Germanium (and other) Counting at SNOLAB

Chris Jillings, for many

2019-03-22

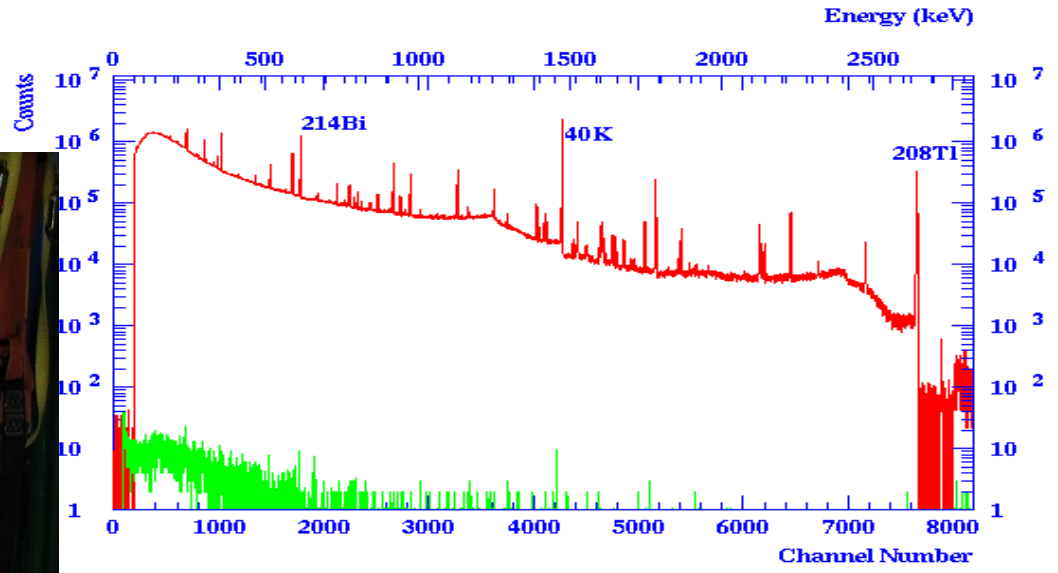
I have gathered a posie of
other men's flowers,
and nothing but the thread that
binds them is mine own.

John Bartlett

Dimpal Chauhan, Bruce Cleveland, Ian Lawson, Silvia Scorza, and Tom Sonley did the work shown here.

SNOLAB PGT HPGe Counter

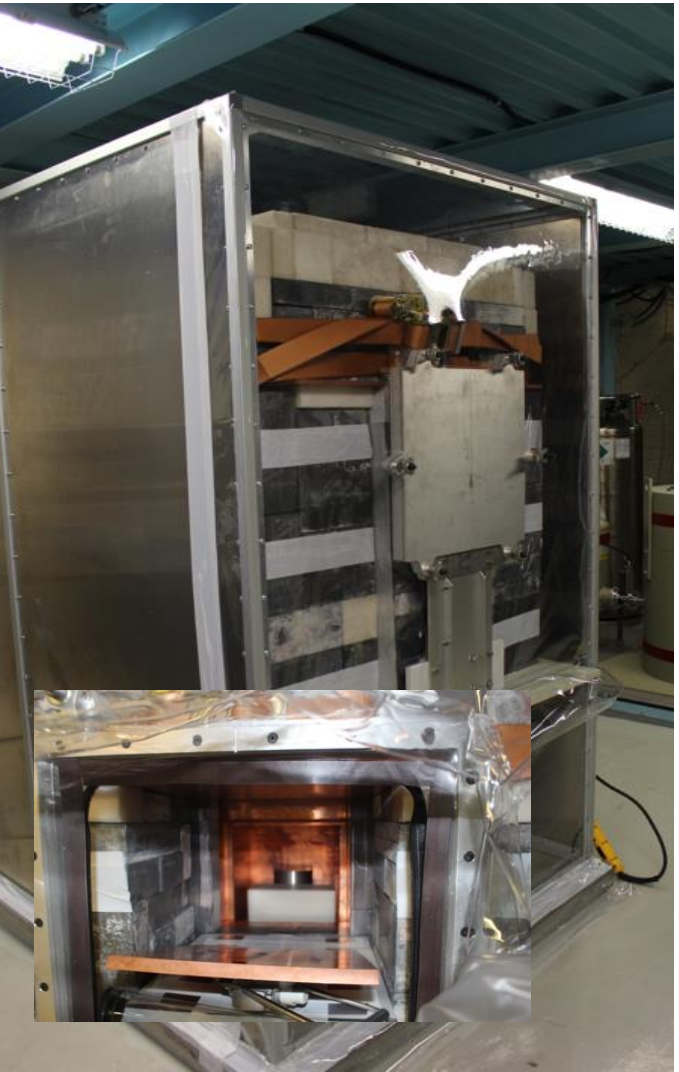
(The workhorse detector at SNOLAB)



Additional lead used to dampen microseismic activity from blasting and rockbursts

Three New Ge Detectors for High-E γ rays

Gopher: MoU with U Minn.

