The SNOLAB science programme

Nigel Smith
SNOLAB

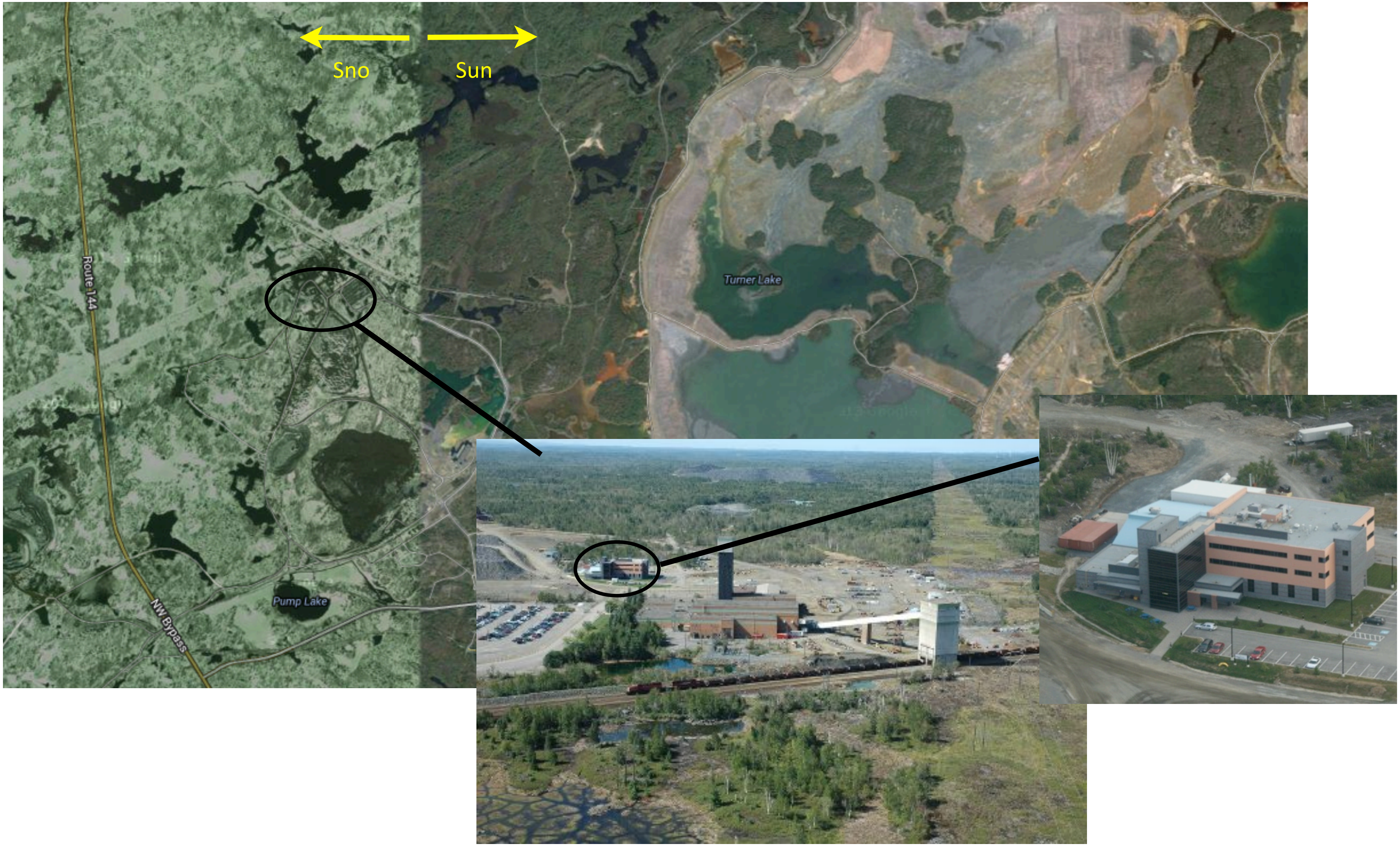
The SNOLAB Science Programme

- 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

The SNOLAB Facility

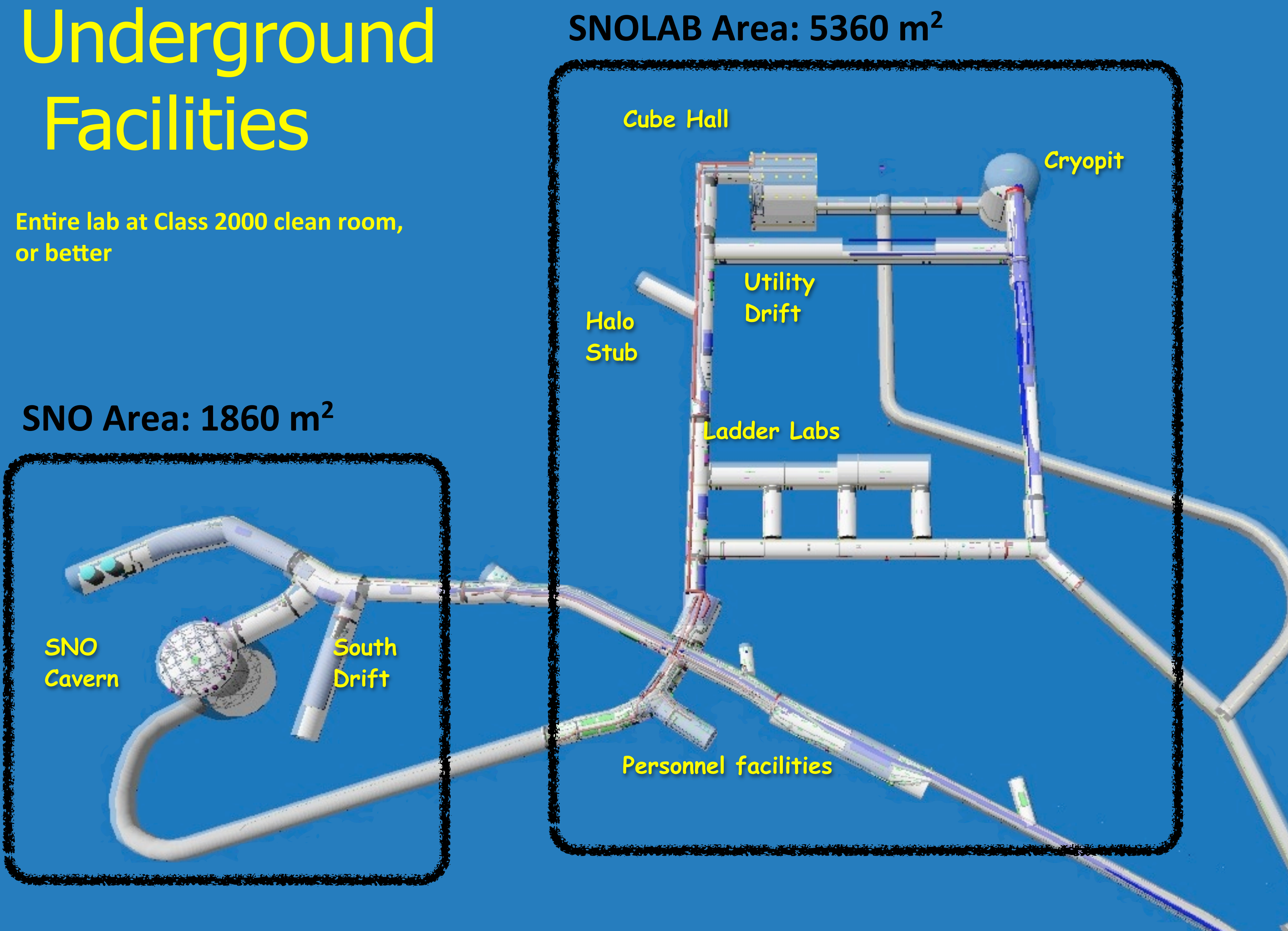
- Operated in the Creighton nickel mine, near Sudbury, Ontario, hosted by Vale.
  - Five University partners (Alberta, Carleton, Laurentian, Montréal, Queen's)
- Underground campus at 6800' level, 0.27μ/m^2/day
- Entire lab at class-2000, or better, to mitigate against background contamination of experiments.
- 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 Facility Location



