CLEANROOM AND MONITORING IN UNDERGROUND LABORATORIES

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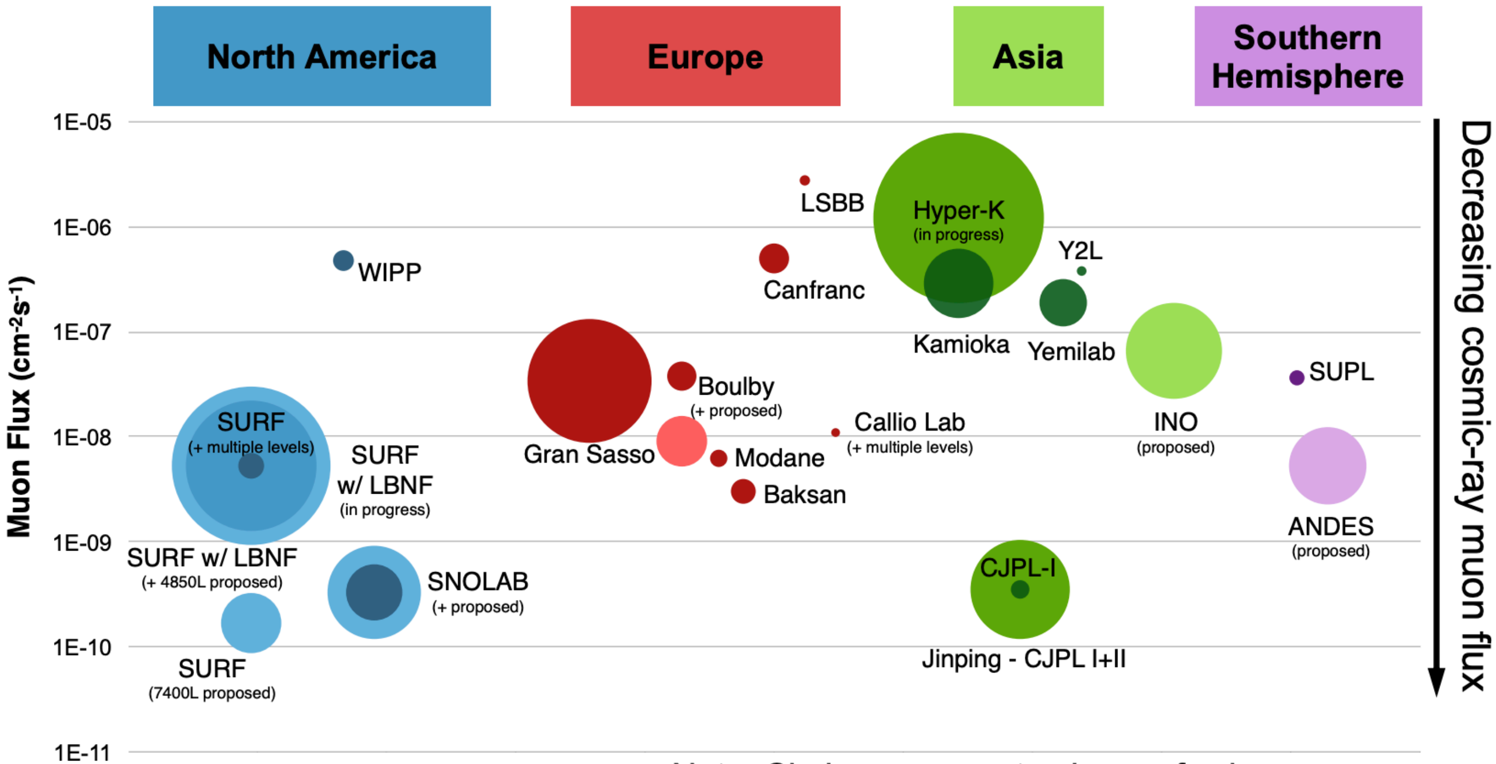
27.01.2024

WORLDWIDE UNDERGROUND LABORATORIES

Underground facilities provide unique environments for astroparticle and multidisciplinary research with the main feature to be the overburden protection from cosmic-ray muons

From J. Heise - TAUP2023



Note: Circles represent volume of science space

WHAT BACKGROUND?

Cosmic rays & cosmogenic activation of detector/shielding materials

Move underground material production and purification (EF copper, liquid noble gas purification and detector fabrication)

Natural radioactivity (^{238}U, ^{232}Th, ^{40}K): γ, e^-, n, α, β

Material screening and assay capabilities
Advanced cleaning techniques
Radon free air supplying system

From S.Sekula - TAUP 2023

radiopurity.org

A community material assay database

- A system for record-keeping
- A place for sharing assay results

Every entry in radiopurity.org is an investment in disseminating information and building cross-calibration capabilities

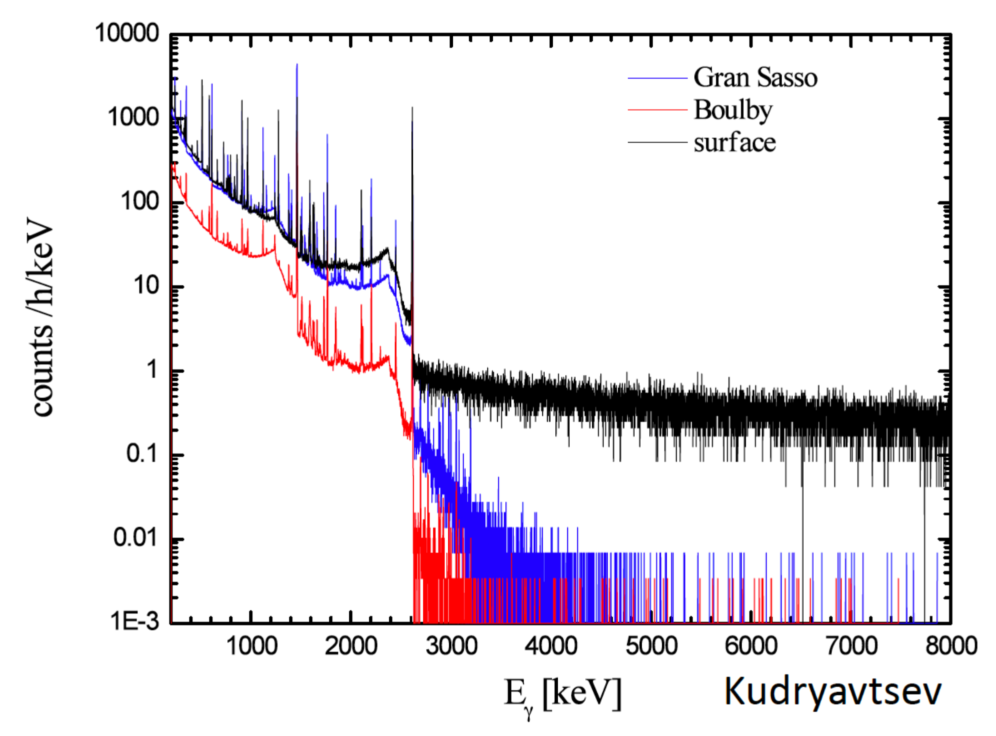
BACKGROUNDS FROM THE ENVIRONMENT DOMINATE UNDERGROUND

