The New SNOLAB Underground Low Background Laboratory (LBL)

Richard Ford and Ian Lawson (SNOLAB)

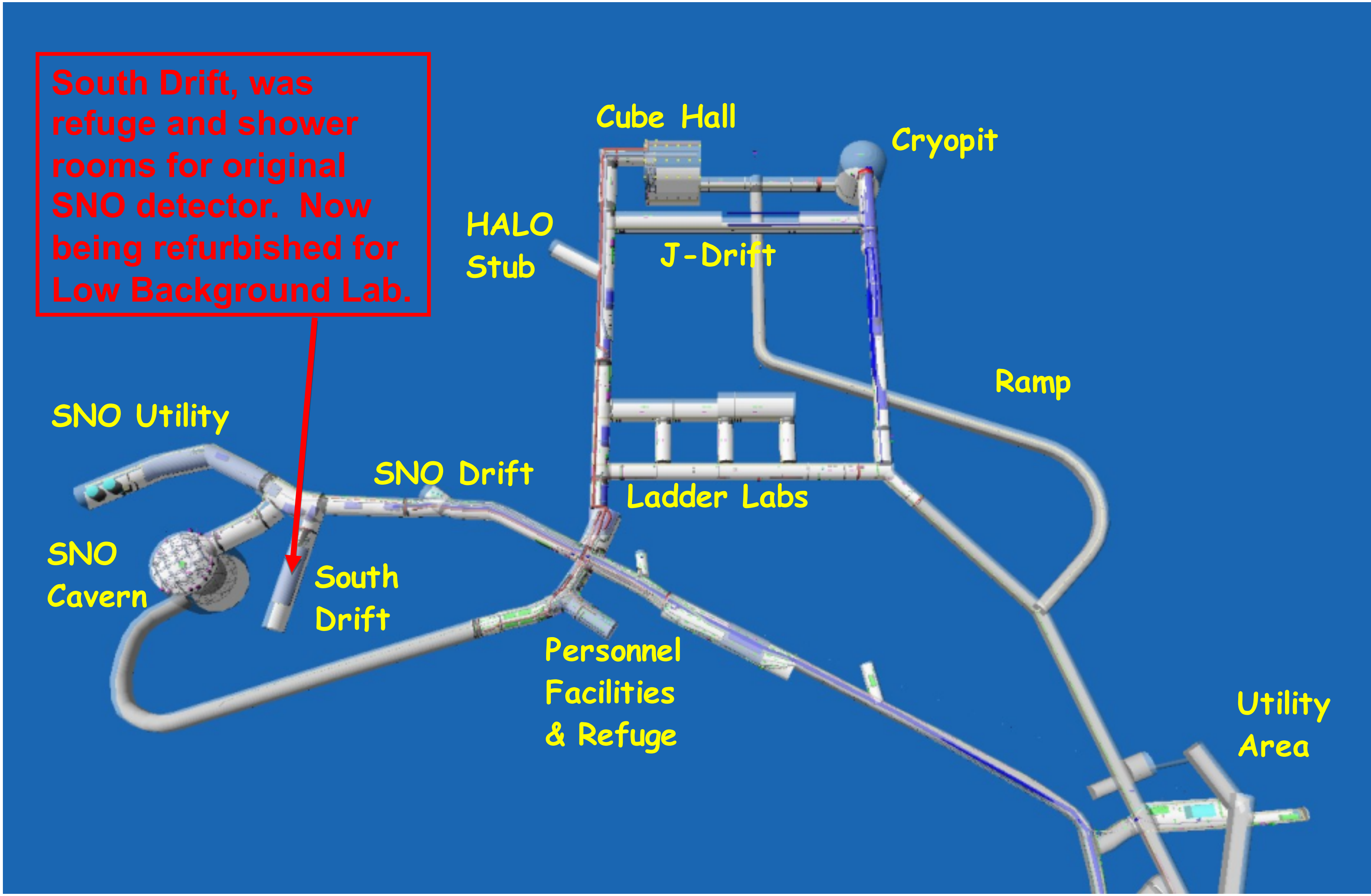
For the SEF Meeting (Toronto)

9th March 2017

Brief Outline

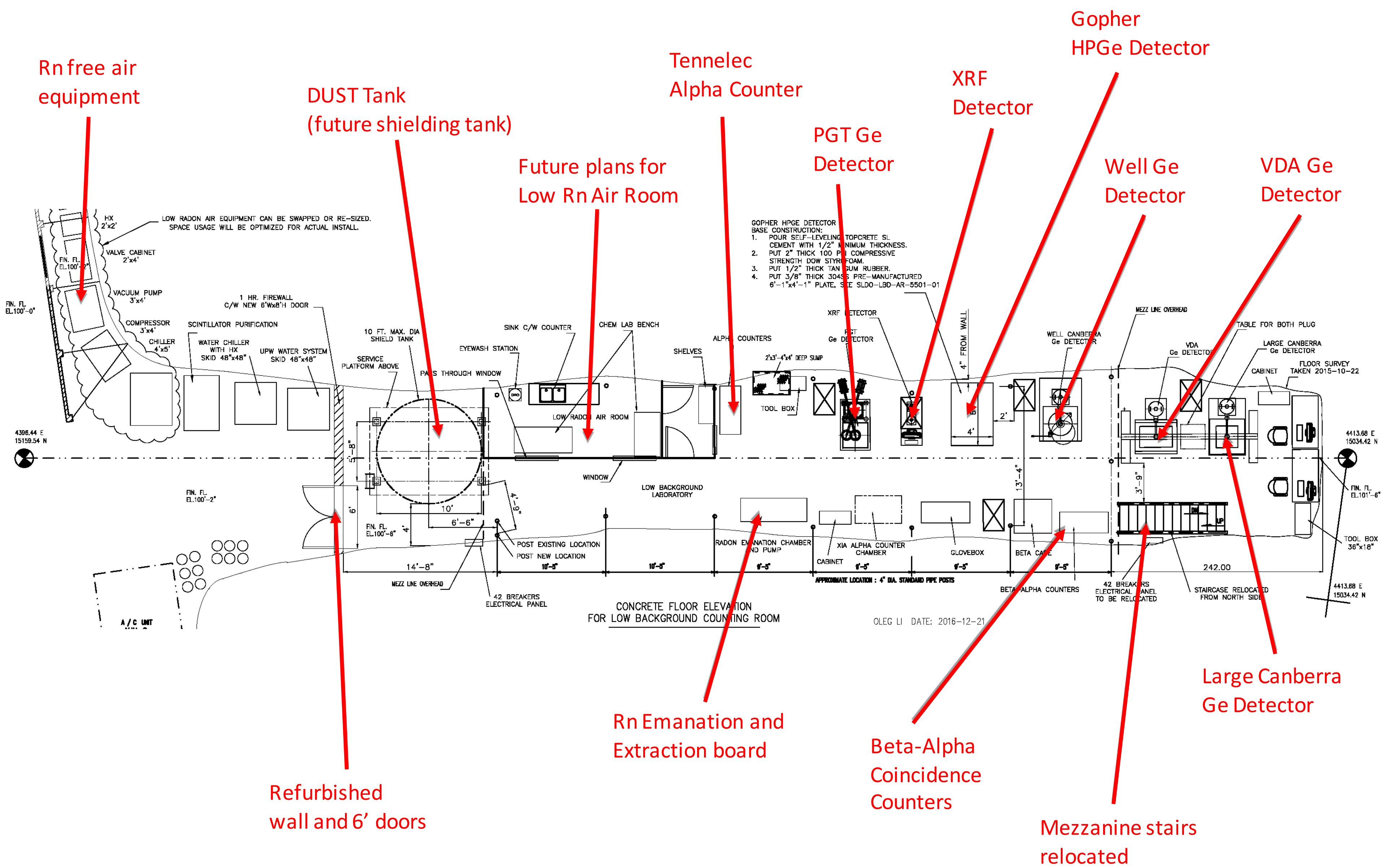
- Current status
- Current detectors and capabilities
- Future capabilities
- Future into the future plans
- AARM and Community Assay Database

