The DarkSide-20k Experiment in 10 Minutes

Michael Poehlmann
University of California, Davis

On behalf of the DarkSide Collaboration

New Perspectives
20 July 2020

The DarkSide Program

Dark matter direct detection using Ar two-phase TPCs

DS-50

2014 - present

First UAr physics detector

DS-Proto-0

2019 - 2020

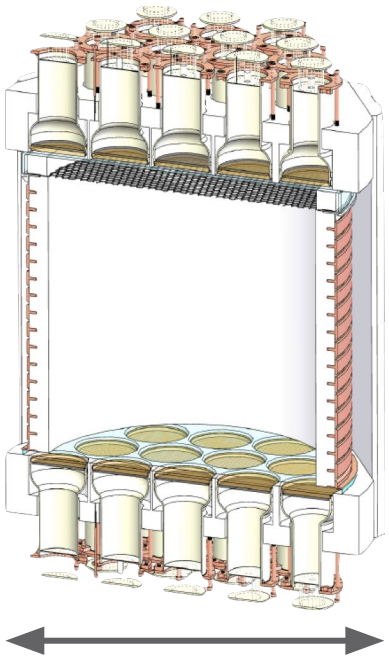
DS-Proto-1

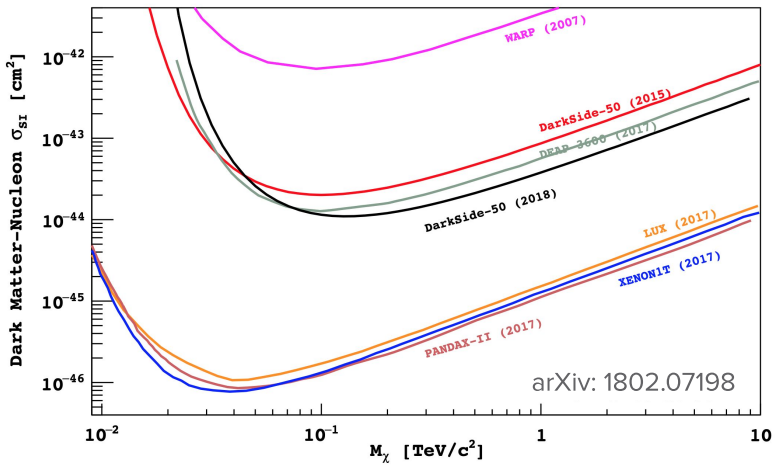
2020 - 2021

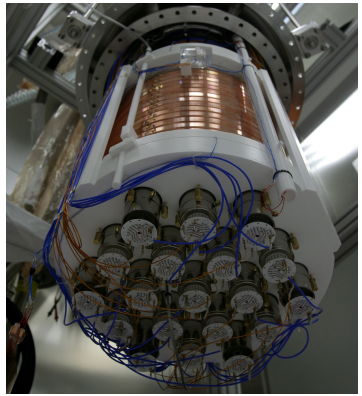
DS-20k

2022 -

DS-50







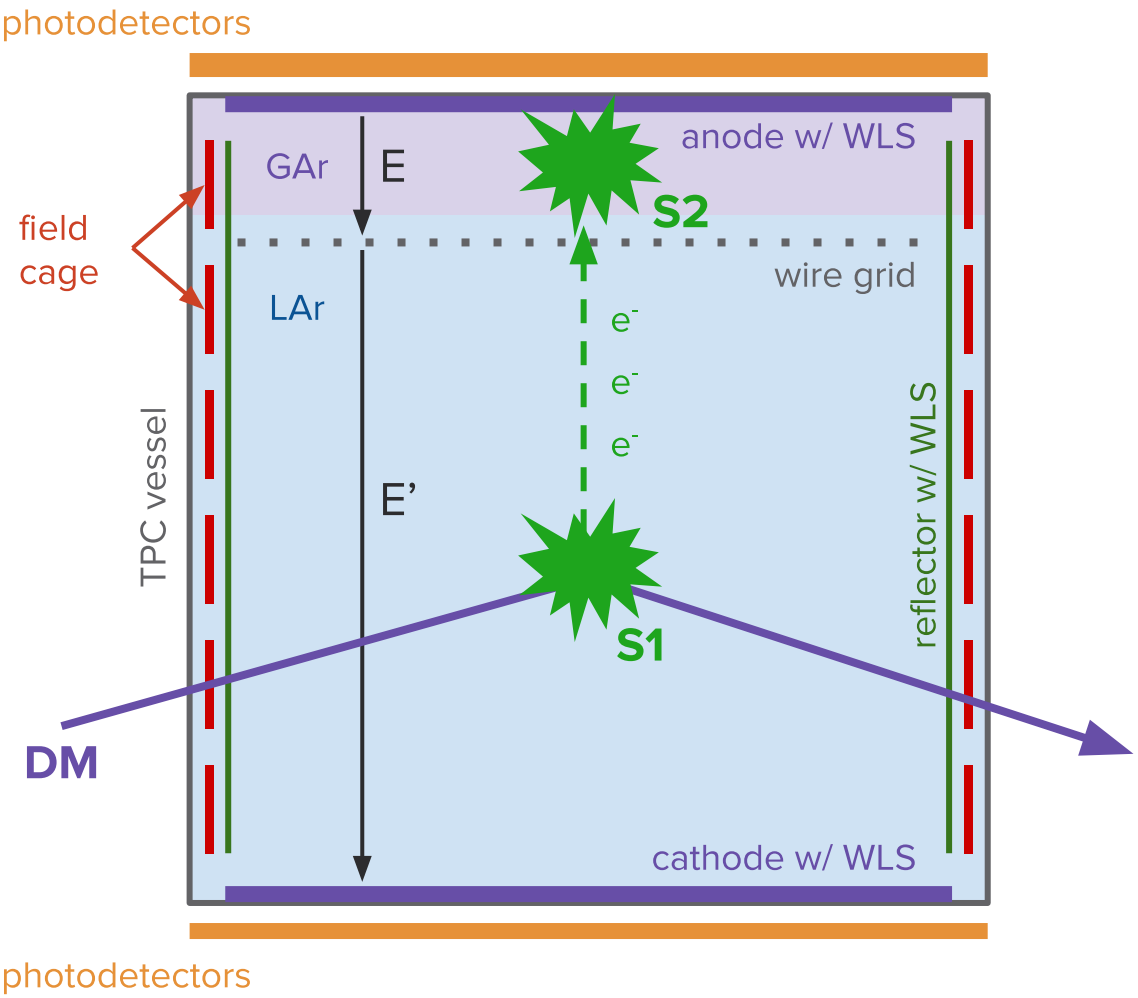
Two-phase Ar Time Projection Chamber (TPC)

Calorimetry + 3D position

Energy deposition in LAr produces **scintillation photons** and **free electrons**

S1: primary scintillation in LAr (energy estimator)

S2: secondary scintillation from electroluminescence of electrons in GAr



Why liquid argon?

