LHCb Alignment Strategy

1. Introduction
2. The alignment challenge
3. Conclusions

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1. Introduction

2. The alignment challenge

3. Conclusions

⇒ If you want to study B-physics, it's nice to have :

❶ A large b quark production in the acceptance

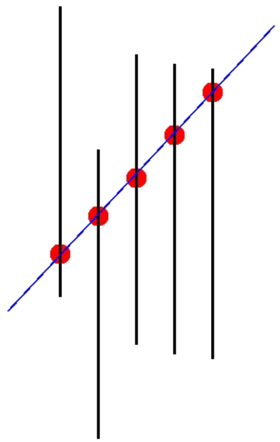
❷ A precise vertex reconstruction *(see JC Wang's presentation)*

❸ A very good particle ID

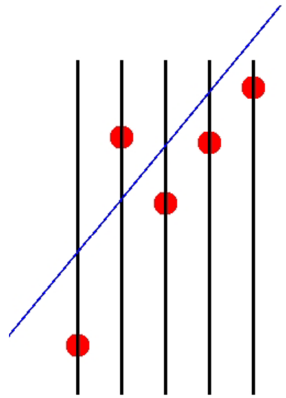
❹ An efficient trigger system *(see T Bowcock's presentation)*

❷ & ❹ heavily rely on a good alignment

⇒ The alignment problem:



❶ A particle passes through a misaligned detector

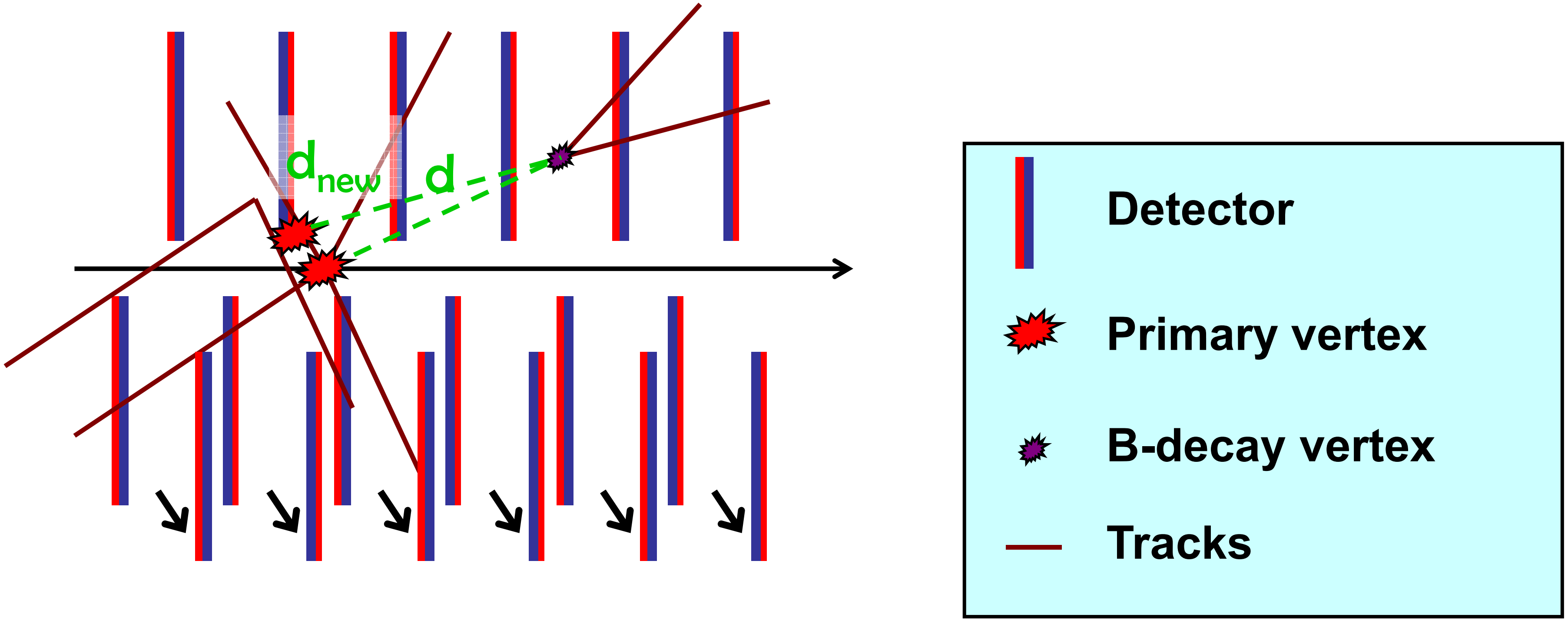


❷ What happens if track is fitted using uncorrected geometry

→ With no correction, one gets a bad quality track (or even no track at all)

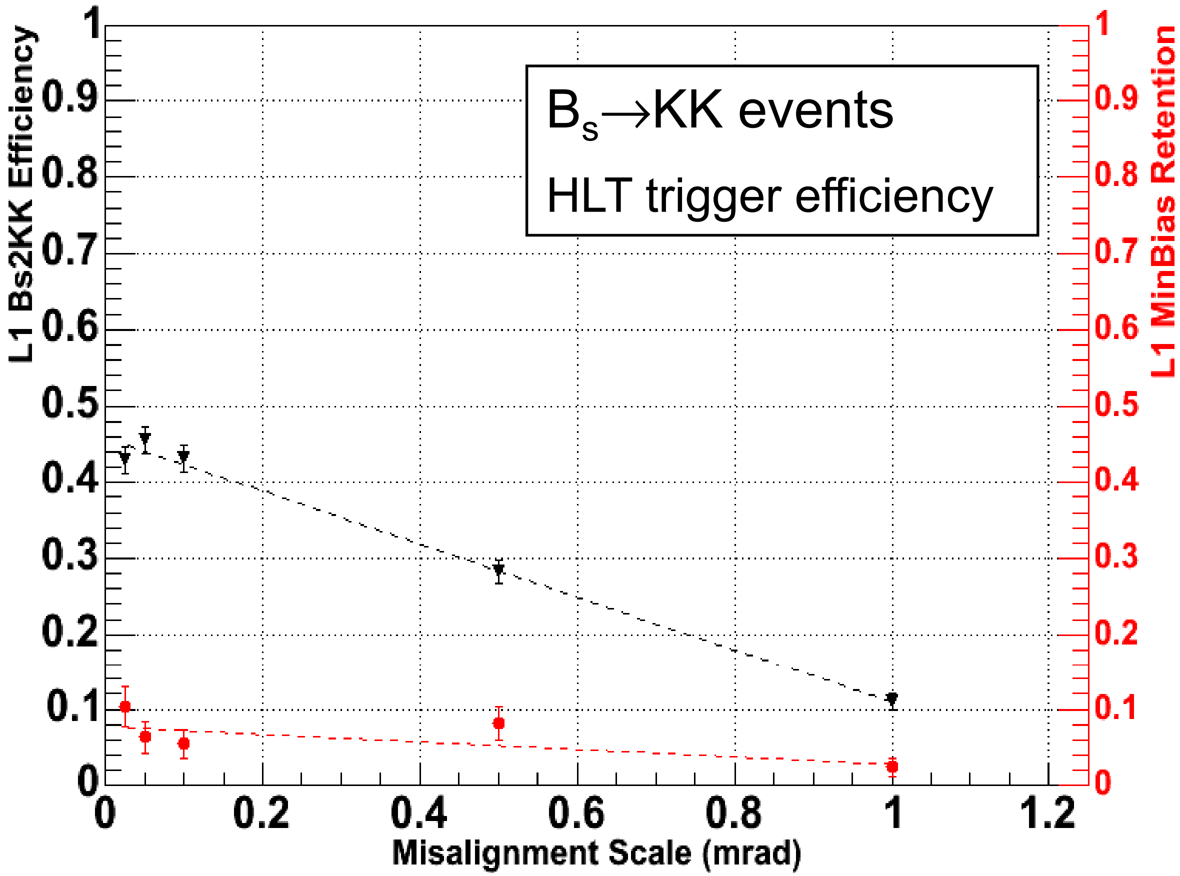
⇒ How could this affect LHCb results ?

