Darkside-50, DarkSide-20k and the Global Collaboration to reach the Neutrino Floor with liquid argon

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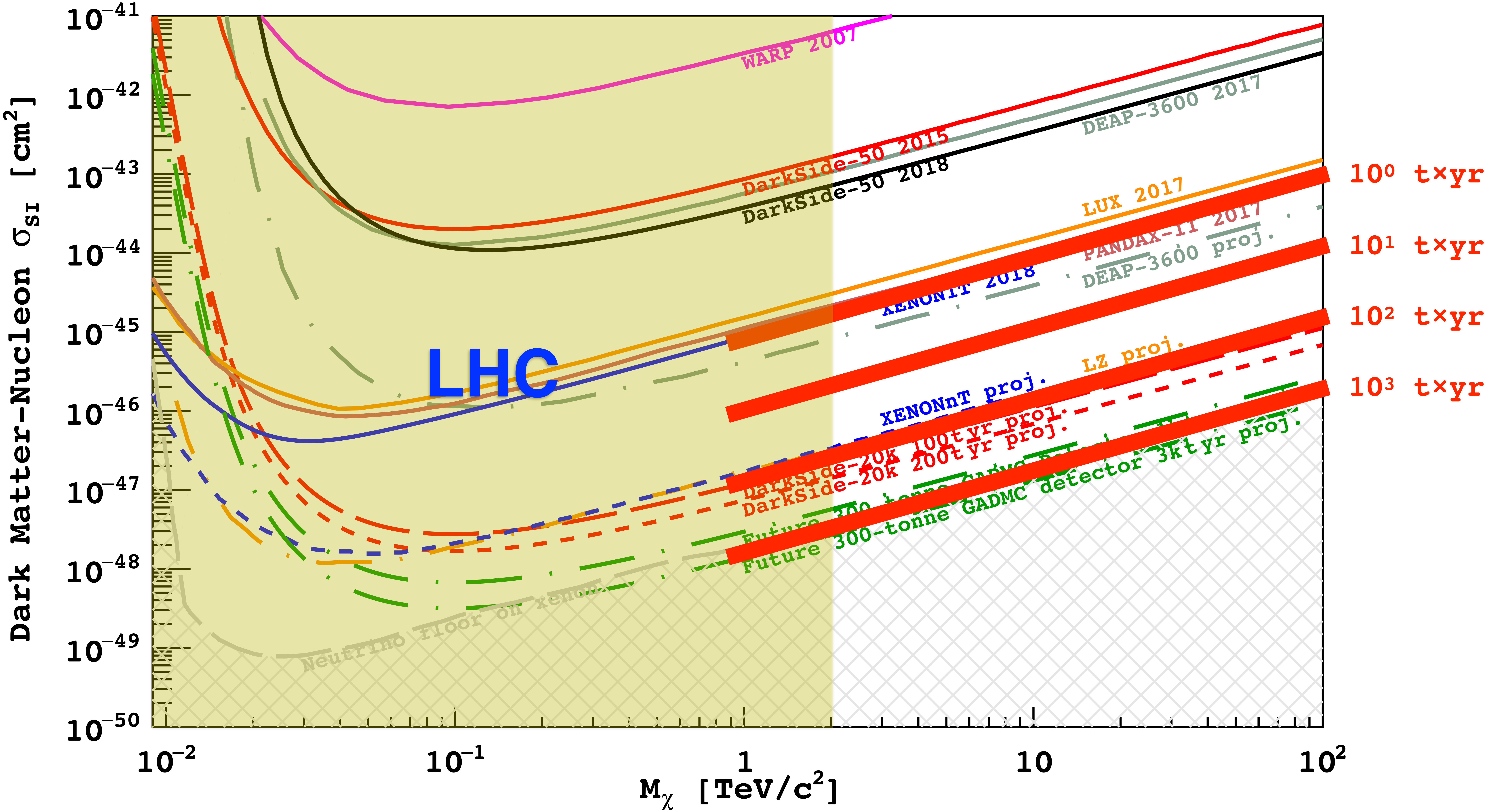
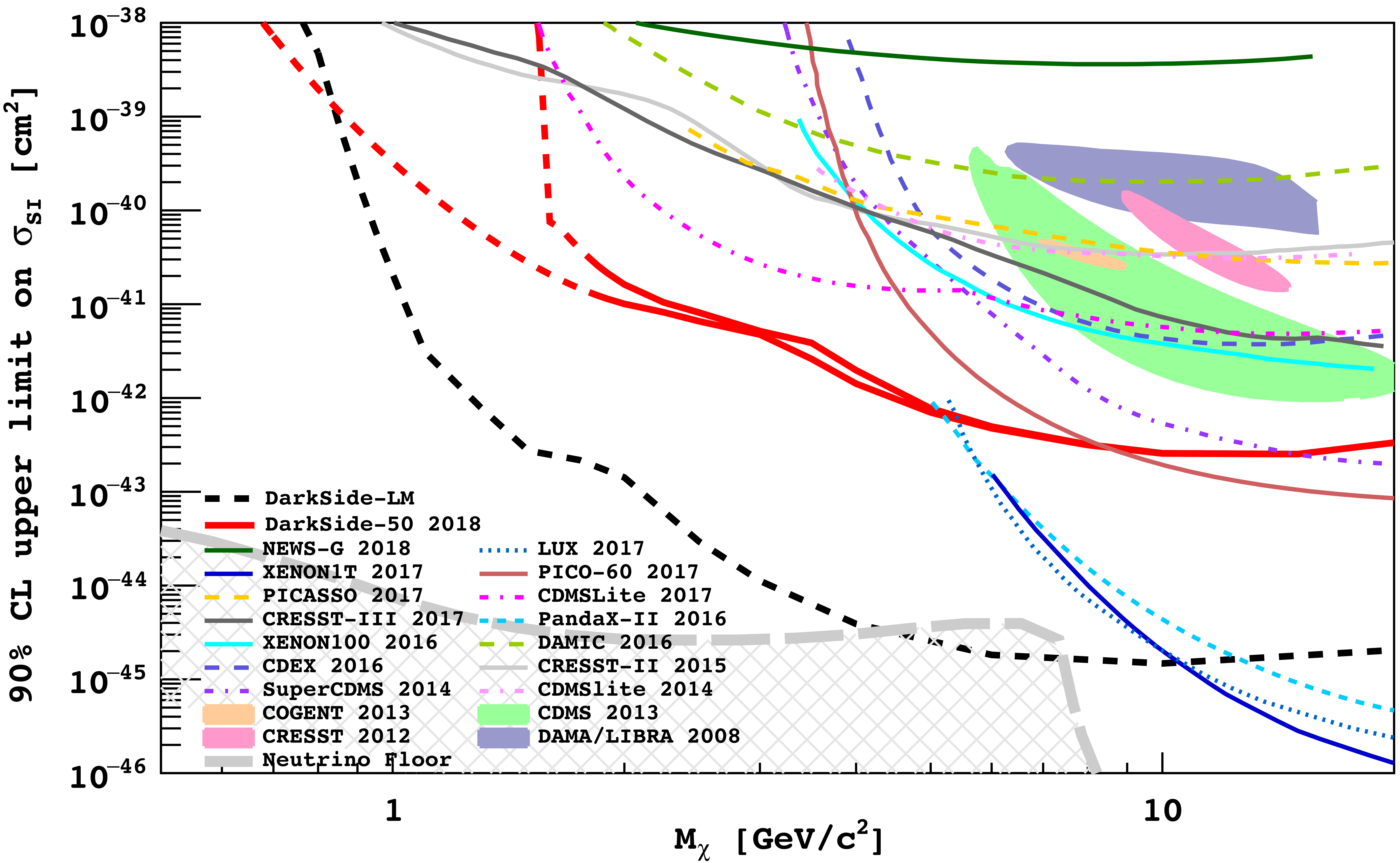
Gran Sasso Science Institute and Princeton University

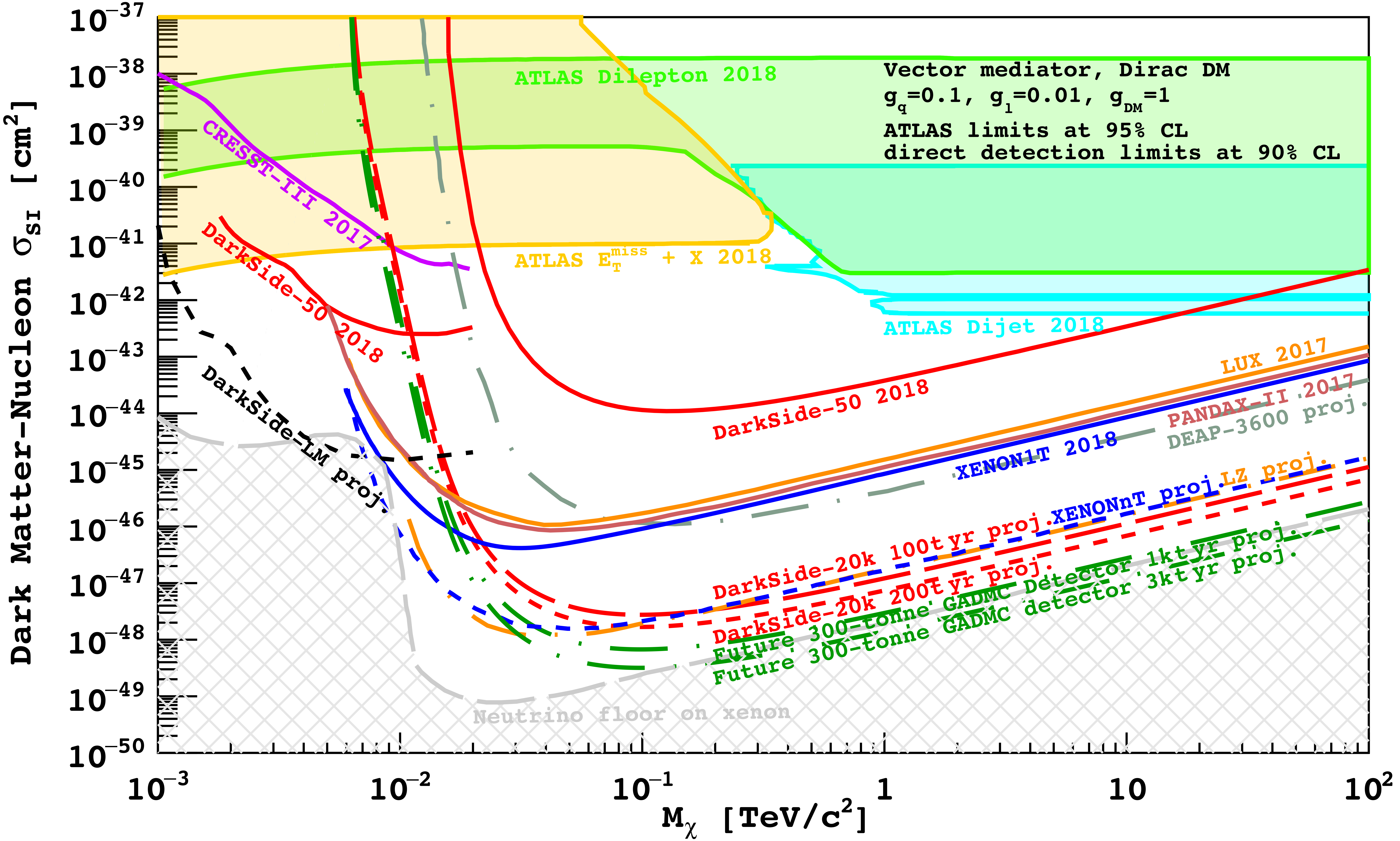
The quest for dark matter with liquid argon
APC Université Paris Diderot
September 4, 2018



Dark Matter-Nucleon σ_{SI} [cm^2]
M_χ [TeV/c^2]
LHC
WARP 2007
DarkSide-50 2015
DarkSide-50 2018
DEAP-3600 2017
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
XENON1T 2018
LZ proj.
XENONnT proj.
DarkSide-20k 100t yr proj.
DarkSide-20k 200t yr proj.
Future 300-tonne GADMC detector 3kt yr proj.
Neutrino floor on xenon
10^0 t×yr
10^1 t×yr
10^2 t×yr
10^3 t×yr

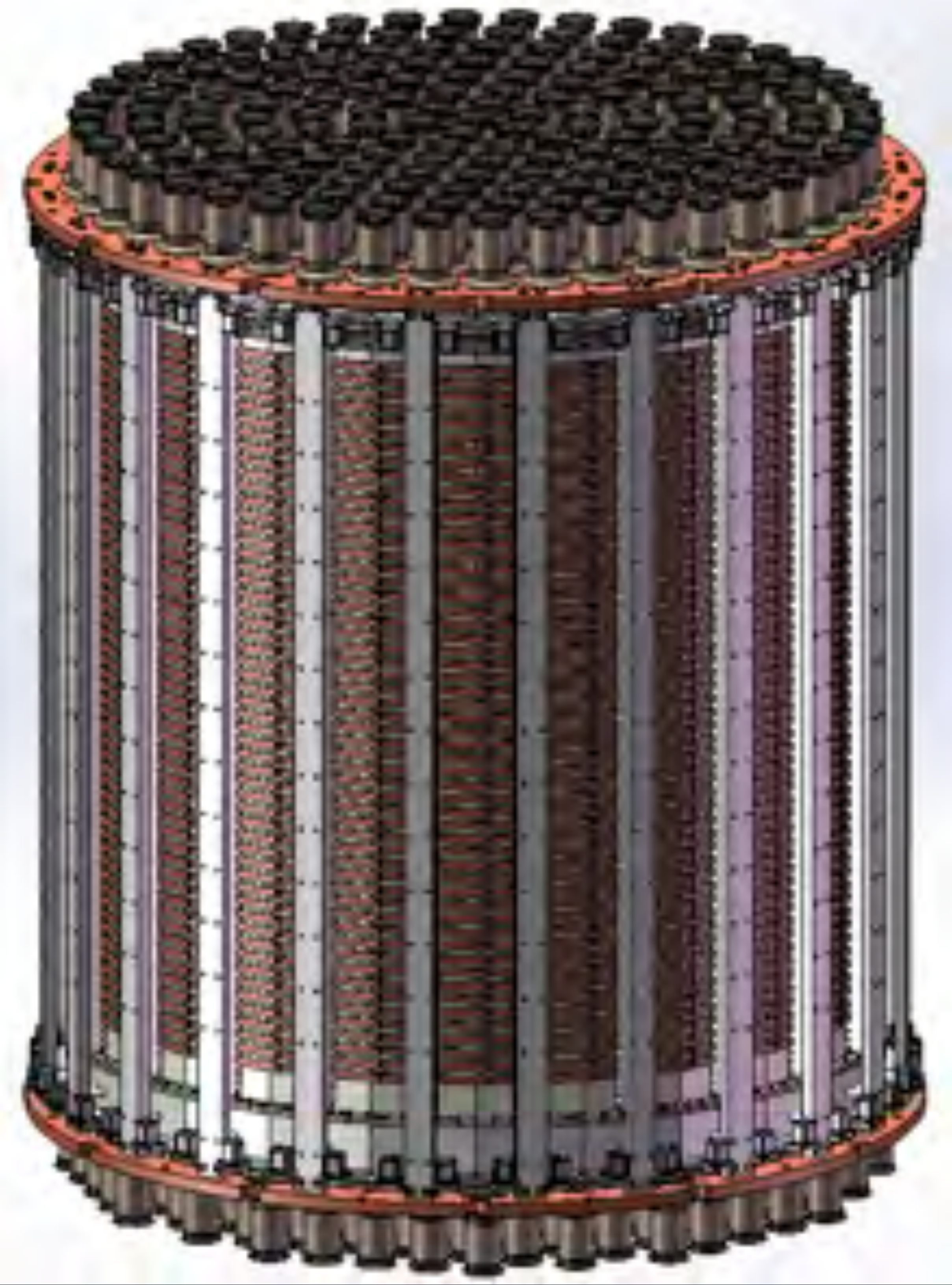


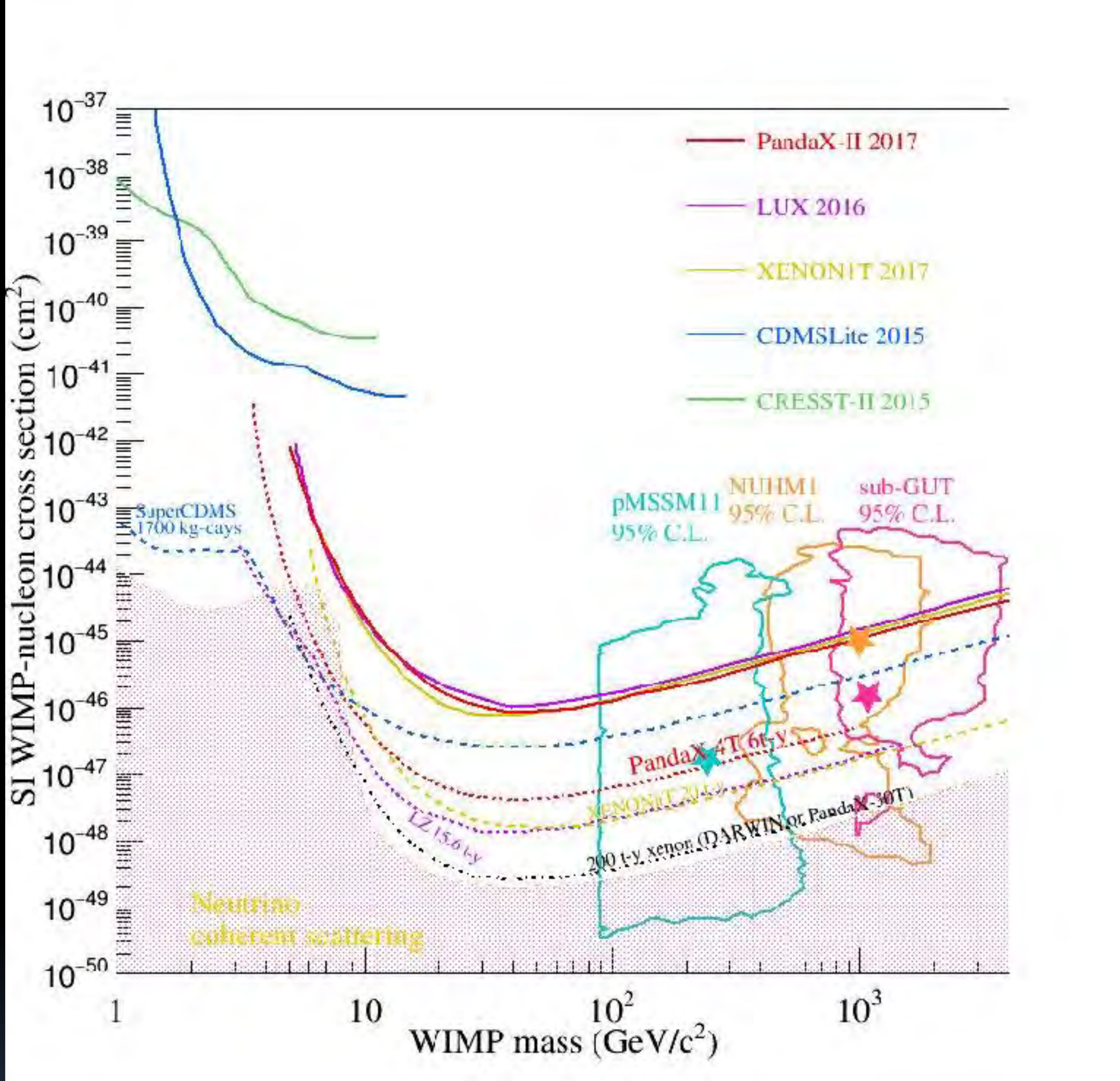
90% CL upper limit on σ_{SI} [cm^2]
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
1
10
M_χ [GeV/c^2]
DarkSide-LM
DarkSide-50 2018
NEWS-G 2018
XENON1T 2017
PICASSO 2017
CRESST-III 2017
XENON100 2016
CDEX 2016
SuperCDMS 2014
COGENT 2013
CRESST 2012
Neutrino Floor
LUX 2017
PICO-60 2017
CDMSLite 2017
PandaX-II 2016
DAMIC 2016
CRESST-II 2015
CDMSlite 2014
CDMS 2013
DAMA/LIBRA 2008



Vector mediator, Dirac DM
g_q=0.1, g_l=0.01, g_DM=1
ATLAS limits at 95% CL
direct detection limits at 90% CL
ATLAS Dilepton 2018
ATLAS E_T^miss + X 2018
ATLAS Dijet 2018
CRESST-III 2017
DarkSide-50 2018
DarkSide-50 2018
DarkSide-LM proj.
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
XENON1T 2018
XENONnT proj.
LZ proj.
DarkSide-20k 100t yr proj.
DarkSide-20k 200t yr proj.
Future 300-tonne GADMC Detector 1kt yr proj.
Future 300-tonne GADMC detector 3kt yr proj.
Neutrino floor on xenon
Dark Matter-Nucleon σ_SI [cm²]
M_χ [TeV/c²]

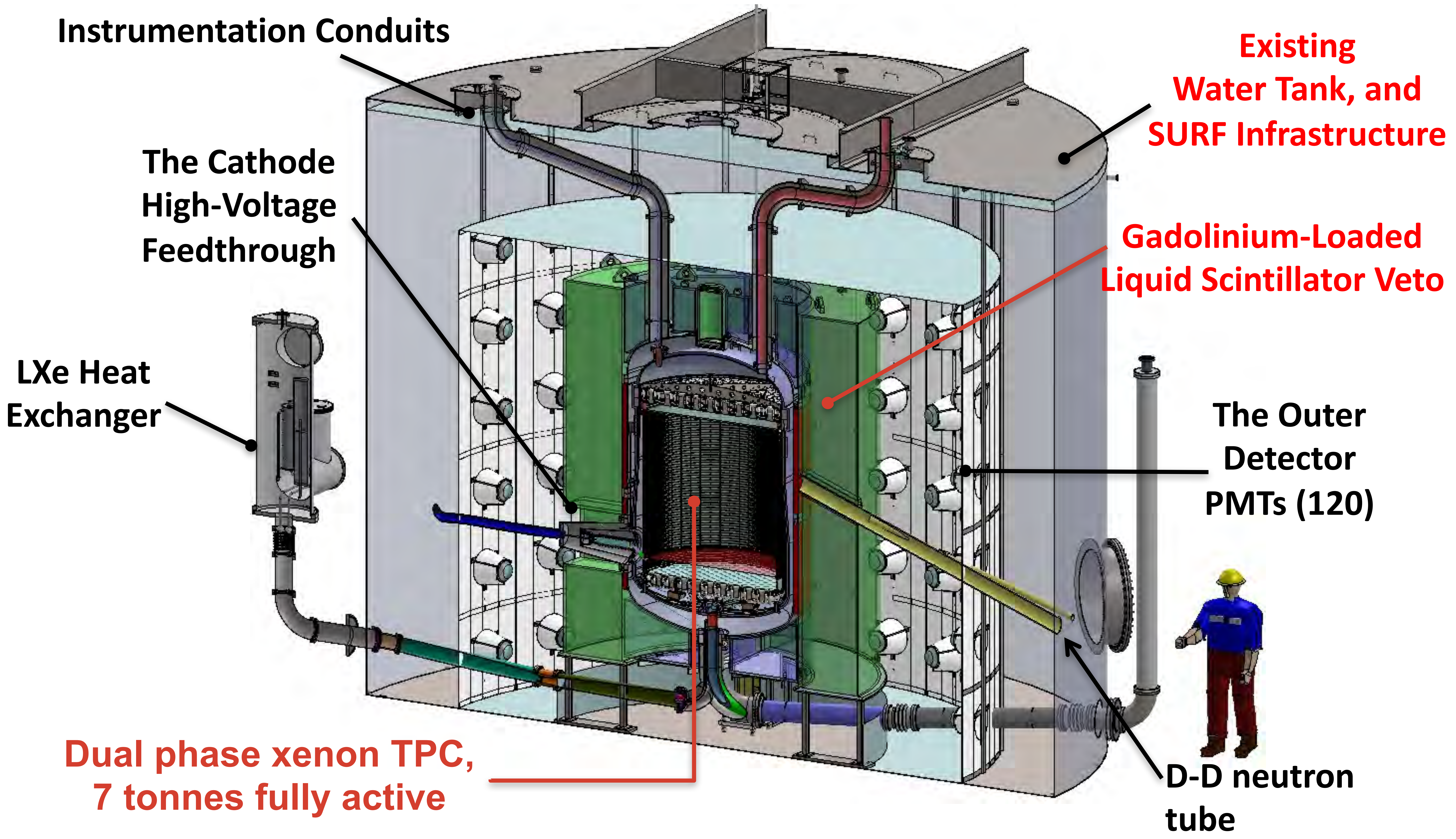
PandaX-xT





- Intermediate stage:
  - **PandaX-4T** (4-ton target) with SI sensitivity ~10^{-47} cm^2
  - On-site assembly and commissioning: 2019-2020

The LUX-ZEPLIN detector



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

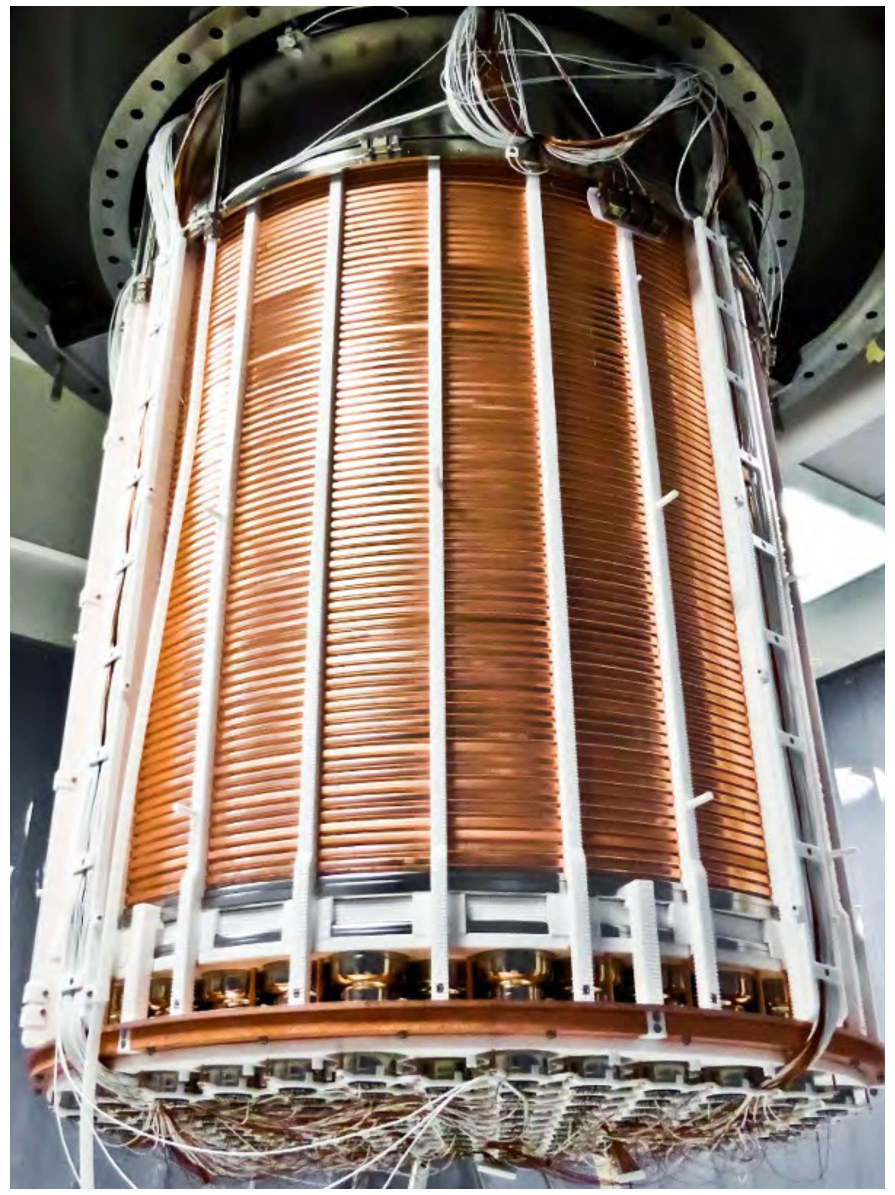
Gamma backgrounds (PMTs, cryostat) are negligible.

