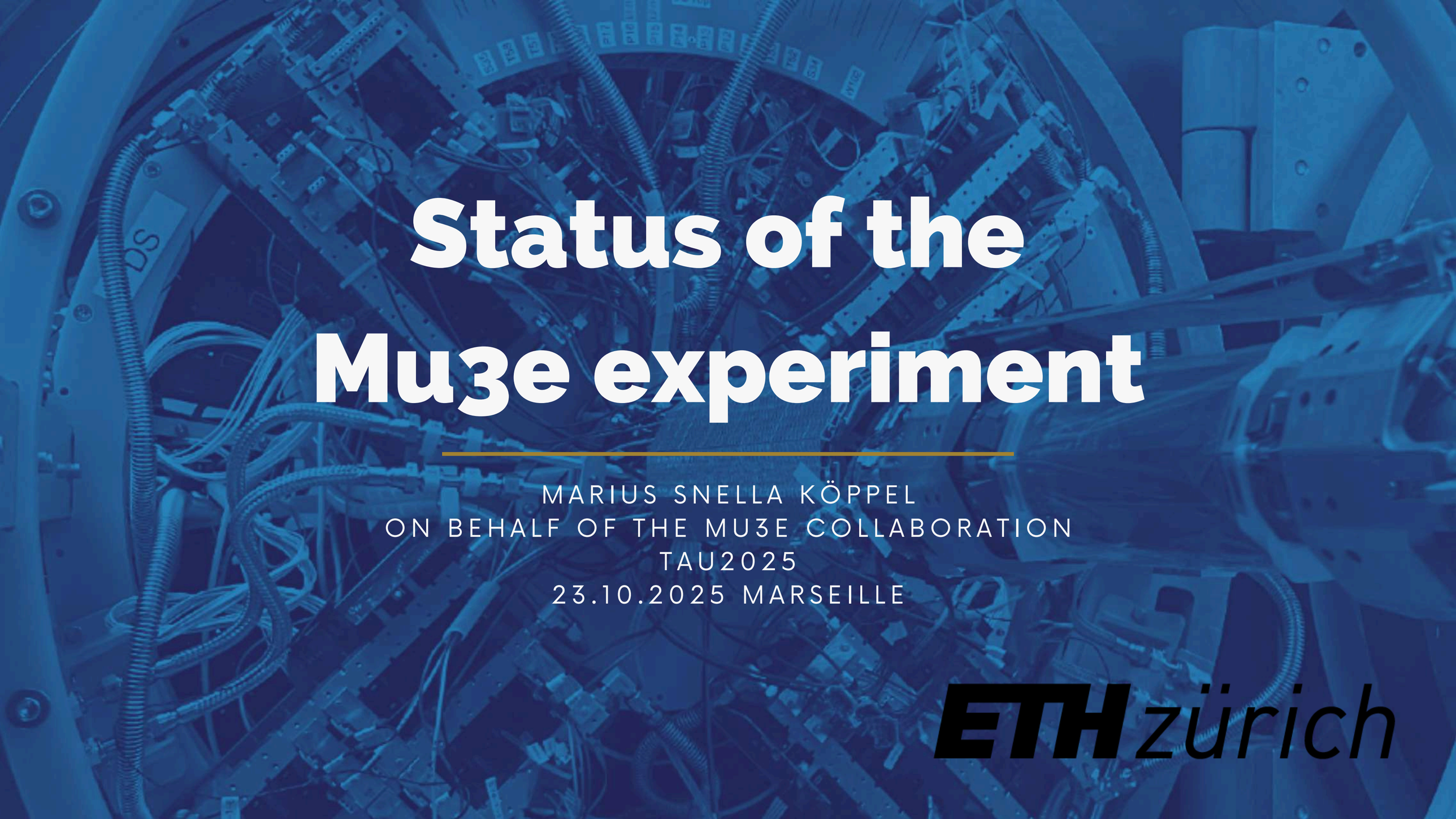

Status of the Mu3e experiment

MARIUS SNELLA KÖPPEL
ON BEHALF OF THE MU3E COLLABORATION

TAU2025
23.10.2025 MARSEILLE

ETH zürich

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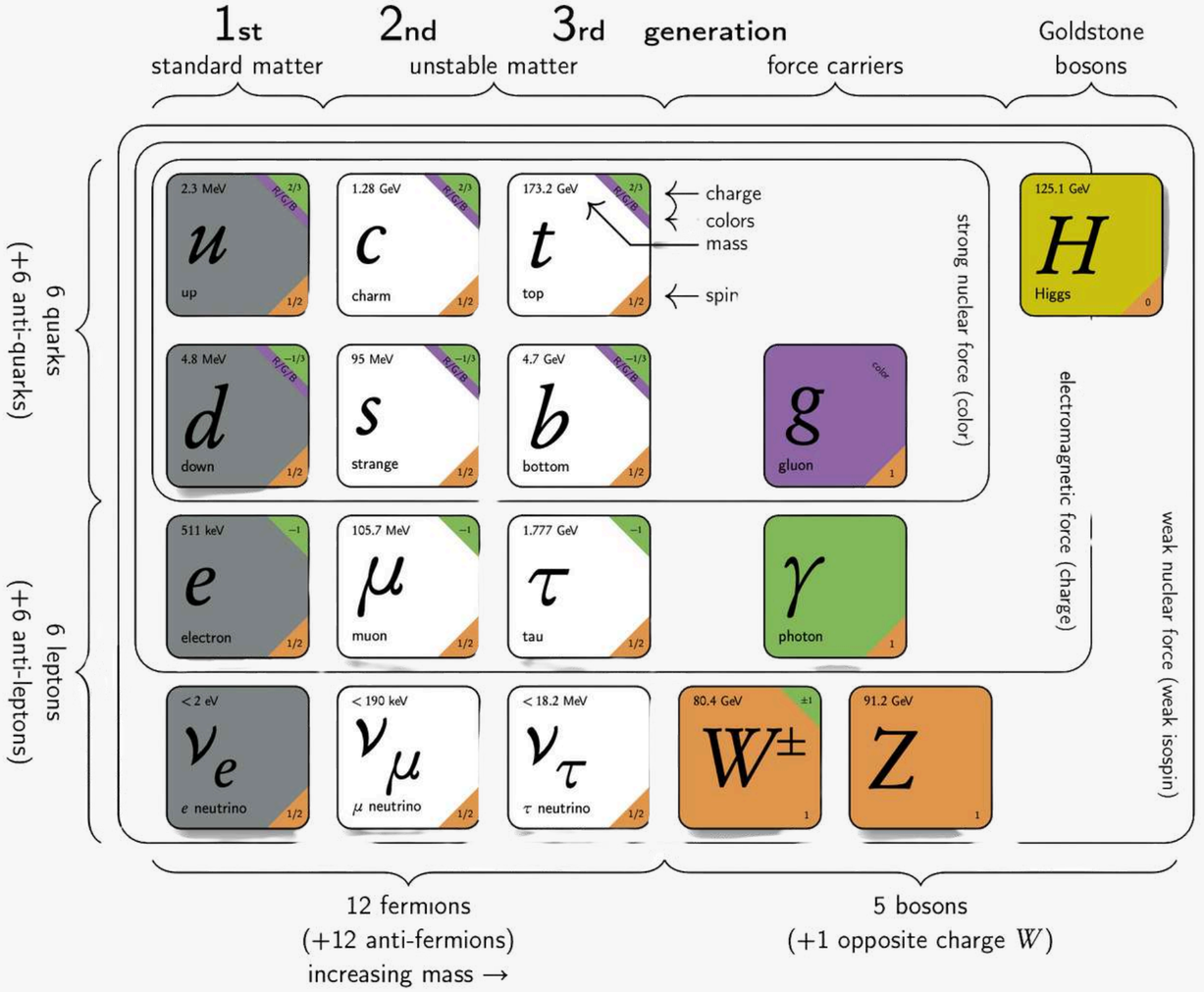
Mu3e Motivation

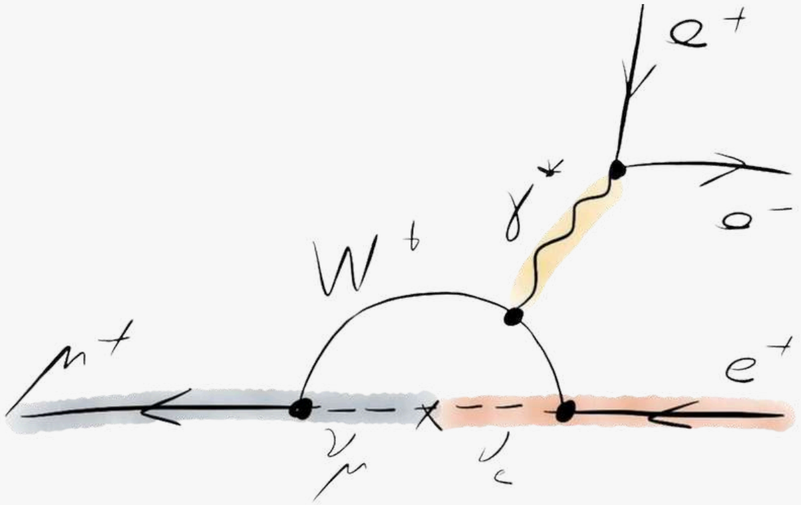
- The Standard Model serves as a theory encompassing "everything"
- Remarkable precision in theoretical forecasts

Many phenomena are not covered in the SM



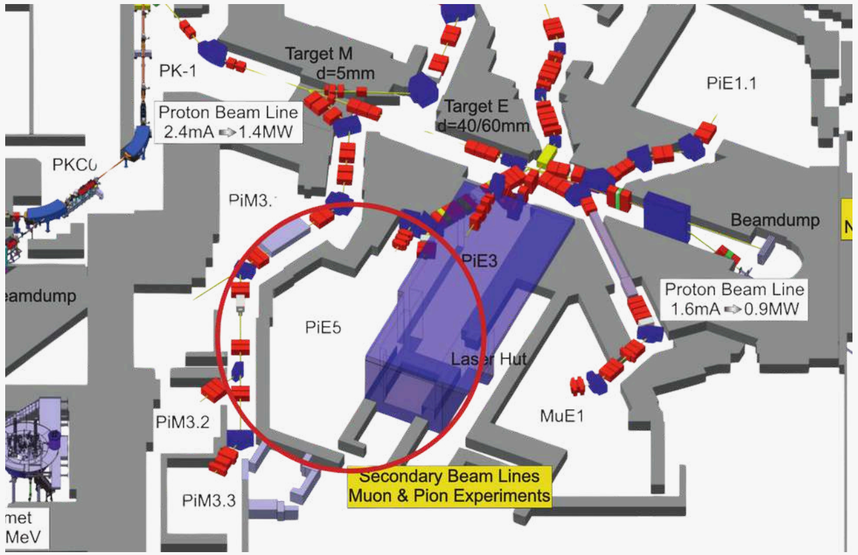
Mu3e Motivation

SM with ν oscillation Br: < 10^{-54}



- Search for Lepton Flavor Violation $\mu^+ \rightarrow e^+e^-e^+$
- One year of data taking
- Use PiE5 beamline of PSI

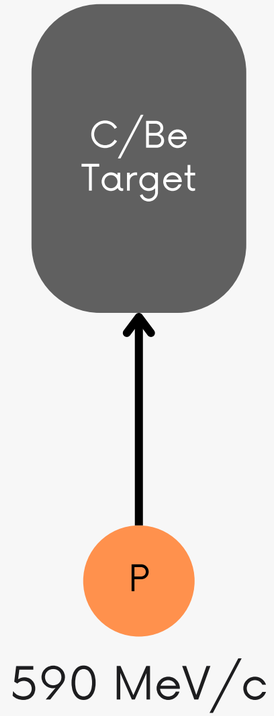
Muon beam of $10^8 \mu/s$



- Current Branching Ratio limit set by SINDRUM (1988) of $< 10^{-12}$
- Mu3e will improve this to two in 10^{15}

