Test Measurements with the Technical Prototype for the Mu3e Tile Detector

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The Mu3e Experiment

• searching for the lepton-flavour violating (LFV) decay $\mu \rightarrow eee$
  → suppressed in extended SM by $O(10^{-54})$
  → enhanced LFV predicted by new physics

• aimed sensitivity of BR < $10^{-16}$
  → precise spatial and timing measurements for background suppression needed
  → tracking: pixel detector (HV-MAPS)
  → timing: scintillating tiles/fibres

The Tile Detector

• to be installed on recoil stations (up- and downstream of target)
  → scintillator tiles ($\approx 6\times6\times5$ mm$^3$)
  → signals read out by silicon photomultipliers (SiPMs)
  → dedicated read-out ASIC MuTRiG
  → targeted timing resolution < 100 ps

structure:
• 2 x 16 tiles per submodule
• 14 submodules per module
• 7 modules per full recoil station
• 2 recoil stations (Mu3e phase I)
  → more than 6,000 channels in total

Thermal Simulation Studies of the Tile Detector

• implementation of prototype design in CAD software
• finite-element simulation of heat flux to investigate cooling system
  → ASIC and SiPMs implemented as heat source
  → water-cooled aluminium support structure
  → excellent agreement of simulation with measured data

enriched simulation:
• 14 ASICs implemented as heat sources (14 x 1.2 W)
• stress test: $T_{\text{water}} = 1^\circ \text{C}, T_{\text{air}} = 50^\circ \text{C}$
  → chip temperature below 42$^\circ$C
  → SiPM PCBs sufficiently cooled

Development of a Technical Prototype

• design and equipping of dedicated front end-boards (FEBs)
  → chip bonding
  → soldering of SiPMs and components
  → individual tile wrapping with reflective foils
  → reduce optical cross-talk
  → gluing of tiles to SiPMs
  → assembly of submodules to cooling structure
  → cooling support structure produced in local mechanics workshop

in progress:
• development of production and assembly line for full detector
  → FEB equipping in local electronics workshop
  → dedicated tooling for wrapping and gluing procedures
  → finished prototyping stage
  → simplified assembly to cooling structure to reduce risks of damage
• development of testing and QA scheme in the laboratory
  → gluing and assembly within tolerance limits
  → ASIC functionality
  → SiPM characteristics

Prototype Measurements at DESY

• two testbeam campaigns in February and June 2018 at DESY
• prototype consisting of three submodules
  → one serving as trigger
  → two devices under test (DUTs)
  → moveable in height and angle with respect to beam

  different contributions to ToT spectrum
  → blue: particle fully traversing the tile
  → red: crosstalk
  → green: particle grazing tile
  → excellent timing measurements achieved
  → single channel resolution at 45 ps
  → down to $\approx 18$ ps possible for 8 hits per track

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