Study of surface contamination on ultralow background (ULB) materials

May 22, 2019

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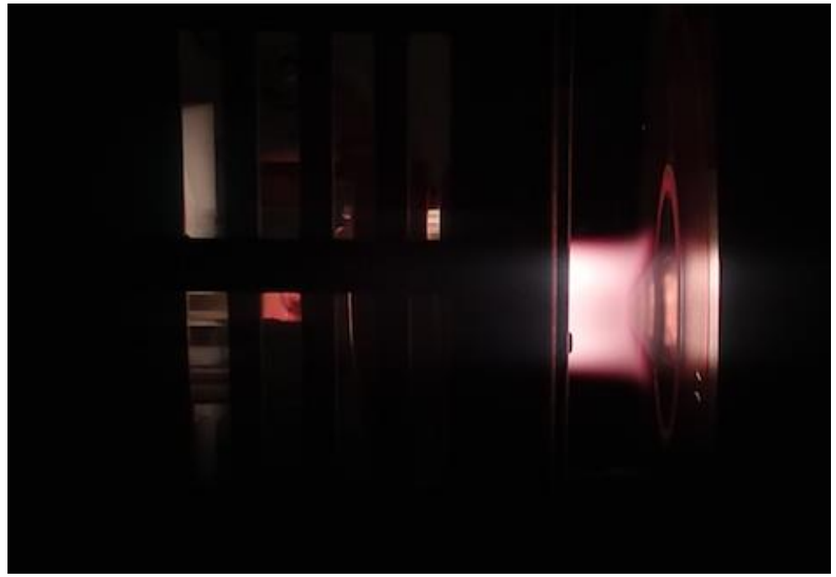
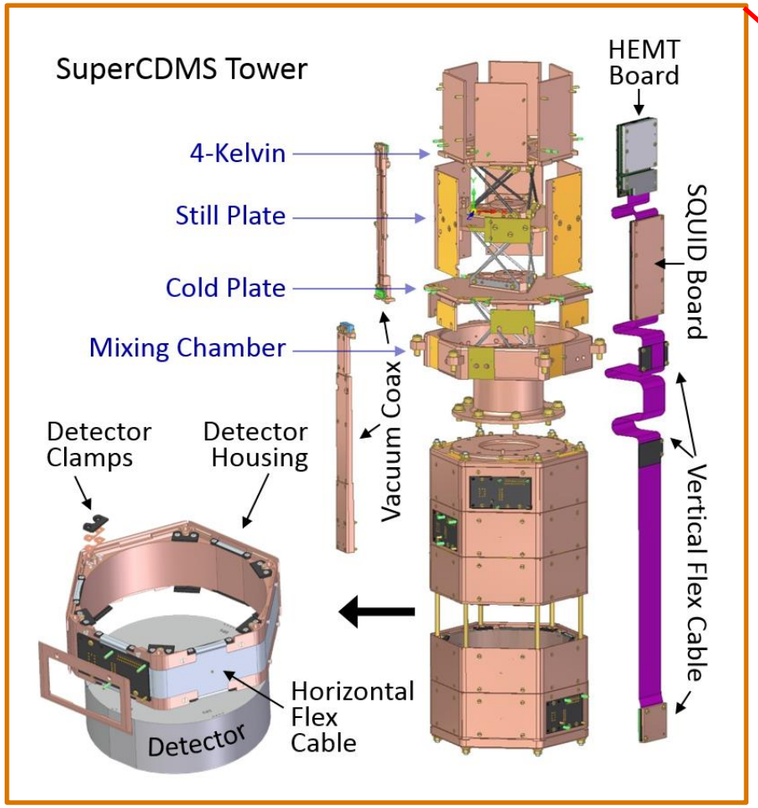
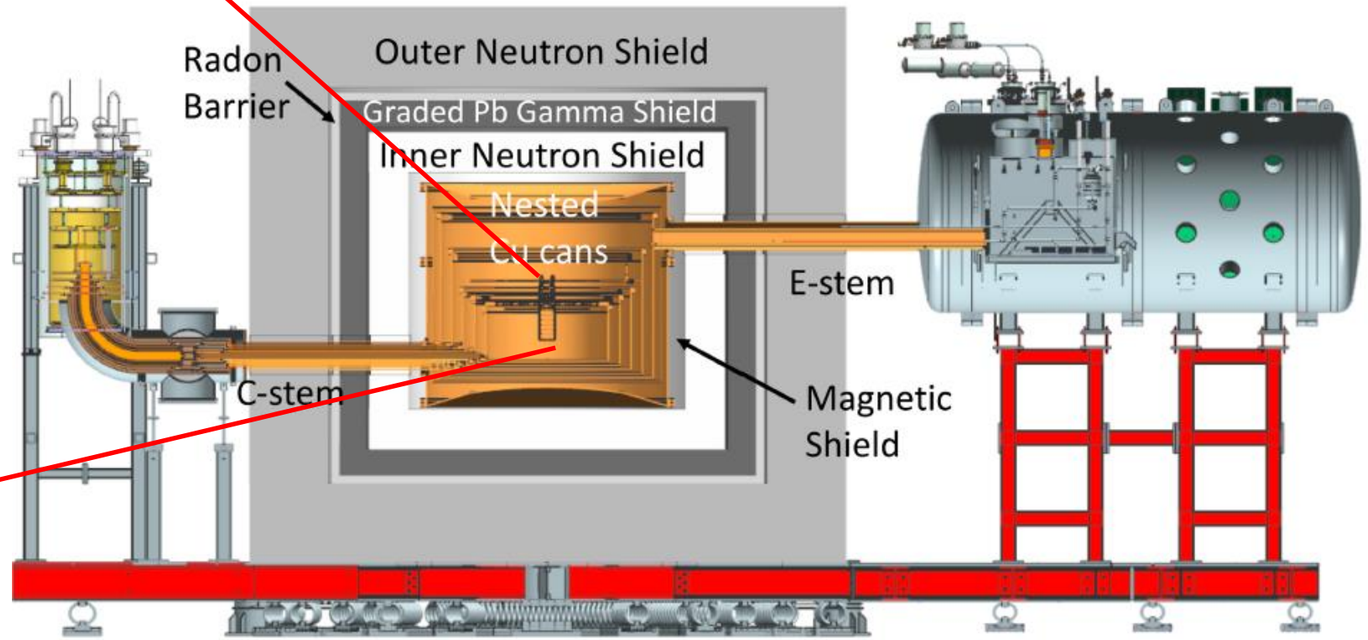
Low Radioactivity Techniques 2019



