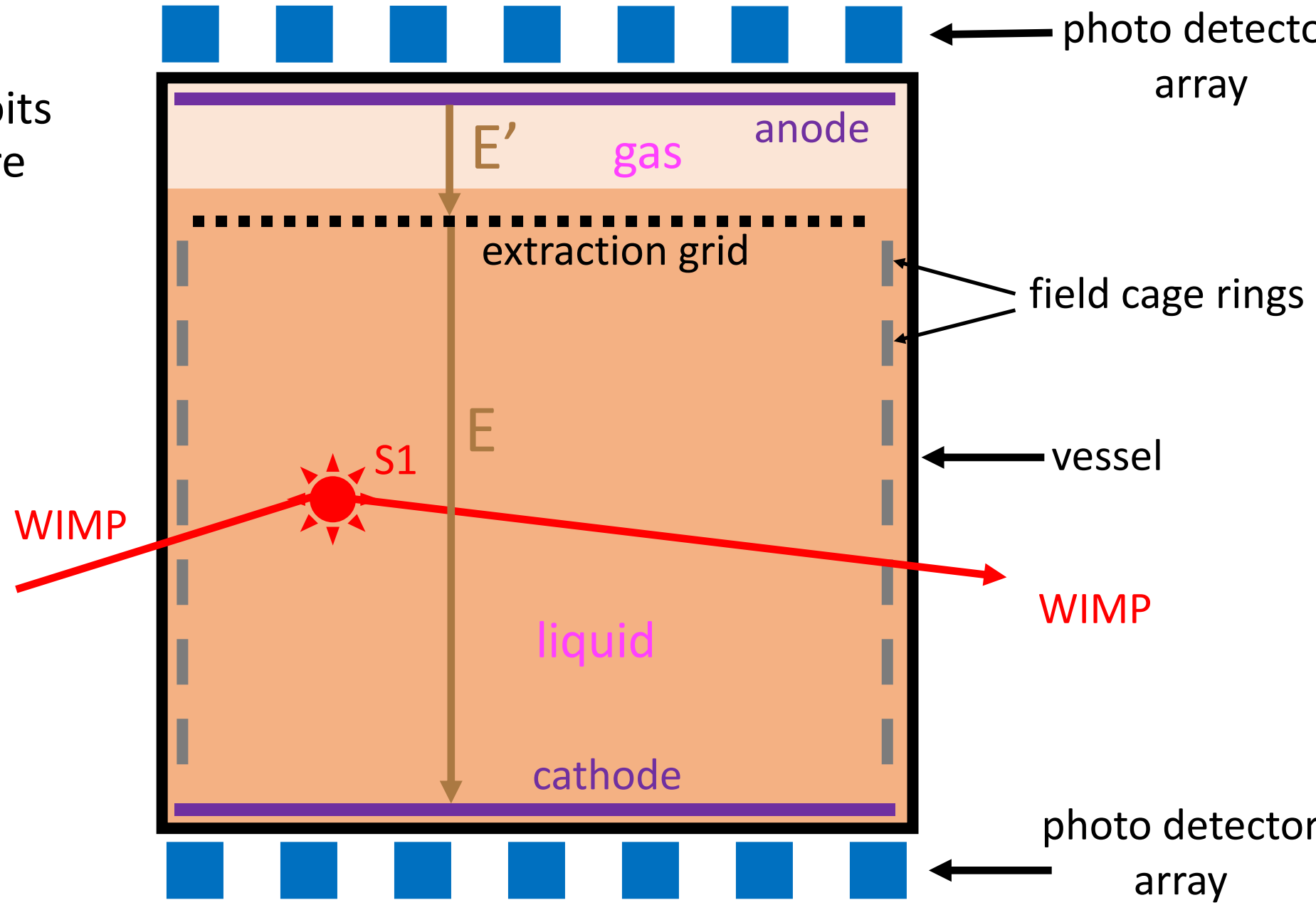
A Glimpse of the DarkSide

Tom Thorpe for the DarkSide collaboration

Detecting Dark Matter in the Laboratory

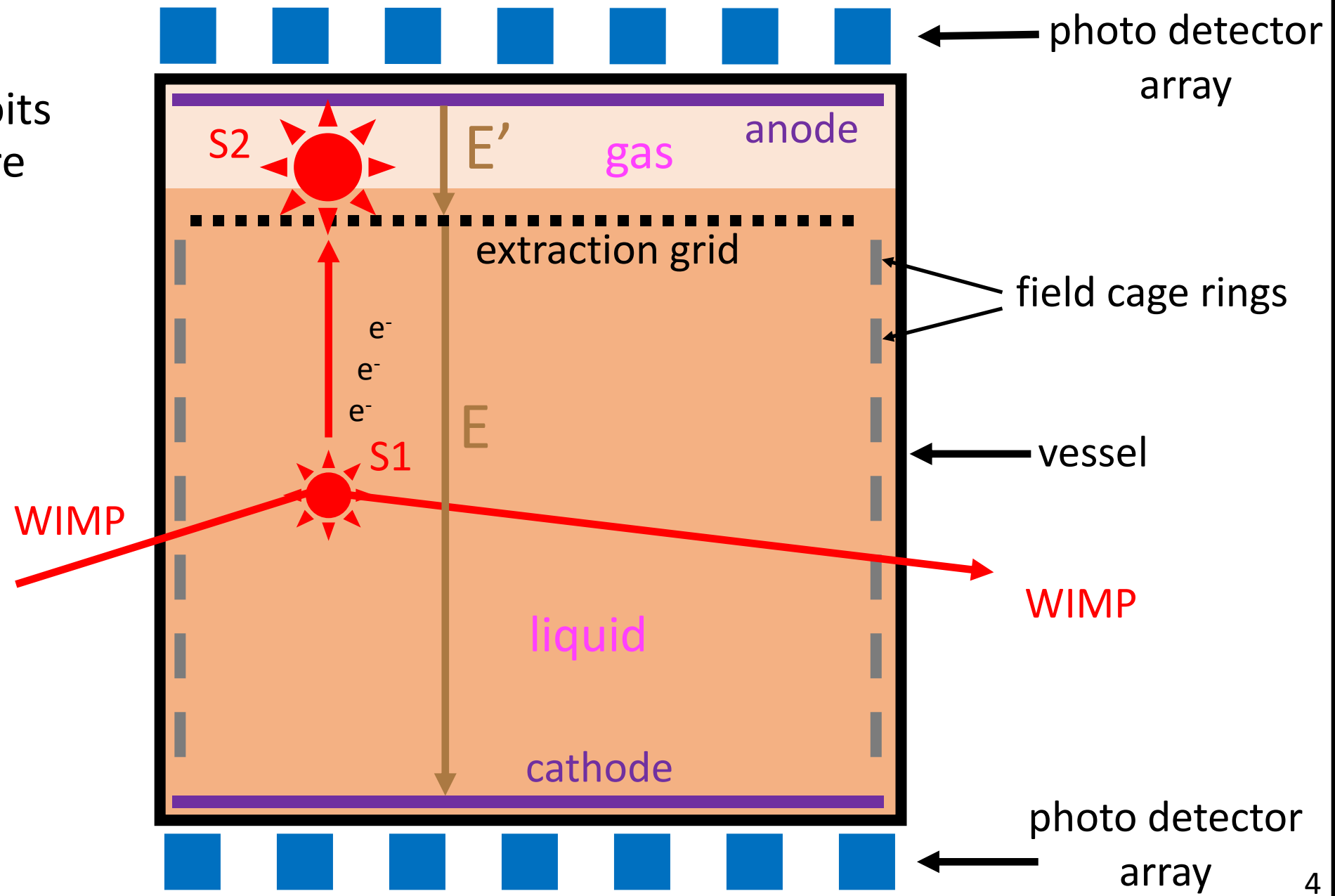
Dual Phase TPC Cartoon

- Primary event discrimination exploits the S1 time signature



Dual Phase TPC Cartoon

- Primary event discrimination exploits the S1 time signature
- X and Y are reconstructed by localizing the S2 signal
- Z is reconstructed via the drift time (time difference between S2 and S1)
- Further event discrimination can be done with S2