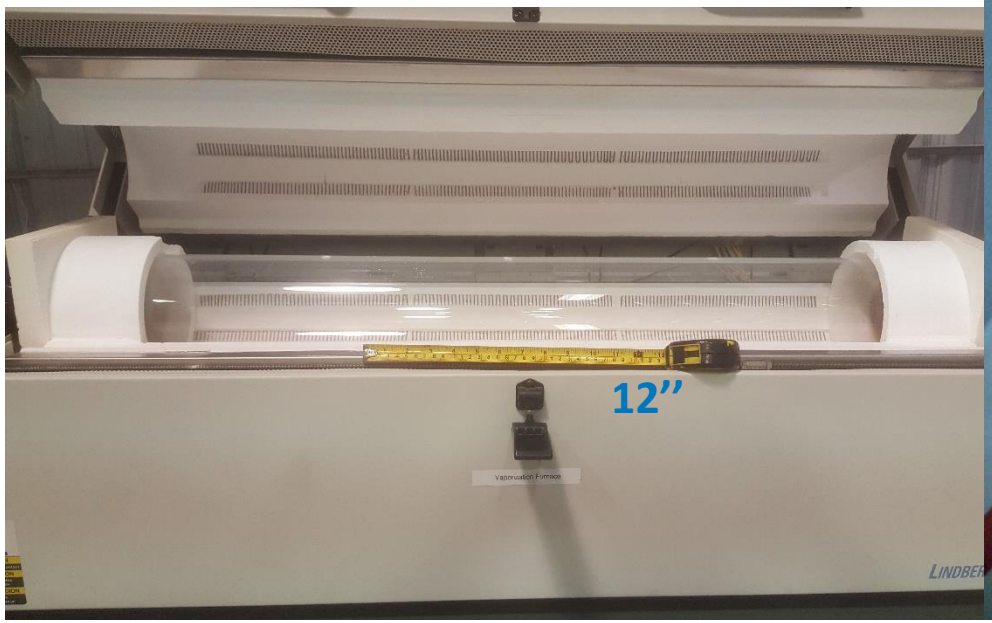


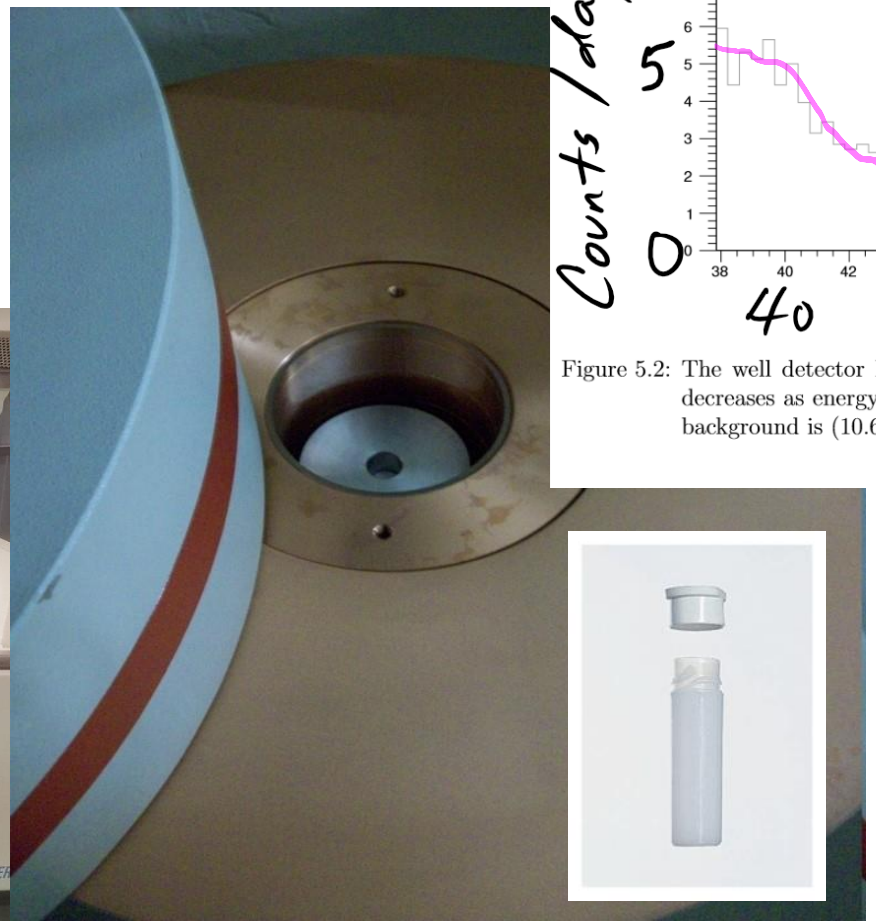
Vieux des Alpes: MoU with EXO

SNOLAB-owned co-axial detector.
Now complete.

Pb-210: Sensitive to 10^{-19} g/g in Plastic

- Acrylic vaporized and bottoms collected with acid rinse.
- Gamma count for 46 keV line, OR
- Plate out Po-210 from aged effluent on metal discs.





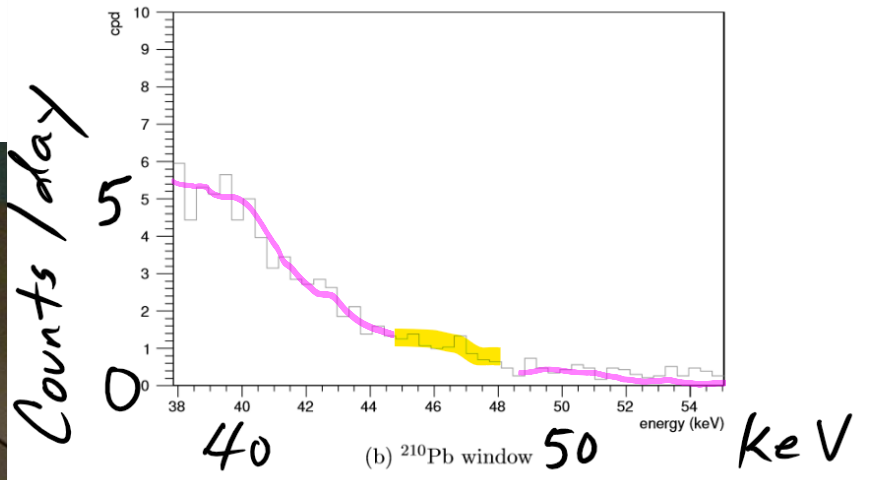
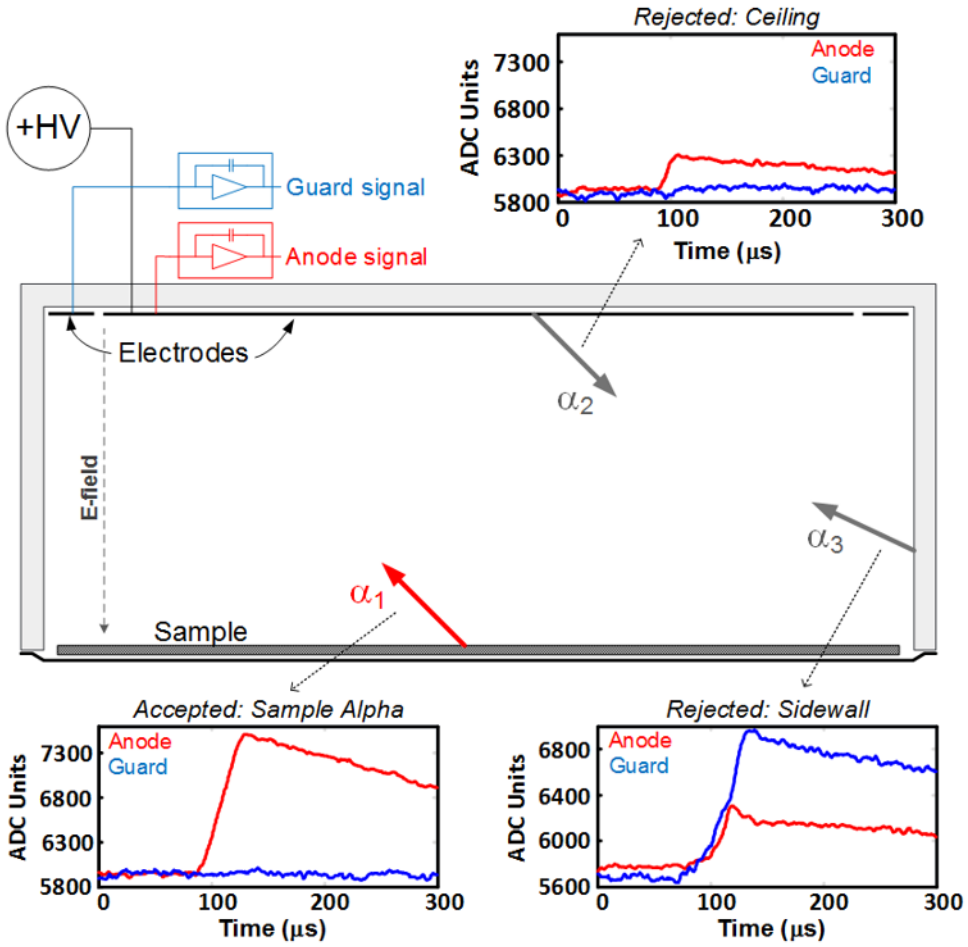


Figure 5.2: The well detector has an acceptable background. (a) The background decreases as energy increases. (b) In the 44.5–48 keV ^{210}Pb window, the background is (10.6 ± 0.7) cpd.

