Software platform for the monitoring and calibration of the upgraded LHCb VELO

Epiphany 2019

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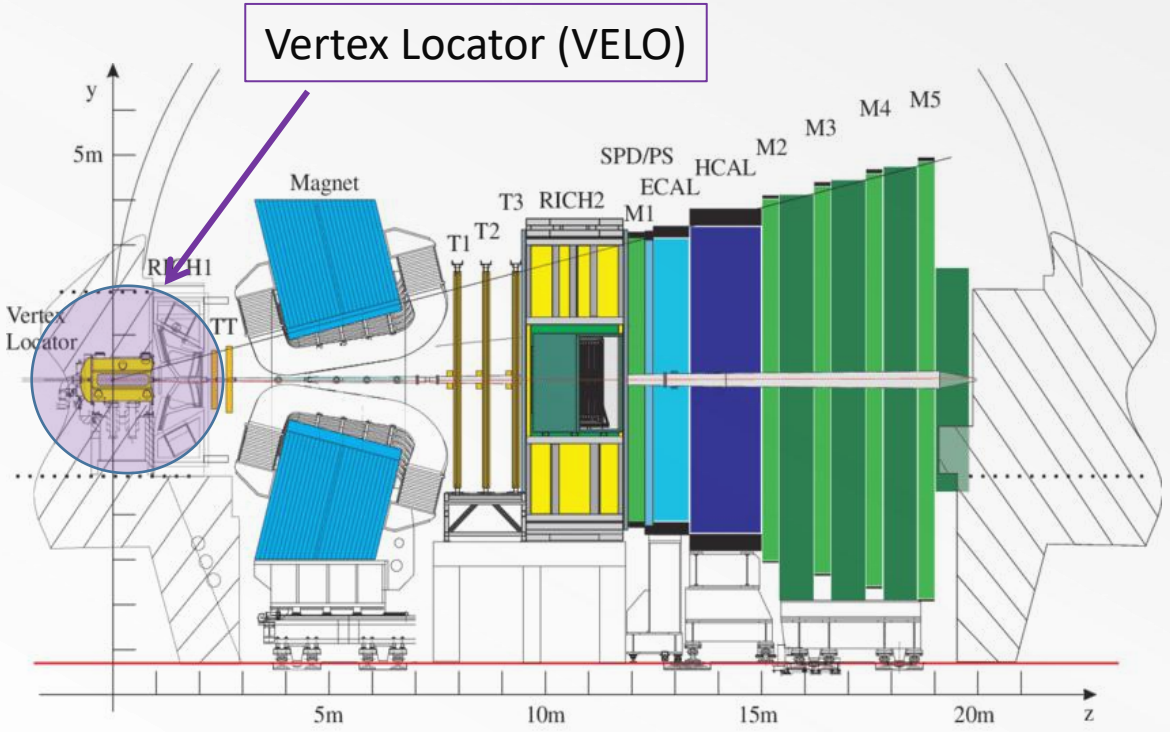
LHCb experiment

- Dedicated to searching for New Physics, by studying rare b- and c-quark decays in pseudo-rapidity region $2<\eta<5$
- Forward single-arm spectrometer with high vertex resolution CERN-LHCC-2011-001
- Upgrade 2019-2020 to triggerless read-out at 40 MHz CERN-LHCC-2014-016

VELO detector

- Vertex Locator (VELO) specialised in reconstructing primary and secondary vertices
- During LHCb Upgrade, replacing VELO strip detector with new silicon pixel detector

