Ultra-Low Background Measurement Capabilities At SNOLAB

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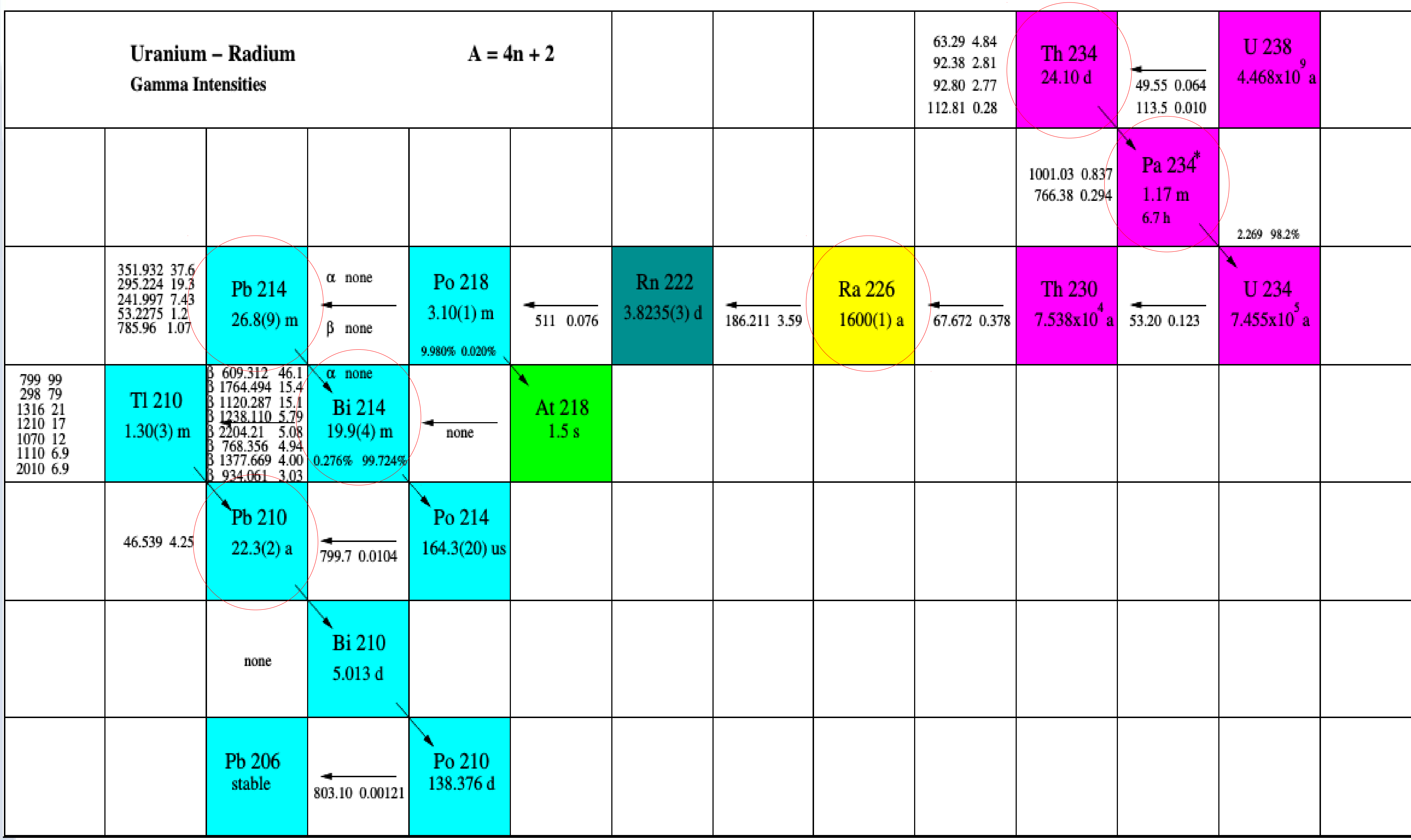
Brief Outline

- Motivation for low background counters
  - Advantages of being deep
- Current facilities in operation at SNOLAB
- The Case for creating expanded and coordinated facilities
- Plans for SNOLAB's new low background counting laboratory
- Future Low Background Counters and Facilities
- Global facilities coordination and Low Background Database

