Edge Studies on Sensors for the LHCb VELO Upgrade

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The LHCb Detector

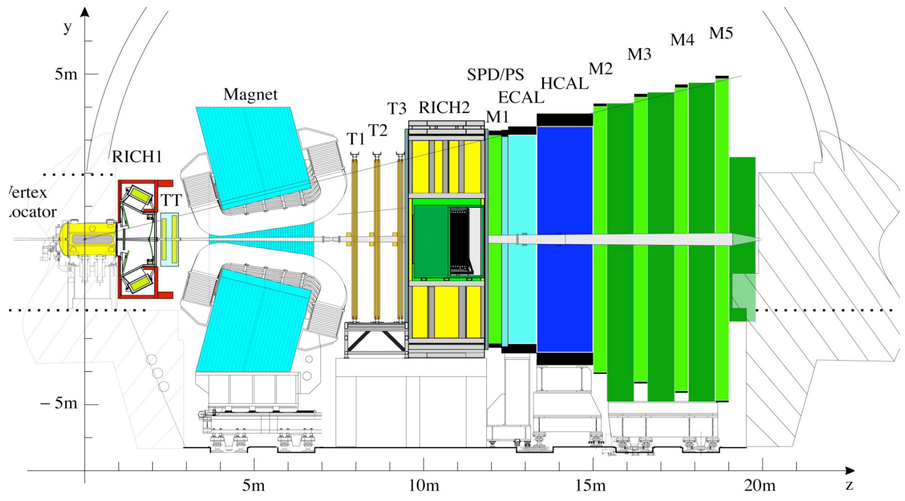


Figure 1 LHCb side view.

The LHCb detector is a single arm spectrometer dedicated to search for New Physics by studying rare decays of beauty and charm hadrons. It runs at a luminosity of 4 x 10^{32} cm^{-2} s^{-1} and the integrated luminosity is expected to increase to 8 fb^{-1} at the end of Run II.

Why Upgrade for Run III (2021)?

- No evidence of New Physics so far → more statistics needed
- Need to increase hadronic yield by factor ~10 → increase luminosity to 2 x 10^{33} cm^{-2} s^{-1}
- Limited to 1MHz readout by hardware trigger → triggerless readout at 40 MHz

VELO Upgrade

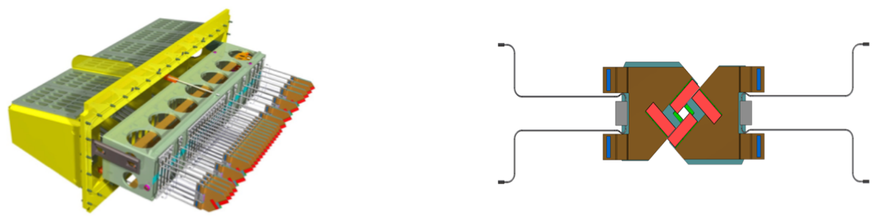


Figure 2 VELO half box comprising 26 modules (left) and front view of one module (right).

Main changes for VELO [1]

- From strip sensors to hybrid pixel detectors
- All data to CPU farm
- CO_2 cooling in micro-channel substrate
- Closer to the beam (from 8.2 mm to 5.1 mm)

Testbeam

The dedicated telescope, assembled in the SPS North Area at CERN, provides particle tracking position and timestamp at high rate with respect to the previous telescope [2]. It comprises 8 Timepix3 detector planes arranged in two arms and angled at 9 degrees in both horizontal and vertical axes to optimise the spatial resolution. The Device under Test (DuT) station is located in the center of the system on a translation and rotation stage.

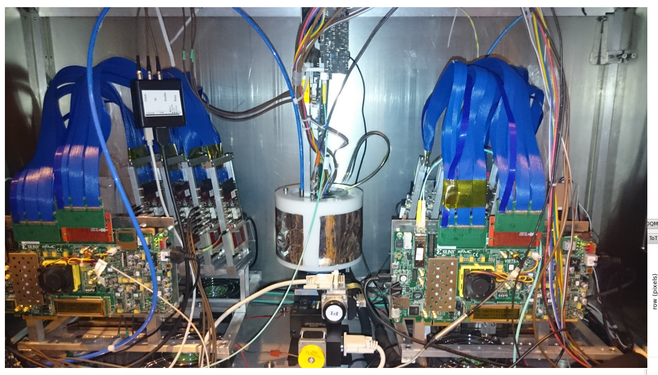
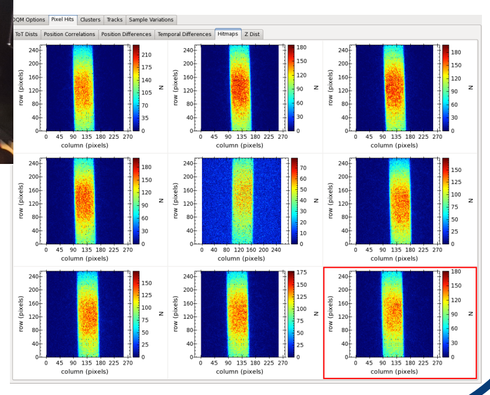


Figure 3 Picture of the telescope (left) and typical acquisition window at the testbeam (bottom) showing the beam spot.