Reduction in γ-ray background at higher

energies from c.r. and neutron reduction

Below 3.5MeV dependent on local geology

and rock material



ENVIRONMENTAL CONTROL

Expanding the environmental background measurement capabilities at underground laboratories, performing systematic surveys of the background radiation

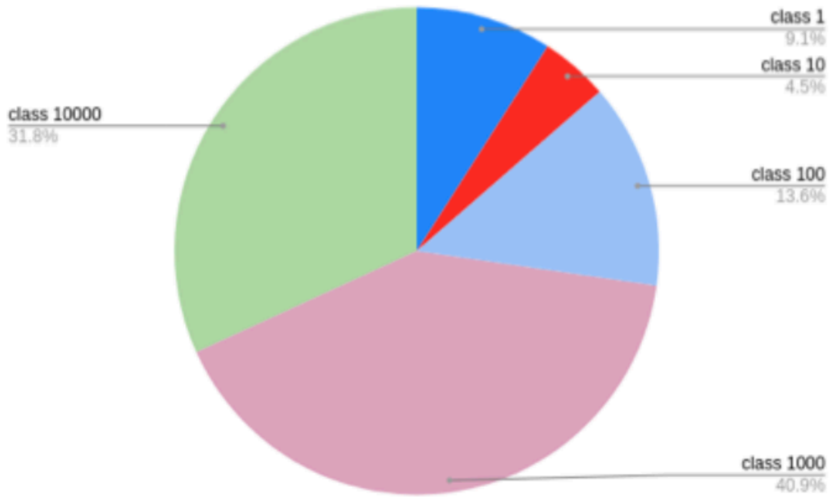
- **Neutron and gamma radiation measurements and spectrometry**
- **Dedicated radon monitoring**
- **Characterization of vibration and electrical noise**
- **Dust background monitoring**

arXiv:2209.07588 [hep-ex]

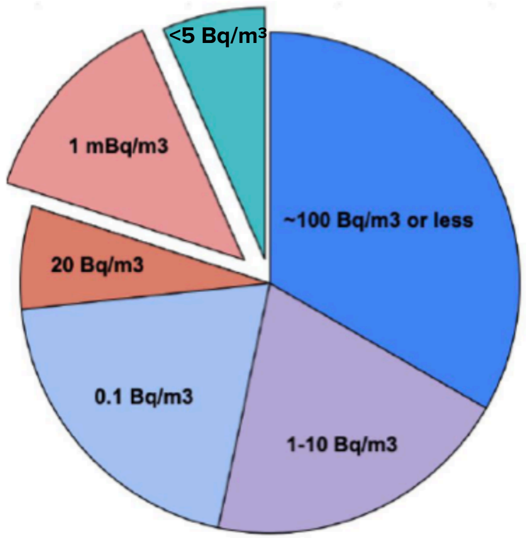
2021 SNOWMASS REPORT

"SUPPORTING CAPABILITIES FOR UNDERGROUND FACILITIES"

Increasing demand for clean room with 1-10000 class, and radon-reduced clean room is also demand for current and future experiments



Cleanroom class requested by future UG experiments

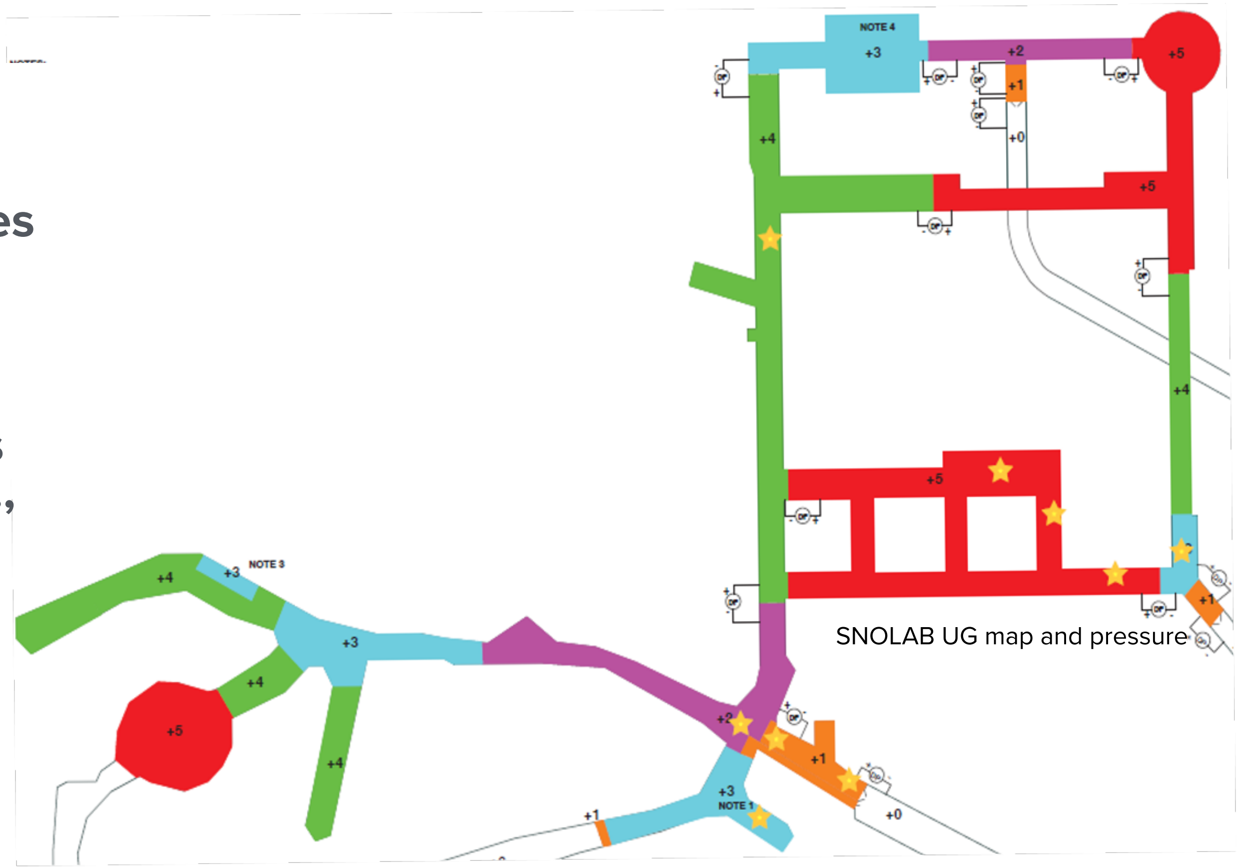


Radon reduced spaces need for future experiments

MONITORING CLEANLINESS

- Ventilation and particulate exchange
- Pressure gauge for different zones

- Commercial particulate devices
- X-ray fluorescence (XRF) analysis for Th and U proxy elements (e.g., Ca and Fe)
- Optical and fluorescence microscopy analysis
- Backgrounds predicted based on dust fallout models and assumed composition



SNOLAB UG map and pressure

DUST PARTICULATE:
A SIGNIFICANT CONTRIBUTION TO MATERIAL SURFACE CONTAMINATION

High purity materials

- Concerning (even in cleanrooms!)

