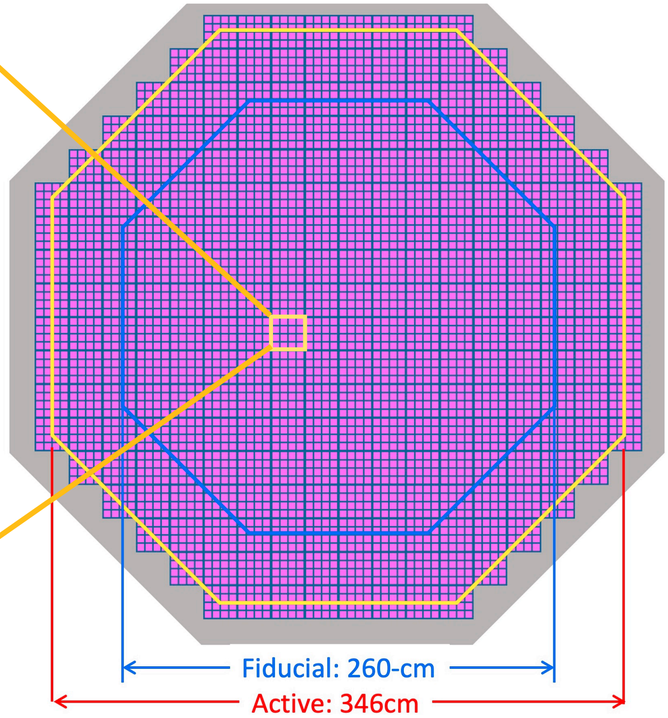
5 x 5 cm²
24 SiPMs

Photo Detector unit (PDU)



20 x 20 cm²
PDU of 16 PDMs

TPC optical plane



~21 m²
528 PDUs

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/mm² at 77K (7 VoV)**
- **Timing resolution ~ 10 ns**
- **SNR>8 for 10x10cm²**

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

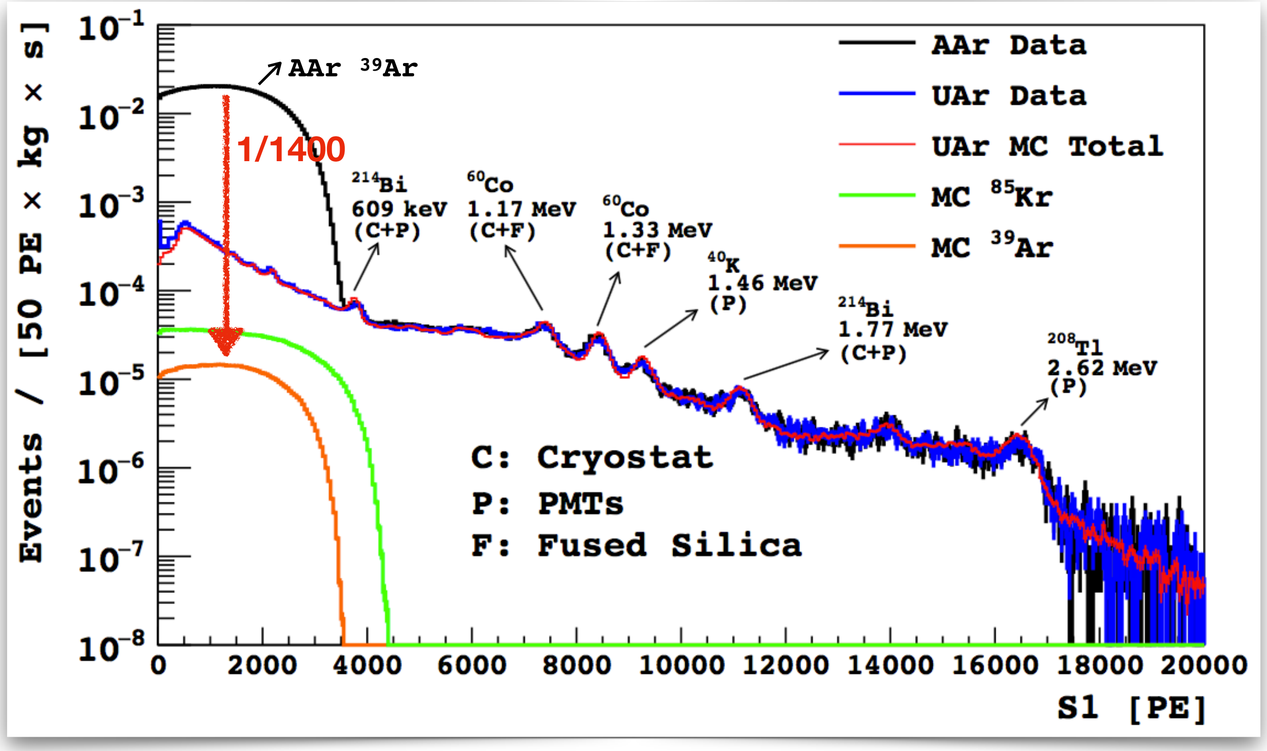
- SiPM testing and assembling facility at **NOA (Nuova officina Assergi).**

