



DARKSIDE-50 RESULTS AND DARKSIDE-20K PROSPECTS

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DARKSIDE-20K IS INTERNATIONAL COLLABORATION WITH ~300 COLLABORATORS

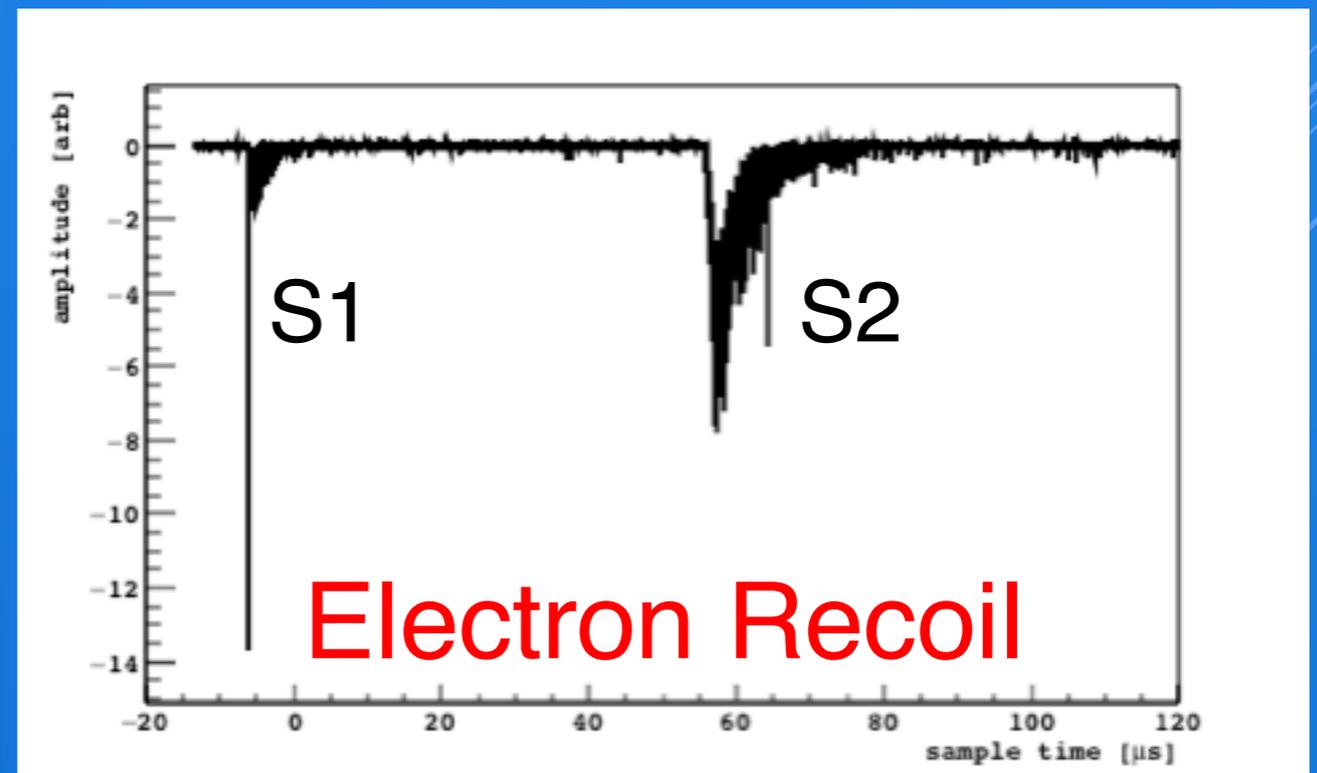
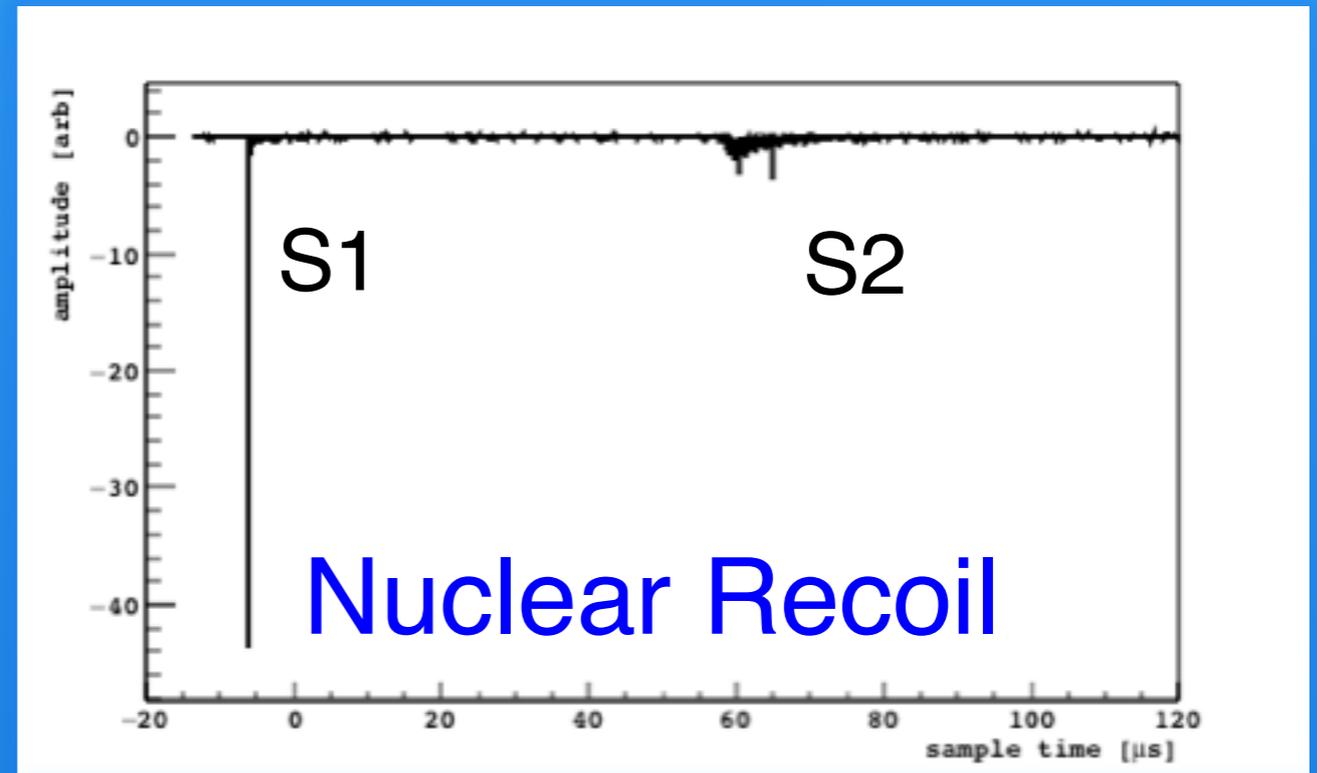
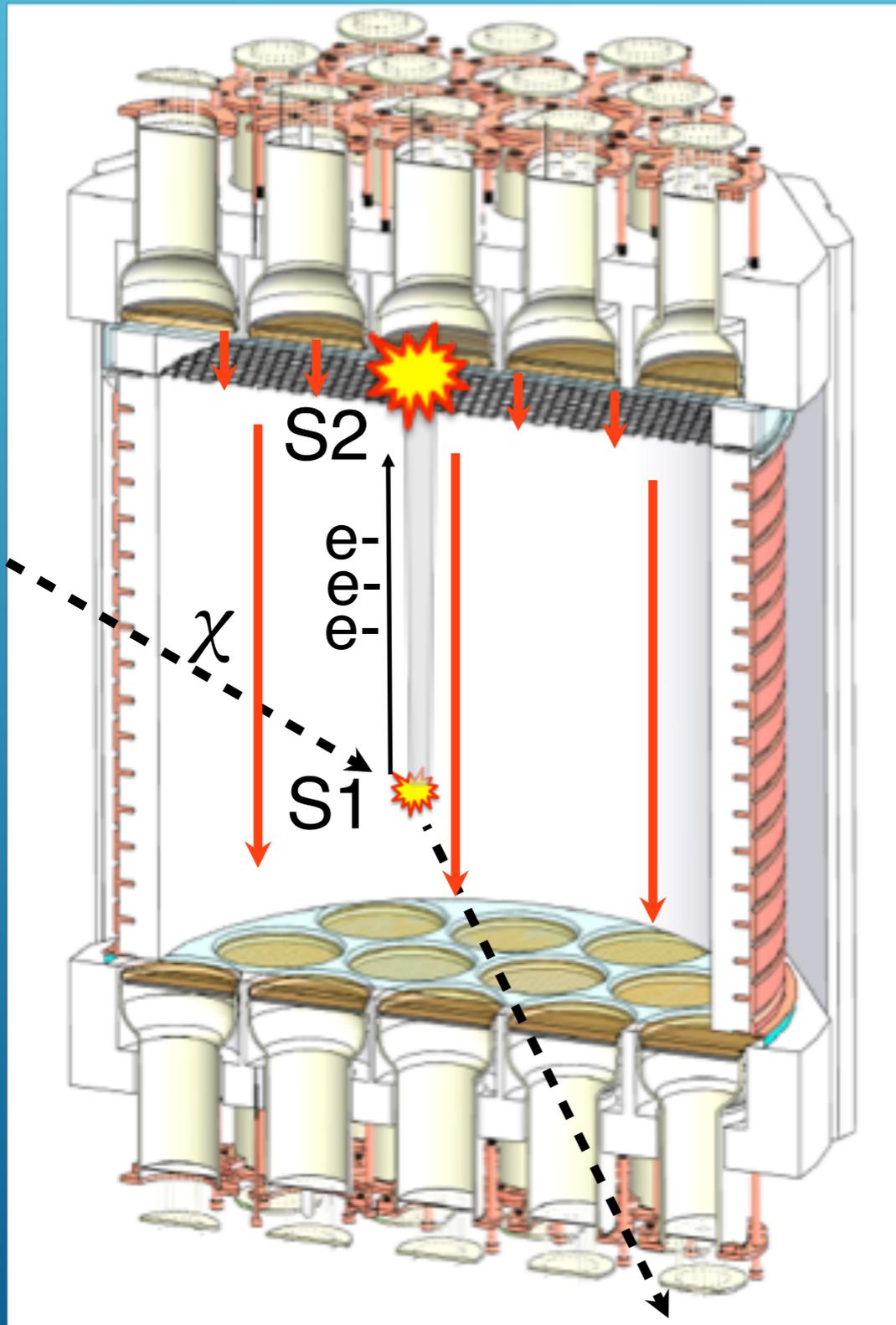


OUTLINE



- Introduction
- DarkSide-50 design for background free WIMP search
- Recent results
 - DarkSide-50 532-day Dark Matter Search with Low-Radioactivity Argon, arXiv:1802.07198v2 (accepted for publication in Phys. Rev. D)
 - Low-mass Dark Matter Search with DarkSide-50 Experiment, *Phys. Rev. Lett.* 121, 081307 (2018) **Editor's suggestion**
 - Constraints on Sub-GeV Dark Matter-Electron Scattering from the DarkSide-50 Experiment, *Physical Review Letters* 121, 111303, (2018)
- The developments toward DarkSide-20k and GADMC
- Summary and Outlook