Muze Detector Concept

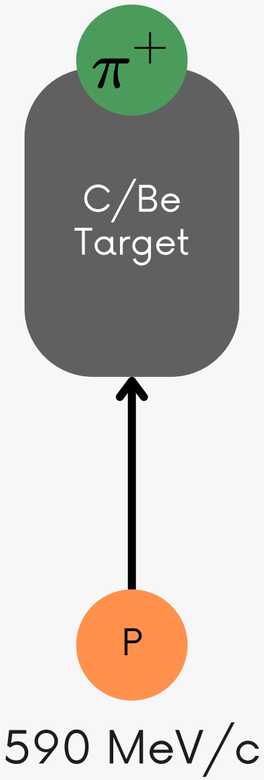
Mu3e Detector Concept



Mu3e Detector Concept

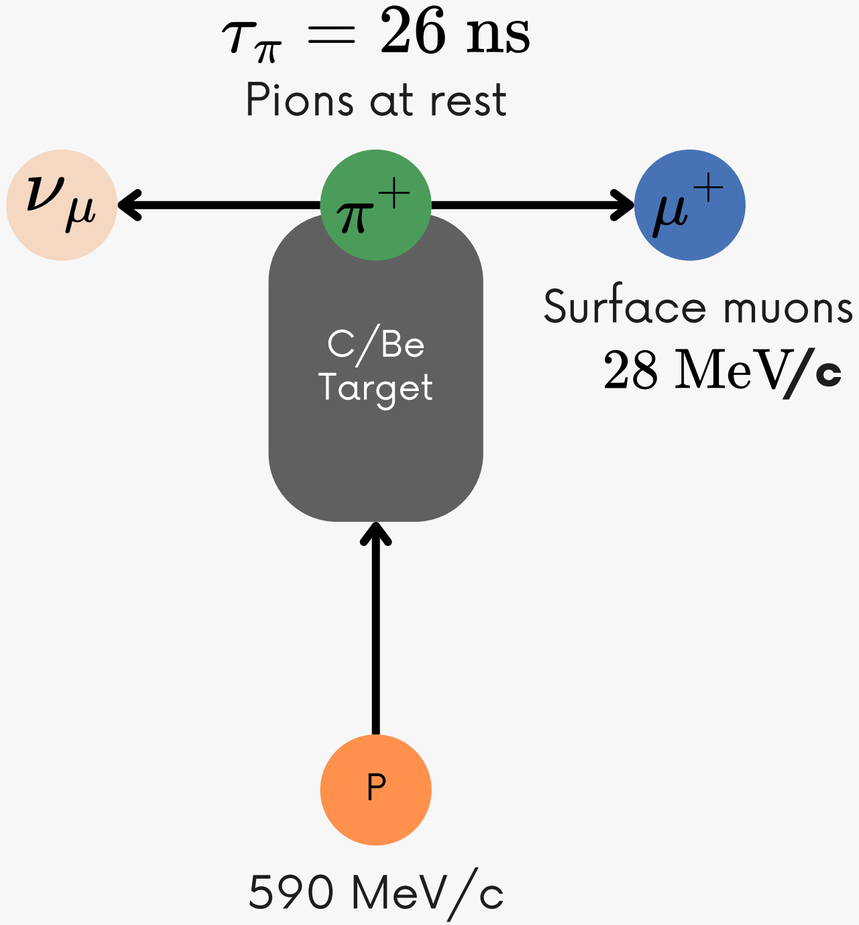
$\tau_\pi = 26$ ns

Pions at rest

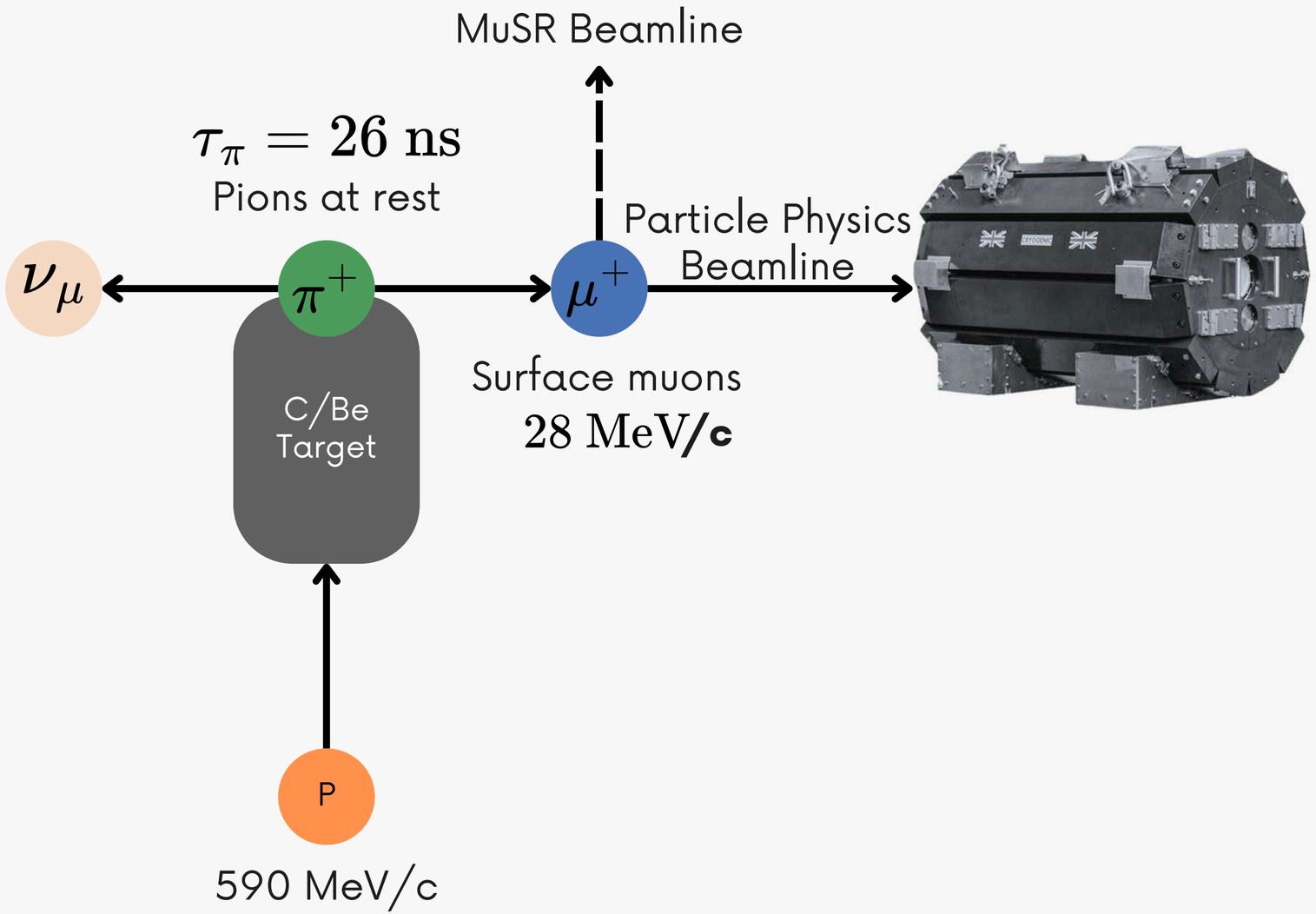


590 MeV/c

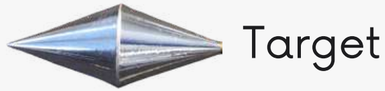
Mu3e Detector Concept



Mu3e Detector Concept



Mu3e Detector Concept



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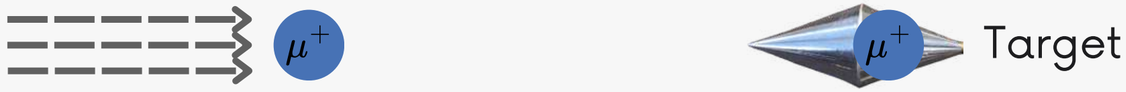
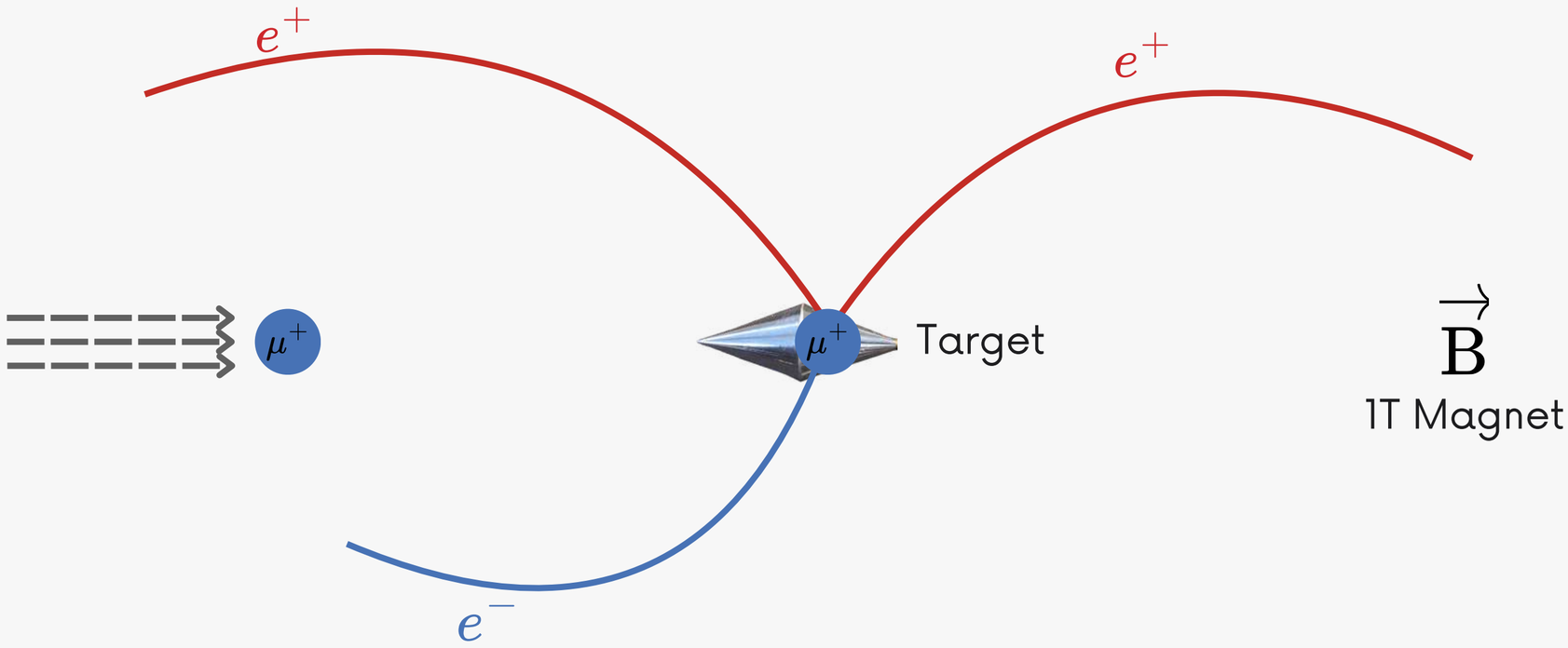
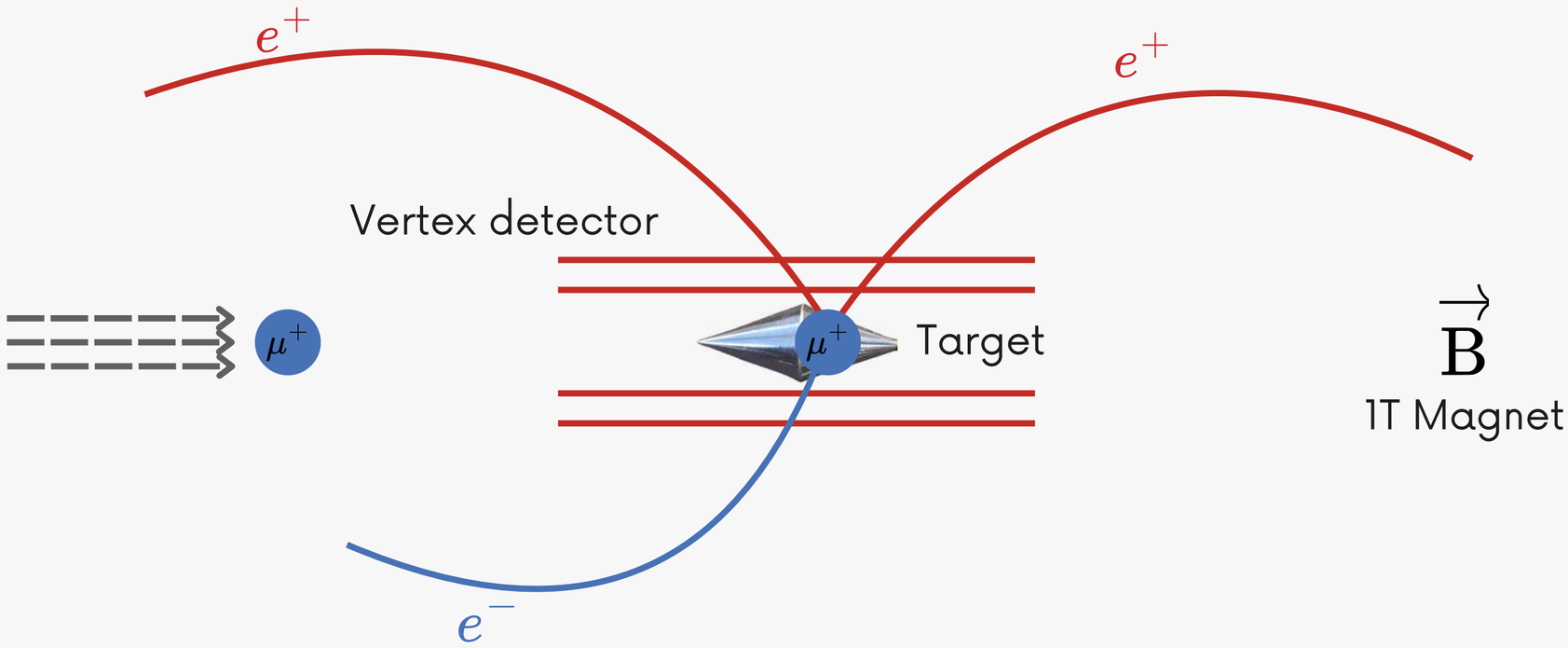


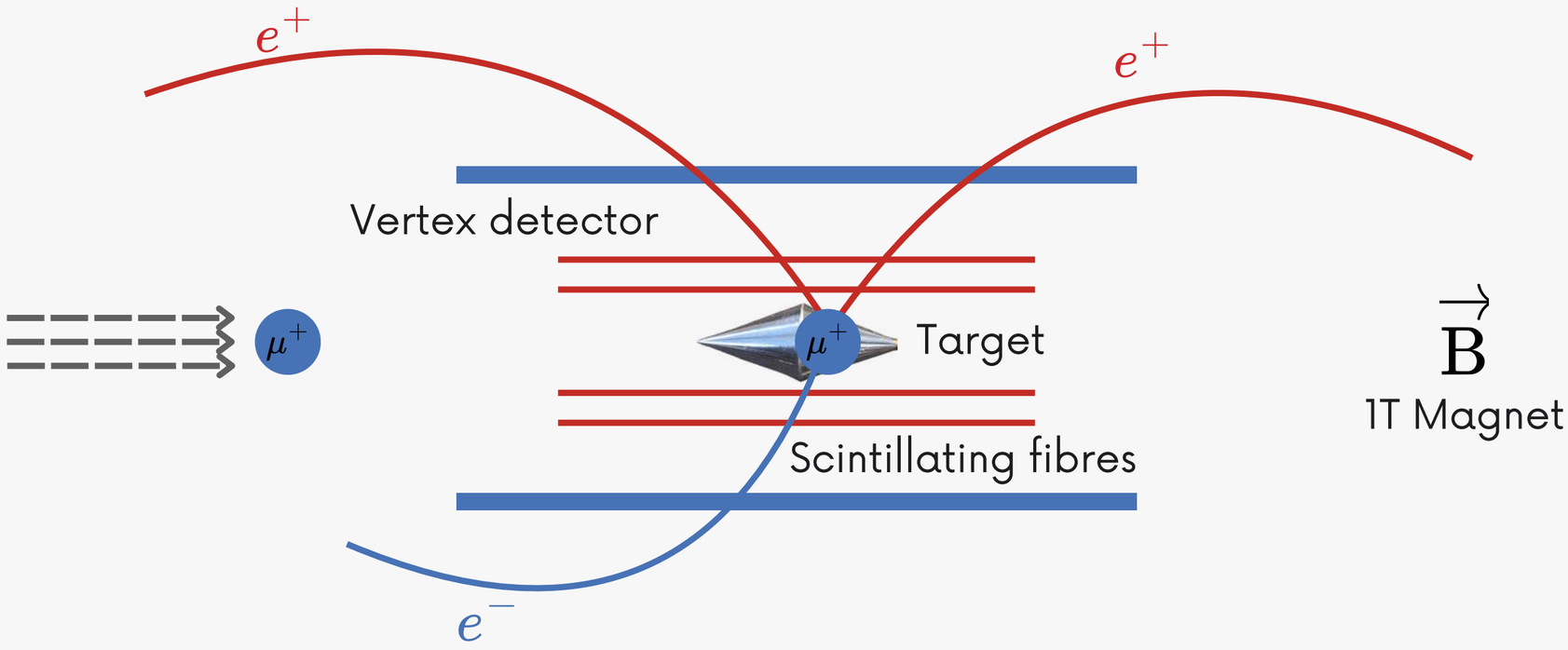
Mu3e Detector Concept



MuSe Detector Concept



Mu3e Detector Concept



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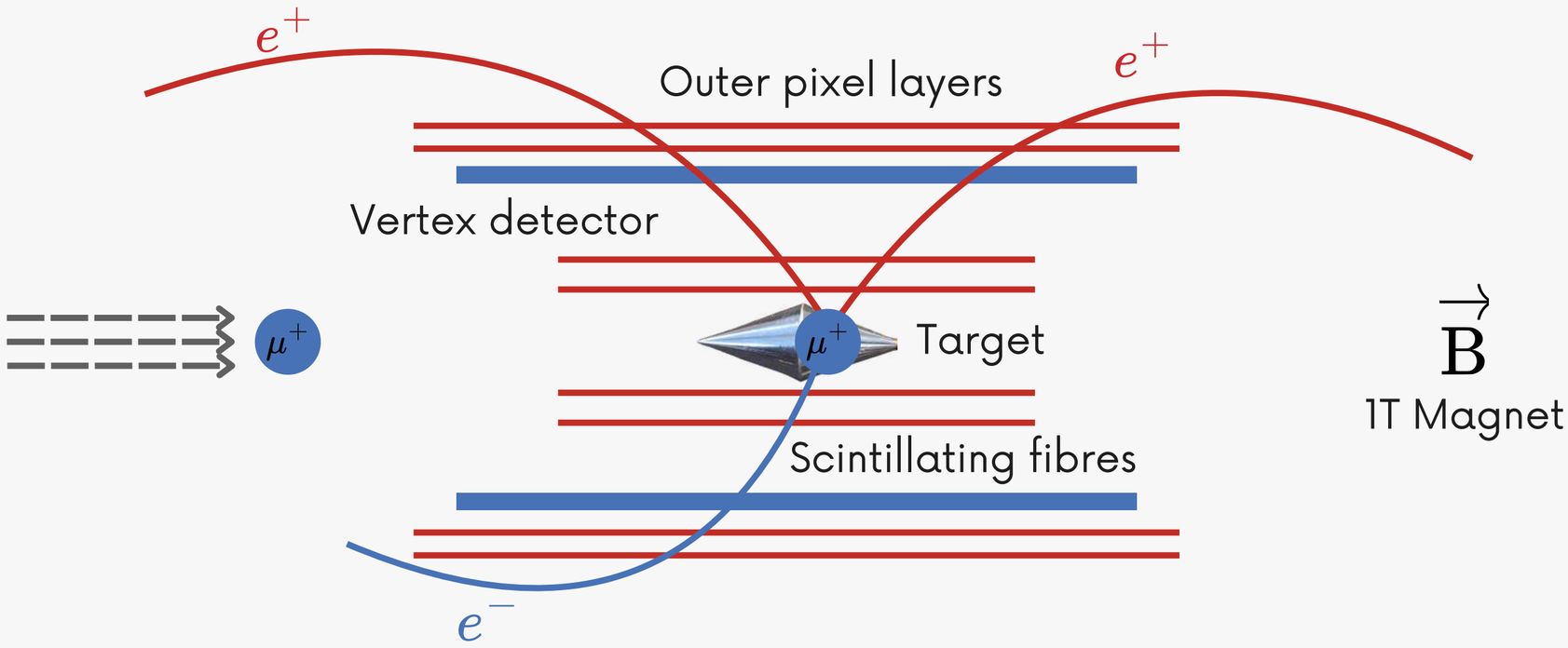

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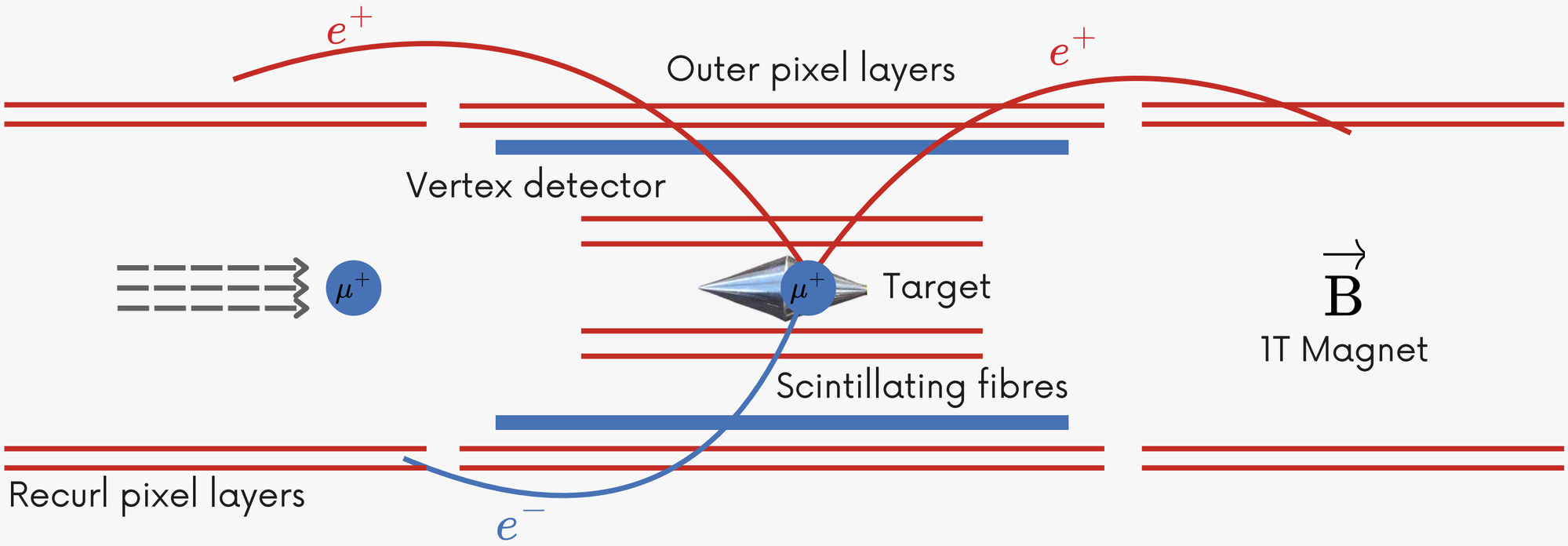

