Rich Mirror Alignment

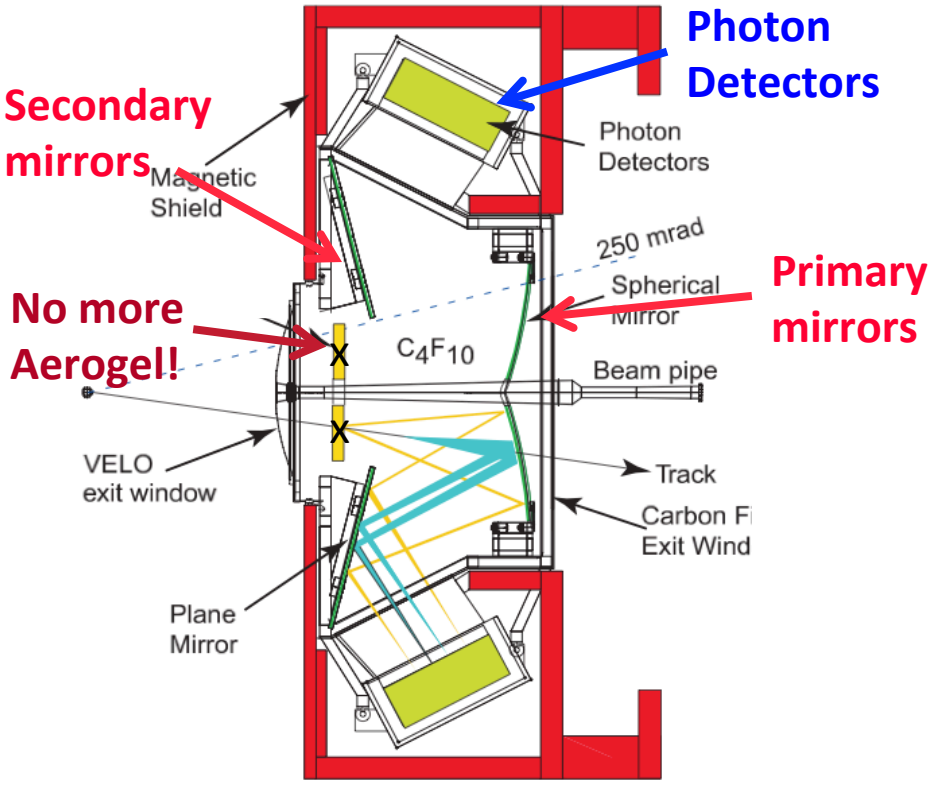
23/05/2016 Claire Prouve

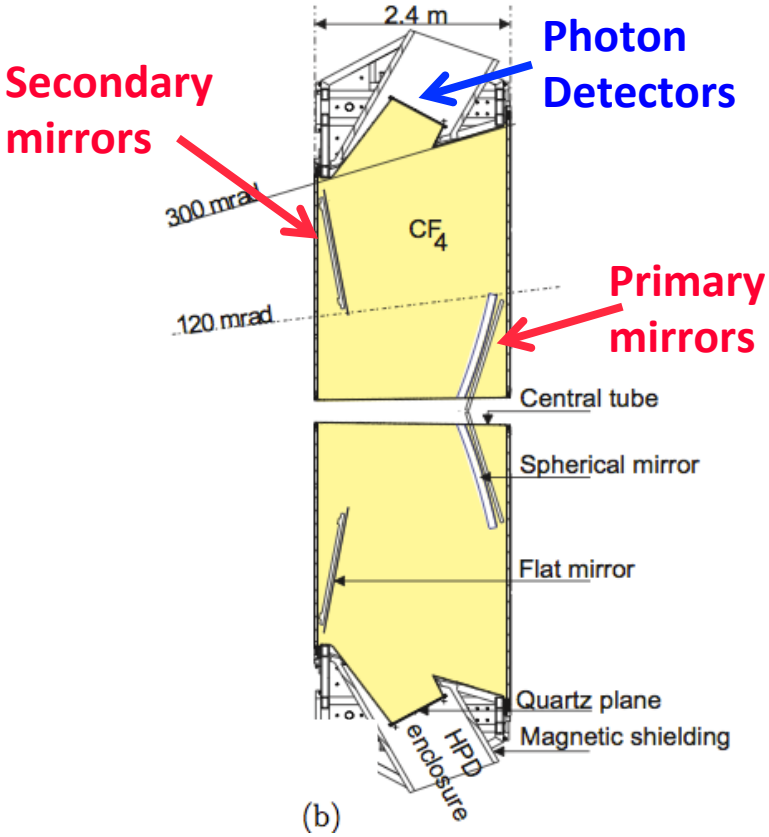
- How does it work?
- What's new in 2016?
- Current status

