TAUP XICHANG

TAUP 2025

19TH INTERNATIONAL CONFERENCE ON TOPICS IN ASTROPARTICLE AND UNDERGROUND PHYSICS

THE DARKSIDE-20K EXPERIMENT AT LNGS STATUS AND GOALS

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On behalf of the

DarkSide-20k Collaboration

XICHANG,
SICHUAN, CHINA 2025.8.24 - 8.30

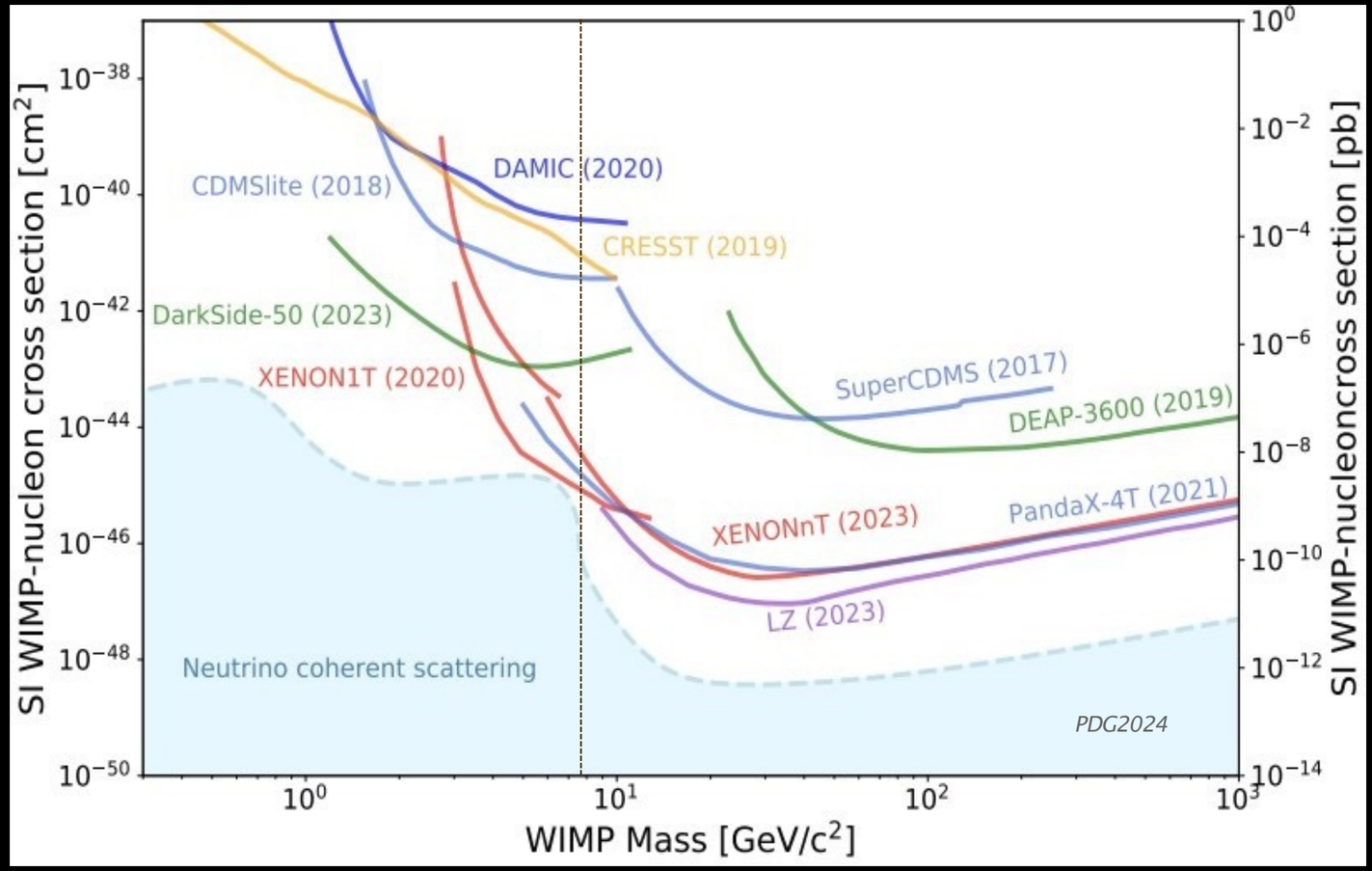
WIMP DIRECT DETECTION

High mass (above 10 GeV) searches sensitivity currently dominated by liquid xenon TPCs

A large liquid argon experiment is needed in case of discovery to confirm/disconfirm it, but also in general to validate this very important search with a different target.

Different backgrounds rejection techniques

The low mass region is very promising for double-phase liquid argon experiments, and it leads to the world's best sensitivities



ARGON AND TIME PROJECTION CHAMBER (TPC)

Why Argon?

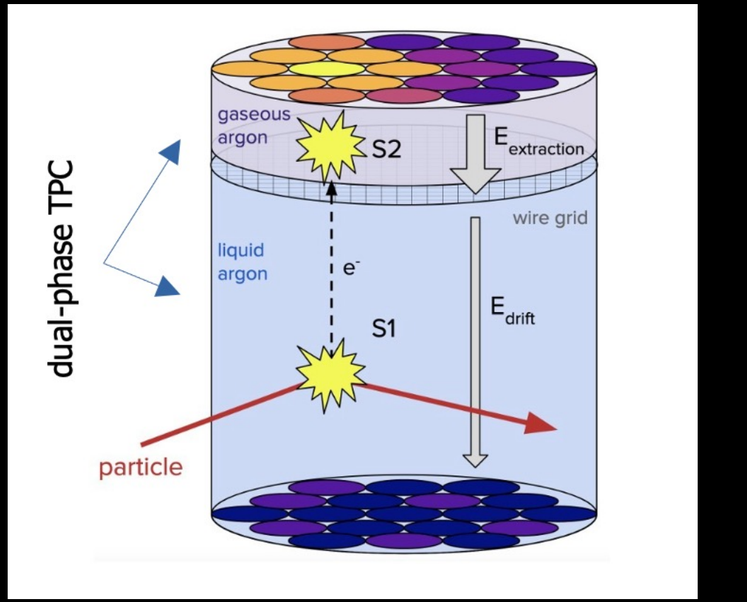
High scintillation and ionization yield, transparency to its scintillation light, dense, can be purified to a high degree

Powerful discrimination against electron recoil background via pulse shape studies

Two de-excitation times:
Singlet **~7** ns Triplet **~1500 n**s

Nuclear recoil (NR): ~2/3 probability to populate singlet state

Electron recoil (ER): ~2/3 probability to populate the triplet state



S1: primary scintillation in LAr (energy information, pulse shape discrimination and position reconstruction)

S2: secondary scintillation from electroluminescence of electrons in gaseous Ar (energy information and position reconstruction)

Neutrons and α induce NRs while **β and γ** induce ERs

WIMPs induce NRs

PSD cut reduces 200M e-recoil background events to 0.1 in 5y above 30keV

DARKSIDE-50

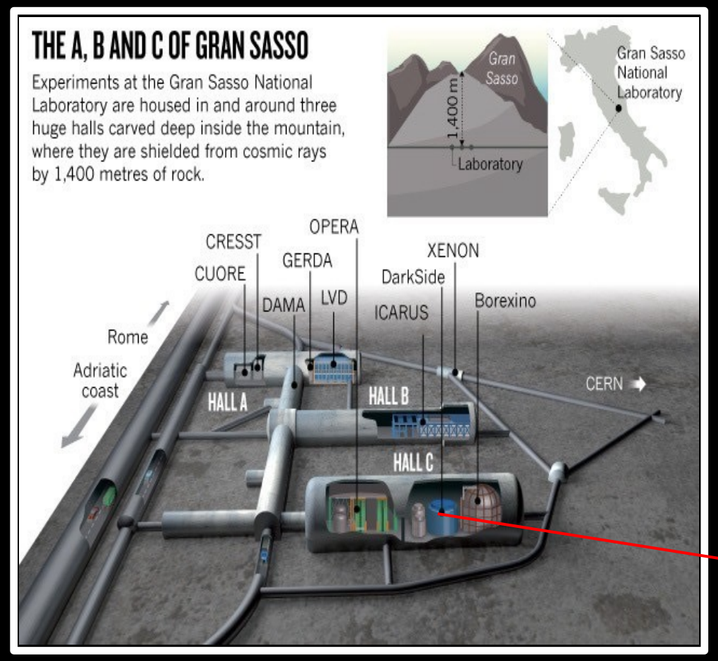
2013-2021 @LNGS

Still, world-leading WIMP search result in the mass range 1 to 4 GeV/c^2

Eur.Phys.J.C 83 (2023) 322,
Phys.Rev.D 107 (2023) 6,

Updated result is going to be presented by M. Wada on Wednesday and L. Pandola on Thursday