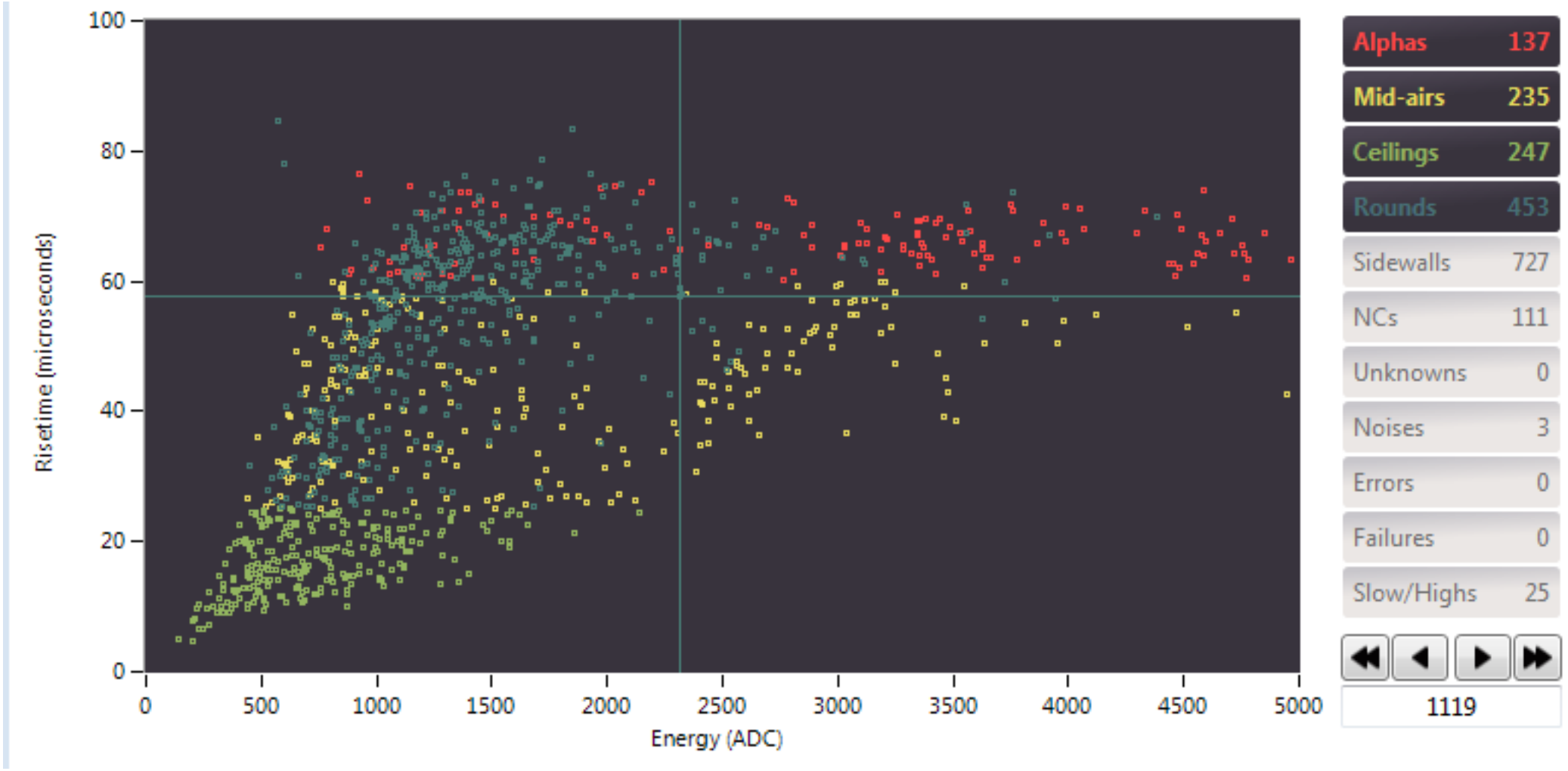
Plot from MSc thesis of Corina Nantais, Queen’s University at Kingston, 2014

XIA UltraLo-1800

- An ionization chamber with no wires.
- Alphas ionize Ar gas.
- The top of the XIA has a 1100 V anode. Charge drifts from the grounded sample tray. As the charges drift, they induce a current on the anode.
- Risetime is the duration of the leading edge of the pulse, the charge drift time.
- Risetime is a discriminating variable to reject mid-air decays. (Short rise time because of short drift distance.) 60us nominal cut.

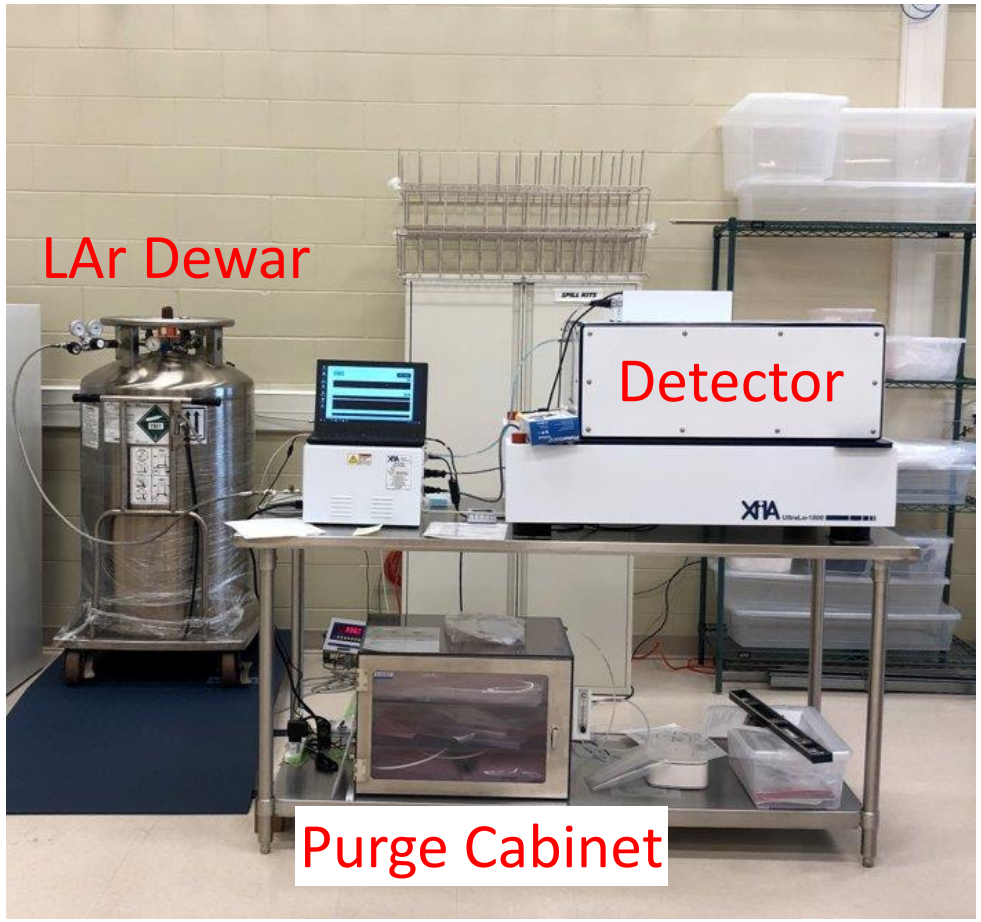


XIA UltraLo-1800



XIA's event classification in the risetime-energy plane.

