Radioactive Background Characterization of the Cryogenic Underground TEst Facility (CUTE)

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on behalf of the CUTE team

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CAP Congress

The Facility

Parallel Talk “CUTE: An Overview and Applications to SuperCDMS”

by Aditi Pradeep - 6 June 2022, 11:15EST

Features:

Operational temperature as low as 15 mK

Low overall radioactive background

Minimal mechanical vibrations

Low level of electromagnetic interference

Availability of calibration sources (gamma and Fe55)

Low-radon cleanroom space to change payload

SNOLAB User Facility maintained and continuously improved

Near term use: SuperCDMS detector testing
MoU in place with SuperCDMS

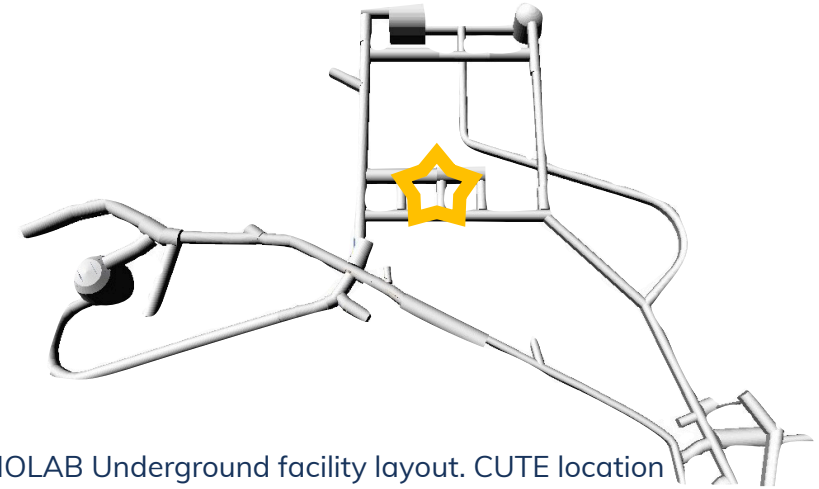
Future use: proposal-based; expect to start soon

