UNIVERSITY
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GLASGOW

Resolution and Alignment of the LHCb VELO

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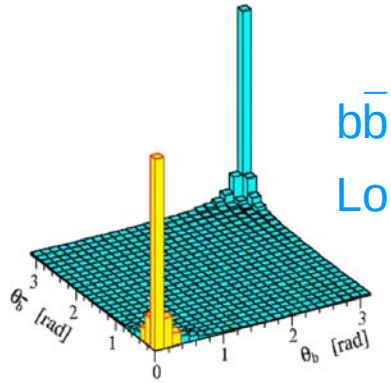
Introduction

- LHCb overview
- VELO mechanicals
- VELO layout
- VELO misalignment studies
- VELO Alignment
- Resolution studies

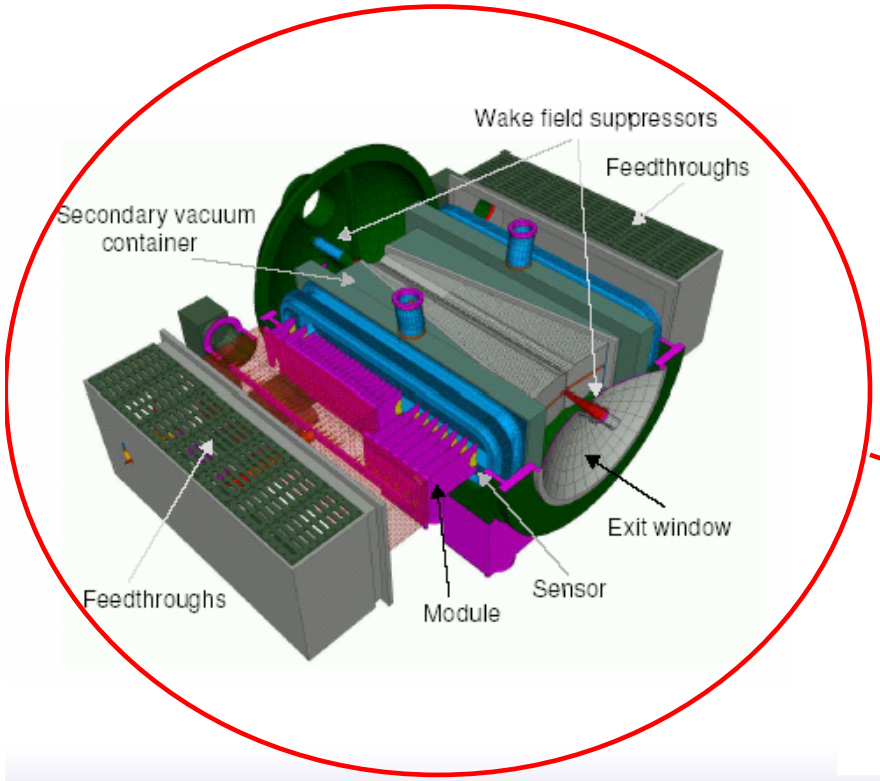
LHCb

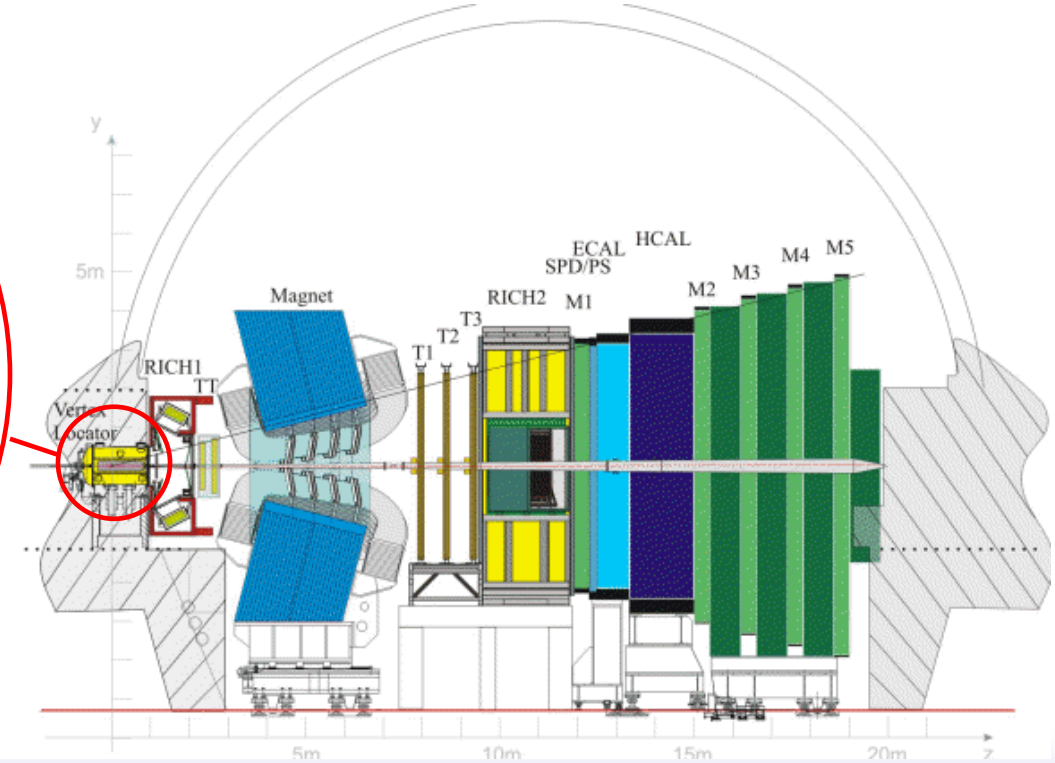
LHCb: forward arm spectrometer specifically designed for the precise measurement CP violation and rare B-meason decays



