

The DarkSide-20k Experiment and the future of Dark Matter Liquid Argon Program.

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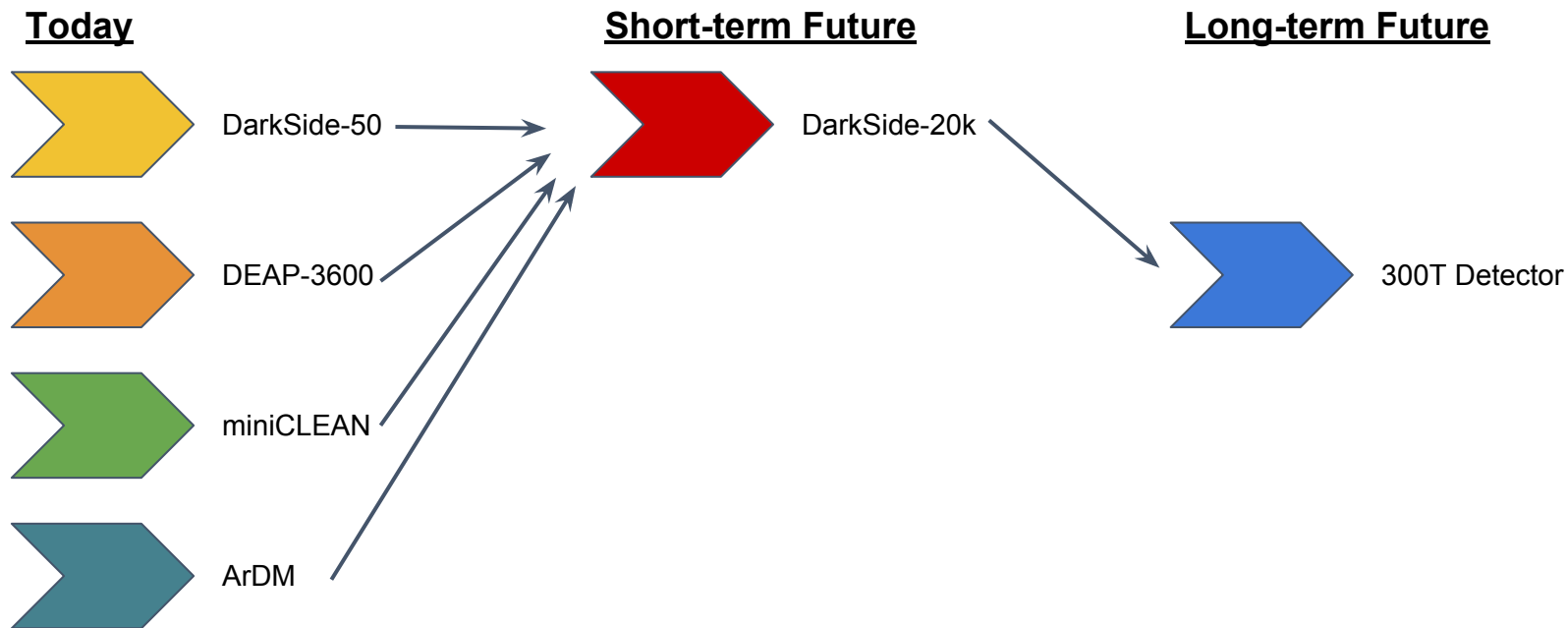
Outline

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- The Global Argon Dark Matter Program
- The DarkSide-20k Experiment
- Cryogenic SiPMs for DarkSide-20k
- Low-Radioactivity Underground Argon
- Conclusions

Global Argon Dark Matter Program

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Global Argon Dark Matter Program

Letter of Intent signed at the Canadian Embassy in Rome, September 2017.
More than 350 researchers, ~80 institutions world-wide.
Supporting letter from from Underground-Physics Laboratories directors.

Letter of Intent
September 8, 2017
Rev B

Scientists at LNGS, LSC, and SNOLAB are joining in an international effort to mount a phased argon dark matter program with the goal of being sensitive to the neutrino floor. This effort will include a broad collaboration of scientists and will represent the global community for dark matter searches with argon. This letter is an update of a previous communication dating June 2017, which detailed the first conception of the program; this letter was expanded to capture the intent of all institutions and scientists participating in the program.

In this document, the undersigned representatives of groups working on argon dark matter searches, including Brazilian, Canadian, Chinese, French, German, Greek, Italian, Mexican, Polish, Romanian, Russian, Spanish, Swiss, US, and UK groups among others, memorialize their intent to form a Global Argon Dark Matter Collaboration to carry out a program for direct dark matter searches, consisting of two main elements.

The first element of the program is the DarkSide-20k experiment at LNGS, whose science goal is to perform a dark matter search with an exposure of 100 tonne-yr of low-radioactivity underground argon (the low intrinsic background, free from any background



