The DarkSide Program of Dark Matter Searches and Its Broader Impact

Cristiano Galbiati
Gran Sasso Science Institute
Princeton University

~

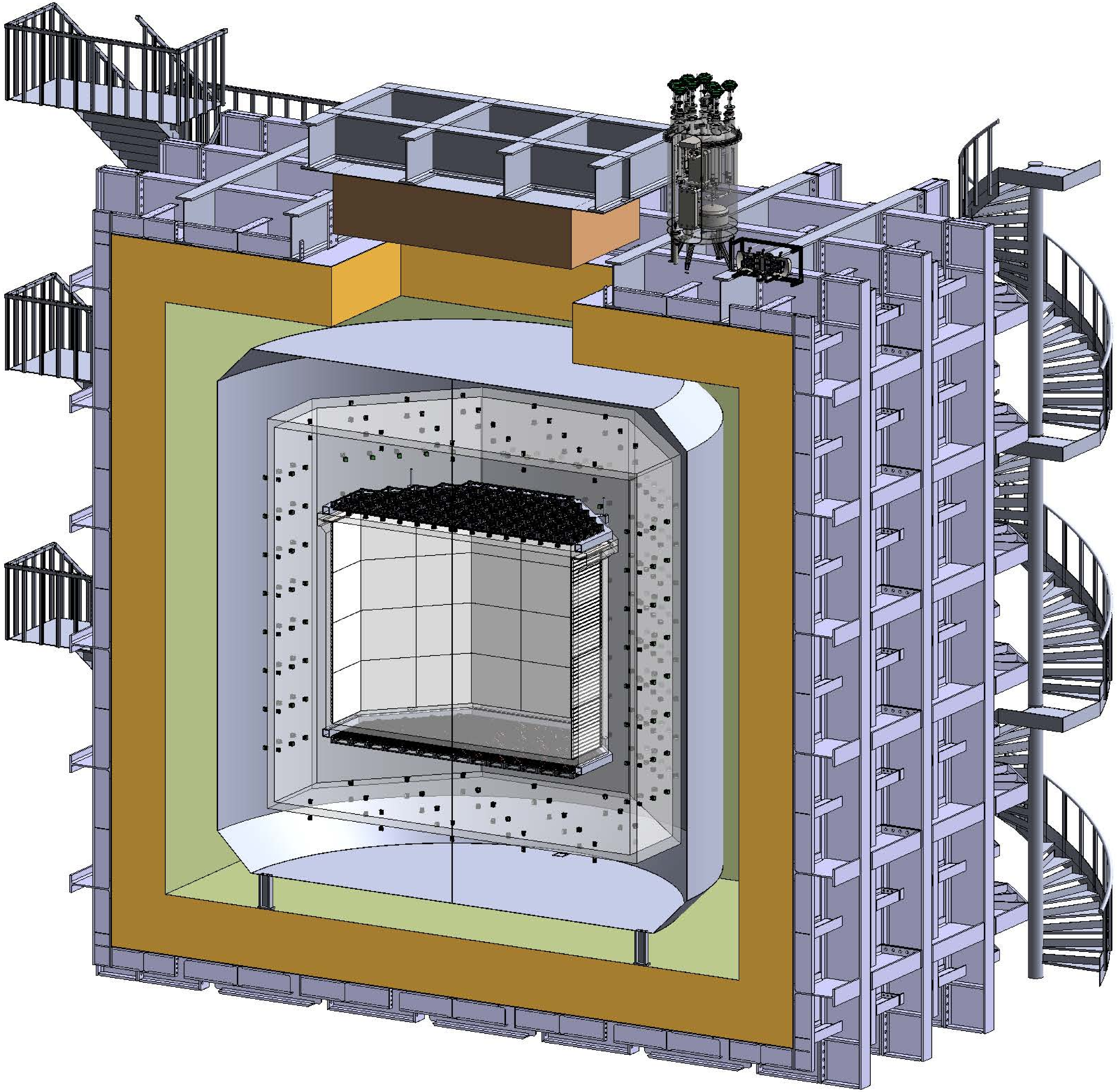
AstroCeNT
Inaugural Event
Warsaw
May 21, 2019

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
NASA

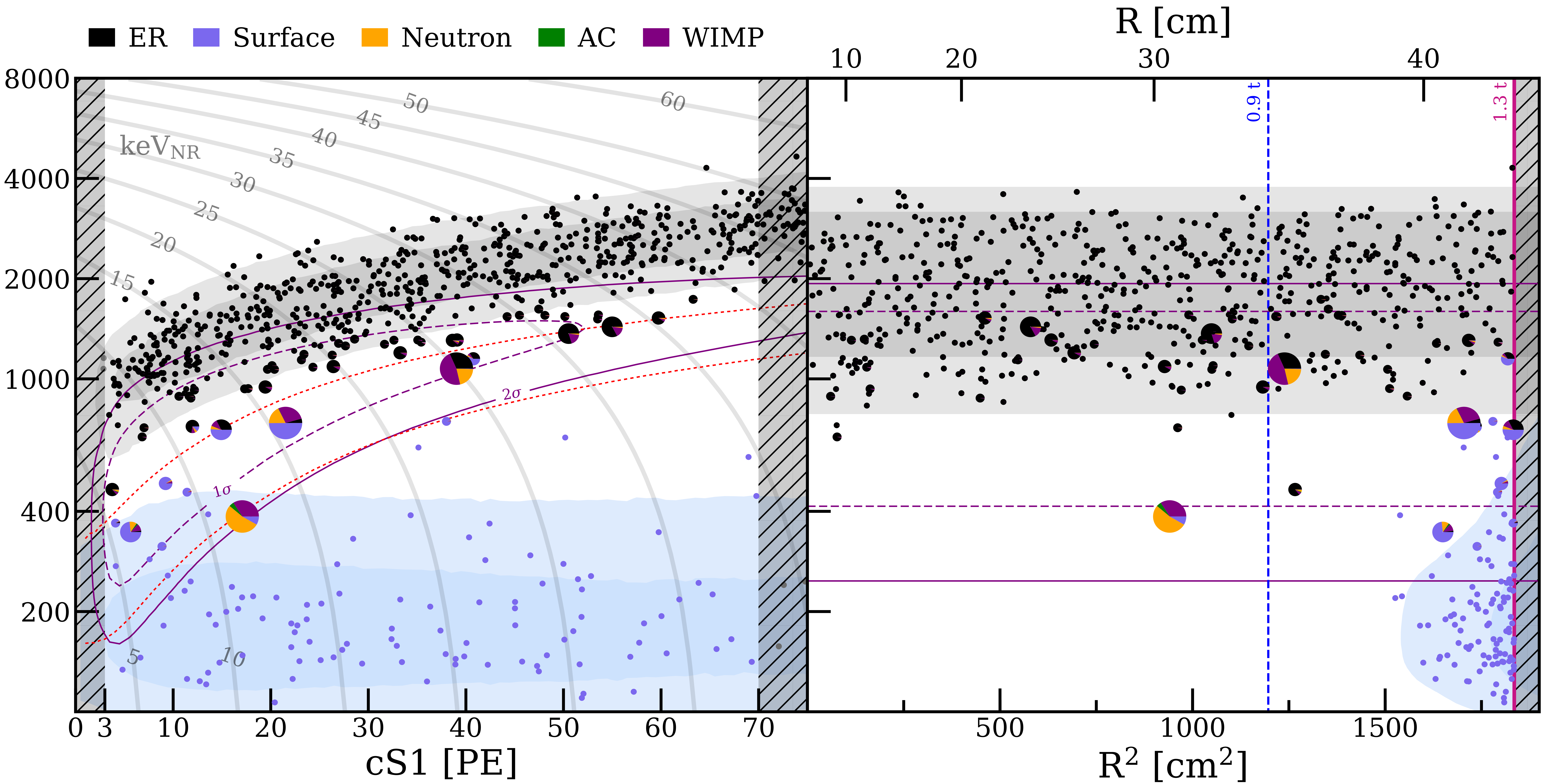
Deep underground laboratory support for global collaboration towards discovery of dark matter utilising liquid argon detectors.