Underground at SNOLAB

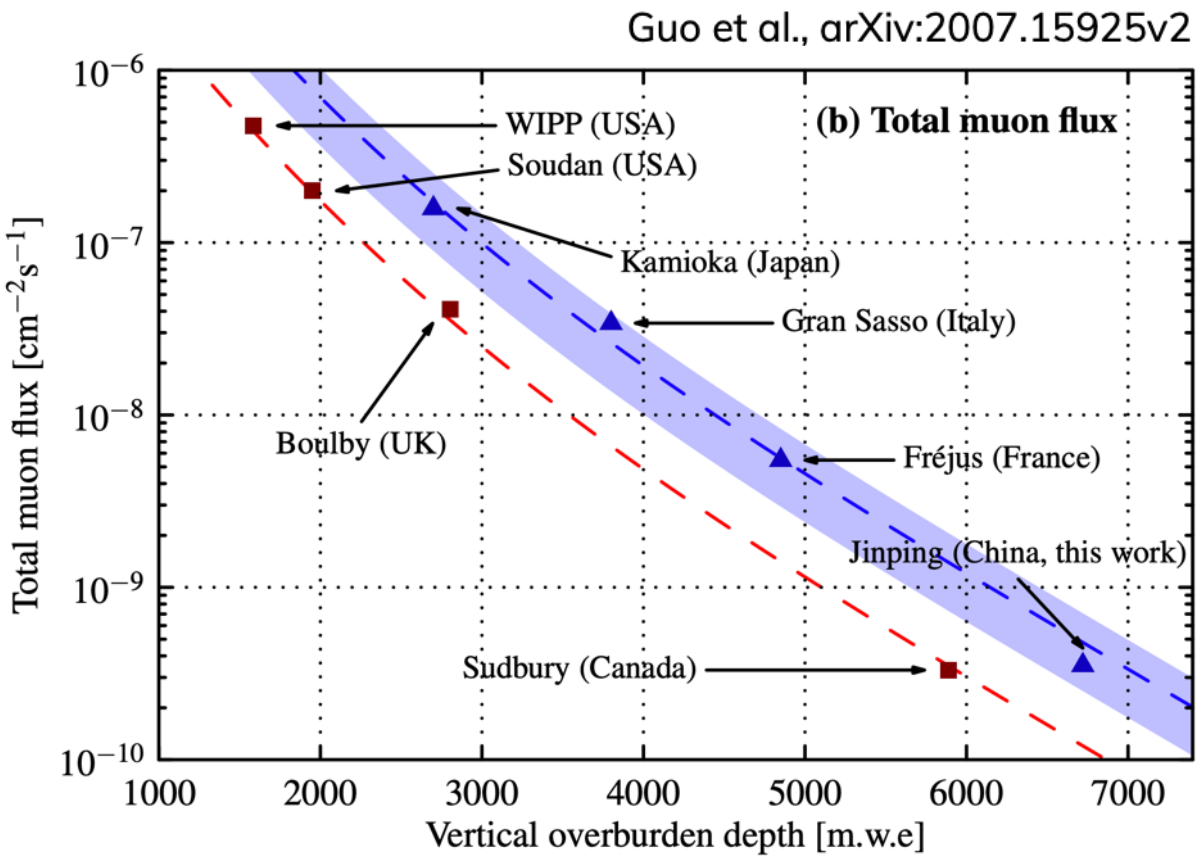
Rock shield: 2 km underground

SNOLAB has the lowest muon fluxes available

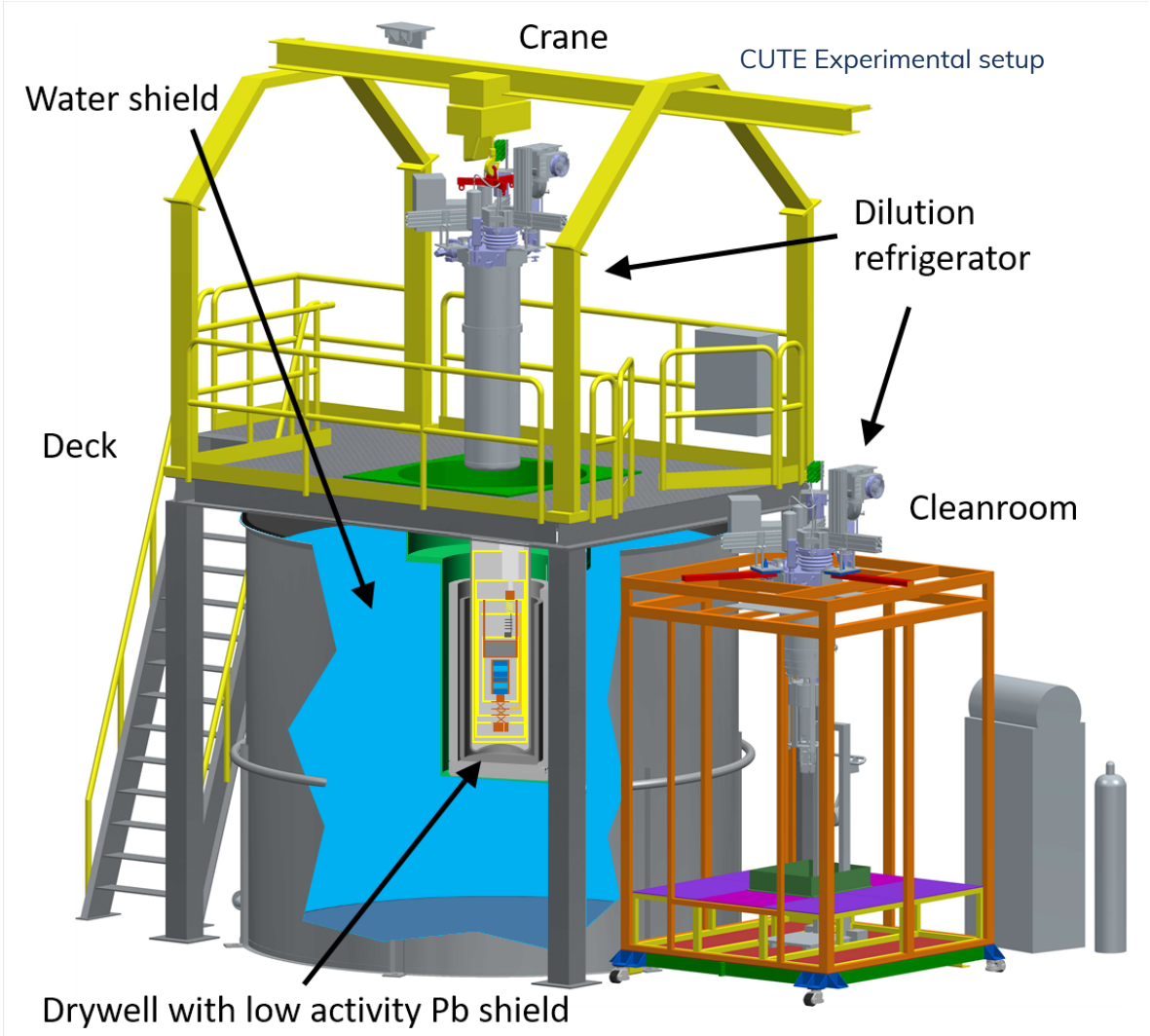
Cleanroom 2000class throughout the underground facility



