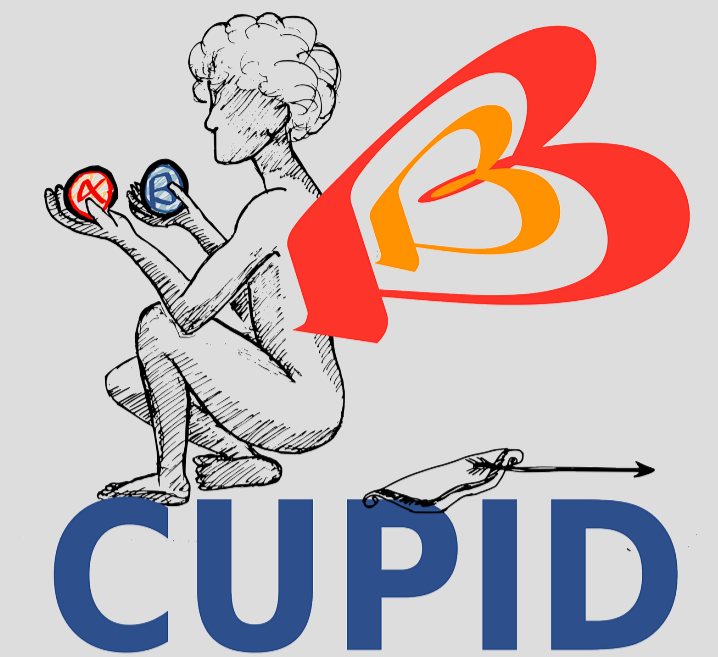


REDUCTION OF COSMOGENIC BACKGROUNDS IN THE CUPID EXPERIMENT

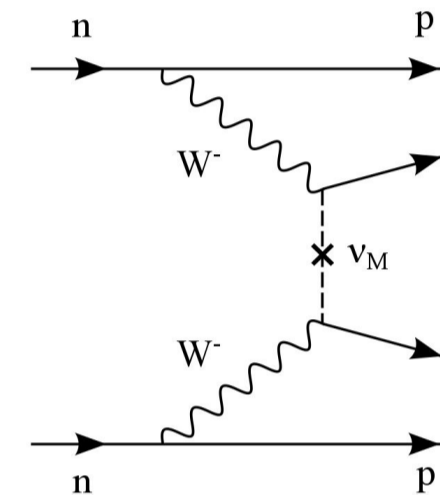
P. L. Slocum, on behalf of the CUPID Collaboration

