Low Background Counting Facilities At SNOLAB

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SNOLAB

Low Radioactivity Techniques 2013

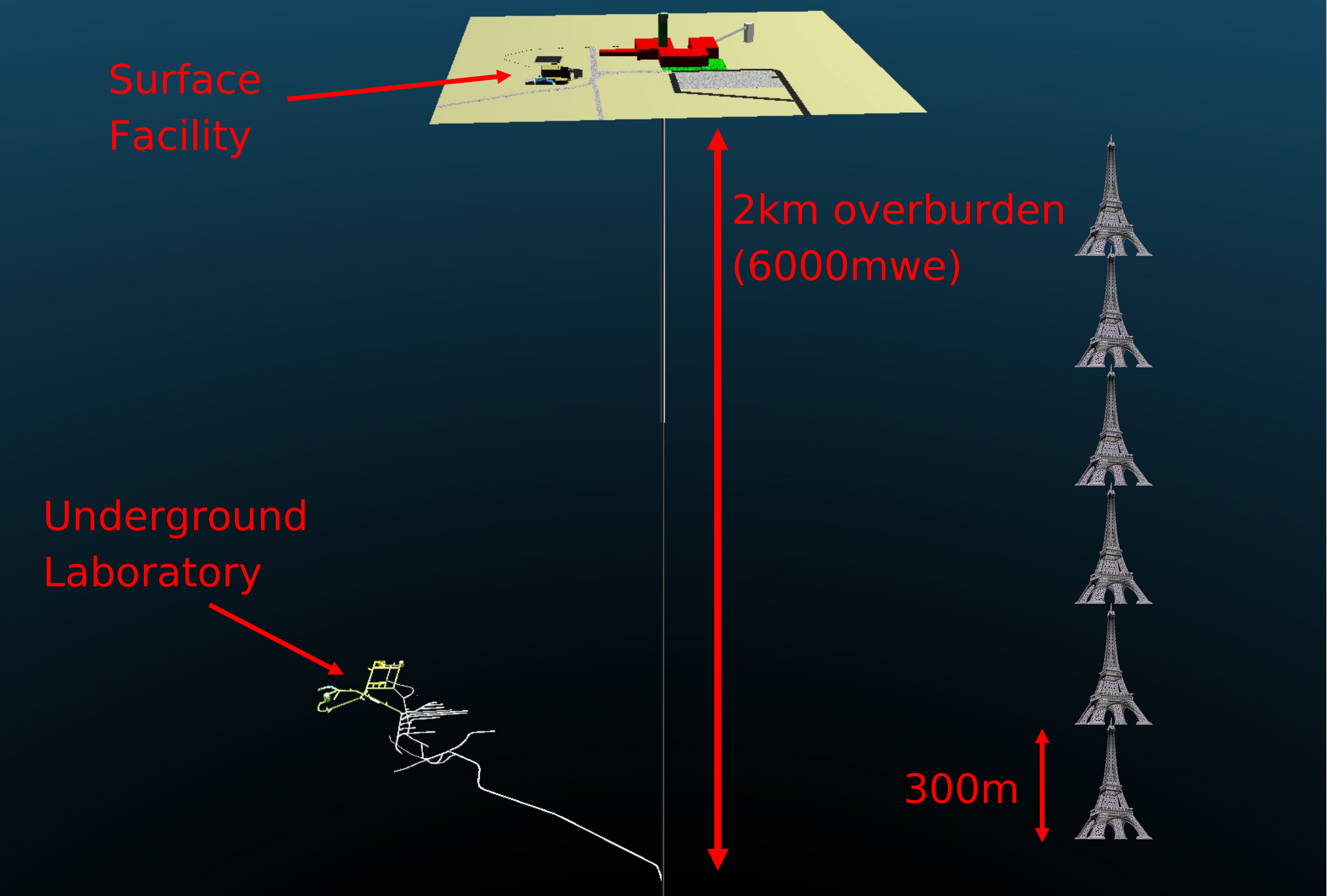
Outline

- Motivation for Low Background Counters
- Current Facilities in Operation at SNOLAB
  - PGT Ge detector
  - Electrostatic Counters (ESCs)
  - Alpha/Beta Counters
- Characterizing A New Germanium Well Detector
- Future Low Background Counters and Facilities