UNDERGROUND ARGON

β & γ Rejection

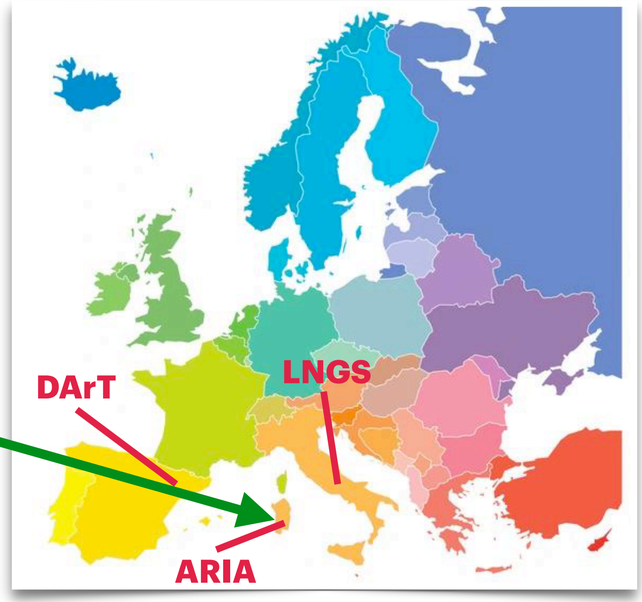
- **Intrinsic ^{39}Ar** radioactivity in atmospheric argon is the primary background for argon-based detectors.
- ^{39}Ar activity sets the dark matter detection threshold at **low energies** (where PSD is less effective).

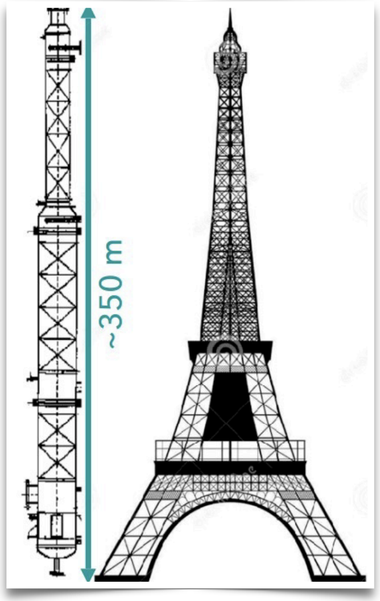
- ^{39}Ar is a cosmogenic isotope, and the activity in argon from underground sources can be significantly lower compared to AAr.
- ^{39}Ar activity in **AAr:1 Bq/kg** while for **UAr: 0.73 mBq/kg**
- **157 kg** of UAr deployed in DarkSide-50 in 2015.
- ^{39}Ar reduction factor of **~1400!**