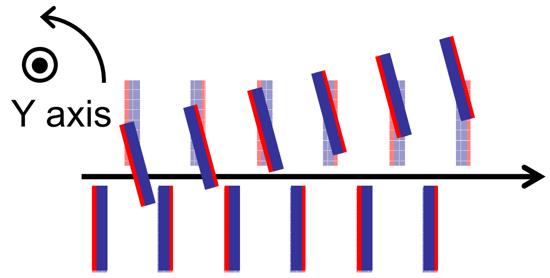
⇒ Example 1 : proper-time estimation



Proper-time ⇒ $\tau = \dfrac{d \cdot m_B}{c \cdot |p_B|}$

⇒ Example 2 : trigger efficiency

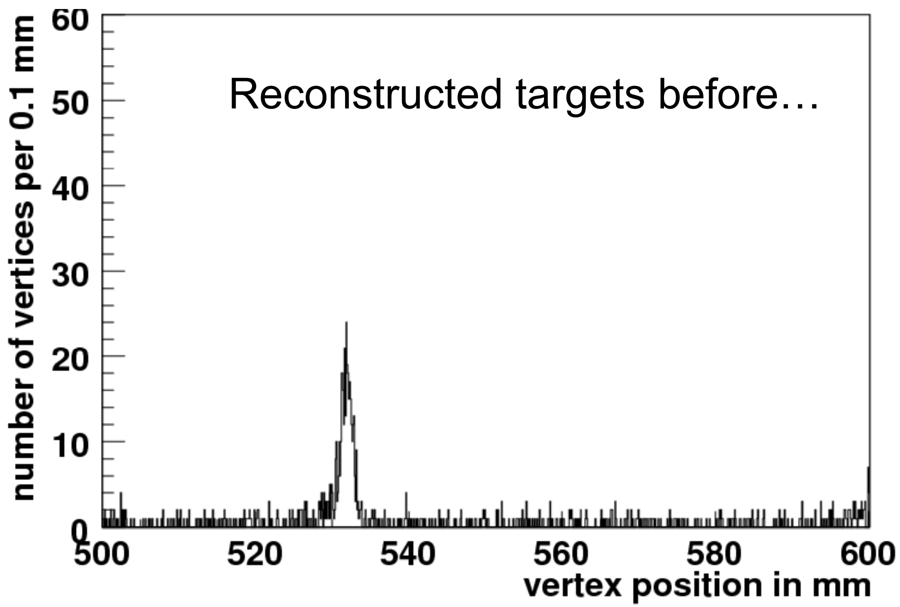


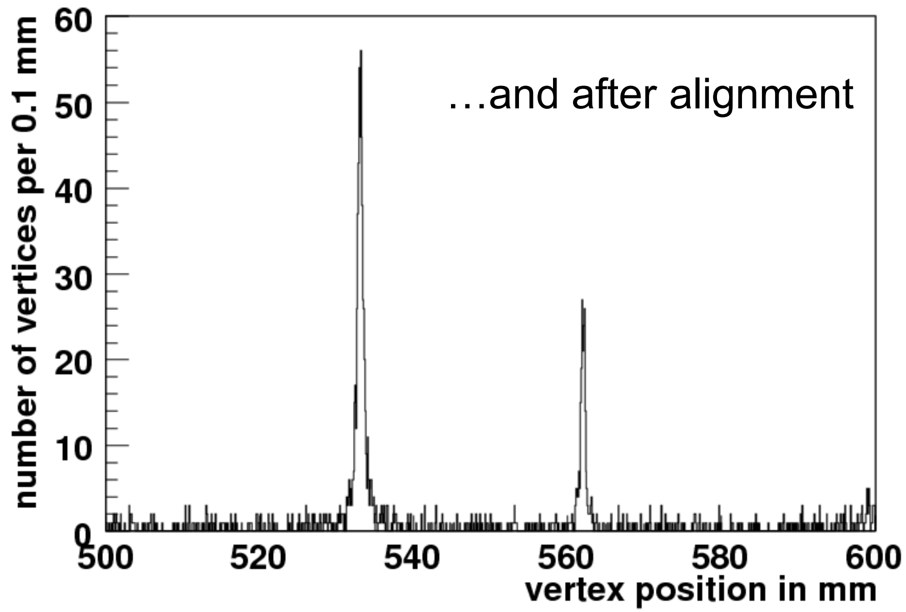


→ With 0.5 mrad tilt of one VELO box, 30% less events selected

→ **These events are definitely lost!!!**

⇒ Example 3 : vertex reconstruction from Nov. 2006 VELO testbeam





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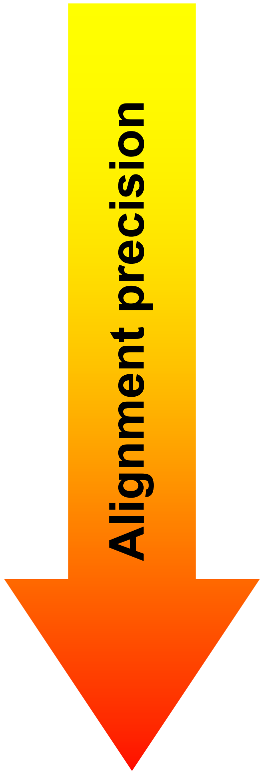
⇒ A 3 steps procedure :



➊ Complete **survey** of every sub-detector and of all the structure when installed in the pit (*work ongoing, huge amount of data collected*)

