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The Scintillating Fibre Tracker for LHCb

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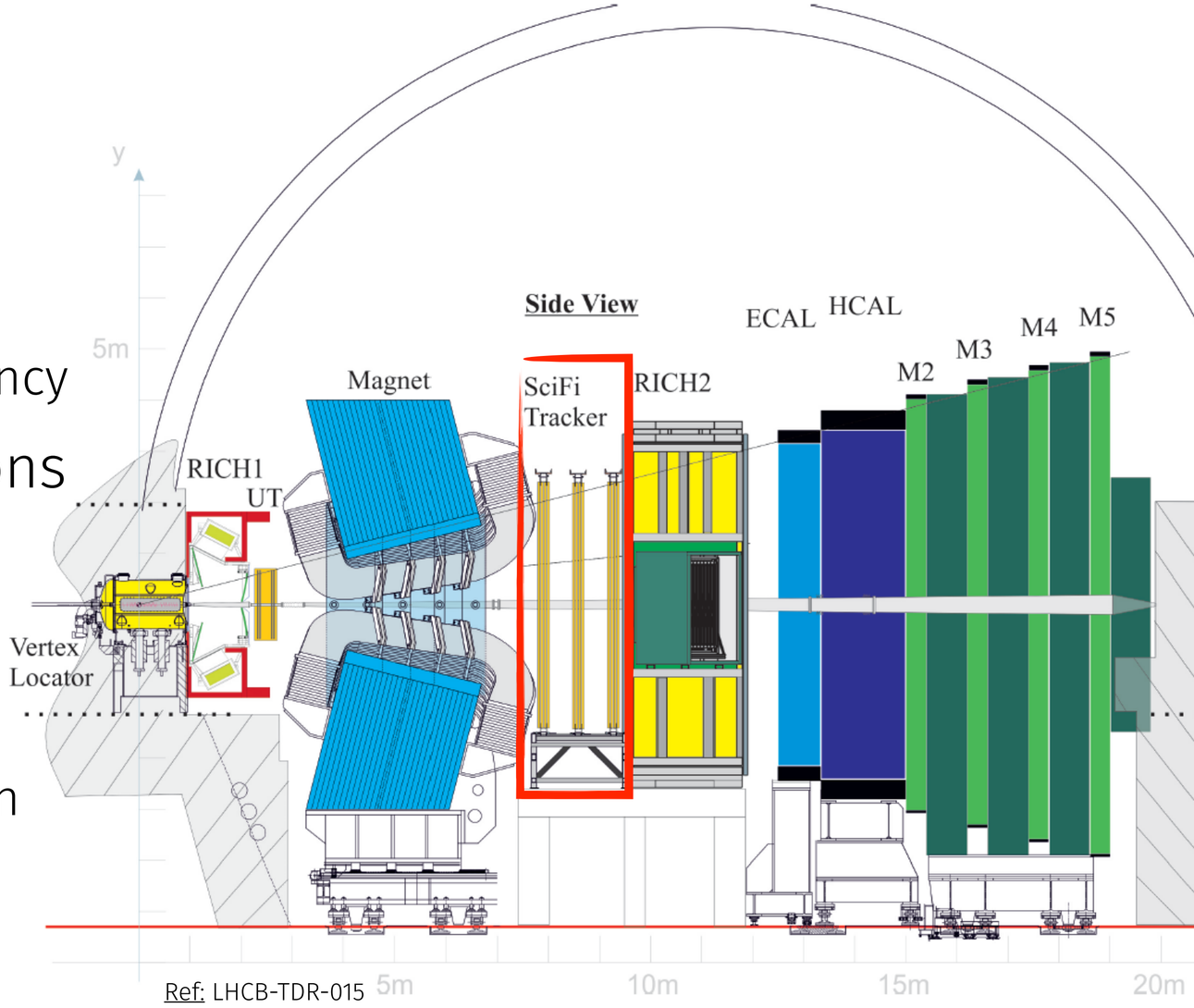
LHCb upgrade plan: increase the rate

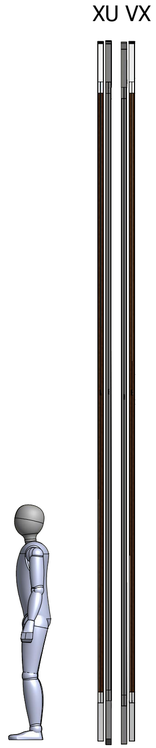
- Upgrade during LS2 in 2019-2020
- Collect 50fb^{-1} over 10 years
- Triggerless 40MHz read out
  - Significantly improved online selection efficiency
- New tracking detectors (and modifications to the others)
  - Cope with higher occupancy and radiation
  - Vertex detector: silicon strips -> pixels
  - Upstream detector: new larger coverage silicon strips
  - Tracking stations: Scintillating Fibre Tracker