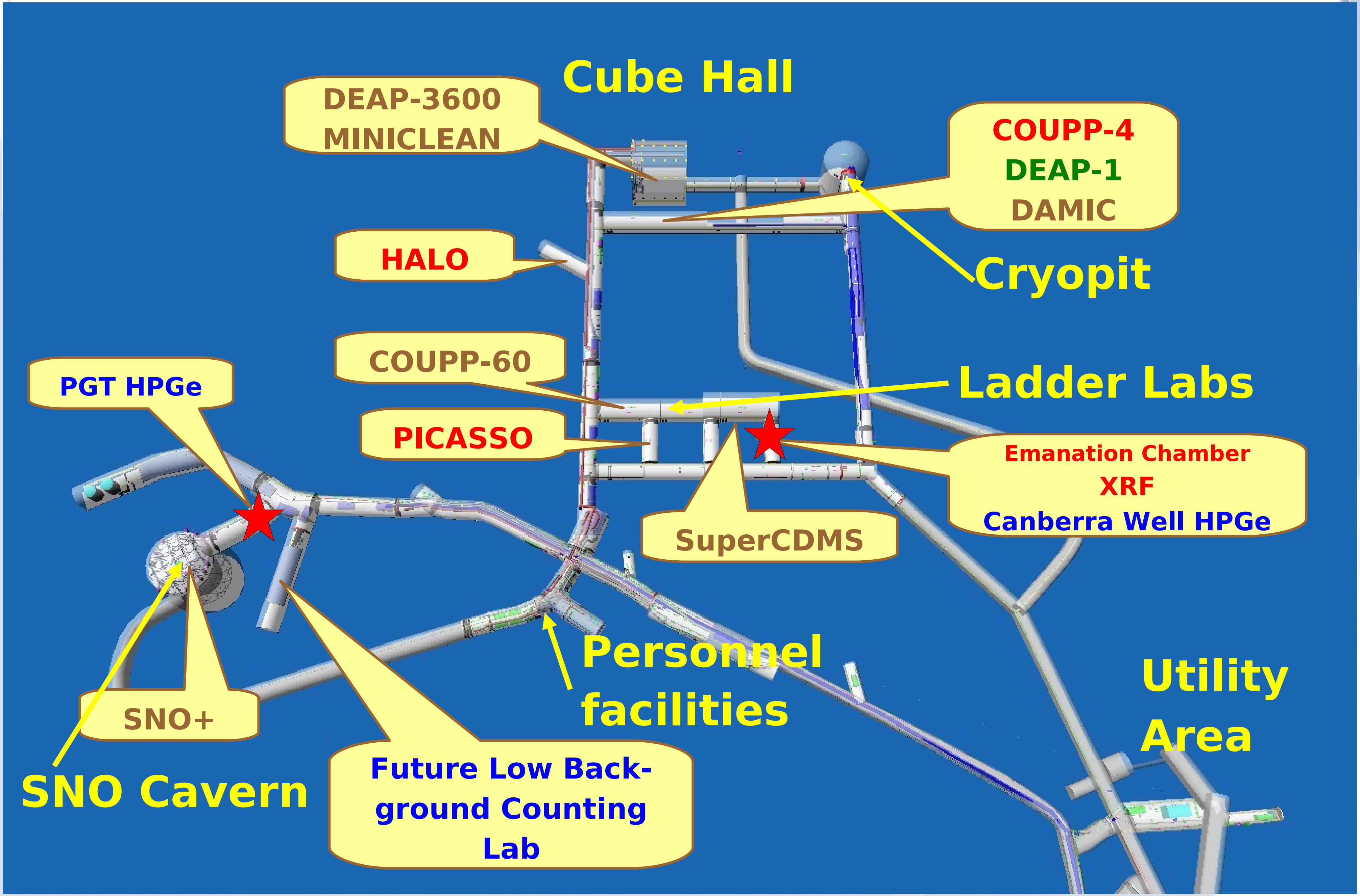
Motivation

- Many of the experiments currently searching for dark matter, studying properties of neutrinos or searching for neutrinoless double-beta decay 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.
- 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.

SNOLAB

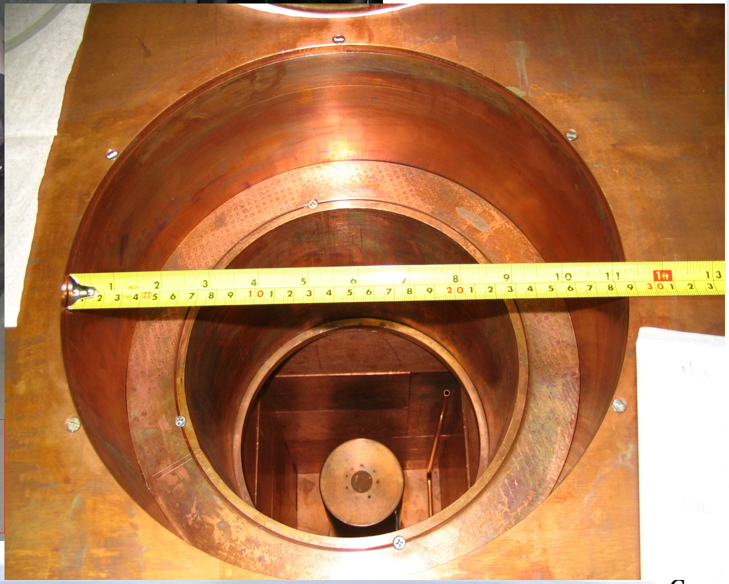

Surface
Facility
2km overburden
(6000mwe)
Underground
Laboratory
300m

SNOLAB


Cube Hall
DEAP-3600
MINICLEAN
COUPP-4
DEAP-1
DAMIC
HALO
Cryopit
COUPP-60
PGT HPGe
Ladder Labs
PICASSO
Emanation Chamber
XRF
Canberra Well HPGe
SuperCDMS
Personnel facilities
Utility Area
SNO+
SNO Cavern
Future Low Back-ground Counting Lab

