

Overview of the DarkSide-20k Dark Matter Experiment

Marek Walczak

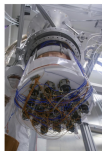
01-09-2026



The Global Argon Dark Matter Collaboration - 500 people



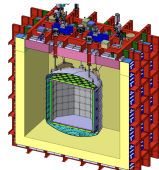
DarkSide-10



DarkSide-50



DEAP-3600



DarkSide-20k
under construction at LNGS

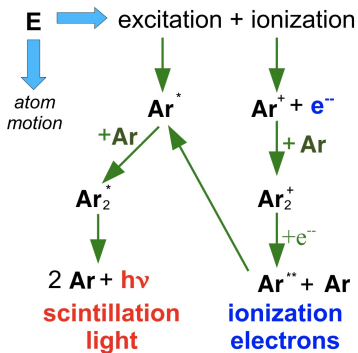
Goals: Darkside-20 and in the future ARGO (SNOLAB, 300 t fiducial)

Argon:

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

Interactions in liquid noble gas

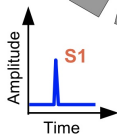
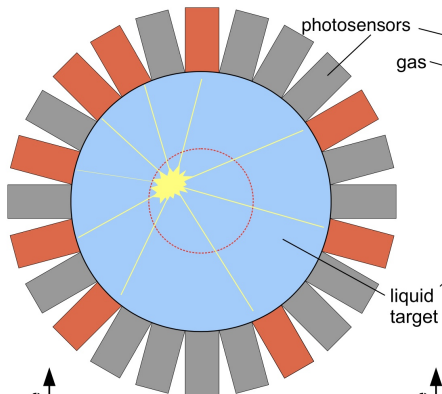
excitation and ionization of the target (Xe works the same)



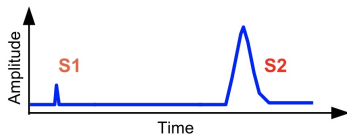
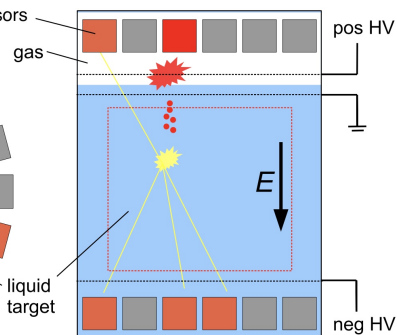
arXiv:1206.2169

Liquid noble gas detector concepts

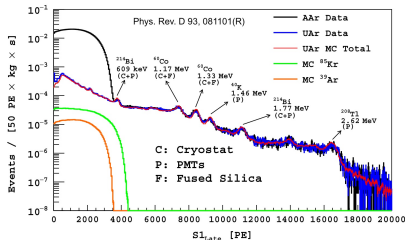
Single Phase Detector



Time Projection Chamber



Underground argon



- ^{39}Ar reduction factor of at least 1400 compared to atmospheric argon (AAr)

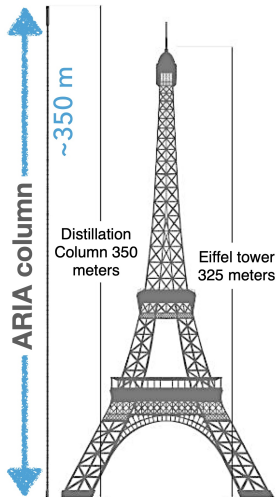


URANIA: Colorado, capacity of 330 kg/day of underground Ar (UAr)

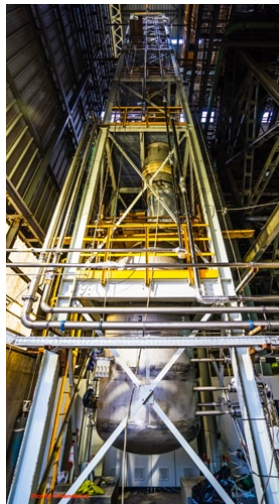


^{39}Ar depletion measured in DArT, Spain

Underground argon: ARIA, Sardinia

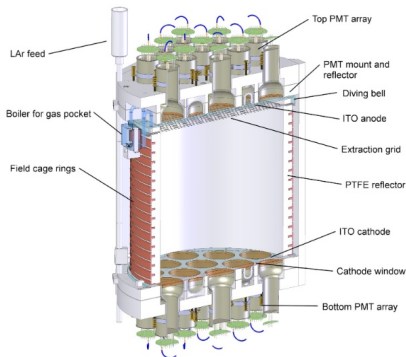


ARIA: 350 m tall column - cryogenic distillation



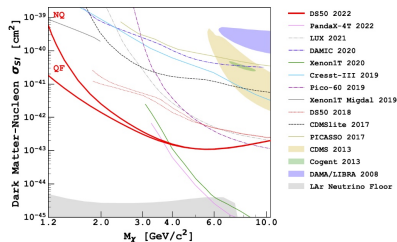
Assembly of the column in progress
[Eur. Phys. J. C 81, 359 (2021), Eur. Phys. J. C 83, 453 (2023)]

