Radioactivity Screening at SNOLAB

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SNOLAB Workshop V

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Outline

- **Overview of SNOLAB Germanium Detector**
- **Underground radioactivity (no Ge detector shielding)**
- **Results after Ge detector enclosed in shielding**
- **Recent results**
- **Summary**

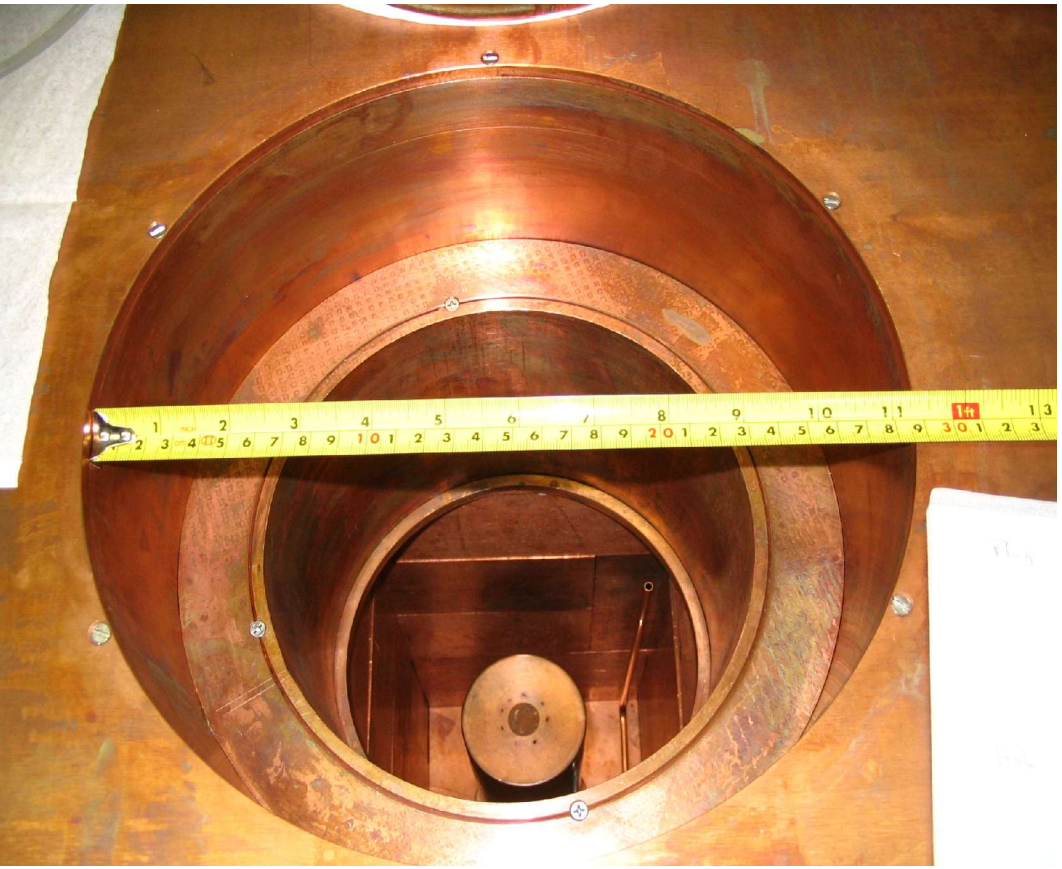
SNOLAB HPGE Detector Setup

- Initial Establishment of the Low Background Gamma Facility @ SNOLAB in 2005
  - Yoram Nir-El, Bruce Cleveland, Doug Hallman, Brian Morisette, Noel Gagnon and Ian Lawson
- Motivation
  - Survey materials for new, existing and proposed experiments (to be) located @ SNOLAB, such as SNO, DEAP1, EXO, ...
- Constructed @ SNOLAB from an HPGE detector and its associated shielding located underground at 4600 ft since 1997.
  - Ge crystal refurbished in 2005 at PGT, in New Jersey and has been working well since its return to SNOLAB in April 2005.
- Future
  - There is another Ge detector located at 4600 ft (originally located at a salt mine in Windsor) that has 3 crystals. This detector could allow us to increase measurement capability and possible precision with larger samples.

SNOLAB HPGE Detector Characteristics

- Manufacturer
  - Princeton Gamma-Tech, Model Number IGC 5021
- Crystal dimensions
  - 63mm x 67 mm
- Efficiency
  - 55%, relative to a 7.62 cm dia x 7.62 cm NaI(Tl) detector for 1332 kev γ-rays from a ^{60}Co source 25 cm from the face of the crystal
- Resolution
  - 1.8 keV FWHM
- Shielding
  - 2 inches Cu + 8 inches Pb
- End-cap diameter
  - 83 mm
- End-cap material
  - Electroformed Copper
- Nitrogen flow rate to purge radon
  - ~2L/min

SNOLAB HPGE Detector



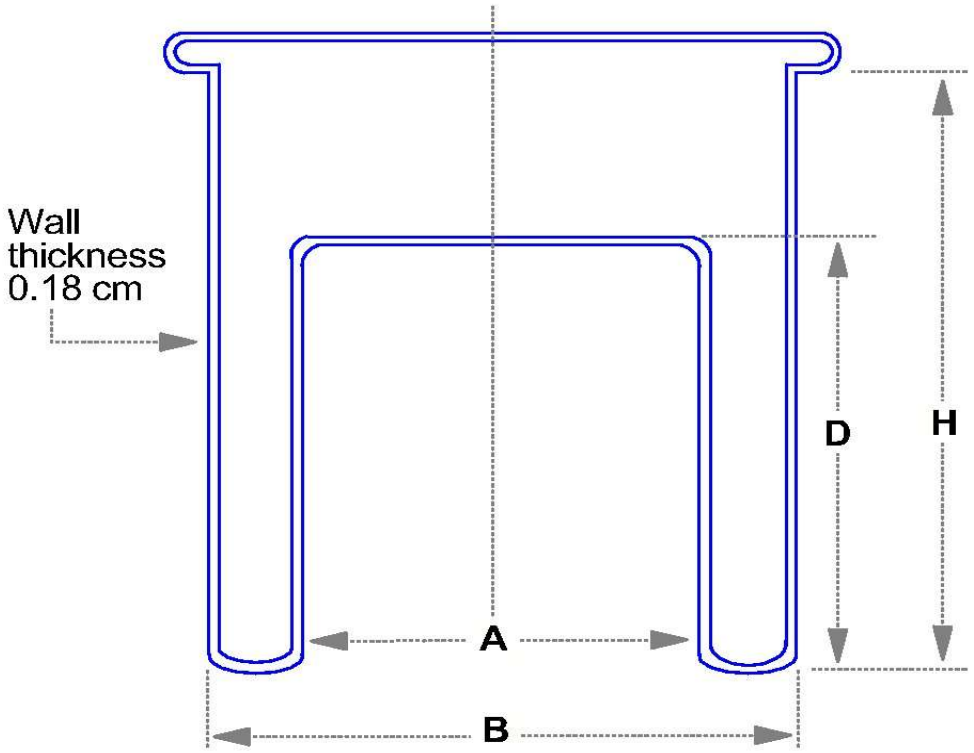
Nitrogen flow meter

Nitrogen bubbler

Detector HV Controller

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.

