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

*Monday 8 August 2022 16:50 (20 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 the cosmic ray cascades in the atmosphere and the propagation of muons through matter in separate steps. It is both efficient 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 spectra in deep underground and underwater laboratories, accurately characterising the uncertainties arising from hadron production models. The implications are that if high-energy atmospheric neutrino flux uncertainties are cross-calibrated with the underground muon intensity data, there is considerable potential for them to be reduced from 40% down to approximately 10%. MUTE can be also used for laboratories located in mines or under mountains. The control of theoretical uncertainties allows us to accurately predict the total muon rates and their seasonal variations, and derive muon-induced backgrounds in underground Dark Matter and neutrino detectors.

### Collaboration name

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