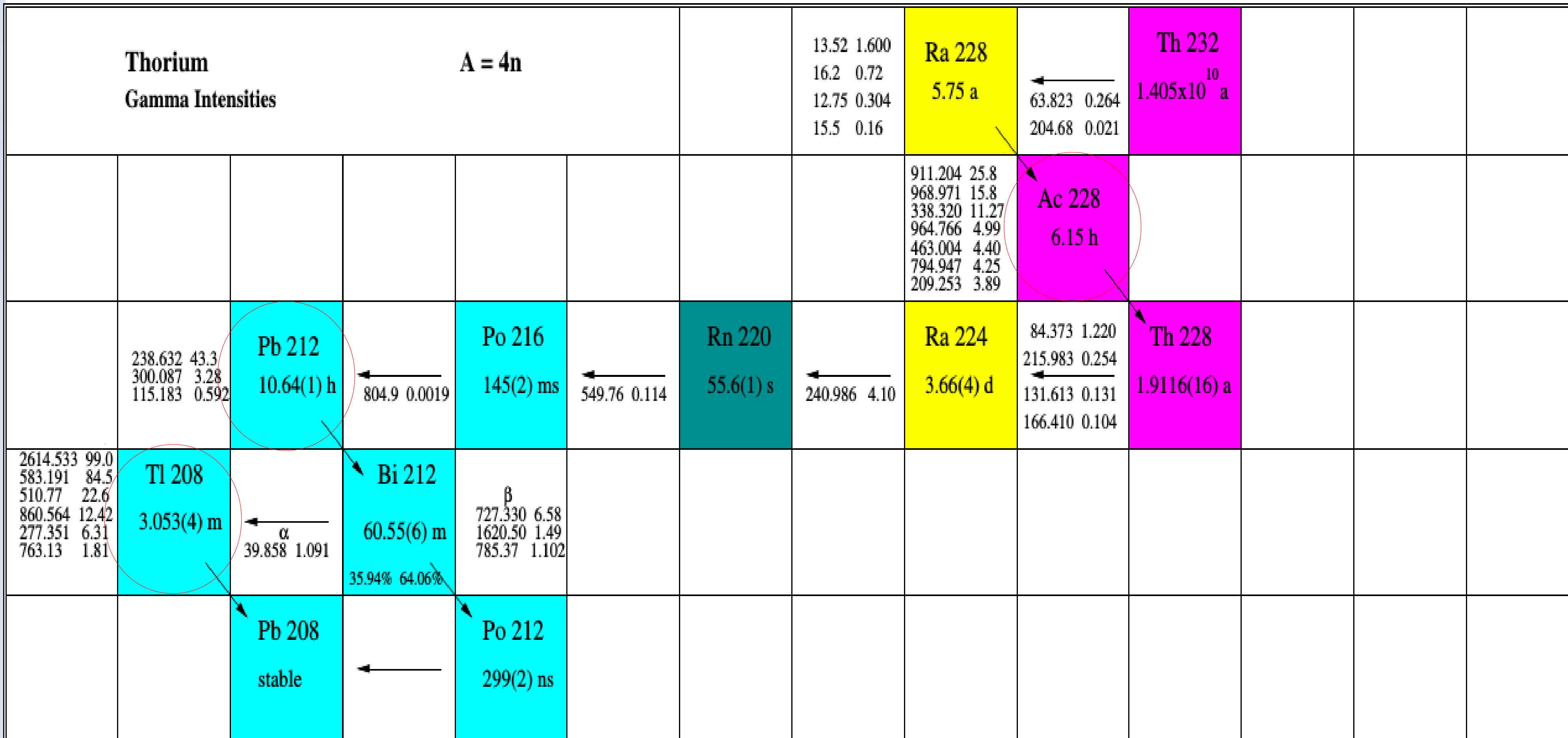
Motivation

- Experiments searching for dark matter and studying properties of neutrinos require very low levels of radioactive backgrounds both in their own construction materials and in the surrounding environment.
- This requires that the fabrication materials have low concentrations of radioactive chain elements (^{238}U, ^{232}Th and ^{40}K), often well below ppt levels.
- These levels are below that generally accessible by chemical analytical techniques, and assay methods are often done by radiation counting.
- Another application is counting of detector target fluids, either as part of a QC requirement, diagnostics or purification testing.
- Backgrounds of interest can be alphas, betas, gammas or neutrons, depending upon the experiment and the component in question. The radiation could be direct or via leaching or emanation. Thus, several detector technologies are used.
- The counting detectors themselves must be very low in background, which requires them to radioactively clean and underground, and fabricated and shielded with low background materials.

Uranium Decay Chain



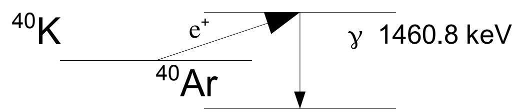
Thorium Decay Chain



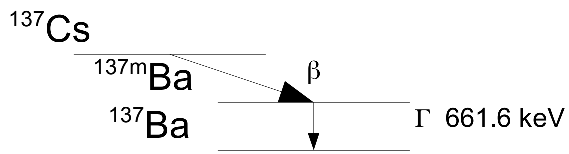
Other Interesting Isotopes

Usually Present:

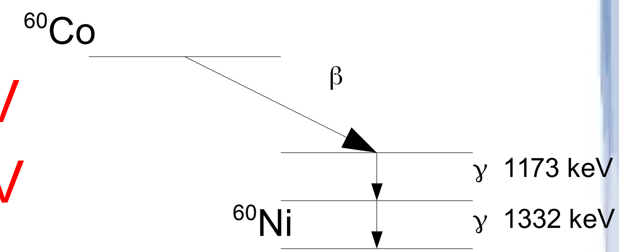
- ^{40}K
  1460.83 keV



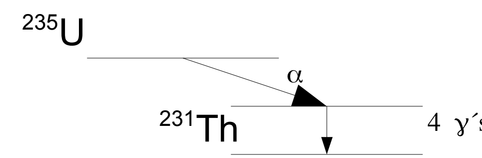
- ^{137}Cs
  661.66 keV



- ^{60}Co
  - 1173.2 keV
  - 1332.5 keV



- ^{235}U
  - 143.76 keV
  - 163.33 keV
  - 185.22 keV
  - 205.31 keV

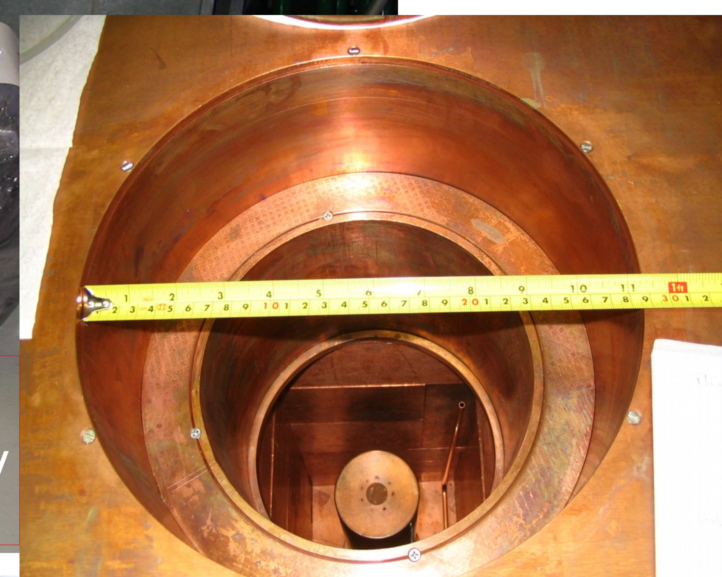


Occasionally Present:

- ^{54}Mn at 834.85 keV — Observed in Stainless Steel
- ^{7}Be at 477.60 keV — Observed in Carbon based materials, often due to neutron activation, samples are particularly affected after long flights.
- ^{138}La and ^{176}Lu — Observed in rare earth samples.

