SciFi: A large Scintillating Fibre Tracker for LHCb

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on behalf of the LHCb SciFi Tracker group

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LHCb Detector Upgrade

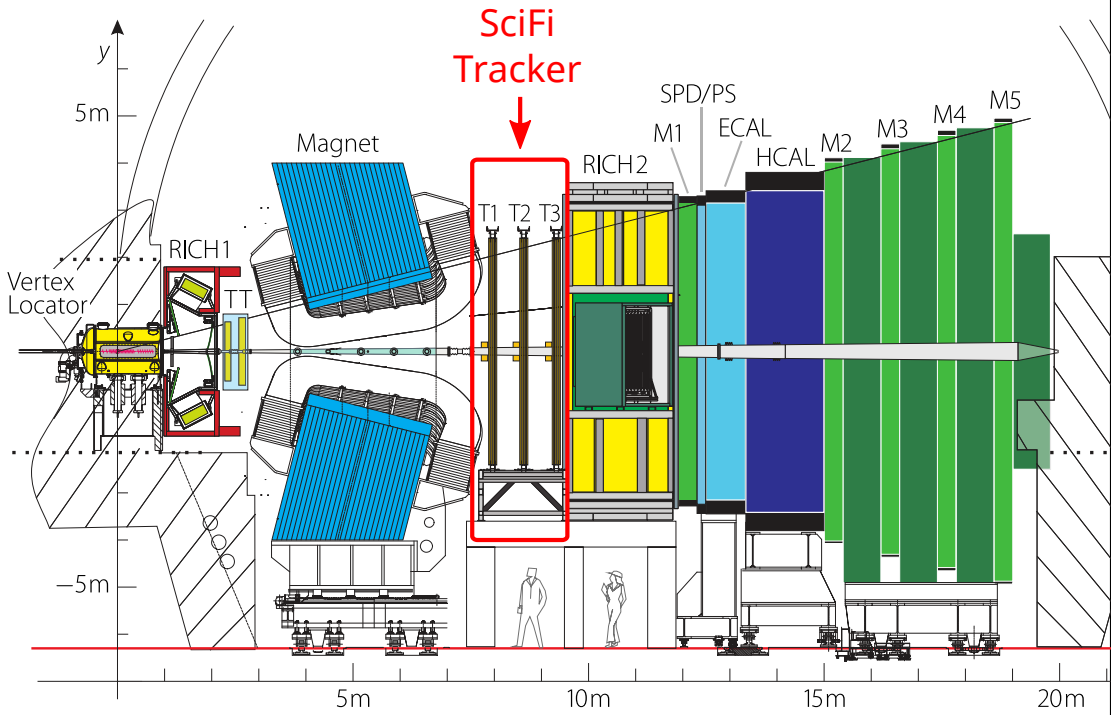
- **LHCb Upgrade: improve precision in the core physics programme**
  - Collect 50 fb^{-1} over 10 years ($\sim$ 5 times more luminosity than initial detector)
  - Installation in LS2 (2019–2020)

- **New tracking detectors** and modifications to the other detectors
  - Cope with higher occupancy and radiation
- **Read-out upgrade from 1 to 40 MHz**
  - **Full software trigger** $\Rightarrow$ significantly improved online selection efficiency

For an LHCb upgrade overview, see talk of Silvia Gambetta on Sat 10 am

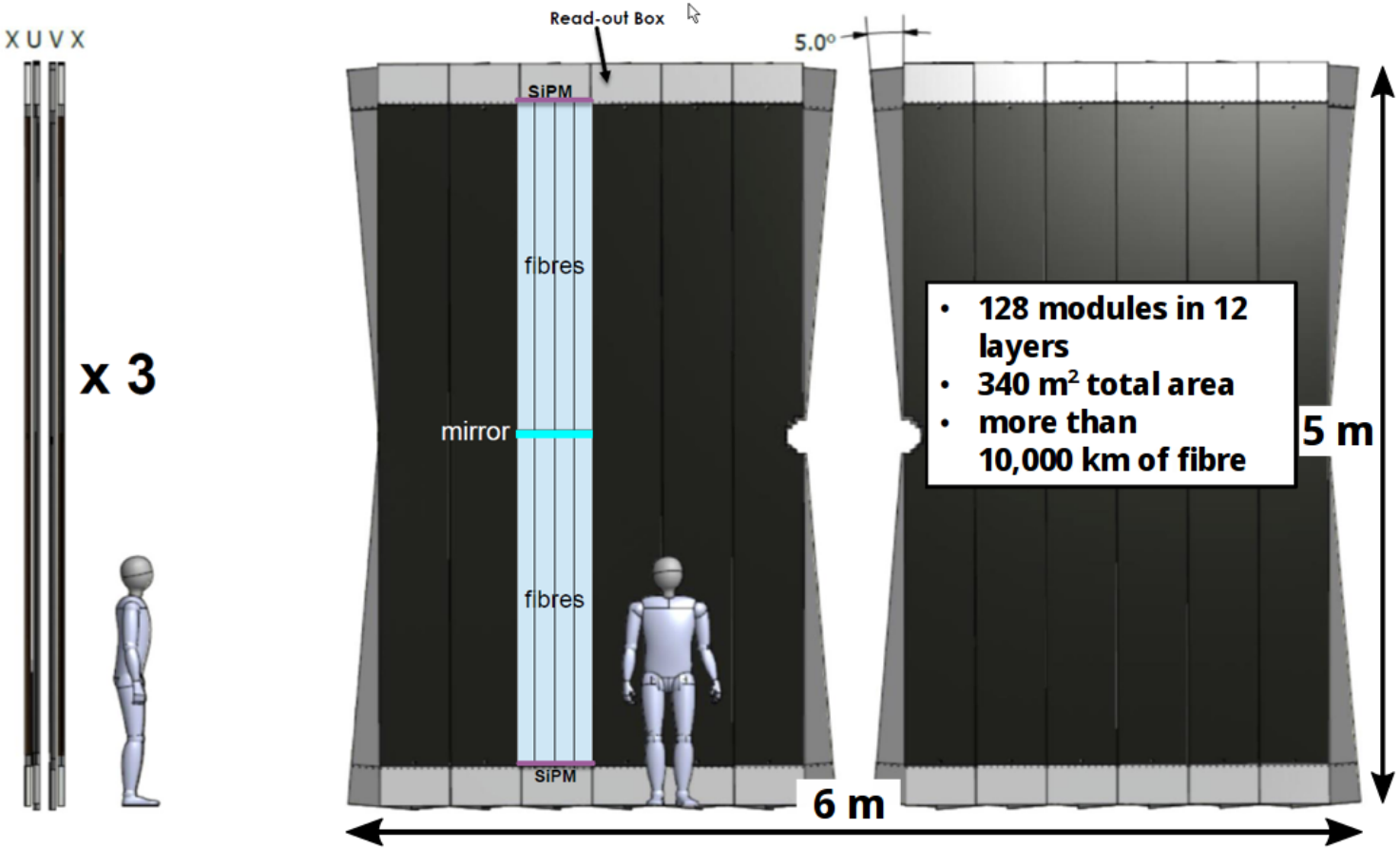
New **Sci**ntillating **Fi**bre tracker will replace the current silicon strip and straw-tube detectors

