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Background Simulations in CUTE: Results and Speed-Ups

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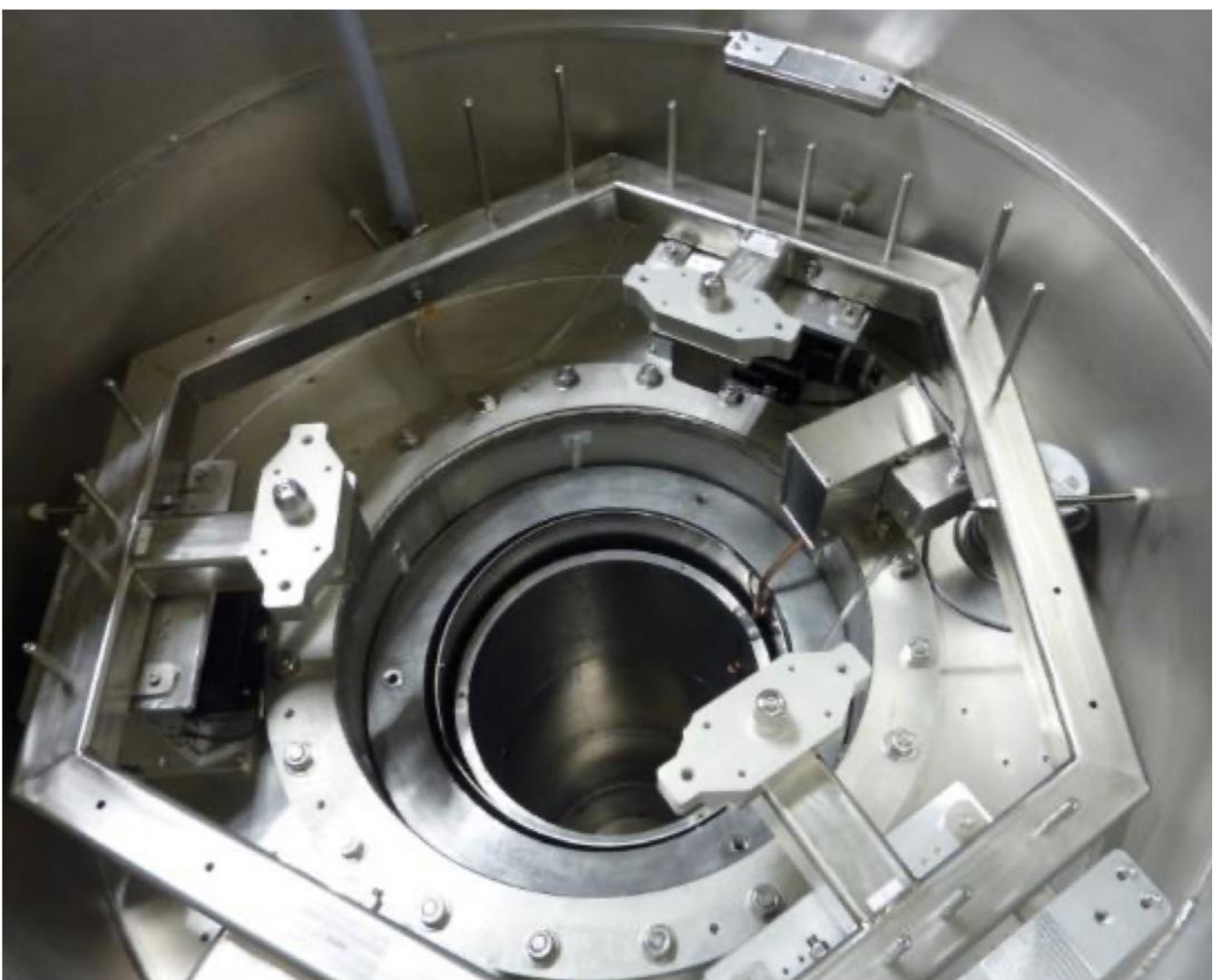
SNOLAB Summer Student, McMaster University

Supervised By: Dr. Silvia Scorza (SNOLAB)

Significant Contributions: Melissa Baiocchi (McMaster University/SNOLAB)



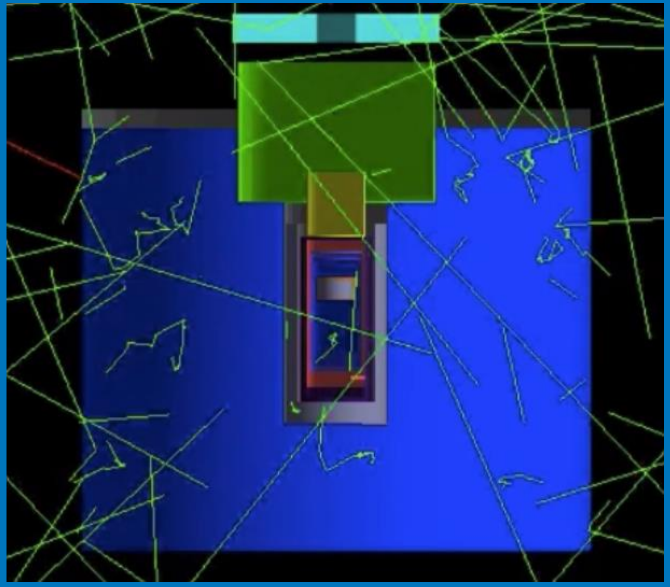
The Cryogenic Underground Test Facility

- CUTE is a cryogenic test facility currently testing Si and Ge dark matter detectors for SuperCDMS
- Low background environment:
  - **Cold:** ~15 mK operating temperature
  - **Clean:** Class 300 cleanroom for all detector work
  - **Quiet:** Vibrational isolation system and <10 radioactive background events/keV/kg/day.

