DarkSide-20k experiment and its veto

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on behalf of The Global Argon Dark Matter Collaboration

TeVPA, Queen's University, Canada, Aug 10th 2022

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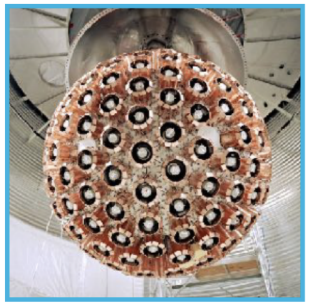
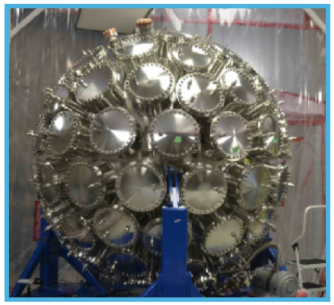
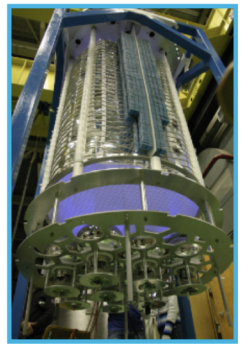
The Global Argon Dark Matter Collaboration

The Global Argon Dark Matter Collaboration - 500 people


DarkSide-50


DEAP-3600


MiniCLEAN


ArDM

Goal: continue work on DS-50 and DEAP-3600,
build: DarkSide-20k, DarkSide-LowMass and in future ARGO

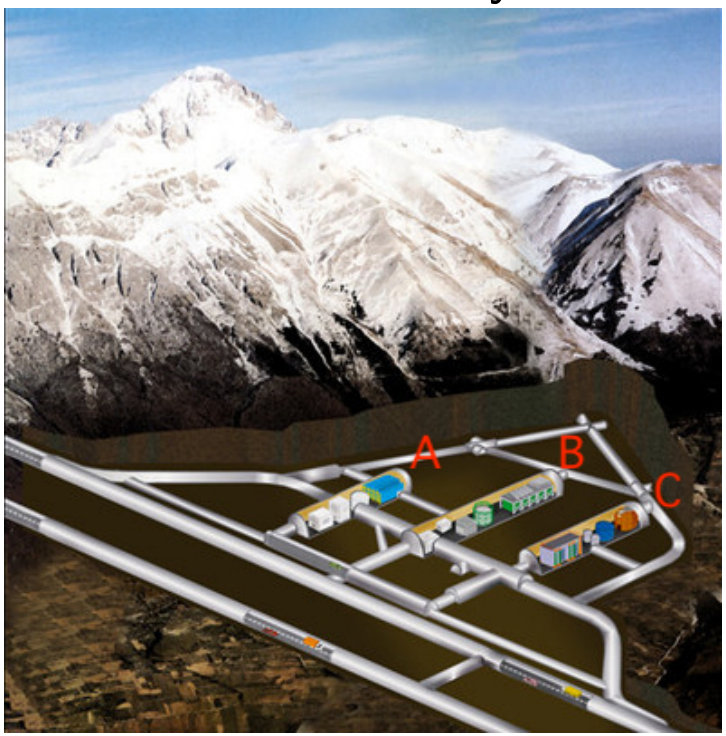
DarkSide-20k Technical Design Report submitted to INFN in Dec 2021

Argon:

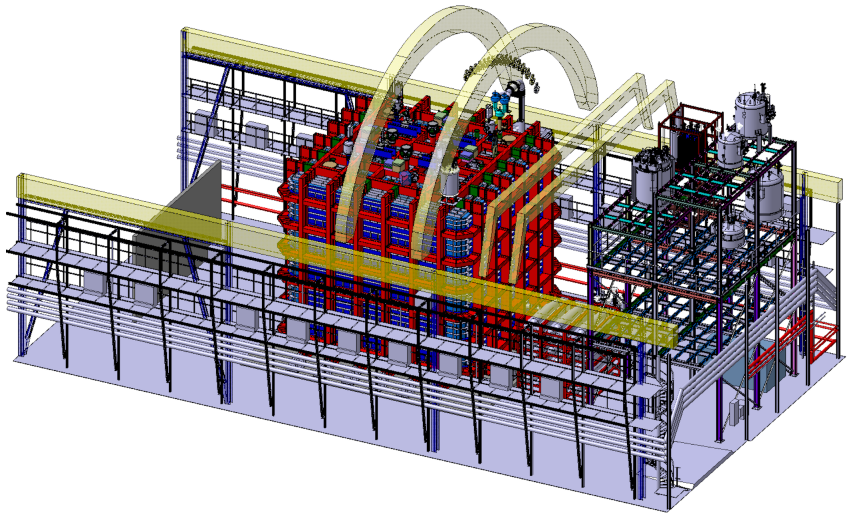
- dense and easy to purify, scalable,
- high ionization, good scintillator - transparent to own scintillation,
- strong electron recoil discrimination via pulse shape.

Laboratori Nazionali del Gran Sasso (LNGS)

- founded in 1987
- largest underground research center
- covered by 1400 m of rock (3800 mwe shielding)
- can be accessed by car