➋ **Hardware alignment** (*position monitoring*):

→ Stepping motors information during **VELO** boxes closing

→ **OT** larges structures positions constantly monitored (*RASNIKs system*)

→ Laser alignment for **RICH** mirror positioning

➌ **Software alignment**

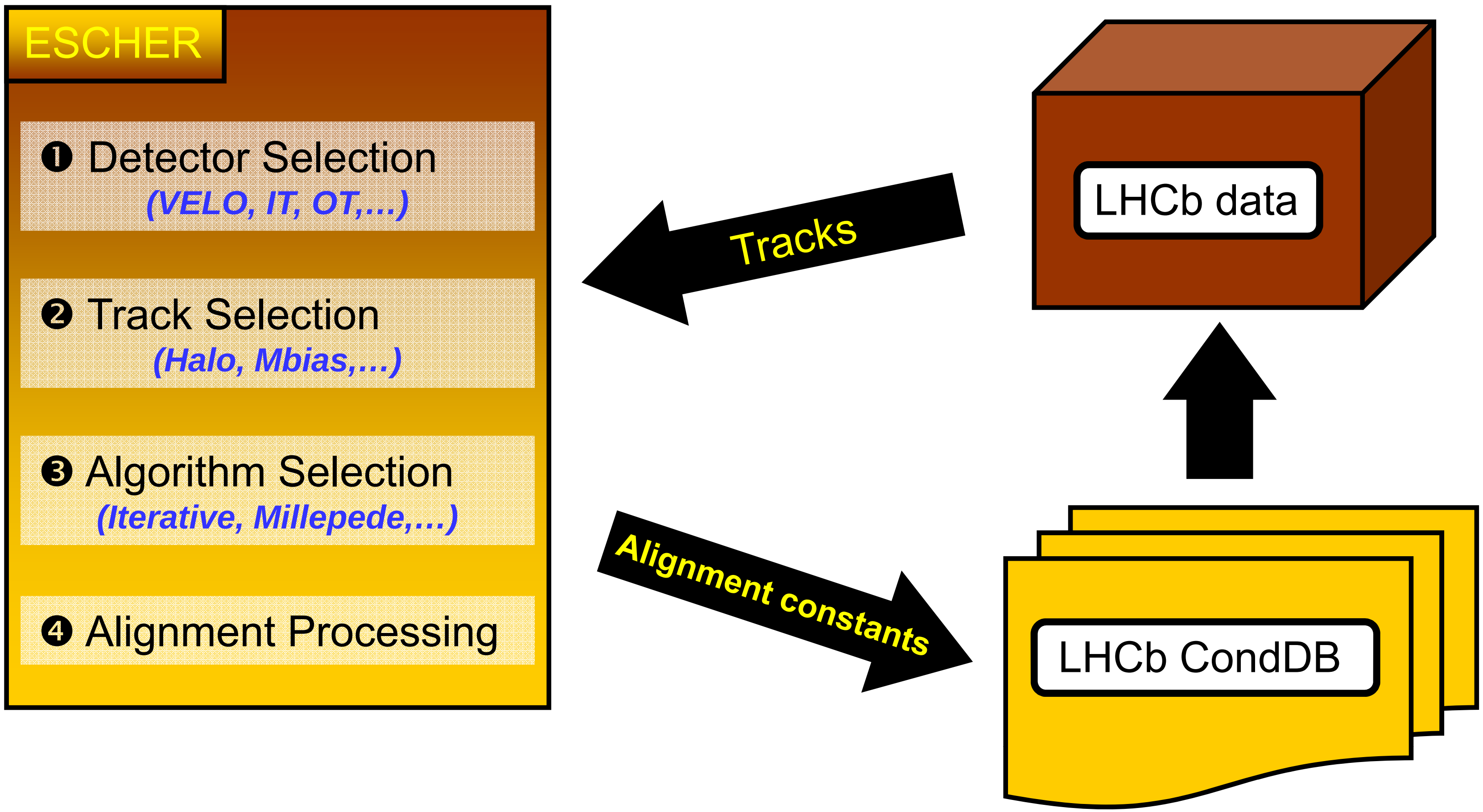
⇒ Software alignment strategy :

❶ Align all sub-detectors (VELO, IT, OT, RICHs) internally

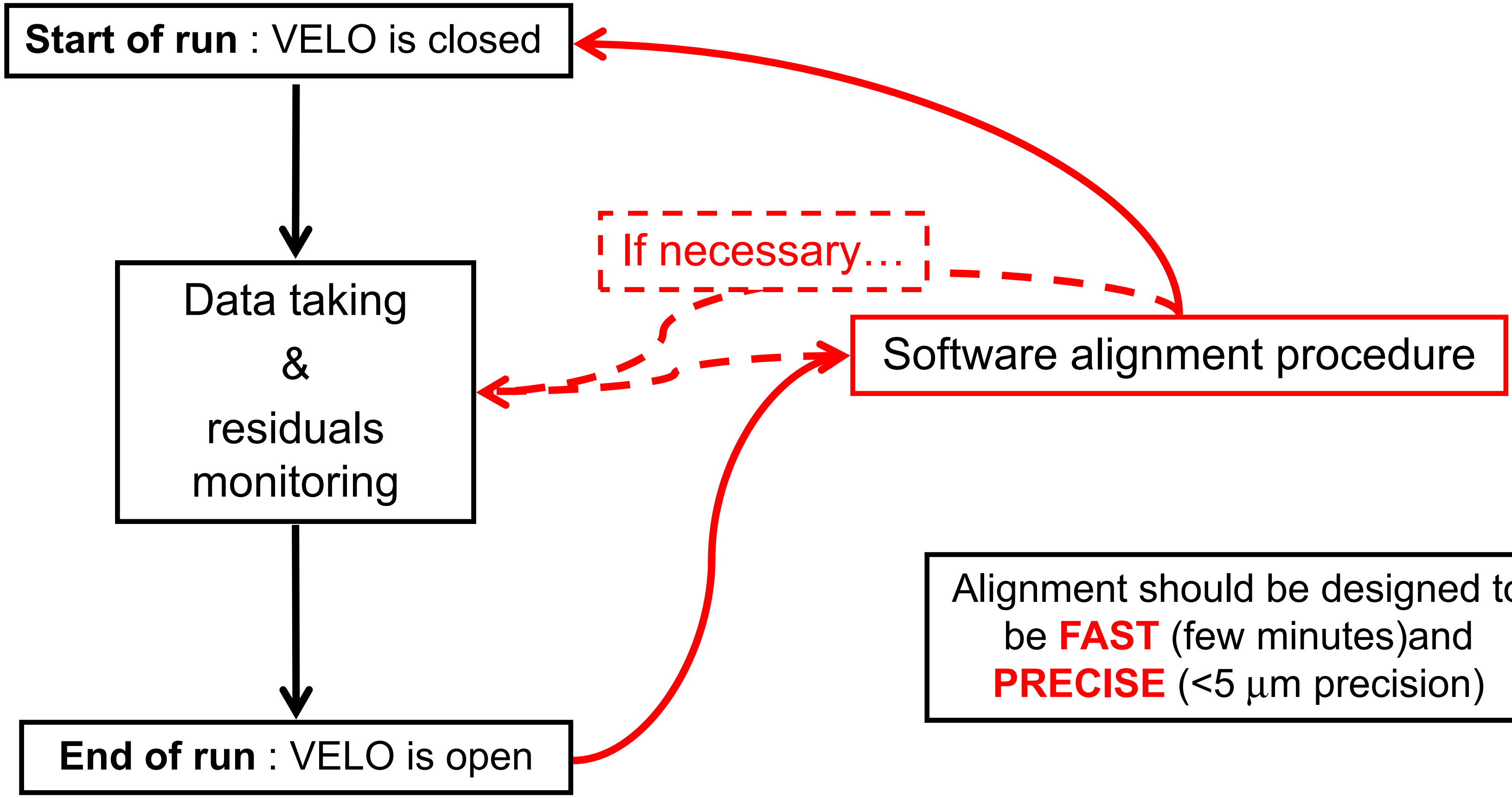
❷ Align the sub-detectors w.r.t. the VELO (***Global alignment***). Start with IT & OT, then TT (*not alignable internally*), RICH and finally Ecal, Hcal and Muon.