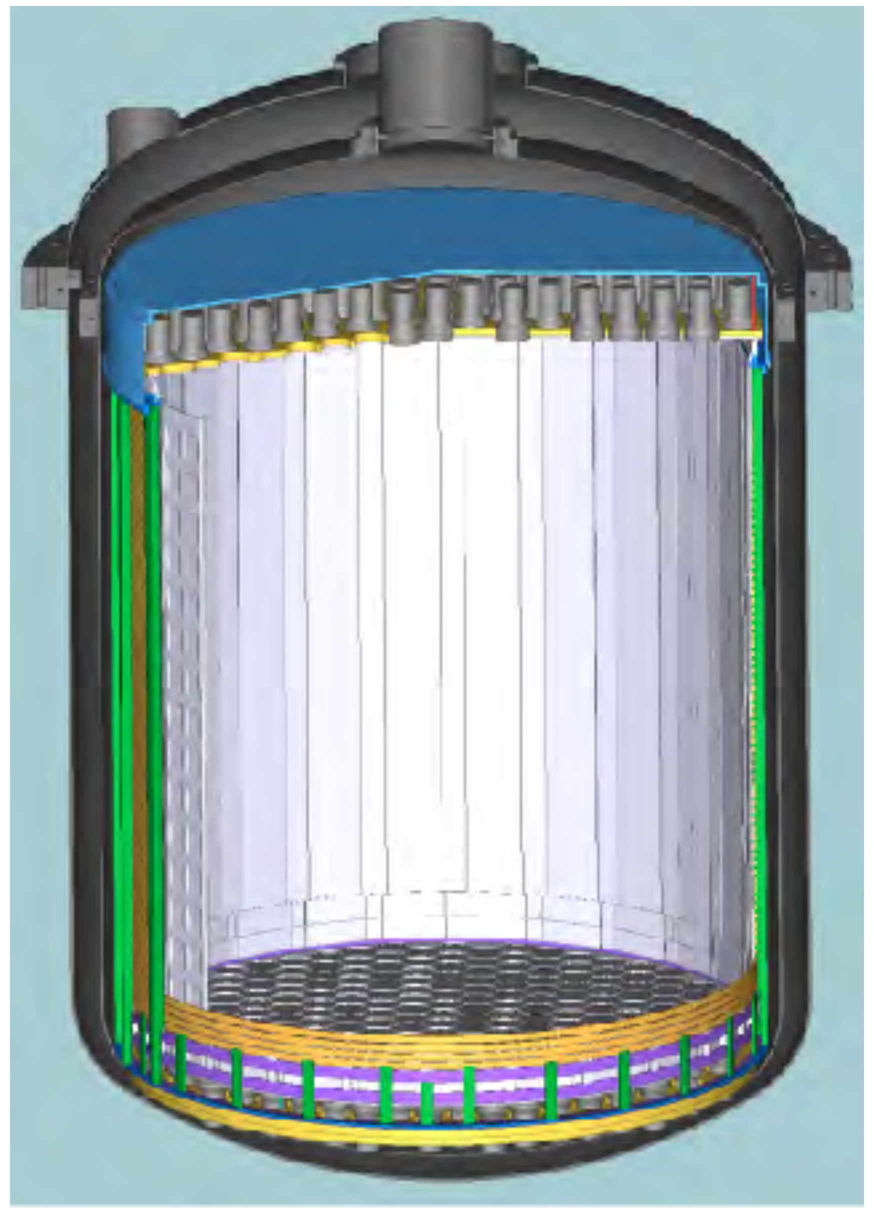
pp solar neutrinos, elastic scattering on atomic electrons

Coherent neutrino scattering on xenon nuclei

The phases of the XENON Program

XENON10	XENON100	XENON1T	XENONnT



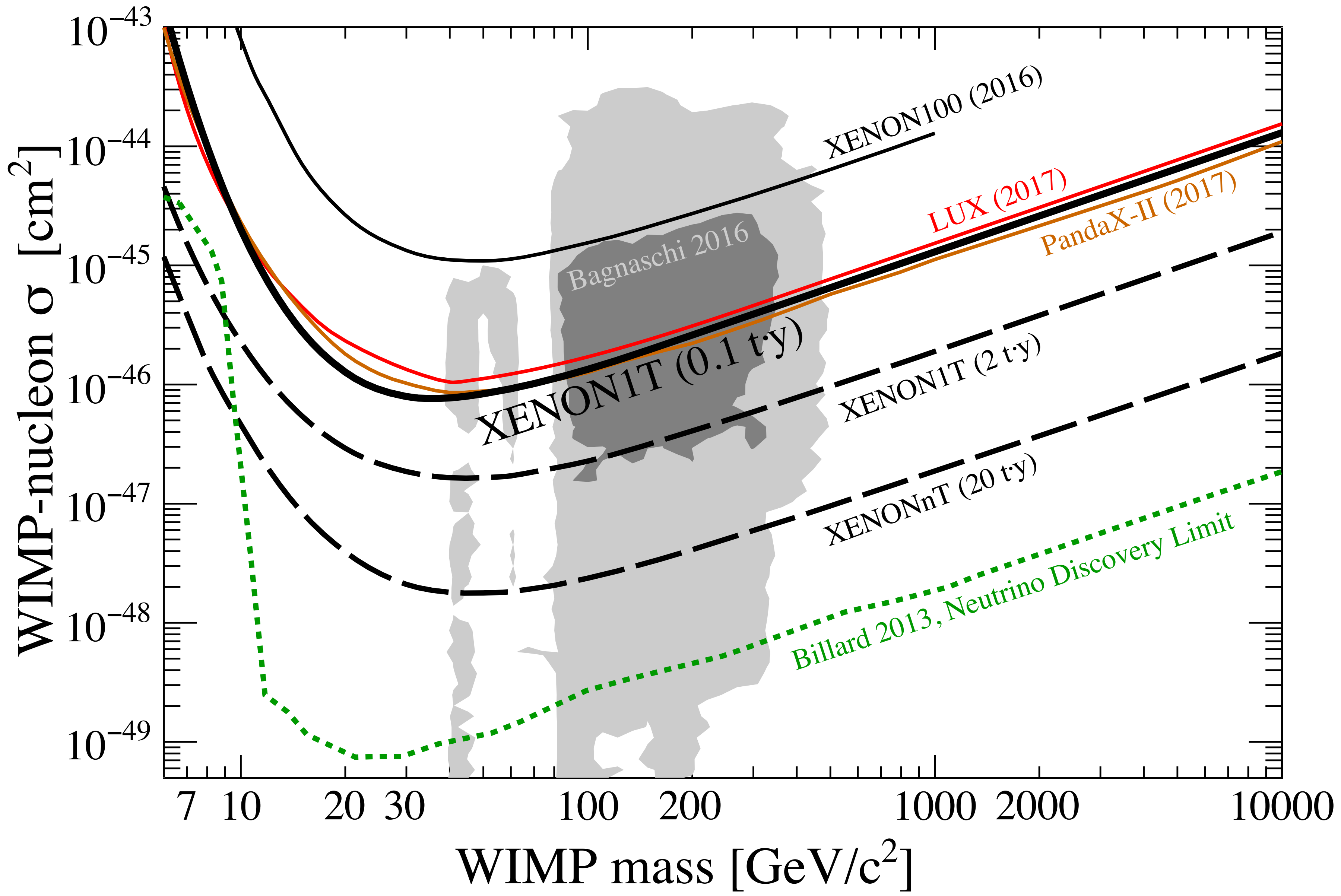


2005-2007	2008-2016	2012-2018	2019-2023
25 kg- 15cm drift	161 kg- 30 cm drift	3200 kg- 100 cm drift	8000 kg-150 cm drift
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2

XENON1T and XENONnT science reach

- XENON1T: 1.6 x 10^{-47} cm^2 with an exposure of 2 tonnes x year
- XENONnT: to start in mid 2019, aiming for 20 tonnes x year exposure

	XENON1T	XENONnT	LZ
Fiducial Volume [tons]	1	4	5.6
Livetime Fraction	80%	80%	80%
WIMP Energy Range [keV_{nr}]	4-50	4-50	6-30
NR Acceptance	40%	40%	50%
ER Rejection	99.75%	99.75%	99.5%
Bkg rate [evt/year]	2.08	1.15	2.35



Background prediction and Unblinding

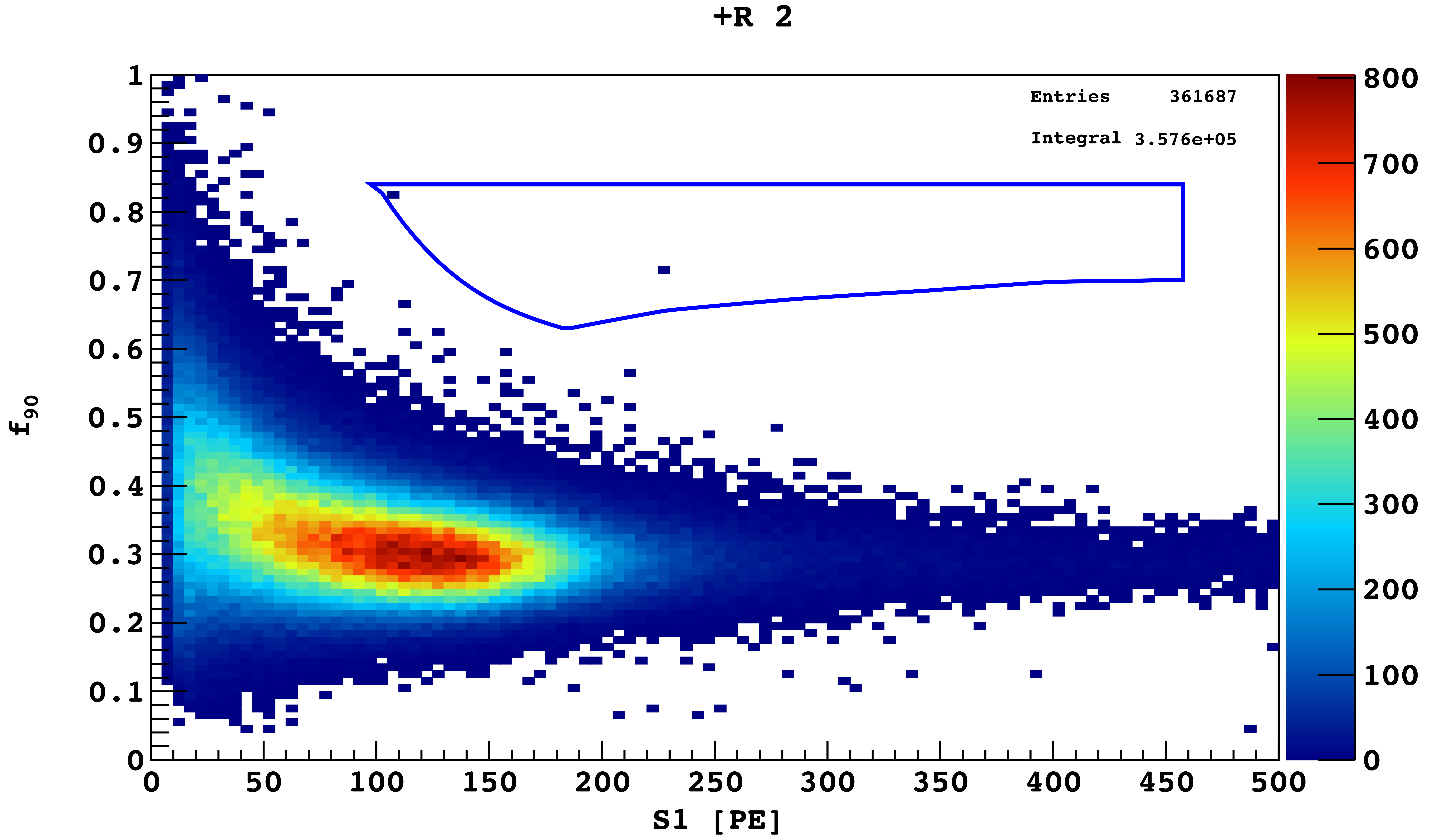
Mass	1.3t	1.3t
(S2, S1)	Full	Reference
ER	627±26	2.2±0.1
Neutron	1.4±0.6	0.8±0.3
CENNS	0.05±0.02	0.02±0.01
AC	0.47±0.15	0.10±0.03
Surface	106±11	5.4±0.5
BG	736±28	8.4±0.6
Data	**739**	**11**
WIMPs best-fit (200GeV)	3.36	1.55

- Reference region is defined as between NR median and NR - 2sigma
- ER is the most significant background and uniformly distributed in the volume
- Surface background contributes most in reference region, but its impact is subdominant in inner R
- Neutron background is less than one event, and impact is further suppressed by position information
- Other background components are completely sub-dominant
- Numbers in the table are just for illustration, statistical interpretation is done based on profile likelihood analysis

TABLE I: Best-fit expected event rates with 278.8 days live-time in the 1.3 t fiducial mass, 0.9 t reference mass, and 0.65 t core mass, for the full ($cS1$, $cS2_b$) ROI and, for illustration, in the NR signal reference region. The table lists each background (BG) component separately and in total, the observed data, and the expectation for a 200 GeV/c^2 WIMP prediction assuming the best-fit $\sigma_{SI} = 4.7 \times 10^{-47}$ cm^2.

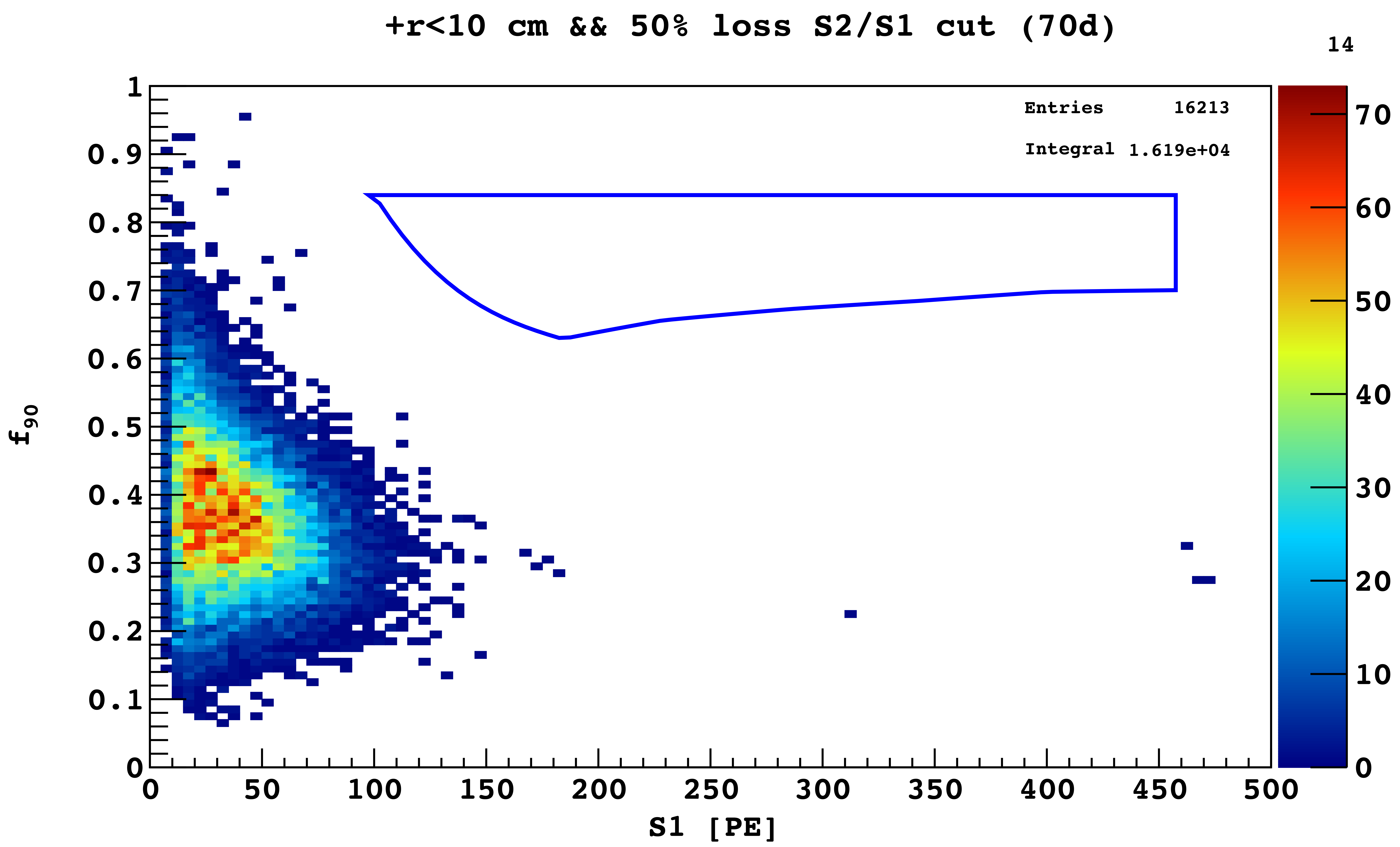
Mass	1.3 t	1.3 t	0.9 t	0.65 t
($cS1$, $cS2_b$)	Full	Reference	Reference	Reference
ER	627±18	1.62±0.30	1.12±0.21	0.60±0.13
neutron	1.43±0.66	0.77±0.35	0.41±0.19	0.14±0.07
CEνNS	0.05±0.01	0.03±0.01	0.02	0.01
AC	$0.47^{+0.27}_{-0.00}$	$0.10^{+0.06}_{-0.00}$	$0.06^{+0.03}_{-0.00}$	$0.04^{+0.02}_{-0.00}$
Surface	106±8	4.84±0.40	0.02	0.01
Total BG	735±20	7.36±0.61	1.62±0.28	0.80±0.14
WIMP$_{\text{best-fit}}$	3.56	1.70	1.16	0.83
Data	739	14	2	2

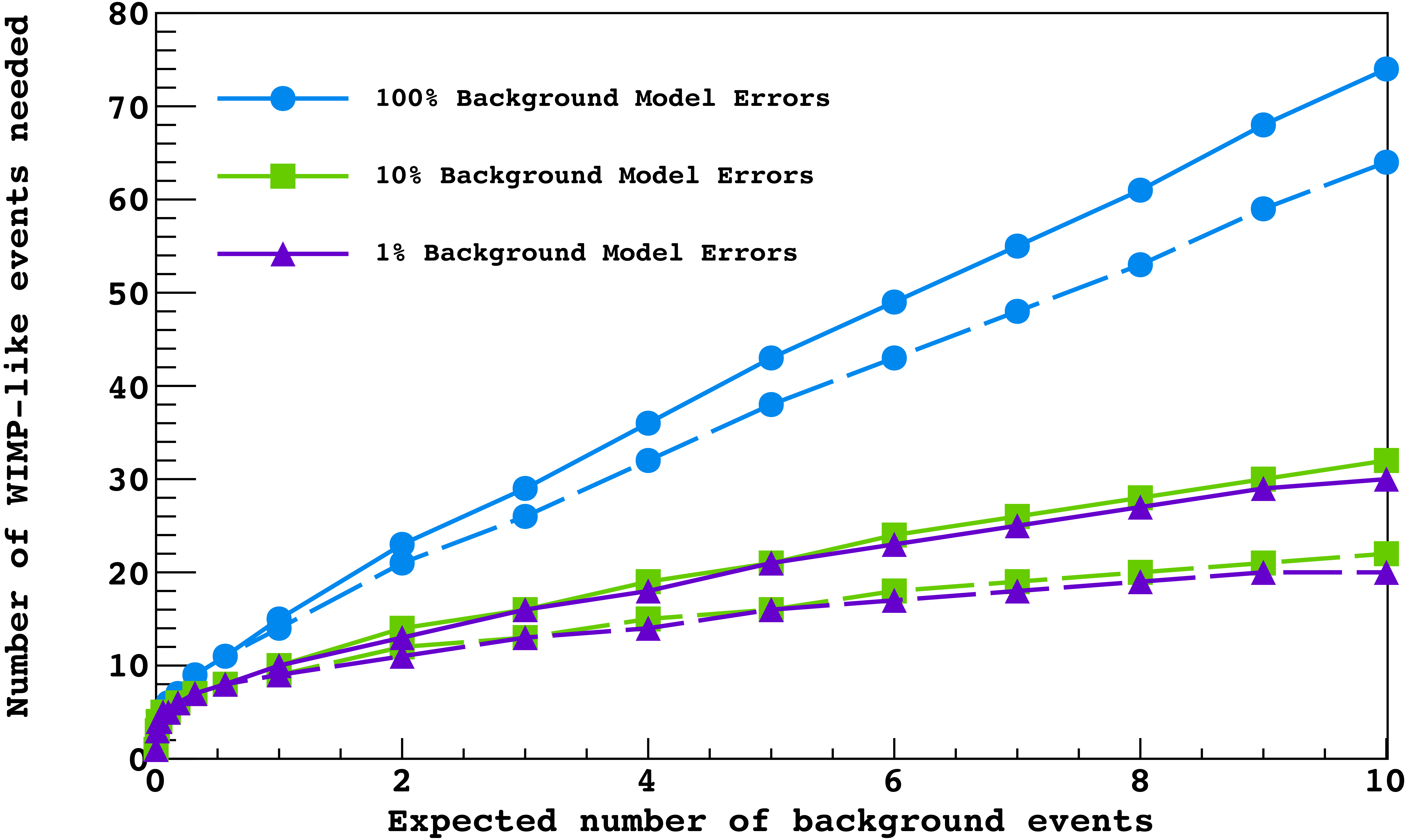
ER
Surface
Neutron
AC
WIMP
keV$_{NR}$
5
10
15
20
25
30
35
40
45
50
60
1σ
2σ
8000
4000
2000
1000
400
200
cS2$_b$ [PE]
0
3
10
20
30
40
50
60
70
cS1 [PE]
R [cm]
10
20
30
40
0.9 t
1.3 t
500
1000
1500
R^2 [cm^2]



+R 2
Entries 361687
Integral 3.576e+05
f90
S1 [PE]
0
50
100
150
200
250
300
350
400
450
500
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800


+Veto
Entries 227934
Integral 2.258e+05
f_{90}
S1 [PE]
0
50
100
150
200
250
300
350
400
450
500
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500


+r<10 cm && 50% loss S2/S1 cut (70d)
Entries 16213
Integral 1.619e+04
f_{90}
S1 [PE]
14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
10
20
30
40
50
60
70



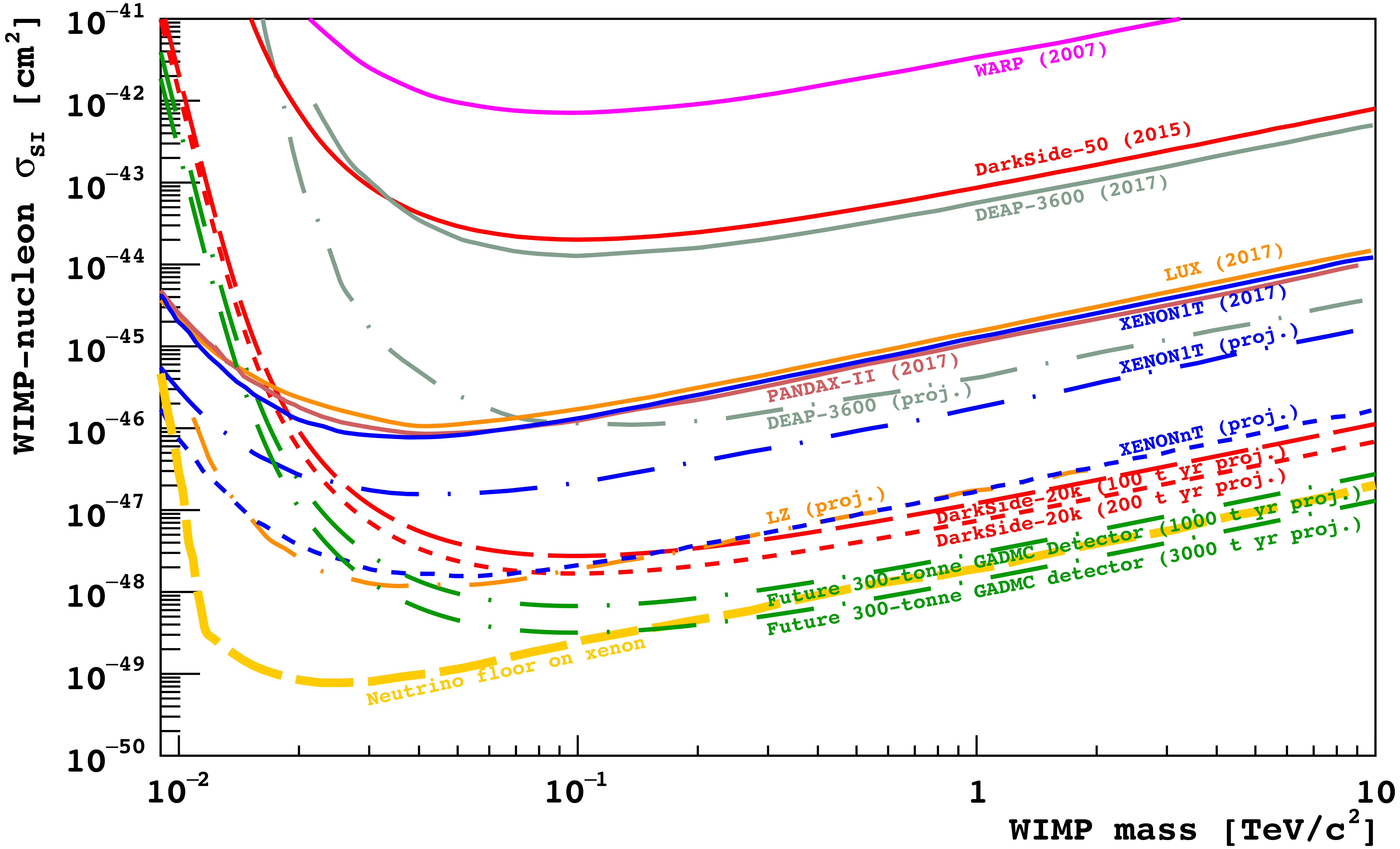
100% Background Model Errors
10% Background Model Errors
1% Background Model Errors
Number of WIMP-like events needed
Expected number of background events
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10

“Zero Background” condition (<0.1 background events) necessary to conduct discovery program

The Global Argon Dark Matter Collaboration

ArDM
DarkSide
DEAP
MiniCLEAN

A Single Global Program for Direct Dark Matter Searches
Currently taking data: ArDM, DarkSide-50, **DEAP-3600**
Next step: DarkSide-20k at LNGS (2021-)
Last Step: **300 tonnes detector**, location t.b.d **(2027-)**



DarkSide-20k approved by INFN and LNGS in April 2017 and by NSF in Oct 2017
Officially supported by LNGS, LSC, and SNOLab
30 tonnes (20 tonnes fiducial) of low-radioactivity underground argon
14 m^2 of SiPM coverage

University of Alberta
LNGS
GSSI
Augustana University
БелГУ 1876
Black Hills State University
Alma Mater Studiorum A.D. 1088
Carleton University

Universitas Studiorum Catanensis
UNICAMP Universidade Estadual de Campinas
Centro Fermi Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
INFN LNS
Universitas Hennae Studiorum — Libera Università Kore Enna

ETH Zürich
Fort Lewis College
University of Hawaii Mānoa 1907
University of Houston Founded 1927
Institute of High Energy Physics Chinese Academy of Sciences
INFN

IPN Institut de Physique Nucléaire Orsay
INSTM
IPHC Institut Pluridisciplinaire Hubert Curien Strasbourg
Joint Institute for Nuclear Research JINR
Laurentian University Université Laurentienne
INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati
LPNHE Paris

MEPhI Moscow Engineering Physics Institute
Politecnico Milano
Universitas Studiorum Mediolanensis
Frid. II
НГУ
Studium Generale Civitatis Perusii A.D. MCCCVIII
In Supremae Dignitatis 1343
Pacific Northwest National Laboratory — Proudly Operated by Battelle Since 1965
Princeton

Queen's University
Studium Urbis
Roma Tre Università degli Studi
Hippocratica Civitas Studium Salerni
SNOLAB
University of Sussex
Universitas Turritana Sacerensis
Temple University
Fondazione Bruno Kessler

TIFPA Trento Institute for Fundamental Physics and Applications
Universitas Studiorum Athesina
Politecnico di Torino 1859–1906
Politecnico di Torino
Taurinorum Augustae Universitas
TRIUMF
Technische Universität München
Universidad Nacional Autónoma de México

The University of California Davis
The University of California UCLA
University of Massachusetts Amherst 1863
Ευρώπη
Universidade de São Paulo
Virginia Polytechnic Institute and State University

Letter of Intent

September 8, 2017

Rev B

Scientists at LNGS, LSC, and SNOLAB are joining in an international effort to mount a phased argon dark matter program with the goal of being sensitive to the neutrino floor. This effort will include a broad collaboration of scientists and will represent the global community for dark matter searches with argon. This letter is an update of a previous communication dating June 2017, which detailed the first conception of the program; this letter was expanded to capture the intent of all institutions and scientists participating in the program.

In this document, the undersigned representatives of groups working on argon dark matter searches, including Brazilian, Canadian, Chinese, French, German, Greek, Italian, Mexican, Polish, Romanian, Russian, Spanish, Swiss, US, and UK groups among others, memorialize their intent to form a Global Argon Dark Matter Collaboration to carry out a program for direct dark matter searches, consisting of two main elements.

The first element of the program is the DarkSide-20k experiment at LNGS, whose science goal is to perform a dark matter search with an exposure of 100 tonne·yr of low-radioactivity underground argon (the low intrinsic background, free from any background other than that induced by atmospheric neutrinos, may also permit a 200 tonne·yr exposure for

Deep underground laboratory support for global collaboration towards discovery of dark matter utilising liquid argon detectors.

