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Muonphilic Dark Matter Searches Using an RPC-based Muon Tomography System

Exploring dark matter remains a central theme in both cosmology and particle physics. Despite compelling cosmological evidence and extensive experimental efforts, no dark matter particle has been directly detected, prompting the search for alternative, theoretically viable approaches.

Muons uniquely bridge applied and fundamental research. Cosmic-ray muon tomography has emerged as an effective tool for imaging the internal structure of large-scale objects and has been widely applied in geology and archaeology. In our work, we propose using muon tomography to search for muon-philic dark matter, offering a novel experimental approach.

Our detection system employs Resistive Plate Chambers (RPCs) as gas detectors for muon tomography. Each RPC module has a sensitive area of $203\times203\,\mathrm{mm}^2$, achieving a spatial resolution better than $\sigma < 1\,\mathrm{mm}$ while maintaining an efficiency above 90%. The tomography system consists of four RPCs, forming a sensitive volume of $203\times203\times500\,\mathrm{mm}^3$.

Since January 2024, we have conducted nearly three months of tests on cosmic-ray muon interactions in air. Simultaneously, a GEANT4 simulation—replicating the dimensions, materials, and spacing of our setup—was performed to model the angular distribution of muon events. The experimental data show a significantly higher fraction of large-angle events than predicted, indicating that muon interactions in air and materials require further investigation.

Next, we plan to suppress air scattering effects by inserting vacuum chambers between the RPCs, upgrading the system to operate in vacuum mode for dark matter searches. Future efforts will focus on reducing background noise and improving the detection threshold of this method.

[1] Phys. Rev. D 110, 016017

[2] arxiv: 2410.20323

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