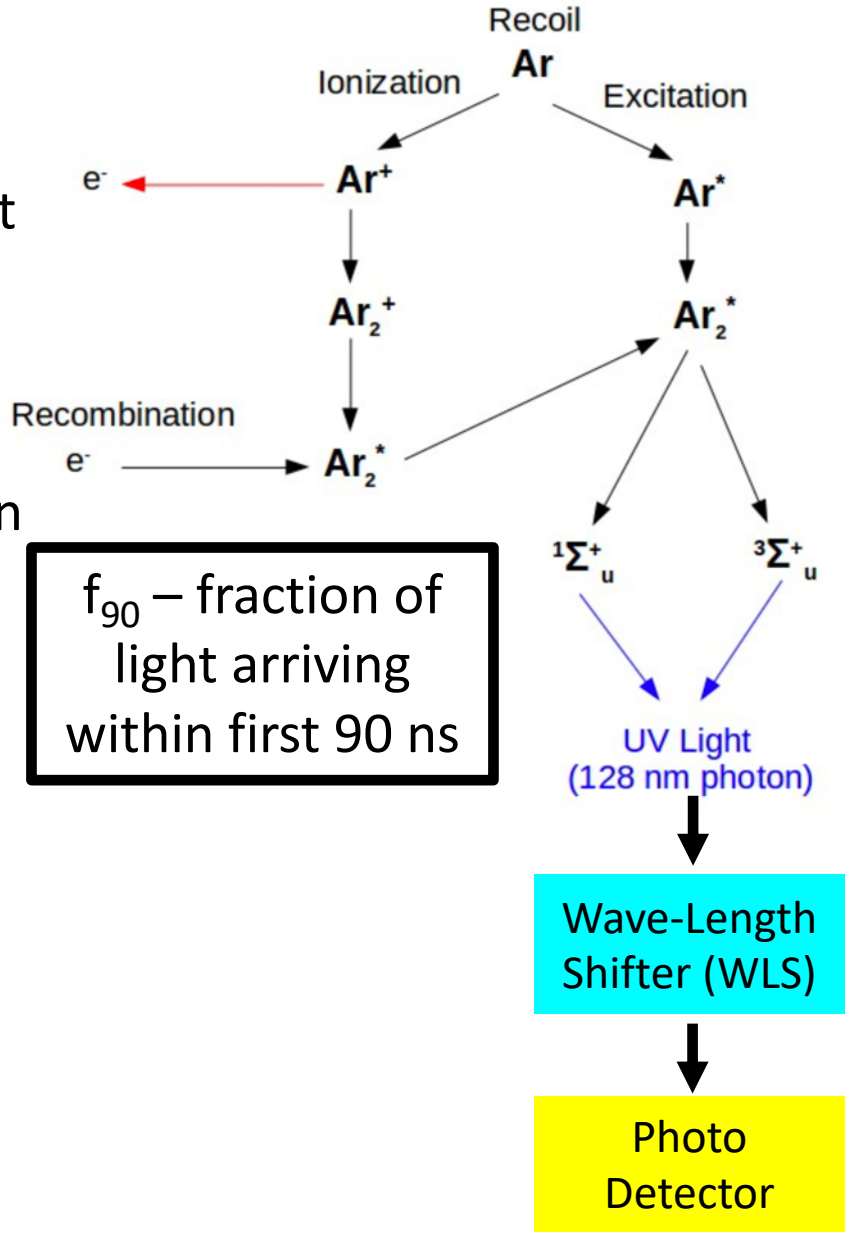
Why Liquid Argon?

- Excited states relax by emitting 128 nm photons
- Very different decay times of singlet (~ 7 ns) vs. triplet (~ 1500 ns) state
- Electron recoils cause a higher fraction of triplet states than nuclear recoils
- Results in superior electron rejection
- DS-50 rejected 1.5 x 10^7, all, ER events in AAr run from 8.6 - 65.6 keV
  - Statistics limited

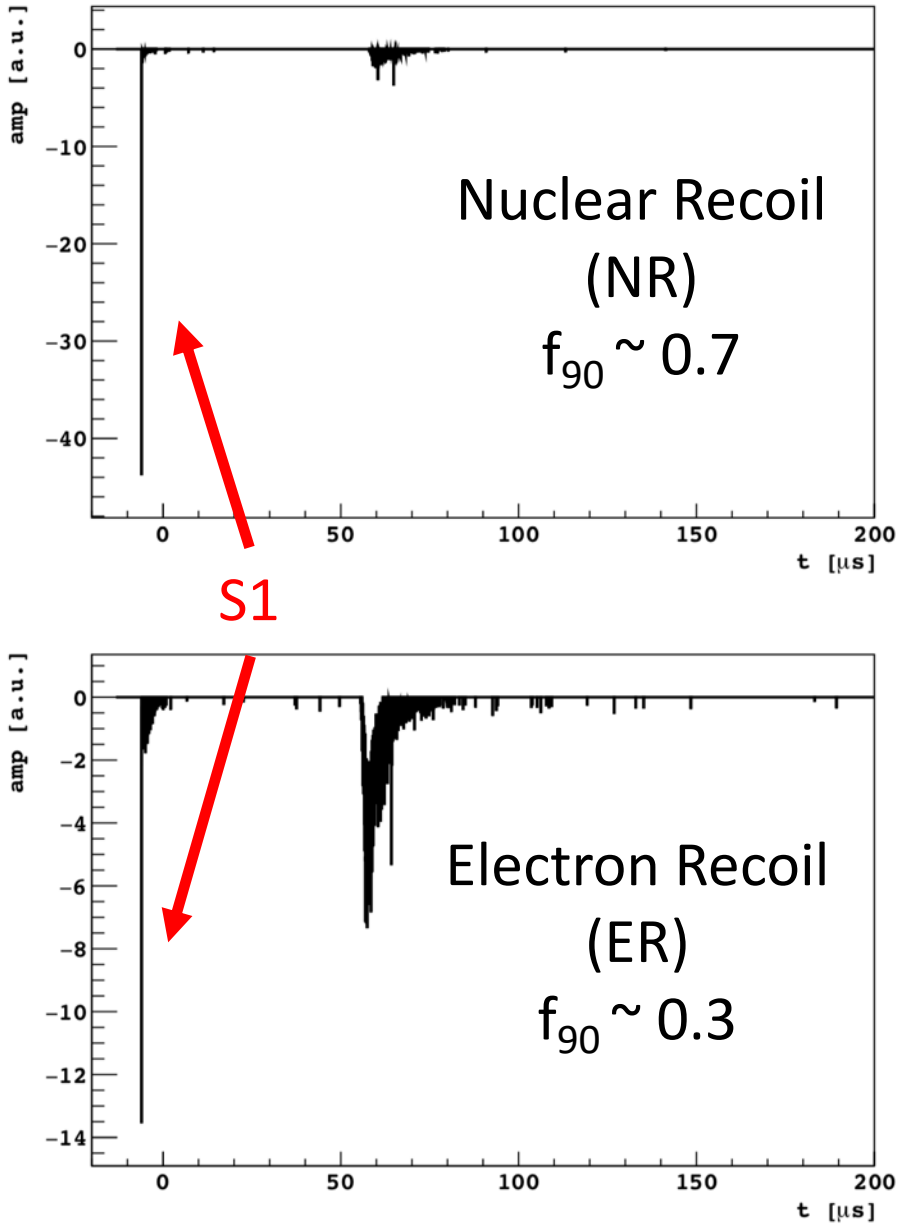
arxiv:1410.0653

- DEAP-3600 has just shown an ER leakage factor of 4.1 x 10^{-9} from 15.6 - 32.9 keV w/ 90% NR acceptance

arxiv:1902.04048



f_{90} – fraction of light arriving within first 90 ns



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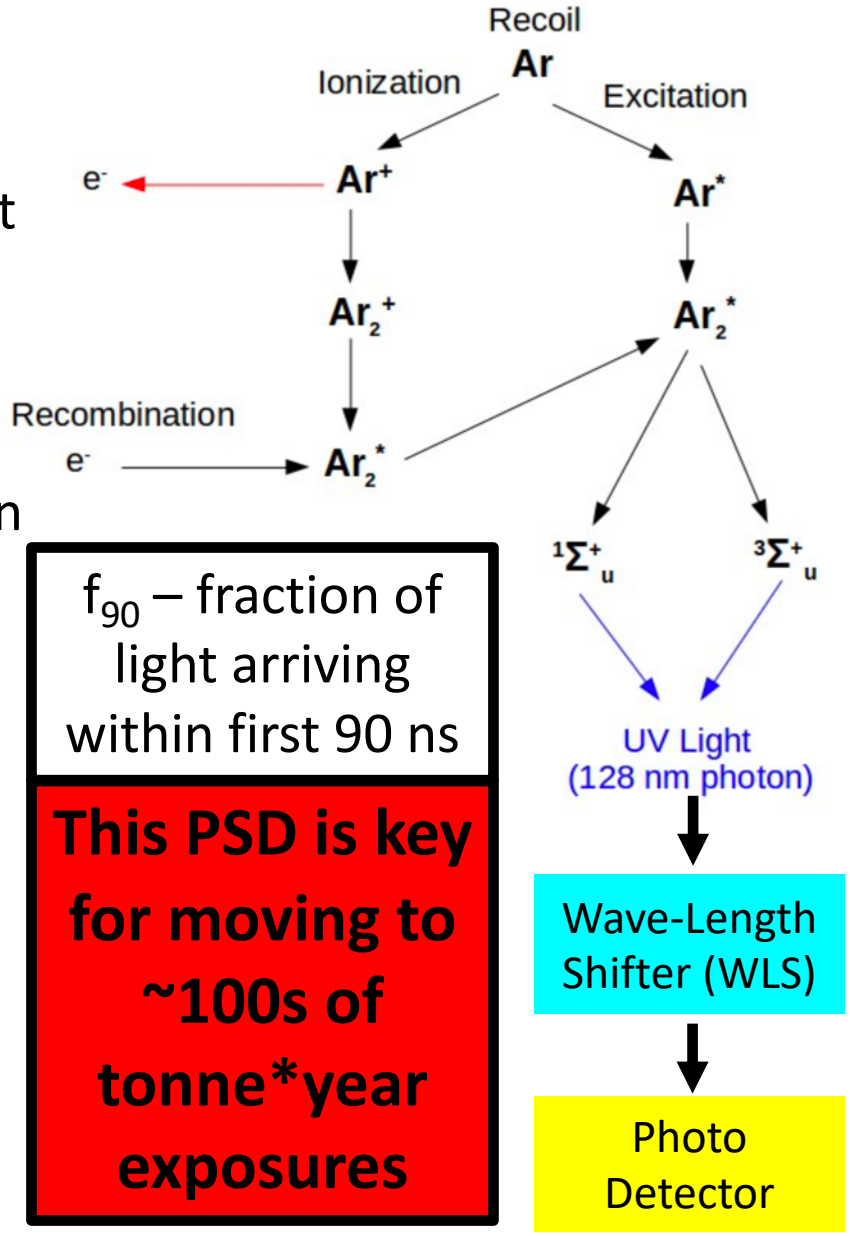

