The LHCb Upgrade VELO

Dónal Murray

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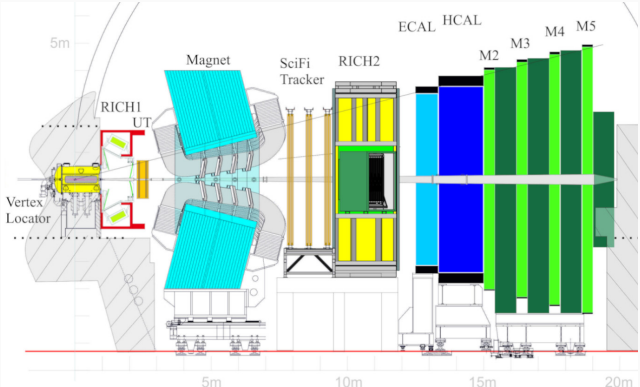
LHCb UK 2020, Huddersfield

- Overview of LHCb Upgrade
- VELO Upgrade
- Production of VELO modules
- Testing of VELO modules

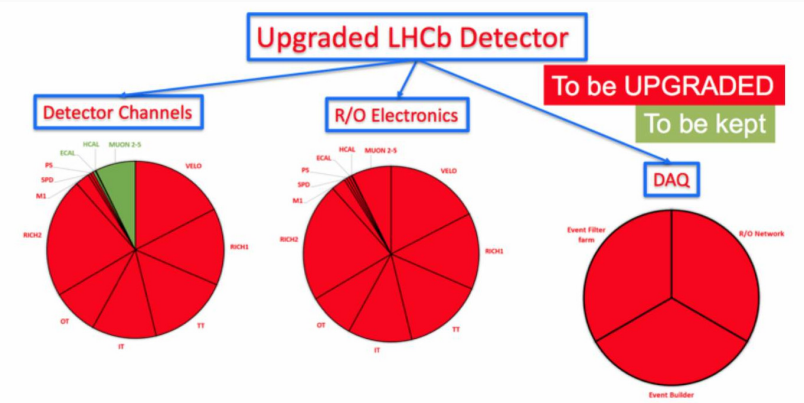
LHCb Experiment Upgrade



- Forward arm spectrometer focusing on b- and c-hadron decays
- proton-proton collisions
- Studies CP violation, rare decays and more in the pseudo-rapidity region $2 < \eta < 5$
- LHCb detector was retired just over a year ago after 10 very successful years and integrated luminosity of 10 fb^{-1} delivered

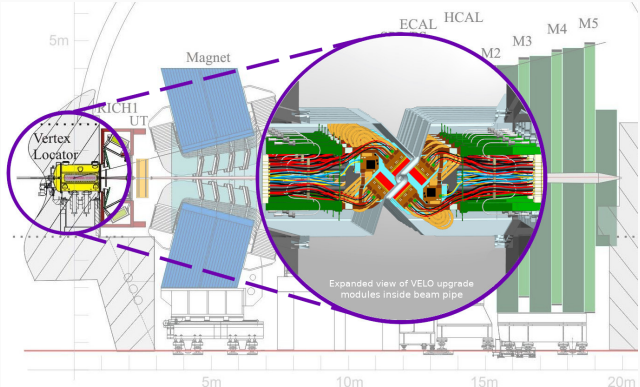
- LHCb Upgrade currently being built with installation before 2021
- Hardware trigger removed for upgrade; full readout at 40MHz with online software trigger

