RICH Mirror Alignment

20/06/2016

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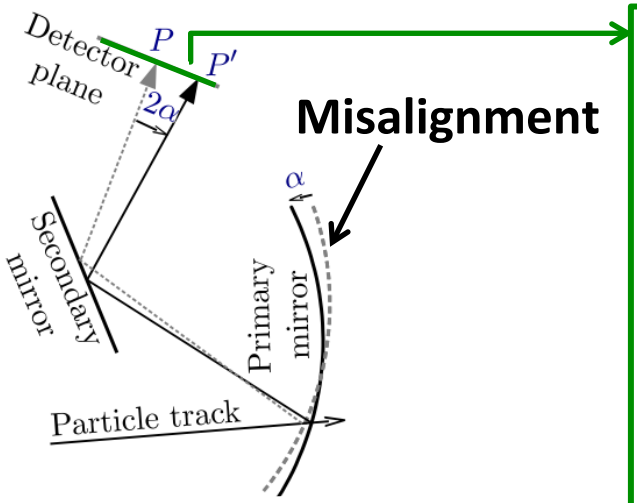
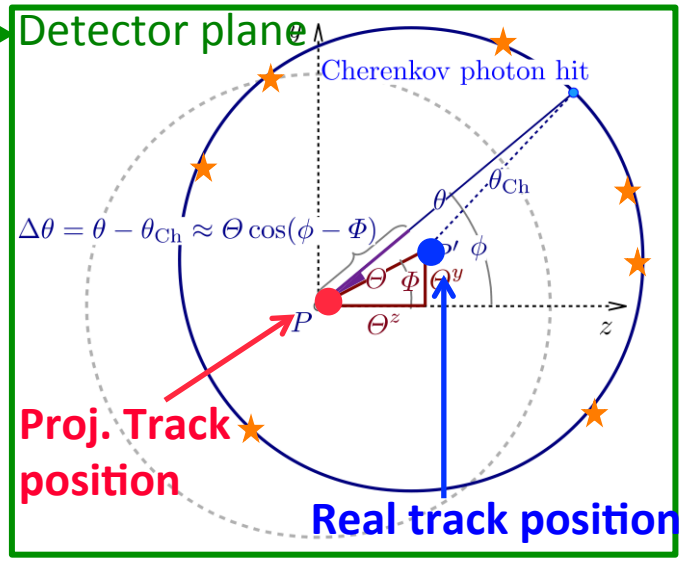
Misalignment





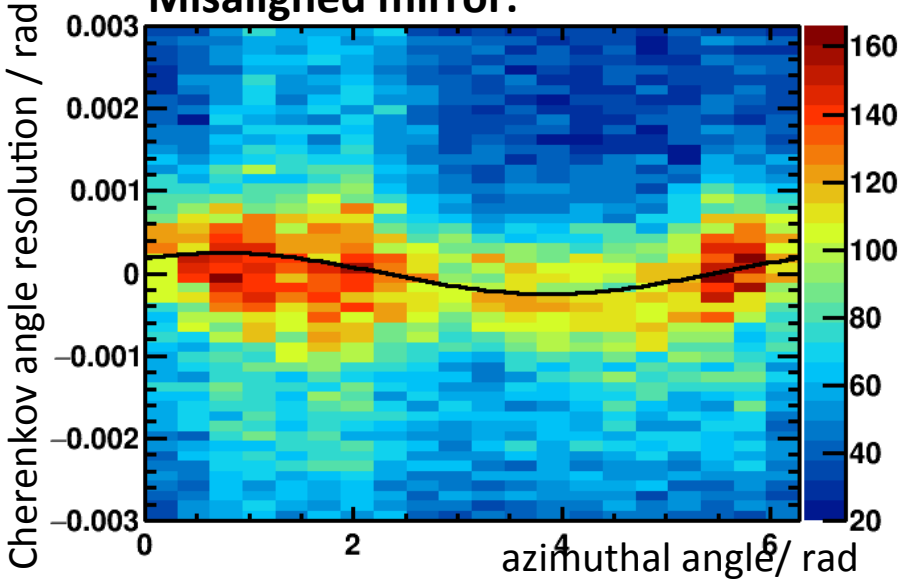
Identify misalignment:

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

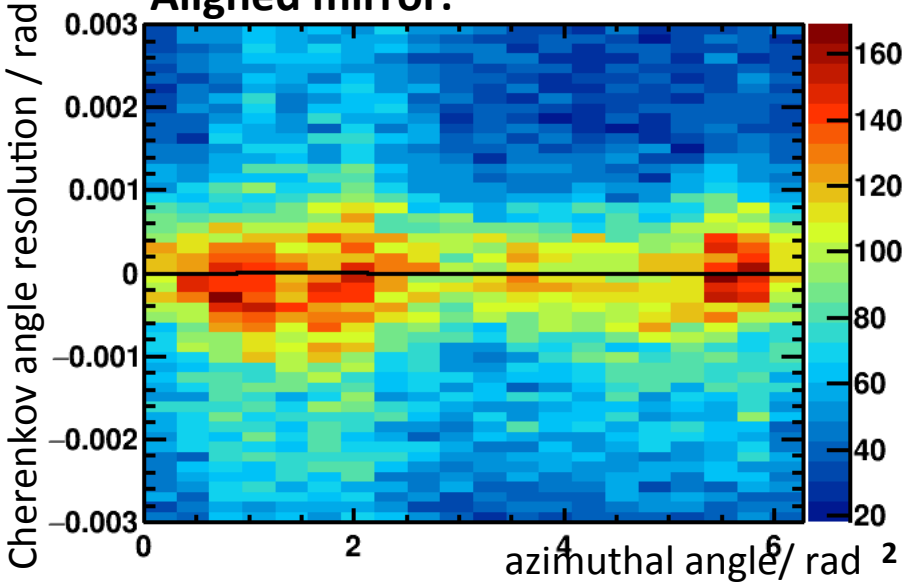
$$\Delta\theta_C(\Phi) = \Theta^y_{p,s}\cos(\Phi) + \Theta^z_{p,s}\sin(\Phi)$$

Misalignments on detector plane

Misaligned mirror:



Aligned mirror:



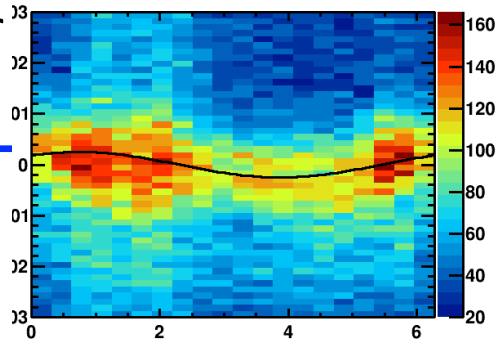
Overview of the procedure

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.

Run I vs. Run II

Run I:

- Offline, after data taking
- with Ganga for the Brunel reconstruction
- Alignment applied at the end-of-year reprocessing

Run II:

- **Online:** after HLT1 and before HLT2
- **HLT farm** (~1700 nodes)
- Alignment runs automatically **for each Fill** in monitoring mode since end of May
- **HLT1 lines** for each RICH detector

  ➔ triggers on tracks that populate the outer mirrors

What’s new in 2016?