Underground Facilities

Entire lab at Class 2000 clean room, or better




Lab
Entry


Cryopit

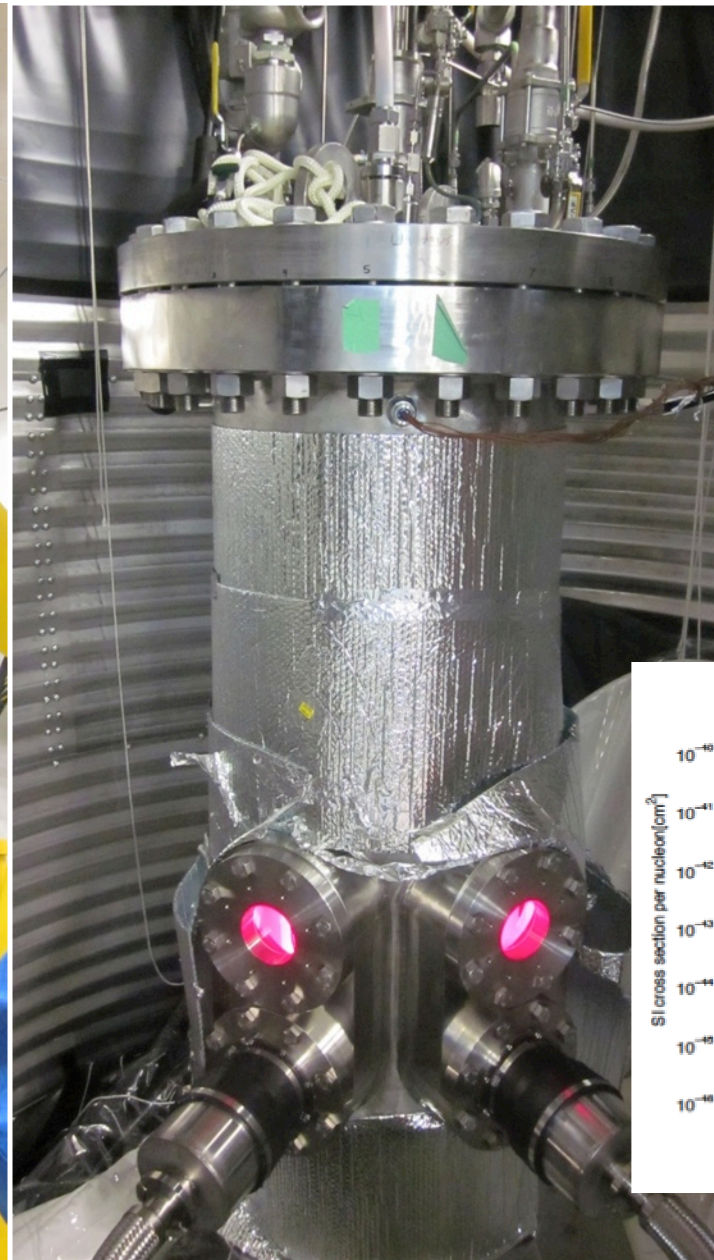

Ladder
Labs

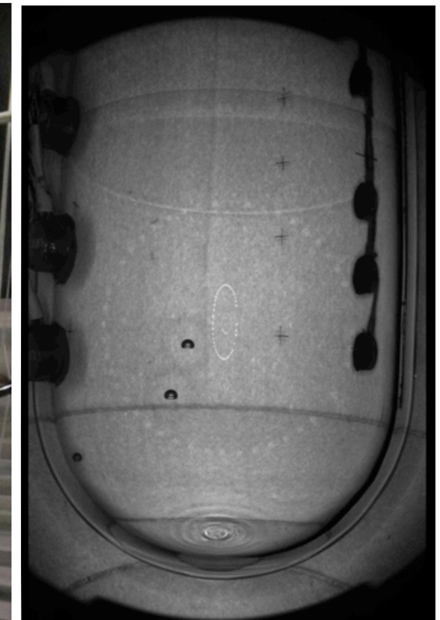
Current programme: Dark Matter at SNOLAB

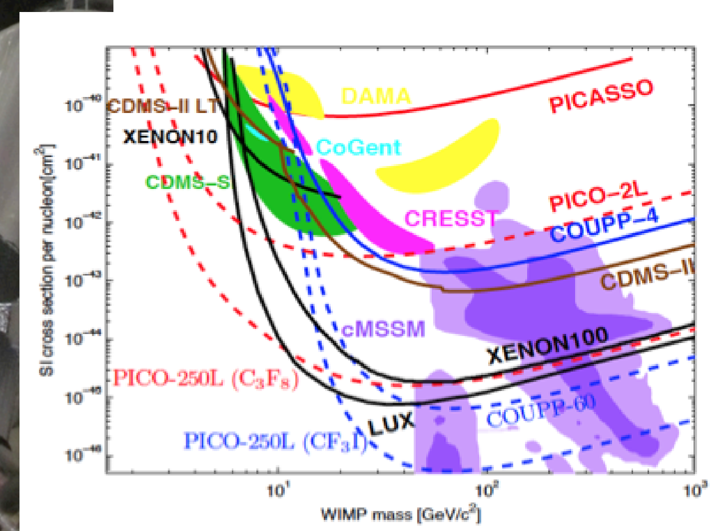
SNOLAB

- 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.

