Background radiation measurements for underground experiments at the University of the Western Cape(UWC) and measurements for Paul

Robbie Lindsay(UWC), Enkosi Ngwadla(UWC), Lumkile Msebi(UWC) and JJ van Zyl (Stellenbosch)

Contents

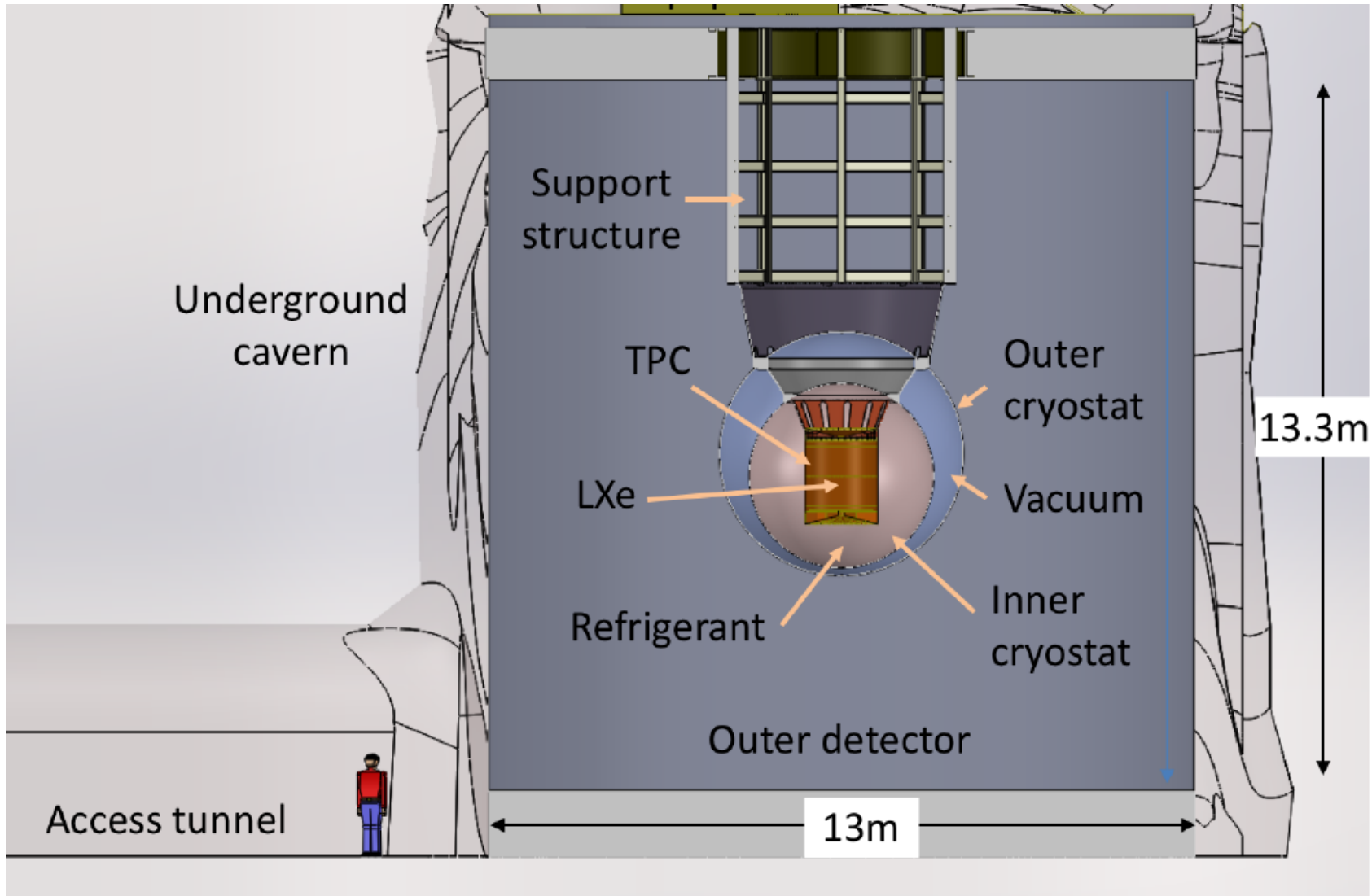
- History of interest in underground LABS
- UWC
- nEXO
- Background issues
  - Muons
  - Natural radioactivity in wall
  - Natural radioactivity in materials.
- Measurements in Tunnel
- Enkosi Ngwada – measurements at SNOLAB

nEXO

UWC physics department joined nEXO in 2020

nEXO is a world-wide effort, including, for the time being, 9 Countries, 33 institutions, 186 collaborators

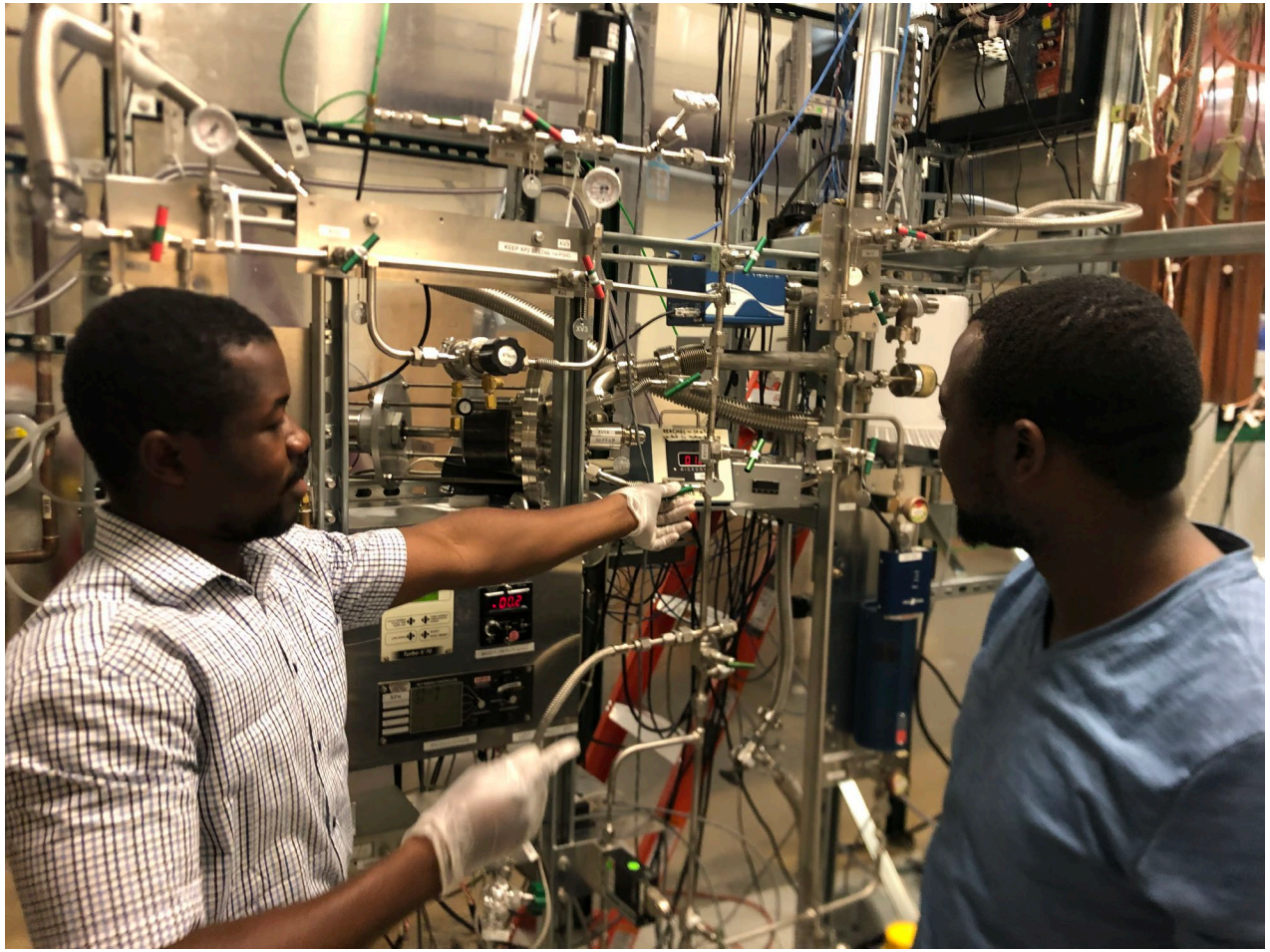
NEXO experiment



The UWC associates involved in the nEXO experiment are from left Goitse Ramonnye, receiving her MSc in absentia this week, Enkosi Ngwadla (MSc student), Jespere Ondze (PhD student), research leader Prof Smarajit Triambak, Professor Robbie Lindsay *[kneeling]* - and Odwa Tyuka (MSc student).

nEXO – large multi country collaboration
Many benefits to UWC and SA such as:

- Vital to collaborate with world experts – collaboration meetings etc
- 2020 – UWC joined the collaboration
  - Students visit to Stanford
  - Enkosi Ngwadla on 3 month trip to Canada supported by Art McDonald foundation
- Smarajit Triambak – Xenon spectroscopy
- Radon measurements – clean room expertise here
- Radon measurement expertise – NB for mines in SA.