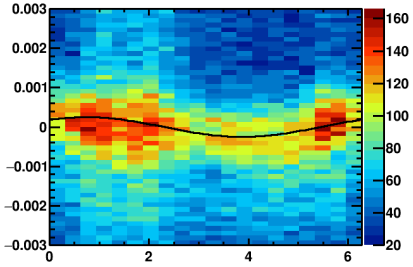
Disentangling mirror-pairs

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

$\Delta\theta_C(\Phi) = \Theta^y_{p,s}\cos(\Phi) + \Theta^z_{p,s}\sin(\Phi)$

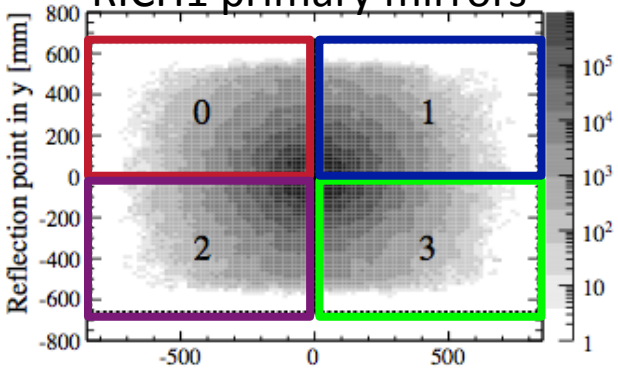


Challenge: not enough information to fully constrain the solution

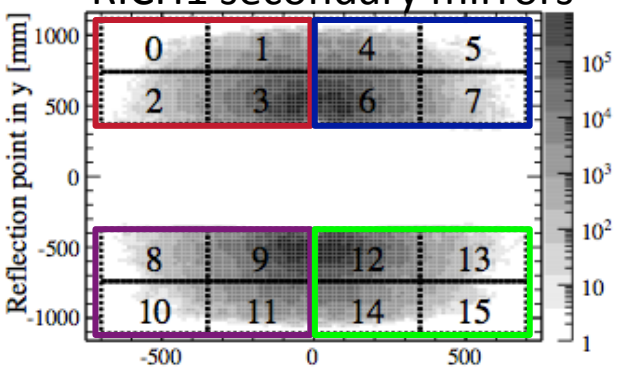
RICH1: 8 equations for 10 unknowns

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

RICH1 primary mirrors



RICH1 secondary mirrors

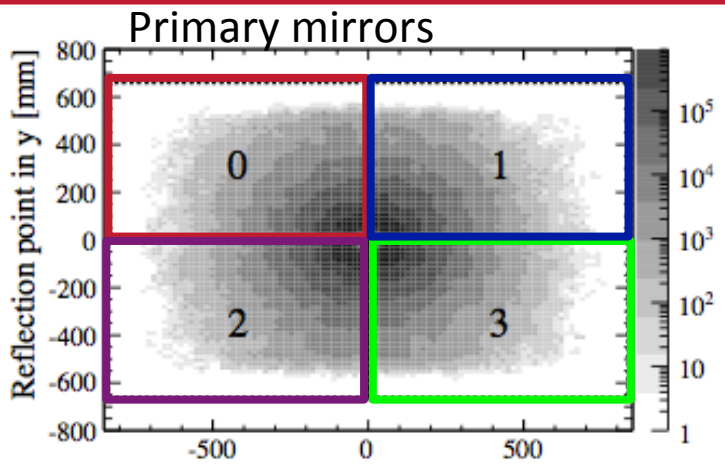


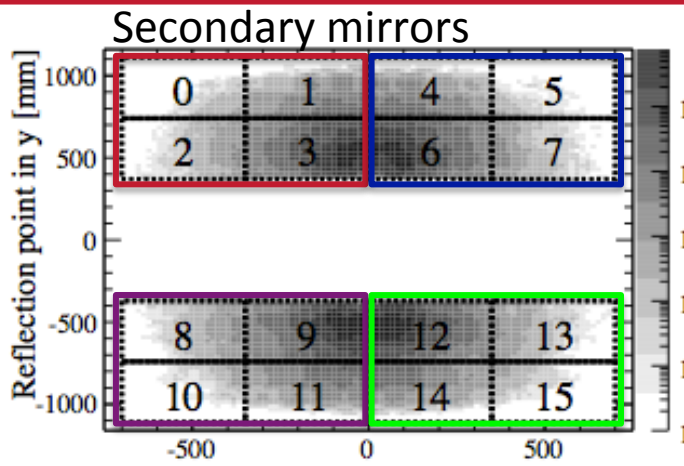
➔ **Need additional constraint**

Disentangling – until 2016

RICH1:

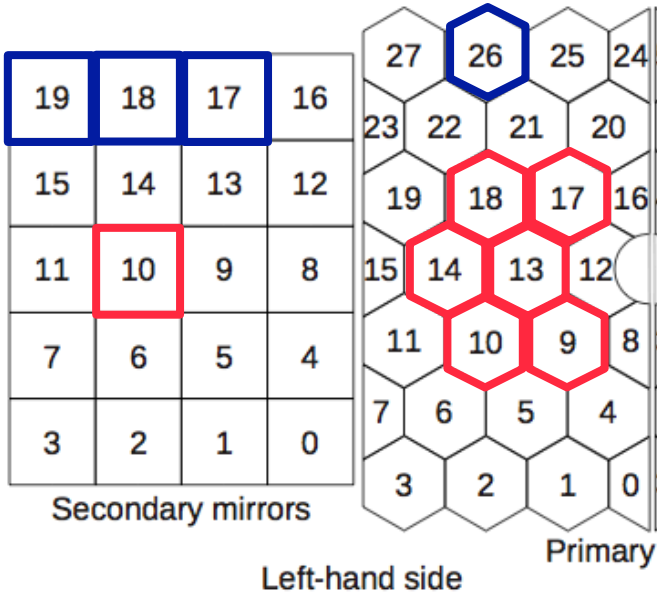
- fix primary mirrors, align secondary mirrors

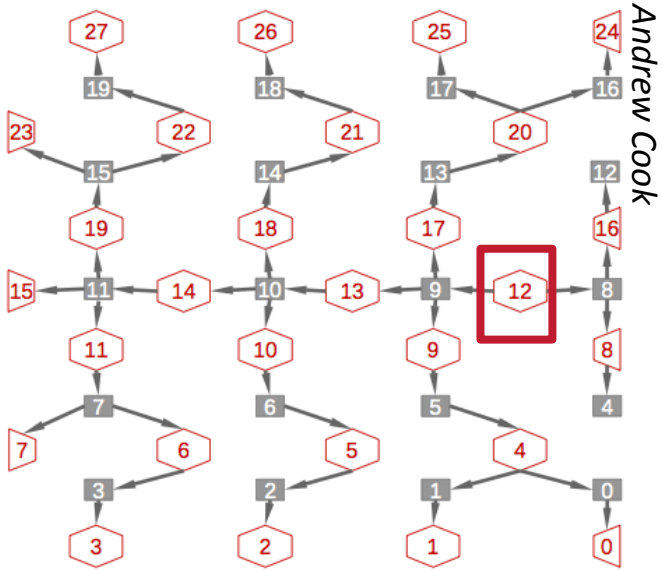




RICH2:

