Construction progress of the DarkSide-20k Dark Matter Search experiment

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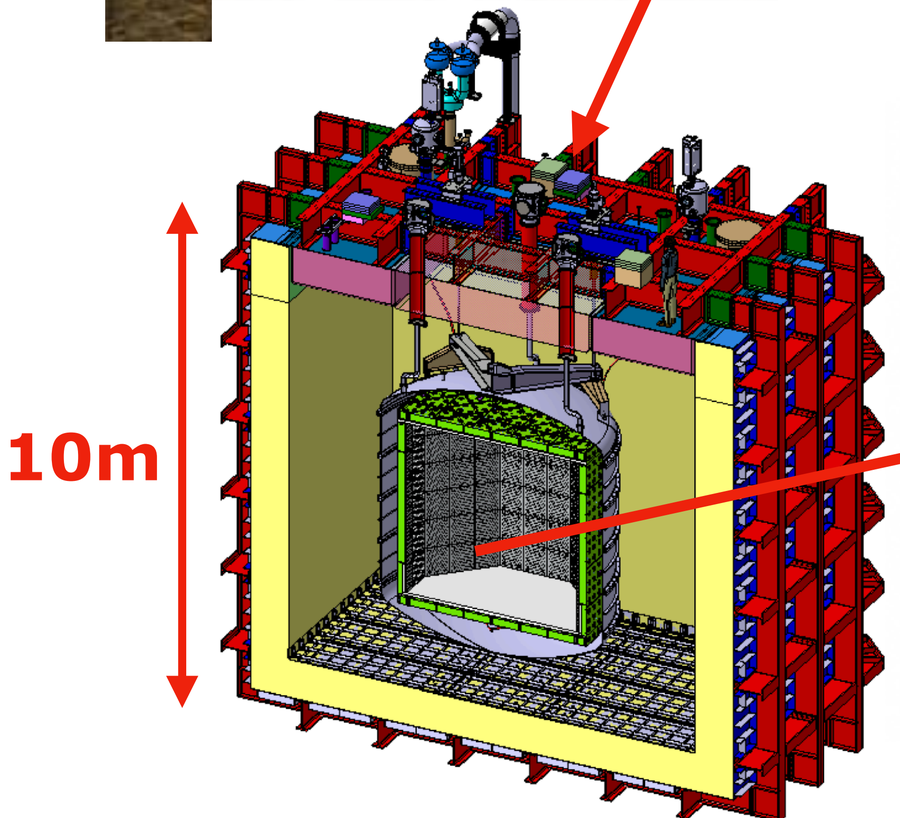
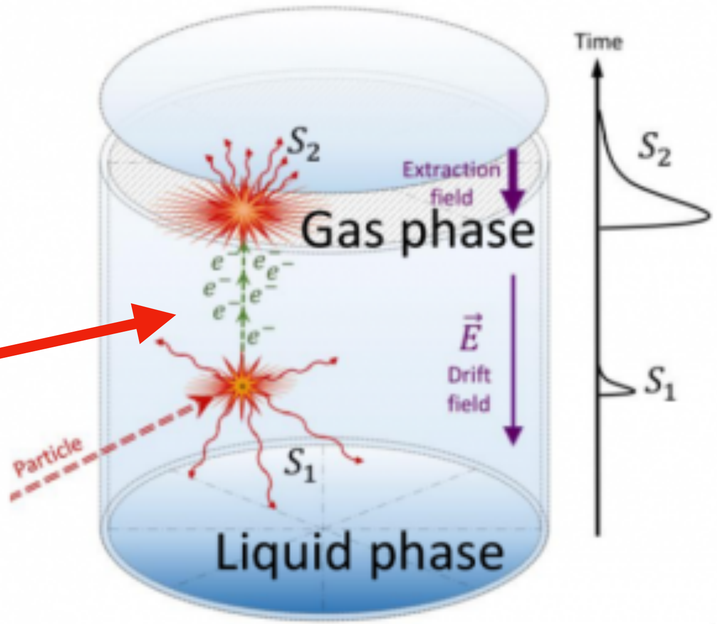
On Behalf of DarkSide-20k collaboration
IOP JOINT APP and HEPP annual conference
10/04/2026, Edinburgh

The DarkSide-20k program

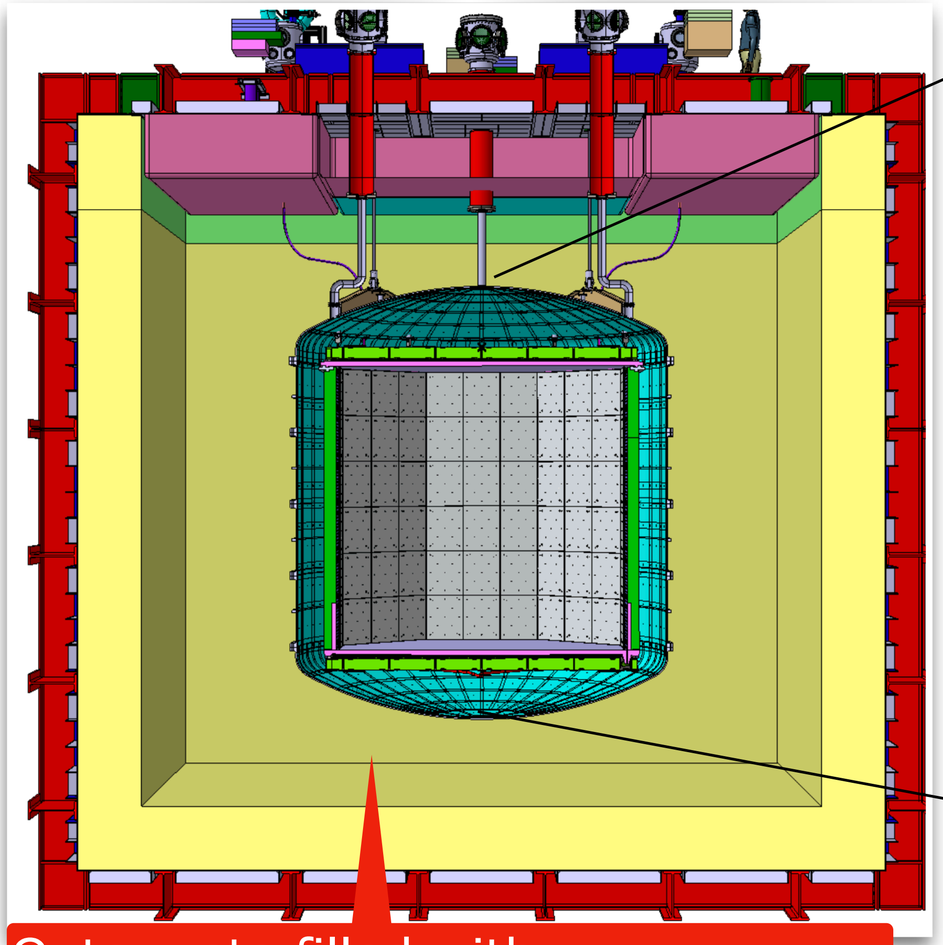
- Global liquid Argon Dark Matter Collaboration (DarkSide-50, DEAP, MiniClean, ArDM)
- Located underground in LNGS
- Detection: dual phase Time Projection Chamber -> S1 (scintillation) + S2 (charge)

