RICH Mirror Alignment

07/01/2016 Claire Prouve - University of Bristol LHCb UK Liverpool

presenting work by Anatoly, Antonis, Chris, Claire, Paras, Roel, and many more

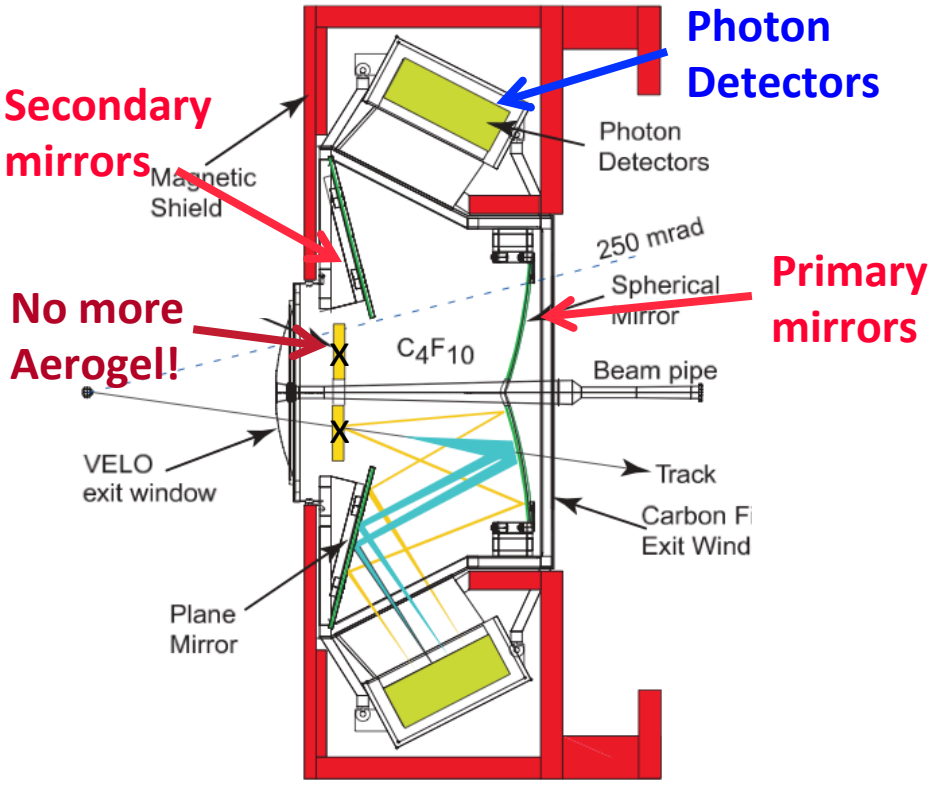
Overview

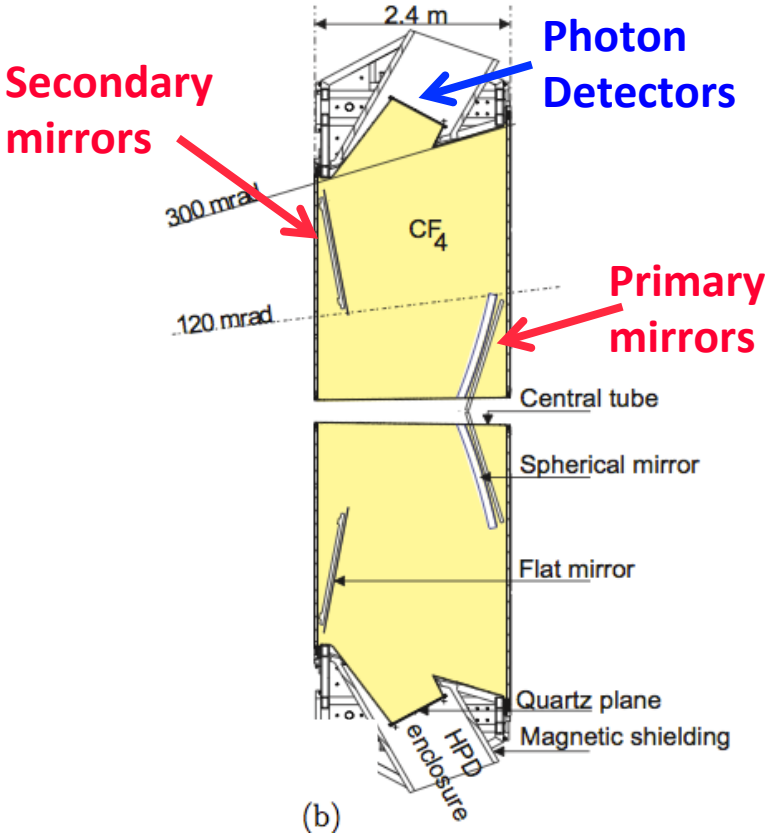
- RICH mirror alignment strategy
- RICH mirror alignment implementation in Run II
- Performance in Run II
- RICH maintenance and operation

RICH Mirror Alignment

RICH 1: 4 primary mirrors
16 secondary mirrors

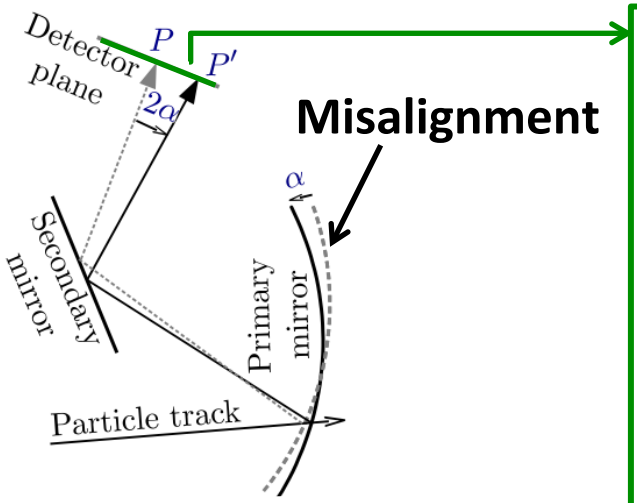
RICH 2: 54 primary mirrors
40 secondary mirrors



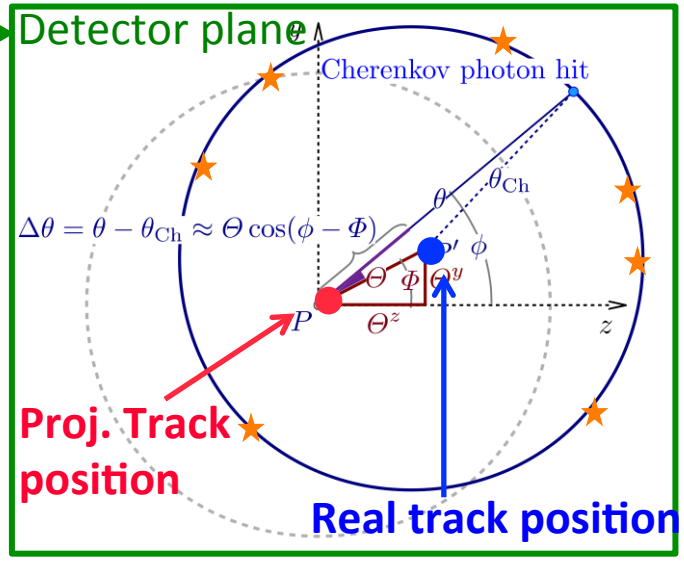


Misaligned mirrors will affect the PID due to incorrectly predicted Cherenkov angle!

