Towards DarkSide-20k

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ON BEHALF OF THE DARKSIDE COLLABORATION
1ST MARCH 2021 - GSSI SCIENCE FAIR

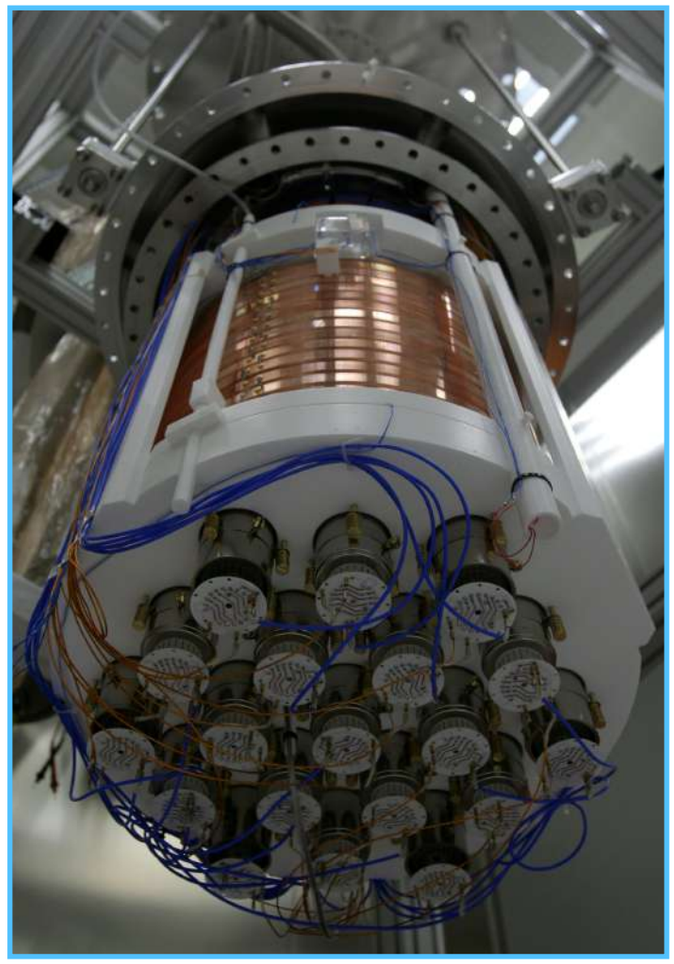
The DarkSide project

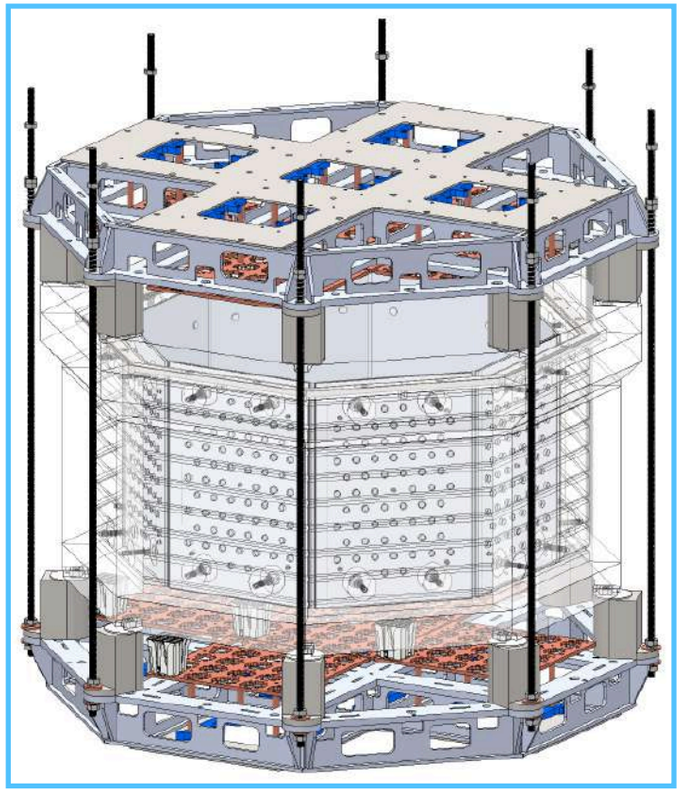
DarkSide-10

2011-2013

DarkSide-50

2015-201X





Proto-1t

2021-2022

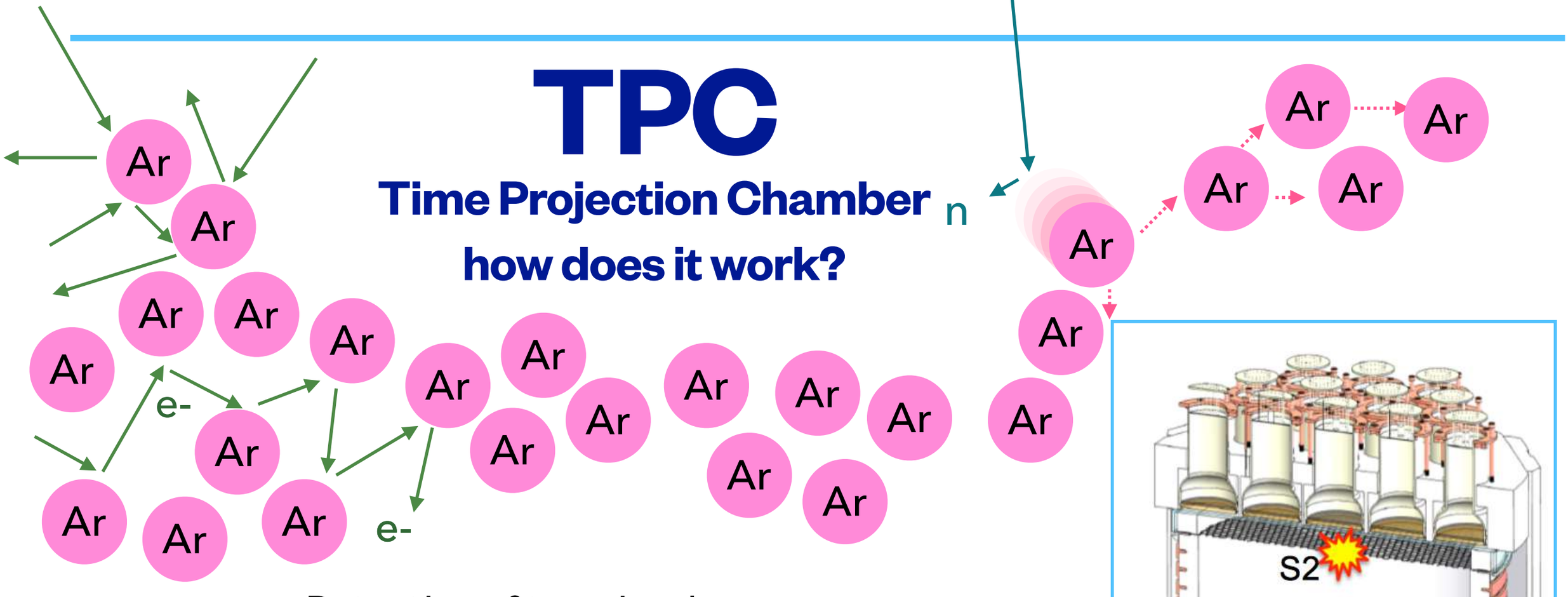
DarkSide-20k

2024-20XX

TPC