DUAL PHASE ARGON TIME PROJECTION CHAMBER CONCEPT



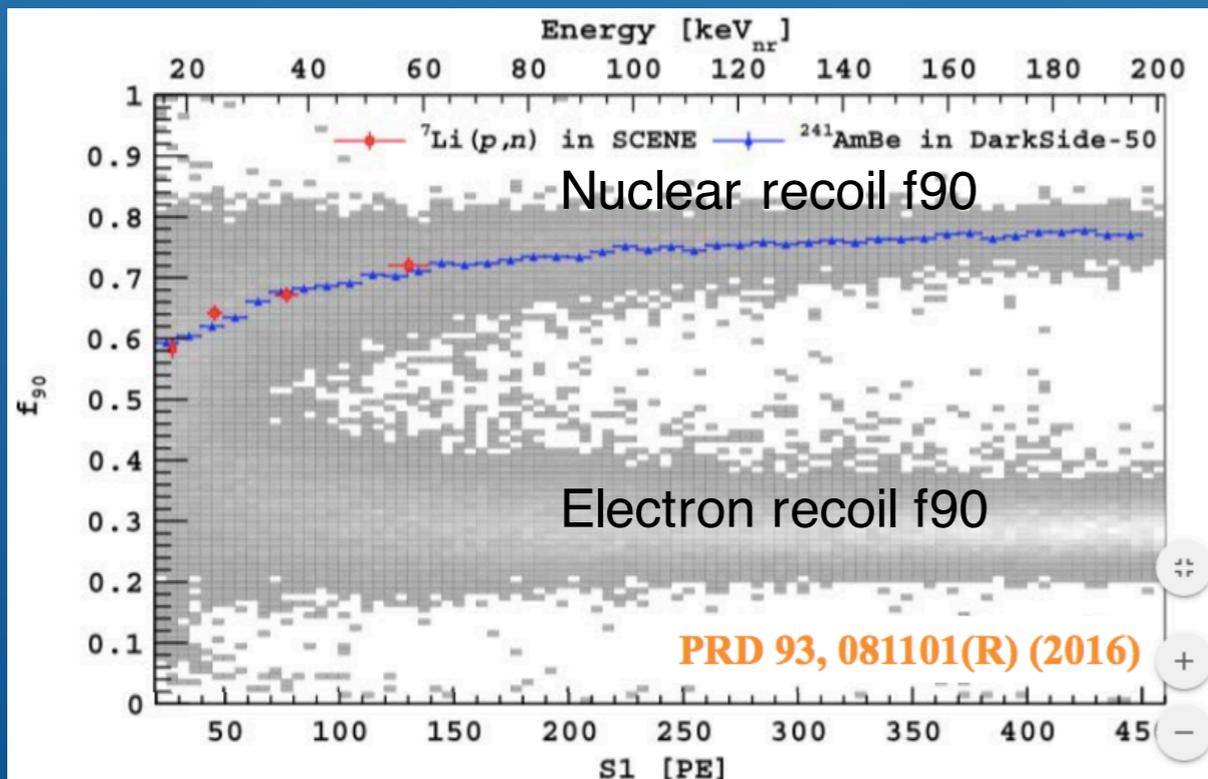
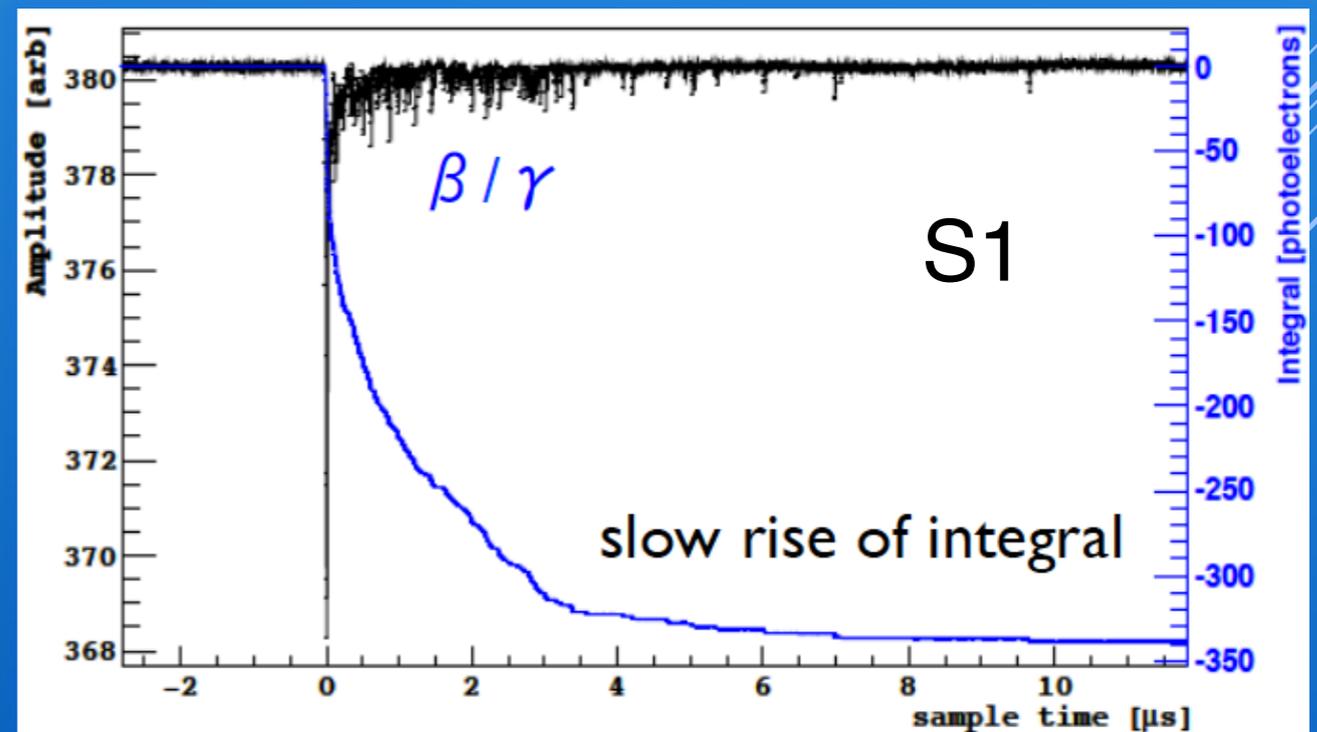
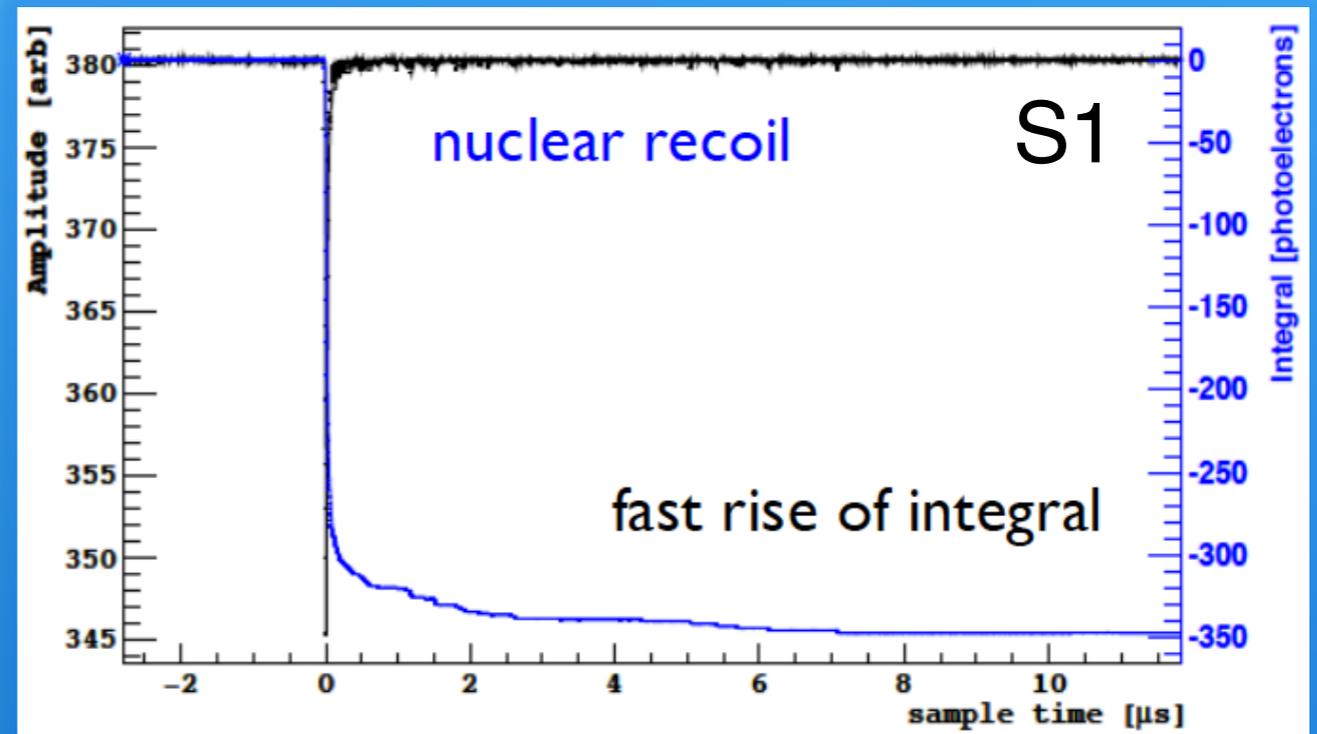
PULSE SHAPE DISCRIMINATION (PSD) IN LIQUID ARGON



$\tau = 7$ ns (singlet)
 $\tau = 1500$ ns (triplet)

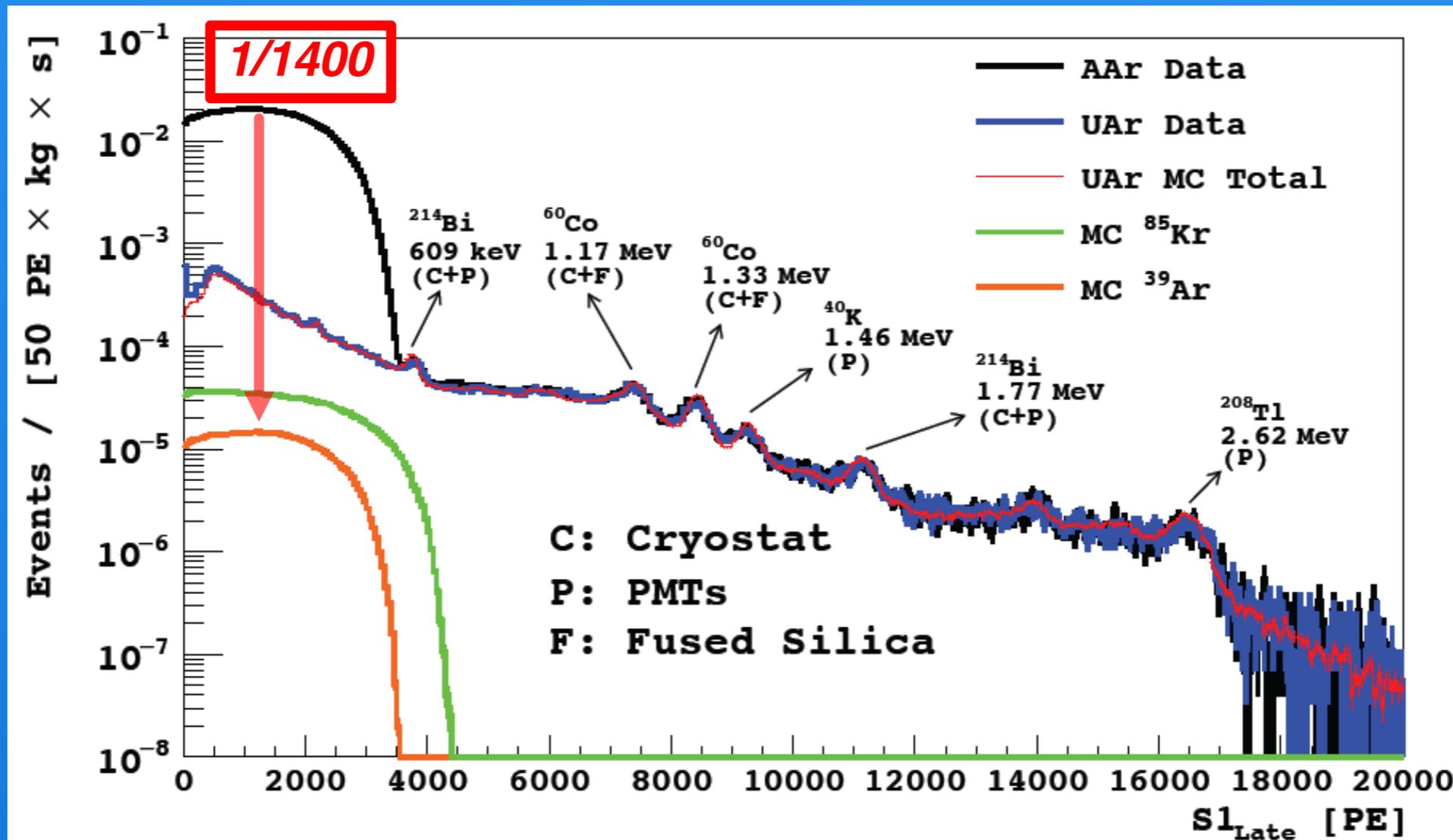
PSD parameter, **F90**

Fraction of total light detected in the first 90 ns of the pulse.