The Uranium Decay Chain

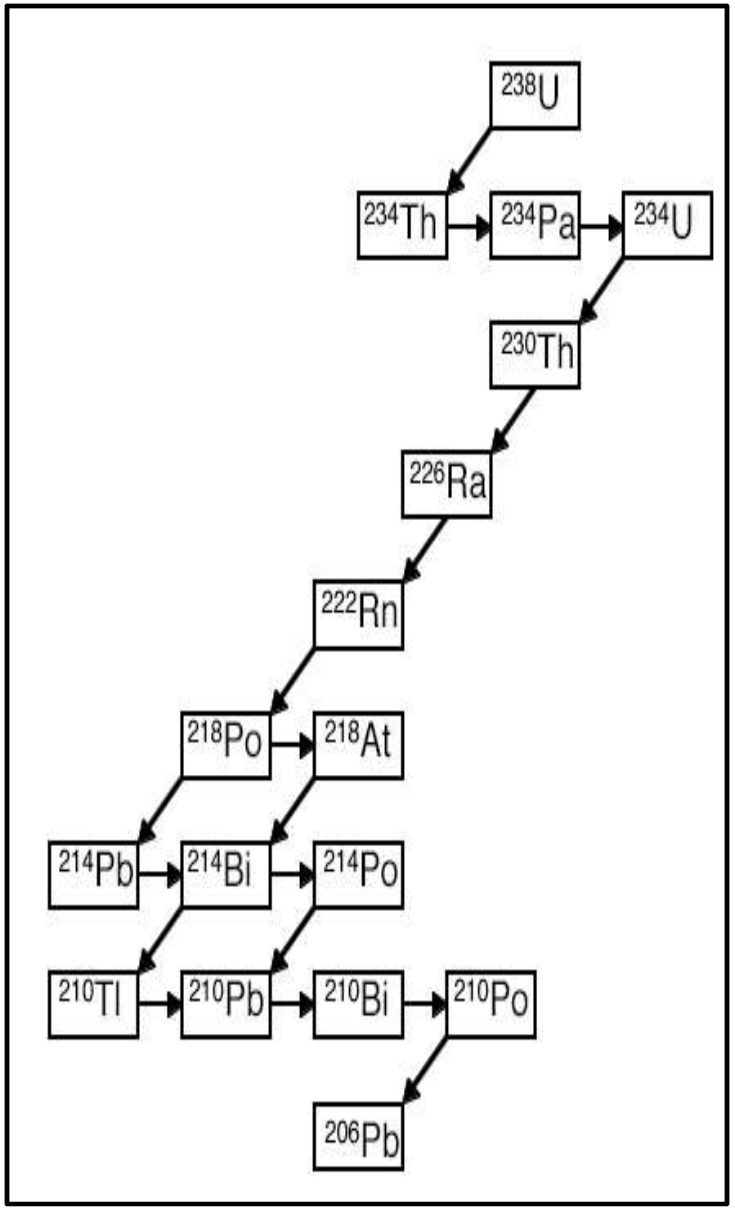
Several gammas are released when ^{238}U decays to ^{206}Pb. The more prominent gammas are used to measure the amount of ^{238}U present in a substance.

These gammas are:

- 186.1 keV from ^{226}Ra
- 295.21 keV from ^{214}Pb
- 351.92 keV from ^{214}Pb
- 609.31 keV from ^{214}Bi
- 1120.29 keV from ^{214}Bi
- 1764.53 keV from ^{214}Bi

In some substances we can also observe additional gammas:

- 63.29 keV from ^{234}Th
- 92.50 keV from ^{234}Th
- 1001.03 keV from ^{234}mPa

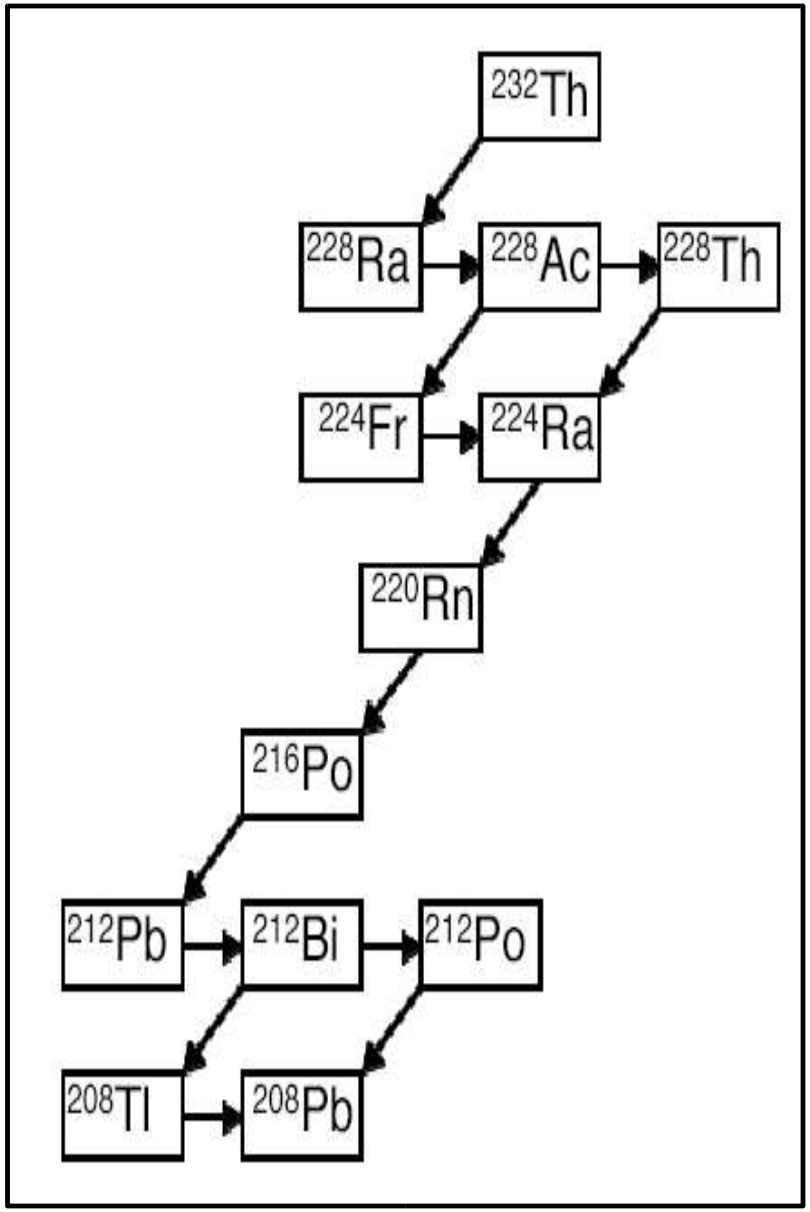


The Thorium Decay Chain

Several gammas are released when ^{232}Th decays to ^{208}Pb. The more prominent gammas are used to measure the amount of ^{232}Th present in a substance.

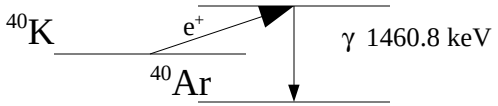
These gammas are:

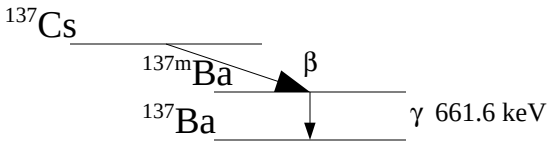
- 238.63 keV from ^{212}Pb
- 300.09 keV from ^{212}Pb
- 583.19 keV from ^{208}Tl
- 911.21 keV from ^{228}Ac
- 2614.53 keV from ^{208}Tl

