Global Alignment in LHCb

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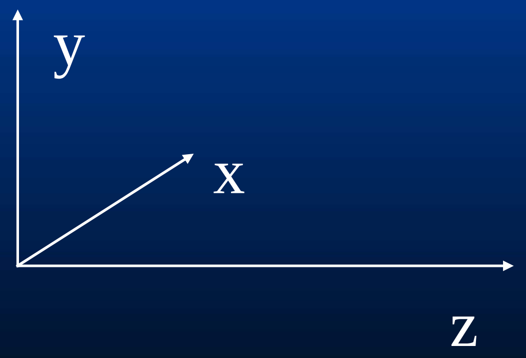
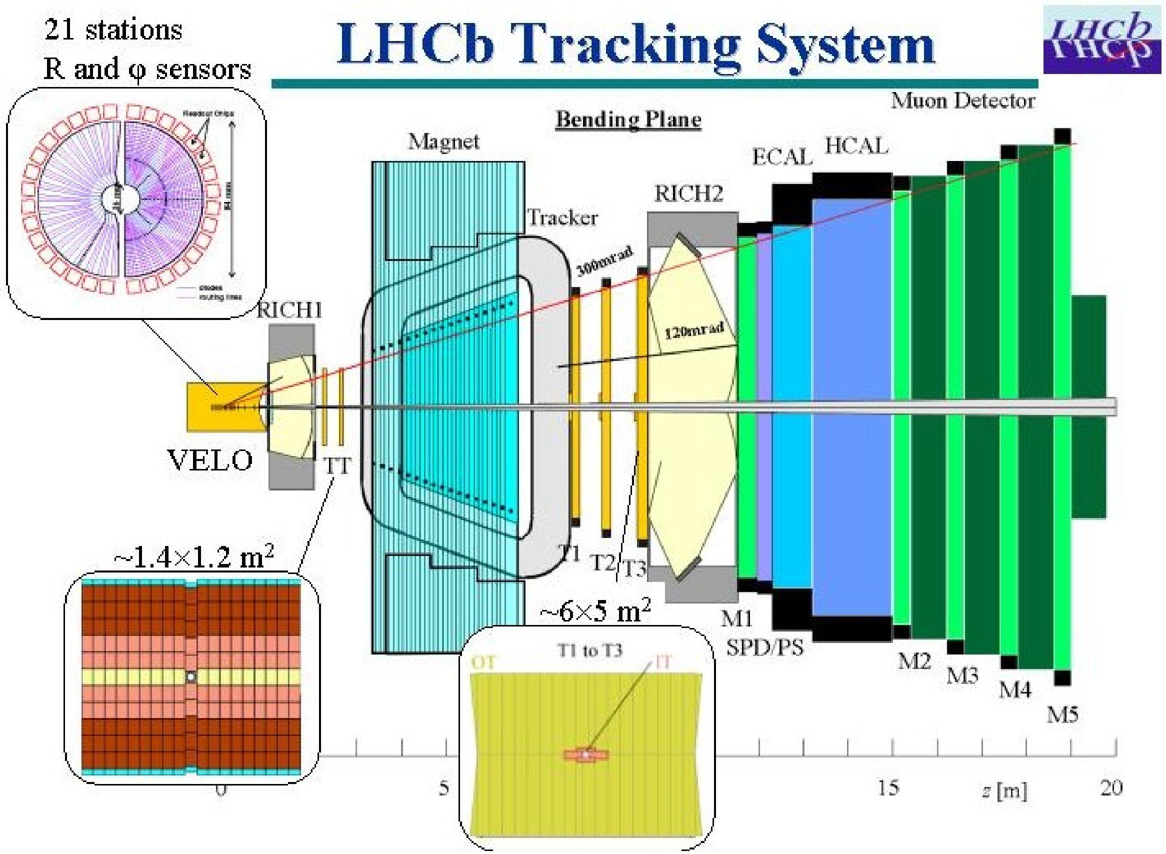
Introduction