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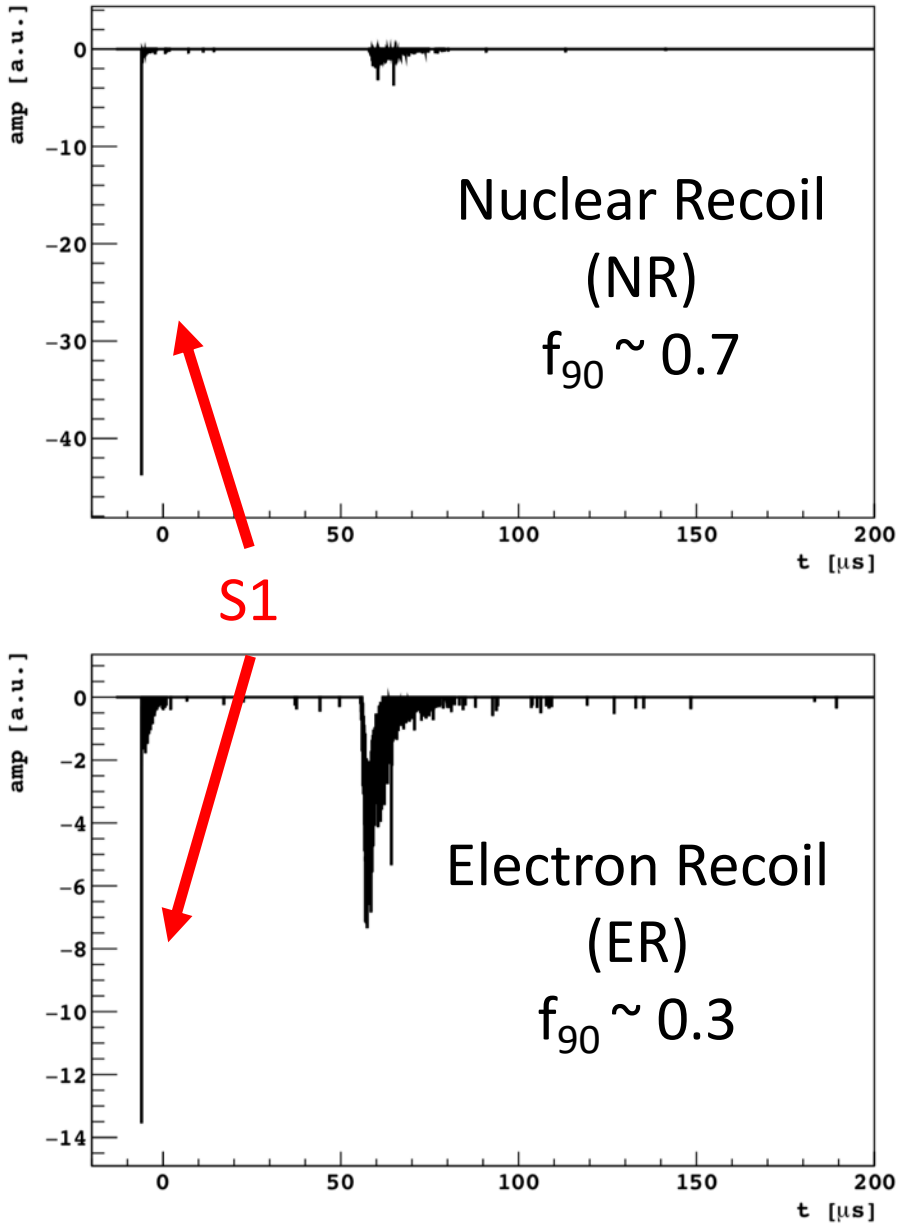
This PSD is key for moving to ~100s of tonne*year exposures



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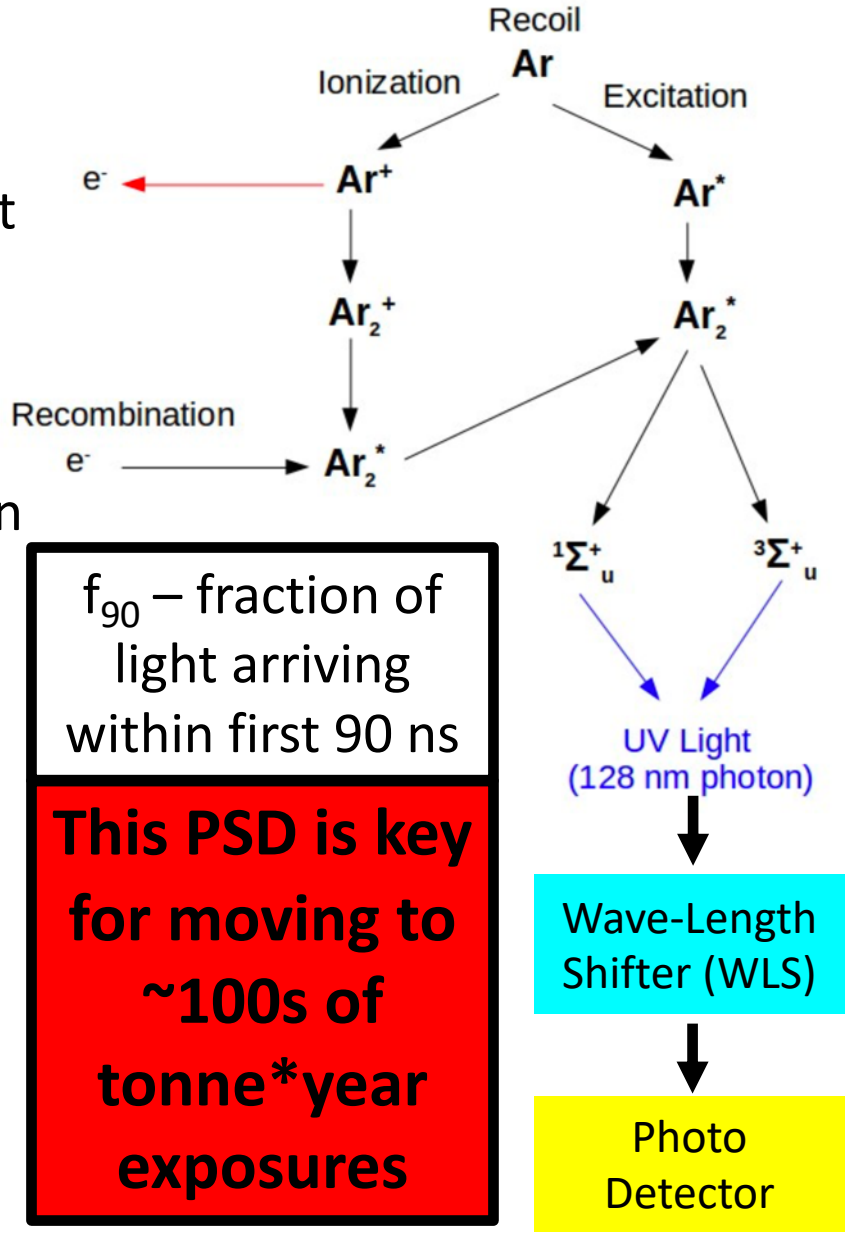

