# RICH Mirror Alignment

07/01/2016 Claire Prouve LHCb UK Liverpool

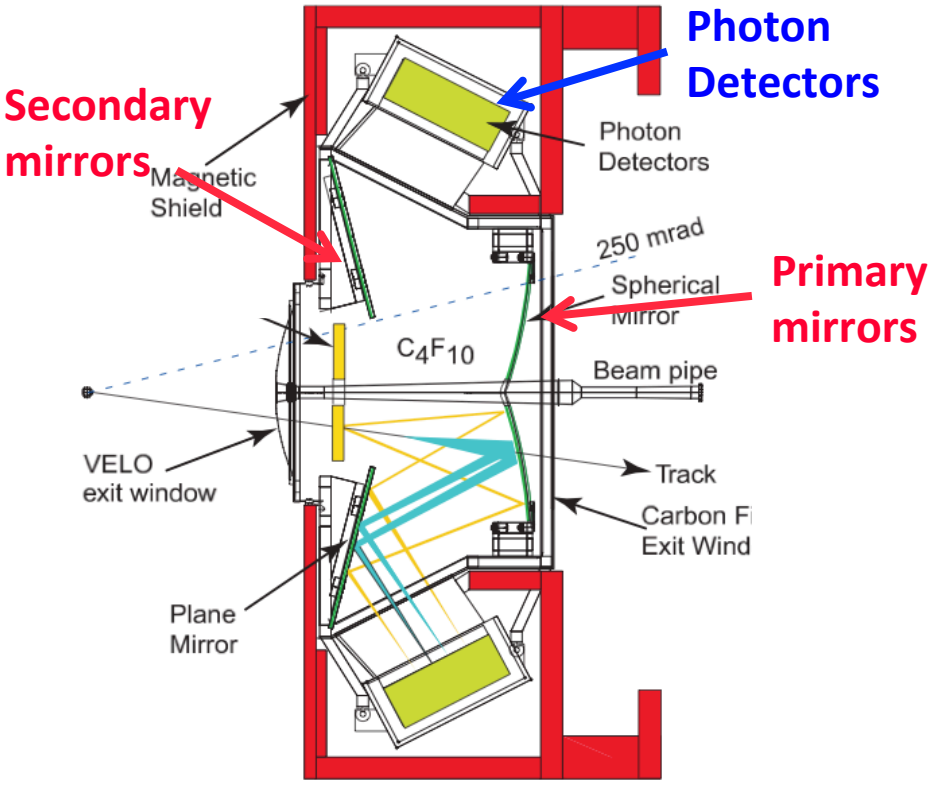
# Overview

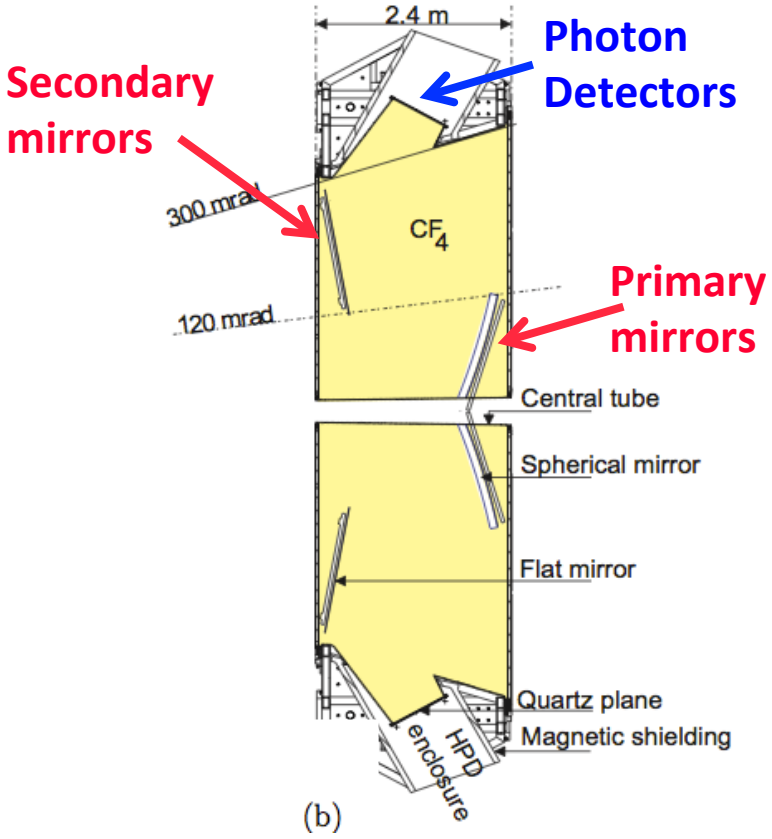
- RICH mirror alignment strategy
- RICH mirror alignment implementation in Run II
- Performance in Run II
- RICH maintenance and operation

