Low Background Measurement Capabilities at SNOLAB

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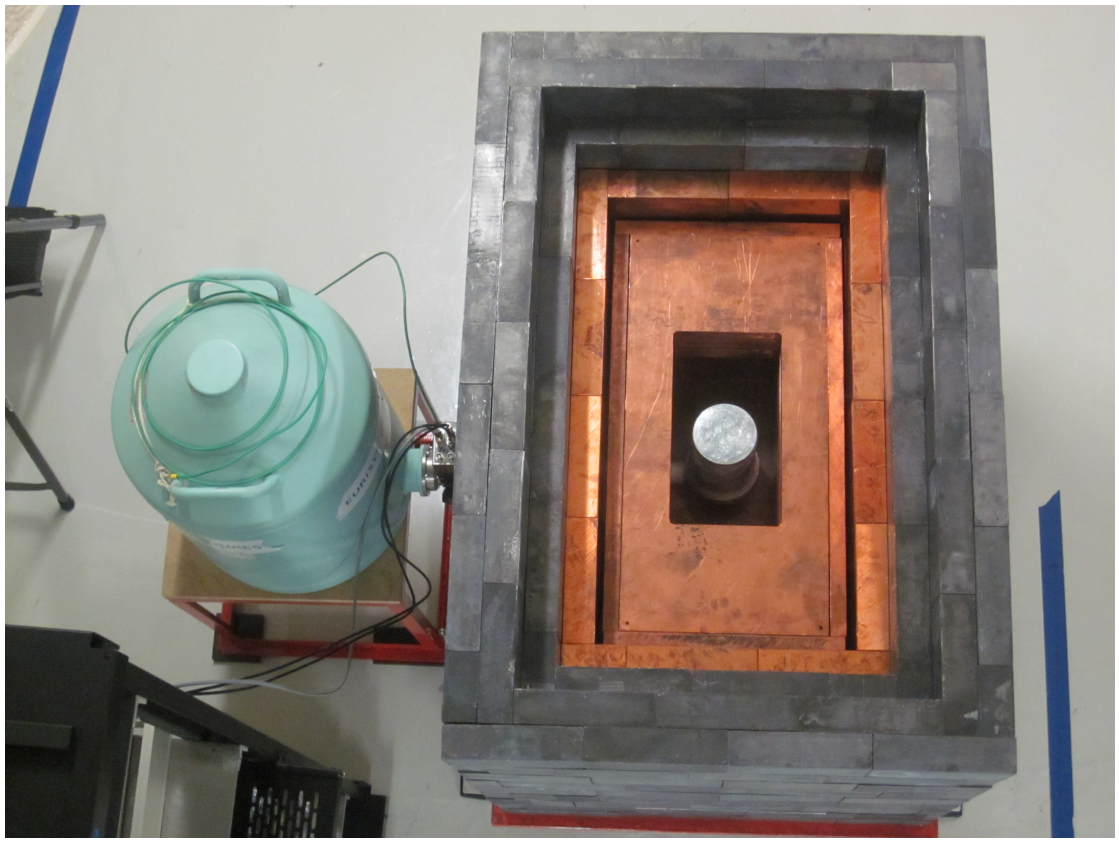
Queen's University



Outline

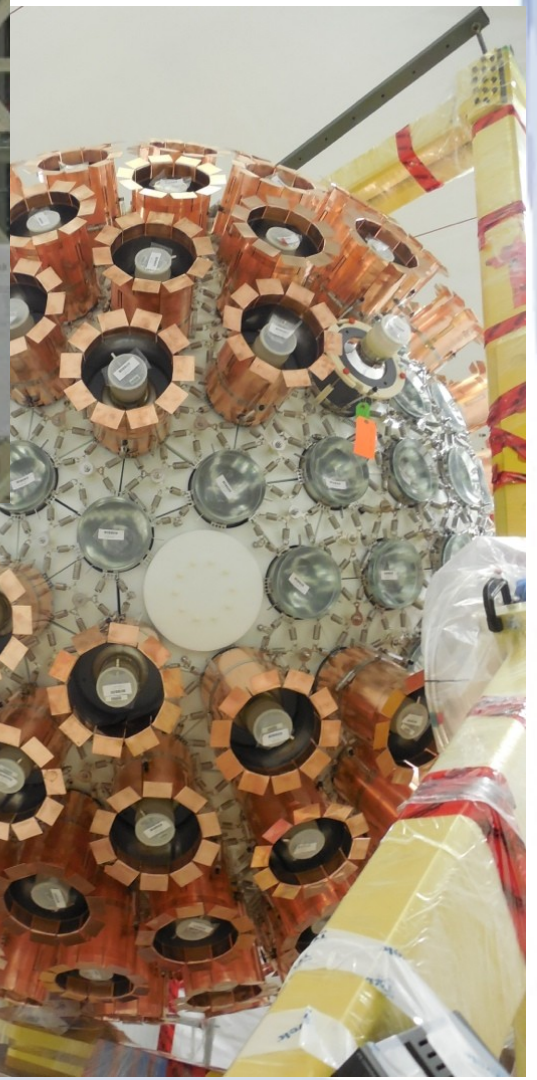
- Motivation – Why do we need to measure radioactivity
- Description of the SNOLAB Low Background Counting System
- Low Background Counting – Some Results
- Future Low Background Counting Facilities
- Radiopurity Database
- Summary