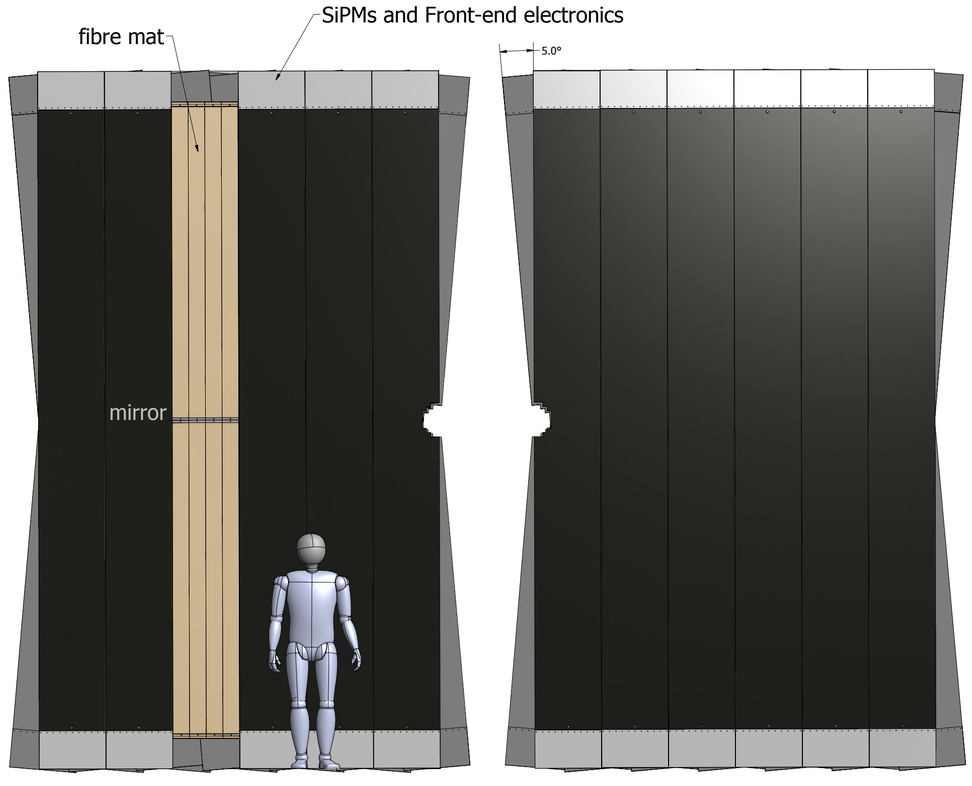


Ref: LHCB-TDR-015

The LHCb SciFi Tracker

- Scintillating fibres arranged in 6 layers with SiPM read out
- 3 stations
- 4 detection layers per station
- 10-12 modules per layer
- 360 m^2 active surface
- Requirements
  - Hit efficiency: ~99%
  - High granularity: 250 µm
  - Hit resolution: <100 µm
  - Material budget: ~1% X_0 / layer
  - Radiation hardness:
    - up to 35kGy near beam pipe (fibres)
    - 6x10^{11} neq/cm^2 (SiPMs)





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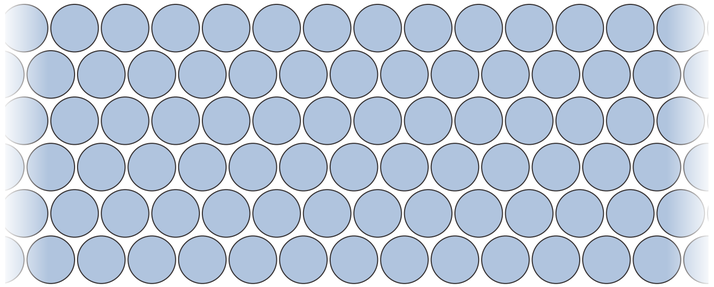
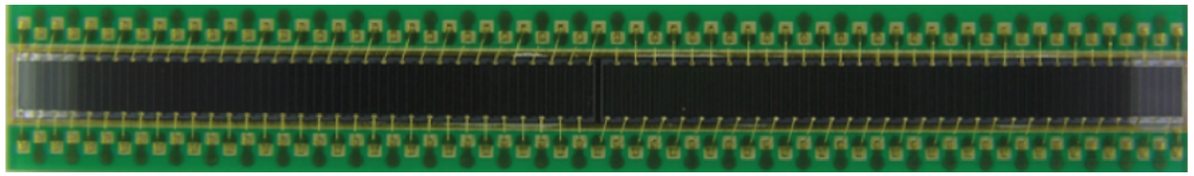
SciFi detector principle

- Each module: 8 fibre mats
- Each fibre mat: 240 cm length, 13 cm width
- Fibre mat consists of 6 layer of scintillating fibre, 275 µm pitch