Efficient scintillator

Scalable

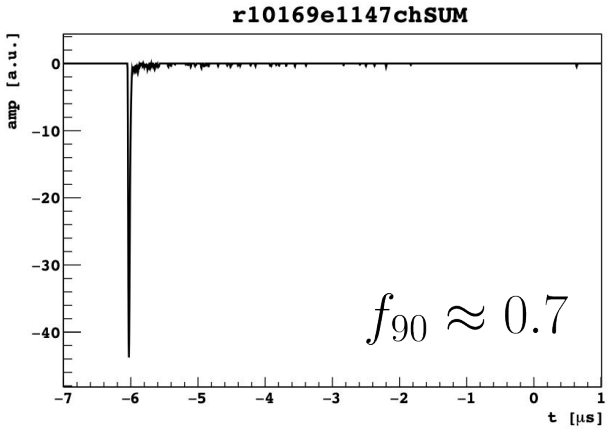
Sensitive to dark matter over large mass range

Pulse shape discrimination (PSD)

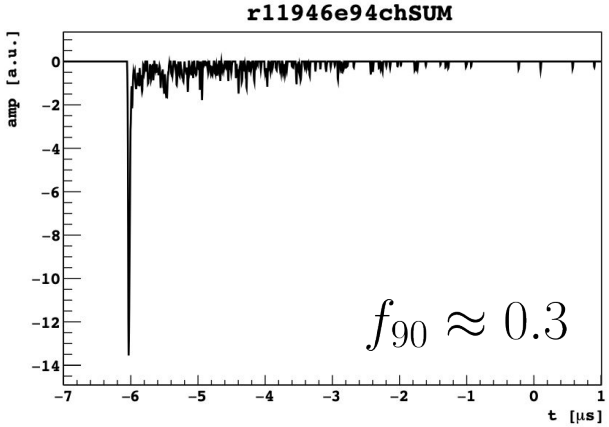
- f_{90}
- S2 / S1

f_{90}

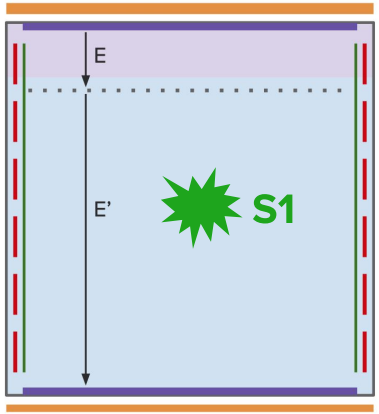
Nuclear recoil (NR)



Electronic recoil (ER)



$$f_{90} = \frac{\text{S1 light in first 90 ns}}{\text{Total S1 light}}$$



Why liquid argon?

Scalable

Efficient scintillator

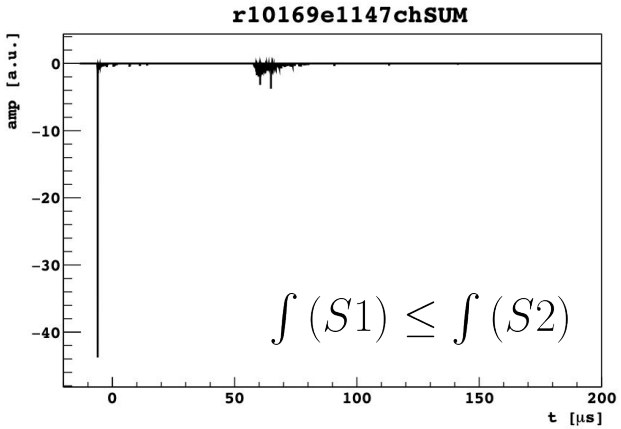
Sensitive to WIMPs over large mass range

Pulse shape discrimination (PSD)

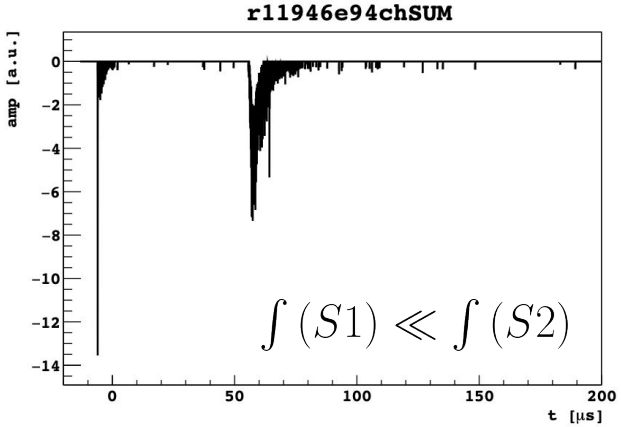
- f_{90}
- **S2 / S1**

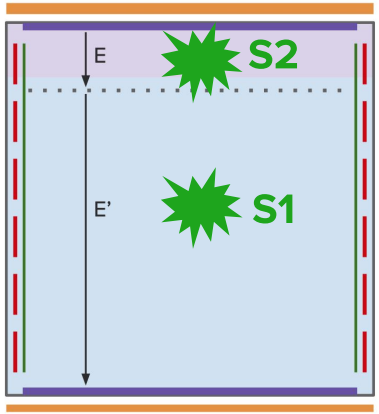
S2 / S1

Nuclear recoil (NR)



Electronic recoil (ER)