Predecessor: DarkSide-50



- underground argon
- dual-phase TPC
- 38 photomultiplier tubes

Phys. Rev. D 107, 063001
(2023)

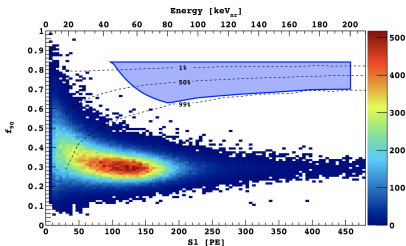


- 524 live-days
- most stringent exclusion for GeV scale dark matter

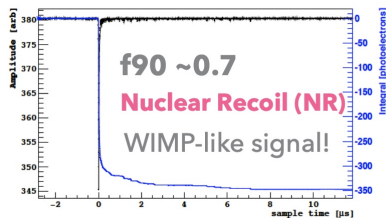
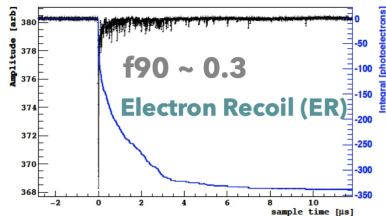
Pulse Shape Discrimination in Ar

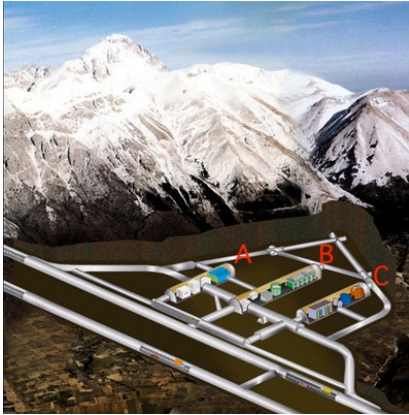
[PHYS. REV. D 98, 102006 (2018)]

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

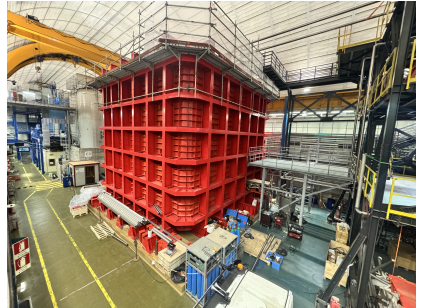


- f_{90} : fraction of the primary scintillation pulse in its first 90 ns
- $S1$: total integral of the primary scintillation pulse (photoelectrons, PE)
- PSD: tool to distinguish light from a recoiling electron and nuclear recoil
- for PSD capabilities for DEAP-3600 detector see also [Eur. Phys. J.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



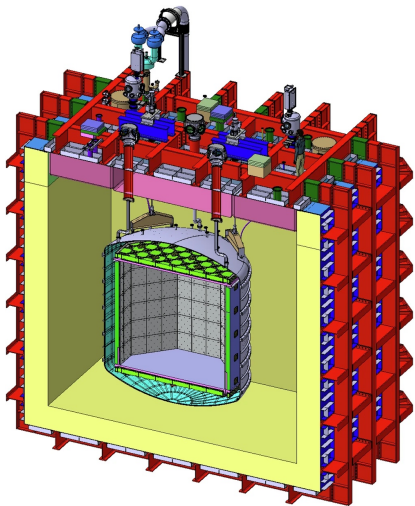


- DarkSide-20k will be installed in LNGS in Hall-C



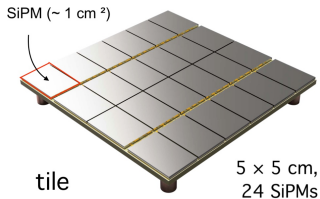
- now under construction
- nominal duration of operation: 10 years

DarkSide-20k (DS-20k) overview

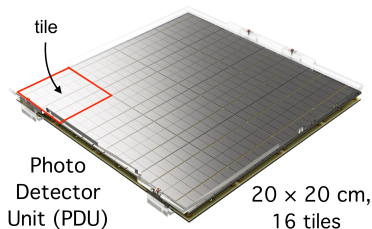


- Time Projection Chamber (TPC) filled with 50 t of underground Ar (UAr) (20 t fiducial)
- Inner Veto (IV): 32 t of UAr between the TPC and the vessel (neutron tagging)
- Outer Veto (OV) filled with 650 t of atmospheric Ar (AAr) (muons and their shower products)
- WLS: TPB coating in TPC, PolyEthylene Naphthalate (PEN) foils in the veto

