The LHCb Velo Upgrade

9th International "Hiroshima" Symposium

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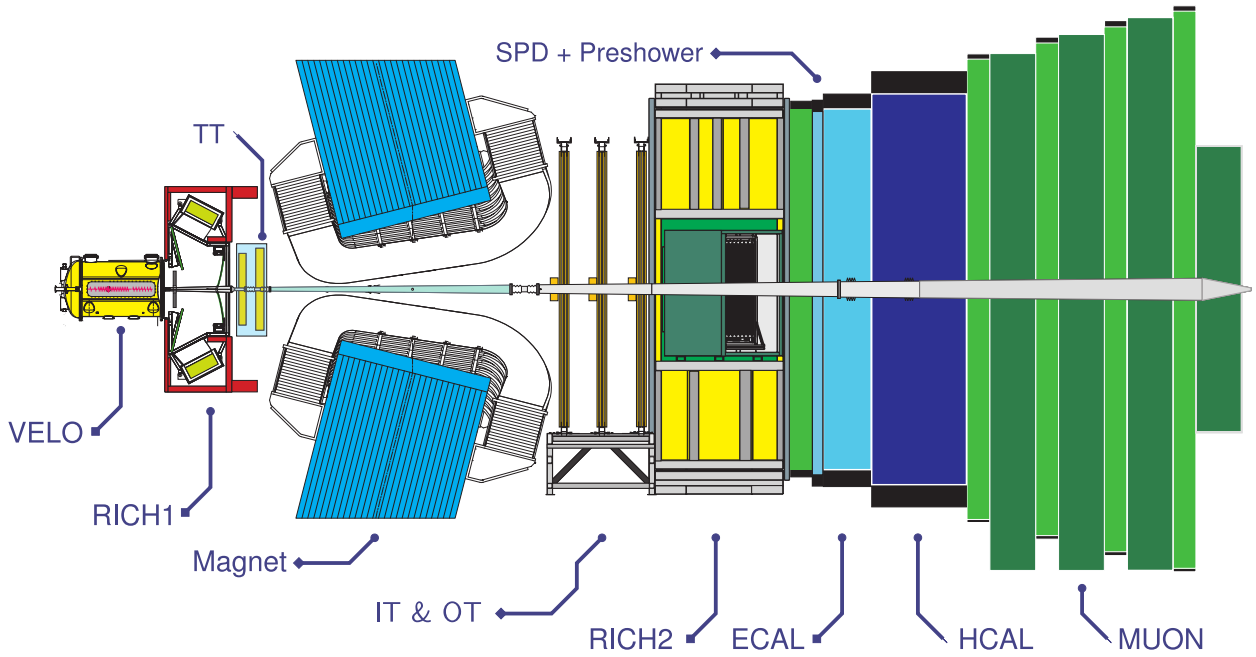
on behalf of LHCb