Jespere and Odwa at Stanford

Enkosi at Snolab

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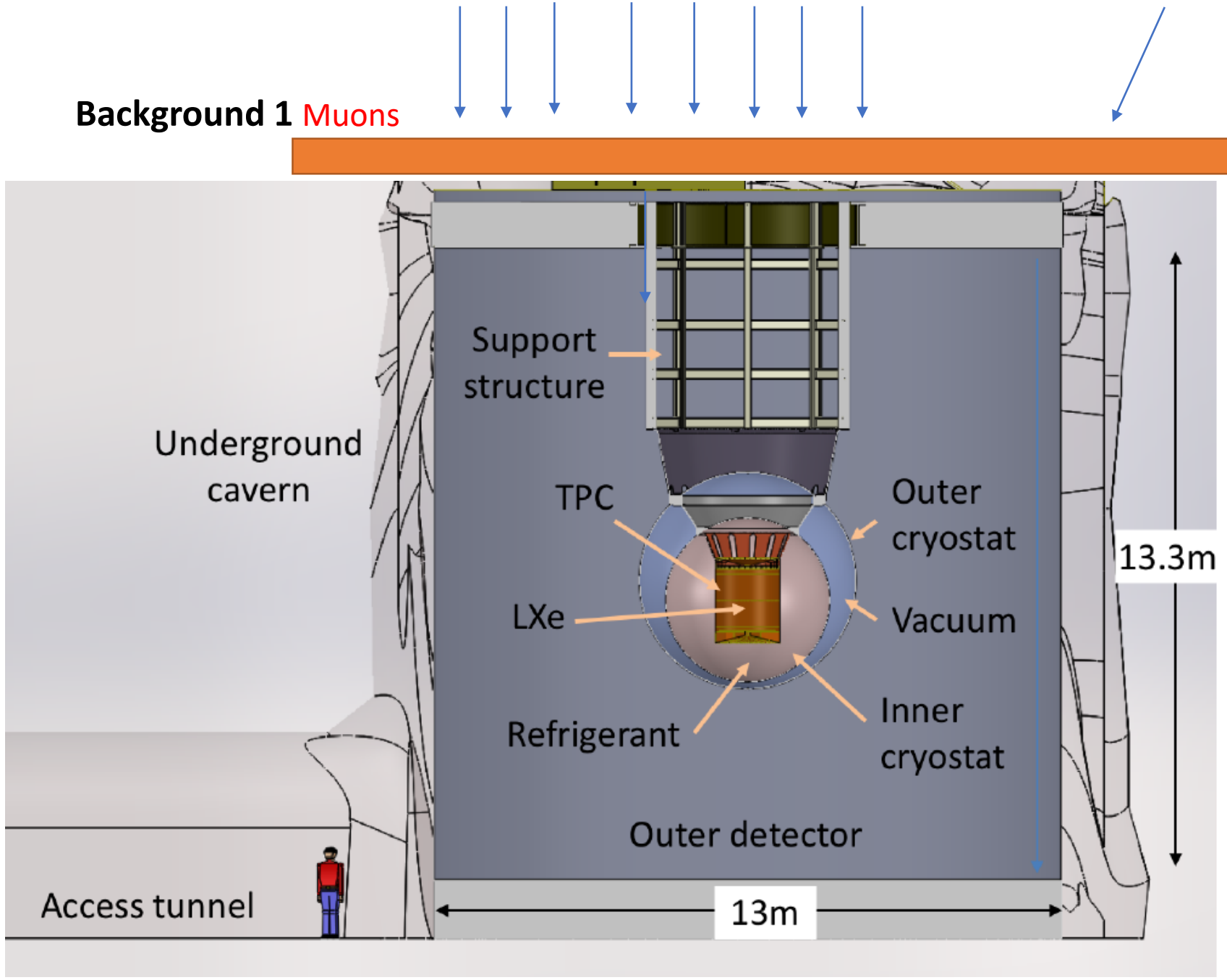
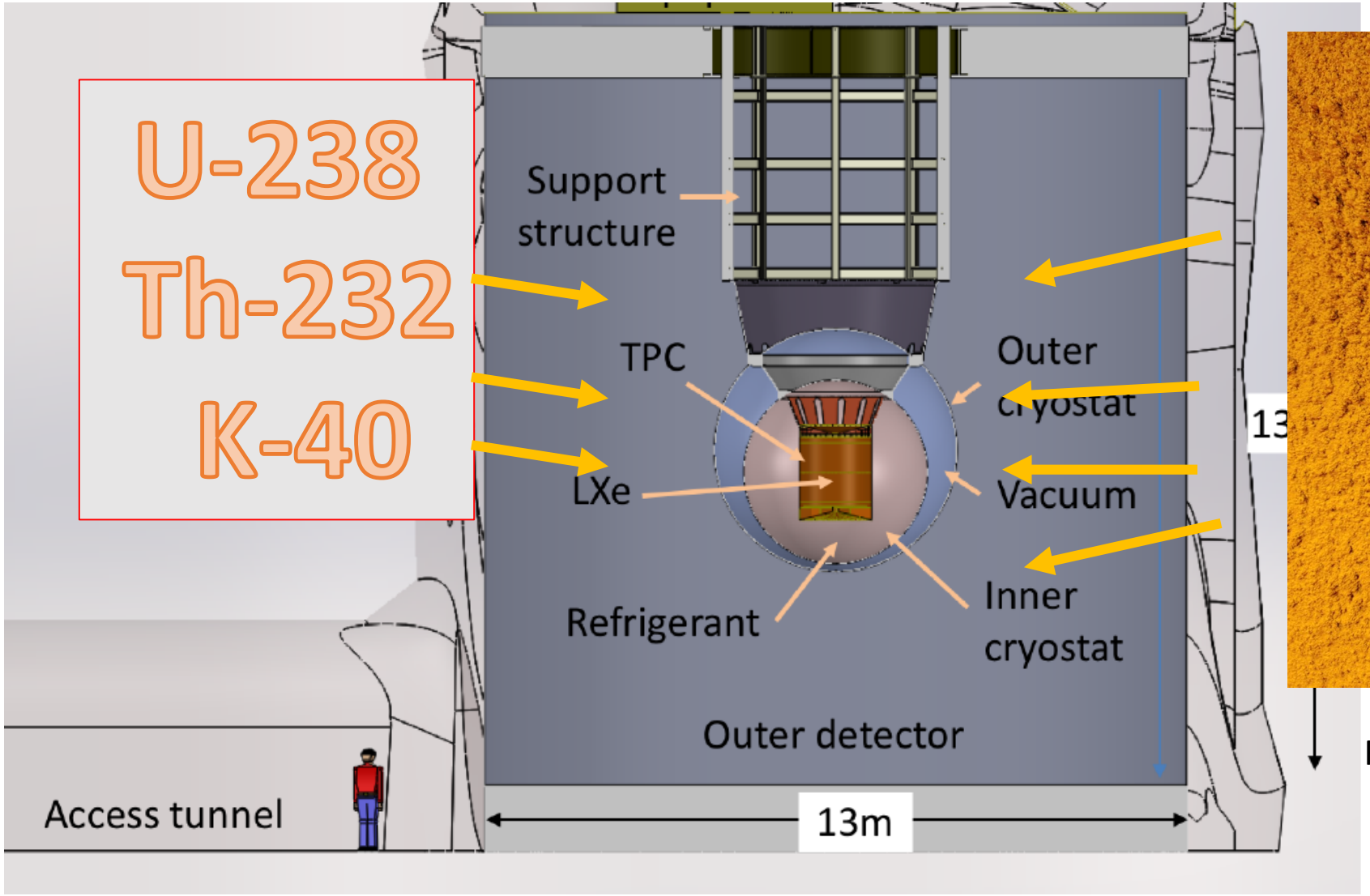
Meet Lenny Susskind

