LArTPC and Dark Matter

Cristiano Galbiati
Princeton University
Gran Sasso Science Institute
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Module of Opportunity for DUNE Workshop
Brookhaven National Laboratory
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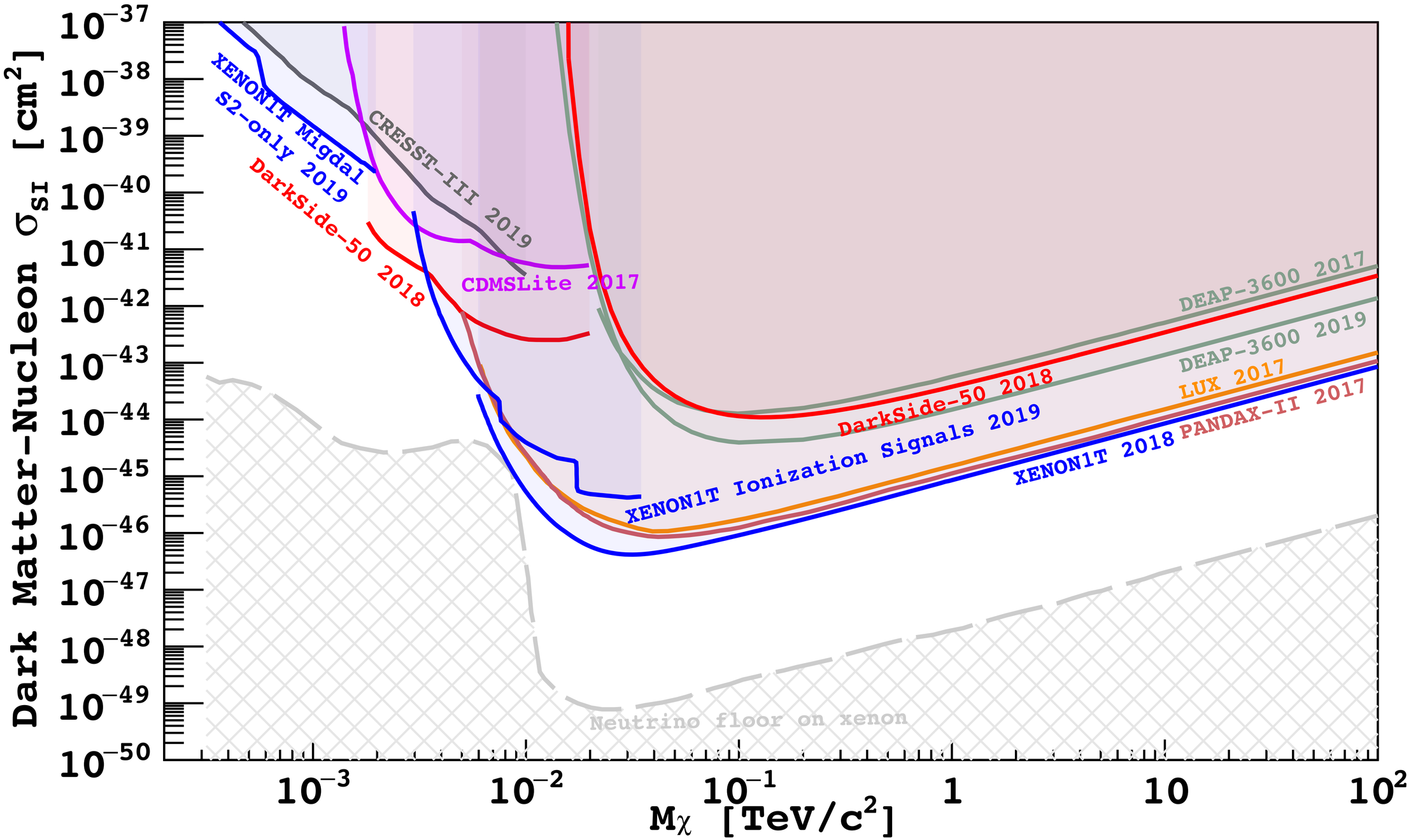

Dark Matter-Nucleon σ_{SI} [cm^2]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-3}
10^{-2}
10^{-1}
1
10
10^{2}
M_χ [TeV/c^2]
XENON1T Migdal
S2-only 2019
DarkSide-50 2018
CRESST-III 2019
CDMSLite 2017
DEAP-3600 2017
DEAP-3600 2019
LUX 2017
DarkSide-50 2018
PANDAX-II 2017
XENON1T Ionization Signals 2019
XENON1T 2018
Neutrino floor on xenon

