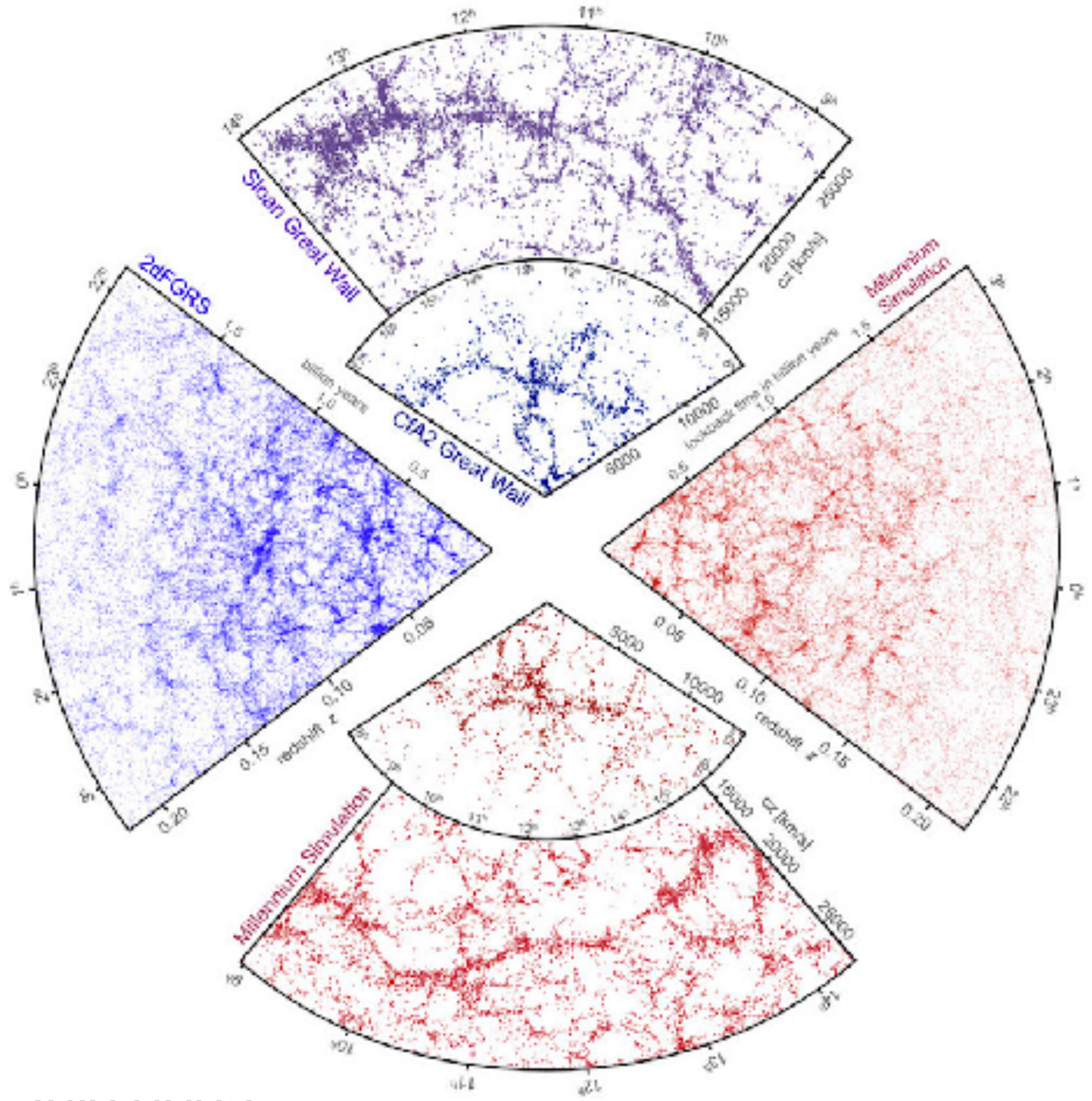
International Consortium

KJ Palladino

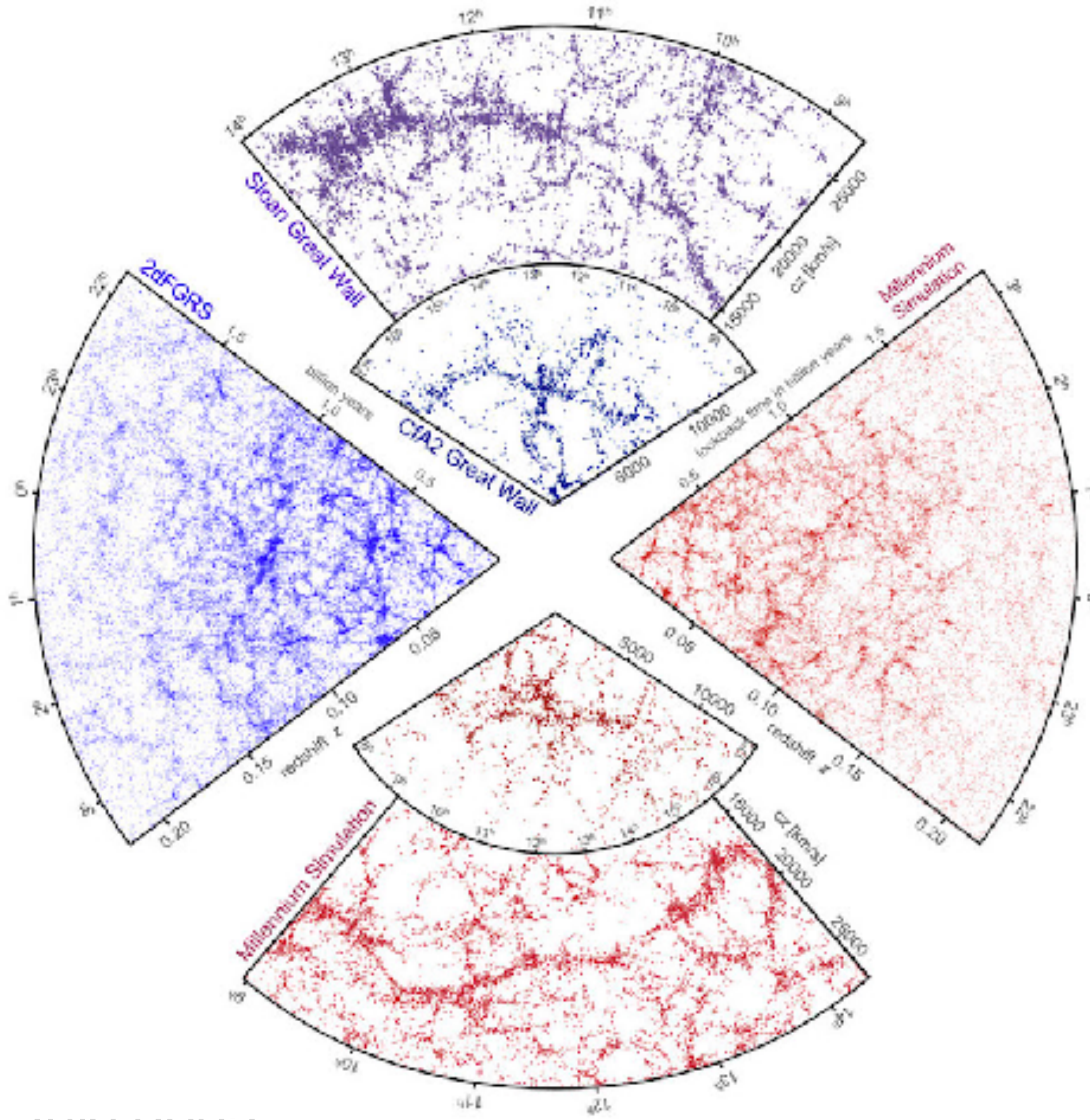
XLZD@Boulby Community Meeting

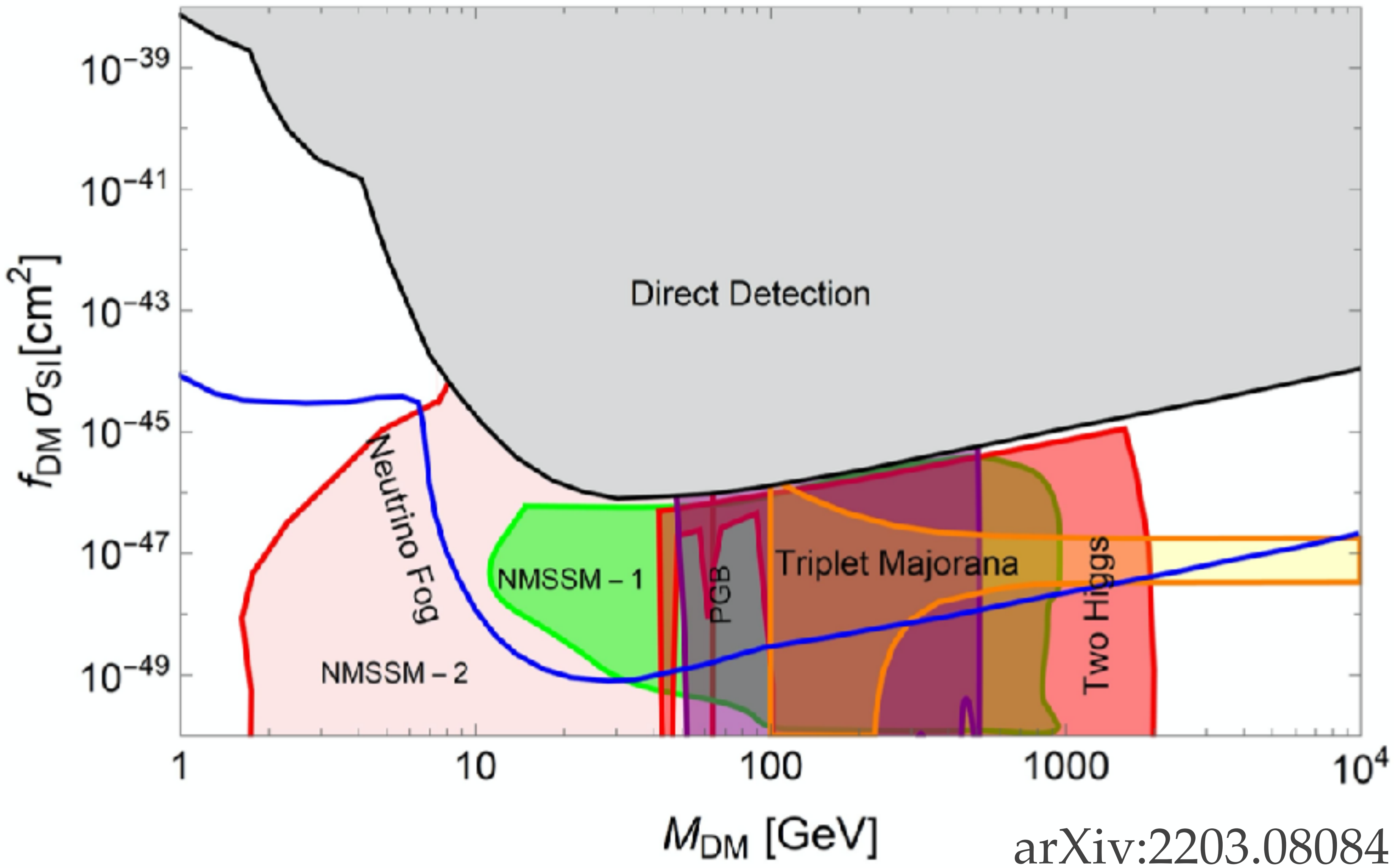
4th July 2023

Particle Dark Matter



Particle Dark Matter

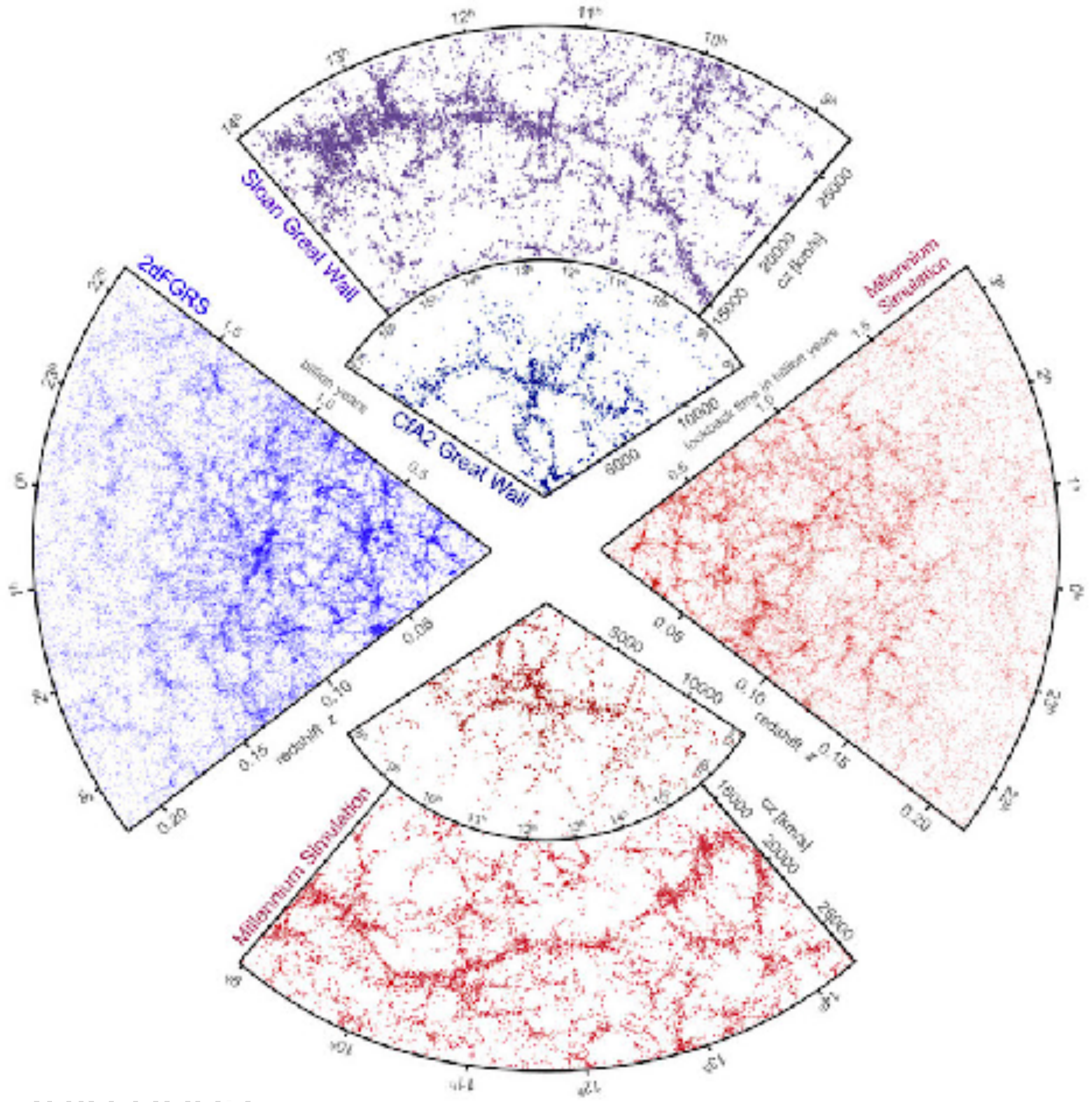


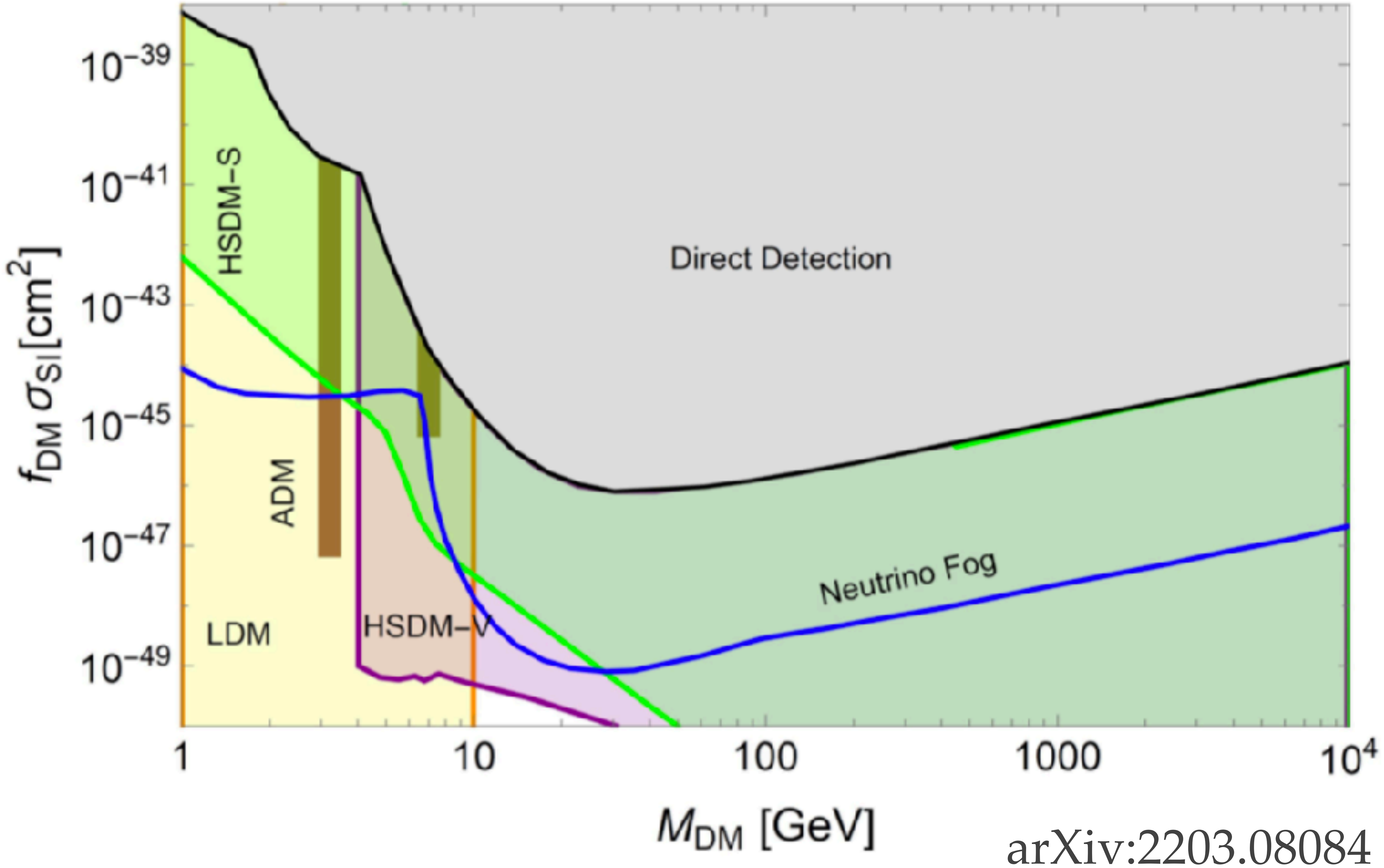


arXiv:2203.08084

Many well-motivated dark matter models to search for in this parameter space

Particle Dark Matter





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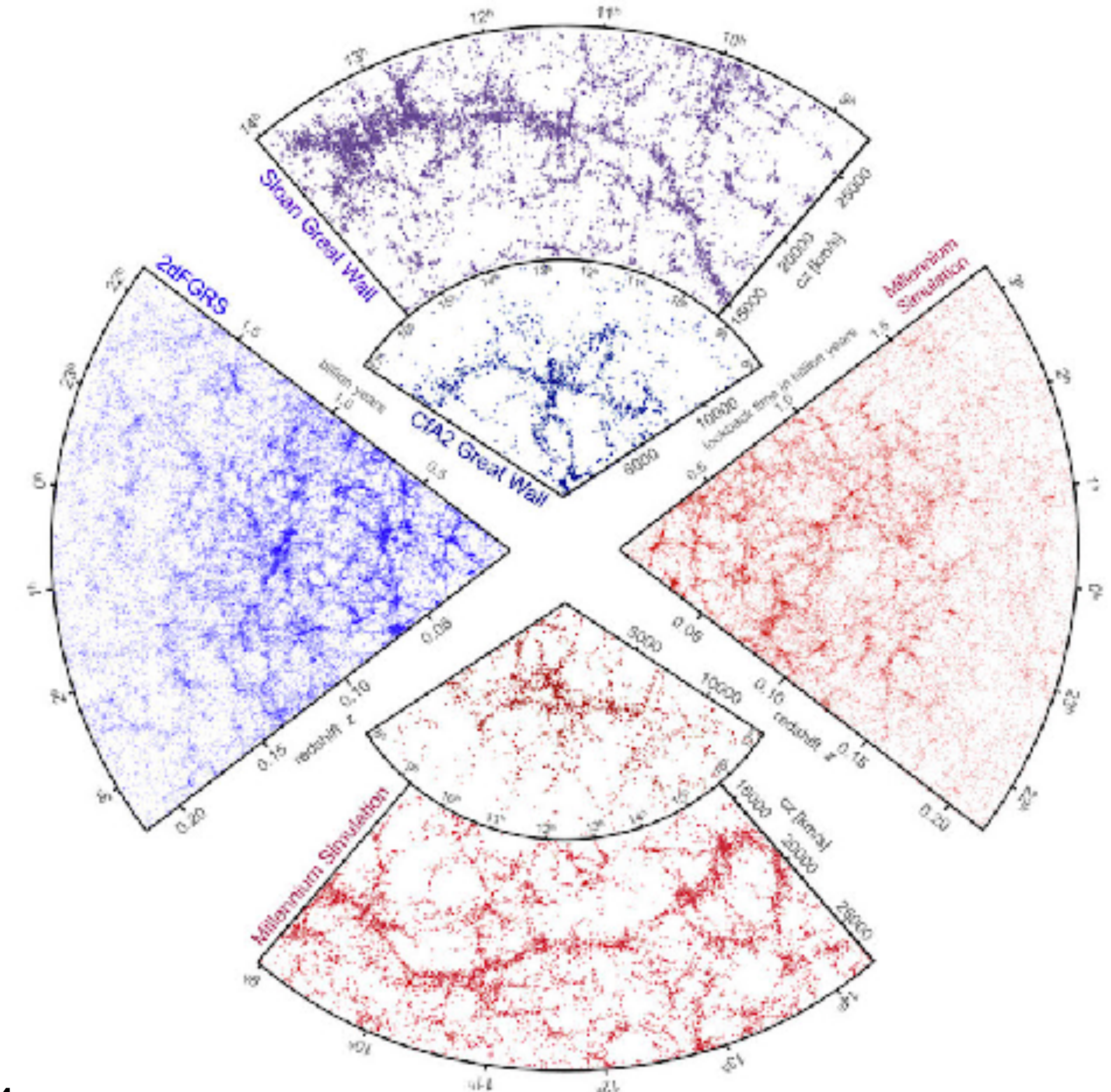

