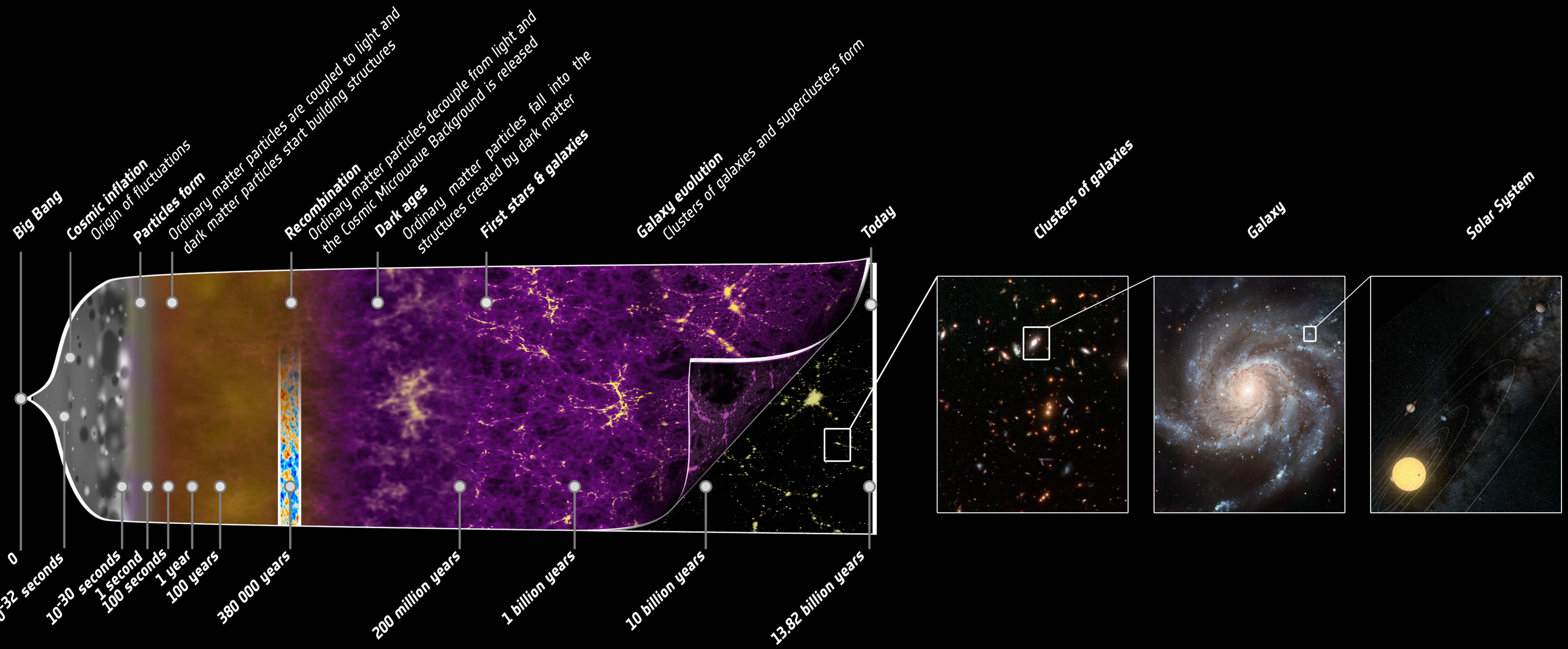
CRISTIANO GALBIATI
57TH INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO, JANUARY 24, 2019

# THE GLOBAL ARGON DARK MATTER COLLABORATION AND ITS PHYSICS PROGRAM

# THE SCIENCE PERSPECTIVE

- The two dark entities dominating the Universe, dark matter and dark energy, do not fit in the Standard Model
- Two big open questions at the intersection of particle physics and cosmology


Big Bang
Cosmic inflation
Origin of fluctuations
Particles form
Ordinary matter particles are coupled to light and dark matter particles start building structures
Recombination
Ordinary matter particles decouple from light and the Cosmic Microwave Background is released
Dark ages
Ordinary matter particles fall into the structures created by dark matter
First stars & galaxies
Galaxy evolution
Clusters of galaxies and superclusters form
Today
Clusters of galaxies
Galaxy
Solar System
0
$10^{-32}$ seconds
$10^{-30}$ seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13.82 billion years

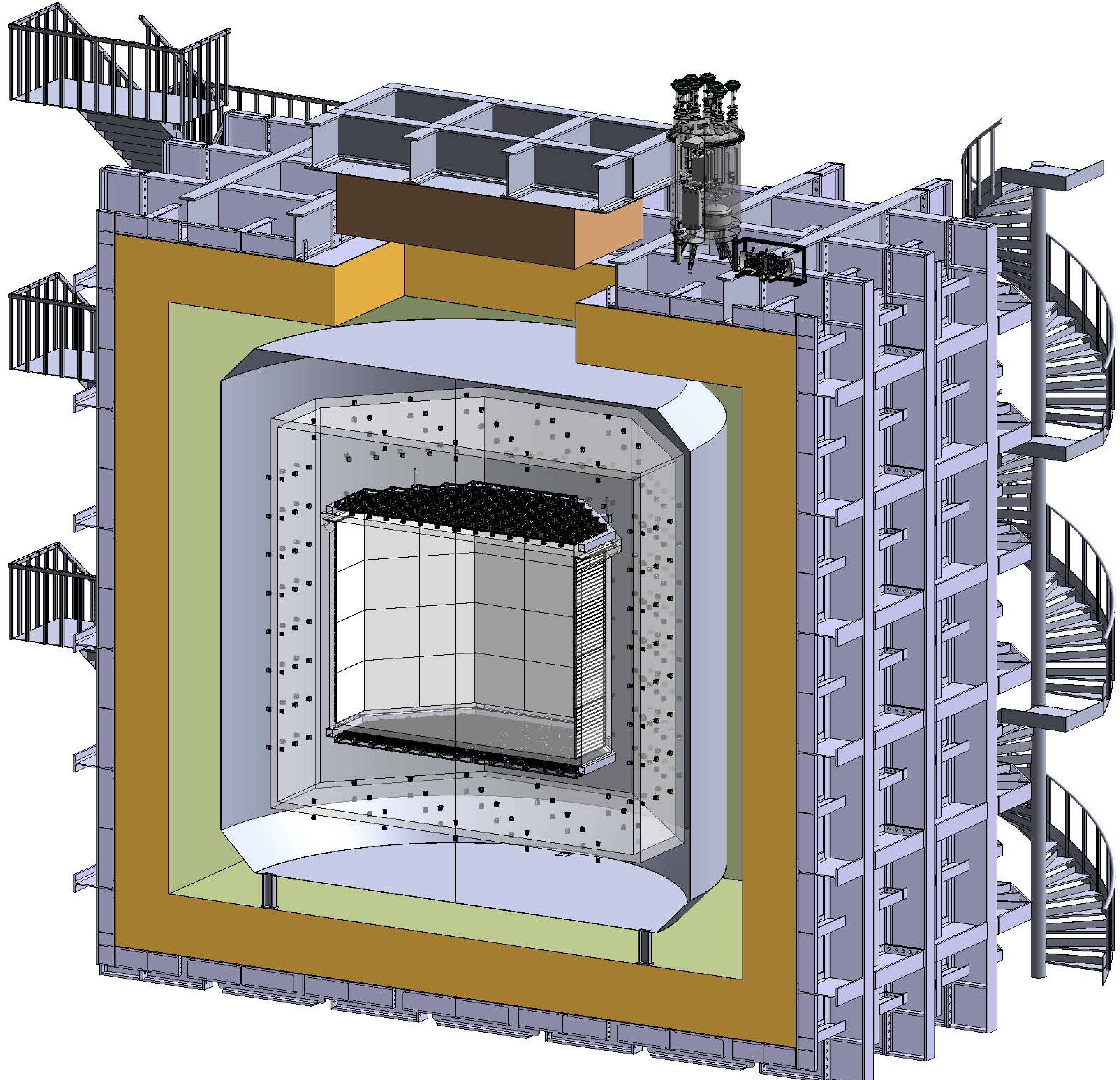
u
c
t
d
s
b
Quarks
e
μ
τ
ν e
ν μ
ν τ
Leptons
Higgs boson
W+
γ
Z0
g
W-
Forces
CERN
ACCELERATING SCIENCE

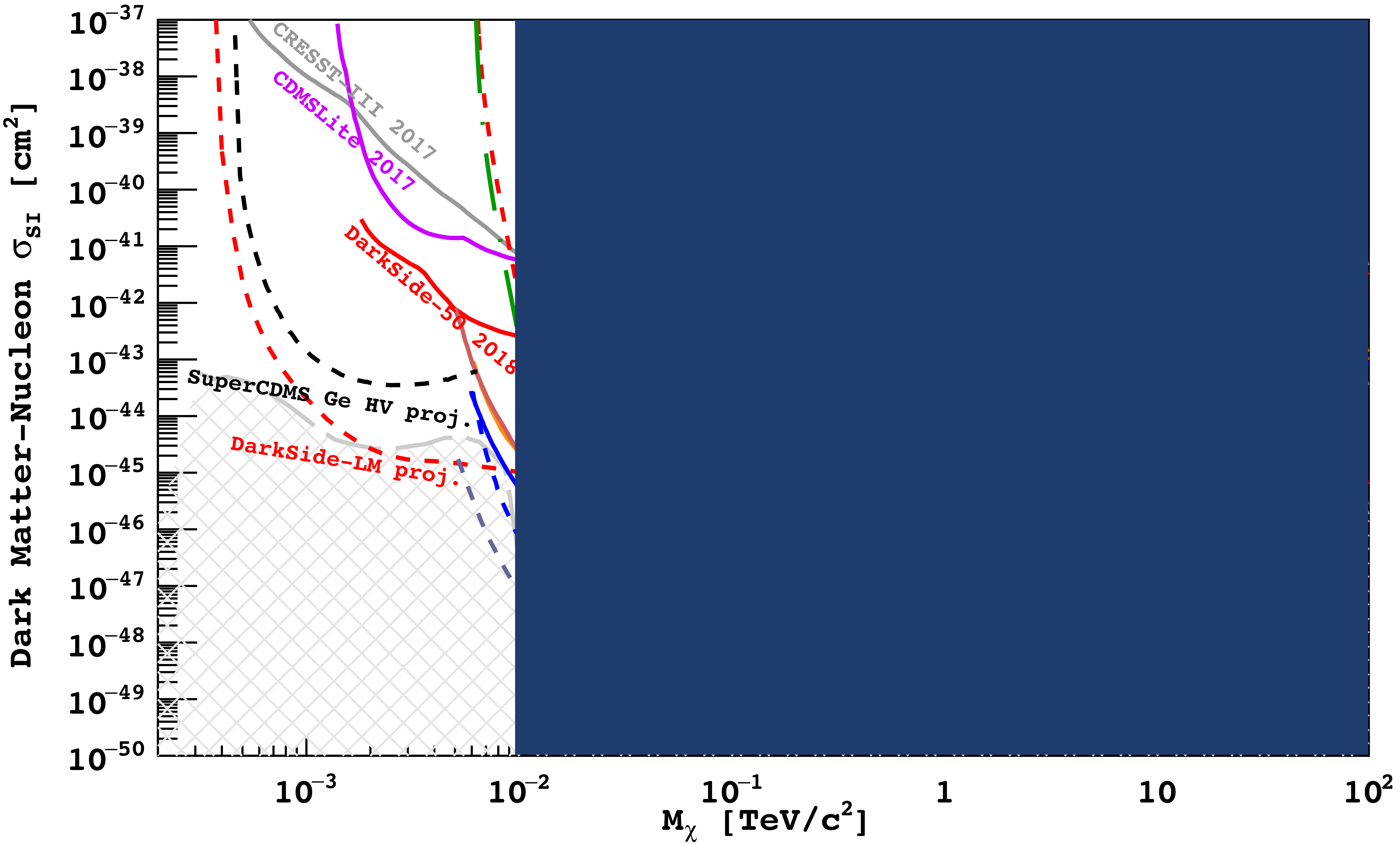
ArDM
DarkSide
DEAP
MiniCLEAN

The Global Argon
Dark Matter
Collaboration

350 COLLABORATORS

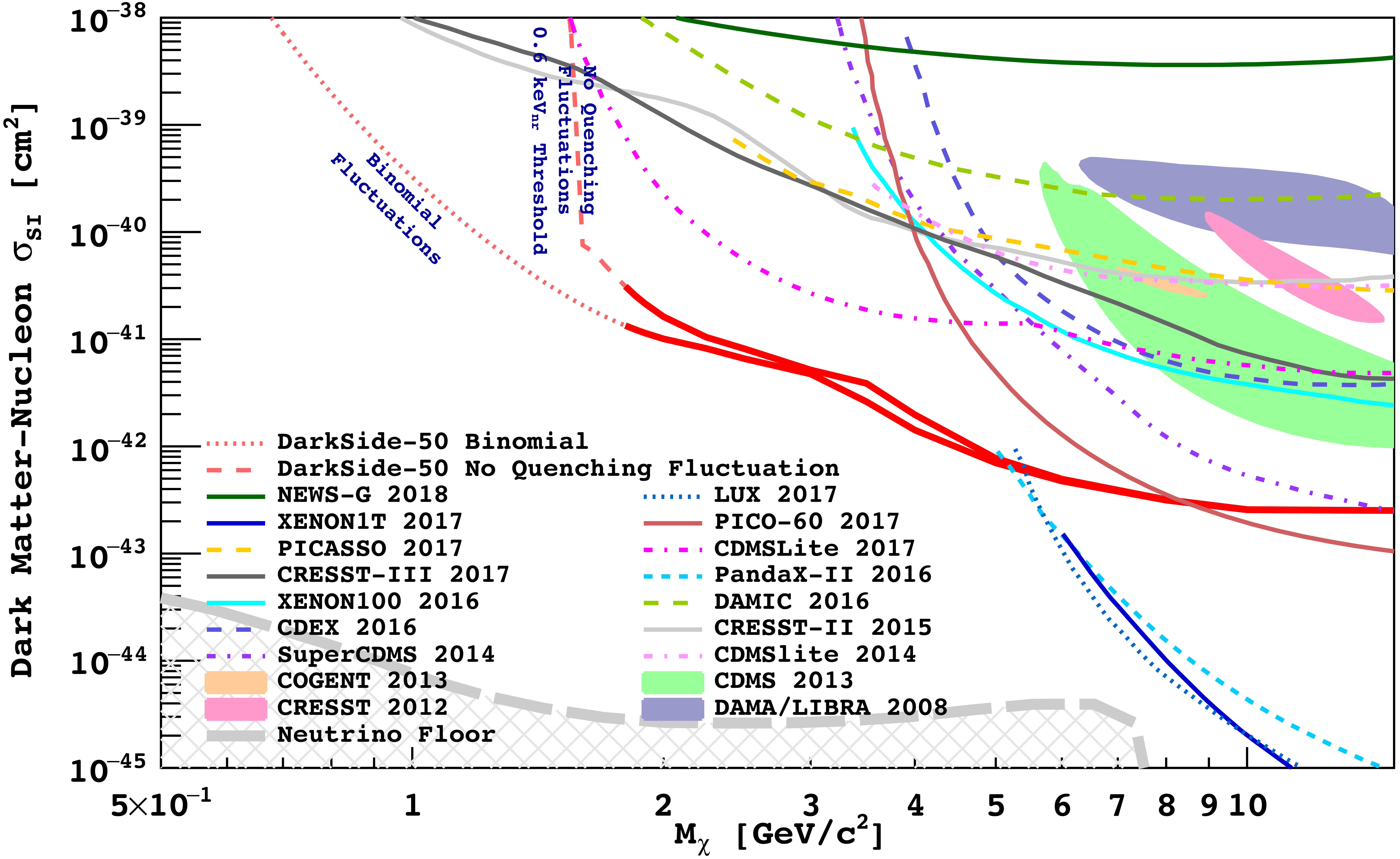
ITALY, US, CANADA, BRAZIL, CHINA, FRANCE, GERMANY, POLAND, RUSSIA, SPAIN, UNITED KINGDOM