SNOLAB PGT HPGe Counter

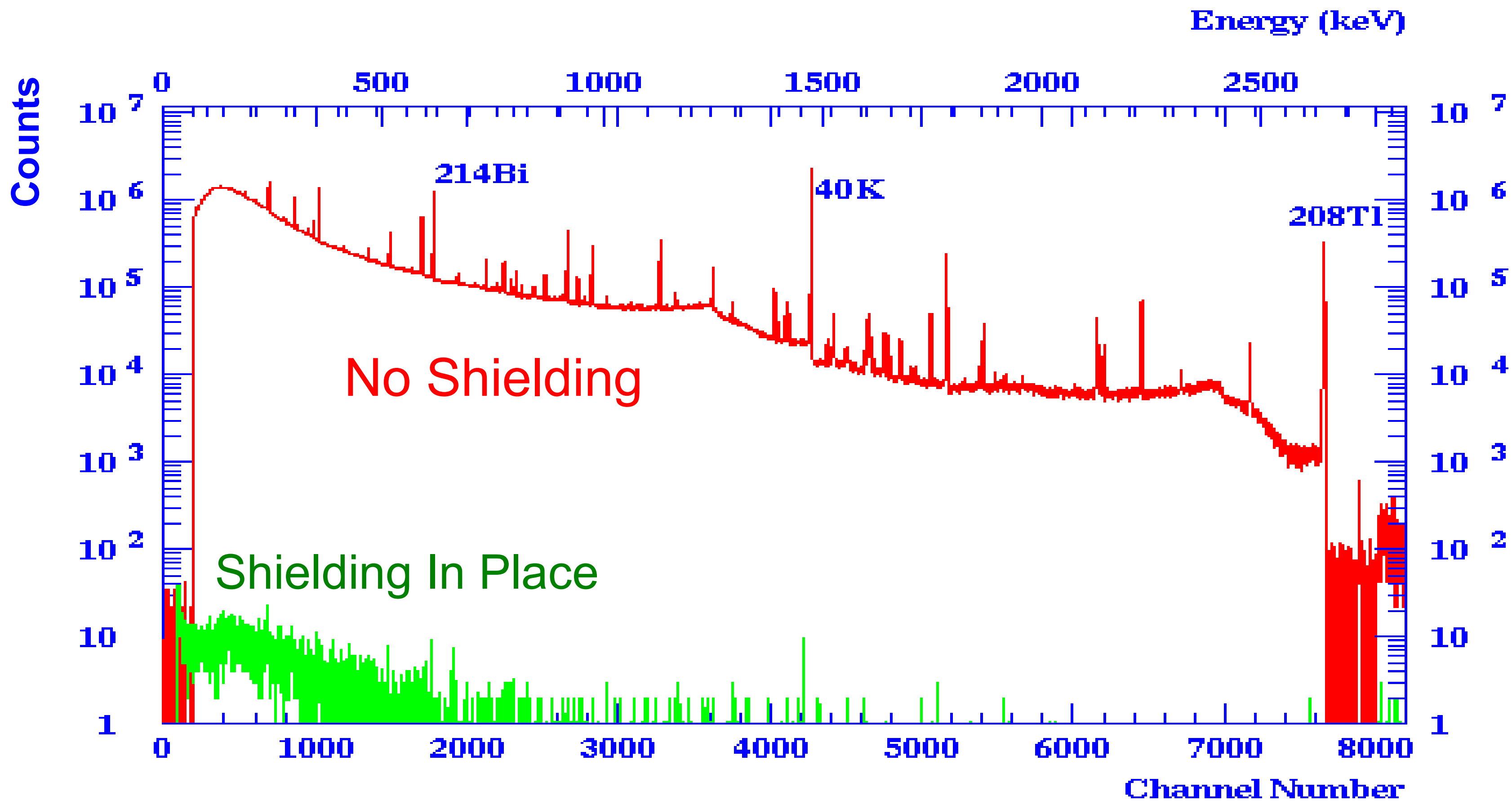
Additional lead used to dampen microseismic activity from blasting and rockbursts



SNOLAB PGT HPGe Detector Specifications

- Motivation
  - Survey materials for new, existing and proposed experiments (to be) located @ SNOLAB, such as SNO/SNO+, DEAP/CLEAN, PICASSO/COUPP/PICO, EXO, ... Also survey materials for the DM-ICE and DRIFT experiments, and Canberra.
- Constructed @ SNOLAB in 2005, detector was in UG storage from 1997, con-tinuous operations since 2005
  - Counter manufactured by PGT in 1992
  - Endcap diameter: 83 mm,
  - Crystal volume: 210 cm^3
  - Relative Efficiency is 55% wrt a 7.62 cm dia x 7.62 cm NaI(Tl) detector,
  - Resolution 1.8 keV FWHM.
- Shielding
  - 2 inches Cu + 8 inches Pb
  - Nitrogen purge at 2L/min, as the lab radon levels are 150 Bq/m^3.
- Detection Region
  - Energy: 90 – 3000 keV

Unshielded and Shielded Spectra
(PGT Coax Detector)



