

Radioactive Background Measurements

Ian Lawson

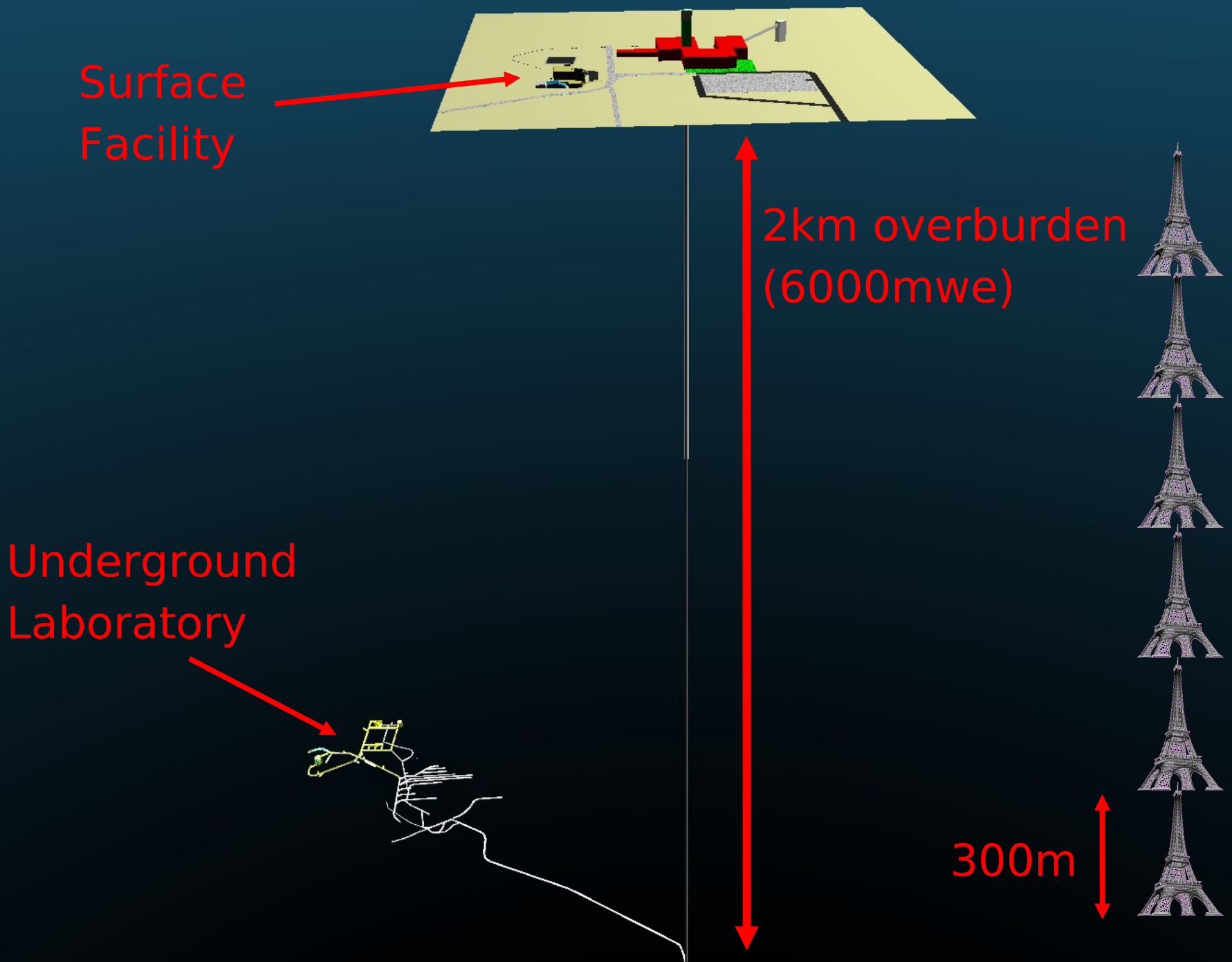
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Outline

- Radioactive Background Information
- Description of the SNOLAB Low Background Counting System
- Low Background Counting, How it is done
- Future Low Background Counting Facilities: Includes the new Canberra Well Detector Now Operational
- Electrostatic (ESC) Counters
- Alpha/Beta Counting System
- Underground Radon Levels at SNOLAB and How to Reduce These Levels
- Future Research and Development Ideas



SNOLAB



Radioactive Backgrounds 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 1ppm for 40K, or less.
- The problem backgrounds can include gammas, alphas and neutrons.
- The goal is to measure these backgrounds and then to reduce them to be as low as reasonably achievable.

Key R&D Topics

- Development and strengthening of the ultra low background facilities and instrumentation in all underground labs
- measurement and monitoring of the background components in the underground Labs – Development of background simulation codes
- application of low background techniques to interdisciplinary fields
- R&D on radiopurity of materials and purification techniques.

Support (from groups such as AARM):

- personnel
- travel money
- contribution to equipment and consumables for selected specific activities codes

^{238}U Decay Chain

Uranium – Radium Gamma Intensities				$A = 4n + 2$								63.29 4.84 92.38 2.81 92.80 2.77 112.81 0.28	Th 234 24.10 d	← 49.55 0.064 113.5 0.010	U 238 4.468x10 ⁹ a
													1001.03 0.837 766.38 0.294	Pa 234 ^m 1.17 m 6.7 h	2.269 98.2%
351.932 37.6 295.224 19.7 241.997 7.43 53.2275 1.2 785.96 1.07	Pb 214 26.8(9) m	α none β none	Po 218 3.10(1) m 9.980% 0.020%	← 511 0.076	Rn 222 3.8235(3) d	← 186.211 3.59	Ra 226 1600(1) a	← 67.672 0.378	Th 230 7.538x10 ⁴ a	← 53.20 0.123	U 234 7.455x10 ⁵ a				
799 99 298 79 1316 21 1210 17 1070 12 1110 6.9 2010 6.9	Tl 210 1.30(3) m	3 609.312 46.1 3 1764.494 15.4 3 1120.287 15.1 3 1238.110 5.79 3 2204.21 5.08 3 768.356 4.94 3 1377.669 4.09 3 834.061 1.03	Bi 214 19.9(4) m 0.276% 99.724%	α none none	At 218 1.5 s										
46.539 4.25	Pb 210 22.3(2) a	← 799.7 0.0104	Po 214 164.3(20) us												
none		Bi 210 5.013 d													
	Pb 206 stable	← 803.10 0.00121	Po 210 138.376 d												

^{232}Th Decay Chain

Thorium				A = 4n											
Gamma Intensities								13.52 1.600 16.2 0.72 12.75 0.304 15.5 0.16				Ra 228 5.75 a			
												Th 232 1.405x10 ¹⁰ a			
												Ac 228 6.15 h			
238.632 43.3 300.087 3.28 115.183 0.592				Pb 212 10.64(1) h				Po 216 145(2) ms				Rn 220 55.6(1) s			
				804.9 0.0019				549.76 0.114				240.986 4.10			
								Ra 224 3.66(4) d				Th 228 1.9116(16) a			
2614.533 99.0 583.191 84.5 510.77 22.6 860.564 12.42 277.351 6.31 763.13 1.81				Tl 208 3.053(4) m				Bi 212 60.55(6) m							
				39.858 1.091				35.94% 64.06%							
				Pb 208 stable				Po 212 299(2) ns							

^{235}U Decay Chain

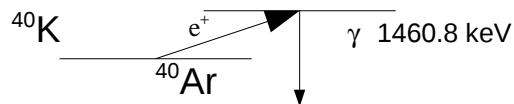
Actinium Gamma Intensities				A = 4n + 3								25.64 14.5 84.214 6.6	Th 231 1.0633 d	185.715 57.2 143.76 10.96 163.33 5.08 ← 205.311 5.01 109.16 1.54 202.11 1.08	U 235 7.028x10 ⁸ a	
		293.54 1000 271.23 55 517.63 19 833.00 14 563.70 13 401.81 10	Bi 215 7.6 m	α none ← β none	At 219 56 s -97% -3%	α none 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 3.276x10 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												

Other Interesting Isotopes

Usually Present:

•⁴⁰K

1460.83 keV

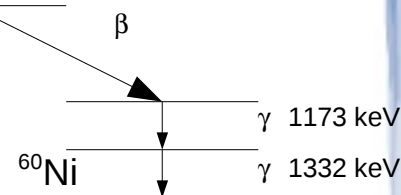


•⁶⁰Co

•1173.2 keV

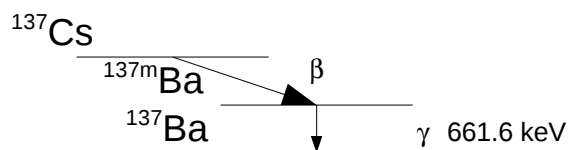
•1332.5 keV

⁶⁰Co



•¹³⁷Cs

661.66 keV



Occasionally Present:

•⁵⁴Mn at 834.85 keV

Observed in Stainless Steel and other metals

•⁷Be at 477.60 keV

Observed in Carbon based materials, due to neutron activation, samples are particularly affected after long flights.

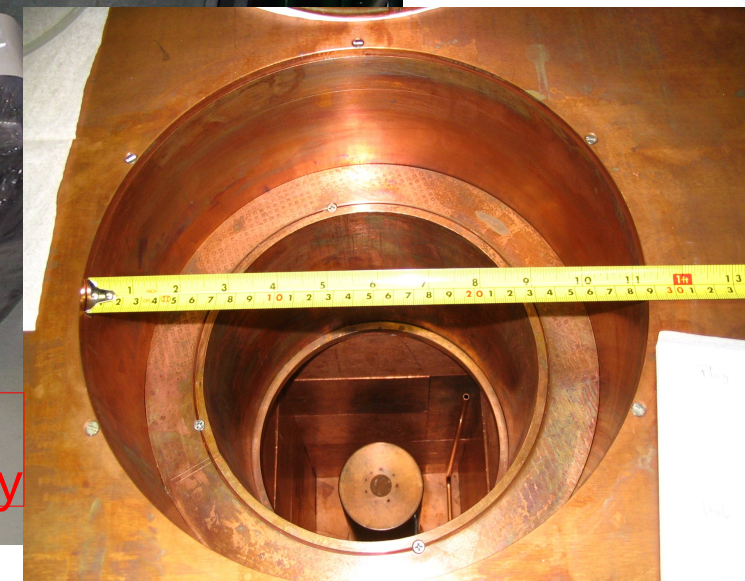
•¹³⁸La and ¹⁷⁶Lu

Observed in rare earth samples such as Nd or Gd.

SNOLAB HPGe Counter



Additional lead used to dampen microseismic activity



SNOLAB 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 experiment.

- Constructed @ SNOLAB from an HPGe detector and its associated shielding located underground at 4600 ft level since 1997.

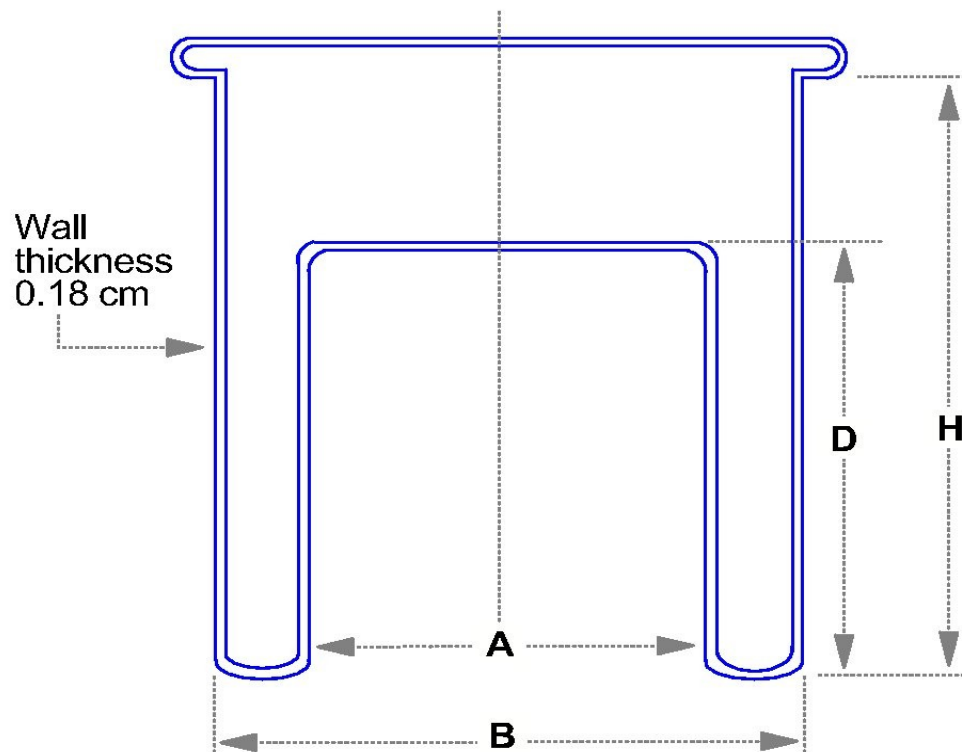
- Counter manufactured by PGT.
 - Endcap diameter 83 mm.
 - Relative Efficiency is 55% wrt a 7.62 cm dia x 7.62 cm NaI(Tl) detector.
 - Resolution 1.8 keV FWHM.

- Shielding

- 2 inches Cu + 8 inches Pb
 - Nitrogen purge at 2L/min to keep radon out.