To whom it may concern;

As hosts of the existing operational liquid argon direct dark matter detectors, and as proponents and supporters of the Underground-GRI initiative, the LNGS, SNOLAB and LSC deep underground research facilities are pleased to recognize the collaborative developments within the global liquid argon dark matter community. The DarkSide project at LNGS, the DEAP project at SNOLAB and the ArDM project at LSC are all developing new technologies and capabilities to search for WIMP dark matter, and are beginning to coalesce into one collaboration to develop future, larger generations of liquid argon direct dark matter detectors. We encourage and support the development of this global community, with a focus on the development of DarkSide-20k at LNGS in the first instance, and a larger detector at a location to be determined from scientific requirements, in the future. Using available assay and research infrastructure,

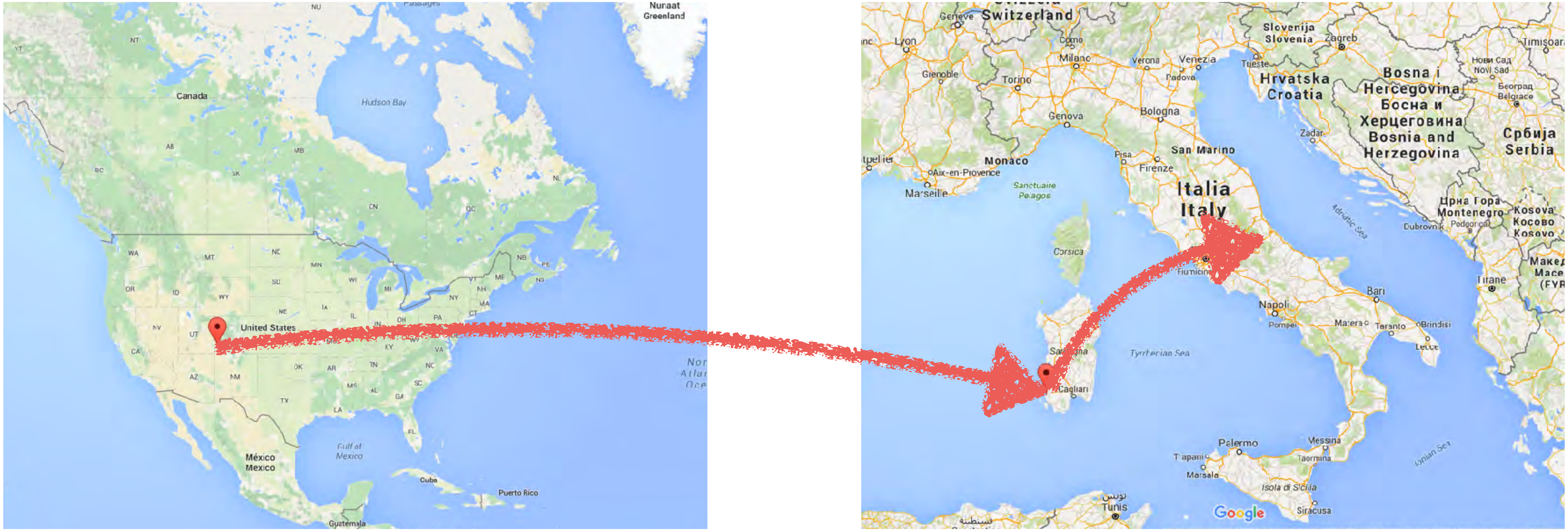
DarkSide-20k

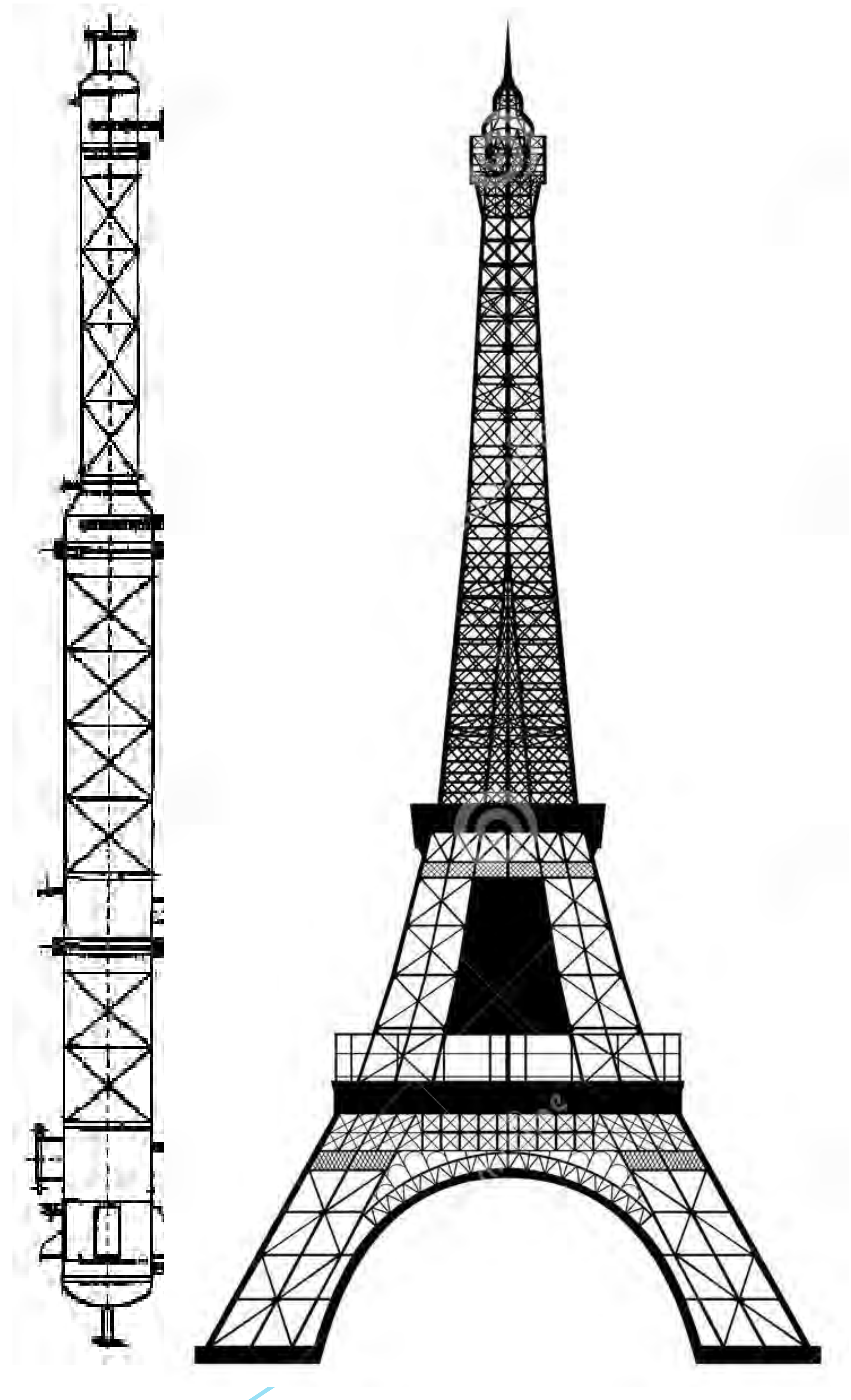
20-tonnes fiducial dark matter detector
start of operations at LNGS within 2021
100 tonne×year background-free search for dark matter

Future 300-tonne Detector

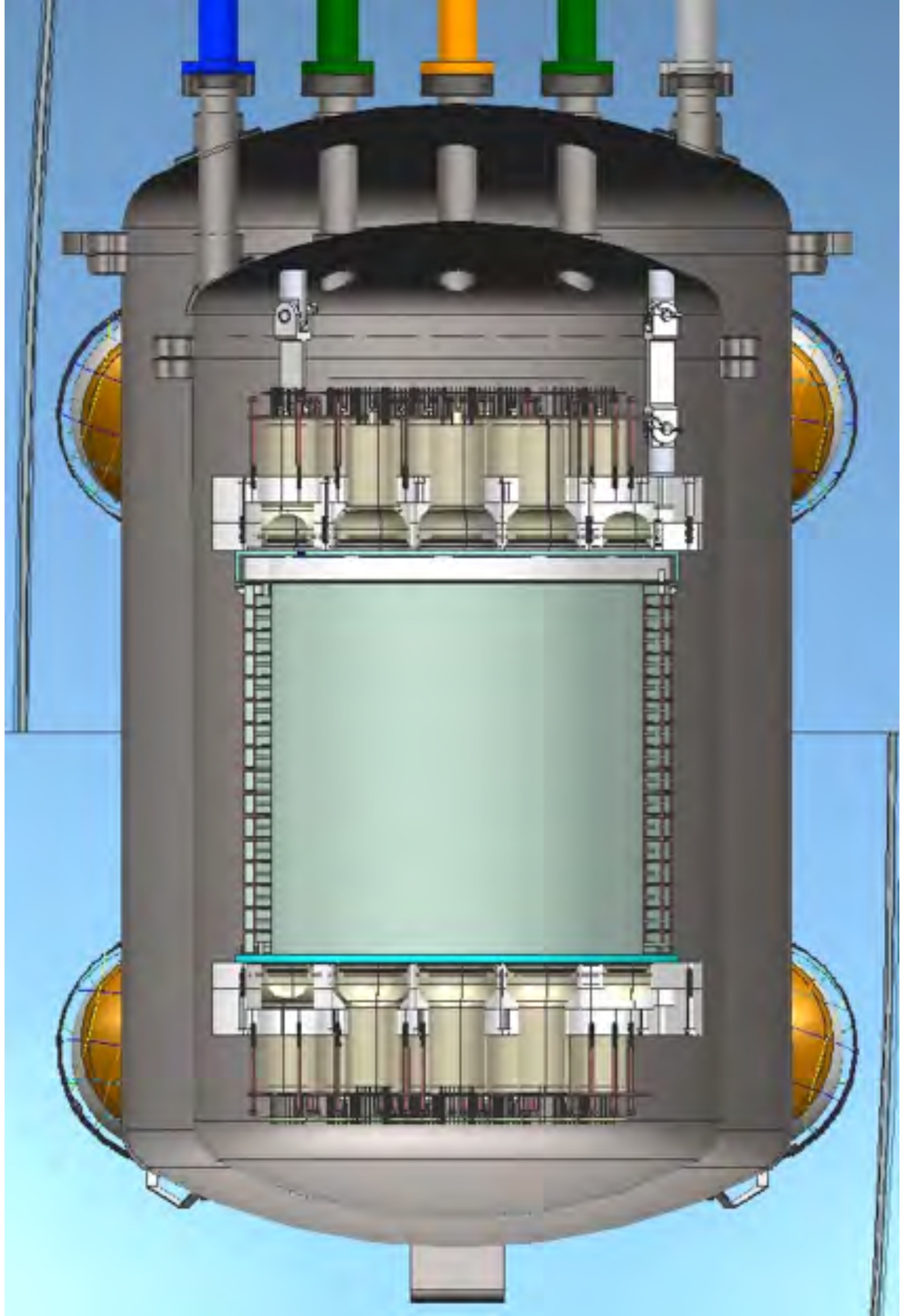
300-tonnes depleted argon detector
start of operations within 2026
1,000 tonne×year background-free search for dark matter
precision measurement of solar neutrinos

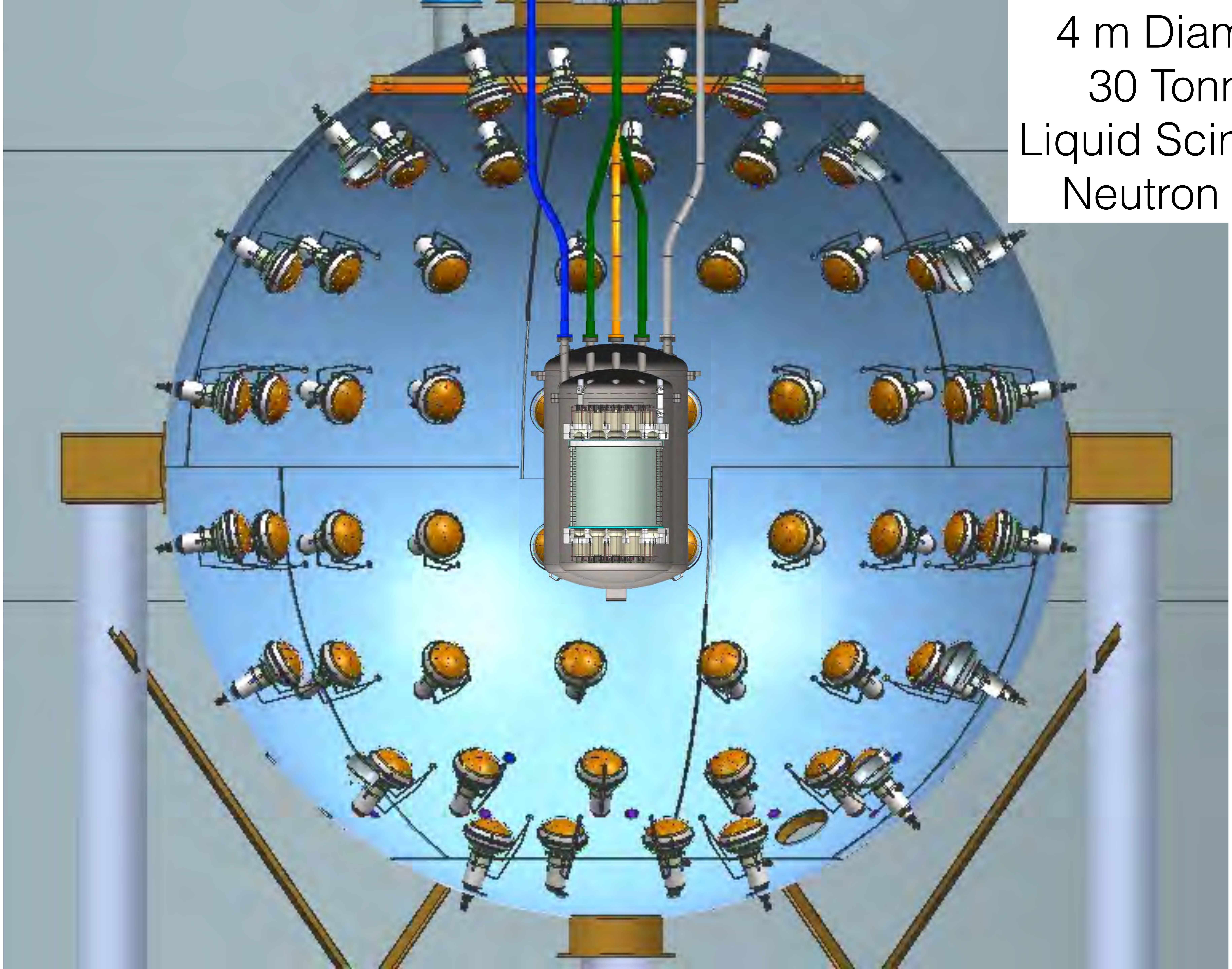
Urania to Aria to LNGS





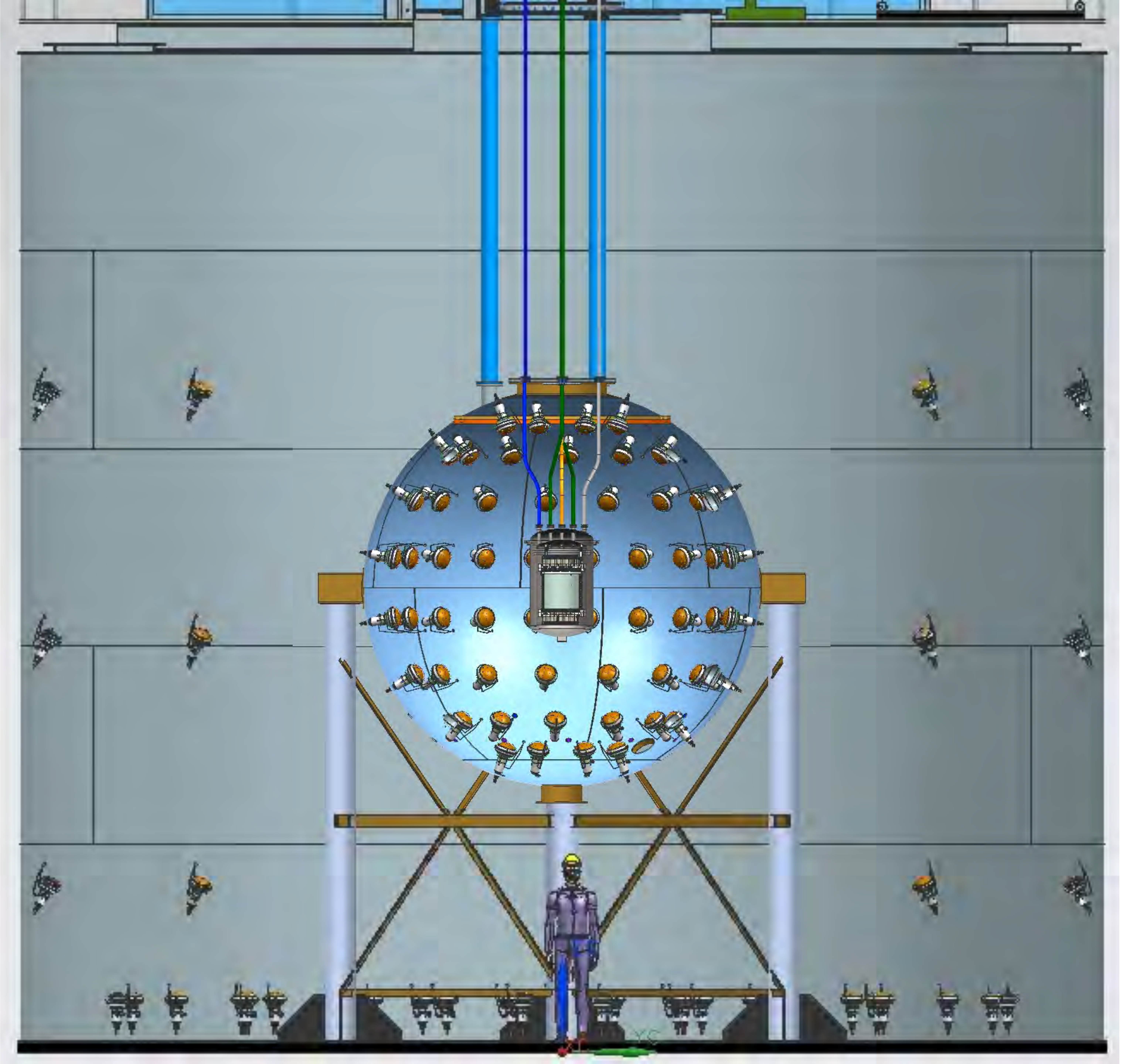
Liquid Argon TPC
153 kg ^{39}Ar-Depleted
Underground Argon
Target





4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto

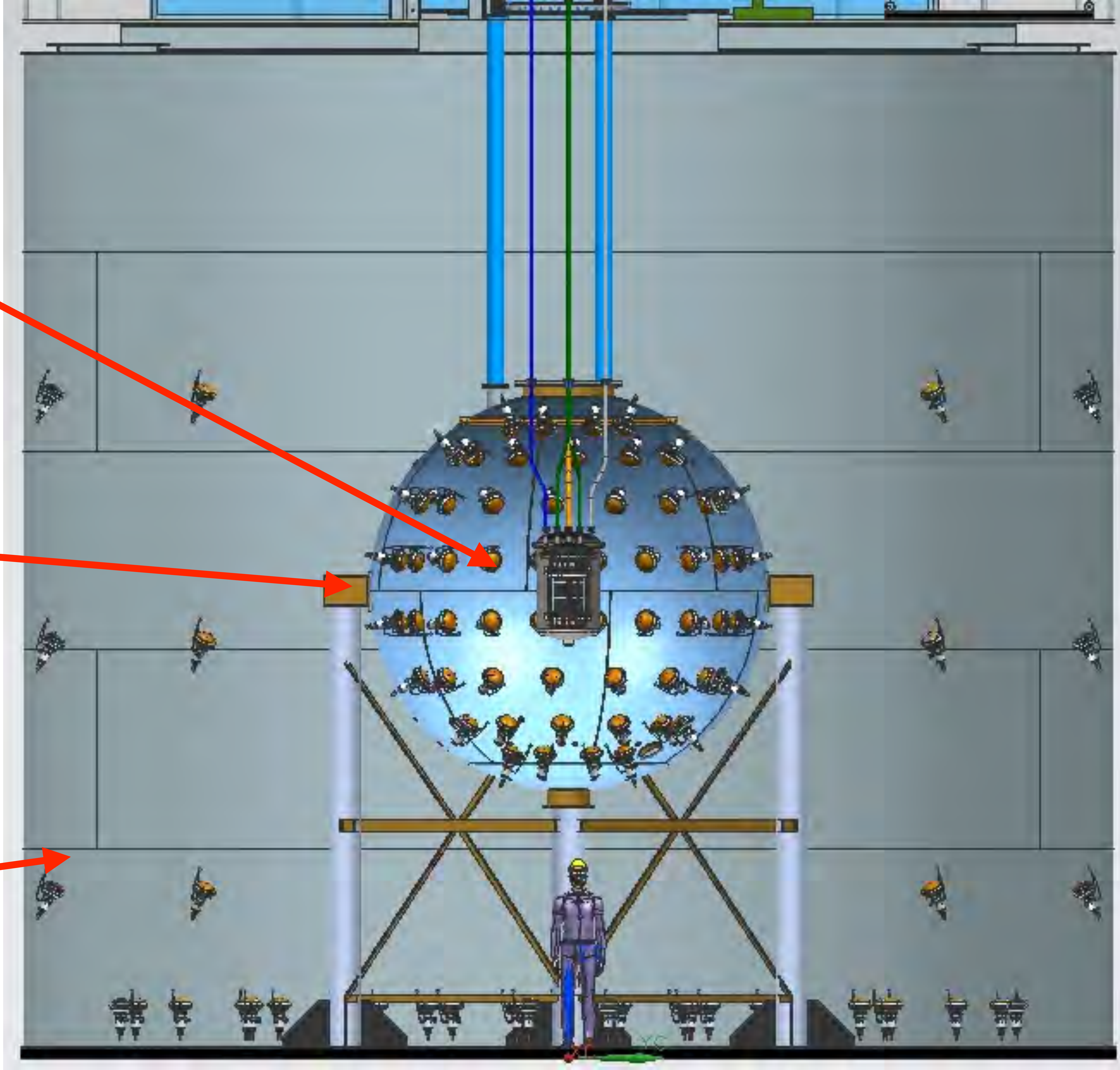
10 m Height
11 m Diameter
1,000 Tonnes
Water Cherenkov
Muon Veto



Liquid Argon TPC
153 kg ^{39}Ar-Depleted
Underground Argon
Target

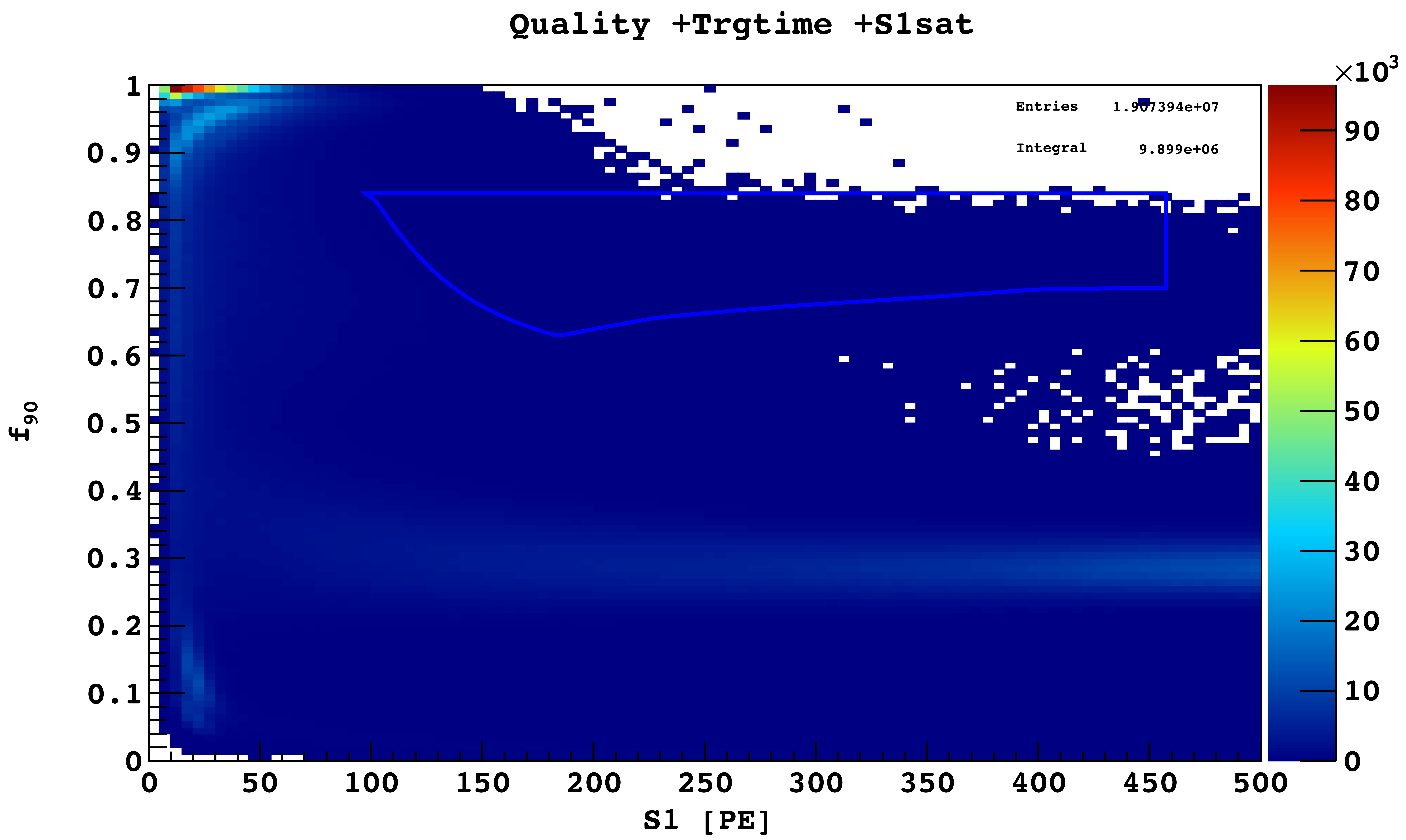
4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto

10 m Height
11 m Diameter
1,000 Tonnes
Water Cherenkov
Muon Veto

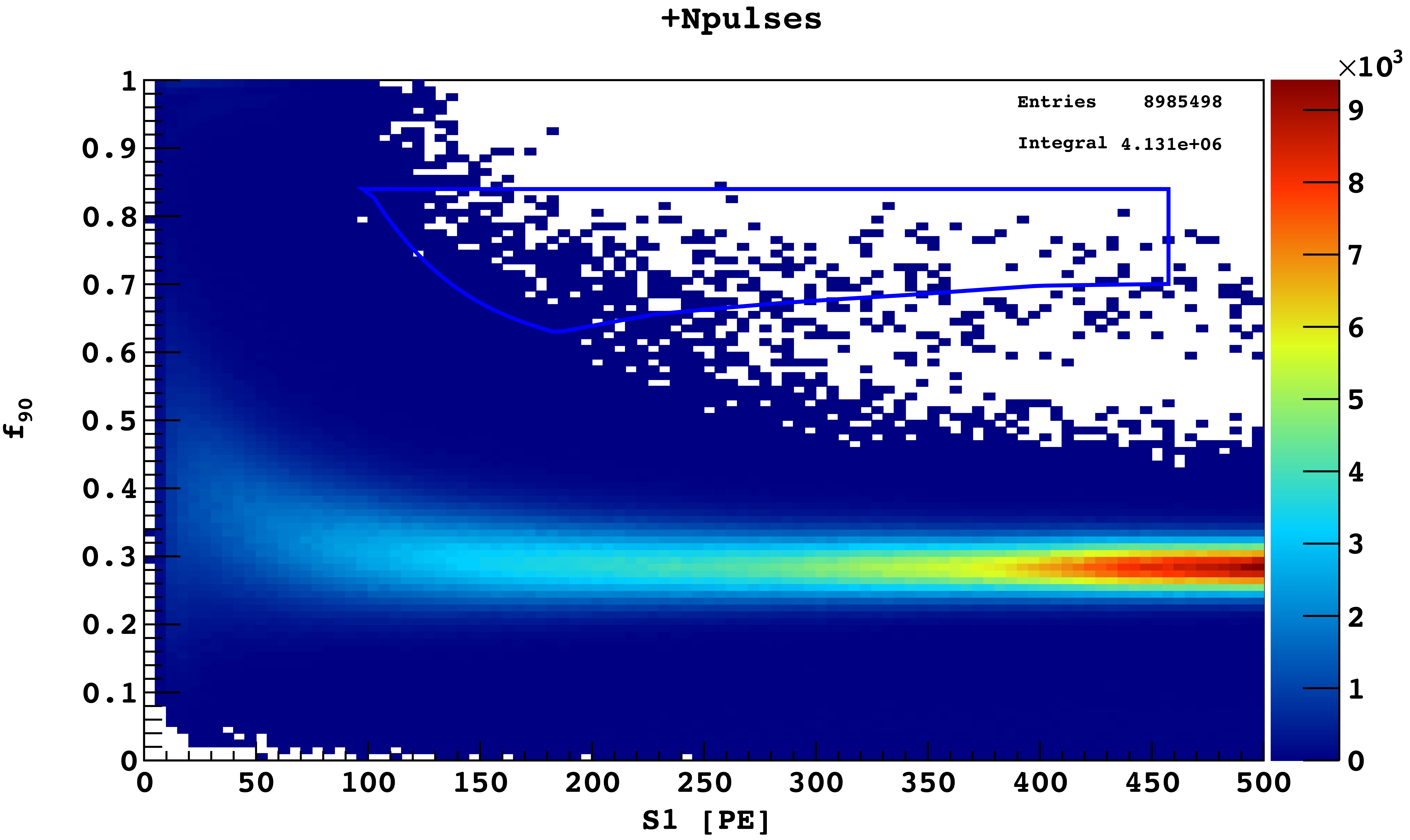


DarkSide-50

- P. Agnes et al. (The DarkSide Collaboration), "DarkSide-50 532-day Dark Matter Search with Low-Radioactivity Argon", arxiv:1802.07198.
- P. Agnes et al. (The DarkSide Collaboration), "Constraints on Sub-GeV Dark Matter-Electron Scattering from the DarkSide-50 Experiment", arxiv:1802.06998.
- P. Agnes et al. (The DarkSide Collaboration), "Low-mass Dark Matter Search with the DarkSide-50 Experiment", arxiv:1802.06994.

