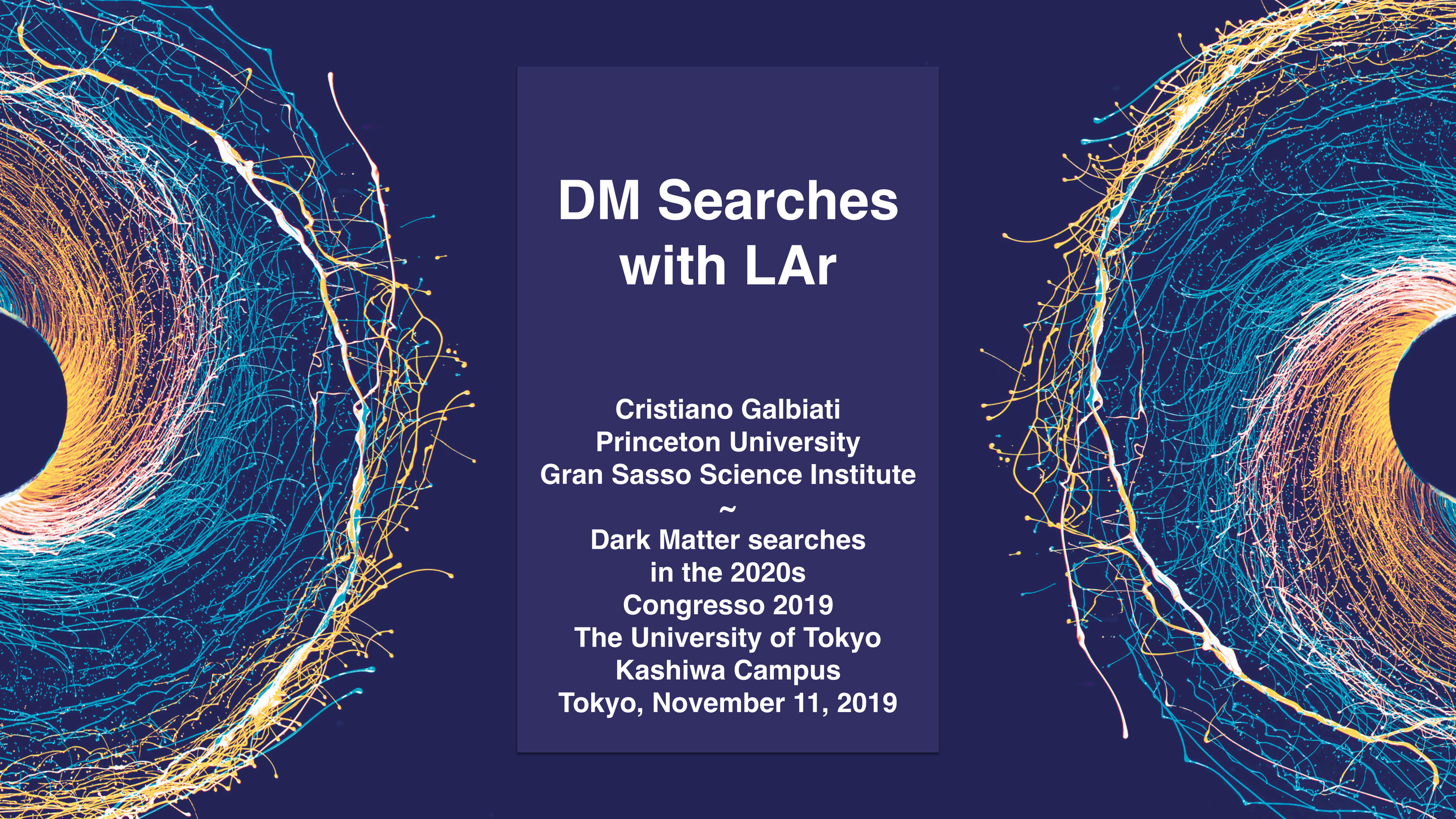
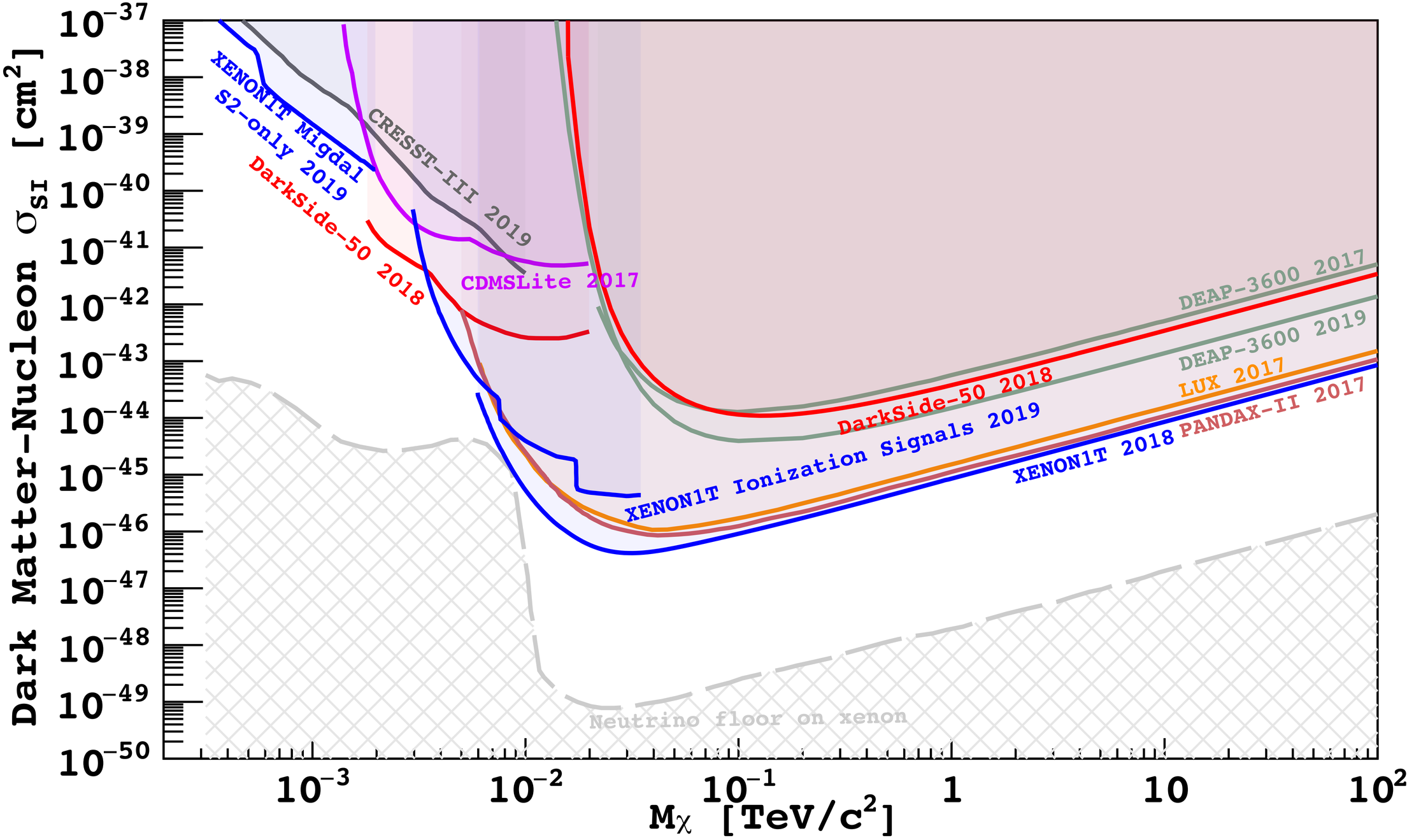


DM Searches with LAr

Cristiano Galbiati
Princeton University
Gran Sasso Science Institute

~

Dark Matter searches
in the 2020s
Congresso 2019
The University of Tokyo
Kashiwa Campus
Tokyo, November 11, 2019


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}
Mχ [TeV/c^2]
XENON1T Migdal S2-only 2019
DarkSide-50 2018
CRESST-III 2019
CDMSLite 2017
DEAP-3600 2017
DarkSide-50 2018
DEAP-3600 2019
LUX 2017
XENON1T Ionization Signals 2019
PANDAX-II 2017
XENON1T 2018
Neutrino floor on xenon

DarkSide-20k

20-tonnes fiducial dark matter detector

start of operations at LNGS within 2023

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

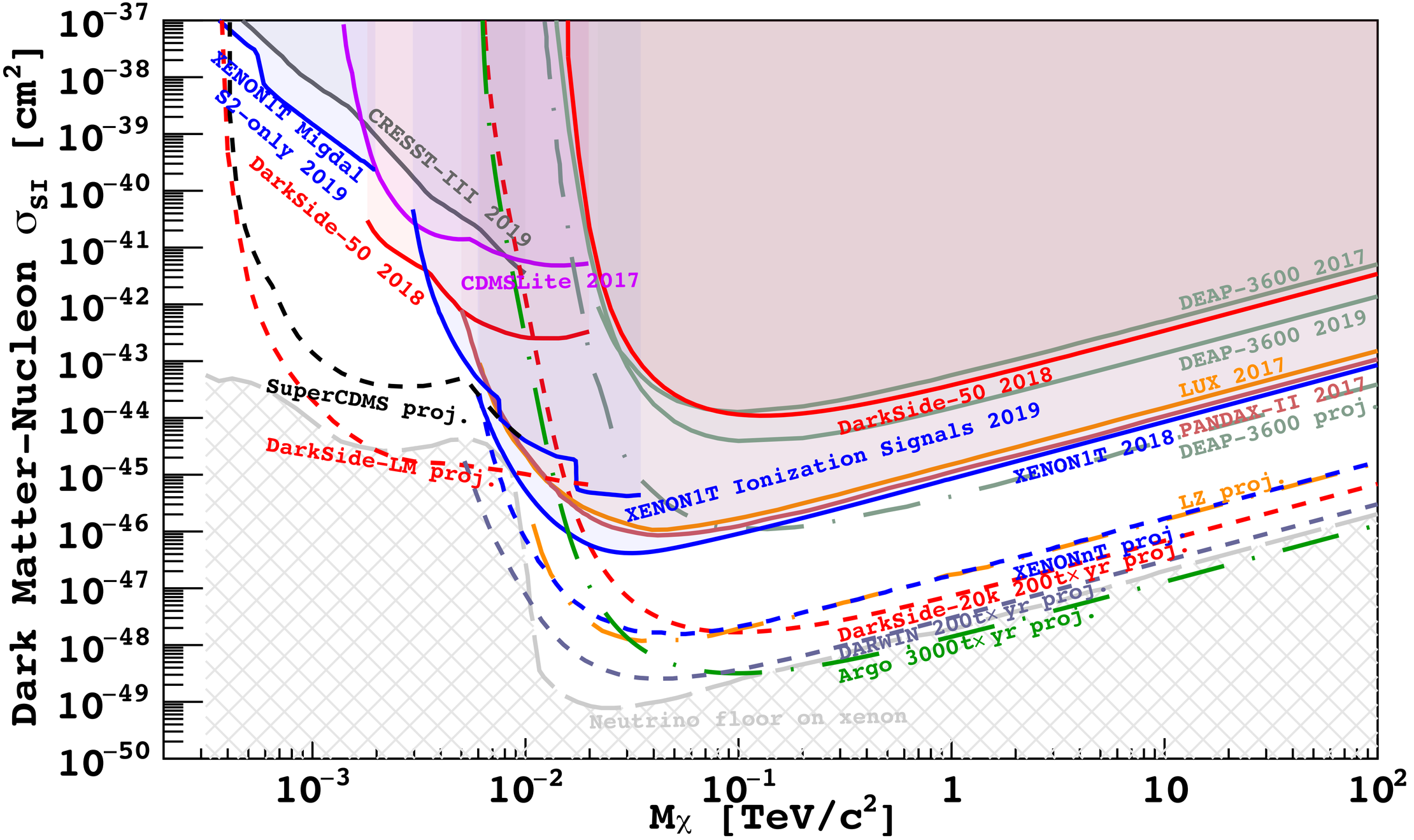
Argo

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]
10^{-37}
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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}
Mχ [TeV/c^2]
XENON1T Migdal
S2-only 2019
DarkSide-50 2018
CRESST-III 2019
CDMSLite 2017
SuperCDMS proj.
DarkSide-LM proj.
DarkSide-50 2018
XENON1T Ionization Signals 2019
XENON1T 2018
DEAP-3600 2017
DEAP-3600 2019
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
LZ proj.
DarkSide-20k 200t×yr proj.
XENONnT proj.
DARWIN 200t×yr proj.
Argo 3000t×yr proj.
Neutrino floor on xenon

