

2021-09-29

North America-Europe workshop on Double Beta Decay: North American Underground Laboratories

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Scope of talk

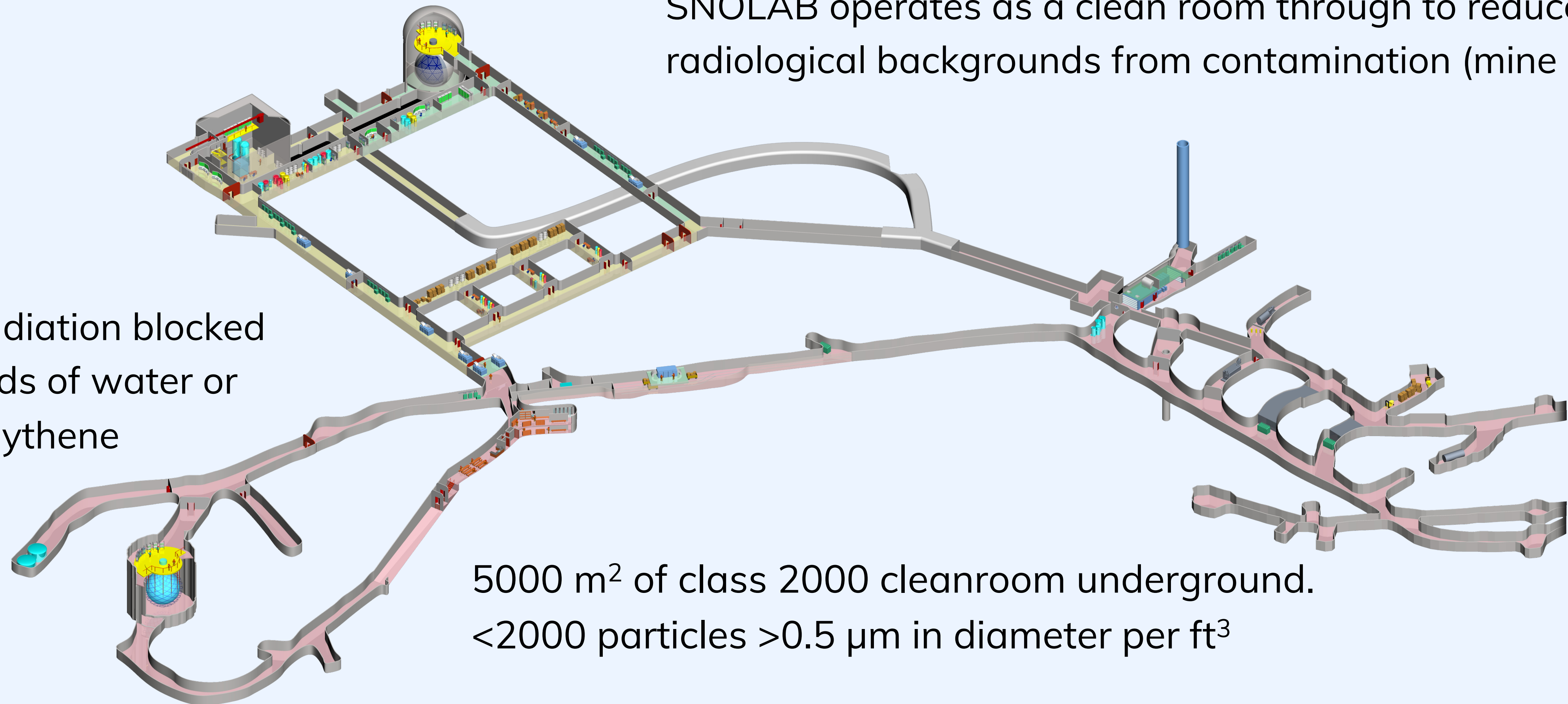
- Review of facilities with potential to host second generation $0\nu\beta\beta$ projects
 - Assuming depth requirement $\sim 2\text{km}$
 - SNOLAB, Northern Ontario, Canada
 - SURF, South Dakota, USA
- Overview of facilities
- Potential infrastructure to host $0\nu\beta\beta$ projects
- Final comments r.e. coordination

SNOLAB Capabilities

SNOLAB layout

SNOLAB operates as a clean room through to reduce radiological backgrounds from contamination (mine dust)

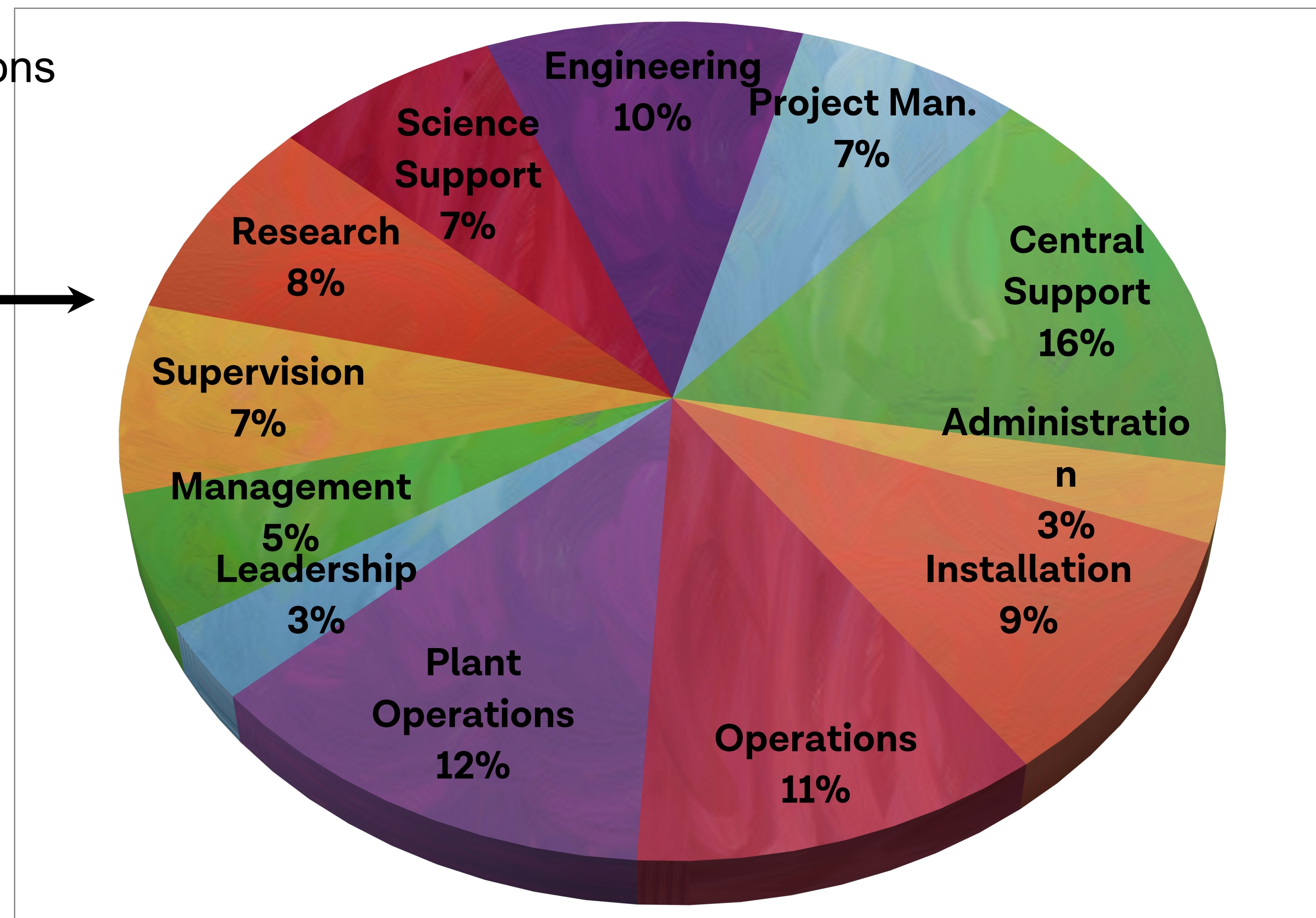
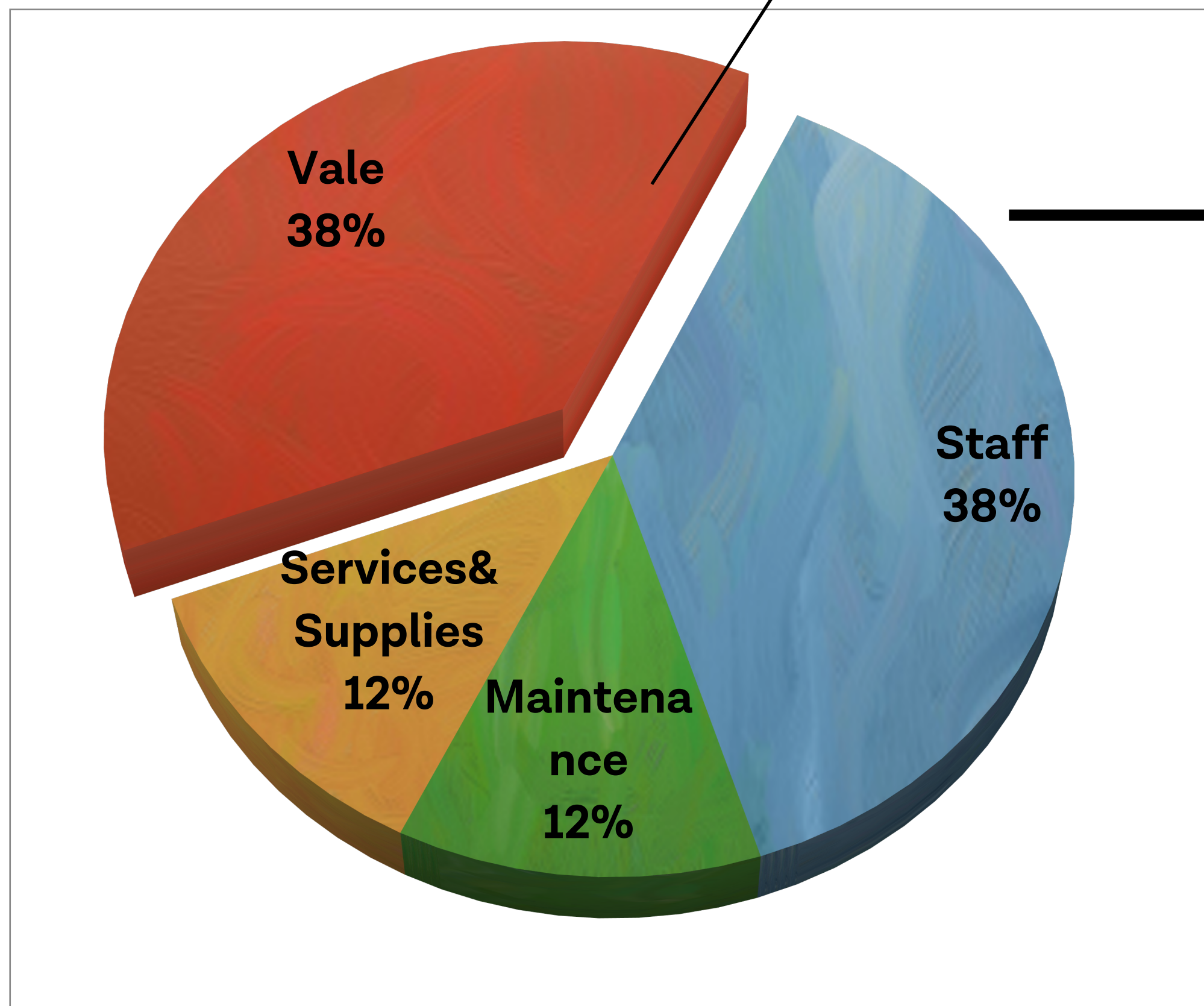
Local radiation blocked by shields of water or lead polythene



