# Low Background Measurement Capabilities at SNOLAB

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# Outline

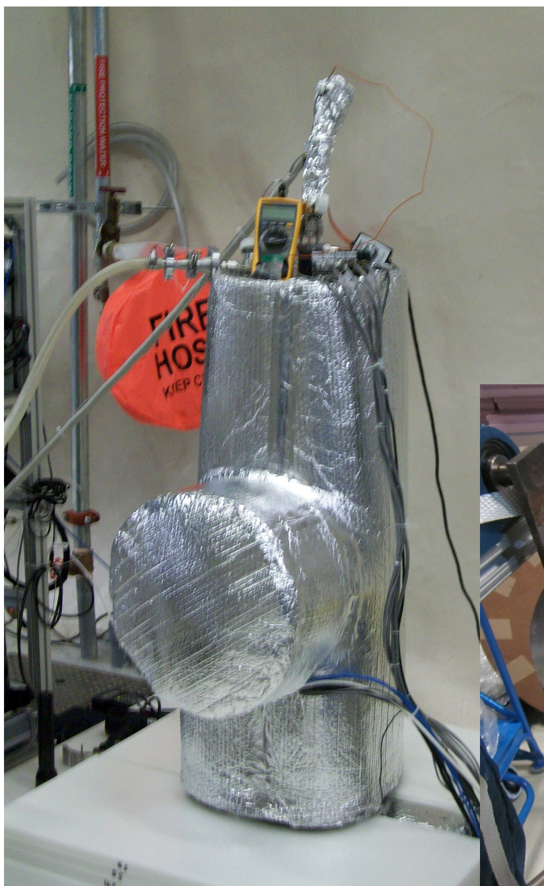
- Motivation – Why do we need to measure radioactivity
- Description of the SNOLAB Low Background Counting Systems
- Low Background Counting – Some Results
- Future Low Background Counting Facilities
- Radiopurity Database
- Summary

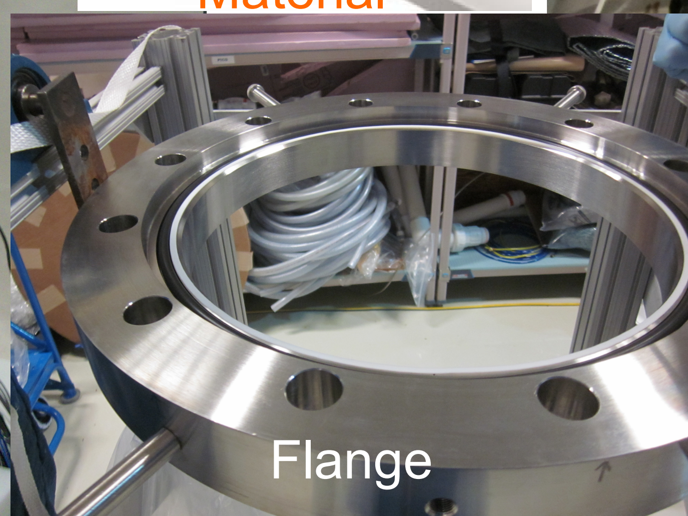
# Motivation

- 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.

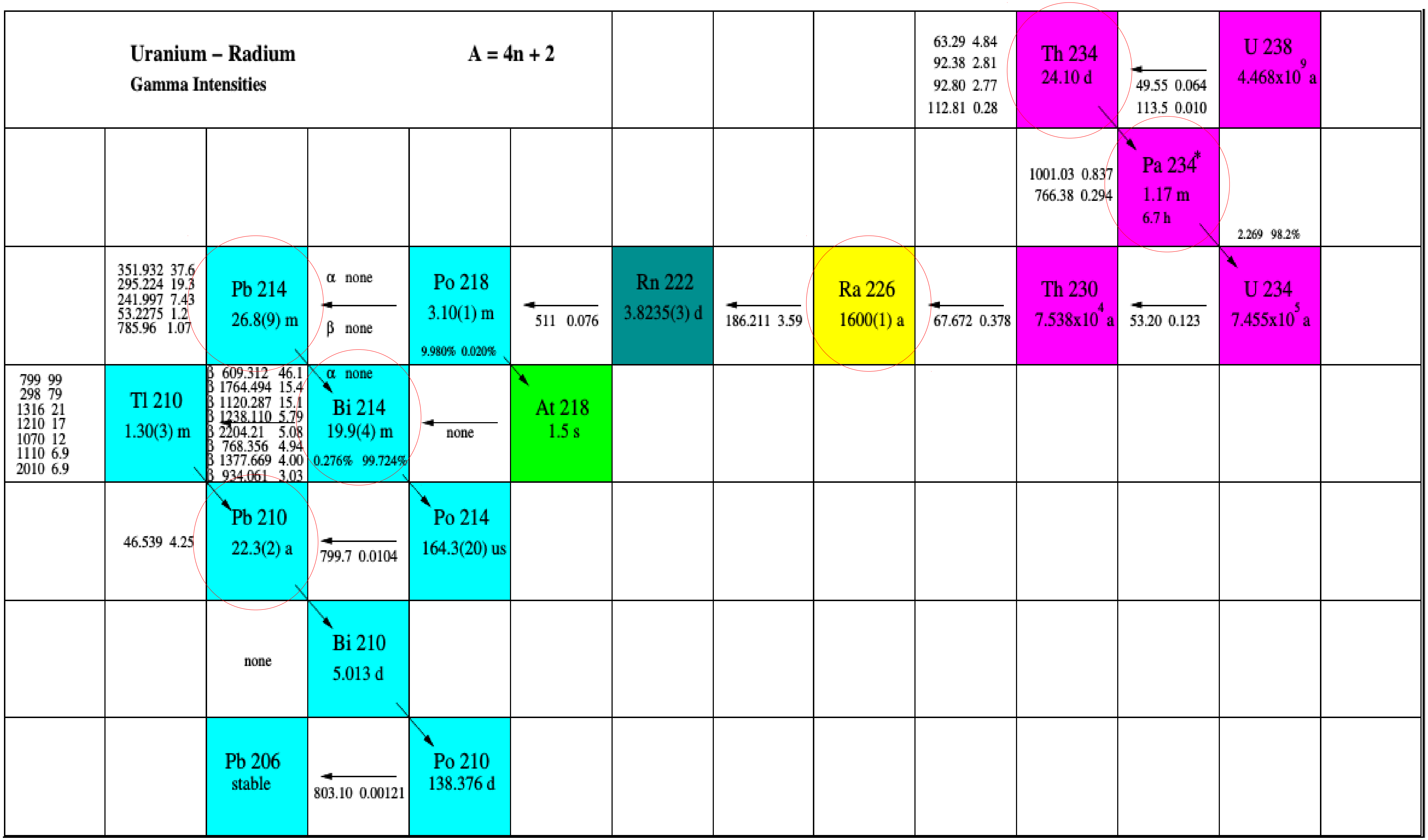
# Progress to a Low Background Experiment – PICO 60 → PICO-40L

