Alignment of the LHCb RICH detectors

On behalf of the LHCb-RICH group

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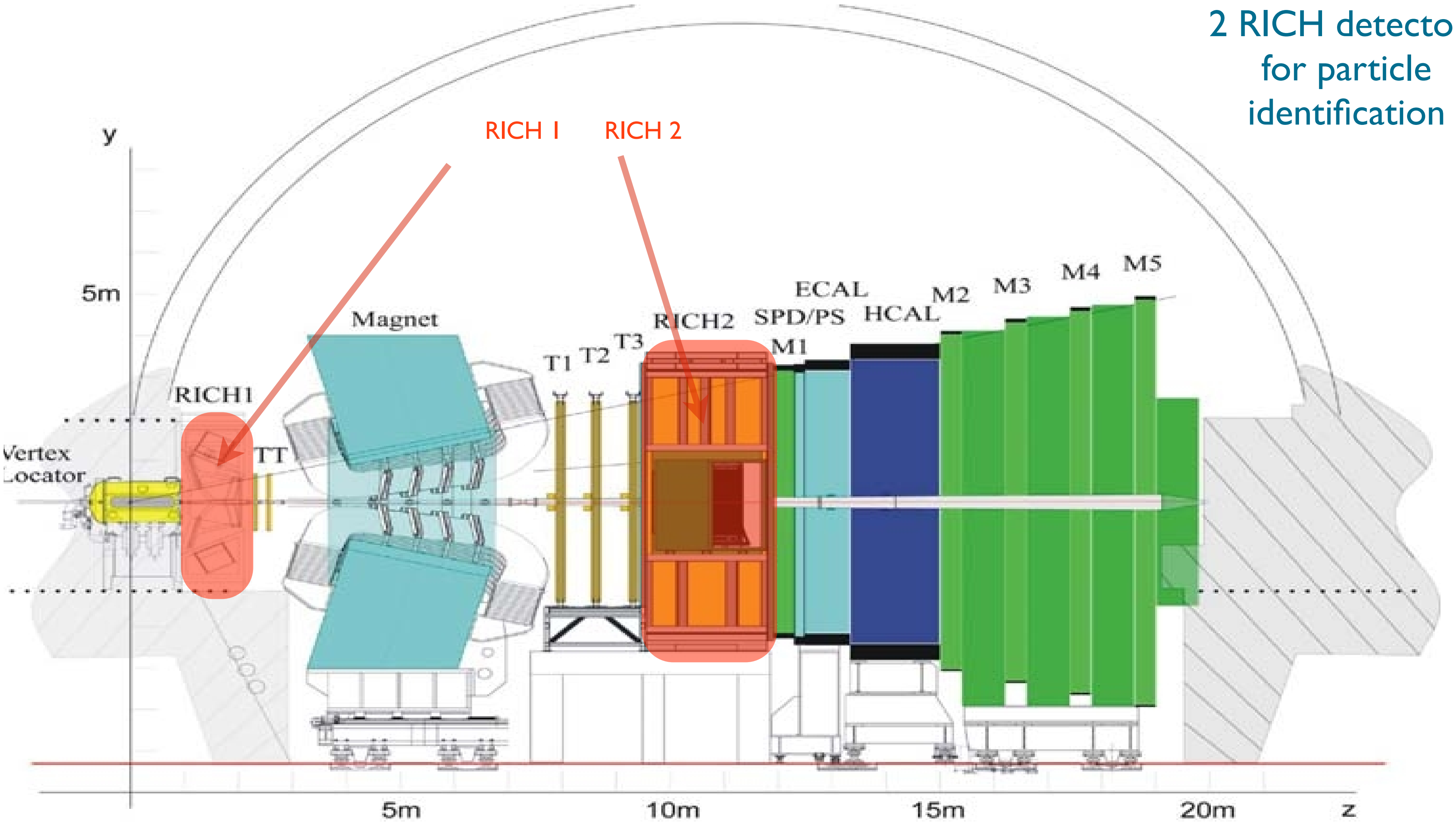
LHCb

Science & Technology Facilities Council

UNIVERSITY OF Southampton

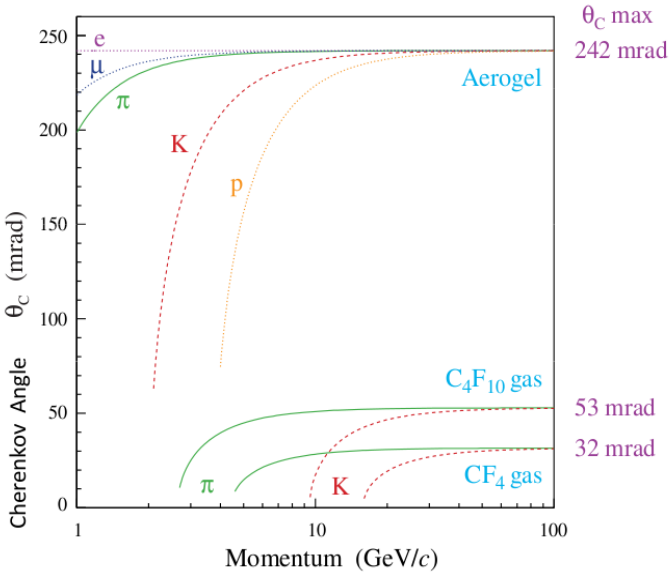
Contents

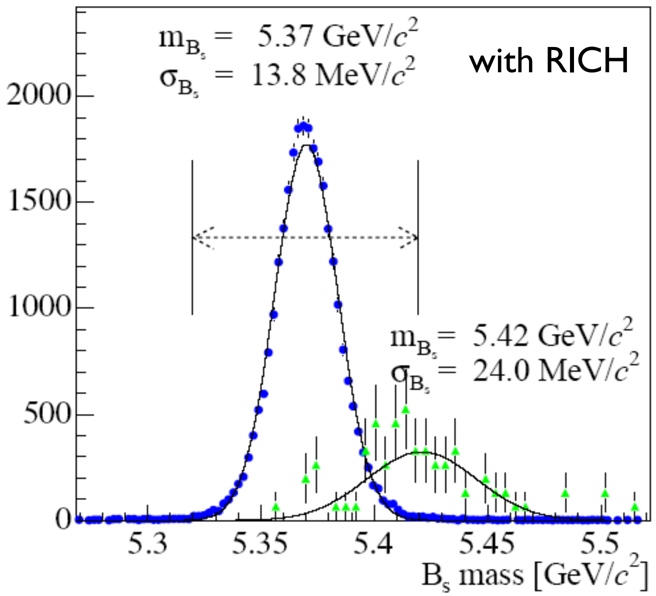
The LHCb detector



2 RICH detectors for particle identification

RICH Detectors at the LHCb experiment





- RICH system covers momentum range 2-100GeV/c

- 2 RICH detectors with 3 different radiators
  - RICH 1 (2-60GeV/c)
    - Aerogel
    - C_4F_{10} gas
  - RICH 2 (-100GeV/c)
    - CF_4 gas

