The LHCb VELO Upgrade

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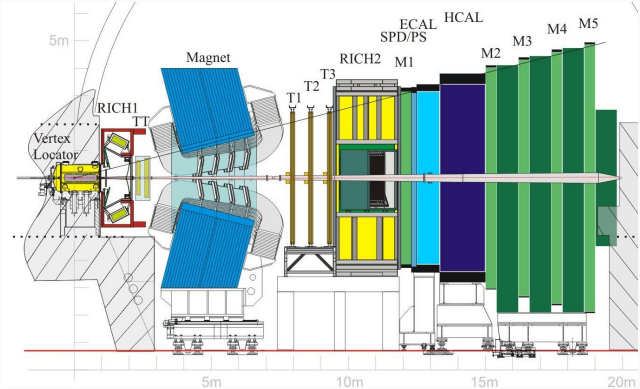
On behalf of the LHCb VELO group

9th International Workshop on Semiconductor Pixel Detectors for Particles and Imaging (PIXEL)

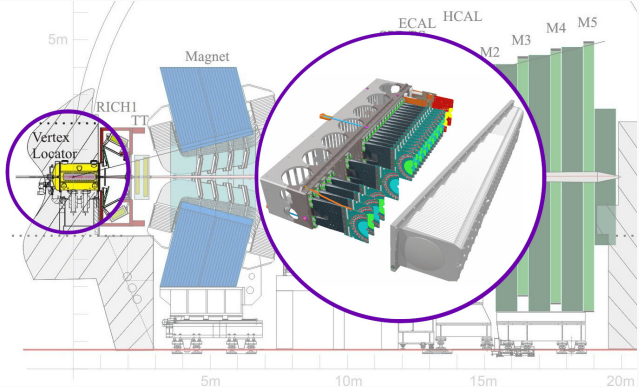
LHCb Experiment



- Forward arm spectrometer focusing on b- and c-hadron decays
- Studies CP violation, rare decays and more in the pseudo-rapidity region $2 < \eta < 5$

- LHCb detector has just been retired after 10 very successful years
- Integrated luminosity of 10 fb^{-1} delivered to detector

Current VELO

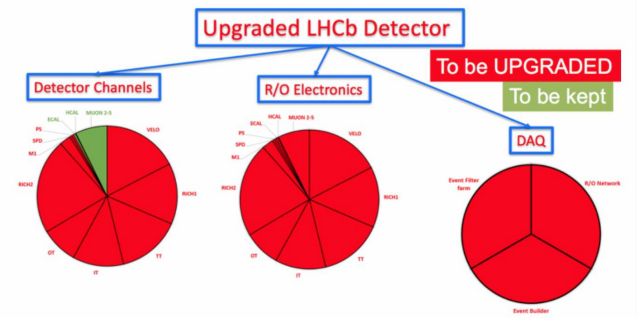


- LHCb physics requires ability to distinguish secondary vertices well
- The old VErtex LOcator (VELO) was a silicon microstrip detector with alternating layers of r- and ϕ-strips
- Most precise vertexing at LHC
- Operates in LHC vacuum

- 1MHz readout system
- Luminosity $4 \times 10^{32} cm^{-2} s^{-1}$

LHCb Upgrade

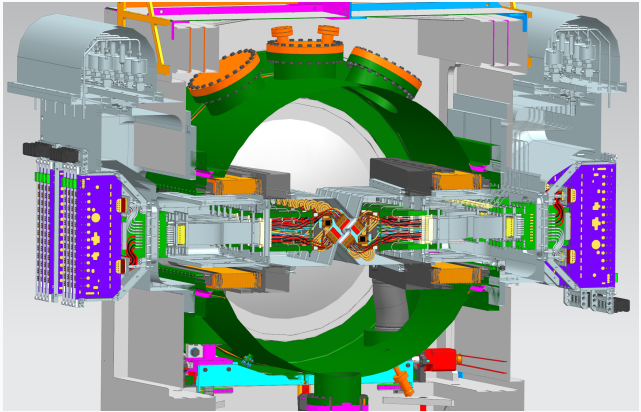
- Precision of results is statistically limited
- Upgrade during LS2 (Starting NOW)
- Remove hardware trigger and read out at full rate
- 40 MHz readout
- Aim to collect $50 fb^{-1}$
- Data taking will begin in 2021