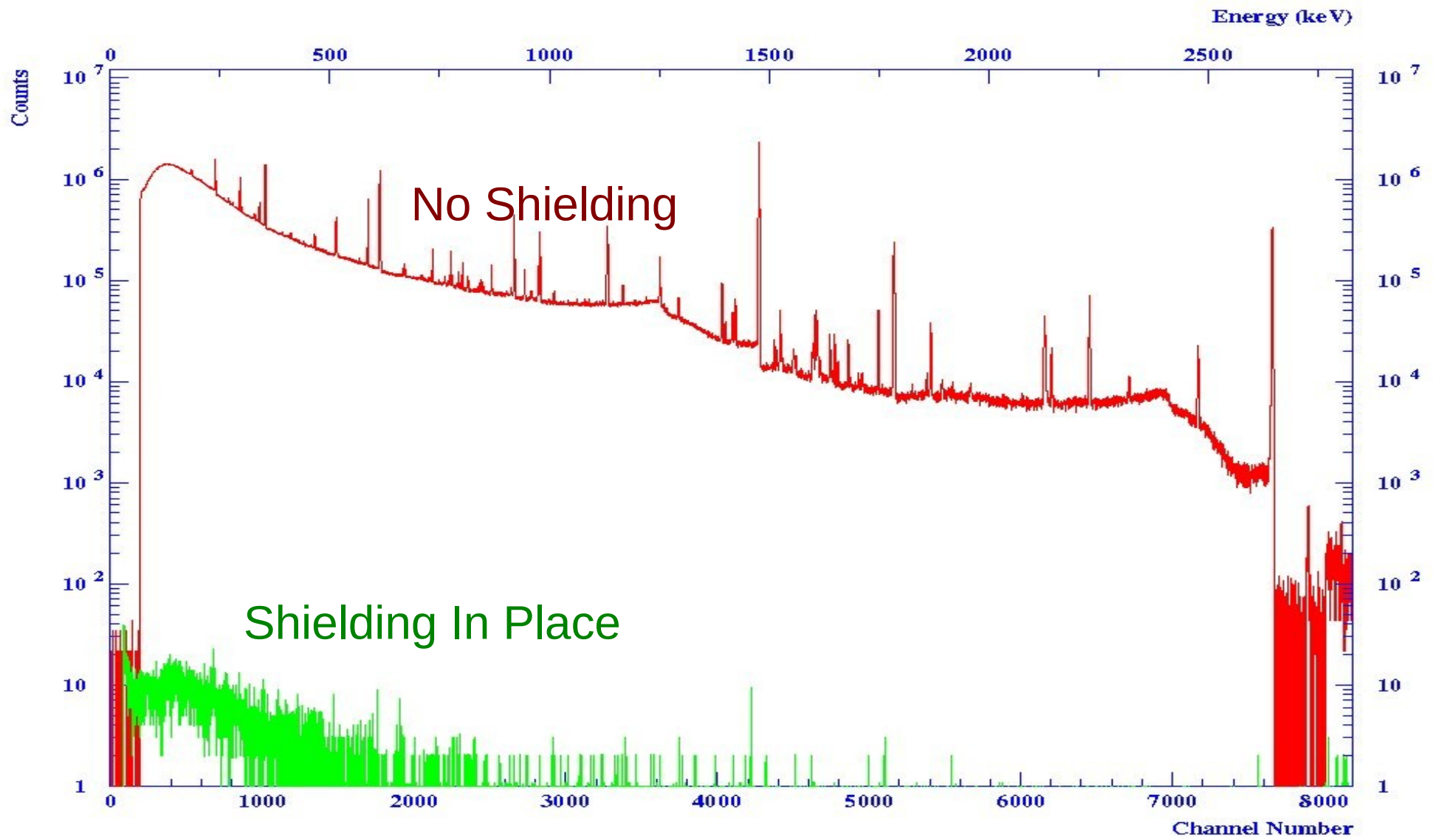
Sample Preparation

Marinelli Beaker



- The current beakers have a volume of 1 L.
- The beakers are made out of polyethylene.
- We have smaller beakers that are 250mL. These can be used for small and/or expensive samples.
- Samples should be made to fit into the beaker so that as much of the sample as possible is near the counter, it is preferable to crush the sample if possible.
- Samples can also be placed directly on top of the crystal.

Unshielded and Shielded Spectra



Background Comparison

Unshielded Versus Shielded Activity

Isotope	Activity Unshielded Crystal(Bq)	Activity Shielded Crystal (Bq)
^{238}U	70.11 ± 1.64	0.00128 ± 0.00016
^{232}Th	36.99 ± 1.21	0.00131 ± 0.00015
^{40}K	1723.33 ± 88.02	0.0189 ± 0.0017
^{137}Cs	1.00 ± 0.15	0.0020 ± 0.0002
^{60}Co	0.023 ± 0.052	0.00036 ± 0.00005

Unshielded Measurements done by Yoram Nir-EL

PGT HPGe Standard 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 %

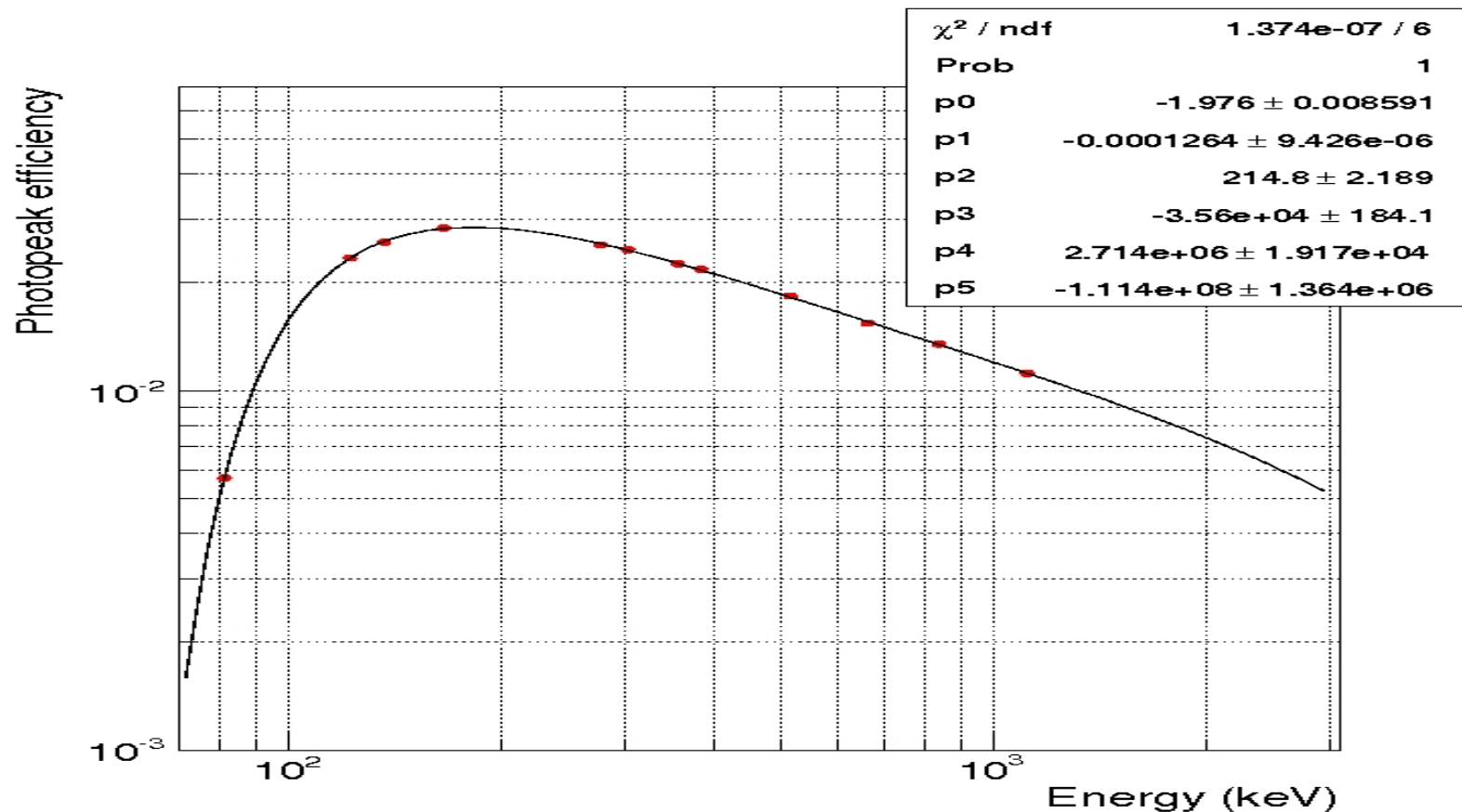
Better sensitivities have been achieved for specialized very large samples combined with an extremely long counting period:

^{238}U : 0.009 ppb,
 ^{232}Th : 0.02 ppb,
 ^{40}K : 87 ppb

Sensitivities of SNOLAB Compared to Some Other Facilities

Isotope	SNOLAB	SOLO	LBCF Surface Facility	LBCF Underground Facility
^{238}U	1 mBq/kg 0.1 ppb	1 mBq/kg 0.1 ppb	9 mBq/kg 0.5 ppb	0.9 mBq/kg 0.05 ppb
^{232}Th	1.5 mBq/kg 0.3 ppb	0.5 mBq/kg 0.05 ppb	12 mBq/kg 2 ppb	1.2 mBq/kg 0.2 ppb
^{40}K	21 mBq/kg 0.7 ppm	10 mBq/kg 0.25 ppm	32 mBq/kg 1 ppm	3.2 mBq/kg 0.1 ppm

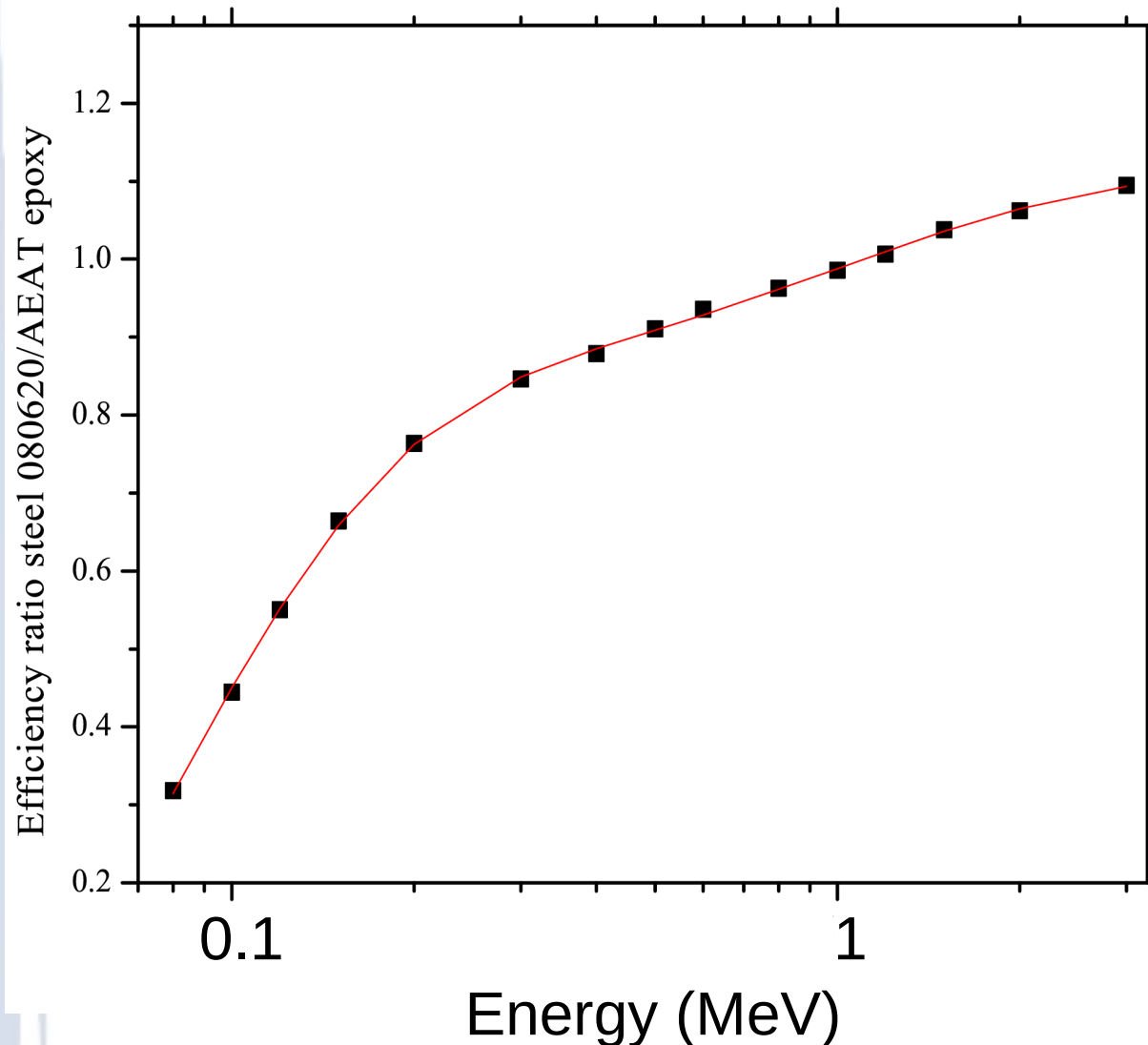
Detector Efficiency From A Mixed Calibration Sample



Plot by James Loach

The efficiency is scaled to individual samples using GEANT 4.9.4 which takes into account the sample components, to account for the density difference between the calibration source and the sample, and the sample geometry.

Typical Efficiency Correction

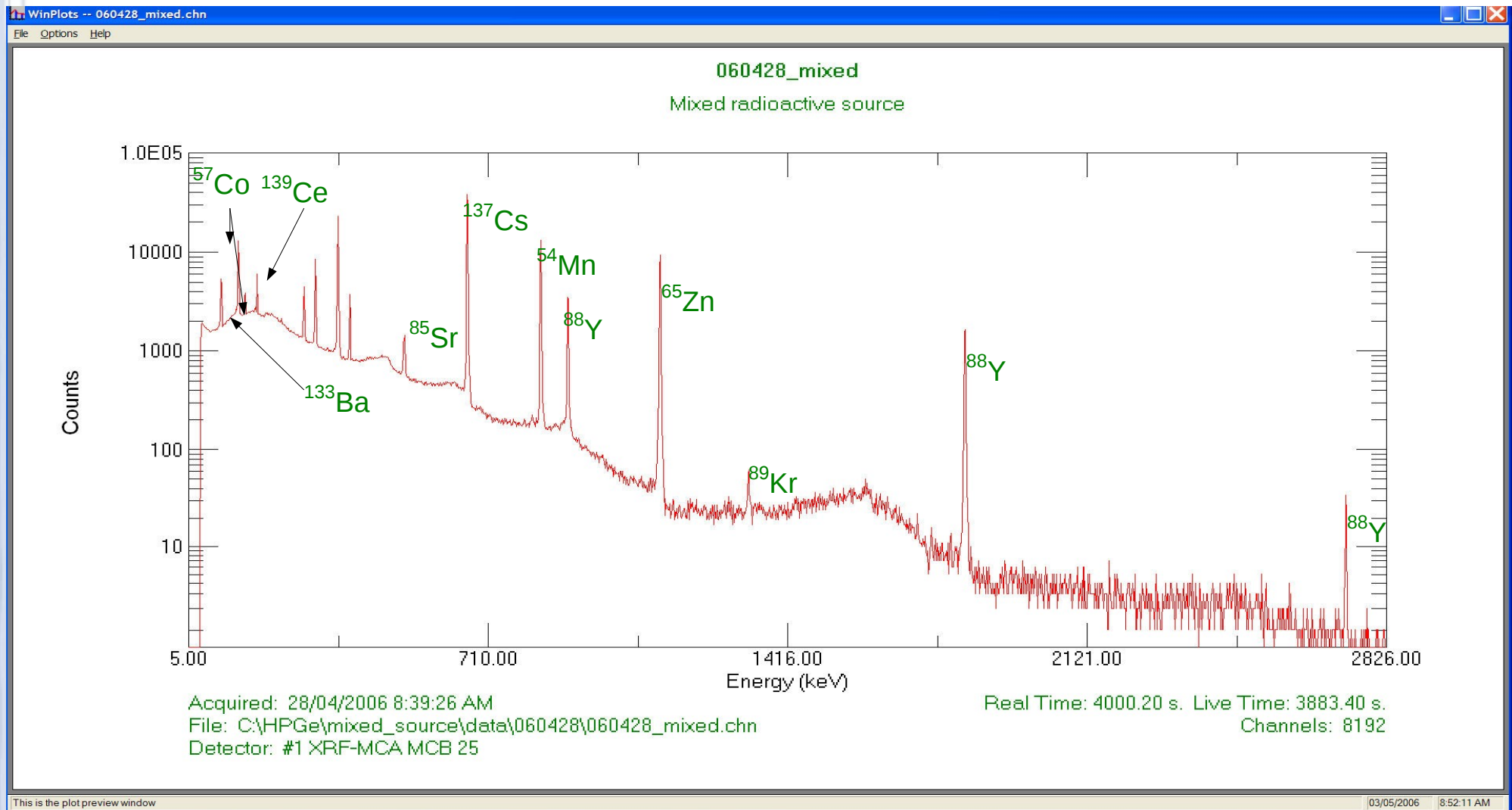


Efficiency correction for steel sample.