- General strategy is to use Millepede for internal detector alignment
  - VELO, using tracks reconstructed with VELO hits only
  - IT, OT and IT-to-OT using hits in IT/OT only

- Need to bring each sub-detector into relative alignment
  - VELO to IT/OT
  - VELO/IT/OT to TT

- Connection to the global reference frame



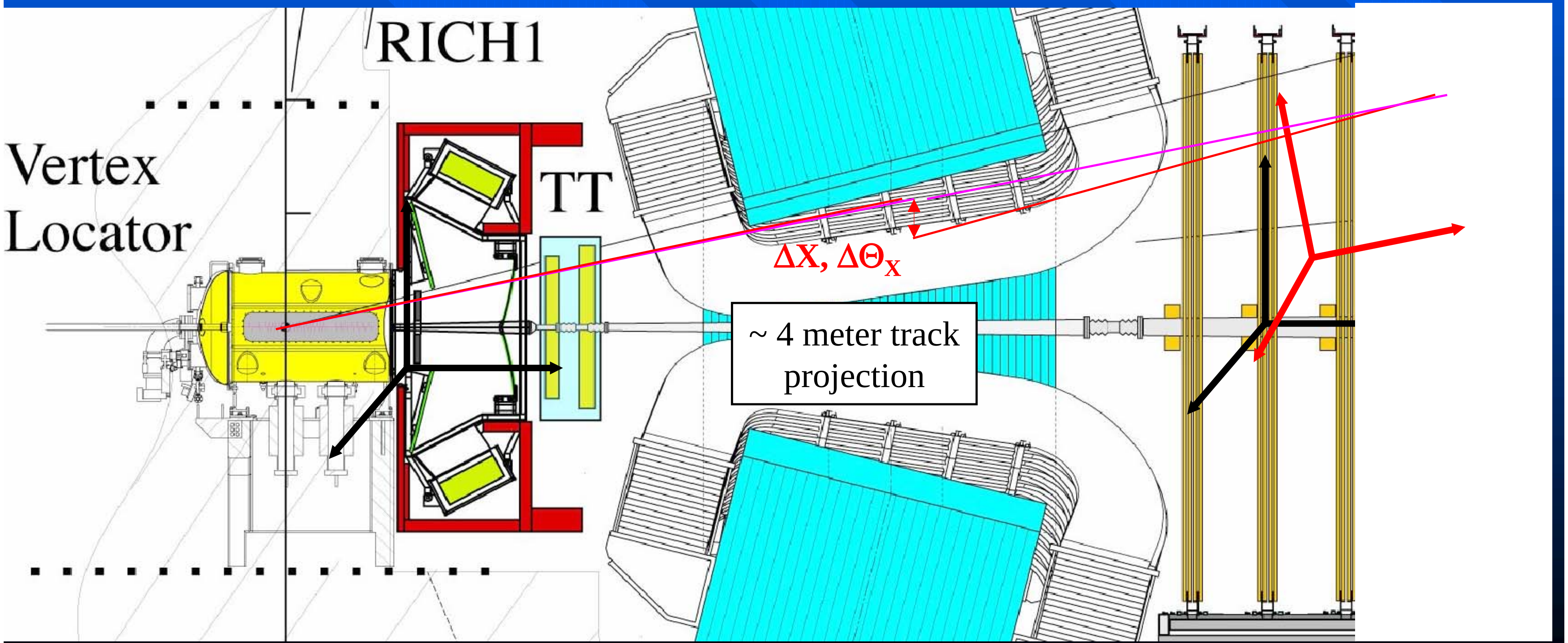


Align IT/OT to VELO

General Strategy

❑ Perform relative VELO-to-IT/OT alignment using $\Delta X, \Delta Y$ at the center of magnet and $\Delta\theta_X, \Delta\theta_Y$ (each vs X, Y).