CERN

5 September 2013

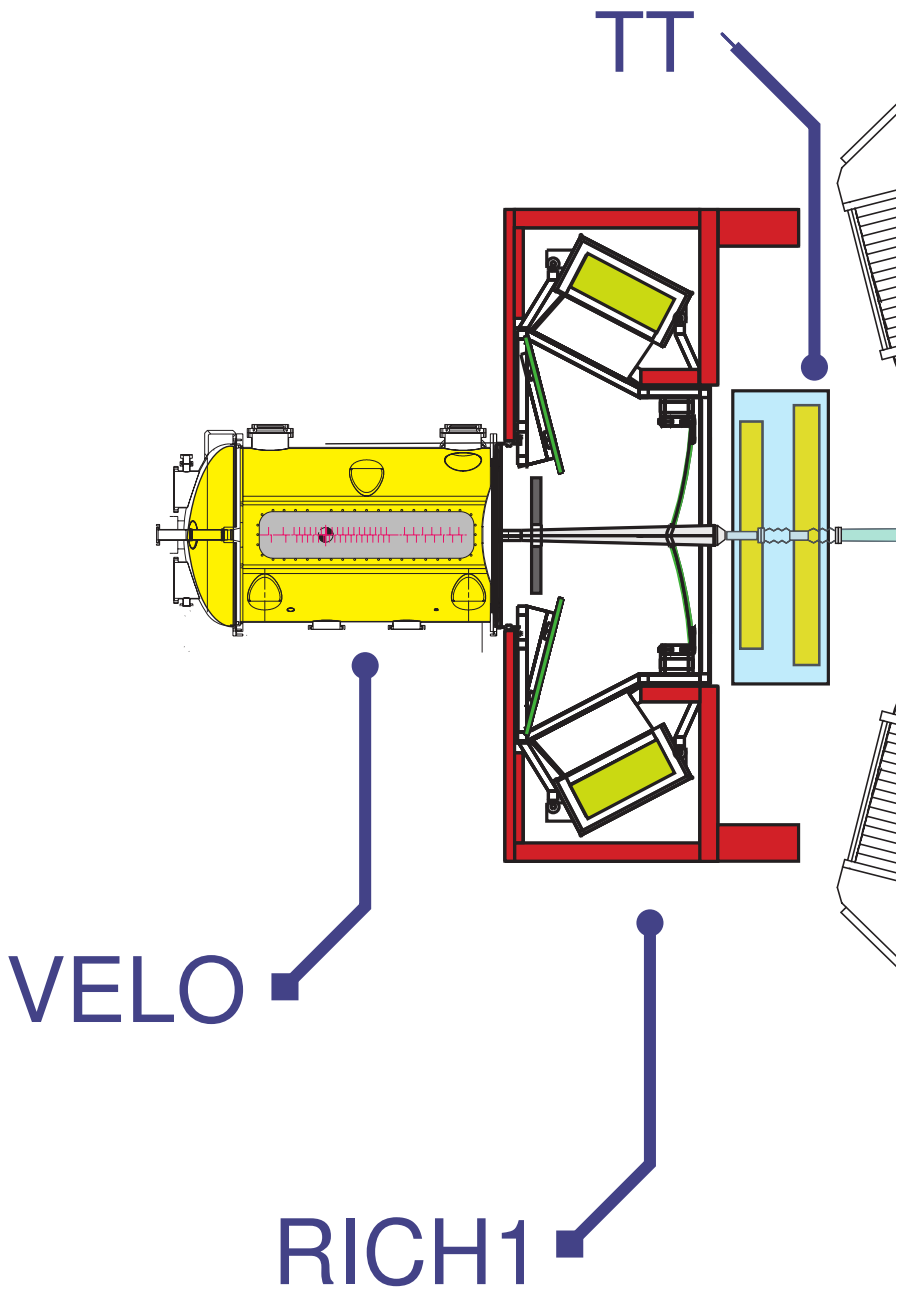
The LHCb Detector



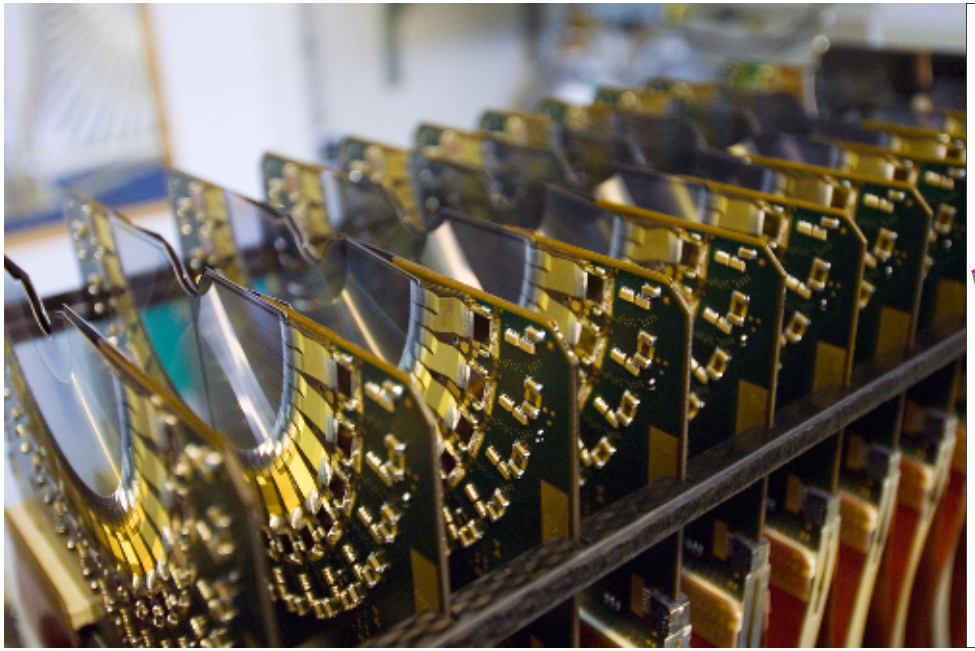
- LHCb is a single-arm ($2 < \eta < 5$) spectrometer at the LHC
  - Precision beauty and charm physics: CP violation, rare decays, heavy flavour production
- Time-dependent analyses require good time resolution: $\sim 40\,\text{fs}$
- Efficient trigger requires precise Impact parameter measurement
- Current detector performance shown earlier this week by Hella [link]

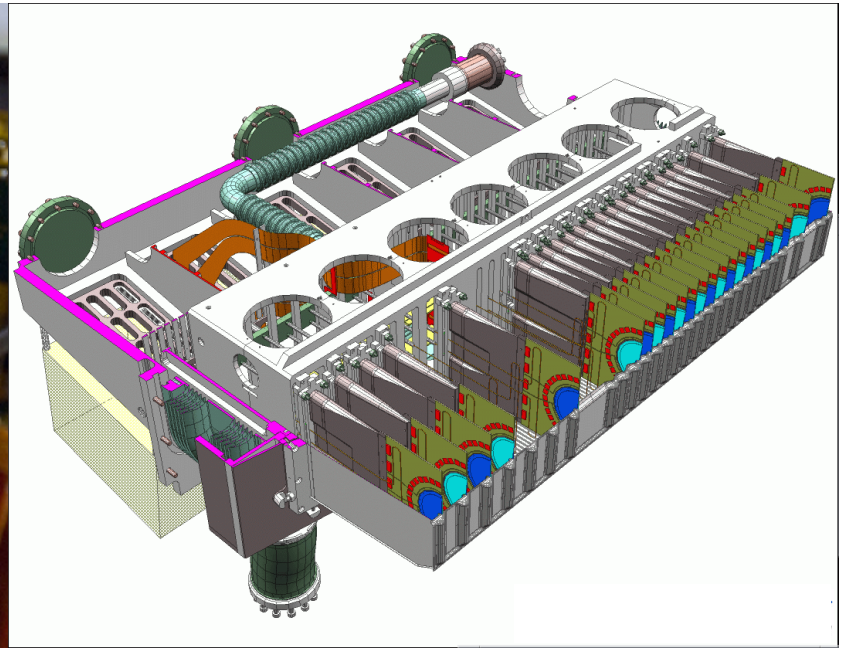
The LHCb Detector

- Vertex Locator surrounds the interaction point
- Made of two halves which can open and close