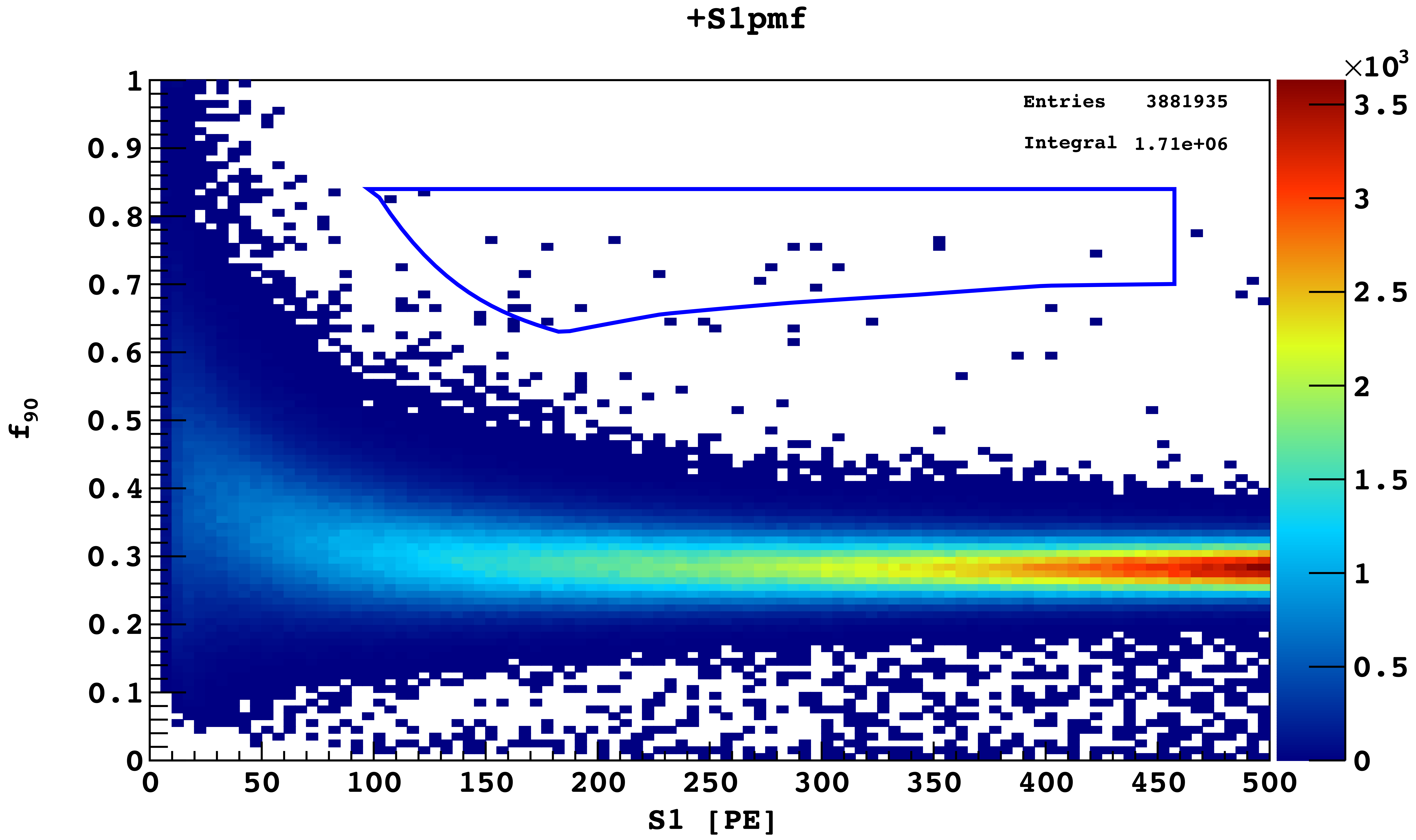


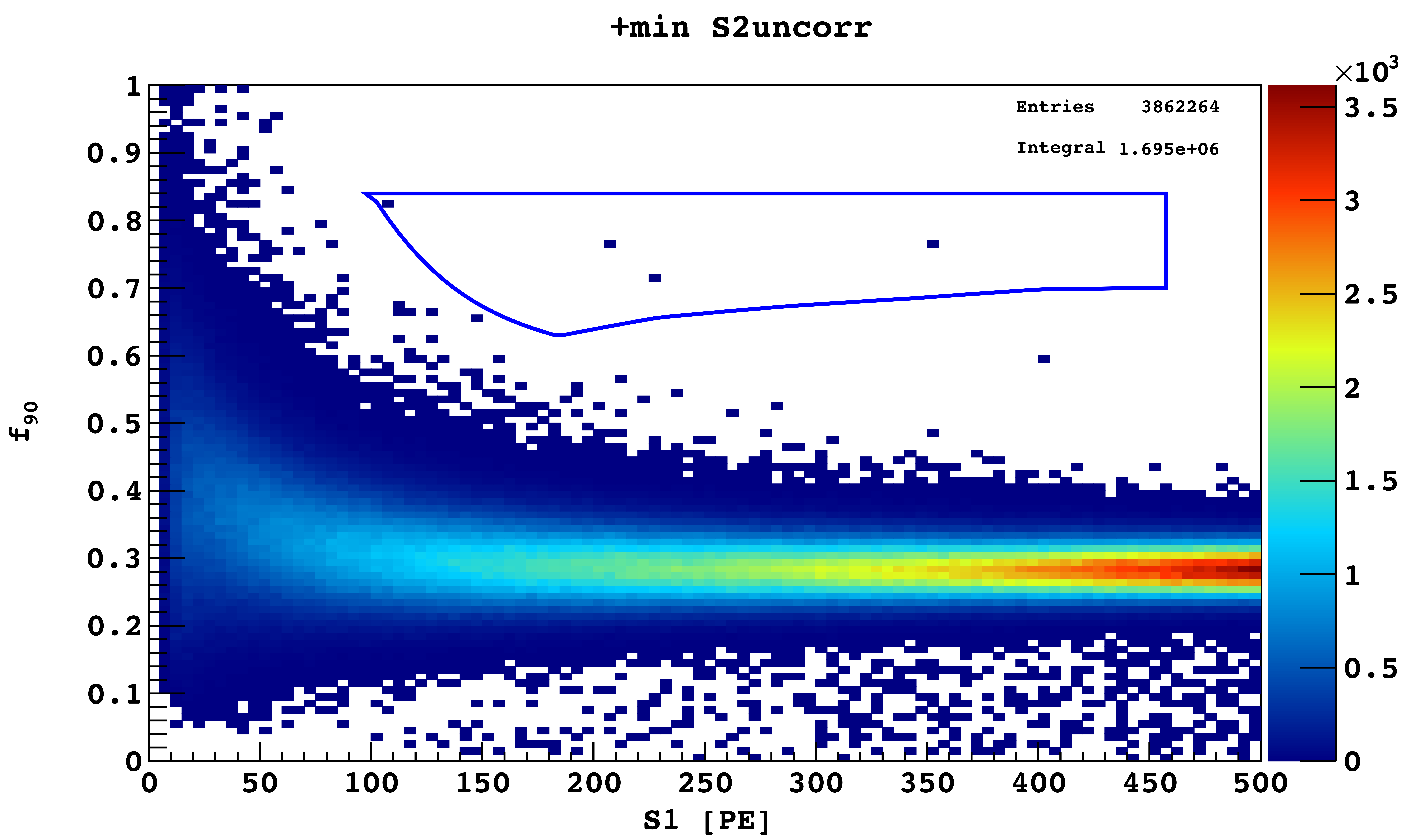
Quality +Trgtime +S1sat
Entries 1.907394e+07
Integral 9.899e+06
f_{90}
S1 [PE]
$\times 10^3$
0
10
20
30
40
50
60
70
80
90
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500

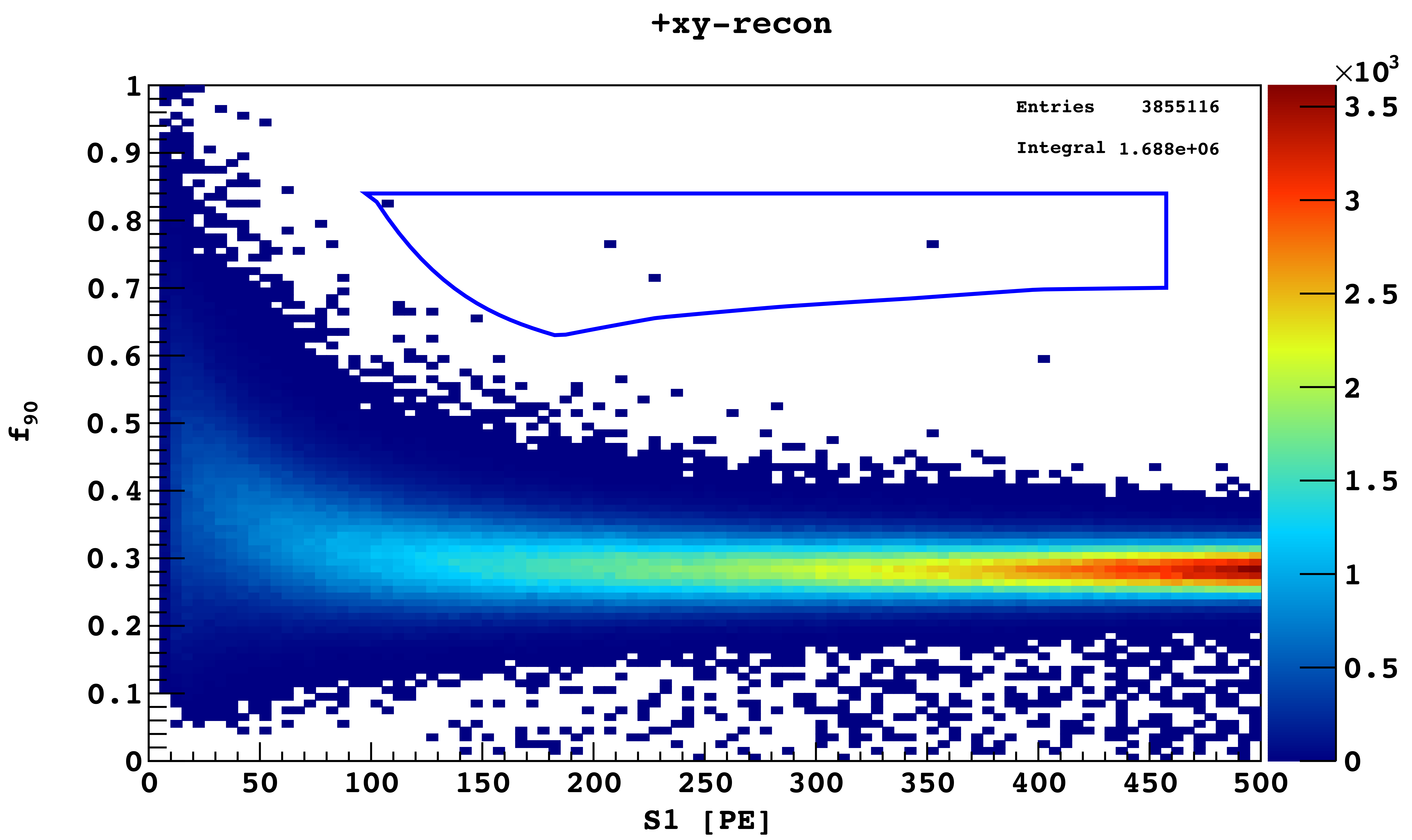


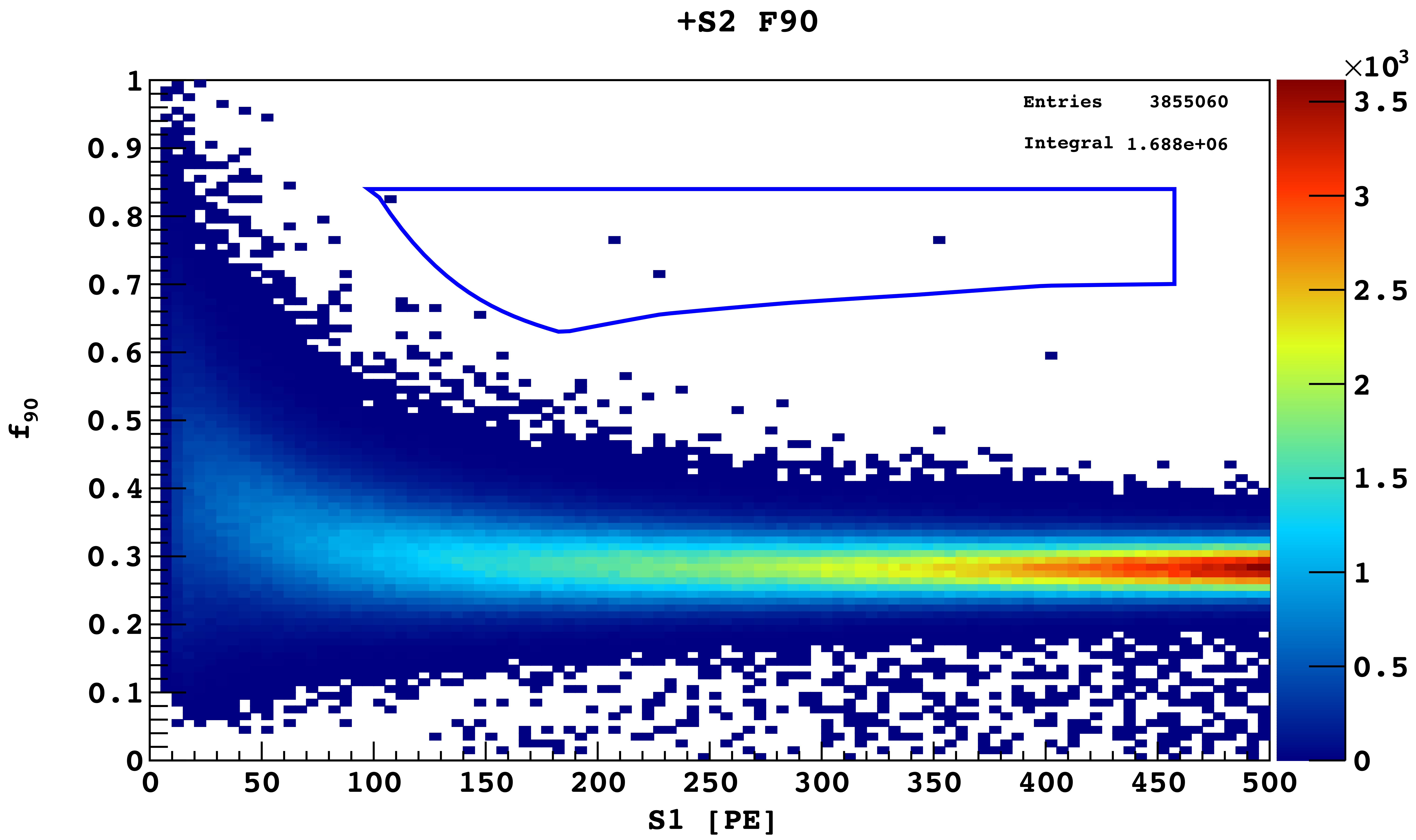
+Npulses
Entries 8985498
Integral 4.131e+06
$\times10^3$
f_{90}
S1 [PE]
0
50
100
150
200
250
300
350
400
450
500
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6
7
8
9

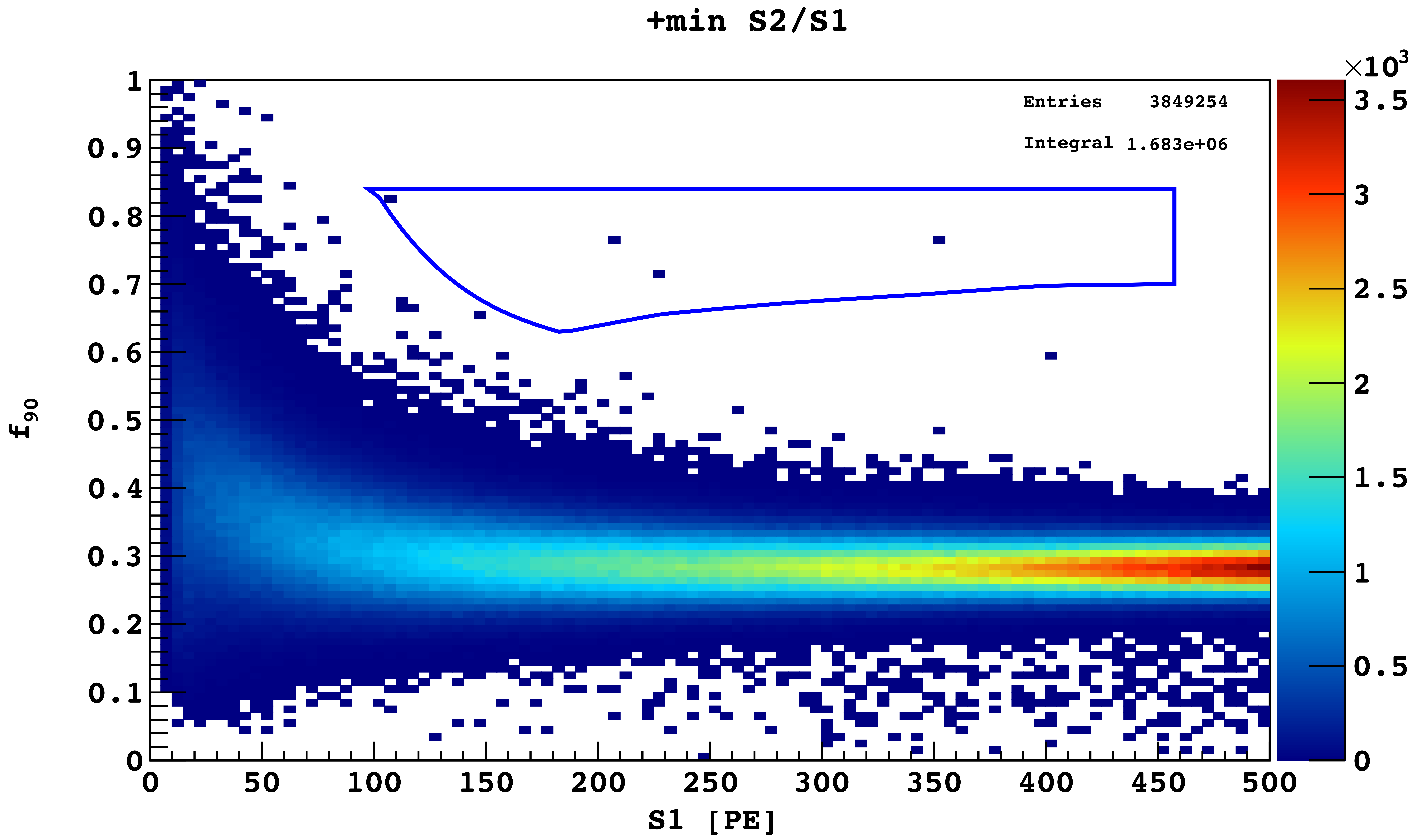
+40μs fid
Entries 4147304
Integral 1.838e+06
f90
S1 [PE]
×10³
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
0
0.5
1
1.5
2
2.5
3
3.5


+S1pmf
Entries 3881935
Integral 1.71e+06
f_{90}
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
×10³
0
0.5
1
1.5
2
2.5
3
3.5


+min S2uncorr
Entries 3862264
Integral 1.695e+06
f90
S1 [PE]
0
50
100
150
200
250
300
350
400
450
500
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
×10^3
0
0.5
1
1.5
2
2.5
3
3.5

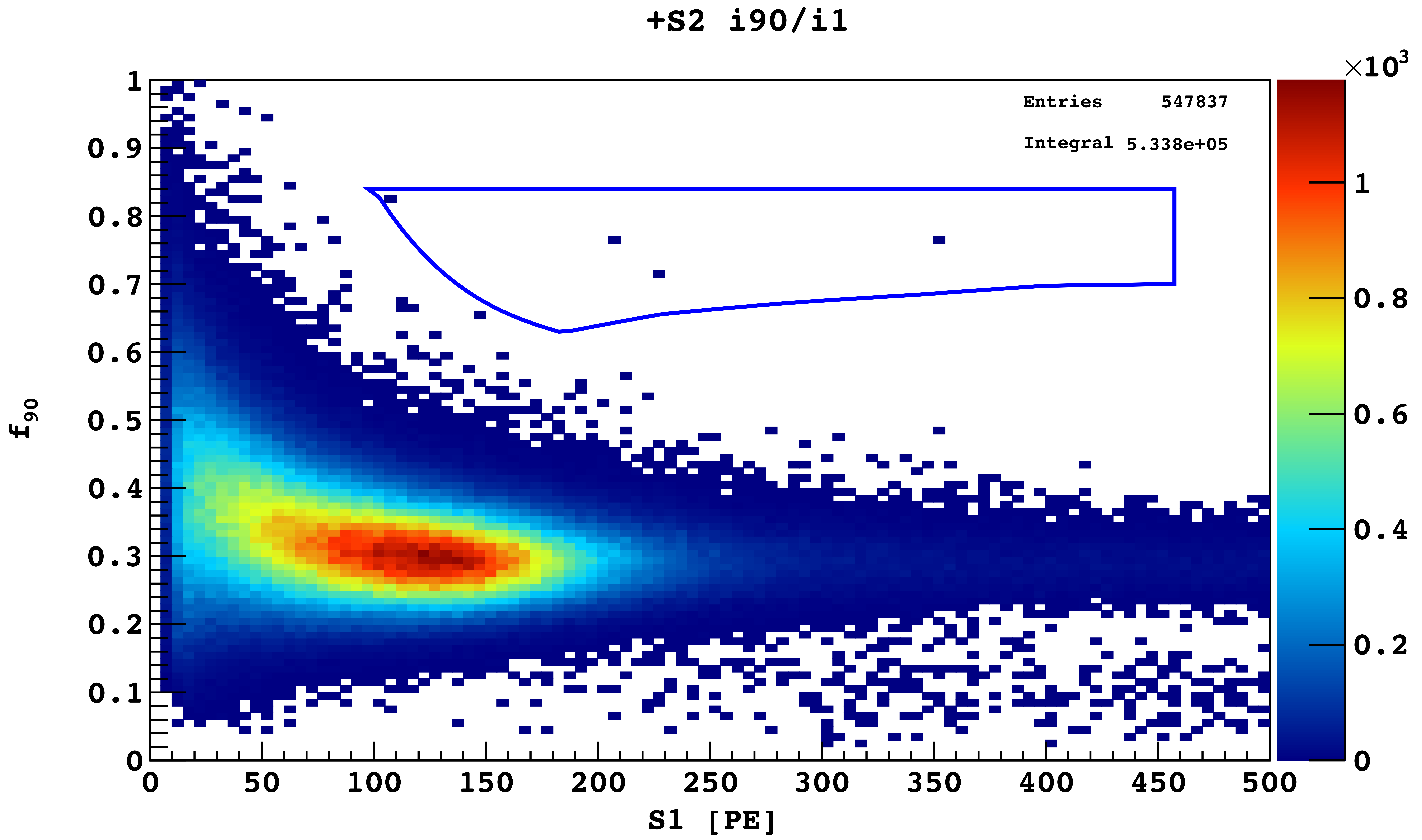

+xy-recon
Entries 3855116
Integral 1.688e+06
f_{90}
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
$\times10^3$
0
0.5
1
1.5
2
2.5
3
3.5


+S2 F90
Entries 3855060
Integral 1.688e+06
$\times 10^3$
0
0.5
1
1.5
2
2.5
3
3.5
f_{90}
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
S1 [PE]

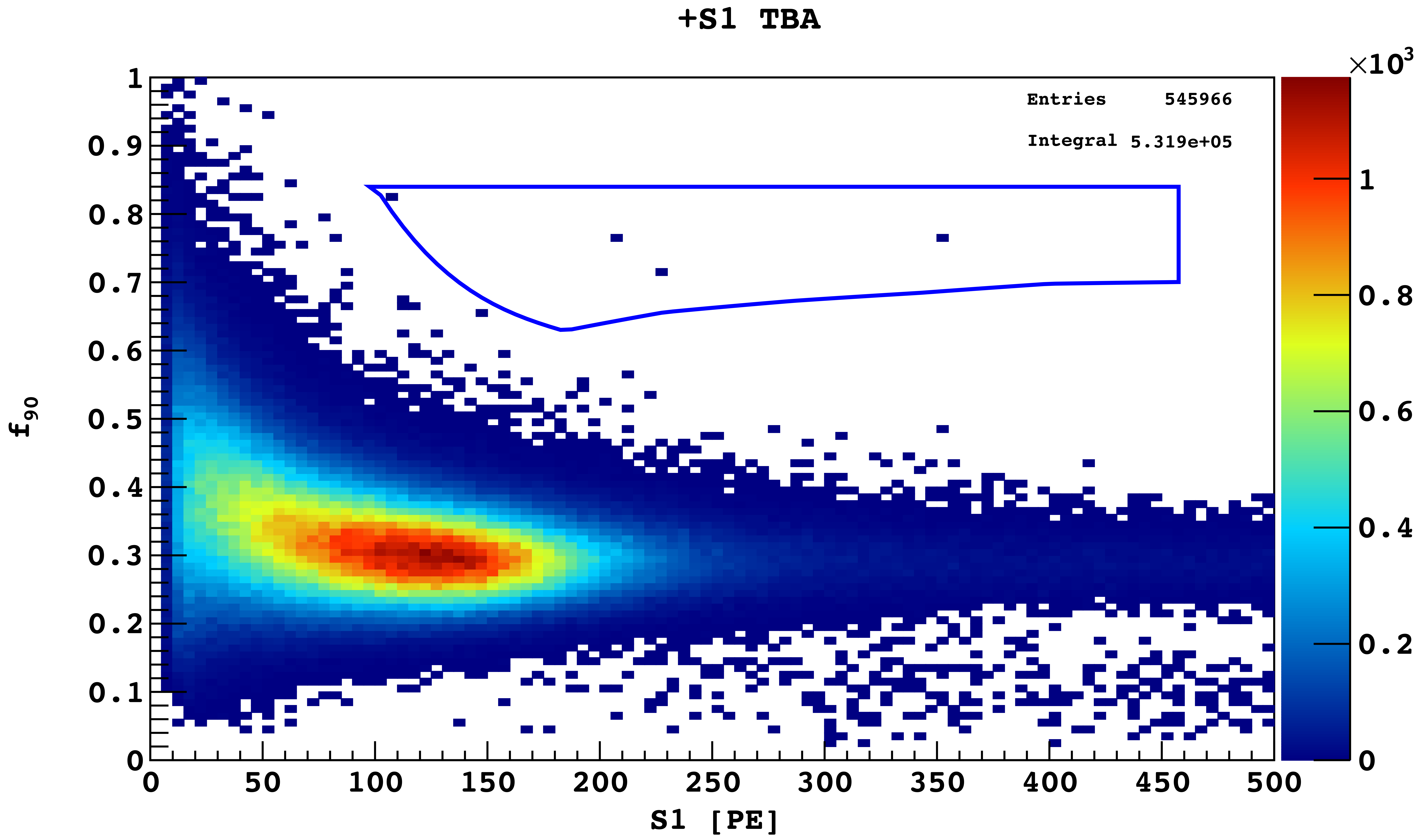


+min S2/S1
Entries 3849254
Integral 1.683e+06
f_{90}
S1 [PE]
$\times 10^3$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
0.5
1
1.5
2
2.5
3
3.5

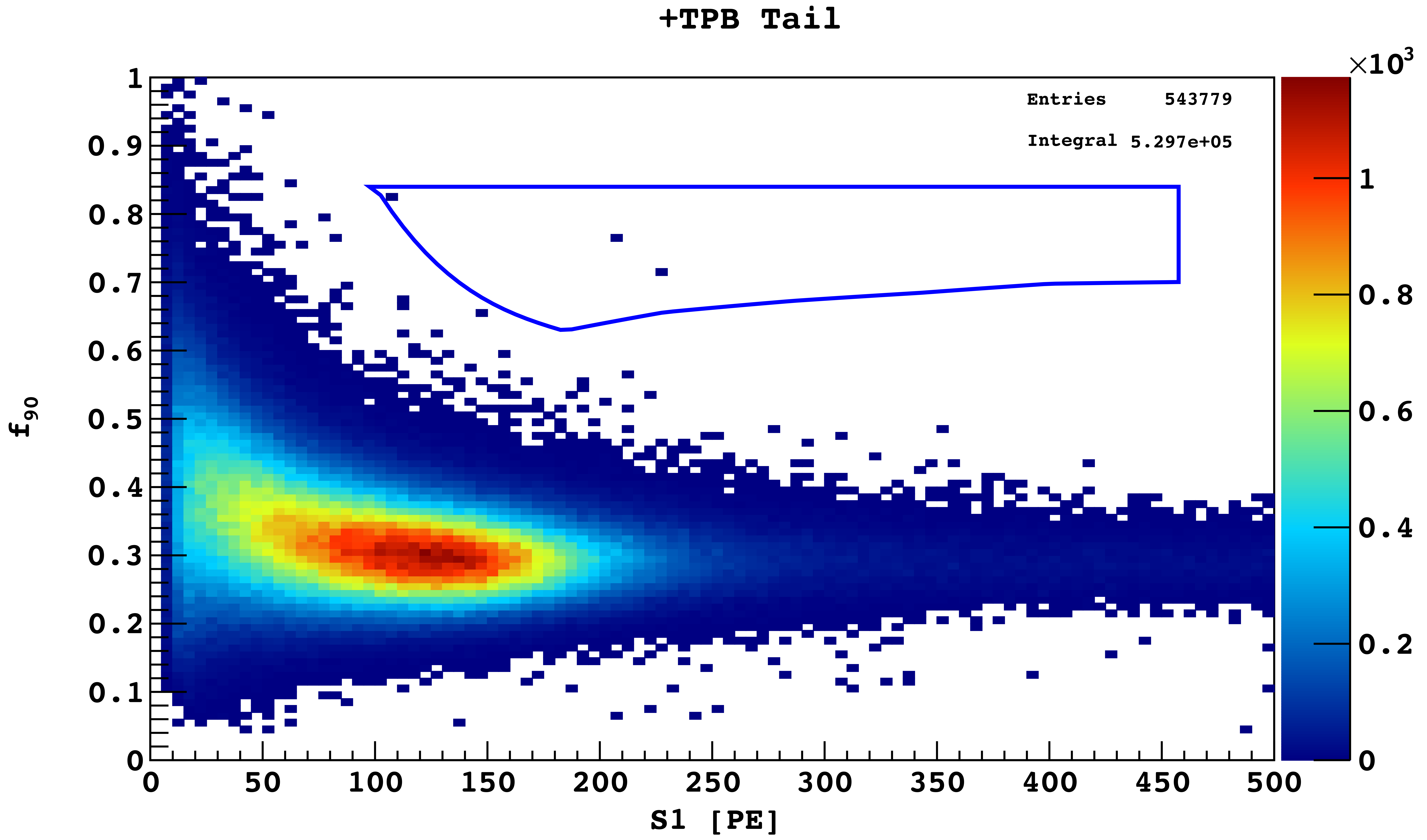
+max S2/S1
Entries 548087
Integral 5.34e+05
×10³
1
0.8
0.6
0.4
0.2
0
f₉₀
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
S1 [PE]