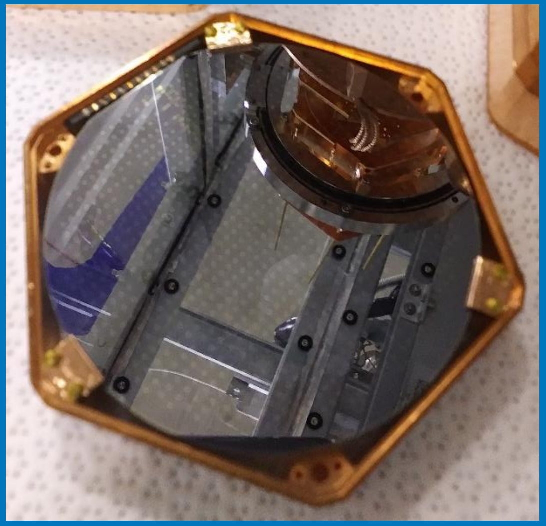
Background Characterization

1. Screening

2. Simulation



3. Validation

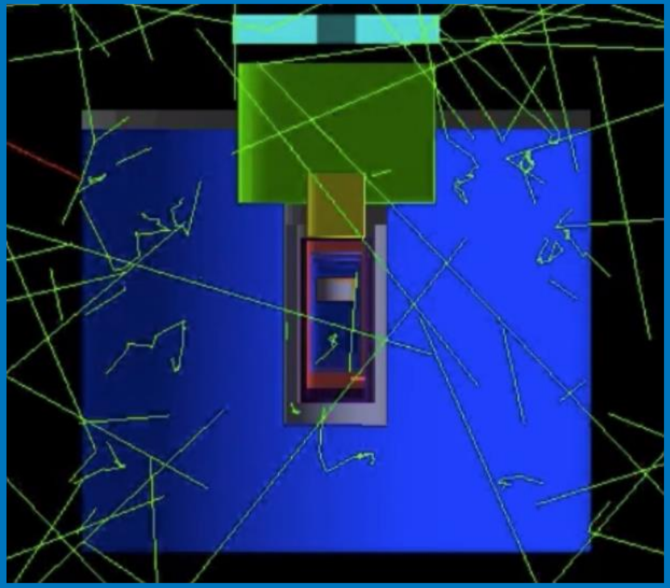


Background Characterization

1. Screening

My Summer

2. Simulation



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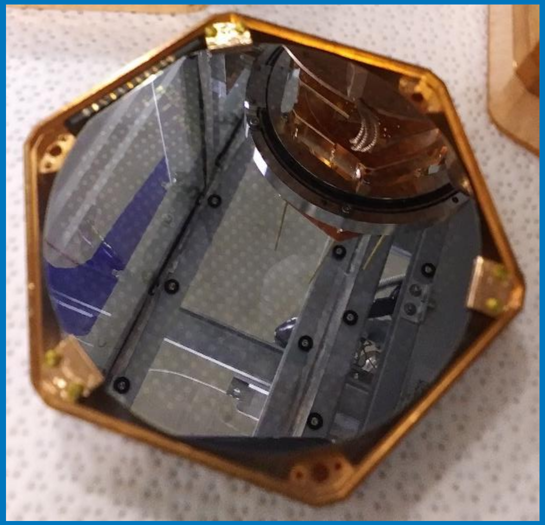
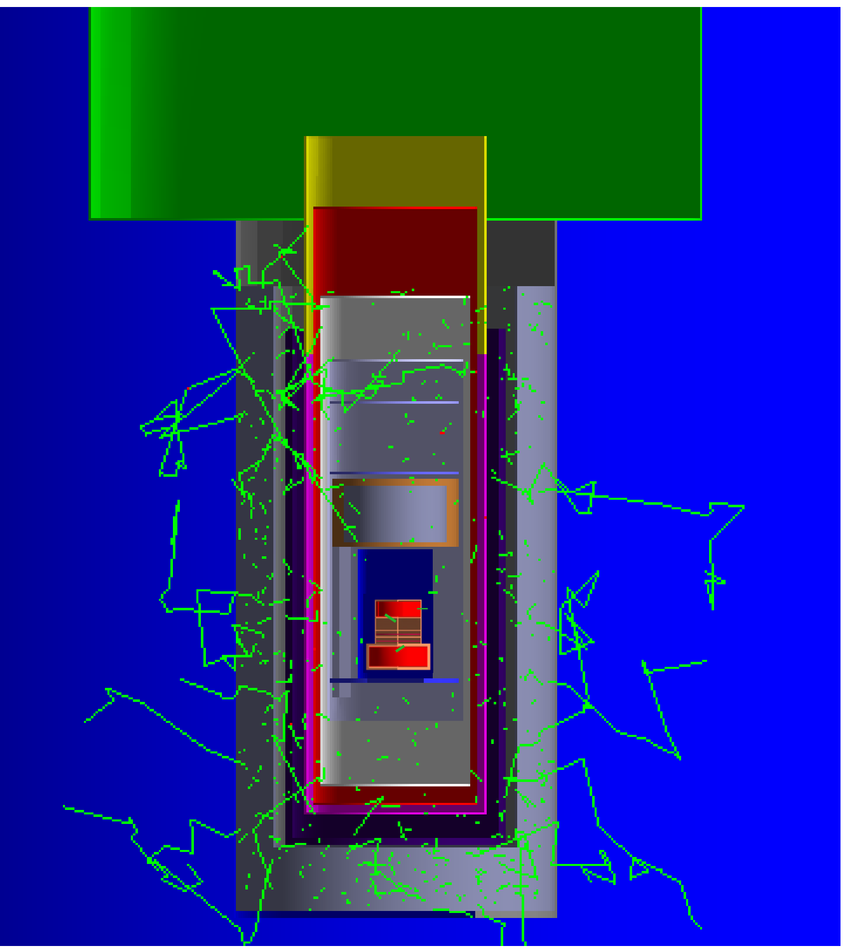


Background Simulations



Goal: To estimate background rate, and model the "background budget".

Simulation outputs are uploaded to *Background Explorer*.