DS-20k Prototyping

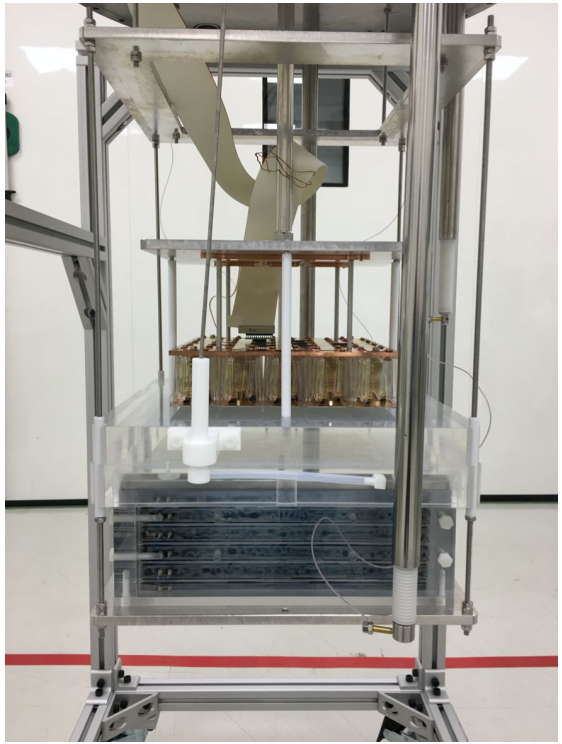
DS-Proto-0

- 2019 - 2020
- 10 kg active mass
- Test bench for DS-20k technologies

DS-Proto-1

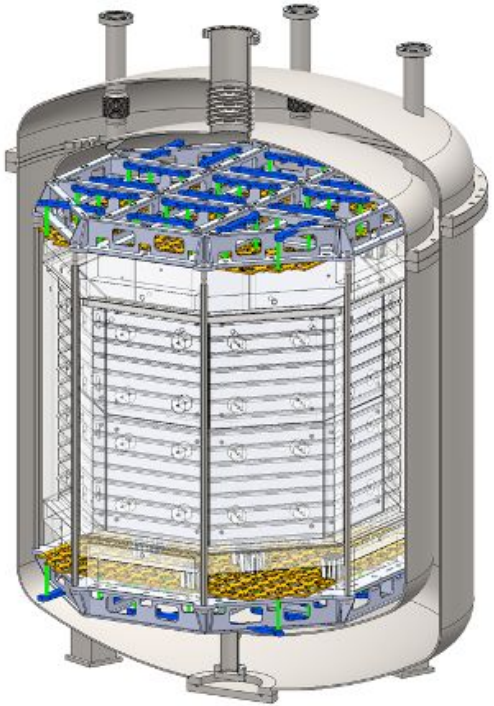
- 2020 - 2021
- 175 kg active mass
- Scaled-down version of DS-20k TPC

DS-Proto-0



36 cm

DS-Proto-1



58 cm

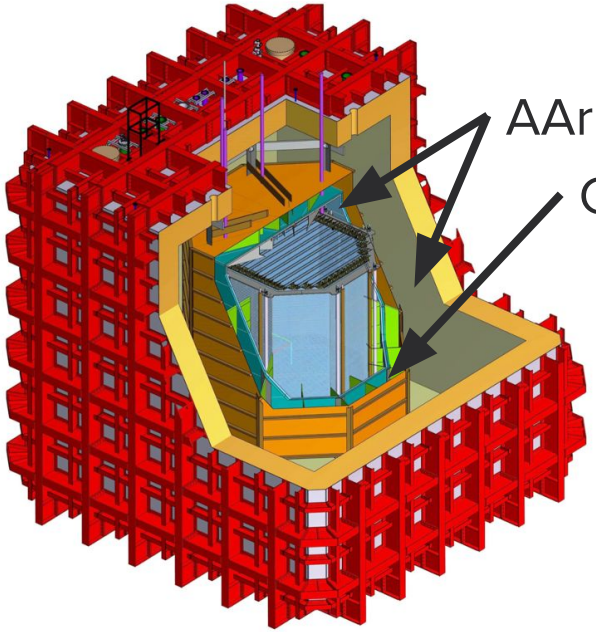
DS-20k New Technologies

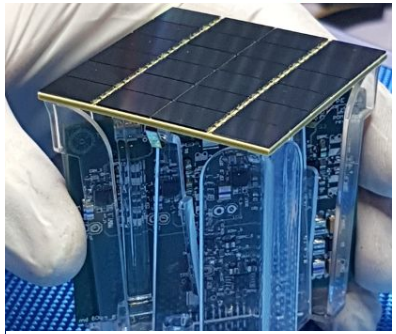
Sealed acrylic two-phase TPC filled with UAr

Custom cryogenic silicon photomultipliers (SiPMs)

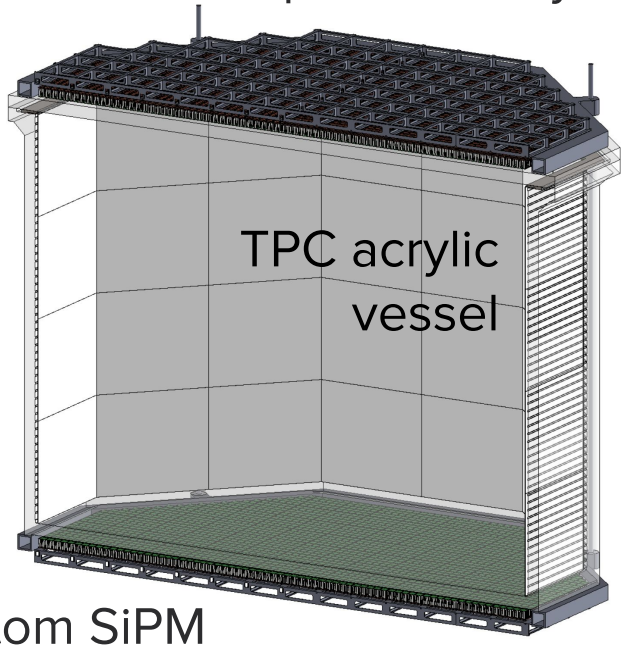
Active AAr neutron veto detector
- 2% Gd doped acrylic panels
- Read out with SiPM