SNOLAB Underground Facilities

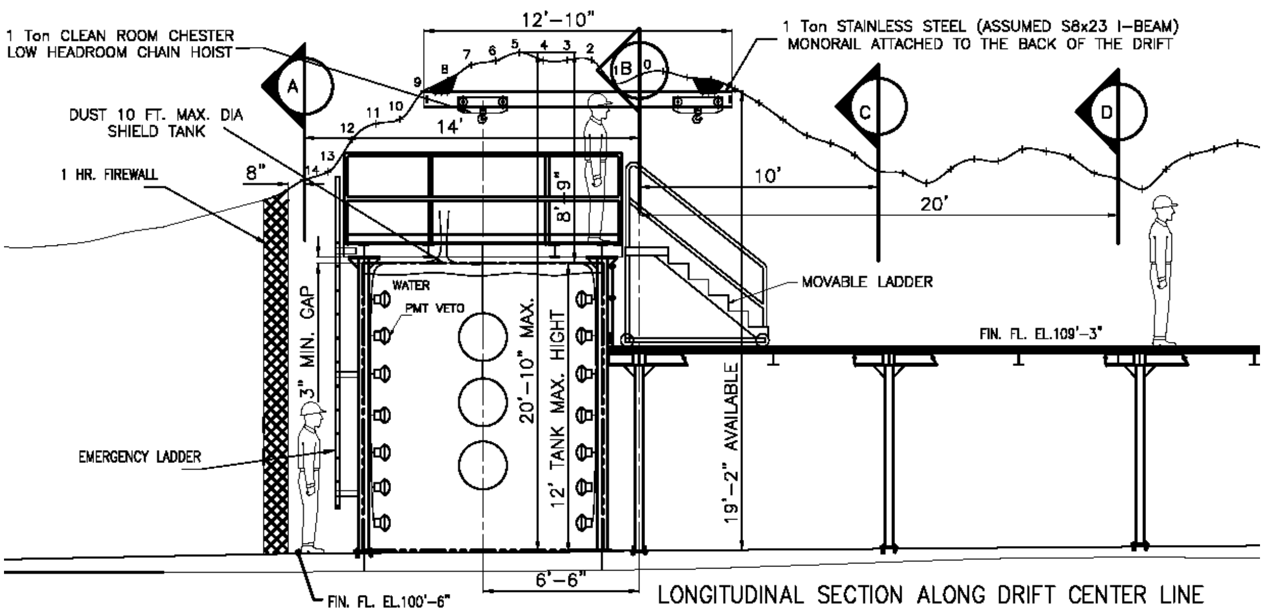


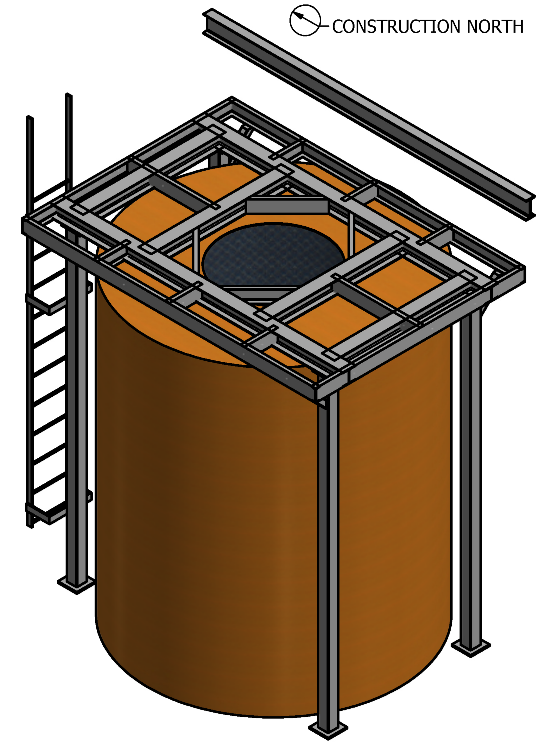
South Drift Today

South Drift Plan for LBL

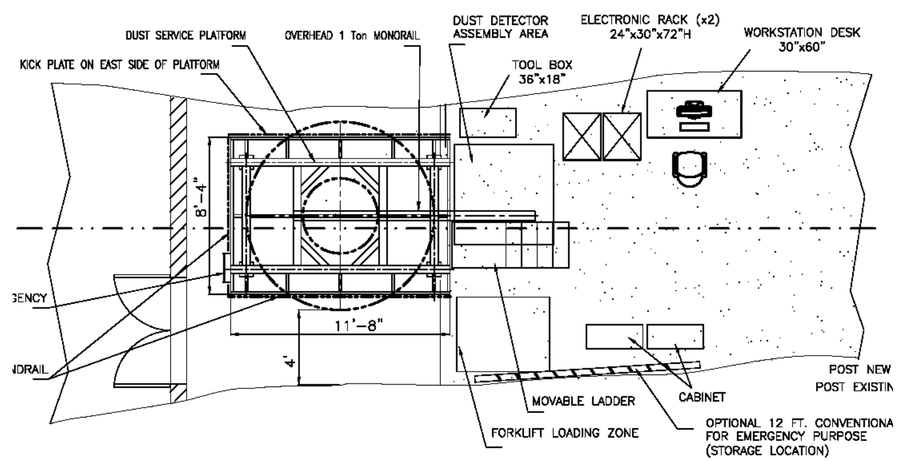


General Purpose Underground Shielding Tank (GUST??)





- Free standing tank with integral deck
- 8 m diameter, 8 m high
- Walls constructed from bolted, corrugated cylindrical segments of galvanized carbon steel
- Polyurea lined tank ~ 1 cm thick coats walls, floor, and transition to ss lid
- O-ring sealed nozzles and penetrations
- Overfilled tank (~ 4 inches above tank lid bottom)

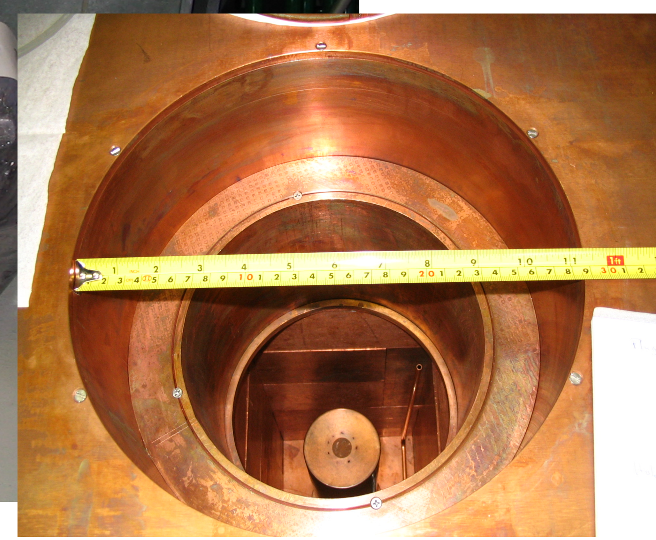


Current Capabilities

- 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 3” Cu + 4” LB-PB + 6” Pb
- Gopher HPGe Detector (SuperCDMS)
  - 2.0 Kg P-type coaxial, 2” OFHC Cu + 2” LB-Pb + 8” Pb
- XIA Alpha Detector
  - UltraLo-1800, < 0.0001 alpha/cm2/hr
- VDA Ge Detector (EXO)
  - Coaxial from U. Bern, 400 cm3, shield 6” Cu + 6” Pb
- 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

SNOLAB PGT HPGe Counter

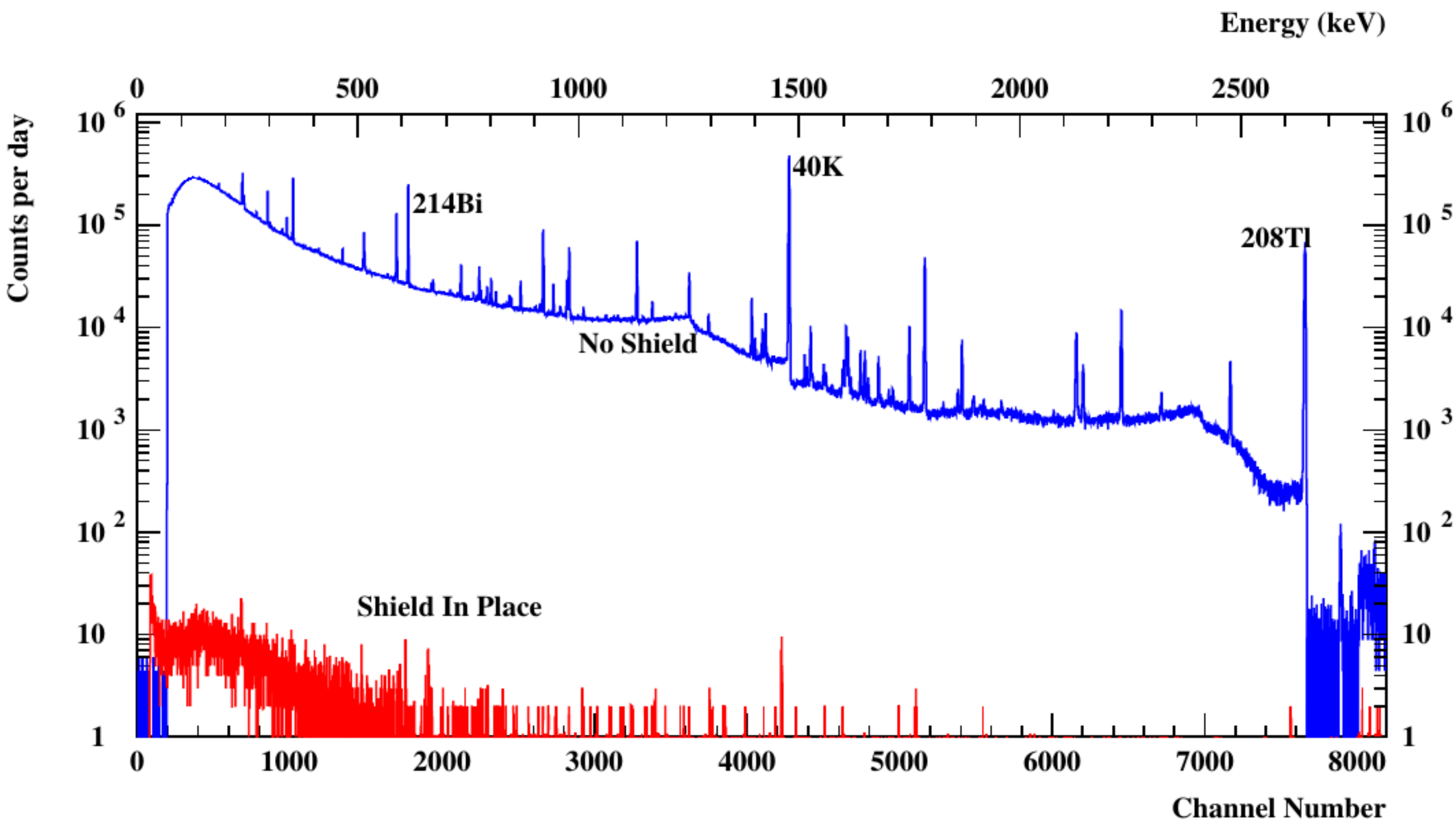
(The workhorse detector at SNOLAB)



