Improving the 2S Module simulation in FairMUonE & Tracker Integration for current Test-Run

HEP annual meeting

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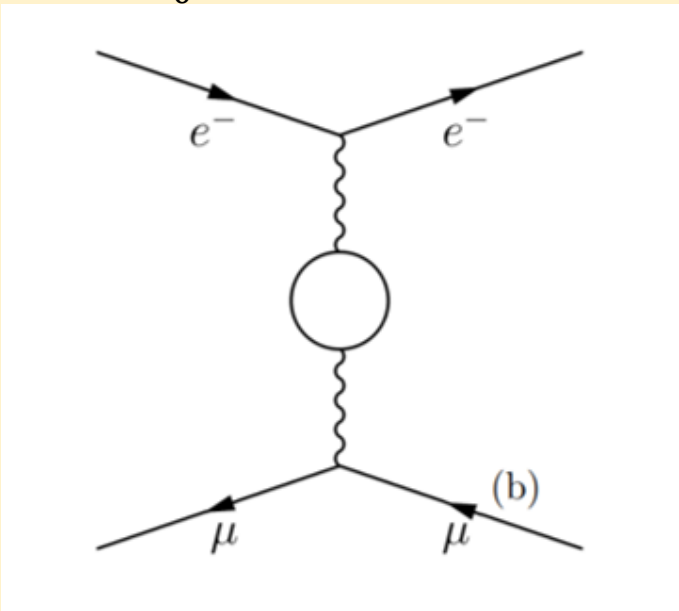
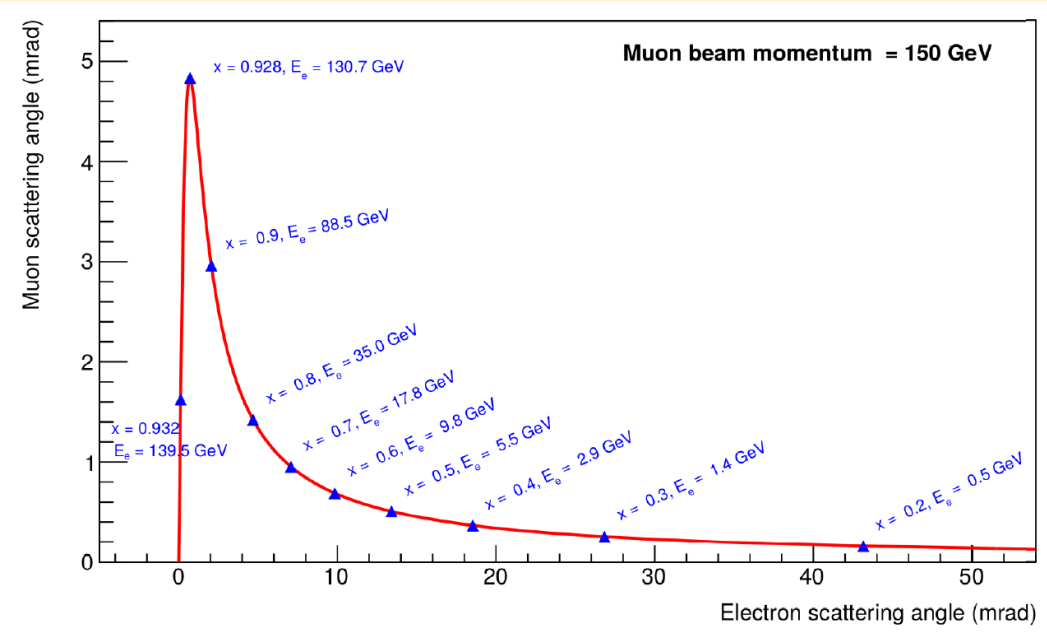
$$a_\mu^{HLO} = \frac{\alpha_0}{\pi}\int_0^1 \mathrm{d}x\,(1-x)\Delta\alpha_{had}[t(x)]$$