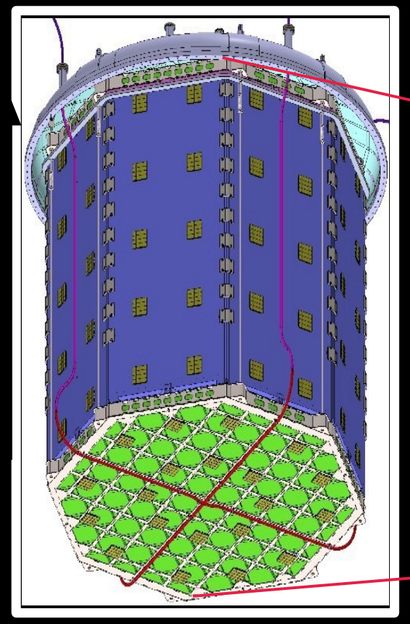
DARKSIDE 20K

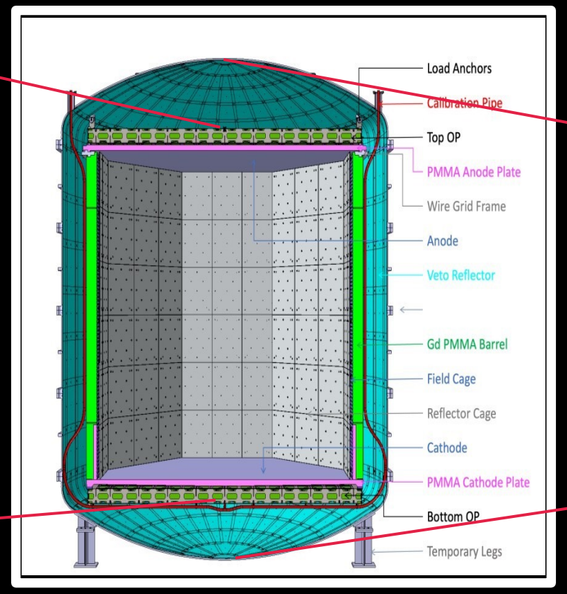


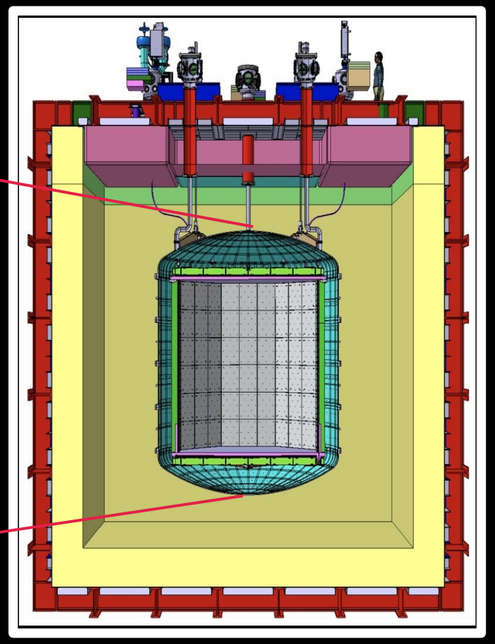
Installation has started. Data taking planned to start in 2028

Located in HALL C @ LNGS

Dual-phase TPC







50 t of UAr (20 t fiducial)
Two optical planes covering **21 m²** with **cryogenic SiPMs**
Acrylic TPC with reflectors in the inner and outer walls; field shaping rings by **Clevios coating**.
Anode and cathode of transparent **pure acrylic** covered with **Clevios** and **TPB** (wavelength shifter)
Wire grid

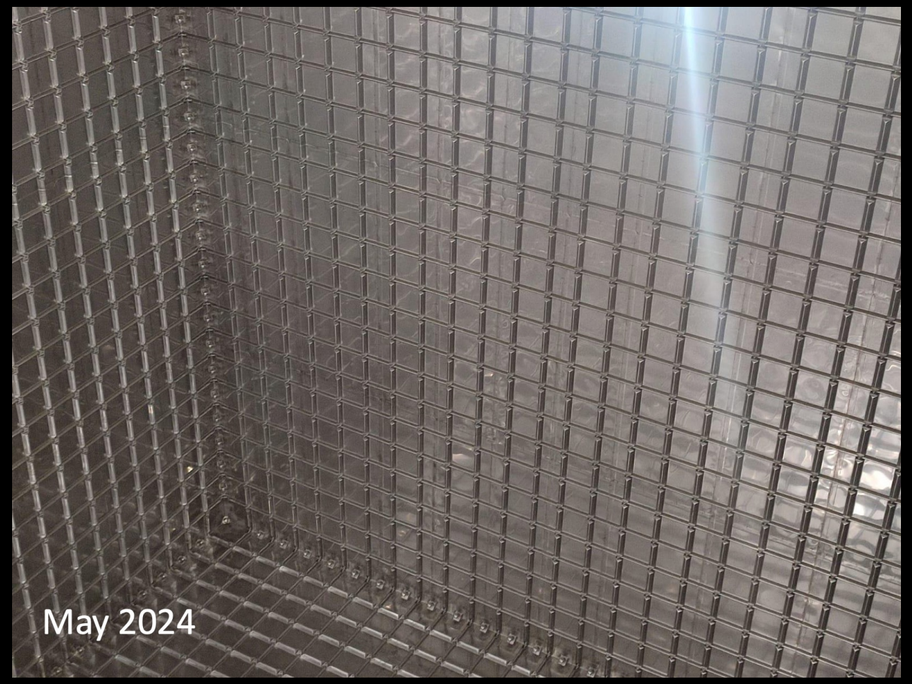
Neutron Veto:

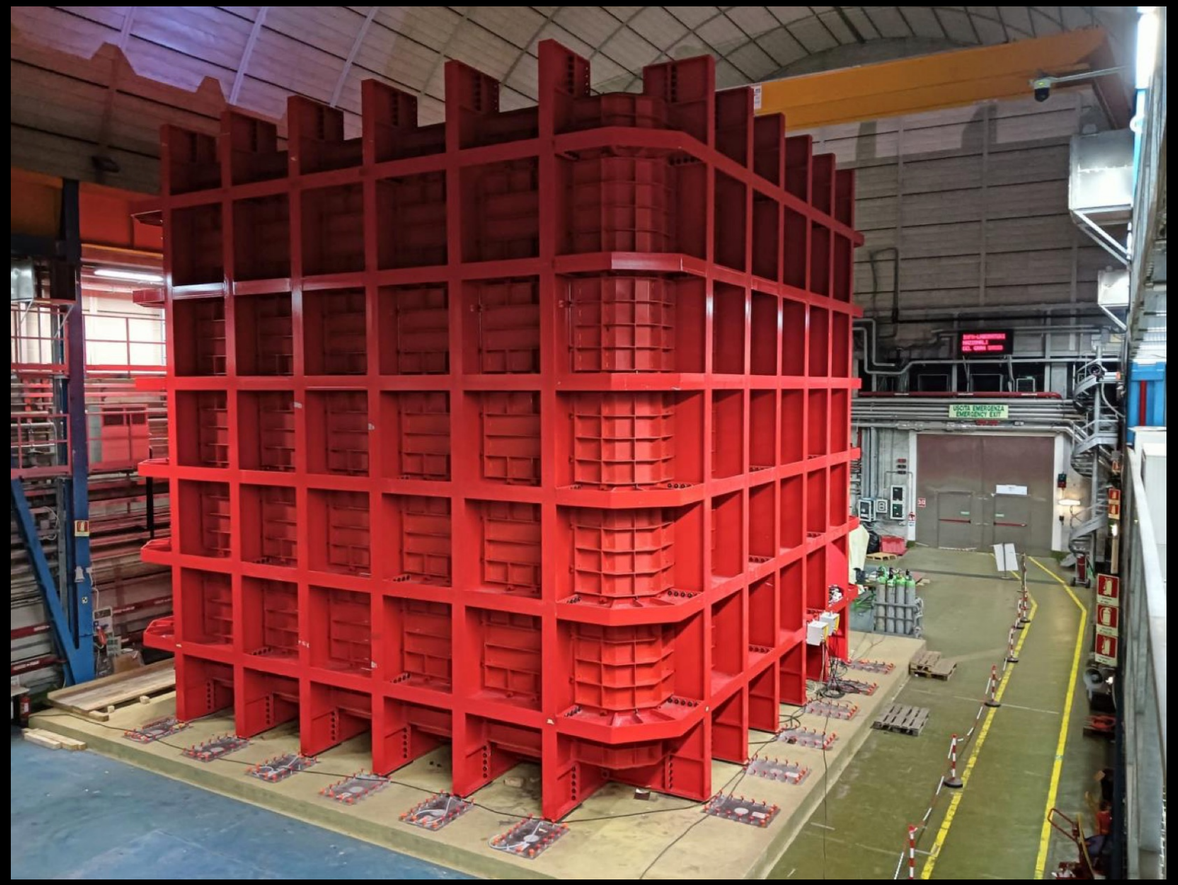
32 t of UAr
Equipped with SiPMs covering **5m²**
40 cm space between the stainless-steel vessel and PMMA.