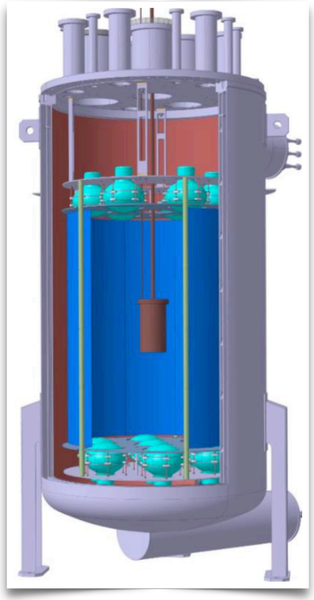


Low-radioactivity argon for dark matter searches and beyond by R. Stefanizzi (Mon-17:50 P1)

EXTRACTION 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):

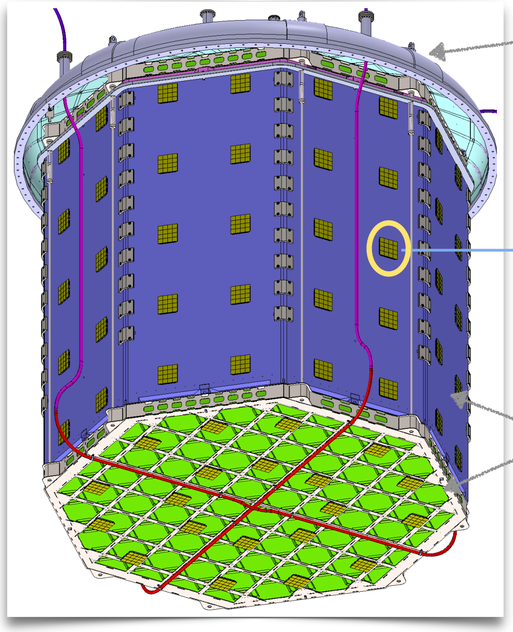
- A **~350m** tall column in the Seruci mine in Sardinia, Italy, for **high-volume chemical (for DS-20k)** and isotopic purification of UAr (not used for DS-20k).
- **A factor 10 reduction of ^{39}Ar** per pass is expected with ~10 kg/day.

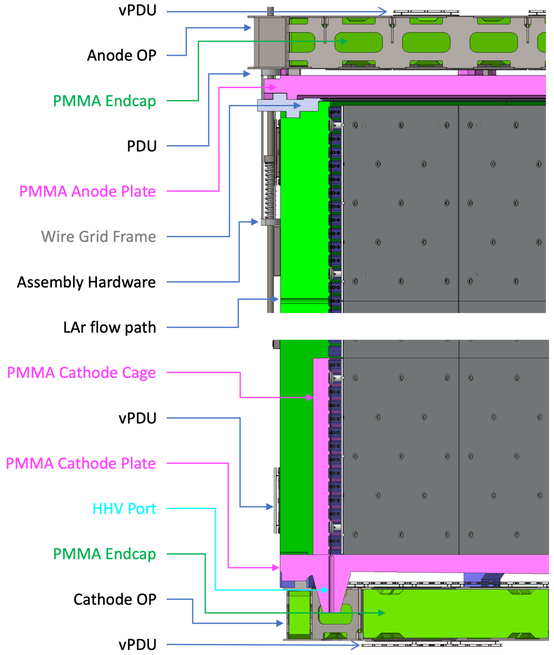
DArT (assay):