Ongoing efforts to estimate backgrounds from dust, mainly from

- Fallout models
- Assumed dust composition

Dust in cleanrooms = local soil ← Not necessarily!

- Generated by handled materials and ongoing activities

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DIRECT METHOD FOR QUANTITATIVE ANALYSIS


Nuclear Inst. and Methods in Physics Research, A 994 (2021) 165051

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Direct method for the quantitative analysis of surface contamination on ultra-low background materials from exposure to dust

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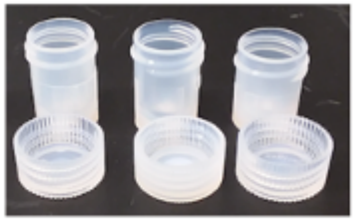

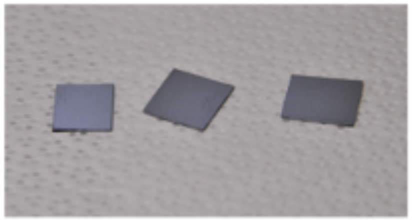

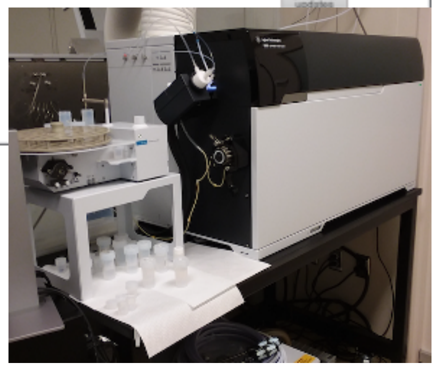

Exposure of dust collection media

Dissolution of deposited contamination

Analysis via ICP-MS (long-lived radionuclides and stable elements) - Triple quadrupole Inductively Coupled Plasma Mass Spectrometer (ICP-MS)

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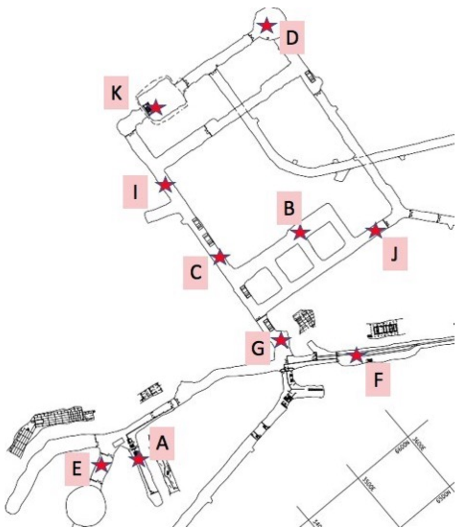
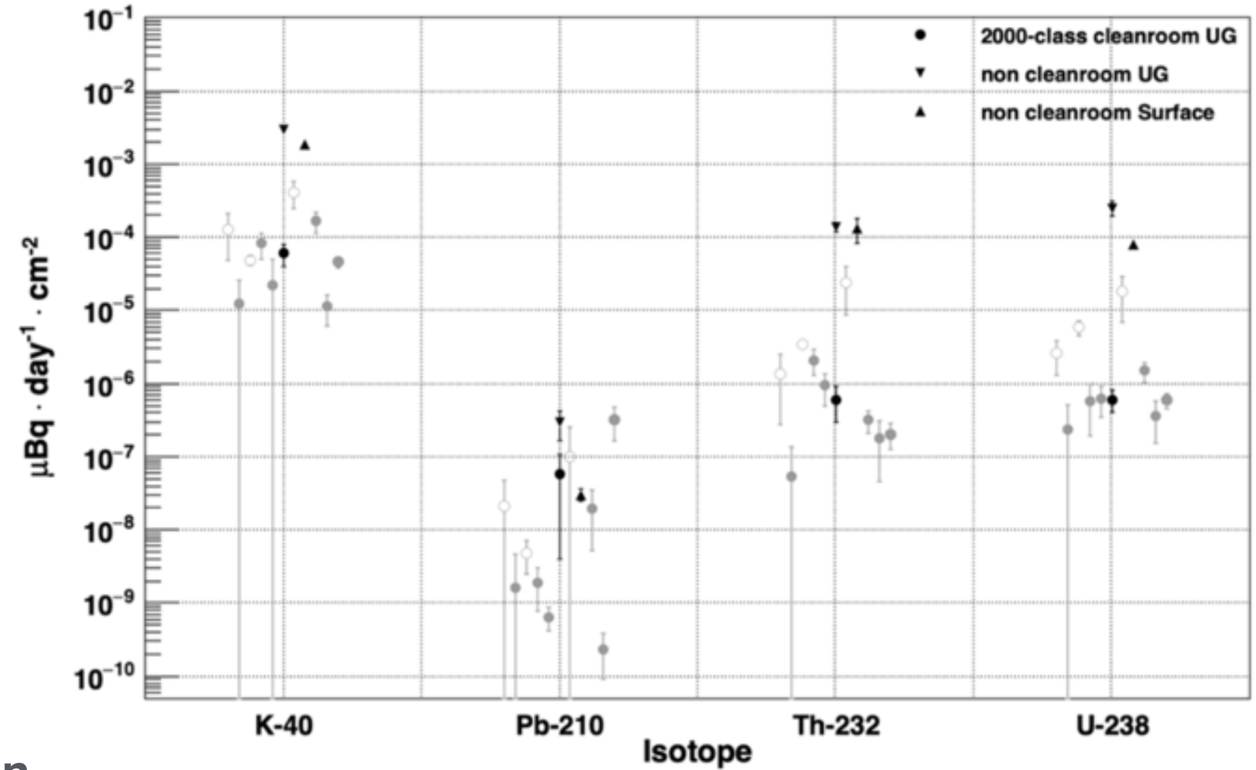
DUST COLLECTION AT SNOLAB