Aim to operate in free instrumental background for 10 years

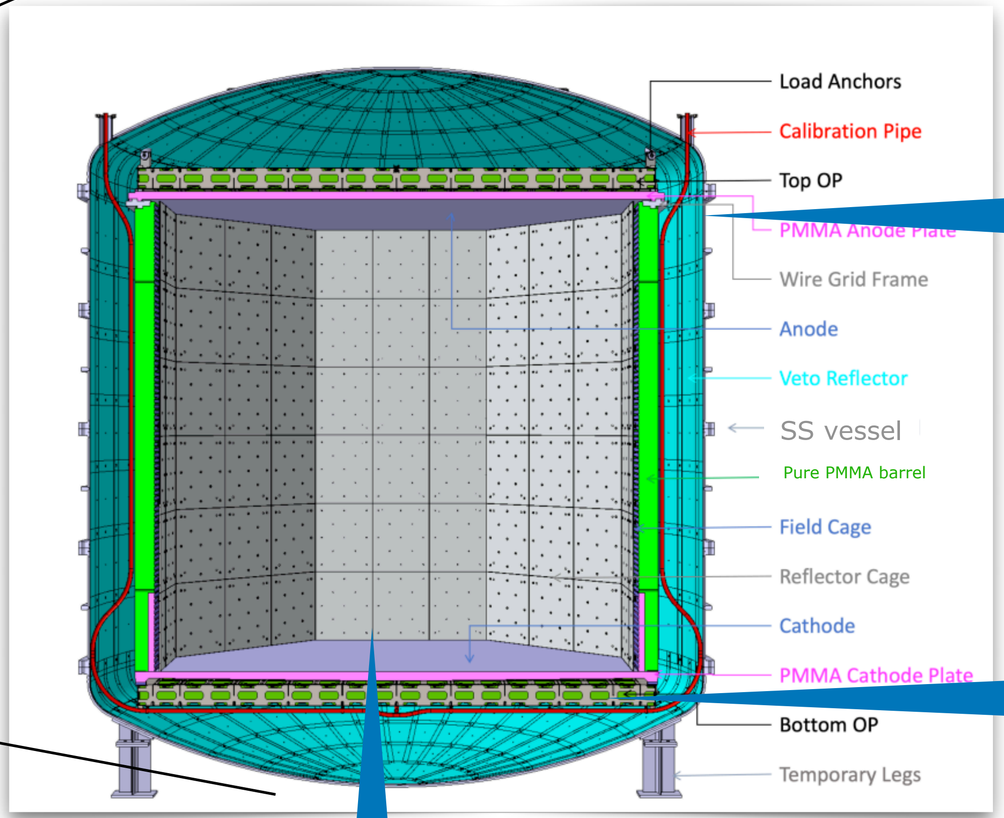




DarkSide-20k: overview



Inner detector



Pure PMMA barrels act as neutron veto

Large SiPM light detector on TPC TOP/ bottom and on PMMA wall

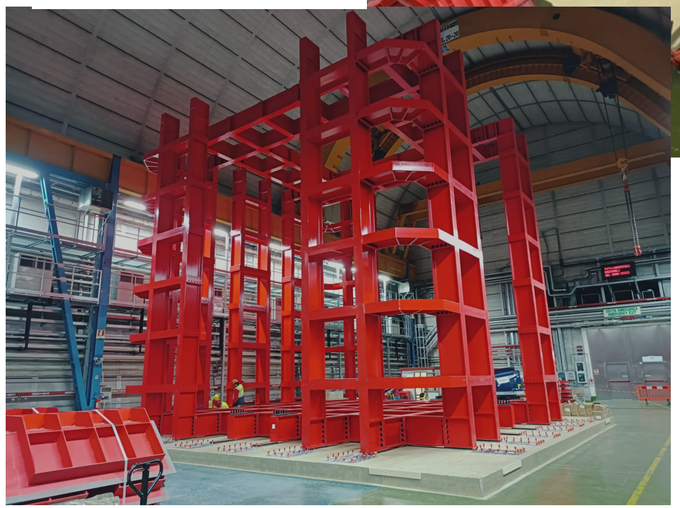
Outer veto filled with 650 tonnes of atmospheric argon as a cosmogenic veto

radiopure underground argon (UAr):
50 (20) active (fiducial) tonnes in TPC
35 tonnes in the inner veto

DarkSide-20k: Construction phase

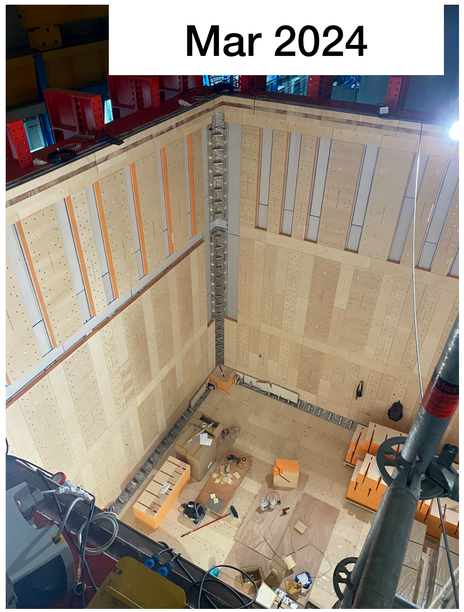
Construction started in 2023

June 2023



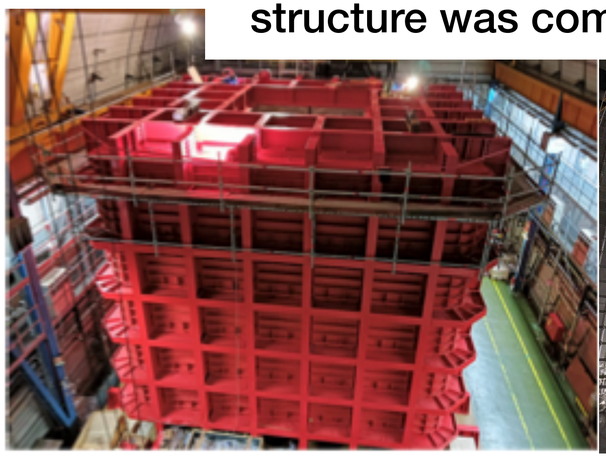
Nov 2023

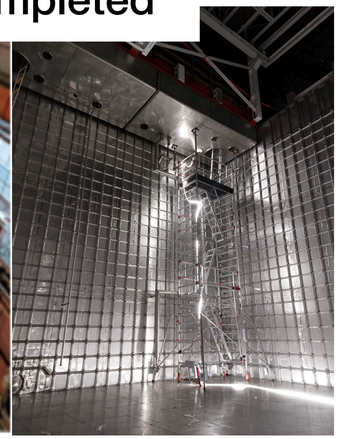
Jan 2024



Mar 2024

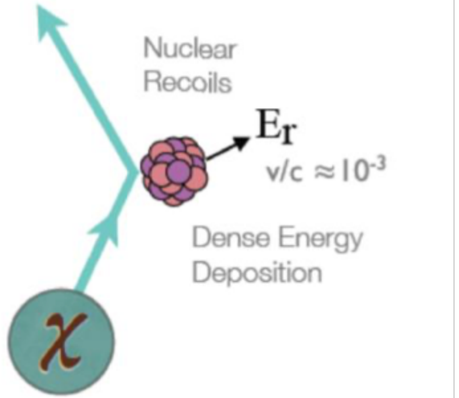
In 2025, the external structure was completed





WIMP signal and Backgrounds

WIMP SIGNAL



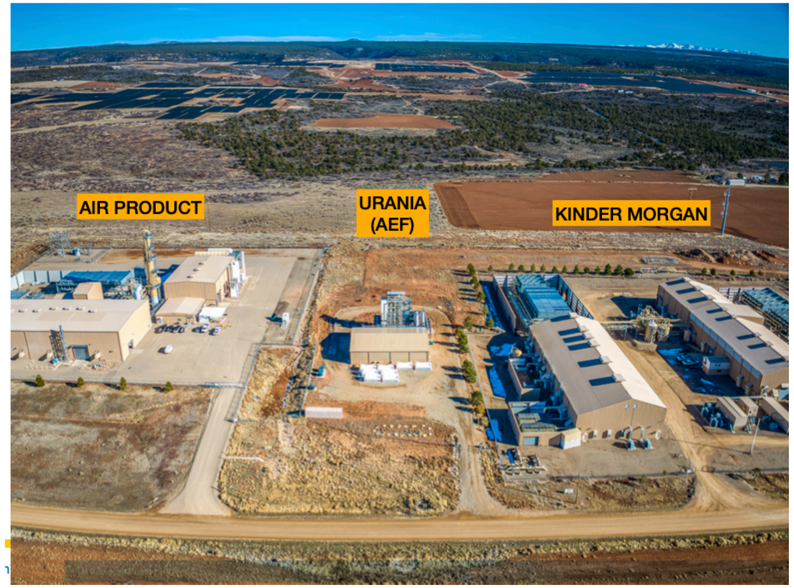
- Single nuclear recoil
- Recoil energy between 1 and 100 keV