Outer Cosmic Veto:

700 t of **Atmospheric Argon** (AAr)
Membrane "ProtoDUNE-like" 8x8x8 m³
Cryostat passive insulation
SiPM arrays near cryostat walls

MEMBRANE CRYOSTAT

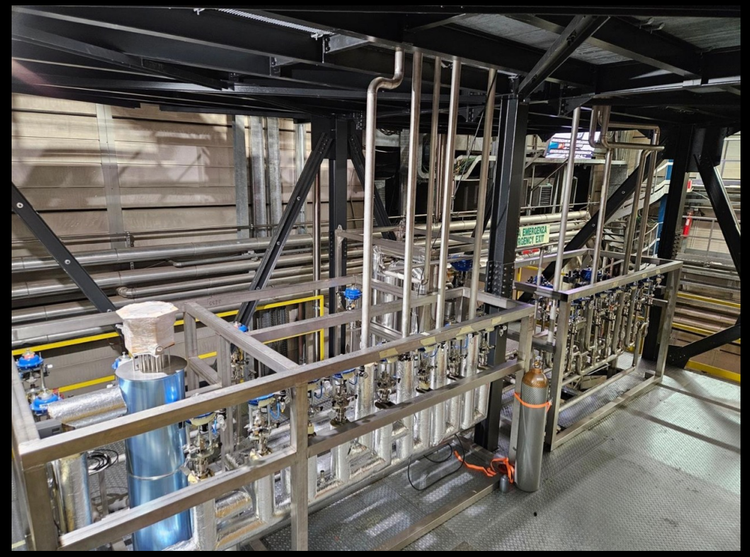




Installation completed in HALL C

CRYOGENICS IN HALL C

JINST 20 (2025) 02, P02016



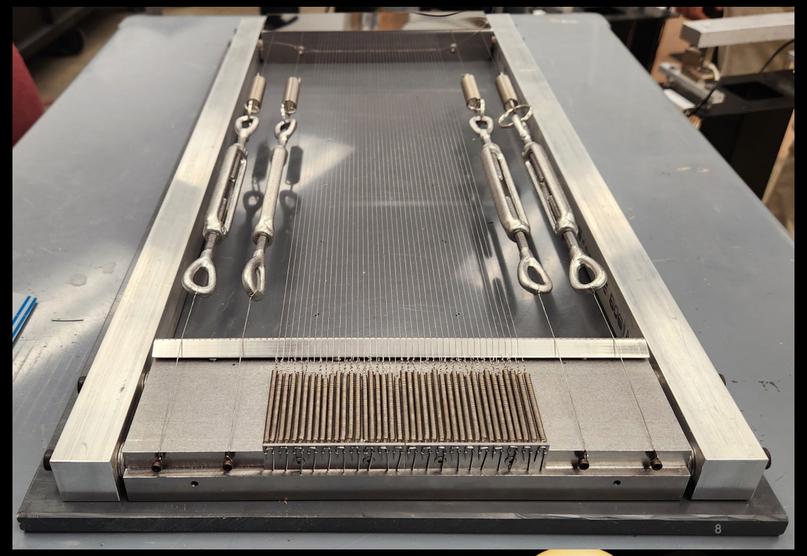
Installation of AAr cryogenics

UAr cryogenics tested with mock-up (see later) and shortly moved into the final position with some new compoments

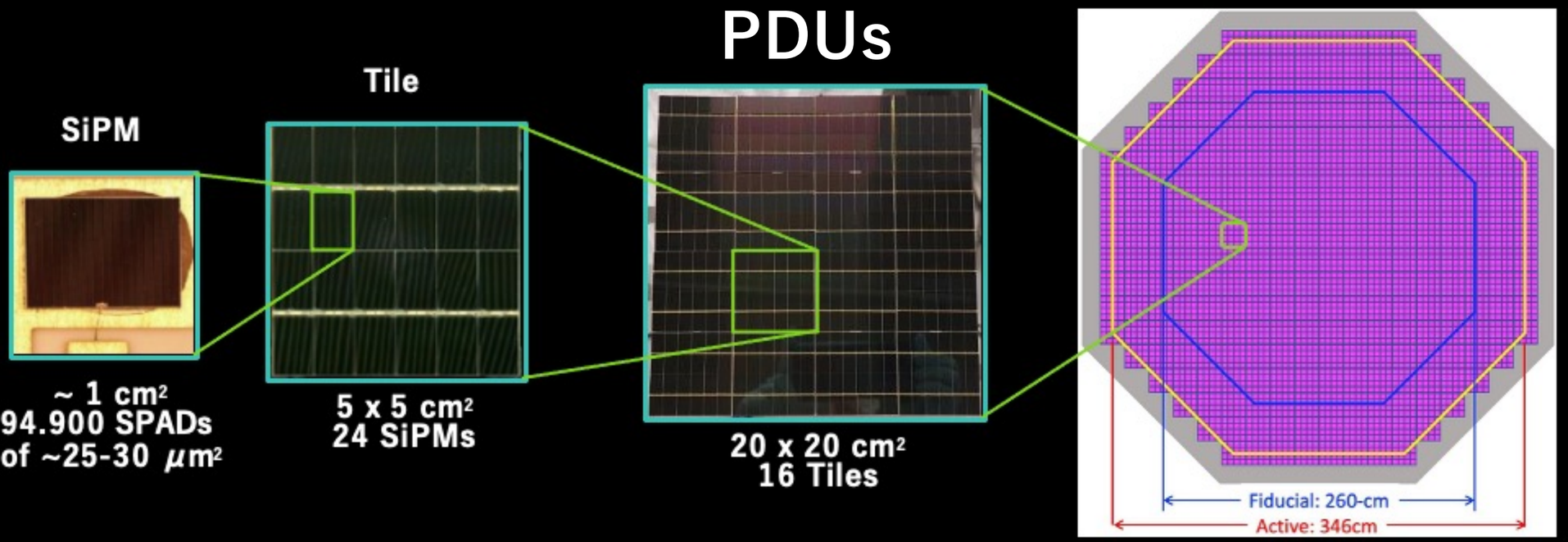
TPC PART PRODUCTION

Acrylic panel production

Wire grid test facility



LIGHT READOUT: LARGE SIPM ARRAYS



528 PDUs in the TPC

>10% assembled so far

Custom **cryogenic SiPMs** developed in collaboration with Fondazione Bruno Kessler (FBK), and produced by LFoundry in Italy

Photon detection efficiency (PDE) **~45%**

Low dark-count rate **< 0.01 Hz/mm²** at 77K (7VoV)

SNR > 8 for 10 x 10 cm²

All 1400 wafers tested ~94% yield

Tiles tested ~13% so far ~90% yield

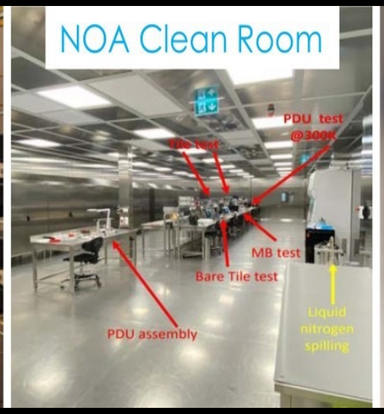
4 Tiles are summed up together in a single DAQ channel

