



The Mu3e Scintillating Fibre Detector

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Context

Goal of the experiment

Mu3e is an experiment for the search for the charged lepton flavour violating decay $\mu \rightarrow eee$ with a single event sensitivity of 10^{-16} , which is an improvement of 4 orders of magnitude over the current limit of

$B < 10^{-12}$ (90 % CL, SINDRUM, 1988).

Different subdetectors provide excellent momentum (< 0.5 MeV), vertex (< 500 μm) and time (< 100 ps) resolutions to achieve this goal.

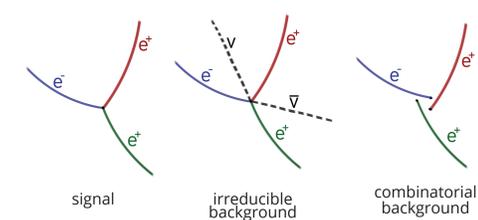
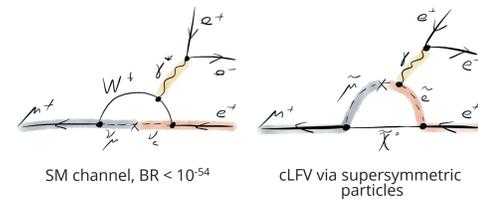
Signal Signature

Three electron tracks with a common vertex, coincident in time, with momentum sum of zero and a total energy equal to the muon mass.

$$\Sigma p_i = 0; m_{eee} = m_\mu$$

The Decay $\mu^+ \rightarrow e^+ e^+ e^+$

In the Standard Model, the decay $\mu \rightarrow eee$ is suppressed to $B < 10^{-54}$, therefore any observation is a clear sign for new physics.



Scintillating Fibres

Fibre Ribbons

Plastic scintillating fibres combine the detection of particles via optical light and subsequent light propagation with a low material budget. The baseline design foresees the use of Kuraray SCSF-78MJ fibres with a diameter of 250 μm .

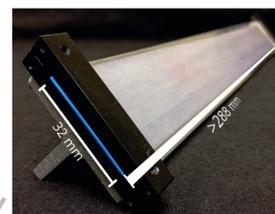
The fibres are arranged in ribbons of 3/4 staggered layers. The material budget of $X/X_0 < 0.3\%$ is needed to minimize multiple scattering.