Motivation

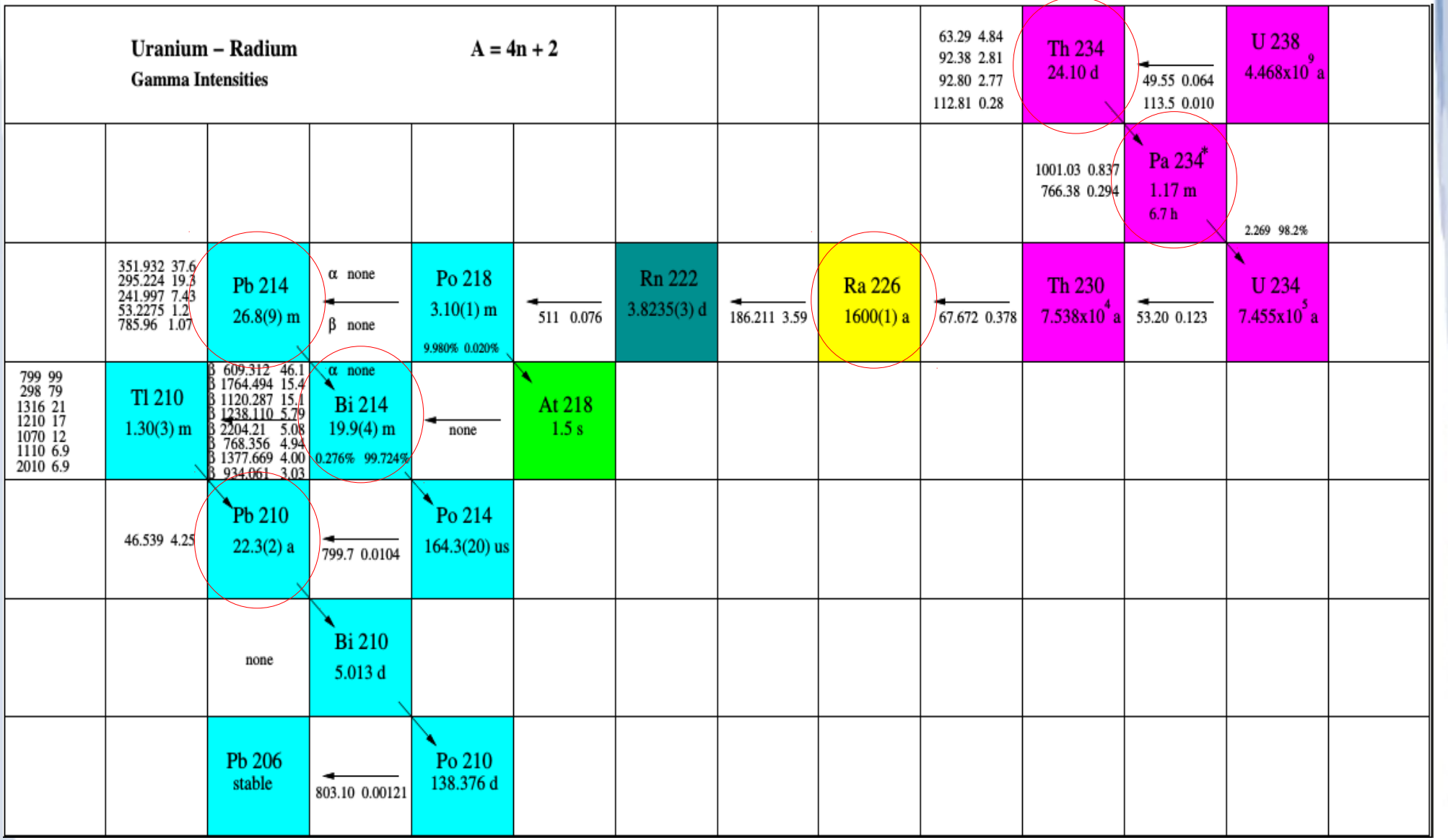
- Experiments currently searching for dark matter, studying properties of neutrinos require very low levels of radioactive backgrounds both in their own construction materials and in the surrounding environment.
- These low background levels are required so that the experiments can achieve the required sensitivities for their searches.
- SNOLAB has several facilities which are used to directly measure these radioactive backgrounds.
- The backgrounds in question are on the order of 1 mBq or 1 ppb for ^{238}U, ^{232}Th and ^{235}U and 1 ppm for ^{40}K, or better, measurements down to 1 ppt are now required for most new experiments under construction.
- The problem backgrounds can include gammas, alphas and neutrons or resulting interaction products.
- The goal is to measure these backgrounds and then to reduce them to be as low as reasonably achievable.

Progress to a Low Background Experiment – DEAP 3600

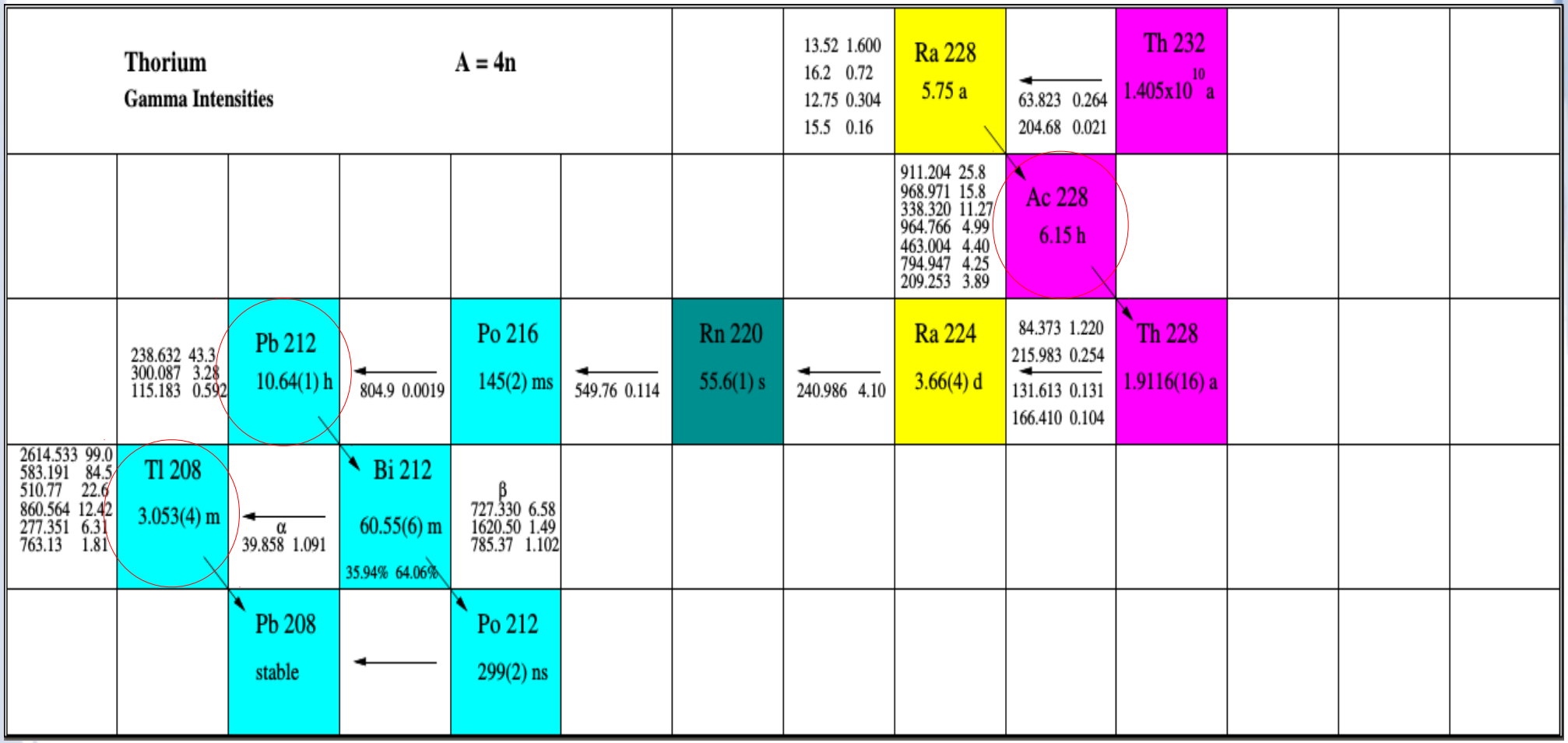
Goal is to measure backgrounds of all materials which will be part of the experiment as the backgrounds may mimic the expected detector signal.