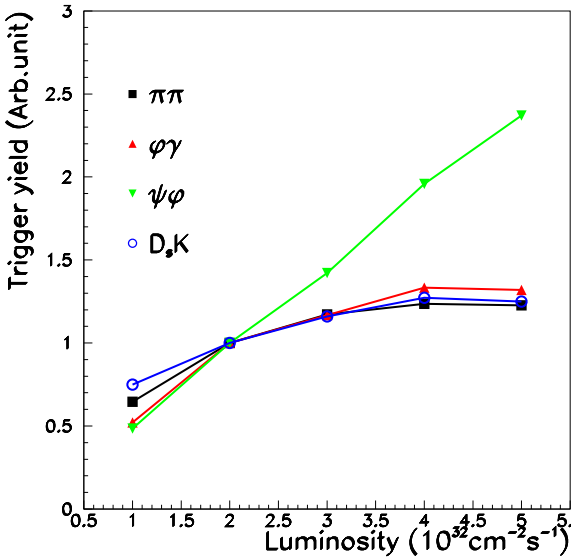
The Current VELO

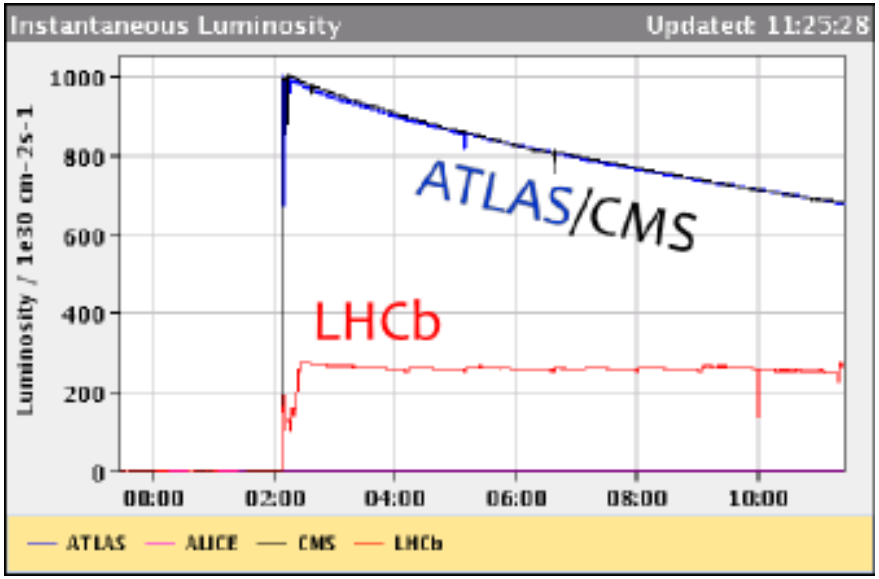




- 88 silicon strip sensors in R-ϕ design
- Active edge at 8.2 mm
- Evaporative CO_2 cooling, each module produces $\sim$ 16 W of heat
- In vacuum, separated from LHC by 300 μm thick foil

Why Upgrade?