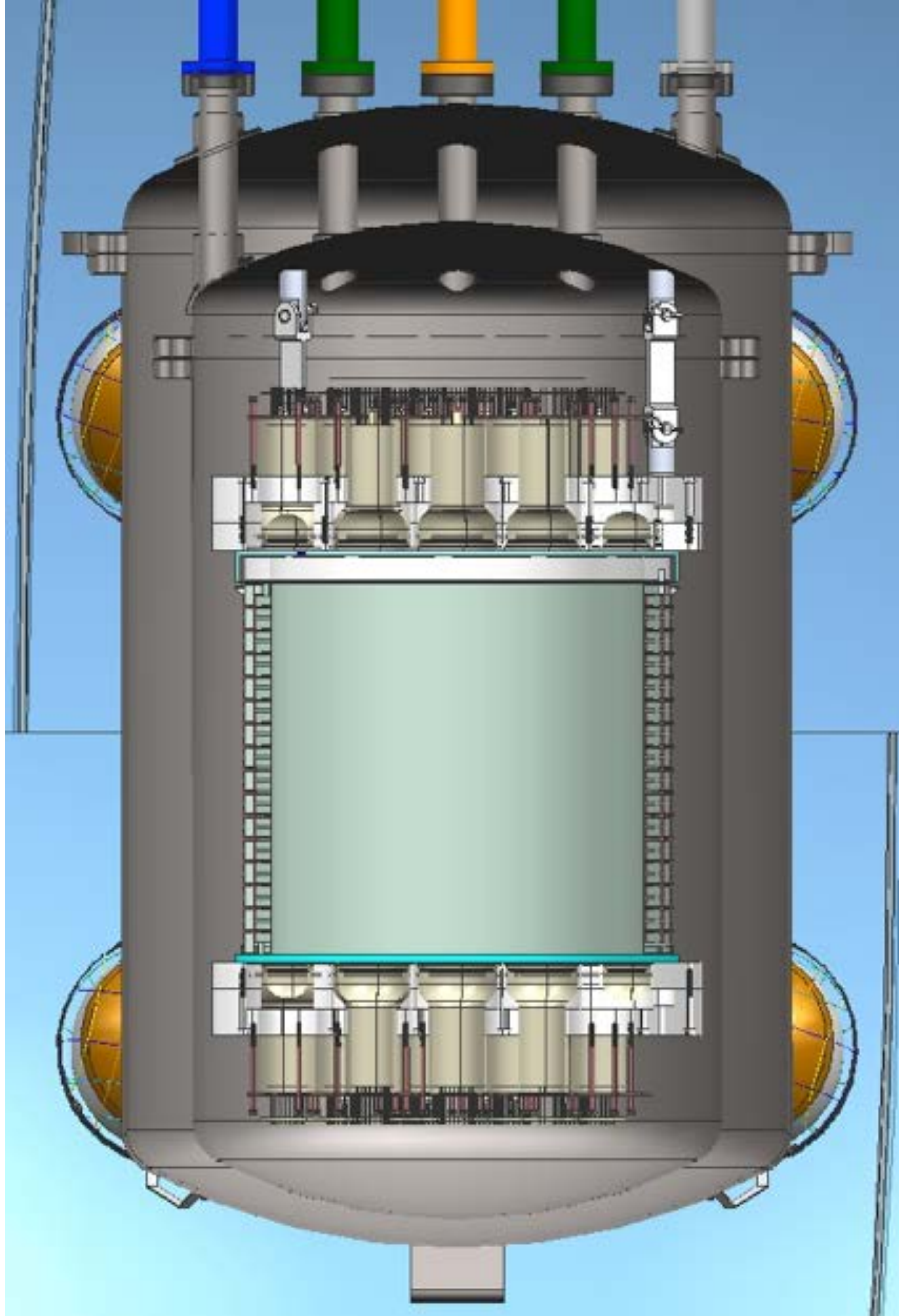


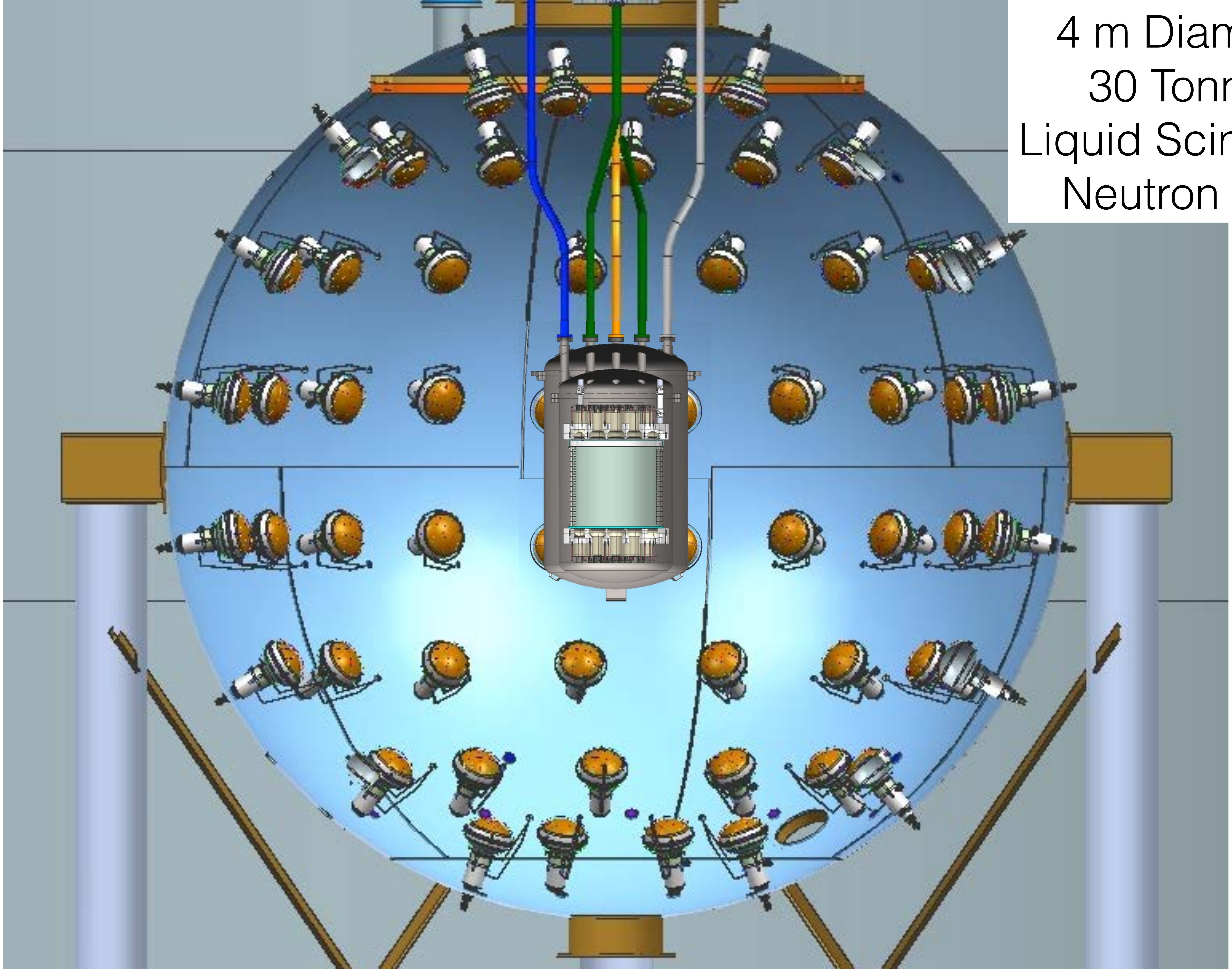
Dark Matter-Nucleon $\sigma_{SI}$ [cm$^2$]
$10^{-37}$
$10^{-38}$
$10^{-39}$
$10^{-40}$
$10^{-41}$
$10^{-42}$
$10^{-43}$
$10^{-44}$
$10^{-45}$
$10^{-46}$
$10^{-47}$
$10^{-48}$
$10^{-49}$
$10^{-50}$
CRESST-III 2017
CDMSLite 2017
DarkSide-50 2018
SuperCDMS Ge HV proj.
DarkSide-LM proj.
$10^{-3}$
$10^{-2}$
$10^{-1}$
1
10
$10^{2}$
$M_\chi$ [TeV/c$^2$]

Physical Review Letters 121, 081307 (2018)



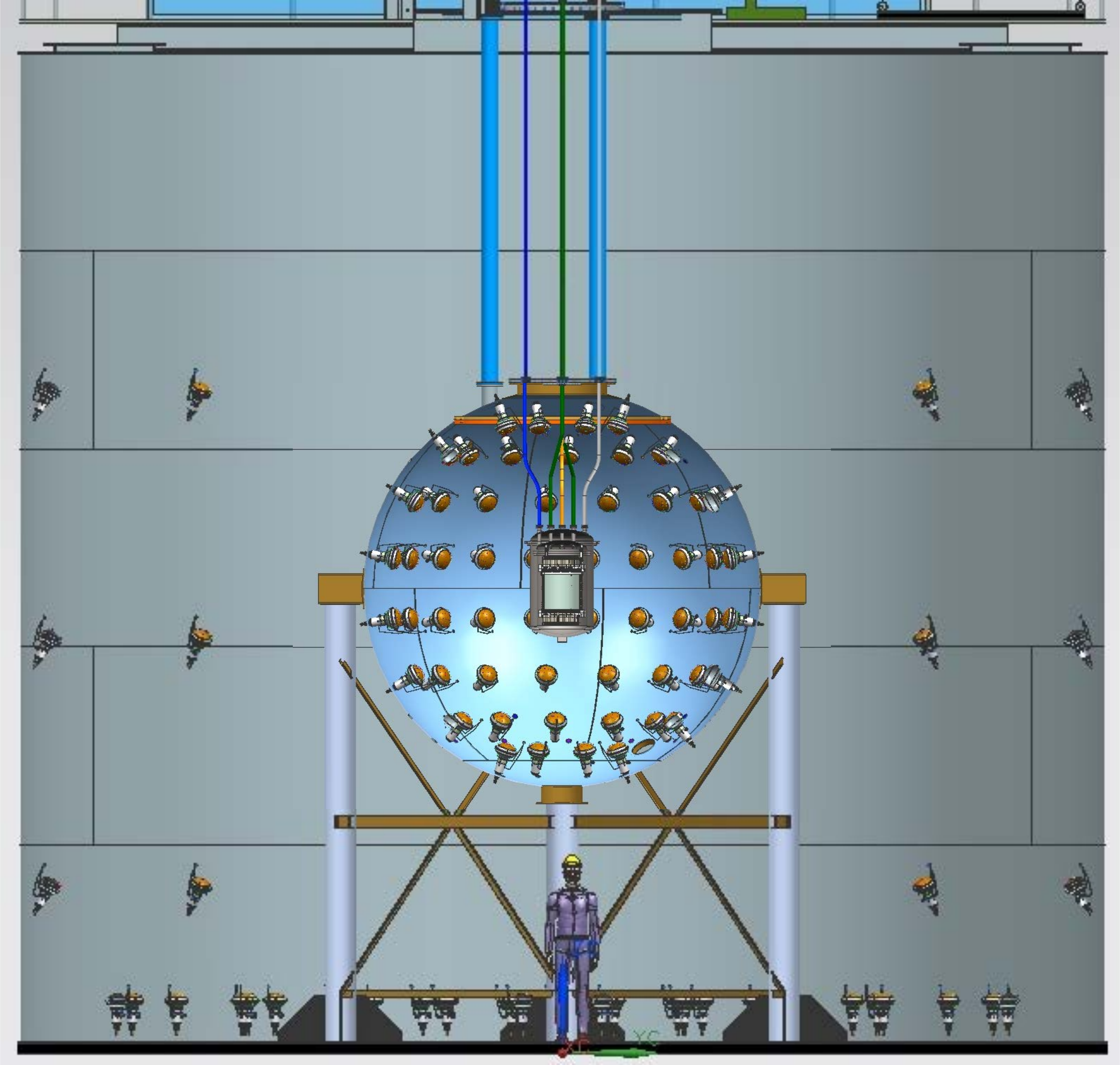
Liquid Argon TPC
153 kg $^{39}$Ar-Depleted
Underground Argon
Target