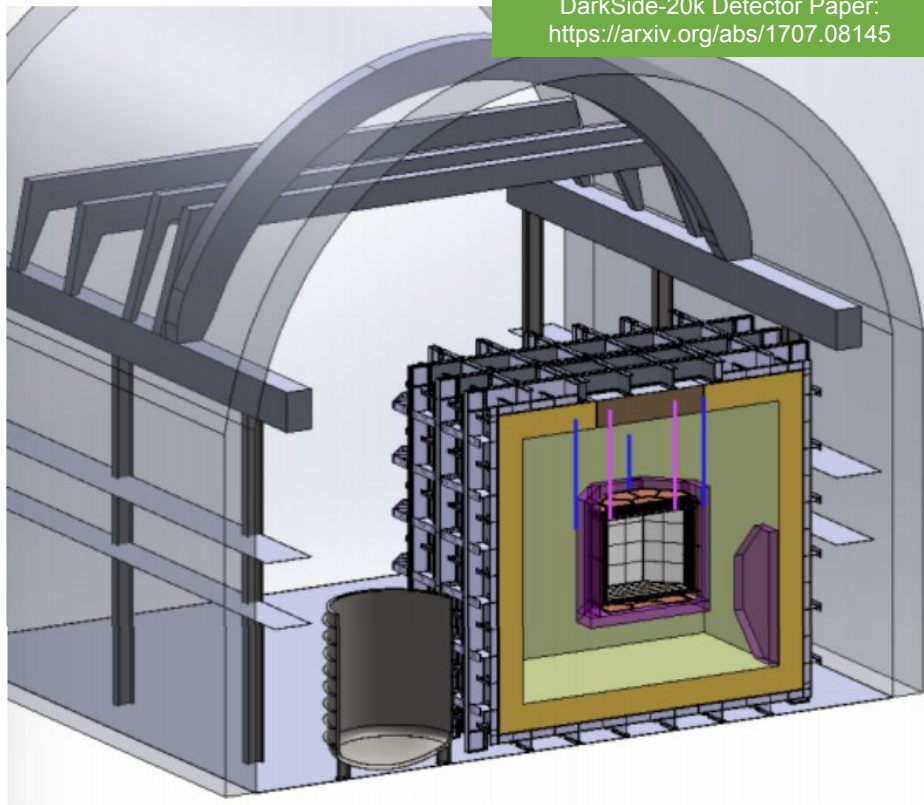
Deep underground laboratory support for global collaboration towards discovery of dark matter utilising liquid argon detectors.

To whom it may concern;

As hosts of the existing operational liquid argon direct dark matter detectors, and as proponents and supporters of the Underground-GRI initiative, the LNGS, SNOLAB and LSC deep underground research facilities are pleased to recognize the collaborative developments within the global liquid argon dark matter community. The DarkSide project at LNGS, the DEAP project at SNOLAB and the ArDM project at LSC are all developing new technologies and capabilities to search for WIMP dark matter, and are beginning to coalesce into one collaboration to develop future, larger generations of liquid argon direct dark matter detectors. We encourage and support the development of this global community, with a focus on the development of DarkSide-20k at LNGS in the first instance, and a larger detector at a location to be determined from scientific requirements, in the future. Using available assay and research infrastructure, the three deep underground research facilities will support the activities and development of the various generations of liquid argon detectors.

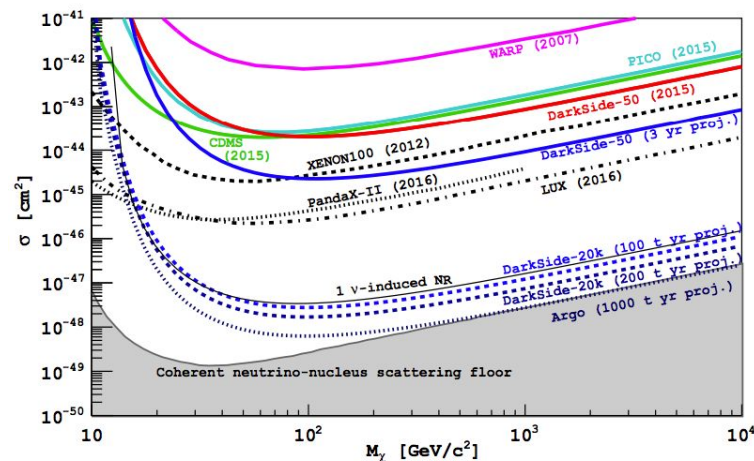
DarkSide-20k Experiment

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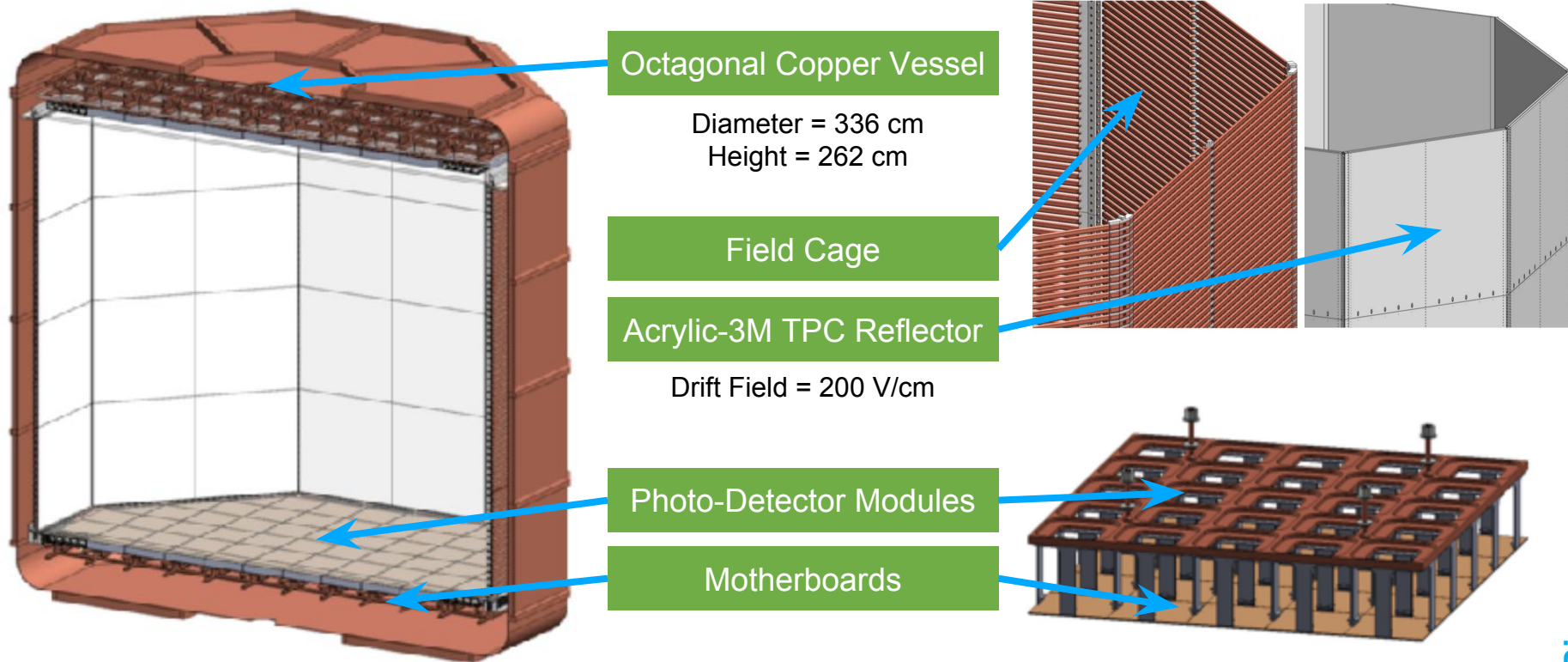
DarkSide-20k Detector Paper:
<https://arxiv.org/abs/1707.08145>