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,



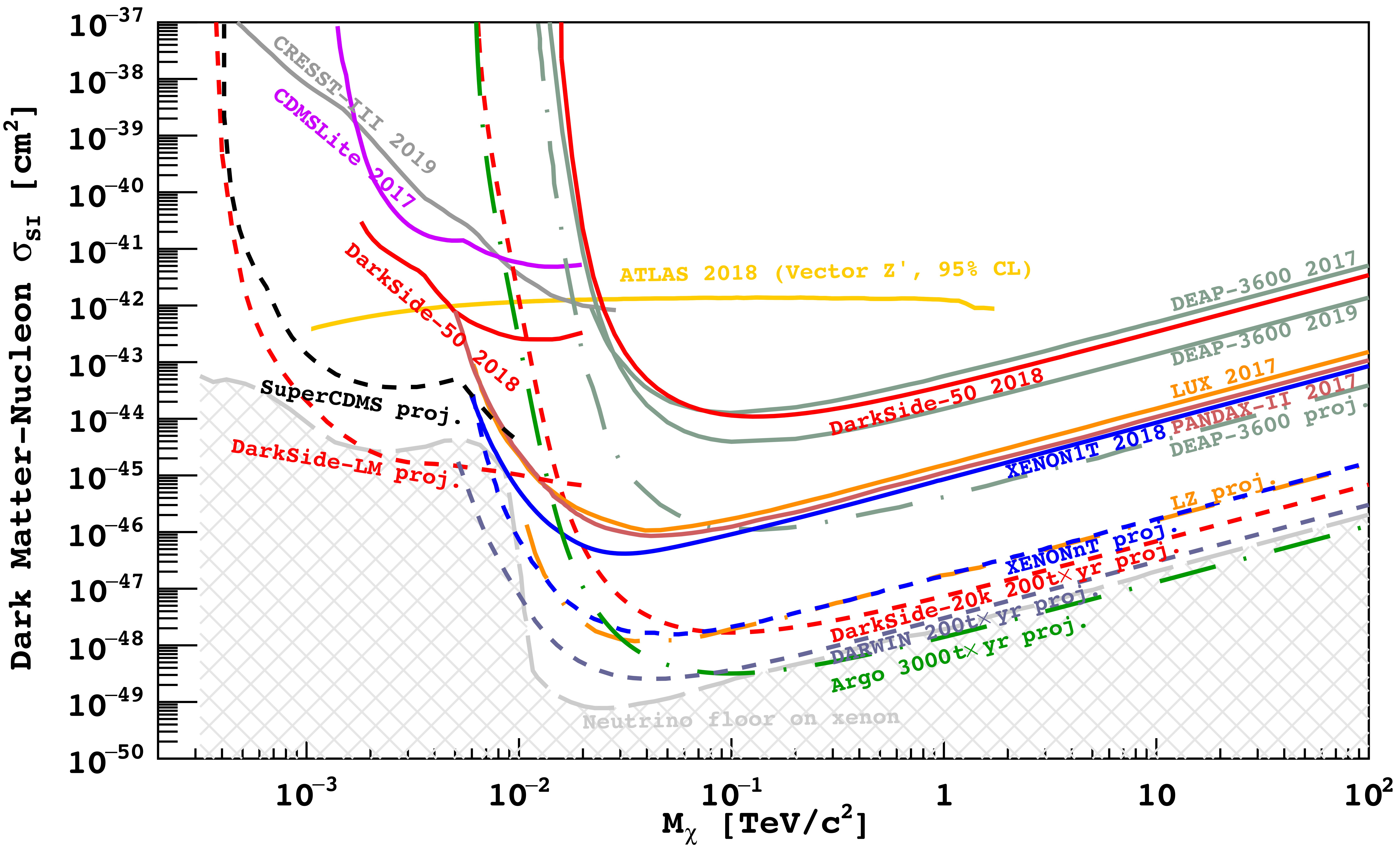
Physical Review Letters 121, 111302 (2018)