Ref: CERN-THESIS-2018-043

- Fibres read out by Silicon Photomultiplier arrays, 250 µm channels



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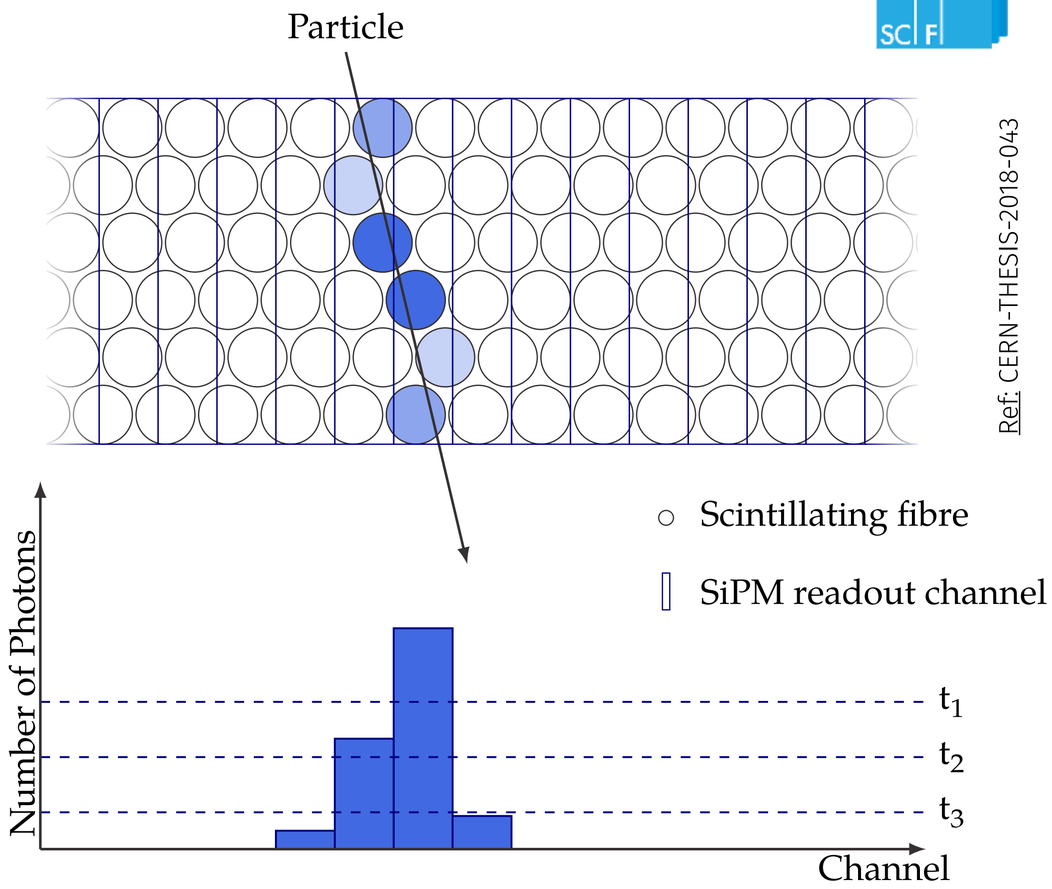
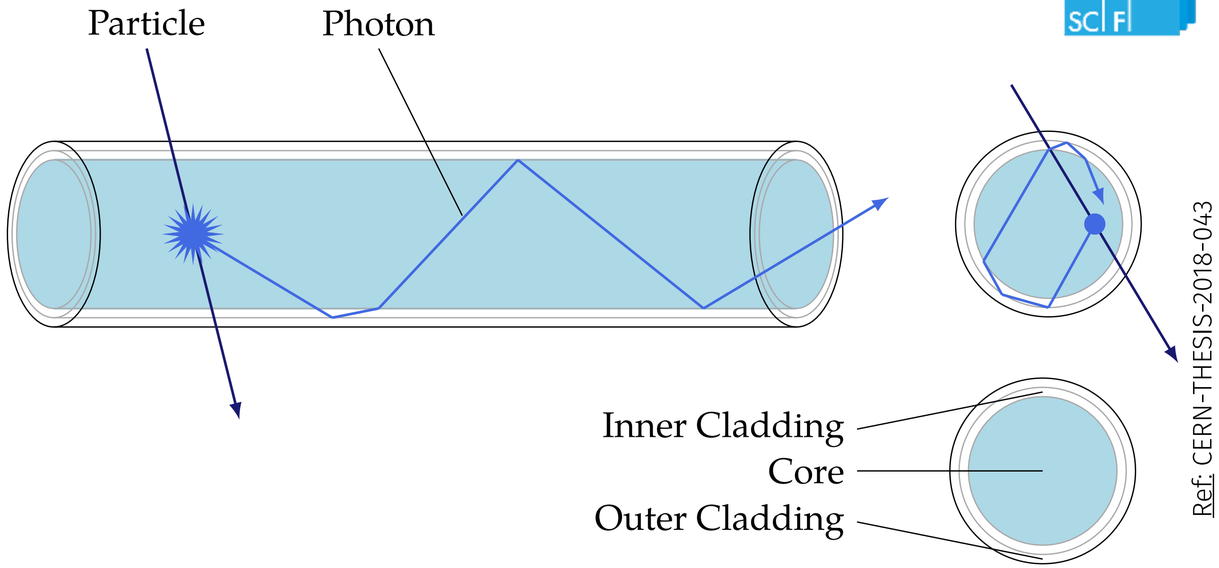


Ref: CERN-THESIS-2018-043

- Signal spread over SiPM channels
  -> Clustering
- Light yield of a 6-layer mat:
  15-20 photon electrons,
  for particles on opposite mat end