Wright Laboratory, Yale University

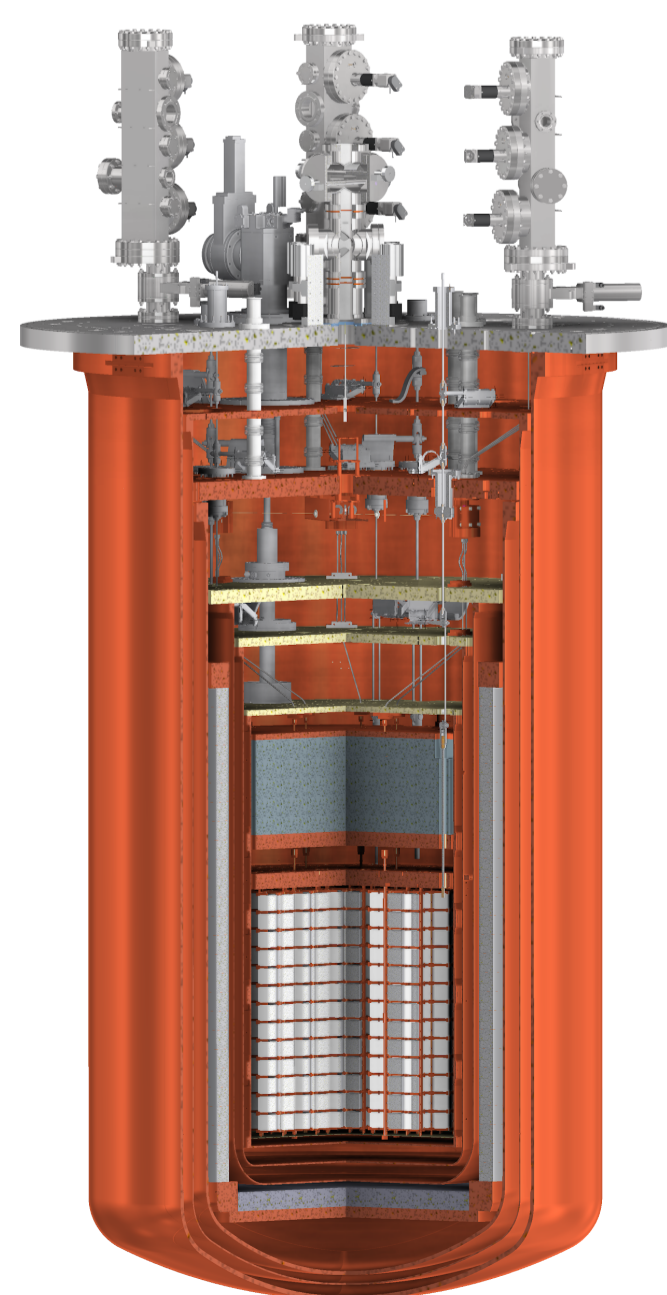


Neutrinoless $\beta\beta$ decay

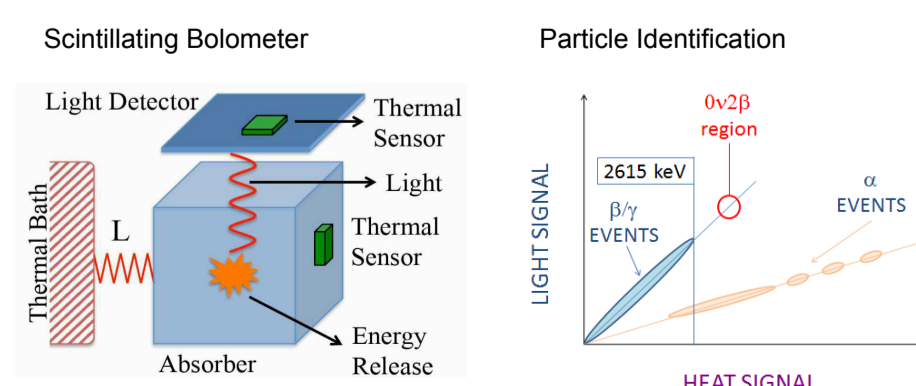
- Foundations for theory in 1937 by Majorana and development in 1939 by Furry.
- Theoretical physical decay: Two neutrons in an atomic nucleus convert to two protons by emission of two electrons.
- Would provide direct evidence of lepton number nonconservation, suggesting $\nu = \bar{\nu}$ and favoring CP violation in the PMNS ν mixing matrix [1].
- Predicted half-life [2] $T_{1/2}^{-1} = g_A^4 |M_{0\nu}|^2 G_{0\nu} m_{\beta\beta}^2 / m_e^2$.



CUPID experiment



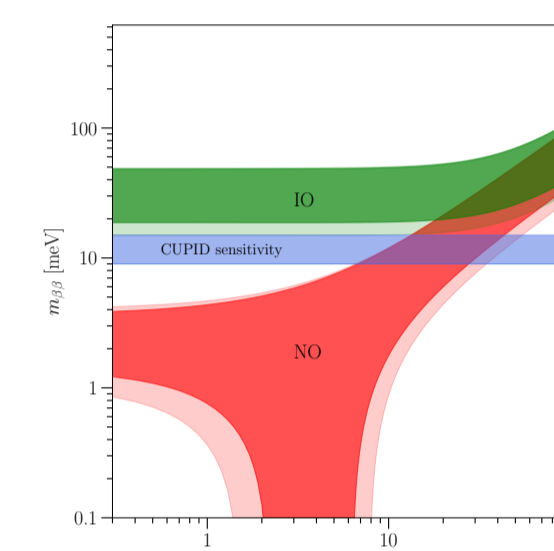
- A next-generation experiment [3] located at the Gran Sasso National Laboratory in Italy designed to search for $0\nu\beta\beta$ decay.
- Li_2MoO_4 scintillating crystals enriched in ^{100}Mo ; $Q \sim 3$ MeV for background reduction.
- Critical particle discrimination in α and β/γ .



Backgrounds and sensitivity

CUPID sensitivity

- Baseline frequentist 3σ discovery sensitivity to $0\nu\beta\beta$ decays in ^{100}Mo with $\hat{T}_{1/2} = 10^{27}$ yr, corresponding to $\hat{m}_{\beta\beta} = 12\text{-}36$ meV [2, 4].
- Uncertainties are defined by the range of possible NME values, assuming a background index = 1.0×10^{-4} counts/keV/kg/yr and an energy resolution = 5 keV.



