UNIVERSITY OF LIVERPOOL

# CLFV in Mu3e experiment

## Quick status description and time frame

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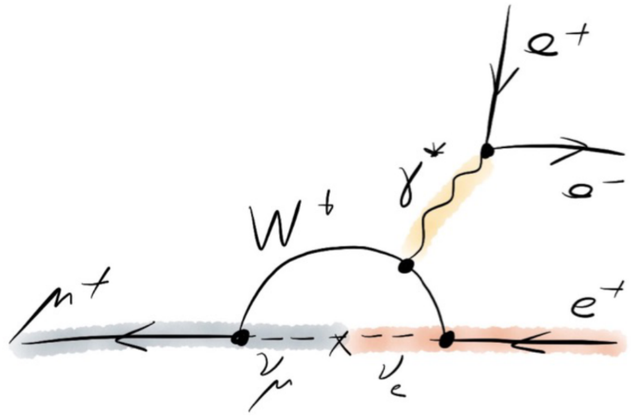
# The Muon search for charge LFV

- **Lepton flavour violation** (LFV) experimentally observed in the neutral leptons sector (neutrino oscillations)
- Physics beyond the Standard Model (SM) predict charge LFV. Any observation: **New Physics**!
- Heavily suppressed in the SM + neutrino mixing: $O(10^{-54})$



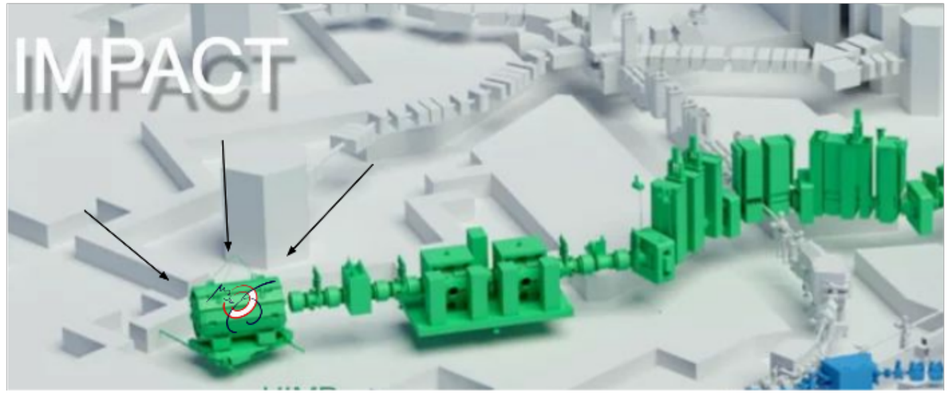

- **Muons** are an excellent probe of cLFV
  - **Sensitive**: New physics effects scale with the squared lepton mass $\mathbf{m}_l^2$
  - **Clean**: Relatively long lifetime and simple, well-understood decay channels, allowing for precise and background-free measurements
  - The strongest limit so far SINDRUM II (PSI 1988) BR $(\mu^+ \rightarrow e^+e^+e^-) < 1.0 \times 10^{-12}$ Nuclear Physics B 299 (1988) 1

- The **Mu3e experiment** looks for muons decaying into three electrons $\mu^+ \rightarrow e^+e^+e^-$

# The Mu3e experiment

- The Mu3e Experiment is located at Paul Scherrer Institute in Switzerland
  - **Most intense** muon beam with low momentum muons 28MeV
- Up to **$10^8$** Muons/s Muon production at HIPA
  - 590 MeV proton accelerator
  - Carbon target, produce pions, decay to surface muons

