

The LHCb Detector

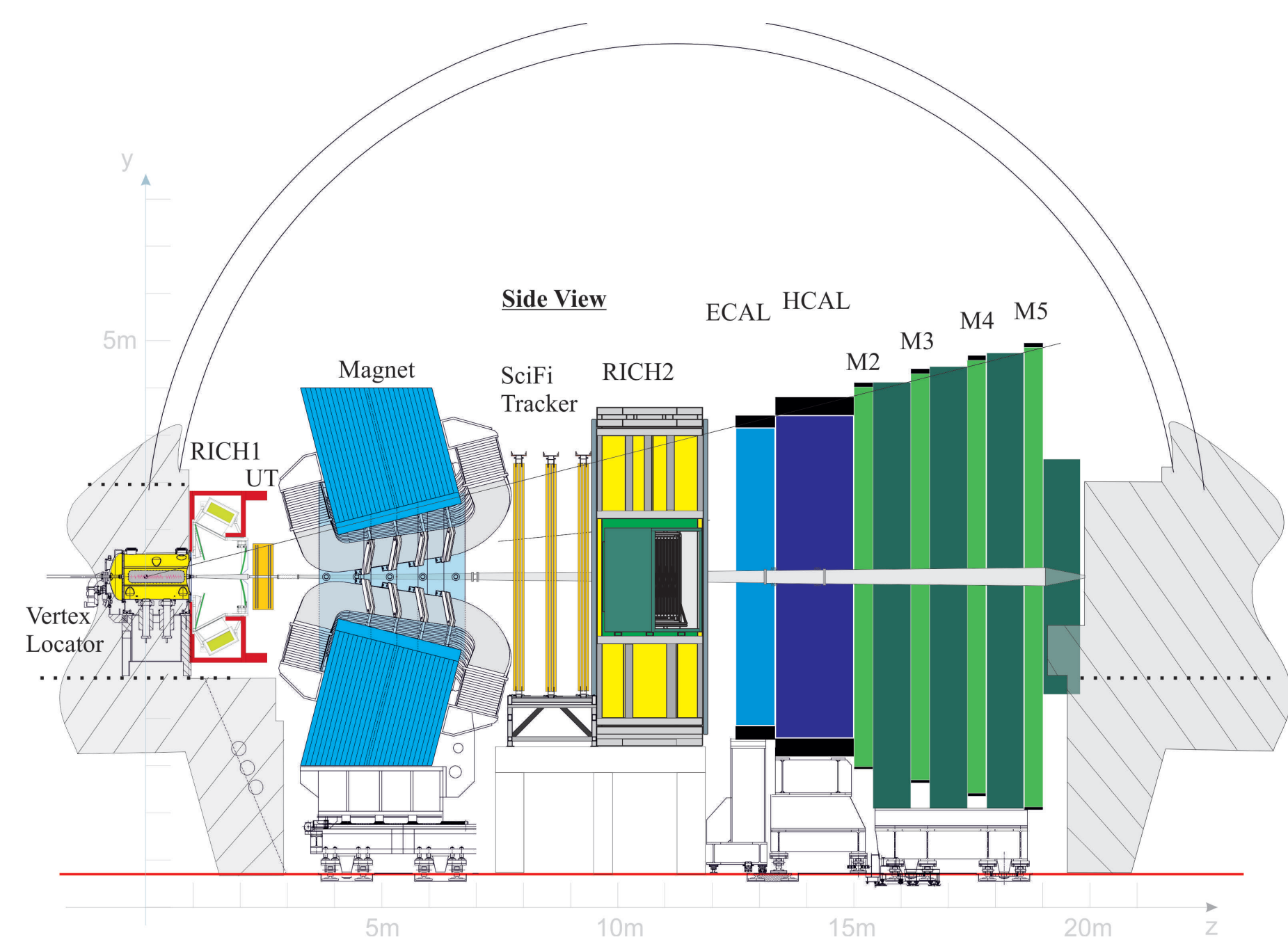


Fig. 1: The upgraded LHCb detector.

Single-arm forward spectrometer dedicated to the search for new physics in decays of beauty and charm hadrons.