9 underground cleanroom locations
1 underground non-cleanroom location
1 non-cleanroom location in the surface building
August 2018 (≈ 40-day exposure, including 20 days of mine shutdown)

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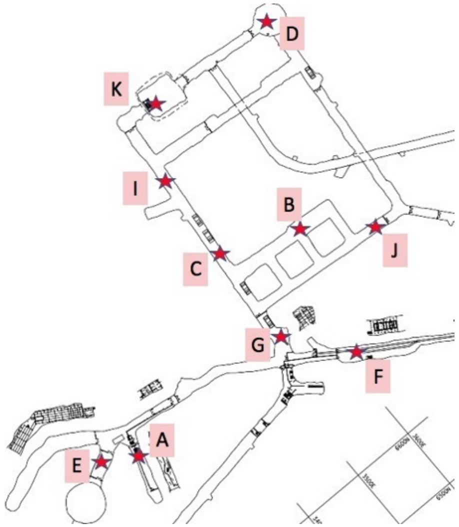
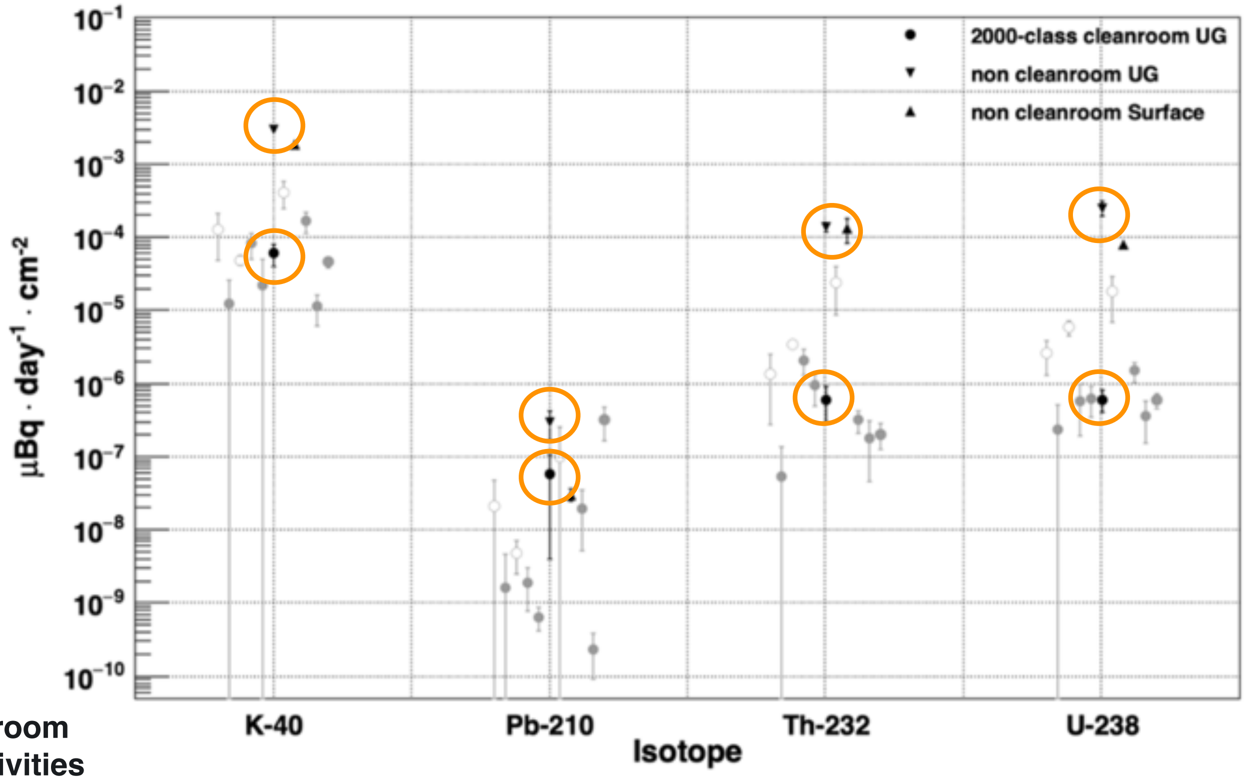
DUST COLLECTION AT SNOLAB



Dust fall-out 2 orders lower in 2000 Class room



	Cleanrooms* [mBq·day^{-1}·cm^{-2}]
K-40	(5.7 ± 5.9)x10^{-5}
Pb-210	(5.7 ± 13)x10^{-8}
Th-232	(6.3 ± 7.8)x10^{-7}
U-238	(6.5 ± 4.4)x10^{-7}

*** Excluding 3 cleanroom locations where activities may have triggered higher accumulation rates (empty circle markers)**

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XRF-BASED METHOD FOR DUST FALLOUT MONITORING

System of witness plates at SNOLAB

X-Ray Fluorescence (XRF) analysis

- Surrogate elements (i.e., Fe and Ca)

Assumption: rock/concrete sole dust source

Deposition rates for other elements (e.g., Th and U) estimated based on relative content in rock/concrete

Element	Rock (avg)	Concrete
K	1.0×10^4	1.6×10^4
Ca	3.6×10^4	1.0×10^5
Fe	6.5×10^4	2.6×10^4
Pb	10,4	13,9
Th	5,4	13,1
U	1,2	2,4

Composition of rock and concrete at the SNOLAB site*

* From: *I.T Lawson, "Analysis of Rock Samples from the New Laboratory", STR-2007-003 SNOLAB Technical Report 2007*

