Timing Detector for the Mu3e Experiment

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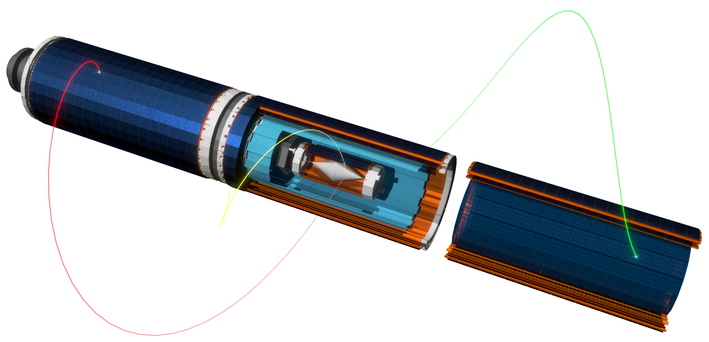
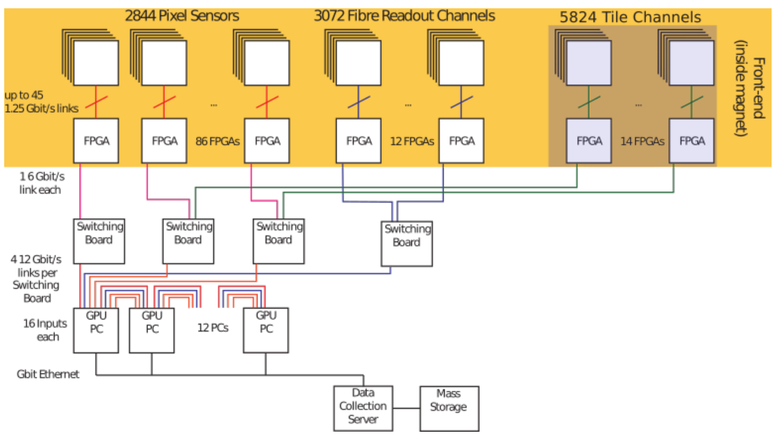
The Mu3e Experiment



- Mu3e[1]: Searching for charged lepton flavour violation (**cLFV**)
- Signal: $\mu^+ \to e^+e^-e^+$
- Branching fraction (SM): ~10^{-54}
- Observation would be clear evidence for **New physics**
- Main challenge: **background** suppression
  Accidental Background
  (excellent **vertex & timing** resolution)
  Internal conversion: $\mu \to eee\nu\bar{\nu}$
  (excellent **momentum** resolution)
- Improve sensitivity to 10^{-16} @ 90% CL
  (current limit: 10^{-12})

Full DAQ System

Fig: Overview of the readout scheme



Full DAQ:

- No hardware trigger
- 3 layers (Front-end FPGA, Switching boards, Farm PCs)
- Front-end FPGA Boards
  Raw data (MuTRiG & MuPix) → sort & package → switching boards
- Switching boards
  Data from Front-end FPGA (in parallel) → merge (synchronously) → filter farm
- Farm PCs
  Data from switching boards → Events building & buffering → fitting & vertex selection → trigger to transfer data to central PC
- Software: based on MIDAS[2] (Maximum Integrated Data Acquisition System)

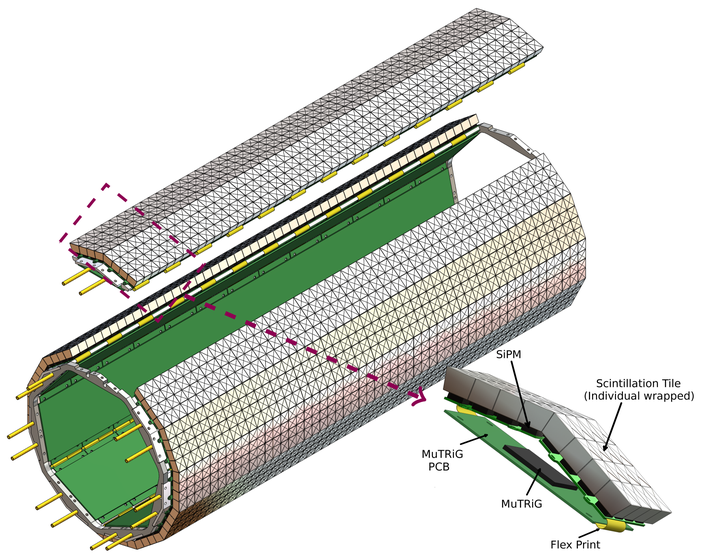
References

[1] Mu3e collaboration. *Research Proposal for an Experiment to Search for the Decay $\mu \to eee$*, arXiv:1301.6113