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
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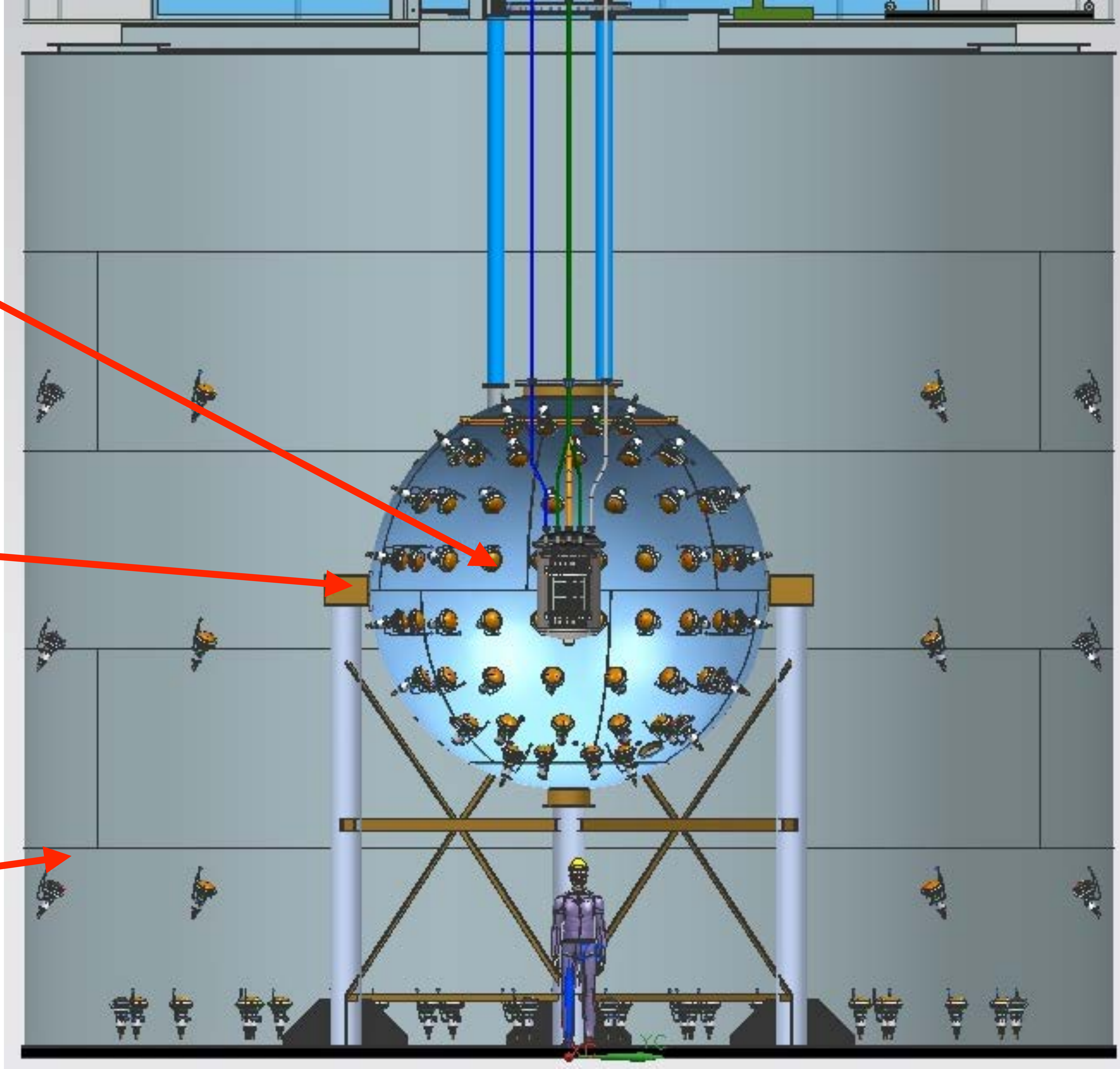
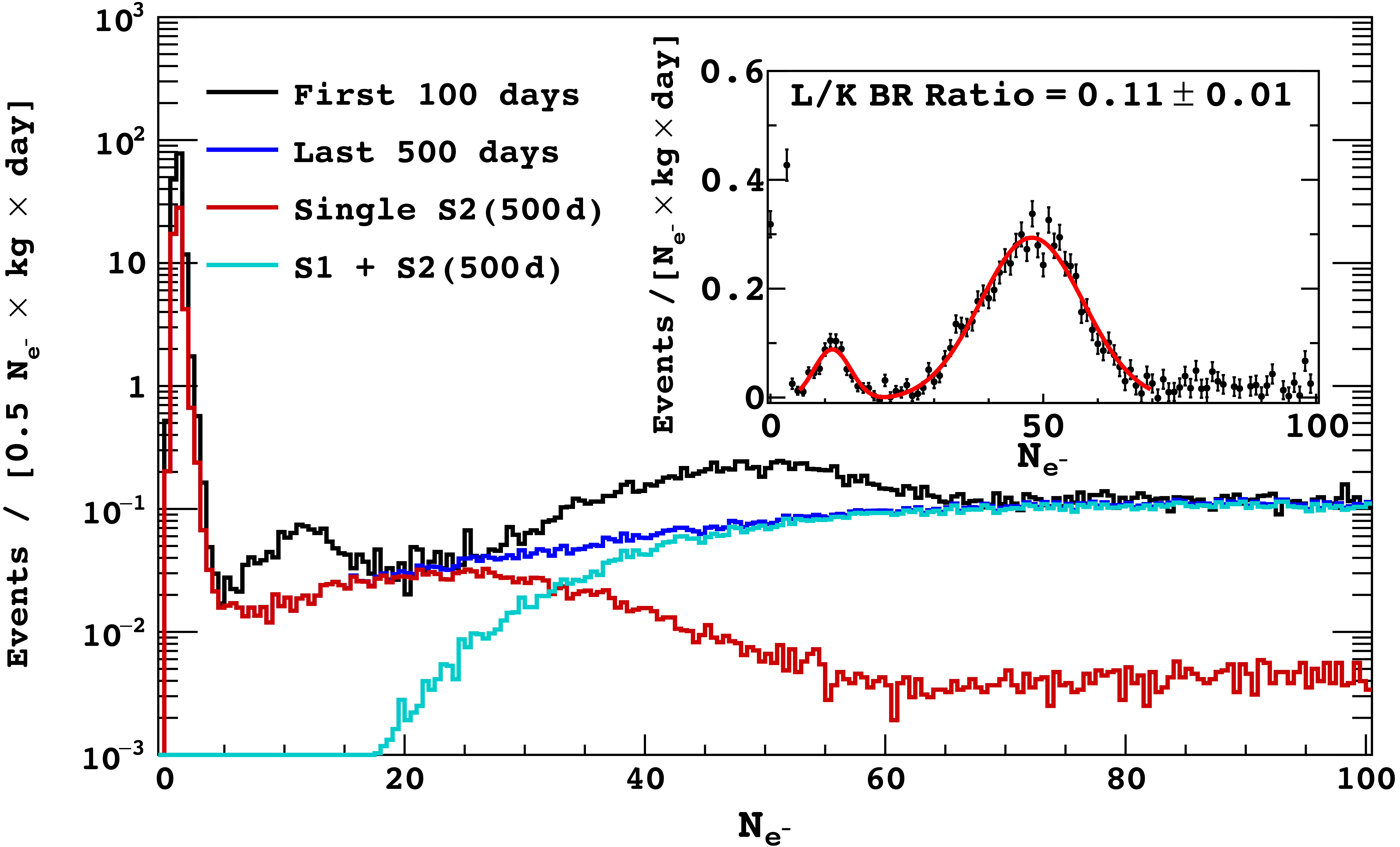


# DARKSIDE-50

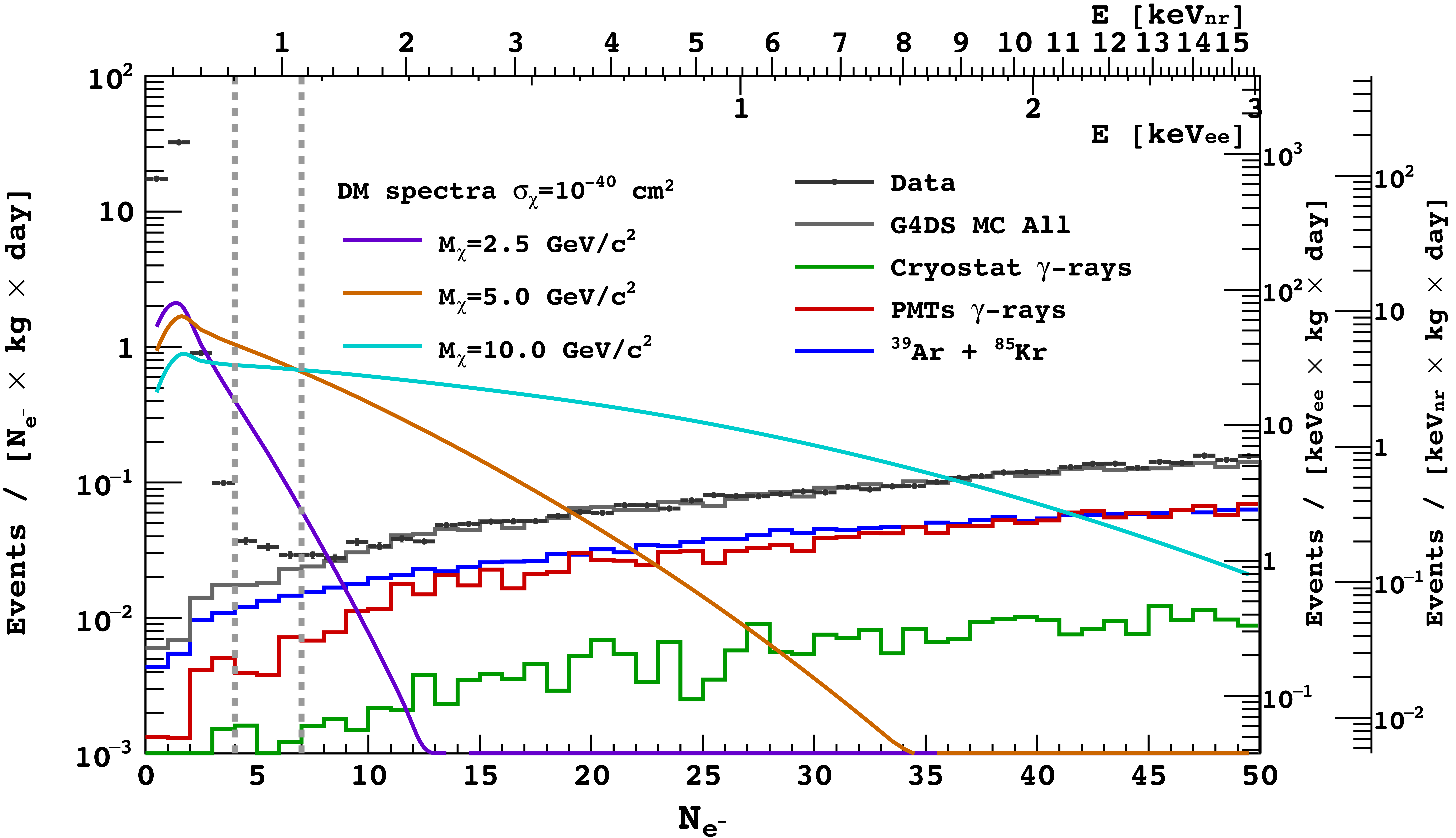

- P. Agnes et al. (The DarkSide Collaboration), "DarkSide-50 532-day Dark Matter Search with Low-Radioactivity Argon", arxiv:1802.07198.
- P. Agnes et al. (The DarkSide Collaboration), "Constraints on Sub-GeV Dark Matter-Electron Scattering from the DarkSide-50 Experiment", arxiv:1802.06998.
- P. Agnes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

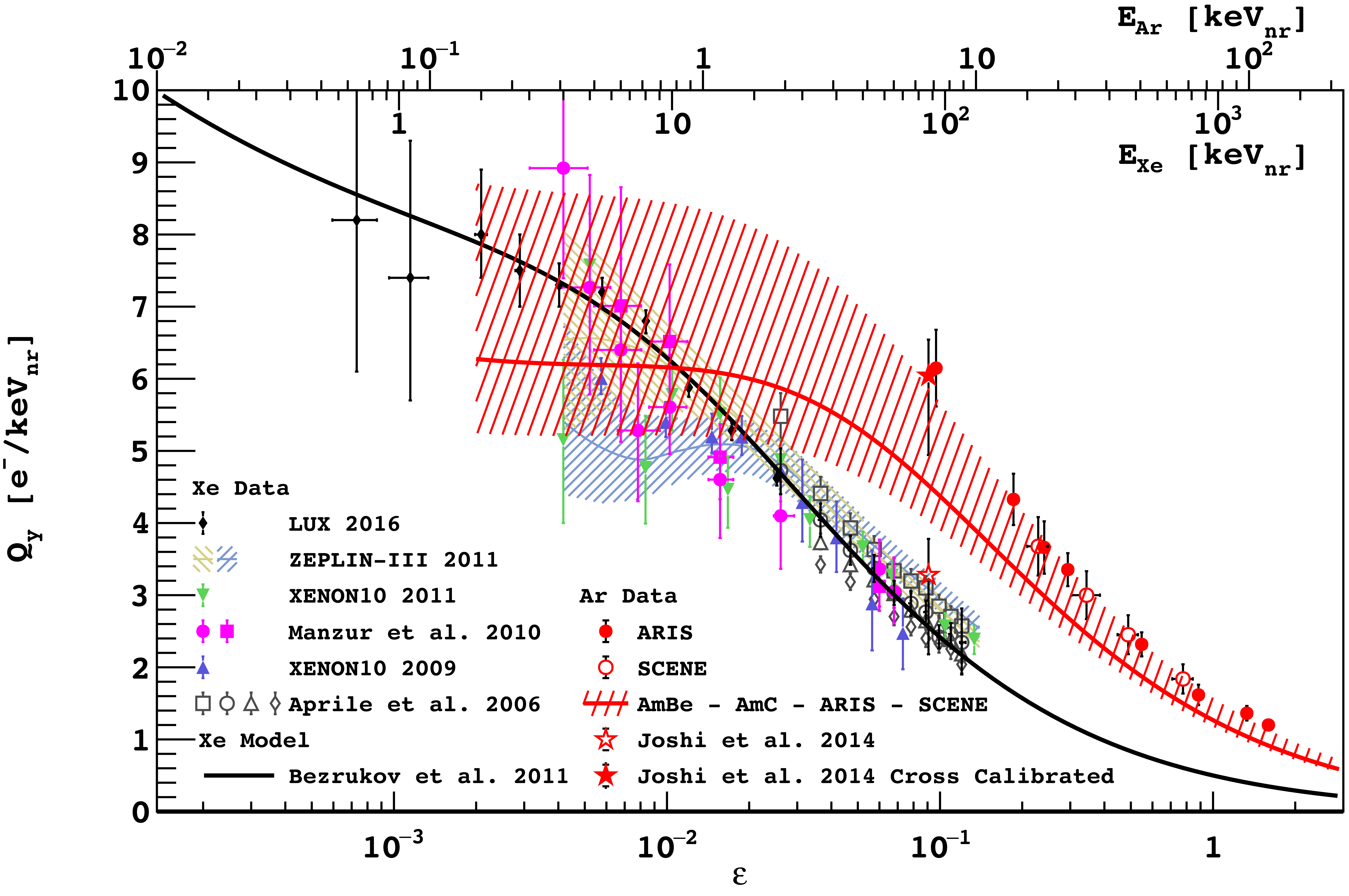

Physical Review Letters 121, 081307 (2018)
0.4 e-
10 $eV_{ee}$
10% Detector
Threshold
4 e-
100 $eV_{ee}$
Analysis
Threshold
Acceptance
S2 [PE]
Fiducialization
× Trigger efficiency
× S2 Identification ($f_{90}$<0.15)
0
10
20
30
40
50
60
70
80
90
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