The 2019-2020 Upgrade

- Upgrade to increase precision on key observables and extend physics reach
- Operate the detector at five times higher instantaneous luminosity
- Triggerless 40 MHz readout
- New frontend and backend electronics
- Replacement of complete tracking system

The Scintillating Fibre Tracker

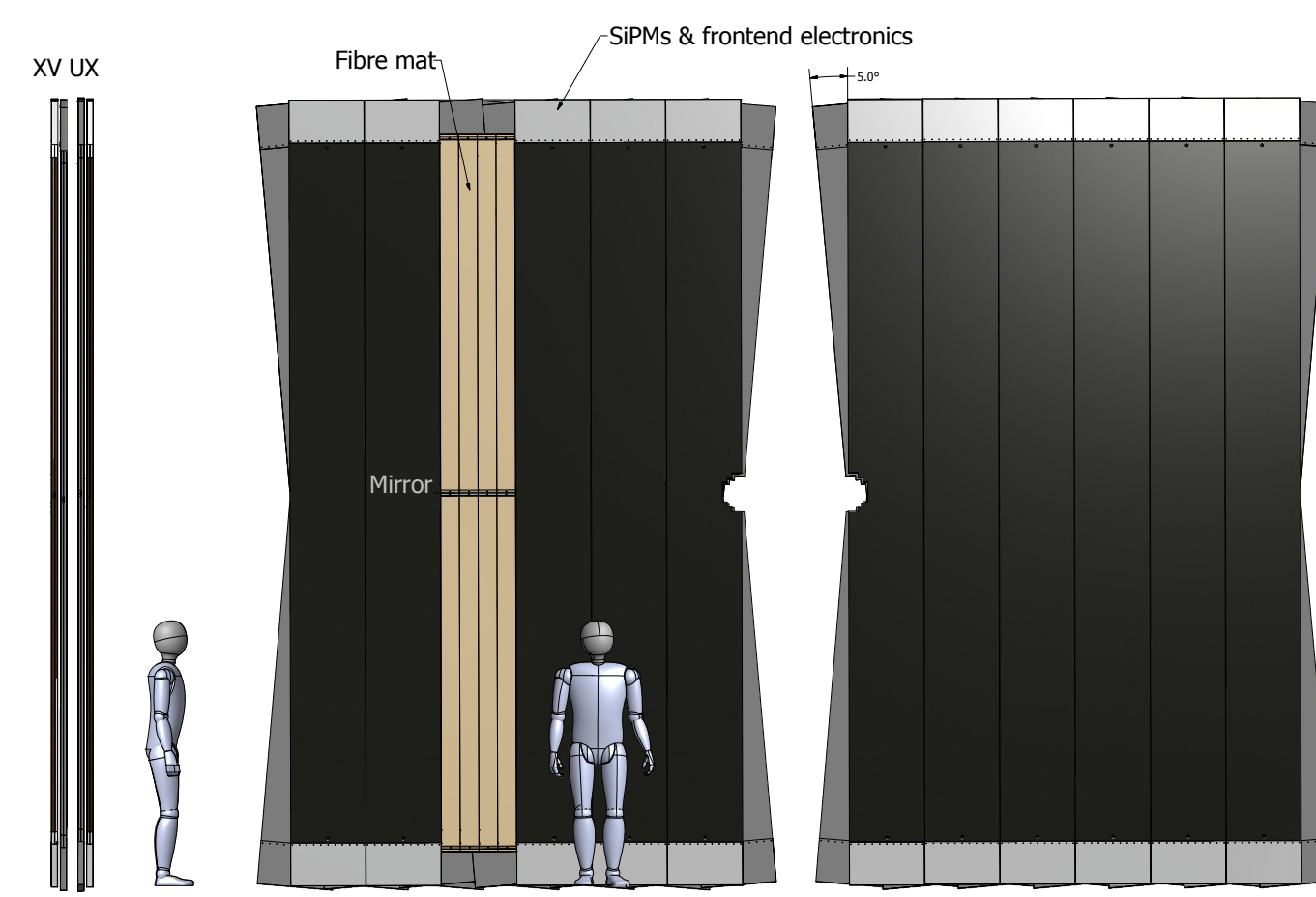


Fig. 5: One station of the SciFi Tracker.

Large, high granular scintillating fibre (SciFi) tracker readout by arrays of silicon photomultipliers (SiPMs).