Existing SNOLAB PGT HPGe Counter

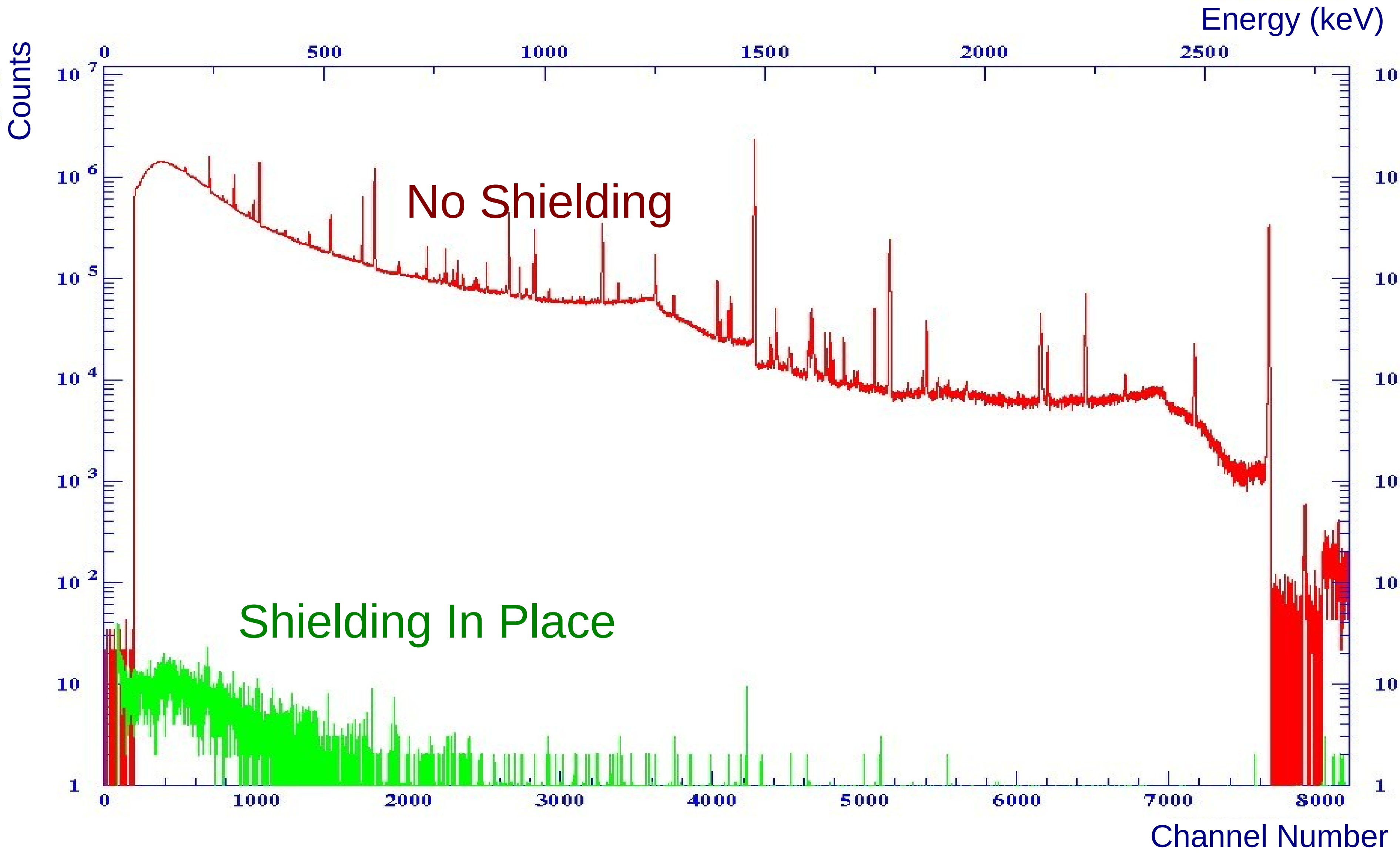
Additional lead used to dampen microseismic activity



SNOLAB PGT HPGe Detector Specifications

- Establishment of the Low Background Gamma Facility @ SNOLAB in 2005.
- Motivation
  - Survey materials for new, existing and proposed experiments (to be) located @ SNOLAB, such as SNO, SNO+, DEAP/CLEAN, PICASSO, EXO, ... Also survey materials for the DM-ICE and DRIFT experiments.
- Constructed @ SNOLAB from a HPGe detector and its associated shielding located underground at 4600 ft level since 1997.
  - 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 to keep radon out, as the lab radon levels are 150 Bq/m^3.

Unshielded and Shielded Spectra



PGT HPGe Typical Detector Sensitivity
(for a standard 1L or 1 kg sample)

Isotope	1 Bq/kg	1 ppb	Sensitivity for Standard Size Samples	Typical for Earth's Crust
^{238}U	81 ppb	12 mBq/kg	~ 1 mBq/kg ~ 0.1 ppb	37 Bq/kg 3 ppm
^{232}Th	246 ppb	4.1 mBq/kg	~ 1.5 mBq/kg ~ 0.3 ppb	45 Bq/kg 11 ppm
^{40}K	32 ppm	0.031 mBq/kg	~ 21 mBq/kg ~ 0.7 ppm	800 Bq/kg 2.5 %

Increased sensitivities have been achieved for specialized very large samples, on the order of 10 kg, combined with a long counting period:

^{238}U: 0.009 ppb,
^{232}Th: 0.02 ppb,
^{40}K: 87.0 ppb

Measurements To Date For Each Experiment

Experiment	2006	2007	2008	2009	2010	2011	2012	2013	Total
SNO	2	7	0	2	0	0	0	0	11
SNO+	0	2	18	14	15	35	5	3	92
SNOLAB	7	3	0	0	9	6	17	2	44
EXO	1	1	0	0	2	1	0	0	5
MiniCLEAN	5	1	9	18	8	3	7	3	54
DEAP	8	8	12	10	8	15	18	4	83
HALO	0	0	0	2	3	1	1	0	7
PICASSO	1	1	4	3	0	0	0	0	9
DM-ICE / DRIFT	--	--	--	--	9	9	5	0	23
COUPP	--	--	--	--	1	15	17	4	37
DAMIC	--	--	--	--	--	--	1	3	4
Total	24	23	43	49	34	85	71	19	369
Calibrations &Tests	30	34	14	9	4	3	11	3	108
Samples in Detector Queue: - 16, counting time per sample averages one week. - the queue is usually very long, so additional counters are very important.									

SNOLAB Data Repository

SNOLAB maintains a database in a spreadsheet format for each experiment.

The data is shown in units of mBq/kg and pp(b or m).

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. These are also included in the spreadsheet for each sample.

The database is available to all SNOLAB users and can be made available to others upon request as it is password protected, contact Ian.Lawson@snolab.ca or Bruce.Cleveland@snolab.ca.