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





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: $\|A\mathbf{x} - \mathbf{b}\|^2 + \|\Gamma\mathbf{x}\|^2$

  least square method

  L2 regularization term

Advantages:

- more stable than the previous method
- Stable w.r.t. small statistical fluctuations (unlike L1 regularization)

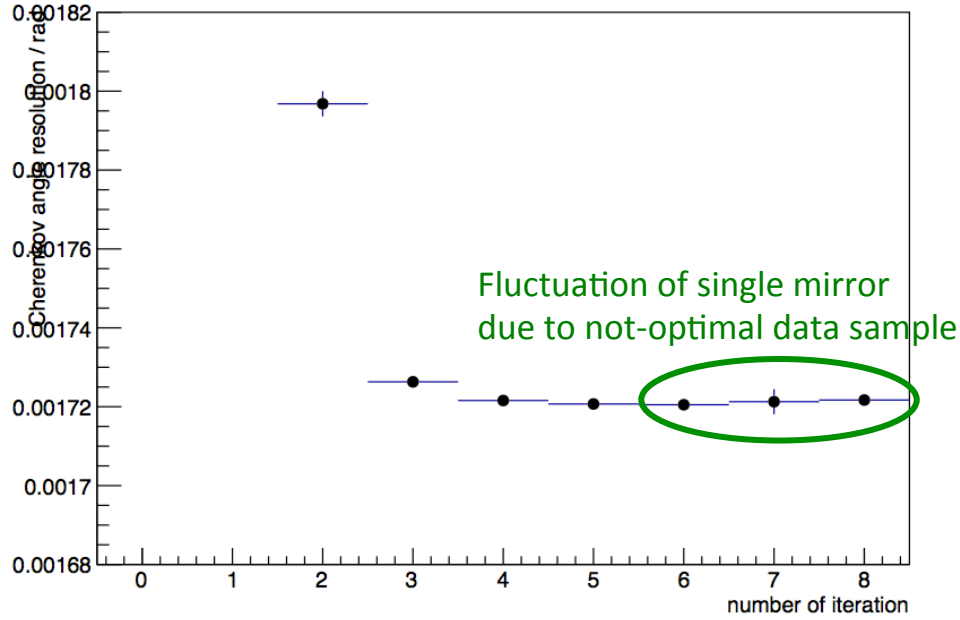
➔ **Fewer iterations needed to converge**

Recent results

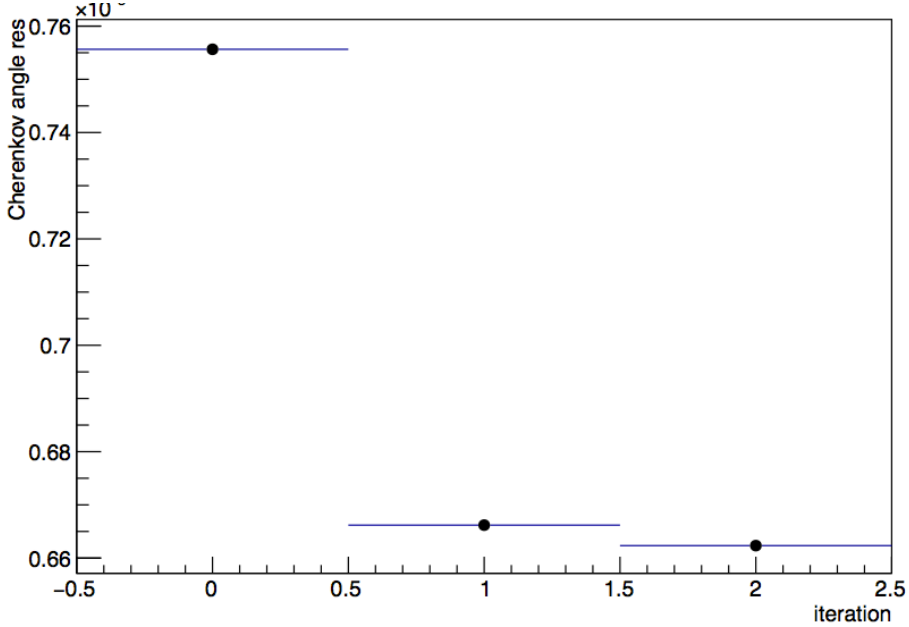
First alignment 2016

- In the global tag cond-20160517
- Started from completely unaligned mirrors

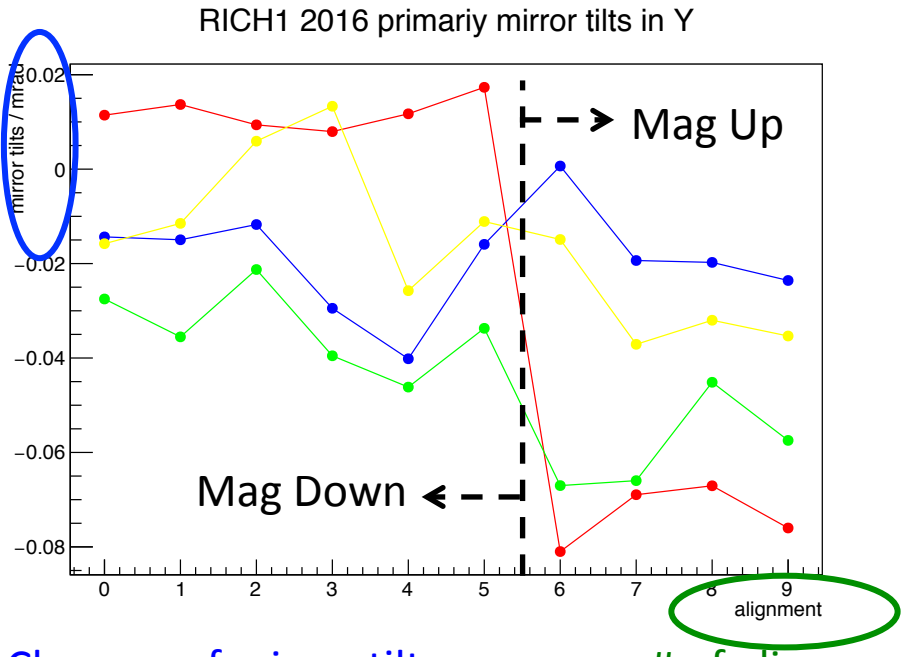
RICH1 Cherenkov angle resolution per iteration of first alignment 2016