- 12 layers, covering 340 m²
- 1% X₀ per layer
- Spatial resolution < 100 μm
- Single hit efficiency ~99%
- 128 channel per SiPM, 524 288 in total
- 40 MHz readout
- ~20 Tb/s data rate

Frontend Electronics for 40 MHz Readout

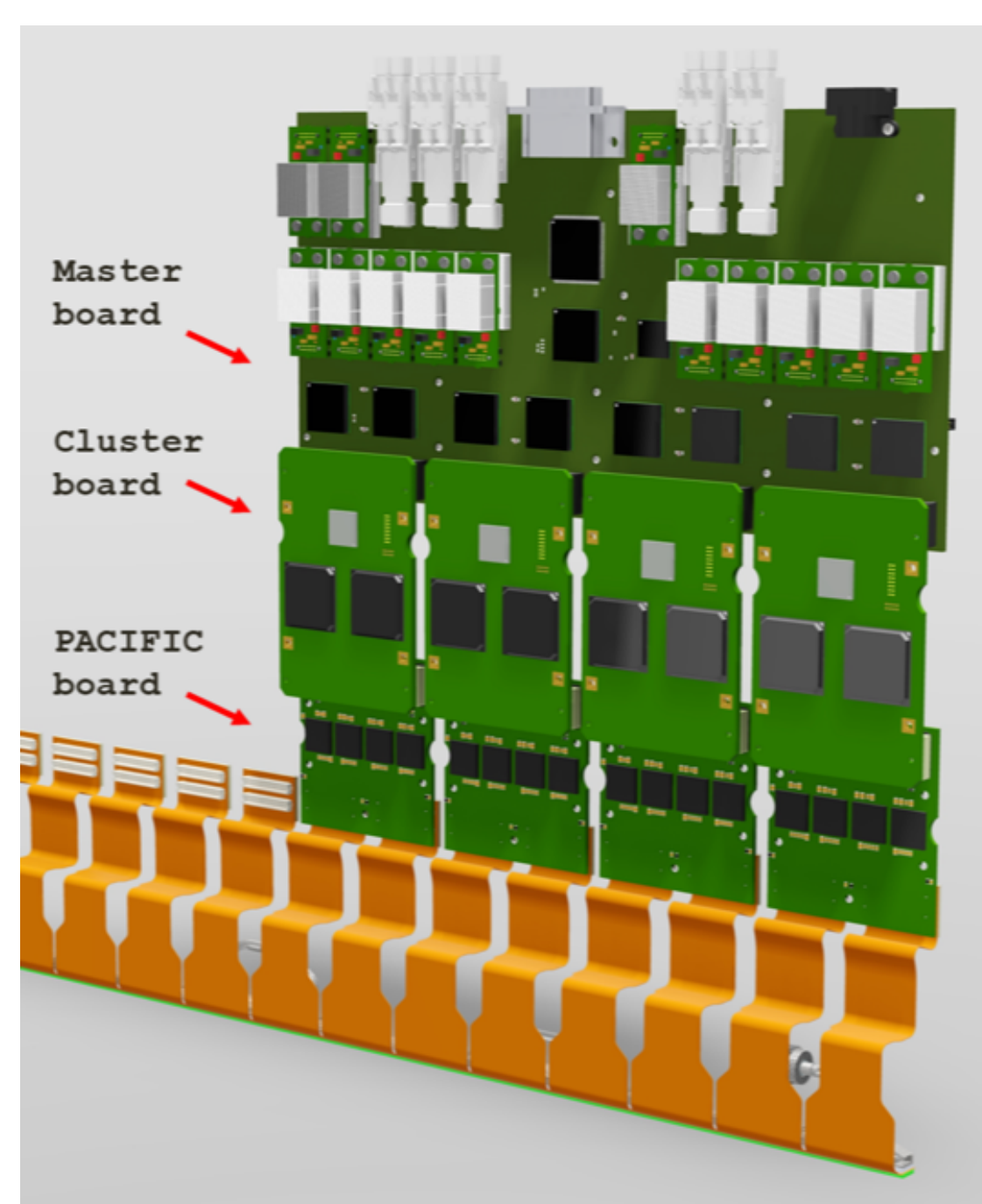


Fig. 2: Schematic of the frontend electronics.

PACIFIC

- 64-channel readout ASIC for SiPMs
- Analogue processing and digitisation at 40 MHz

Cluster FPGA

- Hit reconstruction and noise suppression at 40 MHz

Master Board

- Data encoding and serialisation
- Distribution of bias voltages, timing and control commands

Threshold Calibration

Each PACIFIC comparator has to be calibrated with respect to the spectrum of the connected SiPM channel.