- ΔX, ΔY, $\Delta\theta_X$, $\Delta\theta_Y$ must all peak at 0 (vs X, Y, as well) for proper alignment
- With magnet OFF data the 7 relative misalignments can be determined
  - 3 translations, rotation around Z axis, Shearing along X, Y, & Z scaling



Simulations

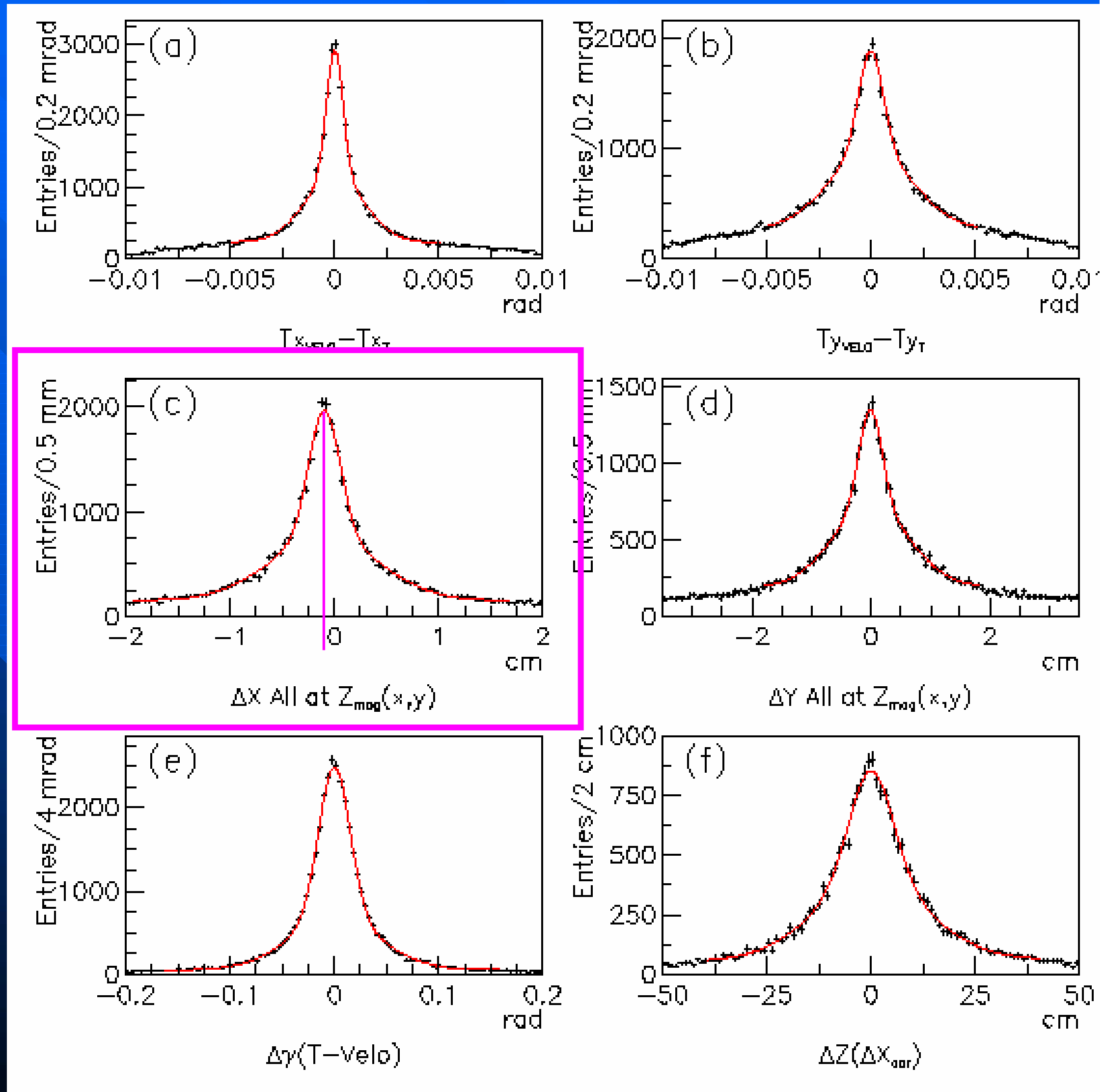
- 5000 minimum bias events
- P_{trk} > 20 GeV/c, VELO slopes < 100 mrad, T slopes < 200 mrad
  - Can use energy in calorimeter for magnet off data, if needed (E_{dep}>10 GeV)
- Extract misalignments by fitting 1D distributions for:
  - X offset: ΔX
  - Y offset: ΔY
  - X Rotation Angle: $\Delta\Theta_X$
  - Y Rotation Angle: $\Delta\Theta_Y$
  - Z Rotation Angle: $\Delta\phi=\phi_T-\phi_{VELO}$
  - Z offset: $\Delta Z = \Delta X/\Theta_X$
  - Z scale: $\Delta Scale_Z = (\Theta_X{}^T - \Theta_X{}^{VELO}) / \Theta_X{}^{VELO}$

