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Monte Carlo Study of PeV Muon Propagation and Secondary Particle Production in Gran Sasso Rock

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High-energy cosmic-ray muons penetrating deep underground undergo stochastic interactions in rock and can produce a significant secondary particle component accompanying the surviving muon. This effect becomes particularly important at muon energies approaching the PeV range, where radiative and photonuclear processes may result in large energy transfers and production of energetic secondary particles. In this work, Monte Carlo simulations of high-energy muon propagation through the rock overburden of the Gran Sasso underground laboratory are performed. The characteristics of the muon and secondary particles emerging from the rock are studied as a function of the initial muon energy. The analysis includes the residual muon energy, secondary-particle multiplicity and total energy, as well as the contributions of electrons and positrons, hadrons, and secondary muons. Particular attention is paid to the formation and evolution of the particle accompaniment generated by stochastic muon interactions in the rock. The obtained results are relevant for the interpretation of high-energy muon events in deep underground detectors and for studies of the response of the LVD setup to the highest-energy component of the underground cosmic-ray muon flux.

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