120 PDUs in the neutron veto (all vTile produced and tested, selection for vPDU ongoing)

30 PDUs in the outer veto

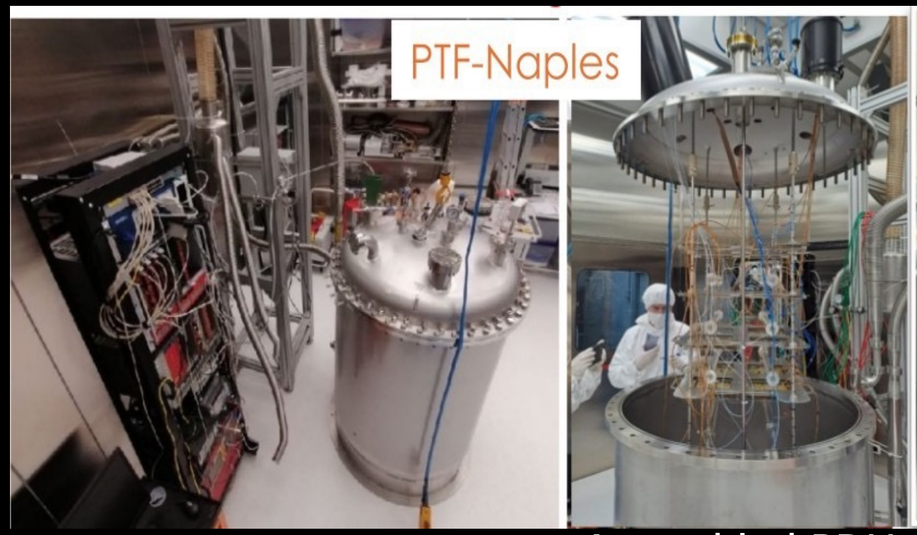
DS-20K PDU PRODUCTION AND TEST

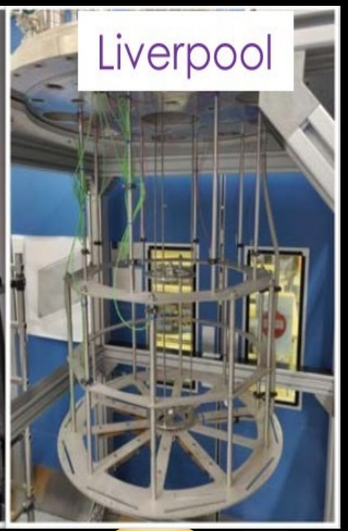
PDU Production: TPC PDUs at NOA@LNGS,
vPDUs at Birmingham, STFC interconnect, Manchester and Liverpool



Eur.Phys.J.C 85 (2025) 5, 5
e-Print: 2507.07226

PDU packaging and assembly in **NOA**, an ISO-6 clean room at **LNGS**





Assembled PDUs tested in a cryogenic test facility in **Naples**
vPDUs tested in facilities at **AstroCeNT**, **Edinburgh** and **Liverpool**

MOCKUP

Acrylic structure

Demonstrated capability to align barrel within 100 μm

HV tests, gas pocket formation exercises

Test runs of UAr cryogenics, cooling technique

Run at LNGS

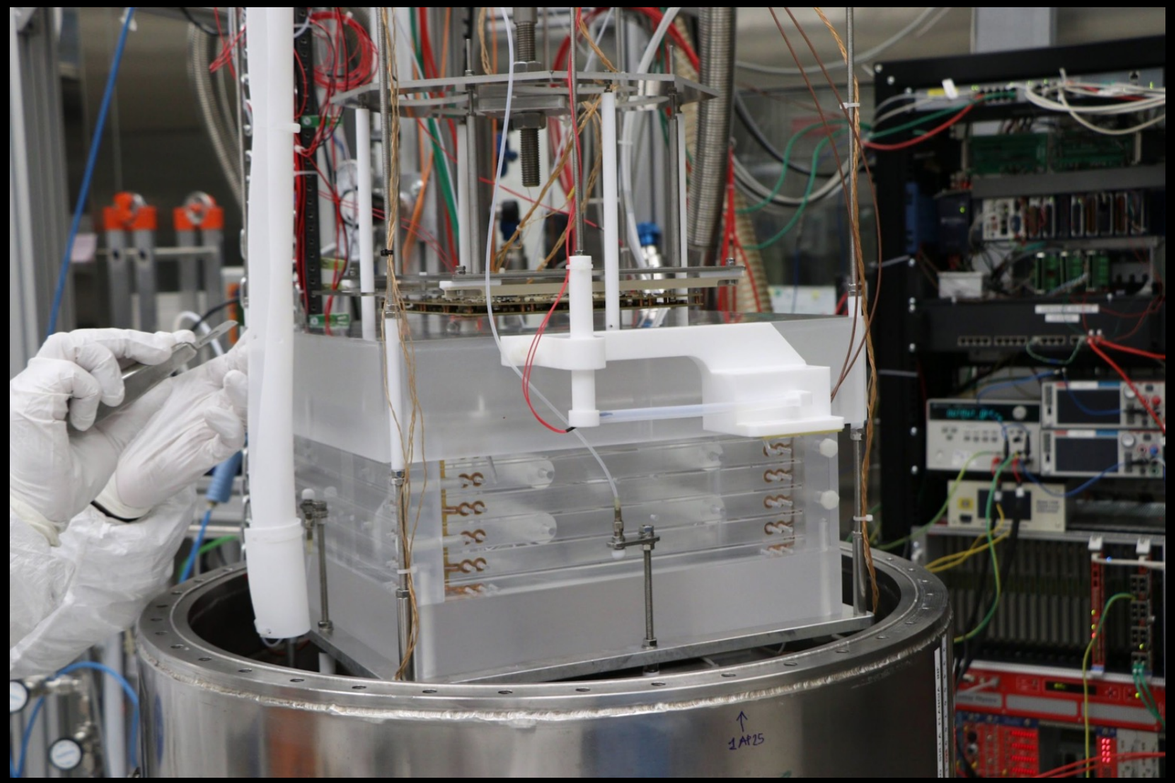
See the talk by Ako Jamil on Thursday

PROTO-0

DarkSide-20k's TPC prototype

7 kg argon in the TPC

Run at Naples



WHY UAR

^{39}Ar: Q=565keV and $T_{1/2}$=269y;

β emitter with specific activity ~1 Bq/Kg

Produced in the atmosphere primarily by neutron-induced reactions of cosmic rays on ^{40}Ar . Very low production, if not zero, going underground (UAr)

With AAr, Darkside-20k would have 100% dead time (not so DEAP3600, which is single phase)

Already used in DS50 → world-leading Wimp low-mass search (1400x suppression of ^{39}Ar)

THE UAR ROUTE

URANIA: A NEW HIGH-PRODUCTION PLANT

Plant is almost completed: some commissioning of components starting now. Uar production at 230kg/day

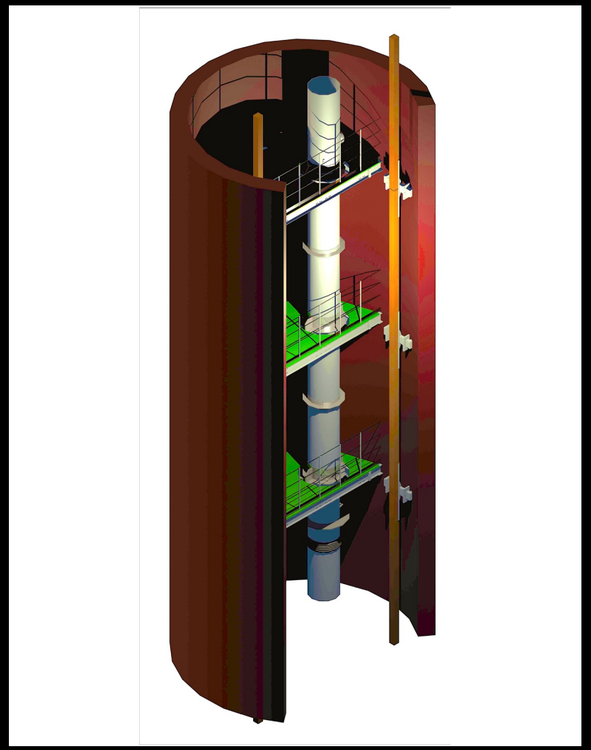
Transportation:

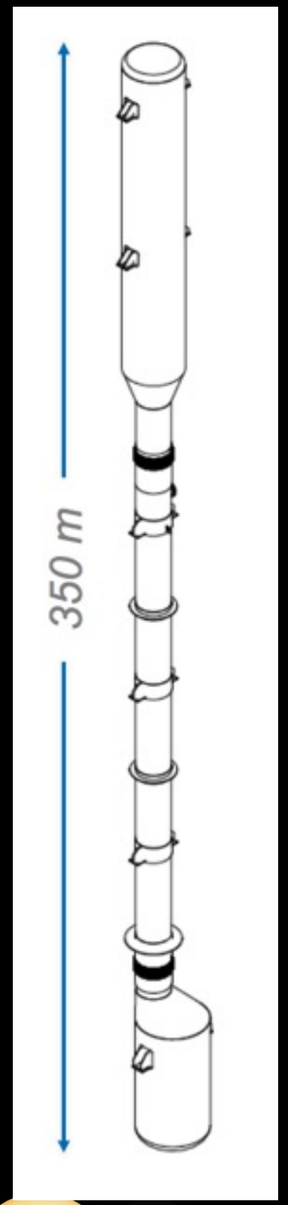
15 t skids with liquid argon

Passive insulation

ARIA

28 central modules



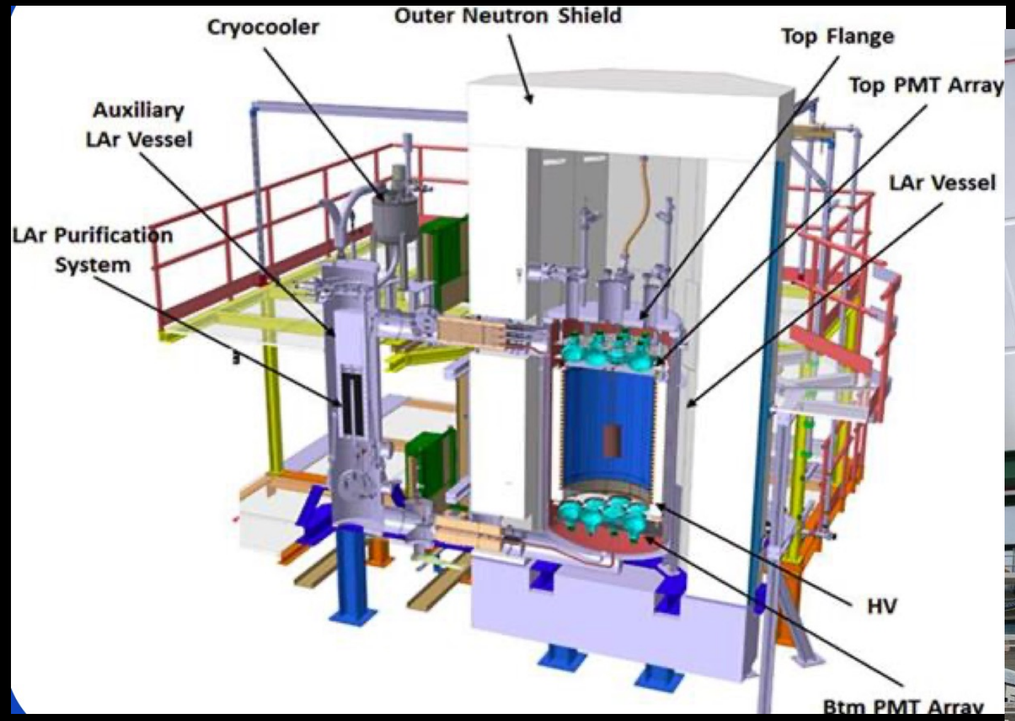


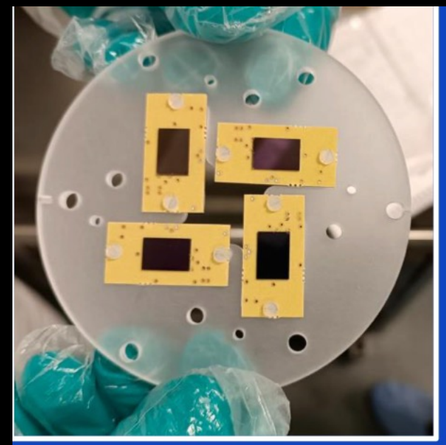
ARIA

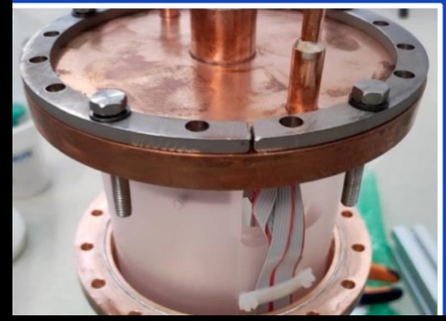
Eur.Phys.J.C 83 (2023) 5, 453

Demonstrated isotopic distillation of argon with a 30 m prototype Seruci-0

DART IN ARDM





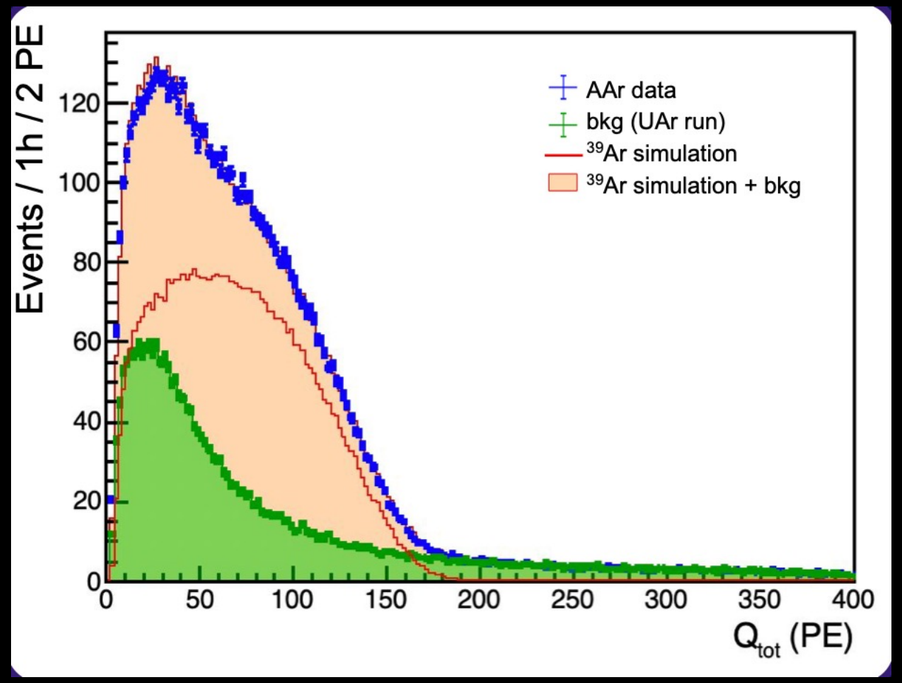


At LSC Spain. Sensitivity O(0.1 mBq/kg)

All the parts tested and functioning

Ready to fill ArDM

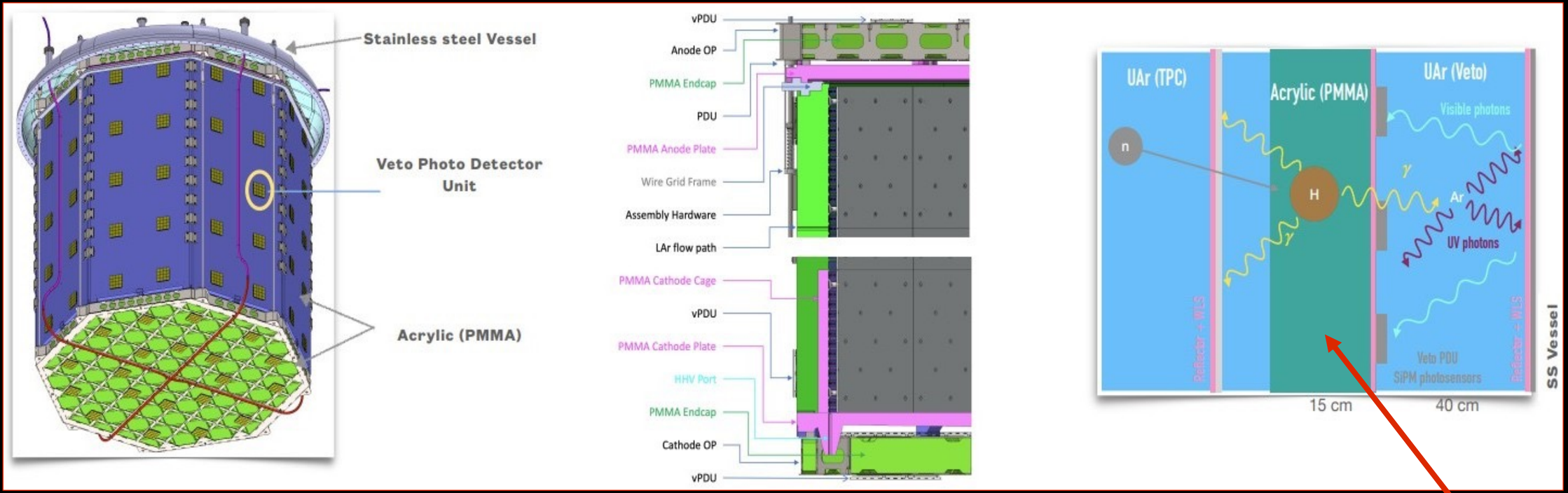
DART IN ARDM



With a prototype, we measured the energy spectra of atmospheric argon and UAr from the DarkSide-50 production batch (1kg argon)