Events generated with shifted geometries, reconstructed with nominal
- Magnet OFF & Magnet ON

ΔX, ΔY evaluated at the center of the dipole magnet

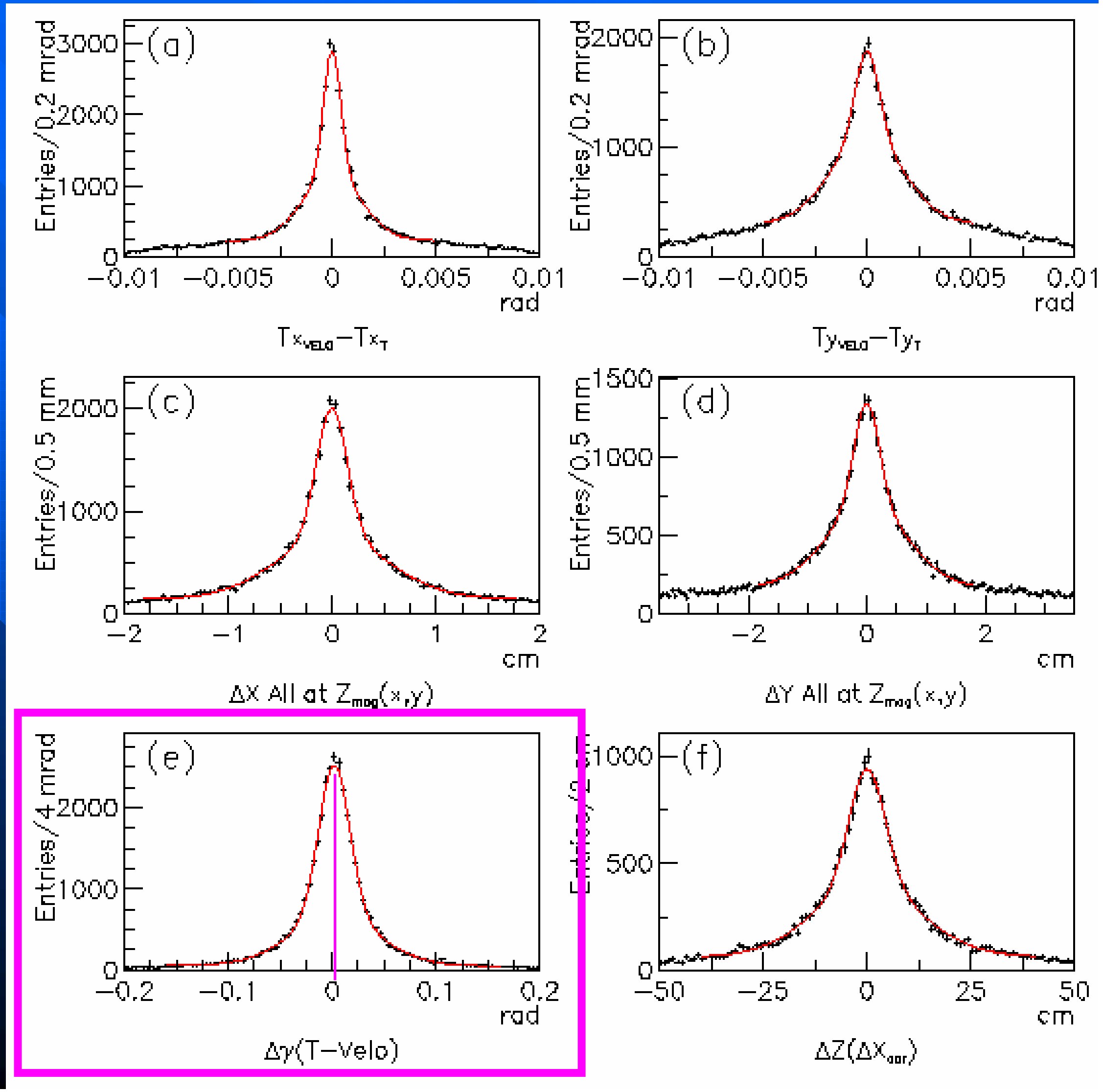
VELO-to-IT/OT - X Translation, B=0 (1 mm X translation)