BACKGROUNDs

Background source	Mitigation strategy
^{39}Ar β decay	Use Underground Argon + pulse shape discrimination
γ from rock and γ,e from material	Pulse shape discrimination Material selection
Radiogenic neutron **(α,n) reaction in detector material**	Material screening & selection Definition of Fiducial volume in the TPC **A 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 scatter	Irreducible

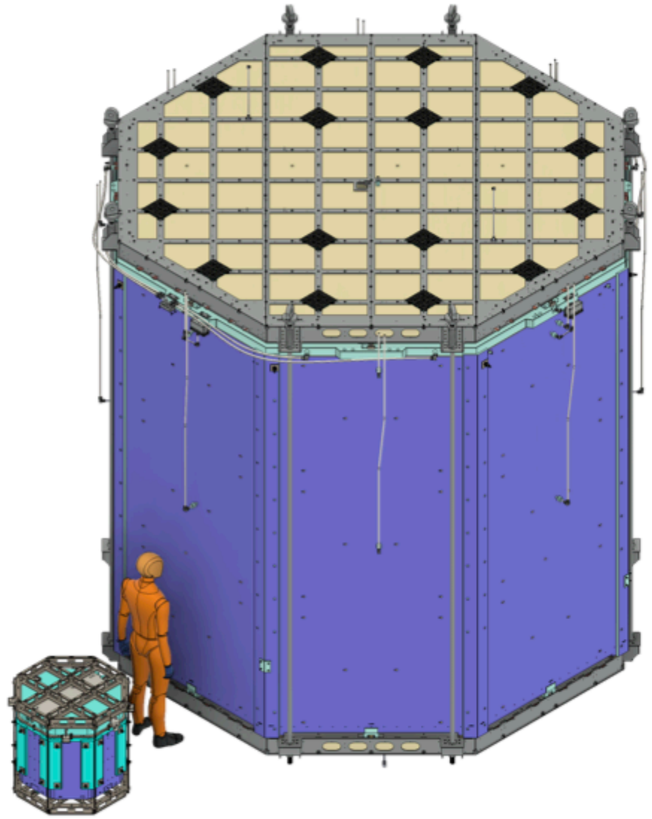
Key technology for DarkSide-20k

Underground argon extraction



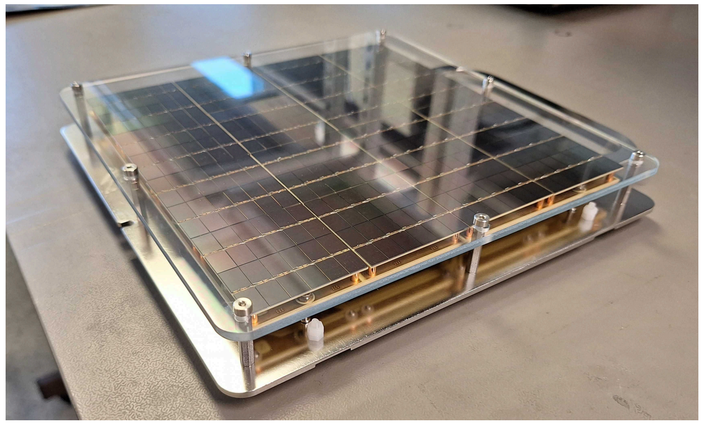
reduction of 1400 in ^{39}Ar compared to atmospheric argon

Radiopure PMMA TPC



Integrated system for neutron tagging

Largest and radiopure SiPM detector array (20 x 20 cm^2)



Total coverage of 26 m^2

THE PATH TOWARDS PURE UAr: Urania->Aria->DArT

1. Urania: UAr extraction

- UAr extraction plant in Cortez, Colorado, USA
- UAr extraction rate up to 330kg/day with 99.99% purity

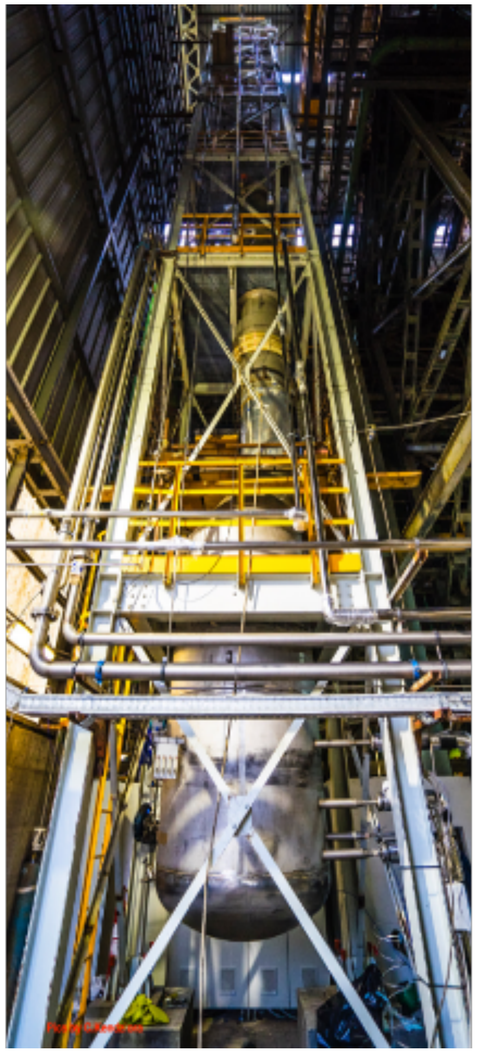
Colorado

2. ARIA: UAr purification

- Cryogenic distillation column in Sardinia (Italy)
- First module operated according to specs with nitrogen in 2019
- Chemical purification rate: 1 t/day