# RICH Mirror Alignment

**RICH 1:** 4 primary mirrors
16 secondary mirrors

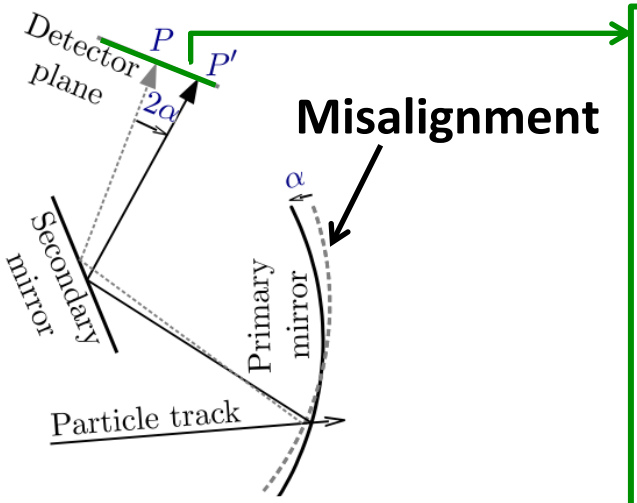
**RICH 2:** 54 primary mirrors
40 secondary mirrors



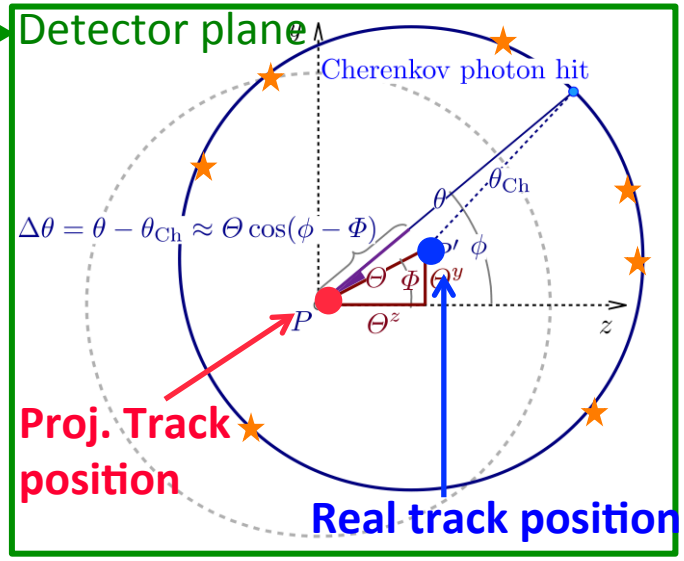




Misaligned mirrors will affect the PID due to incorrectly predicted Cherenkov angle!

# Misalignment




**Misalignment**



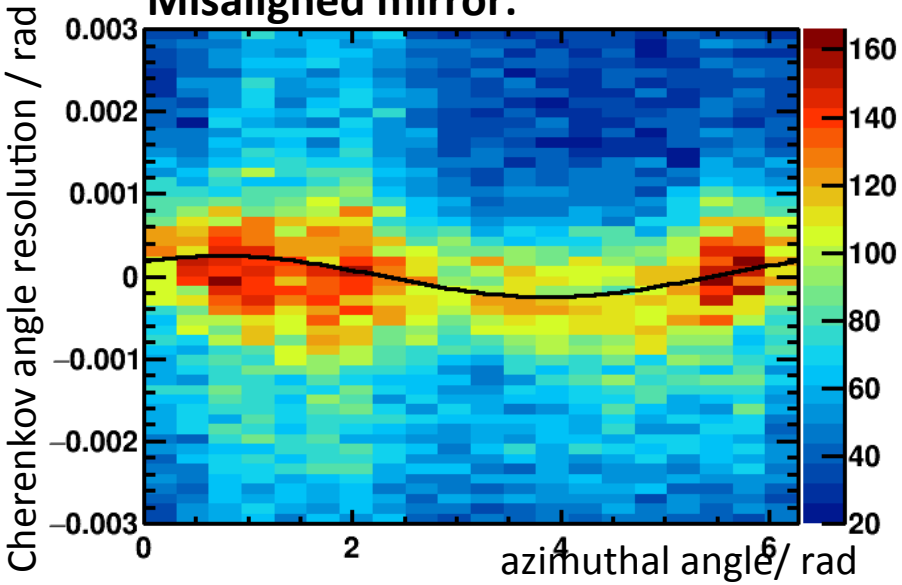

Identify misalignment:

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

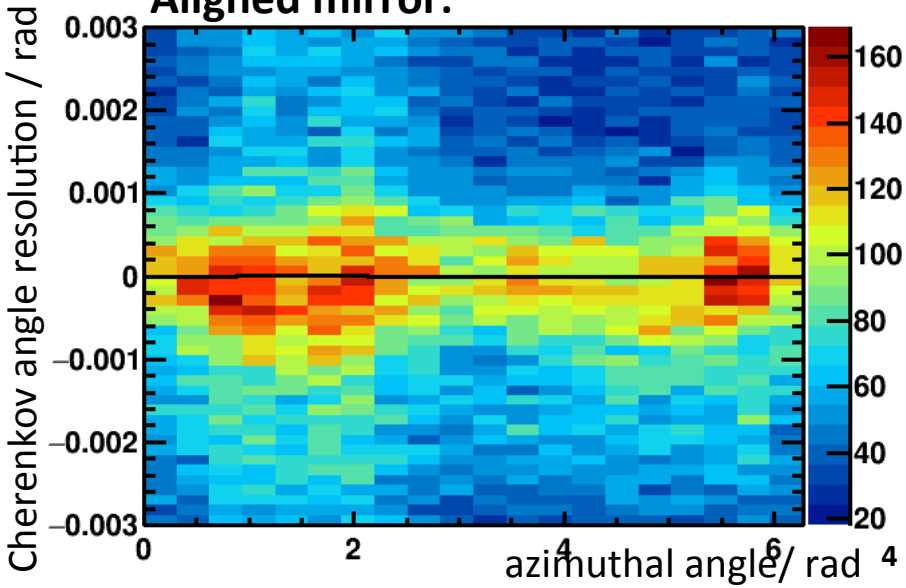
$\Delta\theta_C(\Phi) = \rho_y \cos(\Phi) + \rho_z \sin(\Phi)$

Misalignments on detector plane

**Misaligned mirror:**

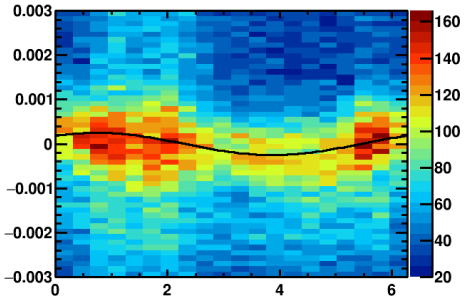



**Aligned mirror:**



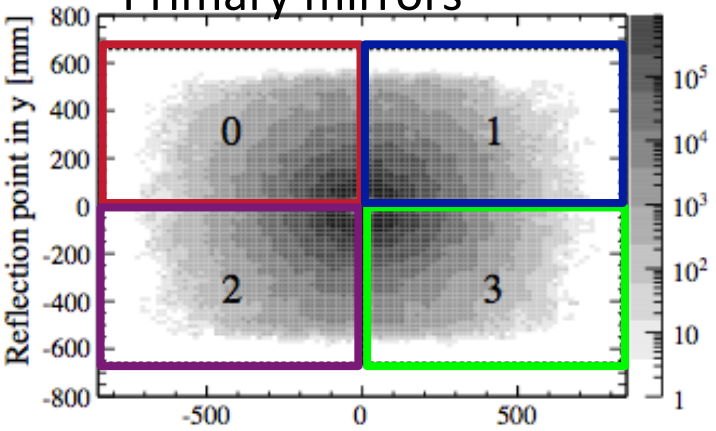
# Decoupling misalignments

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

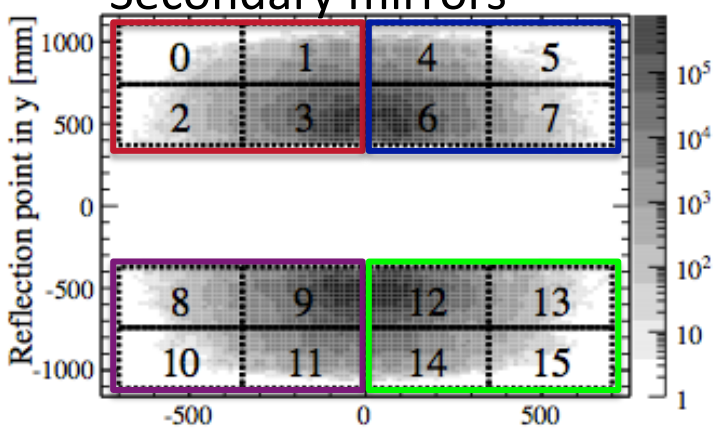



**RICH1**: easy!
**Given secondary mirror only receives photons from one primary mirror.**
➔ Only align secondary mirrors