SciFi TDR: CERN-LHCC-2014-001



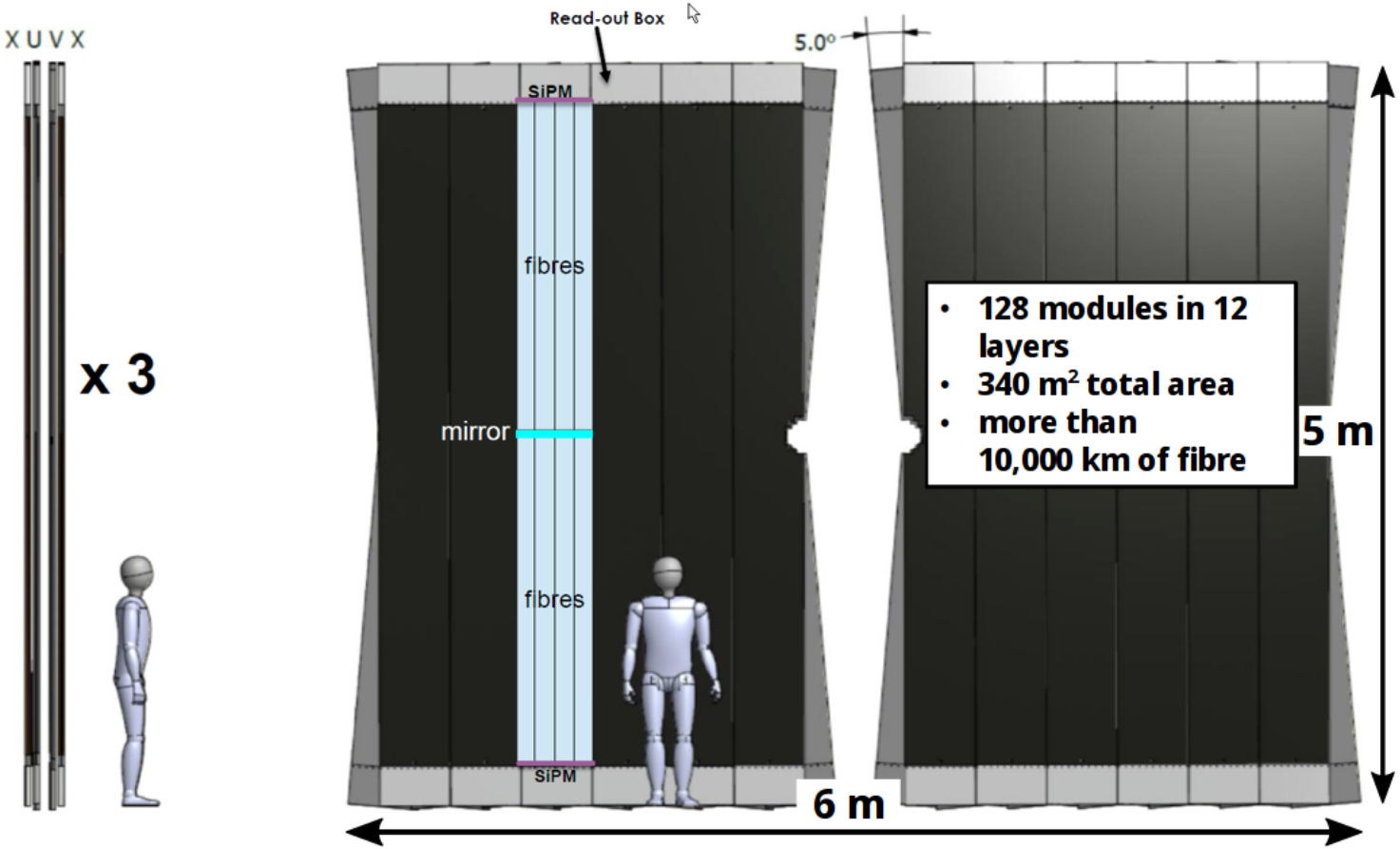
SciFi Tracker

- 3 tracking stations
- 4 detector layers per station (2 are tilted by $\pm 5°$)
- Scintillation light detected with Silicon Photomultipliers (SiPM)
- In total: 590k detector channels