Measurement of ^{39}Ar activity soon to be made public (we project 30 mBq/kg uncertainty)

DARKSIDE-20K VETO STRATEGY



Neutrons are moderated in the acrylic shell and then captured mainly by **hydrogen** or **argon**.
The capture process yields **γ-rays**
γ-rays interact in **argon** of either the **Neutron Veto** or **TPC**
A potential improvement under study: at least 20 Gd-PMMA bricks, which are currently in production, embedded in the optical planes

EXPECTED BACKGROUNDS

nuclear recoil events
after cuts in 200 t-yr: 0.2 ev. in ROI (30-200 keV_{nr}) in the **FID** volume (see next slide)

CEvENS dominates by an order of magnitude

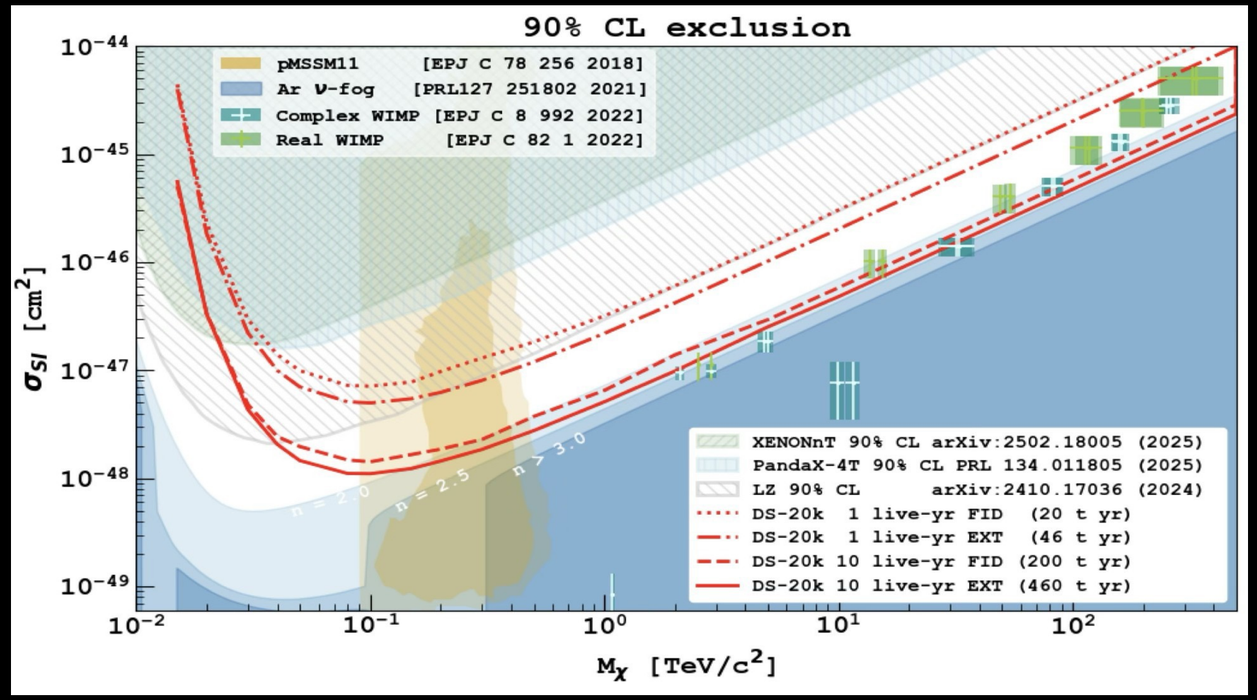
electron recoil events
in the TPC O(35Hz) from material radioactivity and O(35Hz) from ^{39}Ar (if UAr has the same radioactivity of DS50, TBD)

In the VETO O(100Hz) from material radioactivity and O(25Hz) from ^{39}Ar

-→ dead time of O(10%)

Background source	Mitigation strategy
^{39}Ar β decay	Use underground Ar + Pulse shape discrimination (PSD)
γ from rock and γ,e from materials	PSD Selection of materials & procedures
Radiogenic neutron (α,n) reaction in detector materials	Material screening & selection, MC study Definition of Fiducial volume in the TPC Veto to reject neutron signals
Surface contamination due to Rn progeny	Surface cleaning Reduce the number of surfaces Installation of Rn abated system
Muon induced background	Cosmogenic veto
Neutrino coherent scattering	**Irreducible** (~1.6 events in ROI in a 100 t-yr)

HIGH MASS WIMP SENSITIVITY DS-20K



Both signals, **S1** (scintillation) and **S2** (ionization), are used.

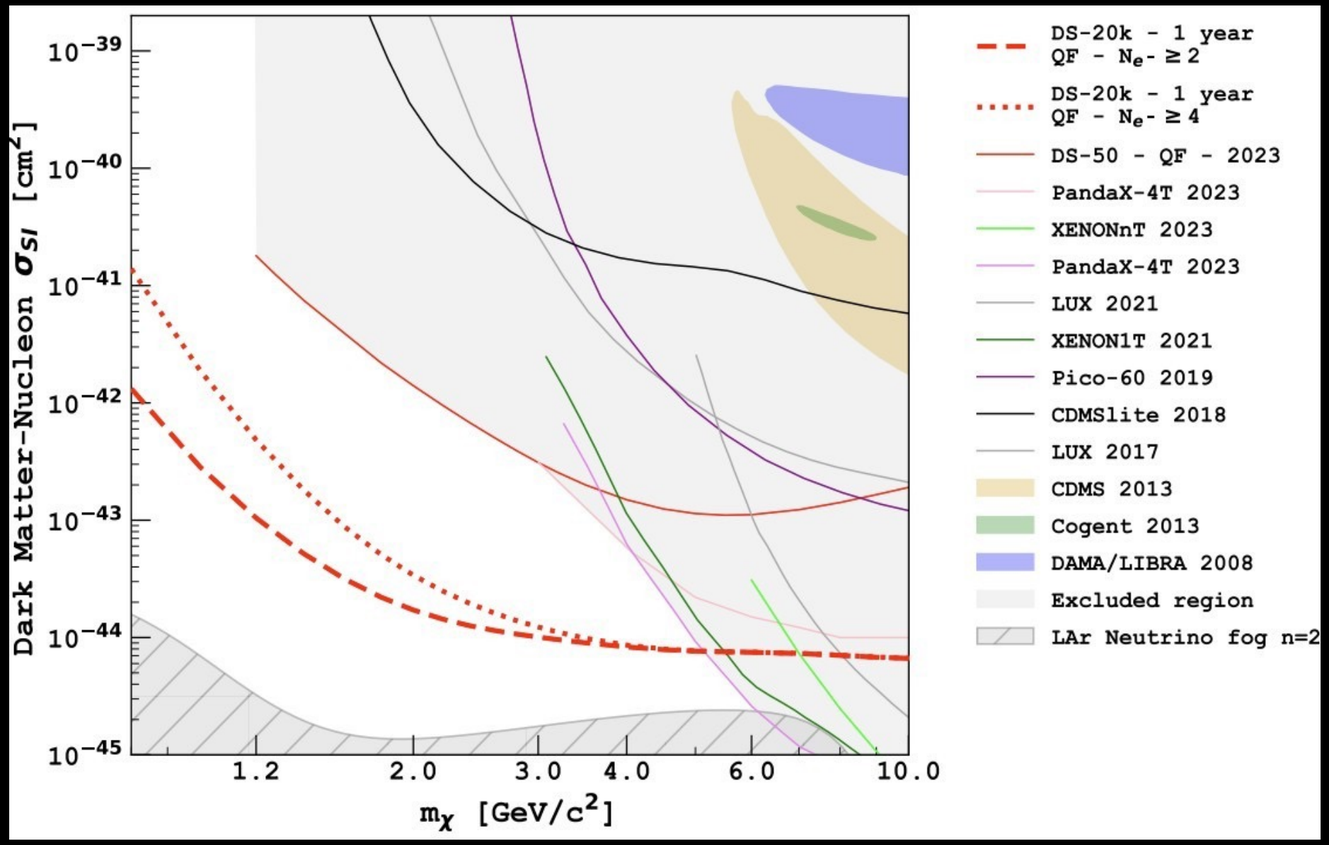
The best G3 sensitivity

Publication in preparation

FID: low instrumental background rate: dominated by CEvENS

EXT: full argon volume inside the TPC is used, background dominated by radiogenic neutrons from photo-sensors and the experimental hall