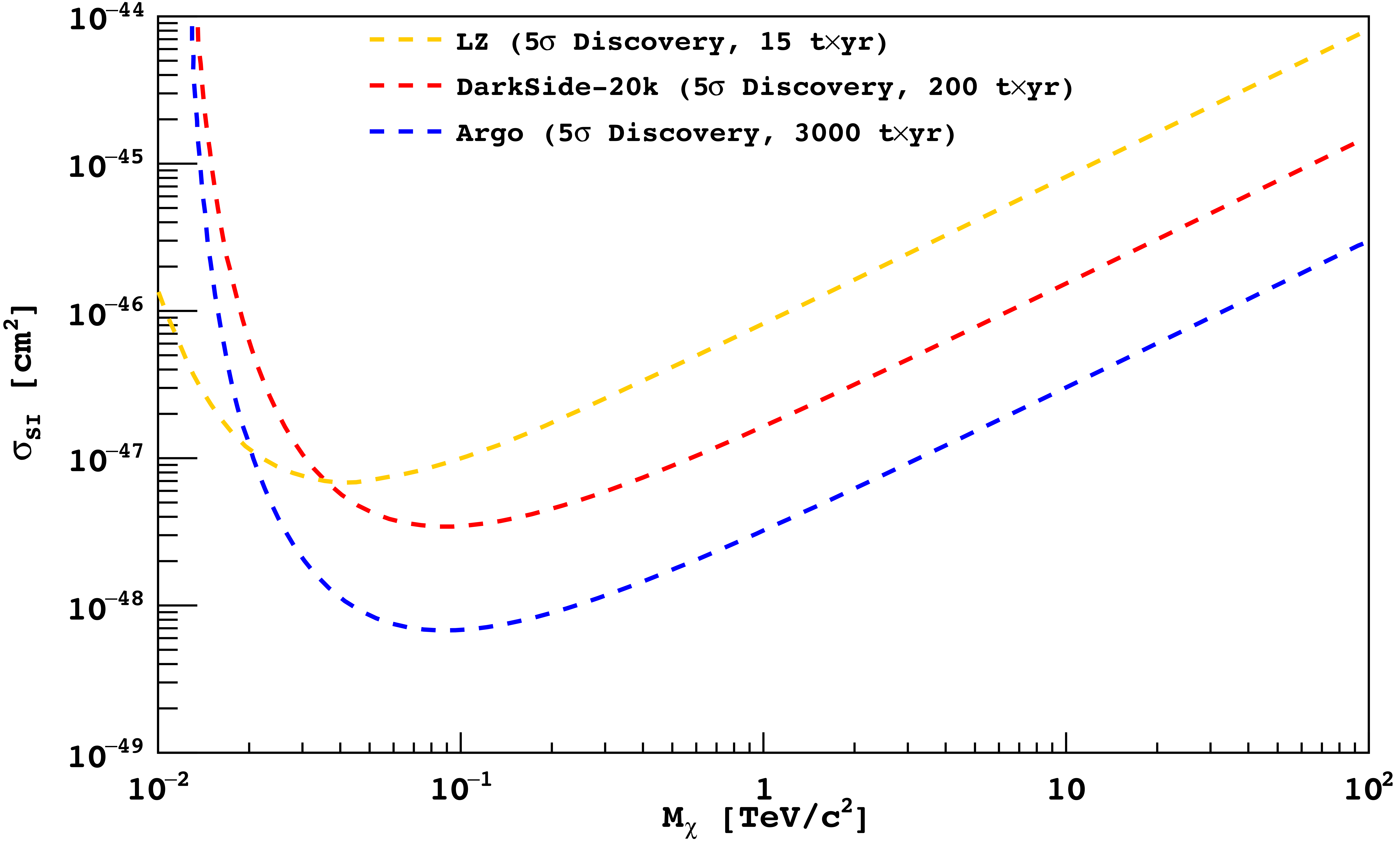
+r<10 cm && 50% loss S2/S1 cut (70d)
Entries 16213
Integral 1.619e+04
f_{90}
S1 [PE]
14
Physical Review D 98, 102006 (2018)

Material	Mass [tonne]	^{238}U [mBq/kg]	^{226}Ra [mBq/kg]	^{232}Th [mBq/kg]	Neutrons $[10\,\mathrm{yr}]^{-1}$	+TPC $[200\,\mathrm{t\,yr}]^{-1}$	+TPC+veto $[200\,\mathrm{t\,yr}]^{-1}$
TPC Vessel	2.7	1.2×10^{-2}	10	4.1×10^{-3}	5.7×10^{2}	0.17	1.7×10^{-2}
TPC SiPMs	0.12	-	-	-	5.4×10^{3}	0.16	1.6×10^{-2}
TPC Electronics	1.0	-	-	-	1.2×10^{4}	0.36	3.6×10^{-2}
TPC Mechanics	1.1	3.9	3.9	1.9	9.0×10^{2}	1.8×10^{-2}	2.0×10^{-3}
Veto SiPMs+elec.	0.40	-	-	-	6.4×10^{3}	0.10	1.0×10^{-2}
Veto Acrylic	13	1.2×10^{-2}	10	4.1×10^{-3}	2.6×10^{3}	4.2×10^{-2}	4.0×10^{-3}
Veto Reflectors	1.0	1.2×10^{-2}	1.0	4.1×10^{-3}	2.0×10^{2}	2.4×10^{-2}	2.0×10^{-3}
Veto Steel	1.1	3.9	3.9	1.9	9.0×10^{2}	1.4×10^{-2}	1.0×10^{-3}
$Gd_2(SO_4)_3$ α's on self	0.26	7.0	7.0	0.2	1.1×10^{2}	2.0×10^{-3}	$<1.0 \times 10^{-3}$
$Gd_2(SO_4)_3$ α's on PMMA	0.26	7.0	7.0	0.2	3.6×10^{2}	6.0×10^{-3}	1.0×10^{-3}
Copper Cage	1.0	0.30	0.30	2.0×10^{-2}	6.0	$<1.0 \times 10^{-3}$	$<1.0 \times 10^{-3}$
Cryostat Steel	250	50	1.0×10^{3}	3.9	1.0×10^{6}	-	$<1.0 \times 10^{-3}$
Cryostat Insulation	40	3×10^{3}	8.0×10^{3}	3.0×10^{3}	8.0×10^{7}	-	$<1.0 \times 10^{-3}$
Total						**0.9**	**0.09**