Primary mirrors




Secondary mirrors



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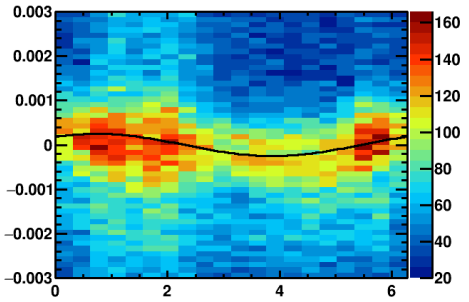
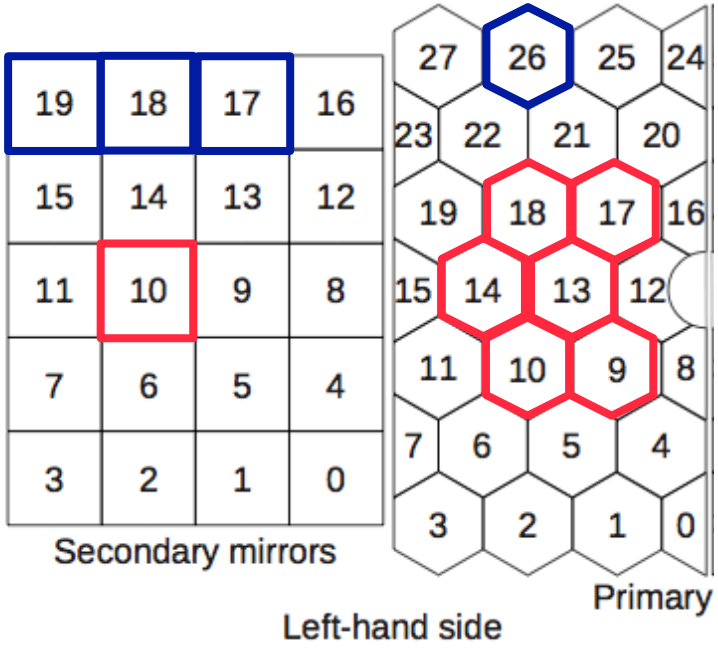
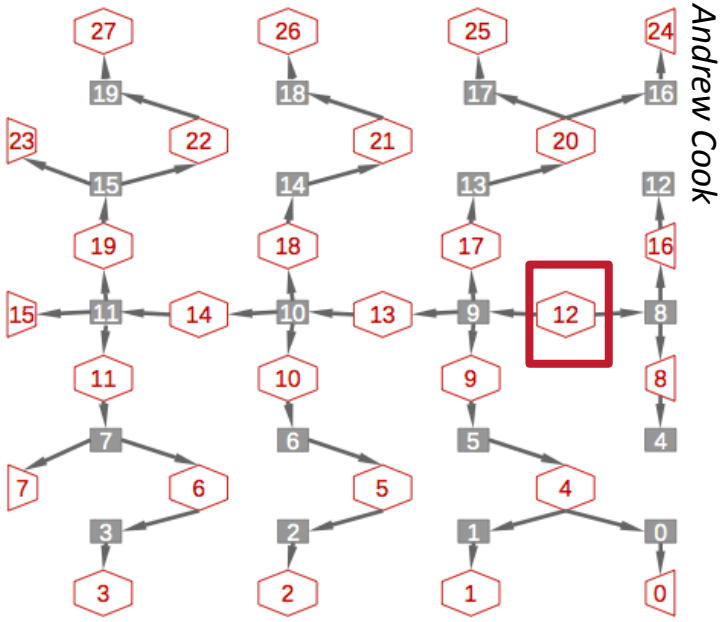



**RICH2**:
**Given secondary mirror can receive photons from several primary mirrors.**
System of equations linking all mirrors starting from primary mirror 12.