Time Projection Chamber

how does it work?



Ar

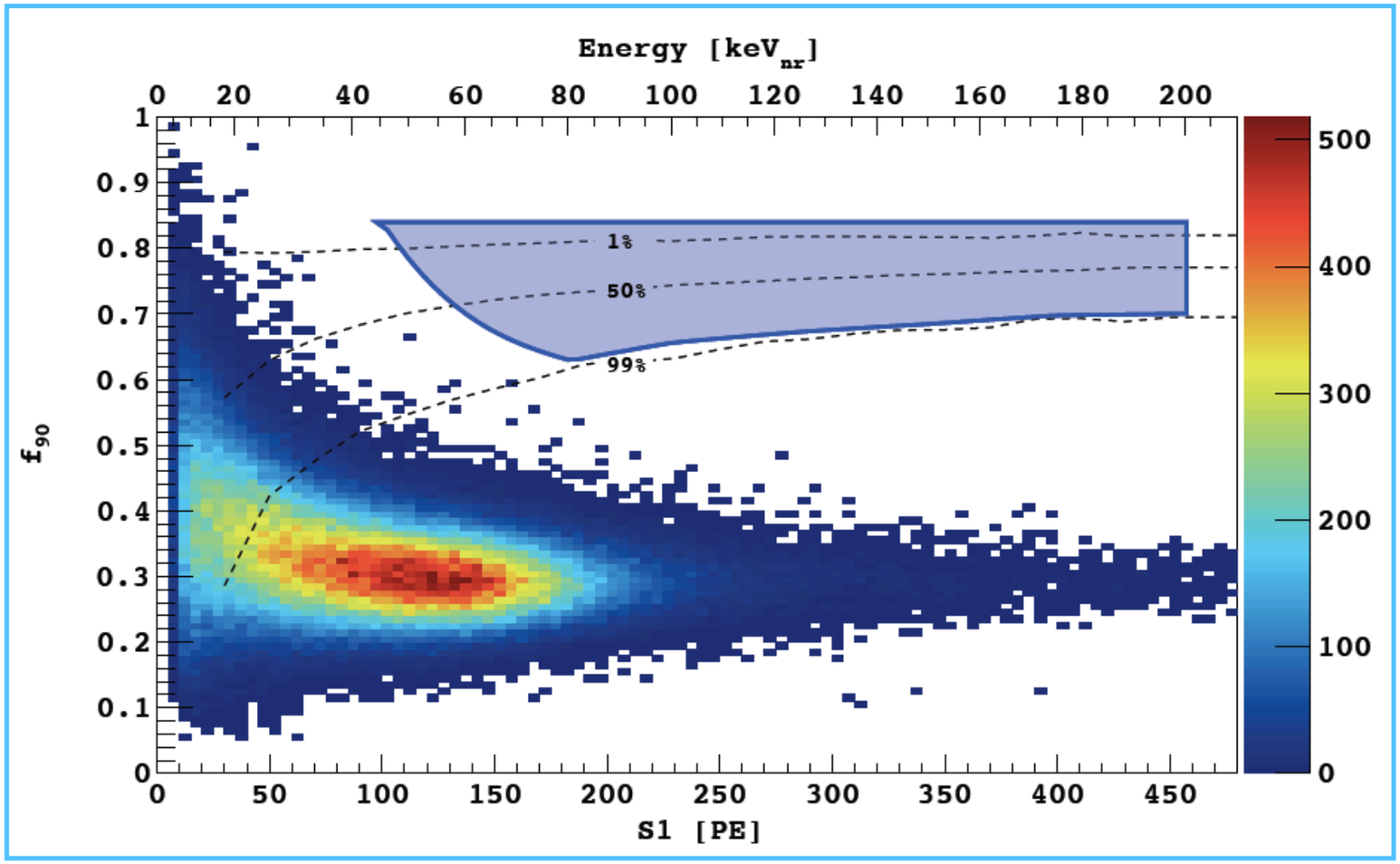
Detection of two signals:

- **S1**: produced in the liquid by the scintillation light due to both the excited Ar atoms, and the recombined fraction of ionized atoms.

- **S2**: produced in the gas layer by the free electrons escaped from recombination and drifted up to the liquid surface.

Why liquid argon?