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

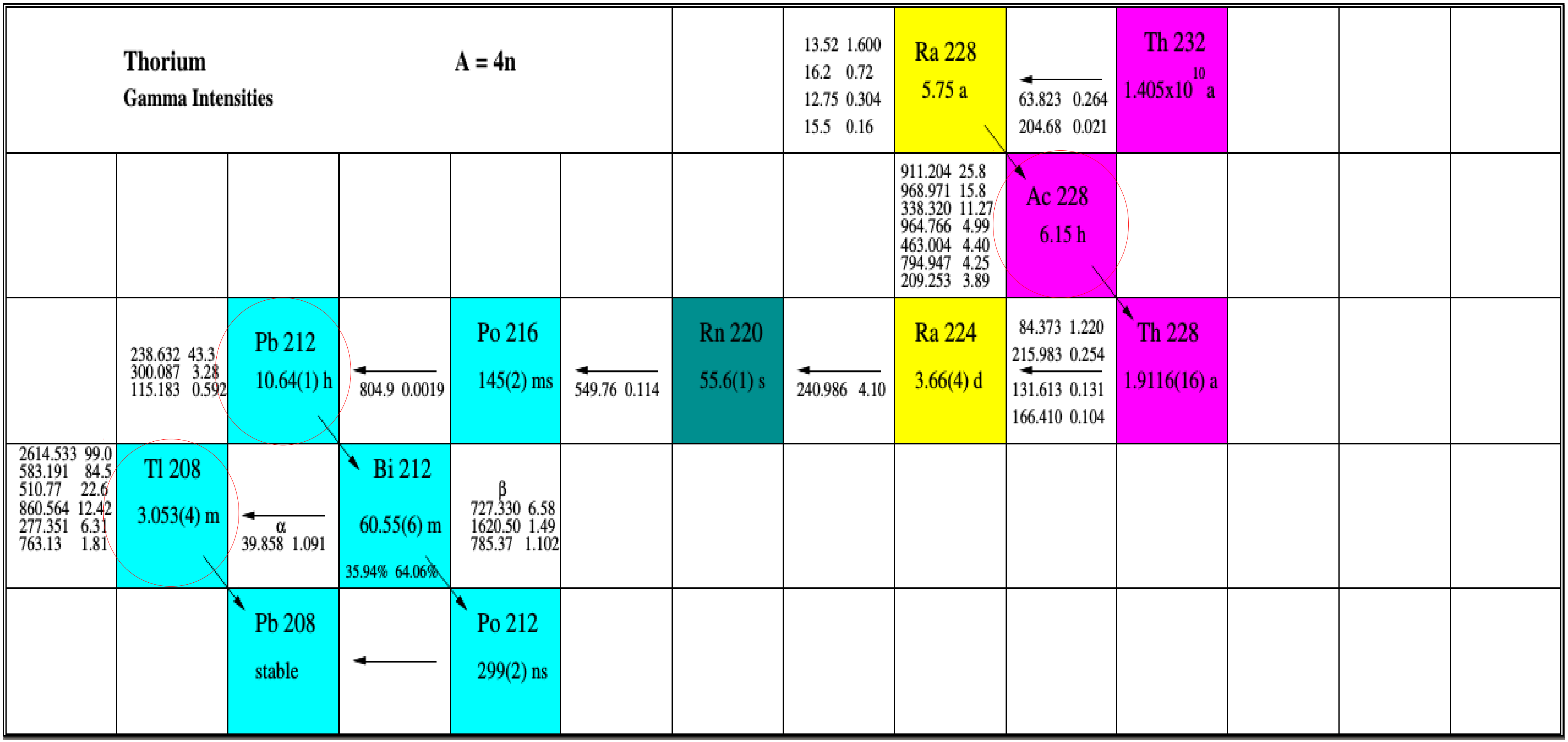



# Uranium Decay Chain



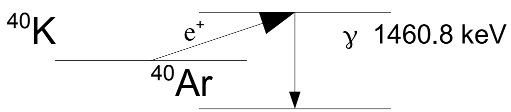
# Thorium Decay Chain



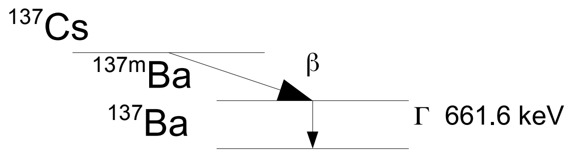
# Other Interesting Isotopes

## Usually Present:

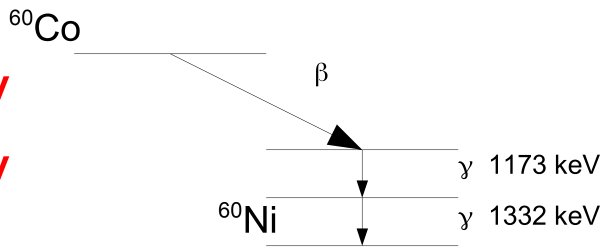
- $^{40}$K
  1460.83 keV



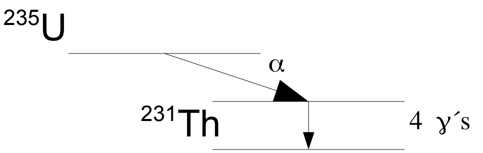

- $^{137}$Cs
  661.66 keV




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



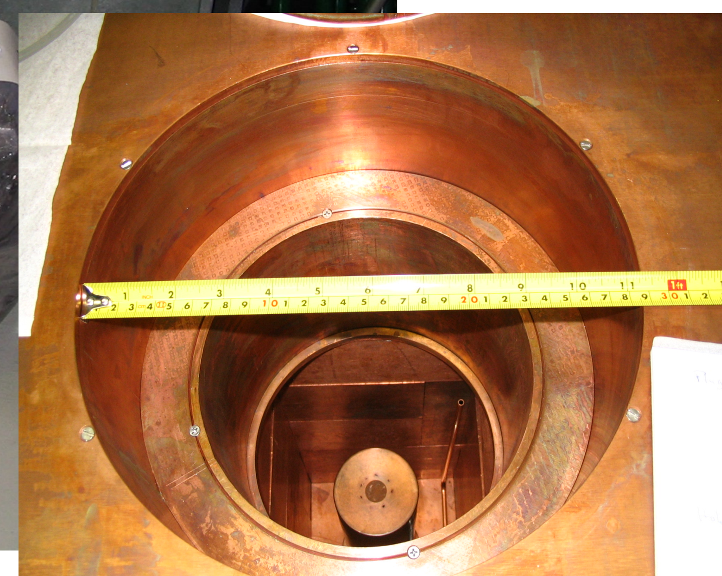

- $^{235}$U
