The Mu3e Cosmic Run 2022

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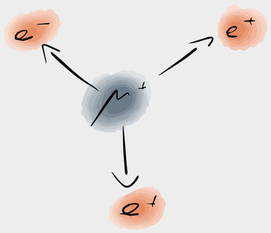
Summary

The Mu3e experiment will search for the lepton flavour violating decay $\mu^+ \rightarrow e^+e^-e^+$ and is aiming for a sensitivity of one in 10^{16} muon decays. Since this decay is highly suppressed in the Standard Model to a branching ratio of $O(10^{-54})$, an observation would be a clear sign for new physics. In the Mu3e detector, four layers of silicon pixel sensors will be used to track electrons and positrons and a time resolution of O(100ps) will be provided by scintillating tile and fibre detectors. The overall detector is expected to produce a data rate from 80 Gbit/s (Phase I) to 1 Tbit/s (Phase II), which will be processed in a three-layer, triggerless data acquisition (DAQ) system using FPGAs and a GPU filter farm for online event selection. A prototype of the detector was operated in summer 2022 in the Mu3e cosmic run with the intent to test and validate a variety of systems and identify possible problems. The operated prototype included two layers of pixel sensors, a scintillating fibre module and a vertical slice of the final DAQ system. The run was also used for commissioning and validation of the DAQ and first tests of the data analysis and track reconstruction with real detector data.

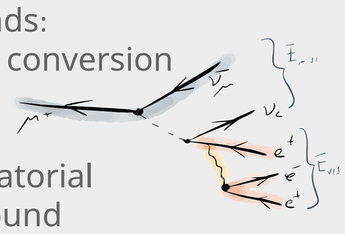
Mu3e

- Search for the charged lepton flavour violating decay $\mu^+ \rightarrow e^+e^-e^+$
- Current limit: BR < 10^{-12} (SINDRUM, 1988)
- Mu3e will aim for a limit of 10^{-15}

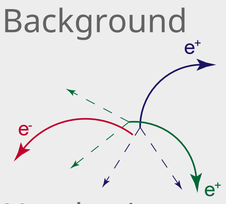


Backgrounds:

- Internal conversion

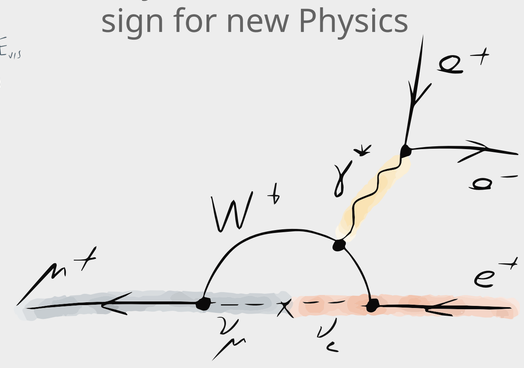


- Combinatorial Background

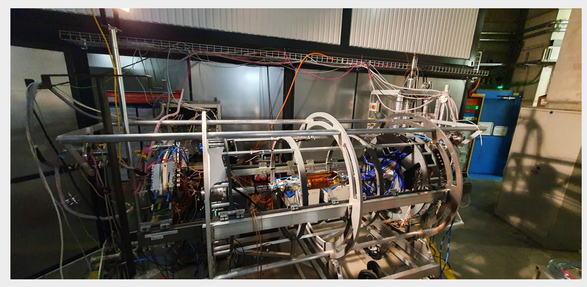


- No physics Background

SM prediction: BR of $O(10^{-54})$
→ Not observable
→ Any observation would be sign for new Physics



Infrastructure



- A permanent test stand for integration and commissioning was put in place at PSI
- Infrastructure and cabling was exercised
- Can be used for limited Detector operation in the future (cosmic runs, detector tuning)

Detector Prototype

Scintillating Fibres

- ~ 500 ps time resolution
- Coupled to SiPMs
- Read out at both ends of the fibre