- Particle identification, particularly between pions and Kaons. Important for physics analysis at LHCb
  e.g $B^0_s \rightarrow D_s^- K^+$
  $B^0_s \rightarrow D_s^- \pi^+$ background (10 times the signal)

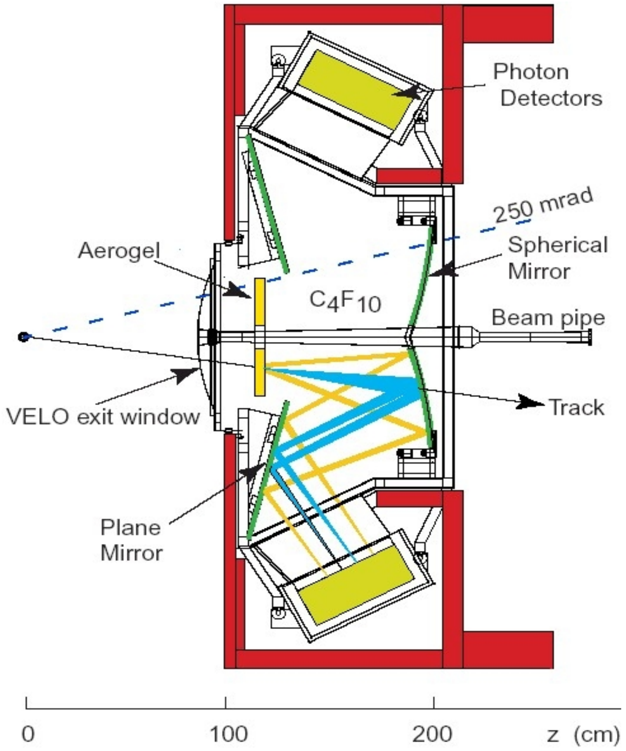
- Particle identification efficiency is decreased by a misalignment in the RICH system

$B^0_s \rightarrow D_s^- K^+$ (signal)

$B^0_s \rightarrow D_s^- \pi^+$ (background)

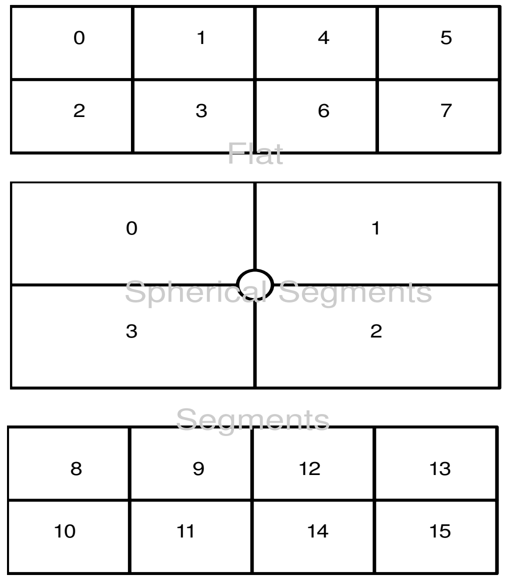
After RICH reduces background from 10 times to ~10%

Misalignments in the RICH1 detector



RICH 1 detector

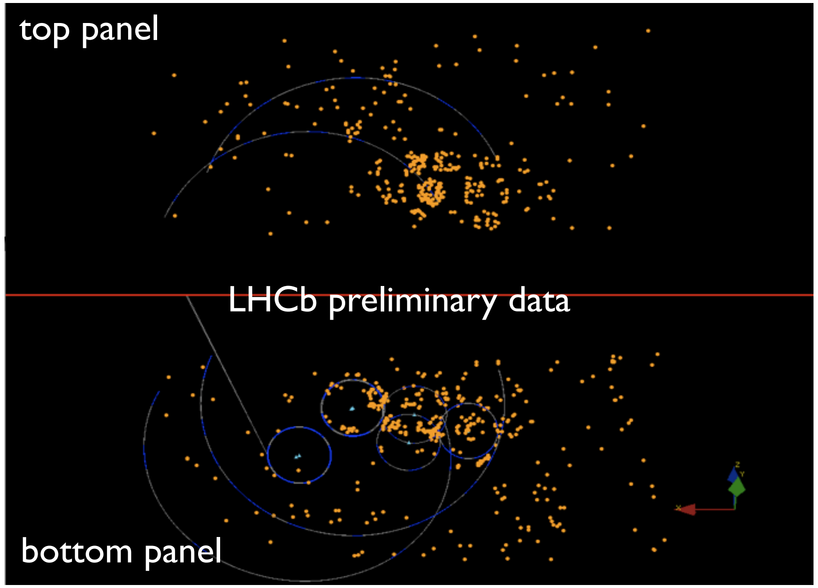
- RICH1 is positioned upstream of the magnet
- Misalignments in RICH1
  - Rotations and translations to the whole detector
  - Rotations and translations to all 4 spherical and 16 flat mirrors in RICH1
  - Rotations and translations to the photon detectors
- Distortions caused by the magnetic field of the LHCb magnet