THE GADMC PROGRAM FOR DARK MATTER SEARCHES

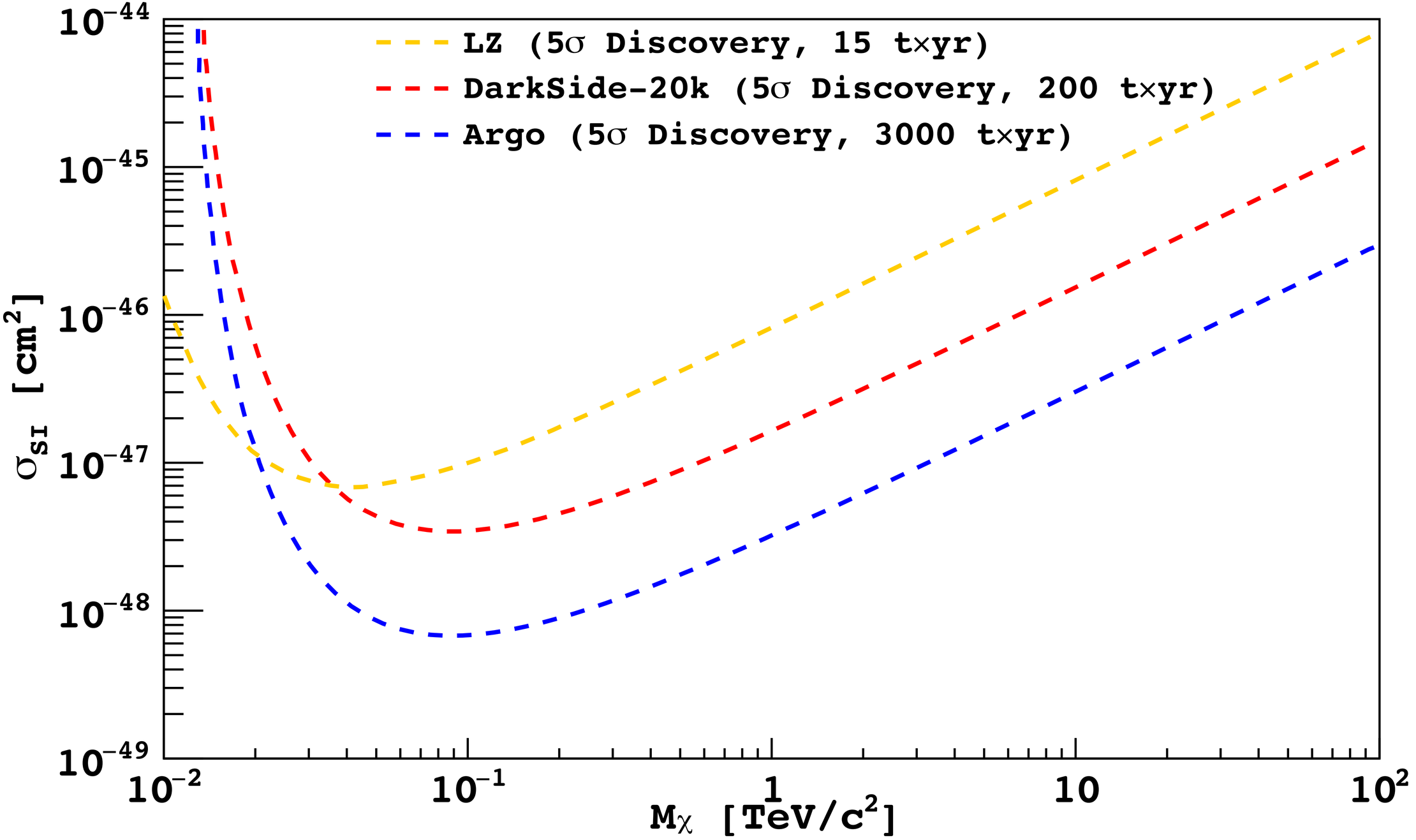
- Explore heavy dark matter through the neutrino floor and beyond
  - Zero instrumental background
  - Exploration of directional signal

HIGH MASS SEARCH REQUIREMENTS

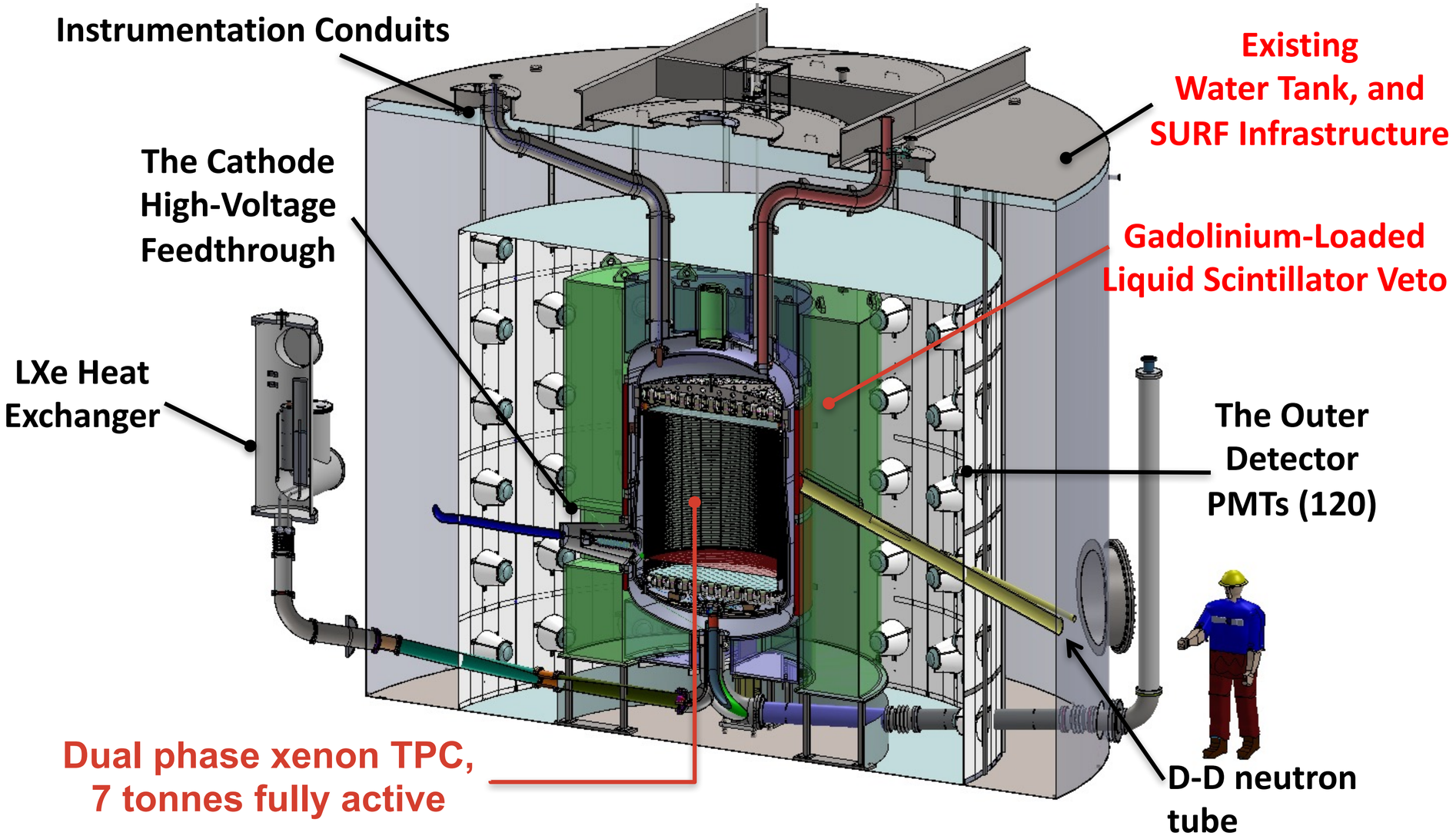
- Exposure of O(1000 tonne × year)
- Background free operation
  - Solar neutrinos become background: rejection of minimum ionizing background must reach at least one part in 10^5

TECHNOLOGICAL ENABLERS

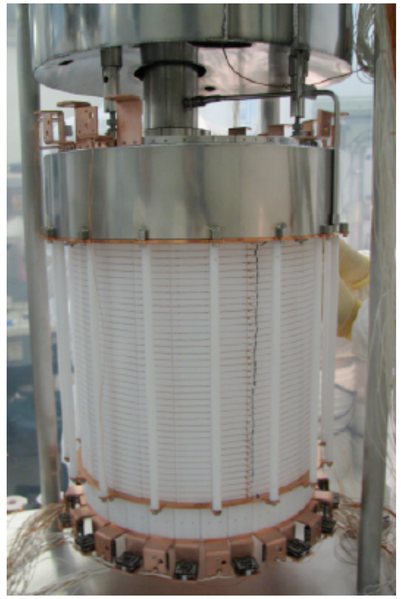
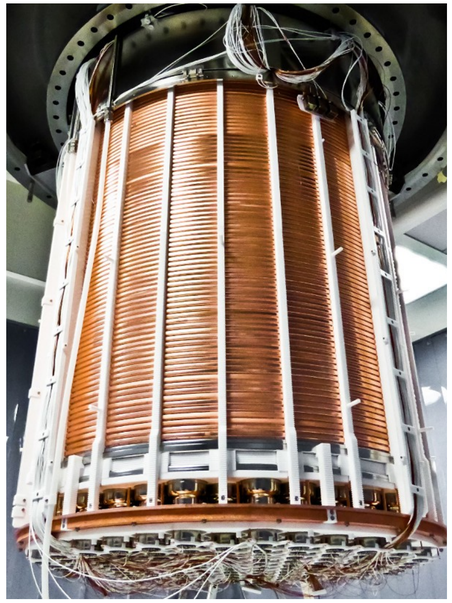
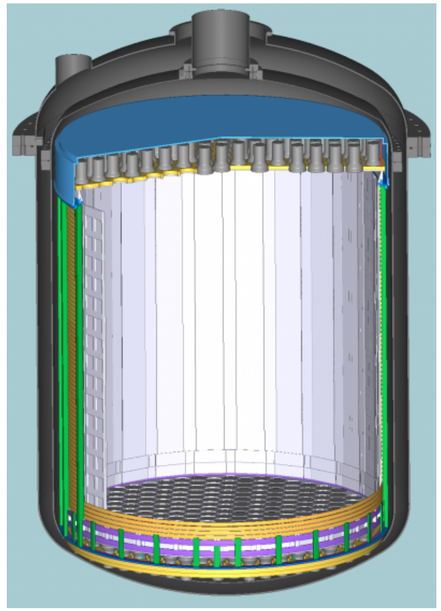
- Custom SiPM-based cryogenic photodetectors
- Custom ^{39}Ar-depleted liquid argon
- ProtoDUNE-like cryostat for hosting detector and active veto