Detector components and surrounding materials: a significant background source

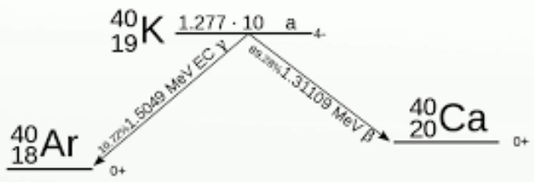
SuperCDMS SNOLAB detector



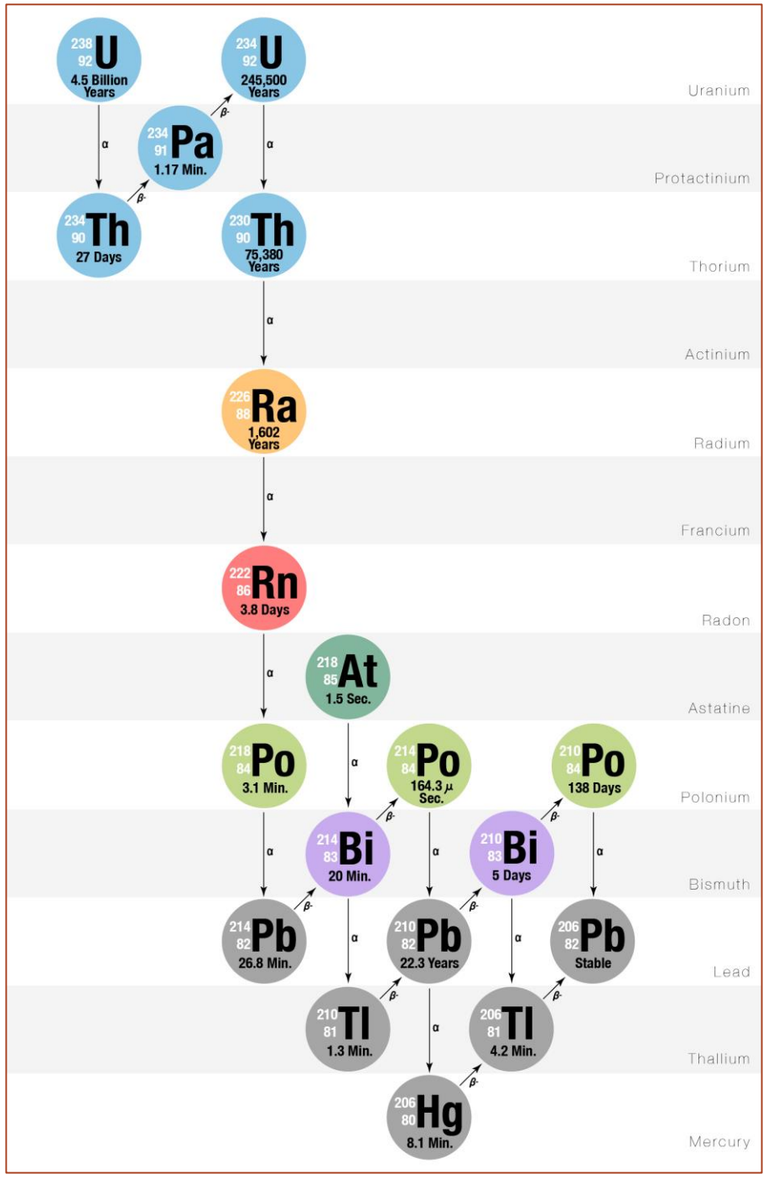


The usual suspects

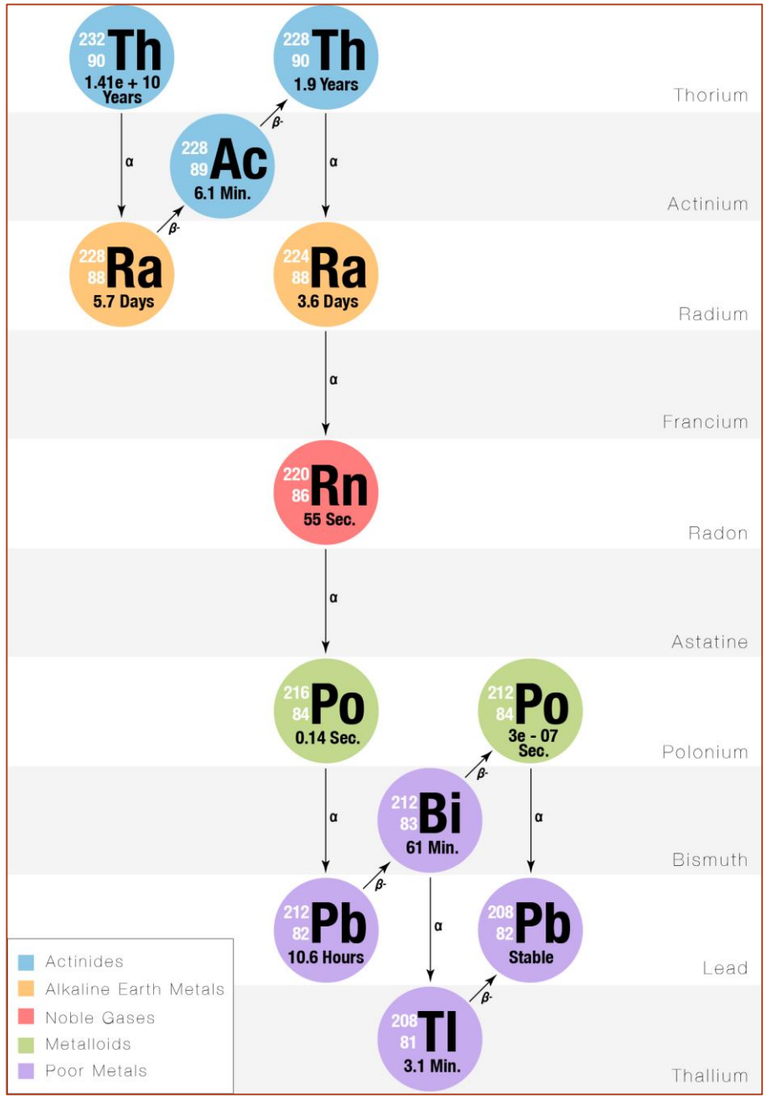
Potassium-40



Uranium-238

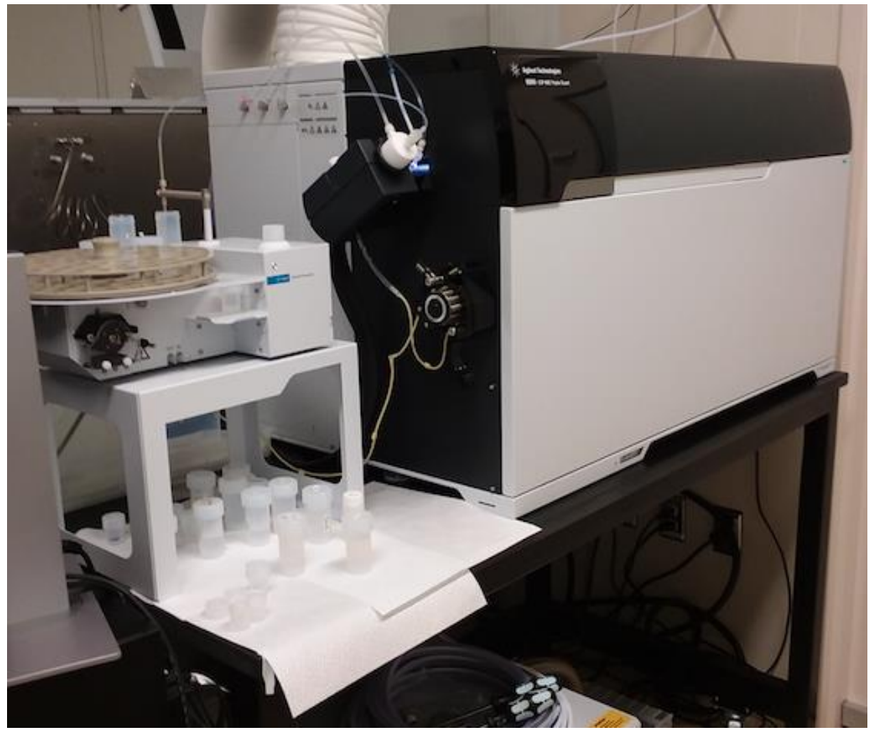


Thorium-232

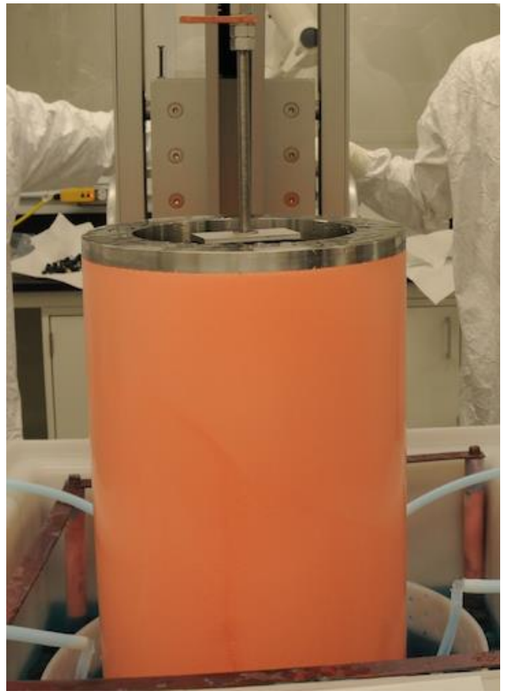


Validation of all materials: a challenging task

→ Extremely stringent radiopurity requirements



μBq/kg
range or lower



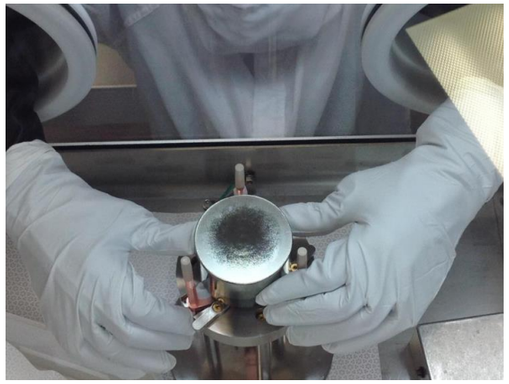