❸ Use a common software infrastructure (*easier to maintain/understand*)

⇒ **ESCHER** : the LHCb software alignment project :

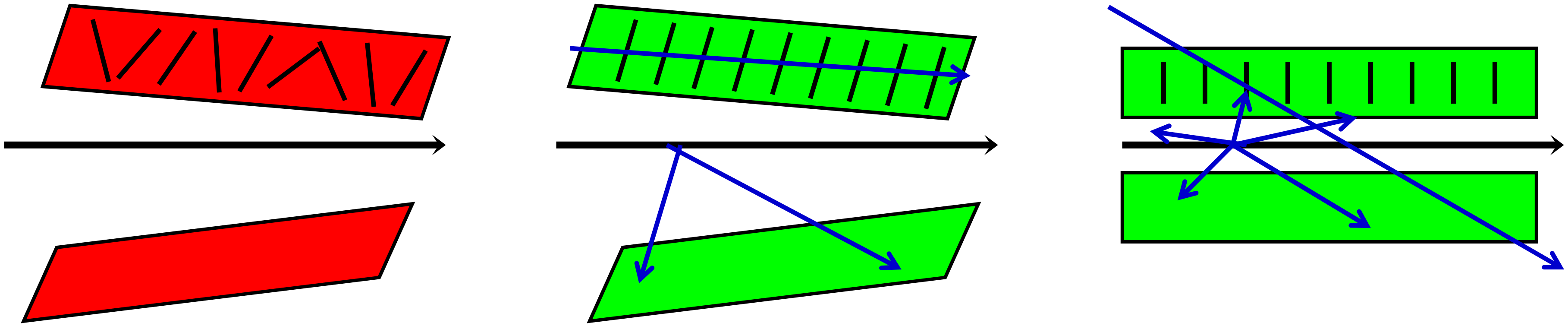


⇒ VELO alignment : how to proceed ?



Alignment should be designed to be **FAST** (few minutes)and **PRECISE** (<5 µm precision)

⇒ VELO: the strategy



Step 0

Misaligned VELO

Step 0.5

R/ϕ sensors internal alignment

Step 1

Internally-aligned VELO

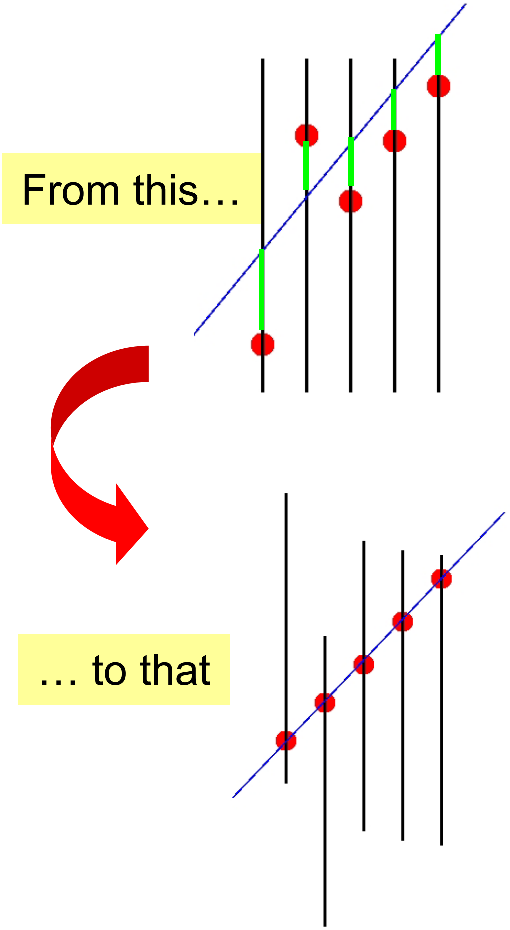
Global fit applied on tracks (**classic** & **beam gas/halo**) in the two boxes

Step 2

Aligned VELO

Align the boxes using **global fit** again on primary vertices, overlapping tracks,...

⇒ Global fit ?



→ **Residuals** are function of the detector resolution, but also of the misalignments

→ The geometry we are looking for is the one which **minimizes the tracks residuals** (*in fact there are many of them but there are ways to solve this problem*).

❶ **<u>GLOBAL FIT IDEA</u>** : Express the residuals as a <u>linear</u> function of the misalignments, and **<u>fit both track and residuals in the meantime</u>**:

$$x_{clus} = \sum a_i \cdot \delta_i + \sum a_j \cdot \Delta_j$$

<u>LINEAR</u> sum on track parameters δ_i (different for each track)