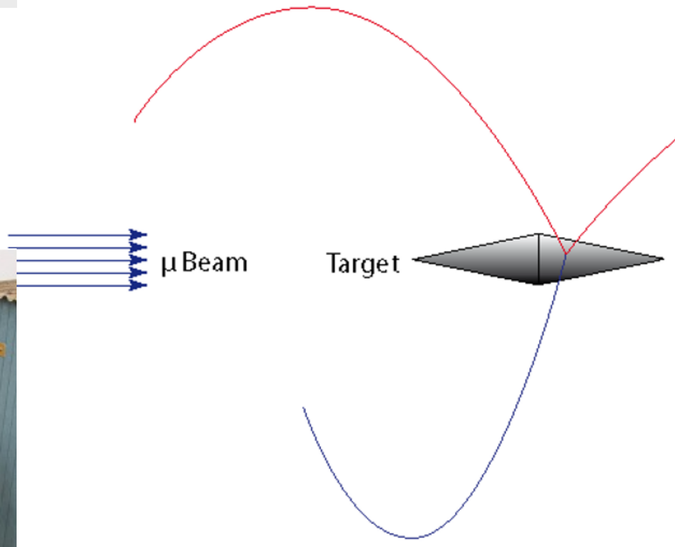
- Goal: Improvement of the current limit by **4 orders** of magnitude in two phases
  - **Phase 1** aims for a sensitivity of $<2.0 \cdot 10^{-15}$ (Start in 2026) First commissioning run in 2025 Currently under construction at PSI
  - **Phase 2** aims for a sensitivity of $<1 \cdot 10^{-16}$ (from 2030) High intensity muon beamline **HIMB** (up to $10^{10}$ Muons/s) R&D started

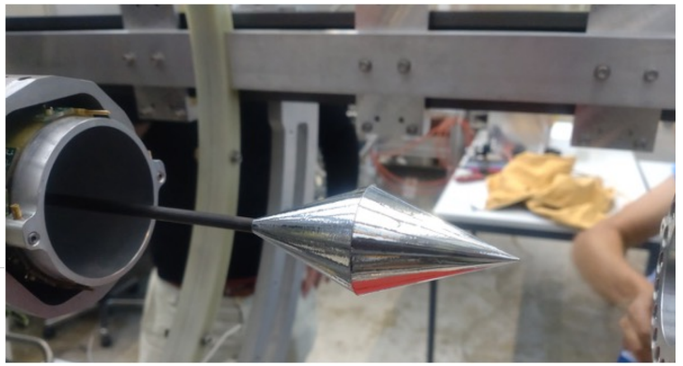


# Mu3e experiment

**Mu3e magnet**
Superconducting solenoid
=> Uniform 1T field
For precise momentum reconstruction

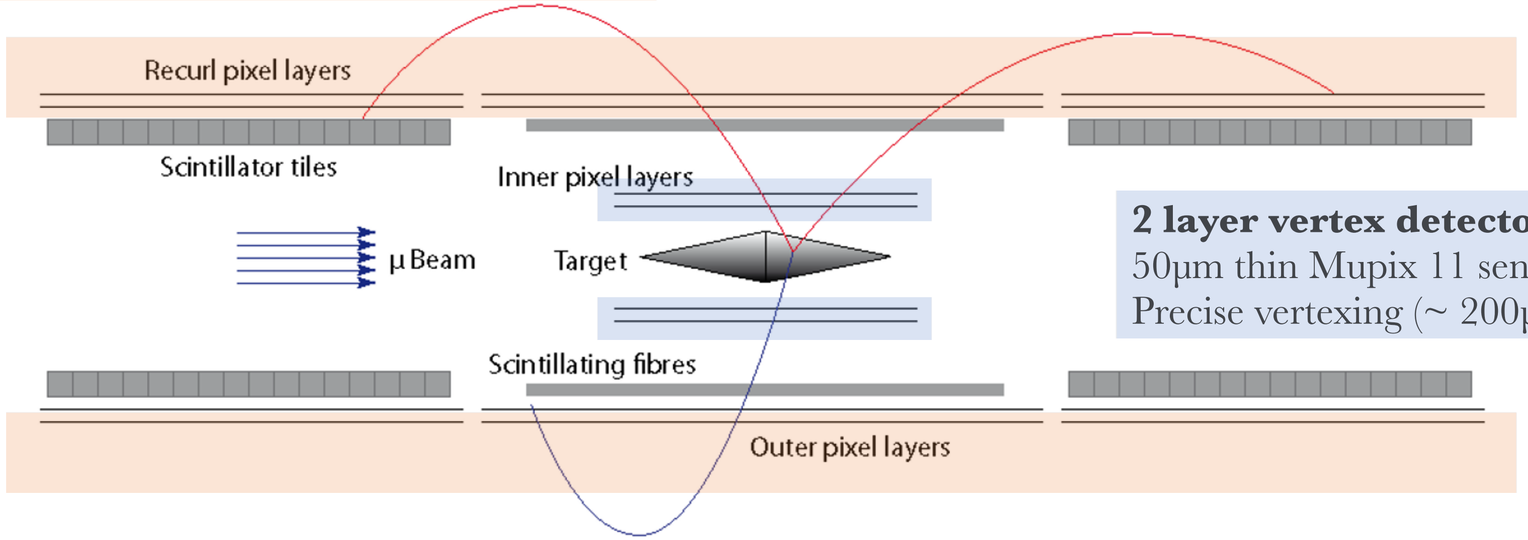
**Target**
- Muons are stopped on aluminised mylar double hollow cone
- Maximum stopping fraction 95.5%
- Minimal material budget (~0.15%)