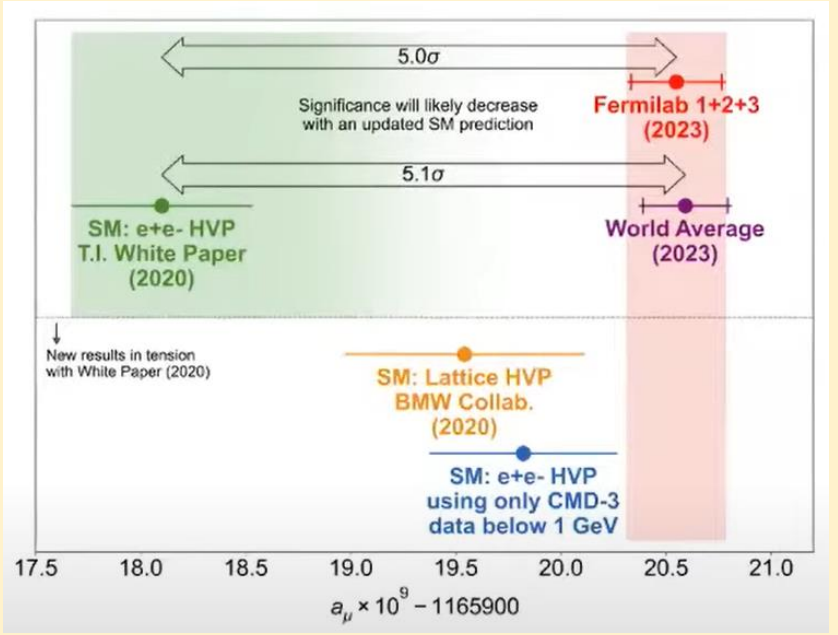
Motivation of MUonE

MUonE is a μ-e scattering experiment

- It will provide an independent method of calculating the hadronic vacuum polarisation contribution to the muon anomaly, a_μ^{HLO}.
- a_μ^{HLO} is the largest source of uncertainty on the theoretical determination of a_μ .







