How SNOLAB Measures Pb-210

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Counters at SNOLAB

- SNOLAB 6000m.w.e underground.
  - Low energy gamma spectra within factor of 10 of surface
  - Radon concentrations in air monitored
- 4 Germanium counters:
  - Canberra Well 10 - 900 keV
    - 2 inches of Cu, 8 inches Pb shielding
  - Other wells 90 – 3000 keV
- Pb-210: 46 keV

Detector Characteristics	PGT Coaxial Detector	Canberra Well Detector	Canberra Coaxial Detector	Vue Des Alpes Coaxial Detector
Manufacturer Details	Princeton Gamma-Tech (PGT) in 1992	Canberra 2011	Canberra 2011	Eurisys Mesures 1997
Operational Dates at SNOLAB	2005	2013	Not Yet Operating	2016
Detector Volume	210 cm^3	300 cm^3	400 cm^3	400 cm^3
Detector Type	p-type	p-type	p-type	p-type
Endcap Diameter	83 mm	105 mm	100 mm	105 mm
Relative Efficiency	55% wrt standard NaI(Tl) Detector		107% wrt standard NaI(Tl) detector	107% wrt standard NaI(Tl) detector

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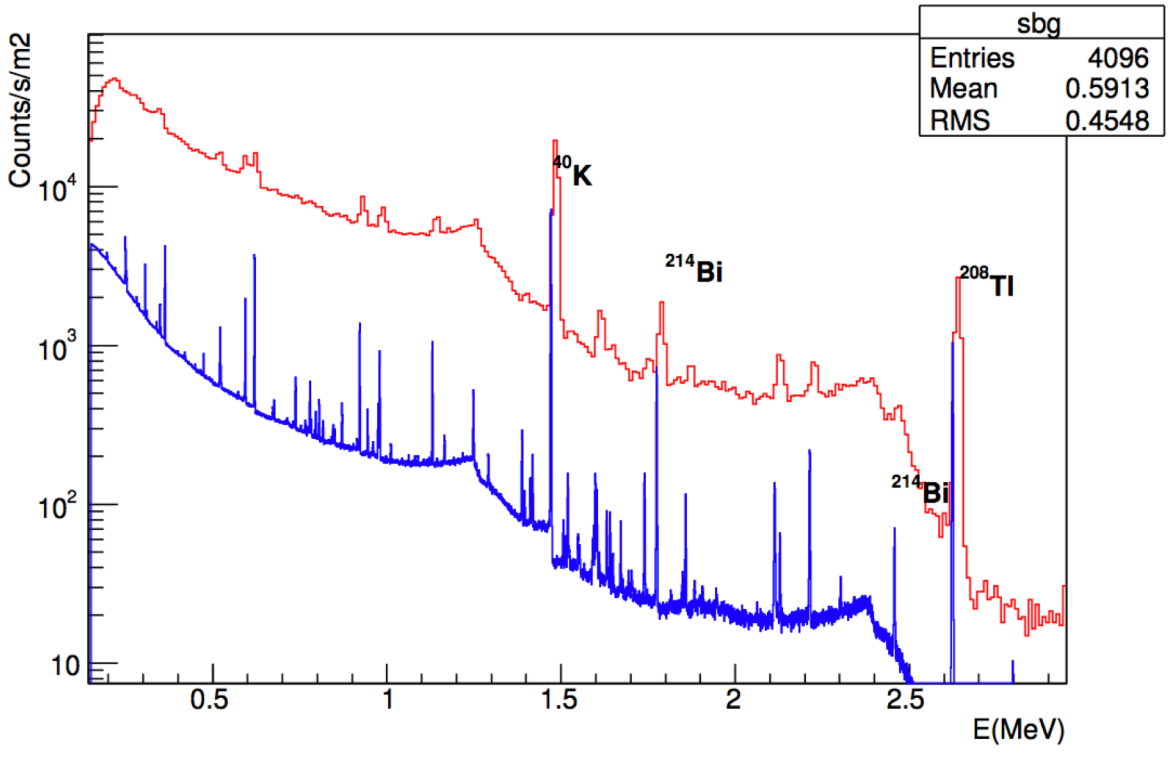

Figure 2.4: Background energy spectrum red - surface, blue - underground at SNOLAB.

