



The DarkSide-20k Experiment in 10 Minutes

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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

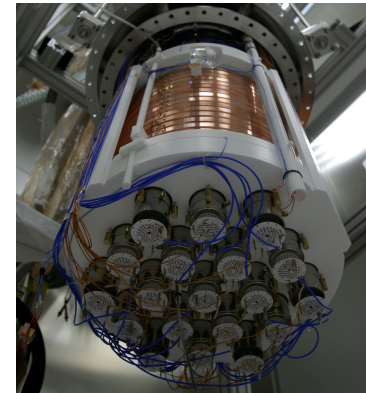
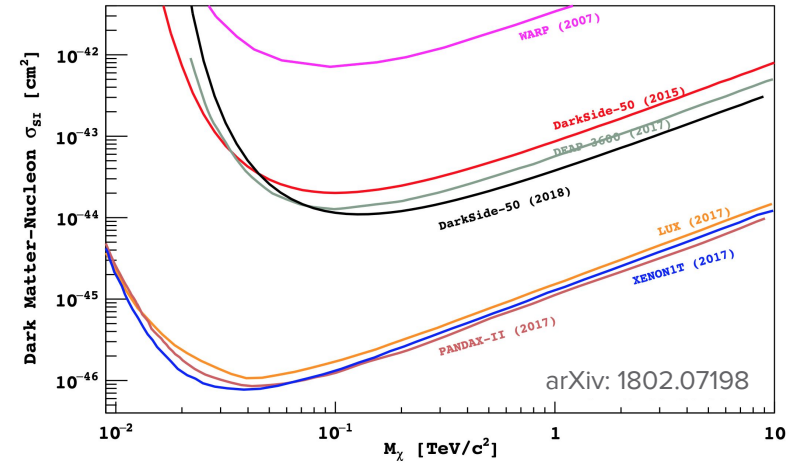
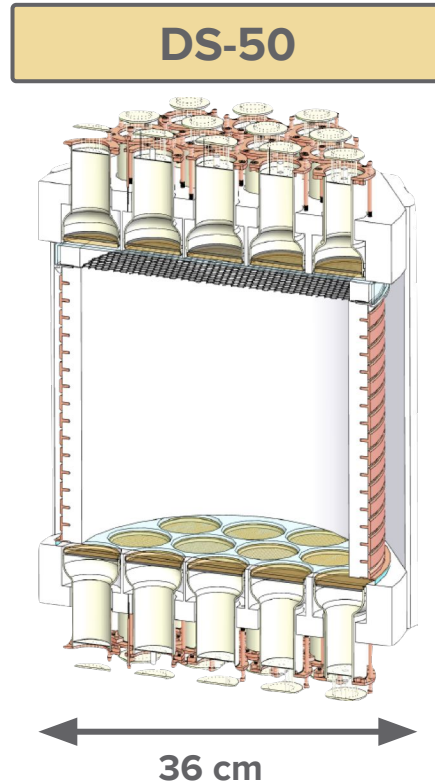
2019 - 2020

DS-Proto-1

2020 - 2021

DS-20k

2022 -



Two-phase Ar Time Projection Chamber (TPC)