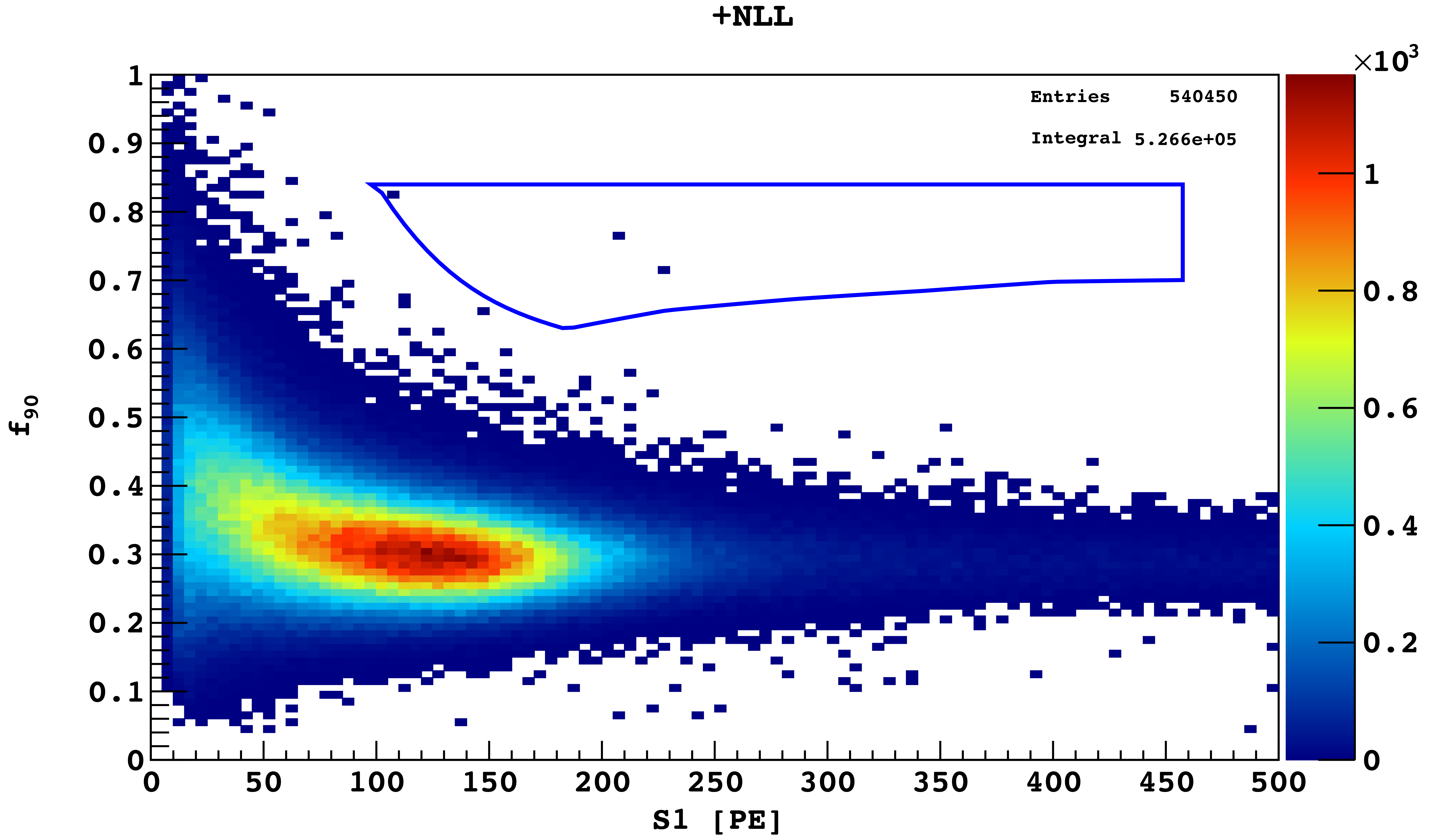
+S2 i90/i1
Entries 547837
Integral 5.338e+05
$\times10^3$
1
0.8
0.6
0.4
0.2
0
f_{90}
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
S1 [PE]



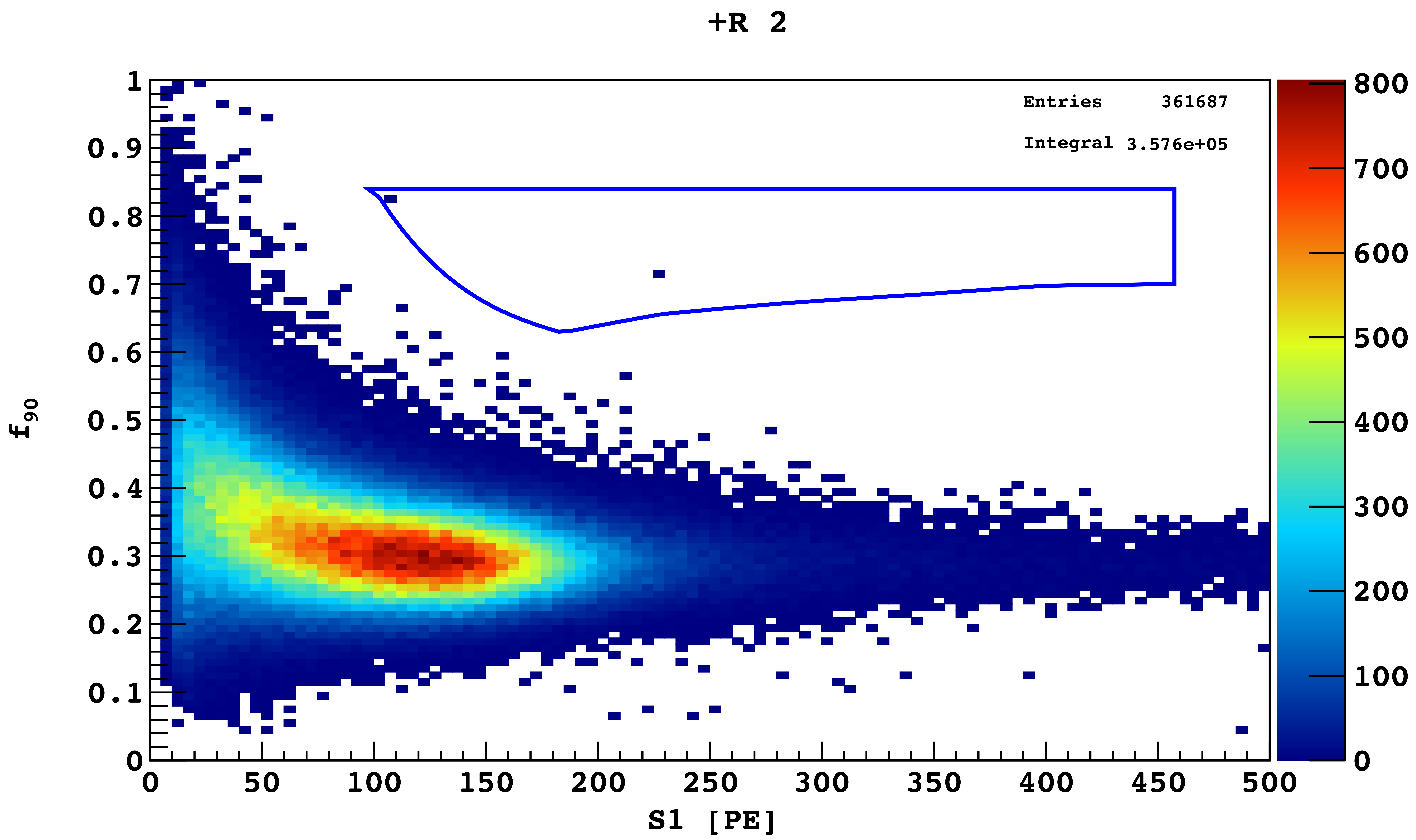
+S1 TBA
Entries 545966
Integral 5.319e+05
f_{90}
S1 [PE]
$\times 10^3$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
0
0.2
0.4
0.6
0.8
1



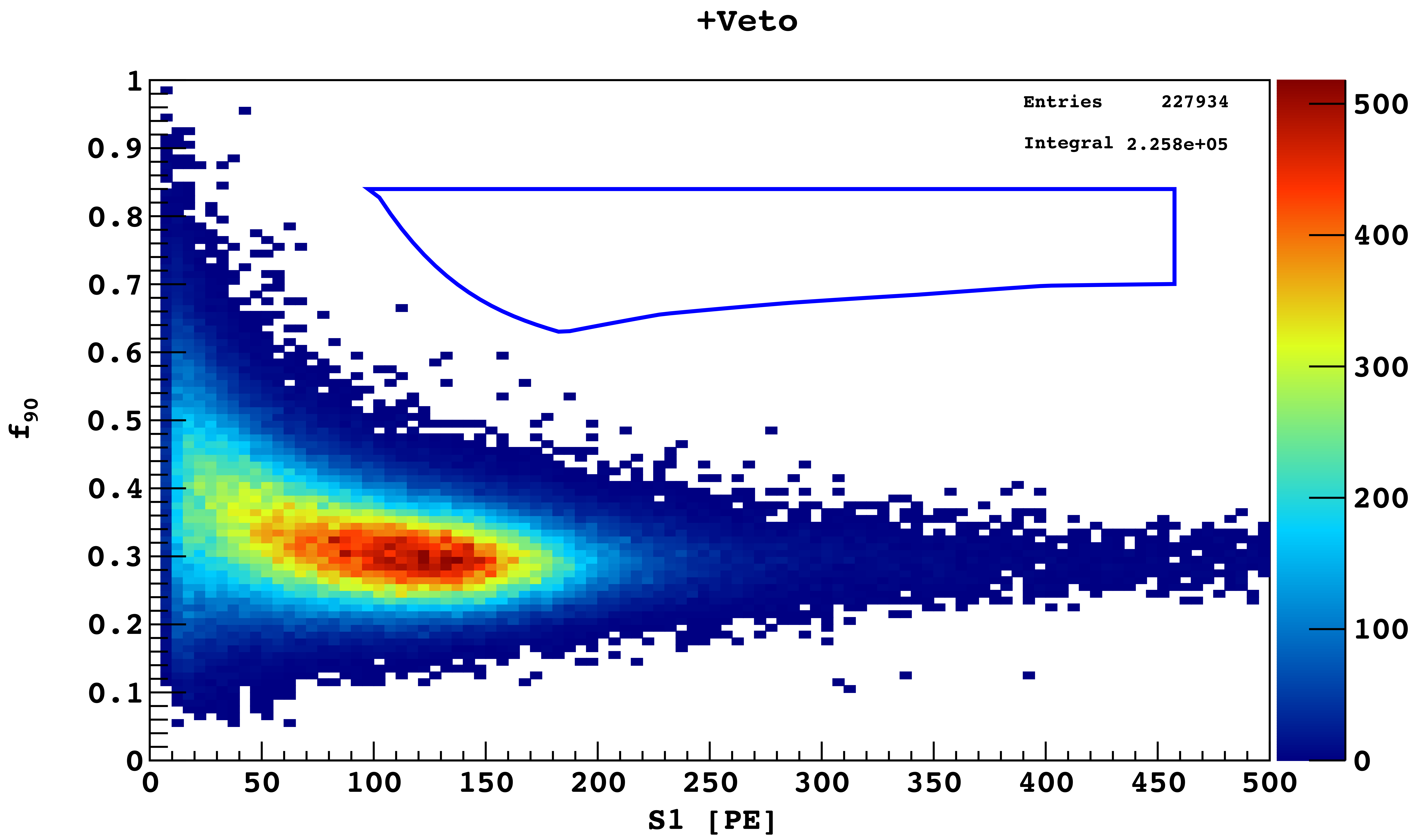
+TPB Tail
Entries 543779
Integral 5.297e+05
$\times10^3$
f_{90}
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
50
100
150
200
250
300
350
400
450
500



+NLL
Entries 540450
Integral 5.266e+05
f_{90}
S1 [PE]
$\times 10^3$

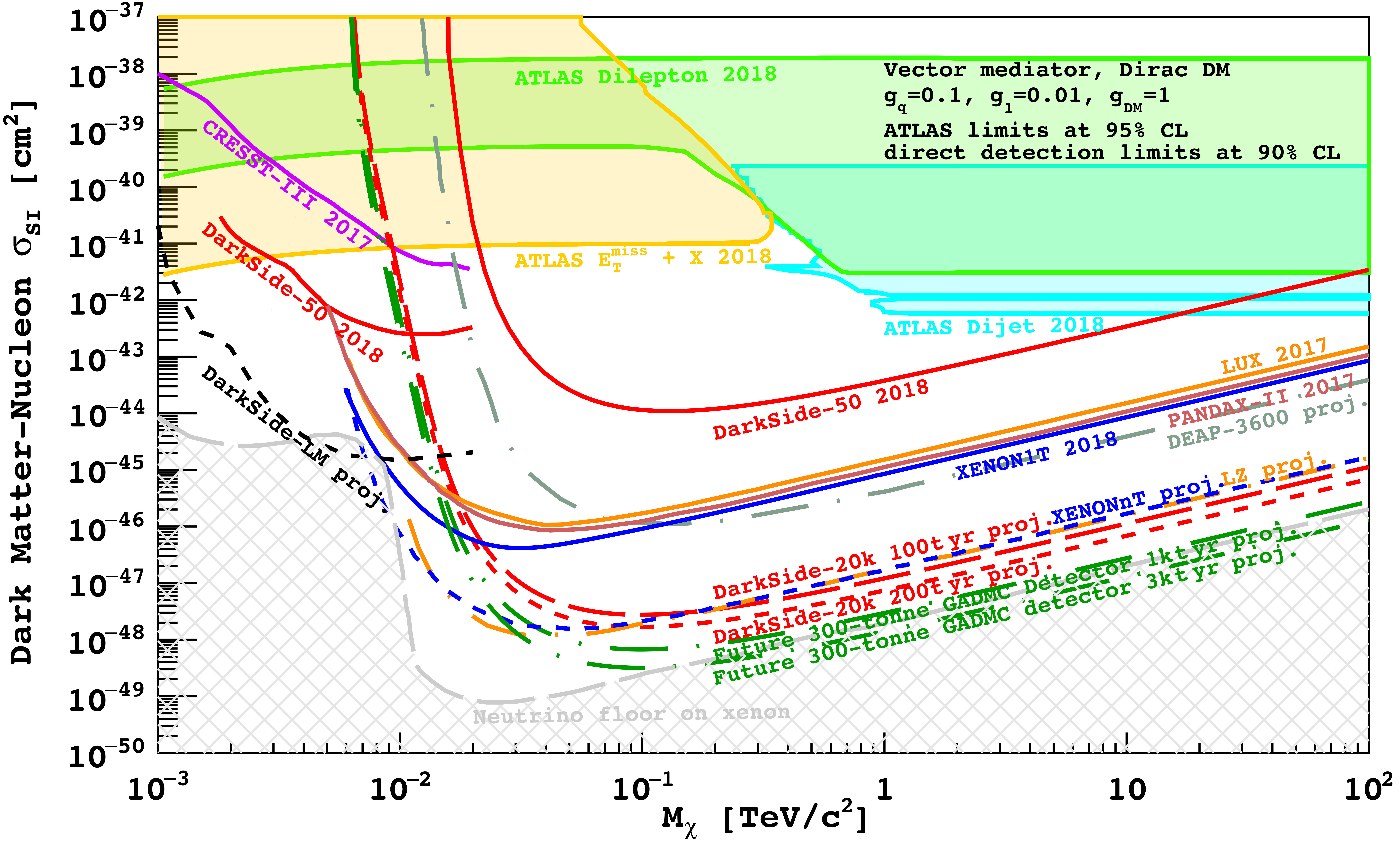


+R 2
Entries 361687
Integral 3.576e+05
f_{90}
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
50
100
150
200
250
300
350
400
450
500
600
700
800


+Veto
Entries 227934
Integral 2.258e+05
f_{90}
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500

+r<10 cm && 50% loss S2/S1 cut (70d)
14
Entries 16213
Integral 1.619e+04
f_{90}
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
50
100
150
200
250
300
350
400
450
500
10
20
30
40
50
60
70

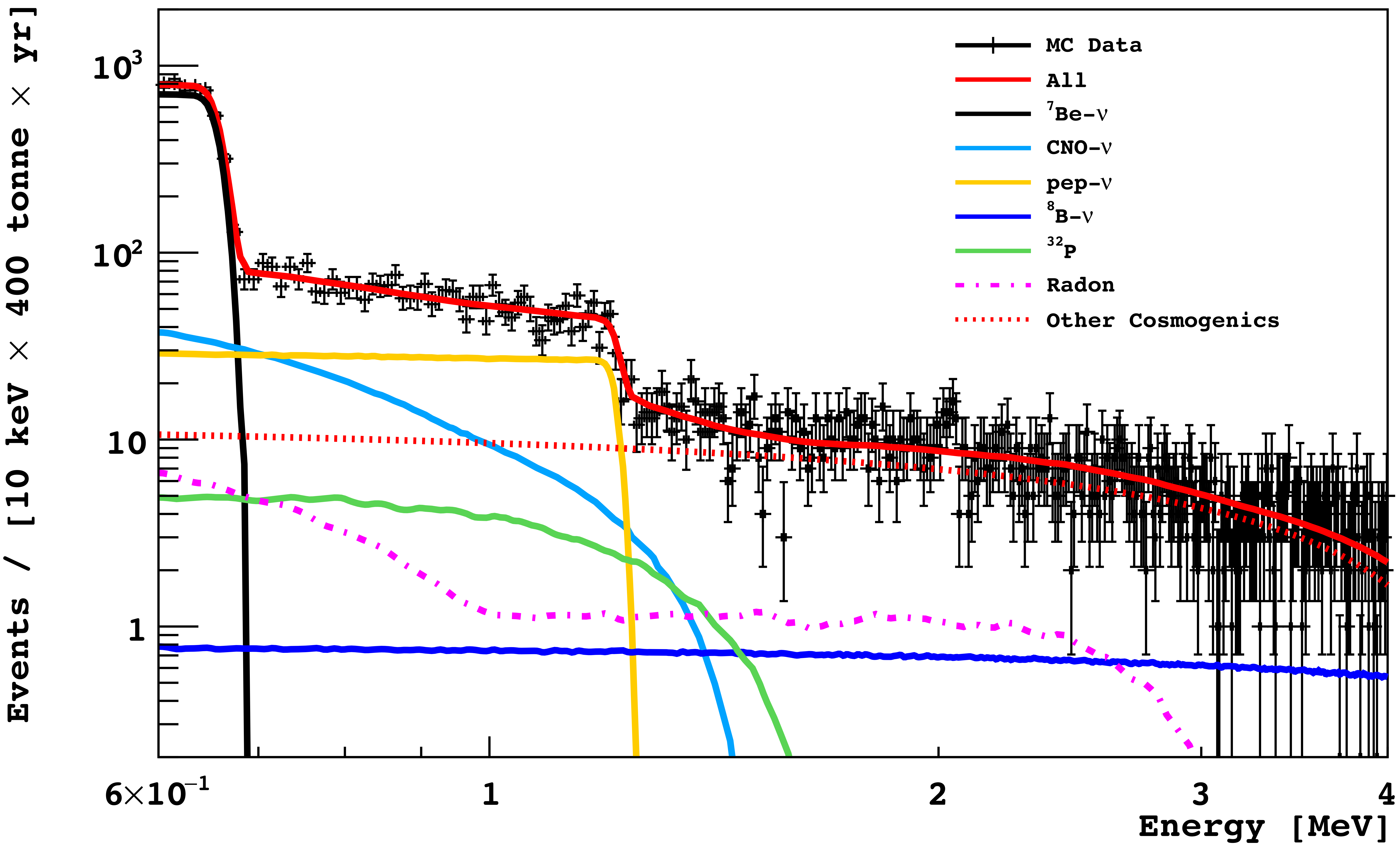
ER
Surface
Neutron
AC
WIMP
keV$_{NR}$
5
10
15
20
25
30
35
40
45
50
60
1σ
2σ
8000
4000
2000
1000
400
200
cS2$_b$ [PE]
0
3
10
20
30
40
50
60
70
cS1 [PE]
R [cm]
10
20
30
40
0.9 t
1.3 t
500
1000
1500
R^2 [cm^2]



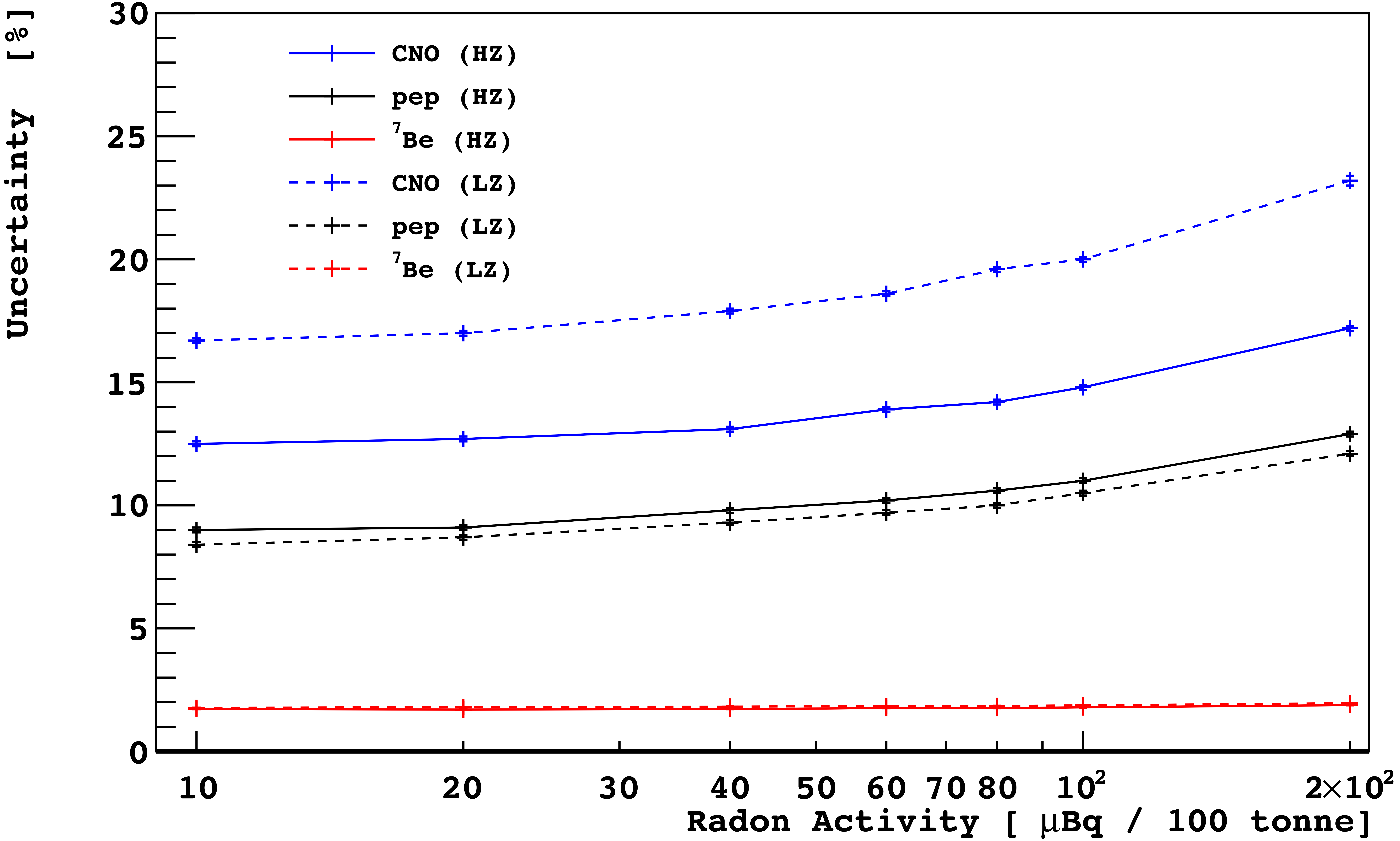
Vector mediator, Dirac DM
g_q=0.1, g_l=0.01, g_DM=1
ATLAS limits at 95% CL
direct detection limits at 90% CL
ATLAS Dilepton 2018
ATLAS E_T^miss + X 2018
ATLAS Dijet 2018
CRESST-III 2017
DarkSide-50 2018
DarkSide-50 2018
DarkSide-LM proj.
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
XENON1T 2018
XENONnT proj.
LZ proj.
DarkSide-20k 100t yr proj.
DarkSide-20k 200t yr proj.
Future 300-tonne GADMC Detector 1kt yr proj.
Future 300-tonne GADMC detector 3kt yr proj.
Neutrino floor on xenon
Dark Matter-Nucleon σ_SI [cm²]
M_χ [TeV/c²]

The DarkSide Strategy

- Background-free through the neutrino limit
- Neutrino limit reached with detector of few hundred tonnes located very deep underground
- Complementary science: solar neutrinos



Events / [10 keV × 400 tonne × yr]
10^3
10^2
10
1
6×10^{-1}
1
2
3
4
Energy [MeV]
MC Data
All
^{7}Be-ν
CNO-ν
pep-ν
^{8}B-ν
^{32}P
Radon
Other Cosmogenics