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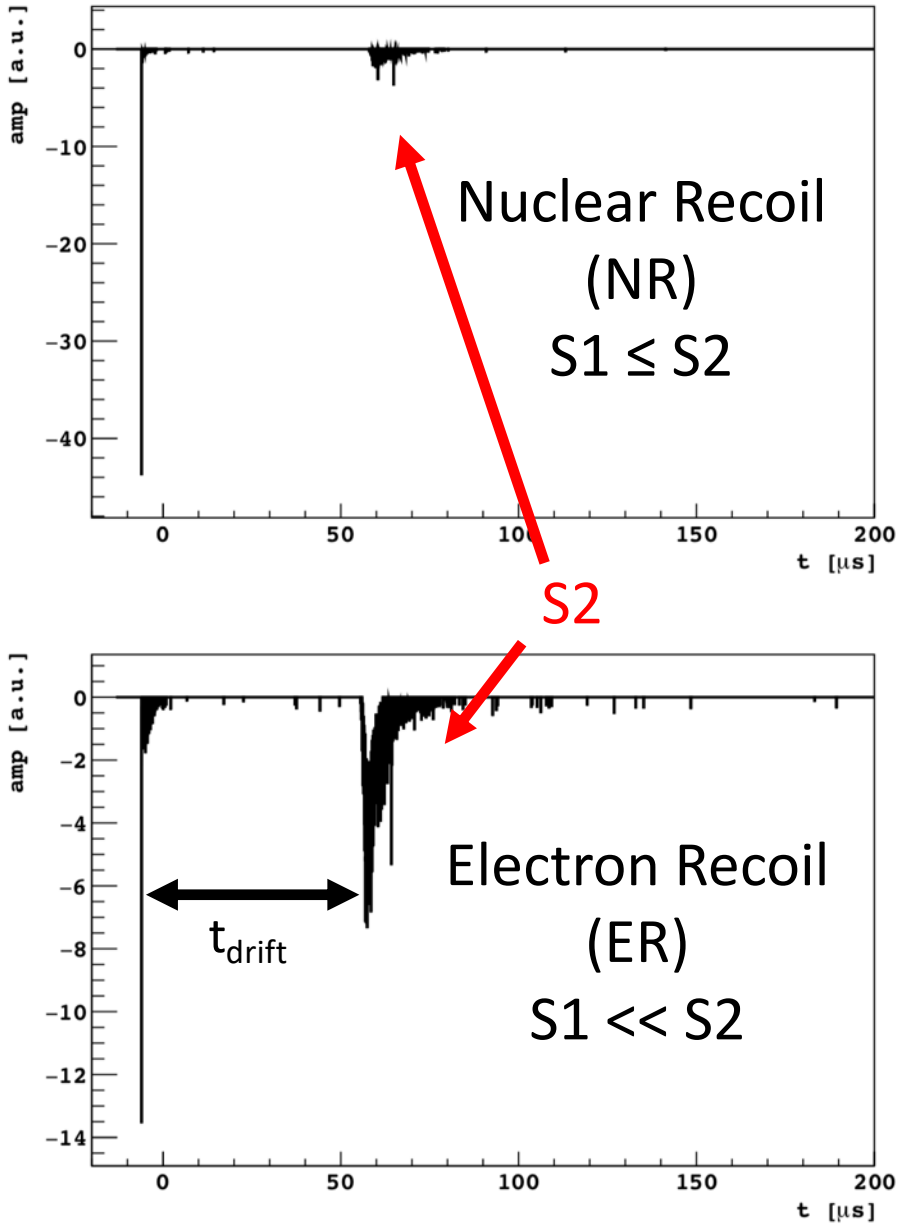
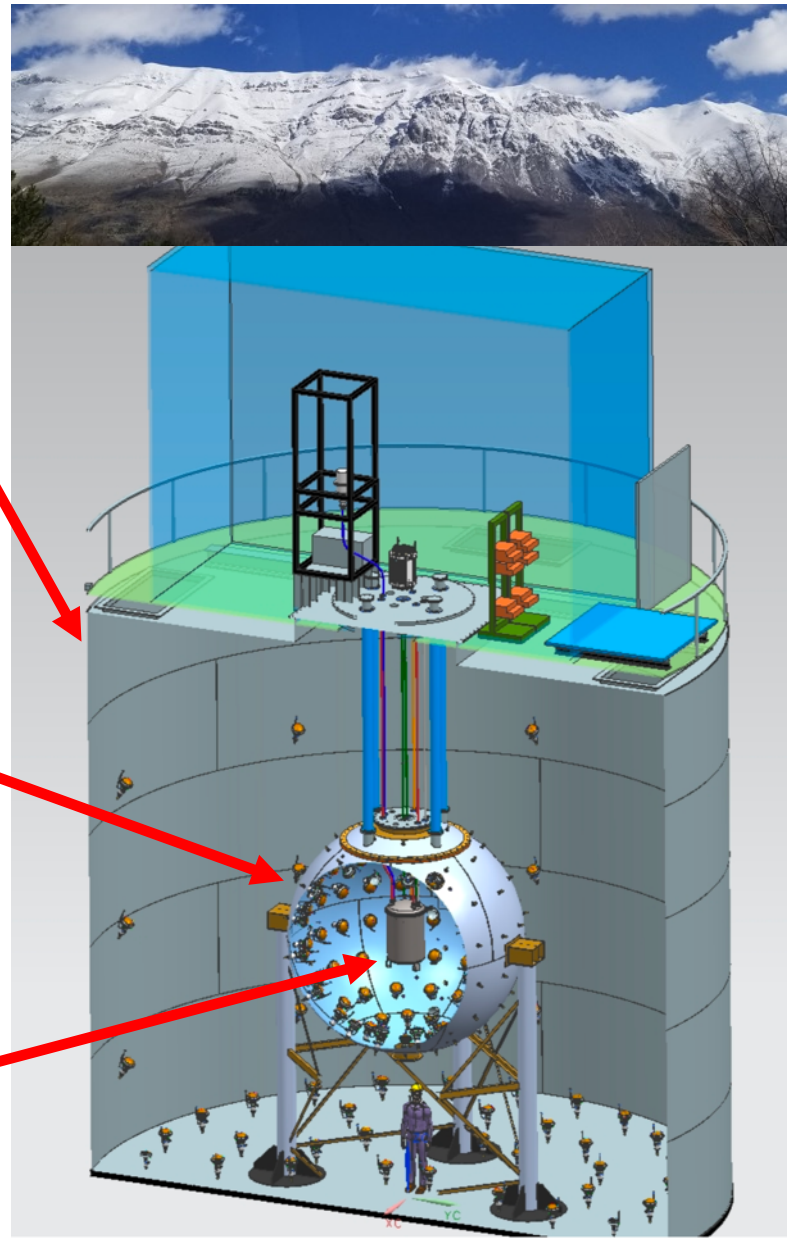
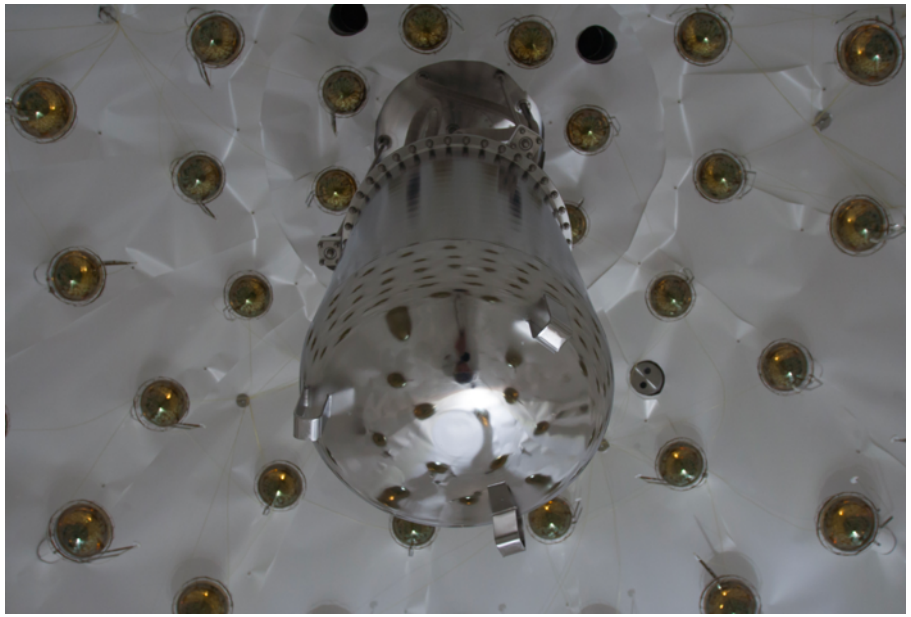
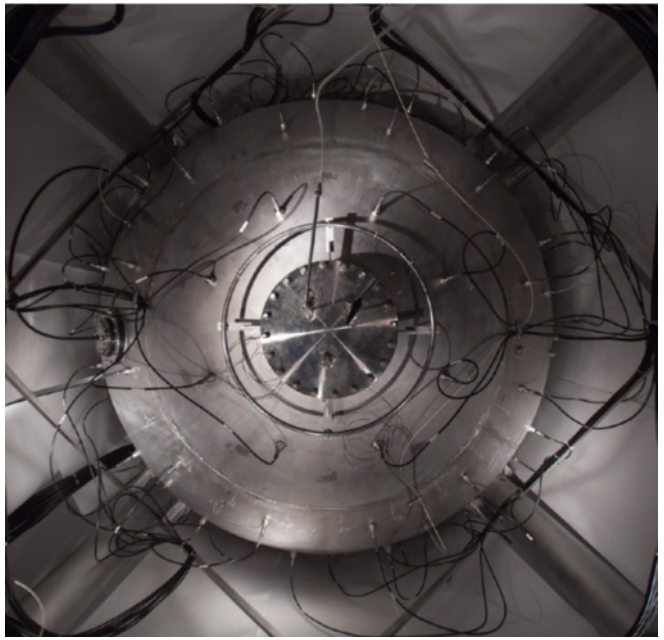


DarkSide-50 Structural Overview

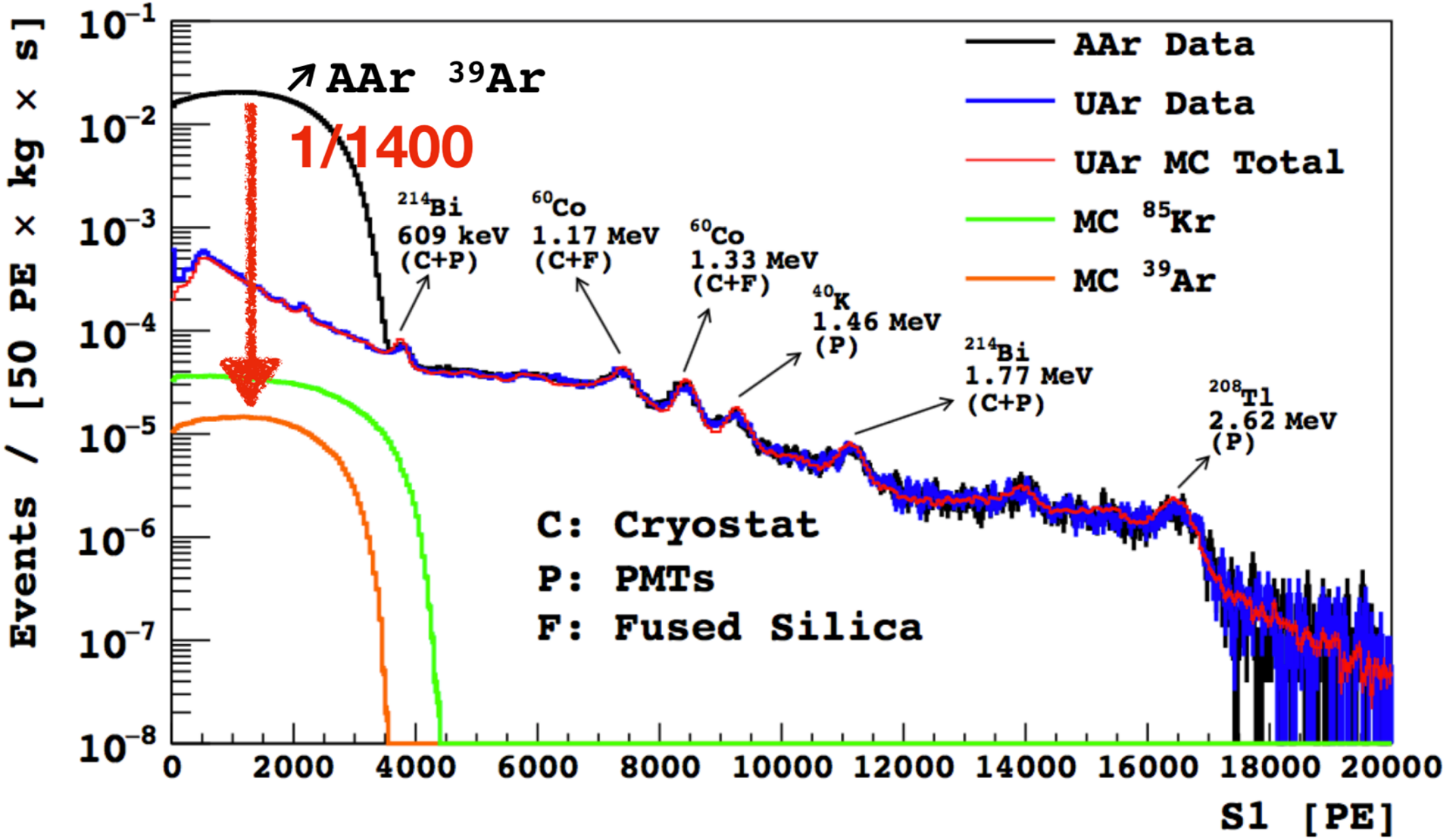
- Water Cherenkov detector
  - Stainless steel cylinder d=11 m; h=10 m
  - 1,000 tonnes of ultra pure water
  - Active veto for muons and passive shield for external radiation
  - 80 8” PMTs
- Liquid scintillator detector
  - 4 m stainless steel sphere
  - 30 tonnes of Boron loaded scintillator
  - Active gamma and neutron veto thanks to ^{10}B loading
  - 110 8” PMTs
- Inner LAr TPC