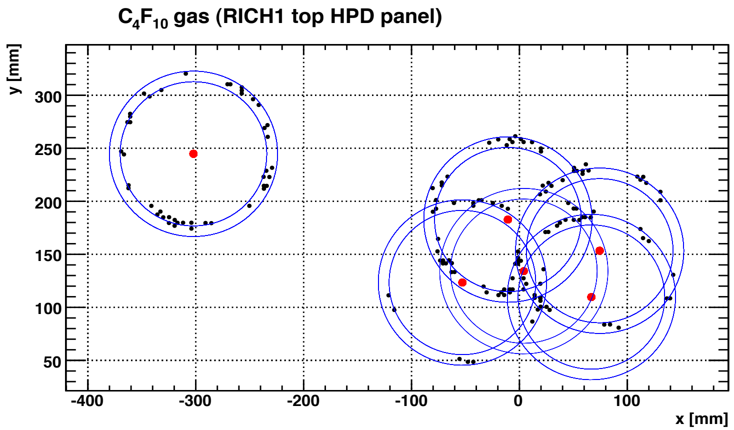


RICH 1 Mirrors

Alignment Strategy

RICH1 Photon Detector panels with CK rings





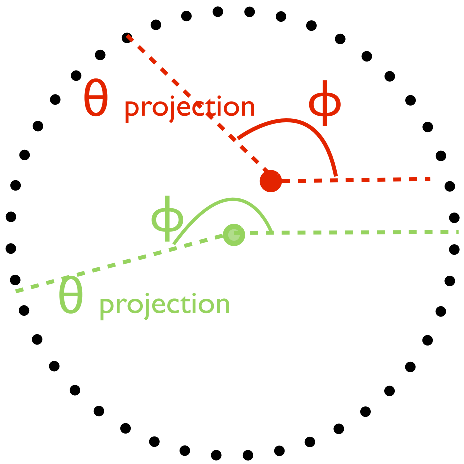
Track projection point

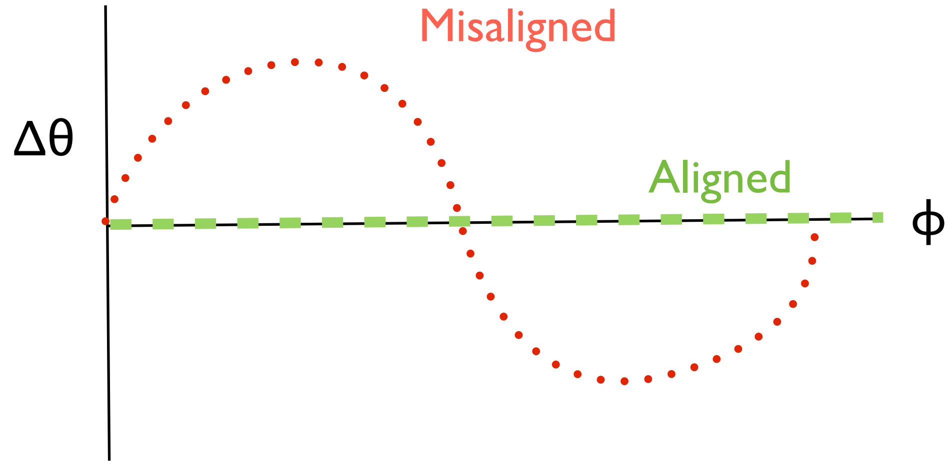
Ring found Cherenkov ring

Photon hits

- Tracks are reconstructed
- Cherenkov rings are found on the photon detector plane
- Tracks are then selected to use for alignment
- Only tracks above 15GeV/c for RICH1 Gas are selected. These tracks have a well defined expected theta.
- Only tracks which are separated from all other tracks by 30mm.
- Only tracks which have a ring with more than 6 photons associated with it are used, to ensure only true rings are selected

Alignment Strategy

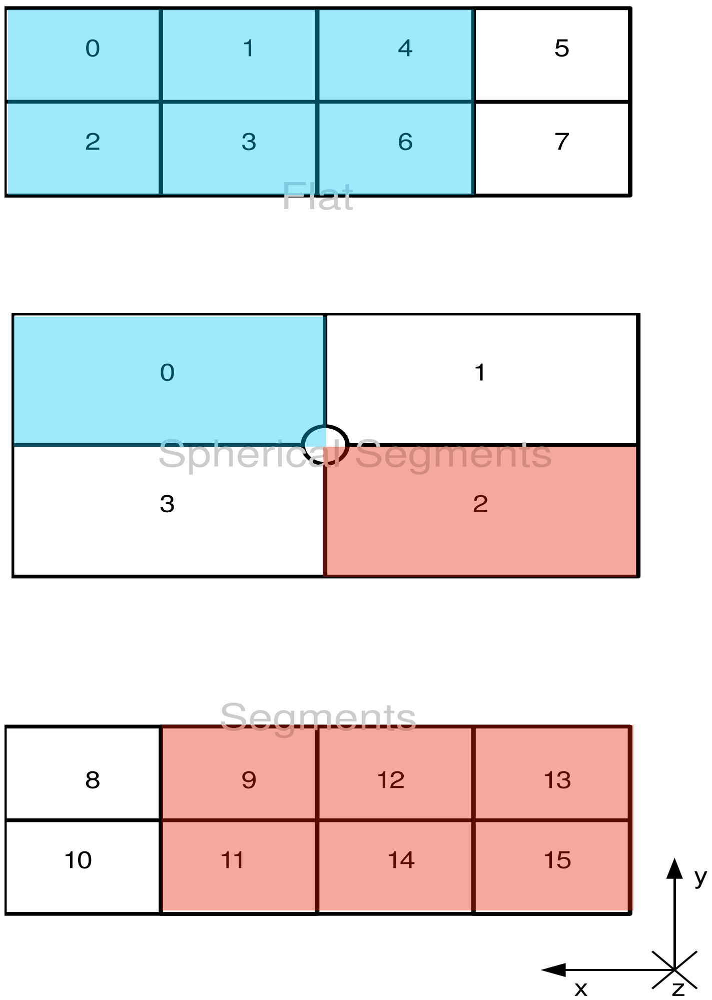




- Spatial co-ordinates are transformed into angle space of Cherenkov emission angle θ and the angle around the ring ϕ
- When the mirrors of the RICH are misaligned the effect is viewed on the detector plane as a shift of the track projection point away from the ring centre.
- Plot Δθ against ϕ for all mirror pairs with more than 2000 hits
- The projected misalignments θ_x and θ_y are extracted by fitting with the following:

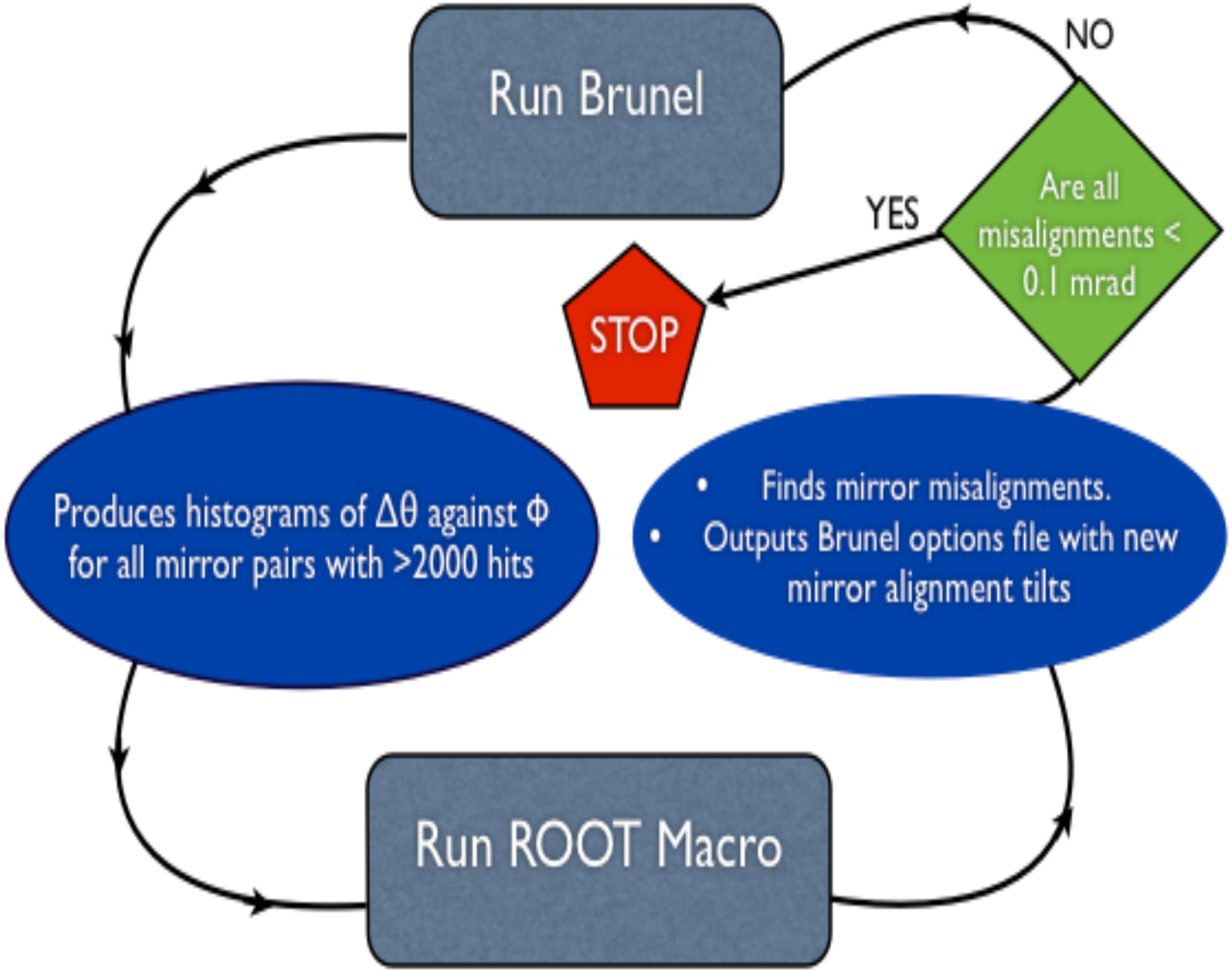
$$\Delta\theta = \theta_{CK} - \theta_0 = \theta_x \cos(\phi_{CK}) + \theta_y \sin(\phi_{CK}).$$

