Optimisation of the Scintillating Fibre detector for the LHCb Upgrade

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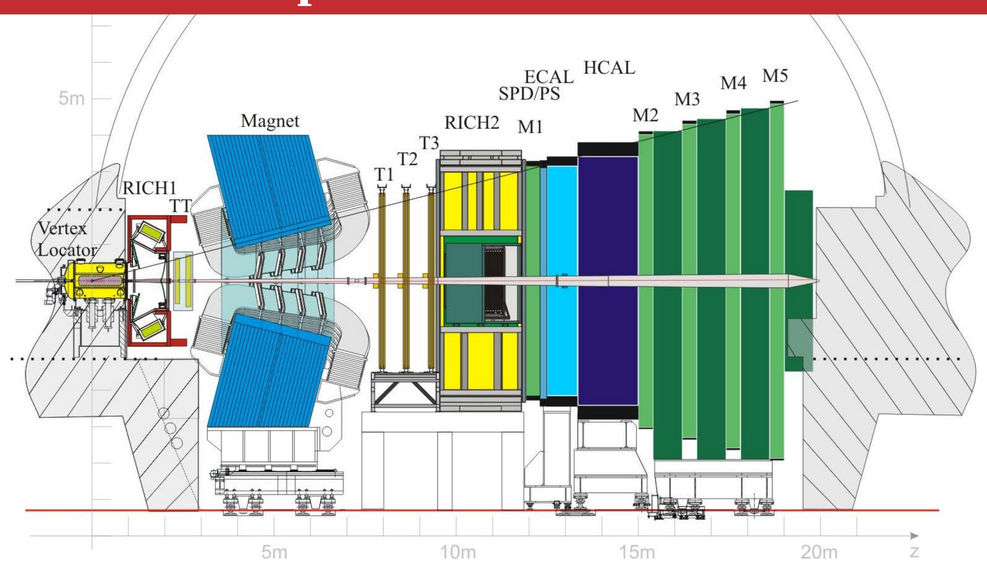
The LHCb experiment



- single arm forward spectrometer installed at the LHC
- precision measurements of decays of *b*-hadrons and *c*-hadrons in the forward direction
- events produced in *pp* collisions with $\sqrt{s}$ up to 13 TeV

The LHCb Upgrade on 2021

LHCb Run III conditions:

- L = 2 x 10^{33} cm^{-2} s^{-1} (x 5 Run II)
- higher spillover and pile-up
- too high occupancy for current tracking detectors

Detector upgrade:

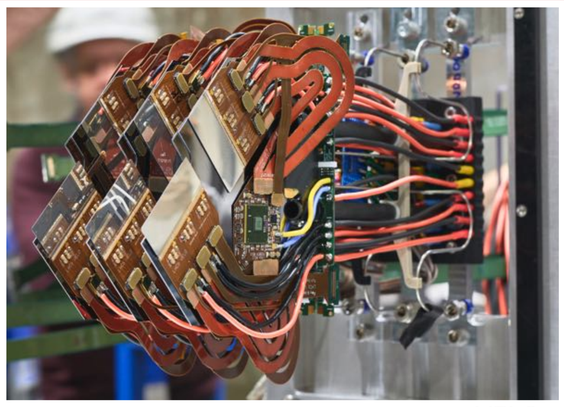
- 40 MHz readout of the full detector (x40)
- increased granularity of tracking detectors
- radiation hardened for recording 50 fb^{-1}

Tracking detectors at the LHCb Upgrade

Vertex Locator:
pixel detector, precise measurement of primary and secondary vertices

Upstream Tracker:
microstrip detector,
fast evaluation of momentum for triggering

Scintillanting Fibre tracker:
plastic scintillating fibers technology,
high-precision measurement of momentum



VELO modules

Reconstruction of particles within the SciFi detector

- detector designed to meet the requirements on the physics performances

δp/p ~ 0.2 – 0.4%	→	hit resolution < 100 μm in the bending plane
full coverage of LHCb acceptance	→	6x5 m^2 sized layers
must cope with large combinatorics	→	12 detector planes
25 ns spacing between events	→	low spillover rate

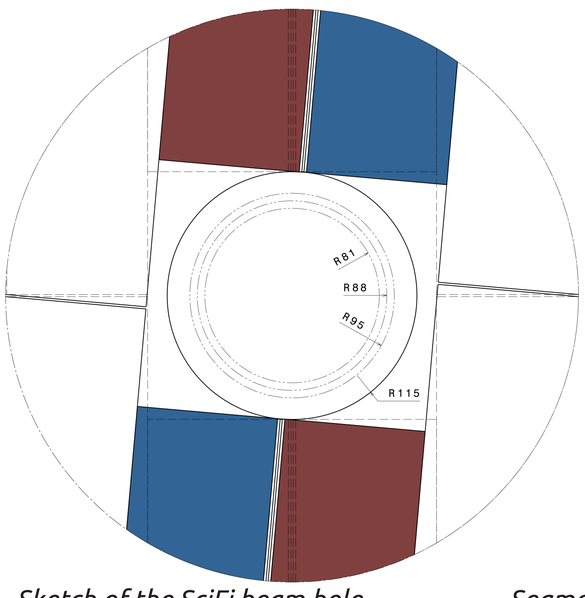
- the design needs to be optimised as function of the tracking performances

+1% *overall* hit inefficiency	→	-2% reconstruction efficiency
higher number of layers	→	more stringent reconstruction requirements, but increased multiple scattering
larger layers	→	larger acceptance, but larger combinatorics