$b\bar{b}$ correlated

Lorentz boost

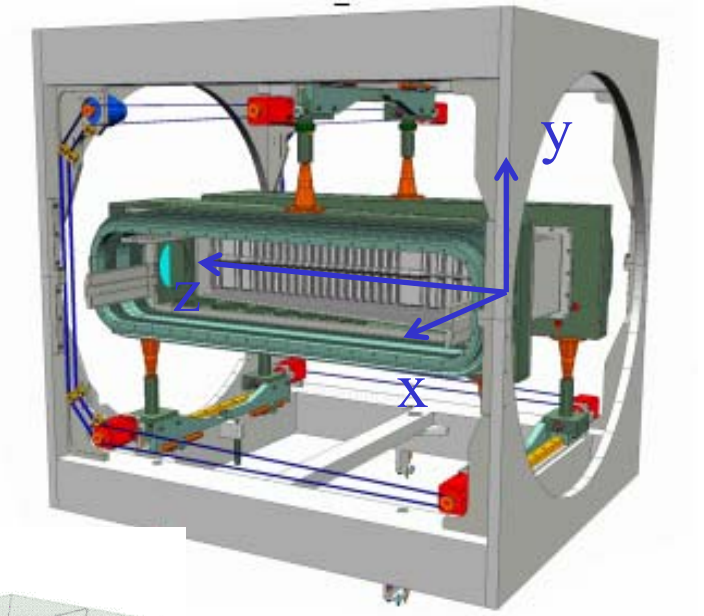


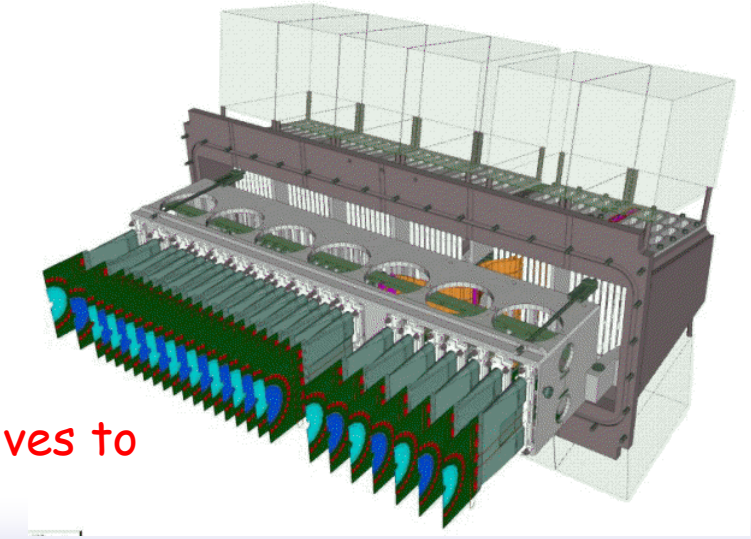


VELO Mechanics

VELO modules split into two halves

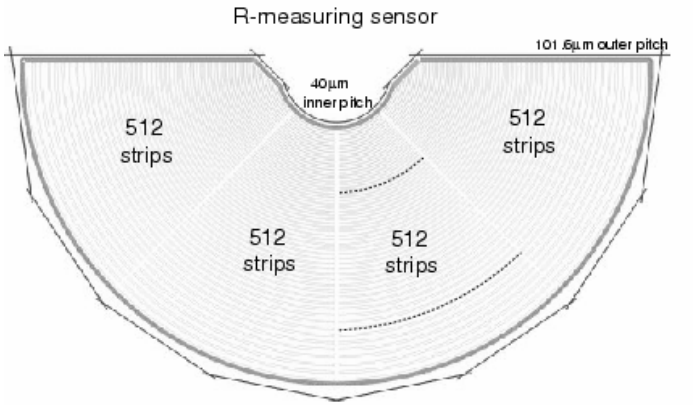
- During injection, VELO both halves retracted 3 cm from beam line
- After injection VELO sensors positioned ~8 mm from beam
- VELO can also move in the x-y plane (~5 mm) to center sensors on beam
- VELO has to be realigned at start of each fill!



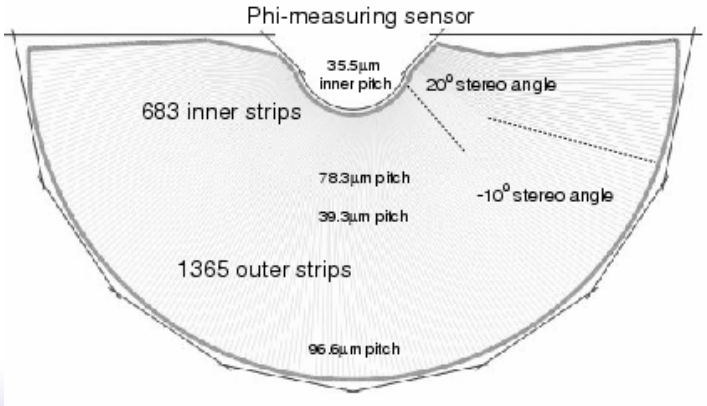


- Overlap of VELO halves to facilitate alignment

Vertex Locator (VELO)



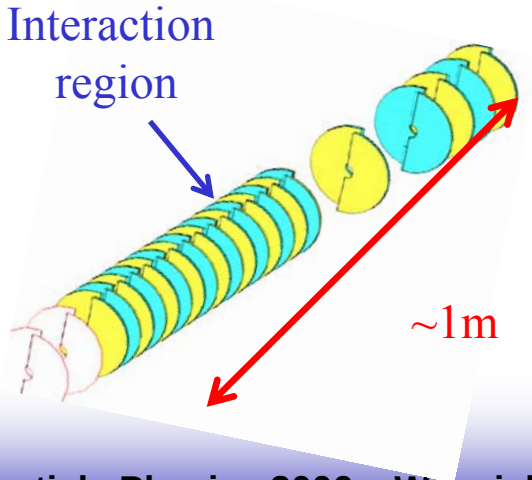
2 types of VELO sensor
- R - measuring
- Phi - measuring