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

The LUX-ZEPLIN detector



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

LZ backgrounds summary

5.6 tonnes, 1000 days

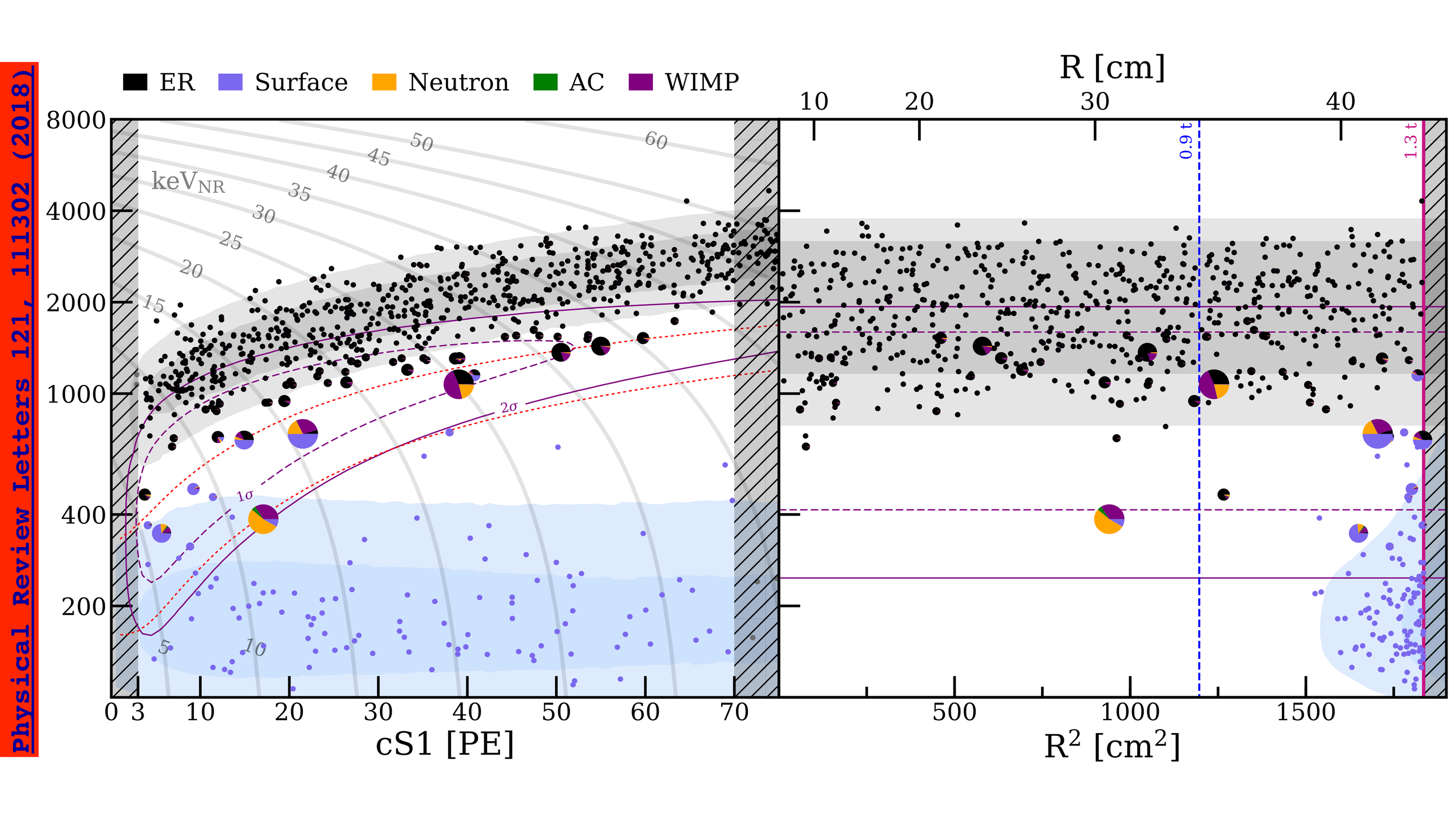
Intrinsic Contamination Backgrounds	ER (cts)	NR (cts) (w/ SF rej.)
Subtotal (Detector Components)	**9**	**0.072**
222Rn (1.81 μBq/kg)	681	-
220Rn (0.09 μBq/kg)	111	-
natKr (0.015 ppt g/g)	25	-
natAr (0.45 ppb g/g)	2	-
210Bi (0.1 μBq/kg)	40	-
Laboratory and Cosmogenics	5	0.06
Fixed Surface Contamination	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.

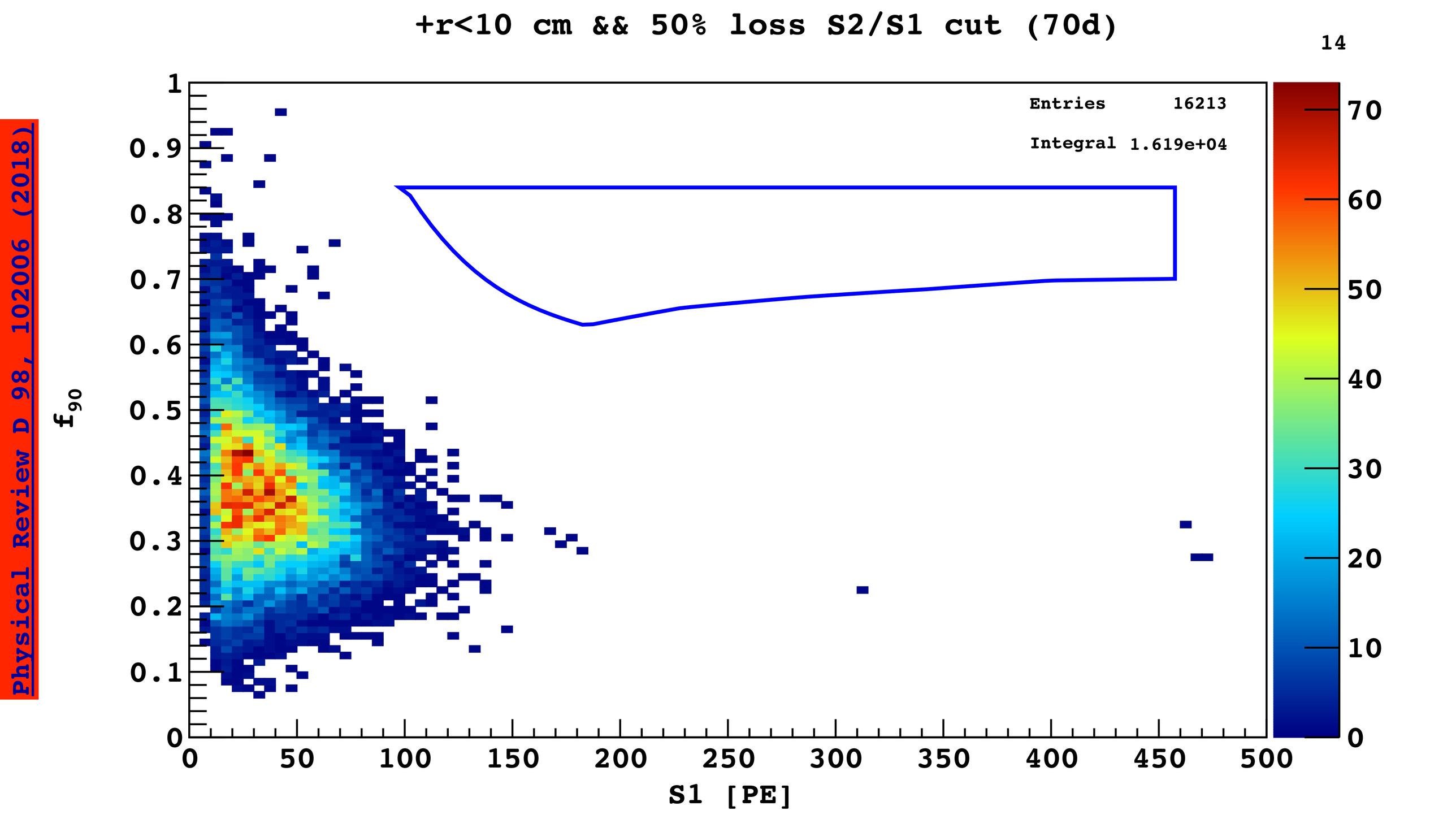
pp solar neutrinos, elastic scattering on atomic electrons