Visit SNOLAB

Background 1 Muons

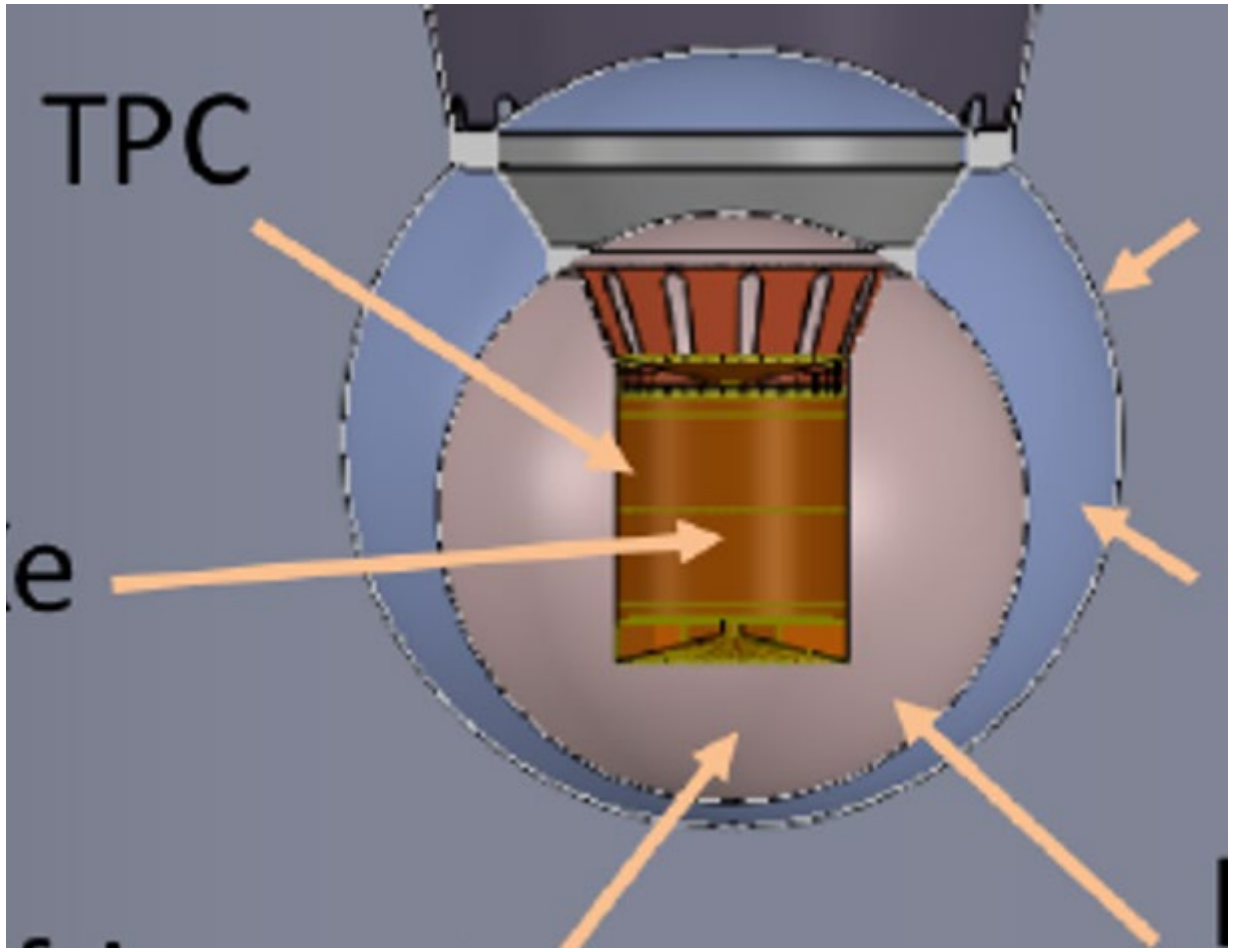


Background 2 - from surrounding Rocks -



Radon barriers on walls and floor

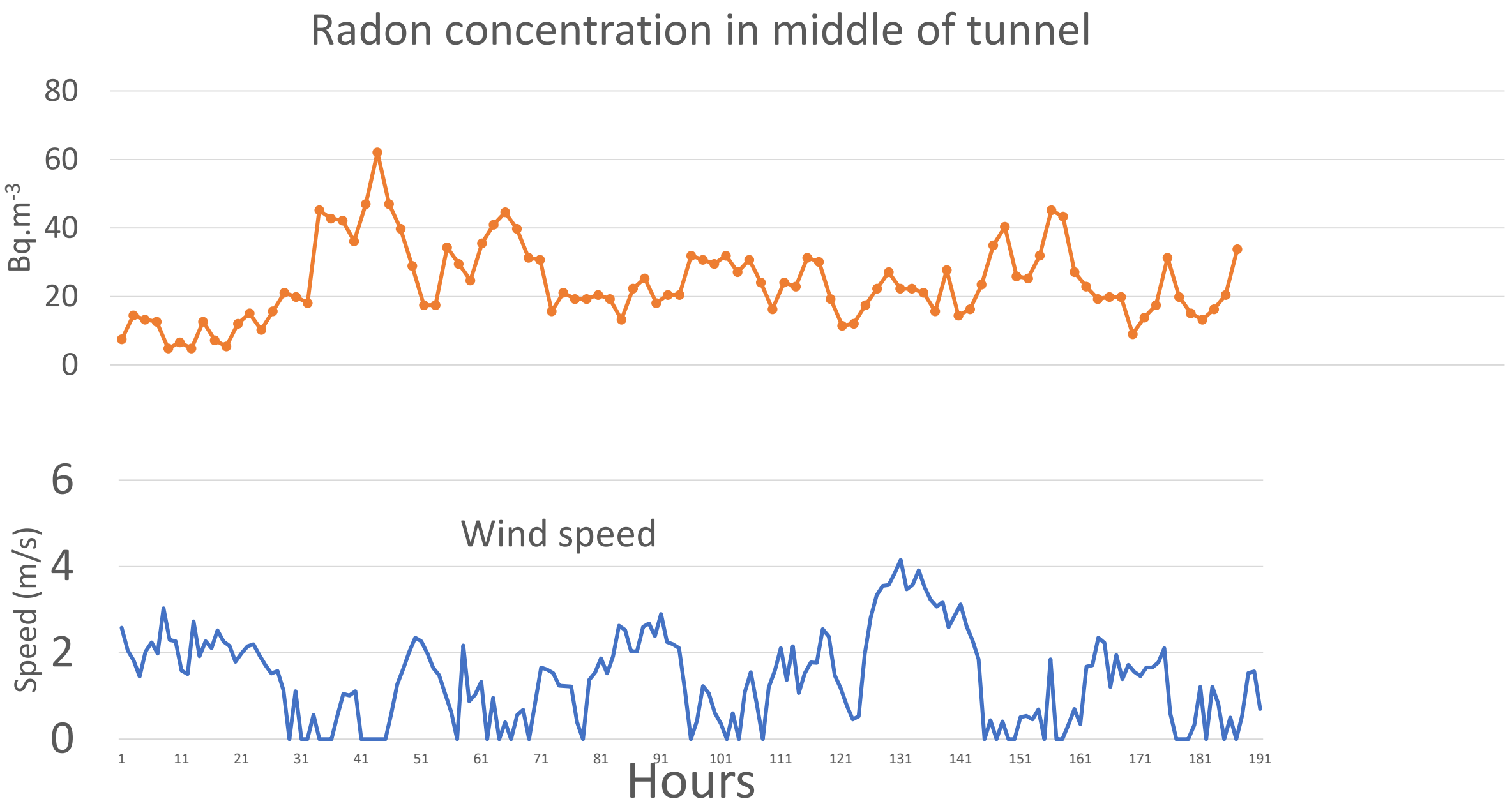
Background 3 - Radon from *INTERNAL* materials – *What Enkosi is doing*