DarkSide-20k at LNGS

20-tonnes fiducial dark matter detector

start of operations at LNGS within 2023

200 tonne×year search for dark matter free of instrumental background

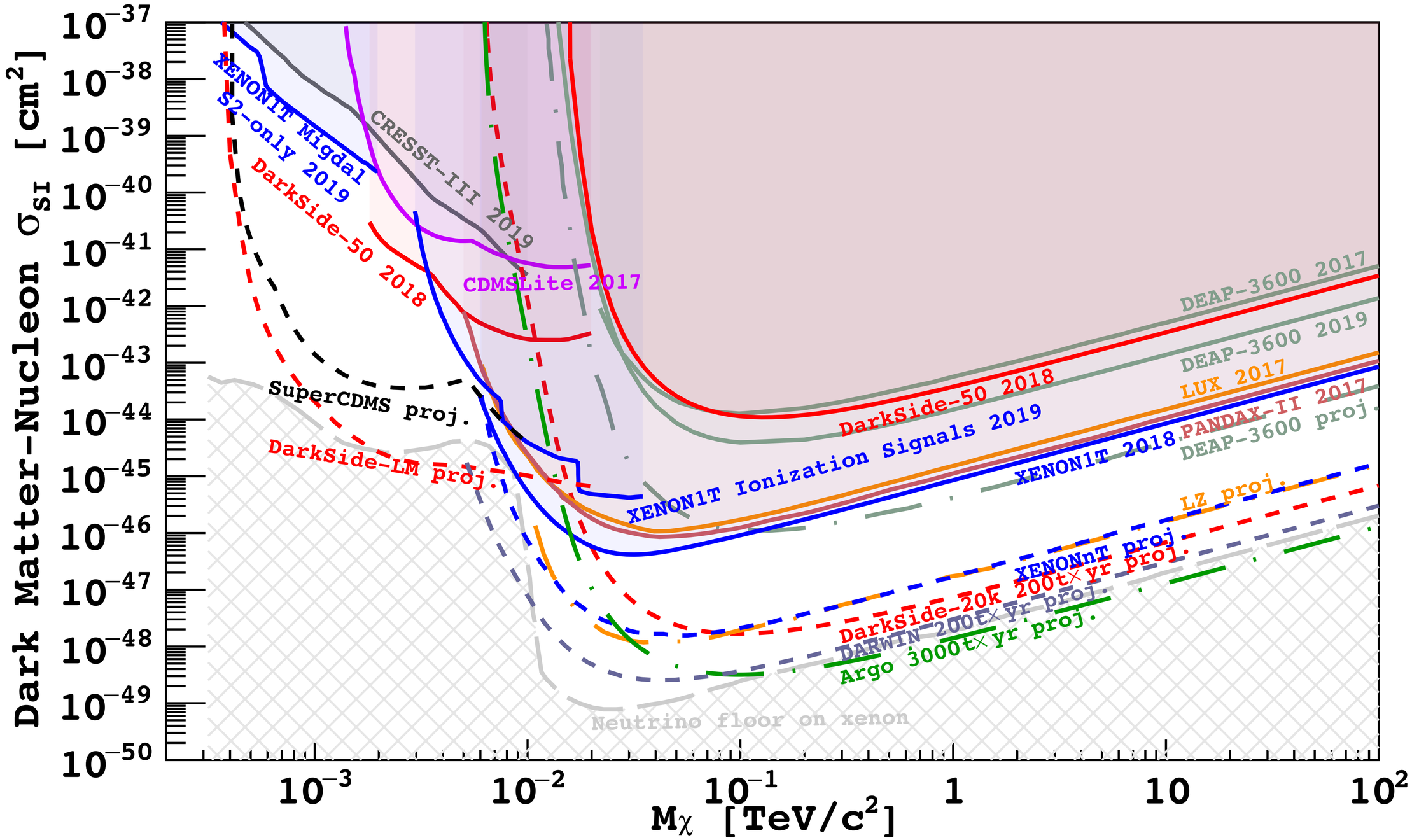
Argo at SNOLAB

300-tonnes depleted argon detector

start of operations within 2030

3,000 tonne×year search for dark matter free of instrumental background

precision measurement of solar neutrinos


Dark Matter-Nucleon σ_{SI} [cm^2]
M_χ [TeV/c^2]
XENON1T Migdal
S2-only 2019
DarkSide-50 2018
CRESST-III 2019
CDMSLite 2017
SuperCDMS proj.
DarkSide-LM proj.
DEAP-3600 2017
DEAP-3600 2019
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
DarkSide-50 2018
XENON1T Ionization Signals 2019
XENON1T 2018
LZ proj.
XENONnT proj.
DarkSide-20k 200t×yr proj.
DARWIN 200t×yr proj.
Argo 3000t×yr proj.
Neutrino floor on xenon

THE GADMC PROGRAM FOR DARK MATTER SEARCHES

- Explore heavy dark matter through the neutrino floor and beyond
  - Zero instrumental background
    - Exposure of O(1000 tonne × year)
    - Solar neutrinos become background: rejection of minimum ionizing background must reach at least one part in 10^5
  - Exploration of directional signal

TECHNOLOGICAL ENABLERS

- Custom SiPM-based cryogenic photodetectors
- Custom ^{39}Ar-depleted liquid argon
- ProtoDUNE-like cryostat for hosting detector and active veto

LZ backgrounds summary

5.6 tonnes, 1000 days

Intrinsic Contamination Backgrounds	ER (cts)	NR (cts) (w/ SF rej.)
Subtotal (Detector Components)	**9**	**0.072**
222Rn (1.81 μBq/kg)	681	-
220Rn (0.09 μBq/kg)	111	-
natKr (0.015 ppt g/g)	25	-
natAr (0.45 ppb g/g)	2	-
210Bi (0.1 μBq/kg)	40	-
Laboratory and Cosmogenics	5	0.06
Fixed Surface Contamination	0	0.39
Subtotal (Non-ν counts)	**873**	**0.52**
Physics Backgrounds		
136Xe 2νββ	67	0
Astrophysical ν counts (pp+7Be+13N)	255	0
Astrophysical ν counts (8B)	0	0**
Astrophysical ν counts (Hep)	0	0.21
Astrophysical ν counts (diffuse	0	0.05
Astrophysical ν counts (atmospheric)	0	0.46
Subtotal (Physics backgrounds)	322	0.72
Total	1,190	1.24
Total (with 99.5% ER discrimination,	5.97	0.62
	6.59	

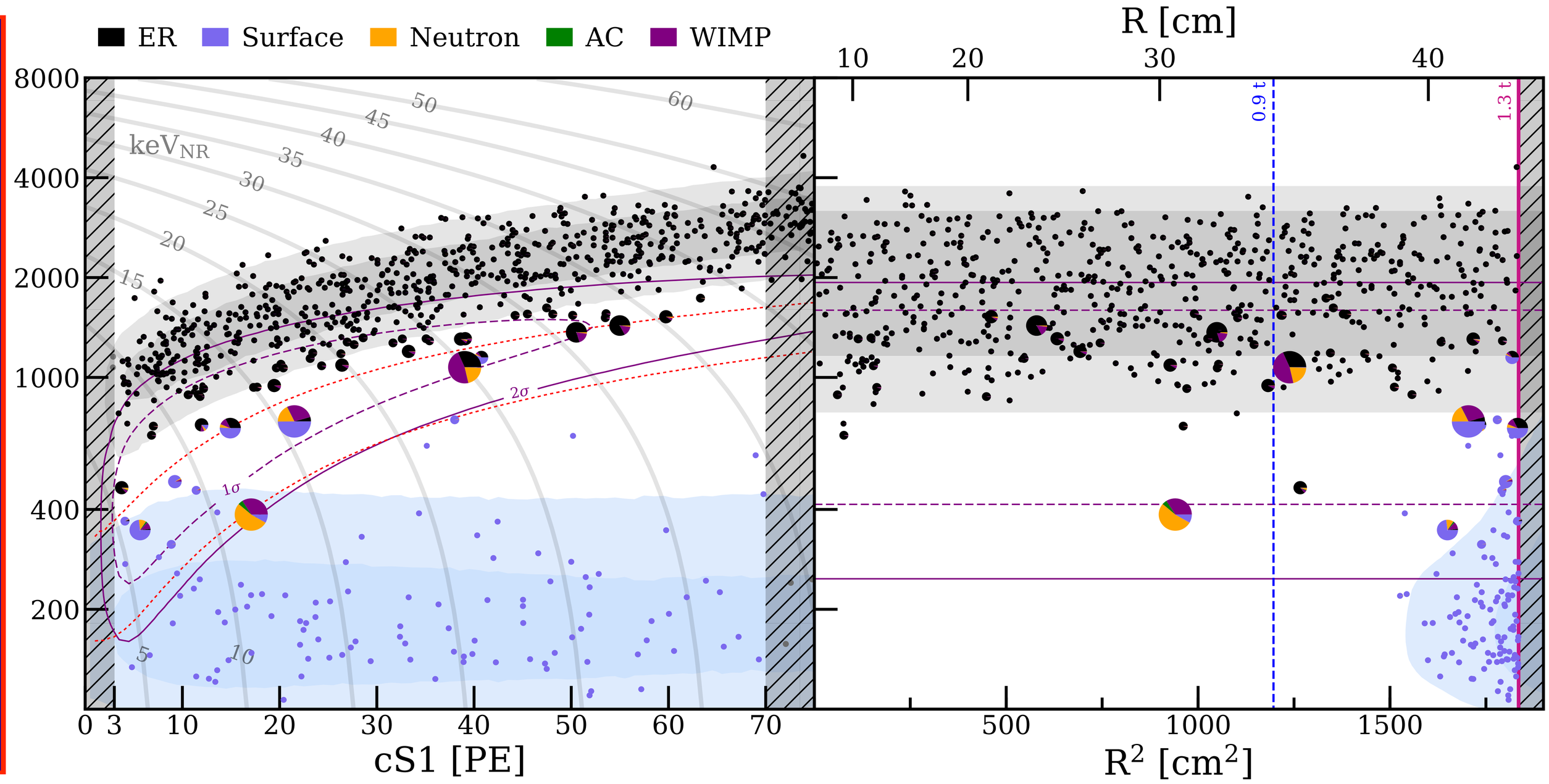
Radon dominates ER backgrounds

Gamma backgrounds (PMTs, cryostat) are negligible.