  - 143.76 keV
  - 163.33 keV
  - 185.22 keV
  - 205.31 keV




## 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

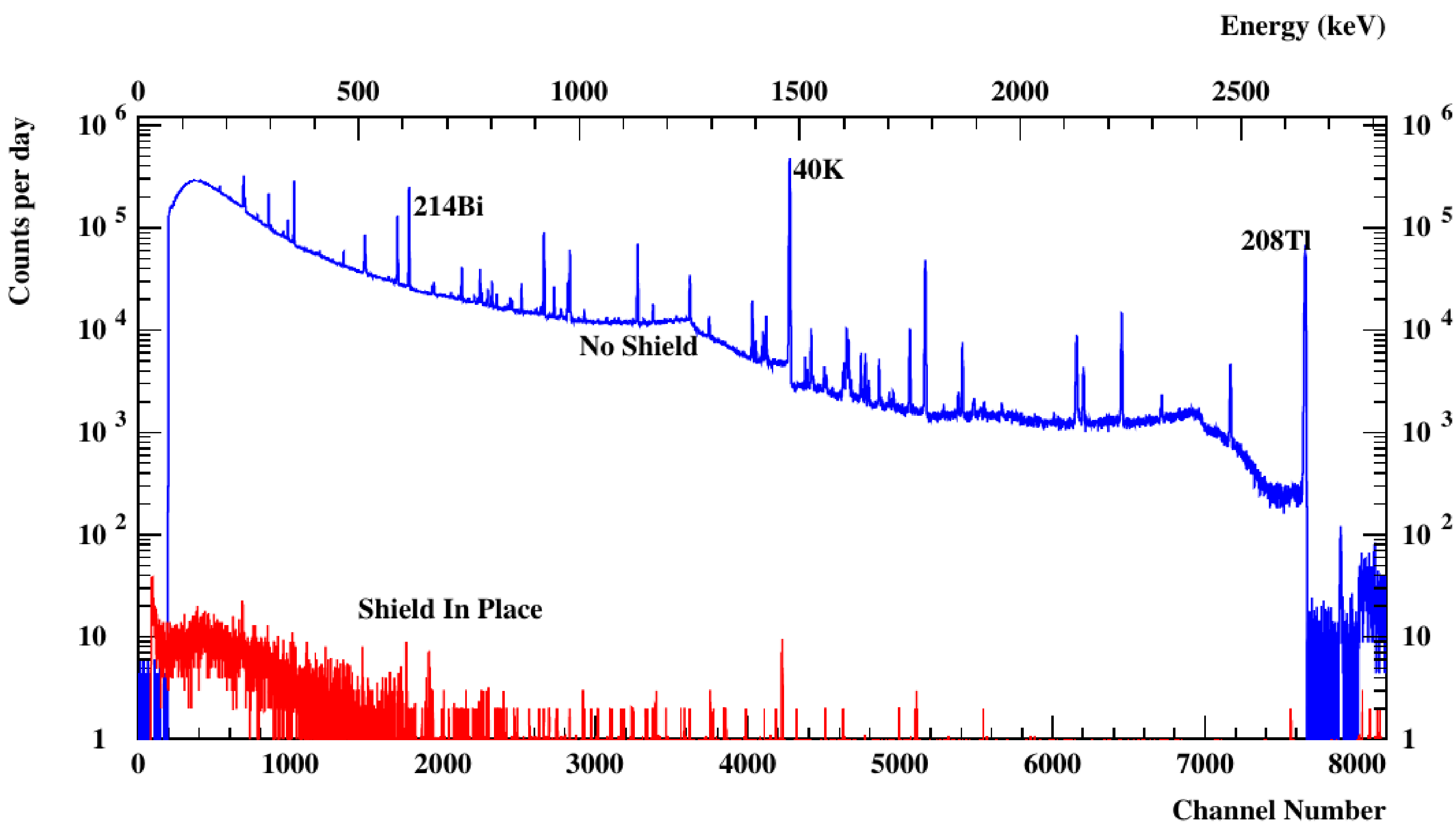
- Motivation
  - Survey materials for new, existing and proposed experiments (to be) located @ SNOLAB, such as SNO/SNO+, DEAP/CLEAN, PICASSO/COUPP/PICO, EXO, ... Also survey materials for the DM-ICE, DRIFT, DARKSIDE20K experiments, and Canberra.
- Constructed @ SNOLAB in 2005, detector was in UG storage 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