Misalignment



Misalignment



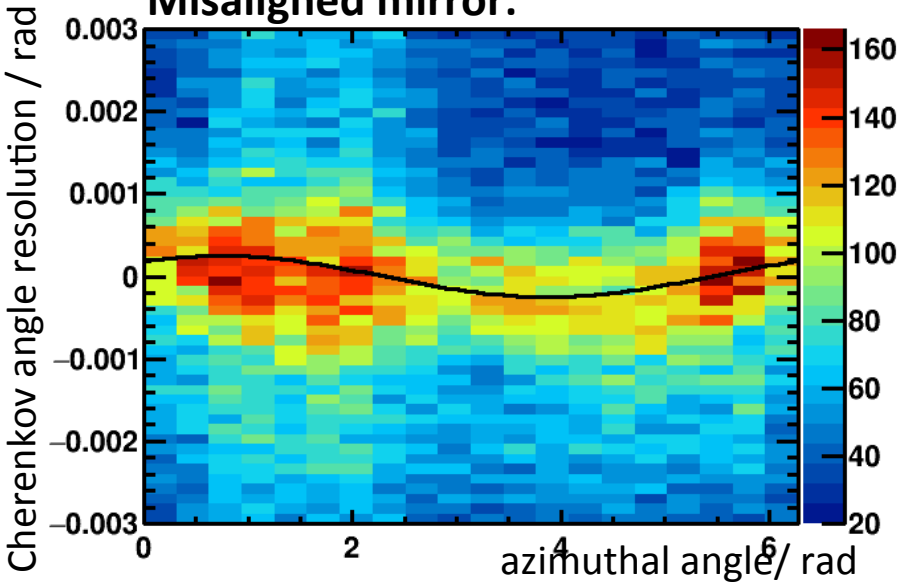
Identify misalignment:

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

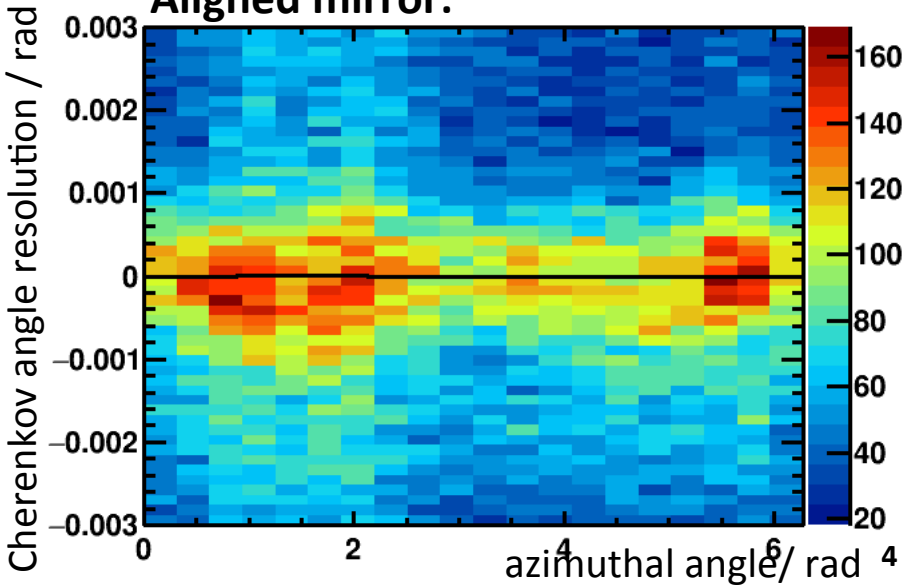
$\Delta\theta_C(\Phi) = \rho_y \cos(\Phi) + \rho_z \sin(\Phi)$

Misalignments on detector plane

Misaligned mirror:

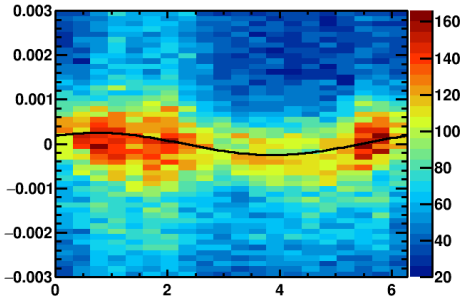


Aligned mirror:



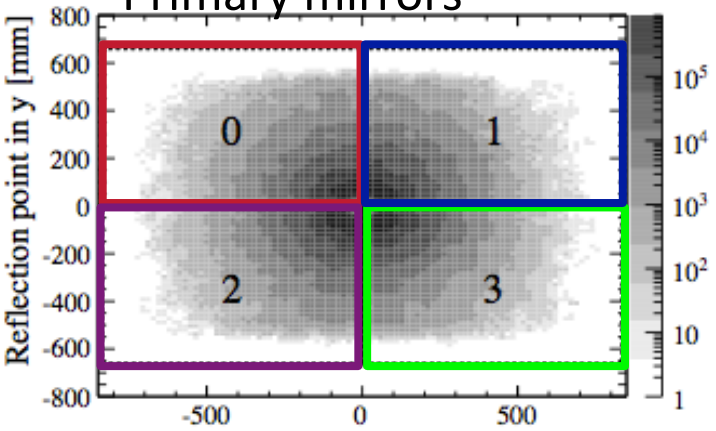
Decoupling misalignments

Mirror-pair: **fit** misalignment on detector-plane in y, z
➔ 2 parameters
need actual misalignment in y,z, for each mirror
➔ 4 parameters

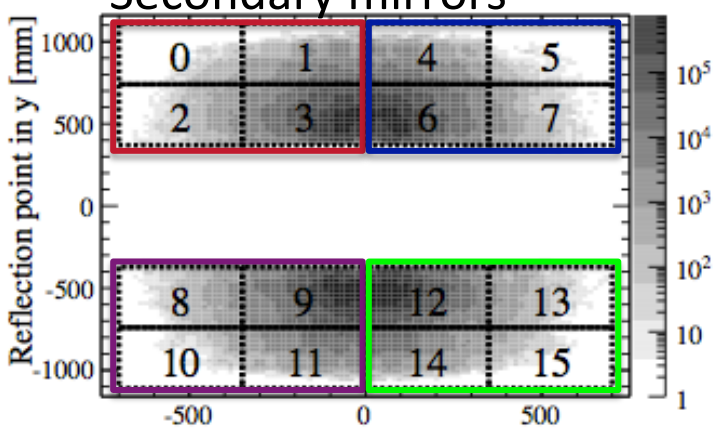


RICH1: easy!
Given secondary mirror only receives photons from one primary mirror.
➔ Only align secondary mirrors

Primary mirrors



Secondary mirrors



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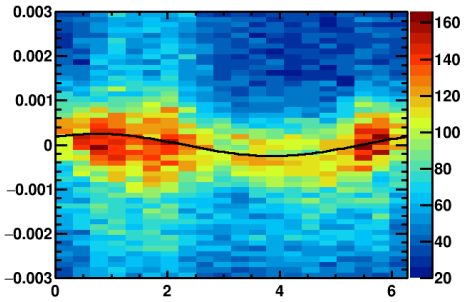
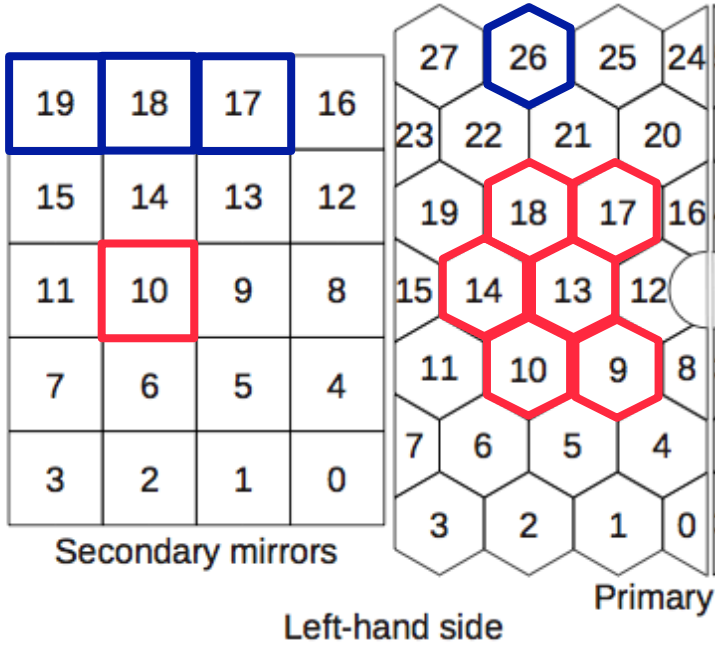
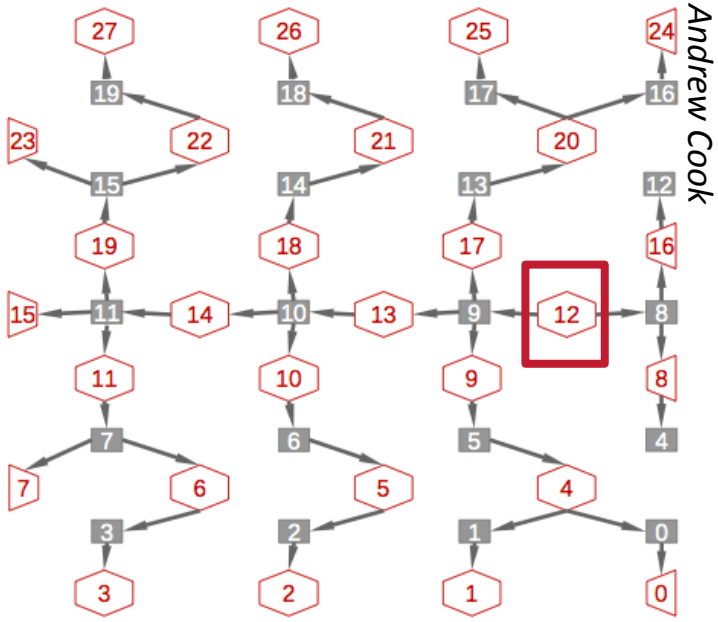


RICH2:
Given secondary mirror can receive photons from several primary mirrors.
System of equations linking all mirrors starting from primary mirror 12.



