Status of non-US Underground Facilities

Nigel Smith

Presented by Ian Lawson

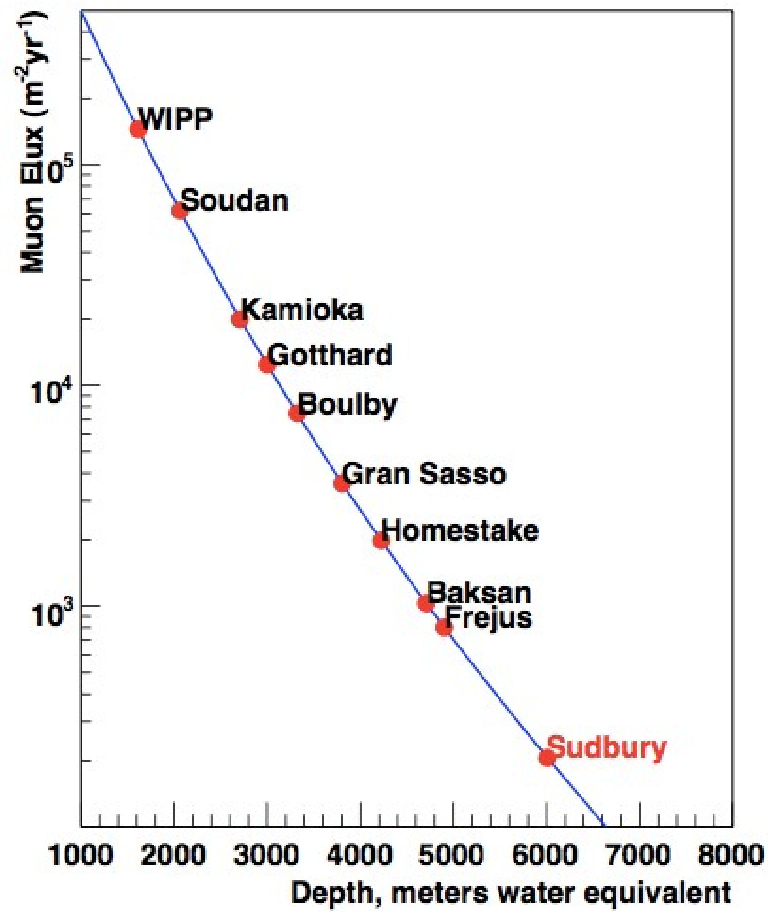
SNOLAB

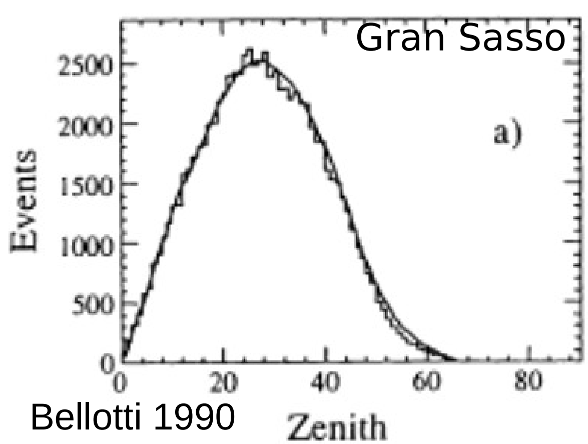
The SNOLAB Science Programme

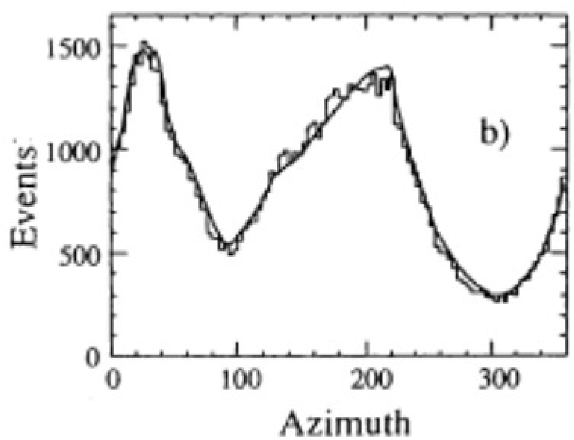
- SNOLAB addresses some of the key questions in contemporary physics
  - What is the nature of the dark matter that pervades and shapes our universe? How has the dark matter affected the evolution of galaxies and the Universe?
  - How have neutrinos shaped the evolution of the universe and the synthesis of heavy elements? What are the fundamental properties of neutrinos?
- We are also supporting other science programmes that need access to a low radiation environment, or techniques/capabilities we have developed
  - Mining data centre, seismic monitoring, deep subsurface life

Effect of over-burden

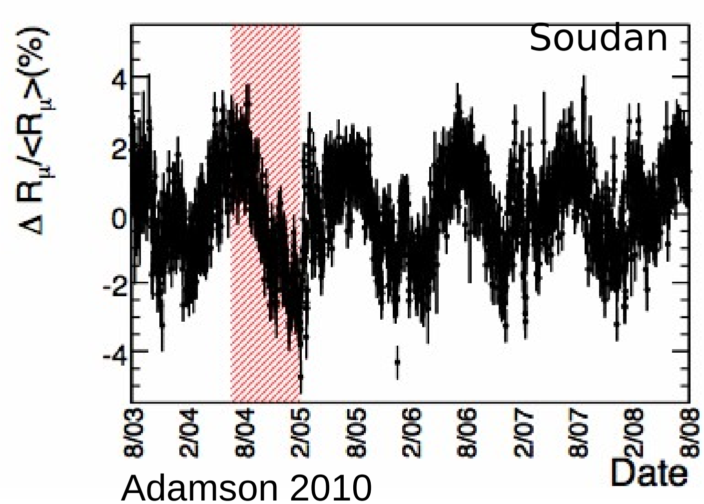
- Deep underground facilities provide significant rock overburden and commensurate reduction in c.r. flux, and c.r.-spallation induced products (neutrons)
- Muons can be veto'd in anti-coincidence shield; secondary products may be an issue
- Cosmogenics may require underground material production or purification
  - May also contribute to b/grounds (e.g. ^{11}C)
- Muon flux depends on
  - overburden
  - overburden profile
  - seasonal effects







Bellotti 1990

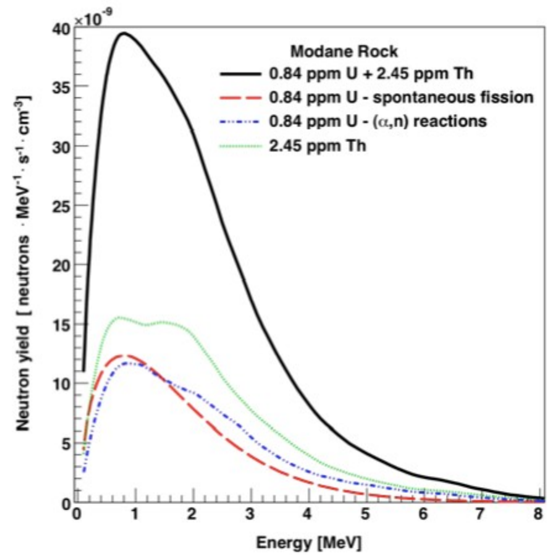


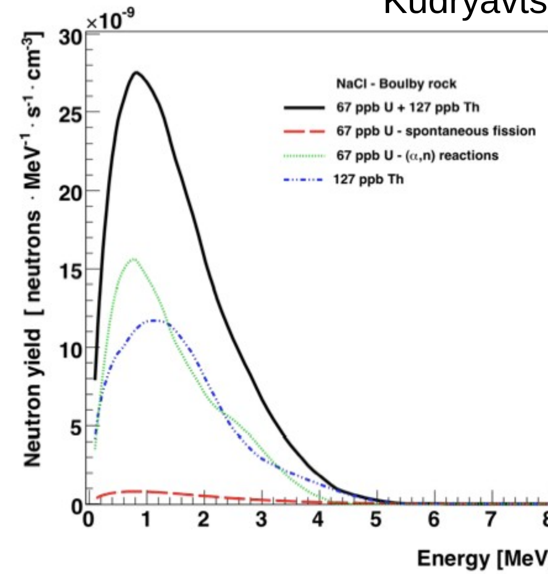
Adamson 2010

Neutron backgrounds

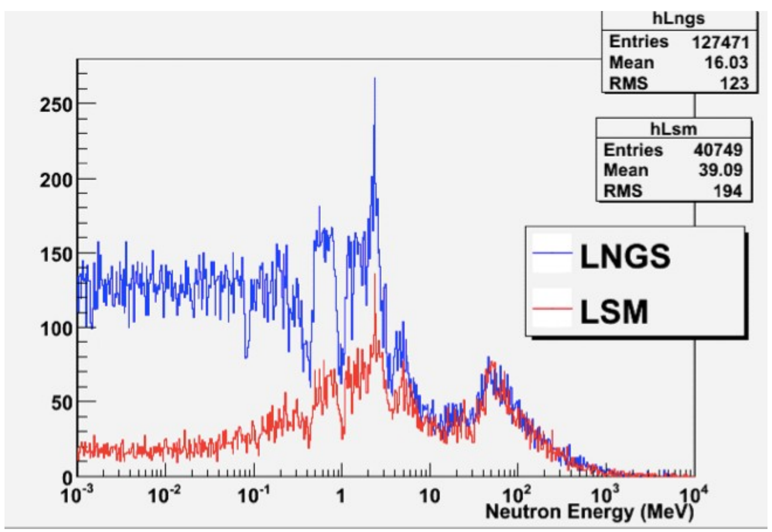
- Neutron production from
  - c.r. muon spallation
  - U/Th fission
  - α, n reactions

Kudryavtsev





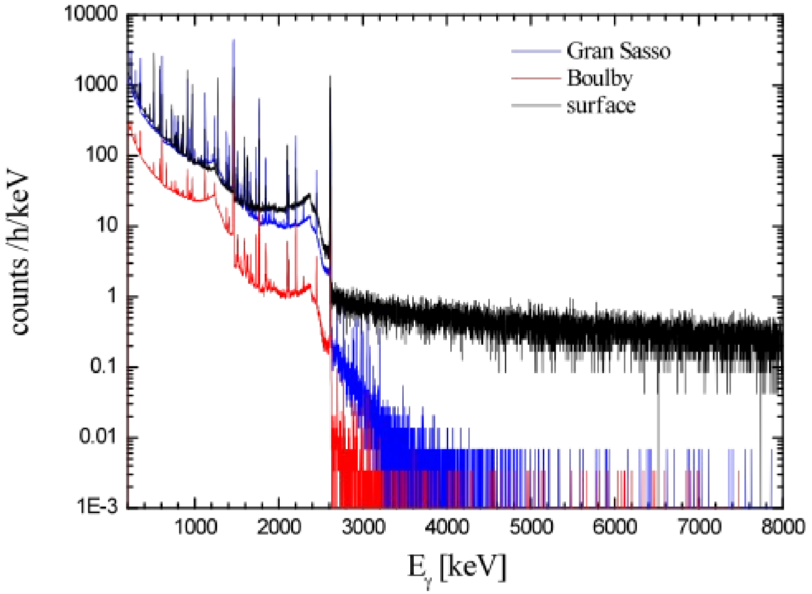
- Spectrum in laboratory depends on local geology (rock composition)
  - both for fast and thermal neutrons
  - U/Th + moderators
  - muons + moderators
  - small levels of high neutron cross-section contaminants make a big difference