Uranium Decay Chain



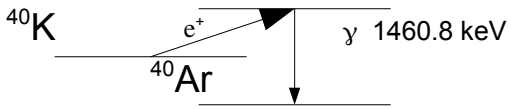
Thorium Decay Chain



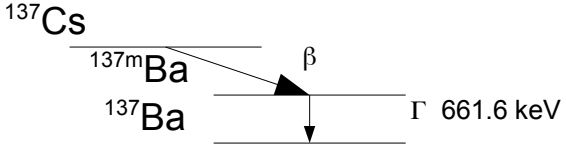
Other Interesting Isotopes

Usually Present:

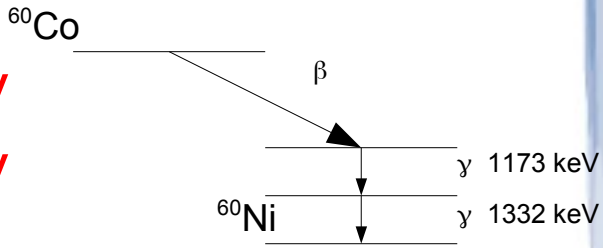
- ^{40}K
  - 1460.83 keV



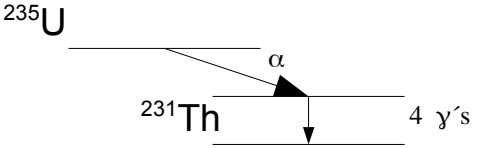
- ^{137}Cs
  - 661.66 keV



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



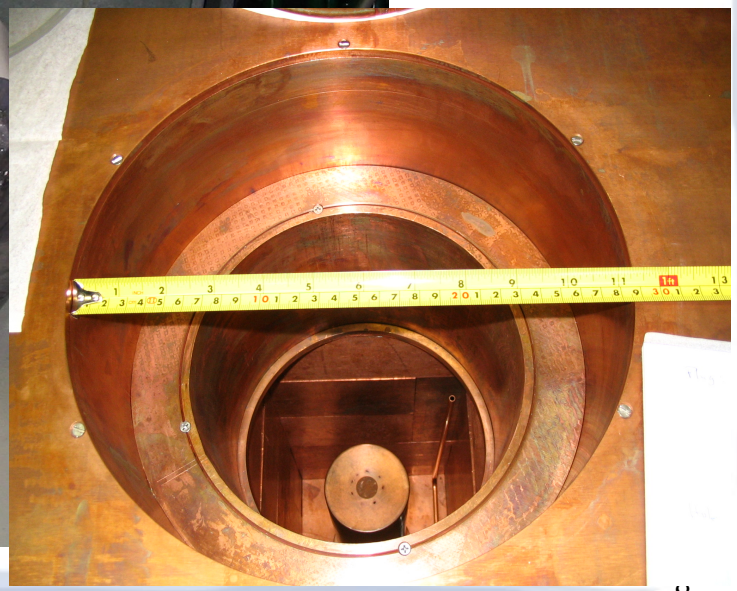
- ^{235}U
  - ·143.76 keV
  - ·163.33 keV
  - ·185.22 keV
  - ·205.31 keV



Occasionally Present:

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

SNOLAB PGT HPGe Counter
(The workhorse detector at SNOLAB)