- ~50 tonne dual-phase LAr time-projection chambers, ~30 tonne of fiducial mass.
- 14 m² of SiPM light coverage.
 (low intrinsic background, high LY).
- High-efficiency neutron active-veto.
 (goal of 0.1 neutron / 100 tonne year)



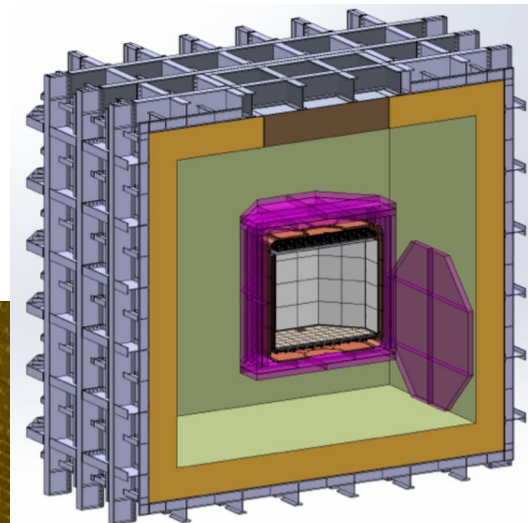
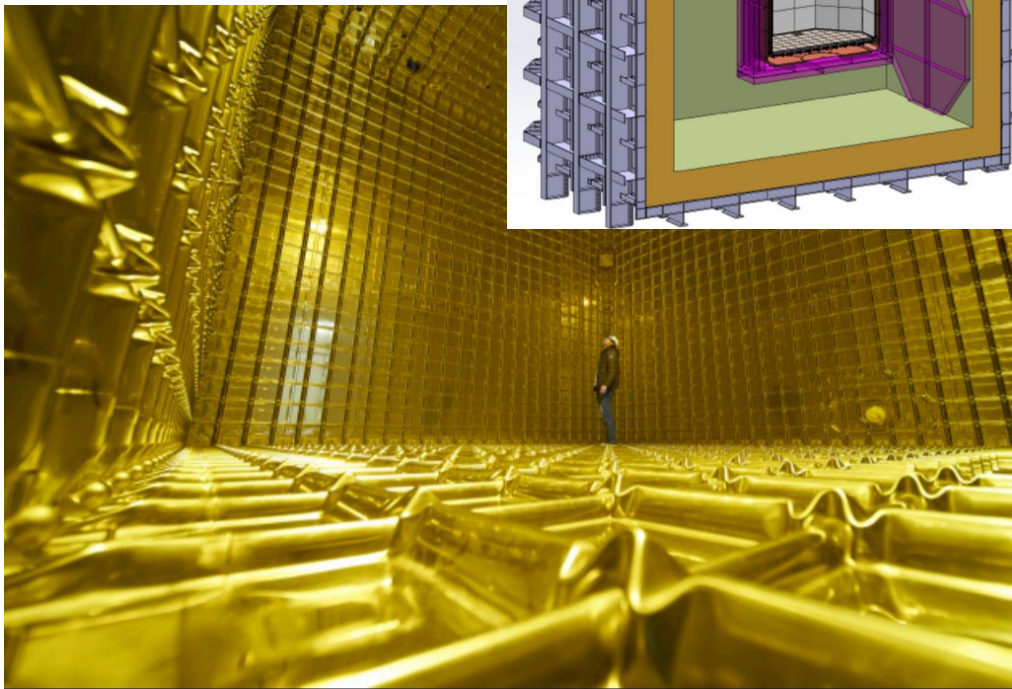
DarkSide-20k Experiment: Inner Detector

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DarkSide-20k Experiment: Veto

