Status of the LHCb Vertex Locator

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on behalf the LHCb VELO Group

UNIVERSITY OF LIVERPOOL

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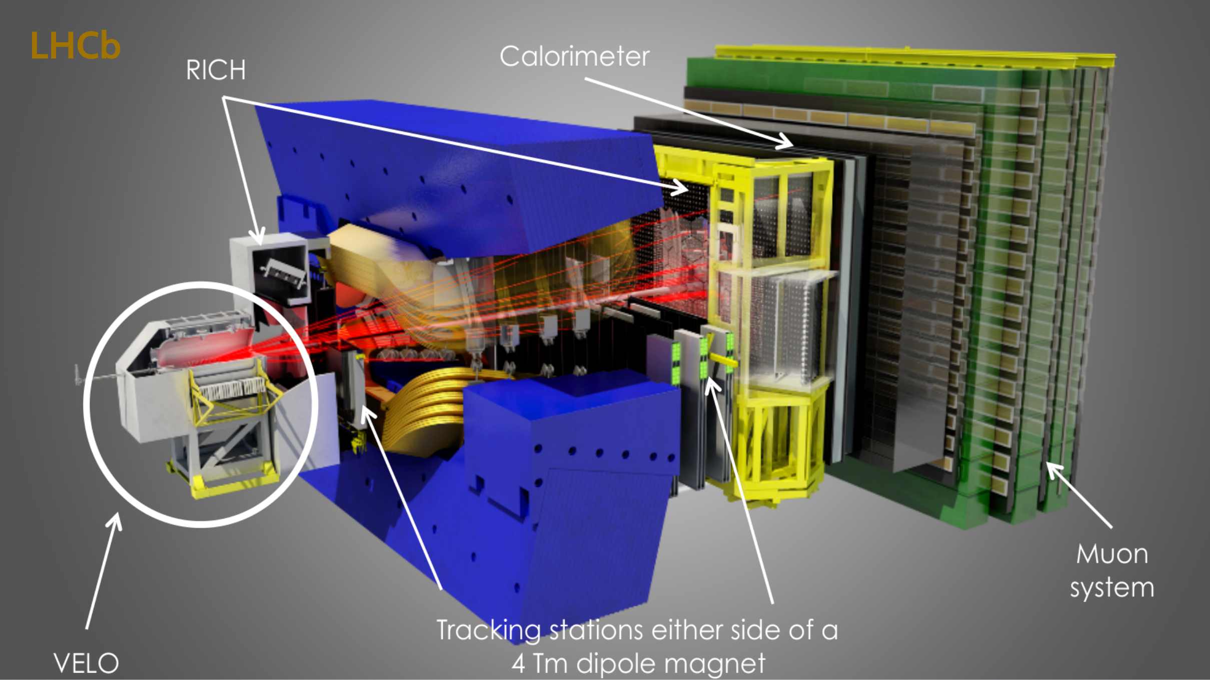
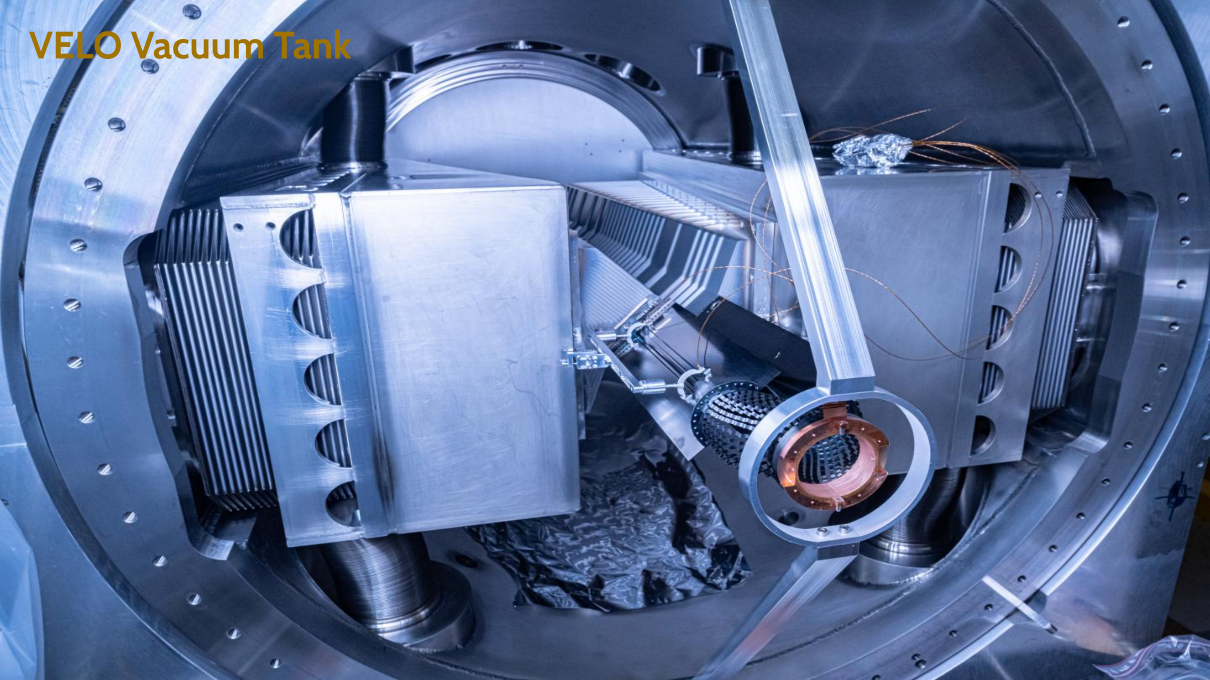
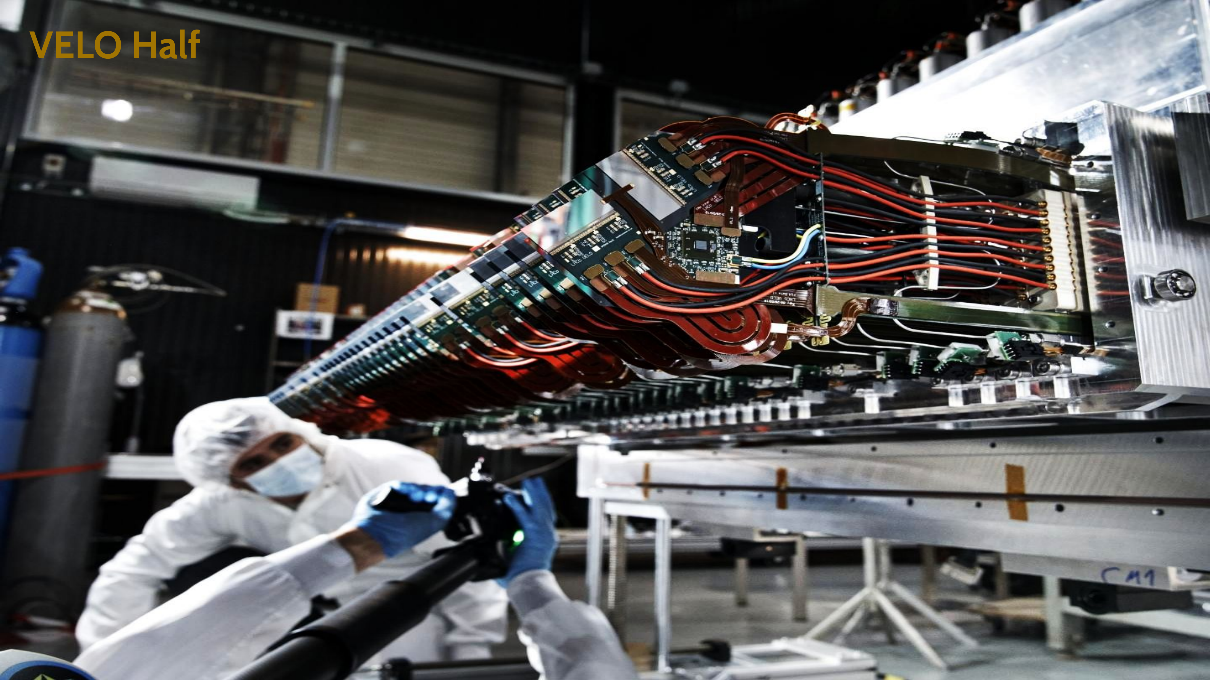