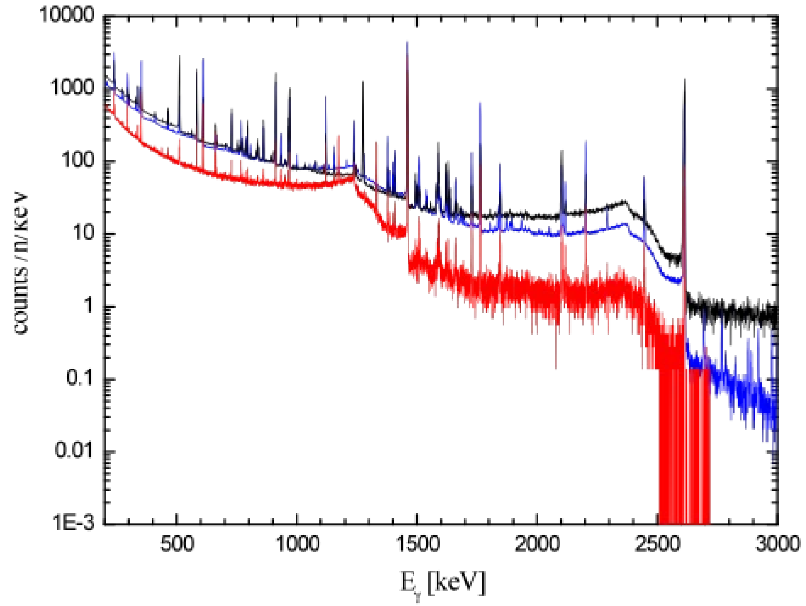


Persiani / Selvi

γ-ray Backgrounds

- Reduction in γ-ray background at higher energies from c.r. and neutron reduction
  - important for nuclear astrophysics dedicated beam experiments, and some 0νββ isotopes
- Below 3.5MeV dependent on local geology and rock material
  - Boulby (red)
  - Gran Sasso (blue)
  - surface (black)





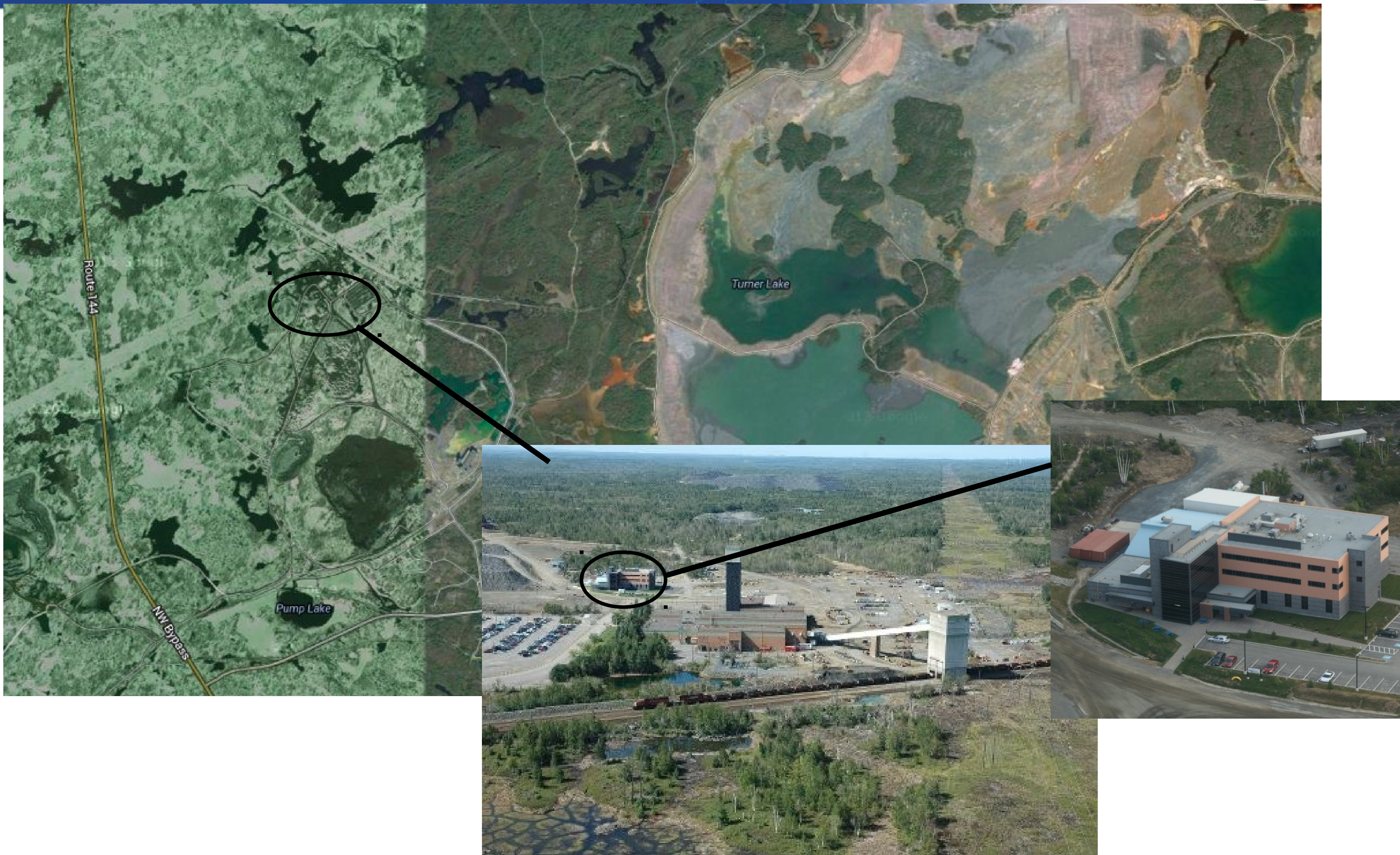
Considerations for a facility

- But... a hole in the ground is not a facility.
- Facilities provide:
  - Surface support and facilities
  - Scientific support and personnel: design, construction, operation/analysis
  - Ancillary science support: low background assay
  - Infrastructure support and personnel: workshops, chem labs, I.T.
  - Access (vertical or horizontal); Space (monolithic or distributed; scale)
  - Utilities: power, ventilation, heat management, water, gases/liquids
- Other characteristics
  - Location (neutrino flux from beam, reactor, Earth, access to facility)
  - Depth - limits muons, cosmogenics
  - Backgrounds - muon, spallation, local environment
  - Cleanliness and radiological interference
  - “Quality of life” for researchers: breadth of programme, access policies
- Health/Safety and security protocols
- Funding and stability: multi-year budgets, host nation support, host organisation stability and engagement

The SNOLAB Facility

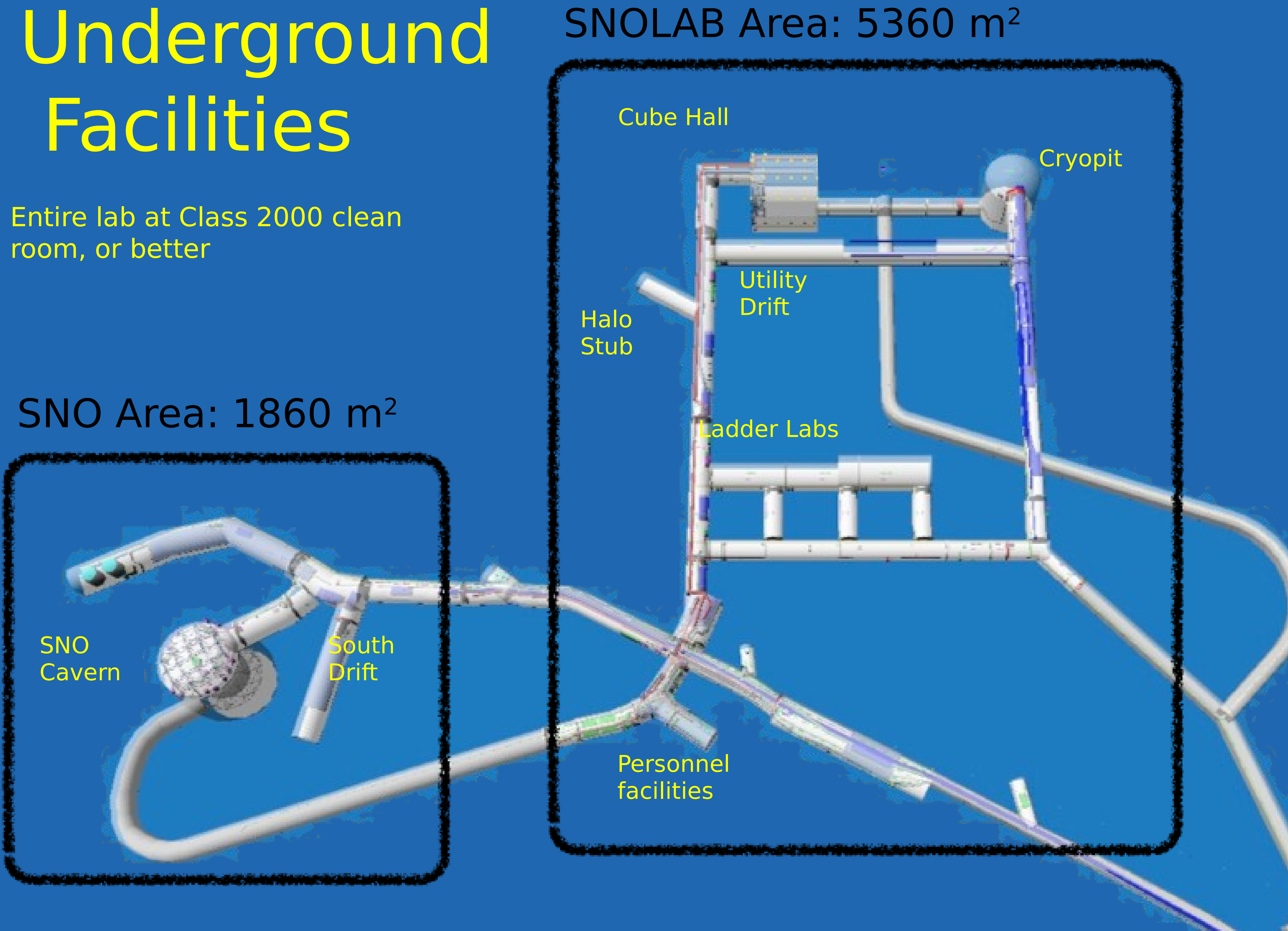
- Operated in the Creighton nickel mine, near Sudbury, Ontario, hosted by Vale.
  - Five University partners (Alberta, Carleton, Laurentian, Montréal, Queen's)
- Underground campus at 6800' level, 0.27μ/m^2/day
- Entire lab at class-2000, or better, to mitigate against background contamination of experiments.
- Focus on kilo-tonne dark matter, double beta decay, solar & SN neutrino experiments requiring depth and cleanliness.
- Surface Facility (3100 m^2)
  - Operational from 2005 - Provides offices, conference room, dry, warehousing, IT servers, clean-room labs, detector construction labs, chemical + assay lab
  - 440m^2 class-1000 clean room for experiment setup and tests
- Underground Construction (5360 m^2)
  - Two additional (to SNO+ cavity) large cavities (Cube Hall, Cryopit) and support drifts
  - Additional linear drifts for smaller scale experiments
  - Materials handling and cleaning areas; tram transportation
  - Personnel areas: refuge/galley, change areas/showers, offices, meeting room