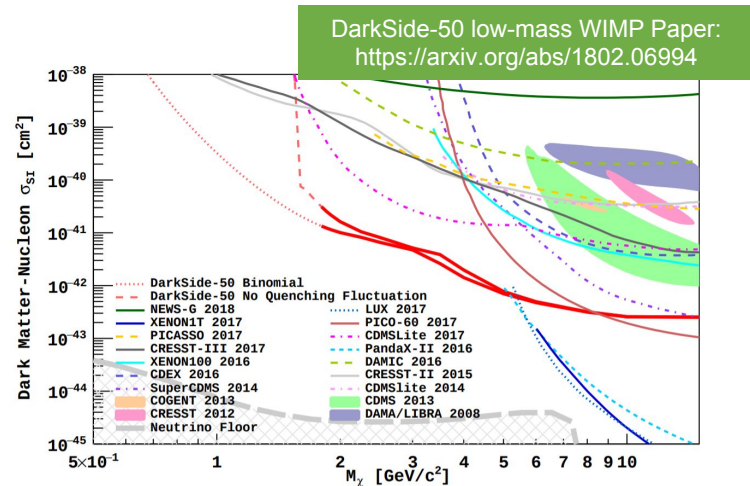
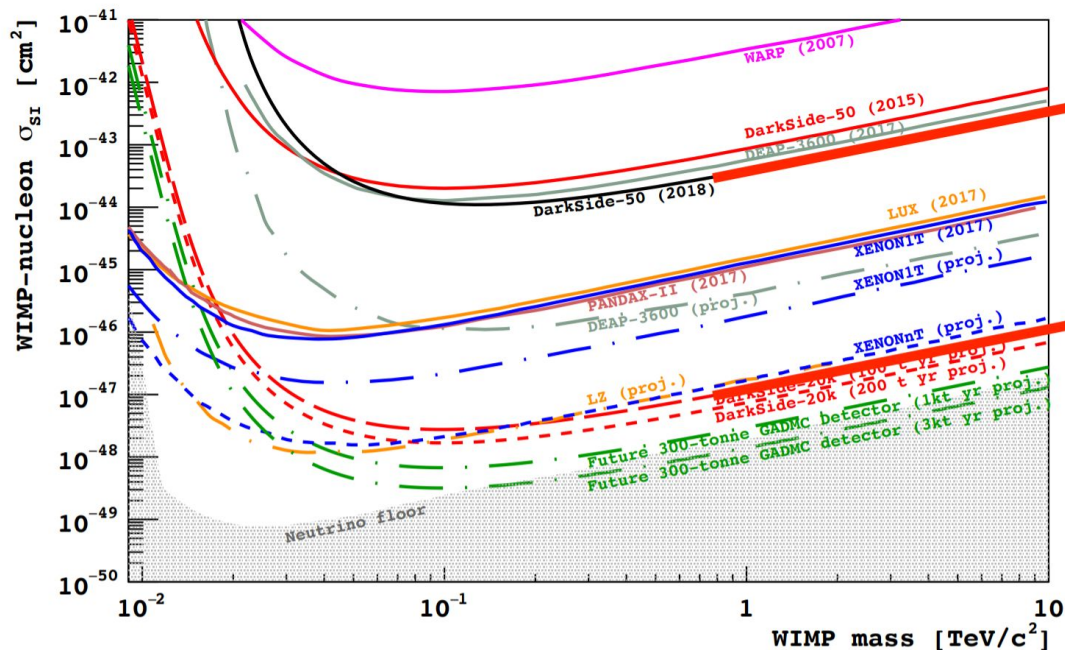
- Atmospheric Argon Cryostat, similar to ProtoDUNE.
- Inner volume $\sim 8 \times 8 \times 8 \text{ m}^3$, 750 tonne of LAr.
- Significantly simplify the overall system complexity and operation.
- Synergy with the CERN neutrino platform.
- Loaded plastic scintillator around the Inner Detector for the active veto.
- Similar SiPM-based readout developed for the inner detector, with small adjustments.
- Fully scalable design for future larger scale experiments.



DarkSide-20k Experiment

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Projected Sensitivity for high-mass WIMPs search.



Possibility for a competitive low-mass WIMPs search

DarkSide-20k Experiment

Two essential technologies for DarkSide-20k and the future liquid argon program.

Cryogenic Si-based
Photo-readout

NOA: nuova officina assergi
Test and assembly of the
cryogenic SiPMs modules

Low-Radioactivity
Underground Argon

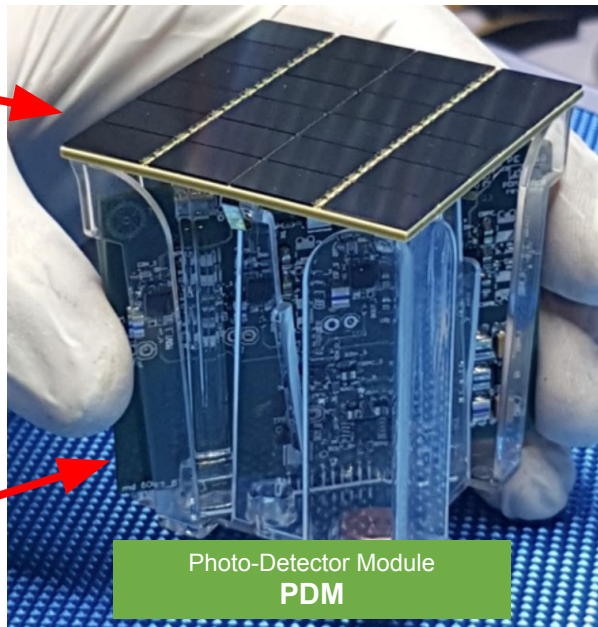
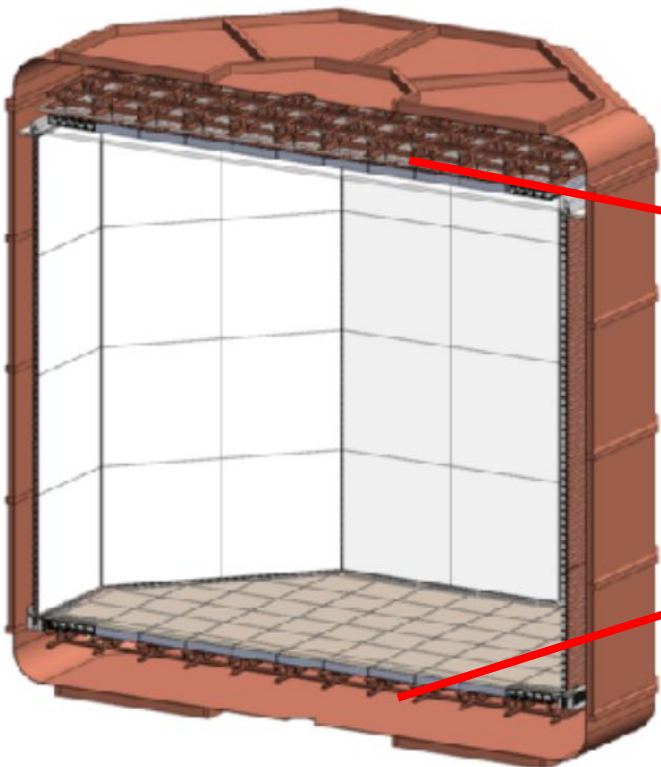
URANIA: extraction of the
underground argon (USA).
ARIA: Isotopic separation via
cryogenic distillation.



