Low Background Counting At SNOLAB

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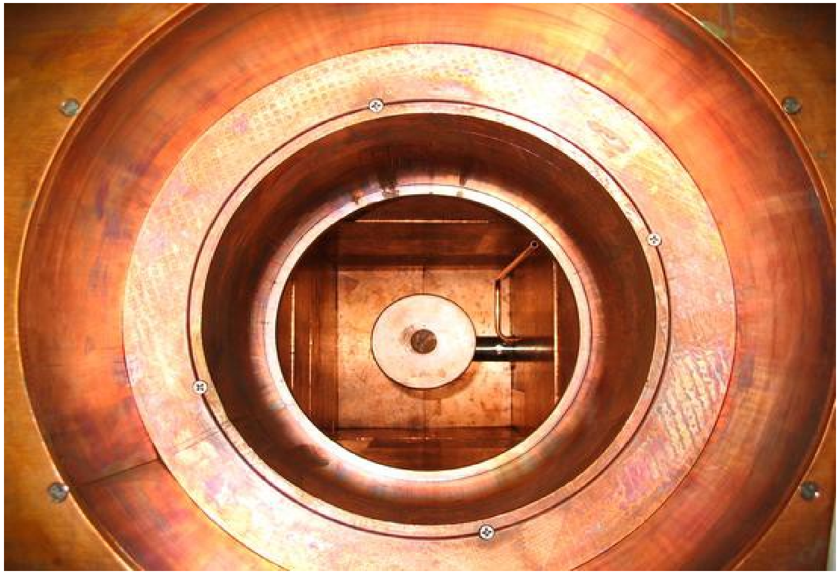
Low Radioactivity Techniques 2010



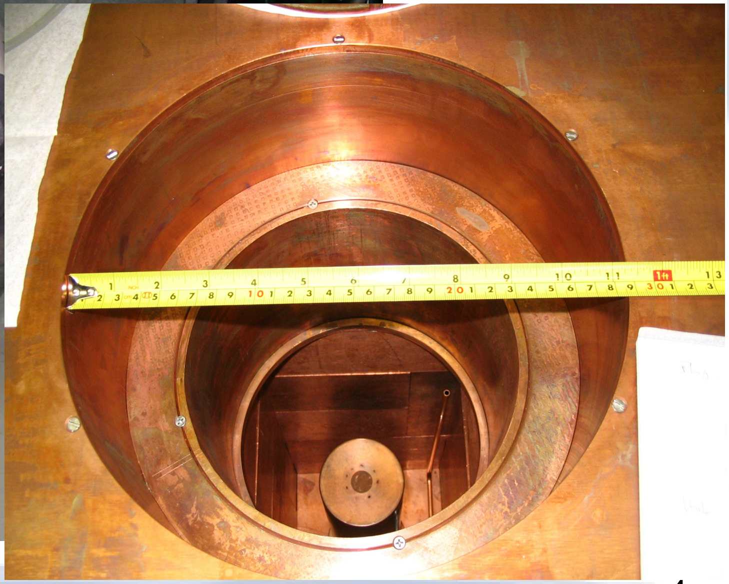
Outline

- Description of the SNOLAB HPGe Counting System
- Electrostatic (ESC) Counters
- Alpha/Beta Counting System
- Underground Radon Levels at SNOLAB
- Future Low Background Counting Facilities

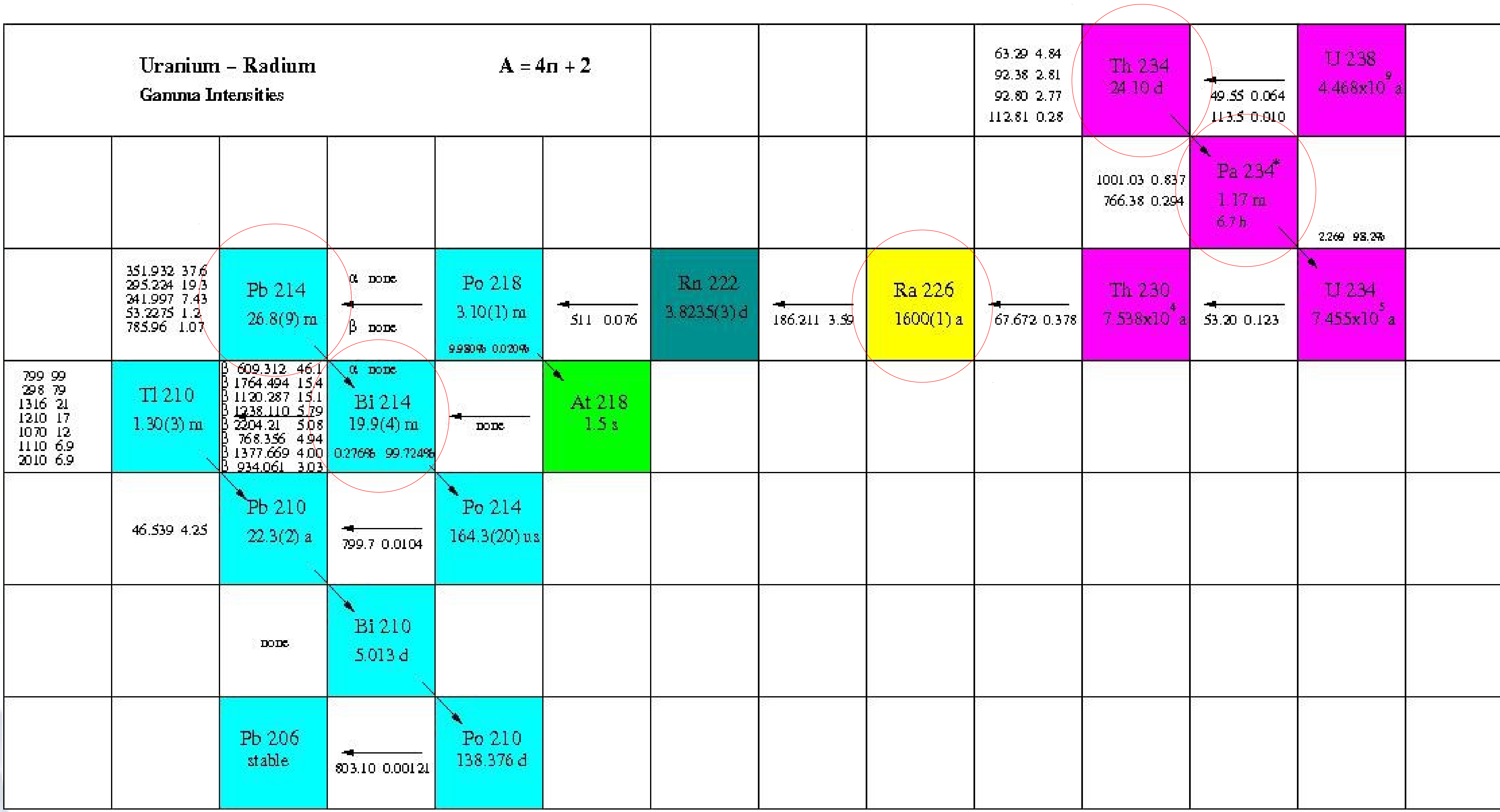
SNOLAB HPGe Detector

- 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+, DEAP1, minCLEAN, PICASSO, EXO, ...
- 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.