SNOLAB Underground facility layout. CUTE location



The Shielding



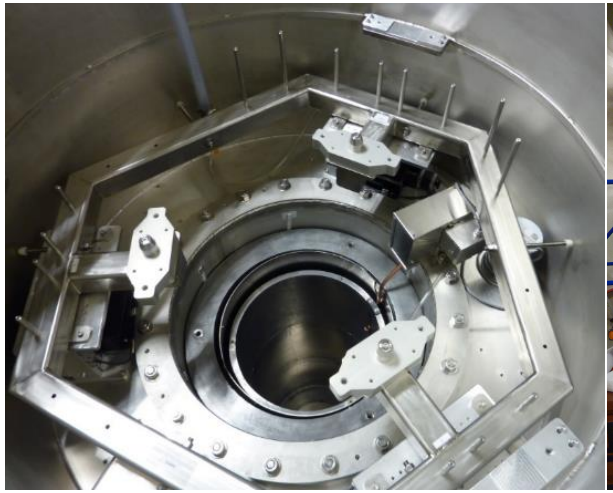
1.5 m water shield

~10 cm of low activity lead

20 cm of polyethylene lid

MuMetal and copper shields

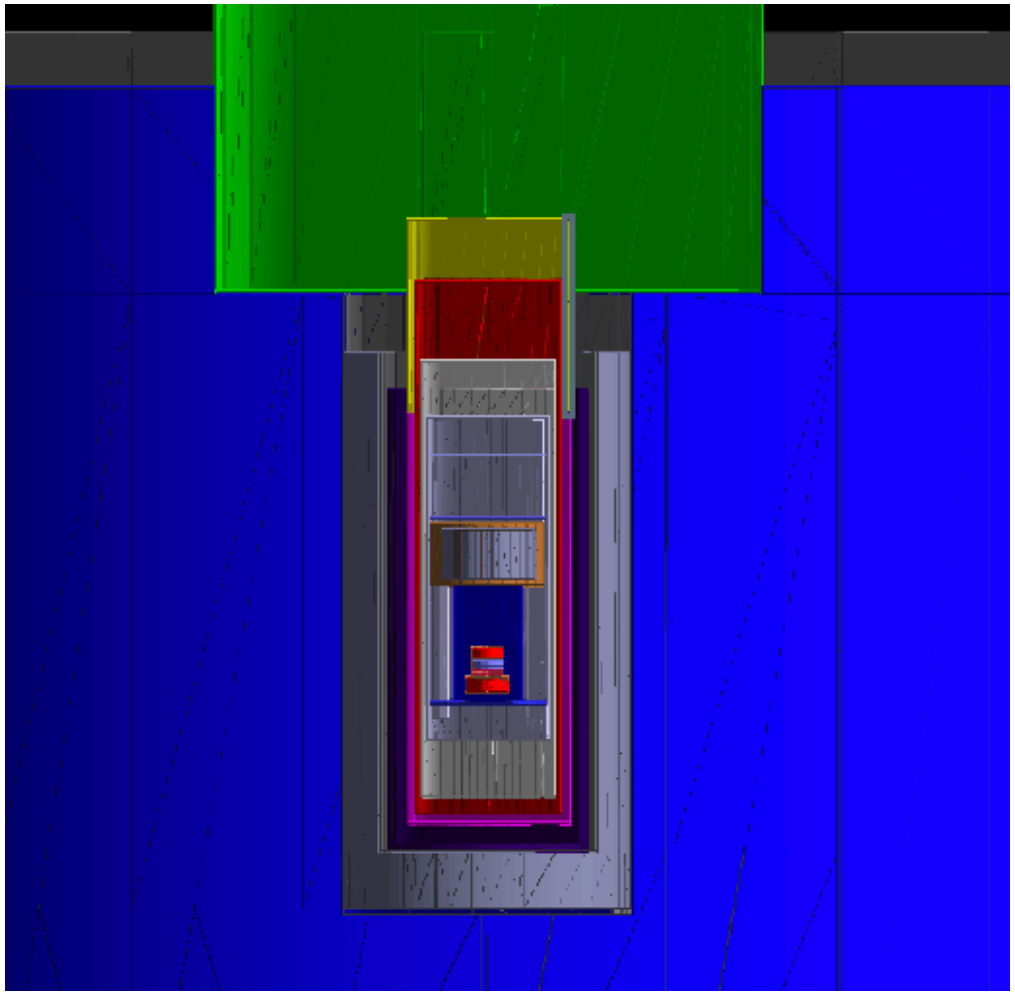
15 cm of internal lead plug + Cu box



CUTE drywell: suspension system and shielding layers

CUTE cryostat open inside the CUTE cleanroom

The Radioactive Background Budget