1. Dense and cheap
2. Cold and easy to purify
3. Good ionization yield and electron mobility
4. High scintillation yield (~40,000 PE/MeV) and transparent to its own light
5. Exceptional discrimination power:
   - light (S1)/charge (S2)
   - **PSD**: Pulse Shape Discrimination



PSD is one of the key features that allowed DarkSide-50 to reach < 0.1 background events in the region of interest

Physical Review D 98 (10), 102006 (2018)

Pulse shape discrimination

Two scintillation time constants in liquid argon:

- Singlet ~ 6 ns
- Triplet ~ 1.6 μs

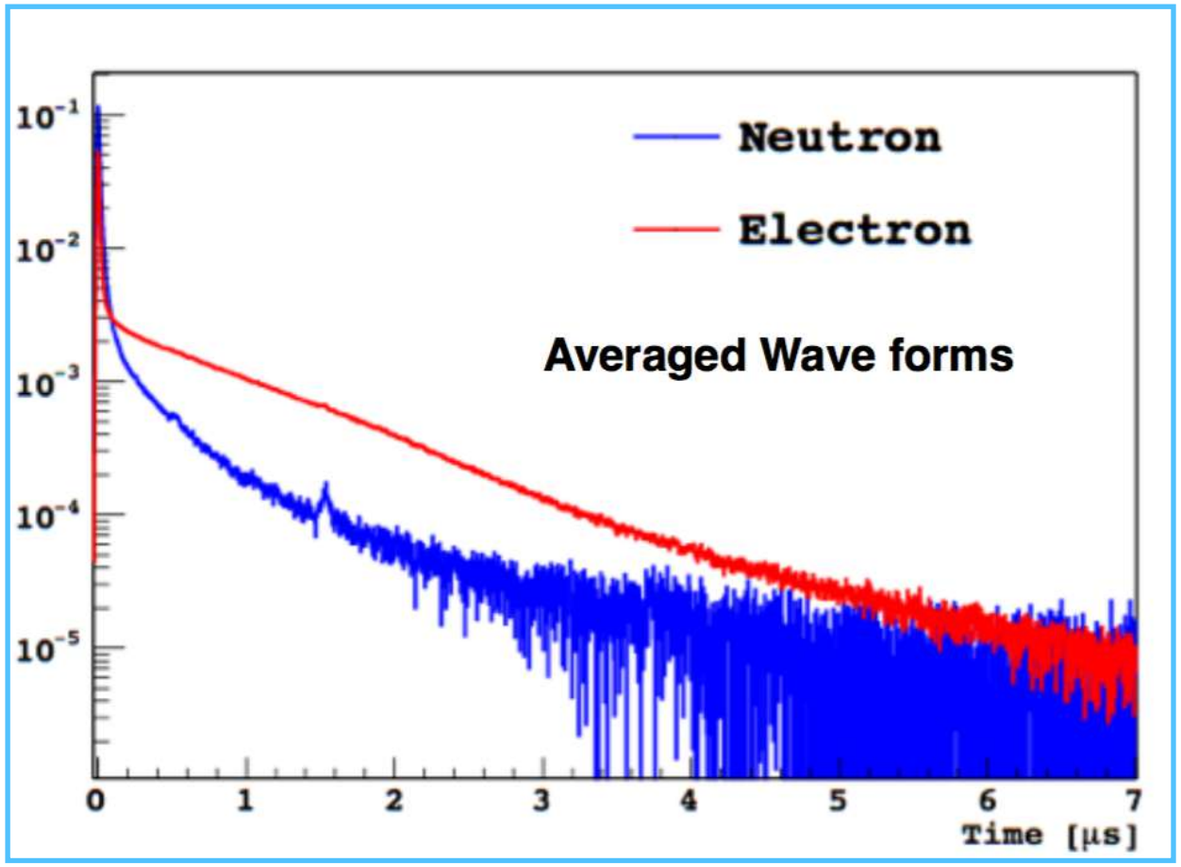
Nuclear and electron recoils have different ratios of singlet and triplet states.

↓

The signals generated by ER and NR have a different shape in time.

↓

This opens the possibility to distinguish between nuclear and electron recoil.



Discrimination parameter

$$f_{prompt} = \frac{Light\ in\ the\ first\ ns}{Total\ light}$$

In DarkSide-50 we use f_{90}

Underground argon

PROBLEM

Atmospheric argon in contaminated with ^{39}Ar radioactive isotope, produced by cosmogenic activation.

