LHCb VELO Upgrade

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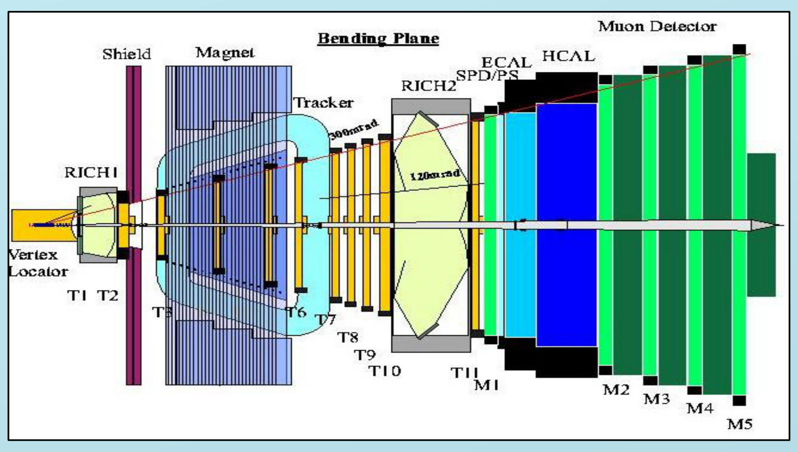
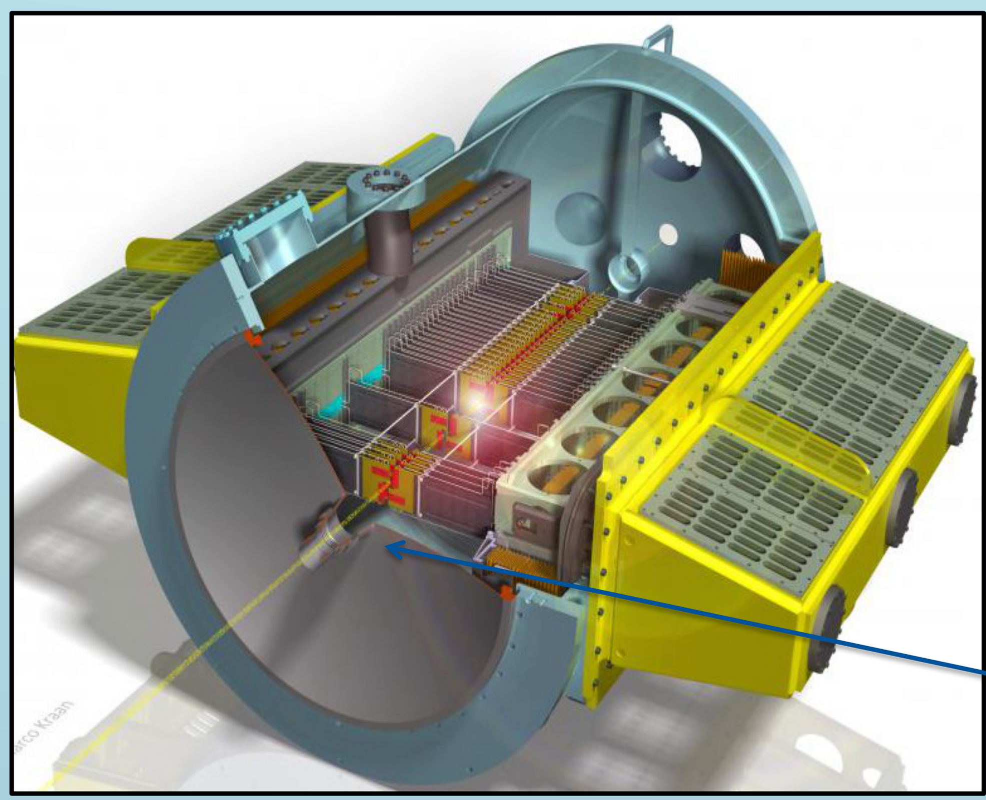
During Long Shutdown 2 (LS2) of the LHC, LHCb will undergo a series of upgrades to many of its sub detectors. LHCb aims to run at a luminosity 5 times greater than the current luminosity, requiring upgrades to the readout to all of the sub detectors and redesign of all front end electronics. The increased rate means many of the detector components will exposed to much harsher running conditions therefore the new detector components must be radiation hard. This is predominantly required for the Vertex Locator (VELO) due its proximity to the beam.[1]