Cryogenic SiPMs

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~8000 SiPM Module for Light Readout (Self-production)
Crucial: selection of low-radioactive material.



PDM Requirements:

For increased Light Yield:

- PDE of PDM > 40%
- PDE of SiPM > 45%

For effective Pulse-Shape Discrimination:

- DCR+Electronic Noise < 0.1 cps/mm².
- Time-Resolution ~10ns.

For good Position-Reconstruction:

- Dynamic Range > 50 PE.

Low intrinsic background levels,
 fraction of mBq of U/Th

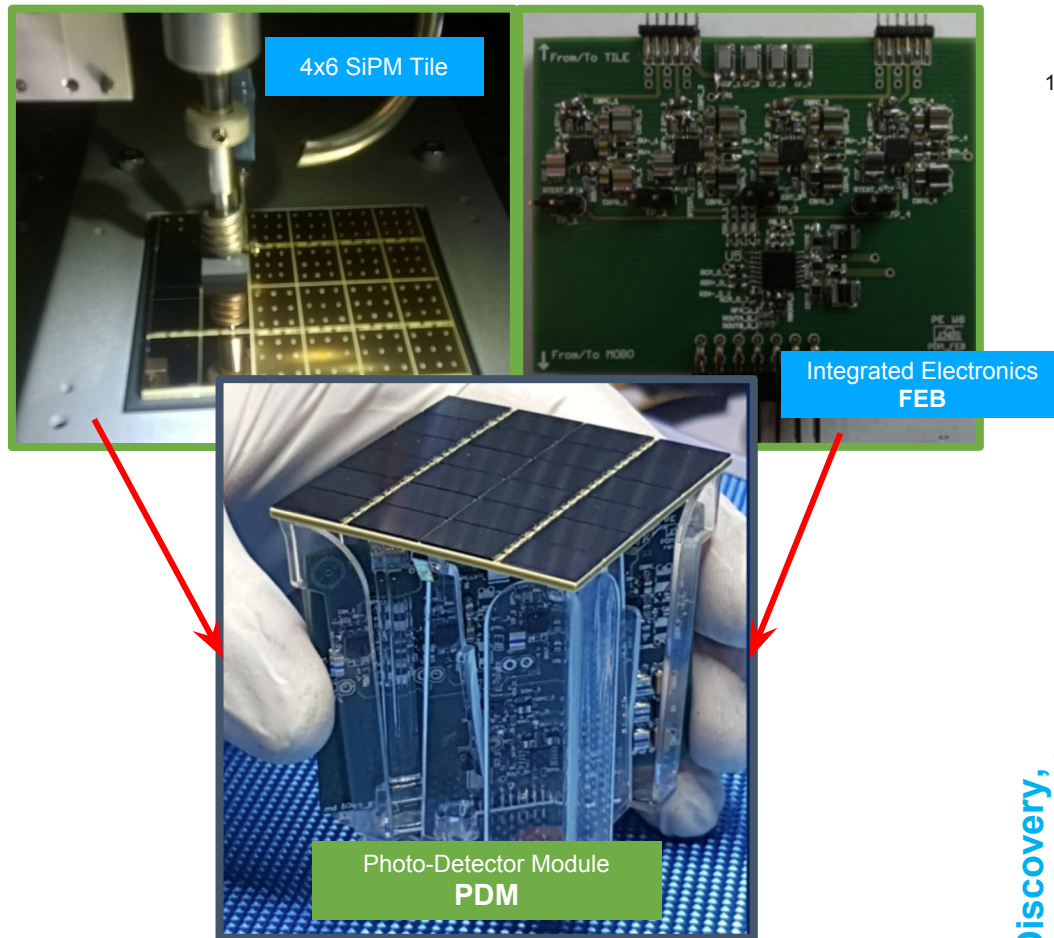
Cryogenic SiPMs: NOA

$$\text{SiPM Tile} + \text{FEB} + \text{Mount} = \text{PDM}$$

The facility includes:

- Warm/Cryogenic test station for SiPMs.
- Cryogenic Wafer Probe.
- Automated die bonder for SiPMs.
- Automated wire bonder.
- Radio-pure SMT reflow process for the FEBs.

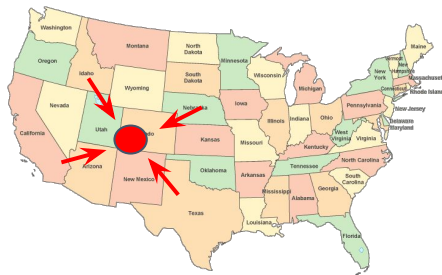
Facility designed to mounted all PDMs within 2 years of production.