SNOLAB PGT HPGe Detector Specifications

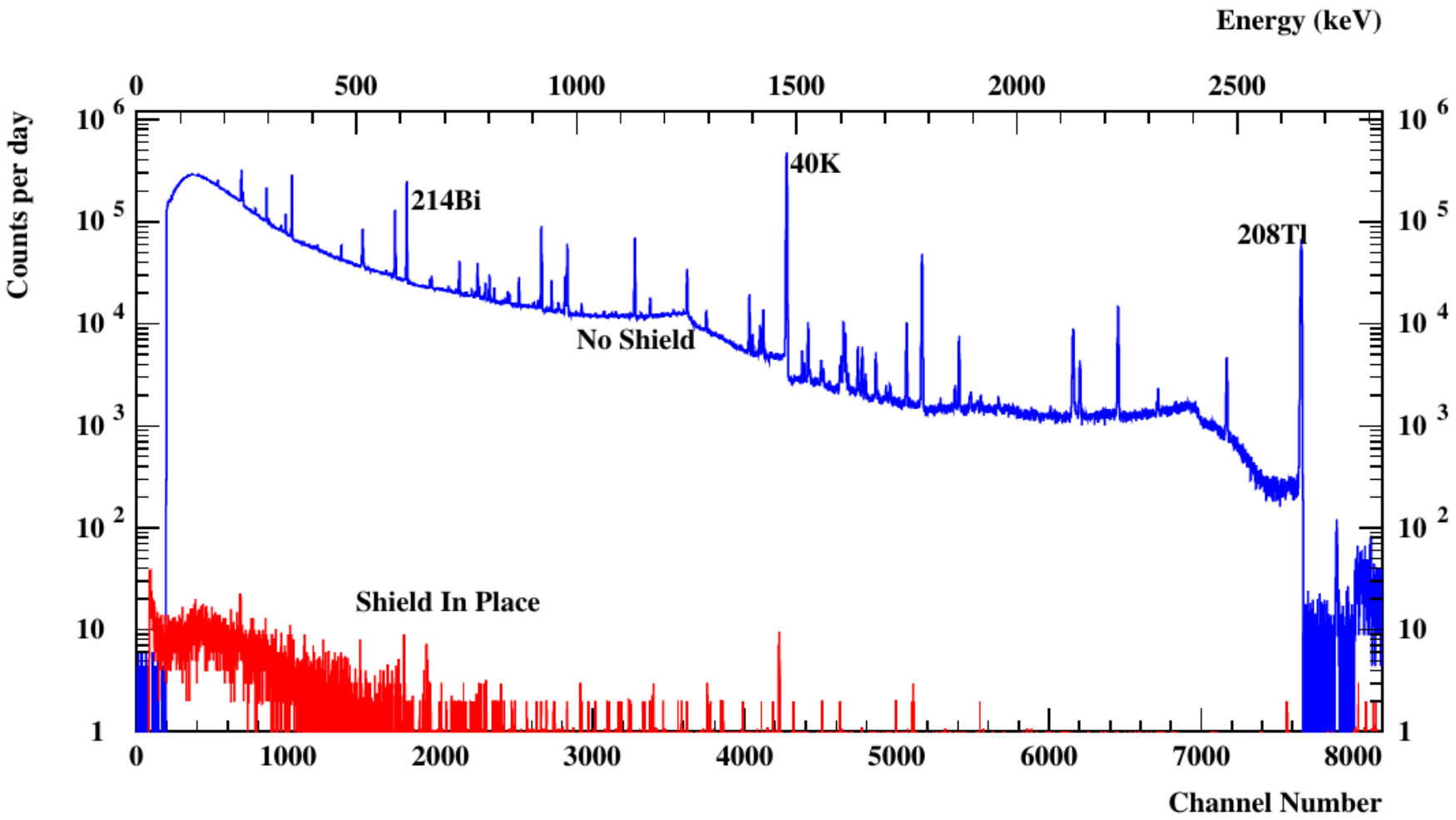
- Motivation
  - Survey materials for new, existing and proposed experiments (to be) located @ SNOLAB, such as SNO/SNO+, DEAP/CLEAN, PICASSO/COUPP/PICO, EXO, ... Also survey materials for the DM-ICE, DRIFT, DARKSIDE20K experiments, and Canberra.
- Constructed @ SNOLAB in 2005, detector was in UG storage from 1997, continuous operations since 2005
  - 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.
  - Counter manufactured by PGT in 1992
- Shielding
  - 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: 90 – 3000 keV

PGT HPGe Typical Detector Sensitivity

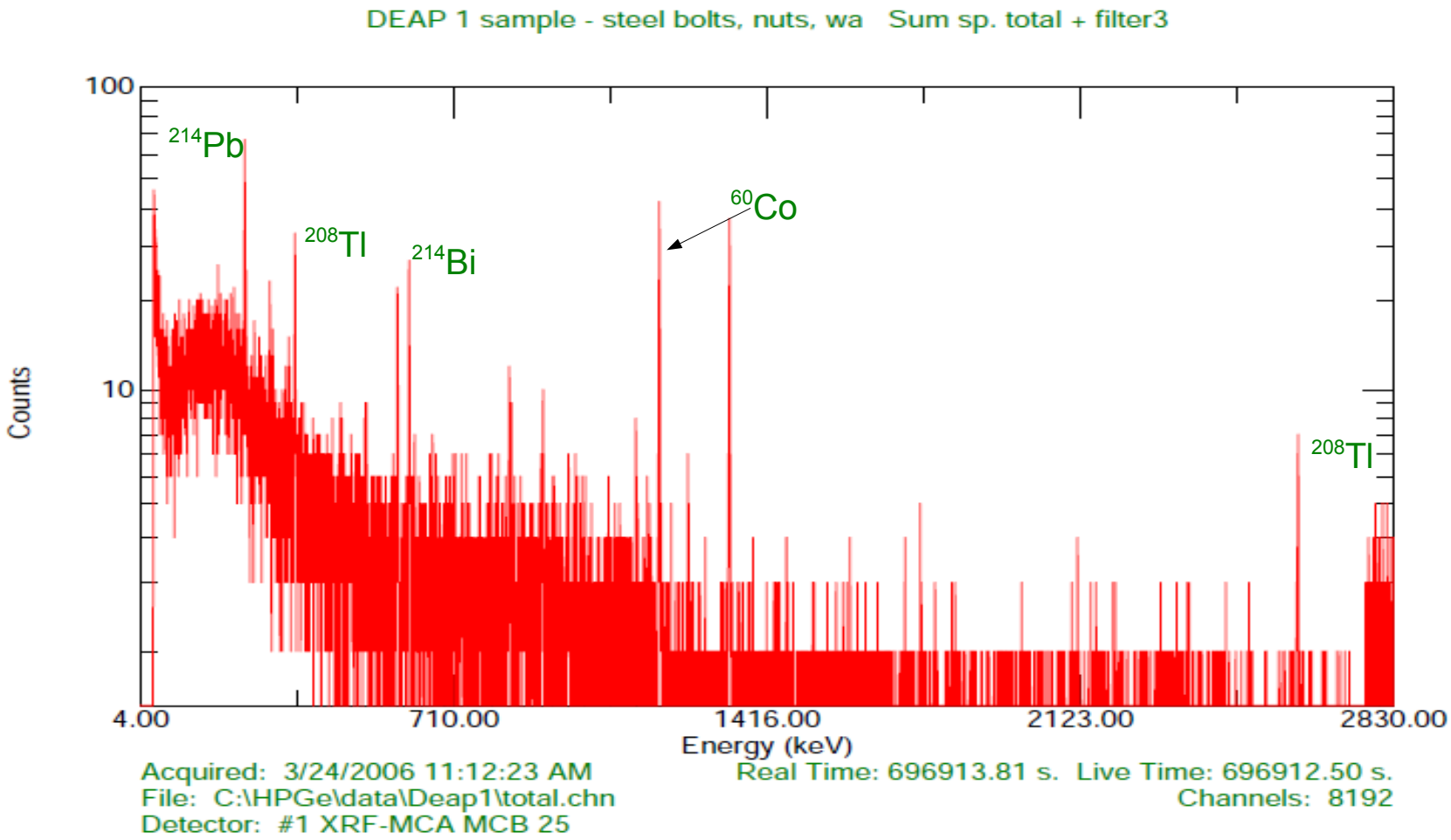
(for a standard 1L or 1 kg sample counted for one week)