Geant4 visualization of the CUTE geometry

Radioactive emission: gamma bulk (assay), cosmogenic activation, cavern backgrounds

- CUTE materials were screened for radioactive contamination via HPGe at the SNOLAB Low Background Counting facility

Component/material: bill of materials of the facility

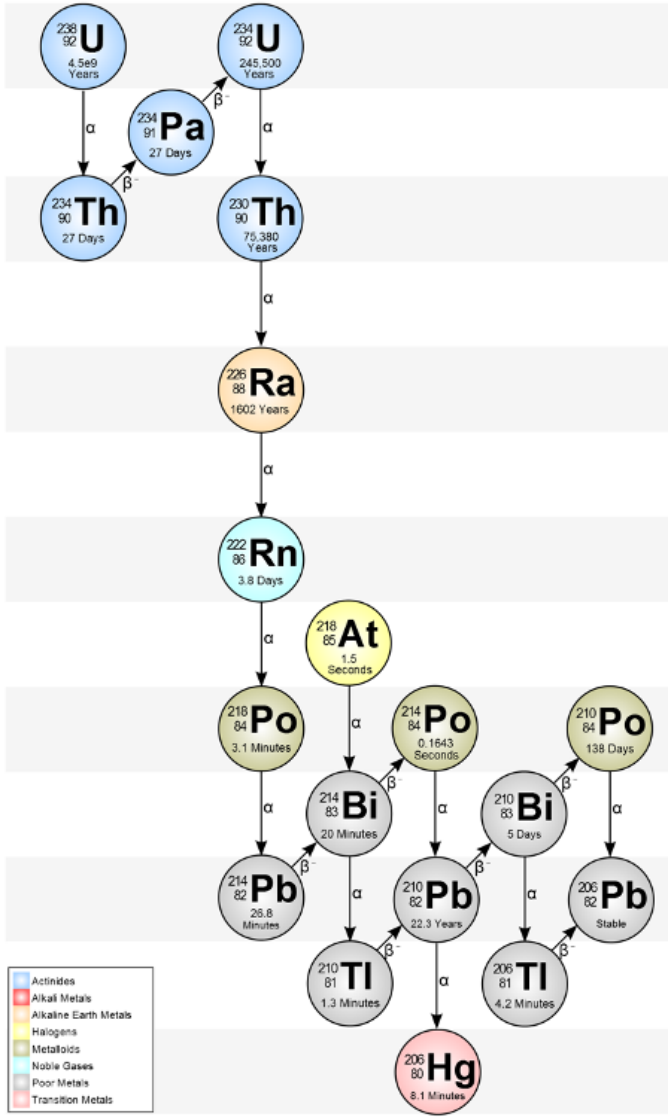
Geant4 (G4) MonteCarlo simulation to propagate the radiation for each contaminant, from each component, into the detector stack