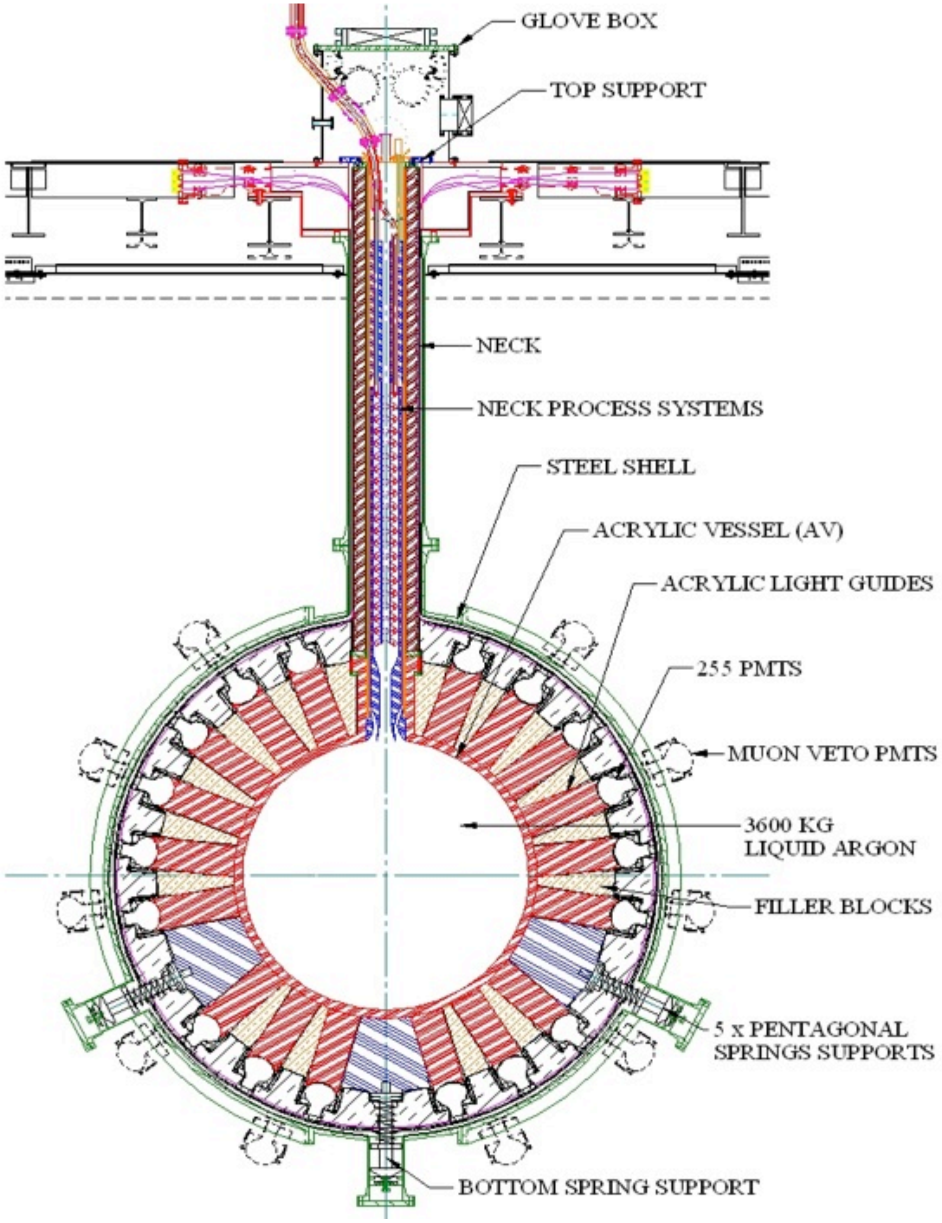
COUPP-60 Operations







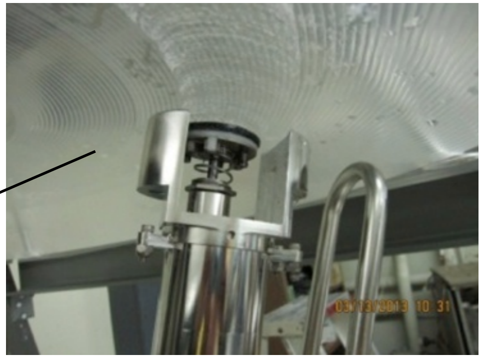
DEAP-3600



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



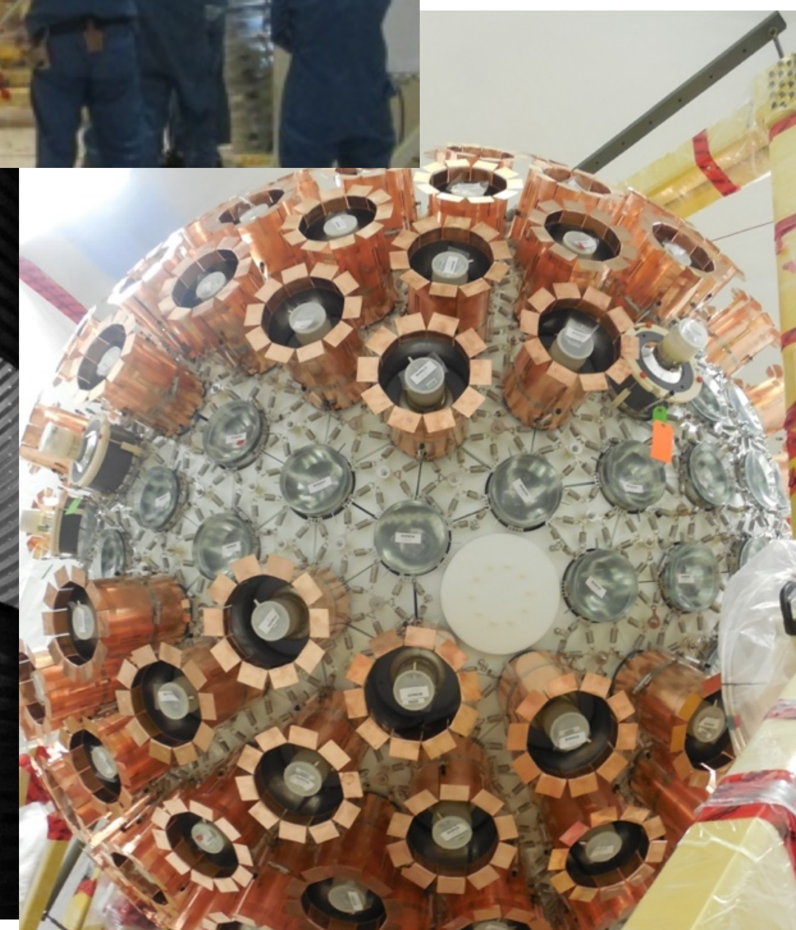
255 Hamamatsu
R5912 HQE PMTs 8-inch
(32% QE, 75% coverage)