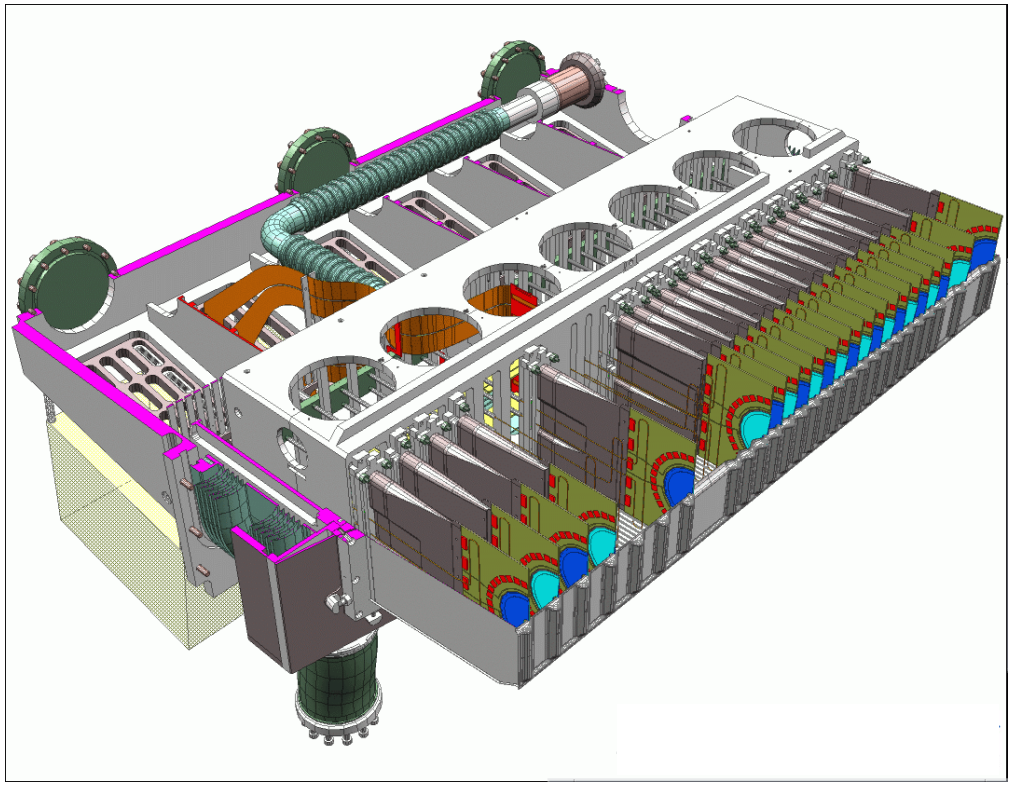


- LHC already provides higher instantaneous luminosities
  - would currently not translate into higher (hadronic) yields
- Current detector is limited due to 1 MHz readout rate of hardware trigger

For the upgrade in 2018:

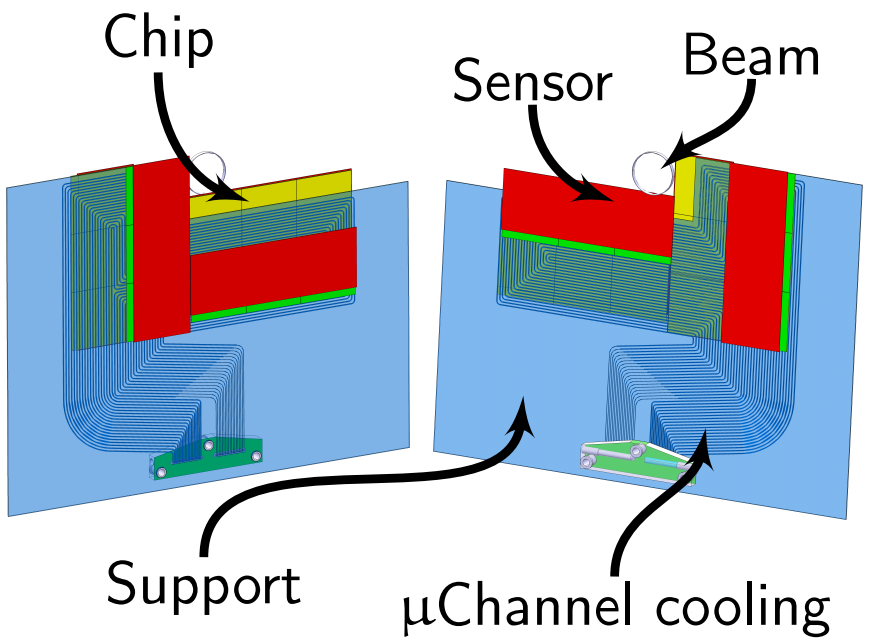
- Read out every detector component at 40 MHz!
- Improve on the excellent performance of the current Velo

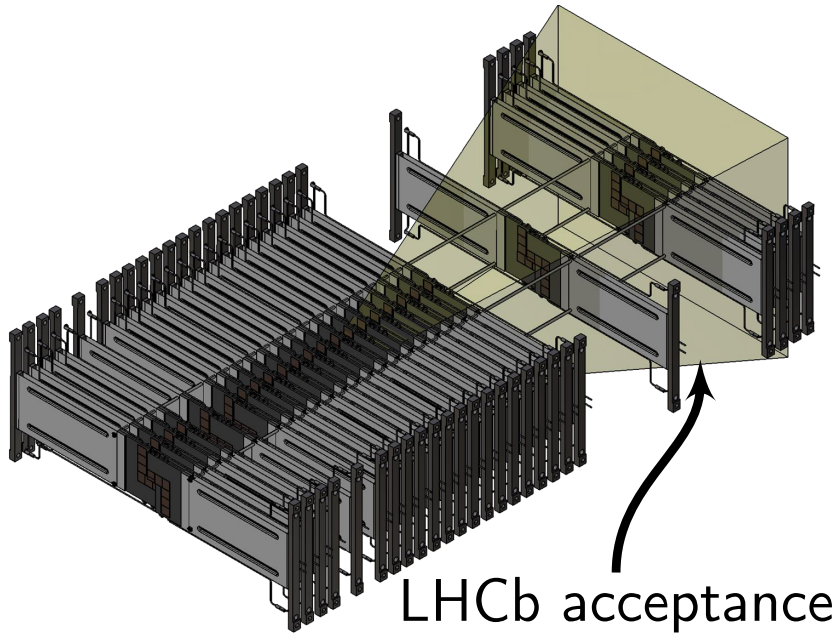
Upgraded VELO



- Keep infrastructure: cooling, vacuum tank, power supply
- Upgrade detector modules, readout, lower material RF shield