LHCb
RICH
Calorimeter
VELO
Tracking stations either side of a
4 Tm dipole magnet
Muon
system

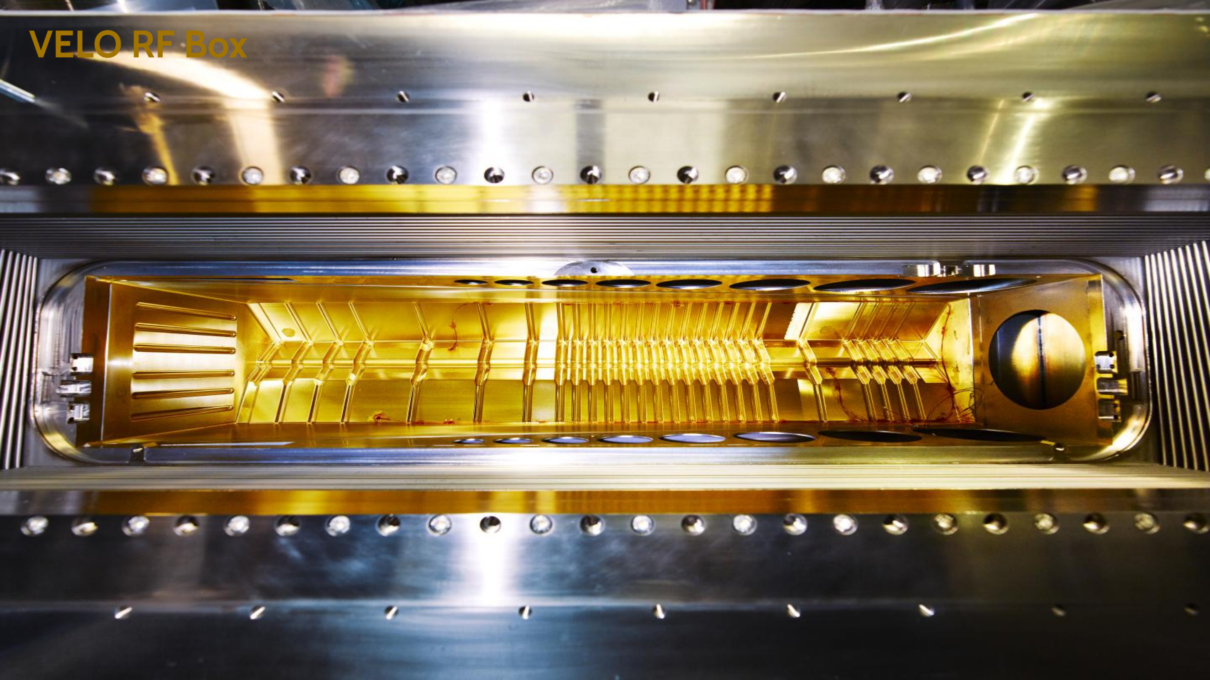
VELO Vacuum Tank



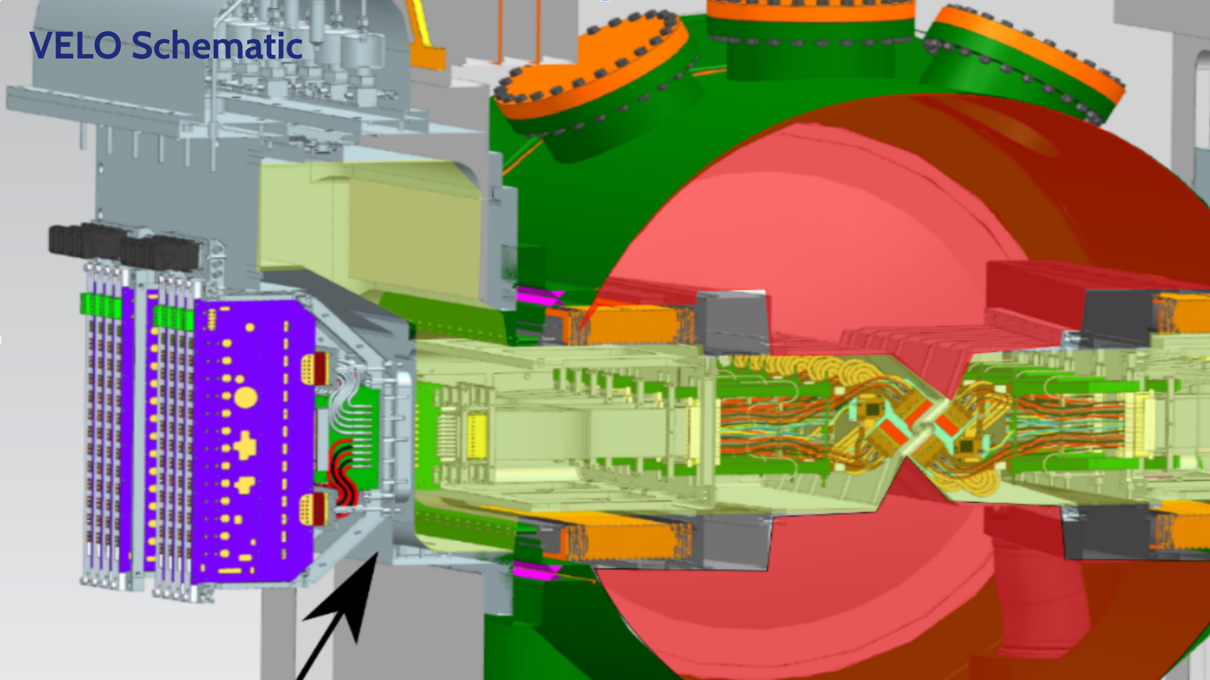
VELO Half



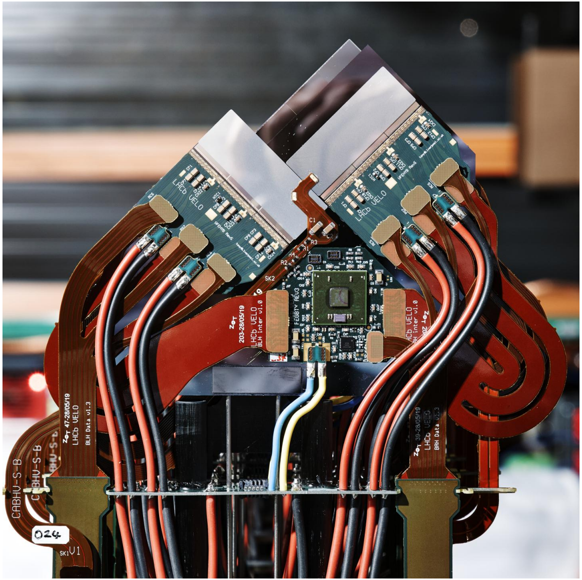
VELO RF Box

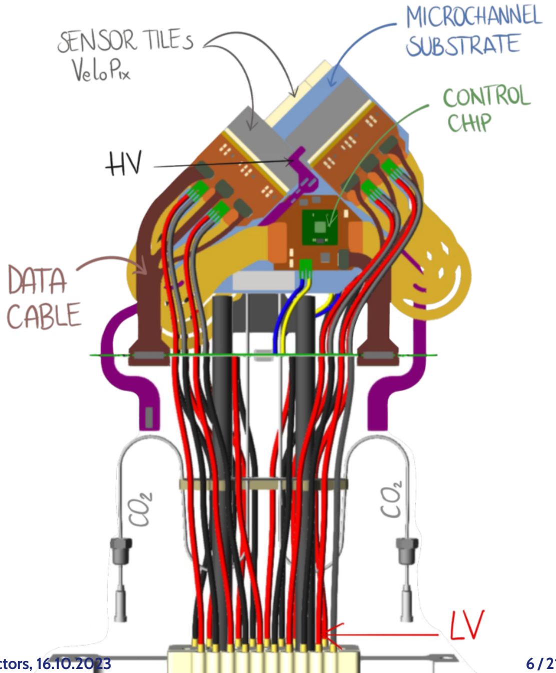


VELO Schematic



VELO Module


LHCb VELO
024

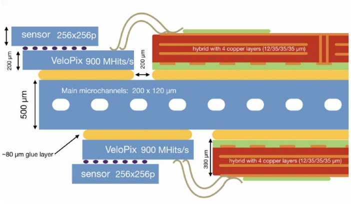

SENSOR TILES
VeloPix
MICROCHANNEL SUBSTRATE
CONTROL CHIP
HV
DATA CABLE
CO_2
CO_2
LV

VELO Module

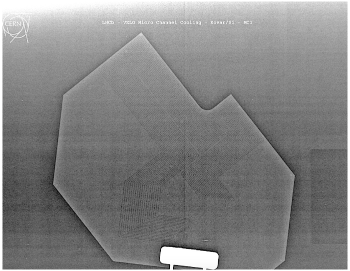