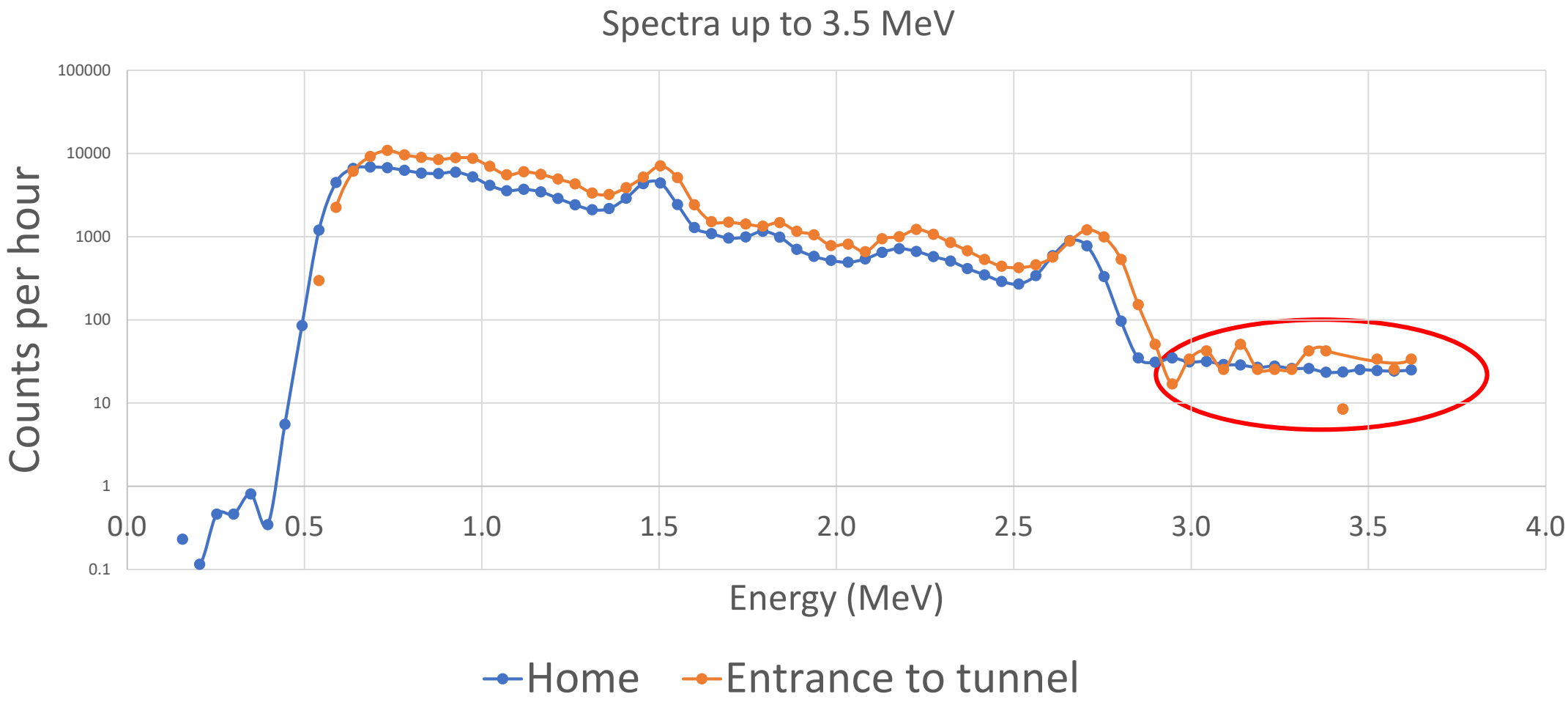
Measurements in the tunnel

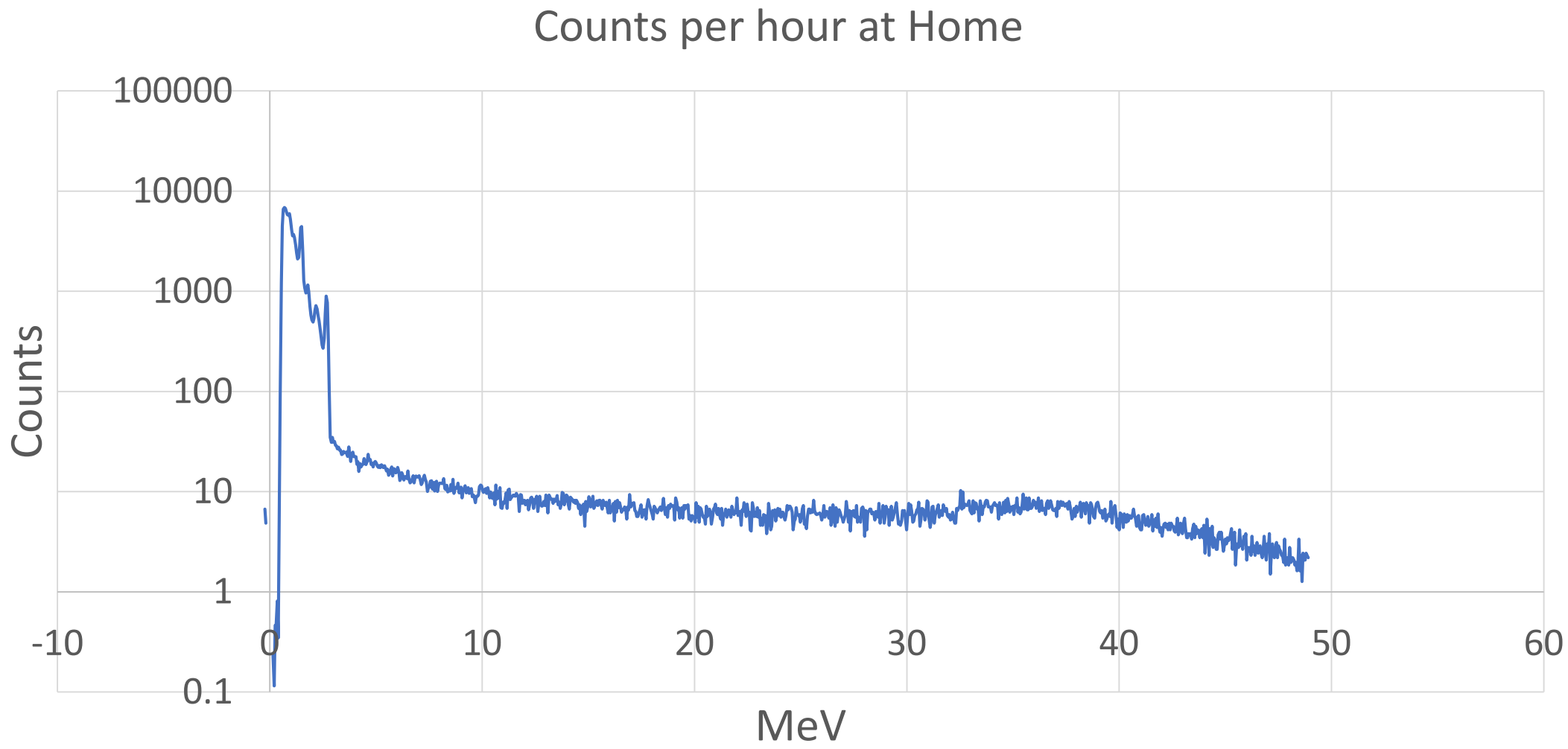
- Radon
  - Quantity – ventilation etc.
  - Exhalation

- Muons from Gammas


Radon concentration in middle of tunnel
80
60
40
20
0
Bq.m-3
Wind speed
6
4
2
0
Speed (m/s)
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141
151
161
171
181
191
Hours

