An Experiment Searching for the **Lepton Flavour Violating** Decay

$\mu^+ \longrightarrow e^+e^-e^+$

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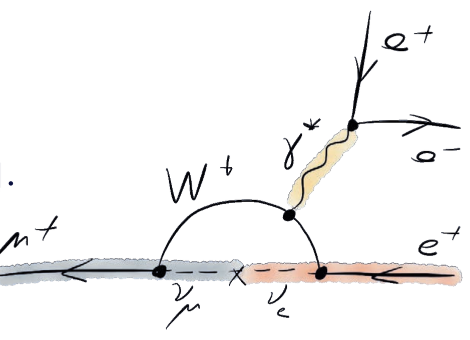
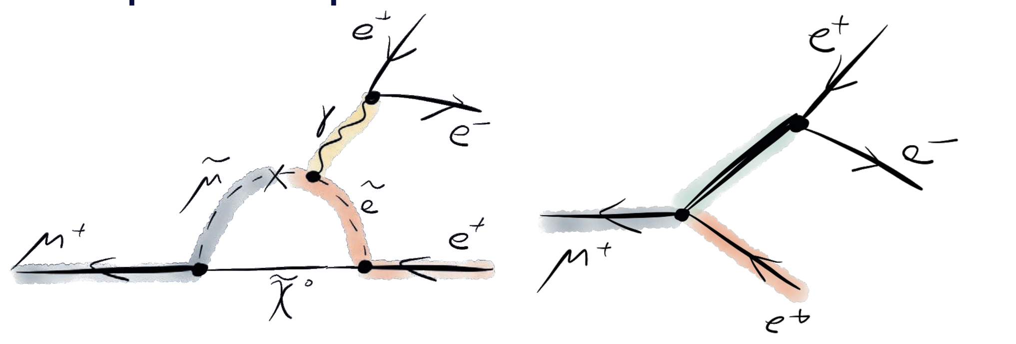
Motivation

$\mu \rightarrow eee$ can occur in the Standard Model of Particle Physics via neutrino mixing. It is however supressed to an unobservably low branching fraction **«10-50**.



Many models for physics beyond the Standard Model **predict lepton flavor violation**.

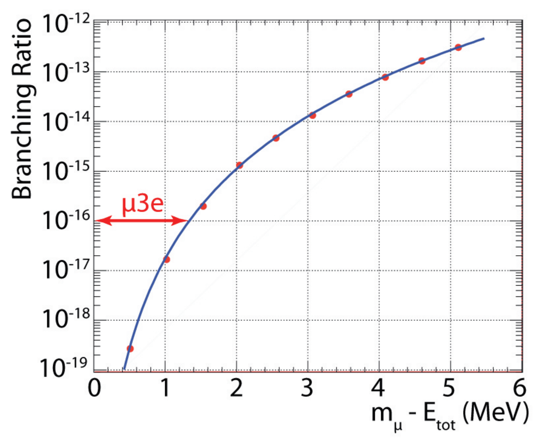


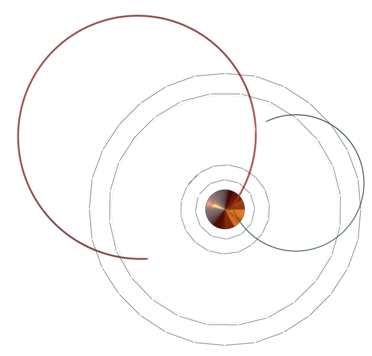
Any observation $\mu \rightarrow eee$ is a sign for new physics.

State: B($\mu \rightarrow eee$) < $1.0 \cdot 10^{-12}$ (SINDRUM, 1988)
Goal: **find or exclude $\mu \rightarrow eee$ at a 10^{-16} level**

Requirements

- best possible momentum resolution
  Energies < 52.8 MeV (Michel Spectrum) cause the momentum resolution to be **multiple Coulomb scattering dominated**
- low material budget



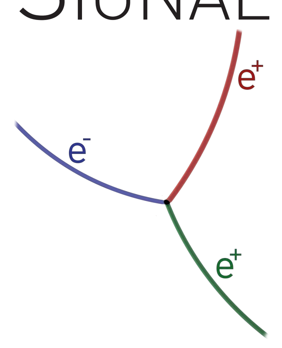


Recurling tracks combine a large lever arm with a high acceptance for low momentum tracks.

