Development and Calibration of a Portable Muon Telescope for Balloon-Borne Atmospheric Muon Flux Studies

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Cosmic ray muons, produced by interactions between high-energy cosmic rays and the Earth's atmosphere, are widely used in muon tomography, an emerging technique for imaging dense structures such as geological formations and nuclear reactors. However, precise muon flux and spectrum measurements are essential for improving these applications. At a vertical cutoff rigidity of 1.3 GV, comprehensive atmospheric muon data are lacking, necessitating dedicated experimental studies. This study presents the development and deployment of a self-constructed scintillation detector system for measuring atmospheric muon flux and angular distribution. The detector, including custom-designed electronics, was launched on a high-altitude balloon, reaching 24 km. The variation of muon flux with altitude was measured, successfully identifying the Regener-Pfotzer maximum at 13.3 km. Ground-based experiments provided zenithal distribution data, confirming expected angular dependencies. Additionally, it was found that is that the light yield of the detector is uniform across its surface, indicating a lack of spatial resolution. To extract the muon spectrum, Monte Carlo simulations were performed using the CORSIKA 8 framework. Various parameters, including primary cosmic ray composition and atmospheric conditions, were iteratively adjusted to best match the measured altitude-dependent flux. The FLUKA model was used for hadronic interactions. Once a realistic flux profile was obtained, the muon momentum spectrum was extracted from the simulation. These findings demonstrate that a scintillation detector can be used to infer muon spectra. This approach offers a cost-effective alternative to obtain muon spectra for muon tomography without the need for large-scale spectrometers.

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