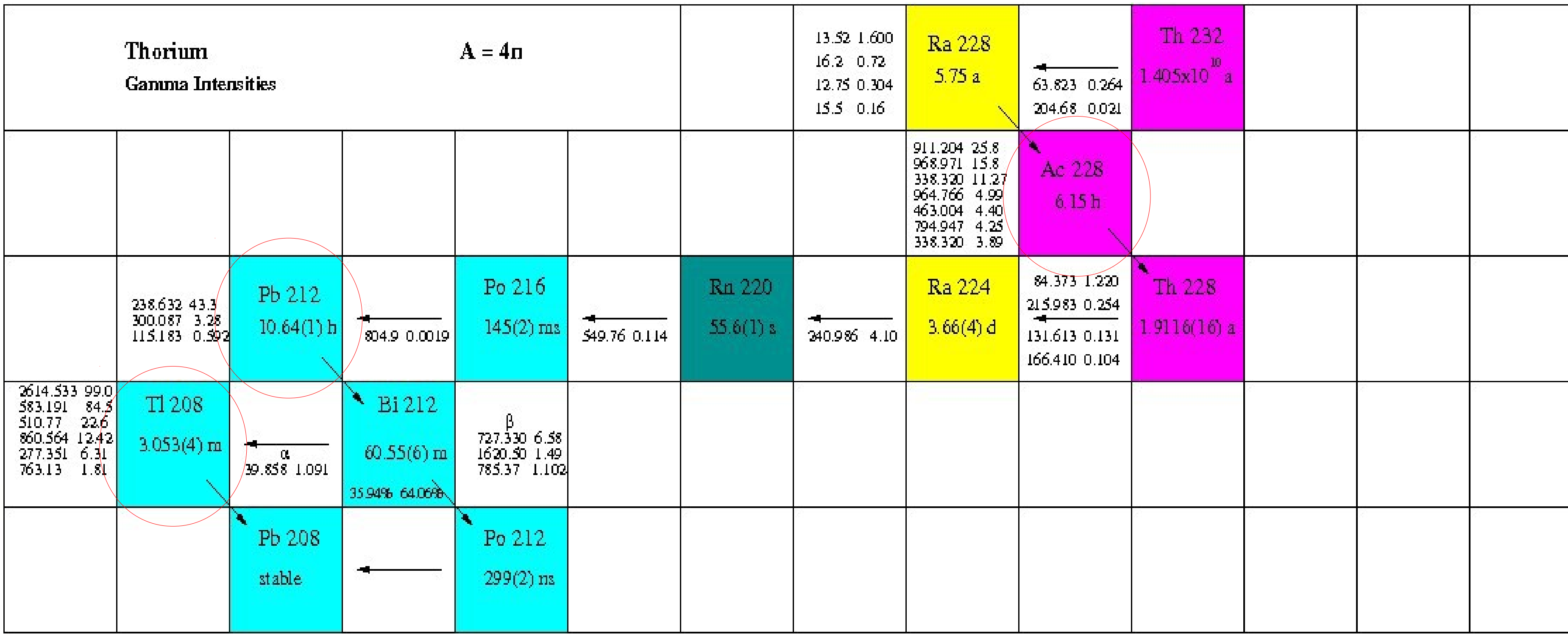
SNOLAB HPGe Counter



Uranium Decay Chain



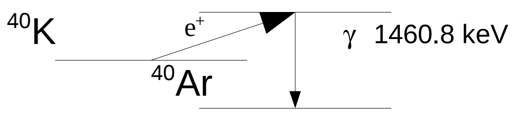
Thorium Decay Chain



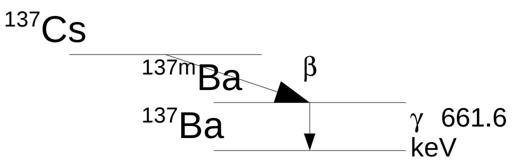
Other Interesting Isotopes

Usually Present:

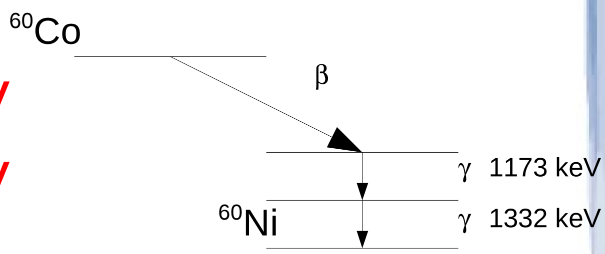
- ^{40}K
  1460.83 keV



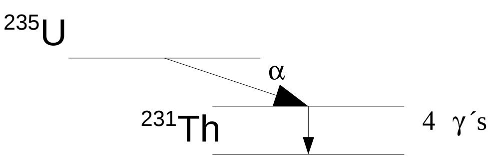
- ^{137}Cs
  661.66 keV



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



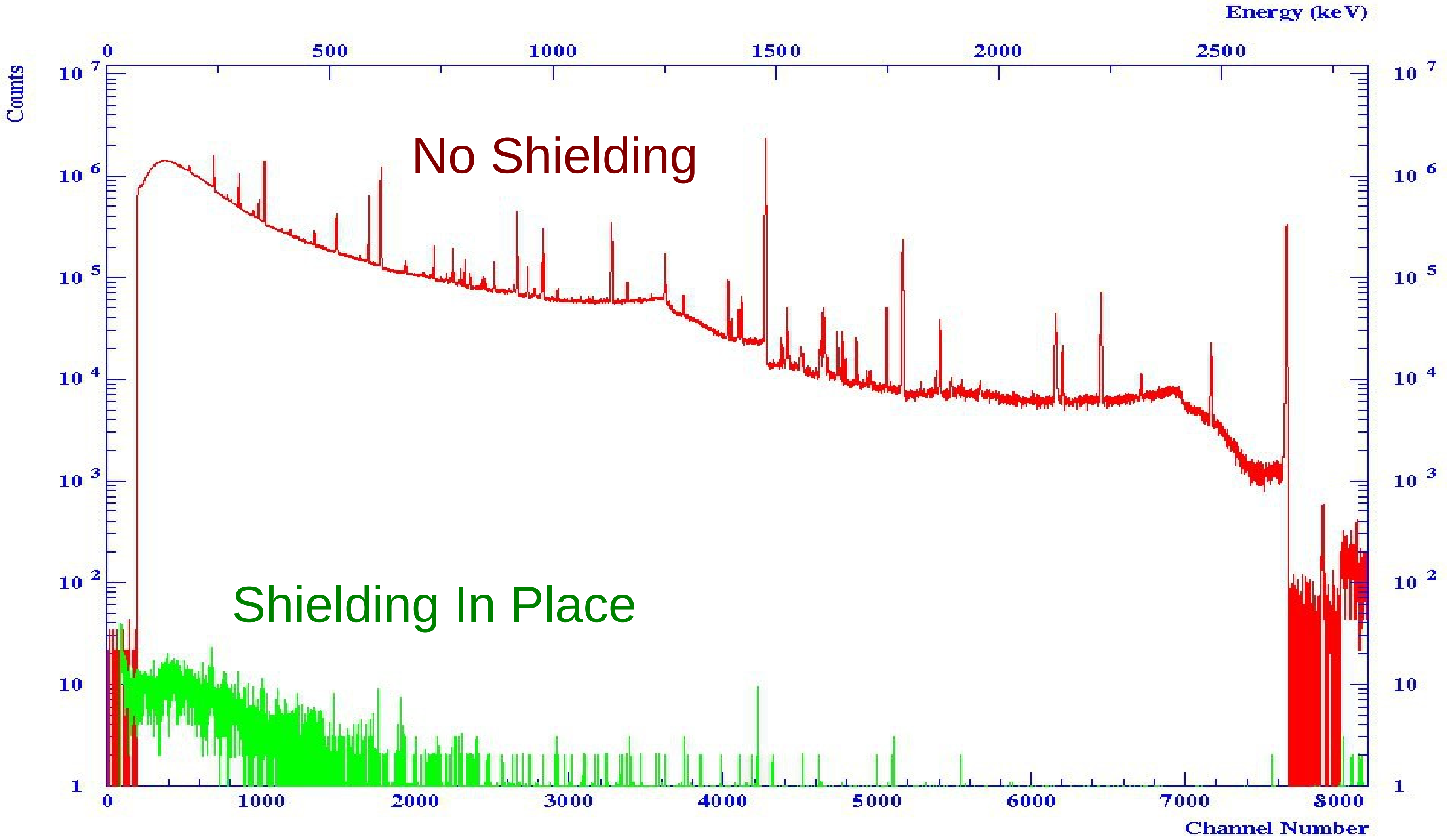
- ^{235}U
  - 143.76 keV
  - 163.33 keV
  - 185.22 keV
  - 205.31 keV



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.

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	0.00141 ± 0.00016
^{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