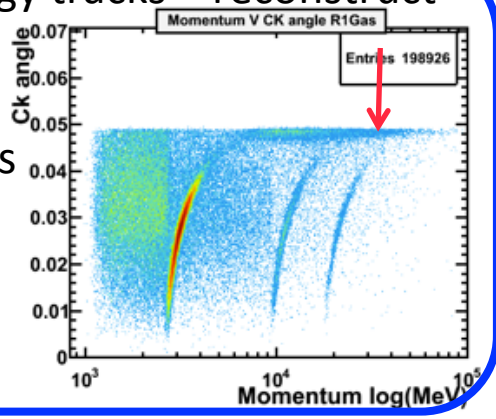


Alignment procedure

Events

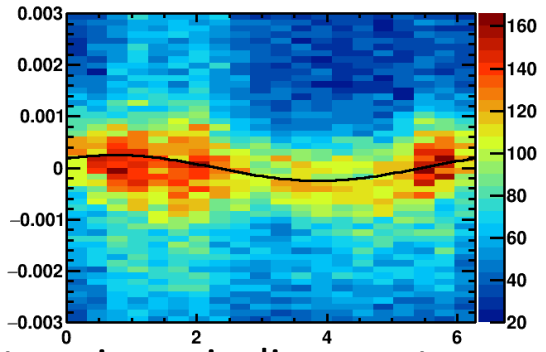
CONDDB database

High energy tracks + reconstruct under pion-hypothesis



Fill histograms with (Δθ vs. Φ) of unambiguous photons for each mirror-pair

Unambiguous photons will be reflected by the same mirror-pair no matter where along the track they were emitted.



Determine misalignment on detector plane

Calculate mirror misalignments for each individual mirror + **Update database**

Y			
-.5	.9	.0	.7
-.2	.0	.1	.1
.0	.0	.2	.6
-.7	.8	-.9	.6

Z			
.2	.3	.3	.3
-.5	-.3	-.2	-.6
.6	.1	.1	.5
-.6	-.1	.6	-.3

new database

Alignment procedure

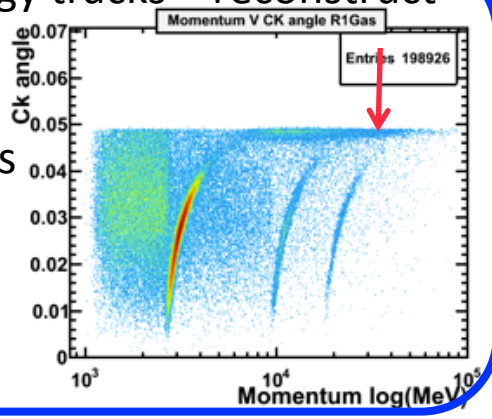
Events

CONDDB database

Any mirror moved > 0.1 mrad?

new database

High energy tracks + reconstruct under pion-hypothesis



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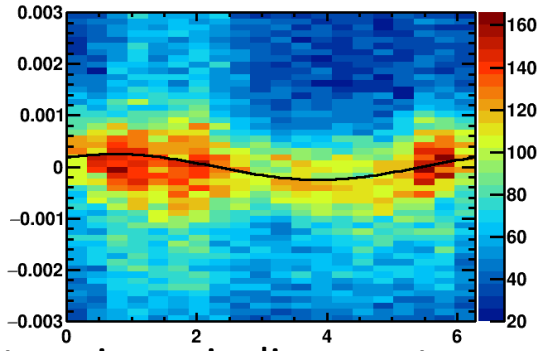

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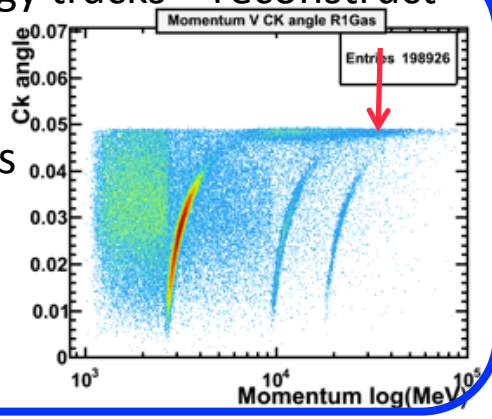
Z			
.2	.3	.3	.3
−.5	−.3	−.2	−.6
.6	.1	.1	.5
−.6	−.1	.6	−.3

Alignment procedure

Events

new database

High energy tracks + reconstruct under pion-hypothesis



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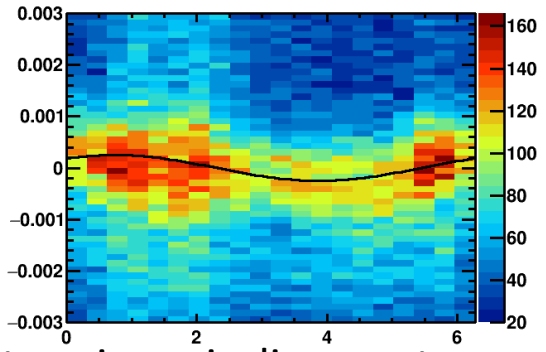

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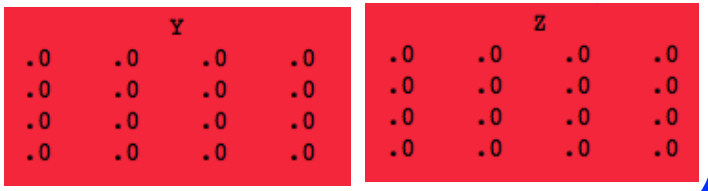


new(er) database

YES!

Alignment procedure

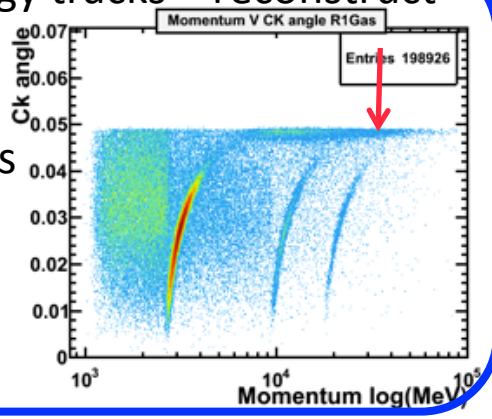
Events

new database

Any mirror moved > 0.1 mrad?

new(er) database

High energy tracks + reconstruct under pion-hypothesis



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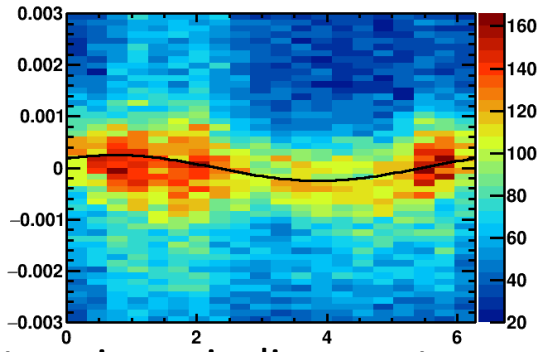