Background Explorer handles normalization and conversion of simulated spectra into event rate

- Developed by Dr. B. Loer @PNNL for SuperCDMS

βαckγroμnd EXplorer https://github.com/bloer/bgexplorer

^{238}U Split Chain



Top of ^{238}U chain lines:

- 63.3keV from ^{234}Th
- 92.6keV from ^{234}Th
- 766.4keV and 1001.0keV from ^{234}mPa

Bottom of ^{238}U chain lines:

- 186.2keV from ^{226}Ra
- 242.0keV, 295.2keV and 351.9keV from ^{214}Pb
- 609.3keV, 768.4keV, 1120.3keV, 1238.1keV, 1377.7keV, 1764.5keV and 2204.2keV from ^{214}Bi

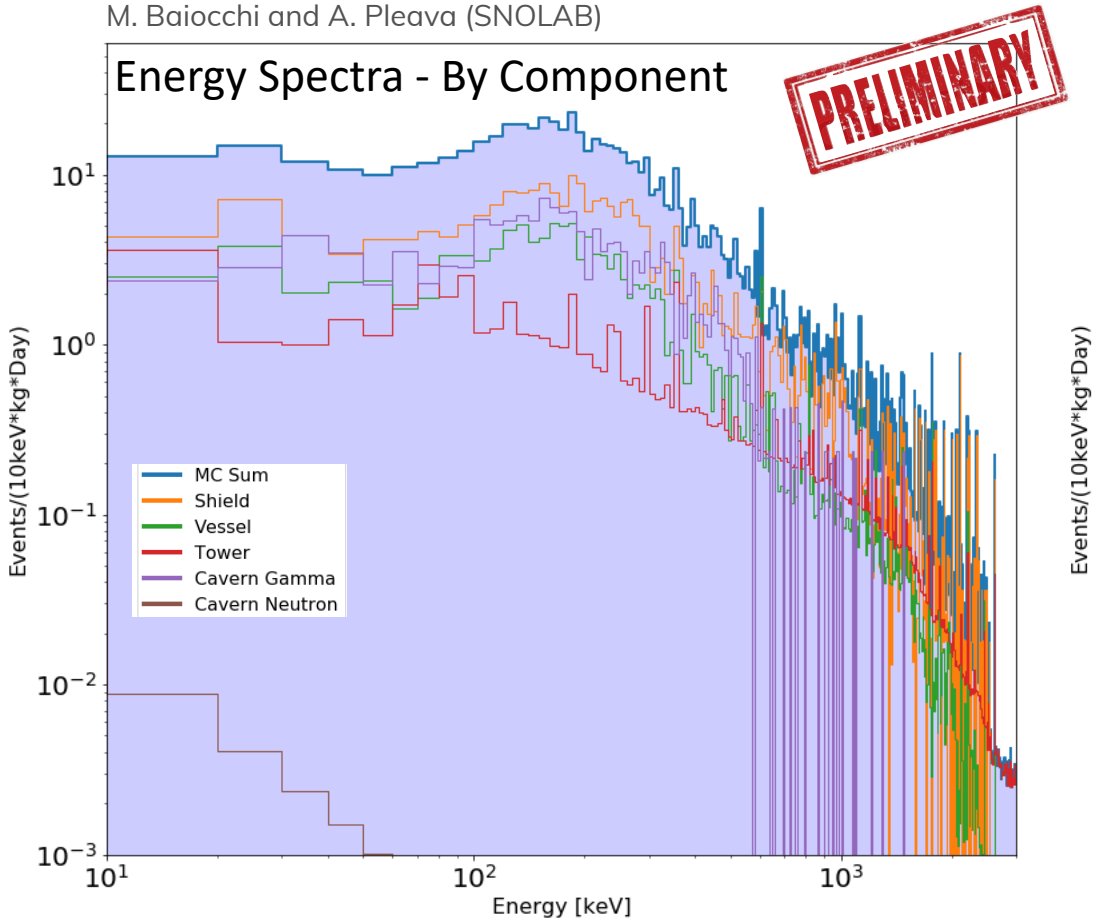
We simulated the upper chain as ^{238}U with nucleus limits at ^{226}Ra, and the lower chain as ^{226}Ra.