SNOLAB Location



Underground Facilities

Entire lab at Class 2000 clean room, or better



Current programme: Dark Matter at SNOLAB

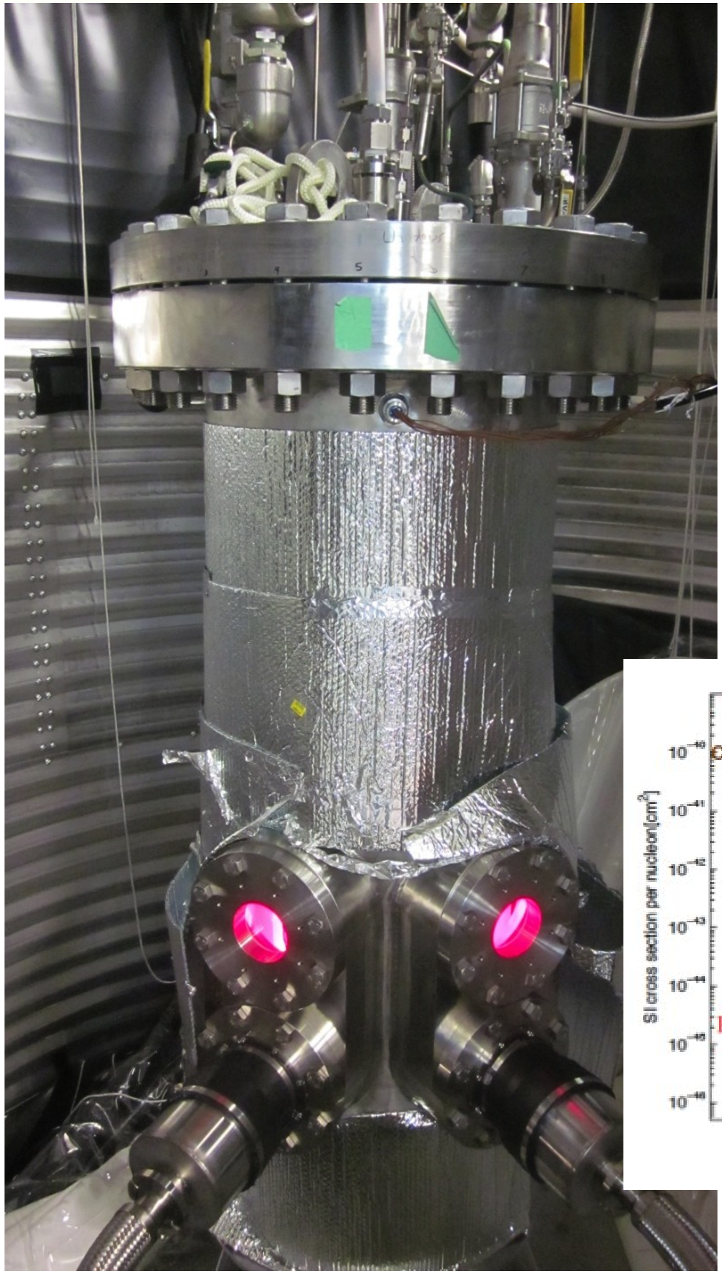
- Noble Liquids: DEAP-I, MiniCLEAN, & DEAP-3600
  - Single Phase Liquid Argon using pulse shape discrimination
  - Prototype DEAP-I completed operation. Demonstration of PSD at 10^8.
  - Construction for DEAP-3600 and MiniCLEAN well advanced.
  - Will measure Spin Independent cross-section.
- Superheated Liquid / Bubble chamber: PICASSO, COUPP & PICO
  - Superheated droplet detectors and bubble chambers. Insensitive to MIPS radioactive background at operating temperature, threshold devices; alpha discrimination demonstrated;
  - COUPP-4 (CF_3I) and PICASSO-III (C_4F_{10}) operation completed; COUPP-60 (CF_3I) and PICO-2l (C_3F_8) in data taking;
  - Measure Spin Dependent cross-section primarily, COUPP has SI sensitivity on iodine;
  - World leading spin-dependent sensitivity published in 2012.
- Solid State: DAMIC, SuperCDMS
  - State of the art CCD (DAMIC) Si / Ge crystals with ionisation / phonon readout (SuperCDMS).
  - DAMIC operational since 2012, 10g CCD; Upgrade planned to 100g
  - CDMS Currently operational in Soudan facility, MN. Next phase will benefit from SNOLAB depth to reach desired sensitivity. Approved in recent G2 decision.
  - Mostly sensitive to Spin Independent cross-section.

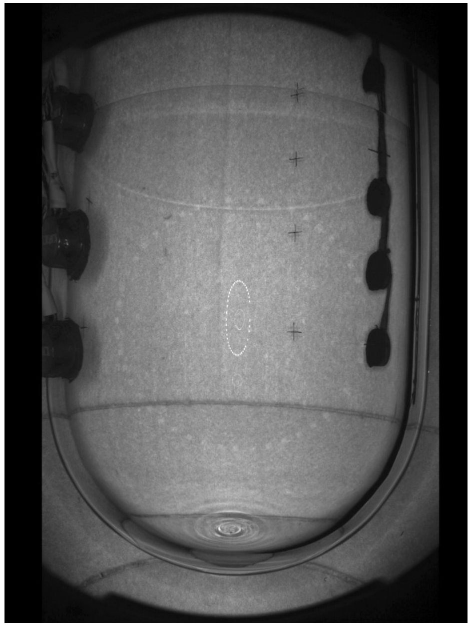
‘J’-Drift: R&D + rapid deployment

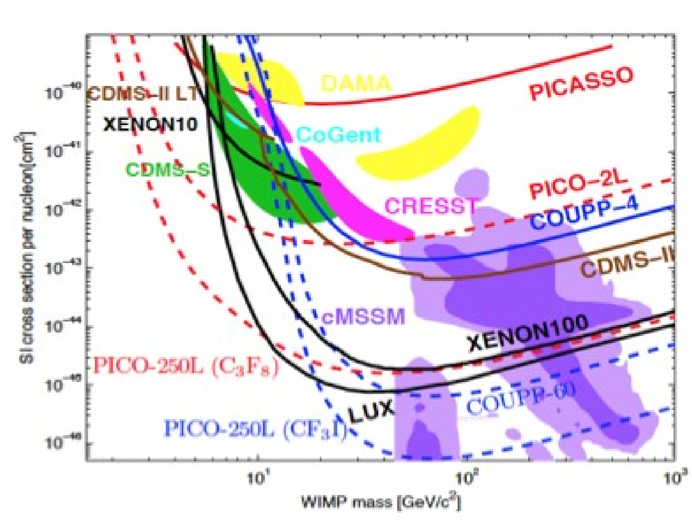
PICO-2 bubble chamber, showing water tank shielding stack, pressure carts, DAQ racks

DAMIC CCD-based dark matter detector, focus on low mass WIMPS. (Currently 10g target, increase to 100g expected)

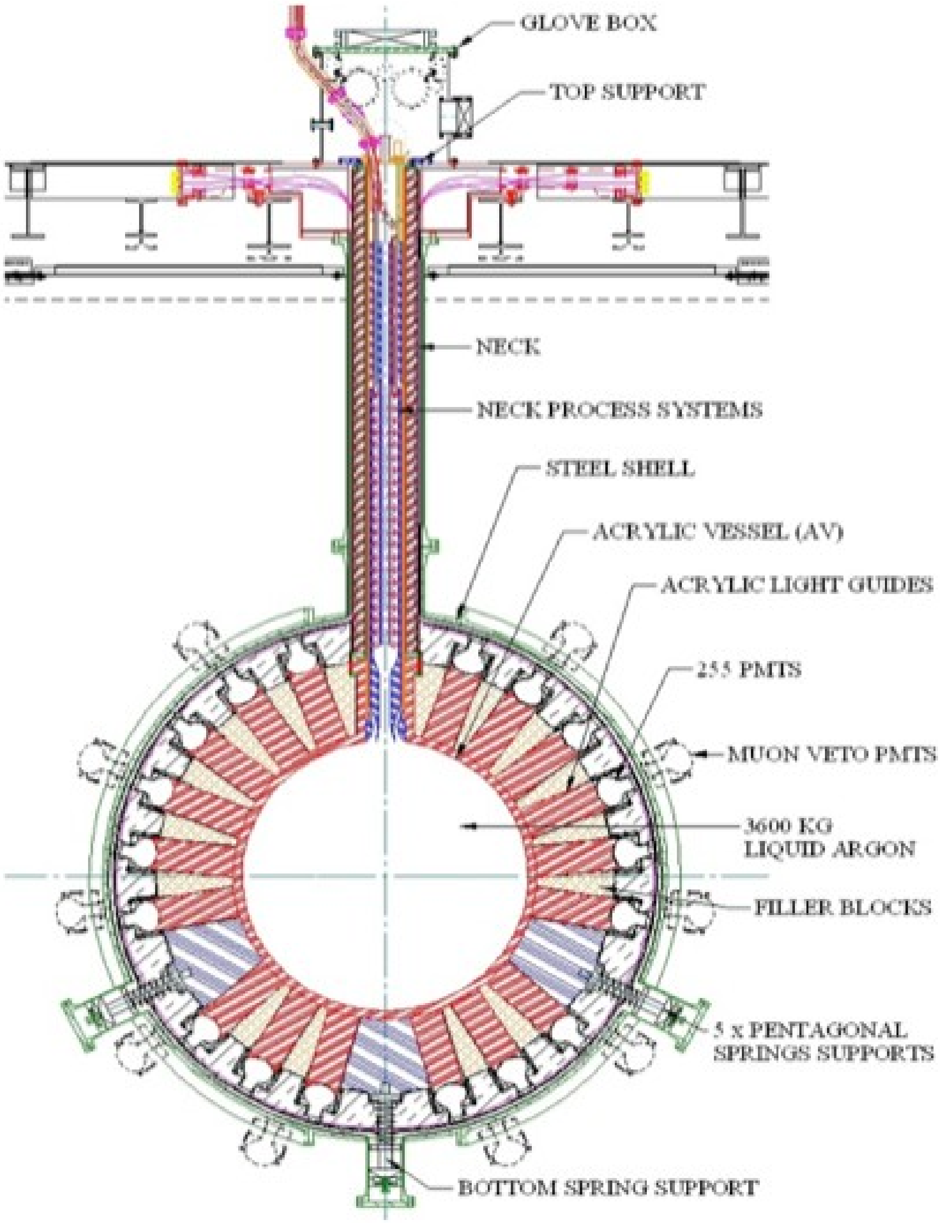
PICO/COUPP-60 Operations







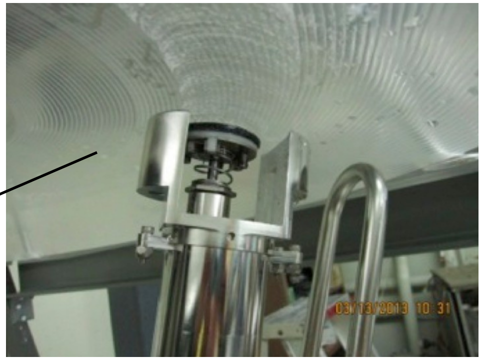
DEAP-3600



DEAP-3600 Detector

3600 kg argon target
(1000 kg fiducial)
in sealed ultraclean
Acrylic Vessel

Vessel is “resurfaced”
in-situ to remove
deposited Rn daughters
after construction



