

The DarkSide Experiment: Venturing into the Low Mass Region

darkside

two-phase argon TPC for Dark Matter Direct Detection



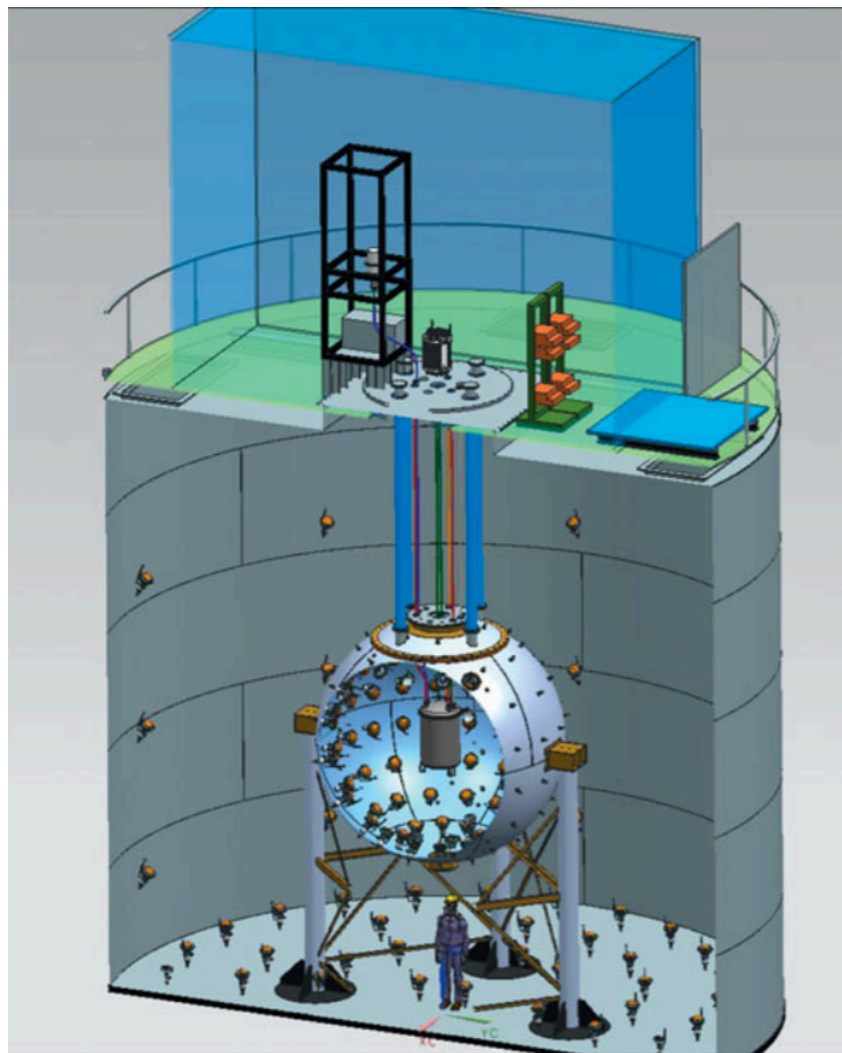
Ivone F. M. Albuquerque
IFUSP
Fapesp - JSPS Workshop
São Paulo - Feb 18-20th - 2019

Outline

1. DarkSide Liquid Argon Program
2. DS50k Dual Phase TPC
3. Recent Results (DS50k)
 - WIMP search
 - Low Mass Search
 - SubGeV Search
4. Proto, DS20K and Beyond

DM Search: LAr Program

DS-50



50 Kg LAr

532 days DATA

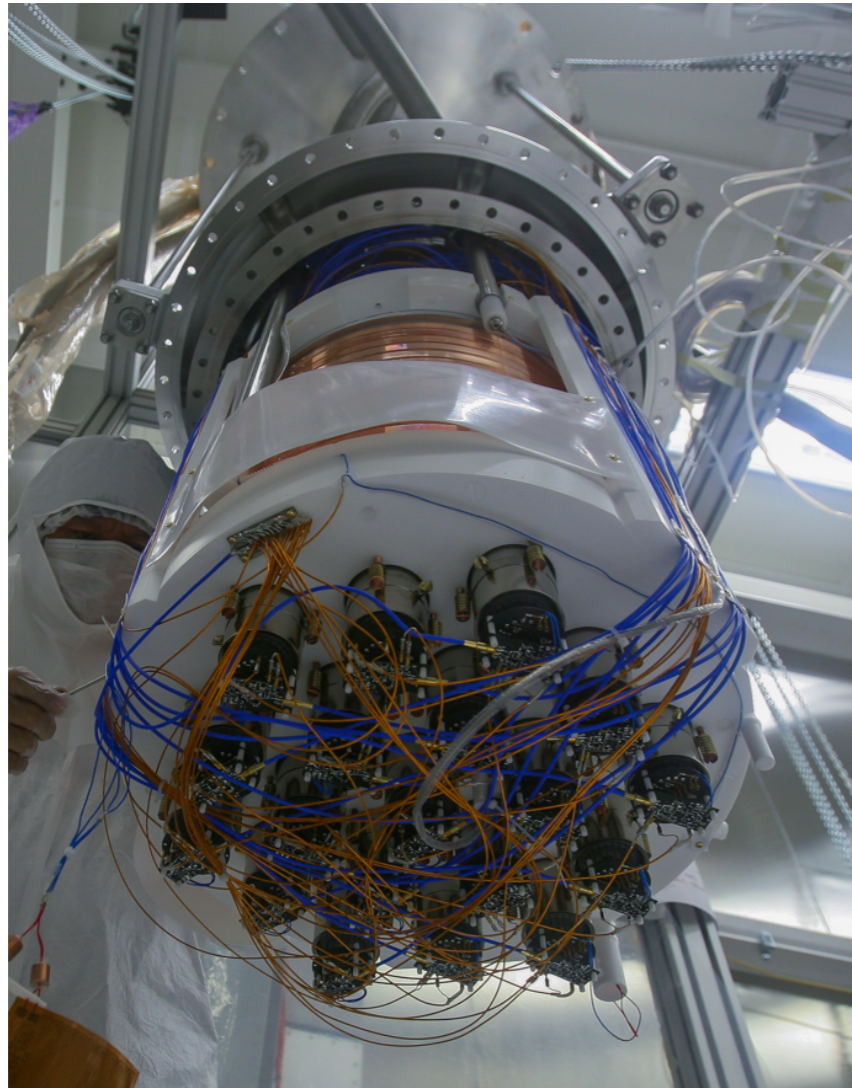
INFN Laboratori Nazionali del Gran Sasso



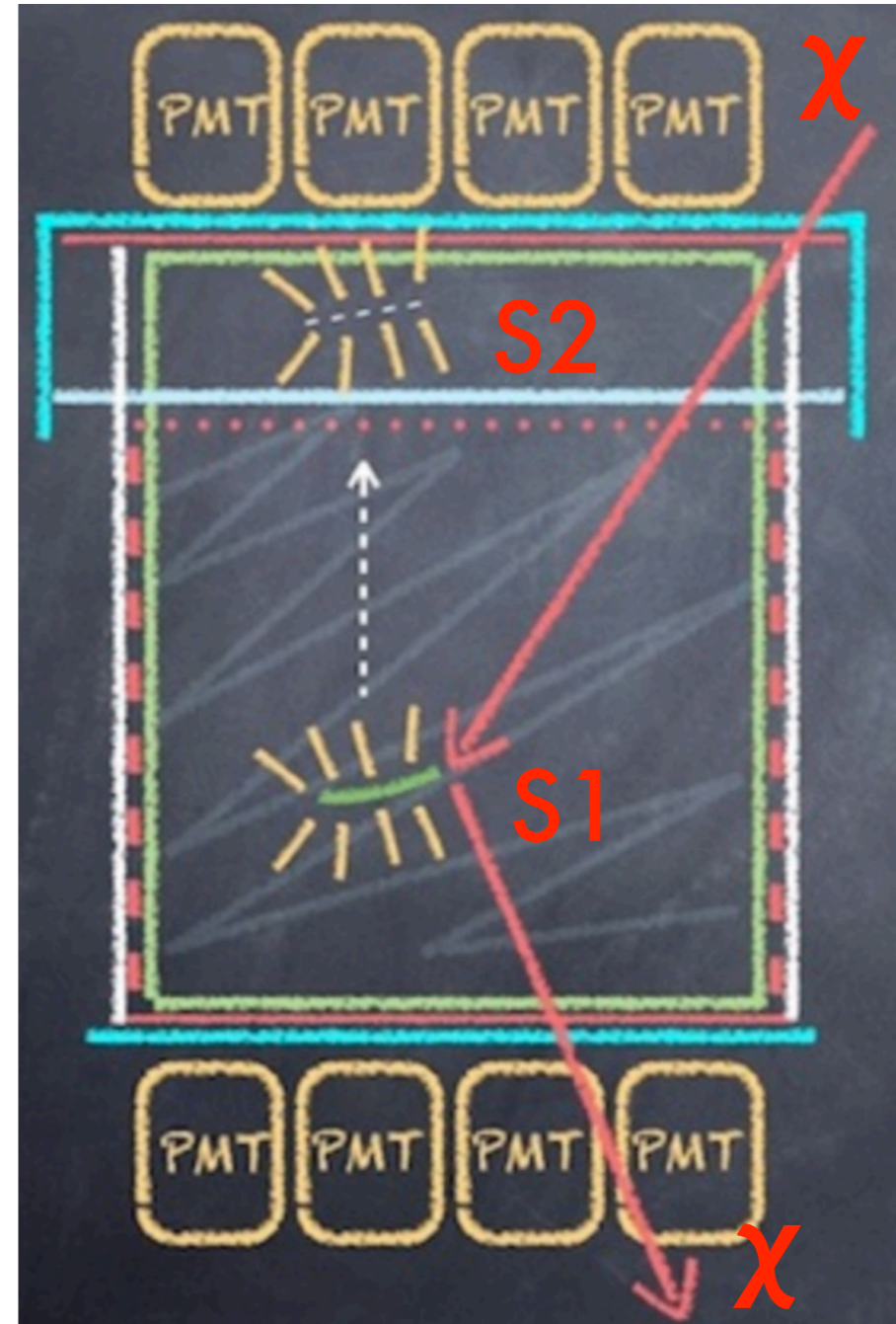
DS-10 → 10 kg
DS-50 → 50 kg
DS-Proto → ~1 ton
DS-20K → ~20 ton
ARGO → ~200 ton