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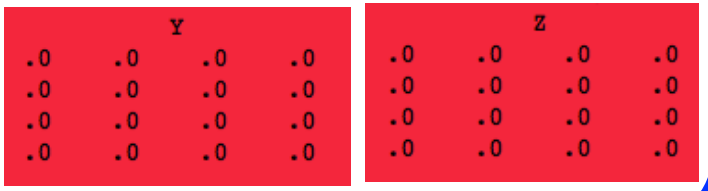
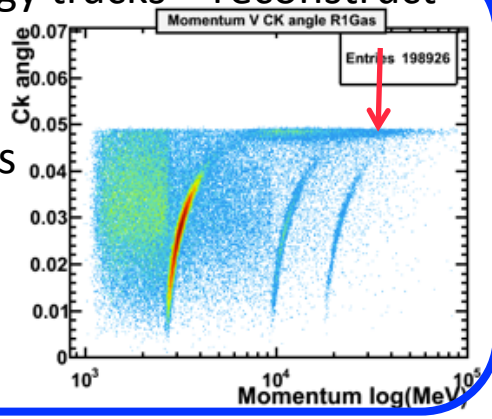


Alignment procedure

Events

new database

High energy tracks + reconstruct under pion-hypothesis



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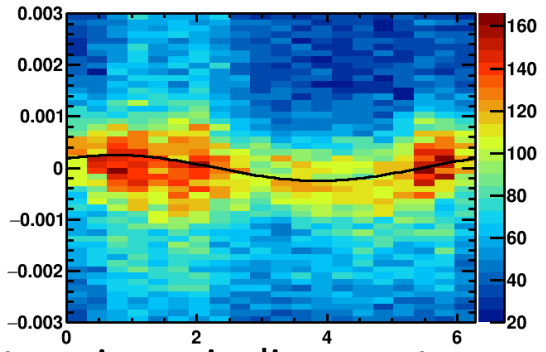

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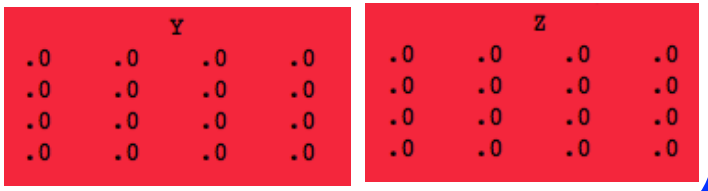
Calculate mirror misalignments for each individual mirror + **Update database**



new(er) database

No! ➔ Alignment converged!!!

RICH mirror alignment implementation in Run II

Run I and Run II

Run I:

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

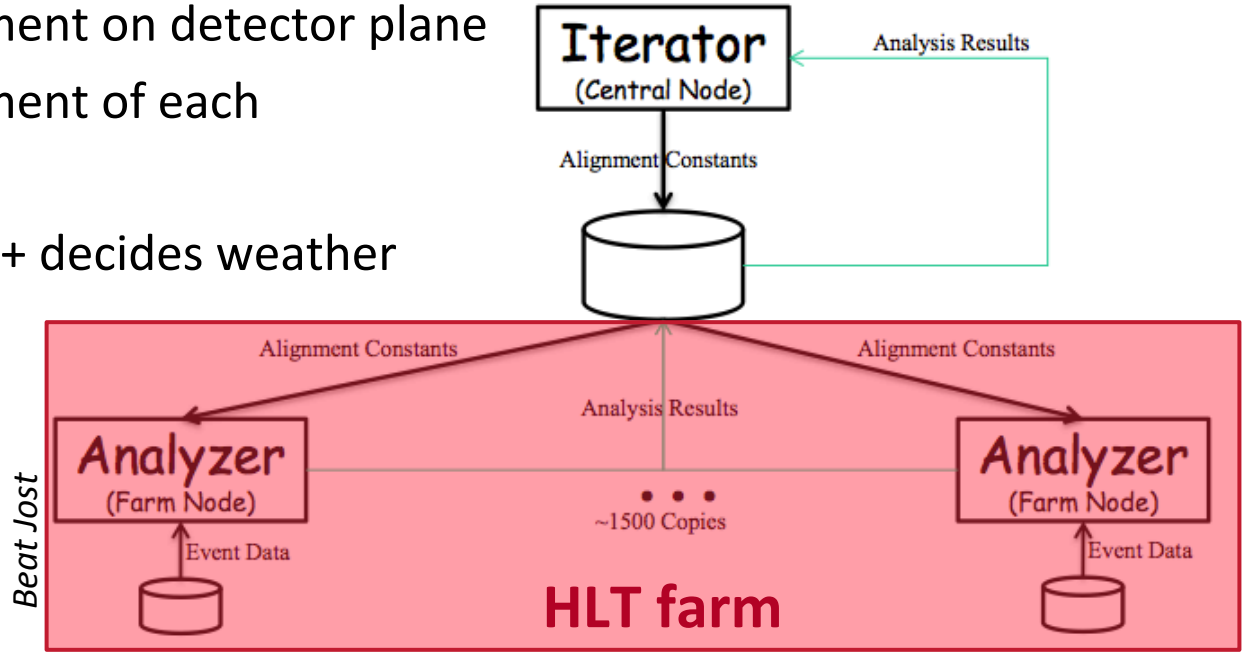
Run II:

- **Online:** after HLT1 and before HLT2
- Alignment run **for each Fill** (monitoring mode)
- **HLT1 lines** for alignment
- **HLT farm** (~1700 nodes)
- Steered by the online **Finite State Machine (FSM)**

HLT farm for Run II

- **HLT farm nodes** (Analysers)
  - Reconstruct data from HLT1 lines
  - Make the histograms

- **Central node** (Iterator)
  - Receives histograms from Analysers
  - Determines misalignment on detector plane
  - Determines misalignment of each individual mirror
  - Makes new database + decides weather or not to continue