Comparison method



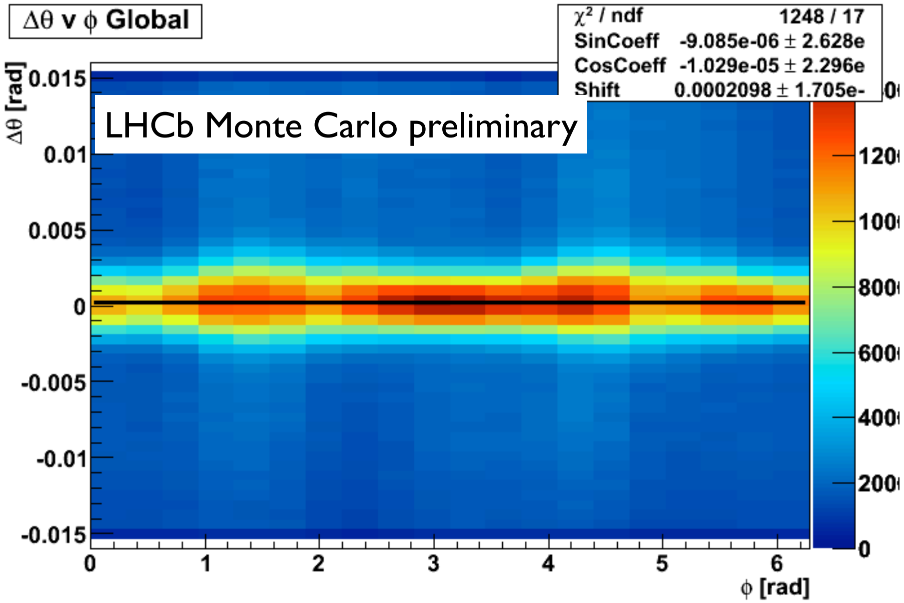
- Look at only mirror pairs associated with a spherical mirror
- If all flat mirrors misaligned in a given axis have same sign tilt (+/-) then align the spherical mirror using the most populated mirror combination
- If flat mirrors for one spherical mirror have different misalignment signs (+/-). Then align each flat mirror individually.
- Extracts alignment parameters for both flat and spherical mirrors
- Should give alignment parameters closer to 'true' mirror tilts

Automation Process



- Automation uses the grid to run an iterative process
- LHCb reconstruction software (Brunel) is run to produce histograms of the alignment plots
- Plots analysed by a ROOT macro which fits alignment histograms to find alignment parameters and mirror tilts.
- New alignment conditions are created and the reconstruction is run again.
- The process stops once all alignment parameters are less the 0.1mrads
- Takes ~7 iterations to converge

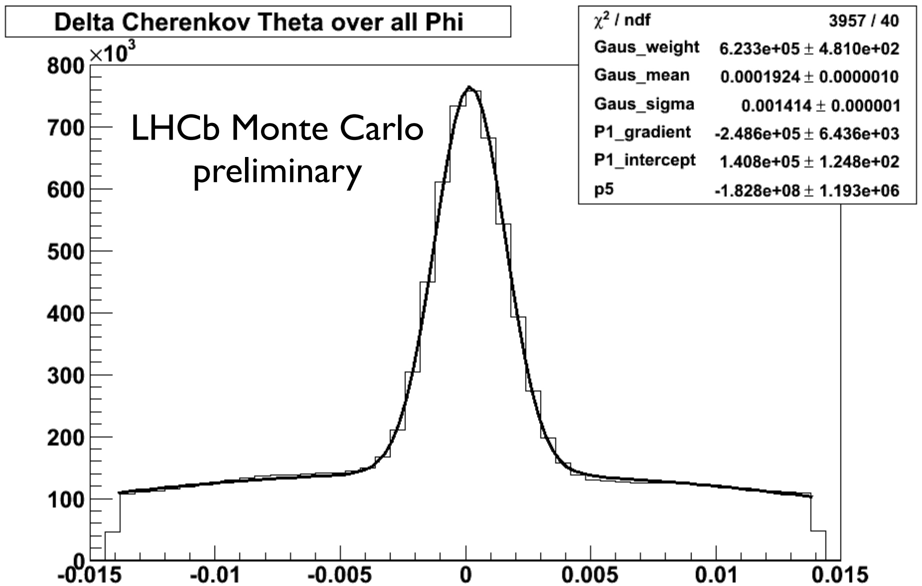
Monte Carlo simulation at 450GeV



- Alignment Histogram of delta theta against reconstructed phi for Monte Carlo data gives all misalignments < 0.1 mrads

- The delta Cherenkov distribution is plotted and fitted with a Gaussian peak

- For a perfectly aligned system a width of the delta Cherenkov angle of 1.41 mrads is expected



