A Scintillating Fibre Tracker

SPS-CHIPP Annual Plenary Meeting, August 2016

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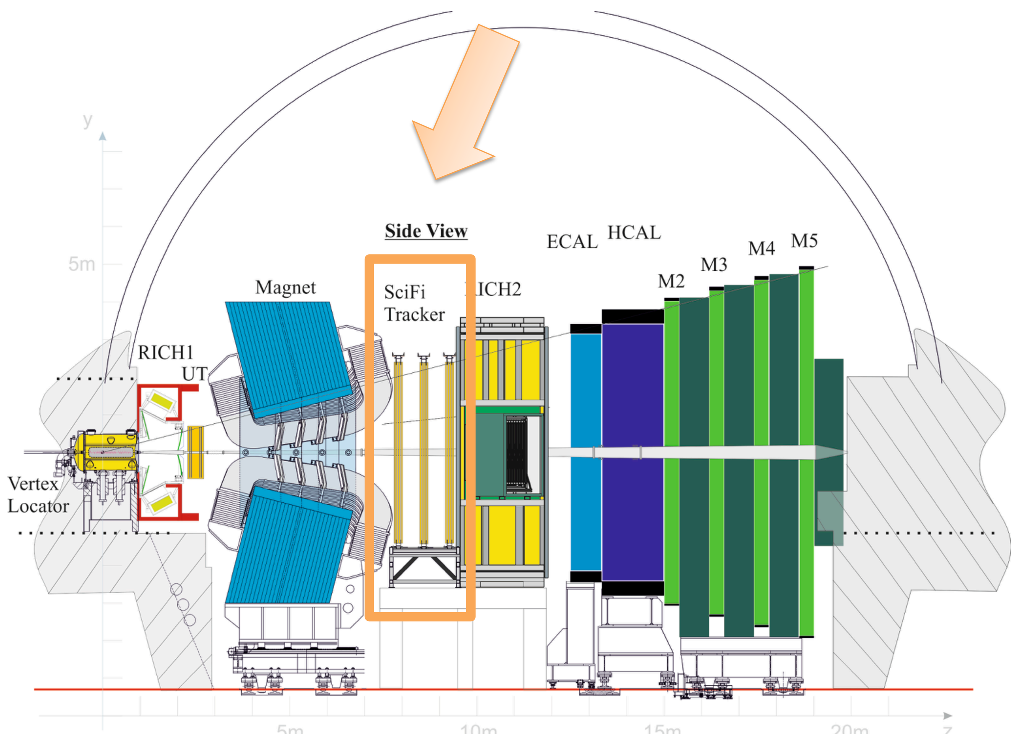
A scintillating fibre tracker for LHCb [1][2]

The LHCb detector will continue collecting data until the second long shutdown (LS2) of the LHC. At this point the detector will be upgraded with several new sub-detectors. The current Inner and Outer Tracker will be replaced with a scintillating fibre tracker (SciFi).

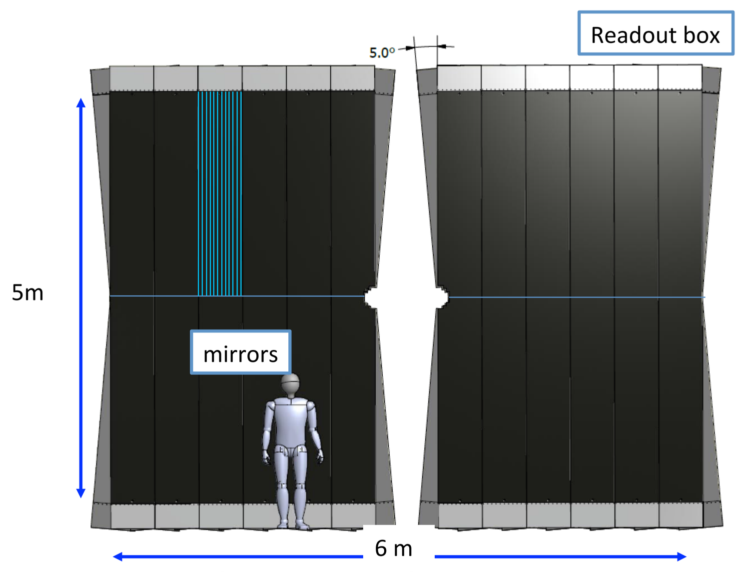
Motivation:

