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Visualizing the internal structure of a cryptodome with cosmic ray muon radiography

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We have developed a multilayer, scintillator based, segmented muon hodoscope with the capacity to create up to 8 layers. One of the most important processes of cosmic ray muon radiography is the ability to select muon trajectories with precision from simultaneously arriving, vertical electromagnetic (EM) background components. As the size of the target increases, the muon path length of the target lengthens and significantly decreases the flux of the penetrating muon. Accordingly, the effect of background (BG) noise becomes more exaggerated as the length of the muon path increases. To address this issue, we attempted to reduce the vertical EM shower originated background events and to screen the low energy muons (muons with energies below 10 GeV) by constructing a multi-layered, rotational muon hodoscope called GDM (gradient of density measurement). Along with other adjustments, this GDM hodoscope was also designed to effectively cancel artifacts in the PMT and scintillator individually as well as facilitating corrections for the horizontal east-west effect. The maximum detectable thickness (MDT) of the present GDM was found to be 4 km.w.e. Four or more position sensitive detector (PSD) layers measured the trajectory of the cosmic-ray muons while low energy muons were screened using GDM analysis. Conventional muon radiography methods require one to two months for data collection, however we were able to measure the internal structure of the 1910 cryptodome of Usu volcano located in Hokkaido, Japan in 290 hours with +/-2% precision in the density measurement. The obtained image indicates the existence of high density magma that is hidden inside the structure of a hill.

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