The DarkSide Program: towards a background free dark matter search

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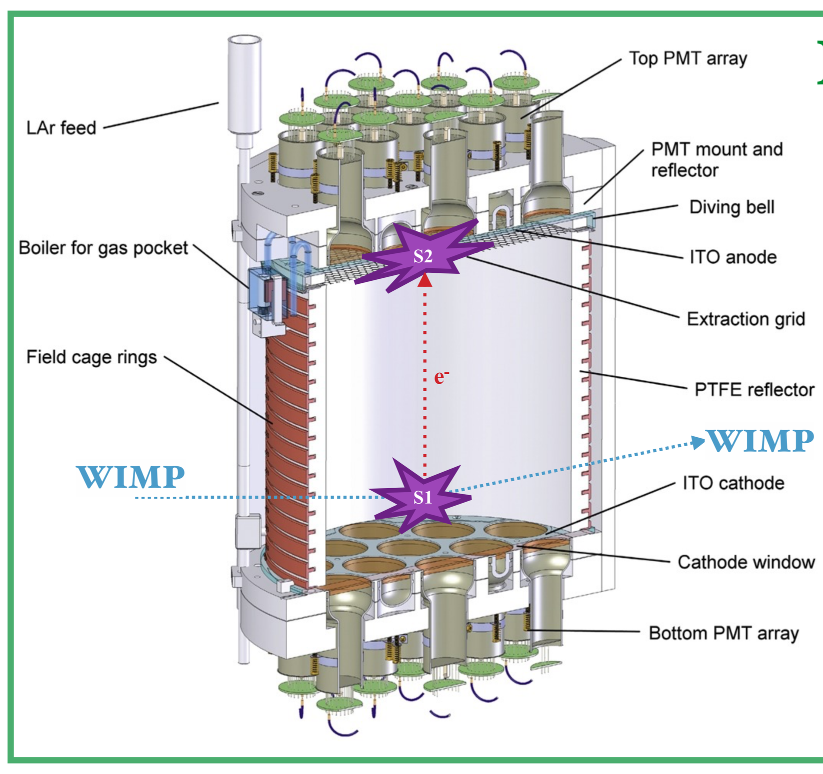
DarkSide-50