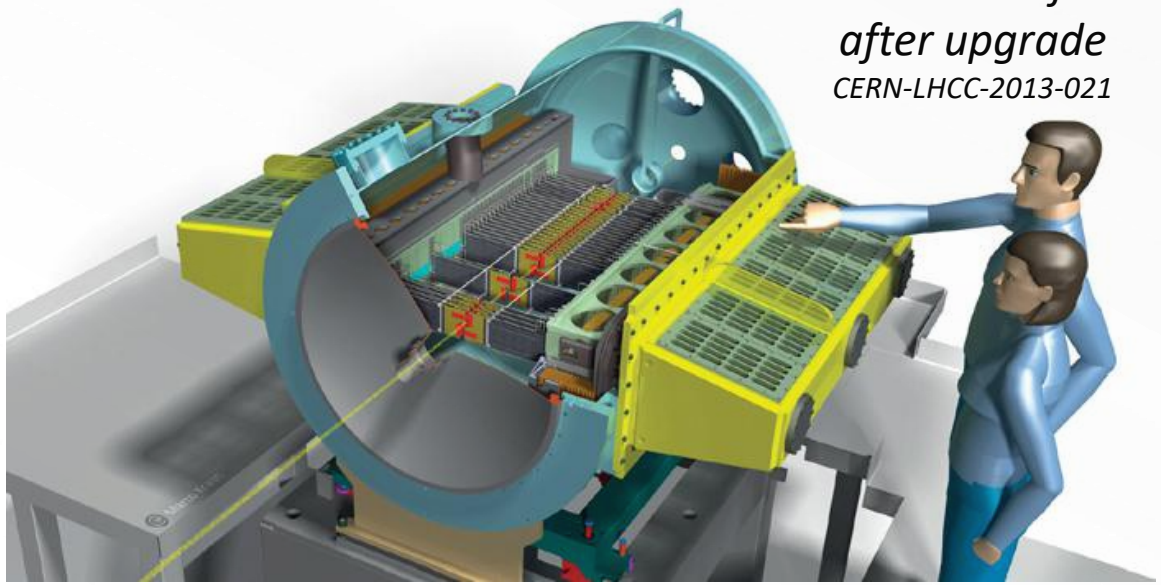


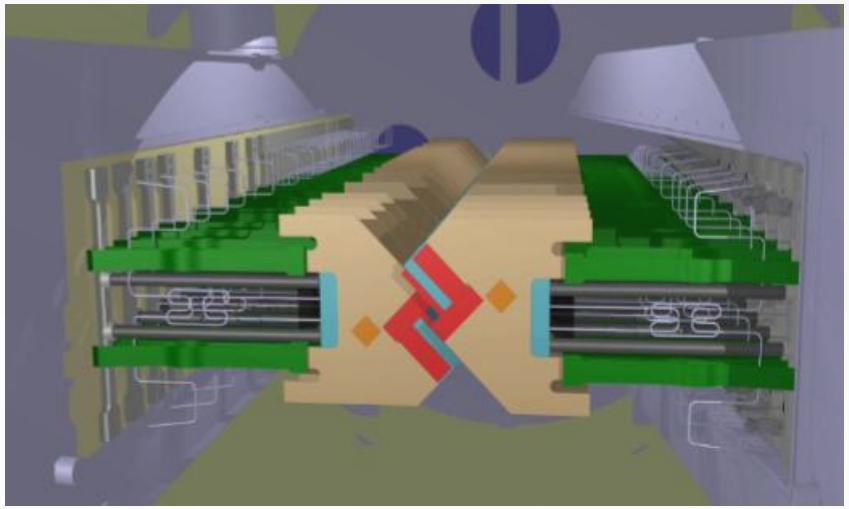
LHCb detector
CERN-LHCC-2011-001

Velo detector upgrade

- From silicon strip detector to pixel detector
- Readout rate improved from 1 MHz to 40 MHz
- Upgrade planned for 2019-2020
- Improved resolution with new ASIC VeloPix - 52 modules with 624 ASICs.