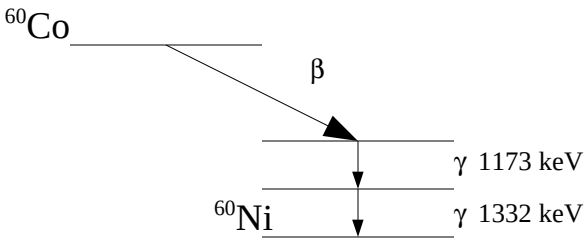


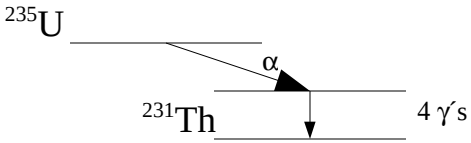
Other Interesting Detectable Isotopes

- ^{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









Low background gamma conversion factors

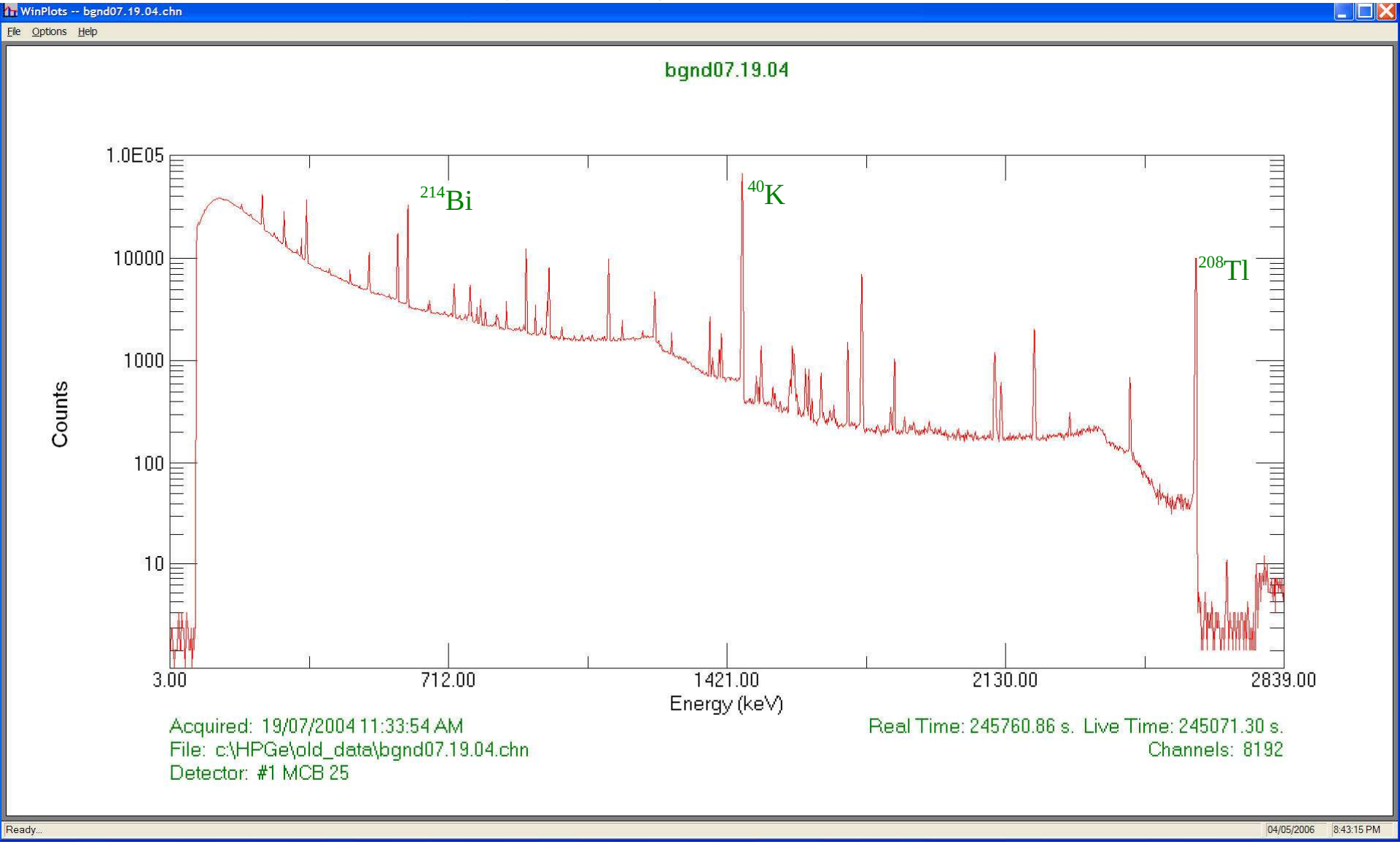
Isotope	1 Bq/kg	1 ppb	Current Sensitivity	Typical for Earth's Crust
^{238}U	81 ppb	12 mBq/kg	~ 1 mBq/kg ~ 0.1 ppb	37 Bq/kg 3 ppm
^{232}Th	246 ppb	4.1 mBq/kg	~ 1.5 mBq/kg ~ 0.3 ppb	45 Bq/kg 11 ppm
^{40}K	32 ppm	0.031 mBq/kg	~ 21 mBq/kg ~ 0.7 ppm	800 Bq/kg 2.5 %

Sensitivities of SNOLAB Compared to some other Facilities

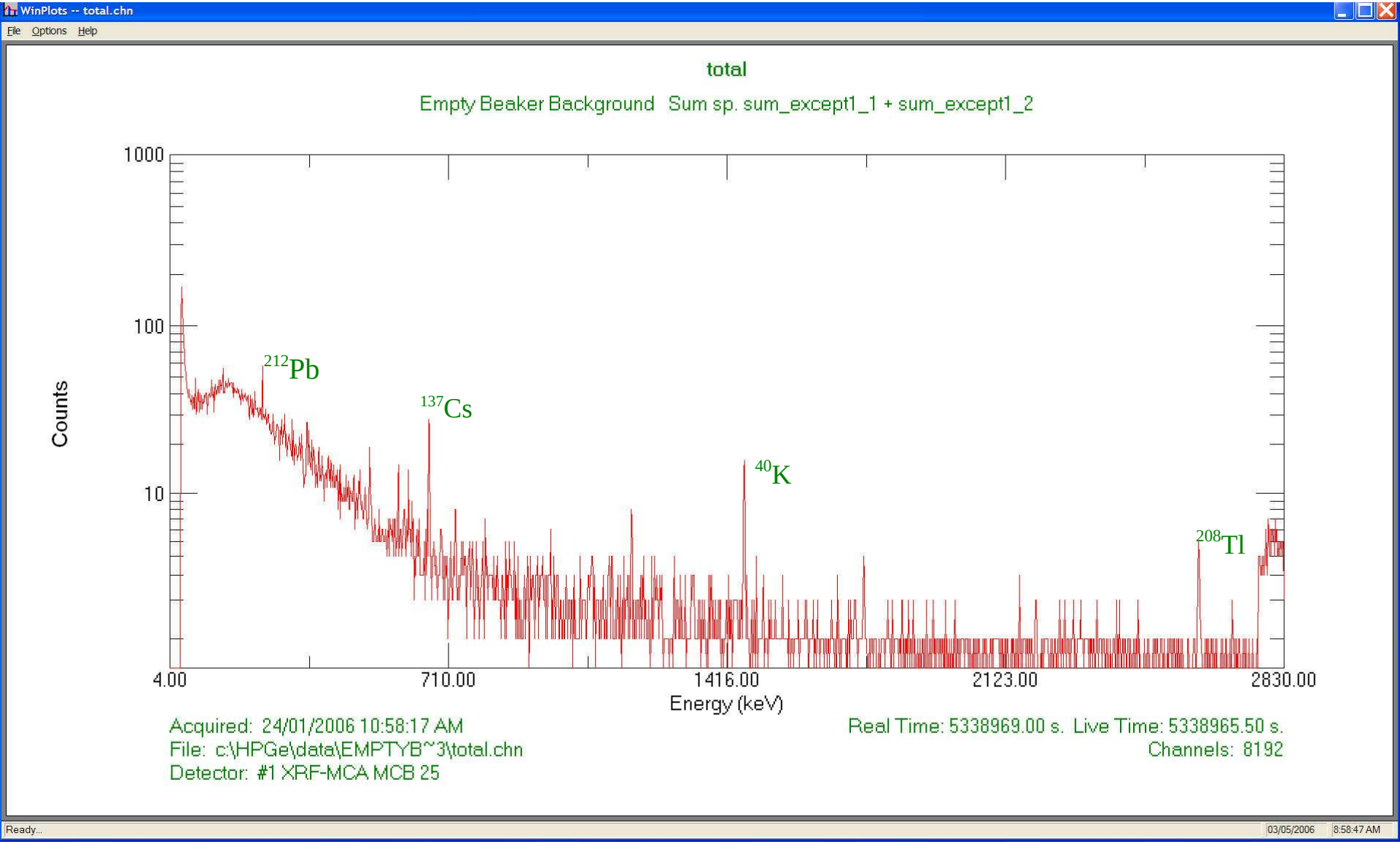
Isotope	SNOLAB	SOLO	LBCF Surface Facility	LBCF Underground Facility
^{238}U	1 mBq/kg 0.1 ppb	1 mBq/kg 0.1 ppb	9 mBq/kg 0.5 ppb	0.9 mBq/kg 0.05 ppb
^{232}Th	1.5 mBq/kg 0.3 ppb	0.5 mBq/kg 0.05 ppb	12 mBq/kg 2 ppb	1.2 mBq/kg 0.2 ppb
^{40}K	21 mBq/kg 0.7 ppm	10 mBq/kg 0.25 ppm	32 mBq/kg 1 ppm	3.2 mBq/kg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