Scintillating fibres

- 250 µm double-clad plastic scintillating fibre (Kuraray, Japan)
- Polystyrene core + claddings with decreasing indices of refraction
  -> total reflection at boundaries
- Light emission peak: ~460 nm
- Attenuation length: ~3.5 m
- Radiation degrades the transmission properties
  - ~40% light loss expected for particles near beam pipe after $50fb^{-1}$
- ~10.000 km fibres needed
  - Fibre QA at CERN
  - Shipment to four mat production sites



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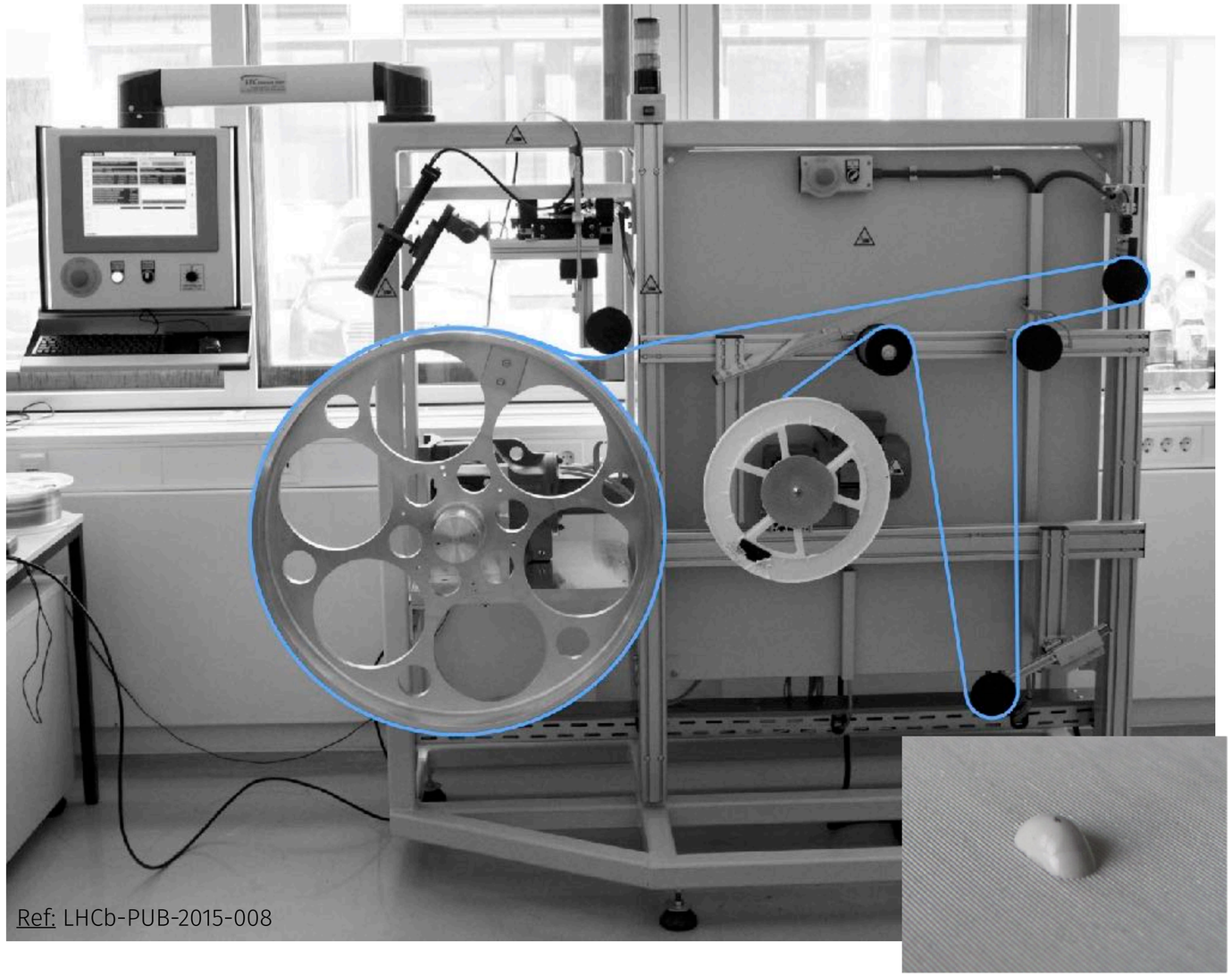
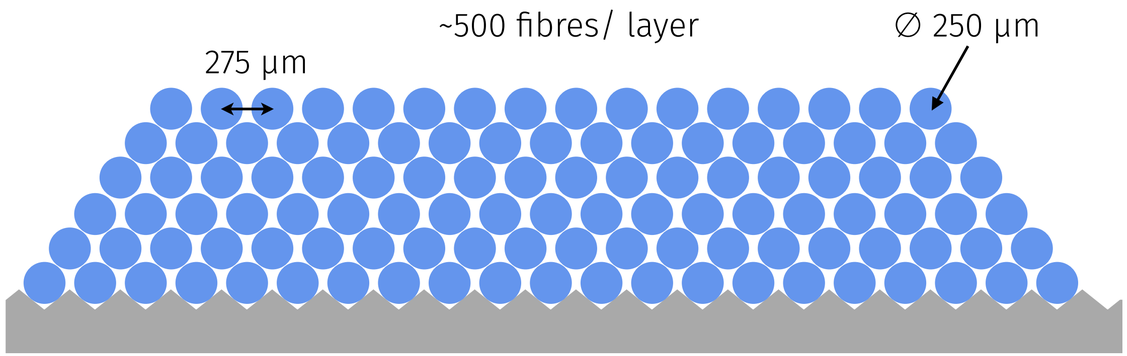
Fibre mat production



