【Grant-in-Aid for Transformative Research Areas（A）】

Multi Scale Muon Imaging : From Signs to Discovery

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Project Information	Project Number : 25A205　Project Period (FY) : 2025-2029 Keywords : Muon, Imaging, Fundamental Particles, Cosmic Rays, Accelerator

Purpose and Background of the Research

●Outline of the Research

Japan has long led research on muons. In recent years, advances in both cosmic-ray muon detection and accelerator-based muon generation have drawn new attention to muons as powerful quantum probes for imaging, not only in science but also in industry. Muons can penetrate deep into matter, with some cosmic-ray muons capable of passing through entire mountains. Thanks to these characteristics, muons can penetrate deeper into matter than other particles such as light (visible light, X-rays, and gamma rays), electrons, or neutrons, making them effective non-invasive probes for remotely sensing internal structures, states, and properties.

This research area aims to establish Multi Scale Muon Imaging (MSMI) that integrates advanced muon measurement with data science to visualize phenomena across a vast range of scales, from atoms to galaxies. Research projects within this initiative focus on developing innovative measurement technologies (A01–A04), demonstrating accelerator-based imaging methods (B01), and refining imaging via Measurement-Oriented Mathematical Modeling (C01). By uniting researchers across disciplines, this effort will accelerate the development of muon imaging. By establishing MSMI, it becomes possible to visualize a wide range of phenomena - from elementary particle interactions to the functions of materials, the interiors of levees, pyramids, and volcanoes, and even environmental conditions in the atmosphere and outer space - enabling not only signs but also discovery. Ultimately, this initiative aims to revolutionize imaging technologies across science and industry, driving innovation toward a safe, secure, and sustainable society.

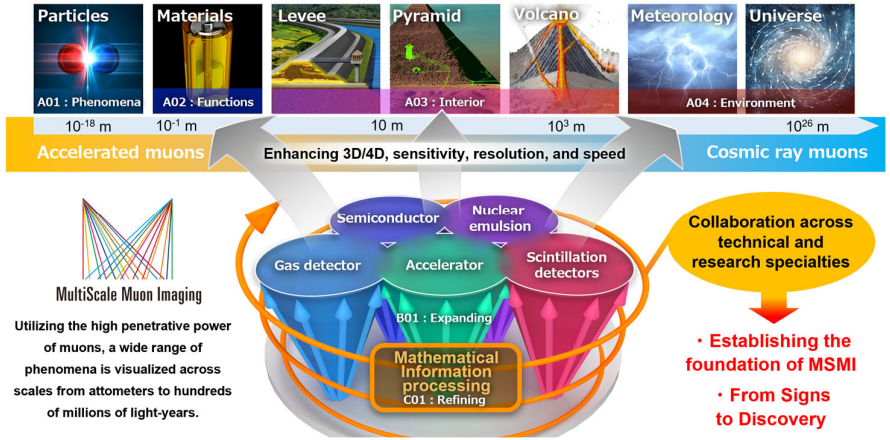

Figure 1. Overview of the Research Area

Expected Research Achievements

●Establishing the Scientific Principles and Technological Foundation for Multiscale Muon Imaging

This research area combines muon detectors (gas, semiconductor, nuclear emulsion, and scintillation detectors), accelerator, and data processing technologies across projects A01–A04, B01, and C01. Through this collaboration, it aims to build a unified scientific framework and develop the MSMI Technology Platform to reveal hidden phenomena.

A01 (Imaging Phenomena: Muon Detection for Particle Physics and Applications)
Using gas detectors, this project develops real-time muon detection in noisy environments to explore rare particles like the Higgs boson. The technique will also be applied to imaging large-scale structures with cosmic-ray muons.

A02 (Imaging Functions: 3D+1 Muon Imaging for Functional Visualization)
Using accelerator muons and semiconductor, a new 3D+1 imaging is developed to analyze the battery's internal state and contribute to low-carbon technologies.

A03 (Imaging Interiors: Imaging Levees, Pyramids, and Volcanoes with Muons)
Observing cosmic-ray muons from multiple positions with nuclear emulsions enables 3D visualization of large natural and man-made structures, with applications ranging from levee, pyramid, volcanoes research to disaster prevention.

A04 (Imaging Environments: Visualizing Space and Atmospheric Phenomena)
Muons from cosmic-ray air showers are measured using scintillation and gas detectors to investigate the origins of high-energy cosmic rays, the structure of galactic magnetic fields, and atmospheric phenomena such as thunderclouds.

B01 (Expanding Imaging: Accelerator-Based Muon Imaging)
Compact muon accelerator technologies will be developed to enable portable muon imaging systems, aiming to achieve higher speed and resolution than cosmic-ray muon imaging.

C01 (Refining Imaging: Analysis via Measurement-Oriented Mathematical Modeling)
Mathematical modeling is used to develop new analysis techniques that extract true physical information from measurement data, aiming to surpass the limits of conventional imaging.

●Societal Impact

MSMI will contribute to a low-carbon society, new device development, and improved disaster prevention for safer communities. Technologies such as accelerators and data analysis hold great potential for applications in the medical field. This research area will promote future-oriented societal implementation.

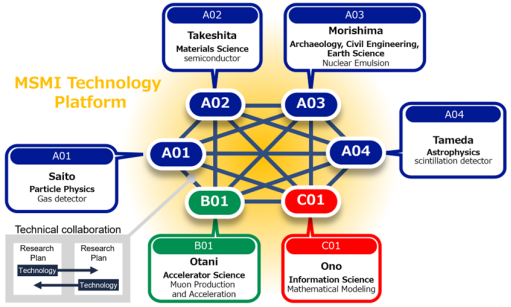

Figure 2. Organizational Structure of the Research Area

Homepage Address, etc.	https://msmi.jp/