ProtoDUNE-like cryostat filled with AAr





Prototype SiPM tile



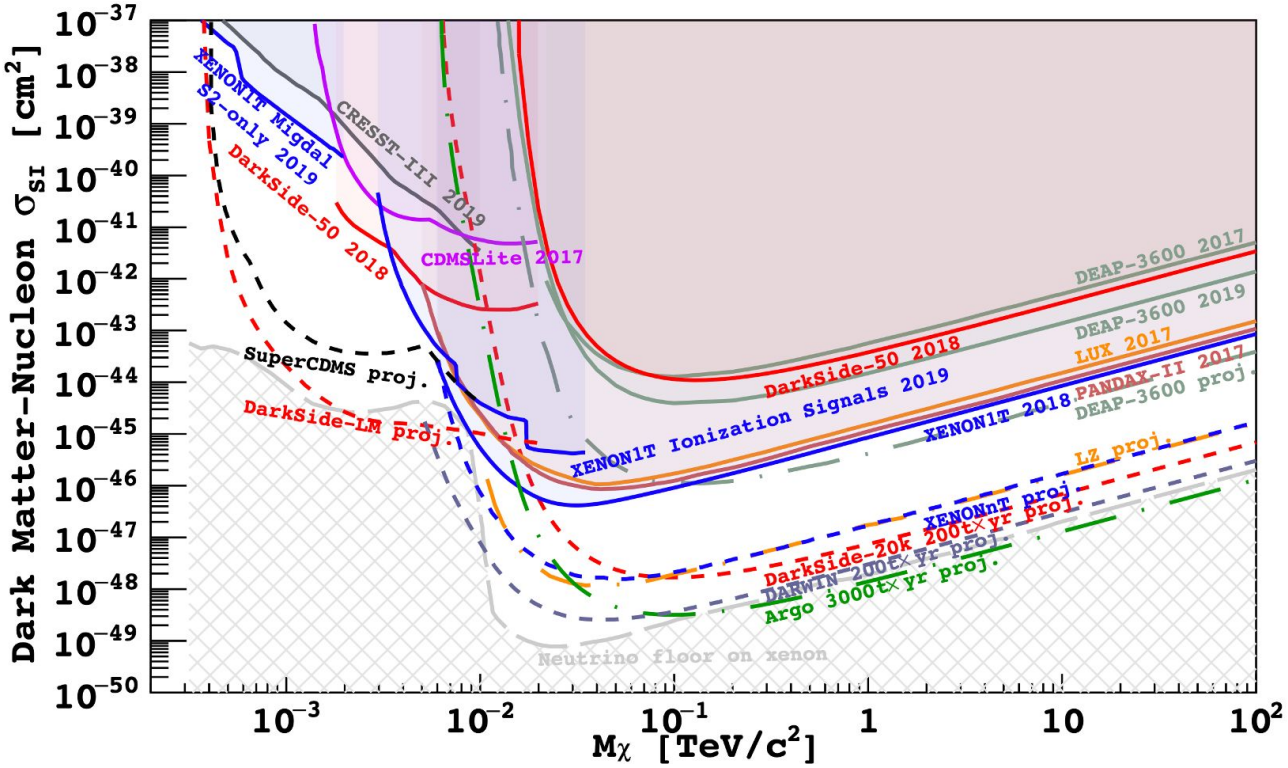
DS-20k Projected Sensitivity

Fiducial mass: 20 tonnes
Exposure: 10 years

How many events make a discovery?

5

...but only if < 0.1 background events expected



Cherenkov + S1 Background

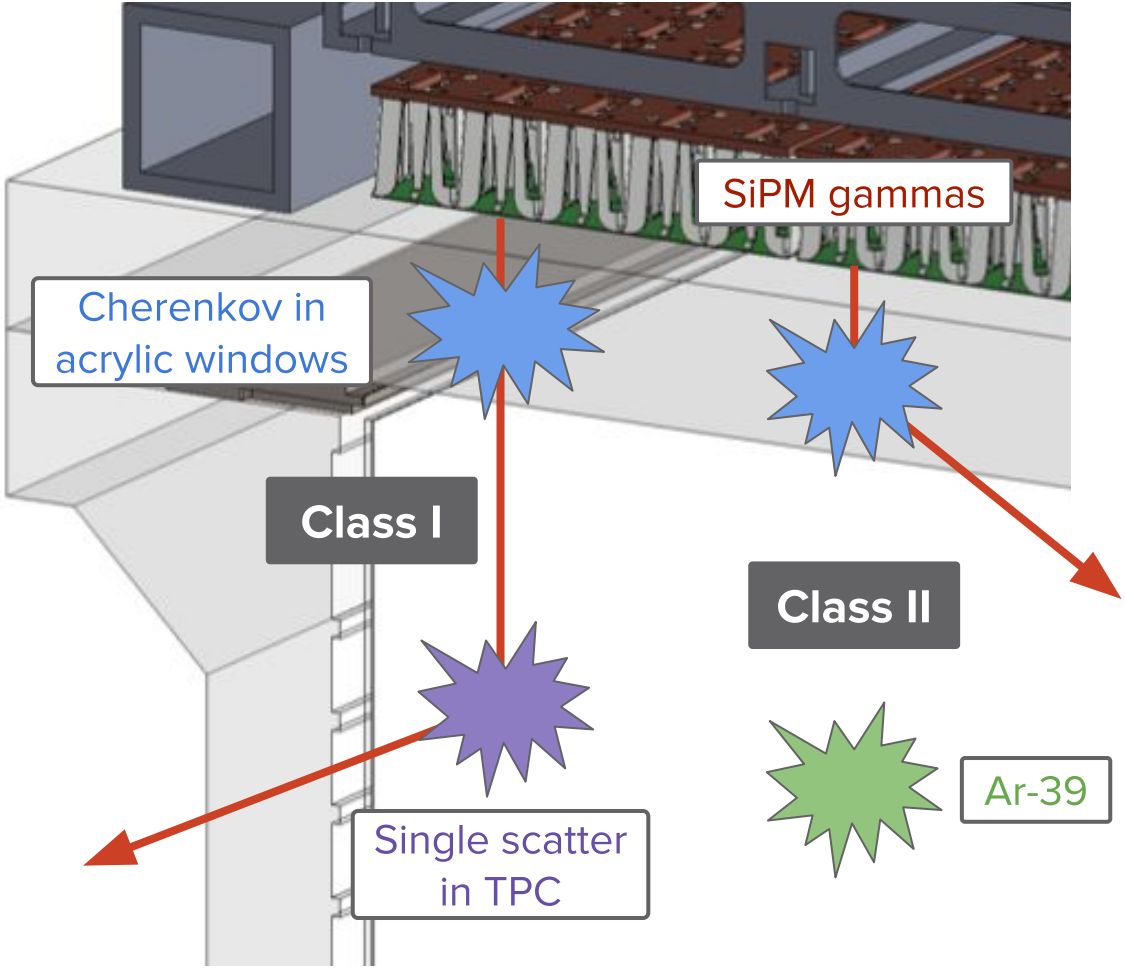
Gamma from SiPMs produces Cherenkov light in TPC acrylic windows