5000 m² of class 2000 cleanroom underground.
<2000 particles >0.5 μm in diameter per ft³

SNOLAB by the numbers (\$20M/yr)

Vale is in-kind shaft operations



2021: 137 staff



The SNOLAB network

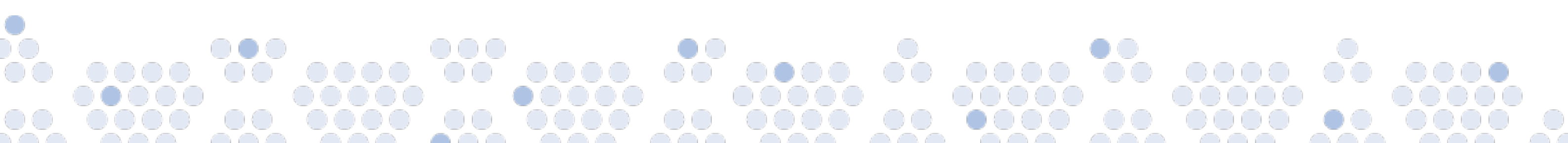
SNOLAB serves a growing community of scientists, researchers, students, and collaborators from across Canada and around the world.

129 institutions

21 countries

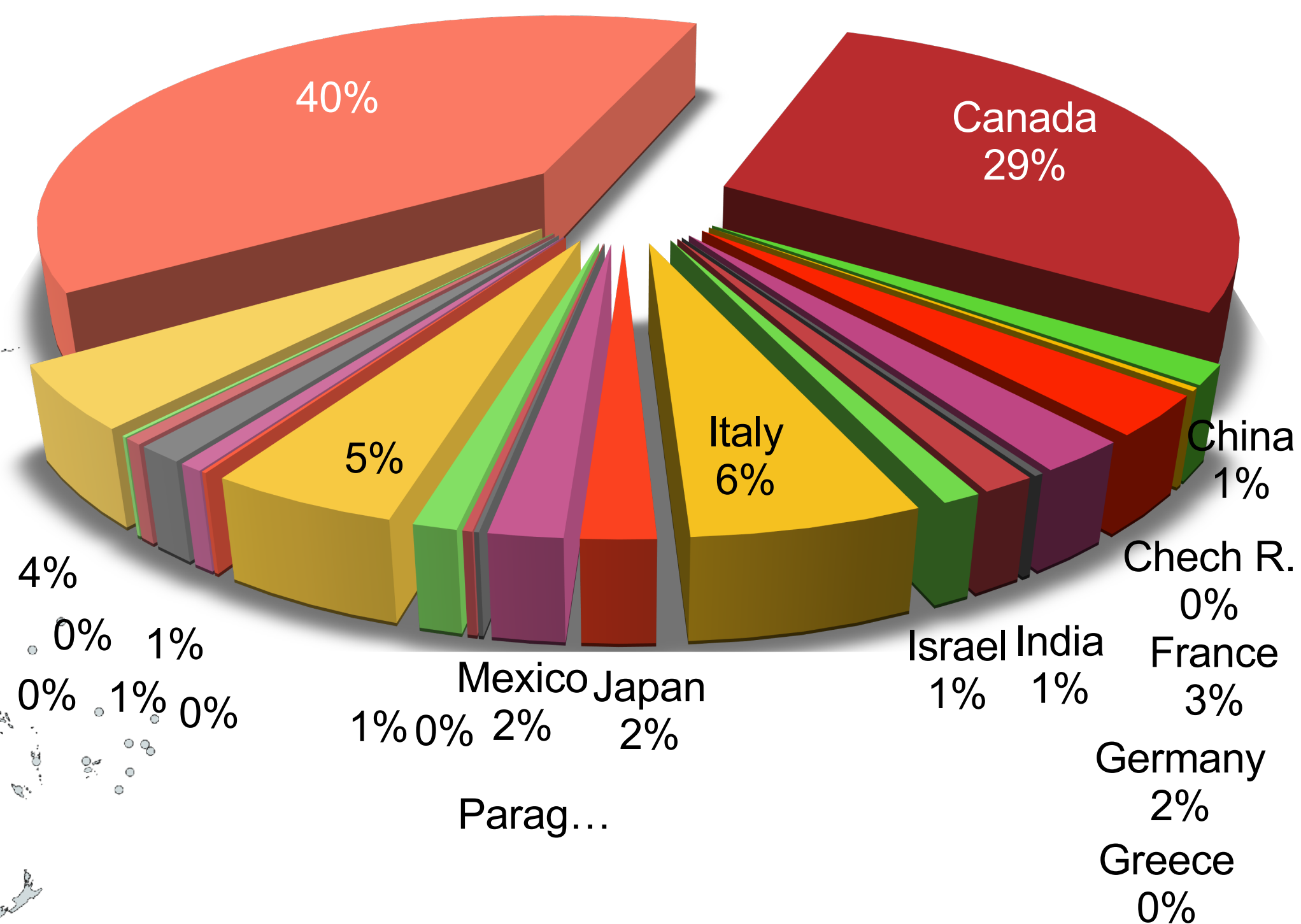
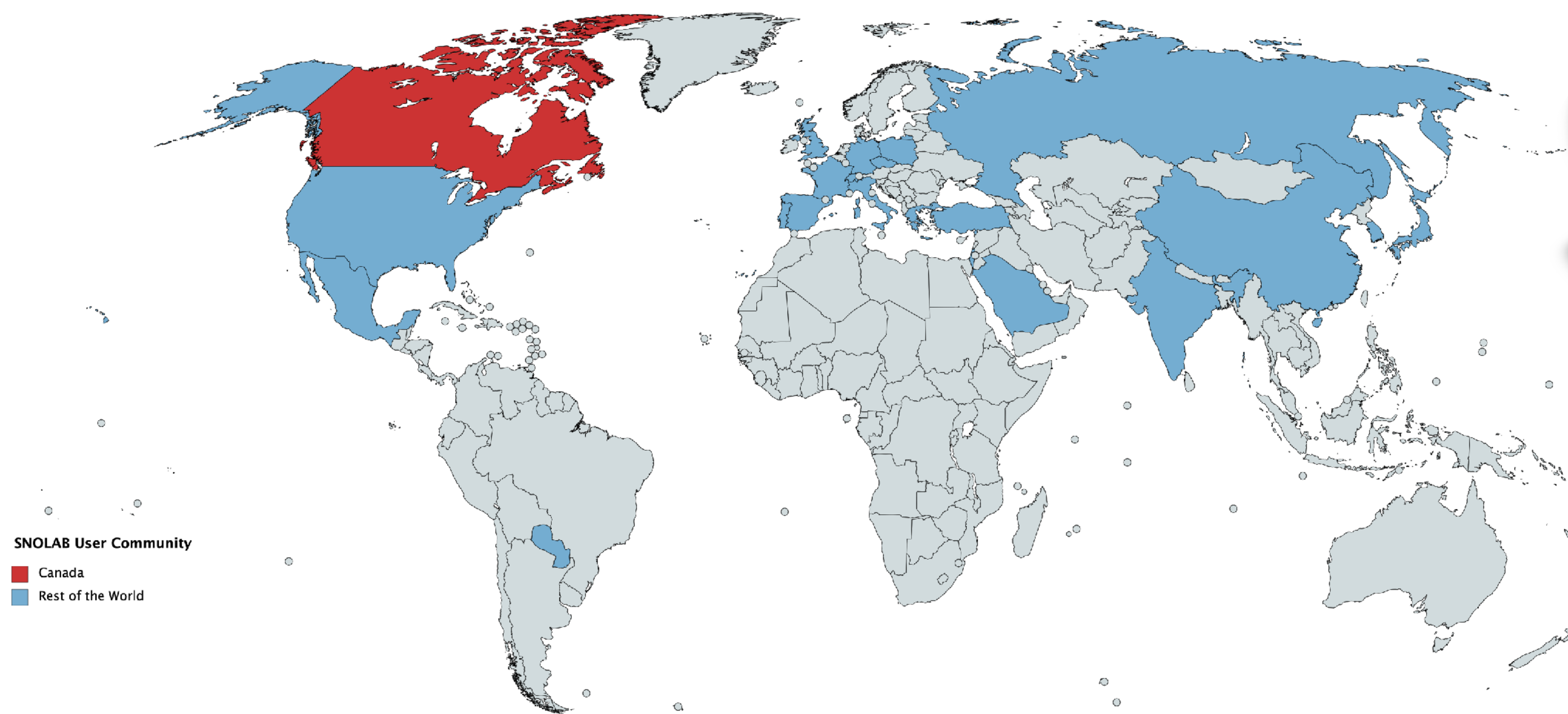
137 full time employees