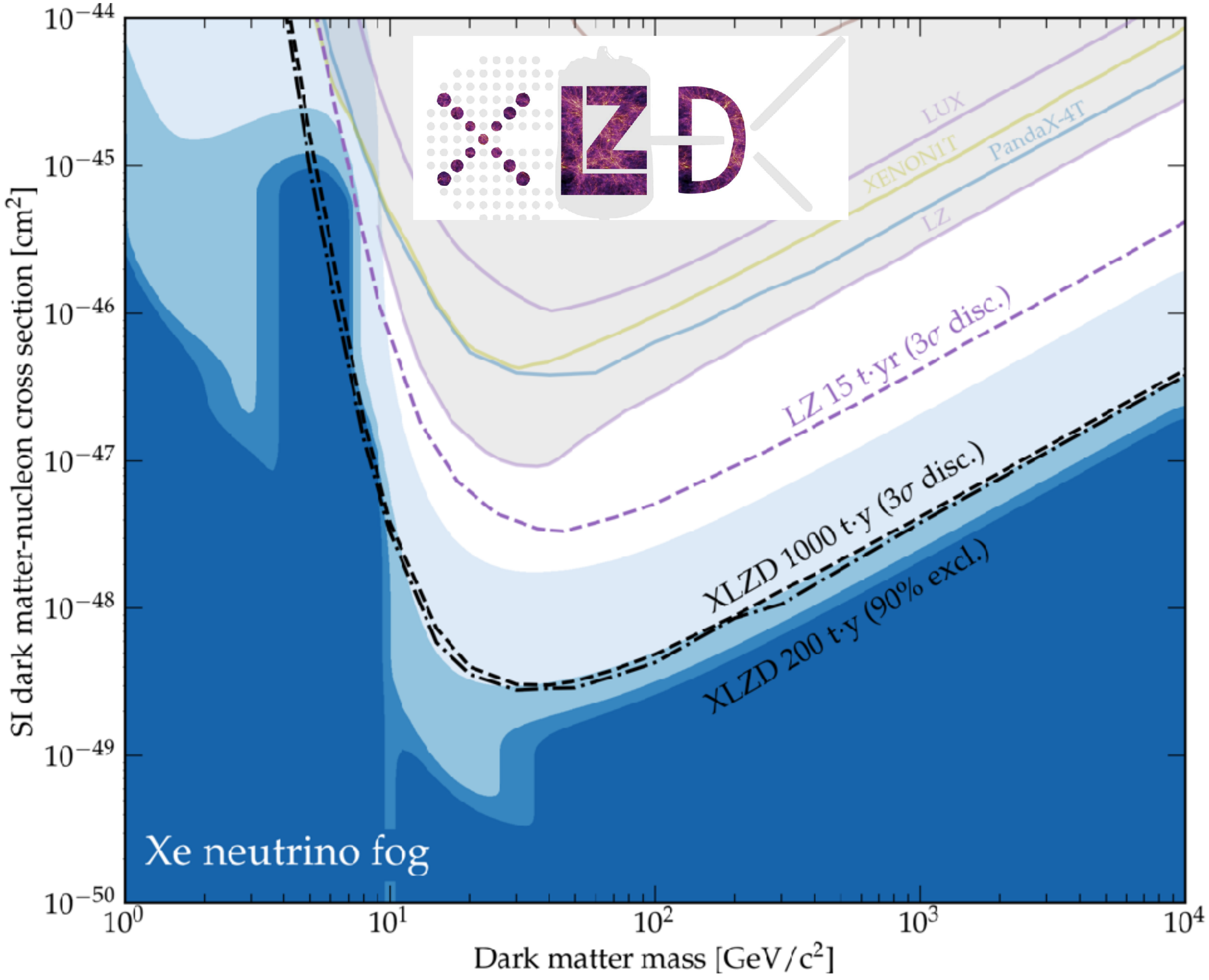

XLZD can cover the high mass parameter space to the neutrino fog

XLZD

- Consortium MOU signed in July 2021 by **X**ENONnT, **L**UX-**Z**EPLIN, **D**ARWIN
- XENONnT and LZ: ongoing science programs, technology progenitors
- DARWIN: initiated R&D and design studies
- Organization
  - Led by Steering Committee
  - Working groups: science, technical, siting
  - In-person meetings - Germany in June 2022
  - xlzd.org

XLZD Meeting at KIT in Karlsruhe, Germany (June 2022)

XLDZ

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  - xlzd.org

XLZD Meeting at UCLA (April 2023)

XLZD Working together

Consortium goal: establish international project and collaboration

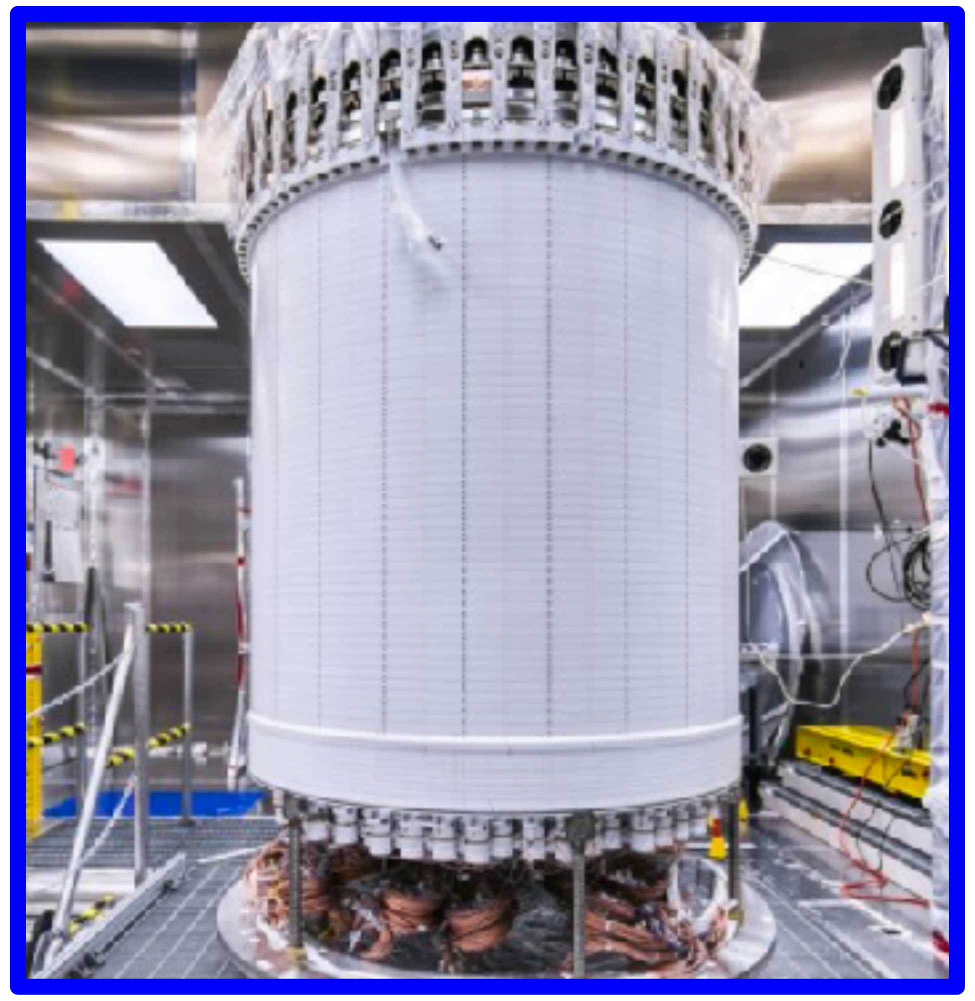
- Planning, planning, planning
  - Design book: science, hardware, R&D needs
  - Siting report (more later)
- Working together
  - shared tools
  - building a wider community and shared culture
- Expect a US P5 recommendation for a next generation dark matter detector to trigger move to a more formal collaboration
- Support ‘local’ efforts to strengthen XLZD
  - German (Helmholtz), UK, and US planning processes

XLZDers at the Getty Center in LA -Florian Jorg

Current Steering Committee

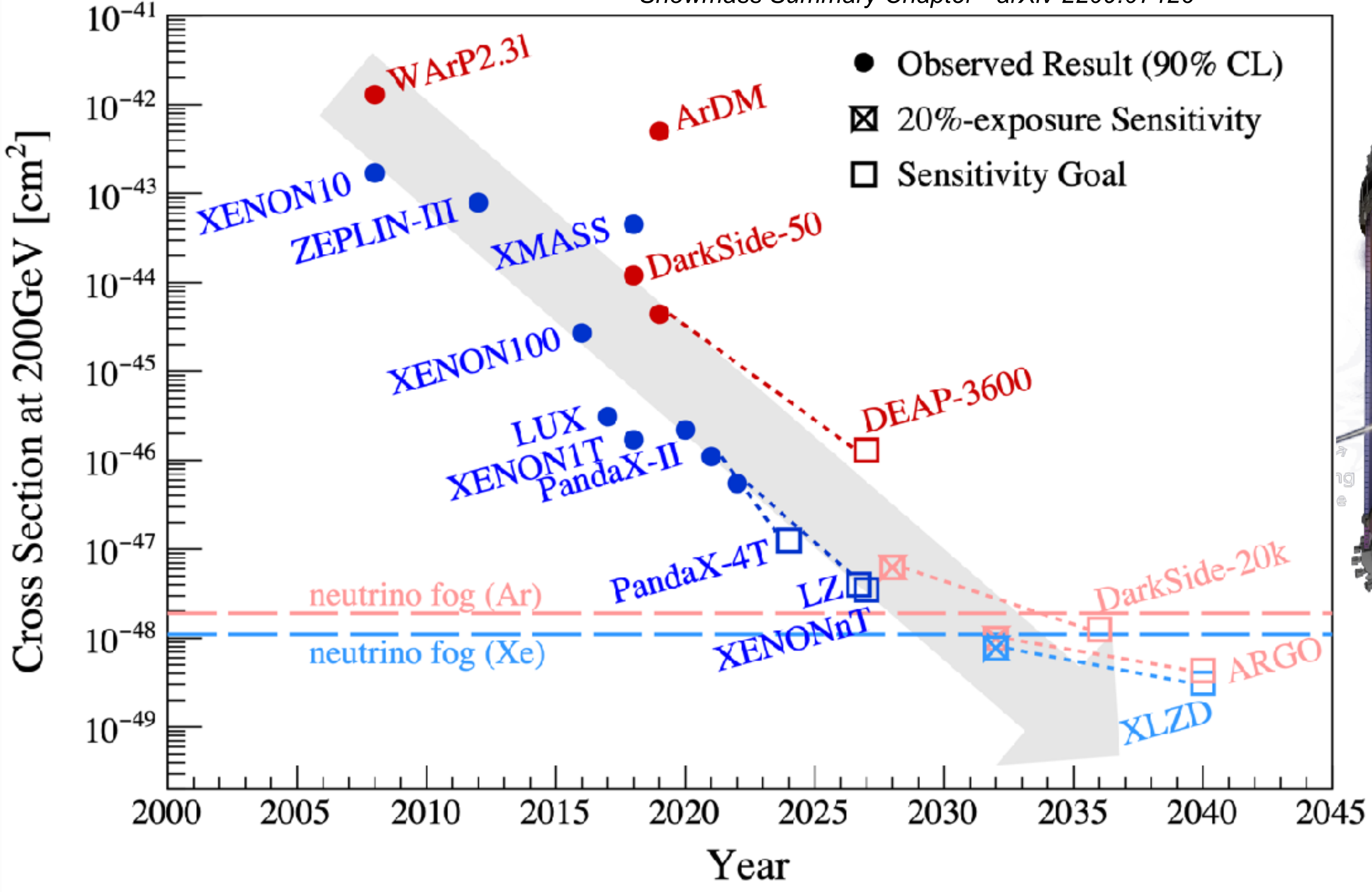
Dan Akerib (LZ, US, SLAC)
Henrique Araújo (LZ, UK, Imperial)
Laura Baudis (DARWIN, SUI, Zurich)
Patrick Decowski (DARWIN, NED, Nikhef)
Theresa Fruth (LZ, AUS, Sydney)
Rick Gaitskell (LZ, US, Brown)
Chamkaur Ghag (LZ, UK, UCL)
Luca Grandi (DARWIN, US, Chicago)
Carter Hall (LZ, US, UMD)
Manfred Lindner (DARWIN, GER, MPIK)
Aaron Manalaysay (LZ, US, LBNL)
Kaixuan Ni (DARWIN, US, UCSD)
Uwe Oberlack (DARWIN, GER,
Kimberly Palladino (LZ, UK, Oxford)
Marc Schumann (DARWIN, GER, Freiburg)
Marco Selvi (DARWIN, IT, INFN)
Kathrin Valerius (DARWIN, GER, KIT)

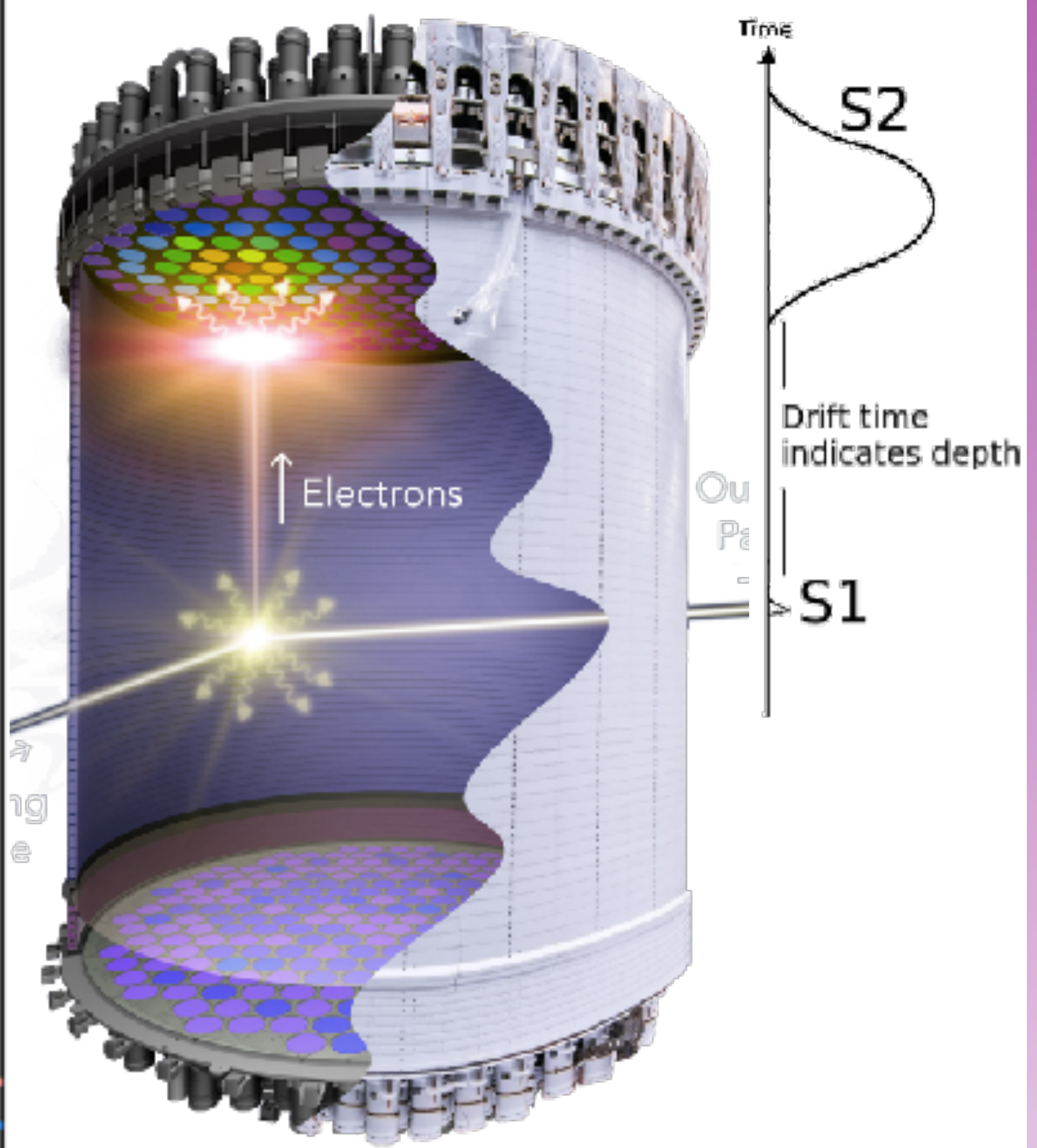
Liquid Noble Detectors



LUX-ZEPLIN

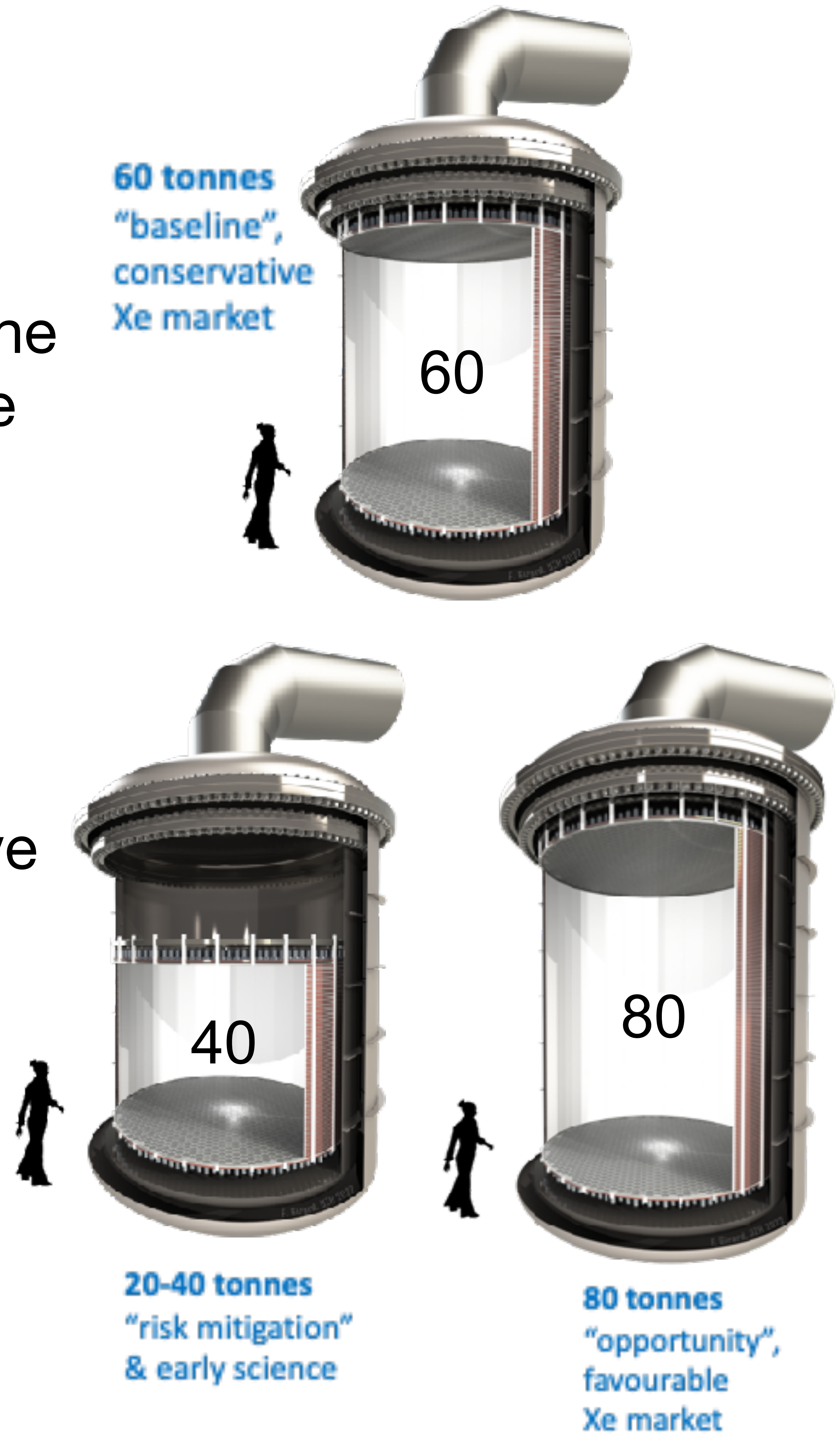
Snowmass Summary Chapter - arXiv 2209.07426

