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Particle tracking with Miniaturized Timepix3 detectors as Compton gamma camera and applications in space

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In nuclear and high-energy physics research and in radiation related applications the measurement of the deposited energy and direction of charged particles may be needed with high discrimination against background and unwanted radiation. This task can be challenging in particular in mixed-radiation fields containing light charged particles (e.g., electrons, muons) and heavy charged particles (protons, ions) in wide range of energies and direction. Conventional instrumentation, such as particle telescopes assembled from single-pad diode detectors, exhibit limitations such as narrow field-of-view (FoV) which require shielding and collimators, limited detection threshold, limited discrimination, complexity, large size and cost. We aim at addressing these issues with a compact integrated device assembled from two detectors Timepix3 stacked in particle telescope architecture MiniPIX-Timepix3 [1]. We make use of the quantum imaging sensitivity, per-pixel spectrometry and tracking response of the semiconductor pixel detector Timepix3 [2] to recognize particle-type events on both pixel detectors operated and readout in sync. This architecture enables to sample the energy loss of single particles in two detectors with different sensors (different material and/or different sensor thickness). The interaction points are registered on each pixel detector with sub-pixel level (55 μm) spatial resolution [3]. Thus, charged particles crossing the telescope can be tracked with high angular resolution (sub degree level) in wide field of view (FoV) −60% of the full 2π for a 10 mm spacing gap [1]. In order to further increase the spectral sensitivity and FoV as well as enhance the tracking response and event-type discrimination [4], valuable e.g., for detection and characterization of atmospheric cosmic rays, we constructed a MiniPIX-Timepix3 telescope with different sensors (Si 500 μm top tracker, CdTe 2000 μm bottom tracker) assembled in closer geometry (4 mm spacing gap) −see Fig. 1. To evaluate the tracking response and resolving power of event discrimination we performed particle beam experiments with 8 −33 MeV protons and 16 −22 MeV electrons at the U-120M cyclotron and microtron accelerators, respectively at the NPI Rez near Prague. We are measuring also atmospheric cosmic rays for which the Si+CdTe configuration provides enhanced muon discrimination against background and unwanted radiations (electrons, gamma rays). Fig. 2 shows the response by the telescope bottom tracker (TPX3 CdTe 2000 μm) to 33 MeV protons resolved in two spectral-tracking groups [4] −shown in Fig. 1a and Fig. 1b −components in the same measured data. Correlated patter recognition analysis of the single particle tracks (Fig. 2c) provides resolving power of particle-type events [4]. Correlated maps of ΔE/Δx values in both tracker sensors are derived for selected events with higher discrimination together with directional flux maps of charged particles in high angular resolution (<1°).

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