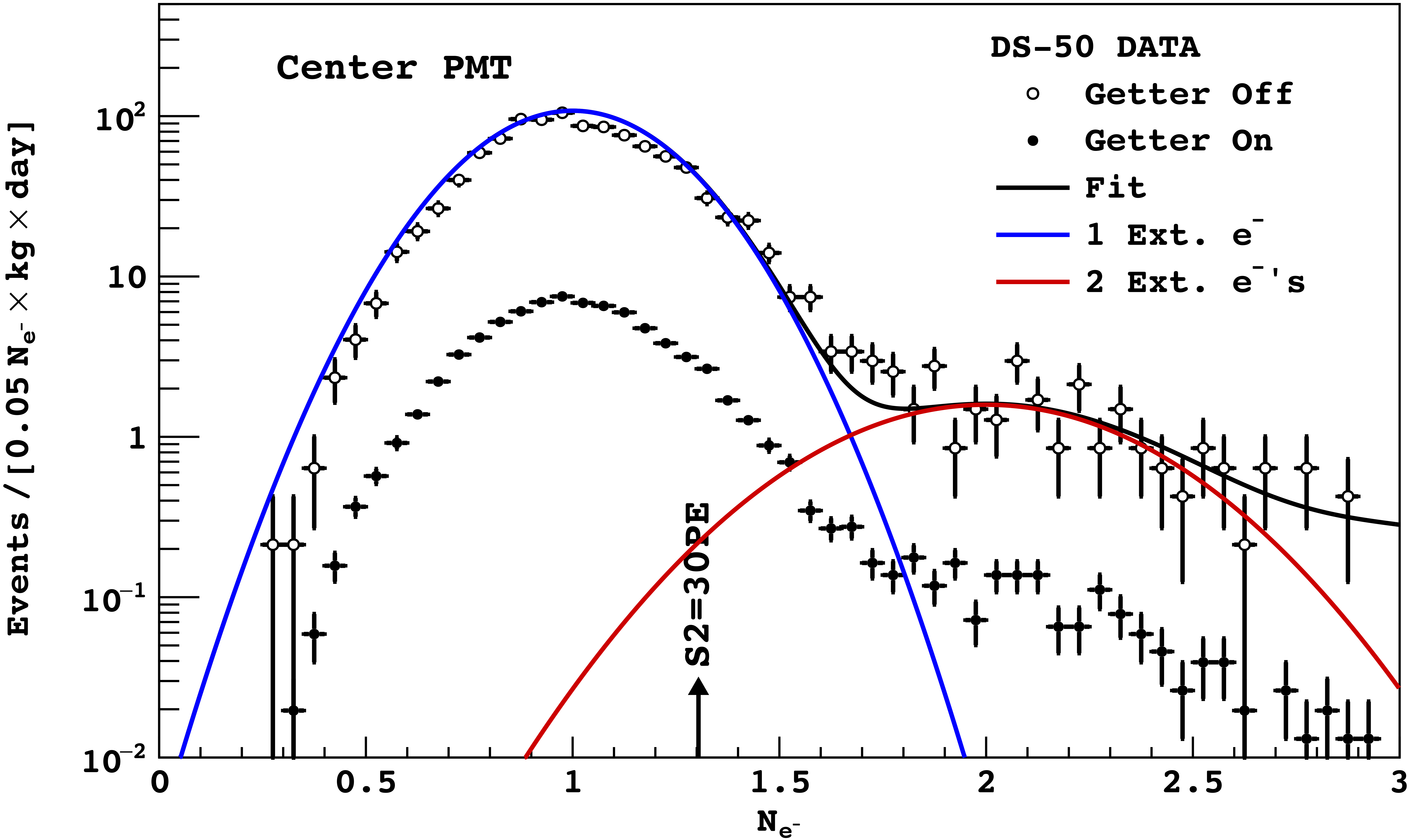


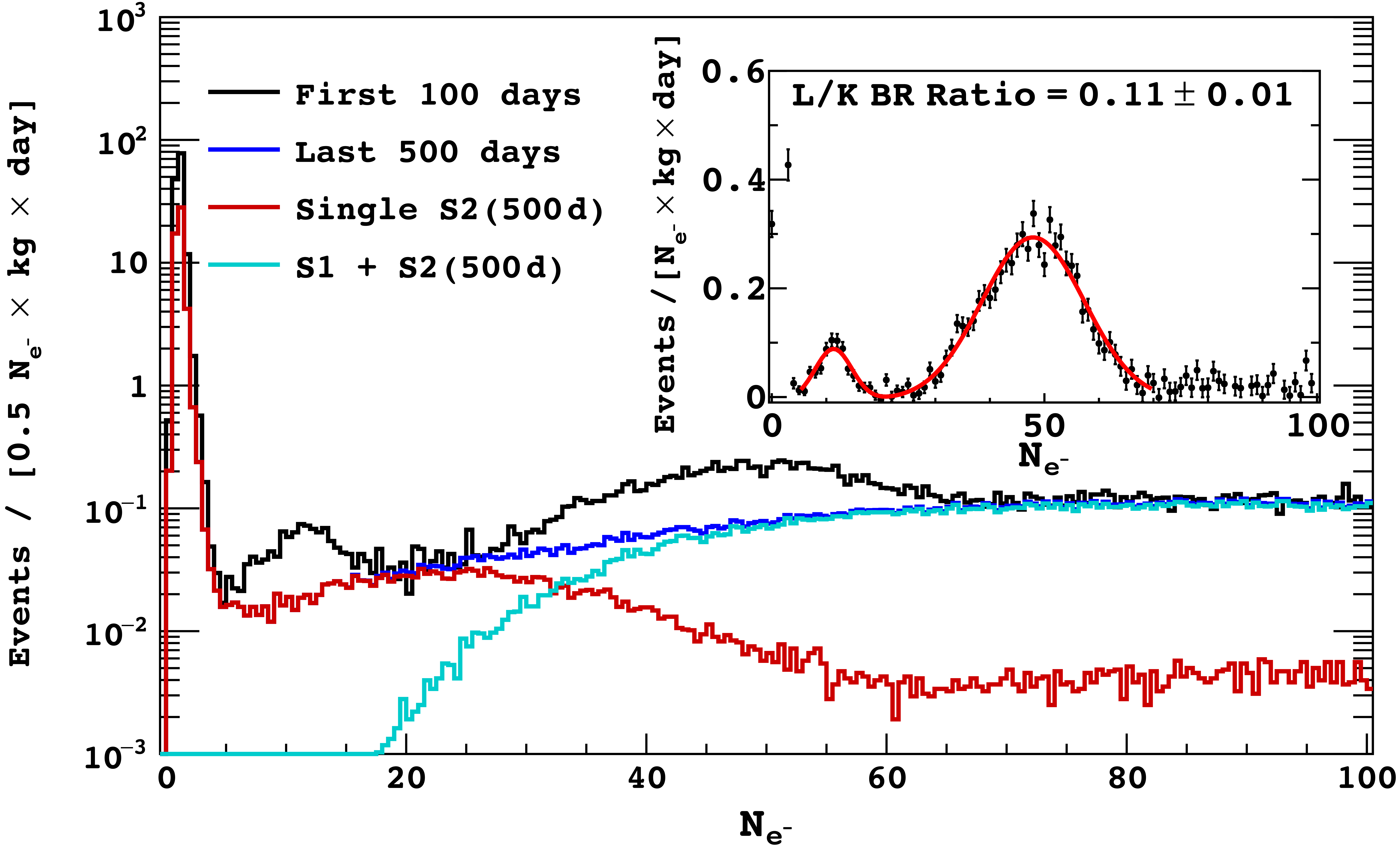
Uncertainty [%]
30
25
20
15
10
5
0
CNO (HZ)
pep (HZ)
^{7}Be (HZ)
CNO (LZ)
pep (LZ)
^{7}Be (LZ)
10
20
30
40
50
60
70
80
10^{2}
2×10^{2}
Radon Activity [μBq / 100 tonne]

Ionization-Only (S2-Only) Signals

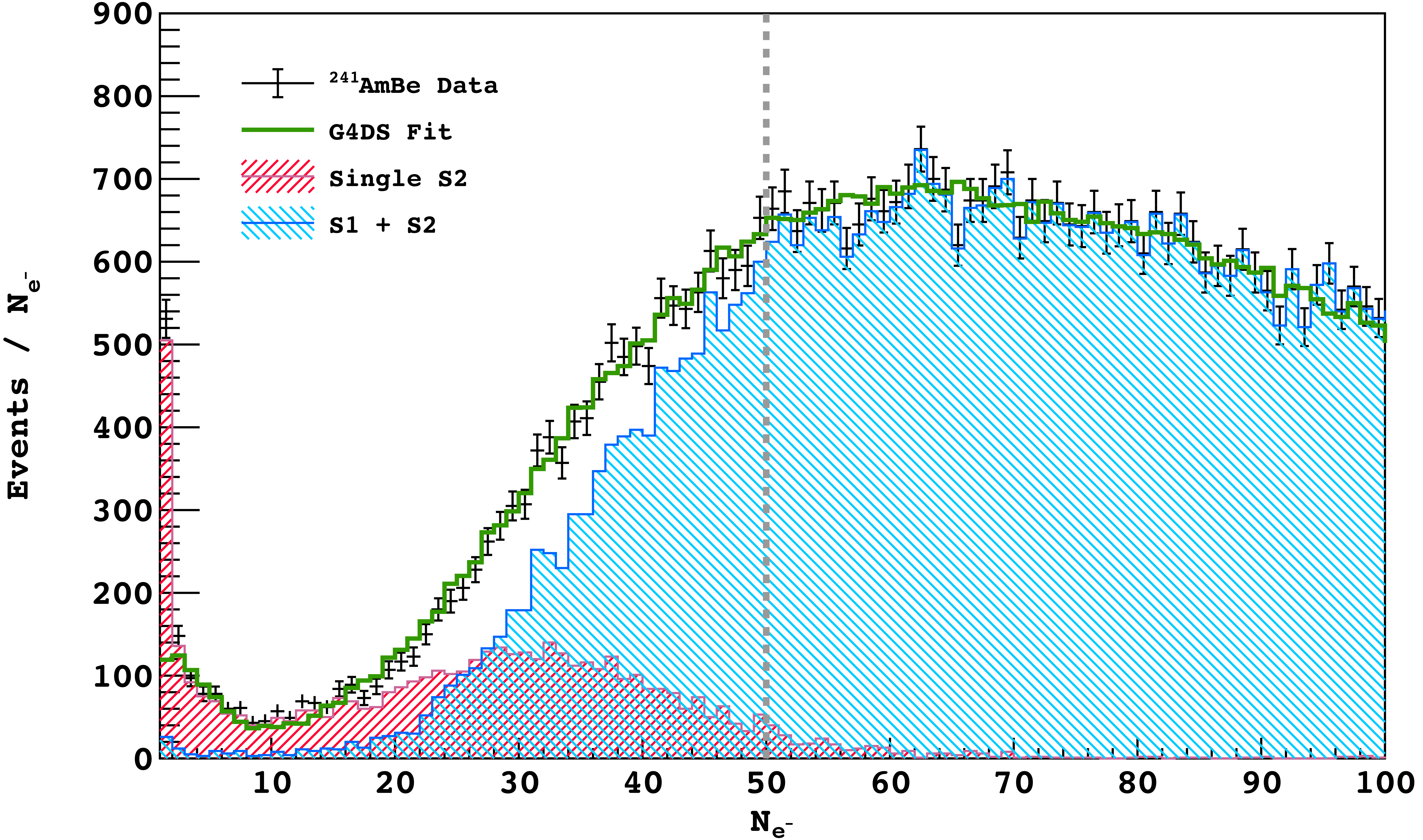
1. The PMTs have zero dark rate at 88 K so a signal is always real
2. The gain in the gas region (~70 PE/e^-, reduced to 23 PE/e^- when accounting for the 30% QE of the PMTs) means that we are sensitive to a single extracted electron
3. The radioactivity rate in the detector is remarkably low, so …
4. We don’t need PSD
5. The electron yield for nuclear recoils rises at low energy

0.4 e-
10 eV$_{ee}$
10% Detector Threshold
4 e-
100 eV$_{ee}$
Analysis Threshold
arxiv:1802.06994
Acceptance
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10
20
30
40
50
60
70
80
90
S2 [PE]
Fiducialization
× Trigger efficiency
× S2 Identification (f_{90}<0.15)

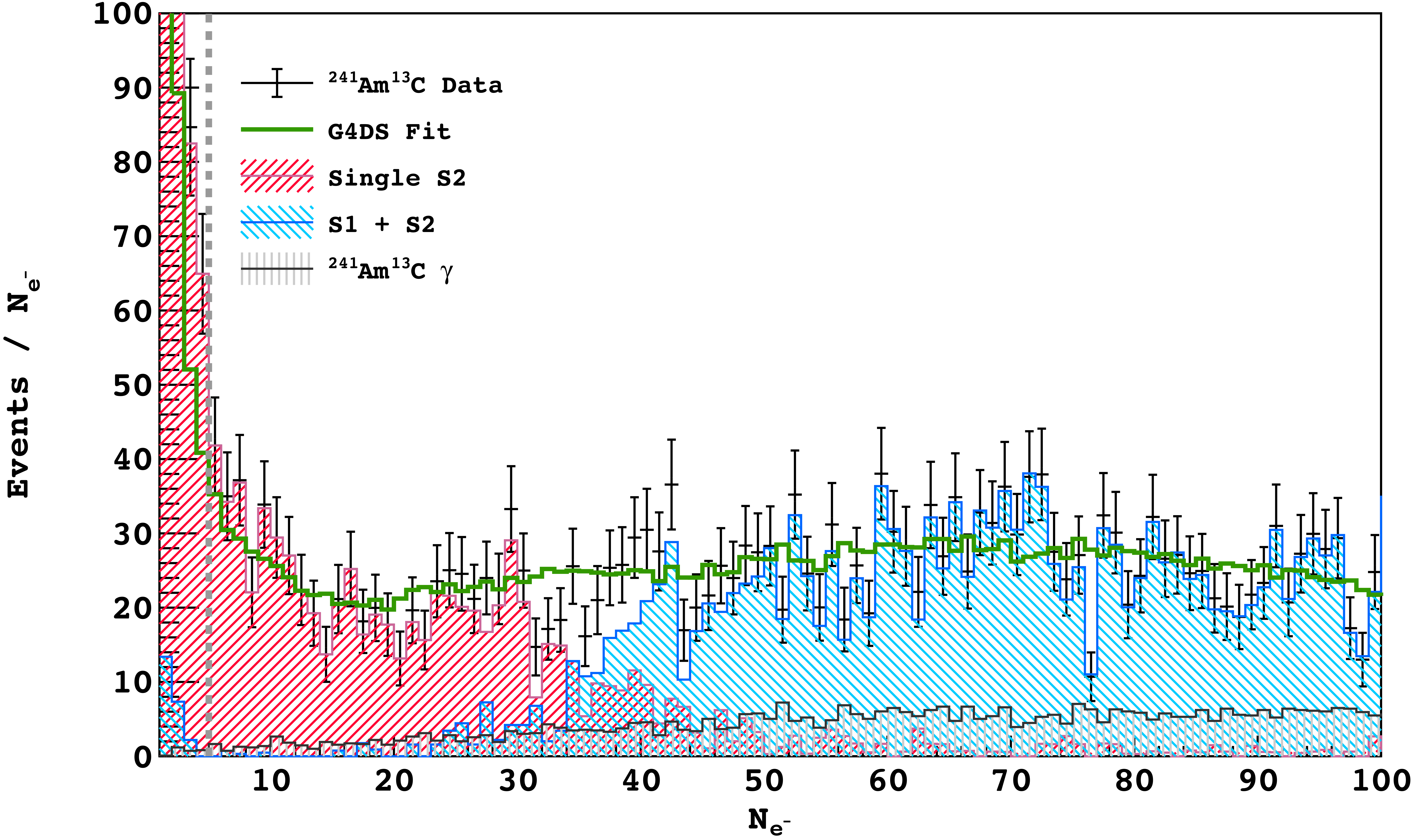

Center PMT
DS-50 DATA
Getter Off
Getter On
Fit
1 Ext. e⁻
2 Ext. e⁻'s
S2=30PE
Events / [0.05 N_{e^-} × kg × day]
N_{e^-}
10²
10
1
10⁻¹
10⁻²
0
0.5
1
1.5
2
2.5
3



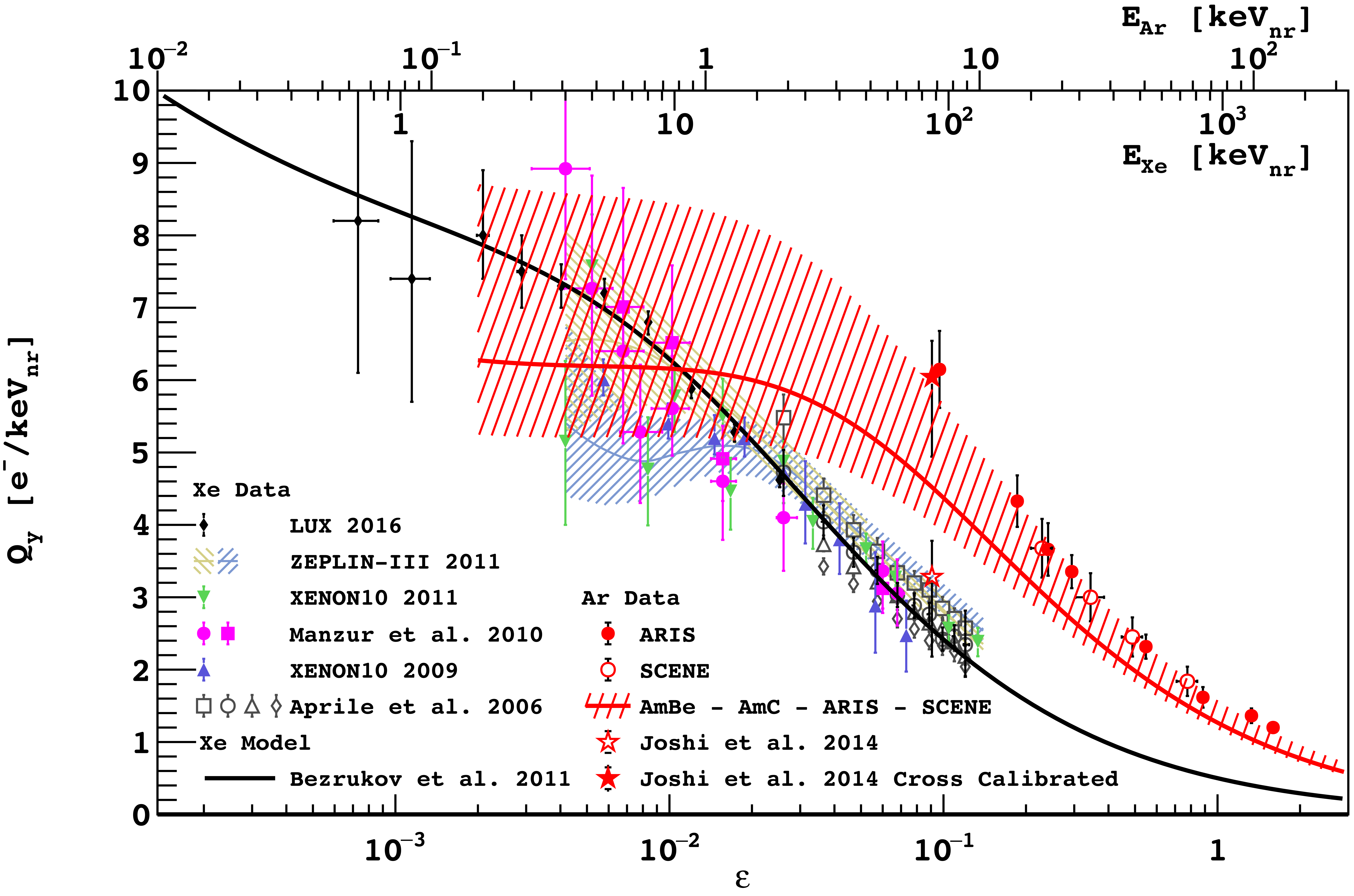
First 100 days
Last 500 days
Single S2(500d)
S1 + S2(500d)
L/K BR Ratio = 0.11 ± 0.01
Events / [0.5 N_e- × kg × day]
Events / [N_e- × kg × day]
N_e-



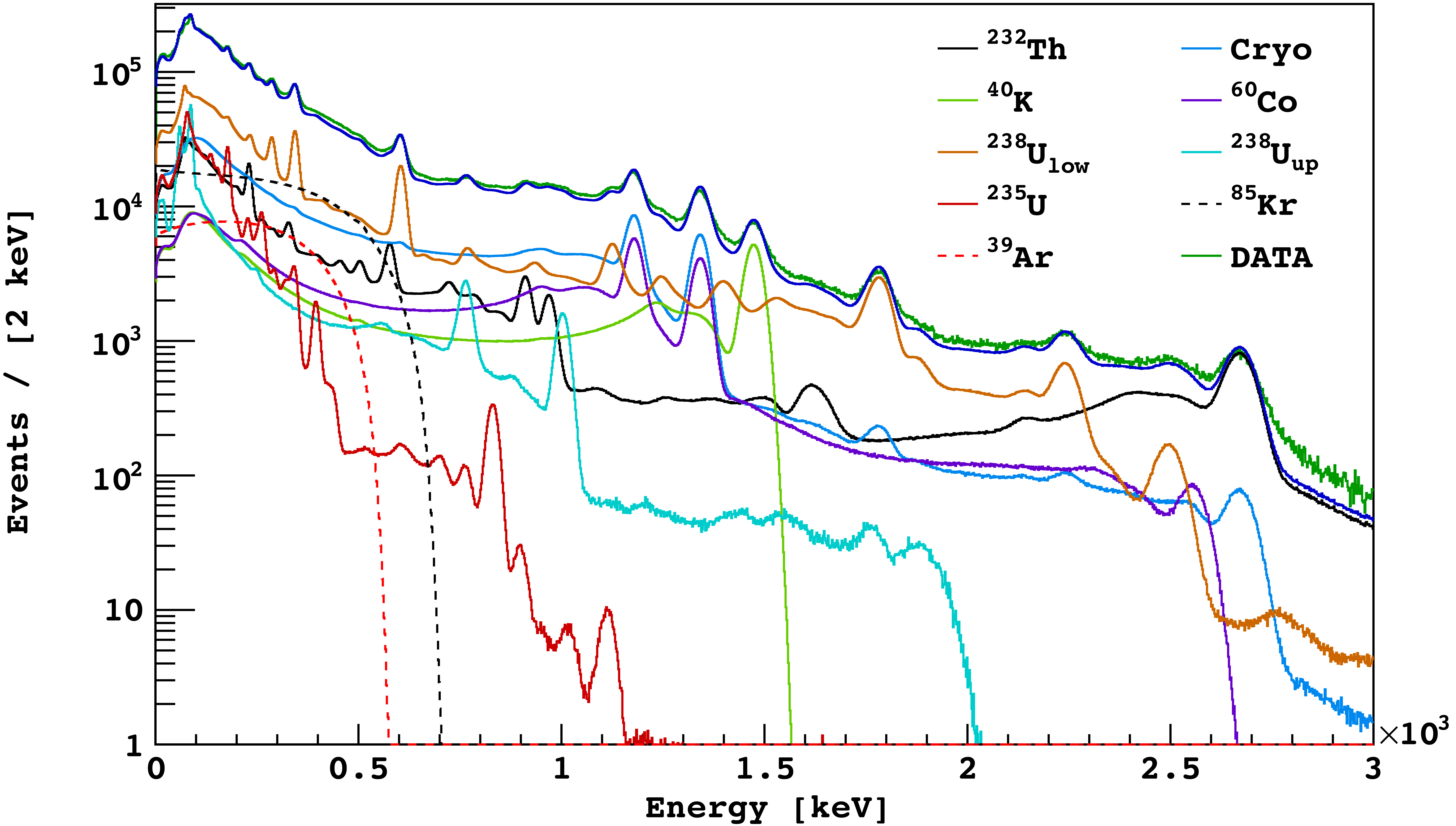
^{241}AmBe Data
G4DS Fit
Single S2
S1 + S2
Events / N_{e^-}
N_{e^-}
0
100
200
300
400
500
600
700
800
900
10
20
30
40
50
60
70
80
90
100



^{241}Am^{13}C Data
G4DS Fit
Single S2
S1 + S2
^{241}Am^{13}C γ
Events / N_{e^-}
N_{e^-}
0
10
20
30
40
50
60
70
80
90
100

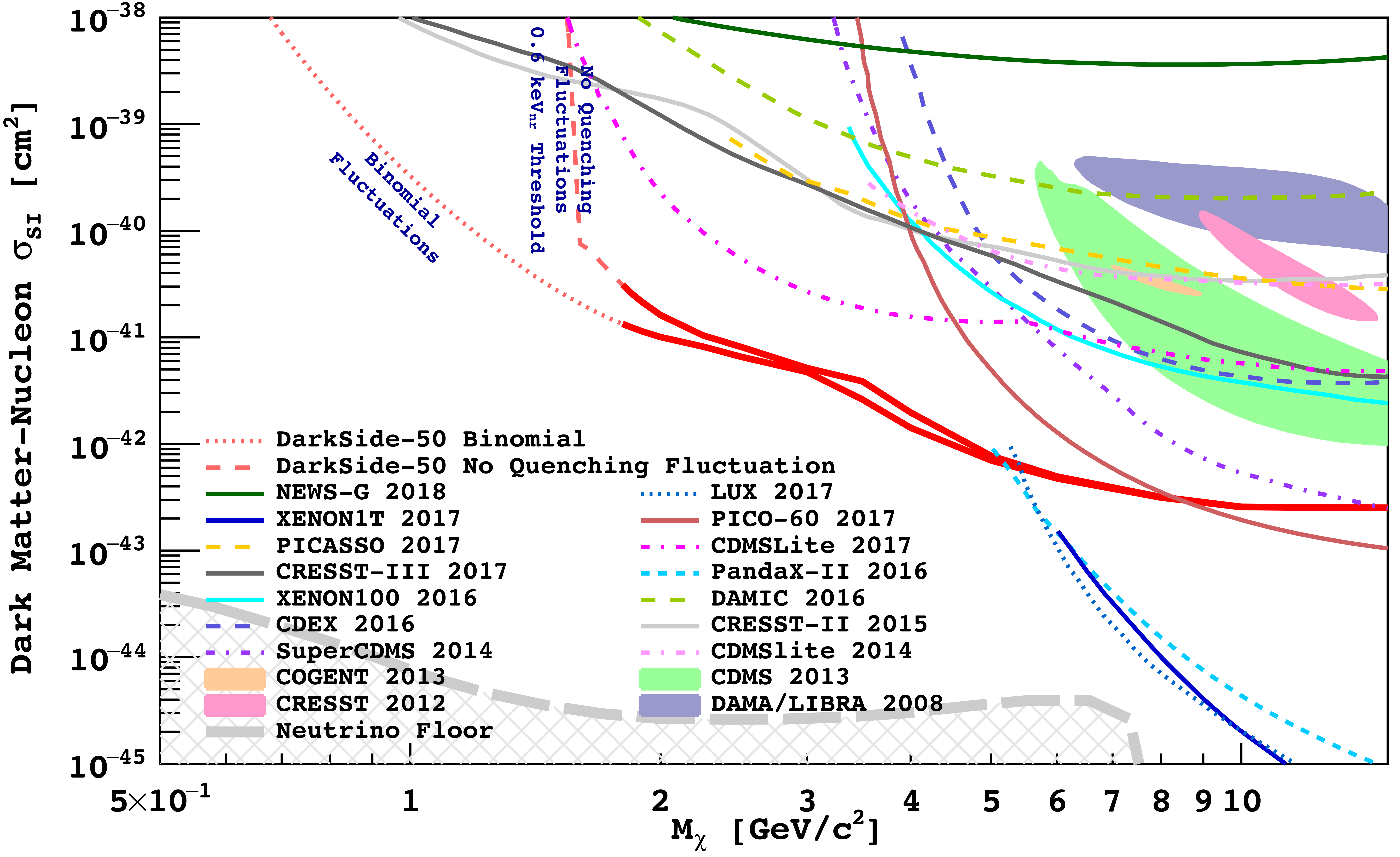


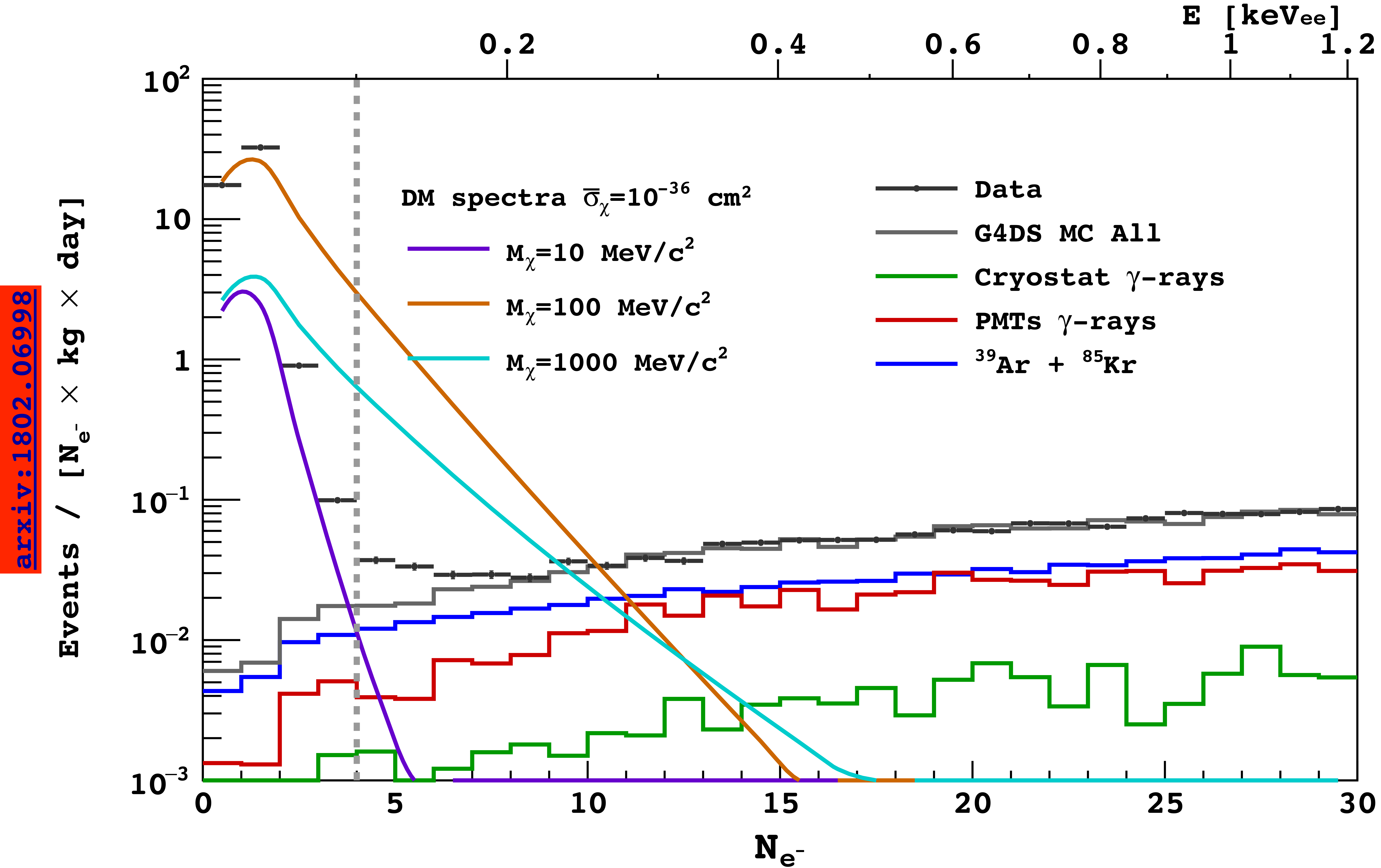
E_Ar [keV_nr]
E_Xe [keV_nr]
Q_y [e⁻/keV_nr]
ε
Xe Data
LUX 2016
ZEPLIN-III 2011
XENON10 2011
Manzur et al. 2010
XENON10 2009
Aprile et al. 2006
Xe Model
Bezrukov et al. 2011
Ar Data
ARIS
SCENE
AmBe – AmC – ARIS – SCENE
Joshi et al. 2014
Joshi et al. 2014 Cross Calibrated



