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P2.34: Particle Tracking and Monitoring of High-Intensity Proton Beams with Scattering Foil and Pixel Detector Timepix3

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Monitoring and characterization of accelerator particle beams is necessary for operation of the facilities and their use in a broad range of applications from basic research (nuclear and high-energy physics) to applied research such as particle radiotherapy. Particle beams are typically produced in high beam intensities (> nAmp) which can be directly monitored by current-integrating devices and gas-based detectors. Conventional beam monitors provide namely the total beam current intensity and time profile with limited information on beam composition, beam size and directionality (beam divergence). When the beam intensity can be significantly decreased, detailed and more complete information can be provided by placing a high-resolution imaging detector directly on the beam path. Detailed information on the beam can be thus directly measured with hybrid semiconductor pixel detectors of the Timepix family [1]. For high-intensity beams however, positioning the detector on the beam path is no longer feasible. For this purpose, we make use of a scattering foil and detect the scattered beam particles behind the target and away from the beam axis –see Fig. 1b. A high-density thin foil (Ta, < 1 mm thick) is chosen for optimal yield of Rutherford scattering. We use a Timepix3 detector operated in compact electronics MiniPIX Timepix3 (Fig. 1a) [2] for directional- and energy-sensitive tracking of the scattered particles (Fig. 1c) [3]. Experiments were performed with proton beams of intensity in the nAmp range at the light ion cyclotron U 120M of the NPI Prague (33 MeV) and at a cyclotron Proteus 235 at the PTC Prague (100 and 226 MeV). We tested various beam settings in terms of beam energy, intensity, beam size, distance, and geometry. Tilting the detector-sensor plane to the direction of the particles increases the spectral-tracking resolution. Pattern recognition analysis of the pixelated tracks of single particles enables to reconstruct the trajectory of the scattered particles in wide (2π) field-of-view (FoV) without the need for collimators and with particle-type resolving power and high discrimination of background [4]. At the detector position Timepix3 registers the spatial and also the directional distribution of scattered protons (Fig. 2). The angular resolution for heavy charged particles and protons is around 10° along the elevation direction and around 2° along the sensor plane (azimuth angle) [3]. The particle beam can be imaged along the beam axis at the foil position by back-projection reconstruction (will be presented). Results provide multiple-parametric information on the primary beam in terms of particle flux, beam size (limited resolution), time dependence and spectral distribution. We extrapolate the detector results and derive information on the primary beam intensity by dedicated Monte-Carlo simulations using MCNP6.2 [5].

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