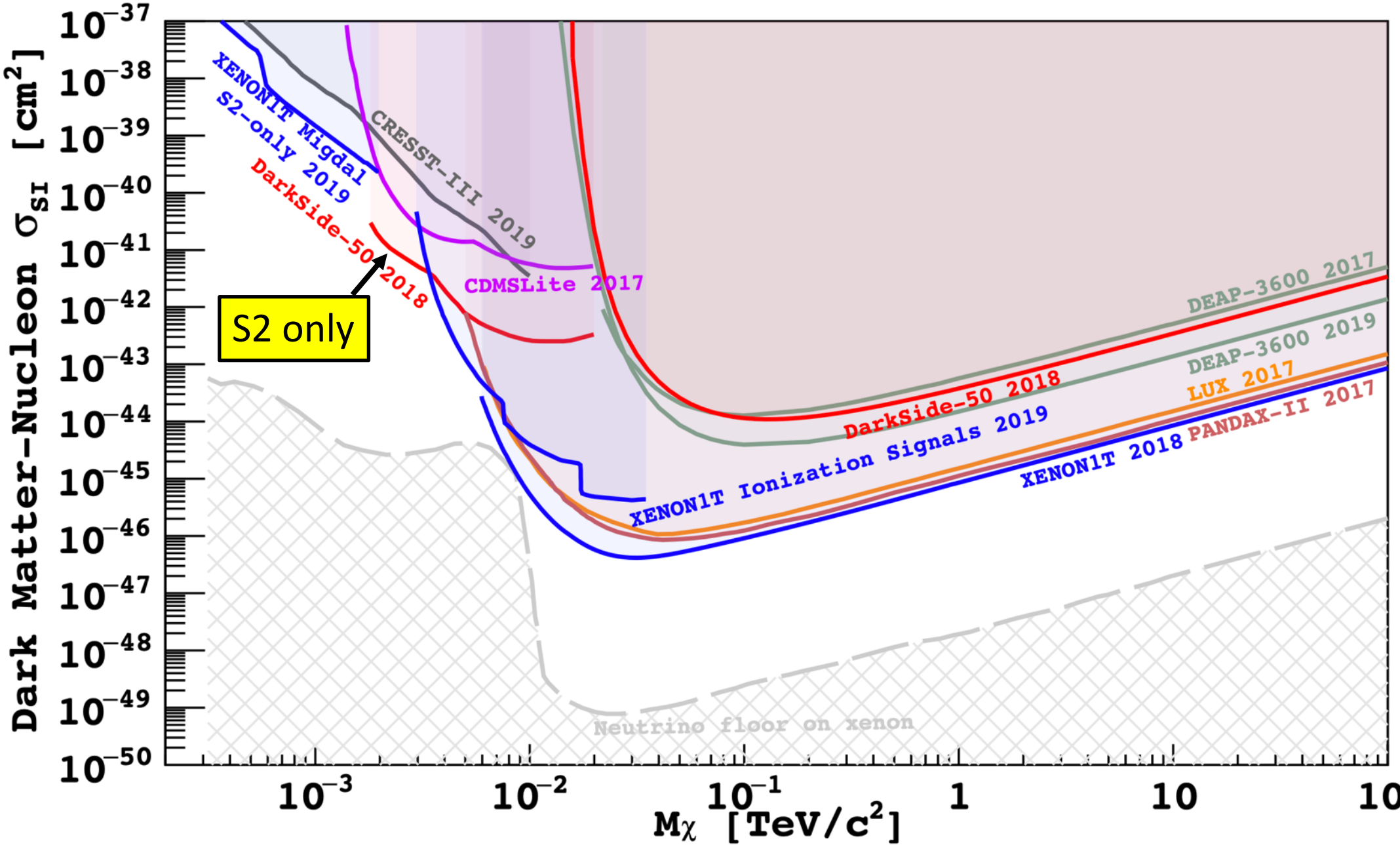


DarkSide-50 Underground Argon

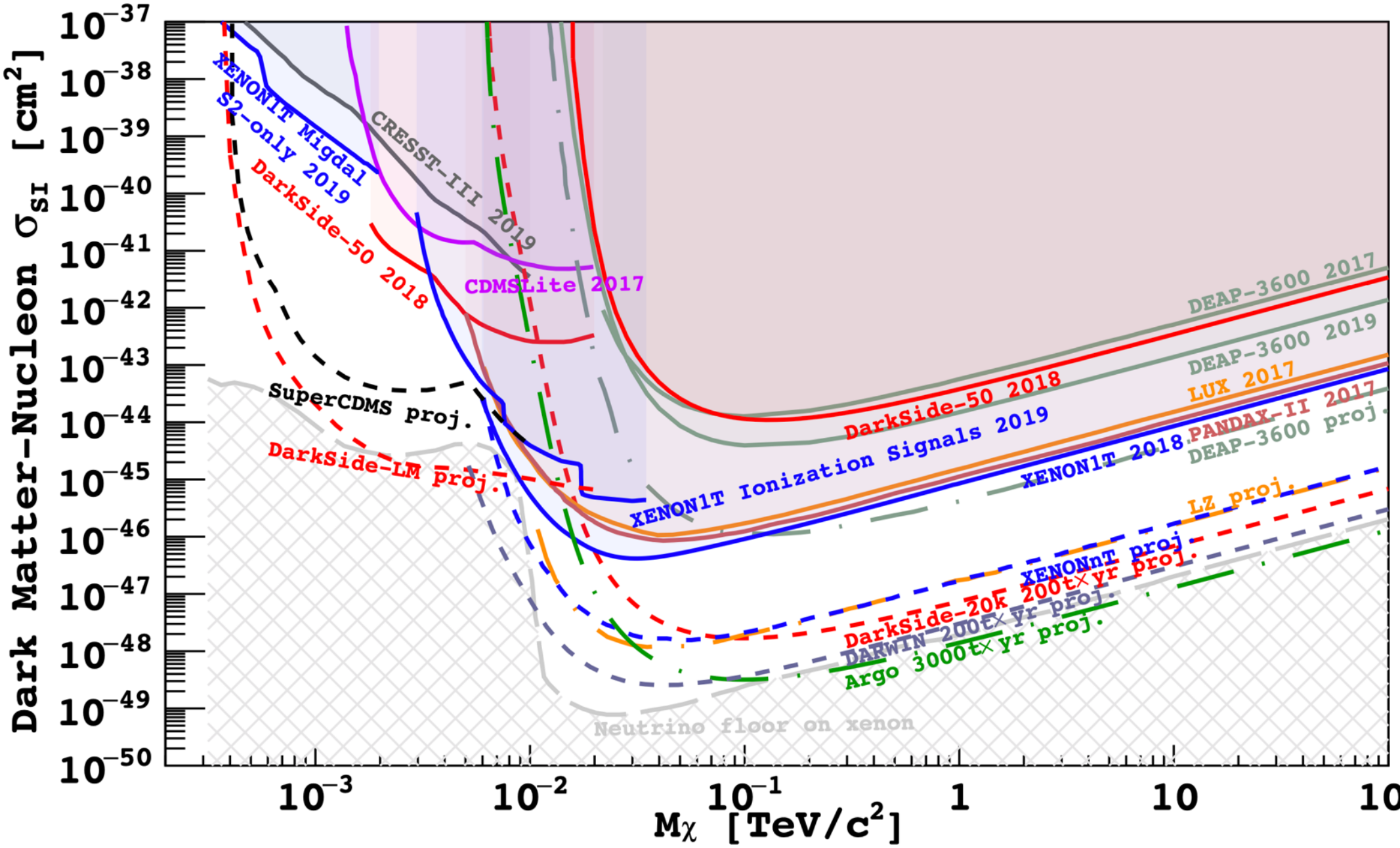


PRD, 93 (2016): 081101(R)