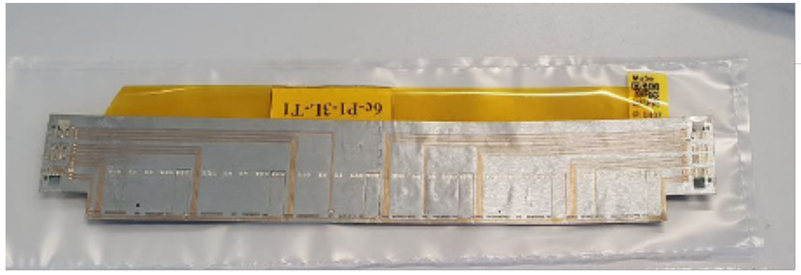



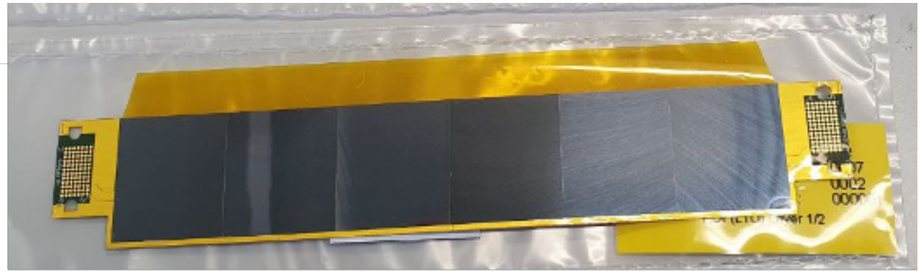
# Mu3e experiment

**2 outer pixel layers**
70μm thin Mupix 11 sensors / Up to 18 sensors per ladder
For good momentum resolution and high $p$ acceptance
=> reconstruction of recurling tracks