863 Users

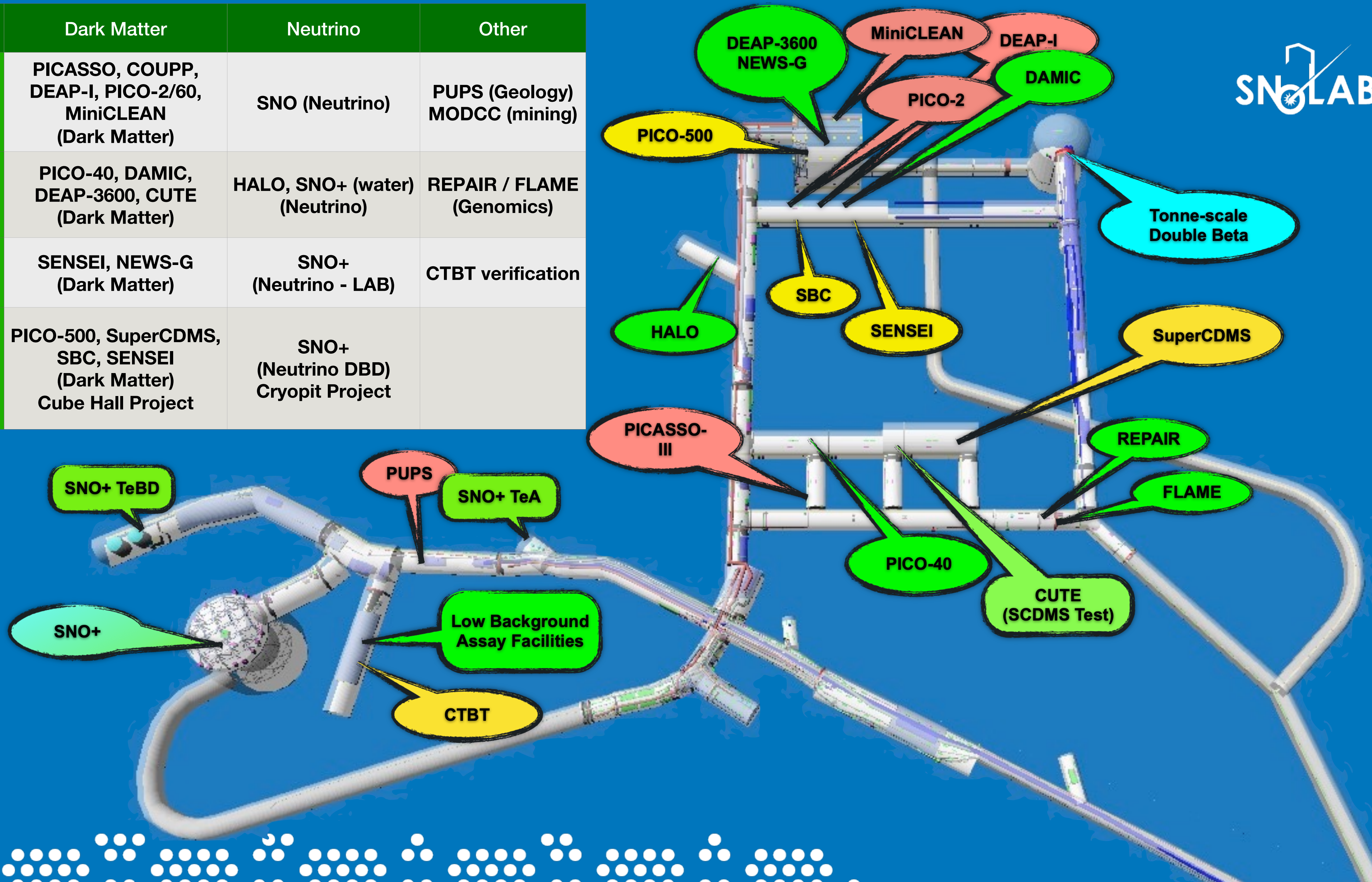


SNOLAB Science stakeholders

- Supported community has grown to >850 users from 129 institutes across 21 countries



	Dark Matter	Neutrino	Other
Completed	PICASSO, COUPP, DEAP-I, PICO-2/60, MiniCLEAN (Dark Matter)	SNO (Neutrino)	PUPS (Geology) MODCC (mining)
Current	PICO-40, DAMIC, DEAP-3600, CUTE (Dark Matter)	HALO, SNO+ (water) (Neutrino)	REPAIR / FLAME (Genomics)
2021 Start	SENSEI, NEWS-G (Dark Matter)	SNO+ (Neutrino - LAB)	CTBT verification
2021	PICO-500, SuperCDMS, SBC, SENSEI (Dark Matter) Cube Hall Project	SNO+ (Neutrino DBD) Cryopit Project	

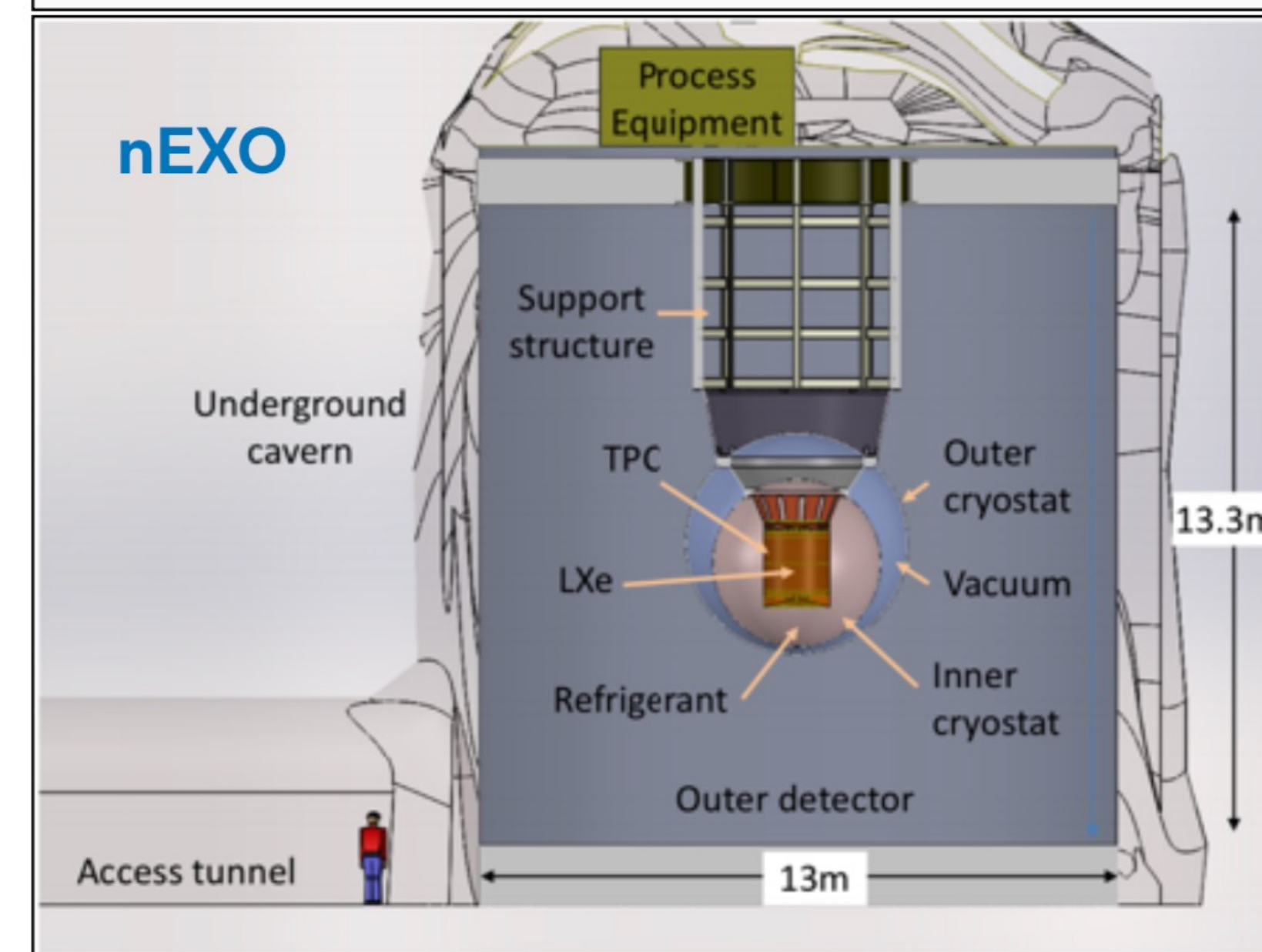
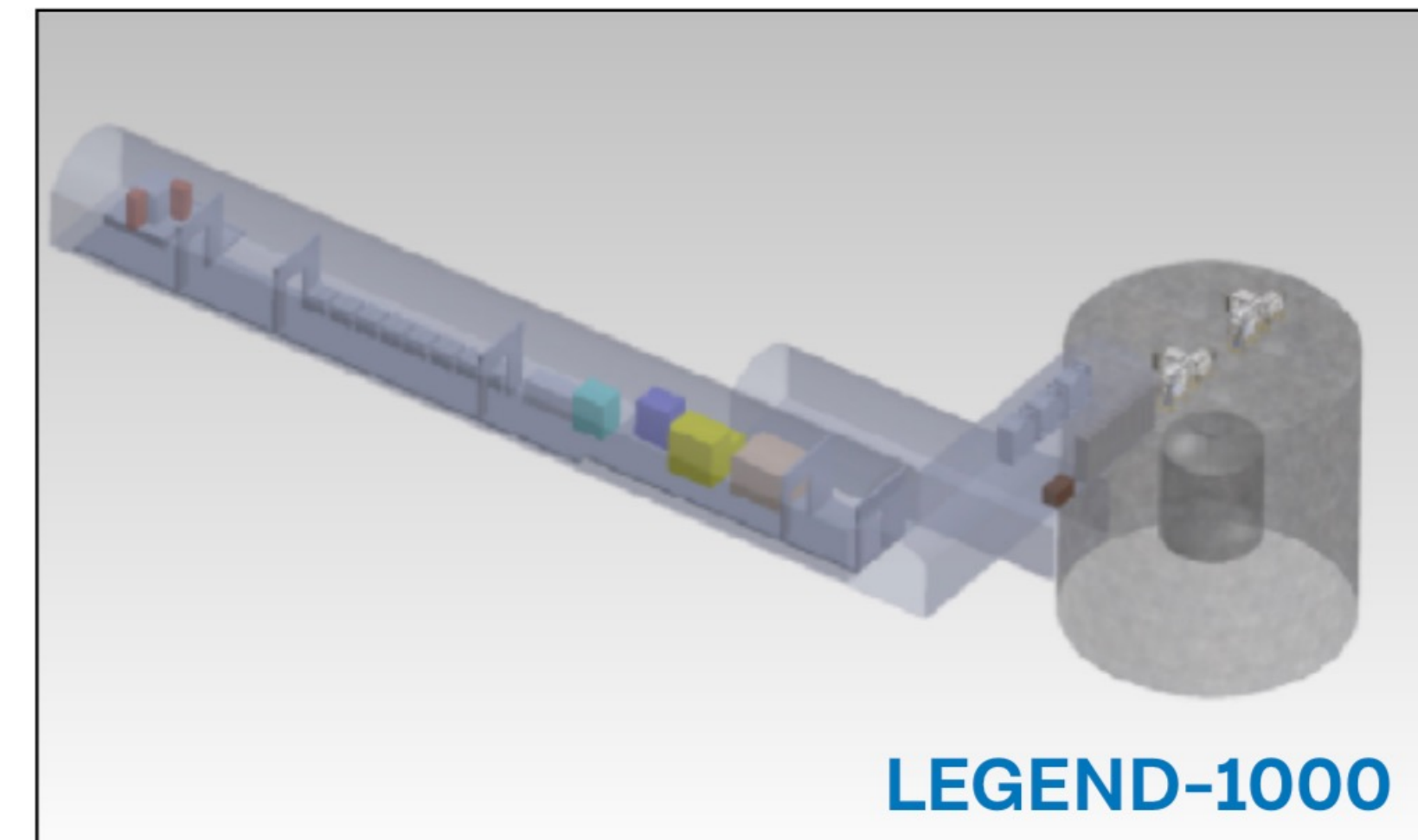


Future strategy overview

- Focus on maximising science return from investment made in SNOLAB and community, following community strategy discussions (ACP, LRP, P5/NSAC, SNOLAB)
 - Next SNOLAB strategic plan in development during 2021 (FY24-FY29 to align with MSI programme)
 - Future Projects workshop in May
- Combination of major projects (\$400M), smaller scale facilities (PICO-500/SuperCDMS), capabilities
- Medium term focus is double-beta decay with second gen project in Cryopit
- Longer term focus is G3 dark matter project (eg ARGO liquid argon 300 tonne, DARWIN liquid xenon)
 - ARGO collaboration has specified SNOLAB as target location
- Maintain some opportunity for smaller scale development and diversification of science
- Maintain and develop capabilities, especially where overlap/connectivity
 - Cryogenics and liquid noble management
 - Low background production, construction, assay, cleaning, etc.