Physical Review Letters 121, 081307 (2018)



Physical Review Letters 121, 081307 (2018)






Physical Review Letters 121, 081307 (2018)

Physical Review D 91, 092007 (2015)

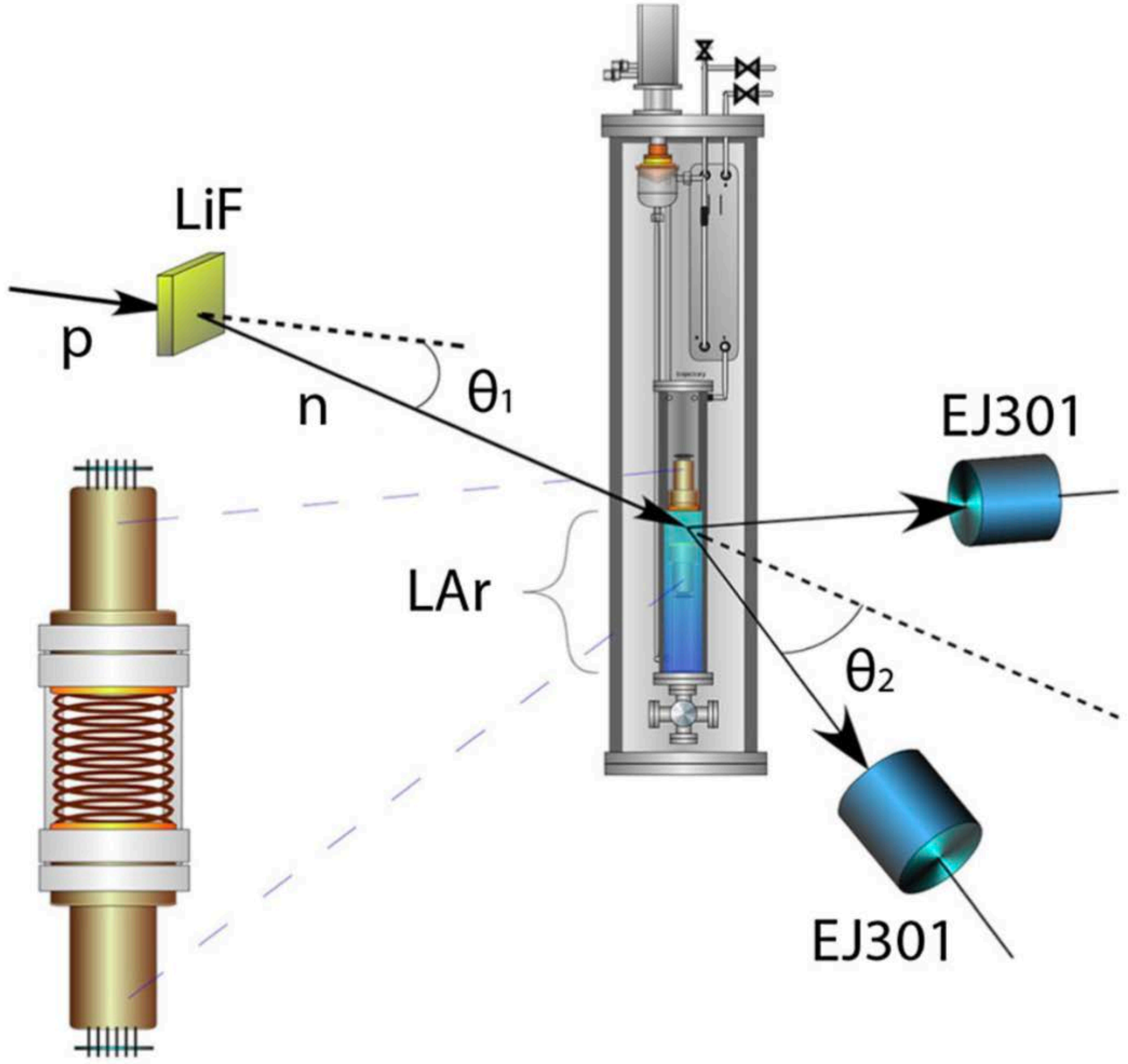
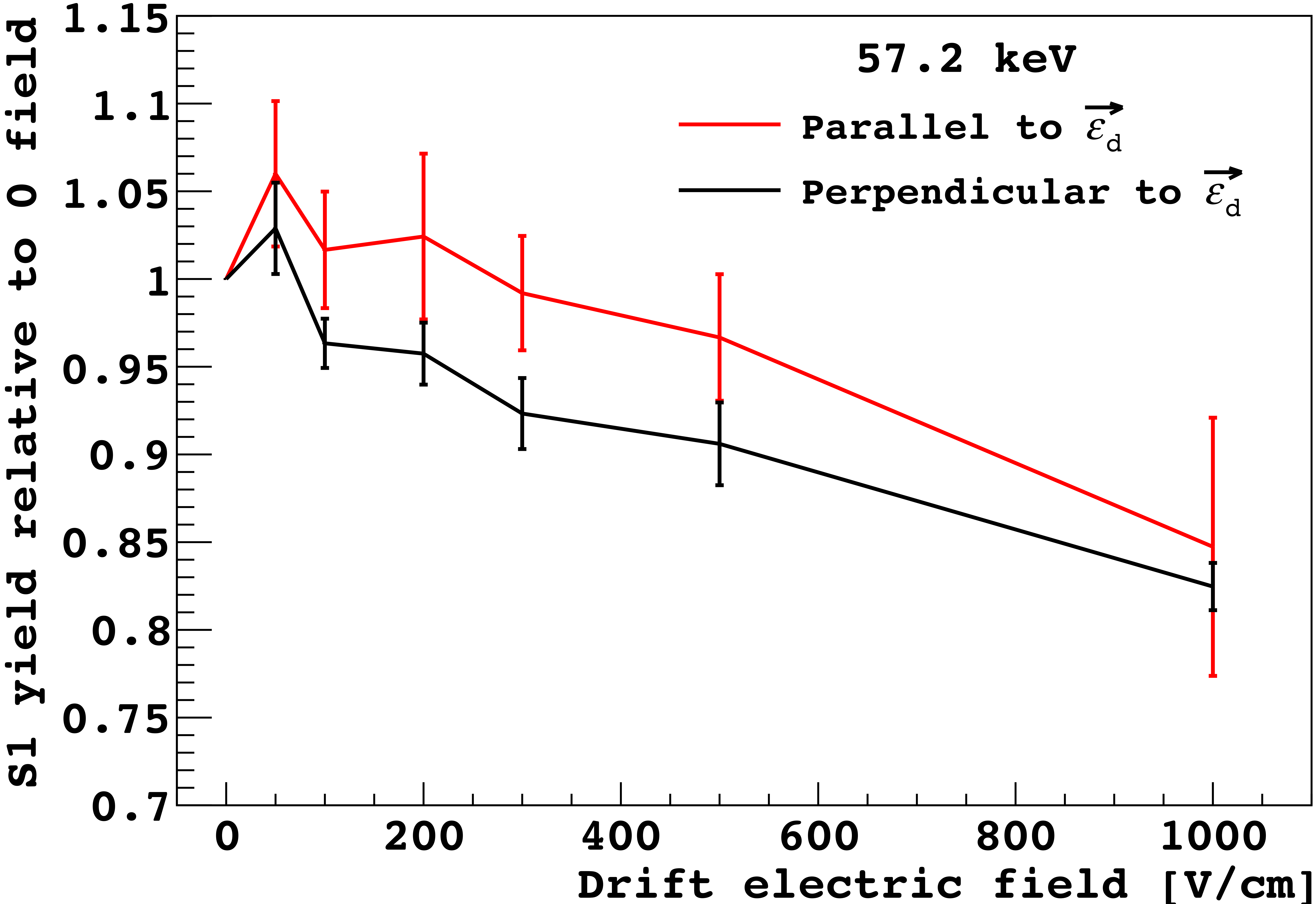
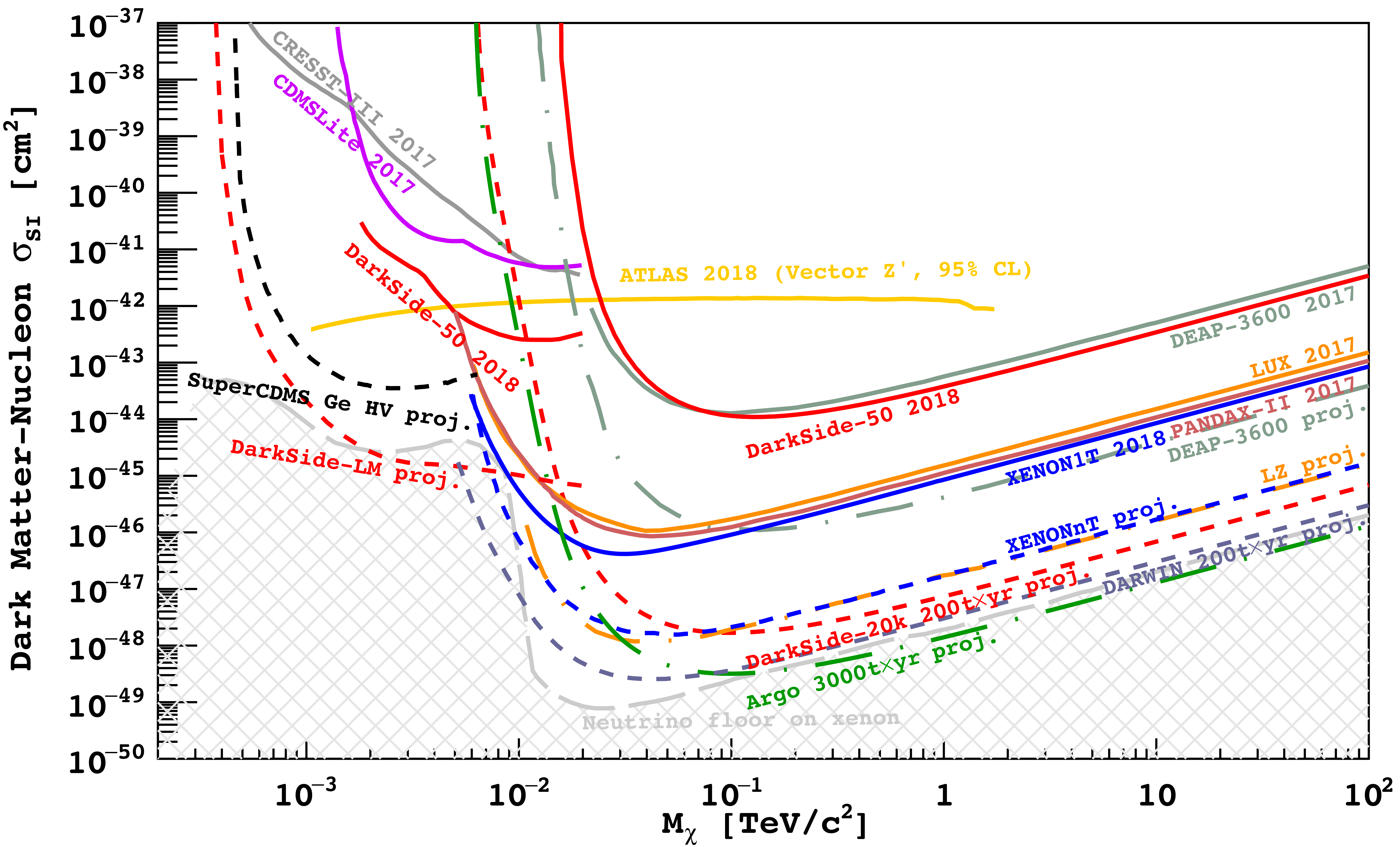