255 Hamamatsu
R5912 HQE PMTs 8-inch
(32% QE, 75% coverage)

50 cm light guides +
PE shielding provide
neutron moderation

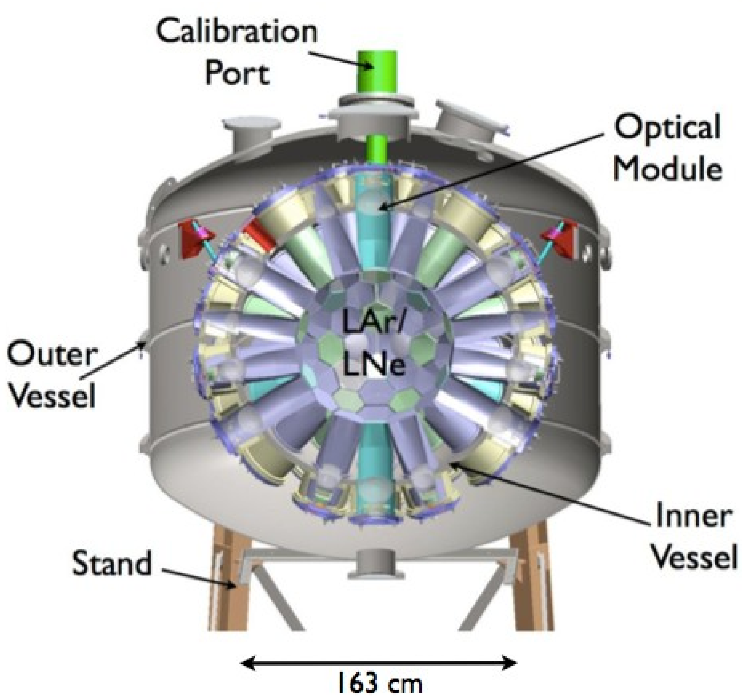
Detector in 8 m water
shield at SNOLAB

DEAP-3600

- Construction sequence of DEAP-3600 dark matter detector

MiniCLEAN Detector

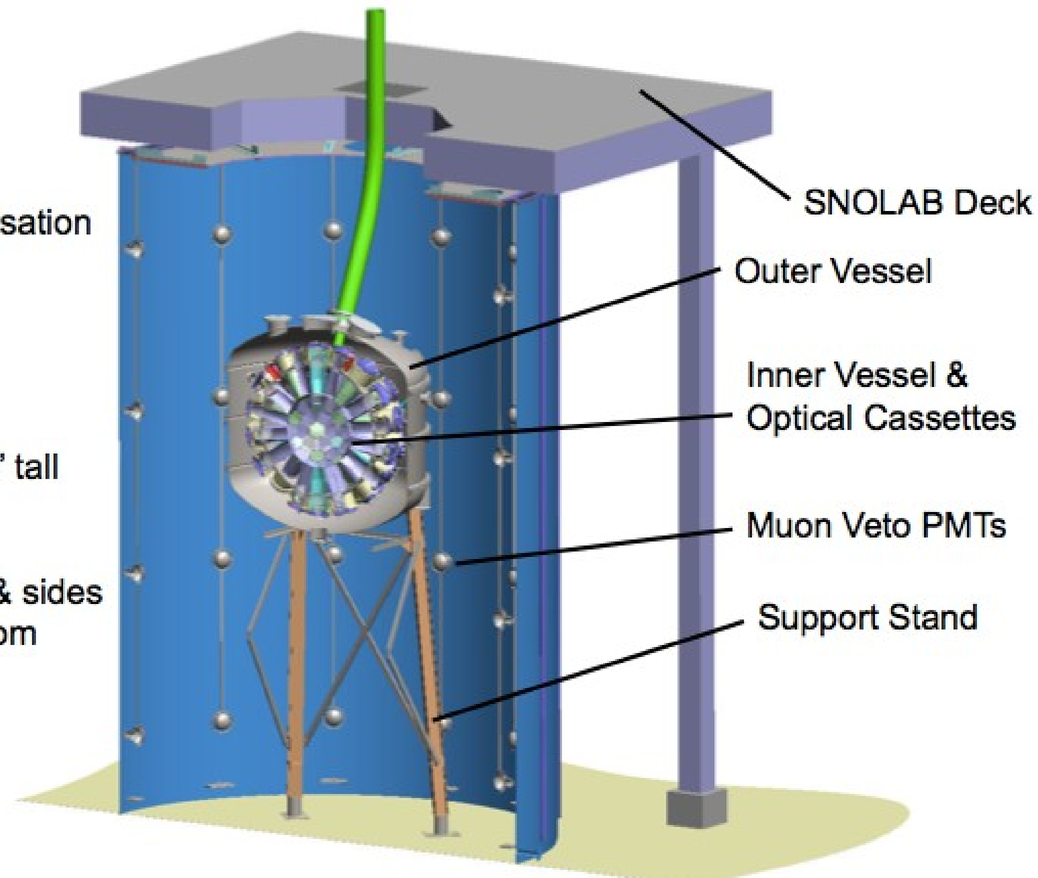
- Single phase LAr/LNe (solar neutrino capability)
- 180kg fiducial volume; PSD discrimination for background rejection
- Wavelength shifter on acrylic plugs
- PMT Cassette into steel vessel



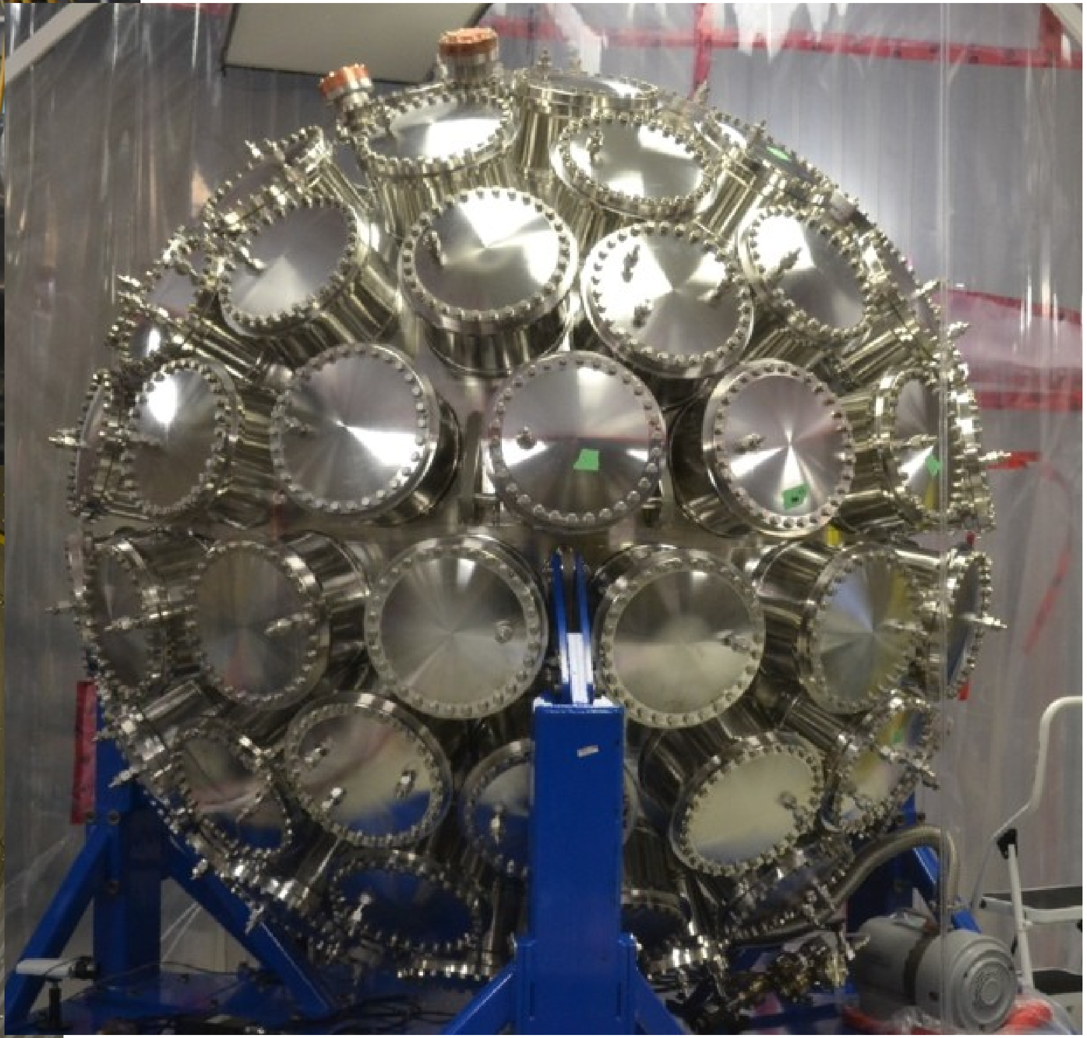
Not Shown:
Magnetic Compensation
Process Systems
Cable Bundles

Tank 18’ dia. x 25’ tall
47,600 gallons

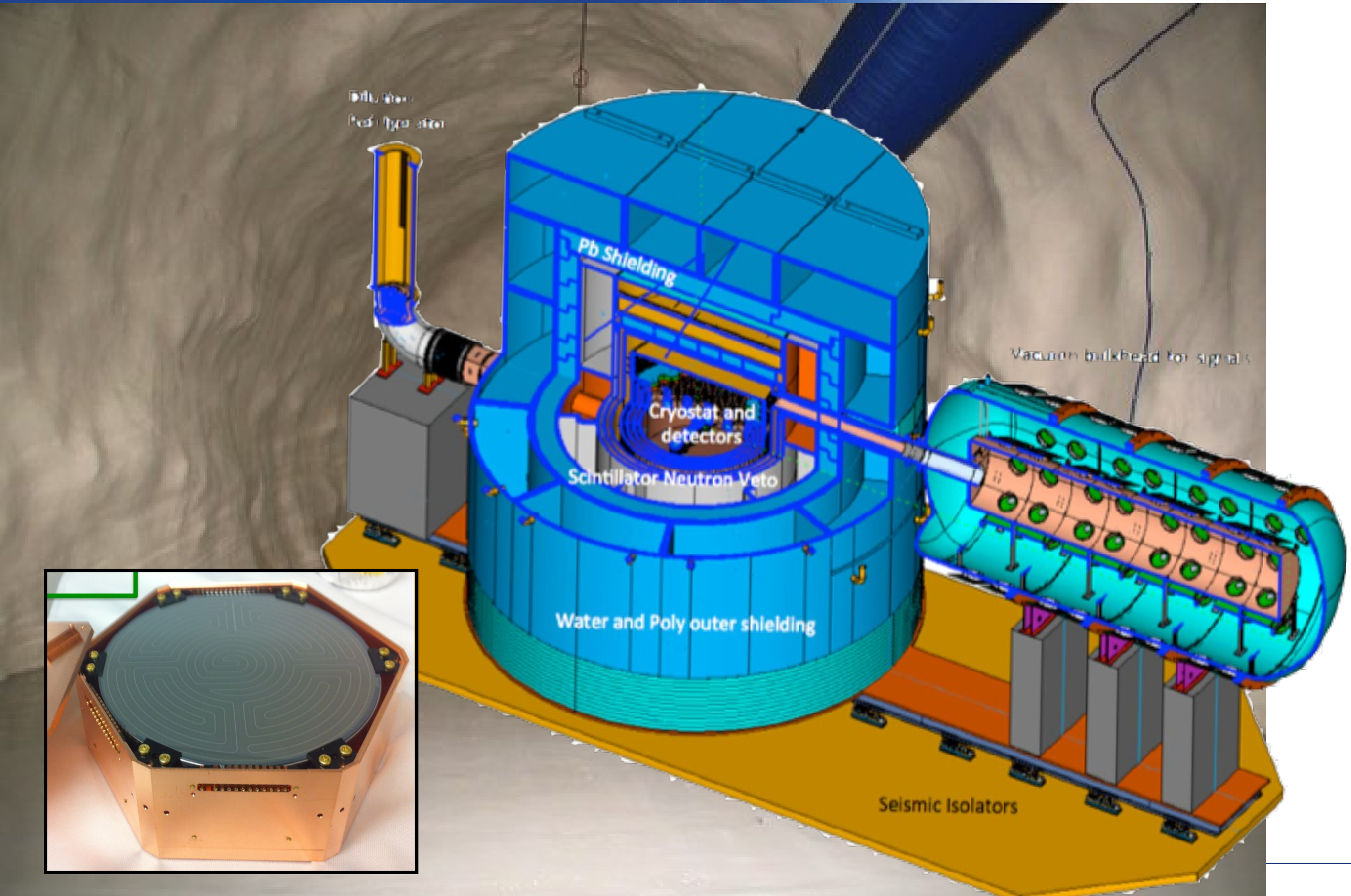
~1.5m water top & sides
~3.5m water bottom