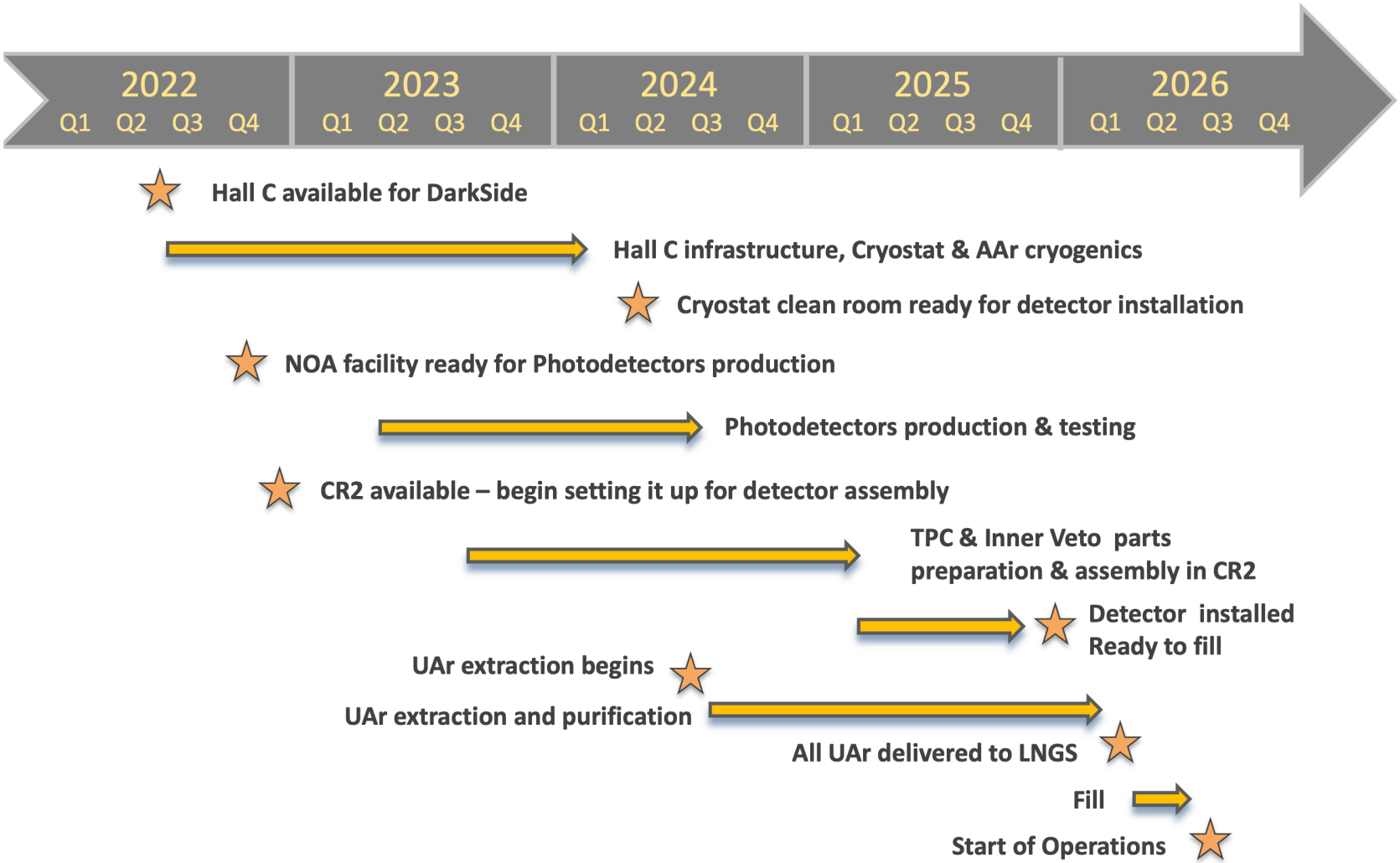
- DarkSide-20k will be installed in LNGS in Hall-C
- construction: 2022 - 2025
- nominal duration of operation: 10 years



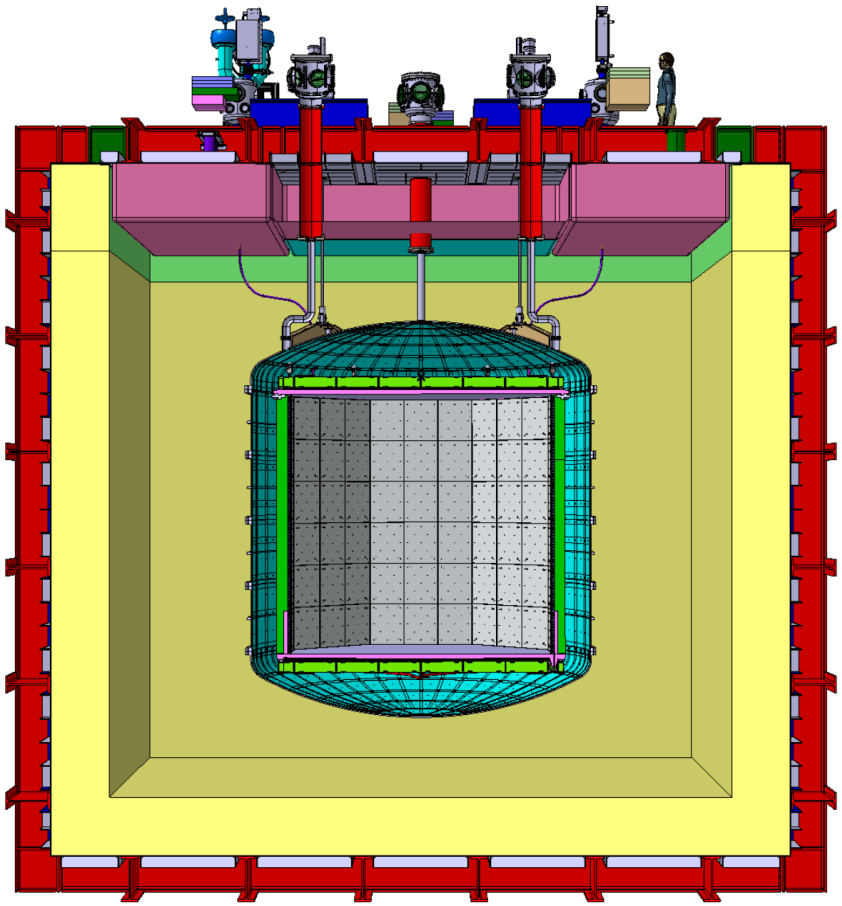
- see talk by Tom Thorpe for details on Underground Argon Cryogenic System