- 4 Sensors
  - $200\mu m$ thick
  - 768×256 pixels, $55 \times 55\mu m$
- 12 VeloPix ASICs
  - based on TimePix 3
  - 256×256 pixels
  - data driven readout
  - up to 900 Mhits/s
  - $200\mu m$ thick
- Microchannel Cooling
  - $500\mu m$ substrate
  - $200 \times 120\mu m$ channels
  - sensor temperature $-25°C$

Ambitious low material design & cooling solution.

Schematic Side View

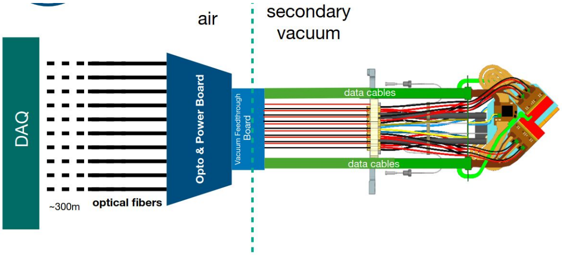


Microchannels in X-ray



Commissioning

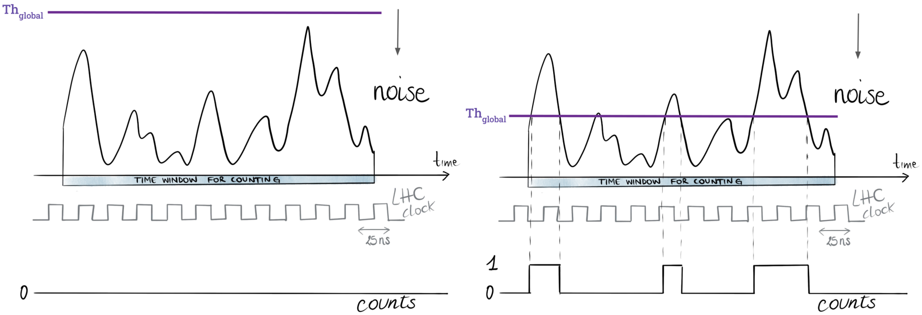
- Calibration Procedures
  - equalisation
  - time alignment
- Configuration
  - per pixel mask & trim
  - readout chain electronics
  - services LV, HV
- FPGA Firmware Development
- Monitoring
  - IV scans, radiation damage
  - data quality



Achieve stable operations & high data quality.

Calibration: Equalisation

- $Th_{local} = trim + Th_{global}$
- global threshold (Th_{global}) per ASIC
- $trim$ defined per pixel (4 bits, 0 - 15)

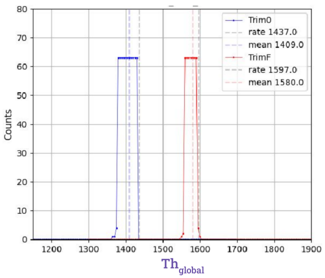


Achieve uniform response across pixels.