RICH2 Cherenkov angle resolution per iteration of first alignment 2016



Stability of tilts – RICH1

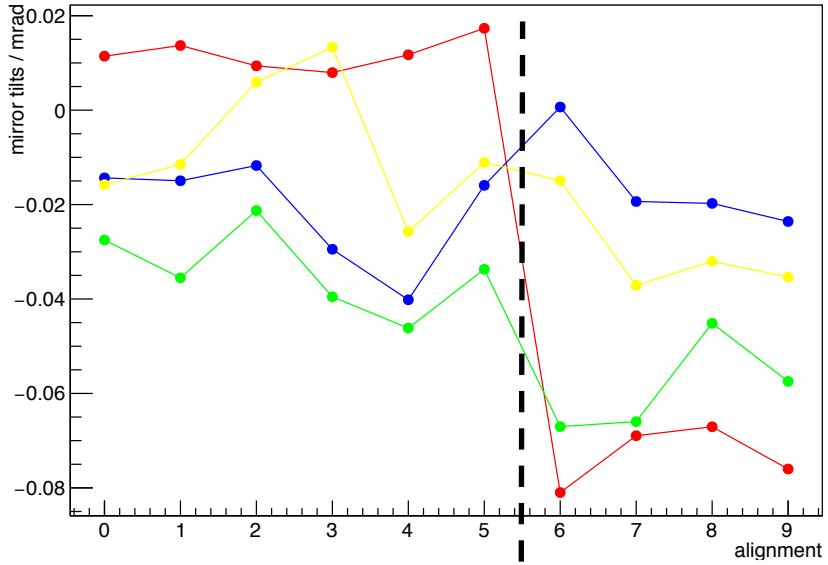


Changes of mirror tilts wrt current DB

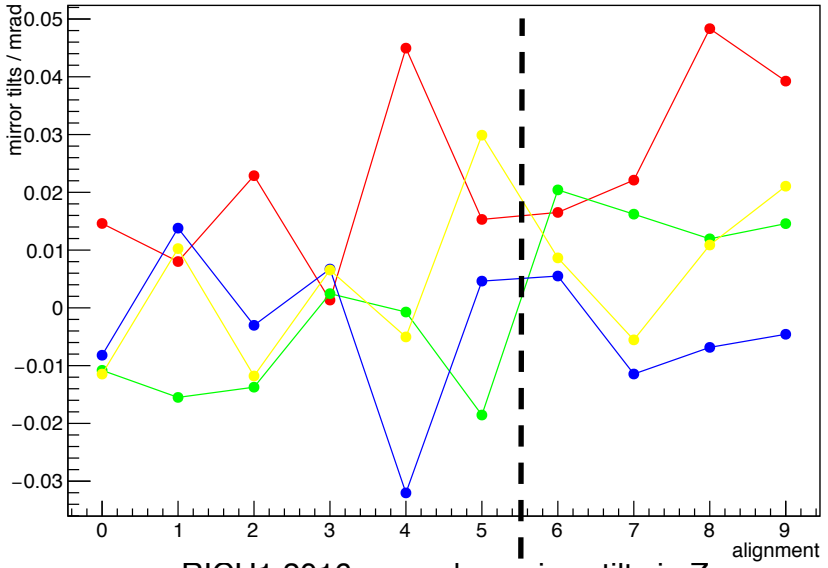
# of alignment run between 24/05 - 19/06