Hall-C in LNGS

DarkSide-20k schedule

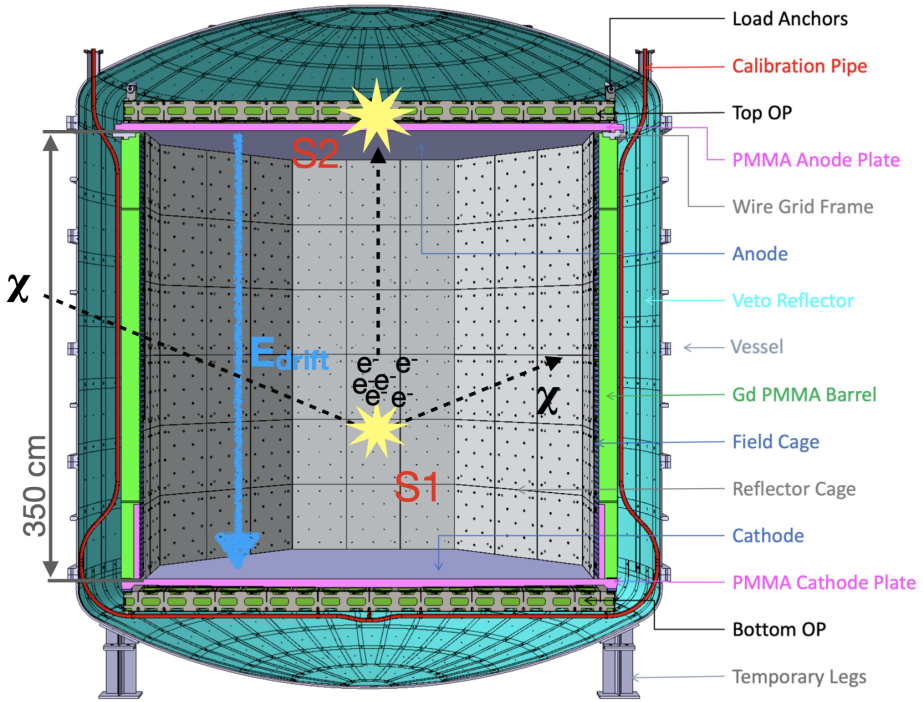


DarkSide-20k overview

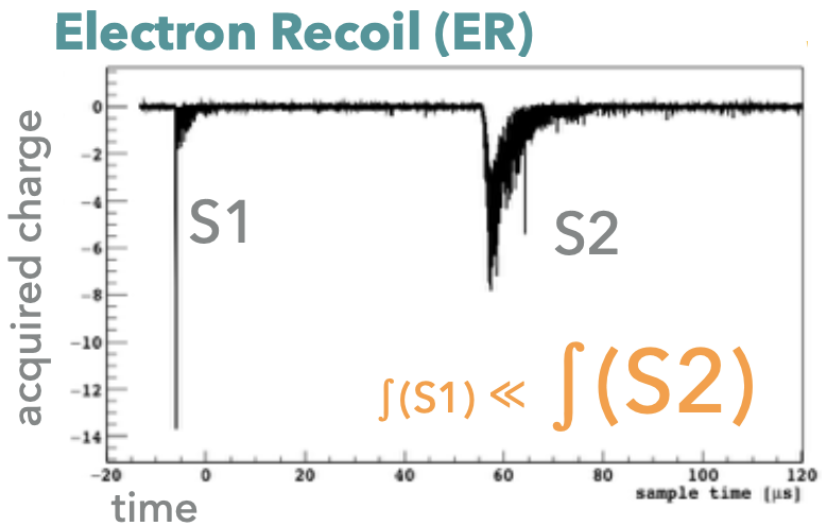


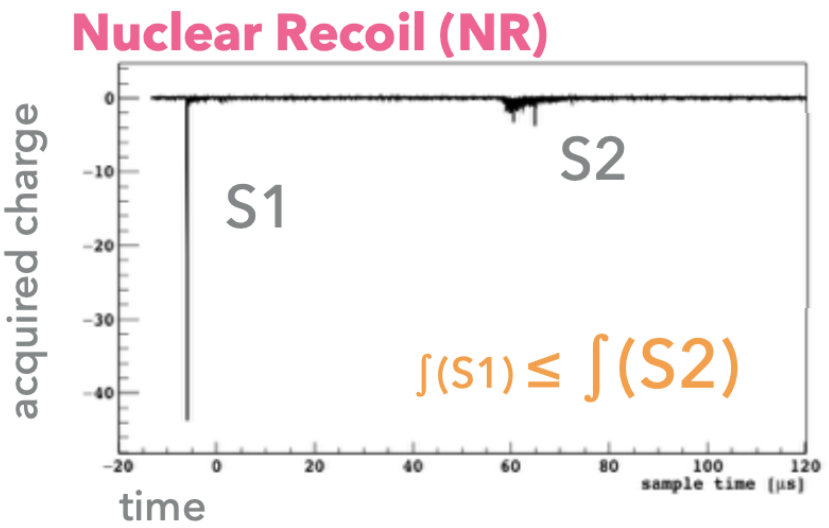
- Time Projection Chamber (TPC) filled with 51 t of underground Ar (UAr) (20 t fiducial)
- Acrylic panels loaded with gadolinium (Gd-PMMA)
- Neutron veto buffer between the TPC and the vessel
- Vessel contains UAr
- Outer cosmic veto filled with atmospheric Ar (AAr) - muons and their shower products

Dual Phase Time Projection Chamber



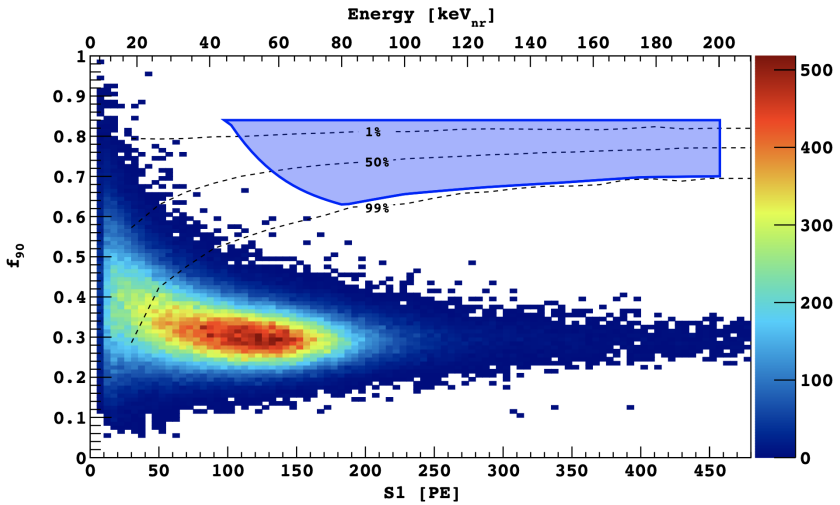
- S1: energy and pulse shape discrimination (PSD)
- S2: energy information and the 3D position measurement of the event
- Resolution: 10 mm horizontal,1 mm vertical