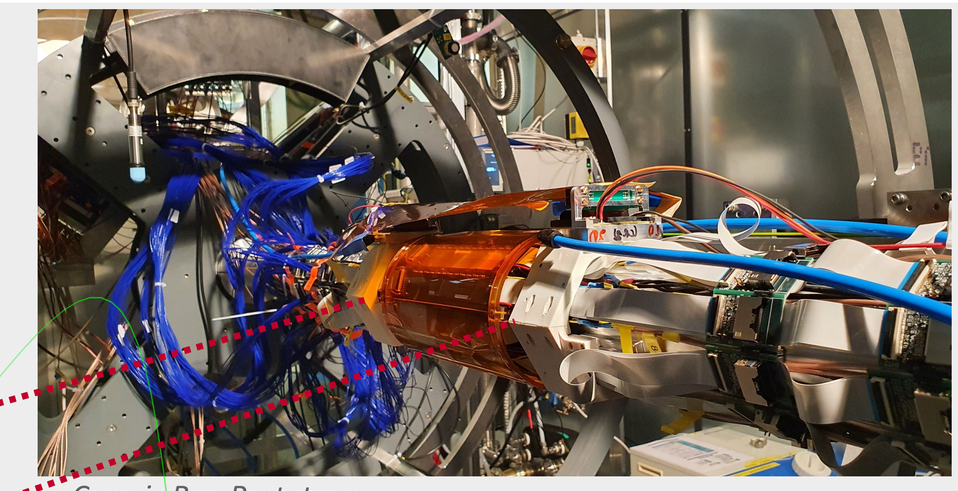
Pixel Sensors

- Can be thinned to 50 μm
- 2x2 cm HV-MAPS Mupix sensors
- 1.25 Gbit/s LVDS readout
- Mounted on U-shaped PCBs for this run
- On kapton flexprints in final detector

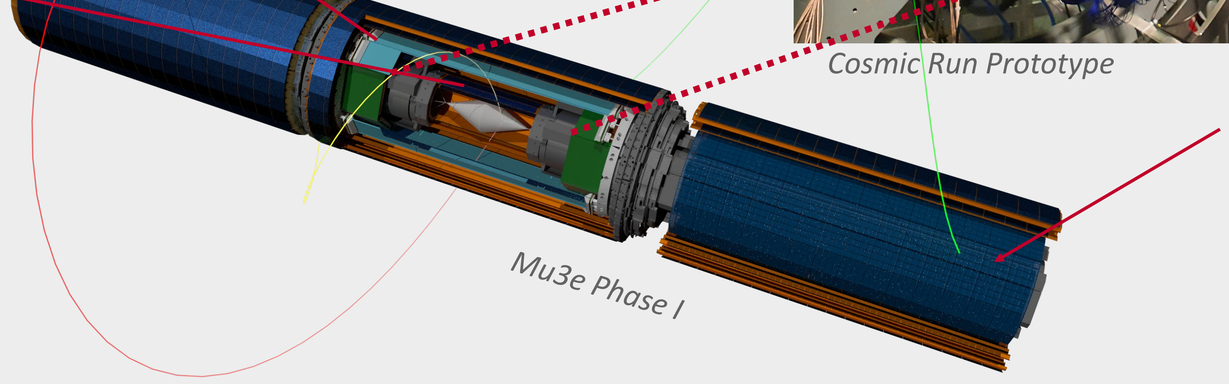
Scintillators

(Added in this run as a reference cosmic trigger, not present in final Mu3e)

The detector used for this run consisted of a prototype of the inner vertex tracker (two barrel layers of pixel sensors) and a single Fibre module. In Additon Scintillator Plates where mounted to build a reference cosmic trigger



Cosmic Run Prototype

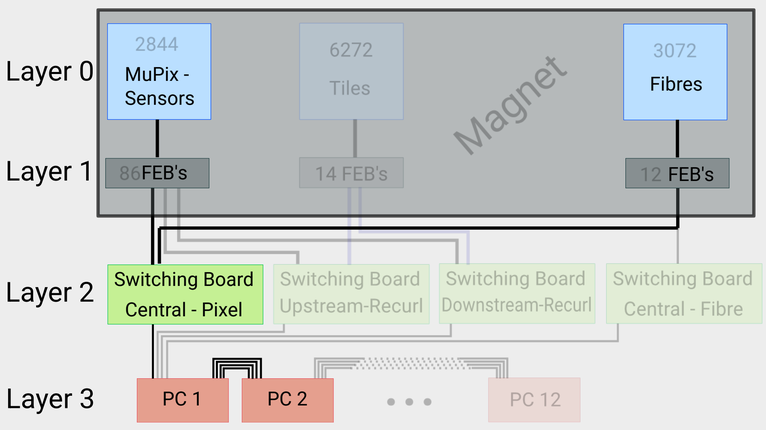


Mu3e Phase I

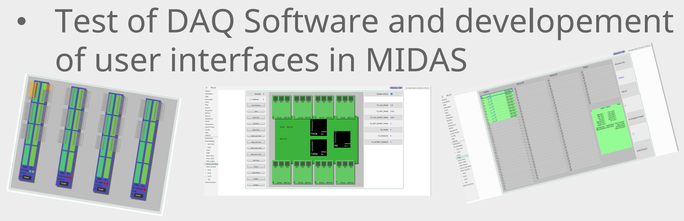
Scintillating Tiles

- Located in upstream and downstream „recurl stations“
- ~ 70 ps time resolution
- Coupled to SiPMs
- Not used in this run