Stability of tilts – RICH1

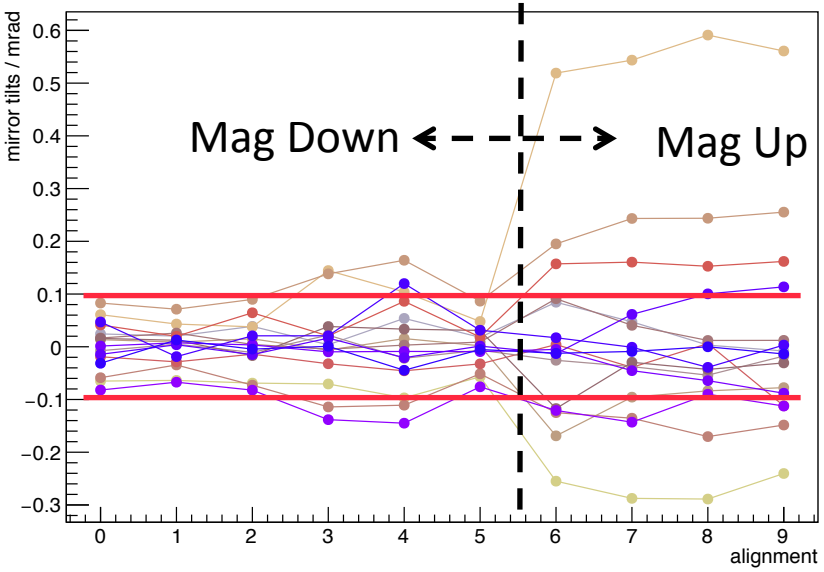
RICH1 2016 primariy mirror tilts in Y



RICH1 2016 primariy mirror tilts in Z

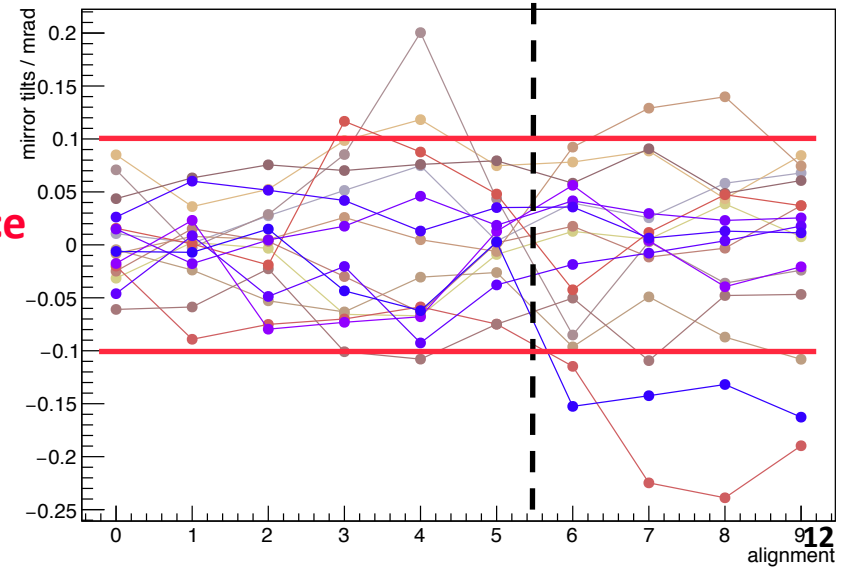


RICH1 2016 secondary mirror tilts in Y



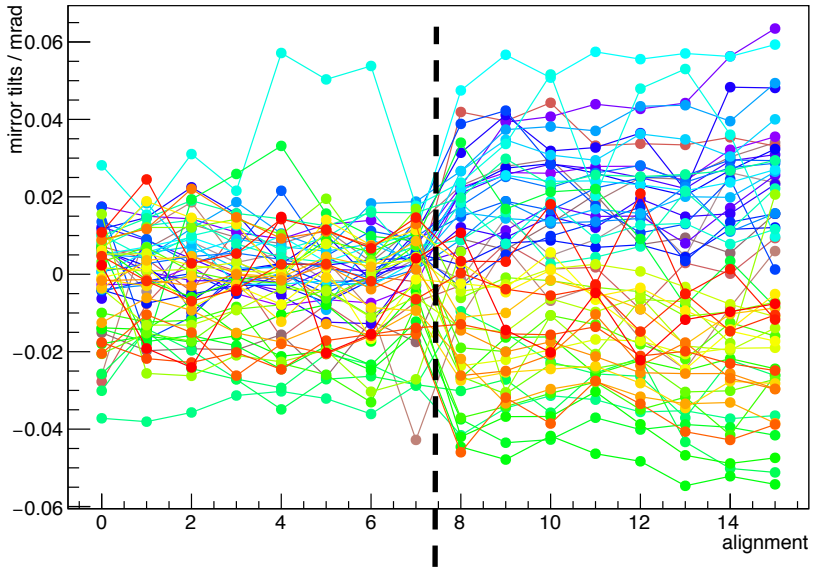
Convergence criteria 0.1 mrad

RICH1 2016 secondary mirror tilts in Z

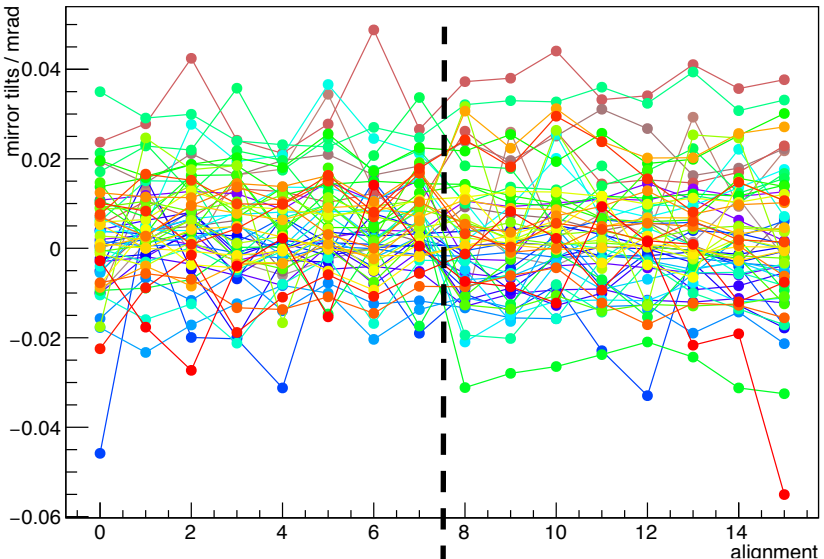


Stability of tilts – RICH2

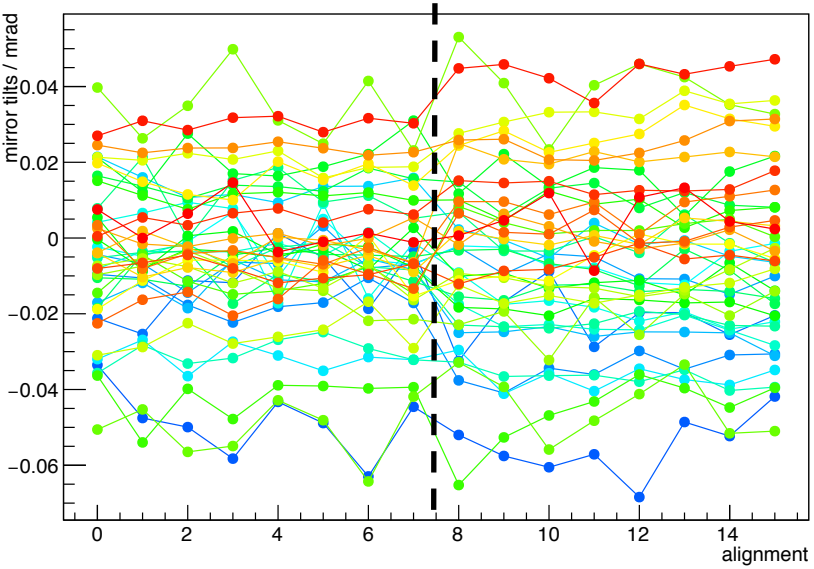
RICH2 2016 primariy mirror tilts in Y



RICH2 2016 primariy mirror tilts in Z

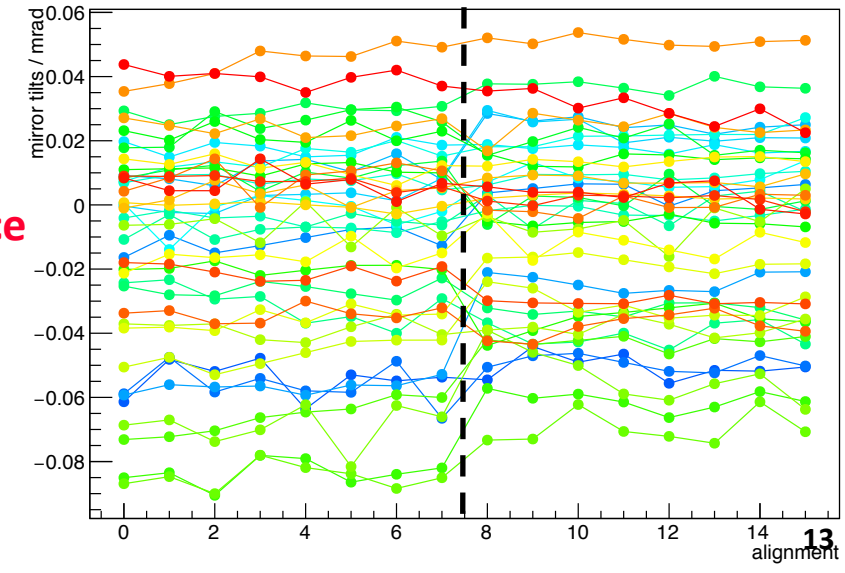


RICH2 2016 secondary mirror tilts in Y