- Ultra sensitive analytical techniques
- Dedicated facilities

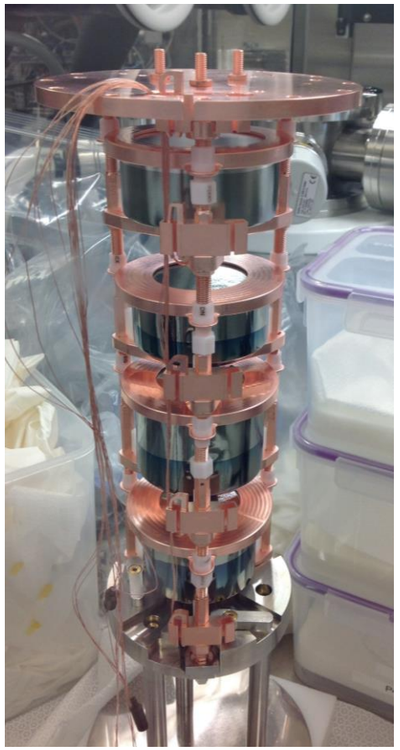
- Meticulously clean analytical procedure specifically developed
- R&D to develop ultrapure materials (*i.e.*, electroformed copper)

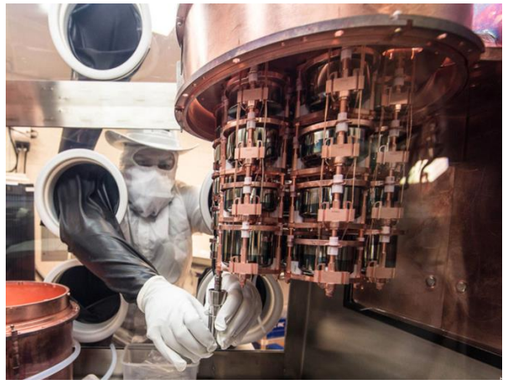
After validation, will materials remain “ultraclean” forever?

→ Surface contamination!

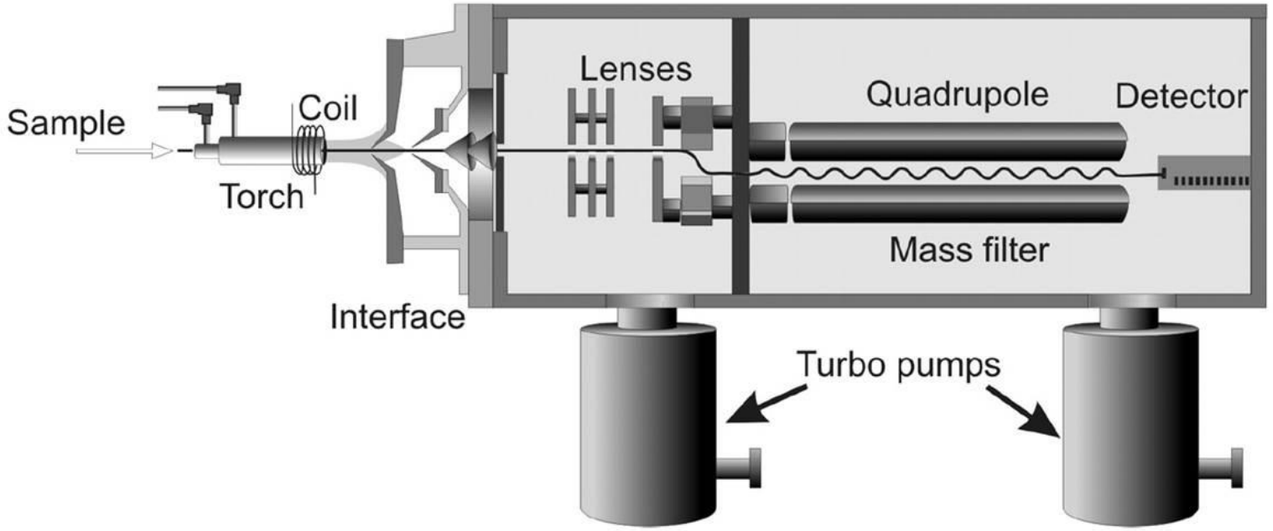
- Manufacturing and processing
- Handling for assembly
- Machining
- Moving and storage
- Exposure to dust, even in clean rooms!