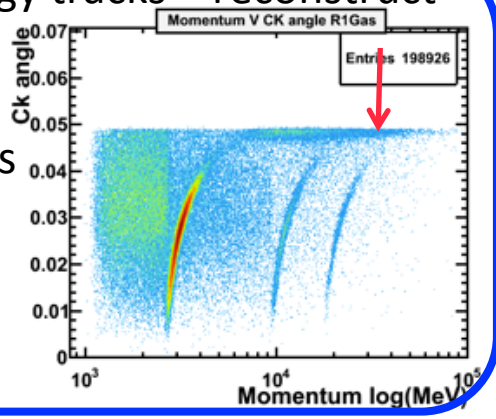



# Alignment procedure

Events

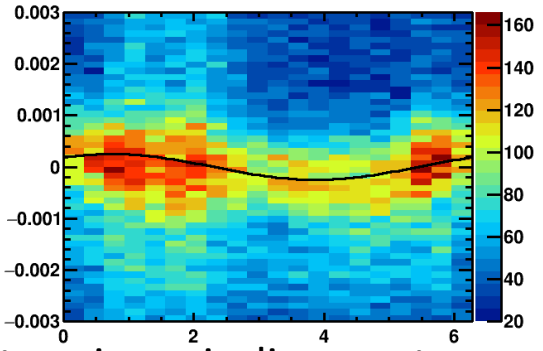
Default database

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

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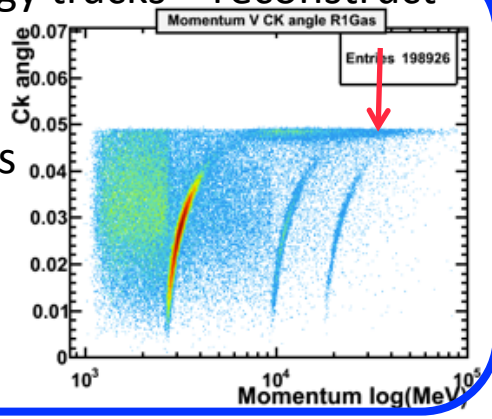


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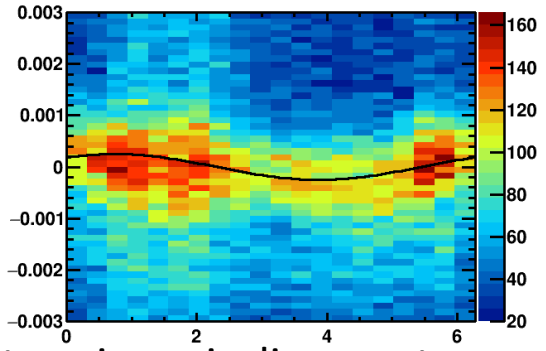


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| Z | | | |
|---|---|---|---|
| .2 | .3 | .3 | .3 |
| -.5 | -.3 | -.2 | -.6 |
| .6 | .1 | .1 | .5 |
| -.6 | -.1 | .6 | -.3 |

new database

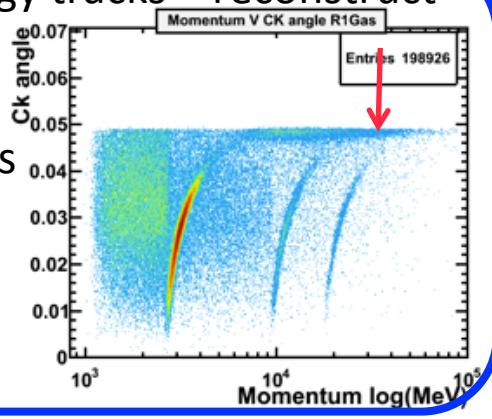
Any mirror moved > 0.1 mrad?

# Alignment procedure

Events

new database

High energy tracks + reconstruct under pion-hypothesis

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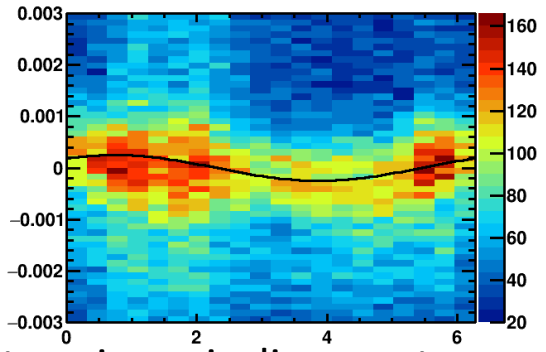
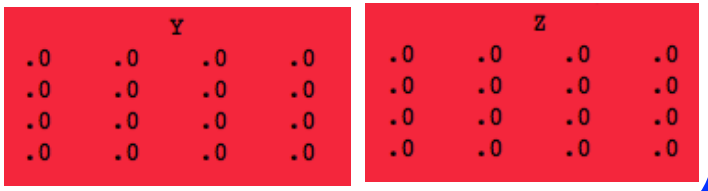