Use GEANT4.9.4, simulate detector with 5 million events at each energy.

Extrapolate between energy bins with a polynomial fit.

Calibration Spectrum



New calibration standards are being proposed which have much longer half-lives to allow the calibration sample to be used for several years unlike most commercial multigamma calibration samples. Would be used to cross-calibrate PGT and Canberra detectors.

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	7	96
SNOLAB	7	3	0	0	9	6	17	18	60
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	14	93
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	9	42
DAMIC	--	--	--	--	--	--	1	4	5
Total	24	23	43	49	55	85	71	55	405
Calibrations & Tests	30	34	14	9	4	3	11	7	112

Samples in Detector Queue: - 10, which means up to 10 weeks or more of counting time!
- the queue keeps getting longer, so the new 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.

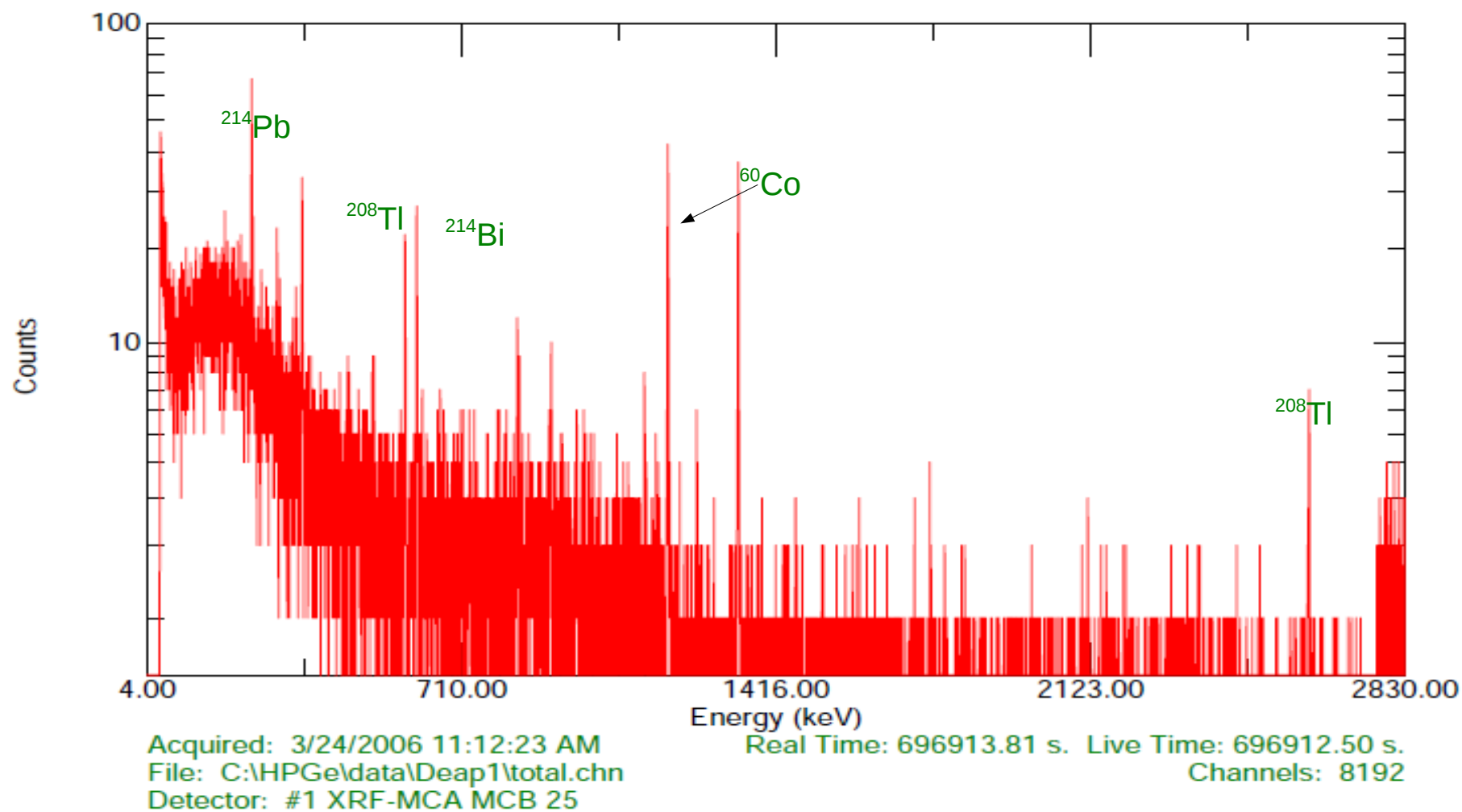
The database is available to all SNOLAB users and can be made available to others upon request as it is password protected, contact Ian.Lawson@snolab.ca or Bruce.Cleveland@snolab.ca.

Common Database

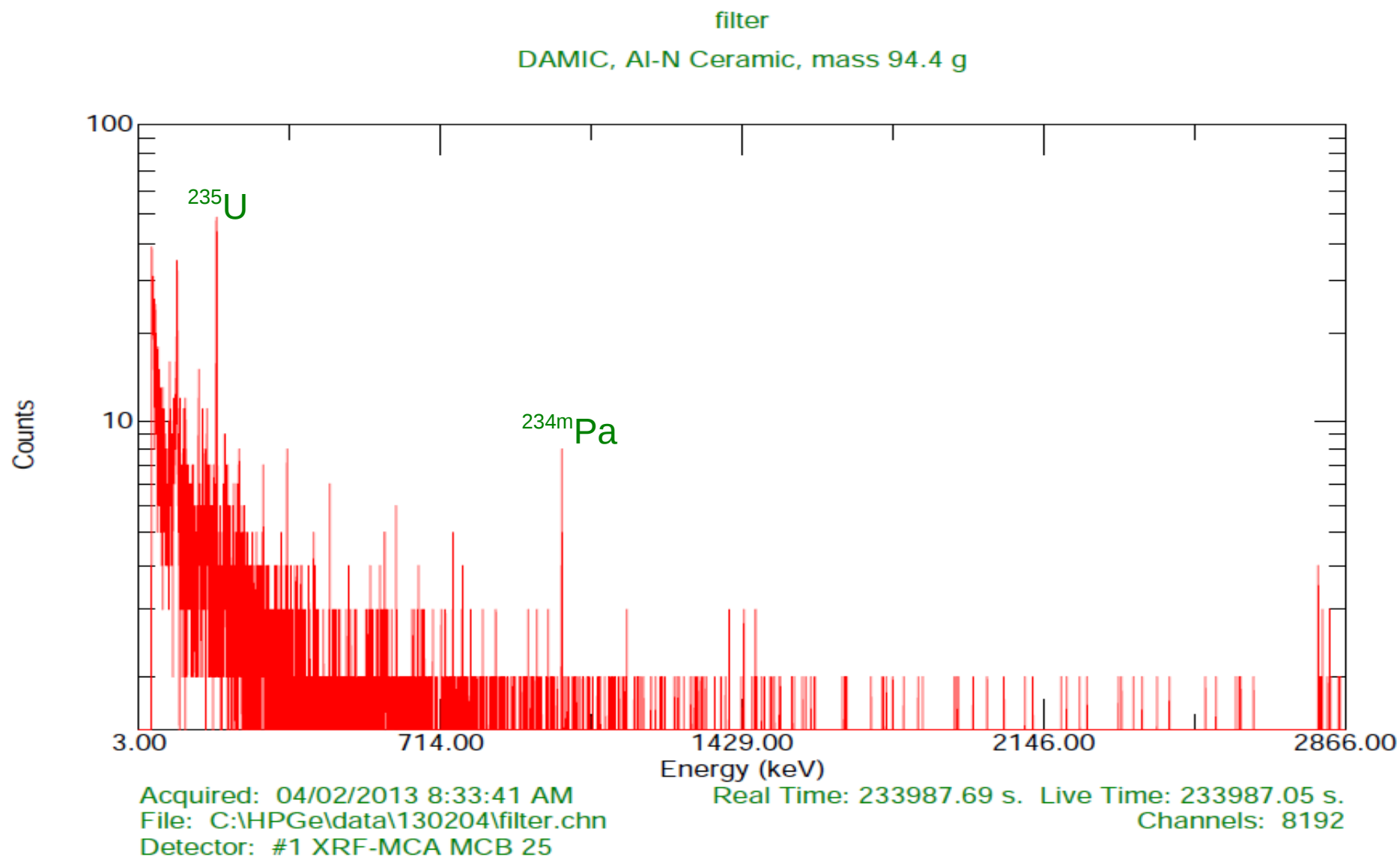
- Currently each counting group has separate databases, some are public and some are very private.
- Common goal of low background counting groups is to have a common database assessable to anyone interested in low background studies, with as much data available as possible.
- Standardize units to mBq/kg.
- The AARM working groups meet regularly and the database is operational, www.radiopurity.org.
- The database uses the CouchDB database.
- Database is hosted by Cloudant for free with backup databases expected to be at SNOLAB.

Typical Stainless Steel Spectrum

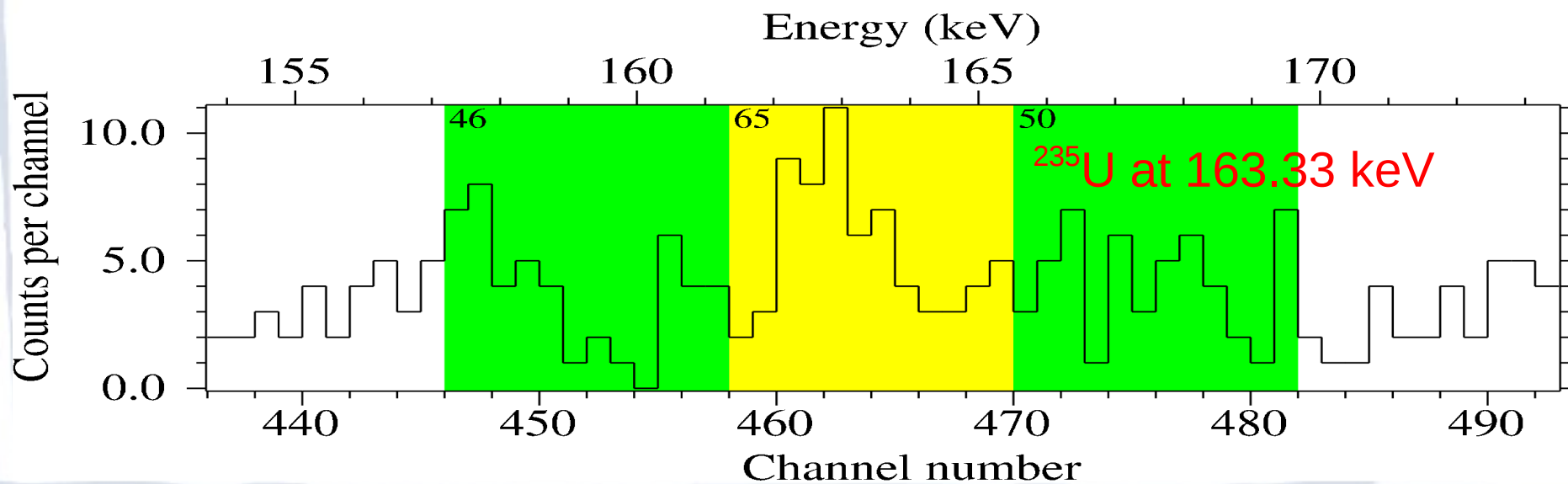
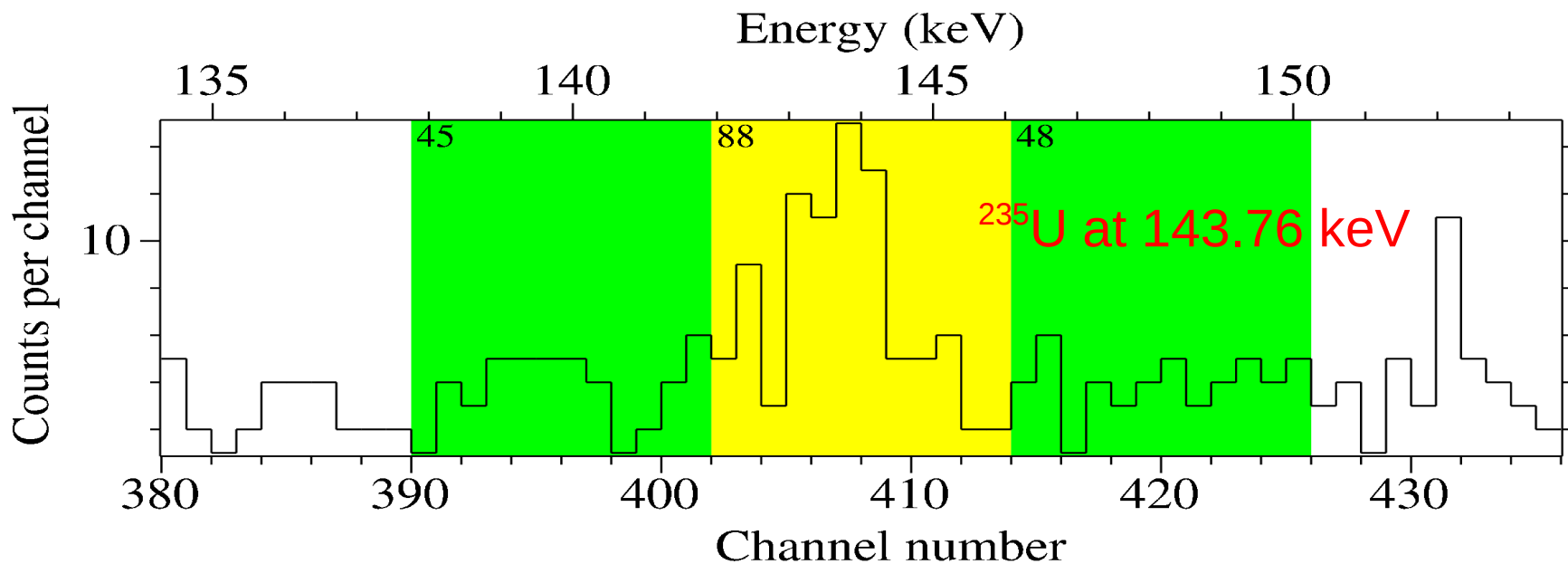
DEAP 1 sample - steel bolts, nuts, wa Sum sp. total + filter3