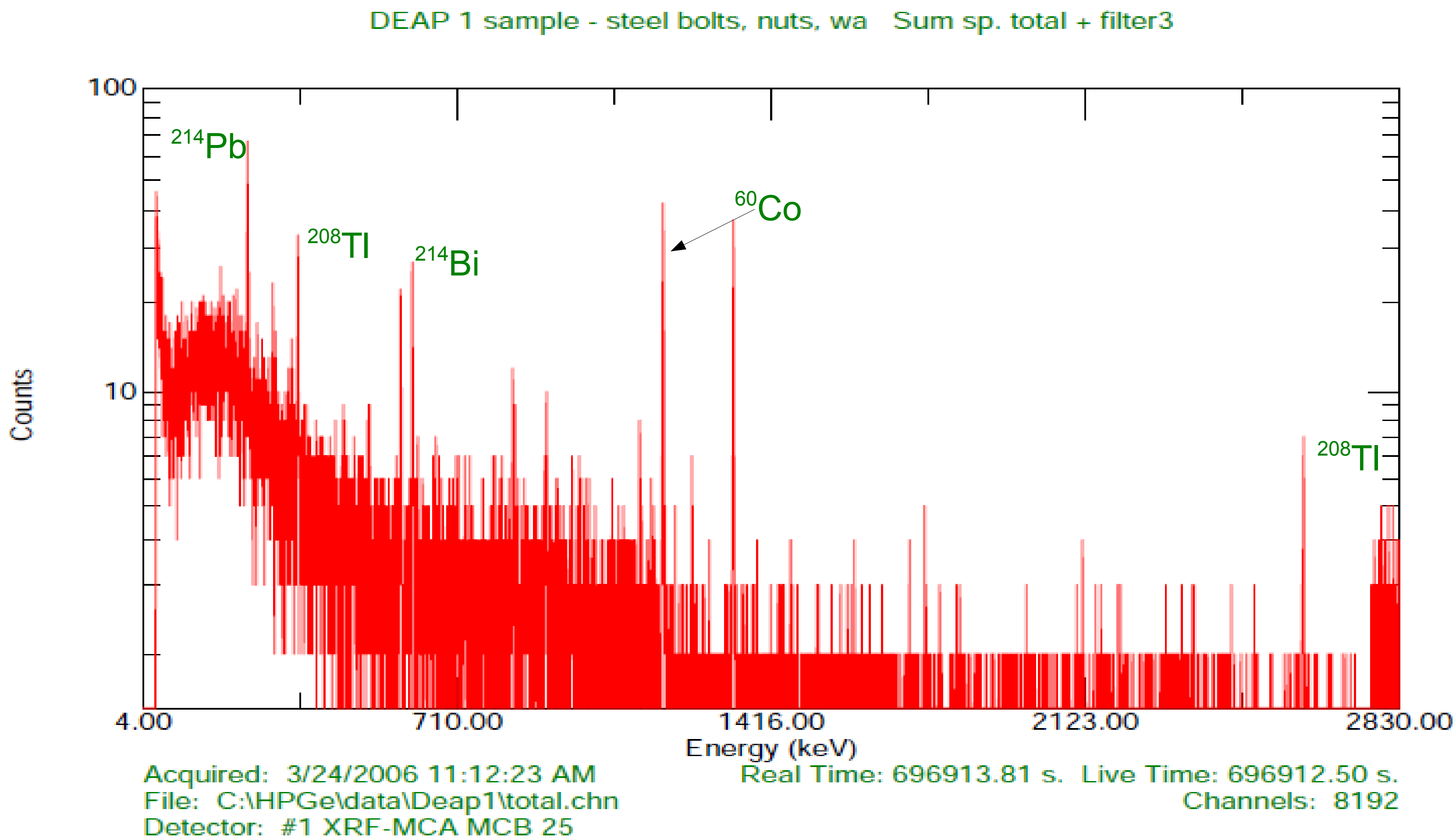
(for a standard 1L or 1 kg sample counted for one week)

| Isotope | Sensitivity for Standard Size Samples |
|---|---|
| $^{238}U$ | 0.12 mBq |
| $^{235}U$ | 0.17 mBq |
| $^{232}Th$ | 0.11 mBq |
| $^{40}K$ | 1.50 mBq |
| $^{60}Co$ | 0.05 mBq |
| $^{137}Cs$ | 0.14 mBq |
| $^{54}Mn$ | 0.05 mBq |

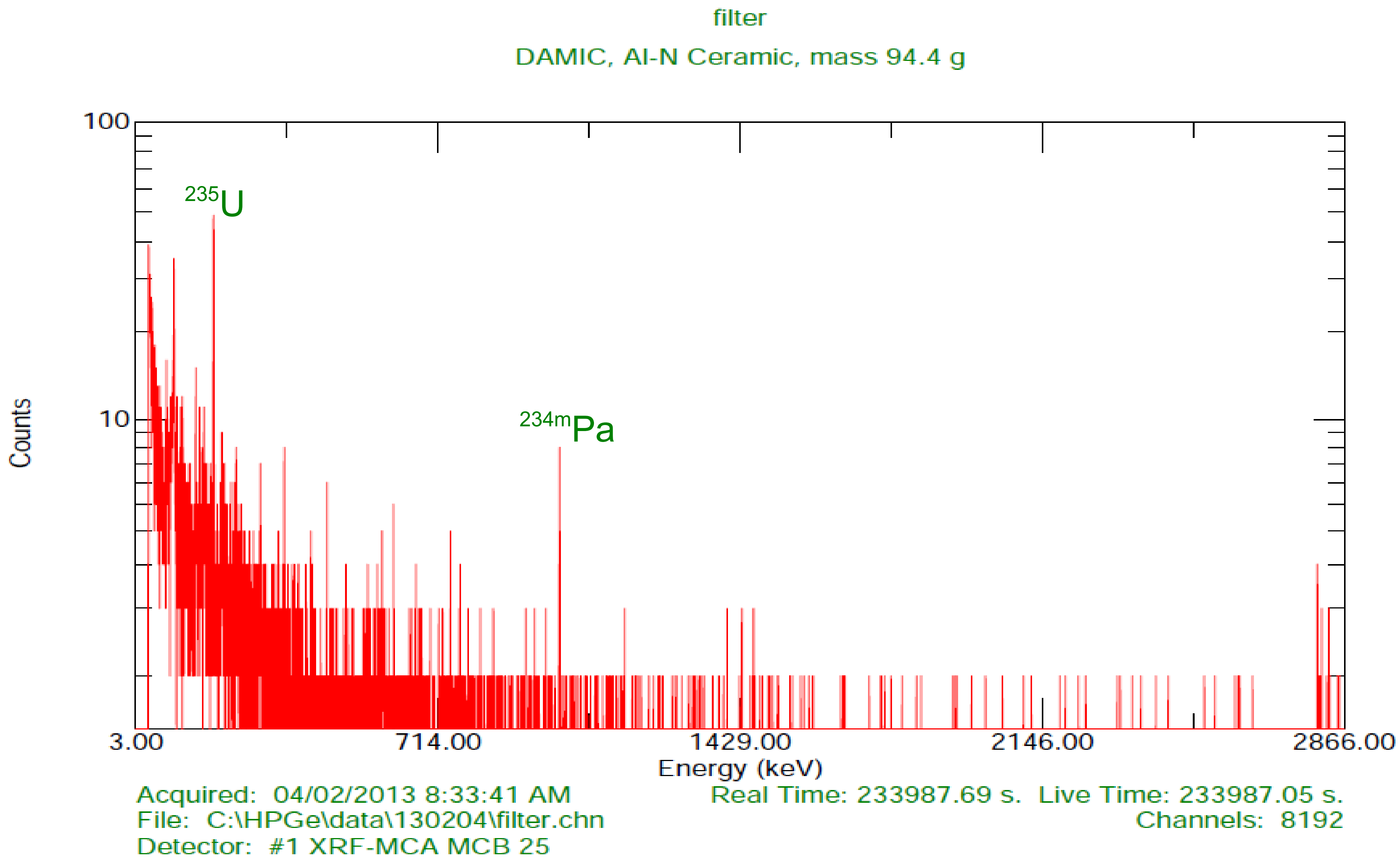
# Unshielded and Shielded Spectra
## (PGT Coax Detector)