Visualisation of VELO after upgrade
CERN-LHCC-2013-021



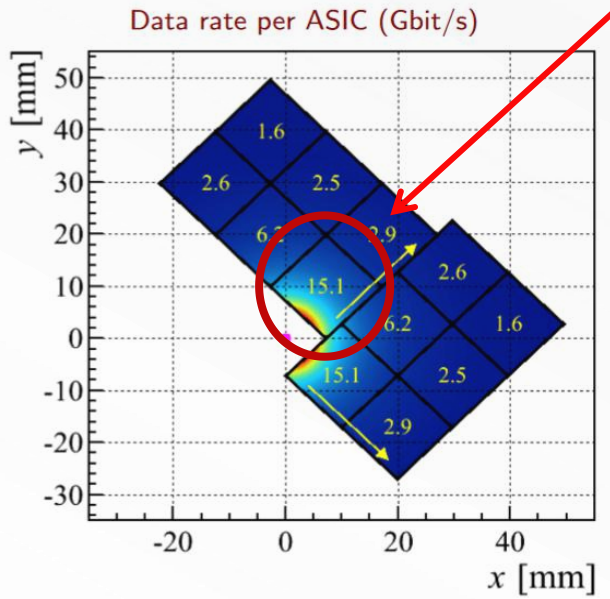


Velopix pixel detector

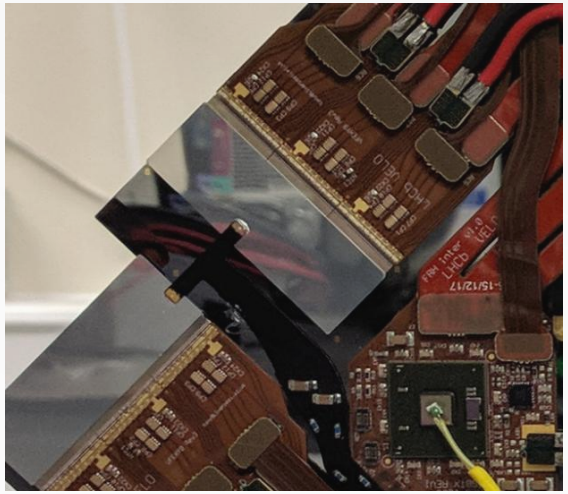
VeloPix singlet used for lab testing

256x256 pixels

- Each ASIC contains matrix of 256x256 square pixels **55x55 µm²**
- Pixels close to the beam (8.1mm to 5.1mm)
- Radiation hardness: expected 400 Mrad total ionising dose. Non uniform fluency.
- Beam closest 15 Gbit/s



