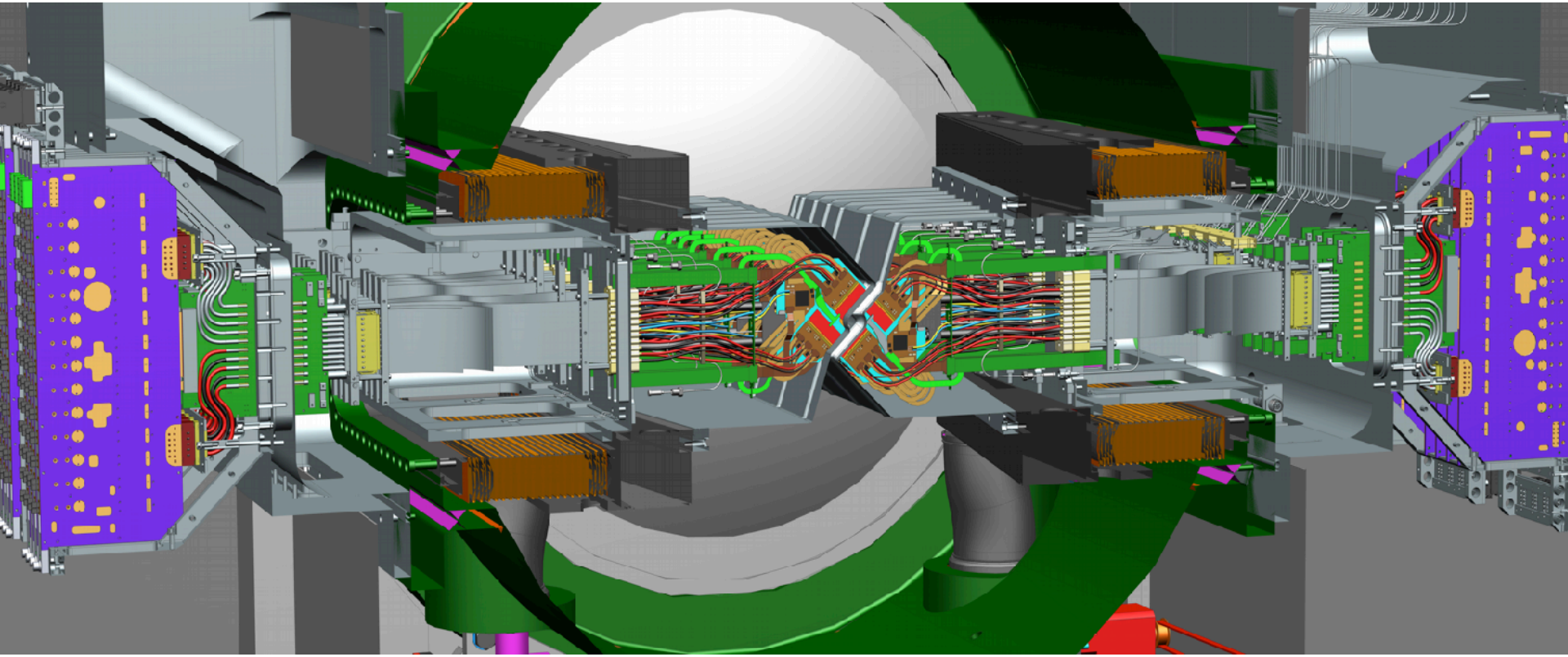
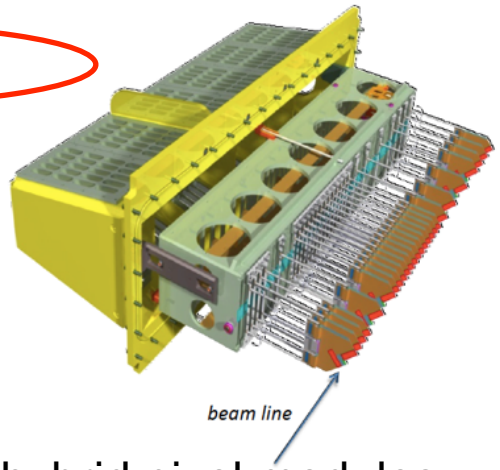
VELO Upgrade Intro