- good vertex resolution
- good timing resolution

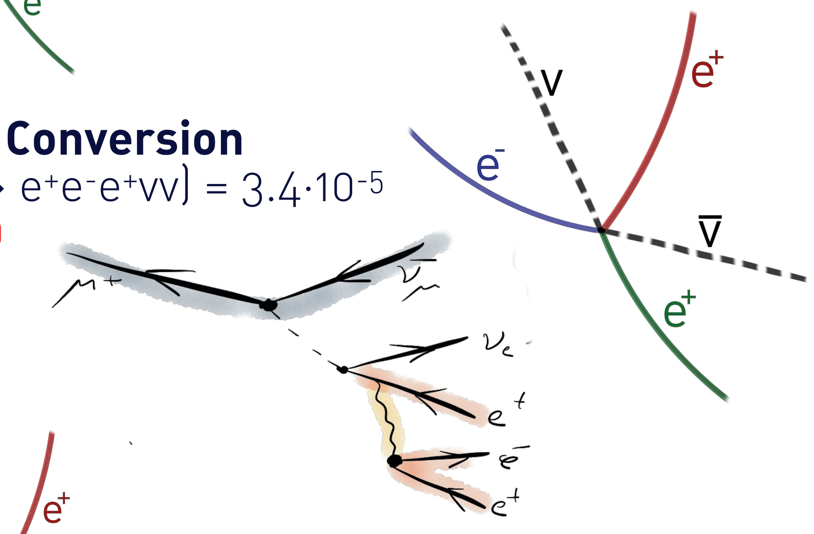
For measuring in a reasonable time periode ~year
- high rates: stop up to $2 \cdot 10^9$ μ/s

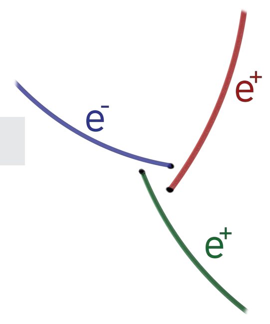
Signal & Background



$\mu^+ \rightarrow e^+e^-e^+$
- single vertex
- coincidence
- $\sum p_i = 0$

Internal Conversion
- B($\mu^+ \rightarrow e^+e^-e^+\nu\nu$) = $3.4 \cdot 10^{-5}$
- $\sum p_i \neq 0$





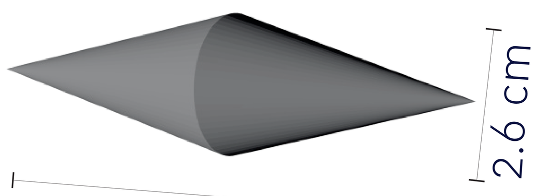
Combinatorial
- e^+ from ordinary μ^+ decay
- e^- from photon conversion, etc.
- no coincidence