Electrostatic Counting System

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

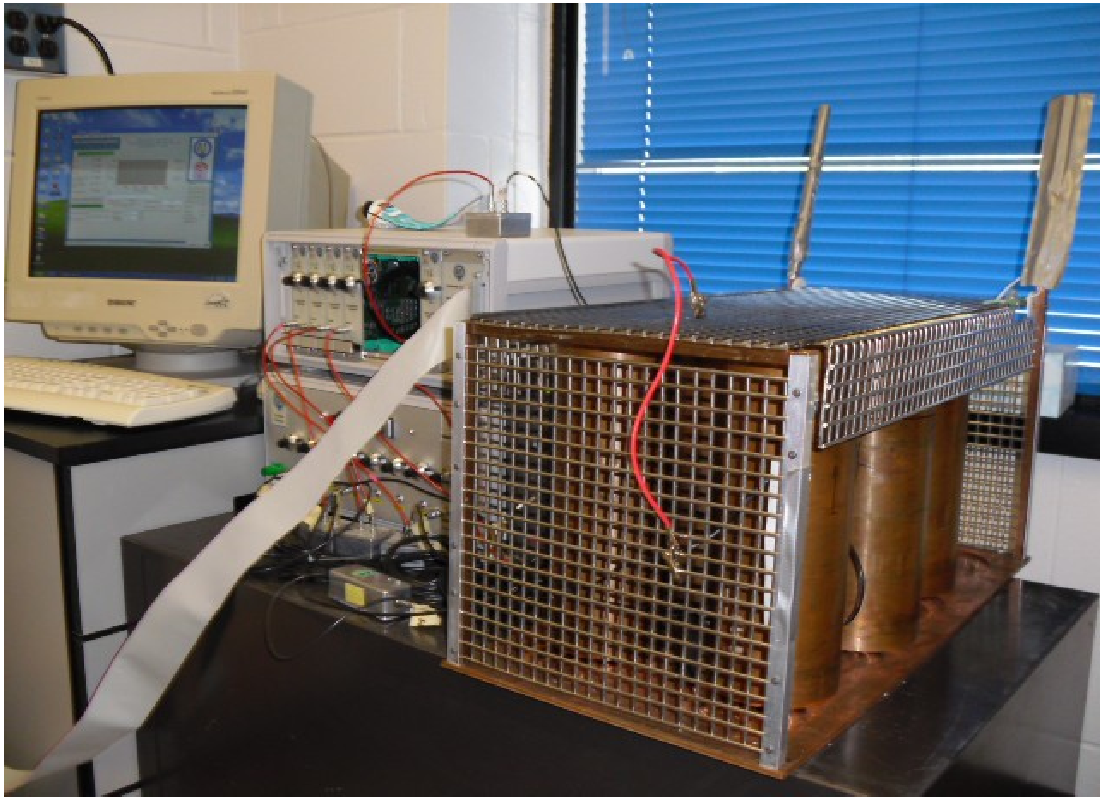
Sensitivity Levels are:

- ^{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).

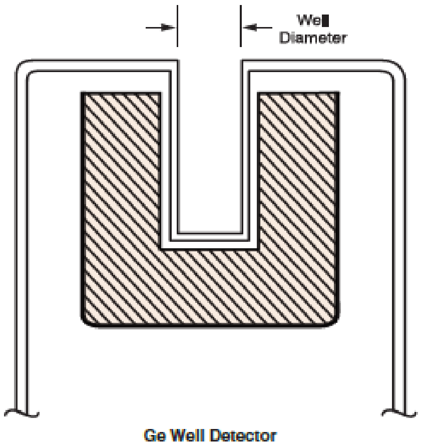
Alpha Beta Counting System



Currently located at the SNOLAB hot lab at LU so that spike sources can be measured.

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

Future Low Background Counting Facilities At SNOLAB
Canberra Well Detector



Two new low background high purity Ge Counters were ordered from Canberra

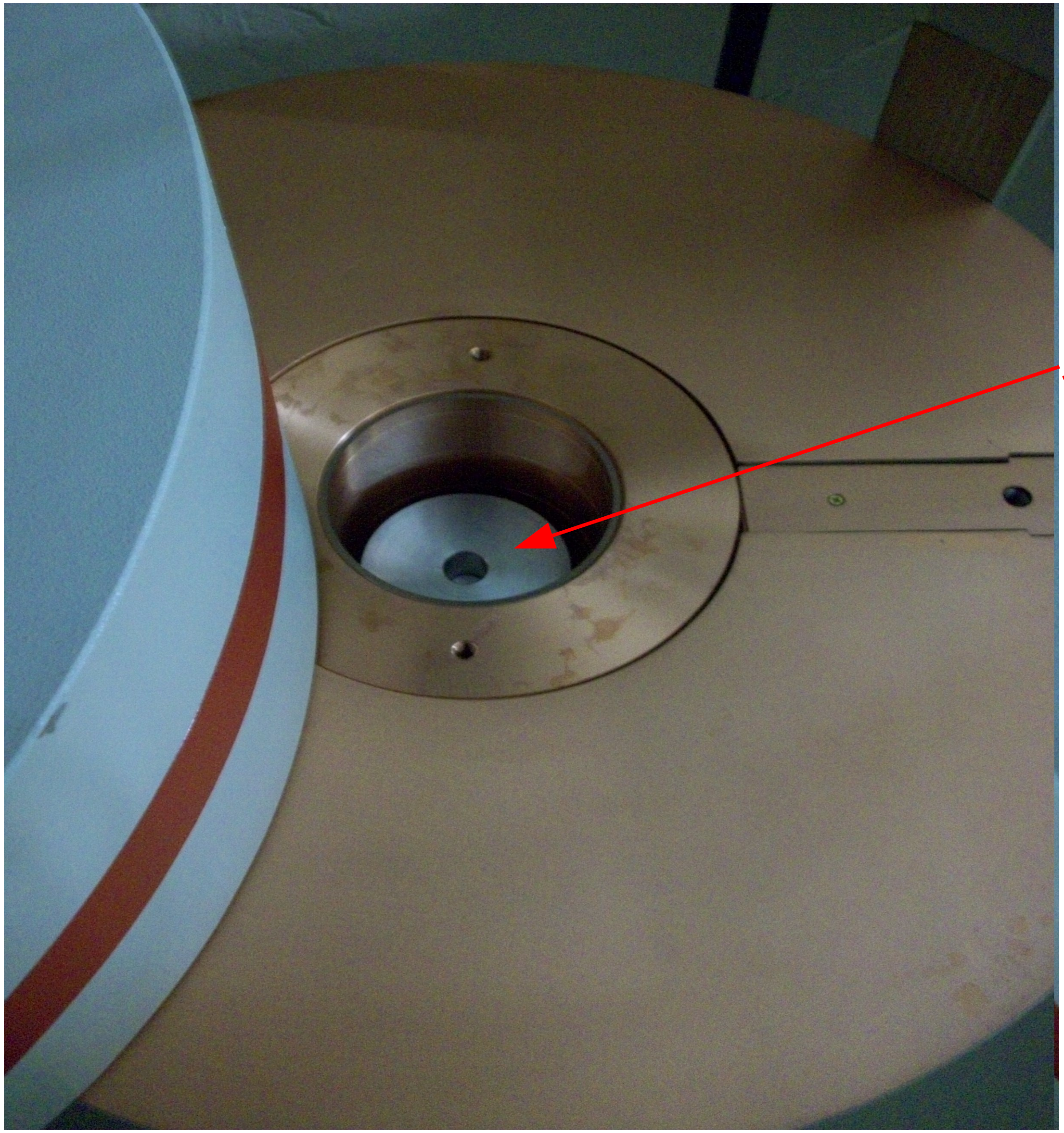
One counter is a p-type coaxial detector and the other is a p-type well detector. Canberra also supplied a specially built shield for the well detector.