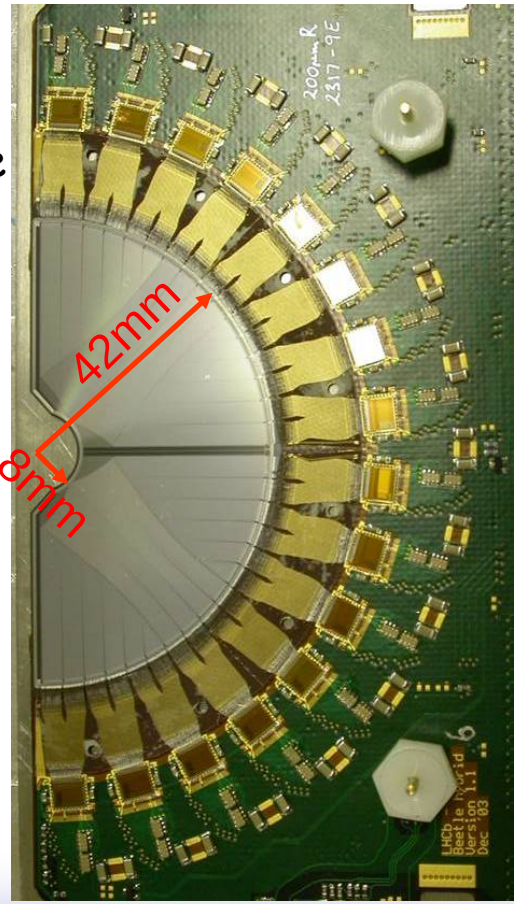


n-on-n silicon microstrip detector
Strip pitch varies for 40 – 100 microns

1xR and 1xPhi sensors
combined to create a module

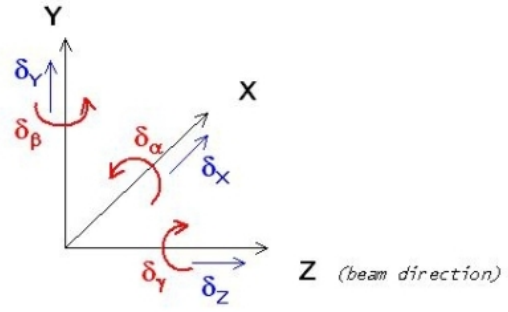
42 modules in total
positioned along z-axis

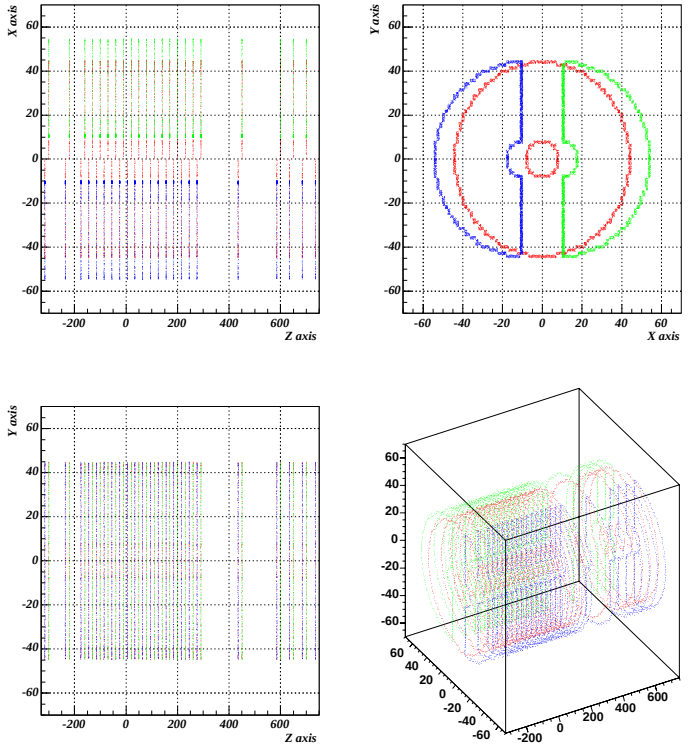




VELO Misalignment Studies

- Misalignments introduced into the LHCb simulation software
- Translational and rotational misalignments of VELO halves as well as VELO modules