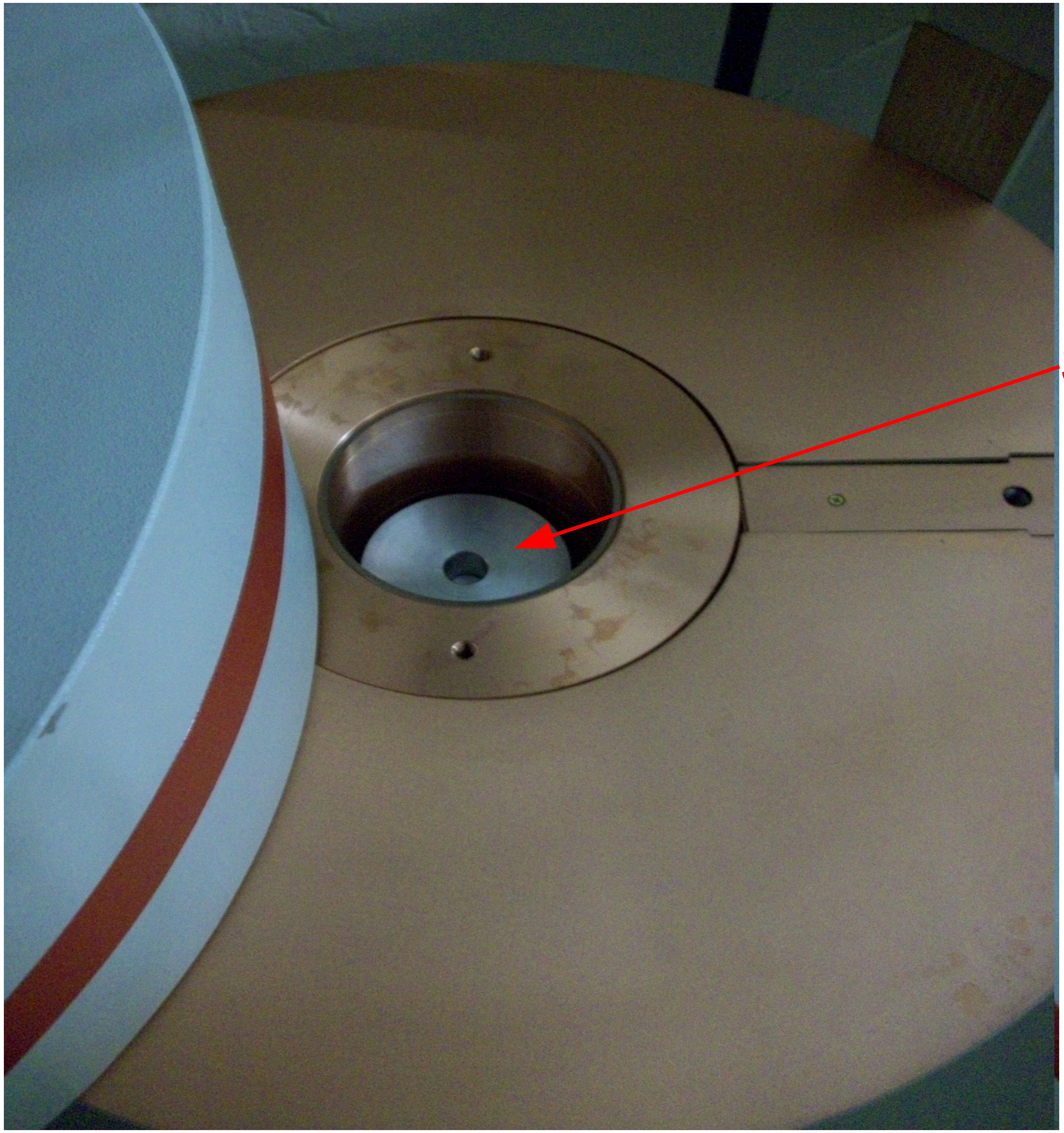
PGT HPGe Typical Detector Sensitivity

(for a standard 1L, 1 kg sample counted for one week)

Isotope	Sensitivity for Standard Size Samples	Sensitivity for Standard Size Samples
^{238}U	0.15 mBq/kg	12 ppt
^{235}U	0.15 mBq/kg	264 ppt
^{232}Th	0.13 mBq/kg	32 ppt
^{40}K	1.70 mBq/kg	54 ppt
^{60}Co	0.06 mBq/kg	
^{137}Cs	0.17 mBq/kg	
^{54}Mn	0.06 mBq/kg	