However, the well detector would not fit into the supplied shield as the base of the well detector was too large for the copper shielding disks and the vacuum tube connecting the dewar with the detector was too short for the shielding thickness.

The well detector was sent back to Canberra and was rebuilt to fit the shielding, the detector is now back at SNOLAB and is being characterized.

Canberra Well Detector at SNOLAB

Canberra Well Detector at SNOLAB



Detector Volume: 300 cm^3

Sample Well

Sample Bottle
Volume is 3 ml

Canberra Well Detector Status

- Background run completed (38 days and ongoing).

  ^{238}U 0.029 ± 0.058 decays per day (10.59 ± 21.17 decays per year)

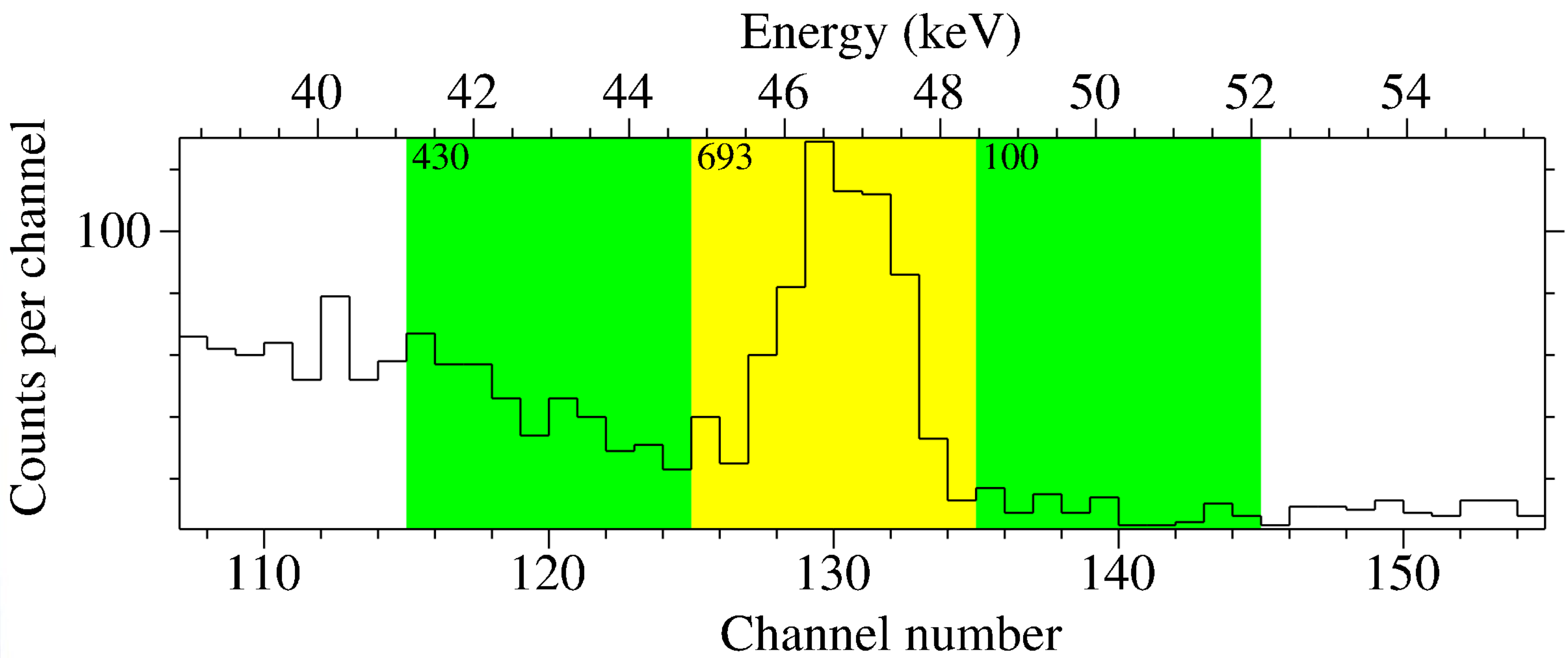
  ^{232}Th 0.048 ± 0.063 decays per day (17.52 ± 23.00 decays per year)

  ^{40}K 0.0 ± 0.02 decays per day (0.0 ± 7.3 decays per year)

  ^{210}Pb not observed

  Total backgrounds at the level of 30 counts / year.
- Calibration sources approved by SNOLAB and efficiency measurements are in progress.
- Samples for SNO+ and DEAP have been counted, final results awaiting efficiency and background measurement.
- Ability to measure small samples, sensitive to gamma energies between 10 keV and 600 keV, therefore can measure several gammas from ^{238}U, ^{235}U and ^{232}Th but not very sensitive to ^{40}K.
- Ability to directly measure ^{210}Pb.