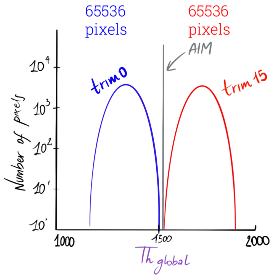
Calibration: Equalisation

- scan noise over Th_{global} for $trim_0$ and $trim_{15}$
- analyse result to find optimum

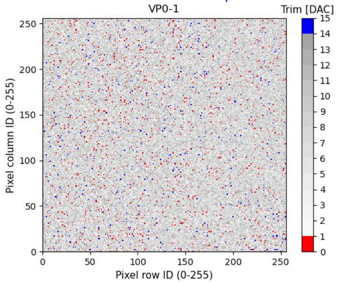
one pixel



one ASIC, 256 × 256 pixels



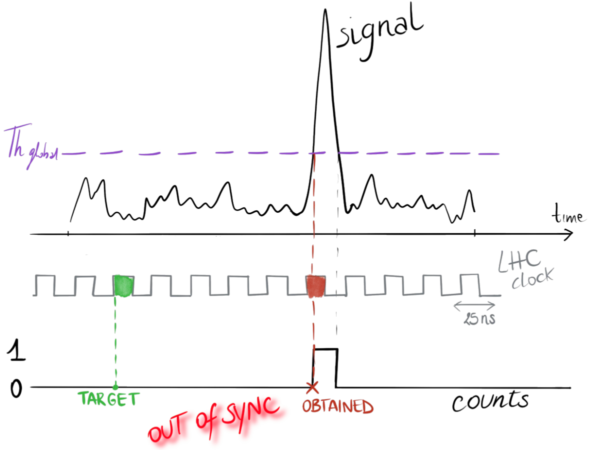
one ASIC, 256 × 256 pixels



Lengthy procedure (~ 30 min), further optimisation by moving scan to FPGA.

Calibration: Time Alignment

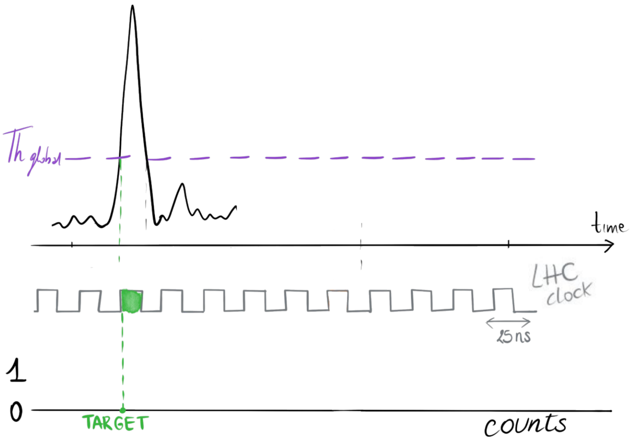
1. coarse alignment, synchronise with the LHC clock



Achieve synchronised timing across ASICs.

Calibration: Time Alignment

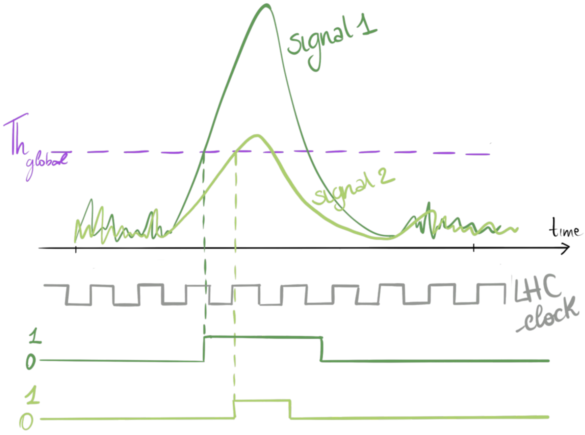
1. coarse alignment, synchronise with the LHC clock



Achieve synchronised timing across ASICs.

Calibration: Time Alignment

2. fine alignment, put low and high amplitude signals at the same clock count



Achieve synchronised timing across ASICs.