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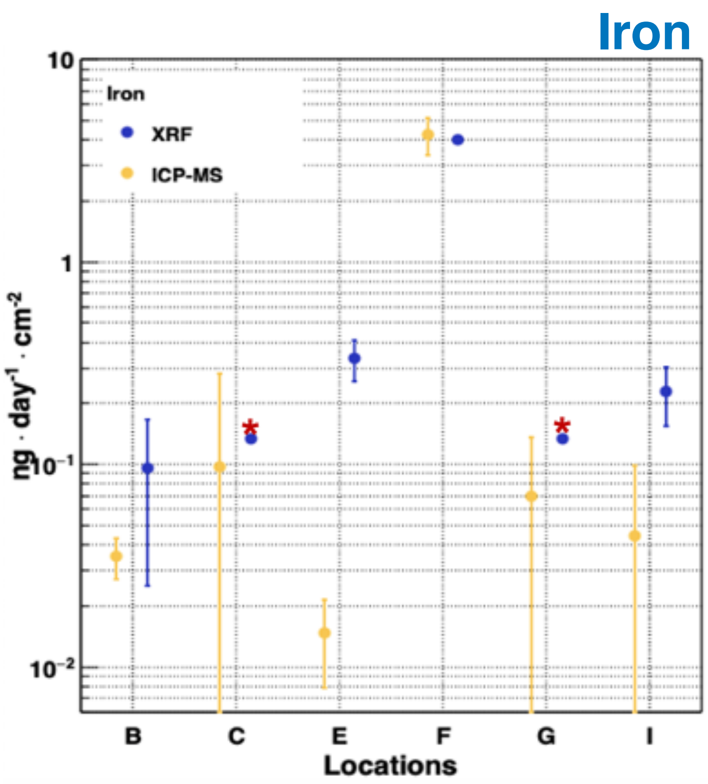
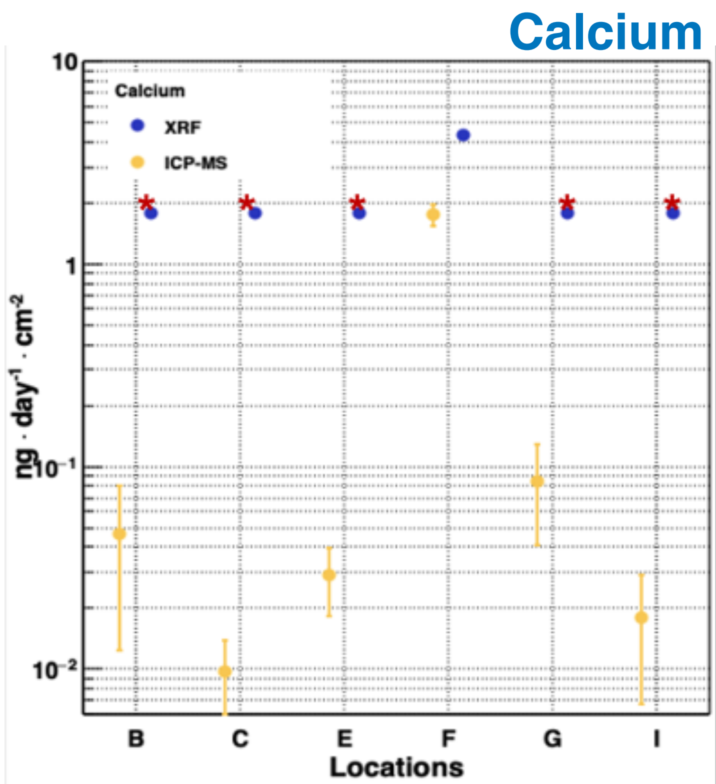
ICP-MS AND XRF DATA COMPARISON





Same locations
Same exposure time
*Upper limits

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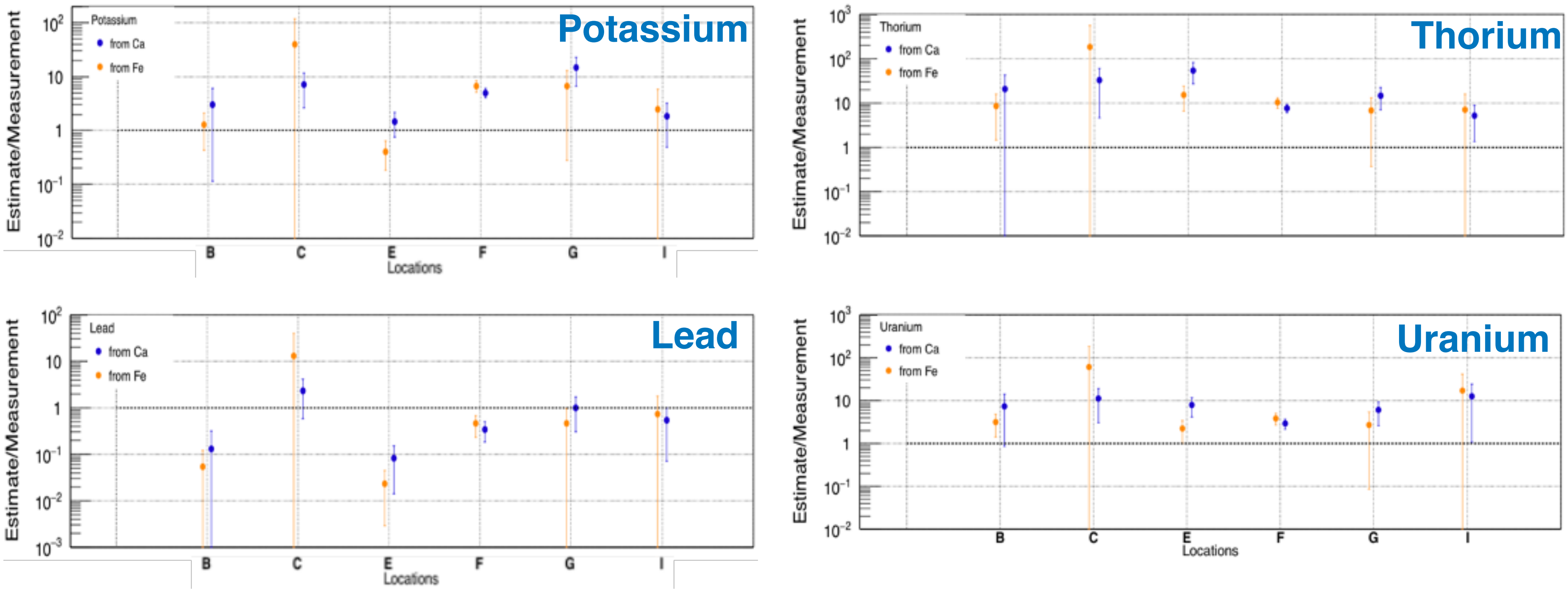
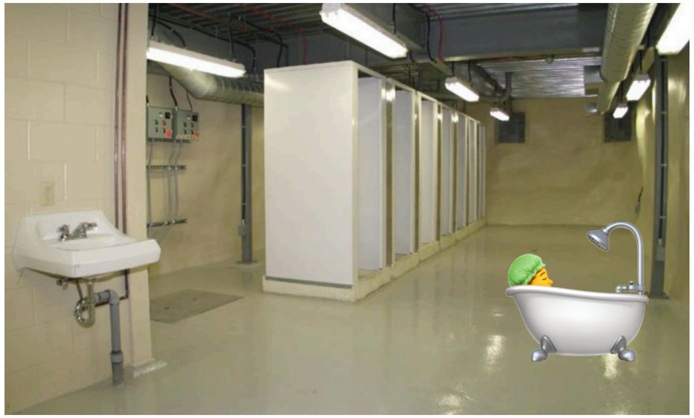
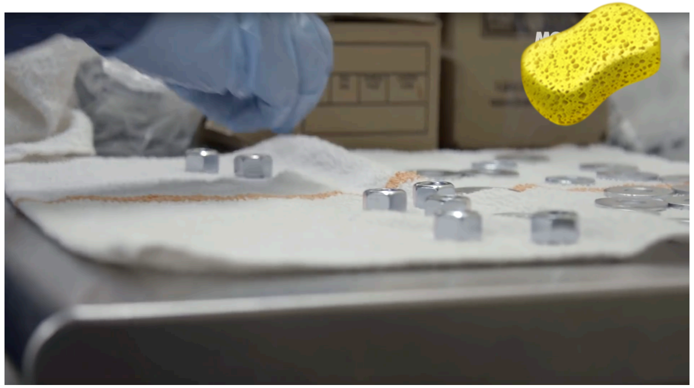
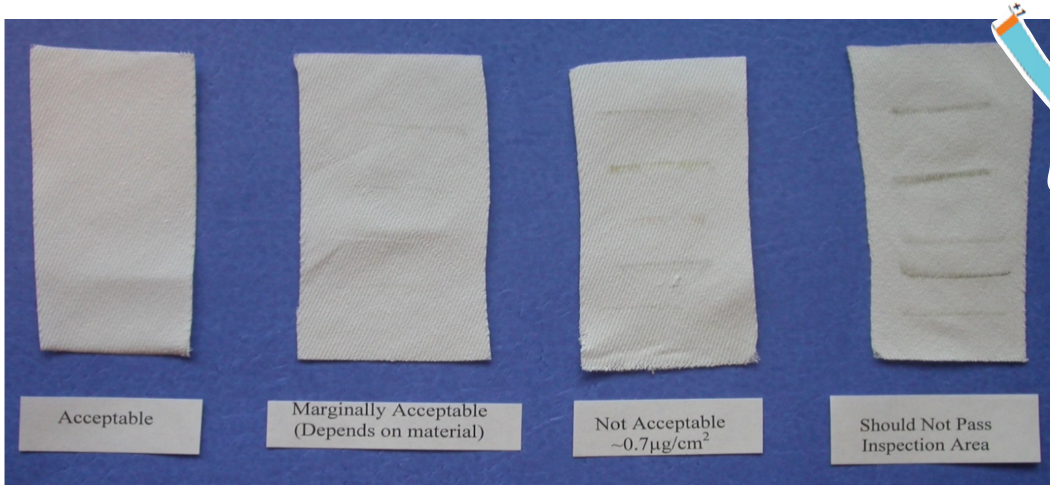
ESTIMATED/MEASURED RATIOS OF FALLOUT RATES