Environment

- Solenoid Magnet ~1T
- Cooling using gaseous Helium

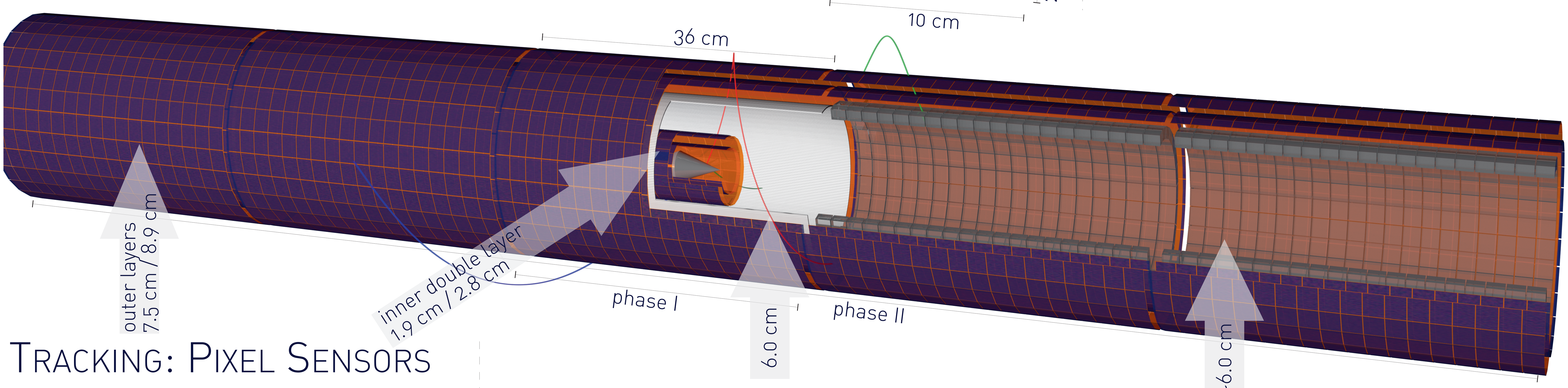
Target

- hollow double cone, ~70 μm Aluminum
- large area for vertex separation



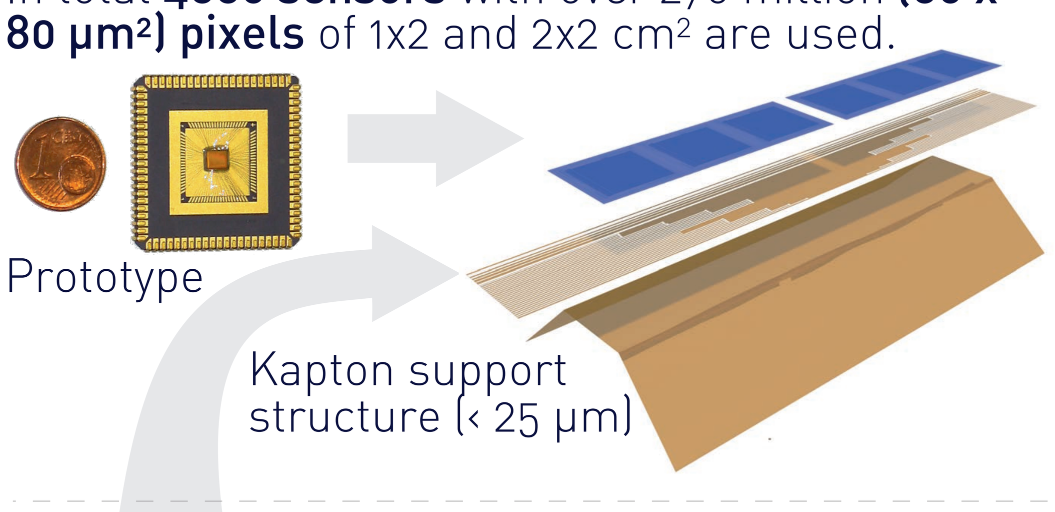
μ-Beam at PSI

- 2.3 mA, 590 MeV/c proton beam
- Phase I: ~10^8 **μ/s** from target E (polerized μ)
- Phase II: **$2 \cdot 10^9$ μ/s** from HiMB (planned)



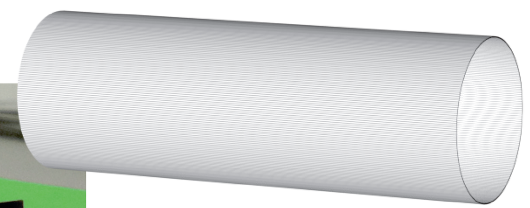
Tracking: Pixel Sensors

High Voltage Monolithic Active Pixel Sensors (**HV-MAPS**) manufactured in a commercial 180 nm CMOS process house the pixel electronics inside a deep N-well . Due to the high voltage (~70 V) the depletion zone is very thin which allows to thin the chips < **50 μm**.
In total **4860 sensors** with over 270 million **(80 x 80 μm²) pixels** of 1x2 and 2x2 cm² are used.