Eur.Phys.J.C 81 (2021) 4, 359

Italy



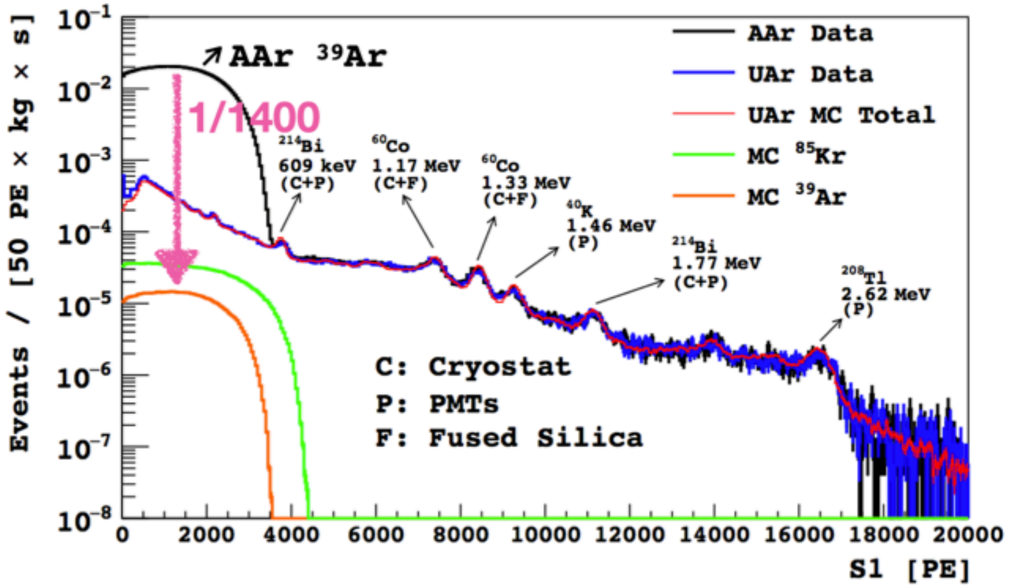
Spain

3. DART

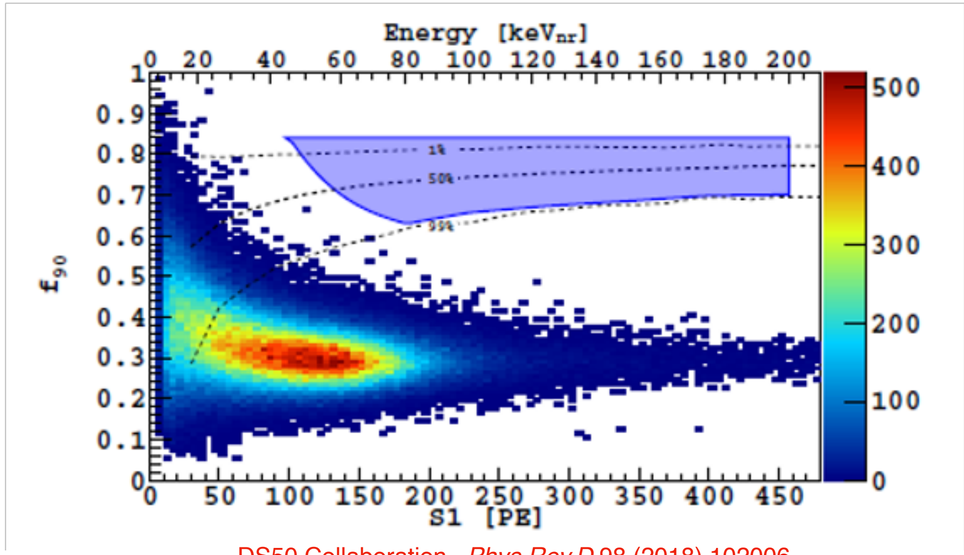
- Double phase TPC with active volume of 1.4 kg of liquid UAr located at Canfranc, Spain
- Ar-39 depletion factor sensitivity: 6 x 10^4 90% C.L

Advantage of UAr and pulse shape distrimiation

DS-50 results: Phys. Rev. D 93, 081101(R) (2016)



Electronic recoils are rejected by pulse shape discrimination, as demonstrated by DS-50 & DEAP



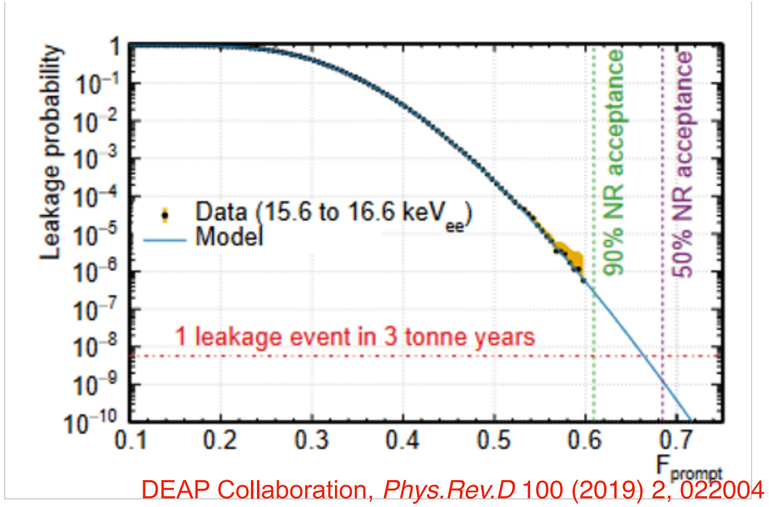
DS50 Collaboration., *Phys.Rev.D* 98 (2018) 102006

Ar-39 depletion factor in UAr: around 1400

- **TPC= 50 tons -> 36 Hz of Ar-39**
- **Veto = 35 tons -> 26 Hz of Ar-39**

Mitigated with pulse shape discrimination:

- residual background is < 0.01 events / 200 tonne x year
- dead time negligible

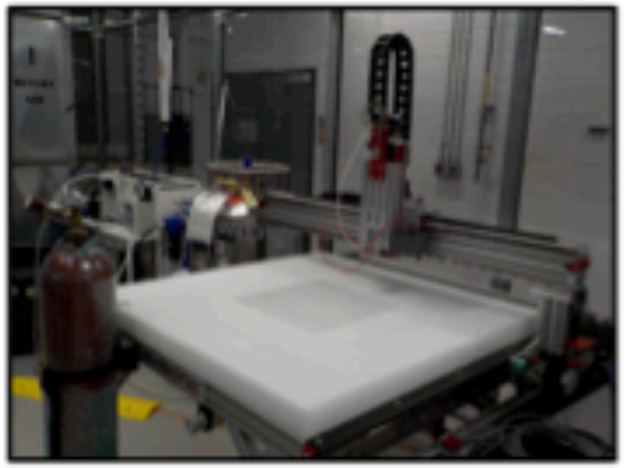


DEAP Collaboration, *Phys.Rev.D* 100 (2019) 2, 022004

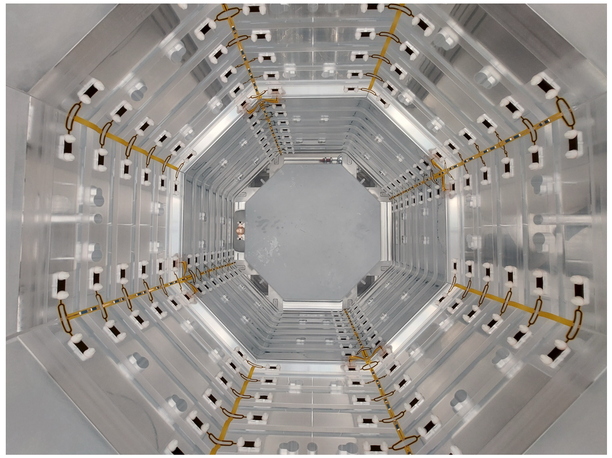
DarkSide-20k TPC: pure PMMA

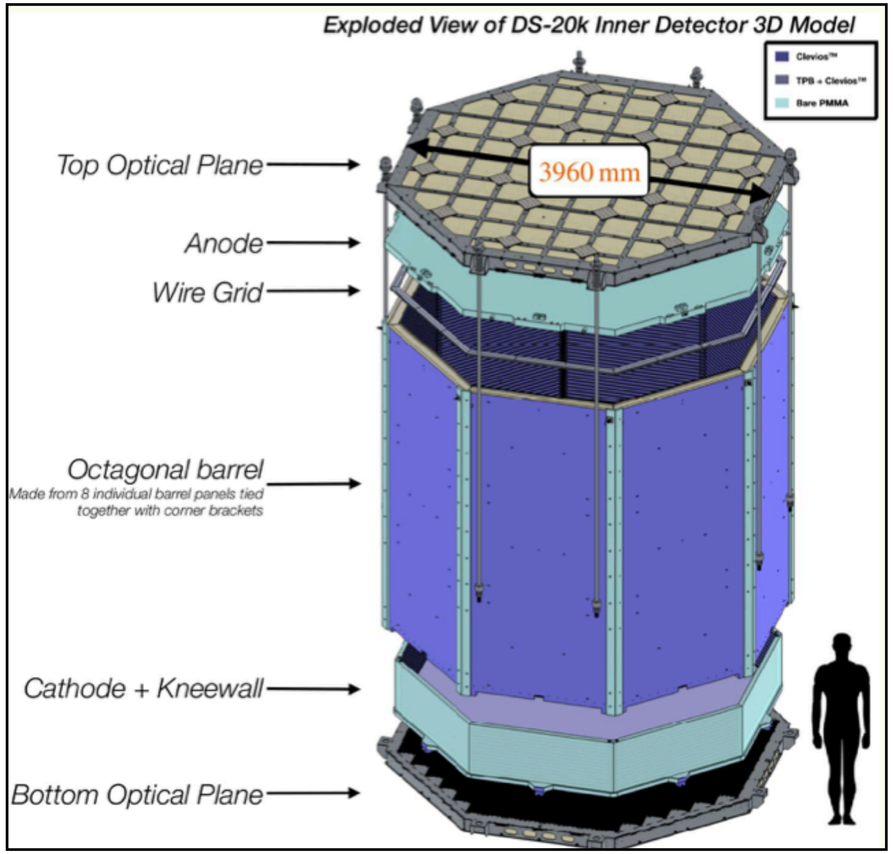
- Octagonal shape dual phase TPC made in pure PMMA
- Transparent conductive polymer coating Clevios + TPB on cathode, anode and barrel
- Reflector around barrel (ESR)
- Two optical plates on top and bottom