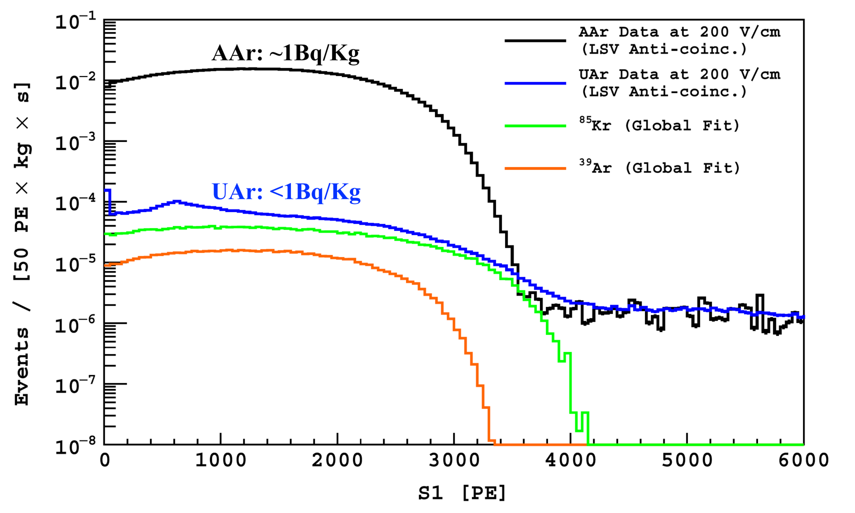
Dual Phase Argon TPC



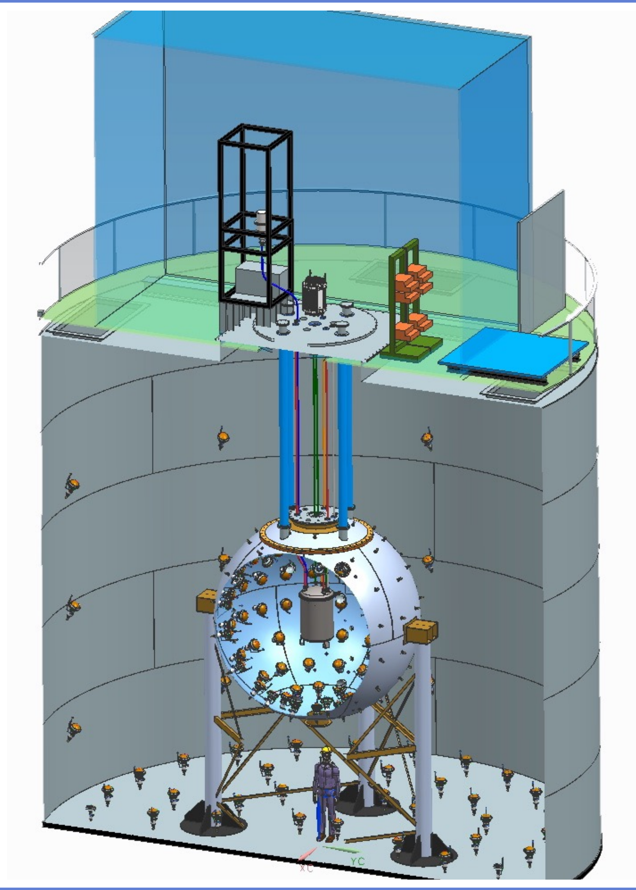
- A WIMP scatters on a ^{40}Ar nucleus, causing it to recoil.
- The recoiling nucleus releases its kinetic via excitation and ionization (heat is lost).
- Excited argon produces scintillation light (S1).
- Electrons are drifted by the electric field to the gas/liquid interface and then stripped by an higher extraction field.
- Stripped electrons in gas produce a second light pulse via electroluminescence (S2).

Underground Argon

- Atmospheric Argon (AAr) naturally contains the radioactive isotope ^{39}Ar which undergoes beta decay with a half life of ~269yr, producing ER events in the TPC.
- Argon extracted in deep natural gas deposits (UAr) has a much lower amount ^{39}Ar.
- The UAr activity measured is a factor 1.4×10^3 lower than AAr

