Commissioning & Operation of the Mu3e Tile Detector

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1 The Mu3e Experiment

The Mu3e experiment searches for the lepton flavor violating decay $\mu^+ \to e^+e^-e^+$ with an ultimate sensitivity of one in 10^{16} muon decays. The first phase of the experiment is currently under construction at the Paul Scherrer Institute (PSI) in Switzerland and aims for a sensitivity of $2 \cdot 10^{-15}$. The detector is designed to cope with muon stopping rates of up to 10^8 muons per second and consists of a silicon pixel tracker made from High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) and scintillating timing detectors. The latter are used to reliably suppress combinatorial background from accidental coincidences. The first timing detector is the scintillating fibre detector surrounding the vertex detector in the central station and the second one is the tile detector in the recurl stations.

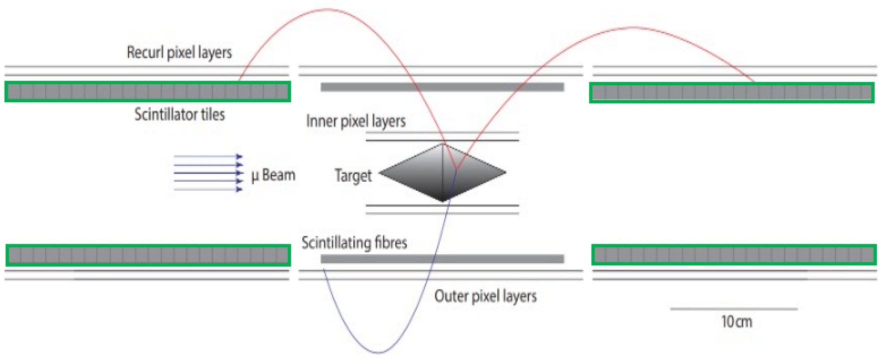

Figure 1: The Mu3e detector design. The tile detector is highlighted in green.

2 The Mu3e Tile Detector

The tile detector is made from 5×5×6 mm scintillating tiles, each read out by a dedicated Silicon Photomultiplier (SiPM). The signals are digitized by a custom-designed ASIC, the MuTRiG chip. To sufficiently suppress the combinatorial background, a time resolution of about 100 ps is needed for each tile hit. In order to reach this level of performance, an extensive online and offline calibration procedure is required. This has not only been the focus of my master thesis but will also be a significant part of my PhD research.

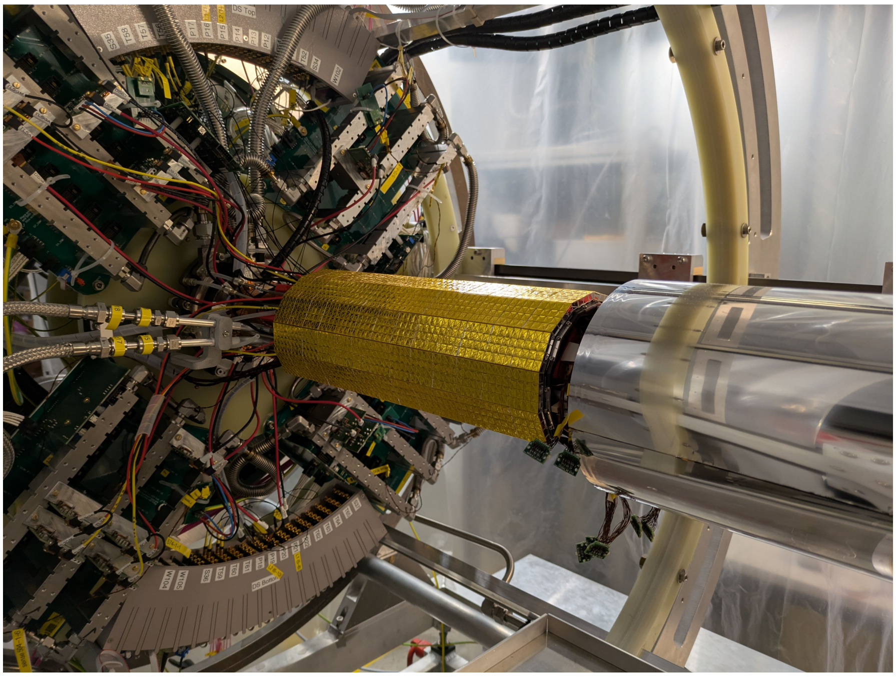

Figure 2: Three installed Mu3e Tile detector modules for the beamtime in June 2025 at PSI.

3 Offline Calibration

The offline calibration consists of several steps. The first step that is currently being implemented is a timewalk correction, which is needed since the MuTRiG chip uses leading-edge discrimination to digitize the SiPM signals. This means that the time measurement depends on the signal amplitude, requiring a calibration procedure to account for these variations. The correction is based on the energy dependent time difference between two neighboring channels. The simplest approach is to use the mean of the time difference distribution to correct individual energy values/bins.
The next step will be a time alignment procedure to ensure that all tile hits are synchronized. This is necessary to account for any time delays in the readout chain and to improve the overall timing resolution. The idea behind the time alignment algorithm is to use time differences between neighboring tiles and build closed loops over the tile detector surface. The sum of the time differences over this loop should be zero, which can be used to identify offsets.