CNC Table for Clevios Spray Coating



Evaporation chamber

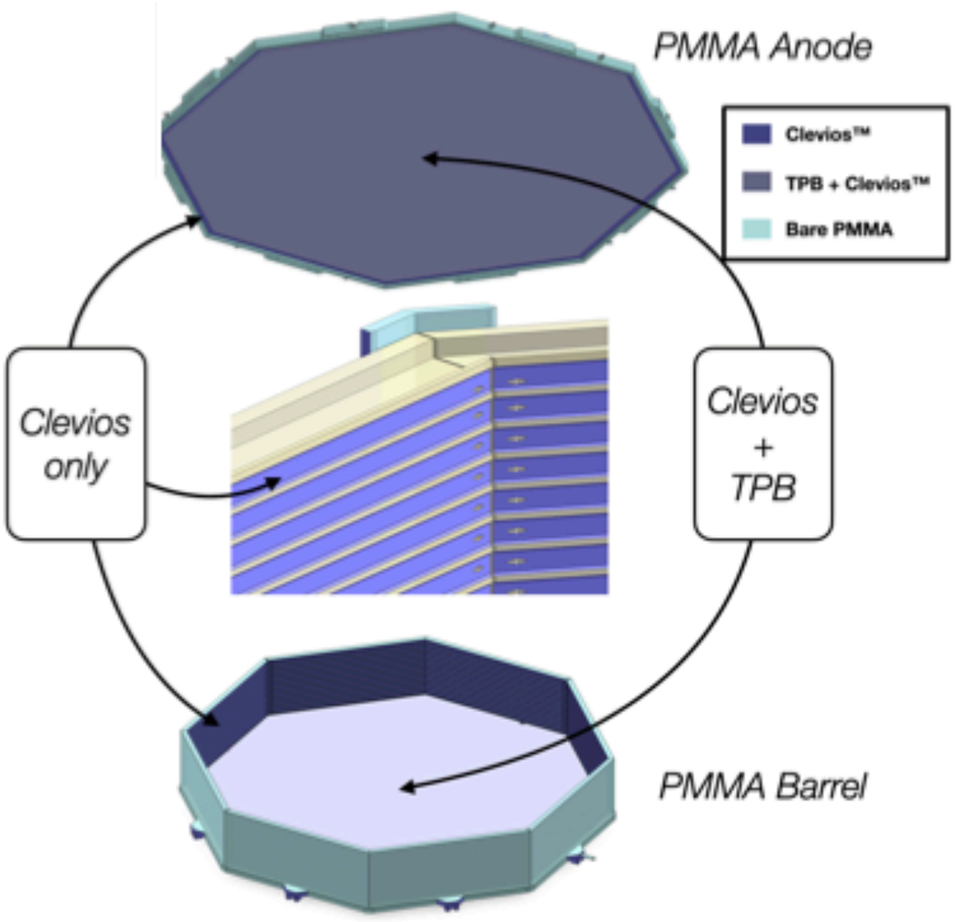




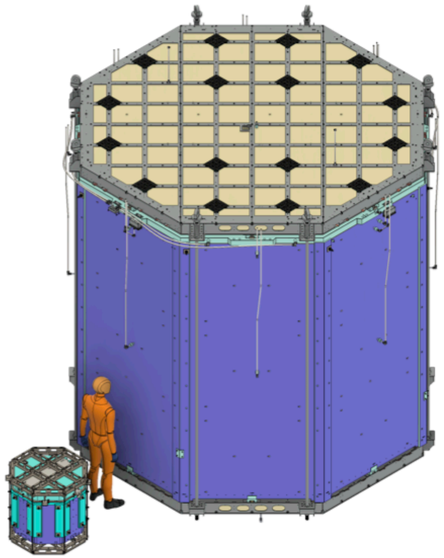
S1: 10 pe/keV
S2: 20 pe/e-

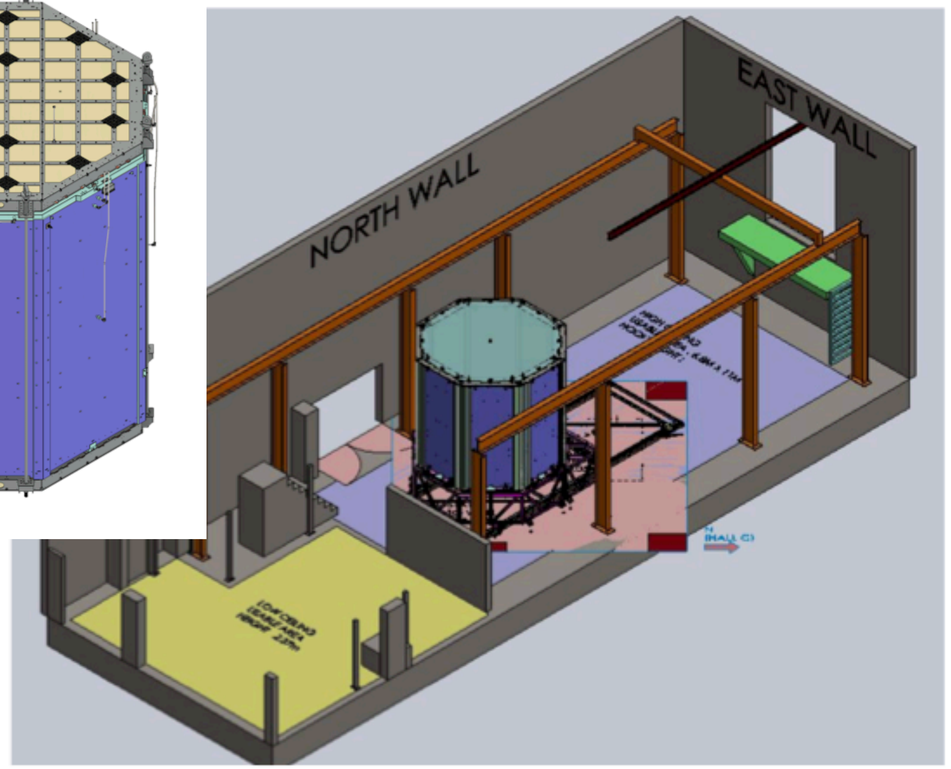
TPC construction underway

Large surface coating (Charleston)



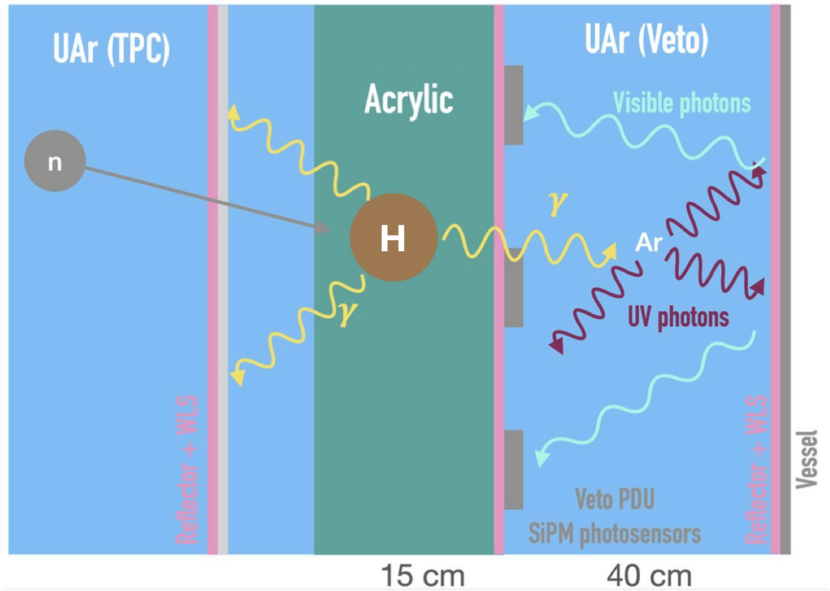
TPC dry fit (Alberta)