DAQ



- Testing and commissioning of the DAQ System with a reduced number of components
- Using the final DAQ hardware for Mu3e Phase I
- Test of DAQ Software and developement of user interfaces in MIDAS



Detector Tuning

- Developement of tuning procedures in order to calibrate a larger amount of Sensors and Detectors
- Noise Masking for each Pixel of the ~ 100 Mupix sensors.
- Calibration of a 1-Photon and 2-Photon threshold for each of the Fibre SiPMs

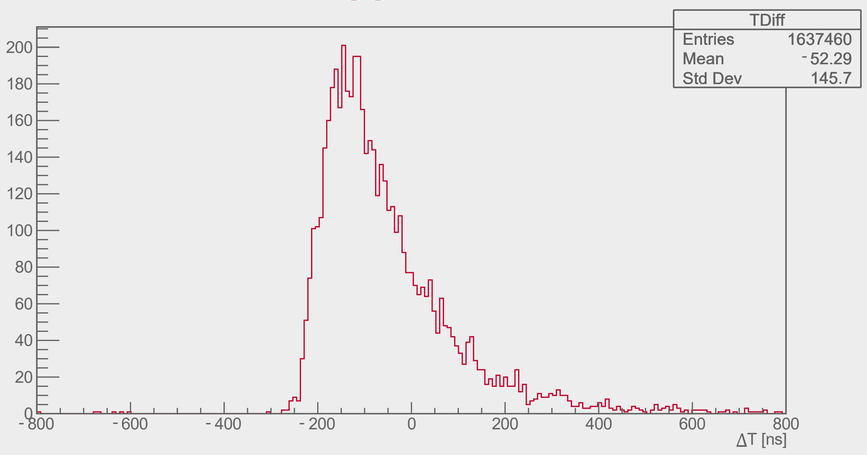
Services

- Cosmic run was used to test the Helium cooling system
- 2 g/s Helium flow
- Environment monitoring included in DAQ system
- Water cooled detector electronics

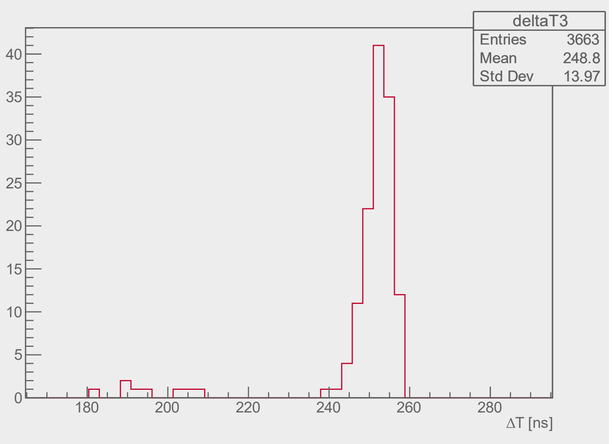
Synchronisation

The data tacken in the cosmic run was also used to test the time synchronisation of the different detector parts of Mu3e.

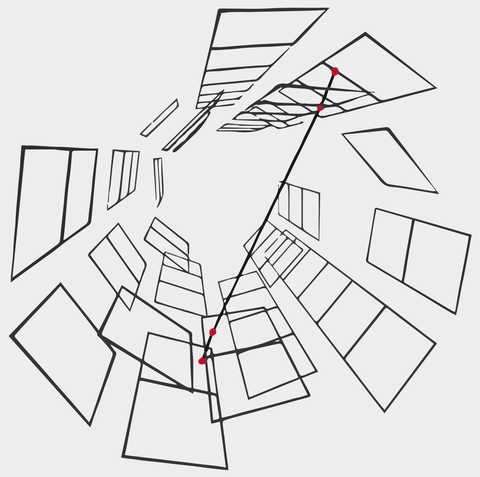
Pixel – Cosmic trigger:



Fibre – Cosmic Trigger



Track reconstruction



- Developement and Tests of online event Displays and reconstruction software using real detector data
- Misalignment of the detector can be observed