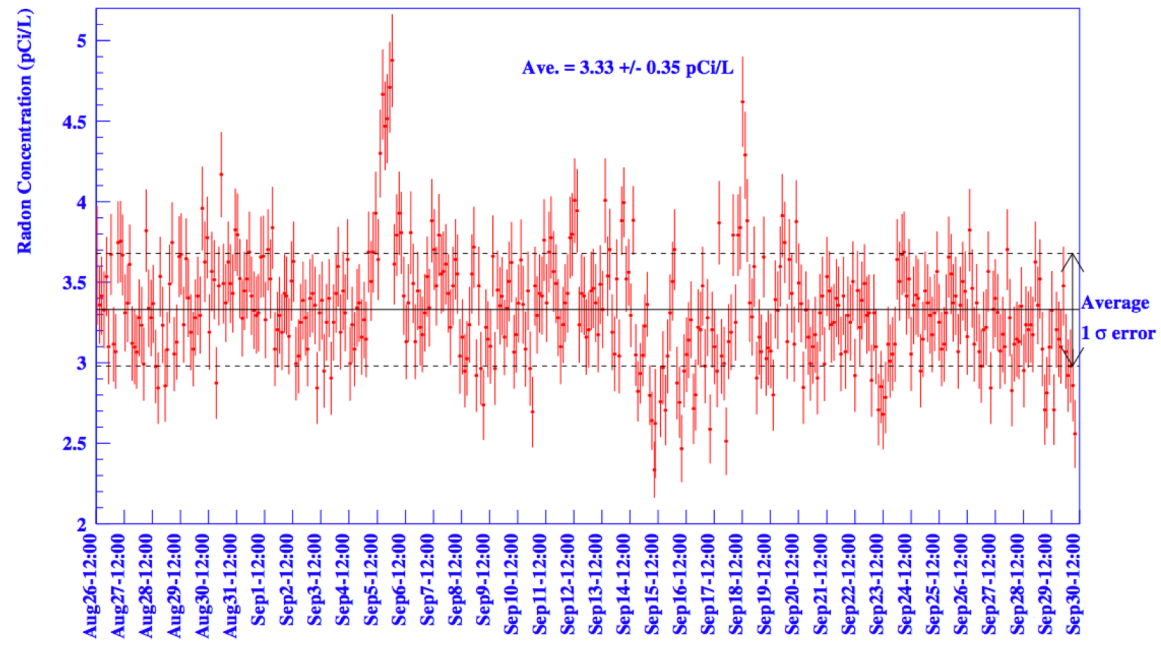

Figure 2.5: The radon concentration levels in the SNO underground control room.

Counter Sensitivities

- The sensitivities for each counter are shown below

Isotope (Assuming 1 kg Samples)	PGT Coaxial Detector	Canberra Well Detector	Vue Des Alpes Coaxial Detector
^{238}U	0.15 mBq/kg (12 ppt)	0.05 mBq/kg (4 ppt)	0.78 mBq/kg (64 ppt)
^{235}U	0.15 mBq/kg (264 ppt)	0.02 mBq/kg (35 ppt)	N/A
^{232}Th	0.13 mBq/kg (32 ppt)	0.26 mBq/kg (64 ppt)	0.14 mBq/kg (34 ppt)
^{40}K	1.70 mBq/kg (54 ppt)	N/A	3.72 mBq/kg (120 ppt)
^{60}Co	0.06 mBq/kg	N/A	N/A
^{137}Cs	0.17 mBq/kg	0.02 mBq/kg	N/A
^{54}Mn	0.06 mBq/kg	1.3 mBq/kg	N/A
^{210}Pb	4.4 Bq/kg (356 ppb)	0.11 mBq/kg (9 ppt)	N/A

Canberra Well Detector

- Canberra Well detector much smaller than other counters at SNOLAB
  - 300 cm^3 volume
  - Teflon vials used
    - Internal volume: 3 mL
  - For aqueous samples: 55% efficiency for 46 keV gamma
  - Able to count small solid samples
- Other SNOLAB counters can hold ~1 litre samples

Calibrating the Canberra Detector

- Two sources (U238, Th232) used to calibrate detector
- Made from grinding natural ore
  - Fine powder
  - No chemical processing
  - Known to be in radiological equilibrium
  - Known source strengths to high accuracy (measured at multiple major labs)

TABLE I: Source activity. Uncertainties are at 68% CL.