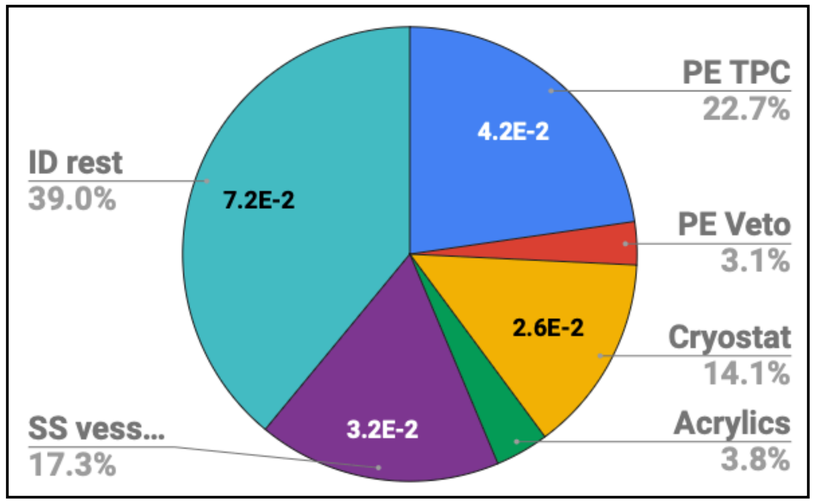
See A.Thompson talk on Monday 8th, DM session
Prototype Validation Studies for the DarkSide-20k TPC

Neutron detection



- 15 cm pure PMMA surrounding the TPC as neutron moderator
- Detection mostly on Hydrogen and Argon
- Detecting gamma rate produced on Hydrogen (2.1 MeV) and on Argon (6 MeV)
- Detection on veto argon buffer or on TPC

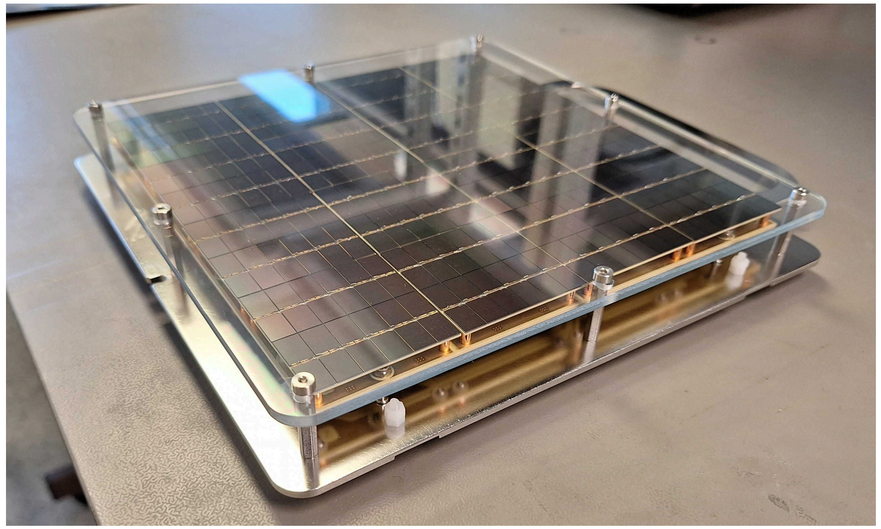
- **Neutron identification**:
  - Single NR
  - Energy in ER: 30< E_{NR}<200 keV_{NR}
  - R-z position cuts—> FV = 20 tons
  - Energy deposit in ER in the TPC > **50 keV OR** energy deposit in UAr veto > **200 keV**
  - TPC-veto window of 800 μs



<0.21 neutron WIMP like event in 200 tonnes x years

Readout: LARGE SiPM ARRAY

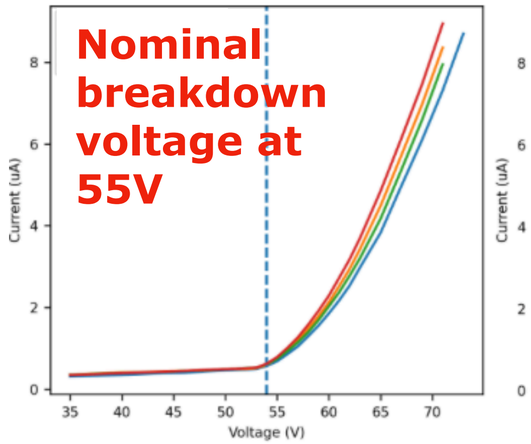
Photo detection unit (PDU)

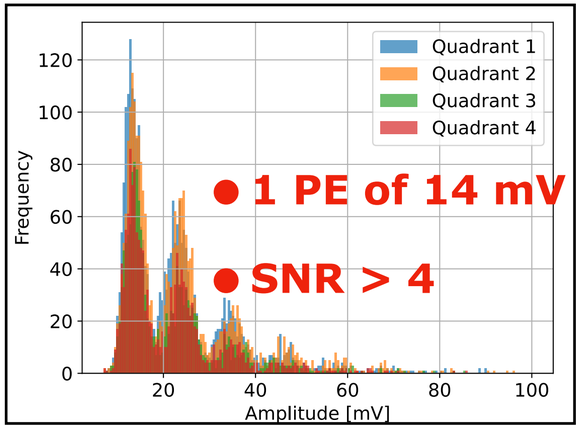


- Compact design to minimize surface
- 16 tiles are assembled together in a **PDU**: **20 x 20 cm²**
- 1 large PCB to individually enable/disable and bias each single tile and to sum the signals from a quadrant
- 4 tiles are summed together, i.e. 4 tiles correspond to 1 DAQ channel
- **4 outputs: 1/4 DAQ channels -> 1/4 cables-> lower radioactivity**

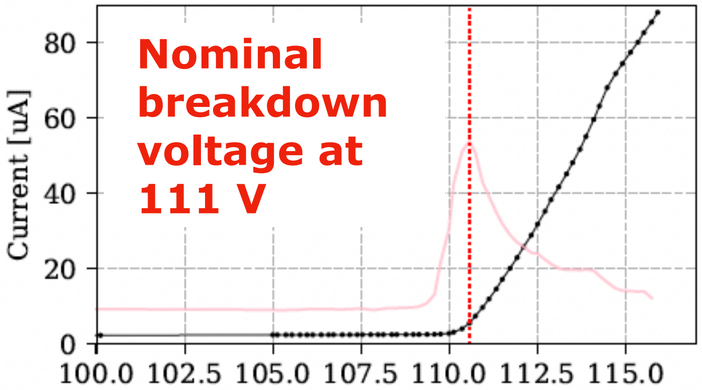
Laser calibration in liquid nitrogen of TPC-veto PDU determines whether a PDU has a single PE performance good enough to be integrated into the detector.