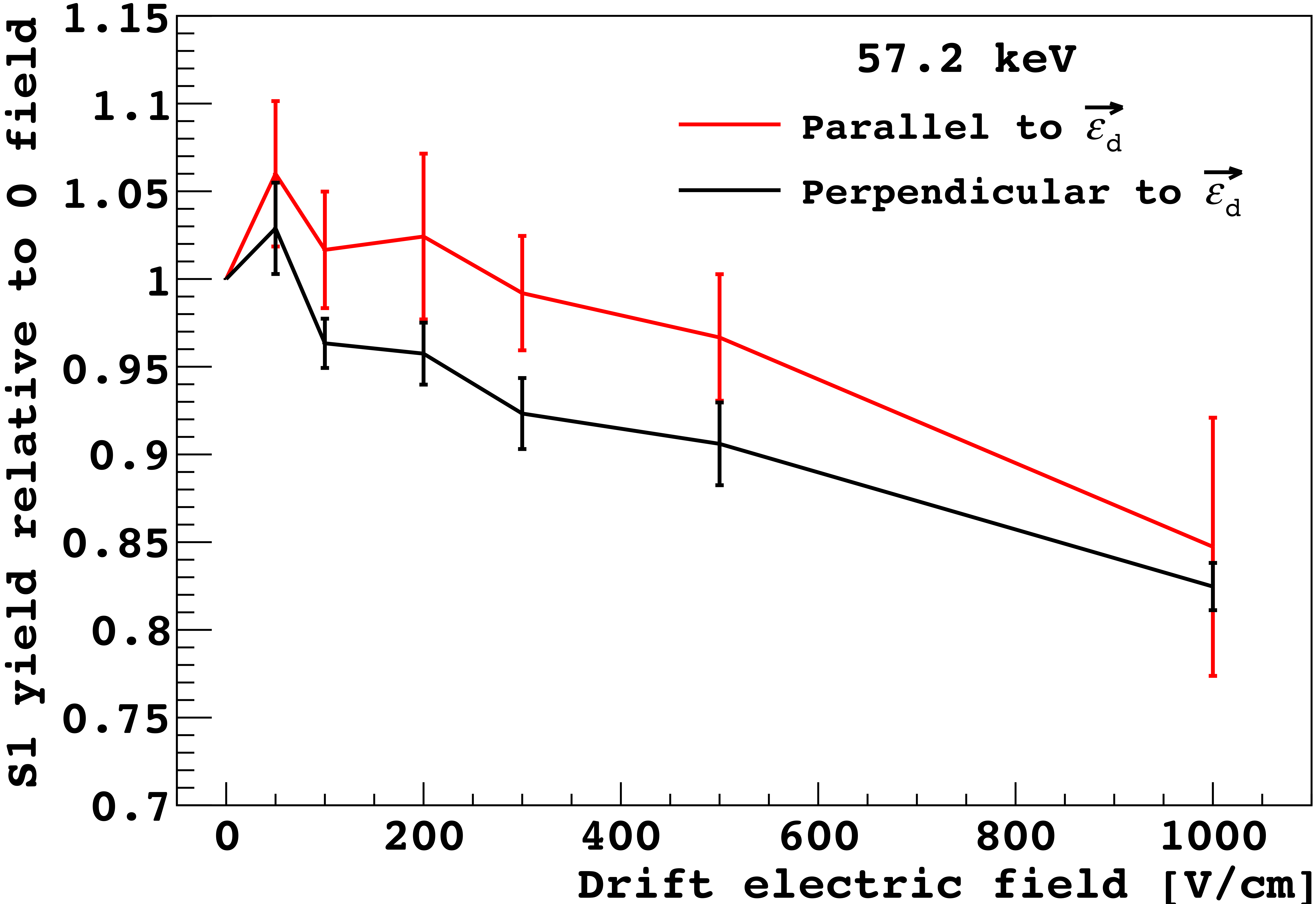
TABLE I. Radiogenic neutrons sourced by the LAr TPC construction materials, veto and cryostat materials, with details of expected contamination levels, background after TPC cuts, and residual background after combined TPC and veto cuts, all relative to the full 10 yr run time and the full fiducial 200 t yr exposure. The number of neutrons source is calculated from the expected contamination levels and material composition. Note that no specific activity is reported for the TPC SiPMs and associated electronics: in this case the predicted neutron yield is the results of an extremely detailed calculation, accounting for the cumulative contribution of several tens of components, individually assayed. The same consideration holds for the veto SiPMs and electronics, whose contribution is reported in combination. For neutrons due to (α,n) reactions from α's from impurities in $Gd_2(SO_4)_3$, the contribution is broken down between those due reactions on Gd sulfate itself and those due to reactions in the PMMA matrix containing the Gd sulfate; the mass fraction of Gd in the GdAS 1 %, for the anticipated 2 % concentration by mass of $Gd_2(SO_4)_3$. (For ease of conversion: $1\,\mathrm{ppt}(^{238}\mathrm{U}) \simeq 1.2 \times 10^{-2}\,\mathrm{mBq/kg}$; $1\,\mathrm{ppt}(^{232}\mathrm{Th}) \simeq 4.1 \times 10^{-3}\,\mathrm{mBq/kg}$.)



Dark Matter-Nucleon σ_{SI} [cm^2]
M_χ [TeV/c^2]
CRESST-III 2019
CDMSLite 2017
DarkSide-50 2018
ATLAS 2018 (Vector Z', 95% CL)
DEAP-3600 2017
DEAP-3600 2019
LUX 2017
PANDAX-II 2017
DEAP-3600 proj.
XENON1T 2018
SuperCDMS 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