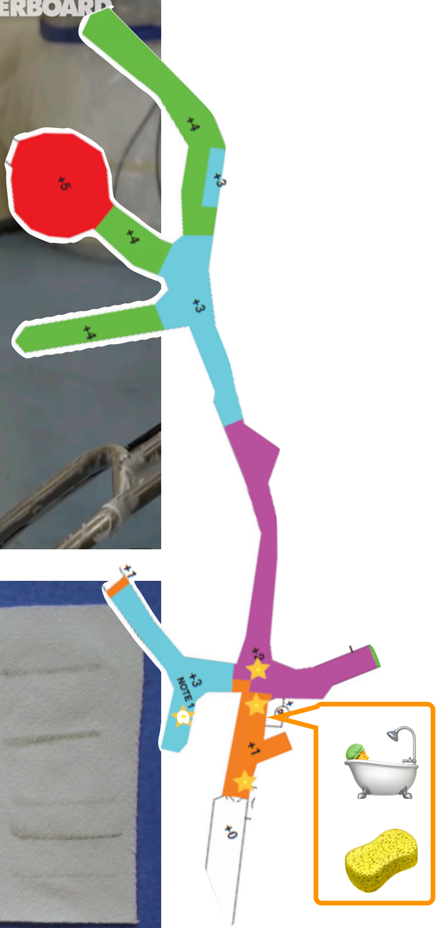


SNOLAB EXAMPLE









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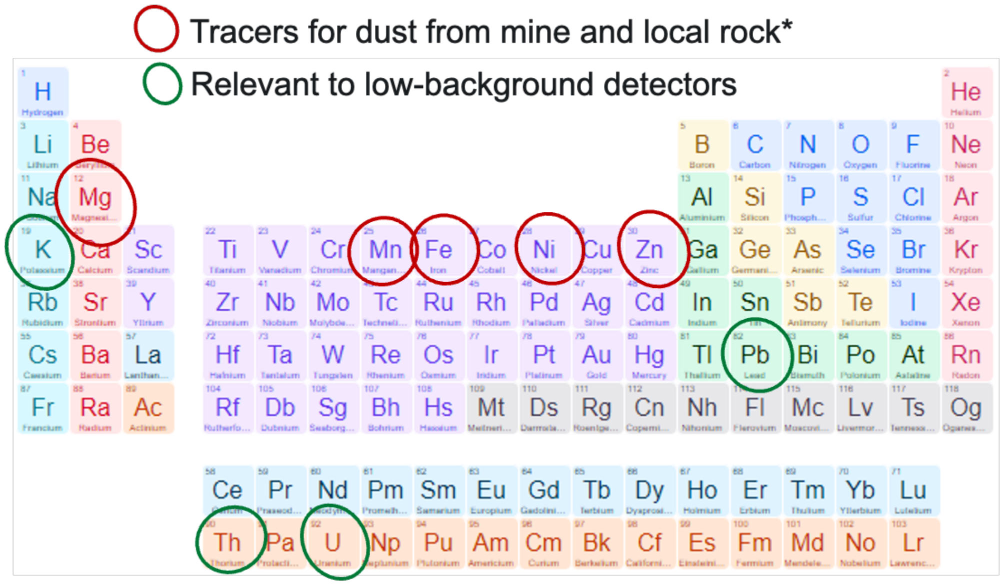
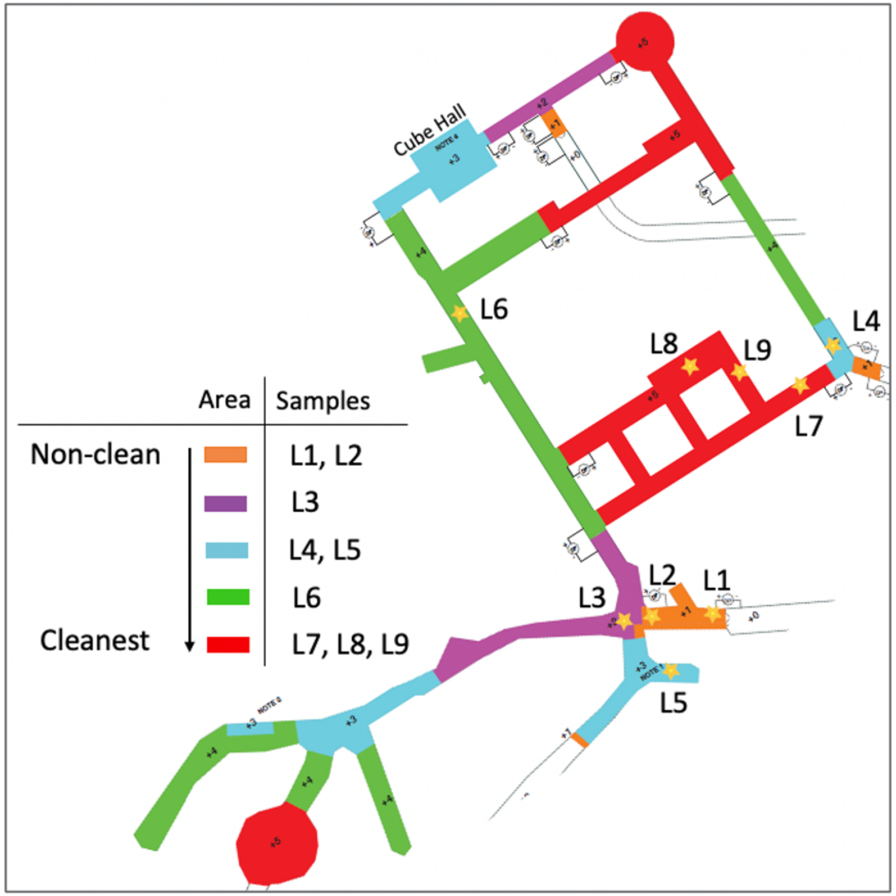
2019 DUST COLLECTION
SNOLAB MITIGATION PROCEDURES EVALUATION