Cherenkov increases f_{90} of an event so that it mimics a DM signal

Event classes

I. Cherenkov + single cluster in TPC

II. Cherenkov + Ar-39 pileup event



Event Class II:
Cherenkov + Ar-39 pileup event

Coincidence of Ar-39 decay within 200 ns of Cherenkov from a SiPM gamma

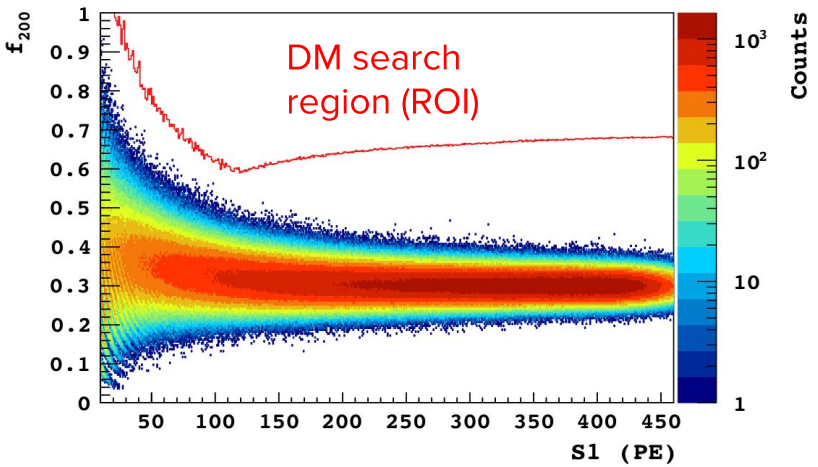
Before cuts:

0.90 ± 0.01 (stat) events in ROI for 5 year exposure

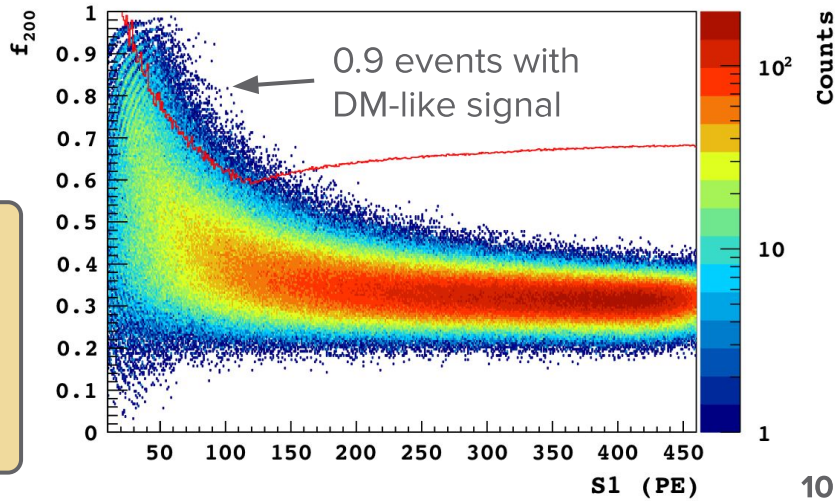
S1NearbyMaxFrac (NMF) cut

< 0.027 ± 0.002 (stat) events expected in ROI, sufficient for radioactivity budget

Simulated Ar-39 Spectrum



Simulated Ar-39 + Cherenkov Events



Objective: to remove WIMP-like events

Event Class II:
Cherenkov + Ar-39 pileup event

Coincidence of Ar-39 decay within 200 ns of Cherenkov from a SiPM gamma

Before cuts:

0.90 ± 0.01 (stat) events in ROI for 5 year exposure

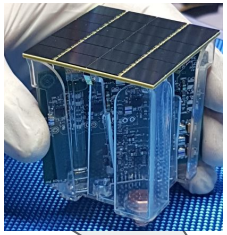
S1NearbyMaxFrac (NMF) cut

< 0.027 ± 0.002 (stat) events expected in ROI, sufficient for radioactivity budget

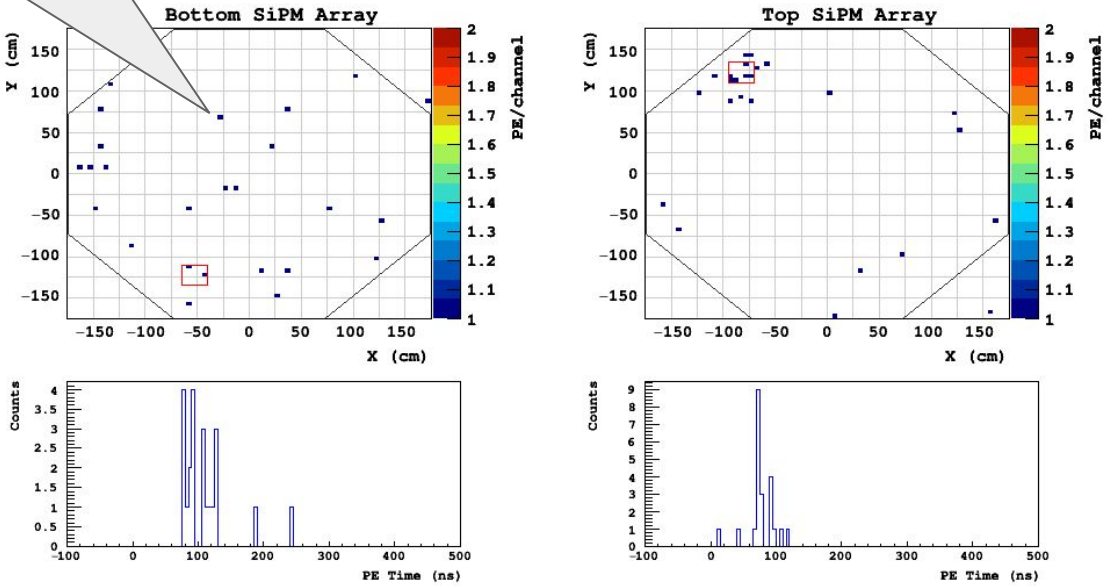
$$f_{\mathrm{NMF}} = \frac{\text{S1 light in 5x5 tiles with most light}}{\text{Total S1 light}}$$

S1NearbyMaxFrac Cut

- Ar-39 S1 XY light pattern sparse for events in fiducial volume
- Cherenkov light has localized XY distribution



S1 = 50 (Cherenkov in top window)