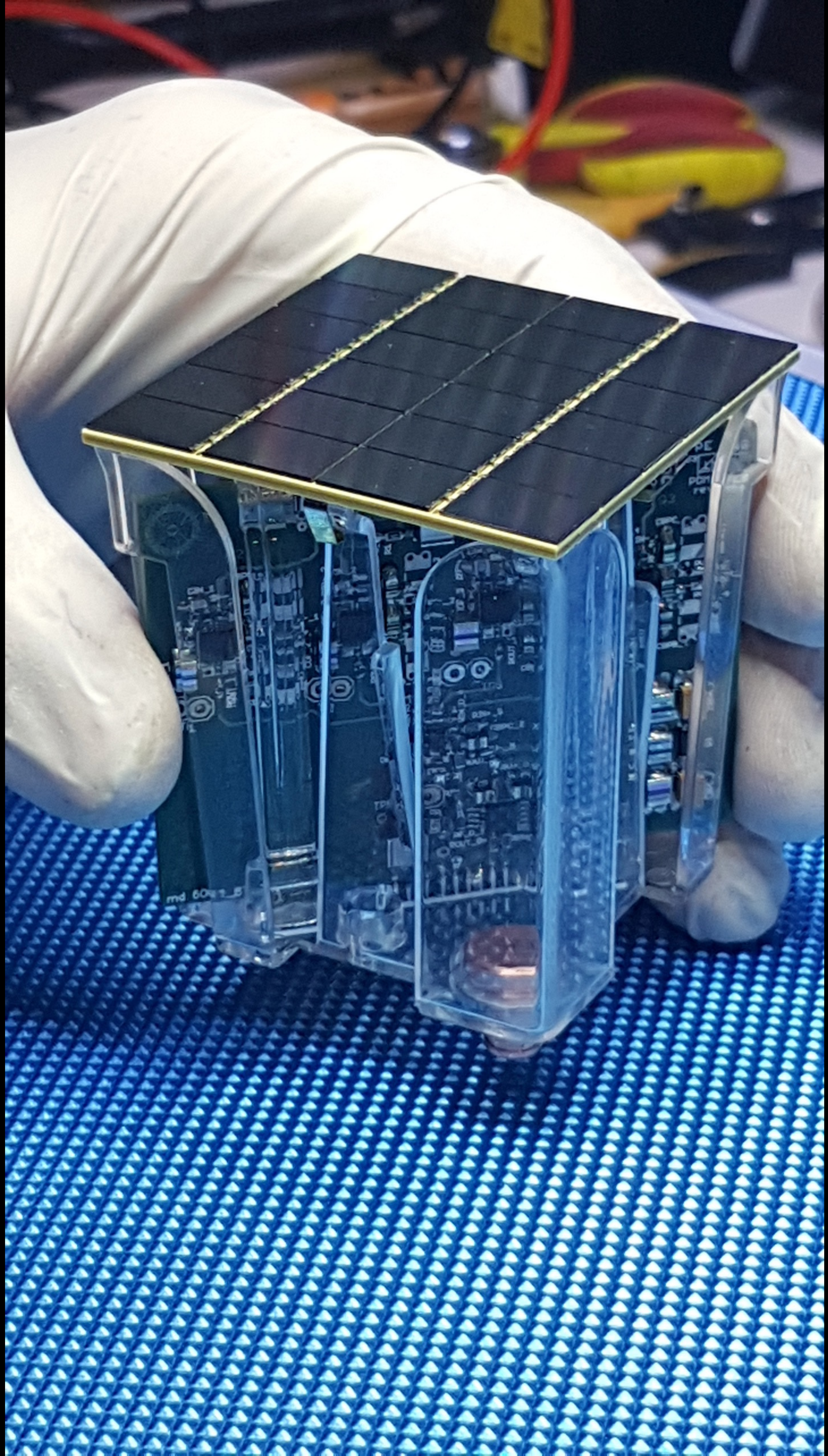


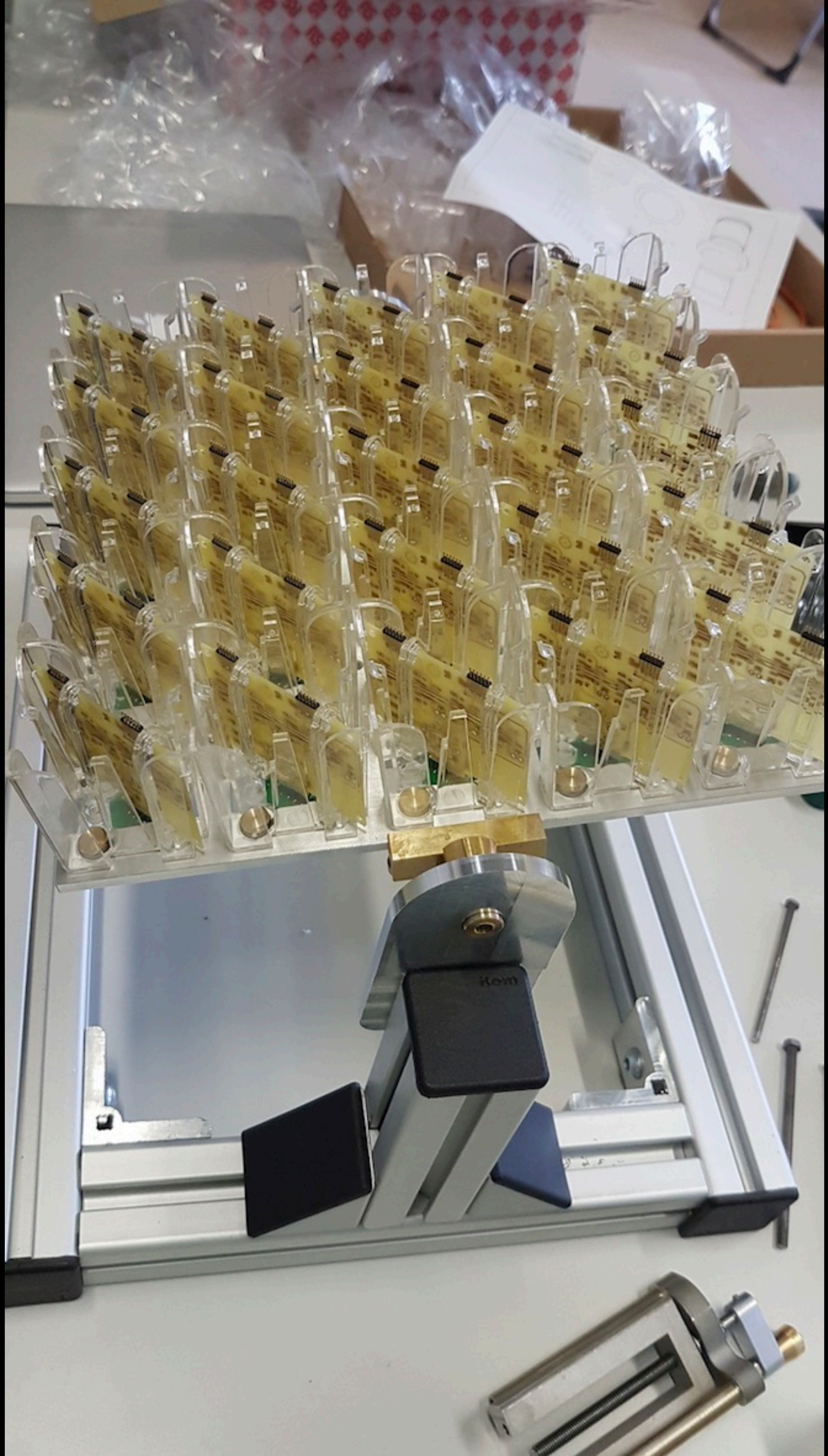
LZ (5σ Discovery, 15 t×yr)
DarkSide-20k (5σ Discovery, 200 t×yr)
Argo (5σ Discovery, 3000 t×yr)
σ_{SI} [cm^2]
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-2}
10^{-1}
1
10
10^{2}
M_χ [TeV/c^2]

