Revealing Secondary Particle Signatures in Muography Based on the PoCA Algorithm

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Introduction

- This work reinterprets so-called "noise" in cosmic-ray imaging, indicating that the data of reconstructed Points of Closest Approach (PoCA points) outside the volume of interest defined by traditional tomography methods contain valuable physical information that has been traditionally disregarded.
- The roof structure significantly impacts the distribution of PoCA points at detector positions, where quantitative analysis demonstrates a strong correlation between roof areal density and the number of reconstructed PoCA points—a relationship that can be precisely measured through z-coordinate distribution analysis in specific intervals. This approach holds significant potential for development into a new tomography technique.

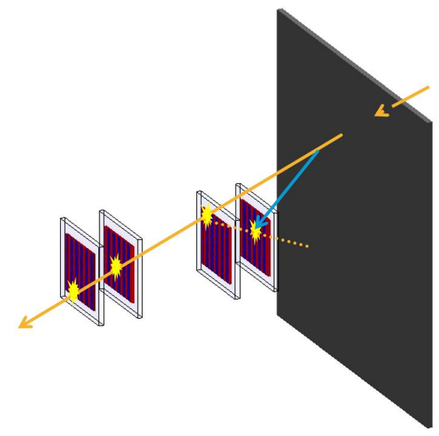
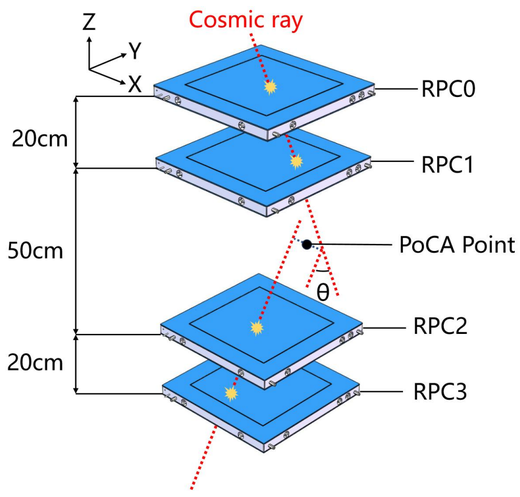


Fig1. Secondary particle signal

Experimental and Simulation Setup



The dark matter search experiment of PKMu serves as the direct background. Detailed information of experimental setup can be found in Cheng-en Liu's poster.

Fig2. Experimental setup

Simulation Setup:

- CRY generates cosmic rays
- In Run0, particles are generated at the top of RPC0; in Run1, at the top of the roof.
- Define a specific readout region in each RPC, and calculate the horizontal position using the centroid of energy deposition.
- Main Physical lists: FTFP_BERT

Event Fraction for Different Roofs

Event Fraction: the integral of the PoCA z-distribution within the [235, 265] mm interval

Potential Imaging Method!

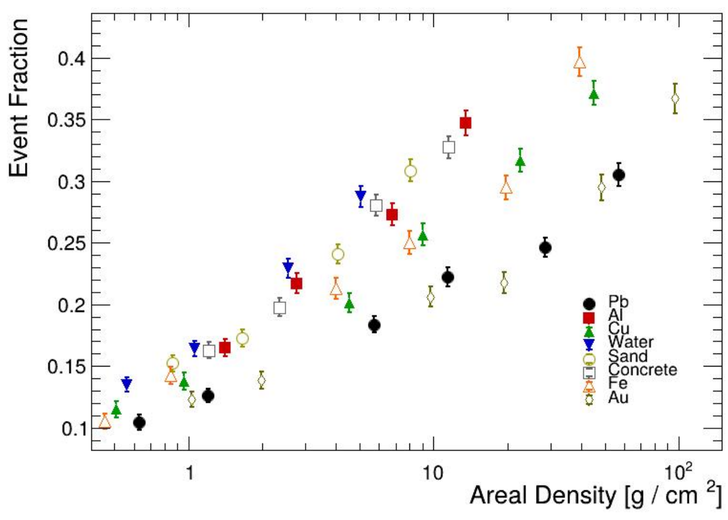


Fig5. The correlation between the areal density of roofs and the corresponding event fractions.

Reconstructed PoCA Points at RPC1

- In the experimental data, we see a clear peak of PoCA points at RPC1—a feature completely absent in Run0. The lead roof in Run1 reproduces this RPC1 feature.

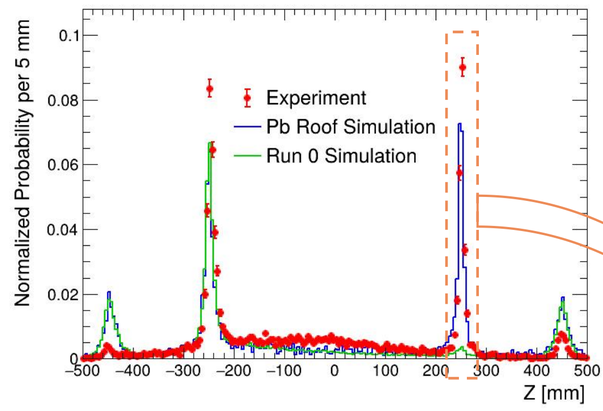


Fig3. Comparison of the filtered PoCA z-distributions from the experiment and simulations.

- A positional deviation at RPC0, with the other layers recording straight-through cosmic rays, naturally yields the peak at RPC1. In the filtered events, most CRY particles pass only through the three lower layers and RPC0 records mainly muon-induced ionization electrons.

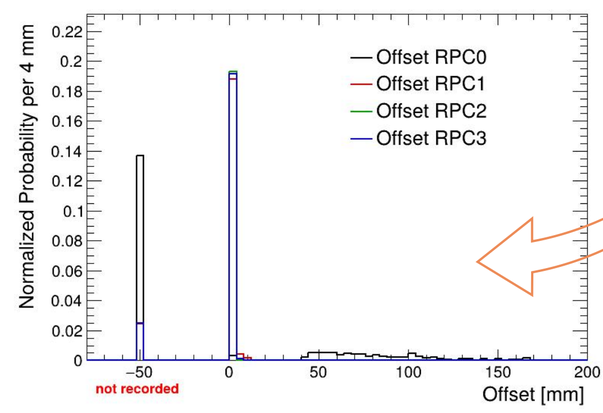


Fig4. The offset distance between the actual recorded positions of RPCs and the CRY particle impact positions on the RPCs.

Conclusion

- PoCA points on the detector are usually considered noise, but this work found that these events actually contain information about the interaction between incident particles and the detector as well as surrounding materials.
- The generation probabilities of muon-induced ionization electrons and bremsstrahlung photons vary in different materials, possessing the potential to develop new imaging methods.

References

[1] R. F. Zhang, et. al, J. Appl. Phys. 139, 014903 (2026).
[2] C.-E. Liu, et al., Phys. Rev. Lett. 136, 151001 (2026).

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