Additional lead used to dampen microseismic activity from blasting and rockbursts

Unshielded and Shielded Spectra

(PGT Coax Detector)



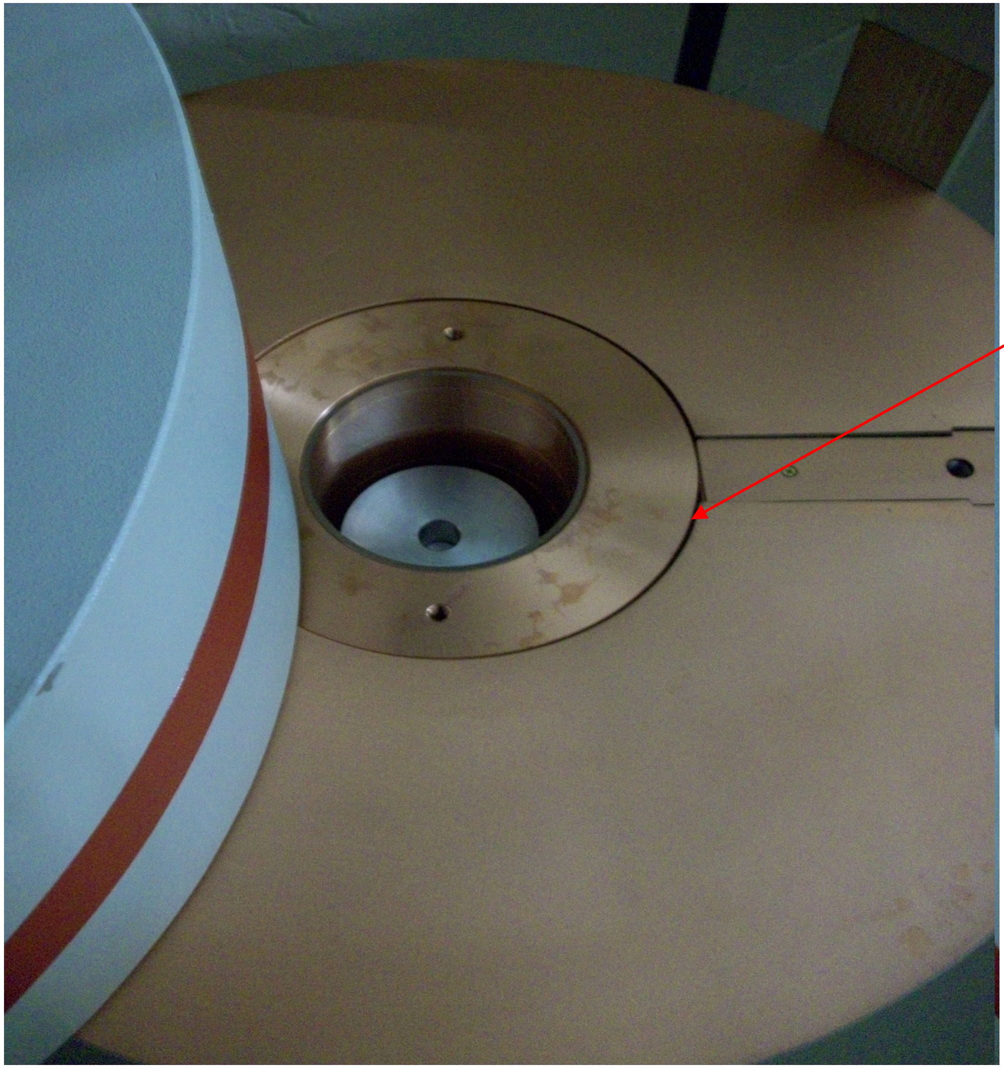
PGT HPGe Typical Detector Sensitivity

(for a standard 1L or 1 kg sample counted for one week)

Isotope	Sensitivity for Standard Size Samples
^{238}U	0.12 mBq
^{235}U	0.17 mBq
^{232}Th	0.11 mBq
^{40}K	1.50 mBq
^{60}Co	0.05 mBq
^{137}Cs	0.14 mBq
^{54}Mn	0.05 mBq

Canberra Well Detector at SNOLAB

Canberra Well Detector at SNOLAB



Detector Volume:
300 cm^3

Sample Well

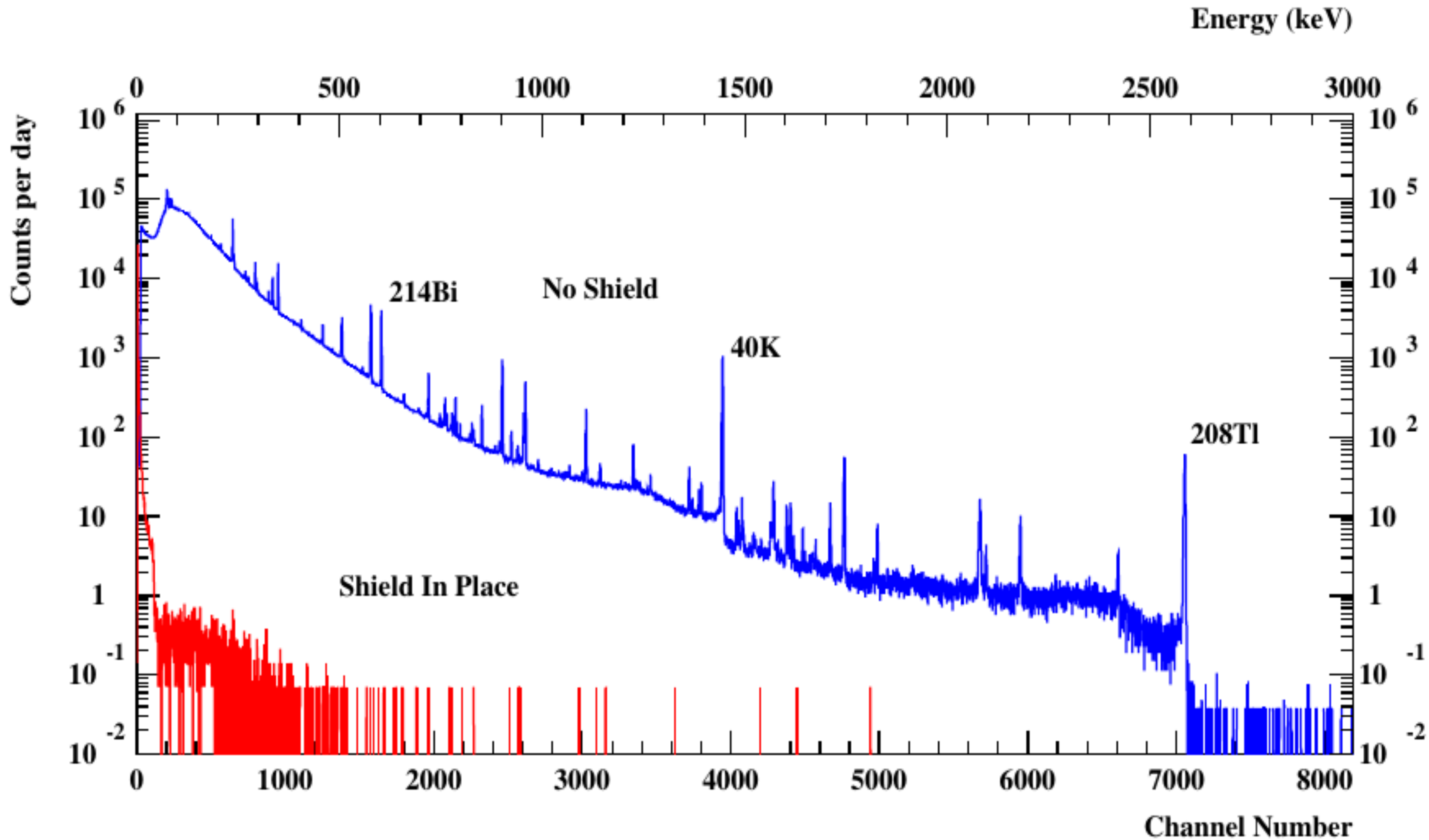
Typical
Sample Containers

Volume is 3 ml

Volume is 8 ml

Unshielded and Shielded Spectra

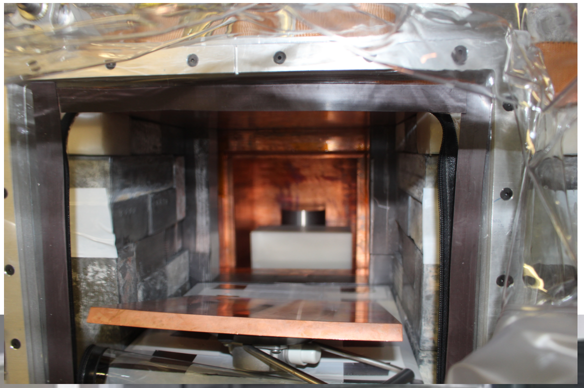
(Canberra Well Detector)