Event Class II:
Cherenkov + Ar-39 pileup event

Coincidence of Ar-39 decay within 200 ns of Cherenkov from a SiPM gamma

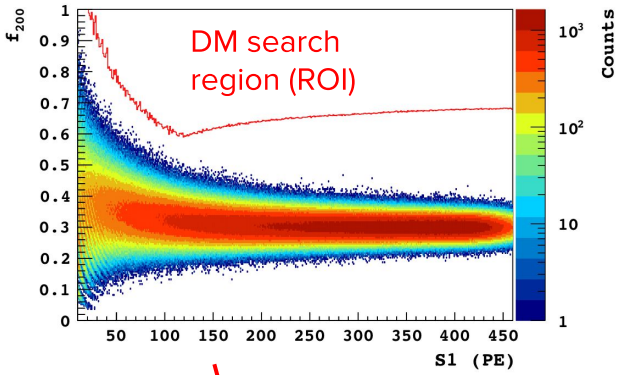
Before cuts:

0.90 ± 0.01 (stat) events in ROI for 5 year exposure

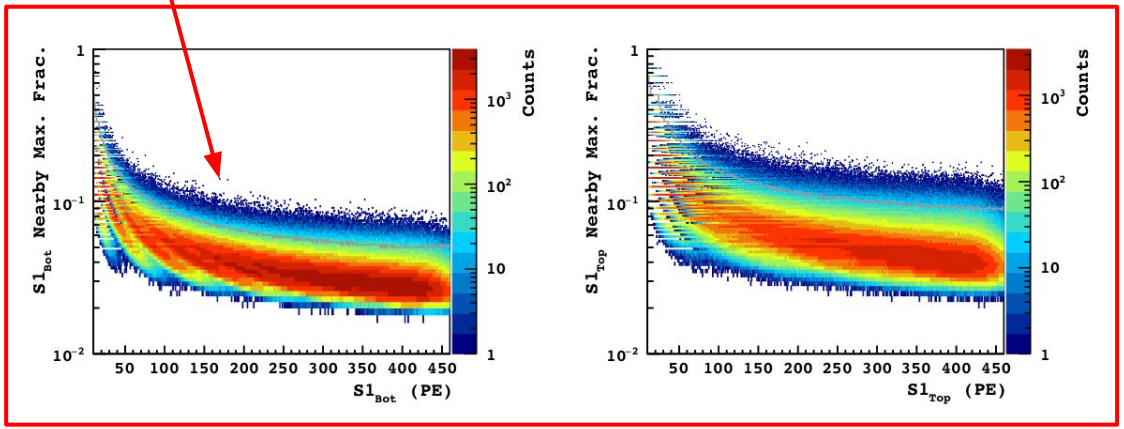
S1NearbyMaxFrac (NMF) cut

< 0.027 ± 0.002 (stat) events expected in ROI, sufficient for radioactivity budget

Simulated Ar-39 Spectrum



99% Ar-39 acceptance



S1NearbyMaxFrac Cut

- Ar-39 S1 XY light pattern sparse for events in fiducial volume
- Cherenkov light has localized XY distribution

$$f_{\mathrm{NMF}} = \frac{\text{S1 light in 5x5 tiles with most light}}{\text{Total S1 light}}$$

Event Class II:
Cherenkov + Ar-39 pileup event

Coincidence of Ar-39 decay within 200 ns of Cherenkov from a SiPM gamma

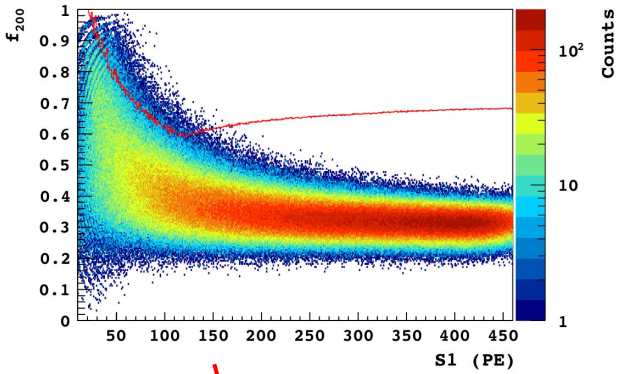
Before cuts:

0.90 ± 0.01 (stat) events in ROI for 5 year exposure

S1NearbyMaxFrac (NMF) cut

< 0.027 ± 0.002 (stat) events expected in ROI, sufficient for radioactivity budget

Ar-39 + Cherenkov

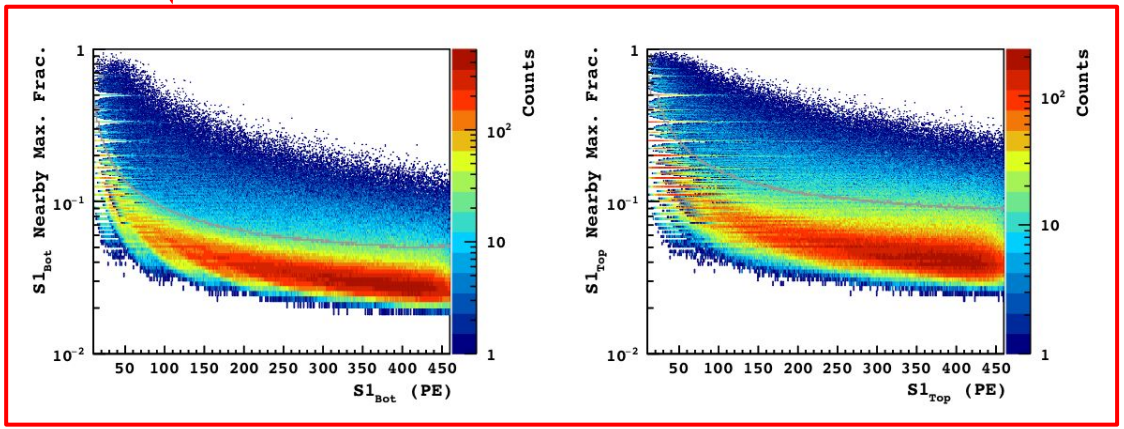


S1NearbyMaxFrac Cut

- Ar-39 S1 XY light pattern sparse for events in fiducial volume
- Cherenkov light has localized XY distribution

$$f_{\mathrm{NMF}} = \frac{\text{S1 light in 5x5 tiles with most light}}{\text{Total S1 light}}$$