VELO Upgrade



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

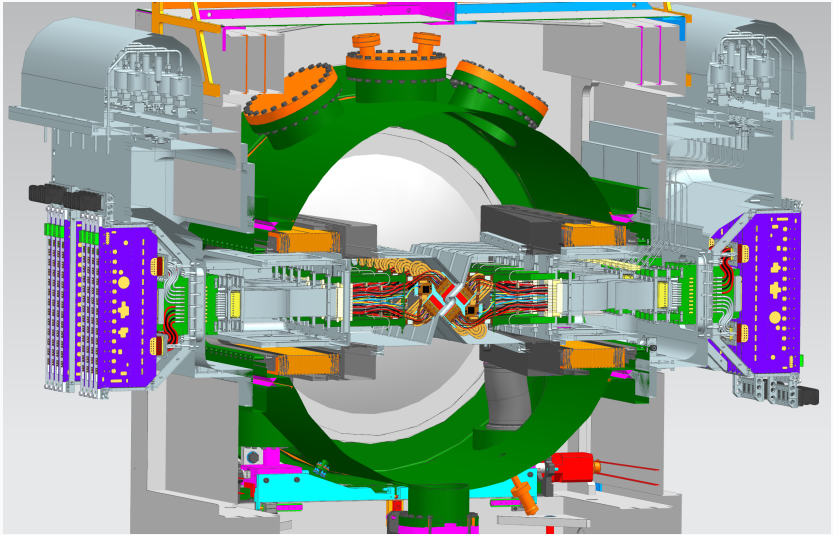
VELO Upgrade



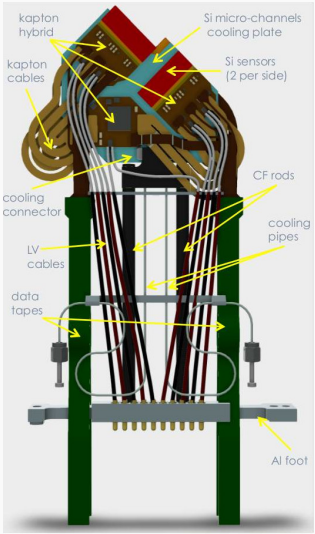
- The VELO upgrade is a silicon pixel detector with $55 \times 55 \mu m$ pixels
- VeloPix ASIC and full readout at 40 MHz
- Closer to the beam: $5.1mm$ vs $8.1mm$ in old VELO
- High radiation environment: 8×10^{15} MeV n_{eq} cm^{-2}
- Luminosity 2×10^{33} cm^{-2} s^{-1} (5 times old detector)

- Modules operate in vacuum, separated from LHC vacuum by RF foil

VELO Upgrade



Module

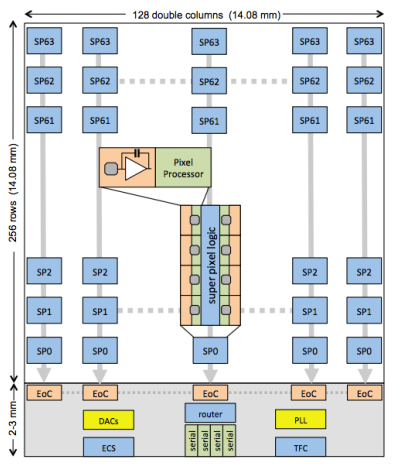


- Active area: four sensors, each bump bonded to three Velopix ASICs
- 41 M pixels across all 52 modules
- Power dissipation 30 W
- Evaporative CO_2 cooling through 120μm microchannels in silicon substrate
- Kapton tapes for readout
- Carbon fibre legs and aluminium ”foot”

Sensor

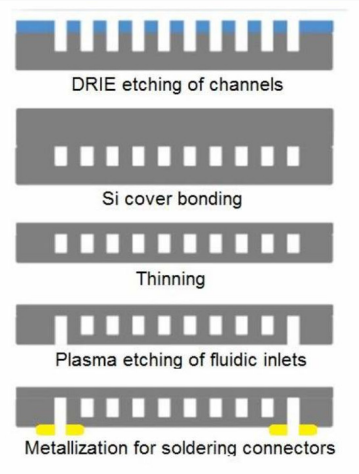
- Electron collecting n-in-p sensor
- $200\mu m$ thick
- $55 \times 55\mu m$ pixels with elongated pixels at the boundary between each ASIC
- Maximum radiation dose $8 \times 10^{15} n_{eq} cm^{-2}$
- Maximum bias voltage 1000V