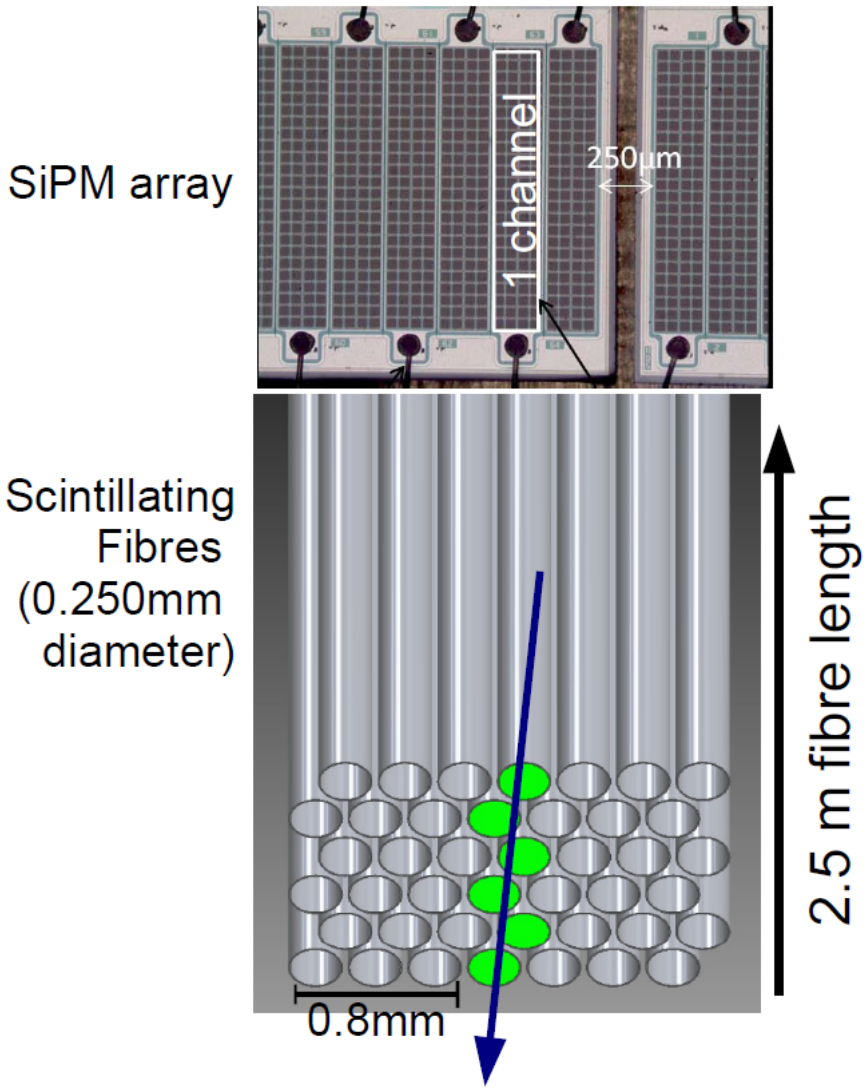


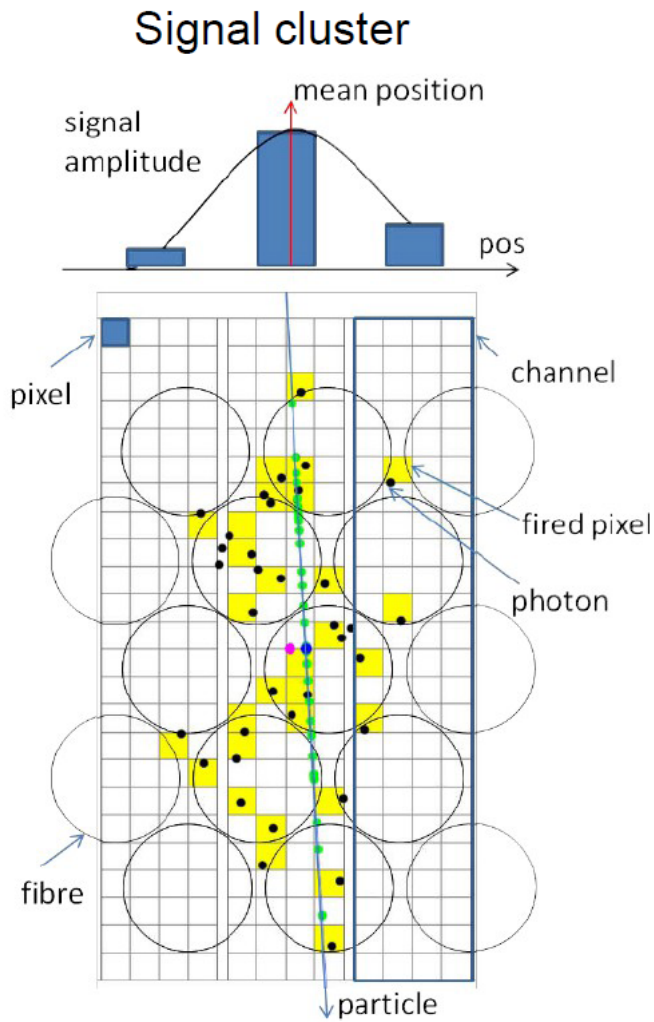
SciFi Tracker

- 40 MHz readout
- Radiation hardness (up to 35 kGy for fibres near beam pipe)
- Hit efficiency $\sim$ 99 %
- Material budget $\sim$ 1 % X_0 / layer
- Hit resolution < 100 μm