LOCAL PART

<u>LINEAR</u> sum on misalignment constants Δ_j

GLOBAL PART

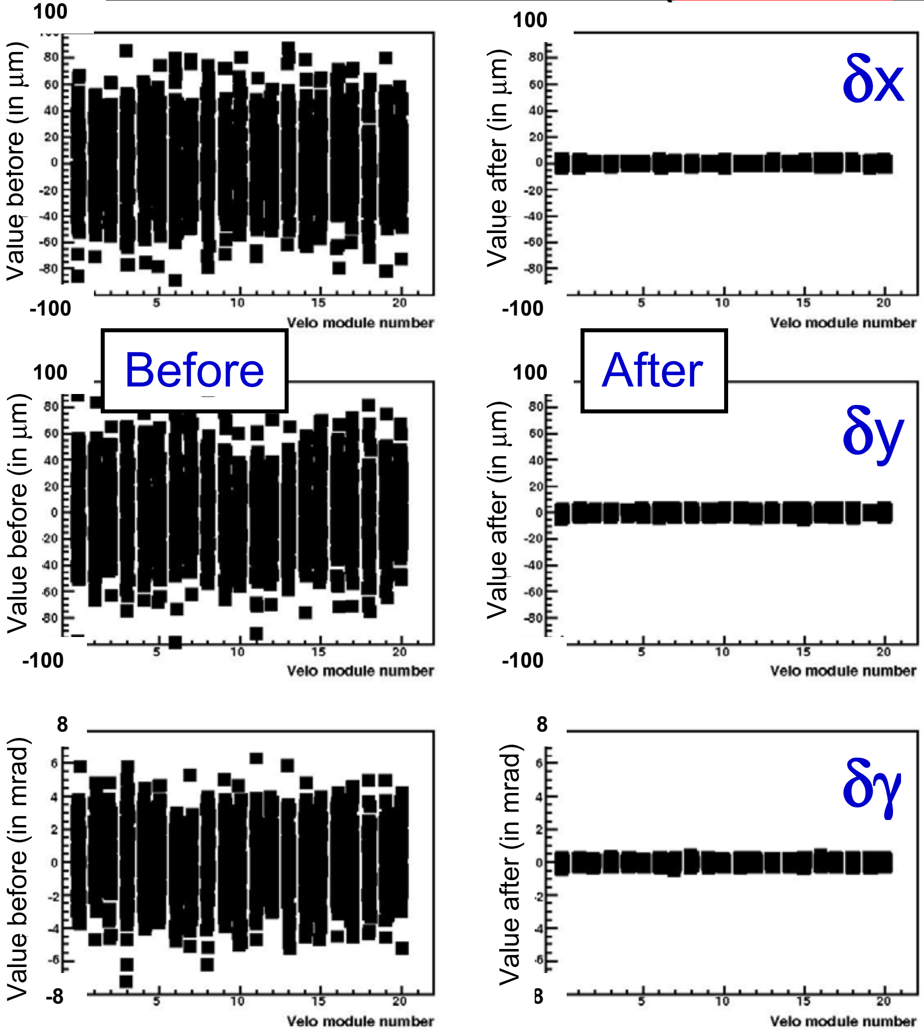
❷ Taking into account the alignment constants into the fit implies a **simultaneous** fit of all tracks (they are now all 'correlated'):

⇨ We get the solution in **only one step**.

⇨ The final matrix is huge ($N_{tracks} \cdot N_{local} + N_{global}$)

❸ **But** inversion by partitioning (*implemented in V.Blobel's **MILLEPEDE** algorithm*), reduces the problem to a $N_{global} \times N_{global}$ matrix inversion !!!

⇒ VELO : MC results (STEP 1 : *modules alignment*)



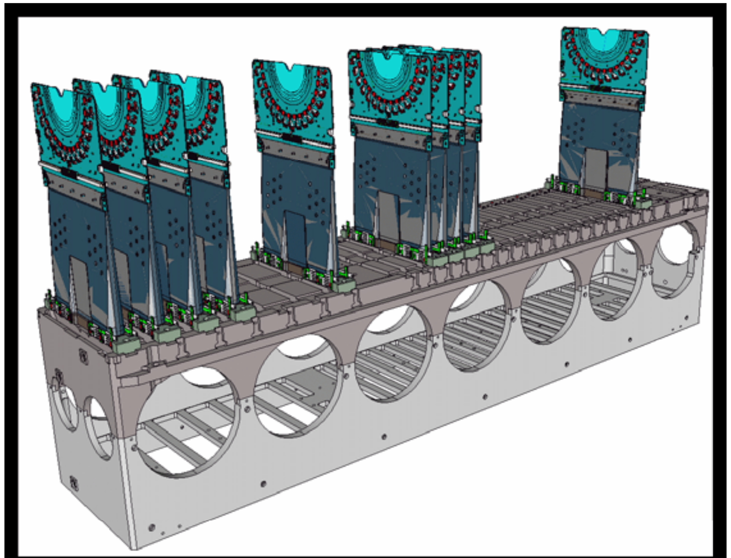
→ Code working within ESCHER. MC tests made with different misaligned geometries.

→ Resolution on alignment constants (with ~20000 tracks/box) are **1.2 µm** (δx and δy) and **0.1 mrad** (δγ)

→ Algorithm is fast (few minutes on a single CPU)

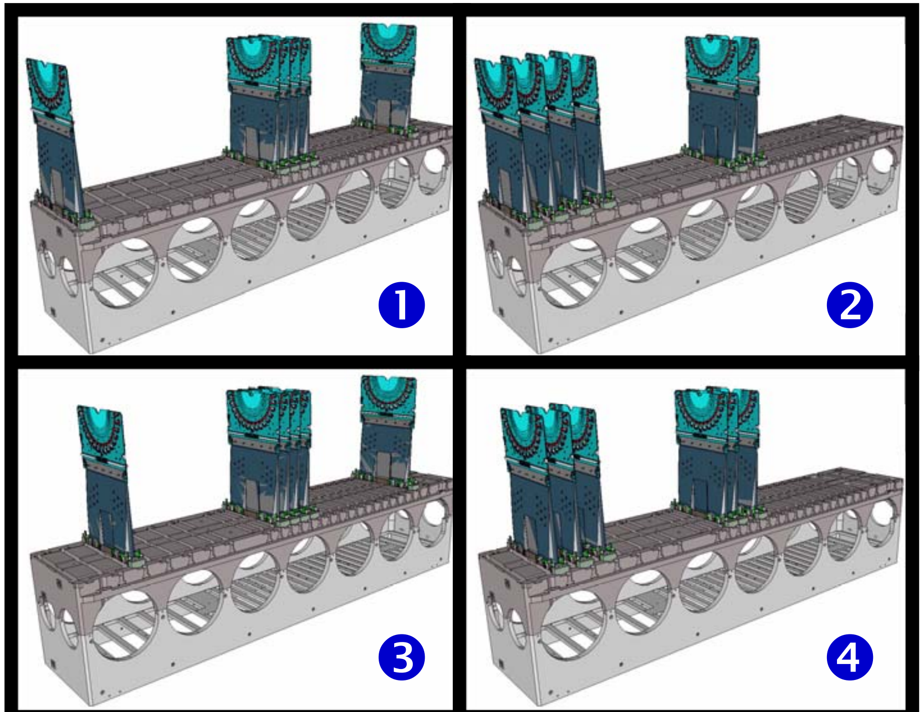
→ **STEP 2** results also within LHCb requirements (see *CERN-LHCb-2007-067*)