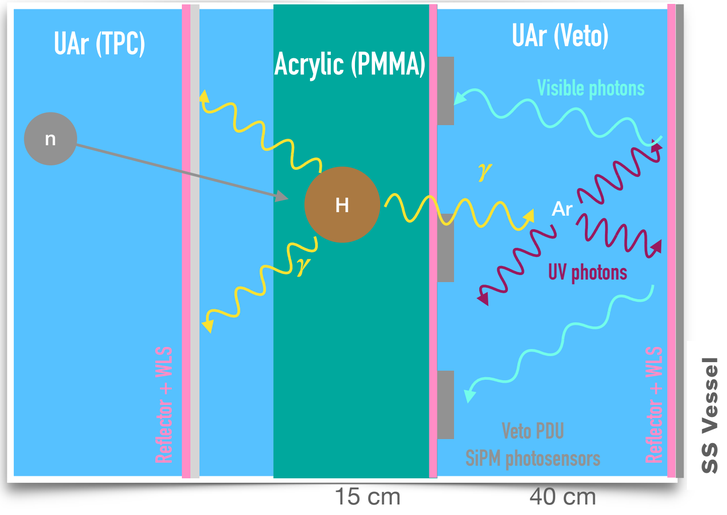
- A single phase low-background detector to measure the ^{39}Ar depletion factor of different UAr batches.
- Located in **ArDM experiment** at Canfranc lab, **~2500 m.w.e.**

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

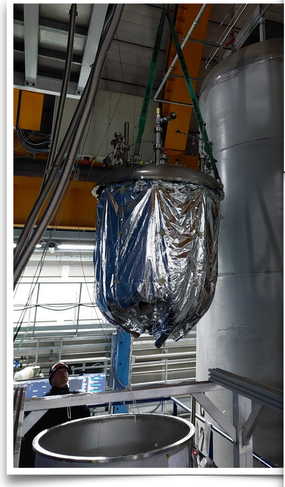
- Neutrons are moderated in the acrylic shell and then captured by **Hydrogen**.
- H emits γ-rays **2.2 MeV.**
- γ-rays interact in the liquid argon buffers.
- LAr scintillation light is wavelength shifted and detected by **~1920 SiPM-based photosensors**.

CRYOGENIC SYSTEM FOR TPC

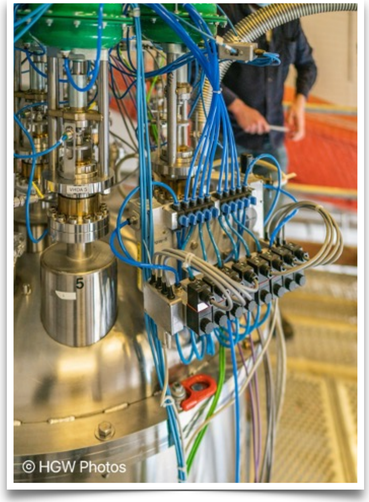
- Integrated test of the **UAr cryogenics** is ongoing at **CERN**.
- Up to **10 kW** (latent heat + heat exchanging) adjustable condenser box.
- **1000 SLM** circulation speed with two homemade pumps in parallel.
- The first test was taken in **July 2021**.
- More tests are planned later this year.

- 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!**

Credit: P. Salomone



In-house fabrication of the gas handling system



Fully instrumented condenser system

UAr cryogenics by Kevin Thieme

TPC Cryogenic system (test installation) at CERN

Mockup at LNGS

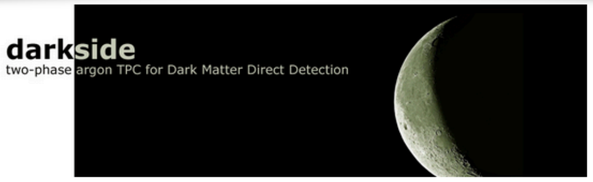
NUOVA OFFICINA ASSERGI (NOA)