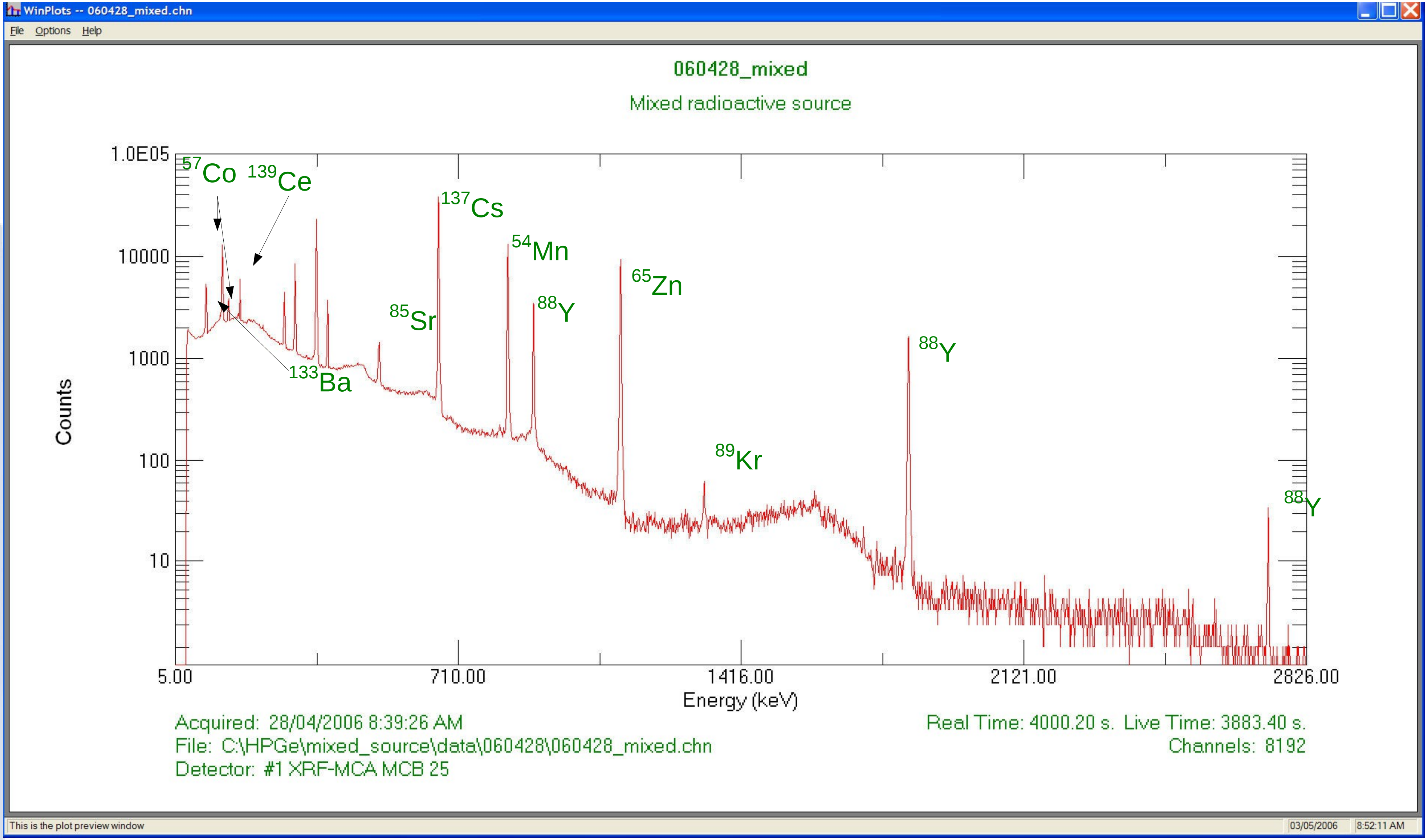
HPGe Detector Sensitivity

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 %

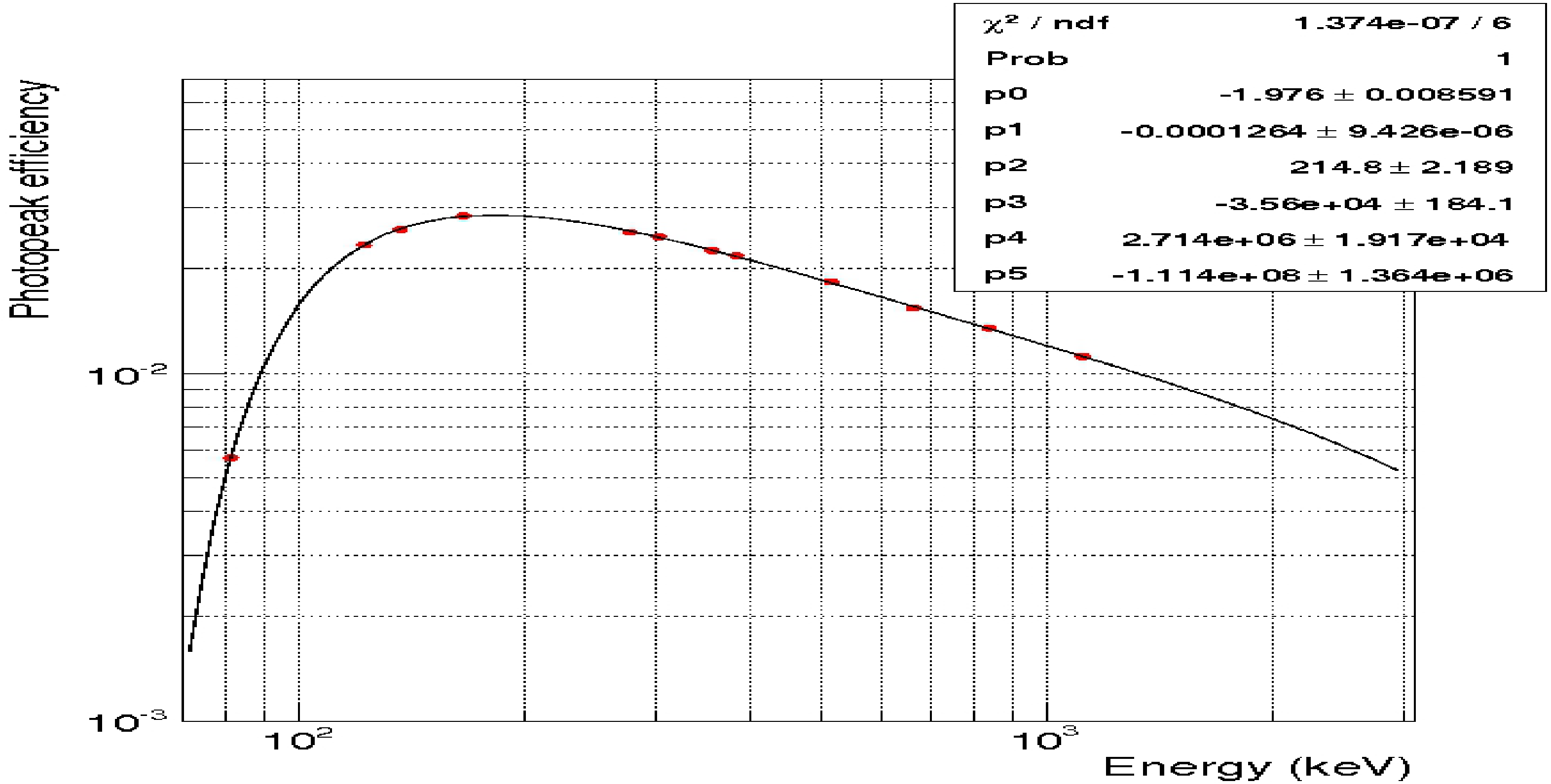
Better sensitivities have been achieved for specialized very large samples combined with an extremely long counting period:

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

Calibration Spectrum



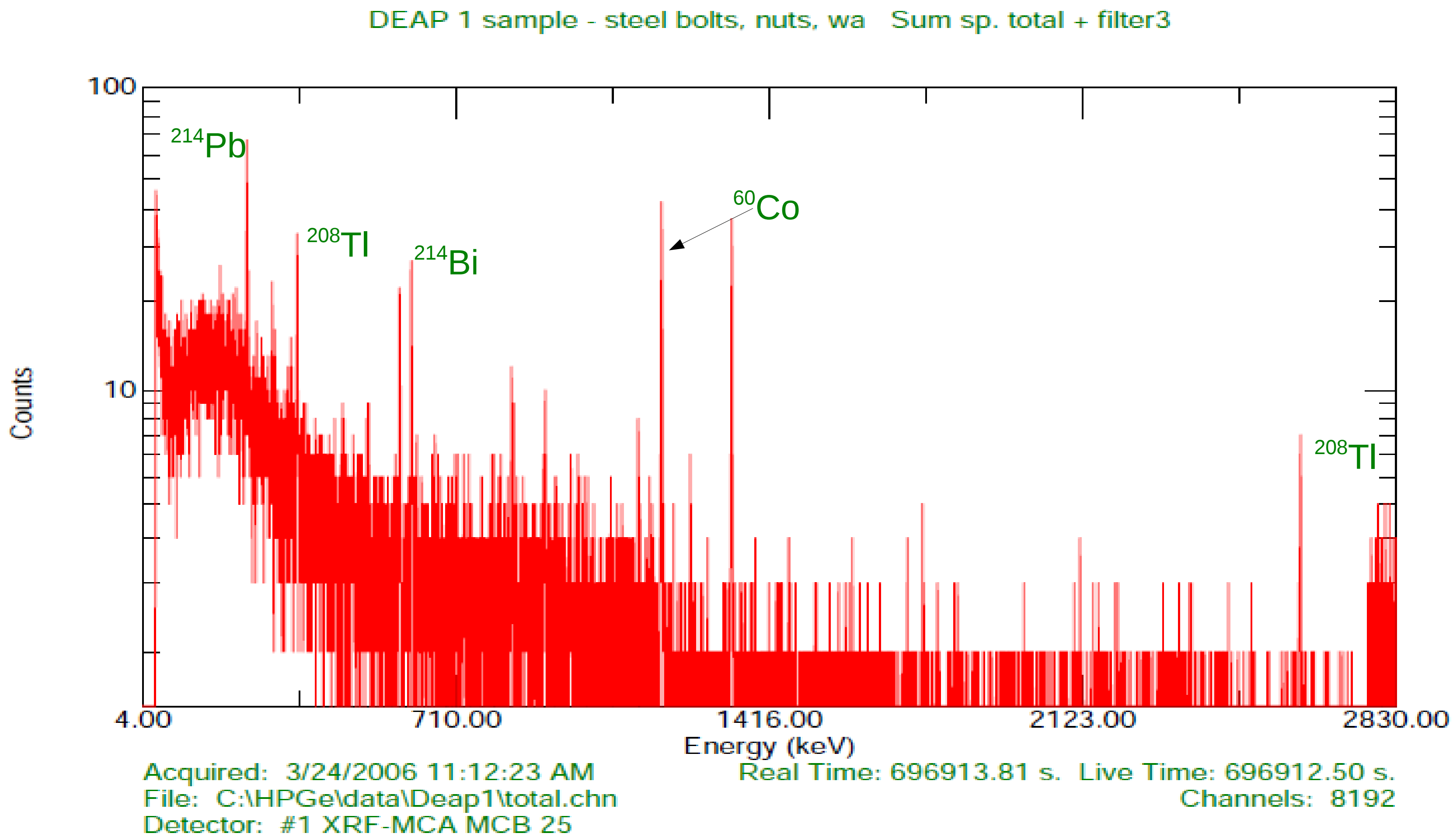
Detector Efficiency From Mixed Calibration Sample



Plot by James Loach

The efficiency is scaled to individual samples using a Geant based Monte Marlo 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 Stainless Steel Spectrum



Measurements To Date For Each Experiment

Experiment	2006	2007	2008	2009	2010 (Jan-Aug)	Total
SNO	2	7	0	2	0	11
SNO+	0	2	18	14	13	47
SNOLAB	7	3	0	0	3	13
EXO	1	1	0	0	0	2
MiniCLEAN	5	1	9	18	8	41
DEAP	8	8	12	10	5	43
HALO	0	0	0	2	2	4
PICASSO	1	1	4	3	0	9
DM-ICE	--	--	--	--	3	3
Total	24	23	43	49	34	173
Calibrations &Tests	30	34	14	9	1	88

Electrostatic Counting System

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

Sensitivity Levels are:

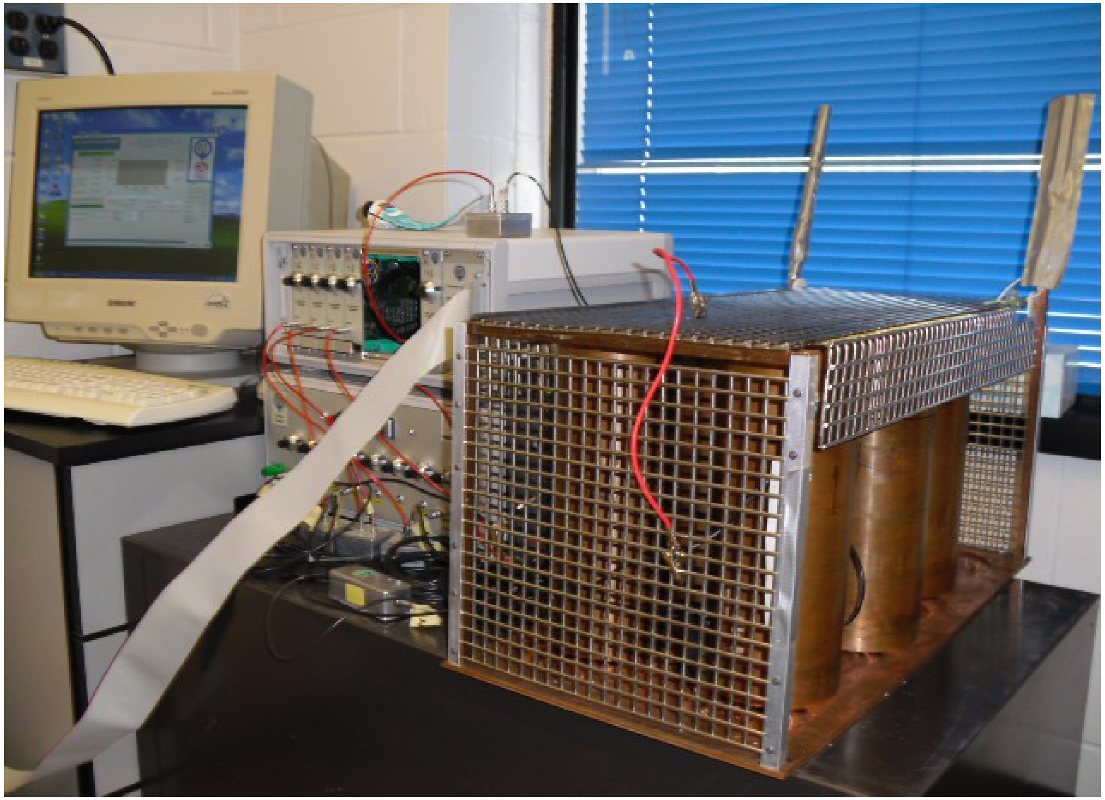
^{222}Rn: 10^{-14} gU/g

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

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

Work is ongoing to improve sensitivity even further.