ICP-MS: a powerful tool

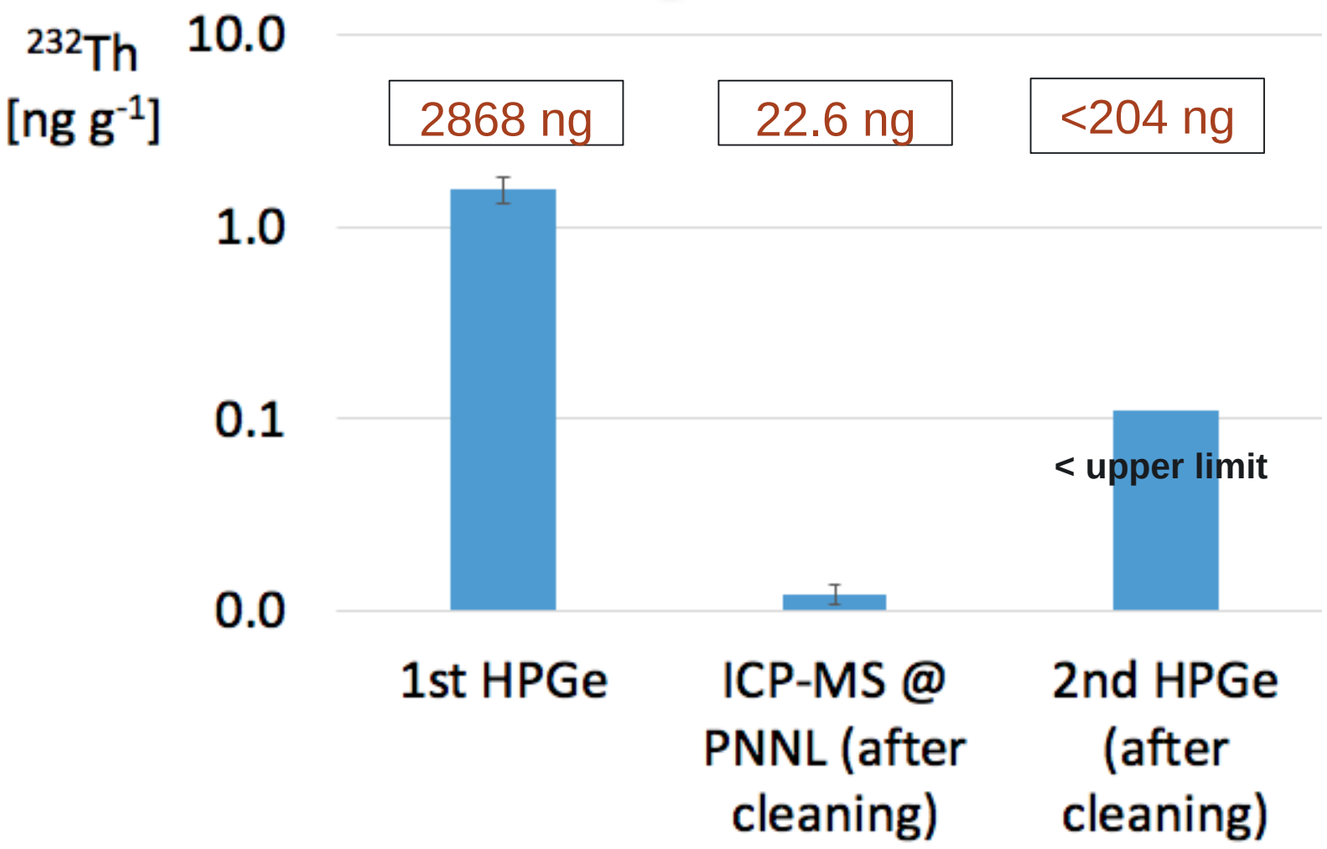


- Direct, fast, quantitative
- Surface and bulk

- **Understanding**
- **Identifying** rather than observing (too late!)
- **Quantifying** and **controlling**

➢ Machining, handling, exposure to dust

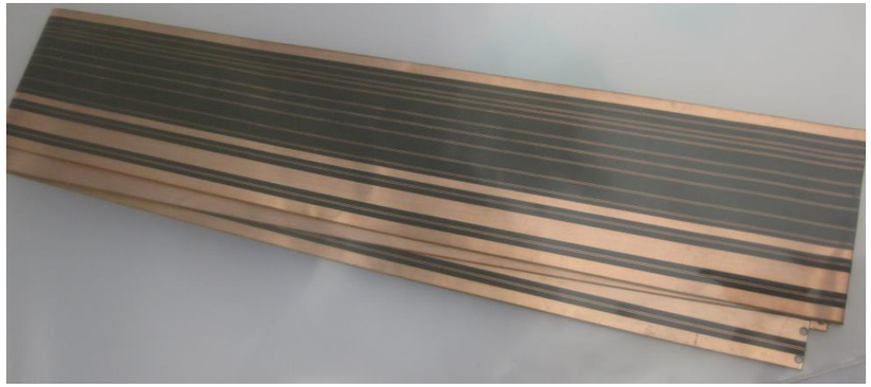
Block of HDPE:
- **1850 g**
- **1600 cm²**



→ 2845 ng, or 2.8 μg, of ^{232}Th to account for ←

➢ Manufacturing and processing

Flex cable



	^{232}Th	^{238}U
	ppt	ppt
PI/Cu laminate	8.06 ± 6.30	**8.72 ± 3.43**
Finished cable (whole sample analysis)	62.8 ±5.2	**6164 ± 112**

➢ 2% HNO_3 solution, 30 sec

Leachate analysis, normalized to sample mass

	^{232}Th	^{238}U
	ppt	ppt
From leach 1	40.4 ± 3.0	**7071 ± 1065**
From leach 2	2.29 ± 0.13	**40.2 ± 12.9**
From leach 3	1.34 ± 0.58	**16.5 ± 5.8**

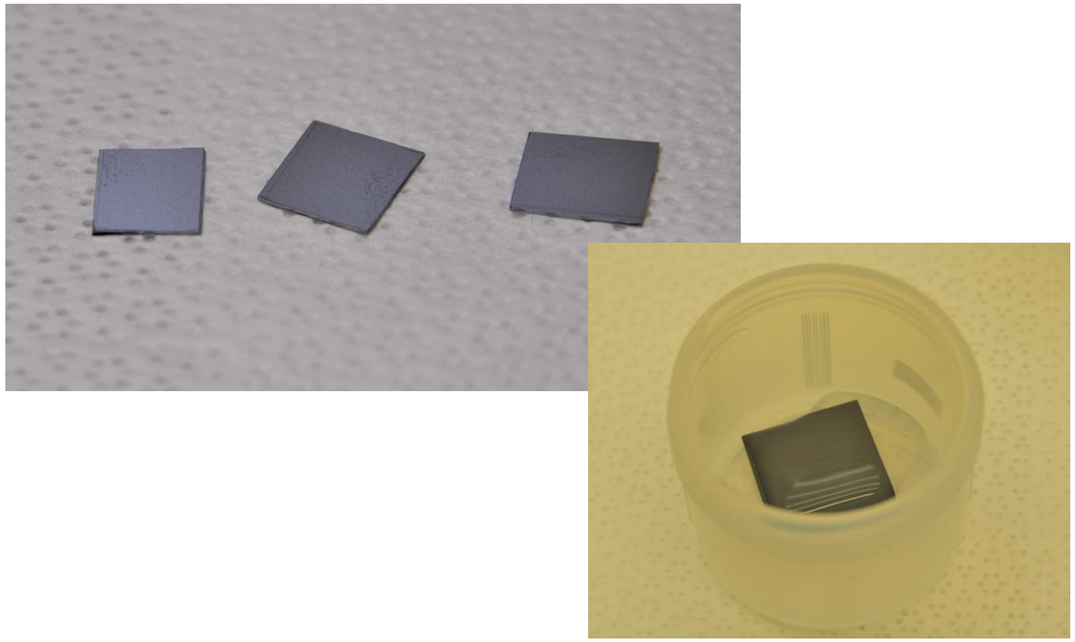
	^{232}Th	^{238}U
	ppt	ppt
Leached sample	35.4 ± 2.9	**55.1 ± 16.6**