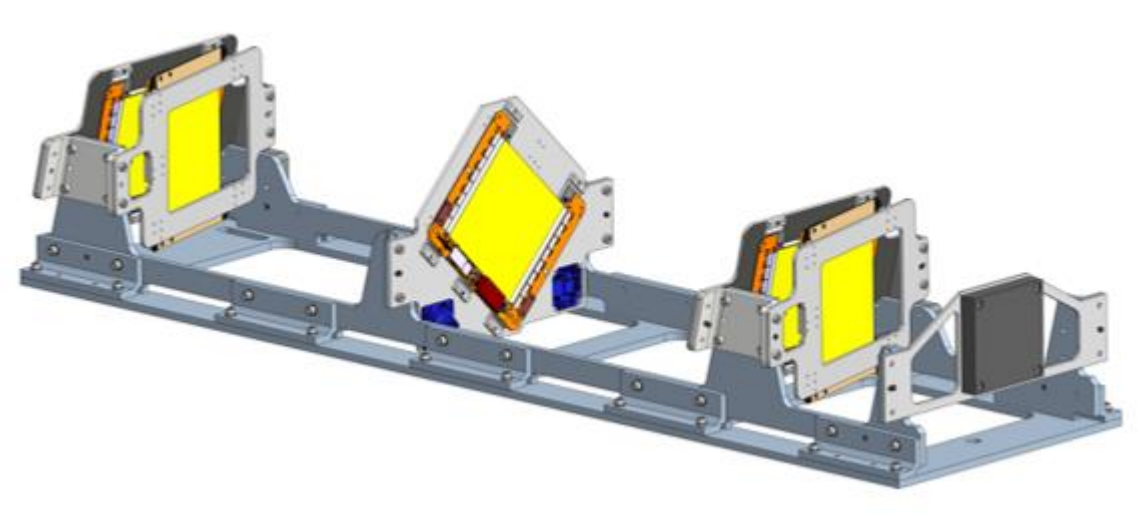
Experimental Setup

MUonE will take place at the M2 beamline at CERN

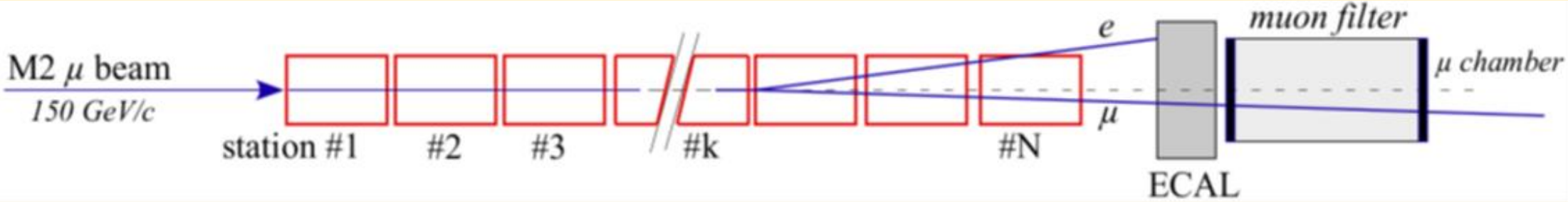
It is a modular experiment made up of repeating 1m long station .
Each with its own target and tracking system.

The station is made up of 6 2S modules which have been developed for the CMS phase 2 upgrade .

Test beam with 2 stations in 2023 and now we are doing a first run with 3 stations

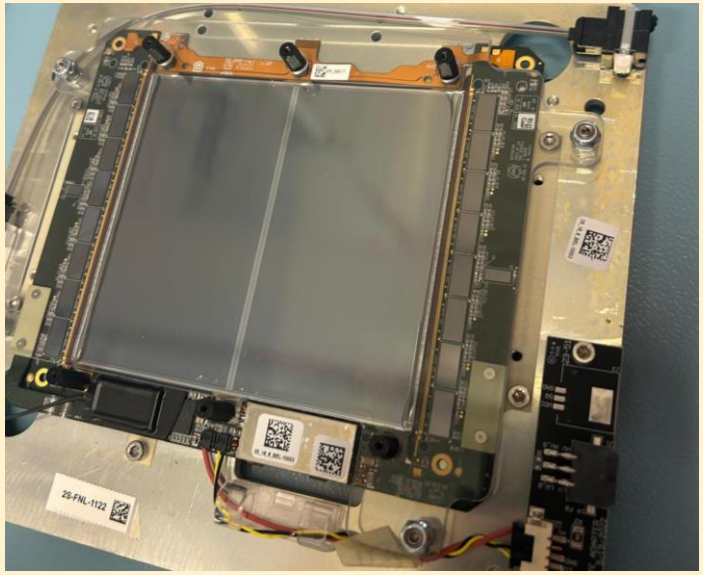


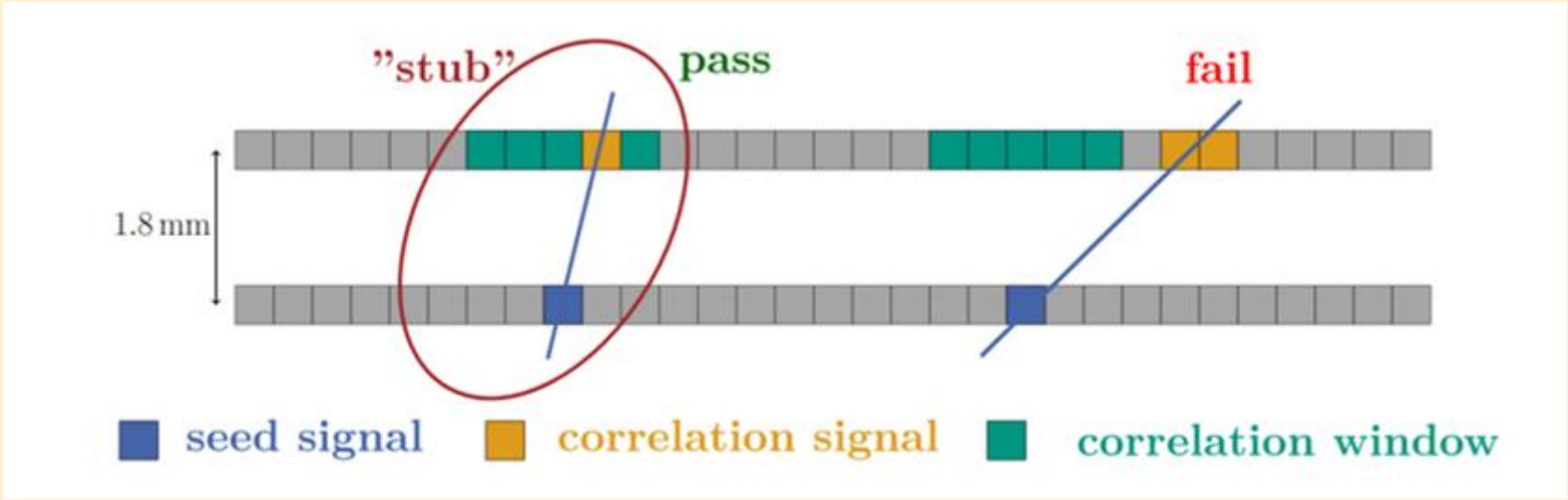
Before the stations there will also be a beam momentum spectrometer (BMS) and afterwards a muon filter and calorimeter for PID.