Alpha Beta Counting System

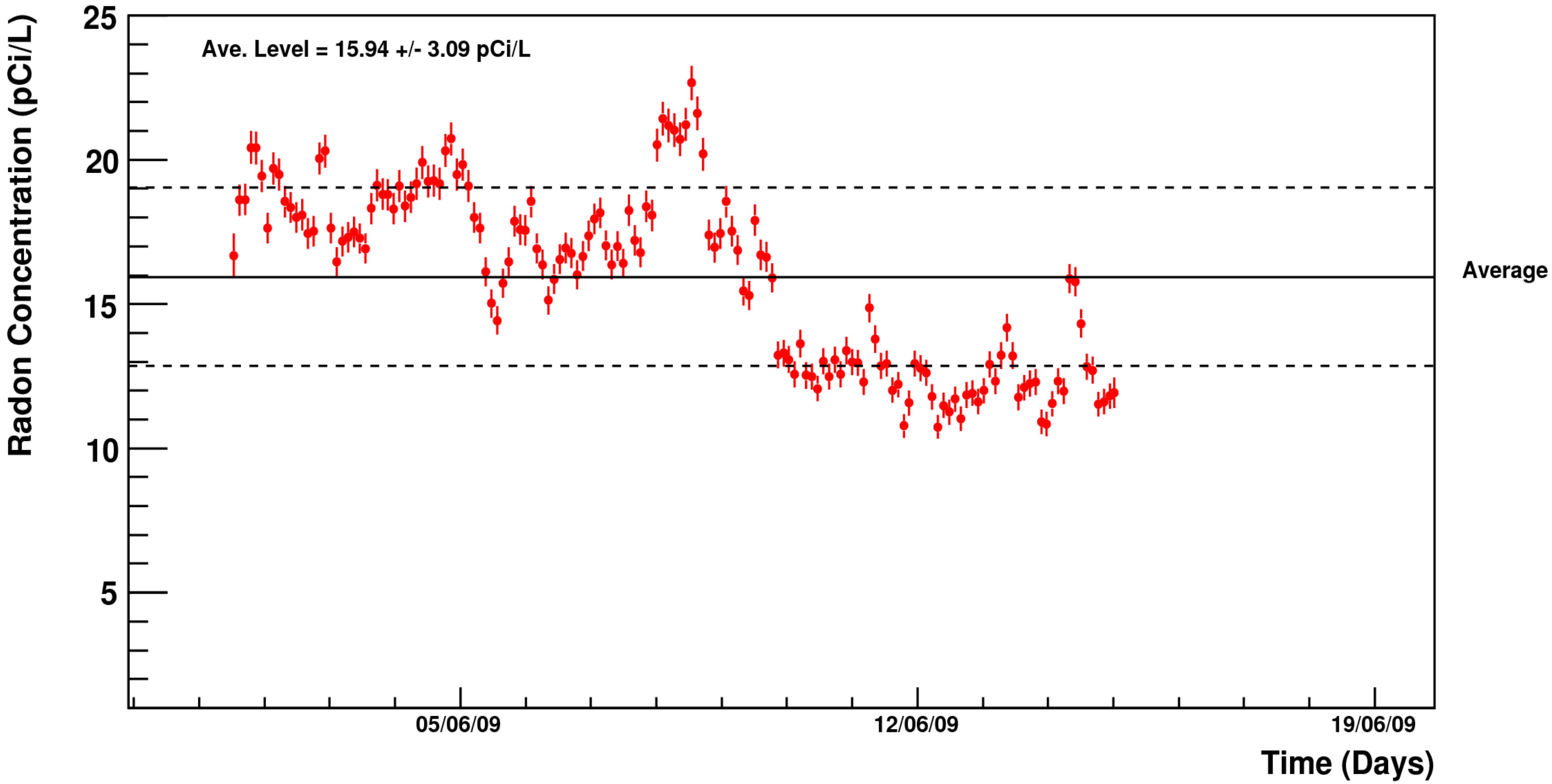


Currently located at the SNOLAB hot lab at LU so that spike sources can be measured.

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

SNOLAB Radon Levels Without Fresh Air

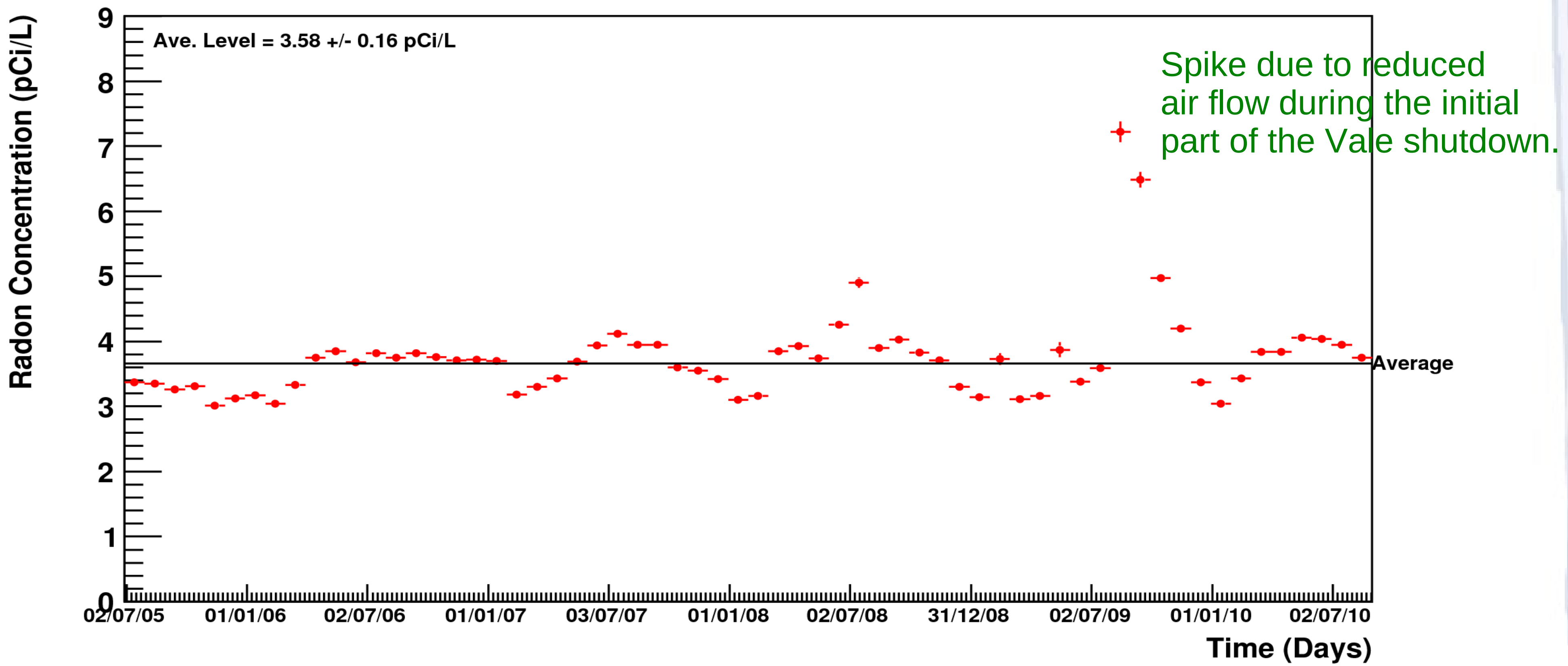
Radon levels: 15.94 ± 3.09 pCi/L or 589.8 ± 114.3 Bq/m^3.