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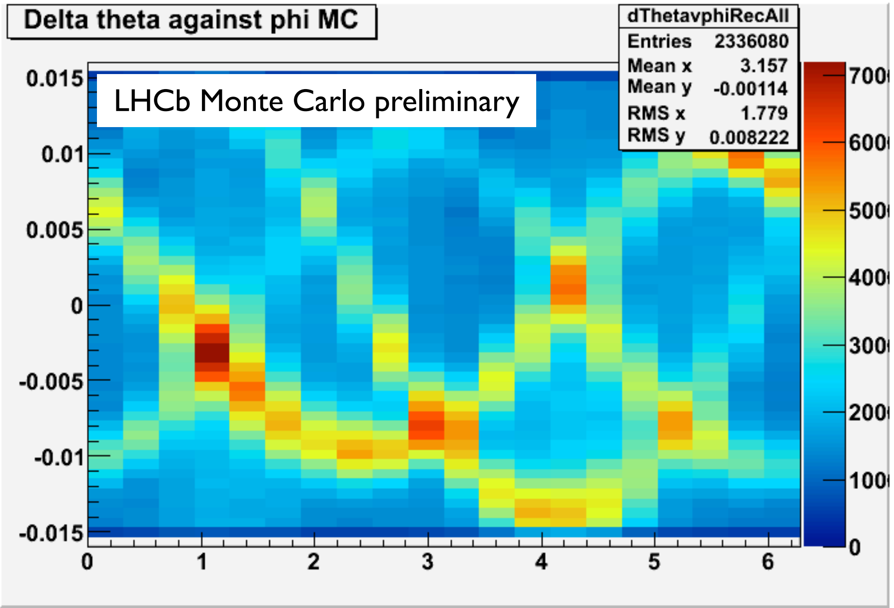
Monte Carlo simulation at 450GeV Misaligned



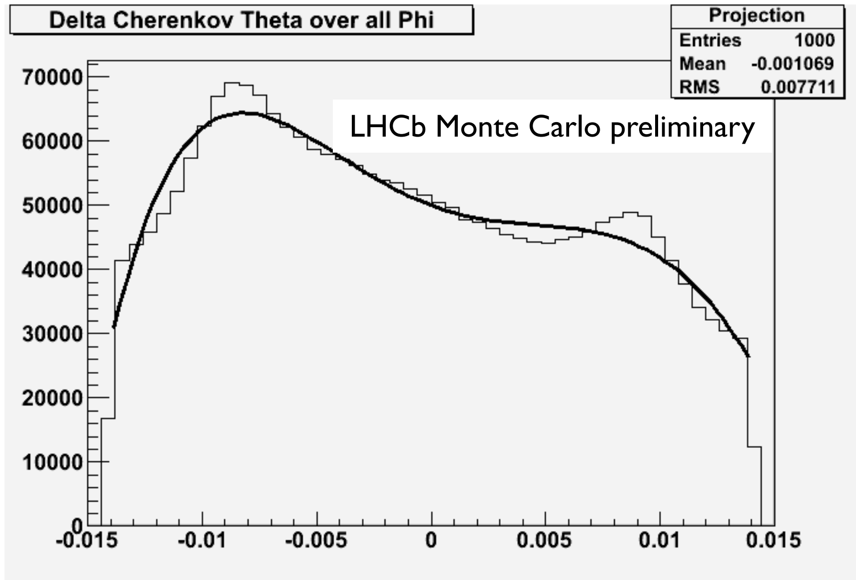
- Monte Carlo data was created with randomly misaligned RICH1 mirror segments.

- This data was then used to trial alignment methods. In attempt to recover the aligned state.

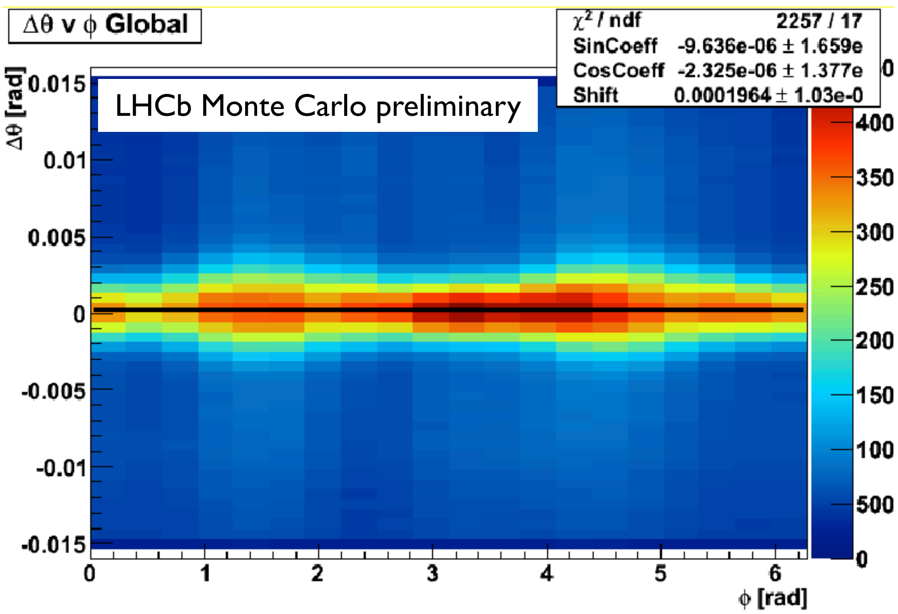
- Several misalignments can clearly be seen

