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Studying Muon Bundles for Improved EHE Neutrino Identification in IceCube

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At extremely high energies (EHE), i.e. from 1 PeV to 10 EeV, one of the main backgrounds in IceCube neutrino analyses comes from atmospheric muon bundles. These consist of several muons produced in the same cosmic-ray air shower that cross the detector simultaneously. Due to their combined energy loss and spatial distribution, bundles can mimic the signature of a single, high-energy muon from an EHE neutrino interaction.

This study aims to characterize the features that differentiate muon bundles from single muon tracks. Using simulated events from CORSIKA (for atmospheric background) and NuGen (for single muons), a range of observables are investigated, including bundle multiplicity, stochastic energy losses or lateral charge spread. The comparison of these features aims to highlight key differences that could be used to improve background discrimination at the reconstruction level. These insights are intended to support the development of more robust and machine learning based EHE event selection strategies.

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