Reconstruction of muon events with CUORE

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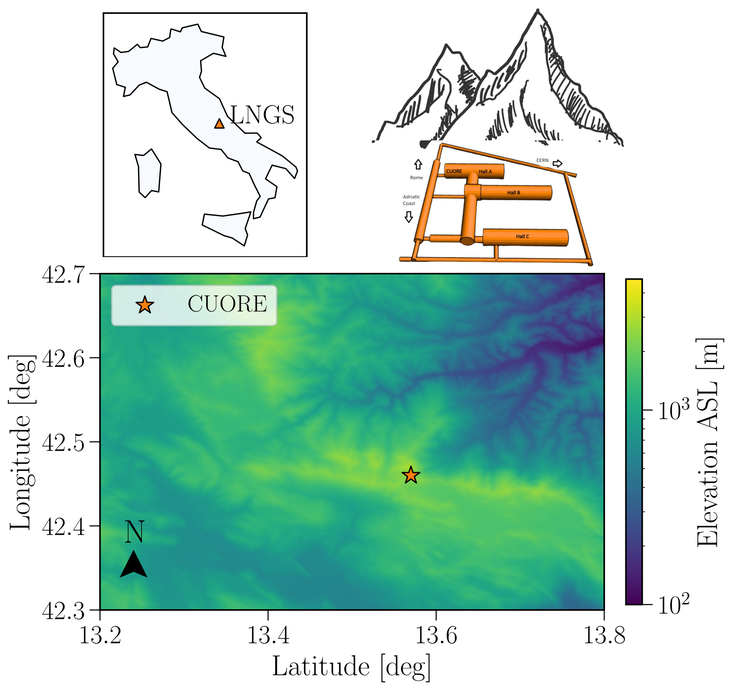
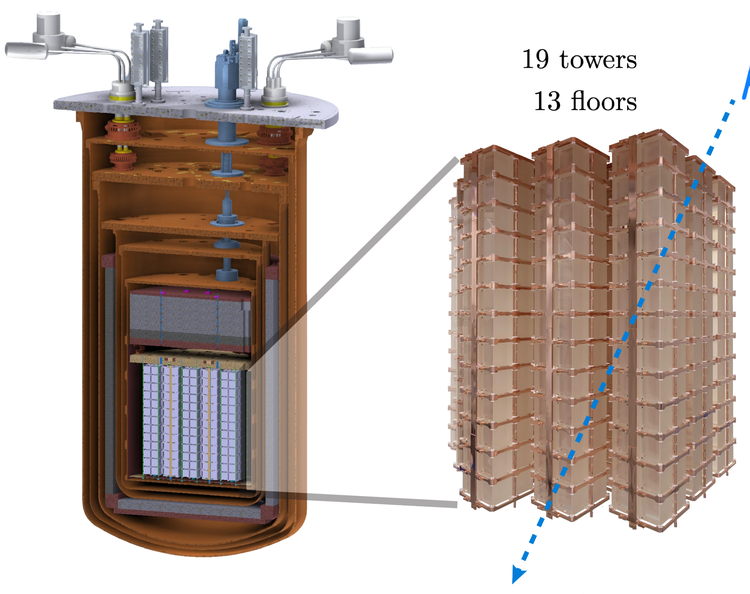
The Cryogenic Underground Observatory for Rare Events (CUORE) experiment