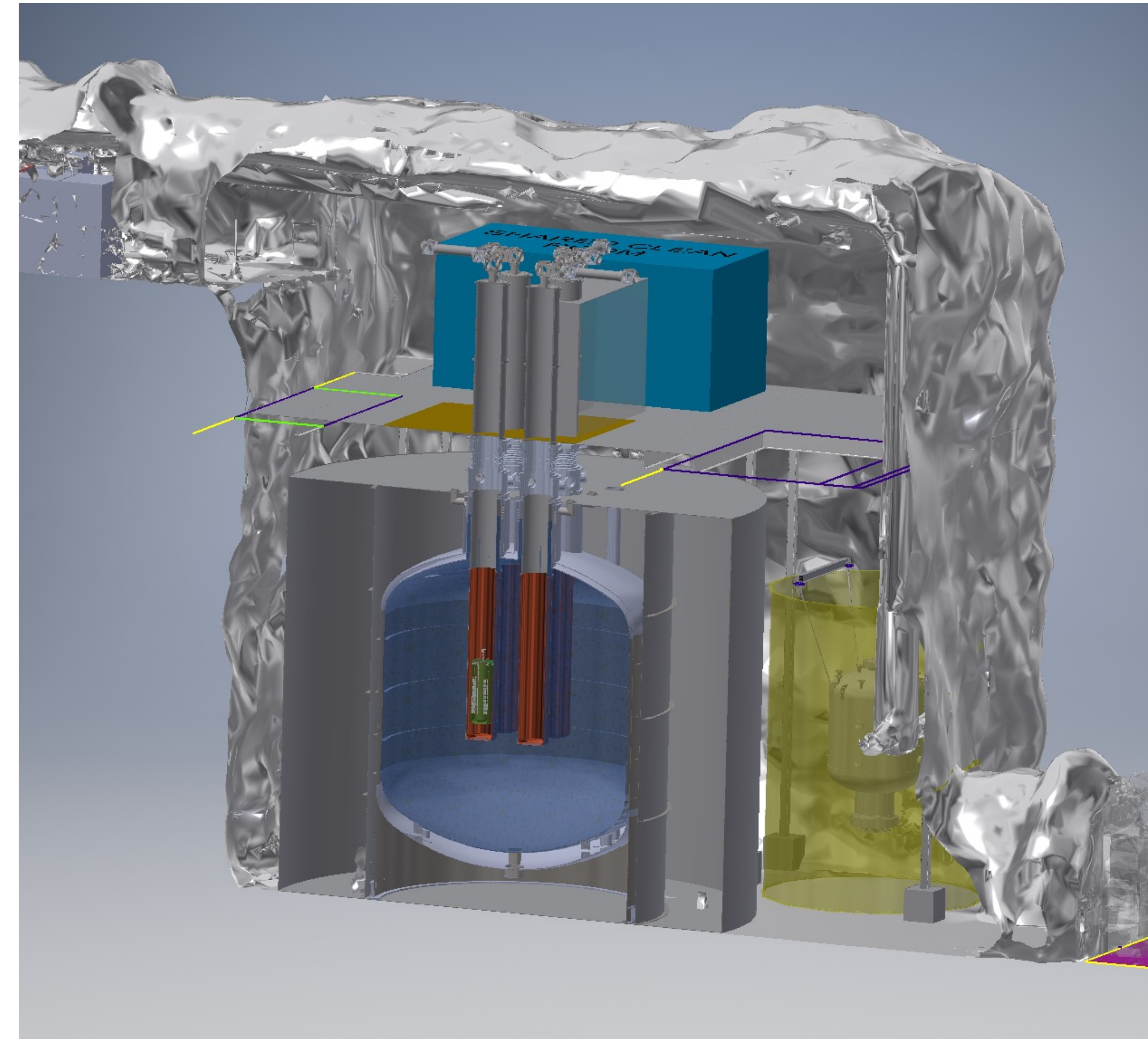
G2 $0\nu\beta\beta$ programme

- US Second generation $0\nu\beta\beta$ programme has CD-0 from December 2108
 - DOE Portfolio review conducted summer 2021
- Both nEXO and LEGEND-1000 have determined that locating at the deeper SNOLAB site would significantly increase the science reach and discovery potential due to the lower cosmic ray backgrounds.
- Both projects have developed their concept designs and proposals with SNOLAB as the baseline preferred location.
- SNOLAB has been working with both projects on ability to host in the Cryopit, and capabilities to support the selected project.
- **This will become our highest priority science project at that point, given near term world-leading potential**
- Following consultation, SNOLAB has undertaken an evaluation of potential to host both tonne-scale projects at SNOLAB

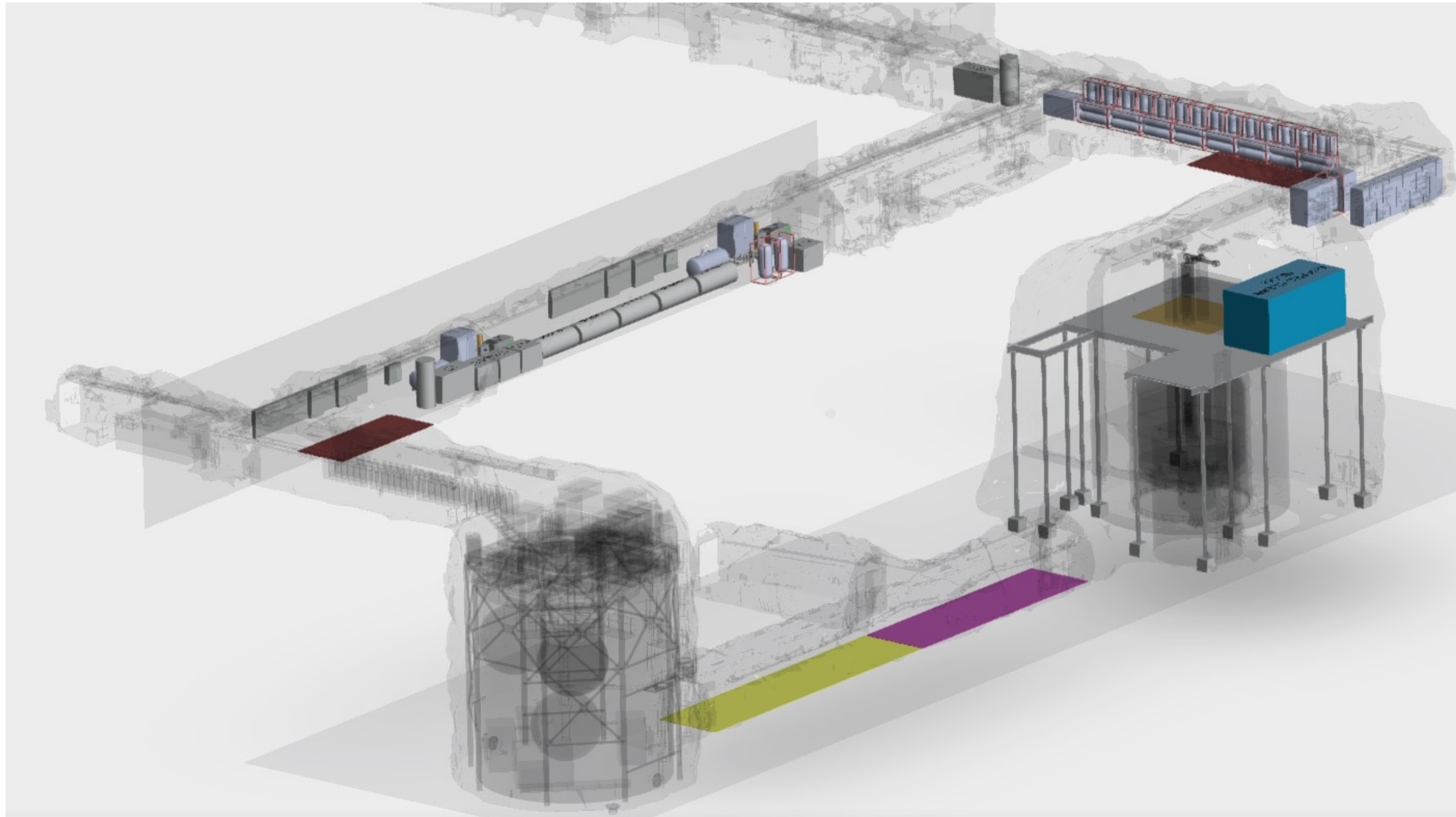


Feasibility of hosting two projects

- Due to the size and shape of the Cube Hall there is space for LEGEND-1000 or nEXO to be built and operated while sharing hall with another experiment (e.g. PICO-500).
- The allocation of which space (Cryopit or Cube Hall) to which project (nEXO or LEGEND-1000) would depend on detailed analysis of the requirements and construction schedules in consultation with the two projects.
- A large platform covering the full hall would provide space for equipment and assembly over top of the shielding tank(s). This platform can be a simple seismically stable structure making use of the existing hitch plates in the hall back.
- All the ancillary equipment and infrastructure for both experiments can be accommodated in the associated neighbouring drifts (BAD, J-Drift, TAD, MHAD), which is helped by the synergies of common plants.