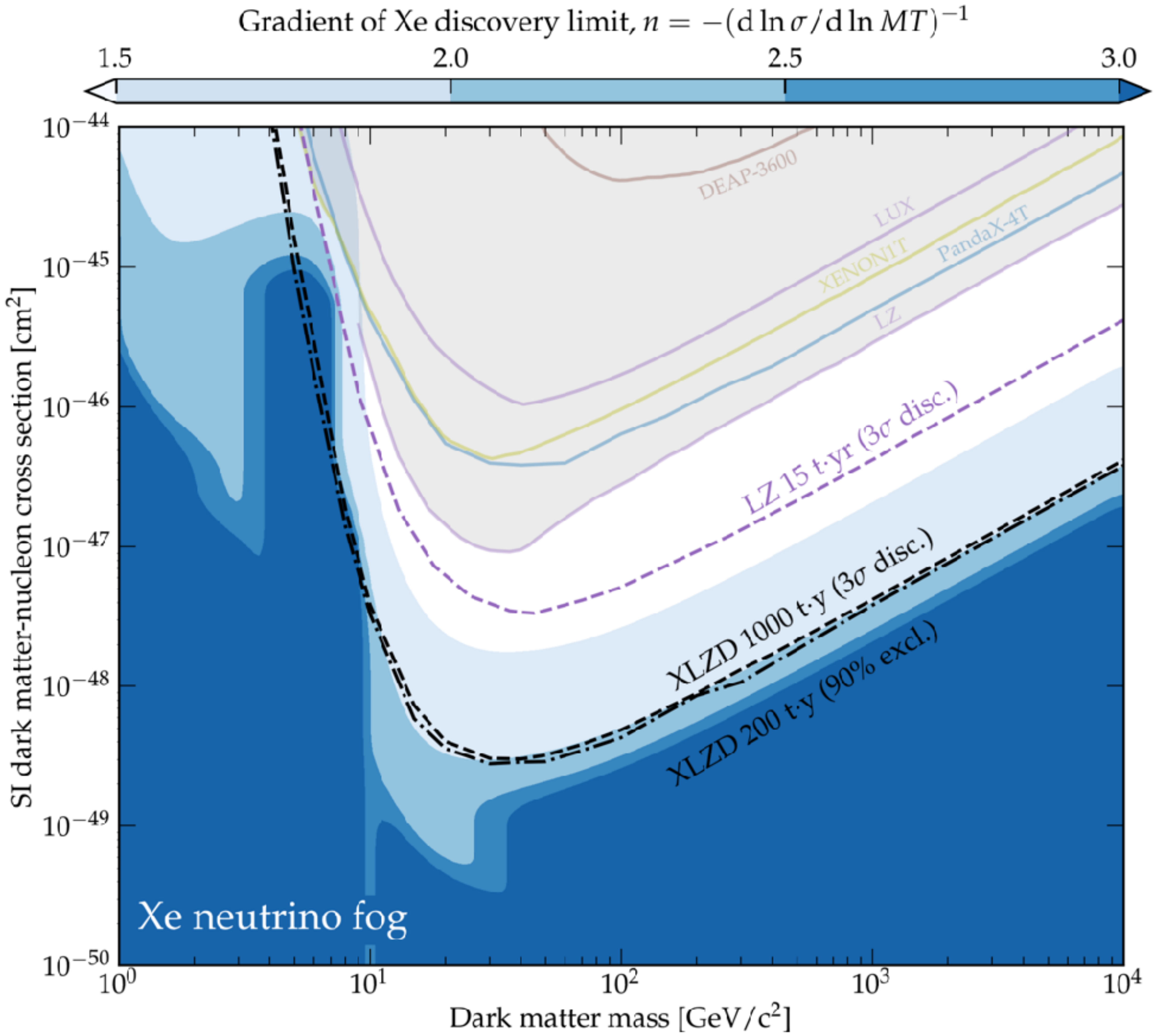




Provisional Design

- Design for Discovery into the neutrino fog
    - a detector that drives the full consortium to come together
- 60t active 1:1 aspect ratio at (300cm)
    - Xe acquisition may drive stages or final scale
- Engineer for access
    - risk mitigation and opportunity for growth

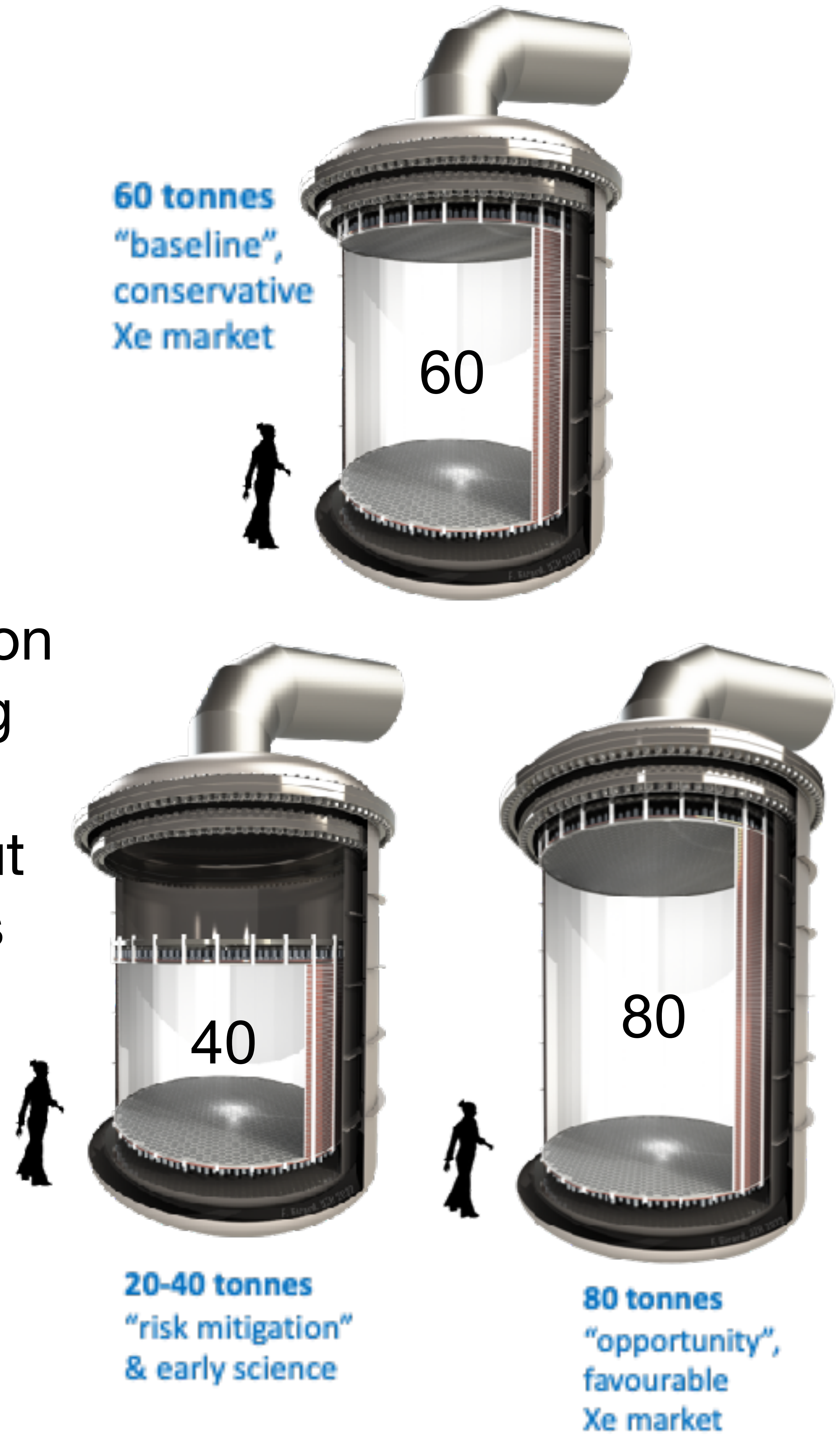


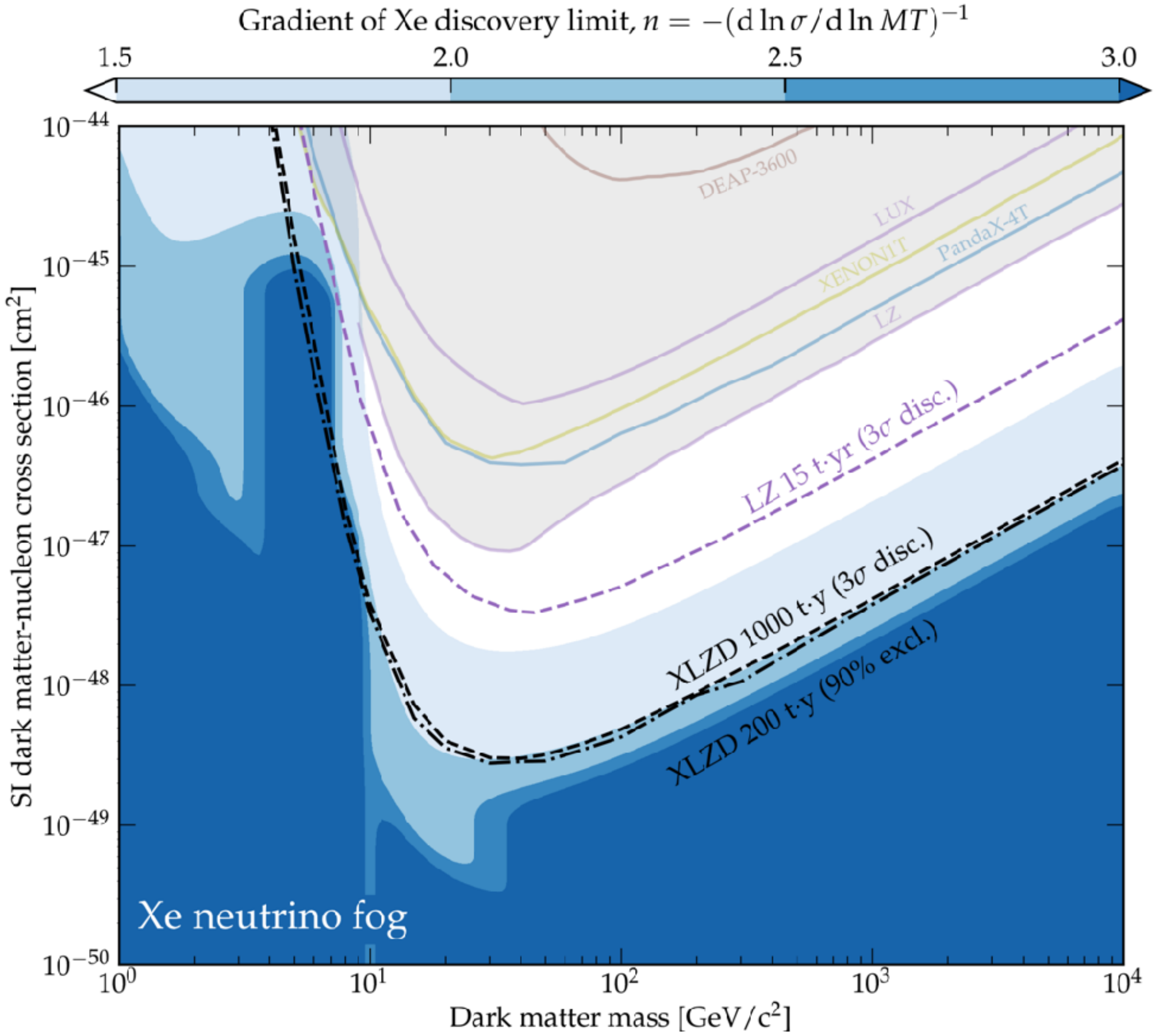


Provisional Design

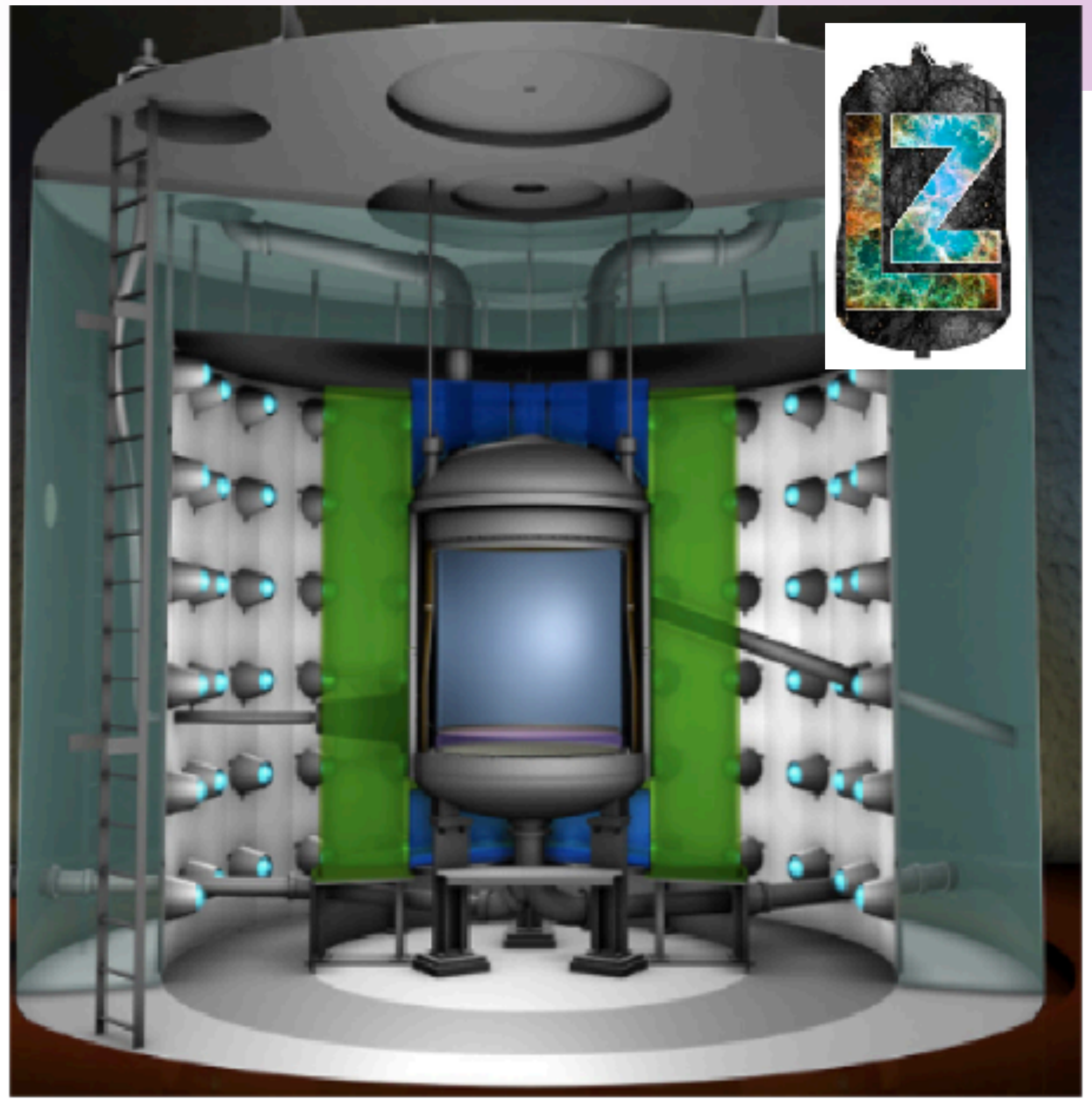
An ambitious programme

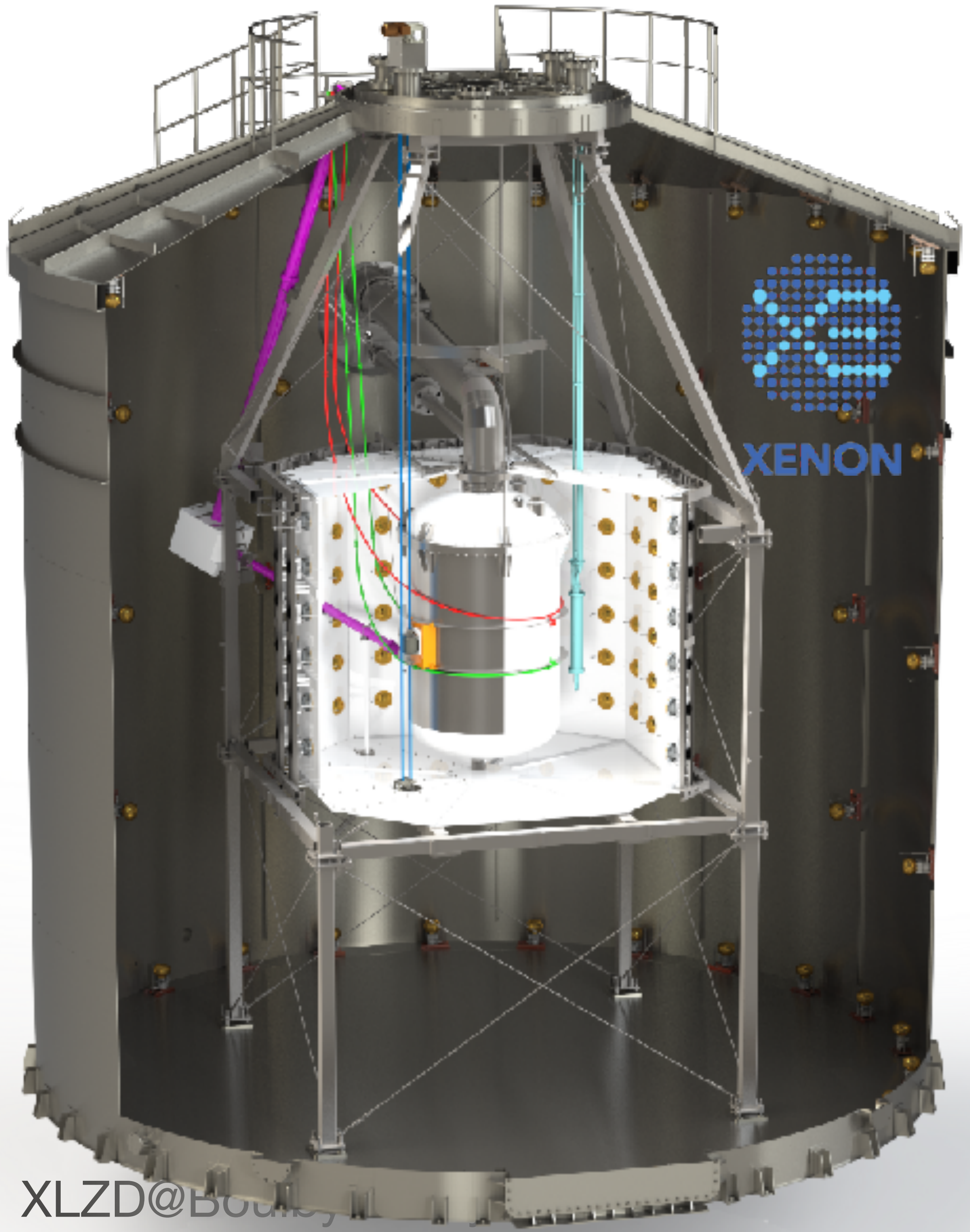
- **Largest and definitive xenon observatory for rare events, both dark matter and $0\nu\beta\beta$**
- Size determined by xenon market and cost/funding
- Realistic parameters, but flexible for opportunities to grow (faster)
- Build this detector together and attract the best & brightest