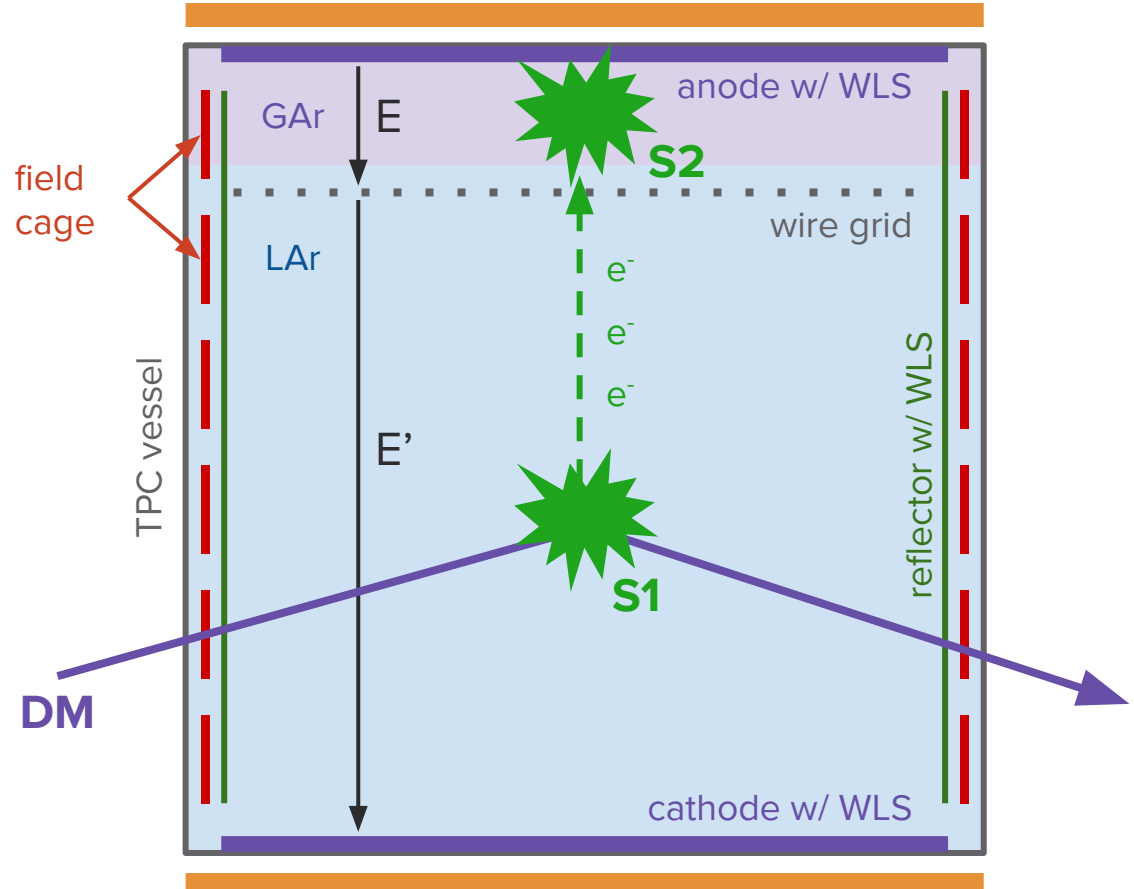
Calorimetry + 3D position

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

photodetectors



photodetectors

Why liquid argon?

Efficient scintillator

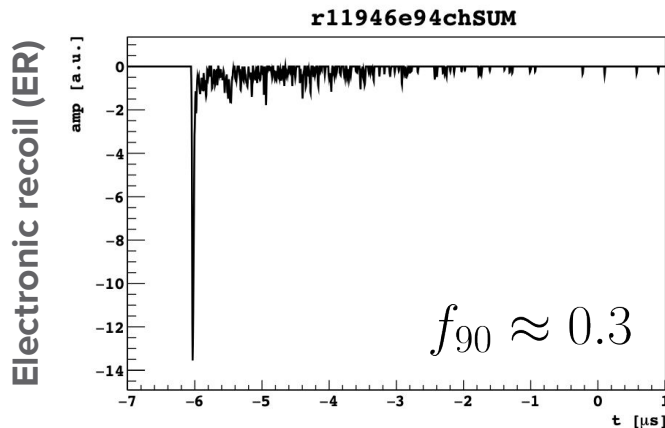
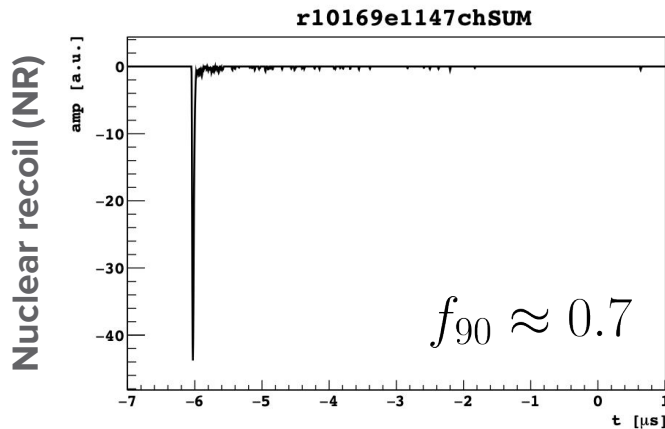
Scalable

Sensitive to dark matter
over large mass range

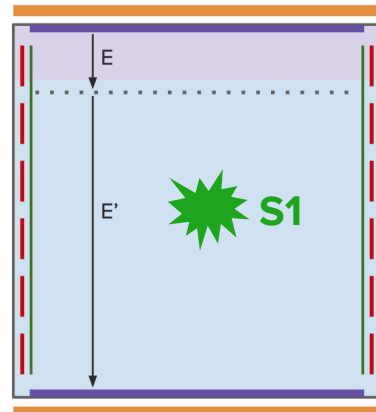
Pulse shape
discrimination (PSD)

$$f_{90} = \frac{S2}{S1}$$

$$f_{90}$$



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



Why liquid argon?

Scalable

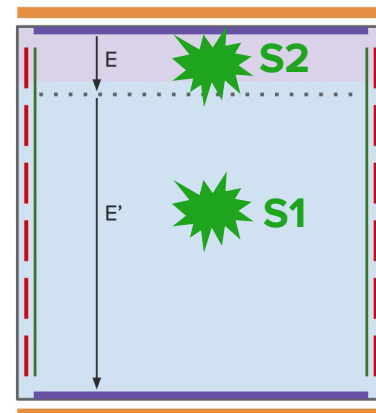
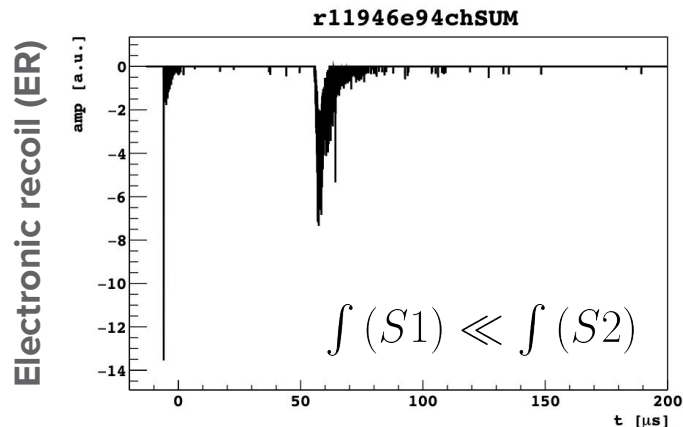
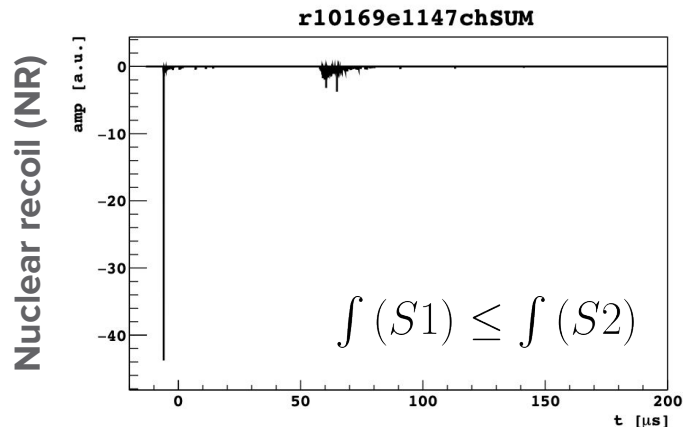
Efficient scintillator

