

# MUTE: A Modern Calculation for Deep Underground and Underwater Muons

*Sunday, 19 February 2023 11:00 (15 minutes)*

I present a new, open-source, pure Python program, MUTE (MUon inTensity codE) (A. Fedynitch, W. Woodley, M.-C. Piro 2022 ApJ 928 27). MUTE combines the state-of-the-art codes MCEq (Matrix Cascade Equation) and PROPOSAL (PRopagator with Optimal Precision and Optimised Speed for All Leptons) to compute cosmic ray cascades in the atmosphere and the propagation of muons through matter in separate steps. It is efficient, precise, and flexible, as the most recent theoretical models can be changed in the code independently of each other. Using these tools, MUTE provides forward predictions for muon intensities in mines or under mountains deep underground and underwater laboratories, accurately characterising the uncertainties arising from hadron production models. MUTE can also provide full information about muon energy and angular spectra underground. The control of theoretical uncertainties allows us to accurately predict the total muon rates and their seasonal variations to calculate muon-induced backgrounds in underground Dark Matter and neutrino detectors.

## Supervisor

Marie-Cécile Piro

## Funding Agency

McDonald Institute

## Supervisor Email

mariecci@ualberta.ca

## Your Email

wwoodley@ualberta.ca

**Primary author:** WOODLEY, William (University of Alberta)

**Co-author:** PIRO, Marie Cecile (University of Alberta)

**Presenter:** WOODLEY, William (University of Alberta)

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