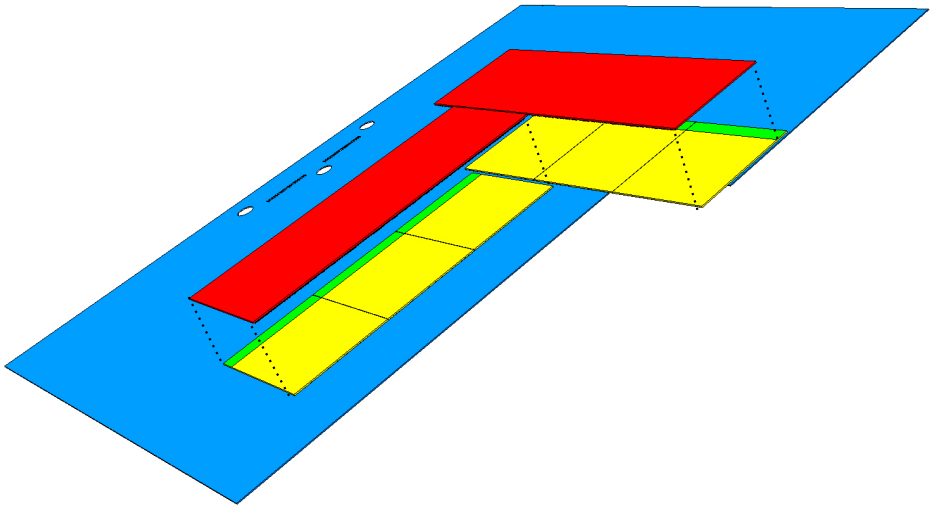
Upgraded VELO Module

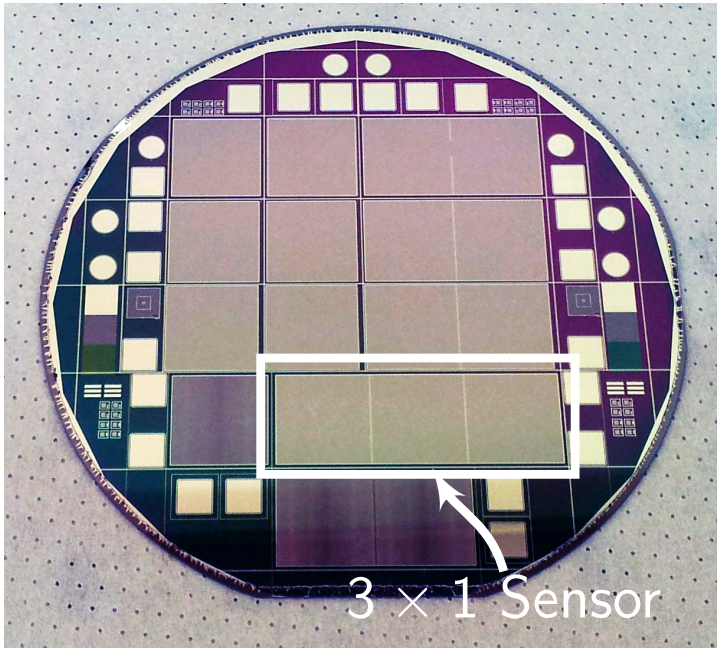




- Active edge at 5.1 mm
- Cooling retracted from sensor tip to minimise material
- One module is made of 4 sensor tiles
- Two modules make one station
- 26 stations with a total of 40 894 464 pixels

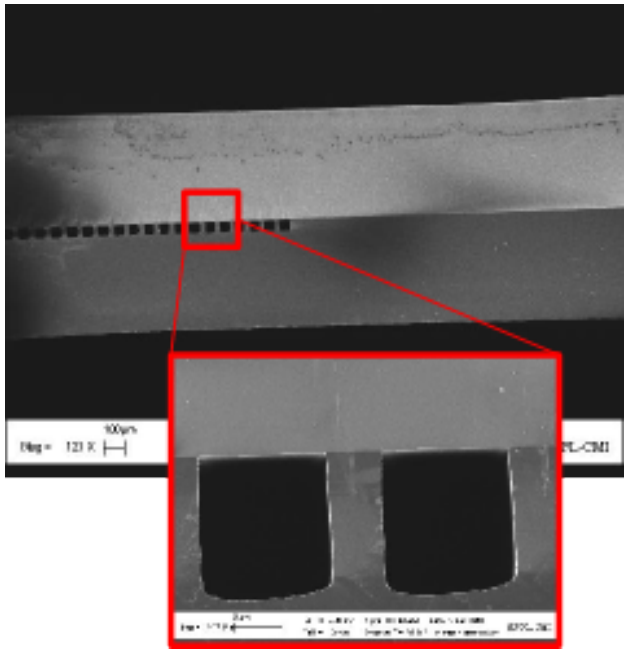
Upgraded Sensors and Chips





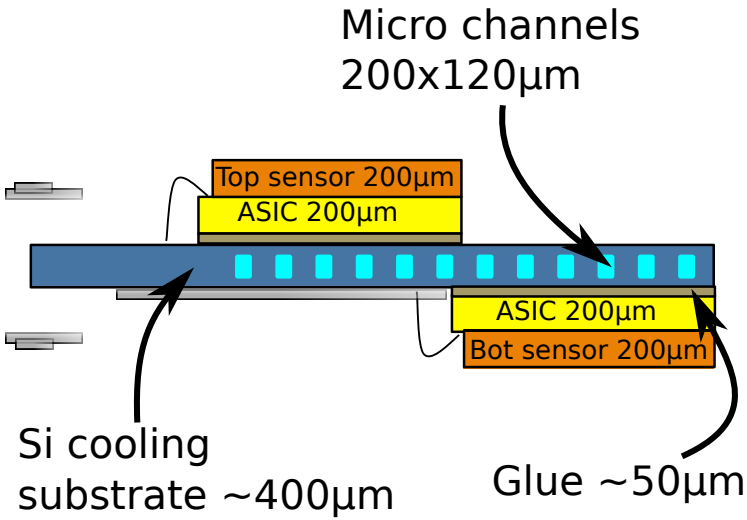
- Each sensor tile (∼15x45 mm) bump bonded to 3 chips
- Silicon sensors with 55x55 µm pixels, 200 µm thick
- VeloPix chip based on TimePix3
  - TimePix team highly experienced
  - VeloPix data rate much larger than for TimePix
- Time stamping, Time over threshold or binary readout possible
- Peaking time <25ns, timewalk <25ns