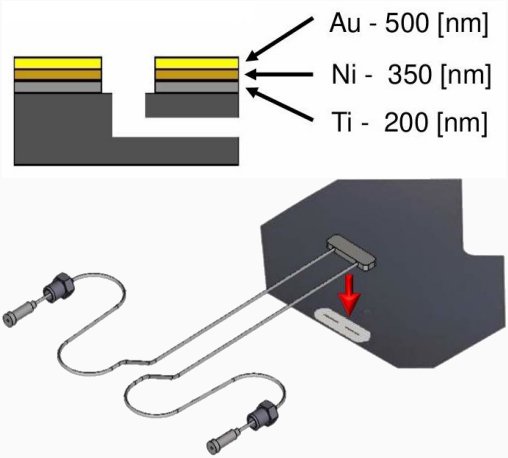
Velopix ASIC



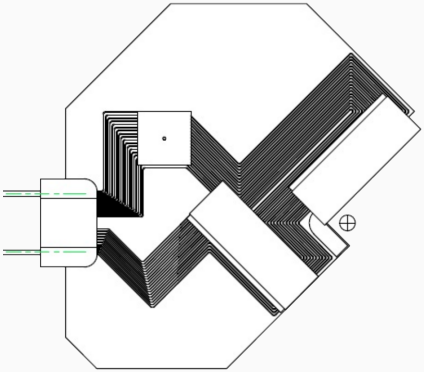
- Data driven readout
- Pixels read out in groups of 8: ”SuperPixels” (4x2 array)
- Three ASICs bump bonded to each sensor

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

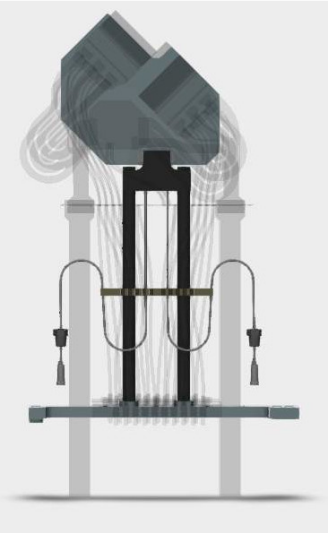
RF Foil

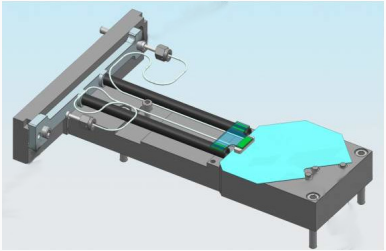
- Protect front end electronics from beam charge
- Ensures that module outgassing does not affect LHC beam by separating LHC vacuum and VELO vacuum
- Also provides beam wakefield suppression

- Machined from one solid block down to 150μm thickness
- Encloses one full module half

Production

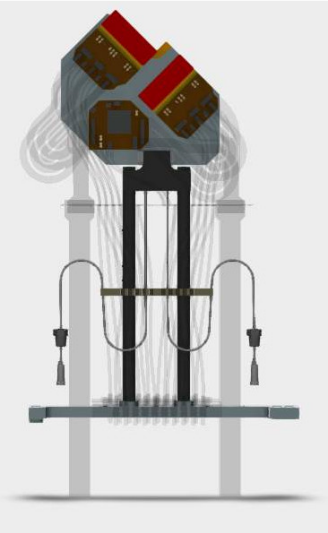
Bare Module

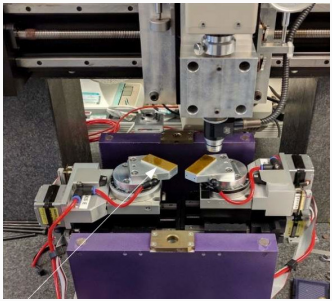




- Production sites at Manchester and Nikhef
- Jig ensures components are placed within tolerance