Coherent neutrino scattering on xenon nuclei

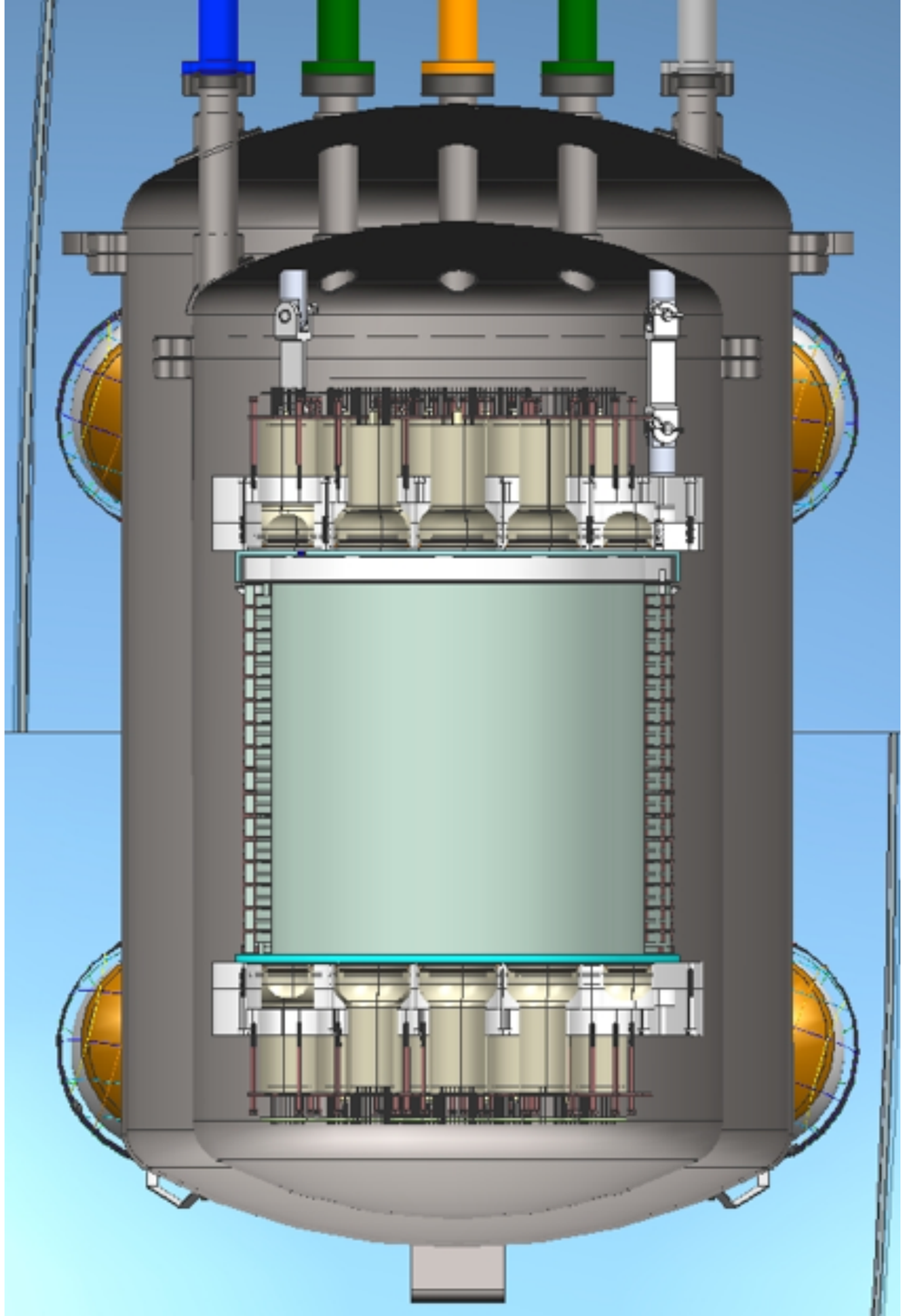


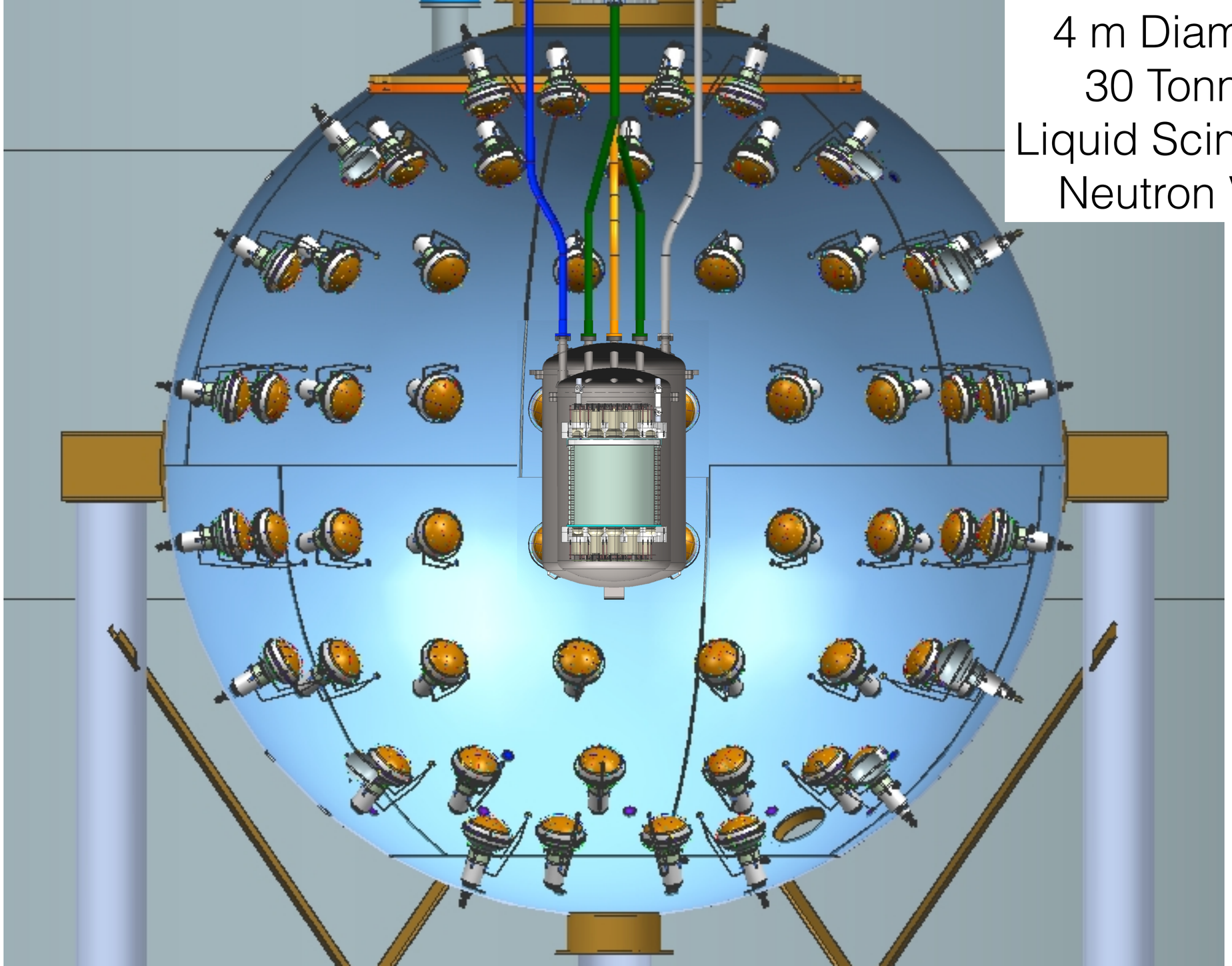
Physical Review Letters 121, 111302 (2018)

Physical Review D 98, 102006 (2018)



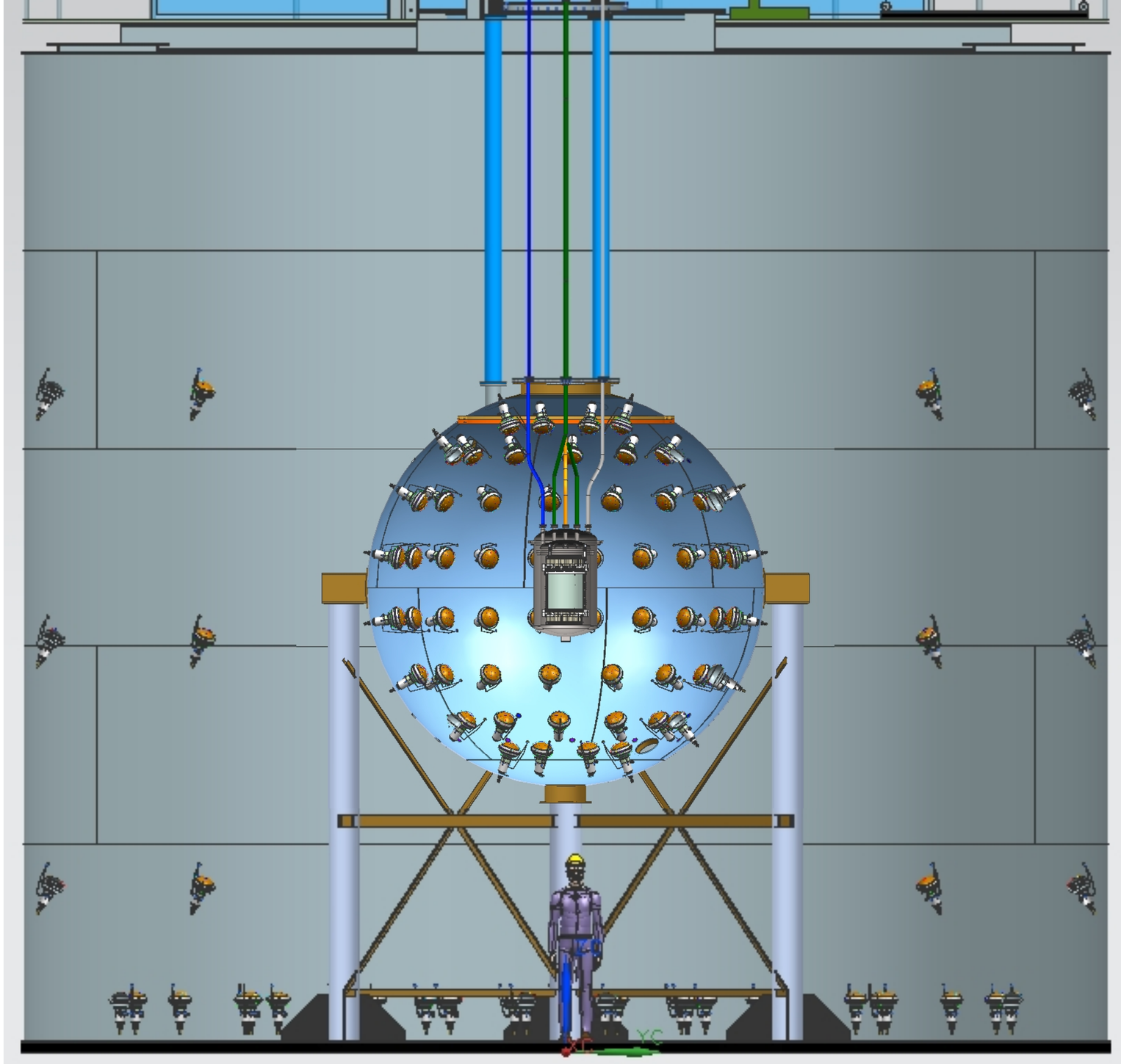
Liquid Argon TPC
153 kg ^{39}Ar-Depleted
Underground Argon
Target





4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto

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



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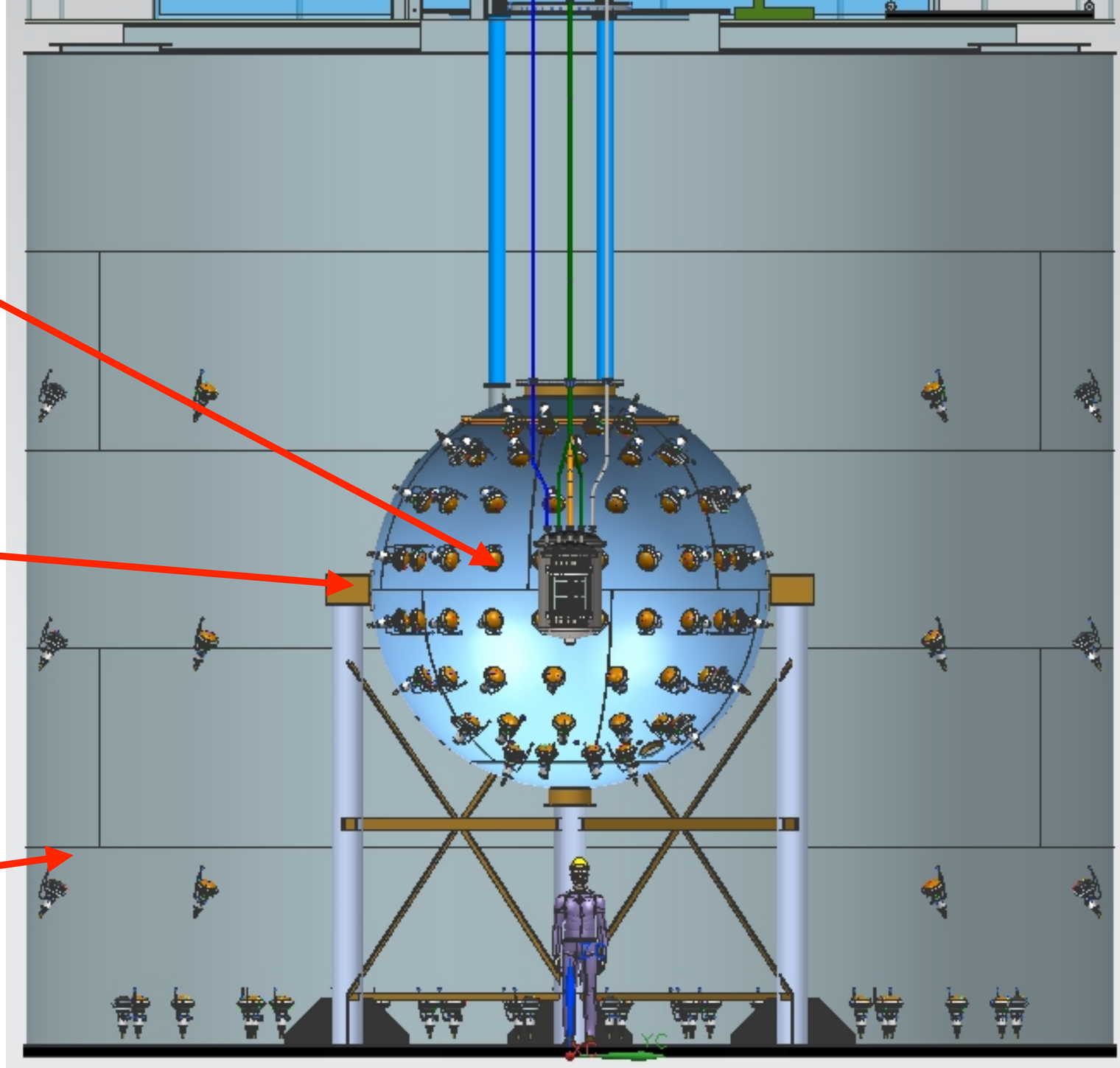
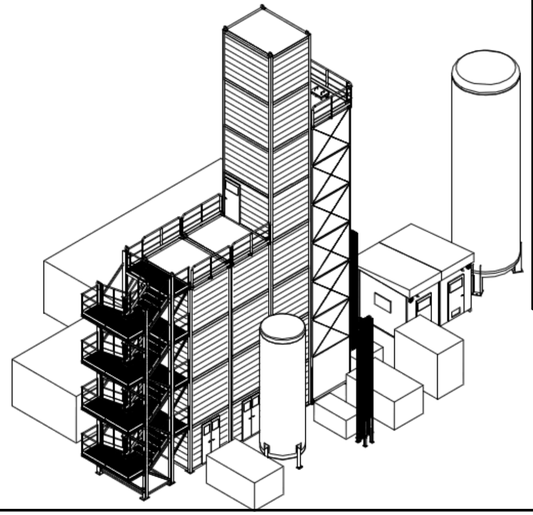
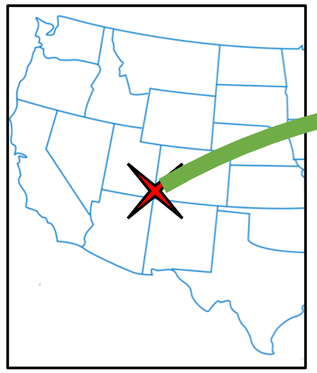


