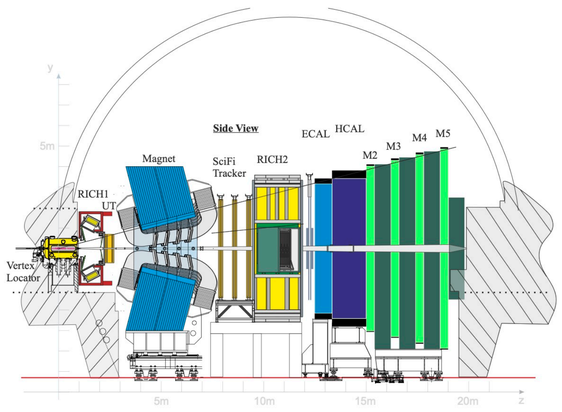
Performance of the LHCb Scintillating Fibre Tracker in Run 3

Lukas Witola, Technische Universität Dortmund, lukas.witola@cern.ch

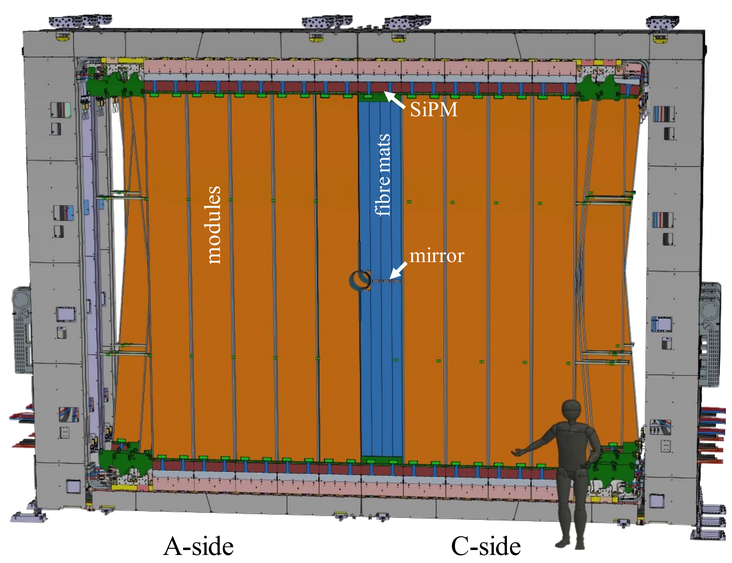
The LHCb Detector



Layout of the LHCb Upgrade I detector. LHCb-DP-2022-002.

- Single-arm forward spectrometer designed to reconstruct decays of beauty and charm hadrons
- Upgrade for LHC Run 3 to operate at five times higher luminosity
  - Trigger-less 40 MHz readout & online selection
  - New frontend & backend electronics

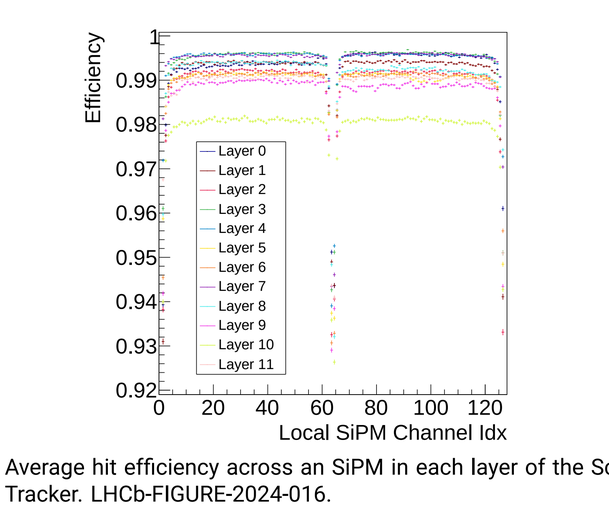
The LHCb Scintillating Fibre Tracker



Front view of the 3D model of the SciFi Tracker. LHCb-DP-2022-002.