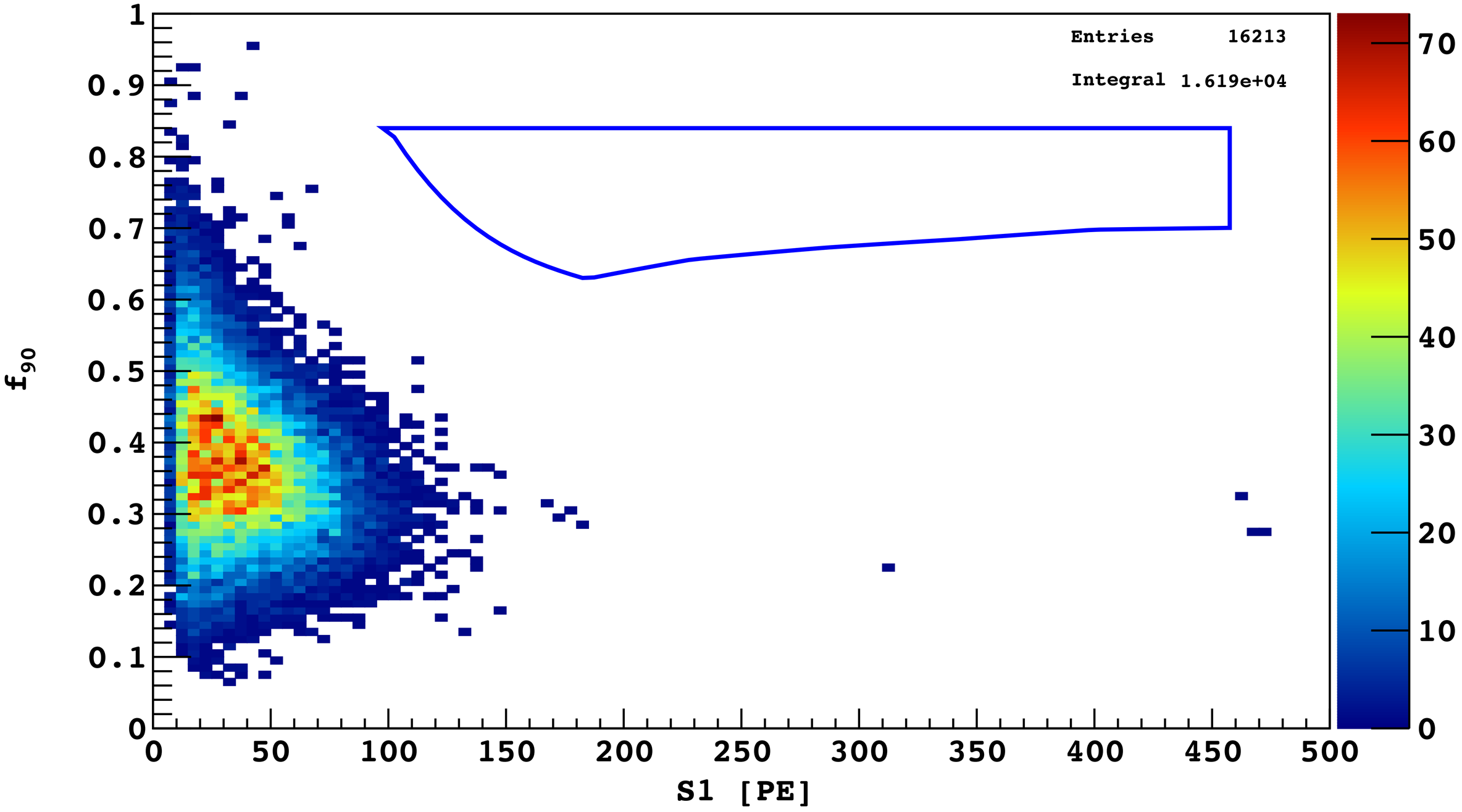
pp solar neutrinos, elastic scattering on atomic electrons

Coherent neutrino scattering on xenon nuclei

Physical Review Letters 121, 111302 (2018)