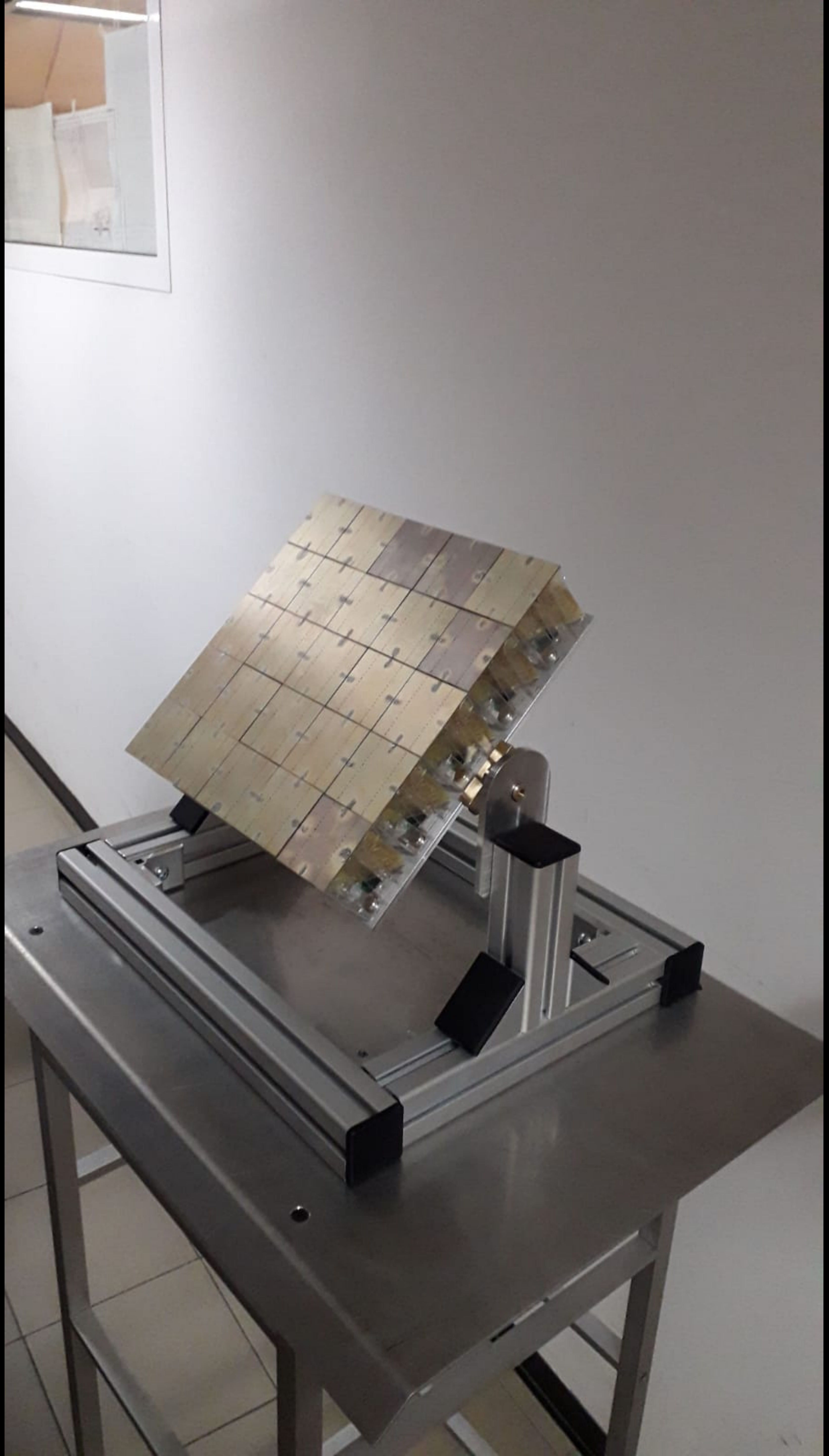
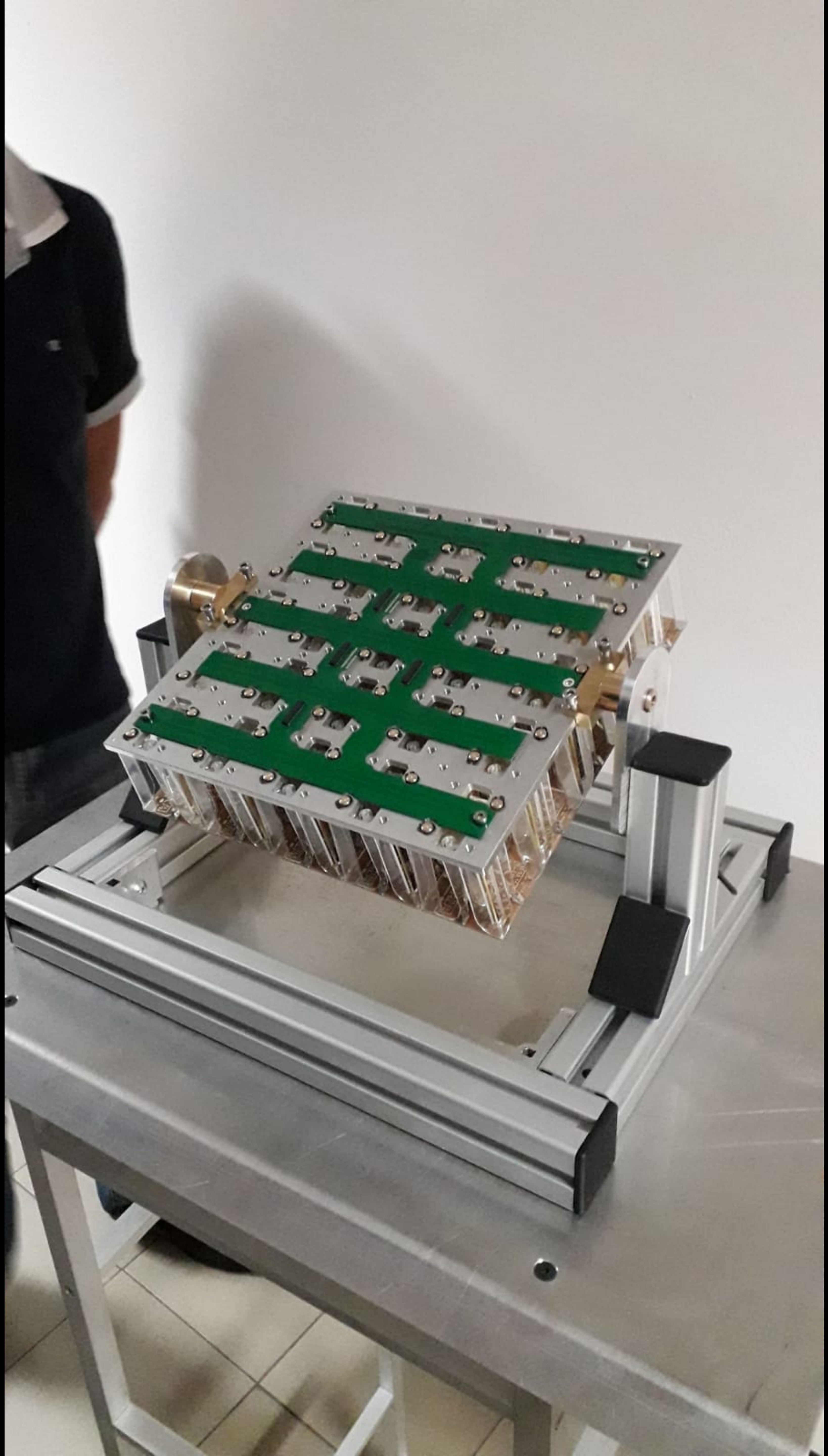


57.2 keV
Parallel to $\vec{\varepsilon}_d$
Perpendicular to $\vec{\varepsilon}_d$
S1 yield relative to 0 field
Drift electric field [V/cm]
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0
200
400
600
800
1000