- **increase luminosity to $2x10^{33}cm^{-2}s^{-1}$**
- **Trigger-less readout at 40MHz**



The SciFi requirements are:

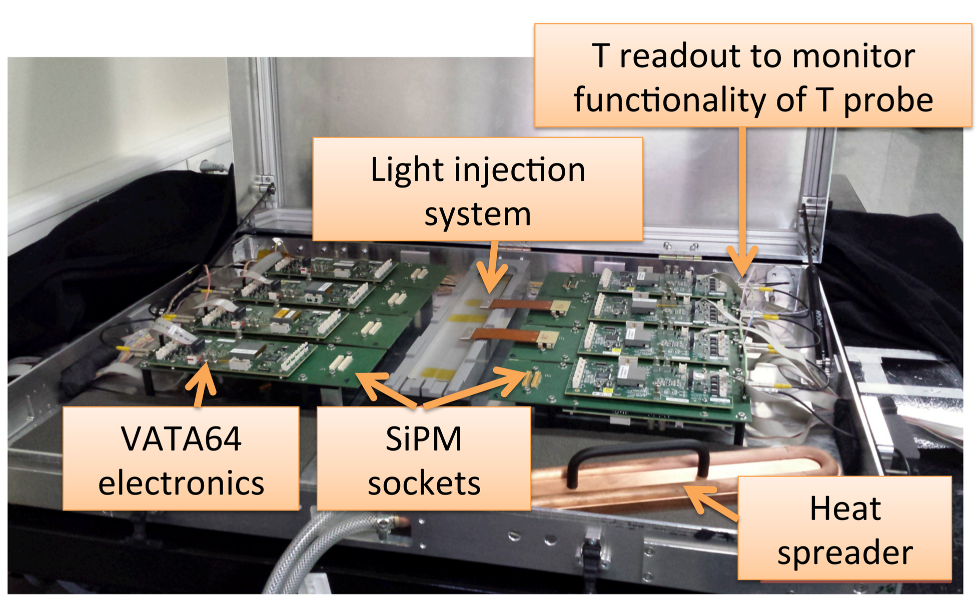
- Hit detection efficiency of >98%
- Spatial resolution of better than 100 µm.
- Operation in radiation environment ($6x10^{11}$ 1MeV n_{eq}/cm^2 at the SiPM)
- Fast recovery time <50ns
- Minimal dead zones with no overlapping planes