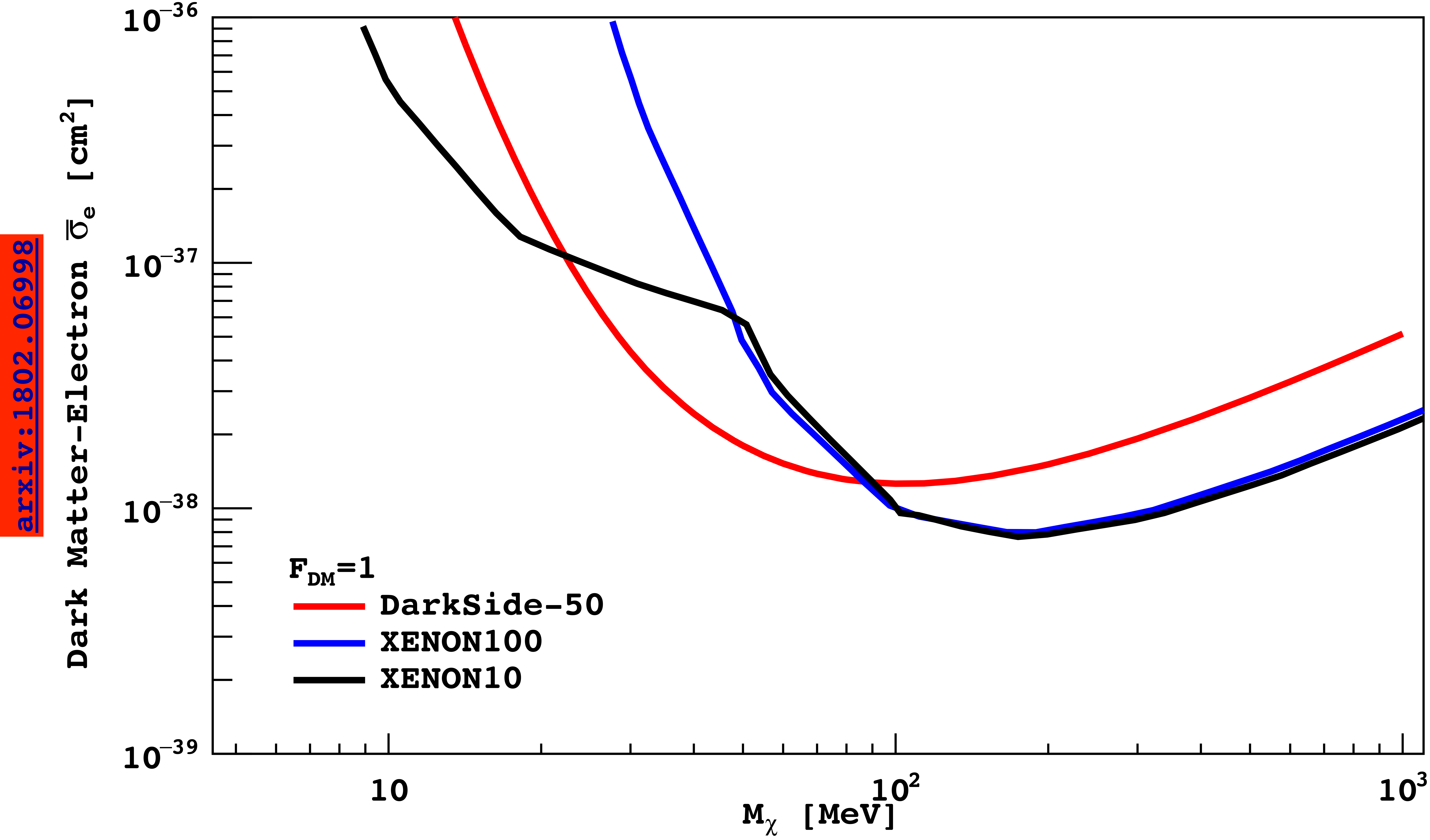
^{232}Th
Cryo
^{40}K
^{60}Co
^{238}U$_{low}$
^{238}U$_{up}$
^{235}U
^{85}Kr
^{39}Ar
DATA
Events / [2 keV]
Energy [keV]
$\times 10^3$
10^5
10^4
10^3
10^2
10
1
0
0.5
1
1.5
2
2.5
3

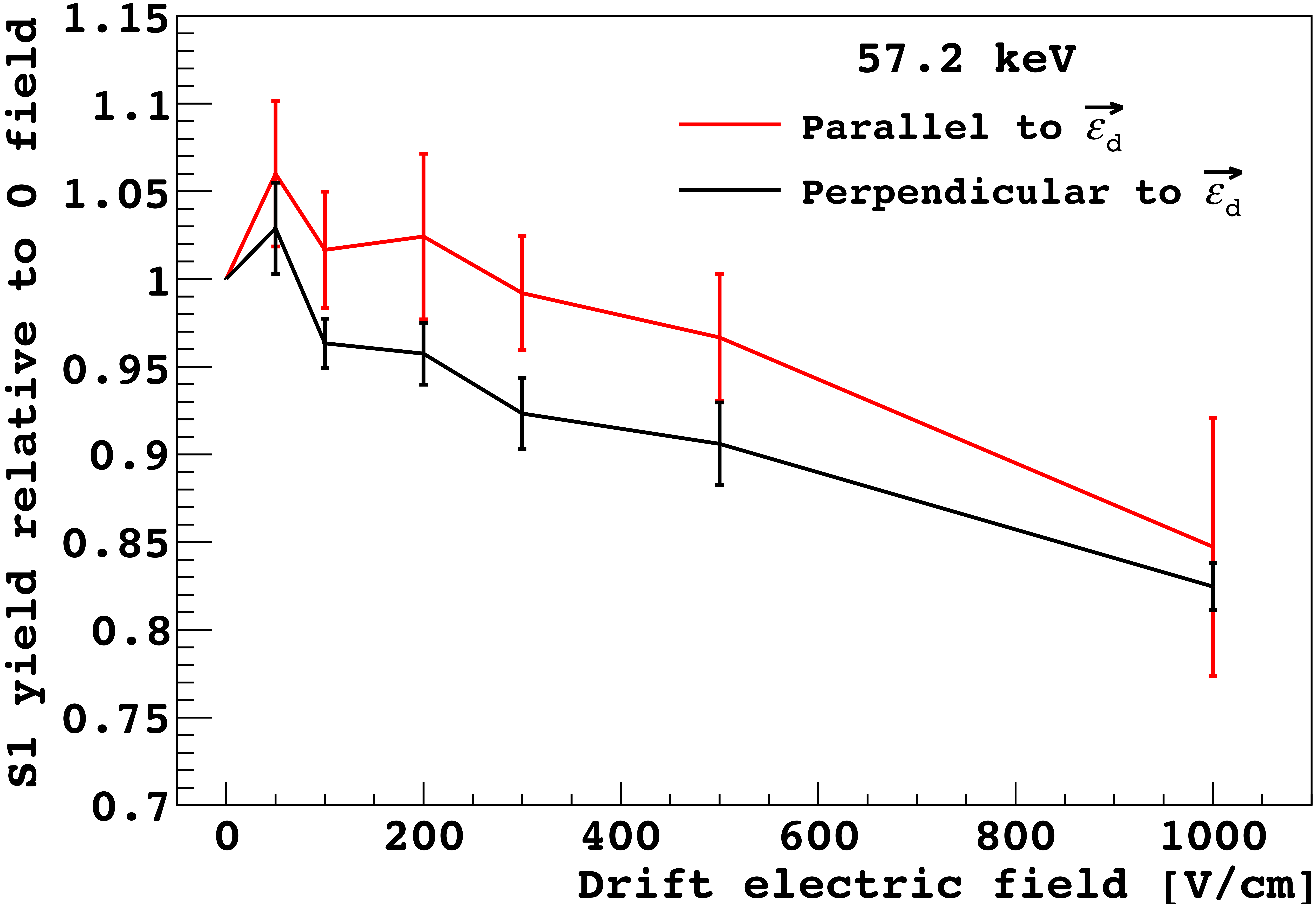
arxiv:1802.06994
E [keVnr]
E [keVee]
DM spectra σχ=10^-40 cm^2
Mχ=2.5 GeV/c^2
Mχ=5.0 GeV/c^2
Mχ=10.0 GeV/c^2
Data
G4DS MC All
Cryostat γ-rays
PMTs γ-rays
39Ar + 85Kr
Events / [Ne- × kg × day]
Events / [keVee × kg × day]
Events / [keVnr × kg × day]
Ne-


Dark Matter-Nucleon σ_SI [cm²]
10^-38
10^-39
10^-40
10^-41
10^-42
10^-43
10^-44
10^-45
5×10^-1
1
2
3
4
5
6
7
8
9
10
M_χ [GeV/c²]
Binomial Fluctuations
0.6 keV_nr Threshold
Fluctuations
No Quenching
DarkSide-50 Binomial
DarkSide-50 No Quenching Fluctuation
NEWS-G 2018
XENON1T 2017
PICASSO 2017
CRESST-III 2017
XENON100 2016
CDEX 2016
SuperCDMS 2014
COGENT 2013
CRESST 2012
Neutrino Floor
LUX 2017
PICO-60 2017
CDMSLite 2017
PandaX-II 2016
DAMIC 2016
CRESST-II 2015
CDMSlite 2014
CDMS 2013
DAMA/LIBRA 2008



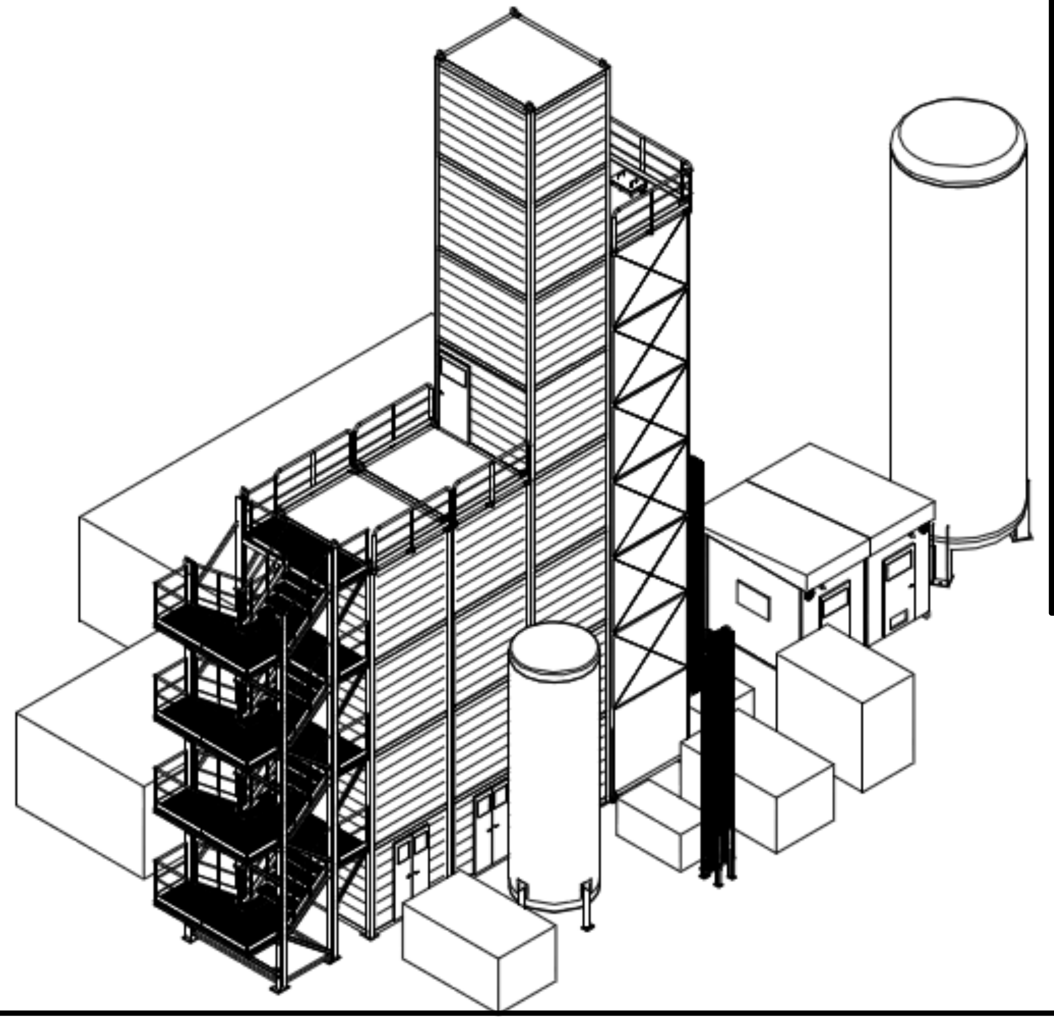
arxiv:1802.06998
E [keVee]
0.2
0.4
0.6
0.8
1
1.2
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
Events / [N_{e^-} × kg × day]
DM spectra $\overline{\sigma}_\chi=10^{-36}$ cm²
M_χ=10 MeV/c²
M_χ=100 MeV/c²
M_χ=1000 MeV/c²
Data
G4DS MC All
Cryostat γ-rays
PMTs γ-rays
^{39}Ar + ^{85}Kr
0
5
10
15
20
25
30
N_{e^-}


arxiv:1802.06998
Dark Matter-Electron $\overline{\sigma}_e$ [cm^2]
10^{-36}
10^{-37}
10^{-38}
10^{-39}
10
10^2
10^3
M_χ [MeV]
F_{DM}=1
DarkSide-50
XENON100
XENON10



57.2 keV
Parallel to $\overrightarrow{\varepsilon_d}$
Perpendicular to $\overrightarrow{\varepsilon_d}$
S1 yield relative to 0 field
Drift electric field [V/cm]
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0
200
400
600
800
1000

Production and Purification



UAr transported via boat for final purification at Aria

<u>Production: Urania</u>

- Commercial-scale plant to extract UAr
- Located in Southwestern Colorado
- UAr extracted from CO_2 well gas at the tonne scale

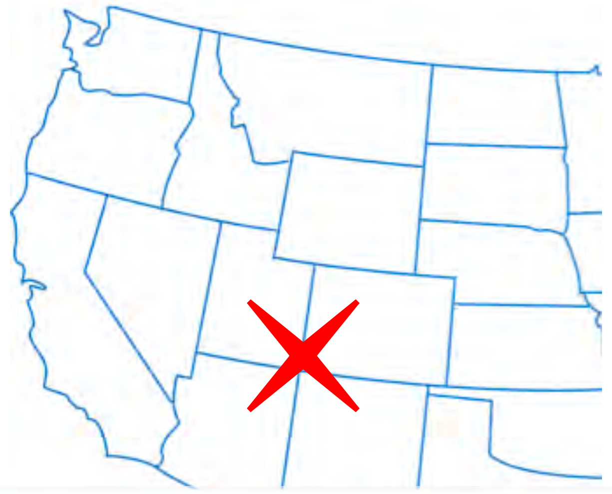
Focus of this talk

<u>Purification: Aria</u>

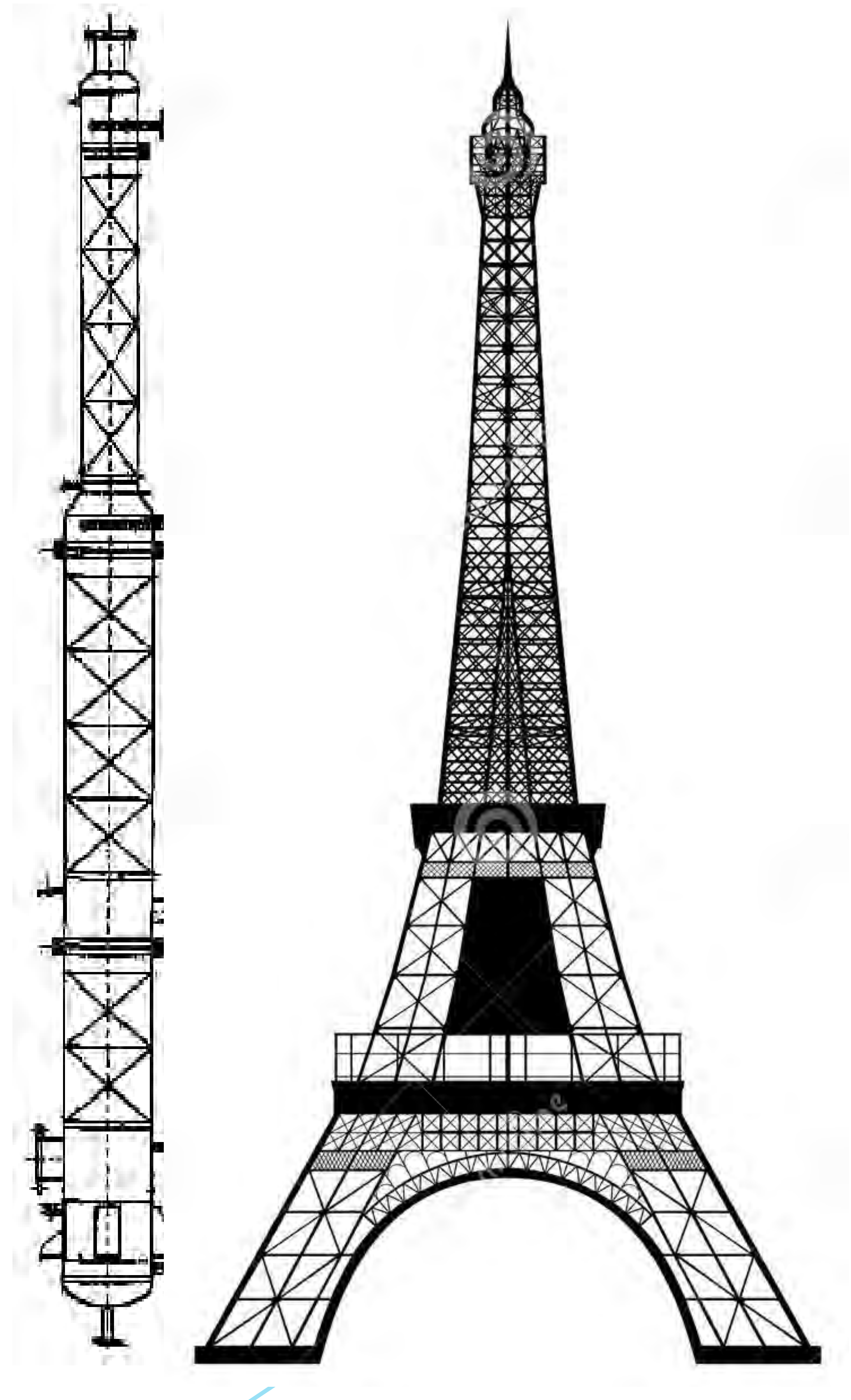
(see M. Simeone's talk for details)

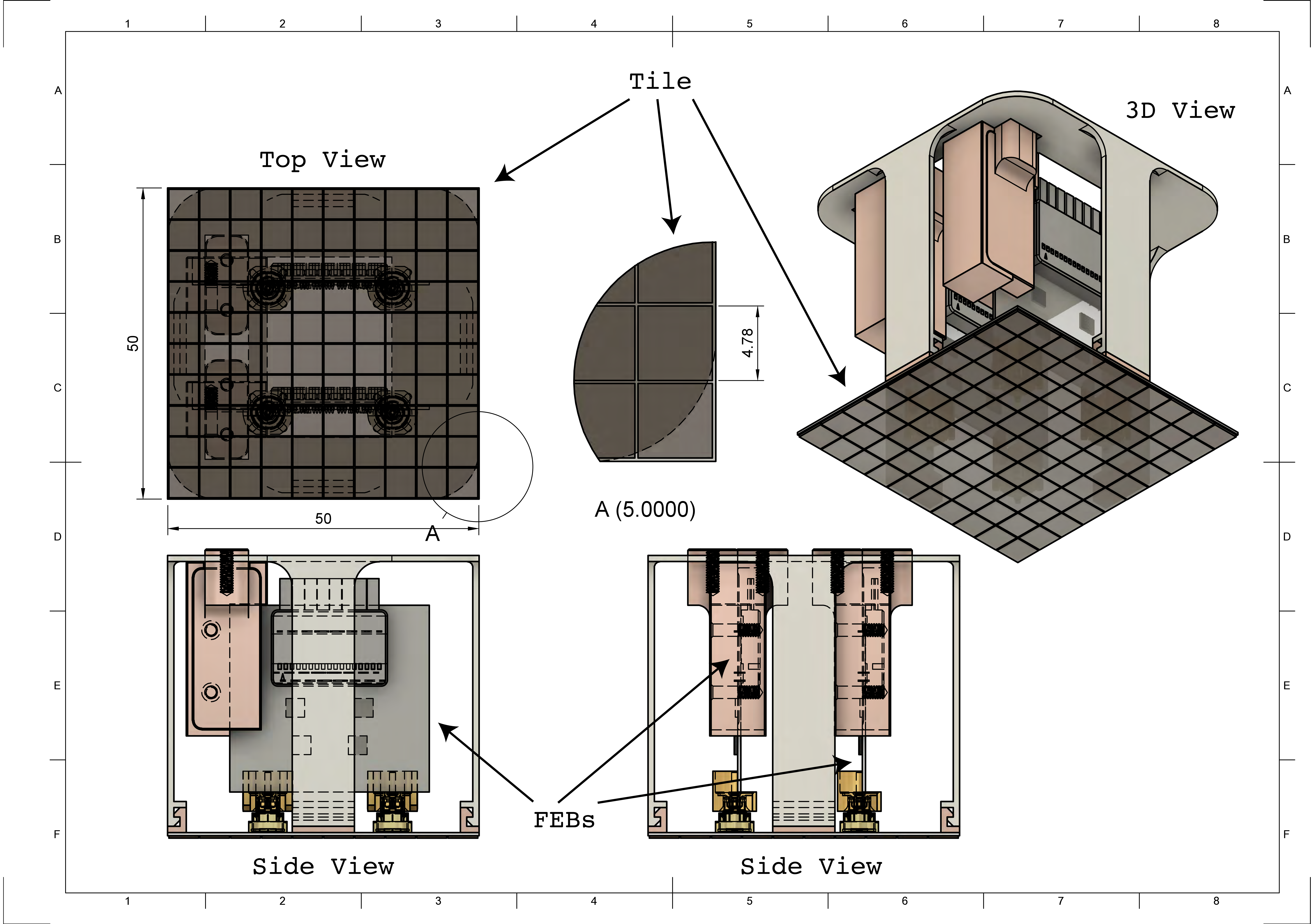
- 350 m tall cryogenic distillation column to purify UAr and isotopically separate argon and other elements
- Located in refurbished carbon mine shaft in Sardinia, Italy
- Will chemically purify the UAr for DS-20k to detector grade