Not just Xe in Vacuum





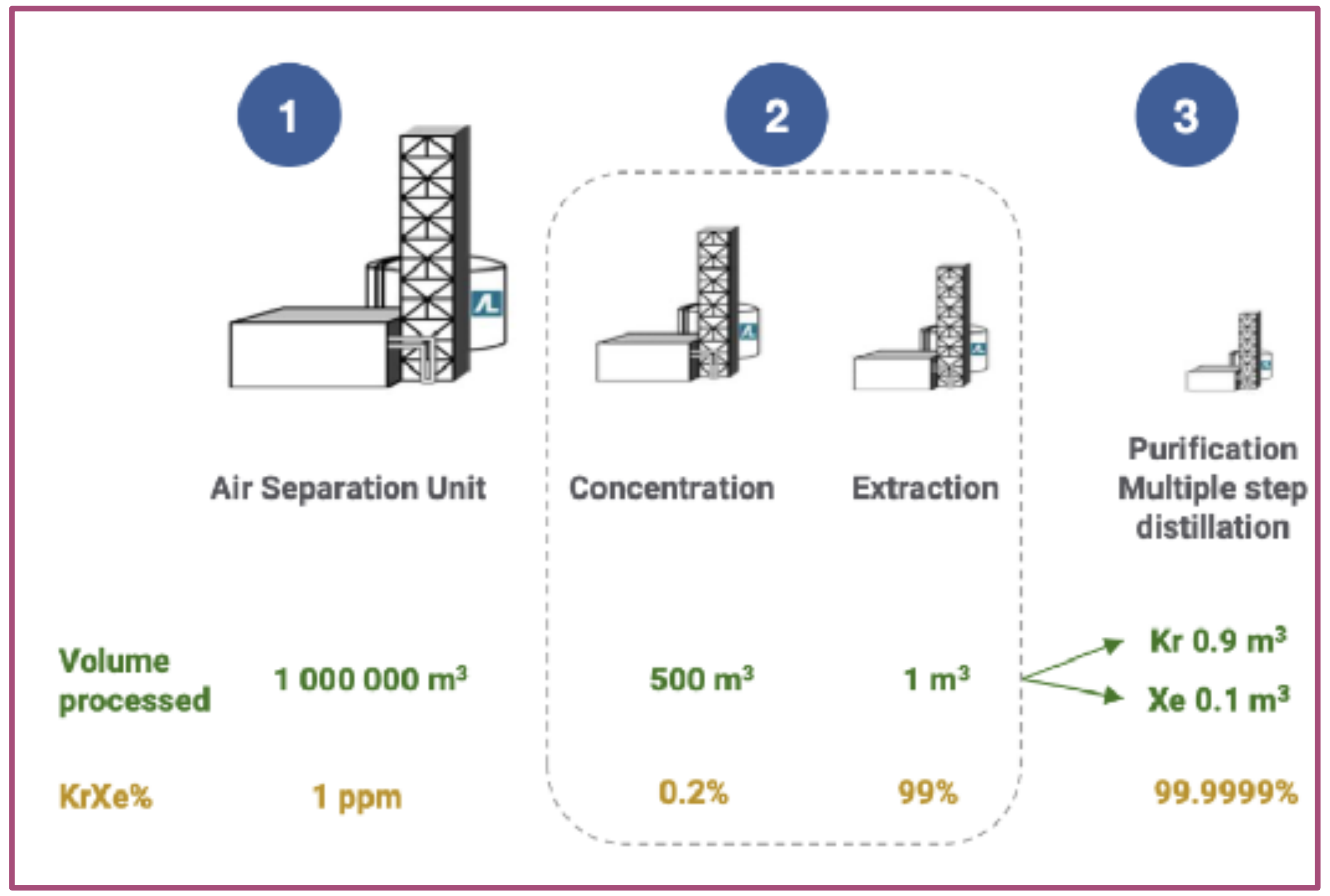
- Two operating systems: XLZD will take the best designs and learn from past experience - lots of decisions and engineering, some R&D

- Many vital subsystems you will/may hear about
  - TPC: fieldcage, electrodes/grids/extraction region/HV system, photosensor arrays
  - Skin, (internal) liquid handling, sensors
  - Cryostat, cryogenics, circulation/purification/Rn removal/Kr removal, injected calibration sources
  - Outer detector: neutron veto, muon veto, calibration sources, DD neutron source, HV feedthrough, water tank, water purification
  - Xenon recovery, xenon storage
  - DAQ/trigger, data storage, data transfer, data processing (online and offline), run control, slow control/PLC, detector monitorring

Known Risks and R&D Areas

Xenon Supply

- Commodity produced at ~60t/yr and increasing - XLZD needs to acquire ~1 year of world production
- Coordinated acquisition through long-term contracts over a decade and multiple suppliers
- Continued discussion with suppliers necessary

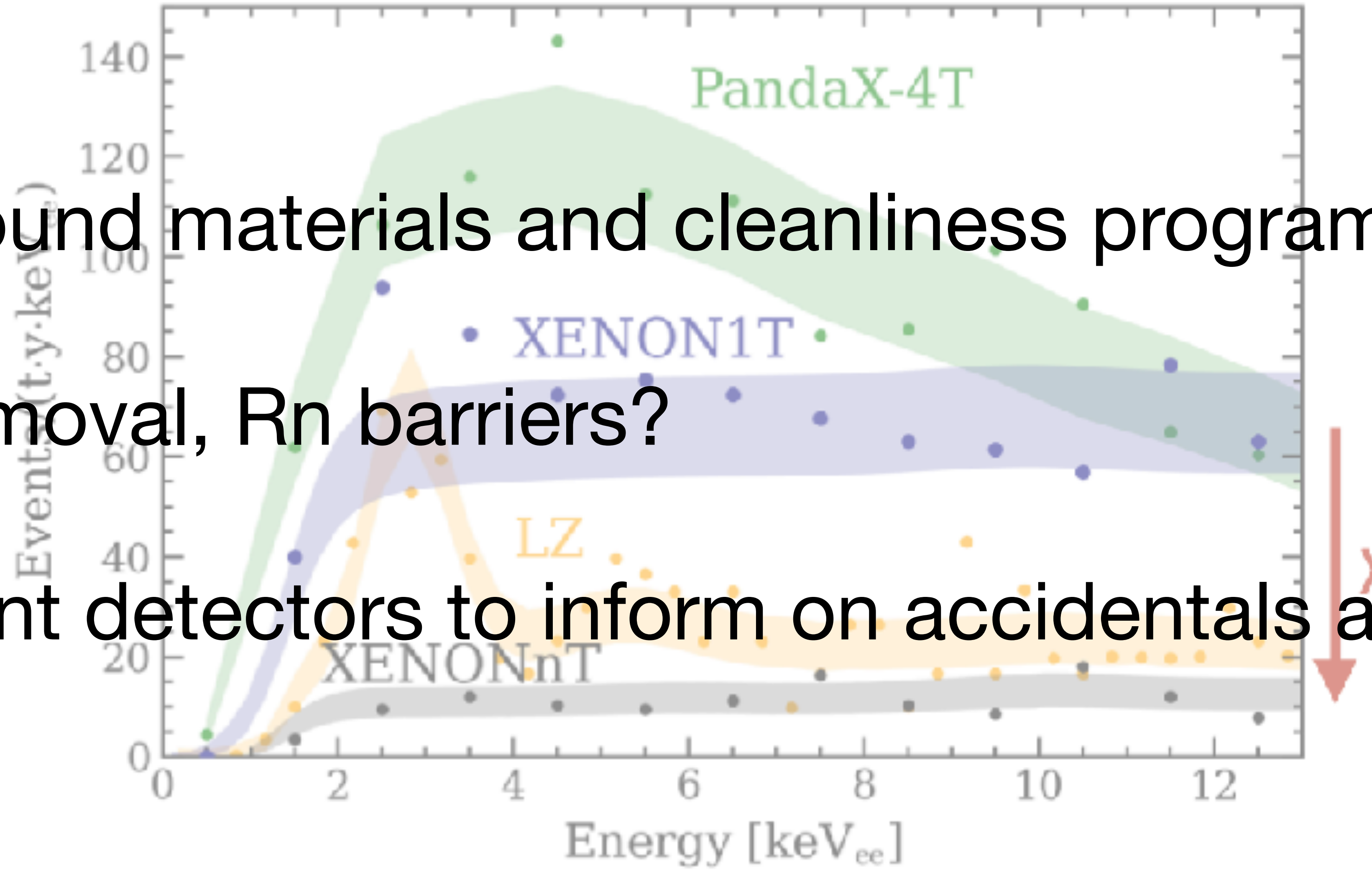


Electric fields

- Increasing scale of HV electrodes and voltage requires R&D, engineering, and a robust QA/testing programme
  - TPC diameter and height 'only' doubling

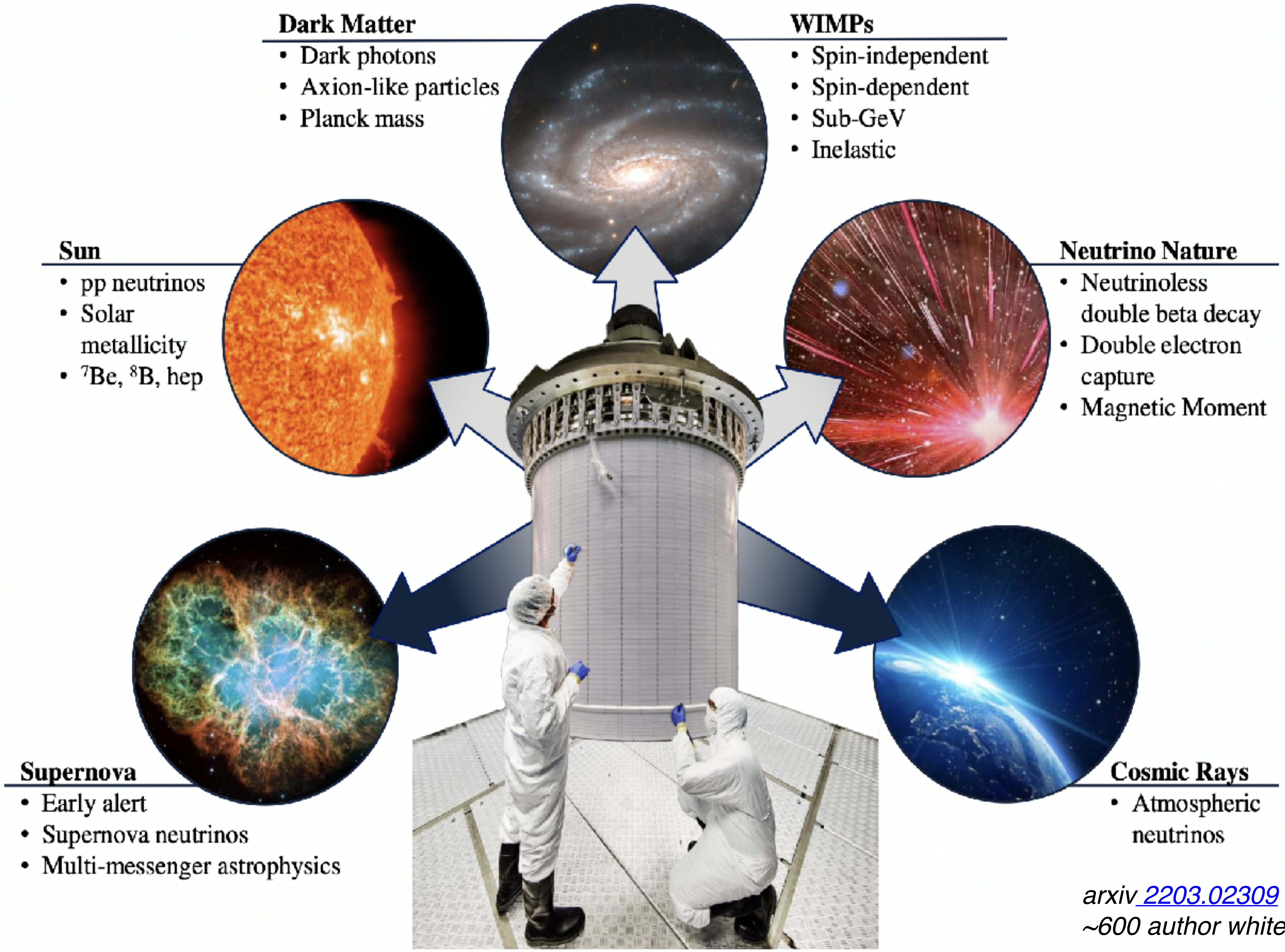
Backgrounds

- Low background materials and cleanliness programme
- In-line Rn removal, Rn barriers?
- Exploit current detectors to inform on accidentals and other effects



Track record of the combined teams in scaling from 10 kg to 10 tonnes provides the technical foundation and capabilities for making the necessary advances

XLZD Science



arxiv [2203.02309](https://arxiv.org/abs/2203.02309) / J. Phys. G: Nucl. Part. Phys.
~600 author whitepaper on the science reach

XLZD Siting: Consortium Perspective

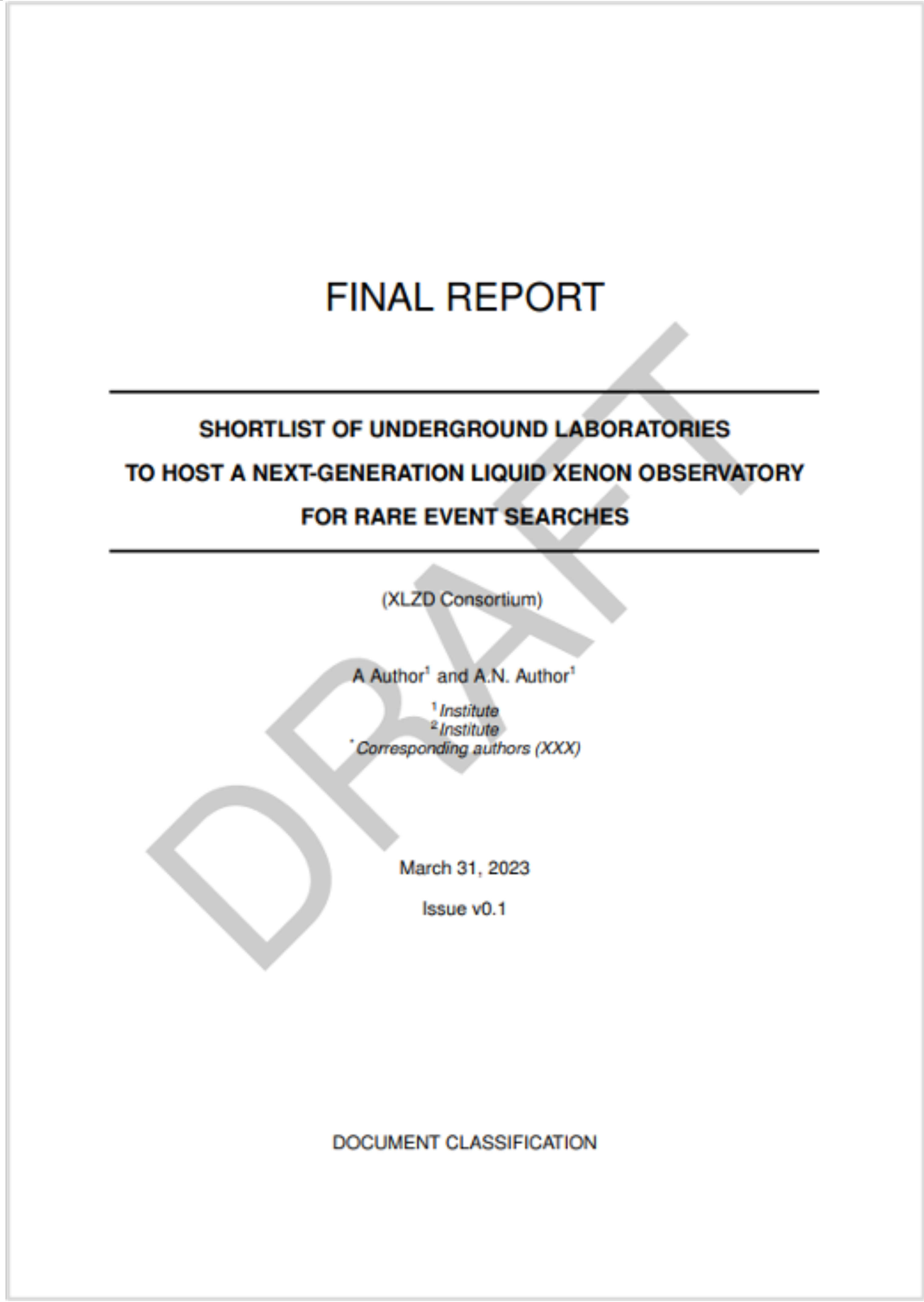
XLZD@Boulby Community Meeting
4th July 2023

The Big Picture

- The final siting decision process not yet defined
  - Likely to be made “above our pay grade”
  - Expect a siting decision will be made in 2025
- XLZD approach:
  - Siting Report (in progress)
  - contact with pertinent venues and funding agencies

XLZD Siting Report

- Led by Henrique Araújo (Imperial) & Marco Selvi (INFN)
  - supported by Tim Sumner and other site liaisons
  - completed draft planned in next few months
  - for internal use, and to share with funding agencies and UG laboratories
- Contents:
  - Flow from physics goals to requirements for backgrounds and facilities
  - Describes the 5 candidate labs and highlights strengths and weaknesses
  - Additional considerations of practicality: from access to costs, safety to seismic environment



FINAL REPORT

SHORTLIST OF UNDERGROUND LABORATORIES
TO HOST A NEXT-GENERATION LIQUID XENON OBSERVATORY
FOR RARE EVENT SEARCHES

(XLZD Consortium)

A Author[1] and A.N. Author[1]
[1] Institute
[2] Institute
[*] Corresponding authors (XXX)

