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Muon Decay as a Robust Long-Term Calibration Method for Water Cherenkov Detectors

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Water Cherenkov detectors (WCDs) are widely used in gamma-ray astronomy. At high altitudes (>4000 m a.s.l.), where detectors such as those in the LAGO network, HAWC, and the upcoming SWGO operate, gamma-induced air showers can be detected more efficiently due to reduced atmospheric absorption. However, the harsh conditions at these sites make regular maintenance and calibration extremely challenging, highlighting the need for remote and reliable calibration methods.
At these elevations, the atmospheric background is dominated by its electromagnetic component, significantly suppressing the muon flux and rendering the traditional muonic hump in the charge spectrum nearly undetectable. This feature, typically used for energy calibration, becomes unusable.
In this work, we apply a previously developed method that exploits the detection of Michel electrons—emitted from muon decays within the detector volume—to calibrate WCDs without requiring complementary instrumentation. The method is robust against variations in altitude, meteorological conditions, and solar activity, and provides a stable calibration reference independent of the features of the total charge spectrum.
We demonstrate the feasibility of this approach by analyzing long-term calibration periods for prototype LAGO detectors, and compare the measured Michel spectra with detailed simulations. Our results confirm that this technique enables consistent and remote energy calibration in WCDs, even under extreme high-altitude conditions.

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