> 10^7 bkg rejection of electron recoils based on S1 PSD.

INTRINSIC BACKGROUND ^{39}Ar MITIGATED IN UNDERGROUND ARGON



In March 2015, DS50 was filled with underground argon UAr. Major undertaking – extracted from Colorado mine and purified at FNAL.

Exhibits 1400 times smaller content of ^{39}Ar in UAr than AAr!

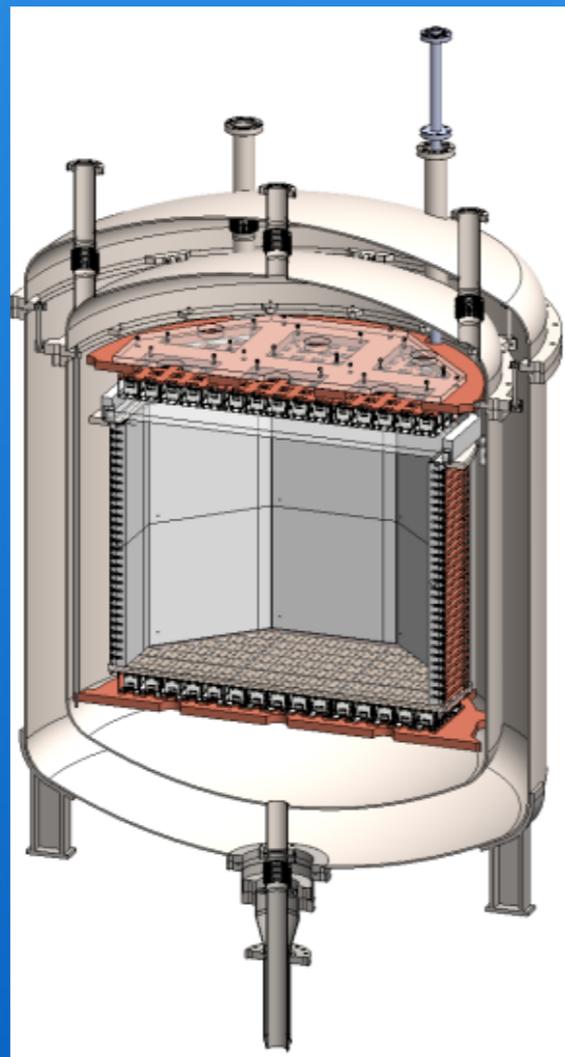
Low level of ^{39}Ar allows extension of DS to ten and hundred ton-scale detector.

DARKSIDE PROGRAM



Multistage program toward **background free** DM search.
Very low background levels from all components, further reduced through active suppression.

DarkSide-prototype



1 ton fiducial

DarkSide-20k



32 ton fiducial

DarkSide-50



50 kg fiducial

GADMC

300 ton fiducial

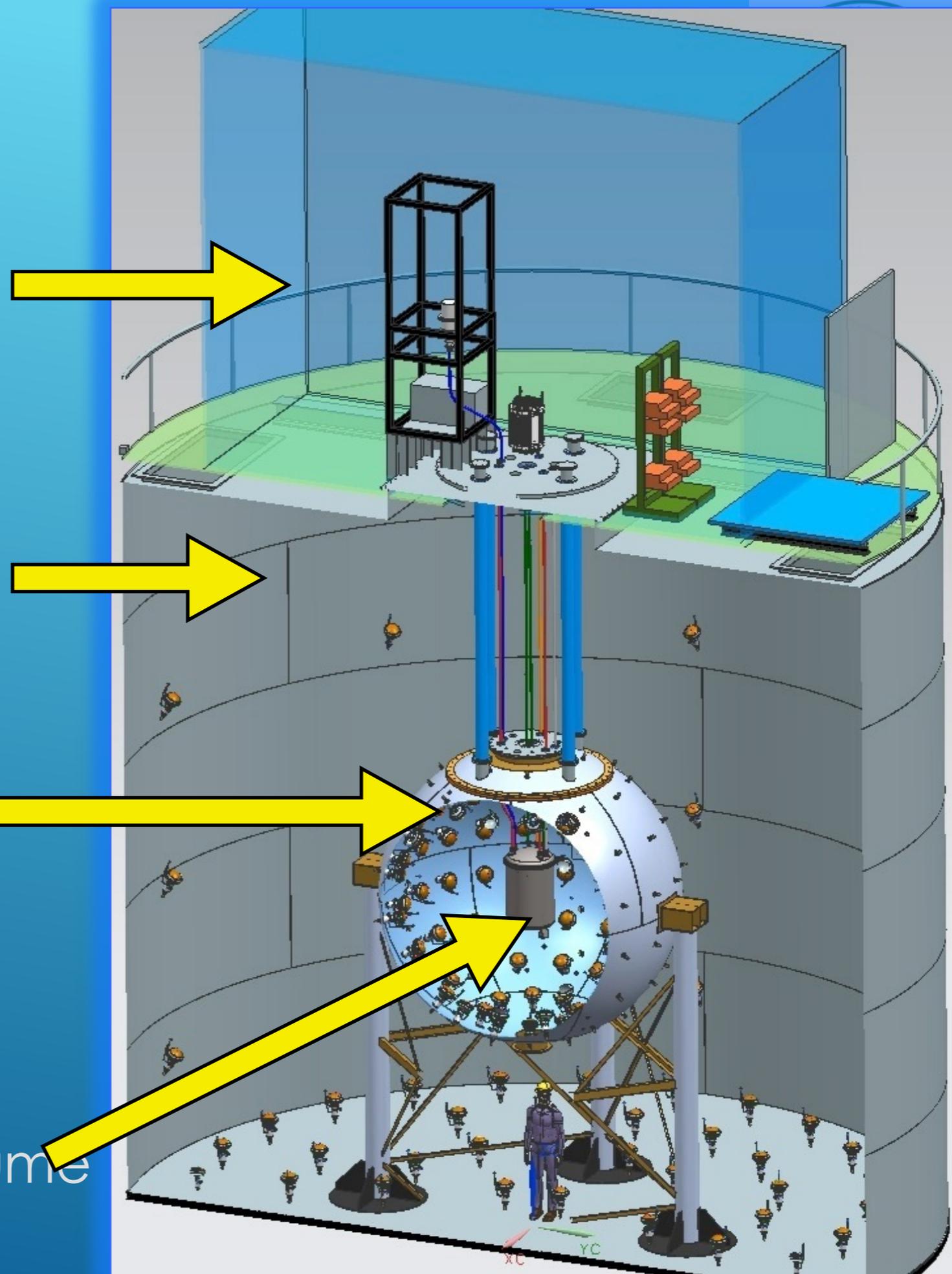
DARKSIDE-50

Radon-free clean room
Rn levels $< 10 \text{ mBq/m}^3$

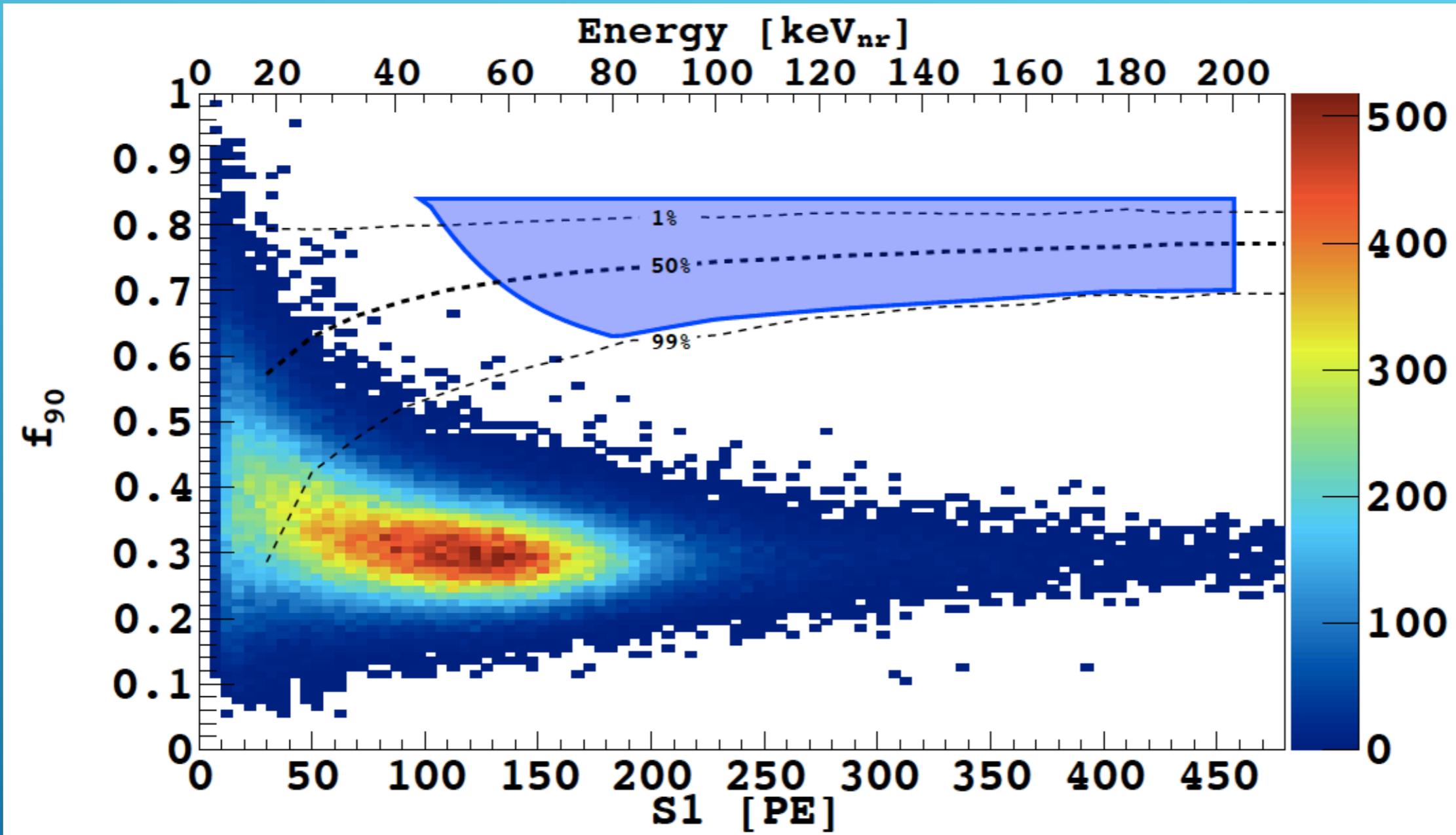
Muon veto – water
Cherenkov detector
(99% efficiency)
(1000 tons, 11 m high)

