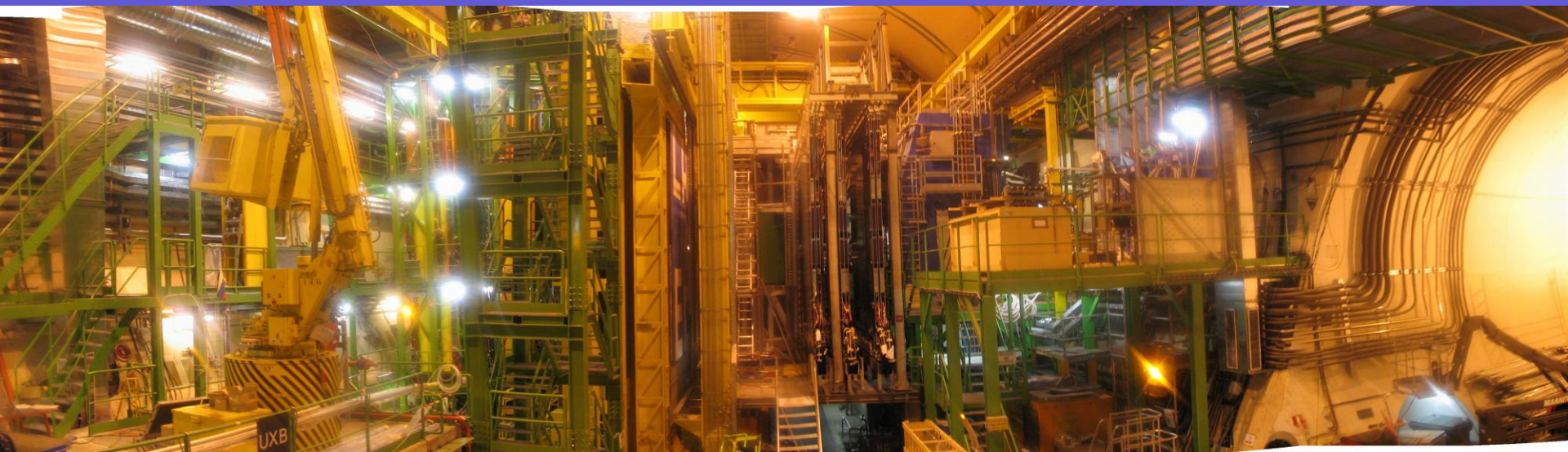
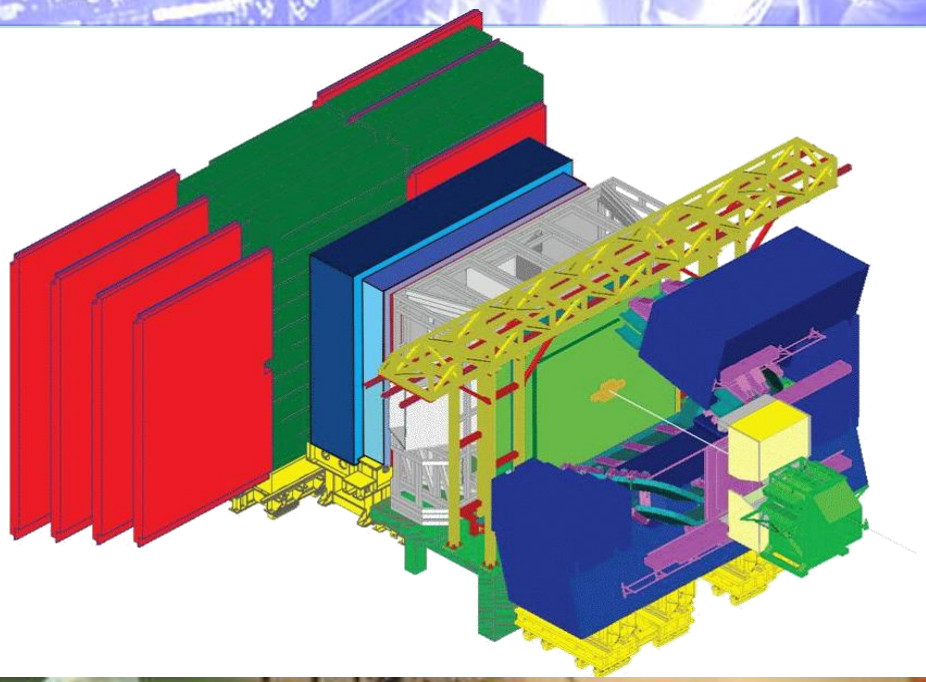
Operation and Performance LHCb Vertex Detector