⇒ VELO : testbeam results (*Nov.06*)



10 modules installed

→ The testbeam setup



4 configurations (*6 modules cabled*) tested

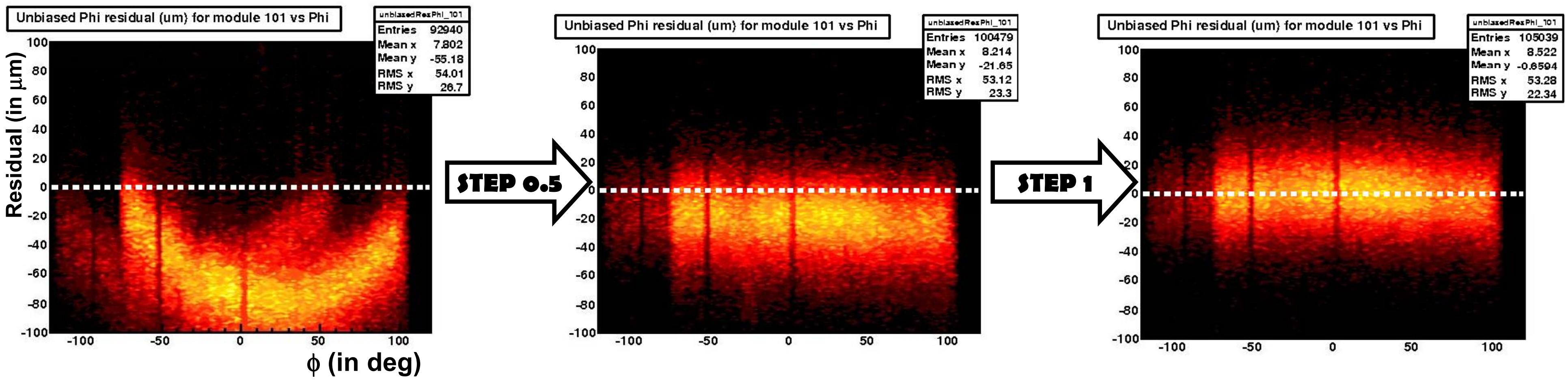
⇒ VELO : phi sensors residuals *vs.* ϕ

⓿ Just for fun, what we got first…

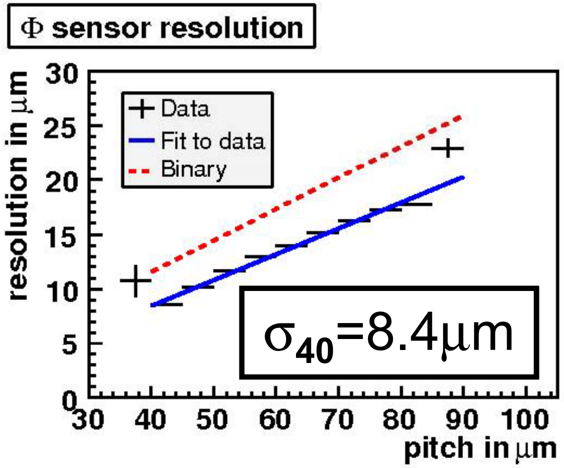
❶ After some bugs corrections we got bananas…

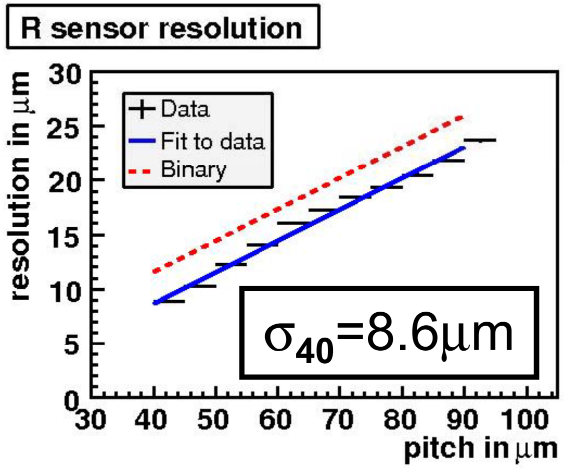
❷ Then we added R/ϕ **metrology** information

❸ And finally we aligned *(more info:* **http://ppewww.physics.gla.ac.uk/LHCb/VeloAlign/VeloACDC3.html***)*

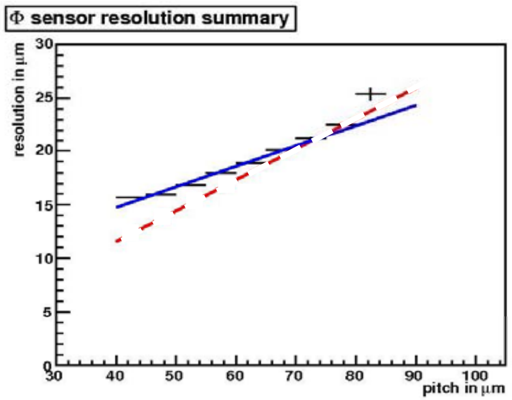


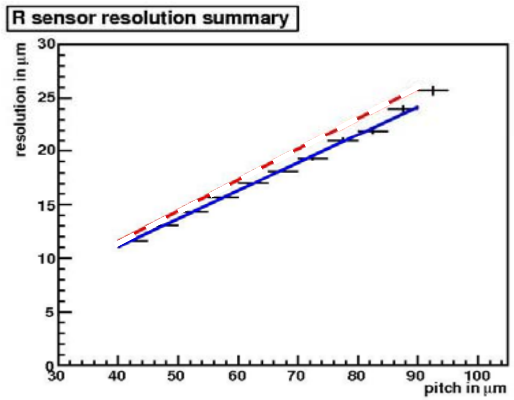
⇒ VELO : sensor resolution





If no alignment…





⇒ Tracking system alignment

⇒ **IT** and **OT** are internally aligned separately, then w.r.t. each other using the overlap areas.

⇒ Use the same method as the **VELO** (*global fit via Millepede*) within the ESCHER framework.