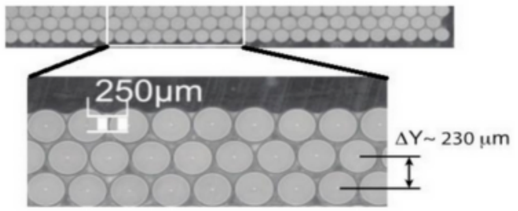



**2 layer vertex detector**
50μm thin Mupix 11 sensors / 6 chips per ladder
Precise vertexing (~ 200μm)

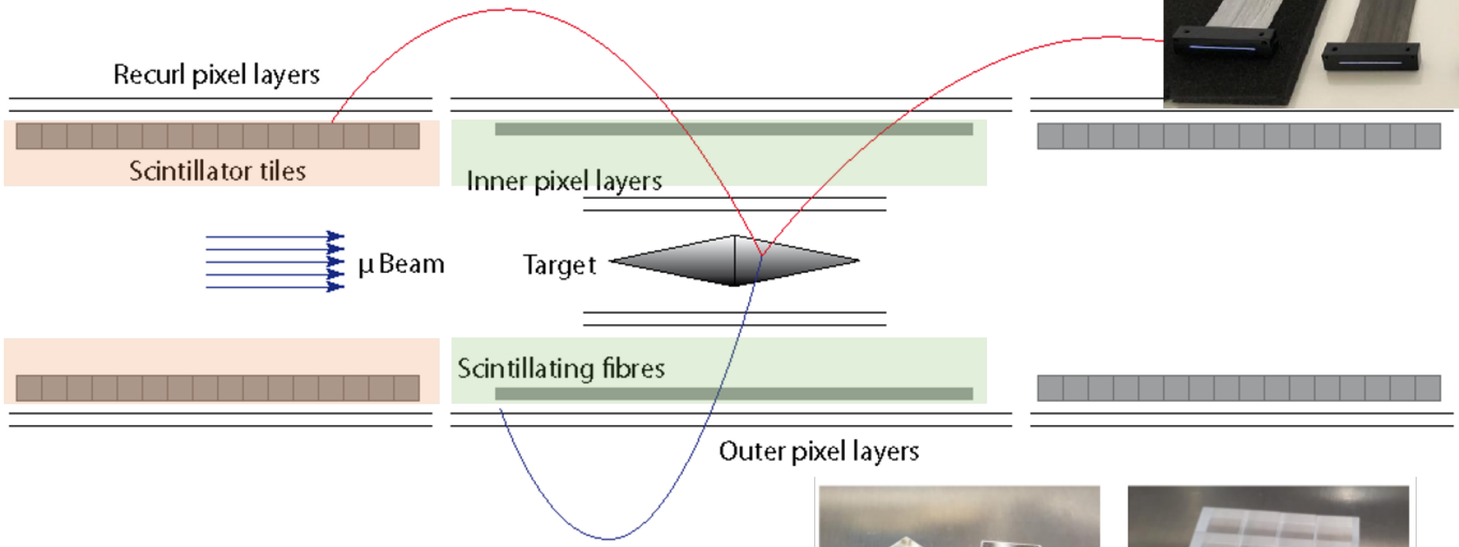




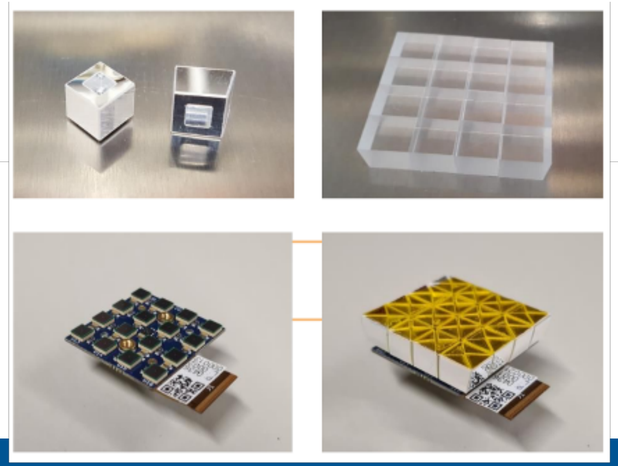
# Mu3e experiment




3 layers of 250µm **scintillating fibres**
Read-out by (SiPMs) and custom ASIC
Timing resolution < 0.5ns