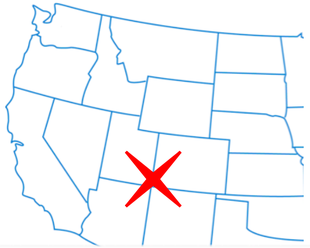


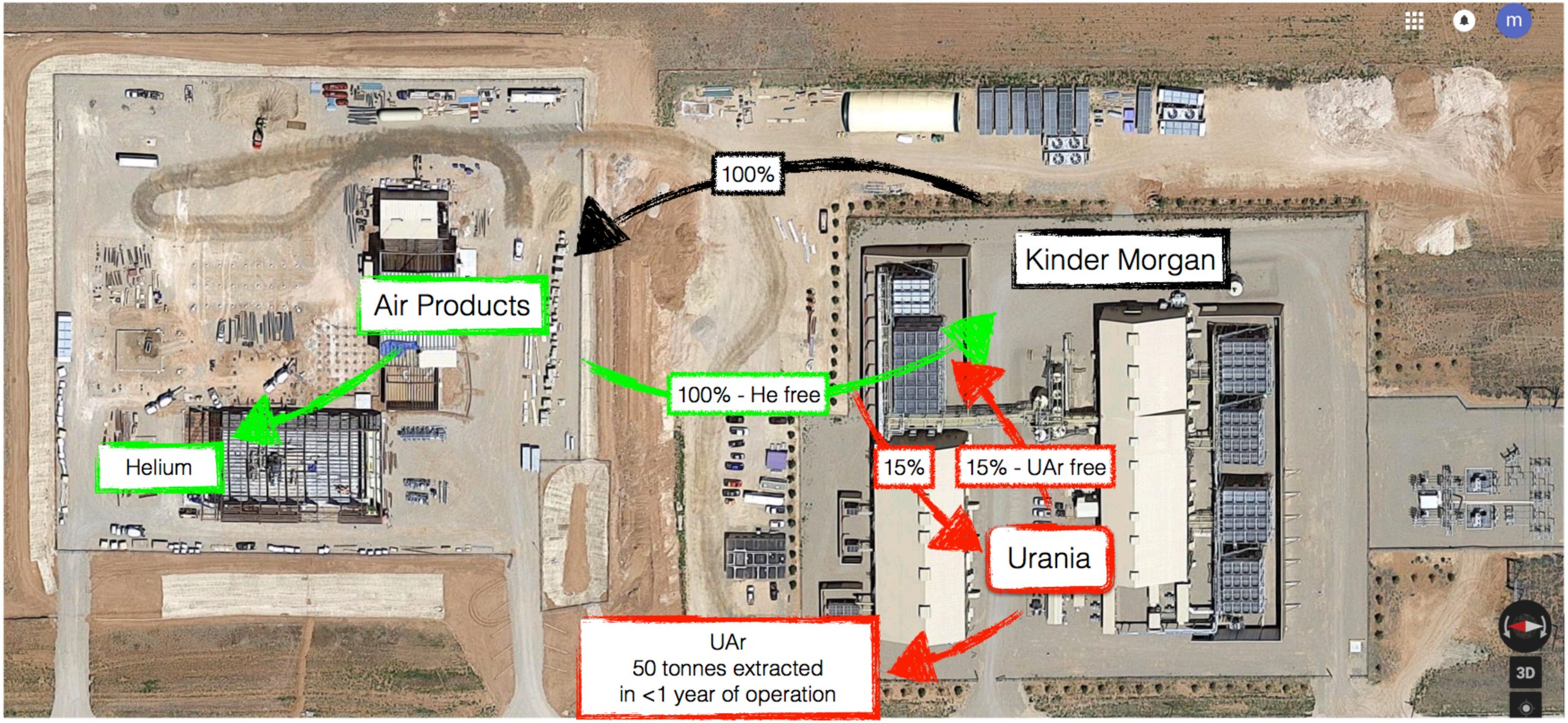
+r<10 cm && 50% loss S2/S1 cut (70d)