Global Argon DM Coll
ArDM, DEAP3600
DS-20K

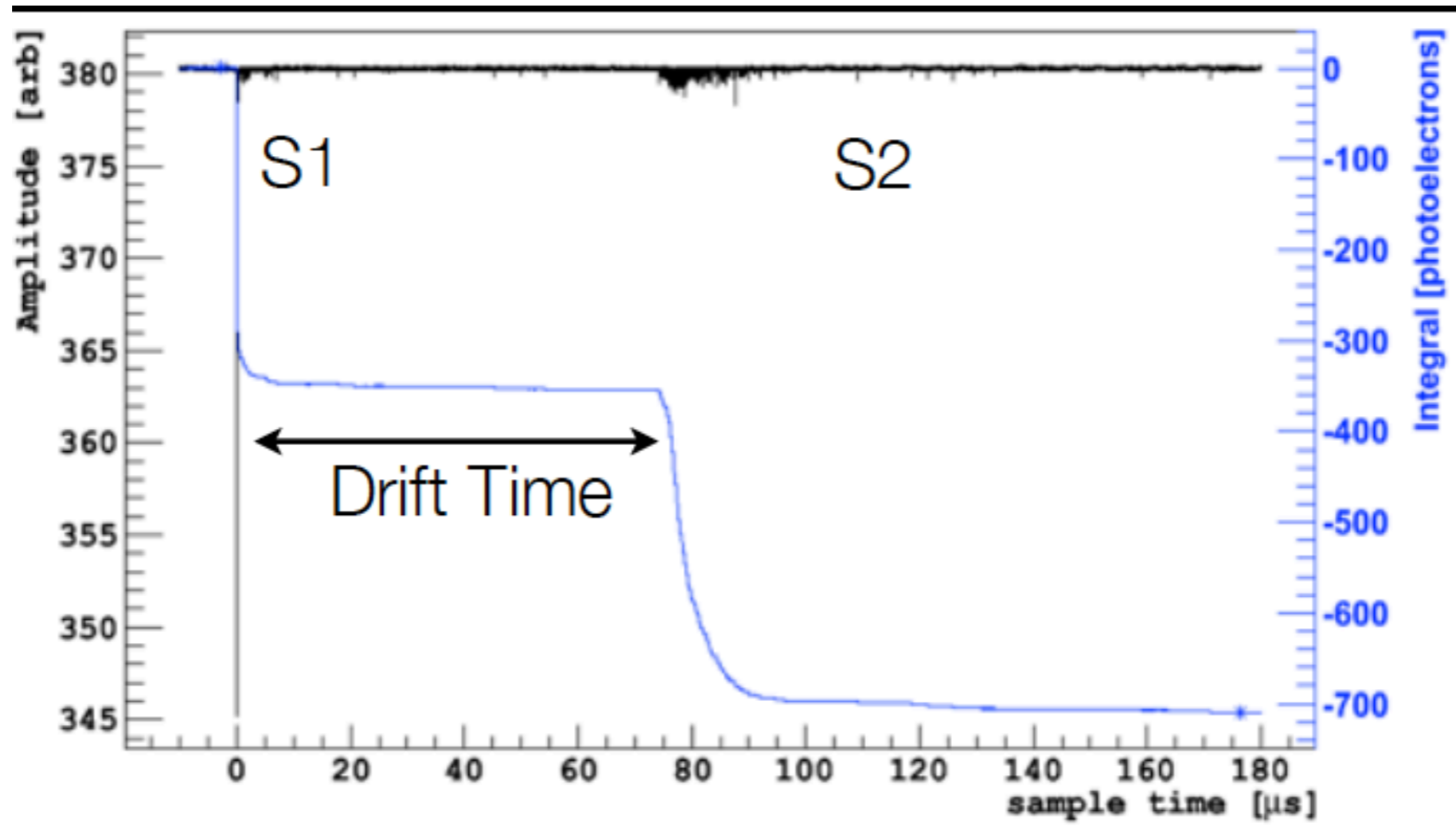
Liquid Argon Dual Phase Time Projection Chamber (TPC)



(46.4 ± 0.7) Kg
Fiducial volume:
 (36.9 ± 0.6) Kg



Dual Phase TPC



S1: prompt scintillation signal

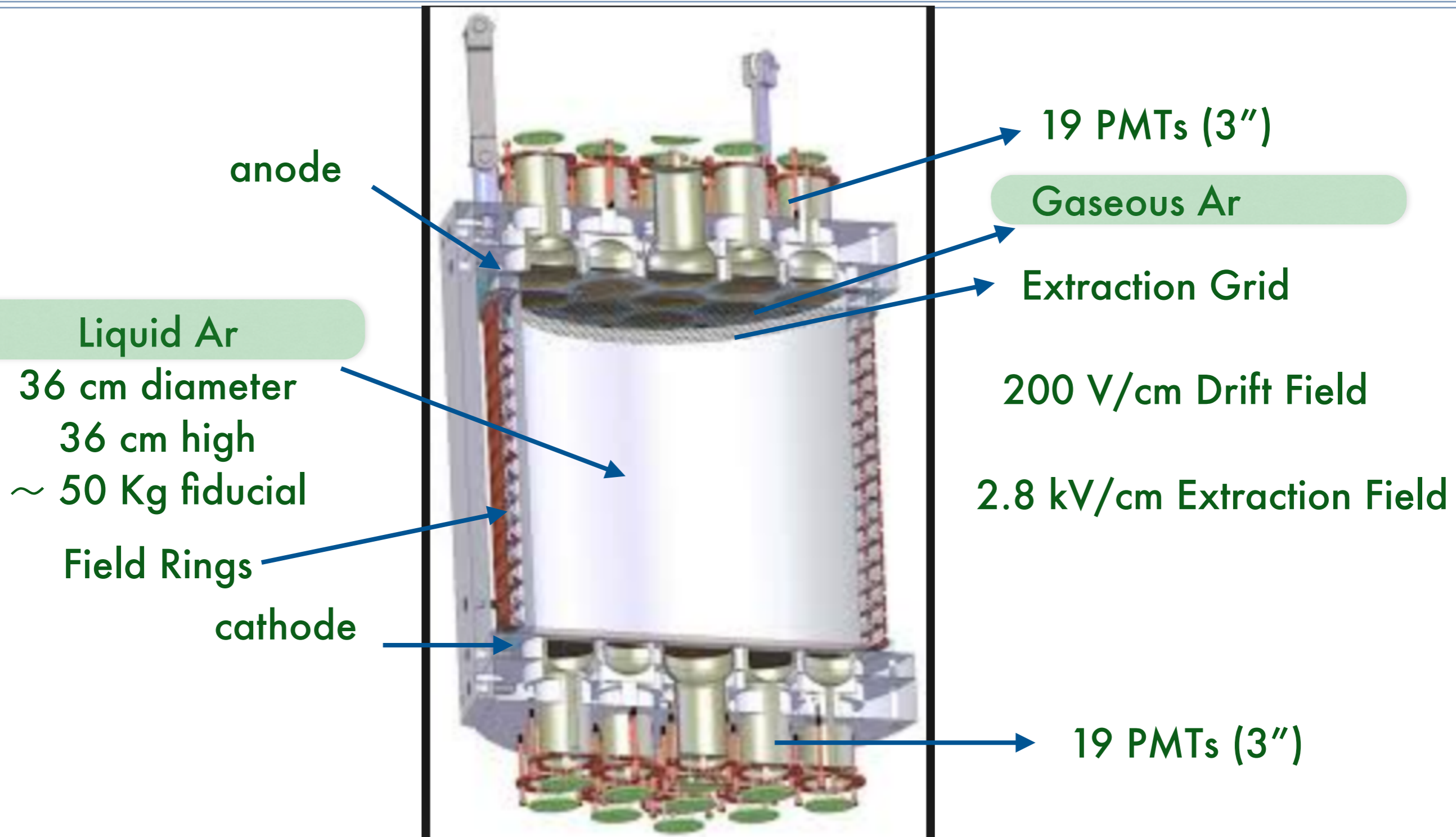
Pulse Shape Discrimination (elec vs nucl recoil)

S2: secondary scintillation (ionization)

light fraction in each PMT: XY reconstruction

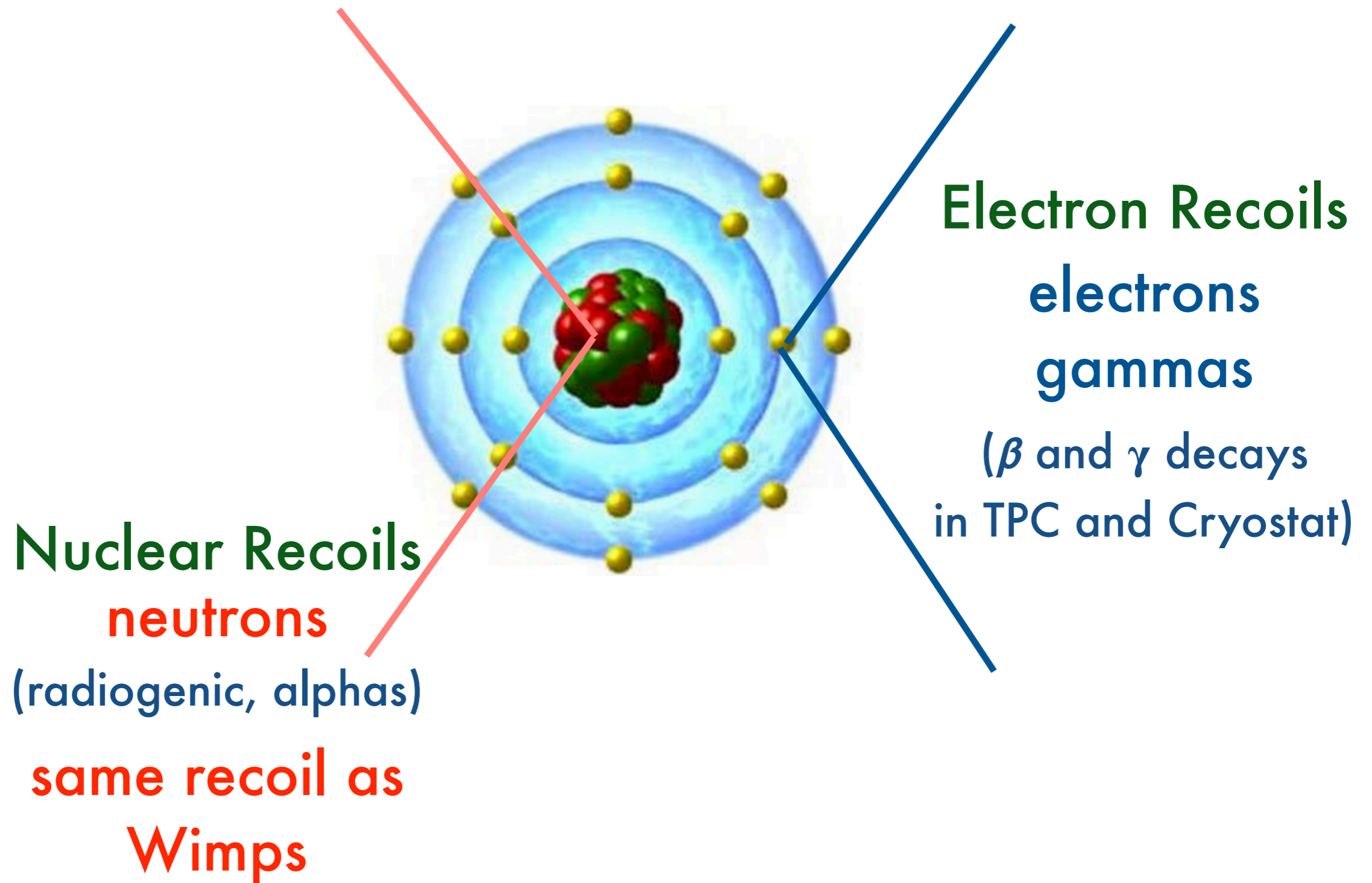
Time difference: Z position + background rejection

Time Projection Chamber (TPC)