Liquid scintillator veto for
neutrons and gamma's
(30 tons, 4 m diameter)
Boron-loaded: PC + TMB

Inner detector TPC
(sensitive DM target volume
Filled with low ^{39}Ar)



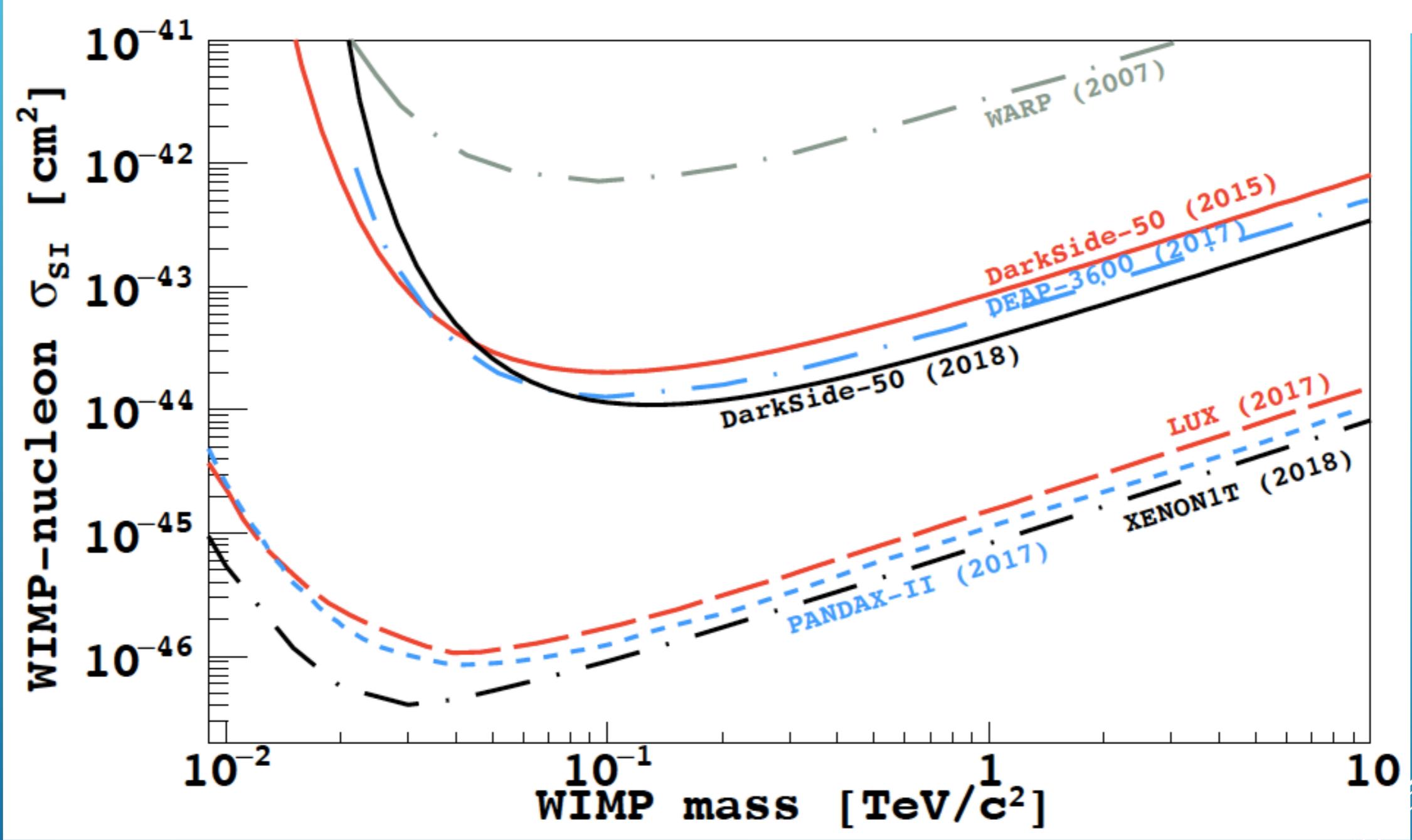
HIGH MASS WIMP SEARCH (> 10 GeV)



- ▶ 532 days data set search
- ▶ Blind analysis applied (blinded region defined on previous 70 day run)
- ▶ Background free (< 0.1 events in WIMP box over entire exposure)



HIGH MASS WIMP SENSITIVITY



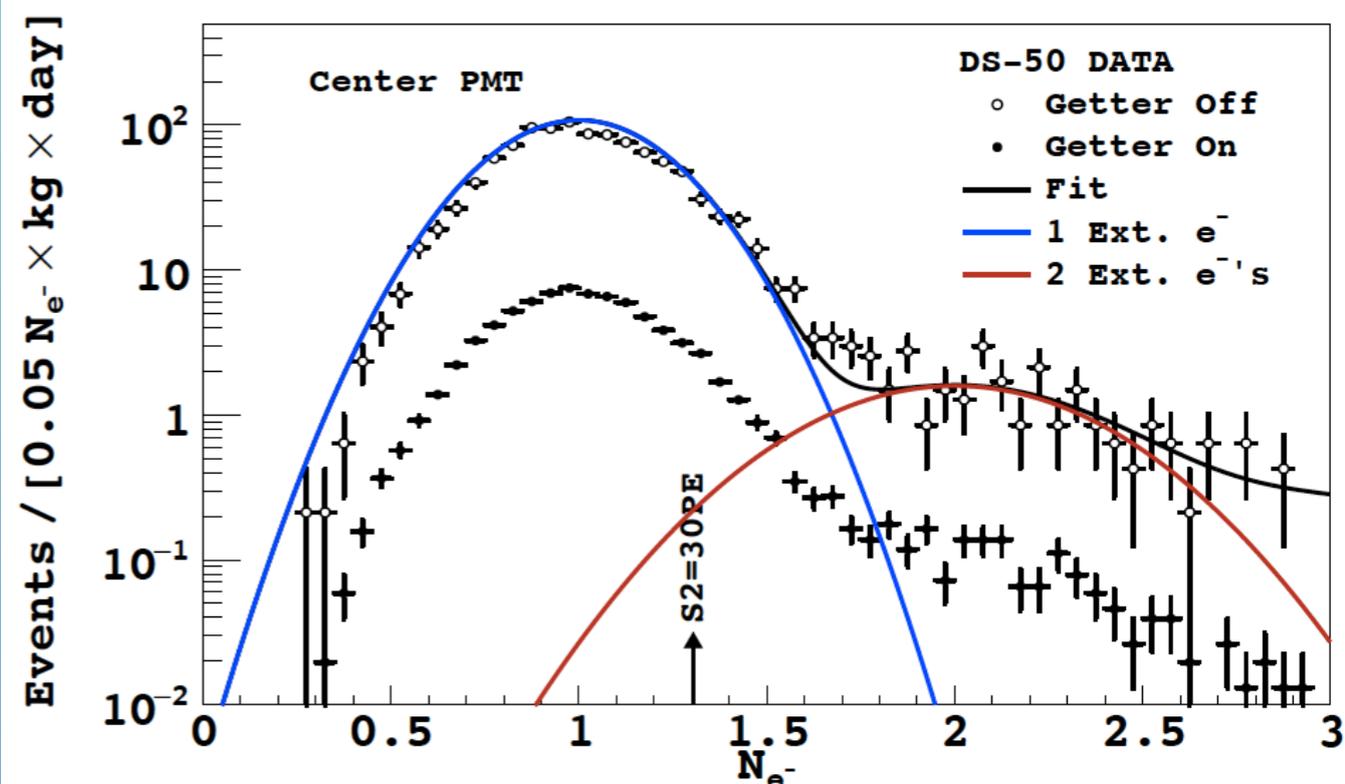
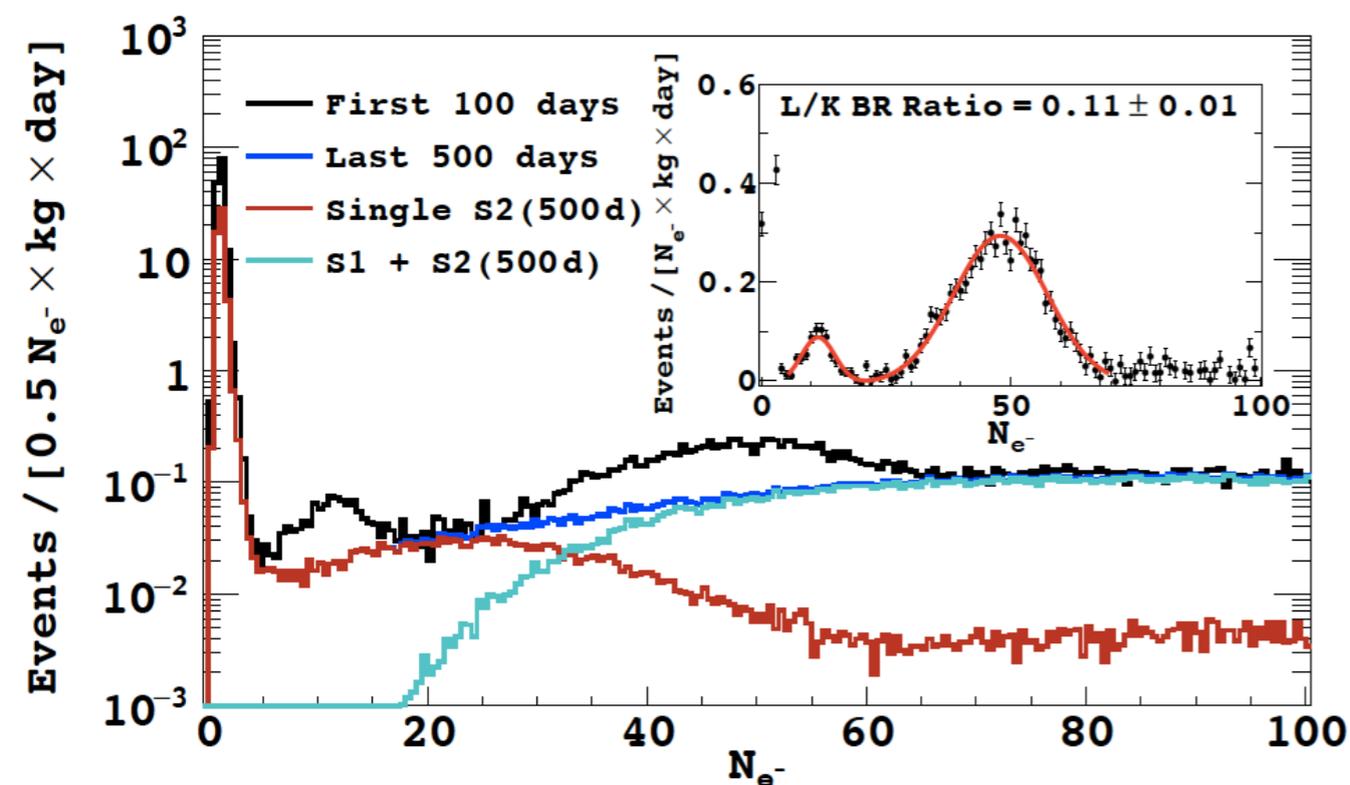
- ▶ 90% C.L. exclusion
- ▶ Excellent sensitivity to high mass WIMPs
- ▶ Background free (< 0.1 events in WIMP box over entire exposure)