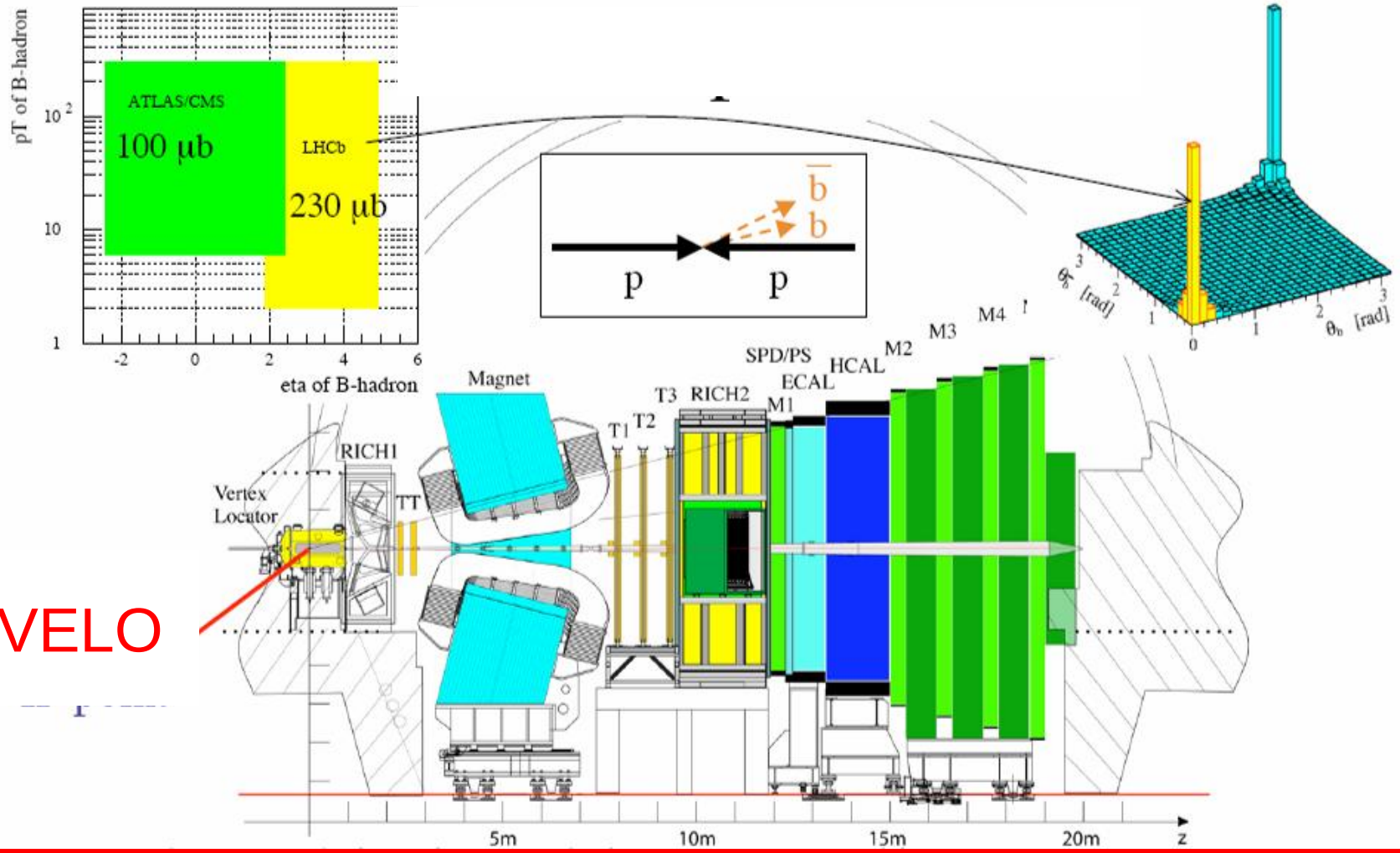


Overview

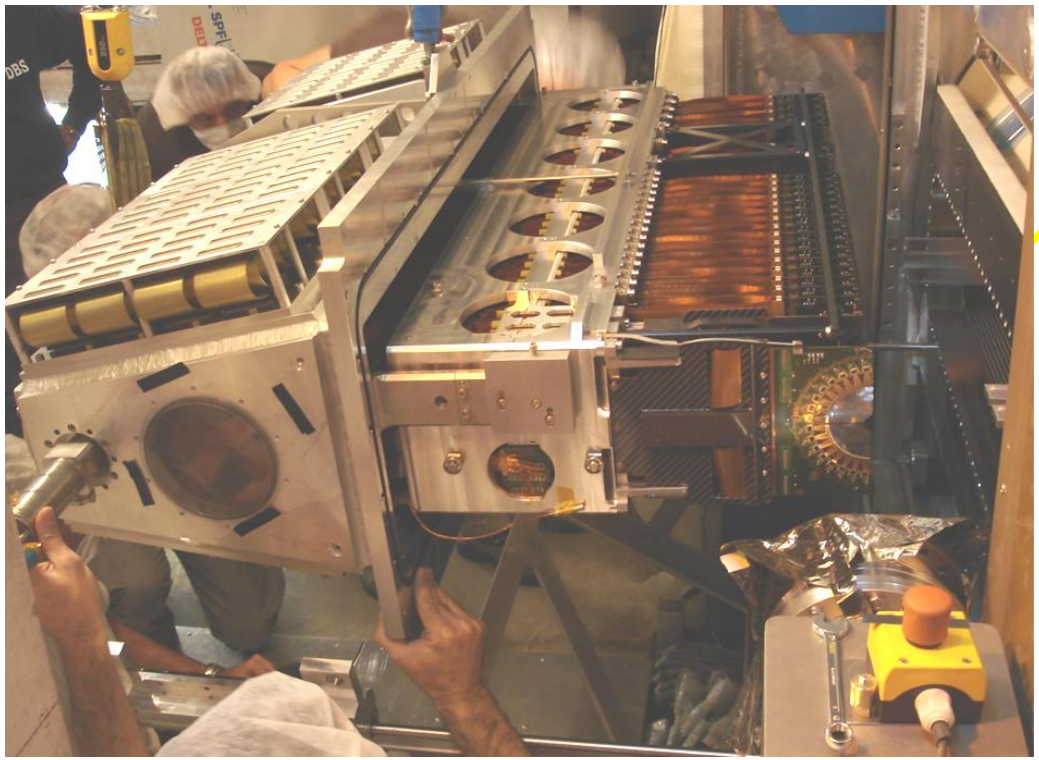


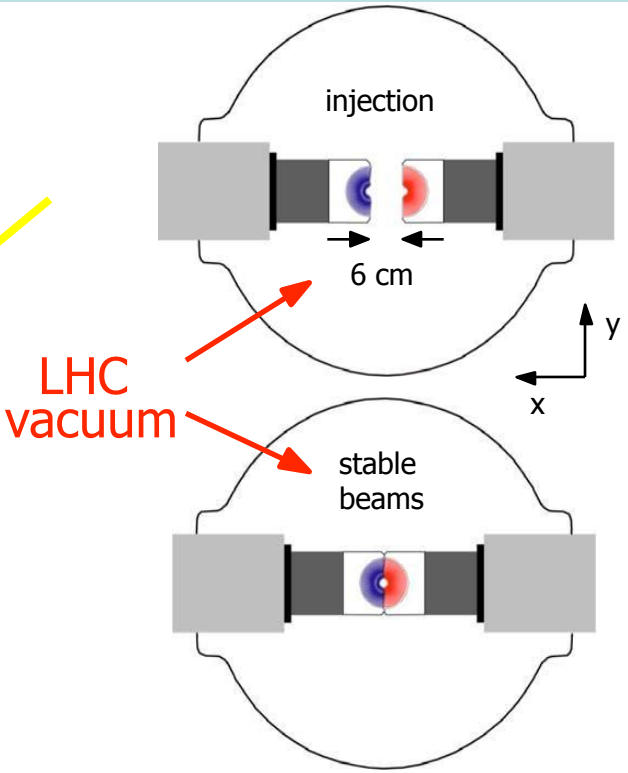
- LHCb & VELO
- Operation
- Performance
  - *M. Gersabeck, S. Redford, & M. Alexander*
- New Issues

LHCb: Spectrometer



VELO: Schematic





- 2 retractable detector halves
- 21 stations per half with an R and ϕ sensor

VELO: Complete half

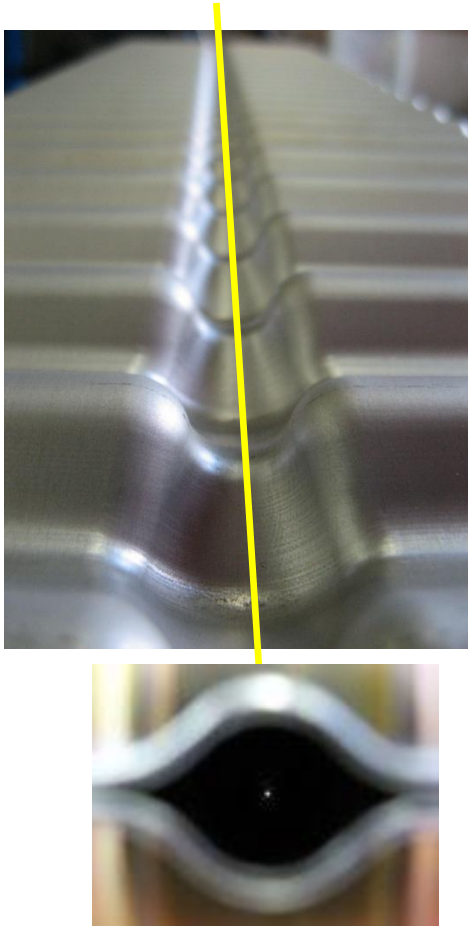
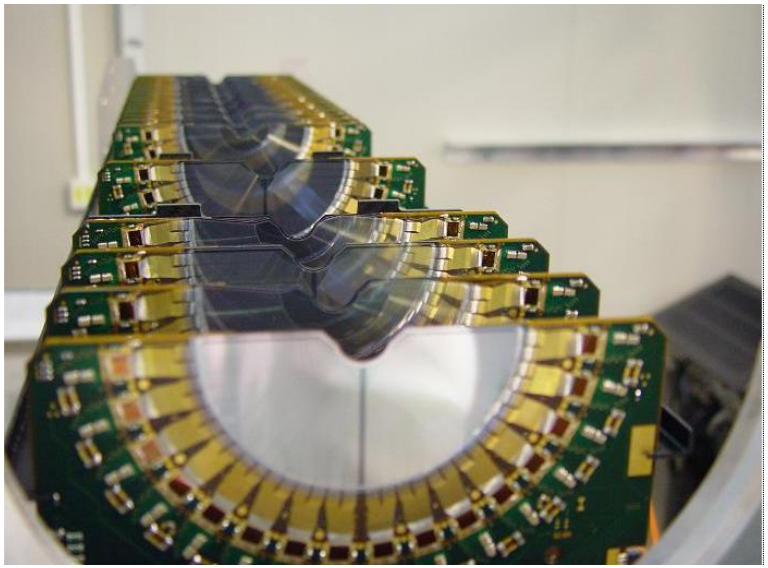


Photo along beam pipe

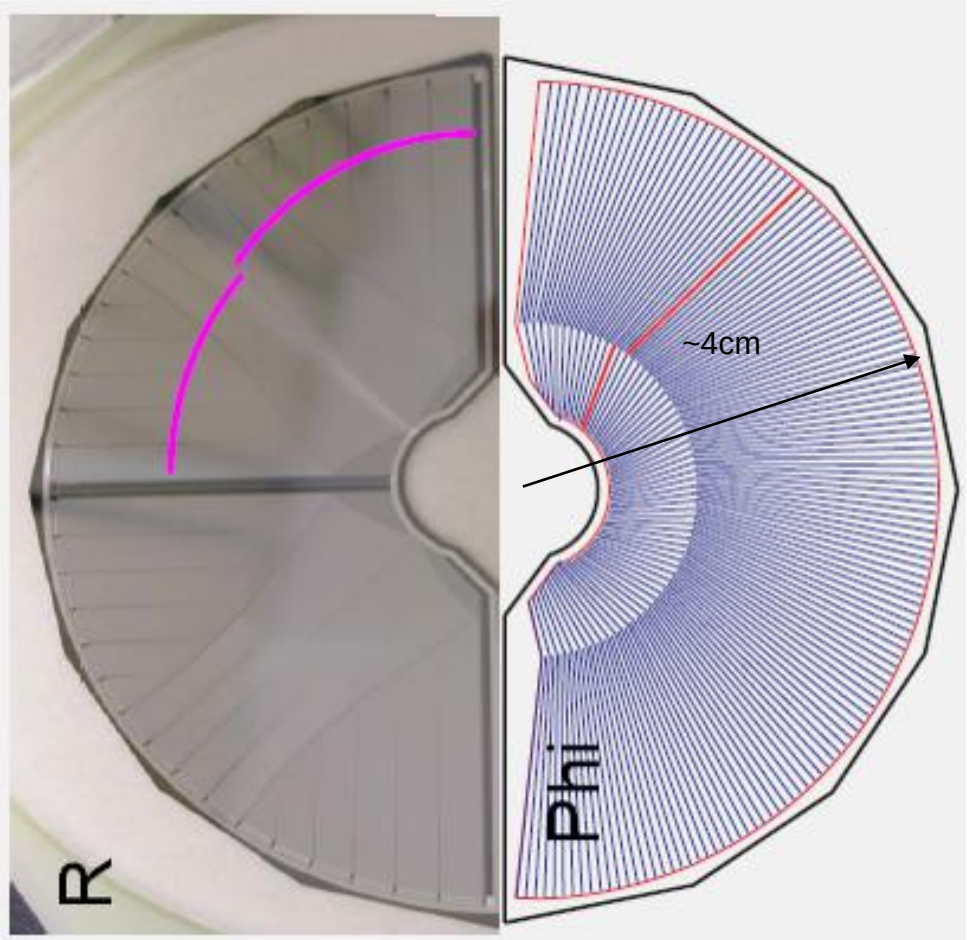


VELO: Electronics

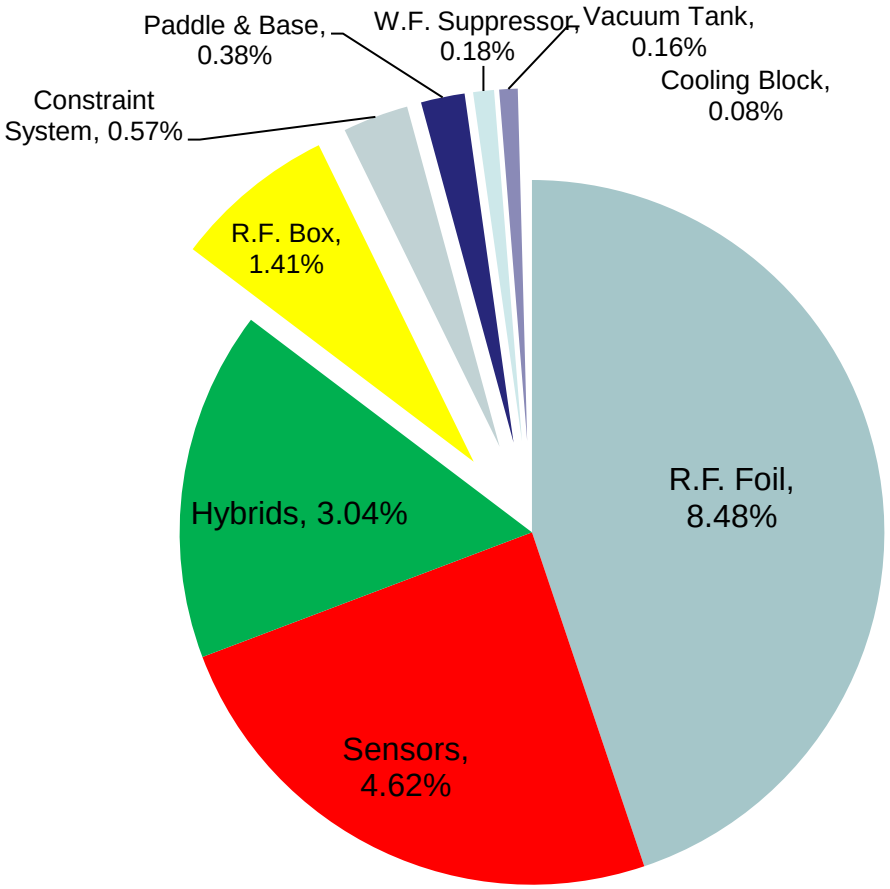
- Analogue output from ASICS on hybrids
  - 40MHz: up to 1MHz trigger rate
  - Repeater cards outside tank
- Digitization 60m away
- FPGAs handle processing of signals and zero suppression
  - 10^6 parameters need uploading
  - 7bit arithmetic
    - Integer pedestals and CM subtractions
  - Possibility of non-zero suppressed data to be sent to storage