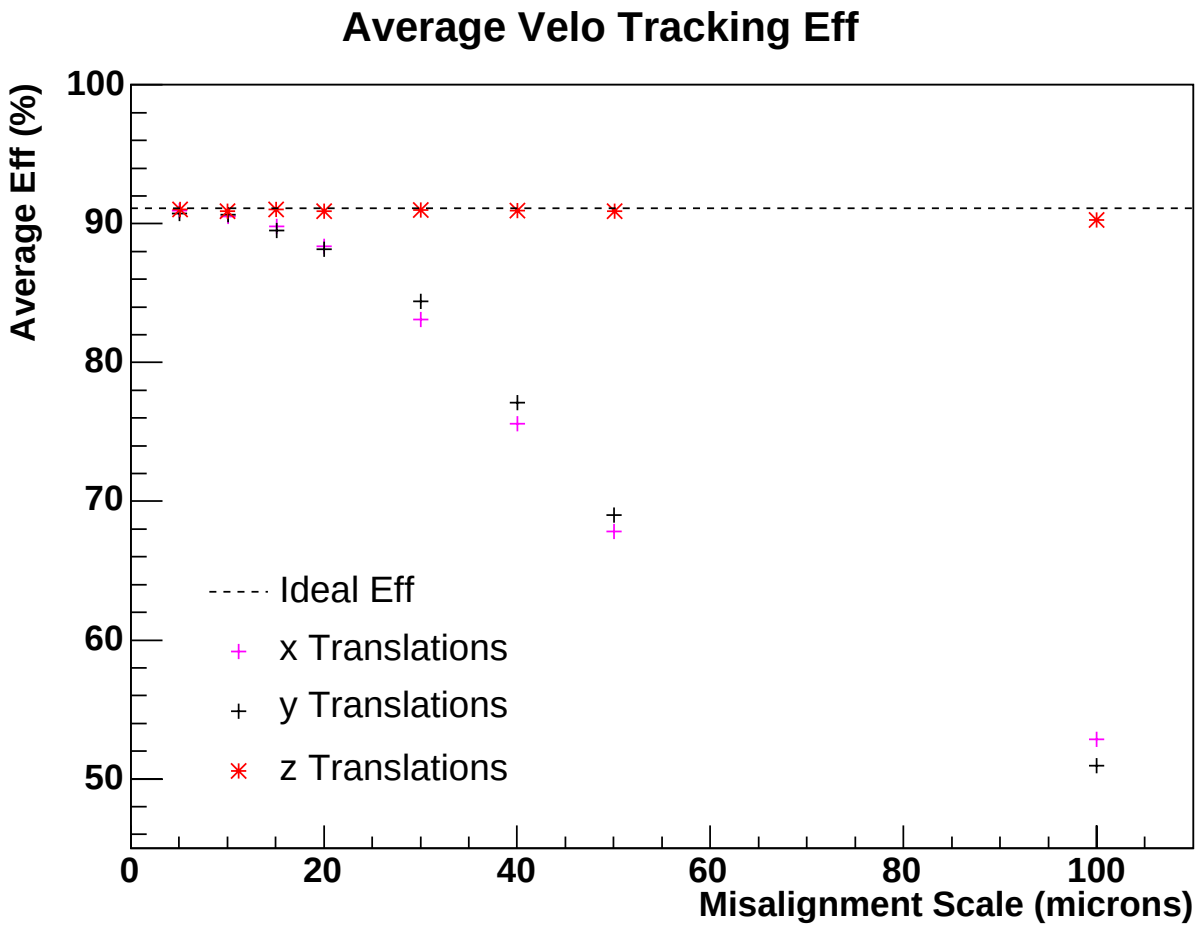


Aims of study

- Determine sensitivity of LHCb track reconstruction code to misalignments
  - Tracking efficiency
  - Ghost rate
  - Impact parameter reconstruction
- Determine Sensitivity of L1 trigger to misalignments

Misalignment Study

- Sensitive to x and y translations of VELO modules and rotations about z-axis (Due to phi strip geometry).
- VELO-halves found to be sensitive to rotations about x and y-axis

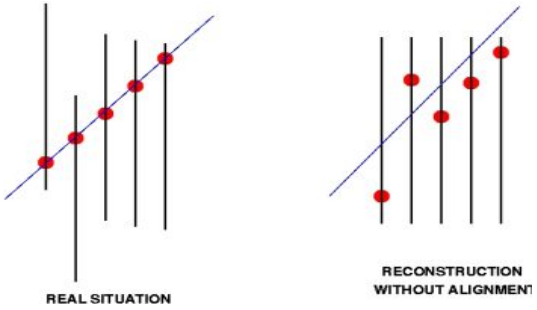


Further details can be found here:

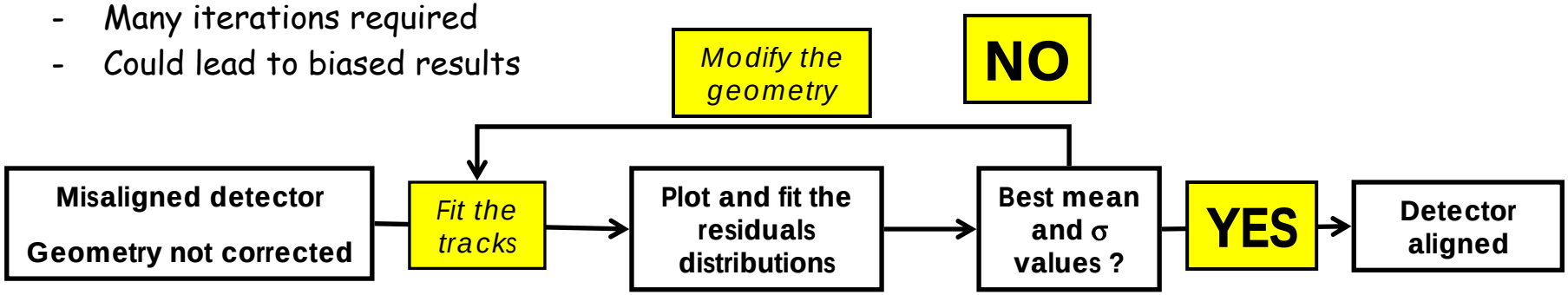
http://ppewww.ph.gla.ac.uk/LHCb/VeloAlign/VeloMisStudies.html

Alignment Methods

- Alignment methods based on minimisation of track residuals and can be split into two categories



- Iterative Methods
  - Many iterations required
  - Could lead to biased results



- Non – Iterative

The residuals are a function of the track parameter and the alignment.

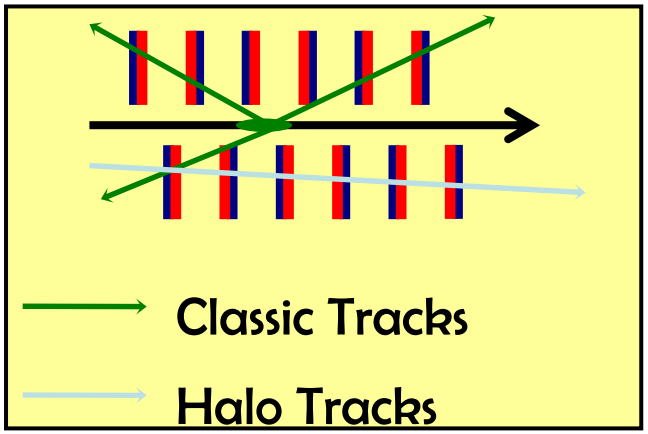
Determine both the track parameters and the alignment at the same time.