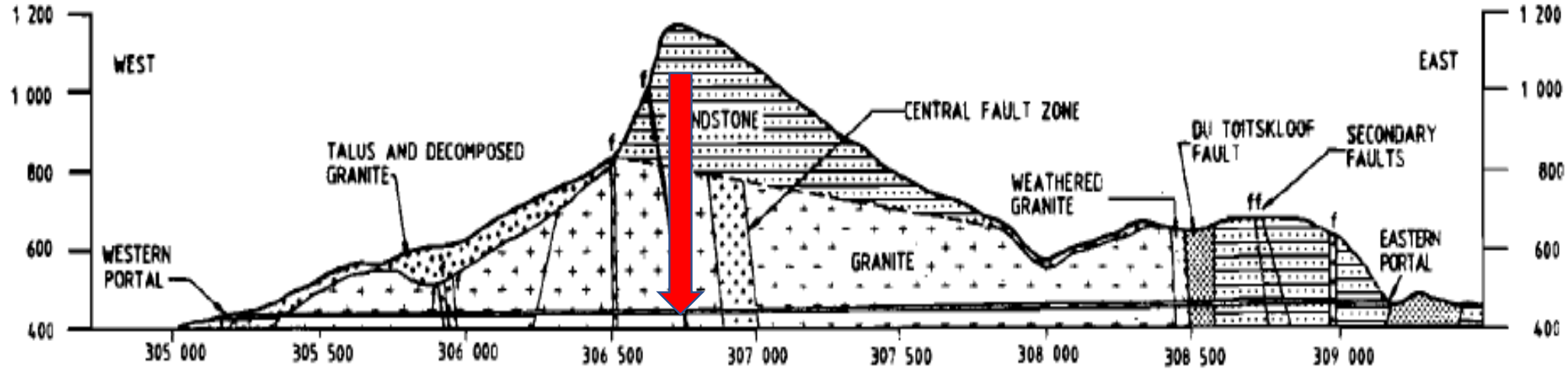
Usual environmental gamma spectrum



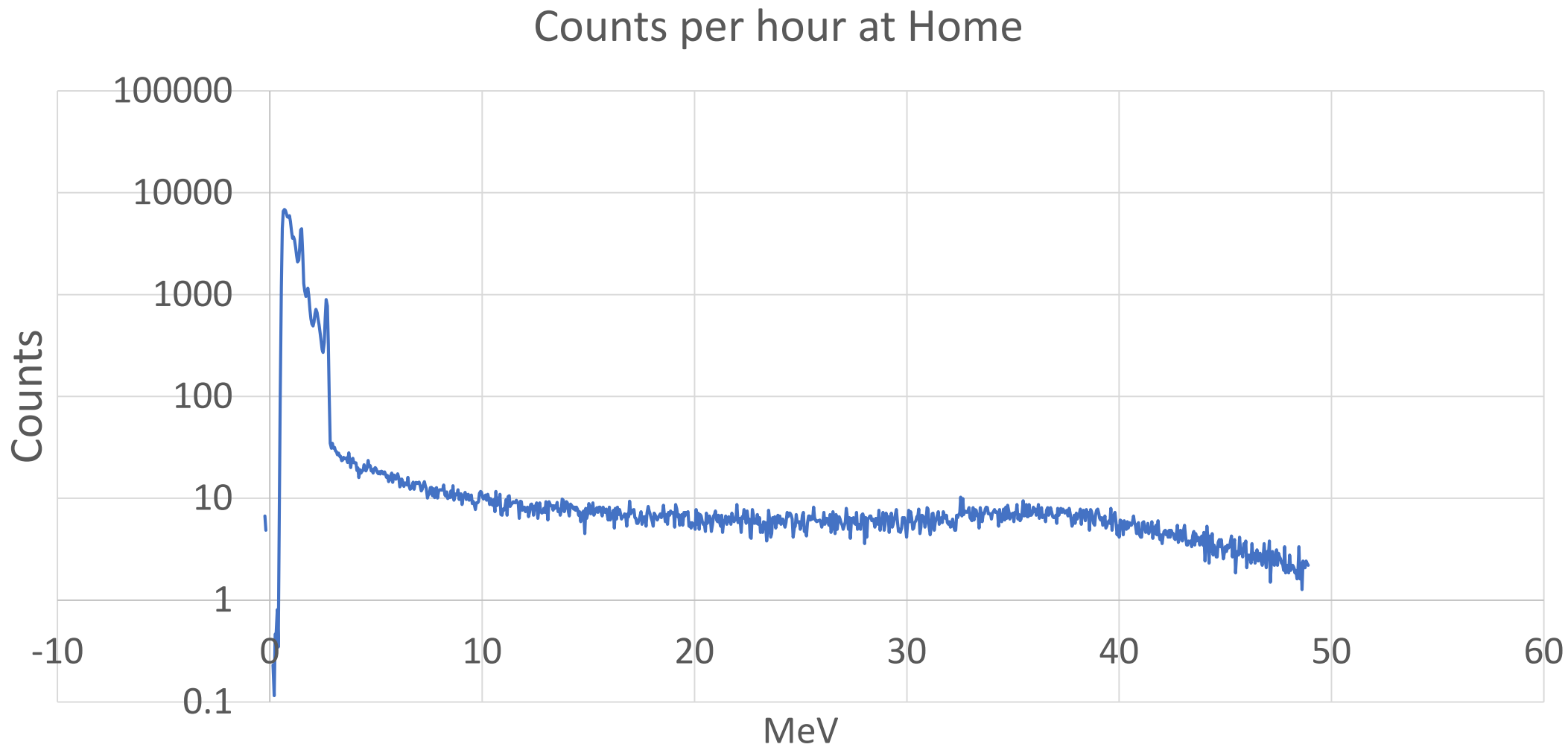


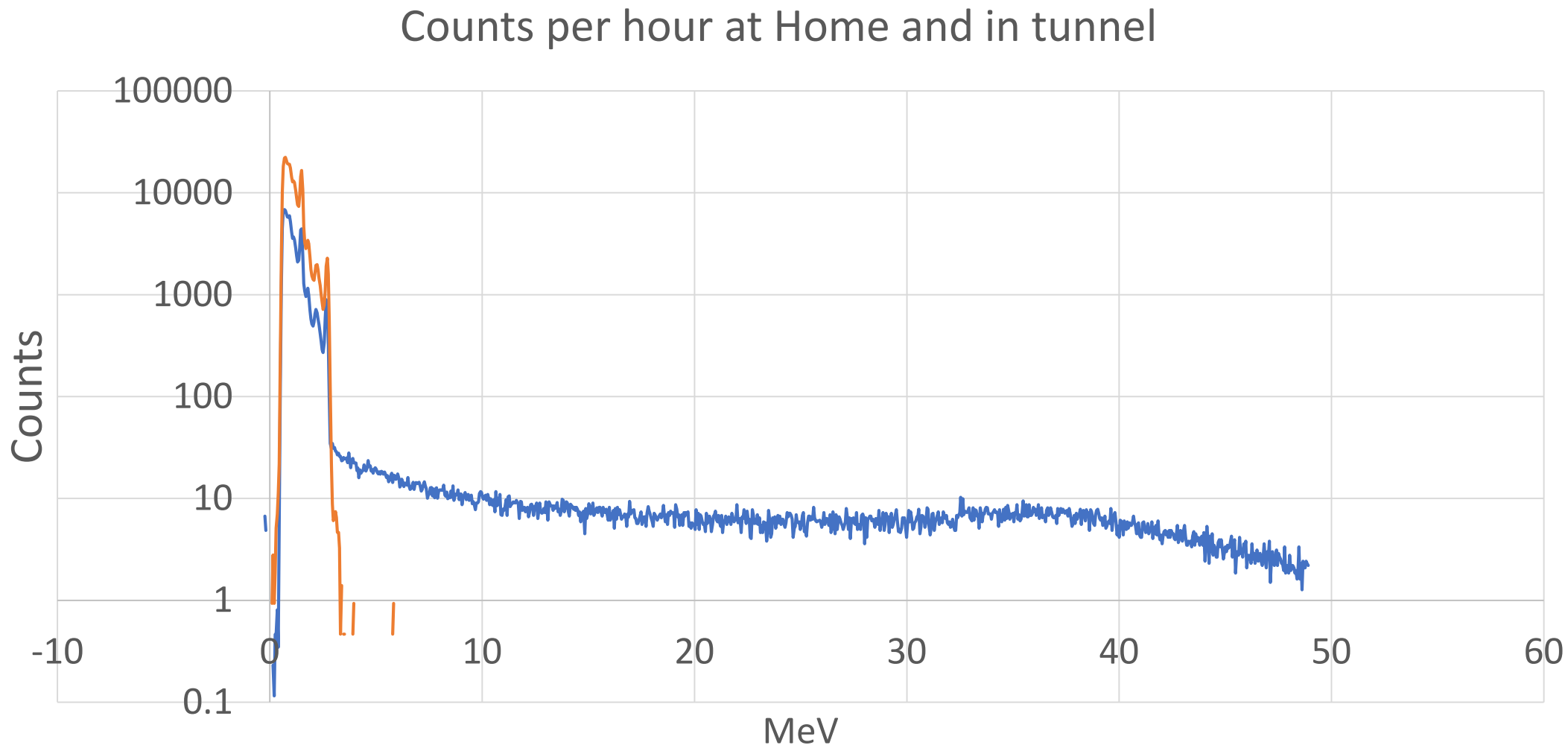
- Note log scale
- From 10 to 50 MeV – 4905 counts per hour
- Implies 6131 muons per hour if lower part of energy spectrum similar
- Implies 0.05 muons.s^{-1}.cm^{-2} assuming detector is 7.5 cm x 7.5 cm

21 December 2023

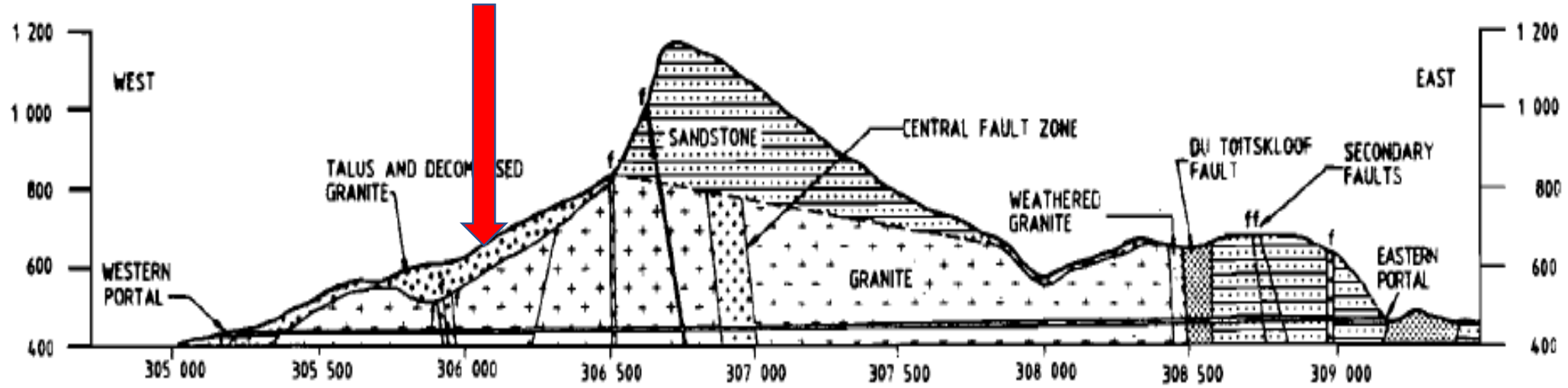


I: Post-pilot bore geology


Counts per hour at Home
100000
10000
1000
100
10
1
0.1
Counts
-10
0
10
20
30
40
50
60
MeV

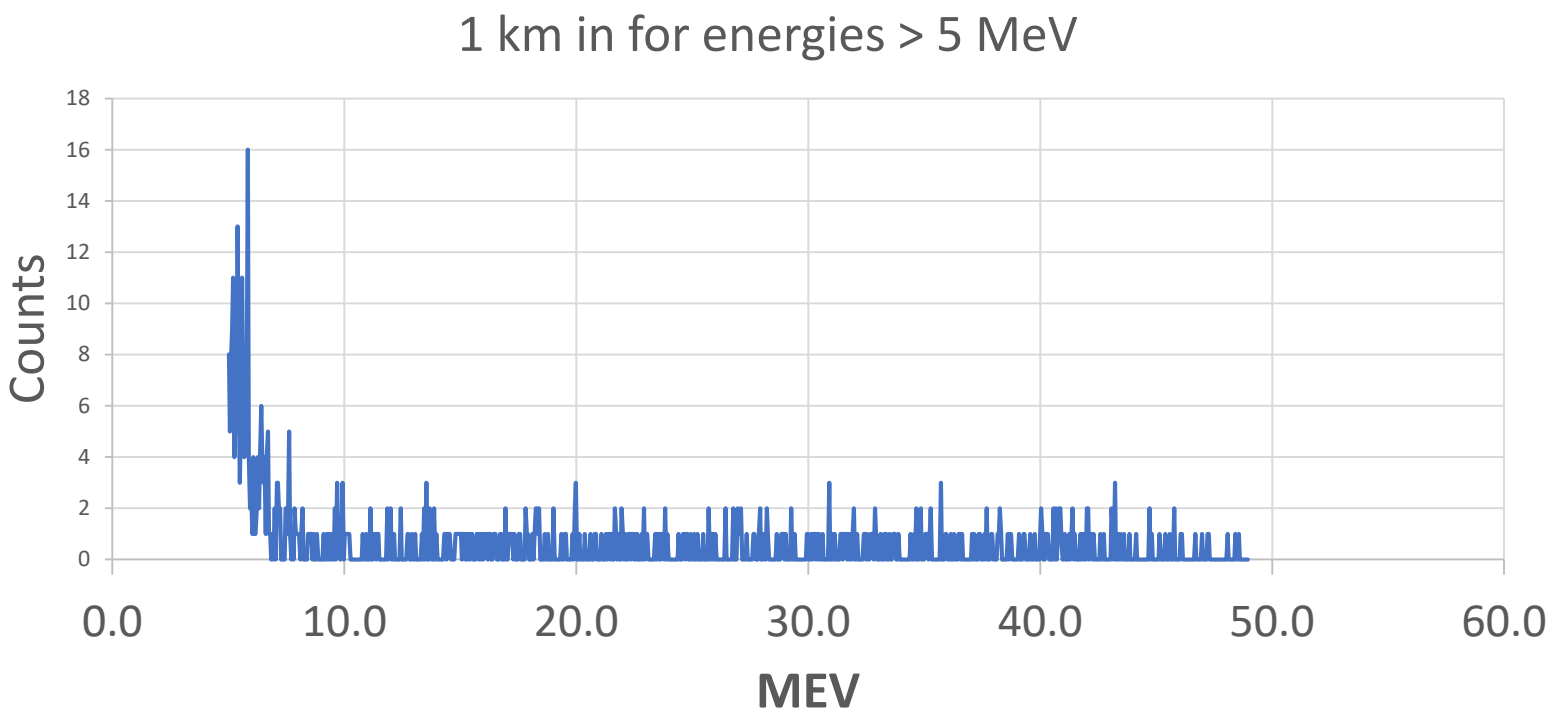

Counts per hour at Home and in tunnel
100000
10000
1000
100
10
1
0.1
Counts
-10
0
10
20
30
40
50
60
MeV