Ref: LHCb-PUB-2015-008

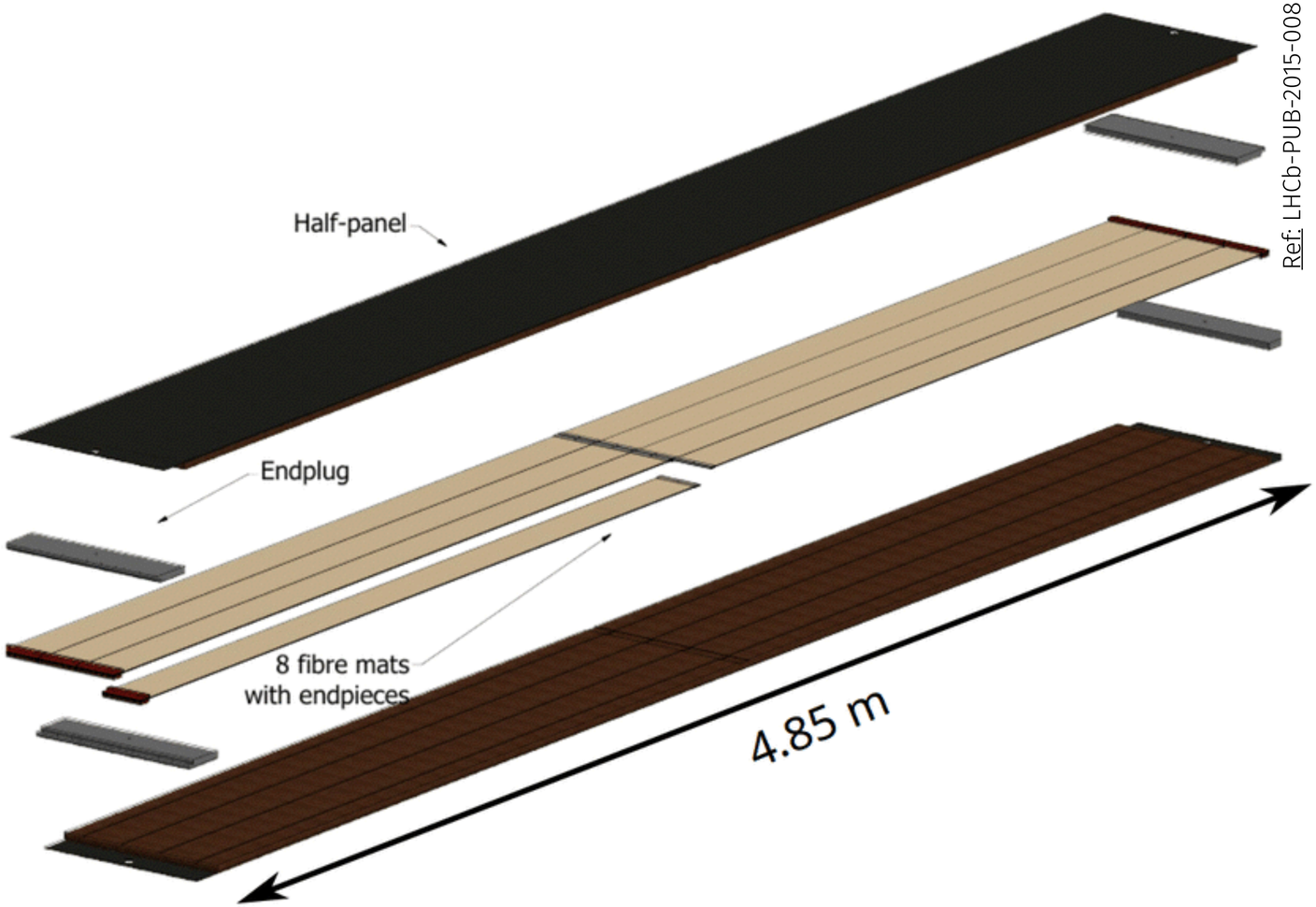


- Custom winding machine with threaded winding wheel
  - Winding and glueing of 6 layers of fibres onto wheel
- Glue alignment pins transfer precision of wheel to mat
- Kapton lamination foil for mechanical stability

SciFi Tracker Modules

- 2x4 mats aligned with the help of a precision table
- 50cm width, 5m length
- Fibre mats sandwiched between carbon fibre and honeycomb panels

- Production ongoing in 2 institutes
- Achieved an alignment precision of 50 µm over 5m length