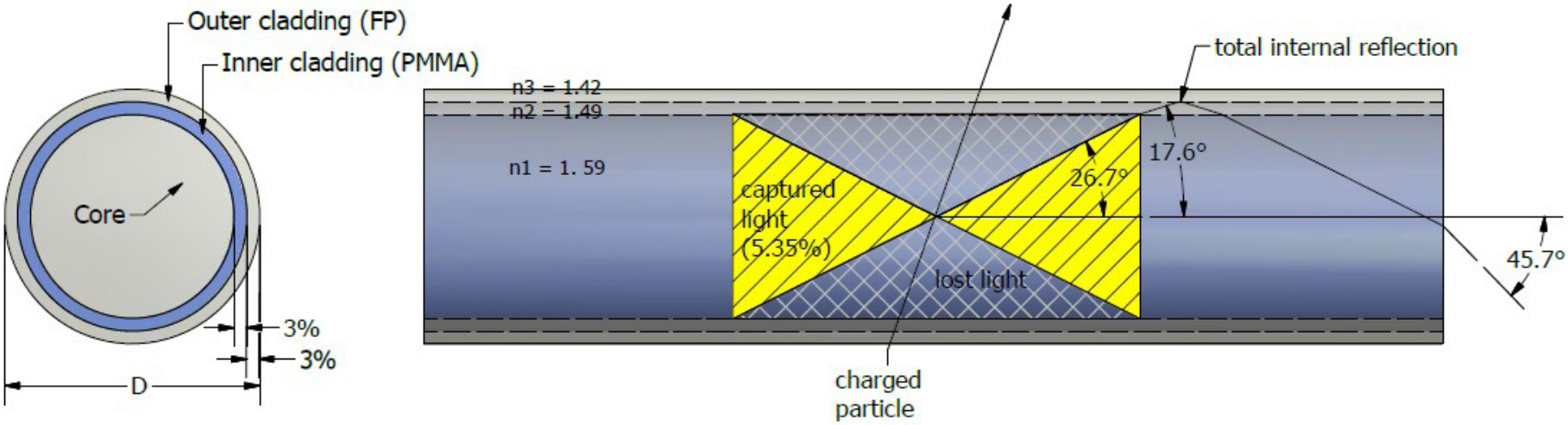
SciFi Detector Principle



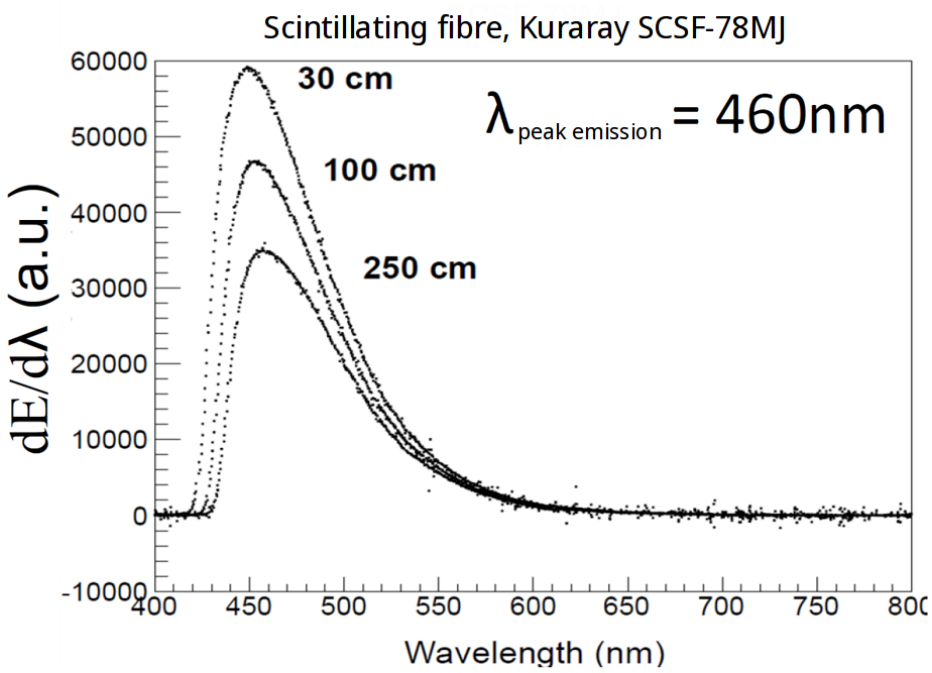


Light yield of a 6-layer mat:
15–20 photo electrons
(for particles near mat mirror)