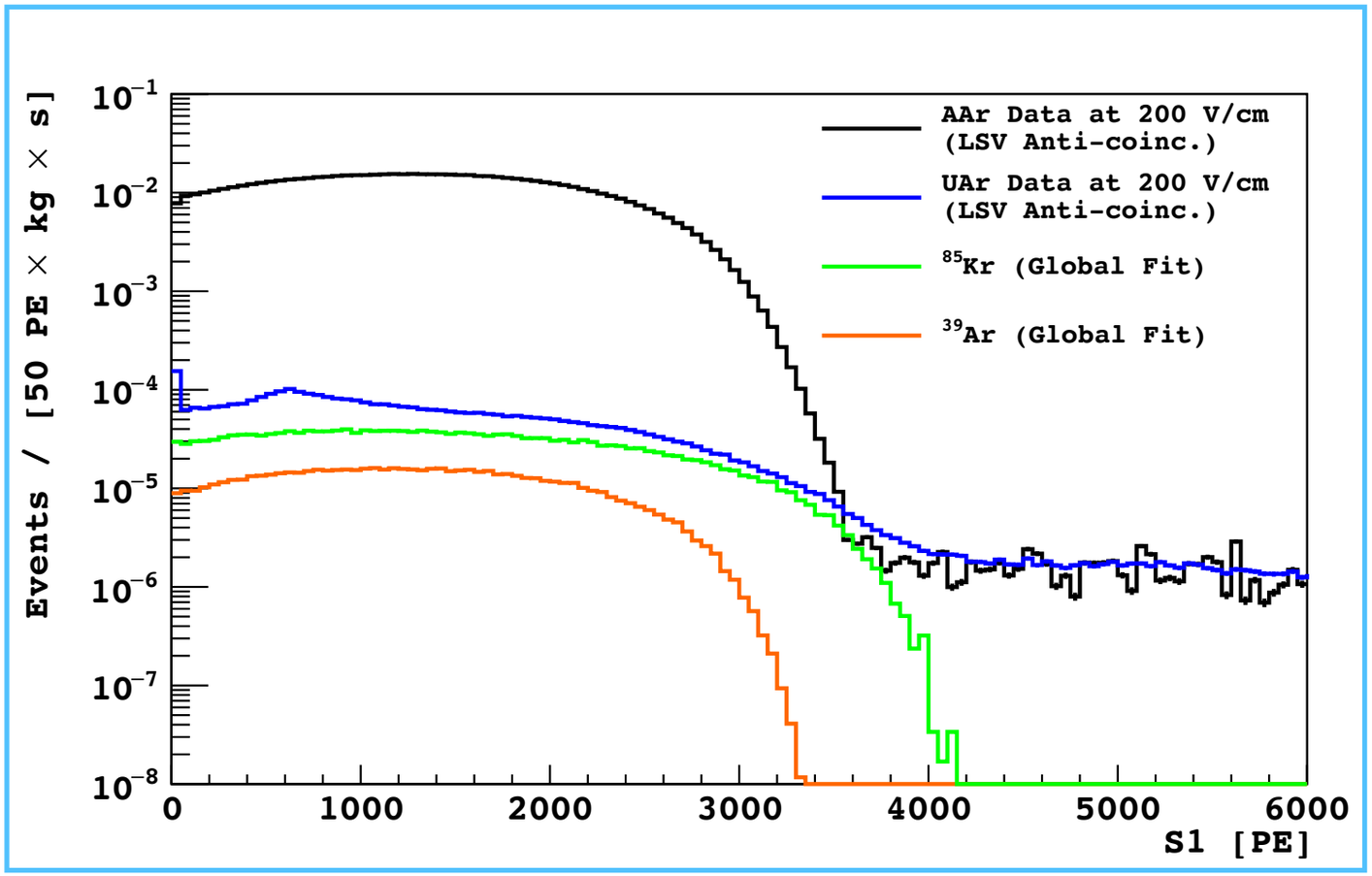
^{39}Ar emits β with τ=269 years and Q-value=565 keV → Limits the sensitivity

SOLUTION

Use underground argon (UAr), extracted from deep sources.

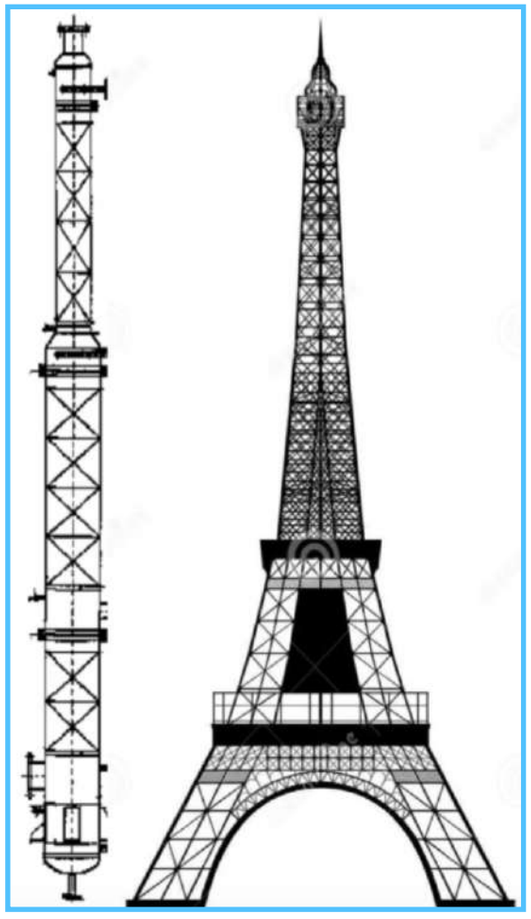
The ^{39}Ar content is 1400 times less than in atmospheric argon, as proved by DarkSide-50.

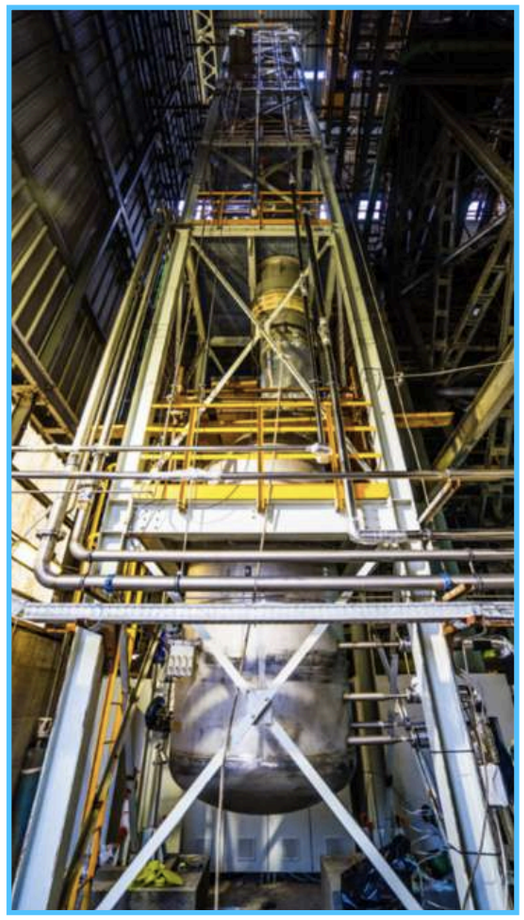
Physical Review D 93 (8), 081101 (2016)