Sensitive to WIMPs over large mass range

Pulse shape discrimination (PSD)

$$f_{90} \\ \mathbf{S2 / S1}$$

S2 / S1



DS-20k Prototyping

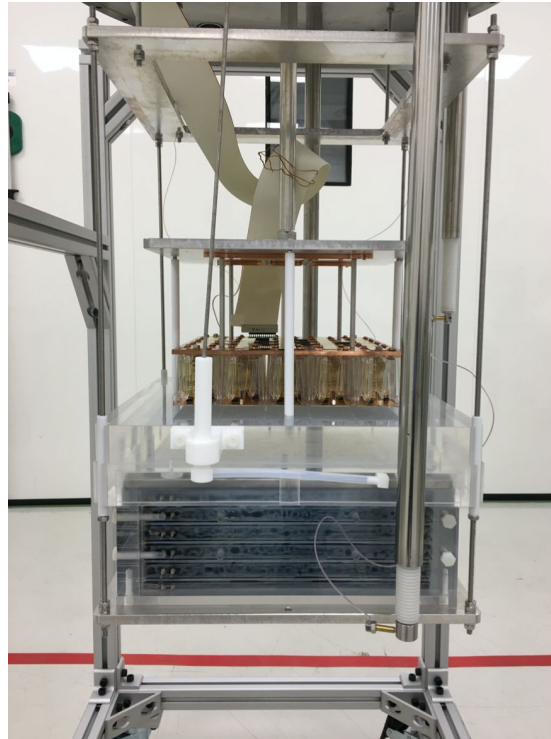
DS-Proto-0

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

DS-Proto-1

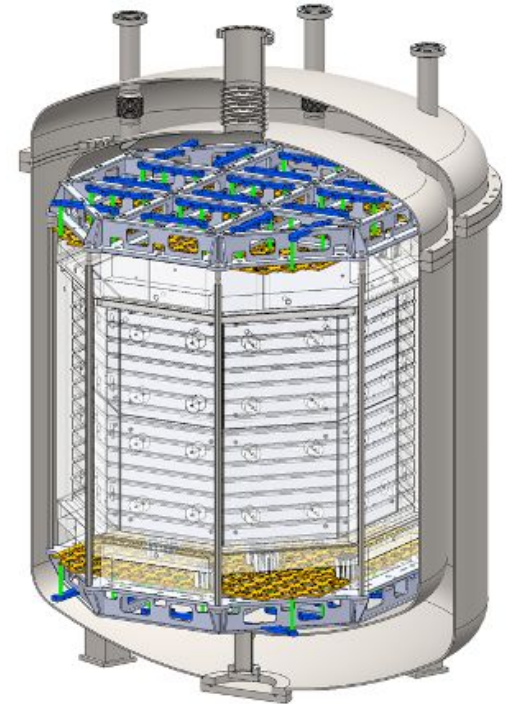
- 2020 - 2021
- 175 kg active mass
- Scaled-down version of DS-20k TPC

DS-Proto-0



36 cm

DS-Proto-1



58 cm

DS-20k New Technologies

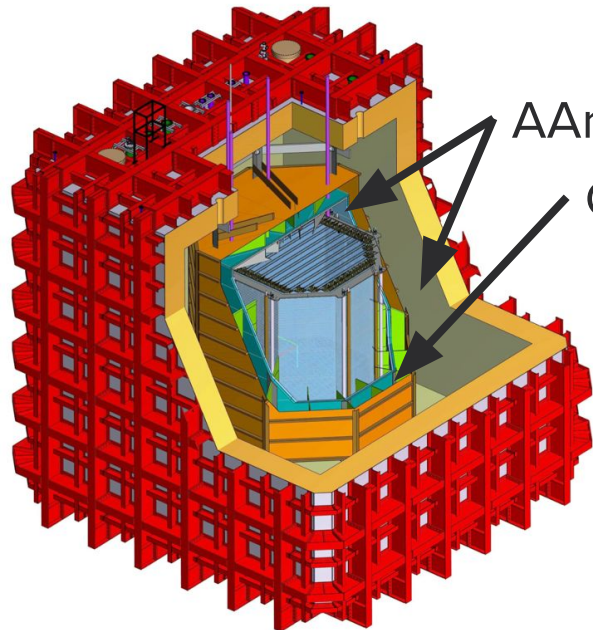
Sealed acrylic two-phase
TPC filled with UAr

Custom cryogenic silicon
photomultipliers (SiPMs)