Source designation	Major isotope	Activity (mBq)
SRS-12-004	^{238}U	780.2 ± 2.4
SRS-12-005	^{232}Th	512.9 ± 6.4

Calibrating the Canberra Detector

- Counting efficiency determined looking Pb-210 peak
- Yellow box defines peak, green boxes define background
- Average background box counts and subtract from signal peak
- Source counted for 210 hours

- Efficiency determined by comparing to expected count rate given source strength
- 54.4±0.8%
- Efficiency a function of source geometry

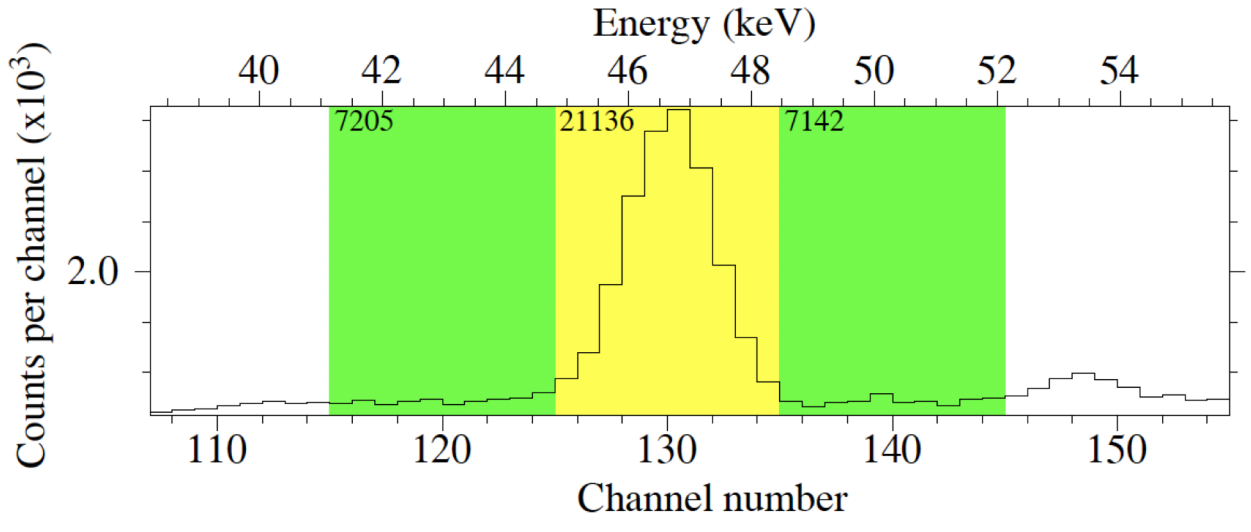

FIG. 1: Spectrum of ^{210}Pb γ rays from source SRS-12-004 in a live time of 8.964 days.

Calibrating the Canberra Detector

TABLE II: Energy, originating isotope, and branching ratio of detected γ rays. Multiple unresolved γ rays were observed at several energies. When this occurred the branching ratio given is for the sum of the separate lines. For example, the entry at 969.0 keV consisted of overlapping lines at 964.8 keV (4.99 ± 0.09)% and 969.0 keV (15.8 ± 0.3)%.

γ energy (keV)	Series	Origin	Branching ratio
46.5	U	^{210}Pb	4.25 ± 0.04
63.3	U	^{234}Th	3.72 ± 0.40
92.6	U	^{234}Th	4.23 ± 0.28
143.8	U	^{235}U + ^{227}Ra	14.18 ± 0.16
186.0	U	^{226}Ra + ^{235}U	6.23 ± 0.10
242.0	U	^{214}Pb	7.25 ± 0.02
295.2	U	^{214}Pb	18.42 ± 0.04
351.9	U	^{214}Pb	35.60 ± 0.07
609.3	U	^{214}Bi	44.80 ± 0.05
39.9	Th	^{212}Bi	1.06 ± 0.09
238.6	Th	^{212}Pb + ^{224}Ra	47.70 ± 0.50
338.3	Th	^{228}Ac	11.27 ± 0.19
583.2	Th	^{208}Tl	30.55 ± 0.11
911.2	Th	^{228}Ac	25.80 ± 0.04
969.0	Th	^{228}Ac	20.79 ± 0.31

Gamma efficiencies calculated from 39.9 to 969 keV

TABLE III: Results of efficiency measurement.

γ energy (keV)	Efficiency
39.9	45.74 ± 4.82
46.5	54.37 ± 0.83
63.3	69.42 ± 7.53
92.6	89.07 ± 5.95
143.8	63.26 ± 2.82
186.0	33.74 ± 0.65
238.6	14.17 ± 0.26
242.0	12.78 ± 0.20
295.2	6.25 ± 0.08
338.3	3.18 ± 0.14
351.9	2.98 ± 0.04
583.2	0.15 ± 0.02
609.3	0.15 ± 0.01
911.2	0.05 ± 0.01
969.0	0.07 ± 0.01