- **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

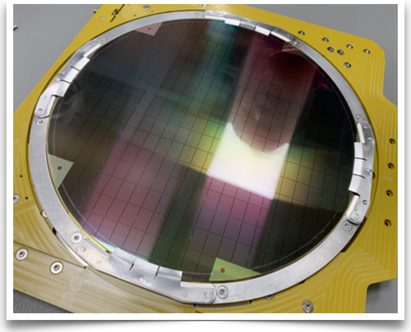
Available apps

Extract data | Veto Production | TPC Production | Wafers


Cryoprobe


Flip Chip Bonder


HESSE
WIRE BONDER

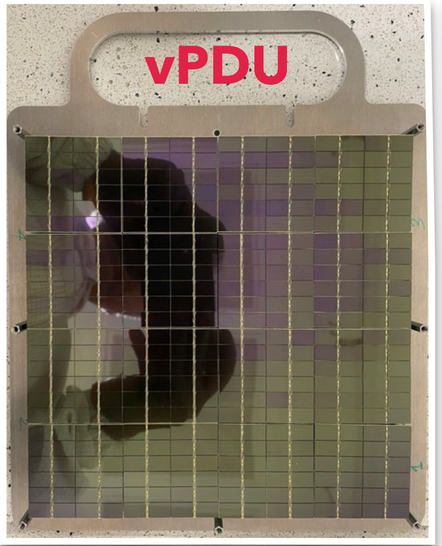

Wafer

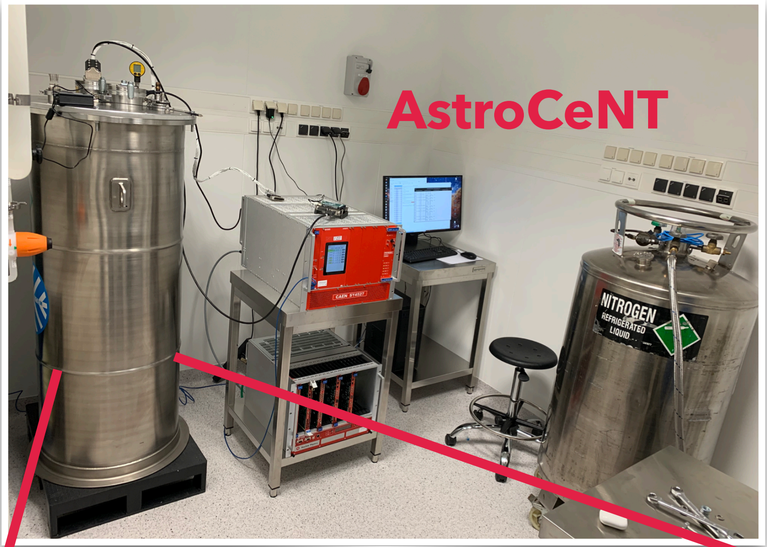

ADT 7122 DICER

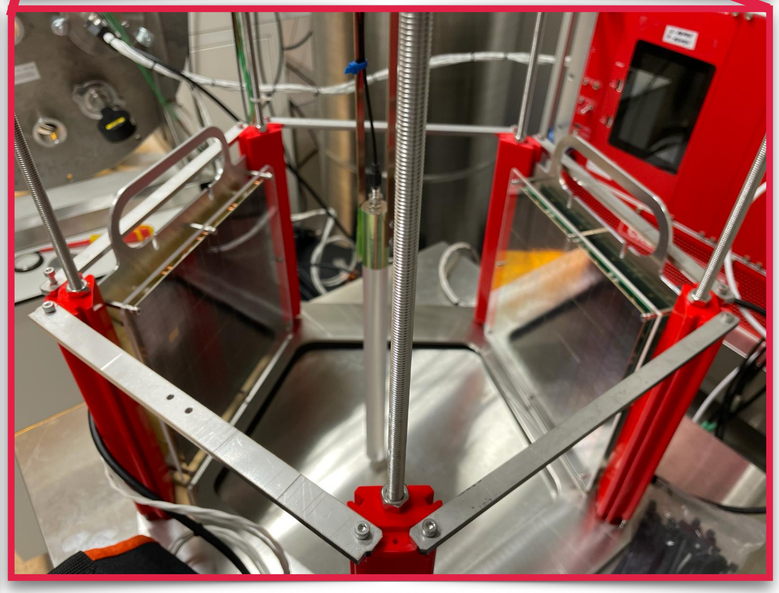
VETO PDU FACILITIES

- 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.