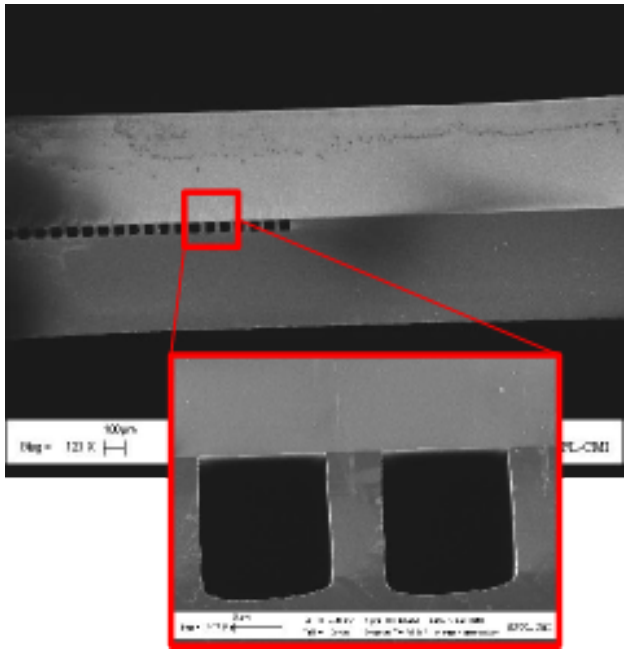
Micro Channel Cooling



- Want a low mass cooling solution
- All material is silicon, no mechanical stress due to CTE mismatch
- Customise routing of channels to go exactly where heat is produced
- Large cooling liquid surface area by using many narrow channels