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	

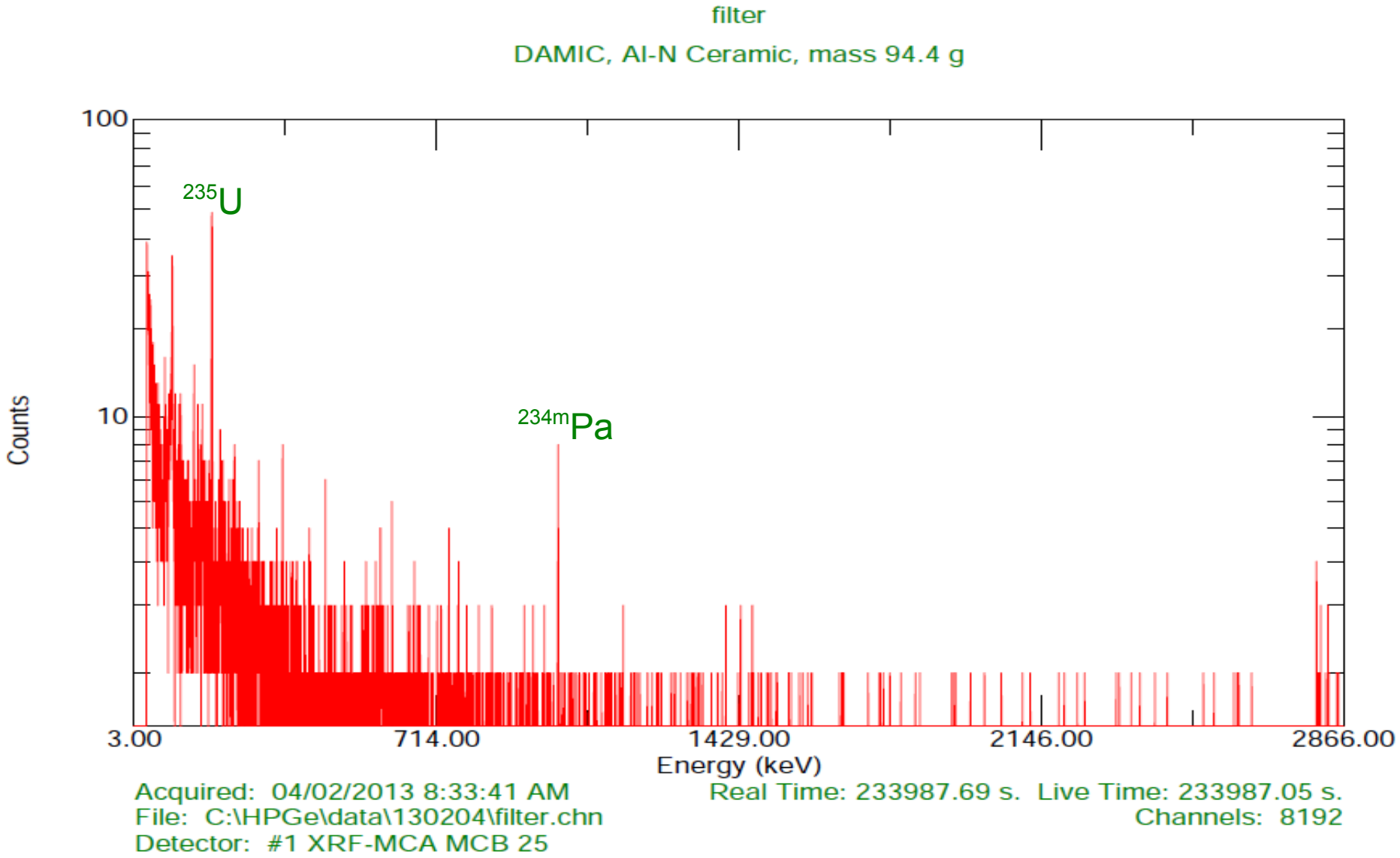
Unshielded and Shielded Spectra
(PGT Coax Detector)