50 cm light guides +
PE shielding provide
neutron moderation

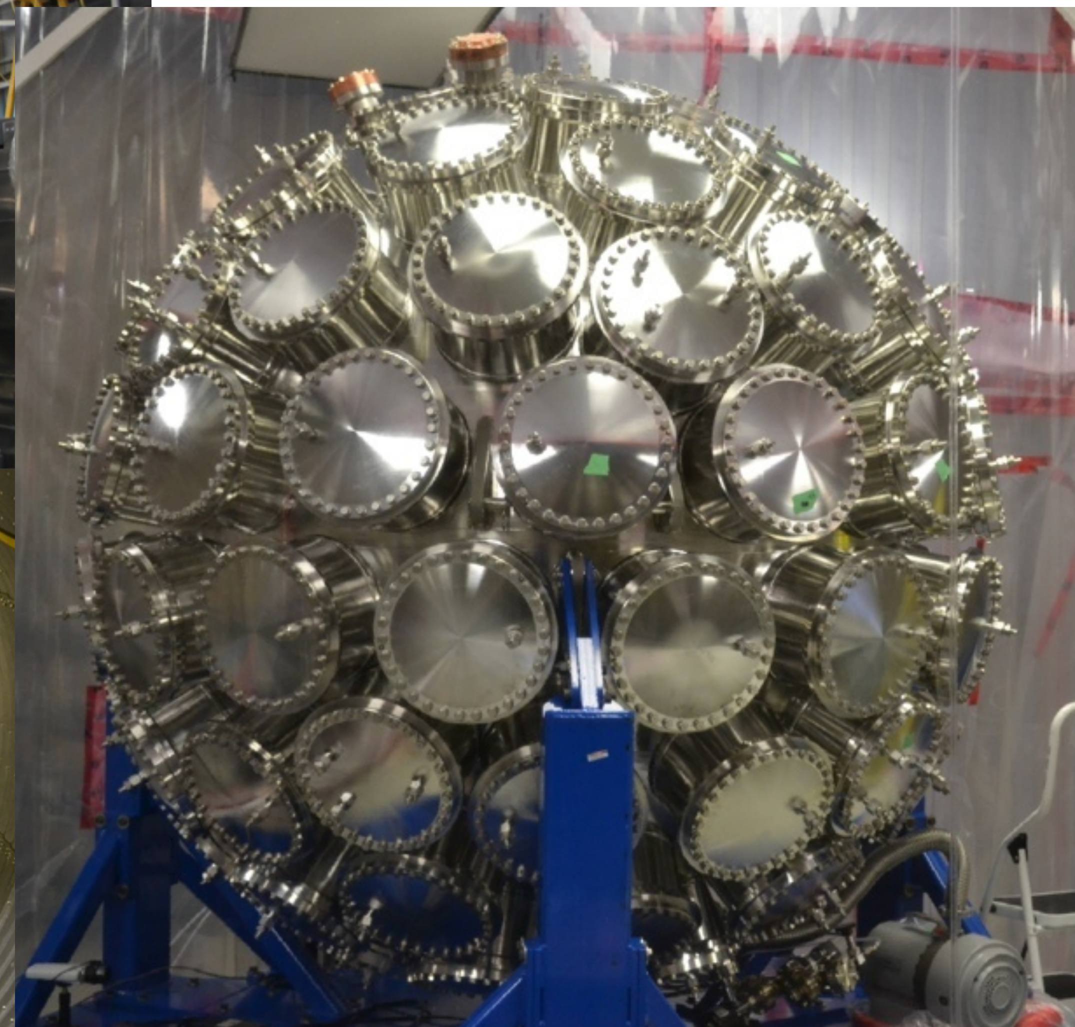
Detector in 8 m water
shield at SNOLAB

DEAP-3600

- Construction sequence of DEAP-3600 dark matter detector



MiniCLEAN Construction



SuperCDMS Project Go-ahead

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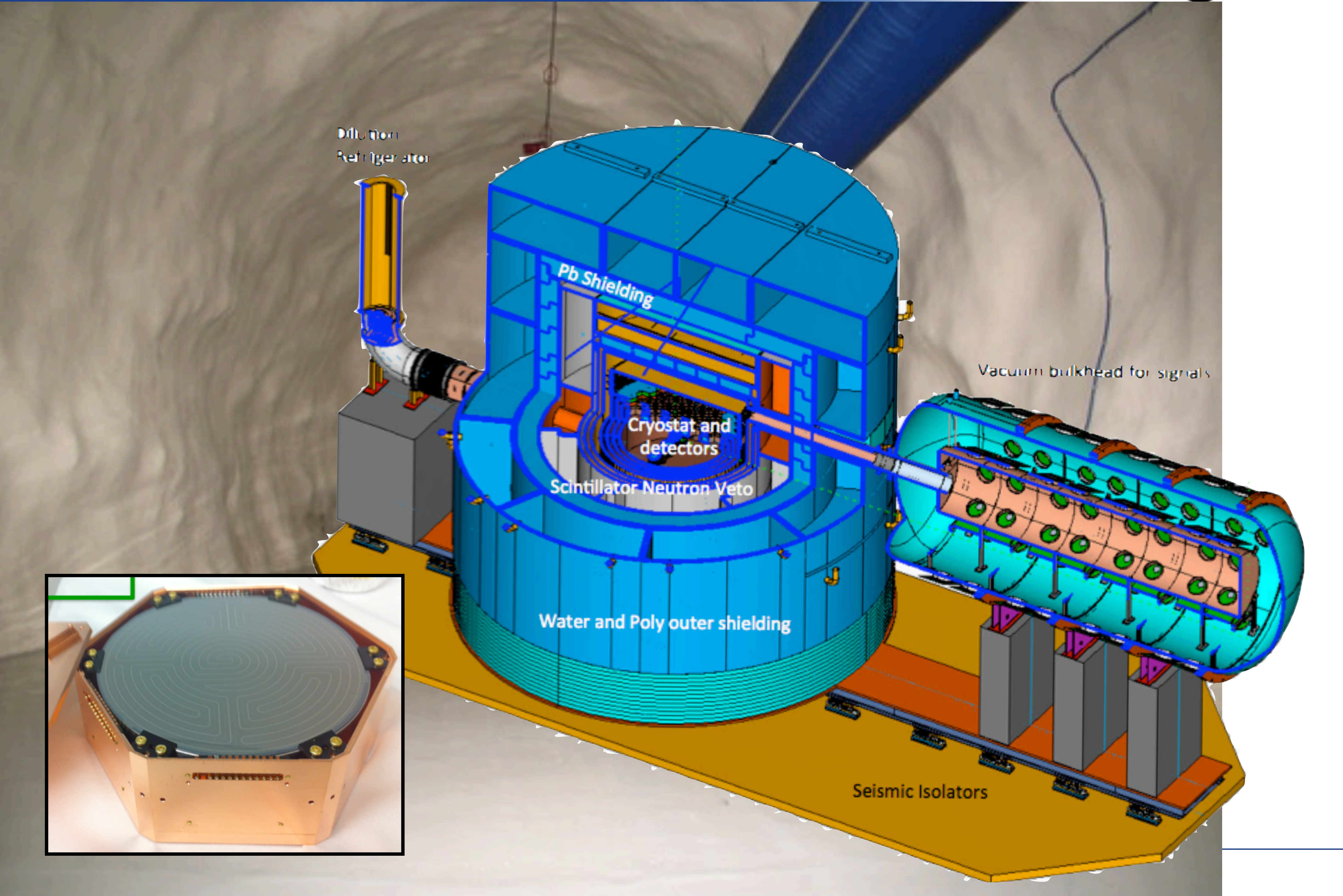
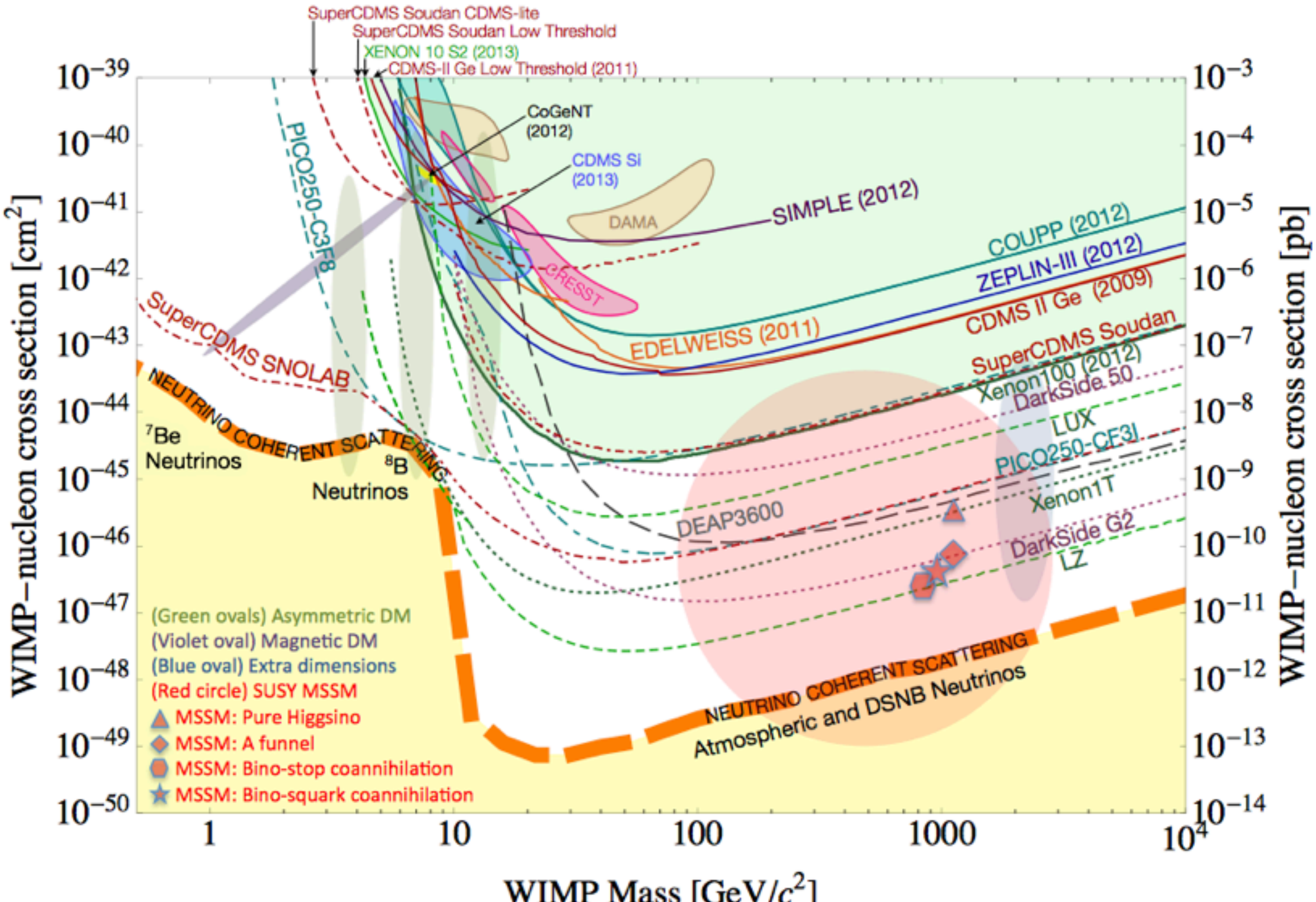


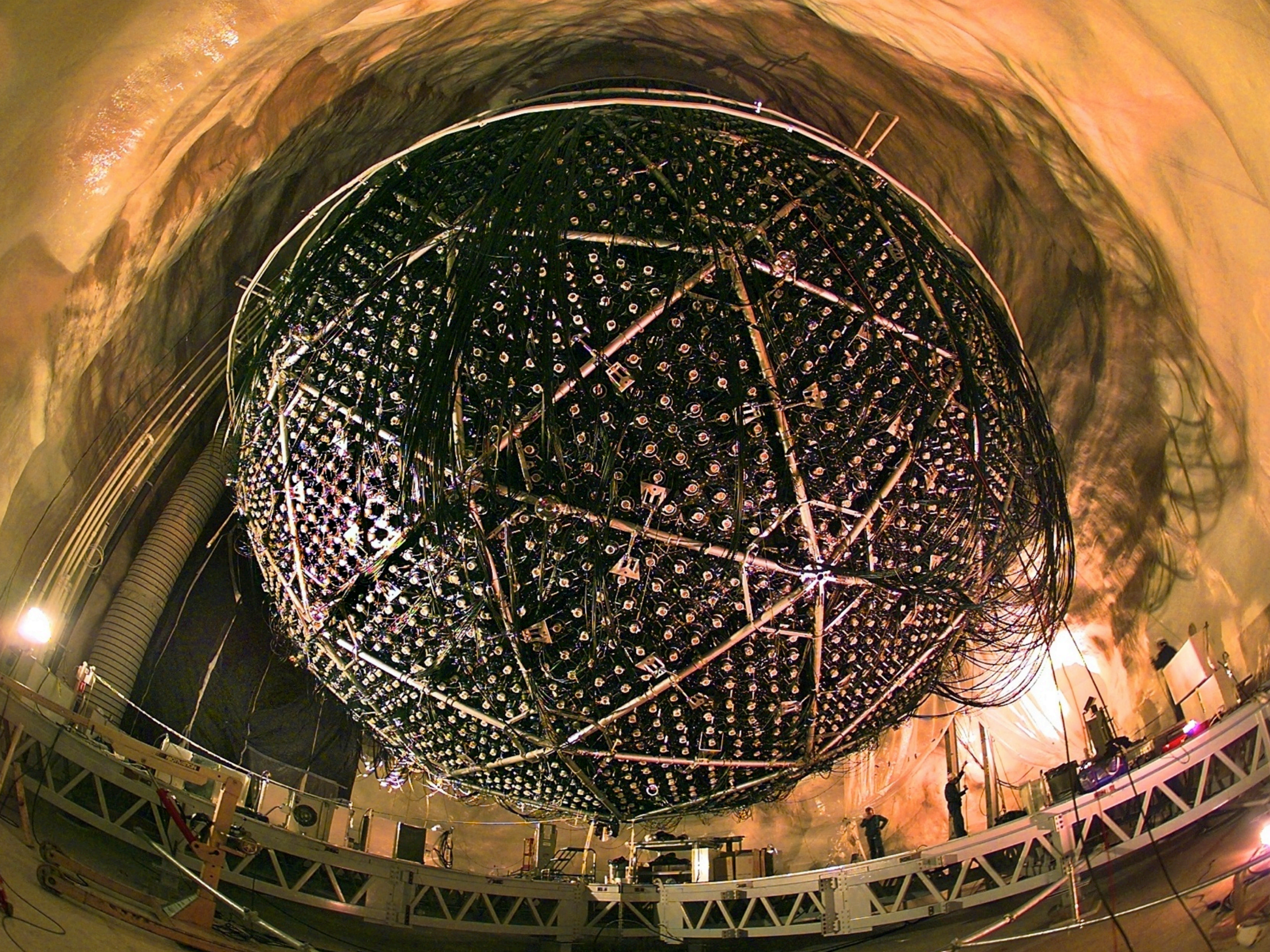
Spin independent limit plot



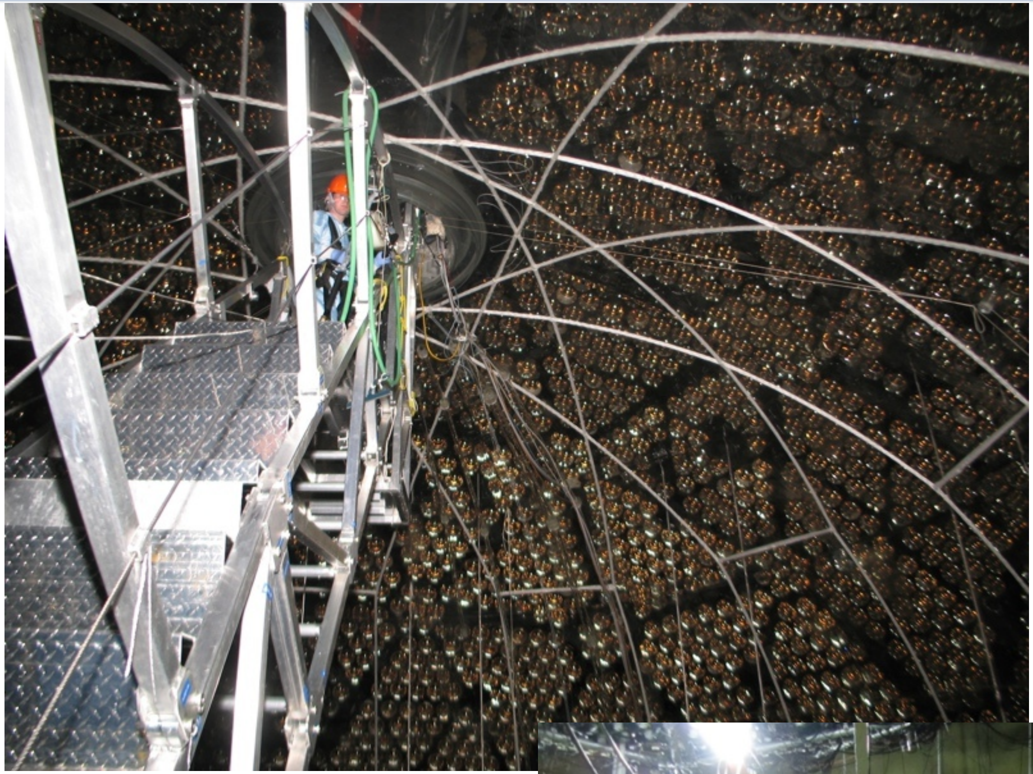
Plot from SNOMASS Review

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)
    - reactor neutrinos (integrated flux from Canadian reactors)
- 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.
- HALO: Dedicated Supernova watch experiment
  - Charged/neutral current interactions in lead
  - Re-use of detectors (NCDs) and material (Pb) from other systems
  - Operational 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....