Offset	Expected	Fit Value (mm, mrad)
$\Delta\Theta_X$	0	0.012
$\Delta\Theta_Y$	0	-0.004
ΔX	**-1**	**0.96±0.02**
ΔY	0	0.005±0.004
$\Delta\gamma$	0	0.056±0.014
ΔZ	0	0.7±0.9



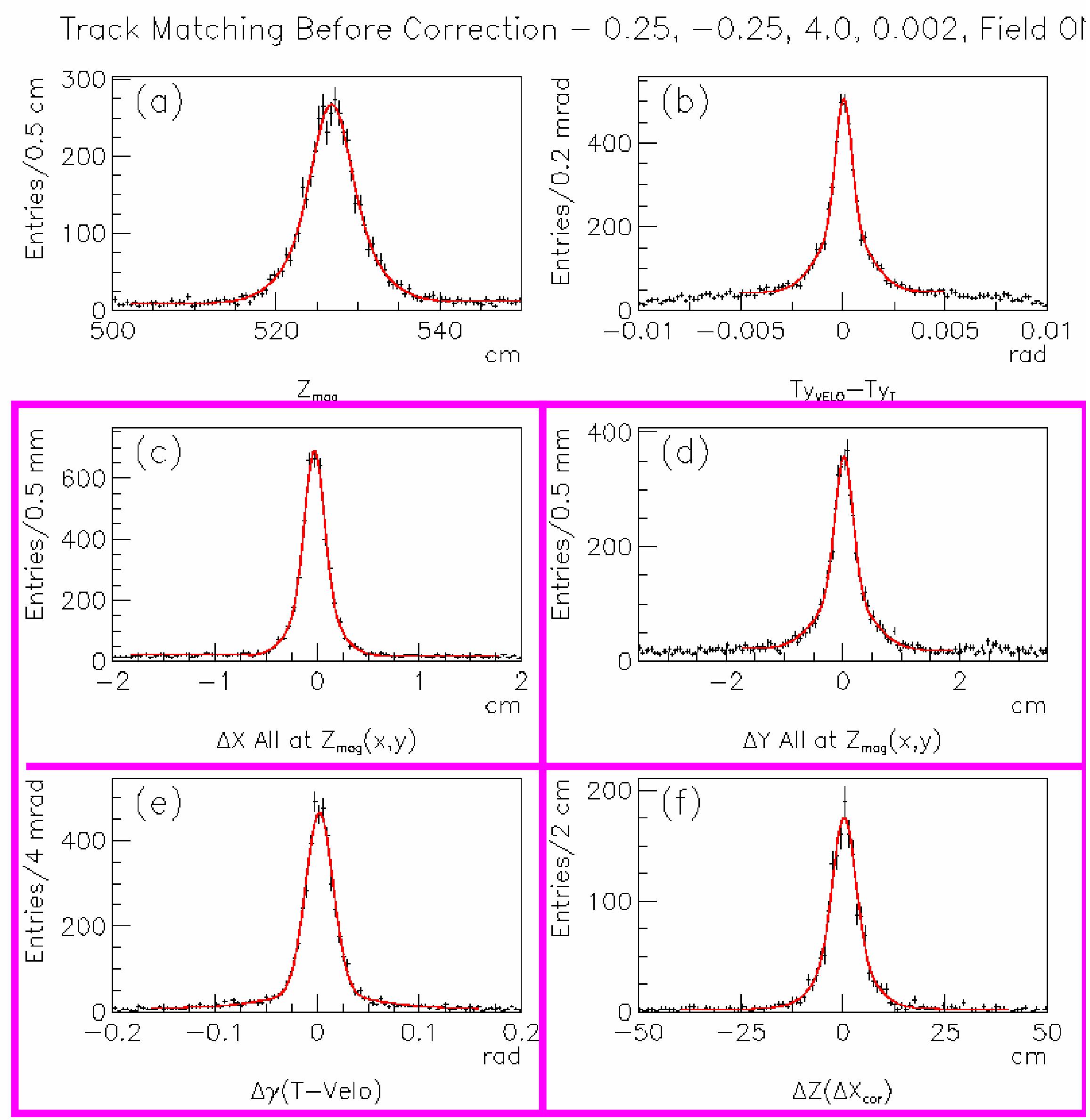
VELO-to-IT/OT, B=0
2 mrad Z Rotation

Offset	Expected	Fit Value (mm, mrad)
$\Delta\Theta_X$	0	-0.004
$\Delta\Theta_Y$	0	0.012
ΔX	-1	0.031
ΔY	0	0.005
$\Delta\gamma$	0	2.0±0.28
ΔZ	0	0.7



Magnet ON, ΔX, ΔY, ΔZ, Δγ

Offset	Expected (mm,mrad)	Fit Value (mm, mrad)
$\Delta\Theta_X$	N/a	N/a
$\Delta\Theta_Y$	0	0.04
ΔX	-0.25	0.253±0.023
ΔY	+0.25	0.200±0.054
Δγ	2	2.38±0.24
ΔZ	4.0	0.32±0.12



A second option

- With B=0 data, could also project high momentum tracks into TT, IT, OT and do a residual-based alignment.
- This may be helpful, especially for OT, where the LR ambiguity adds to the hit confusion.
- Still needs to be explored

Alignment of Other Detectors

- ❑ After VELO and T-Stations brought into alignment, TT (Trigger Tracker) is aligned to the VELO/T-Station system.
  - ❑ Residual-based alignment, work in progress here.

- ❑ Other detectors rely on a well-aligned tracking system

- ❑ RICH most sensitive, see talk by Antonis Papanestis

- ❑ ECAL (HCAL) using electrons (hadrons)

- ❑ Muon system using muon candidates
  - ❑ J/ψ for improved purity

Connection to the Global Frame

❑ Every fill, the VELO is "re-centered" on the beam.

❑VELO motion controller gives VELO position to 10 μm accuracy.
➔ Absolute coordinates of VELO only known to this accuracy.

❑ Since rest of detector is aligned to VELO, absolute LHCb coordinate are only known to ~10 μm.

❑ This is fine, since relative alignments, where needed (e.g. VELO), will be much better than this.

❑So, what defines the absolute coordinate system?

- ❑ Define it at the beginning of the run
- ❑ Then, track changes using the readback from the motion controller

Summary

- VELO well advanced on implementation and misalignment studies

- Further development of algorithms and infrastructure for IT, OT, TT in progress. Expect results soon…

- Aim for a common set of tools/interfaces shared by various alignment tasks.

- Need to automate the alignment tasks, as they will run in real time, online.

- Online alignment important for trigger, but pretty robust against small misalignments.