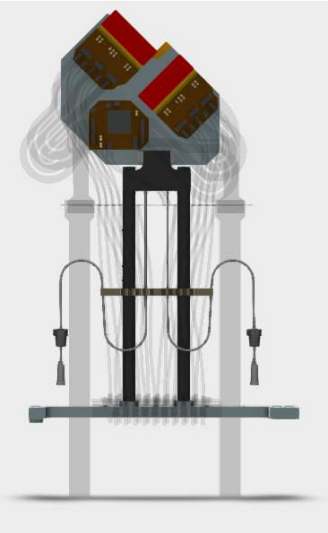
Gluing tiles and Hybrids

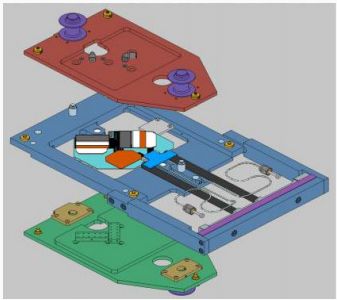




- Robot used to align tiles
- Glue robot deposits glue in star pattern to avoid bubbles in high vacuum

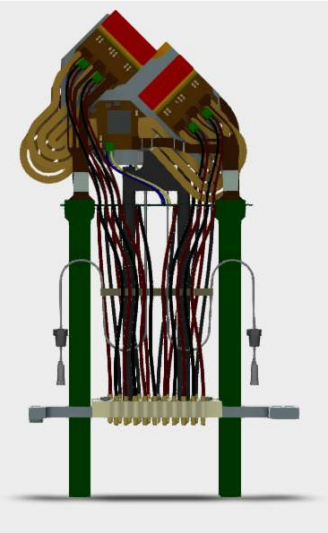
Gluing tiles and Hybrids

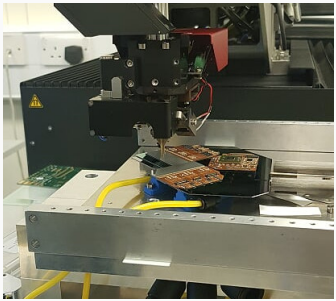




- Module is sandwiched between turnplates
- Back and front glued at the same time