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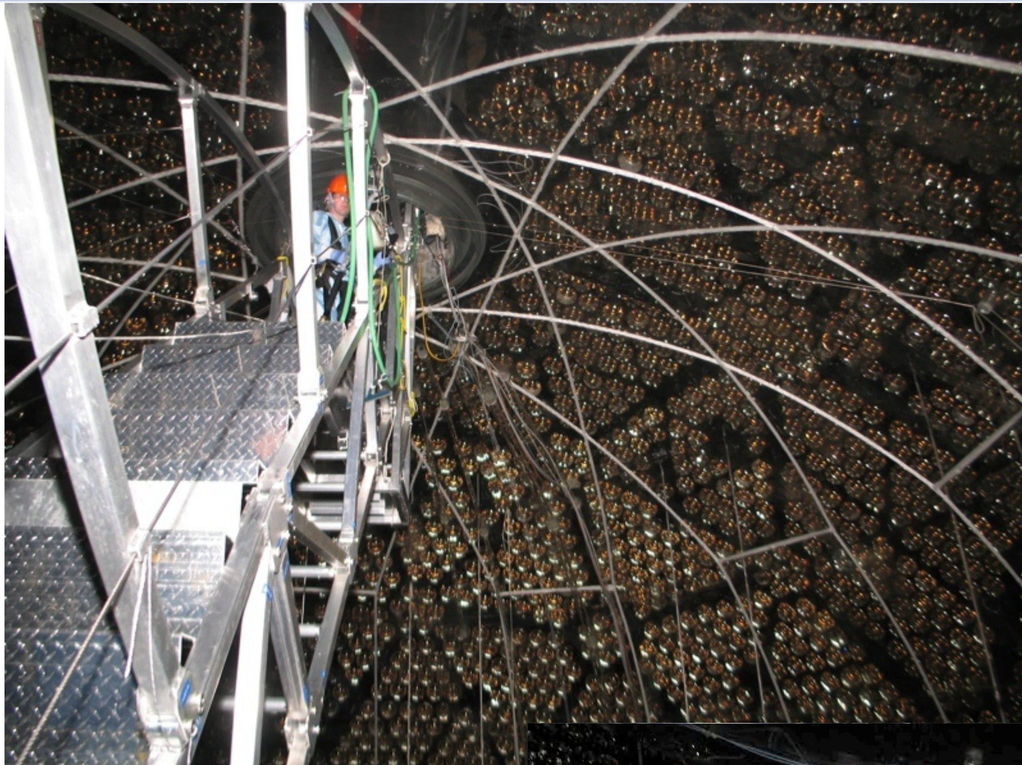

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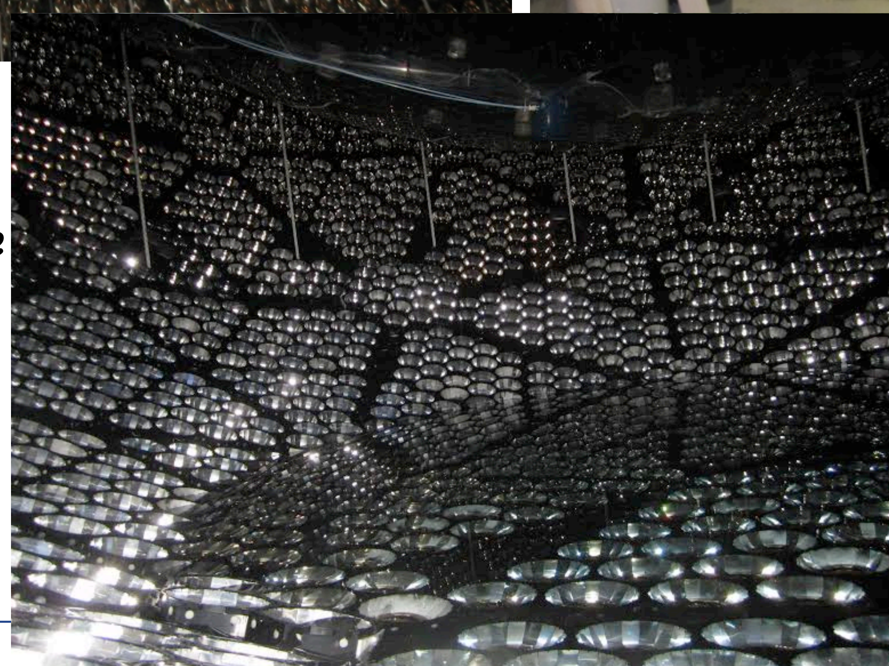

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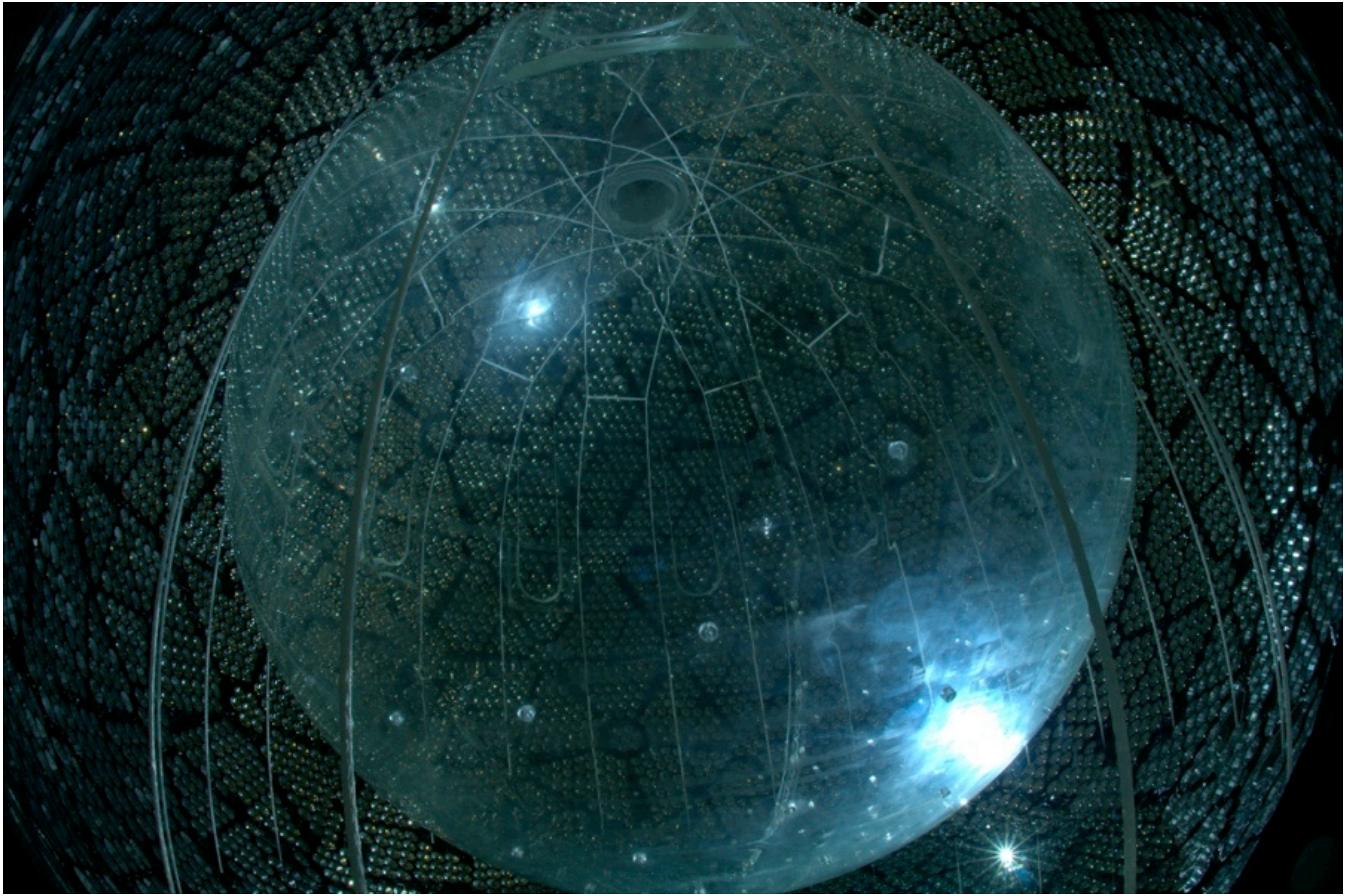
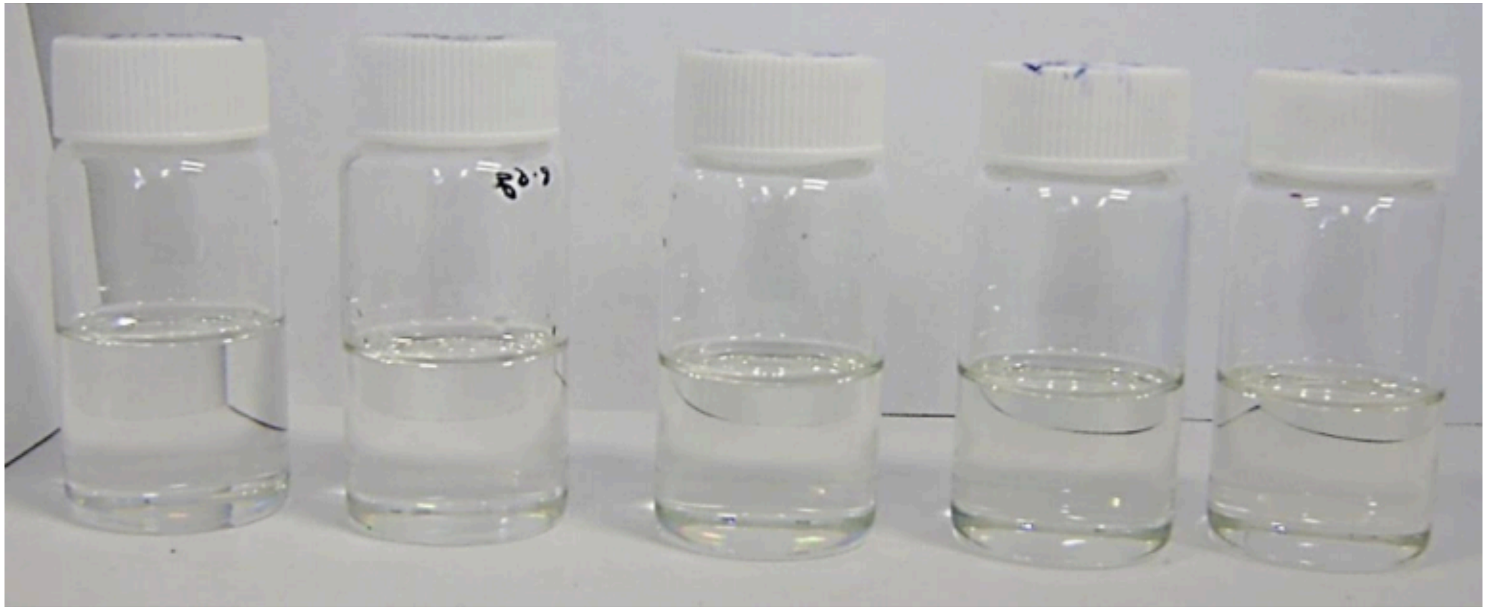
SNO+ Rope Net in place