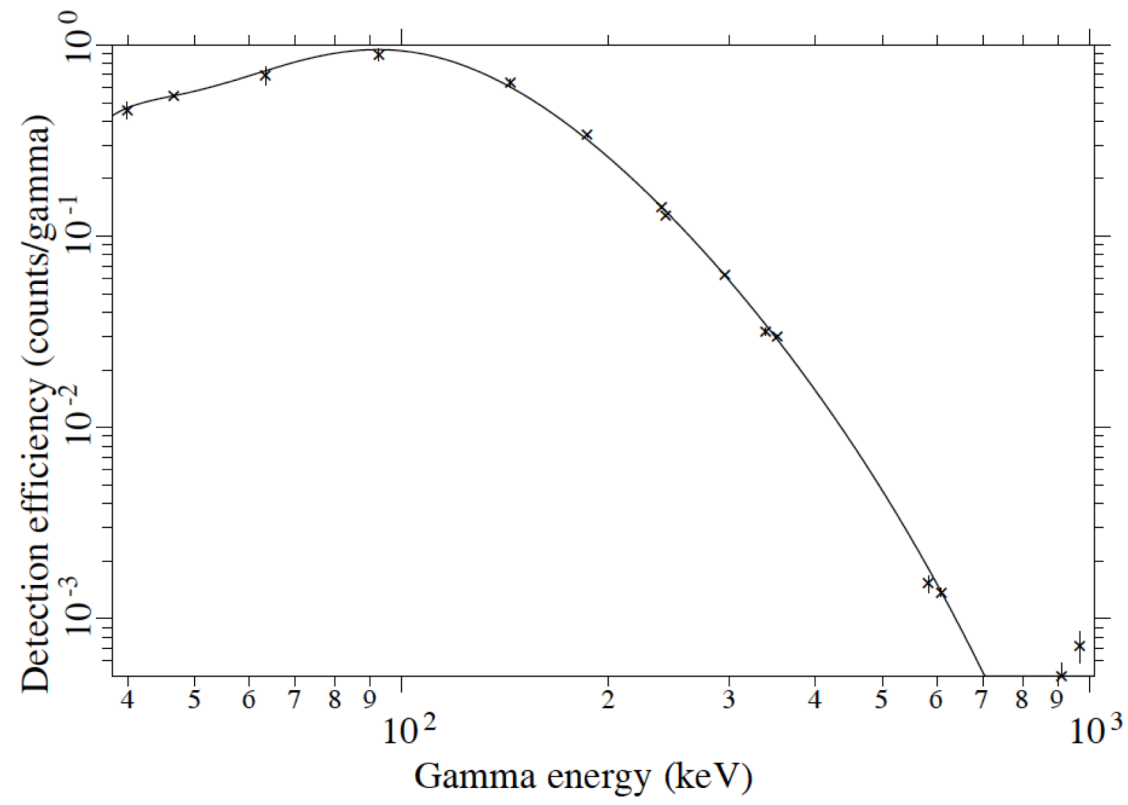

FIG. 2: Empirical fit to efficiency measurements. Measurements at 911 and at 969 keV were not used in the fit.

SNOLAB Counting Procedure

- All samples prepared by SNOLAB staff
- Counting times are typically days to reach ppb-ppt sensitivity
- Energy calibration done as needed
- For samples with sufficient count rates, samples are self calibrating
- For low rate samples ex-situ energy calibration can be done prior to sample counting

Reporting results

- Done via dedicated webpage
- Lists levels of each isotope
- Background count rate taken periodically

Sample Description	Manufacturer	Mass (g)	Live Time (days)	Counting Dates (if applicable)		238U from 226Ra	238U from 234Th	235U	232Th	228Ac	137Cs	210Pb	Comments
SNOLAB CW01			17.199	Feb 14, 2013 — Feb 19, 2013	(mBq)	0.281 +- 0.168	0.047 +- 0.133	0.039 +- 0.036	1.833 +- 0.974	<0.183	<1.815	0.598 +- 0.760	
Empty Cowie Bottle Background				May 8, 2013 — May 21, 2013									
KCM CW01a	Sample #1a	15 g (total)	7.741	Jan 31, 2018	(Bq/kg)	81.23 +- 2.55	17.80 +- 1.74	2.66 +- 2.79	61.01 +- 2.75	142.25 +- 4.57	3.25 +- 2.72	<0.65	
Water Sample from Kidd Creek Mine Level 7850	29.01.2018_KC7850_12299_SLRS	7.5 g (inside well)		Feb 8, 2018	(ppb or ppm)	6.58 ppm +- 0.21 ppm	1.44 ppm +- 0.14 ppm	4.69 ppm +- 0.49 ppm	15.01 ppm +- 0.68 ppm	34.99 ppm +- 1.12 ppm		<53.03 ppb	