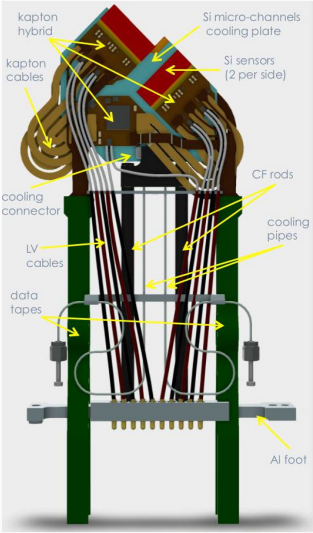
Less than 10% of detector channels will be kept
100% of R/O electronics will be replaced

VELO Upgrade

- The VELO upgrade is a silicon pixel detector with $55 \times 55 \mu m$ pixels
- New ASIC with a 40MHz readout system
- Thinner RF foil
- More radiation hard with better cooling
- Luminosity $2 \times 10^{33} cm^{-2} s^{-1}$



Module

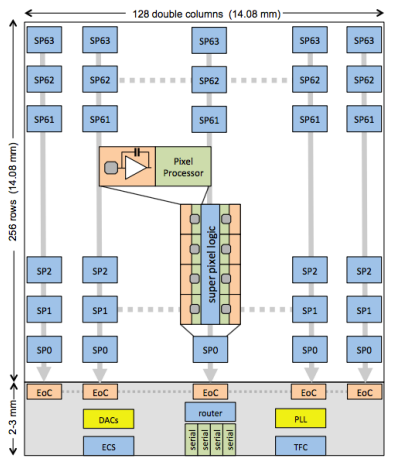


- Active area: four sensors, each bump bonded to three Velopix ASICs
- 41 M pixels across all 52 modules
- Power dissipation 30 W
- Evaporative CO_2 cooling through 120μm microchannels in silicon substrate
- Kapton cables for readout
- Carbon fibre legs and aluminium "foot"

Sensor

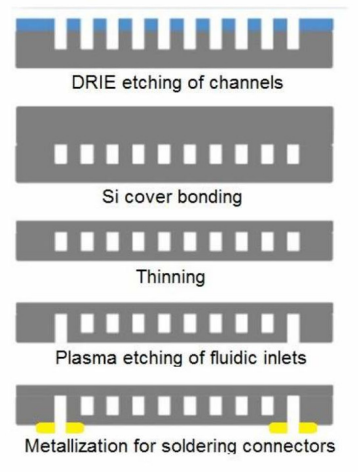
- Electron collecting n-in-p sensor
- $200\mu m$ thick
- $55 \times 55\mu m$ pixels with elongated pixels at the boundary between each ASIC
- Maximum radiation dose $8 \times 10^{15} n_{eq} cm^{-2}$
- Maximum bias voltage 1000V

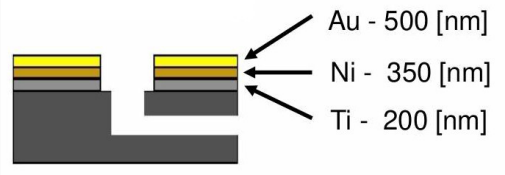
Velopix ASIC

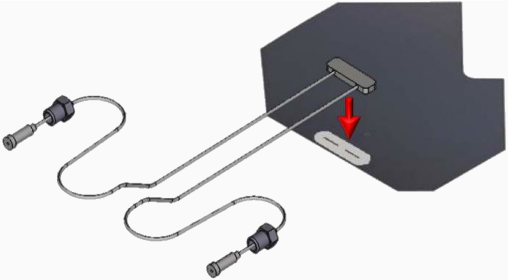


- Data driven readout
- Pixels read out in groups of 8: "SuperPixels" (4x2 array)
- Three ASICs bump bonded to each sensor
- See also: talk "VeloPix Readout and ASIC" by K. De Bruyn, Wednesday at 09:25