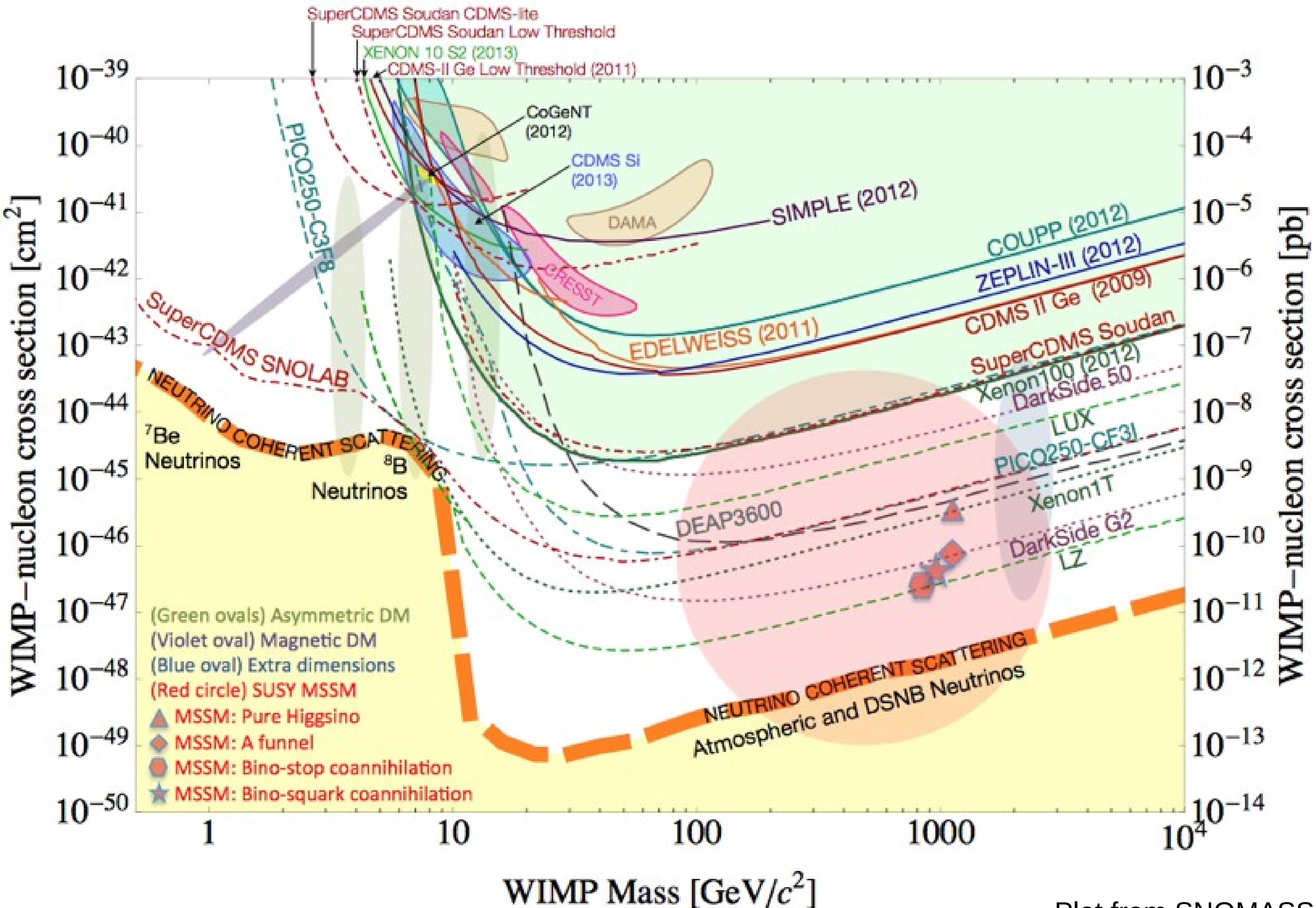
MiniCLEAN Construction



SuperCDMS Project Go-ahead



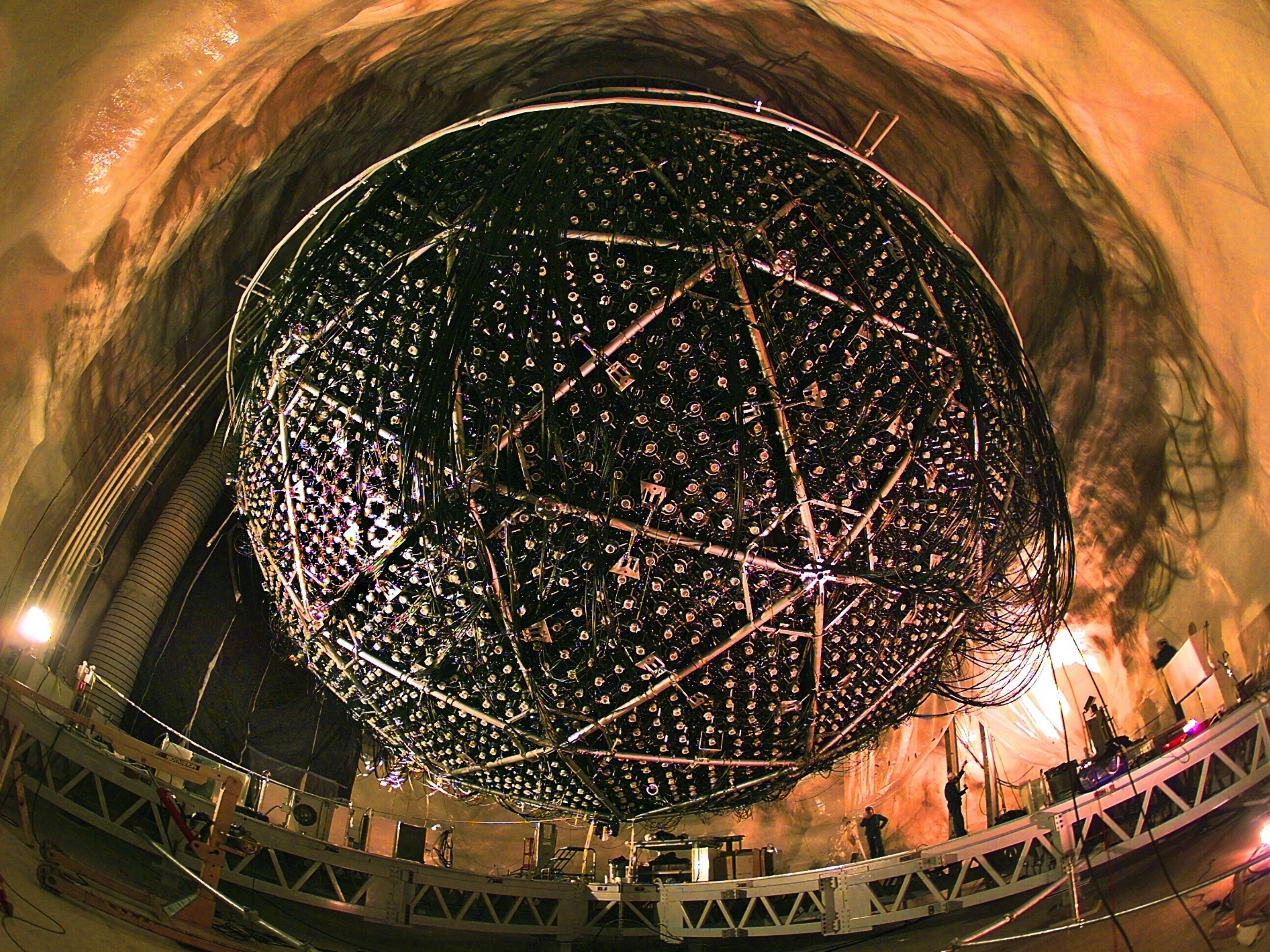
Spin independent limit plot



Plot from SNOMASS Review

Current programme:
$0\nu\beta\beta$ and neutrino at SNOLAB

- SNO+ : $^{130}Te \rightarrow {}^{130}Xe + e^- + e^-$
  - Uses existing SNO detector. Heavy water replaced by scintillator loaded with ^{130}Te. Modest resolution compensated by high statistical accuracy.
  - Requires engineering for acrylic vessel hold down and purification plant. Technologies already developed.
  - Will also measure
    - solar neutrino pep line (low E-threshold)
    - geo-neutrinos (study of fission processes in crust)
    - supernovae bursts (as part of SNEWS)
- EXO : $^{136}Xe \rightarrow {}^{136}Ba^{++} + e^- + e^-$
  - Engineering work for nEXO next generation liquid xenon double beta decay target, assessing potential for location at SNOLAB
  - Development work at SNOLAB surface facility on Ba daughter tagging for EXO-gas. Potential option to develop zero (non-double beta) background gas phase targets.
- Ge1T/nEXO: Letters of intent and presentations at “Future Projects Workshop”
- HALO: Dedicated Supernova watch experiment
  - Charged/neutral current interactions in lead
  - Re-use of detectors (NCDs) and material (Pb) from other systems
  - Operational since May 2012
  - Will form part of SNEWS array