Exposure to dust: direct measurement of dust activity

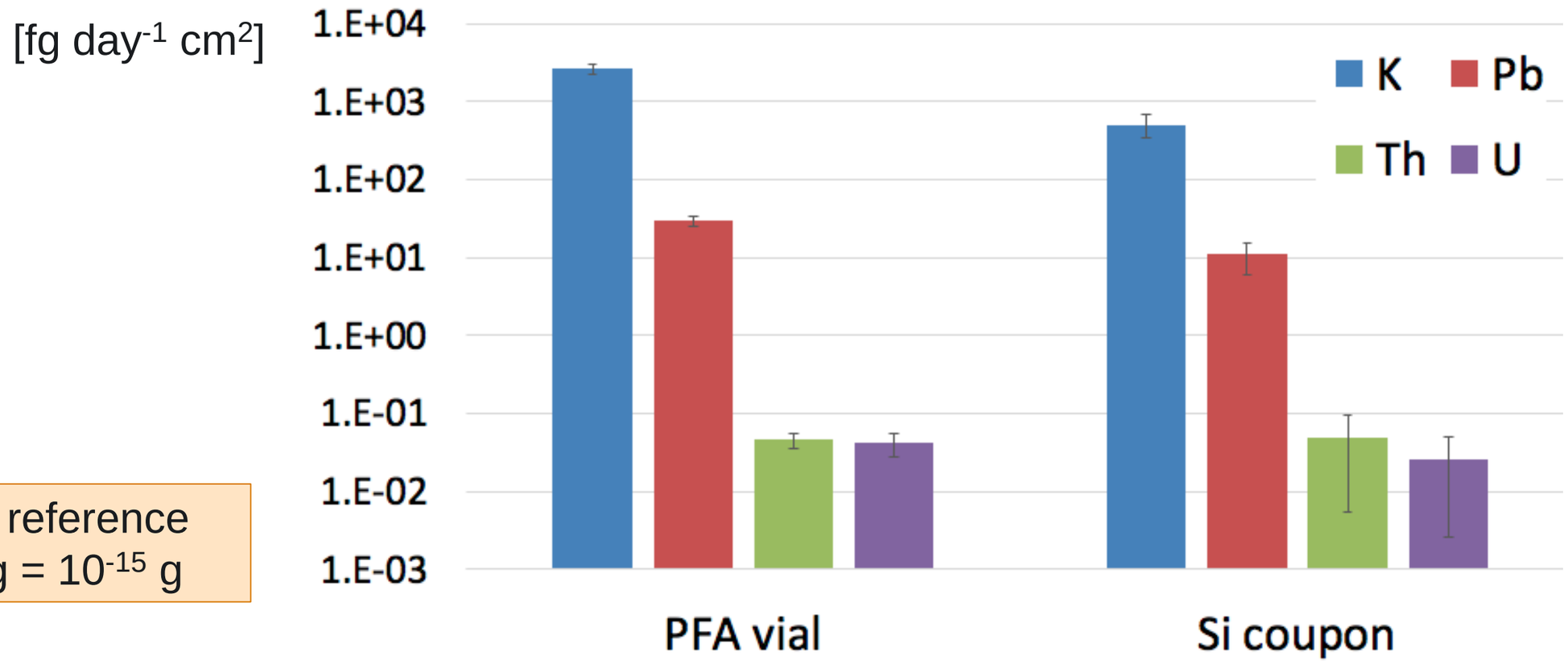
- Surface exposure
- Surface leaching
- Quantitative analysis

PFA (Perfluoroalkoxy alkane)