March 31, 2023

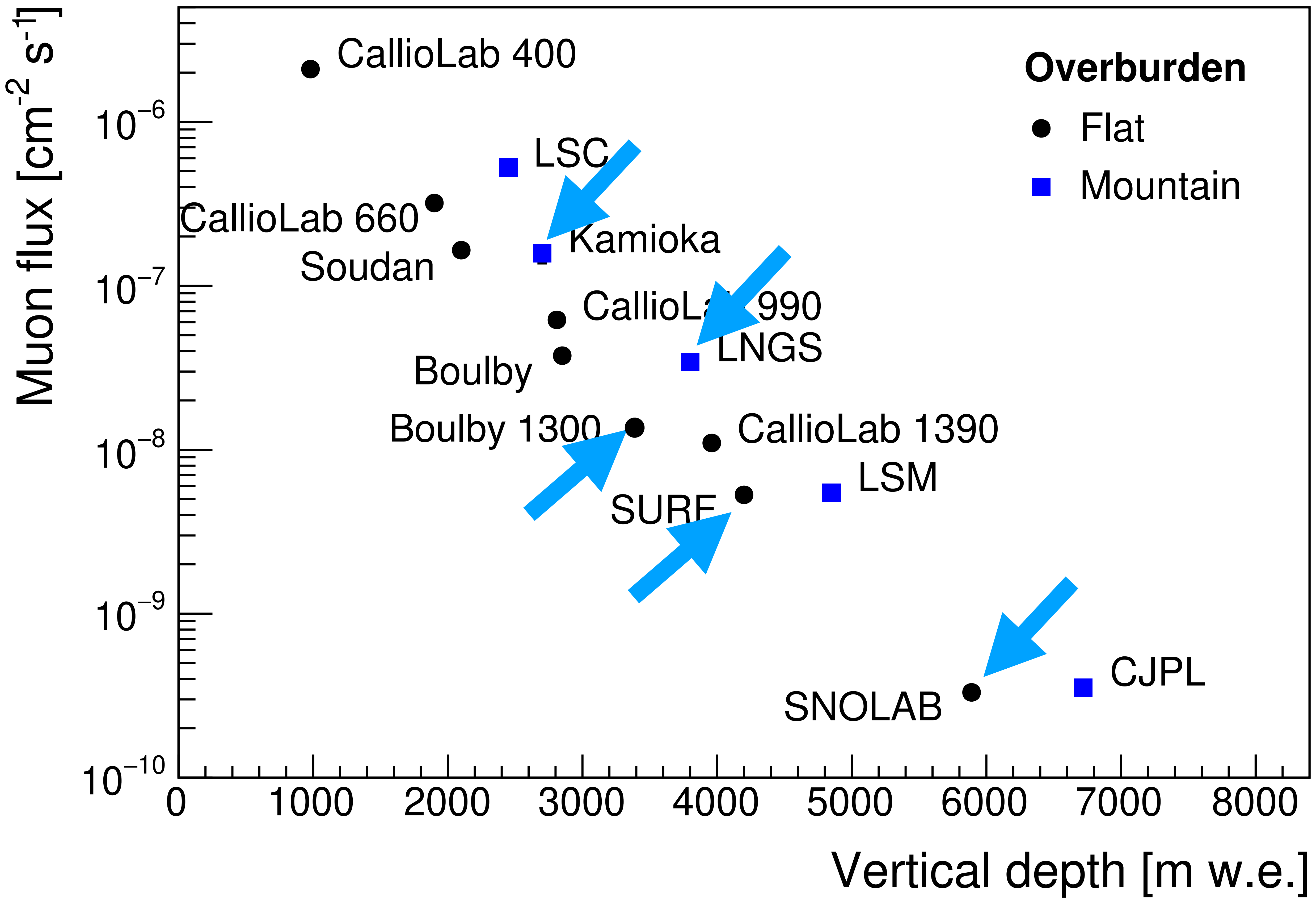
Issue v0.1

DOCUMENT CLASSIFICATION

DRAFT

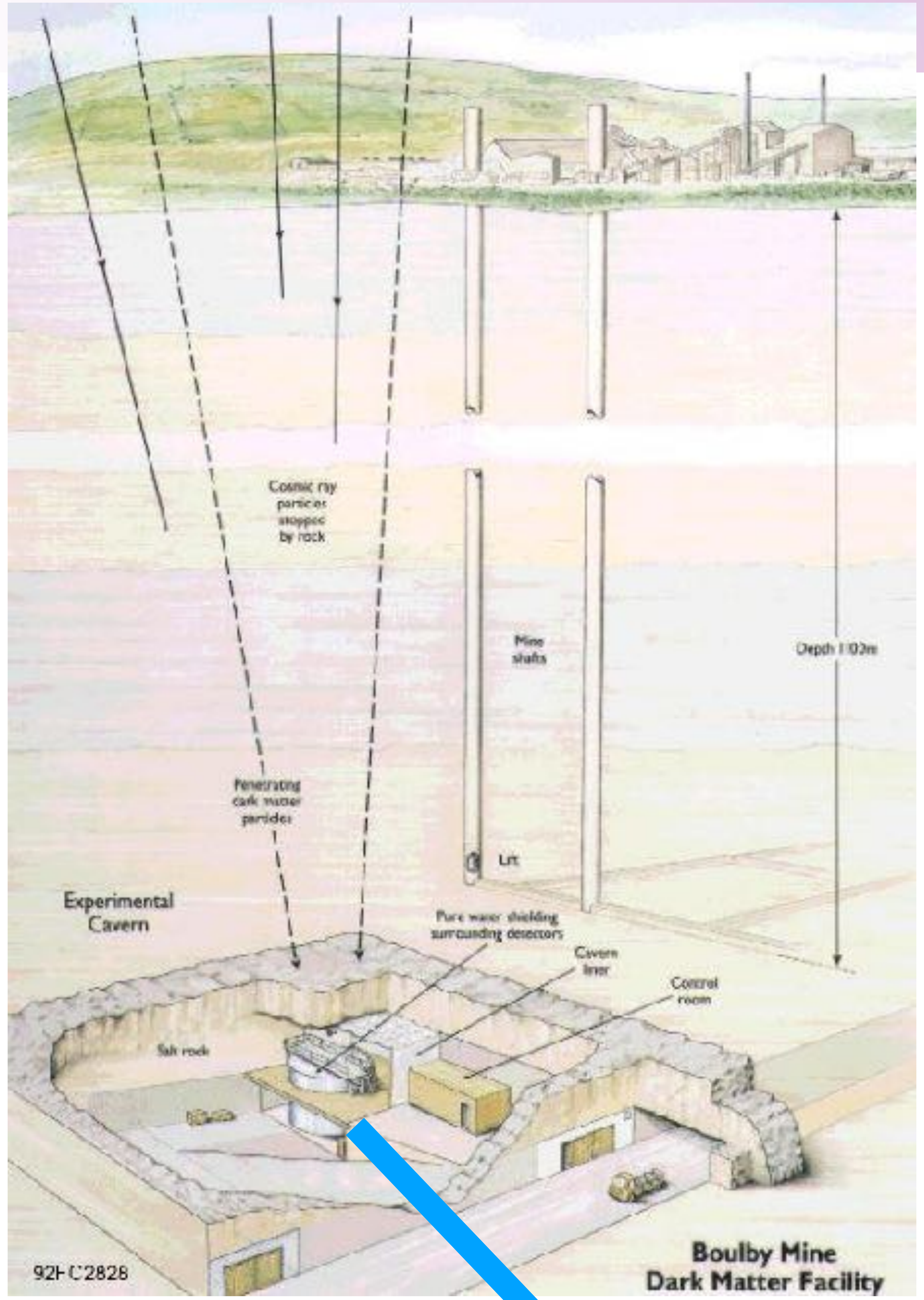
5 Candidate Lab Overview

- Candidate labs in alphabetical order
  - Boulby (UK)
  - Kamioka (Japan)
  - LNGS (Italy)
  - SNOLAB (Canada)
  - SURF (USA)



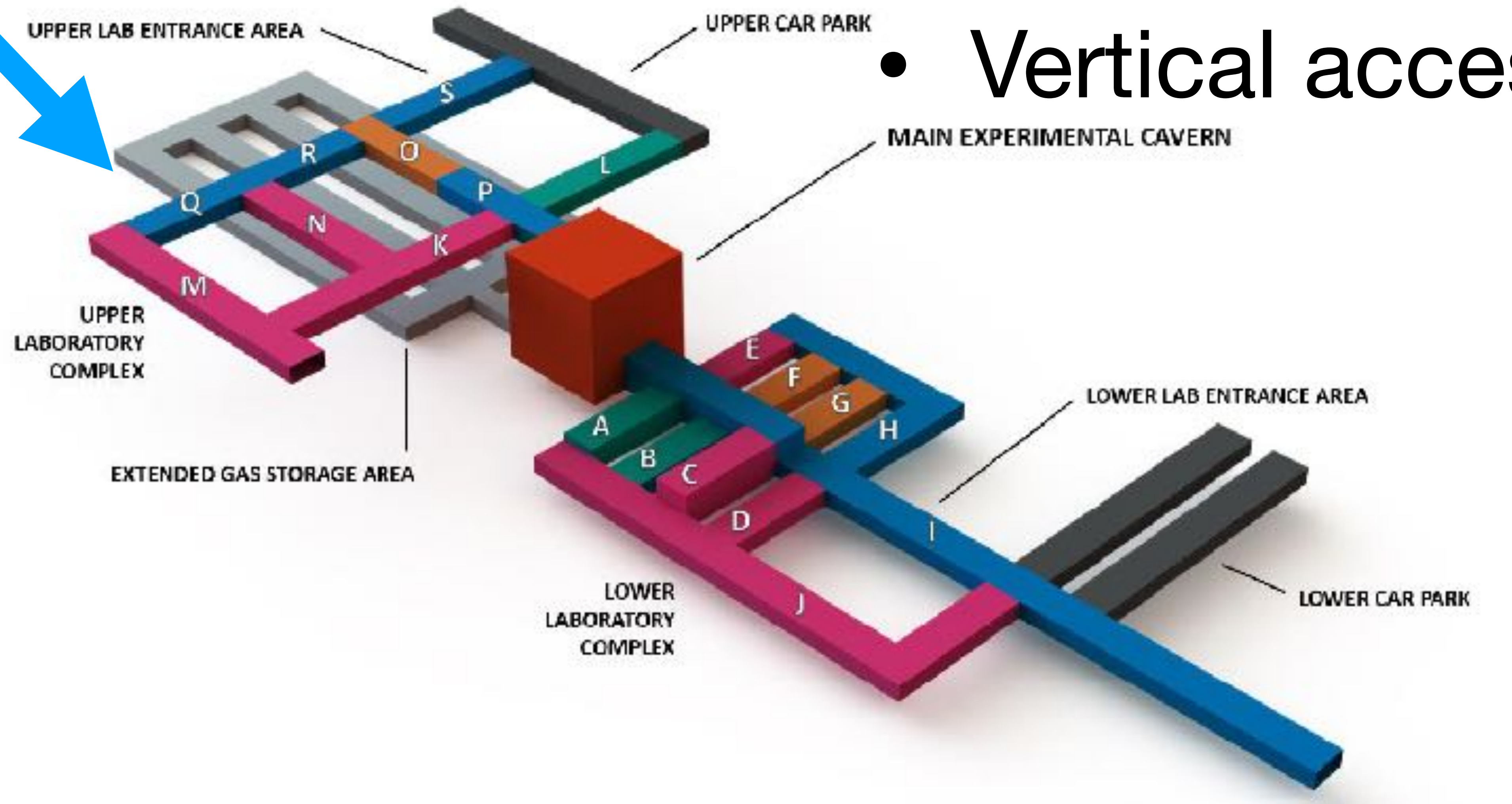
- Initial concerns are backgrounds from muon induced neutrons and cosmogenic activation
  - 0vbb has more stringent requirements than DM

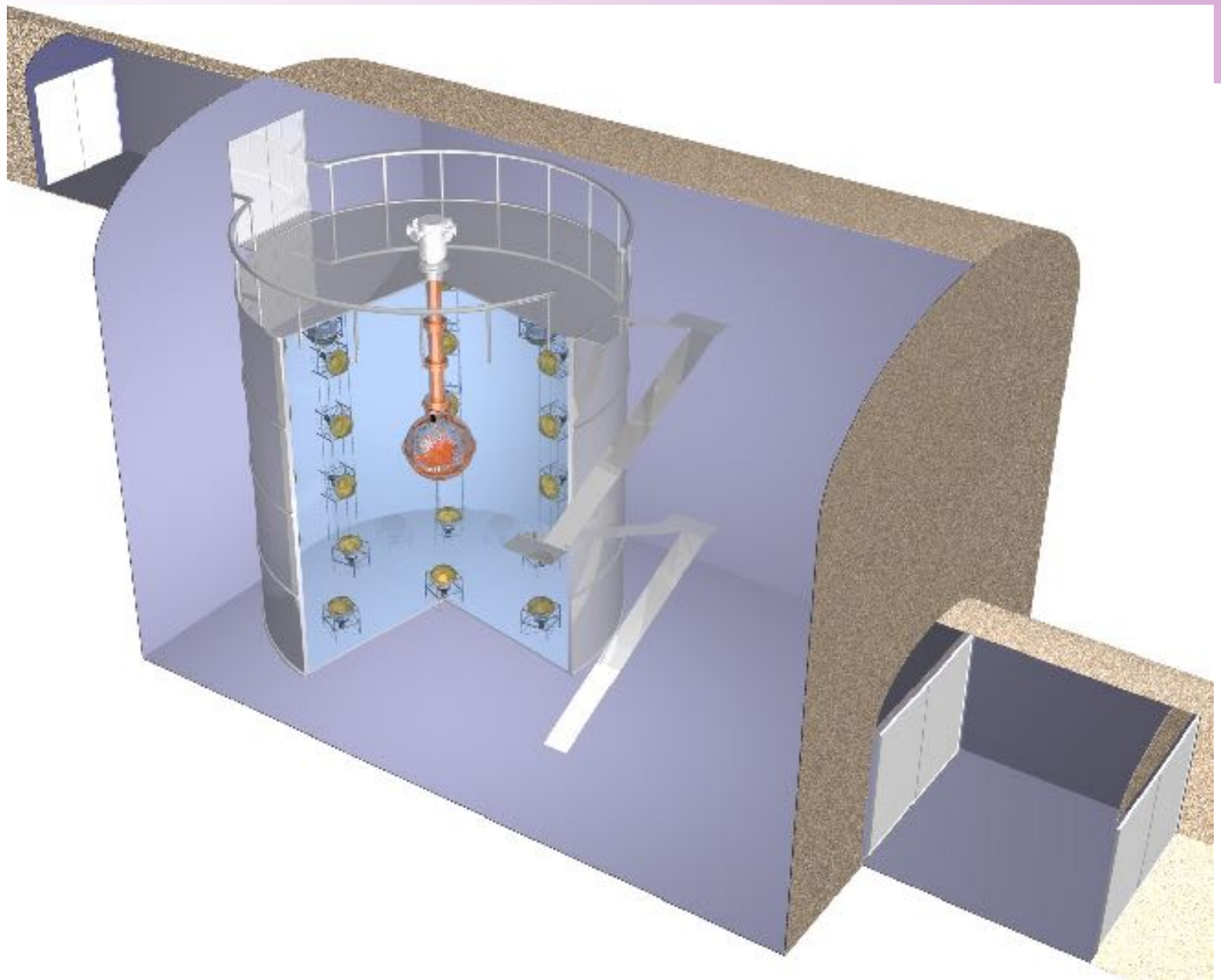
Boulby



Much more later today!

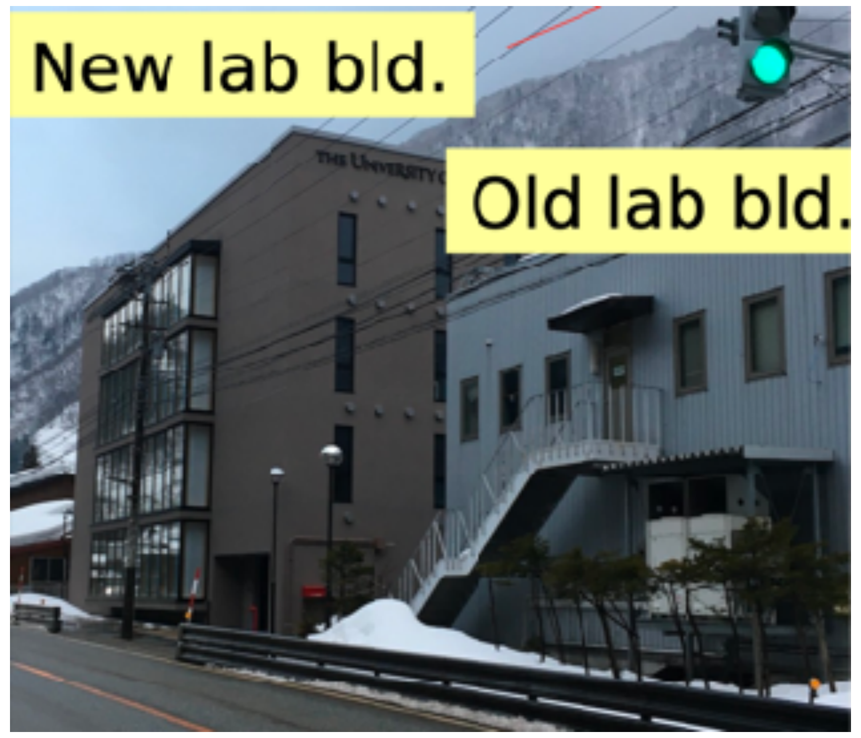
- Hosting requires expansion, planned for 1.3 km depth
  - Planned experiment UG construction starting in 2030
- Operating rock salt and polyhalite mine
- 5 hour drive from London, 2.5 from Manchester
- Vertical access shaft



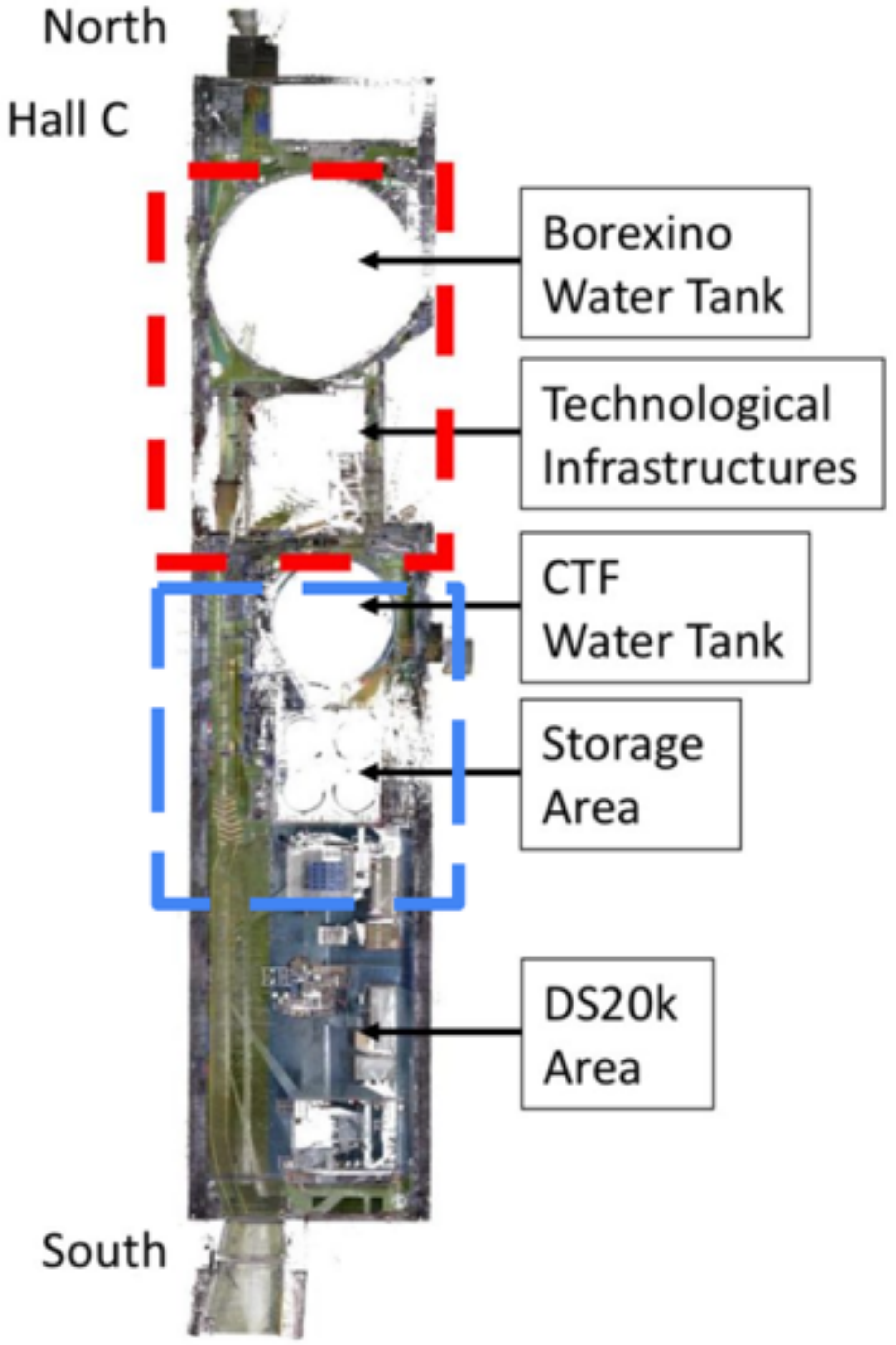


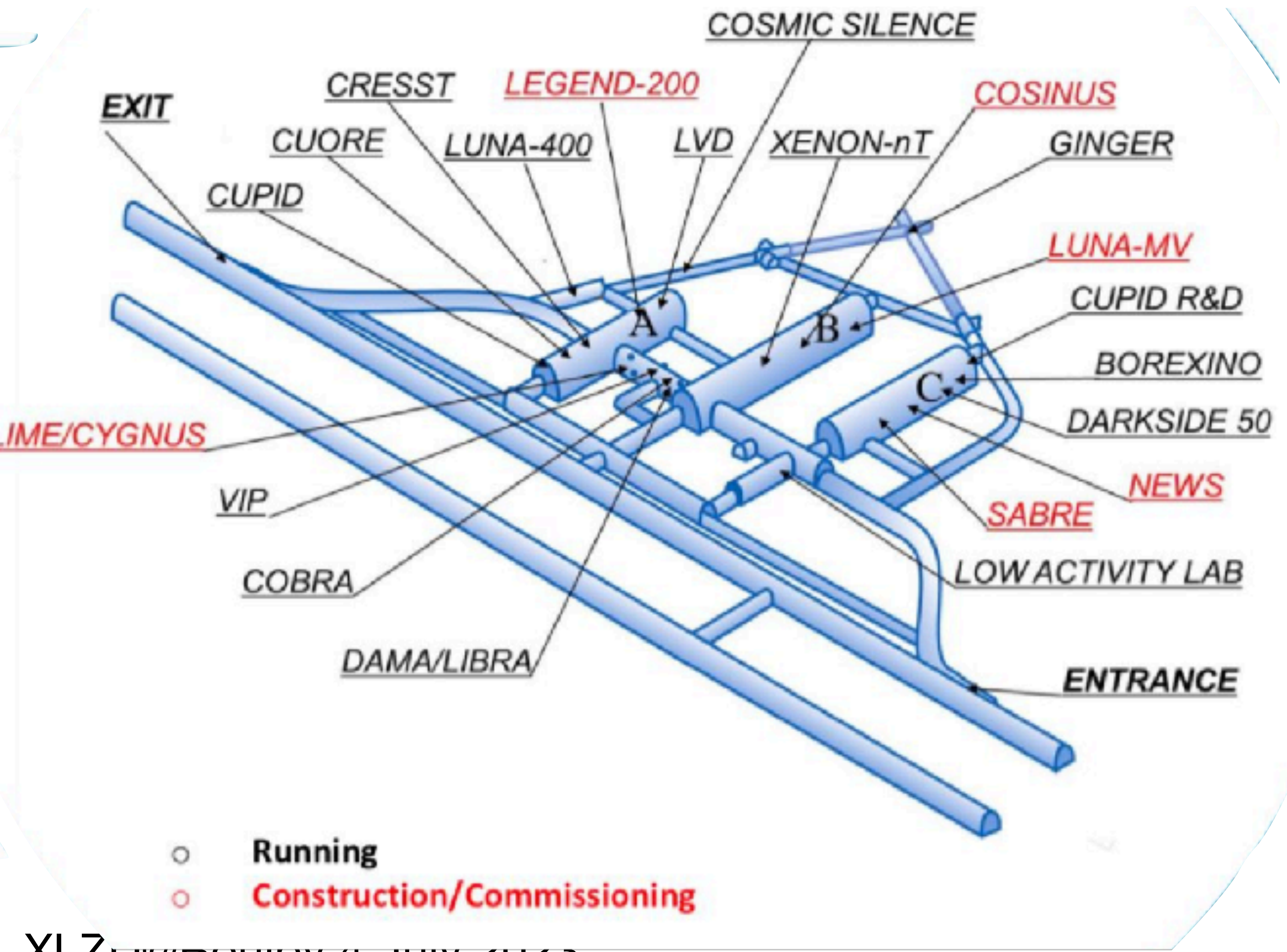
Kamioka

- Lab C - former XMASS location - available now
  - HYPER-K is priority until it's operating
  - experience and support infrastructure in place
- Mine under a mountain with horizontal access
- 1 hour from Toyama
- Relatively shallow site
  - KamLAND-zen sees spallation backgrounds



