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P_{tail} - a high-resolution gamma/hadron and composition discriminant variable for Water Cherenkov Detector cosmic-ray observatories

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The precise and efficient identification of the nature of the primary cosmic rays on an event-by-event basis stands as a fundamental aspiration for any cosmic ray observatory.
In particular, the detection and characterization of gamma ray events are challenged by their occurrence within an overwhelmingly greater flux of charged cosmic rays spanning several orders of magnitude. The intricacies of distinguishing between cosmic ray compositions and the inherent uncertainties associated with hadronic interactions present formidable challenges, which, if not properly addressed, can introduce significant sources of systematic errors.

In this presentation, we introduce a novel composition discriminant variable, $P^{\alpha}_{\mathrm{tail}}$, which quantifies the number of Water Cherenkov Detectors with a signal well above the mean signal observed in WCDs located at an equivalent distance from the shower core, in events with approximately the same energy at the ground. This new event variable is then shown to be, in the reconstructed energy range 10 TeV to 1.6 PeV, well correlated with the total number of muons that hit, in the same event, all the observatory stations located at a distance greater than 200 m from the shower core. The two variables should thus have similar efficiencies in the selection of high-purity gamma event samples and in the determination of the nature of charged cosmic ray events.

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