Scintillating Fibre

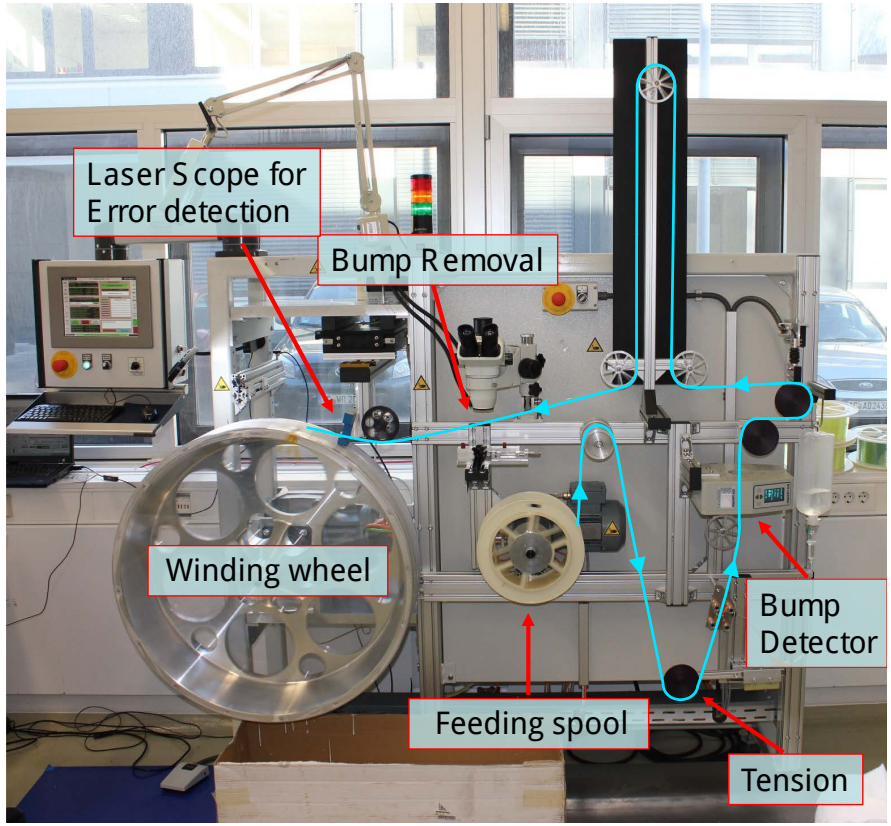


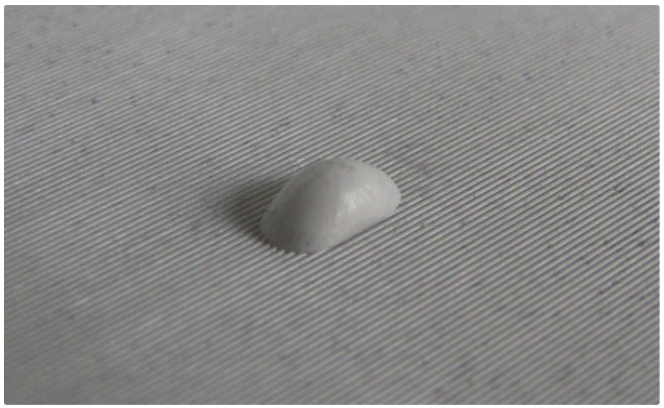
- 250 μm double-clad plastic scintillating fibre (Kuraray, Japan)
- Core made of polystyrene base + activator + wavelength shifting dye
- Light emission peak $\sim$ 460 nm
- Attenuation length $\lambda \sim 3.5$ m
  - Ionising radiation degrades the transmission property – after 50 fb^{-1} expect 40 % light reduction for particles near the beam-pipe

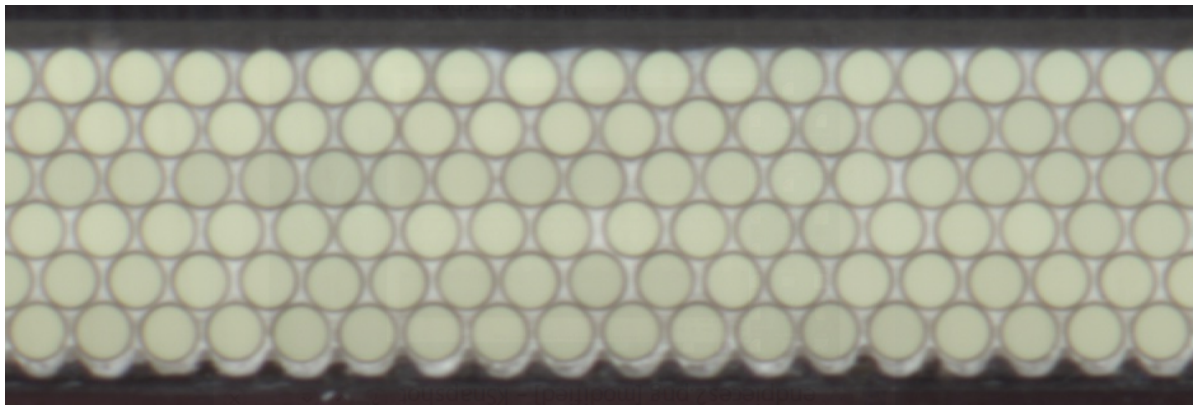


Fibre Mats

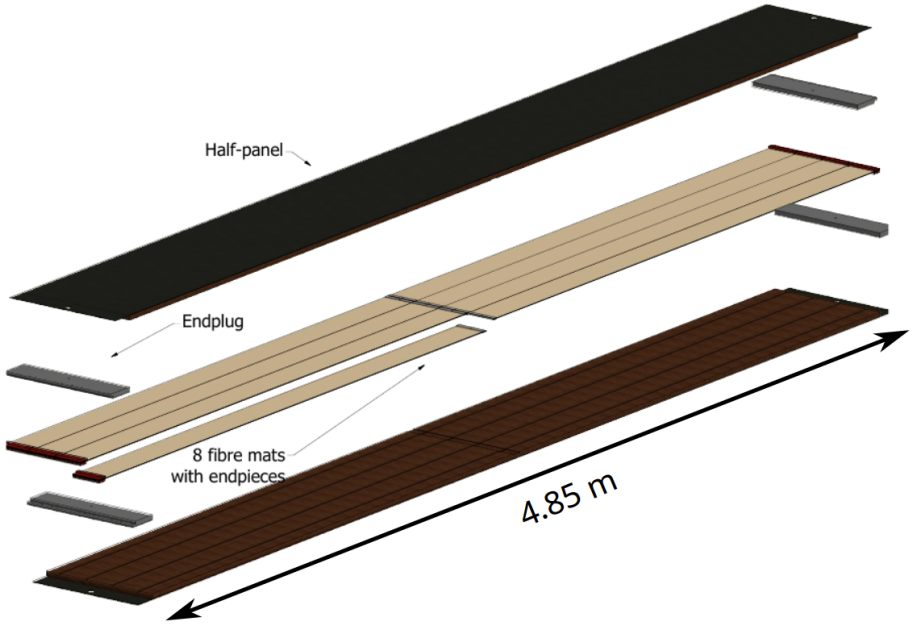
- Custom winding machine used to lay 6 layers of fibre and glue onto a threaded wheel
  - Mat dimension:
    L x W x H = 2424.0 x 130.6 x 1.4 mm
- Glue pockets on the wheel are used to create alignment pins
- The mat production is ongoing at 4 institutes (1–2 mats/day/institute)