Canberra Well Detector at SNOLAB

Canberra Well Detector at SNOLAB



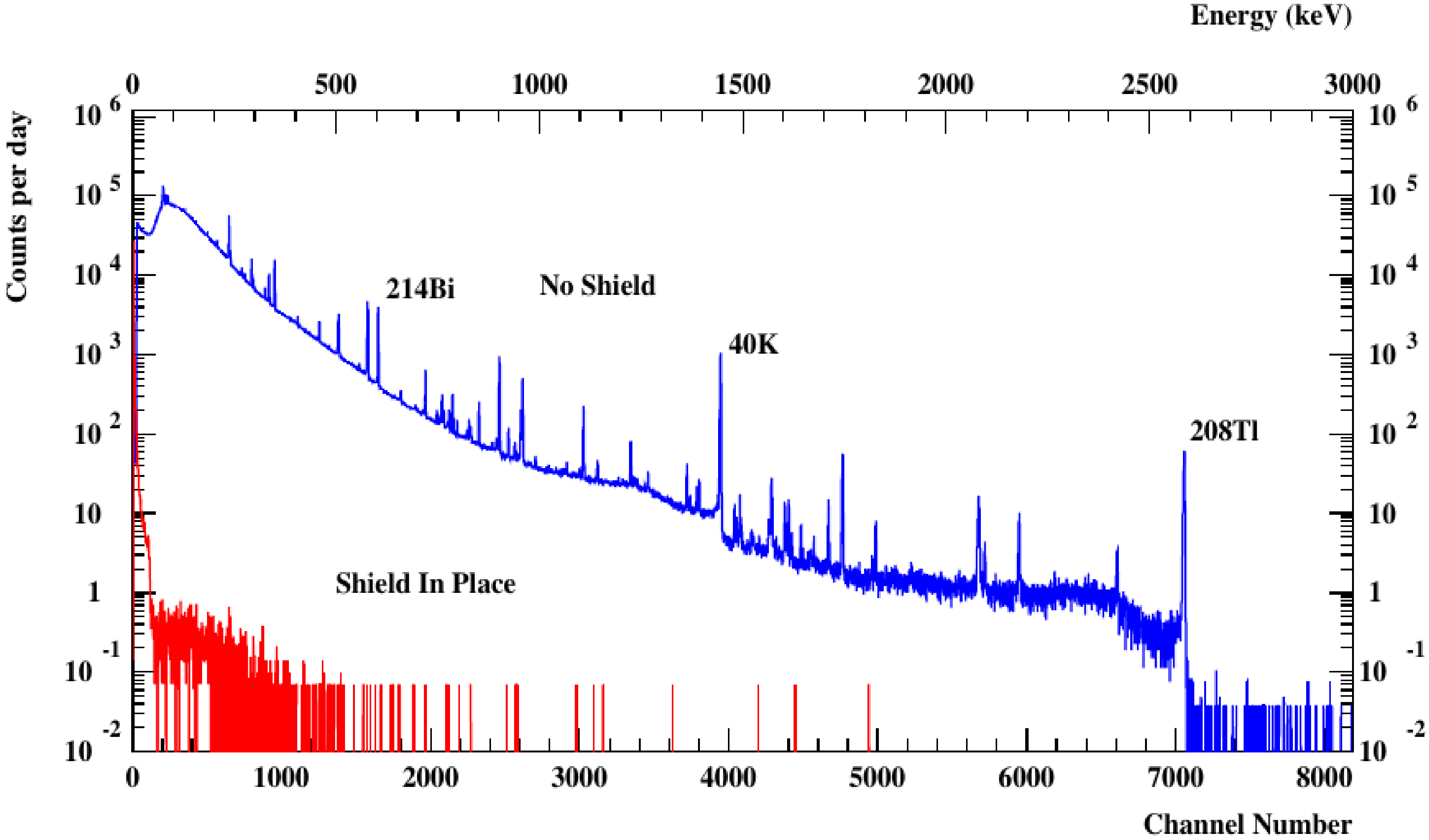
Detector Volume:
300 cm^3

Typical
Sample Bottle
Volume is 3 ml

SNOLAB Canberra Well Detector Specifications

- Motivation
  - Survey very small quantities of materials, concentrated samples or very expensive materials. Used by DAMIC, DEAP, PICO & SNO+ so far.
- Constructed by Canberra using low activity materials and shielding.
  - Counter manufactured by Canberra in 2011 and refurbished in 2012, the cold finger was lengthened as it was too short to fit the shielding and some components were replaced to reduce radioactivity levels.
  - Crystal volume: 300 cm^3.
- Installed and operational in 2013.
- Shielding
  - Cylindrical shielding of 2 inches Cu + 8 inches Pb
  - Nitrogen purge at 2L/min to keep radon out, as the lab radon levels are 150 Bq/m^3.
- Detection Region
  - Energy: 10 – 900 keV

Unshielded and Shielded Spectra
(Canberra Well Detector)



Canberra Well Detector Background
(is the detector an ultra-low counter)

- Background run completed, ~150 days.

Isotope	Counts per day
^{238}U	1.16
^{232}Th	0.51
^{228}Ac	0.39
^{235}U	0.48
^{40}K	0
^{210}Pb	0

- Total backgrounds at the level of ~2.5 counts / day in regions of interest, qualifies the detector as ultra-low background.
- Calibration sources from IAEA approved by SNOLAB and efficiency measurements up to ~900 keV have been completed.
- Samples for DAMIC, DEAP, PICO and SNO+ have been counted or are in progress.

Canberra Well Detector Sensitivity

Isotope	Sensitivity for Standard Size Samples	Sensitivity for Standard Size Samples
^{238}U (↑ ^{226}Ra)	0.05 mBq/kg	4 ppt
^{238}U (↓ ^{226}Ra)	0.08 mBq/kg	6 ppt
^{228}Ac	0.2 mBq/kg	49 ppt
^{232}Th	0.4 mBq/kg	98 ppt
^{235}U	0.02 mBq/kg	35 ppt
^{210}Pb	0.15 mBq/kg	12 ppt

Electrostatic Counting System

Originally built for SNO, now used primarily by EXO. However, these counters are owned by SNOLAB so samples can be measured for other experiments.

Measures ^{222}Rn, ^{224}Ra and ^{226}Ra levels.

Sensitivity Levels are:

^{222}Rn: 10^{-14} gU/g

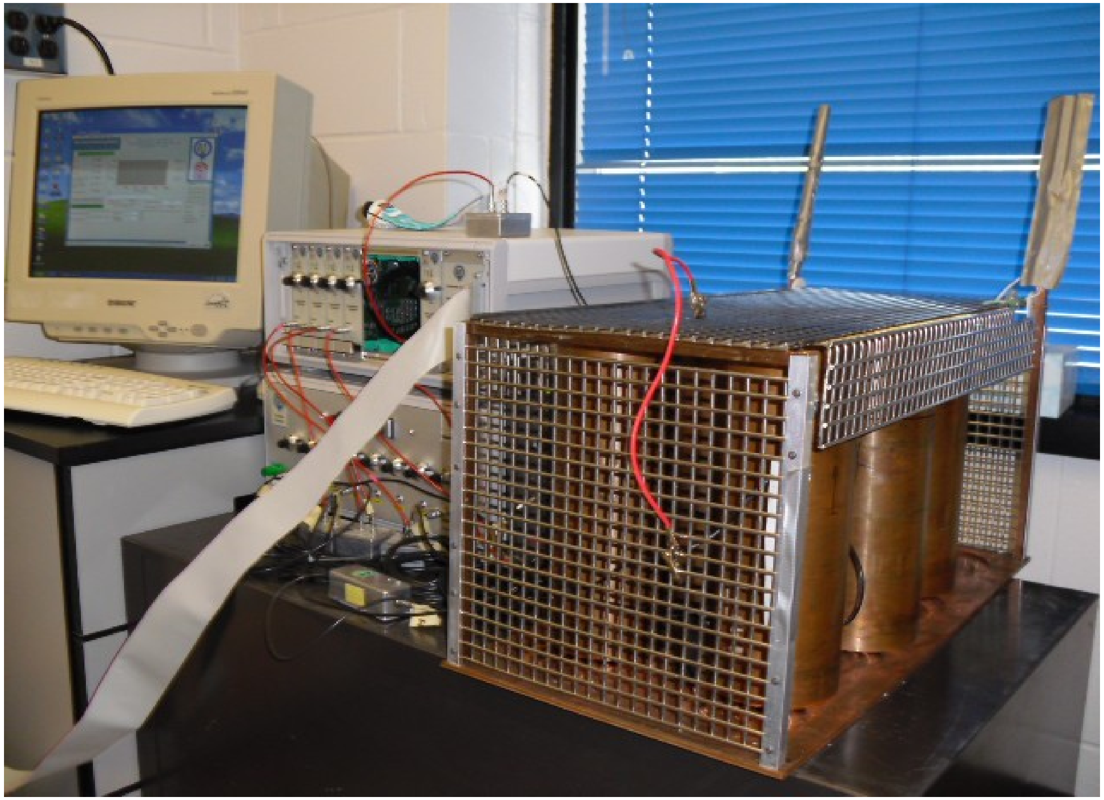
^{224}Ra: 10^{-15} gTh/g

^{226}Ra: 10^{-16} gU/g

Work is ongoing to improve sensitivity even further.

9 counters located at SNOLAB,
1 on loan to LBL (EXO),
1 on loan to U of A (DEAP).

Alpha Beta Counting System



Transparent liquid scintillator vials optically coupled to 2" PMTs.

The technique is combination of pulse shape discrimination and coincidence counting for identifying BiPo events.