VELO: Sensors

- highly segmented
- n^+n
  - One n^+p module
  - Replacement n^+p
  - p-spray isolation
- 2048 strips/sensor
- ~40 micron inner pitch

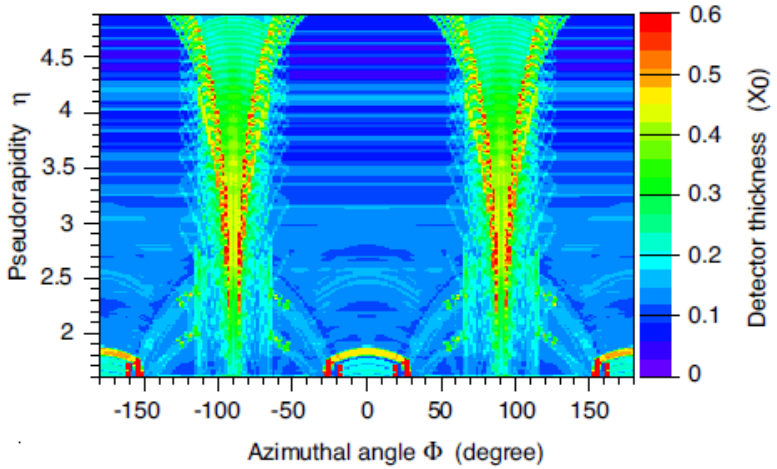


VELO: Material Budget



Material Budget (% X_0)

Average is 18.91% X_0
Particle exiting the VELO



See M. Gersabeck's talk for "tomographic" view of the VELO

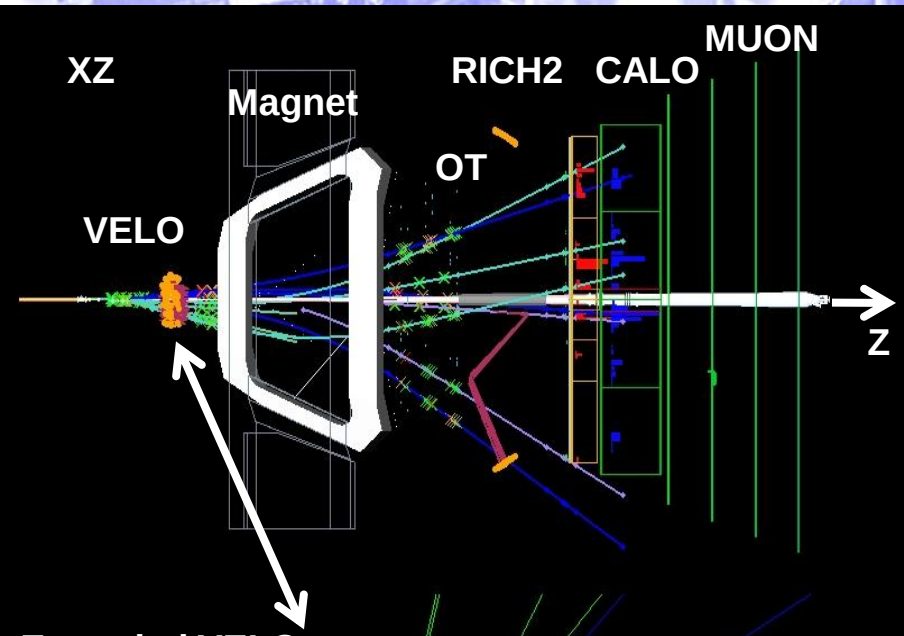
Operation: Key Decisions

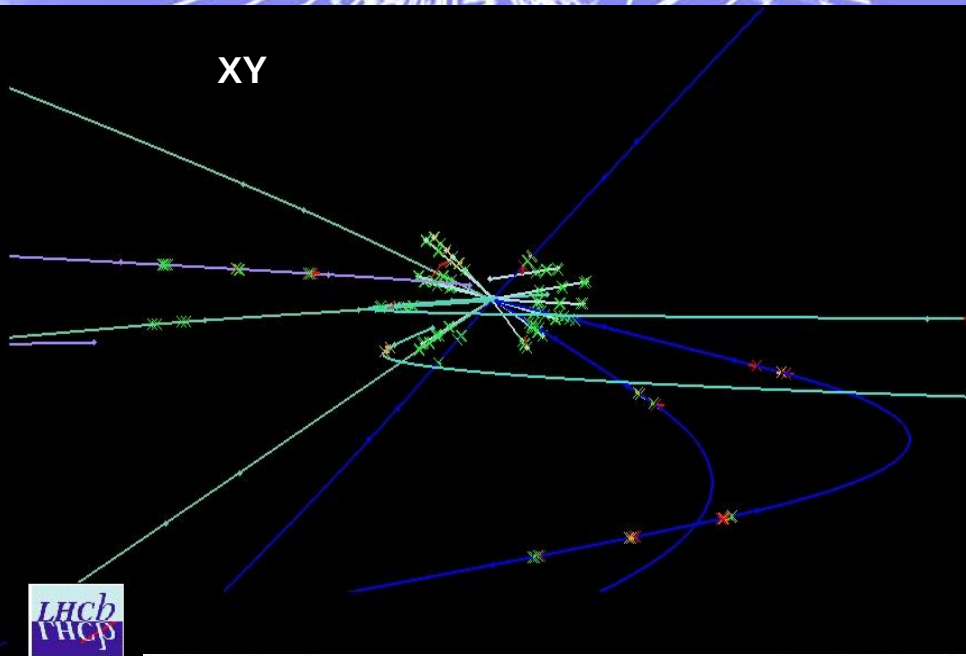
- Keep Detector LV power on except MD
  - To avoid thermal cycling
- Operate Cooling at -30°C (tested to -35°C)
- HV ramped at Beam Stable to 150V
- Closing
  - Manual operation/verification
    - (*Automation see S. Redford's talk*)
  - VELO would not be closed below 2TeV/c per beam
    - This to avoid maximize proximity of beam to foil at low energies
- Provide 24x7 coverage with VELO shifts
  - When collisions foreseen
- Non-Zero Suppressed Data read out
  - Small percentage of bandwidth O(1%).

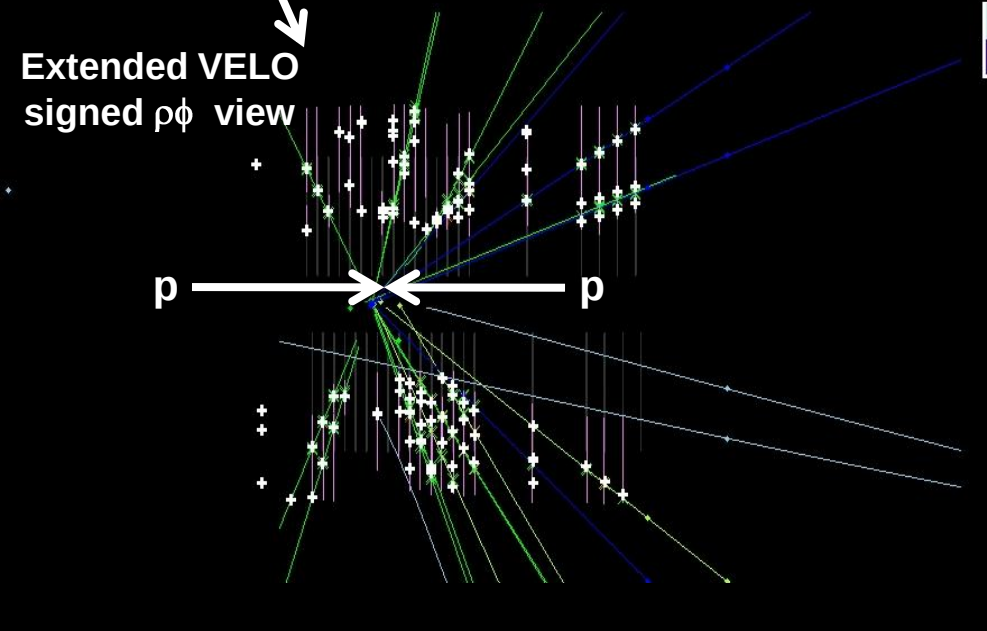
Operation: Shifters

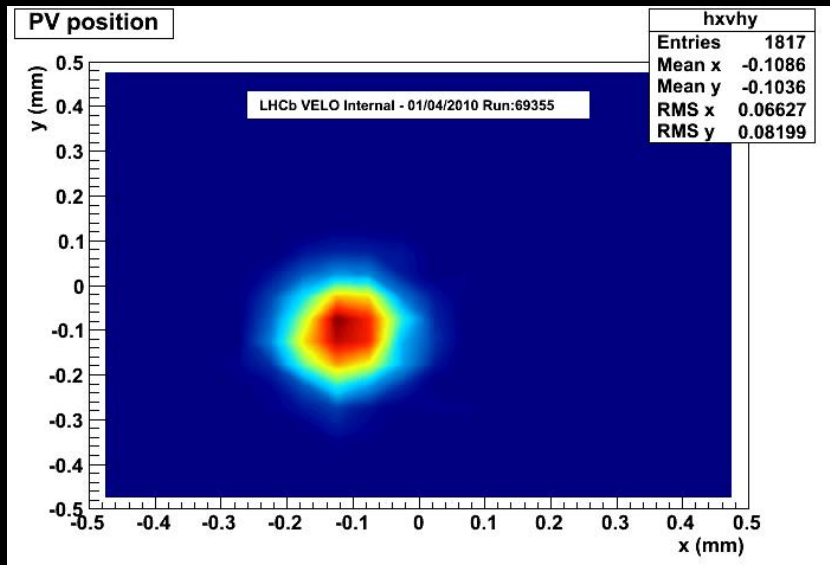
- What do they do?
  - Supervise safety of VELO
  - Learning about environment
    - Vacuum, temperatures as we increase beam current
  - Ensuring quality (occupancy, noise etc) all look fine
    - On the look out for common mode
  - Control the closing!
  - Follow vertex position & Luminosity monitors
- Hard to remove humans from the loop quite yet!