SNO Laboratory Background Spectrum

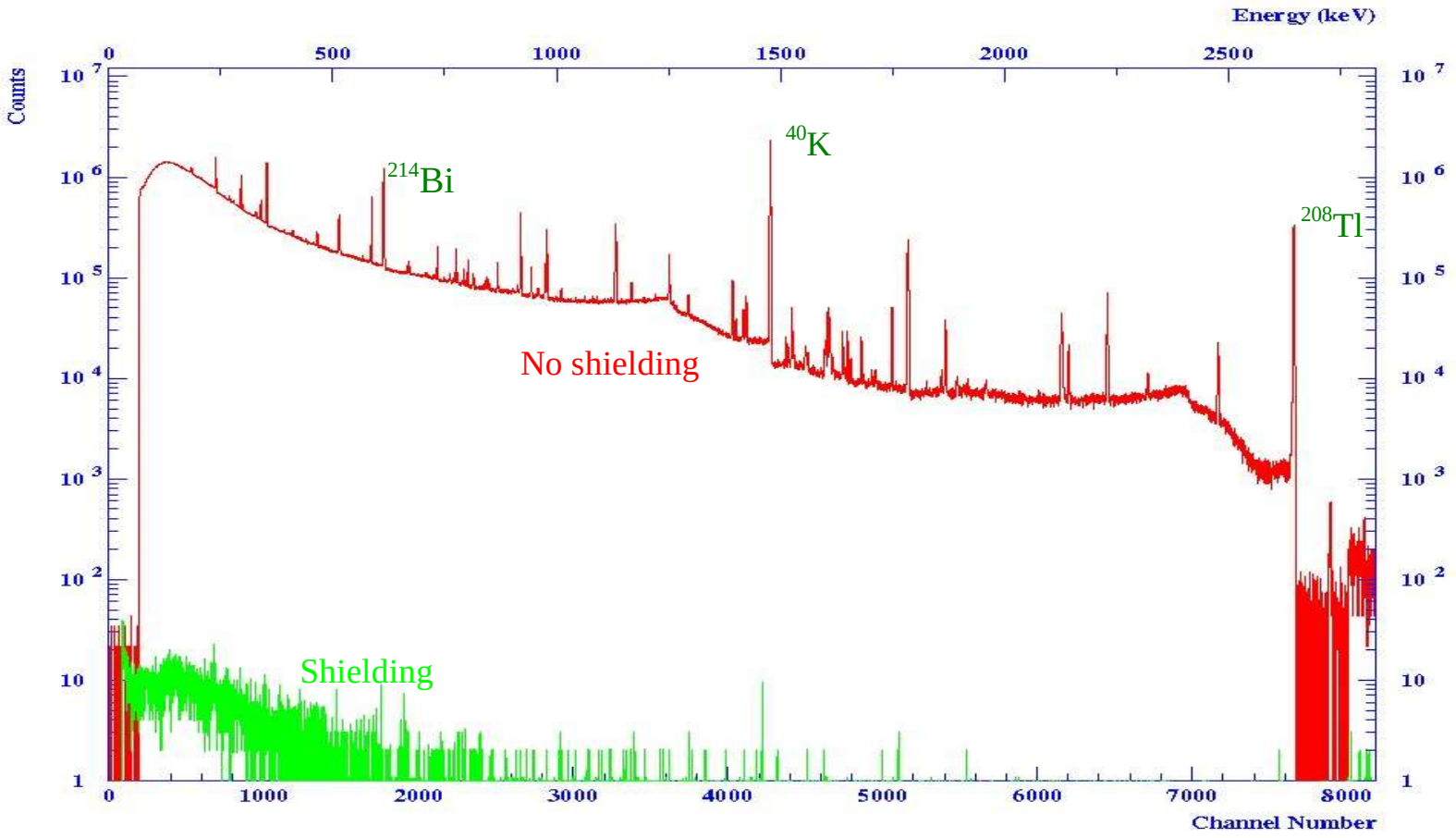
(Unshielded detector located in the junction area, the volume of air in this area is circulated by AHU4; the junction volume is 34330 ft^3.)