- Measure at VCC1



I: Post-pilot bore geology

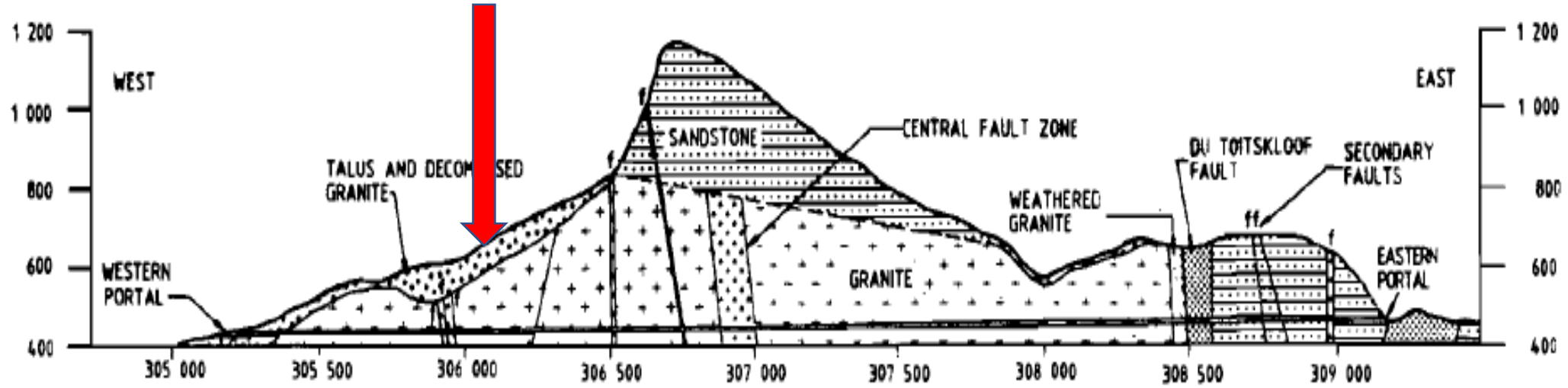
Measurement 1 km in for 8 days



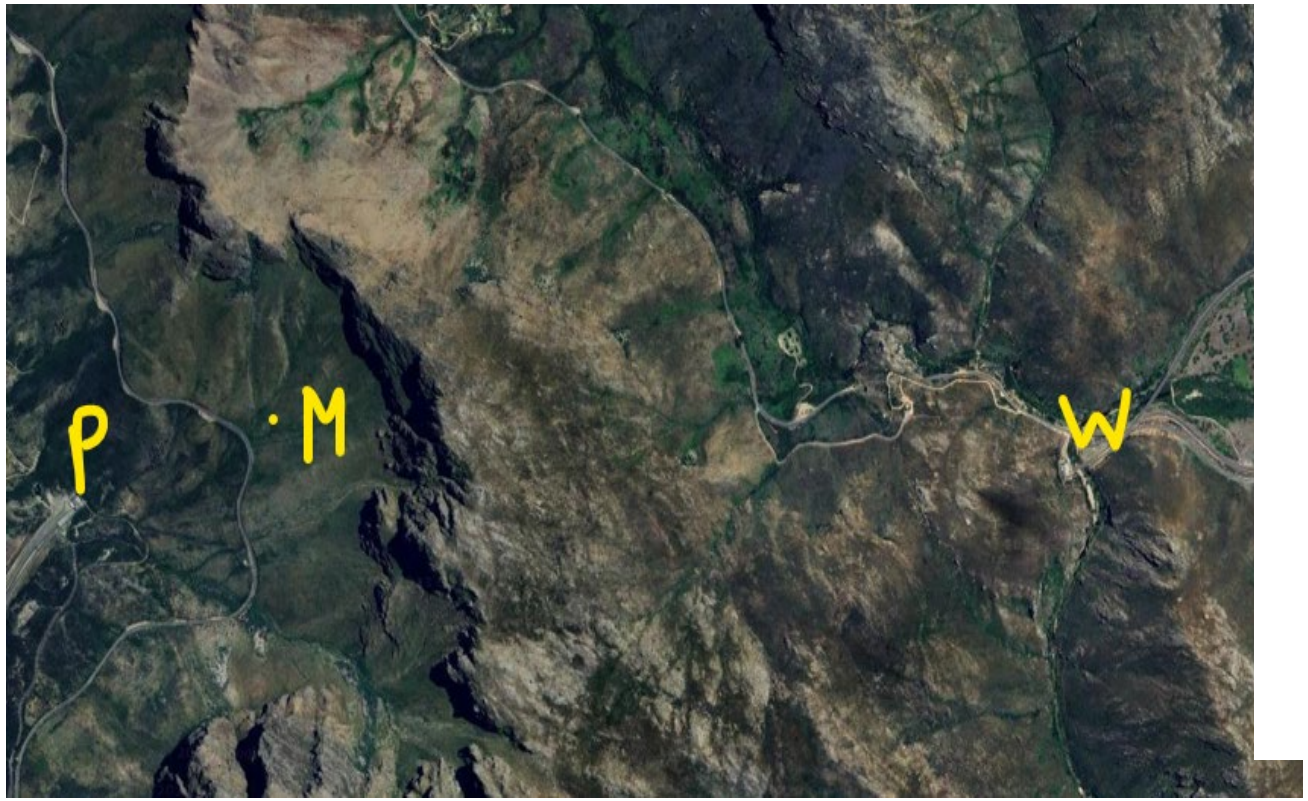
- Linear scale
- From 10 to 50 MeV – 313 counts in 8 days
- Implies 2.2 muons per hour

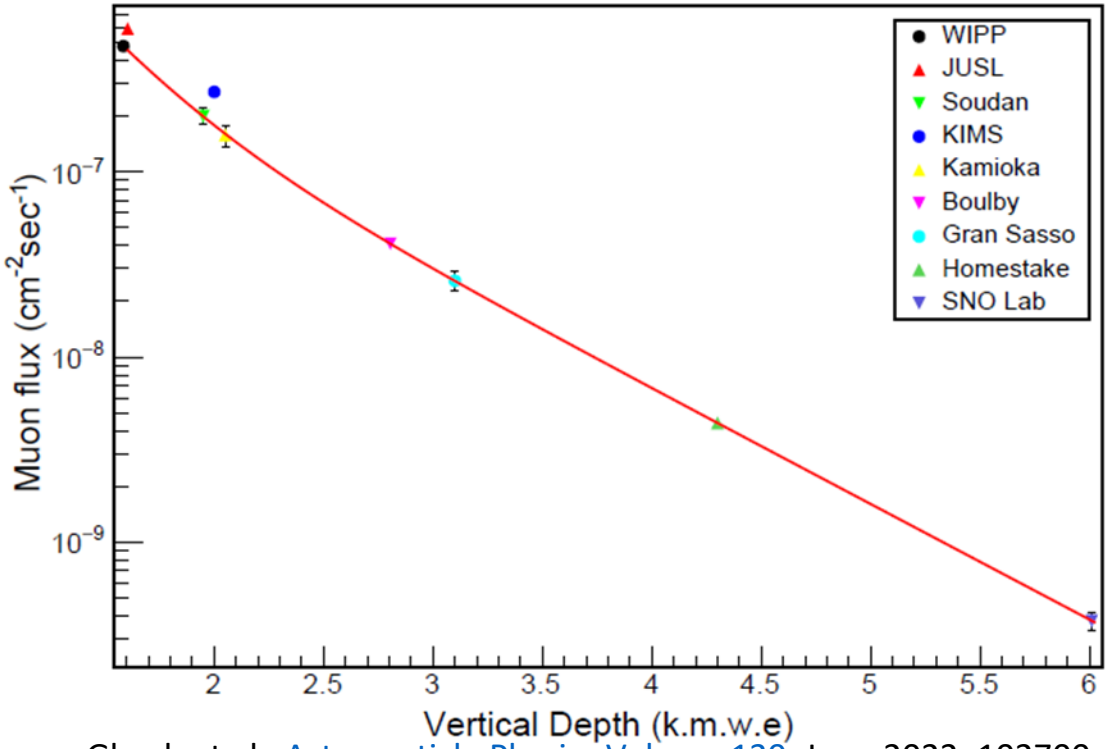
Thus the muon flux at this point, with only about 200 m of rock above it, is around 2.184/3600/(7.5*7.5) as before

$= 1.07 \times 10^{-5}$ muons.cm^{-2} s^{-1}



I: Post-pilot bore geology





Ghosh et al., Astroparticle Physics Volume 139, June 2022, 102700

1.07×10^{-5} muons.cm^{-2} s^{-1} at about 200 m depth. Max point at least 3x more overburden.
Prediction USING FLAT EARTH ASSUMPTION is 3.52×10^{-5} muons.cm^{-2} s^{-1} for 200 m from Mei, D. M. and Hime, A. (2006) 'Muon-induced background study for underground laboratories', *Physical Review D*, 73(5), pp. 1–18.

Is this work of practical use?