⇒ An iterative method is also implemented for **OT**, using the LHCb tracking framework (*based on **BaBar** SVT alignment algorithm*)

⇒ Both methods are currently under development, first results have already been obtained (*retrieve simple misalignments,…*)

⇒ Global alignment

⇒ Most critical step is tracking system alignment:

❶ VELO to T-stations (IT & OT)
❷ TT to VELO/IT/OT

⇒ Strategy for step ❶ has been defined (*match tracks fitted independently in both tracking systems*) and successfully tested on MC. Has to be extended to step ❷

⇒ The algorithm is ready for LHCb alignment challenge (*full-dress rehearsal of the alignment project using MC misaligned samples*), which is foreseen for the end of 2007

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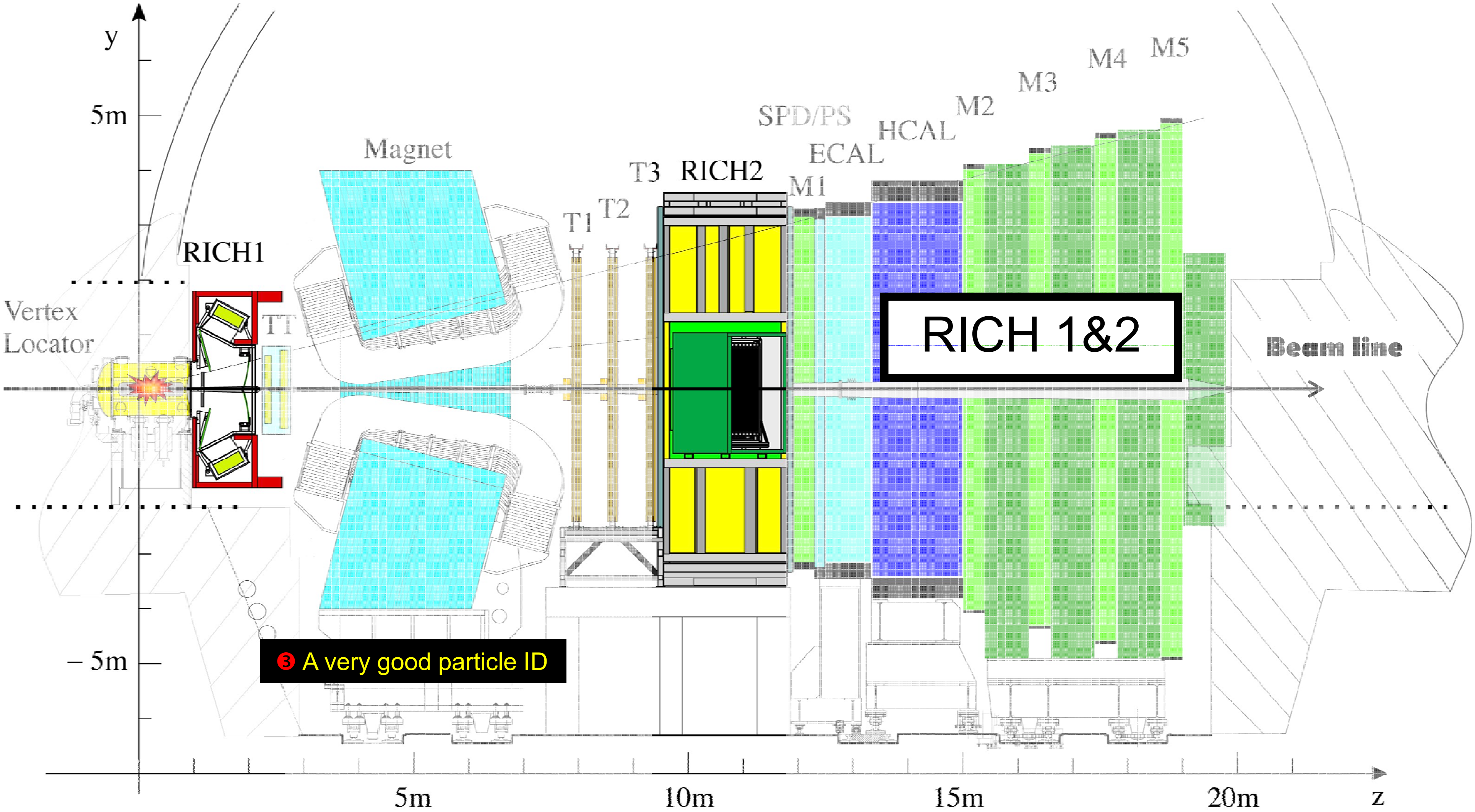
⇒ LHCb tracking system alignment strategy has been presented (*available in* CERN-LHCb-2006-035).

⇒ It has to take into account LHCb unique specificities (*e.g. moving VELO*) and requirements (*online vertex trigger*)

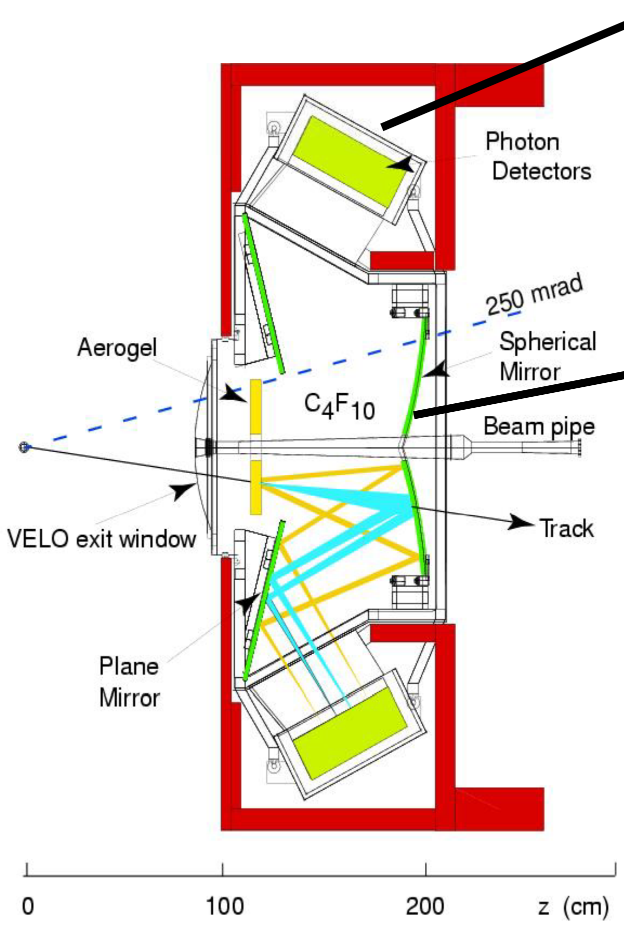
⇒ Work is ongoing on many fronts, and some nice results have already been obtained (*VELO testbeam alignment). A* common software framework is now in place and will be tested soon (*Alignment Challenge*).