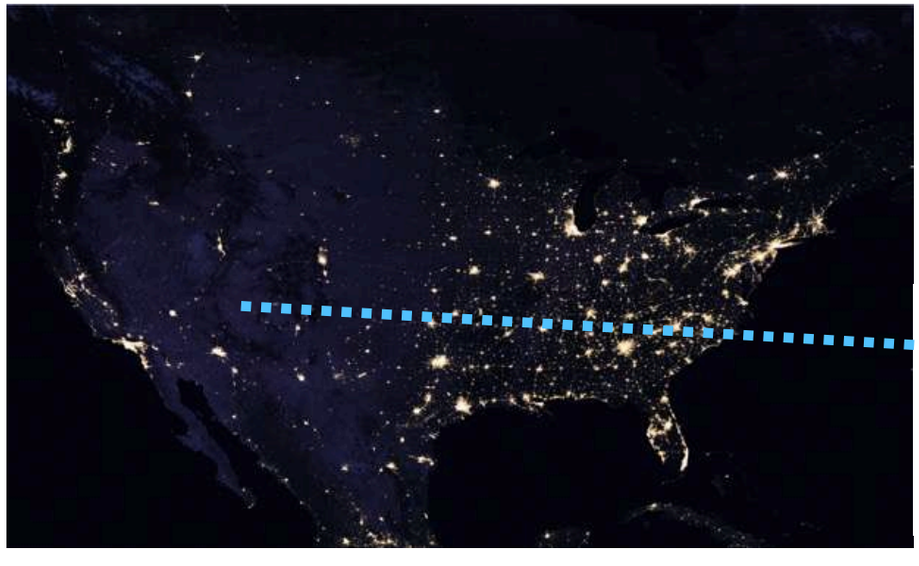
How to get UAr?

Urania - Argon extraction and purification plant in Cortez, Colorado. Capable to provide 330 kg/d of UAr with a 99.99% purity.

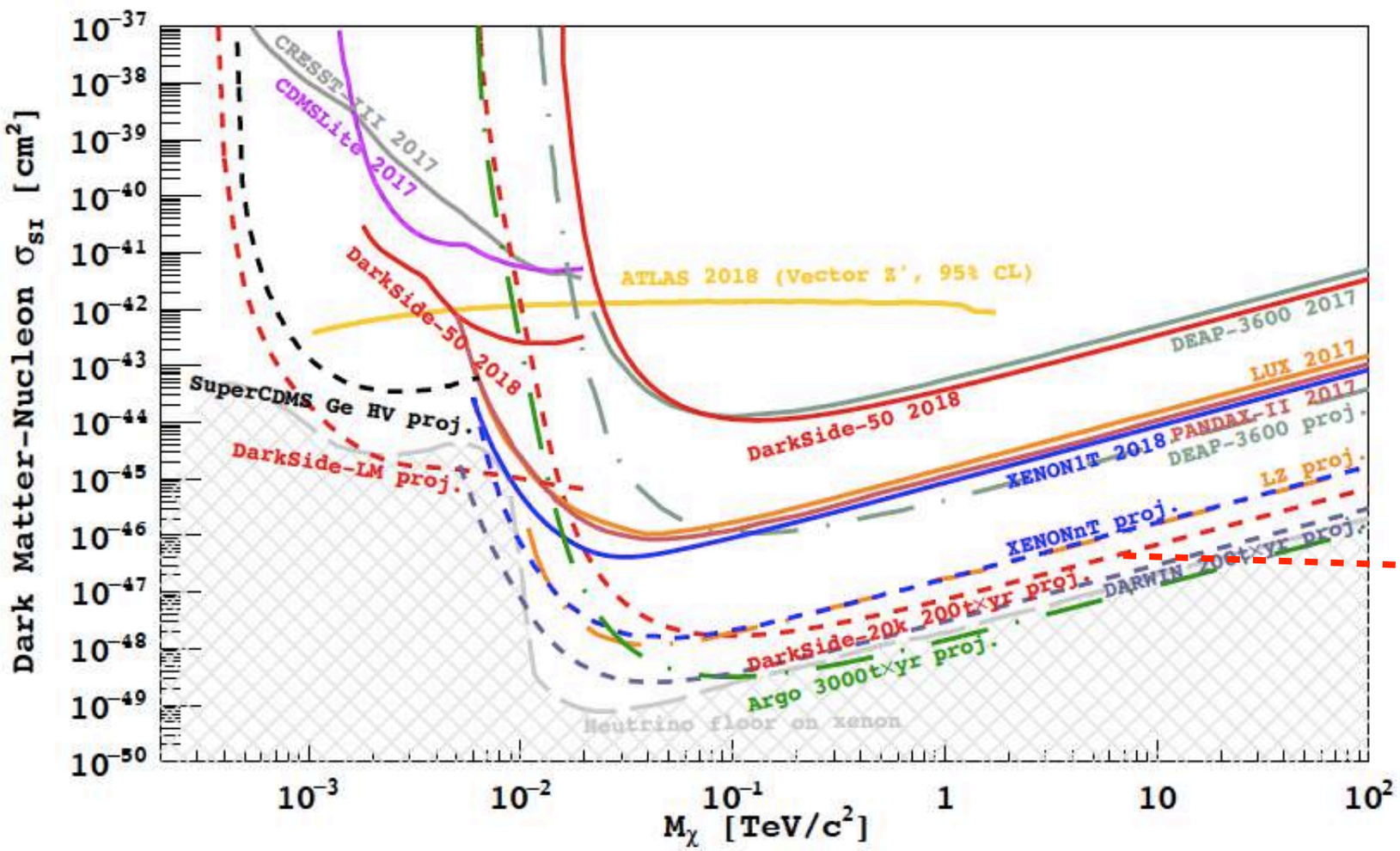




Aria - final chemical purification plant in Seruci, Sardinia, Italy. Capable of separating isotopes using a 350 m cryogenic distillation column.