RICH Mirror Alignment

RICH 1: 4 primary mirrors
16 secondary mirrors

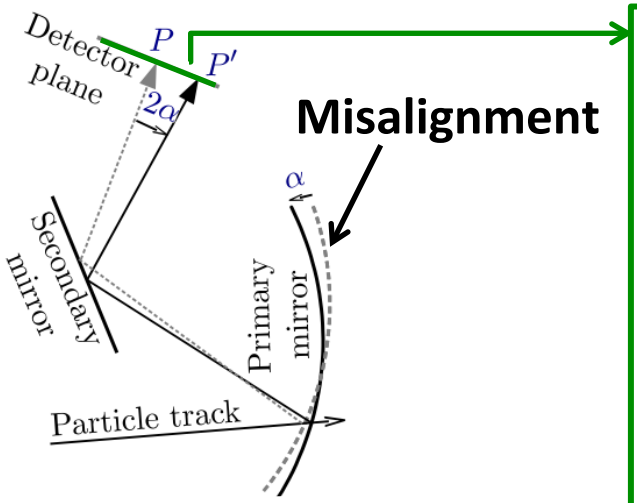
RICH 2: 54 primary mirrors
40 secondary mirrors

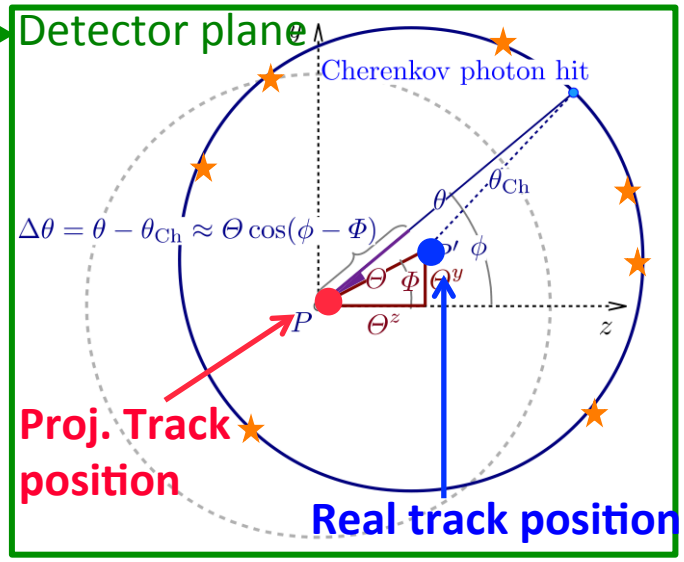




Misaligned mirrors will affect the PID due to incorrectly predicted Cherenkov angle!

Misalignment





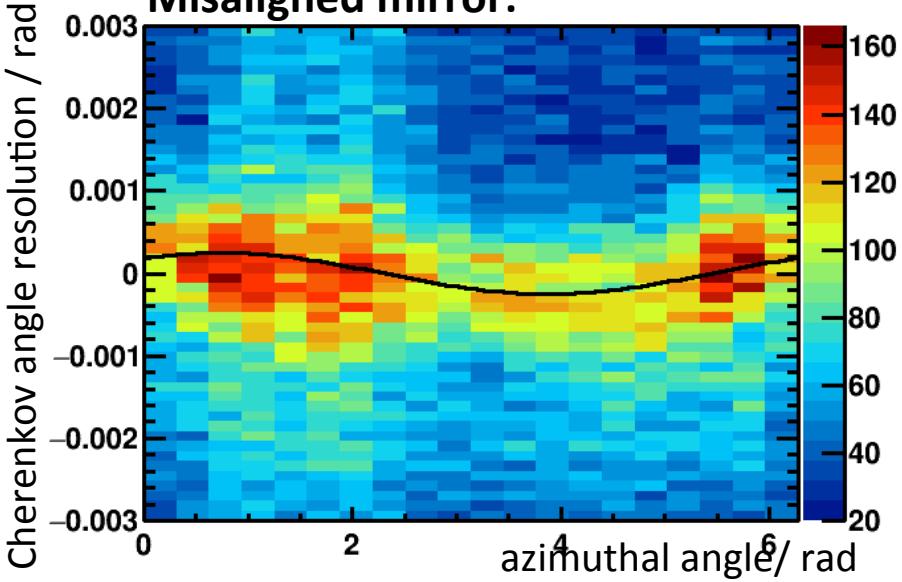
Identify misalignment:

$\Delta\theta_C(\Phi) = \theta_{meas.} - \theta_{exp.}$

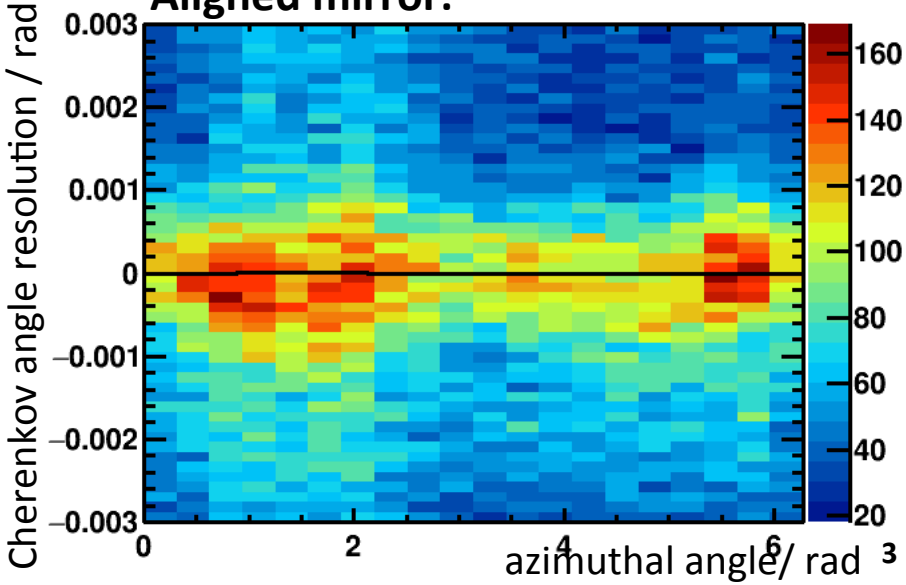
$\Delta\theta_C(\Phi) = \rho_y \cos(\Phi) + \rho_z \sin(\Phi)$

Misalignments on detector plane

Misaligned mirror:



Aligned mirror:



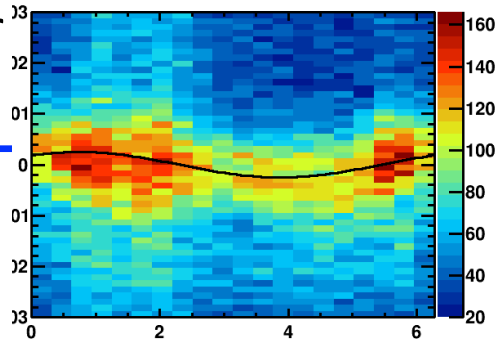
Overview procedure

Events from HLT1 line

database

Select high energy tracks and reconstruct them under the pion hypothesis.

Fill histograms with Δθ vs. Φ distribution of unambiguous photons for each mirror combination.



Fit misalignments on detector plane for each mirror combination and determine individual mirror misalignments.

Produce new database and verify if the convergence criteria was met.

NO

YES

Alignment converged!

Replace database and perform another iteration.

What’s new in 2016?

Disentangling mirror-pairs

Each pair of **primary mirror *p*** and **secondary mirror *s*** has 2 equations:

$$A^y_{p,s}\alpha^y_p + B^y_{p,s}\beta^y_s + a^y_{p,s}\alpha^z_p + b^y_{p,s}\beta^z_s = \Theta^y_{p,s}$$
$$A^z_{p,s}\alpha^z_p + B^z_{p,s}\beta^z_s + a^z_{p,s}\alpha^y_p + b^z_{p,s}\beta^y_s = \Theta^z_{p,s}$$

Magnification factors

individual mirror tilts

Results of fit to histogram

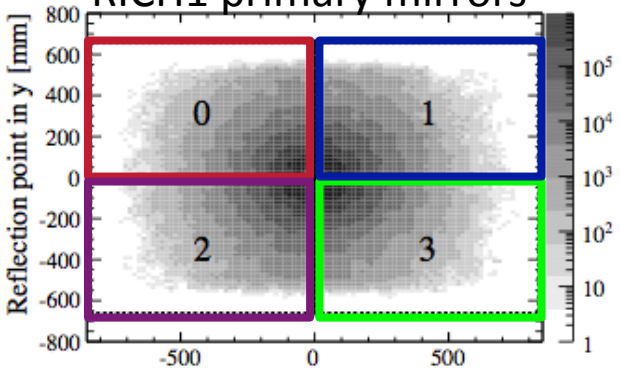
Problem: not enough information to fully constrain the solution

RICH1: 8 equations for 10 unknowns

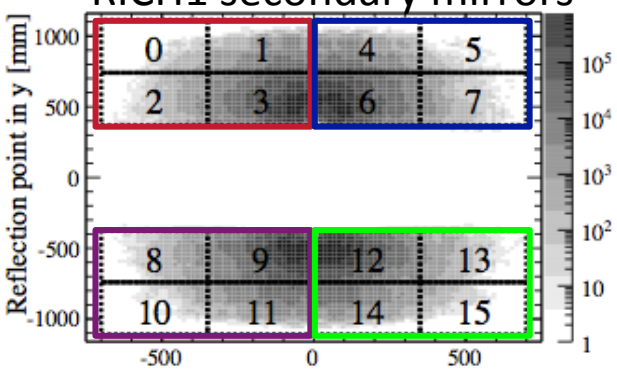
Rotation of primary mirrors followed by according rotation of secondary mirrors yields same results