Calibration: Time Alignment

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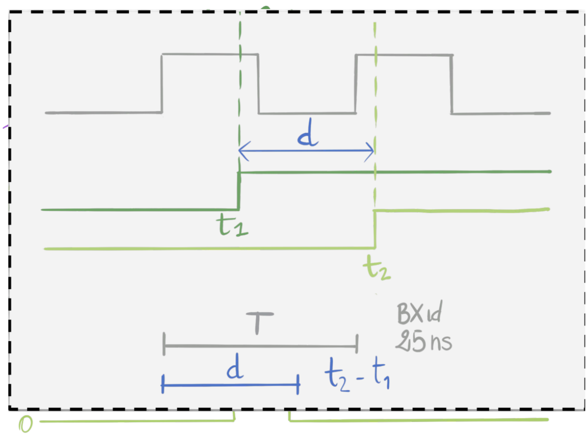
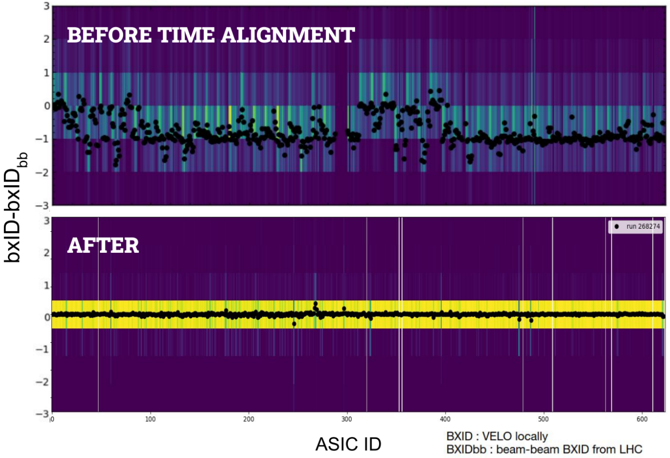


Achieve synchronised timing across ASICs.

Calibration: Time Alignment

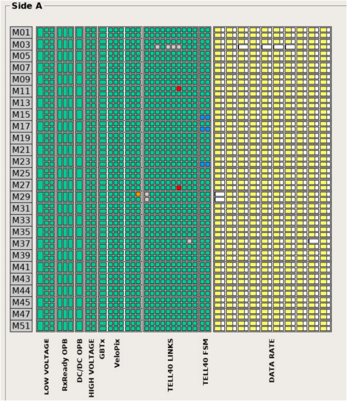
3. tune the various phases/delays of the electronics



Time alignment procedure is in place.

Front End Configuration

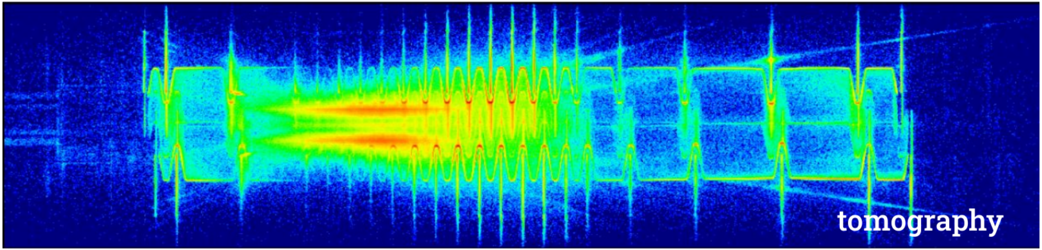
order matters



- The front end has many components
  - VeloPix ASICs
  - GBTx chips
  - OPB boards
- One ASIC alone has > 300 parameter data points
- WinCC configuration code has to be robust and scalable
- Calibration files have to be well managed
- Errors must be recovered smoothly & automatically (SEU's)

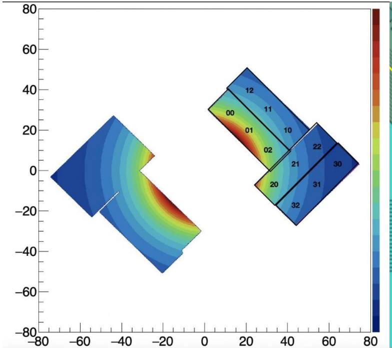
The calibration & control has been streamlined, channel efficiency is at 99.6%.