Active AAr neutron veto
detector

- 2% Gd doped acrylic panels
- Read out with SiPM

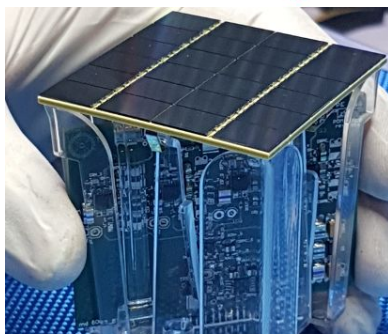
ProtoDUNE-like cryostat
filled with AAr



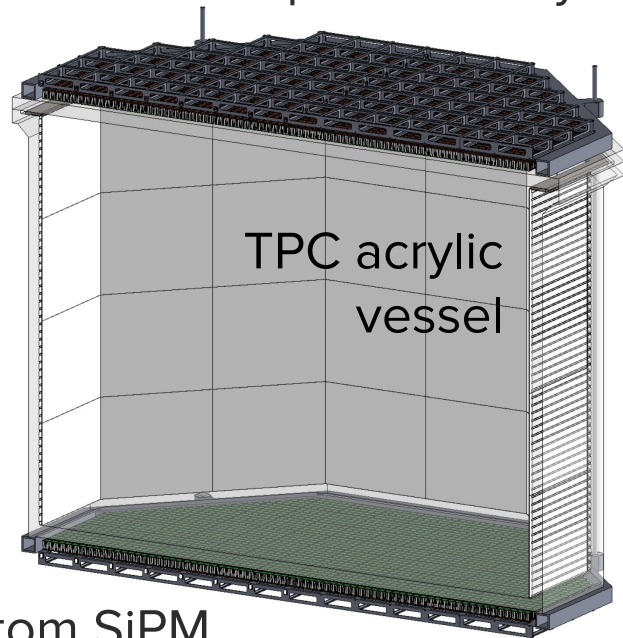
AAr vetoes

Gd doped acrylic veto

TPC top SiPM array



Prototype SiPM tile



TPC acrylic
vessel

TPC bottom SiPM
array

360 cm

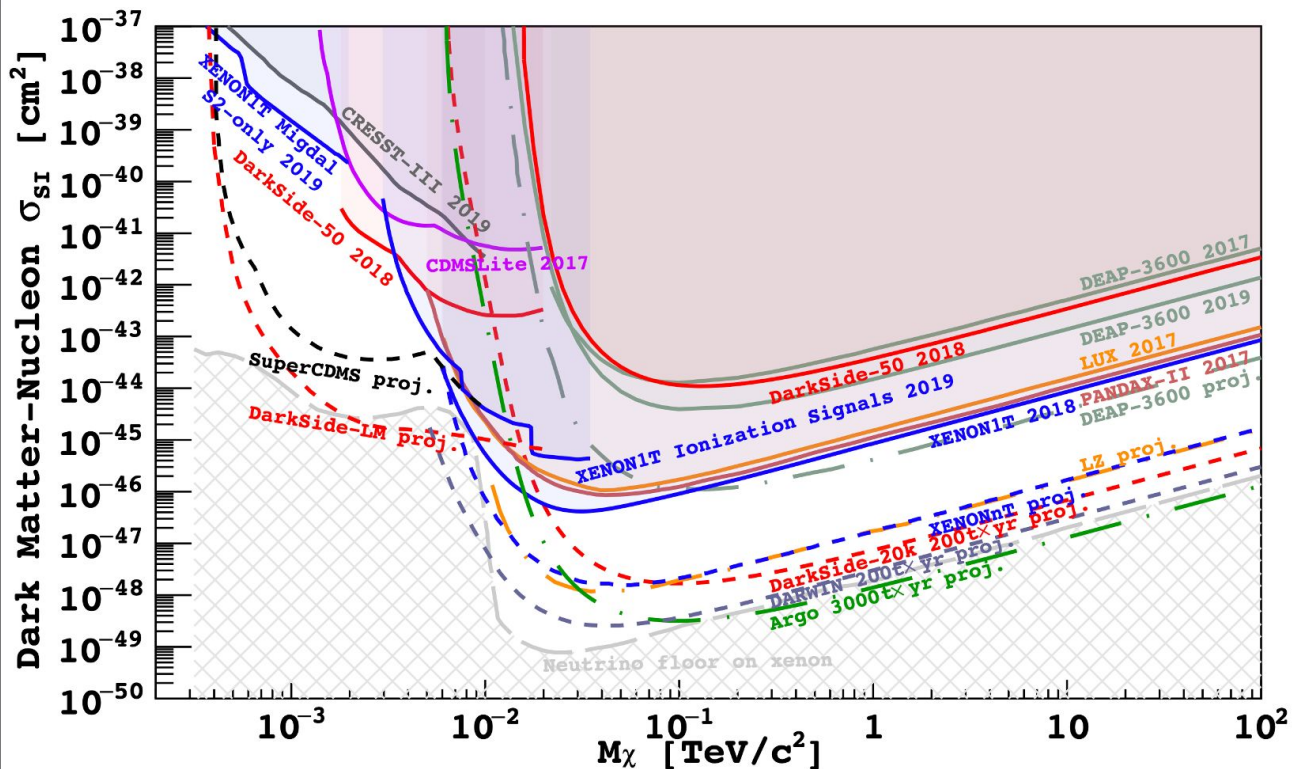
DS-20k Projected Sensitivity