Feasibility of hosting two projects



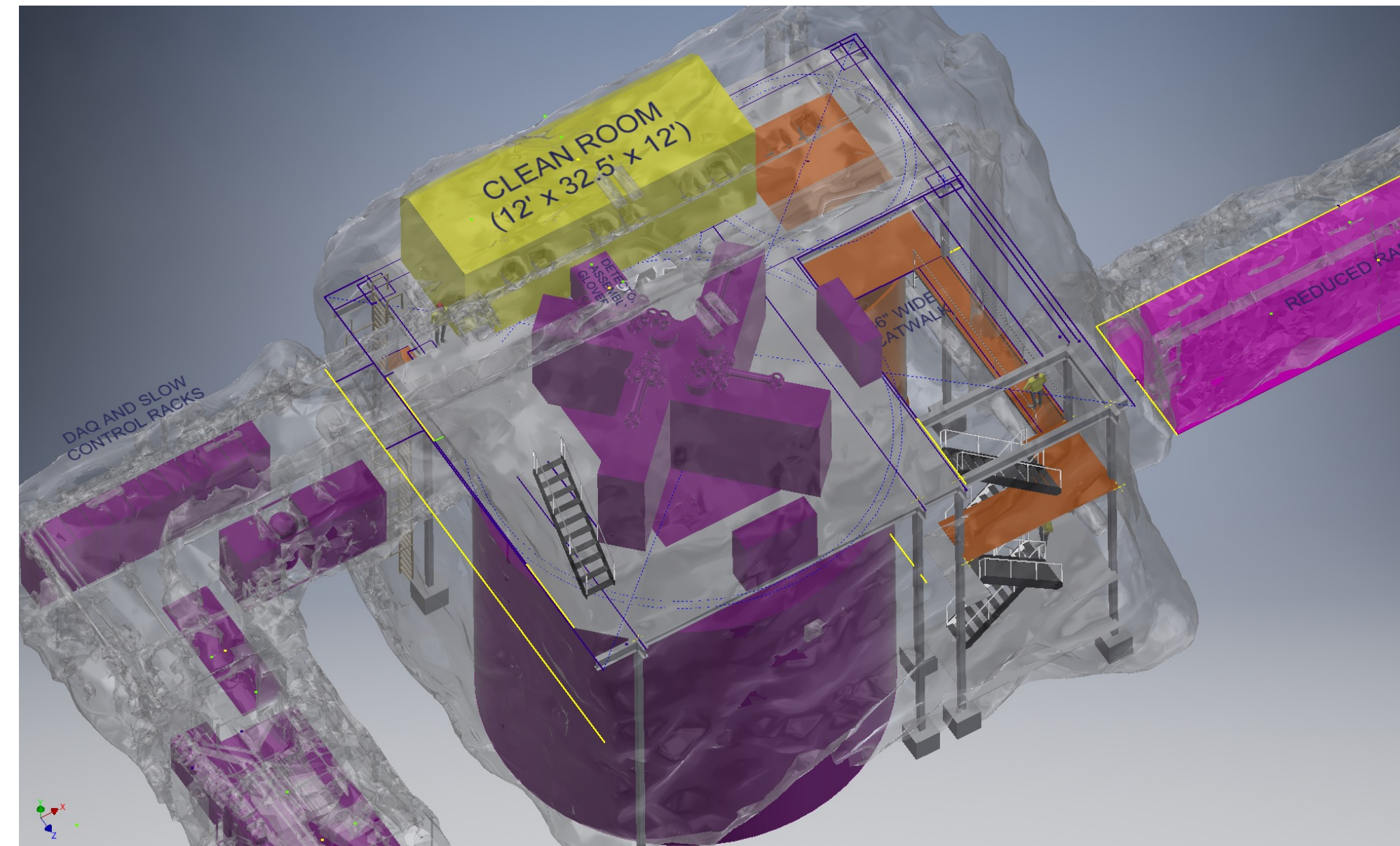
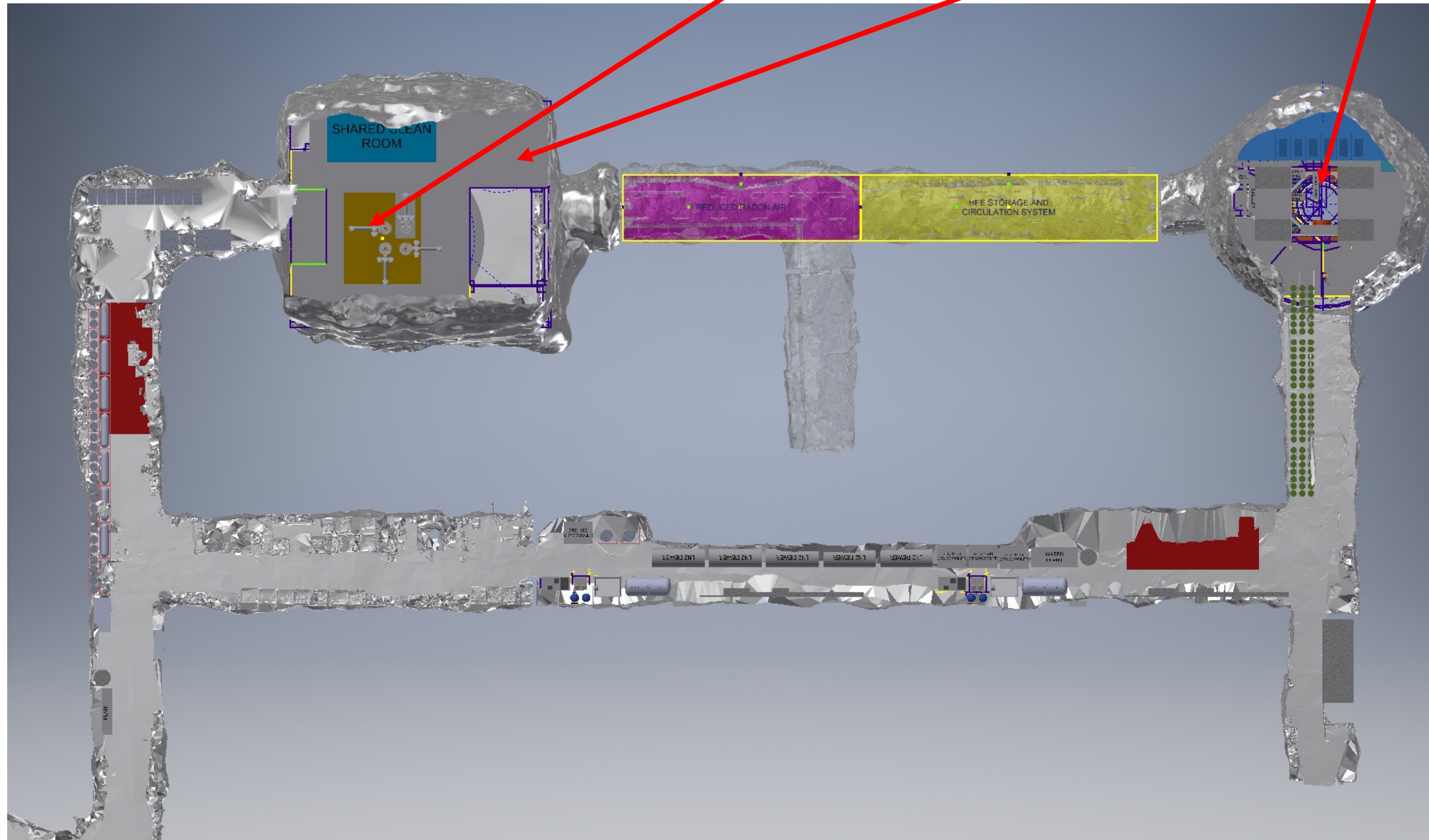
Feasibility of hosting two projects