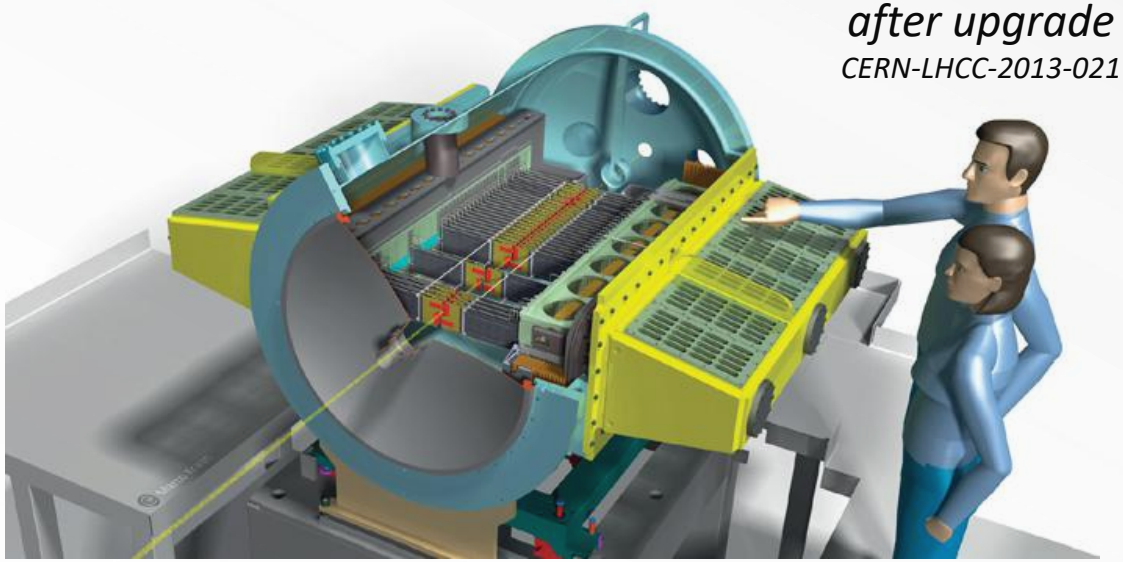
15.1 Gbit/s



Detector monitoring - motivation

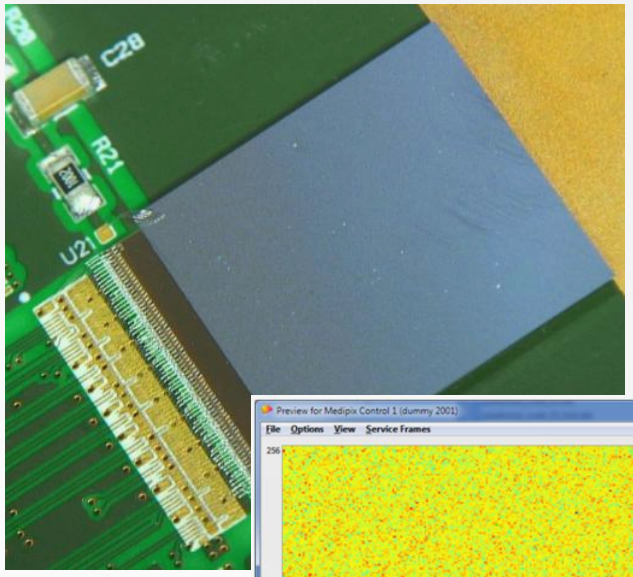
- Detector calibration parameters must be always valid, to avoid taking corrupted data
- Continuous verification of data quality, to check if all pixels in ASIC works properly - even one noisy pixel can disturb the data read-out
- Due to expected high ionising dose, detector must be monitored for radiation damage

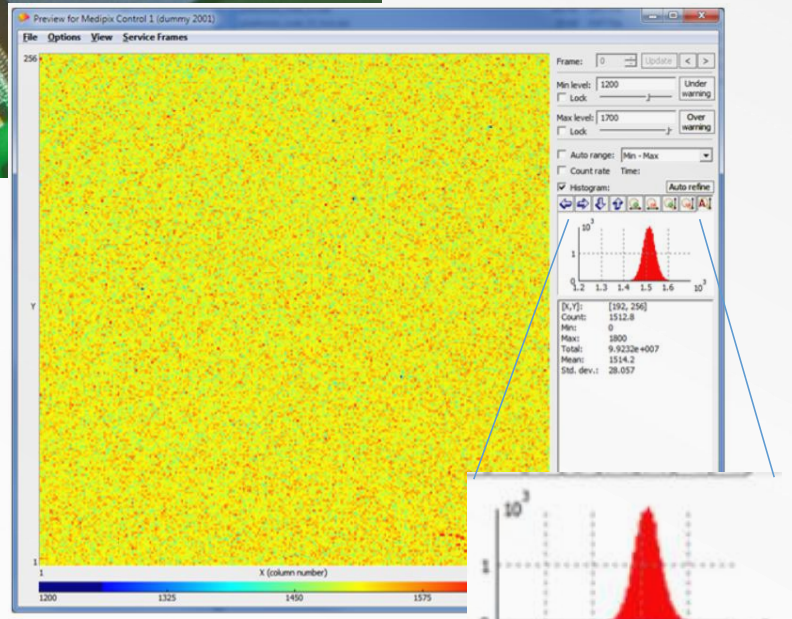
Visualisation of VELO after upgrade
CERN-LHCC-2013-021



Calibration of VELO pixel detector

- Calibration parameters can be set for each pixel separately
- Each pixel has 6-bit memory, configurable after power-up
- Two steps of calibration:
  - **Equalisation** the pedestals (baseline voltage). Algorithm trying to add trims between 0-15 DAC (1 DAC ~ 25mV) to equalise pedestal voltages
  - Absolute necessity of **masking noisy pixels**
- Continuous calibration required (monitoring)