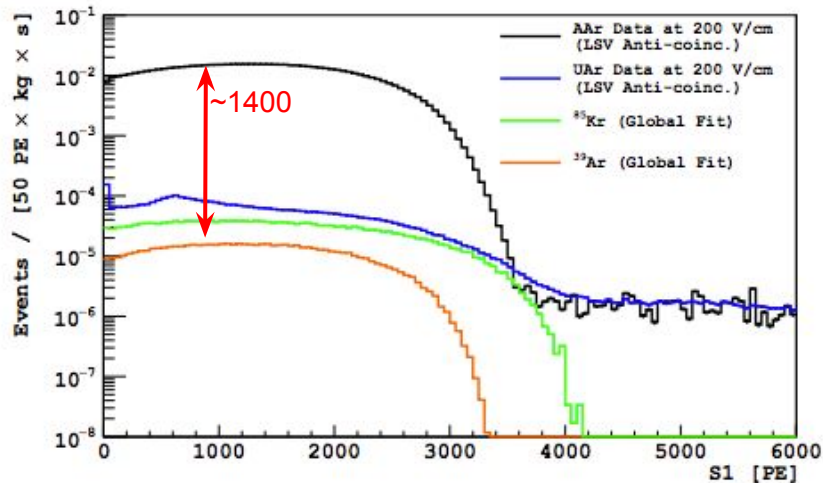
Low-Radioactivity Underground Argon

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- Extraction of Underground Argon (UAr) from a CO₂ well in SW Colorado USA.
- The UAr extraction for DS-50 was a key learning experience for next phase.
- URANIA will extract 250 kg/day of UAr, with a 99.9% purity.



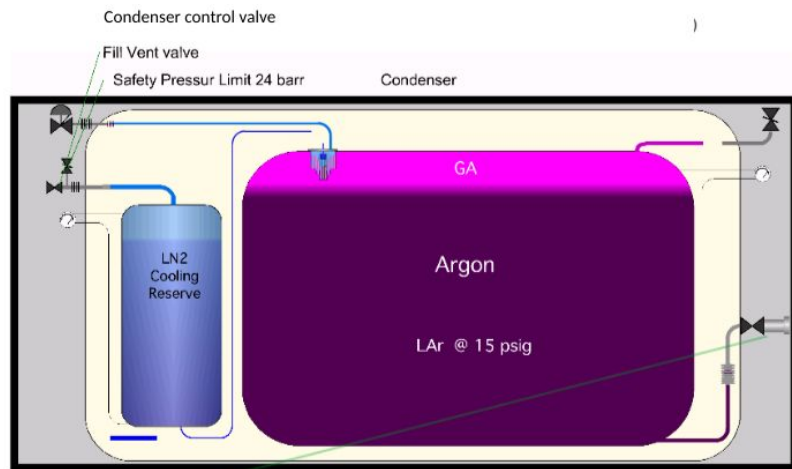
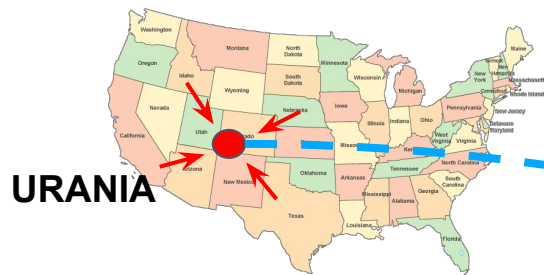
DarkSide-50 UAr Paper:
<https://arxiv.org/abs/1510.00702>



Underground Argon ~1400 reduction in ³⁹Ar activity.
 This was demonstrated with DarkSide-50.
 Argon was extracted in Colorado USA.

Low-Radioactivity Underground Argon

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C.Kendziora 3.30.17

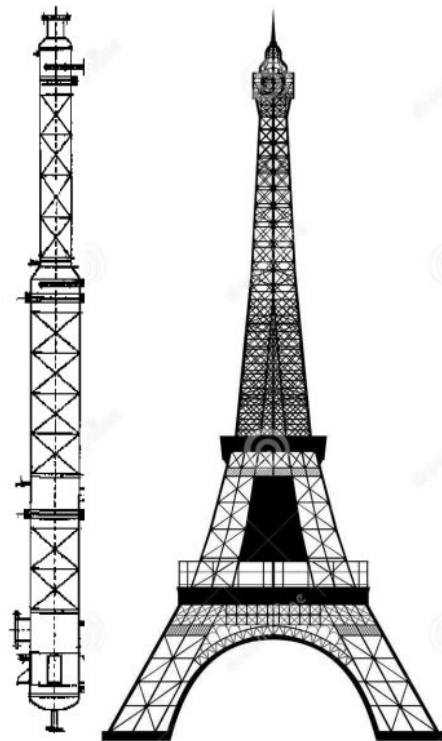


The extracted UAr is then transported to Italy for further purification and depletion.
Custom designed cryogenic shipping vessel.

Low-Radioactivity Underground Argon

ARIA

- Cryogenic Distillation column in Seruci, Sardinia.
 - Final chemical purification of the UAr.
 - Can further deplete UAr of ^{39}Ar .
 - Funded by INFN, NSF, RAS, Carbosulcis and Princeton University.
 - Contribution by CERN for leak testing.
-
- **SERUCI-0:** ~25m distillation column that serves as a pilot set up.
 - **SERUCI-I:** 350m distillation column that will handle the UAr from Colorado for DS20k. To be installed in the Seruci mine.
 - **SERUCI-II:** same height as SERUCI-I but larger diameter, will allow for further ^{39}Ar depletion.