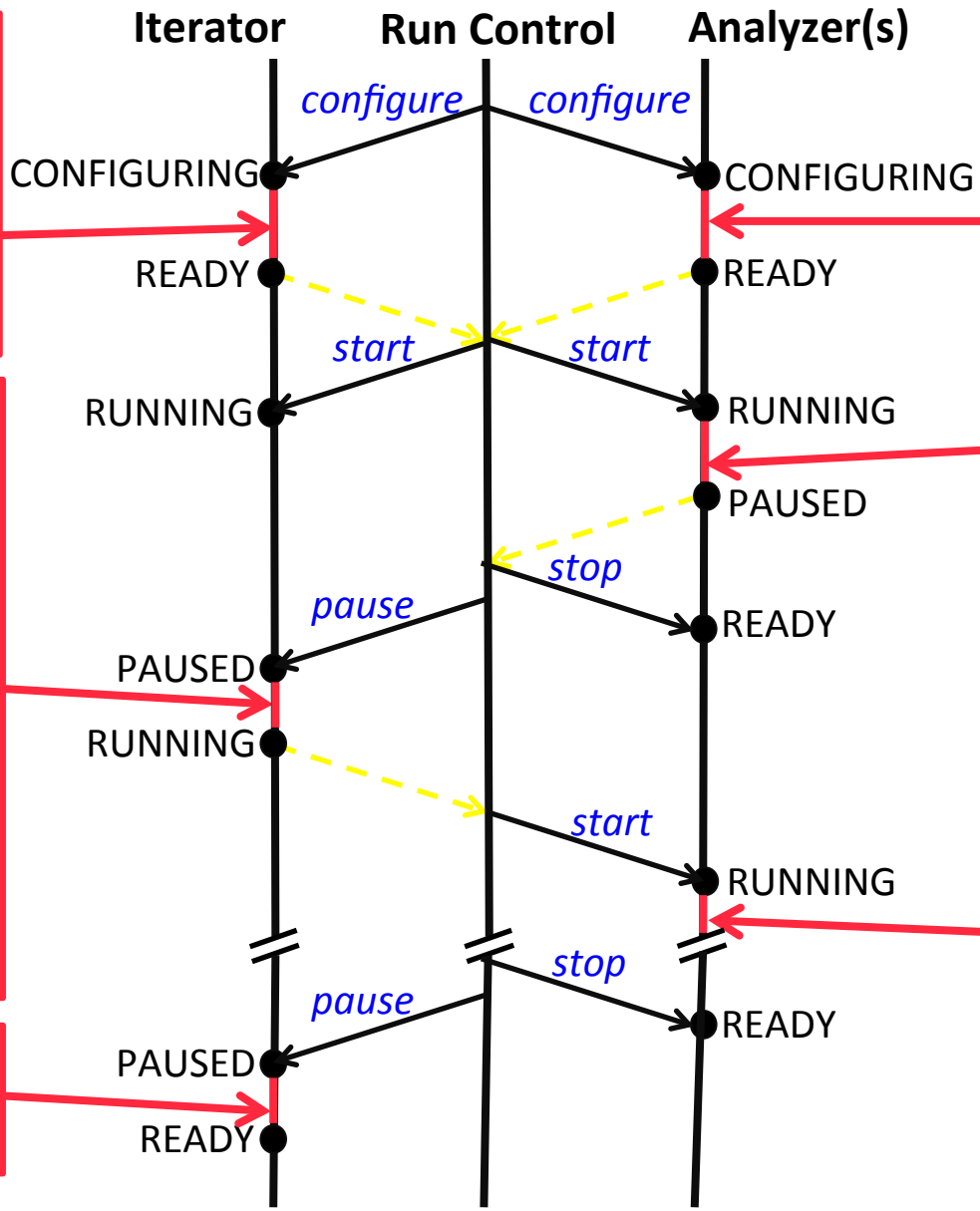
Finite State Machine

Get default database and place where analyzers will pick it up, etc.

Mirror misalignments + new database.

In case of continue: place new database where the analyzers will pick it up.

Alignment converged!



Set up Brunel reconstruction options.

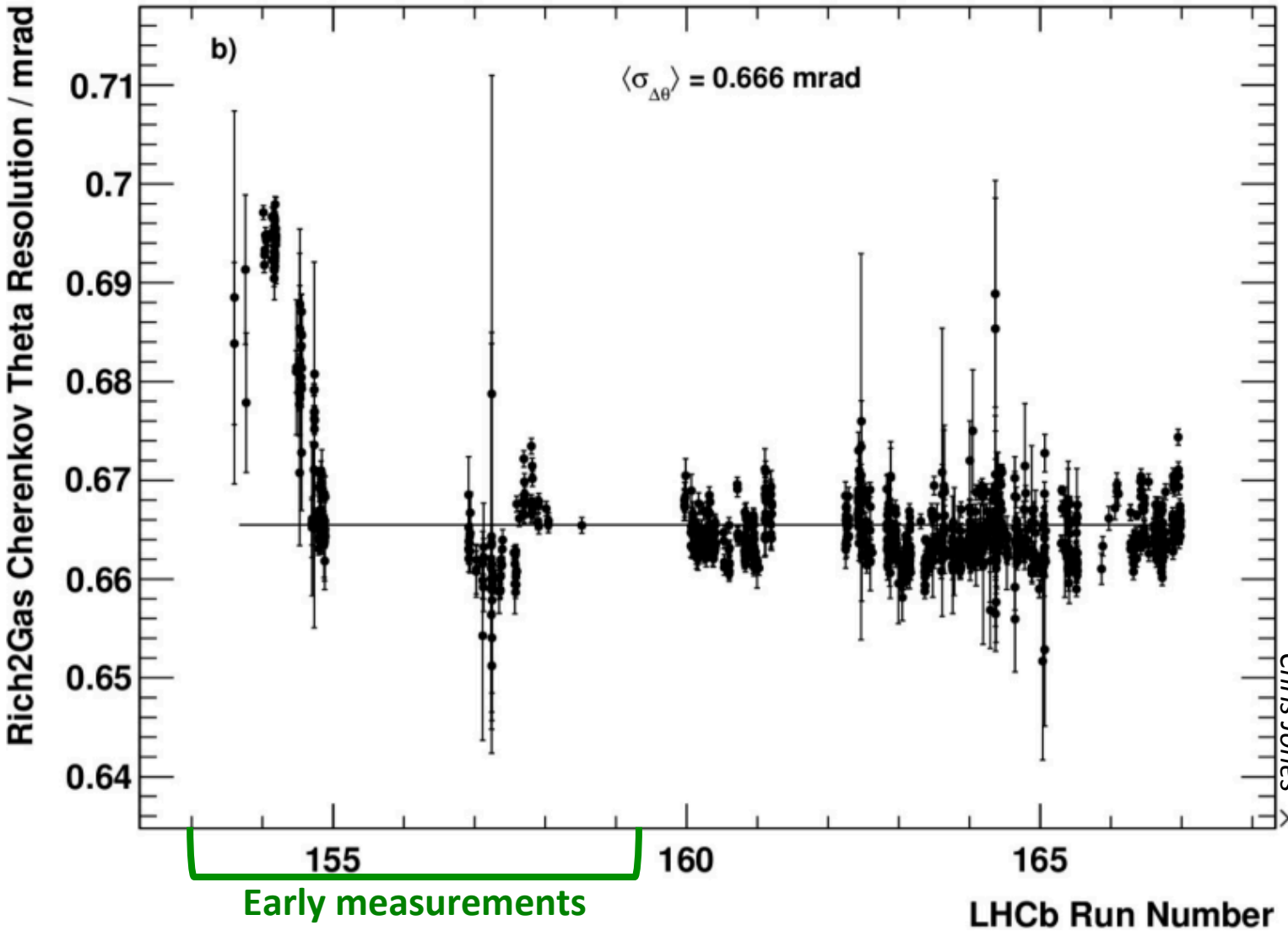
Reconstruct events and fill histograms.

Reconstruct events and fill histograms.