NO4



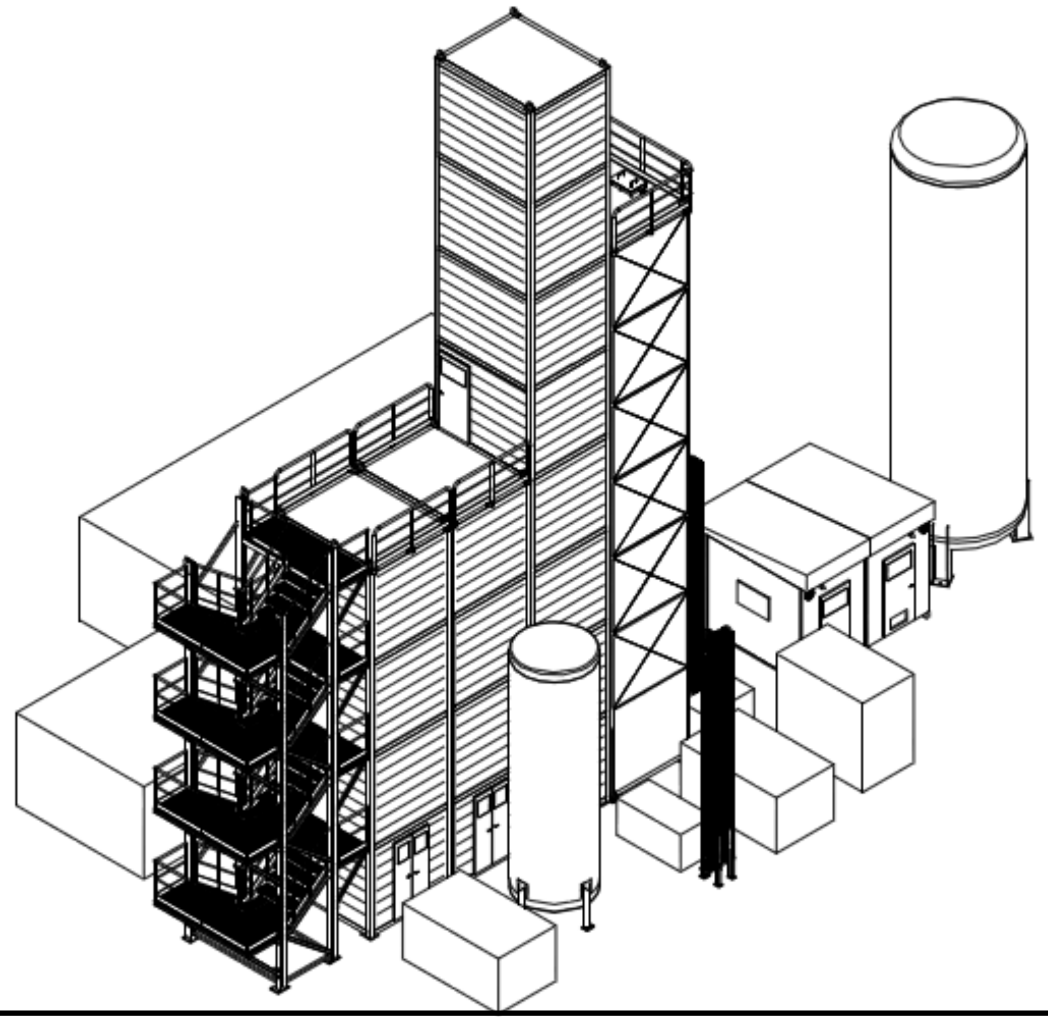


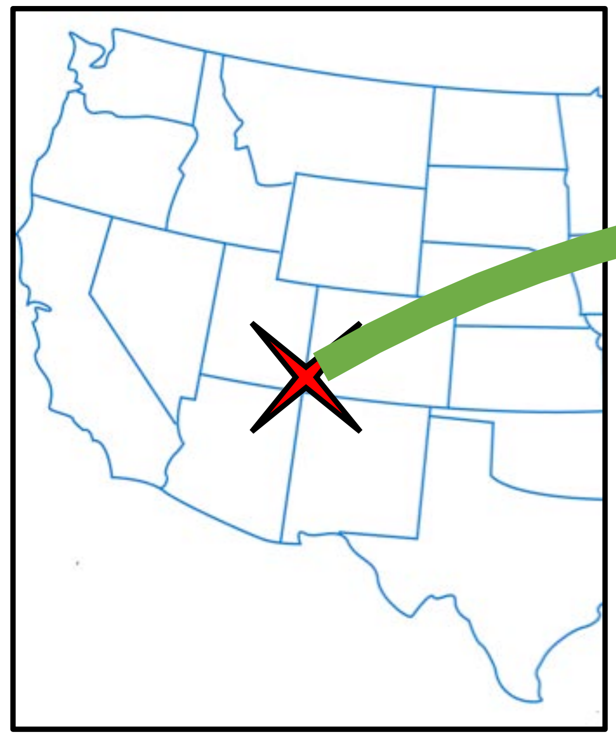



Obiettivo Economico

- Creare in Abruzzo il leader mondiale in:
    - Produzione di rivelatori di luce al silicio per Big Science
    - Produzione di rivelatori di luce al silicio per Medical Physics
    - Produzione di Skipper CCD (<1e noise) per missioni satellitari Dark Energy Science