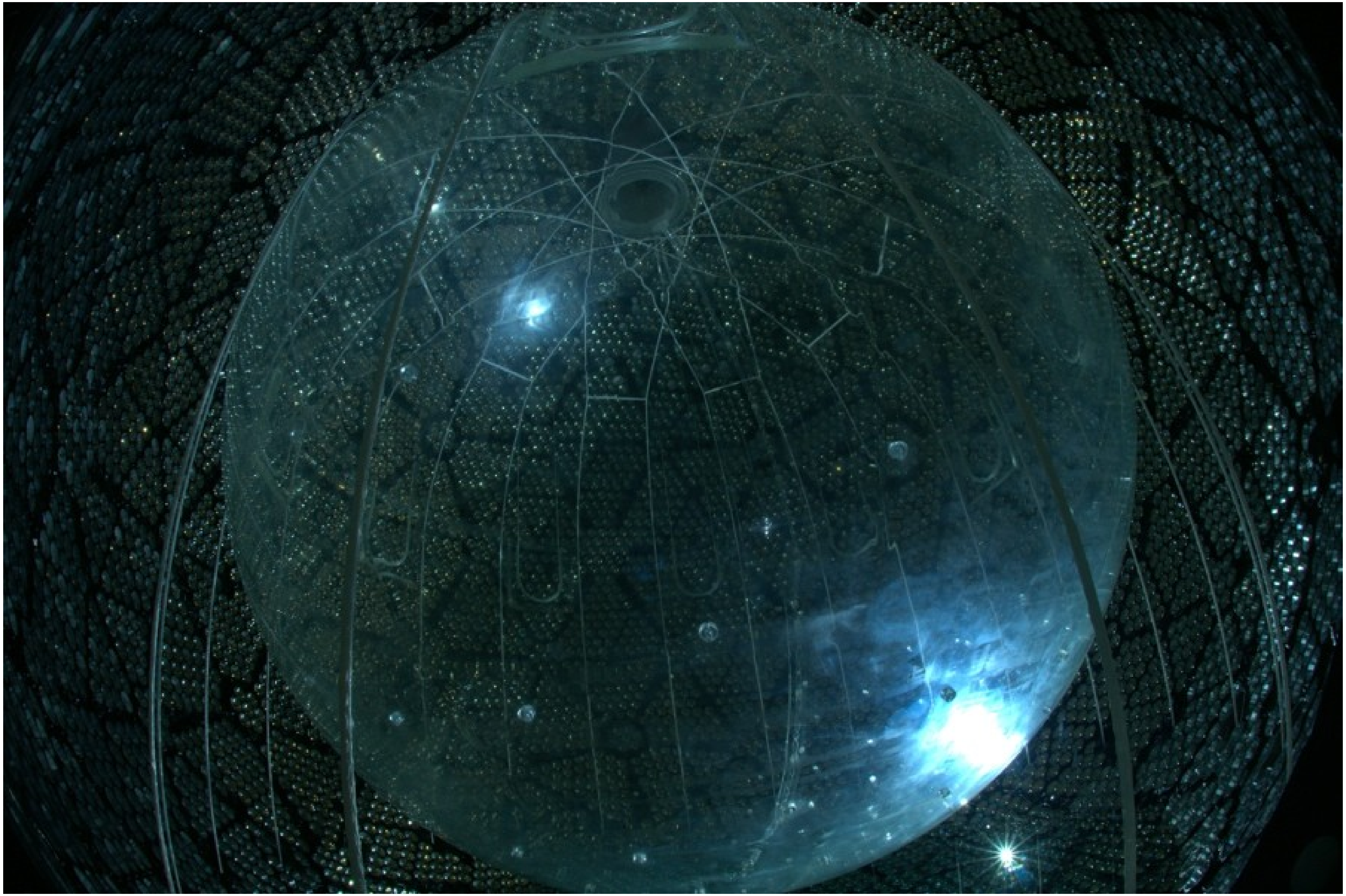
SNO+ Refurbishment

Development of a scaffold for cleaning internal surface of the acrylic vessel

First LAB plant vessel being installed into utility drift (prior to completion of steelwork)

Cavity now being filled with UPW....

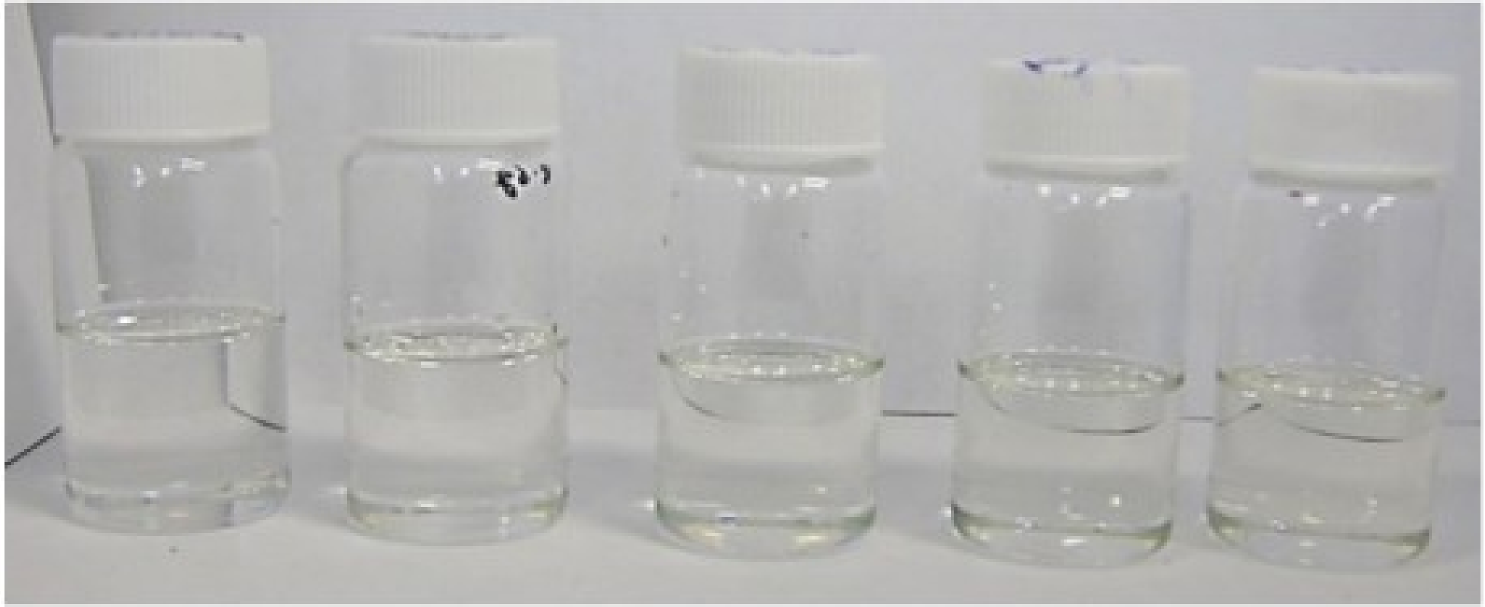
SNO+ Rope Net in place



Loading of LAB with tellurium

Percent Loading of Tellurium is Feasible

- 0.3%, 0.5%, 1%, 3%, 5% (from left to right)

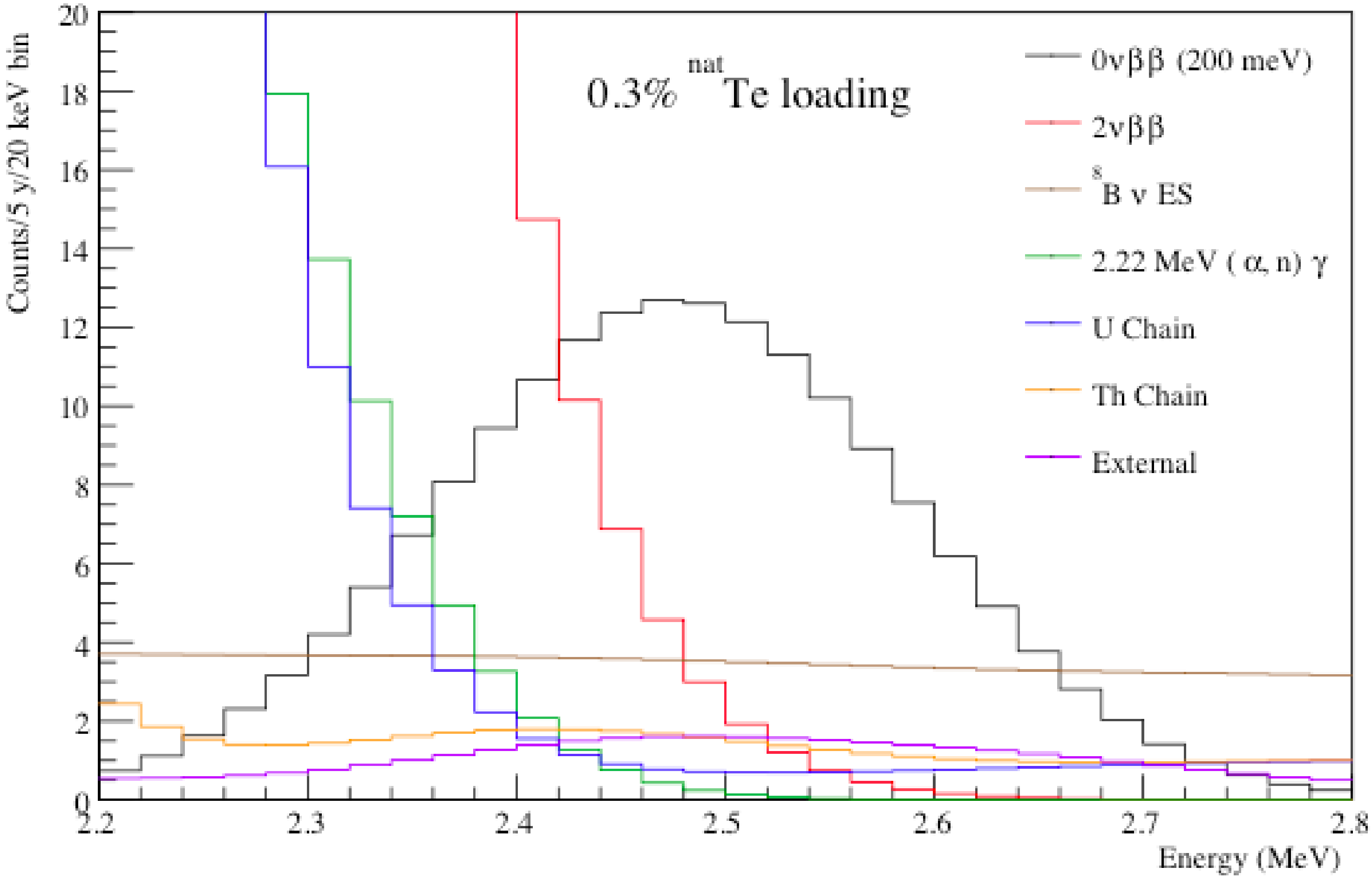


- 3% Te in SNO+ Phase II DBD corresponds to 8 tonnes of ^{130}Te *isotope* (cost for this much tellurium is only ~$15M)