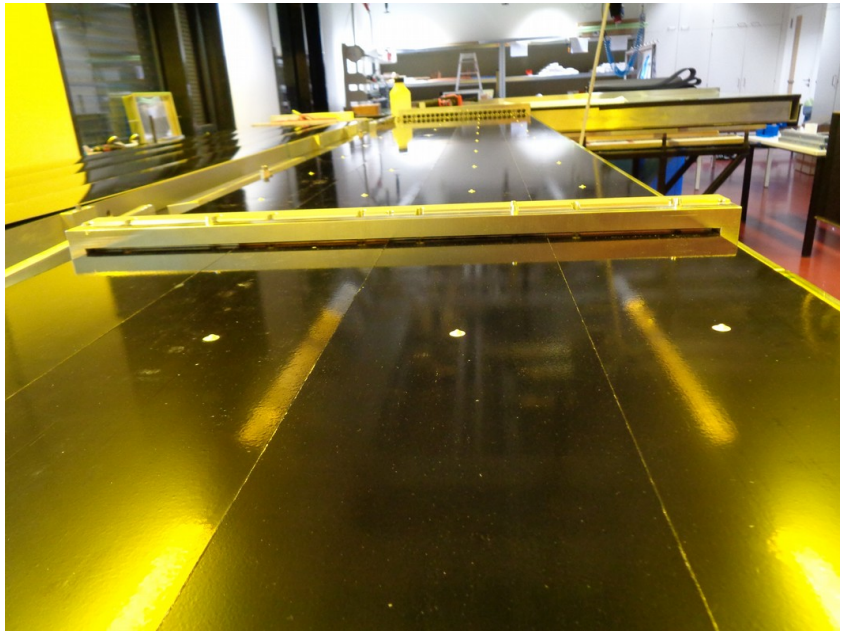






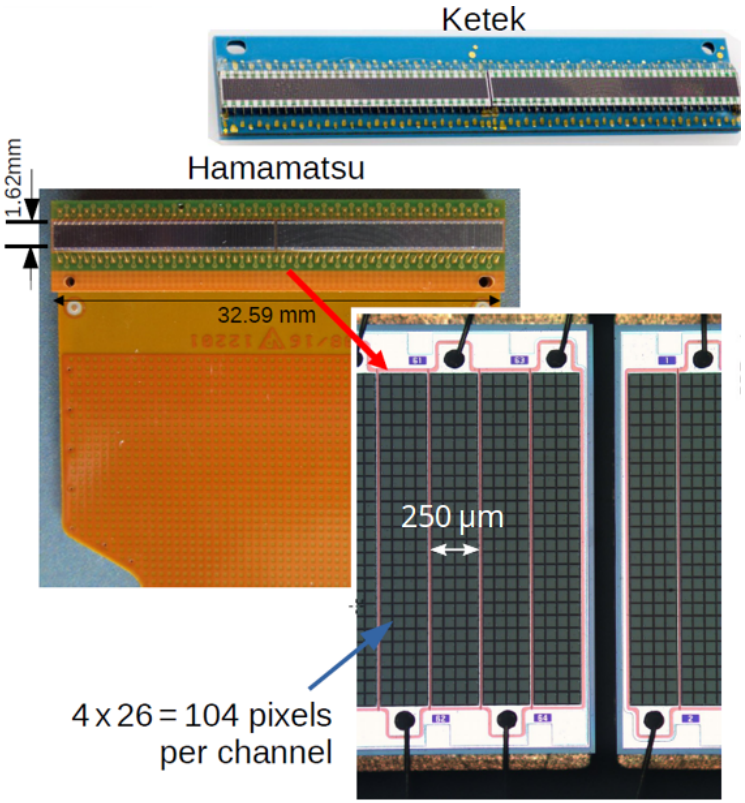
Modules



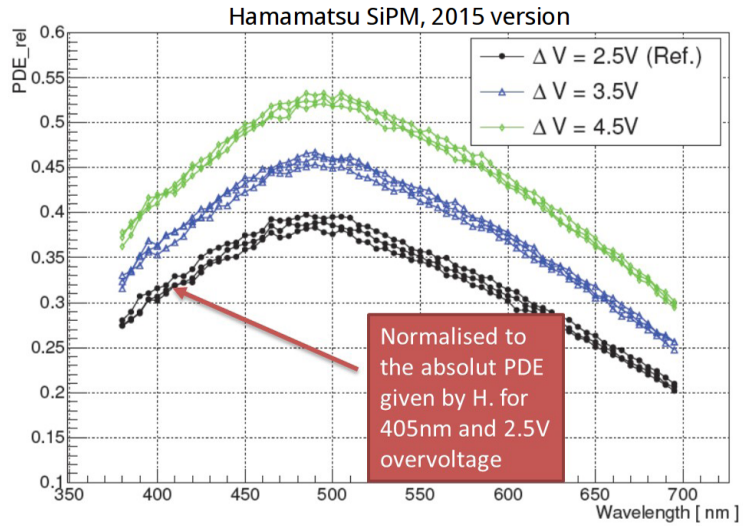


- 8 fibre mats assembled into a module
- Rigidity provided by carbon fibre and Nomex core structure
- Material budget: 1.1 % X_0
- Production ongoing at 2 institutes
- Achieved module straightness better than 50 μm (over length of 5 m!)

Silicon Photomultipliers



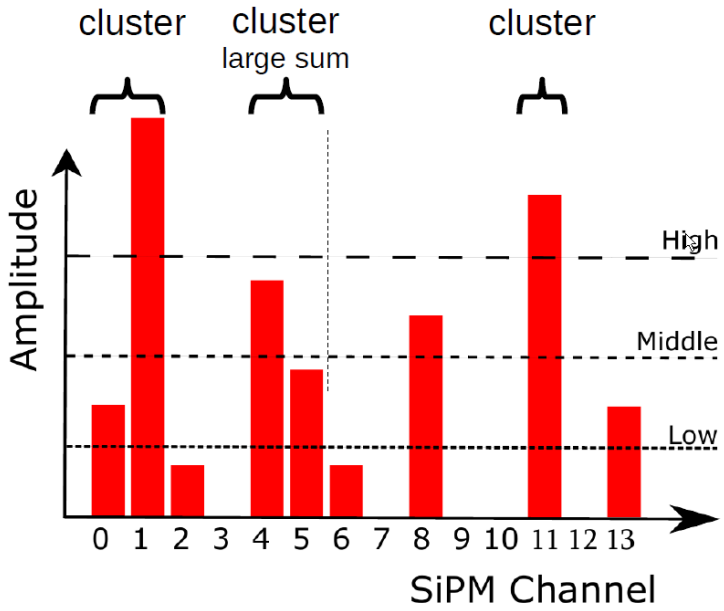
- 128-channel SiPM arrays
- Channel size: 250 μm
- The final version of the detector is in production (Hamamatsu)
- High photon detection efficiency $\sim$ 45 %