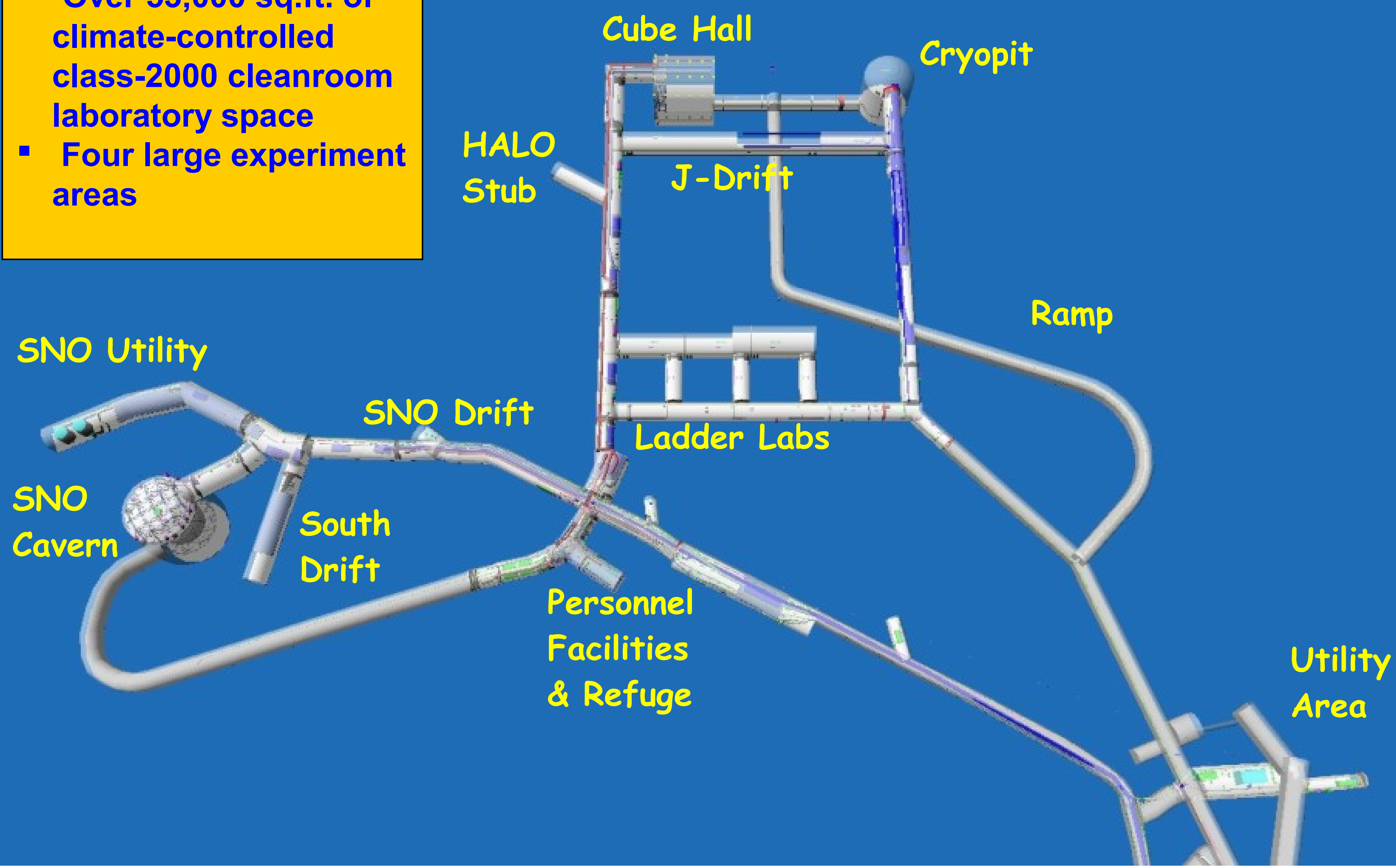
Sensitivity for ^{238}U and ^{232}Th is ~ 1 mBq assuming that the chains are in equilibrium.

The Case For Expanded Low Background Counting Facilities

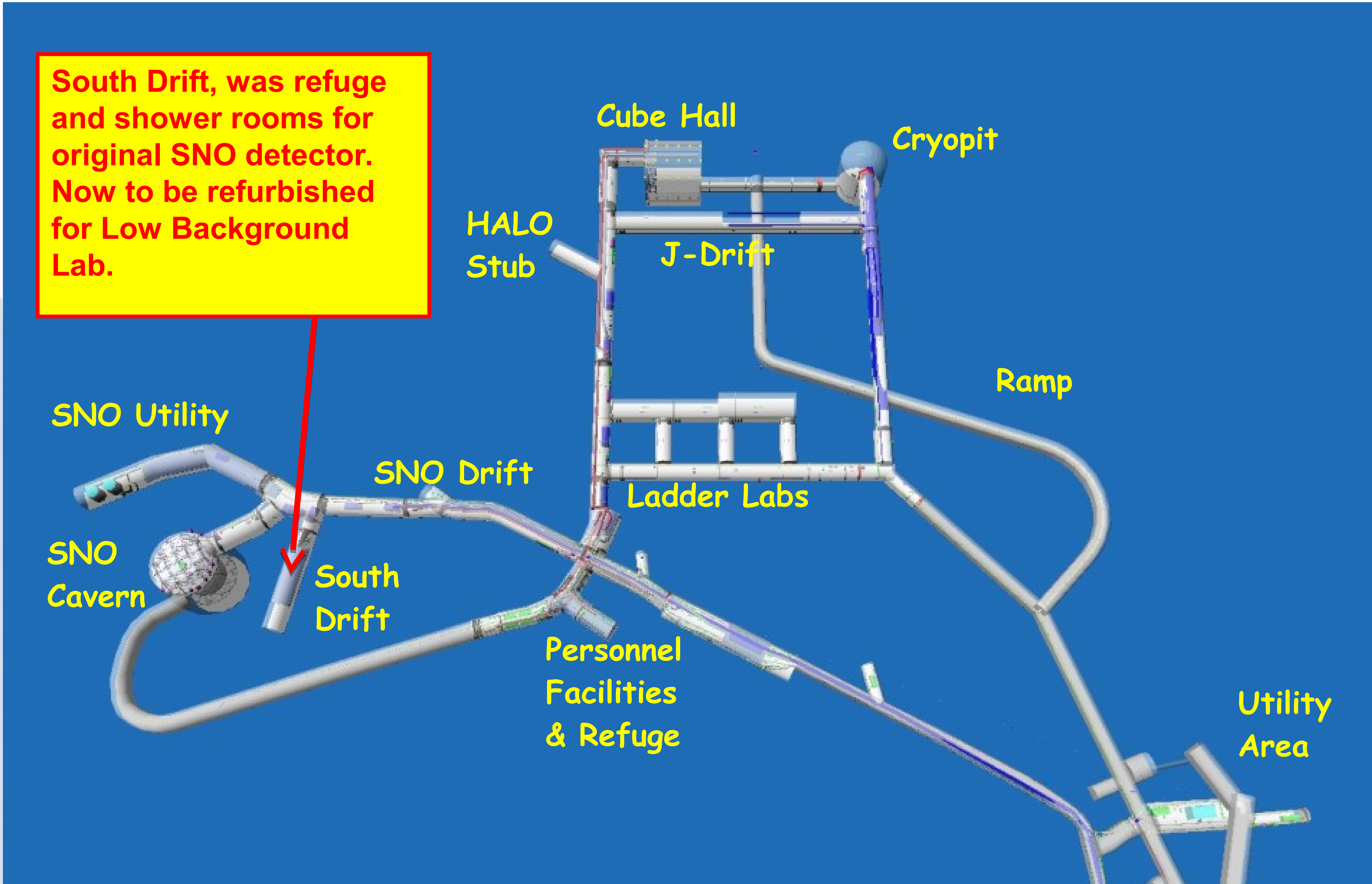
- One trait most of the current detectors/capabilities share, is that they are “left over” from previous experiments.
- Until now, experiments had to develop low background techniques within collaboration for each experiment, often “re-inventing the wheel”, at large cost.
- It is desirable to have these low background counting methods and detectors as part of the underground lab facilities. As experiments typically need these facilities most during detector design and construction, it requires a lot of funding and development time for experiments to take this on themselves. Then this developed resource can be under utilized once the supporting experiment is in operation.
- Beyond this, a global sharing and networking of low background counting facilities and resources would further benefit experiments and collaborations, allowing faster experiment design and identification of suitable materials.