- Convert from signals measured in units of DAC to photoelectrons (pe)
- Threshold scan with pulsed light for each comparator
- Extract threshold DAC values by fitting the spectrum

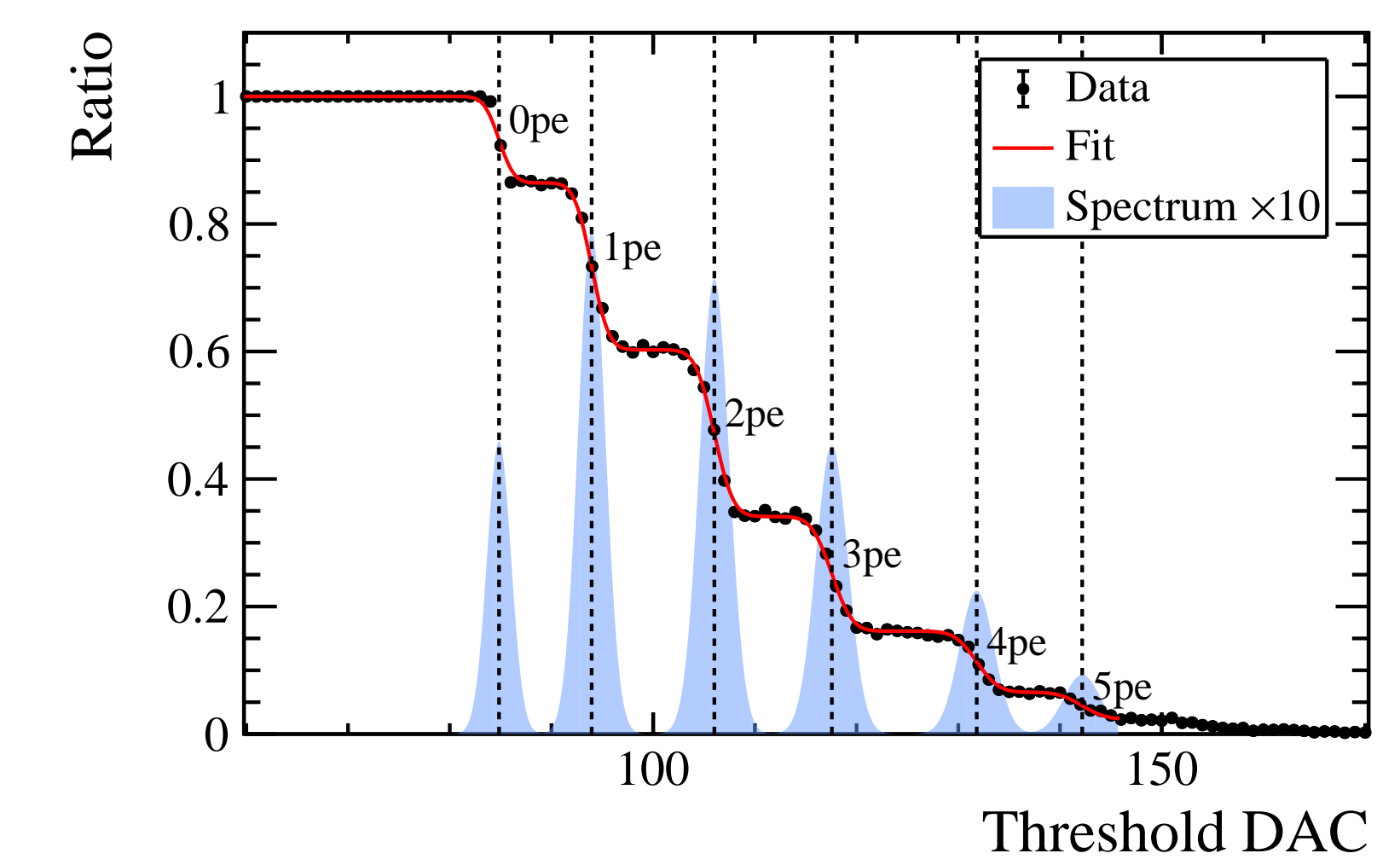


Fig. 4: Threshold scan and SiPM spectrum.