DarkSide-20k goal



Ultra low background

+

Ability to measure background in situ

↓

Expected sensitivity

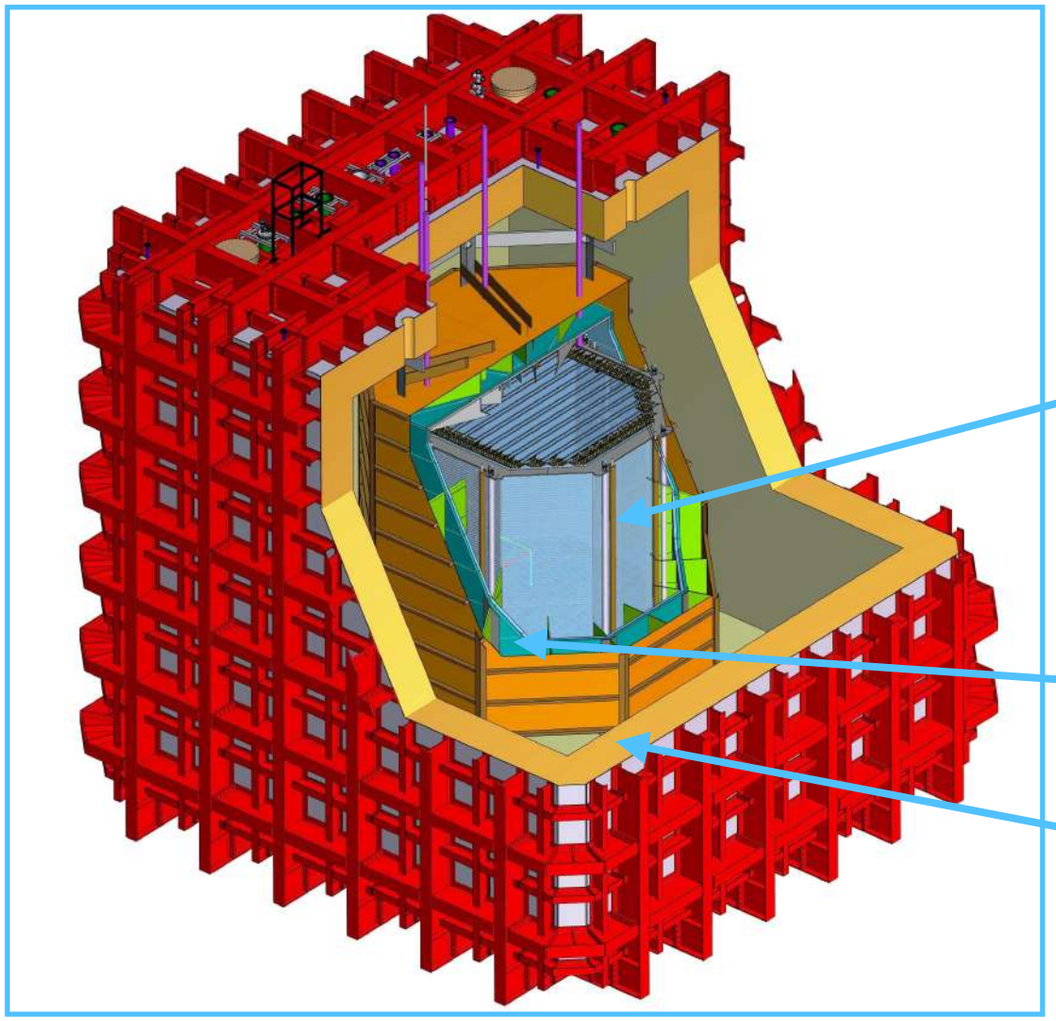
7.4 x 10^{-48} cm^2

for 1 TeV/c^2 WIMP

with a 200 t yr exposure

To achieve this goal all sources of **instrumental background are reduced to < 0.1 events over a 200 t yr exposure.**

DarkSide-20k



DarkSide-20k will be installed underground at the Gran Sasso National laboratories.

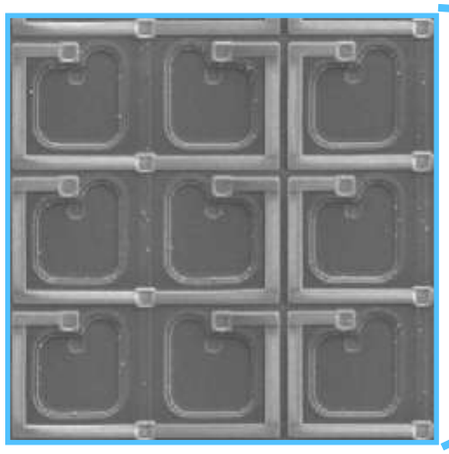
The detector has a nested structure:

- Sealed acrylic TPC filled with 50 t of UAr
- Neutron veto
  - Two liquid atmospheric argon buffers
  - Gadolinium loaded shell between the buffers
- Membrane cryostat like the ProtoDune one

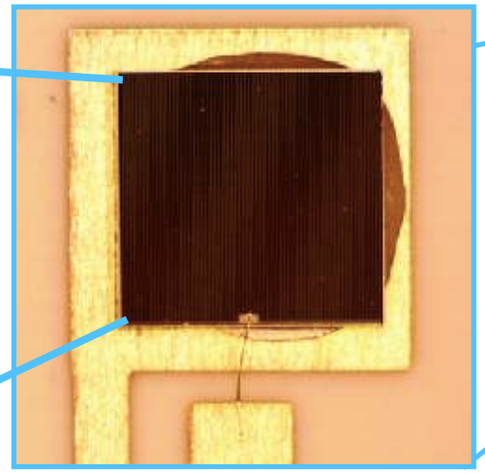
Both TPC and veto signals are read with low-background, cryogenic photosensors based on silicon photomultipliers (SiPMs).