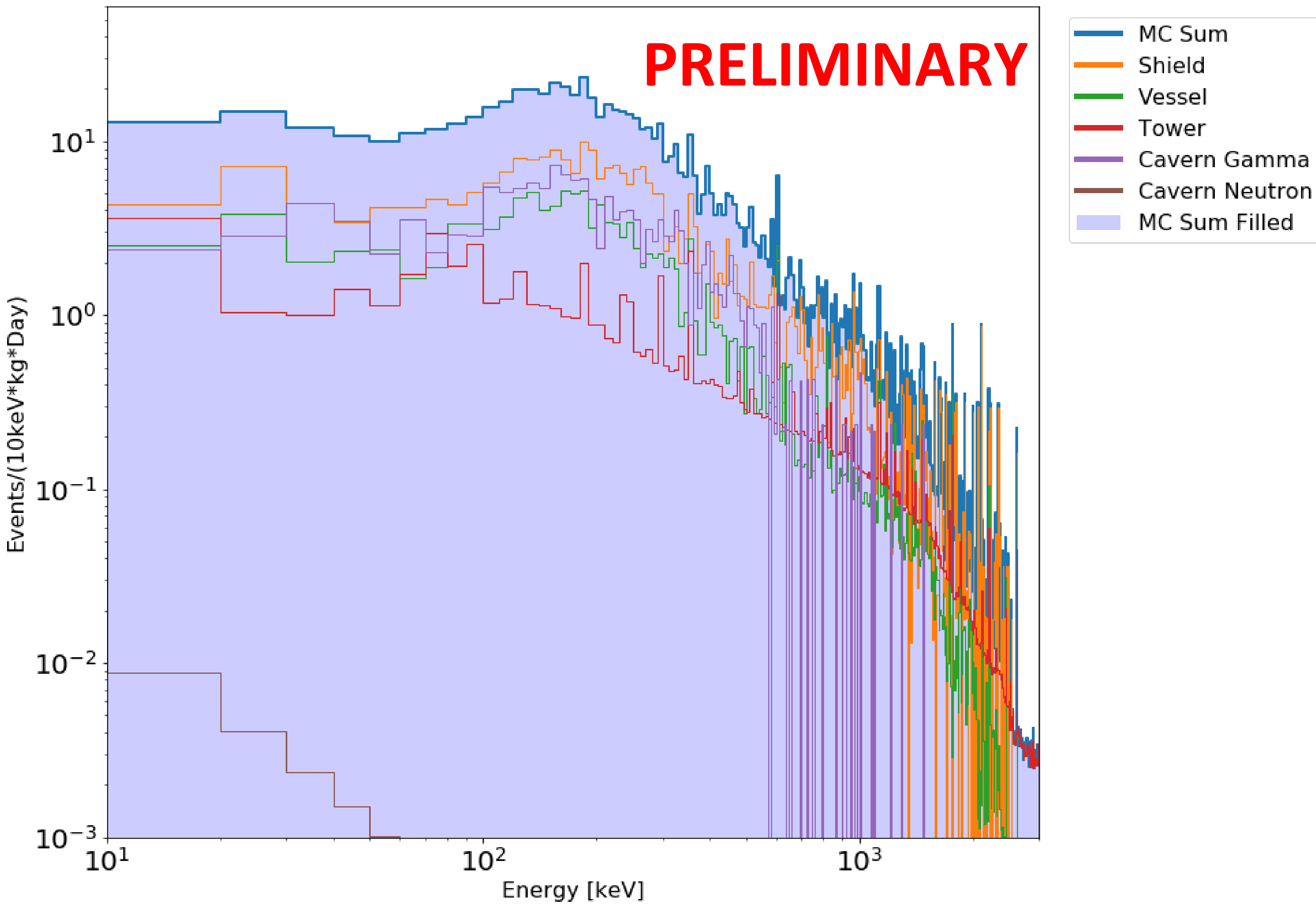
Background Explorer factors in material screening results and component masses, to get background rate in DRU.

$$1\ DRU = \frac{1\ Background\ Event}{(1\ keV) * (1\ kg\ of\ target\ mass) * (1\ Day)}$$