Canberra Well Detector Sensitivity

Isotope	Sensitivity for Standard Size Samples
^{238}U (↑ ^{226}Ra)	0.04 mBq
^{238}U (↓ ^{226}Ra)	0.03 mBq
^{228}Ac	0.12 mBq
^{232}Th	0.23 mBq
^{235}U	0.01 mBq
^{210}Pb	0.08 mBq

Gopher HPGe



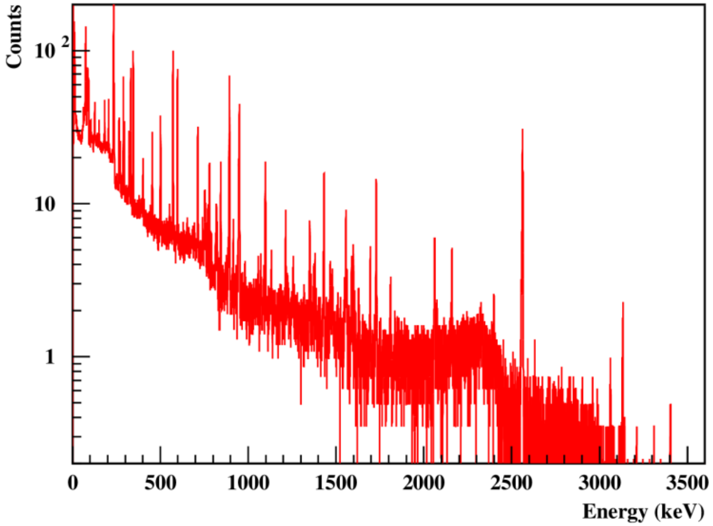
2.0kg of Ge. P-type coaxial

- Canberra Ge detector with thin 1.6 mm Al window, allows sensitivity to 210Pb
- Detector is 400 cm3 and is shielded by
  - 2” inner OFHC copper
  - Surrounded by 2” low-activty Pb
  - Surrounded by > 10” normal Pb
  - Plus some outer polyethelene
- The shielding box is purged with 1.8 lpm of nitrogen boil-off gas.
- Dedicated to SuperCDMS
- Sensitivity of ~ 1 mBq/kg for 3 week run
- Sample changes by SNOLAB scientists and staff
- Queue and Analysis by SuperCDMS
- Current status: Background run in progress

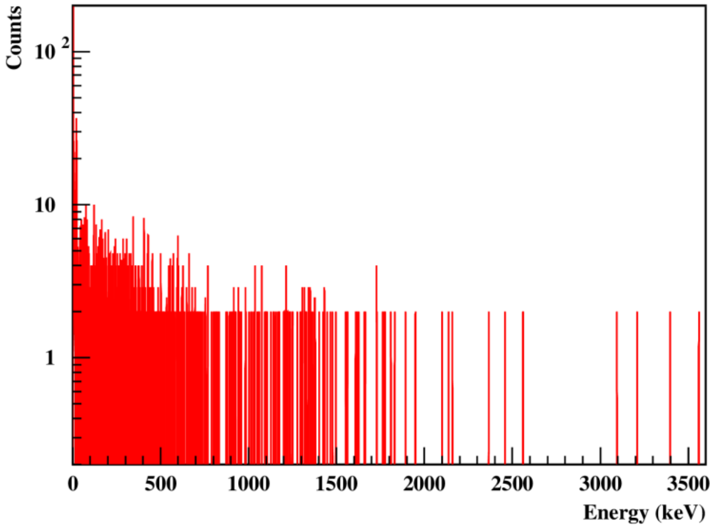
Vue des Alpes HPGe Detector

The VdA HPGE detector has been reconditioned by baking and vacuum pumping for several months.

Calibration runs have been done to verify peak resolution and now a long-term background run is in progress.



Calibratio



Backgroun

Canberra Coaxial HPGe Detector

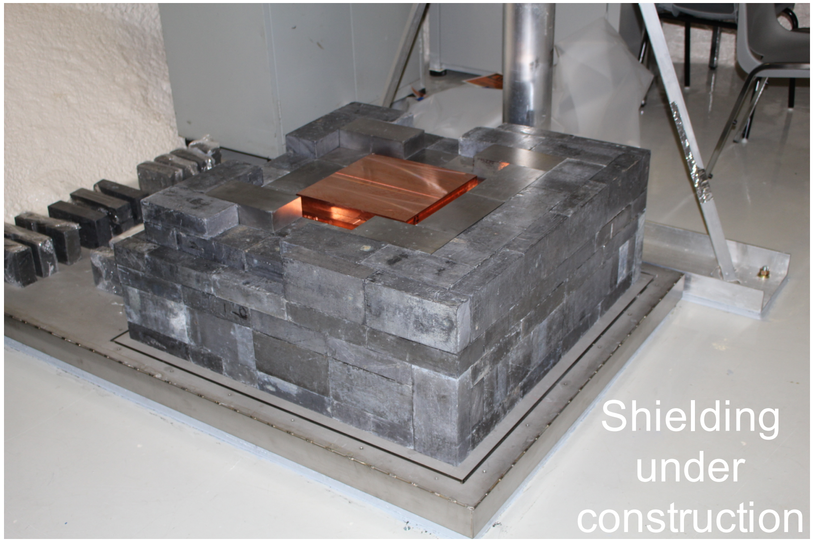
Canberra 400 cm^3 p-type coaxial HPGE detector acquired in 2011.

Refurbished into an ultra-low detector in 2013 with verified low-background materials.

Shielding is partially assembled.

Machining of the lead bricks is underway for the cold finger and nitrogen purge lines.

Construction of the shielding plug is underway.



Electrostatic Counting System (ESCs)

Originally built for SNO, now used primarily by EXO. However, these counters are owned by SNOLAB so samples can be measured for other experiments.

Measures ^{222}Rn, ^{224}Ra and ^{226}Ra levels. The technique involves recirculation of low pressure gas from sample volume to the ESC.

Sensitivity Levels are:

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

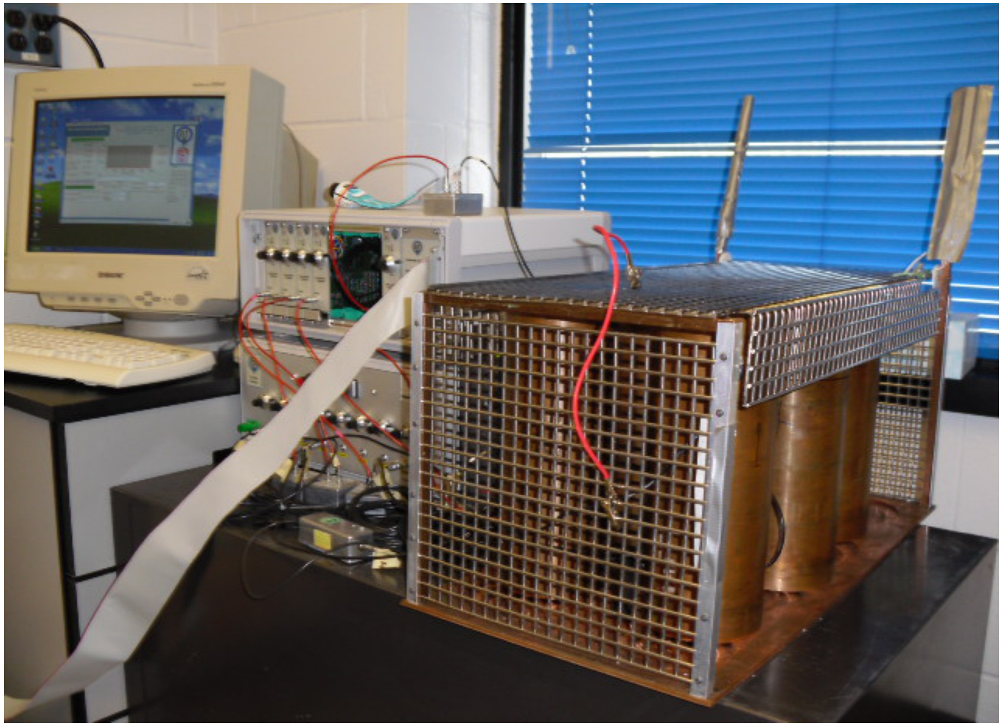
^{224}Ra: 10^{-15} gTh/g

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

Work is ongoing to improve sensitivity even further.

9 counters located at SNOLAB,
1 on loan to LBL (EXO),
1 on loan to U of A (DEAP).