- Misalignments are caused by individual mirror misalignments

- Misalignments can not be corrected for by rotating the whole detector only

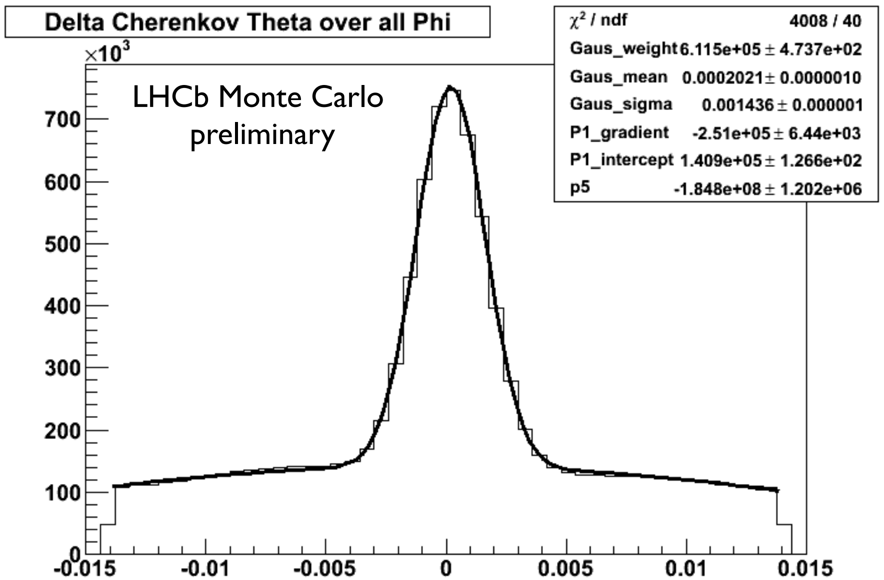


Monte Carlo simulation at 450GeV After Alignment



- Alignment process converged after 5 iterations

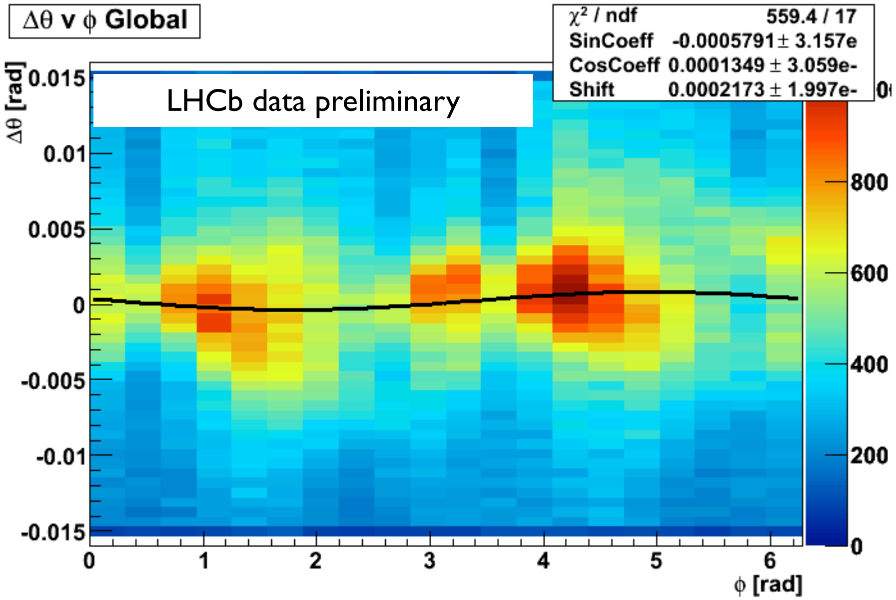
- All alignment coefficients returned less than 0.1mrads



- Delta Cherenkov angle distribution returned has a width of 1.43mrads

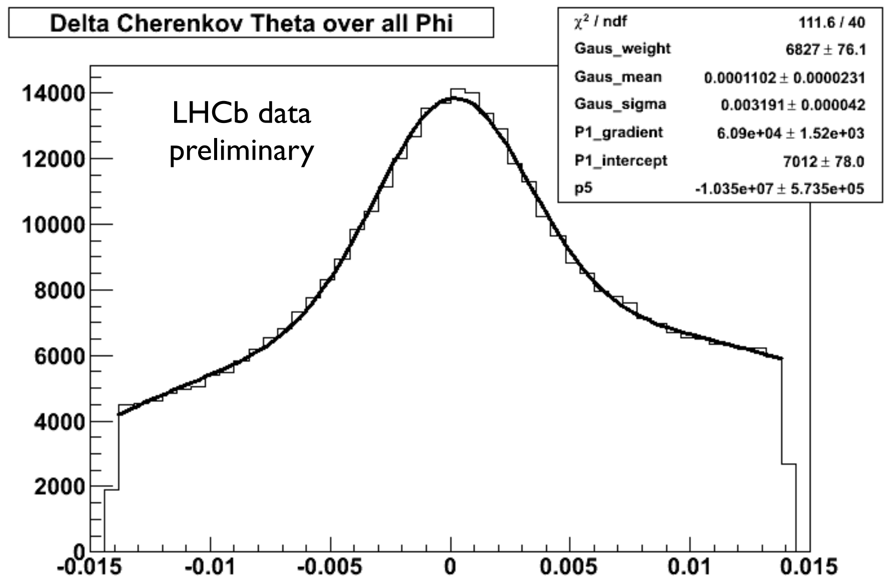
- Only 0.02 mrads larger than a perfectly aligned Monte Carlo system

2009 450GeV Collisions Data Before Alignment

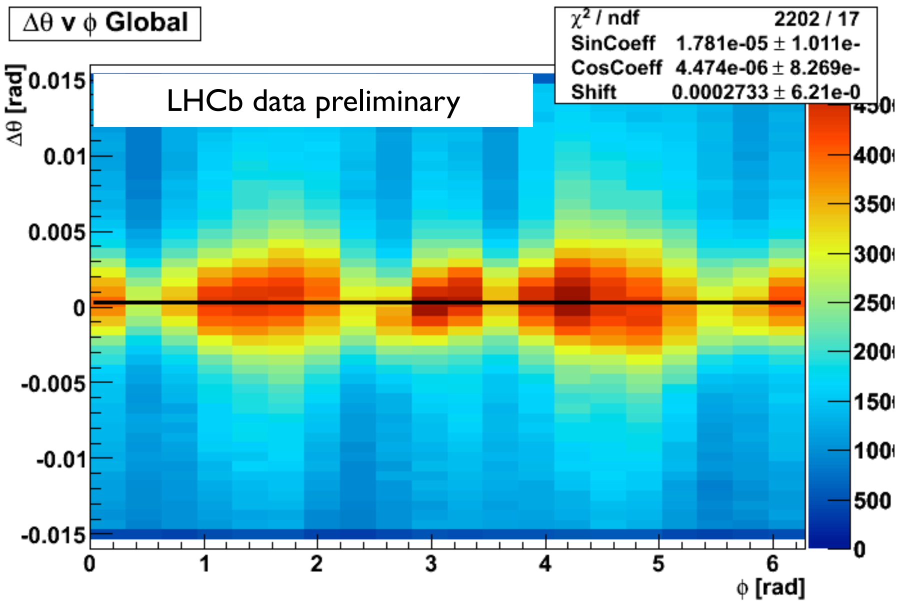


- A misalignment is observed
- Parameters are larger than required 0.1mrads
- Statistics allow for the correction of one mirror pair per spherical mirror only

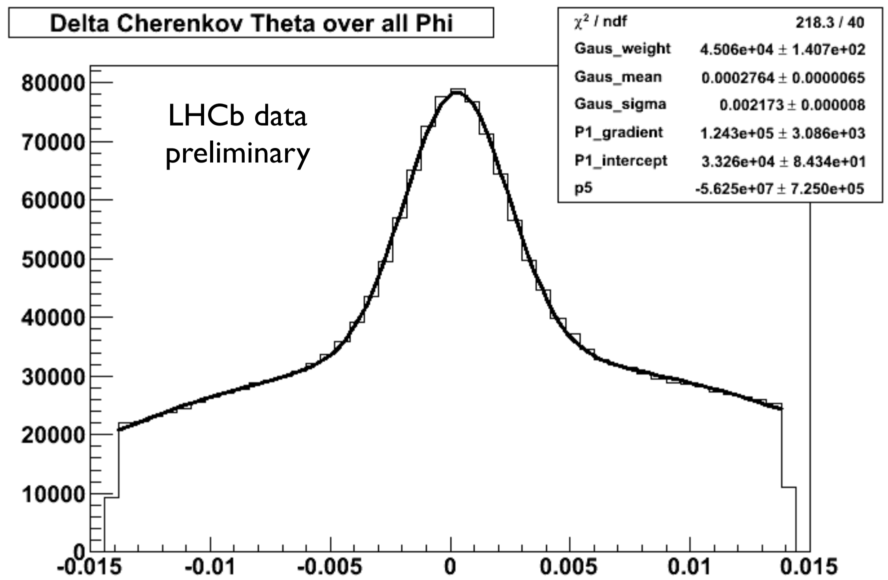
- The delta Cherenkov angle has an initial distribution with width 3.19 mrads