Performance in Run II

Performance – RICH2

RICH2 Cherenkov Resolution Stability : 2015

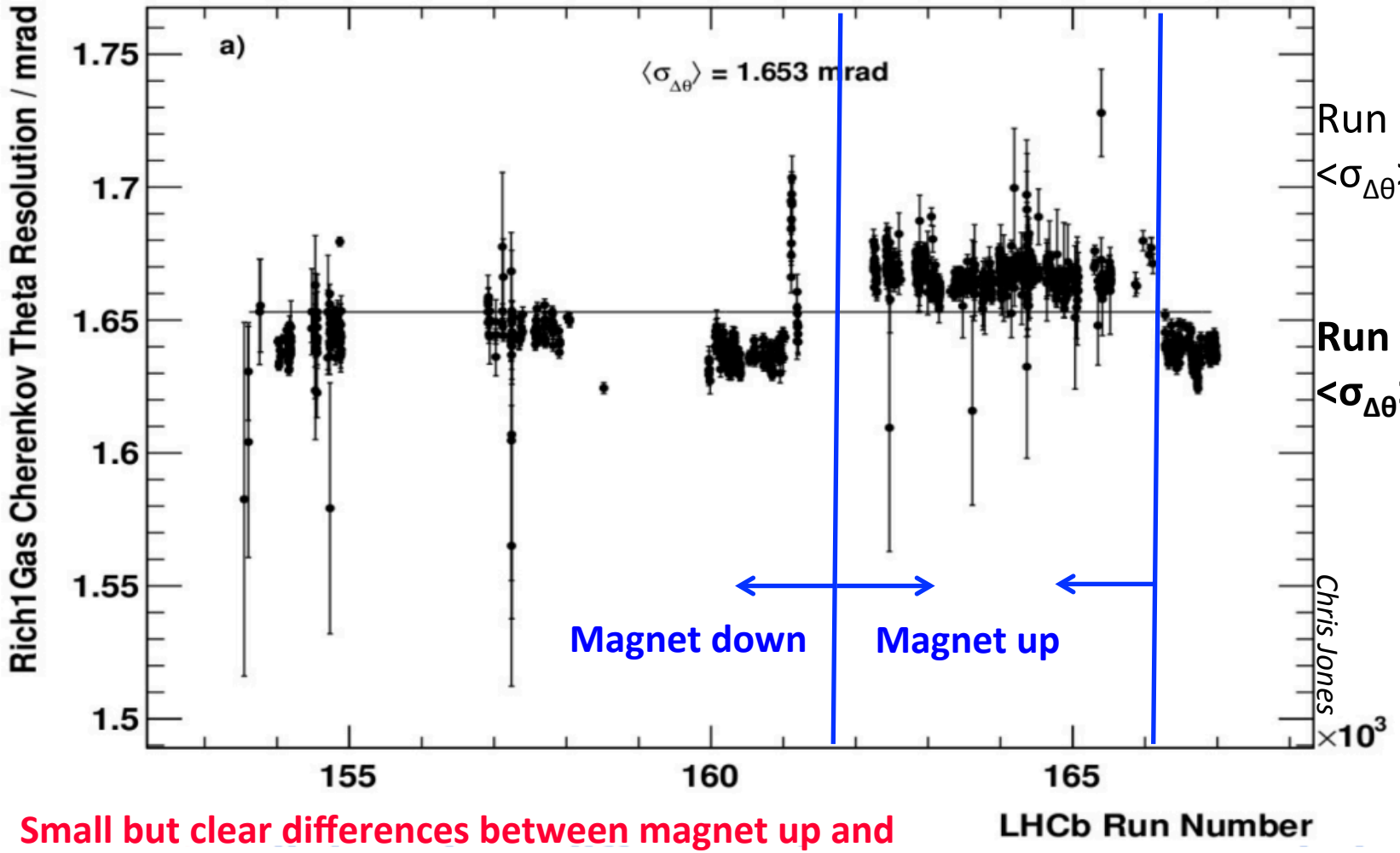


Run I:
$\langle\sigma_{\Delta\theta}\rangle$ ~ 0.67 mrad

Run II average:
$\langle\sigma_{\Delta\theta}\rangle$ ~ 0.67 mrad

Performance – RICH1

RICH1 Cherenkov Resolution Stability : 2015

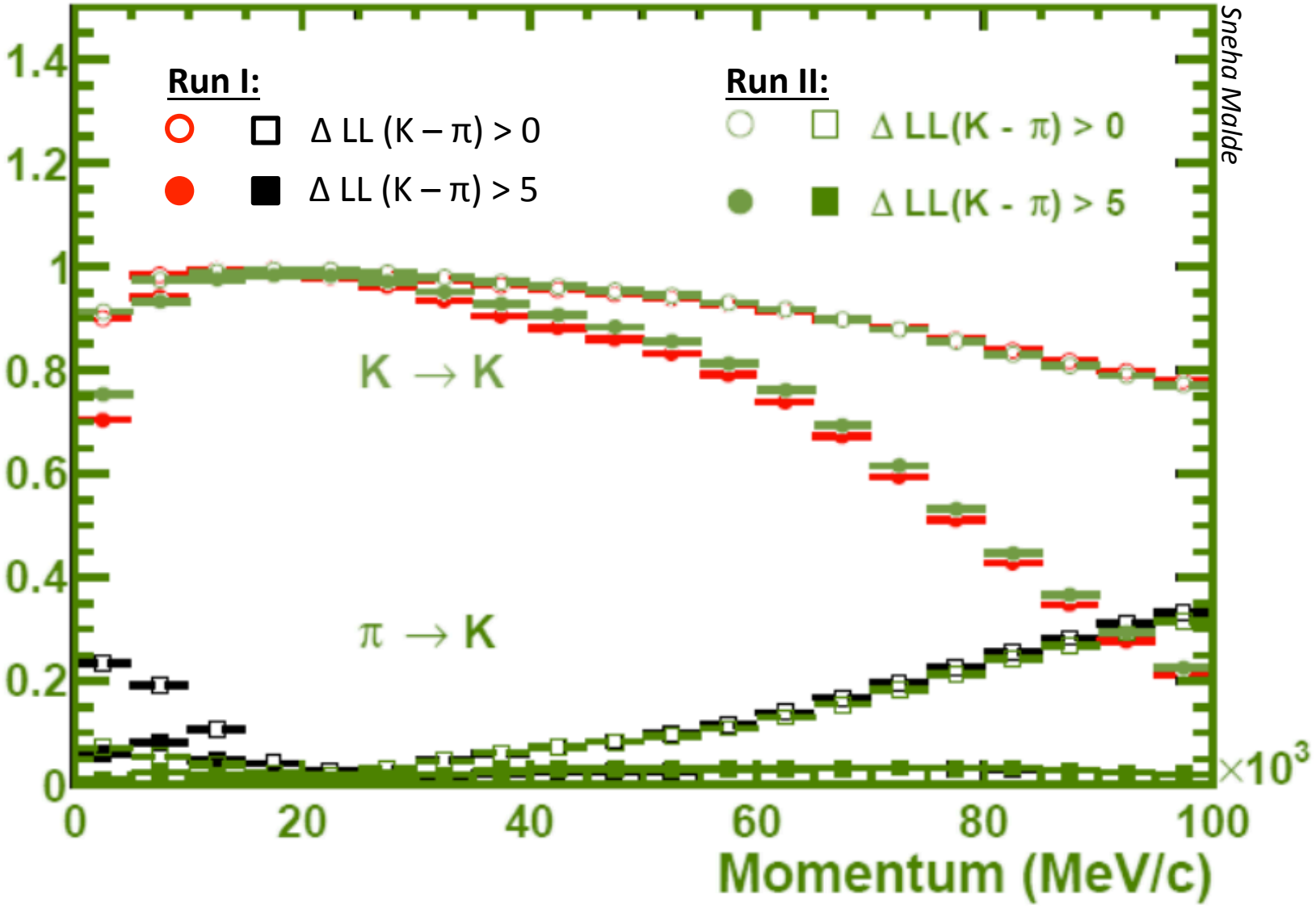


Run I:
$\langle\sigma_{\Delta\theta}\rangle$ ~ 1.62 mrad

Run II average:
$\langle\sigma_{\Delta\theta}\rangle$ ~ 1.65 mrad

Small but clear differences between magnet up and magnet down!

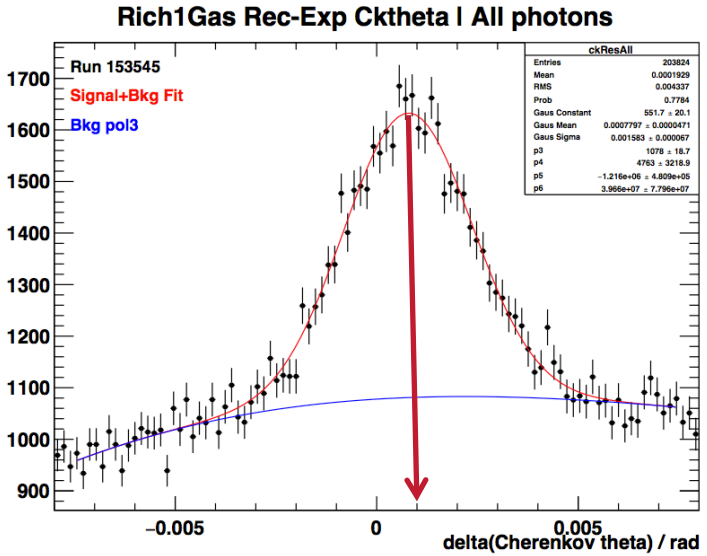
PID Performance



Maintenance and operation

Calibrations

Online calibrations at the end of each run.

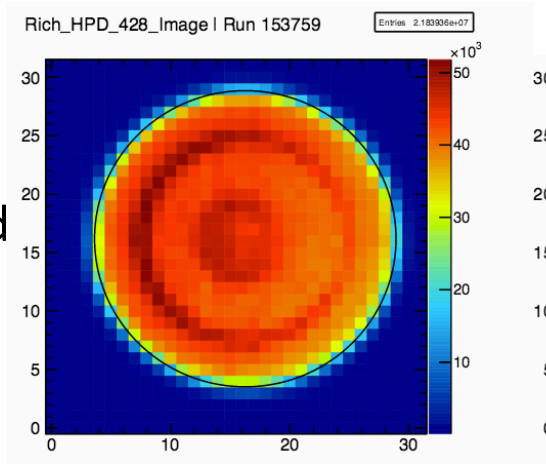


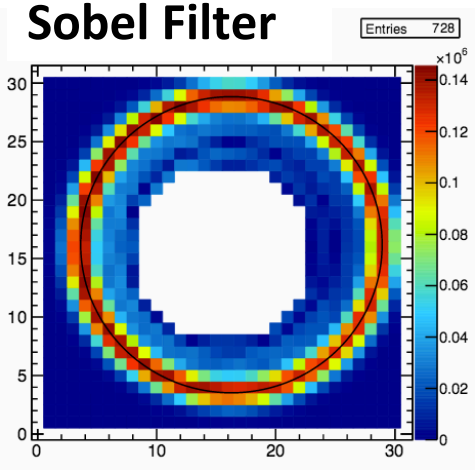
Refractive Index Calibration:

- Hardware sensors monitor pressure and temperature.
- Limited precision and does not account for gas mixture changes.
- Simple fit to reconstructed-expected Cherenkov angle yields (n-1) scale factor.