XIA Ultralo-1800 – surface



- Under commissioning at the SNOLAB surface clean lab
- Teflon liner tray background runs show 400 nBq/cm^2 emissivity over full energy range (1-10MeV)
- Plan to move it underground by summer 2019

Count region: 1800cm^2 square and 707cm^2 circular
Maximum sample weight: 9kg
Maximum sample thickness: 6.3mm

Monitor system of environmental parameters (radon, humidity, temperature, particulates ..)

Efficiency calibration for Ge detectors designed to minimize effect of systematic uncertainties in Monte Carlo

Use efficiency derived from measurement of a calibrated source.

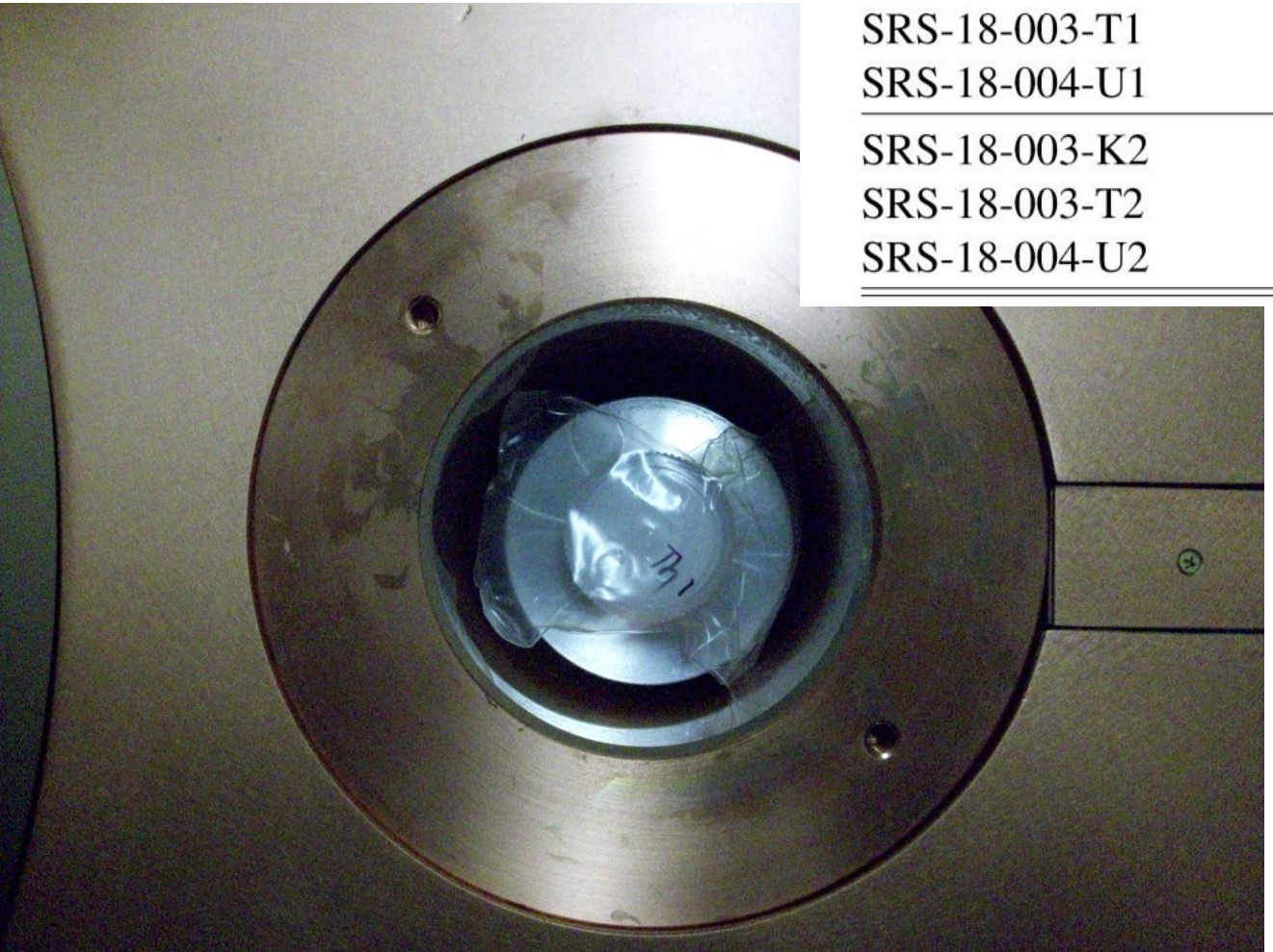
Monte Carlo corrections are always done in ratio

$$\epsilon_{sample}\,(E) = \epsilon_{cal}(E) \times \frac{\epsilon_{MC\ sample}\,(E)}{\epsilon_{MC\ cal}(E)}$$

SNOLAB counting has always used this technique. New crystals being brought online required new calibration sources. What is shown today is preliminary results for one calibration for illustration.