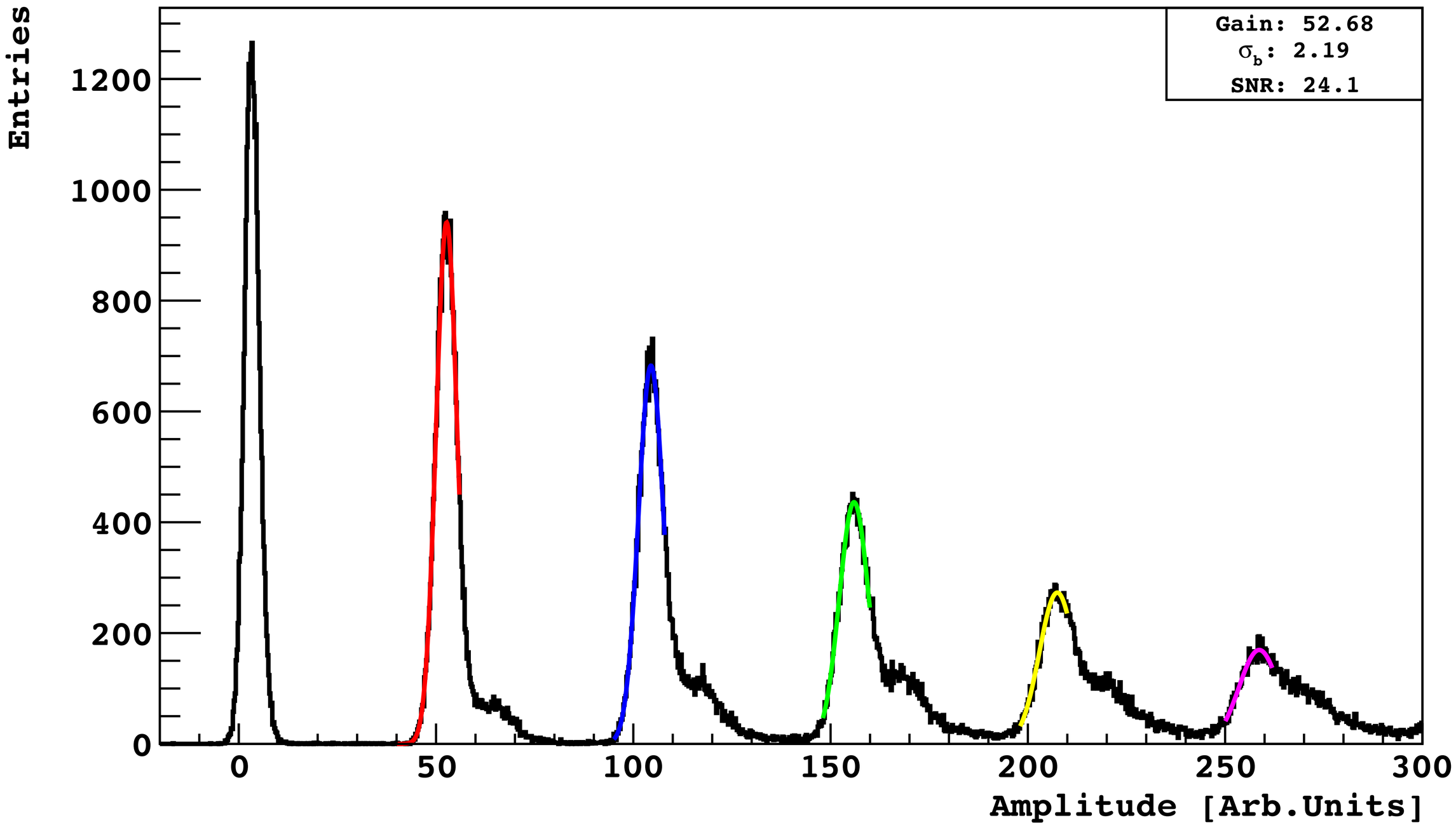


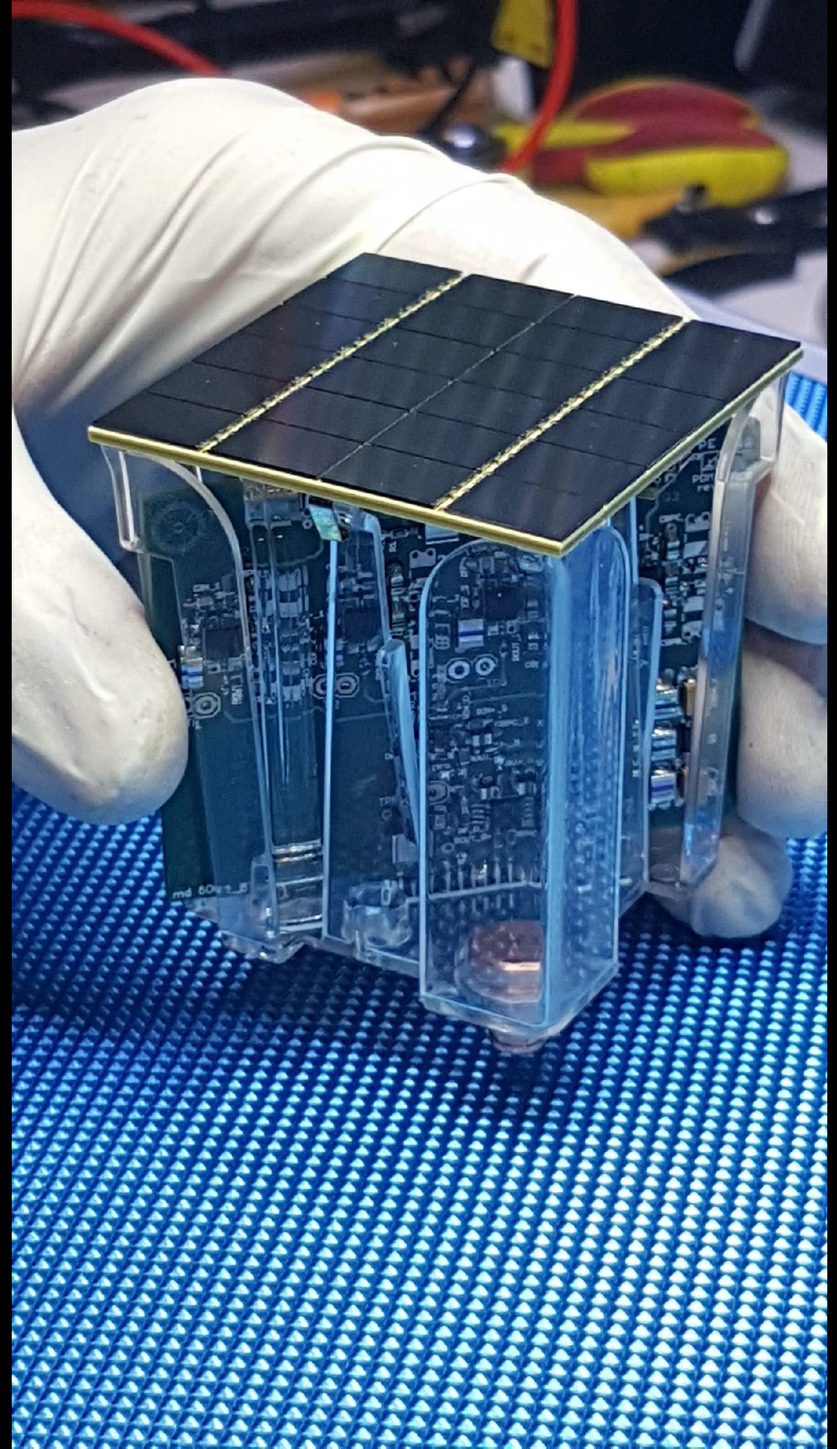
Physical Review D 98, 102006 (2018)