SNOLAB Underground Facilities

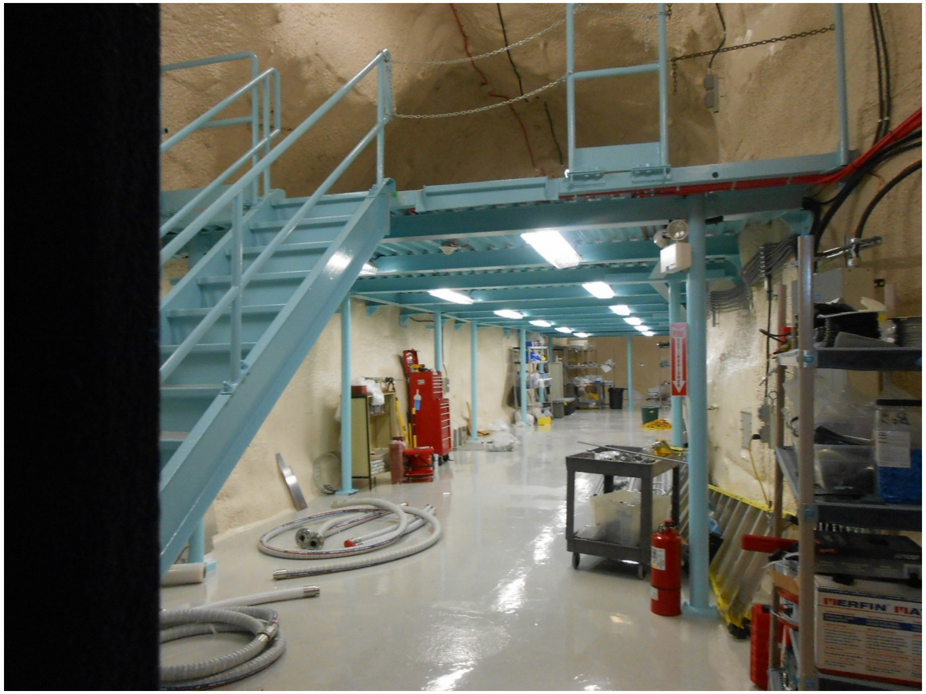
- Over 53,000 sq.ft. of climate-controlled class-2000 cleanroom laboratory space
- Four large experiment areas



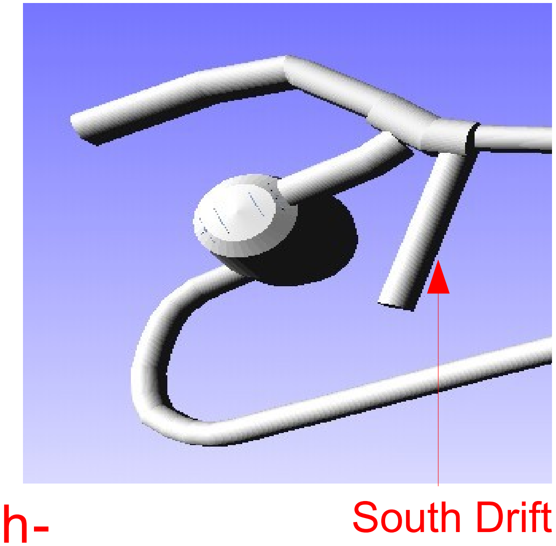
SNOLAB Underground Facilities



South Drift Today, Assembly and Storage Area



Future Low Background Counters and Facilities



A new dedicated space will be constructed at SNOLAB for a low background lab located in the South Drift.