LOW MASS WIMP SENSITIVITY DS-20K



Commun.Phys. 7 (2024) 1, 422

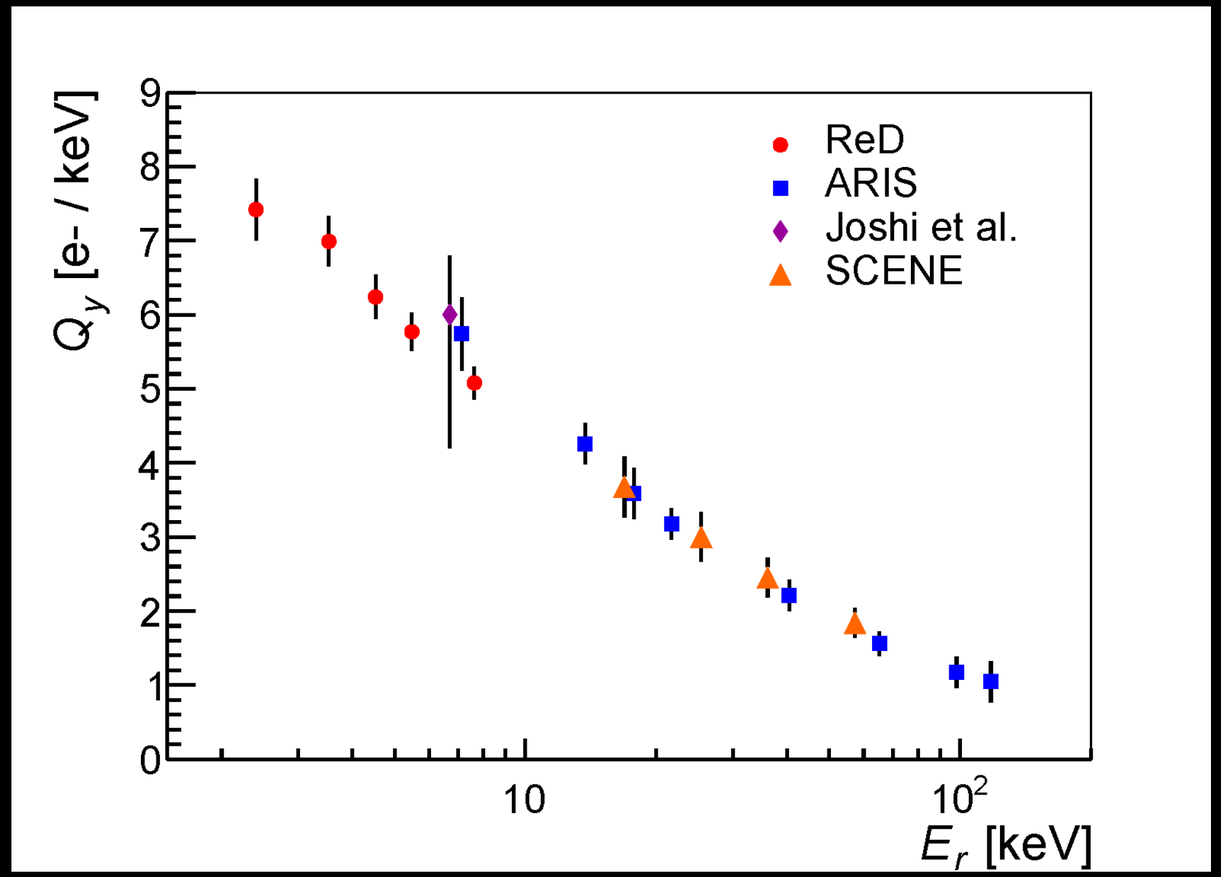
Using **S2** (ionization signal) only.

Detailed background study, information from DarkSide-50 data.

Sensitivity update is going to be presented by M. Wada on Wednesday and L.Pandola on Thursday based on…

NB: 1 year sensitivity!!!!!

NEW CHARGE YIELD MEASUREMENT IN LAR



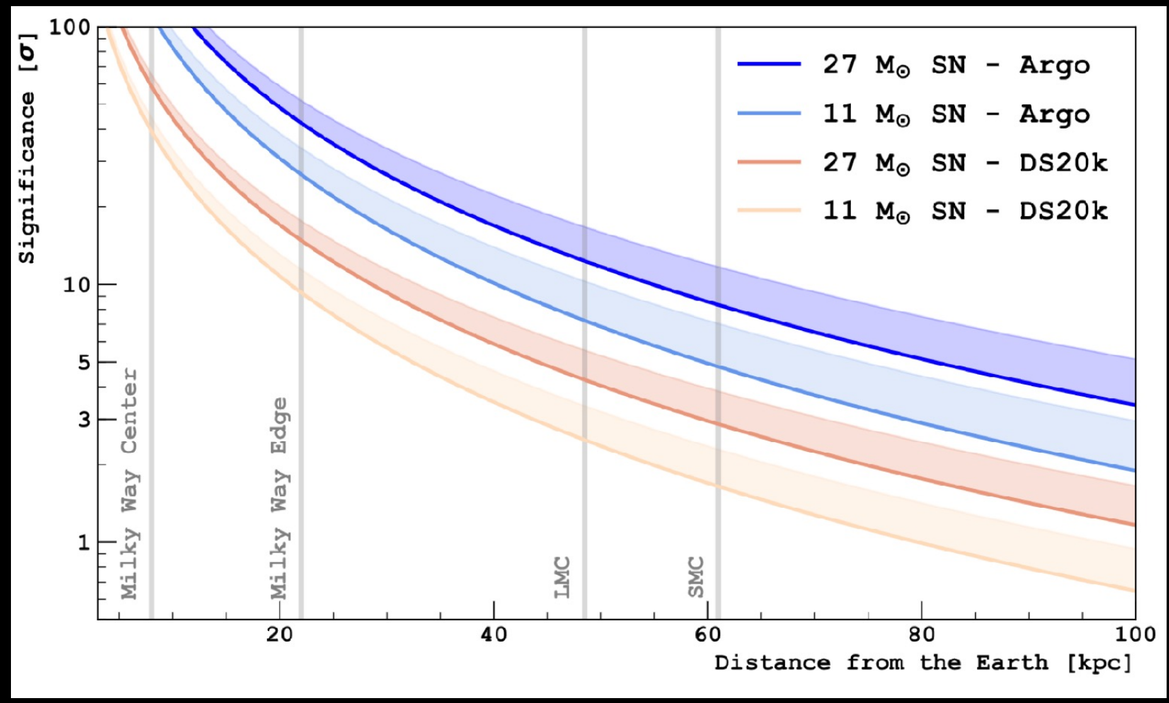
Using **S2** (ionization signal) only.

New charge yield measurement with the ReD experiment in Catania with ^{252}Cf source, extending the measurement down to 2keVnr, detailed presentation by M. Wada on Wednesday and L.Pandola on Thursday

SUPERNOVA NEUTRINOS

Detection in the whole Milky Way with CEvENS using **S2** (ionization signal) only.