Production and Purification





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

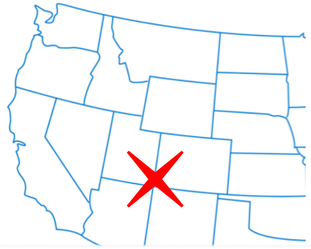
Focus of this talk

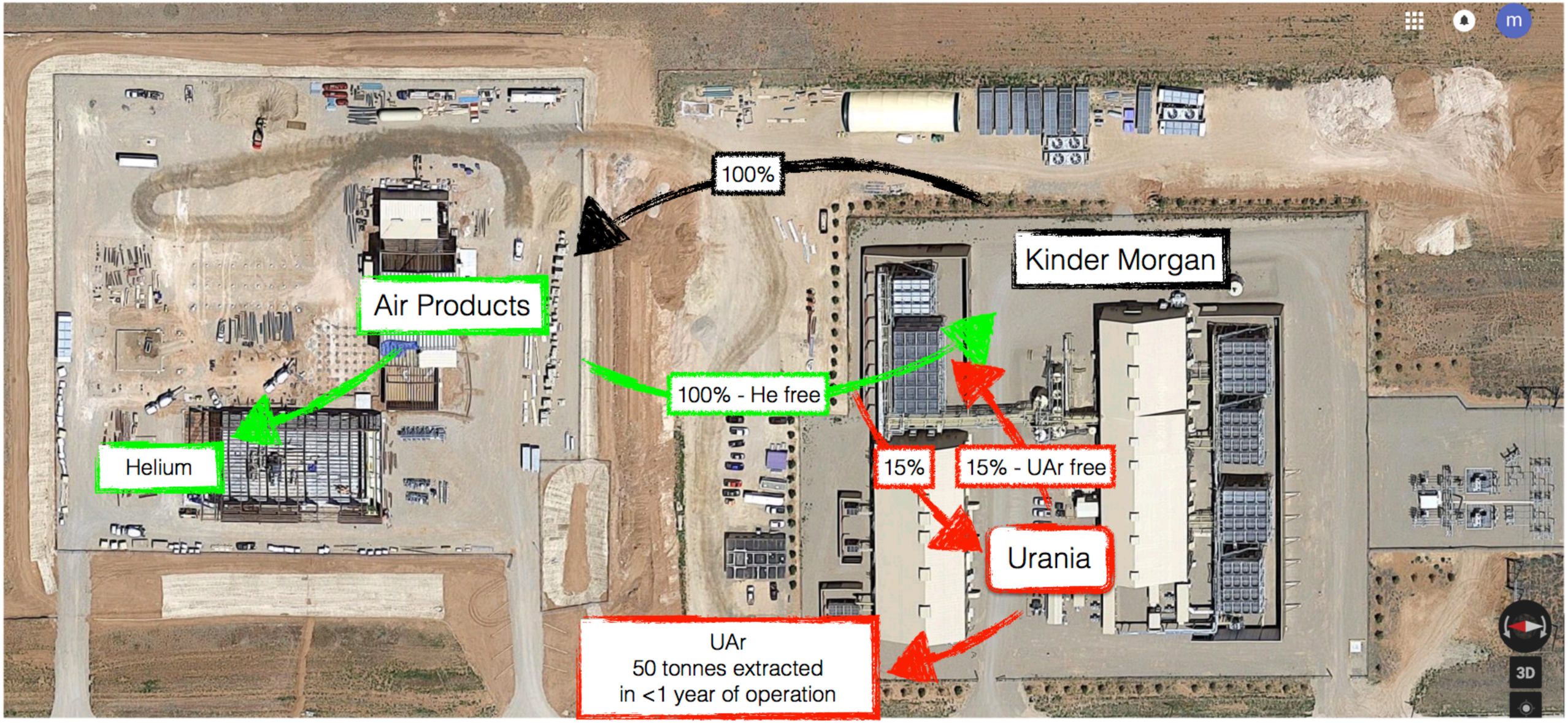
Purification: Aria

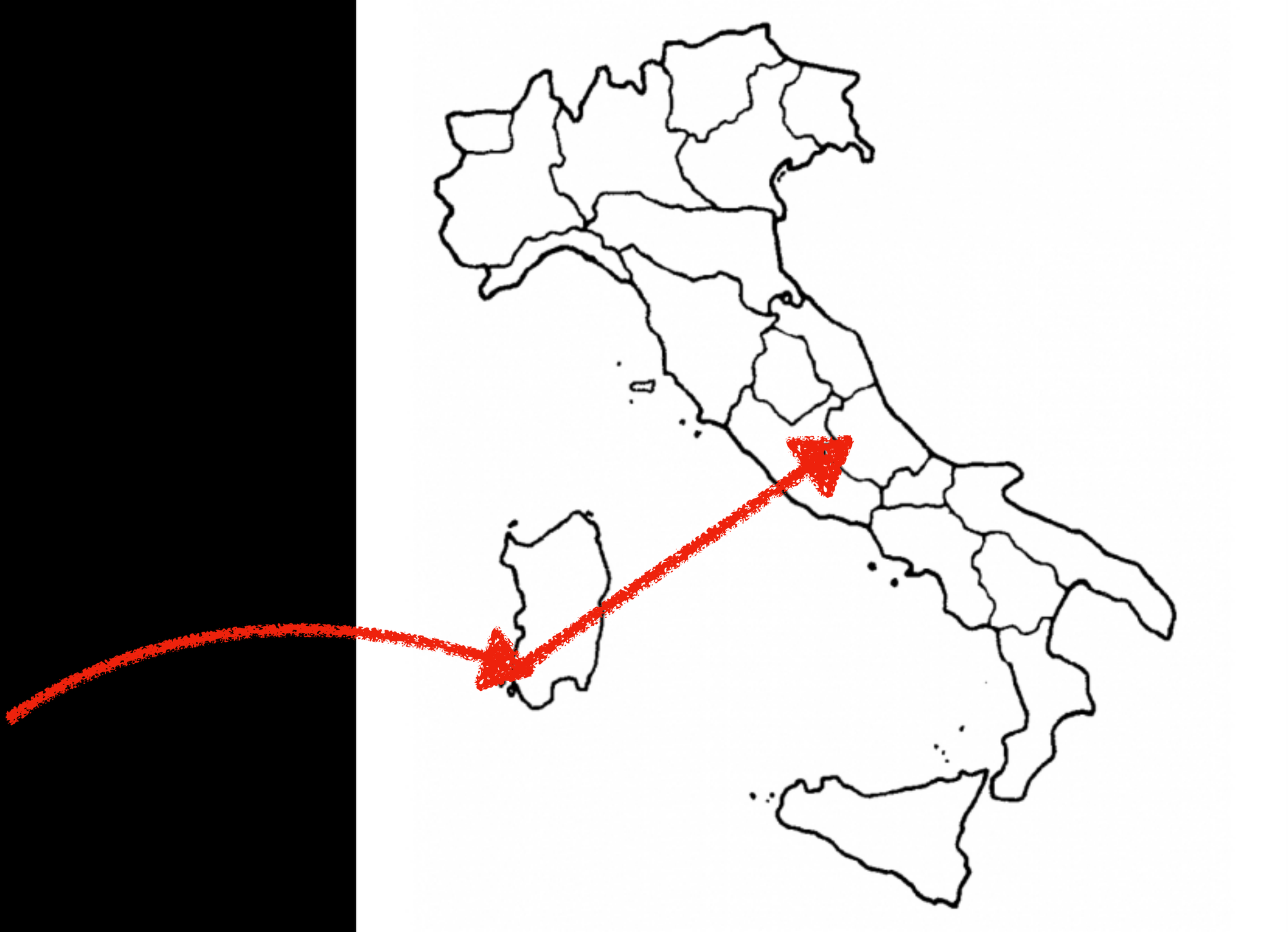
(see M. Simeone's talk for details)

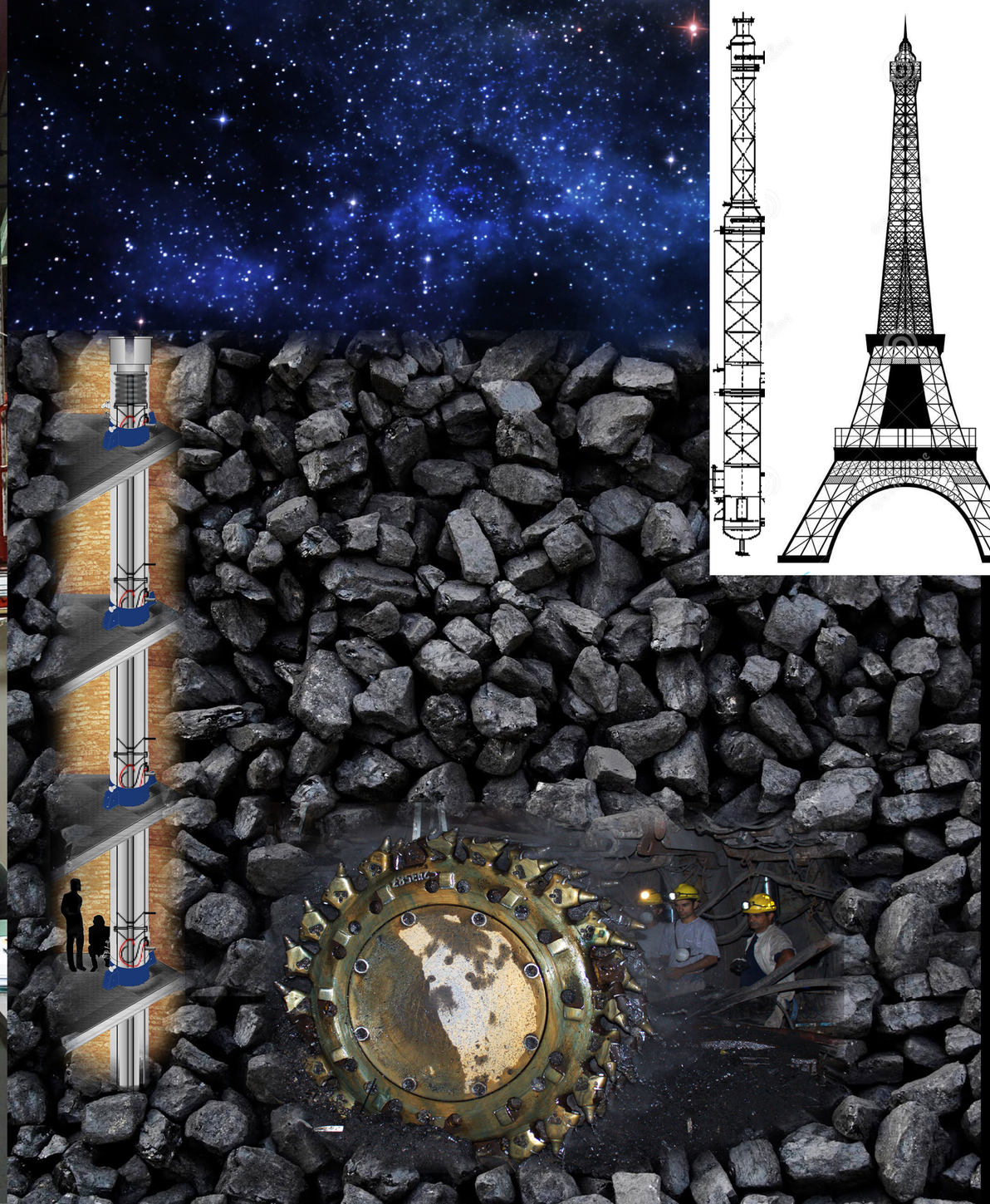
- 350 m tall cryogenic distillation column to purify UAr and isotopically separate argon and other elements
- Located in refurbished carbon mine shaft in Sardinia, Italy
- Will chemically purify the UAr for DS-20k to detector grade