➔ **Need additional constraint**

RICH1 primary mirrors



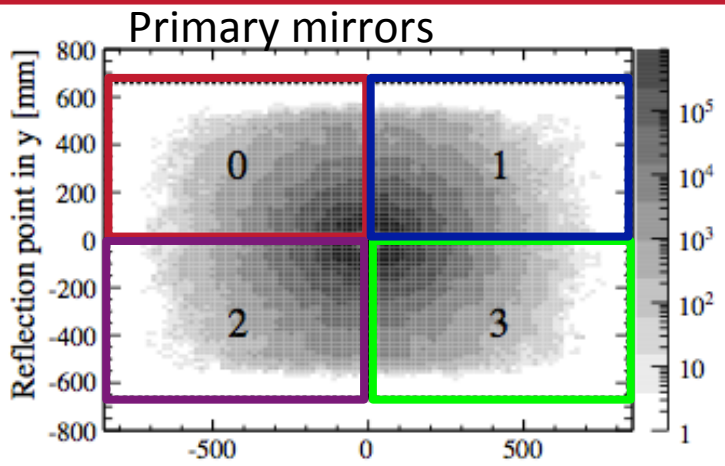
RICH1 secondary mirrors

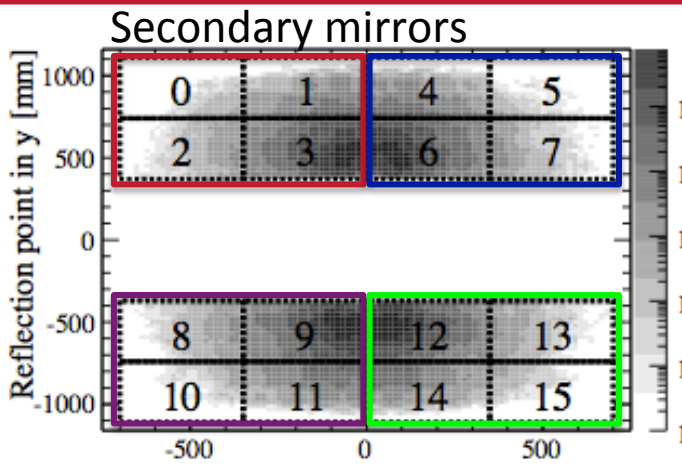


Disentangling – until 2016

RICH1:

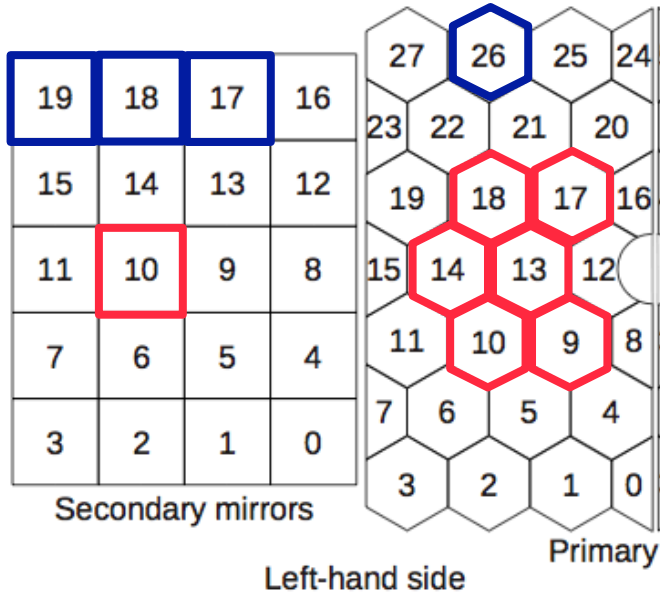
- fix primary mirrors, align secondary mirrors

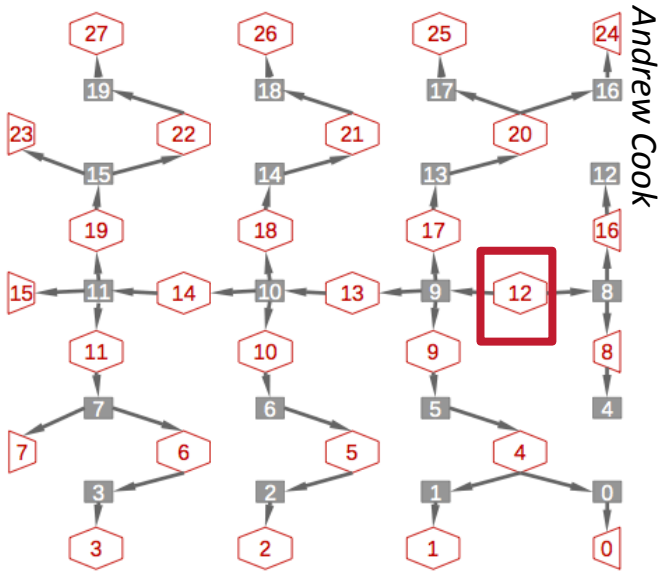




RICH2:

- Left half: system of equations linking all mirrors starting from primary mirror 12.
- Equivalent for right half





27 primary mirrors, 18 secondary mirrors

Disentangling – from 2016

L2 regularization (ridge regression):

- rewrite problem as $A\mathbf{x} = \mathbf{b}$

  Vector of results of fit to histograms

  Matrix of magnification factors

  Vector of individual mirror tilts

- Minimize $\underbrace{\|A\mathbf{x} - \mathbf{b}\|^2}_{\text{least square method}} + \underbrace{\|\Gamma\mathbf{x}\|^2}_{\text{L2 regularization term}}$

Advantages:

- does not tend to set many x's to zero (unlike L1 regularization)
- stable (unlike L1 regularization)
- more stable than the previous method

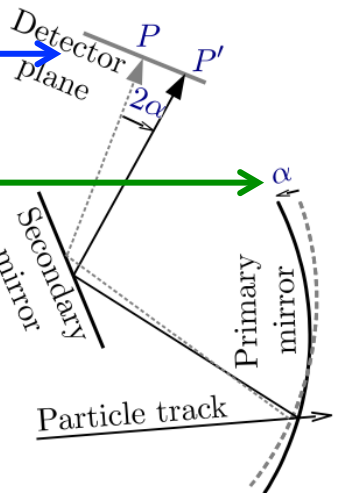
➔ **Fewer iterations needed to converge**

Further improvements

Magnification coefficients:

- translate the misalignment-on-the-detector-plane into actual mirror tilts
- Previously calculated for every alignment for each iteration on data
- Tested using the same set for all alignments and all iterations

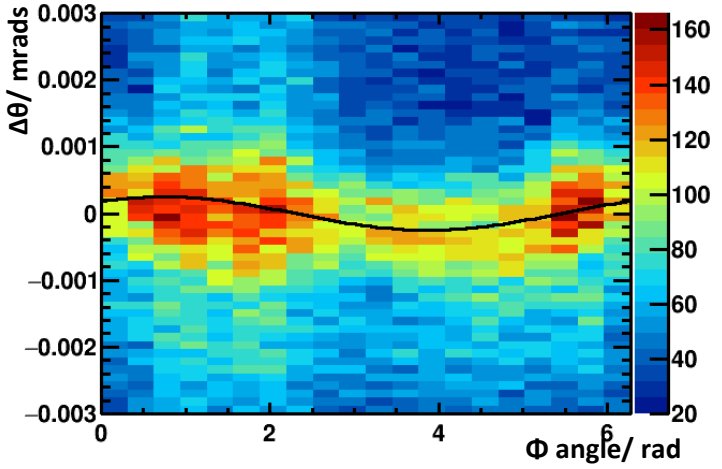
➔ No significant difference in resulting mirror tilts and **procedure 9 times faster!!!**



Improved method for fitting histograms:

- use same Gaussian width for each slice in phi

➔ Same resulting mirror-tilts and **3 times faster**

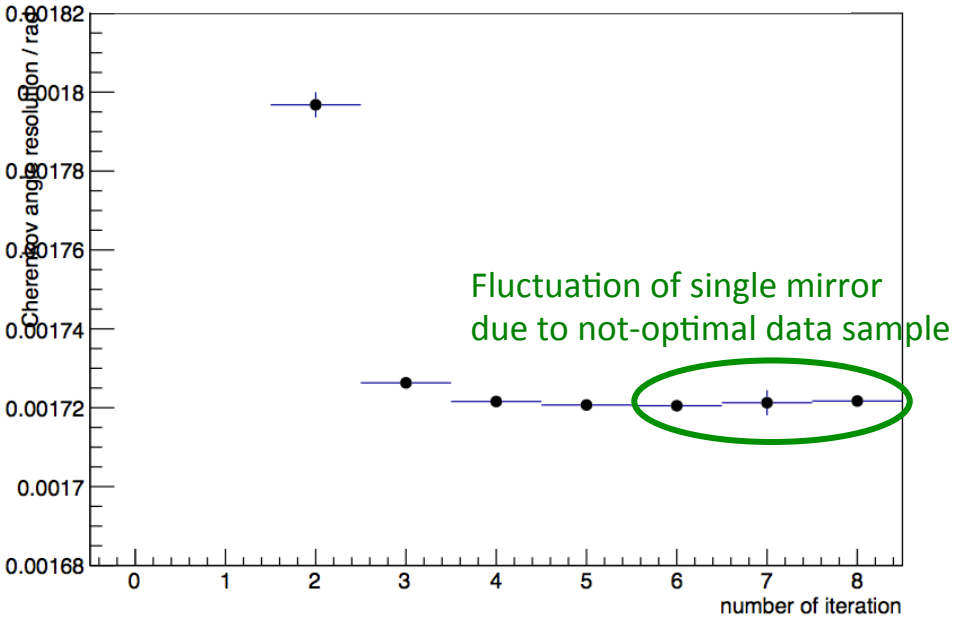


Current status

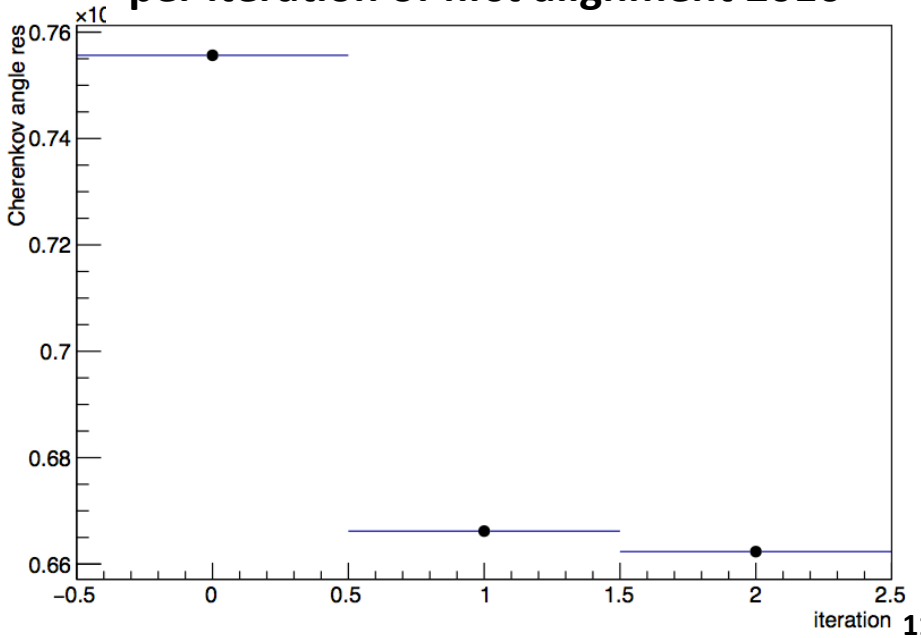
First alignment 2016

- Started from completely unaligned mirrors
- Calculated the magnification factors
- In the global tag cond-20160517
- Improvement in resolution w.r.t. last alignment: RICH1 0.1 mrad, RICH2 unchanged

RICH1 Cherenkov angle resolution per iteration of first alignment 2016



RICH2 Cherenkov angle resolution per iteration of first alignment 2016



More news & future plans

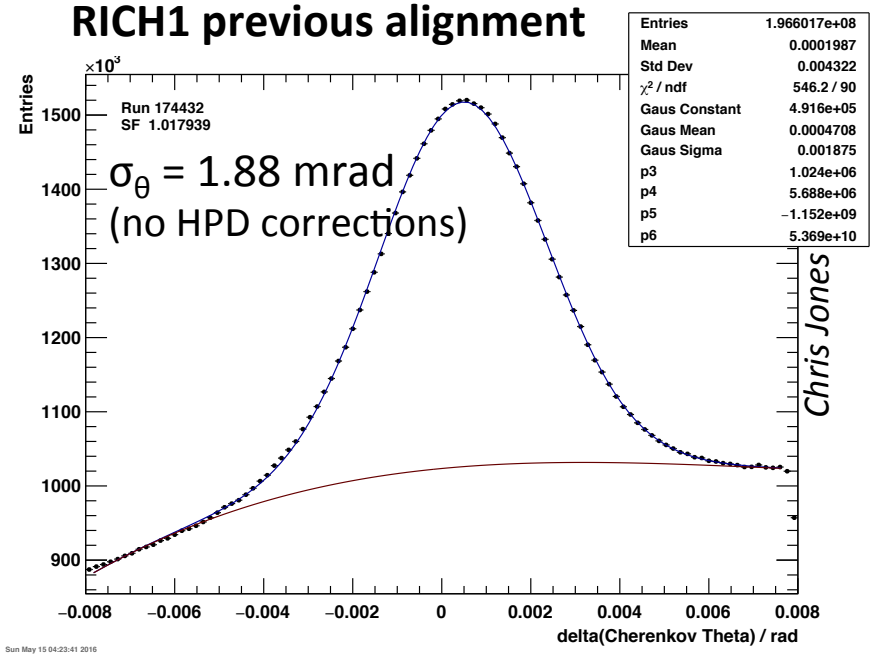
All following alignments:

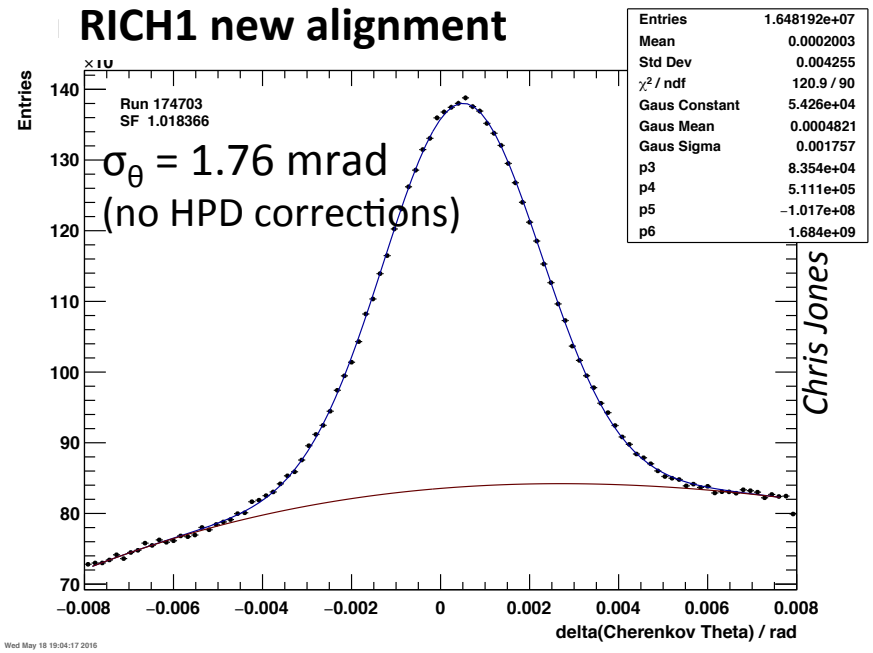
- Performed with all new improvements, starting from new database
- Converged after first iteration
- ~ 6 minutes per alignment

- Alignment will be run for each fill to monitor behavior over time

- Tune scale factors for RICH1 HLT1 line
- Update to AlignmentOnline v11 (use newest Brunel version)
- Monitoring (most parts done, need to be put together when Roel is ready)
- Parallelize the fits
- Tune the factor in front of the regularization term

Some plots


RICH1 previous alignment
Entries 1.966017e+08
Mean 0.0001987
Std Dev 0.004322
χ² / ndf 546.2 / 90
Gaus Constant 4.916e+05
Gaus Mean 0.0004708
Gaus Sigma 0.001875
p3 1.024e+06
p4 5.688e+06
p5 −1.152e+09
p6 5.369e+10
Run 174432
SF 1.017939
σθ = 1.88 mrad
(no HPD corrections)
Entries
delta(Cherenkov Theta) / rad
Chris Jones


RICH1 new alignment
Entries 1.648192e+07
Mean 0.0002003
Std Dev 0.004255
χ² / ndf 120.9 / 90
Gaus Constant 5.426e+04
Gaus Mean 0.0004821
Gaus Sigma 0.001757
p3 8.354e+04
p4 5.111e+05
p5 −1.017e+08
p6 1.684e+09
Run 174703
SF 1.018366
σθ = 1.76 mrad
(no HPD corrections)
Entries
delta(Cherenkov Theta) / rad
Chris Jones

Backup

Cherenkov angle resolution

Limiting factors to Cherenkov angle resolution:

	σ [mrad]		
	RICH1		RICH2
	Aerogel	C_4F_{10}	CF_4
Emission point	0.4	0.8	0.2
Chromatic dispersion	2.1	0.9	0.5
Pixel size	0.5	0.6	0.2
Tracking	0.4	0.4	0.4
Total	2.6	1.5	0.7