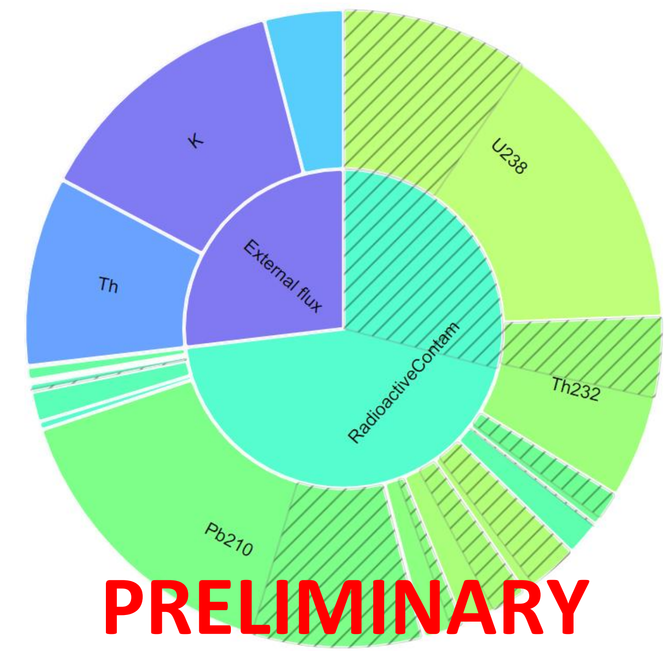
https://github.com/bloer/bgexplorer

Background Budget Visualization

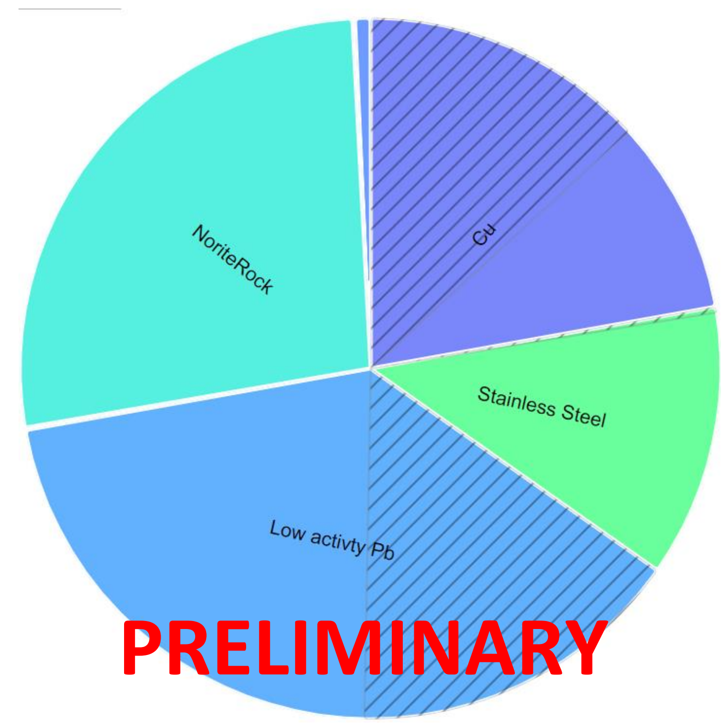
By Facility Component



By Decay Chain

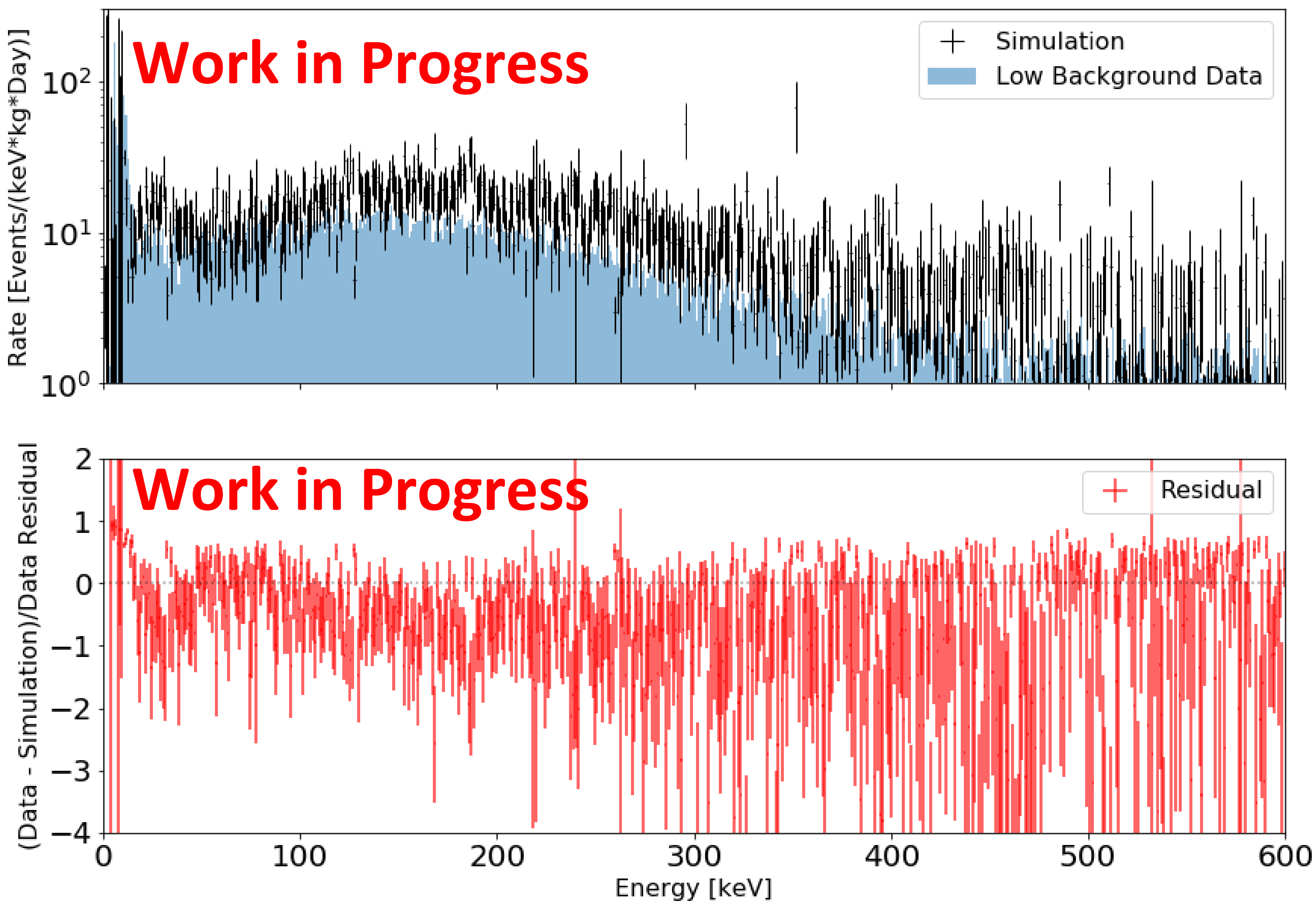


By Facility Material



M. Baiocchi and A. Pleava (SNOLAB)

Background Model Validation



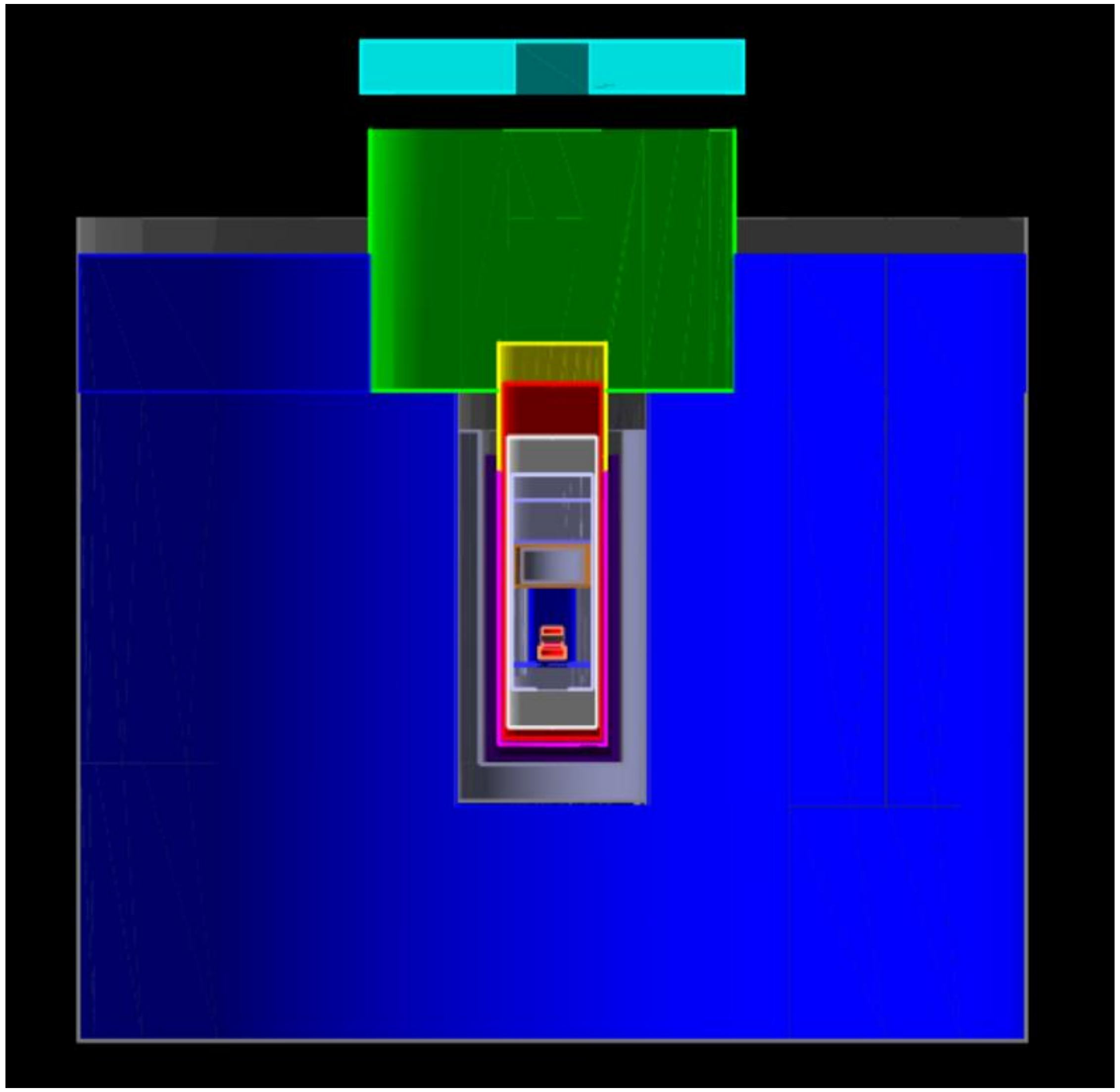
Good match between simulated and measured energy spectra from 600g Ge detector.