Timing I: Scintilating Fibres

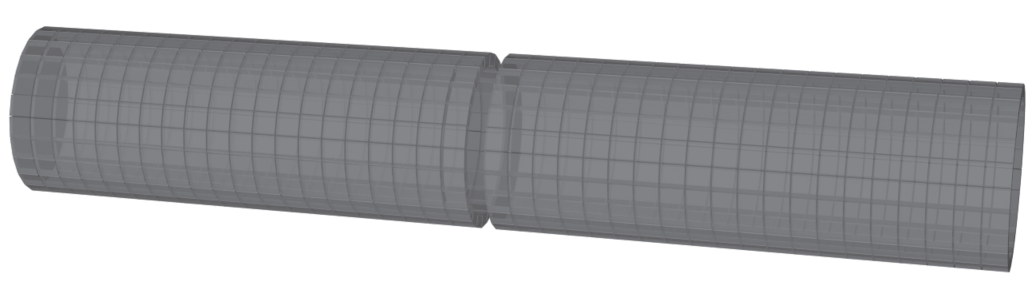
Between 2 and 4 layers of scintilating fibres with a diameter of **250 μm** in the middle barrel provide a first timing measurment of a **few 100 ps**. Fibres are used to reduce the material and hence multiple scatering inside the detector. In total **~4000 fibres** are used and red out with Silicon photo multipliers (SiPM).



length: 36 cm
diameter: 12 cm

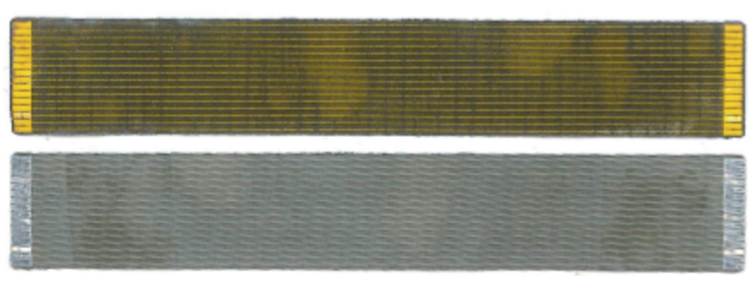
Time II: Scintilating Tiles

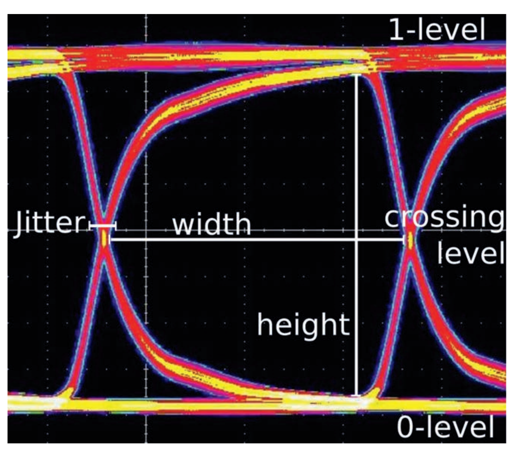
In the recurl stations relative thick **~1 cm** scintilating tiles are used for a precise time measurment **~100 ps**. In total **~7000 tiles** are used.



Kapton Flexprints

Kapton-Aluminum (12 μm) flexprints are used inside the active detector for **LVDS** signal lines and sensor supply.