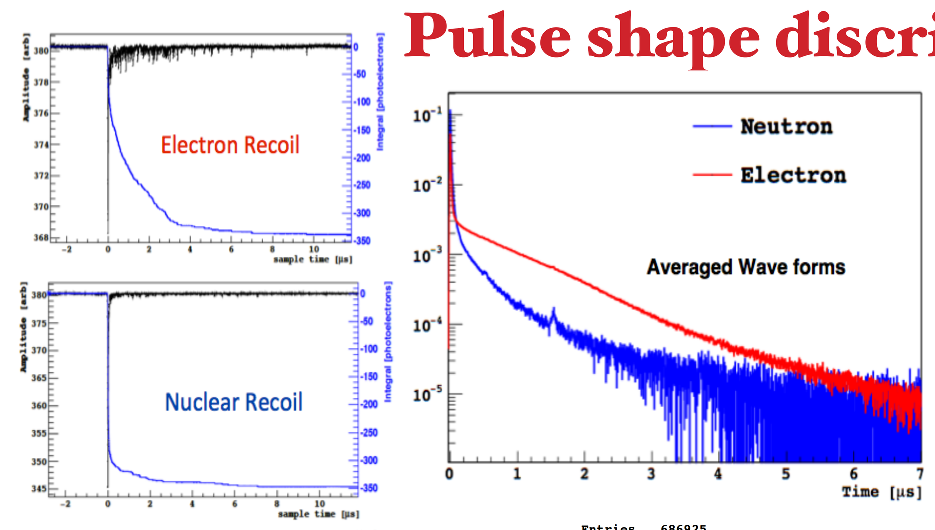


Veto systems

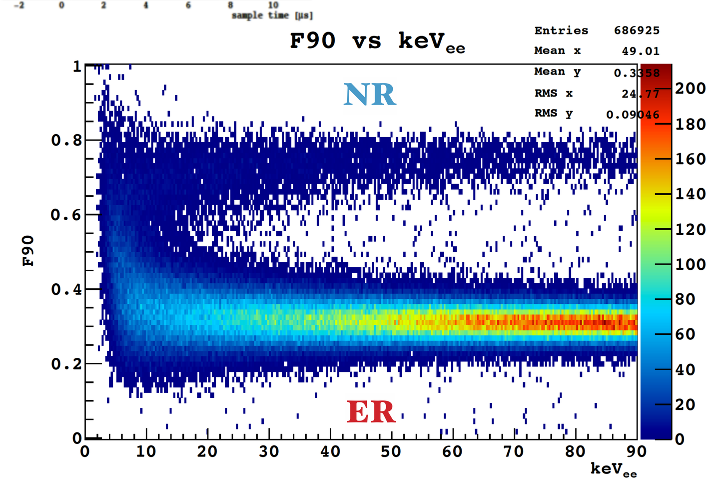


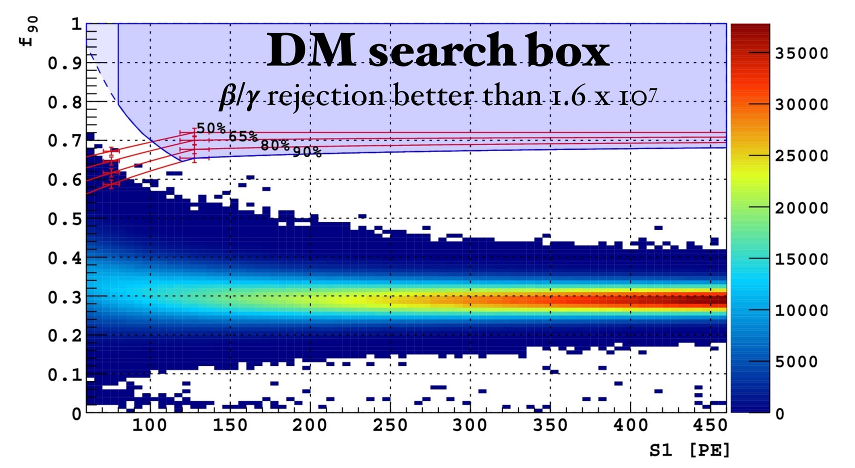
- An active veto for neutrons is fundamental in order to achieve the zero background goal.
- The TPC is enclosed in two nested veto systems.
- The outermost system is the Water Cherenkov Veto (WCV) consisting of a stainless steel vessel containing 1000 tonnes of water and 80 PMTs. The WCV looks for cherenkov light produced by muons. These can in turn generate high energy neutrons entering in the TPC.
- The innermost veto system is the Liquid Scintillator Veto (LSV), containing 30 tonnes of Boron loaded pseudocumene and 110 PMTs. This veto system provides signals both from neutron thermalization and neutron capture.
- The overall veto efficiency is estimated to be above 99.5%.

Pulse shape discrimination in LAr



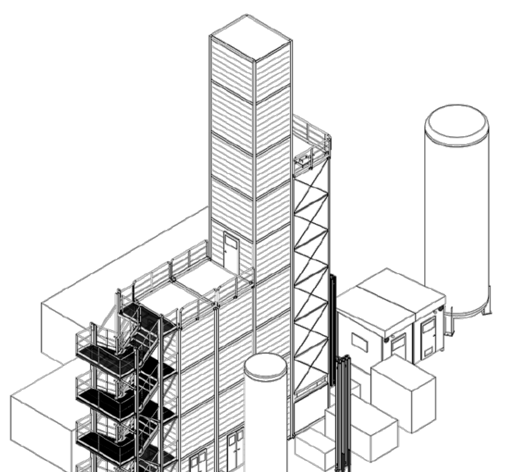
- ER and NR produce different excitation densities in Ar, leading to different ratios of singlet and triplet excitation states.
- Singlet and triplet states have different de-excitation times (τ_s~7 ns, τ_t ~1.6 μs).
- PSD variable: fraction of prompt S1 light against total S1. In DS-50 the optimal time window is 90ns, thus F90.