Yes – see article published in Health Physics in 2022 based on measurements in mine

Paper

Pilot Study of Thoron Concentration in an Underground Thorium Mine

R. Lindsay,[1] S. Mngonyama,[1,2] P. Molahlehi,[1] X. E. Ngwadla,[1] and G. J. Ramonnye[1]

Abstract—**The Steenkampskraal mine in the Western Cape Province in South Africa provides some interesting challenges for radiation protection practitioners in view of the high thoron values encountered in this mine. The mine contains high natural thorium**

There is currently major interest in reopening the mine for the valuable rare-earth minerals that are also present in the monazite deposits (Andreoli et al. 1994; Blench 2018). These minerals are used in the fast-growing battery industry

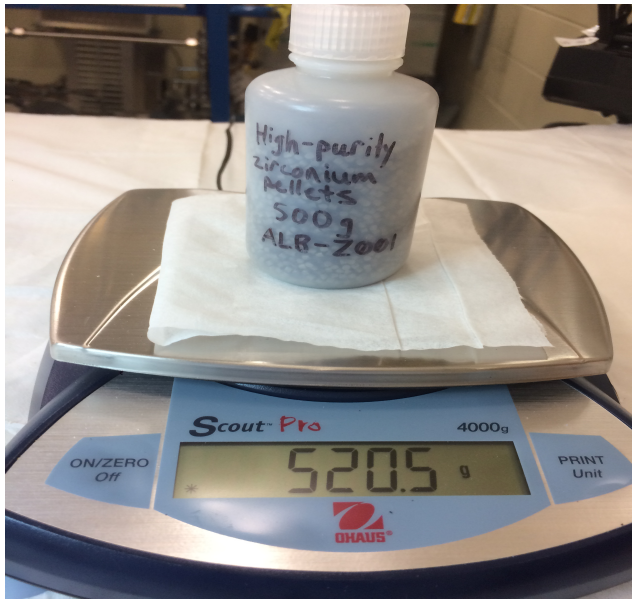
This presentation looks at the radon escaping from material used to clean the Xenon gas in the planned **nEXO** experiment.

-
-
- Mass = 501.0 g
- Presentation: pellets 2.3 mm dia., 2 mm long

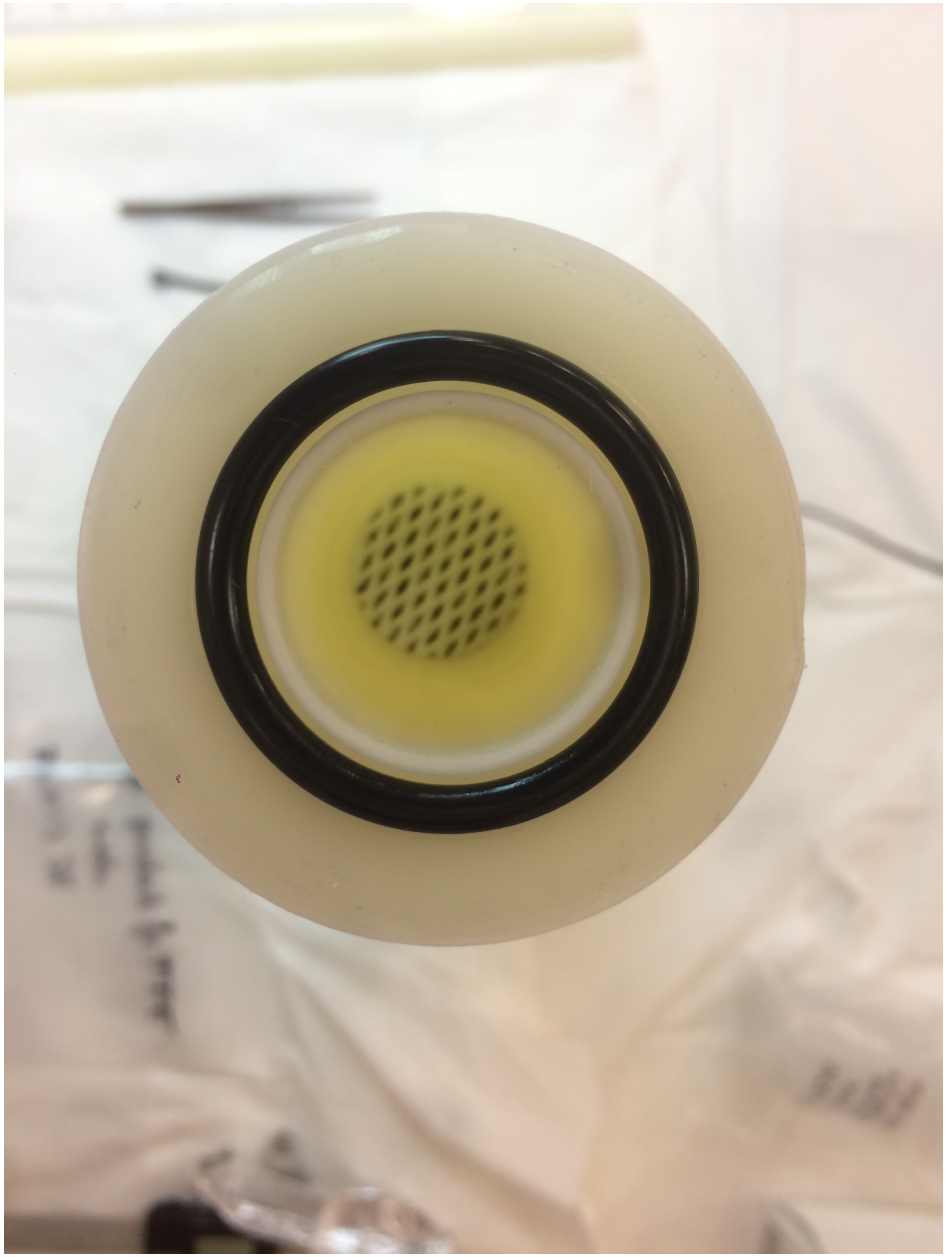
  Area exposed $\simeq$ 1980 cm^2

  Number of pellets $\simeq$ 8630

The area and number of pellets were estimated by measuring the mass and dimensions of a small sample of pellets, see the next slide.



One pellet is twice longer. Out of 60% of all pellets, only two such anomalies were found.

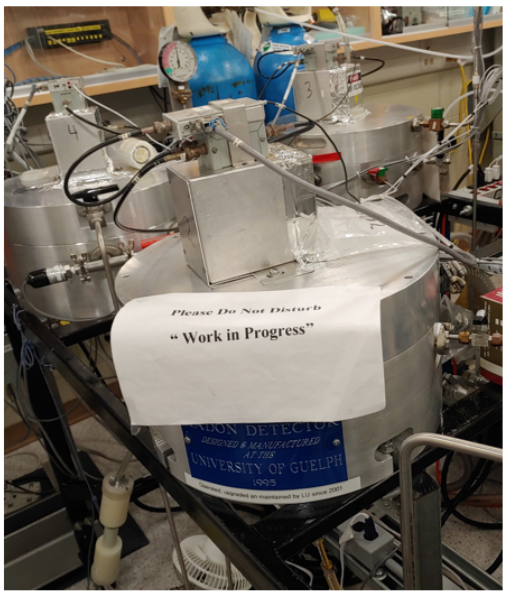


Used a one-inch diameter, 13-inch long polypropylene column to minimize empty space.

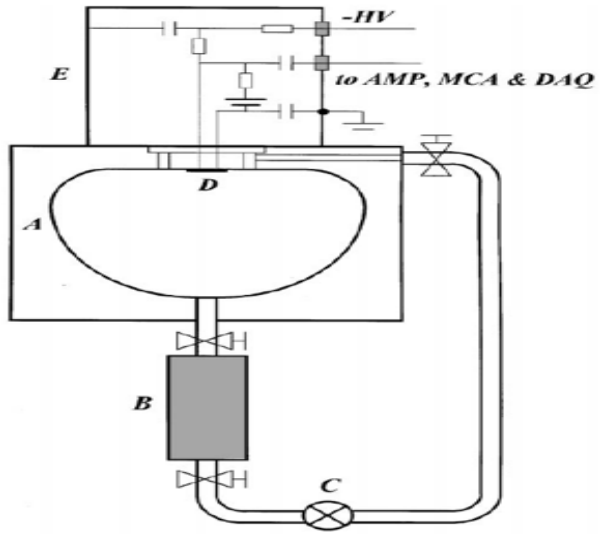
ESC Assay - Recirculation Mode

- Sample in B, carrier gas (Ar/N2/..) fills system 25mBar-1Bar (depends on assay)
- Rn (222/220/219) emanation from sample into gas
- Pump (C) mixes gas in system, Rn pushing it into the ESC chamber (A)
- ^{222}Rn decays in ESC form charged $^{218}Po \approx 88\%$ of the time in dry air at 1 Bar
- ESC field drifts ions in A to SiDiode (D) where further alpha decays create counts 50% of the time
- Con - Efficiency loss of volume sharing (Rn decaying in B/C) + needs re-circulation pump
- Pro - Rn emanation grows to steady state providing more statistics + sensitive to ^{220}Rn and ^{219}Rn