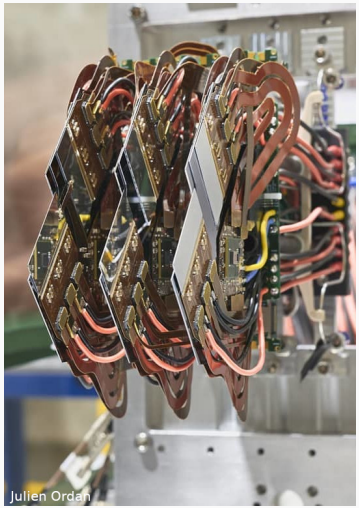
Wire Bonding and Cabling

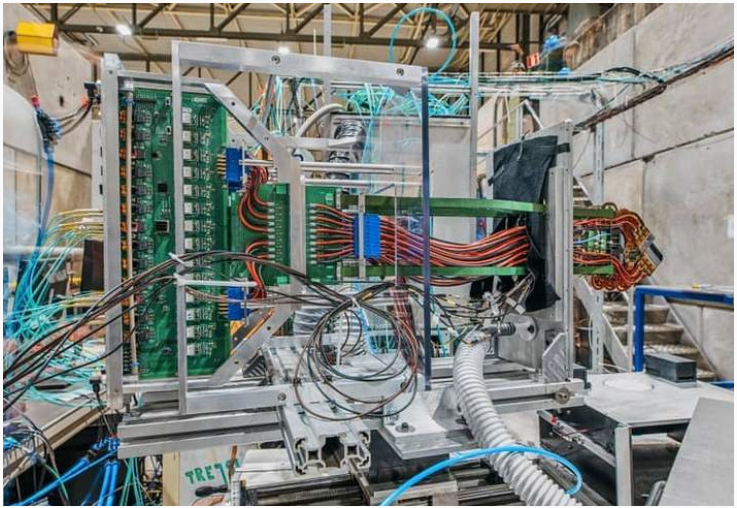




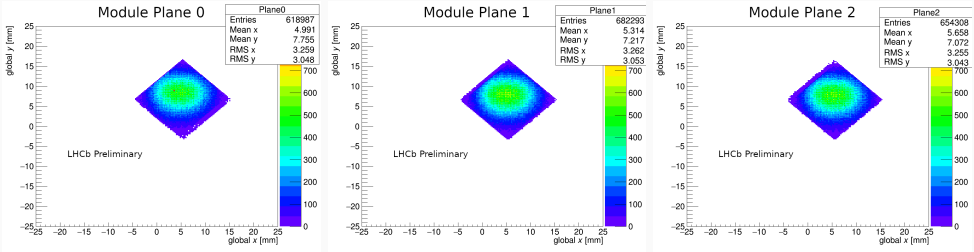
- Jig used to support module during bonding
- Cables attached in specific order to avoid damaging microchannels

October 2018 Testbeam



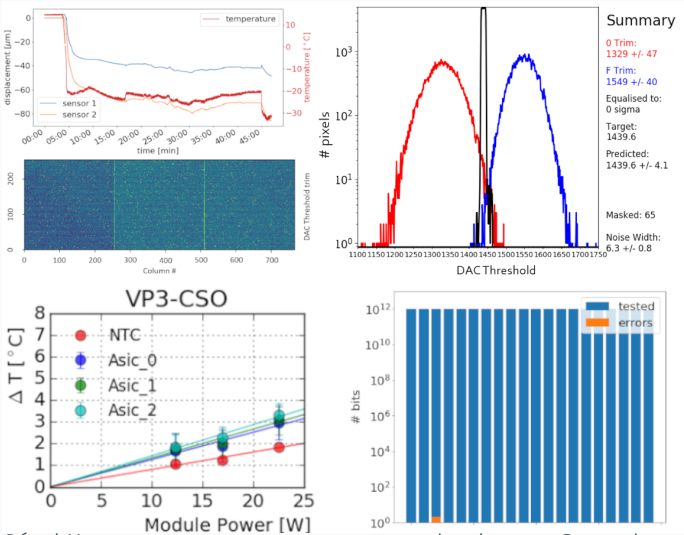


October 2018 Testbeam



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

Production Testing

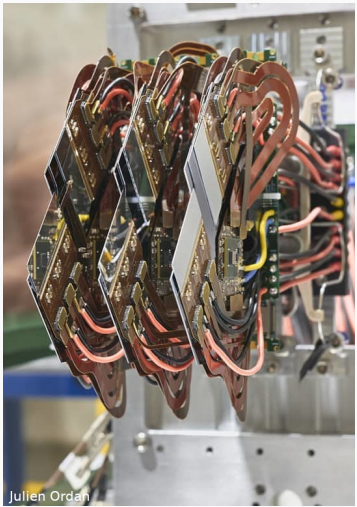


- Mechanical and electronic tests done on all modules
- Mechanical tests ensure assembly is within tolerance
- Electronic tests ensure good connections between all components
- Also makes sure nothing is damaged during assembly

Outlook

- VELO production underway – first production modules in June 2019, work ongoing
- Successful testbeam in October 2018 with full readout chain
- Electrical and mechanical tests allow us to ensure that assembly is within tolerances
- 52 modules + spares being made in Manchester and Nikhef
- Two module halves to be assembled at Liverpool
- Installation and commissioning at CERN

Summary



- The LHCb detector is undergoing a major upgrade
- including a brand new VELO
  - 55 x 55 μm pixels
  - Velopix ASIC
  - Microchannel evaporative CO_2 cooling to minimise material in particle path
- Hardware trigger removed, full readout at 40MHz with software trigger
- VELO module production underway
- Nearly ready to start taking 40MHz data in Run 3!