Shielded Background Spectrum



Unshielded and Shielded Background Spectra



Background Comparison

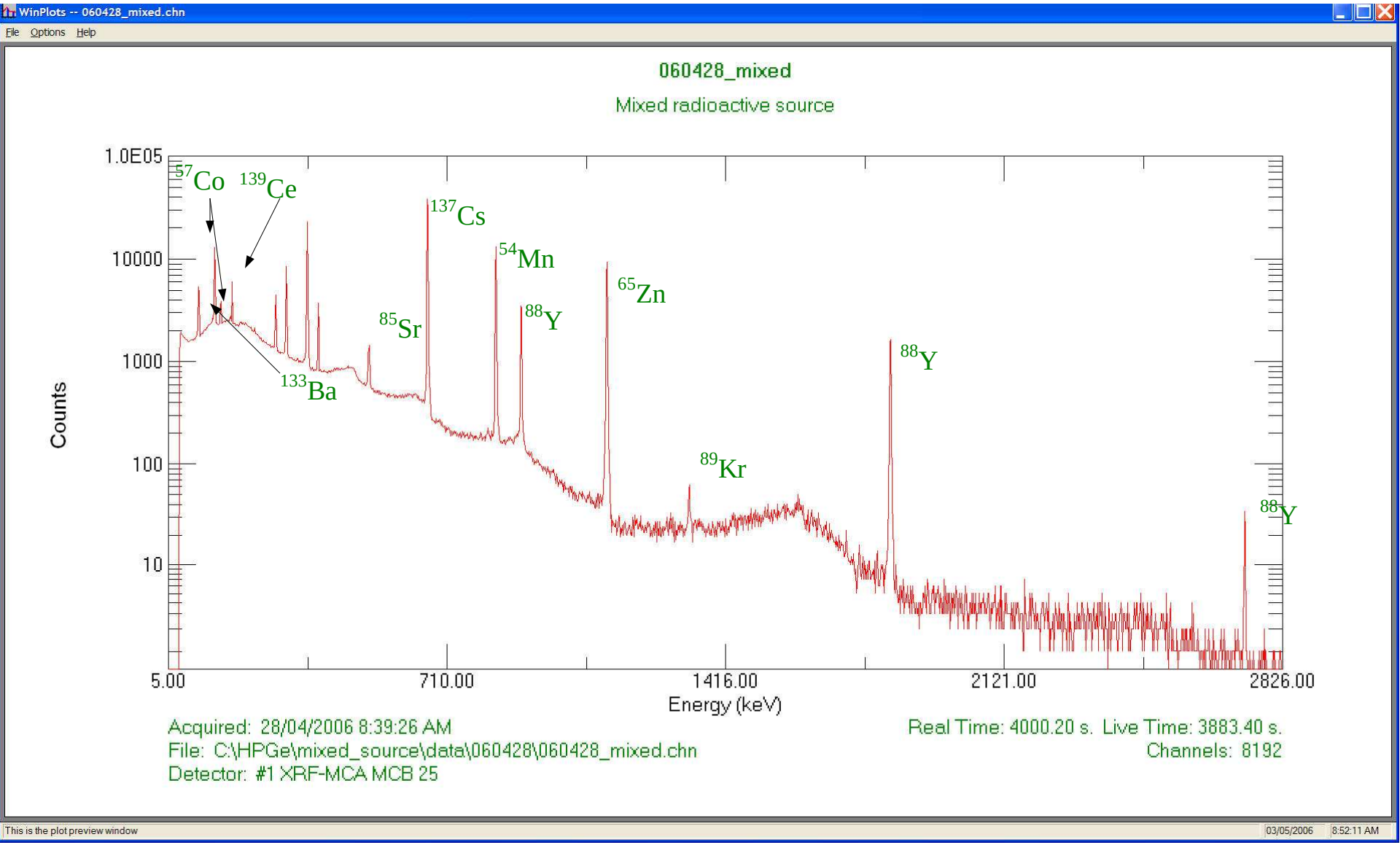
Unshielded Versus Shielded Ge Detector

Isotope	Activity Unshielded Crystal(Bq)	Activity Shielded Crystal (Bq)
^{238}U	70.11 ± 1.64	0.00131 ± 0.00021
^{232}Th	36.99 ± 1.21	0.00147 ± 0.00019
^{40}K	1723.33 ± 88.02	0.0213 ± 0.0024
^{137}Cs	1.00 ± 0.15	0.0019 ± 0.0002
^{60}Co	0.023 ± 0.052	0.00045 ± 0.00007

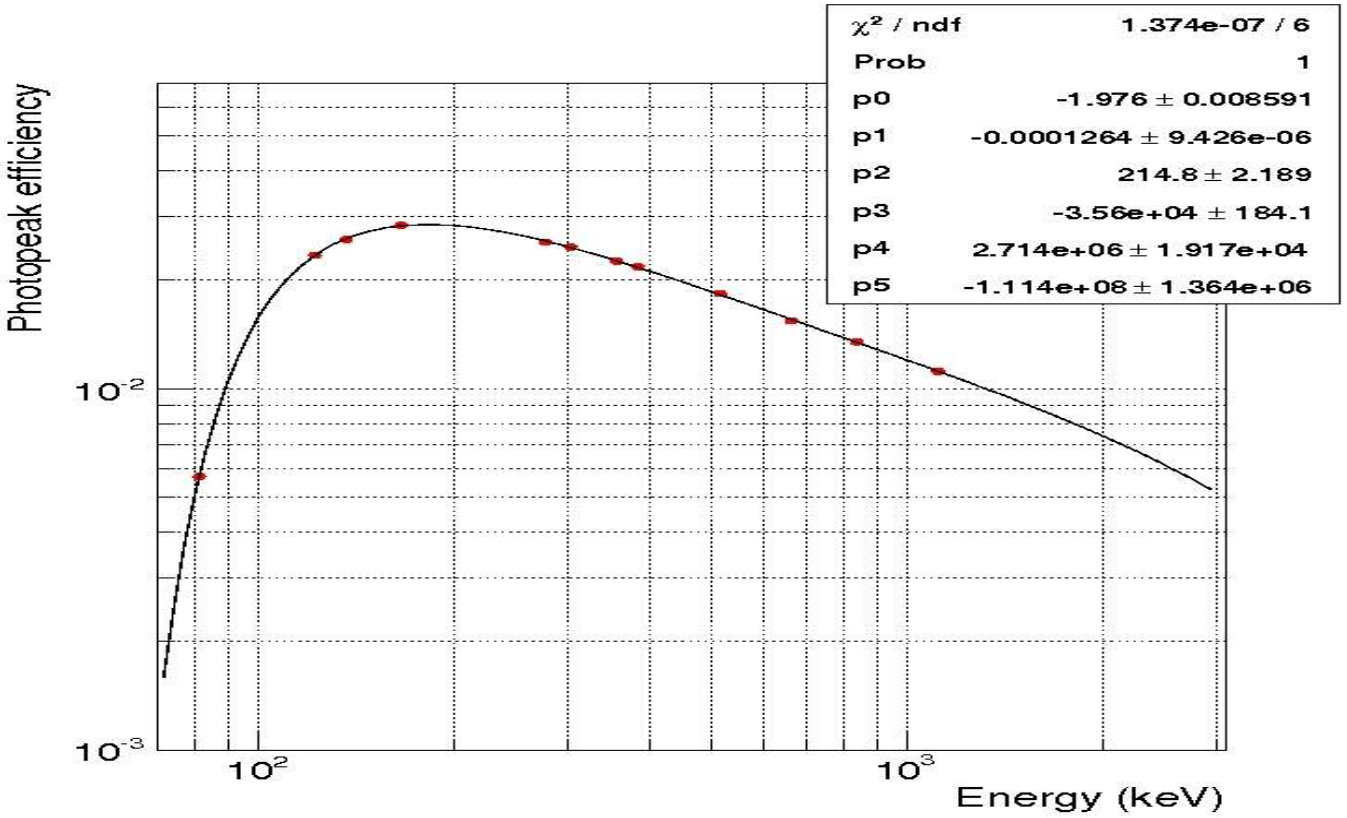
Unshielded Measurements done by Yoram Nir-EL