TOWARD LOWER ENERGY THRESHOLD

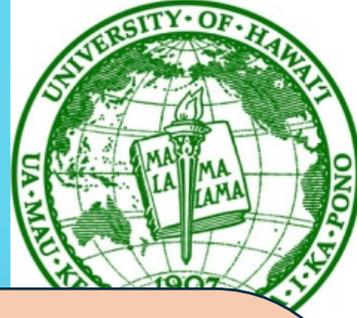


- ▶ S1 scintillation signal threshold at 2 keVee = 10 keVnr
- ▶ S2 ionization signal threshold at < 0.1 keVee = 0.4 keVnr
- ▶ → give up S1 → trigger on S2 → lower energy threshold, BUT no PSD and S2/S1
- ▶ Requires very low background level

- ▶ PMTs have negligible dark rate at 88 K
 - ▶ center PMT sees ~23 photoelectrons per electron
 - ▶ high trigger efficiency
 - ▶ single electron sensitivity

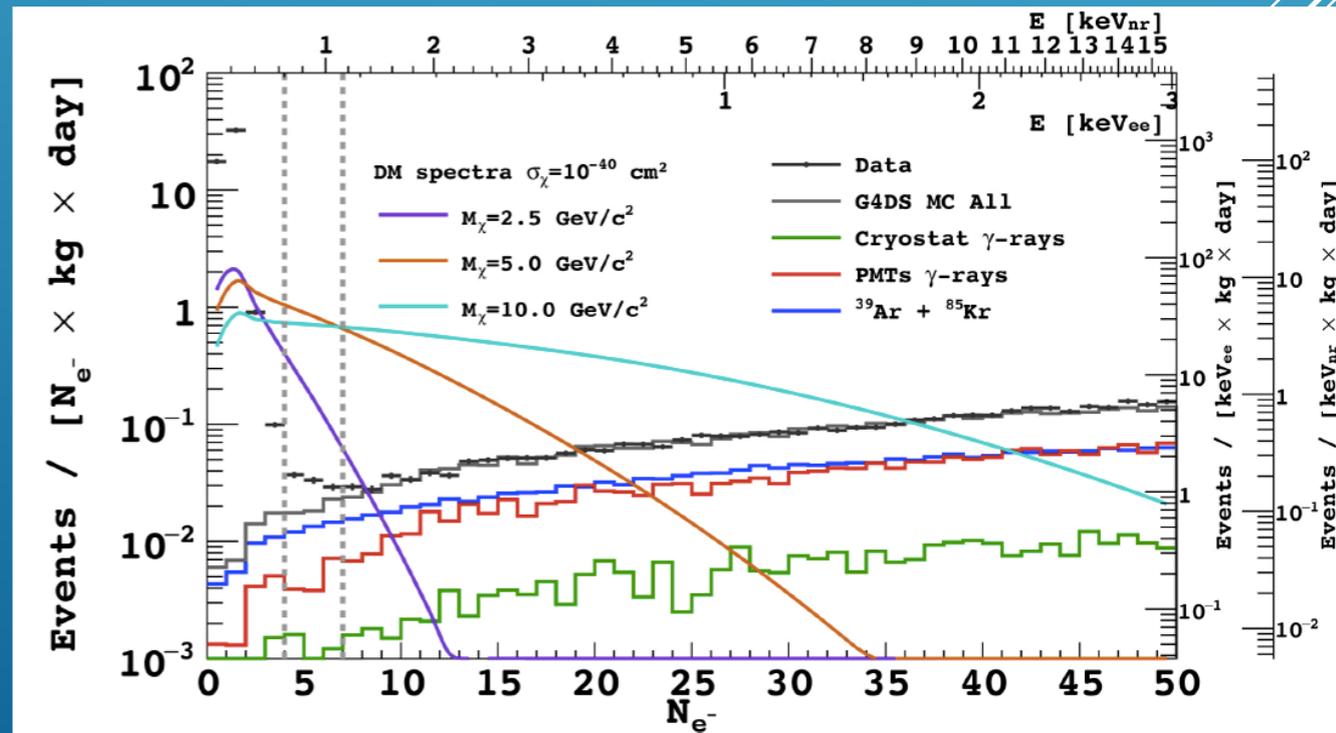
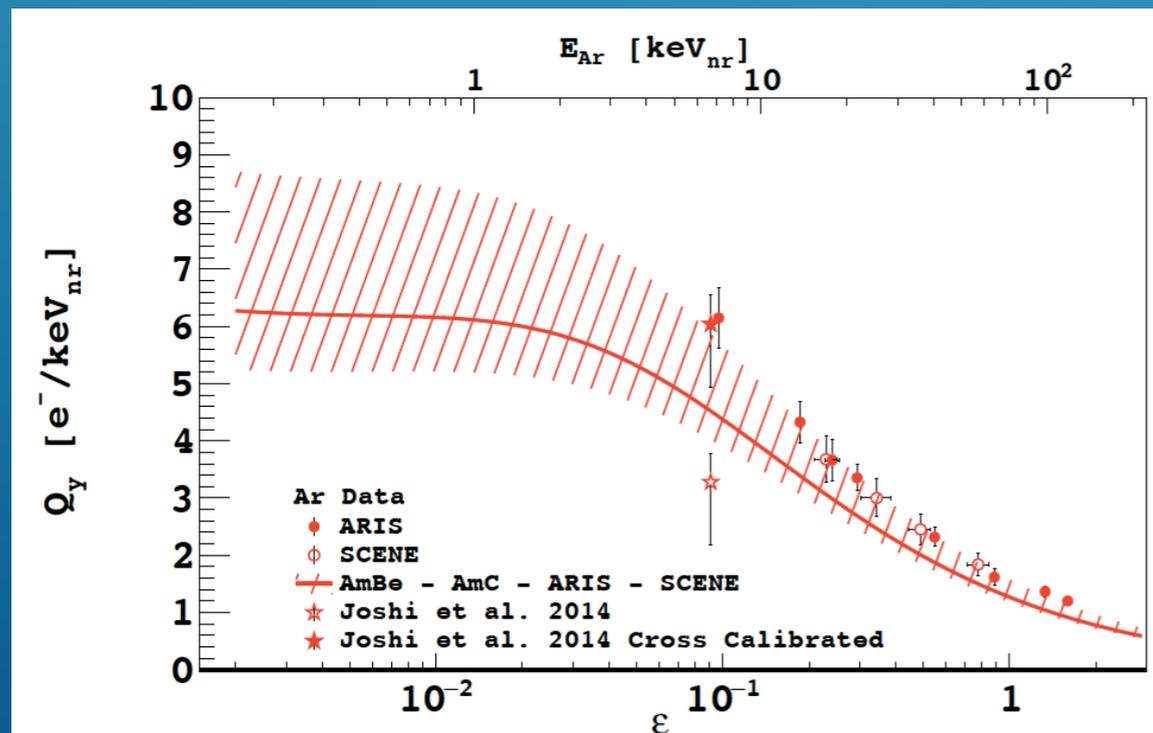


TOWARD LOWER ENERGY THRESHOLD

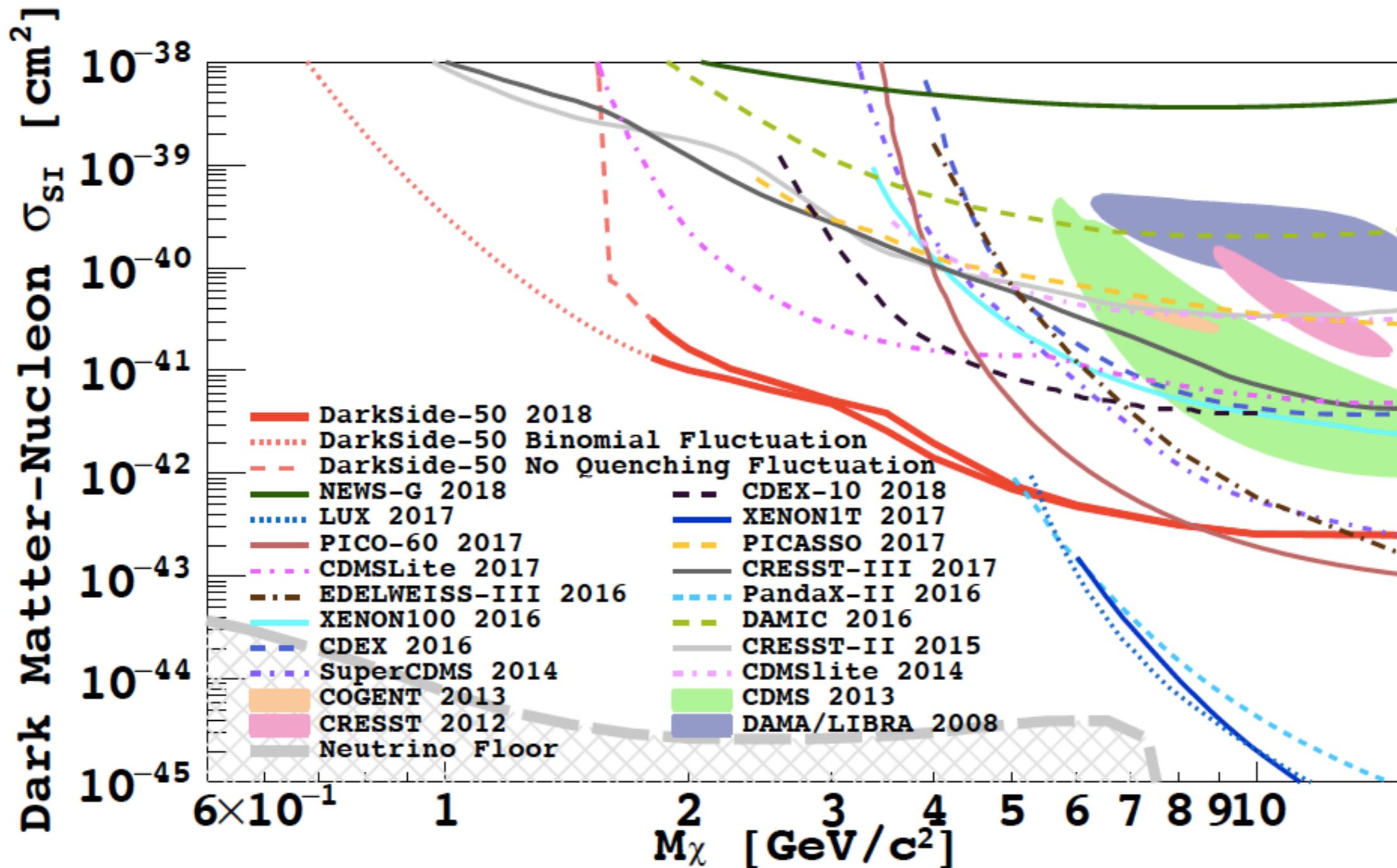


- ▶ Ionization yield from NR energy (Bezrukov model)
- ▶ Measured with DS-50 neutron calibrations (AmBe, AmC) and neutron beam experiments SCENE and ARIS (scintillation yield converted to ionization yield with DS-50 data)
- ▶ ReD experiment collecting data: sub-keV NR, directionality

- ▶ Background measured over a much wider energy range accounts for event rate well down to several electrons
- ▶ Expected signal assumes standard DM halo
- ▶ Uncertainties in signal dominated by fluctuations in ionization yield (width of ionization distribution in LAr unknown)

