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Seasonal Variation of Atmospheric Muons and Shower-to-Shower Fluctuations in CORSIKA Simulations

Seasonal changes in the South Pole atmosphere affect muon production in cosmic-ray air showers, while hadronic-model uncertainties and intrinsic shower fluctuations complicate interpretation. We analyze CORSIKA 7.8050 simulations with SIBYLL 2.3e, EPOS-LHC-R, and QGSJet-III, using FLUKA at low energies. Proton and iron primaries are simulated at 16 energies from 10^6 to 10^9 GeV in January, April, and August atmospheric profiles. The extracted samples contain 9,939–9,999 showers per SIBYLL point, 1,998–2,000 per QGSJet-III point, and 1,997–2,000 per EPOS-LHC-R point. Surface observables include the muon number above 500 GeV, its relative shower-to-shower fluctuation coefficient, muon energy spectra, and lateral footprints. A complementary PROPOSAL study propagates seasonal samples to 1450 m; cross-model comparisons at depth are not included here.

Across the simulated model, primary, and energy points, the mean muon number is higher in January than April by 1.3–9.3%, and lower in August by 3.0–8.7%. In contrast, the seasonal change in the fluctuation coefficient varies in sign across points, providing no universal seasonal ordering. In April, EPOS-LHC-R and QGSJet-III differ from SIBYLL by −2.4% to +11.1% in mean muon number and −16.4% to +3.1% in the fluctuation coefficient across proton and iron samples. These comparisons establish a quantitative baseline for seasonal and hadronic-model effects. Separating those contributions from intrinsic shower fluctuations remains an objective of ongoing analysis.

Academic position of the presenting author

Undergraduate Student

Primary author: DIAZ, Braither

Presenter: DIAZ, Braither

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