Loading of LAB with tellurium

Percent Loading of Tellurium is Feasible

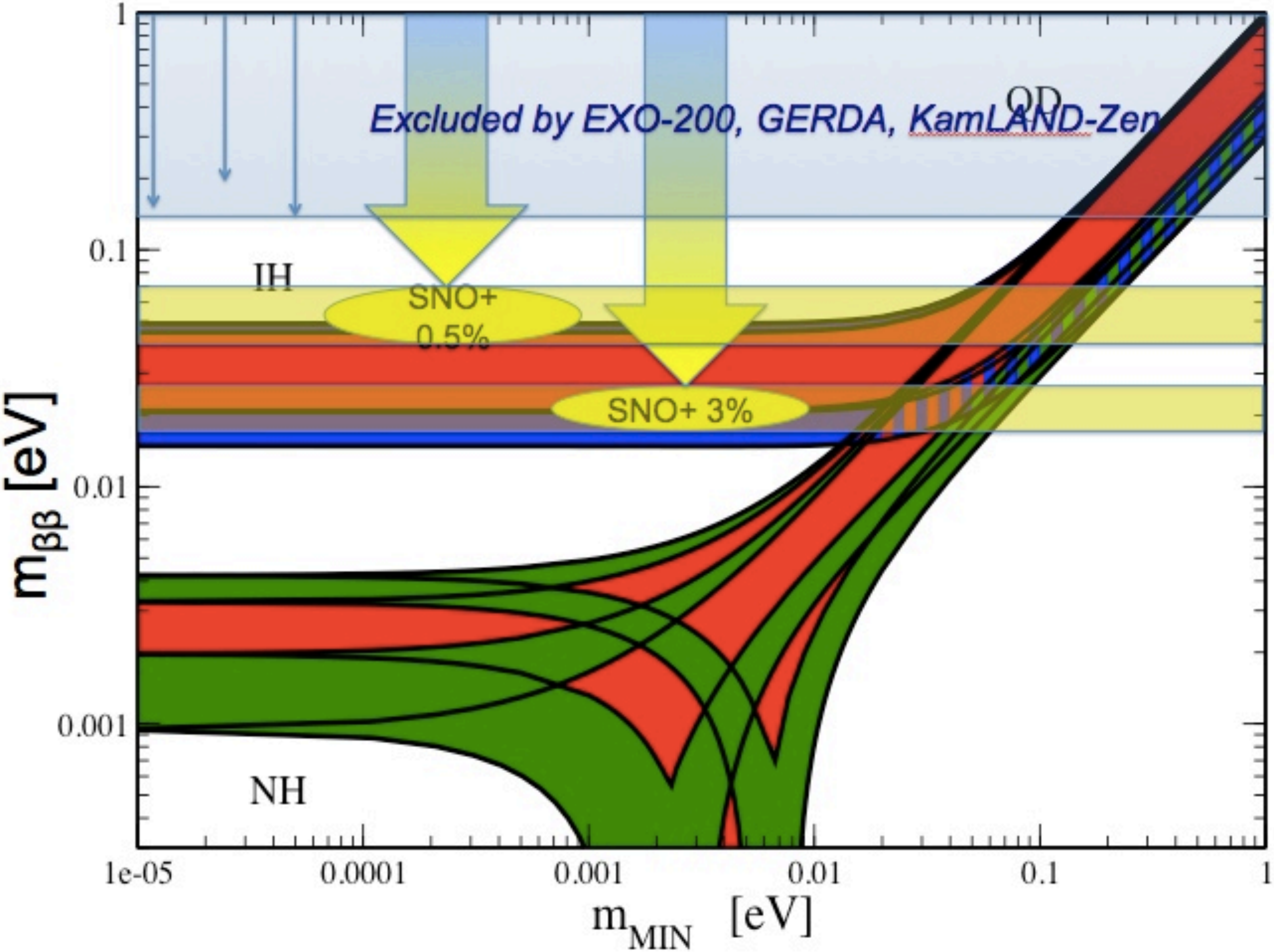
- 0.3%, 0.5%, 1%, 3%, 5% (from left to right)



- 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

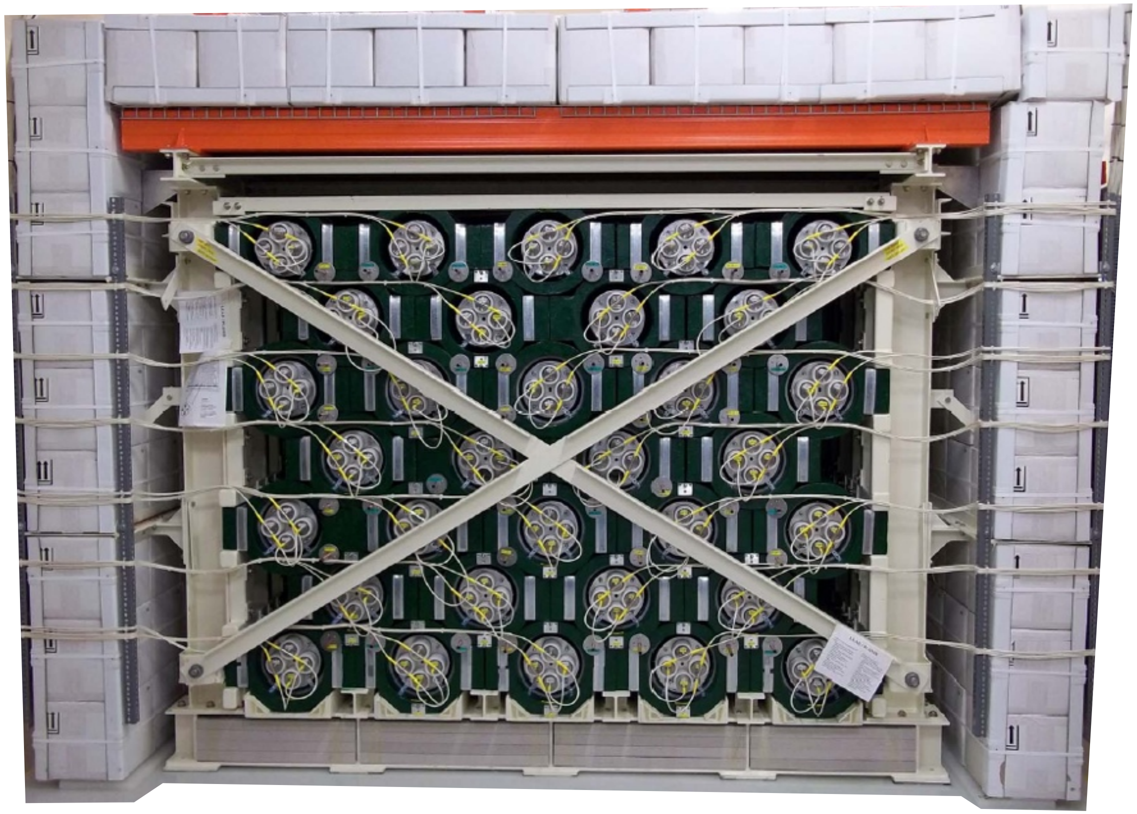
SNO+ Sensitivity Projection



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



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

NC:

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

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

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

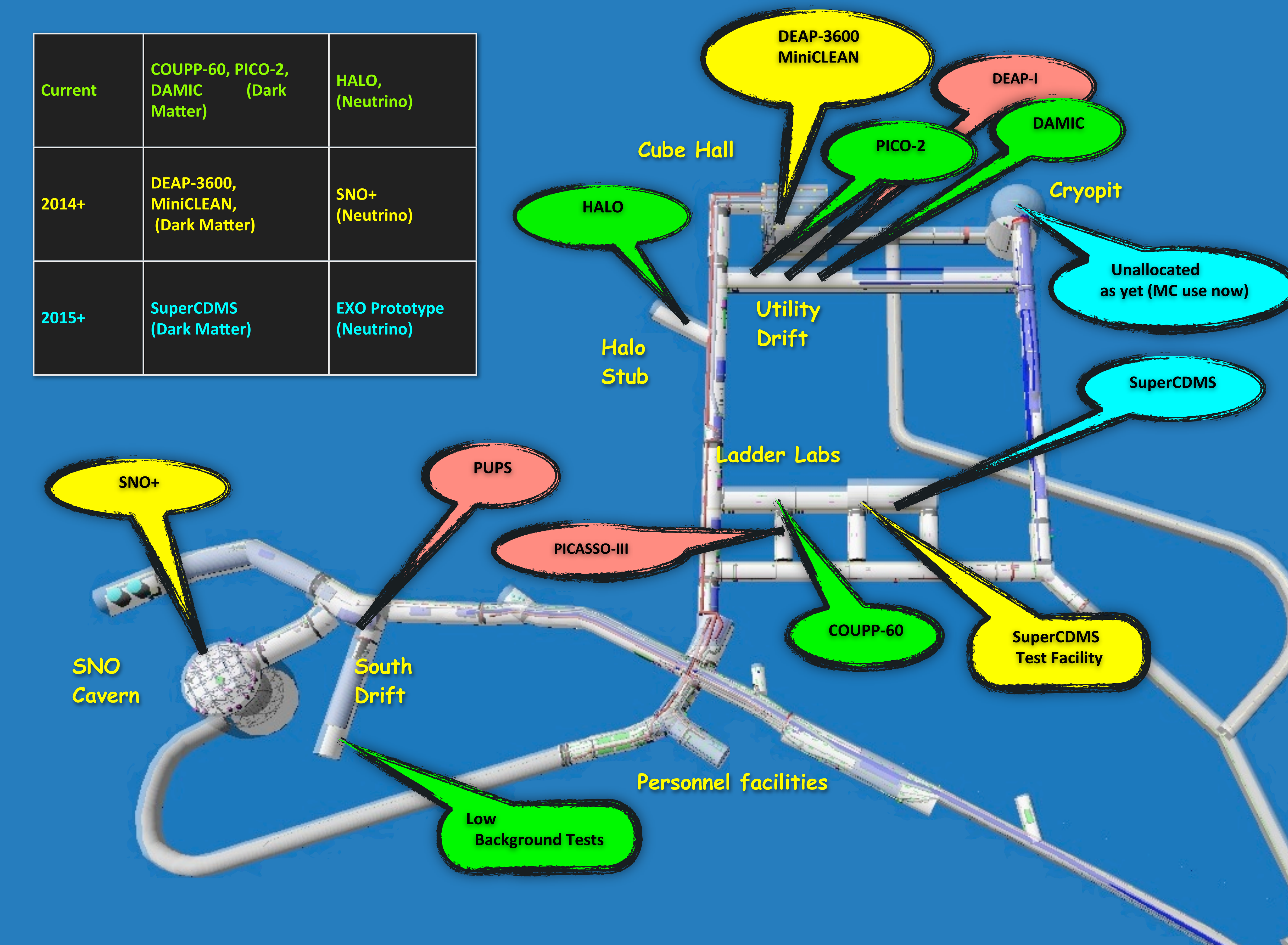
- In 79 tonnes of lead for a SN @ 10kpc†,
  - Assuming FD distribution with T=8 MeV for ν_μ's, ν_τ's.
  - ~ 88 neutrons liberated; ie. ~1.1 n/tonne of Pb

C. Virtue

The SNOLAB Science Programme

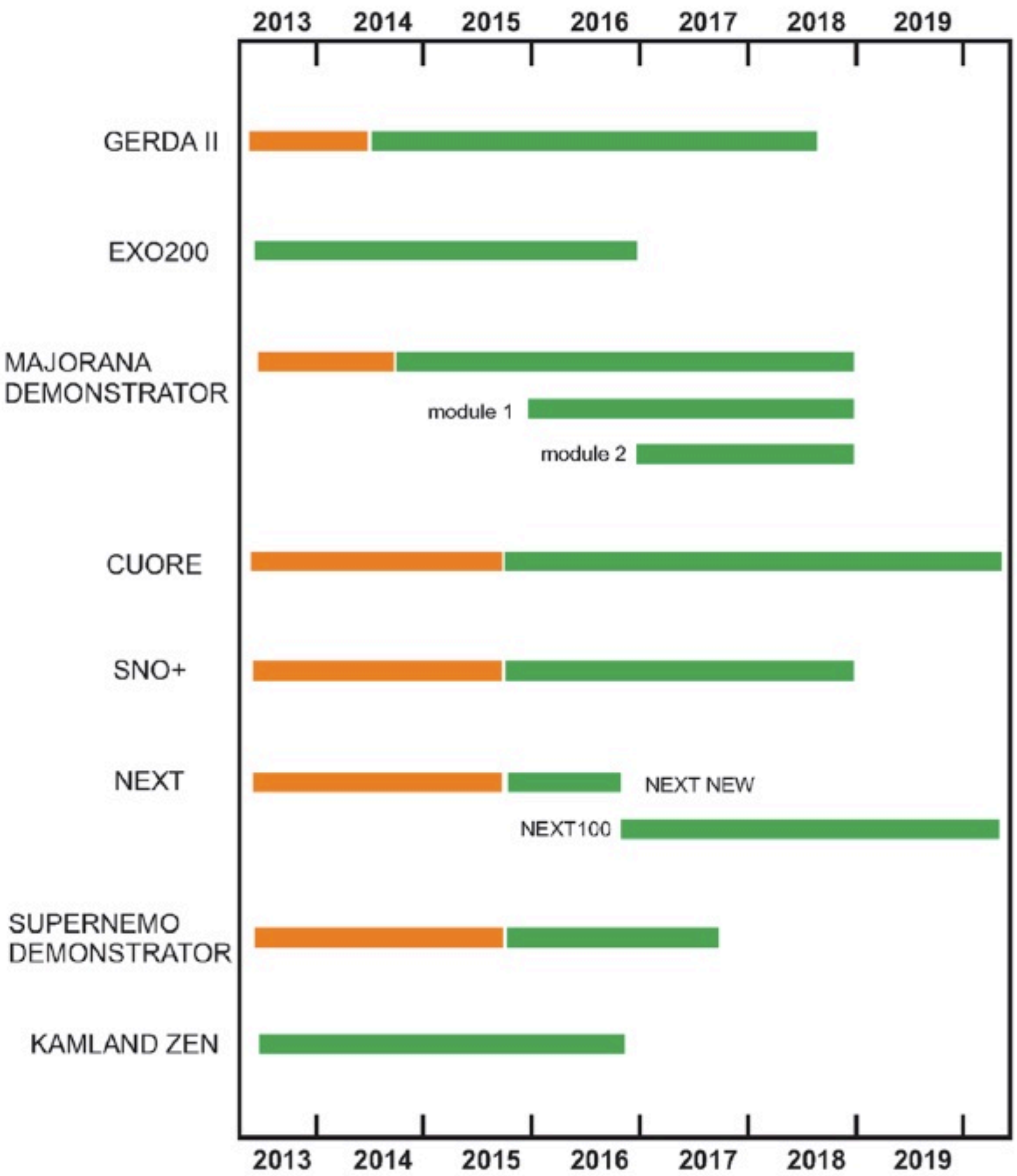
Experiment	Solar ν	0νββ	Dark Matter	S/Nova ν	Geo ν	Other	Space allocated	Status
CEMI						Mining Data Centre	Surface Facility	In Construction
COUPP-4			√				"J"-Drift	Completed
COUPP-60			√				Ladder Labs	Operational
DAMIC			√				"J"-Drift	Operational
DEAP-1			√				"J"-Drift	Completed
DEAP-3600			√				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