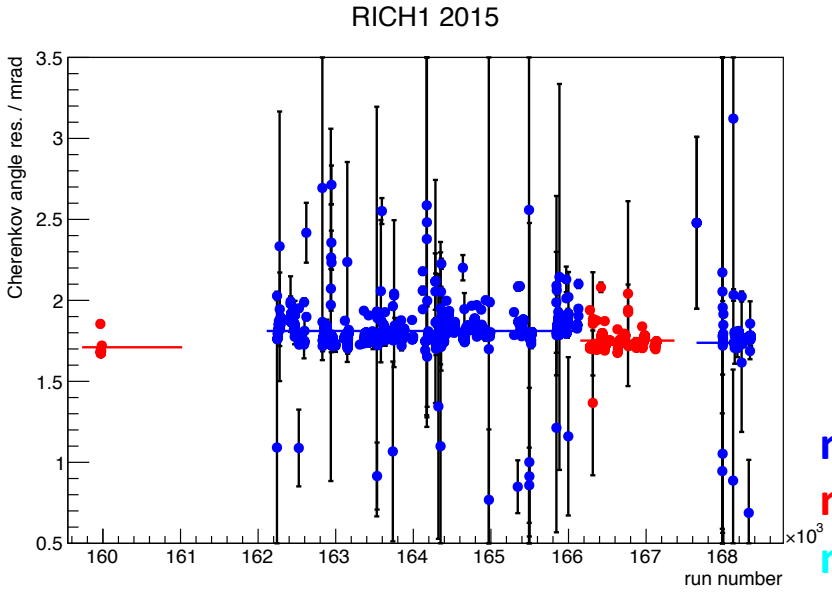
Convergence criteria 0.1 mrad

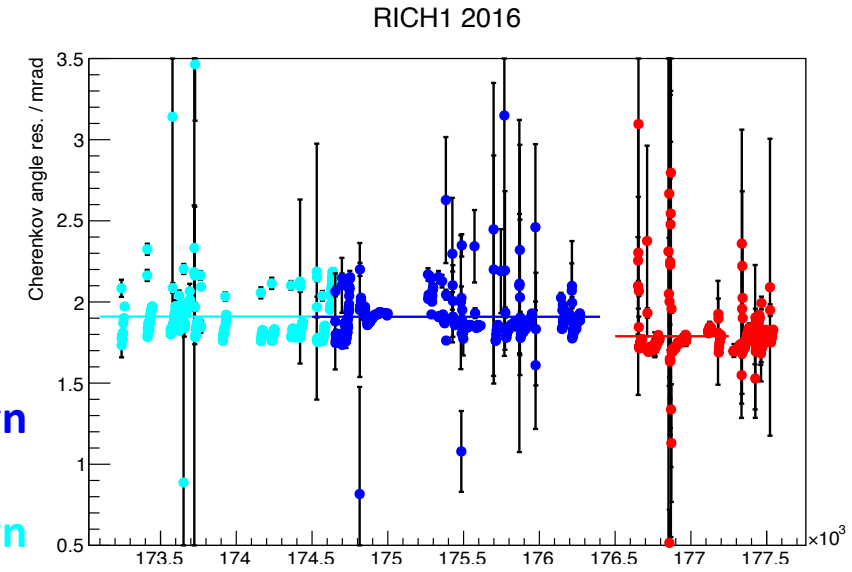
RICH2 2016 secondary mirror tilts in Z



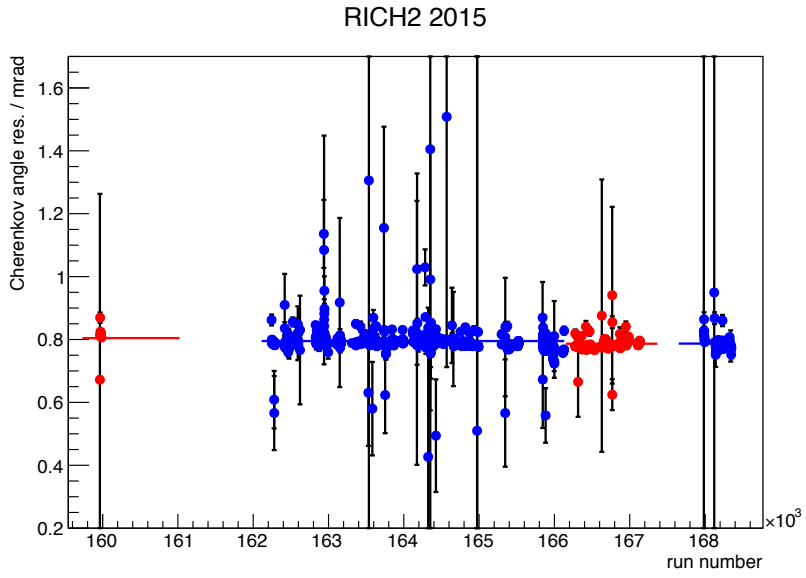
Stability of Resolution

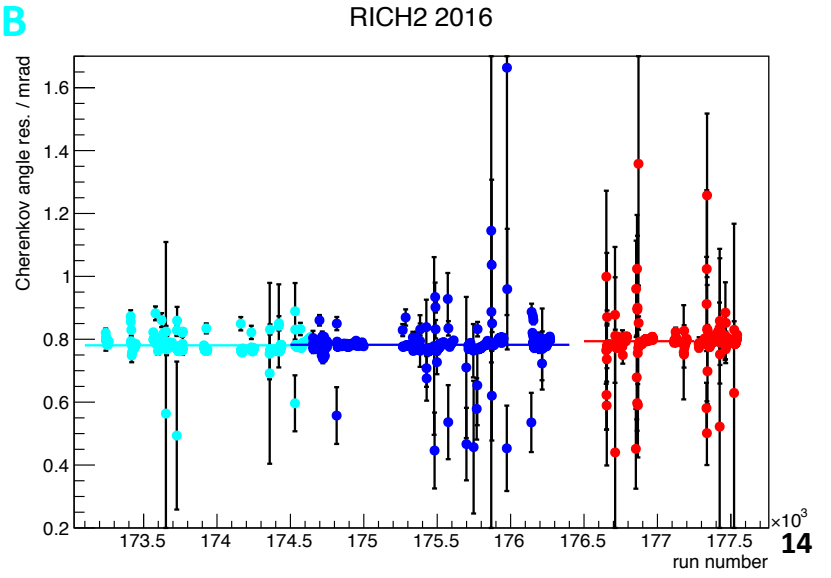
Resolutions from refractive index calibration (without HPD image correction).





magnet down
magnet up
magnet down
before new DB

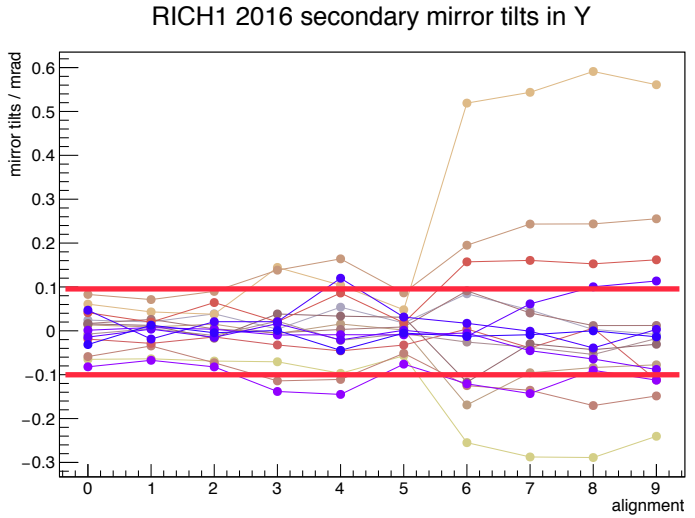


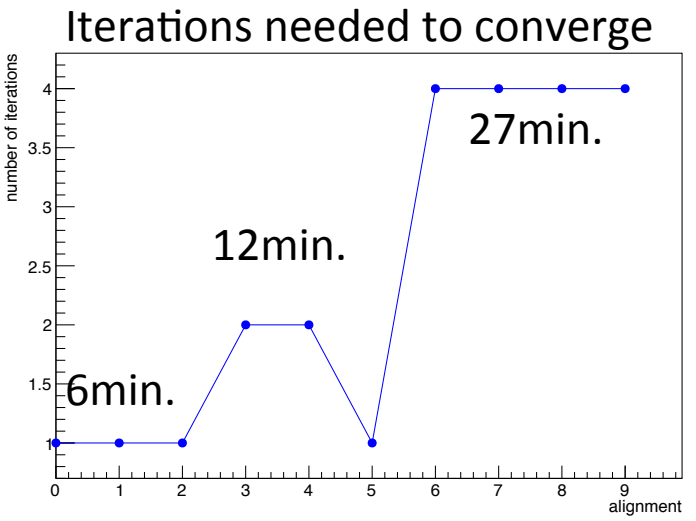


More very new features

- **Different convergence criteria** for primary and secondary mirrors in y and z respectively