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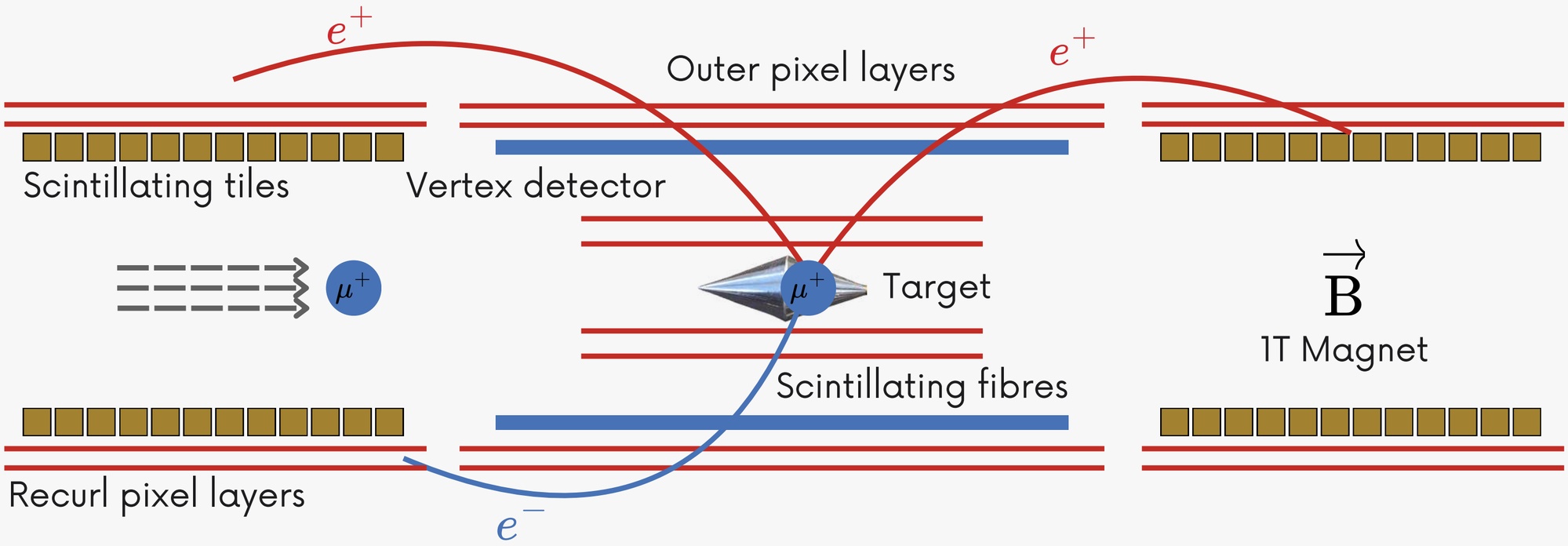

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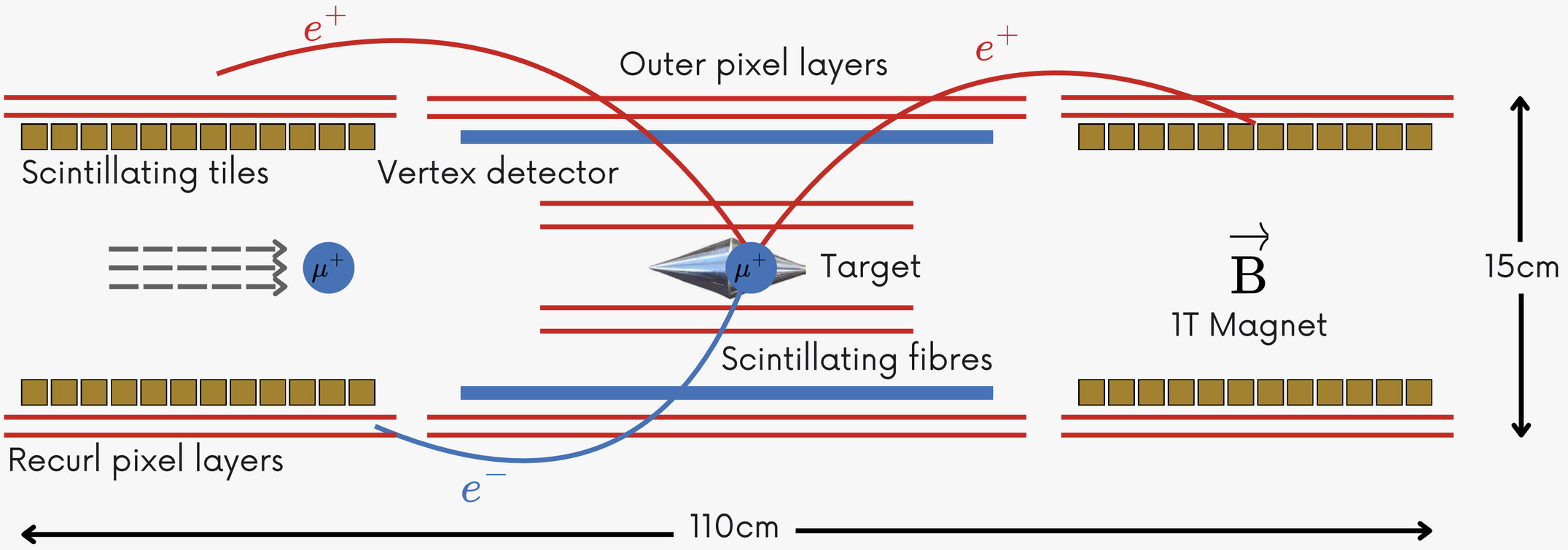
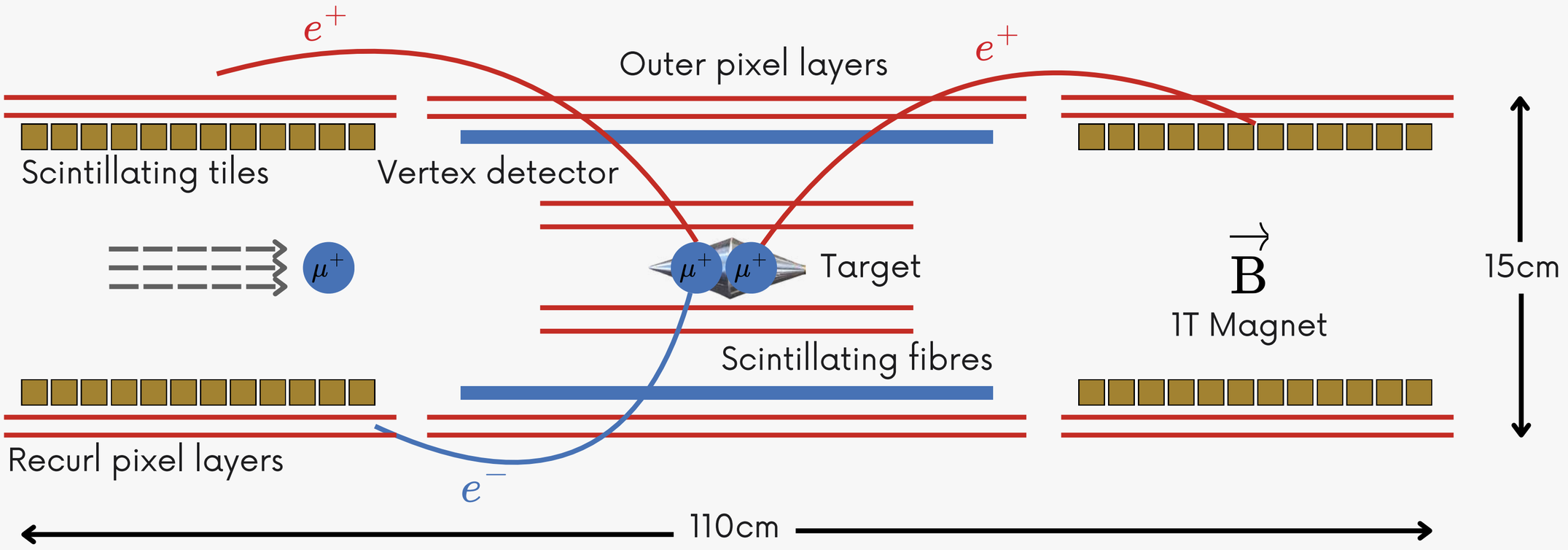


DAQ challenge: no “hardware” trigger for 3 tracks

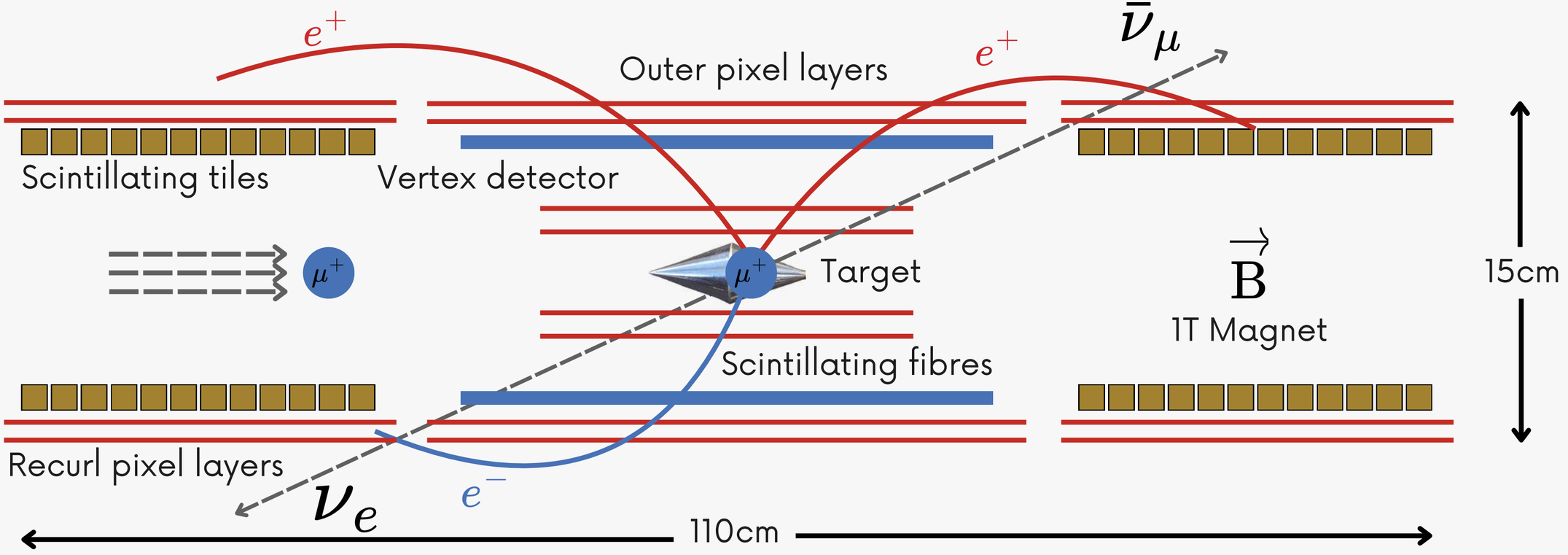
→ need to reconstruction all decays online

Main Backgrounds - Random Combinations



Detector challenge: need for good vertex and time resolution

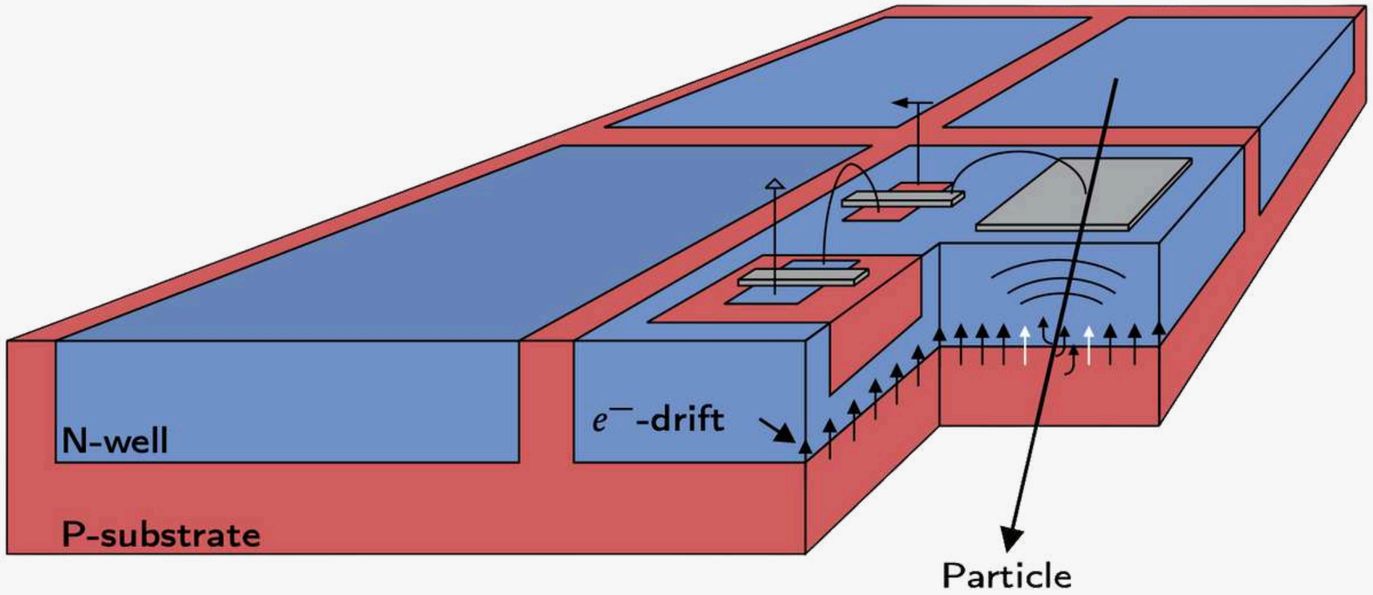
Main Backgrounds - Internal Conversion $\mu^+ \to e^+ e^- e^+ \nu_e \bar{\nu}_\mu$



Detector challenge:need for good momentum resolution

$\sum E_e = m_\mu$ **&** $\sum p_e = 0$

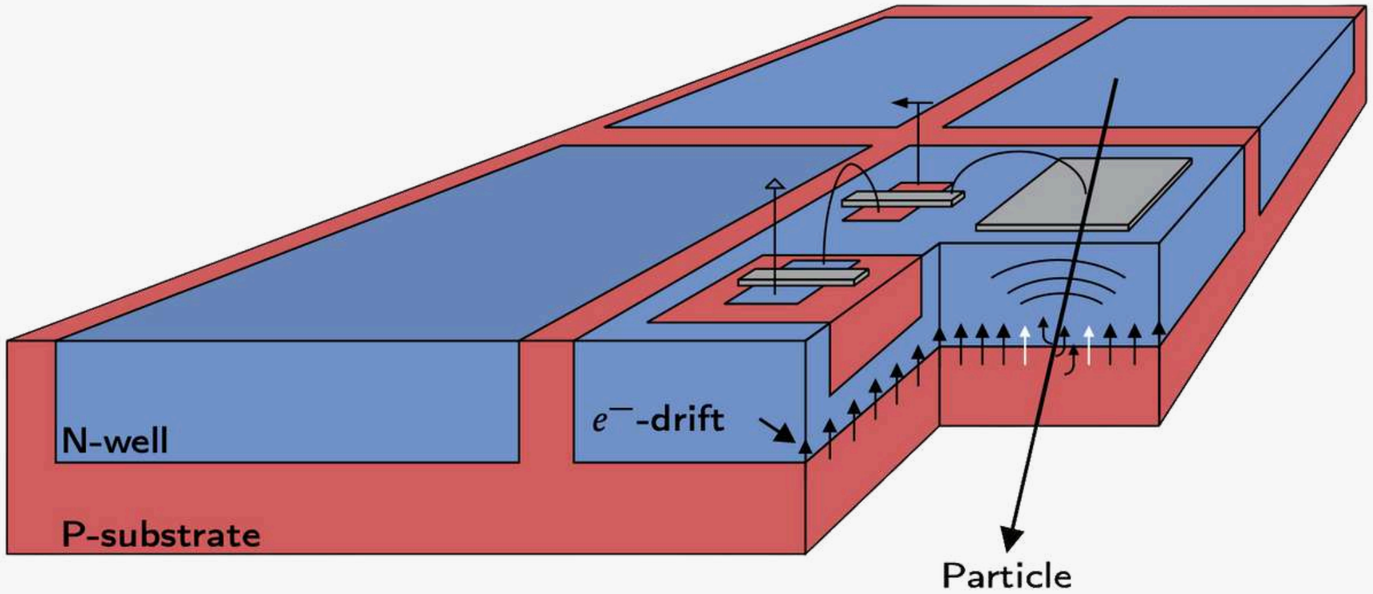
High Voltage Monolithic Active Pixel Sensors (HV-MAPS)



Ivan Perić et al., NIM A582 (2007) 876-885

- High Voltage Monolithic Active Pixel Sensors
- Thinned down to 50 µm
- Fast charge collection via drift
- Time resoluton of a few ns
- Digitalization and zero suppression on the chip

High Voltage Monolithic Active Pixel Sensors (HV-MAPS)



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- High Voltage Monolithic Active Pixel Sensors
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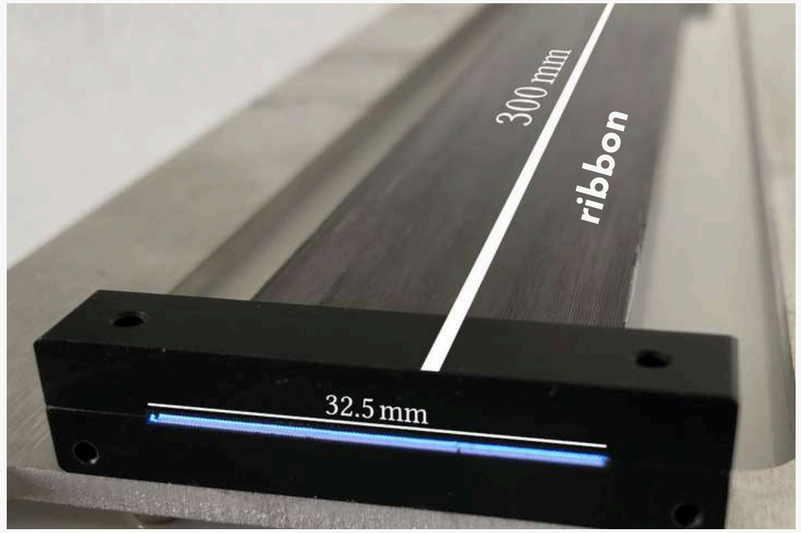
good vertex resolution and momentum measurment