Current	COUPP-60, PICO-2, DAMIC (Dark Matter)	HALO, (Neutrino)
2014+	DEAP-3600, MiniCLEAN, (Dark Matter)	SNO+ (Neutrino)
2015+	SuperCDMS (Dark Matter)	EXO Prototype (Neutrino)

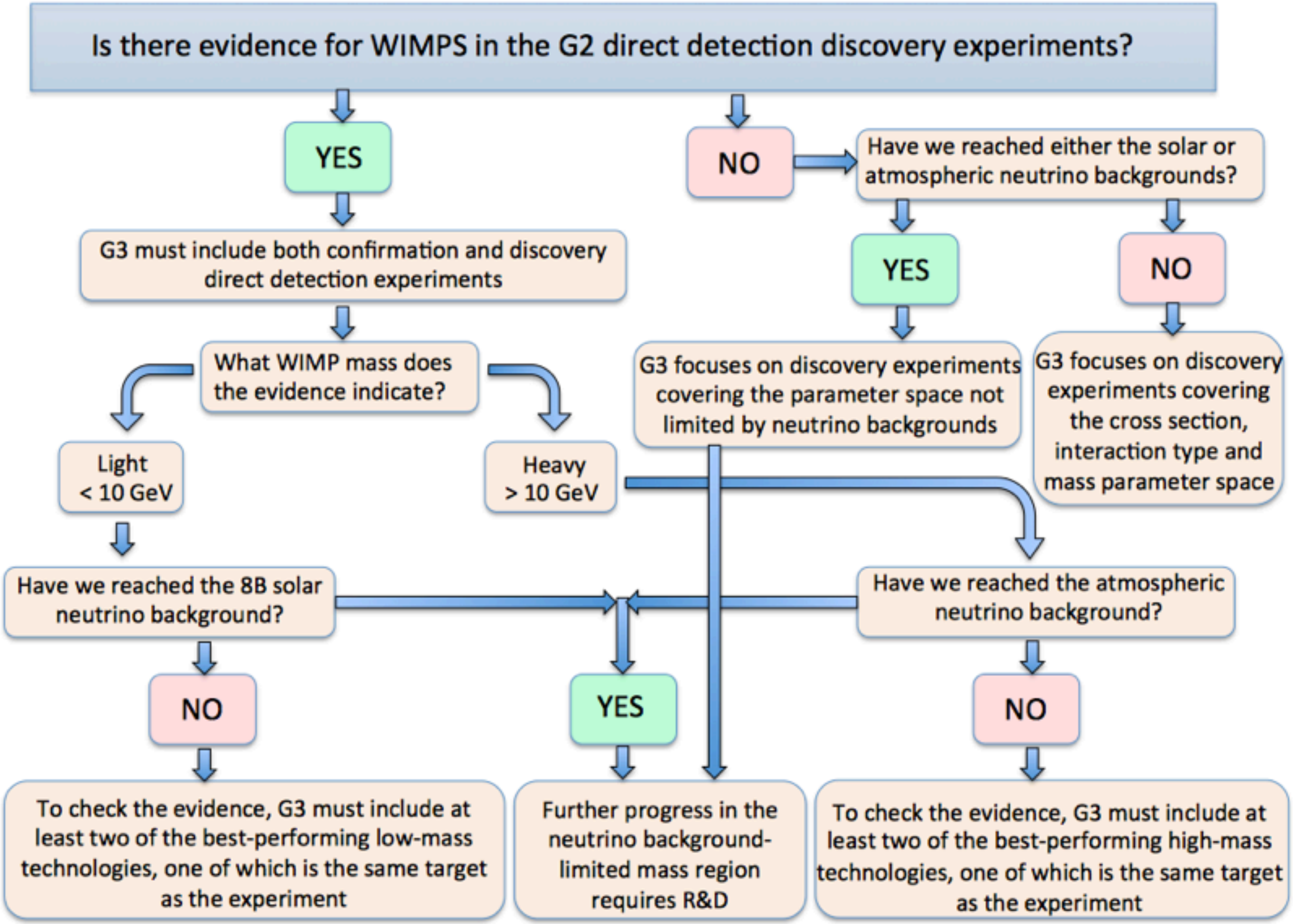


U.S. NSAC Timeline

- Justification of 2-3 year horizon for decision process
- GERDA/Majorana in discussion of a single future detector
- SNO+, EXO, nEXO with Canadian involvement



Snowmass decision mapping



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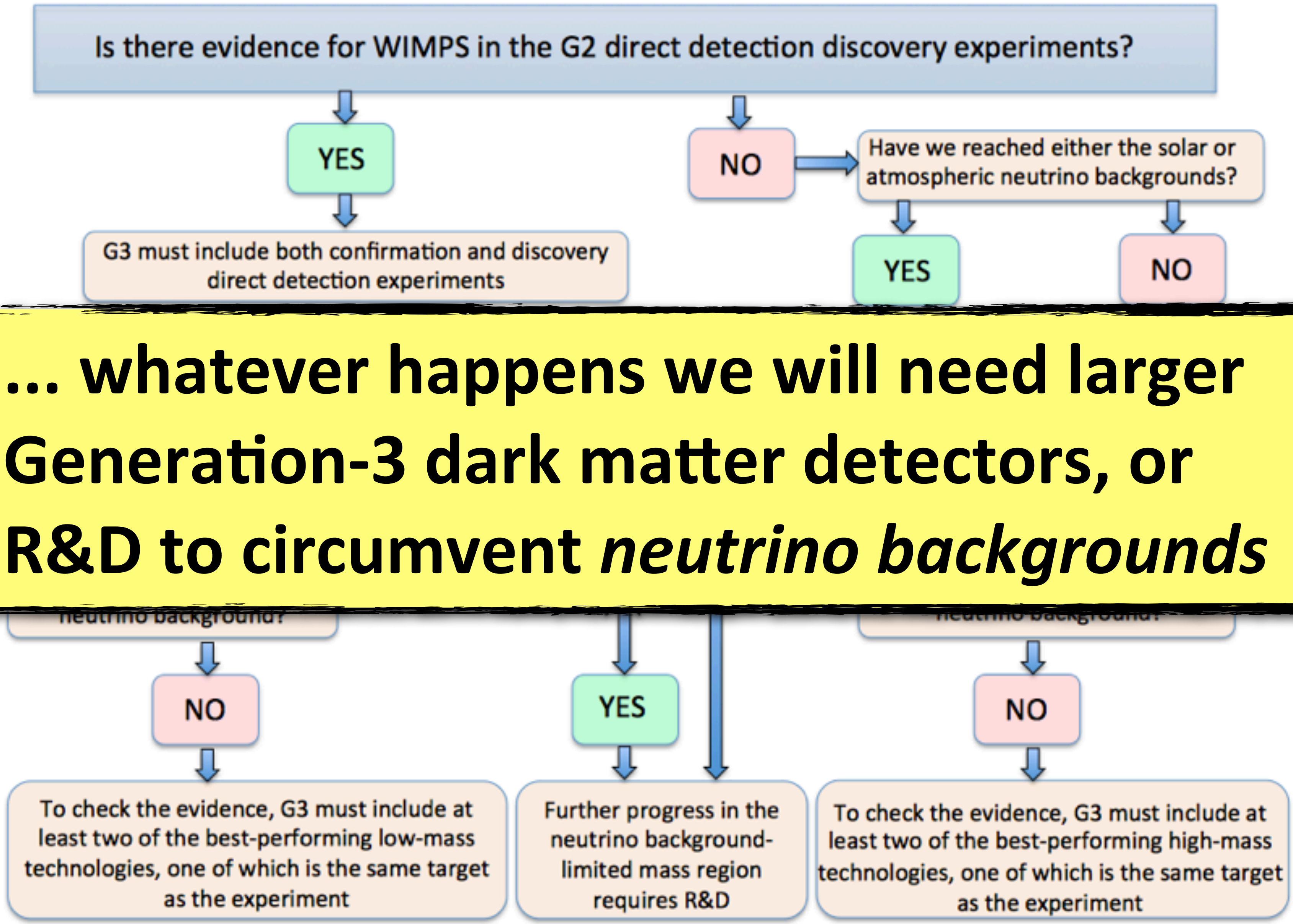

... whatever happens we will need larger Generation-3 dark matter detectors, or R&D to circumvent *neutrino backgrounds*

U.S. DOE/NSF 'G2' Process

- Following P5 report, additional funds directed to US second generation Dark Matter Programme from initial call for proposals
- "*The DOE Office of High Energy Physics and the NSF Physics Division have jointly selected a portfolio of projects for the "second generation" of direct detection dark matter experiments. We are pleased to announce that the joint DOE/NSF second-generation program will include the LZ and SuperCDMS-SNOLAB experiments with their collective sensitivity to both low and high mass WIMPS, and ADMX-Gen2 to search for axions. It will also include a program of R&D to test and develop technologies for future experiments, consistent with the recent P5 recommendations. The agencies will work with the proponents to develop project plans that can achieve their compelling science goals as expeditiously as possible*.
- PICO-250 deemed not yet ready for decision; additional R&D support available to understand detector performance

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