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Identifying Quark-Gluon Plasma Signatures in Ultra-High-Energy Cosmic Ray Air Showers via Secondary Particle Distributions at Ground Level

The study of quark-gluon plasma (QGP) in heavy-ion collisions provides a crucial window into quantum chromodynamics under extreme conditions. While collider experiments aim to create and analyze QGP, similar phenomena may naturally occur in ultra-high-energy cosmic ray (UHECR) interactions, where collision energies can exceed those achieved in laboratories. In this work, we employ the CORSIKA simulation framework with EPOS-LHC and QGSJET models to investigate potential QGP signatures in extensive air showers. Our analysis focuses on distinguishing QGP-induced events from non-QGP events based on secondary particle distributions at ground level. Preliminary results indicate notable differences in the spatial and energy distributions of secondary particles, particularly muons, between the two event types. These findings suggest that collective effects in muon distributions may serve as a promising observable for identifying QGP formation in UHECR-induced air showers. The proposed method could be tested in large-scale cosmic ray observatories, such as China's Large High Altitude Air Shower Observatory (LHAASO).

Collaboration(s)

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