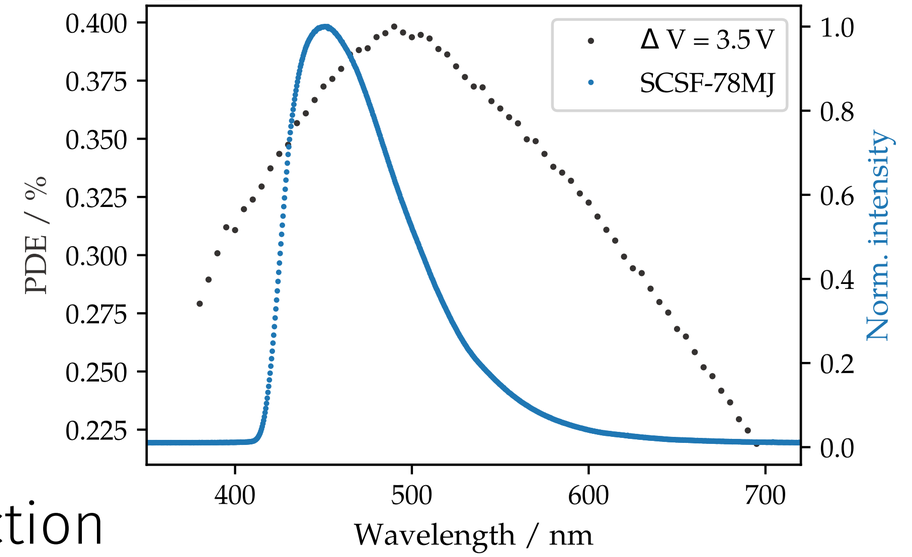


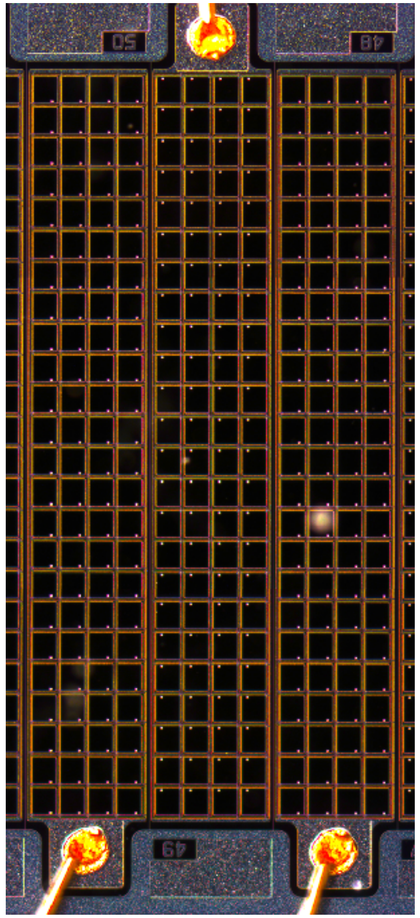
Ref: LHCb-PUB-2015-008

Silicon Photomultiplier

- 128-channel SiPM arrays
- Channel width: 250 µm
  - 4x26 pixels per channel
- High photon detection efficiency: ~45%
- Low cross talk probability
- Final version of the detector is in production (Hamamatsu)