Detector at SNOLAB to measure radon exhalation

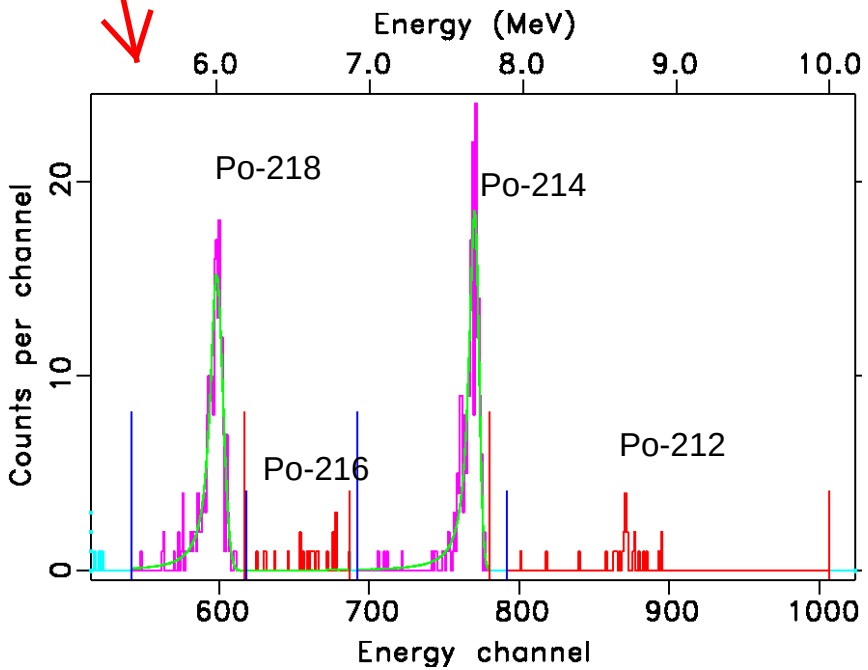


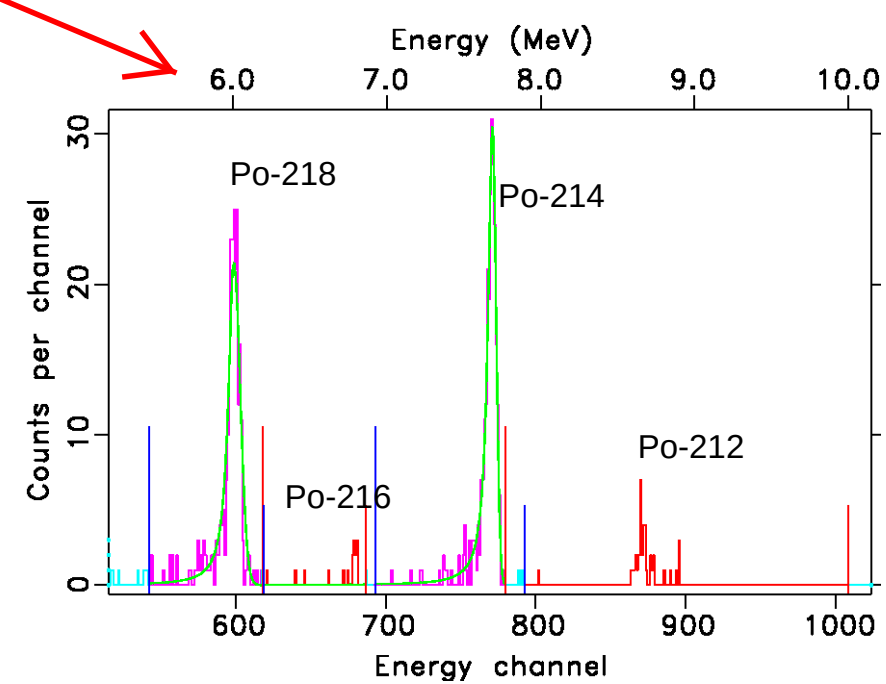
Schematic of the set-up



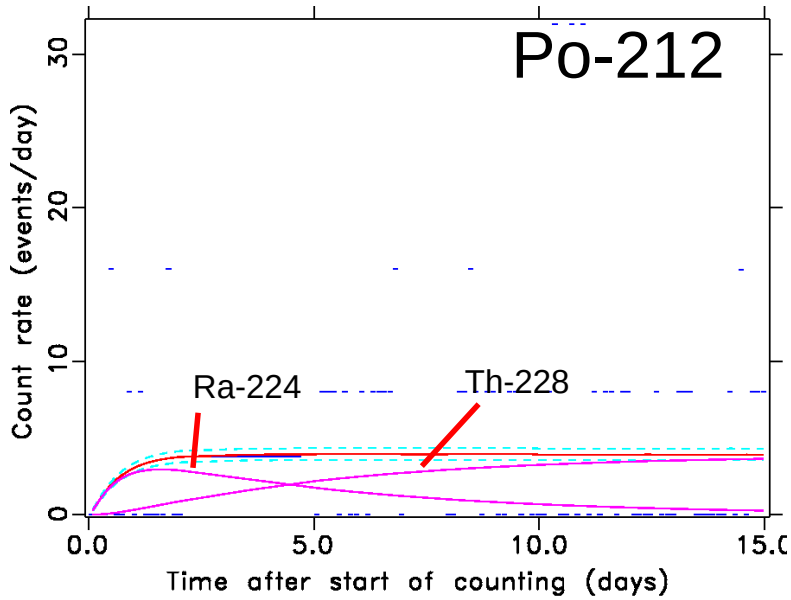
Energy Spectra SPL

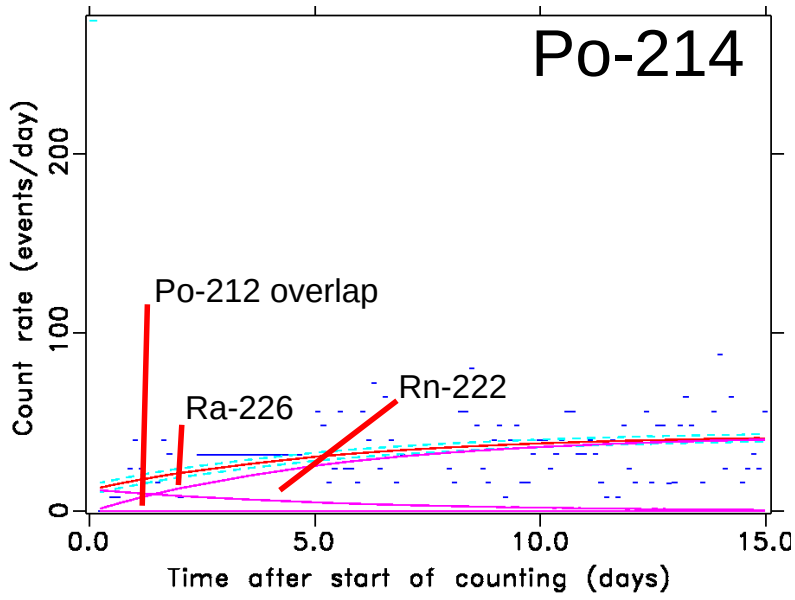
- 221116E4.034 (6.97 days)
- 221124E4.057 (7.13 days) Note: no ^{219}Rn signal in this sample!
- Color code
  - Purple: Mostly U
  - Red: Mostly Th
  - Green: Fitted peaks, to set E scale (fit line)
  - Azure: Not used

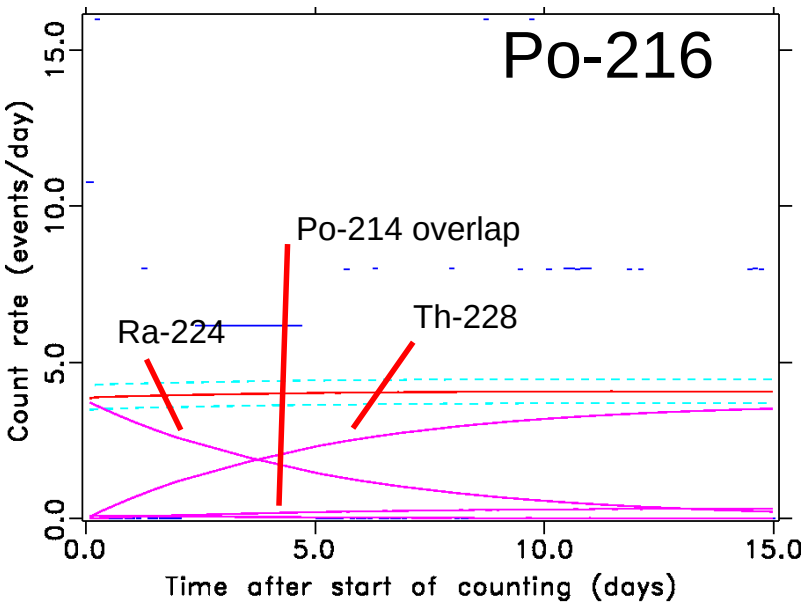


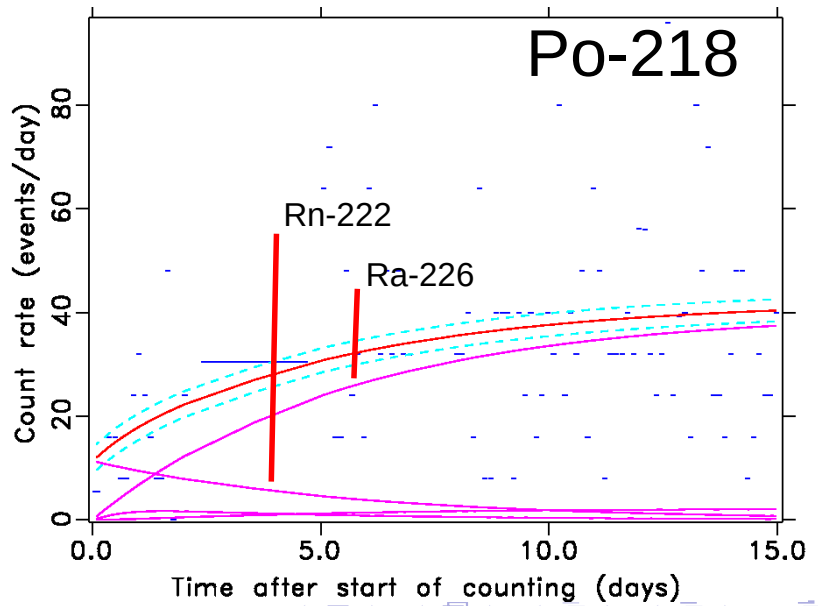


Time Spectra SPL.









RESULS of exhalation from pellets

Net ^{222}Rn specific emanation rate R_{net}:

Pure Zr pellets; $R_{net} = 82 \pm 23 \frac{atoms}{day.kg}$

Future plans: Heat treat the Pure Zr pellets using a high-temperature furnace under vacuum and see whether we can promote Radium removal.

SET UP A CLEAN ROOM TO DO SIMILAR MEASURMENTS AT THE University of the WESTERN CAPE

Thank You!