The LHCb Detector

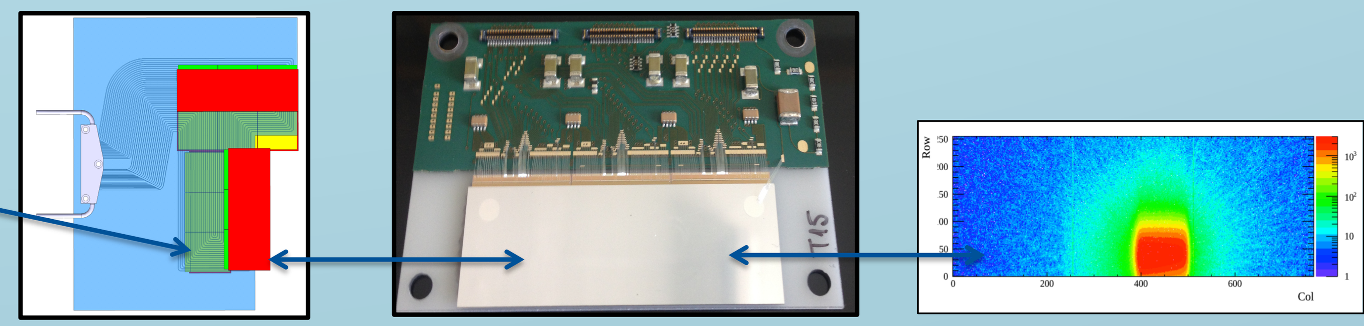
Vertex Locator (VELO)

The VELO measures the particle trajectories close to the interaction point, separating the primary and secondary vertices. Much of the mechanical infrastructure will be reused, but the previous silicon strip sensors will be replaced with hybrid pixel detectors. The VELO will be installed within the LHC beam pipe vacuum, allowing the closest pixel to be 5.1mm away from the beam centre.[1]