The SciFi Tracker stations

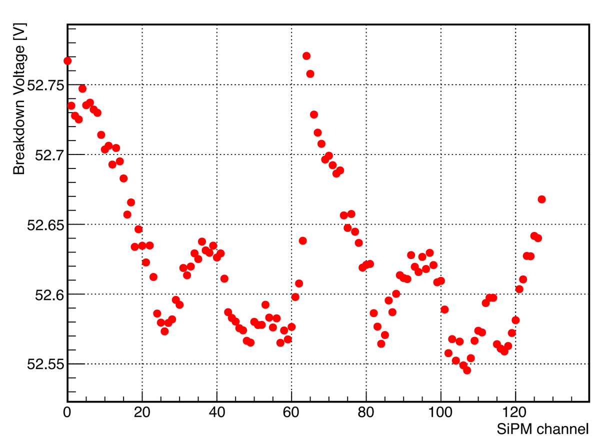
SiPM QA

SiPM functional test and breakdown voltage measurement ΔV_{bd}=50mV

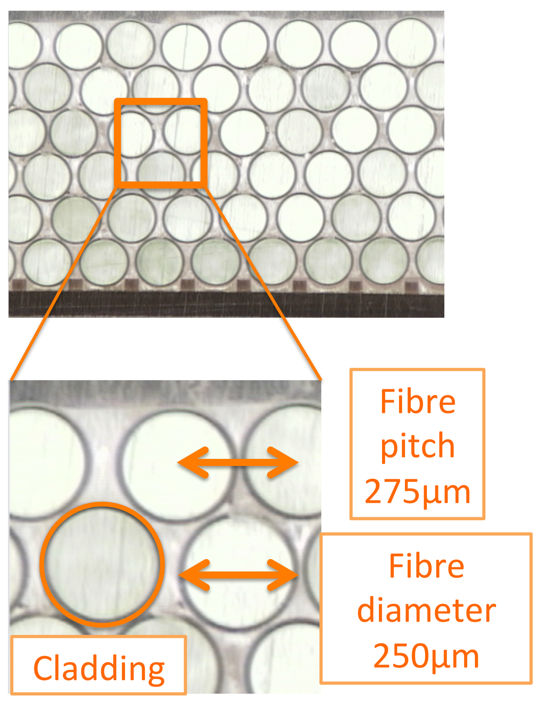


Goal: Quality assurance and characterisation of breakdown voltage for each SiPM channel

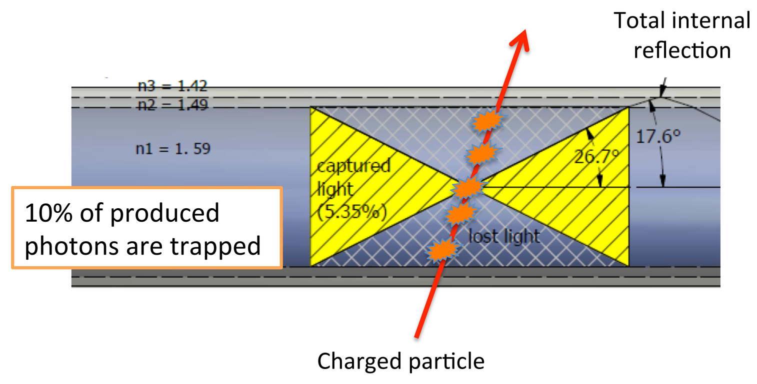
- Light tight box, easy access for detectors, cooling for temperature control with homogenous light injection
- Test of all electrical connections
- Breakdown voltage measurement for 8 detectors in less than 10min

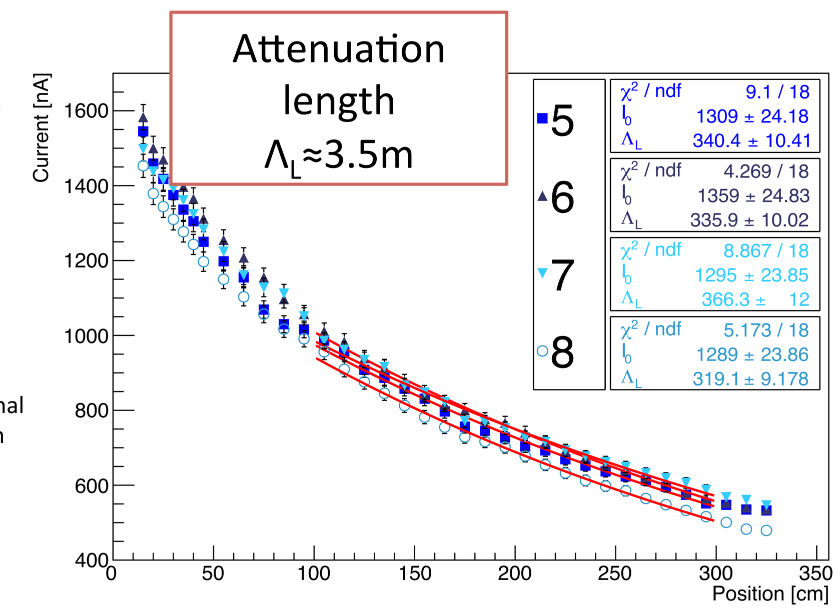


Scintillating fibres Kuraray SCSF-78, 250µm diameter [3]