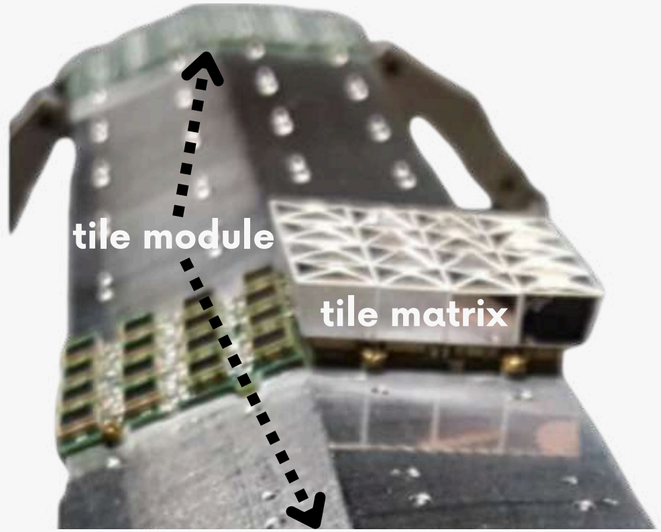
Timing Detectors

Fibre < 250 ps time resolution



- 128 fibres per ribbon
- 3 layers of fibres
- Readout via SiPMs arrays

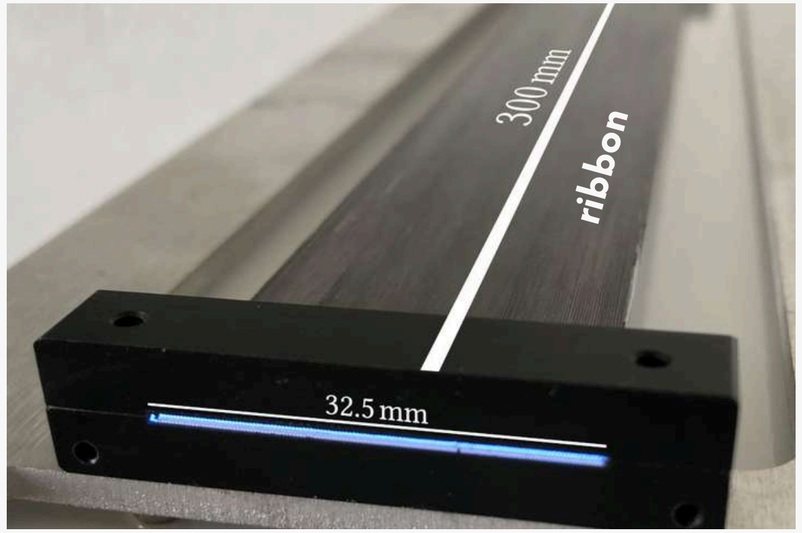
Tiles < 70 ps time resolution



- $6.3 \times 6.2 \times 5.0\ \mathrm{mm}^3$ tiles
- 4 x 4 tiles per matrix
- One SiPM per tile

Timing Detectors

Fibre < 250 ps time resolution



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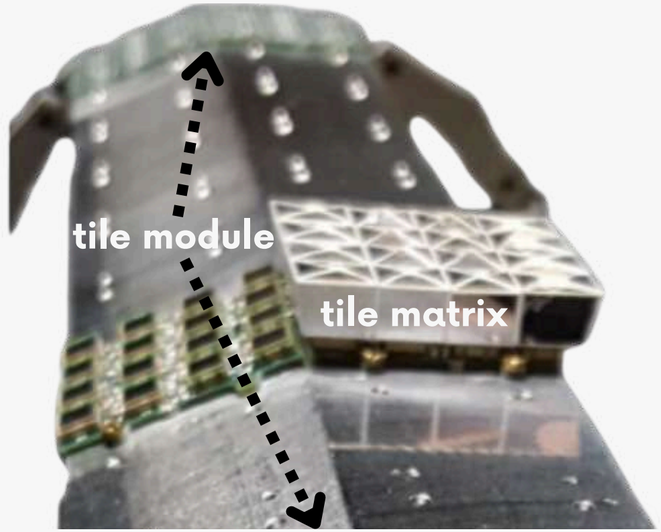

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good time resolution

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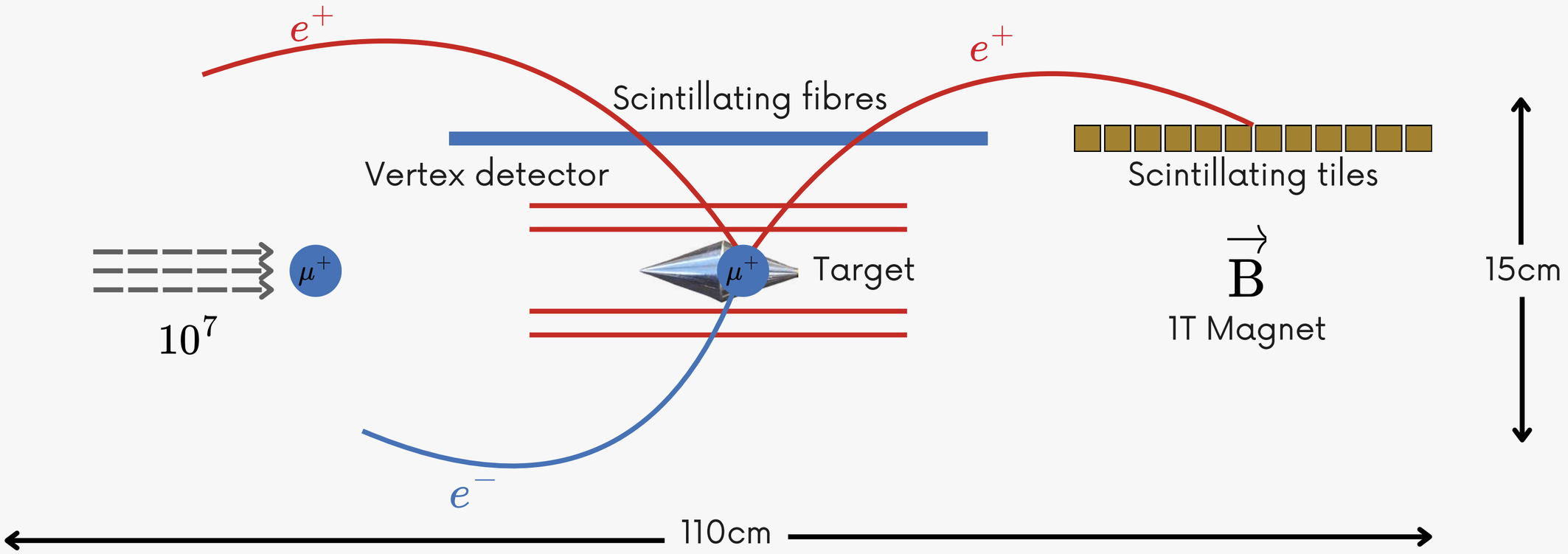
The Commissioning Run 2025



Minimal detector configuration

Installation of Mu3e

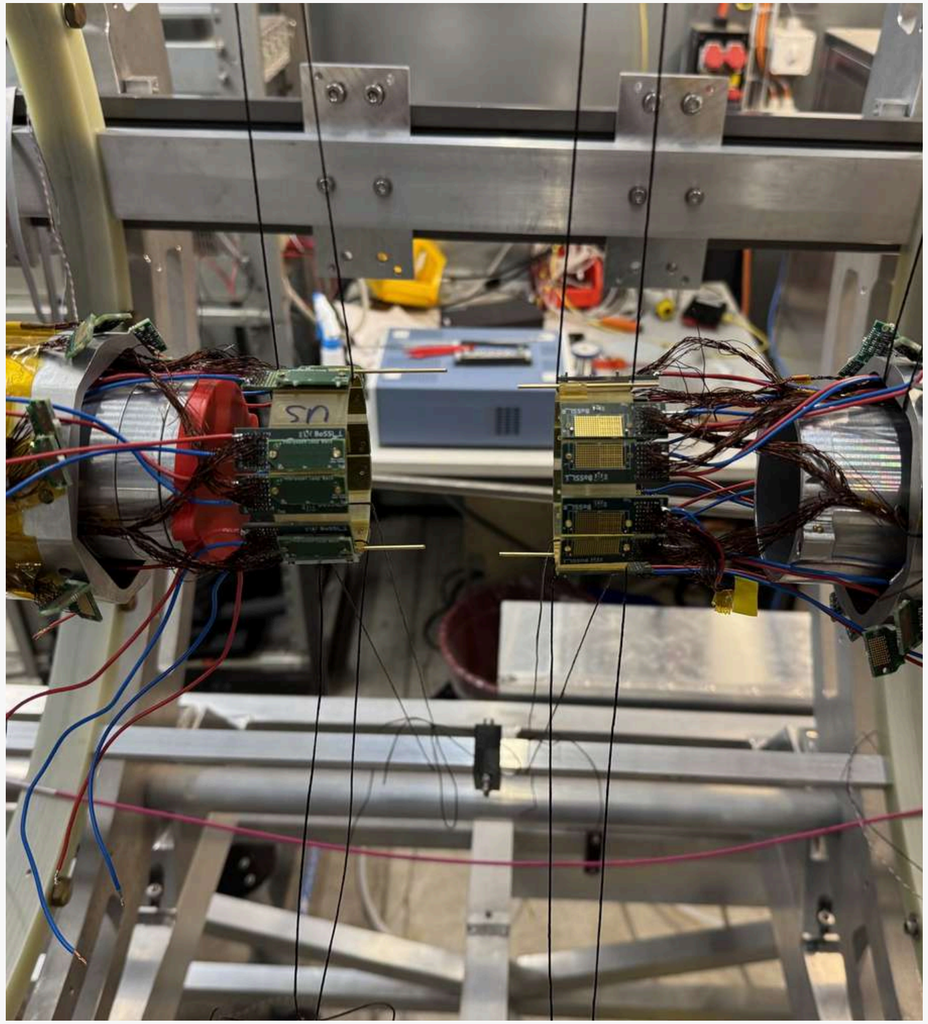
Installation

- First all services have to be installed and tested

Installation of Mu3e

Installation

- First all services have to be installed and tested
- Usage of CMS based micro-twisted pair cables (uTP cables) for data readout



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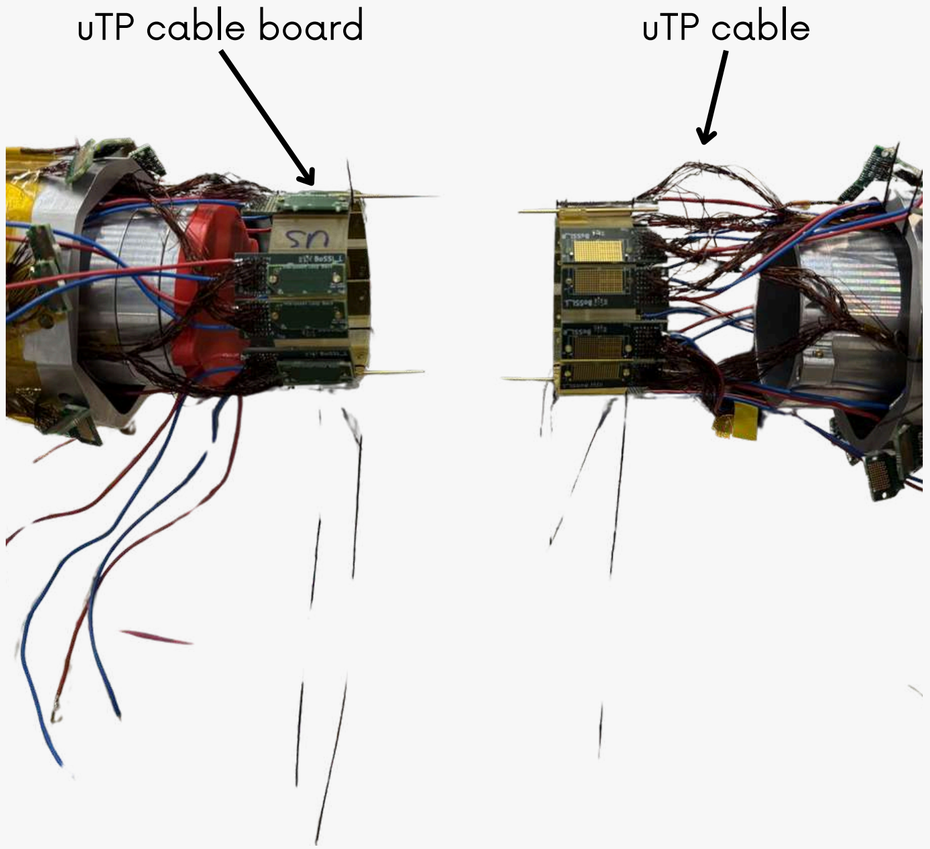
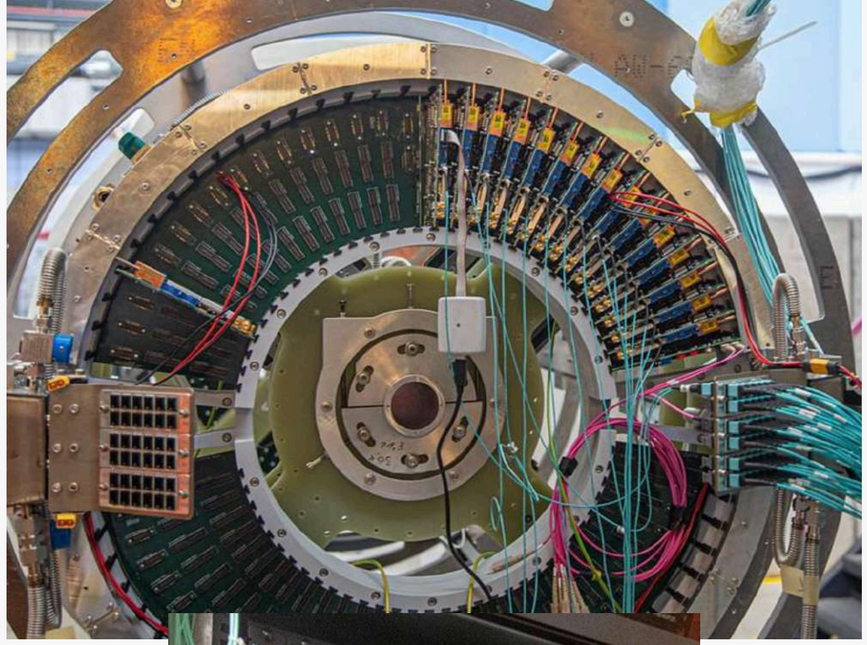
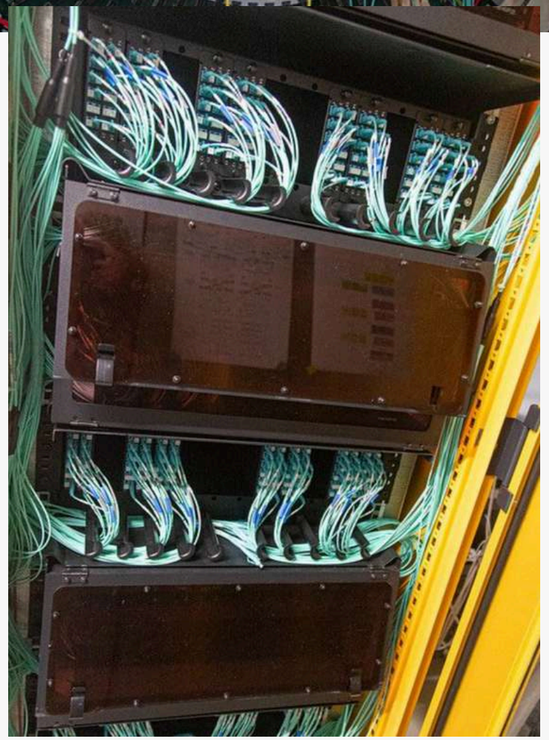


Installation of Mu3e

Installation

- First all services have to be installed and tested
- Vertex comes with flex connections installed which connect to the uTP cables
- DAQ fibre optical cables





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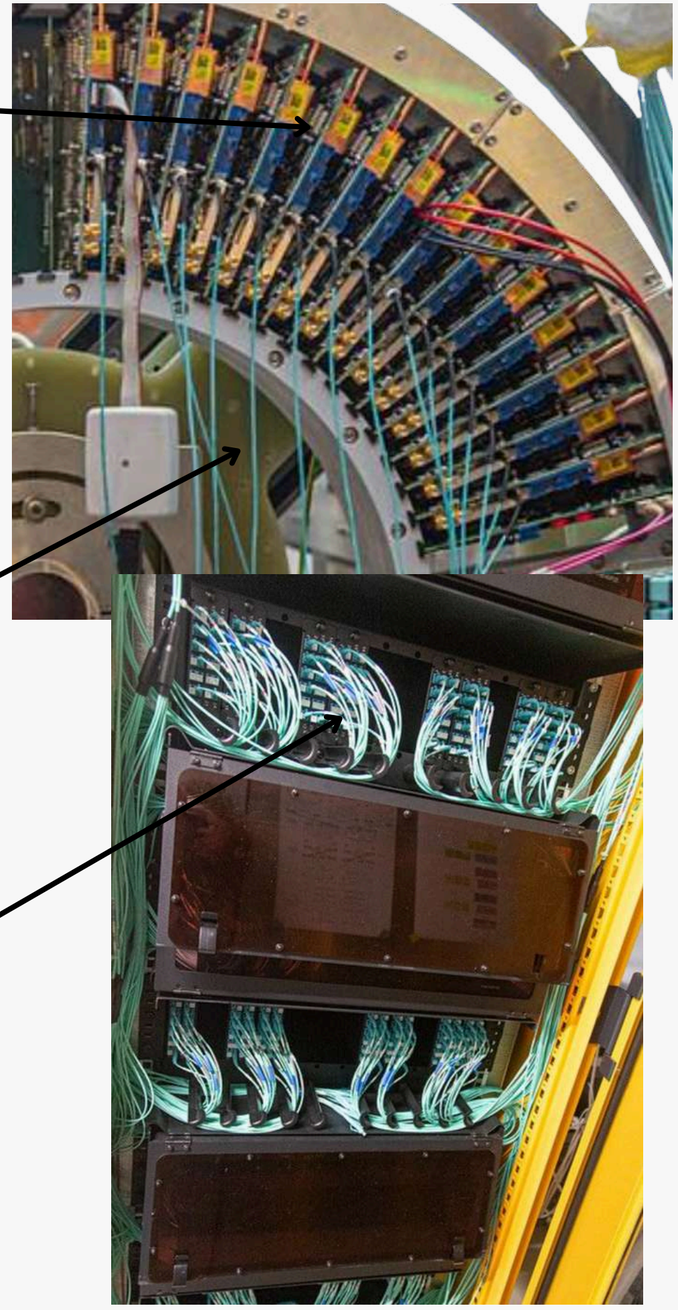
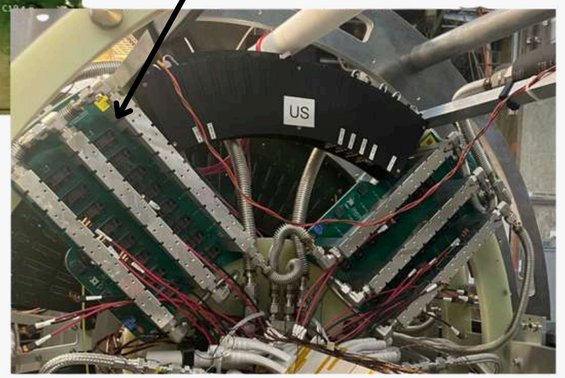


Installation of Mu3e

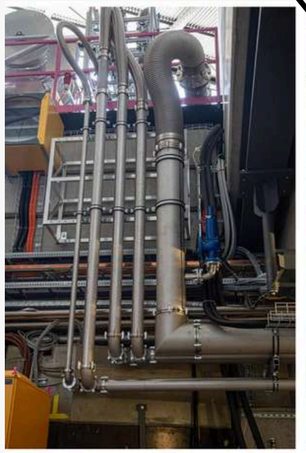
Installation

- First all services have to be installed and tested
- Vertex comes with flex connections installed which connect to the uTP cables
- DAQ fibre optical cables
- LV, HV, gasus helium system, etc.