LEGEND-1000
or nEXO

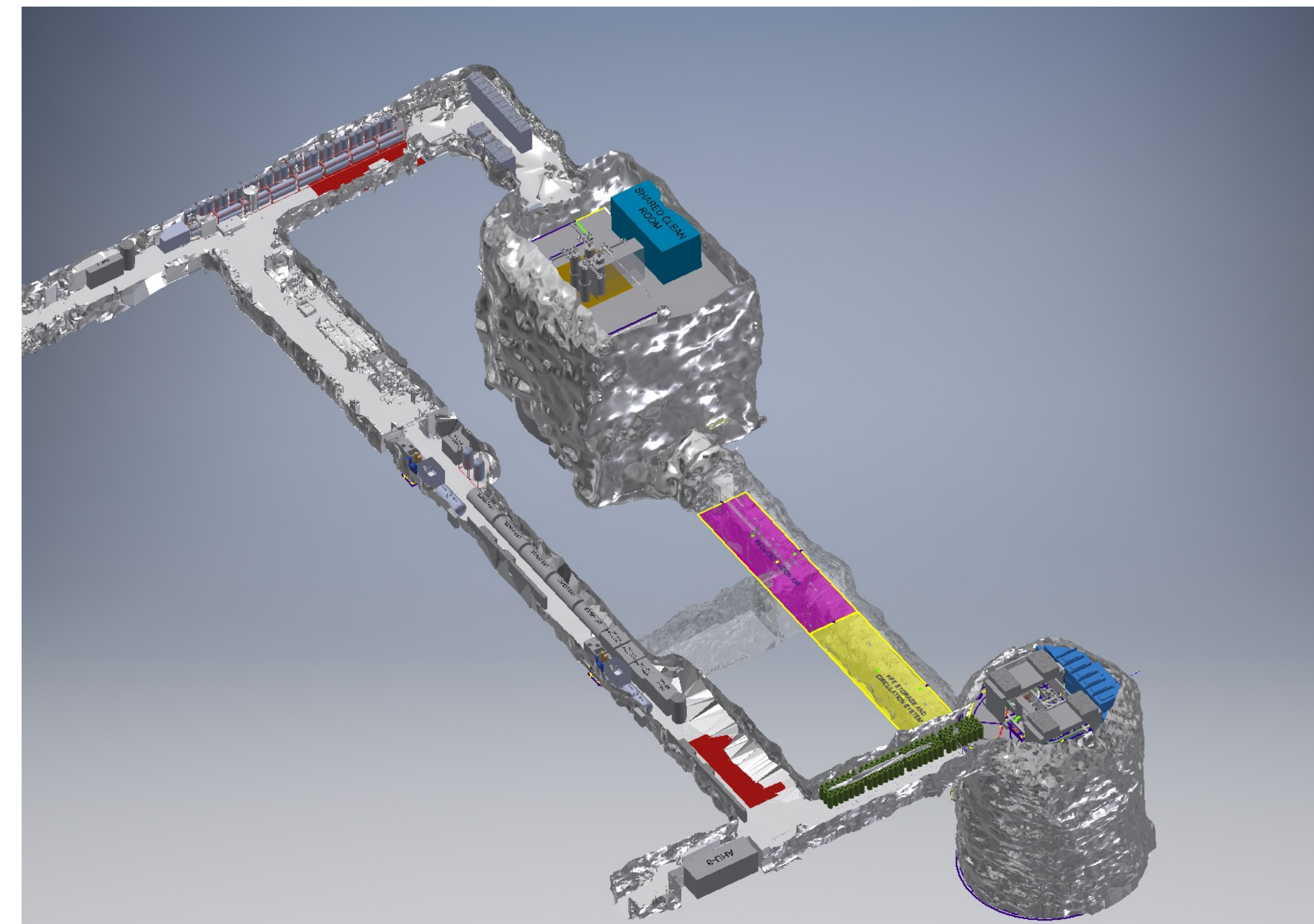
PICO-500

LEGEND-1000
or nEXO



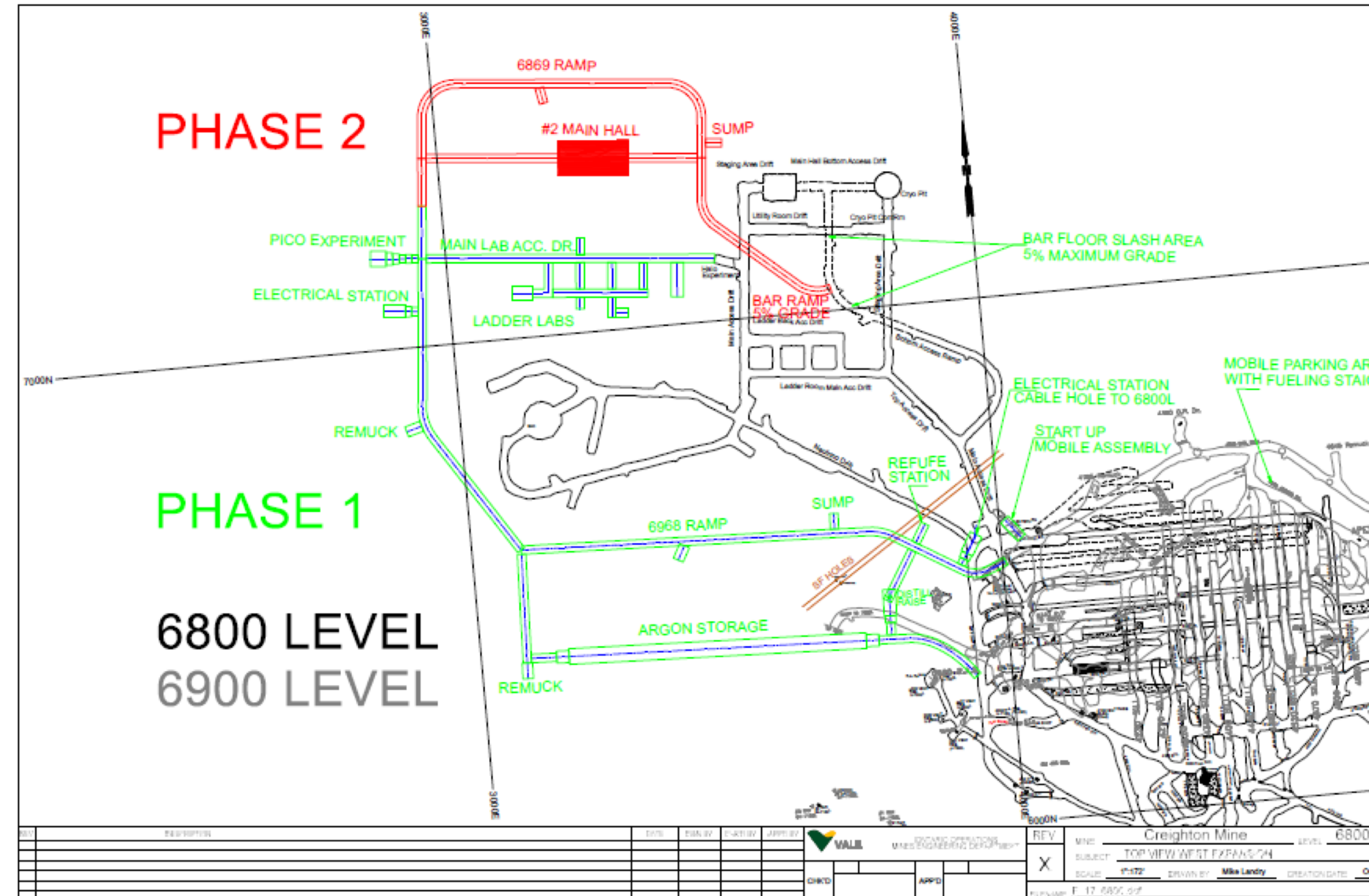
Synergies

- Common liquid nitrogen (LN2) production plant sized to cool single experiment at one time.
- Common water recirculation/purification plant for both tanks.
- Common Radon-Reducer Air plant for clean rooms.
- Electrical infrastructure reduced (due to common plants).
- Clean room space can be shared or reused.
- Shared use of HP copper electro-forming facility.
- Contractor/vendor savings and risk reduction for common or similar infrastructure (e.g. building two water tanks).
- -> Potential substantial savings across programme



Potential future expansion

- Evaluation of expansion possibilities completed
- Included current (ambitious) plans as communicated by international community for additional major cavity (ARGO focus)
- Cost prohibitive O(\$200M) without appropriate funding programme – 10-year excavation timescale
- Such development would require substantial RoI and substantial support from community
- Space will be fixed at SNOLAB for the foreseeable future, recycling cavities for new experiments



The Sanford Underground Research Facility



September 2021



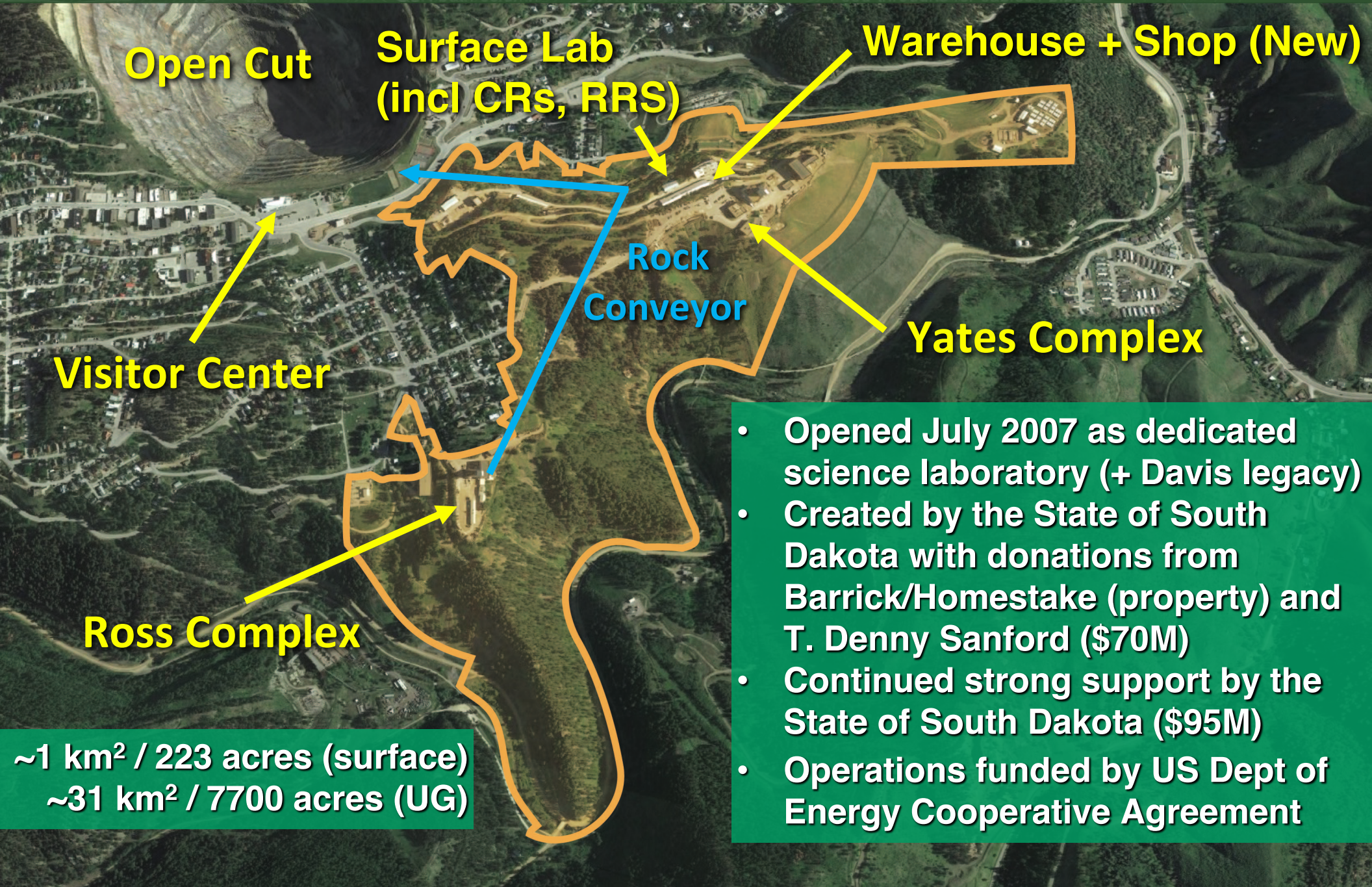
Sanford

Underground Research Facility

South Dakota Science and Technology Authority

Sanford Underground Research Facility

Nation's underground lab to advance multi-disciplinary research

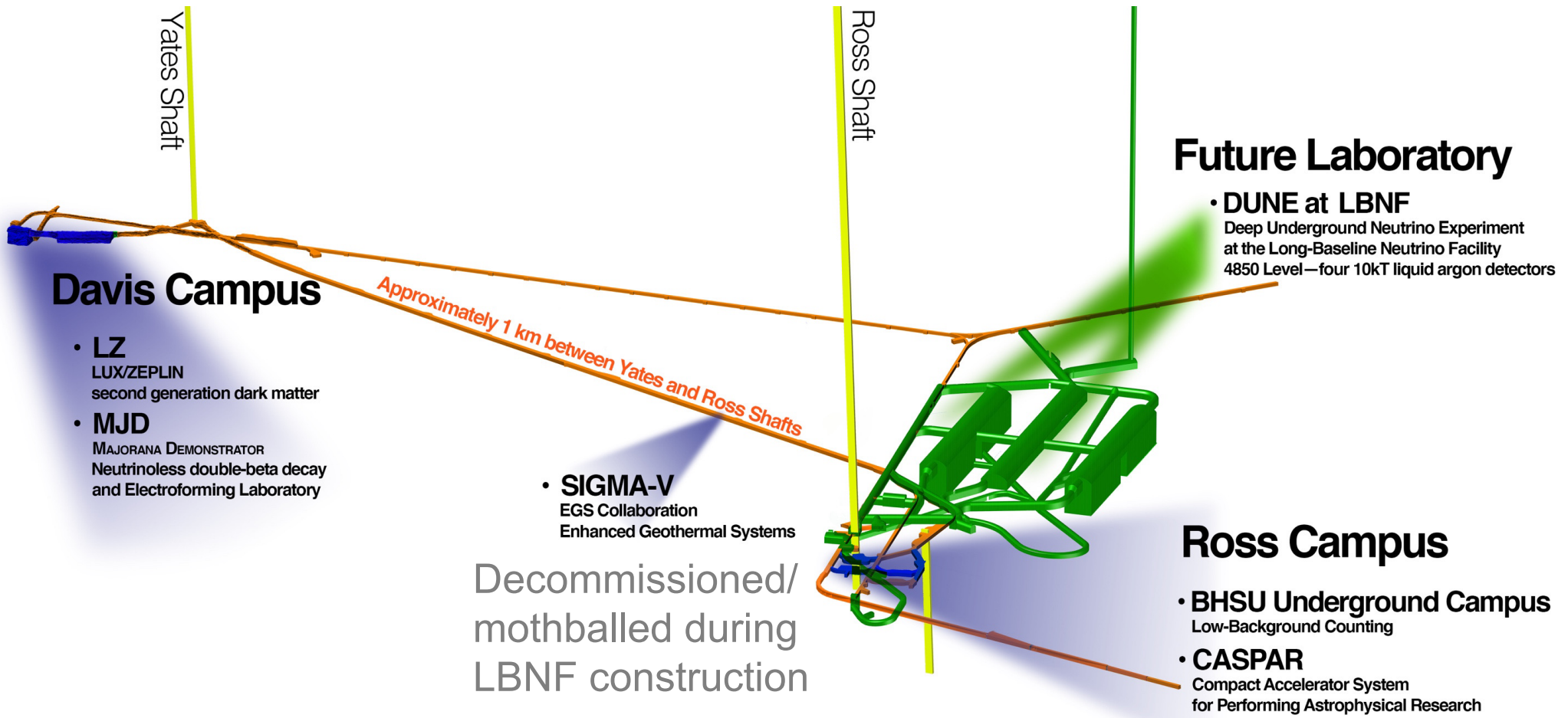


- Opened July 2007 as dedicated science laboratory (+ Davis legacy)
- Created by the State of South Dakota with donations from Barrick/Homestake (property) and T. Denny Sanford (\$70M)
- Continued strong support by the State of South Dakota (\$95M)
- Operations funded by US Dept of Energy Cooperative Agreement

~1 km² / 223 acres (surface)
~31 km² / 7700 acres (UG)