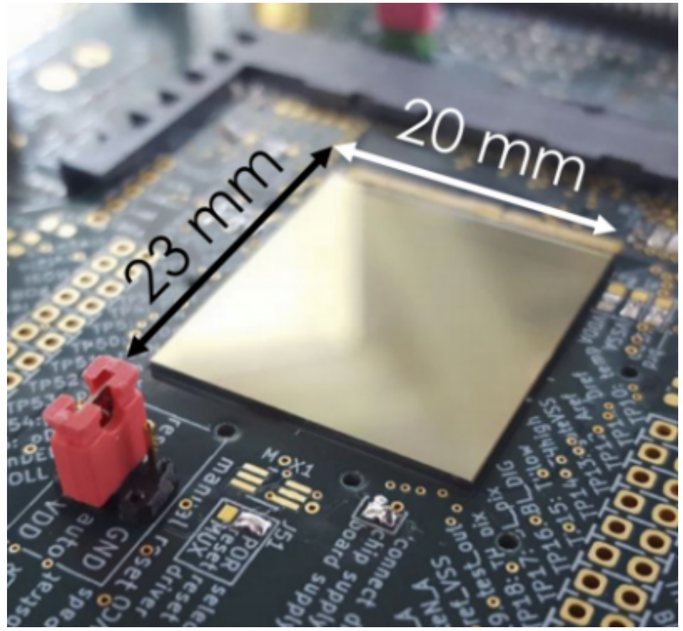


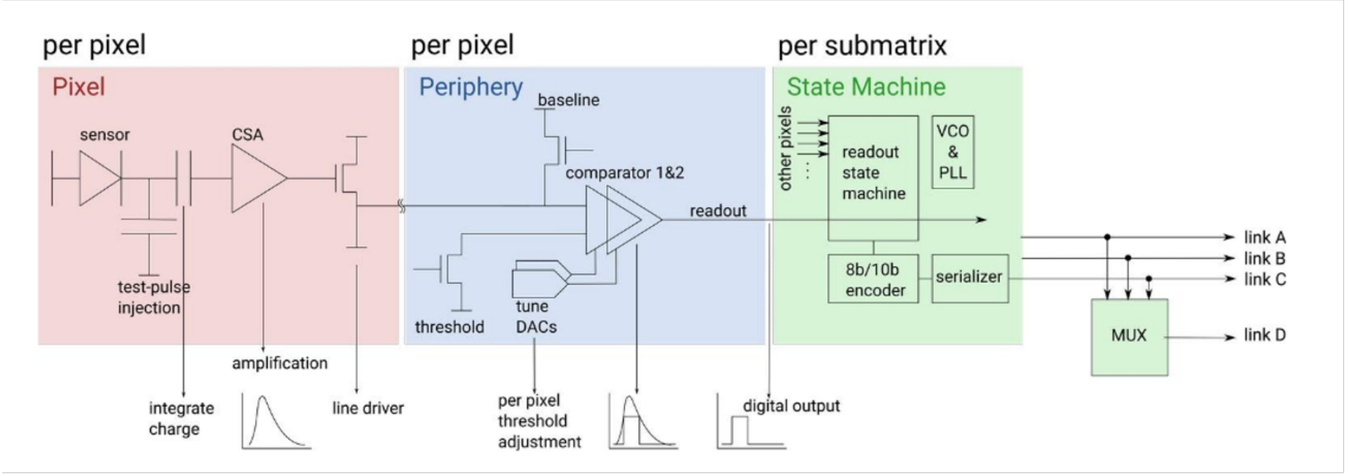

≈0.5cm$^3$ **scintillating tiles**
Readout by SiPMs and custom ASIC
Timing resolution 80ps



# Mupix 11

- High-Voltage Monolithic Active Pixel Sensor (HV-MAPS)
- Detection and Readout combined in one chip
- Fully digital 1.25Gbit/s LVDS output
- Pixel size 80µm x 80µm
- 99% efficiency with less than 20ns time resolution
- 2 comparator design
- Tuning/trimming and masking available
- Chip sub-divided into 3 matrices:
  1 data link each + 1 multiplexed link

