Contribution ID: **83** Type: **Oral**

Investigation of Muon Excess from Initial Hadronic Interactions in Cosmic Air Showers with a One-ton Scintillator Detector at CJPL

Monday 25 August 2025 14:51 (17 minutes)

Over the past decade, ground-based array experiments have observed a notable muon deficit when simulating extensive air showers (EAS) induced by high-energy cosmic rays, compared to experimental measurements. This discrepancy is referred to as the muon puzzle. In this report, we present the first investigation on this topic at the China Jinping Underground Laboratory (CJPL), which, with its 2400-m vertical rock overburden, limits muons to energies above 3 TeV, with an average primary cosmic-ray energy of 0.4 PeV. This provides a clean window for studying the initial EAS processes. The data, collected over 1178 live days from the 1-ton prototype of the Jinping Neutrino Experiment, along with a GEANT4-based flux simulation framework, are used for comparison in this work. Our results show that the measured muon flux is approximately 30% higher than predicted, with a 2σ significance (3σ excluding model-related uncertainties), and no significant angular dependence is observed. These findings highlight the potential for future high-energy cosmic-ray research in deep underground environments.

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Session Classification: High-Energy Astrophysics and Cosmic Rays

Track Classification: High-Energy Astrophysics and Cosmic Rays