Monitoring a period of increased activity compared to previous collection - Aug 2018





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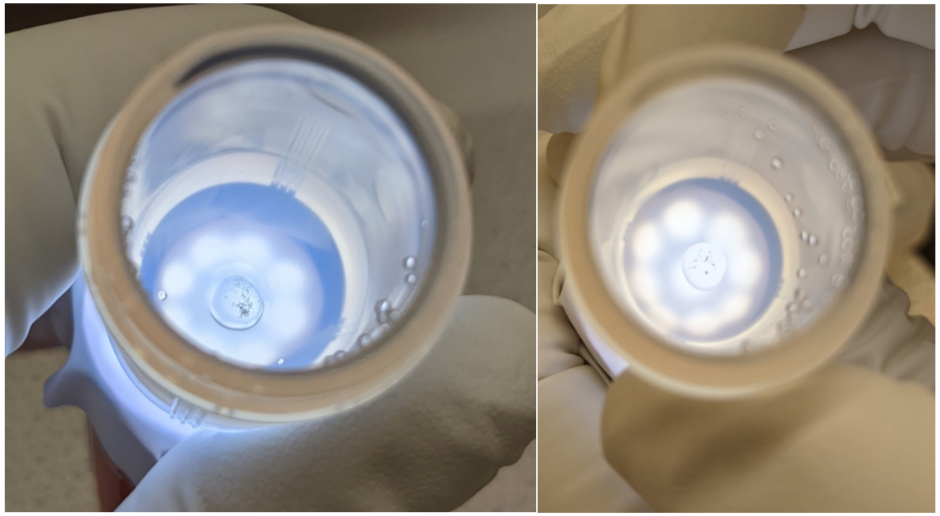
2019 DUST COLLECTION
SNOLAB MITIGATION PROCEDURES EVALUATION

Monitoring a period of increased activity compared to previous collection - Aug 2018

Dirty Carwash | Clean Carwash



- Visible particulate found in several samples
- Analytical procedure adjusted
  - Dissolution with strong acid at high temperature followed by acid boil off and reconstitution in diluted acid
  - In some of the samples, a fraction of the particulate remained undissolved
  - Solution transferred, particulate excluded from ICP-MS analysis

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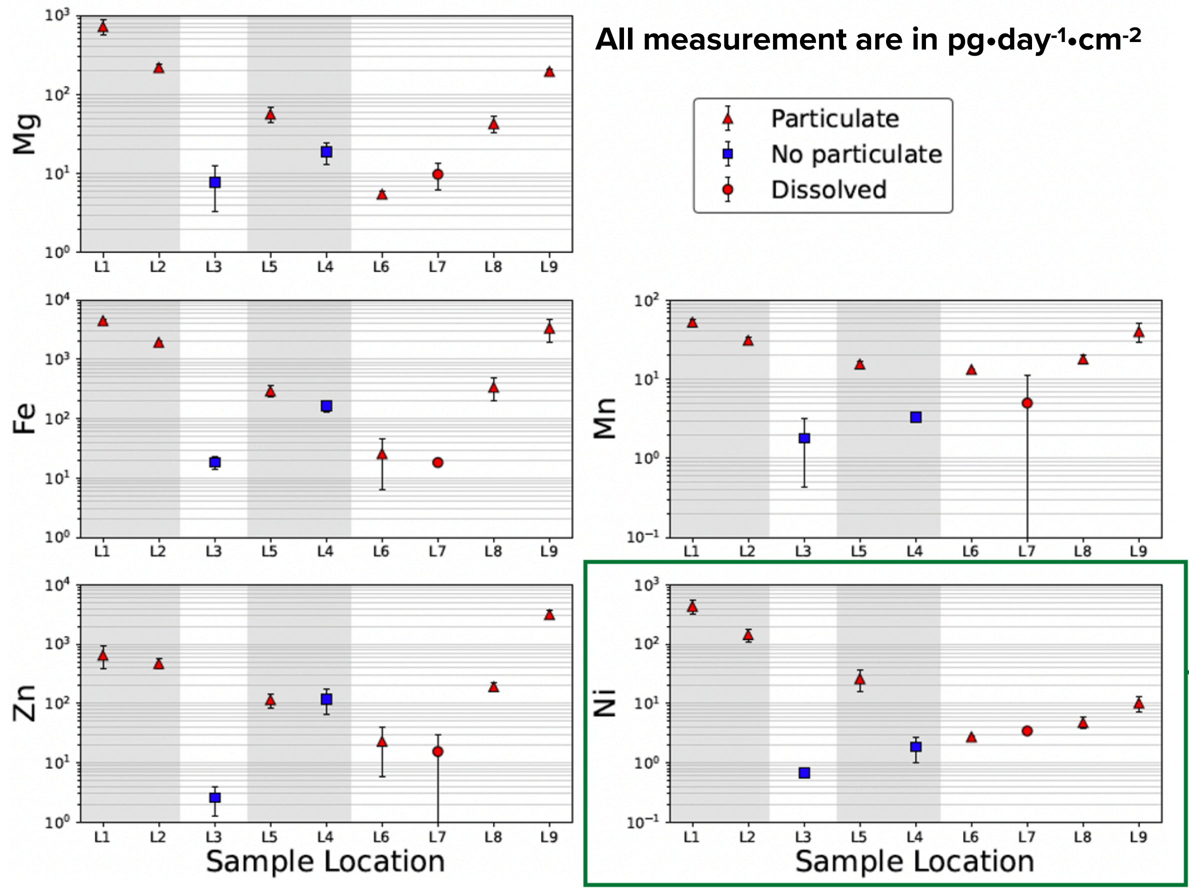
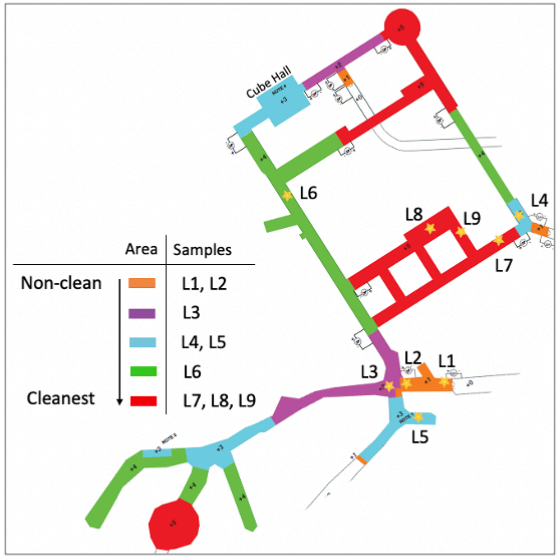
SNOLAB MINE DUST MITIGATION