[2] K.Olchanski, S. Ritt, P.Amaudruz. *Maximum Integration Data Acquisition System*, http://midas.psi.ch

[3] Huangshan Chen. *A Silicon Photomultiplier ASIC for the Mu3e Experiment*, DOI: 10.11588/heidok.00024727

The Tile Detector for the Mu3e Experiment



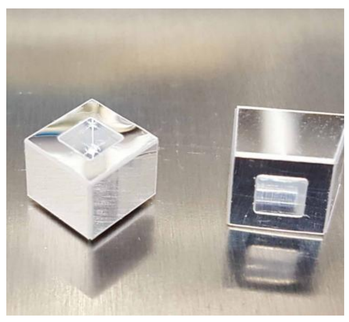
Detector design:

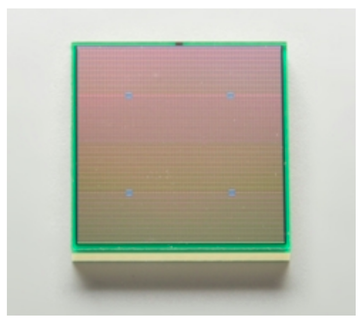
- Single channel: Scintillating tile + SiPM
- Submodule: 32 channels read out by one MuTRiG chip
- Module: 13 submodules readout by one long PCB board
- Station: 7 modules

Goal:

- Timing resolution: < 100 ps (Eff: ~100%)

Tile + SiPM





Tile: EJ-228

- Fast timing: $t_r < 0.5$ ns and $t_d < 1.4$ ns
- High light yield: ~10200 photons/MeV
- Wavelength: high PDE in SiPM
- Wrapped with Enhanced Specular Reflector (ESR) foil

SiPM: Hamamatsu S13360-3050VE

- Low V_{br}: ~53 V
- High Gain: 10^5 to 10^6
- Immune to magnetic field

MuTRiG

Fig: Functionality diagram of MuTRiG

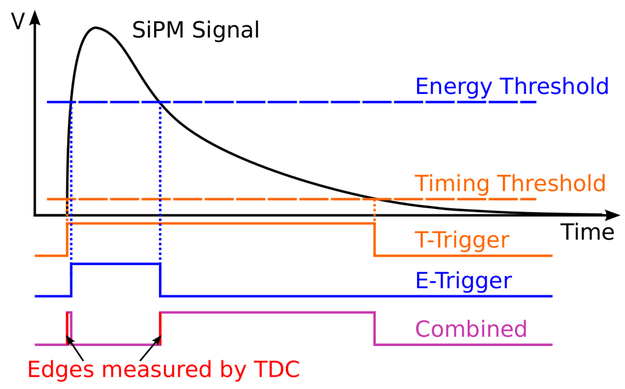
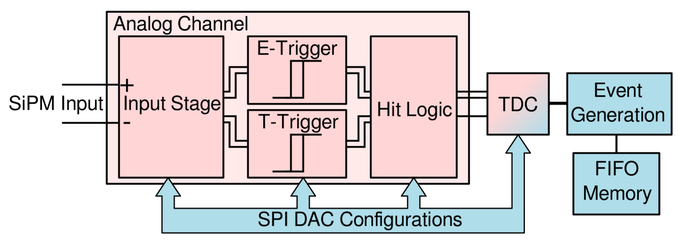
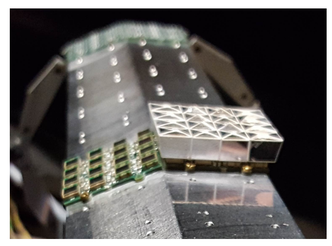