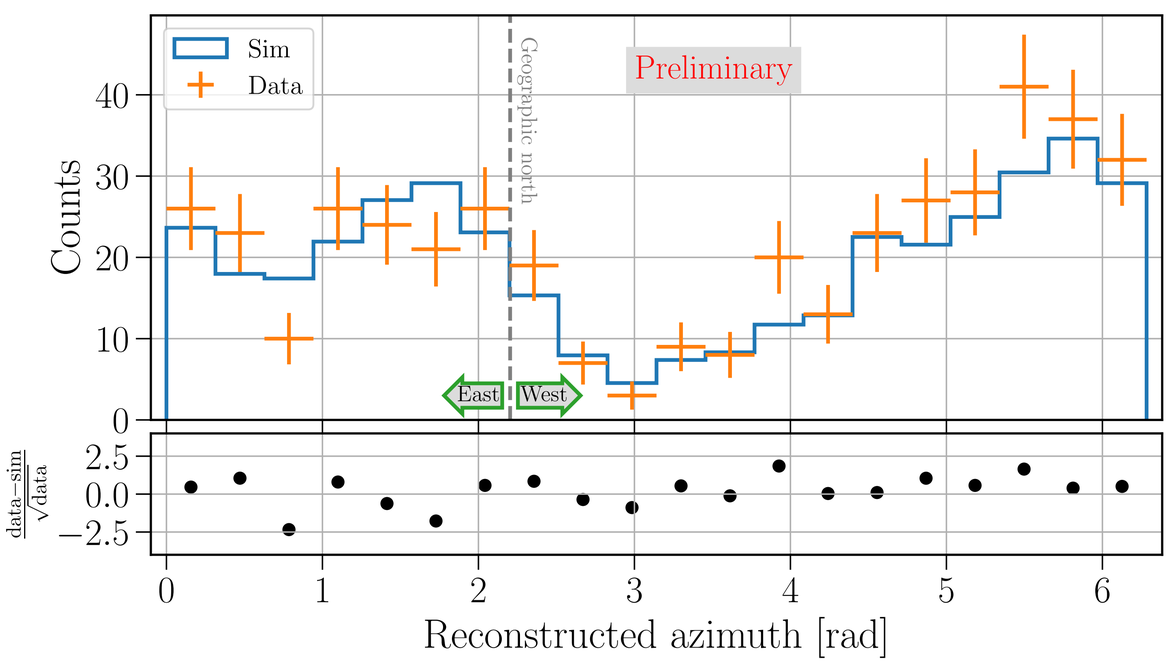
- Tonne-scale experiment searching for neutrinoless double beta ($0\nu\beta\beta$) decay in ^{130}Te using cryogenic calorimeters [1].
- Located at the Laboratori Nazionali del Gran Sasso, with about 3600 m.w.e. overburden to shield cosmic-ray byproducts.
- Detector segmentation into 988 cubic-crystals (5 cm side) aids event selection via coincidences.
- Segmentation also enables observation of track-like particles such as muons and searches for exotics (see D. Mayer, Contribution #417).

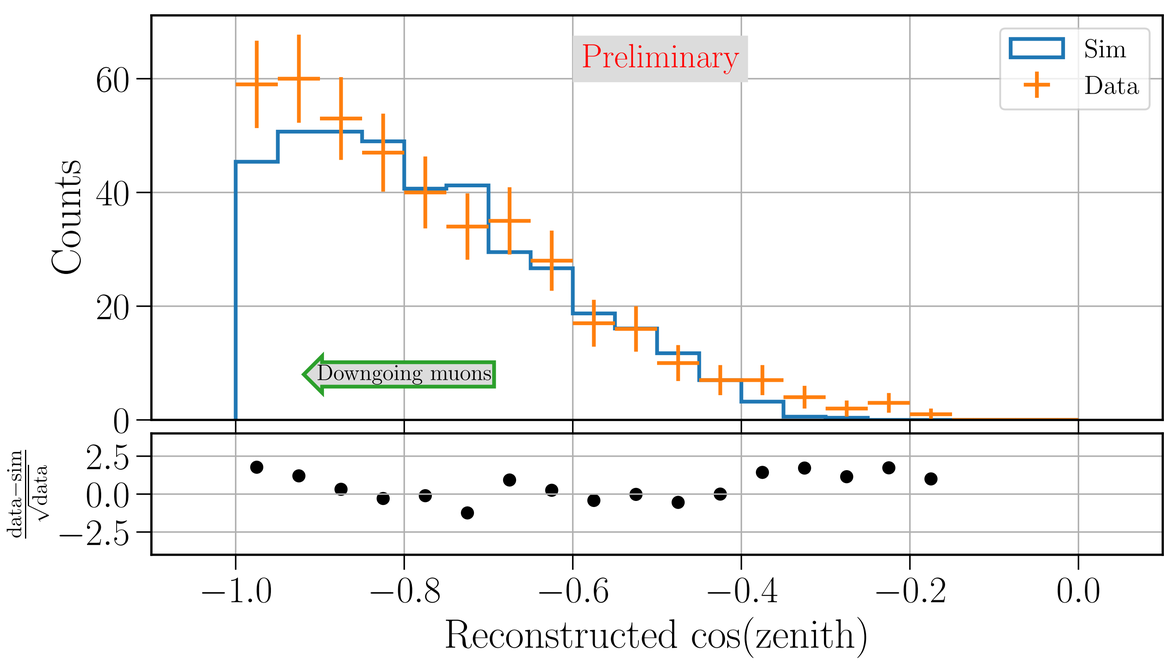




Credits: The CUORE Collaboration (modified)