Ref: CERN-THESIS-2018-043



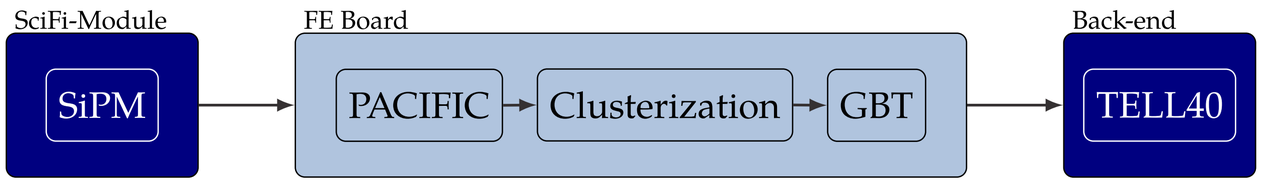


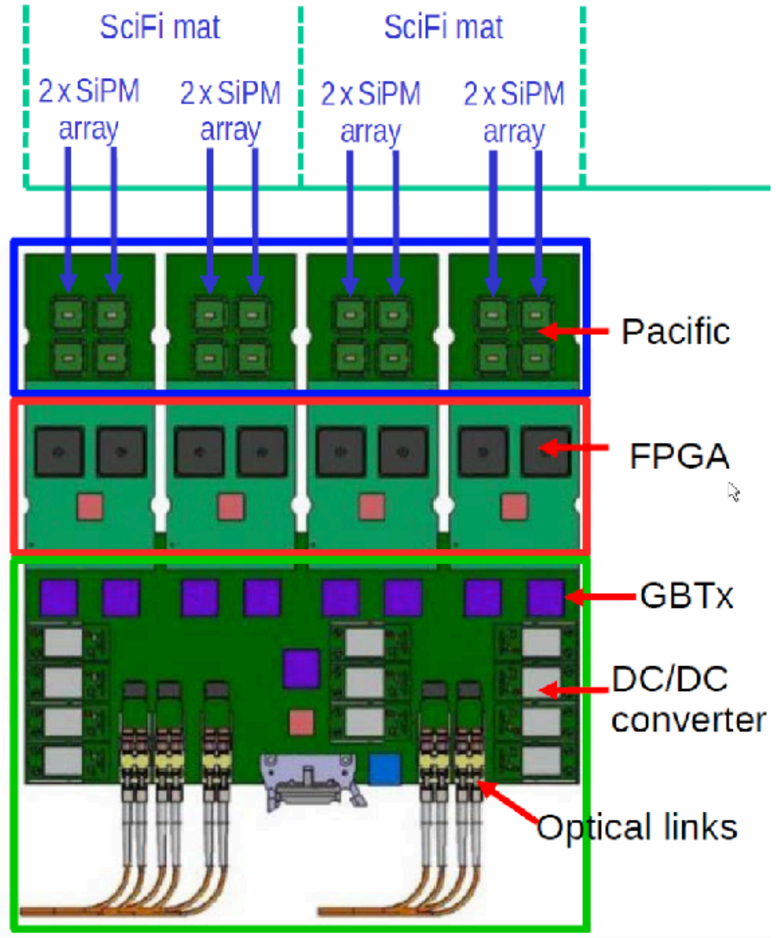
Ref: LHCB-TDR-015

- Cooling to -40 °C to reduce dark count rate after irradiation
  - Dark count rate increases linearly with neutron flux
  - 14MHz per channel after 6×10^{11} neq/cm^2

Readout

- SiPM sensor on Flex cable
- PACIFIC carrier board
  - Custom-made ASICS
  - 64 channels, 3 threshold discriminator
  - Noise suppression
- FPGA cluster board
  - Cluster building + zero suppression
- Master board
  - Transfer data and distribute signals



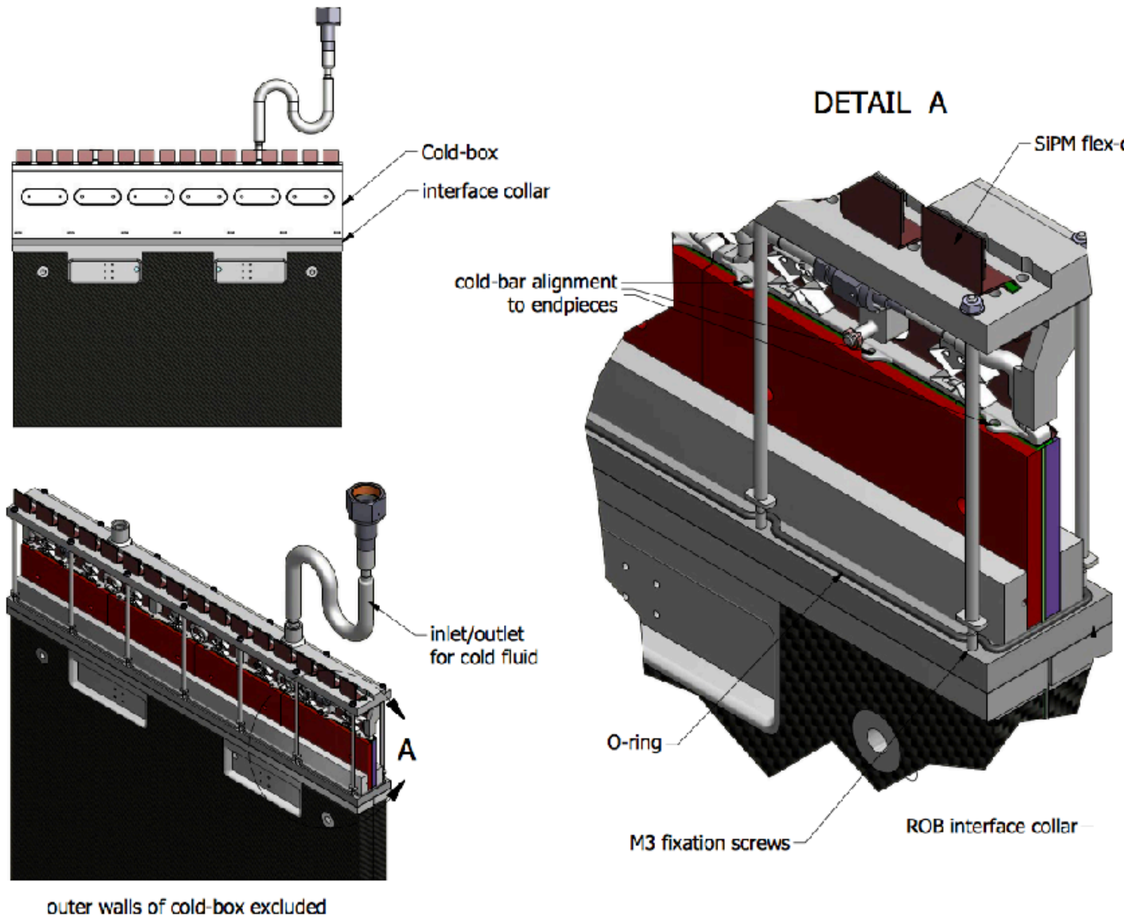


Read out box

- SiPMs cooled to -40°C
  - reduce the dark count rate
- Electronics need to kept warm