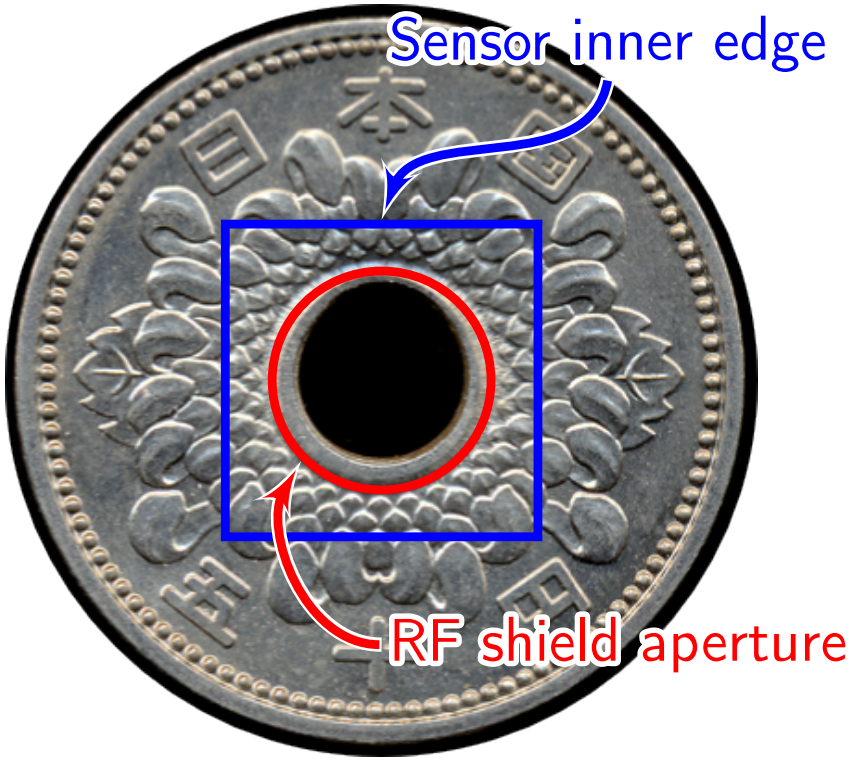
Micro Channel Cooling

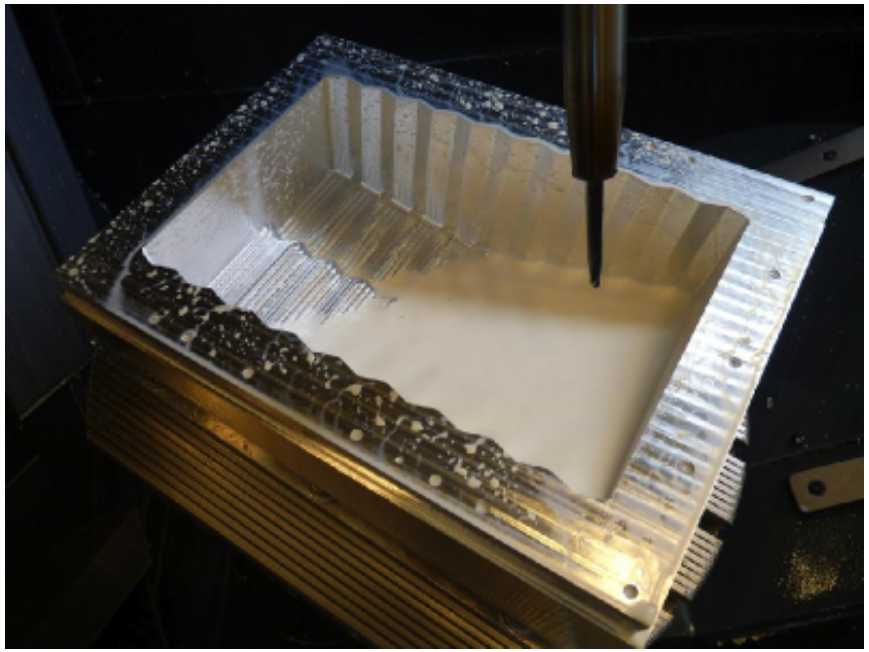




- Want a low mass cooling solution
- Each module produces $\sim 40\,\mathrm{W}$
- Successfully pressure tested to $> 10\times$operating pressure
  - nominal pressure 15bar at -30C, 60bar at room temperature
  - tested to over 700 bar!
- Large scale endurance testing campaign underway

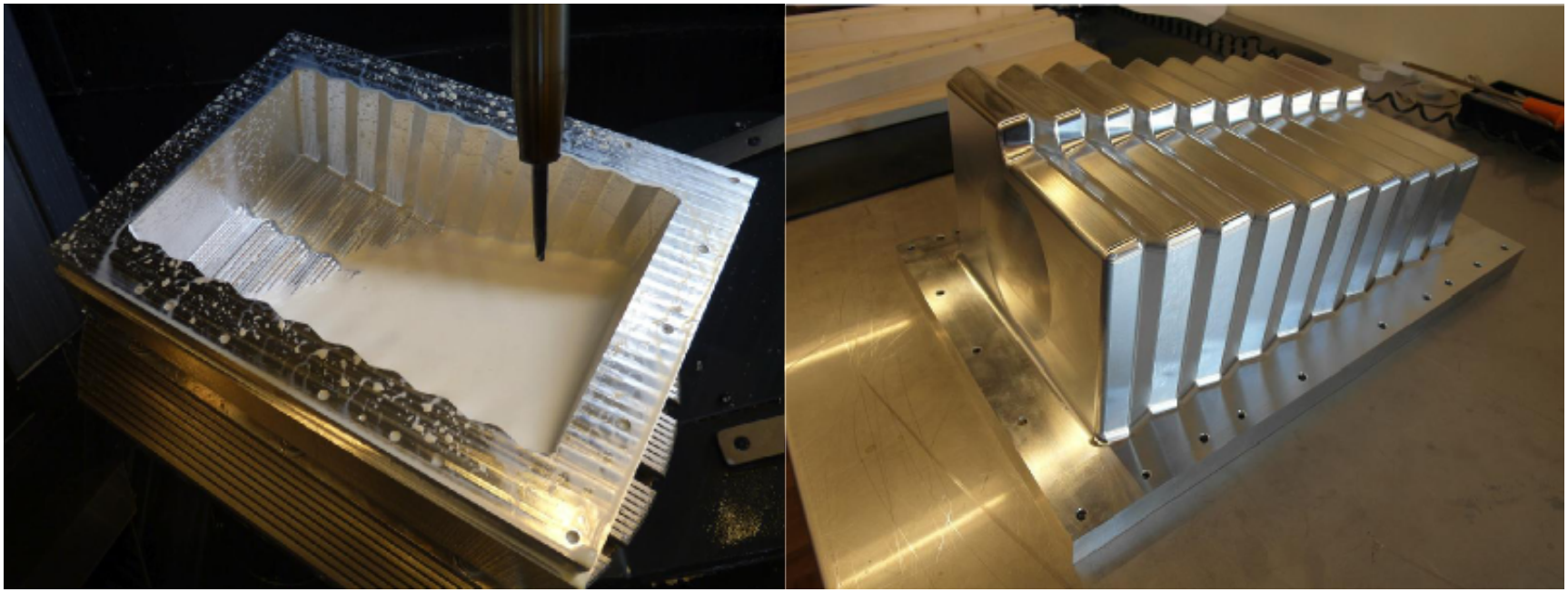
Upgraded RF Shield





- Requirements: vacuum tight, low mass yet mechanically stable, radiation hard, thermally stable
- Mill a 300 µm thick foil from a solid block of Aluminium
- RF shield aperture: 3.5 mm, sensor inner edge: 5.1 mm