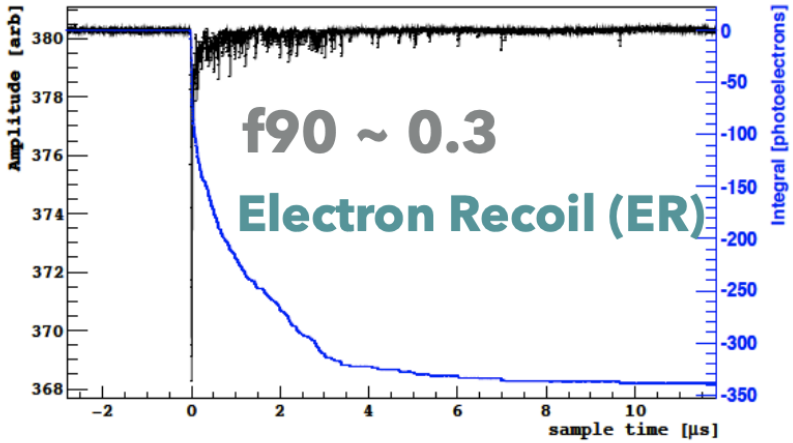


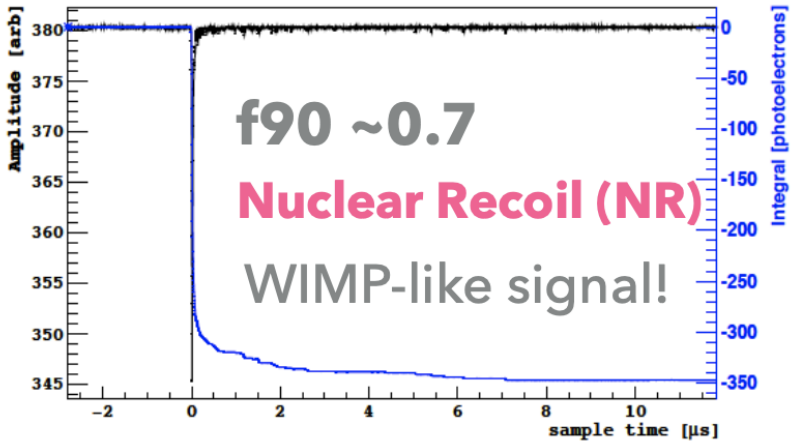
Pulse Shape Discrimination in Ar

Results from a run of DarkSide-50 with a UAr fill for a 532.4 live-days livetime:

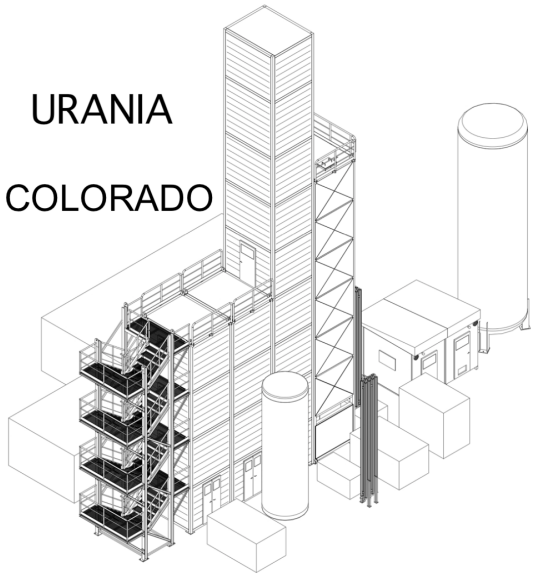


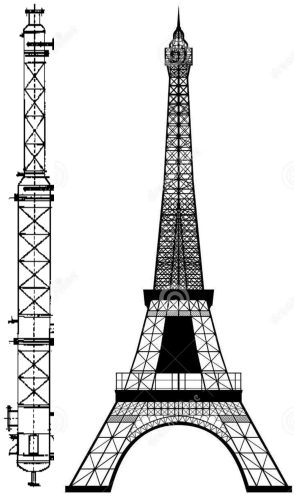
- **f_{90}**: fraction of the primary scintillation pulse in its first 90 ns
- **S1**: total integral of the primary scintillation pulse (photoelectrons, PE)
- **PSD**: tool to distinguish light from a recoiling electron and nuclear recoil
- for PSD capabilities for a single-phase Ar DEAP-3600 detector see also [Eur. Phys. J. C 81, 823 (2021)]





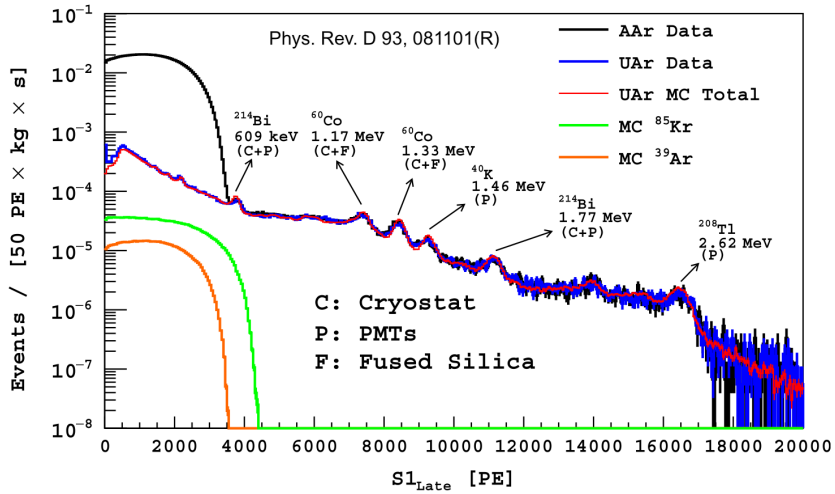
Underground Argon





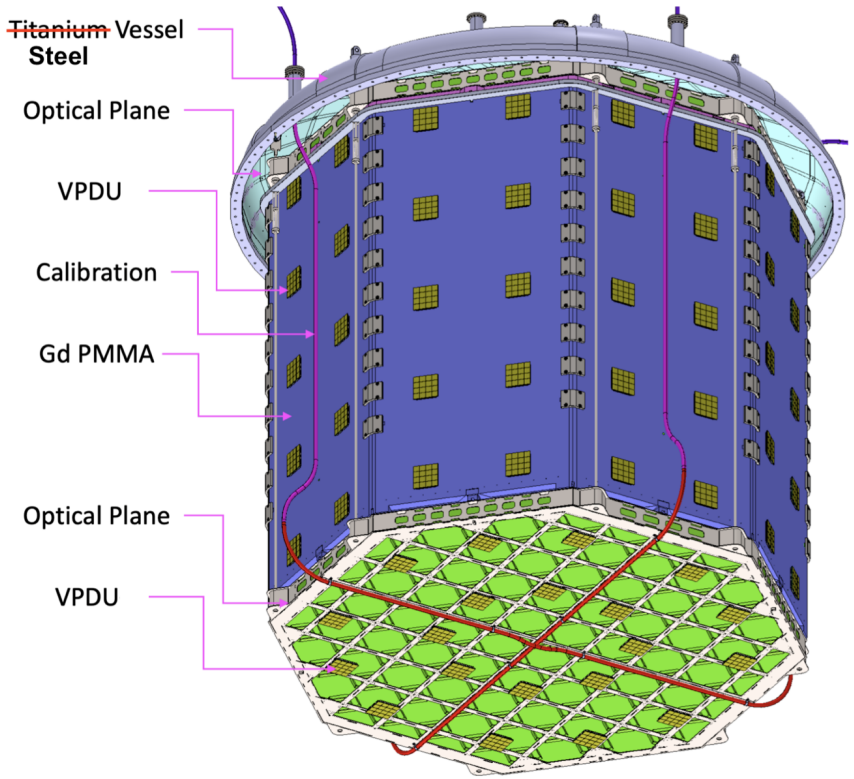
ARIA, Seruci mine in Sardinia

- URANIA: Colorado, capacity of 330 kg/day of Underground Ar
- ARIA: 350 m tall column - removes the remaining nitrogen from UAr. Assembly of the column in the shaft this year [Eur. Phys. J. C 81, 359 (2021)]