Production and Purification





UAr transported via boat for final purification at Aria

Production: Urania

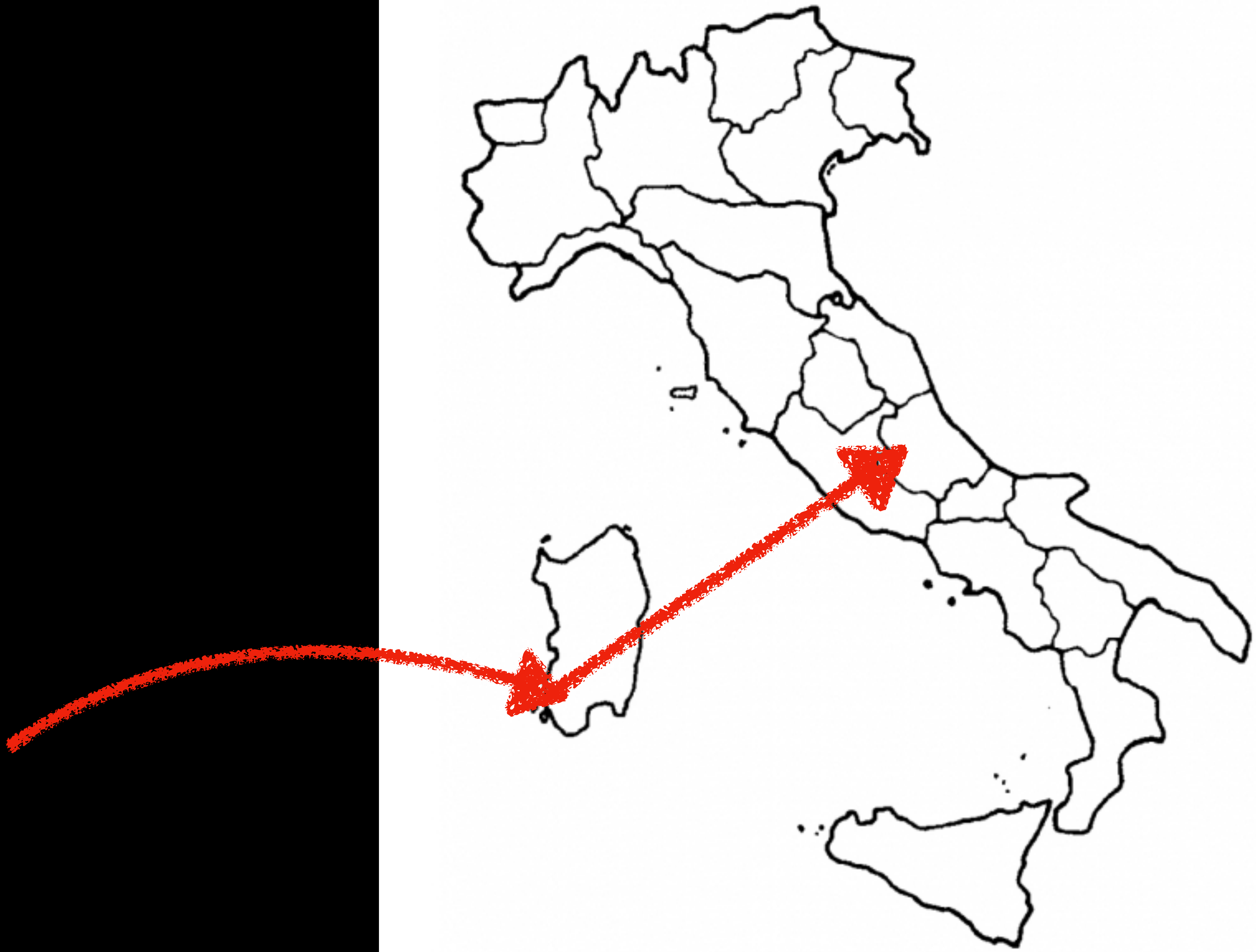
- Commercial-scale plant to extract UAr
- Located in Southwestern Colorado
- UAr extracted from CO_2 well gas at the tonne scale

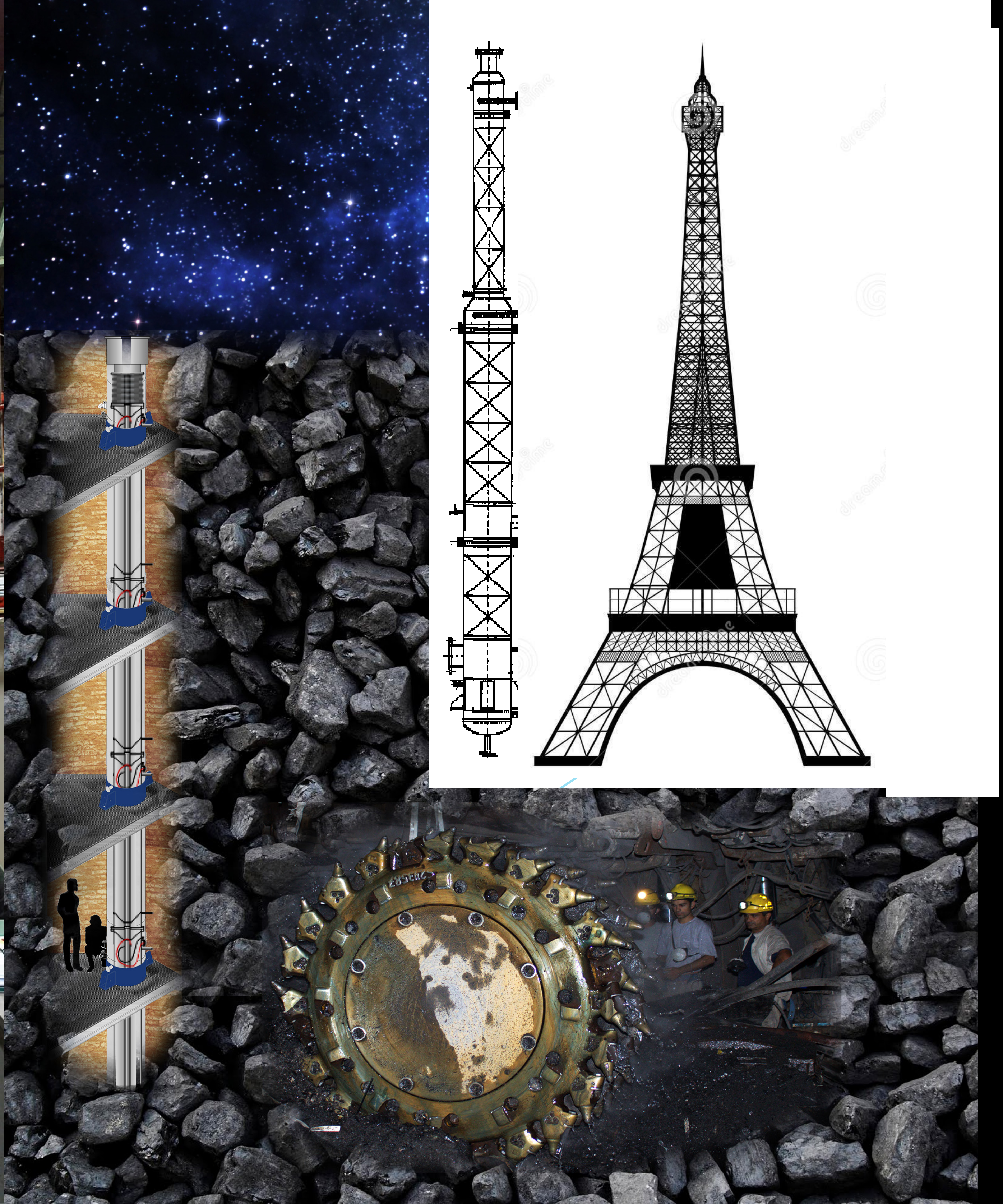
Focus of this talk

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





Collaboration with AstroCeNT

- Leszek Roszkowski
- Nektarios Benekos, Marcin Kuzniak, Masayuki Wada
- Marcin Ziembicki

Collaboration with AstroCeNT

- Photoelectronics Cryogenic Positron Emission Tomography
- Detector Development
- Adaptation of DarkSide Technology to $0\nu\beta\beta$ searches

The End