^{210}Pb Measurement



Concentrated sample of leachate from SNO+ Acrylic Vessel

Future Low Background Counting At SNOLAB
Canberra Coax Detector

The well detector shielding was slightly modified to allow the coax detector to fit so that it could be tested while the well detector was rebuilt.

The coax detector was ran inside the well detector shielding to characterize the backgrounds in the hope the detector had backgrounds less than the PGT detector.

However, it was determined that the coax detector is anything but low in backgrounds. It has substantial amounts of ^{232}Th and ^{235}U, the other backgrounds are similar to those observed from the PGT counter.

Future Low Background Counting At SNOLAB
Canberra Coax Detector

The background levels for a true ultra-low background detector should be no more than 100 counts/year from all backgrounds.

The activities present are:

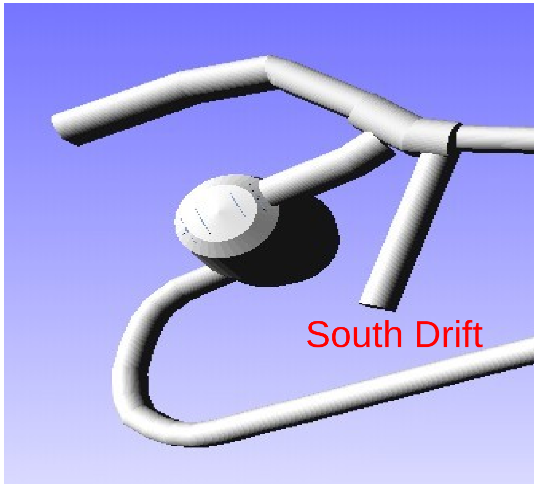
- ^{228}Th progeny at 30 counts/day
- ^{228}Ra progeny at 30 counts/day
- ^{238}U progeny at 500-600 counts/day, although below ^{226}Ra the rate is only about 5 counts/day.
- ^{40}K at 18 counts/day

The detector was dismantled by Canberra and the pieces will be counted at SNOLAB to determine if there is a smoking gun causing the high background rate.

Canberra Coax Detector Components

CRYSTAL SUPPORT COMPONENTS OF EGPC 100-220-R N° 54204

SNOLAB Low Background Laboratory
(under construction)



A new dedicated space is being constructed at SNOLAB for a low background lab located in the South Drift (former refuge station).

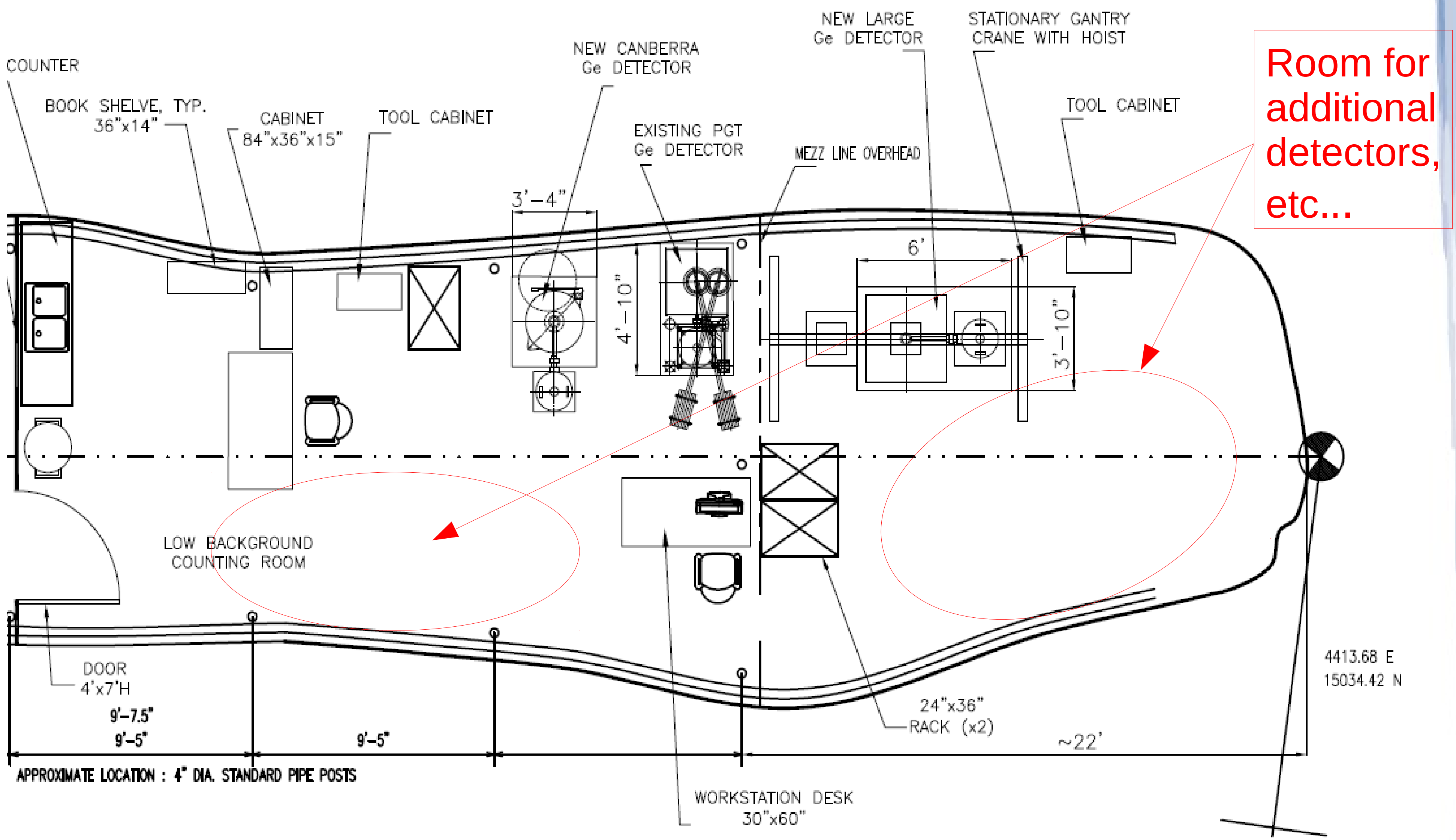
This drift is isolated from other drifts and is inaccessible to large equipment. This will help reduce micro-seismic noise which can effect Ge detectors.