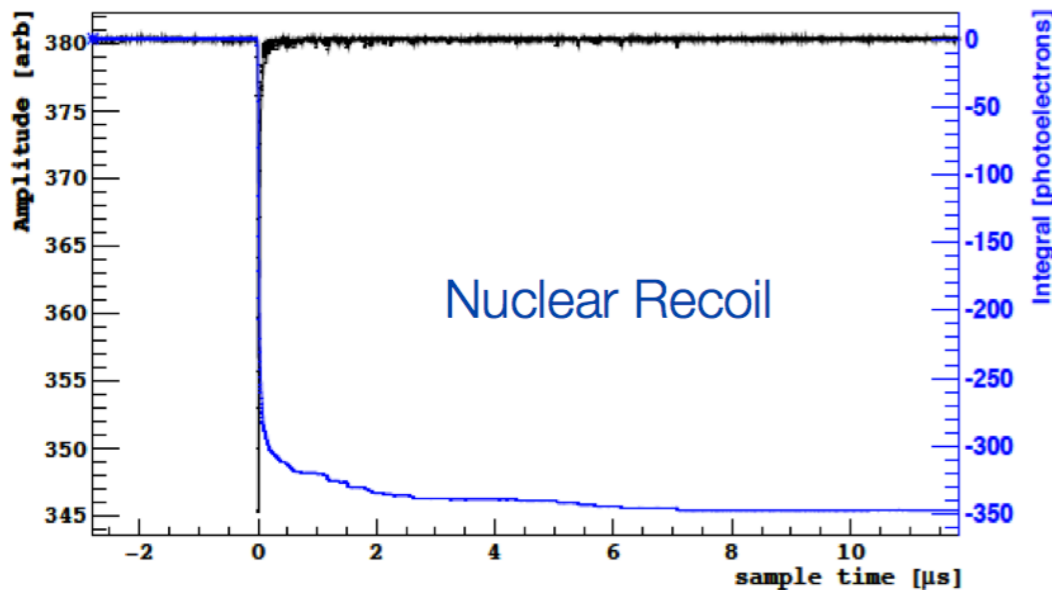
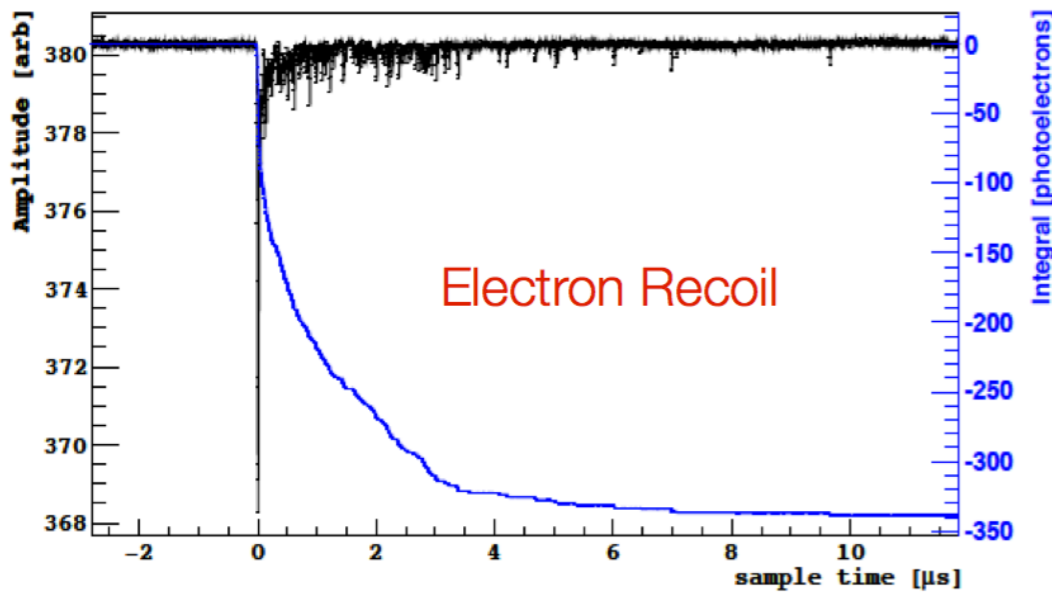


DS50 Dual Phase TPC

Backgrounds



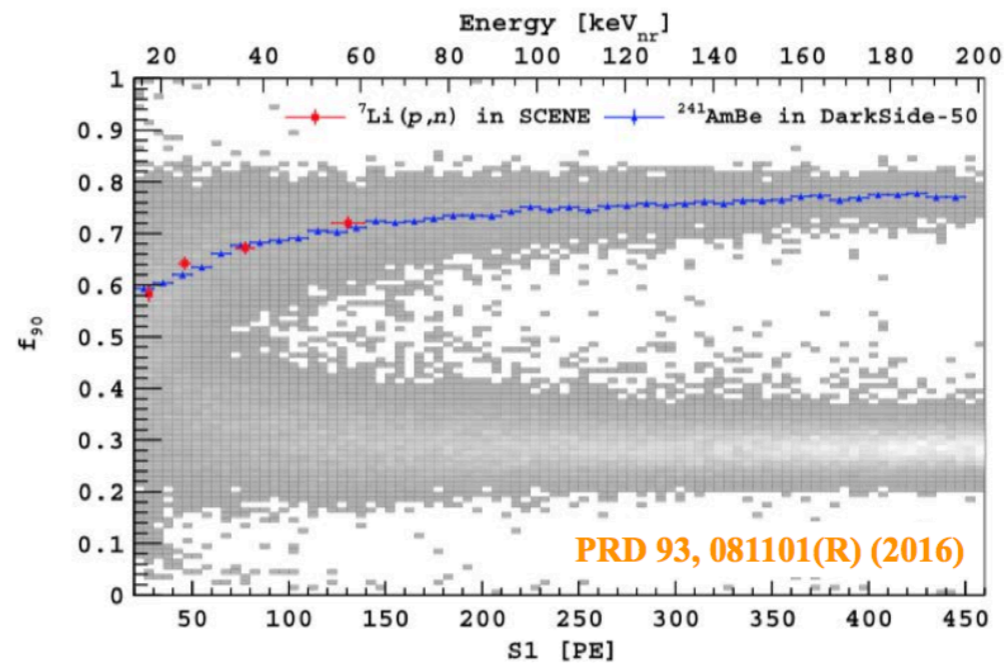
Pulse Shape Discrimination in LAr



τ singlet ~ 7 ns
 τ triplet ~ 1500 ns

PSD parameter, **F90**

Fraction of total light detected in the first 90 ns of the pulse
 (Fraction of singlet state excited dimers)



Nuclear recoils
 Electron recoils

Powerful only for LAr

Detector Shielding

Clean Room

Water Cherenkov Detector
(WCD)

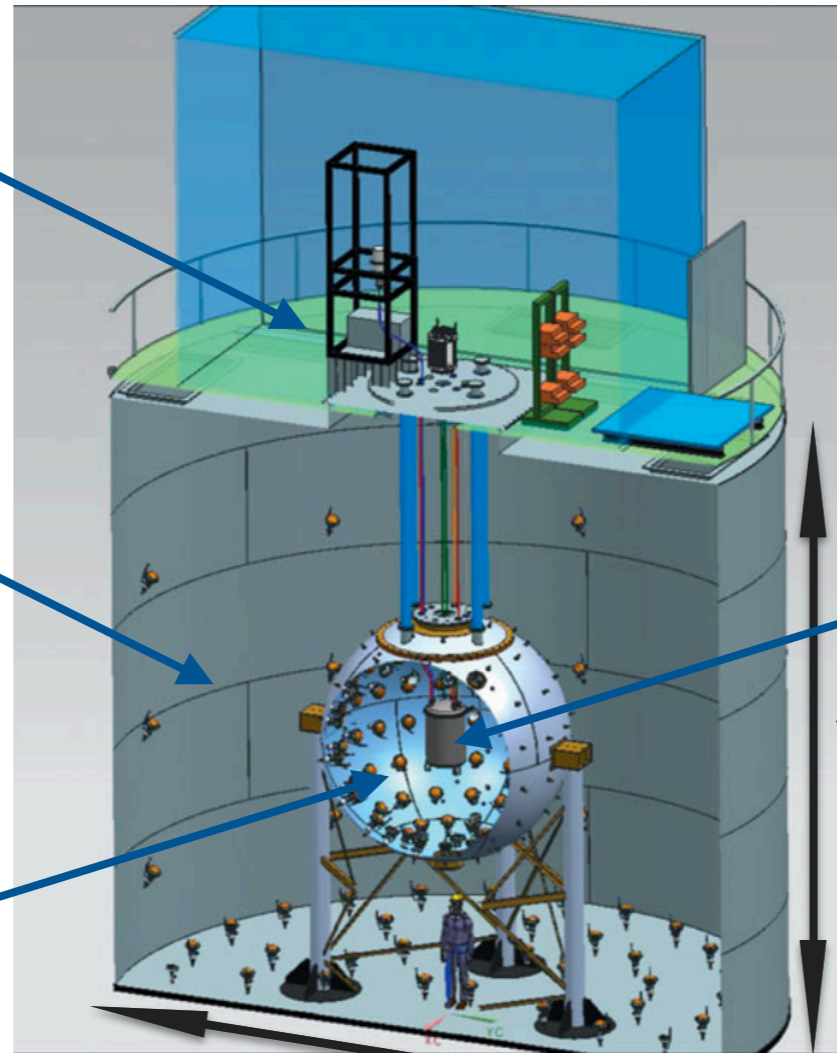
80 PMTs (8")

1000 Tons

Liquid Scintillator Veto
(LSV)