Photosensors

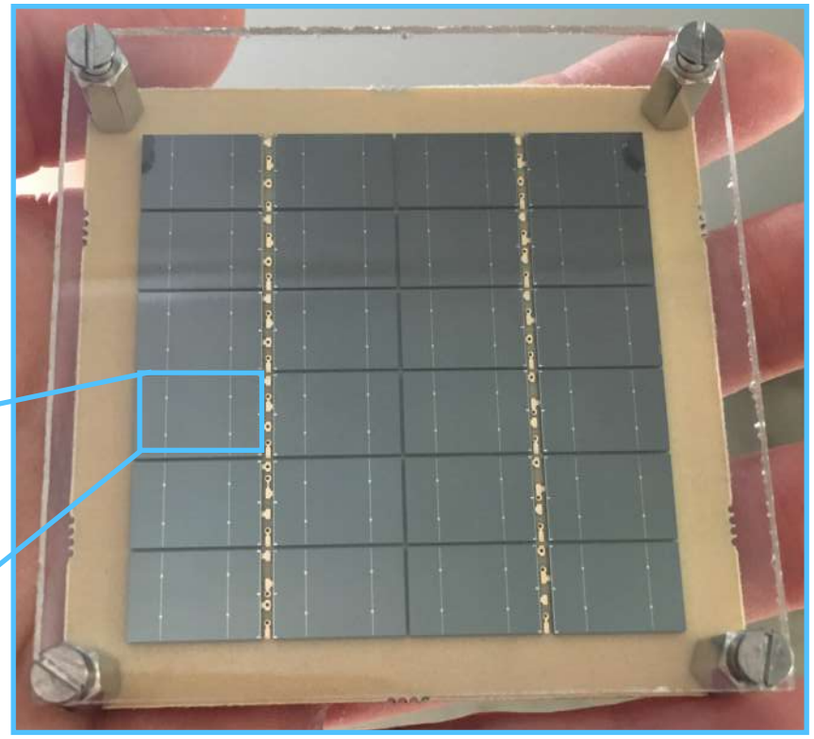
Custom cryogenic SiPMs developed in collaboration with Fondazione Bruno Kessler (FBK).



Single SPADs
~25-30 μm²

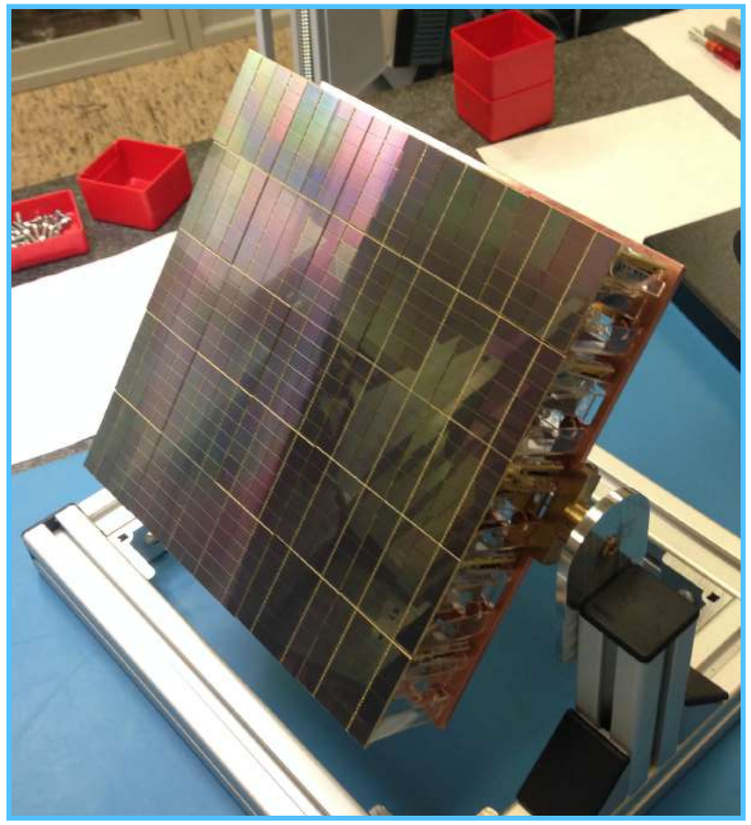


Single SiPM
~1 cm²



Single tile
24 SiPMs

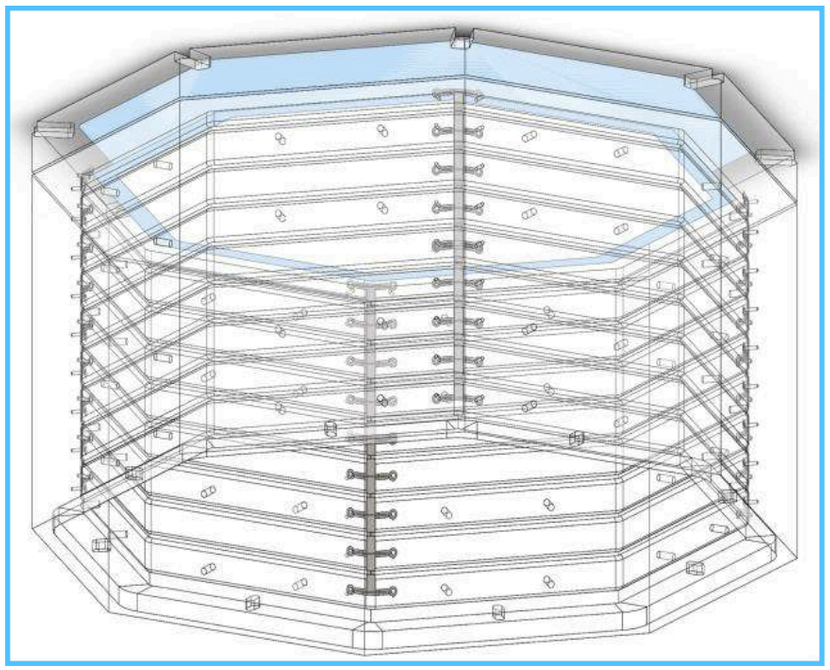
PDU
(PhotoDetection
Unit)
25 tiles

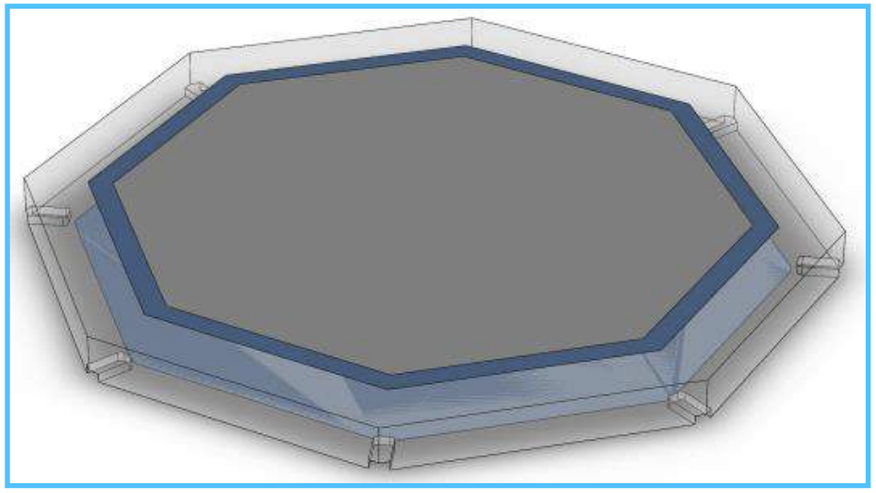


KEY FEATURES OF THE TILE

- Photon detection efficiency (PDE) ~45%
- Fill factor ~90%
- Low dark-count rate < 0.1 Hz/mm²