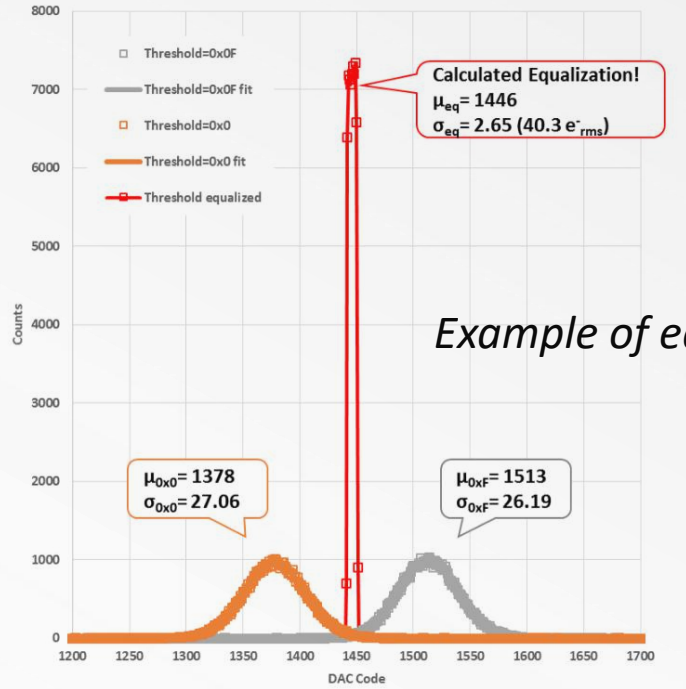
Voltage scan - unequalised pixel matrix

Trim bits	...	...	...	Masking bit	Test pulse on/off bit

Pixel memory cell

Equalisation

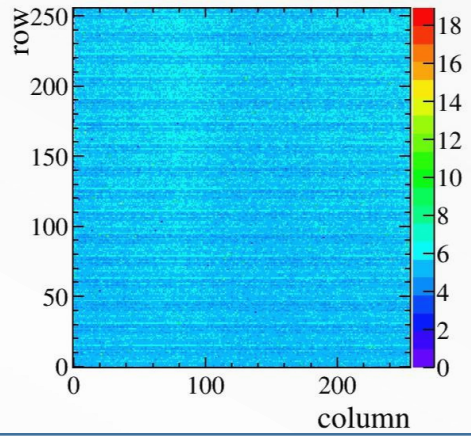
- **Equalising pedestal level** of all pixels is the most important thing in view of calibration
- Equalisation required frequency to be examined



Example of equalisation

Noise scan

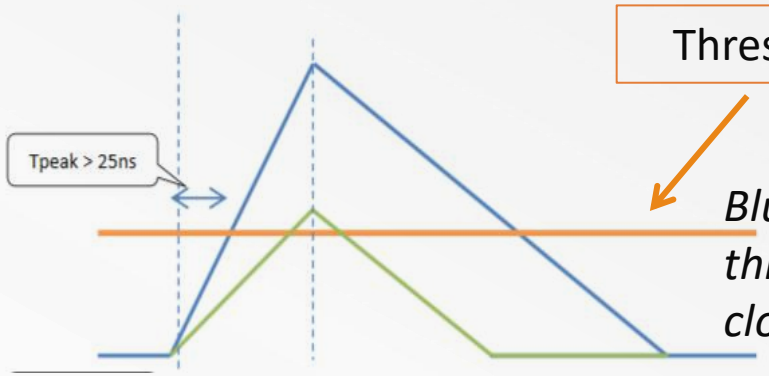
- From noise distribution we can **eliminate (mask) noisy pixels**, as pixel's sigma of noise is higher than certain value.
- Noise map is also correlated with temperature map, which can be used in temperature evaluation, thus in radiation damage rating



