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17:35～17:50:00

宇宙線ミュオン観測システムの刷新とアイスランドへの導入計画

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Upgrading the Cosmic-Ray Muon Observation System and the Iceland Deployment Plan

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The momentum-space distribution function of galactic cosmic-rays (GCRs) is observed as their anisotropy at Earth, enabling us to probe three-dimensional solar wind structures based on the GCR transport equation. Thanks to the high penetration power of cosmic-ray muons in the atmosphere, ground-based muon detectors feature an excellent angular resolution, angular acceptance, and statistics for GCRs, all essential to measure the anisotropy. The Global Muon Detector Network (GMDN) [1] has been a unique experiment deploying muon detectors worldwide to secure high sensitivity to the anisotropy. GMDN started with two-hemisphere observations in Nagoya (Japan) and Hobart (Australia) from the 90s, and the core 4-station network was established in the 2000s by initiating Sao Martinho da Serra (Brazil) and Kuwait stations. The initial goal of construction was achieved in 2016 by expanding the Kuwait detector.

GCR anisotropy varies with GCR rigidity, and combining the anisotropies with their rigidity dependence enables us to fully reconstruct the momentum-space distribution of GCRs. Recent advances in data analysis techniques are shedding new light on rigidity-dependent anisotropy [2,3,4], but there are still limitations in the observation network. The geomagnetic field deflects GCR trajectories, causing the muon detector's viewing direction to be biased eastward and toward the opposite hemisphere in the magnetosphere. This effect prevents low- and mid-latitude detectors from observing high-latitude directions, especially for low-rigidity (below ~50 GV) GCRs. Only muon detectors in the geographic polar region are sensitive to low-rigidity GCRs incoming from high-latitude directions. We are planning to install a muon detector in Iceland, and its polar conjugate observation with the Syowa Station detector, which was started in 2018, will address this insensitive region in the GCR momentum space.

This new observation opportunity in Iceland also provides a chance to upgrade the GMDN observation system and data pipeline, whose basic designs were established in the 2000s. In addition, constraints specific to the Icelandic observation site, unlike those at other GMDN stations, enable us to demonstrate a new design concept, such as a field-deployable or portable observation unit.

The scientific impact of the Icelandic observation was quantitatively evaluated by the GCR trajectory simulation in the geomagnetic field. Deploying plastic scintillator paddles as a multi-directional muon detector is studied by evaluating their characteristics, developing a custom front-end board, and performing a particle transport simulation. A compact size and low-cost signal processing unit is also under development. We also demonstrated the conversion of muon observation data into the Common Data Format, and its publication through IUGONET [5] with a data analysis tool [6], aiming to establish an end-to-end data pipeline. We will report on these activities related to the Iceland observation plan.

[1] <http://hdl.handle.net/10091/0002001448>

[2] R.R.S. de Mendonca et al., 2016, ApJ, <https://doi.org/10.3847/0004-637X/830/2/88>.

[3] K. Munakata et al., 2022, ApJ, <https://doi.org/10.3847/1538-4357/ac91c5>.

[4] M. Kozai et al., 2024, ApJ, <http://dx.doi.org/10.3847/0004-637X/825/2/100>.

[5] <https://search.iugonet.org/metadata/001/00003723>

[6] <https://doi.org/10.5281/zenodo.15844859>