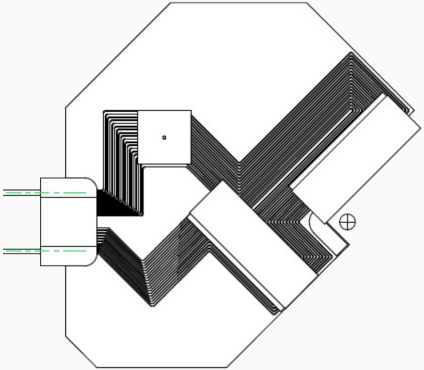
Microchannels







Cooling



- Evaporative CO_2 cooling
- 500 μm silicon substrate
  - 120 x 200 μm microchannels
  - Cooling power around 40 W
  - Input restrictions prevent instabilities across 19 parallel channels
- See also: poster "Microchannel CO_2 cooling for the LHCb VELO Upgrade" by O. De Aguiar Francisco

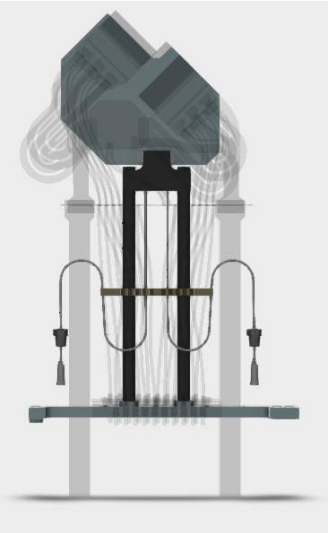
RF Foil

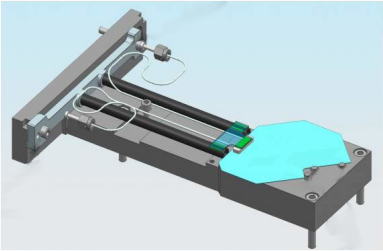
- Protect front end electronics from beam charge
- Ensures that module outgassing does not affect LHC beam by separating LHC vacuum and VELO vacuum
- Also provides beam wakefield suppression

- Machined from one solid block down to 250μm thickness
- Encloses one full module half

Production

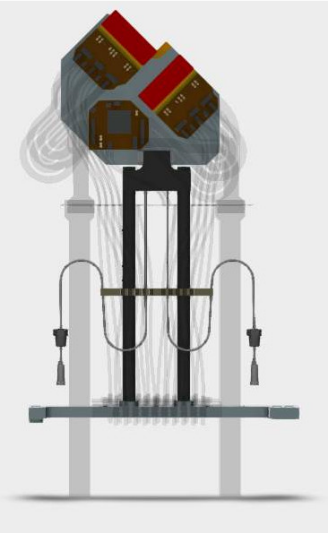
Bare Module

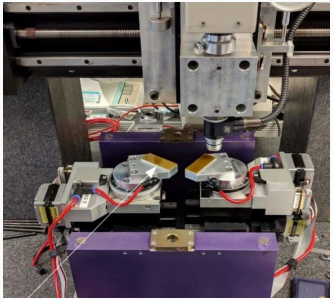




- Production sites at Manchester and Nikhef
- Jig ensures components are placed within tolerance