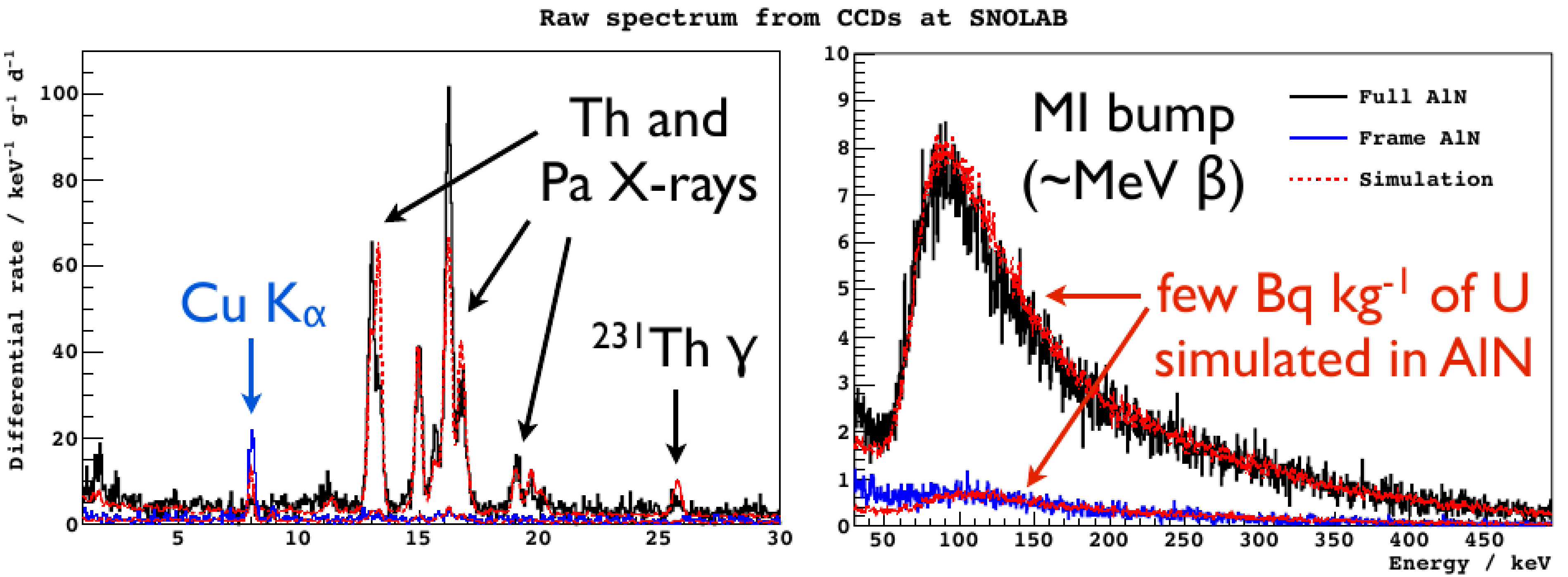
# Typical Stainless Steel Spectrum



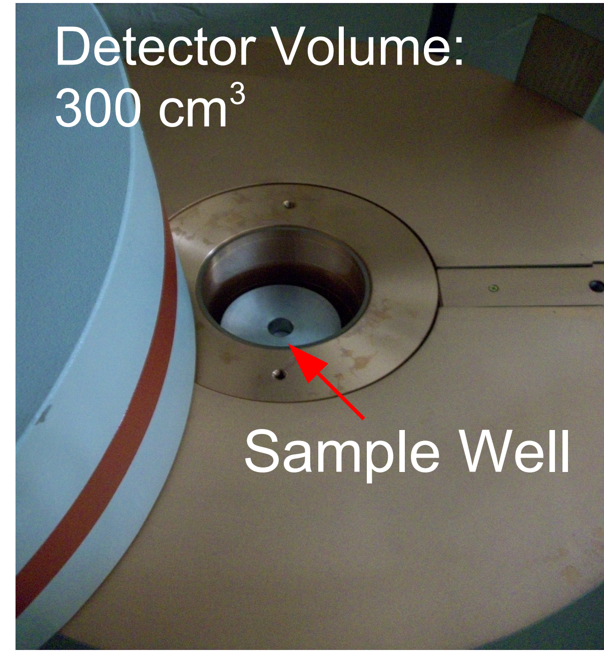
# DAMIC Ceramic Spectrum



# DAMIC Data and Simulation Using Results From PGT HPGe Counter



# Canberra Well Detector at SNOLAB


Typical
Sample Bottle
Volume is 3 ml

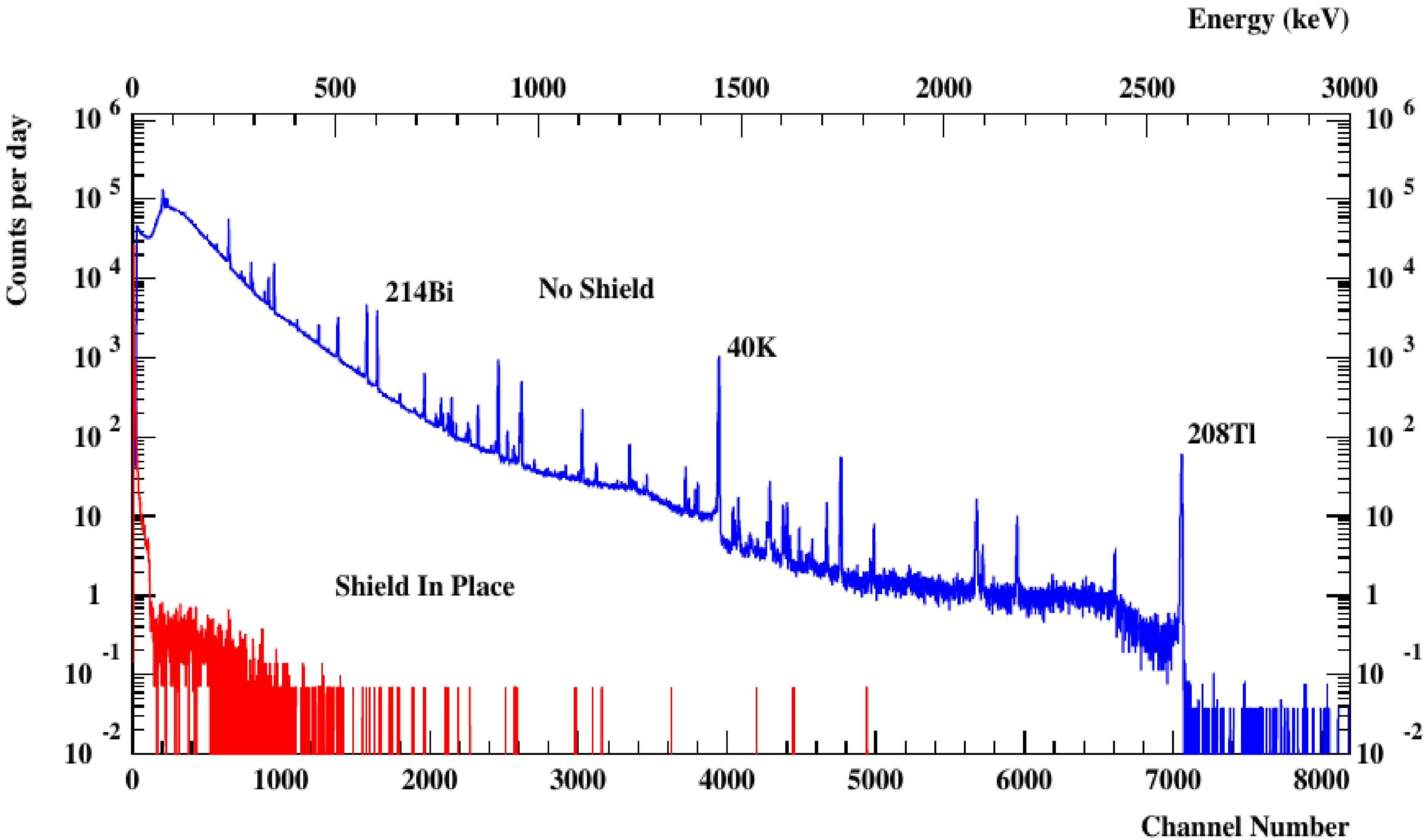