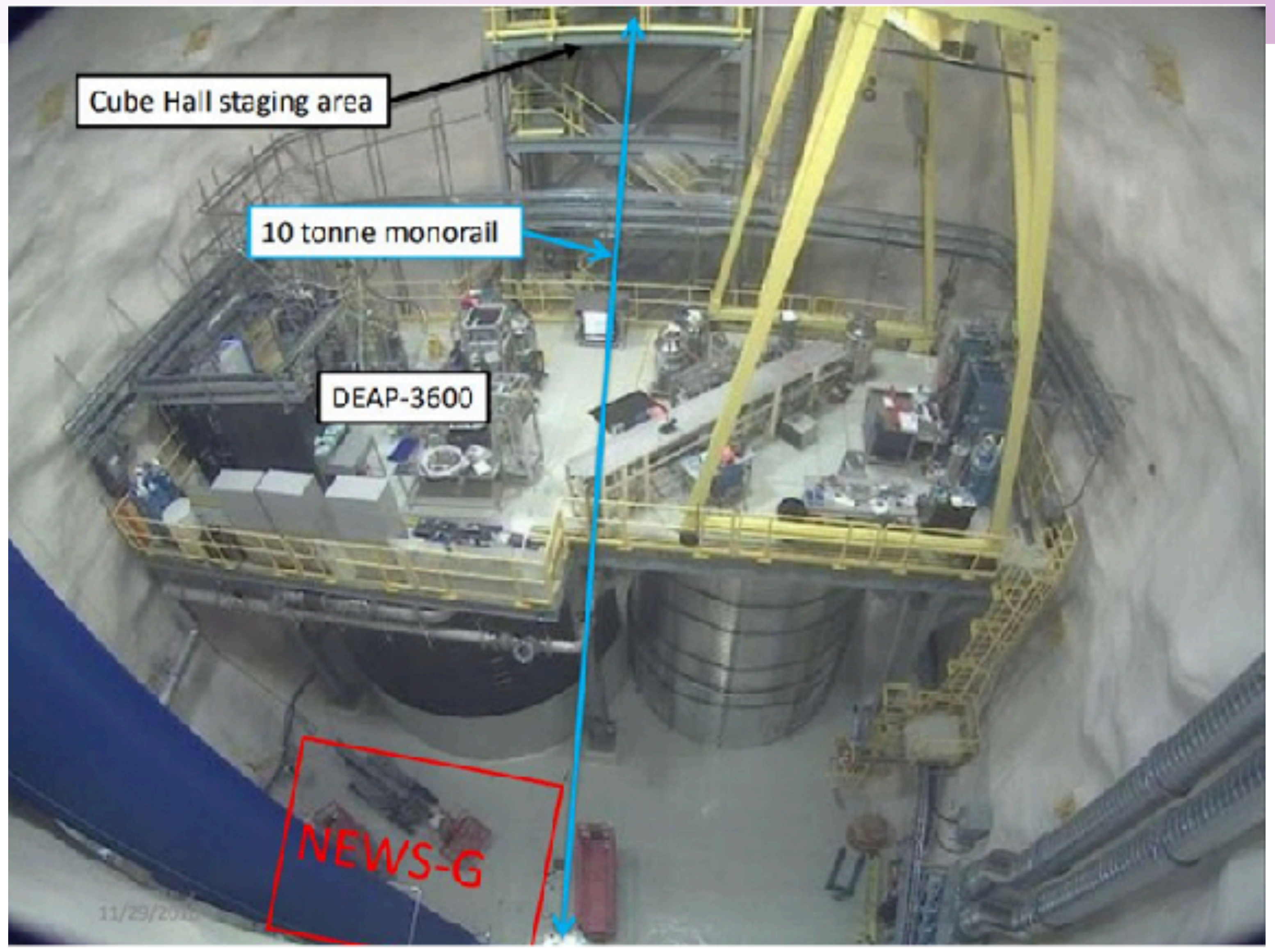
LNGS

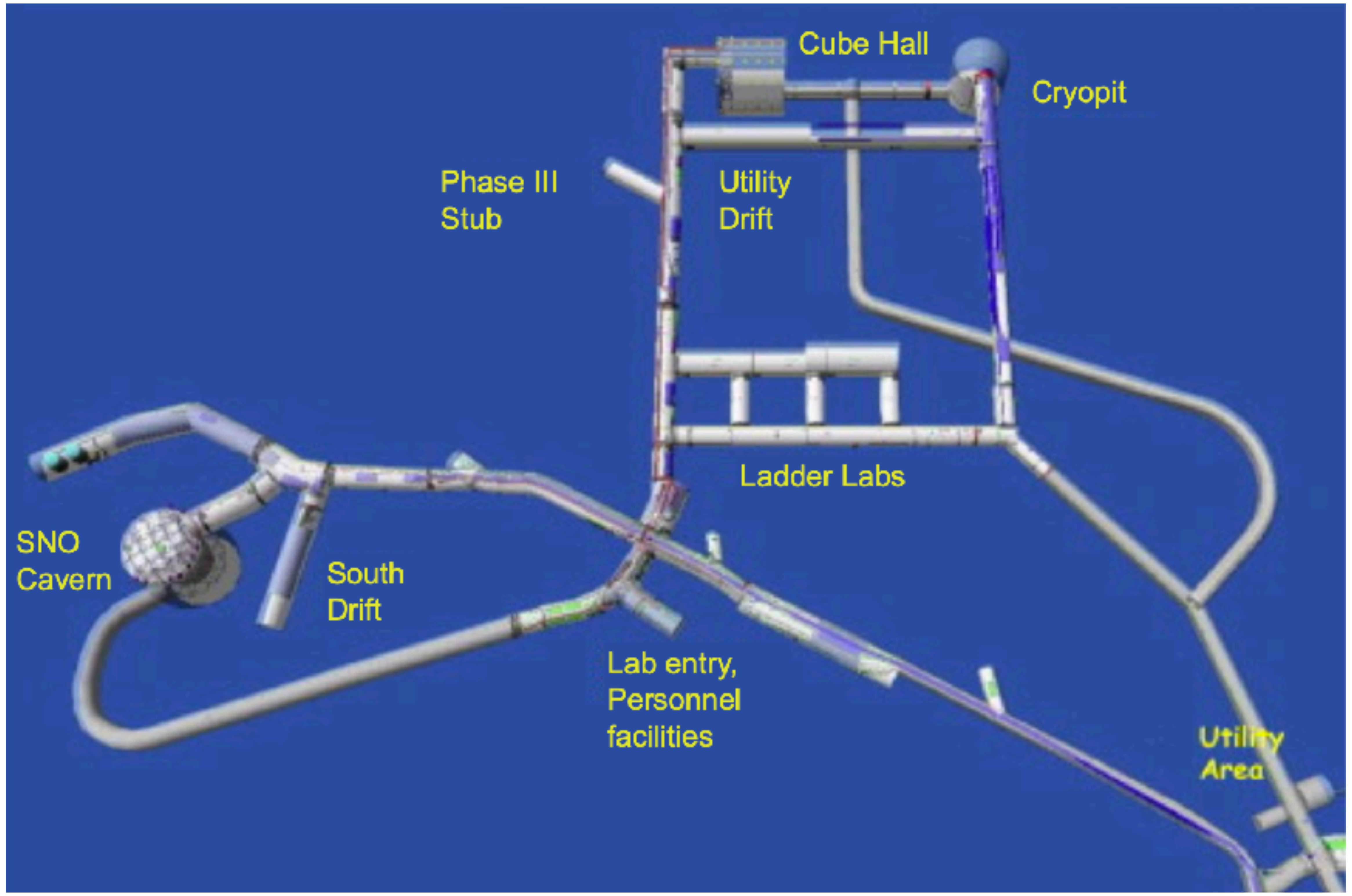




- Space available in Hall C in former CTF location in 2025
- Lab off highway tunnel under mountain
- Easy vehicular horizontal access
- 2 hour drive from Rome
- Safety concerns limit use of liquid scintillator -> Gd-doped water
- LOI submitted by DARWIN collaboration

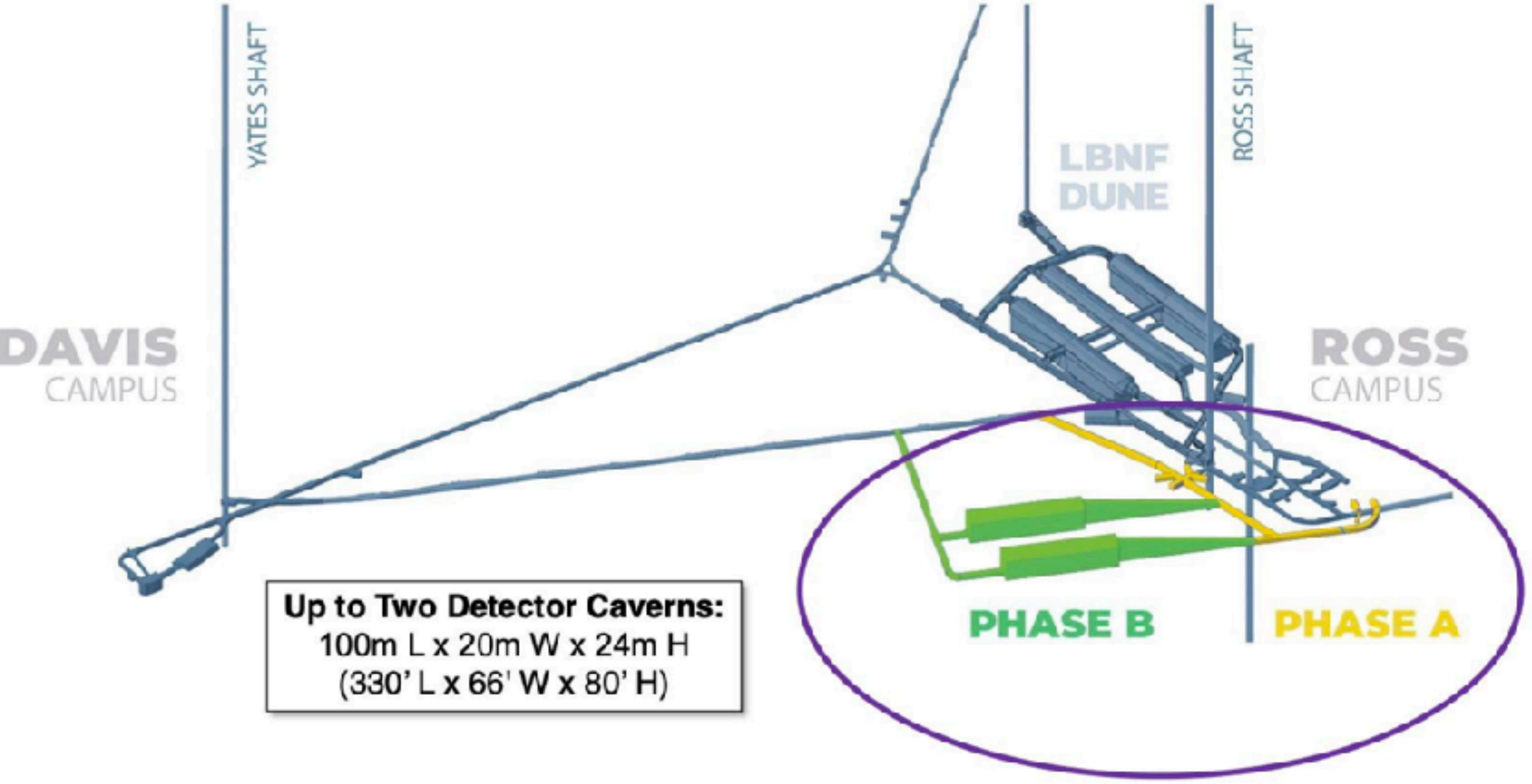
SNOLAB





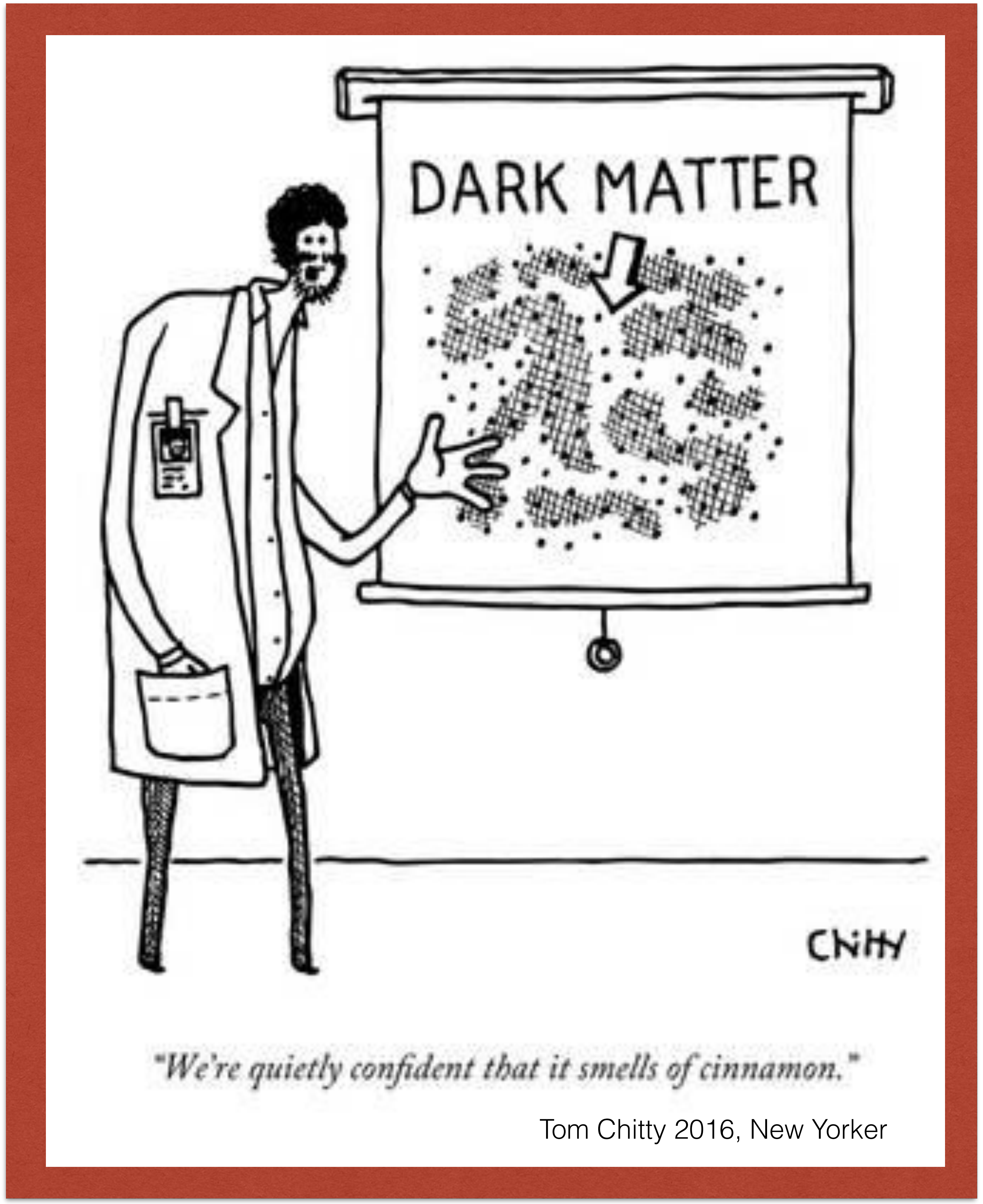
- Cube Hall possibly available in 2027
- Active nickel mine
- Vertical access, and constrained horizontal drift space too
- 45 minutes from Sudbury airport, 5 hours from Toronto
- Deepest site considered

SURF



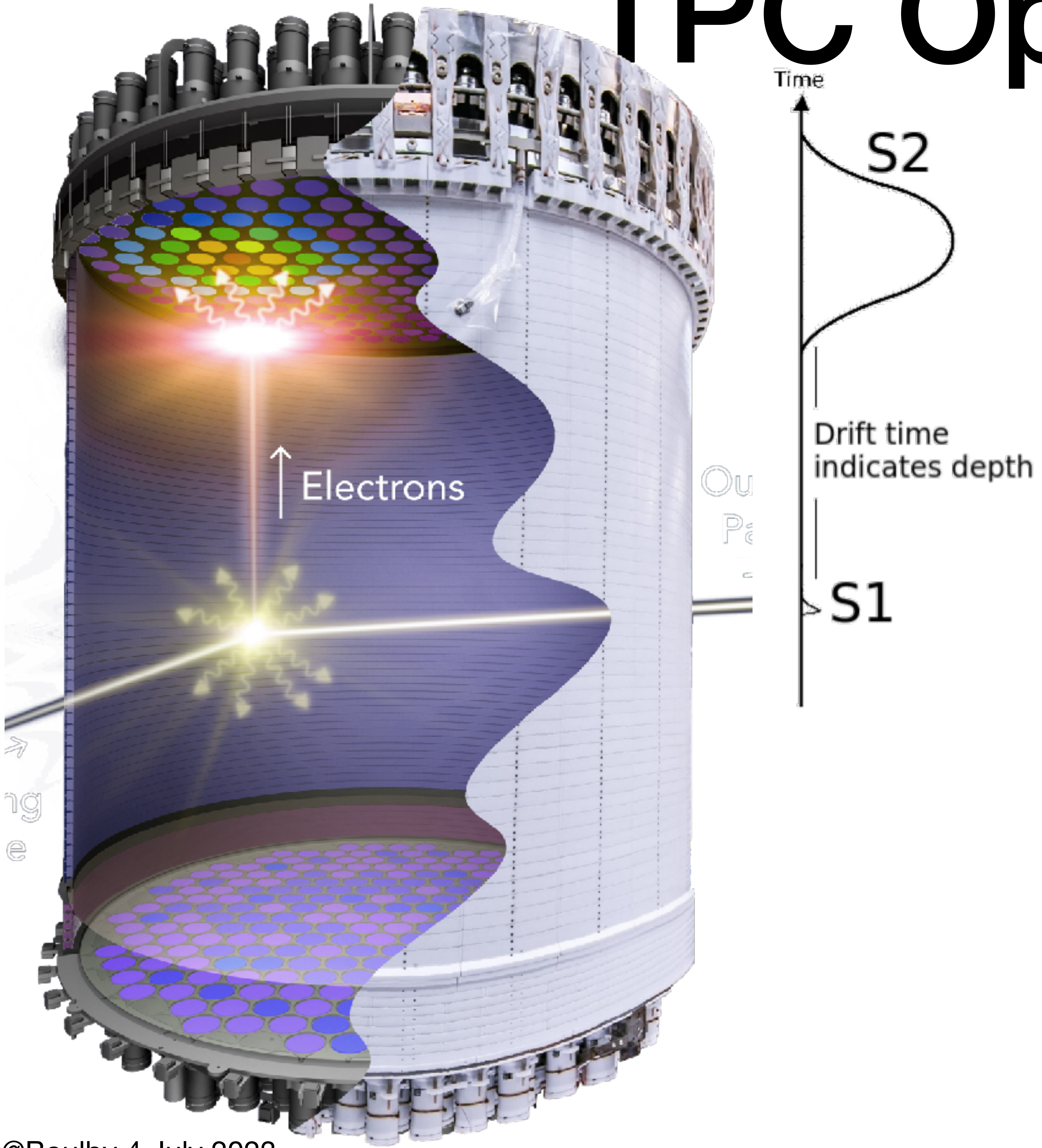
- Hosting requires expansion
  - Excavation following DUNE installation, starting in 2027
  - Planned experiment UG installation starting in 2030
- Repurposed gold mine
- Vertical access shaft, same as DUNE
- 1 hour from Rapid City, SD