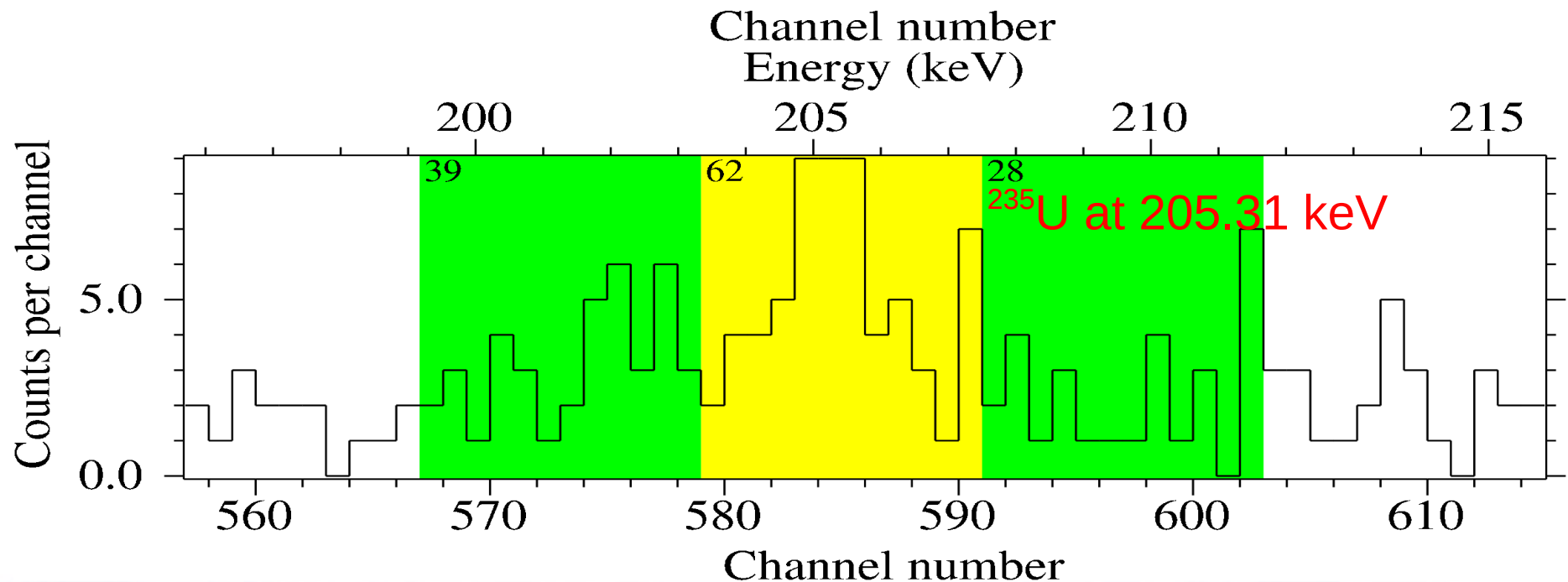
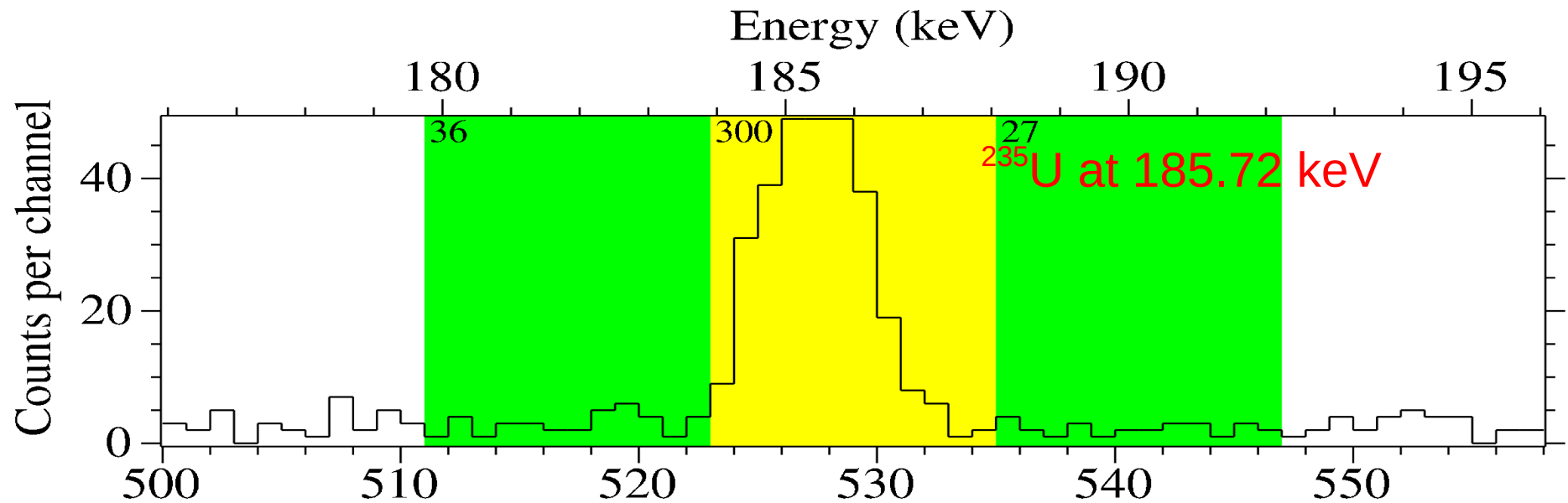
DAMIC Ceramic Spectrum



Analysis Techniques (^{235}U Chain)



Analysis Techniques (^{235}U Chain)



Analysis Techniques (How the rate is calculated)

Calculate Rate:
$$\text{Rate} = \frac{(N_p - N_{ab} - N_{pb})}{(\text{Eff} \times \text{Int} \times T_L)}$$

where N_p is the number of peak events

N_{ab} is the average number of events from the two background bands, if there are peak interferences then only one band may be used.

N_{pb} is the intrinsic detector background in the peak window

Eff is the detector efficiency at the peak energy

Int is the gamma intensity at the peak energy, sometimes referred to as the branching fraction, this is corrected to give the rate of the parent in the decay chain.

T_L is the detector live time.

Analysis Techniques

(²³⁵U Chain)

If the decay chain is in equilibrium the results from each peak are combined to give the overall background for the parent isotope.

Energy	N _p	N _{ab}	N _{pb}	N	Int (%)	Eff (%)	Rate (mBq)
143.76	88 ± 9.4	46.5 ± 4.8	0 ± 0	41.5 ± 10.5	10.96 ± 0.14	6.095 ± 0.457	26.6 ± 7.0
163.33	65 ± 8.1	48.0 ± 4.9	0 ± 0	17.0 ± 9.4	5.08 ± 0.06	6.216 ± 0.466	23.0 ± 12.9
185.715	300 ± 17.3	31.5 ± 4.0	0 ± 0	268.5 ± 17.8	57.20 ± 0.80	6.147 ± 0.461	32.6 ± 3.3
205.311	62 ± 7.9	33.5 ± 4.1	0 ± 0	28.5 ± 8.9	5.01 ± 0.07	6.001 ± 0.450	40.5 ± 13.0

Live Time: 233987.0 sec

Sample Mass: 94.4 g

Average Rate: 31.53 ± 2.84 mBq

333.958 ± 30.063 mBq/kg

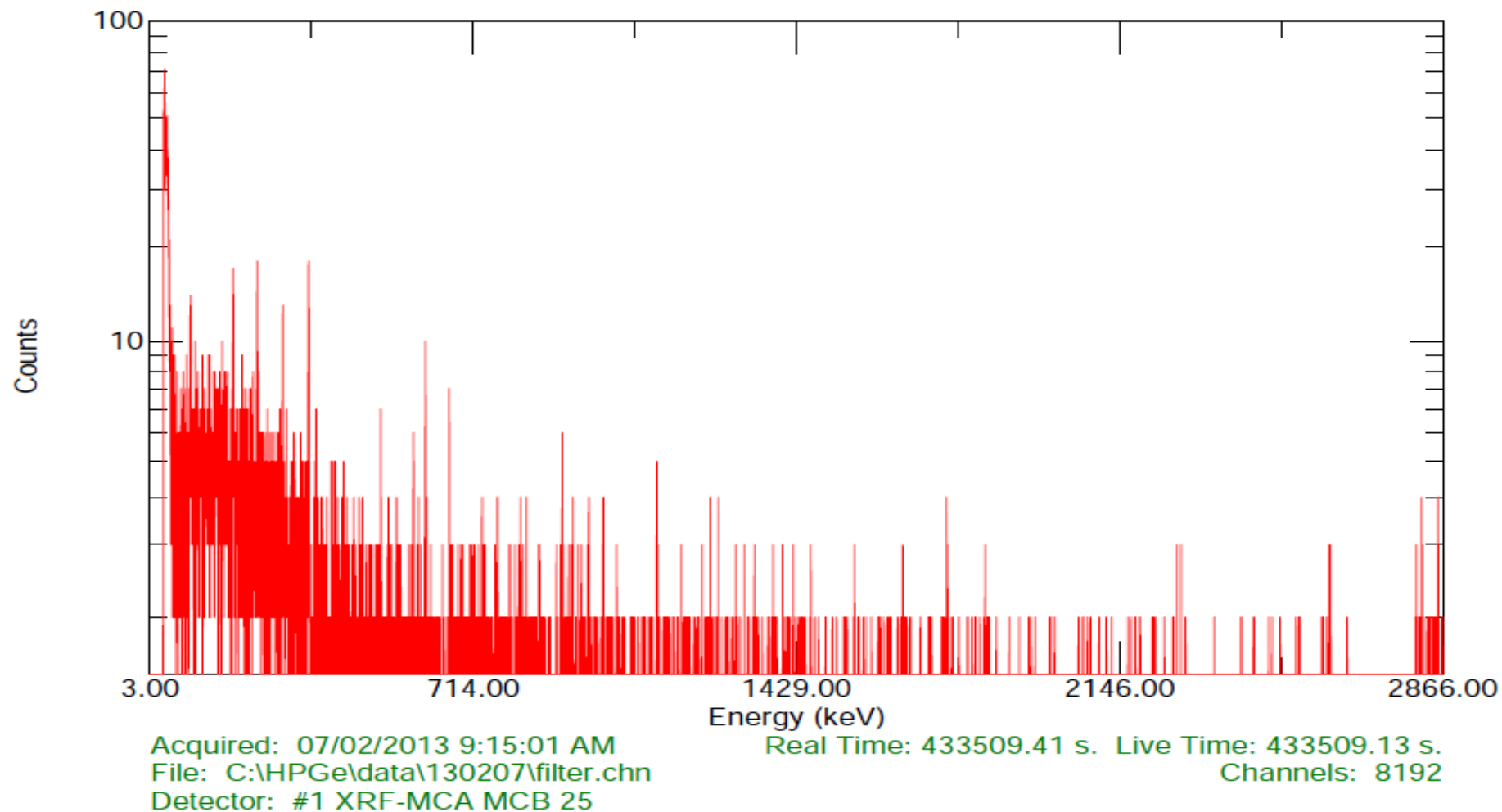
587.767 ± 52.911 ppb

DAMIC CCD

(Note that the CCD is attached to a thin wafer)

filter

DAMIC, CCD, mass 18.5 g



Results from DAMIC Aluminium Nitride Ceramic and CCD

Ceramic (94.4 g)

^{238}U from ^{226}Ra	^{238}U from ^{234}Th	^{235}U	^{232}Th	^{40}K
42.16 +- 9.25 mBq/kg	4109.85 +- 530.95 mBq/kg	333.96 +- 30.06 mBq/kg	32.10 +- 8.61 mBq/kg	45.55 +- 66.74 mBq/kg
3.42 +- 0.75 ppb	332.90 +- 43.01 ppb	587.77 +- 52.91 ppb	7.90 +- 2.12 pb	1471.29 +- 2155.61 ppb

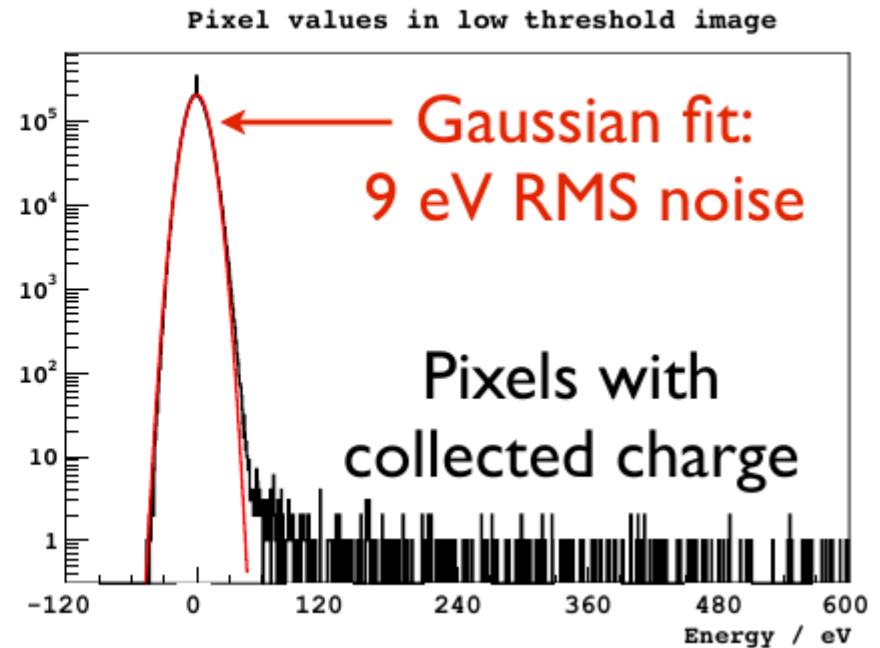
CCD (18.5 g)

429.95 +- 47.05 mBq/kg	2017.87 +- 702.85 mBq/kg	227.27 +- 41.40 mBq/kg	209.10 +- 31.80 mBq/kg	<110.45 mBq/kg
34.83 +- 3.81 ppb	163.45 +- 56.93 ppb	399.99 +- 72.86 ppb	51.44 +- 7.82 ppb	<3.57 ppm