First Collisions 2009







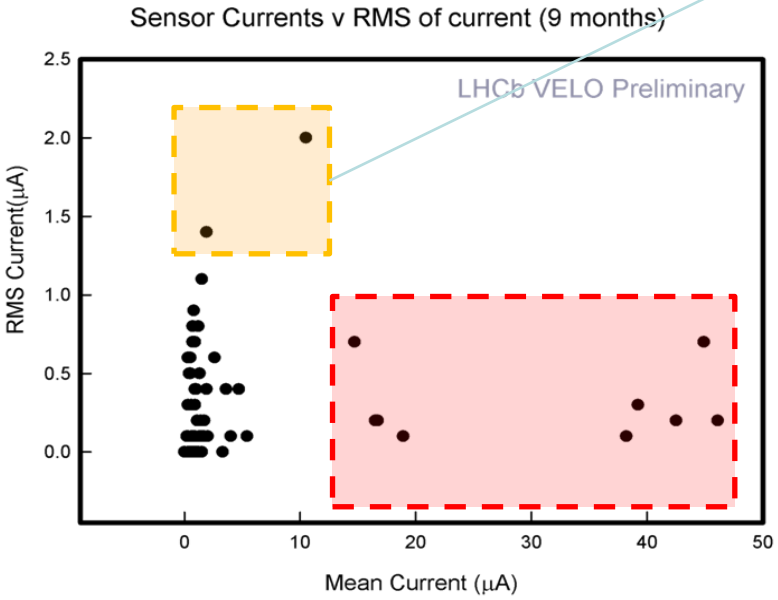


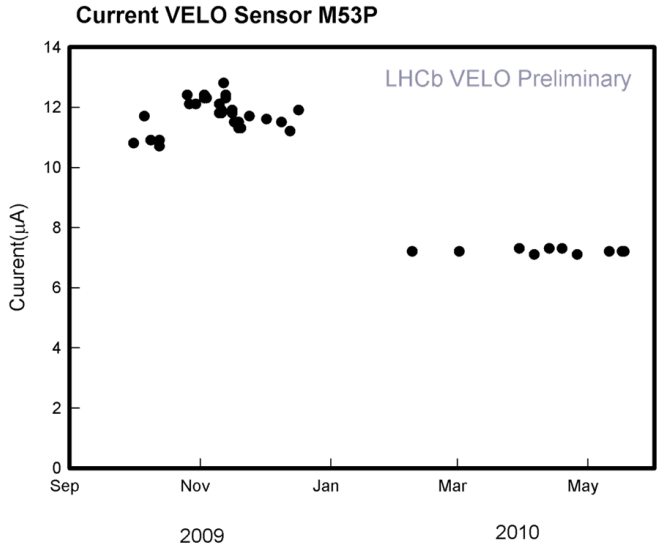
Performance: 2010 – June

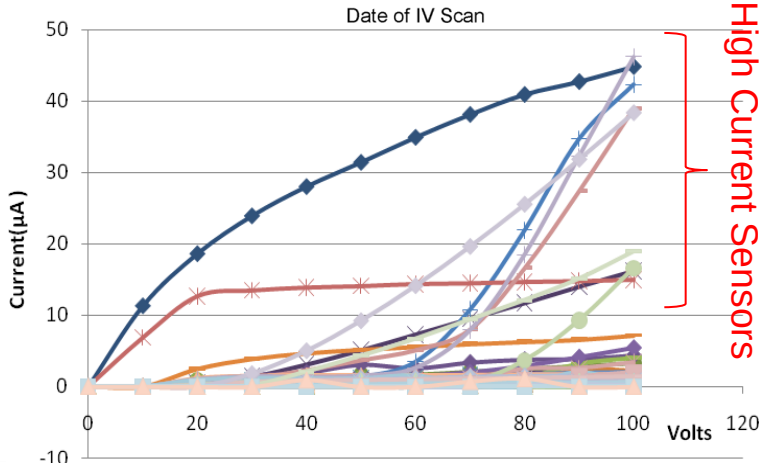
- Six months later
  - LHC much higher luminosity
    - New beam conditions (squeeze)
    - Increasing the numbers of bunches
- We now have $>10^9$ events
  - Many orders of magnitude away from radiation damage regime!
- What has changed with huge sample?

Performance: Silicon

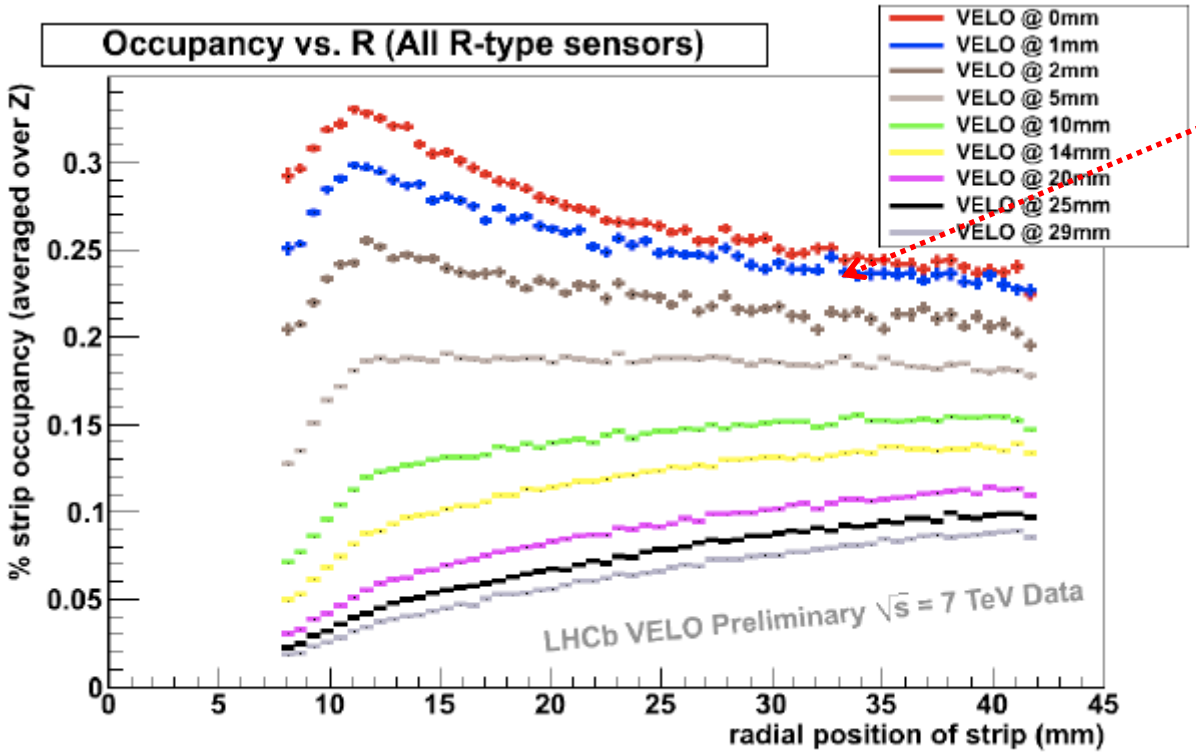
- No sign of Si changes
- IV scans run regularly
  - Currently use 100V as benchmark







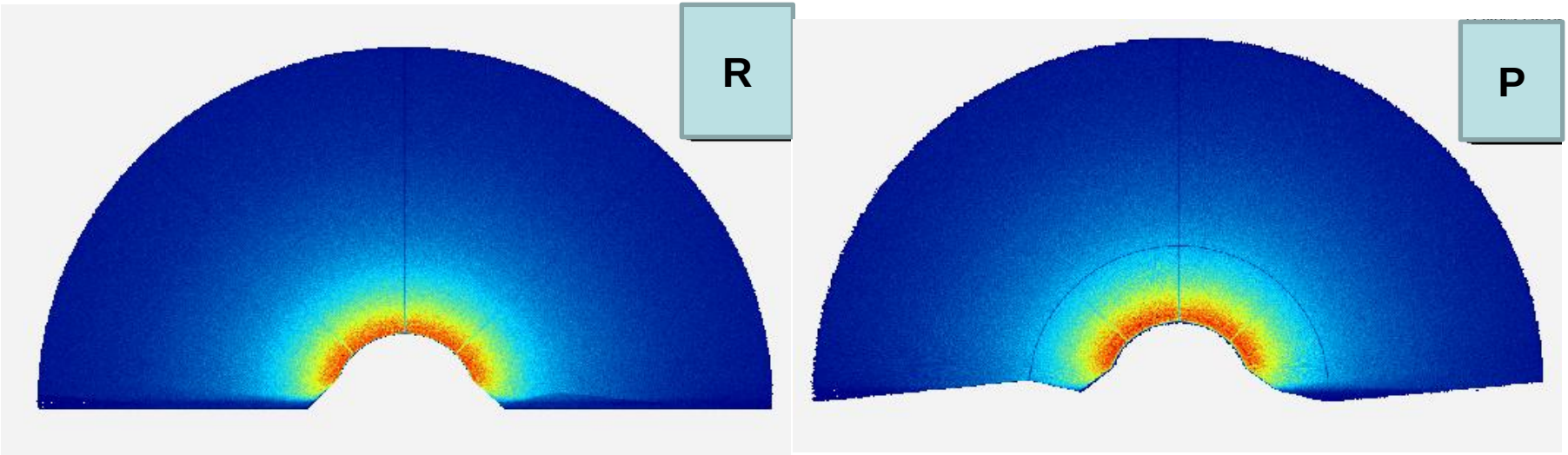
Performance: Occupancies



Design aimed to try and keep occupancy approx flat. (depends on trigger etc)