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

Work is in progress to understand discrepancies.

M. Baiocchi and A. Pleava (SNOLAB)

Flux Surface Speed-Up



Simulations are done for all new detector tower configurations.

Simulations can take up to 3 weeks of runtime.

We want to optimize the simulation CPU and simulate only components that change (detector tower).

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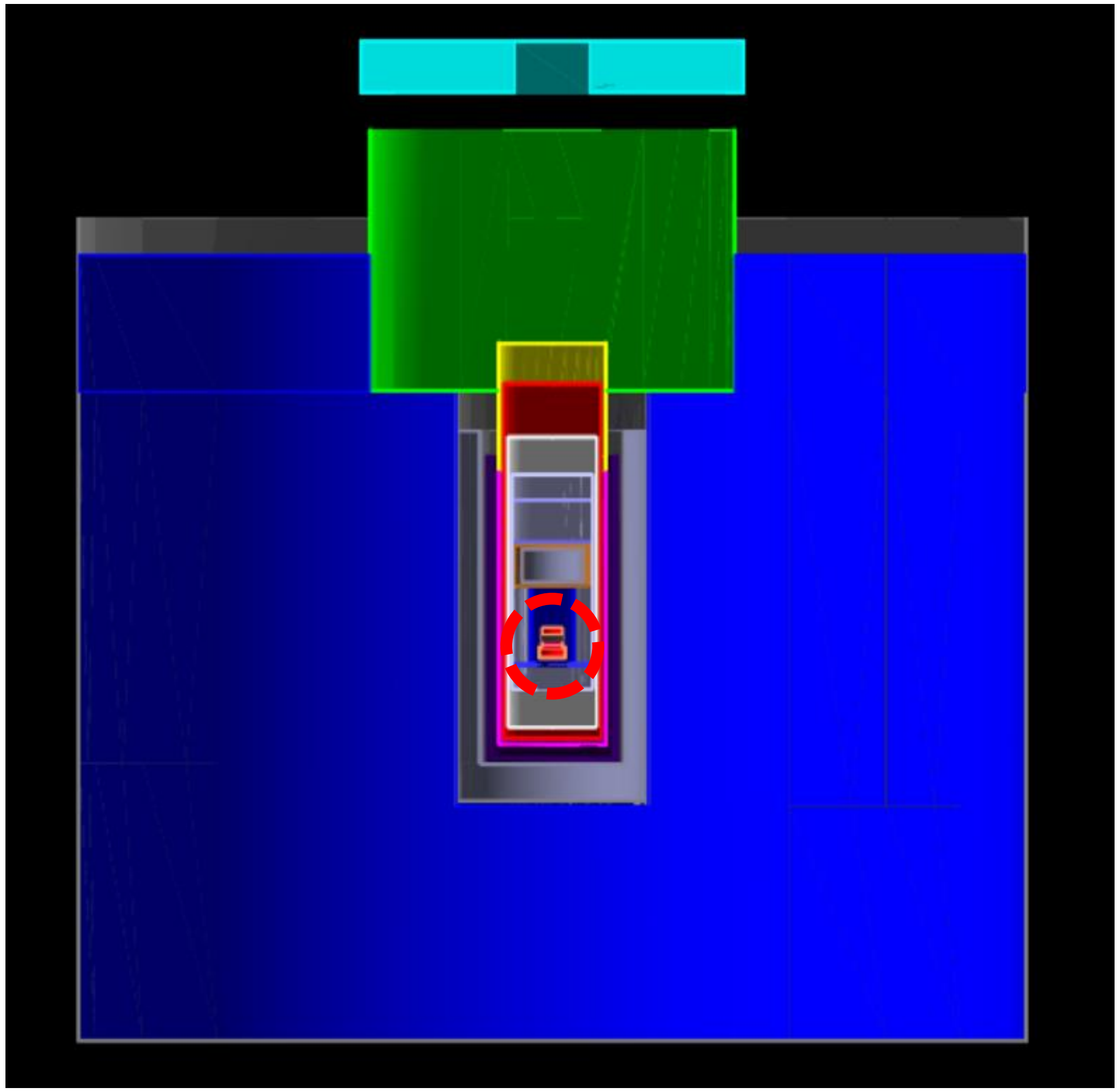