Current & Future Underground Facilities

SURF research through 2050 and beyond



Existing Facilities

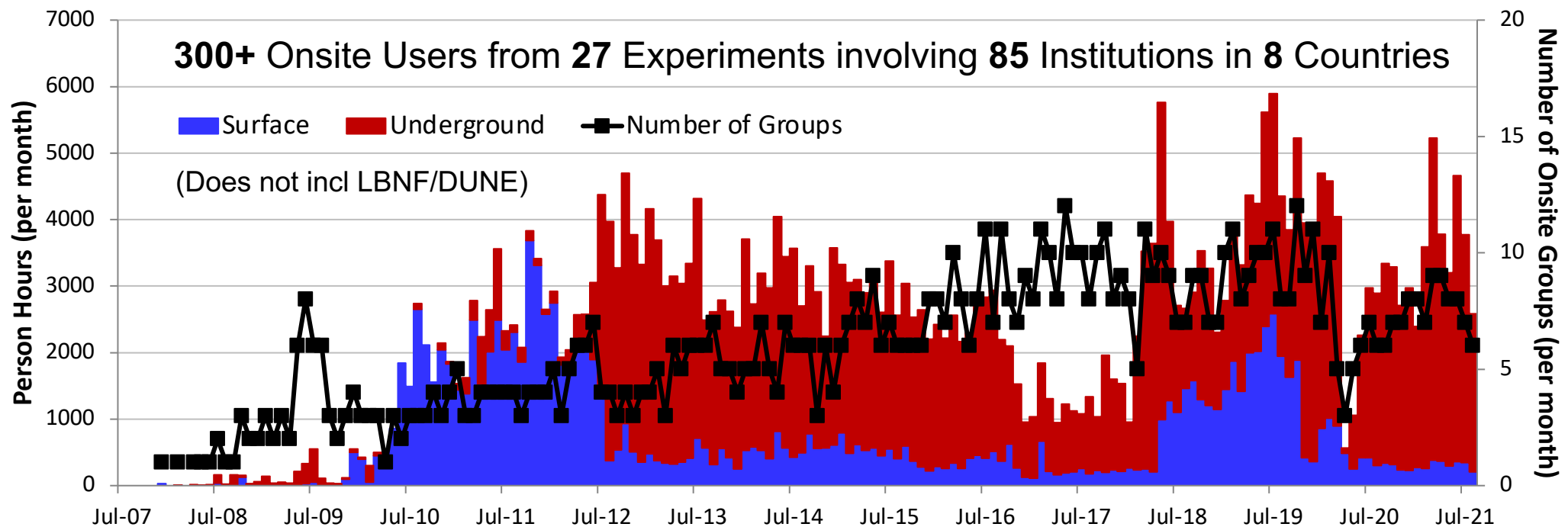
Future Facilities

SURF Overview

Serving a diverse community of researchers

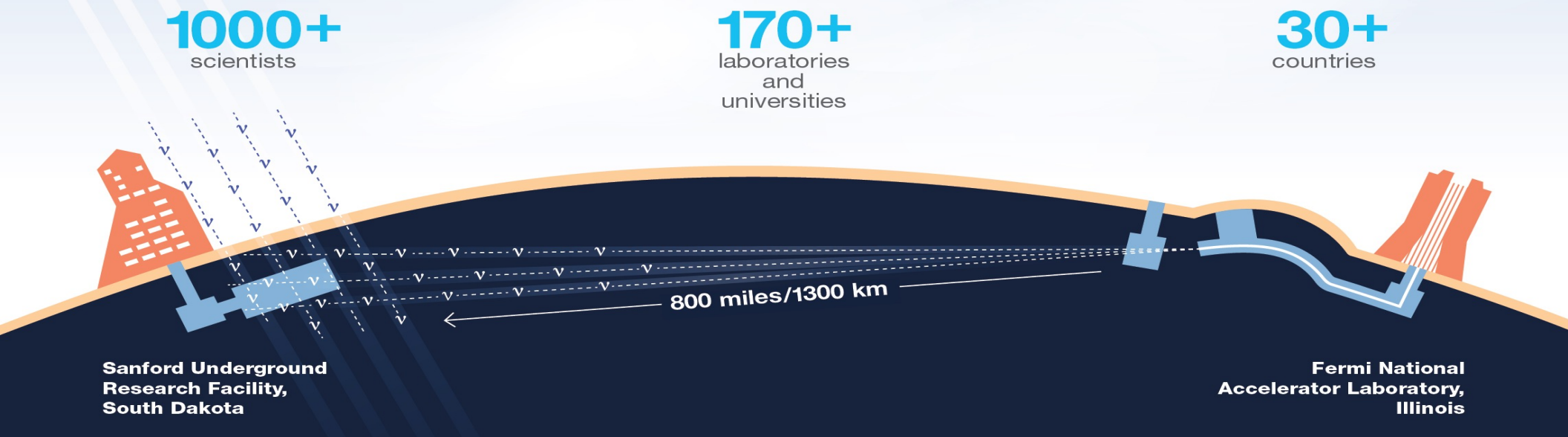
- Facility Highlights

- **World-class services** and **unique attributes** attractive to physics, biology, geology and engineering
- **Deep** (1500 m, 4300 mwe) underground facility dedicated for science, with **capacity & expansion** possibilities (SURF strategic plan incl additional laboratories and deeper access to 2300 m, 6500 mwe)
- **Redundant** safe access with 2 principal shafts (incl redundant **power** and **network** utilities)
- **Robust Organization:** Resources to ensure safe and successful science: 187 full/part-time staff, 11 departments, ESH (incl nurse, 24-hr emergency response), Engineering, Operations, Science + others
- **Mature Programs:** Experiment implementation & safety
- **Community:** SURF **User Association** launched in 2020, establishing SURF **Science Program Advisory Cmttee**. Also preparing application to become DOE Office of Science **User Facility** (~2023)



Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

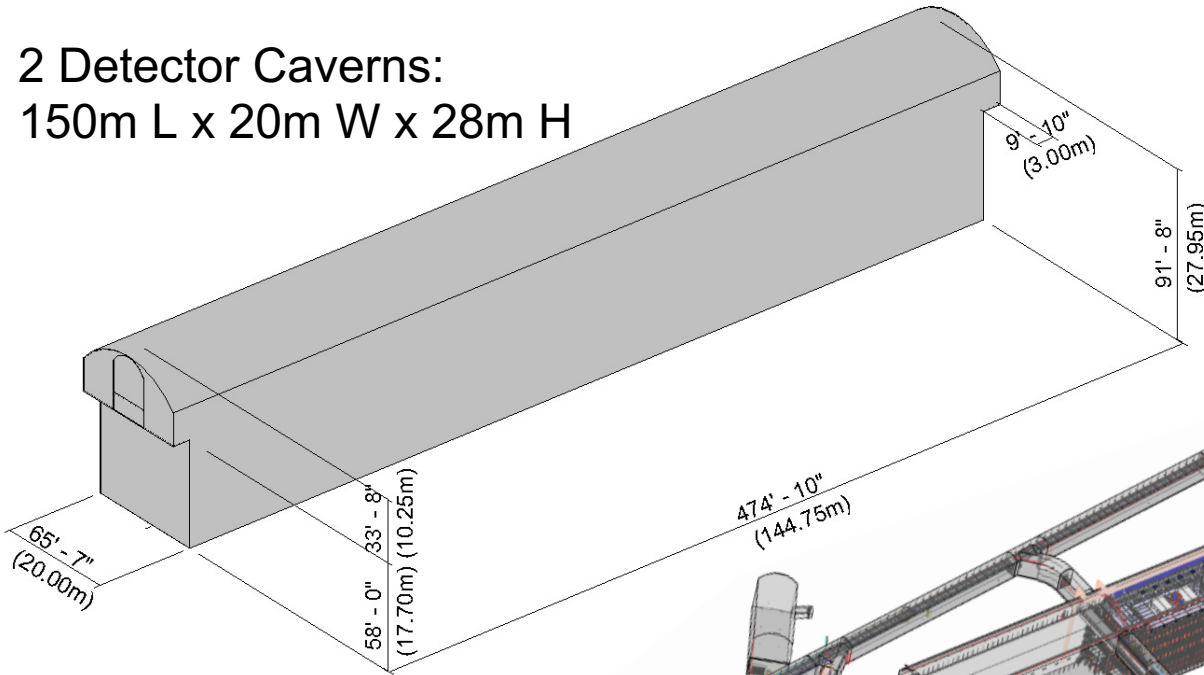


- First **internationally** conceived, constructed, and operated project hosted by the DOE in the **United States**. Significant international contributions (incl CERN).
- Two detector caverns to host 4 detectors (70 kT liquid argon) + utility cavern.
- **Reliability projects** rehabilitate key SURF infrastructure (incl main ventilation fan, Ross Shaft and hoisting systems). In progress since 2016, essentially complete.
- **Pre-excavation construction** at SURF in Jan 2019 – Feb 2021. Transportation system for excavated rock operational (first rock to Open Cut May 2021).
- **Excavation** started Jun 2021 and will last ~3 years. Recent efforts incl ventilation borehole and access tunnels.
- **Infrastructure outfitting** and **cryostat construction** expected to begin in 2024.

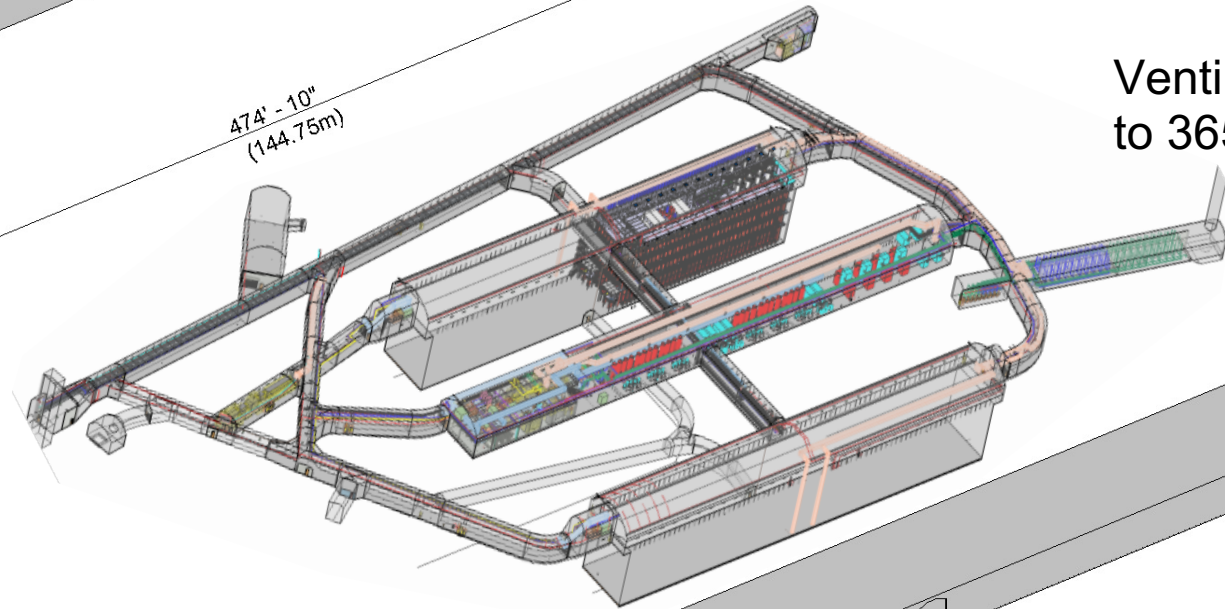
Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