LV Board (DCDC converter)



Turbo compressors for helium cooling



General service area

Installation of Mu3e

Installation

- First all services have to be installed and tested
- Vertex comes with flex connections installed which connect to the uTP cables
- DAQ fibre optical cables
- LV, HV, gasus helium system, etc.
- Vertex detector installation

Installation of Mu3e

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- Vertex comes with flex
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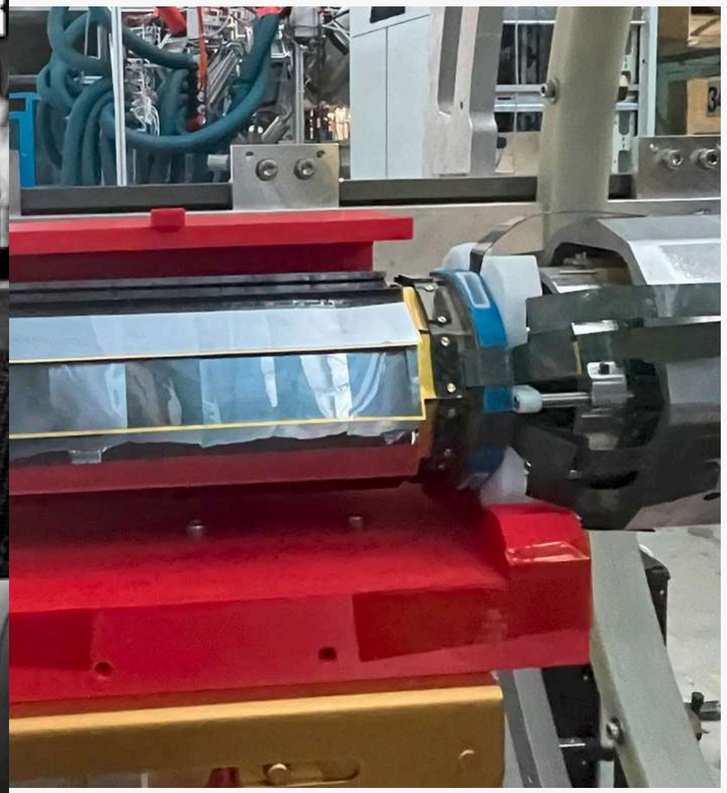
- DAQ fibre optical cab
- LV, HV, gasus helium sy
- Vertex detector instal



Installation of Mu3e

Installation

- First all services have to be installed and tested
- Vertex comes with flex connections installed which connect to the uTP cables
- DAQ fibre optical cables
- LV, HV, gasus helium system, etc.
- Vertex detector installation
- Installation of the SciFi detector

Installation of Mu3e

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- First all services have to be installed and tested
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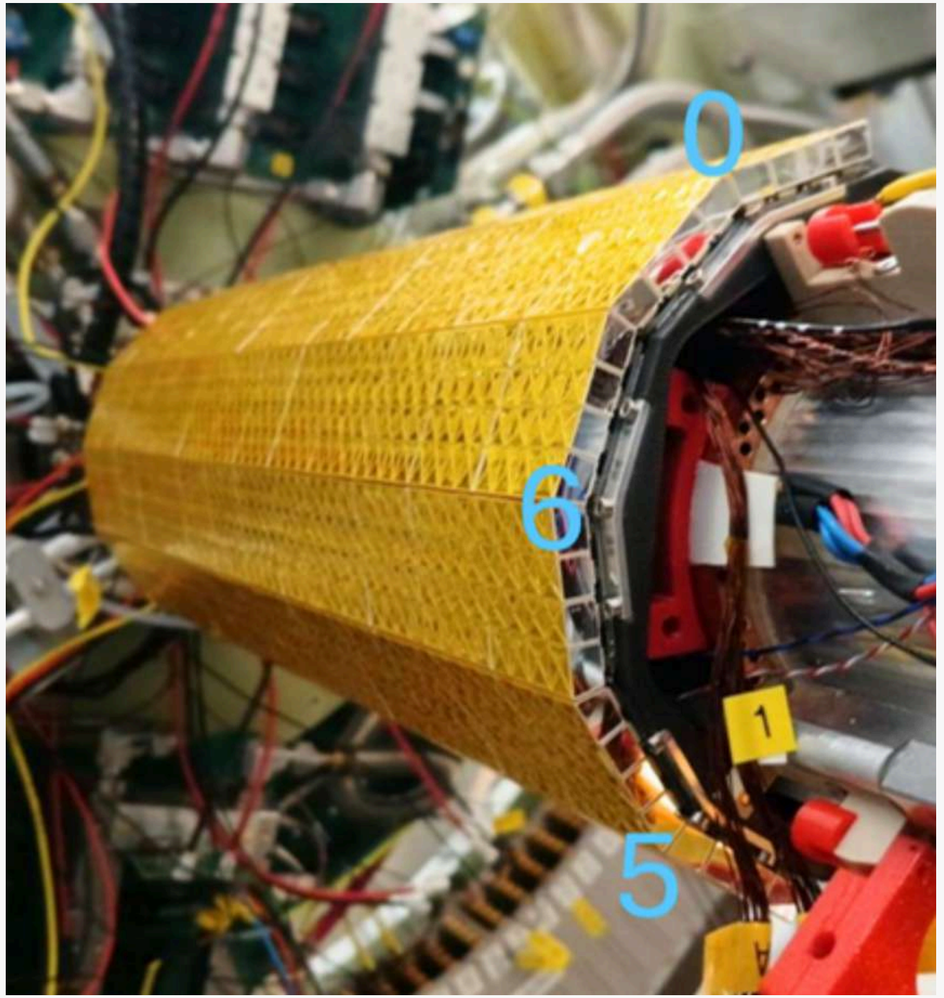
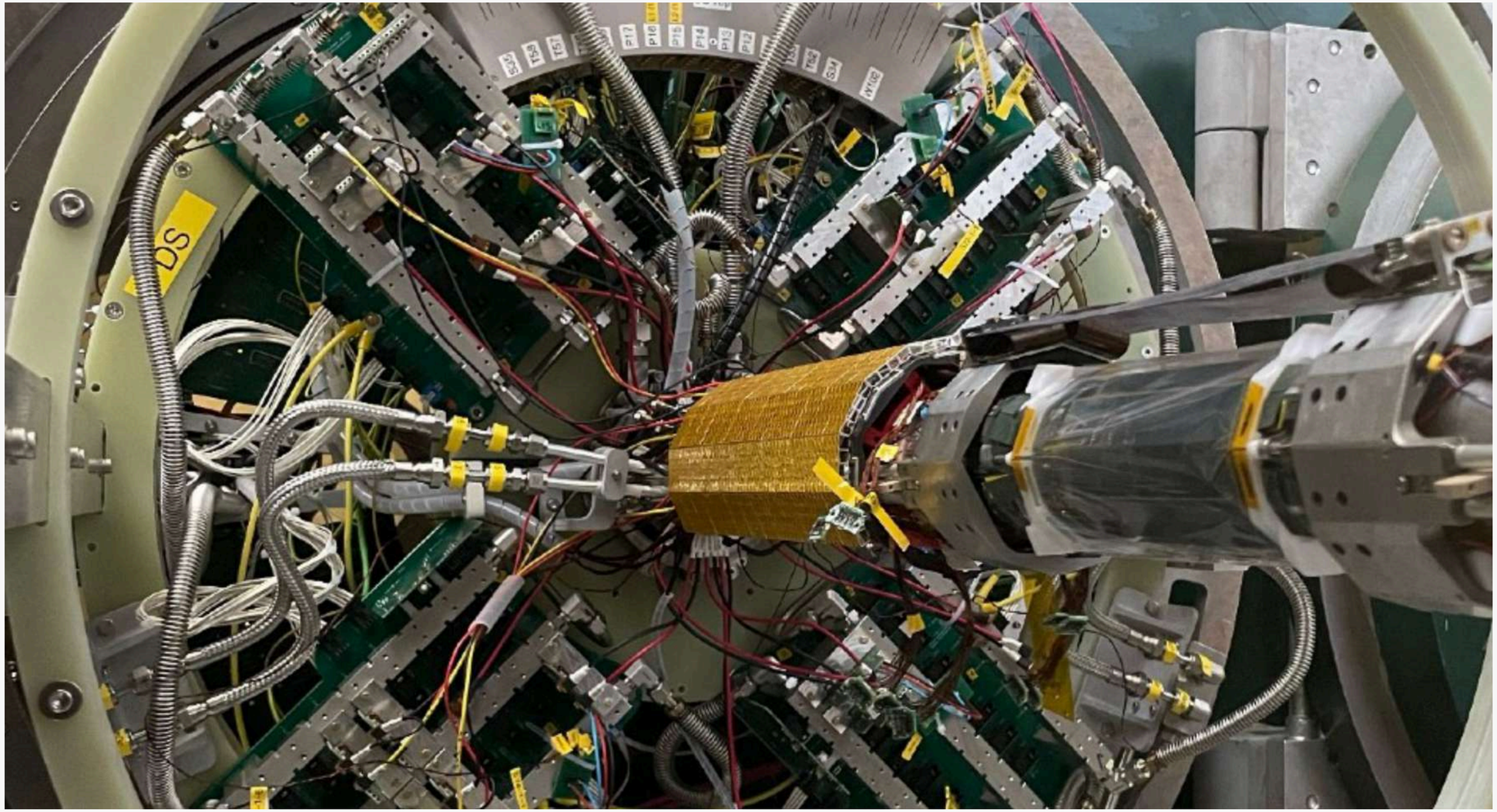
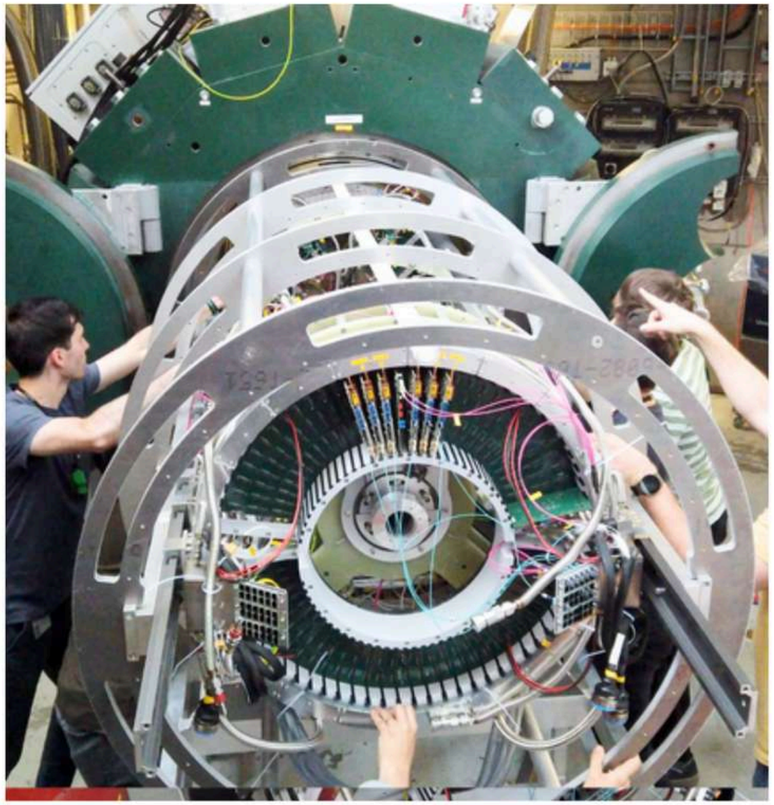
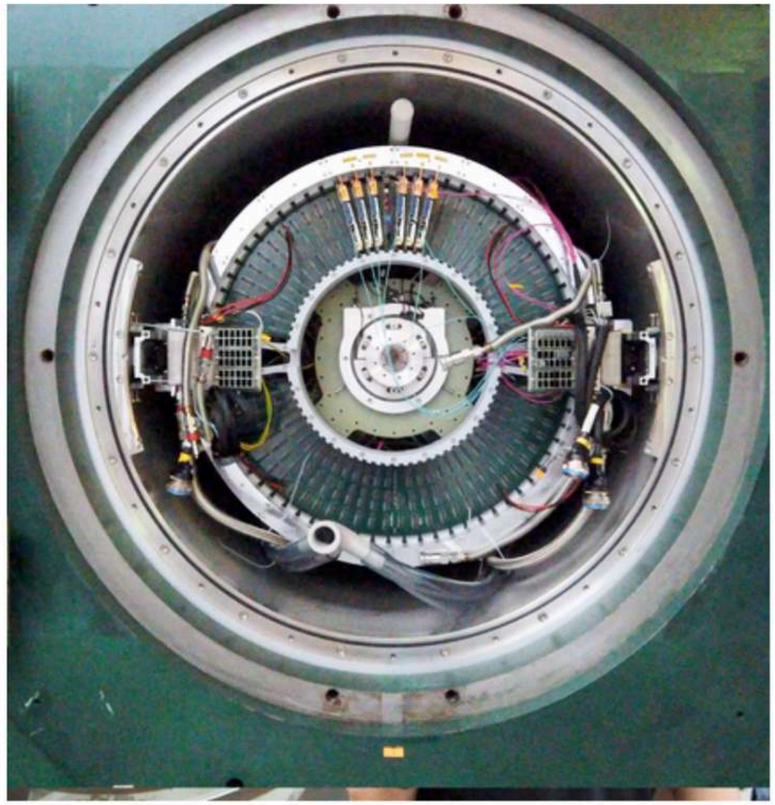