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

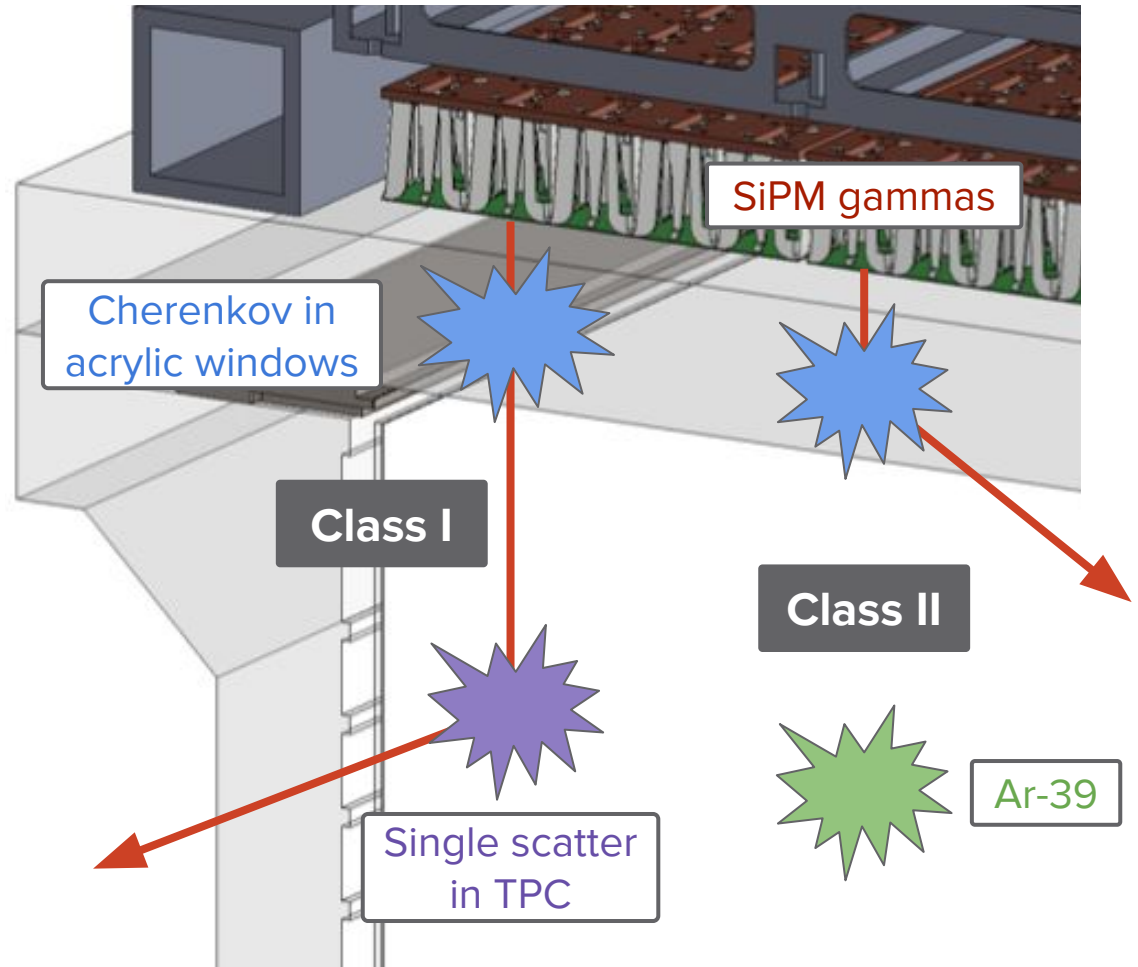
Gamma from SiPMs produces Cherenkov light in TPC acrylic windows

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

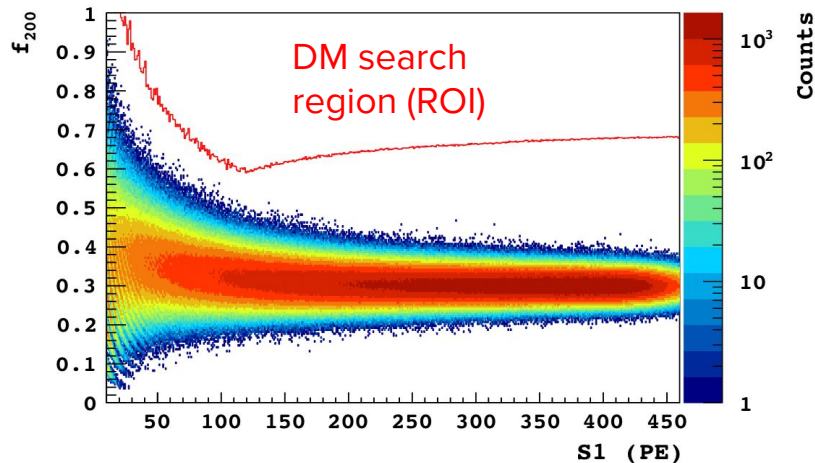
Coincidence of Ar-39 decay
within 200 ns of Cherenkov
from a SiPM gamma

Before cuts:

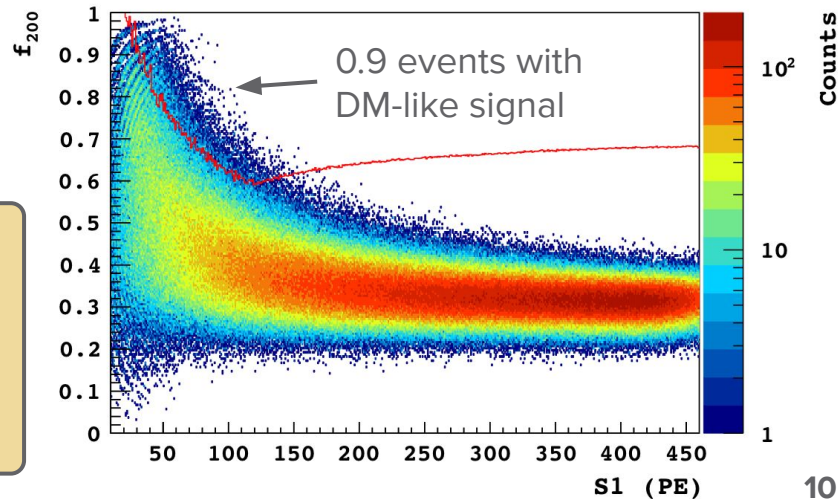
0.90 ± 0.01 (stat) events in ROI
for 5 year exposure