25th Jan 2019
Machine Protection Panel
P. Collins

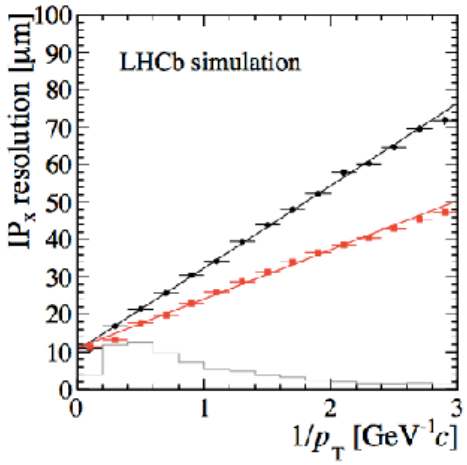
Tracking Upgrade

- **Vertex LOcator Si strips → pixels**
- TT Si strips → new **Si strip detector**
- Inner (Si) and Outer (straws) Tracker
- Novel Scintillating Fibre Tracker



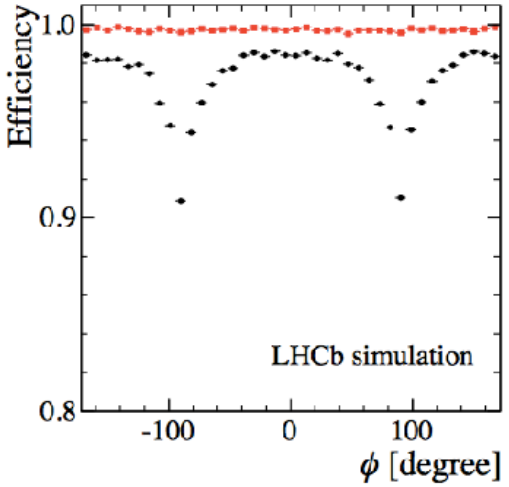
rows of silicon microstrip modules

rows of silicon hybrid pixel modules

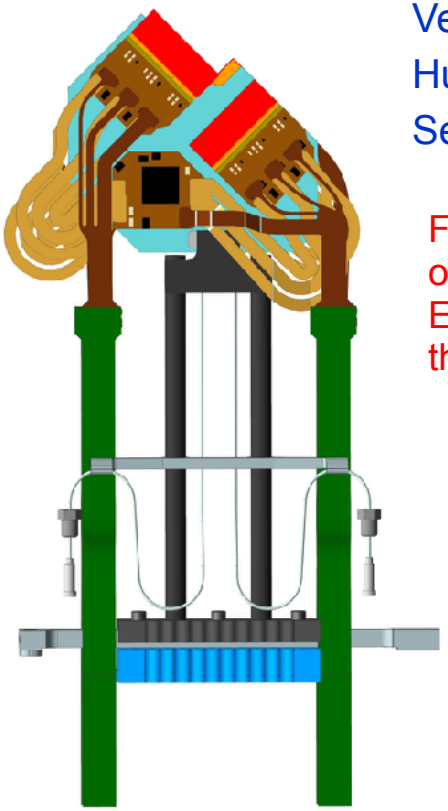


Pixel design with superior to strips for impact parameter resolution and efficiency

However, strip style cooling insufficient for pixel solution



VELO Sensors and ASICs



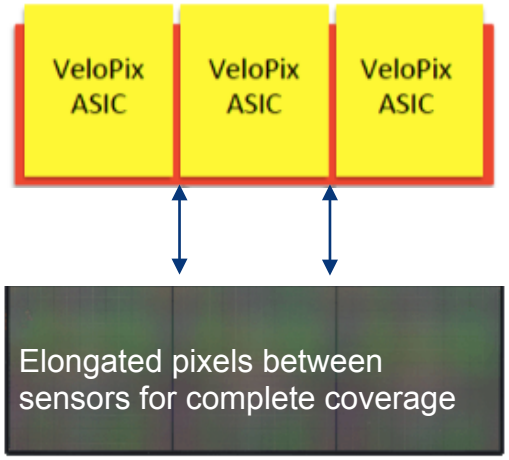
Challenges:

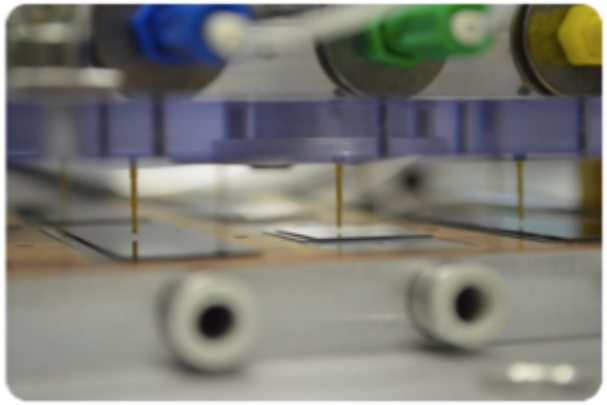
Very high (8 x 10^{15} n_{eq}/cm^2 for 50 fb^{-1}) & non-uniform irradiation (~ $r^{-2.1}$)

Huge data bandwidth: up to 20 Gbit/s for central ASICs and ~ 3 Tbit/s in total

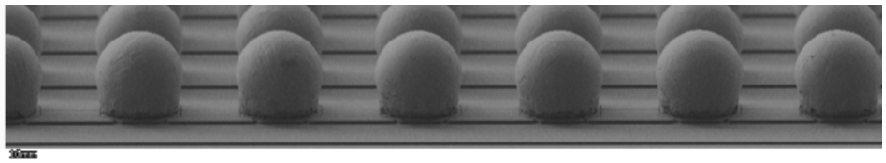
Sensor temperature must be maintained < -20°C with minimal cooling

Four sensors per module (sensors on other side shown with dotted lines)
Each sensor (43 x 15 mm) bonded to three VeloPix ASICs





Sensors are bump bonded and automatically probed before vacuum testing to 1000V with spring loaded needle contacts to ASIC backplane



SEM image of 55 µm pitch SgAn bumps
courtesy Sami Vähänen, ADVACAM Oy

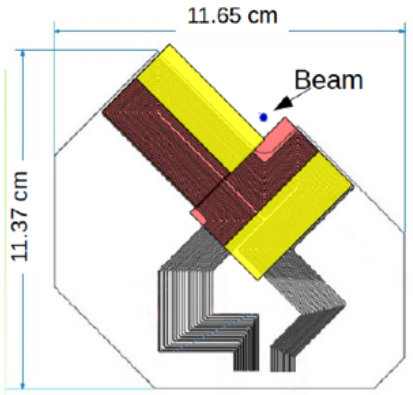
VELO Cooling

Due to the harsh radiation environment an efficient cooling solution is required to maintain the sensors at < -20°C

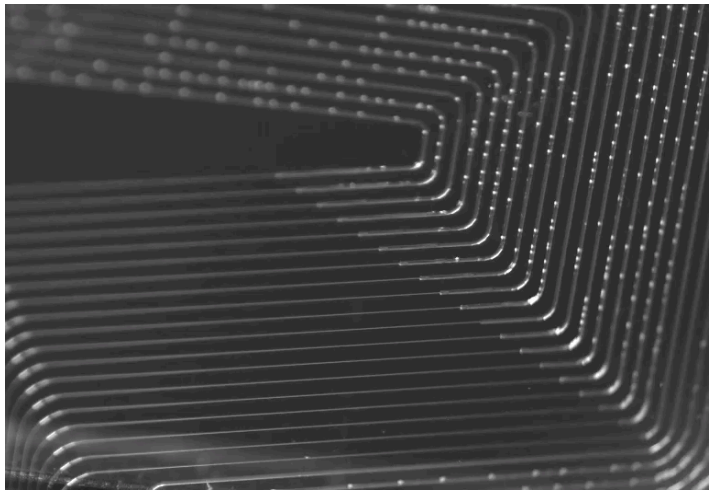
This is provided by the novel technique of evaporative CO_2 circulating in 120 µm x 200 µm channels within a silicon substrate.