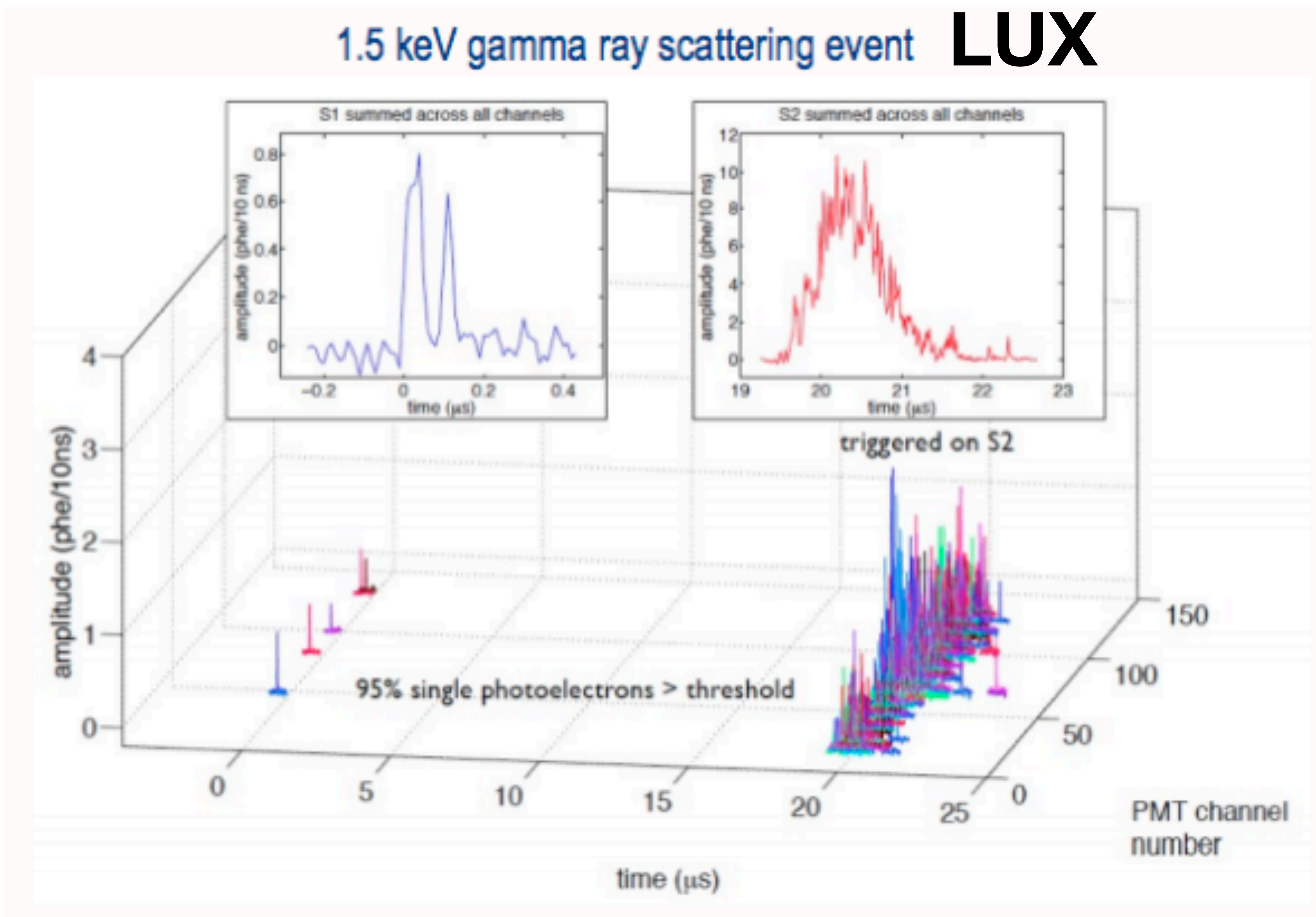
Backup Slides



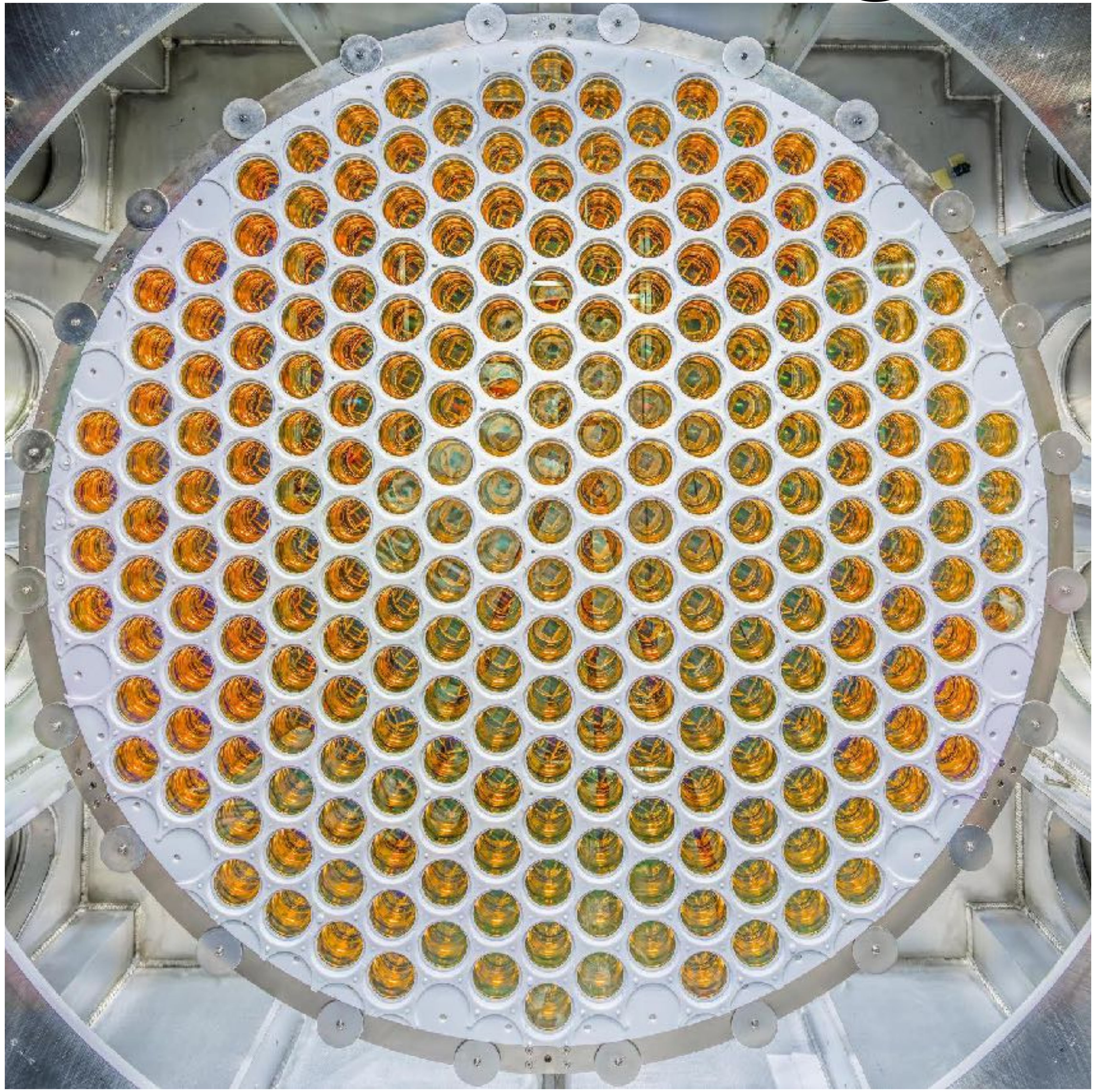
Tom Chitty 2016, New Yorker

TPC Operations

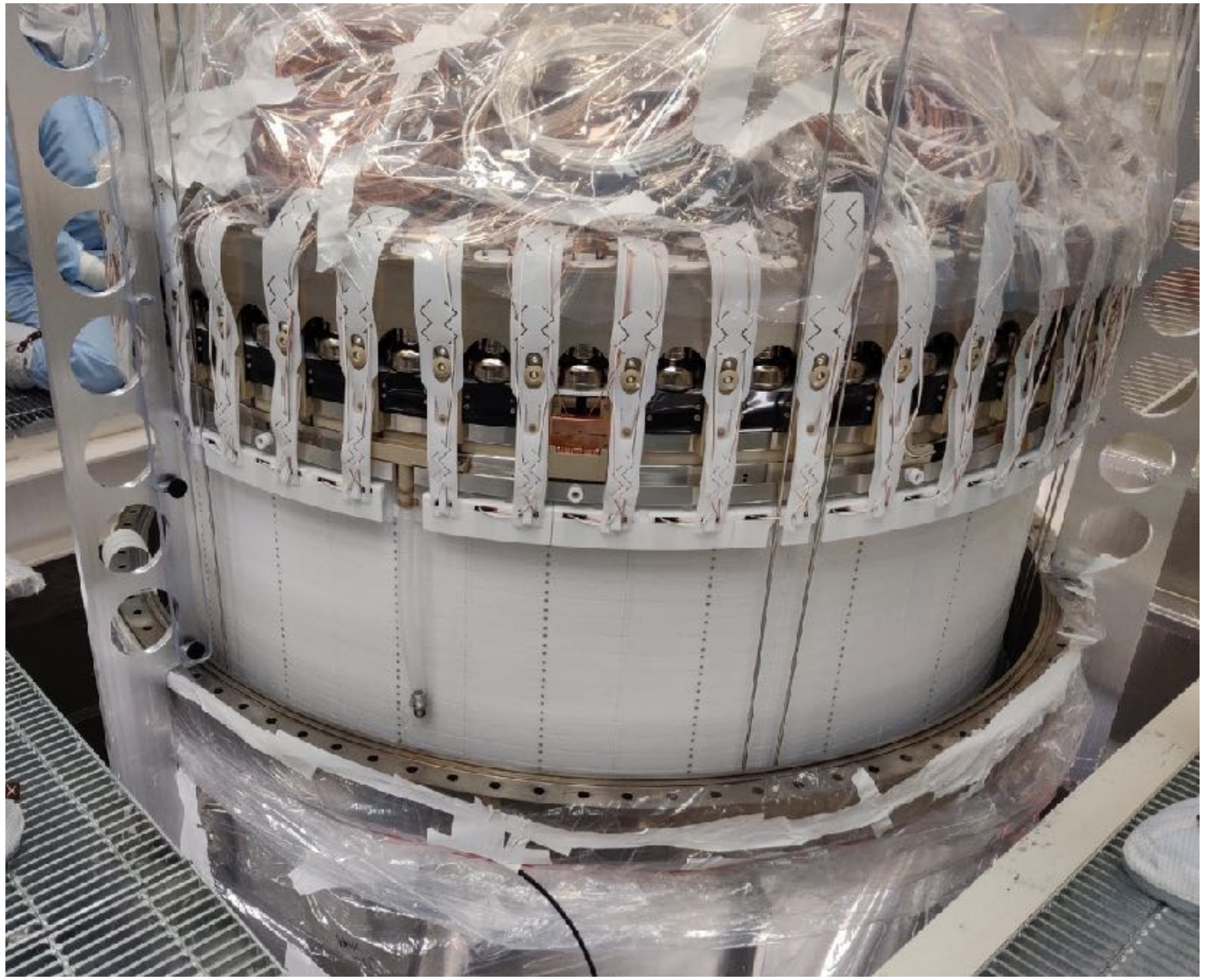




PMT Arrays and Cabling

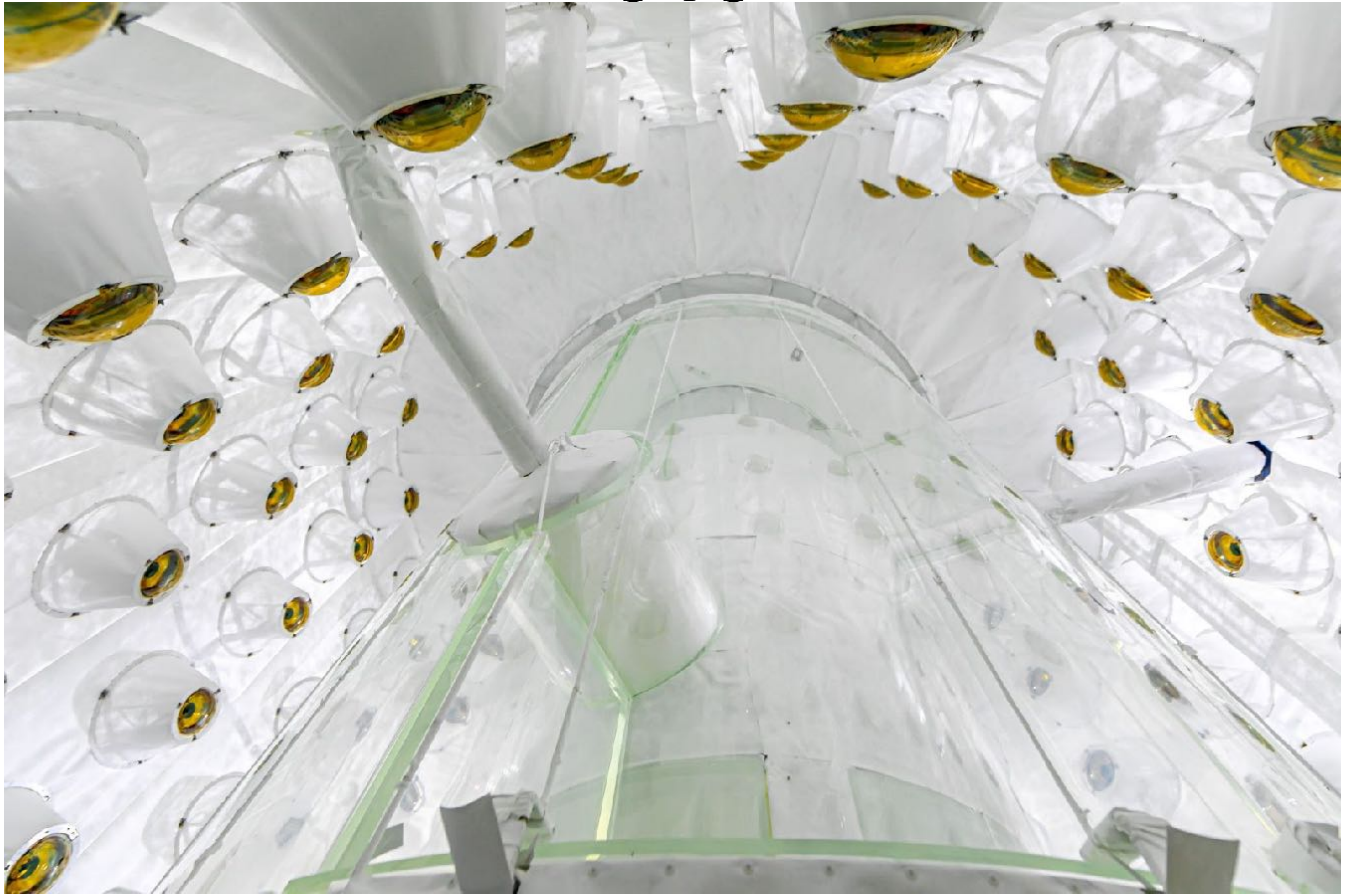


Grids, Skin

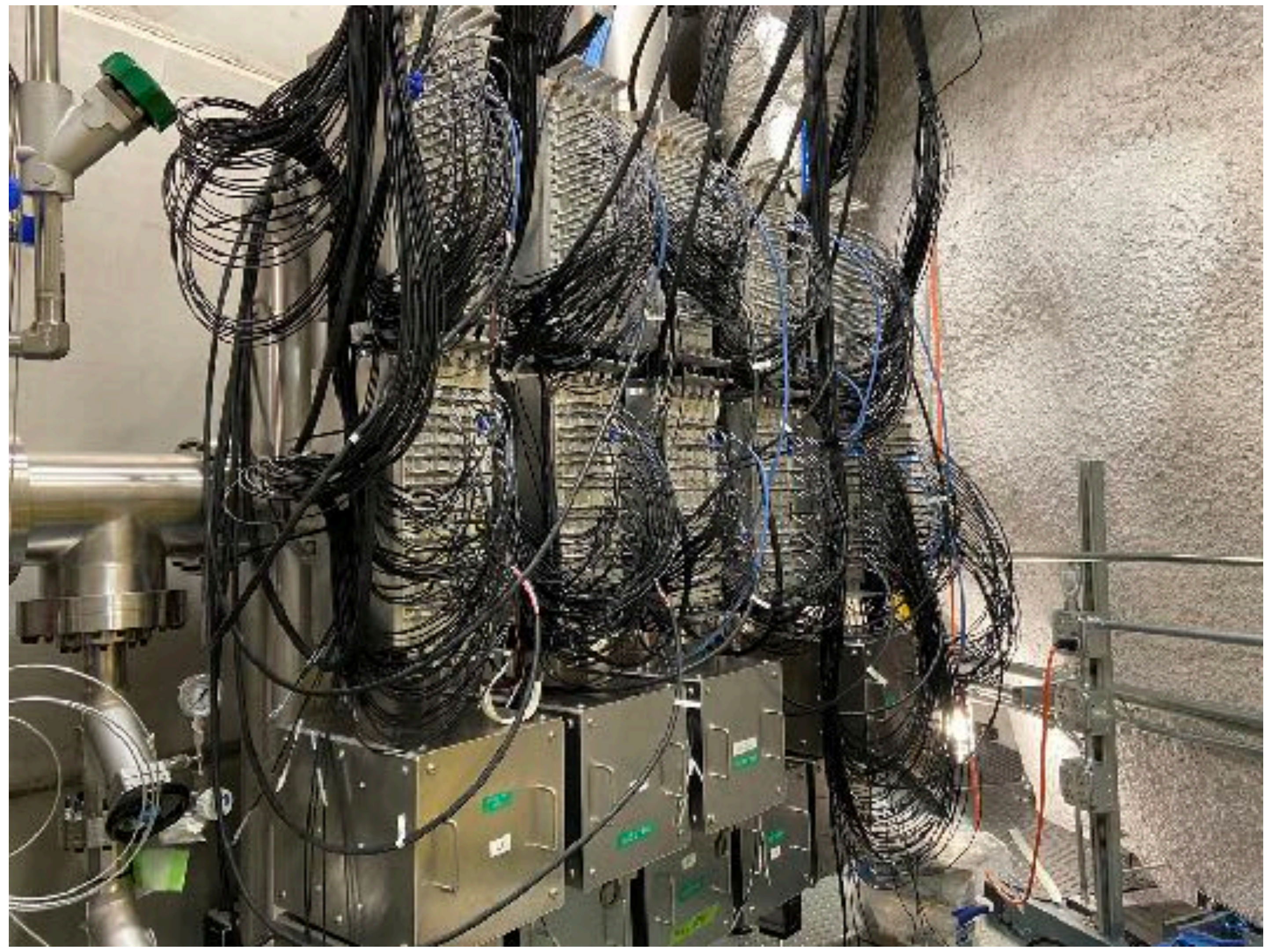


Cathode HV in Water Tank

Veto

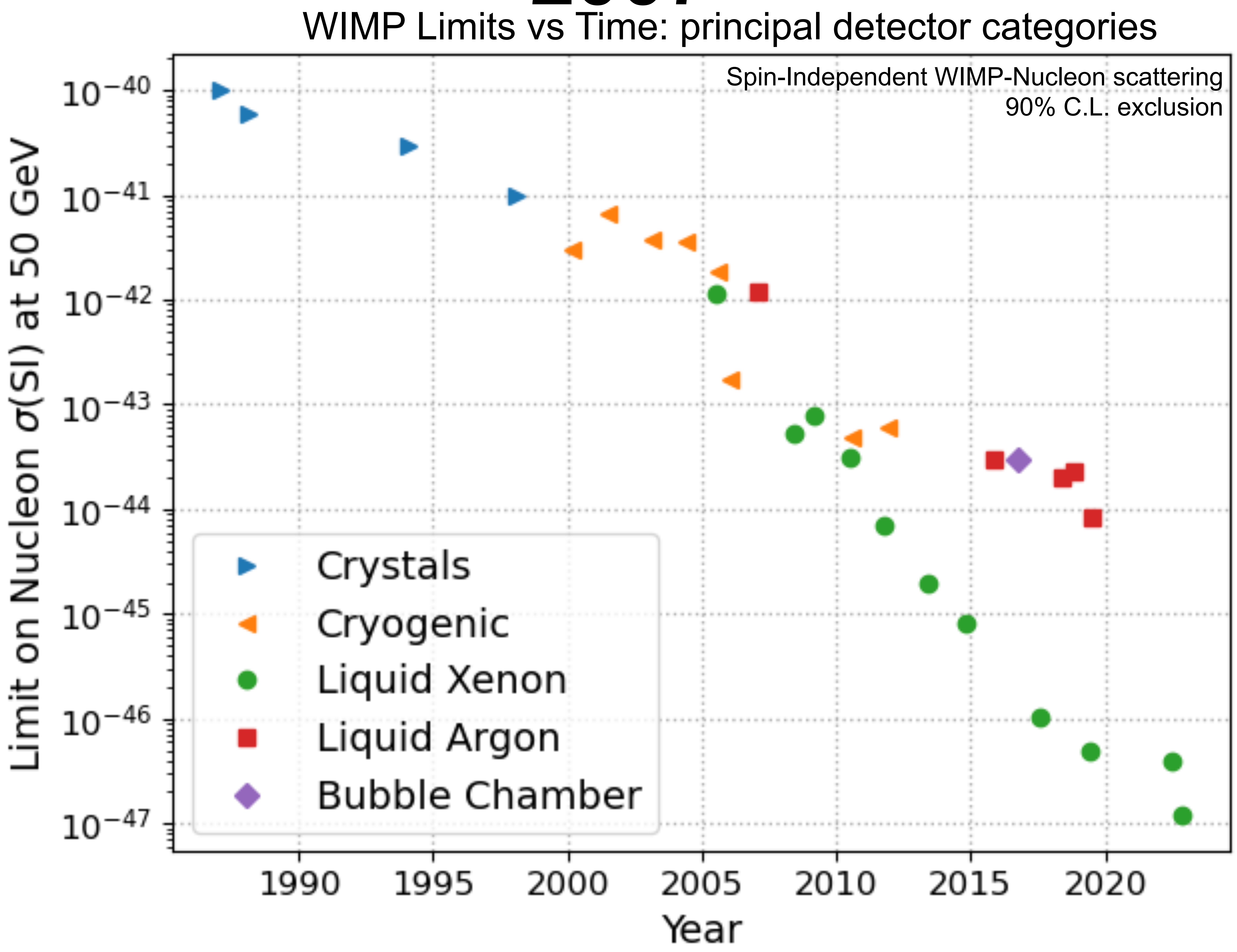


Electronics



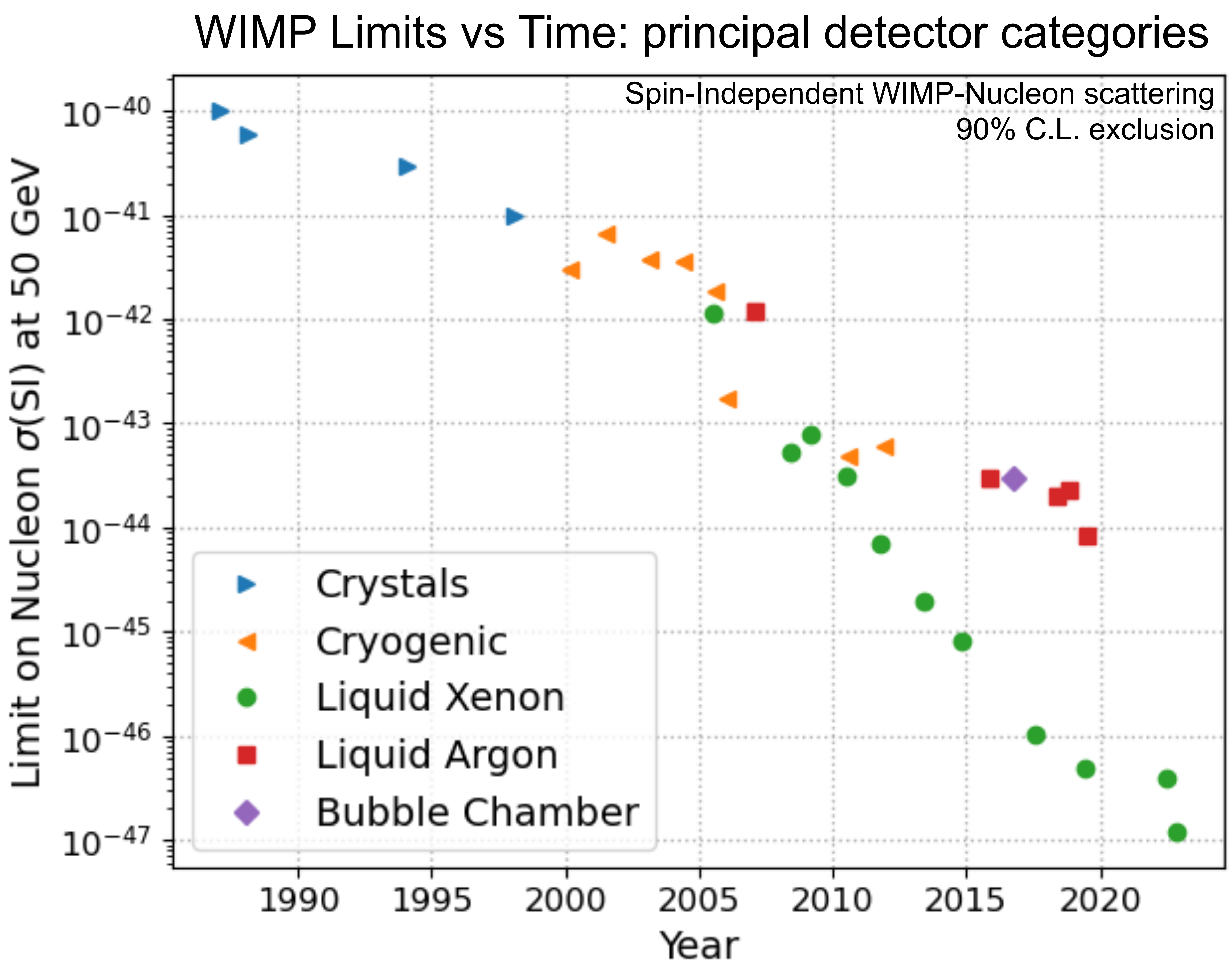
Xe Circulation

Liquid Noble Technology: World leading since 2007

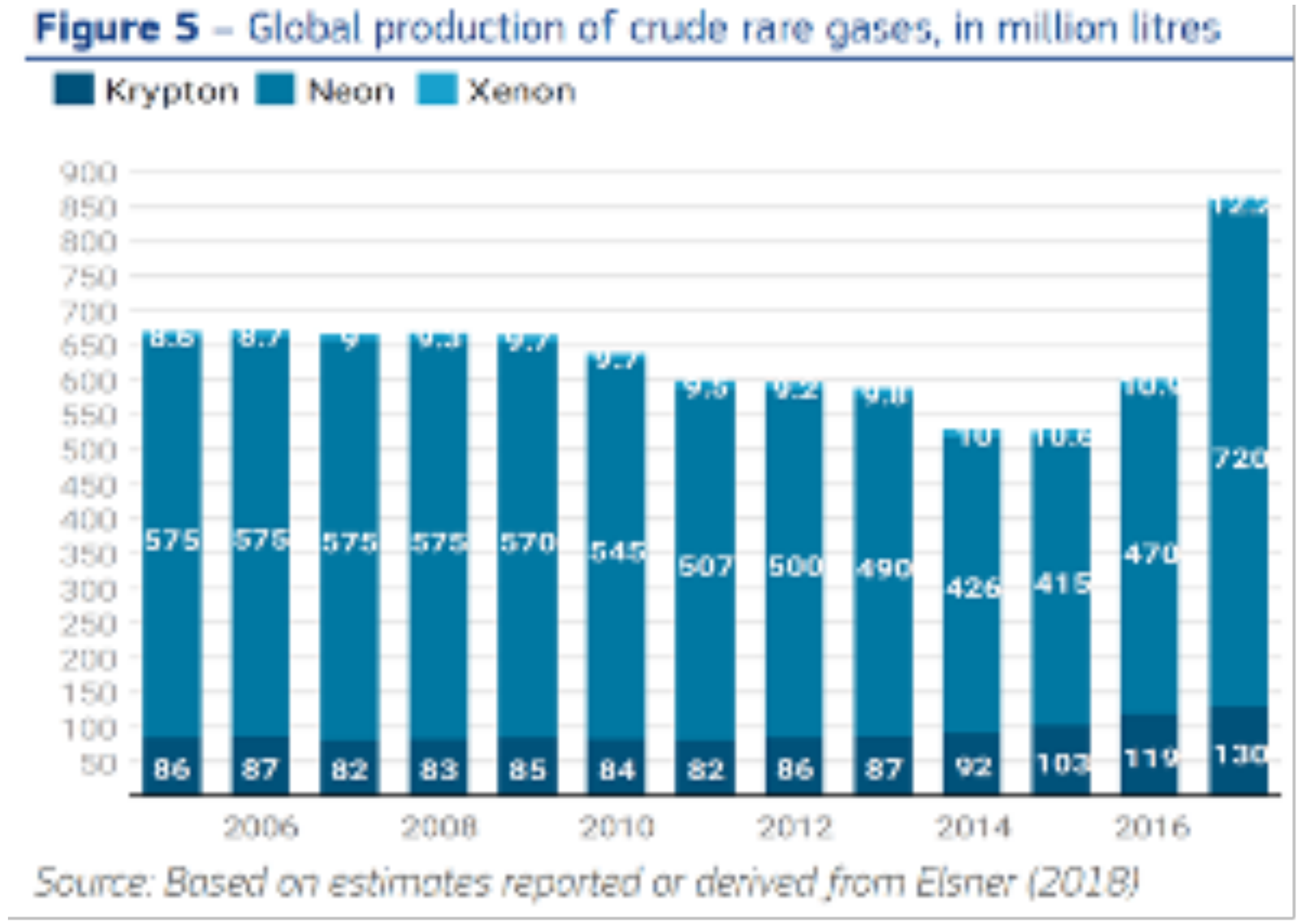


Liquid Noble Technology: World leading since 2007

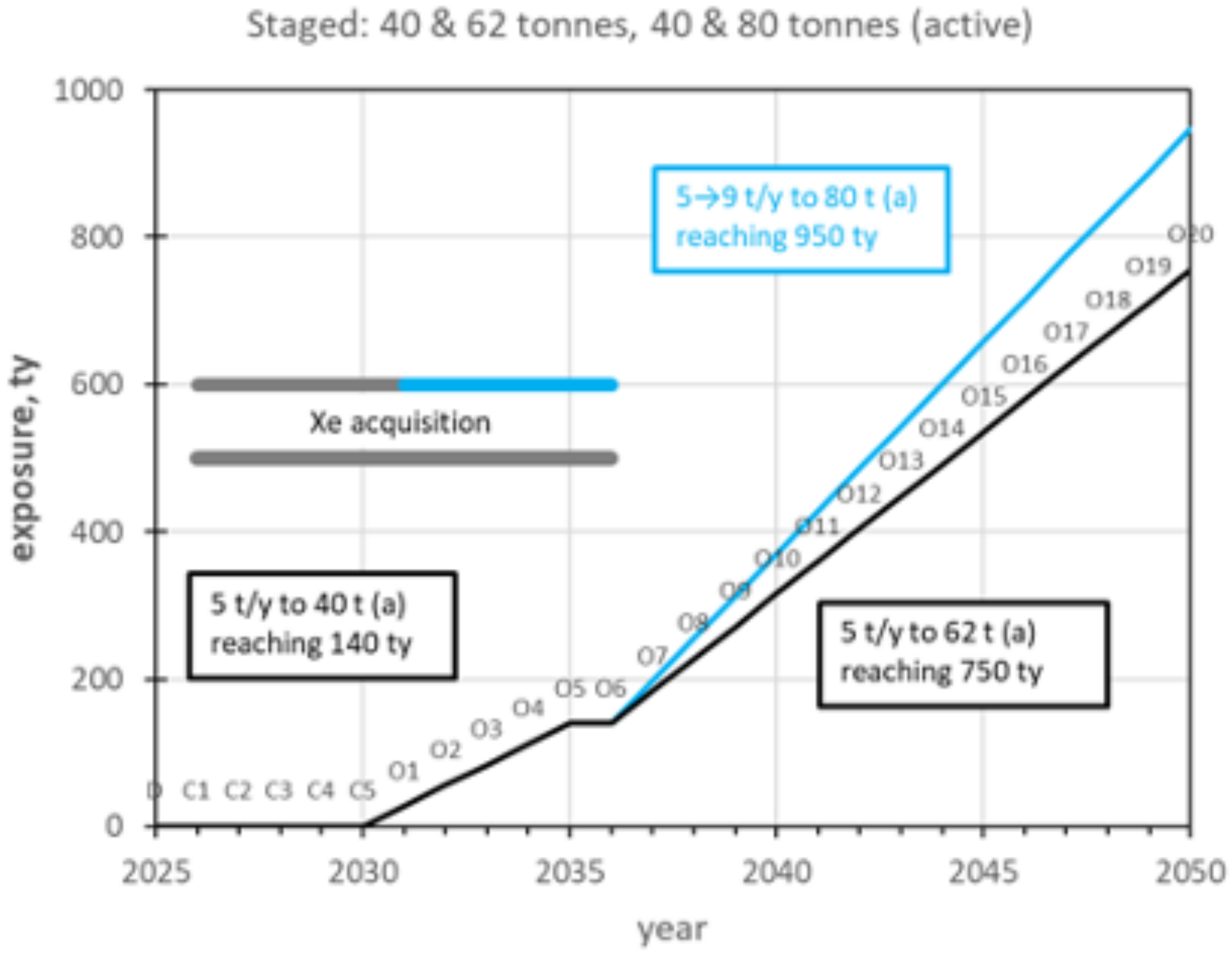
- Tool of choice for massive detectors
  - Liquid targets can scale "easily" (⬆ mass)
  - Readily purified (⬇ backgrounds)
- Architectures explored → 2-Phase TPCs
  - ER/NR discrimination
  - Low energy threshold
  - 3D position - self-shielding, singles/multiples
- LXe world leading, 10-tonne scale
  - High density, large A^2, many isotopes (SI, SD, NR-ETF, inelastic)
- LAr alternative
  - Confirmation in case of DM discovery
  - DM couplings/properties



Acquisition and exposure



Rare Gases (Krypton, Neon, Xenon): Impact assessment for supply security (2022 EU report link)



It’s all in the Xenon

- XLZD needs
  - 20+ t in LZ+XnT – acquire additional 55-75 t: ~1 year of world’s production (12.2 ML/y = 68 t/year)
  - Planning steady **coordinated acquisition through long-term contracts spread over a decade**
- Xenon market
  - Shocked by recent events (Ukraine+Russia ~20-30% of world’s supply), but price starting to recover