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.

Future Low Background Counting Lab

Future Low Background Counting Lab



Future Low Background Counting Lab

Goal is to have new space ready by end of 2013, so far the room has been painted to help keep the space clean.

Requires installation of new walls, electrical utilities and air conditioning.

Relocate Canberra Well detector, XRF and Emanation Chamber.

PGT detector to be moved over the longer term and only after Canberra Coax detector is declared ready for use.

Additional space reserved for future counting facilities.

Summary

- SNOLAB PGT HPGe low background counting system has run continuously for the past since 2005 and has counted 369 samples so far.

    Counting queue is long at ~16 samples, this sometimes limits when samples can be counted in a timely manner.

    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 need refurbishing, one was not built to specifications and the other is not ultra-low background.

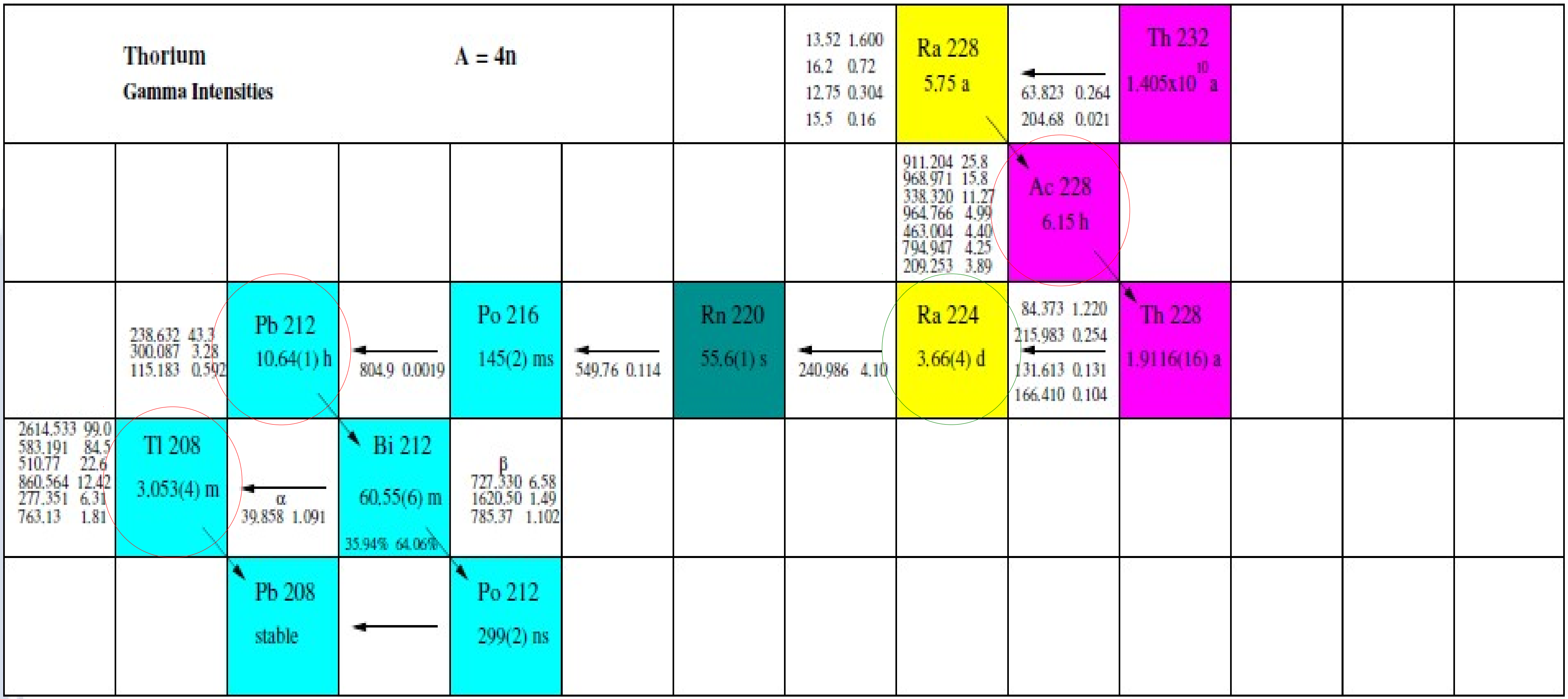
    The new counters should allow much higher sensitivity, effort underway to ensure all materials are low background. The well detector will be used for very specialized small samples such as vapourized acrylic and can search for ^{210}Pb.

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

- New low background counting lab is being constructed at SNOLAB, final preparations are now underway.