Total thickness: 500 µm

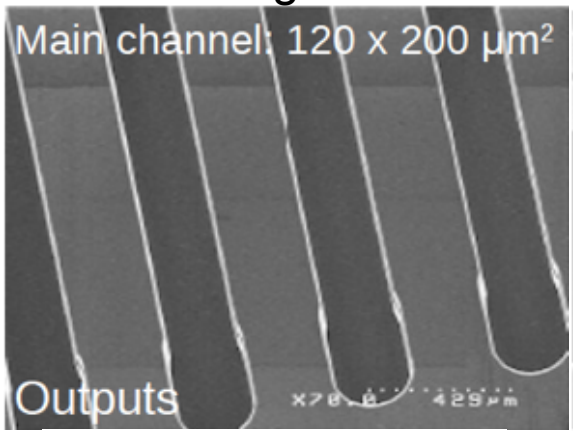
- High thermal efficiency
- CTE match to silicon components
- Minimum and uniform material
- radiation hard



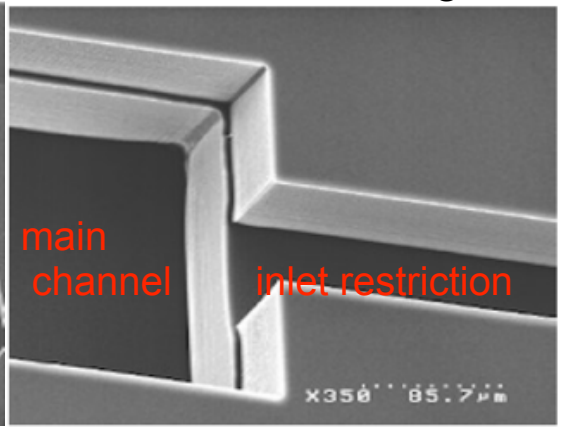
SEM images of etched wafer before bonding



(click for movie)

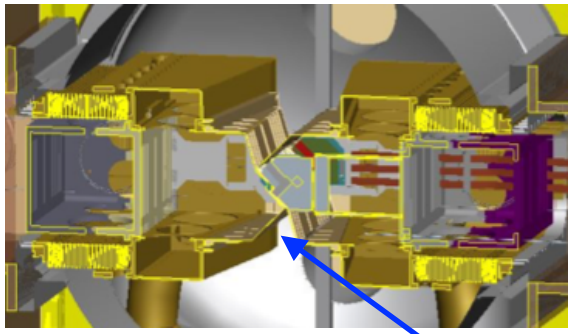


channels output directly to connector



Two step channel etching

VELO RF Foil

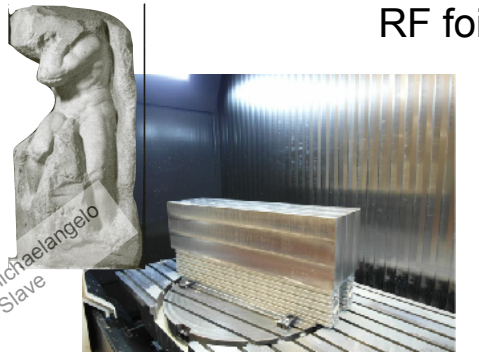


The VELO is separated from the primary vacuum by the 1.1 m long thin walled "RF foil" which also shields the detector and guides the beam wakefields

At just 3.5 mm clearance from the beam and 900 μm clearance from the sensors, production represents a huge technical achievement

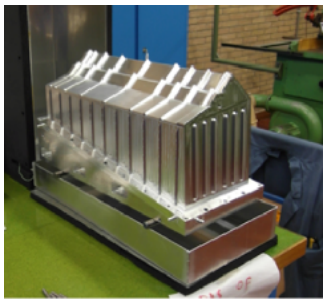
The final foil withstands 10 mbar pressure variations, is leak tight, and has a final thickness of 250 μm, with an option to go to 150 μm maintained