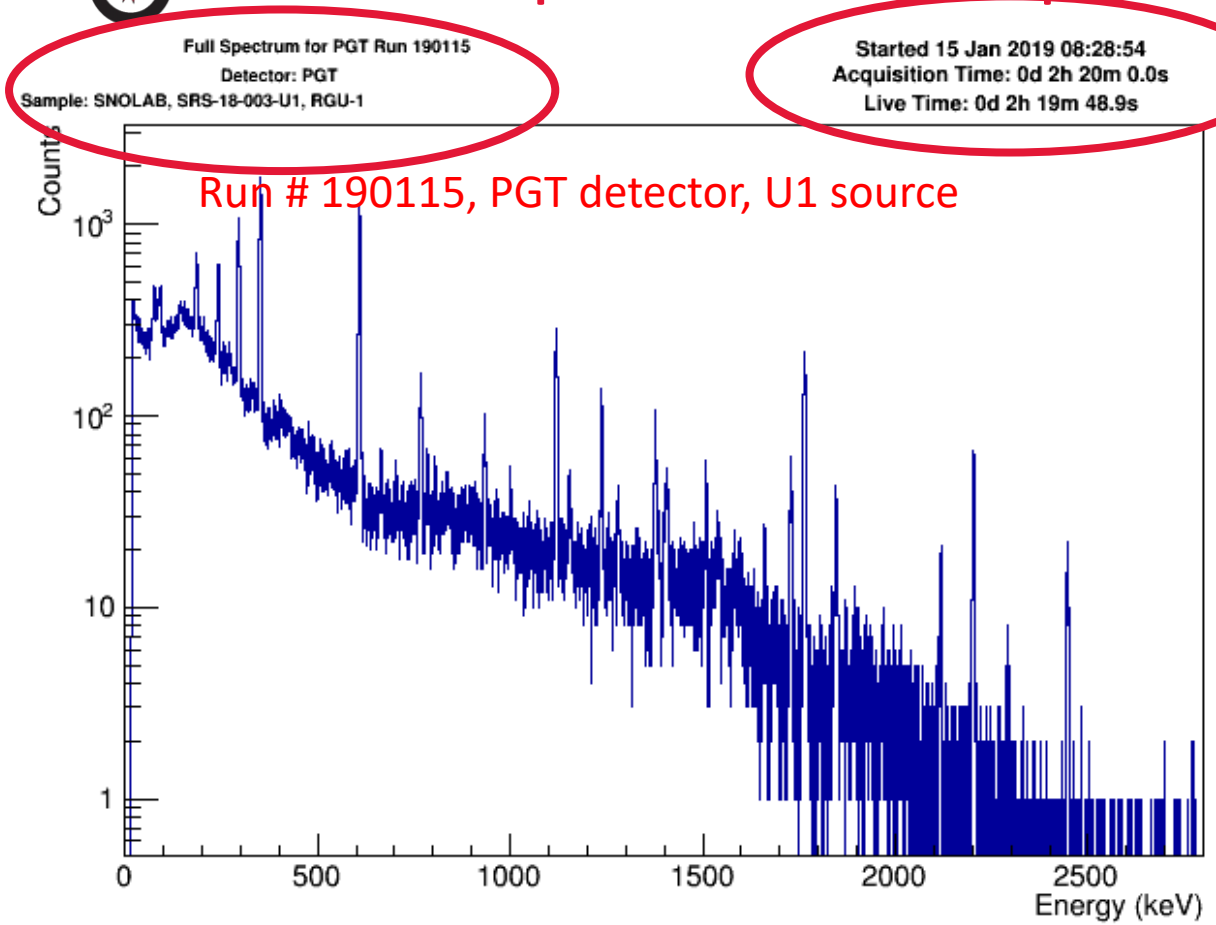
Pairs of Sources Made

Sample jar designation	Major isotope	Mass of IAEA component (g)	Activity (Bq major isotope)
SRS-18-003-K1	^{40}K	49.998 ± 0.005	699.97 ± 1.0
SRS-18-003-T1	^{232}Th	49.966 ± 0.003	162.39 ± 2.25
SRS-18-004-U1	^{238}U	49.950 ± 0.005	246.75 ± 0.75
SRS-18-003-K2	^{40}K	49.928 ± 0.005	698.99 ± 1.00
SRS-18-003-T2	^{232}Th	50.150 ± 0.005	162.99 ± 2.26
SRS-18-004-U2	^{238}U	49.933 ± 0.005	246.67 ± 0.75



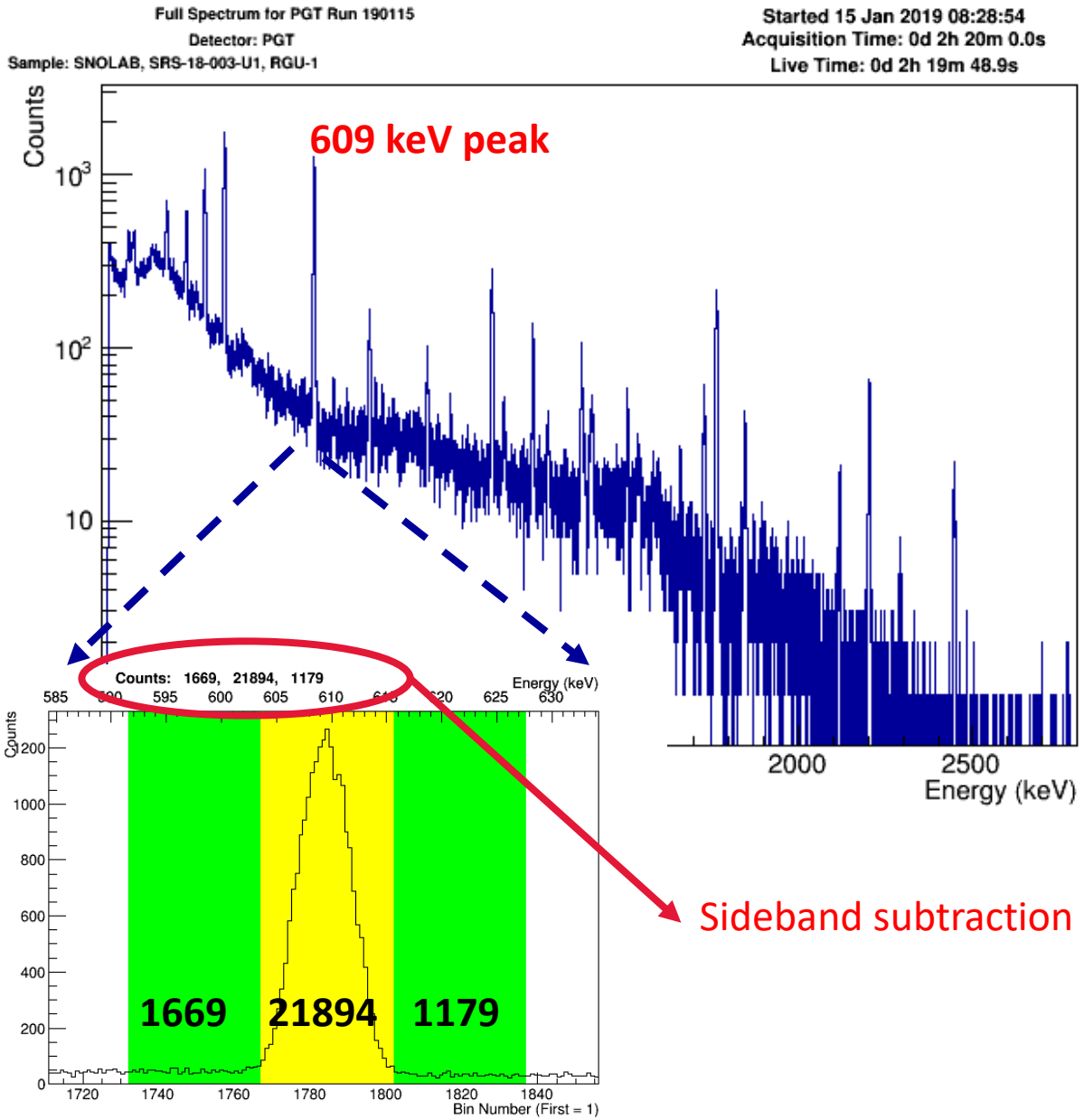
IAEA certificates available

Explicit Example:



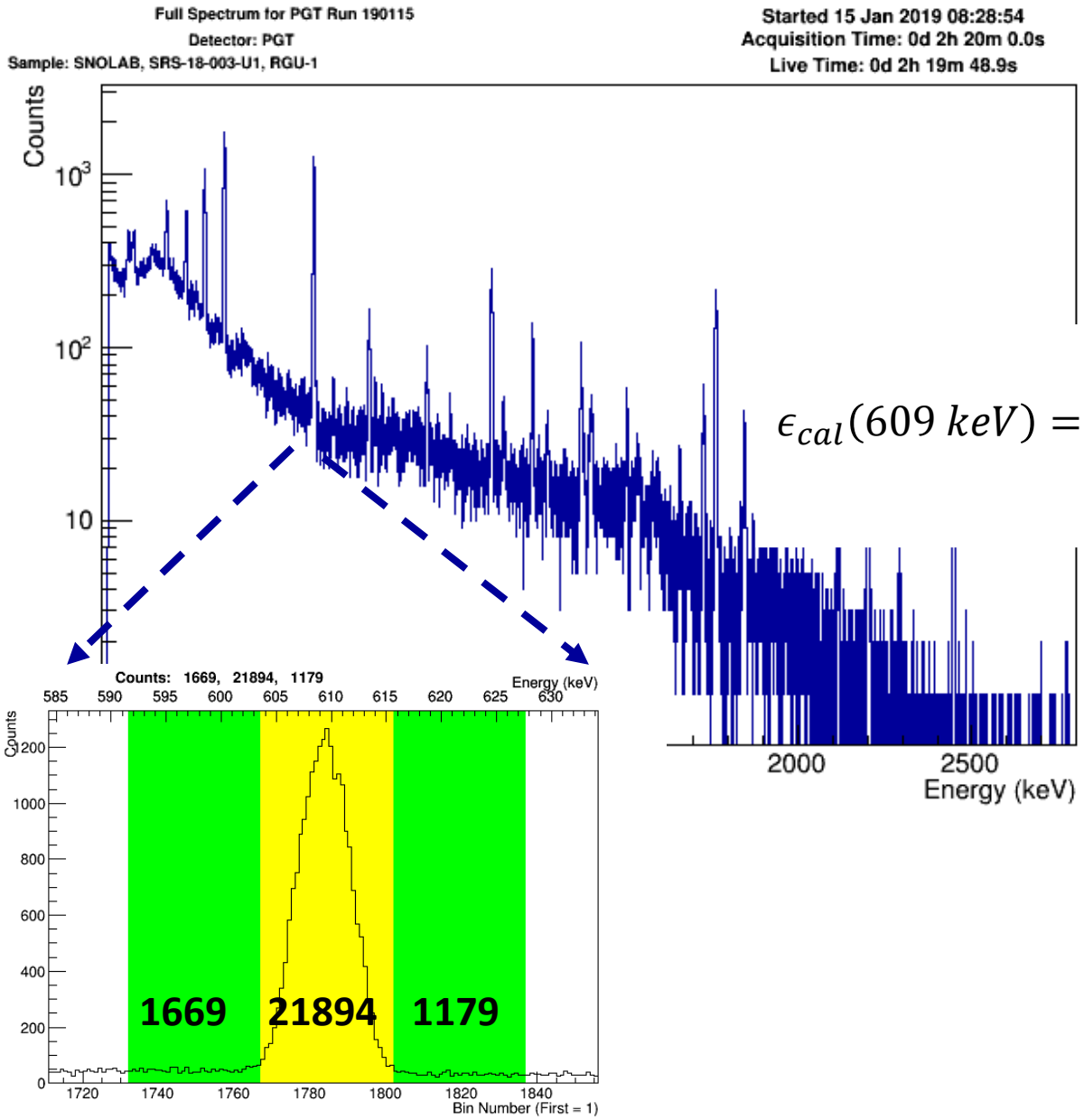
Run Time information
Live time = 8389 s

Explicit Example:



Sideband subtraction analysis

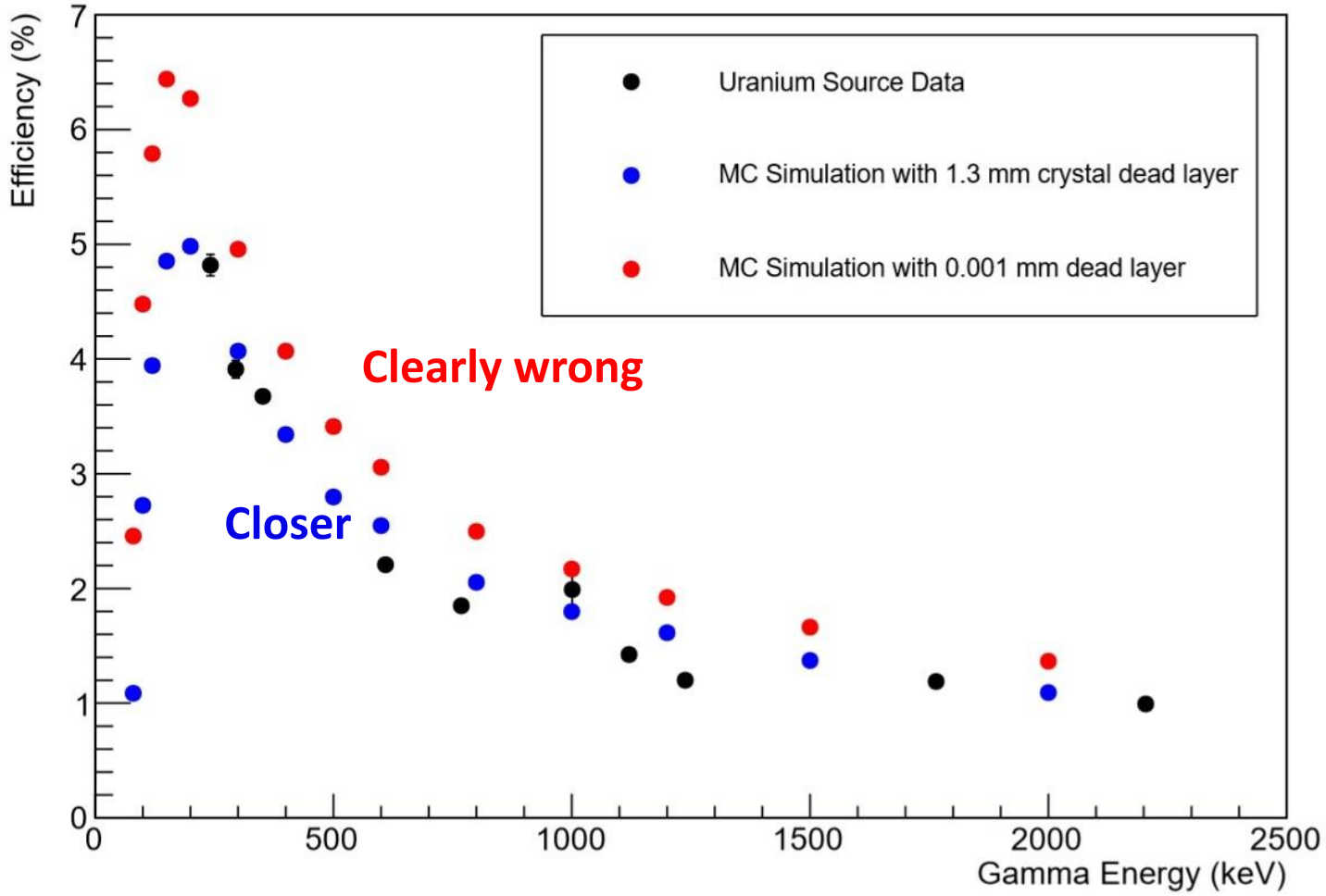
Explicit Example:



$$\epsilon_{cal}(609\ keV) = \frac{N_{counts} - N_{bgnd}}{A \times t \times BR} = \frac{21894 - (1669 + 1179)/2}{246.75Bq \times 8389s \times 0.448} = 0.022$$

Branching ratio

MC tuning

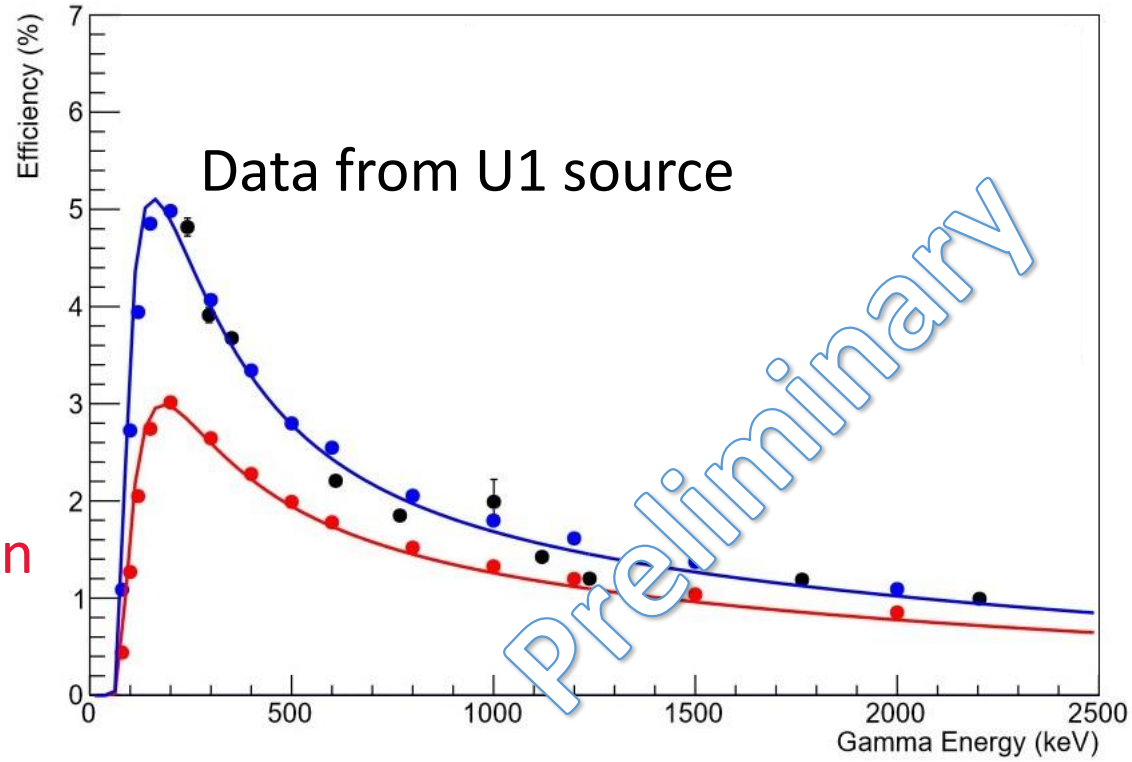


By taking the MC efficiencies in ratio, discrepancies between MC and calibration data, to first order, cancel.

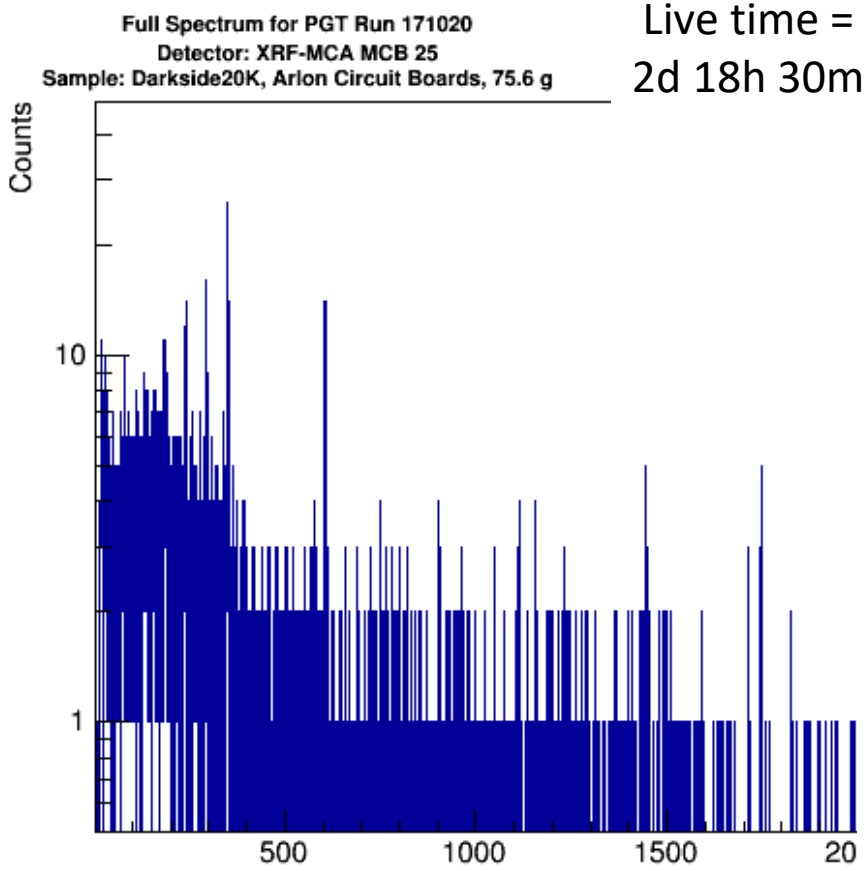
If we apply the old calibration to the new source, we get the right answer.