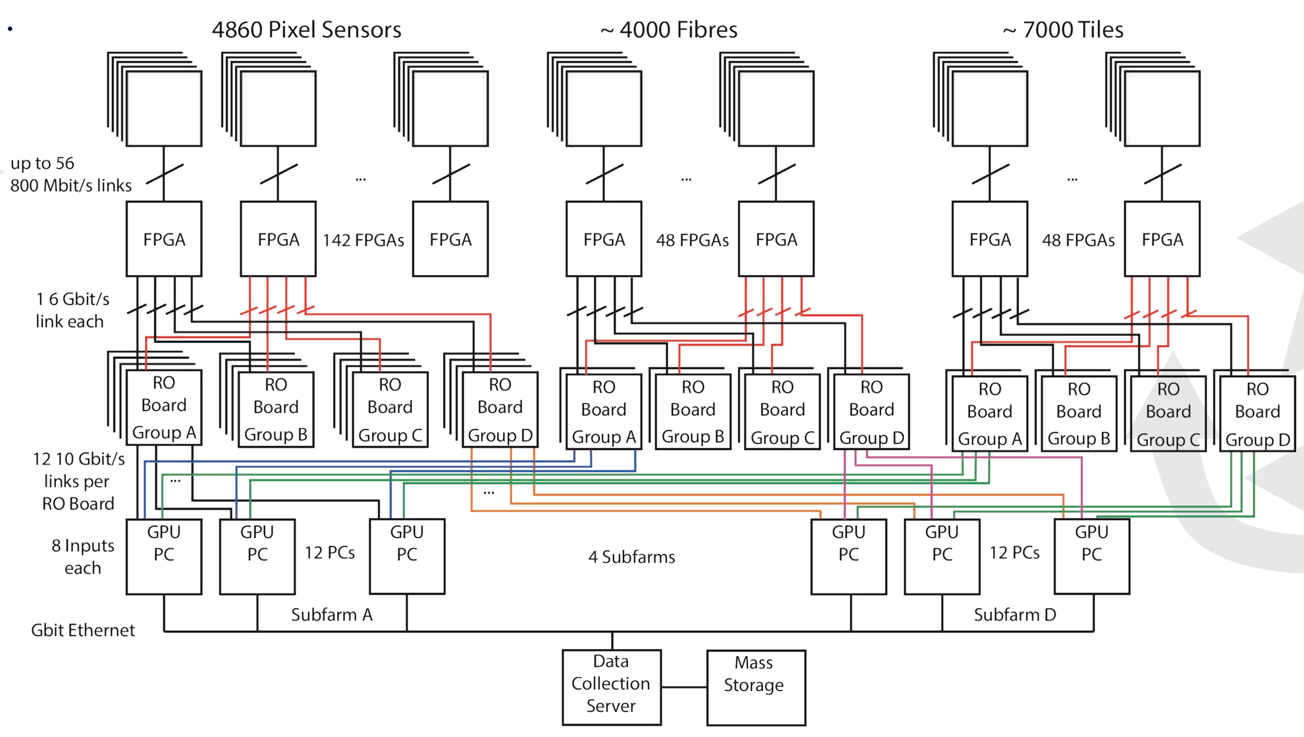




Eye diagrams are used to investigate the quality of optical links.

Readout Concept

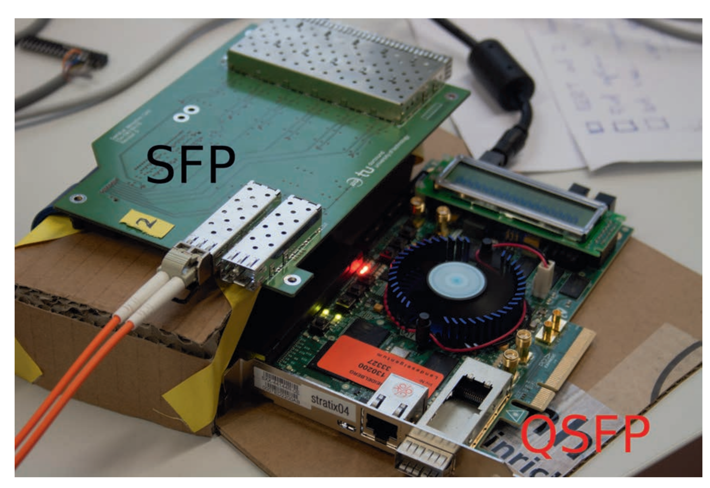
A **triggerless** data acquisition system processed **~1 Tbit/s zero-suppressed** data. Up to 10^9 tracks per seconds are reconstructed online on a graphical processing units (**GPU**) based filterfarm and reduced to ~100 Mbyte/s for offline storage and analysis.



Optical Links

Optical links connect the active detector with the filterfarm providing a galvanic separation.

Altera FPGAs are used for **preprocessing** (time sorting and merging) and transmitting the sensor data. Development Kits are used for various tests.



- parity controle on a 80 bit base is needed
- SFP: **6.4 Gbit/s** (BER < 10^{-16})
- QSFP: **11.3 Gbit/s** (BER < 10^{-16})