- Possibility to automatically **compare output of alignment** with another given alignment
  ➔ during MagUP start from MagUP alignment (which is not in the database currently)
  ➔ converge within few iterations
  ➔ calculate the difference to alignment in the current Conditions Database





Current ‘monitoring’

RICH alignment summaries

https://lbgroups.cern.ch/rich/alignmentview.php

Date: 2016/06/16

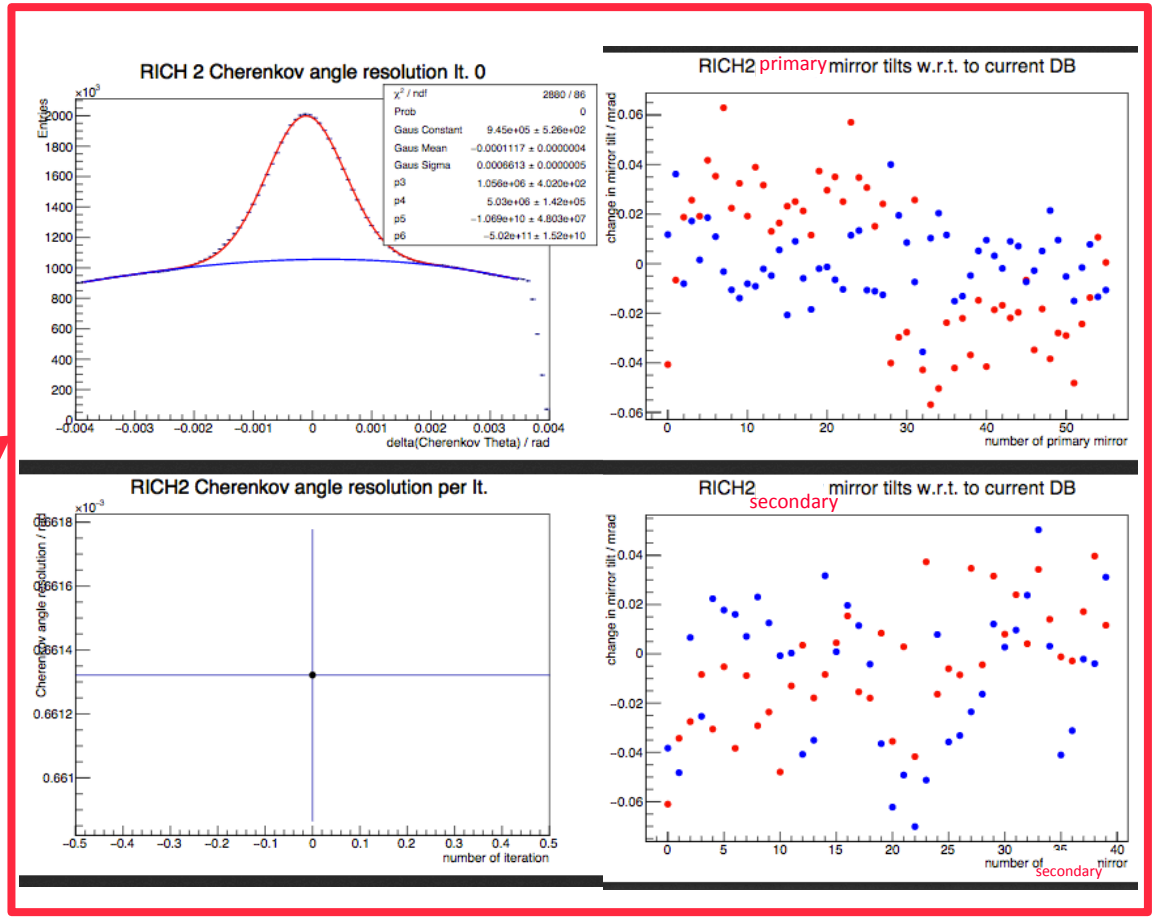
End date: 2016/06/20 ☑ Use end date?

Submit Query

RICH 1 alignments	RICH 2 alignments
20160616_170644	
20160616_174432	
20160616_180427	
20160616_182620	
20160616_185541	
20160616_191413	
20160616_192744	
20160616_195828	
20160616_203146	
20160616_205455	
20160617_162358	
	20160617_163833
20160618_202237	
	20160618_203859
	20160619_103743
20160619_155907	
	20160619_161042
20160619_183331	
	20160619_185109