Predicted eff curve for new U1 source based on red points and MC ratio

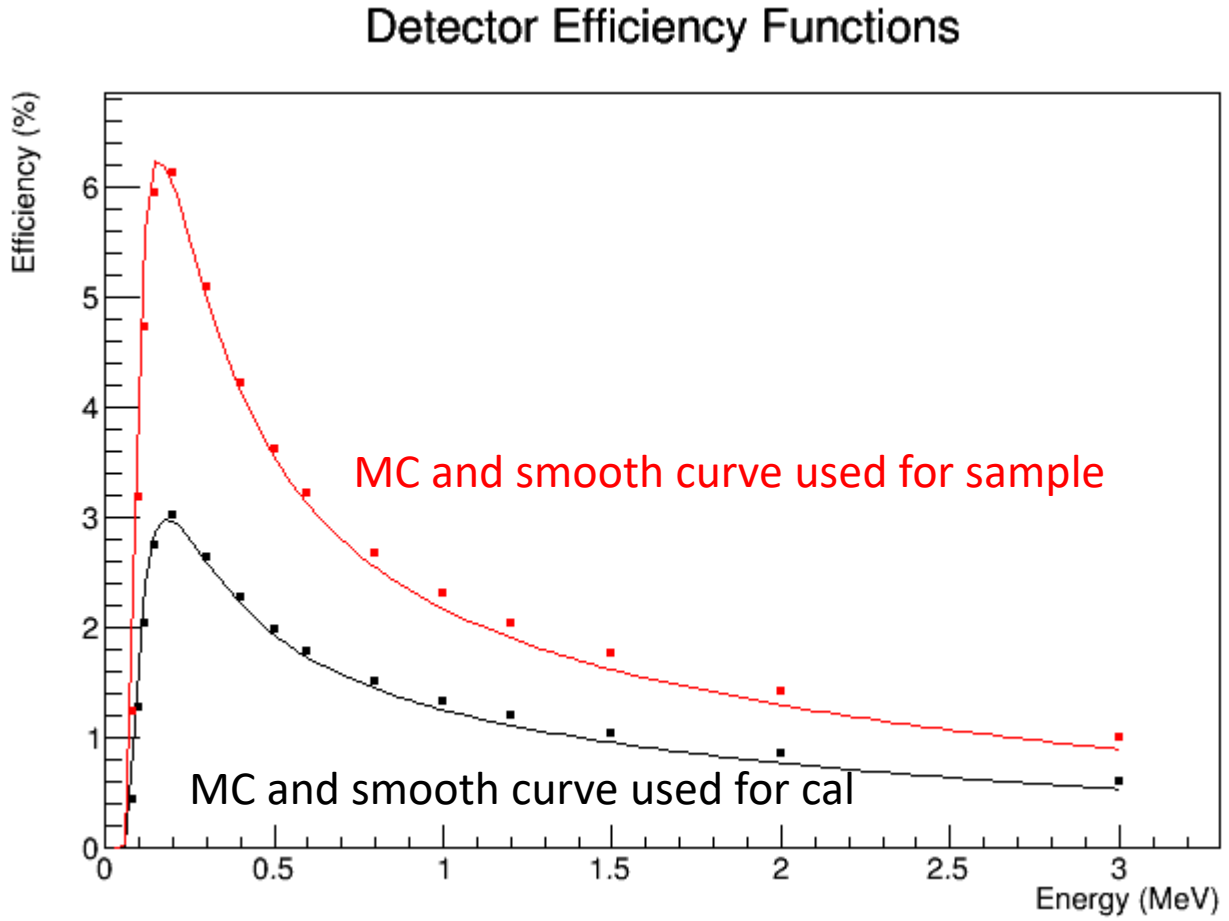
Efficiency curve from 2005 calibration



DS Example (from our original calibration)



Live time =
2d 18h 30m



http://www.snolab.ca/~tjsonley/HPGE_Test/PGT/171020/

Data combines to give upper and Lower U238 activity

Species	Background Removed (mBq/kg)	Activity (mBq/kg)	90% Limits (mBq/kg)
Top of 238 U Chain	0 ± 0	371.9 ± 314	0 - 889
Bottom of 238 U Chain	13.92 ± 1.52	550.5 ± 33.6	495.3 - 605.8
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
Thorium Chain: Below Actinium	21.69 ± 1.9	97.25 ± 18.7	66.52 - 128
60 [illegible]	[illegible]	[illegible]	0 - 8.654
57 Co Chain	0 ± 0	-10.81 ± 12.7	0 - 13.07
23[illegible] Chain	1.865 ± [illegible]	77.61 ± 21.3	42.53 - 112.7
[illegible]	[illegible]	[illegible]	654 - 1372
137 Cs Line	12.89 ± 1.05	-7.545 ± 11.5	0 - 14.9
54 [illegible]	[illegible]	[illegible]	0 - 15.98
7 Be Line	7.555 ± 4.53	47.[illegible] ± 85.9	0 - 188.9
210 Po Line	7.651e+04 ± 3.11e+04	-2.793e+05 ± 1.03e+06	0 - 1.54e+06
210 Pb Line	0 ± -nan	5.219e+10 ± 1.99e+11	0 - 3.797e+11
58 Co Line	0 ± -nan	-1.057 ± 10.4	0 - 16.49

CAVEAT: Approximate online analysis. See Ian Lawson's official analysis

Robust Calibration

- Being applied to 5 counters
- Analysis ongoing
- Should be able to use these sources as a cross calibration
- The sources are a bit hot: may want a standoff for resolution calibration.

Our software

1. Proprietary conversion of DAQ files to open standard.
2. After that, all code is GPL or equivalent.
3. Analysis can be called online for your sample.
4. Monte Carlo requires human intervention to get geometry right.
5. A bit more work is needed, but we will make code available on gitlab.

Other news

- We get access to a good ICP-MS sometime in April
  - New to us but important
  - (Translation: This will be a significant effort of our chemical technologists but should be viewed by Darkside as a R&D effort until we say it is production ready.
  - Then we will ask for some well-understood Darkside samples and retest them.)

Reference

https://www.snolab.ca/users/services/gamma-assay/index.html

- PGT Ge Detector
  - 210 cm^3, 83mm endcap, 1.8 KeV FWHM, shield 2” Cu + 8” Pb
- Canberra Well Ge Detector
  - 300 cm^3 with 3ml well sample volume
- Canberra Large Ge Detector
  - Coaxial 400 cm^3, shield 2” Cu + 8” Pb
- Gopher HPGe Detector (SuperCDMS)
  - 2.0 Kg P-type coaxial, 2” OFHC Cu + 2” LB-Pb + 8” Pb
- VDA Ge Detector (EXO)
  - Coaxial from U. Bern
- XRF detector
  - From SNO, developed for dust sample counting (Fe, Ca, Zn)
- Tennelec Alpha Counters
  - With front glove box
- Beta-Alpha PSD Coincidence Counters (currently on surface)
  - From SNO developed for Ra counting in liquid scintillator
- Electrostatic Counters (ESCs) - (currently on surface)
  - With low pressure N2 recirculation for Rn and Ra counting.
- Radon Emanation and Extraction Board
  - Small Marinelli shaped chamber – to be rebuild with large chamber
- Liquid particle counting – process systems high-purity cleaning evaluation