Depending on the material, the difference between the two measurements can vary.

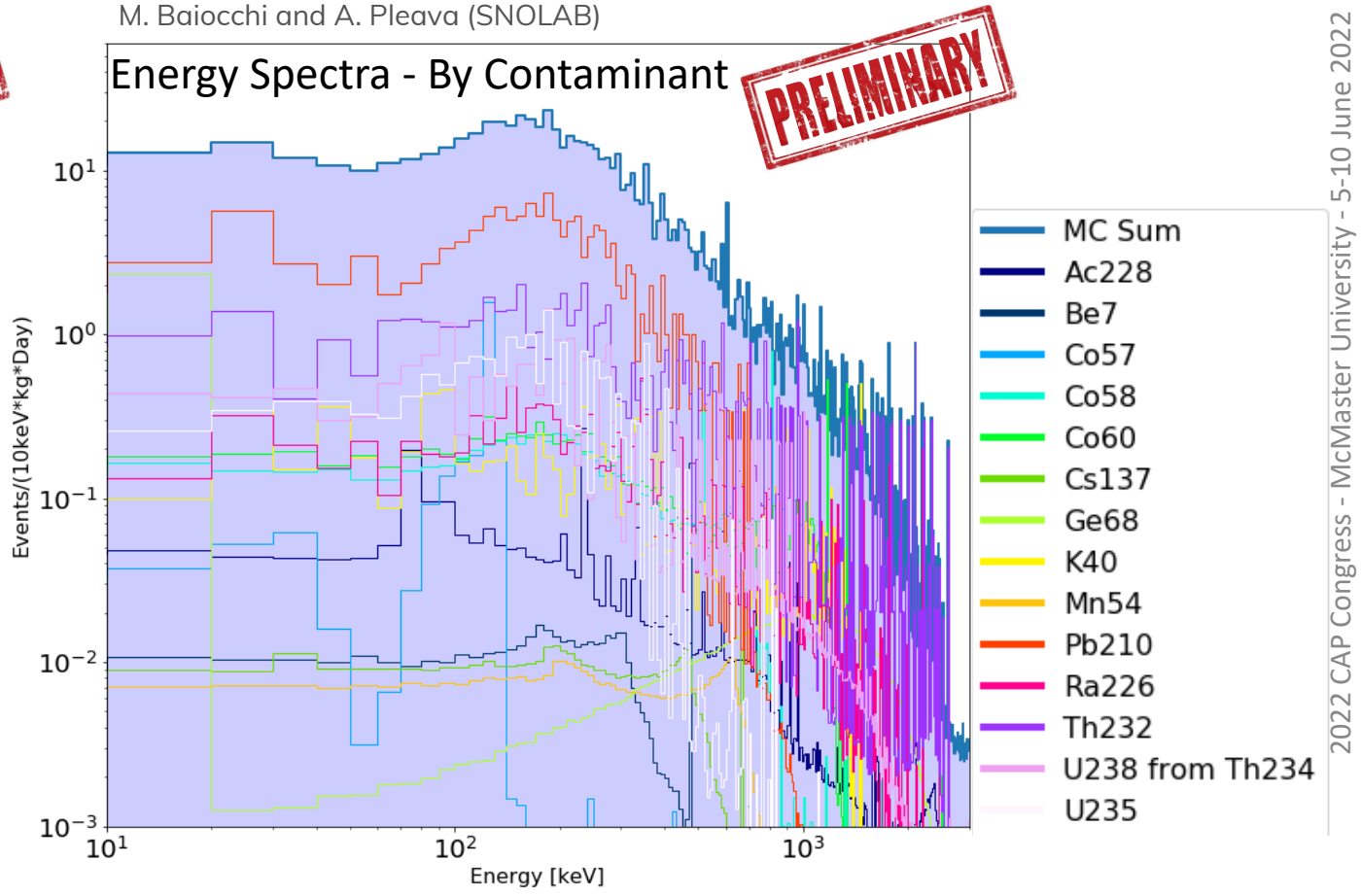
Simulating the ^{238}U full chain the total DRU is ~40% higher than the split chain model in [1-1000keV]. ^{238}U full chain simulation model is conservative.