HPD images calibration:

- Image fit performed for each HPD and used to provide calibration for anode element.

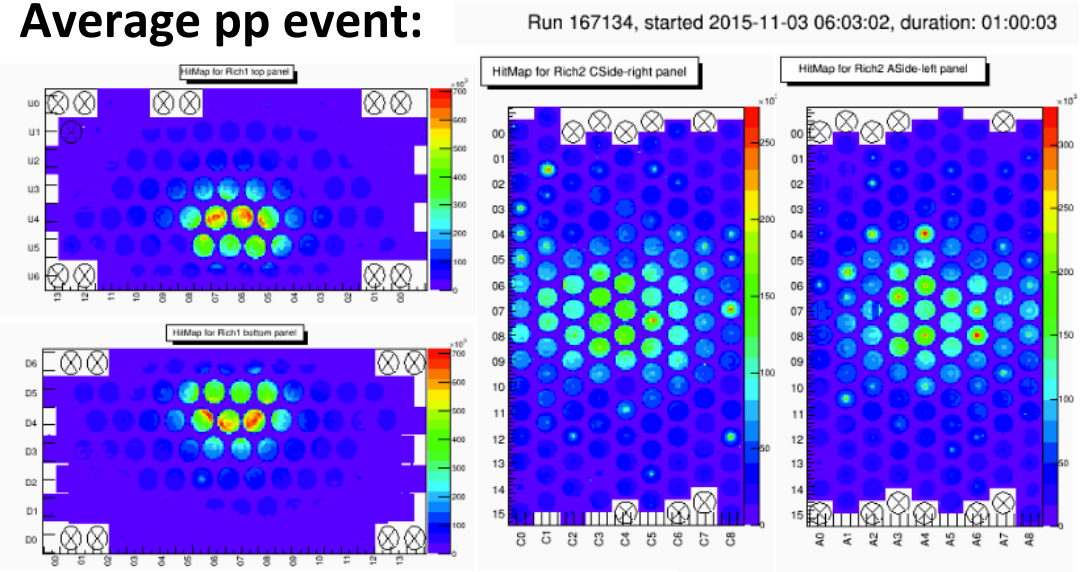




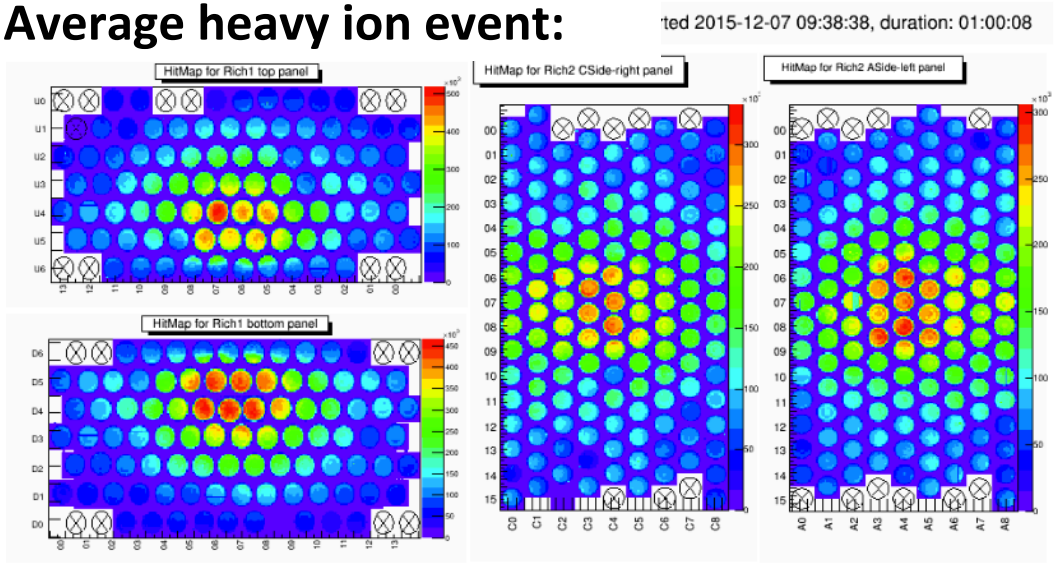
Maintenance and Operation

- Aerogel in RICH1 removed
- ~50% of HPDs in RICH1 replaced and many in RICH2 ➔ quite new detector
- Gas leak in RICH1: not found but workaround developed
- Gas pressure generally well handled
- Some incomplete events due to RICH detectors ➔ bug in UKL0 firmware found and fixed
- RICHes performed well during the heavy ion runs

Average pp event:



Average heavy ion event:



Summary

- RICH detectors are performing very well
- Alignment will be run online for every fill
  - PID can be used in HLT2
  - Very fast (<2h wrt. ~2 days)
- RICH2 reached precision of RunI already
- RICH1 needs a bit more work
- More optimisation is being done

Backup

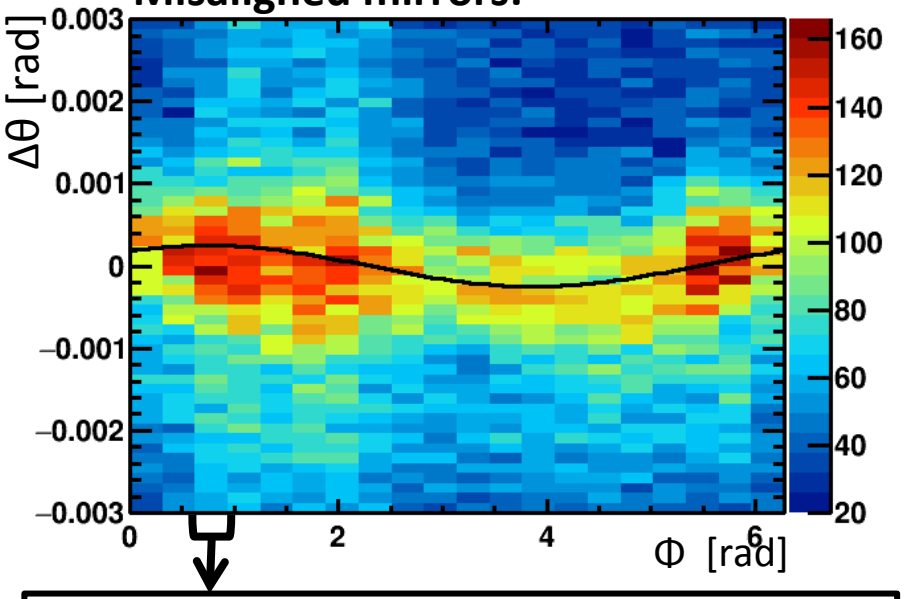
Cherenkov angle resolution

Limiting factors to Cherenkov angle resolution:

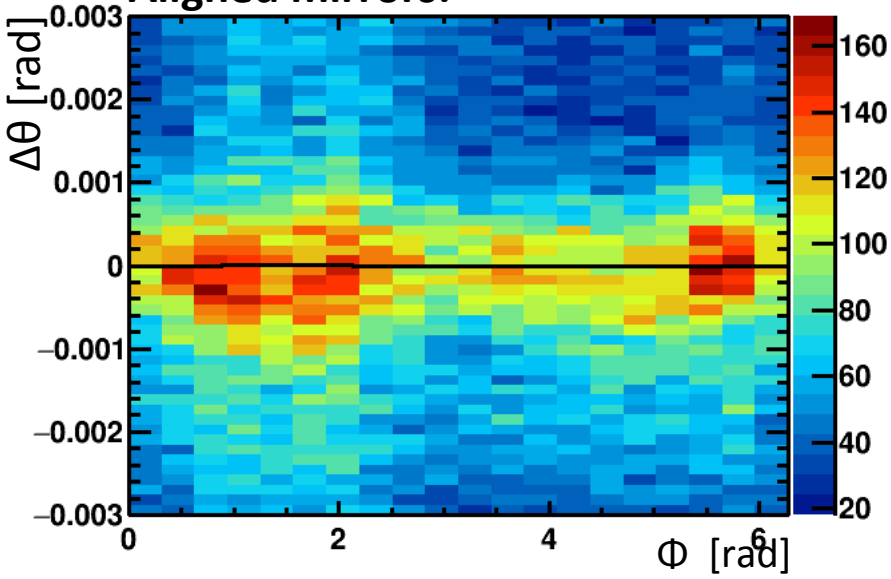
	σ [mrad]		
	RICH1		RICH2
	Aerogel	C_4F_{10}	CF_4
Emission point	0.4	0.8	0.2
Chromatic dispersion	2.1	0.9	0.5
Pixel size	0.5	0.6	0.2
Tracking	0.4	0.4	0.4
Total	2.6	1.5	0.7