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

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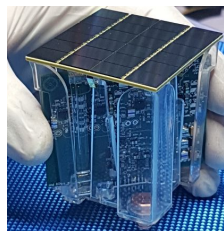
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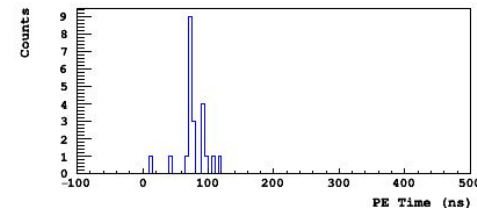
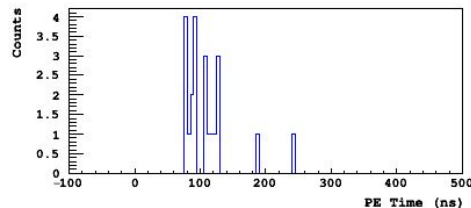
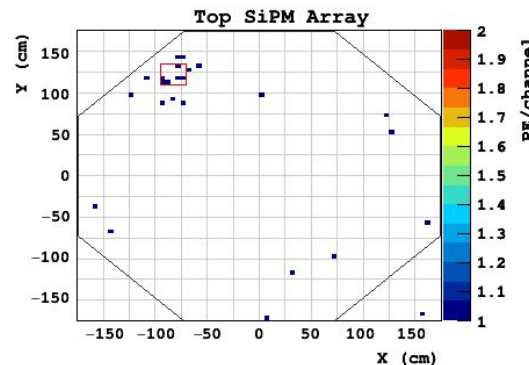
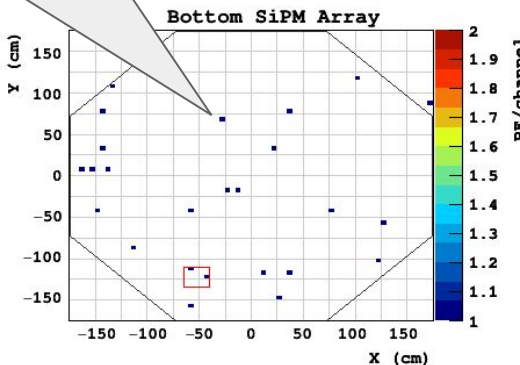
S1NearbyMaxFrac (NMF) cut

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radioactivity budget

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



S1 = 50 (Cherenkov in top window)



S1NearbyMaxFrac Cut

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

Event Class II: Cherenkov + Ar-39 pileup event

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

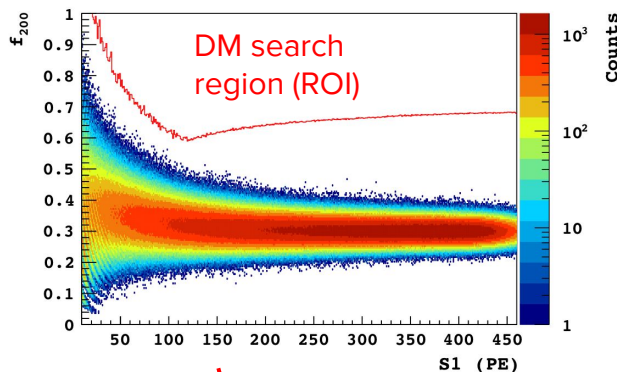
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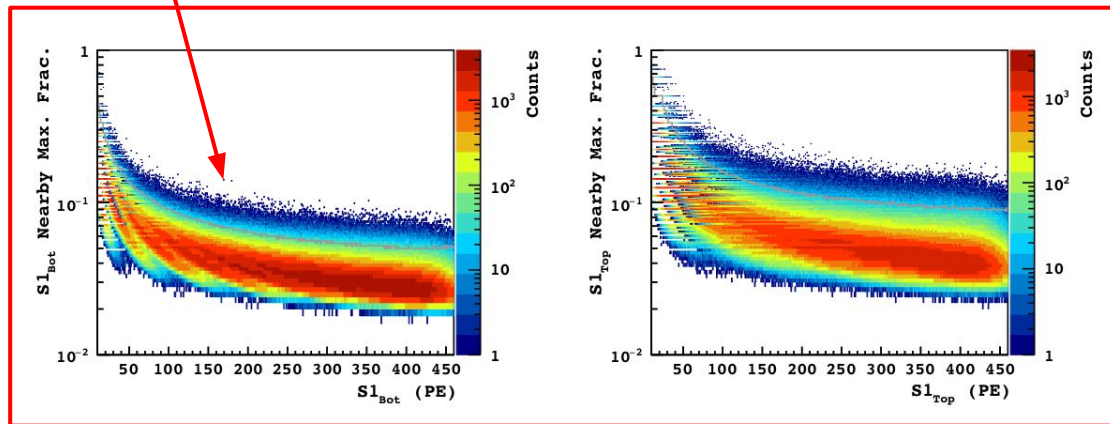


S1NearbyMaxFrac Cut

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99% Ar-39 acceptance



Event Class II: Cherenkov + Ar-39 pileup event

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

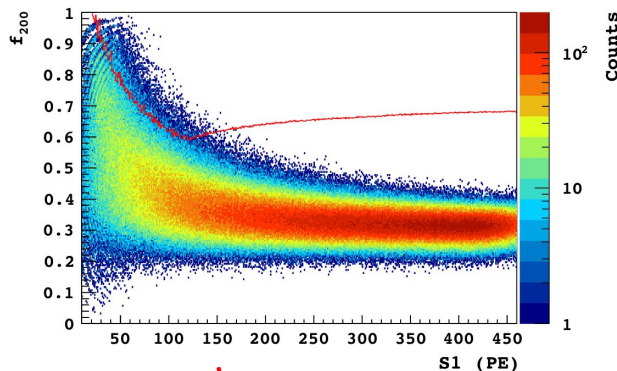
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Ar-39 + Cherenkov