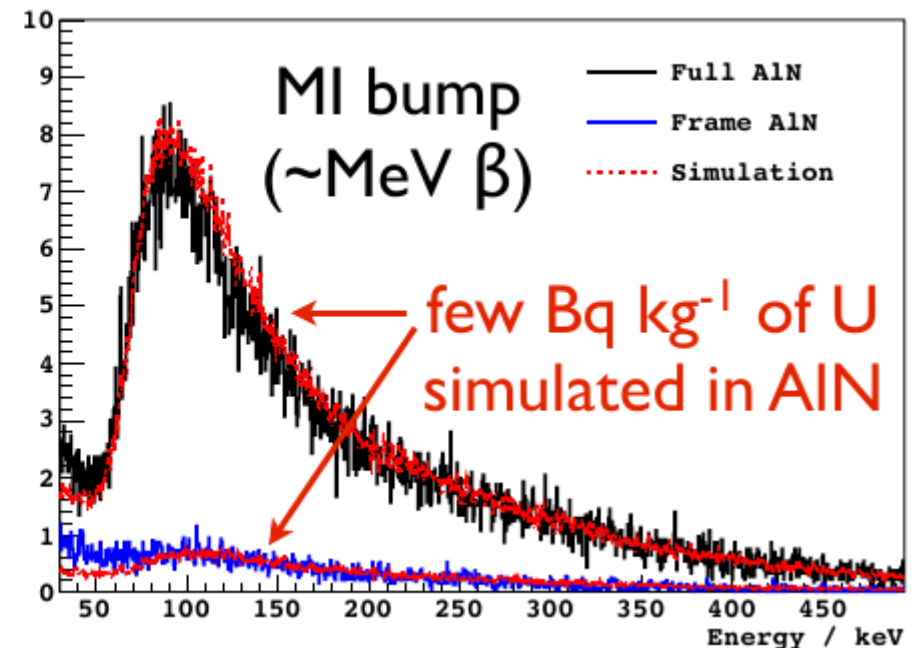
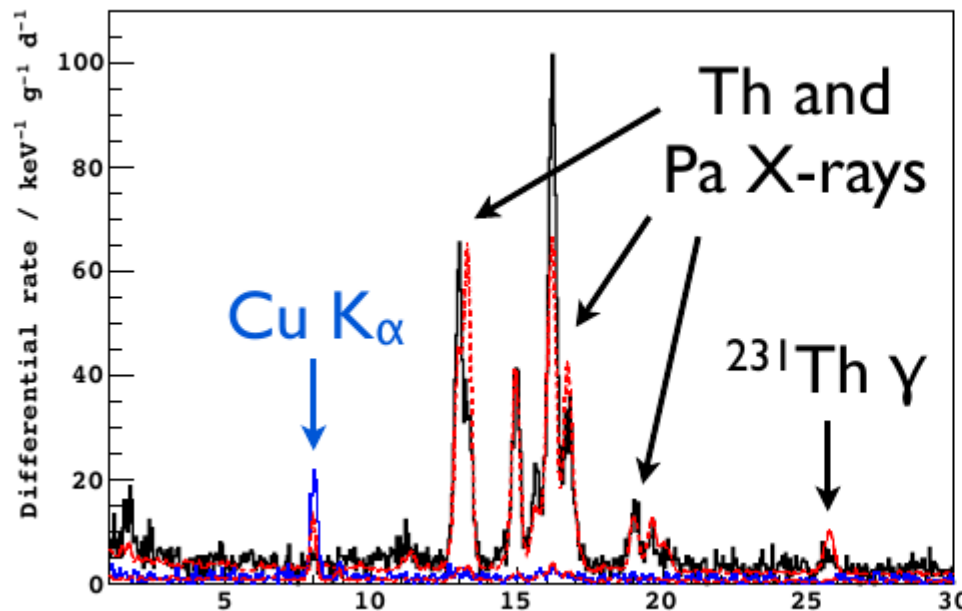
DAMIC Data and Simulation Using Results From PGT HPGe Counter

SNOLAB data

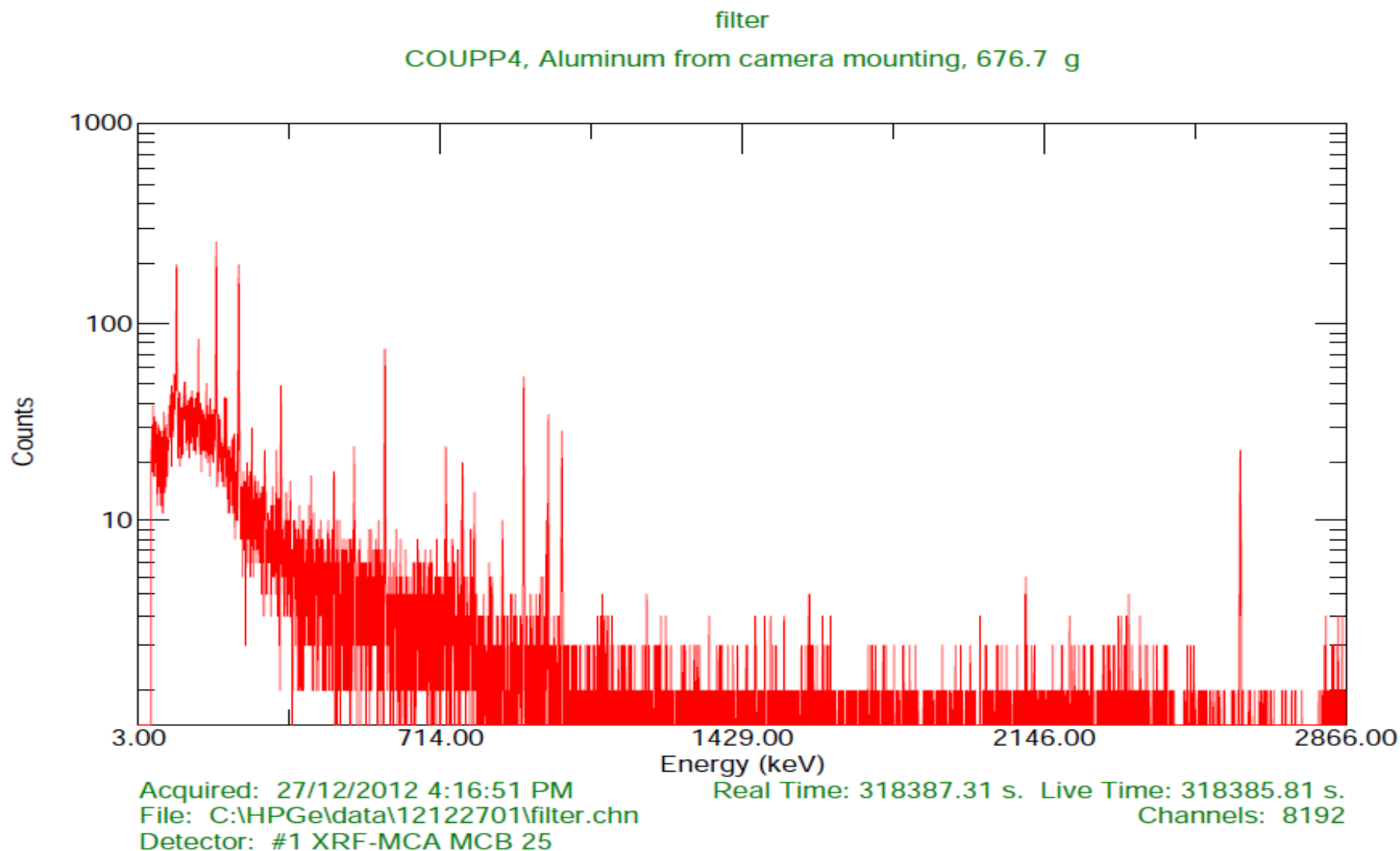
1 g, 8 Mpixel CCDs
6 cm x 3 cm x 250 μm
~50 days of data
2 CCDs with full AlN
and 2 with **frame** AlN



Raw spectrum from CCDs at SNOLAB

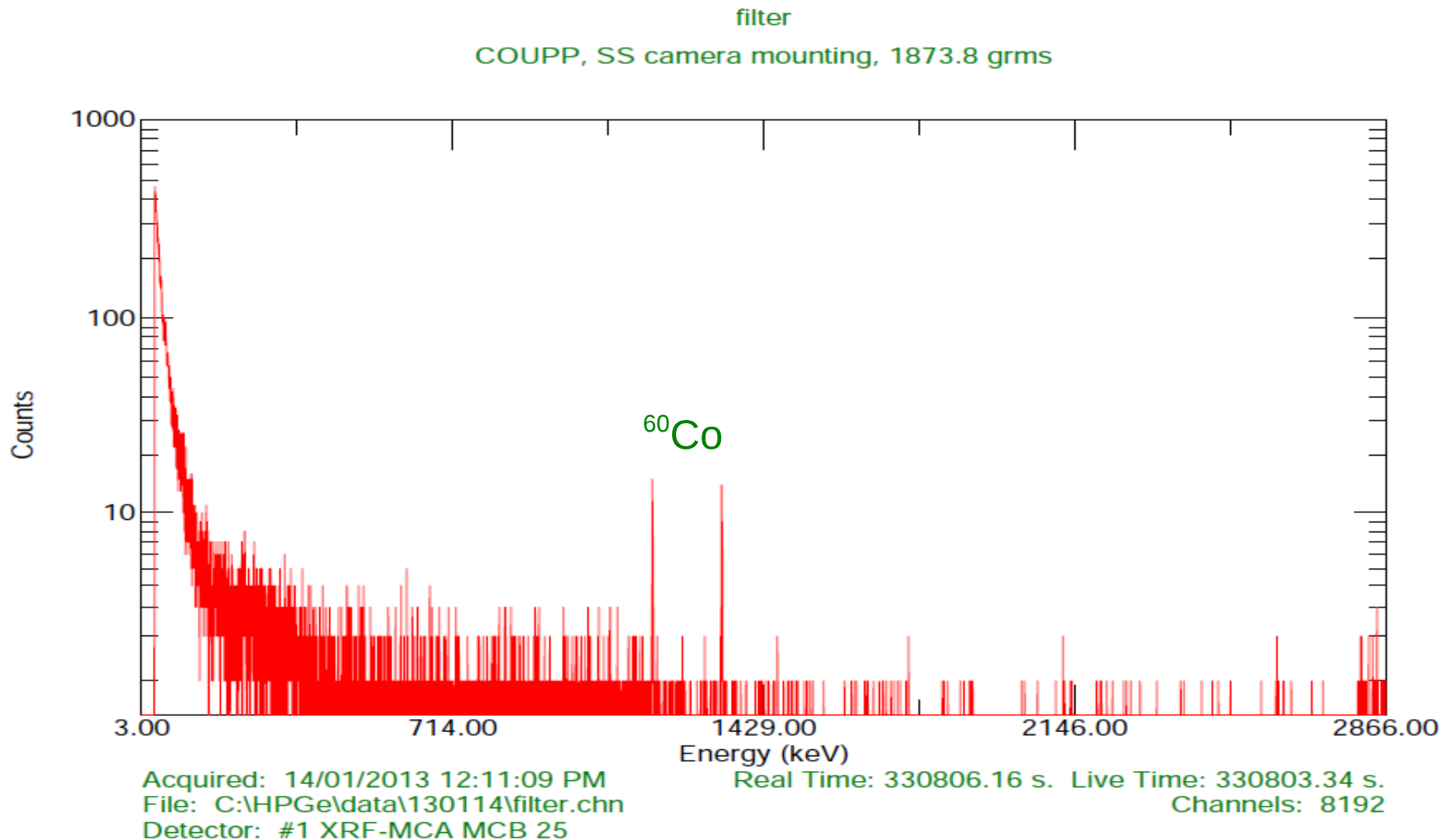


COUPP Sample, Aluminium Camera Mount From COUPP-4



Lots of peaks from ^{235}U and ^{232}Th , and ^{238}U above ^{226}Ra .

COUPP Sample, New Stainless Steel Camera Mount For COUPP-4



Only observable background is from ^{60}Co , which is expected to be present in stainless steel.

Other Background Results

Several rock, shotcrete and concrete samples have been assayed from the new laboratory using a Ge counter at U. of Guelph and ICP-MS methods. Each area of SNOLAB has several measurements.

Ge Detector Results

Material	^{232}Th	^{238}U	^{40}K
	(ppm)	(ppm)	(%)
Average rock results	5.56 ± 0.57	1.11 ± 0.15	1.01 ± 0.12
Shotcrete	15.24 ± 0.14	2.46 ± 0.09	1.78 ± 0.05
Concrete	15.38 ± 0.40	2.41 ± 0.03	1.75 ± 0.05

Comparison of Ge Counting and ICP-MS

Element	Rock Sample 8		Rock Sample 11	
	Ge	ICP-MS	Ge	ICP-MS
K (%)	1.09 ± 0.01	0.97	1.08 ± 0.03	1.02
U (ppm)	1.24 ± 0.16	1.21	1.09 ± 0.03	1.14
Th (ppm)	5.44 ± 0.37	5.54	5.72 ± 0.05	5.19

Element	Shotcrete Sample 15		Concrete Sample 14	
	Ge	ICP-MS	Ge	ICP-MS
K (%)	1.78 ± 0.05	1.76	1.75 ± 0.05	1.61
U (ppm)	2.46 ± 0.09	2.56	2.41 ± 0.03	2.38
Th (ppm)	15.24 ± 0.14	14.90	15.38 ± 0.40	13.10

Future Low Background Counting Facilities At SNOLAB

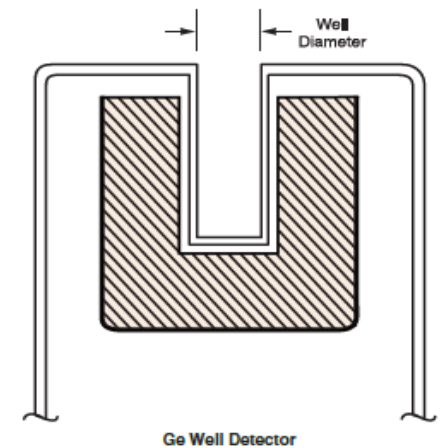
Canberra Well Detector

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.