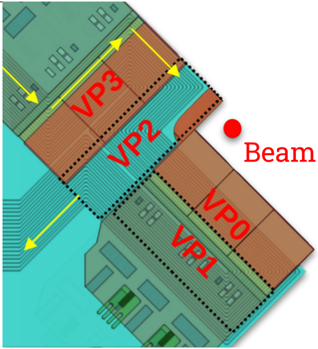
Radiation Damage: Expectation

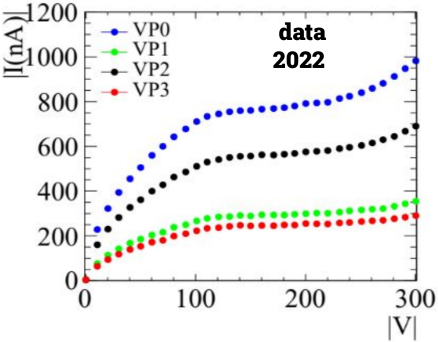


Expected irradiation depend on distance to interaction point.

Radiation Damage: IV Curves

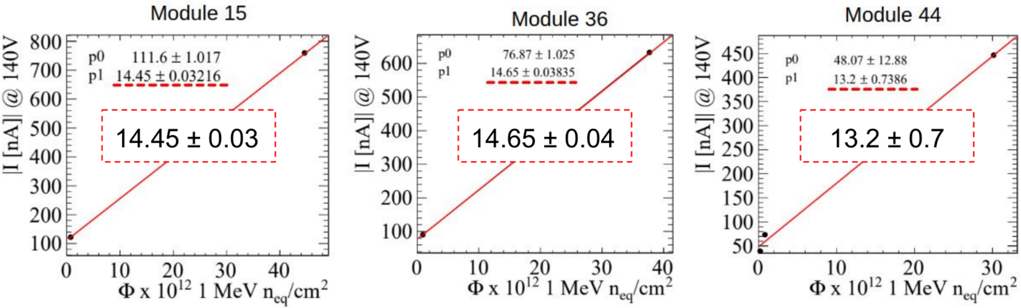






Measured irradiation varies for different sensors.

Radiation Damage: Current vs. Fluence

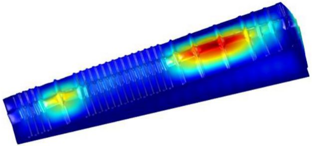


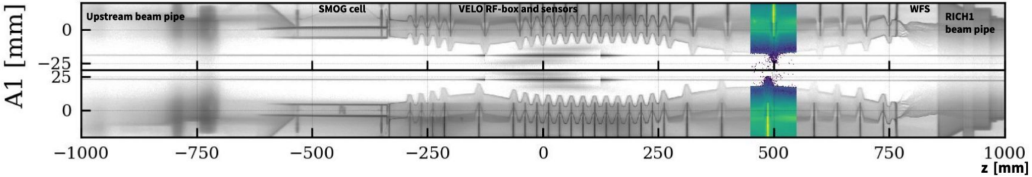
The radiation damage is consistent across all modules.

RF-Foil Incident

- Multiple equipement failures in the vacuum protection system resulted in pumping action on the primary volume…
- …leading to too high differential pressure
- The RF-foil sustained permanent plastic damage
- The VELO modules have not been damaged
- Deformation assessed with tomography

simulation

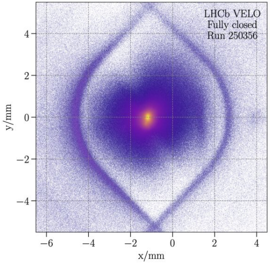




The VELO could not be safely closed after the incident. The foil will be replaced in 2024.

Conclusion

- Robust calibration & configuration procedures have been established.
- Channel efficiency is at 99.6%.
- The VELO is in stable operations and well monitored.
- The damaged RF foil will be replaced.



We are looking forward to stable operations under nominal conditions.

reference: LHCb VELO Upgrade Technical Design Report

reference: Microchannel cooling for the LHCb VELO Upgrade I

acknowledgement: all drawings credit *Alice Biolchini*