G4 Simulated Energy Spectra

M. Baiocchi and A. Pleava (SNOLAB)



M. Baiocchi and A. Pleava (SNOLAB)

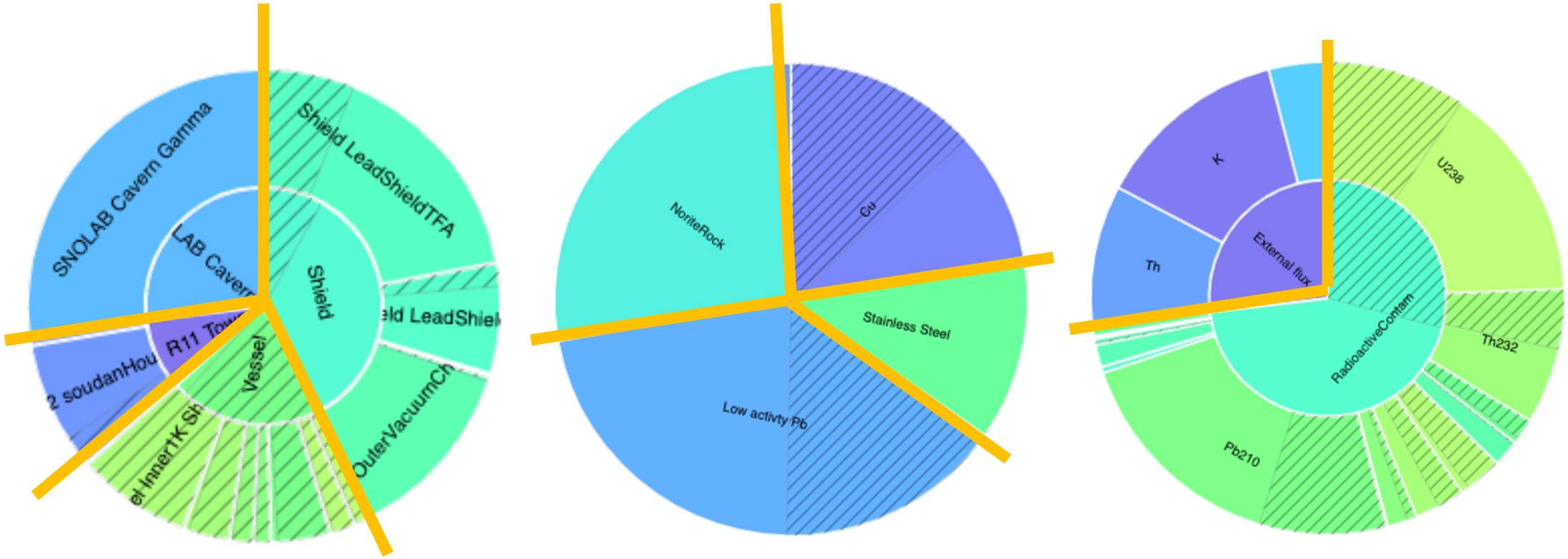


Breakdown of the Total Rate

Dashed areas refer to the use of upper limit contaminations when no positive contamination could be detected by HPGe measurements

Total rate (including detector stack): 6.2 ± 0.7 evts/keV/kg/day [1-1000keV]