RF foil: some production steps

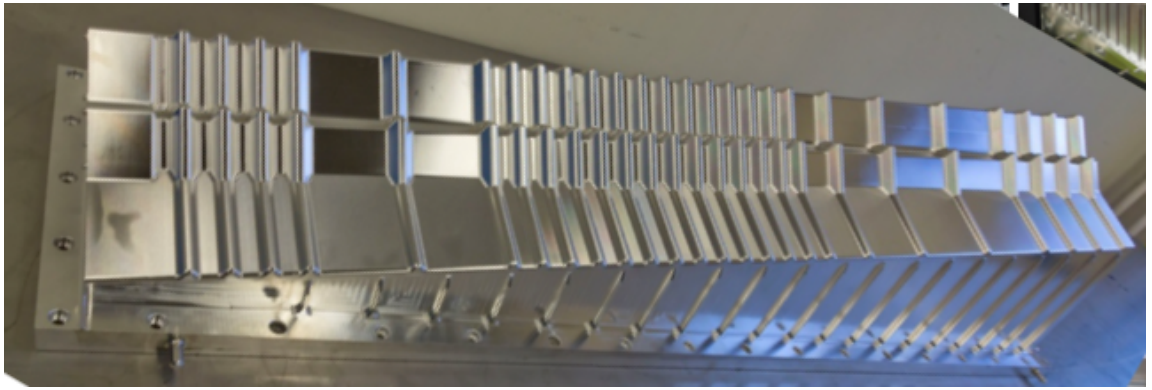


Initial solid forged Al alloy block

>98% of material removed



Internal mould support during machining steps



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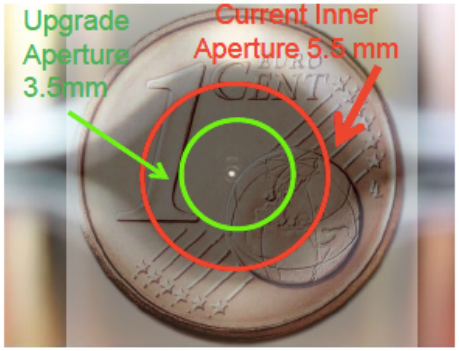

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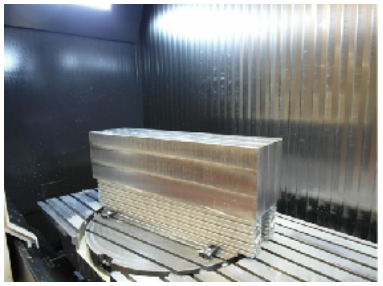

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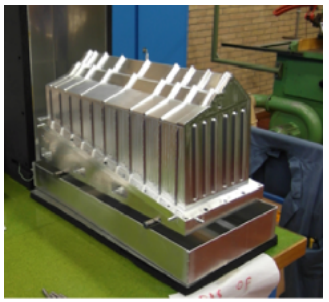

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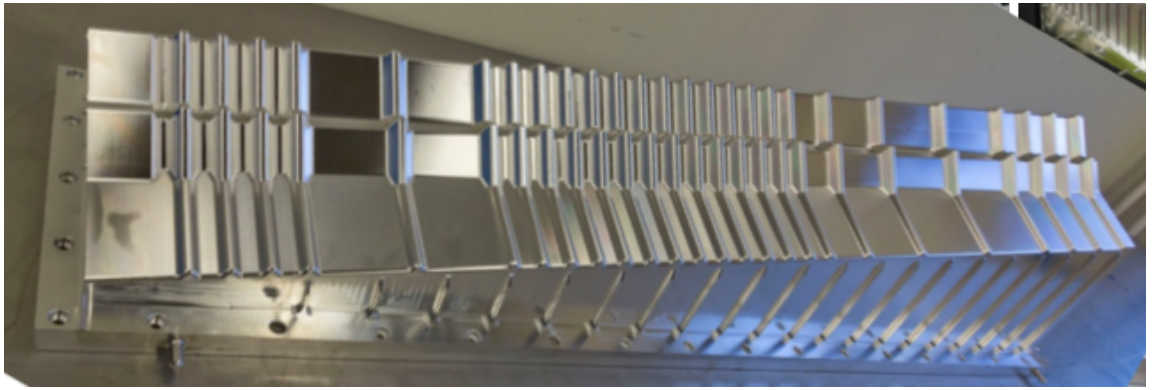
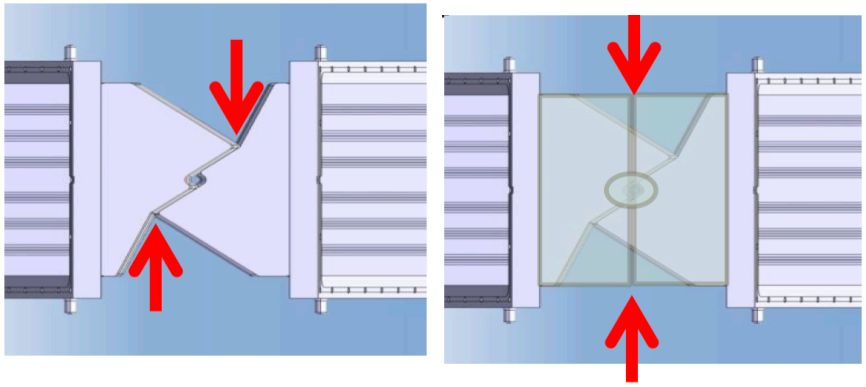
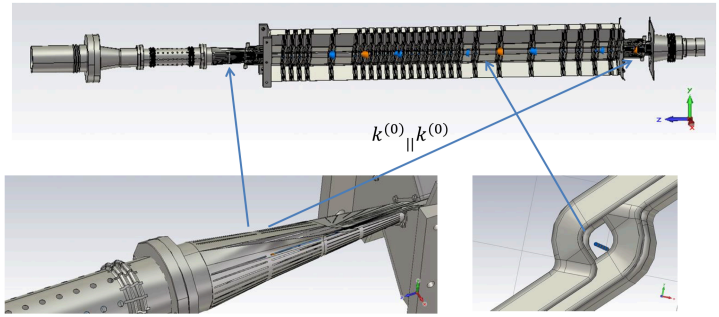