Silicon



Measured accumulation rate on PFA and Si surfaces

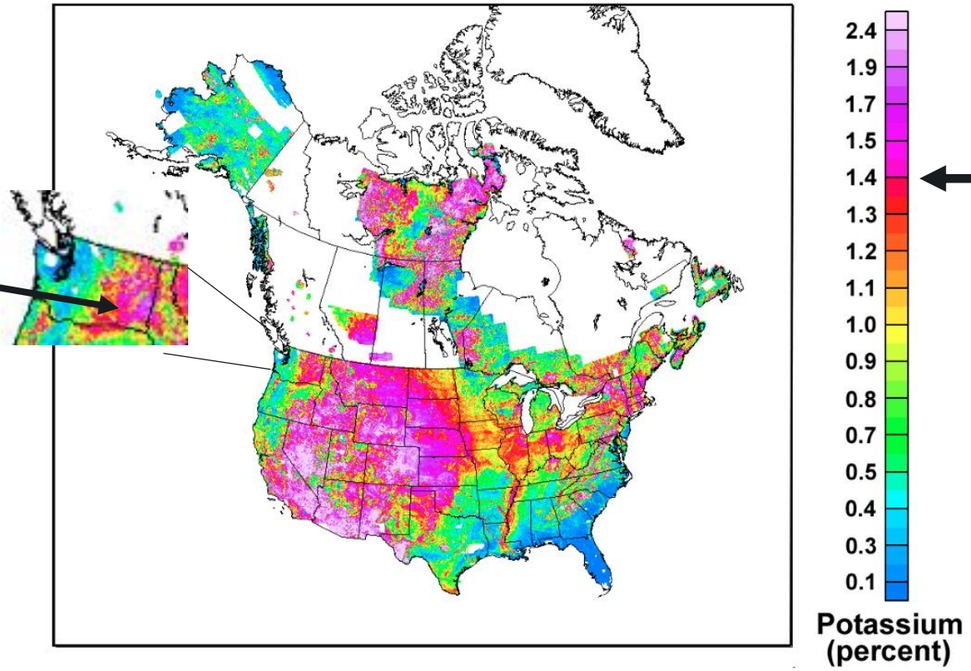


For reference
1 fg = 10^{-15} g

Class 10000 clean room at PNNL, 29 day exposure

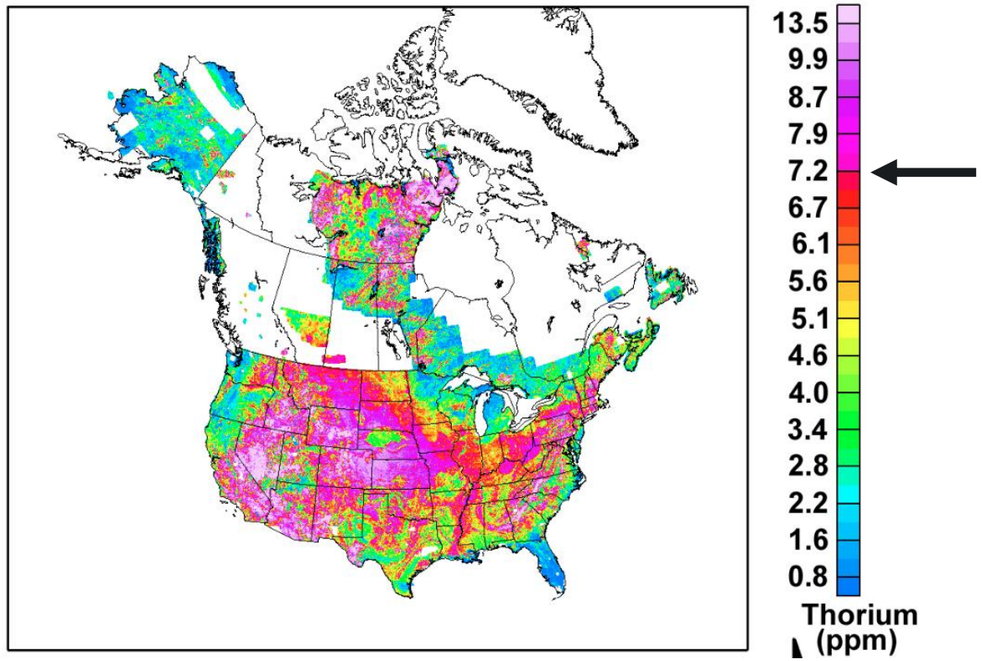
Pacific Northwest
NATIONAL LABORATORY

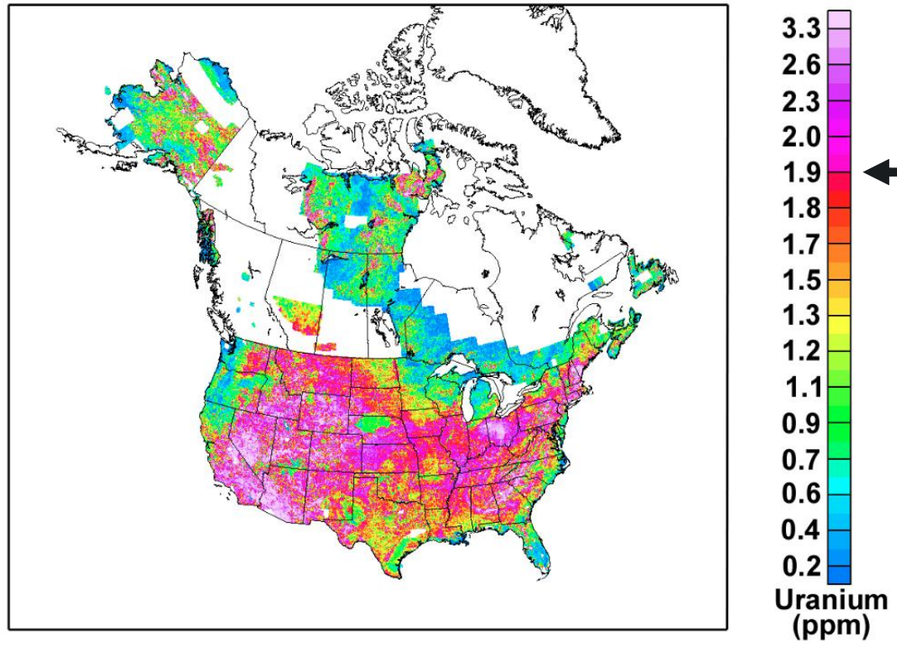
PNNL



K ~ 1.4 E+4 ppm
Th ~ 7.2 ppm
U ~ 1.2 ppm

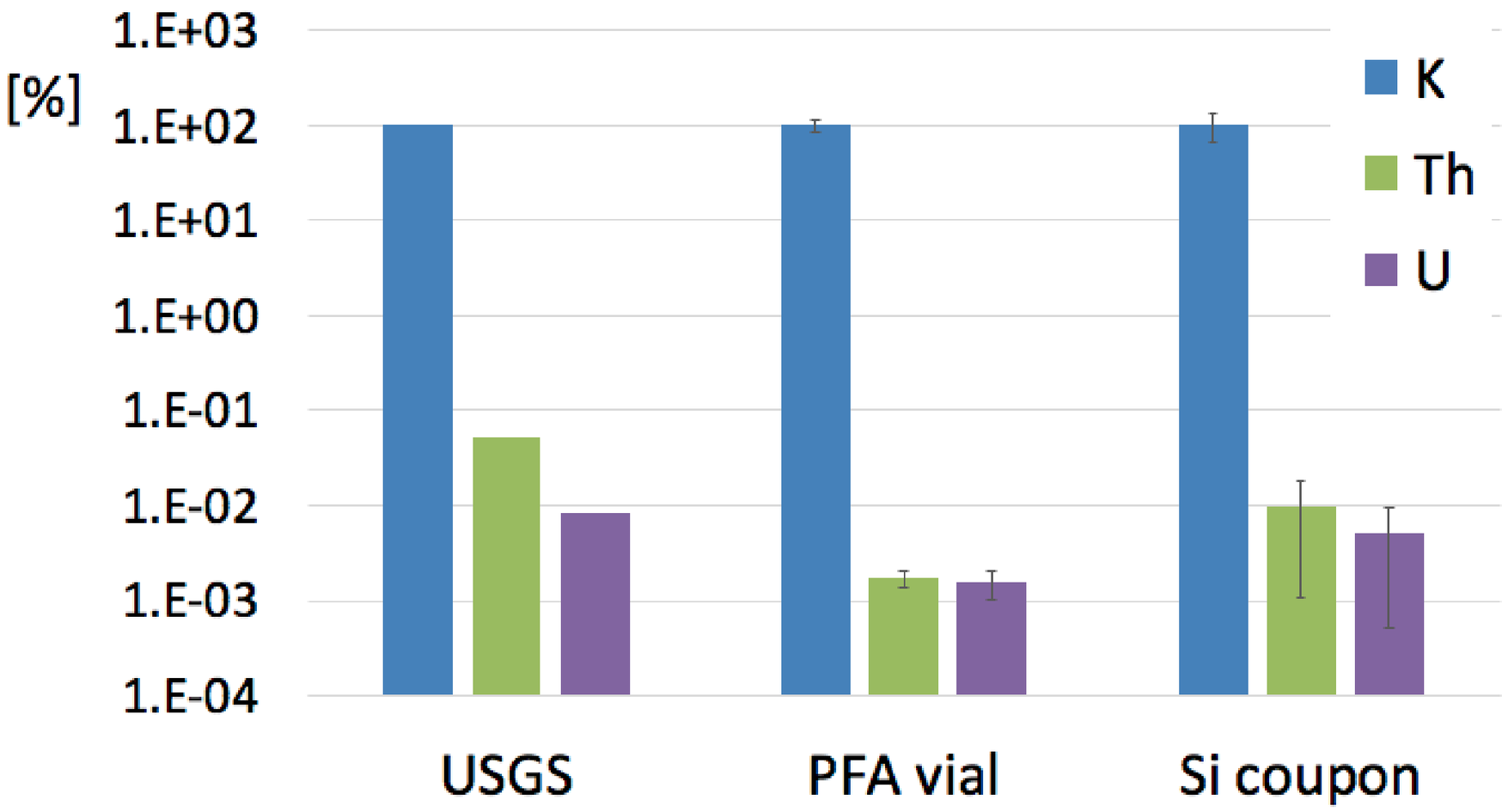
K ~ 99.94 %
Th ~ 0.051%
U ~ 0.009%





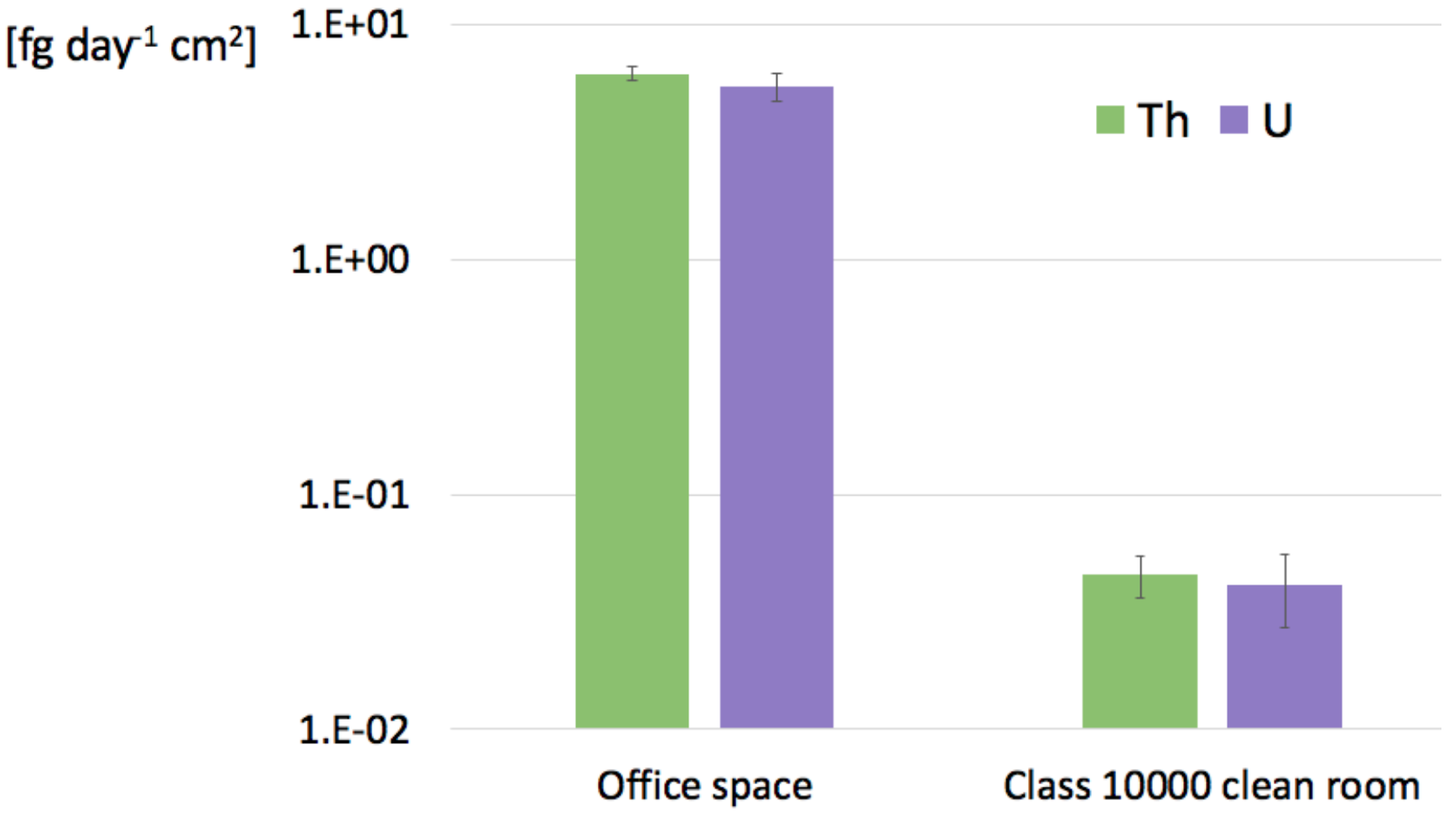
Source: https://pubs.usgs.gov/of/2005/1413/maps.htm

K, Th and U relative content in dust (%)



Room air – Class 10000 clean room comparison

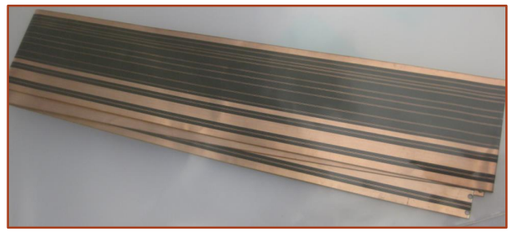
- Accumulation rate scaling of 100X, as expected
- Exposure in a Class 10 area (30 days) : instrumental background level



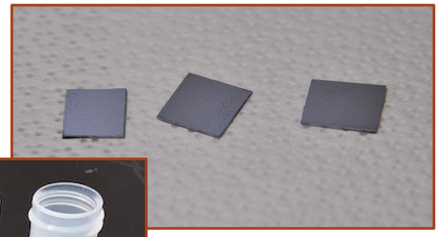
PFA surface, 30 day exposure

Summary

- 2.8 μg of ^{232}Th (→ ~1g dust???) on HDPE block surface
  - Removed with specific cleaning procedure
  - ICP-MS → material assay at ppt levels, not an upper limit



- ~6 ng g^{-1} of ^{238}U measured in a flex cable
