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# Low Background Material Assay

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# Introduction

- The world of low-background material assay spans many fields
  - Particle Physics – eg Dark Matter, 0vBB
  - Geophysics
  - Environmental Science
  - Aviation
  - Etc
- An array of techniques are used to determine various parts of the NORM decay chains
  - E.g. U238

ICP-MS/GDMS/NAA

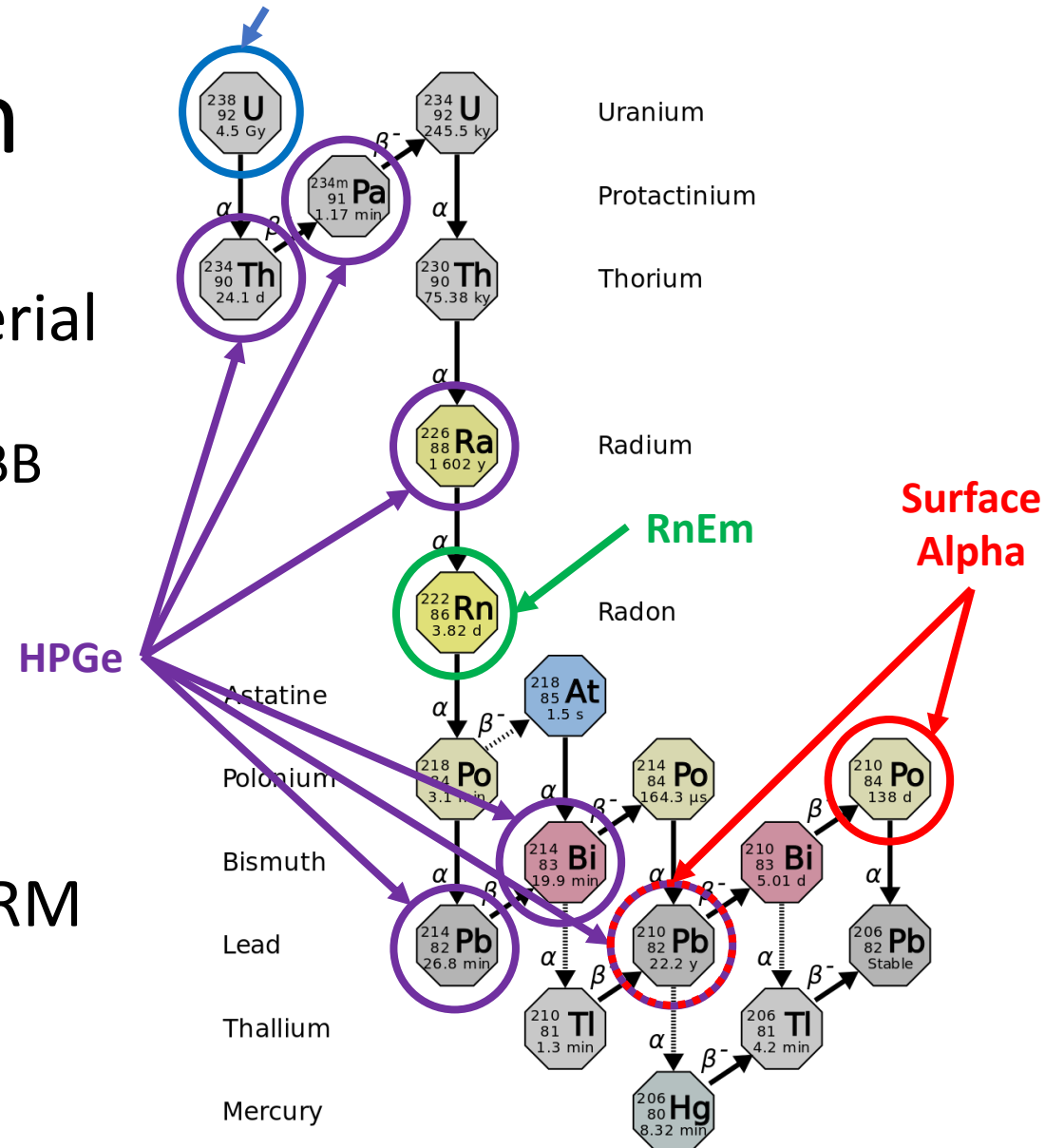


Image taken from Wikipedia – User: Tosaka



# How to Maximise Sensitivity

- Assay detectors constructed from low background materials
  - Reduce ambient radon (can be challenging!)
  - Low background shielding
  - Large active detector volume – also maximises throughput
  - Low energy capabilities
  - Go underground?
- 
- And keep it all clean, background stable, aim for 100% duty cycle!