VELO RF box redesign

- **No problems expected in terms of aperture (M. Giovannozzi, R. Appleby, M. Neat, M. Ferro-Luzzi, B. Holzer)**
  - VELO model implemented in LHC aperture model with pessimistic configurations
  - Standard mechanical tolerances used: note that upgraded foil by construction will be more precise
  - Closed orbit variation 100 μm; half external crossing angle 239 μrad
  - **CERN-ATS-Note-2012-101 TECH, LHCb-PUB-2012-018, TREX9 (2015)**



Vacuum simulations (C. Yin Vallgren P. Pinto, G. Bregliozzi RF foil workshop and checkpoint meetings)



Impedance calculations (B. Salvant, O. Zagorodova), CATIA -> CST MW Studio 3D calculations

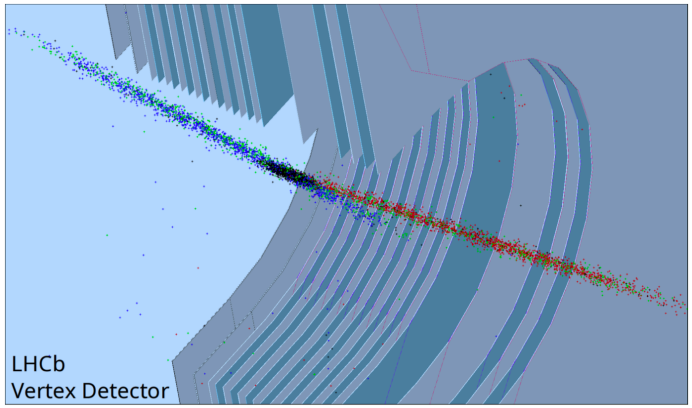
VELO Upgrade safety concerns similar to current VELO:

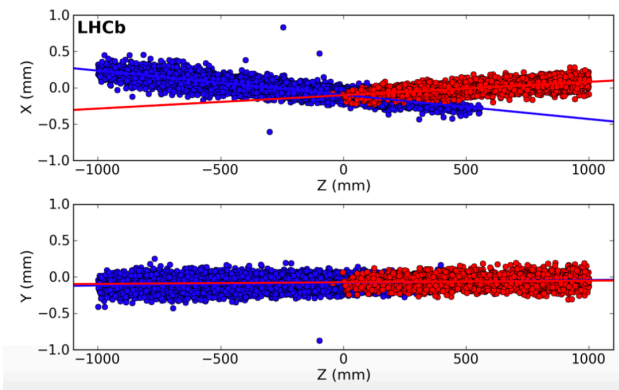
- Differential pressure of primary and secondary vacuum and effect on mechanical integrity of foil
- Protection of silicon sensors against high currents

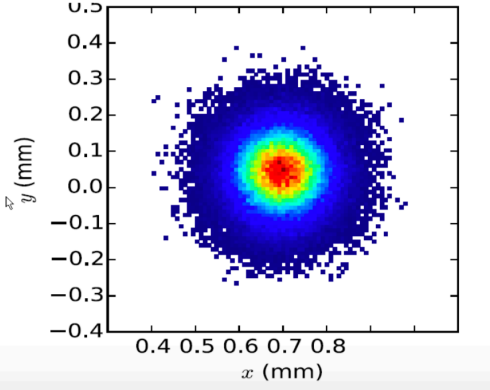
Action in case of extreme UE affecting LHCb (or LHC) also the same:

- Extract sensors and install blind flanges, Extract RF boxes and install emergency WF supressor, Install emergency pipe

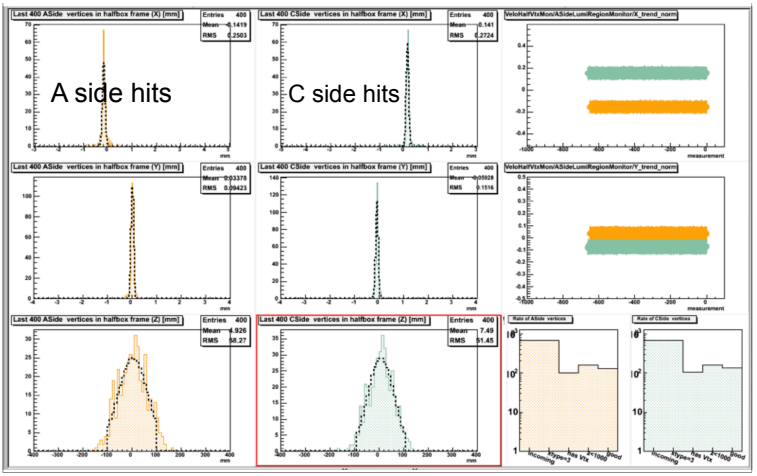
VELO - the mobile detector

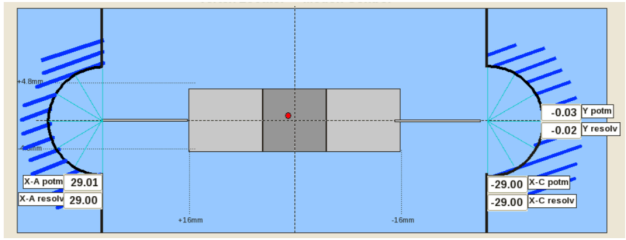


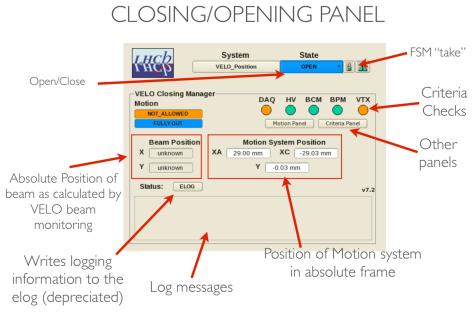




VELO supplies extremely precise beam imaging; here seen with SMOG to reconstruct position and angle, transverse profile, bunch population, ghost charge etc. The reconstruction also used as the ultimate safety factor during VELO closing