2009 450GeV Collisions Data After Alignment



- After alignment method is applied all parameters less than required 0.1mrads
- Alignment tilts applied are within the order of 1mrad



- Delta Cherenkov angle distribution of 2.17mrads achieved with limited statistics
- Difference from Monte Carlo possibly due to HPD misalignment, magnetic distortion effects not being fully understood or lack of statistics. Currently being studied

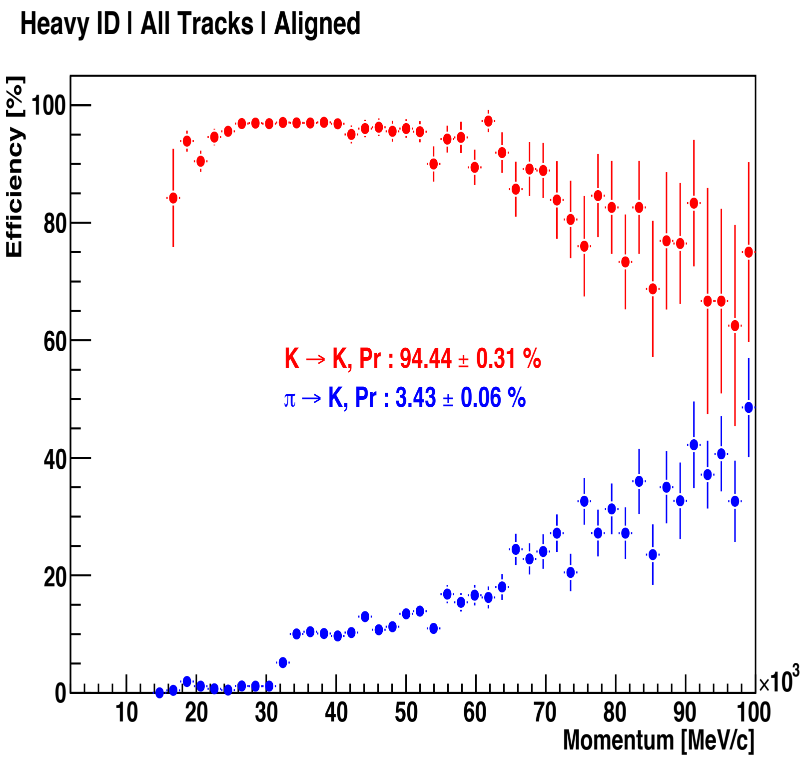
Summary

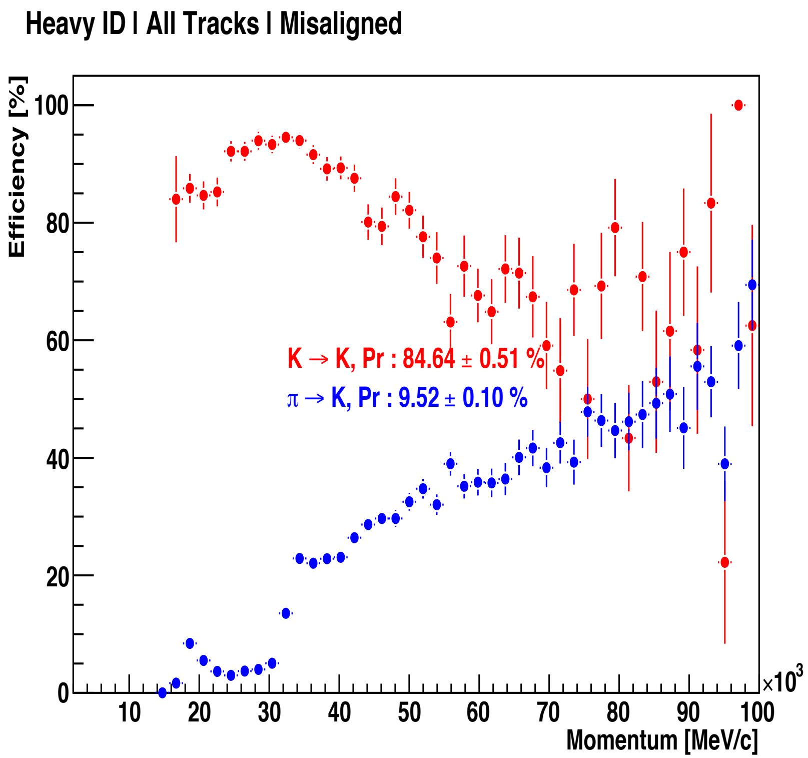
- Alignment method shown to be successful for Monte Carlo data.
- Aligned Monte Carlo state has a delta CK width 0.02mrads larger than a perfectly aligned system
- After the alignment all mirror combinations have misalignment parameters less than 0.1mrads as required
- Alignment process has been applied 2009 data and is ready for use on data to be taken this year
- Photon detector alignment is currently being studied
- Method automated and ready for use on collision data during 2010

Back-up slides

Matthew Coombes

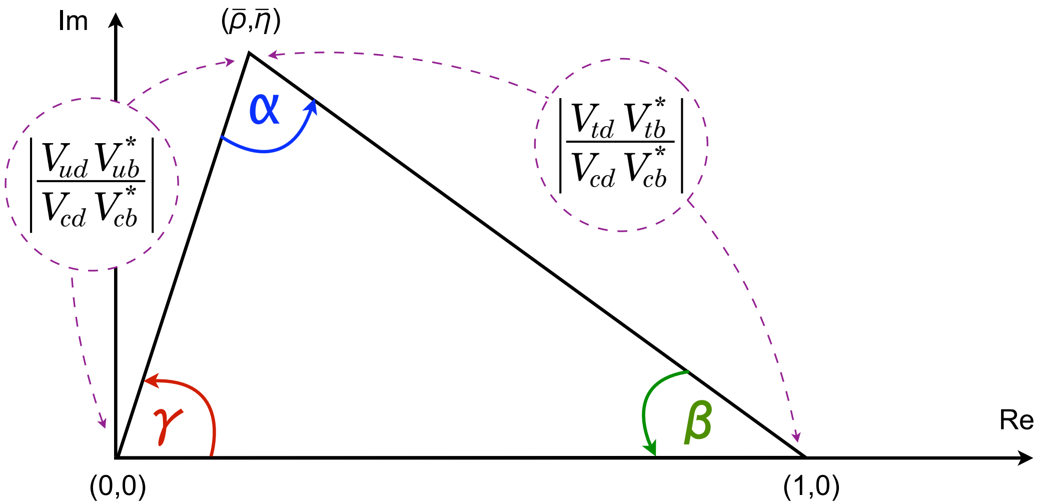
Misalignment effects in RICH detectors at the LHCb





Kaon identification decreases by 10% when
this misalignment is applied.