Backgrounds and on-going improvements:

- Natural radioactivity, dominated in the CUPID ROI by β and γ backgrounds from ^{208}Tl and ^{214}Bi decays.
- Cosmogenics, requiring mitigation with muon veto (MV) system.
- Signal pileup, identifiable with light detectors, leveraging fast signal rise times.
- Total background index of $1.1^{+0.2}_{-0.1} \times 10^{-4}$ ckky is compatible with CUPID science goal.

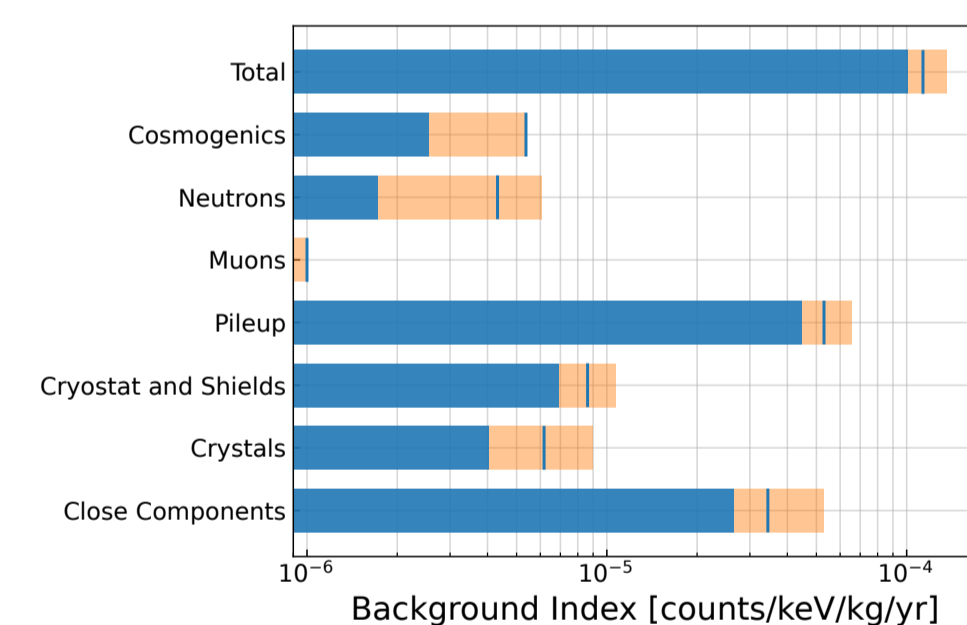
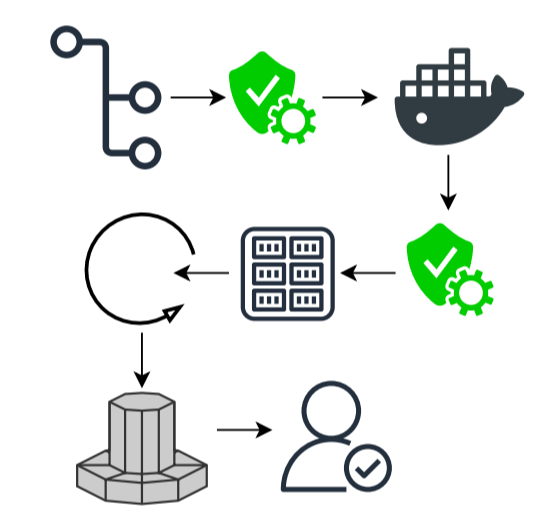
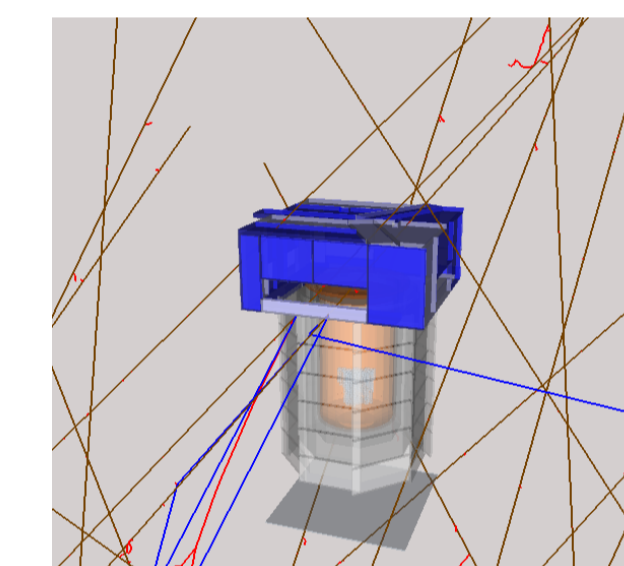


Figure: Backgrounds (blue) and uncertainties (orange).