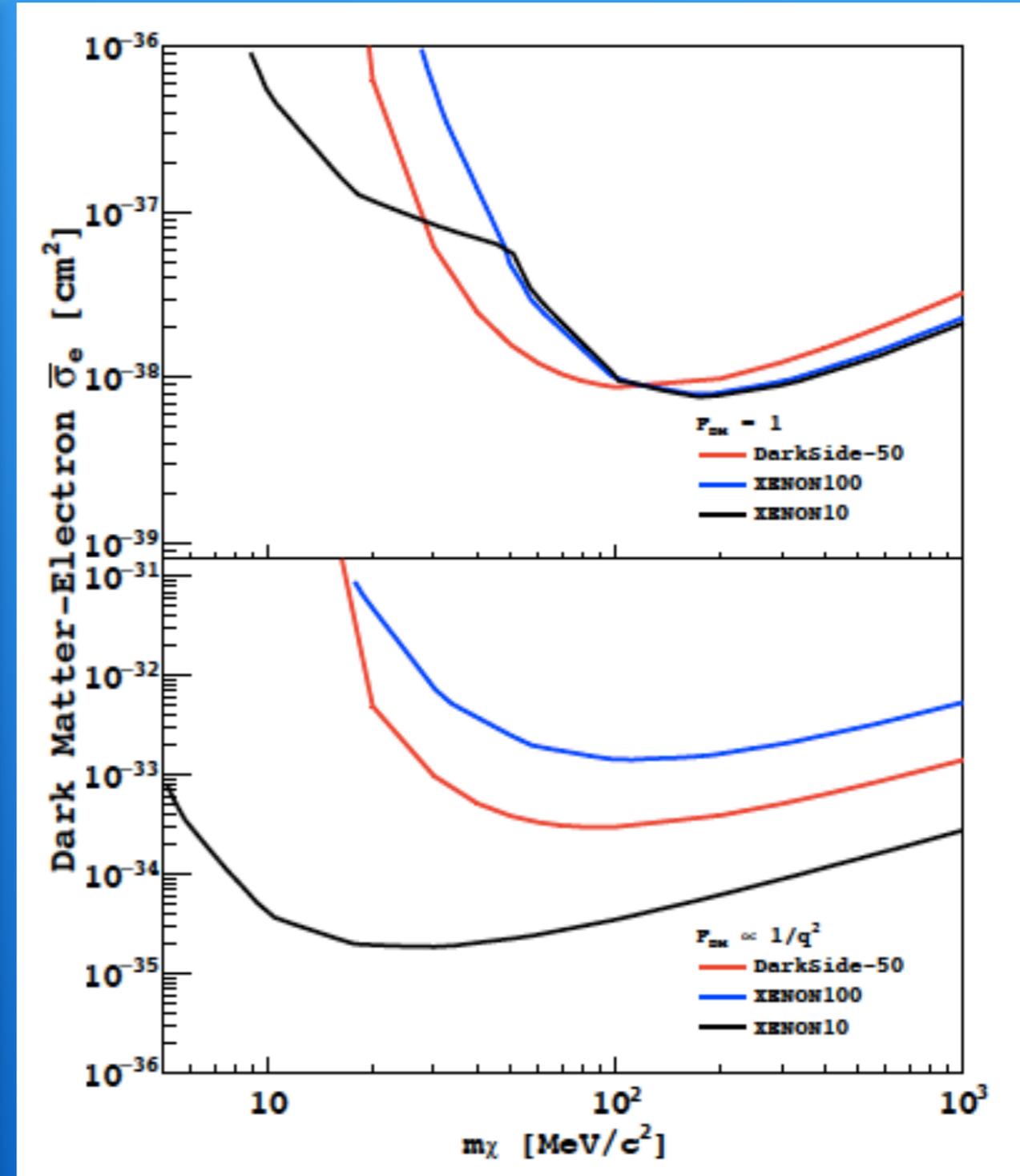
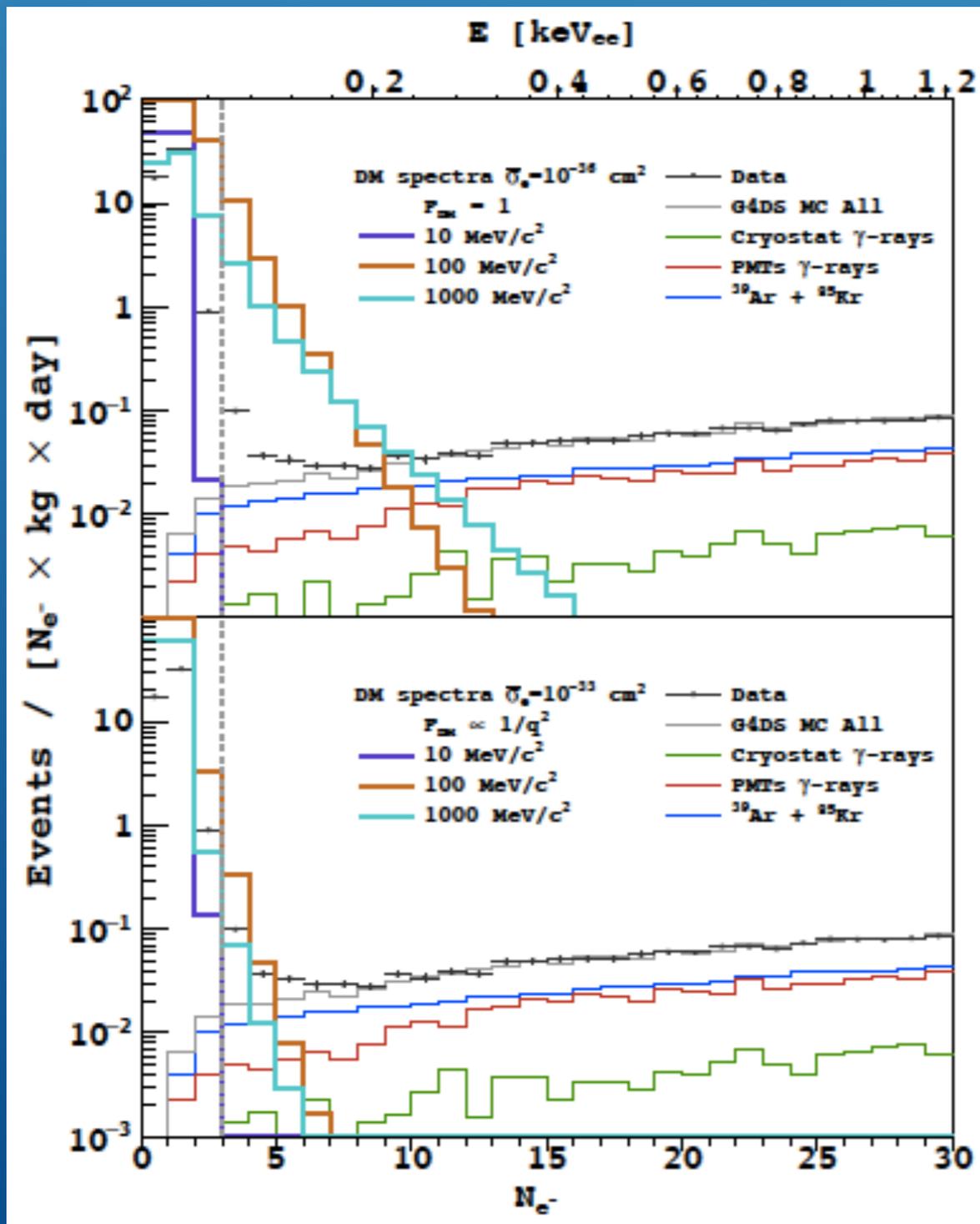


S2-ONLY SPIN-INDEPENDENT DM-NUCLEAR INTERACTION – 90% C.L.



- ▶ Two cases: no quenching fluctuations and binomially distributed fluctuations

SUB-GeV DM-ELECTRON SCATTERING



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

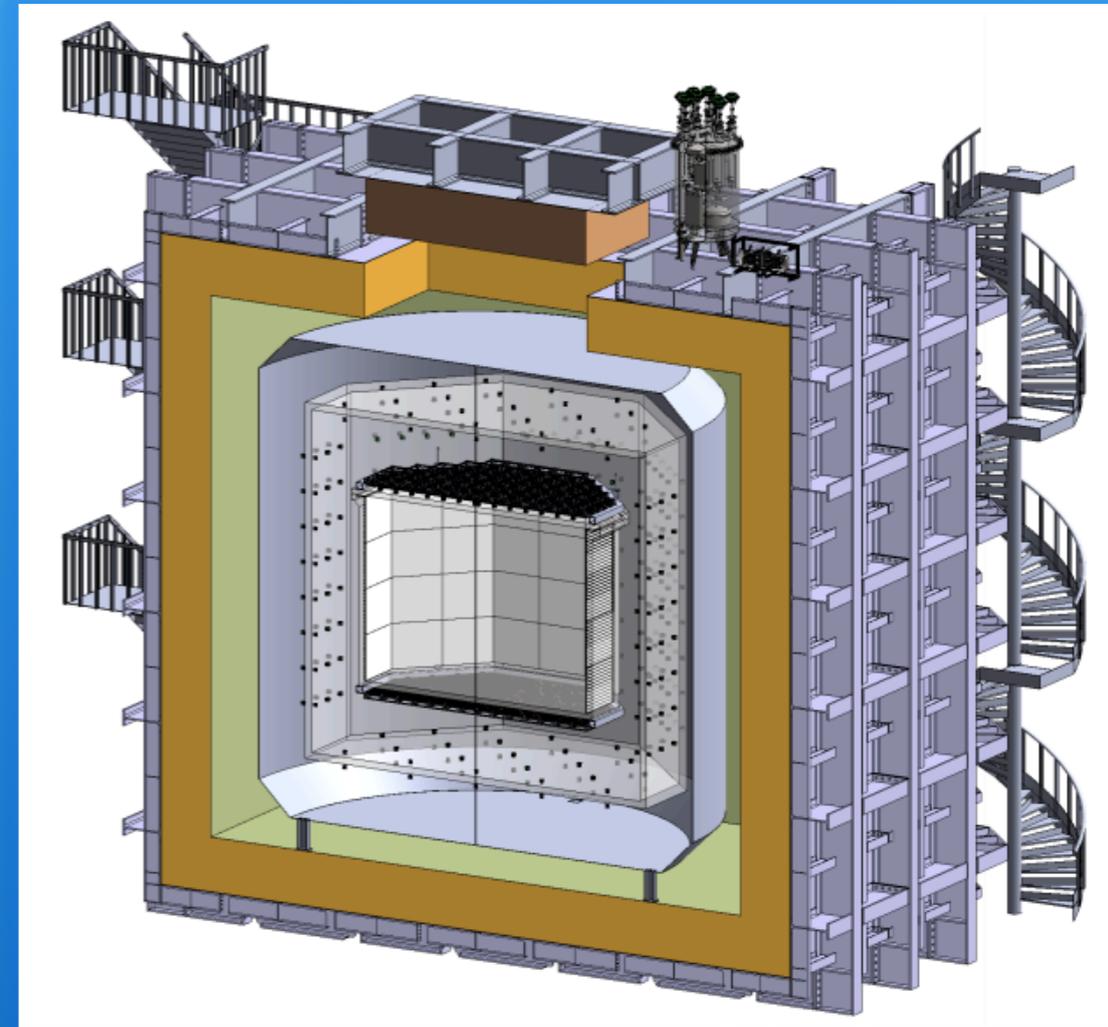
DS-20K DESIGN

DarkSide-20k at Gran Sasso

- 39-tonne LAr dual-phase TPC
- 32 tonnes fiducial
- Depleted liquid argon fill
- 20 m² of SiPM scintillation detecting surface on top and bottom
- background-free: < 0.1 'instrumental' background event in 100 tonne-year exposure