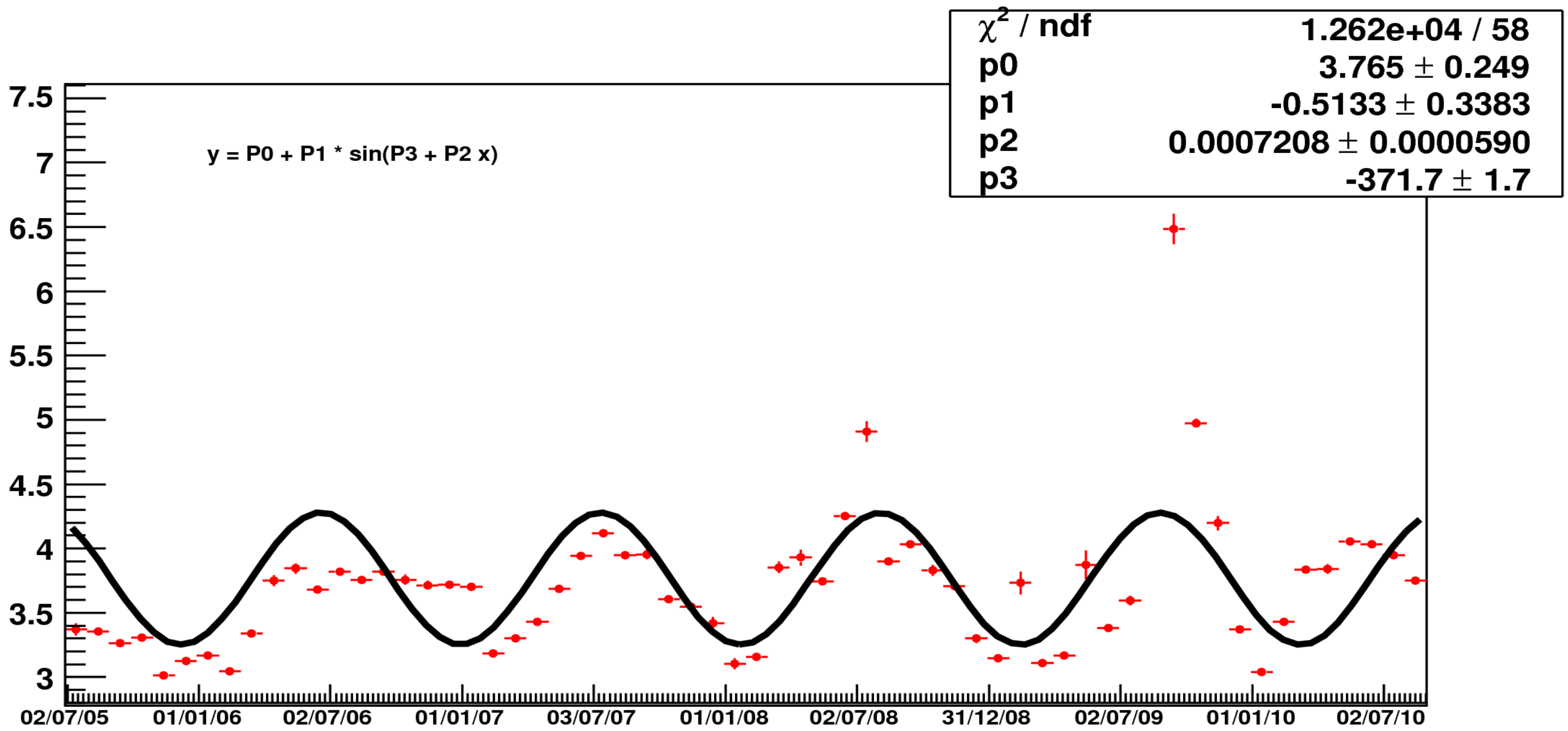
Radon Levels at SNOLAB With Fresh Air

(Normal Laboratory Operating Conditions)

Radon continuously monitored for the several years now.
Radon levels are: 3.50 ± 0.16 pCi/L or 129.5 ± 5.9 Bq/m^3.