Frontend Data Processing

PACIFIC

- 3 comparators with adjustable thresholds
- $\text{Thr}_{\text{Neighbour}} < \text{Thr}_{\text{Seed}} < \text{Thr}_{\text{High}}$
- 2-bit output: 10.2 Gb/s per SiPM

Cluster FPGA

- Fast clustering algorithm
 - Single channel $\geq \text{Thr}_{\text{High}}$
 - One channel $\geq \text{Thr}_{\text{Seed}}$ & at least one neighbouring channel $\geq \text{Thr}_{\text{Neighbour}}$
- Reduces data rate to 4.8 Gb/s per SiPM

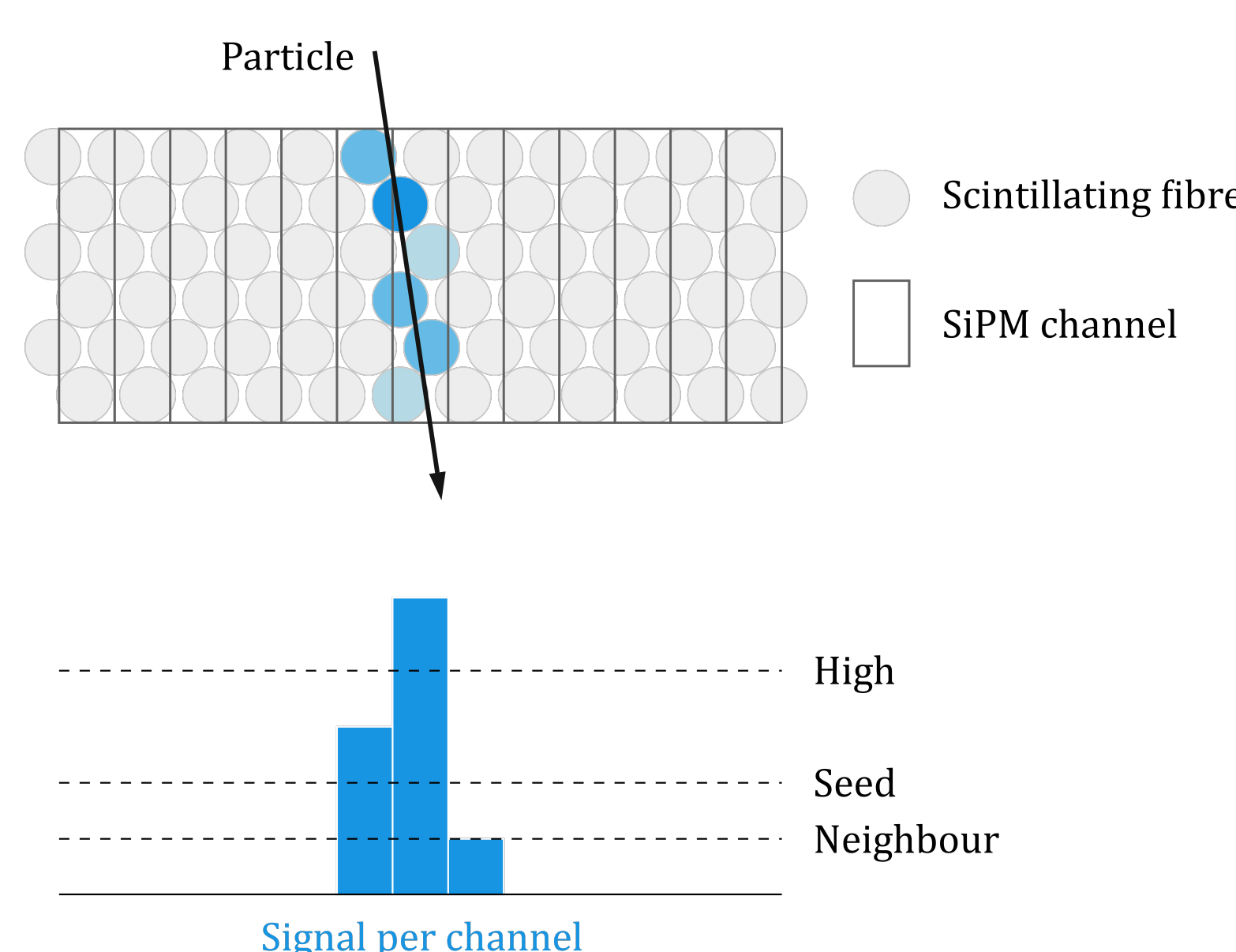


Fig. 3: Working principle and clustering.