Current Sensitivity



Projected Sensitivity



DarkSide-20k Structural Overview

- ProtoDUNE like cryostat
- Optical and EM barrier
- Neutron veto will use Gd doped acrylic panels and Atmospheric Argon (AAr)
- Inner TPC will be a sealed acrylic vessel containing UAr
- Separate cryogenic systems for UAr and AAr volumes
- Acrylic knowledge from DEAP-3600 is being implemented
- Silicon Photo Multipliers (SiPMs) will replace PMTs in TPC and veto (not shown)

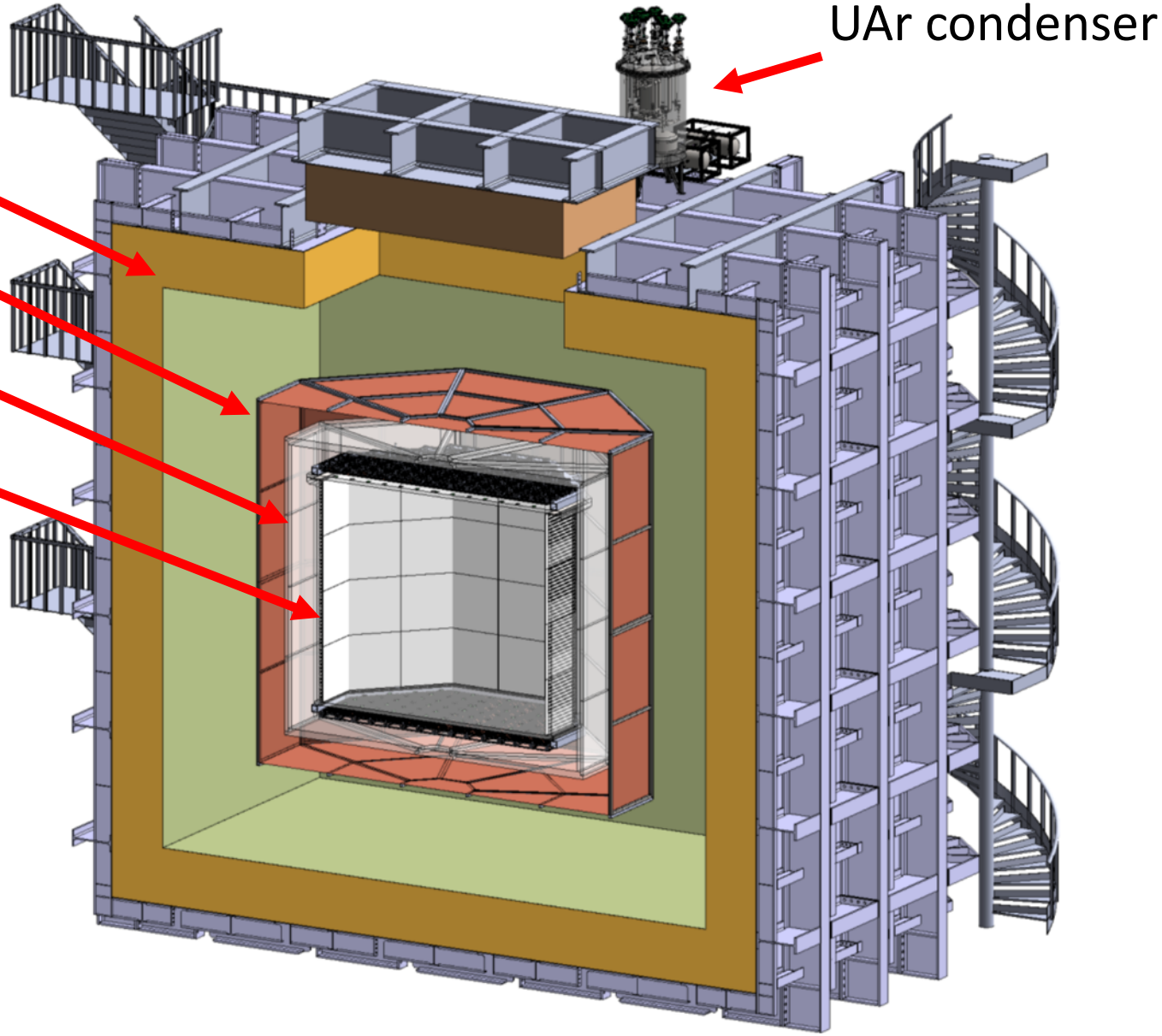
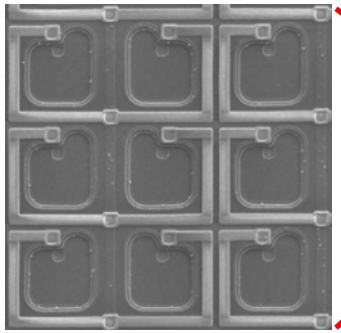
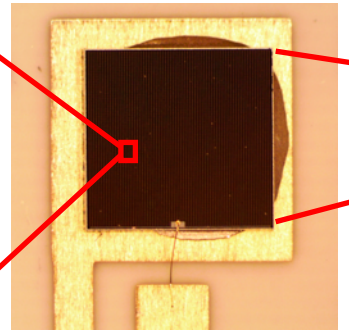


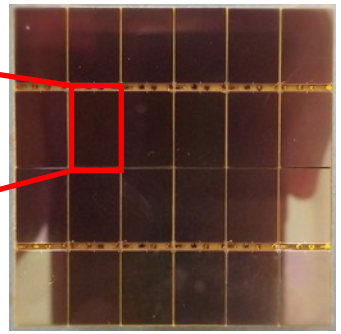
Photo Detector Modules (PDMs)



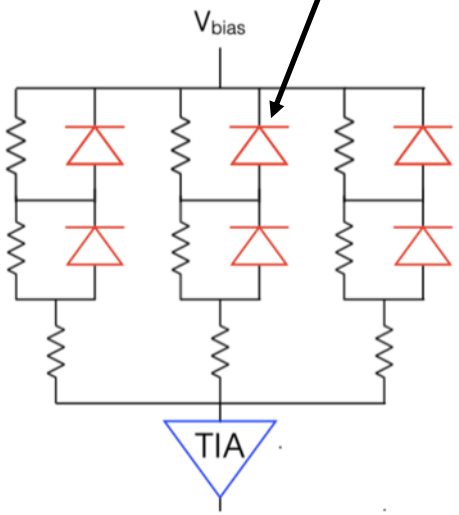
Individual SPADs
25-30 um²



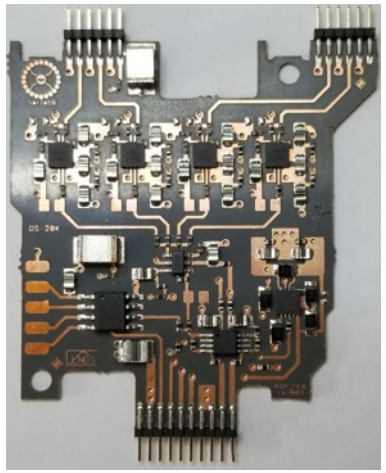
Single SiPM
~ 1cm²



Single tile
(24 SiPMs;
(2_3|)x4;
~ 5 cm x 5 cm)



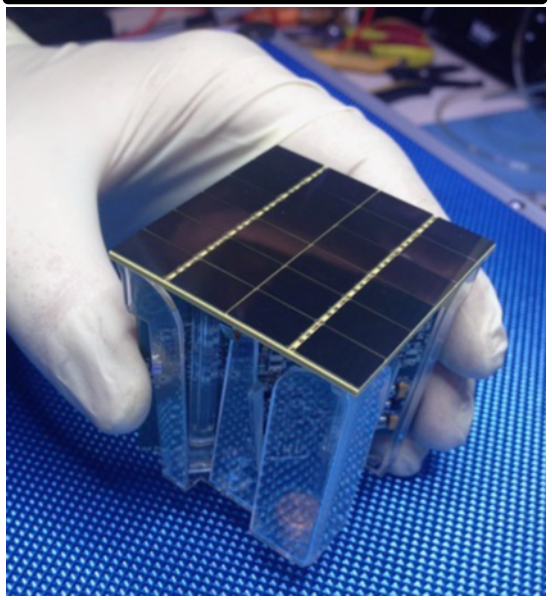
x4 then summed



Front End Board

87K also allows for electronic advantages!