Installation of Mu3e



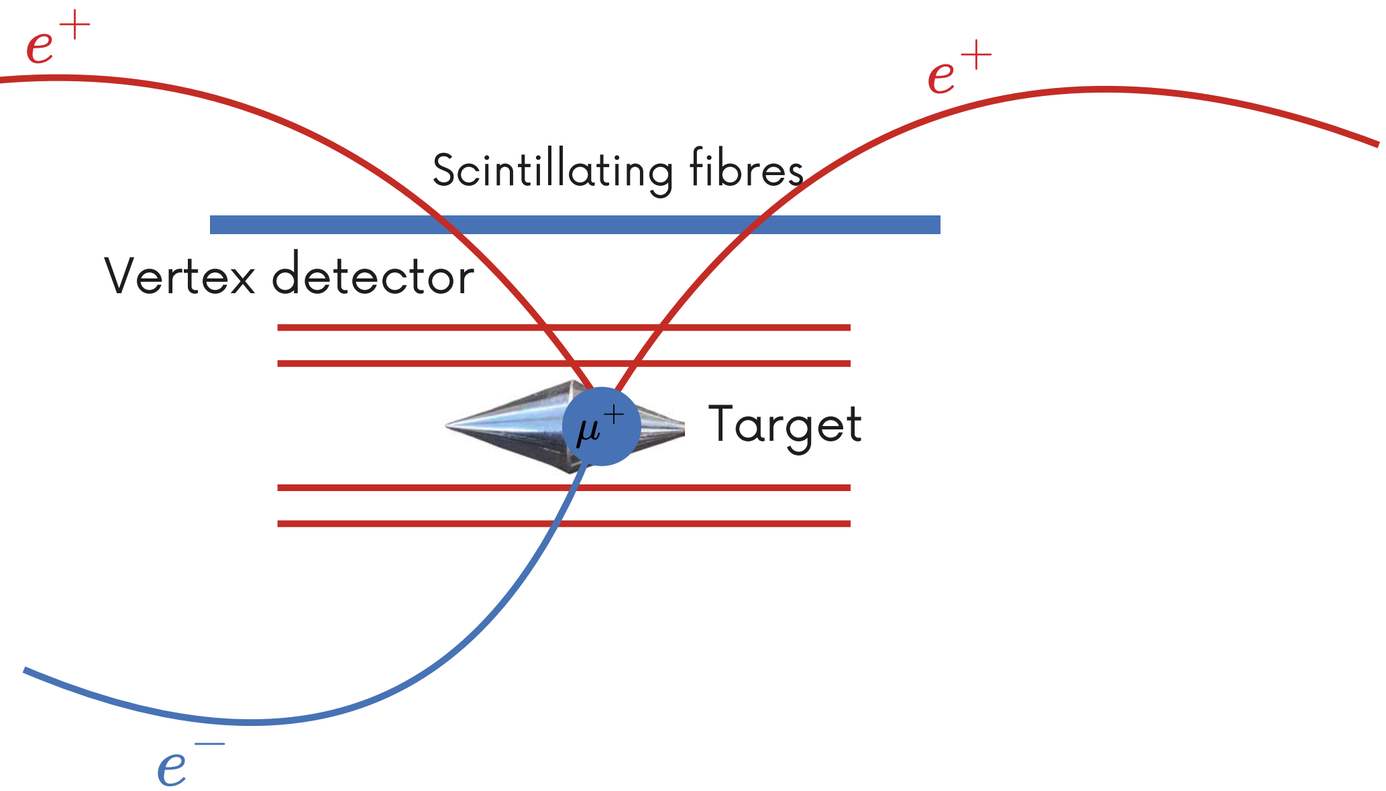
Installation of Mu3e



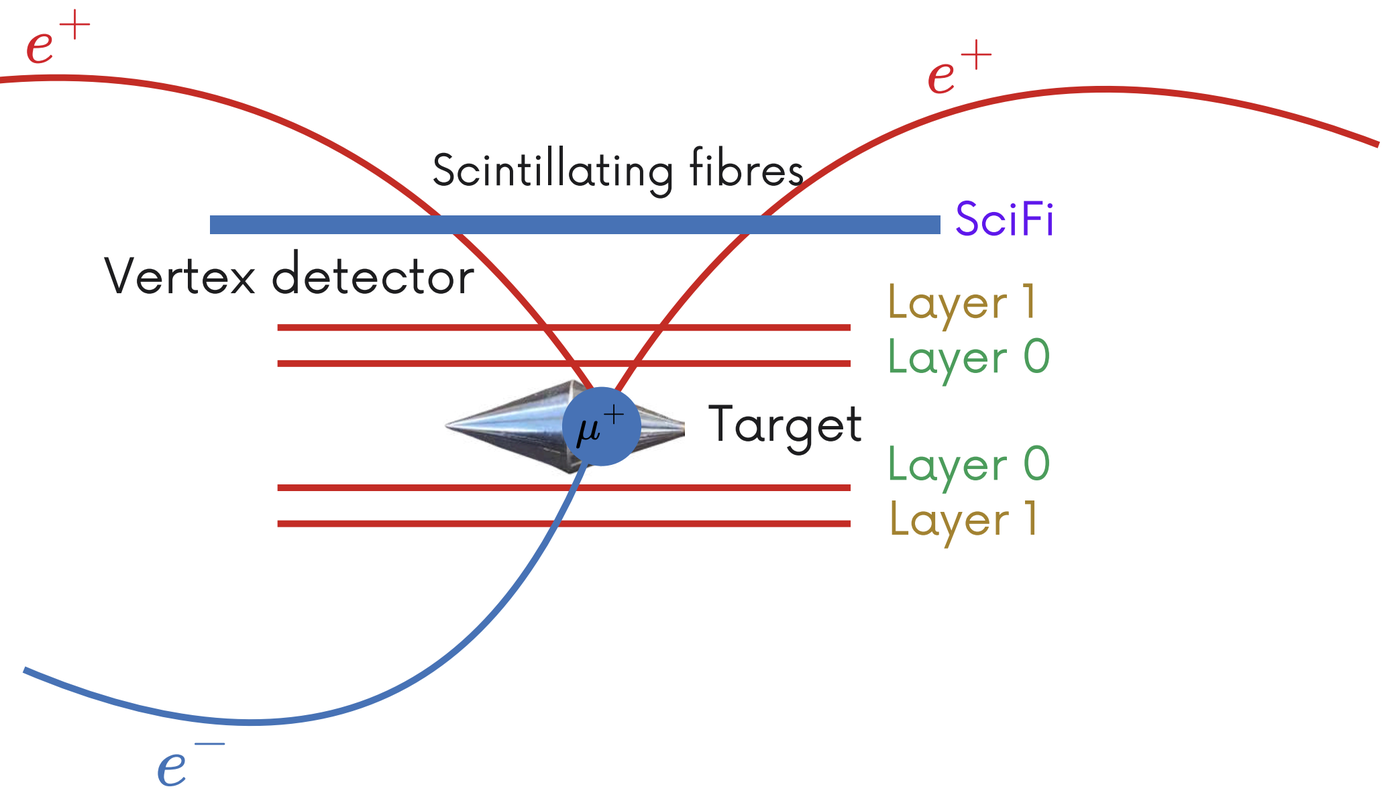


The flight of Mu3e

Data Flow from the Physics to the GPU



Data Flow from the Physics to the GPU



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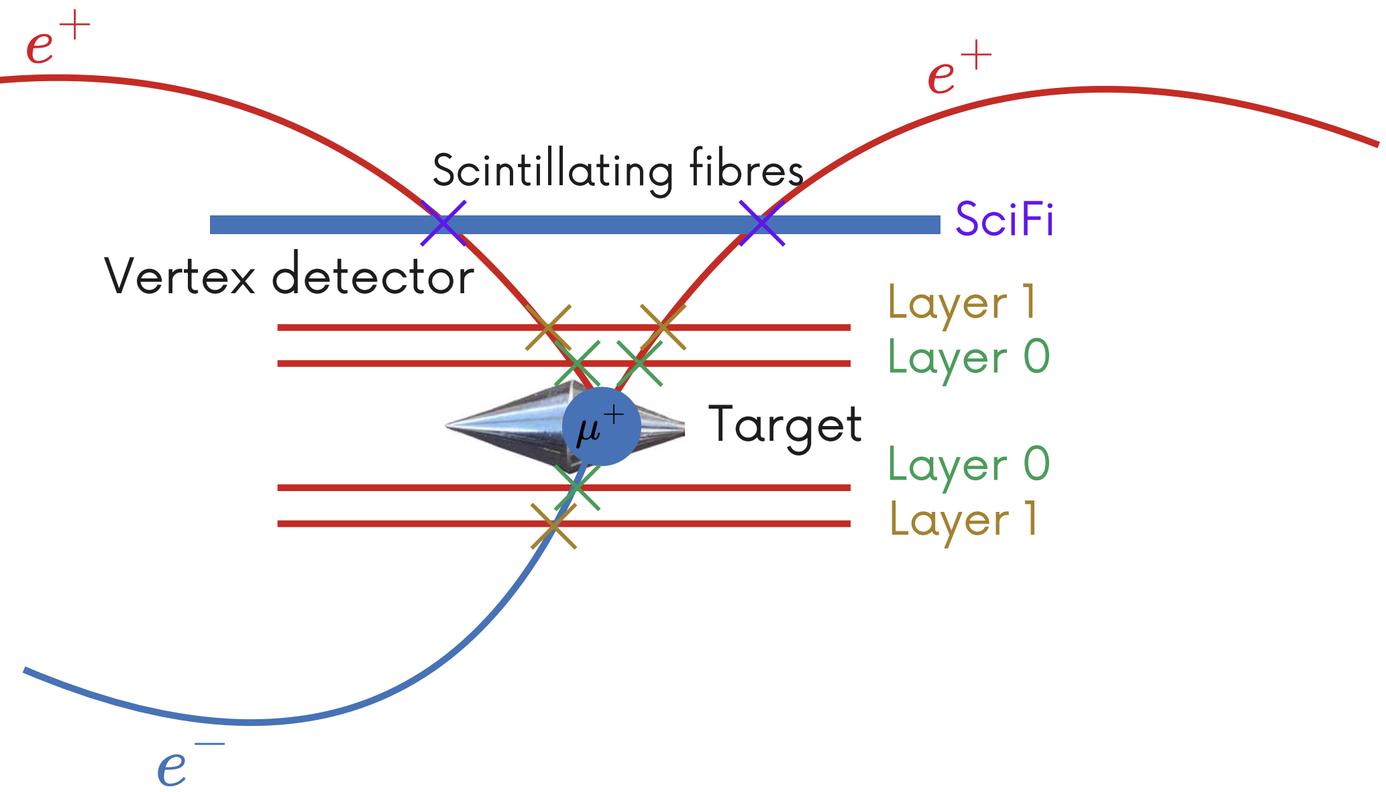

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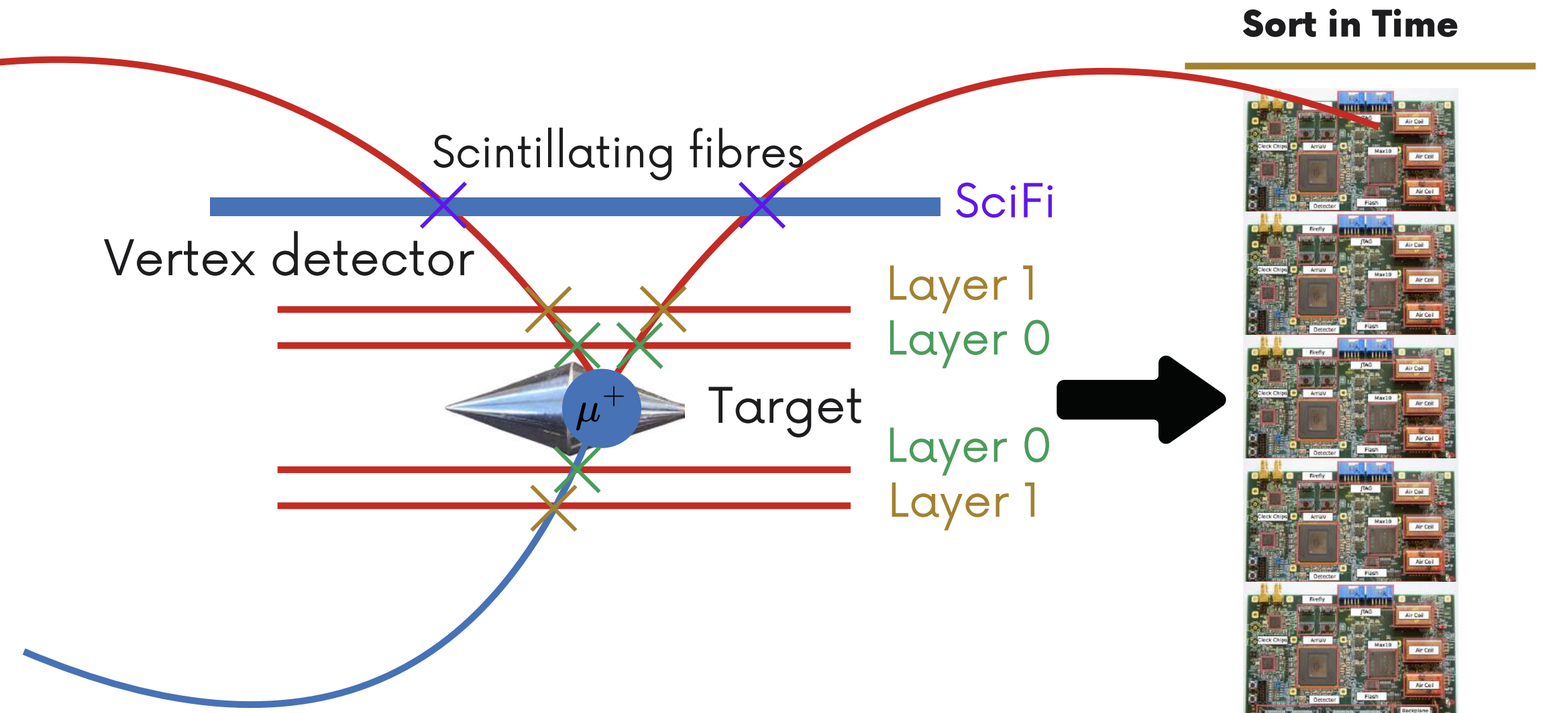
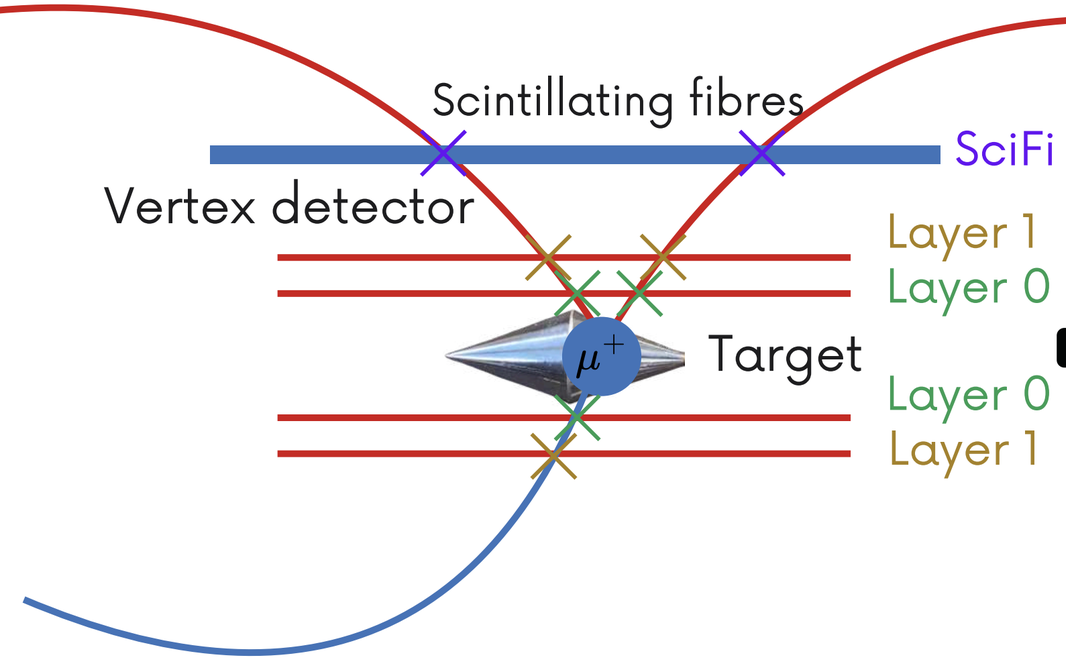


Sort in Time

Custom Frontend FGPA Boards

Data Flow from the Physics to the GPU



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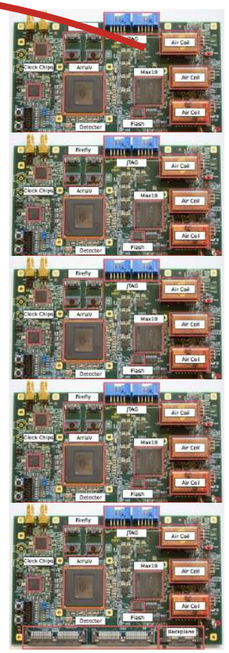
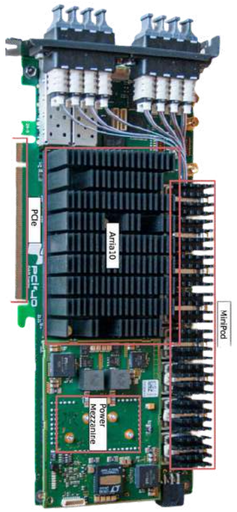
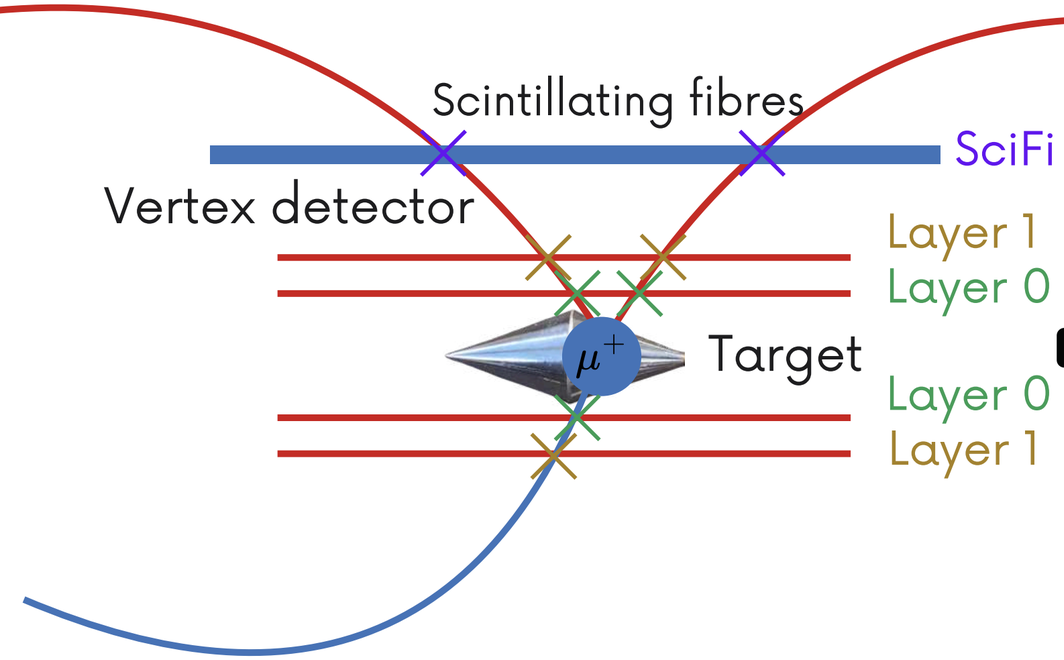


Time synchronization

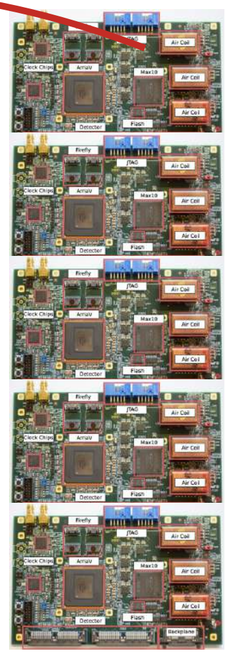


LHCb PCIe40 Boards

Data Flow from the Physics to the GPU



Sort in Time



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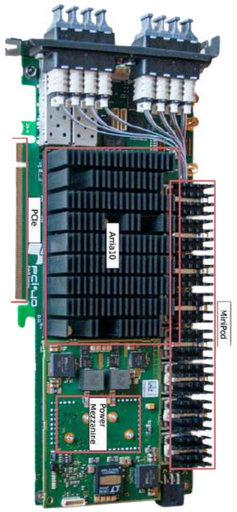
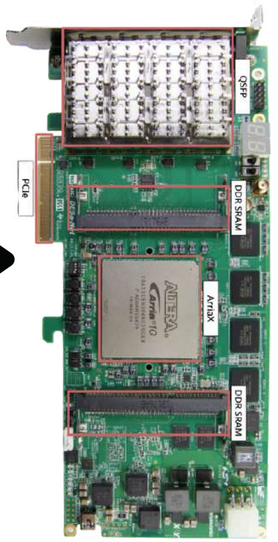
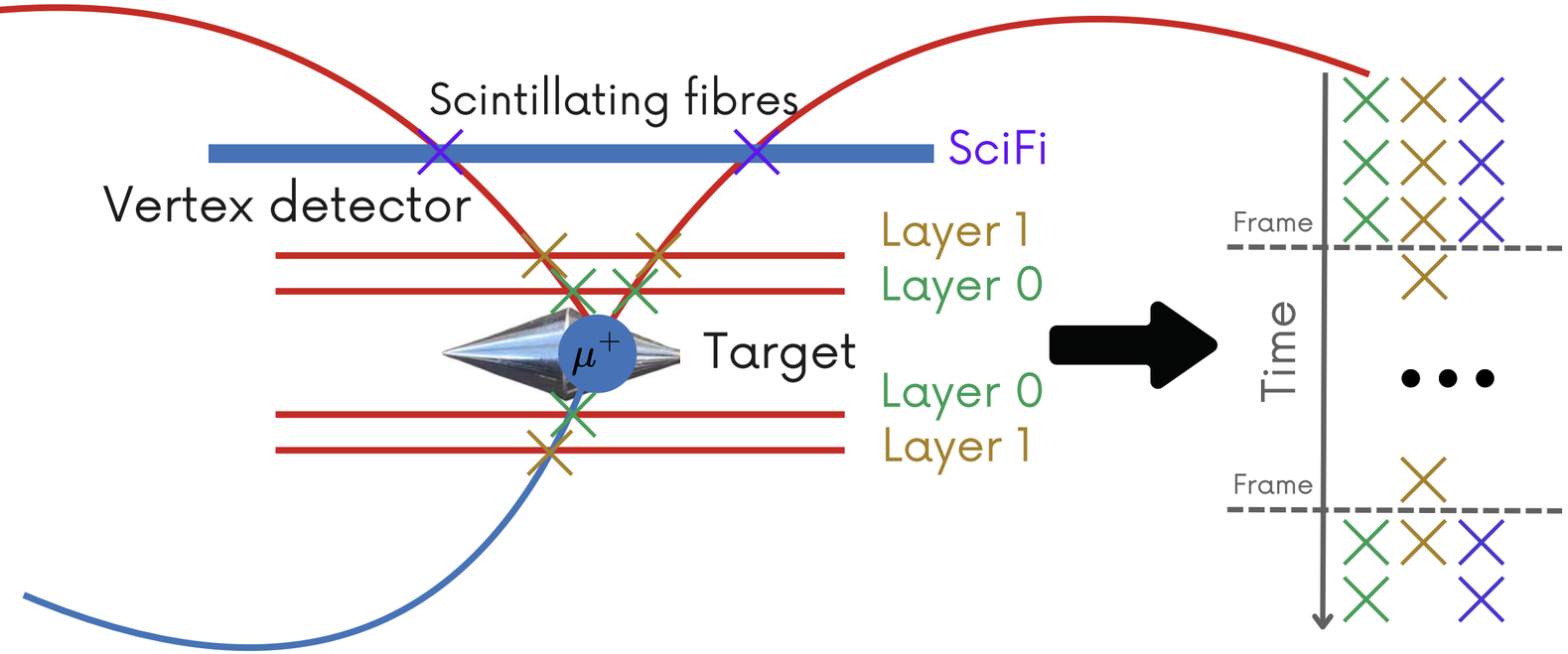