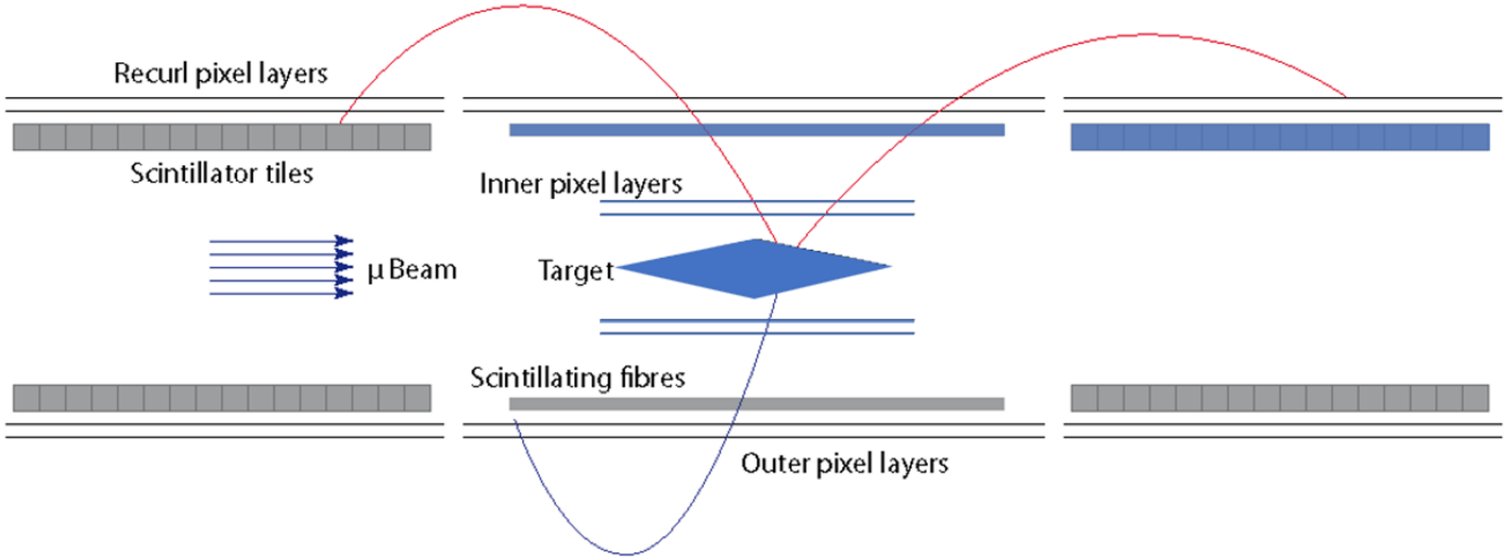


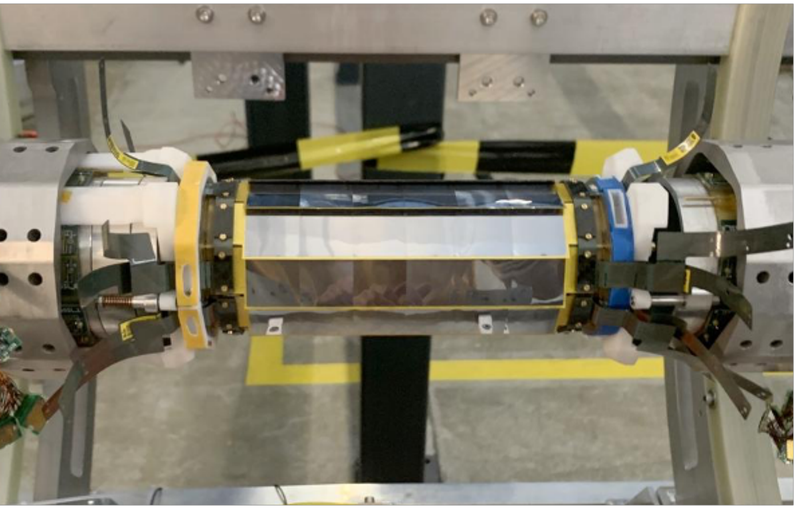
# Minimal detector configuration

Three weeks of commissioning run campaign in 2025 at PSI in PiE5

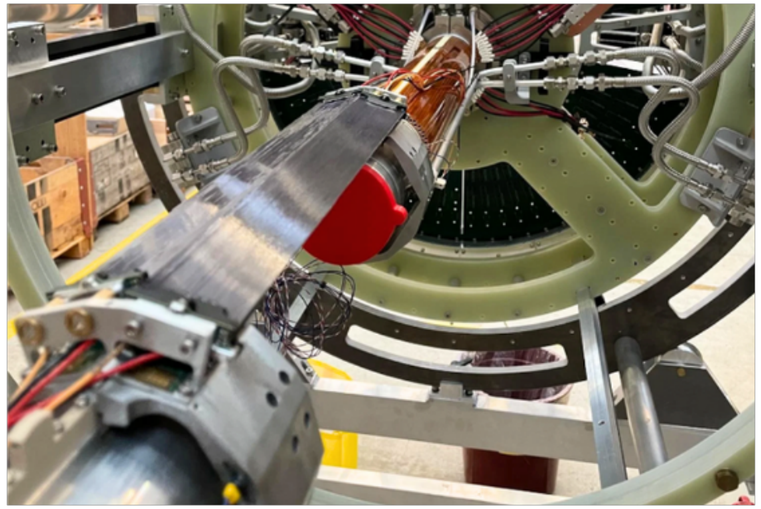
- **Full vertex detector** installed with 108 sensors
- **One** of six SciFi modules
- **Three** of fourteen SciTile modules
- Operation with gaseous helium cooling and 1T magnetic field
- Most services independent of the sub-system have been installed and tested