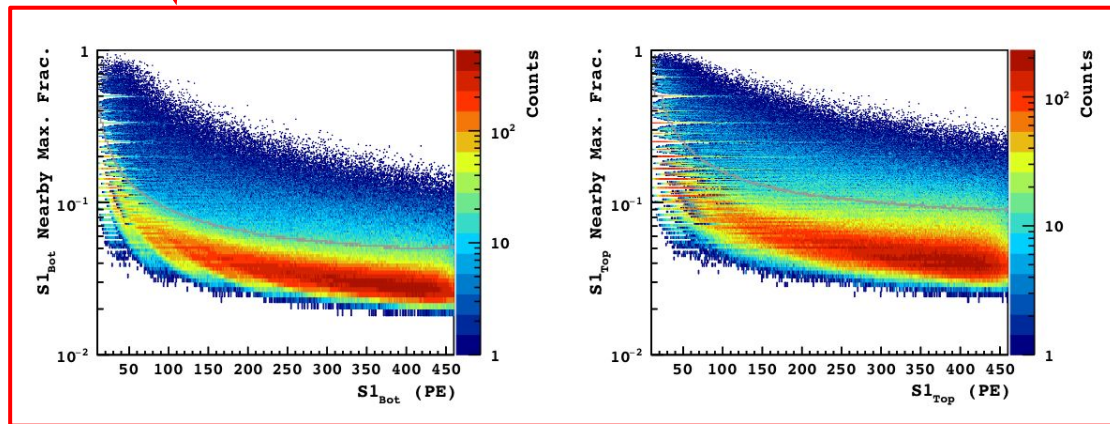


S1NearbyMaxFrac Cut

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

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

Apply S1NearbyMaxFrac cut to Ar-39 + Cherenkov events



Event Class II: Cherenkov + Ar-39 pileup event

Coincidence of Ar-39 decay
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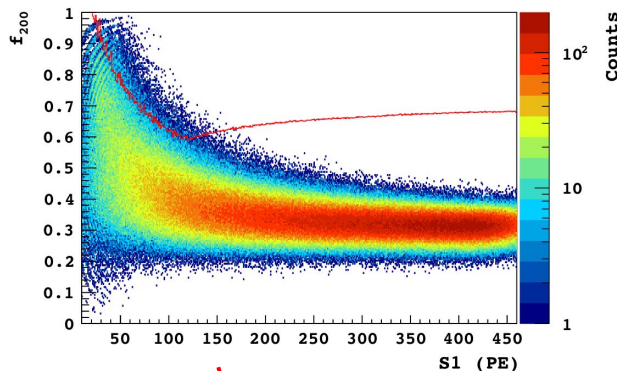
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Ar-39 + Cherenkov