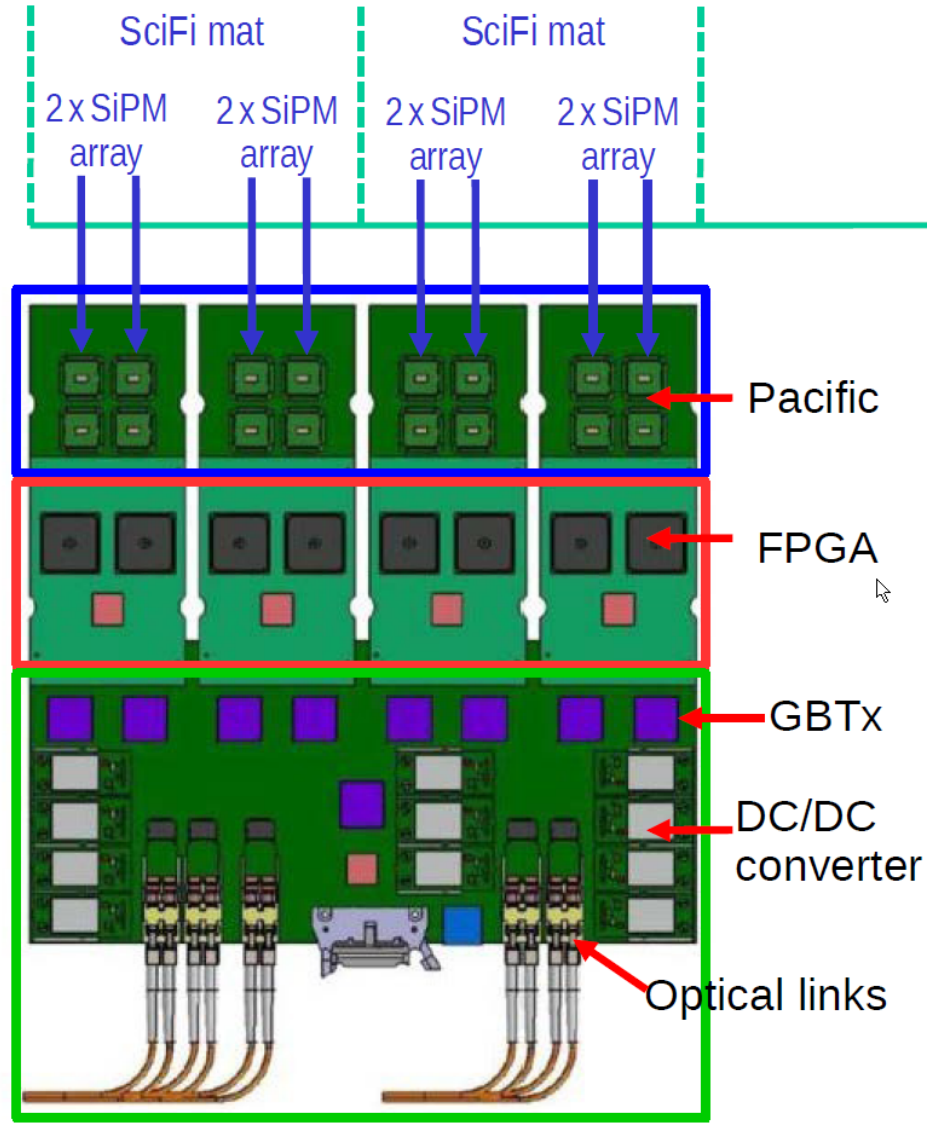
- Low X-talk/noise
- Cooling needed to keep low DCR (Dark Count Rate) after irradiation
  - DCR is 14 MHz per channel at -40° C and ΔV = 3.5 V for 6×10^{11} neq/cm^2
  - Increases linearly with neutron fluence

Readout

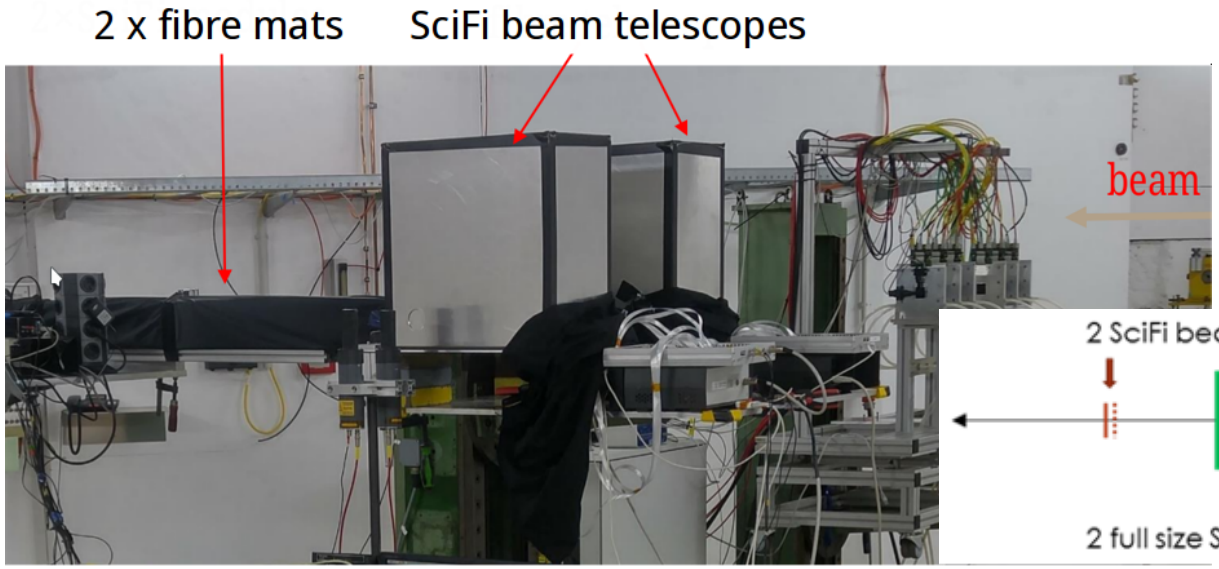
- **PACIFIC**: custom-made ASIC
  - 64 channels, 3 threshold discriminator