How the 2S modules work

- 2 silicon strip sensors of 320 µm thickness
- The two sensors are separated by 1.8mm
- The sensors are read out by CMS Binary Chips (CBC), there are 16 CBC's on each module
- The CBC finds correlated hits in the two silicon sensors, which are known as stubs using the stub finding logic





What I am working on :

- Modifying the geant4 simulation of 2S modules to improve the Data – MC comparison

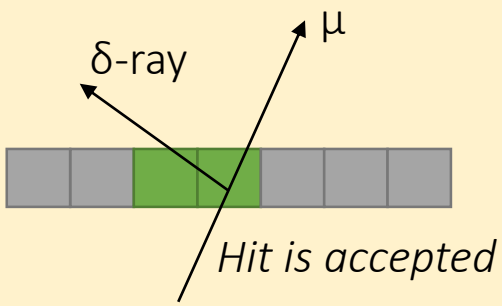
  The modifications:

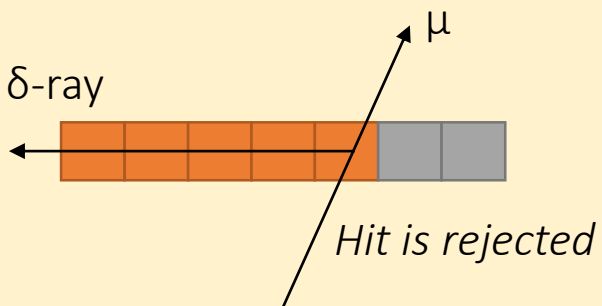
- Implementation of delta rays
- Increasing the sampling throughout the silicon
- Changing the active thickness
- Adding timing effects

Implementation of δ – ray production

We expect delta rays to travel in the silicon and be emitted at large angles

By changing the range cut to be 10 microns rather than 2.3 cm the particles that were not generated before due to having too low an energy are now present.





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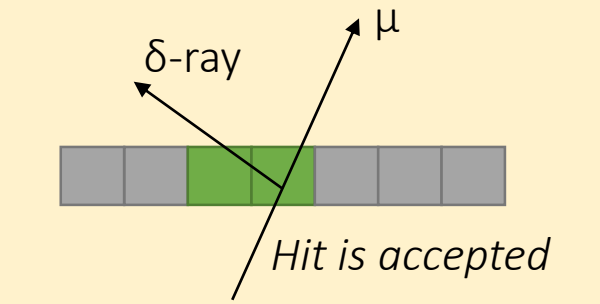
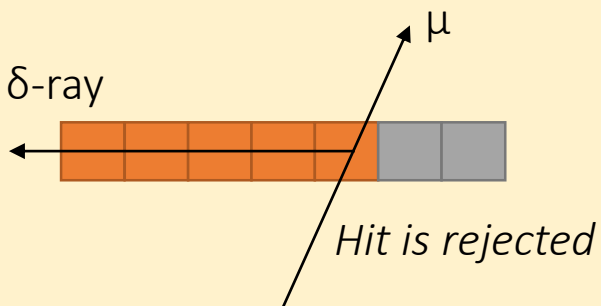
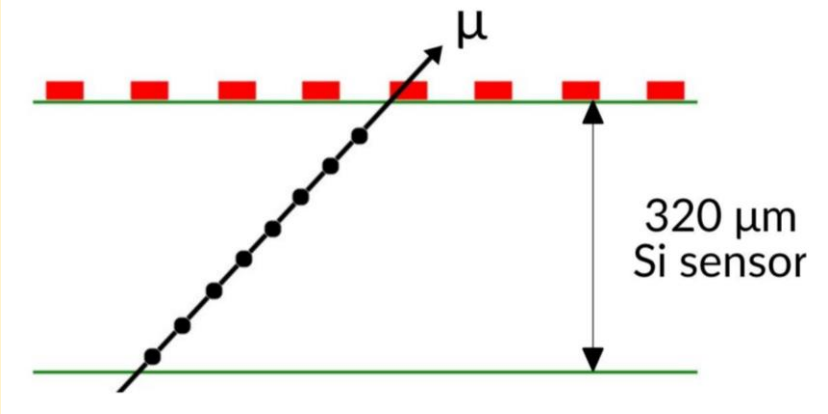