TPC





DARKSIDE-20K

MAIN CHARACTERISTICS

- Ultra pure acrylic vessel, sealed with the bonding technique
- Octagonal shape
- Cathode and anode coated with new transparent conductor (Clevios) and wavelength shifter
- No copper rings → grooves with Clevios
- Wire grid
- Sides covered with multilayer polymeric reflector evaporated with wavelength shifter
- SiPMs planes external to anode and cathode

PROTO-0

The Veto detector

WHY WE NEED A NEUTRON VETO

Neutrons elastically scattering from argon nuclei are indistinguishable from WIMPs. We can not discard neutron events using PSD.

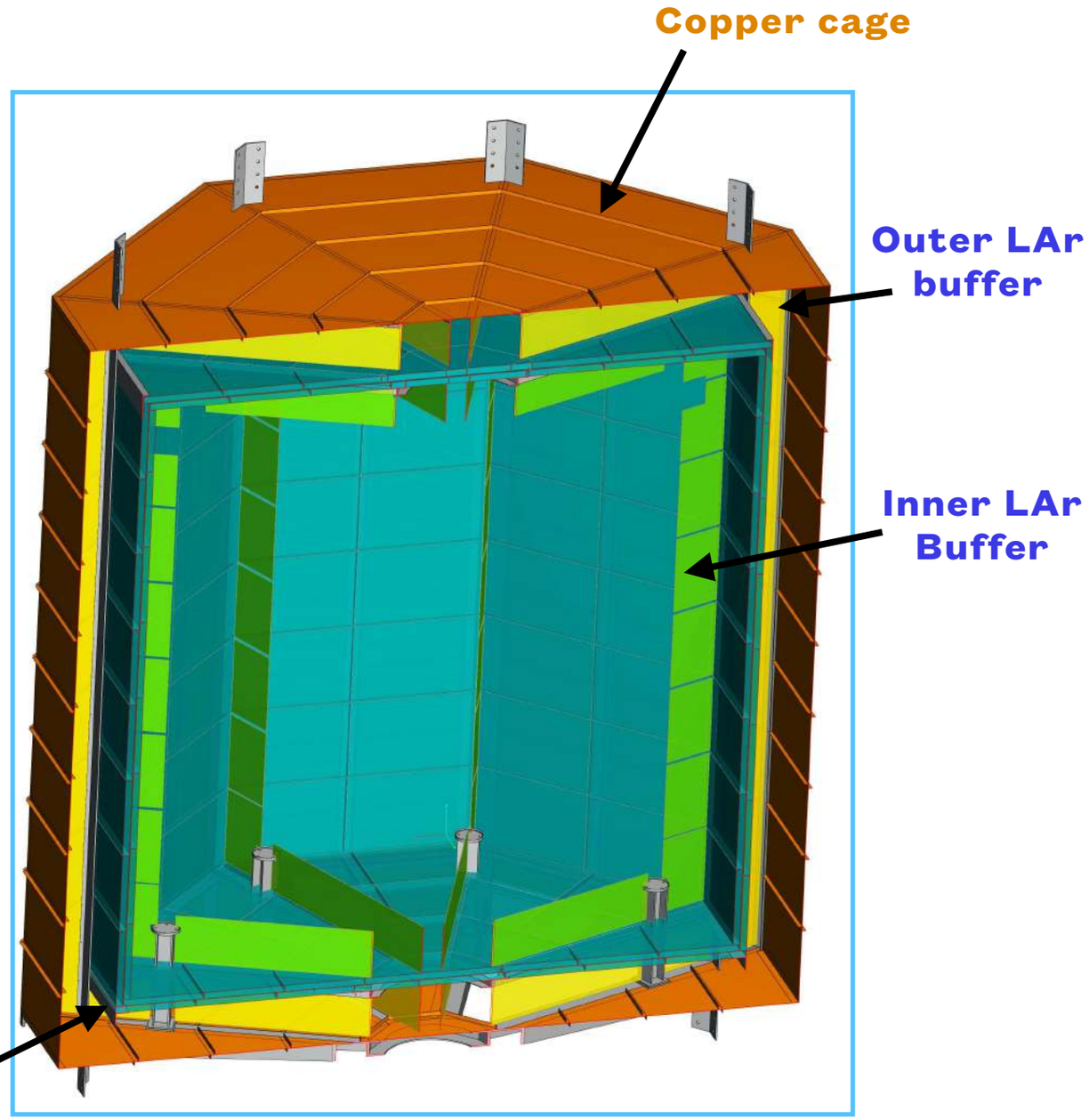
VETO WORKING PRINCIPLE

1. Neutrons are moderated in a gadolinium loaded acrylic shell and then captured;

2. Gd emits multiple γ-rays;

3. γ-rays interact in one of the two liquid argon buffers;

4. Argon scintillation light is shifted and detected by 3000 SiPM-based photosensors.



What next?

All the key ingredients for DarkSide-20k are almost ready, but still some crucial steps need do be done! For example:

- Finalize the tests on SiPMs tiles and signal read out;
- Build and run a 1 ton scale TPC to optimise all the new features;
- Conclude the R&D project on the gadolinium loaded acrylic for the veto

For more info about DarkSide next steps and possible thesis projects contact us!

THANK YOU