# SNOLAB Canberra Well Detector Specifications

- 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 |
|---|---|
| $^{238}U$ (↑ $^{226}Ra$) | 0.04 mBq |
| $^{238}U$ (↓ $^{226}Ra$) | 0.03 mBq |
| $^{228}Ac$ | 0.12 mBq |
| $^{232}Th$ | 0.23 mBq |
| $^{235}U$ | 0.01 mBq |
| $^{210}Pb$ | 0.08 mBq |

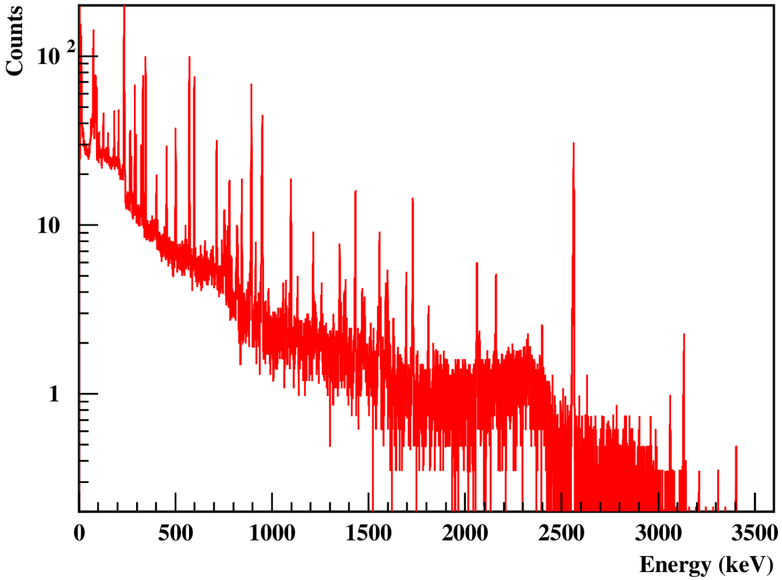
# Unshielded and Shielded Spectra
## (Canberra Well Detector)