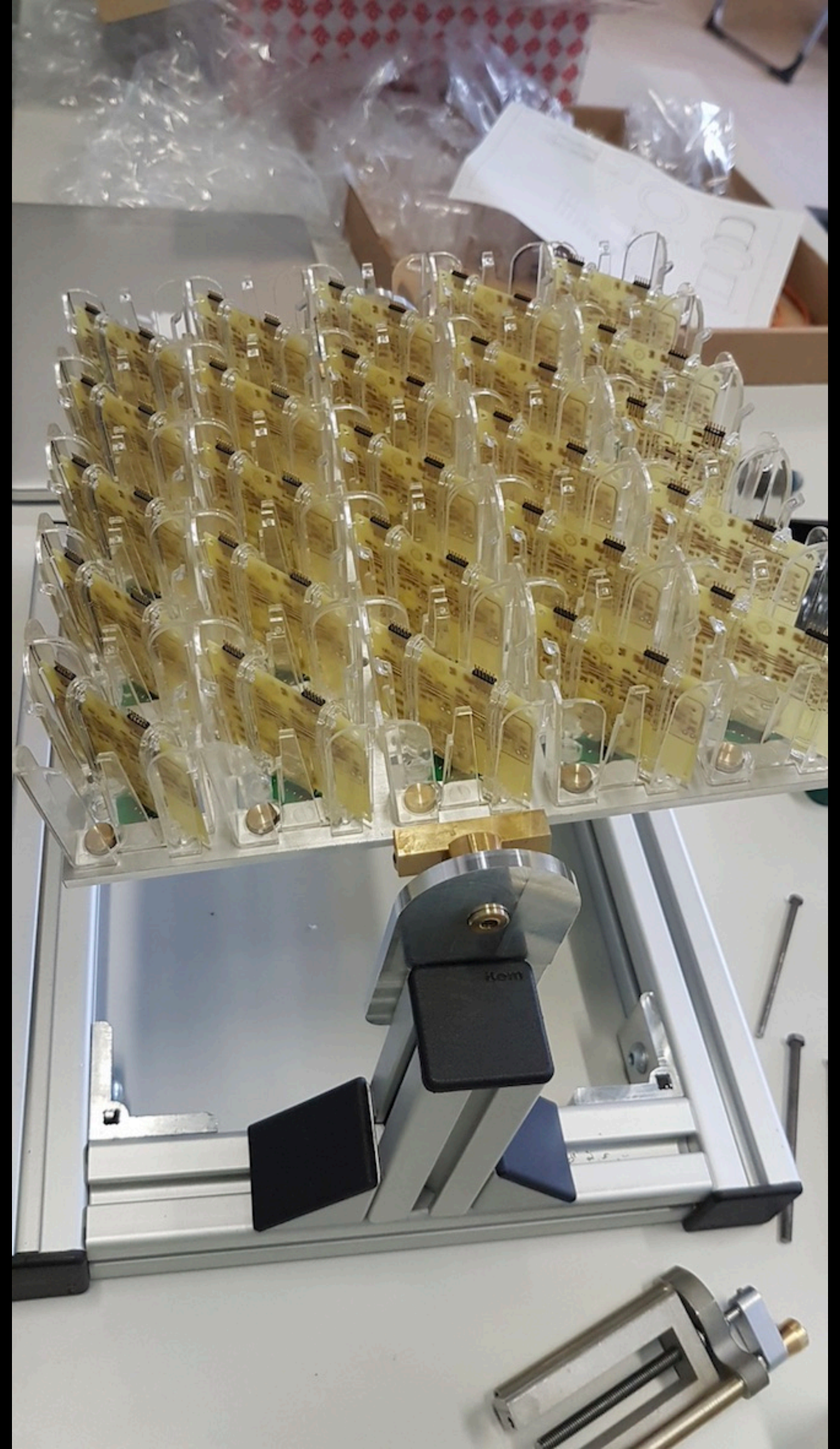
Enter the Age of Urania

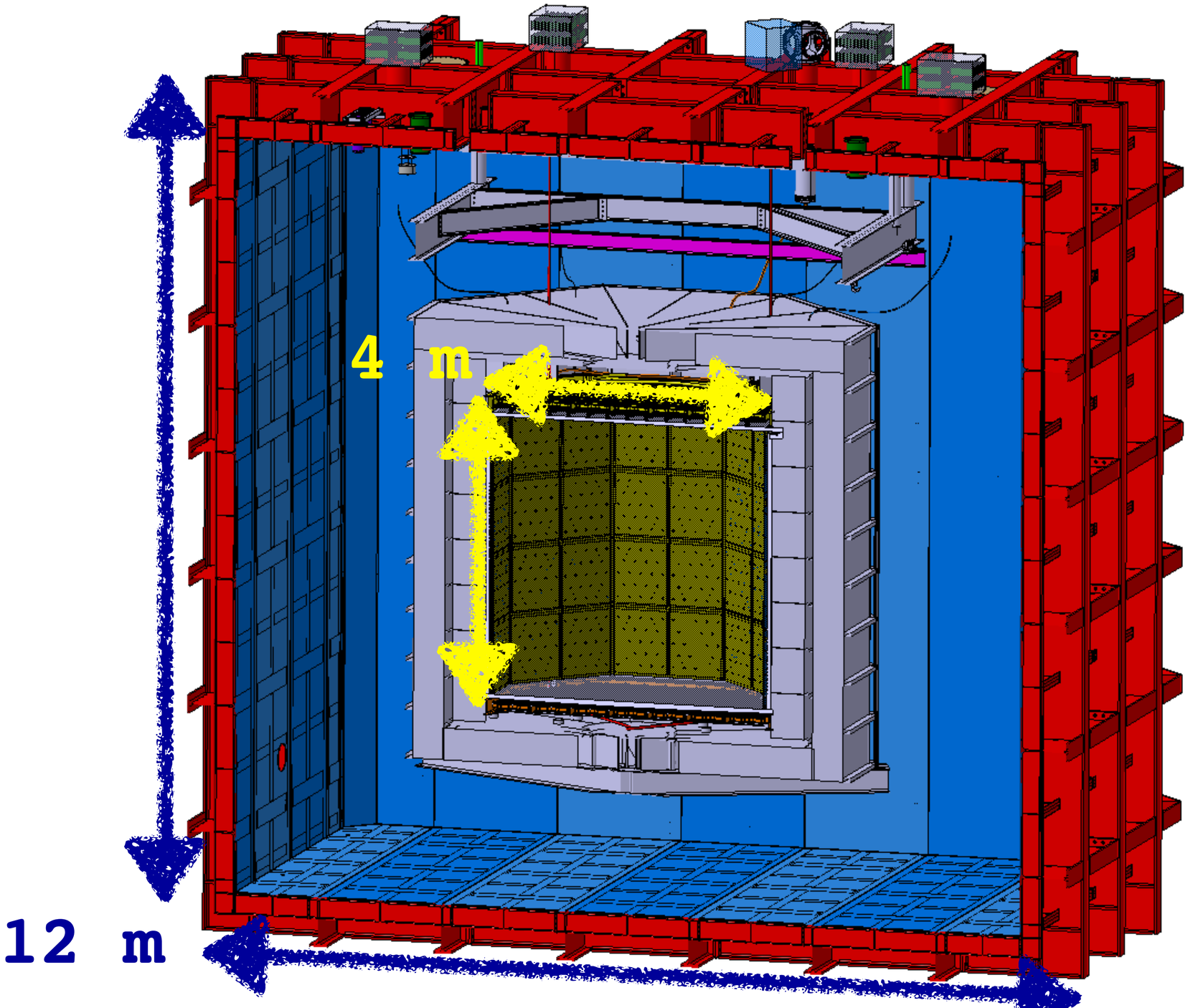





Gain: 52.68
σ_b: 2.19
SNR: 24.1
Entries
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
Amplitude [Arb.Units]






4 m
12 m

ArDM
DarkSide
DEAP
MiniCLEAN

The Global Argon Dark Matter Collaboration

DS-20k
DS-LM
Argo
DarkNoon

350 COLLABORATORS

ITALY, US, CANADA, BRAZIL, CHINA, FRANCE, GERMANY, POLAND, RUSSIA, SPAIN, UNITED KINGDOM

R. Heastie and C. Lefebvre, Proc. Phys. Soc. 76, 180 (1960)

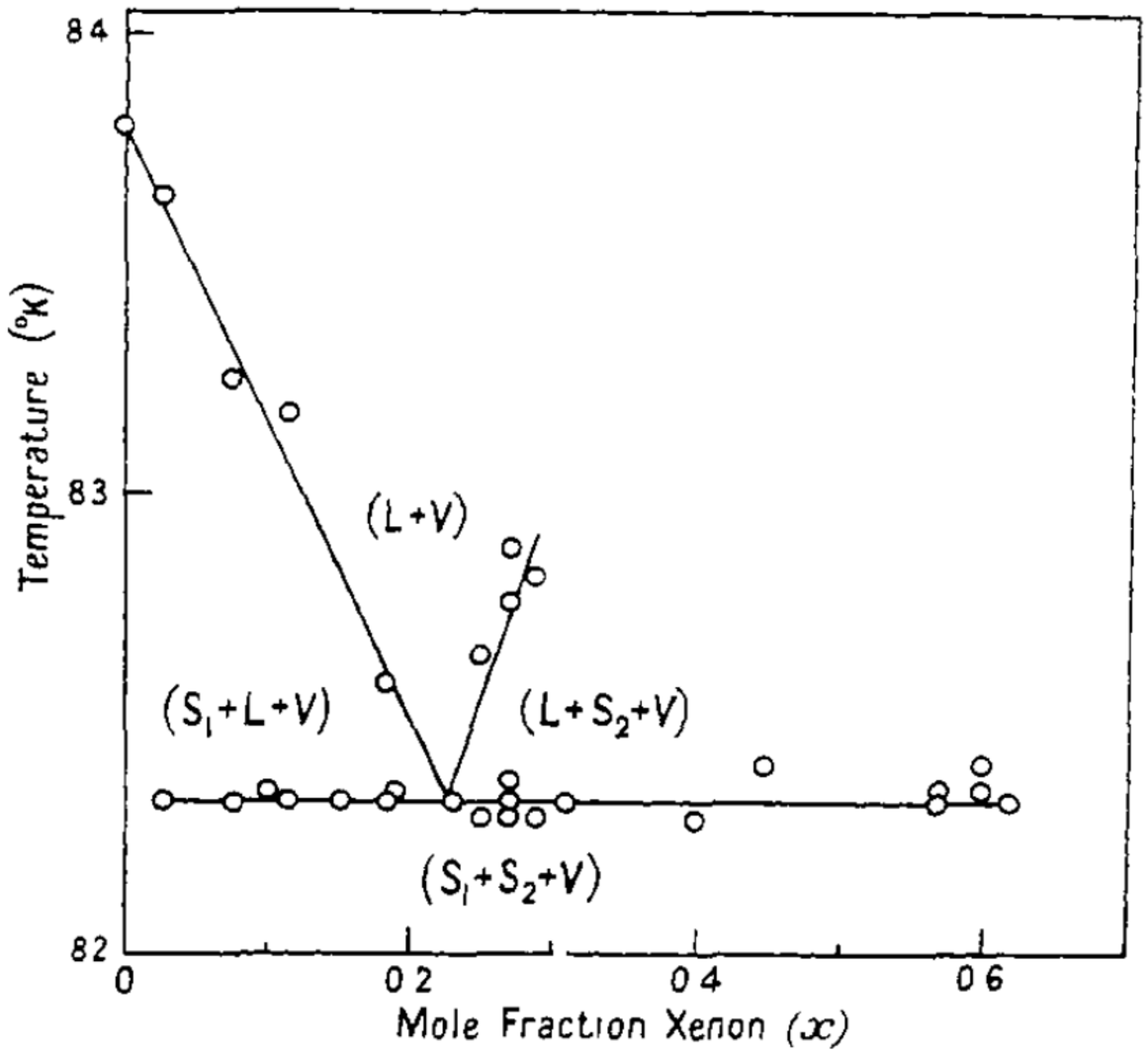


Figure 2 The temperature, composition phase-equilibrium diagram of argon and xenon