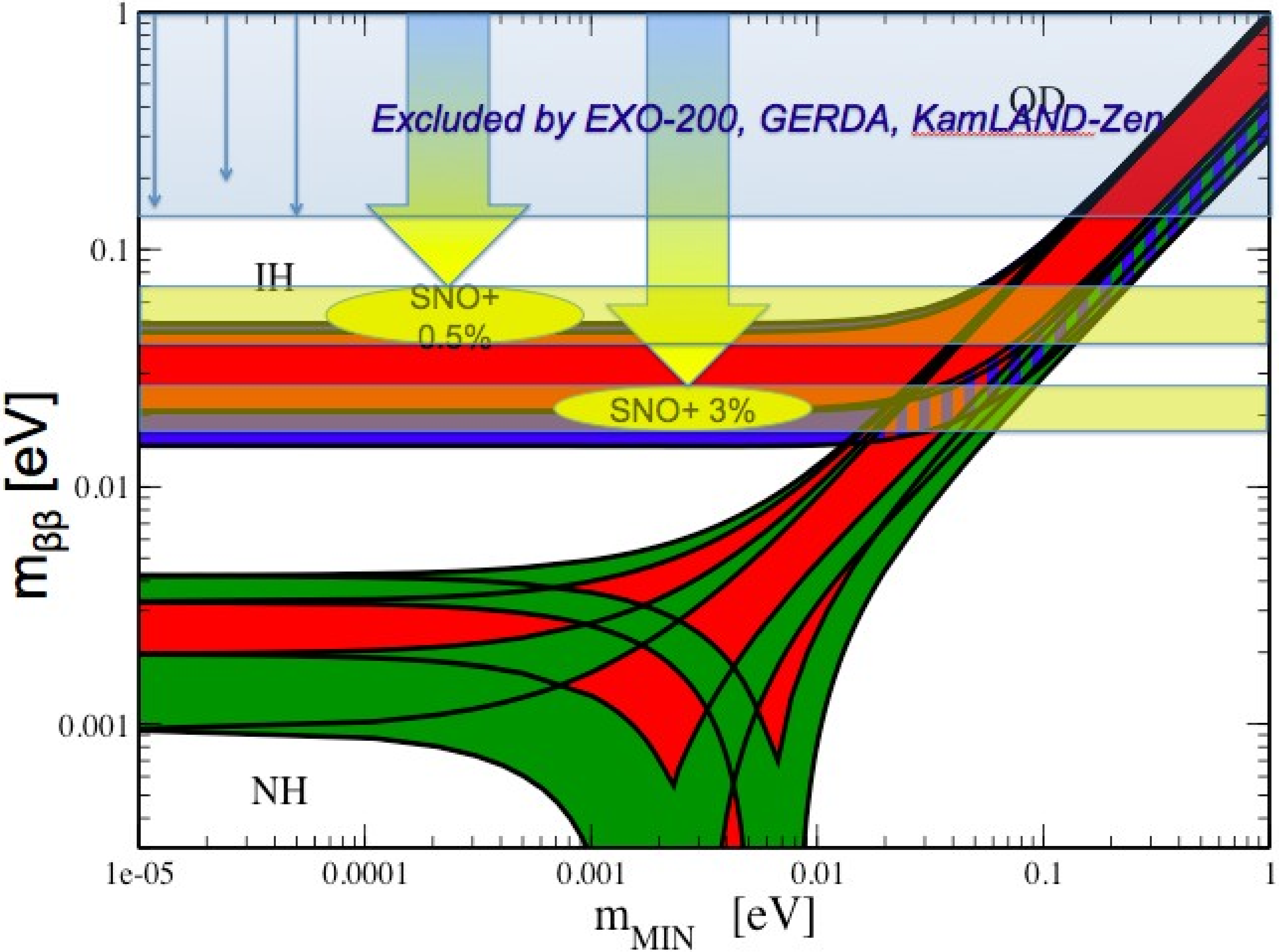
M. Chen

SNO+ Projections

- Spectrum plot (5-year simulated)



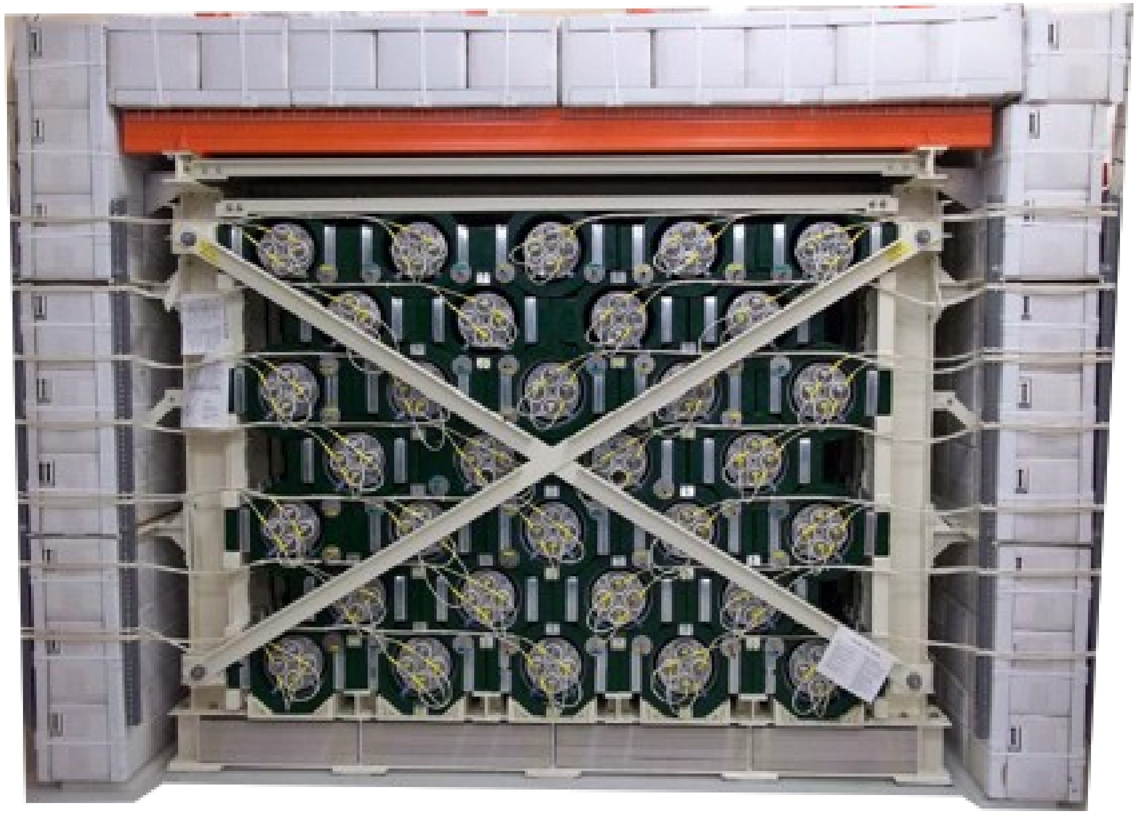
SNO+ Sensitivity Projection



M. Chen

HALO - a Helium and Lead Observatory

"Helium" – because of the availability of the ^{3}He neutron detectors from the final phase of SNO
"Lead" – because of high ν-Pb cross-sections, low n-capture cross-sections, complementary sensitivity to other SN detectors



$$\text{CC:}\quad \nu_e + {}^{208}\text{Pb} \rightarrow {}^{207}\text{Bi} + n + e^-$$

$$\text{NC:}\quad \nu_e + {}^{208}\text{Pb} \rightarrow {}^{206}\text{Bi} + 2n + e^-$$

$$\nu_x + {}^{208}\text{Pb} \rightarrow {}^{207}\text{Pb} + n$$

$$\nu_x + {}^{208}\text{Pb} \rightarrow {}^{206}\text{Pb} + 2n$$

- In 79 tonnes of lead for a SN @ 10kpc†,
  - Assuming FD distribution with T=8 MeV for ν_μ's, ν_τ's.
  - ~ 88 neutrons liberated; ie. ~1.1 n/tonne of Pb