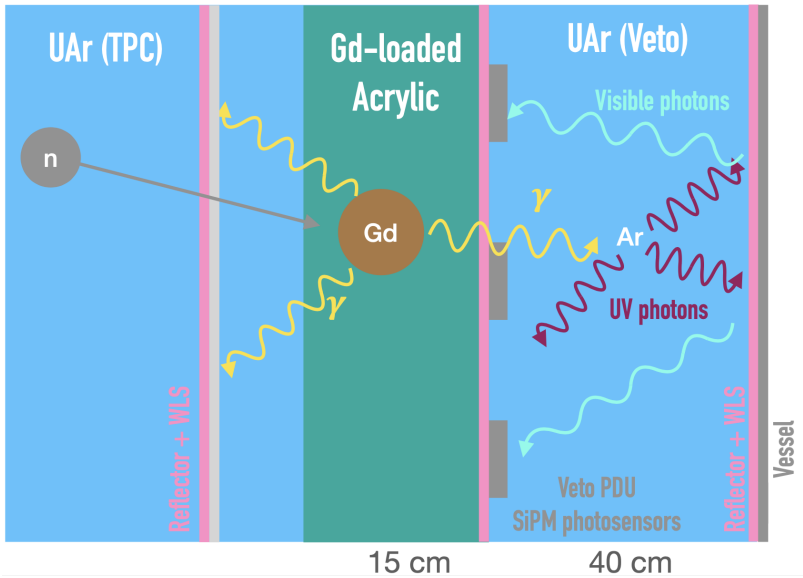
- **^{39}Ar reduction factor of at least 1400**(to be measured by DArT [JINST 15, P02024 (2020)])

Neutron Veto



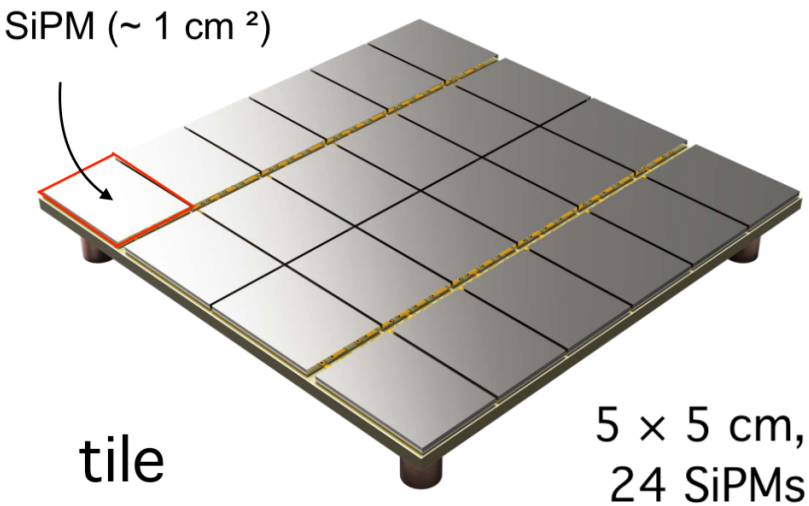
- 40 cm thick space between the vessel and Gd-PMMA
- 8 walls made from 15 cm thick Gd-PMMA
- ESR reflector with PEN WLS foils on all the surfaces

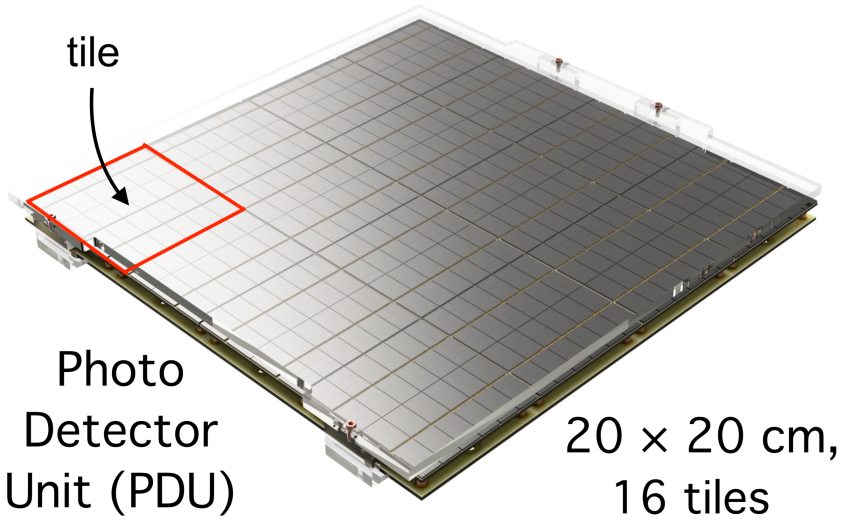
Neutrons elastically scattering from argon nuclei are indistinguishable from WIMPs.



- Neutrons are moderated in the PMMA and captured by Gd,
- Gd emits multiple γs with energy up to 8 MeV,
- UAr scintillation light is shifted and detected by veto photodetectors

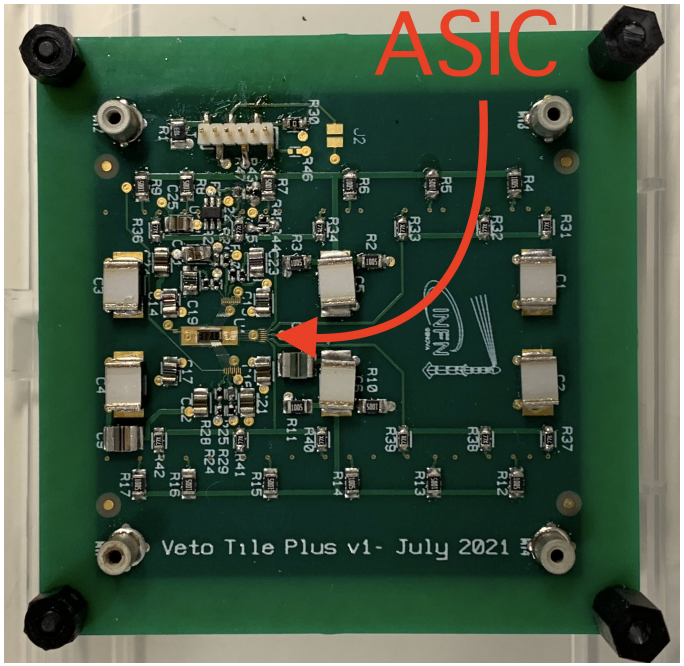
Silicon photomultipliers





- Custom silicon photomultipliers (SiPM)
- low noise at 88K, tuned sensitivity vs light spectrum
- Photon detection efficiency: 45%
- Timing resolution: 10 ns
- Dark-count rate: few mHz/mm^2
- 26 m^2 overall
- 156 PDUs for the veto (vPDUs)
- Scintillation light from Ar peaks at 128 nm, a wavelength shifter (WLS) is required for its detection
- Enhanced Specular Reflector (ESR) film covers all passive surfaces
- WLS: TPB coating in TPC, PolyEthylene Naphthalate (PEN) foils in the veto