Radon Level Annual Cycle

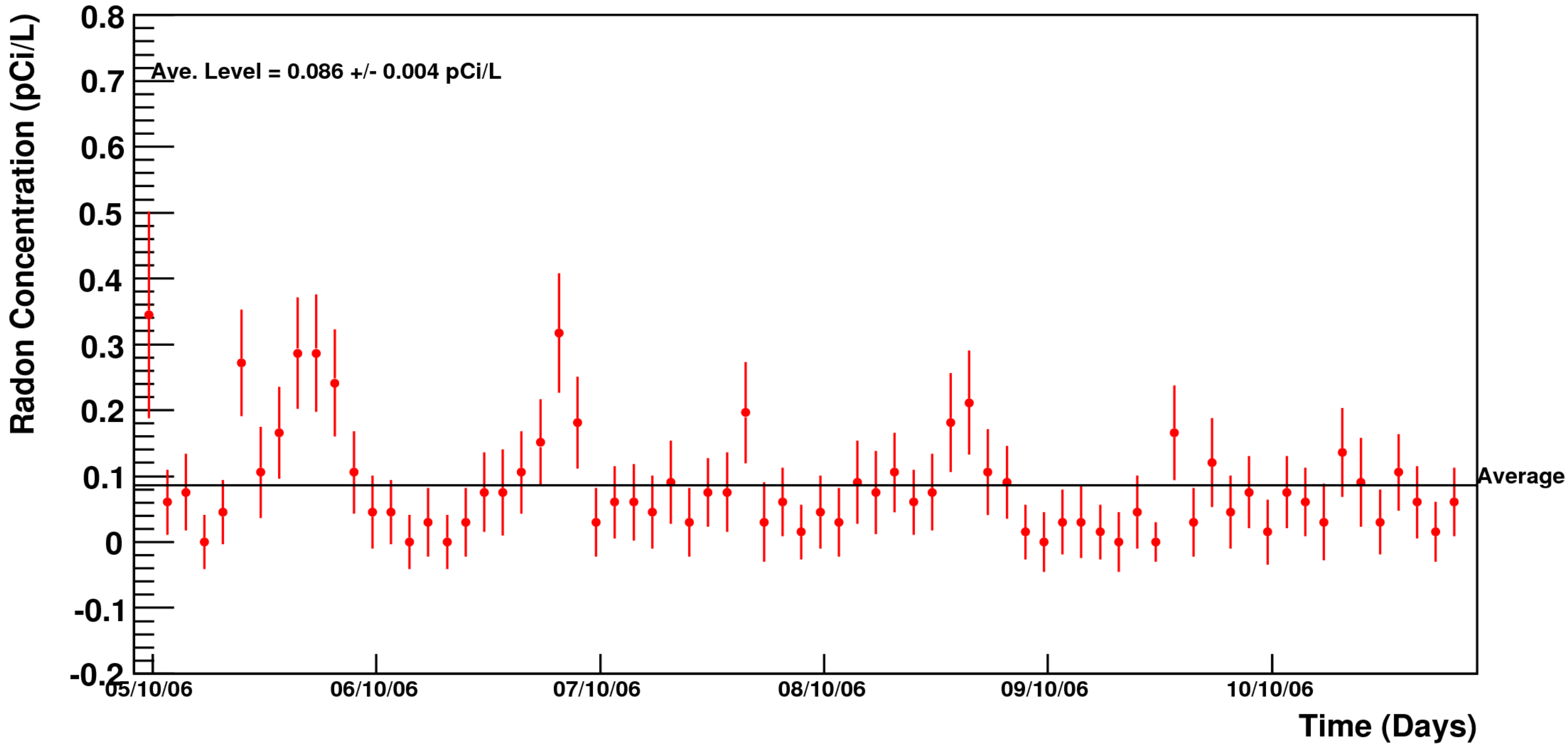


The annual cycle corresponds to 363.21 +- 29.73 days, the expected cycle is one year.

Achievable Radon Levels

Using Compressed Air Supplied From Surface

Radon levels: 0.086 ± 0.004 pCi/L or 3.18± 0.15 Bq/m^3.



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 deployed.

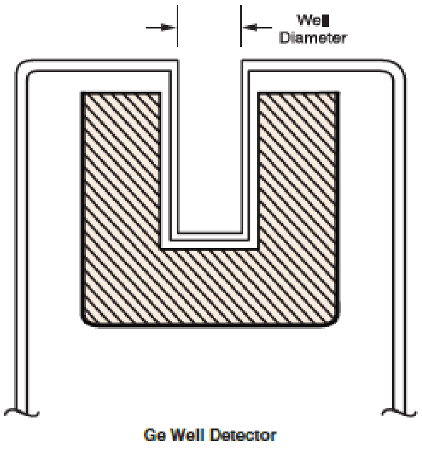
Future Low Background Counting At SNOLAB (I)

- Two new low background high purity Ge Counters have been ordered from Canberra

  One counter is a p-type coaxial detector and the other is a well detector. They are expected to arrive at the end of 2010.

  Canberra will supply the low background shielding for the well detector while SNOLAB will use copper and lead currently in storage together with additional low background material to be acquired.

  Will measure existing lead to determine ^{210}Pb content, this will help us understand the current backgrounds in existing detector and to determine requirements for the new detector.



Future Low Background Counting At SNOLAB (II)

- Neutron background measurements have been started in the SNOLAB expansion (PICASSO).

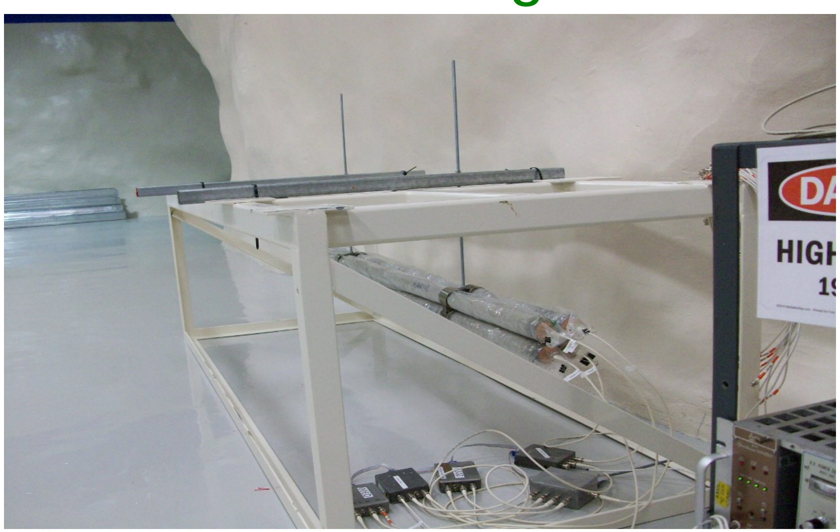
  System uses 4 2m-long ^{3}He proportional counters from SNO.

  Sensitivity to neutrons is 0.00003 mRem/hr, therefore they will observe neutrons even at very low levels.

  Counters can be deployed inside shielding structures to determine how effective the shielding is at stopping neutrons.

  Previous measurements indicate that the flux varies from 4.8×10^{-6} to 1×10^{-5} neutrons/cm^{2}/s.

No shielding



Shielding In Place

Summary

- SNOLAB HPGe low background counting system has run continuously for the past five years and has counted 173 samples so far.

  Counting queue usually remains at between 6 and 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.

- Two new Ge counting systems are expected to arrive by the end 2010.

  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.
- Neutron backgrounds can be determined throughout the underground lab and the effectives of neutron shields can be tested.