110 PMTs (8")

30 diameter - 30 Tons



TPC

153 Kg

38 PMTs (3")

200 V/cm Drift Field

2.8 kV/cm Extraction
Field

10 m

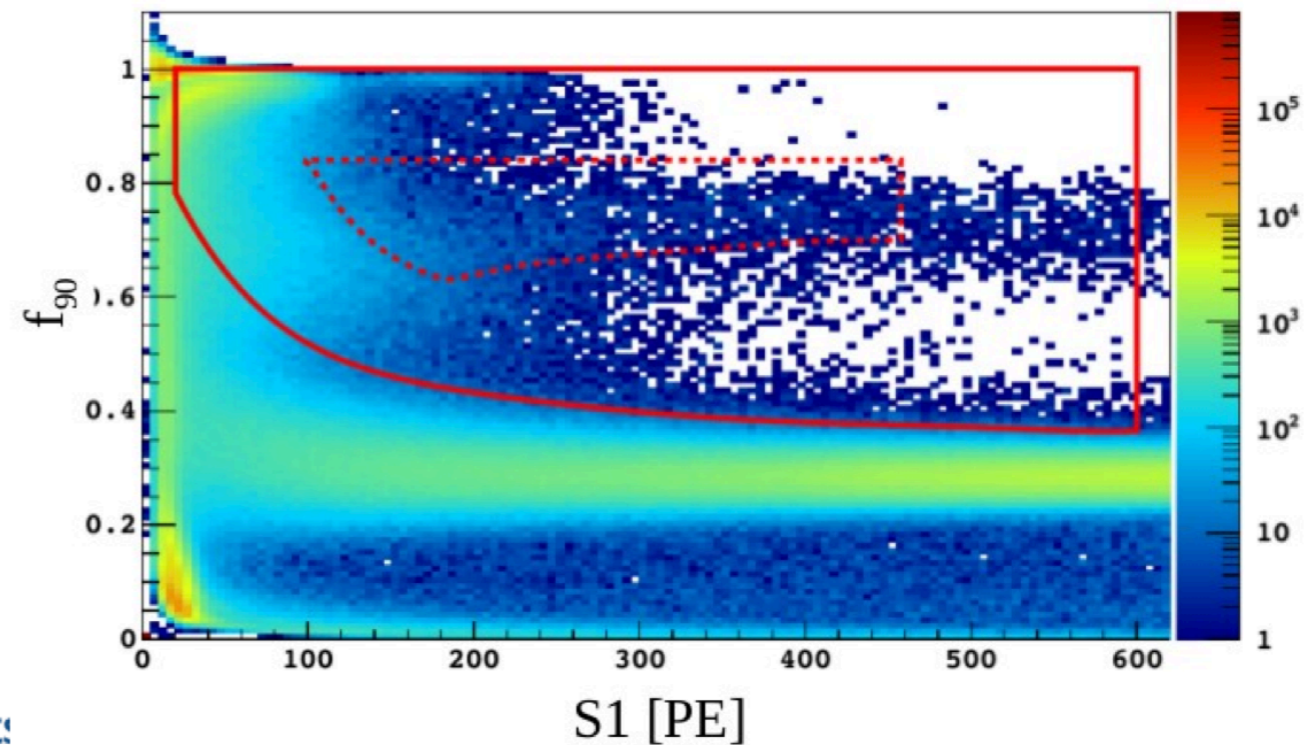
11 m

Shielding and anti-coincidence
radiogenic and cosmogenic neutrons
 γ and $CR\mu$

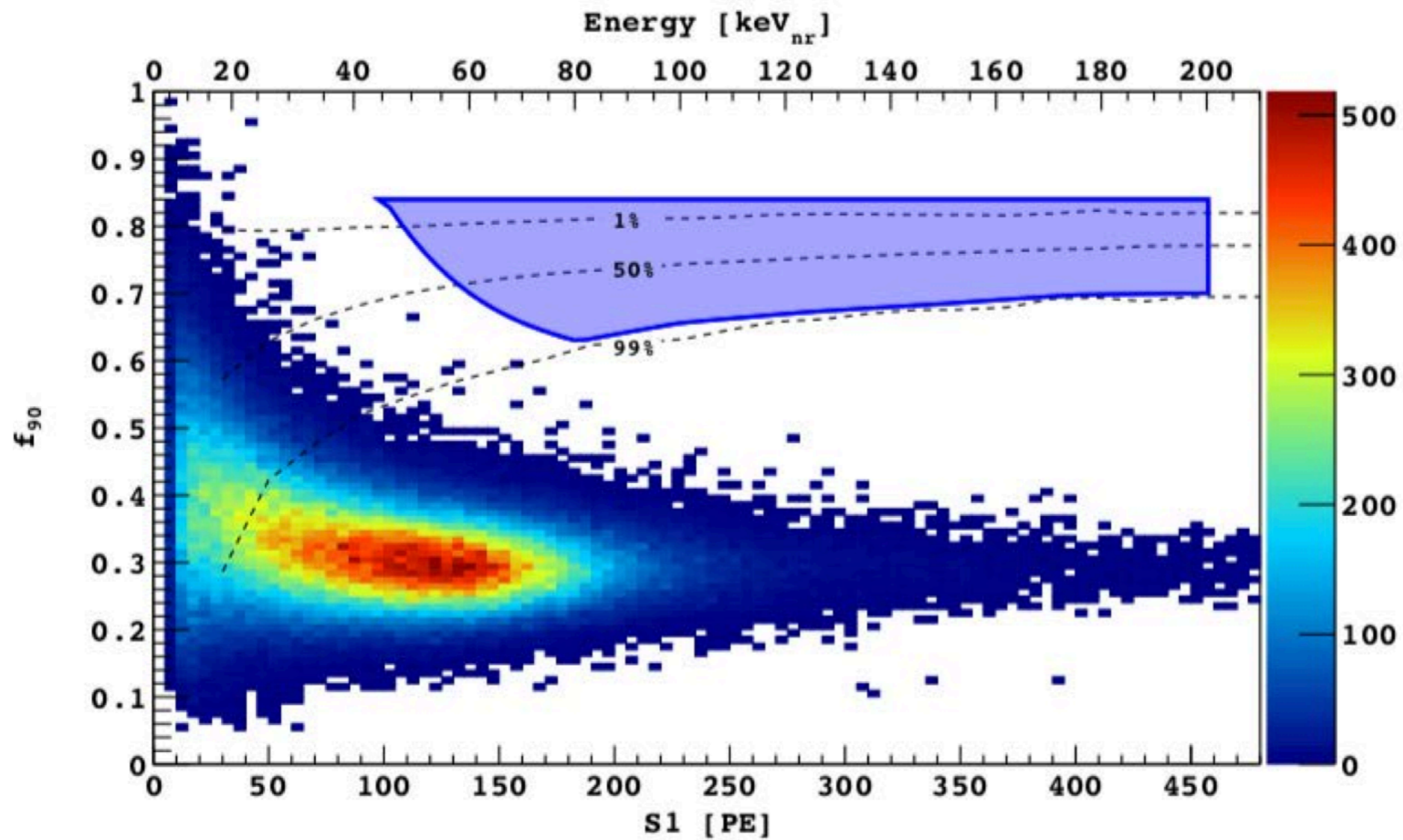
DS50k 532.4 days

Blind analysis

- blind enlarged box containing WIMP search region in the a F90 vs S1 parameter space (at event reconstruction level)
- model BG events: calibration data and MC tuning
- Refine cuts based on leakage BG events (≤ 0.1 events total)
- Test BG models on outer strip of blind box
 - Unblind WIMP region



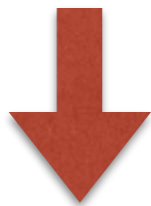
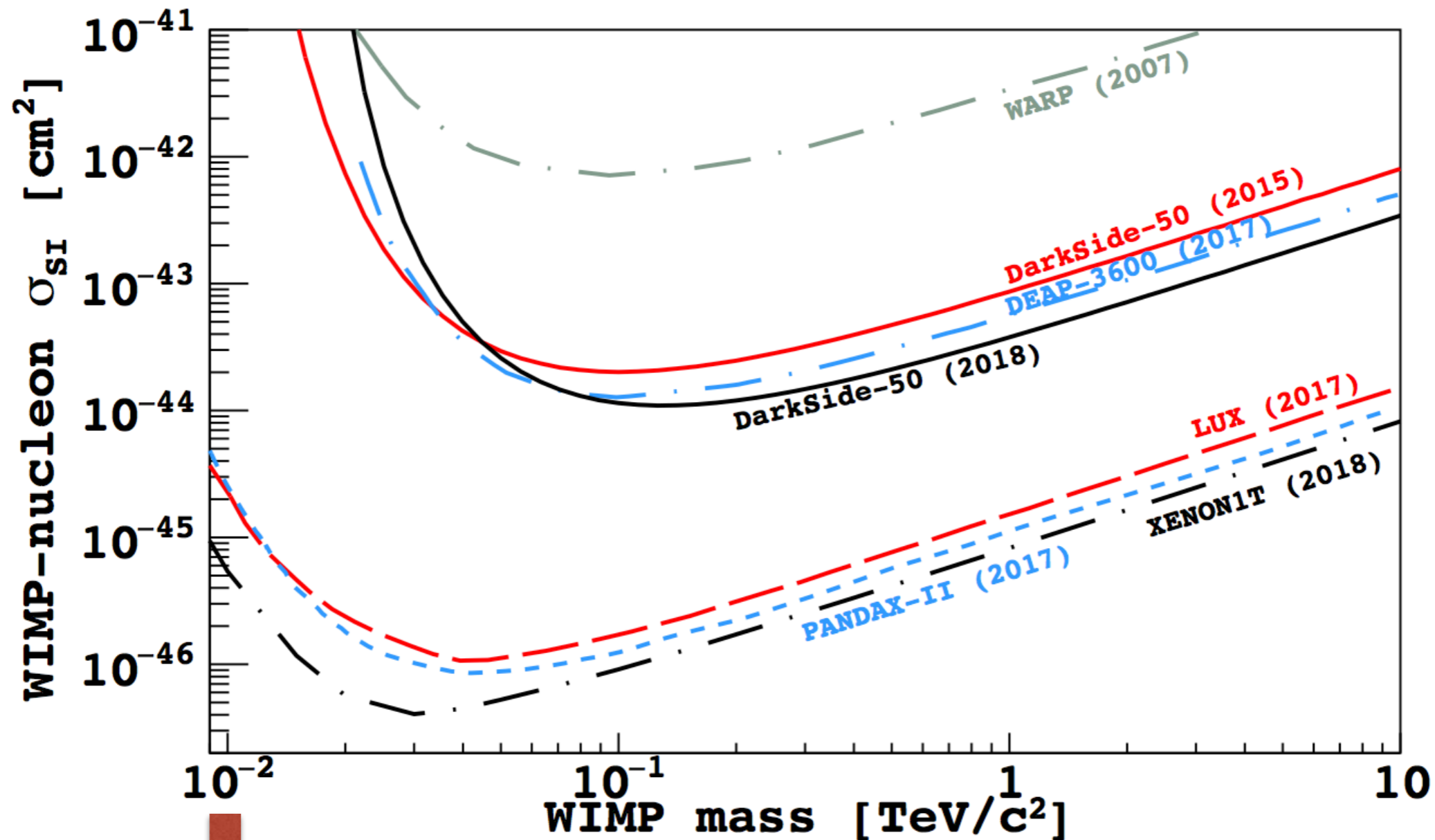
DarkSide WIMP Search



arXiv:1802.07198

DS50K Coll - PRD 98 (2018)

Current SI WIMP limits



10 GeV/c^2

DS50K Coll - PRD 98 (2018)

Low Mass Motivation

Asymmetric Dark Matter

$$\frac{\rho_{\text{DM}}}{\rho_{\text{Baryons}}} \sim 5$$

- No connection in standard WIMP scenario
 - ρ_{DM} is set by freeze out temperature
- However a connection arises when