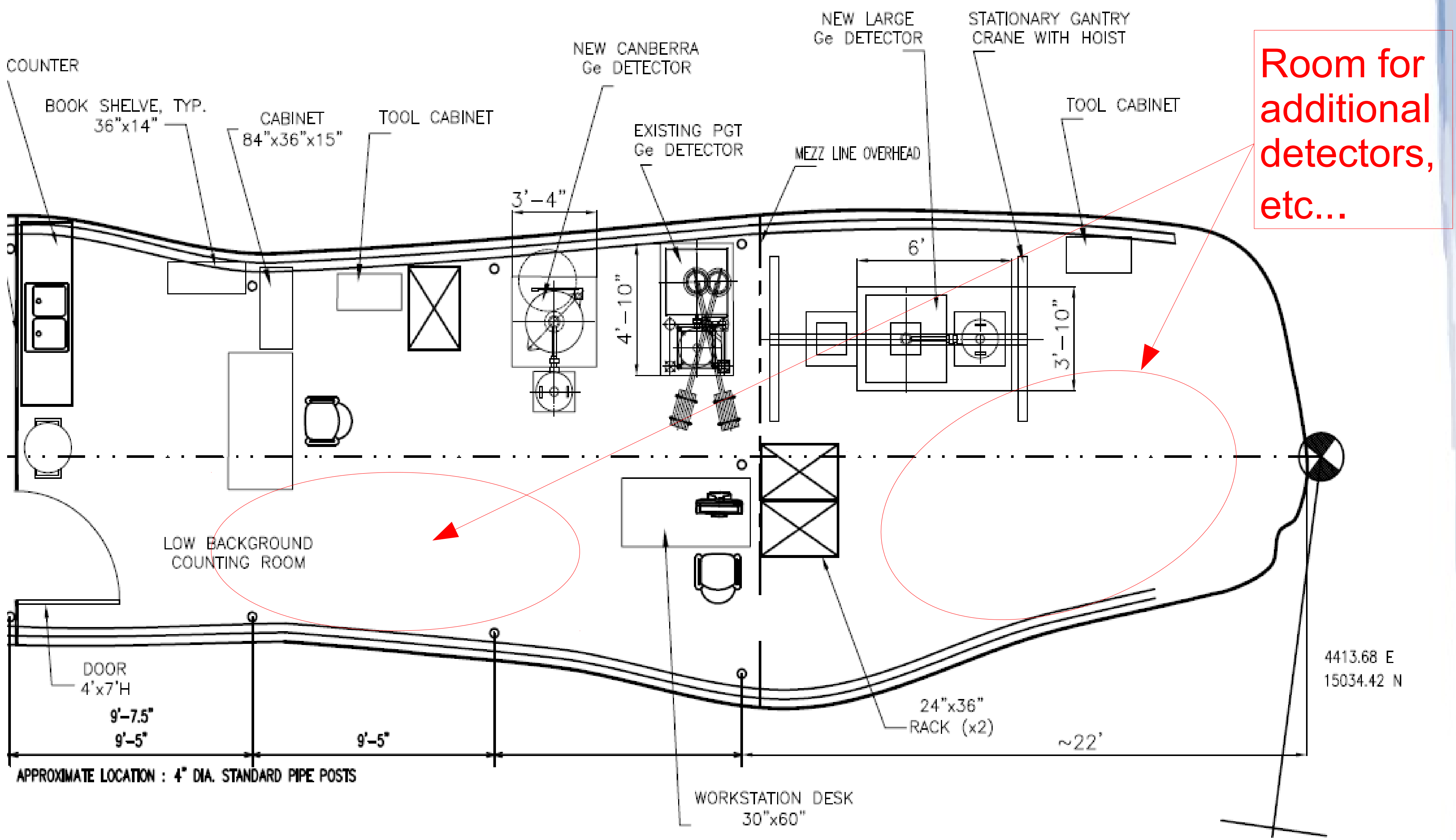
This drift is isolated from other drifts and is inaccessible to large equipment. This will help reduce micro-seismic noise which can effect Ge detectors.

Increased air flow and perhaps other radon reduction techniques will be used. It is known that the compressed air from surface has substantially less radon than the lab air and can be used to reduce radon levels from 135-150 Bq/m^3 to 1-5 Bq/m^3.

Space can accommodate up to 5 Ge detectors, XRF, radon emanation chamber and have room for other types of counters which would benefit from low-cosmic ray background.

Engineering design drawings are now in progress.

Refurbishing South Drift for Low Background Facility



Additional Low Background Counters Coming Soon

Three additional high purity germanium detectors will be installed.

1. SNOLAB Canberra 400 cm^3 coaxial detector acquired in 2011 and refurbished into an ultra-low counter in 2013 to be installed, the shielding apparatus is currently being designed.

2. Bern Coax detector is being moved from U. of Bern and will be relocated to SNOLAB. This detector has been used extensively by the EXO experiment. It is currently being shipped to SNOLAB, with installation expected this fall.

Additional Low Background Counters Coming Soon

3. Soudan Gopher HPGe, to be relocated to SNOLAB:

- 2.0 kg of germanium, P-Type coaxial, made be Canberra.
- Dedicated to SuperCDMS
- Sensitivity of 1 mBq/kg for 3 week run
- Sample changes by staff.
- Queue and Analysis by UM Students

Options for SNOLAB Low Background Facilities

- We are currently surveying the community for input on capabilities that would best benefit future experiments at SNOLAB, and enhance SNOLAB's position as a leader in low background techniques.

- Items being investigated:
  - Low radon air supply
  - Low radon nitrogen supply
  - Emanation chambers with Rn cryotraps
  - XIA alpha screener (large area wire detector)

Low Background Data Repository

SNOLAB maintains a database in a spreadsheet format for each experiment.
https://www.snolab.ca/users/services/gamma-assay

The table shows data from the standard gamma searches:
^{238}U, ^{235}U, ^{232}Th, ^{40}K ^{137}Cs, ^{60}Co.

While searching for the above gammas, we also search for any other peaks in the spectrum between 100 keV and 2800 keV, For example, ^{54}Mn is usually observed in steel.

SNOLAB is a member of the Assay and Acquisition of Radiopure Materials (AARM) Collaboration, which has developed the Community Material Assay Database radiopurity.org.

AARM website www.hep.umn.edu/aarm has information about individual detectors and contact details, an assay request form, MC tools, cleaning and handling procedures, etc...

Going forward, SNOLAB and PNNL will host the website and data base which is currently being developed.

Summary

- SNOLAB PGT HPGe low background counting system has run continuously for the past since 2005.
  - Counting queue is usually long.
  - The counter is available for all SNOLAB experiments and can be made available to non-SNOLAB experiments upon request (eg. DM-ICE, DRIFT).
- Two Canberra Ge detectors were delivered to SNOLAB, but each needed to be refurbished.
  - The Canberra Well detector is now in fully operational.
  - The Canberra Coax detector is underground and engineering drawings of the shielding design are in progress.
  - The EXO Bern detector is currently in transit to SNOLAB.
  - The CDMS Gopher detector is expected to move to SNOLAB in 2016.
- Specialized counting can be done using the Electrostatic Counters, Alpha-Beta Counters and materials can be emanated for Radon.
- New low background counting lab will be constructed at SNOLAB, final design drawings are now underway.