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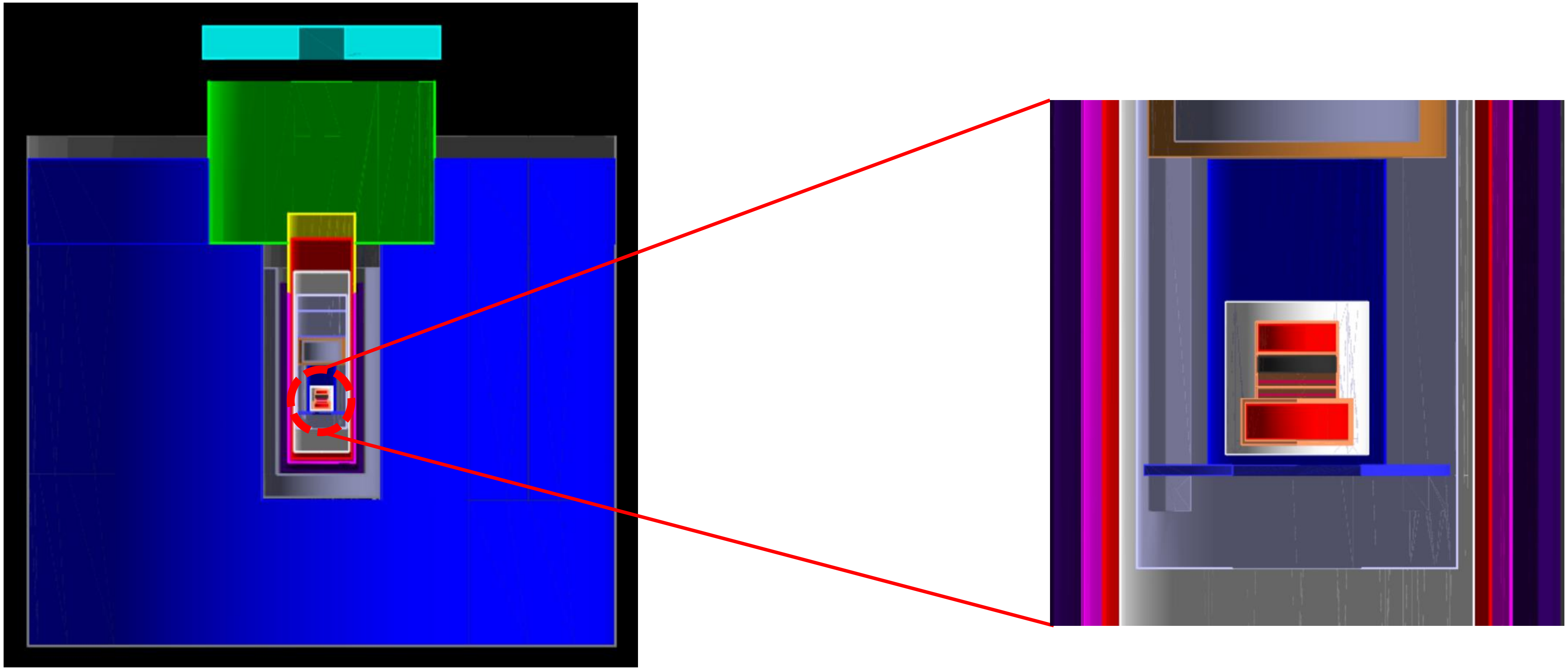
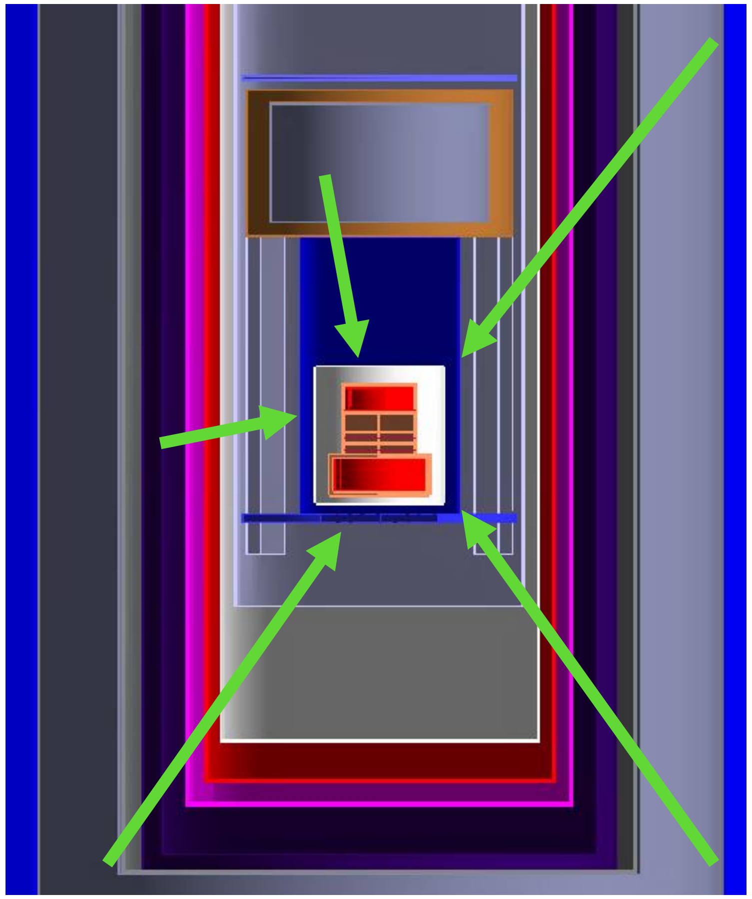
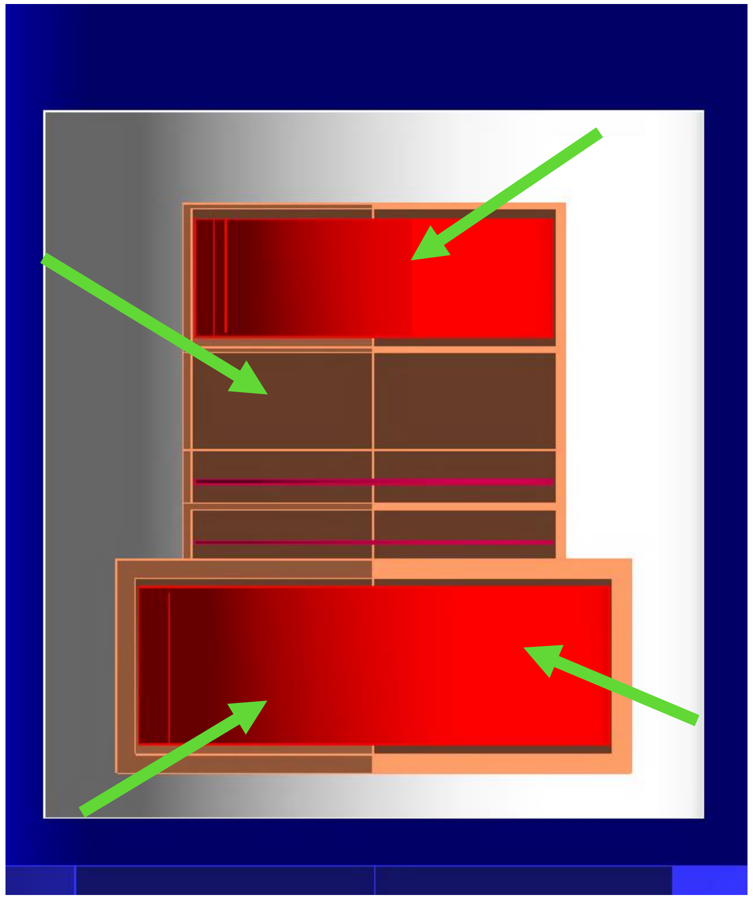