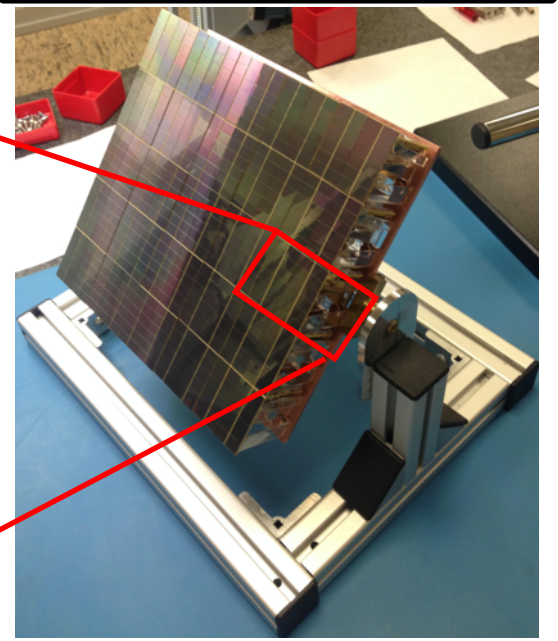
~ 5 cm x 5 cm x 5 cm



PDM

Photo Detection Module
(Tile + FEB in acrylic cage; base detection unit; one summed readout channel)

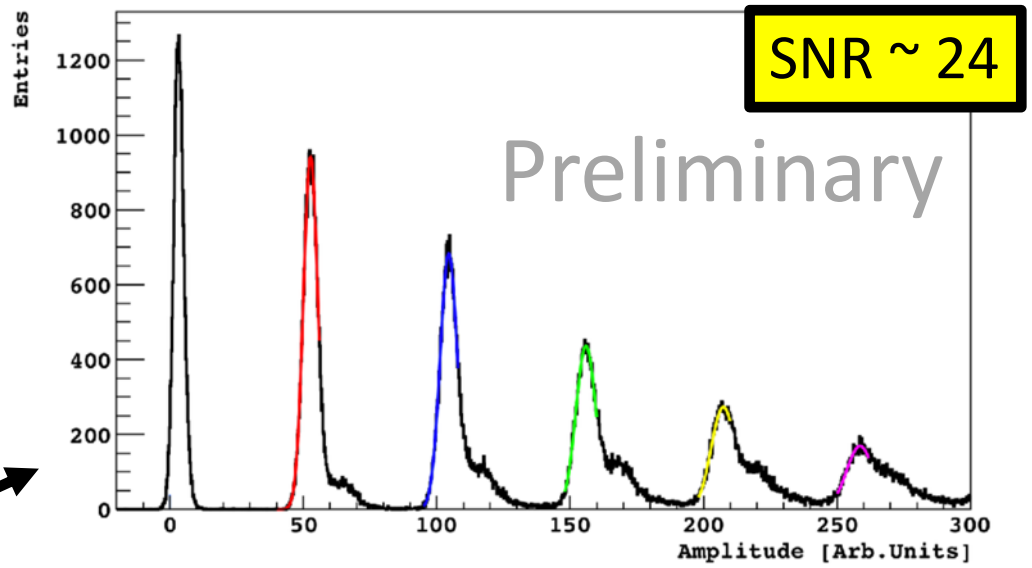
~ 25 cm x 25 cm x 5 cm

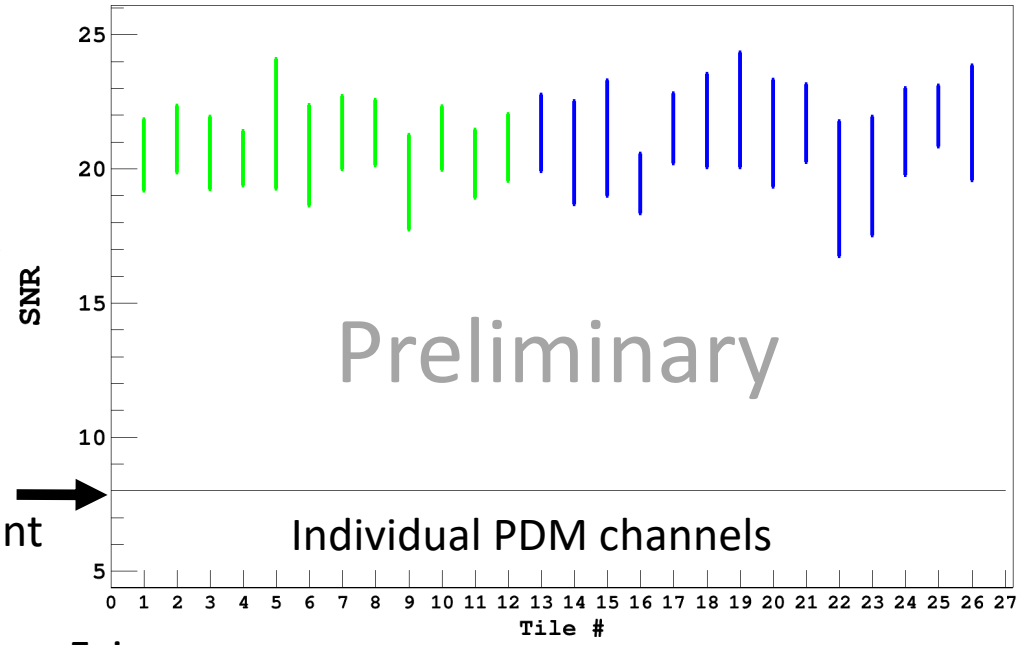


25 PDMs with mechanical support structure; base mechanical unit for DS-20k; routing structure for power and signal readout contained

PDM Performance

- Photo Detection Efficiency (PDE) ~50%
- FBK, Trento IT, NUV-HD-Cryo tech
  - Optimized for LAr temperatures
  - > 90% fill factor
- Power consumption required to be < 100 μW/mm^2
- 0.1 Hz/mm^2 dark count rate
- < 10 ns timing resolution
- Single Photo Electron (SPE) resolution
- High SNR

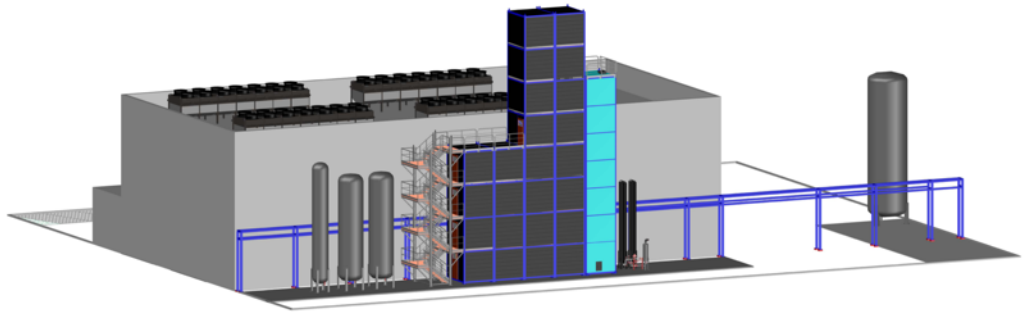




Details:		
arxiv:1706.04213	arxiv:1706.04220	arxiv:1610.01915

Underground Argon (UAr)

Production - Urania - CO, US



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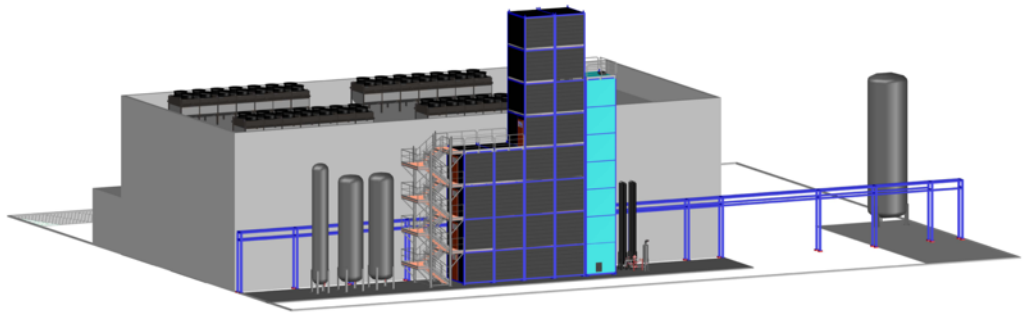
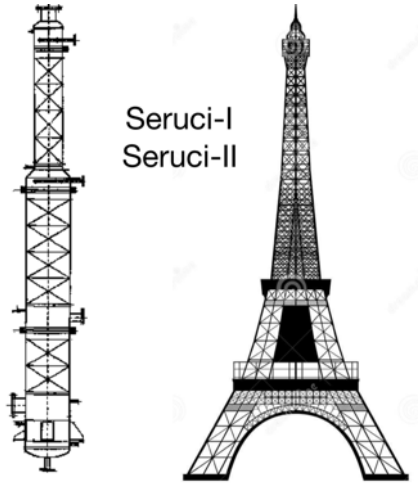
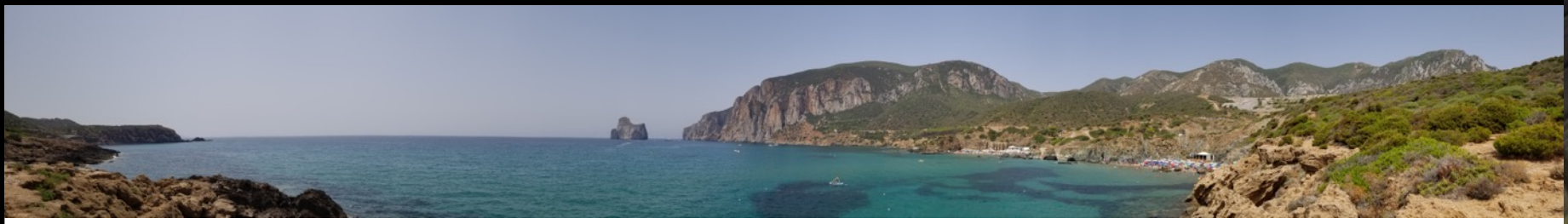