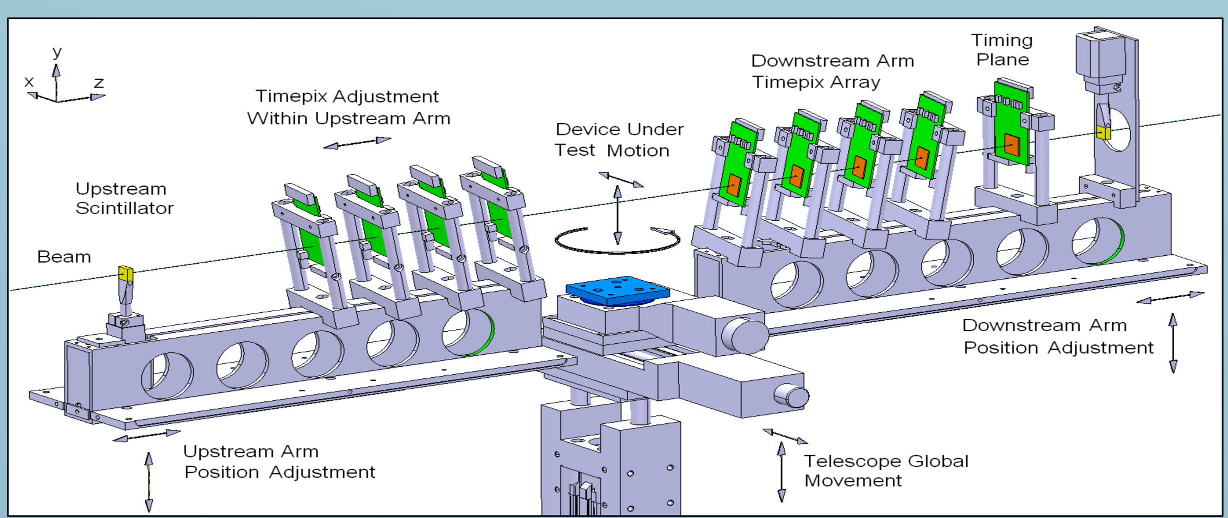
Sensors

Timepix3 ASIC bump bonded to 200 micron planar silicon n-on-n or n-on-p to silicon sensor chip. 256x256 square pixels (55mm per side) resulting in an active area of ~14x14mm^2. Providing time over threshold (ToT) information and time stamping.



Artist impression of upgraded VELO detector, Pixel module, Triple sensor, Data from SPS testbeam.

Testbeam – Timepix Telescope



Schematic of the Timepix Telescope

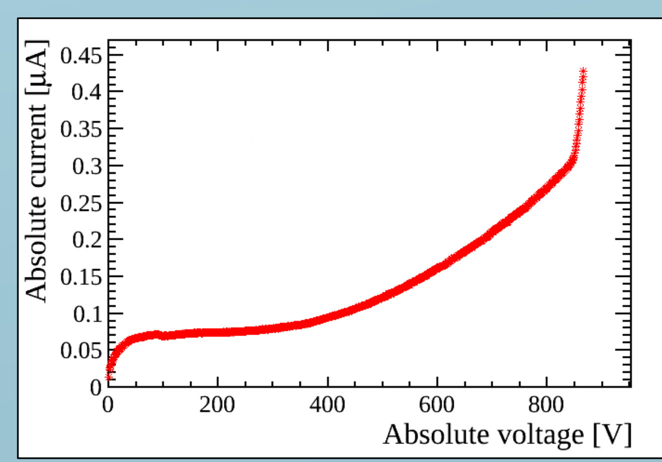
To study different characteristics of sensors it is useful to have information about the incoming trajectory. The timepix telescope can be placed into the SPS beam line to investigate the performance of the sensors while varying bias voltage, track incident angle and chip settings, leading to detailed analysis of the resolution, efficiency and charge sharing performance.[2]

Lab Testing

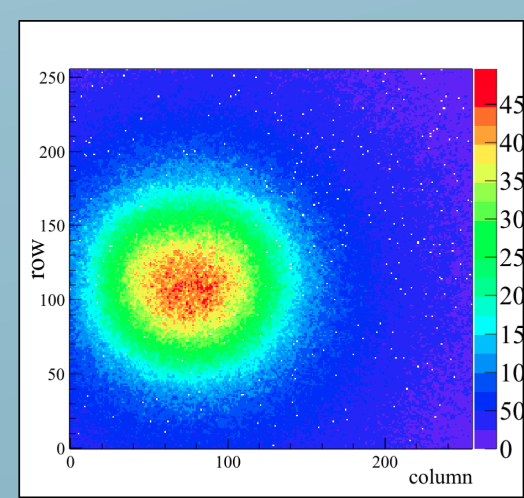
The sensors go through a series of testing in a lab environment before they can be tested using the TimePix3 Telescope. The standard testing procedure includes:

- IV scan - provides information about the breakdown voltage
- Threshold Equalisation –determines a global threshold for all pixels
- Charge Calibration - obtains the relationship between raw ToT values and the charge deposited in each pixel
- Source Scan – exposing the sensor to ^{90}Sr source and measuring at multiple voltages.

Testing sensors from Hamamatsu and Micron of both n-on-n and n-on-p with different thicknesses. Selection of sensors sent to irradiation faculties, JSI and KIT to test the performance after irradiation damage. The sensors are tested at different temperatures in both vacuum and dry air environments.