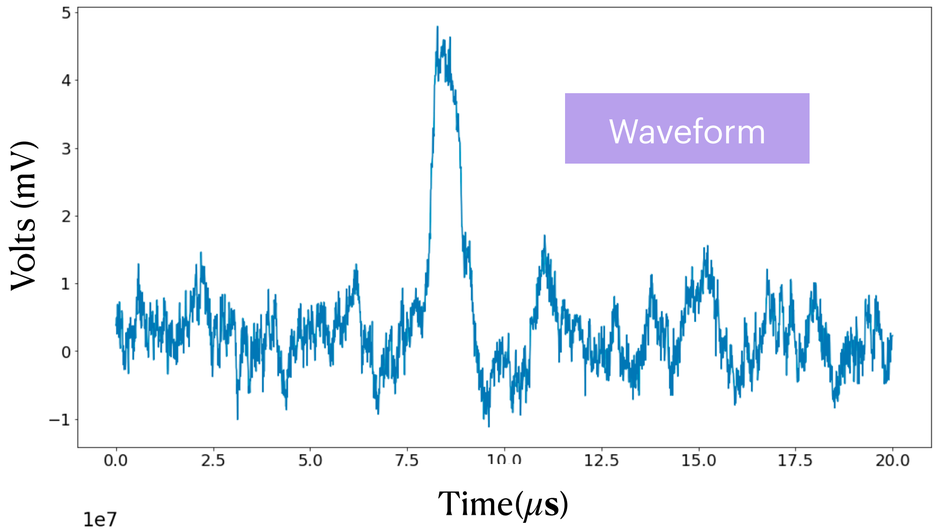
PDU production by Paolo Salomone

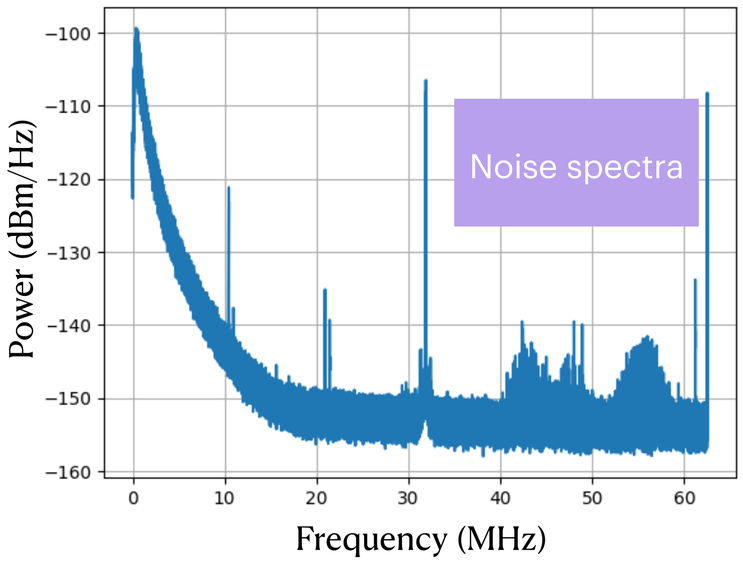