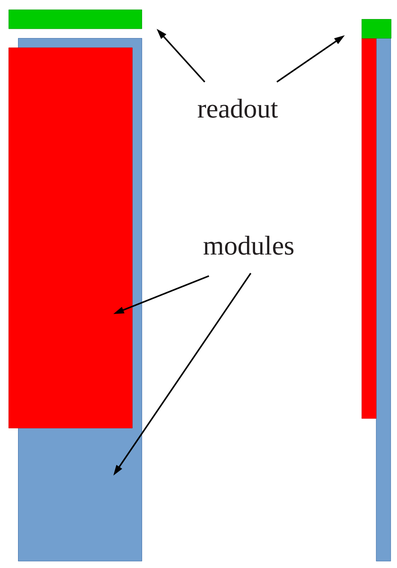
First layer frame of the SciFi tracker

Detail of the SciFi infrastructure

SciFi geometry optimisation



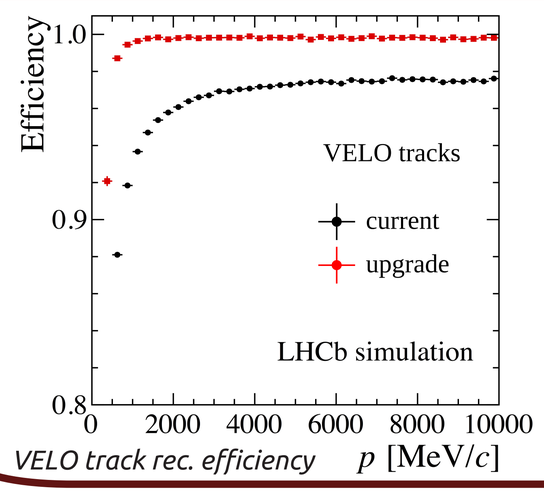
Sketch of the SciFi beam hole



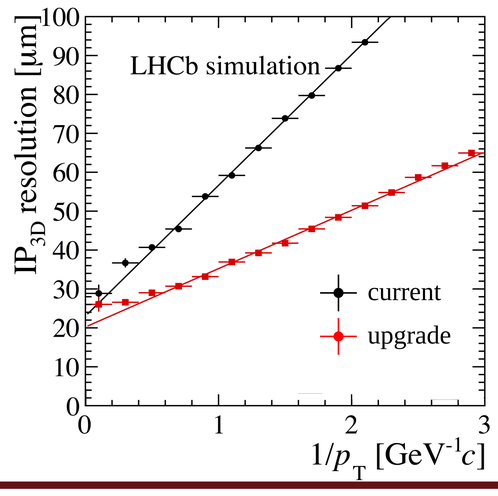
Segmentation of the SciFi layers, by coupling modules of different sizes

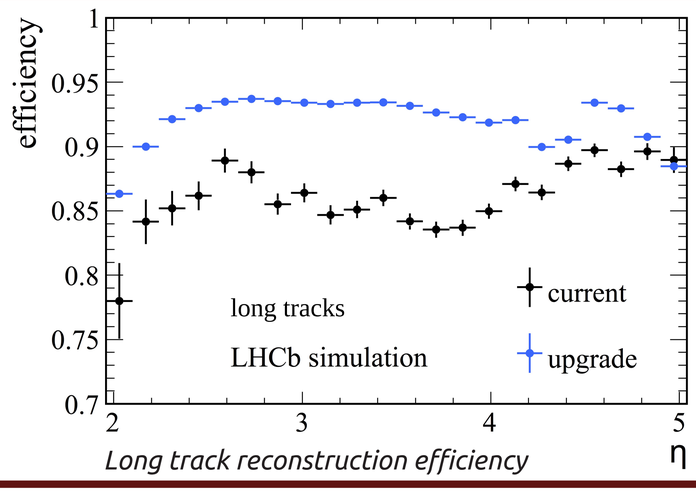
- the detector geometry has been optimised for achieving the best tracking performances
- detailed simulations implemented in GEANT for various geometries of the tracker
- optimisation of the beam hole to meet the engineering constraints
- study of an alternative segmentation of the detector with coupled modules
- impact of the detector hit inefficiency on the tracking performances
- impact of the hit clustering on the hit resolution, spillover and tracking performances
- **tracking studies have been important for defining the final detector design**

Reconstruction performances

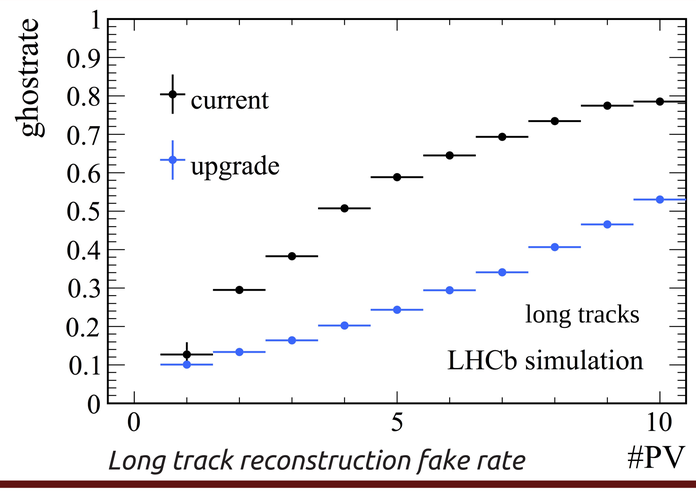


VELO track rec. efficiency





Long track reconstruction efficiency



Long track reconstruction fake rate

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**

[3] **A. Piucci, A. Mogini, S. Esen.** *A study on Scintillating Fiber tracker optimisation for the LHCb upgrade*, **LHCb-PUB-2017-016**