Under test are a wide range of different sensors, irradiated (both uniformly and non-uniformly) and non-irradiated.

Edge Analysis

The sensors considered for the LHCb VELO upgrade use guard ring electrodes to gradually reduce the electric field towards the edge. The purpose of this study is to understand if the pixel matrix is isolated from the edge effect and which type of device is the most suitable for the upgrade according to this aspect.

Sensors

Analyzed sensors from 2 different vendors tested at the 2014-2015 testbeams.

- 55 x 55 micron pixel size
- sensor n-in-n and n-in-p type
- different guard ring width (450-250 micron)

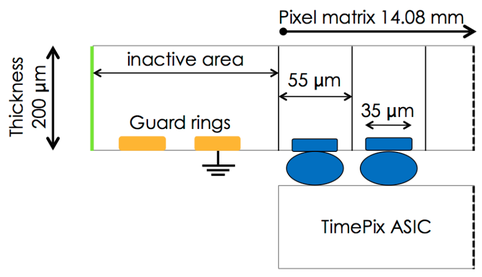


Figure 4 Sensor scheme.

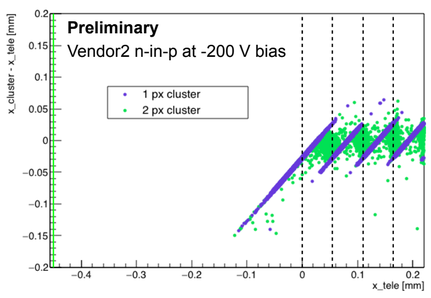


Figure 5 Residuals in X as a function of the X coordinate predicted by the telescope at the edge of the sensor. The dotted lines represent the pixel boundaries and the green line the physical edge. The plot shows that there are clusters associated to tracks beyond the edge.

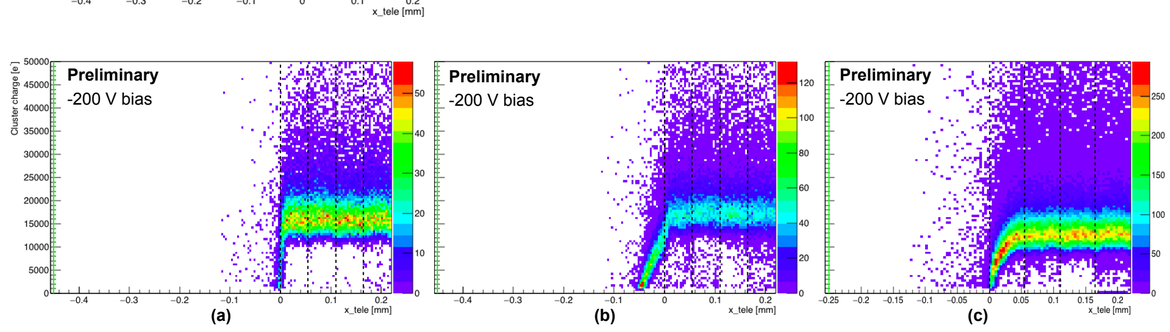


Figure 6 Charge distribution as a function of the X coordinate as predicted by the telescope at the edge of the sensor. The dotted lines represent the pixel boundaries and the green line the physical edge. (a) Vendor1 n-in-p sensor. (b) Vendor2 n-in-p sensor. (c) Vendor2 n-in-n sensor.

Every type of sensor presents a low charge deposit at the edge. The charge excess in Fig. 6b has a linear behaviour and extends beyond the edge, involving ~1 order of magnitude more tracks than the others. This charge is collected from the edge region in the first pixel column. The shape of the charge distribution of Fig. 6c instead indicates a loss of charge in the last pixel near the edge.

Outlook

These preliminary results show that the 3 types of non irradiated sensors have a different behaviour at the edge.
The probe of more sensor of the same type (tested at the July testbeam) is needed to confirm these results. Further analysis on angle runs will allow to look deeper into the reasons for the different charge deposit distributions.
The analysis of irradiated sensors will follow to understand the effect of radiation on the charge distribution at the edge.

Aknowledgments

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References

[1] LHCb Collaboration, LHCb VELO Upgrade Technical Design Report, Tech. Rep. CERN-LHCC-2013-021, CERN, Geneva, Nov, 2013.

[2] K. Akiba, et al., The Timepix Telescope for High Performance Particle Tracking, Nucl. Instrum. Meth. 723 (2013) 47, arXiv:1304.5175v1.