Veto tile



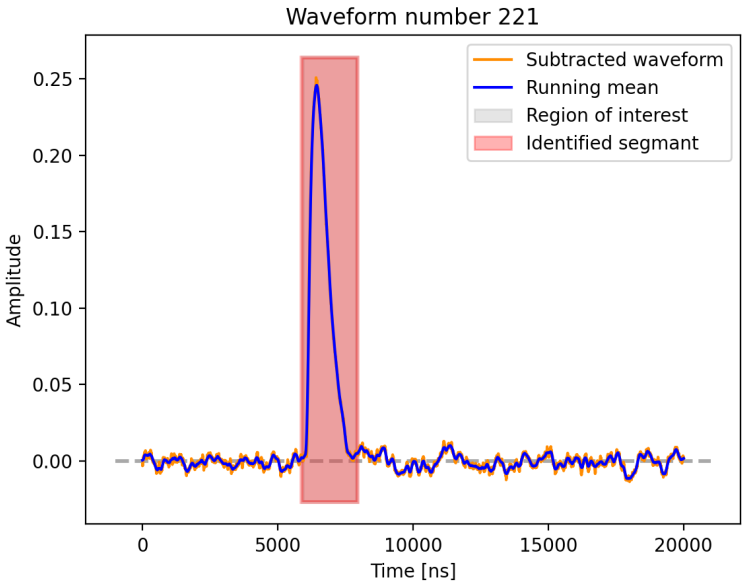
- ASIC - application specific integrated circuit - coupled to SiPM
- Customized for a particular use
- Linear behavior up to 700 mV and an RMS noise of 0.8 mV

Tests performed in Genova

Tests at warm and cold (liquid nitrogen) included:
- current draw,
- RMS and baseline,
- SNR vs VoV,
- thermal cycle, stability

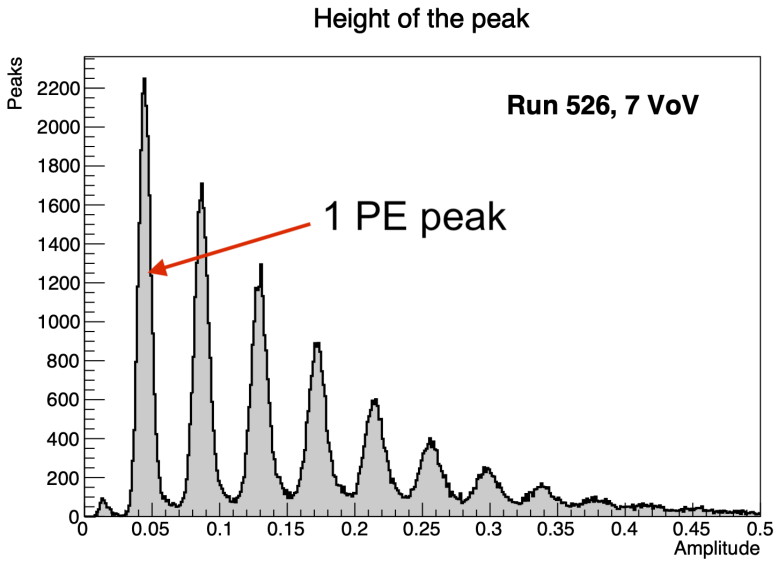
Veto tile tests

Waveform with laser pulse after the reconstruction with the DarkSide PyReco software



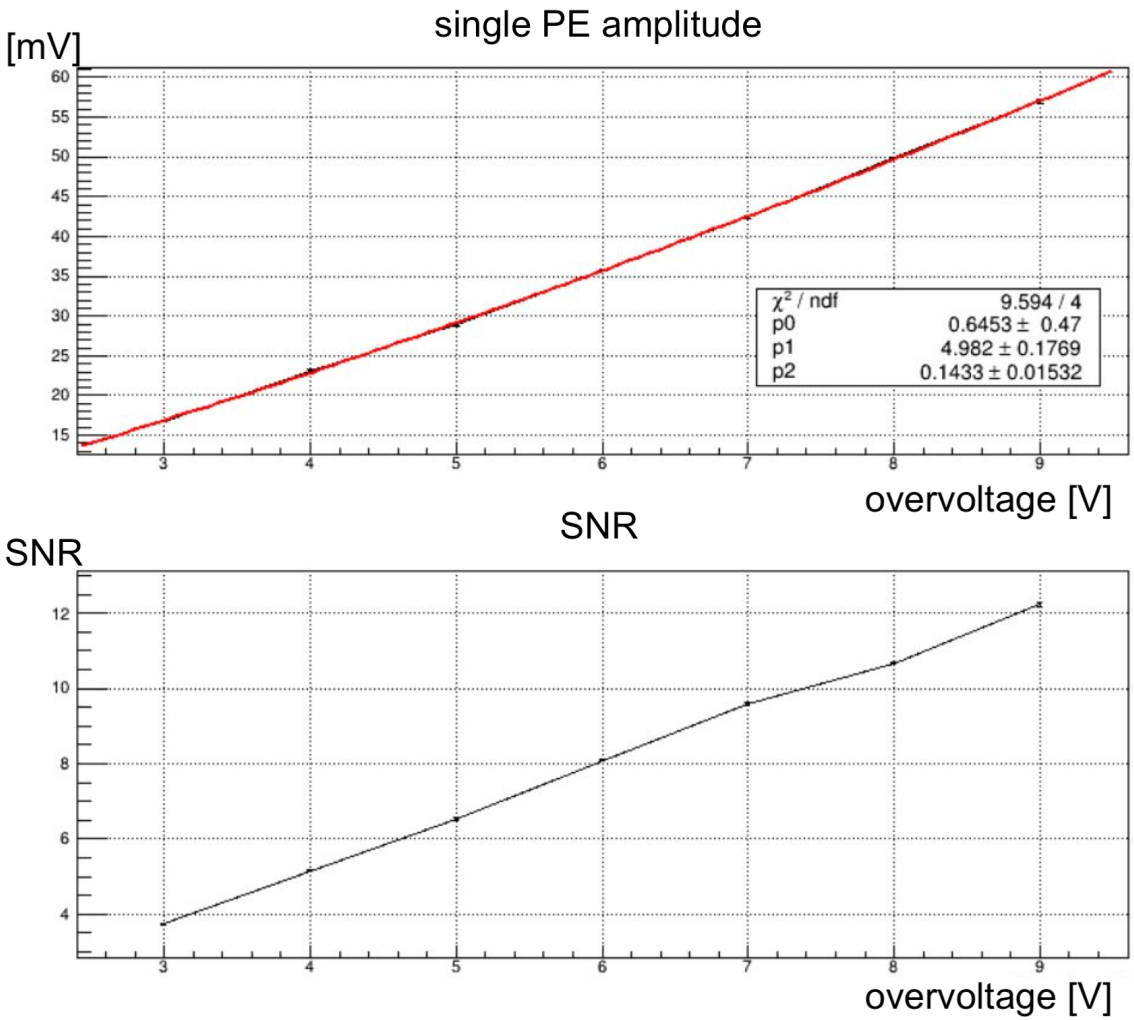
sampling rate: 250 MHz
running mean gate: 120 ns