Detector Configuration

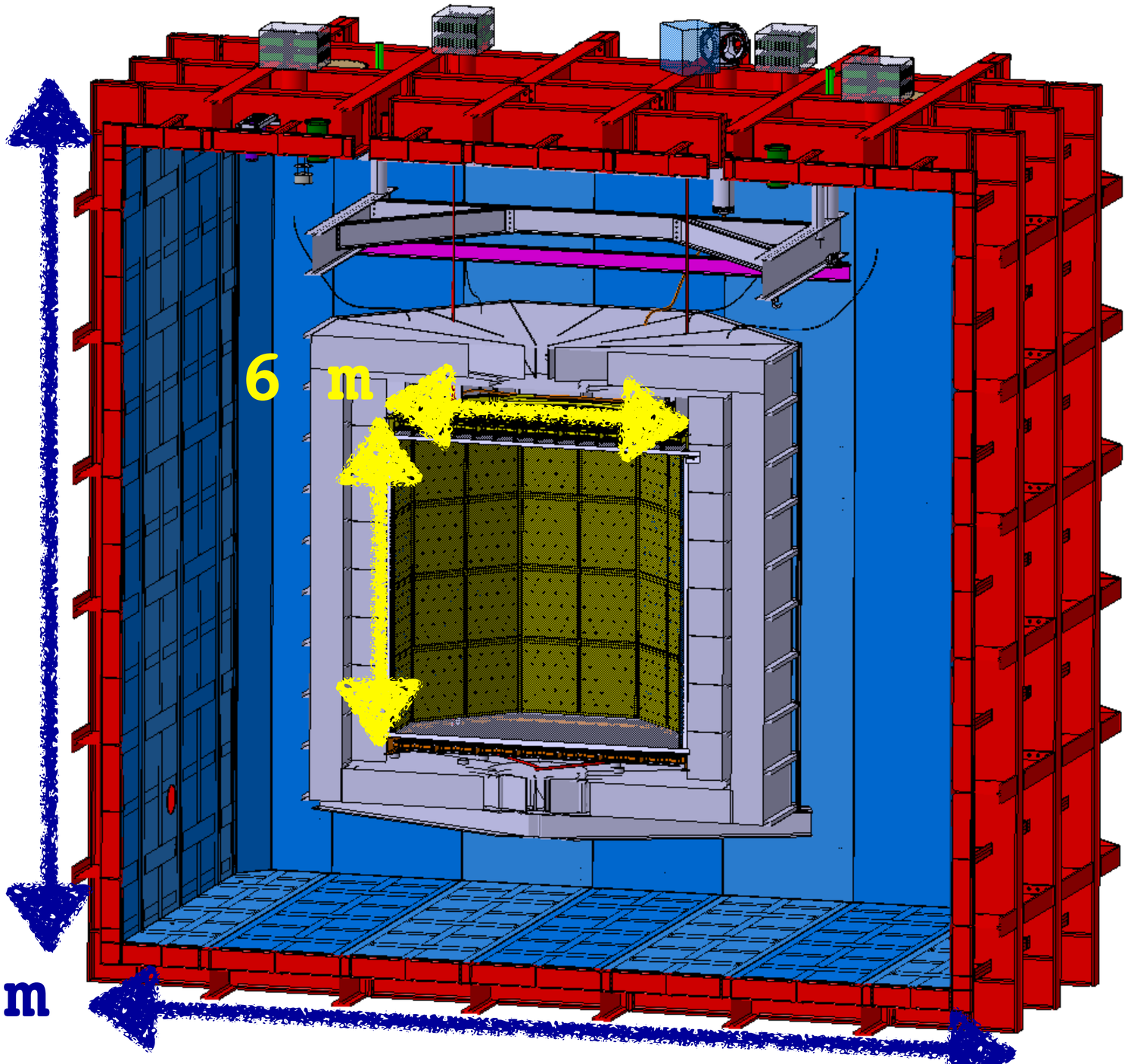
- TPC as of DarkSide-20k,
  Veto as DUNE cryostat