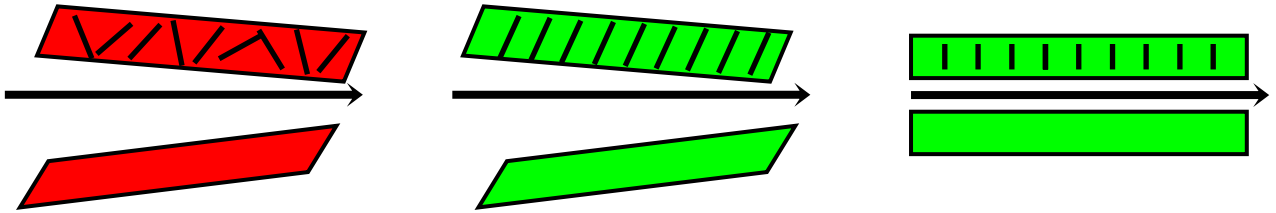
Involve huge matrix inversions! However can determine alignment constants in one step!

VELO is using Millepede *developed by Volker Blöbel*

VELO Alignment

- Proposed VELO alignment performed in several steps
- Step 1 aligns the modules within a VELO half
- Step 2 determines relative alignment of the two halves using primary vertices and module overlaps.





Step 0

Misaligned VELO

Step 1

Internally-aligned VELO

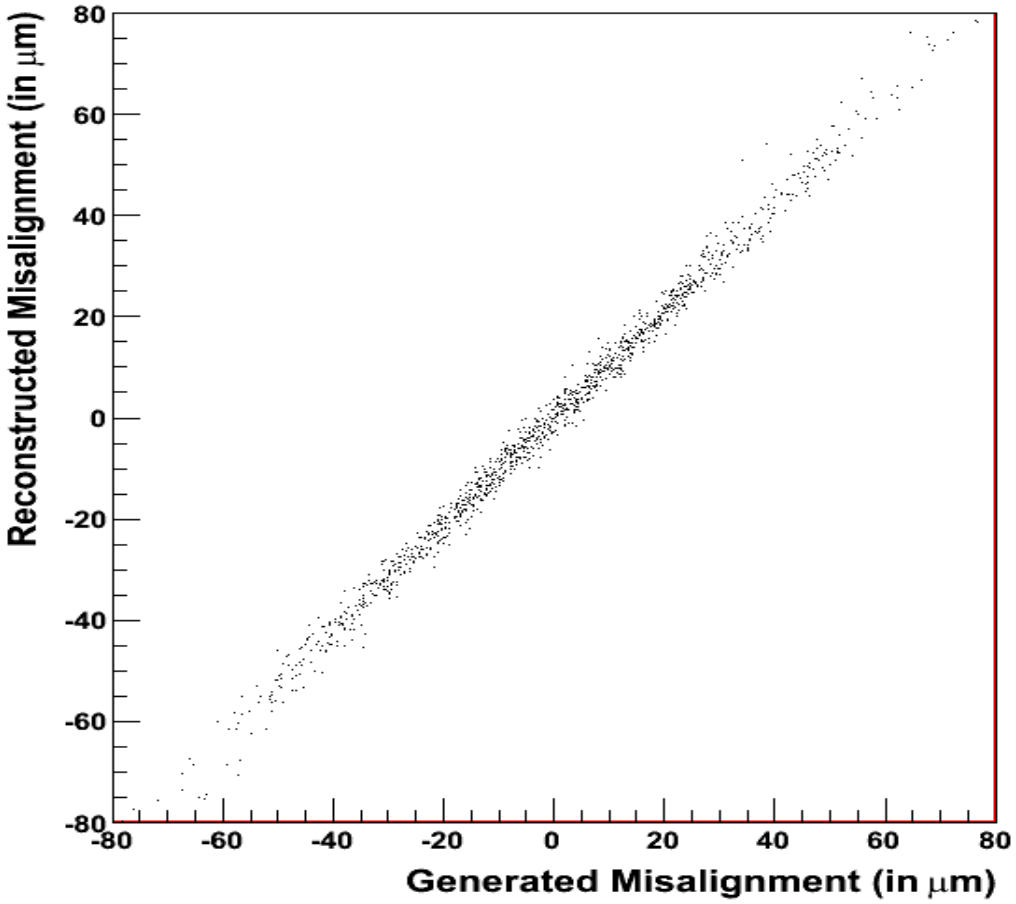
Millepede applied on single tracks in the two boxes

Step 2

Aligned VELO

Align the boxes using primary vertices, overlaps,...

VELO Alignment



- Residual distribution of after internal alignment ~ 5 microns
- Alignment of the VELO halves using primary vertices only ~ 10 microns

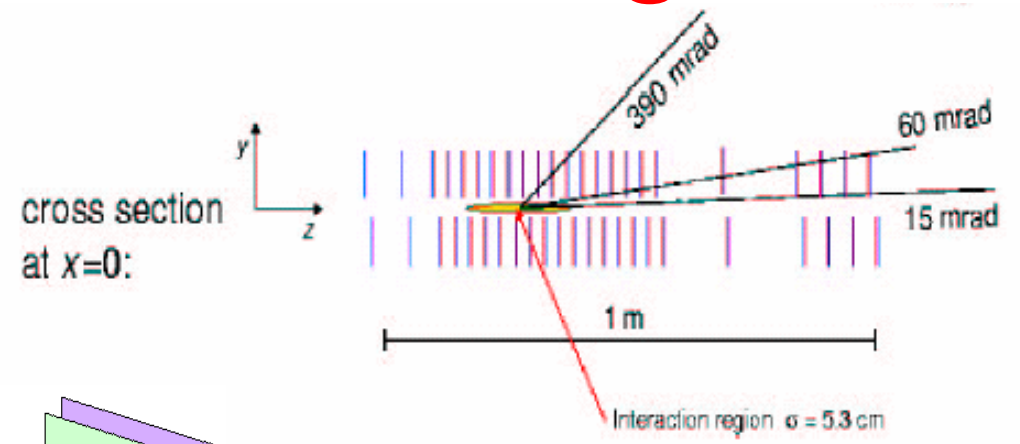
Further details can be found here:

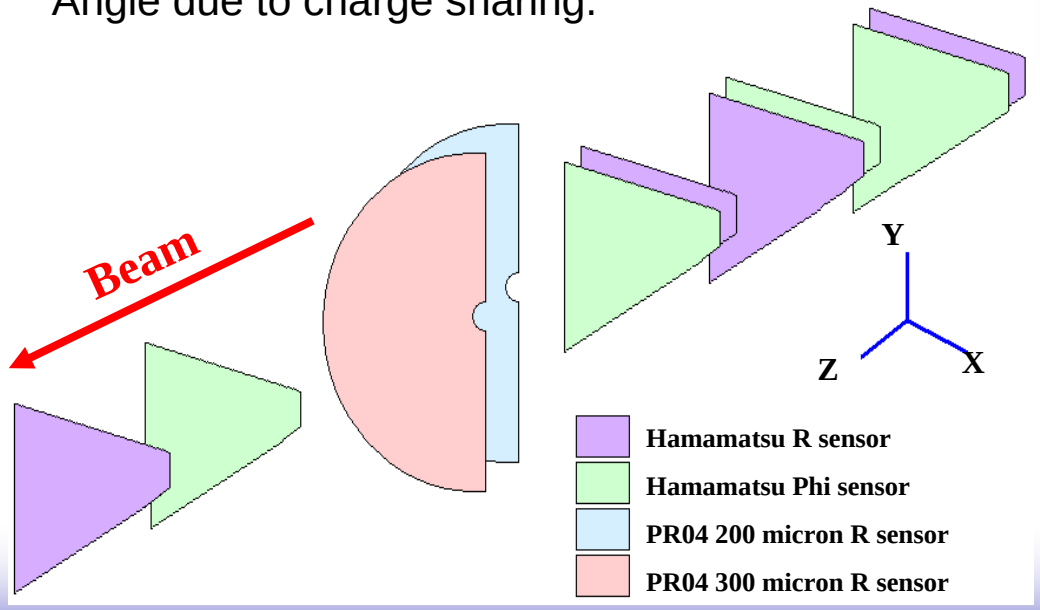
http://ppewww.ph.gla.ac.uk/LHCb/VeloAlign/VeloLastNews.html

VELO Resolution as a Function of Track Angle

- Tracks in the VELO can have angles between 15 mrad and 390 mrad.

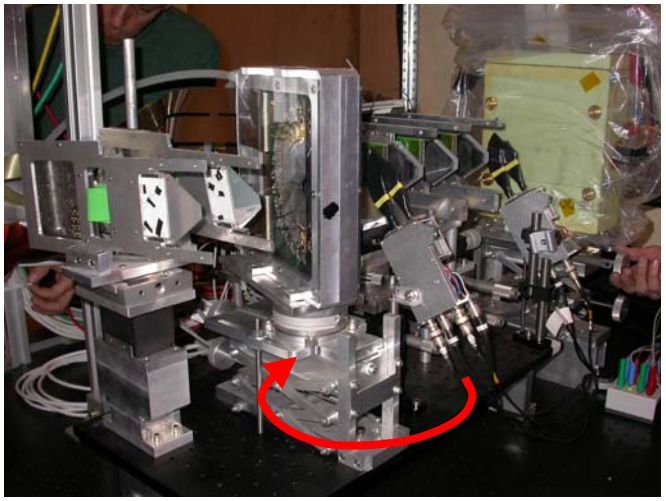
- Resolution of silicon strip sensors are a function of track Angle due to charge sharing.





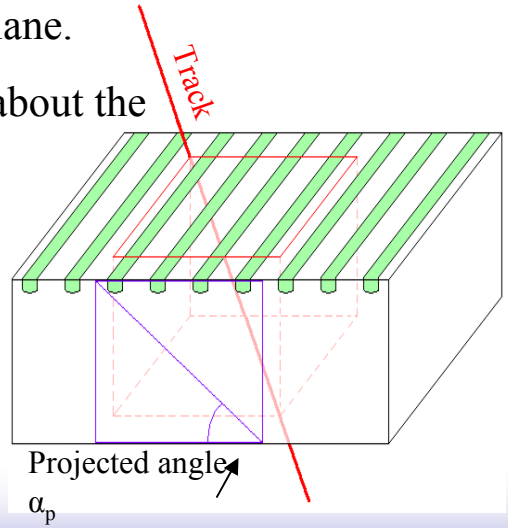
- **CERN X7 SPS 120GeV pions**
- **2x PR04 Micron n-on-n R sensors**
  200 micron
  300 micron
- **Non-irradiated.**
- **Each sensor is equipped with 16 Beetles.**
- **4 Beetles readout on each sensor.**