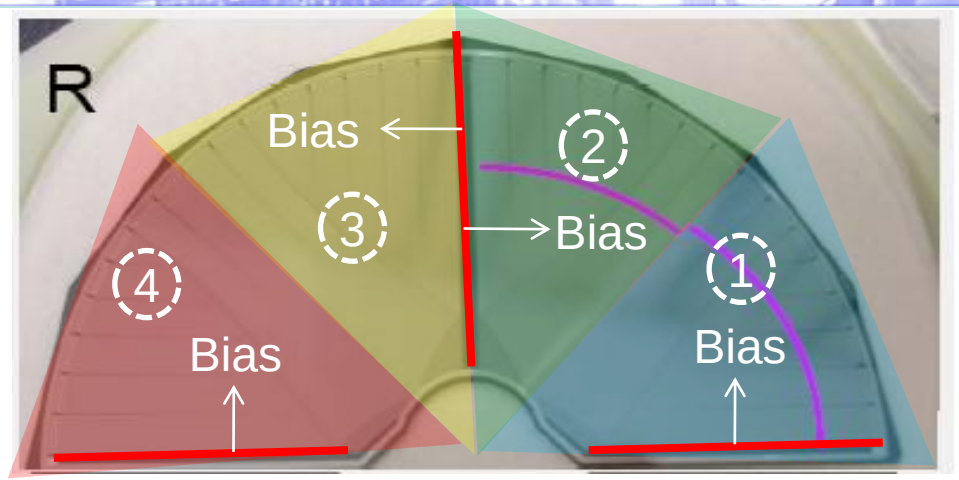
More detailed studies reinforce our expectations of distributions....

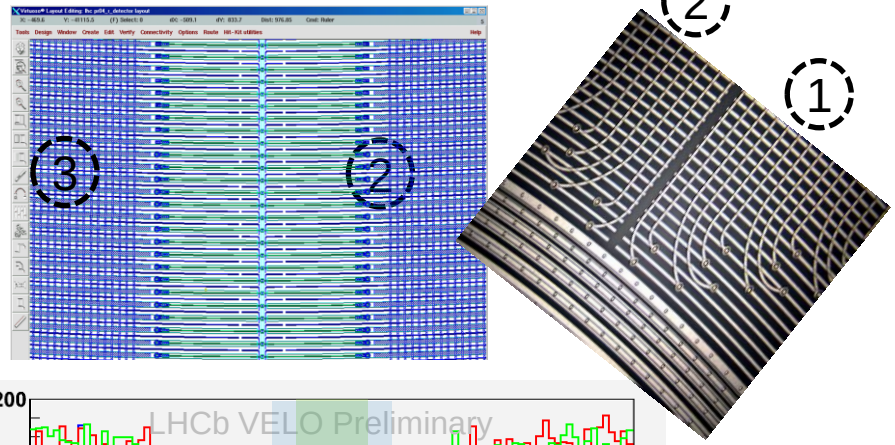
Performance: Hit Maps



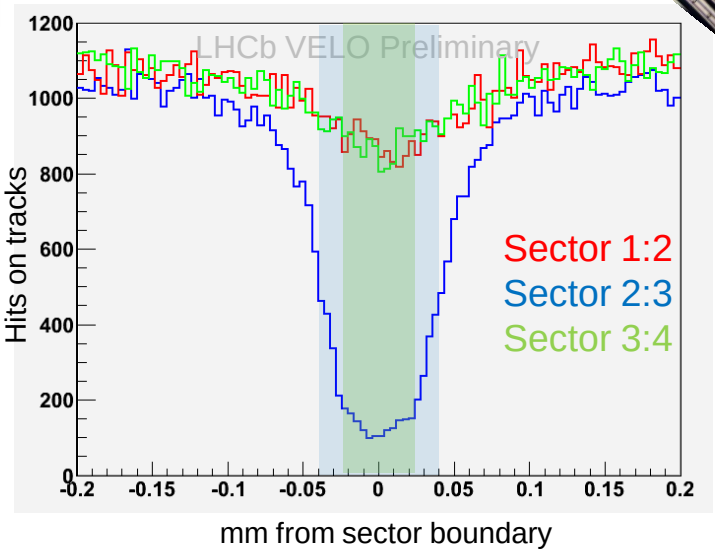
- Huge statistics (!)
- Pseudo Hit maps as sensor 1D
  - Require interpolation

Performance: Boundaries



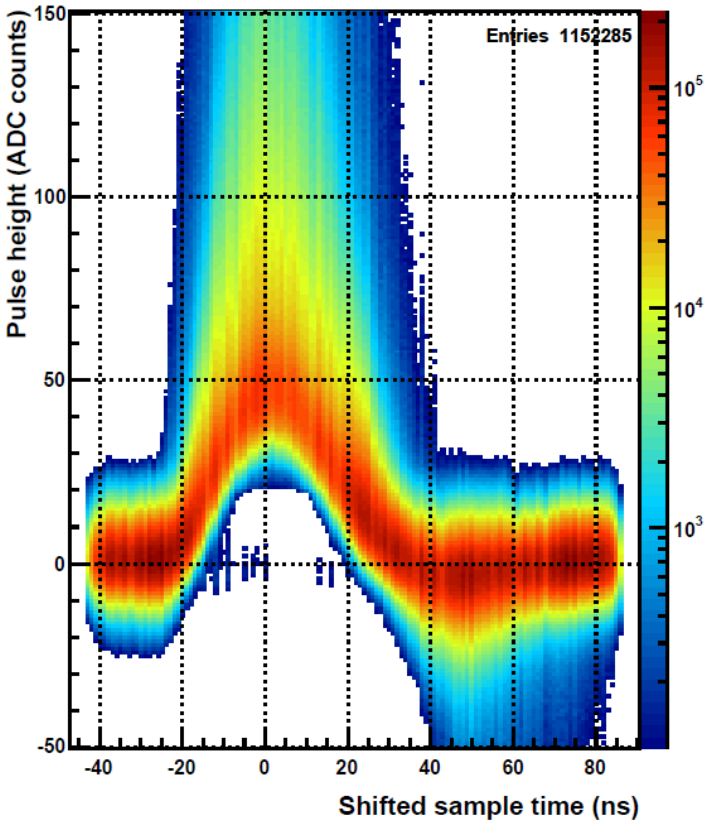


- Boundary 2:3 polysilicon bias line
  - 77 micron gap between strip implant
  - Intermediate bias line with implant
  - Charge in this region “lost”
- Boundary 1:2 and 3:4 no bias line
  - 38 micron gap between implant