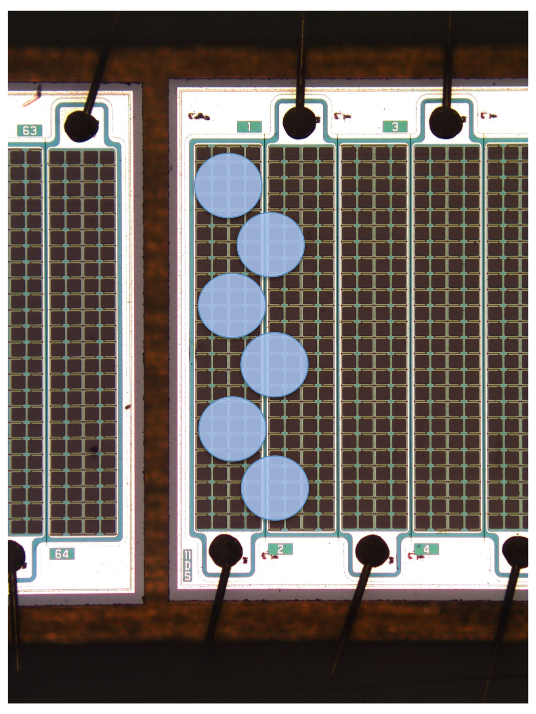
- Polystyrene, double cladded, blue emitting (peak at 440nm), fast decay time (2.8ns)
- Fibre mats, six layers, 2.5m long, tightly packed
- One sided readout with mirror on the opposite side





Attenuation length measured for different fibre batches

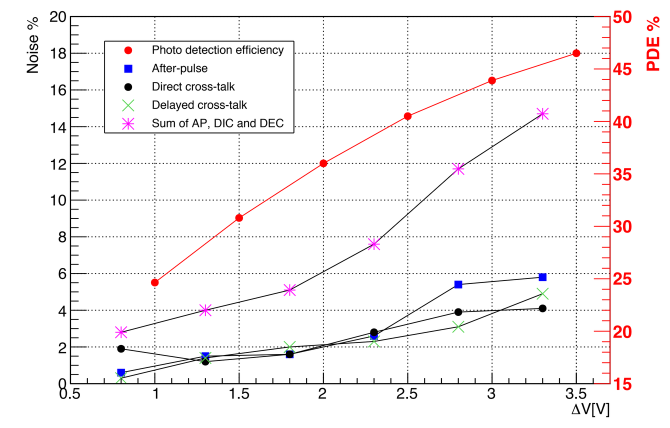
Silicon photomultiplier Hamamatsu 128 channel array [4]



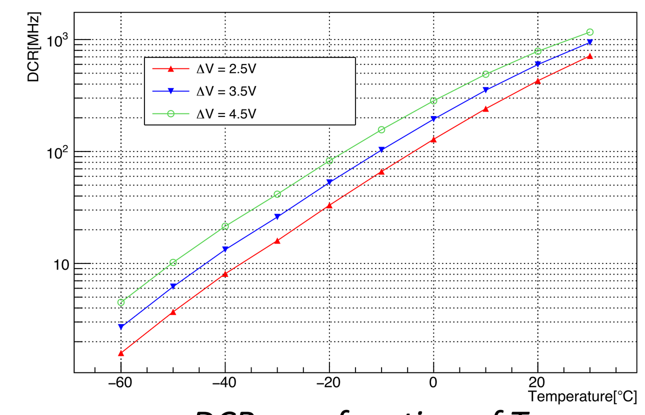
Hamamatsu LCT5 SiPM
128 ch x (250µmx1620µm)
104 pixel/ch
(57.5µmx62.5µm),

Customised SiPM from Hamamatsu (H2015):
(Benchmarked at ΔV=3.5V)

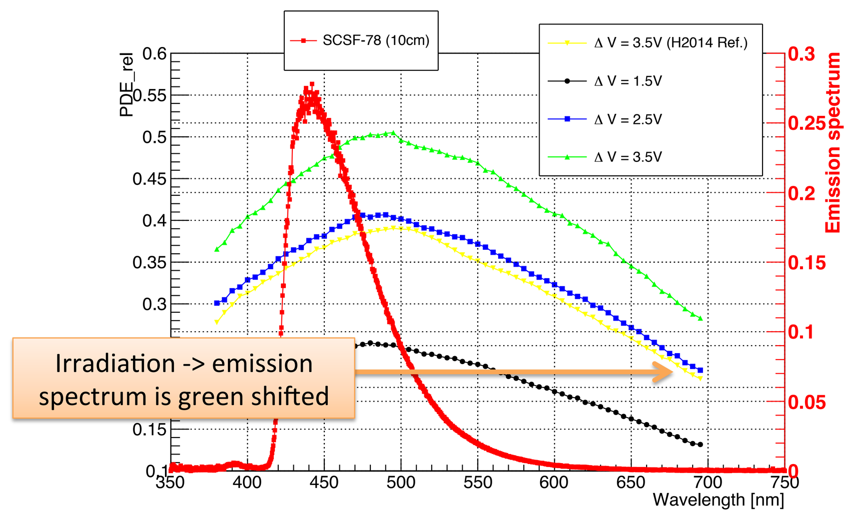
- Photon detection efficiency (PDE) = 50% and excellent match to the fibres emission
- Dark count rate (DCR) = 15MHz/ch (at -40°C) after irradiation with neutrons at $6x10^{11}$ 1MeV n_{eq}/cm^2
- Pixel recovery time = 50ns
- Cross-talk = 9% (trenches for optical cross-talk suppression)
- After-pulse = 6%