Increasing of sampling throughout the silicon



Currently FairMUonE saves only the entering position into the silicon sensor and the exiting position.

Then in the digitization the energy deposit is divided into 10 micron segments

By adding more steps through the silicon in the simulation, this will increase the sampling and we will be more precise with having the landau fluctuations over smaller paths.

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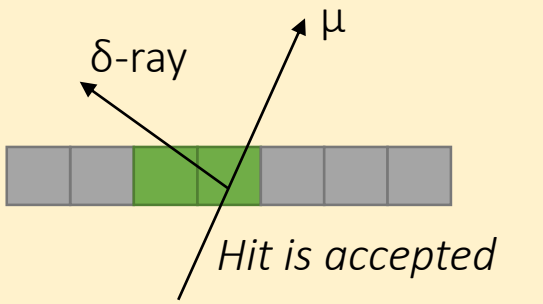

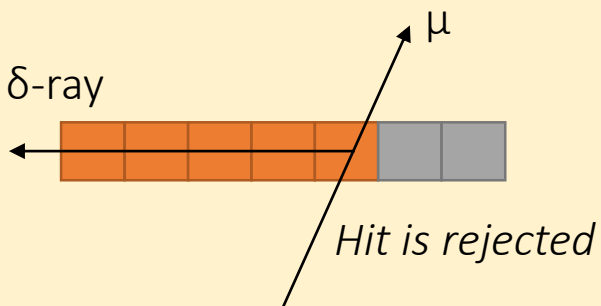

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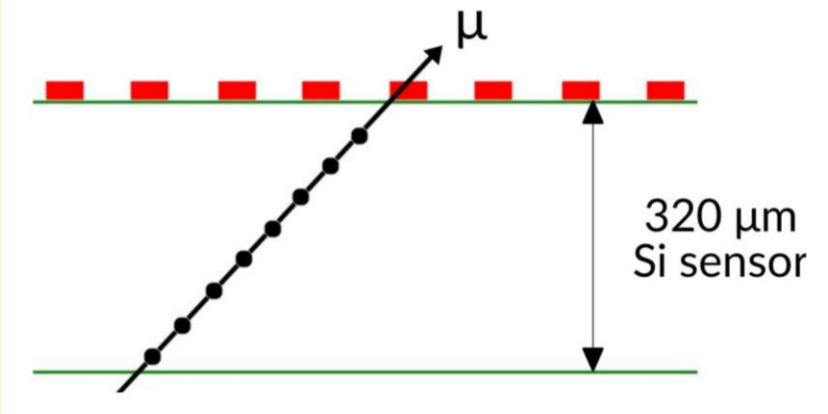