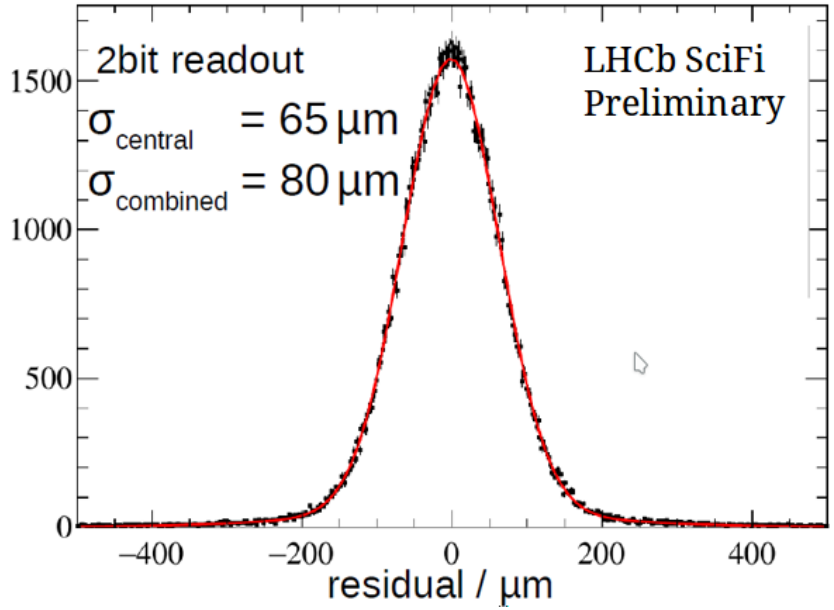
- **Clusterisation board**: clustering / zero suppression
- **Master board**: transfer data and distribute signals
  - Clock, fast and slow control



Testbeam



- Several campaigns in the last 2 years, demonstrating good performance:
  - Light yield 16 p.e.
  - 99 % hit efficiency
  - 70 μm hit resolution
- Tests of irradiated mats and SiPMs show the expected results

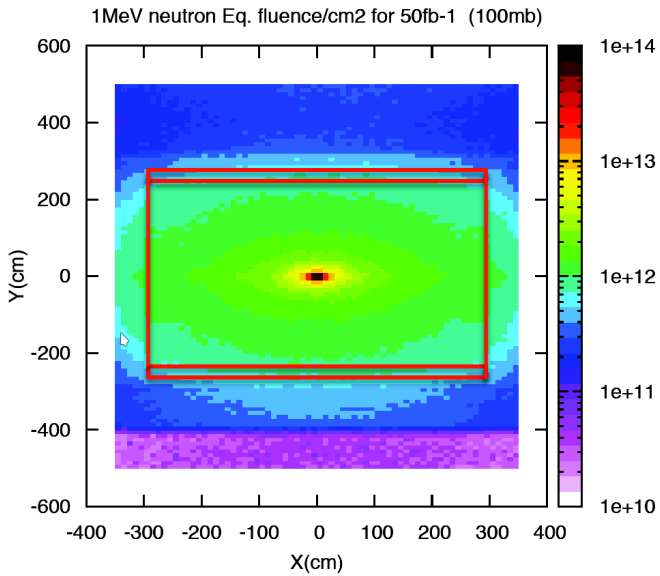


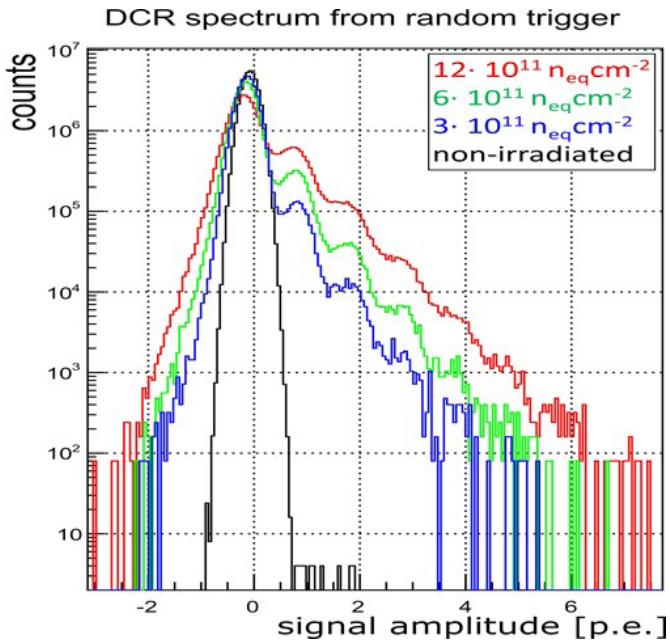
Conclusion

- The LHCb Upgrade *Scintillating Fibre tracker* is a high-resolution detector covering area of 340 m^2
- It is based on $\varnothing$ 0.25-mm scintillating fibres, read-out with SiPMs
- Nominal performance parameters have been achieved in laboratory and testbeam measurements
  - The 2.5-m long fibre mats provide $\geq$ 16 p.e. light yield and 99 % hit efficiency
  - Hit position resolution $\sim$70 μm
- The detector and electronics are in production stage, with planned installation in LS2 (2019–2020)

Additional Slides

SiPM Cooling





- Maximal ionising dose
  - 25–35 kGy (fibres)
  - 40–80 Gy (SiPMs)
- Neutron fluence at SiPMs location: 6×10^{11} neq/cm^2 (after)
- DCR decreases by a factor of 2 every 10 degrees
- Nominal operation temp.: $-40\,^{\circ}$C
- Use single-phase coolant Novec 649 or C_6F_{14}