⇒ We are now waiting the first beams (*as we can't play with cosmics* ☹)

SPARES

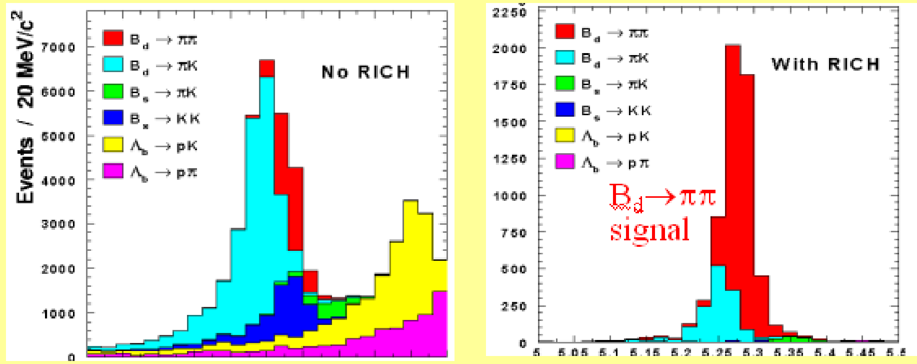

y
5m
– 5m
Vertex
Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5
RICH 1&2
Beam line
5m
10m
15m
20m
z
❸ A very good particle ID

⇒ RICH design :



⇒ Photon collected by HPD detectors (484 in total RICH 1&2)

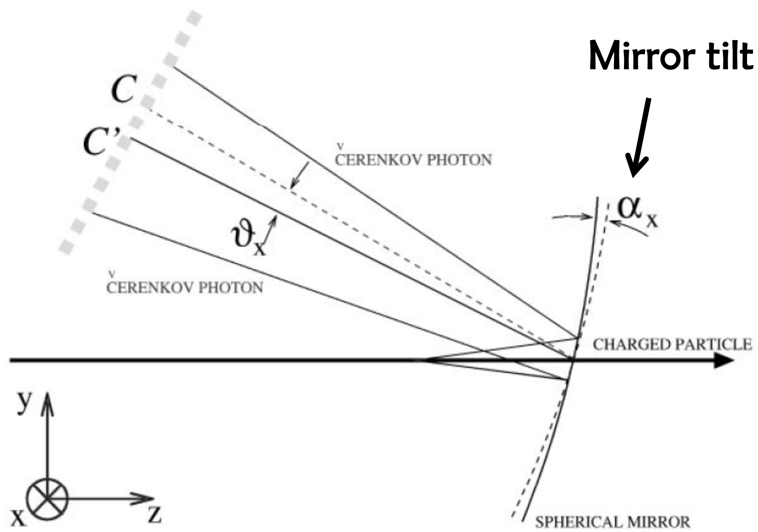
⇒ Number of mirrors:
RICH 1 : 4 sphericals / 16 planes
RICH 2 : 56 sphericals / 40 planes

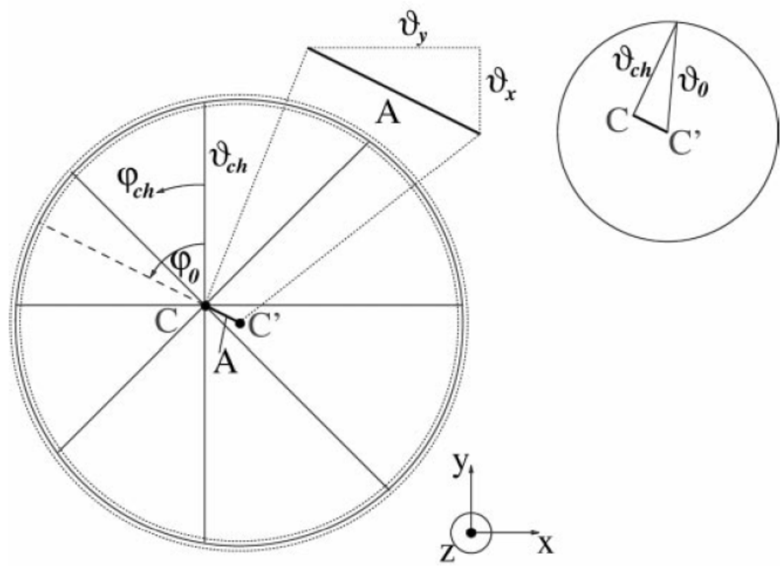


Some advertising…

⇒ RICH alignment : principle

Mirror tilt





ϑ_{ch} : Expected Cherenkov angle

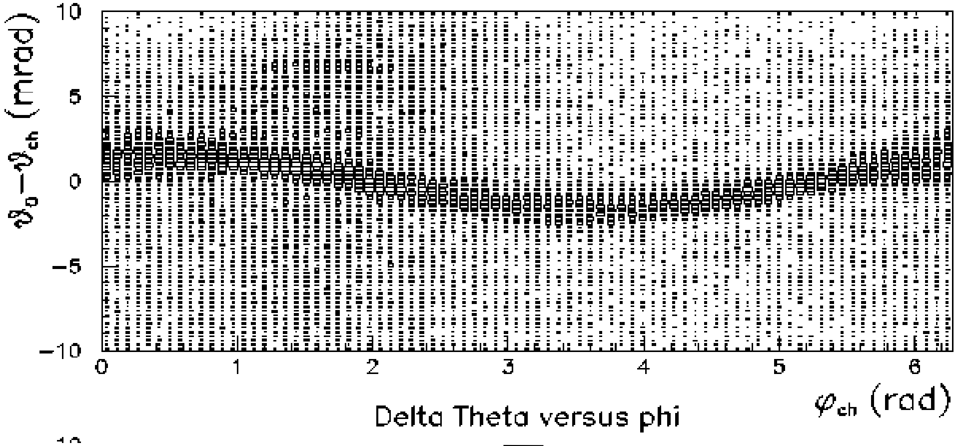
ϑ_0 : Measured angle

ϑ_x ϑ_y : Distortion due to mirror tilts

$$\vartheta_{ch} = \vartheta_0 - \vartheta_x \cos(\varphi_{ch}) + \vartheta_y \sin(\varphi_{ch})$$

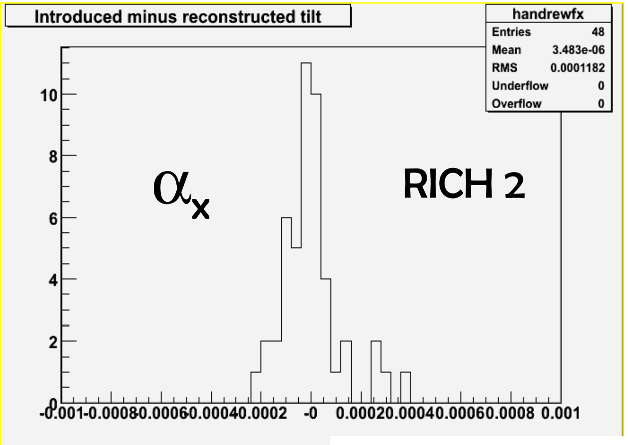
⇒ RICH alignment : results

$$\vartheta_{ch} = \vartheta_0 - \vartheta_x \cos(\varphi_{ch}) + \vartheta_y \sin(\varphi_{ch})$$



Fit those distributions for all the mirrors combinations in order to get their individual orientation (tilt around X and Y axis).

Alignment code implemented
Minimization using MINUIT



Measured - expected

0.1 mrad resolution obtained, well within requirements