$$\frac{\rho_{\chi}}{\rho_{\bar{\chi}}} \neq 1$$

$$(1 \leq m_{\chi} \leq 10) \text{ GeV}/c^2$$

Zurek
Phys. Reports 537, 2016

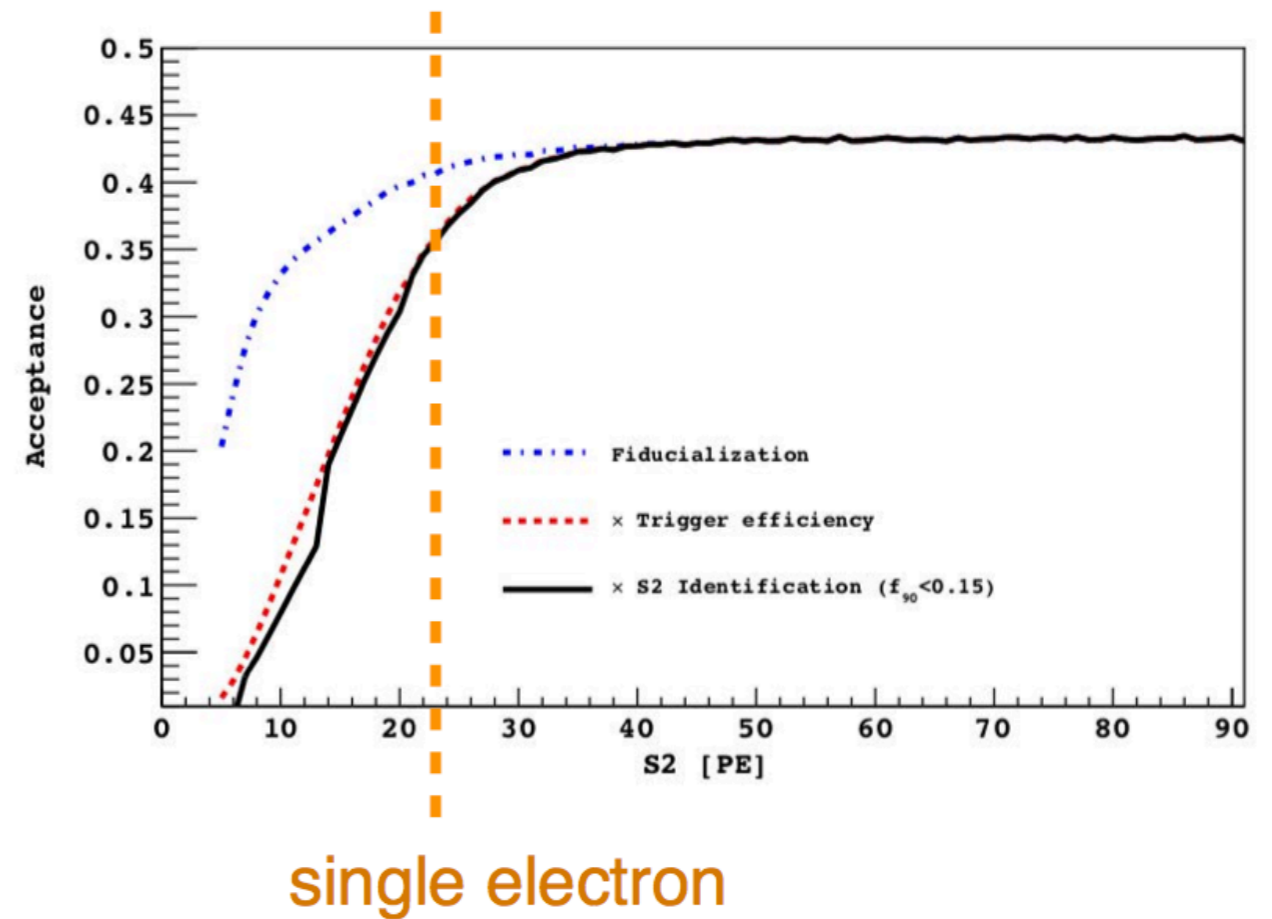
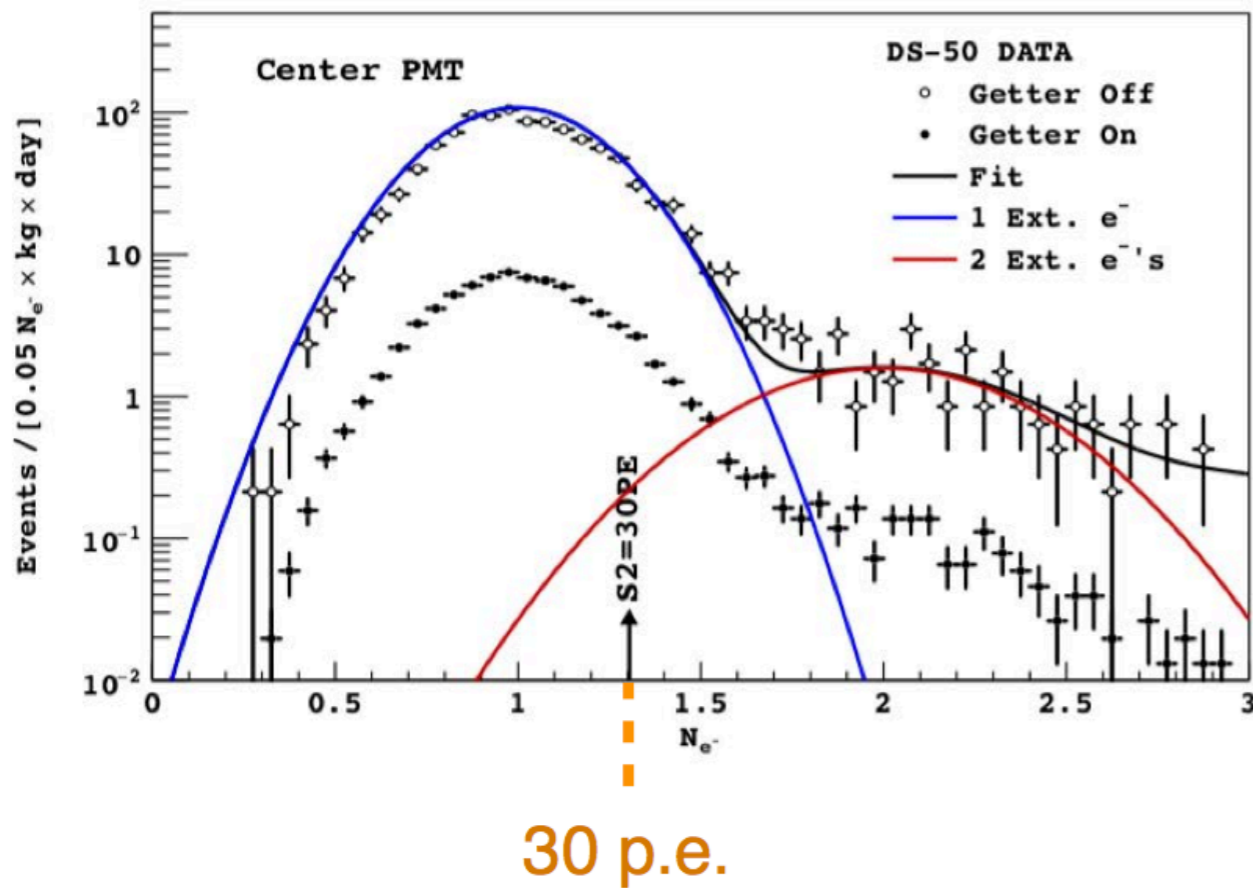
Low Mass Analysis

$$(1 \leq m_\chi \leq 10) \text{ GeV}/c^2$$

S2 only analysis

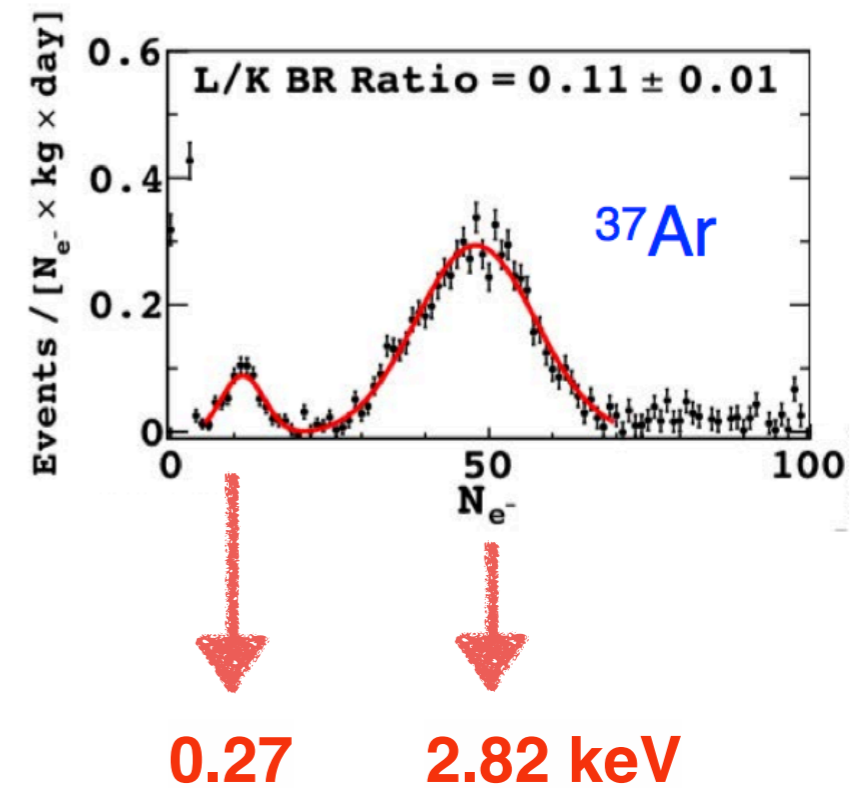
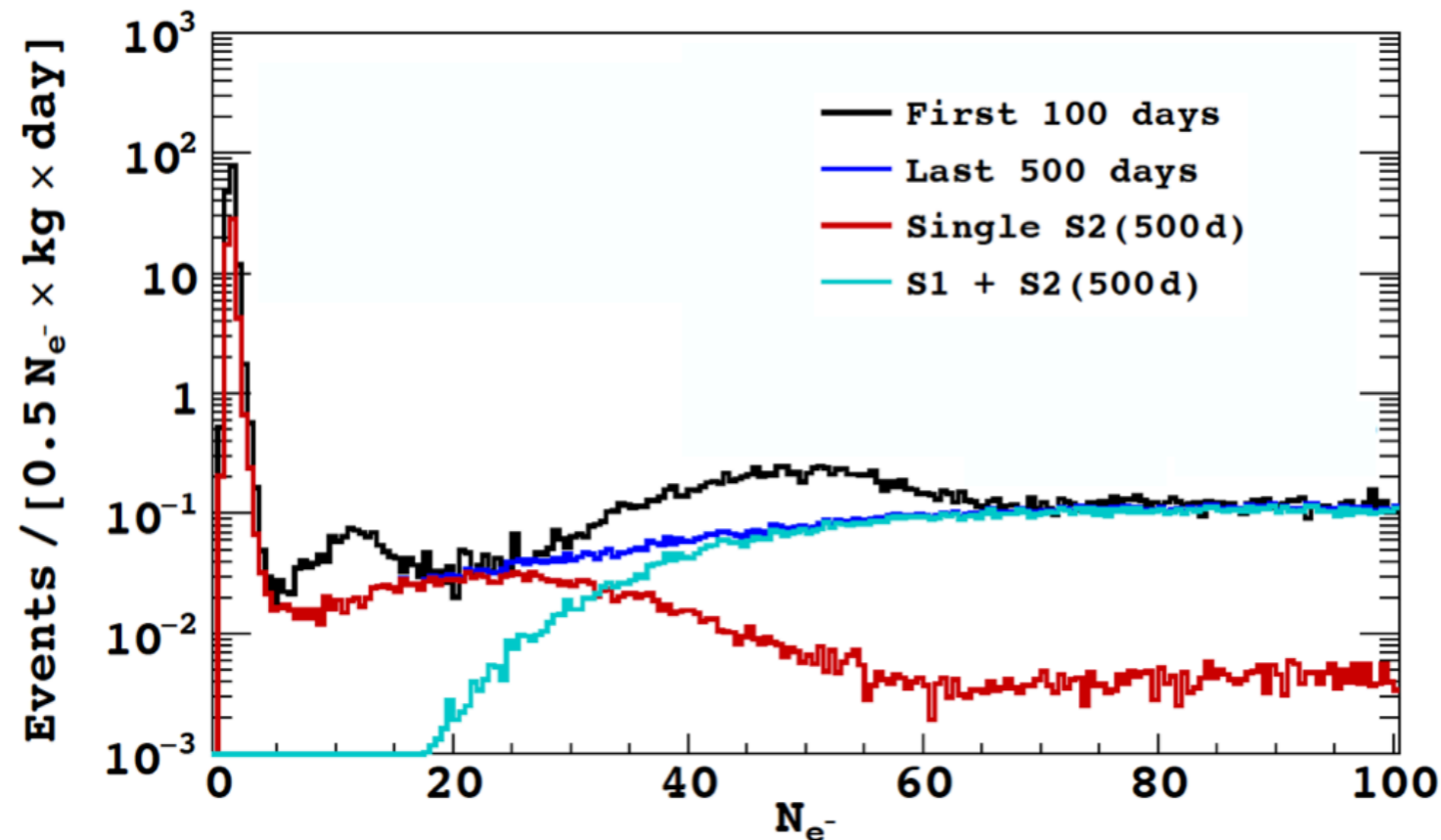
- Scintillation light (S1) is too low => not detectable
 - Give up Pulse Shape Discrimination