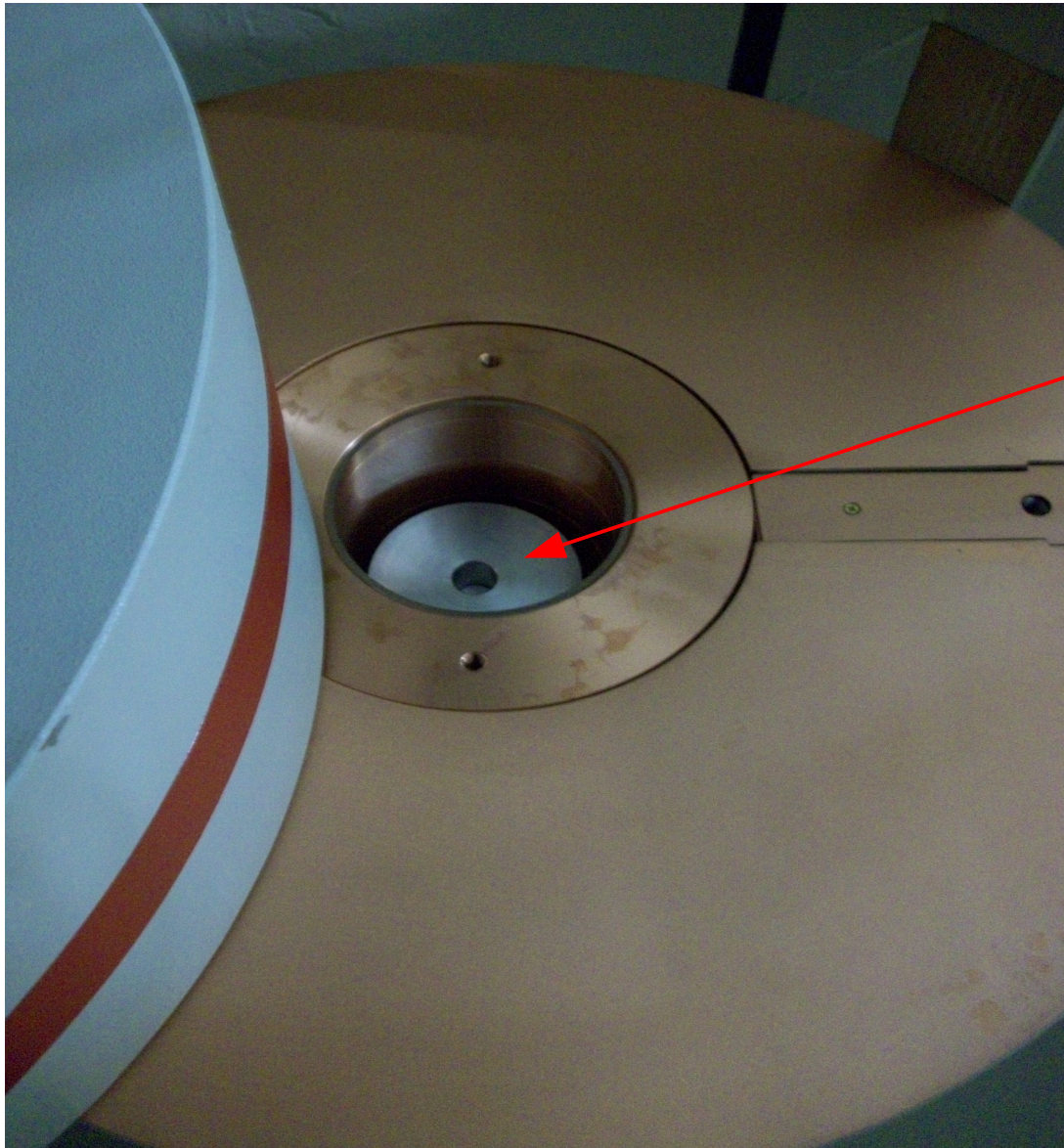
The well detector was sent back to Canberra and was rebuilt to fit the shielding, the detector is now back at SNOLAB and is being characterized.



Canberra Well Detector at SNOLAB



Canberra Well Detector at SNOLAB



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)

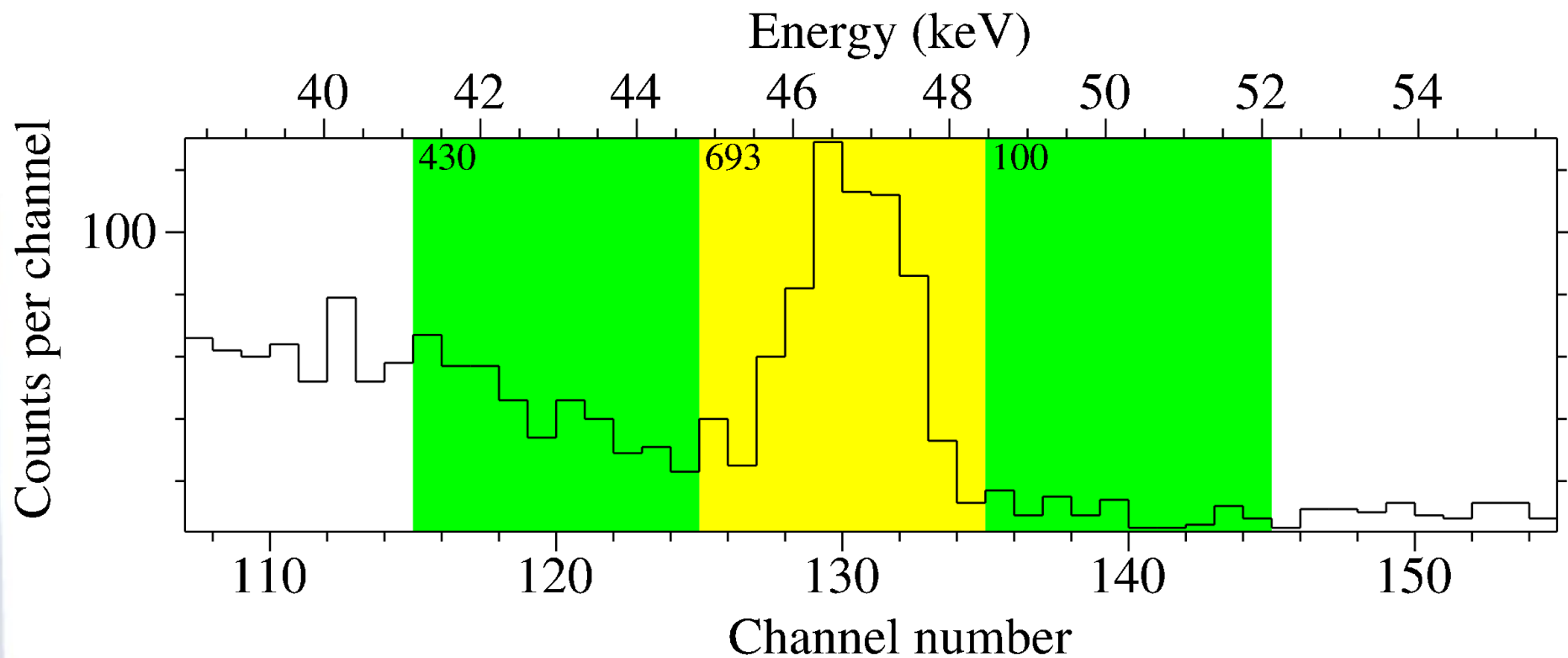
^{40}K 0.0 ± 0.02 decays per day (0.0 ± 7.3 decays per year)

^{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 .

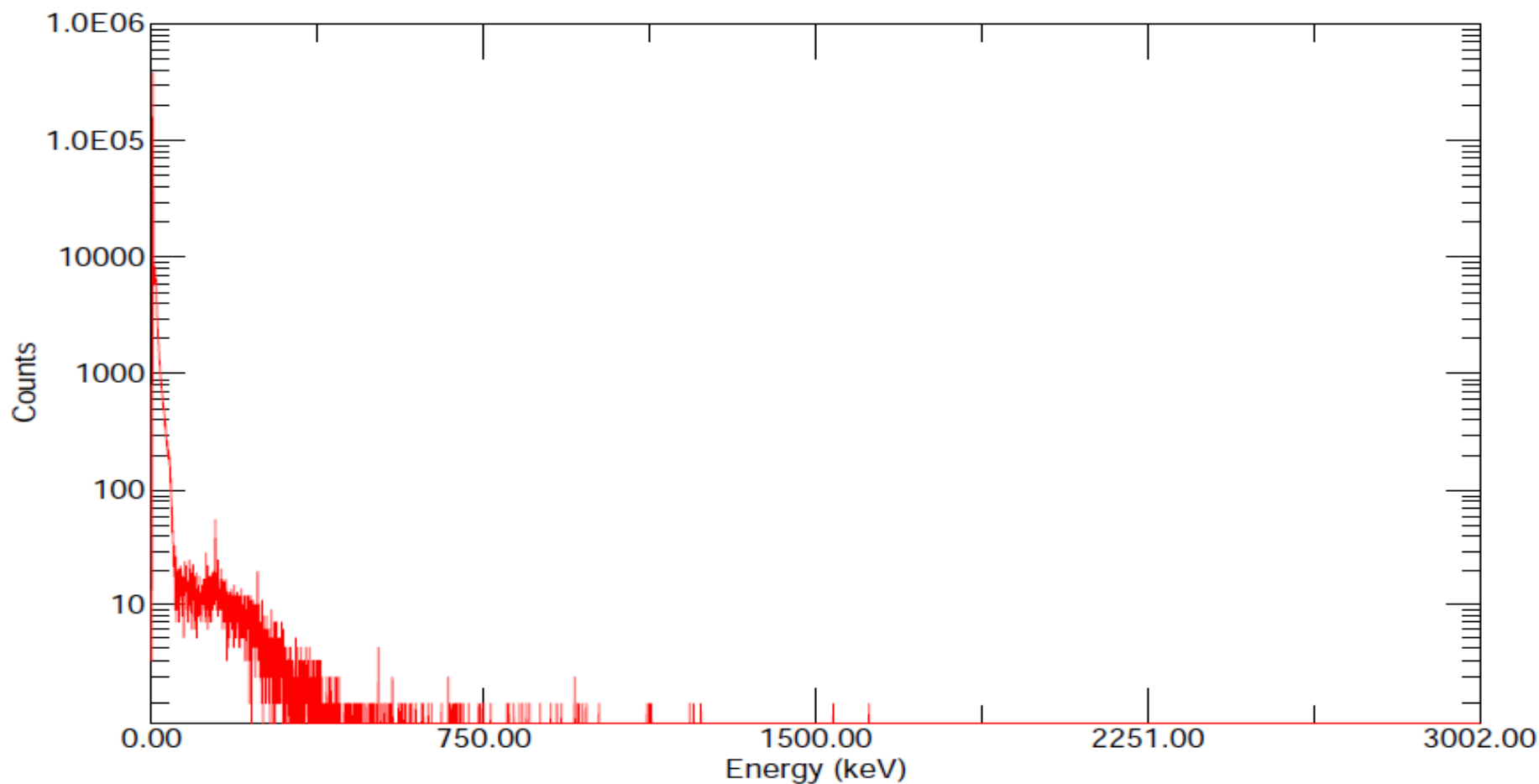
^{210}Pb Measurement



Concentrated sample of leachate from SNO+ Acrylic Vessel

Well Detector Background Spectrum

filter
sample chamber empty



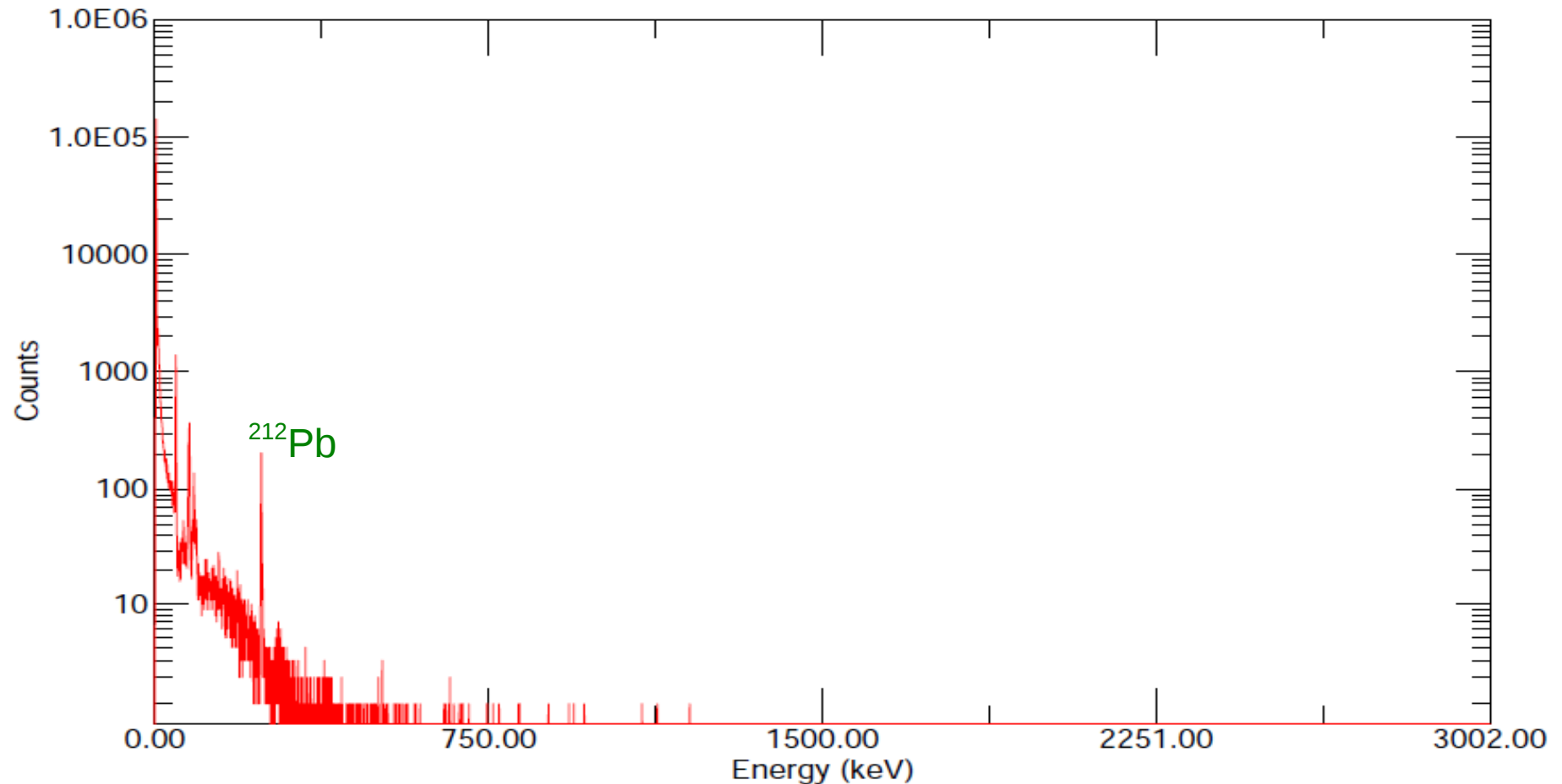
Acquired: 21/11/2012 10:37:00 AM
File: C:\HPGe\well\121121\filter.chn
Detector: #1 WELL

Real Time: 3307800.00 s. Live Time: 3307440.75 s.
Channels: 8192

Well Detector Example Spectrum (Concentrated Water Sample from SNO+ Acrylic Vessel)

filter

UPW wash, AV sector 5, 3.6 L UPW evaporated



Acquired: 18/01/2013 10:13:12 AM
File: C:\HPGe\well\130118\filter.chn
Detector: #1 WELL

Real Time: 1096800.00 s. Live Time: 1096627.13 s.
Channels: 8192

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

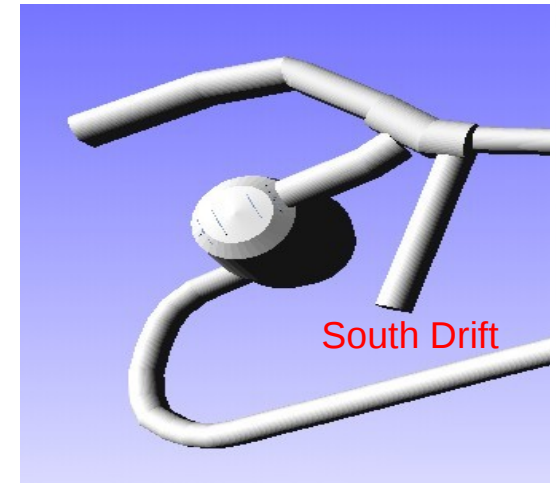
SNOLAB Low Background Laboratory (under construction)

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/m³ to 1-5 Bq/m³.