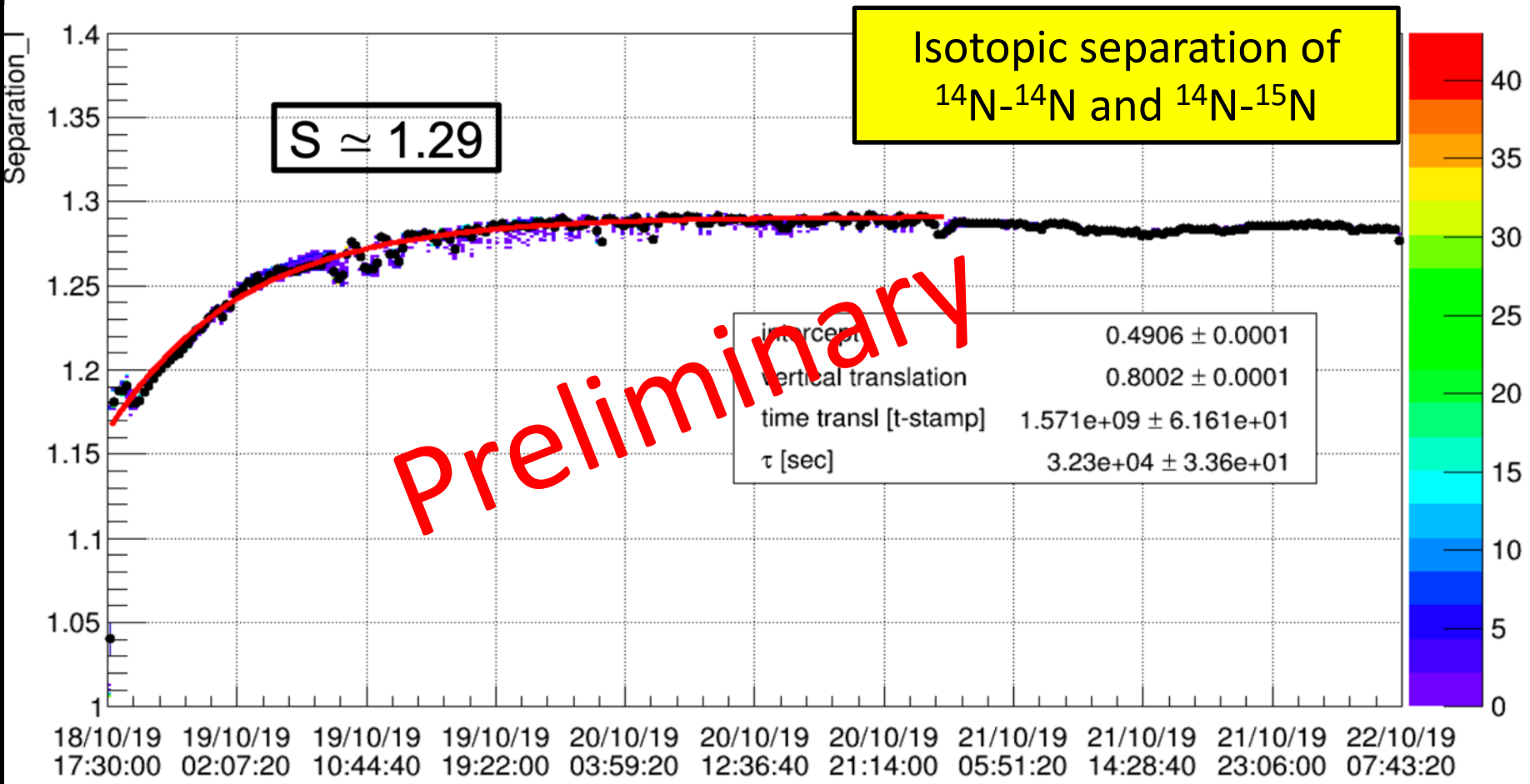


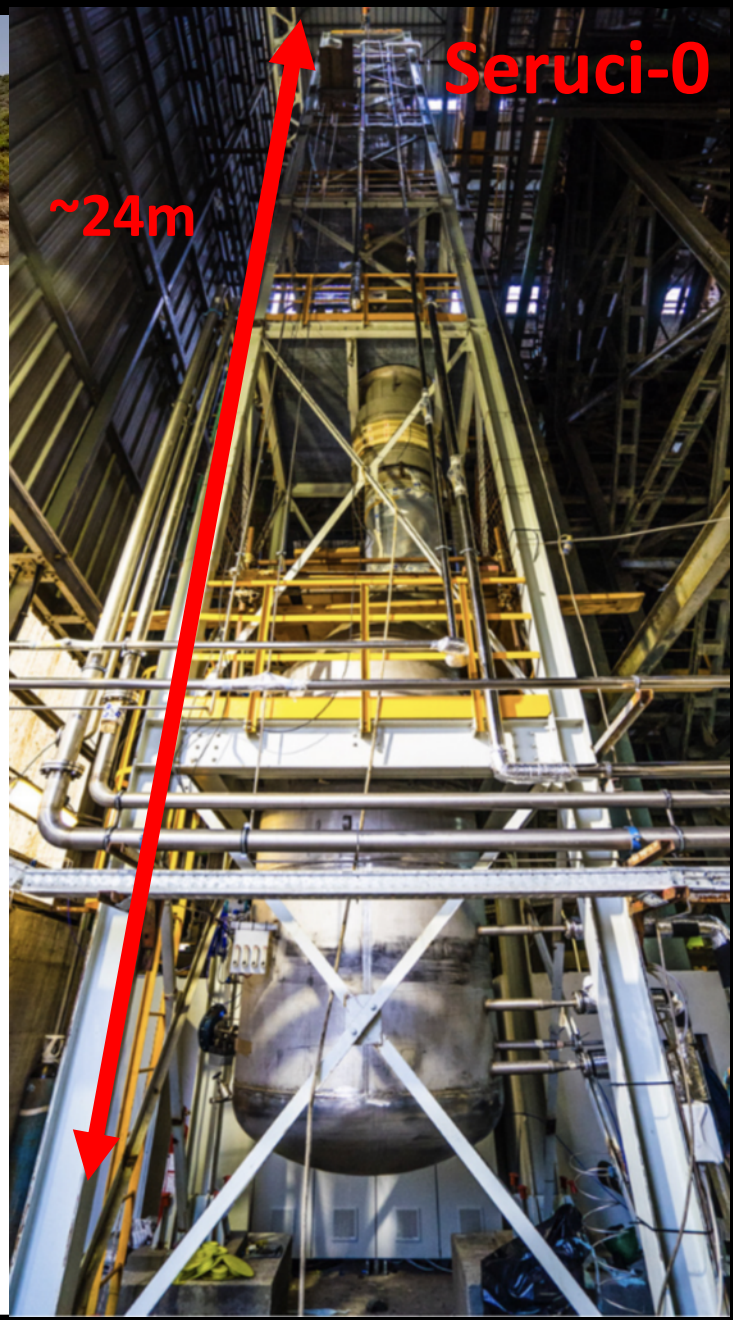
Purification - Aria - Sardinia, IT

- Ground/sea transport
- Final product will allow for multi-tonne scale experiments

Aria - First Results w/ Nitrogen



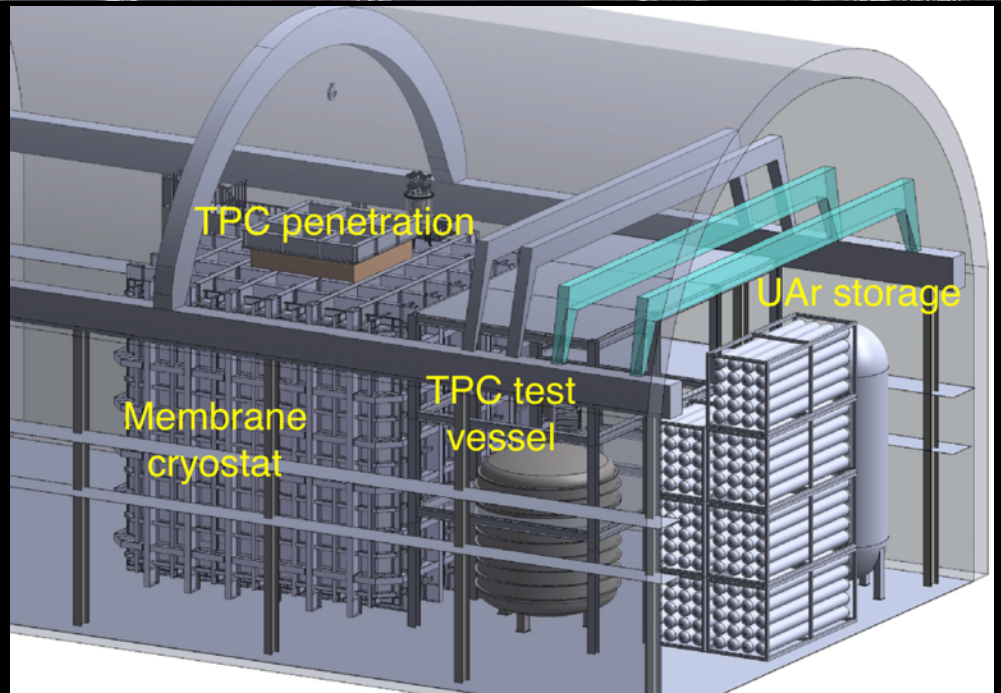




Summary

- Dual phase Argon TPCs are a proven technology for background-free dark matter searches
  - Zero background > 10 GeV
- The GADMC is now pooling resources with DarkSide-20k as the next step
- DarkSide-20k could reach the neutrino floor using key technologies:
  - Large scale production of novel SiPM based cryogenic photo detectors
  - Extraction and purification of large quantities of low radioactivity underground Argon
  - TPC technologies – Clevios, reflectors, SS wire grid, gas pocket formation…
  - Active neutron veto utilizing atmospheric Argon, Gd doped acrylic, SiPM readout
  - Acrylic structural R&D
  - Acrylic knowledge and experience from DEAP-3600
- DarkSide-20k technology could also decrease the low mass WIMP cross section by orders of magnitude
- The future of this technology (Argo) aims to fully cover the parameter space to the neutrino floor

Thank You


TPC penetration
UAr storage
TPC test vessel
Membrane cryostat