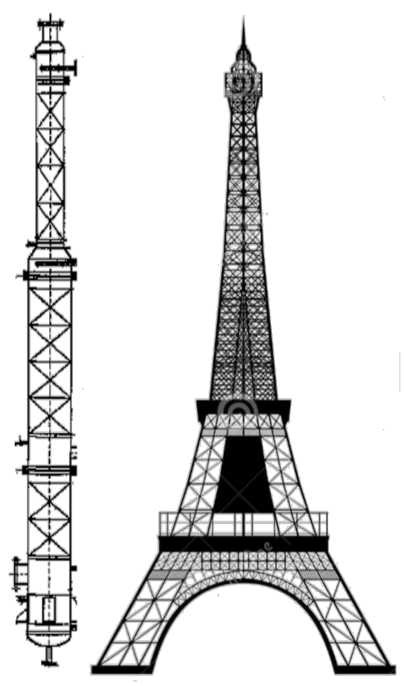


DarkSide-20k

Argon extraction and purification

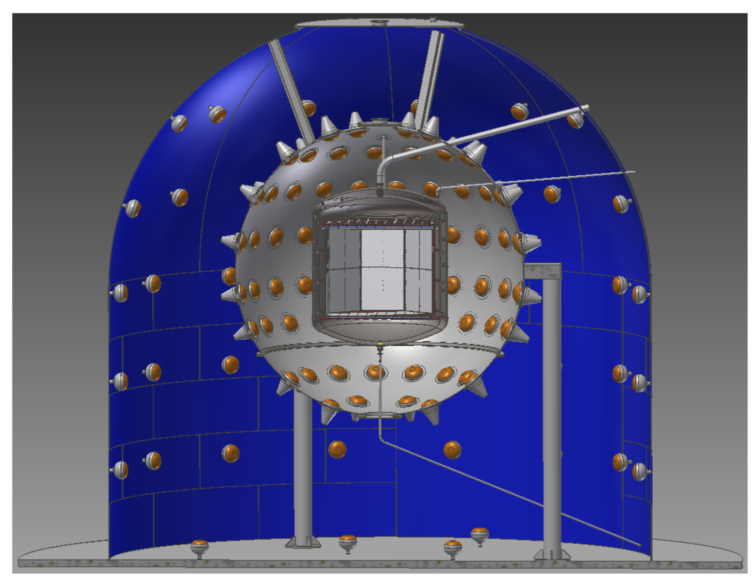


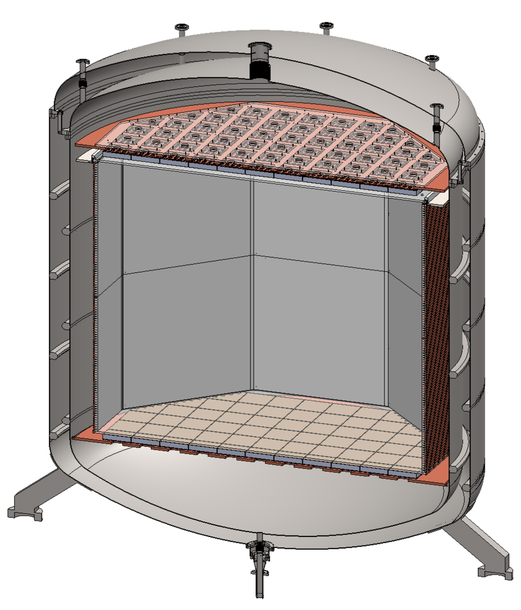
The **Urania** project will extract and purify the UAr from the CO2 wells at the Kinder Morgan Doe Canyon Facility located in Cortez, CO at a production rate of 100 kg/day.



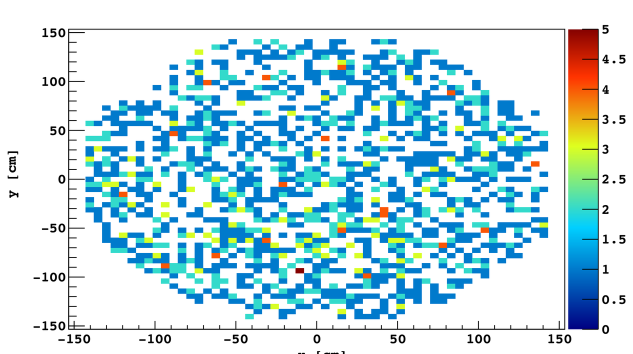
The **Aria** project will serve to further purify the UAr and further deplete it of ^{39}Ar by cryogenic distillation. The goal of the Aria project is to process about 150 kg/day of argon with an additional depletion factor between 10 and 100.