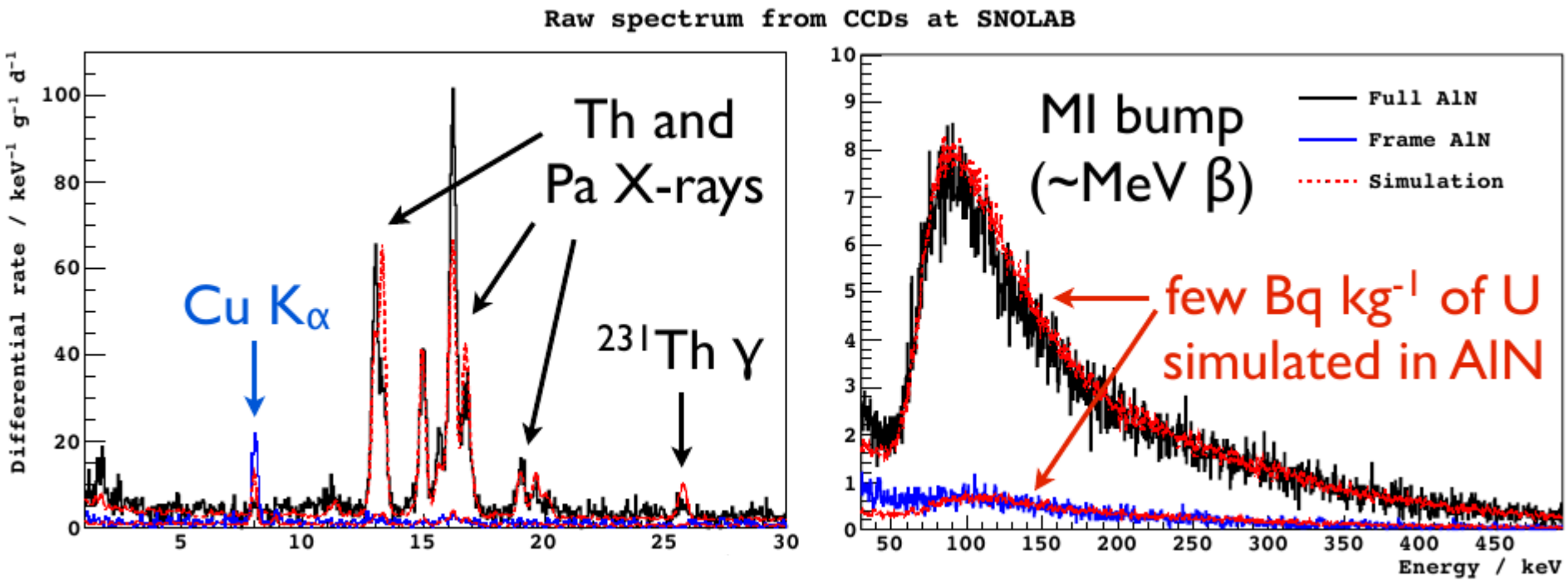
Typical Stainless Steel Spectrum



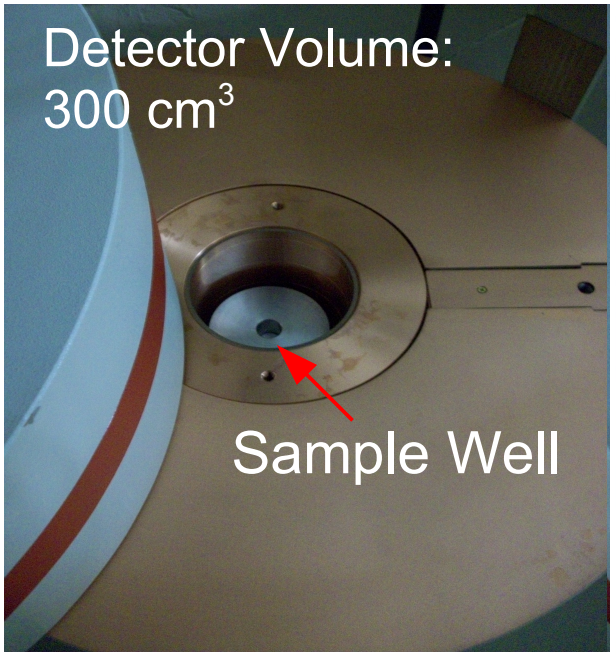
DAMIC Ceramic Spectrum



DAMIC Data and Simulation Using Results From PGT HPGe Counter



Canberra Well Detector at SNOLAB



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+, NEWS and SuperCDMS.

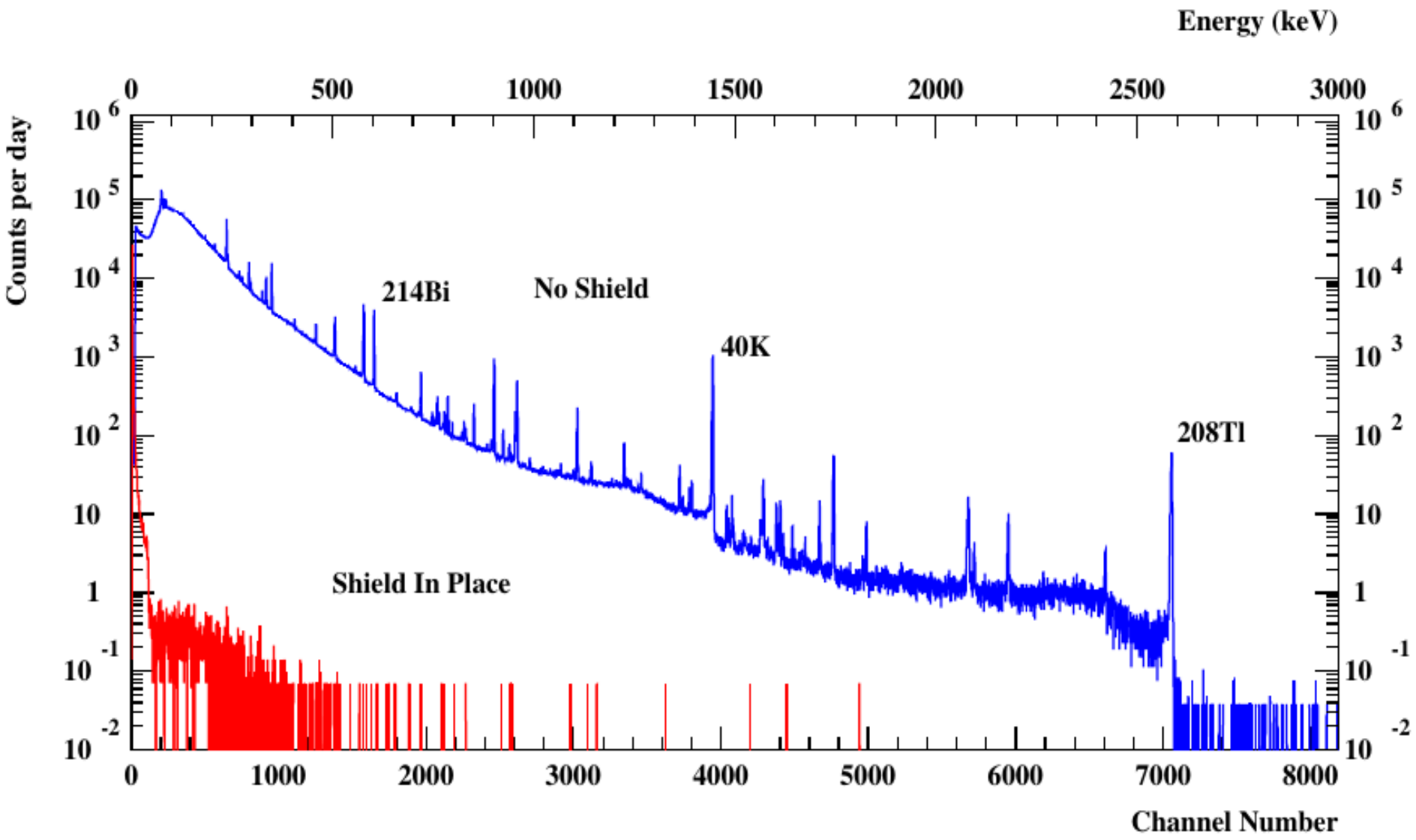
- Constructed by Canberra using low activity materials and shielding.
  - Counter manufactured by Canberra in 2011 and refurbished in 2012.
  - Crystal volume: 300 cm^3.
- Installed and operational in 2013.