Alpha Beta Counting System

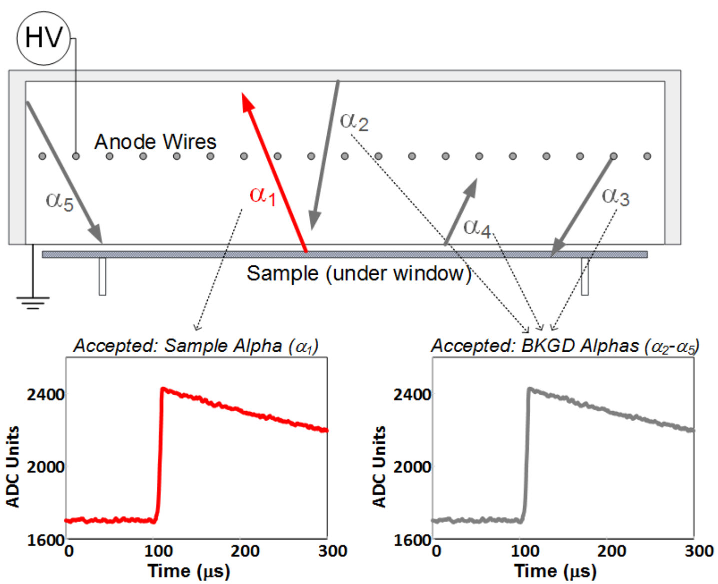


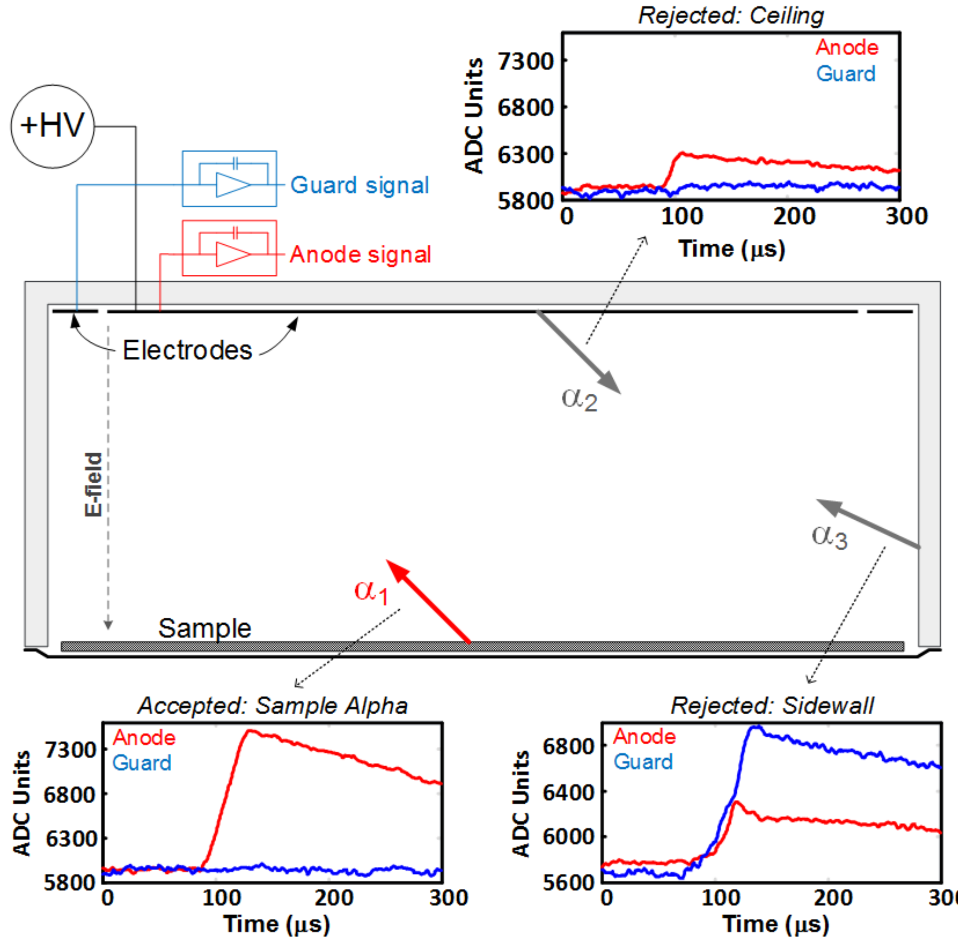
Transparent liquid scintillator vials optically coupled to 2” PMTs.

The technique is combination of pulse shape discrimination and coincidence counting for identifying BiPo events.

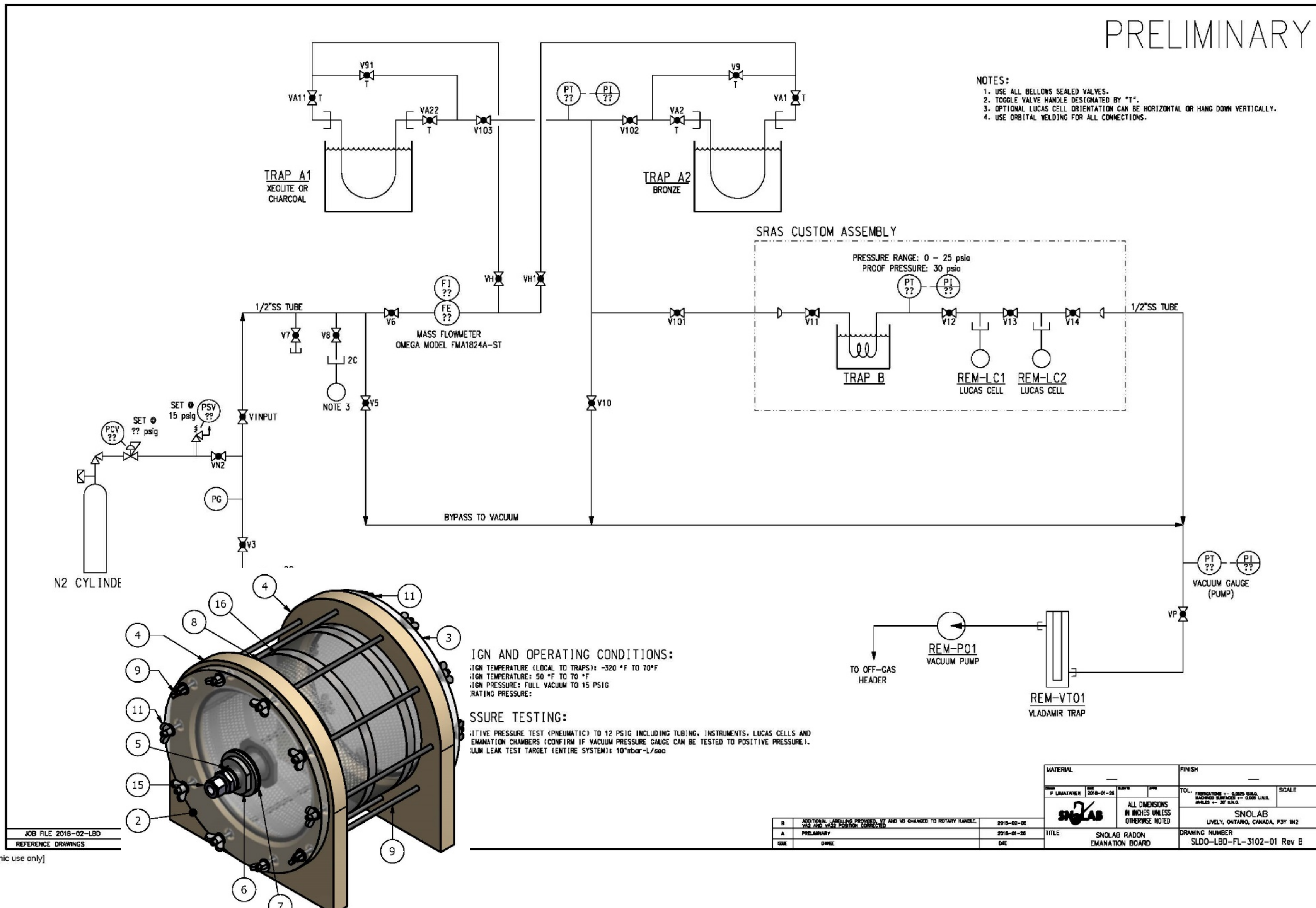
Sensitivity for ^{238}U and ^{232}Th is ~1 mBq assuming that the chains are in equilibrium.

XIA Alpha Counter





Radon Emanation Chamber



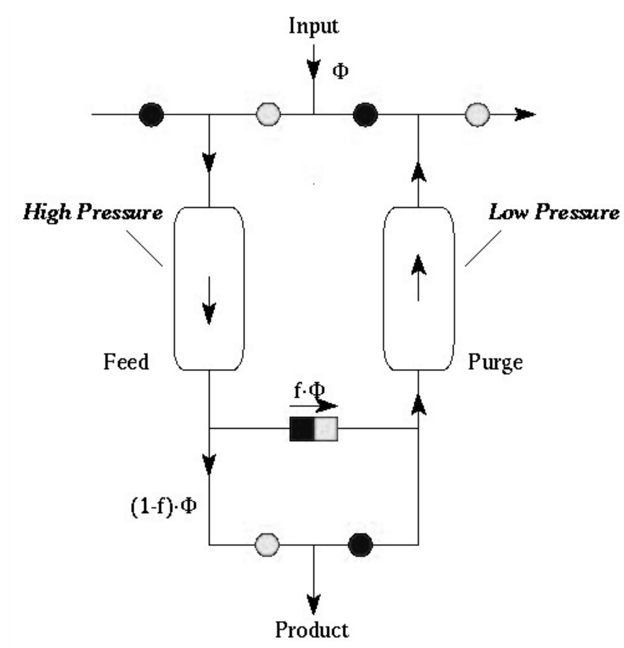
[Academic use only]