Low-Radioactivity Underground Argon

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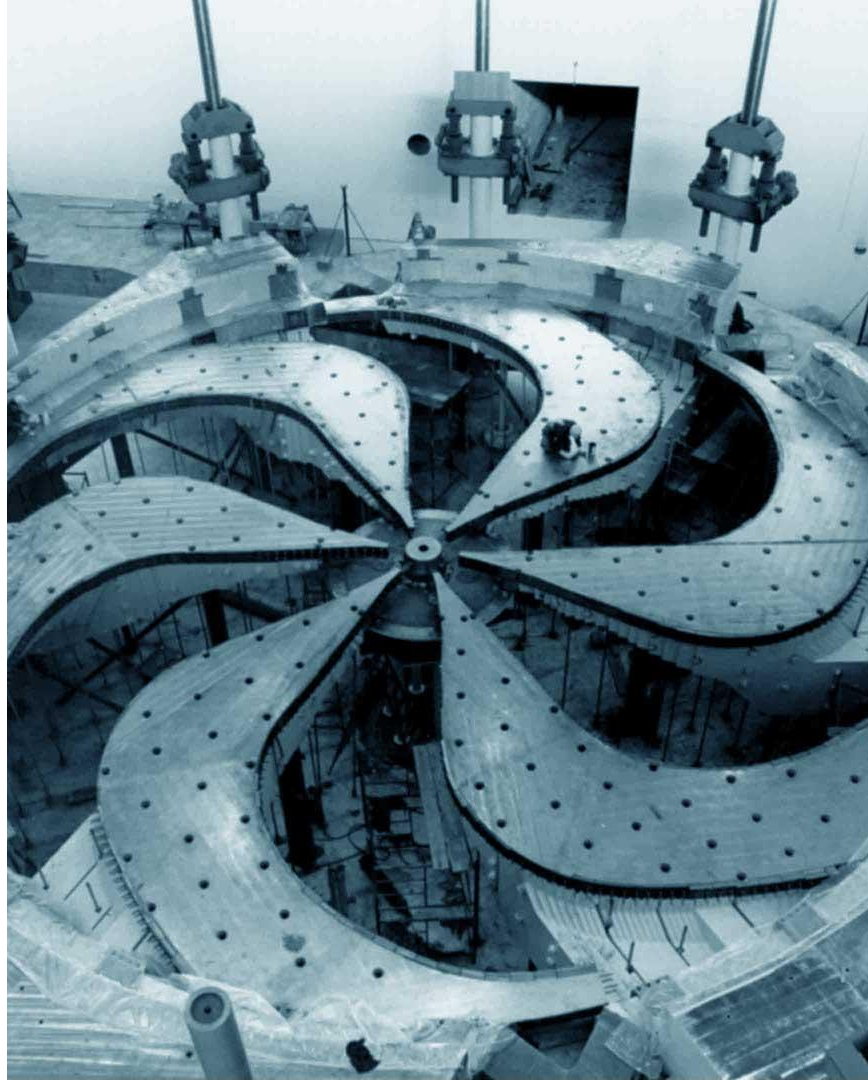
Conclusions

- New Global Argon Dark Matter Collaboration with a two steps program. DarkSide-20k (step 1), future multi-hundred tonne argon detector (step 2).
- DarkSide-20k has a projected sensitivity of 10^{-47} cm² for a 1TeV/c² dark matter particle mass, and a total exposure of 100 tonne / year.
- New ProtoDUNE style 750 tonne LAr cryostat for the active veto.
- Advanced development of the SiPM-based photo-detector modules, on the right path to match all requirements. Optimization for mass production at NOA is the next step.
- The extraction of UAr in Colorado will continue with URANIA. Plan for the extraction of 250 kg/day, 99.9% purity.
- The ARIA project (SERUCI) will perform the last purification of the UAr and further depletion, before deployment in DS20k.

Thank you
Merci

www.triumf.ca

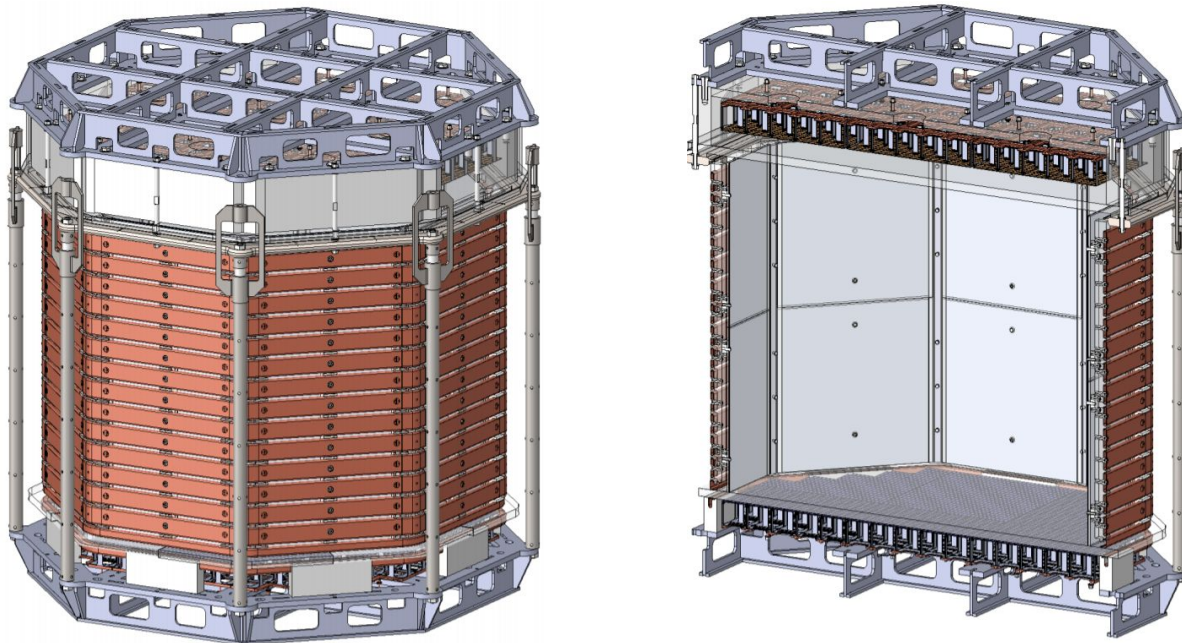
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BackUp Slides