From M.L.DiVacri - TAUP2023

All measurement are in pg•day^{-1}•cm^{-2}





Mine dust tracer

Shaded areas refer to locations that are not maintained at cleanroom levels

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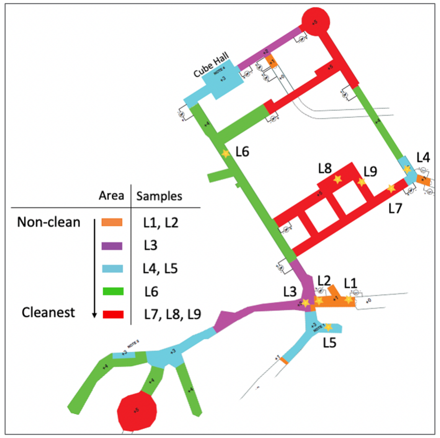
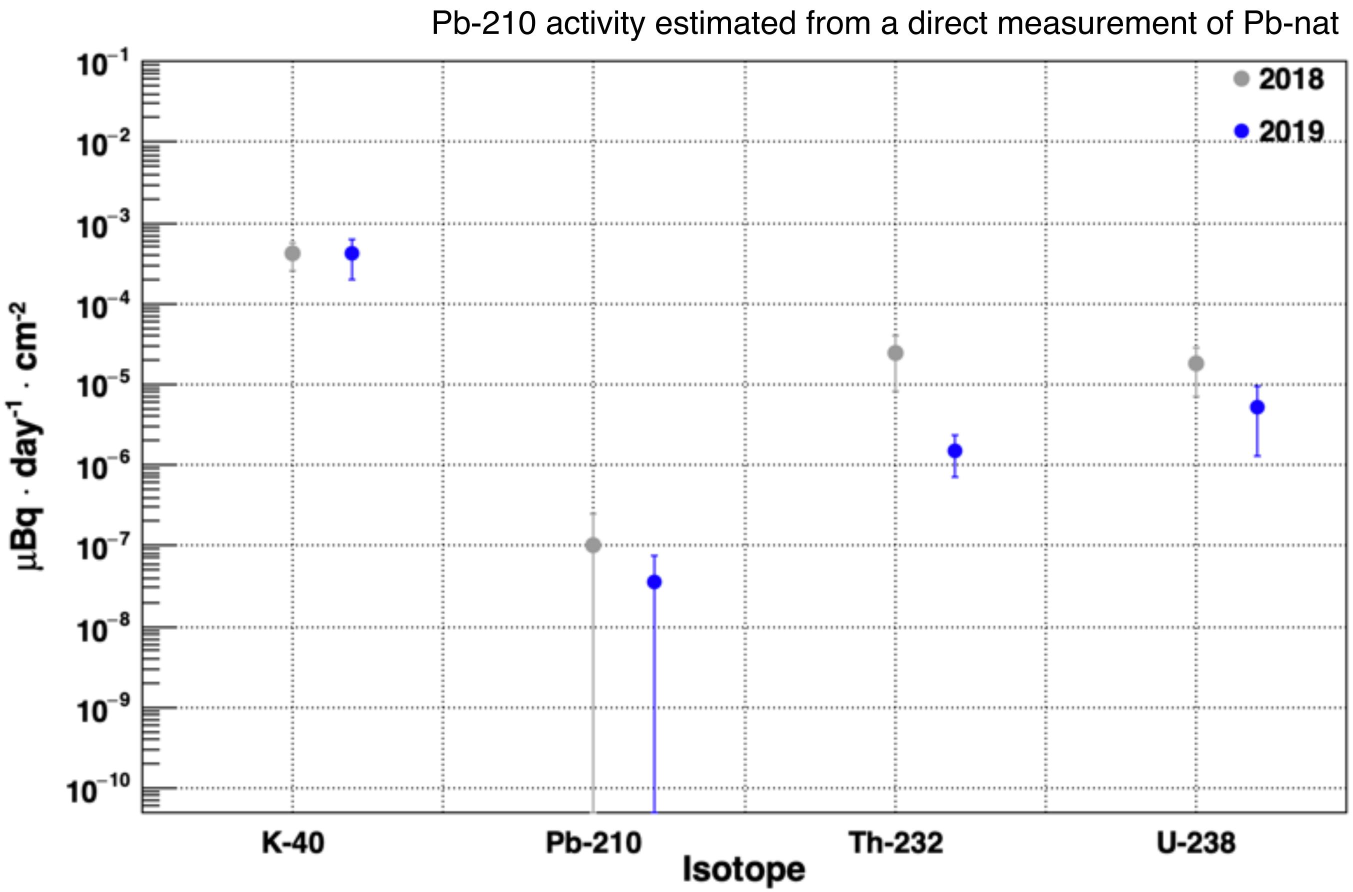
SNOLAB UNDERGROUND CHEM LAB

Effect of mitigation in place at the underground chemistry laboratory

2018: no door requirement

2019: door requirement in place





- **Cleanrooms are in high demand for future experiments and R&D projects.**
- **Environmental control and monitoring is critical.**
- **Dust backgrounds in clean laboratories are strongly affected by ongoing activities and handled materials.**