Group detectors



Terasic DE5a-Net-DDR4

Data Flow from the Physics to the GPU



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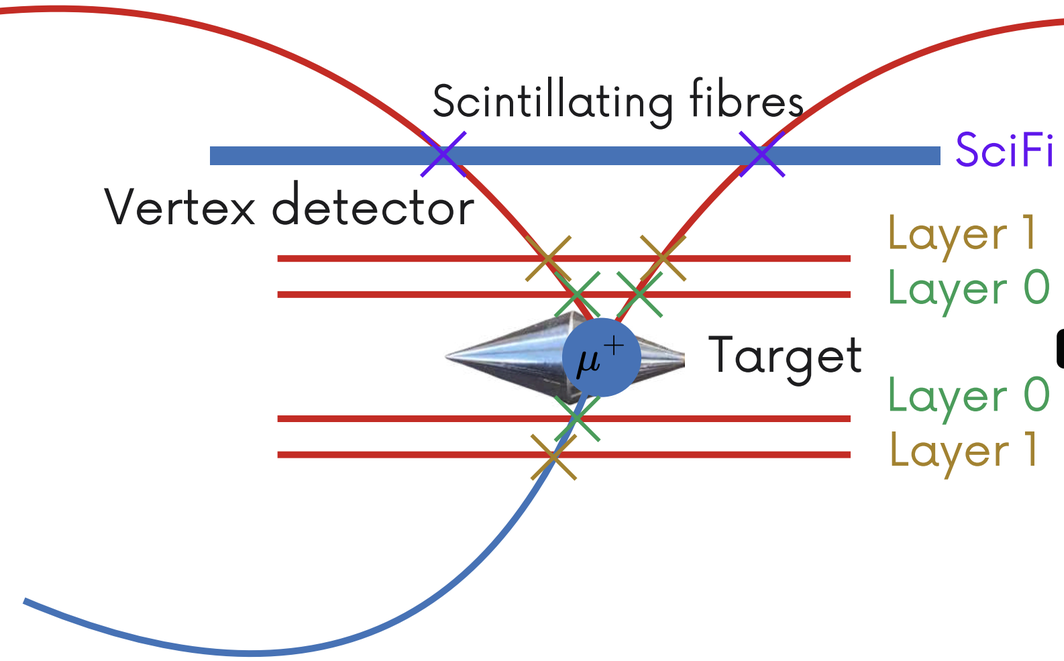
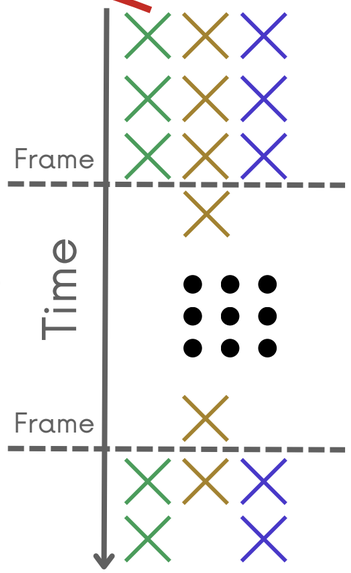


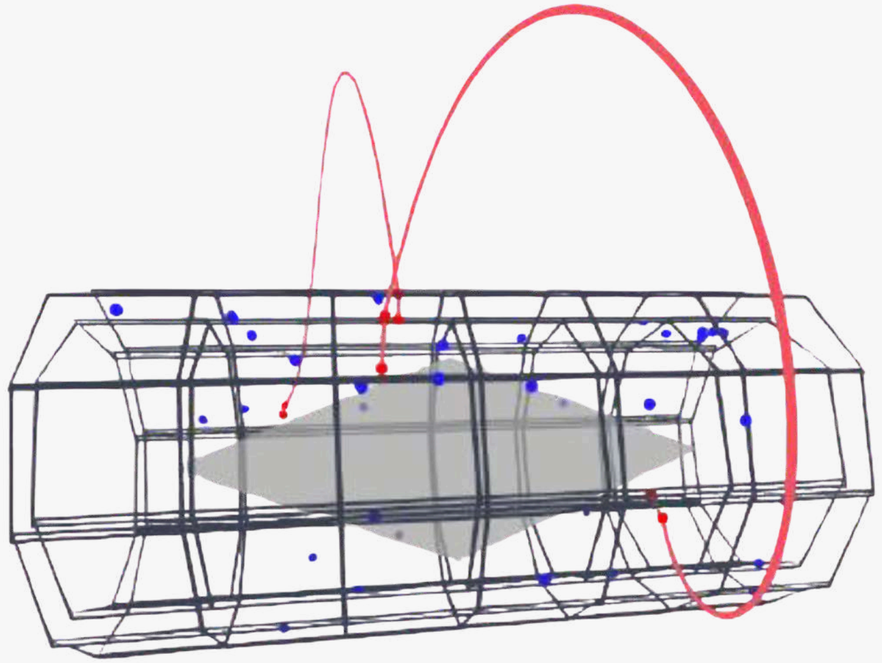


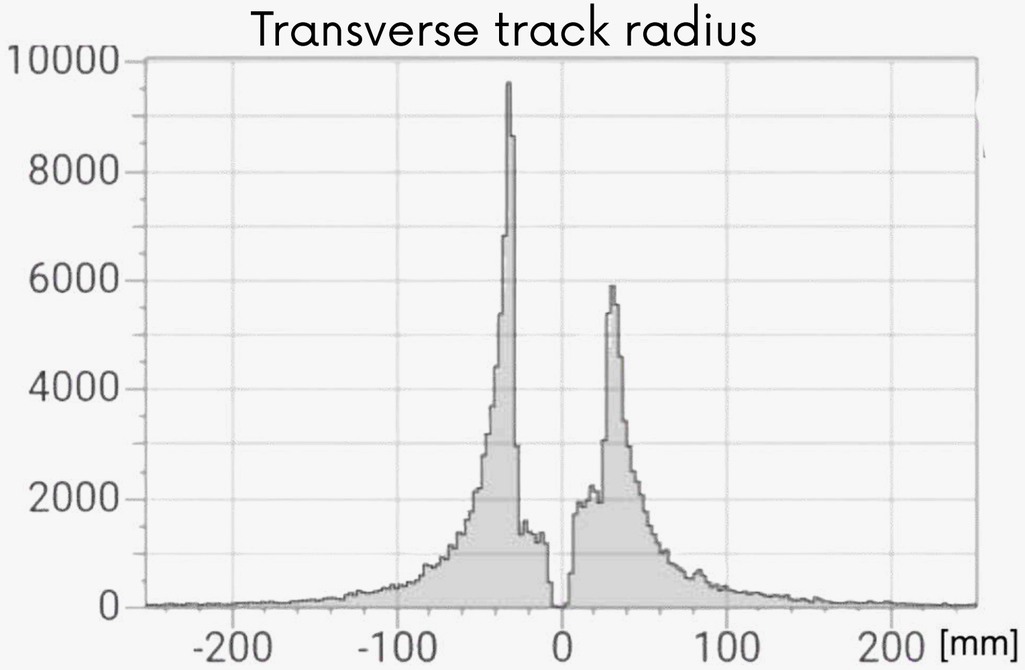
Track reconstruction

The Commissioning Run 2025

Operation

- First time running the filter farm

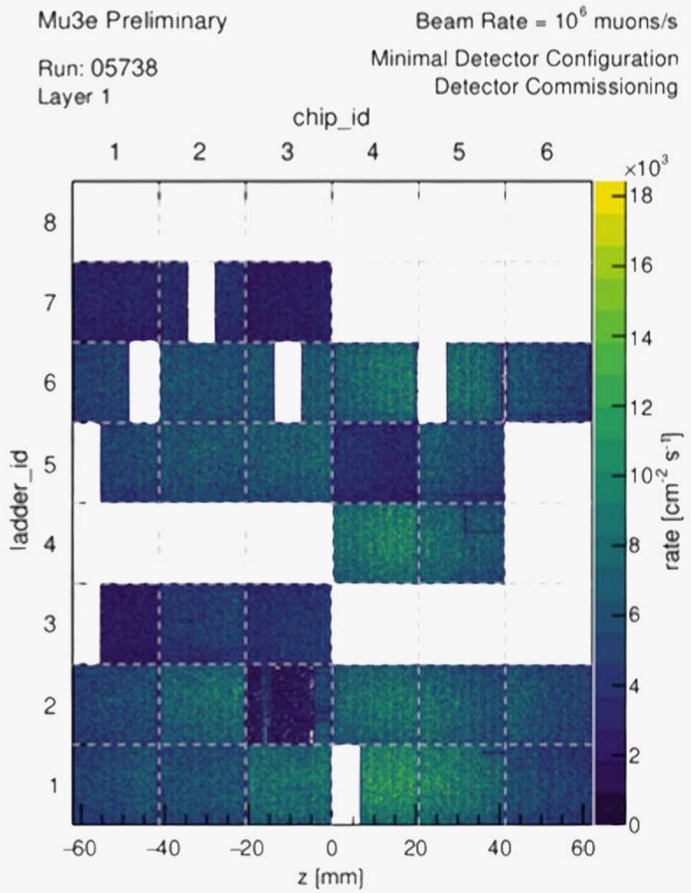


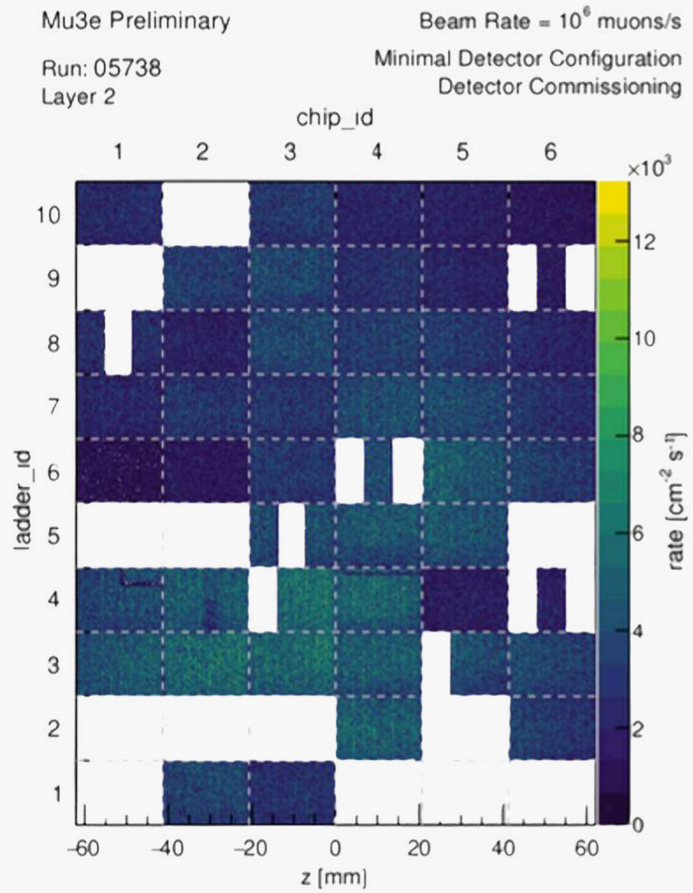


The Commissioning Run 2025

Operation

- First time running the filter farm
- Detector performance still under investigation

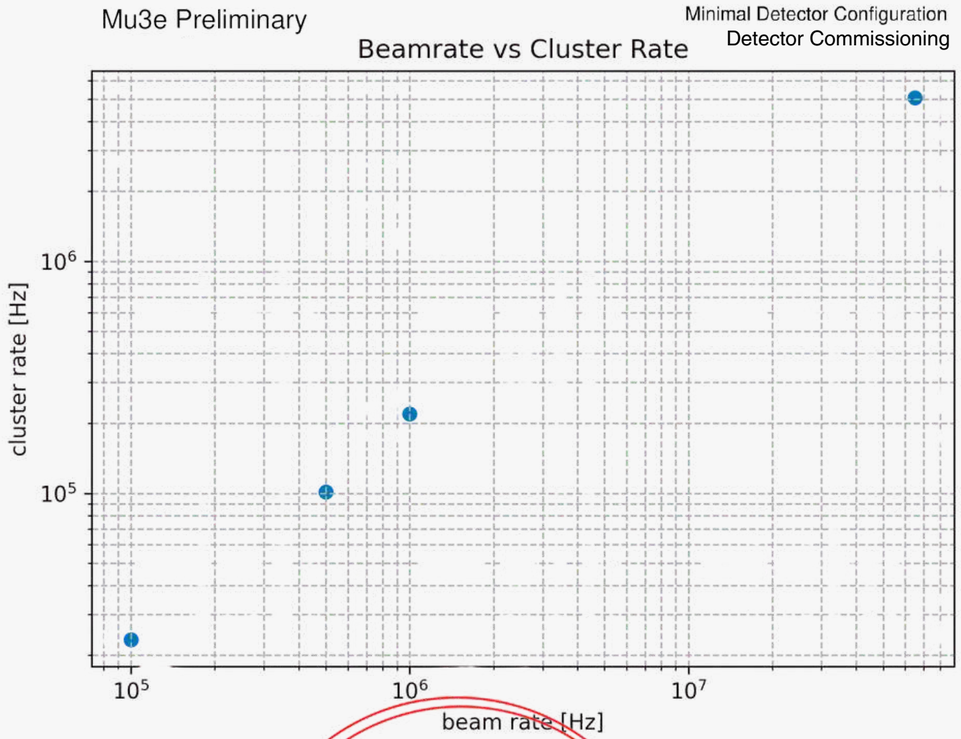


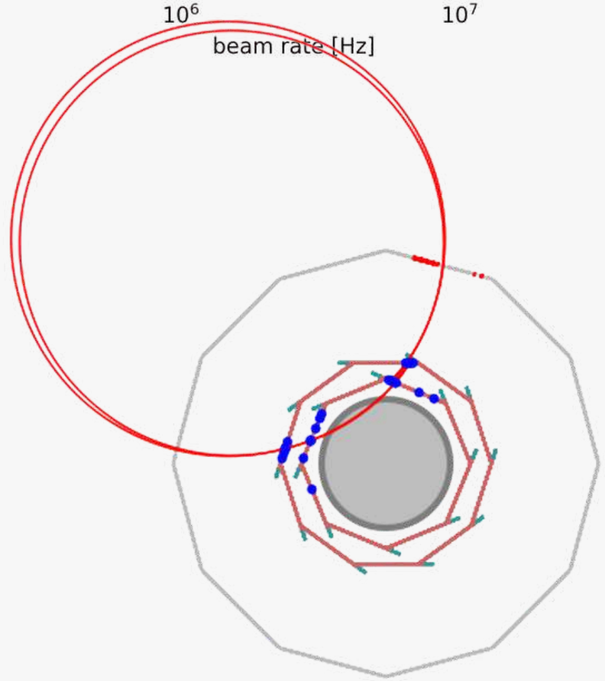


The Commissioning Run 2025

Operation

- First time running the filter farm
- Detector performance still under investigation
- SciFi detector can be matched online to tracks