Light detection

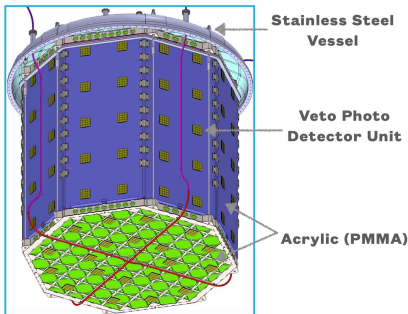


one channel: 4 tiles



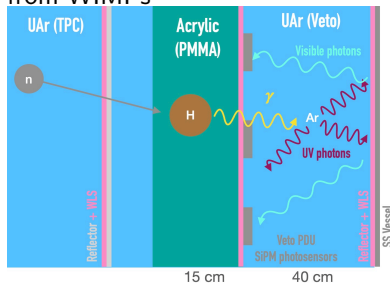
- Low noise at **88 K**
- Tuned sensitivity vs light spectrum
- SNR** for single tile > 13
- Photon detection efficiency: 45%
- Timing resolution: 10 ns
- **Dark-count rate**: few-tens mHz/mm^2
- 26 m^2 overall

Neutron Veto



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

Neutrons elastically scattering from argon nuclei are indistinguishable from WIMPs



- Neutrons are moderated and captured in the PMMA
- multiple γ s are emitted
- UAr scintillation light is shifted and detected by veto photodetectors

Goals of the Data Acquisition system (DAQ)

To reduce possible sources of bias, the DAQ:

- continuously acquires signals from the TPC and vetos (**triggerless operation**),
 - system doesn't wait for the trigger decision,
- the waveforms are digitized and transferred for further processing,
- analysis of the signals for physics searches delegated to a computing farm.

Readout channels:

	PDUs	channels
TPC	528	2112
IV	120	480
OV	30	120
total	678	2712

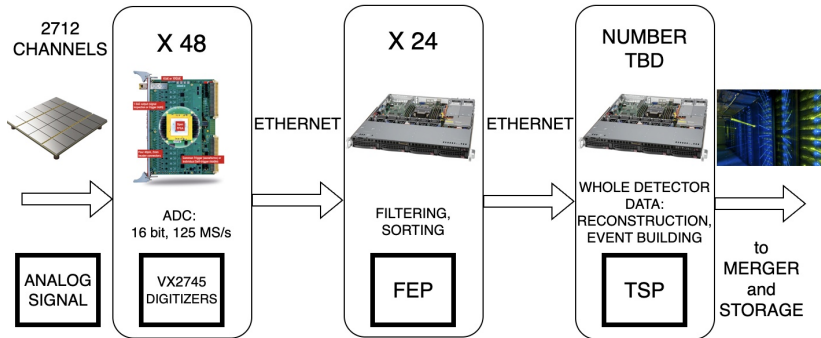
4 **identical racks**, each having:

- 12 **waveform digitizers** receive analog data from PDUs
 - (48 in total)

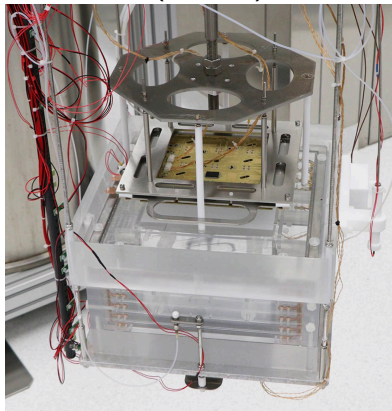
Additional racks in IT room:

- 24 **Front End Processors (FEPs) machines**
 - (1 per 2 digitizers)
 - readout, filtering, sorting
- **Time Slice Processors (TSPs) machines**
 - number under discussion
 - receive sorted data from FEPs
 - analysis, sending data for storage

Data Flow (simplified)



PROTO-0 (Naples)



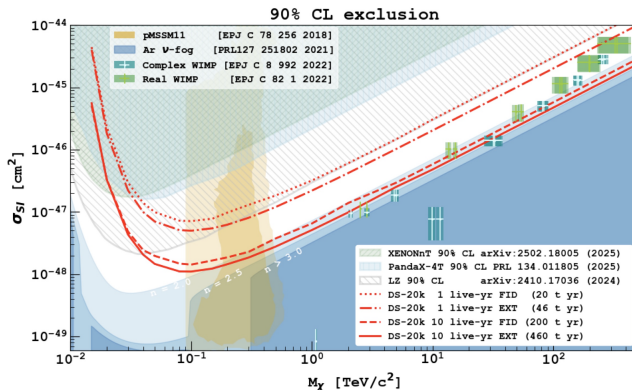
- First data with Photon Detection Units in LAr
- Successfully demonstrated dual-phase operation

