SciFi – The Scintillating Fibre Tracker for the LHCb Upgrade

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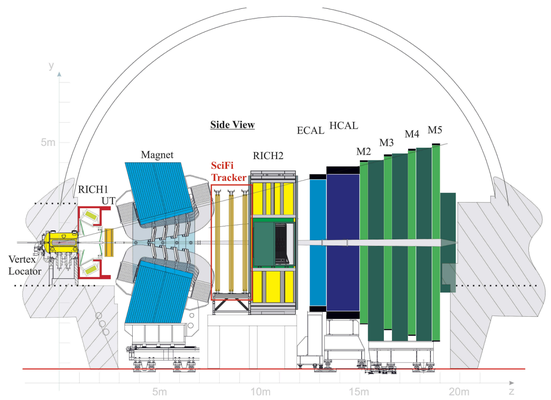
on behalf of the LHCb Scintillating Fibre Tracker Collaboration

LHCb Detector Upgrade

Single-arm forward spectrometer designed to study CP violation and b and c-hadron decays



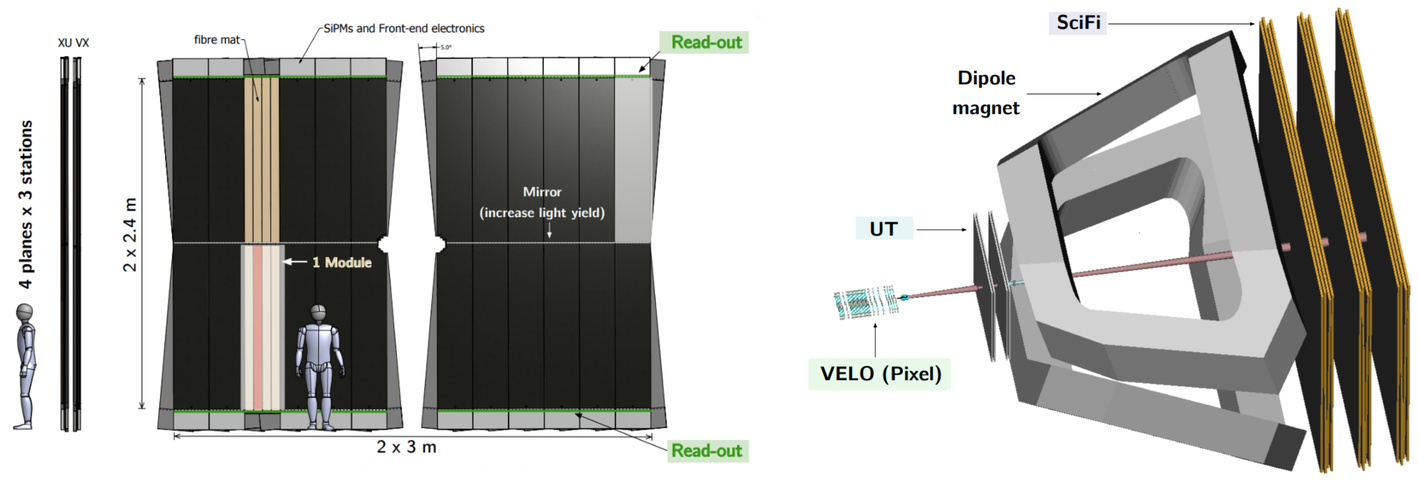
The upgraded LHCb detector

LHCb Upgrade for Run 3 (2022+):

- **Factor 5** higher instantaneous luminosity ($4 \times 10^{32} \rightarrow 2 \times 10^{33} cm^{-2} s^{-1}$)
- Readout upgrade from 1MHz $\rightarrow$ **40 MHz**
- New tracking detectors:
  - » New Vertex Locator (VELO), Si-pixel
  - » New Upstream Tracker (UT), Si-strips
  - » **New downstream tracker (SciFi Tracker)**

The Scintillating Fibre Tracker (SciFi)