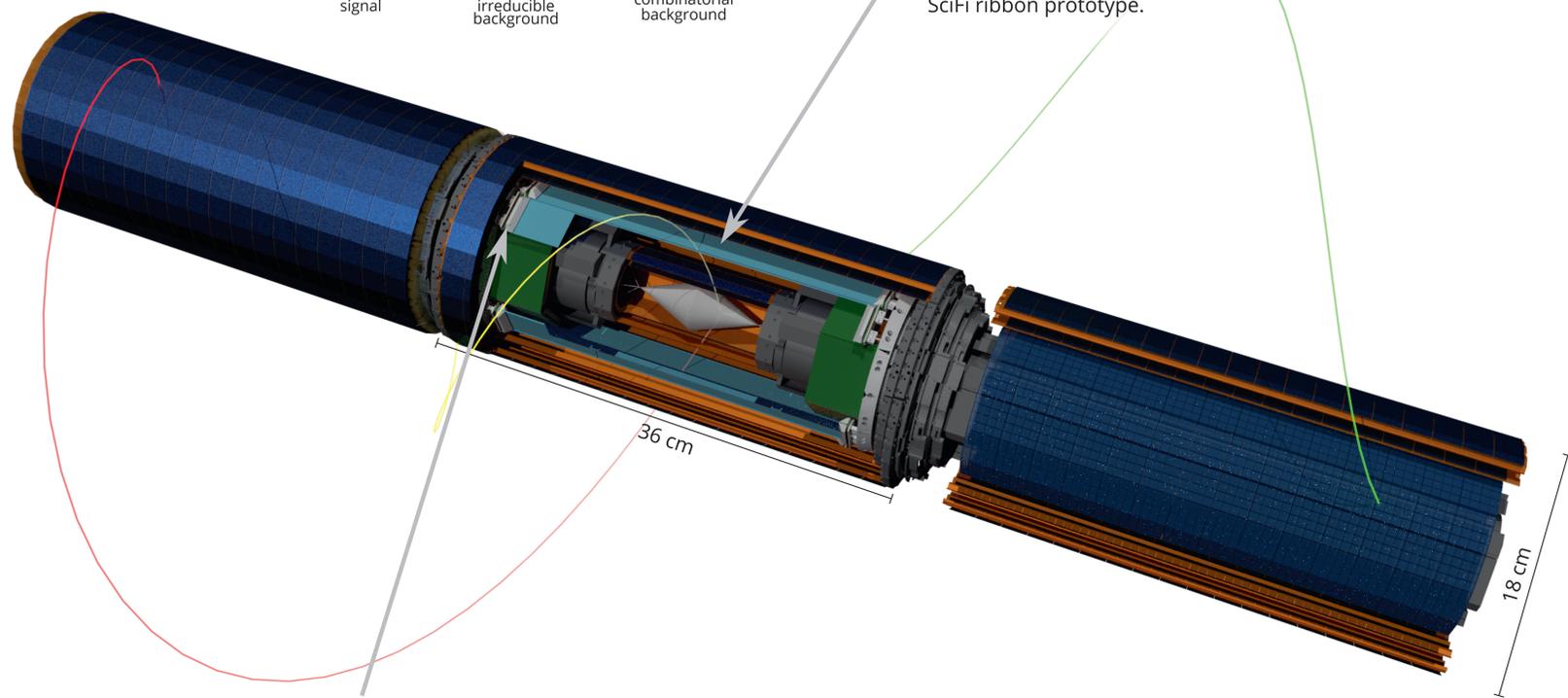
Ribbon winding station



Edge-on view of a 3-layer SciFi ribbon prototype.



SciFi ribbon prototype.



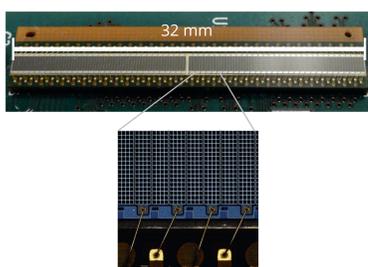
Silicon Photomultipliers and Readout

SiPM Column Arrays

Scintillating fibre ribbons are coupled to Hamamatsu S13552-HRQ 128-column arrays of silicon photomultipliers (SiPMs), each column consisting of 4×26 Geiger-mode photodiodes.

SiPMs allows for single photon counting at high quantum efficiencies (up to 50 %) with good time resolution.

In Mu3e a total of 24 column arrays are used to read out 12 SciFi ribbons, totalling in 3072 readout channels.



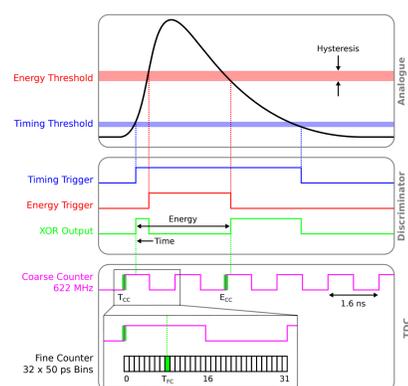
SiPM column array.

Readout: MuTRiG

MuTRiG is a mixed-mode readout ASIC for SiPMs. In contrast to its predecessor STiCv3 it has 32 channels and a gigabit LVDS serial data link.

The time and energy information of the analogue input signal is obtained via two discriminator units. The discriminator output is processed by a TDC with a 625 MHz coarse counter and a fine counter with a bin size of 50 ps.

To accommodate the high rate in the fibre detector one can opt to omit the energy information.



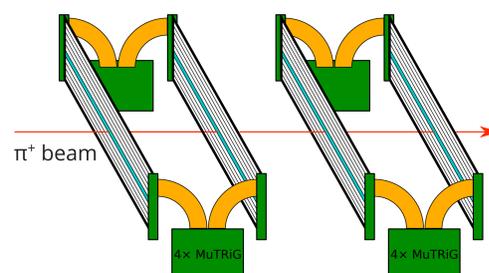
Test Beam Campaigns

Fibre Ribbon Telescope

For the first time, we operated a system of multiple MuTRiG chips on SciFi-frontend board prototypes during 2019 testbeams.

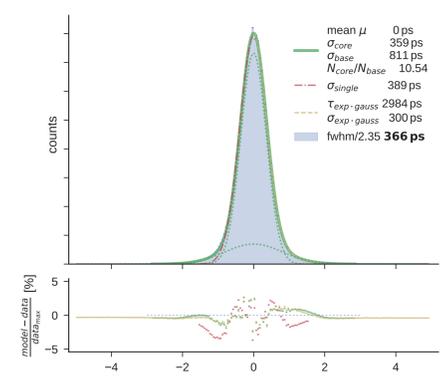
Four boards with the capability to read out 128 channels each were used to read out a telescope of four scintillating fibre ribbons. The total number of readout channels corresponds to 1/6 of the full Mu3e SciFi detector.

The fibres, as well as the SiPMs are the same models that are foreseen for the Mu3e SciFi detector. Data analysis is ongoing.



Time Resolution

In test beam and lab measurements, we were able to confirm time resolutions better than 500 ps with the baseline fibre ribbons and SiPMs. The results are consistent between DRS4-based waveform analysis and MuTRiG-based data acquisition.



Time Resolution of a 4 layer SCSF-78 ribbon obtained with a single MuTRiG and stimulation with a ^{90}Sr source. The result is compatible with waveform analysis of signals from a π^+ beam of (361 ± 23) ps.

[Taken from S. Corrodi's PhD thesis]

Acknowledgement

We acknowledge the funding support from the Swiss National Science Foundation grant no. 200021_172519.