MOCKUP (LNGS)



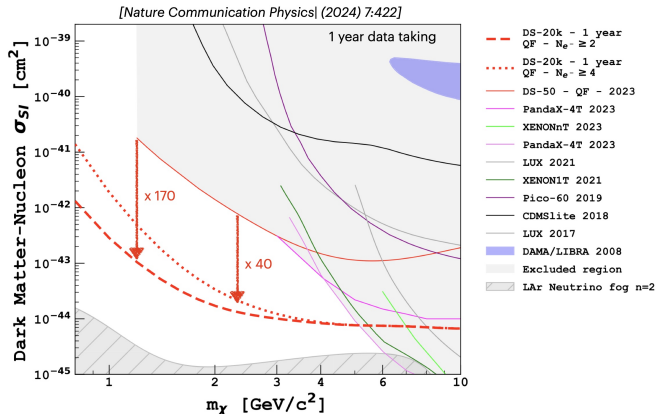
- Tonne-scale mockup: integration, thermal cycling, high voltage connection

DS-20k sensitivity to high mass WIMP



- > FID: low instrumental background rate < 0.4 events in ROI (30-200 keVnr) with 200 t-yr exposure
- > EXT: background dominated by radiogenic neutrons from photosensors and experimental hall

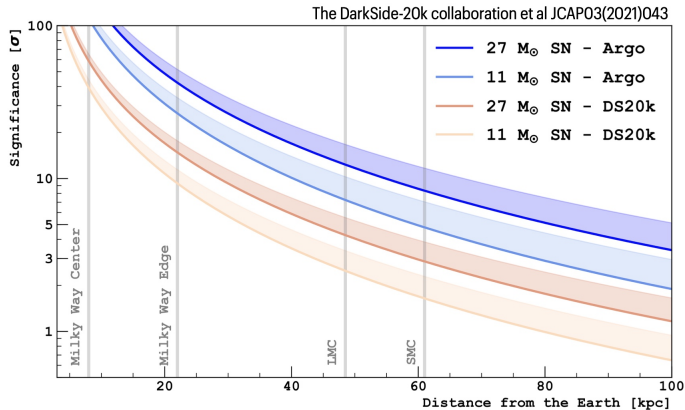
DS-20k sensitivity to light dark matter



-> Conservative (almost indep. of Spurious Electron (SE) modelling): Fit from $= 4 N_e$

-> Ultimate: Fit from $= 2 N_e$ assuming good control spectral shape of SE in DS-20k

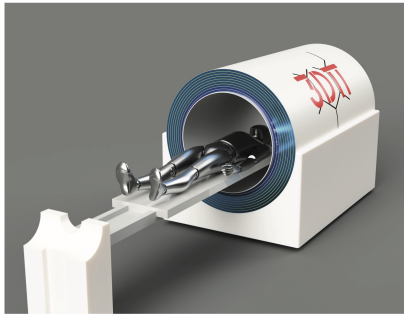
DS-20k sensitivity to supernova neutrinos



- > coherent elastic neutrino-nucleus scattering, S2 only analysis
- > DS-20k is sensitive to all flavors of neutrinos from supernovas within our galaxy

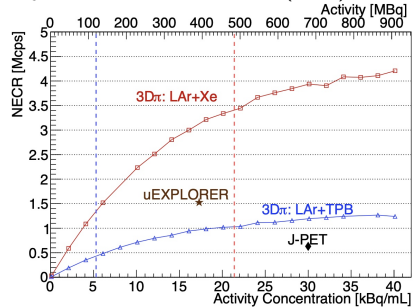
Technology transfer: Positron Emission Tomography (PET)

ongoing work on UAr + SiPM based next gen PET



- Lower radiation dose / higher res images
- Quicker scans
- Lower cost

Phys. Med. Biol. 70 065015 (2025)



noise equivalent count rate
(NECR)

Summary

- The construction of DarkSide-20k is ongoing at LNGS
- The high-mass WIMP sensitivity complementary with Xe-based detectors
- Leading sensitivity below 5 GeV
- Expect to probe > 1 order of m. of uncharted theory parameter space within 1 year for a variety of DM particles
- Sensitive to supernova neutrinos within our galaxy
- Possible technology transfer to medicine (PET)



DarkSide-20k collaboration @ LNGS