Apply S1NearbyMaxFrac cut to Ar-39 + Cherenkov events



Event Class II:
Cherenkov + Ar-39 pileup event

Coincidence of Ar-39 decay within 200 ns of Cherenkov from a SiPM gamma

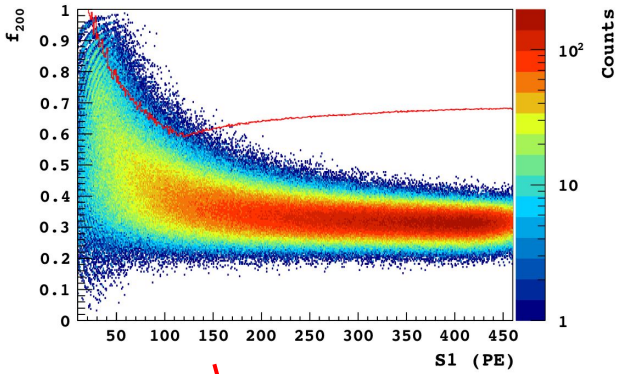
Before cuts:

0.90 ± 0.01 (stat) events in ROI for 5 year exposure

S1NearbyMaxFrac (NMF) cut

< 0.027 ± 0.002 (stat) events expected in ROI, sufficient for radioactivity budget

Ar-39 + Cherenkov

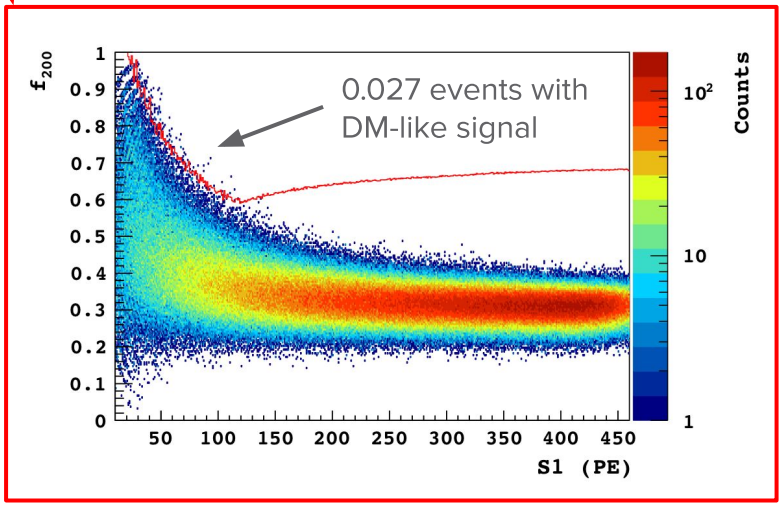


S1NearbyMaxFrac Cut

- Ar-39 S1 XY light pattern sparse for events in fiducial volume
- Cherenkov light has localized XY distribution

$$f_{\mathrm{NMF}} = \frac{\text{S1 light in 5x5 tiles with most light}}{\text{Total S1 light}}$$

Apply S1NearbyMaxFrac cut to Ar-39 + Cherenkov events



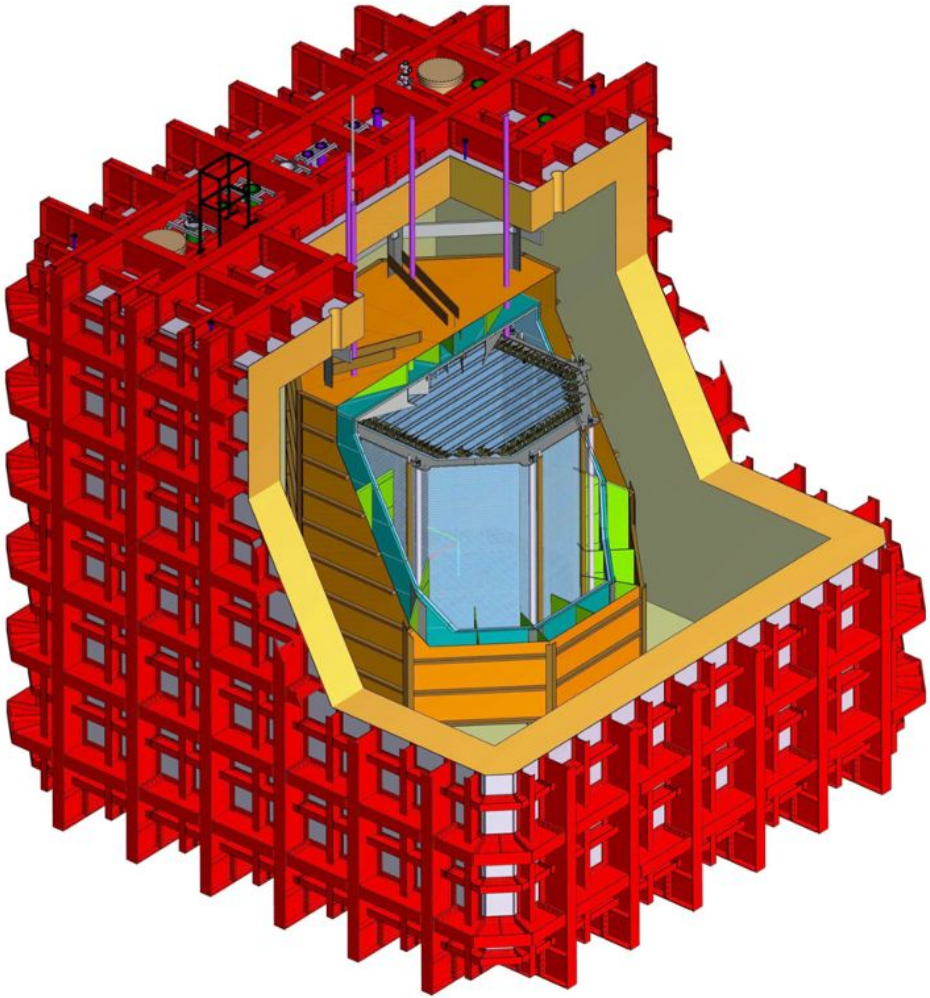
Summary

DarkSide-20k will be the most **sensitive dark matter experiment** ever built

- 7.4×10^{-48} cm^2 for 1 TeV/c^2 WIMPs for a 10 year run

Tests of DS-20k innovative design features **currently ongoing** with DS-Proto-0 and DS-Proto-1

S1NearbyMaxFrac cut **reduces Cherenkov + S1 background** to below required level



Questions?

