Optimization of Track Readout Conditions for HTS and Development of the Next-Generation Readout System HTS3

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Introduction

Cosmic-ray imaging is a technique for probing the internal structure of large-scale objects using cosmic-ray muons, and we employ nuclear emulsions as detectors. For reading out tracks recorded in nuclear emulsions, we use the Hyper-Track-Selector (HTS), which enables rapid and large-volume track readout. HTS1 was developed in 2015, followed by the latest system, HTS2, around 2022. Since 2025, HTS2 has been extensively applied to cosmic-ray imaging studies. A key feature of HTS2 is that its field of view is twice as large as that of HTS1. While this improvement is expected to increase the track readout speed, the total number of pixels in the imaging sensor remains unchanged, leading to a larger pixel size and a potential decrease in track detection accuracy. To address this, we evaluated nuclear emulsions with large silver bromide crystals using HTS2 and attempted to optimize its scanning conditions by adjusting scanning parameters. In addition, development and design of the next-generation system, HTS3, are currently underway. HTS3 employs an optical system equipped with multiple objective lenses, aiming for further improvements in track readout speed compared to HTS1 and HTS2. This study reports on the optimization of scanning conditions for HTS2 and the current development status of HTS3.

Experimental Procedures

Muon tracks in nuclear emulsions with silver bromide crystal sizes of 200 nm and 300 nm were read under various scanning conditions using HTS2. In the HTS readout process, tomographic images of the emulsion layer are acquired and subjected to binarization. The binarized images are then shifted in the planar (X, Y) directions, and the pixels recognizing silver grains (Hit Pixels) are accumulated along the depth (Z-axis). When the accumulated value exceeds a certain threshold, it is identified and output as a track. For performance evaluation of the readout system, we employ two indices: the Pulse Height , defined as the number of Hit Pixels constituting a single track and representing the signal strength of the track, and the detection efficiency, defined as the fraction of muon tracks penetrating the emulsion that are successfully detected as signals. In this study, by adjusting parameters such as Gain—the threshold for silver grain recognition—and PH Cut, a filter used to remove tracks with low Pulse Height, we investigated the scanning conditions under which HTS2 achieves the highest detection efficiency in track readout.