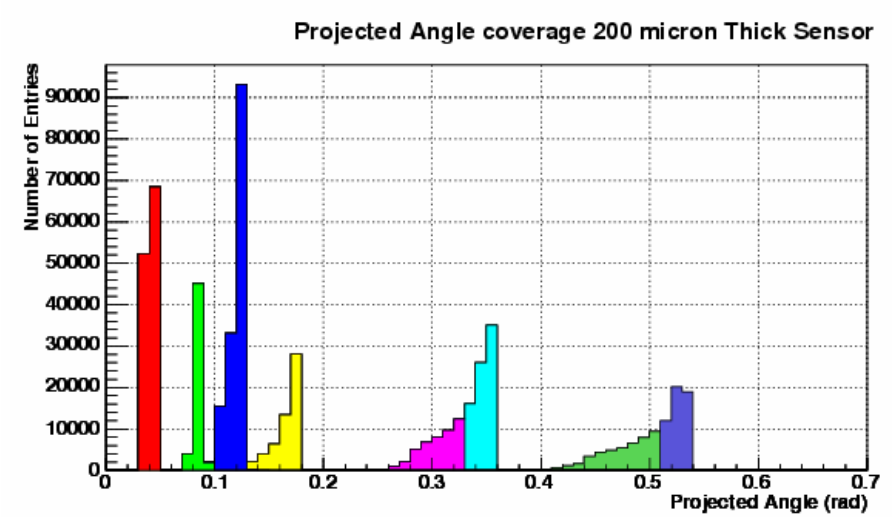
Projected Angle

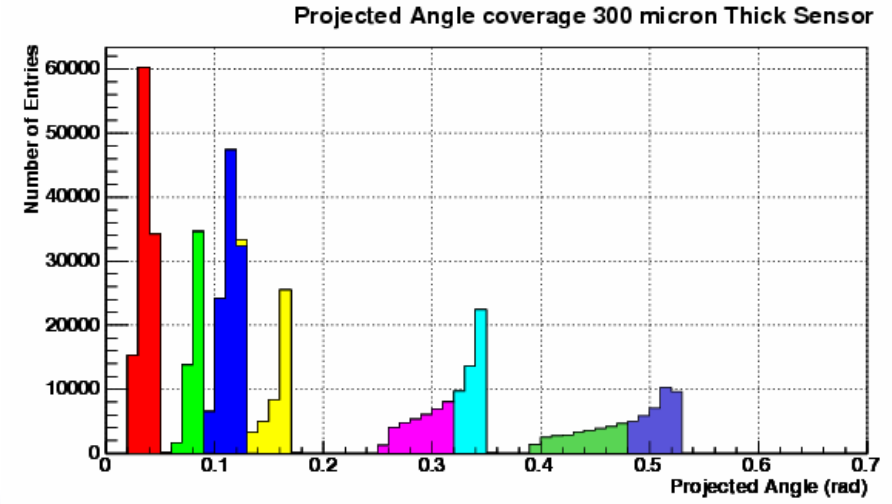


- Testbeam tracks along z axis perpendicular to x-y plane.
- Test sensors rotated about the y-axis.
- Angles measured:

2, 5, 7, 10, 20, 30 degrees.

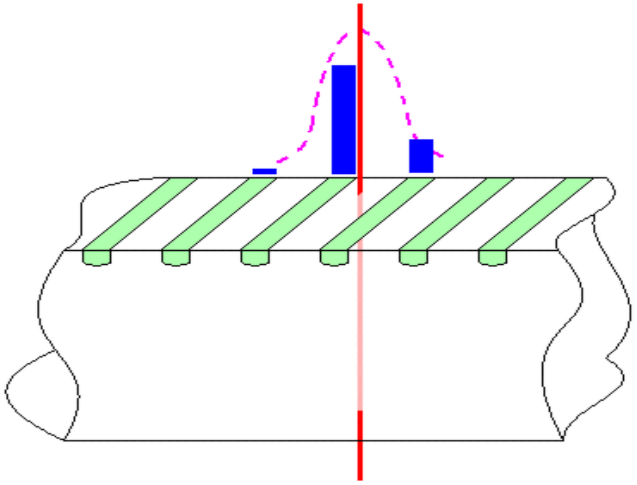




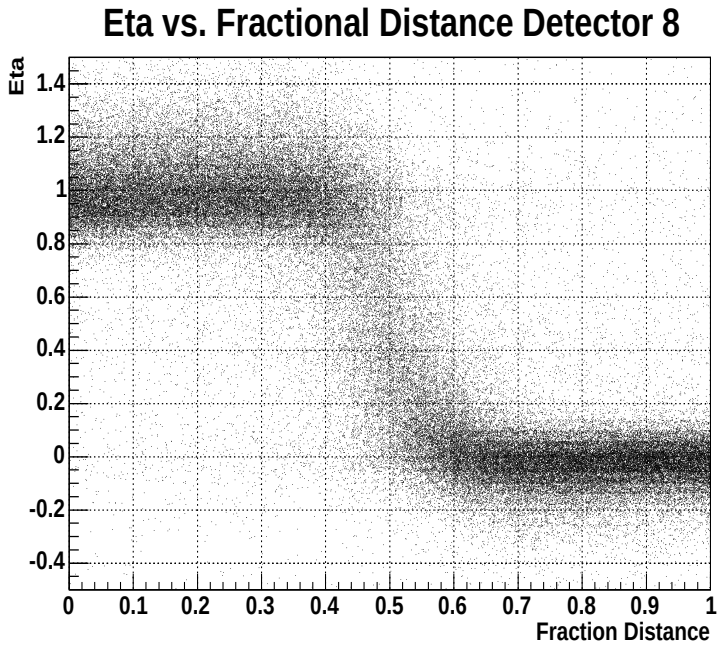


Resolution and Eta Distributions

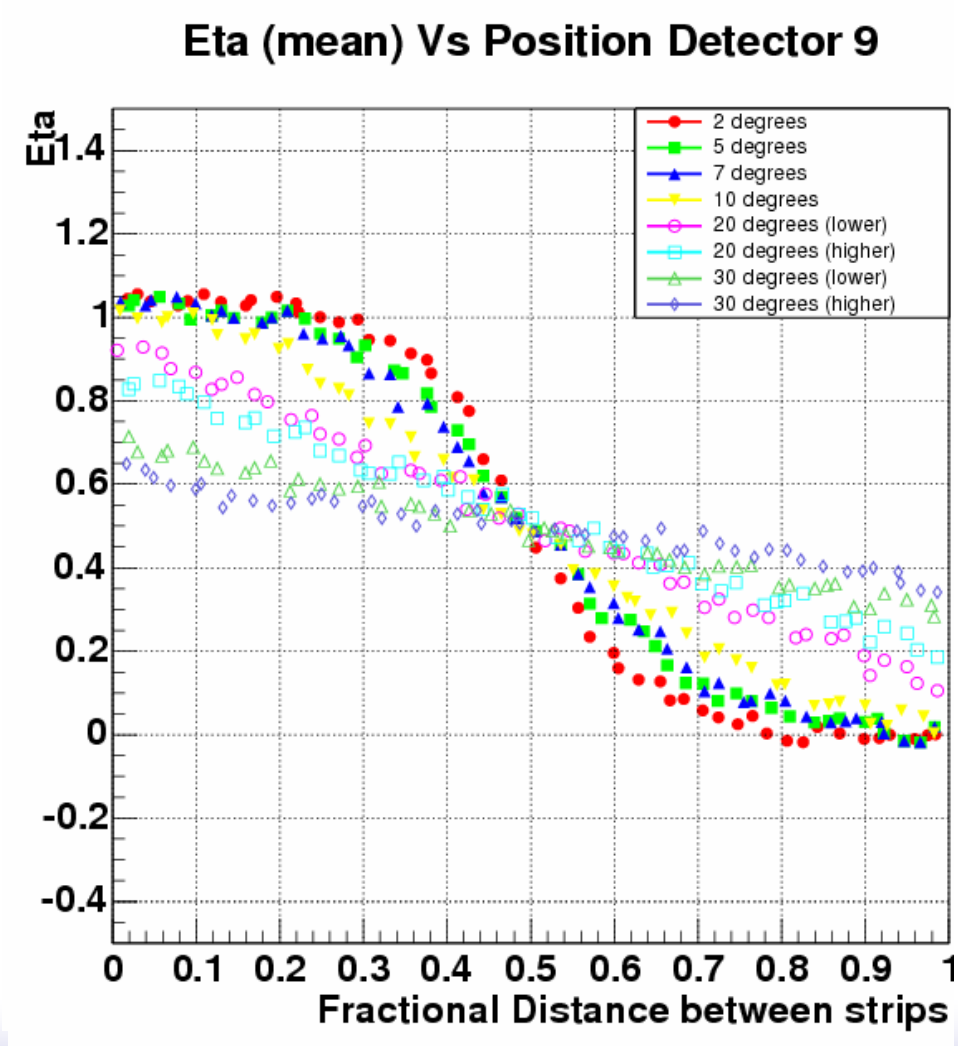
- Resolution of defined as distance between extrapolated track position to weighted center of cluster
- Poor charge sharing at low angles results in incorrect cluster center



