Development of a Microscope System for the High-Precision Measurement of Cosmic Gamma Rays with the Nuclear Emulsion Telescope

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Introduction

The observation of cosmic gamma rays contributes significantly to cosmic ray physics by elucidating the mechanisms of cosmic-ray acceleration and identifying gamma-ray sources. However, due to the technical challenges of the measurement, many aspects of this field are less developed compared to other wavelengths. In particular, the polarization of cosmic gamma rays is a physical quantity that can reveal the magnetic field structures of astronomical objects and is expected to provide a new approach to understanding the radiation mechanisms. However, there are few observations of its observation. The Gamma-Ray Astro-Imager with Nuclear Emulsion (GRAINE) experiment aims to precisely observe cosmic gamma rays with a balloon-borne telescope using nuclear emulsions with excellent spatial resolution. GRAINE can observe cosmic gamma rays with the world's highest angular resolution by measuring electron pair production originating from cosmic gamma rays in the sub-GeV/GeV energy range and is sensitive to polarization. Polarization measurement requires grain-by-grain analysis in track images at the vicinity of pair-production conversion point, and we are currently developing a precision measurement system using an optical microscope.

Development of a Microscope System

We have developed a new microscope system optimized for precision measurements by selecting a wide-angle camera and a low-aberration lens. The system achieves a pixel size of 97.3 nm × 97.3 nm and a field of view of 456 μm × 332 μm, corresponding to an approximately six-fold increase compared to conventional precision microscope systems [1]. Figure1 shows the microscope we developed. The stability of the Z-axis stage drive was verified to be sufficient with respect to the silver grain position determination accuracy in nuclear emulsions (Z: 0.20 μm). Using the developed system, we evaluated the angular resolution of 9 reconstructed tracks for 400 GeV proton beams incident at 45°. For track angles of $\tan\theta = 1.08$ and 0.02, angular resolutions of 0.003 and 0.002 were achieved, respectively. These results demonstrate an improvement over the performance of high-speed readout systems, particularly for large-angle tracks.

Prospects

Further studies will be conducted to evaluate the angular resolution of large-angle tracks using the developed microscope system with increased statistics. The system will also be applied to the analysis of the GRAINE 2023 flight films, with the aim of enabling precision measurements of cosmic gamma rays and initiating measurement of gamma-ray polarization.

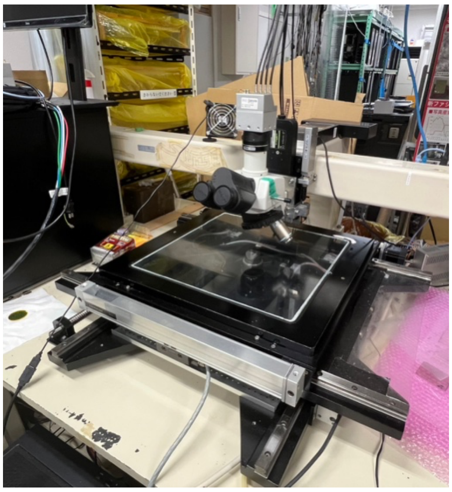

Figure 1. Precision measurement microscope we developed

References

[1] Y. Nakamura, et al. Astroparticle Physics 165 103055 (2025)