S2 Single Electron Yield



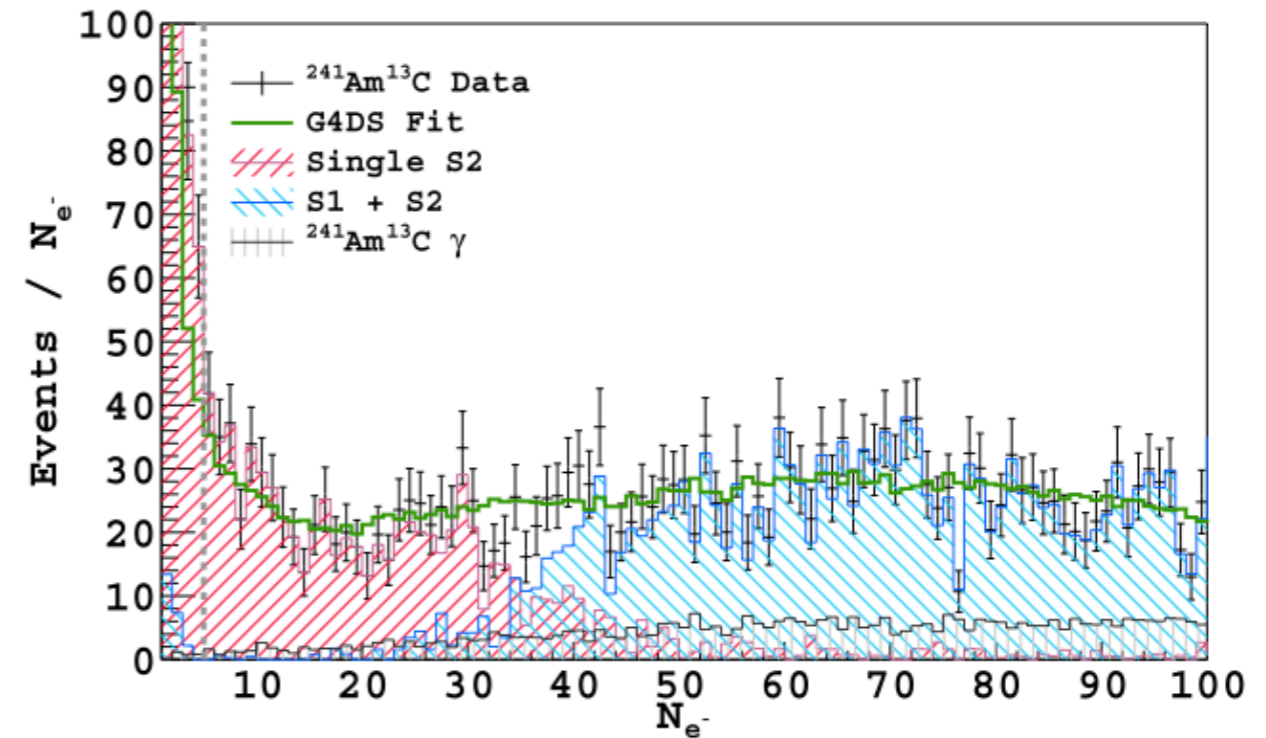
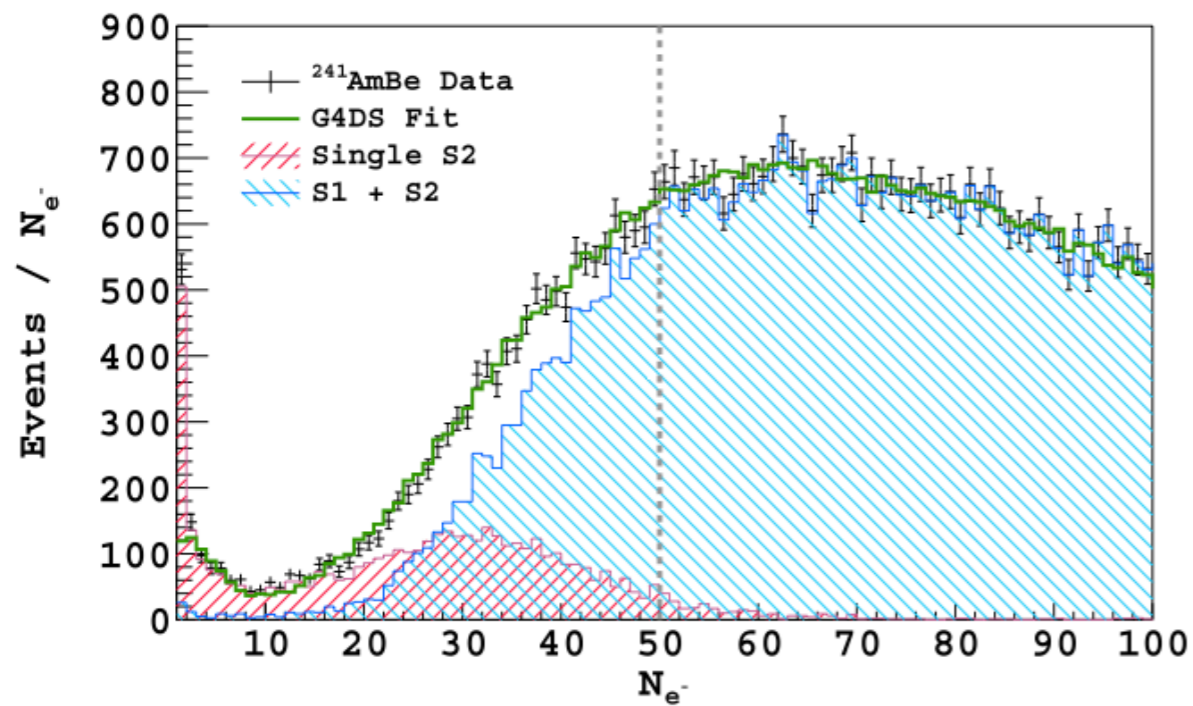
- Signal down to single electron
- approximately 23 PE/e⁻ at detector axis

S2 Only Analysis - Ar^{37}



direct N_e calibration for low energy electrons

Ionization Yield (Q_y) from Nuclear Recoils



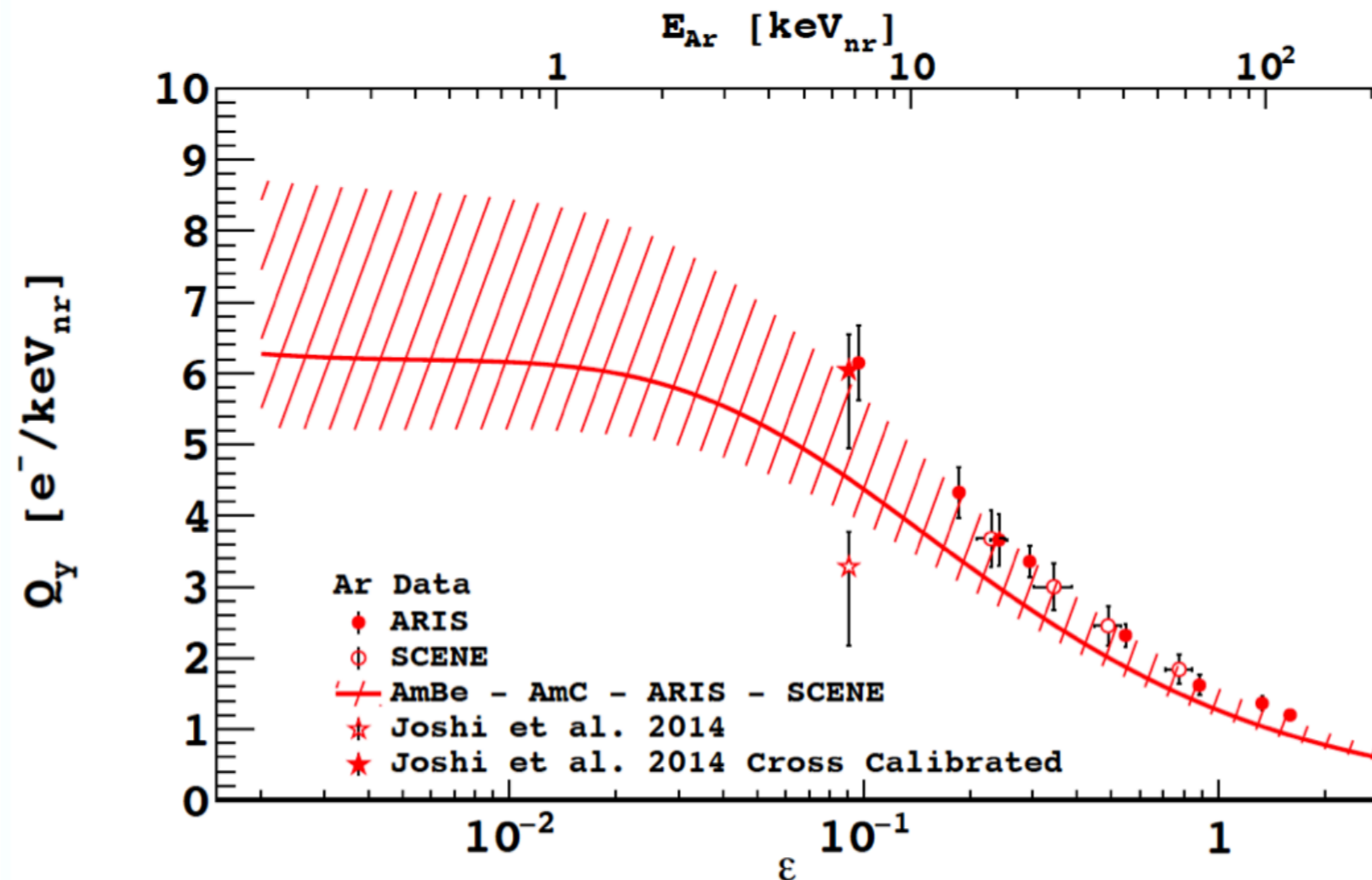
4.4 MeV γ signal in veto
required

only 4 farthest PMTs

G4DS uses Bezrukov model

(Bezrukov et al., Astropart.Phys. 35 (2011))

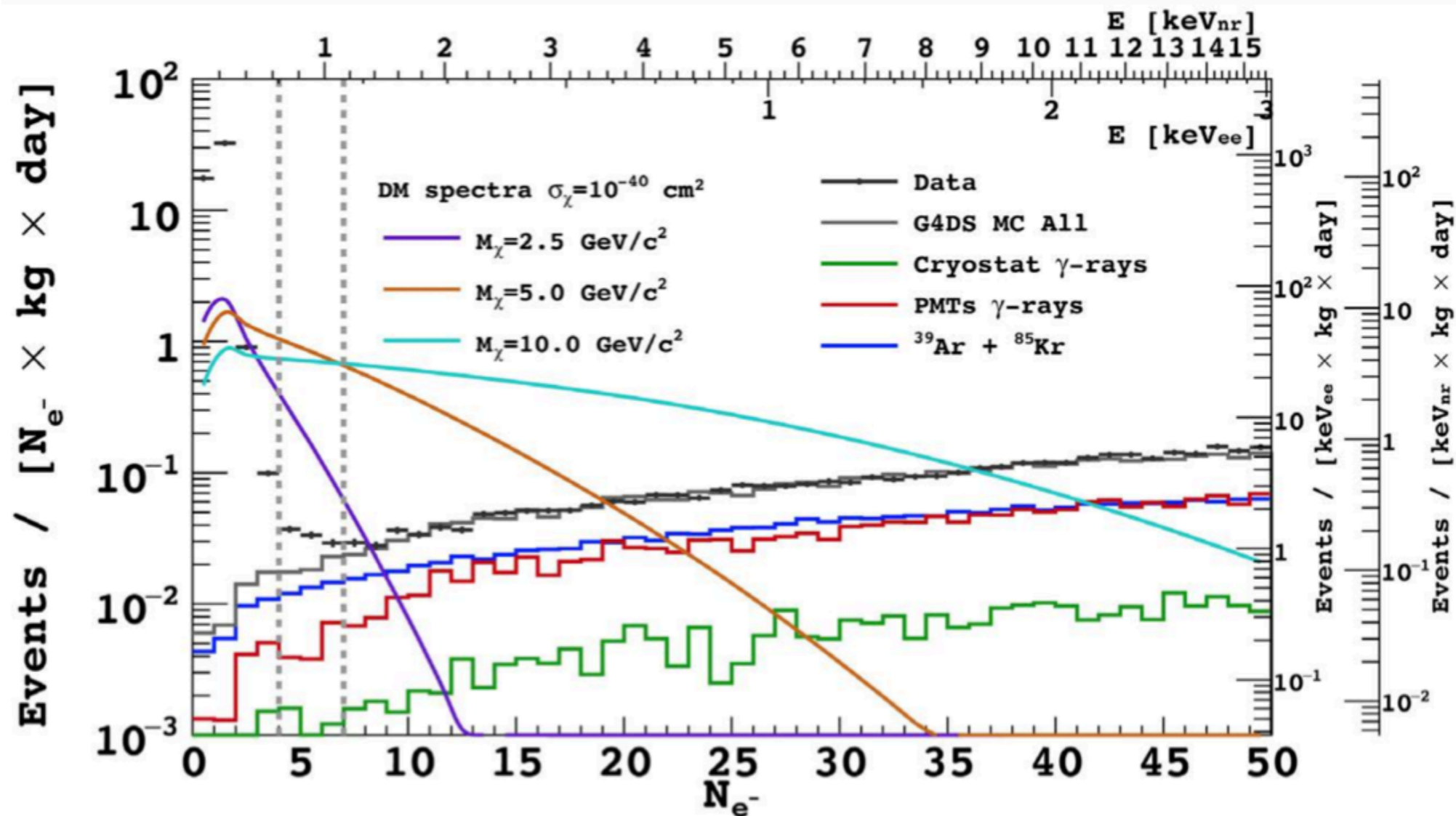
Ionization Yield (Q_y) from Nuclear Recoils