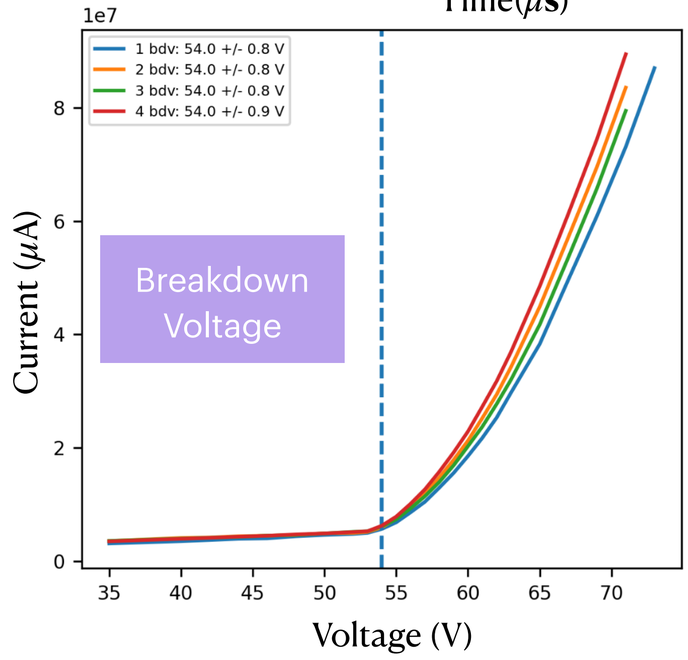


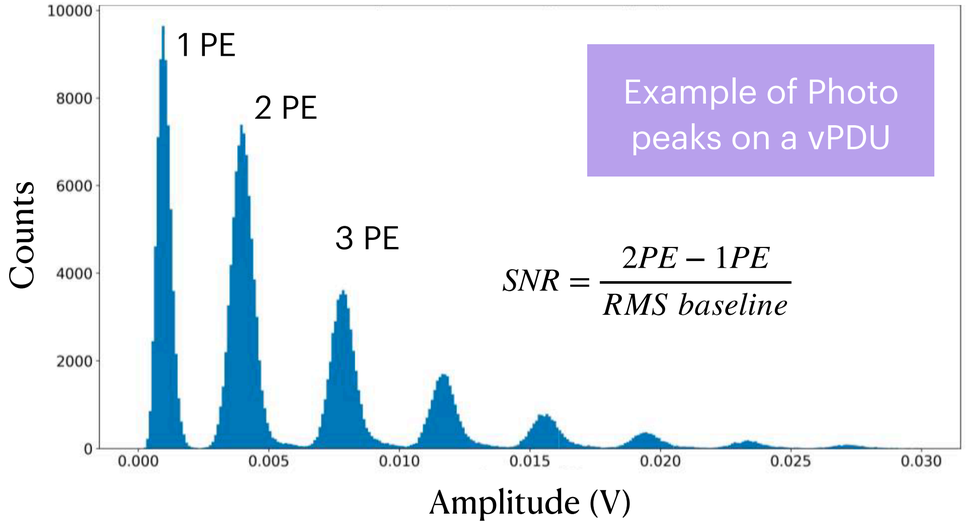


VETO PDU FACILITIES (ANALYSIS)