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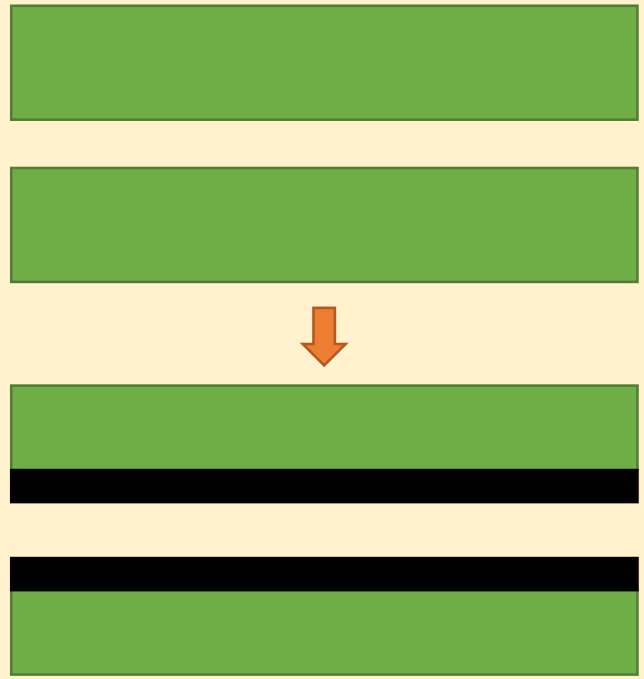
30 μm of inactive thickness

290 μm of active thickness

Changing the active thickness of the silicon

The 2S modules have 290 μm of active thickness but FairMUonE had 320 μm

320 μm of active thickness



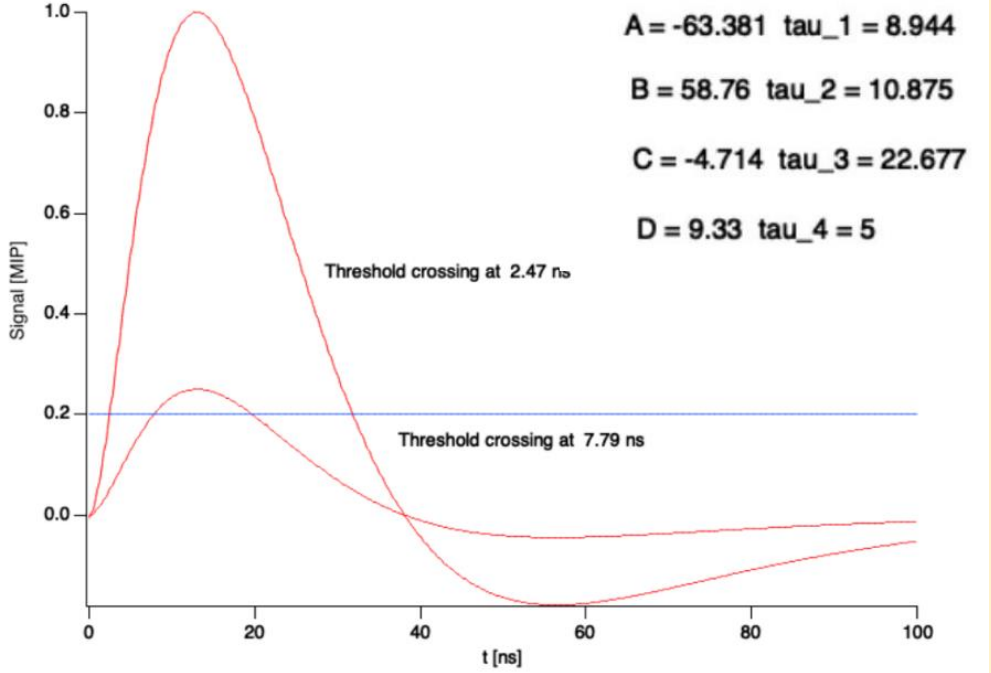
Implementation of timing effects and the CBC pulse shape

- The muon beam is asynchronous with the DAQ clock but this is not reflected in FairMUonE
  -> Uniform offset was added to every event
- Gaussian offset was added for the relative synchronisation between modules.