Q_y from AmBe + AmC + Bezrukov model

Agree within bounds with other data => systematics

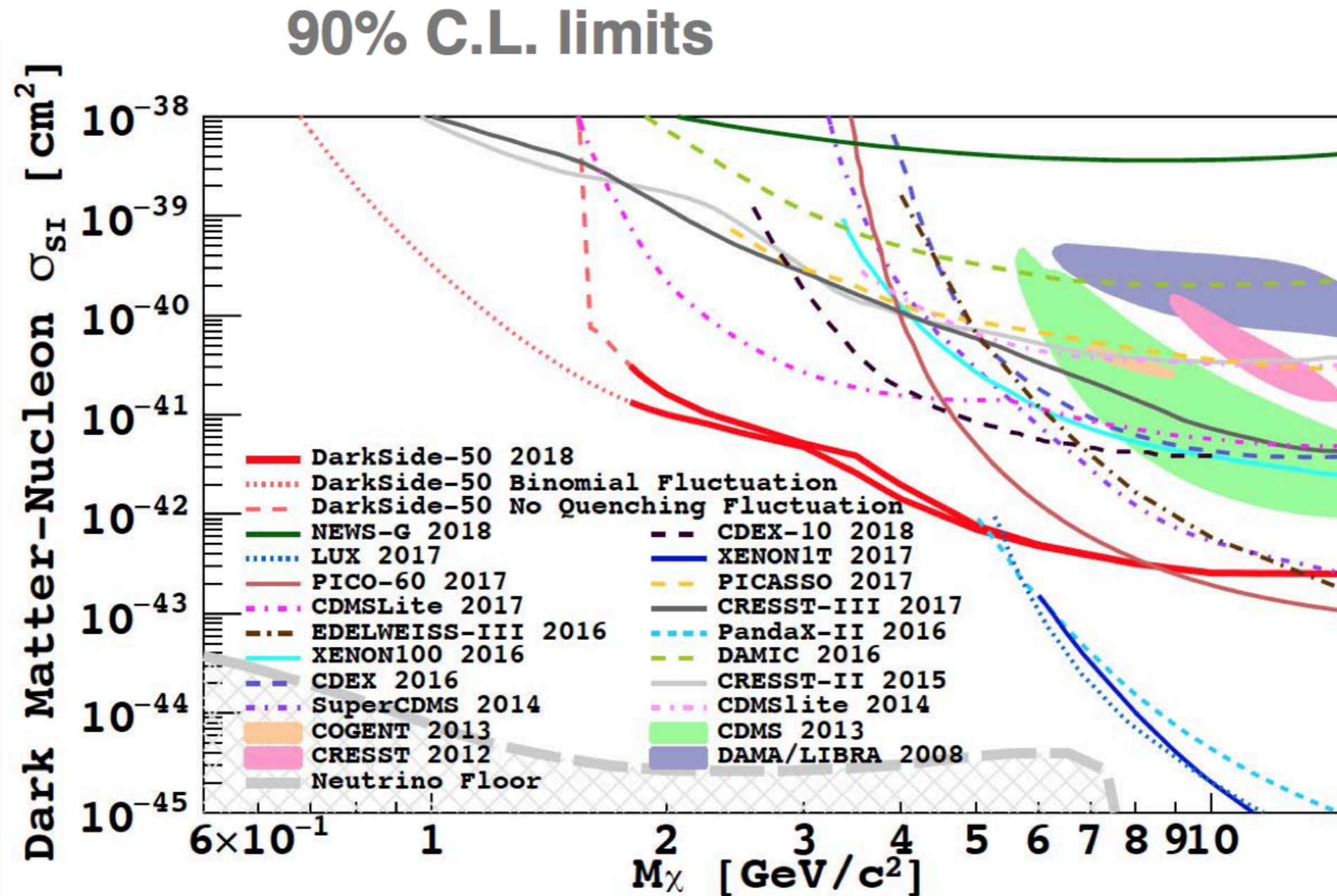
Low Mass Wimps: Signal vs Backgrd



Expected signal assumes standard DM halo

Uncertainties in signal dominated by Q_y fluctuations

Low Mass Wimps: Limits



DS50K Coll - PRL 121 (2018)

SubGeV Search

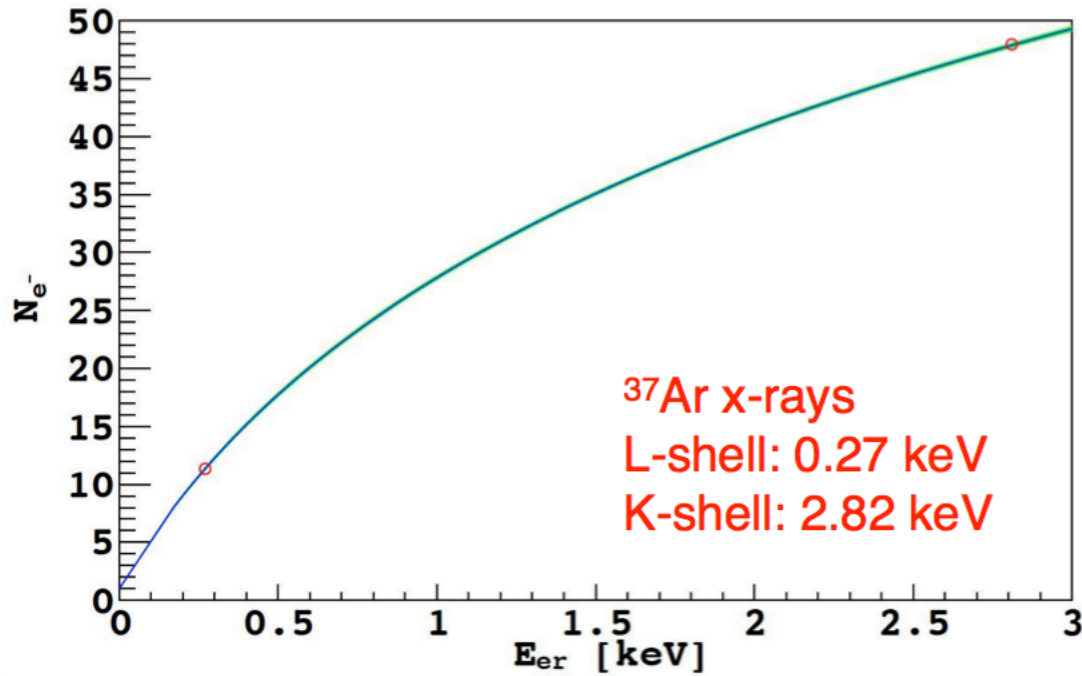
DARK SECTOR

- Hidden sector with not only one DM particle, but multiple particles and forces
- Portals connecting with Standard Model particles

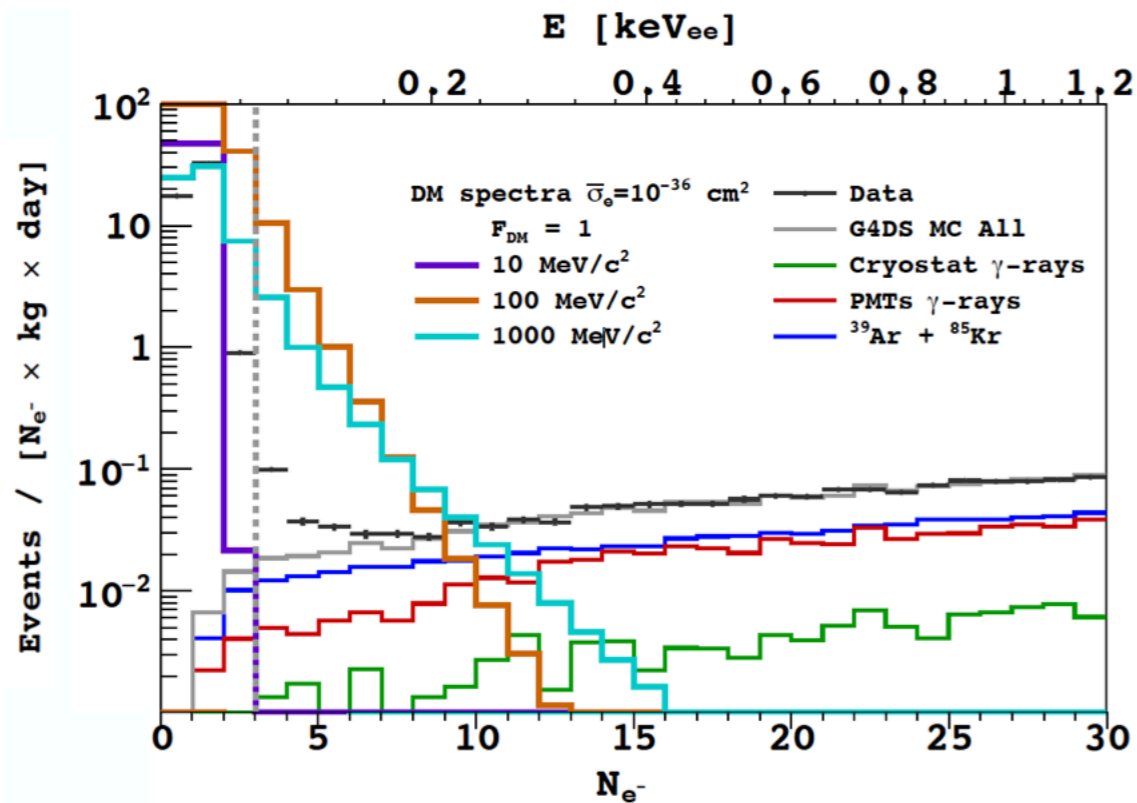
Also an S2 only analysis

DM - electron scattering

SubGeV Analysis

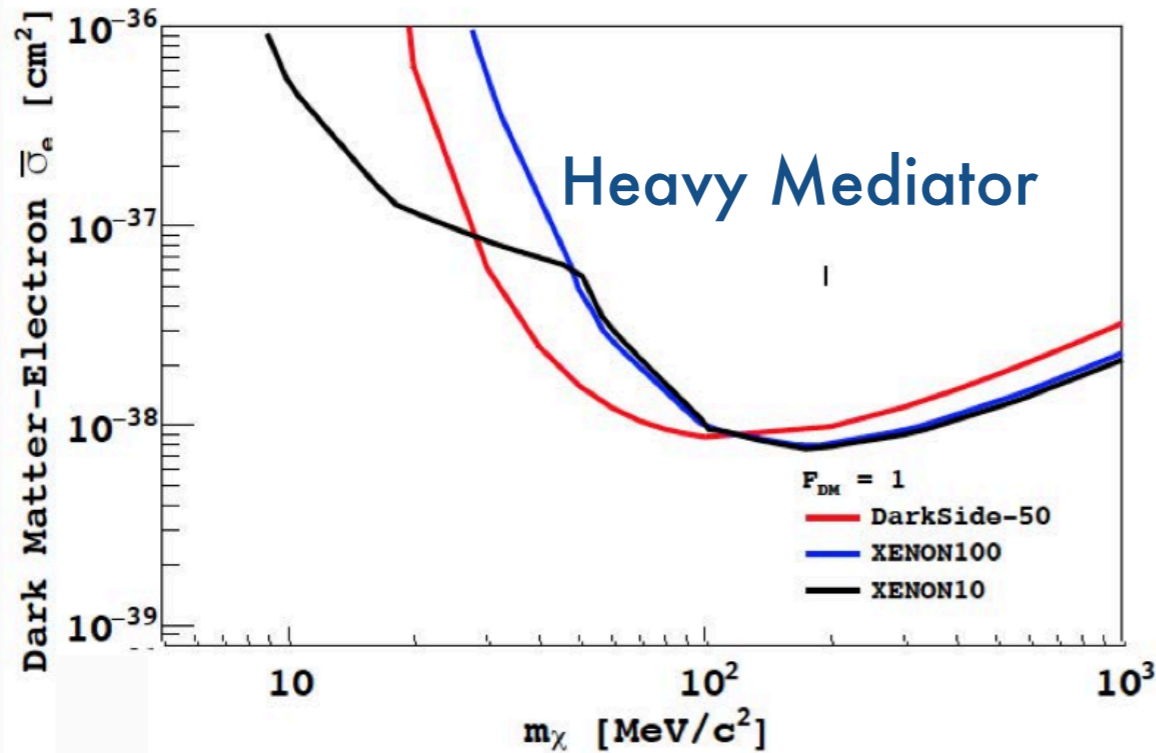


- DM-electron interaction parametrized by a DM form factor with two limiting values (heavy and light mediator)