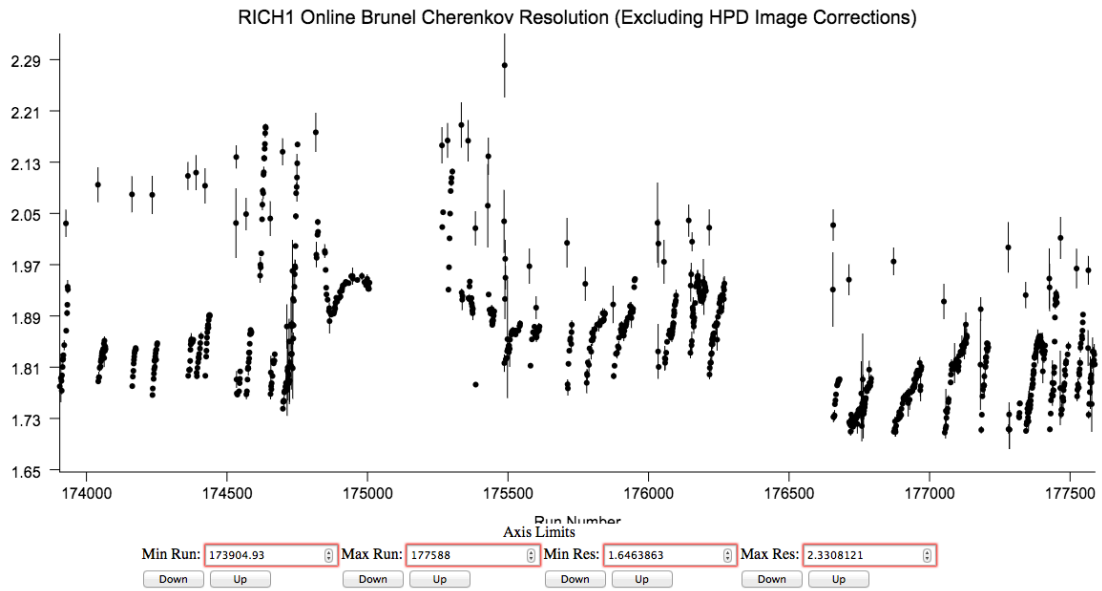
Browse Raw Files

- Tilts in y
- Tilts in z



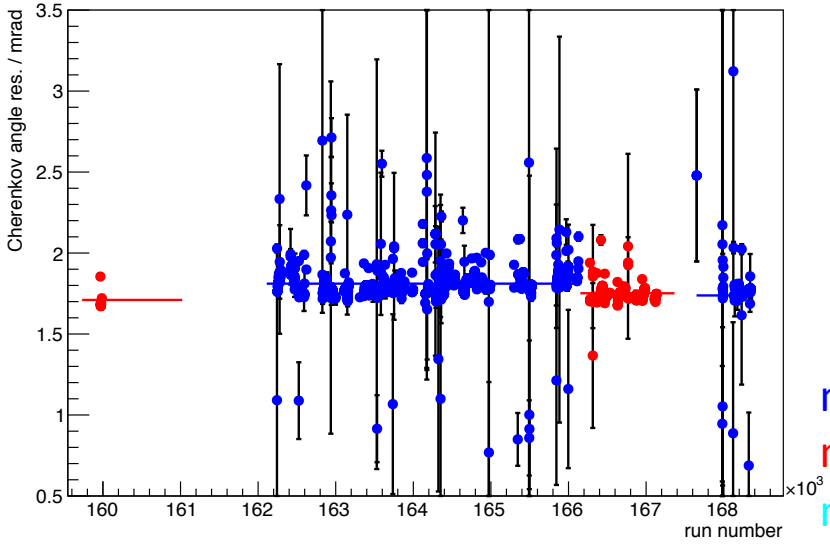
Backup

Resolution



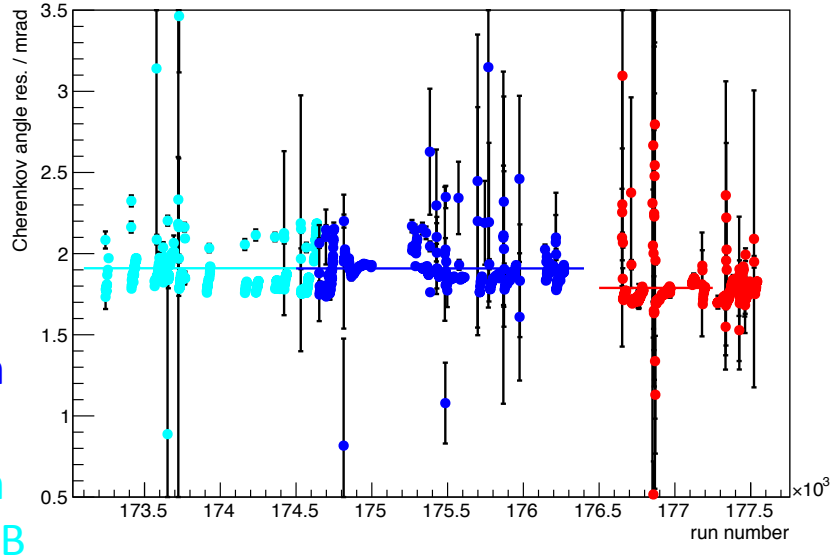
Without HPD image correction:
Degradation of resolution over fill.
➔ Longer fills in 2016

RICH1 2015



magnet down
magnet up
magnet down
before new DB

RICH1 2016



New HLT Lines

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

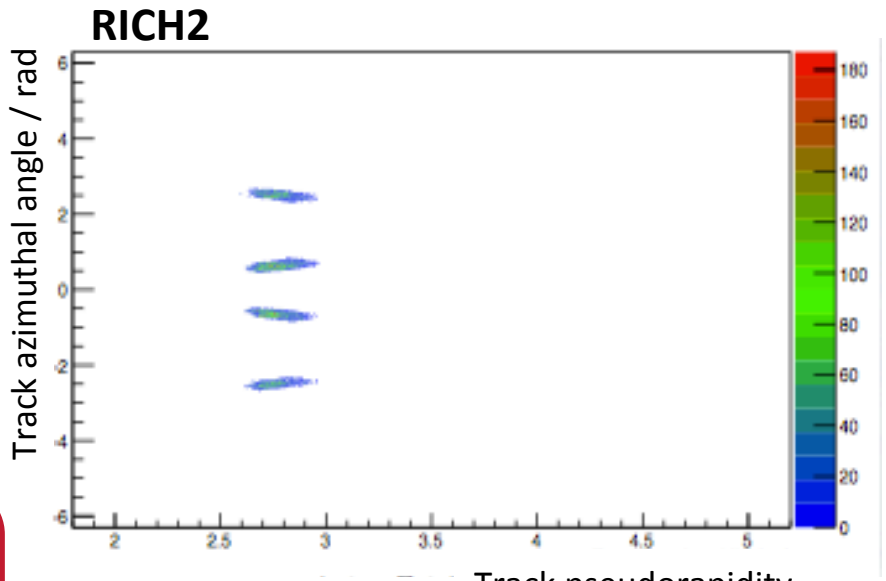
➔ usually the very outer mirrors

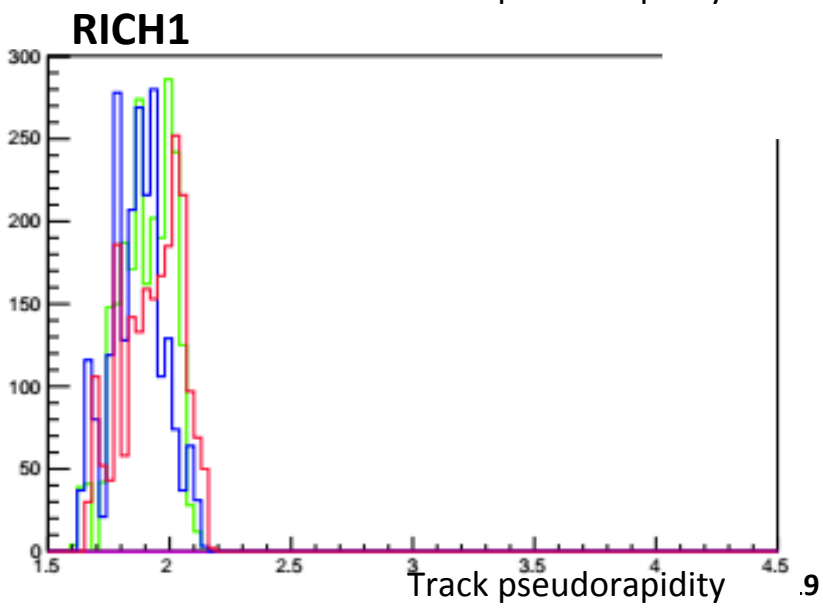
- Other tracks in the events will populate the rest

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!

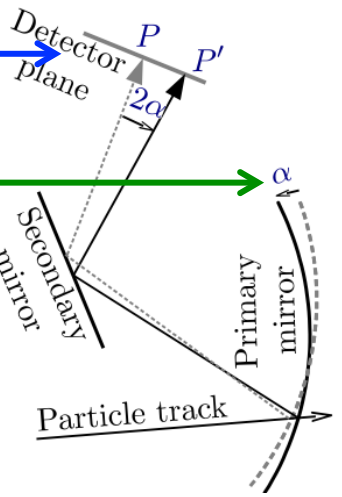
$$\Theta^y \approx 2.0\,\alpha^y - 0.9\,\beta^y \quad \text{and} \quad \Theta^z \approx 1.8\,\alpha^z + 0.6\,\beta^z.$$

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**