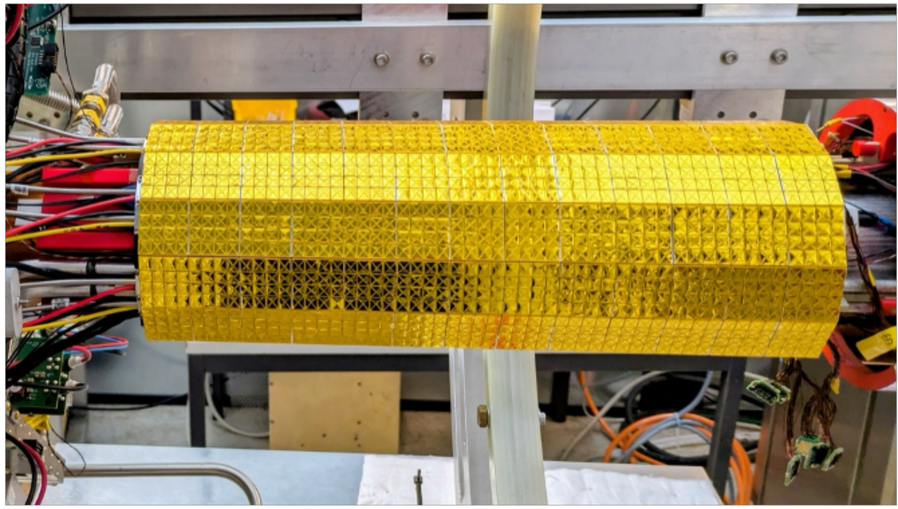
# Commissioning Run 2025



Full Vertex Detector



2 SciFi ribbons

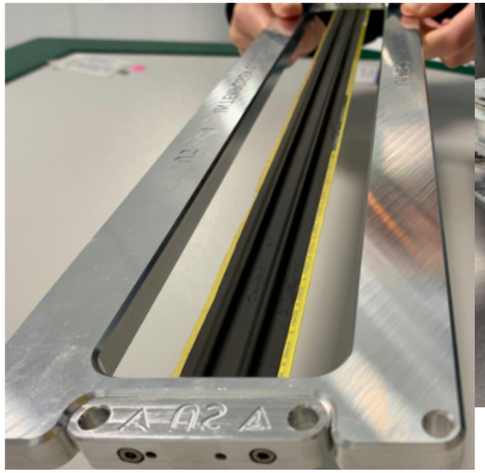


3 SciTile modules

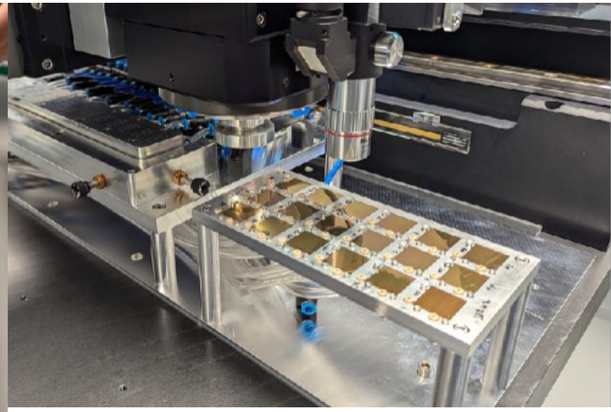
**More details will be given by Jak at one of the Muon Meeting in January/February**

# Towards physics in 2026

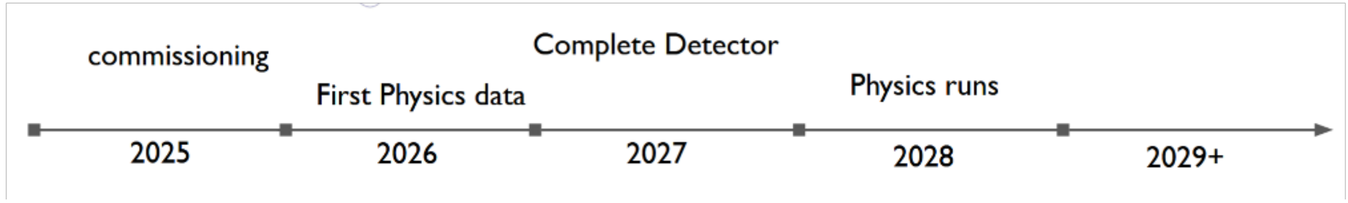
- Aim for a physics run in 2026
  - Construct Vertex V2 (70μm thin sensors)
  - Outer pixel production (central detector)
    - Use 25μm uni-directional carbon-fibre stiffner