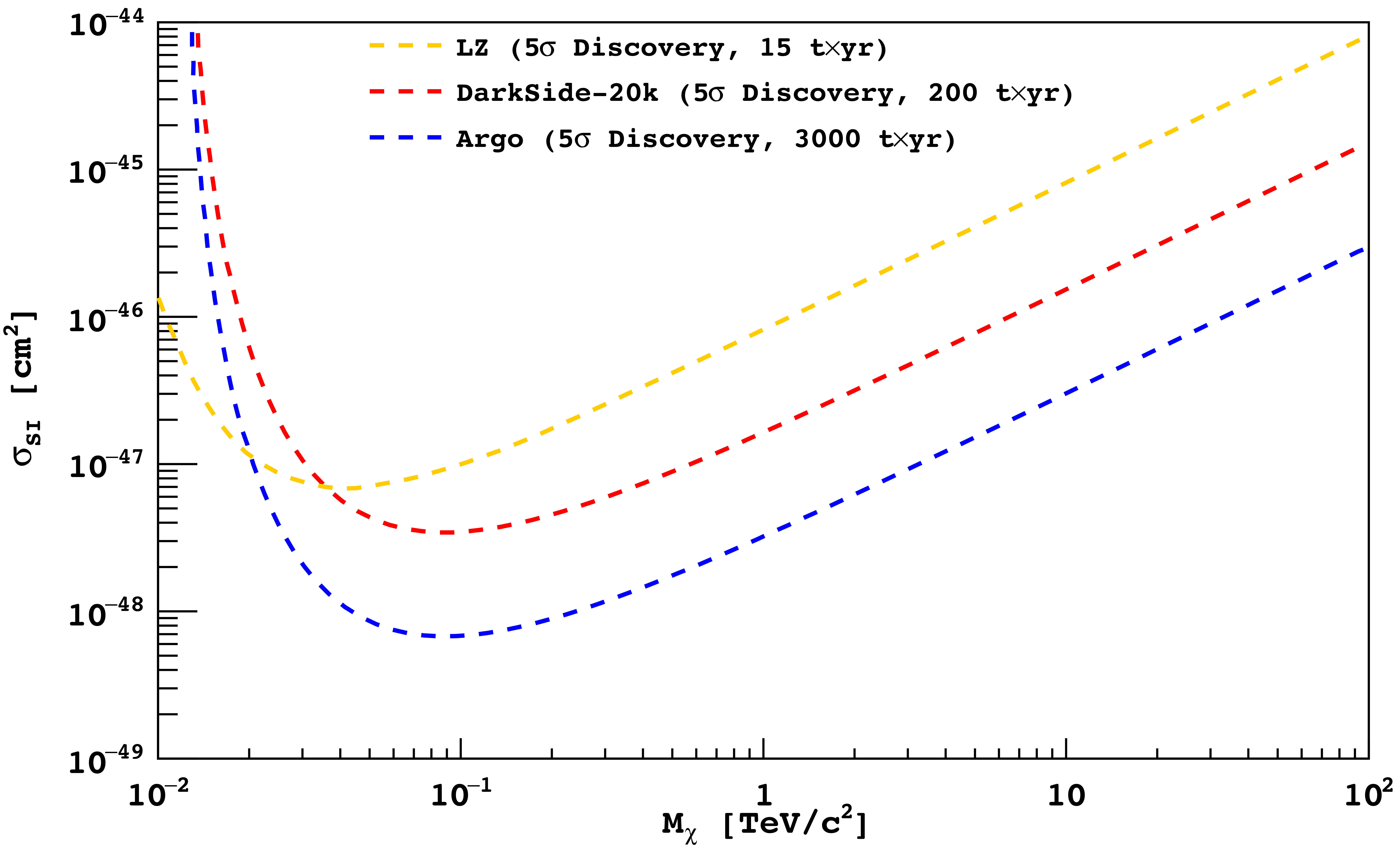

FIG. 1 (color online). A schematic of the experiment setup. $\theta_1$ is the neutron production angle and $\theta_2$ is the scattering angle. The inset shows a zoomed-in view of the TPC including the PMTs, field shaping rings and PTFE support structure. It does not include the inner reflector.



57.2 keV
Parallel to $\vec{\mathcal{E}}_d$
Perpendicular to $\vec{\mathcal{E}}_d$
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

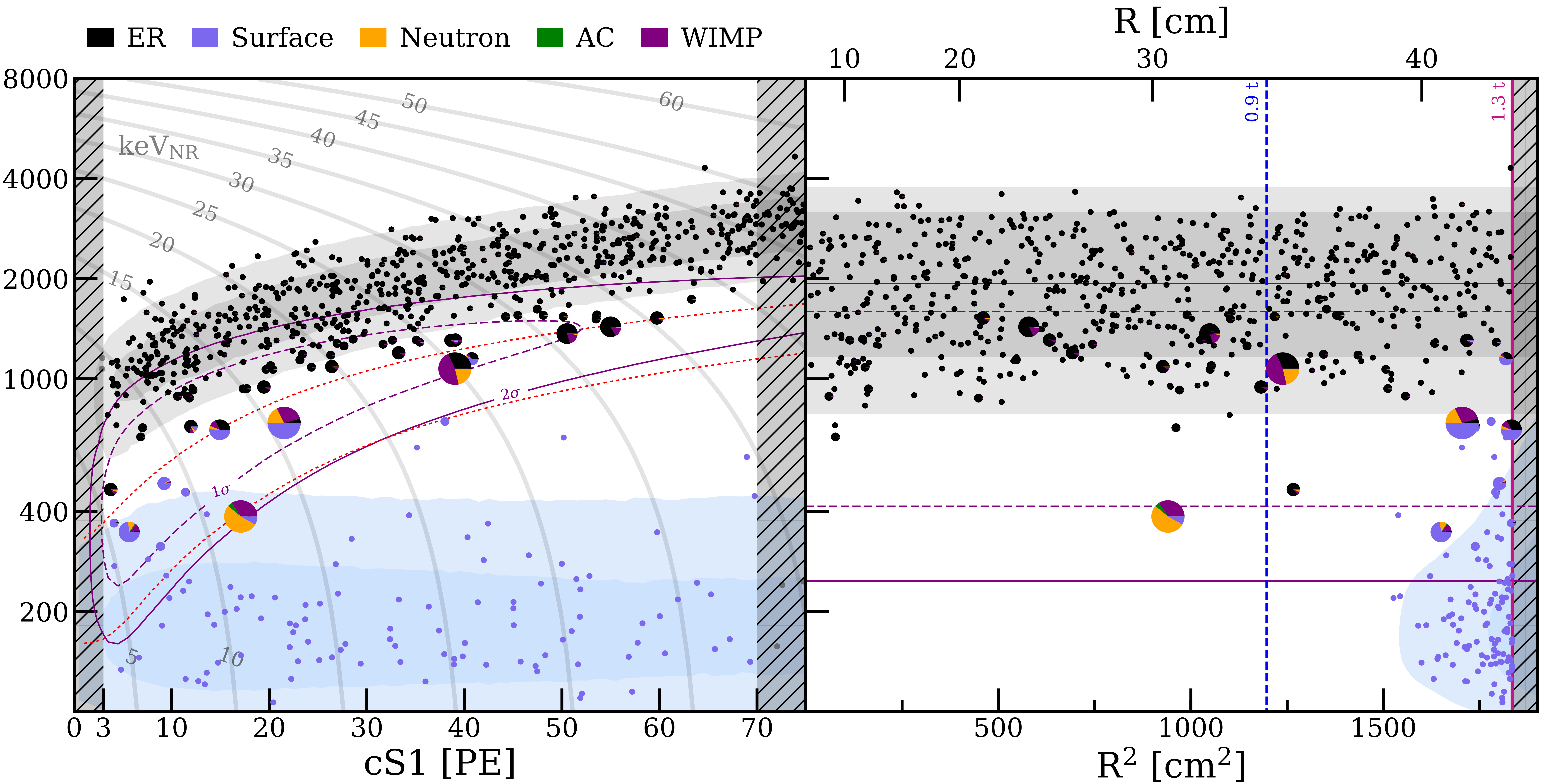


Dark Matter-Nucleon $\sigma_{SI}$ [cm$^2$]
$M_\chi$ [TeV/c$^2$]
CRESST-III 2017
CDMSLite 2017
ATLAS 2018 (Vector Z', 95% CL)
DarkSide-50 2018
DEAP-3600 2017
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
XENON1T 2018
SuperCDMS Ge HV proj.
DarkSide-LM proj.
LZ proj.
XENONnT proj.
DarkSide-20k 200t×yr proj.
DARWIN 200t×yr proj.
Argo 3000t×yr proj.
Neutrino floor on xenon



LZ (5σ Discovery, 15 t×yr)
DarkSide-20k (5σ Discovery, 200 t×yr)
Argo (5σ Discovery, 3000 t×yr)
$\sigma_{SI}$ [cm$^2$]
$M_\chi$ [TeV/c$^2$]
$10^{-44}$
$10^{-45}$
$10^{-46}$
$10^{-47}$
$10^{-48}$
$10^{-49}$
$10^{-2}$
$10^{-1}$
1
10
$10^2$

Physical Review Letters 121, 111302 (2018)



# 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

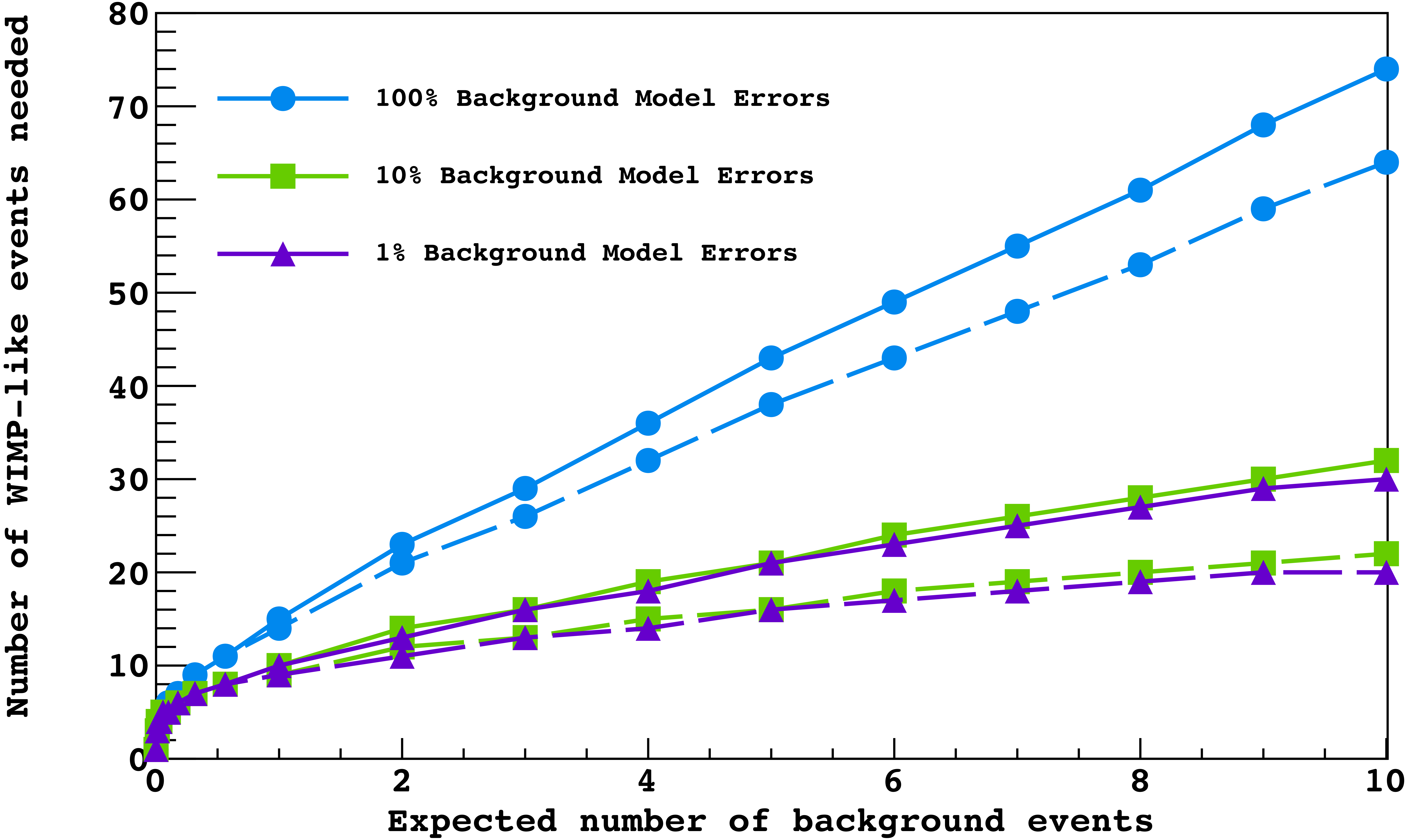
# Counts/1000 days: WIMP-search ROI

**5.6 ton fiducial, 1000 live-days**

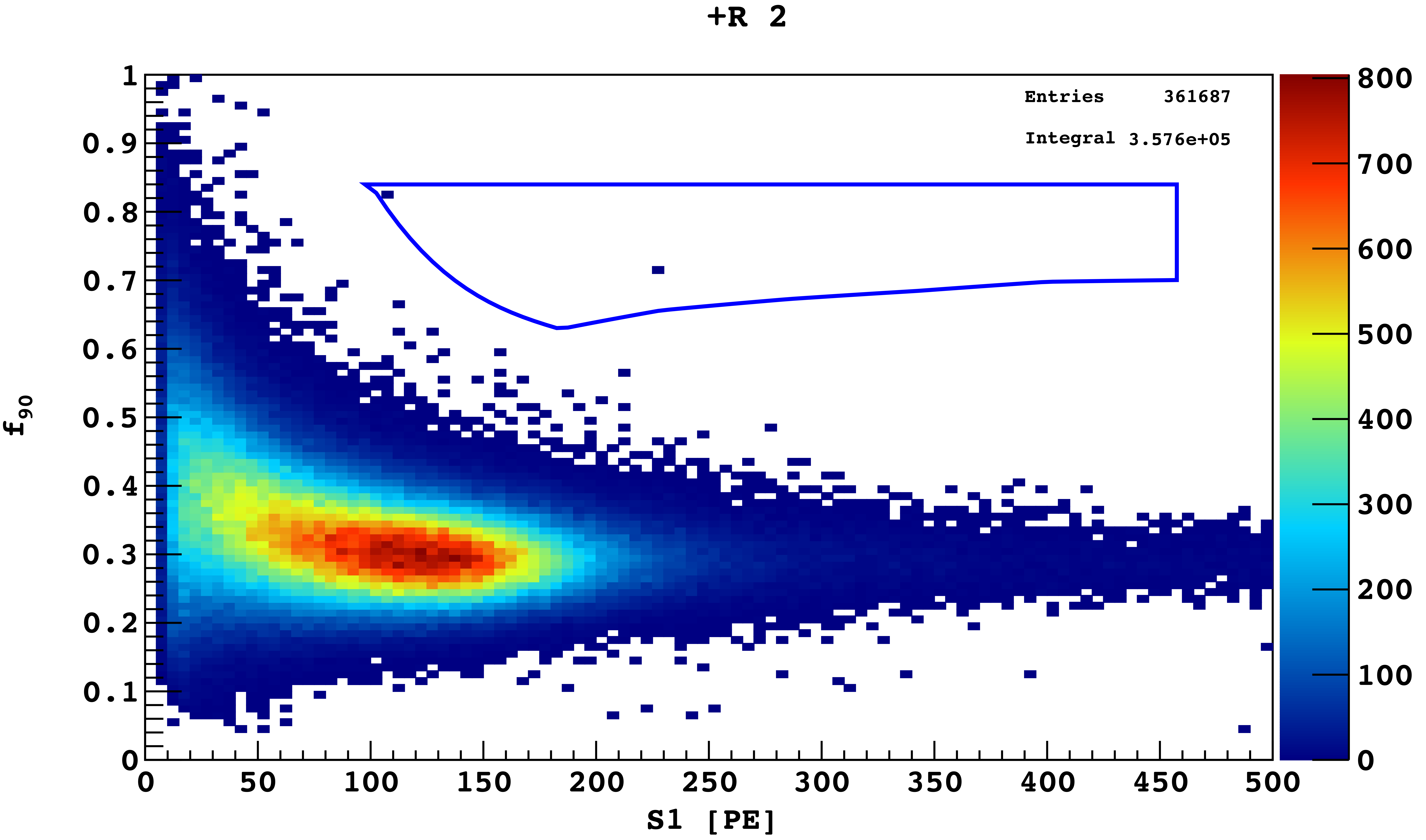
**~1.5 - 6.5 keV, single scatters, no coincident veto**

| Background Source | ERs | NRs |
|---|---|---|
| Detector Components | 9 | 0.07 |
| Dispersed Radionuclides — Rn, Kr, Ar | 816 | — |
| Laboratory and Cosmogenics | 5 | 0.06 |
| Surface Contamination and Dust | 40 | 0.39 |
| Physics Backgrounds — 2β decay, neutrinos* | 322 | 0.51 |
| **Total** (after 99.5% discrimination and 50% NR efficiency) | **6.48** | |