The upgrade

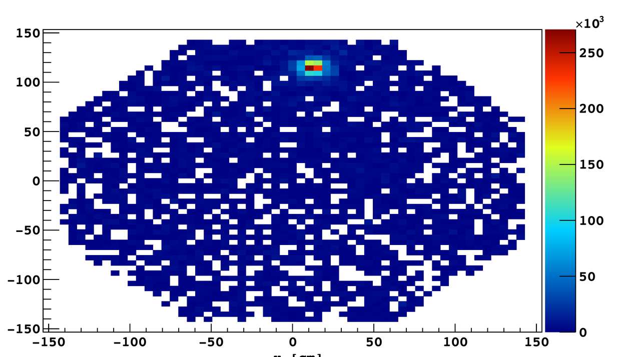




- The three nested detectors structure will remain, although all the systems will be upgraded.
- The new TPC will contain a total (fiducial) mass of 23 tons (20 tons) of LAr.
- Top and bottom of the TPC will be equipped with 5210 Photo Detector Modules (PDM), arrays of SiPMs of 24 cm² surface, each one read out as a single channel.



Typical S1

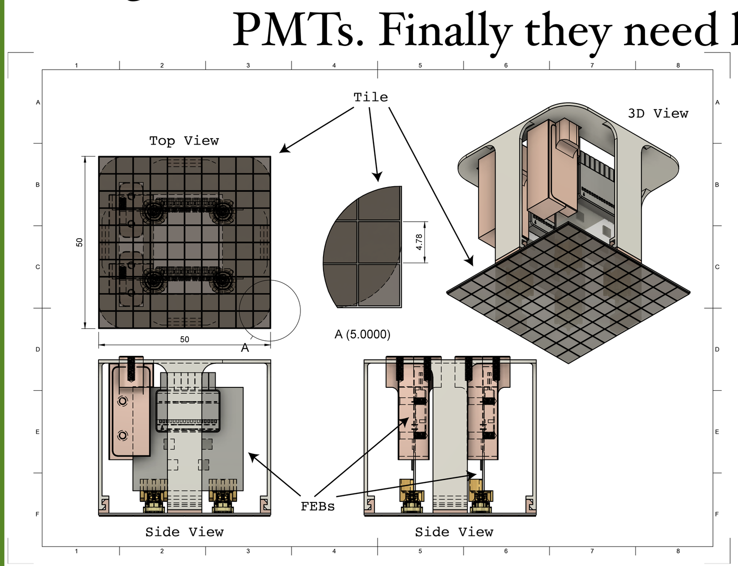


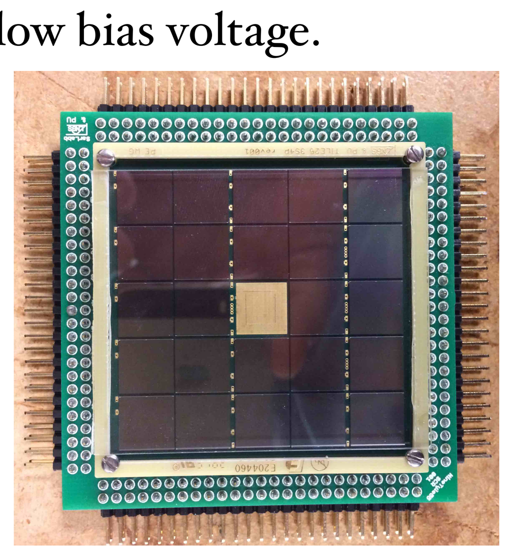
Typical S2

Silicon PhotoMultipliers as photo-detectors

Goal: develop SiPM arrays with 24 cm² surface as single photo-detector modules.

Why? SiPMs are very radio-pure. Moreover they show higher PDE and much better resolution than traditional PMTs. Finally they need low bias voltage.