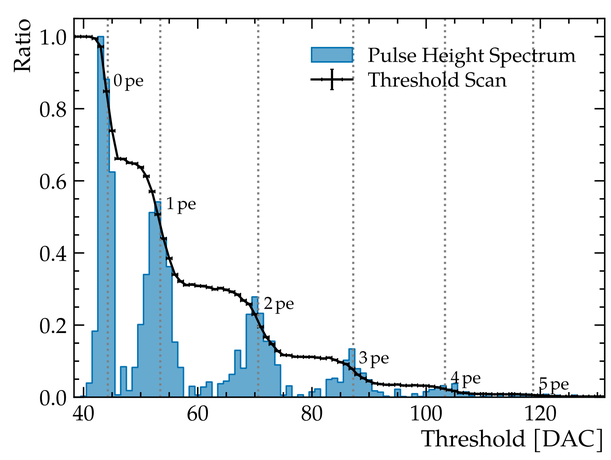
- Three stations with four layers each, covering a total active area of 340 m^2
- Eight 2.5 m long six-layer fibre mats per module
  - 250 µm diameter scintillating fibres
  - 11 000 km of fibre used throughout the detector
- Readout by silicon photomultiplier (SiPM) arrays
  - 524 288 readout channels in total
  - Cooled to −40 °C to mitigate radiation damage
- Signal processing with 40 MHz readout electronics
  - Custom ASIC (PACIFIC) for analogue processing & digitisation with three comparators per channel
  - Online zero-suppression & clustering on FPGAs

Working Principle



- Schematic representation of a charged particle traversing one layer of the SciFi Tracker

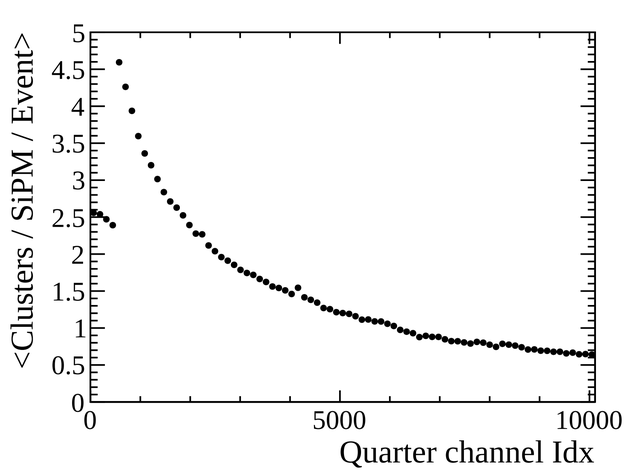
Threshold Calibration



Threshold scan of one comparator. CERN-THESIS-2024-152.

- PACIFIC comparator thresholds are calibrated by performing threshold scans with pulsed light
- Convert signal from digital values (DAC) to photo electrons (pe) to set desired thresholds

Detector Occupancy



Average number of clusters per SiPM per event for one quadrant of the detector. LHCb-FIGURE-2024-016.

- Lower occupancy in the first ~500 channels due to beam pipe cutout
- A few noisy channels contribute to a pair of bumps along the distribution

Hit Efficiency

Average hit efficiency across an SiPM in each layer of the SciFi Tracker. LHCb-FIGURE-2024-016.

- Reduced efficiency in the middle and edges due to gaps between neighbouring silicon dies
- Layer 10 unusually low due to some SiPMs excluded from data taking

Mass Resolution

$\mu^+\mu^-$ mass distribution. LHCb-FIGURE-2024-037.

- Track based alignment to a few tens of microns to achieve best physics performance
- Achieve excellent mass resolution after global alignment

Dark Count Rate

Dark count rate (DCR) per SiPM channel extracted from currents in absence of collisions. LHCb-FIGURE-2024-039.

- Non-ionising radiation damage of SiPMs increases dark count rate as expected
- Partial annealing at room temperature during periods without beam

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