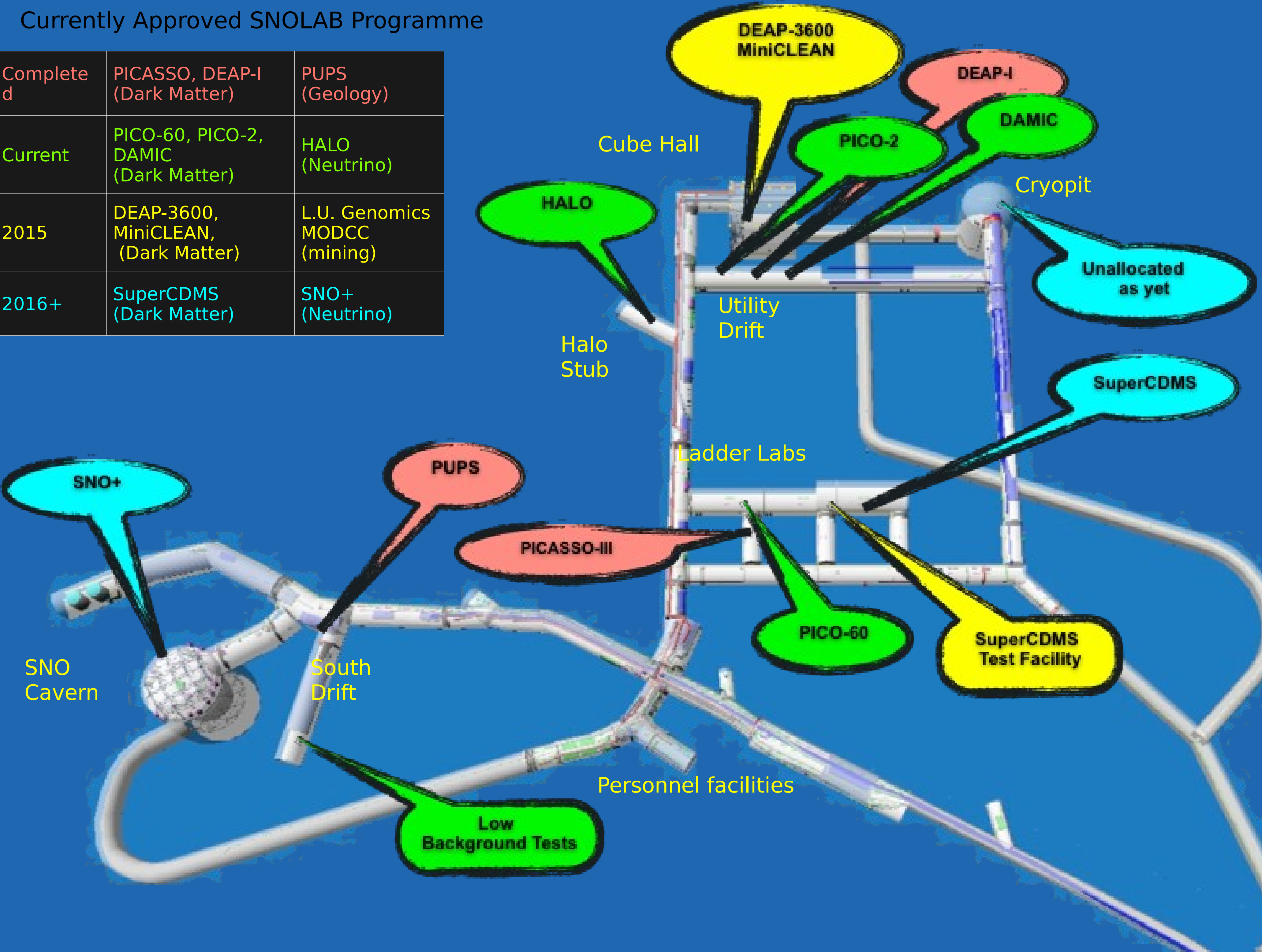
C. Virtue

The SNOLAB Science Programme

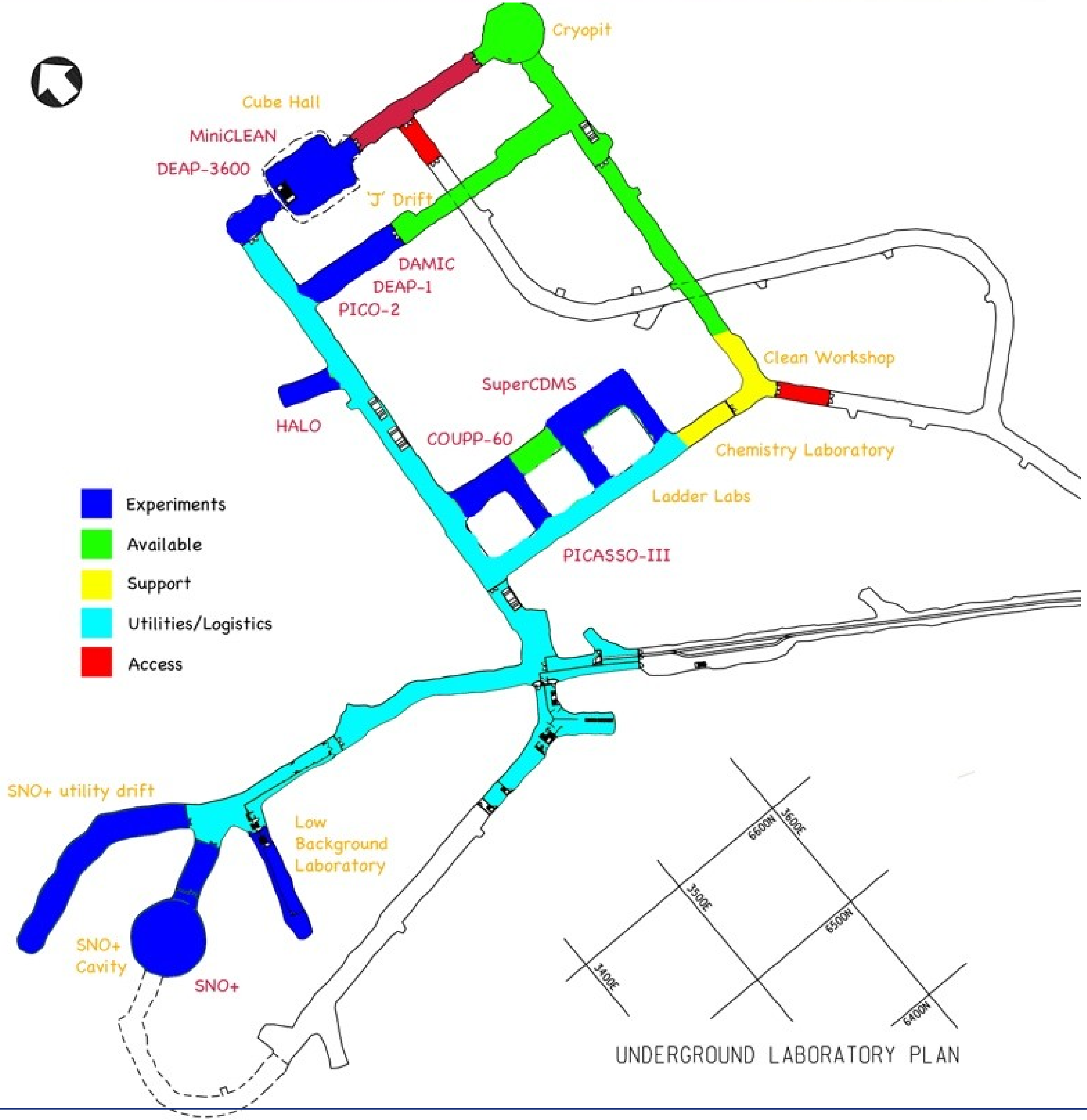
Experiment	Solar ν	0νββ	Dark Matter	S/Nova ν	Geo ν	Other	Space allocated	Status
CEMI						Mining Data Centre	Surface Facility	In Construction
COUPP-4			√				"J"-Drift	Completed
COUPP-60			√				Ladder Labs	Operational
DAMIC			√				"J"-Drift	Operational
DEAP-1			√				"J"-Drift	Completed
DEAP-3600			√				Cube Hall	In Construction
DEAP-50T/CLEAN			√				Cube Hall	Letter of Intent
Ge-1T		√					Cryopit	Letter of Intent
nEXO		√					Cryopit	Request
HALO				√			Halo Stub	Operational
MiniCLEAN			√				Cube Hall	In Construction
PICASSO-III			√				Ladders Labs	Completed
PICO-2			√				"J"-Drift	Operational
PICO-500			√				Ladder Labs	Letter of Intent
PUPS						Seismicity	Various	Completed
SNO+	√	√		√	√		SNO Cavern	In Construction
SuperCDMS			√				Ladder Labs	Commitment
U-Toronto						Deep Subsurface Life	External Drifts	Completed

Currently Approved SNOLAB Programme

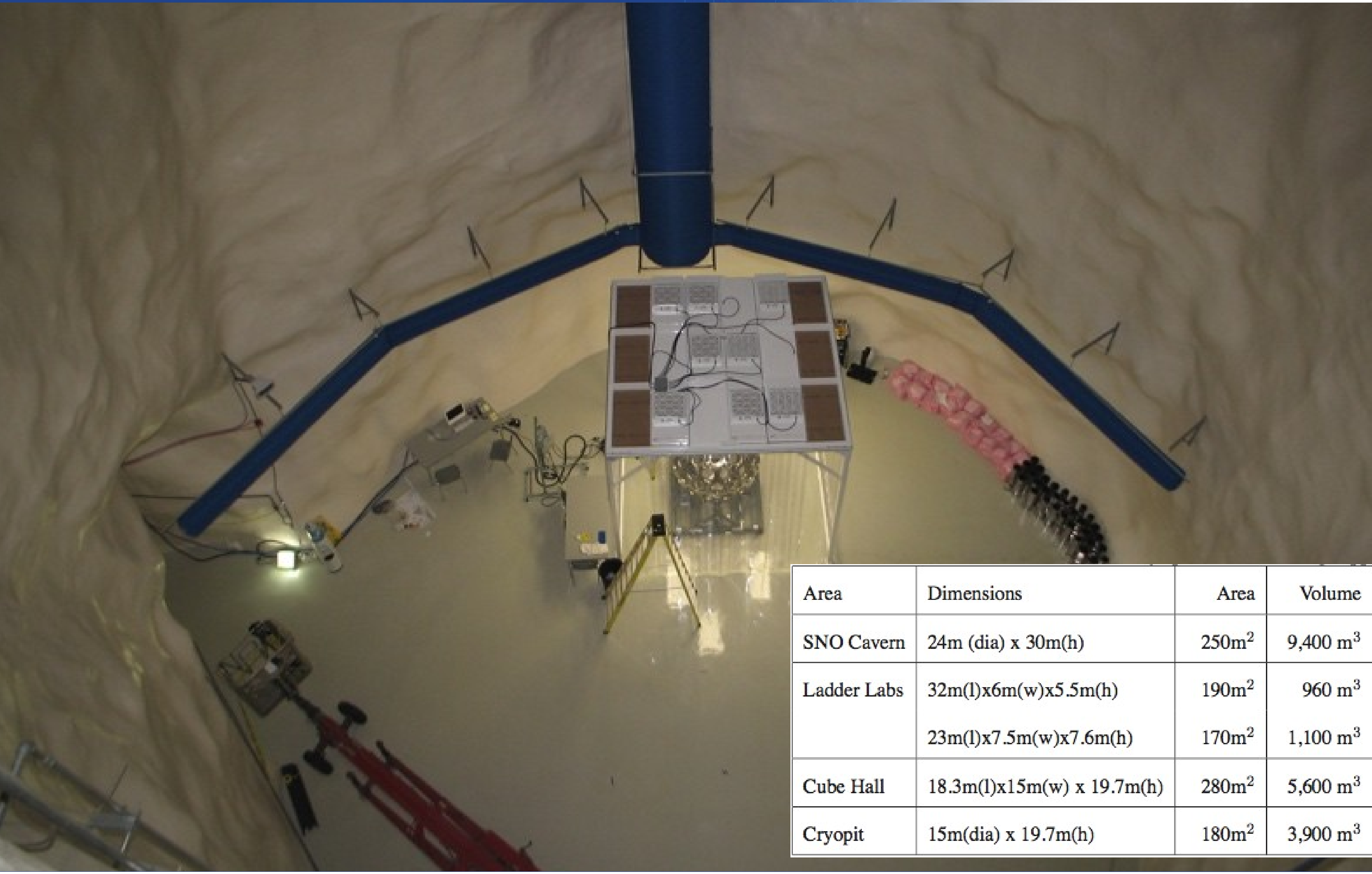
Complete d	PICASSO, DEAP-I (Dark Matter)	PUPS (Geology)
Current	PICO-60, PICO-2, DAMIC (Dark Matter)	HALO (Neutrino)
2015	DEAP-3600, MiniCLEAN, (Dark Matter)	L.U. Genomics MODCC (mining)
2016+	SuperCDMS (Dark Matter)	SNO+ (Neutrino)



Underground Space Allocation



Cryopit staging area



Area	Dimensions	Area	Volume
SNO Cavern	24m (dia) x 30m(h)	250m^2	9,400 m^3
Ladder Labs	32m(l)x6m(w)x5.5m(h)	190m^2	960 m^3
	23m(l)x7.5m(w)x7.6m(h)	170m^2	1,100 m^3
Cube Hall	18.3m(l)x15m(w) x 19.7m(h)	280m^2	5,600 m^3
Cryopit	15m(dia) x 19.7m(h)	180m^2	3,900 m^3

Strategic Planning Process

- Next SNOLAB Strategic Plan will need to be in place 2017-2022
- Anticipated process (under alignment with other Canadian strategic processes)
  - Community engagement through Town Meetings (SNOLAB / TRIUMF?)
    - expected during Spring 2016
  - Steering committee to manage process (Community lead)
  - Feed into writing group (SNOLAB lead)
  - Draft Strategic plan iterates with community
  - Finalisation by Board
  - Release by September 2016
- In addition, the next Future Projects Meeting will take place in conjunction with the EAC meeting
  - August 24th/25th: Future Projects Meeting
  - August 26th: SEF/ST&RC Meeting (internal SNOLAB user engagement)
  - August 27th/28th: EAC Meeting

Outlook

- SNOLAB provides a world-class infrastructure for rare event and weak interaction studies (presently) at the kilo-tonne scale
- SNOLAB initial science programme developing well:
  - Initial science programme operational and has already delivered world-leading science (PICASSO, COUPP-4)
  - PICASSO, COUPP-4, DAMIC-10 completed science run
  - HALO, PICO-2 on-line and COUPP-60 operational
  - DAMIC-100 upgrade underway
  - Three large scale detectors continue construction
    - DEAP-3600, SNO+, MiniCLEAN
  - Super-CDMS now approved for deployment
- International context evolving over the next few years
- Global community looking towards co-operation in both dark matter and natural neutrino source experiments