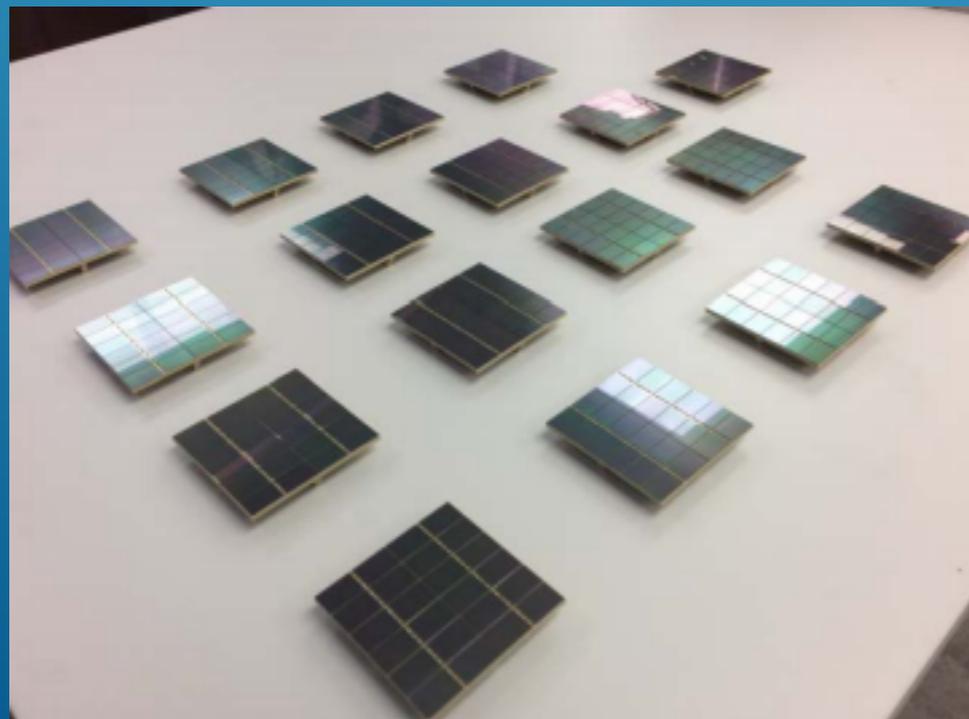
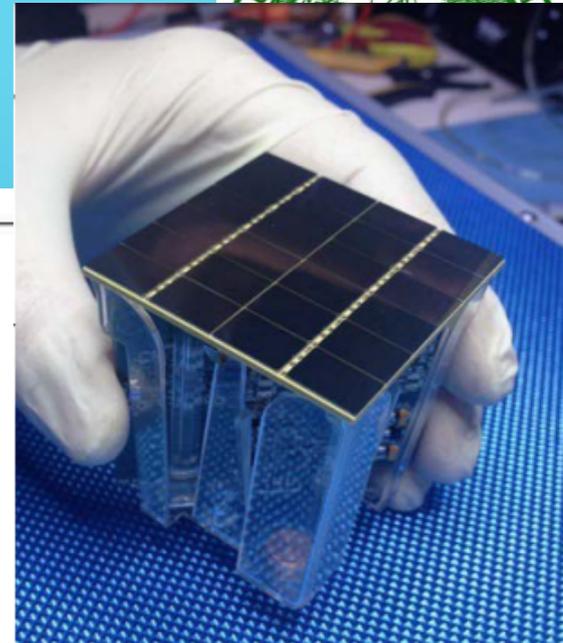
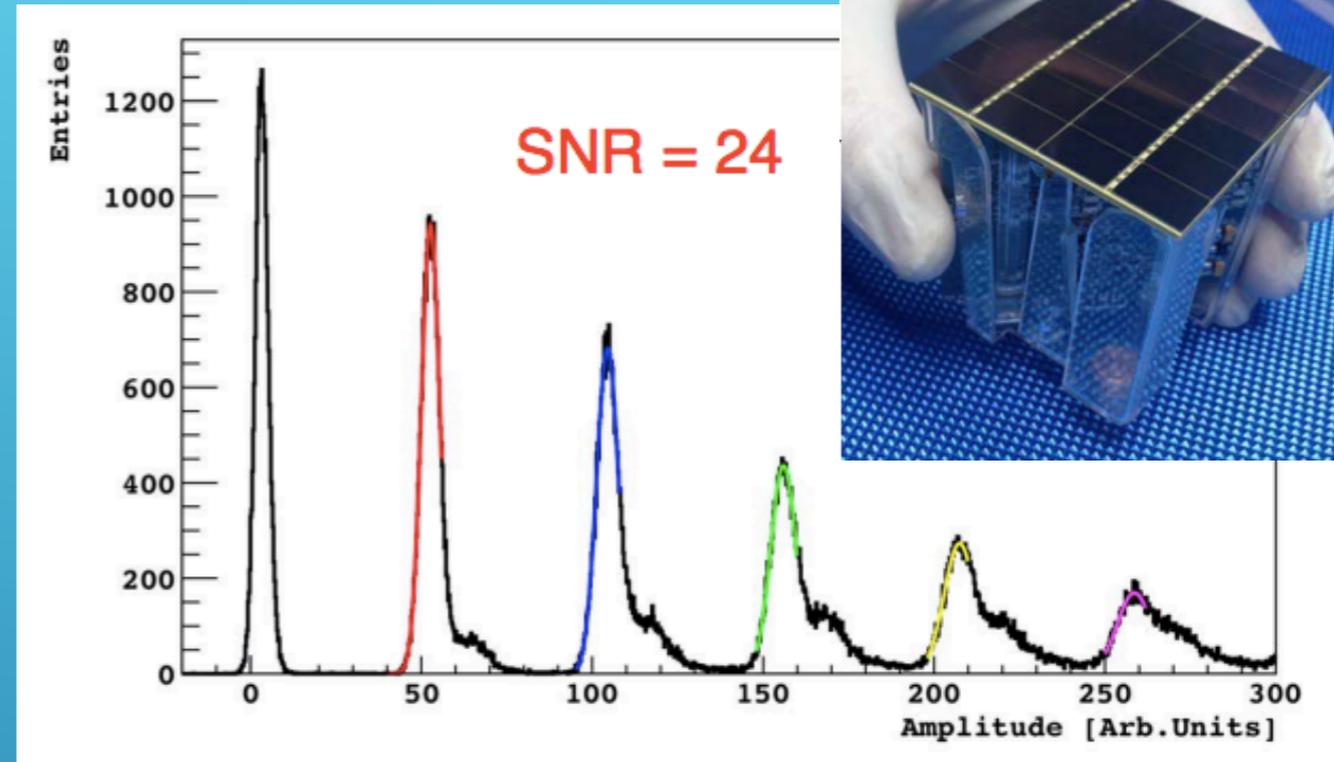
GADMC

- merger of all existing LAr dark matter experiments

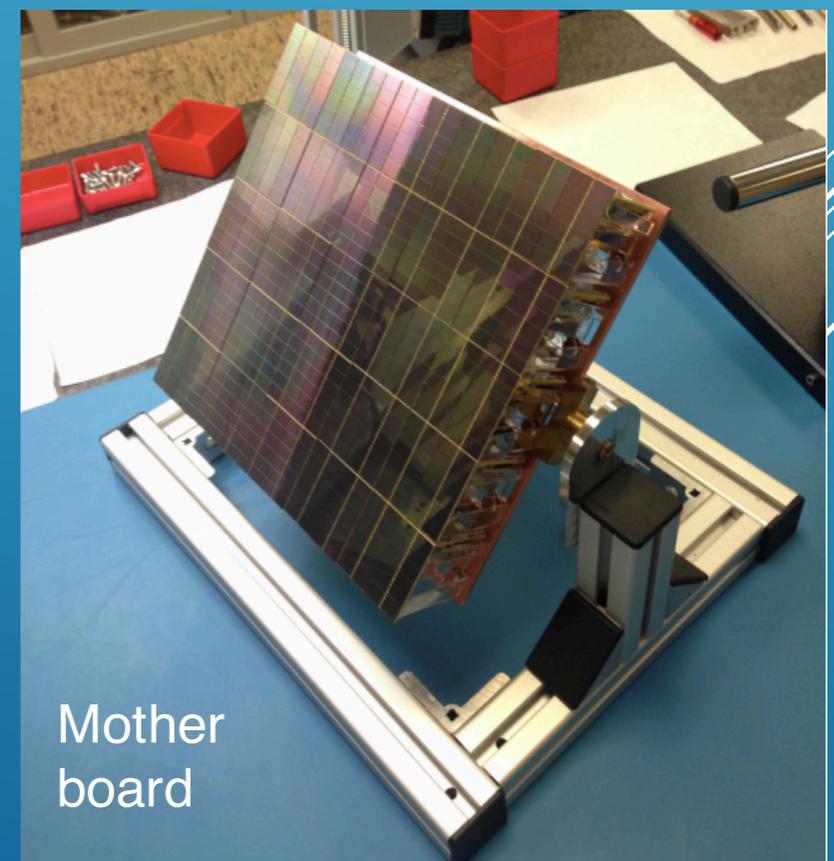


NEW PHOTODIODES – SIPMs – PMTs no more

- 5×5 cm² single-channel modules (array of 24 SiPMs)
- < 10 ns timing resolution
- PDE > 40%
- Gain > 10⁶
- 250 Hz dark rate + correlated noise (cryogenic electronics)
- Compact and radio-clean



50 modules under way
400 will follow in 2019



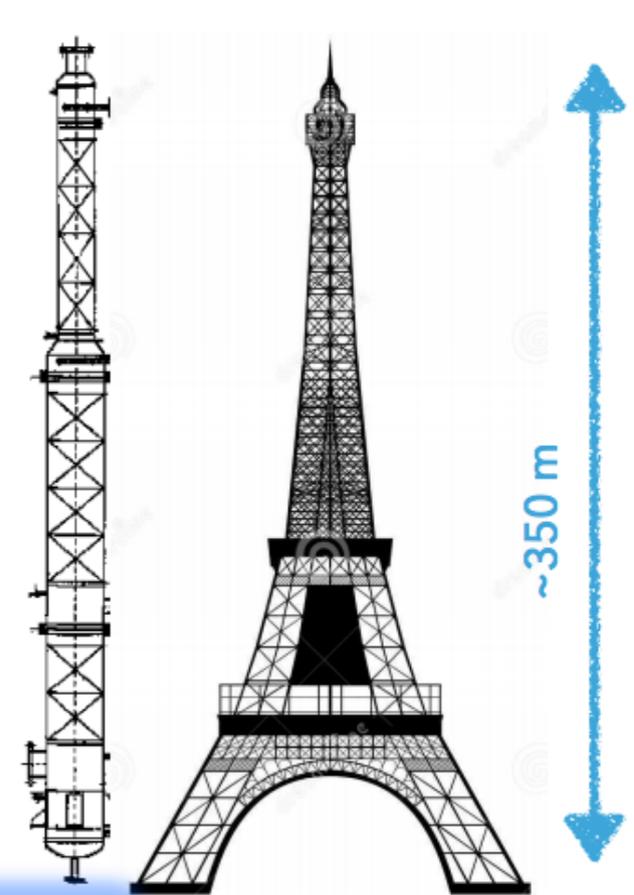
LOW RADIOACTIVITY ARGON – PROCUREMENT AND PURIFICATION

Urania plant

- extraction plant in Cortez, Colorado
- 250 kg/day UAr production (compare to 153 kg/6 years for DS-50)

Aria plant

- Distillation plant in Seruci, Sardinia
- production of depleted argon DAr with 0.01 content of ^{39}Ar compared to UAr
- removal of impurities such as Kr
- isotopic cryogenic distillation: utilizes tiny difference in the volatility of ^{39}Ar and ^{40}Ar
- two 350 m tall distillation columns under construction in Sardinia: Seruci I (30 cm diameter column) and Seruci II (1.5 m diameter column) with 10 depletion factor