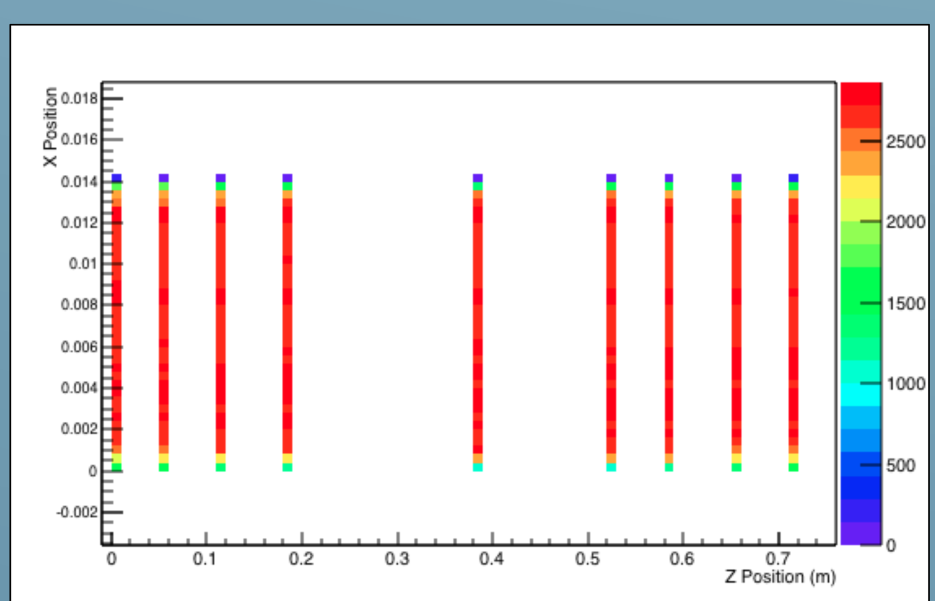
IV Scan



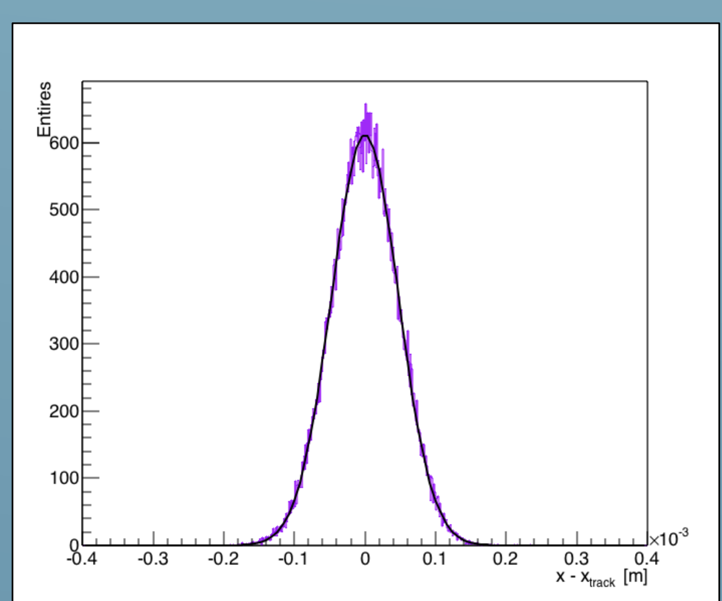
Source Scan

Telescope Alignment

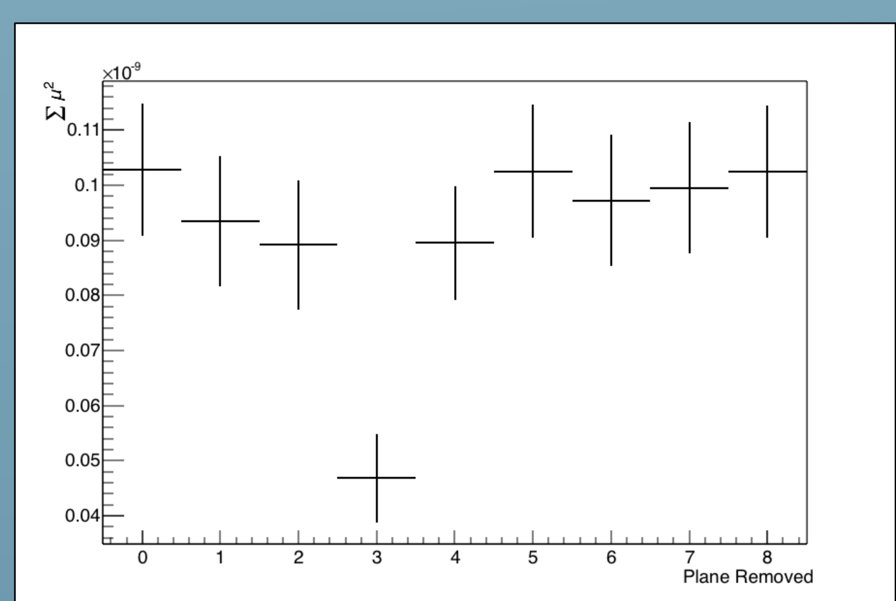
A good alignment of the telescope is crucial for the subsequent physics analysis. Track based alignment aims to reduce the χ^2 of the track fits, improving the precision of reconstructed tracks and vertex resolution. Using simulated tracks, alignment methods can be investigated before being applied to real data. One method is to simulate tracks through the telescope and compare the fitted and measured track position, where the mean residual is the difference. If the telescope is well aligned, the mean residual should tend to zero, otherwise the residual