Enter the Age of Urania



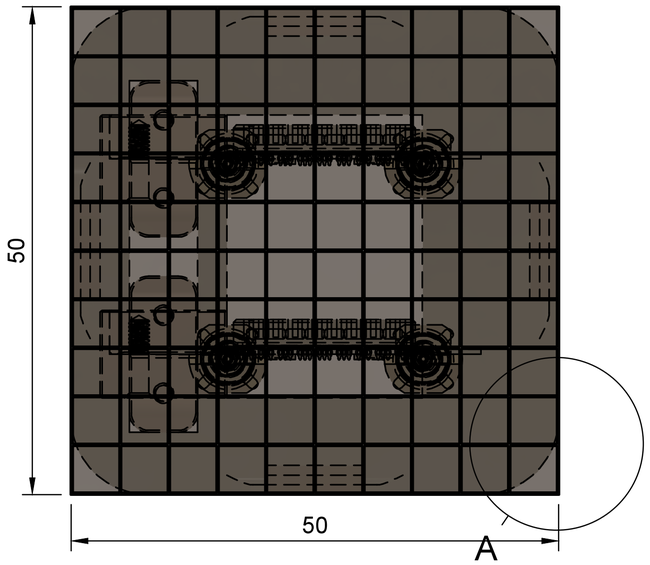


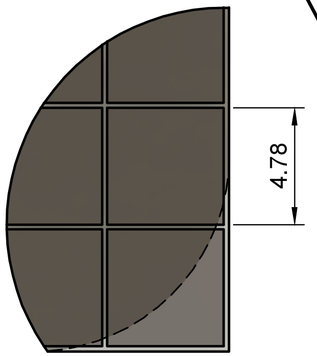




Tile

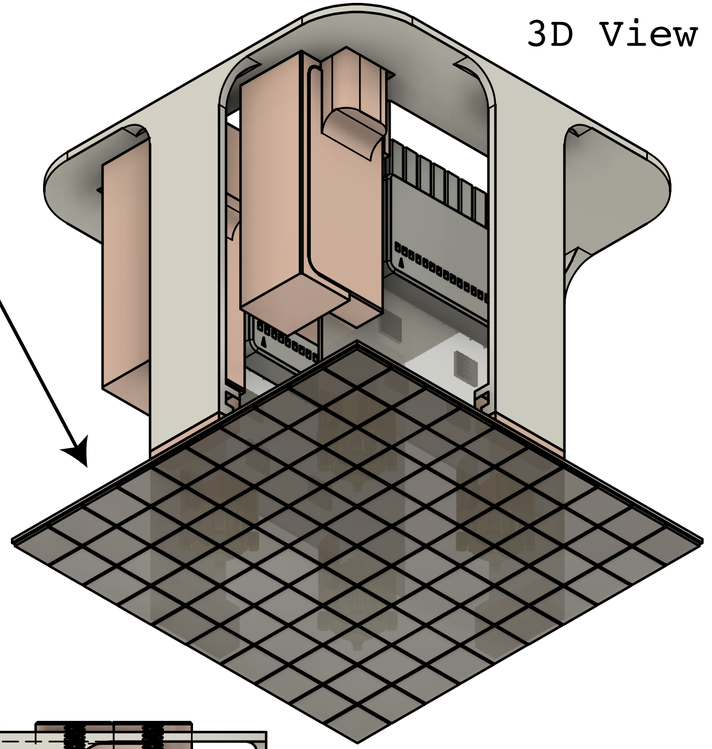
Top View

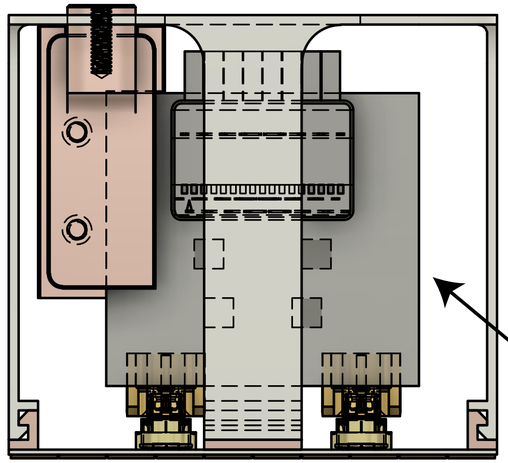




A (5.0000)