Multi photoelectron (PE) plot (finger plot) for the veto tile obtained during tests at cold in Genova



Bump on the left comes from noise and depends on the threshold for finding peaks (8 RMS here).

Veto tile tests

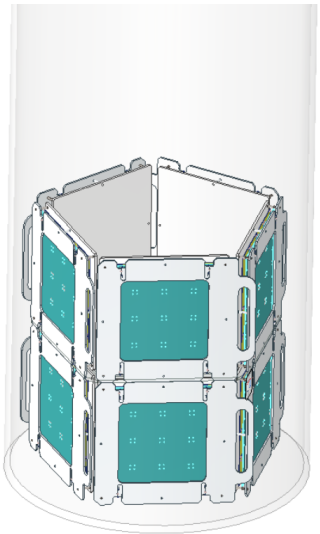


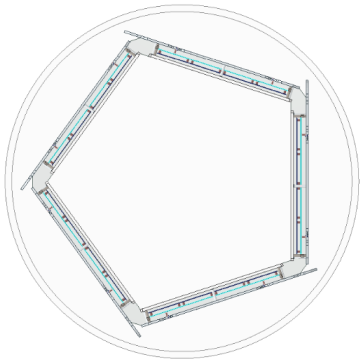
vTile connected to 1/4 Mother Board – @ 7 VoV:

1 PE amplitude = 42 mV, RMS = 4.5 mV, SNR = 9.5

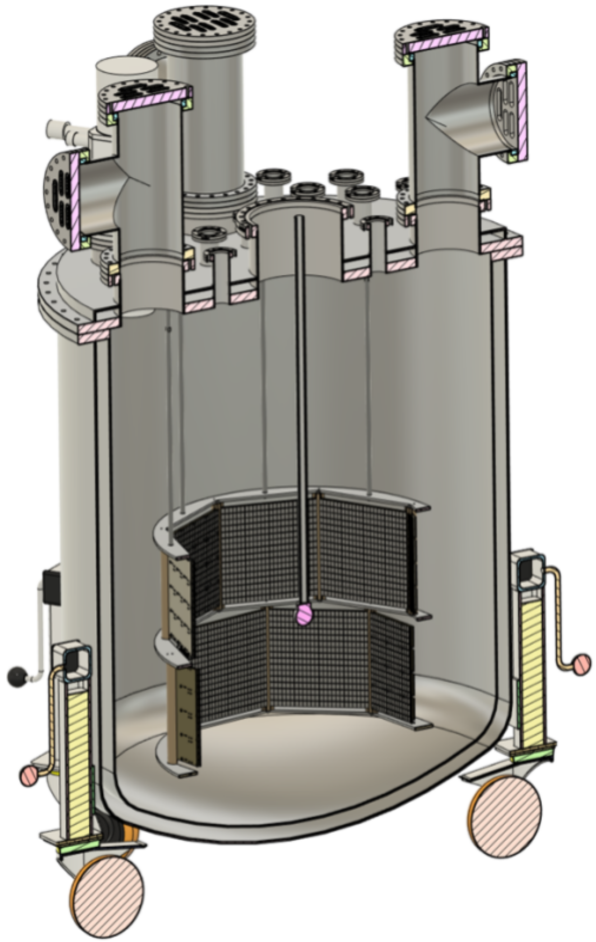
Cryogenic veto PDU tests

- Tests of the final veto PDUs will start this year
- AstroCeNT (Warsaw), Edinburgh and Liverpool
- Cryogenic tests in liquid Nitrogen