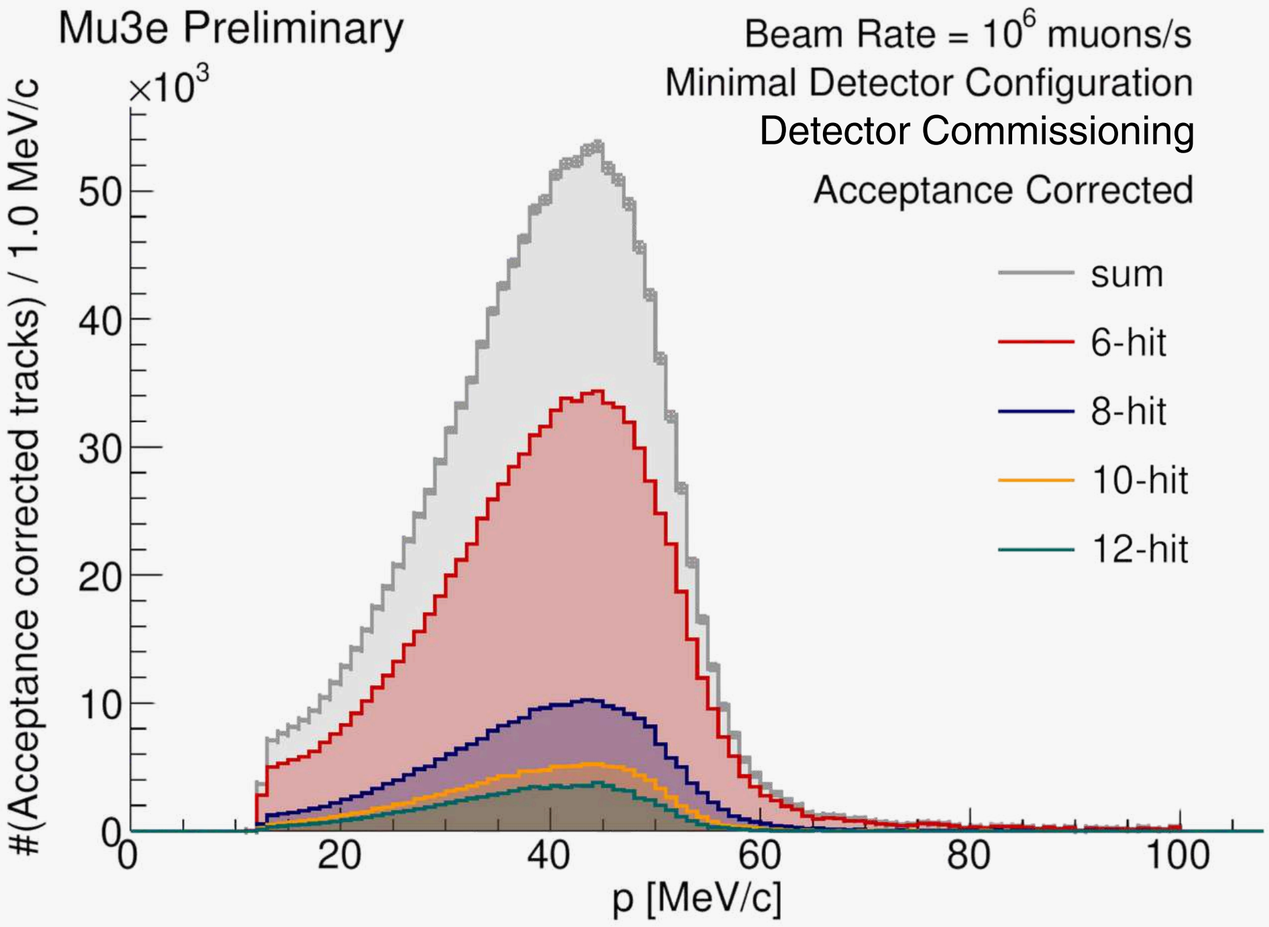




The Commissioning Run 2025

Operation

- First time running the filter farm
- Detector performance still under investigation
- SciFi detector can be matched online to tracks
- Measured re-weighted momentum distribution for 6-, 8-, 10- and 12-hit long tracks



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01 | Mu3e Experiment

02 | Commissioning Run 2025

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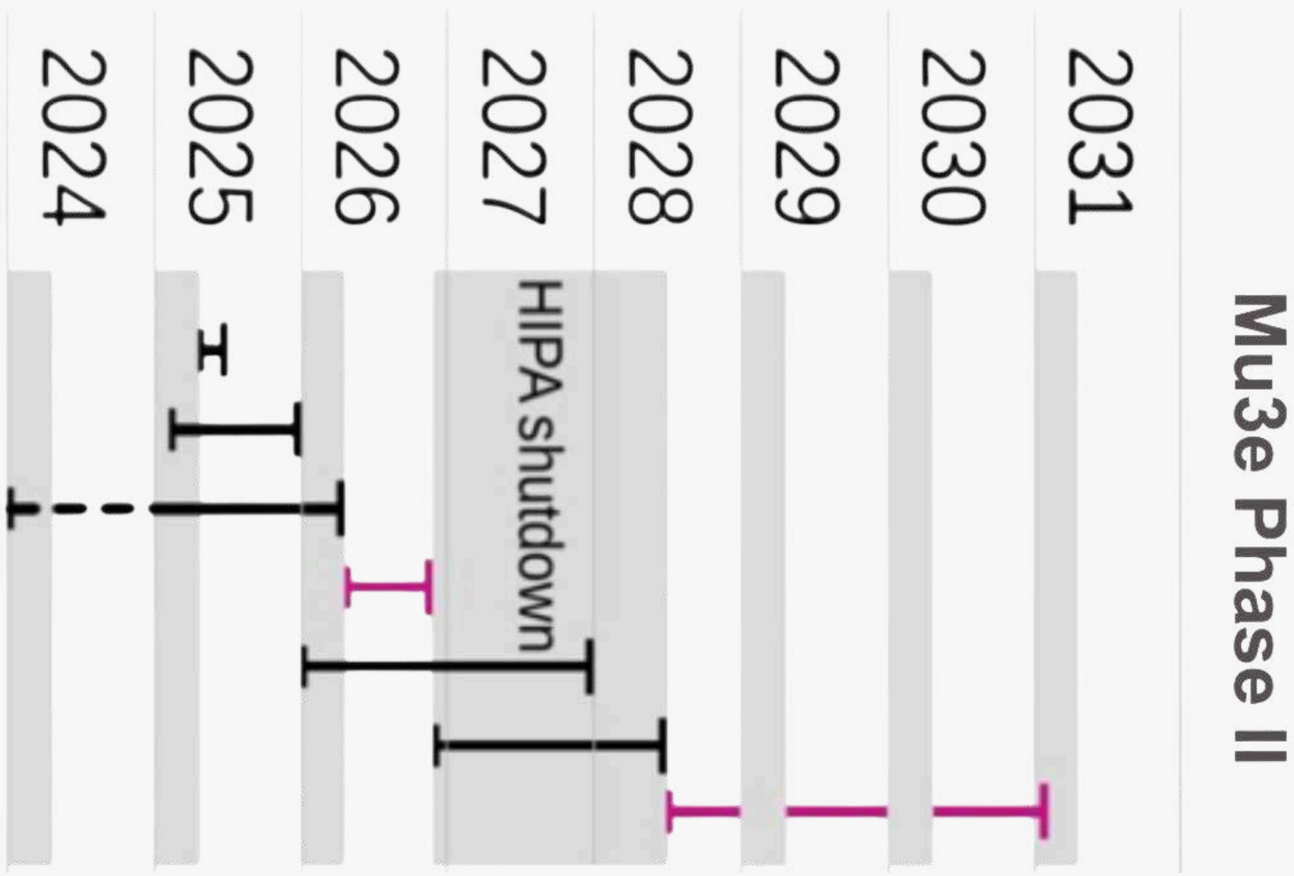
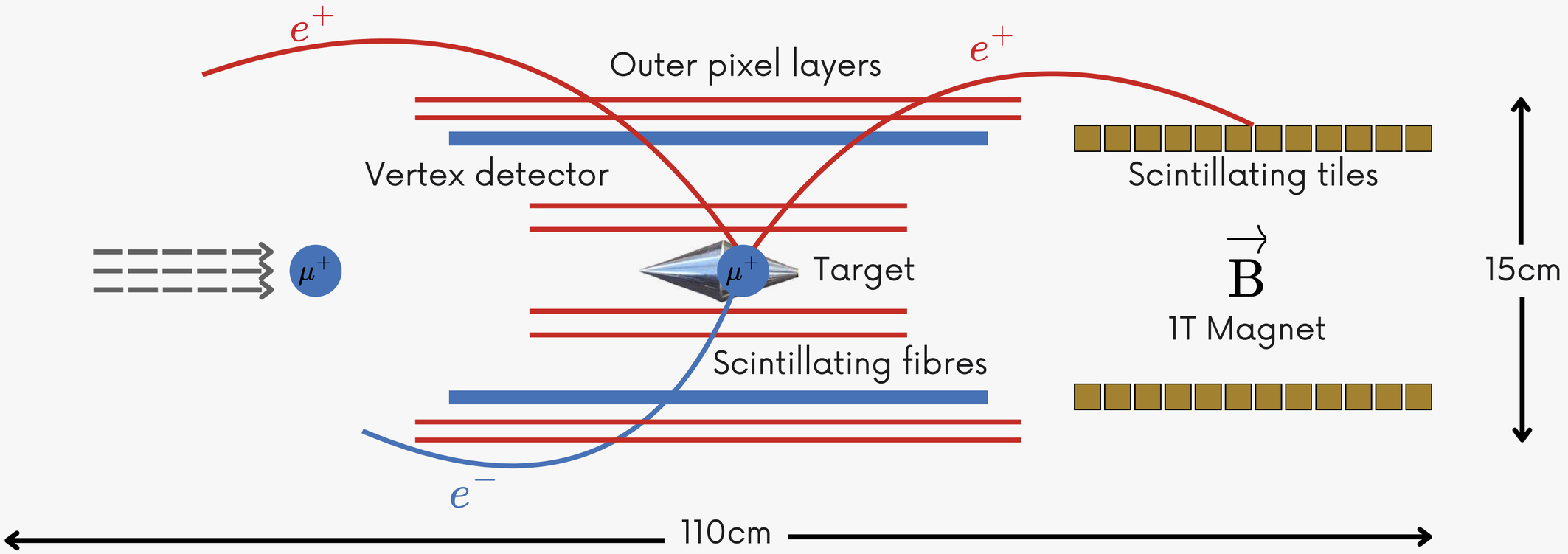
Detector Configuration for 2026

- PSI will upgrade the muon beamline starting 2027
- We can only do a physics measurment in parts of 2026 → beamtime is shared with MEG



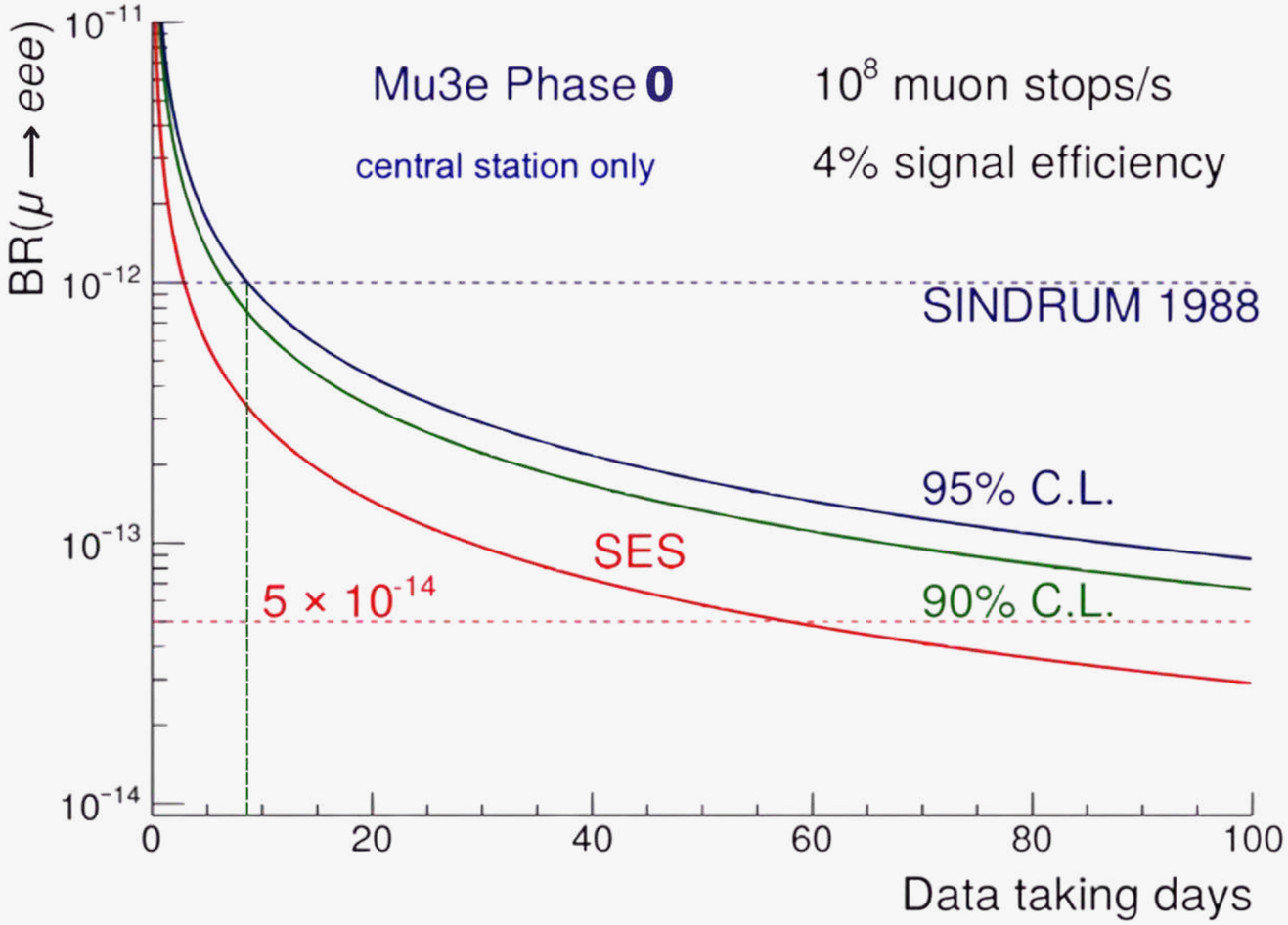
Detector Configuration for 2026



Run with a Phase 0 Detector

Detector Configuration for 2026

- Single Event Sensitivity Projections for the detector planed in 2026
- Surpass the SINDRUM limit in less than two weeks
- Still a lot of MC studies needs to be performed
- Detector efficiencies has to be studied



Wrap-Up

- **Commissioning run in 2025**
  - All **three detector** systems were operated
  - Filter farm with **online reconstruction** was tested
  - Lots of **first times** during construction

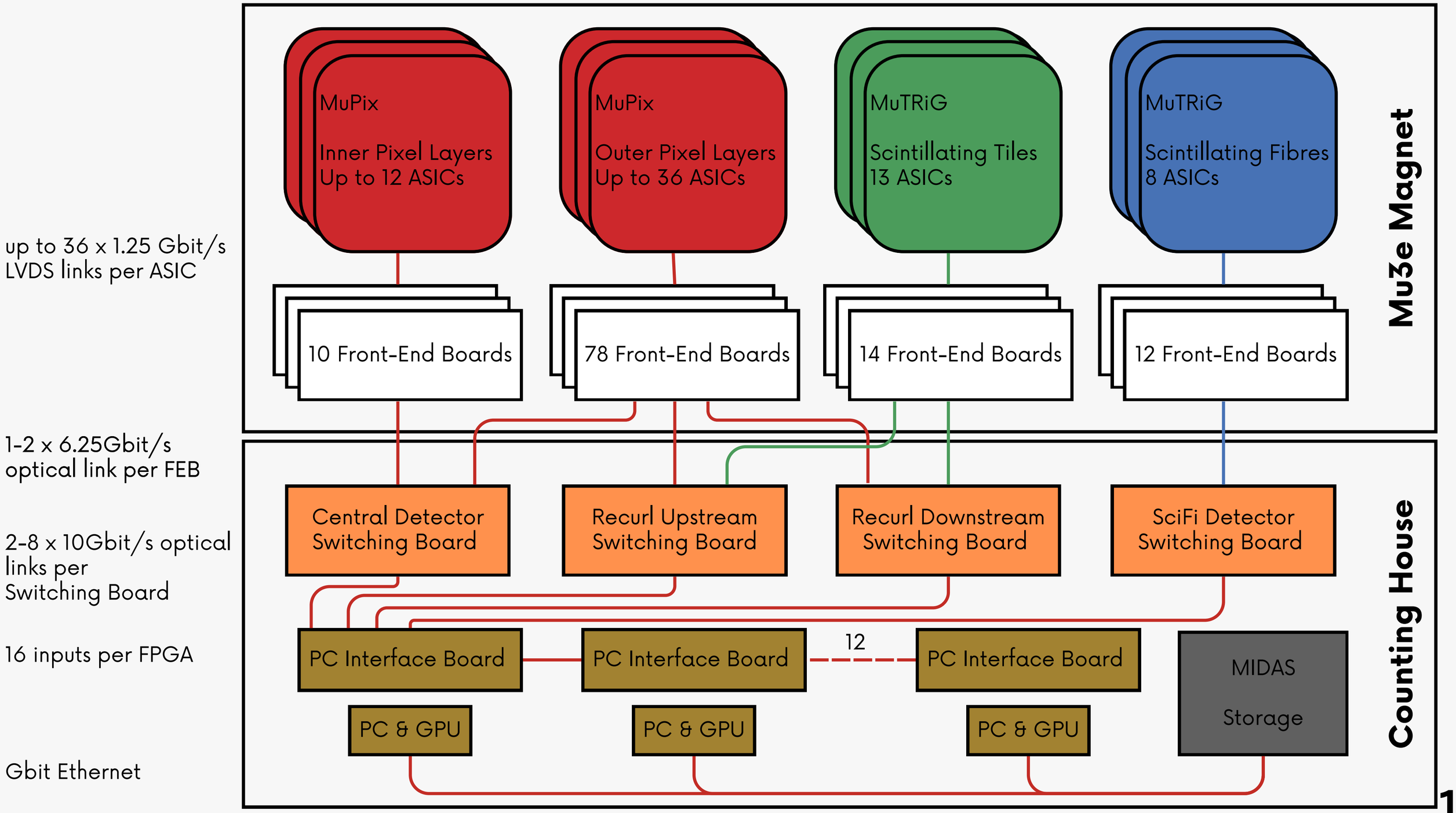
- **Data run in 2026**
  - Lots of **detector performance** analysis has to be done
  - **SINDRUM limit** even with a Phase 0 detector in reach
  - Currently ongoing **MC production**
  - **Outer layers** are in **production**

Stay tuned!



THANK YOU!

BACKUP


MuPix
Inner Pixel Layers
Up to 12 ASICs
MuPix
Outer Pixel Layers
Up to 36 ASICs
MuTRiG
Scintillating Tiles
13 ASICs
MuTRiG
Scintillating Fibres
8 ASICs
Mu3e Magnet
10 Front-End Boards
78 Front-End Boards
14 Front-End Boards
12 Front-End Boards
up to 36 x 1.25 Gbit/s
LVDS links per ASIC
1-2 x 6.25Gbit/s
optical link per FEB
2-8 x 10Gbit/s optical
links per
Switching Board
16 inputs per FPGA
Gbit Ethernet
Central Detector
Switching Board
Recurl Upstream
Switching Board
Recurl Downstream
Switching Board
SciFi Detector
Switching Board
PC Interface Board
PC Interface Board
12
PC Interface Board
MIDAS
Storage
PC & GPU
PC & GPU
PC & GPU
Counting House