The SciFi tracker will replace the current LHCb downstream tracker. The detector consists of 12 planes of scintillating fibres readout by arrays of silicon photomultipliers (SiPMs)



Sketch of the SciFi tracker

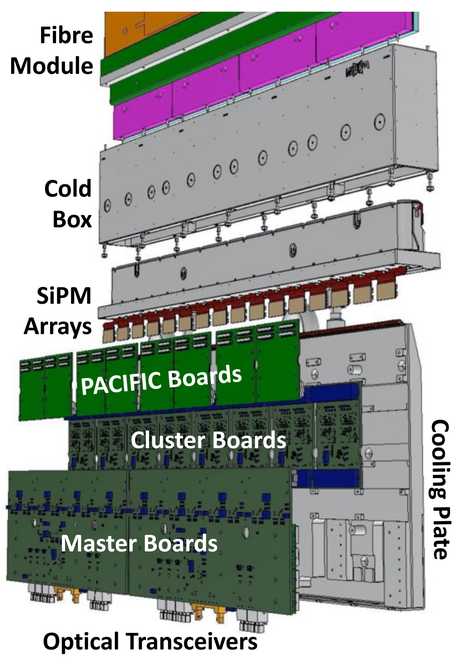
Requirements:

- Low material budget: ~1 % X_0 per layer
- Spatial resolution < 100 µm
- Single hit efficiency ~99 %
- Ionising radiation up to 35 kGy near the beam pipe and a 1-MeV neutron-equivalent fluence of up $6 \times 10^{11} n_{eq}/cm^2$ at the electronics

SciFi characteristics:

- 3 stations (T1, T2, T3) with 4 layers each
- Covering a total area of 340 m^2
- 10,000 km fibers in 128 modules
- Readout by 4096 SiPMs $\rightarrow$ 524k channels

SciFi Components



The SciFi components

Fibre Module

- Nomex honeycomb and CFRP sandwich (1 % X_0 per module)
- 6 layers of 0.250 mm scintillating fibre

SiPM Array

- 128 SiPM channels with 250μm pitch
- Cooled with -50°C single phase fluid, Novec 649

Front-end Electronics for 40 MHz readout

- **PACIFIC ASIC board**
  - » 10 ns shaping with dual 25 ns integrators
  - » Digitization with 3 comparator thresholds
- **Cluster board**
  - » Clustering and zero suppression by FPGA
- **Master board**
  - » Transfer data and distribute signals

Light Injection System

- 5ns VCSEL laser diode pulses driven by GBLD

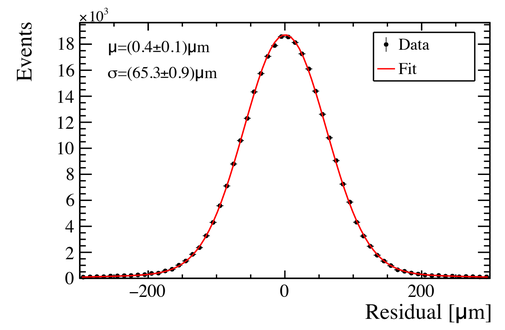
Cooling Plate

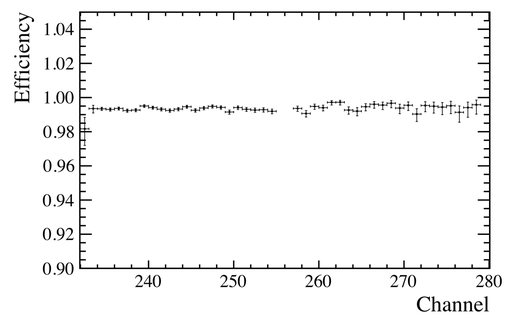
- 120 W to dissipate per electronic box (30.7 kW in total)

Test Beam Results

2 half-modules with final electronics were tested sucessfully at the CERN SPS in 2018