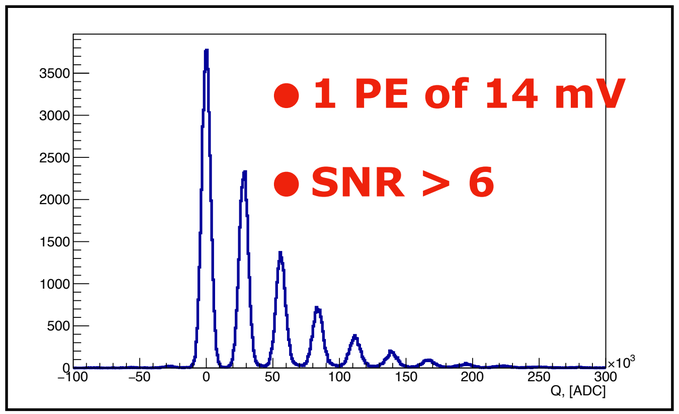
Veto PDU





TPC PDU





Largest Readout area 10x10 cm²

Readout: LARGE SiPM ARRAY

Photo detection unit (PDU)

-
-
-
- signals from a quadrant
- 4 tiles are summed together, i.e. 4 tiles correspond to 1 DAQ channel
- **4 outputs: 1/4 DAQ channels -> 1/4 cables-> lower radioactivity**

More talks:

E. Ellingwood on Thursday 9th: "*Cryogenic characterization of the DarkSide-20k veto photo-detector units" ,detector session*

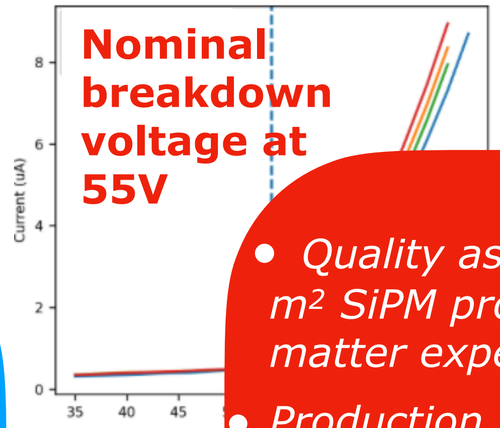
I. Seargent on Thursday 9th : "Preparing for DarkSide-20k veto photodetector installation", precision measurement session

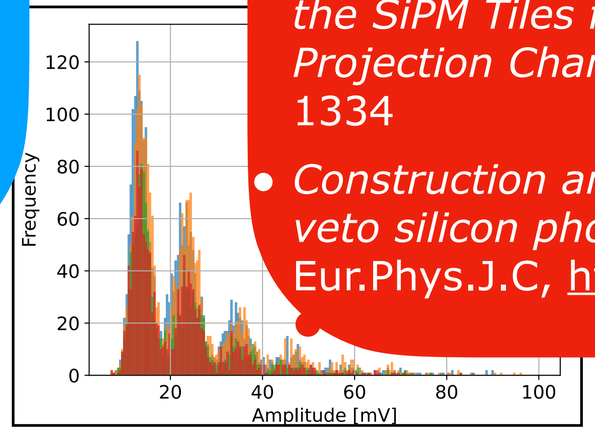
Later …

P. Franchini:"*Production of 26 m² of SiPM Detectors for DarkSide-20k"*

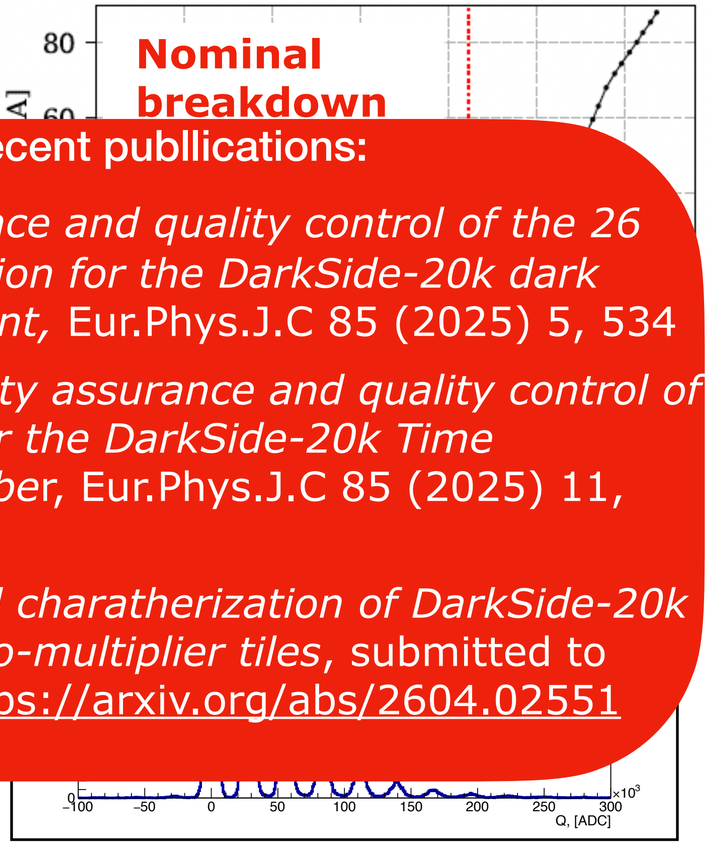
Laser calibration in liquid nitrogen of TPC-veto PDU determines whether a PDU has a single PE performance good enough to be integrated into the detector.

Veto PDU





TPC PDU



Recent publlications:

- *Quality assurance and quality control of the 26 m² SiPM production for the DarkSide-20k dark matter experiment,* Eur.Phys.J.C 85 (2025) 5, 534
- *Production, quality assurance and quality control of the SiPM Tiles for the DarkSide-20k Time Projection Chambe*r, Eur.Phys.J.C 85 (2025) 11, 1334
- *Construction and charatherization of DarkSide-20k veto silicon photo-multiplier tiles*, submitted to Eur.Phys.J.C, https://arxiv.org/abs/2604.02551

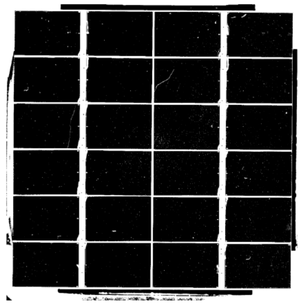
Largest Readout area 10x10 cm²

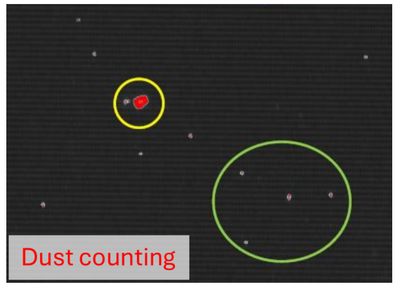
Building a radio-pure detector

1. All components and a full board has been assayed

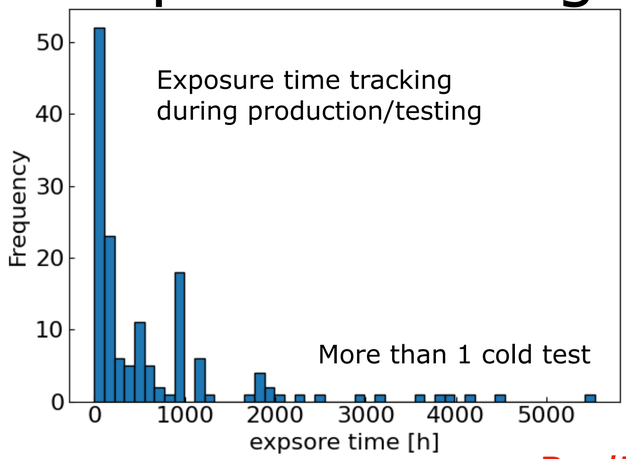
Isotope	Summed components activity [mBq/vTile]	Populated vTile activity [mBq/vTile]
^{238}U-up	$0.91\ ^{+0.18}_{-0.17}$	1.2 ± 0.6
^{238}U-middle	1.28 ± 0.10	0.9 ± 0.1
^{238}U-bottom	33.7 ± 1.9	60.2 ± 4.2
^{232}Th	0.50 ± 0.06	0.4 ± 0.2
^{40}K	$4.8\ ^{+0.5}_{-0.4}$	5.1 ± 1.0