Future Plans for SNOLAB LBL

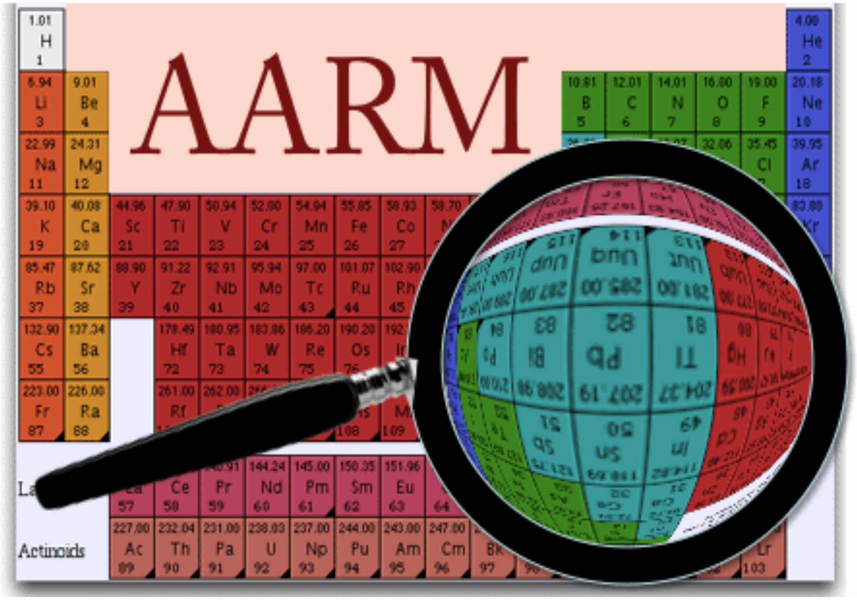
- Extended use for the DUST tank as general purpose shielding tank with veto. For example, may install acrylic scintillator tank and PMT array for counter.
- Low radon air supply.
- Low radon air room for assembly and sample preparation.
- New Radon emanation capabilities, eg. large emanation tanks and system to extract from experiment process systems.
- New detectors as needed and motivated:
  - Alpha counters
  - XIA high sensitivity large area surface alpha counter
  - Beta cage counter
- New chemical analytical capability, eg. HP-ICPMS.
- Improved liquid particle counting.

Low Radon Air Supply

- To supply to assembly rooms, detectors or gloveboxes
- General methods are low-pressure adsorption, or pressure/vacuum swing adsorption, or a hybrid or these.
- Flow rates over 50 m^3/hr and radon levels below 100 mBq/m^3 have been demonstrated.
- Maybe able to use Vale mine compressed air system as input air, which is surface air (3 – 9 Bq/m^3), versus UG air ~130 Bq/m^3.



SNOLAB is a member of AARM:



Communication and Collaboration on common issues related to Assay and Acquisition of Radiopure Materials

Content and management of the AARM website to be moved to LRT website

www.lowradioactivity.org

The AARM Integration Website

Home Page

Assay and Acquisition of Radiopure Materials

a cooperative approach to low radiation techniques and sensitive background measurement

- Home
- Community
- Facilities and Scheduling:
  - Detectors info
  - Assay request
  - Storage request
- Community Assay Database
- Background Studies
- Laboratory Materials
- Clean-handling Procedures
- Resources:
  - Publications
  - AARM presentations
  - LRT presentations
- Go to Lowrad Wiki
- Interdisciplinary Research Portals

The purpose of this website is to share knowledge and resources across the community of those involved in low-radioactivity experimental techniques. The tasks covered include

1. Coordinating users and providers of sensitive assay facilities
2. Linking to information on availability of radiopure materials
3. Sharing knowledge concerning backgrounds in low-background experiments

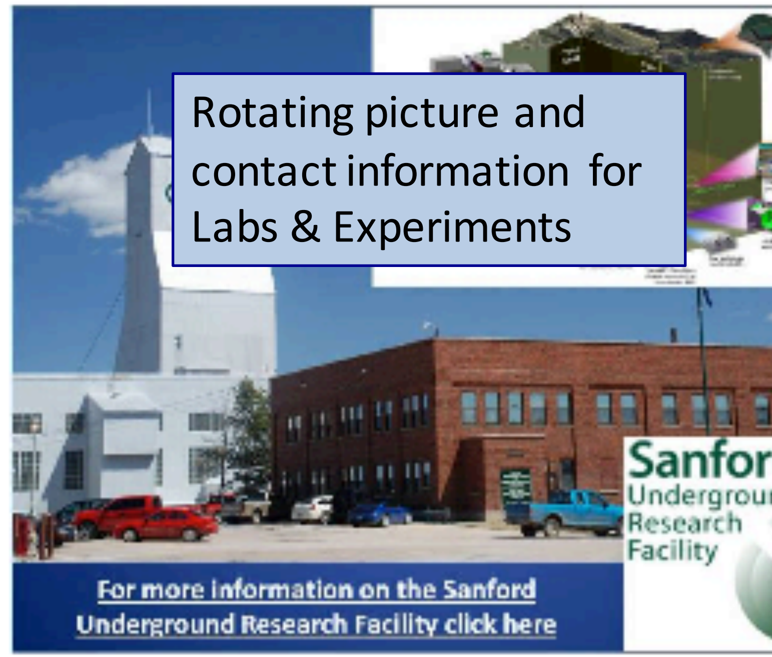
NEWS:

The next AARM meeting is May 20-21, 2015. It will be held right after the Conference on Science at SURF hosted at the *South Dakota School of Mines & Technology*.

Summary agenda on the AARM wiki and copied below. For more detail see the full agenda.

May 20 (Wednesday)

12:30-1:45 Discussion over **box lunch**:
- AARM (website and other common tools)
- G2 collaboration infrastructure priorities
- $0\nu\beta\beta$ background infrastructure



Rotating picture and contact information for Labs & Experiments

Suggestions? Send them to fritts@physics.umn.edu and astrong@umn.edu

The AARM Integration Website

Facilities and Scheduling: Assay or Storage Request

What the user submits

- Check out the available assay from Detector Info
- Fill out request form – goes to the contact listed

Storage request also available

Assa

- Home
- Community
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Click here to request login information

For general information on proper handling of samples refer to the Clean-handling procedures.

For information on the results of previous assays please see the Community Assay Database

*Login:

*Password:

*Requester Name:

*email address:

*Experiment:

Select detector: Gopher (Soudan Underground Laboratory)

Number of samples:

Sample dimensions: Please describe sample size, shape, mass etc. here.

Sample composition: Please describe the chemical composition of the sample. Include links to material data sheets if applicable.

Sample description: Please provide any additional description of the sample including the name of the vendor (if applicable).

Suggestions? Send them to fritts@physics.umn.edu and astrong@umn.edu

The AARM Integration Website

Resources:

Easy reference for relevant papers

Links to LRT and AARM presentations

Add your own paper

Home

Community

Facilities and Scheduling:

- Detectors info
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- Storage request

Community Assay Database

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Laboratory Materials

Clean-handling Procedures

Resources:

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- AARM presentations
- LRT presentations

Go to Lowrad Wiki

Interdisciplinary Research Portals

Aluminum as a source of background in low background exp
B. Majorovits, I. Abt, M. Laubenstein, O. Volynets.
[arXiv:1105.3591 [physics.ins-det]].

Cosmogenic Production as a Background in Searching for Ra
D.-M. Mei, Z.-B. Yin, S.R. Elliott.
[arXiv:0903.2273 [nucl-ex]].

Cosmogenic activation in germanium and copper for rare ev
S. Cebrian, H. Gomez, G. Luzon, J. Morales, A. Tomas, J.A.

Cosmogenic activation of a natural tellurium target.
V. Lozza, J. Petzoldt.
[arXiv:1411.5947 [physics.ins-det]].

Measurement of the specific activity of ar-39 in natural argo
WARP Collaboration (P. Benetti et al.).
[astro-ph/0603131].

Geant / FLUKA

Cosmogenic Backgrounds in Borexino at 3800 m water-equivalent depth.
Borexino Collaboration (G. Bellini et al.).
[arXiv:1304.7381 [physics.ins-det]].

Monte Carlo Simulation of HERD Calorimeter.
M. Xu, G.M. Chen, Y.W. Dong, J.G. Lu, Z. Quan, L. Wang, Z.G. Wang, B.B. Wu et al..
[arXiv:1407.4530 [astro-ph.IM]].

Muon-induced neutron production and detection with GEANT4 and FLUKA.
H.M. Araujo, V.A. Kudryavtsev, N.J.C. Spooner, T.J. Sumner.
[hep-ex/0411026].

Suggestions? Send them to fritts@physics.umn.edu and astrong@umn.edu

Presentations from Low Radiation Techniques (LRT) wo

The Low Radioactivity Techniques (LRT) workshop series examines topics in low radioactivity techniques, a fundamental aspect of rare event searches. Topics include dark matter, solar decay, and long half-life phenomena. This conference's wide scope includes all aspects of the background detectors and techniques.