Seruci 0
- prototype
column

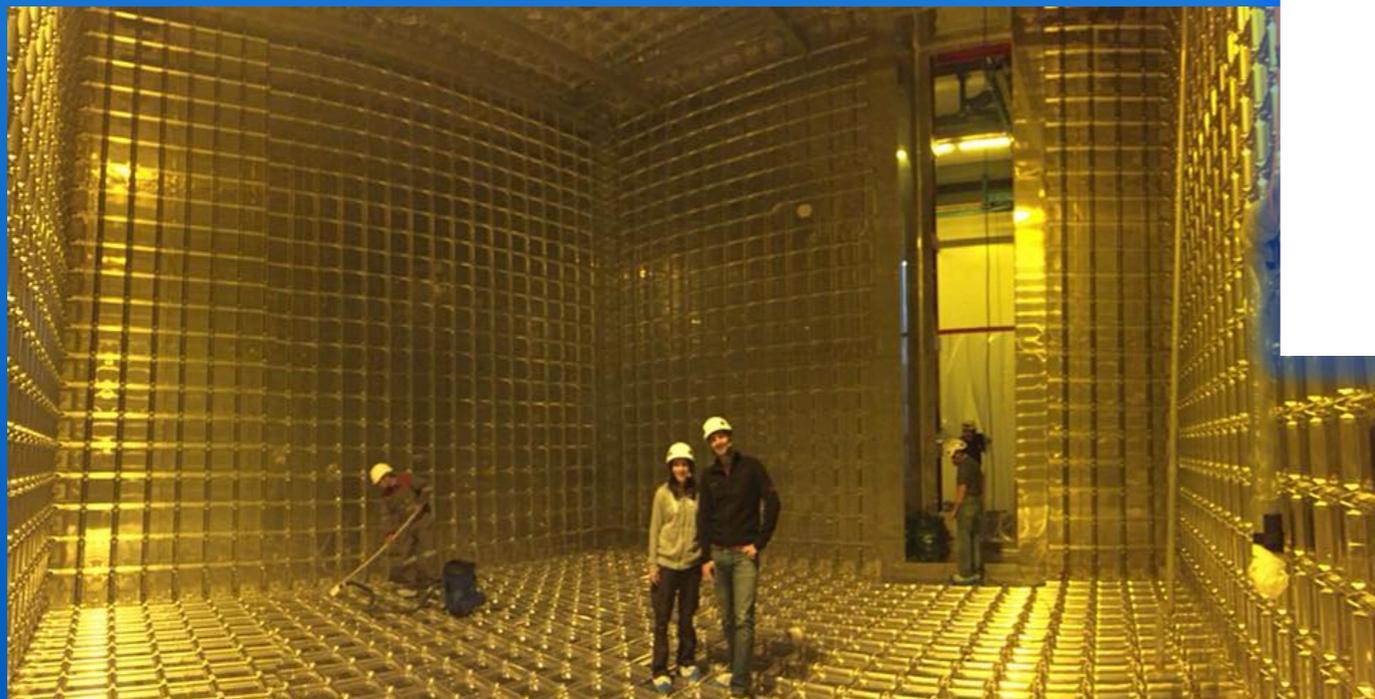
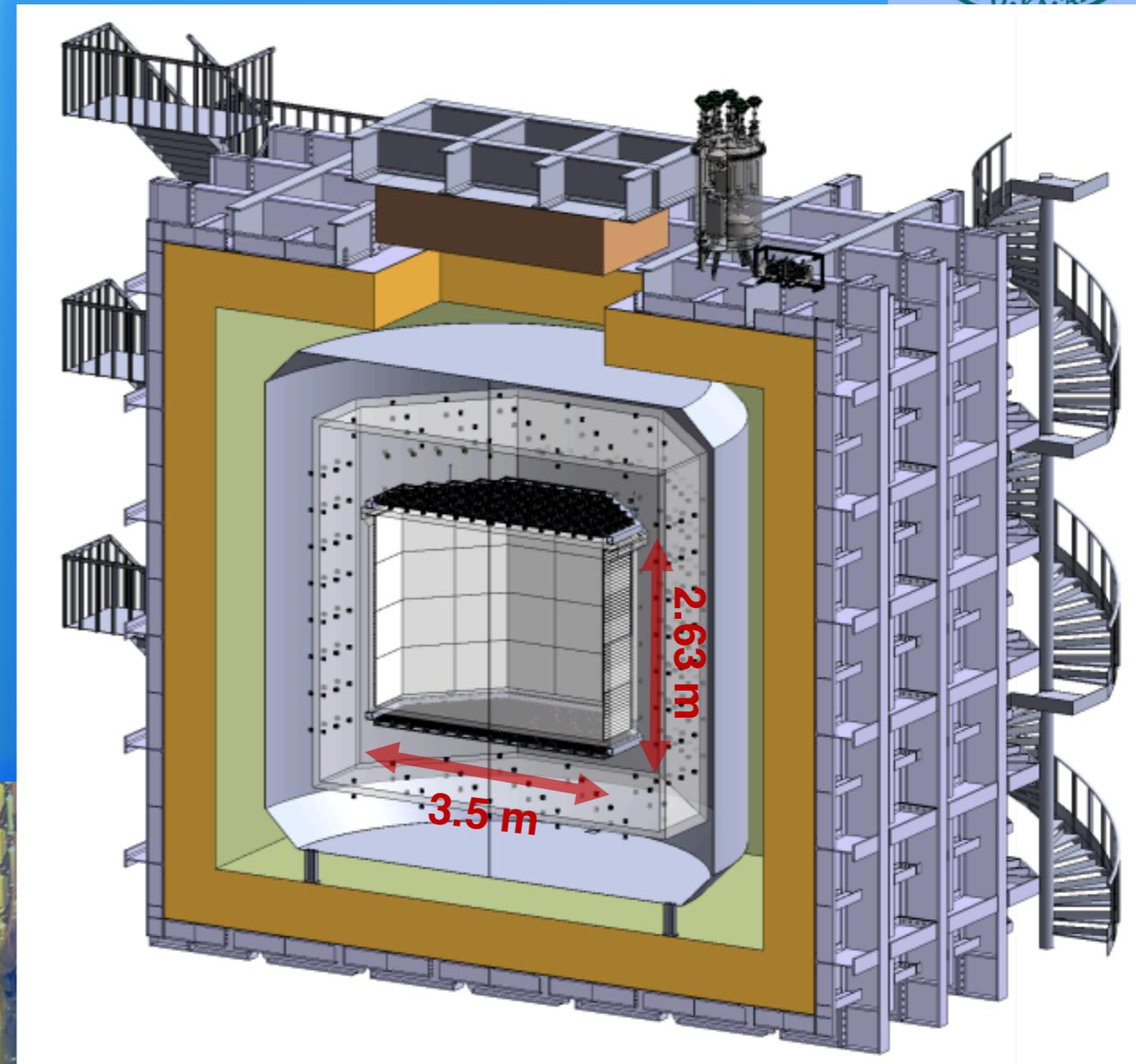
PROTODUNE CRYOSTAT + VETO AND TPC DESIGN



ProtoDUNE cryostat → no double cryostat → radioactivity reduction

Gd loaded Poly(methyl methacrylate) PMMA shell veto detector

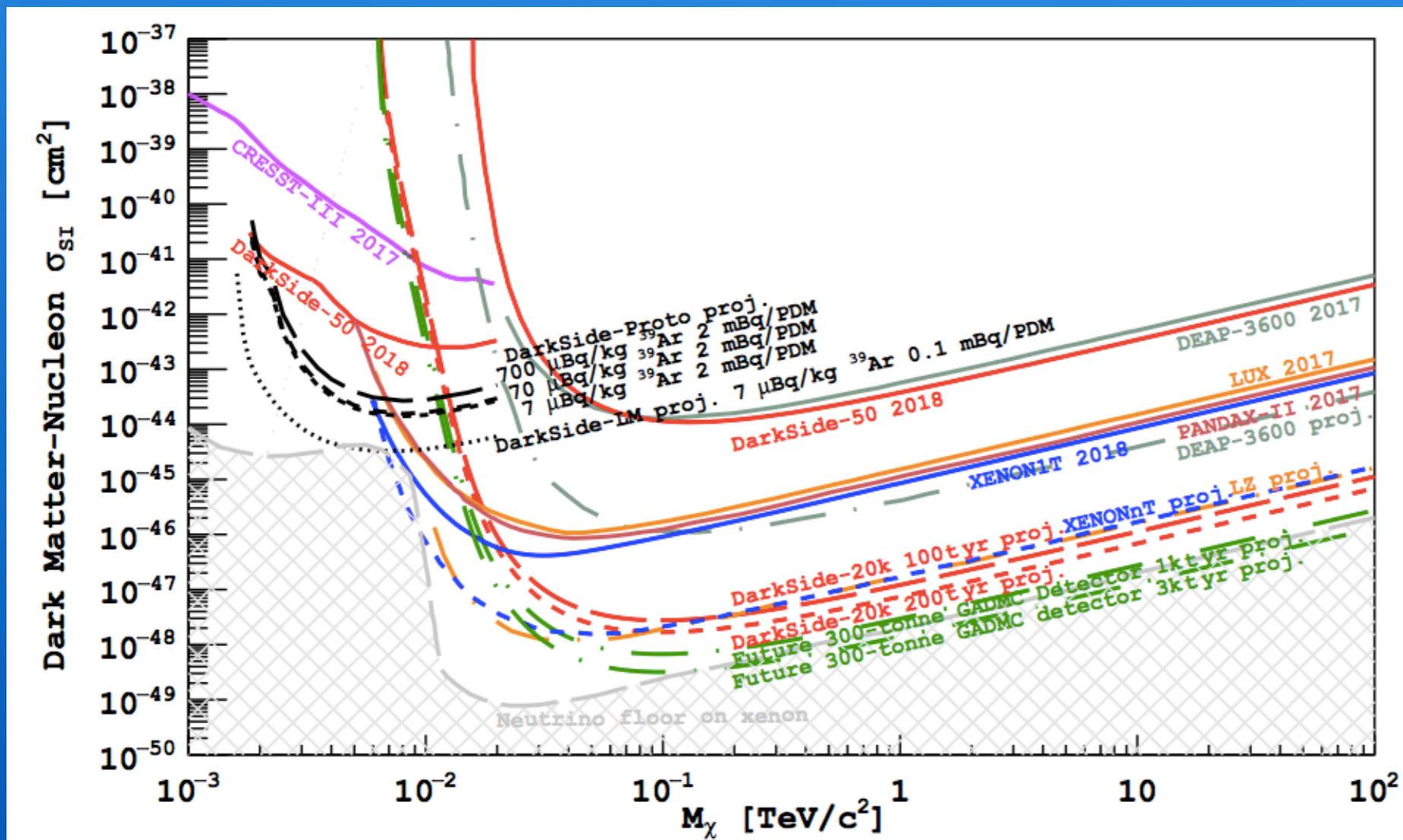
PMMA ultra pure TPC (PMMA used in DEAP-3600), no need for stainless steel cryostat



SUMMARY AND OUTLOOK



- DS-50 demonstrated excellent performance and proven technology for wide range WIMP masses:
 - best sensitivity for 1.8 – 5.5 GeV
 - background-free for > 10 GeV
- Ambitious dark matter search program with the Global Argon Collaboration
 - DarkSide-20k at LNGS (bg-free 100 tonne-year exposure)
 - Future massive detector \sim ktonne-year exposure (possibility of neutrino physics)
 - DarkSide-LM – low mass DM search with DarkSide-Proto



DarkSide offers program of discovery complementary to LHC.



THE END