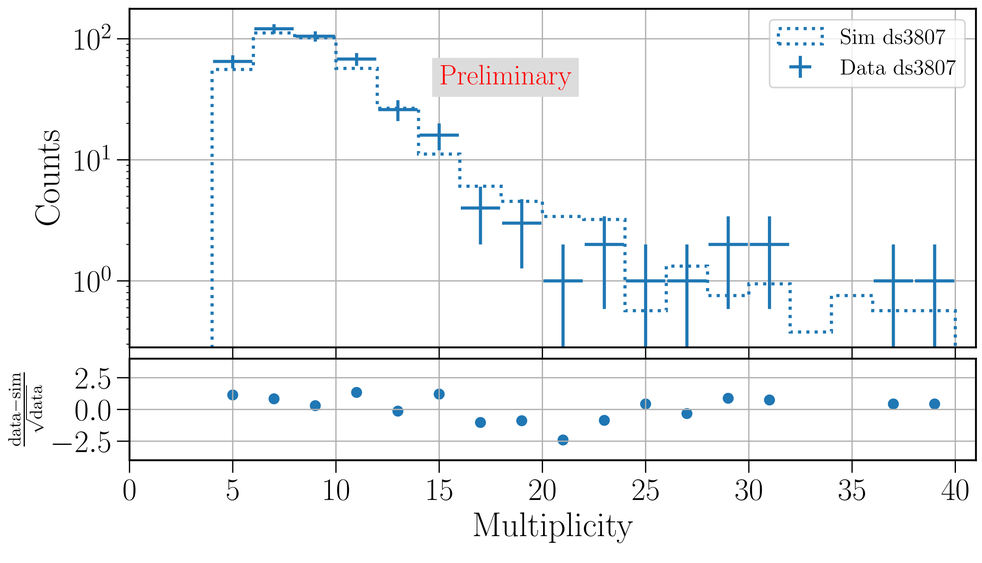
Reconstruction of muon events (validation dataset)





Methods

- Data divided into 1-month long datasets. Reconstruction done at the dataset level.
- Event selection to maximize muon-sample purity:
  - Energy deposition > 9 MeV/crystal or saturated.
  - Multiplicity > 5.
  - Basic cuts to reject unphysical, spurious, and calibration events.
- Expect $\sim 12,000$ muon events with analyzed exposure of 2-tonne·yr.
- Events that pass cuts have their track fitted by a multi-objective optimization-based algorithm [2].
- Tuning simulation to match real-detector effects:
  - Correlated dead-time via mock-time technique.
  - Saturation effects via data-driven approach.
- High-level observables used to evaluate the performance of the algorithm and compare MC/data.



Next steps and conclusions

Next steps:

- Shifting from validation to measurement.
- Tuning of cuts to be performed on a fraction of all the datasets of 2-tonne·yr TeO_2 analyzed exposure, before full measurement.
- Differential and integral flux of through-going muons to be extracted.

Conclusions:

- This work demonstrates that CUORE, a $0\nu\beta\beta$ decay experiment, can do 3D reconstruction of track-like particles to study muon-backgrounds and search for exotic phenomena.
- Validation of simulations of muons to be useful for next-generation experiment CUPID [3].

References:

[1] D. Q. Adams et al. (CUORE), "With or without ν? Hunting for the seed of the matter-antimatter asymmetry", arXiv:2404.04453 (2024).

[2] J. Yocum, D. Mayer, J. Ouellet, and L. Winslow, "Muon track reconstruction in a segmented bolometric array using multi-objective optimization", Journal of Instrumentation **17**, P07004 (2022).

[3] W. R. Armstrong et al. (CUPID), "CUPID pre-CDR", arXiv:1907.09376 (2019).

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