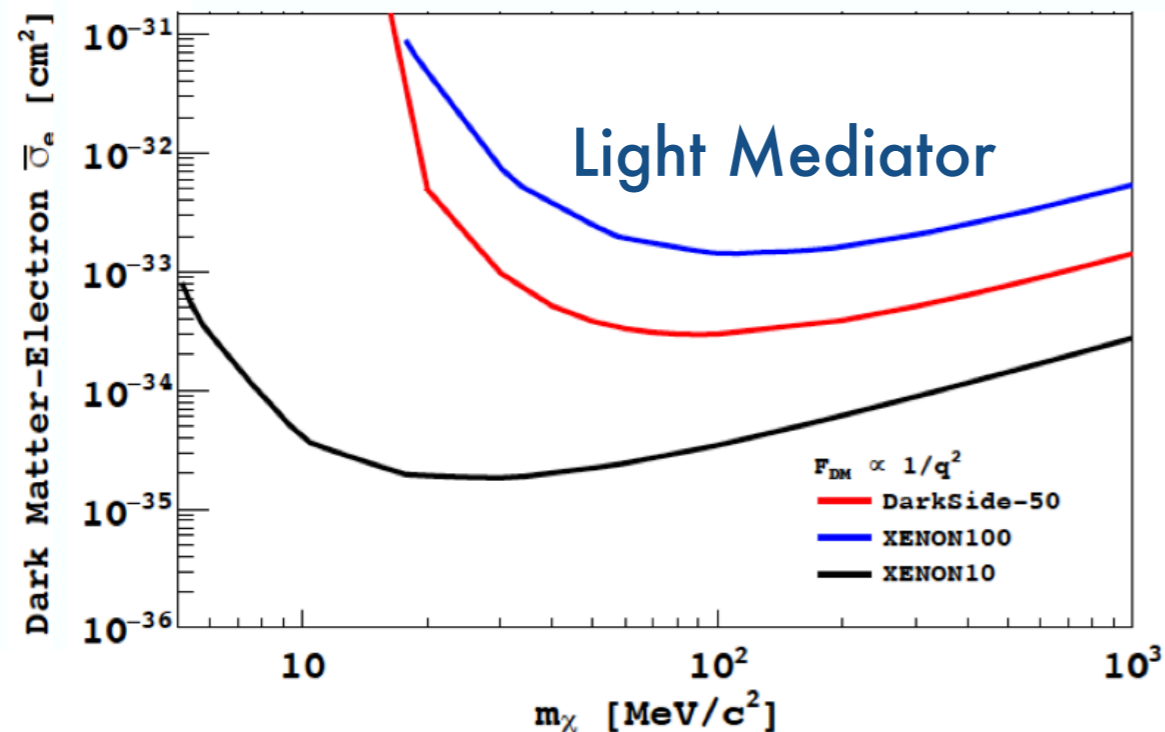
$$|F_{DM}(q)|^2 = \begin{cases} 1, & m_{\text{med}} \gg \alpha m_e \\ (\alpha m_e / q)^4, & m_{\text{med}} \ll \alpha m_e, \end{cases}$$

SubGeV Limits



DS50K has best result
25 -100 MeV region

DS50K Coll - PRL 121 (2018)

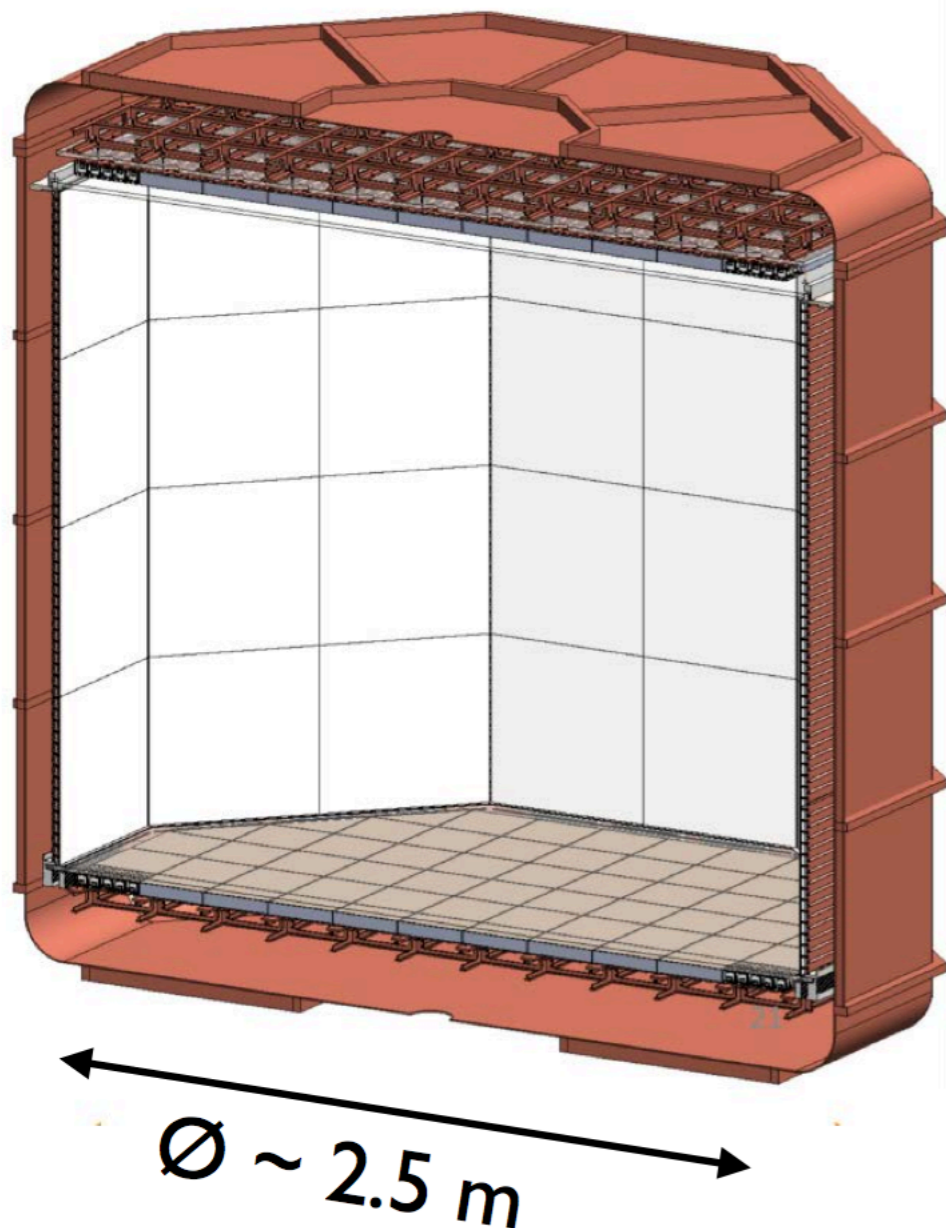


Xe analysis
Essig, Volansky and Yu,
PRD 96 (2017)

LAr Program: Beyond DS50

PROTO

- Assembly and test of DS20k cryostat
- Tests of SiPM
- CERN



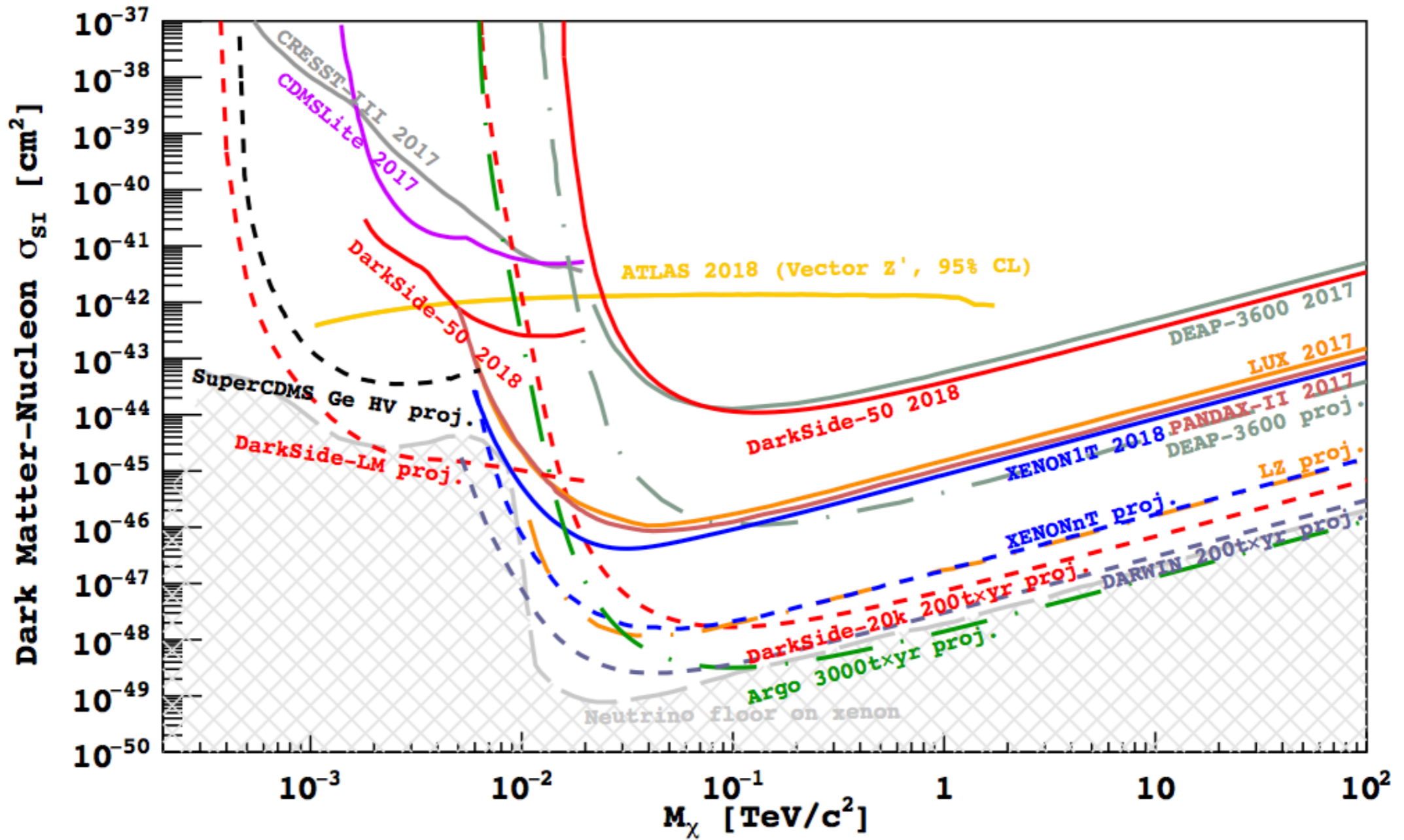
DS20k

- 50 ton UAr Dual Phase TPC (30 ton fiducial)
- SiPM
- Background free ($<0.1/100$ ton year)
- Data from 2022

ARGO Coll

- 300 ton LAr

Near Future Sensitivities



5 σ Sensitivity