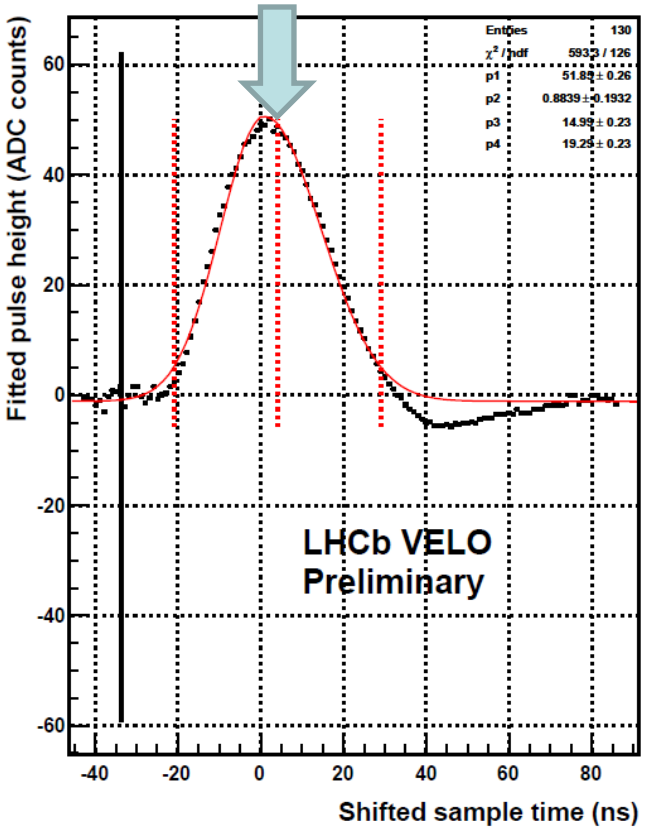
Performance: Timing

Combined pulse shape



Distribution of pulse heights v time

Operating point

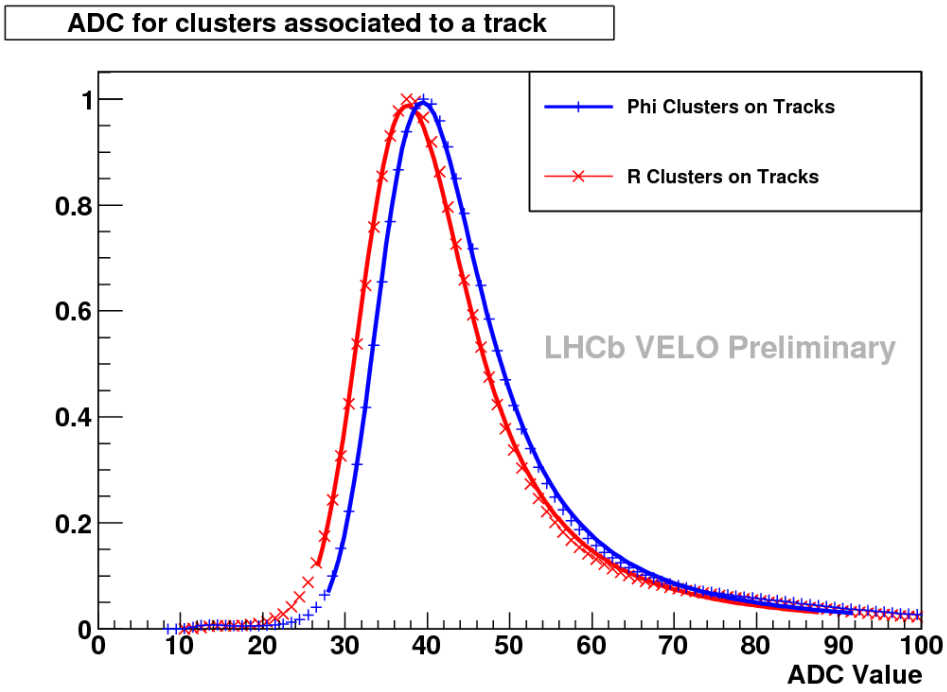


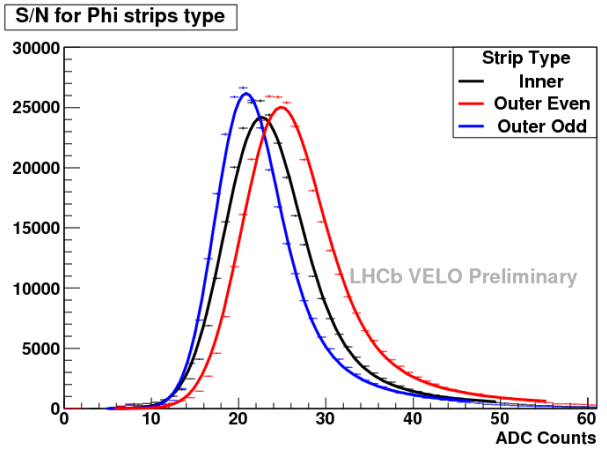
Set to equalize pre/post spill

All links timed ~1ns

Interactions can be separated by 25ns

Performance: Signal/Noise



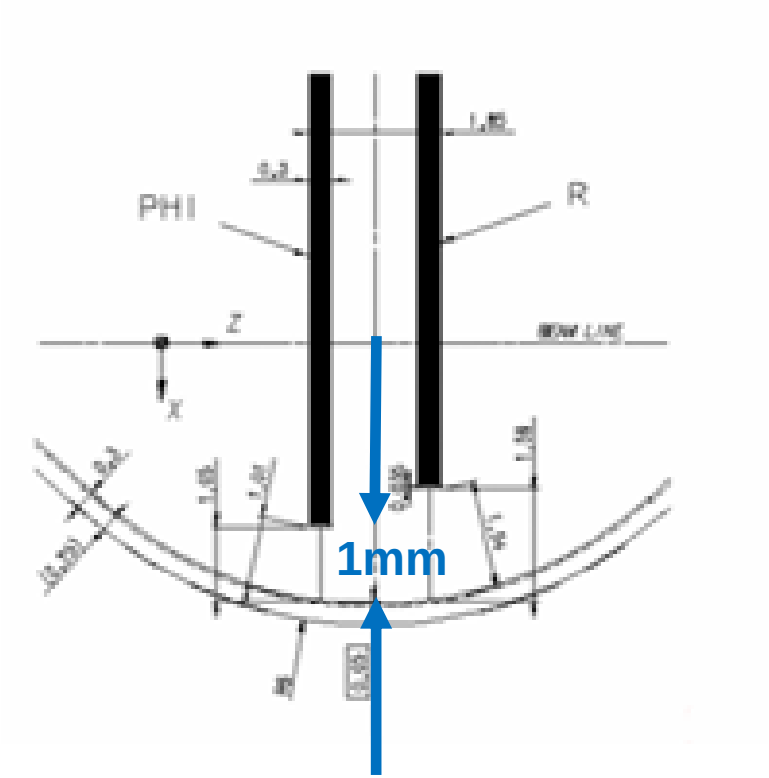


Detector	S/N
R	18.3
Phi Inner Strips - Routed over outer strips	21.2
Phi Outer Strips - *No* overlaid routing lines	23.3
Phi Outer Strips - Overlaid routing lines	19.6

After several years of operation expect S/N to drop to O(10).

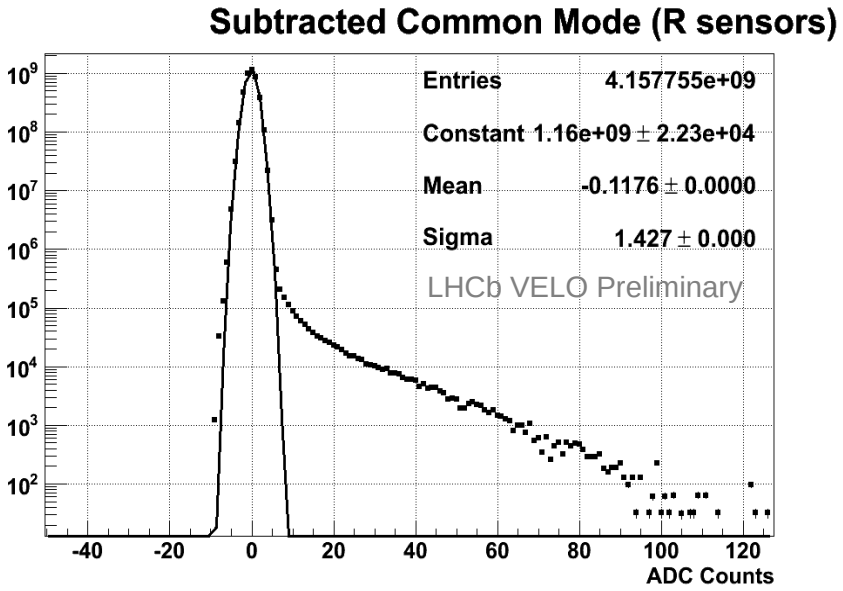
Performance: Common Mode

- VELO close to beam and O(1mm) from r.f. foil
  - Common mode pickup a concern
  - NZS studies to search for beam related effects



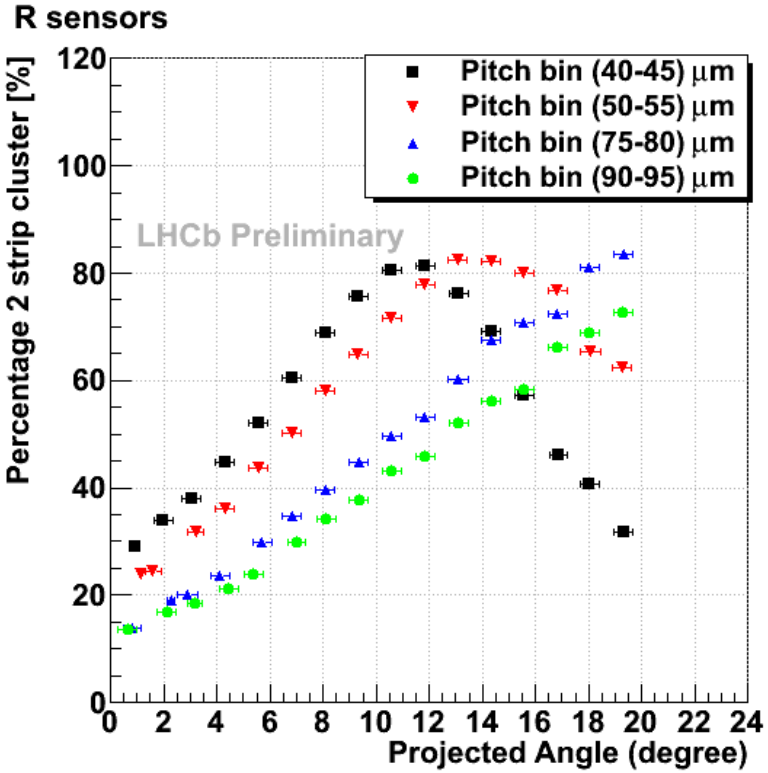
Performance: Common Mode

- Use our 1% NZS data
  - Deploy a 32 channel “flat” common mode substraction
  - Also need a 32 channel linear (or higher) CM
- Still under study
  - Causes/sources of large CM corrections in collision data
  - Beam intensity correlation
  - Minimization of CM effects with ASIC settings



No serious effects yet!

Performance: Charge Sharing



Eta distributions

M. Alexanders poster Thursday ...

A puzzle:

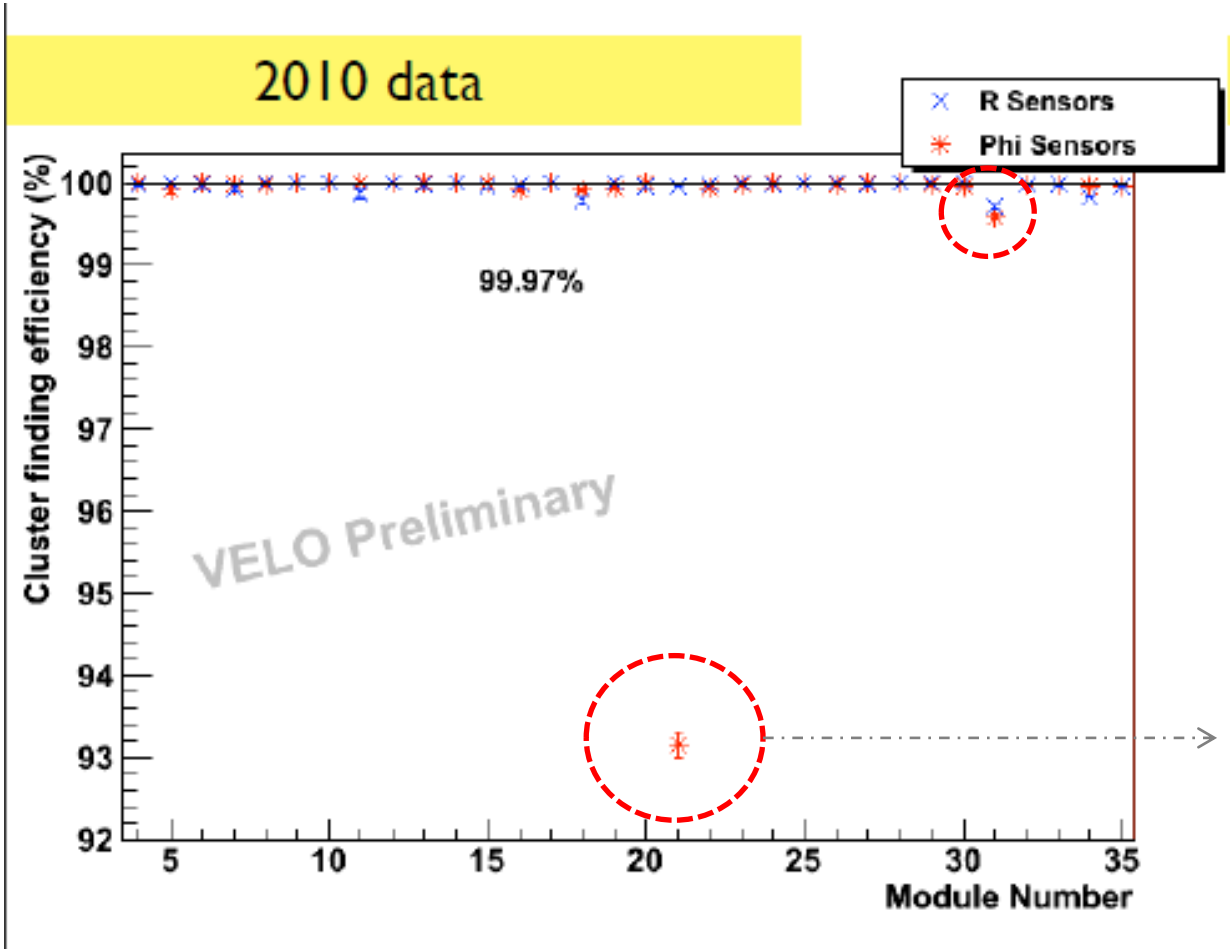
Our resolution at small incident angles seems is dominated by our fraction of single strips O(60%) at normal incidence

Too many 1 strip clusters => Could the p-spray have affected the implant => effectively broadning it?