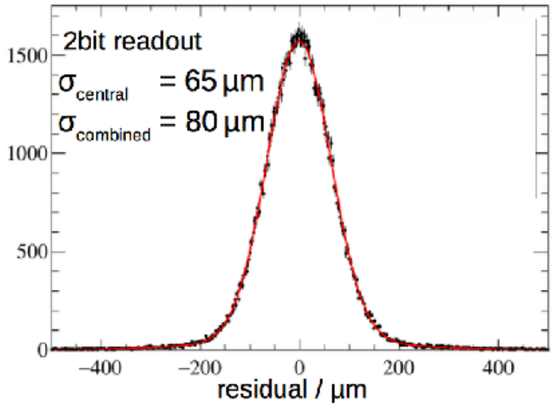
- Cold box:
  - SiPMs + cooling bars
  - Flushed with nitrogen

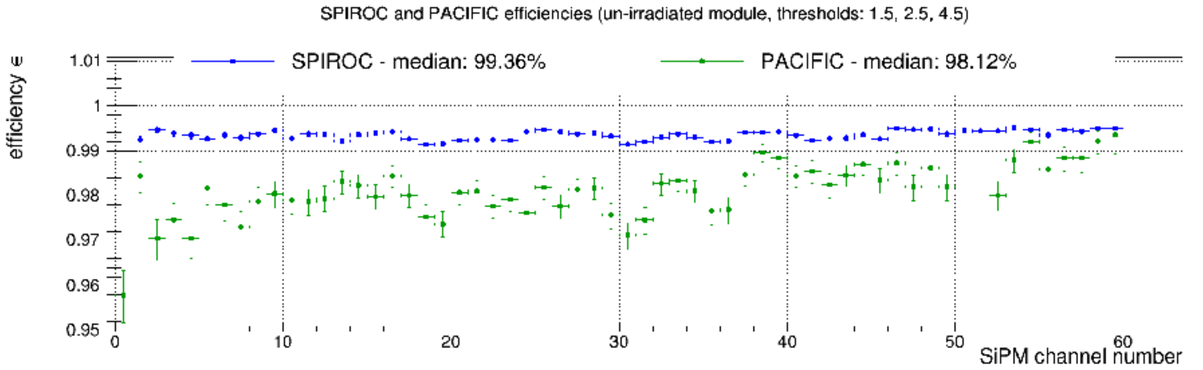
- Isolated warm part with the front end electronics

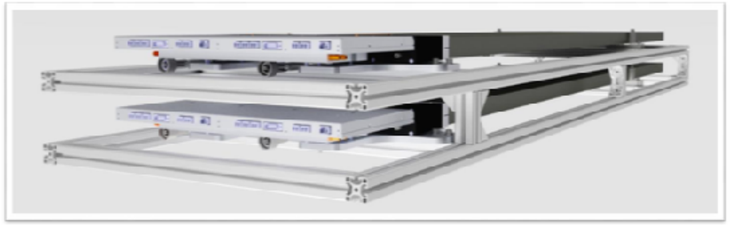


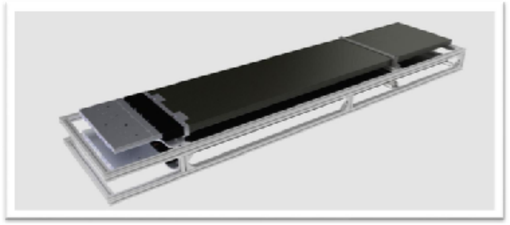
Testbeam results

- Several campaigns in the last years demonstrated a good performance of the detectors
  - Hit resolution: 80 µm
  - Hit efficiency: 99%
- Ongoing: slice test with 2 half-modules
  - 2.5 m, fully instrumented
  - Measure hit efficiency and resolution with final electronics









Conclusion

- The LHCb Scintillating fibre tracker is a high resolution detector covering an area of 360 m^2
- Based on 250 µm diameter scintillating fibres
- Silicon multiplier array read out
- Nominal performance parameters achieved in test beam campaigns
  - <100 µm hit resolution, >99% hit efficiency
- Advanced detector production
  - ~80% fibre mats, ~65% modules
- Installation in 2019-2020

LHCb gets ready for a SciFi upgrade

by Kate Kahle

Posted by Harriet Kim Jarlett on 24 Aug 2017. Last updated 29 Aug 2017, 14.39.
Voir en français

Each of the four boxes houses five detector modules. 128 modules will make up the new scintillating fibre (SciFi) tracker, part of the major upgrade of the LHCb detector (Image: Christian Joram/ CERN)

The very first detector elements of the LHCb upgrade, early pieces of the scintillating fibre (SciFi) tracker, have arrived at CERN. Four boxes housing the first 20 of 128 modules were unloaded from trucks after an international tour: the scintillating fibres from Japan had been verified at CERN months ago before travelling to either Aachen, Dortmund, Lausanne or Moscow and then being assembled into modules in Heidelberg, Germany. Today they arrived at their final destination, CERN LHC Point 8.

Thanks for your attention!