Upgraded RF Shield



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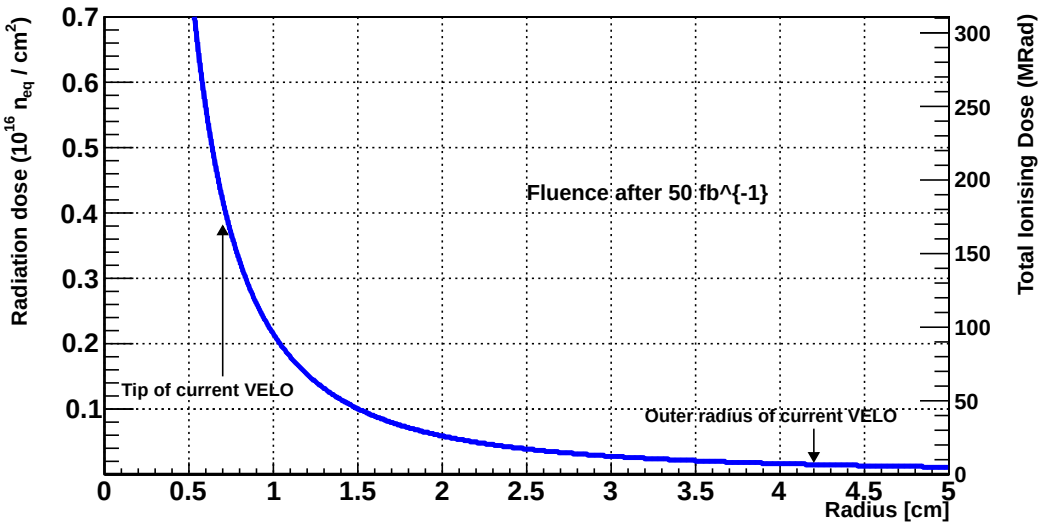
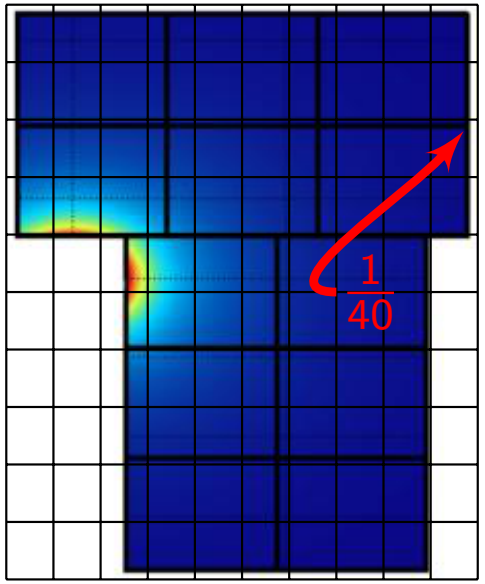
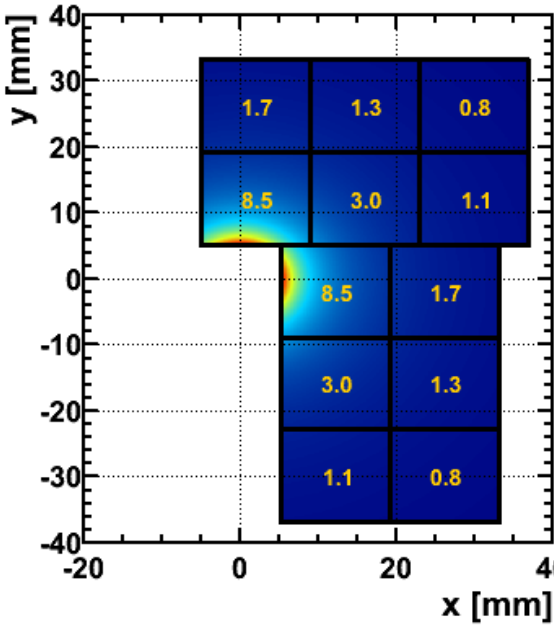
Radiation Damage

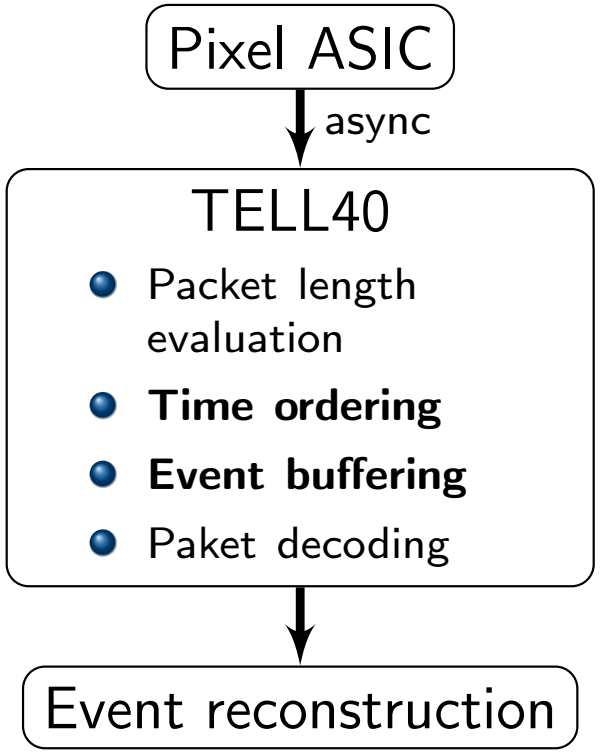




- Sensor has to withstand $8 \times 10^{15} \frac{n_{eq}}{cm^2}$ ($\sim$ 400 MRad after 10yrs) at edge closest to beam
  - ... and only $\sim 1/40$ of that at point furthest from beam
- Irradiated areas require higher bias voltage
- Need to apply 1000 V to fully deplete
- Solution might be asymmetric guard rings

Data Rates @ 40 MHZ





- Whole detector produces data at a rate of 2.5Tbit/sec
- Rate varies greatly across different regions
- ASIC readout is data driven, results in out of order arrival of data
  - on chips zero suppression
- Innermost region, hottest ASIC:
  - 8.5 tracks $\times$ 40 MHz $\approx$ 320 Mtracks/sec/chip
  - equates to a data rate of 20Gbit/sec/chip

Conclusion

- The current Velo detector is performing extremely well
- The upgraded Velo detector will be a silicon pixel detector
- Pioneering extremely light weight micro channel cooling
- Improved IP resolution compared to current detector
- Will allow us to record more data
- On course for installation for 2018 upgrade