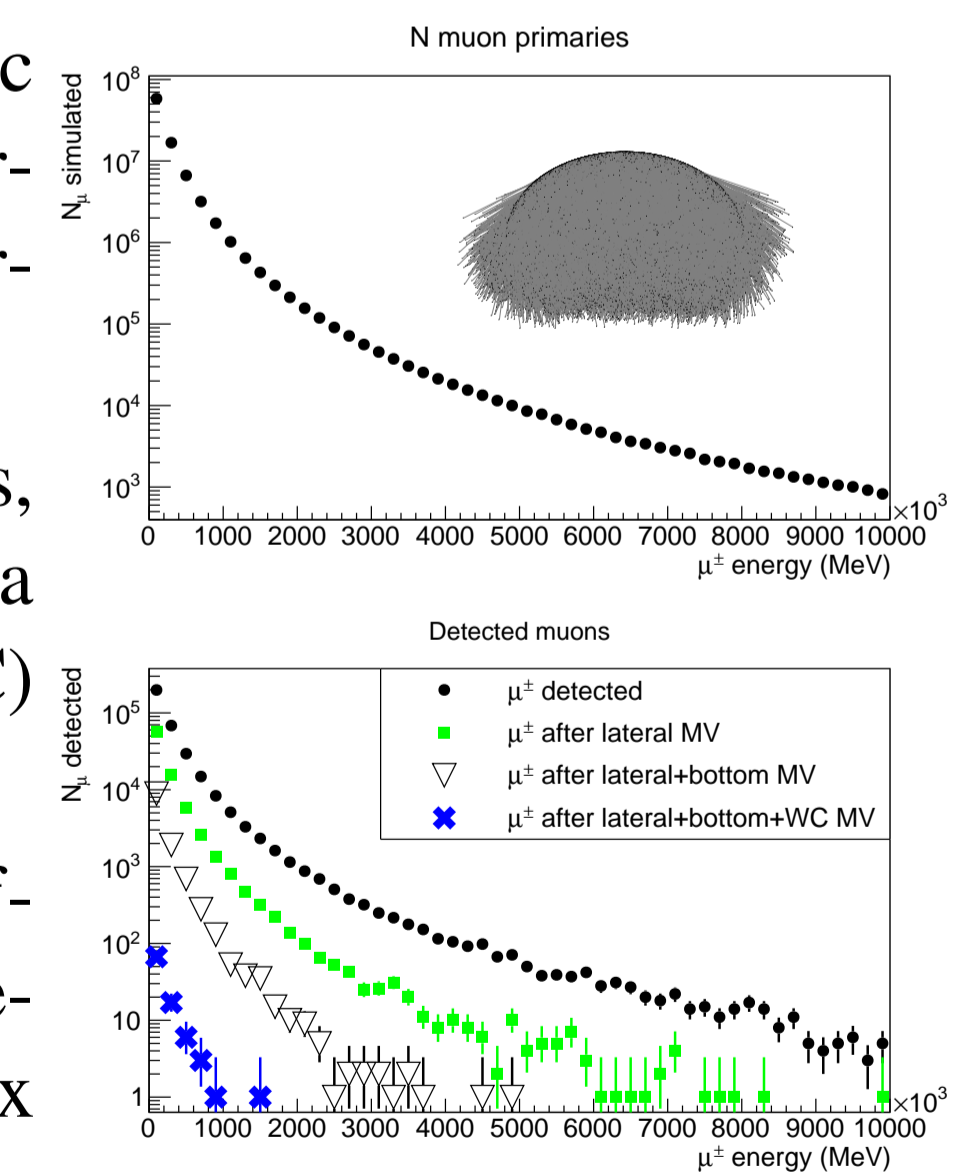
Simulation pipeline

The Agata simulation package, developed by the CUORE and CUPID collaborations, is built with Geant4:

- MV geometry is imported directly from detailed CAD models.
- Containerized gitlab pipeline for versioning.



- Simulation models the energy deposition by cosmic muons, and secondary particles, in CUPID underground at LNGS.
- Includes lateral MV panels, a bottom MV panel, and a top water Cherenkov (WC) detector.
- Geometric MV tagging efficiency is $>99\%$, with a reduced μ background index $\leq 10^{-6}$ ckky.



[1] NuFit-6.0 (2024).

[2] Eur. Phys. J. C 86, 633 (2026).

[3] PRL 126, 181802 (2021), arXiv:1907.09376.

[4] Eur. Phys. J. C 85, 737 (2025).

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