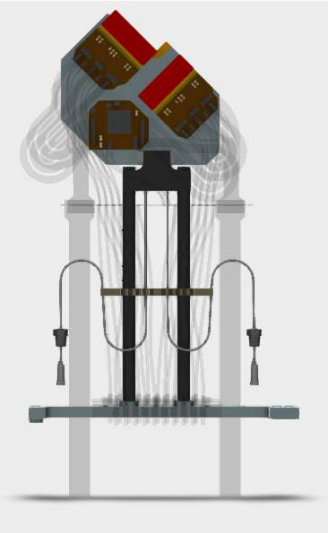
Gluing tiles and Hybrids

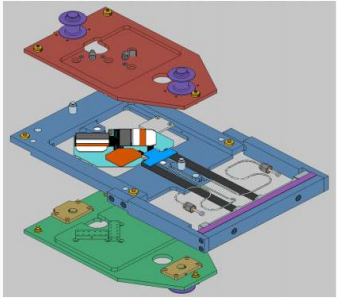




- Robot used to align tiles
- Glue robot deposits glue in snake pattern to avoid bubbles in high vacuum

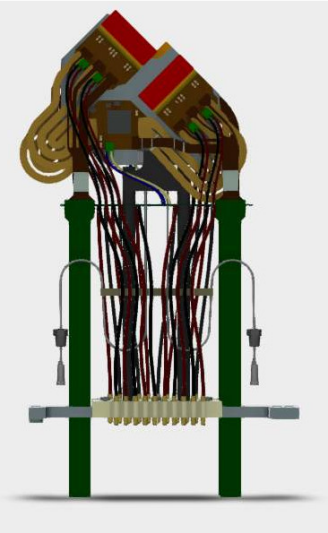
Gluing tiles and Hybrids

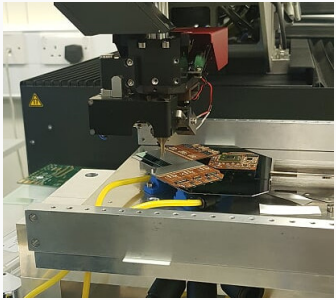




- Module is sandwiched between turnplates
- Back and front glued at the same time

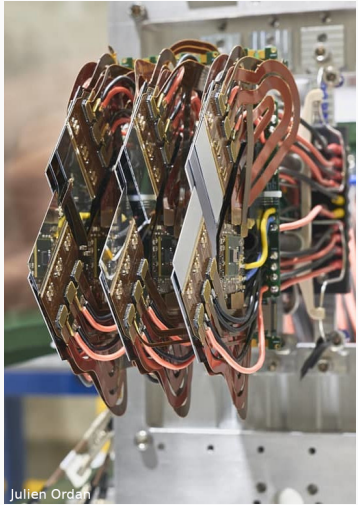
Wire Bonding and Cabling



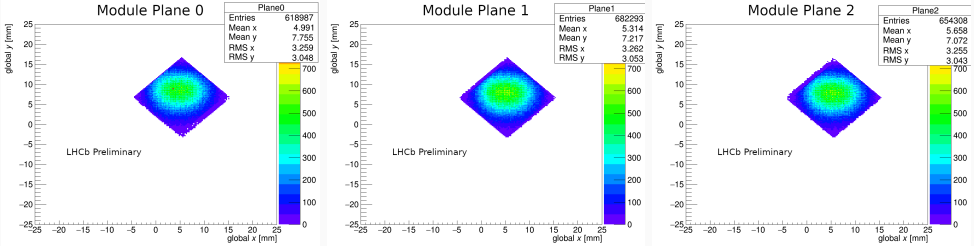


- Jig used to support module during bonding
- Cables attached in specific order to avoid damaging microchannels

October 2018 Testbeam



October 2018 Testbeam



- First time the full final system has been used to read out real data
- Testbeam at SPS with a 120 GeV pion beam
- Data taken in conjunction with the Telescope
- Analysis ongoing

Summary

- LHCb detector has been retired and is being replaced in the next two years
- VELO strip detector being replaced with pixel detector
  - 55 x 55 μm pixels
  - Velopix ASIC
  - Microchannel evaporative CO_2 cooling to minimise material in particle path
- VELO upgrade capable of forty times the readout rate
- Three modules tested together recently in testbeam facility
  - Analysis ongoing