PDE and correlated noise as a function of ΔV



DCR as a function of T

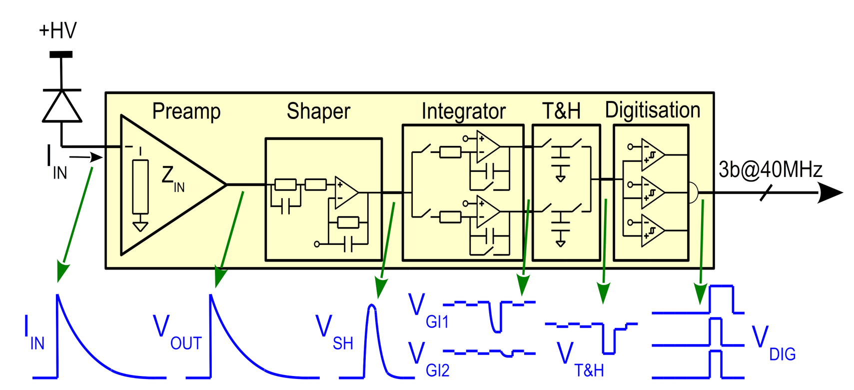


PDE as a function of wavelength

Readout electronics [5]

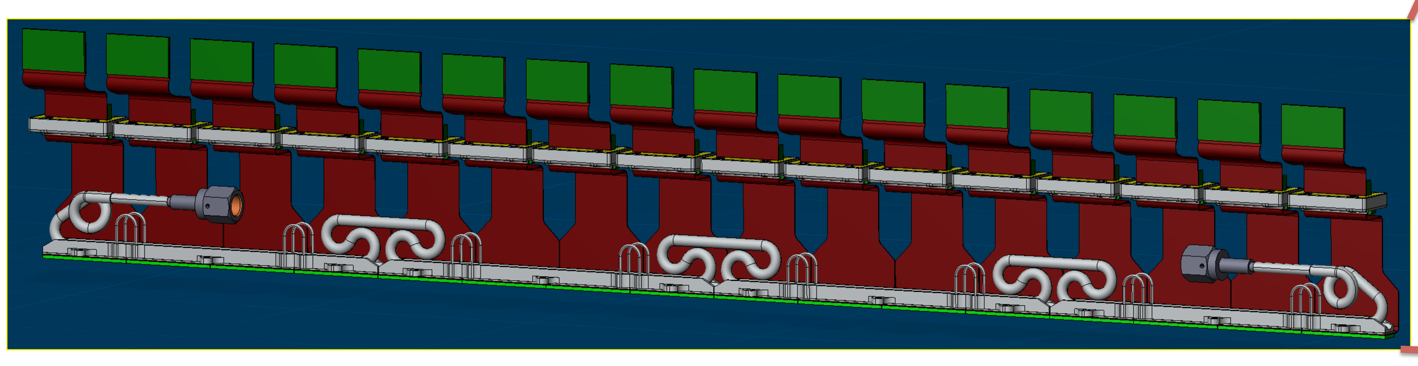
Custom LHCb front-end ASIC (PACIFIC)