Nominally implant ~40% pitch – looks bigger

Complicated – vary with angle and increasing pitch!
Resolution (*see Gersabeck's talk*)

Performance: Efficiency



Efficiency close to 100%

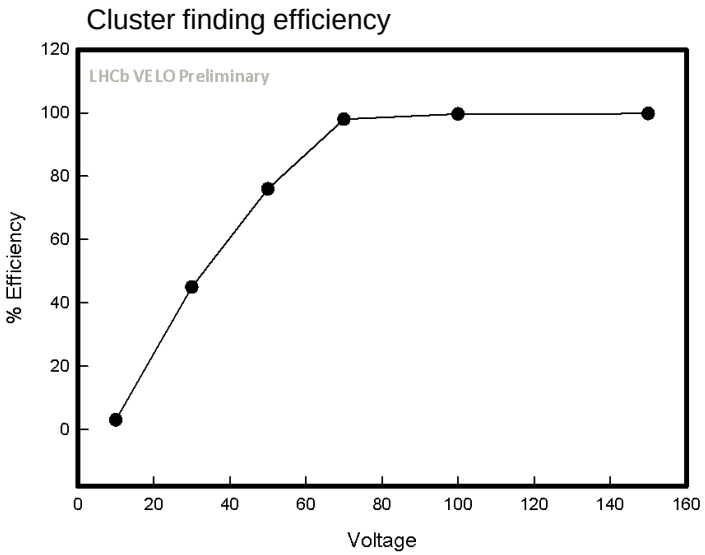
Note: 0.7% dead strips from 172032 fabrication/build removed.

Chip died post installation.

Tried to reproduce error assuming pulling single bonds off.

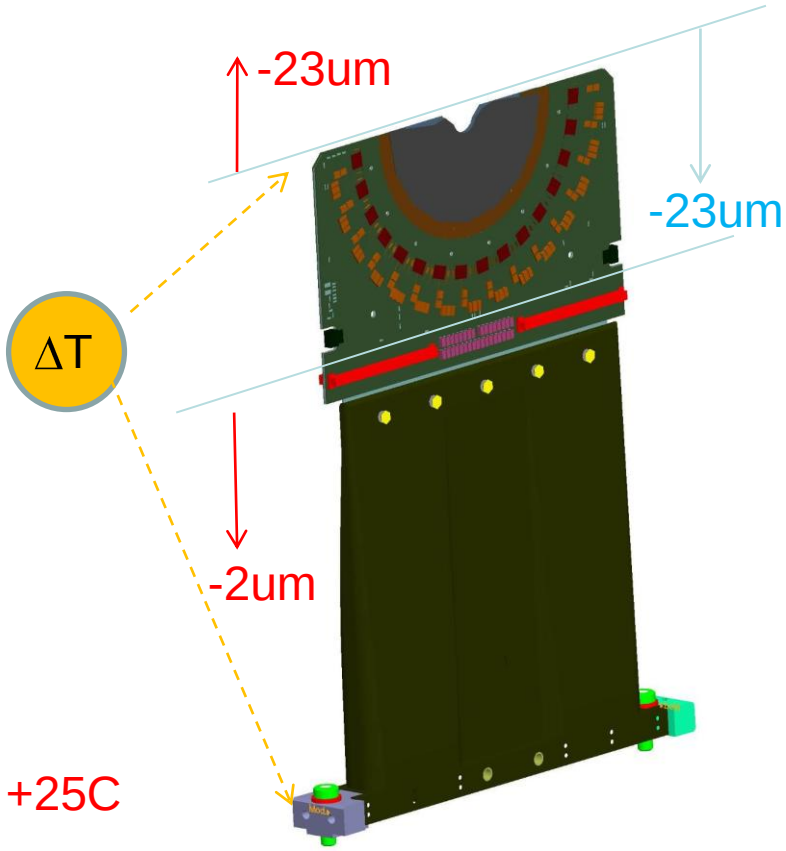
Performance: Rad. Damage

- In preparation the infrastucture to study detector degradation
  - Regular HV scans
  - Gain normalization
- Other possible systematic effects not yet studied
  - Cluster shifting
  - Loss of charge sharing



Issues: VELO Closing

- VELO when “closed” is open by approx 300um
- Why?
  - designed to be ~0 CTE
    - Expected CF/Epoxy CTE O(-1 to 1 ppm/C)



“ISOTHERMAL”
Measured Shifts for ΔT = +25C

“ISOTHERMAL”
PredictedShifts for ΔT = -25C

Issues: VELO closing

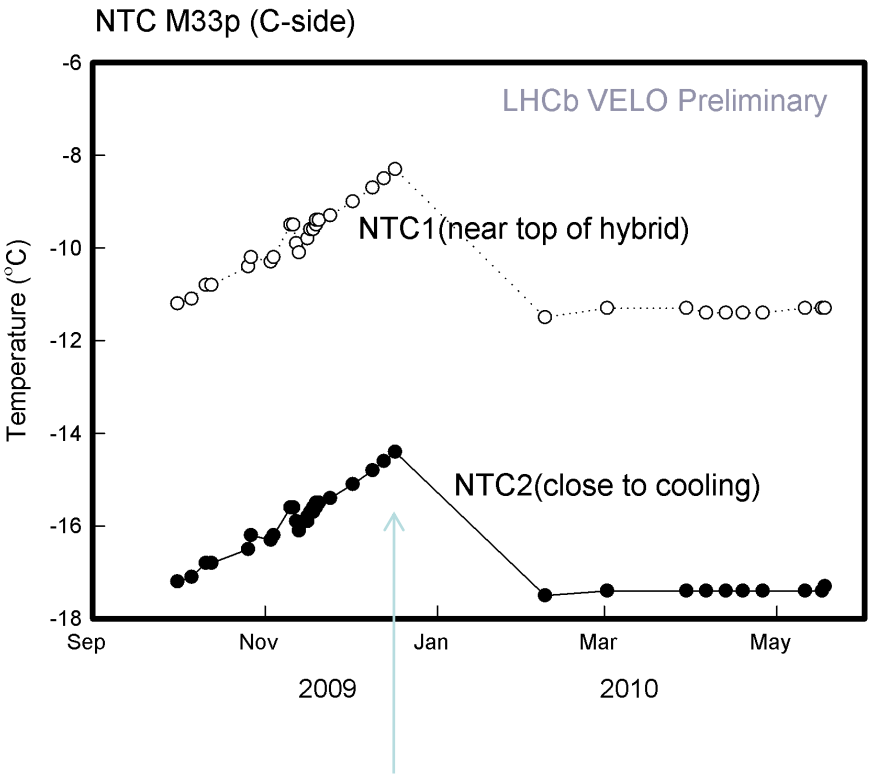
- Of 300 microns opening about O(70um) estimated due to module contraction
  - To be verified in situ with different cooling points. Data at different operational temperature(s)
- Further 150 microns known from survey
  - Not quite all 300μm accounted for!
- In future
  - Can (in principle) be solved by “overdriving” the VELO halves against each other
    - Unfortunately the foils already touch
    - Need to see if “overdrive” really needed

Comment:

- Difficulty of thermal measurements on modules so far from room temp
  - Same for irradiated objects
  - How do you measure under real conditions?

Issues: Cooling

- Biphase CO_2
  - See last years VERTEX proceedings
  - **Has worked beautifully** but one or two (minor) issues
    - On *restart* at -30°C (readjusted to minimum point) full cooling power took over 48 hours to establish
    - In 2009 a blockage slowly occured in the filters of the CO2
  - No problems in 2010.



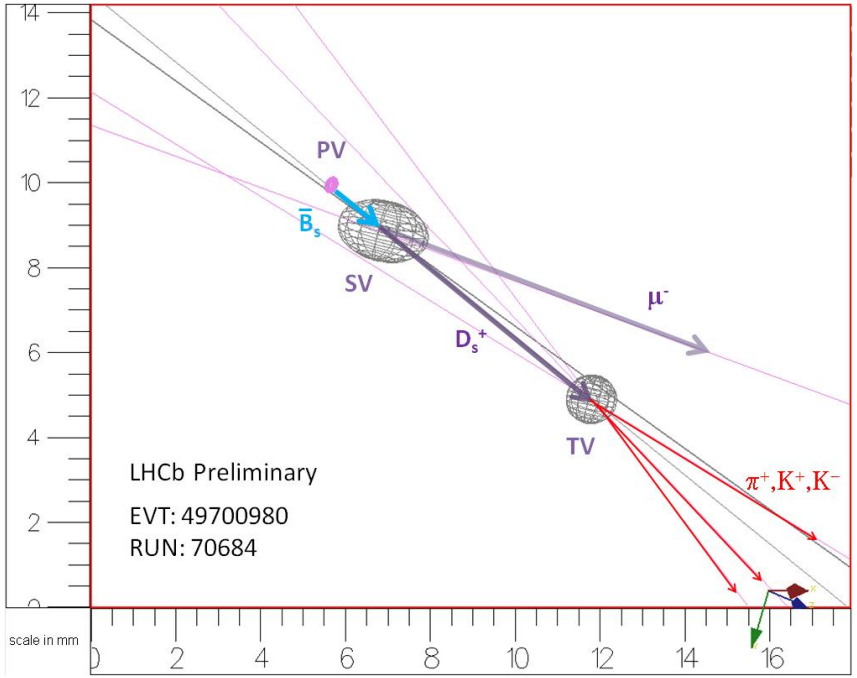
Intervention to unblock fliter

Comment: Software

- Software/Firmware
  - Enormous effort to *emulate* (bitwise) in detail what the FPGA does. **Very successful**
- Non-zero suppressed data critical to deep understanding of detector
  - May need to use “non emulated” mode for this in future
    - Remove integerization and cluster threshold effects for special studies
- Must fight keep our NZS bandwidth!