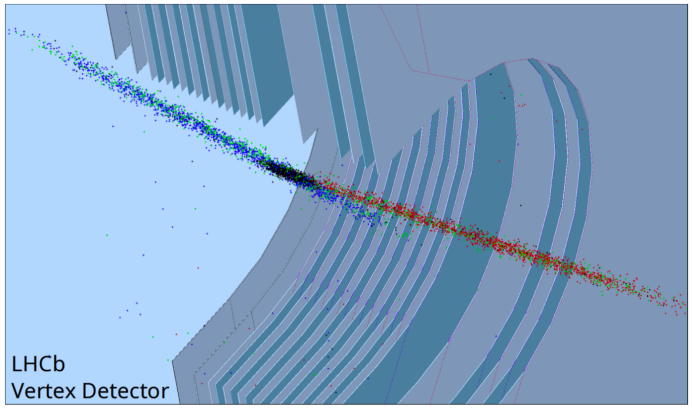


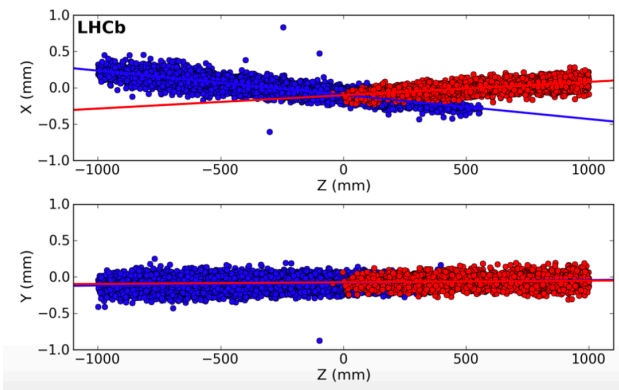


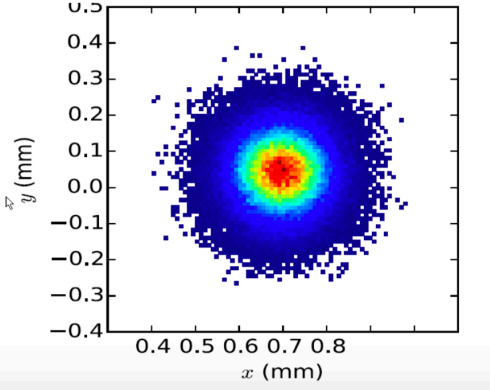


VELO closing monitor, panel, and Motion UI
32 criteria to be satisfied to allow each movement
After first year of operation - and ironing out of most glitches - move to automatic closing procedure
VELO has now opened and closed in real conditions thousands of times

VELO - the mobile detector







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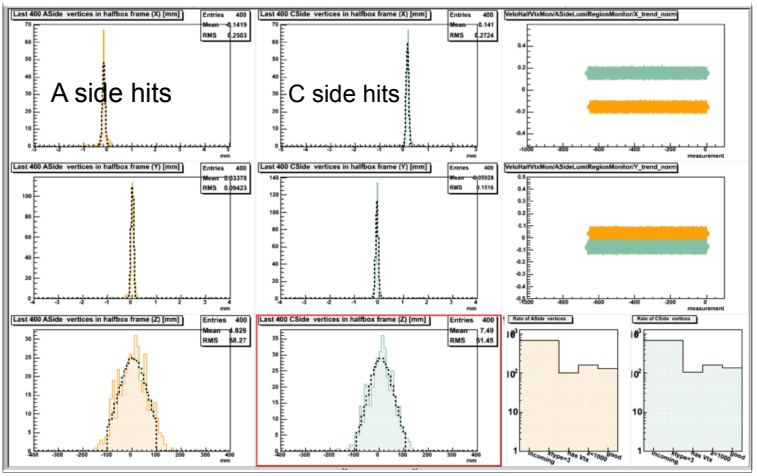

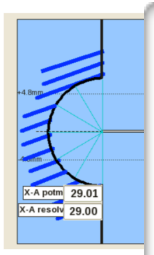

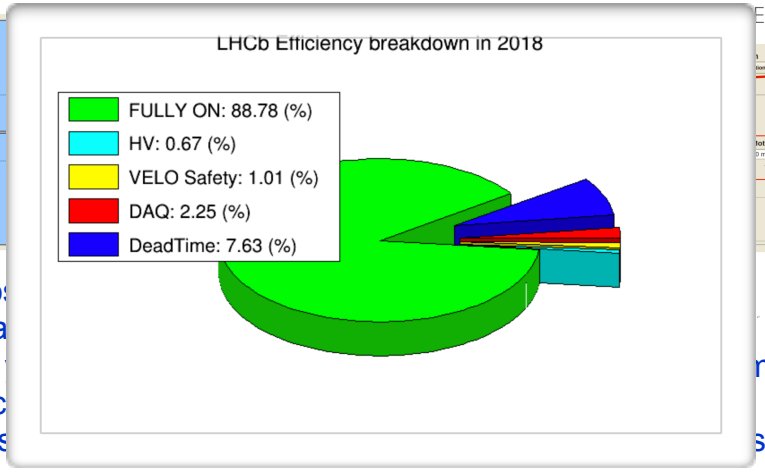

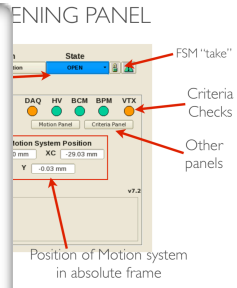

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32 criteria
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Conclusions

- **To be discussed today:**
  - Review of motion system EoR incident
  - Safety matrix and implementation
  - New features related to enhanced pressure sensors (CO_2)

Thank you for your attention