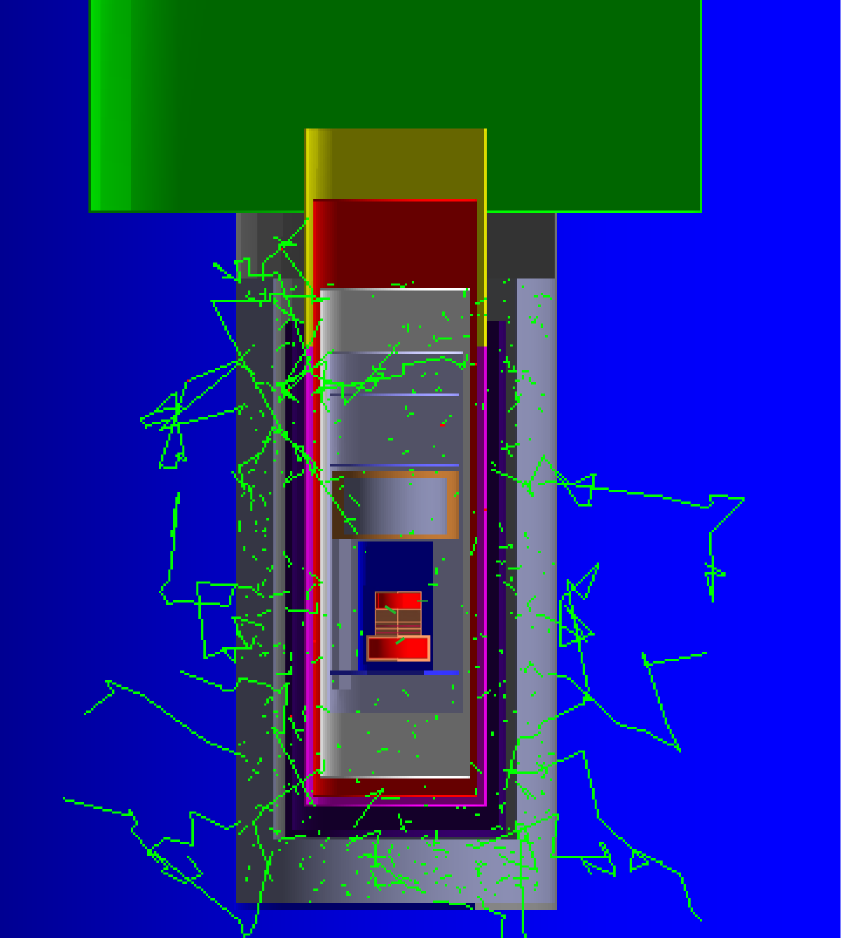
Flux Surface Speed-Up

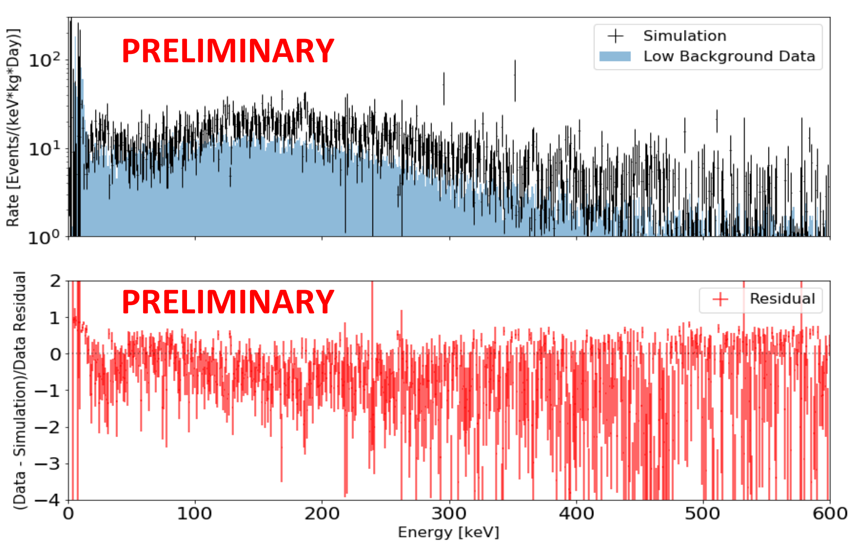
1. Simulate particles from contaminants to flux surface