* not including $^{8}$B and hep


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

Physical Review D 98, 102006 (2018)



+Veto
Entries 227934
Integral 2.258e+05
$f_{90}$
S1 [PE]
Physical Review D 98, 102006 (2018)

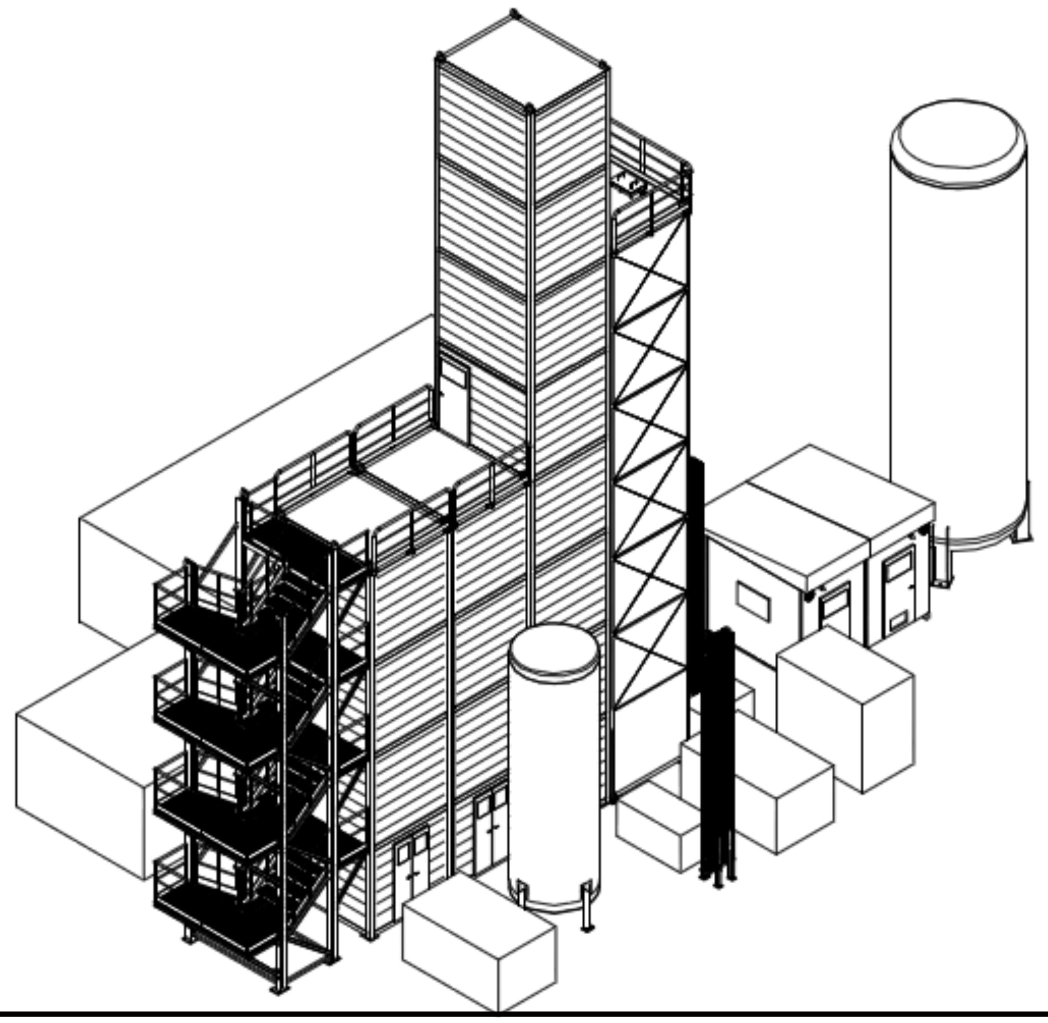
+r<10 cm && 50% loss S2/S1 cut (70d)
14
Entries 16213
Integral 1.619e+04
$f_{90}$
S1 [PE]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
0
10
20
30
40
50
60
70
Physical Review D 98, 102006 (2018)

+r<10 cm && 50% loss S2/S1 cut (70d)
Physical Review D 98, 102006 (2018)
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
0
50
100
150
200
250
300
350
400
450
500
14
0
10
20
30
40
50
60
70

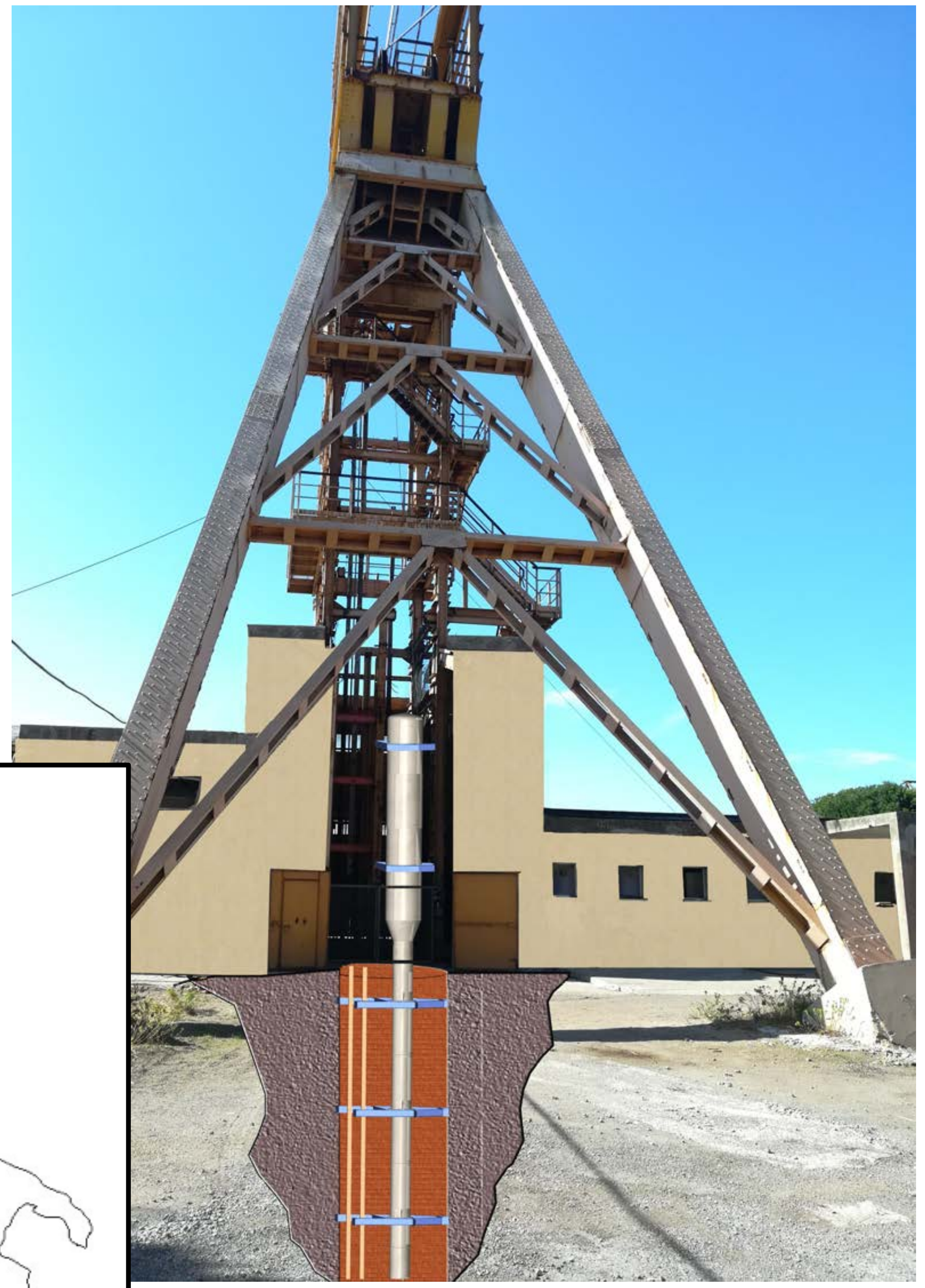
# THE DARKSIDE-20K PROJECT

- €90M
- Capital funding by IT INFN, US NSF
- Capital funding requests to CAN CFI, UK STFC in 2019
- Strong synergies with LAr programs at FNAL and BNL
- RE-37 at CERN