- 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

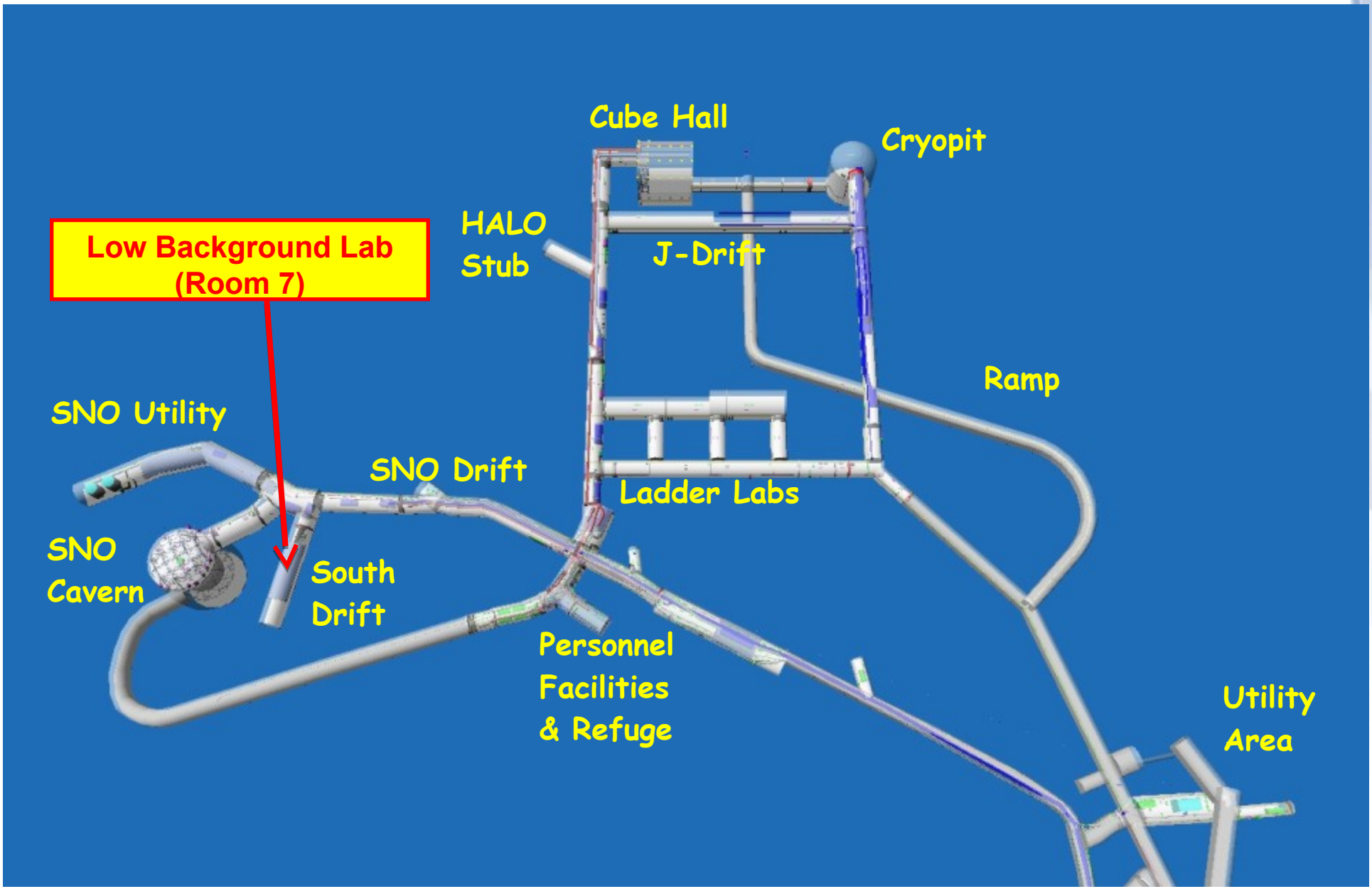
Canberra Well Detector Sensitivity

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

Unshielded and Shielded Spectra
(Canberra Well Detector)



Low Background Lab



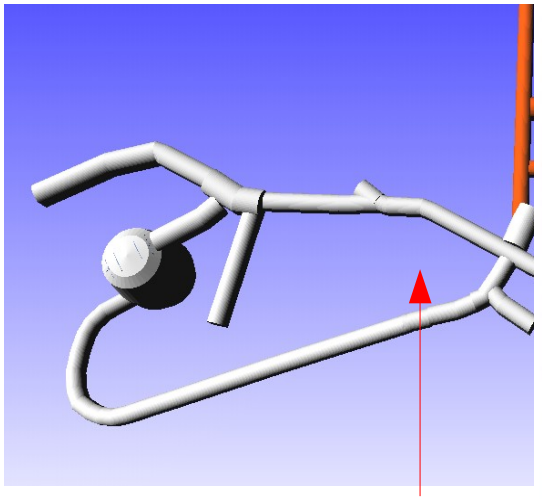
Future Low Background Counters and Facilities

A new dedicated space is under construction for a low background lab located in the South Drift (Rm 7.)

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

A radon free room will be constructed for sample preparation and sample storage underground. Surface air will be used and further purified to reduce radon levels to the order of ~ 1 mBq/m^3. Ambiant radon levels in the UG lab are 135-150 Bq/m^3.

Space can accommodate several HPGE detectors, XRF, radon emanation chamber, alpha counters and there is some unallocated space for additional counters which would benefit from low-cosmic ray background.

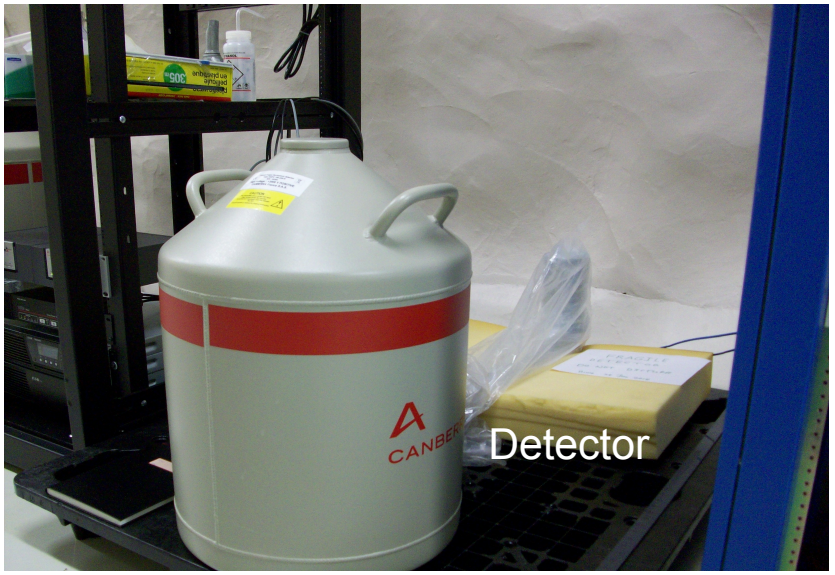


South Drift
(Room 7)