New HLT Lines

- Trigger on tracks that will populate the hardest-to-populate mirror-pairs

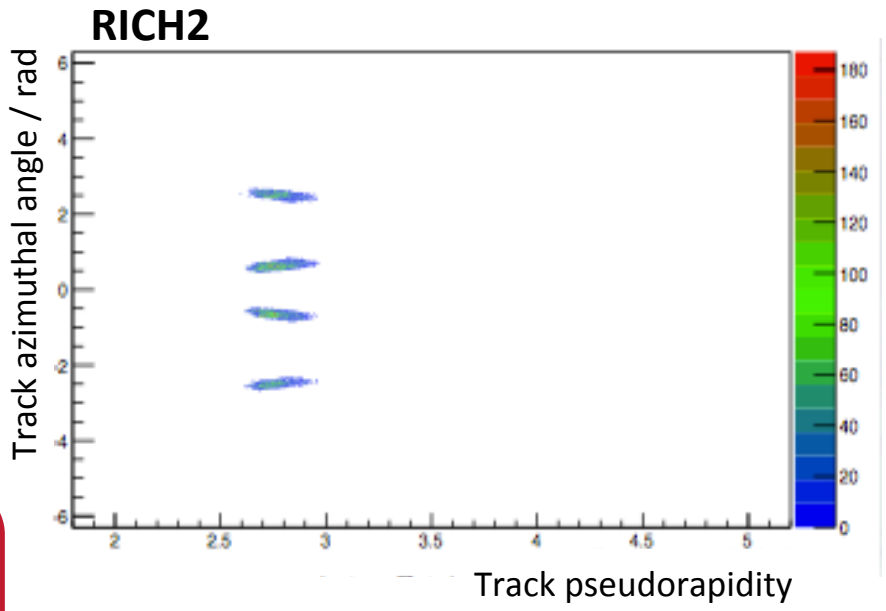
➔ usually the very outer mirrors

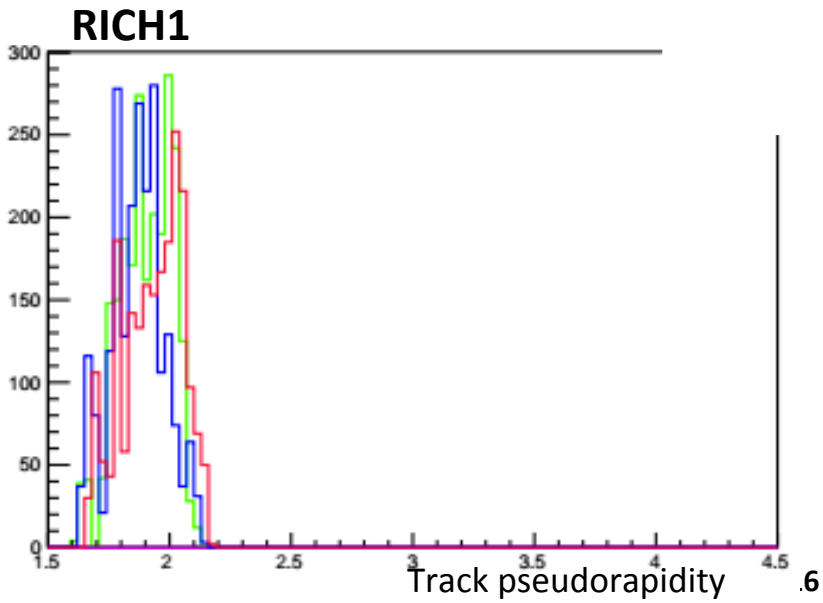
- Other tracks in the events will populate the rest

RICH2 line:
p > 40 GeV **&&** $\chi^2 < 2$ **&&** $2.65 < \eta < 2.80$
$(-2.59 < \Phi < -2.49)$ **||** $(-0.65 < \Phi < -0.55)$ **||**
$(0.45 < \Phi < 0.65)$ **||** $(2.49 < \Phi < 2.59)$

RICH1 line:
p > 10 GeV **&&** $\chi^2 < 2$ **&&** $1.6 < \eta < 2.04$
$(-2.65 < \Phi < -2.3)$ **||** $(-0.8 < \Phi < -0.5)$ **||**
$(0.5 < \Phi < 0.8)$ **||** $(2.3 < \Phi < 2.65)$

Need to reconstruct ~10 times less events!





Magnification coefficients

Magnification coefficients: Translate the tilt on the detector plane into actual mirror tilts

$$\Delta\theta_C = \theta_x \cos(\phi) + \theta_y \sin(\phi)$$

Misalignments on detector plane

$$\Theta^y \approx \frac{2\, l_{\text{pri}}}{l}\alpha^y - \frac{2\, l_{\text{sec}}}{l}\beta^y$$

Mirror tilts

Magnification coefficients are calculated new for each iteration:

- Introduce 8 rotations: primary and secondary mirrors rotated around ±y and ±z axis respectively
- Rotate about 0.3 mrad (half the resolution of RICH2)
- Reconstruct events for each rotation and evaluate the tilts on the detector plane

Need to reconstruct all events 9 times!

$$\Theta^y \approx 2.0\,\alpha^y - 0.9\,\beta^y \quad \text{and} \quad \Theta^z \approx 1.8\,\alpha^z + 0.6\,\beta^z.$$