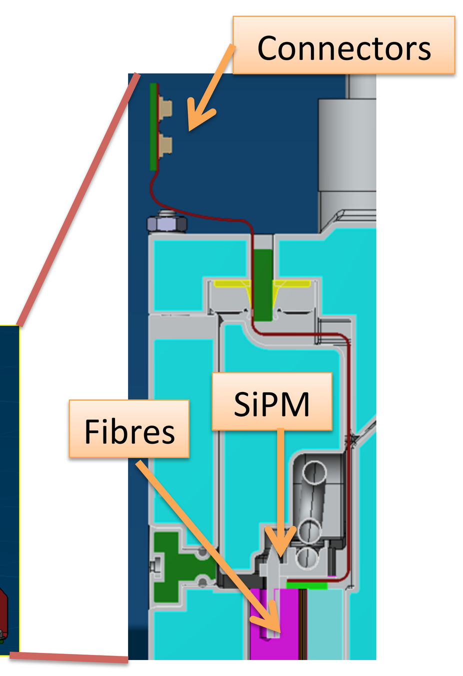
- 64 channel current mode input
- High bandwidth = 250MHz
- Adjustable input anode DC voltage (4-bit DAC) (0-1V)
- Configurable fast shaper
- Interleaved two gated-integrator (no dead time)
- 2-bit non-linear digitalisation per channel (3 thresholds)
- Zero suppression and clusterisation on FPGA, data transmission with optical link



Cooling box

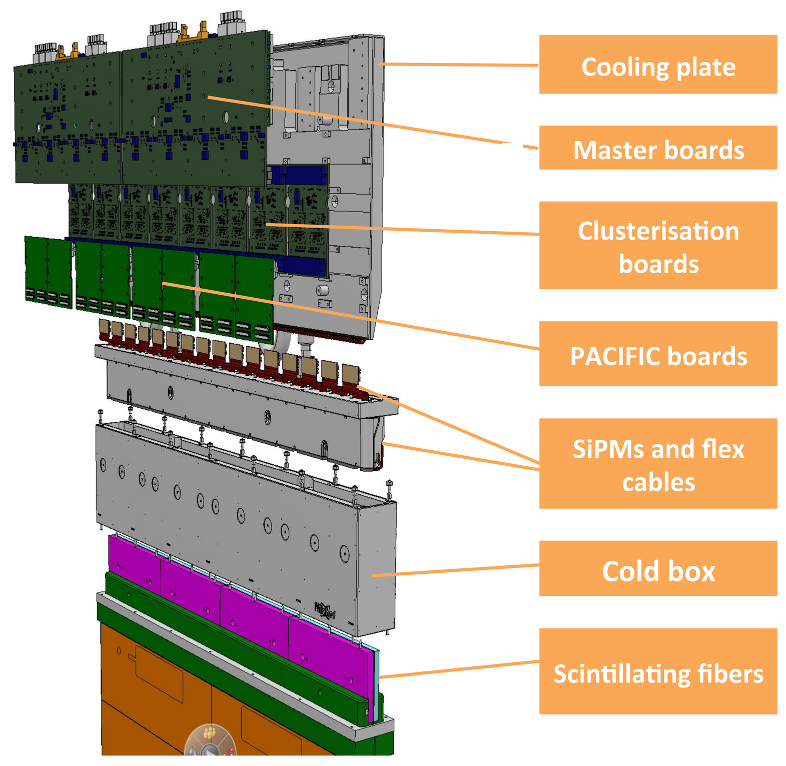
- SiPM cooled down to -40°C
- SiPM is glued to the cooling pipe and optically aligned
- 3D printed Ti cooling pipe
- Integration into a vapour tight cooling enclosure, vacuum insulated cooling pipes
- Cooling with a liquid chiller (Novec or C_6F_{14}))





SiPM feedthrough

Exploded view



References

[1] LHCb collaboration, A. A. Alves Jr. et al., *The LHCb detector at the LHC*, JINST 3 (2008) S08005.
[2] The LHCb collaboration, *LHCb Tracker Upgrade, Technical Design Report*, CERN, CERN LHCC 2014-001
[3] The LHCb SciFi collaboration, *LHCb Scintillating Fibre Tracker Engineering Design Review Report: Fibres, Mats and Modules*, CERN LHCb-PUB-2015-008
[4] Axel Kuonen et al., *Characterisation of the Hamamatsu MPPC multichannel array for LHCb SciFi Tracker v.12.2015*, CERN LHCb-INT-2016-017
[5] The LHCb SciFi collaboration, *LHCb Scintillating Fibre Tracker Engineering Design Review Report: PACIFIC Readout ASIC*, CERN LHCb-PUB-2016-013