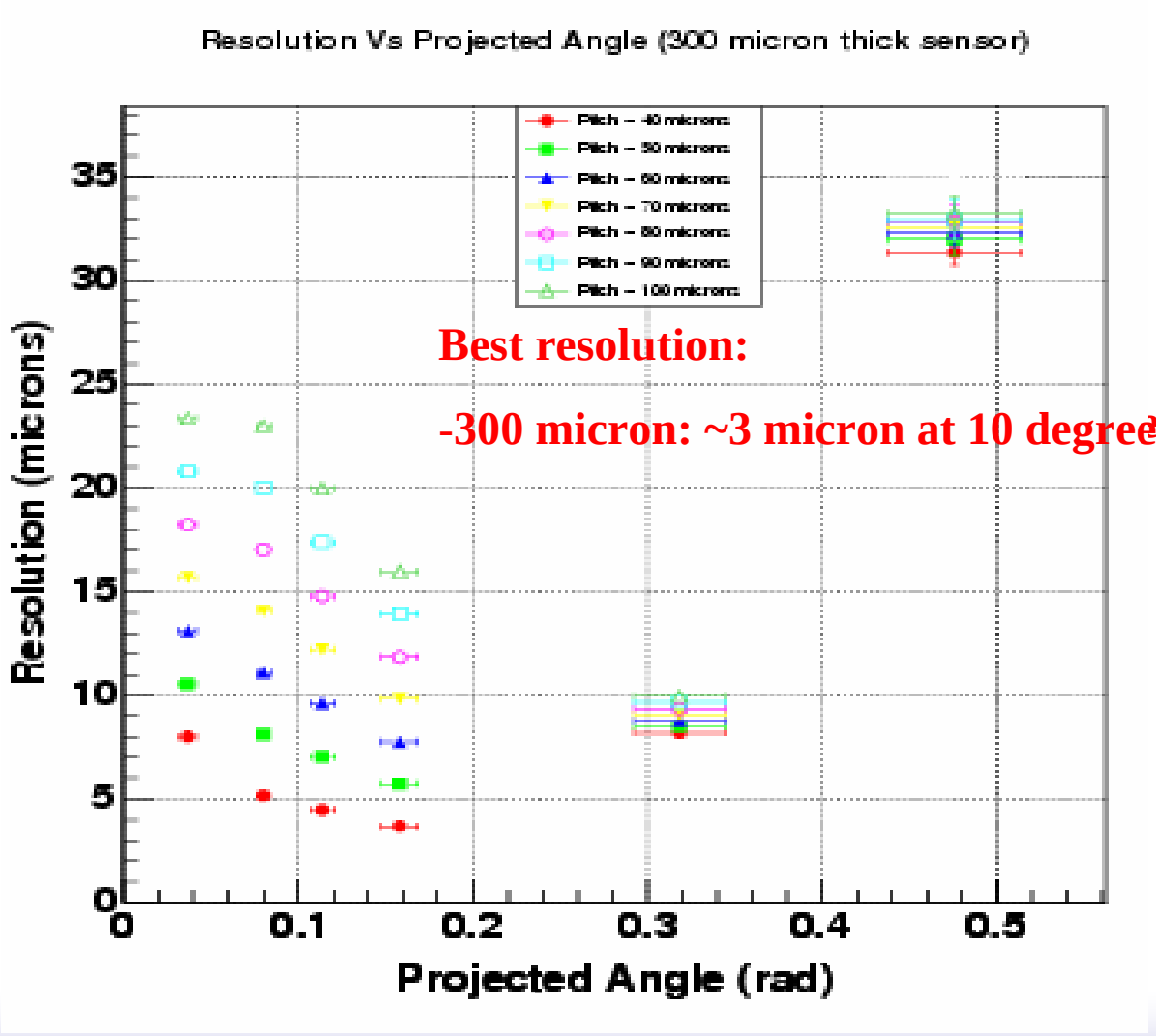
$$Eta = R_{charge}/L_{charge}+R_{charge}$$



Eta Distribution



Resolution



Best resolution:

-300 micron: ~3 micron at 10 degrees

Concluding Remarks

- VELO testing and construction at advanced stage
- Misalignments studies have indicated sensitivity of reconstruction code to particular degrees of freedom
- Clear VELO alignment strategy defined.
  - First results indicate alignment comparable to intrinsic resolution of sensors
- Test beam studies of prototype sensors conducted
  - Resolution studies show superior resolution for 300 micron thick sensors