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# Boulby As an Example

*Pic: Trevor Palin*

- Dedicated cleanroom space for material assay
- Class 1k
- Detectors purged using MFCs
- LN2 produced underground
- Environmental parameters monitored & logged
- 6x Ge, 2x alpha, 1x RnEm (under construction)
- Above ground cleanliness facilities (under development)



# Low Background Particle Physics

- A comprehensive material assay programme is an important part of a successful low background experiment
- Aim setting out is to cover as much of the decay chain for as much material as possible
- A typical experiment can have 1000s of individual components which themselves can be constructed from multiple materials
  - Photomultiplier tubes are a good example
- Through the BHUC & BLBF, SURF has been heavily involved in material assay in partnership with other facilities worldwide



# LZ as an Example

- Hundreds of samples assayed
  - Across ICP-MS, GDMS, NAA, HPGe, RnEM, Surface Alpha
  - A bit over half of Ge samples assayed at SURF
- Used expertise and worldwide coordination
  - SURF, LBNL, University of Alabama, U. Maryland, SDSM&T, BHSU – USA
  - STFC Boulby, UCL – UK
  - CUP – Korea
- 13x Ge, 4x RnEm, 4x ICP-MS, NAA, GDMS, Surface Alpha
- Very much empowered all members of the LZ collaboration to take ownership of radioactivity and cleanliness
- However... this is just a preview of what is to come...



# Increasing Sensitivity

	Detector	Relative Efficiency or type	Count rate (/kg/day)				
			352 keV ( <sup>214</sup> Pb)	609 keV ( <sup>214</sup> Bi)	238 keV ( <sup>212</sup> Pb)	1461 keV ( <sup>40</sup> K)	2615 keV ( <sup>208</sup> Tl)
<b>For U/Th</b>  <b>Underground Used for Current Generation</b>	Lumpsey (pre-refurb) <b>ppb</b>	SAGe-Well	104(2)	60(2)	166(3)	7.0(6)	12(1)
	Lunehead	100% p-type	5.6(5)	4.7(4)	8.3(5)	9.1(6)	2.0(3)
	Chaloner	BE5030	5(1)	4(1)	7(1)	8.4(14)	2.1(5)
	Morgan	85% p-type	-	8.8	-	4.8	3.2
	SOLO	30% p-type	-	3.3	-	-	-
	Mordred	60% n-type	-	3.9	-	7.4	2.1
	Maeve <b>10 ppt</b>	85% p-type	-	1.4	-	3.5	1.8
<b>Developed for Next Generation @Boulby</b>	Merrybent	110% p-type	2.5(3)	1.8(3)	0.3(1)	1.9(3)	0.8(2)
	Lumps	BLBF and LLNL developing “twins” and “rhyme” and “reason” for G3. Expecting 5x better sensitivity than Maeve		1.3(3)	1.1(7)	1.7(7)	0.7(2)
	Belmo			0.4(1)	0.13(6)	1.0(2)	0.3(1)
	Roseb			0.15(7)	0.8(3)	0.8(2)	0.2(1)
<b>Gold Standard</b>	Gator	100% p-type	0.3(1)	0.3(1)	<0.2	0.23(5)	0.09(5)
	Ge-MPI <b>a few ppt</b>	100% p-type	<0.07	<0.07	-	0.24(3)	0.05(1)

# Challenges for the future

- Next generation particle physics will put huge pressure on facilities
  - Potentially 10s of 1000s of measurements needed
- At LRT2019, I calculated at least 77 germanium crystals dedicated to material assay of varying sensitivity
  - Challenge here becomes one of worldwide coordination, cross-calibration & QA/QC
- For **radon emanation**, mass-spec, NAA and **surface alpha** there may still be too few facilities to meet future demand
  - Some labs starting to ramp up but there is certainly room for more!
  - Most relatively low cost but high impact
- And don't forget cleanliness!

<μBq/kg required for next-gen!\*

Numbers growing!

\*XENONnT reports 2 μBq/kg achieved (as of TAUP2021)!