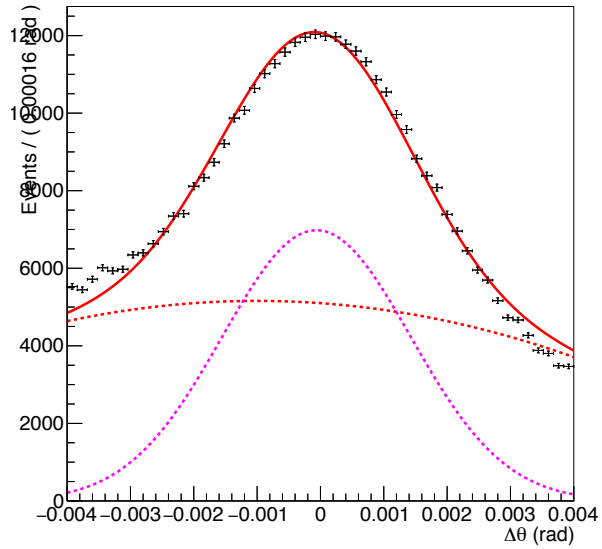
Misalignment

Misaligned mirrors:



Aligned mirrors:





Signal:
Gaussian

BKG:
2nd order polynomial

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!

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

New HLT Lines

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

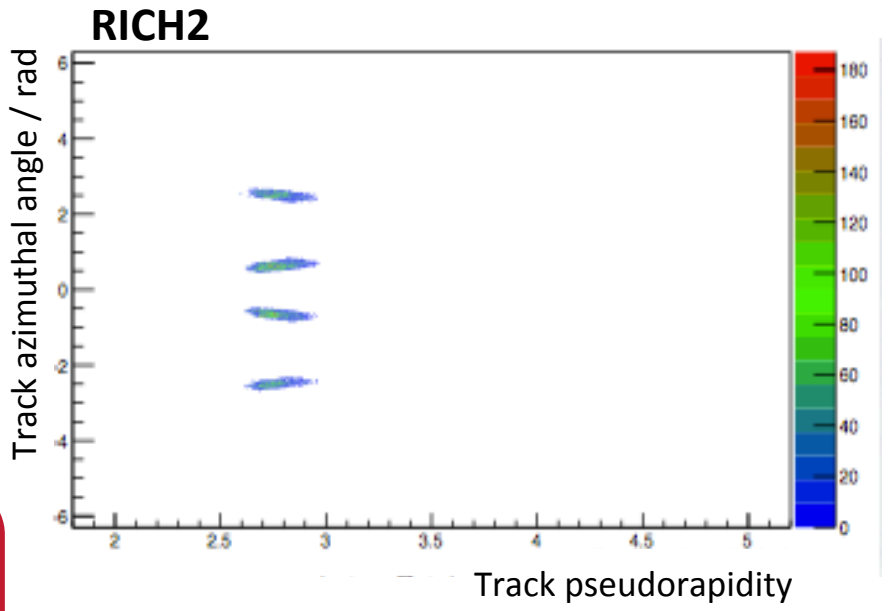
➔ usually the very outer mirrors

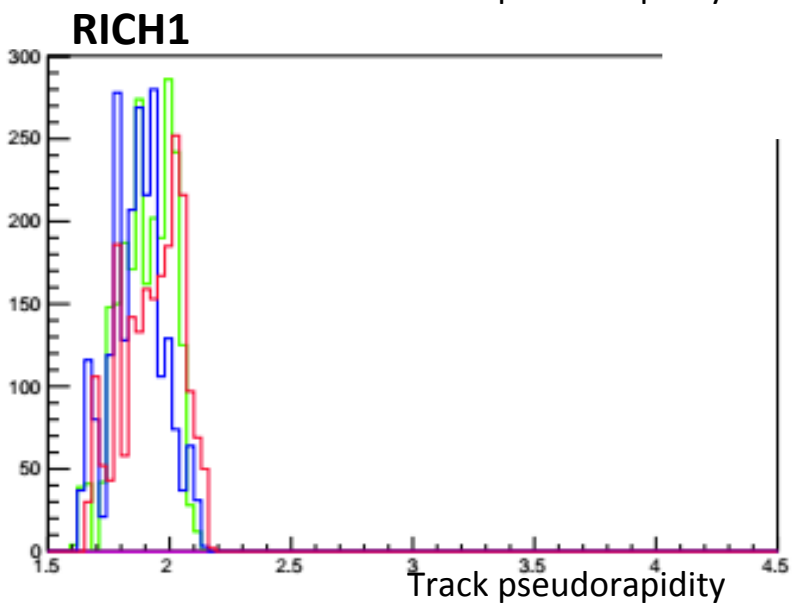
- Other tracks in the events will populate the rest

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 **&&** $\chi^2 < 2$ **&&** $1.6 < \eta < 2.04$
$(-2.65 < \Phi < -2.3)$ **||** $(-0.8 < \Phi < -0.5)$ **||**
$(0.5 < \Phi < 0.8)$ **||** $(2.3 < \Phi < 2.65)$

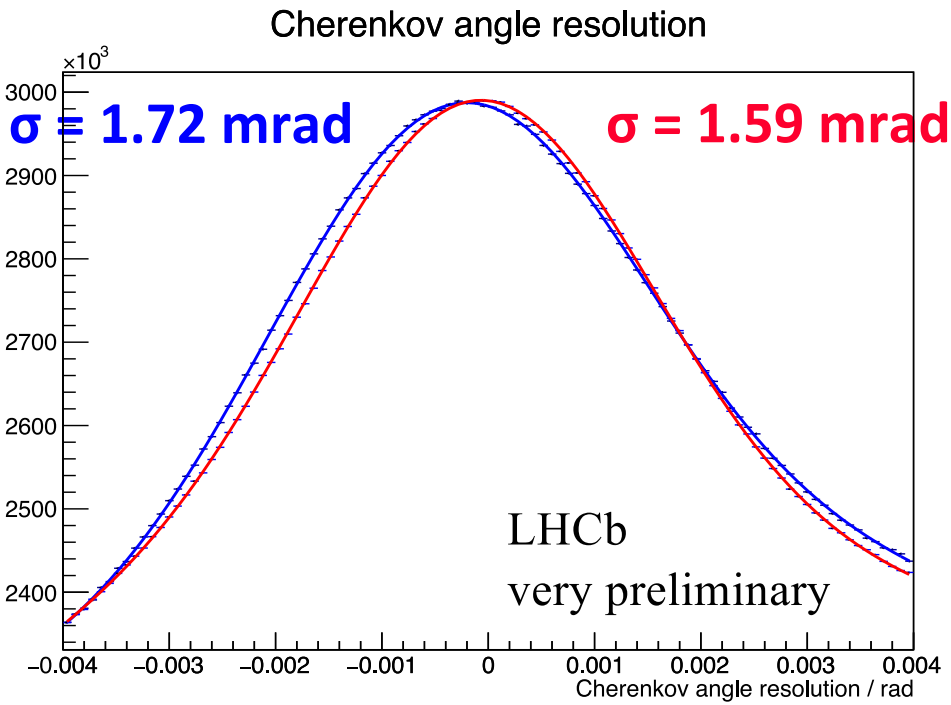
Need to reconstruct ~10 times less events!





Example RICH1 improvement

First alignment in RunII



Second alignment in RunII