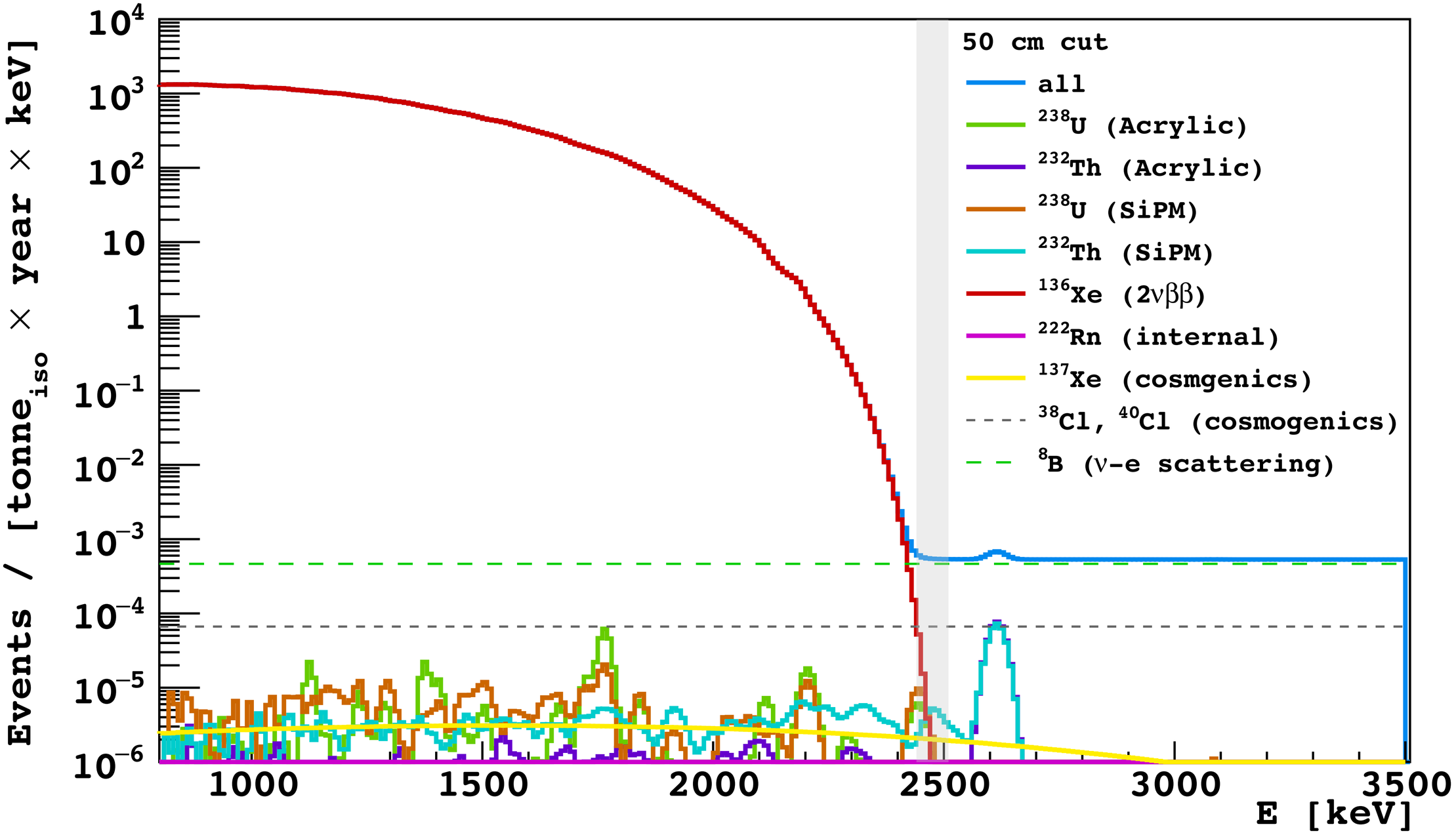
- AAr in veto, UAr+Xe in TPC

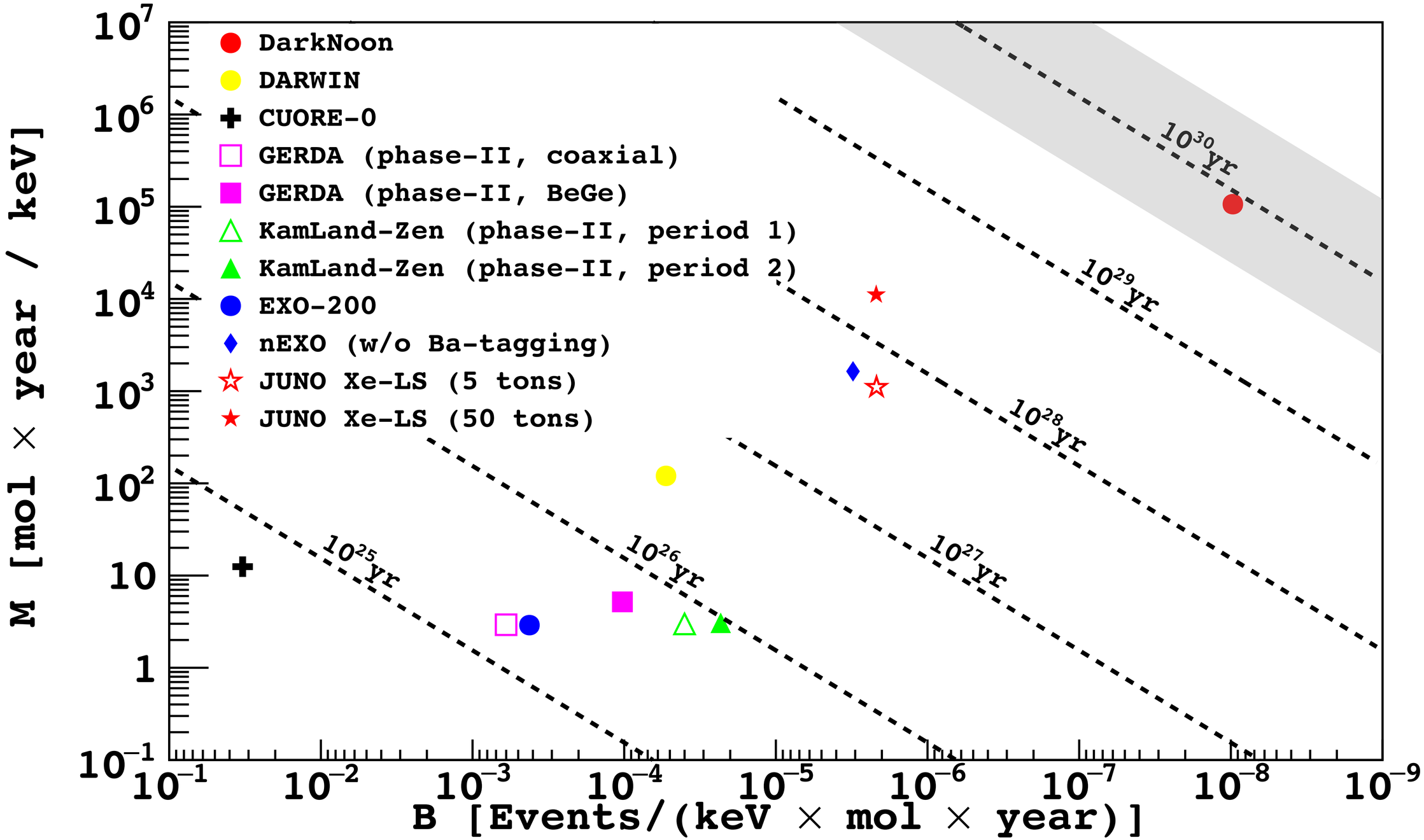
- Fiducial mass of 50 t of ^{136}Xe,
  Xe 20% molar fraction,
  ^{136}Xe enriched to 90% via Aria technology

- 4π SiPM coverage,
  0.1ns timing resolution,
  0.8% σ resolution

- ^{222}Rn reduction and SiPMs' single photon counting by operation at 87 K,
  Cherenkov-based discrimination of single and multiple electrons




50 cm cut
all
238U (Acrylic)
232Th (Acrylic)
238U (SiPM)
232Th (SiPM)
136Xe (2νββ)
222Rn (internal)
137Xe (cosmgenics)
38Cl, 40Cl (cosmogenics)
8B (ν-e scattering)
Events / [tonne_iso × year × keV]
E [keV]
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
1000
1500
2000
2500
3000
3500


DarkNoon
DARWIN
CUORE-0
GERDA (phase-II, coaxial)
GERDA (phase-II, BeGe)
KamLand-Zen (phase-II, period 1)
KamLand-Zen (phase-II, period 2)
EXO-200
nEXO (w/o Ba-tagging)
JUNO Xe-LS (5 tons)
JUNO Xe-LS (50 tons)
10^{25} yr
10^{26} yr
10^{27} yr
10^{28} yr
10^{29} yr
10^{30} yr
M [mol × year / keV]
B [Events/(keV × mol × year)]

THE END