The goal of this workshop series is to bring together experts in this field for presentations ar broadly the issues of low radioactivity techniques. The intention is to foster and continue the resource sharing required for new generations of detectors to be developed at underground

The LRT workshop series started in 2001 at Laurentian University in Sudbury. Presentations 2004 are available at the links below:

LRT 2015:	Presentations
LRT 2013:	Presentations
LRT 2010:	Presentations
LRT 2006:	Presentations
LRT 2004:	Presentations

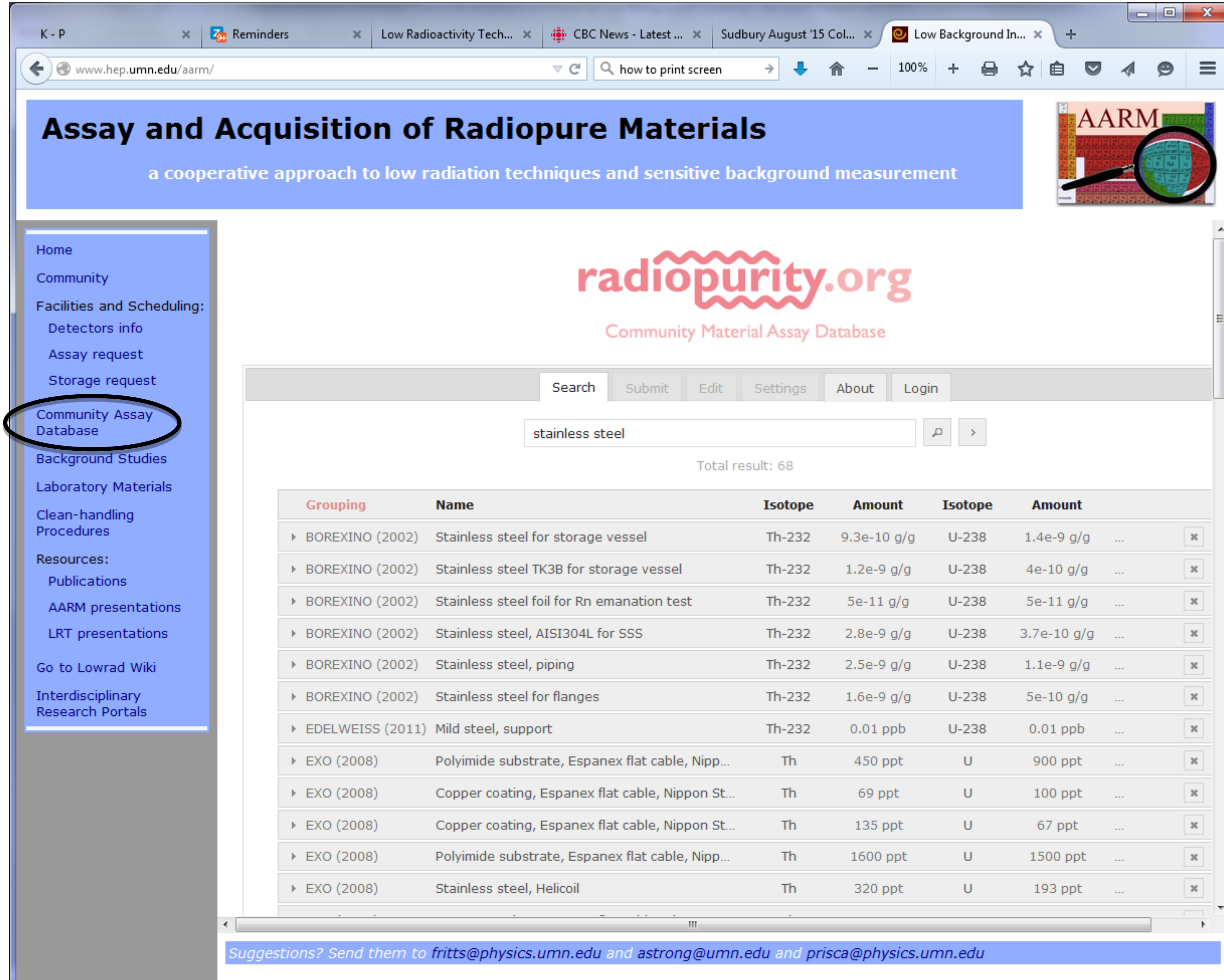
Presentations from AARM meetings

The original purpose of the Acquisition and Assay of Radiopu Facility for AARM (or FAARM) at DUSEL. This effort was fund Tools for Underground Science", was funded beginning in 20 background community, as represented by this website.

The AARM group has held meetings since 2010 to define go meetings are available at the links below:

- March 19-22, 2014 at Fermilab
- March 4, 2013 at SLAC National Accelerator Laboratory
- June 22-23, 2012 at University of Minnesota
- November 11-12, 2011 at University of Minnesota
- February 25-26, 2011 at University of Minnesota
- November 12-13, 2010 at Sanford Underground Researc
- March 19-20, 2010 at UC Berkeley

http://www.radiopurity.org/



K - P | Reminders | Low Radioactivity Tech... | CBC News - Latest ... | Sudbury August '15 Col... | Low Background In...

www.hep.umn.edu/aarm/

how to print screen

100%

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a cooperative approach to low radiation techniques and sensitive background measurement

AARM

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radiopurity.org

Community Material Assay Database

Search | Submit | Edit | Settings | About | Login

stainless steel

Total result: 68

Grouping	Name	Isotope	Amount	Isotope	Amount
BOREXINO (2002)	Stainless steel for storage vessel	Th-232	9.3e-10 g/g	U-238	1.4e-9 g/g
BOREXINO (2002)	Stainless steel TK3B for storage vessel	Th-232	1.2e-9 g/g	U-238	4e-10 g/g
BOREXINO (2002)	Stainless steel foil for Rn emanation test	Th-232	5e-11 g/g	U-238	5e-11 g/g
BOREXINO (2002)	Stainless steel, AISI304L for SSS	Th-232	2.8e-9 g/g	U-238	3.7e-10 g/g
BOREXINO (2002)	Stainless steel, piping	Th-232	2.5e-9 g/g	U-238	1.1e-9 g/g
BOREXINO (2002)	Stainless steel for flanges	Th-232	1.6e-9 g/g	U-238	5e-10 g/g
EDELWEISS (2011)	Mild steel, support	Th-232	0.01 ppb	U-238	0.01 ppb
EXO (2008)	Polyimide substrate, Espanex flat cable, Nipp...	Th	450 ppt	U	900 ppt
EXO (2008)	Copper coating, Espanex flat cable, Nippon St...	Th	69 ppt	U	100 ppt
EXO (2008)	Copper coating, Espanex flat cable, Nippon St...	Th	135 ppt	U	67 ppt
EXO (2008)	Polyimide substrate, Espanex flat cable, Nipp...	Th	1600 ppt	U	1500 ppt
EXO (2008)	Stainless steel, Helicoil	Th	320 ppt	U	193 ppt

Suggestions? Send them to fritts@physics.umn.edu and astrong@umn.edu and prisca@physics.umn.edu

radiopurity.org

Community Material Assay Database

AARM recognized 10 years ago the need for an Assay Database
with an easy-to-use interface to enter new data
and to search for radiopure materials, vendors, etc.
The Majorana database (J. Loach) was chosen as a template

The more globally used, the more useful for everyone.

- Began by entering legacy data:
  ~300 assays; data from ILIAS, EXO and XENON100
- Now have ~ 1000 assays, primarily historical.
- Database is being used by SuperCDMS and DarkSide, LZ evaluating it
- In the process of adding features to the software for easier distributed use.

radiopurity.org

Community Material Assay Database

Search | Submit | Edit | Settings | About | Login

(pf? polyimide kapton -ptfe -raw) AND grouping:EXO

Total result: 10

Grouping	Name	Isotope	Amount	Isotope	Amount		
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	450 ppt	U	900 ppt	...	×
EXO (2008)	PFA, Saint Gobain supplied DuPont 450-HPB	Th	65 ppt	U	75 ppt	...	×
EXO (2008)	PFA, Saint Gobain DuPont 440-HP	Th	13.3 ppt	U	3 ppt	...	×
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	1600 ppt	U	1500 ppt	...	×
EXO (2008)	Polyimide tape, Stanford stock room	Th	5400 ppt	U	5800 ppt	...	×
EXO (2008)	Copper coating, Espanex flat cable, Nippon Ste...	Th	3 ppt	U	19 ppt	...	×
EXO (2008)	Sheldal superinsulation, DuPont Kapton alumini...	Th	1540 ppt	U	2500 ppt	...	×
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	50 ppt	U	450 ppt	...	×
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	317 ppt	U	3880 ppt	...	×
EXO (2008)	Sheldal superinsulation, DuPont Kapton alumini...	Th	1640 ppt	U	6100 ppt	...	×

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Community Material Assay Database

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(pf? polyimide kapton -ptfe -raw) AND grouping:EXO

Total result: 10

Grouping	Name	Isotope	Amount	Isotope	Amount	
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	450 ppt	U	900 ppt	...
EXO (2008)	PFA, Saint Gobain supplied DuPont 450-HPB	Th	65 ppt	U	75 ppt	

Sample	Description	Saint Gobain supplied DuPont 450-HPB PFA. Material finished using supplier's default procedures.
	ID	Table 3. #47
Measurement	Results	K 740 (77) ppb Th 65 (6.5) ppt U < 75 (95%) ppt
	Technique	NAA
	Description	For each of K, Th, and U, natural terrestrial abundance ratios were used to covert from isotopic to total elemental abundances.
Data	Reference	D.S.Leonard et al., Nucl. Instr. and Meth. A 591 (2008) (http://dx.doi.org/10.1016/j.nima.2008.03.001)
	Data entry	Matthew Bruemmer / James Loach mbruemmer@smu.edu / james.loach@gmail.com on 2013-01-30 spec v2.01

Grouping	Name	Isotope	Amount	Isotope	Amount	
EXO (2008)	PFA, Saint Gobain DuPont 440-HP	Th	13.3 ppt	U	3 ppt	...
EXO (2008)	Polyimide substrate, Espanex flat cable, Nippon...	Th	1600 ppt	U	1500 ppt	...

End

Reasons for Low Background Counting

- Rare event detector experiments (eg. dark matter searches and neutrino detector) require low radioactivity background. This requires that fabrication materials have low concentrations of radioactivity chain elements (^{232}Th, ^{238}U, and ^{40}K), often well below ppt levels. These backgrounds can be due to manufacturing cleanliness (inclusion of mineral dust), chemical contaminations (eg. potassium), or intrinsic to materials (eg. steel).