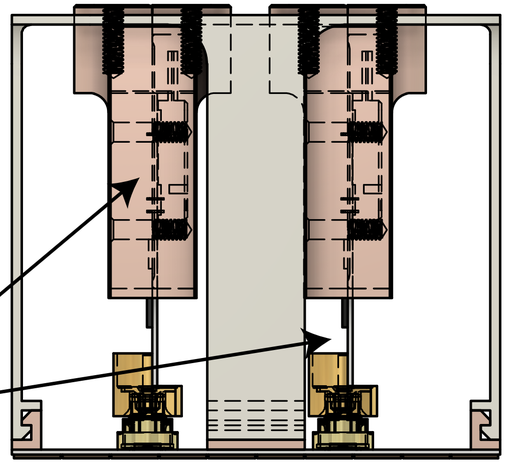
3D View



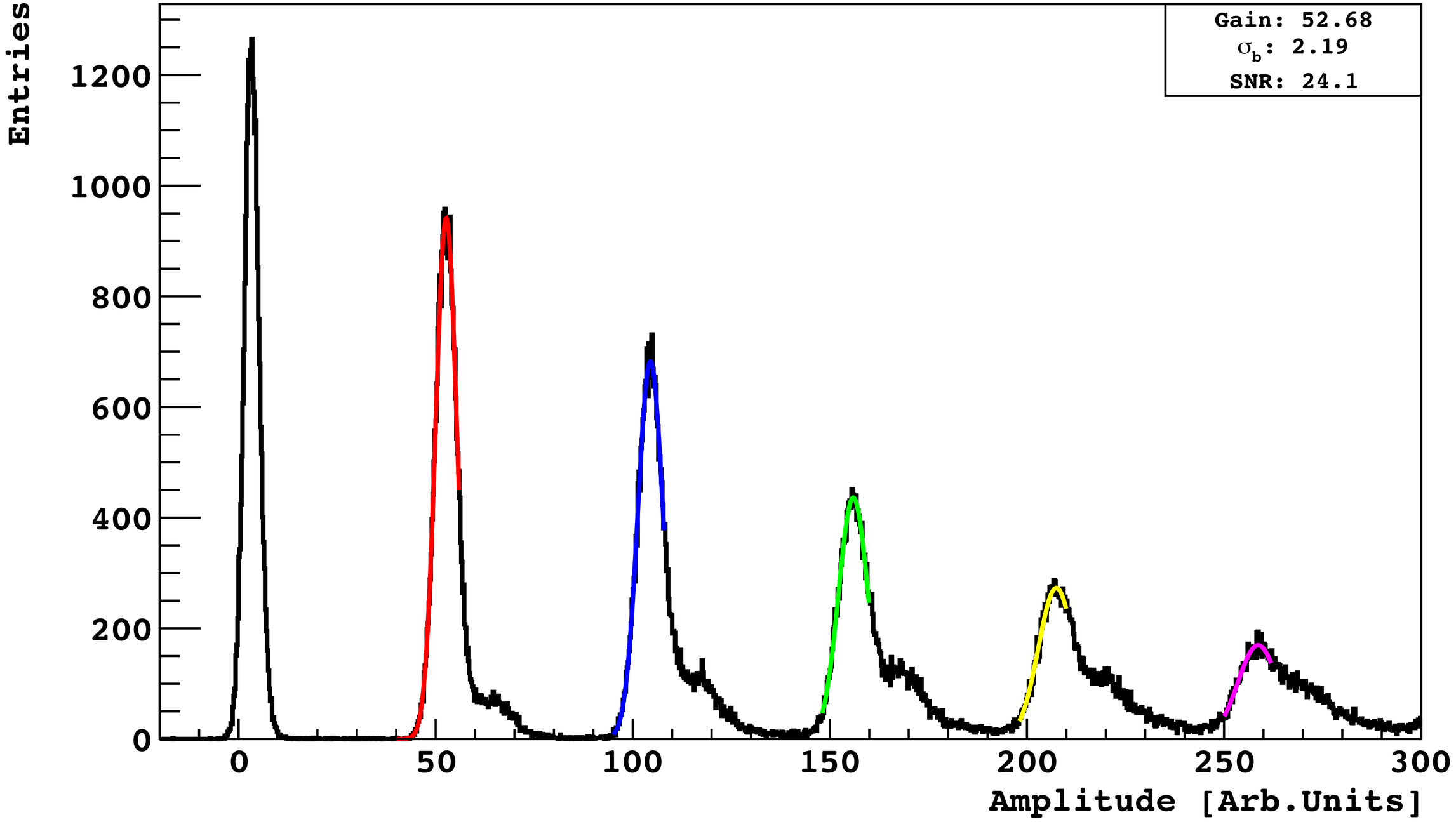


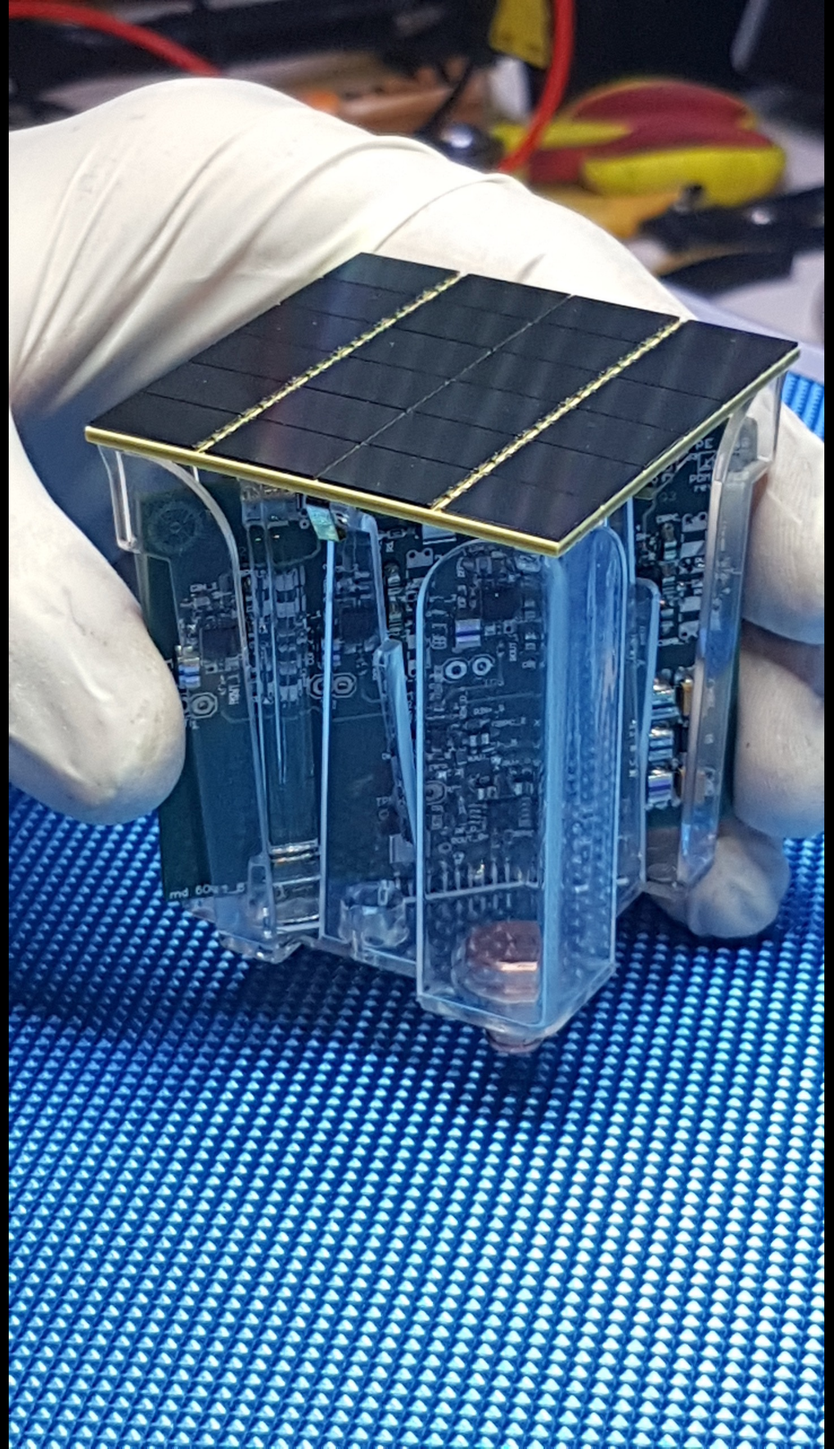
Side View

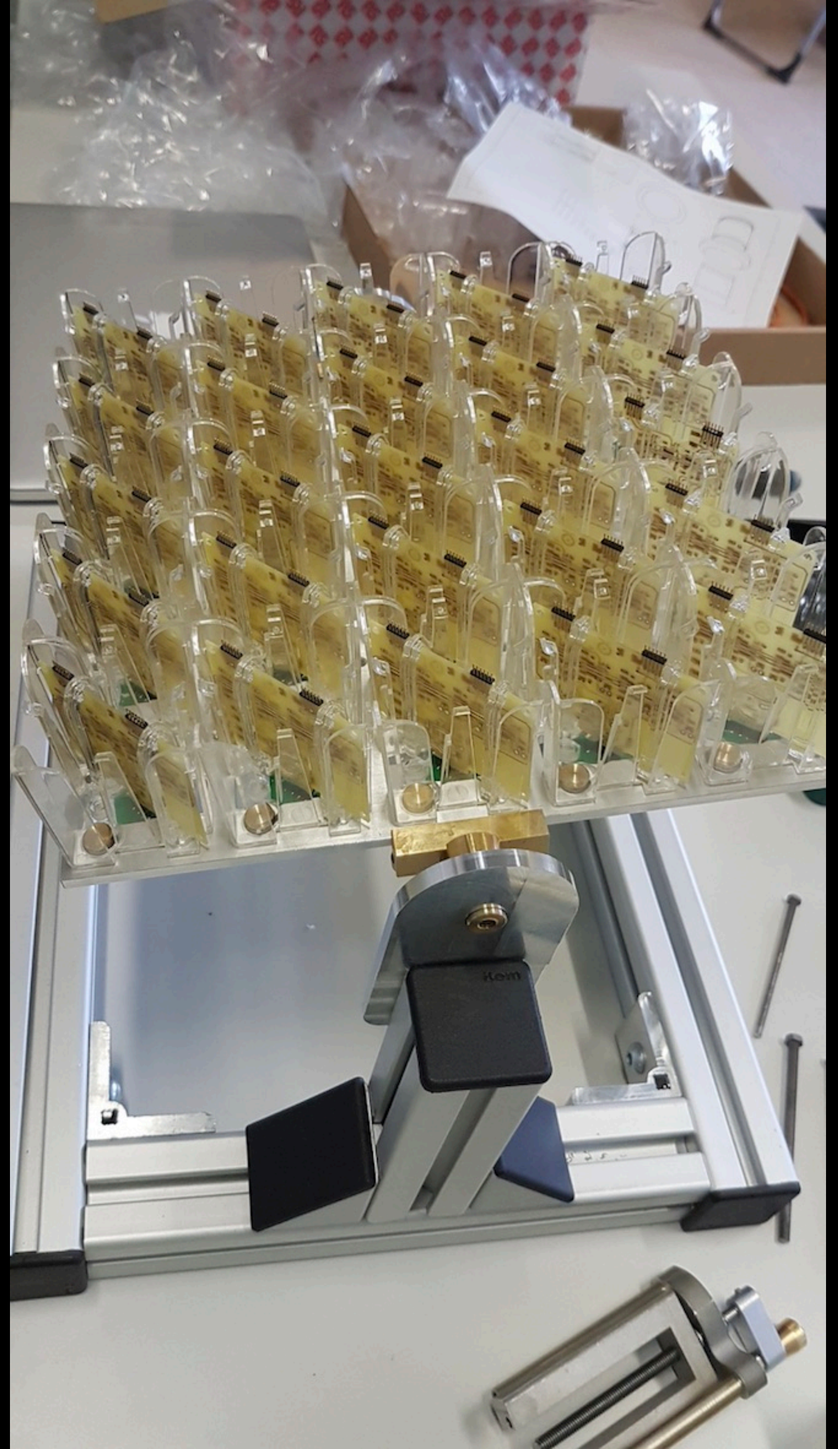
FEBs

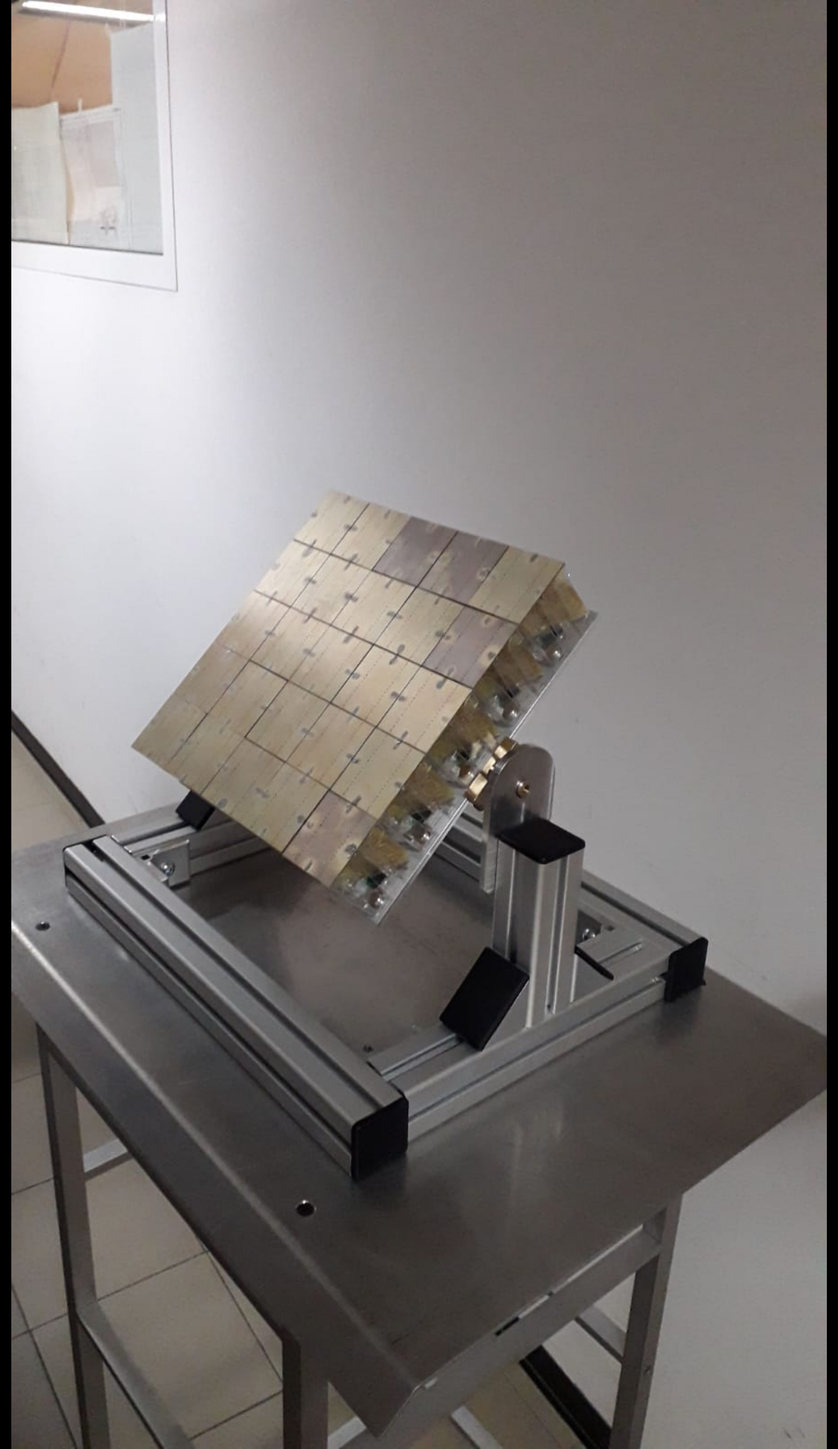


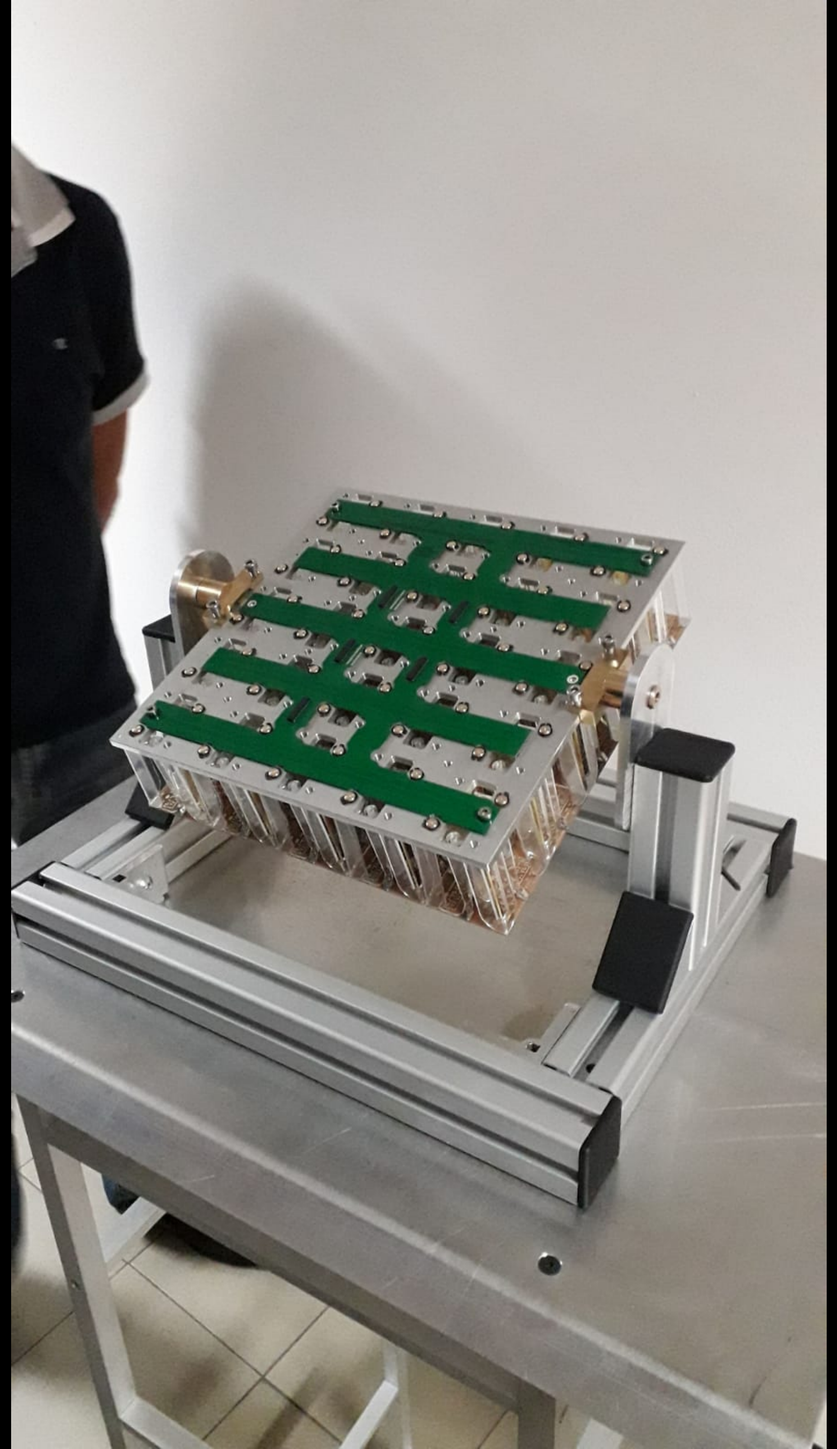
Side View

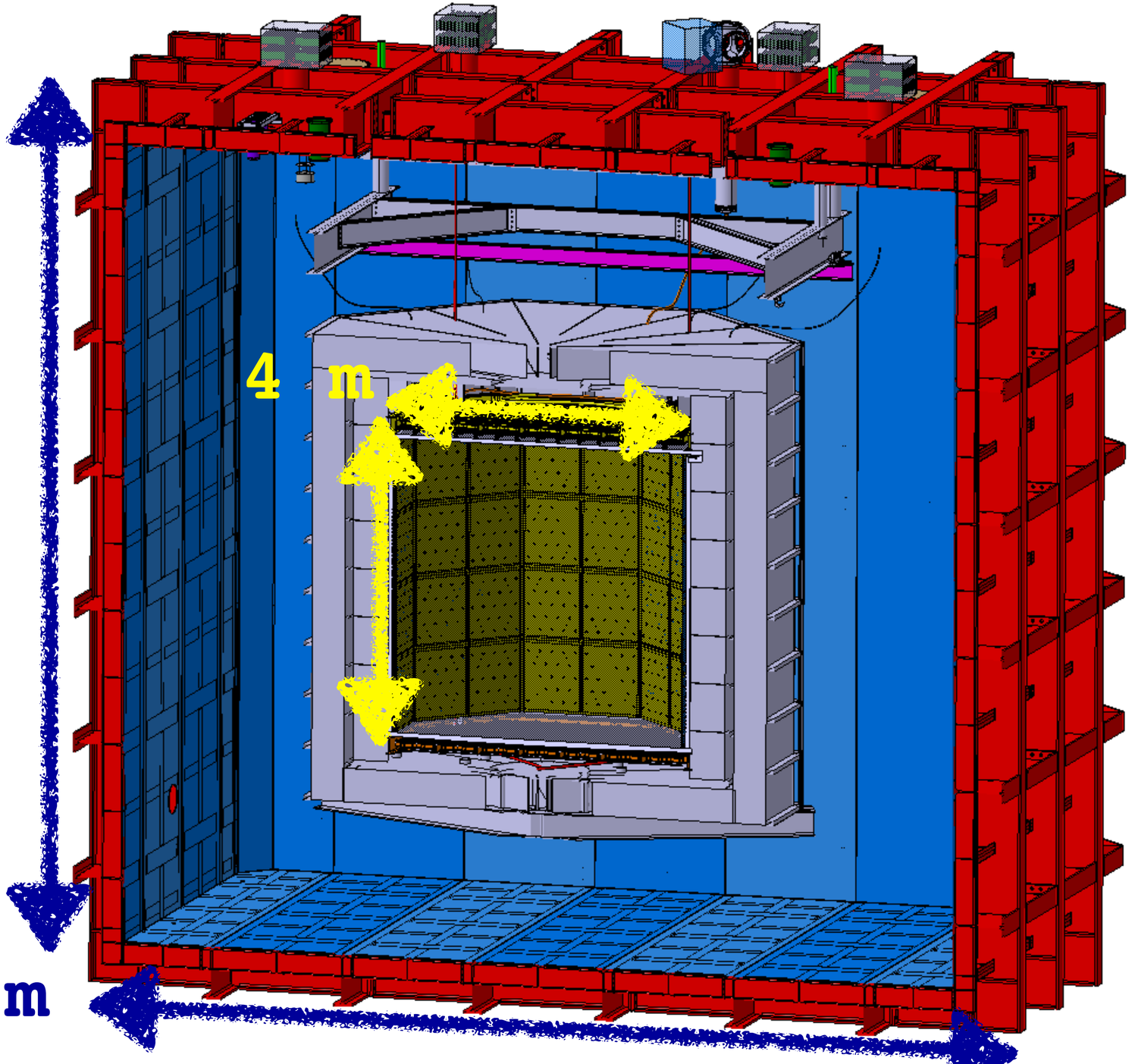

Entries
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
Amplitude [Arb.Units]