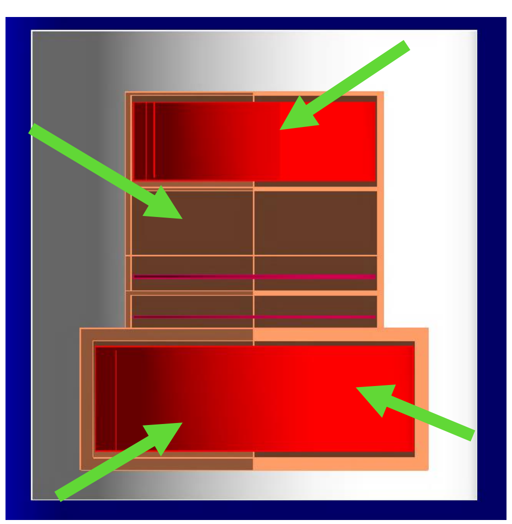


2. Simulate particles from flux surface to detectors









Conclusions

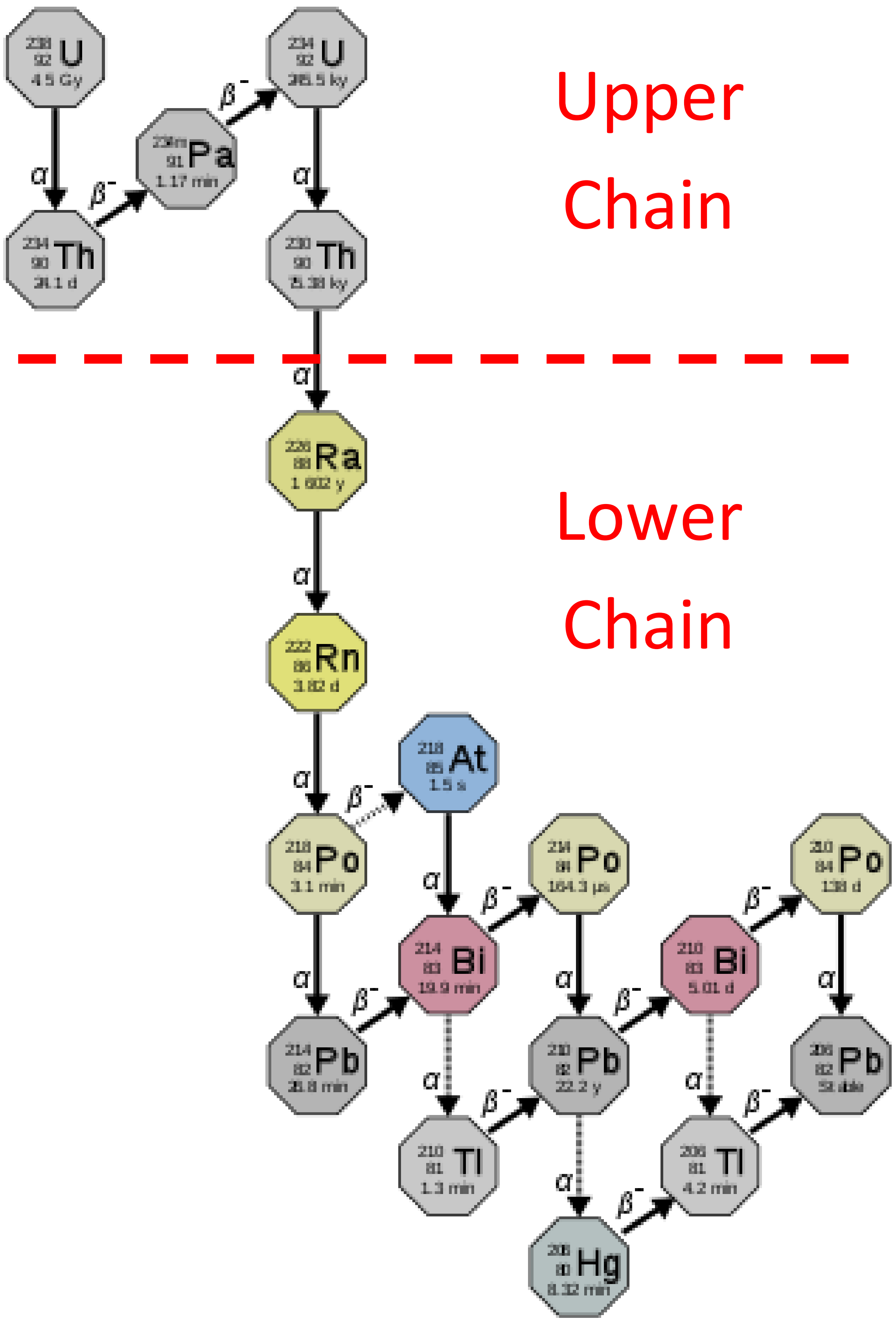
1. CUTE uses Geant4 simulations and HPGe/ICP-MS material assays to estimate radioactive background budget.

2. Good data/simulation agreement, and quality checks are ongoing. Work is in progress.

3. Future work will include finalizing and validating the Flux Surface approach which will speed up the simulations.

Thank you!

Questions?



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The Split-Chain Model

The U238 chain is in disequilibrium due to the long half-life of Ra226.

We use HPGe assay to measure the activity of the upper and lower U238 chains, and simulate them separately.

Validated by Melissa Baiocchi with data from Run 12 – 15.

Adapted From: User:Tsokasa, 2014. Decay chain(4n+2, Uranium series). Wikimedia Commons.

Background Explorer Normalization

1. Simulations produce hit count as a function of energy.

$$Hits(E)$$

2. Divide by number of primaries to get distribution of hits as a function of energy.

$$\frac{1}{\#\ Decay\ Events} * Hits(E)$$

3. Scale the distribution by component & decay chain activity (or flux rate) so it represents 1 full day.

$$\text{Activity [Bq]} * \frac{1}{\text{\# Decay Events}} * \text{Hits}(E)$$

4. Divide the distribution by the detector mass.

$$\frac{1}{\text{Detector Mass [kg]}} * \text{Activity [Events/s]} * \frac{1}{\text{\# Decay Events}} * \text{Hits}(E)$$

5. Divide by the energy bin width to produce a spectrum in DRU

$$\frac{1}{\text{Bin Width [keV]}} * \frac{1}{\text{Detector Mass [kg]}} * \text{Activity [Events/s]} * \frac{1}{\text{\# Decay Events}} * \text{Hits}(E)$$