  - Main users: electronics, space, dark matter, medical
  - Main suppliers: Linde, Air Liquide; Messer, Air Products, China
    - Some capacity (new ASUs) being added in Europe and China
    - Markets for Kr & Ne (co-produced with Xe) driving new investment
- Contacts with suppliers are (always) ongoing
  - Procured 21 t for LZ + XnT concurrently w/o disturbing market
  - Suppliers suggest 5 t/year is achievable with sufficient planning
  - Consultants concur that prices are likely to regress to the mean
    - Sensible approach given historical prices

NB: Xe is a commodity which historically has retained its value

Laboratory details

Table 1: Underground laboratories: present experimental areas.

Laboratory		Overburden m	Overburden m w.e.	Muons $/m^2/d$	Volume m^3	Access	Mining	Operator	Refs.
LSC (Canfranc)	SP	850	2,450	371	10,000	H	N	U. Zaragoza	[1]
Kamioka	JP	1,000	2,700	105	150,000	H	N	ICRR/U. Tokyo	[2]
BUL (Boulby)	UK	1,100	2,850	32.3	7,200	V	Y	STFC	[3]
LNGS (Gran Sasso)	IT	1,400	3,800	29.7	180,000	H	N	INFN	[4]
LSM (Modane)	FR	1,700	4,850	4.7	3,500	H	N	CNRS/CEA	[5]
SURF (Sanford Lab)	USA	1,490	4,200	4.6	7,160	V	N	SDSTA	[6]
SNOLAB	CA	2,070	5,890	<0.29	30,000	V	Y	SNOLAB Institute	[7]
CJPL (Jinping)	CN	2,400	6,720	0.30	300,000	H	N	U. Tsinghua	[8]

SNOWMASS Underground Facilities report

Another perspective on UG labs

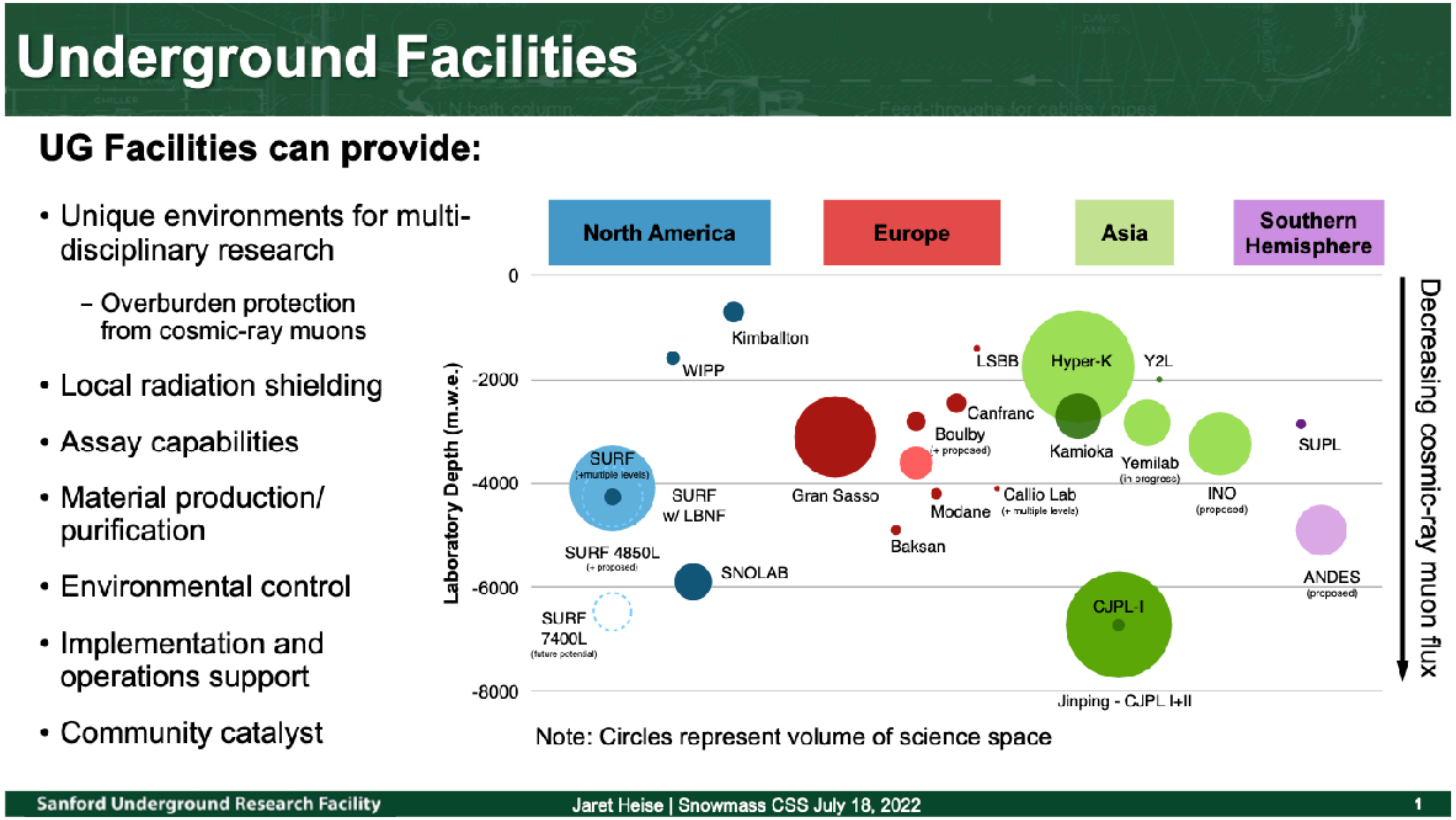


Figure 1: Overview of underground facilities located around the world, showing various key characteristics in depth and underground laboratory capacity. Slide from Jaret Heise (SURF).

SNOWMASS Underground Facilities report