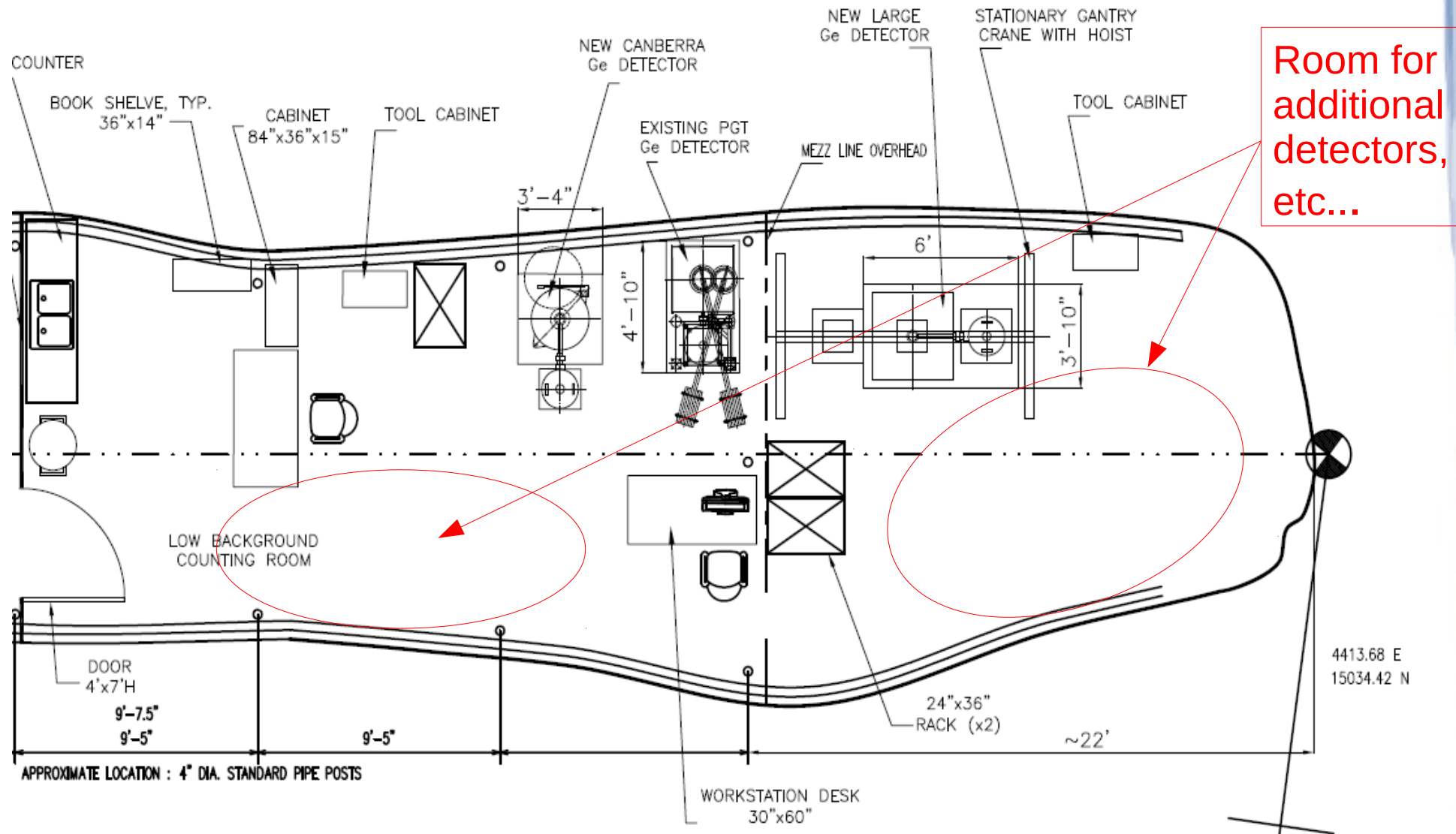
Space can accommodate up to 5 Ge detectors, XRF, radon emanation chamber and have room for other types of counters which would benefit from low-cosmic ray background.



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.

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

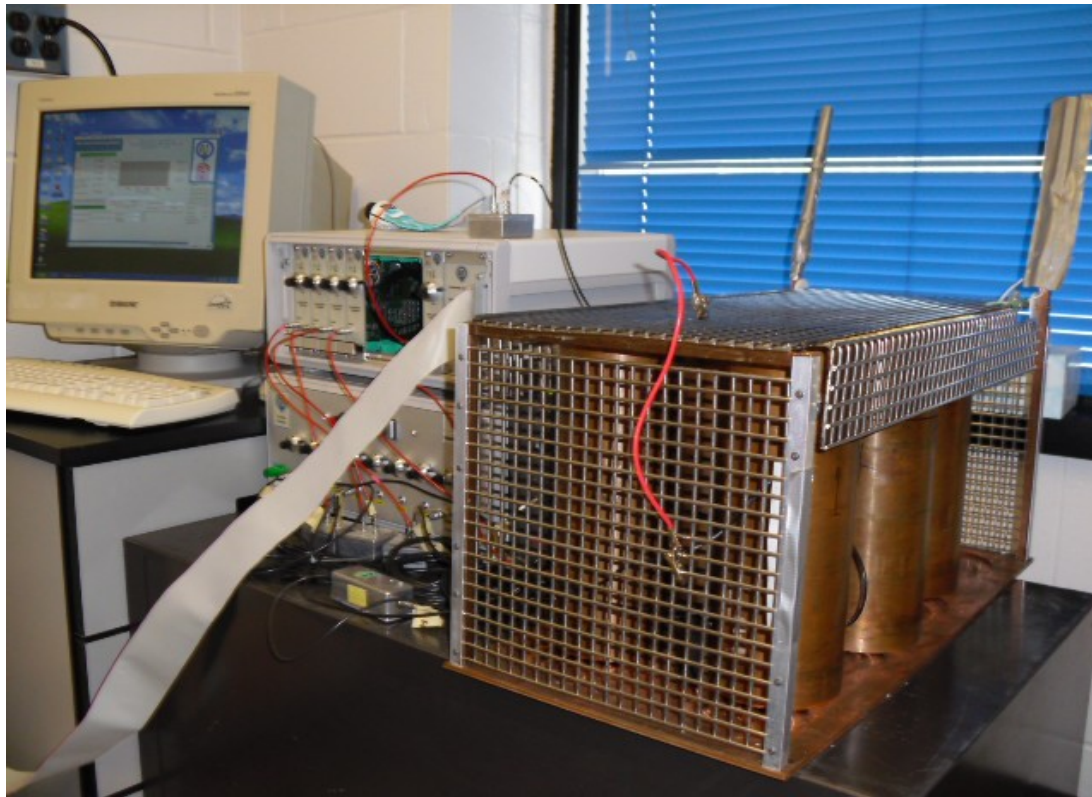
^{226}Ra : 10^{-16} gU/g

Work is ongoing to improve sensitivity even further.



9 counters located at SNOLAB,
1 on loan to LBL,
1 on loan to U of A,
1 remains at U. of Guelph

Alpha Beta Counting System



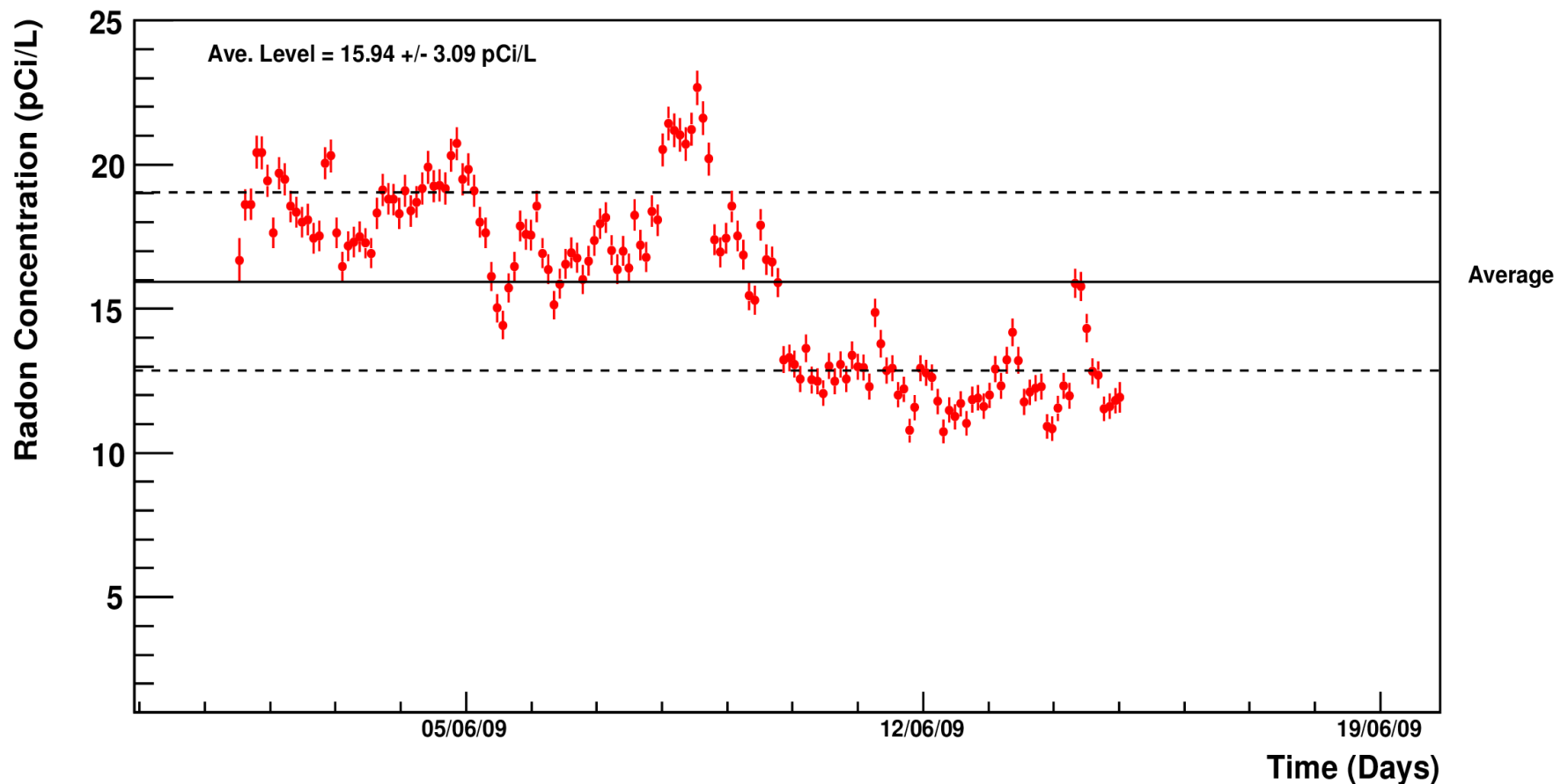
Currently located at the SNOLAB hot lab at LU so that spike sources can be measured.

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

SNOLAB Radon Levels Without Fresh Air

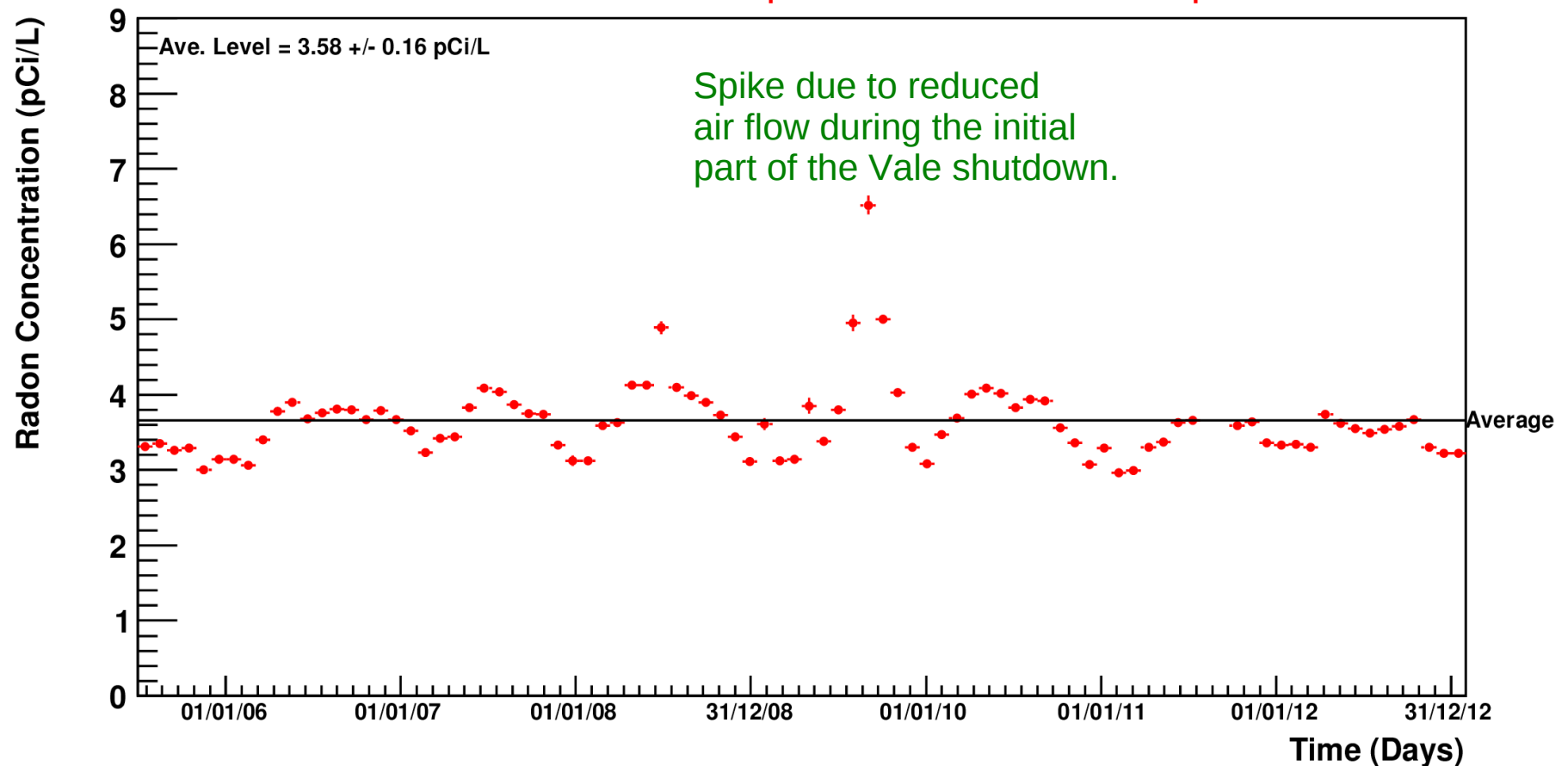
Radon levels: 15.94 ± 3.09 pCi/L or 589.8 ± 114.3 Bq/m³.