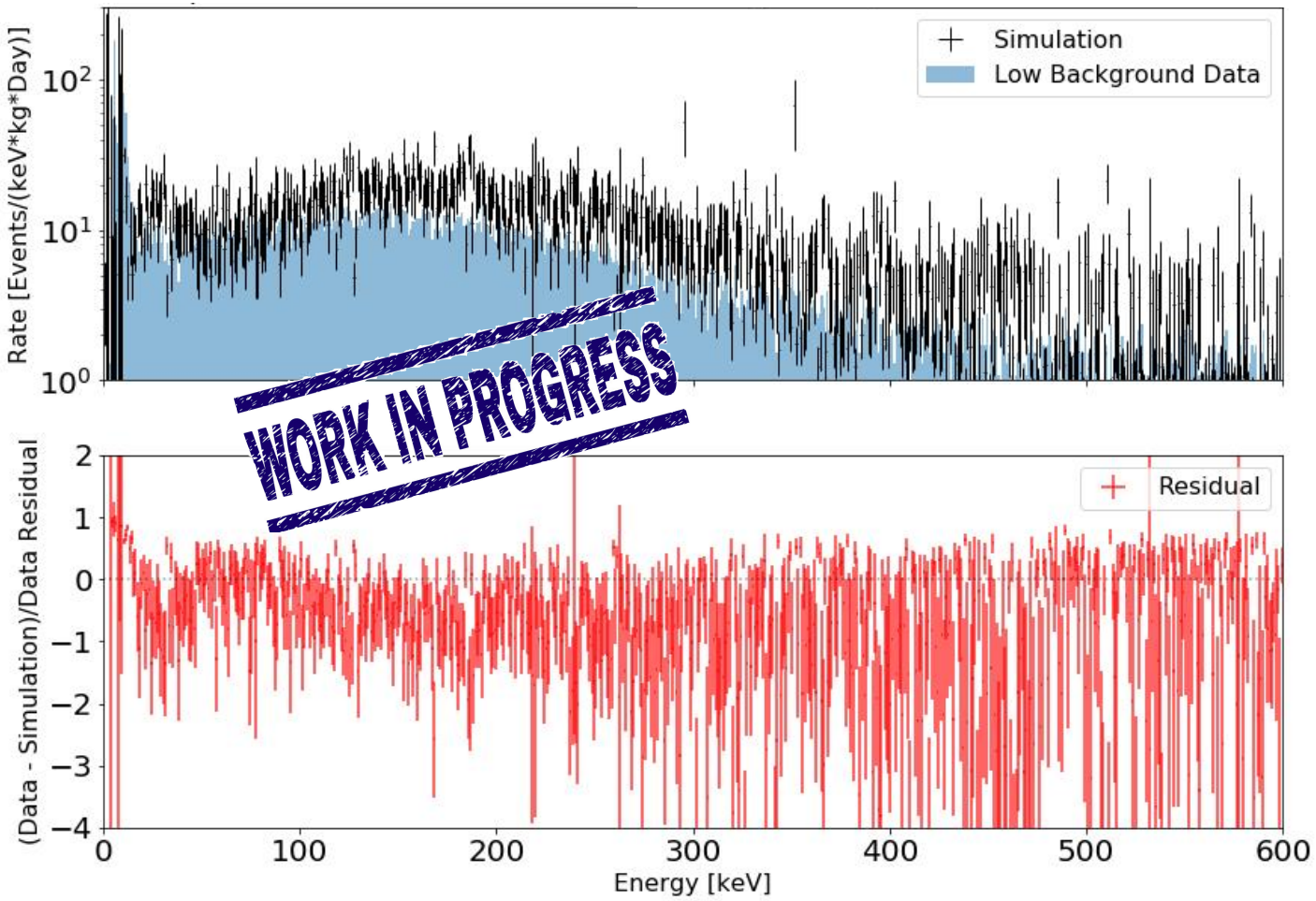
Facility rate: 5.6 ± 0.6 evts/keV/kg/day [1-1000keV]



Component Material Contaminant

Data/Simulation Validation

M. Baiocchi and A. Pleava (SNOLAB)



Data and Geant4 Simulation comparison - not a fit

Very good agreement

The small deviation might be due to the use of upper limits from HPGe screening results where no contamination was identified

Work In Progress...

Conclusions

CUTE is a cryogenic (~10 mK), low-background (few evts/keV/kg/d) and low-noise facility operational at SNOLAB.

Background study based on Monte Carlo (MC) simulation with GEANT4 using detailed set-up geometry were performed. Measured radioactivity values of all relevant set-up components have been considered and quality checks are ongoing.

The radioactive background budget of the facility has been validated using a 600g Ge crystal. It is ~5 dru in [1-1000keV] for the facility itself.

Gamma MC simulations already show a good agreement with data. Work is in progress...


That's all Folks!