Mixed Source Calibration Spectrum

Epoxy source made by AEA Technology QSA GmbH, density is 1.5 g/cm^3

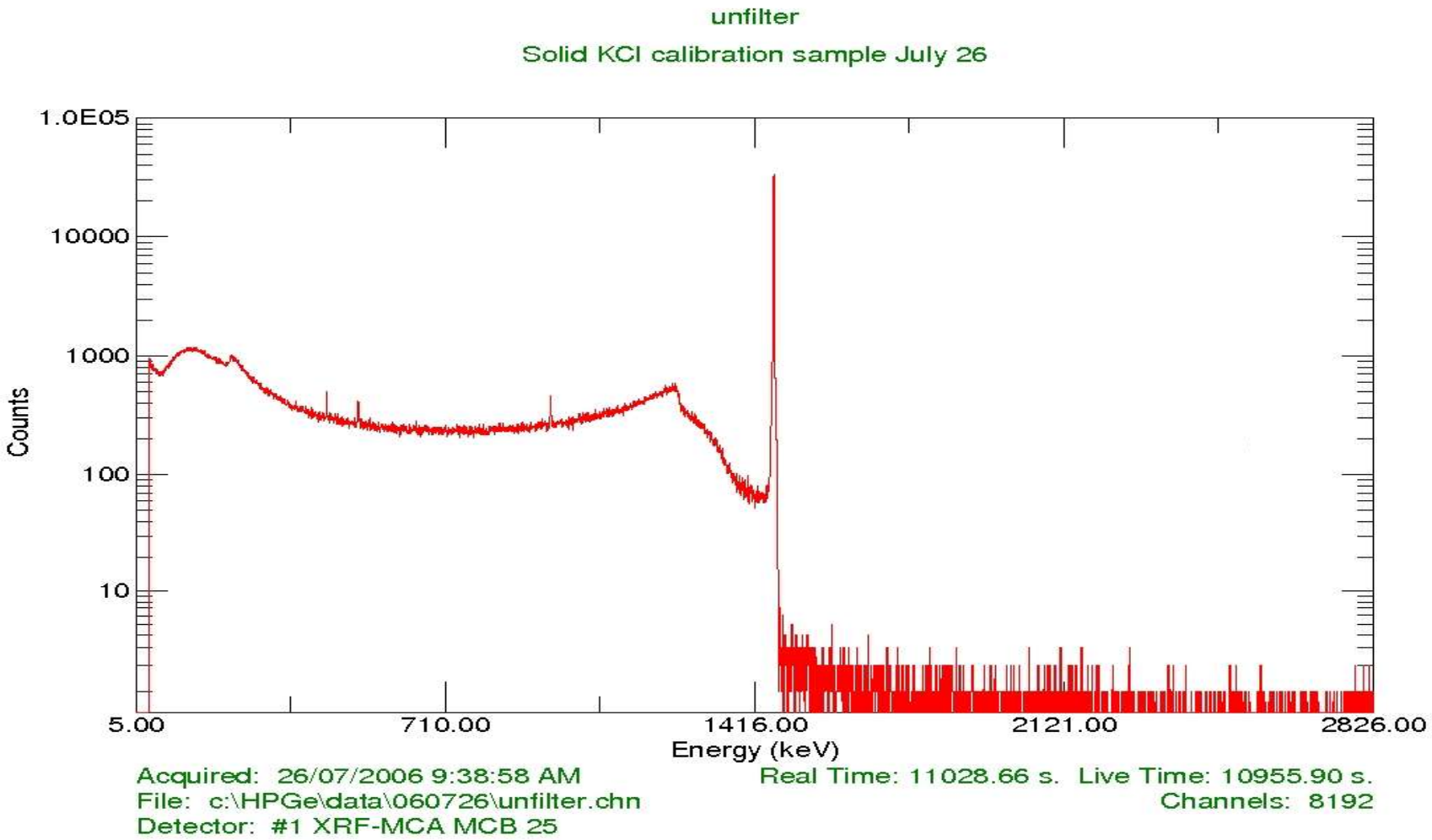


Ge Detector Efficiency from Mixed Calibration Source

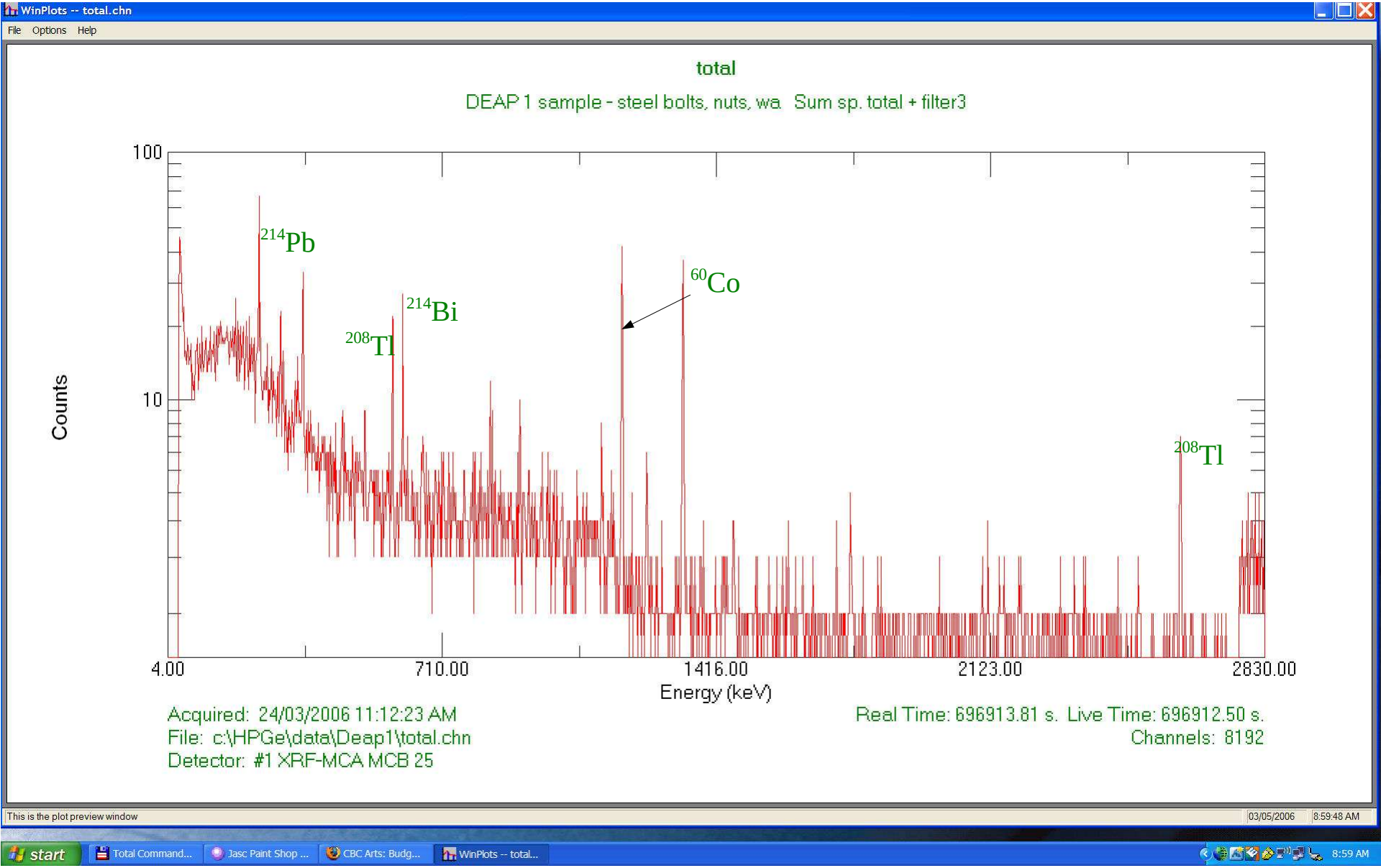


Plot by James Loach

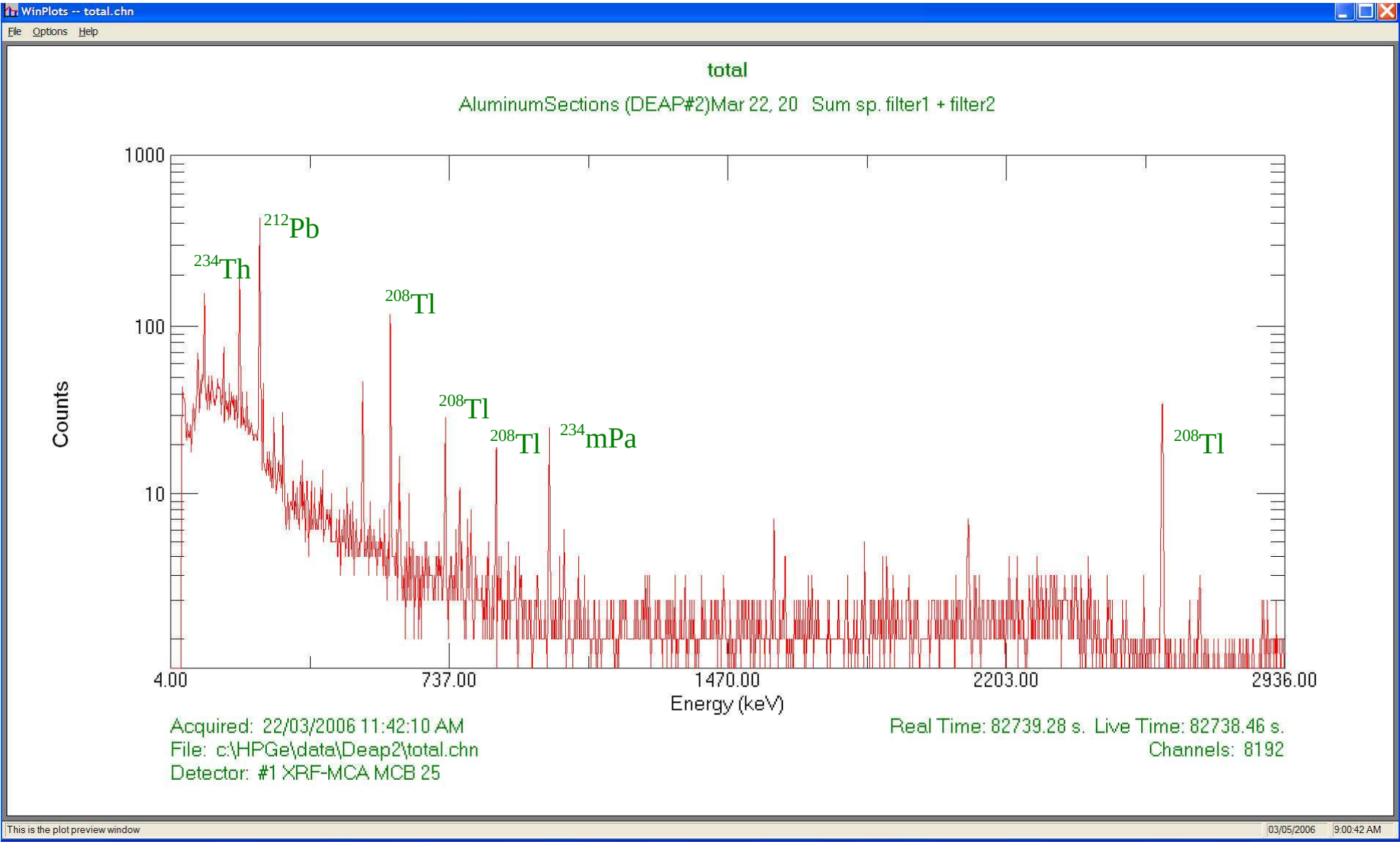
KCl Calibration Sample



DEAP1 #1 Stainless Steel Bolts and Nuts Spectrum



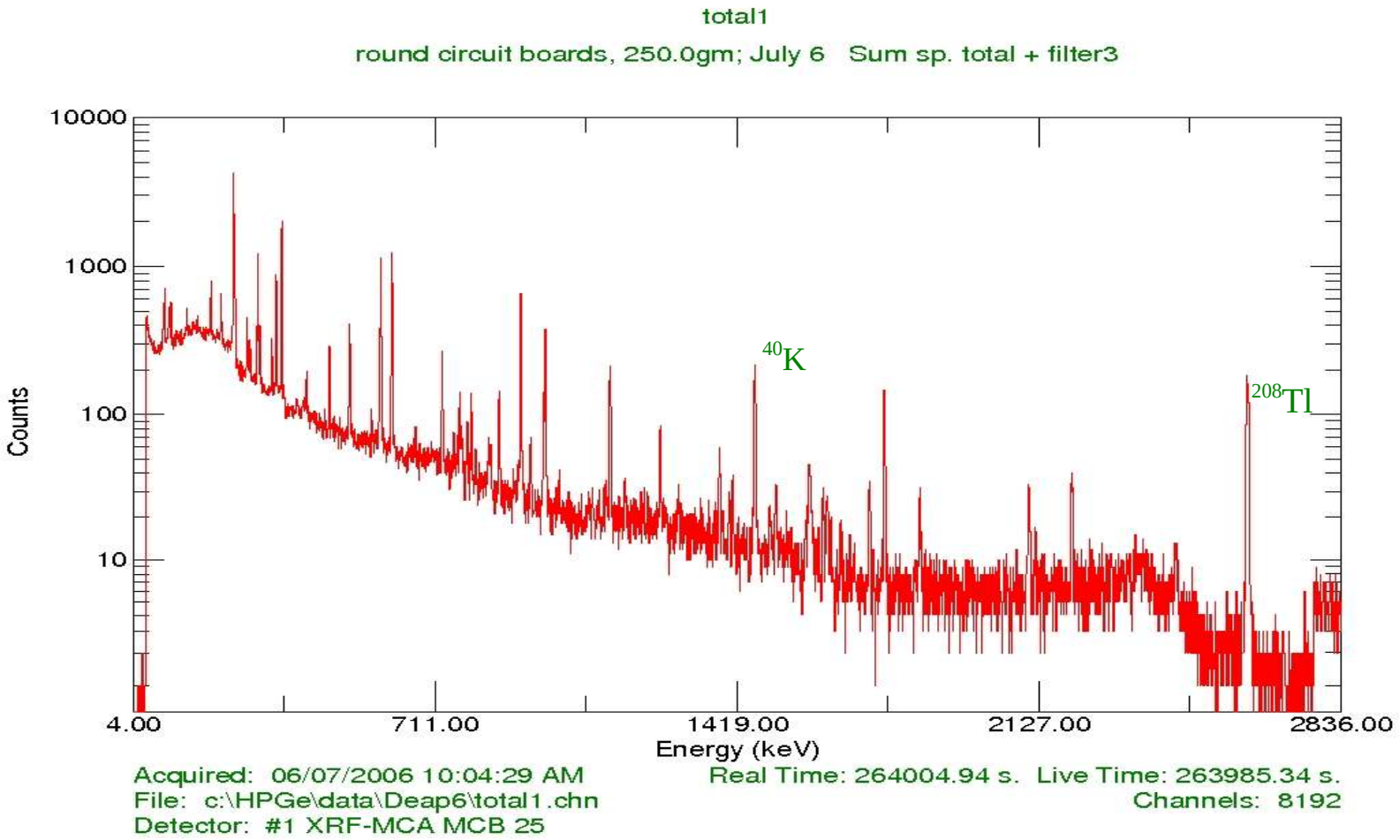
DEAP1 #2, Aluminum Sections Spectrum



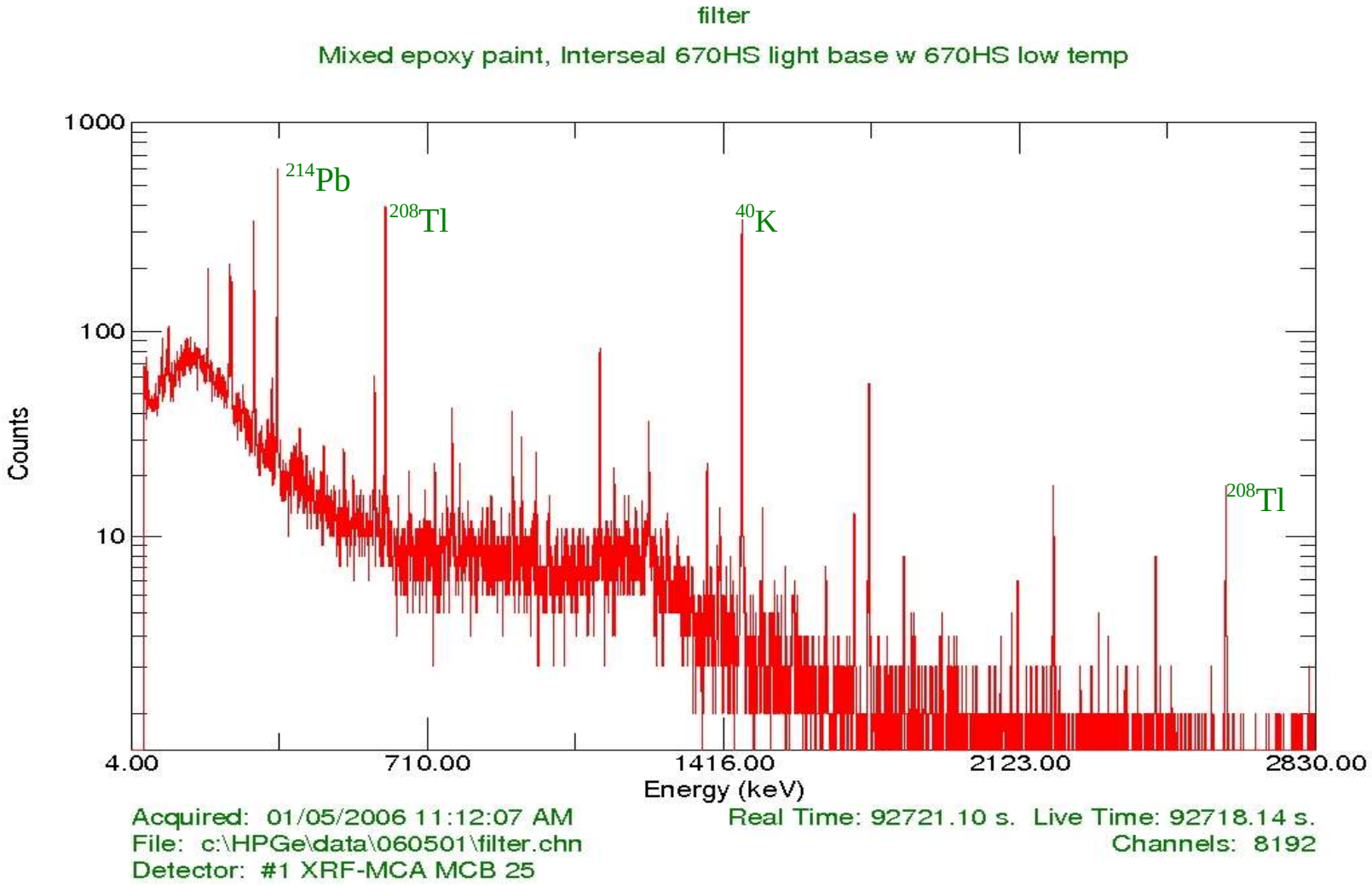
Detailed Results of the Aluminum Sample

	Element	Energy(keV)	Activity (mBq)
^{238}U	^{214}Pb	295.21	100.7 ± 40.3
	^{214}Pb	351.92	48.8 ± 18.5
	^{214}Bi	609.31	47.8 ± 14.7
	^{214}Bi	1120.29	76.3 ± 29.5
	^{214}Bi	1764.49	79.5 ± 42.3
^{235}Th	^{212}Pb	238.63	1975.8 ± 112.7
	^{212}Pb	300.09	1576.4 ± 263.5
	^{208}Tl	583.19	1565.9 ± 103.2
	^{228}Ac	911.21	47.0 ± 19.9
	^{208}Tl	2614.53	1869.7 ± 144.2
^{40}K	^{40}K	1460.83	119.8 ± 49.3
^{238}U	^{234}Th	63.29	62774.6 ± 27054.1