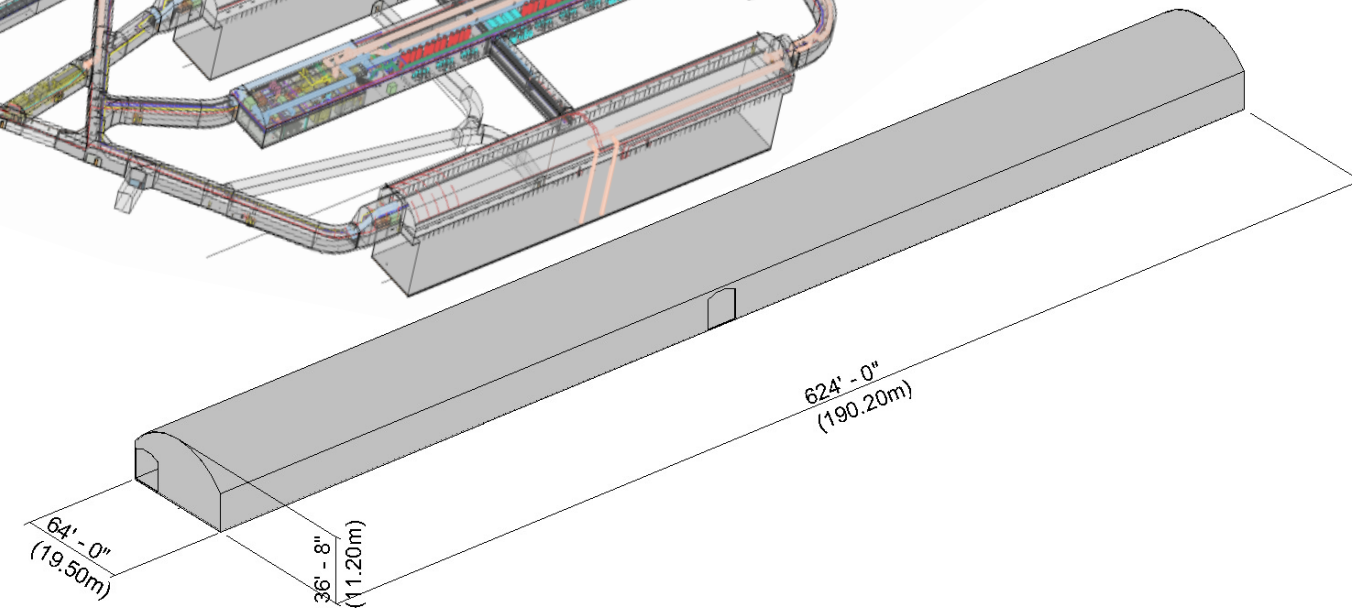
2 Detector Caverns:
150m L x 20m W x 28m H



Ventilation Borehole
to 3650L



1 Utility Cavern:
190m L x 20m W x 11m H



Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)



Rock conveyer
to Open Cut



Borehole reamer
(on 4850L)



Excavation
(4850L)

SURF Underground Facility Expansion

Future space development must be responsive to community's needs

- SURF participating in Snowmass, SURF LOI submitted for Underground Facilities Frontier: <https://www.snowmass21.org/docs/files/?dir=summaries/UF/>
- Planning Snowmass whitepaper to document SURF capabilities and future plans

SURF Strategic Plan long-term goals (15-year horizon):

- LBNF/DUNE is constructed and fully operational.
- Two additional large lab modules on the 4850L constructed and operational.
- Construction is underway on two 7400L lab modules including required access.
- Provide broader access to a range of science disciplines including below 5000L.
- A SURF Institute is constructed and operational with compelling, vibrant science and education programs.
- Foster commercial partnerships to advance technology development in the region, increase facility operations efficiency and safety, and expand workforce development opportunities.

SURF underground facility expansion

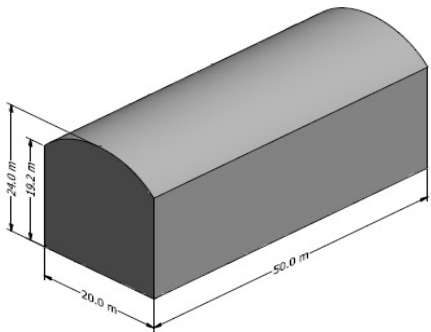
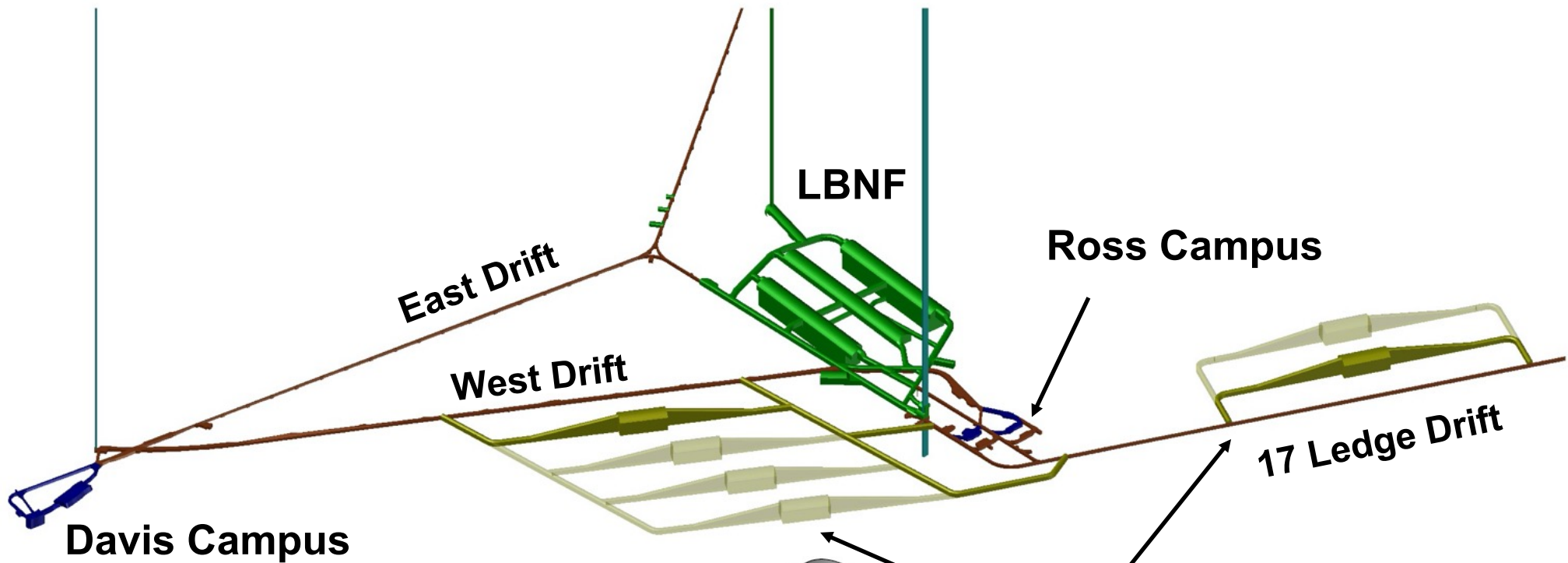
- Several module options have been studied and designed over past decade+
- 4850L is well characterized (incl recent LBNF + other research efforts)
- Design firm conducting 4850L feasibility study in 2021

SURF Underground Facility Expansion

4850L Future Expansion Planning

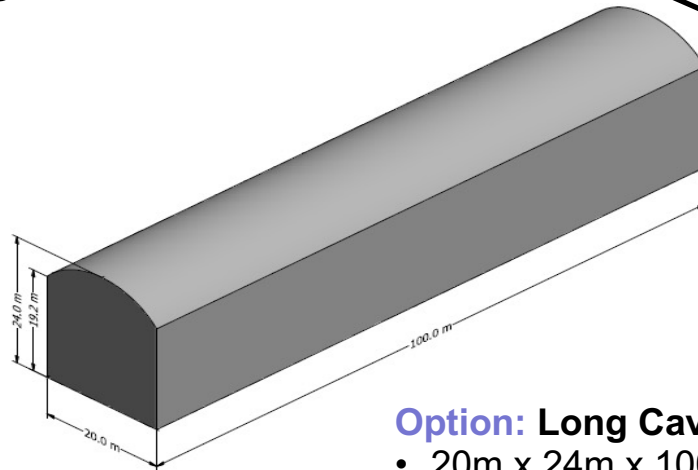
Yates Shaft

Ross Shaft



Option: Medium Cavern

- 20m x 24m x 50m



Option: Long Cavern

- 20m x 24m x 100m

Lab Module Expansion Sites

- Utilizes LBNF rock handling system
- Dimensions scalable to meet experiment needs

SURF Laboratory Space

Summary for various science campuses, including timelines

Location	Laboratory	Existing/ <i>Planned</i> Space		Available (CY)	Comments
		Area (m ²)	Vol (m ³)		
Surface	Surface Lab (served by RRS)	210	600	2021	LZ use ~complete, allowing use by others
Davis Campus (4850L)	LZ Lab – Davis Cavern (2 levels)	372	1,956	~2027	LZ operations beginning 2021, complete by ~2026 + decommissioning
	MJD Lab – 2 Rms + BHUC share	300	1,279	~2024/2026	Initial scope complete by end of 2021, Ta-180m data to ~mid-2023 + decommissioning; e-form Cu through 2025
	Cutout Rms (4)	100	412	~2027	LZ timeframe for most spaces
Ross Campus (4850L)	Former E-forming	228	742	?	LBNF use + SURF UG WWTP
	BHUC (BHSU owns cleanroom)	266	773	~2025	Mothballed, most equipment and systems relocated to Davis Campus; re-occupy after LBNF construction
	CASPAR	395	1,130	~2024/2027	Mothballed, equip remains, re-occupy after LBNF construction? Use to expand Refuge Chamber during DUNE install
	Refuge Chamber	258	866	?	Long-term use TBD
LBNF (4850L)	<i>LBNF</i>	9,445	191,863	~2024	<i>Excavation started 2020, lasts ~3 yrs</i>
4100L	<i>Multiple labs</i>	<i>TBD</i>	<i>TBD</i>	<i>TBD</i>	<i>SIGMA-V in progress, also RESPEC</i>
4850L	<i>Propose 2 labs</i>	<i>2 x 2,300</i>	<i>2 x ~46,738</i>	<i>Responsive to community need</i>	<i>Each 20m (W) x 24m (H) x 115m (L)</i>
7400L	<i>Propose 2 labs</i>	<i>2 x 1,125</i>	<i>2 x 14,288</i>		<i>Each 15m (W) x 15m (H) x 75m (L)</i>

Final comments

- North American facilities have projected capability to host $0\nu\beta\beta$ projects
 - Immediate space available in SNOLAB Cryopit
 - Reconfigured SNOLAB Cube Hall would provide space for 2nd project
 - Potential future expansion at SURF to greater depths for large caverns
- A global $0\nu\beta\beta$ programme requires coordination for the supporting infrastructure as well as the experiments themselves
- Host country usually supports the operations of the infrastructure – is this still achievable? Coordination on capital component likely required.
- $0\nu\beta\beta$ programme and move to greater depth may be a trigger for the facilities to collaborate on the global underground science programme, to ensure that all facilities have viable programmes (DM and $0\nu\beta\beta$)