JCAP 03 (2021) 043



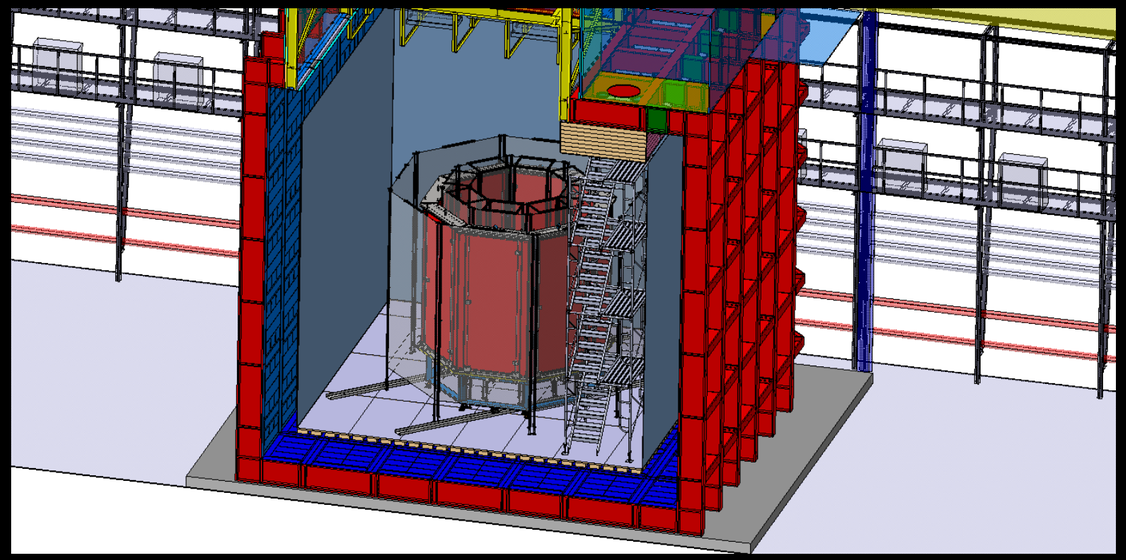
SUMMARY

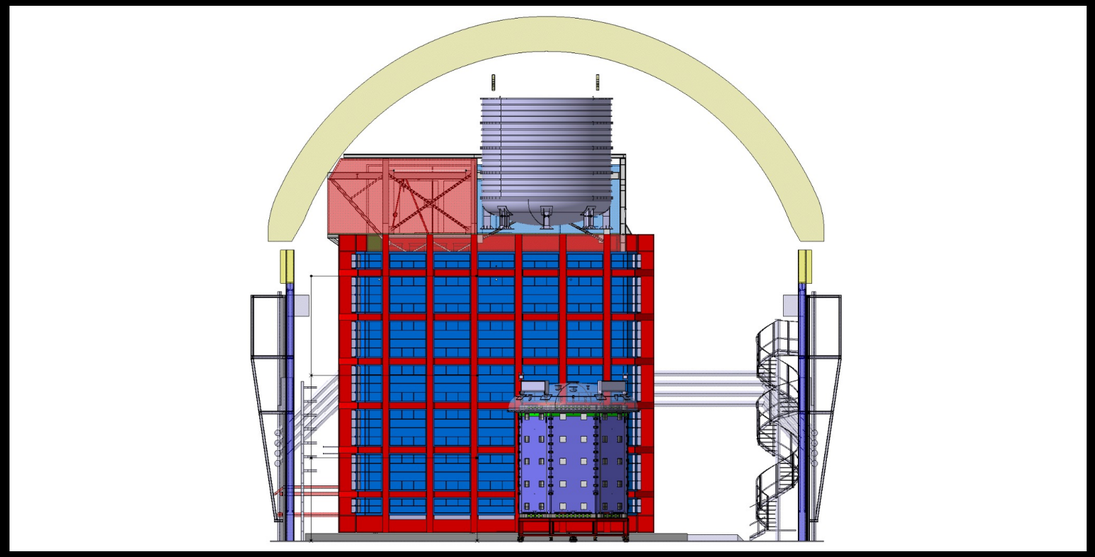
DarkSide-20k is under construction

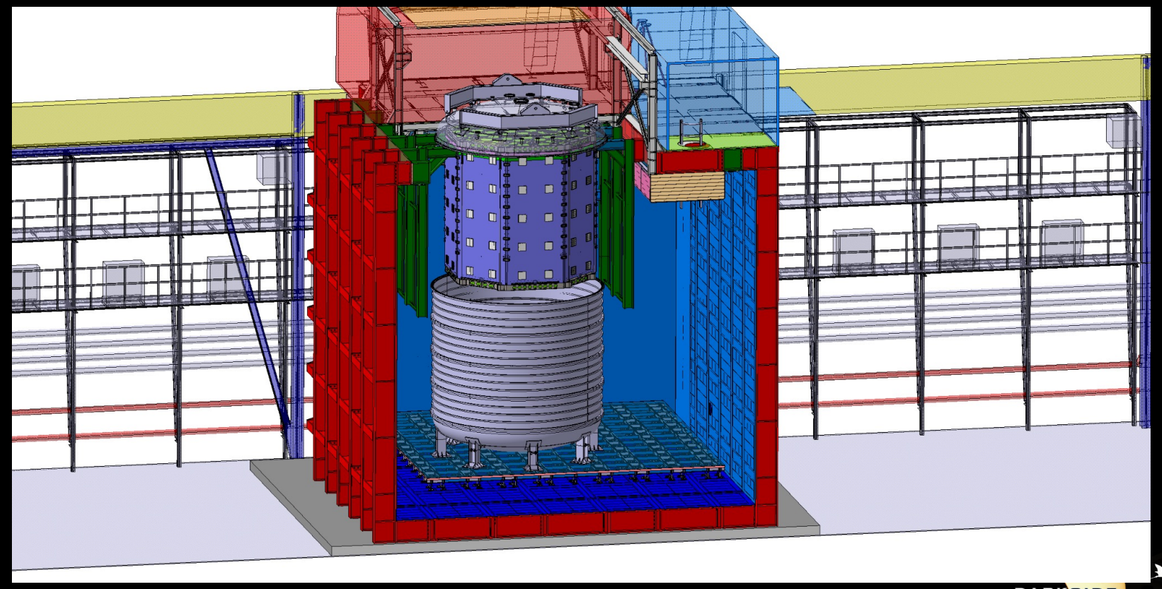
Many new technologies from which the whole field may benefit (e.g., UAr, cryogenic SiPMs, large acrylic structures, conductive coatings on acrylic, etc.)

BACKUP

TPC INSTALLATION PLANS







Inside the cryostat, equipped as Rn free clean room

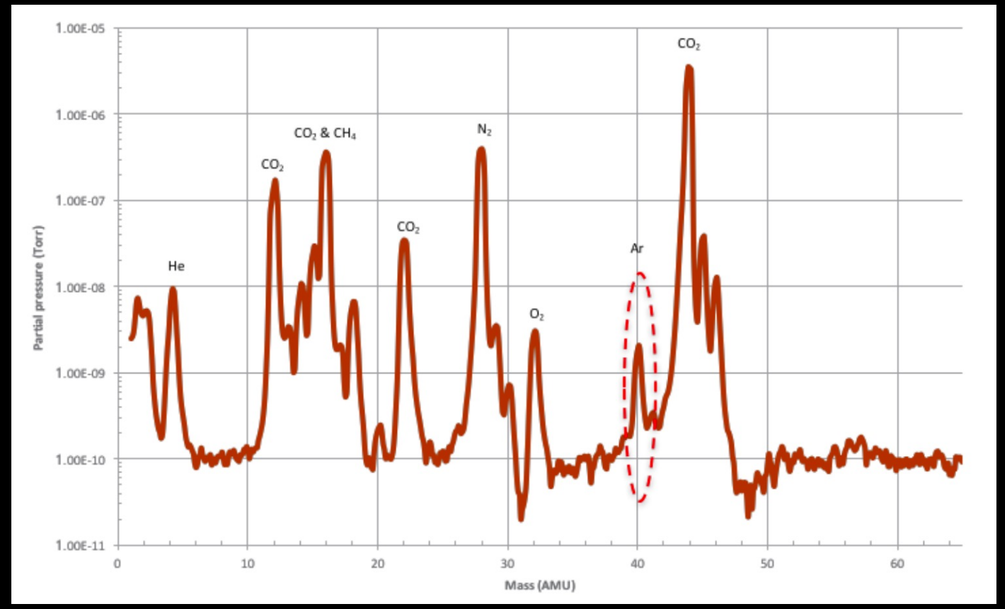
False floor already installed

THE UAR EXTRACTION SITE

DOE canyon, Dolores County, Colorado

the Kinder-Morgan (KM) company, for petroleum purposes, extracts gas from the subsoil, with composition: CO2 95%, UAr 430ppm; DarkSide "takes" the argon and returns the rest to KM

The gas comes from the mantle ("magmatic CO2"); the concentration of uranium and thorium in the mantle is typically at the level of ppb, 1/1000 compared to the crust (Well depth 3 KM) —>low probability of production of 39Ar



Composition	# of atoms (neutrons) yr^{-1} kg^{-1}			
	^{4}He	neutrons	^{21}Ne	^{39}Ar
Upper Continental Crust	1.64×10^{10}	10,680	753	28.7
Middle Continental Crust	8.98×10^{9}	6114	416	13.9
Lower Continental Crust	1.53×10^{9}	1129	70.2	0.749
Bulk Continental Crust	9.43×10^{9}	6253	433	15.3
Bulk Oceanic Crust	3.79×10^{8}	260	15.8	0.0235
Depleted Upper Mantle	2.51×10^{7}	22.4	1.06	0.000257

(O. Šrámek, et al., Geochimica et Cosmochimica Acta 196 (2017) 370)