  - Leaching + ICP-MS:
    - *Identification*: ^{238}U localized on the surface
    - *Reduction*: 1st 30 sec mild leaching pulled out all ^{238}U surface contamination



- ICP-MS: first direct measurement of dust activity
  - Relative contribution from K, Th and U
  - Deposition rate

In conclusion

- **Surface contamination: a potentially limiting source of background**

How can we support ULB detectors?

- **ICP-MS: a very powerful technique**
  - Rapid, direct **identification and quantitation**
  - Developing procedures to **control and reduce**:
    - Cleaning
    - Working with manufacturer

- **Dust activity measurement**
  - Contribution to contamination from **exposure to dust** (even in clean rooms!)
  - Study of contribution in **significant locations**
    - Valuable for planning **assembly and installation of detectors**
    - Collaboration with underground labs, work in progress for a publication

Thank you

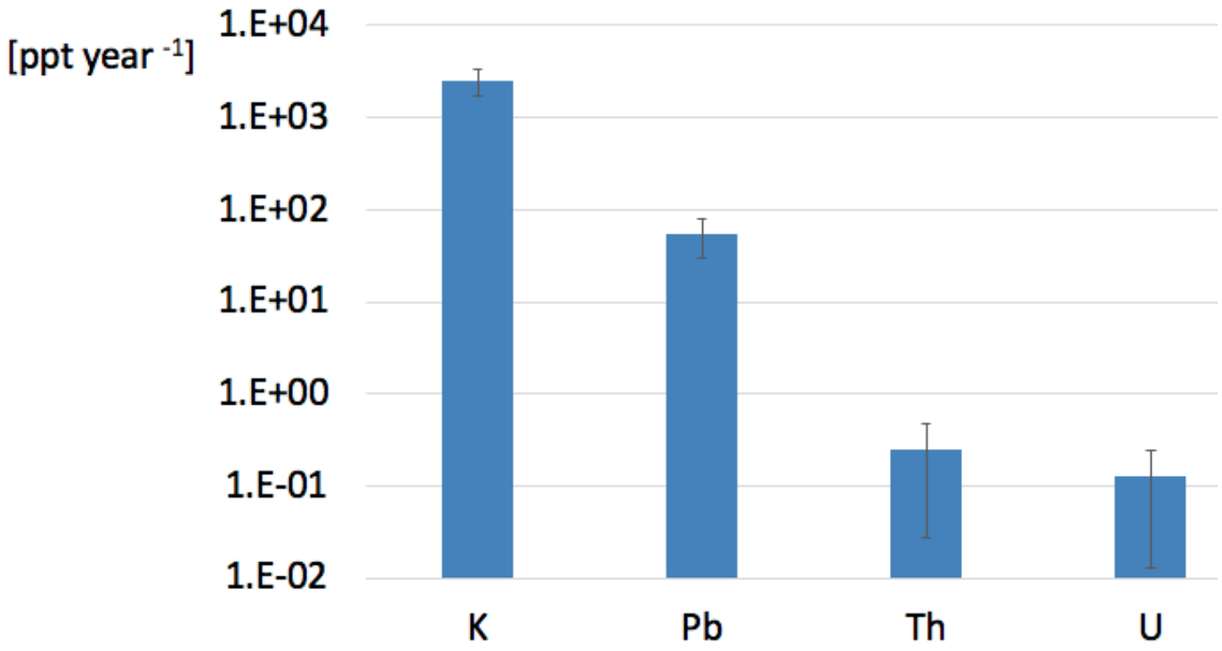
Sonia Alcantar
Khadouja Harouaka

DOE Detector R&D for High Energy Physics (KA-25)