Extra Slides Follow

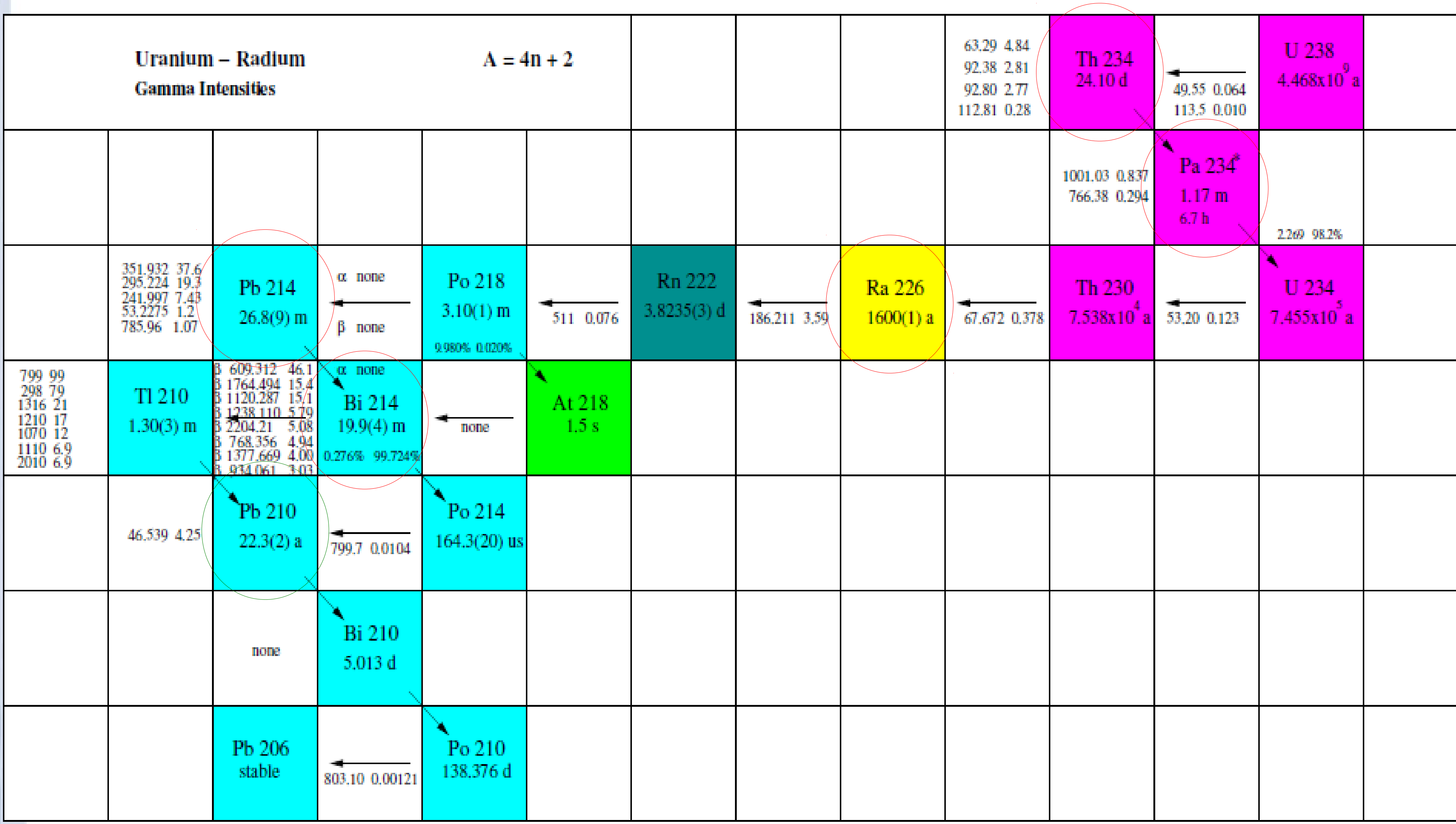
^{232}Th Decay Chain



^{235}U Decay Chain

Actinium **Gamma Intensities**				**A = 4n + 3**					25.64 14.5 84.214 6.6	Th 231 1.0633 d	185.715 57.2 143.76 10.96 163.33 5.08 ← 205.311 5.01 109.16 1.54 202.11 1.08	U 235 7.028×10^{8} a	
		293.54 1000 271.23 55 517.63 19 833.00 14 563.70 13 401.81 10	Bi 215 7.6 m	α none ← β none	At 219 56 s ~97% ~3%	α none β 50.13 36.0 β 79.72 9.1 ← β 234.81 3.0 β 49.89 2.7	Fr 223 21.8 m 0.006% 99.994%	α 160.26 0.0059 ← β none	Ac 227 21.773(3) a 1.380% 98.620%	27.36 10.29 300.07 2.47 302.65 2.19 ← 283.69 1.70 330.06 1.40 19.00 0.374	Pa 231 3.276×10^{4} a		
	404.853 3.78 832.01 3.52 427.088 1.76	Pb 211 36.1(2) m	← 438.8 -0.040	Po 215 1.781(4) ms	← 271.23 10.8 401.81 6.37	Rn 219 3.96(1) s	269.459 13.70 154.21 5.62 323.871 3.93 ← 144.232 3.22 338.281 2.79 445.031 1.27	Ra 223 11.435(4) d	235.971 12.3 50.13 8.26 256.25 7.01 ← 329.85 2.69 300.00 2.32 286.12 1.53	Th 227 18.72(2) d			
897.80 0.260 569.702 0.00159 328.12 0.00140	Tl 207 4.77 m	α 351.059 12.91 ← β none	Bi 211 2.14(2) m 99.724% 0.276%										
		Pb 207 stable	← 897.80 0.561 569.702 0.5	Po 211 516 ms									

^{238}U Decay Chain

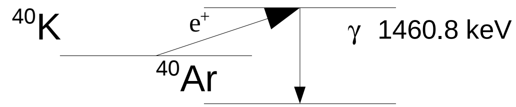


Other Interesting Isotopes

Usually Present:

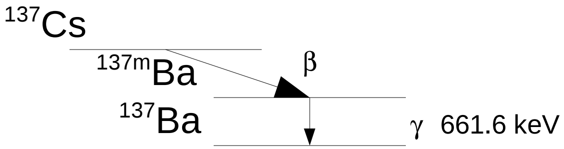
- ^{40}K

  1460.83 keV

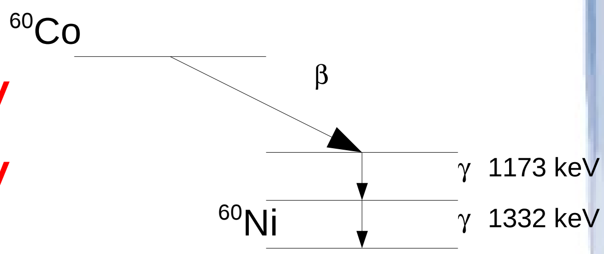


- ^{137}Cs

  661.66 keV



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



Occasionally Present:

• ^{54}Mn at 834.85 keV	Observed in Stainless Steel and other metals
• ^{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.