	^{234}Th	92.59	10976 ± 1146.4
	^{234m}Pa	1001.03	14921.5 ± 1655.9

Circuit Board Spectrum



Paint Spectrum



A Few Ge Detector Sample Results

Material	^{232}Th	^{238}U	^{40}K	
	(ppb)	(ppb)	(%)	
Paint, CC EP100 (SNO floor paint)	57.02 ± 3.14	26.28 ± 1.20	2.50 ± 0.13	
Paint, Interzone 954 (white)	76.80 ± 3.43	88.24 ± 2.55	0.267±0.015	
Paint, Interzone 670HS	81.16±4.30	157.91 ± 4.37	0.489±0.027	
BM Epoxy mastic	249.91±7.34	127.97±3.17	0.074±0.005	
Plastic Lumber(HDPE)	19.80±0.97	9.34± 0.38	0.060±0.004	
S.S. bolts, nuts	1.29±0.14	0.479±0.041	0.011±0.073	9.78±0.60 mBq/kg ^{60}Co
Aluminum plating	248.4±1.1	788.77±12.88	<0.03 ppm	6.59±0.28 ppb ^{235}U
Circuit Boards	5309±135	1359.0±34.0	1.00±0.06	

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.

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

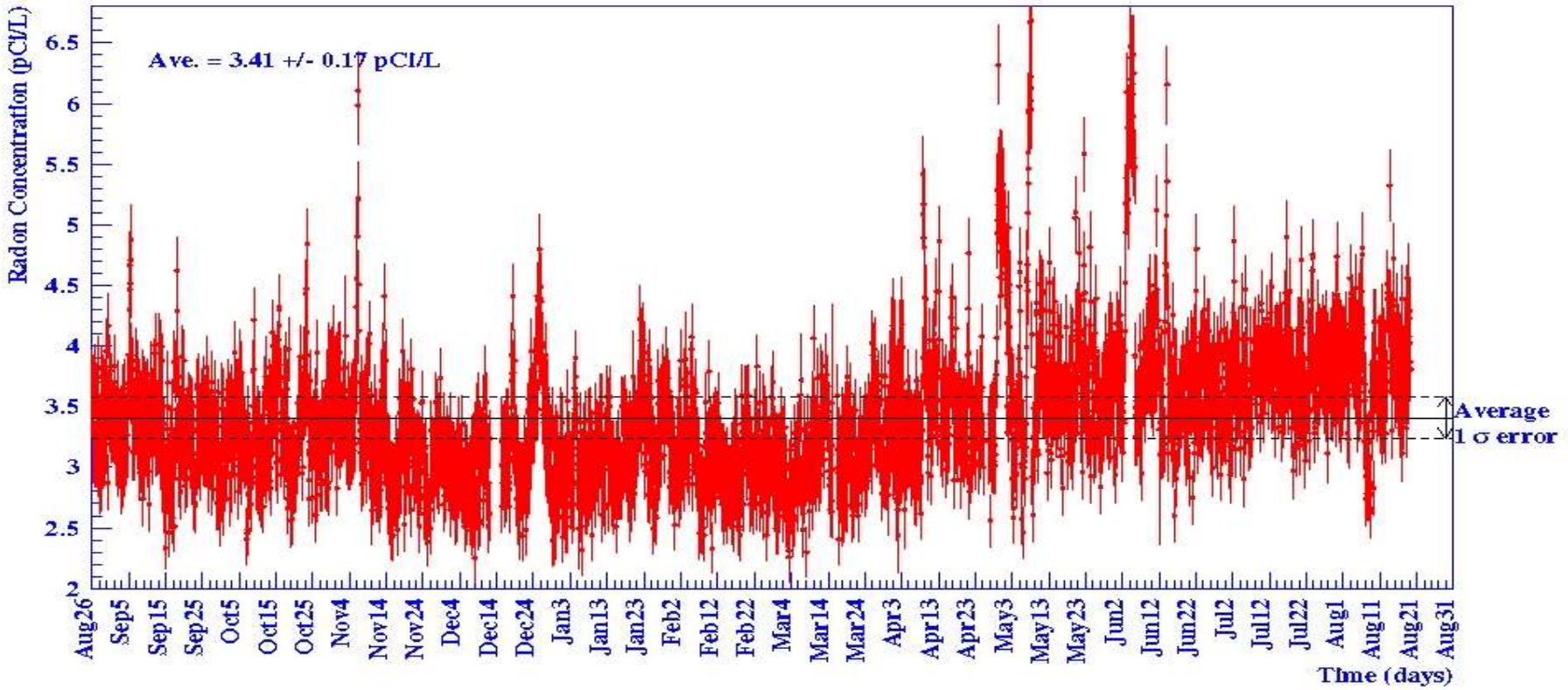
Comparison of Ge Counting and ICP-MS

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

Radon Background in SNO Laboratory

- Radon continuously monitored for the last year using the RAD7 radon monitor from Durridge.
- Average radon levels in the underground lab is 3.41 ± 0.17 pCi/L or 126.2 ± 6.29 Bq/m^3.
- Radon monitoring is expected to continue to see if there are seasonal effects, these are hard to observe due to power interruptions, air handler 5 outages and air flow changes from INCO.



Summary

- SNOLAB low background counting facility is operational and currently counting samples and is available upon request through Bruce Cleveland or myself.
- The sensitivities for U,Th and K are:
  - U ~1 mBq/kg
  - Th ~ 1.5 mBq/kg
  - K ~ 21 mBq/kg
- Currently able to screen samples up to 1 L.
- Studying microphonics to reduce this noise to increase detector live time
- Future counting, the 3 crystal detector at 4600 ft level could be moved to 6800 ft level. This would allow counting of larger samples and increased sensitivity.