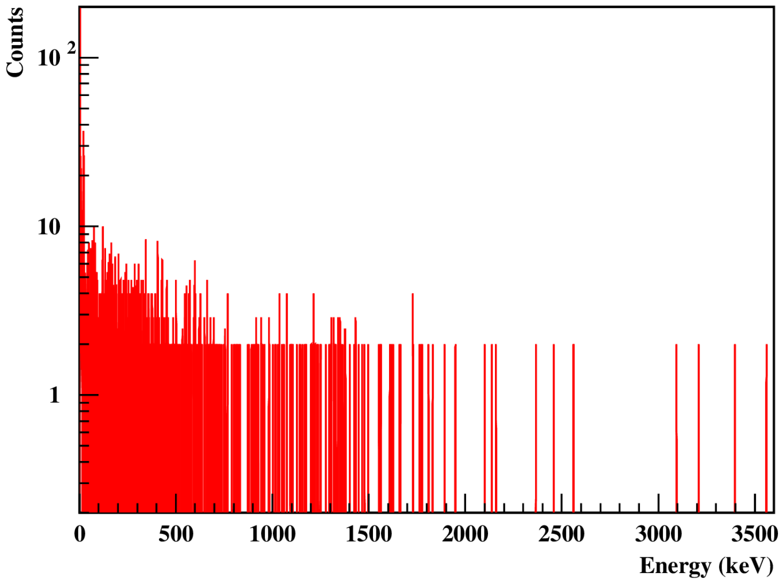
# Vue des Alpes HPGe Detector

The VdA HPGE detector has been reconditioned by baking and vacuum pumping for one month.

Calibration runs have been done to verify peak resolution and now a long-term background run is in progress.

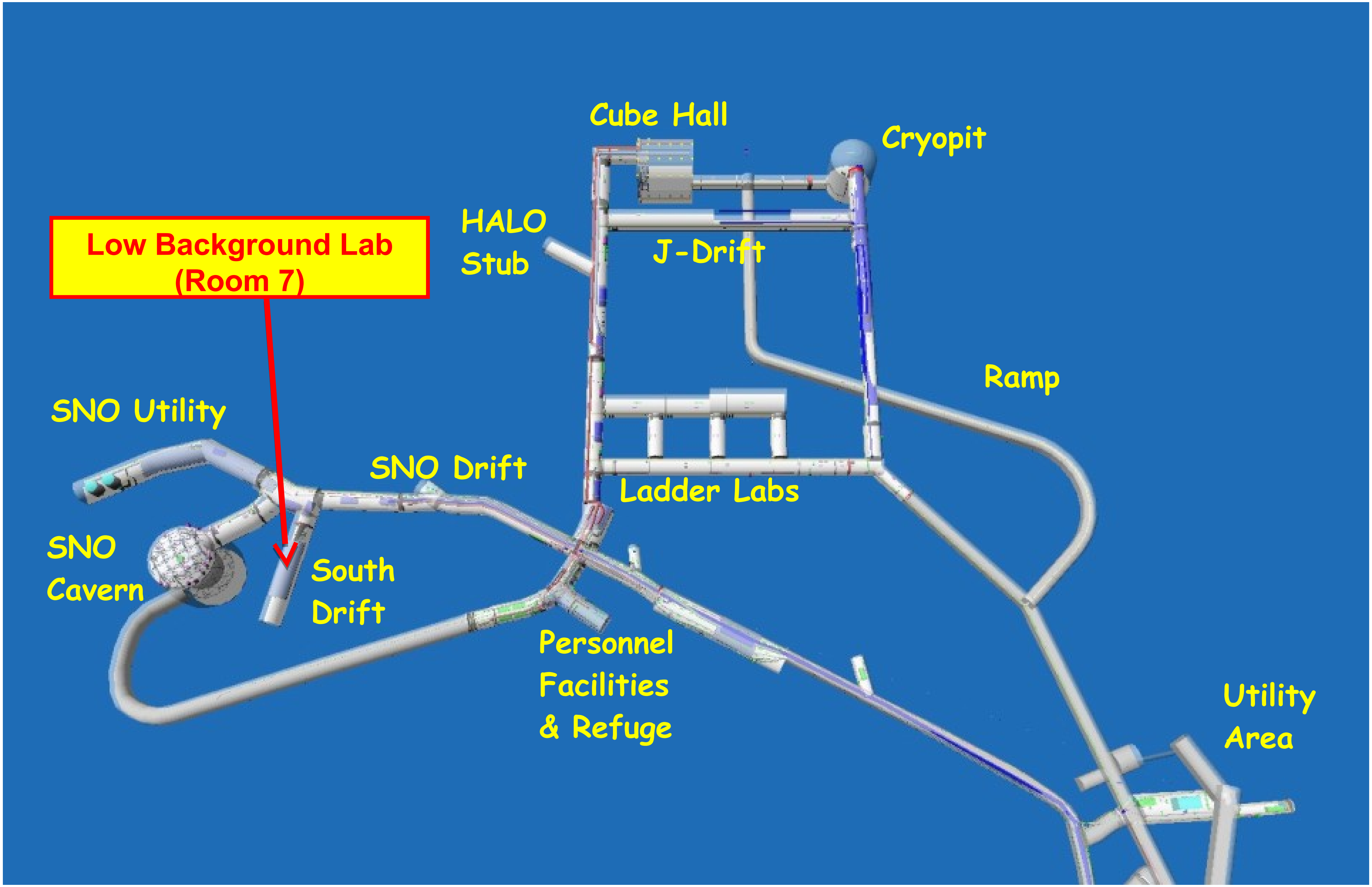



Calibration Spectrum




Background Spectrum

# Low Background Lab



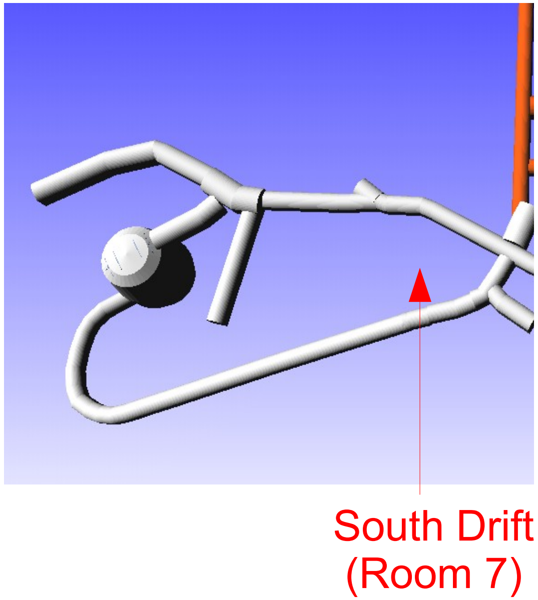
# Future Low Background Counters and Facilities

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 $Bq/m^3$.