Gain: 52.68
σb: 2.19
SNR: 24.1







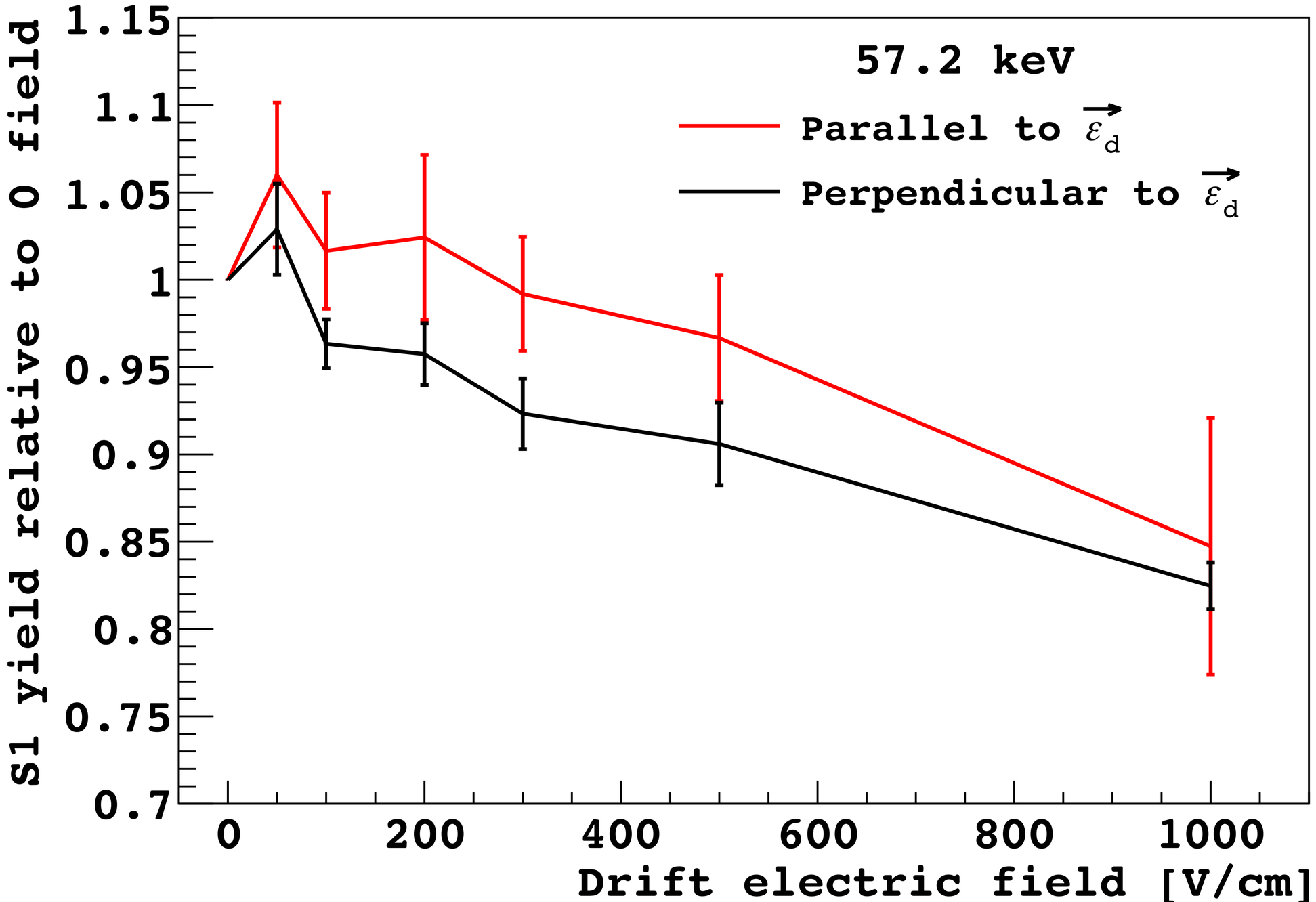


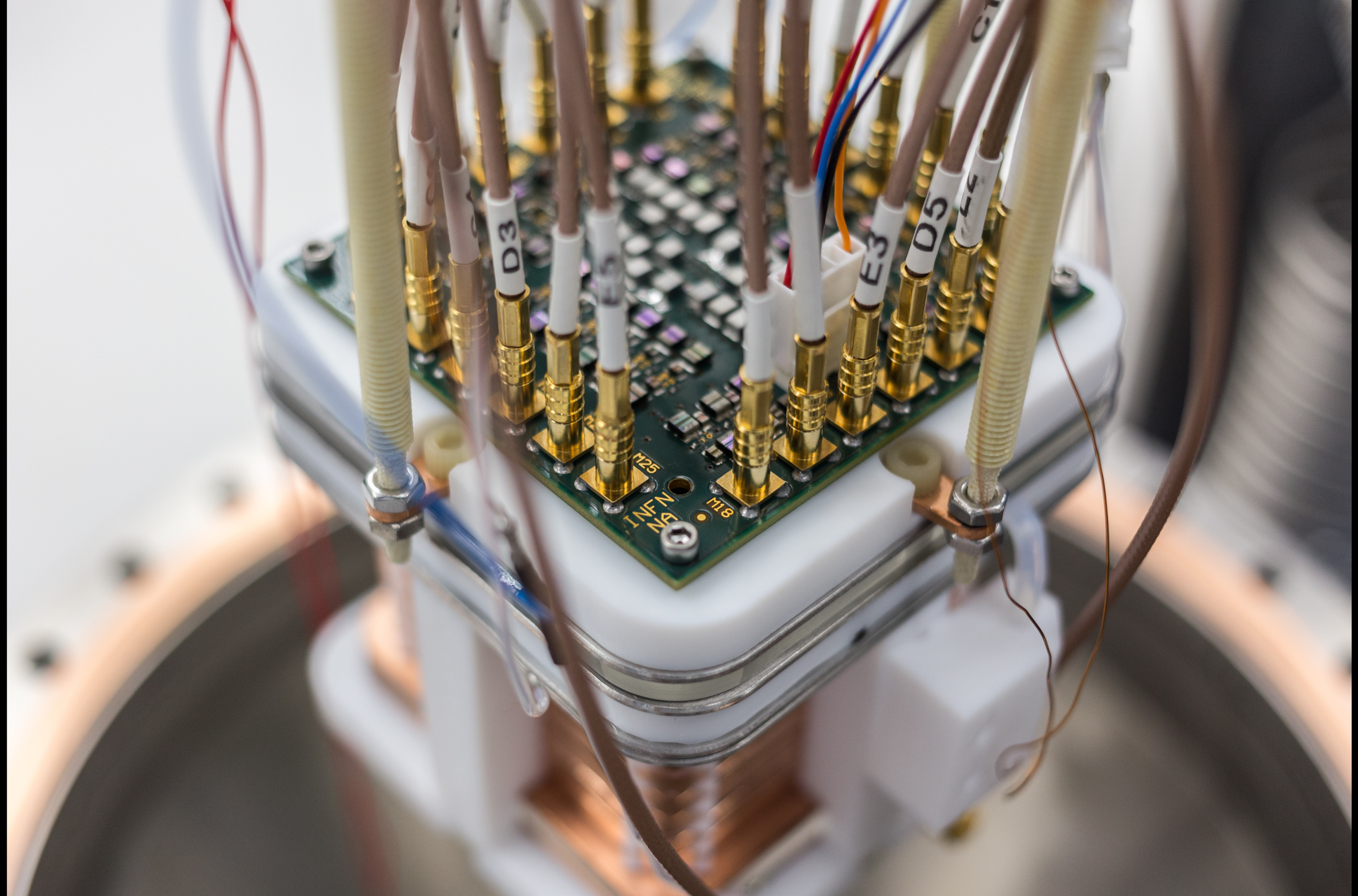

4 m
12 m

DIRECTIONALITY REQUIREMENTS

- Directional sensitivity to be deployed on the top of technology already independently able to provide background free operation for O(1000 tonne × year) exposure

Physical Review D 91, 092007 (2014)




D3
E3
D5
M25
M18
INFN


THE END