Backup Slides

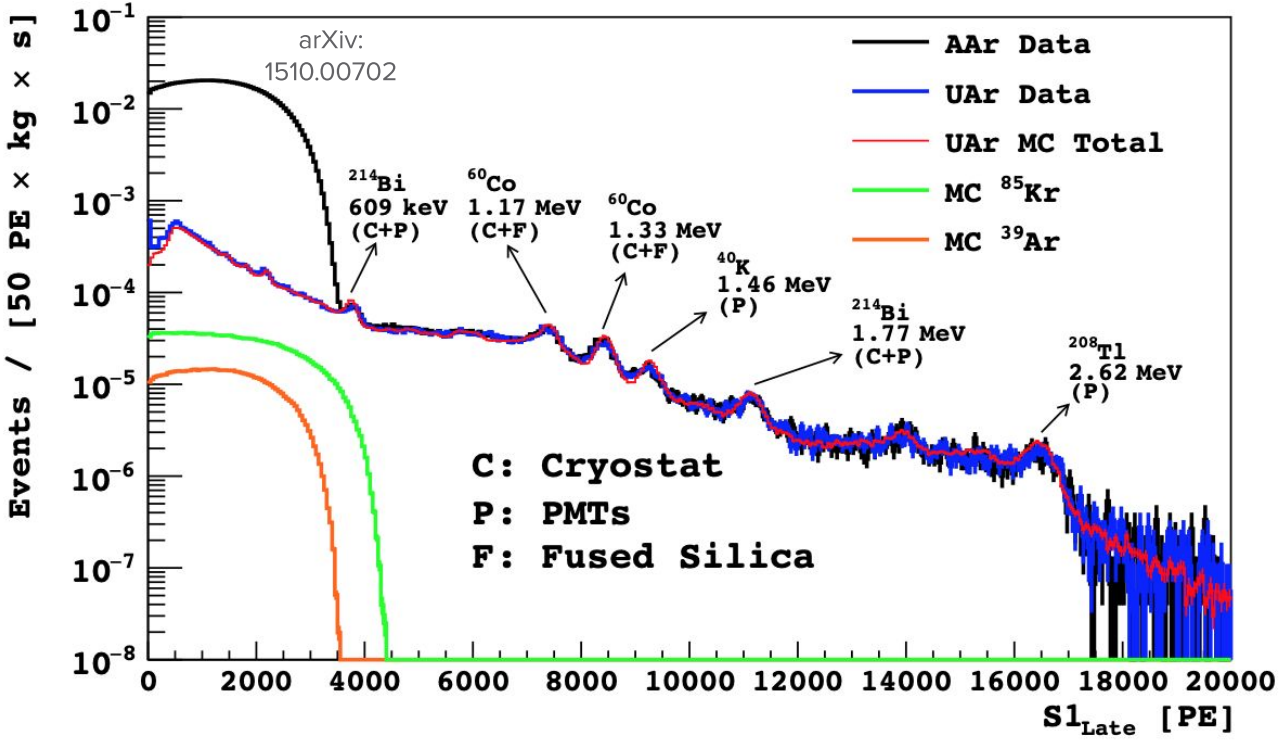
Backgrounds in DS-20k

DS-50 demonstrated Ar-39 activity in AAr

Neutron recoil backgrounds
- Cosmogenic
- Spontaneous (α,n) reactions

Electron recoil backgrounds
- Ar-39, Kr-85, and external gamma rays
- **Cherenkov + S1**

Backgrounds in DS-50



Event Class II:
Cherenkov + Ar-39 pileup event

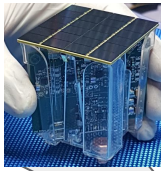
Coincidence of Ar-39 decay within 200 ns of Cherenkov from 2.61 MeV gamma

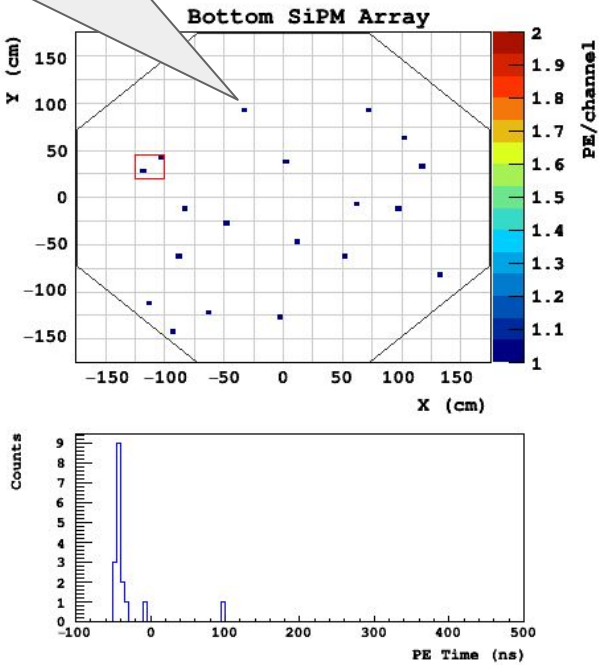
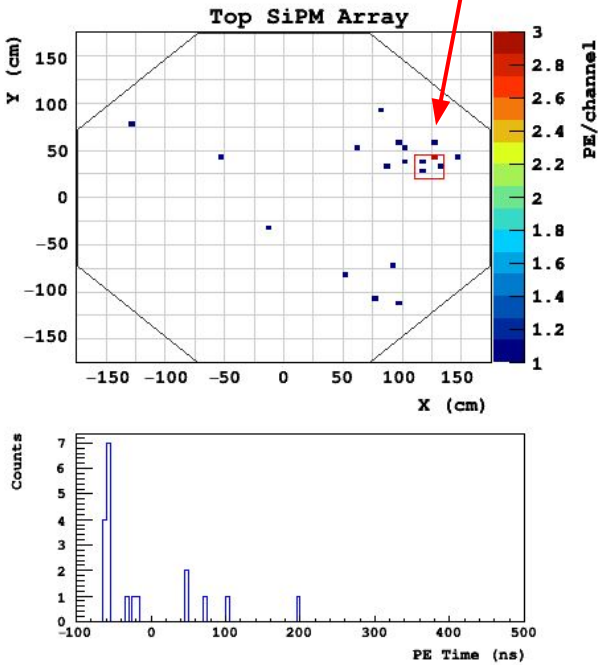
Before cuts:

0.90 ± 0.01 (stat) events in ROI for 5 year exposure

S1NearbyMaxFrac (NMF) cut

< 0.027 ± 0.002 (stat) events expected in ROI, sufficient for radioactivity budget



Room for further optimization

Example Event Passing S1NearbyMaxFrac Cut