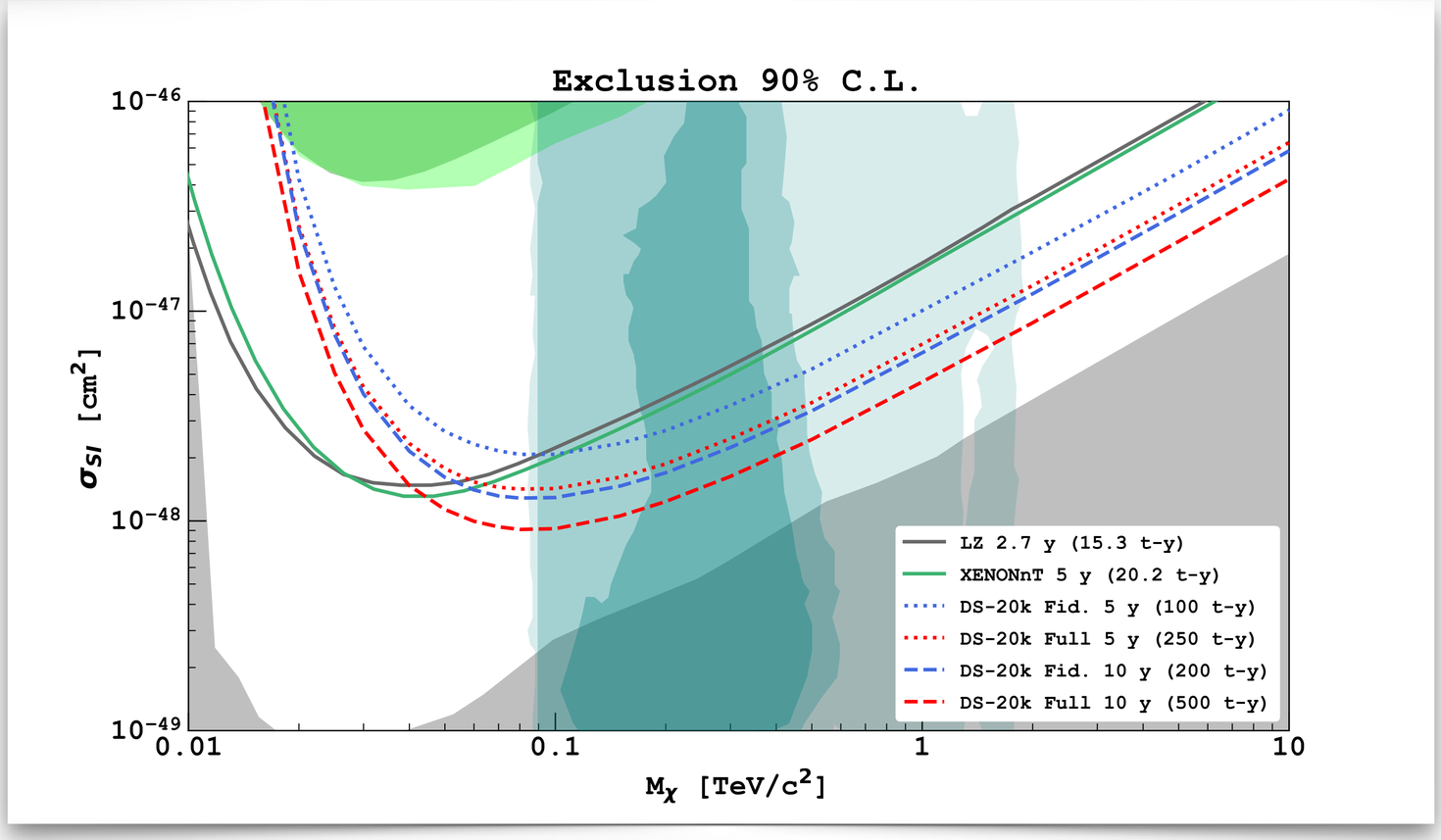


Quality control Criteria

- **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**.



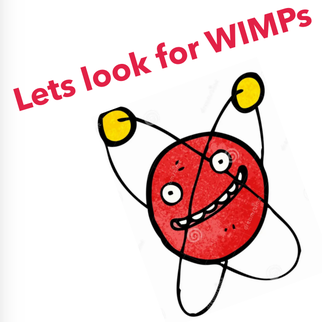
Prospects for DarkSide-20k sensitivity to light dark matter particles by Marie van Uffelen (Thu-15:40 P3)

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 x 10^{-48} cm^2 for 1 TeV/c^2** 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

- Low-radioactivity argon for dark matter searches and beyond by R. Stefanizzi (Mon-17:50 P1)
- 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)
- 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)
- Status of the DEAP-3600 experiment by P. Adhikari (Mon-16:30 P1)

Photo-electronics by Andrea Marasciulli

UAr cryogenics by Kevin Thieme

PDU production by Paolo Salomone

ReD with ML by Noemi Pino