    - Robotic gantry used for placement of chip
  - SciFi & Tile production
- Could **surpass** the SINDRUM limit in less than two weeks
- Install the full detector in 2027
  - Production of recurl stations (2026)
- Phase I data taking in HIMB
  - Need 1 year of data taking to reach the BR of $10^{-15}$

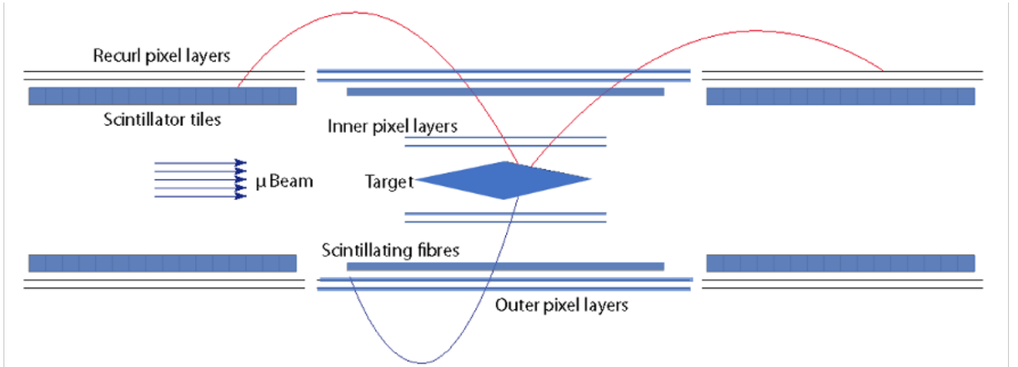


Carbon stiffner attached to a ladder



Robotic gantry for chip placement




Detector Setup for 2026 Physics data taking campaign

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