- ✓ Hit efficiency > 99 %
- ✓ Hit resolution ≈ 65 µm





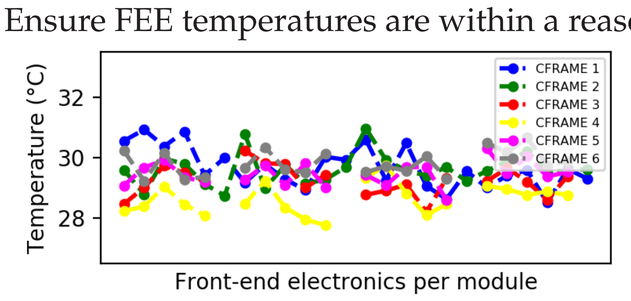
Assembly & Commissioning

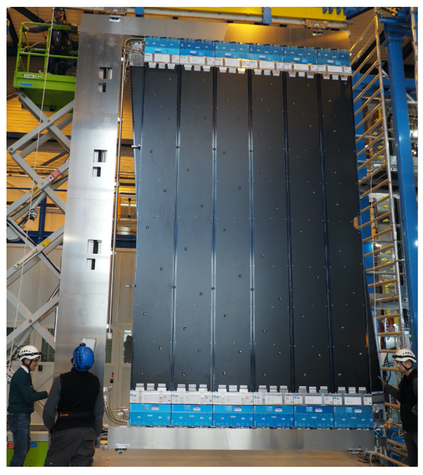
Assembly

- In units of 1/12 of the detector, the so-called C-Frames

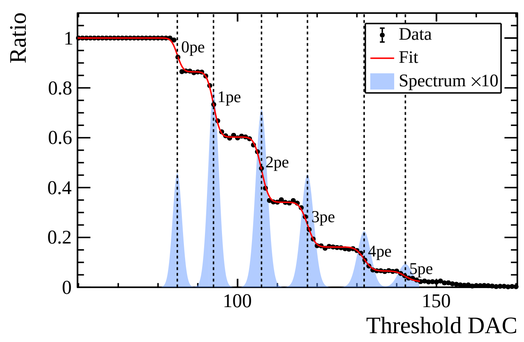
Commissioning before underground installation

- Fully commissioned and installed 6 out of 12 C-Frames to date
  - » FEE test-system: 2048 channels on each of the 256 front-end electronics boxes are tested before and after installation on the C-Frame (524,288 channels total)
  - » Optical power and fibre mapping checks of 384 data links & 96 control per C-frame
  - » Test configurability of front-end electronics
  - » Bit-Error-Rate Tests
  - » Light Injection and Threshold Calibration
  - » Readout temperature and voltage sensors
    - ∗ Ensure FEE temperatures are within a reasonable range





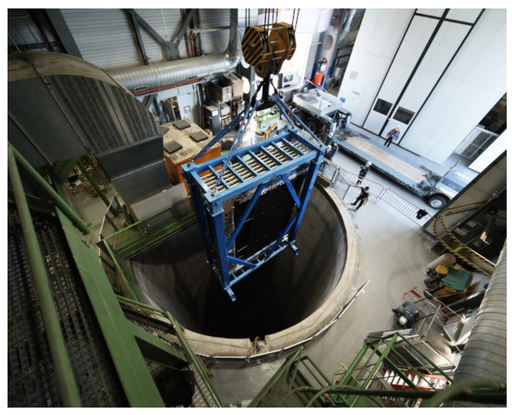
A SciFi C-Frame



Threshold scan and SiPM spectrum [3]

Installation in the LHCb cavern

- 6 C-Frames installed in Summer 2021
- International team effort of ~20 institutes
- Installation of all 12 C-Frames estimated to be finished in spring 2022



References

[1] LHCb collaboration. *The LHCb Detector at the LHC*, JINST 3 (2008) S08005

[2] LHCb collaboration. *LHCb Tracker Upgrade TDR*, CERN-LHCC 2014-001, LHCb TDR 15

[3] Lukas Witola. *Calibration and performance studies of the readout ASIC for the LHCb SciFi Tracker*, MSc Thesis