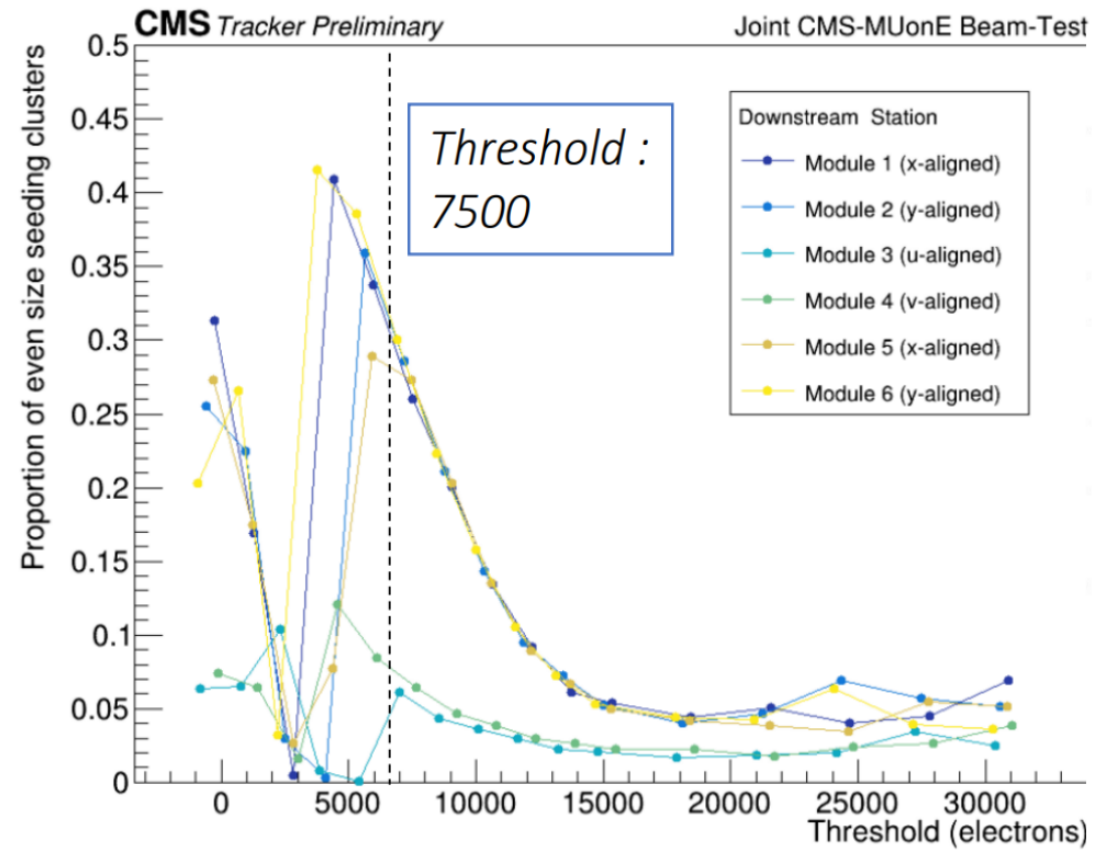
For the CBC pulse shape :