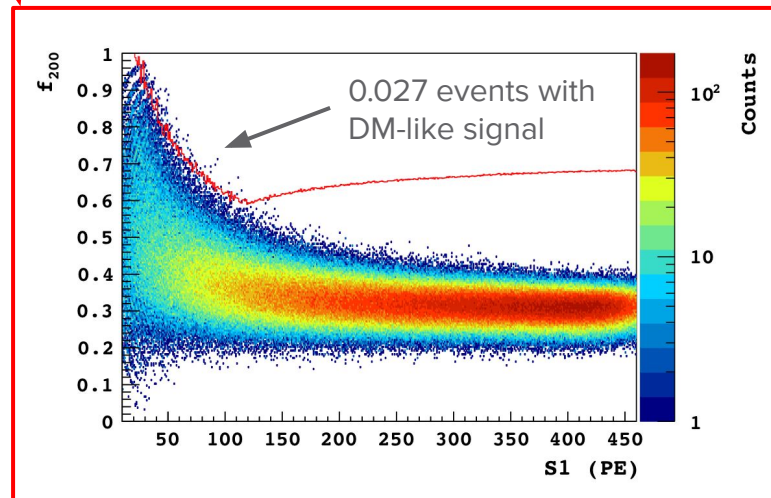


S1NearbyMaxFrac Cut

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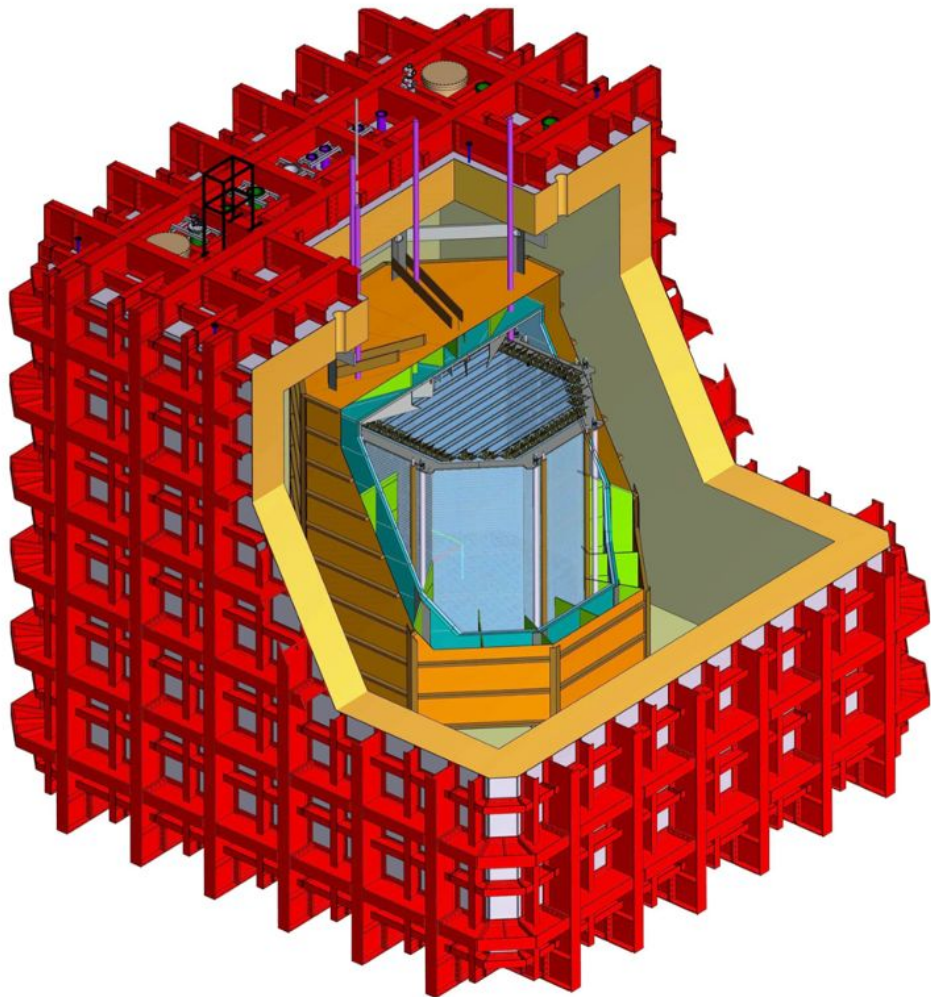
Summary

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

- $7.4 \times 10^{-48} \text{ cm}^2$ for $1 \text{ TeV}/c^2$ 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

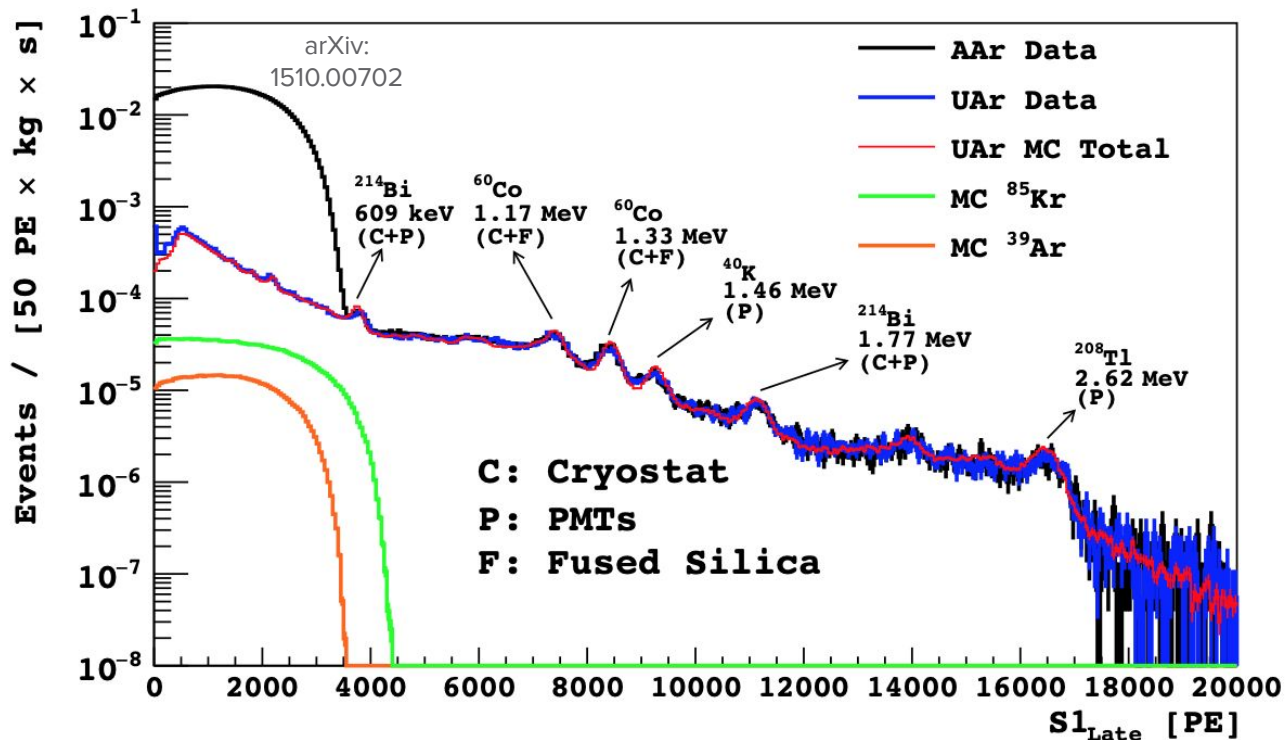
Neutron recoil backgrounds

- 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

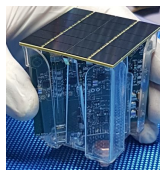
Coincidence of Ar-39 decay
within 200 ns of Cherenkov
from 2.61 MeV gamma

Before cuts:

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

S1NearbyMaxFrac (NMF) cut

$< 0.027 \pm 0.002$ (stat) events
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Example Event Passing S1NearbyMaxFrac Cut

Room for further
optimization