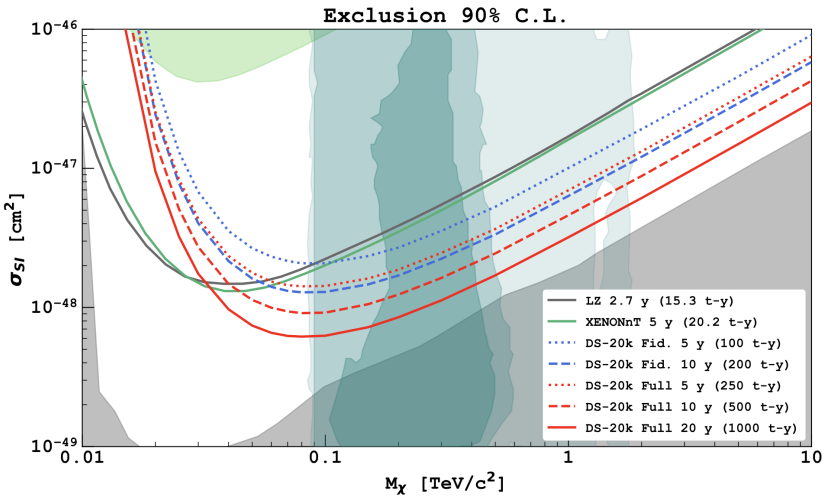


Setup in AstroCeNT: 10 PDUs per 1 week cycle



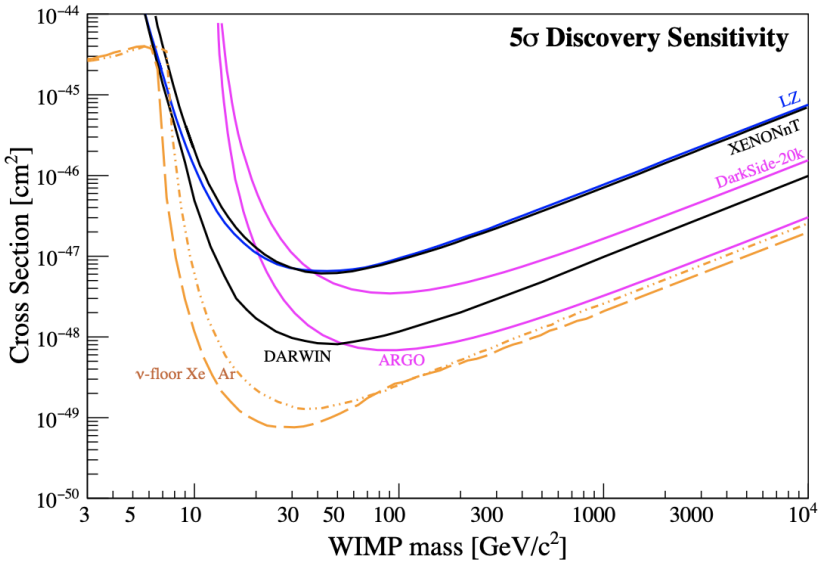
PHAEDRA (Liverpool)

The sensitivity of DS-20k to spin independent WIMPs



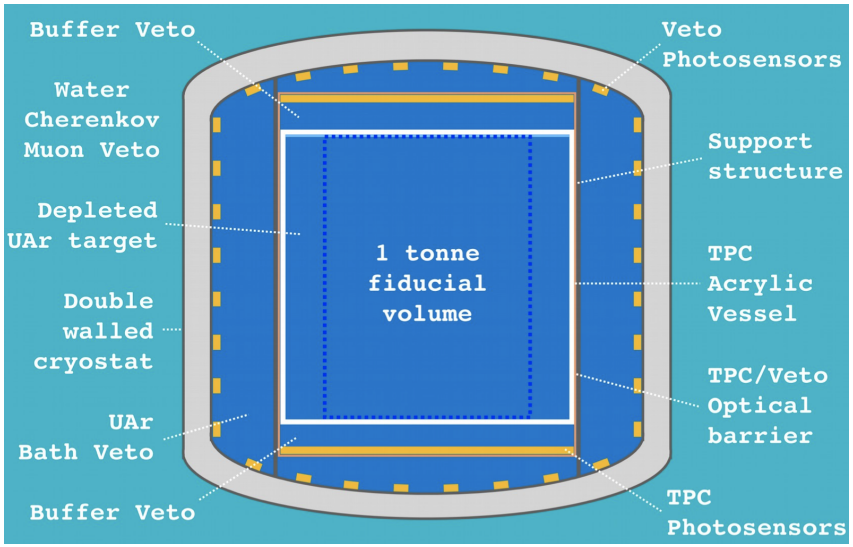
90% C.L. exclusion limits for DarkSide-20K for different lengths of runs compared to the currently funded experiments: LZ and XENONnT that are expected to lead the field for high mass WIMPs searches in the next few years

Direct Detection of Dark Matter – APPEC Committee Report, arXiv:2104.07634



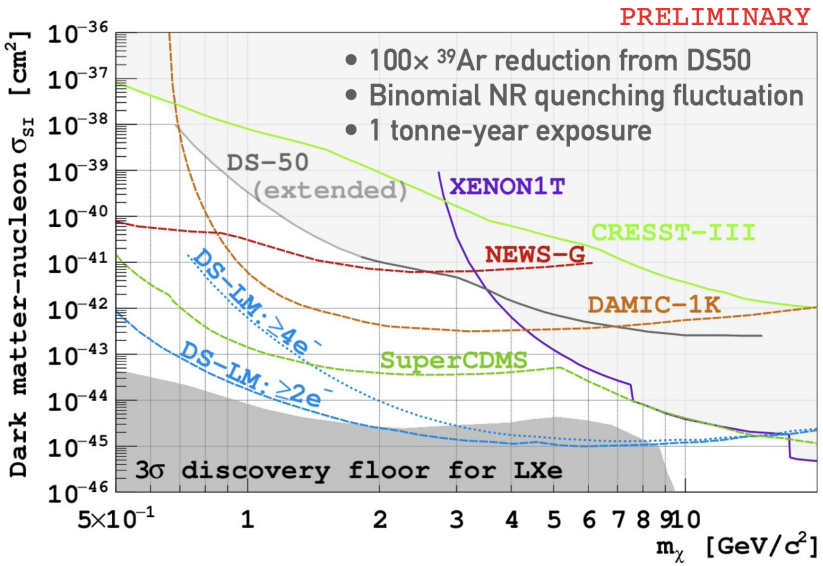
Projected 5σ discovery sensitivity of upcoming and proposed experiments:
- XENONnT (LXe, 20 t-y),
- LZ (LXe, 15,3 t-y),
- DarkSide-20k (LAr, 200 t-y),
- DARWIN (LXe, 200 t-y),
- ARGO (LAr, 3000 t-y).

DarkSide-LowMass (under consideration)



- Would use ionization signal (S2) only
- Ionization threshold < 0.1 keV$_{ee}$ or 0.4 keV$_{nr}$
- Sensitive to a single extracted electron

Discovery sensitivity of DarkSide-LowMass



- Sensitive to low mass WIMPs up to neutrino floor
- Complements DarkSide-20k programme
- 1 year of data taking enables to reach the neutrino floor

Conclusions

- Argon: excellent properties suited to high and low mass WIMP searches
- well developed projects for UAr extraction (URANIA) and purification (ARIA)
- UAr: ^{39}Ar reduction factor of at least 1400
- background-free Dark Matter search thanks to strong PSD, radio pure materials and novel neutron veto
- large scale production of SiPMs started
- construction of the DarkSide-20k cryostat starts now, data taking in 2026
- two complementary detectors: DarkSide-20k and DarkSide-LowMass (under consideration)

Backup - background

Background type	**Bg events in ROI** $[200\,\mathrm{t\,yr}]^{-1}$
(α,n) neutrons from U and Th	9.5×10^{-2}
Fission neutrons from U-238	$<2.3 \times 10^{-3}$
Neutrons from Rn-222 diffusion and surface plate-out	$<1.4 \times 10^{-2}$
Cosmogenic neutrons	$<6.0 \times 10^{-1}$
Neutrons from the lab rock	1.5×10^{-2}
Random surface α decay + S2 coincidence	$<5.0 \times 10^{-2}$
Correlated ER + Cherenkov	$<1.8 \times 10^{-2}$
Uncorrelated ER + Cherenkov	$<3.0 \times 10^{-2}$
ER	$<1.0 \times 10^{-1}$

Nuclear recoil (NR) backgrounds expected during the full DS-20k exposure, based on current data and Monte Carlo simulations.