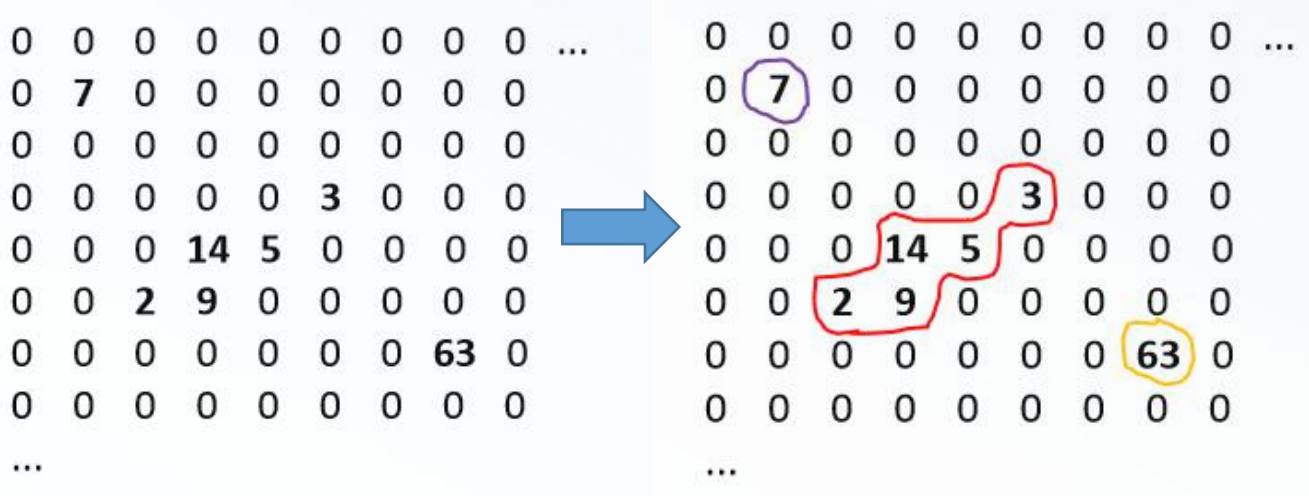
Example pixel noise map

Time over threshold (ToT) scan

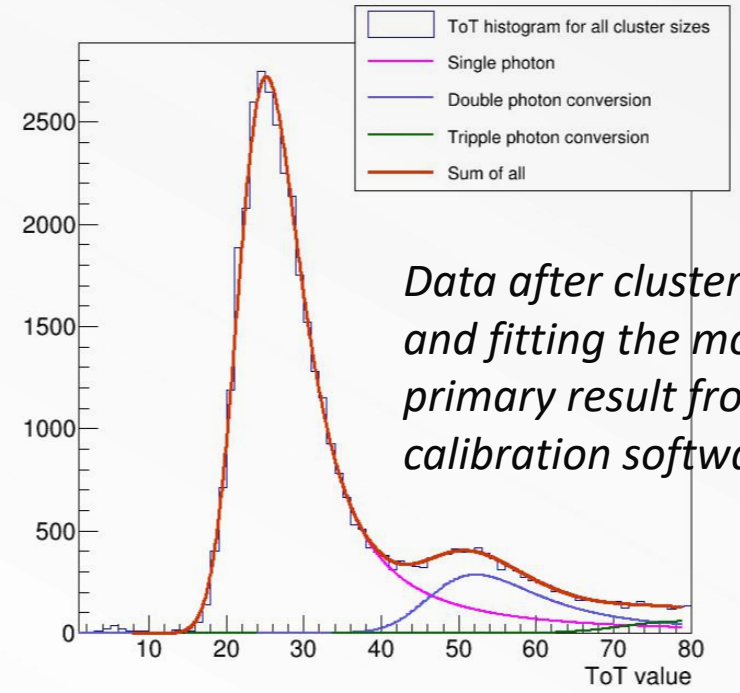
- Selected example of functionality - ToT scan
- Data collected by calibration software are grouped in text files of 256x256 5-bit integer numbers
- Necessity of clusterization (charge from one event can spread to nearly located pixels)



Blue/green signal crosses threshold and lasts n clock cycles (ToT)



Example of clusterization



Data after clusterization and fitting the model - primary result from calibration software

Summary

Current status:

- Software implemented and tested on Velopix prototypes and during the October 2018 testbeam

Goals:

- Developing of continuous monitoring, calibration and data storage system
- Examine the required frequency of performing equalization (or noise scans)
- Further software improvement
- Platform ready to use before end of LHCb Upgrade

Velopix singlet under lab testing in Krakow