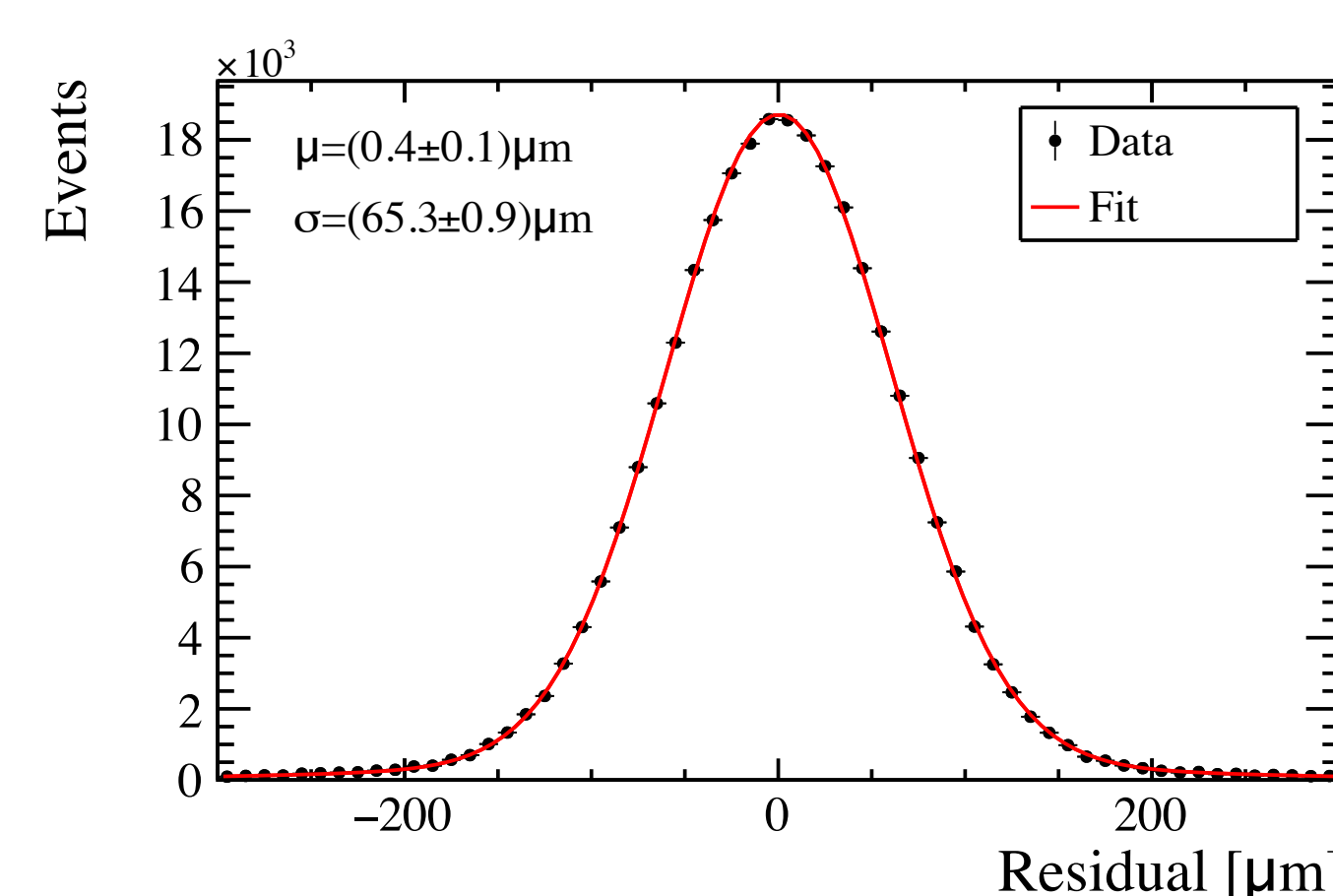
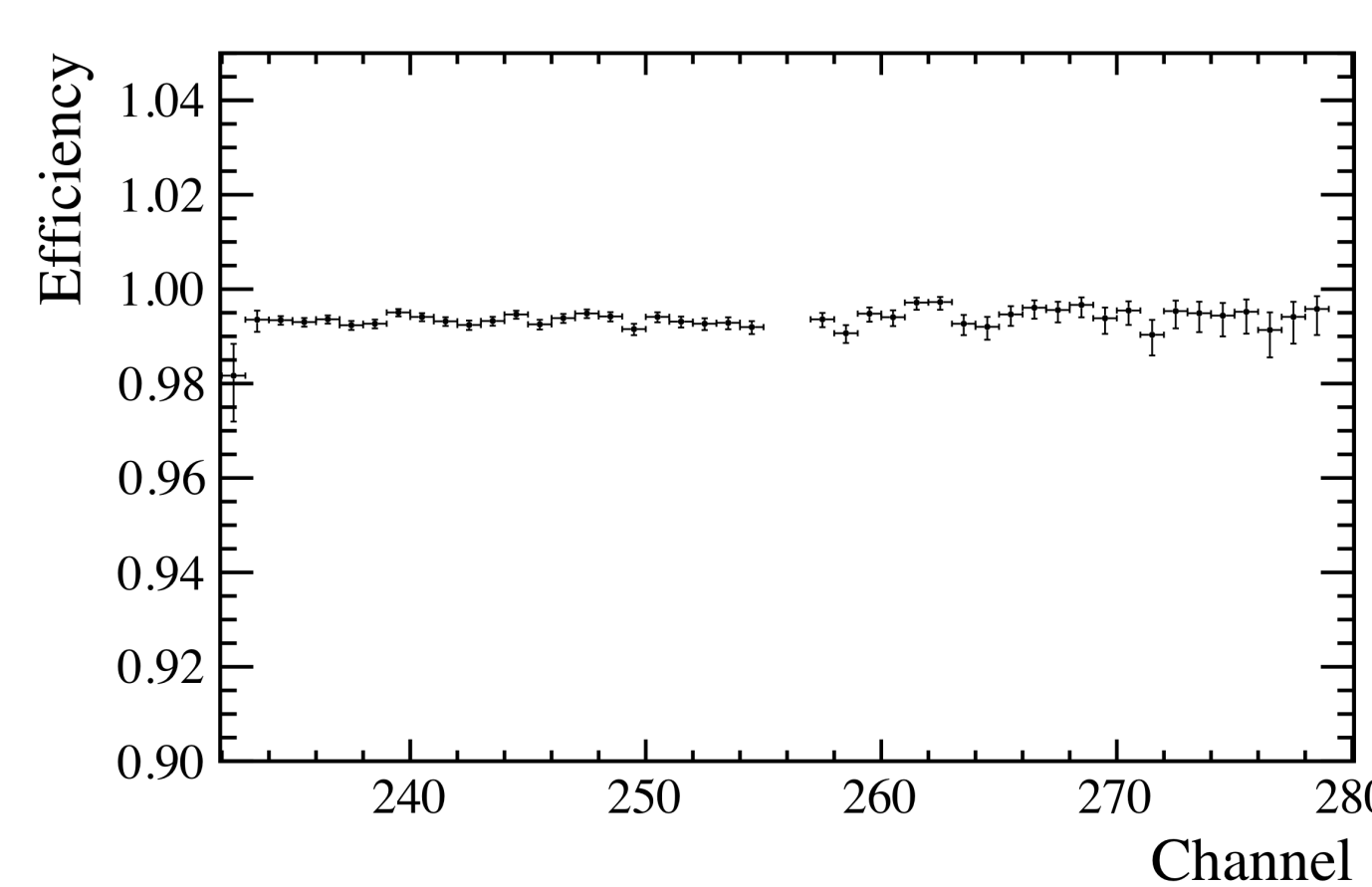
Test Beam Results

First full system test at CERN SPS in July 2018.

- Two full width, half length SciFi modules
- Fully equipped with 32 SiPMs (4096 channels)
- Complete chain of frontend electronics
- 40 MHz readout
- 153.6 Gb/s data rate

Results

- Validated performance of readout electronics at 40 MHz
- Online hit reconstruction & noise suppression work as expected
- Hit efficiency > 99%
- Hit resolution $\approx 65 \mu\text{m}$



Outlook & Challenges



Fig. 6: First half station currently being assembled at CERN.

- Assembly and commissioning started
- Highly complex system:
 - 256 sets of frontend electronics
 - 4096 SiPMs and data links
 - Calibration of $\sim 2 \cdot 10^6$ parameters

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