A large Scintillating Fibre Tracker for LHCb

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The LHCb Detector

The upgraded LHCb detector.

Front-end electronics schematic.

The Scintillating Fibre (SciFi) Tracker

Large and high granular scintillating fibre tracker that is readout by arrays of silicon photomultipliers (SiPMs).

- 3 stations (T1, T2, T3) with 4 layers each
- Covering a total area of 340 m²
- 1% X₀ per layer
- Spatial resolution < 100 µm
- Single hit efficiency ~99%
- 524,288 channels in total
- 250 µm fibre diameter and channel width
- 40 MHz readout
- ~20 T/s data rate

Front-End Electronics for 40 MHz Readout

SiPM Array
- Array of 128 SiPM channels
- Cooled down to ~ –40 °C to mitigate radiation damage effects

PACIFIC ASIC
- 64-channel readout ASIC for SiPMs
- Analogue processing and digitisation at 40 MHz
  - Integrate SiPM signal within 25 µs intervals
  - Digitise signal into 2 bits per channel by applying 3 adjustable thresholds

Cluster FPGA
- Signal clustering and noise suppression at 40 MHz

Master Board
- Data encoding and serialisation
- Distribution of power, clocks and control commands

Test Beam Results

First full system test at the CERN SPS in July 2018.
- 180 GeV beam of protons and pions (mixed)
- Two half-length SciFi modules ≈ 4096 channels
- Validated complete data chain at 40 MHz
- Verified online clustering & noise suppression
- Hit efficiency ~ 99%
- Hit resolution ≈ 65 µm

Threshold Calibration

The threshold of each PACIFIC comparator has to be calibrated with respect to the spectrum of the connected SiPM channel.
- Threshold scan with pulsed light for each comparator
- Convert from signals measured in units of DAC to photoelectrons (pe)
- Extract threshold DAC values by fitting the spectrum

Assembly, Commissioning & Installation

Assembly & commissioning on the surface of Point 8 at CERN
- In units of 1/12 of the detector, the so-called C-Frames
- Fully assembled & commissioned 4 out of 12 C-Frames to date
  - Verify low- and high-voltage cabling
  - Check optical power and fibre mapping
  - Test configurability of front-end electronics
  - Read out temperature and voltage sensors
  - Measure Bit-Error-Rate (< 10⁻¹⁸)
  - Full system test (< 10⁻¹⁸ channels malfunctioning)

Installation underground in the LHCb cavern
- Transported first 4 C-Frames on 3rd May 2021
- International team effort of ~20 institutes
- Installation of all 12 C-Frames estimated to be finished in spring 2022