Summary

- VELO
  - Operated well from day 1
  - High Efficiency
  - Enables physics of LHCb
    - *See M. Gersabecks talk*
  - Expect to reach full potential in 2010
- Substantial challenge lies ahead with radiation damage ...

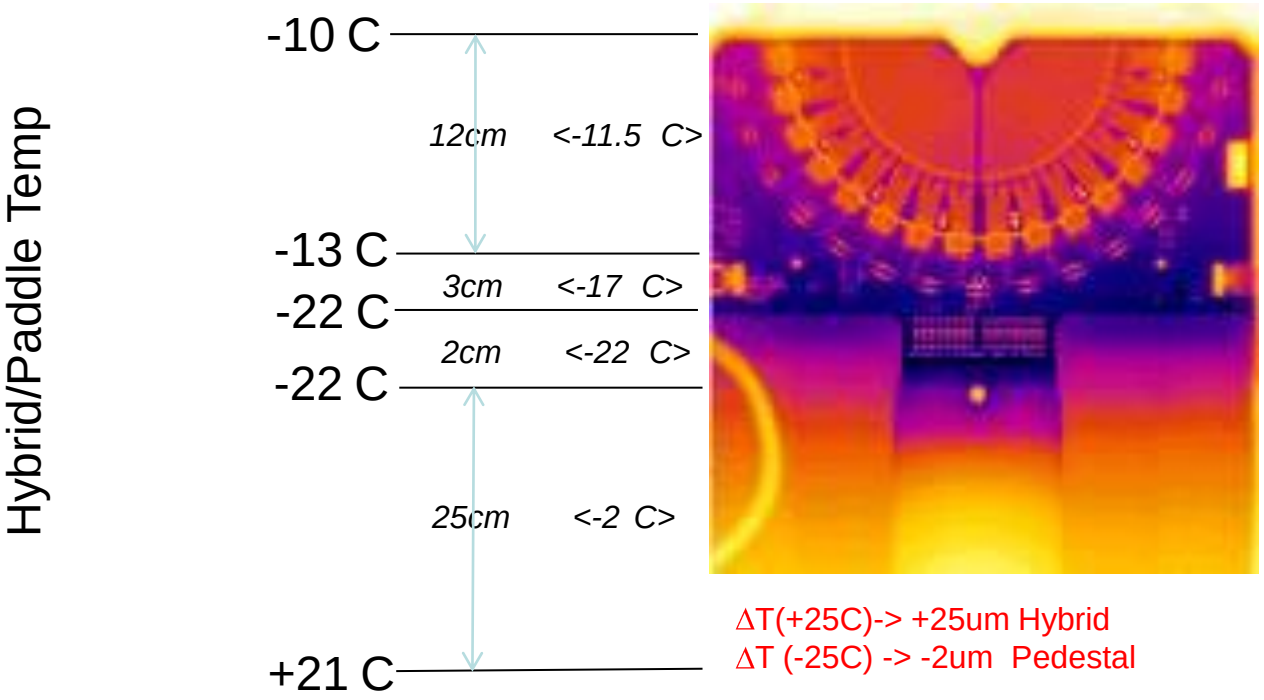


BACKUP

Operation: Components

- 2009/2010
  - Thermo/Mechanics/Vac
  - DAQ & ECS
  - Timing
  - Online Monitoring
  - Closing
  - Offline Monitoring
  - Alignment
  - *Data Quality*
  - Software Coordination
- Safety, Safety, Safety
  - Total unknown operating environment for us
    - Extended operation in vacuum
    - Moveable detectors
  - Emergency Procedures
    - Installed overide of all computer systems to provided a failsafe (DSS control) to kill all power to VELO

Issues: VELO Closing



Shift expected is approx
-32 to -34μm/side

Opening ~ -62μm to -68um

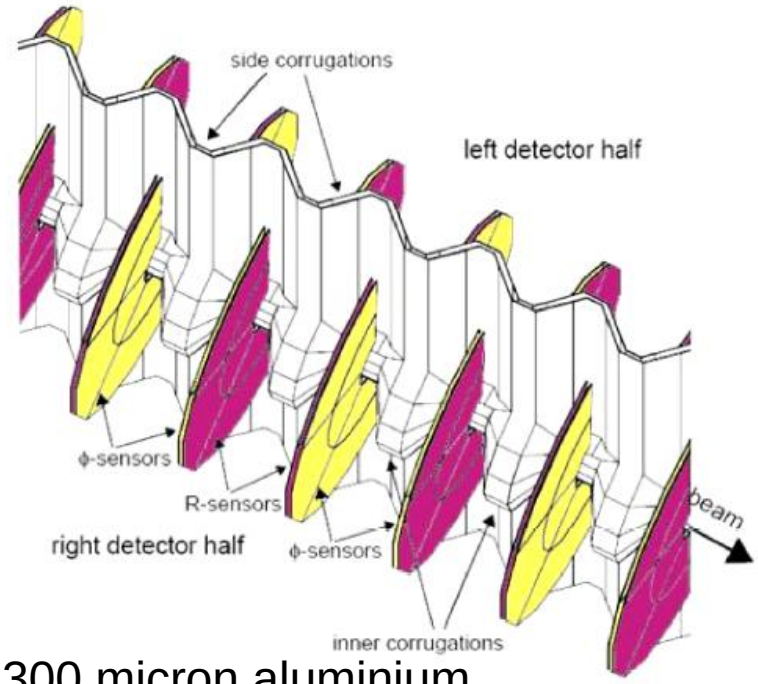
i.e. O(70um)

About 30% of 300micron opening atrributable to module shrinkage

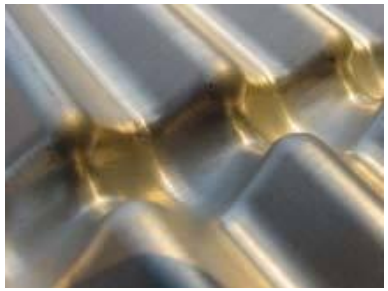
Temp Hybrid ~<-14 C> corresponding to non thermally isolated (thermally isolated Pedestal)

ΔT(-30C) -> -35μm Hybrid
Pedestal ~(-1) -> +1μm Pedestal
Pedestal ~(-25) -> +3μm

Foil



300 micron aluminium



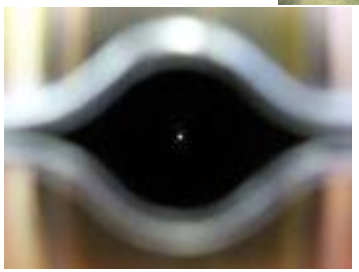
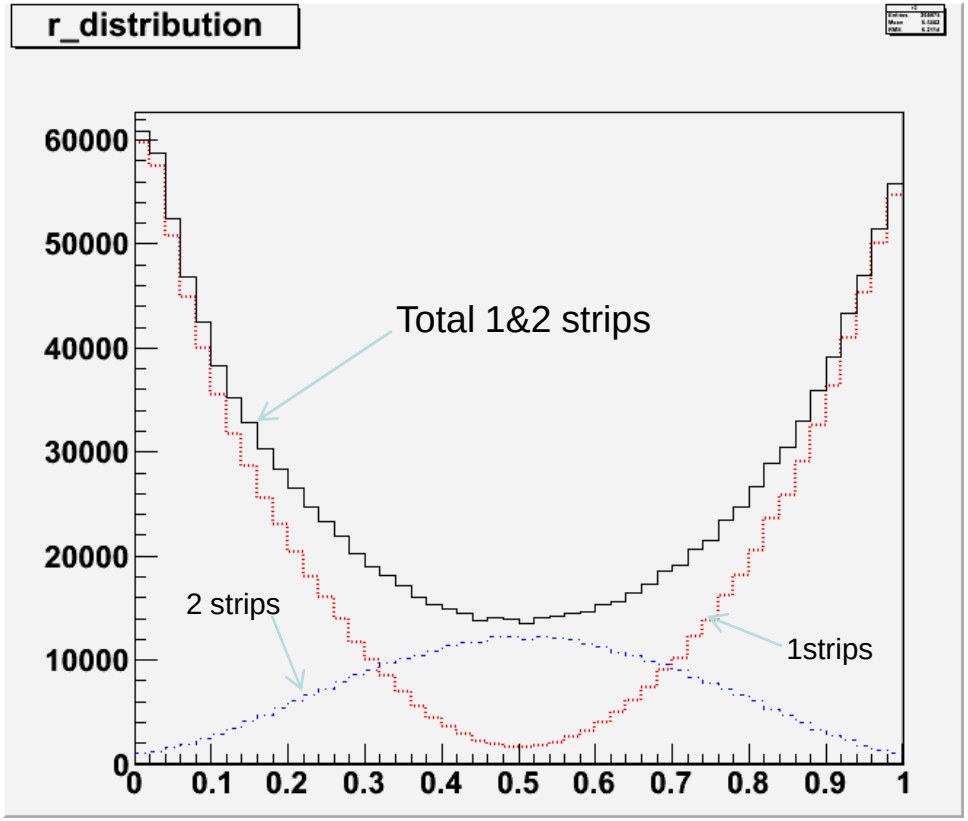


Photo along beam pipe
Foils (Box) closed

- Foil
  - RF protection
  - Secondary Vacuum

Foil a key element in any future VELO detector... See Buytaert's talk

Projection: Two strip clusters



Distance between strips (fraction of pitch)