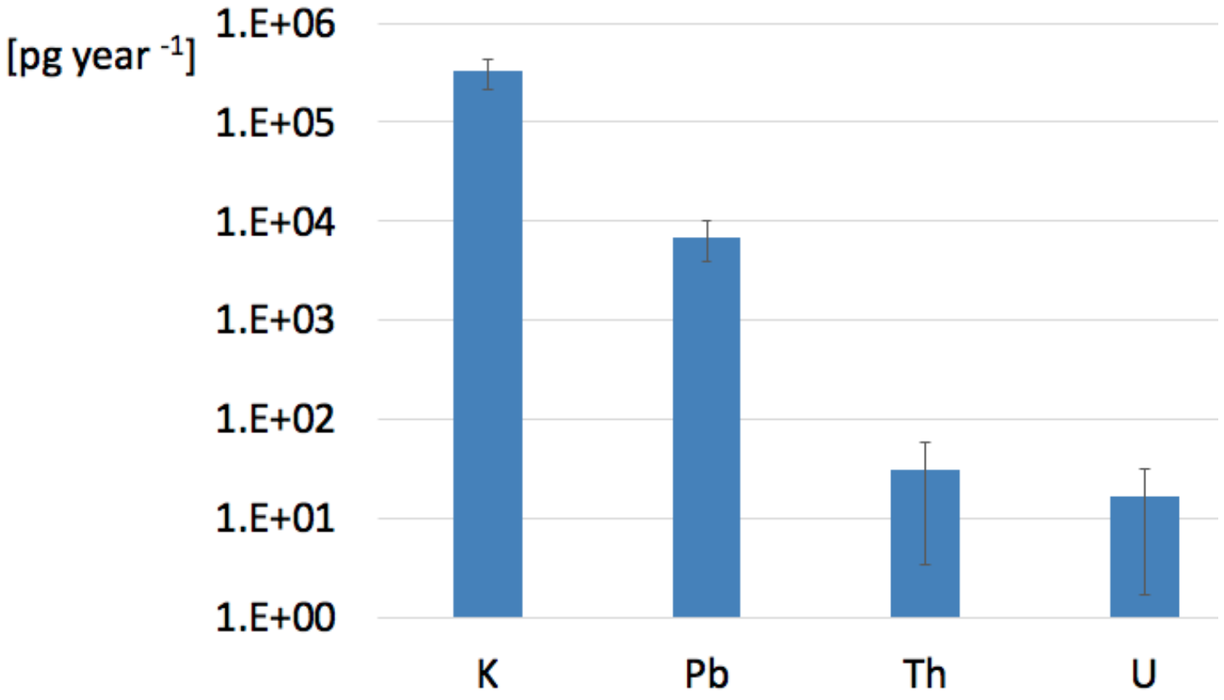
BACK UP SLIDES

1 year exposure in a Class 10000 clean room

Si wafer
Surface ~ 700 cm^2
Thickness 0.77 mm
Density 2.33 g cm^{-3}



https://www.svmi.com/silicon-wafers/300mm-wafers/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1.E+06
1.E+05
1.E+04
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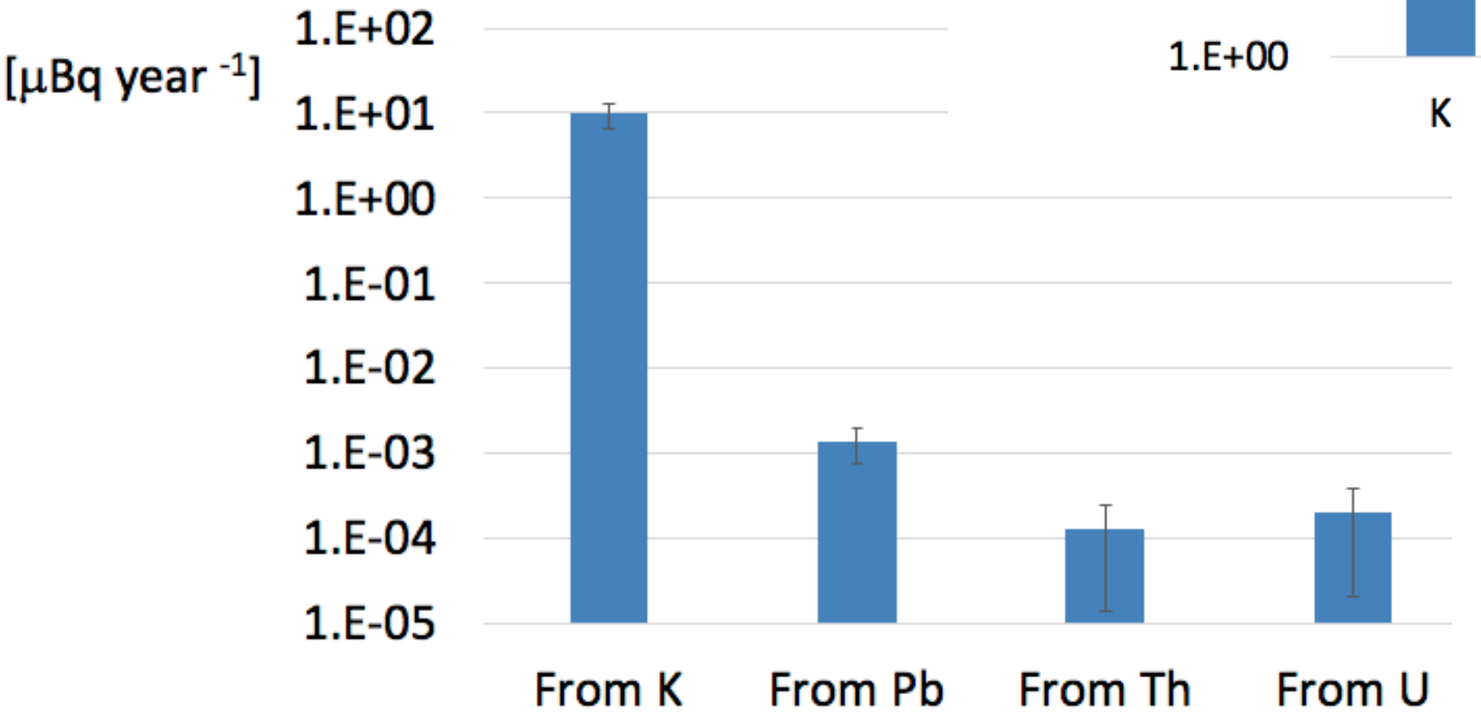
1.E+02
1.E+01
1.E+00
K
Pb
Th
U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From K
From Pb
From Th
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