The physics at the LHCb

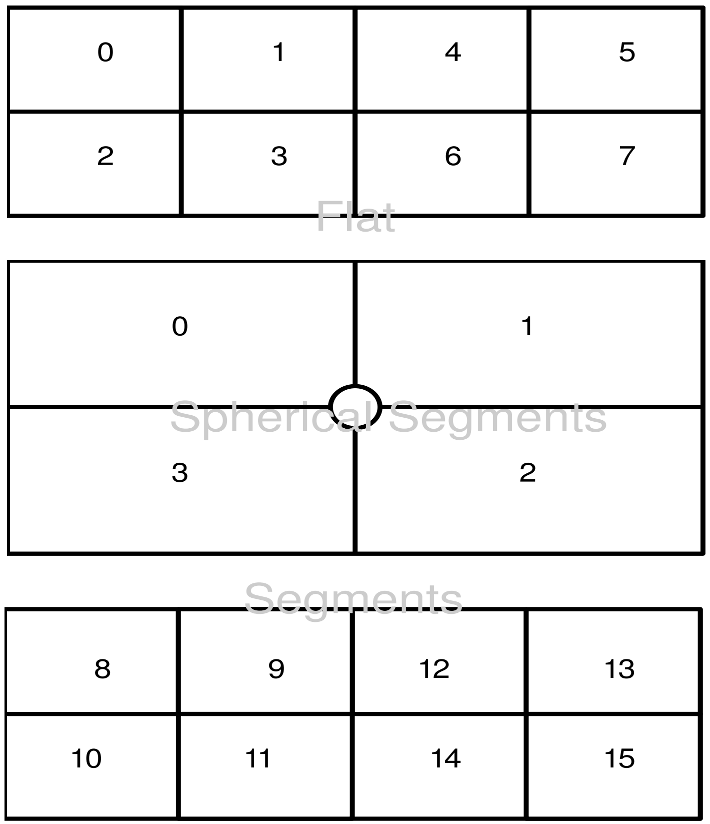


The LHCb is a dedicated B physics experiment at the LHC

Aims to perform precision measurements of CKM angles.

Search for physics beyond the standard model through rare B decays

Alignment Strategy



Various methods have been trailed:

- Align only the spherical mirrors
- Align only the flat mirrors
- A system to align the top and bottom half separately with respect to one mirror segment
- A system to disentangle a misalignments in spherical mirrors from flat mirrors

Alignment Strategy

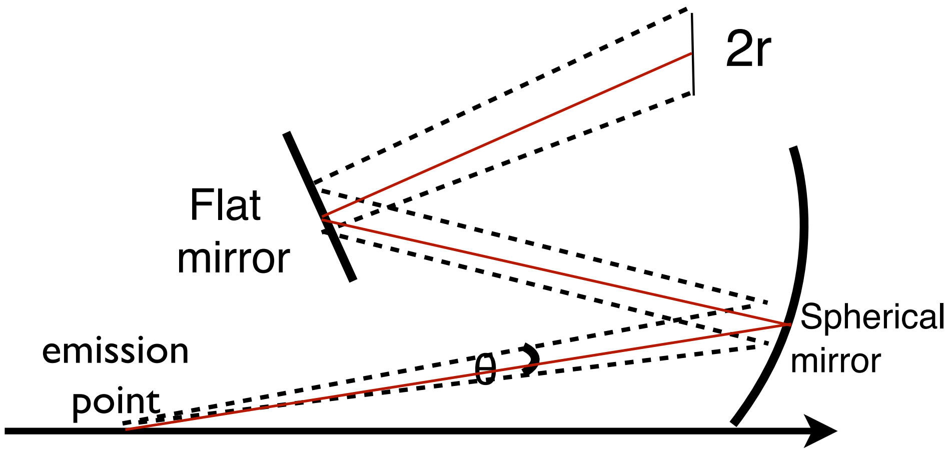
- From these projections the mirror tilts can be found

$$x_s = \mu^x_{ij}\theta_x$$

*s index for spherical mirror

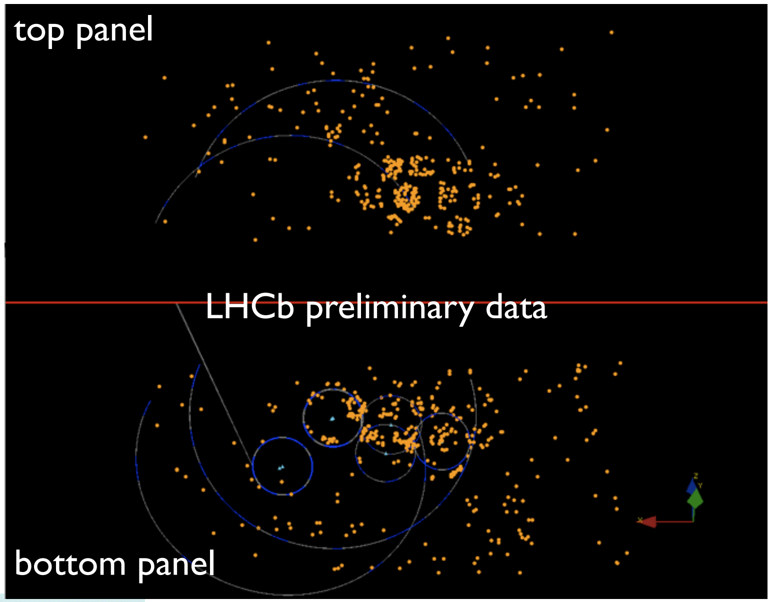
- Find the magnification factor (μ_{xij}) by tilting the mirrors by a known angle (1mrad) using Monte Carlo data and extracting θ projected misalignment from the alignment plots
- μ_{xij} must be found for each mirror pair, i,j.
- The alignment parameters are then found for real data.
- Applying the magnification factors from Monte Carlo data the mirror tilts are found
- The mirrors are aligned by tilting them by the negative of the misaligned tilt found
- Process is repeated until all alignment parameters less than 0.1mrads

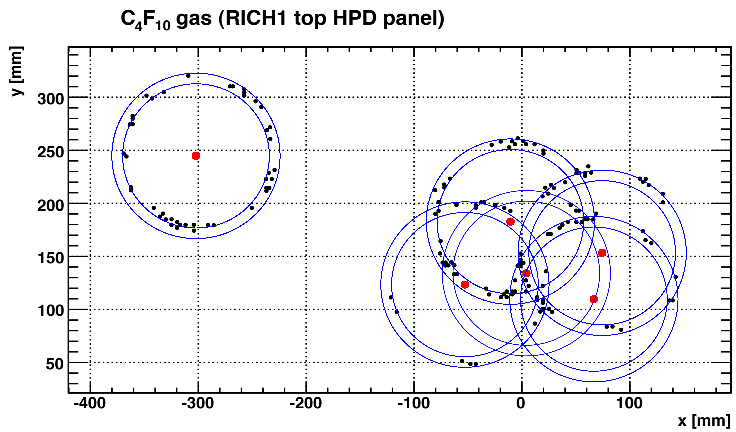
Alignment Strategy



- Tracks are reconstructed
- Cherenkov rings are found on the HPD plane
- Tracks are then selected to use for alignment

RICH1 HPD panels with CK rings





Track projection point

Ring found Cherenkov ring

Photon hits