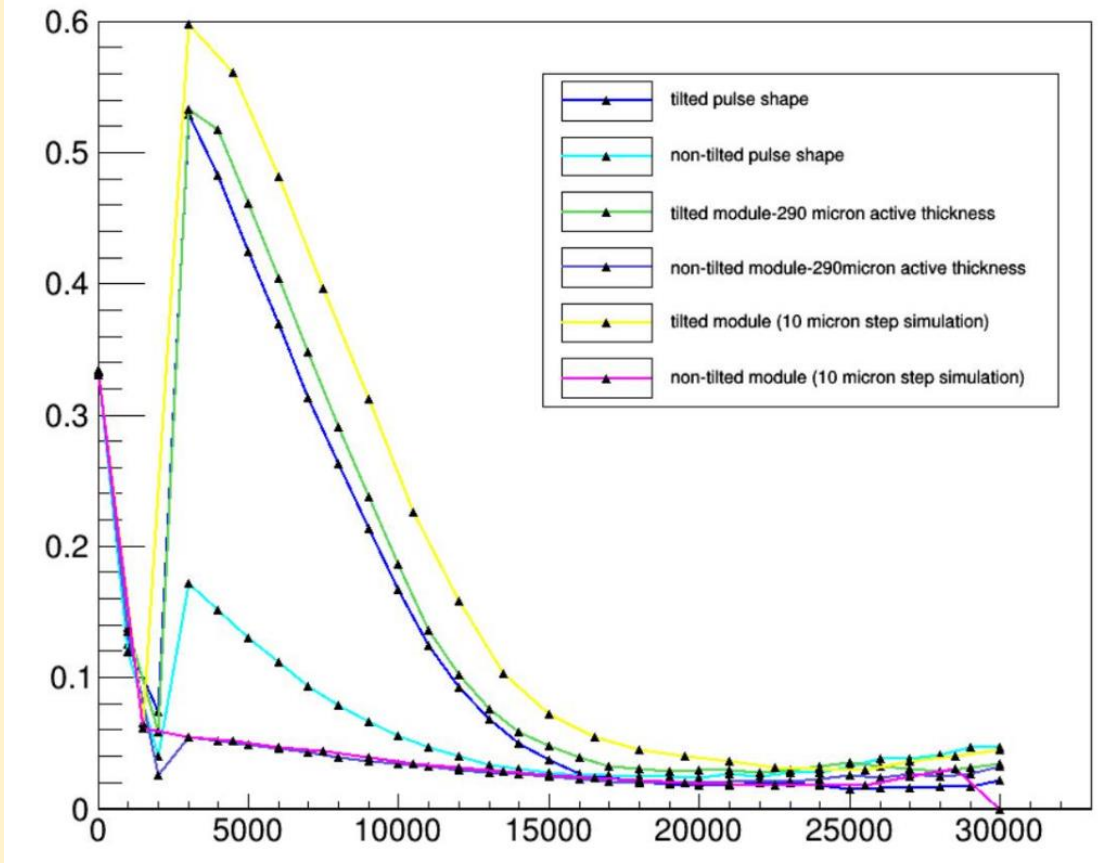
- The time when a signal is over the threshold depends on the charge of the signal
- By adding in the pulse shape function into the digitization we calculate the time it takes for a particle to surpass the Strip Threshold

$$f(t) = Ae^{-at} + Be^{-bt} + Ce^{-ct} + De^{-dt}$$



Data Vs Different versions of simulation

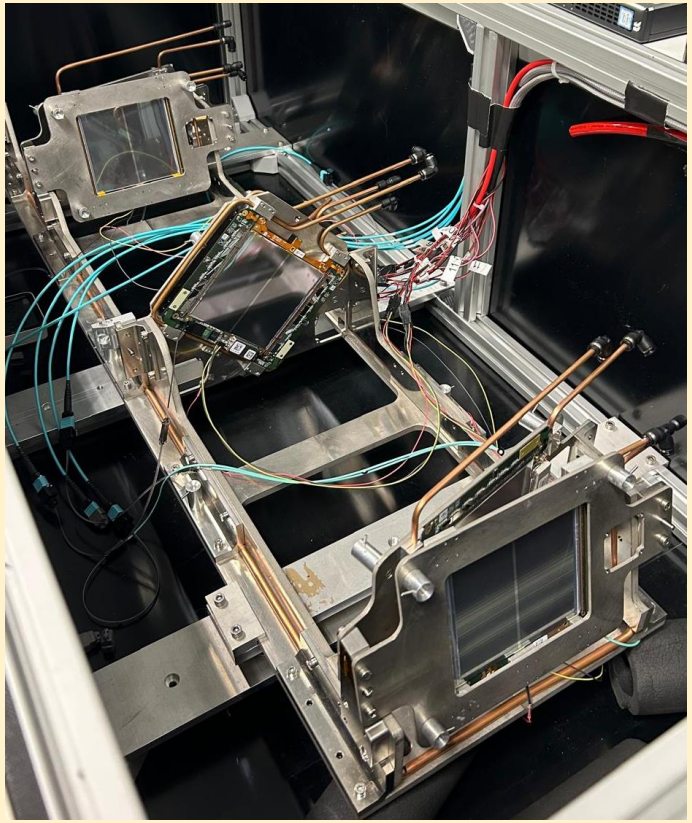




Test-Run Tracker Integration

- I was part of the group that tested the 2S modules for the 2025 test-run and contributed to the mounting of the three stations as well as the muon filter

- I will be going back to CERN for the test run from June to July and will be assisting with the integration of the BMS



Thank you for listening !