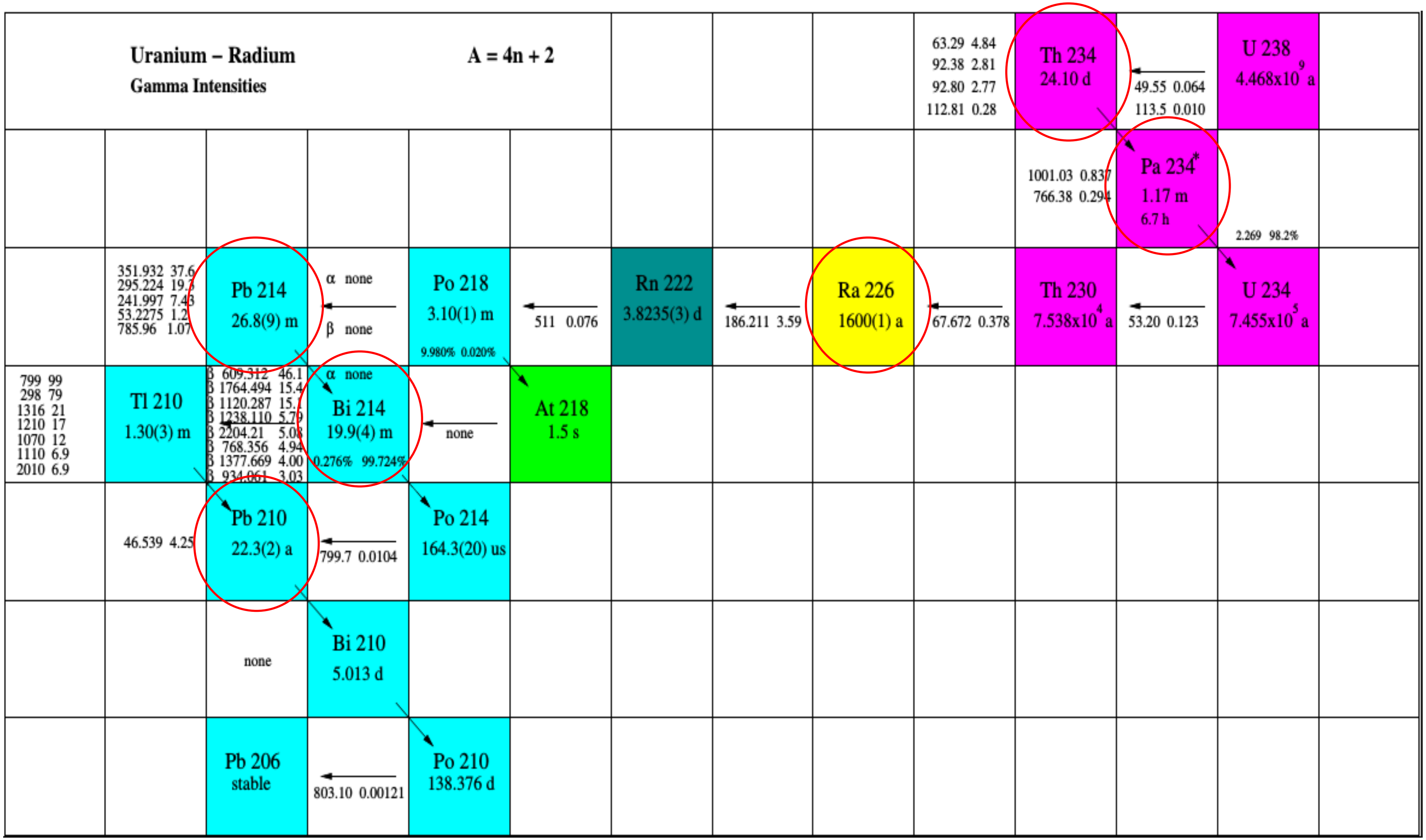
- These levels are below that generally accessible by chemical analytical techniques, and assay method is often by radiation counting.

- Another application is counting of detector target fluids, either as part of a QC requirement, diagnostics, or purification testing.

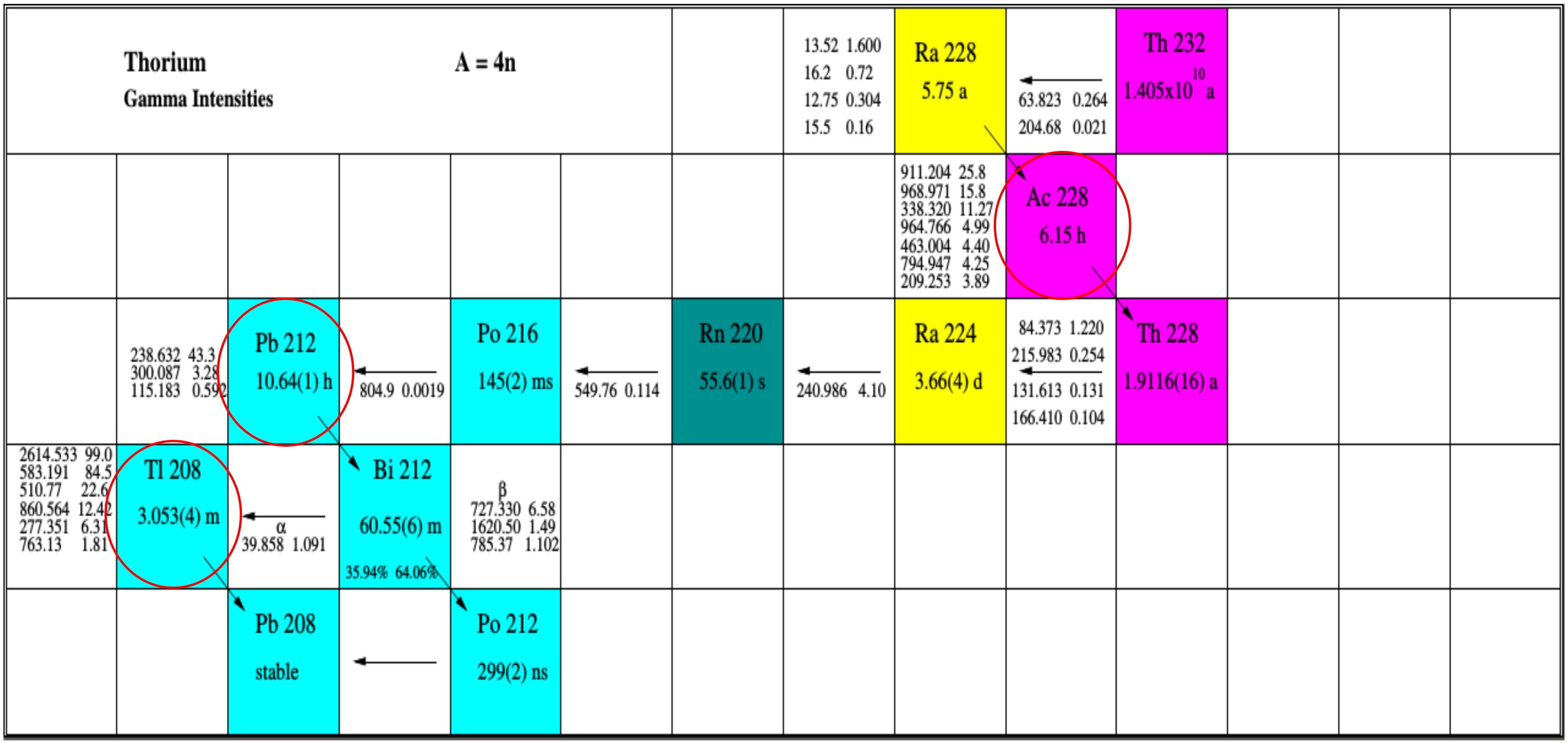
- Backgrounds of interest can be alphas, betas, gammas or neutrons, depending on the experiment and the component in question. The radiation could be direct, or via leaching or emanation. Thus several detector technologies are used.

- Generally these counting detectors must themselves be very low background, which requires them to be clean and underground, and fabricated and shielded with low background materials.

Uranium Decay Chain



Thorium Decay Chain

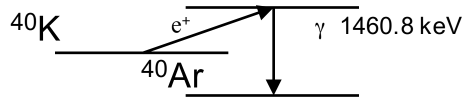


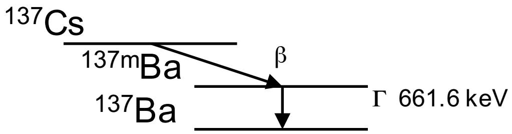
Other Interesting Isotopes

Usually Present:

- ^{40}K

  1460.83 keV

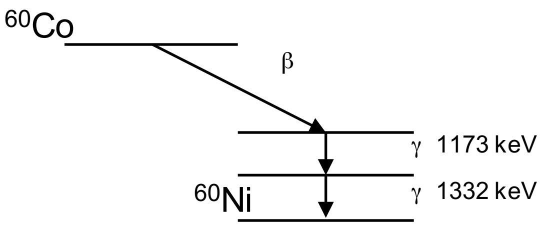




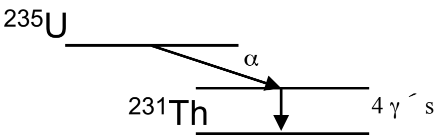
- ^{137}Cs

  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.