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GEANT4 Simulation of a Portable Scintillator-Cube/GEM Detector for Cosmic-Ray Muography

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We present the design and GEANT4 Monte Carlo characterization of a portable, modular cosmic-ray muon telescope intended for small-to-medium-scale muography applications. The instrument combines a segmented plastic-scintillator cube, arranged as an $N \times N \times N$ array of individually wrapped cells (default $N = 3$, $50 \times 50 \times 50$ cm^3), with a single Gas Electron Multiplier (GEM) tracking plane mounted below it at a variable stand-off distance. The full assembly is mounted on a mechanically realistic aluminium support structure – corner posts, a GEM-holder frame and a base plate – that in turn pivots, about a fixed floor stand, through an adjustable zenith angle, so that the instrument's line of sight can be swept from the local zenith to near-horizontal. We describe the GEANT4 implementation of the geometry, materials and physics, the cosmic-ray primary generator, and the ROOT-based data output used for per-hit track reconstruction. We then present a feasibility study for using the instrument in a muography configuration: a fixed, vertically-standing target of standard rock (Particle Data Group definition, $\rho = 2.65$ g/cm^3), sized to a Tusa-natural-pyramid-like scale 230 m base, 140 m height, 400 m stand-off), is introduced along the telescope's line of sight, and the muon transmission through it is obtained by comparing paired open-sky and with-target runs at matched zenith angles. We discuss the geometrical and event-generation methodology required for this comparison to be physically meaningful, give analytic cross-checks of the expected rock path length and the minimum surface muon energy needed to traverse it as a function of zenith angle, and outline the full-statistics Monte Carlo campaign needed to obtain a quantitative transmission curve.

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