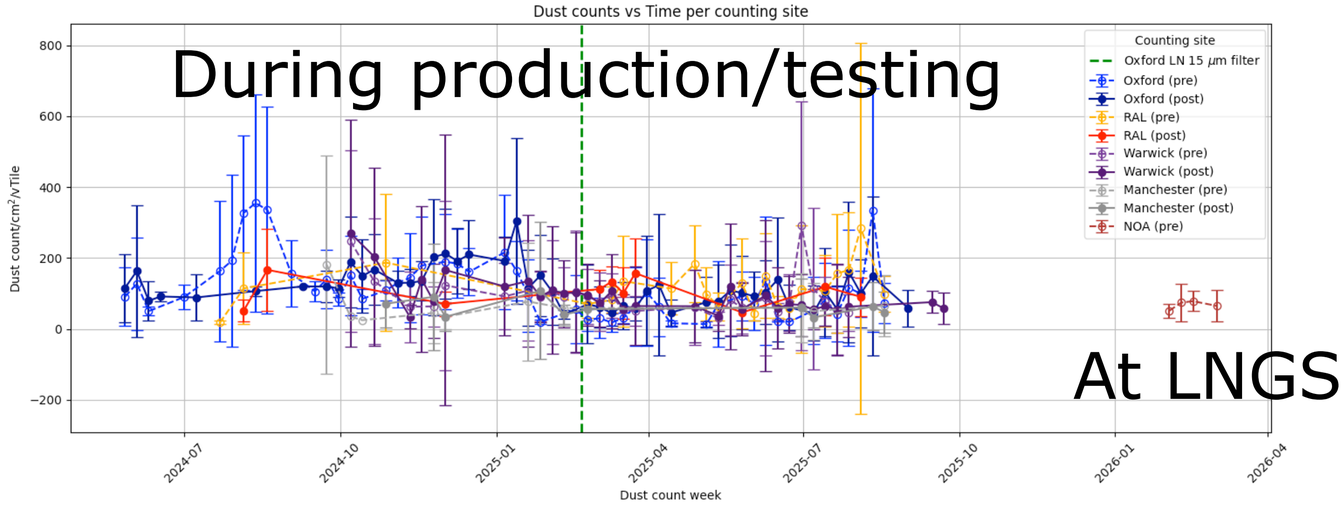
2.Dust monitoring during production & testing





3. Exposure timing tracking

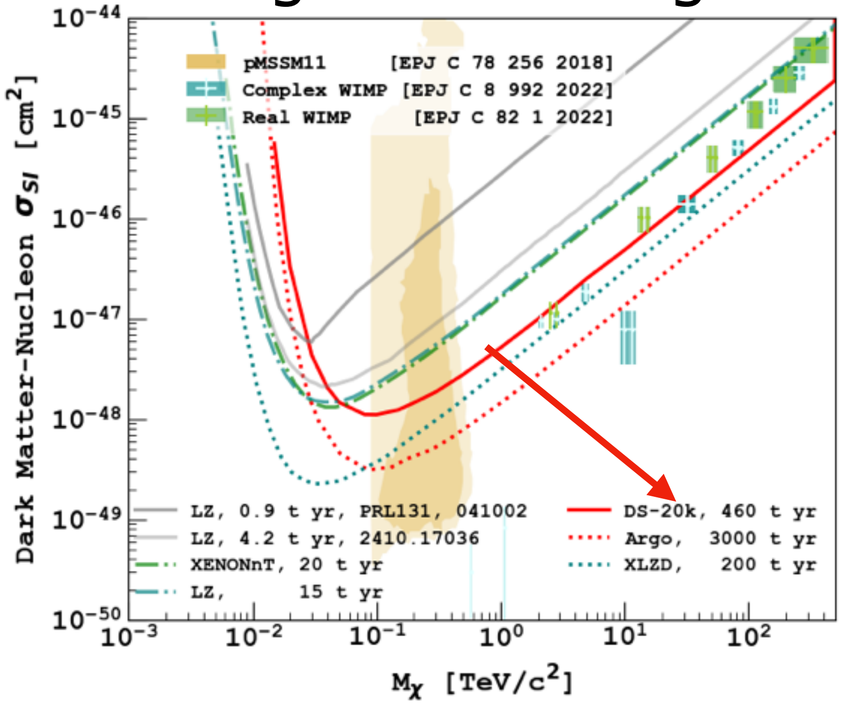




Radio-purity control is essential to minimize background; the photodetector case has been reported, and similar efforts are ongoing for other components to reduce exposure time and surface contamination

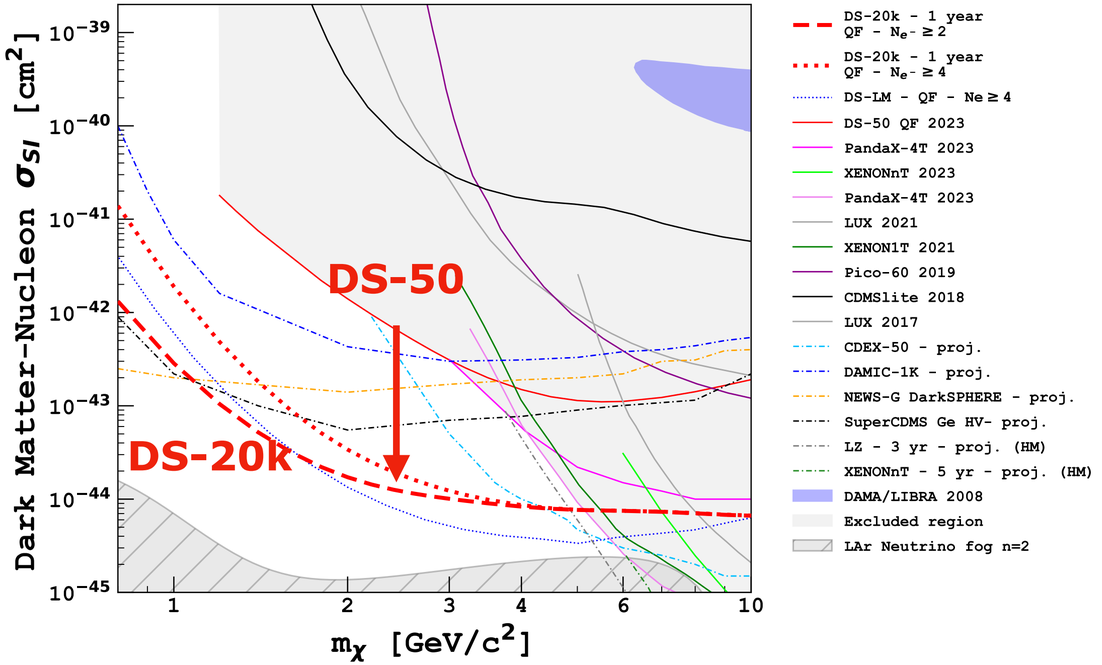
Dark matter search

High mass range



Sensitivity to high mass WIMP-nucleon scatter cross section of 7.4 x 10-^{48} cm^2 for a 1 TeV/c^2 WIMP for a total exposure of 200 tons x years

Low mass range

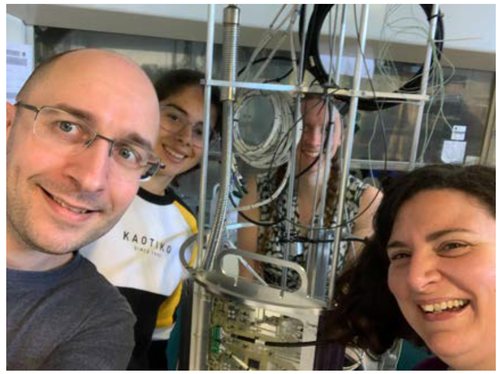


S2 only analysis, sensitivity below 5 GeV/c^2, more than 1 order of magnitude respect DarkSide-50

See talk A. Ritchie-Yates on Monday 8th, DM session
Spin-dependent dark matter sensitivity of DarkSide-20k

Conclusions

- **DarkSide-20k is pushing the state-of-the-art in several directions**: SiPM technology, underground argon extraction & purification, background assay campaign
- **DarkSide-20k stands among the leading direct detection experiments for WIMPs**, with sensitivity complementary to collider and indirect searches
- **Fundamental role played by neutron veto detector** which is key to achieving free instrumental backgrounds to the dark matter search! And expanding the reach beyond heavy WIMPs…
- DarkSide-20k construction is advancing:
  - Outer cryostat structure **complete in 2025!**
  - Veto PDUs completed in **March 2026!** TPC production 50%, completed **by 2027**
  - TPC production, argon extraction and purification **ongoing….**



Thank you for listening

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The University of Chicago · Princeton University · UC Riverside · UC Davis · Virginia Tech
Fort Lewis College · University of Hawai'i · PNNL · Williams College · University of Washington

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Questions?