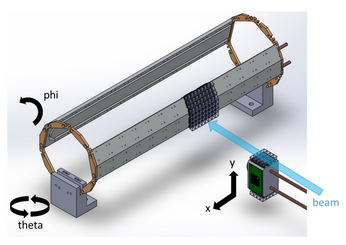
Fig: Diagram of MuTRiG channel



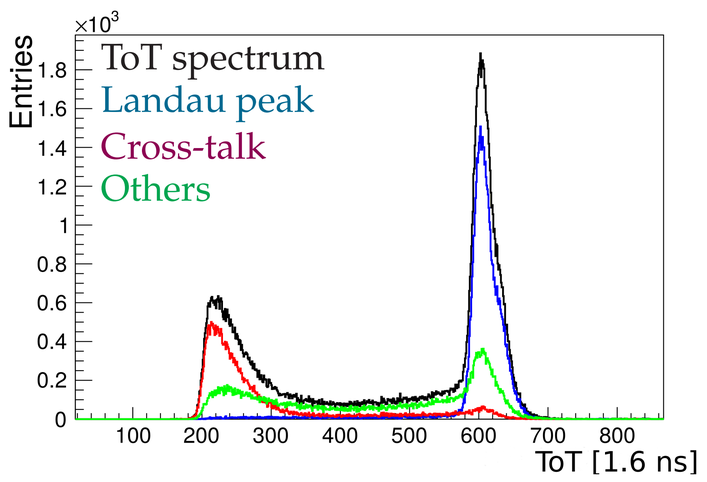
- MuTRiG[3]: Muon Timing Resolver including Gigabit-link
  HighRR student: Huangshan Chen
- Specific ASIC for Fibre Detector (**high rate**) and Tile Detector (**good timing**)
- High rate: 25 MHz (781 kHz/channel)
- Full chain timing resolution: < 50 ps

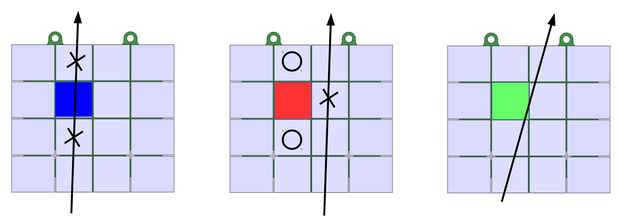
Testbeam results



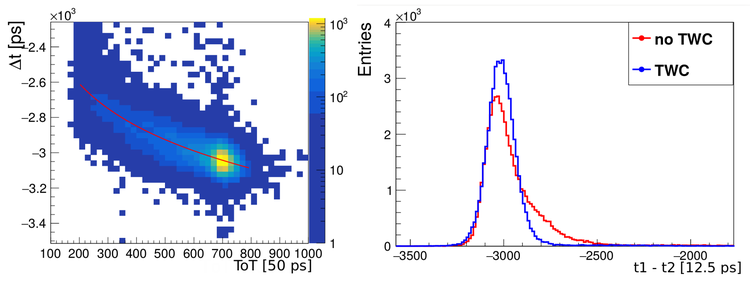


- Setup: 3 submodules (common DAQ)
- Electron beam in DESY

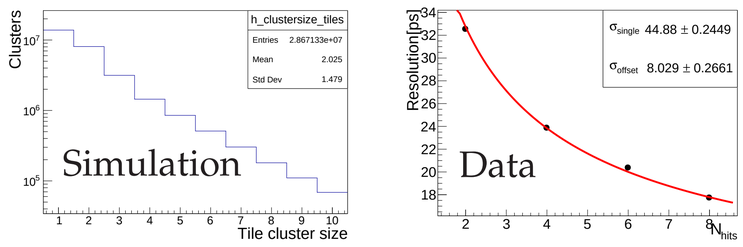




- ToT (Time over Threshold) spectrum



- Time walk: $t_{corr} = t - t_0 \ln(\frac{\mathrm{ToT}}{\mathrm{ToT_{MPV}}})$
- Time walk leads to better timing



- Number of hits for same event
- Time resolution vs. N_{hits}:
  $\sigma(N_{hits}) = \frac{\sigma_{single}}{\sqrt{N_{hits}}} \oplus \sigma_{offset}$
- Single channel resolution: ~45 ps

Testbeam study shows that the prototype fulfills the **time resolution** requirement
Outlook: better **efficiency** estimation