Maximum recommended radon levels: 200 Bq/m³.

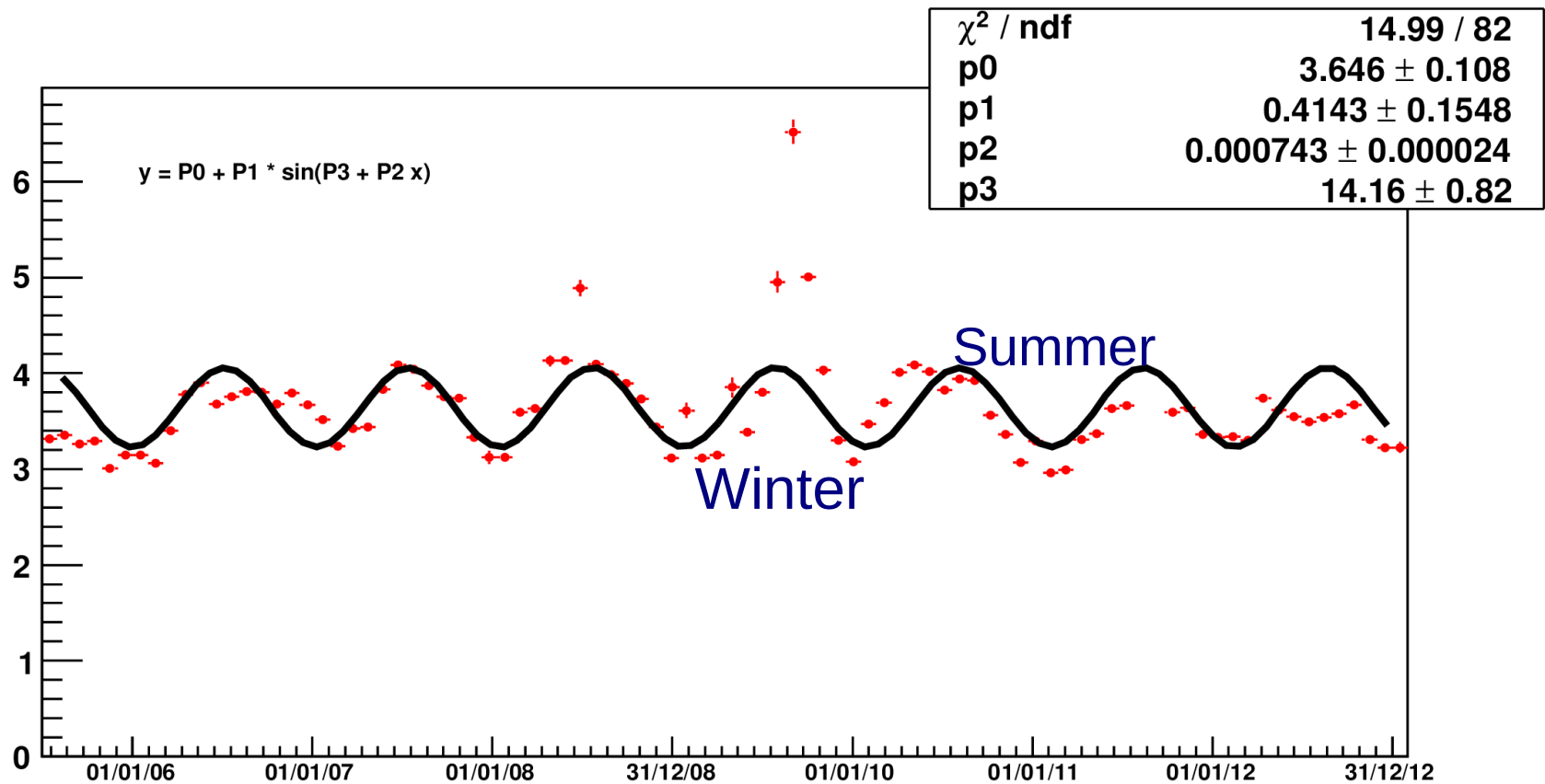


Radon Levels at SNOLAB With Fresh Air (Normal Laboratory Operating Conditions)

Radon continuously monitored for the several years now.
Radon levels are: 3.58 ± 0.16 pCi/L or 129.5 ± 5.9 Bq/m³.



Radon Level Annual Cycle

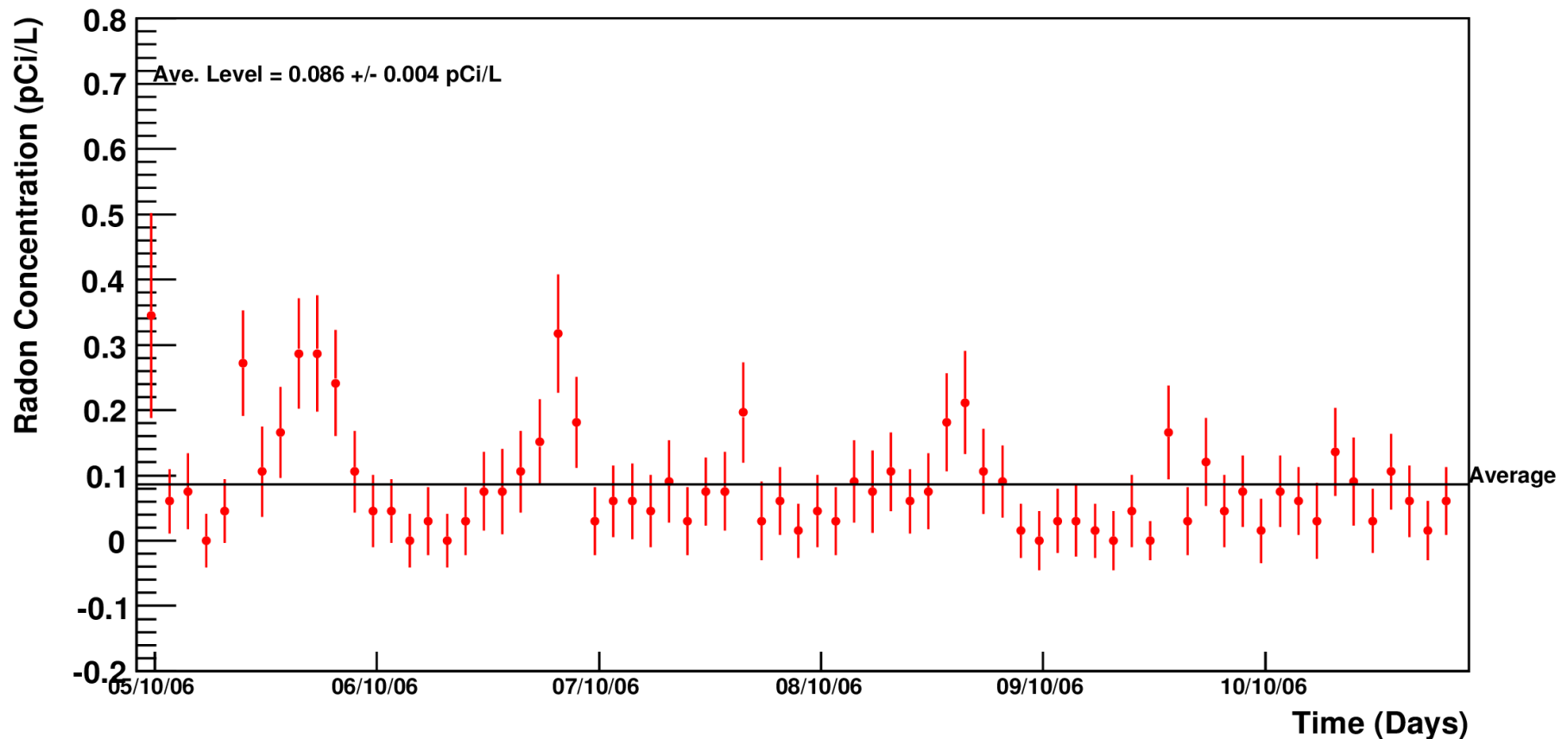


The annual cycle corresponds to 363.21 ± 29.73 days, the expected cycle is one year.

Achievable Radon Levels

Using Compressed Air Supplied From Surface

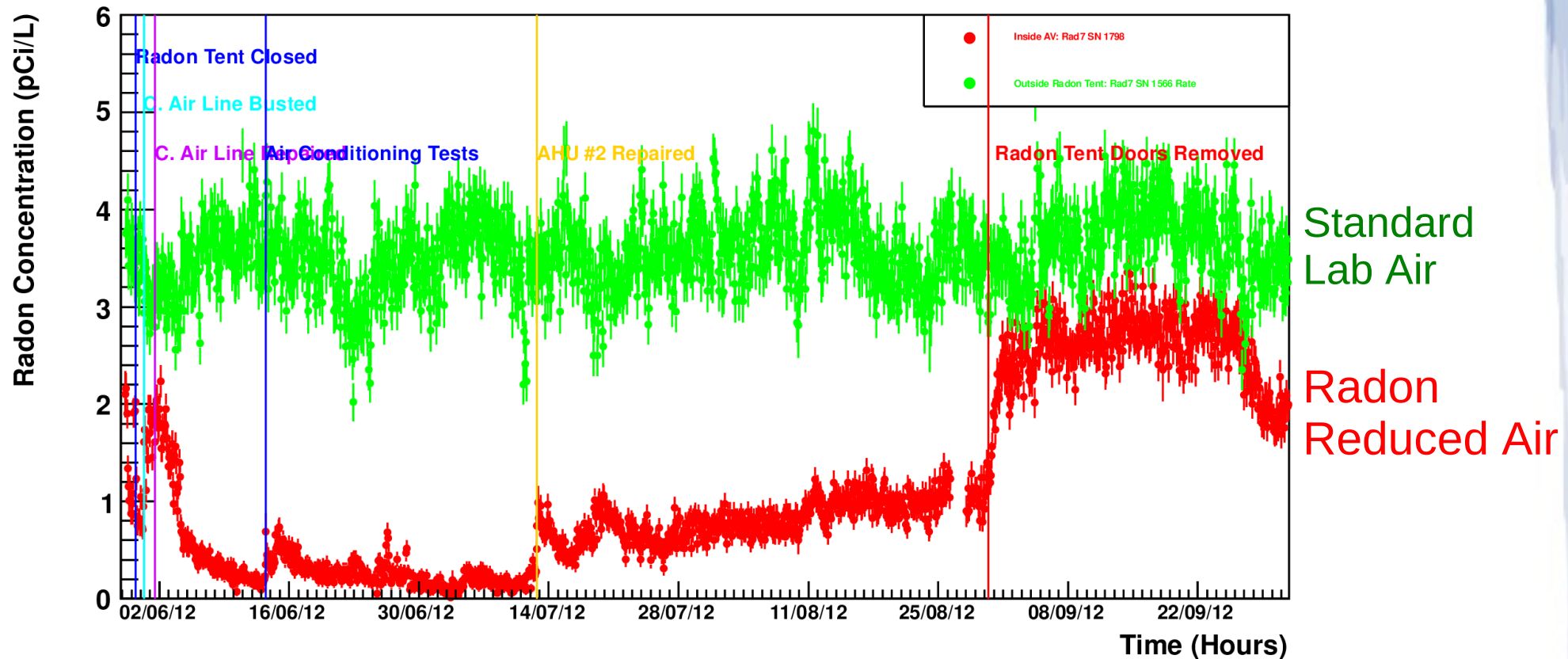
Radon levels: 0.086 ± 0.004 pCi/L or 3.18 ± 0.15 Bq/m³.



To use this air, specialized filters have to be used to ensure that all particulate matter is removed from the air before it is used.

To achieve lower levels of radon, radon scrubbing systems would have to be deployed.

Radon Reduction Room (SNO+ Experiment)



With proper controls the radon levels can be reduced to that of the input compressed air.

Ongoing Improvements and R&D

- Improved neutron shields (detector response, spectrum)
- Improved material selection (more sensitive, better radiopurity e.g. PbWO₄ with archaeological lead)
- Active shielding
- Going deeper underground
- Storage of freshly made construction materials underground
- Multisegmented crystals or multiple crystals
- Collaboration with producers (e.g. depleted Ge, crystal growing, Cu electroforming underground)
- The "ultimate" ultra-low background facility

Ongoing Improvements and R&D

- Future experiments need more sensitive screening techniques ($< \mu\text{Bq/kg}$ for ^{226}Ra) \Rightarrow use of today's (e.g. CTF) or tomorrow's (e.g. GERDA) most sensitive detectors for screening.
- Future experiments need dedicated and highly sensitive screening and test techniques for measuring and monitoring surface contamination (development and adaptation of existing techniques and methods to need, e.g. LA-ICP-MS).
- Reorganisation and optimisation of existing screening facilities is necessary, because they are costly and measurement times can be rather lengthy.
- Harmonisation of how to report data and intercomparison programs for ultra low-level measurement techniques.

Research Applications

- Ultra low-level chemistry
- Particle astrophysics (material and techniques applicable to rare events experiments)
- Space science (e.g. micro meteorites, Mars samples, cosmic activation products, comet tail samples)
- Atmospheric samples ((very) short lived isotopes, radionuclide composition, stratospheric samples)
- Ocean samples (e.g. deep ocean water - ^{60}Fe)
- In general application of low background techniques to interdisciplinary fields:
 - Low-level environmental radioactivity measurement and monitoring
 - Radiodating (extension of determined ages towards the past)
 - Geophysics (palaeoseismology, palaeogeology, sedimentation)

Summary

- SNOLAB PGT HPGe low background counting system has run continuously for the past since 2005 and has counted 350 samples so far.

Counting queue is usually ~10 samples, this sometimes limits when samples can be counted in a timely manner.

The counter(s) is available for all SNOLAB experiments and can be made available to non-SNOLAB experiments upon request (eg. DM-ICE).

- Two new Canberra Ge detectors were delivered to SNOLAB, but need refurbishing since they are not ultra-low background as expected.

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.

- 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.