# Production and Purification



UAr transported via boat for final purification at Aria



**Production: Urania**

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

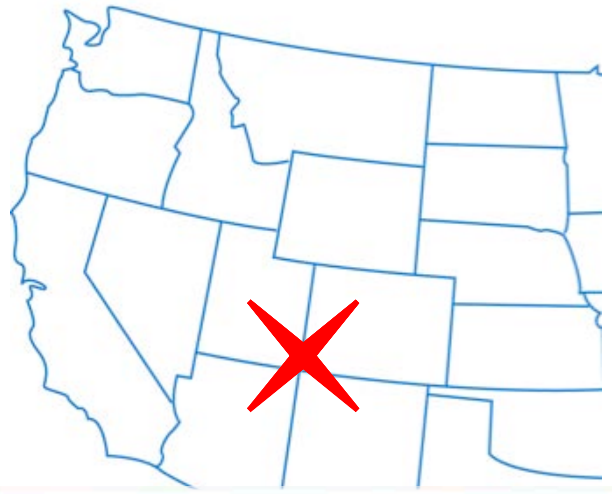
**Focus of this talk**

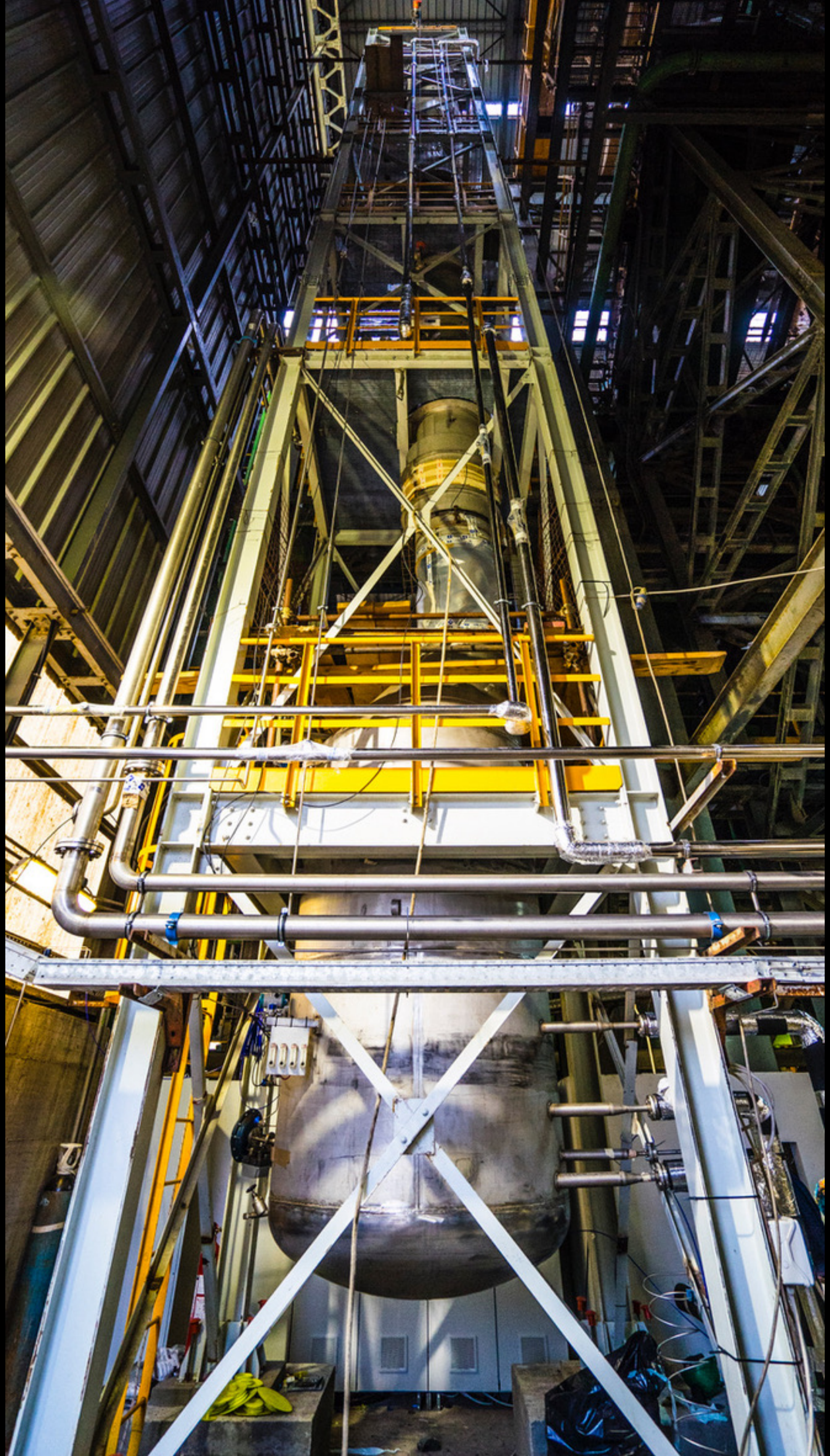
**Purification: Aria**

**(see M. Simeone's talk for details)**

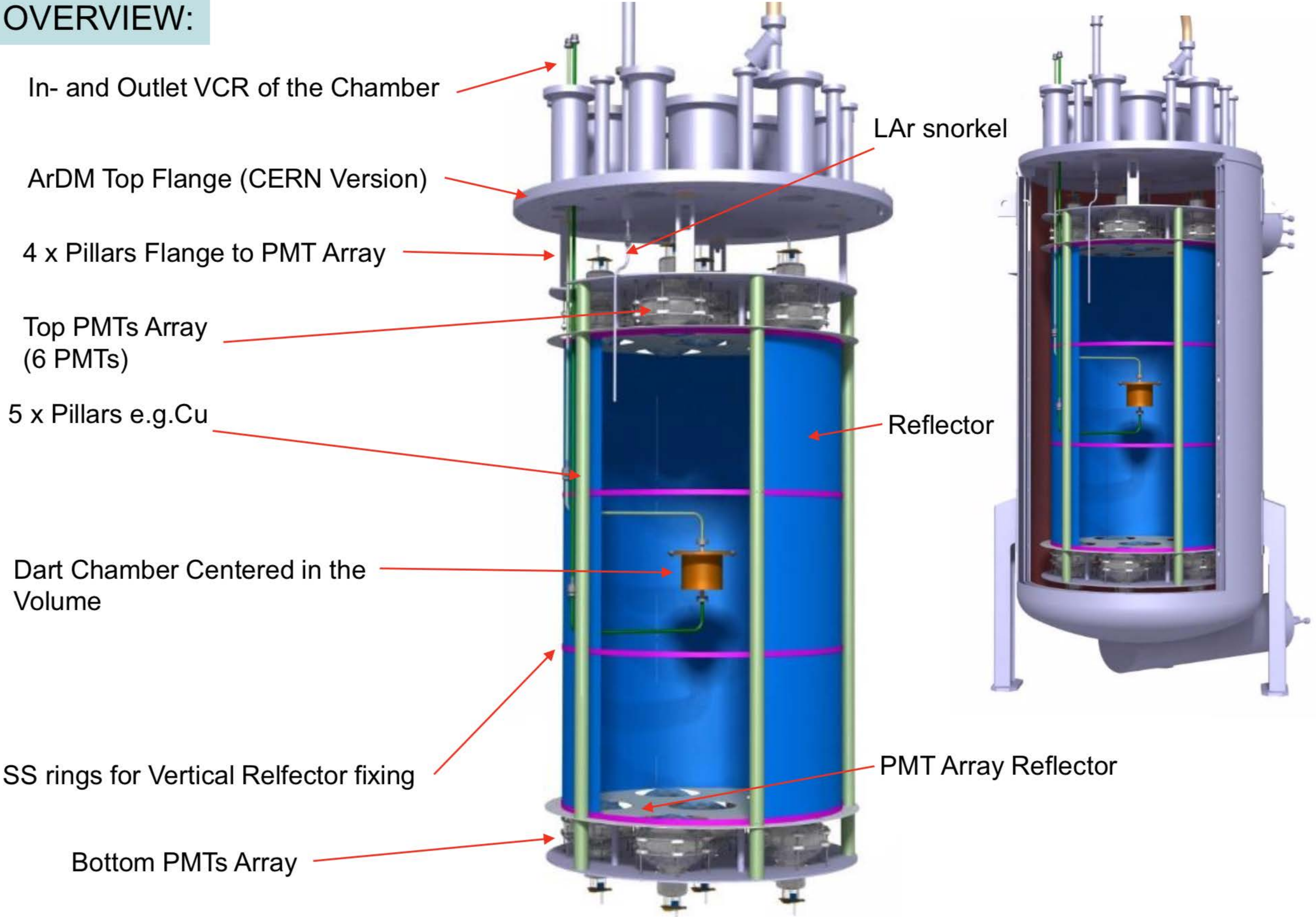
- 350 m tall cryogenic distillation column to purify UAr and isotopically separate argon and other elements
- Located in refurbished carbon mine shaft in Sardinia, Italy
- Will chemically purify the UAr for DS-20k to detector grade