Enter the Age of Urania

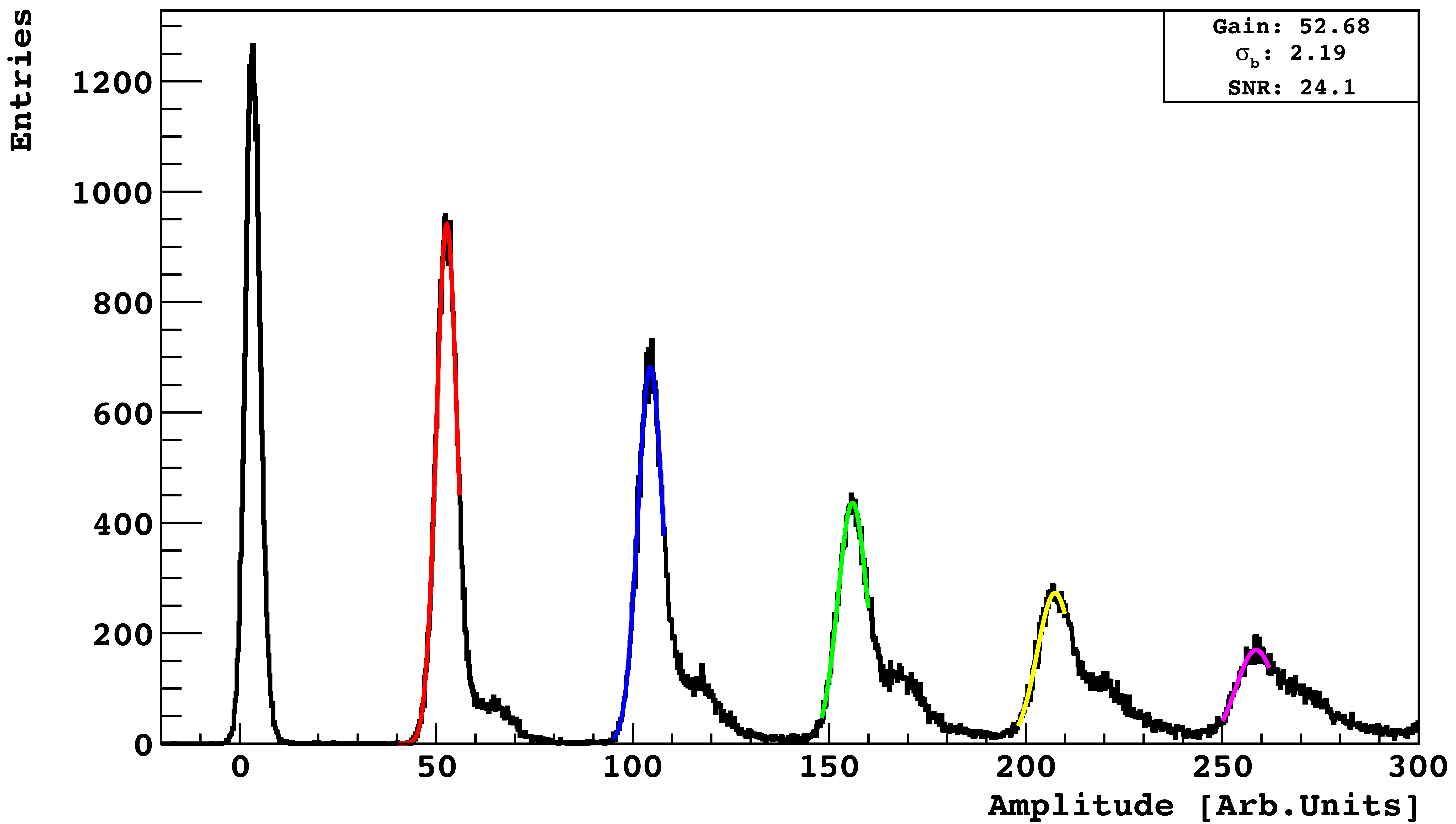




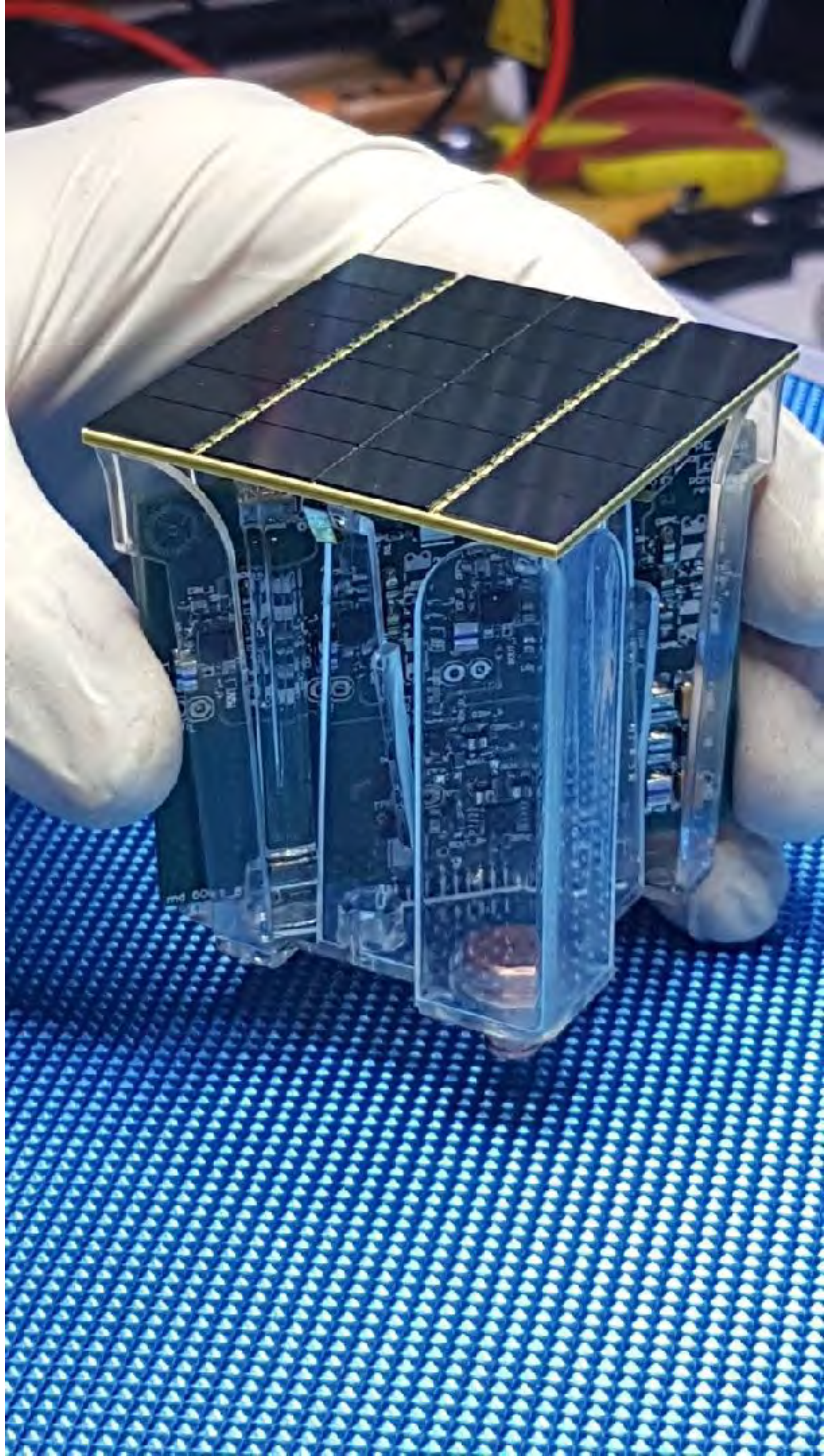
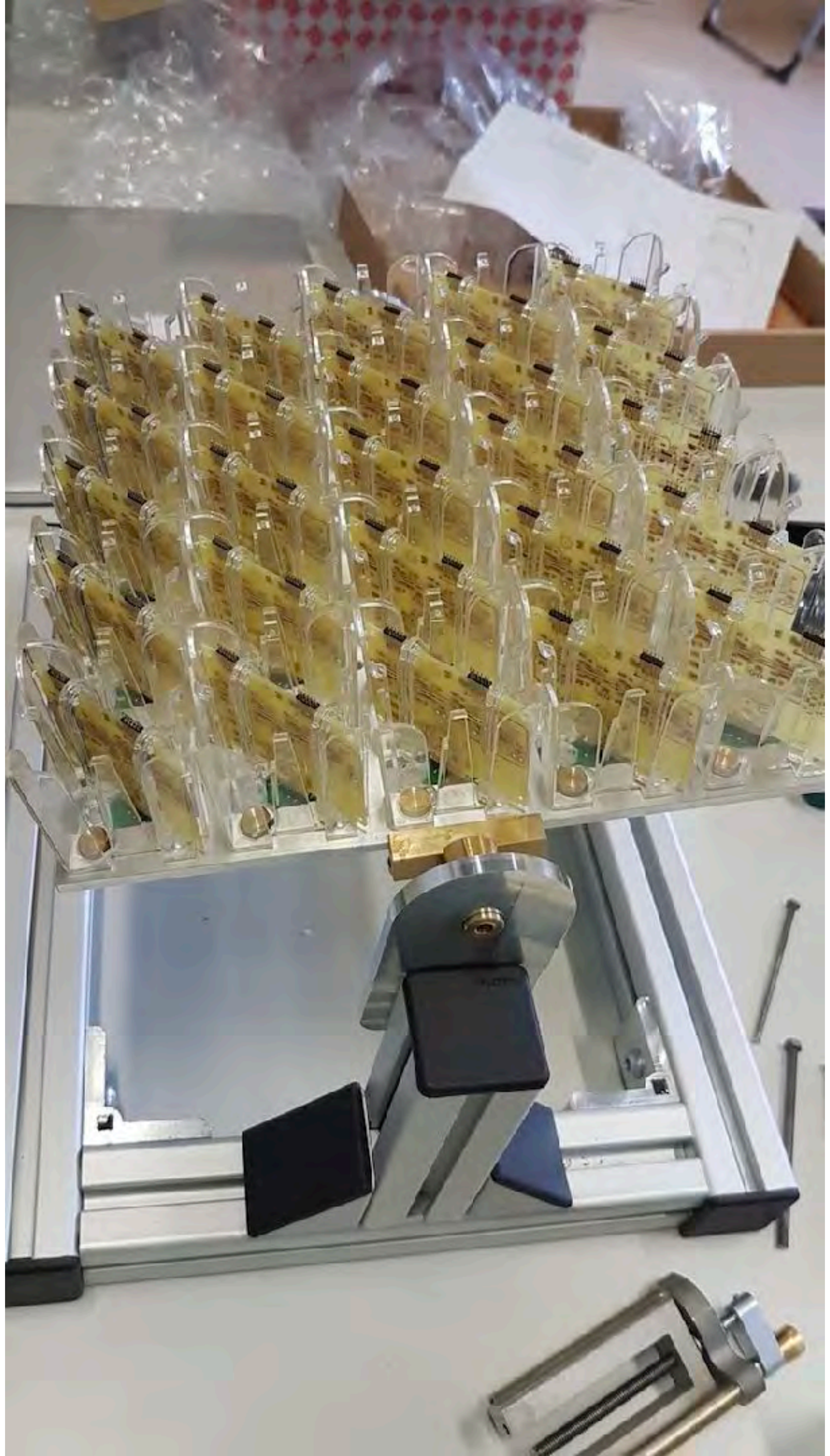
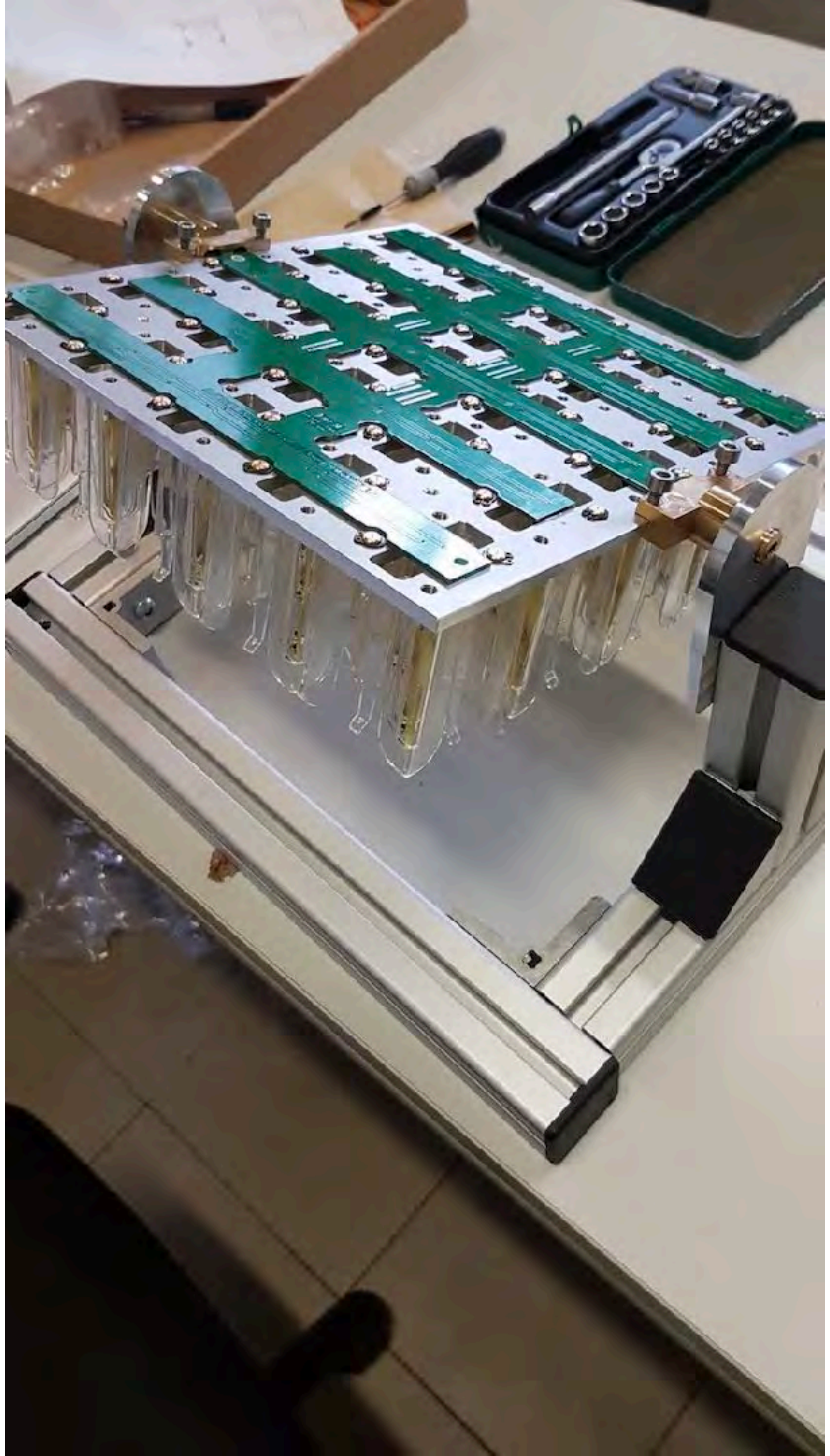


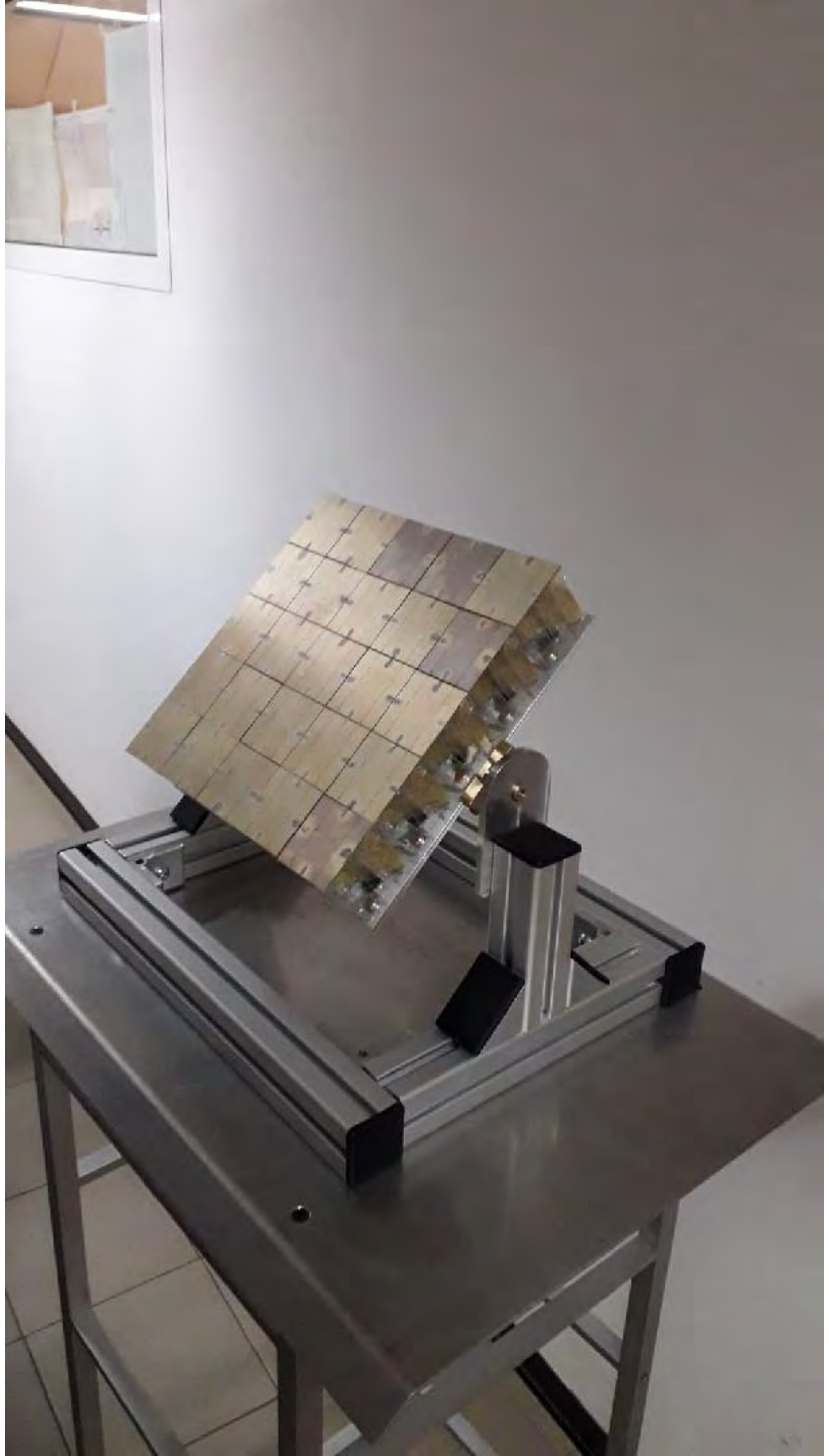
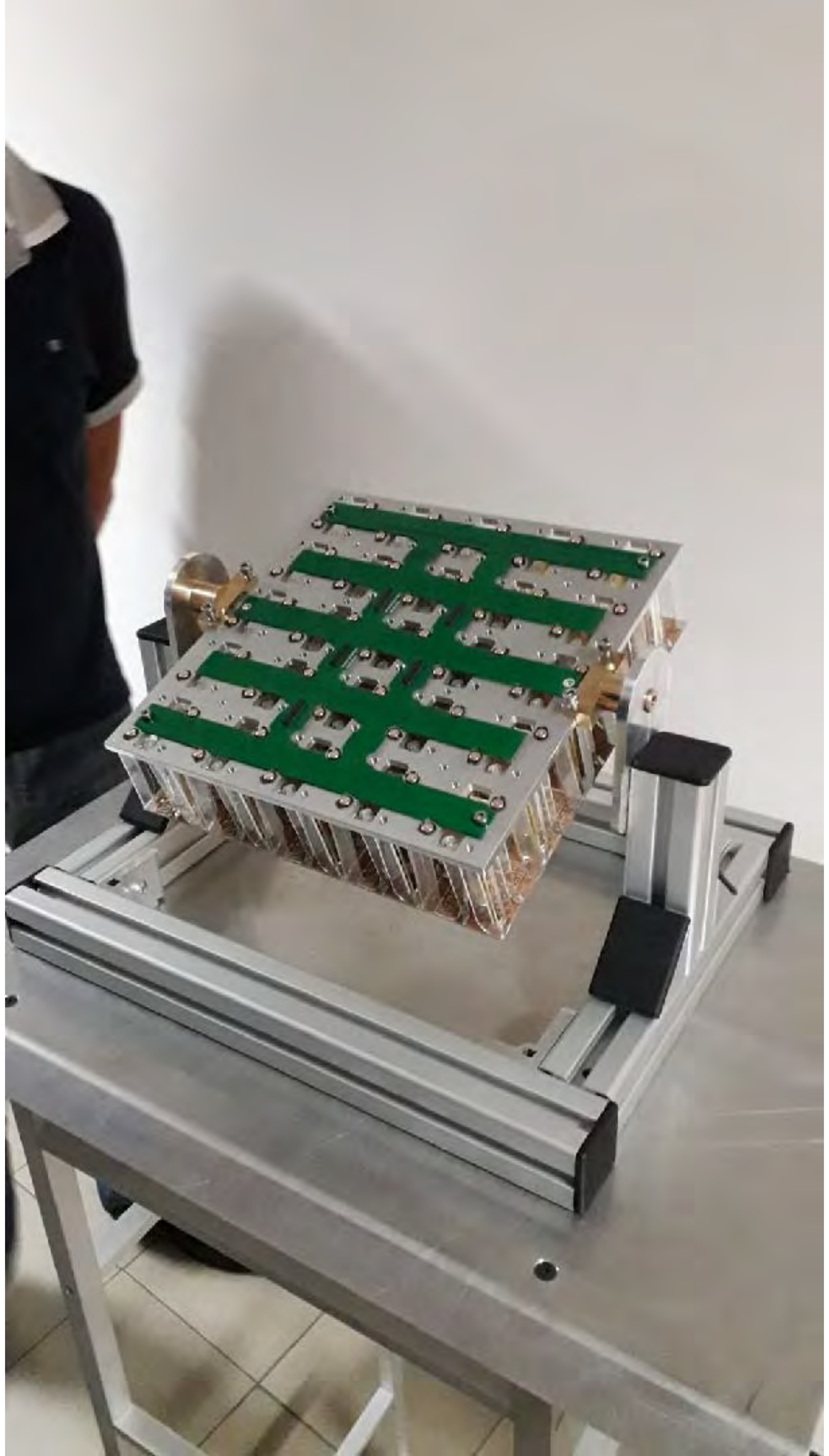



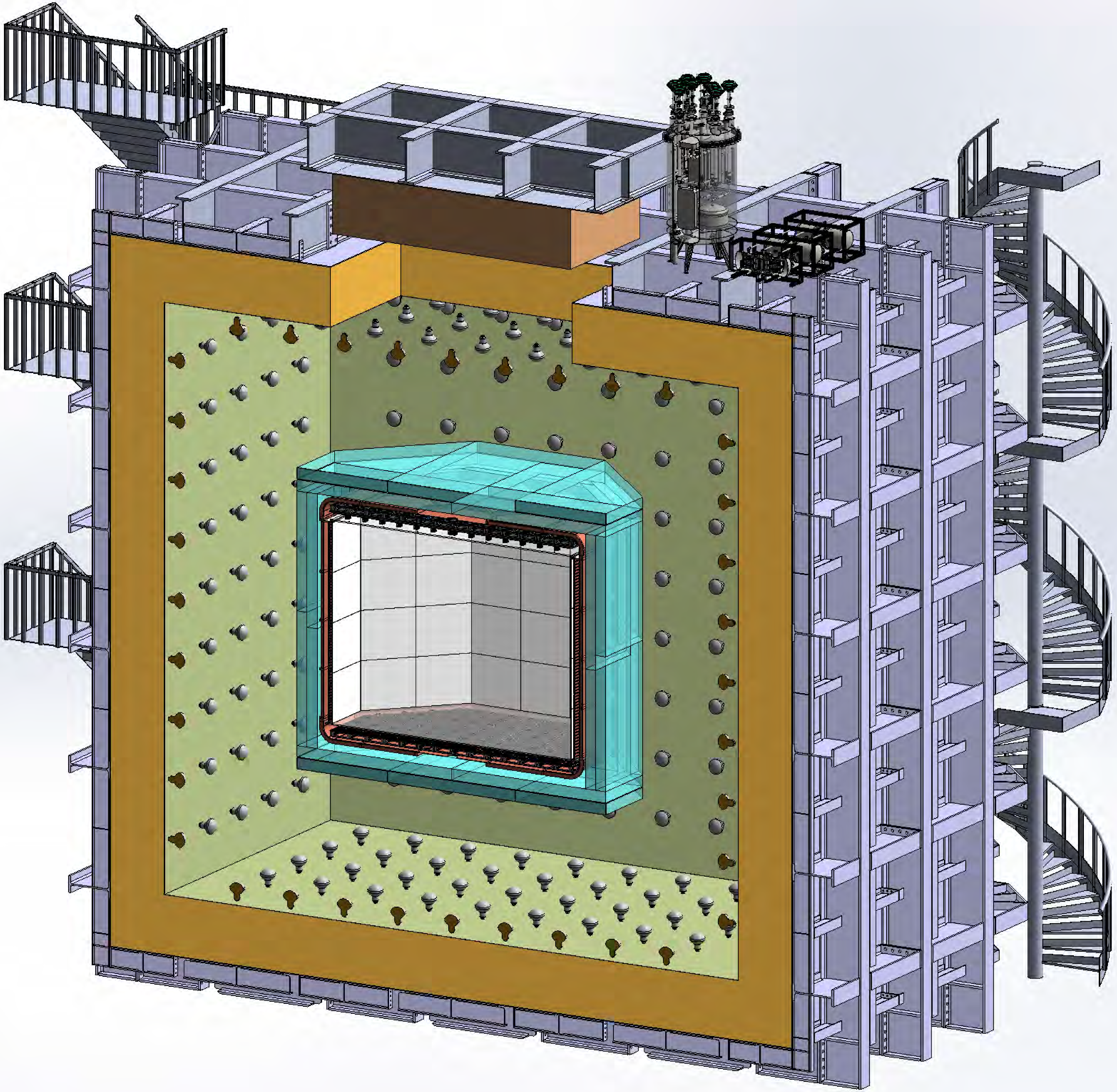
Tile
Top View
3D View
50
50
A
4.78
A (5.0000)
FEBs
Side View
Side View

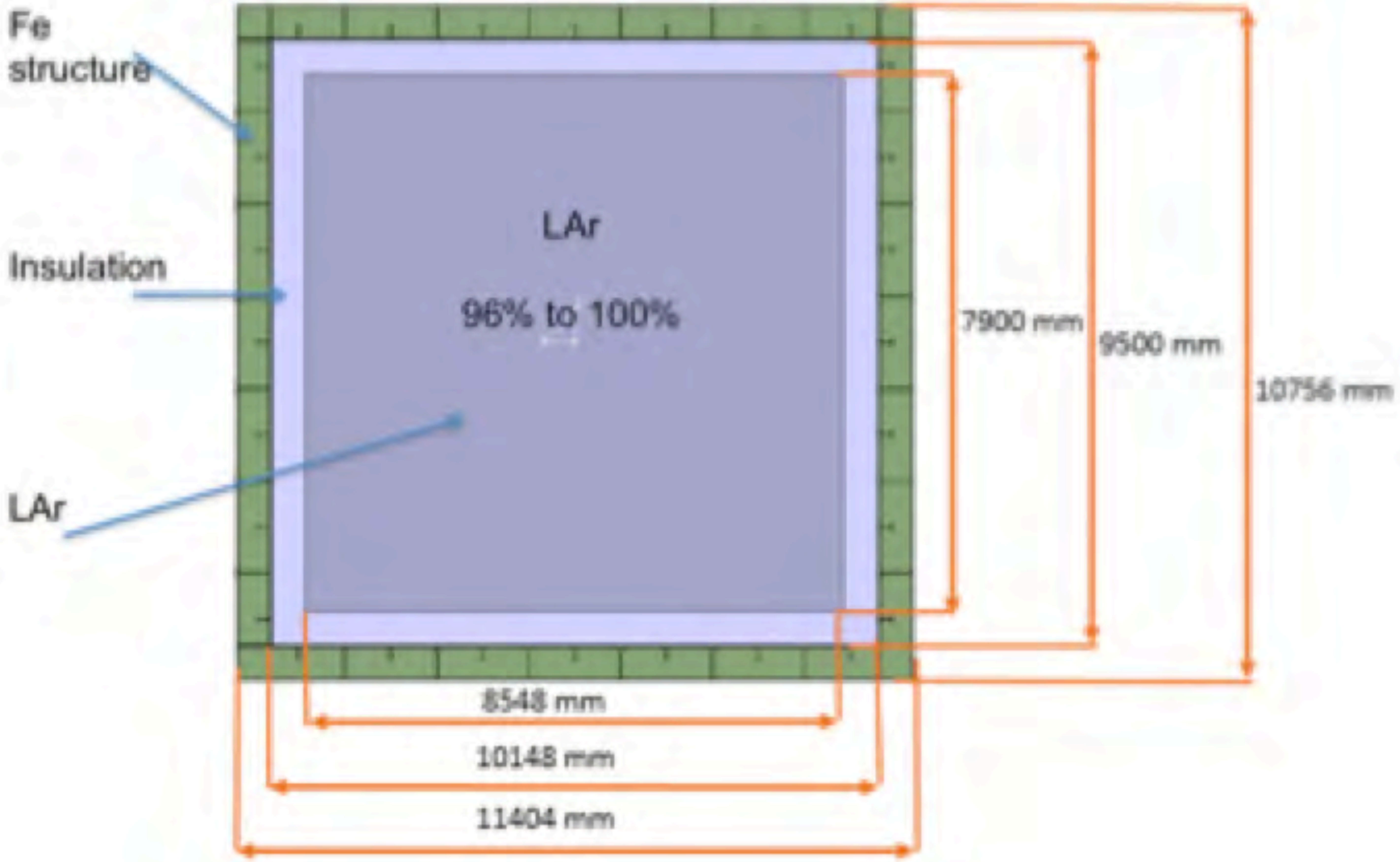


Gain: 52.68
σ_b: 2.19
SNR: 24.1
Entries
0
200
400
600
800
1000
1200
0
50
100
150
200
250
300
Amplitude [Arb.Units]

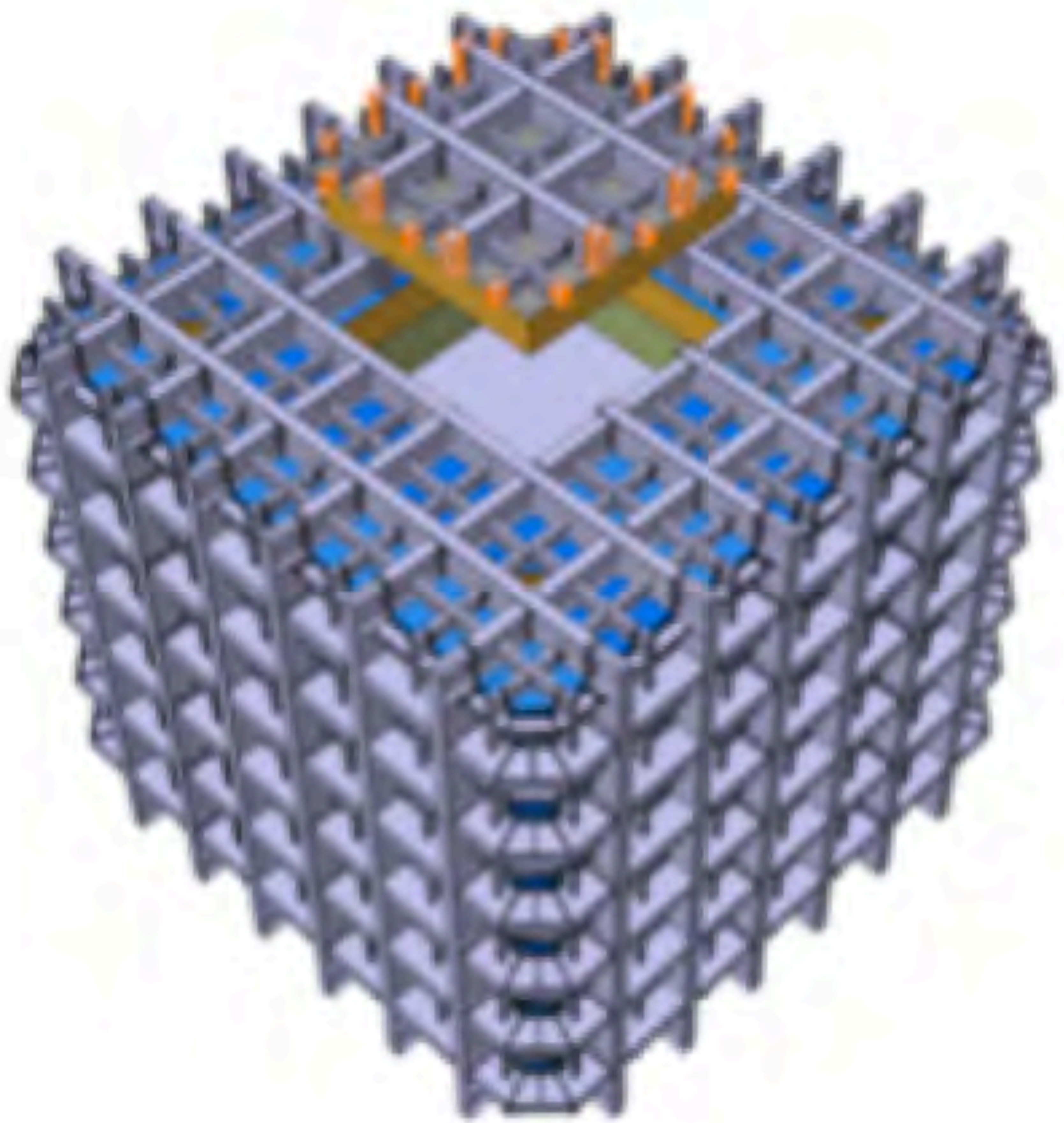




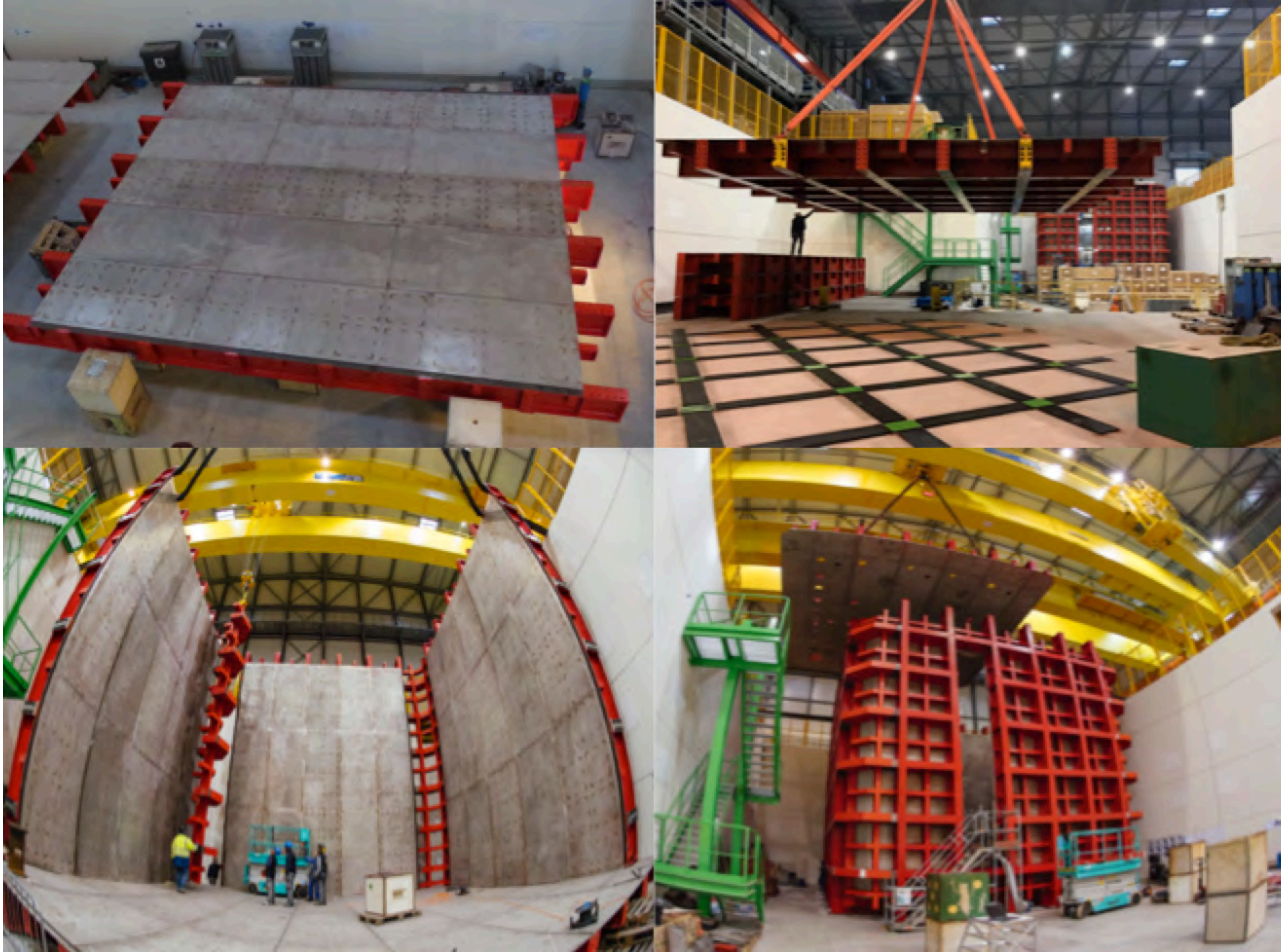







Fe structure
Insulation
LAr
LAr
96% to 100%
7900 mm
9500 mm
10756 mm
8548 mm
10148 mm
11404 mm






The End