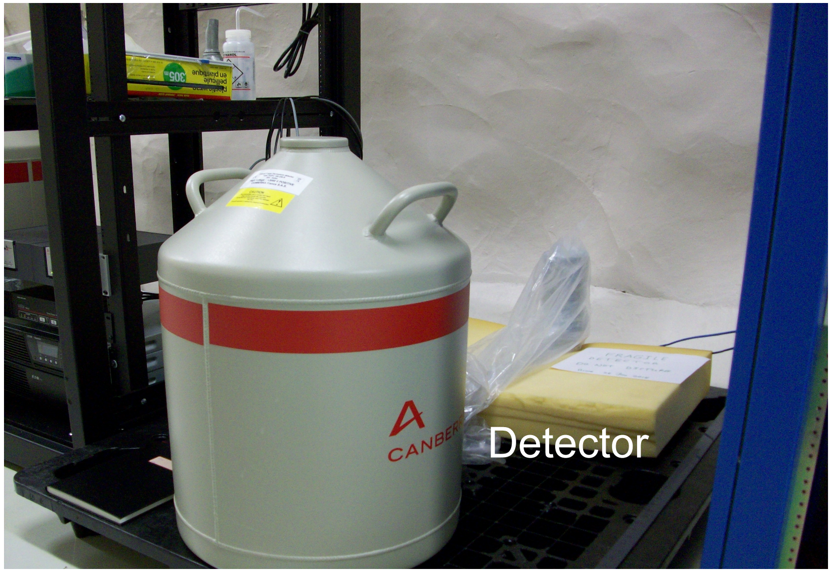
Space can accommodate several HPGE detectors, XRF, radon emanation chamber, alpha counters and there is some unallocated space for additional counters which would benefit from low-cosmic ray background.



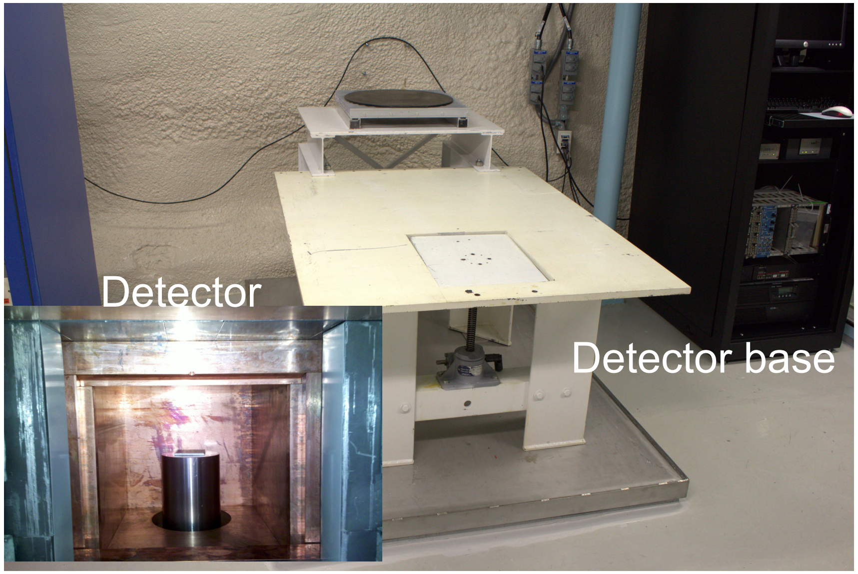
# Additional Low Background Counters Coming Soon

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 and low background lead is being cleaned.




2. SOUDAN Gopher HPGE detector, shielding base is assembled, awaiting lead and copper shielding, the low background lead is has just been cleaned.



# Additional Low Background Counters Coming Soon

3. Alpha Counters

SOUDAN Tennelec alpha counter to be assembled and restarted in a radon-free glove box assembly. Assembly will begin next week.

## 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.

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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 and $^{58}$Co is usually in materials such as brass.

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

radiopurity.org

Search | Submit | Edit | Settings | Login

reflector

Total results: 3

| Grouping | Name | Isotope | Amount | Isotope | Amount |
|---|---|---|---|---|---|
| LUX | Reflector panels (main) | Th-232 | 1 mBq/unit | | |
| LUX | Reflector panels (grid supports) | Th-232 | 1.3 mBq/unit | | |
| XENON100 (2011) | PTFE, McMaster-Carr | | | U-238 | 0.25 mBq/kg |

**LUX — Reflector panels (main)**

Sample Description: PTFE

Measurement Results:

| | | | | |
|---|---|---|---|---|
| Ra-226 | < | 3 | (90%) | mBq/unit |
| Th-232 | < | 1 | (90%) | mBq/unit |

**LUX — Reflector panels (grid supports)**

Sample Description: PTFE

Measurement Results:

| | | | | |
|---|---|---|---|---|
| Ra-226 | < | 5 | (90%) | mBq/unit |
| Th-232 | < | 1.3 | (90%) | mBq/unit |

**XENON100 (2011) — PTFE, McMaster-Carr**

Sample Description: PTFE, McMaster-Carr, veto reflector

Measurement Results:

| | | | | |
|---|---|---|---|---|
| Ra-228 | | 0.5 | (1) | mBq/kg |
| Th-228 | | 0.5 | (1) | mBq/kg |
| U-238 | | 0.25 | (5) | mBq/kg |
| Ra-226 | | 0.25 | (5) | mBq/kg |
| U-235 | | 0.011 | (2) | mBq/kg |
| K-40 | < | 3.1 | (95%) | mBq/kg |

# 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 Vue des Alpes detector is now operational and counting background.

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

  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.