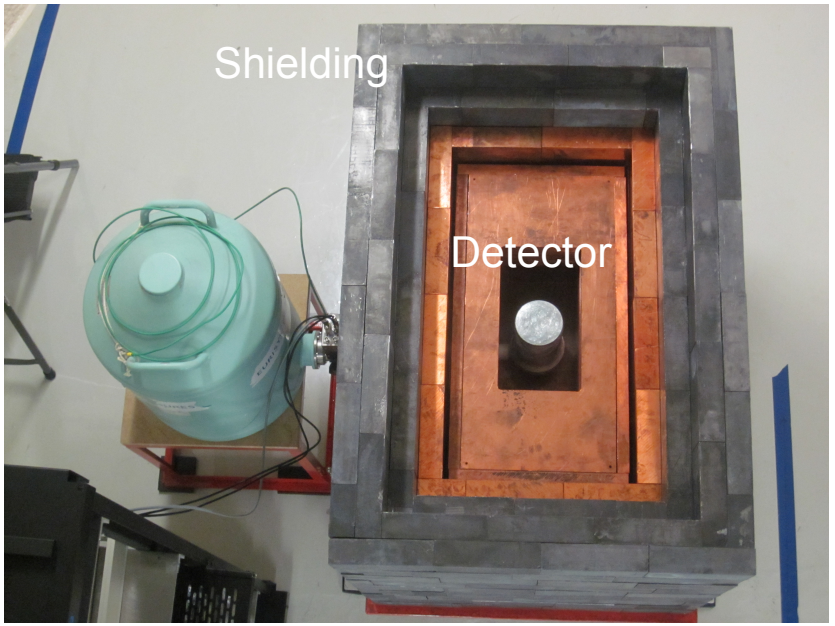
Additional Low Background Counters Coming Soon

Three additional high purity germanium detectors will be installed.

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

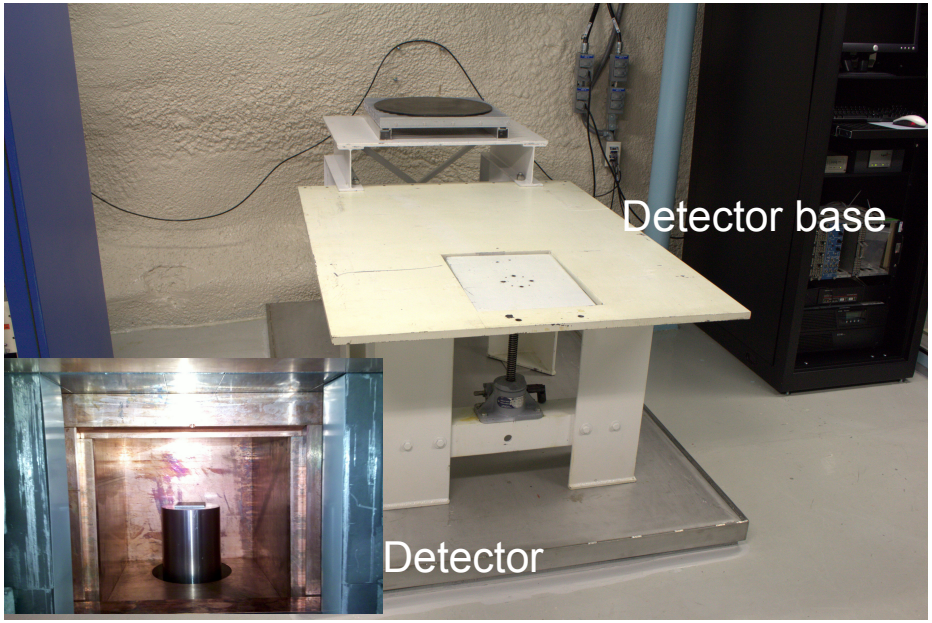


2. Vue des Alpes HPGE detector, it is currently being reconditioned and should be in service soon.



Additional Low Background Counters Coming Soon

3. SOUDAN Gopher HPGE detector, shielding base is assembled, awaiting lead and copper shielding.



4. Alpha Counters

SOUDAN Tennelec alpha counter to be assembled and restarted in a radon-free glove box assembly

SNOLAB Data Repository

SNOLAB maintains a database for each experiment at 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 observed in stainless steel products.

The Assay and Acquisition of Radiopure Materials (AARM) Collaboration originally developed the Community Material Assay Database radiopurity.org. The database is now hosted at SNOLAB.

Material Assay Database

www.radiopurity.org

Search | Submit | Edit | Settings | About | Login

(pf? polyimide kapton -ptfe -raw) AND grouping:EXO

Total result: 10

Grouping	Name	Isotope	Amount	Isotope	Amount	
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	450 ppt	U	900 ppt	...
EXO (2008)	PFA, Saint Gobain supplied DuPont 450-HPB	Th	65 ppt	U	75 ppt	...
EXO (2008)	PFA, Saint Gobain DuPont 440-HP	Th	13.3 ppt	U	3 ppt	...
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	1600 ppt	U	1500 ppt	...
EXO (2008)	Polyimide tape, Stanford stock room	Th	5400 ppt	U	5800 ppt	...
EXO (2008)	Copper coating, Espanex flat cable, Nippon Ste...	Th	3 ppt	U	19 ppt	...
EXO (2008)	Sheldal superinsulation, DuPont Kapton alumini...	Th	1540 ppt	U	2500 ppt	...
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	50 ppt	U	450 ppt	...
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	317 ppt	U	3880 ppt	...
EXO (2008)	Sheldal superinsulation, DuPont Kapton alumini...	Th	1640 ppt	U	6100 ppt	...

Summary

- PGT and Canberra Well germanium detectors fully operational.

  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).

- Canberra Coax, Vue des Alpes and Gopher germanium detectors are currently being assembled and conditioned using ultra-low background materials.

  The Canberra Coax detector is underground and construction of the shielding is in progress.

  The Vue des Alpes detector is shielded and is now undergoing reconditioning.

  The Gopher detector is underground and awaiting its shielding

- Specialized counting can be done using the Electrostatic Counters, Alpha-Beta Counters and materials can be emanated for Radon.

- Low background counting lab is under construction and some counters are already installed and collecting data.