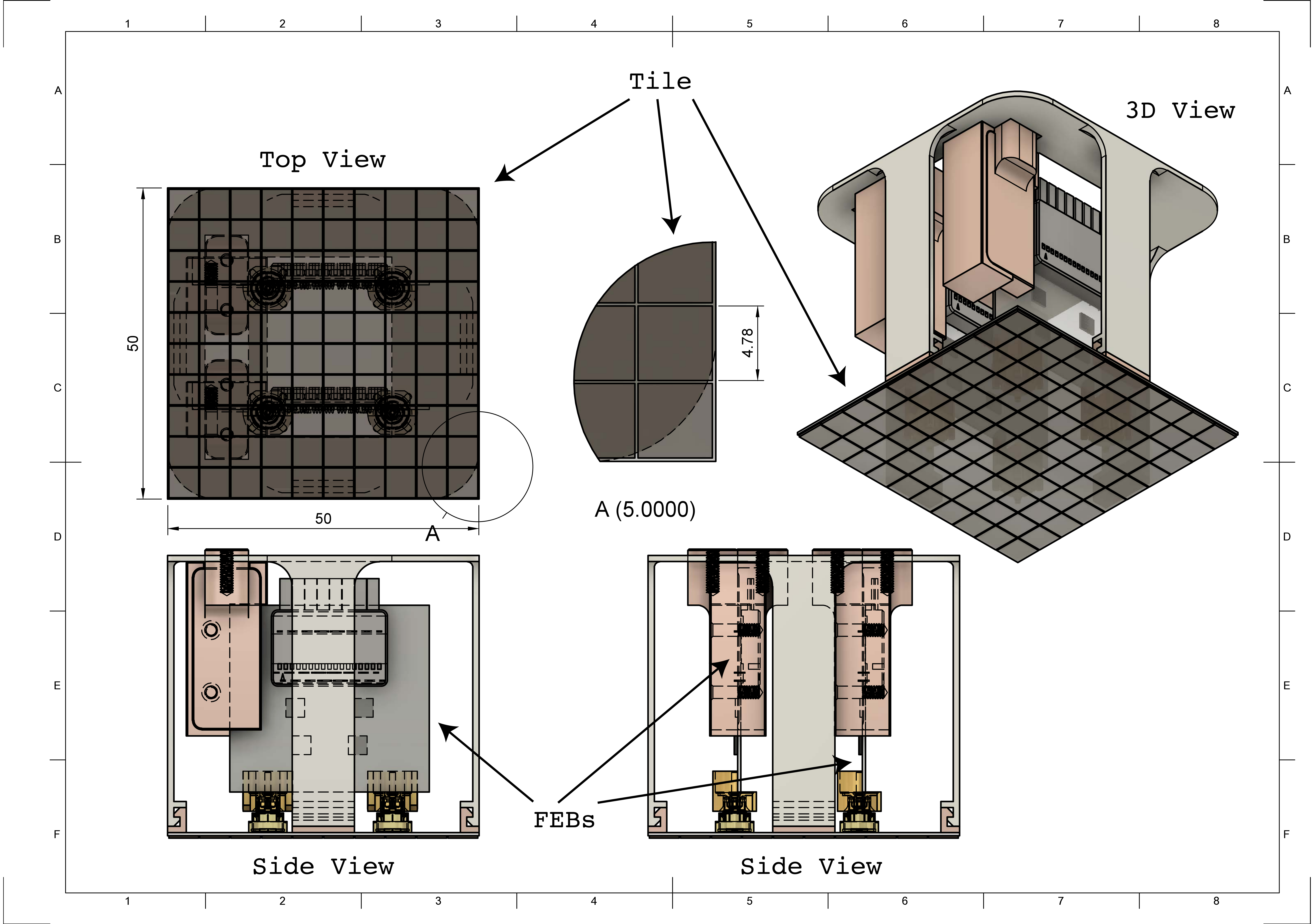
# Enter the Age of Urania



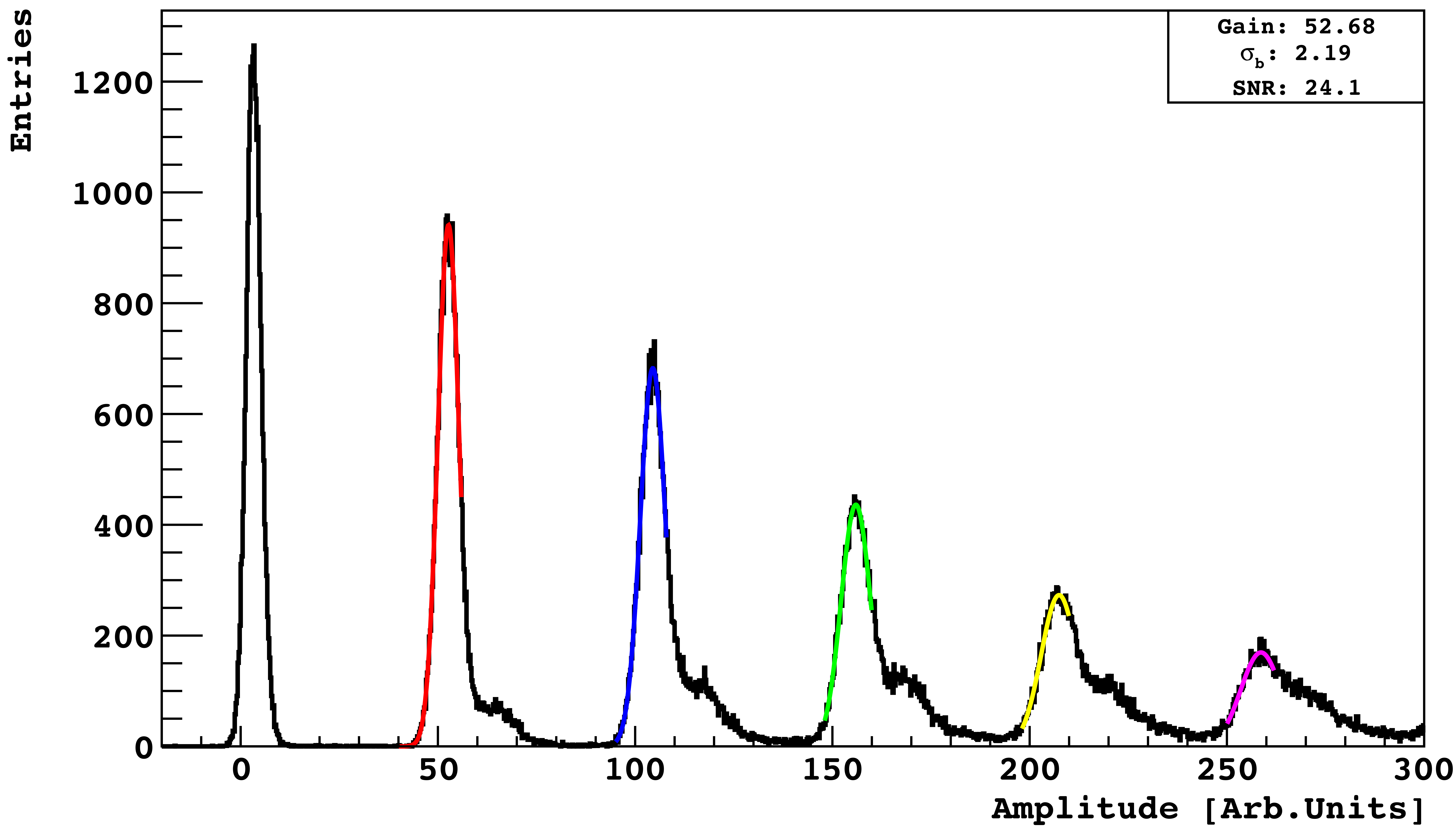



# OVERVIEW:

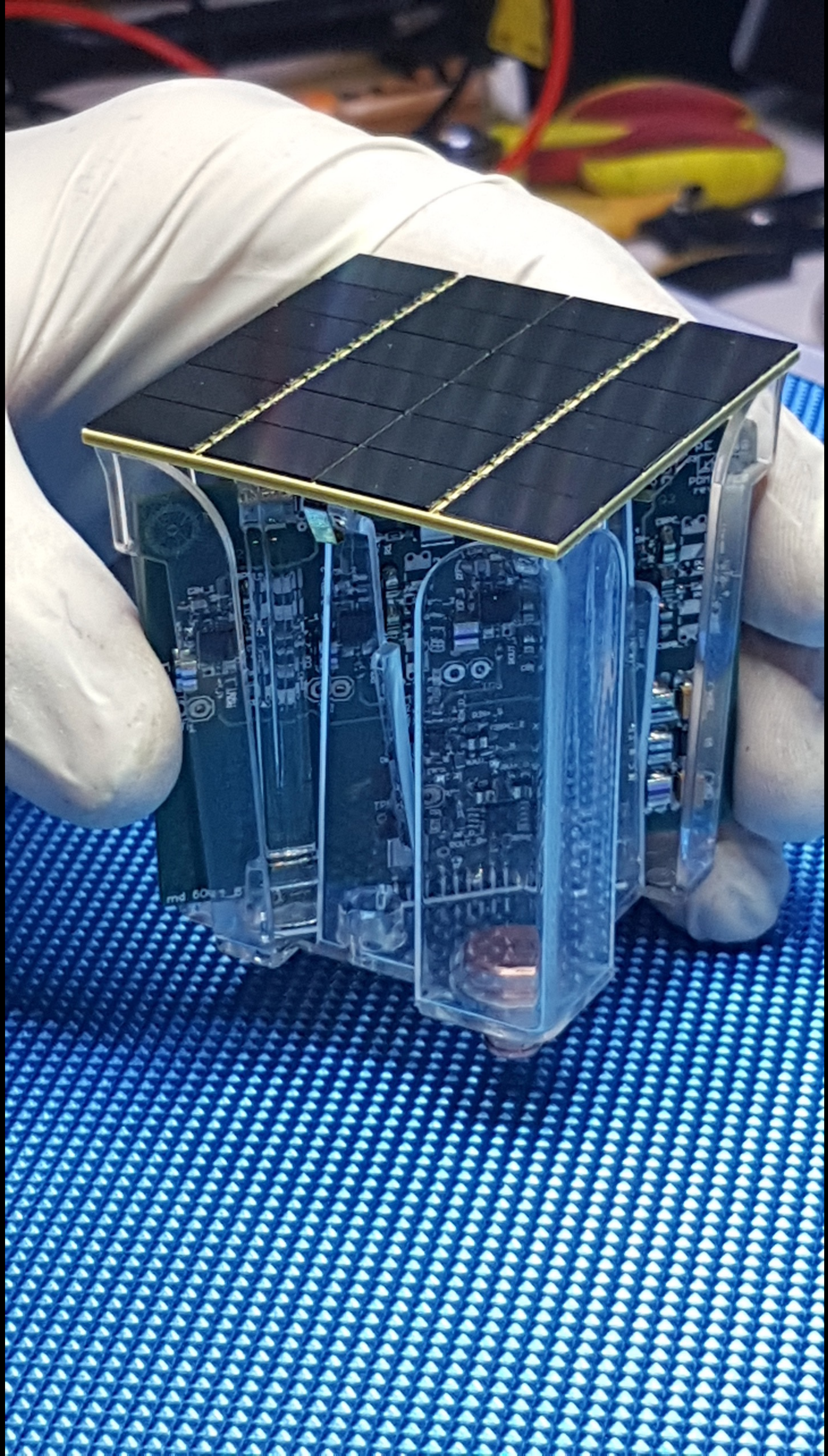
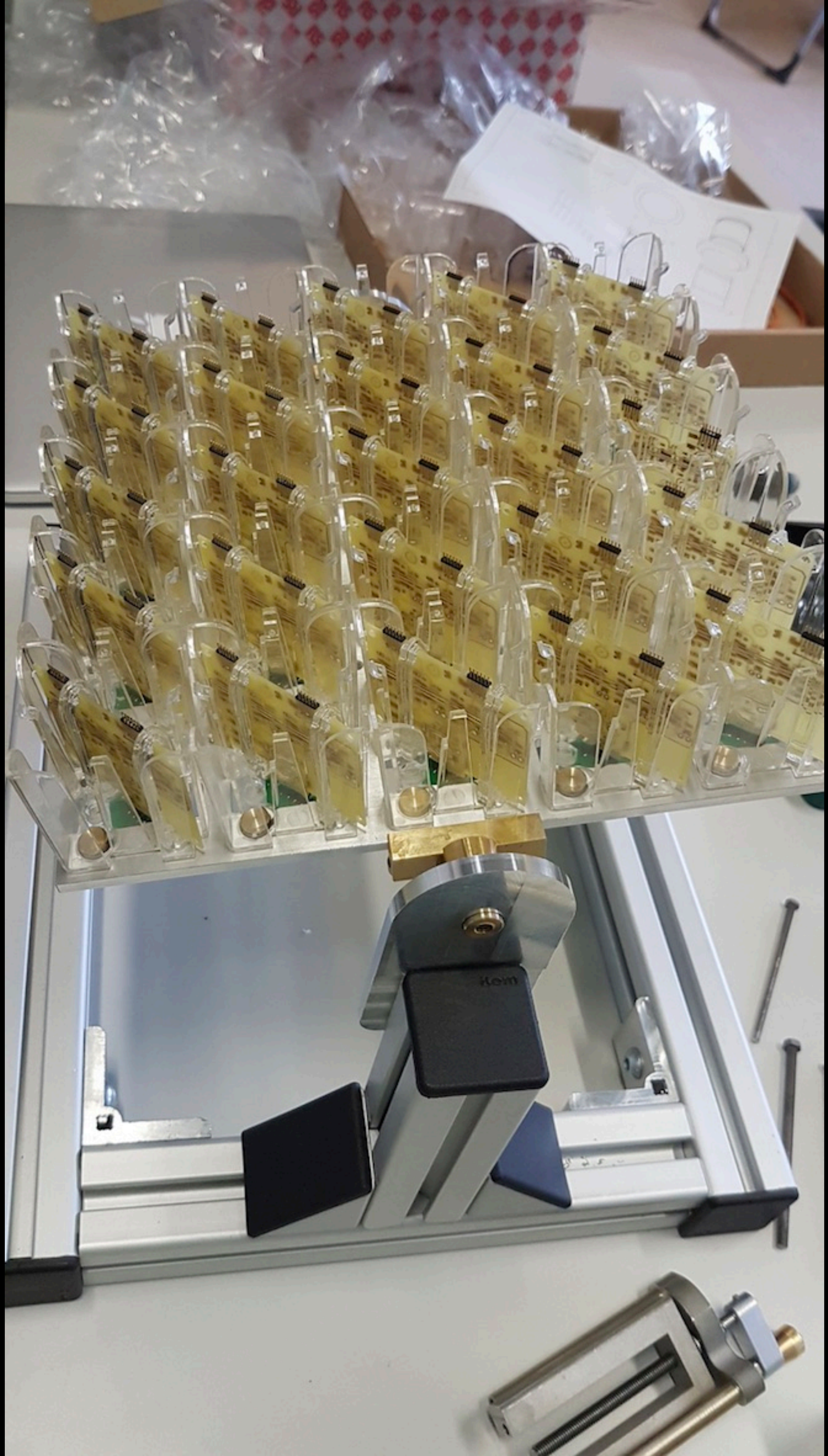

In- and Outlet VCR of the Chamber
ArDM Top Flange (CERN Version)
4 x Pillars Flange to PMT Array
Top PMTs Array
(6 PMTs)
5 x Pillars e.g.Cu
Dart Chamber Centered in the
Volume
SS rings for Vertical Relfector fixing
Bottom PMTs Array
LAr snorkel
Reflector
PMT Array Reflector

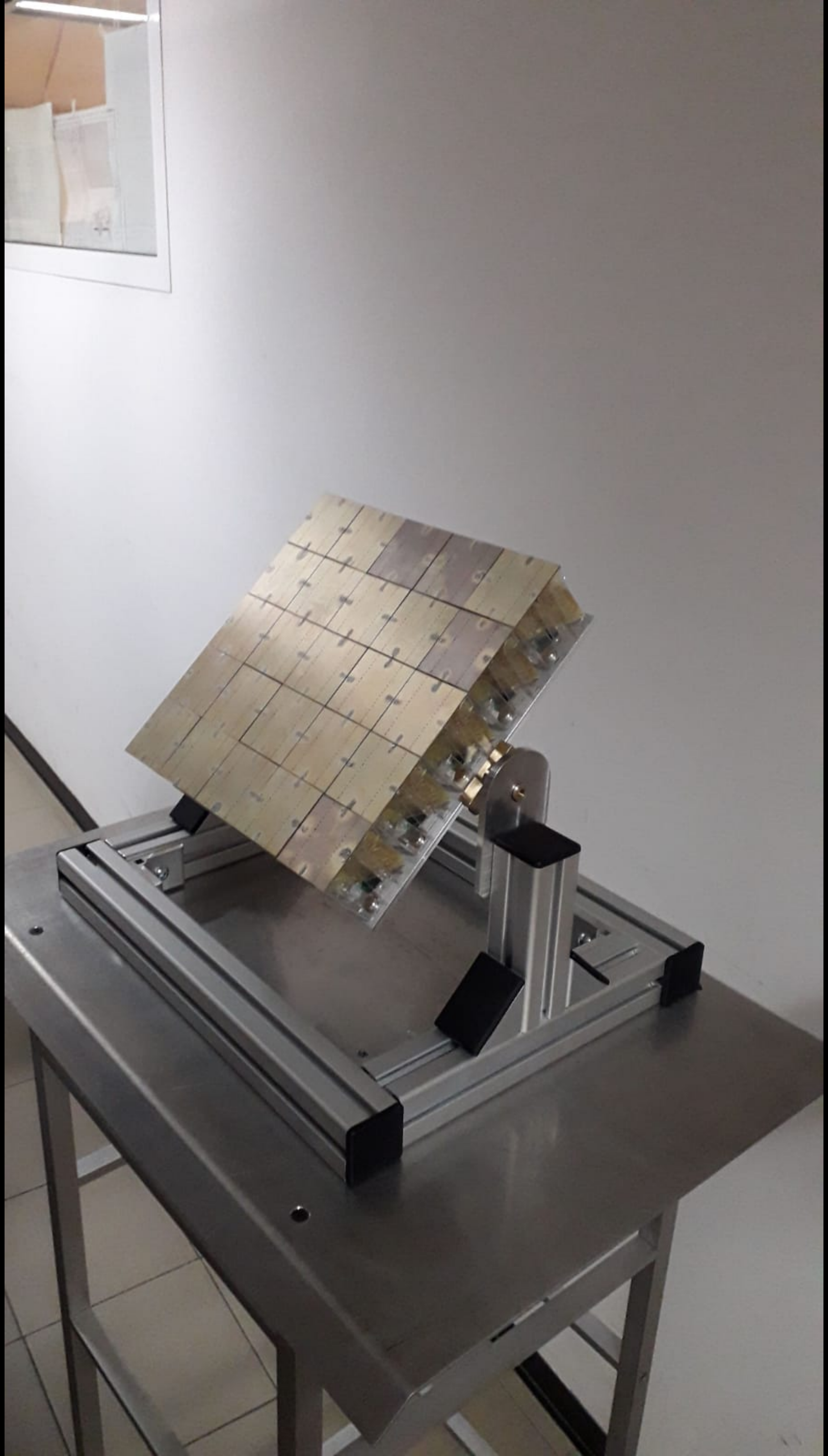
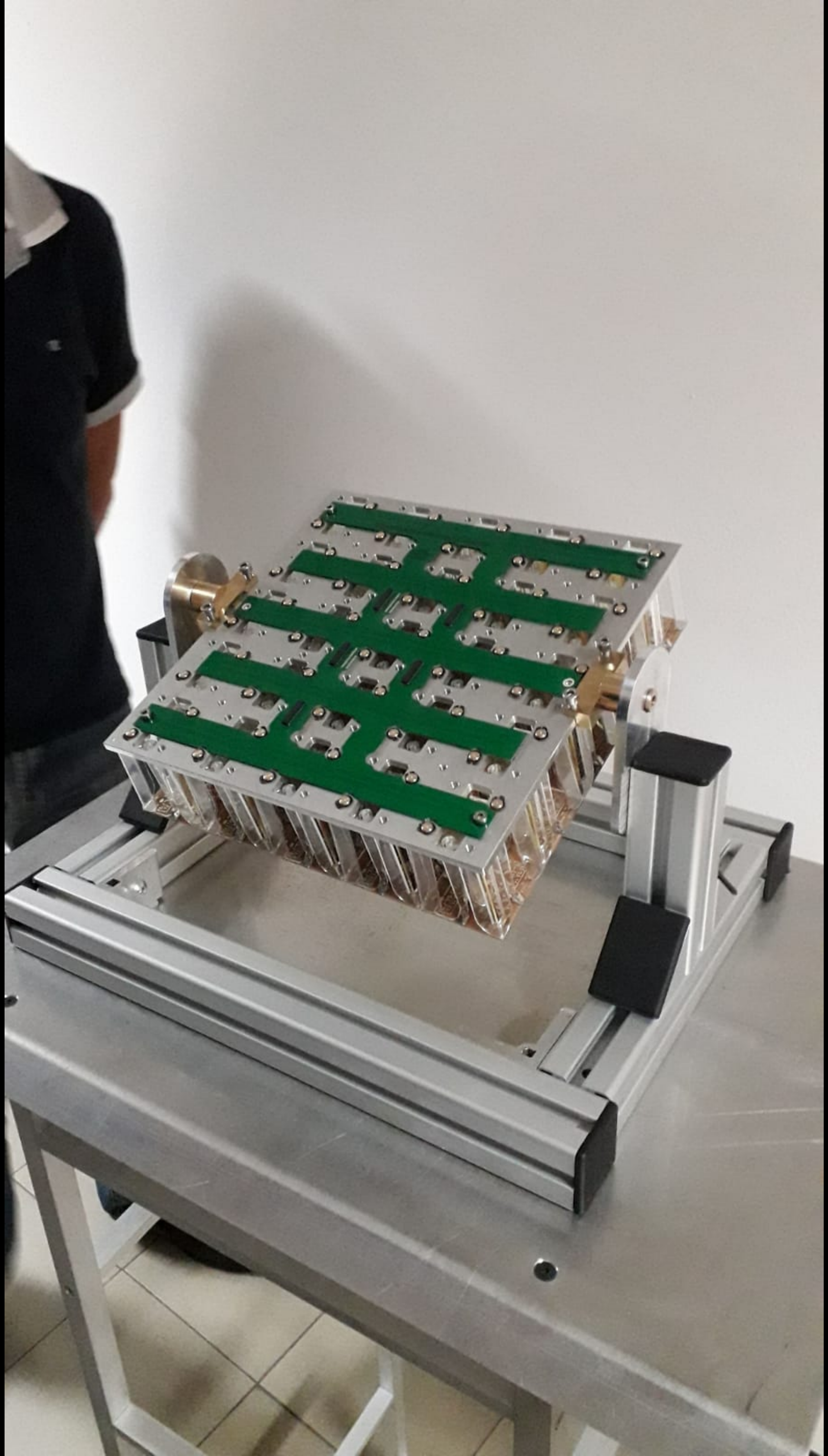


Tile
Top View
3D View
50
50
A
4.78
A (5.0000)
FEBs
Side View
Side View



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


THE END