will be offset from zero. By calculating the sum of mean of the residuals squared and removing one plane each time, the most offset plane can be found and be corrected.



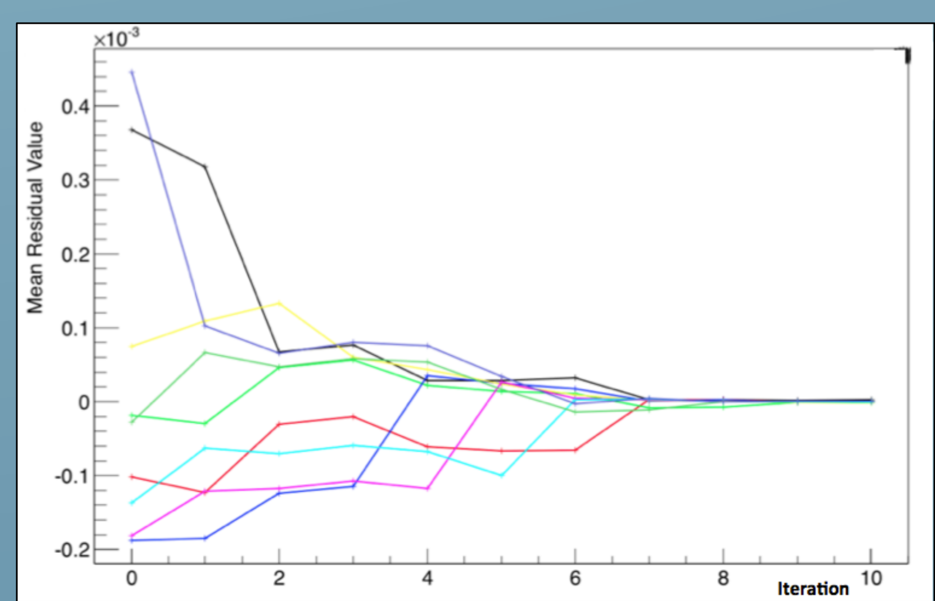
Simulated hits on telescope



Residual



The sum of the mean of the residuals, when one plane is removed. Clear that plane 3 is the most offset plane.



Plot of the mean of the residuals for all 9 planes, after each offset has been identified and corrected.

References

[1] **The LHCb Collaboration**, *LHCb VELO Upgrade Technical Design Report*, **CERN/LHCC 2013-021 (2013)**
[2] **K. Akiba et al**, *The Timepix Telescope for High Performance Particle Tracking*, **Nucl. Instrum. Meth. A 723 (200) 47-54**