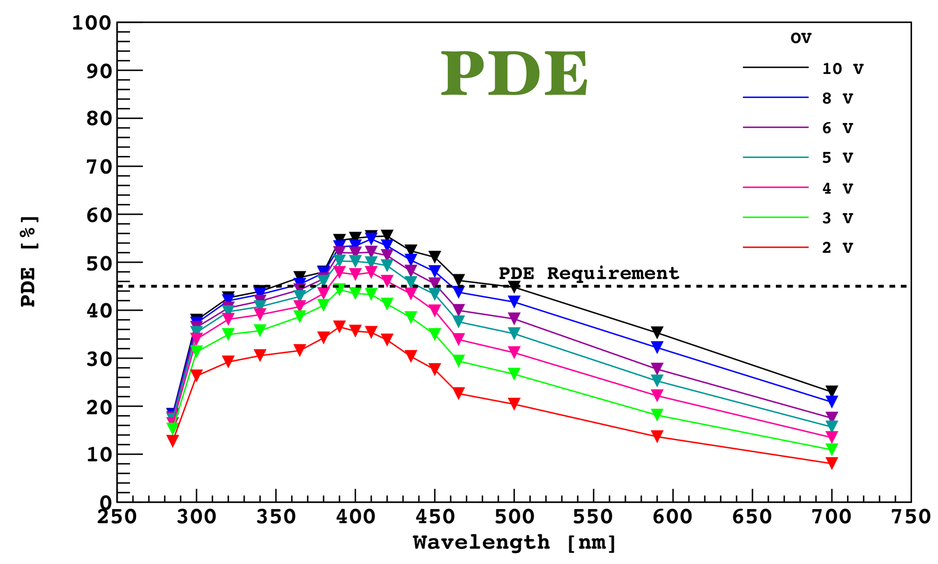


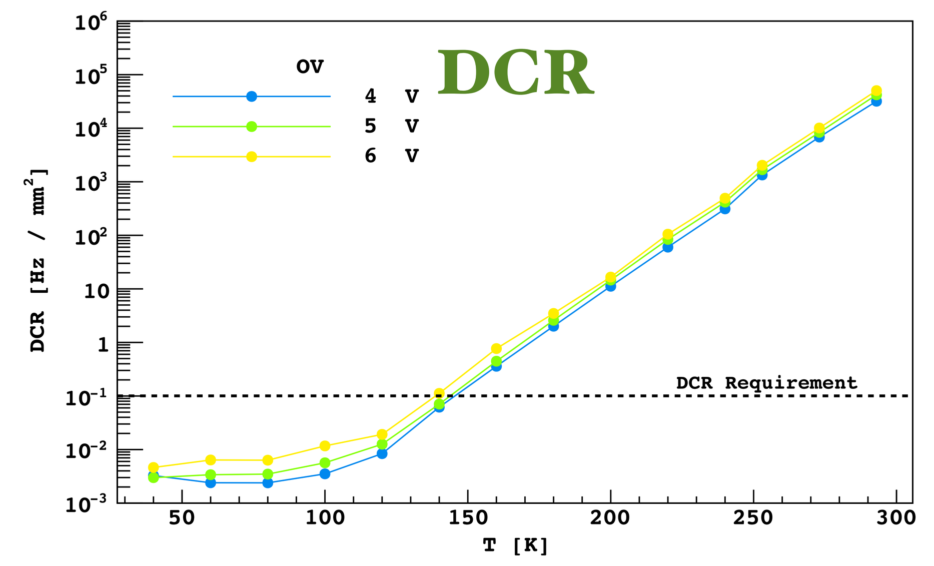


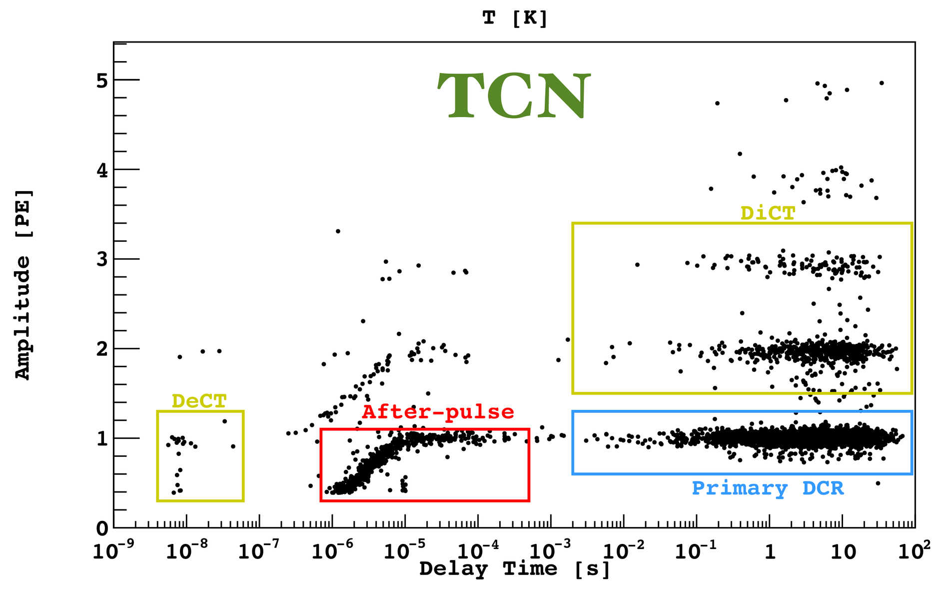
DS-20k SiPM requirements for operation at 87K:

- PDE ≥ 45% at 420 nm
- DCR < 0.1 cps/mm²
- TCN < 60%

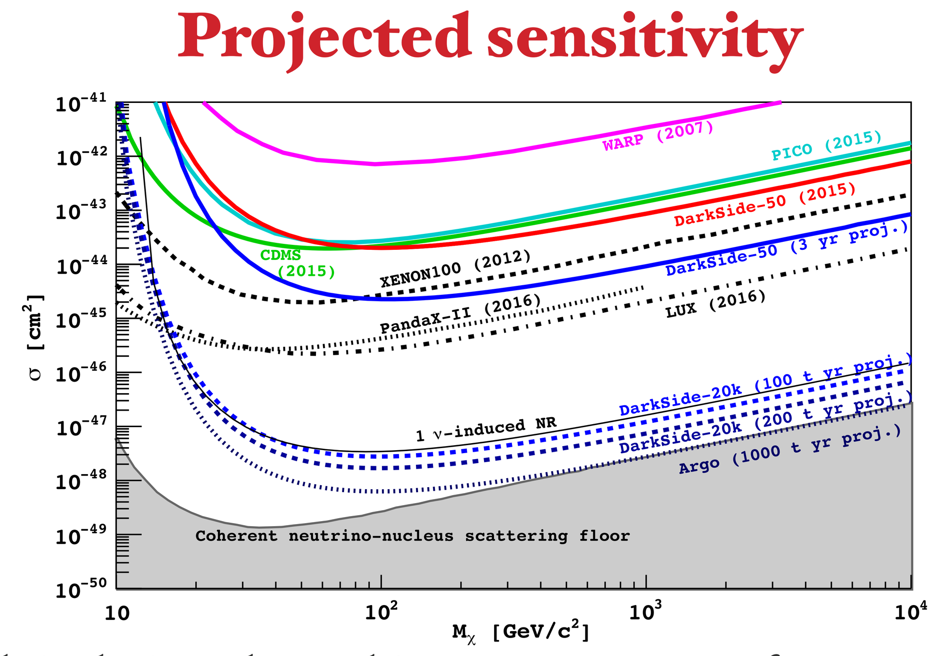
Moreover each PDM should produce an output signal with SNR > 8 in order to minimize the rate of fake hits due to electronic noise. Currently 2 fully working tiles of 24 cm² surface has been produced, showing a **SNR in excess of 10** after signal digital filtering.







Projected sensitivity



DS-20k is designed to achieve an exposure of 100 t yr giving a sensitivity to WIMP-nucleon interaction cross-section of 1.2×10^{-47}cm² for WIMPs of 1 TeV/c² and 1.1×10^{-46}cm² for WIMPs of 10 TeV/c²