DarkSide-20k Prototype

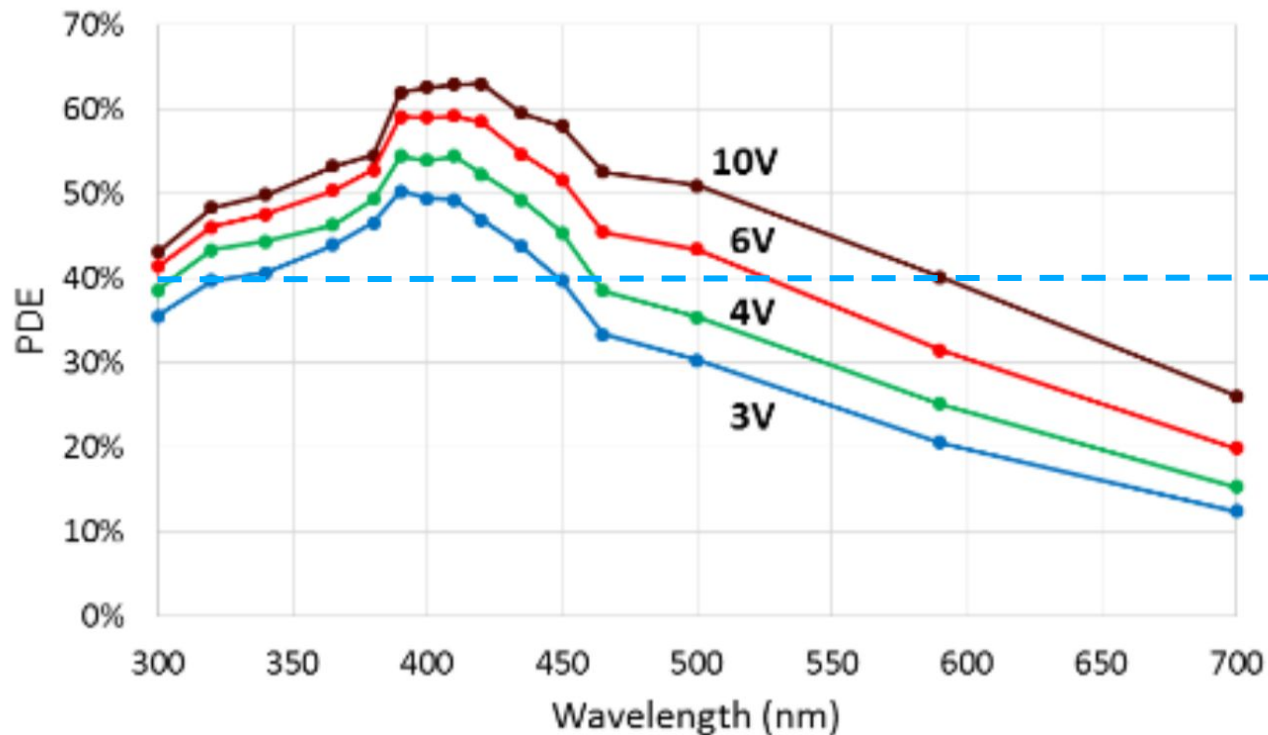
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Development of a 1 tonne DS-20k Prototype (CERN -> LNGS), for testing of the cryogenics, electronics, inner components. Possibility for competitive low-WIMP mass search.

Photo-detection Efficiency PDE

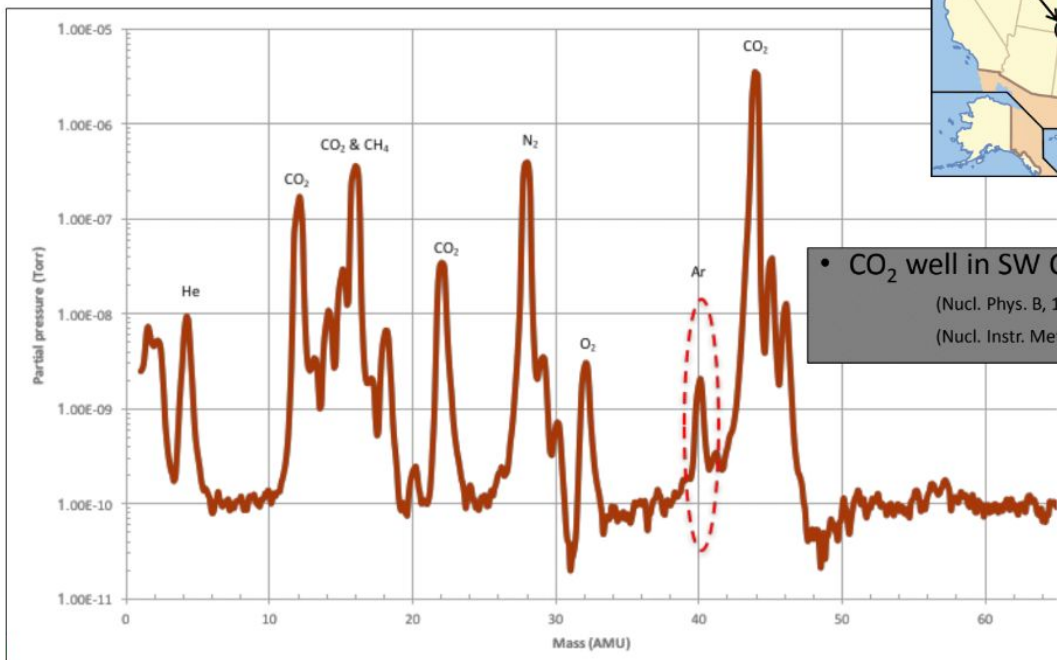
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PDM Requirement

Underground Argon Source

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- CO₂ well in SW Colorado with 400 ppm Ar
(Nucl. Phys. B, 197 (2009) 70-73)
(Nucl. Instr. Meth. A 587 (2008) 46-51)

ARIA Distillation Column