Determine misalignment on detector plane

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




new(er) database

**YES!**

# Alignment procedure

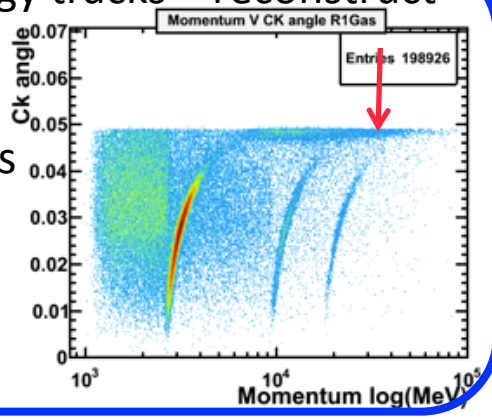
Events

new database

Any mirror moved > 0.1 mrad?

new(er) database

High energy tracks + reconstruct under pion-hypothesis

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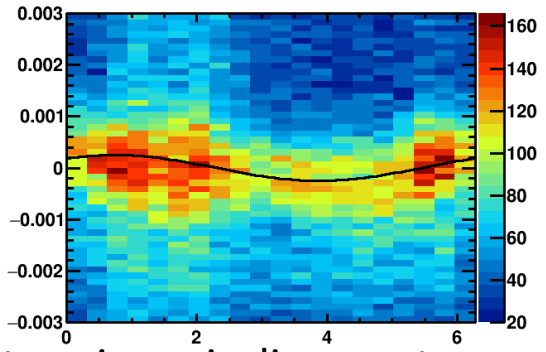
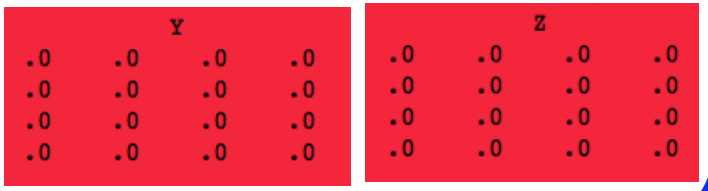



Determine misalignment on detector plane

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

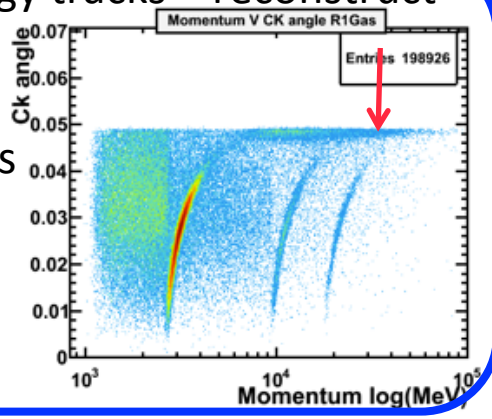


# Alignment procedure

Events

new database

High energy tracks + reconstruct under pion-hypothesis

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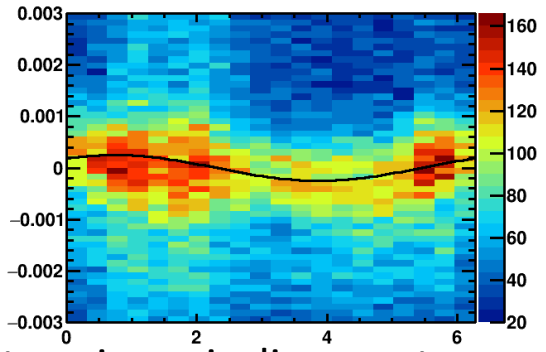
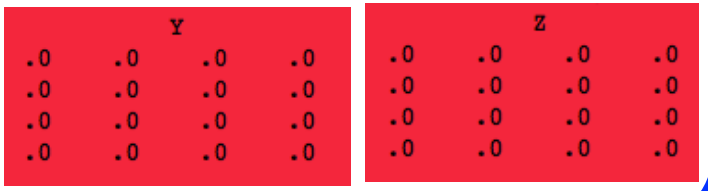



Determine misalignment on detector plane

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

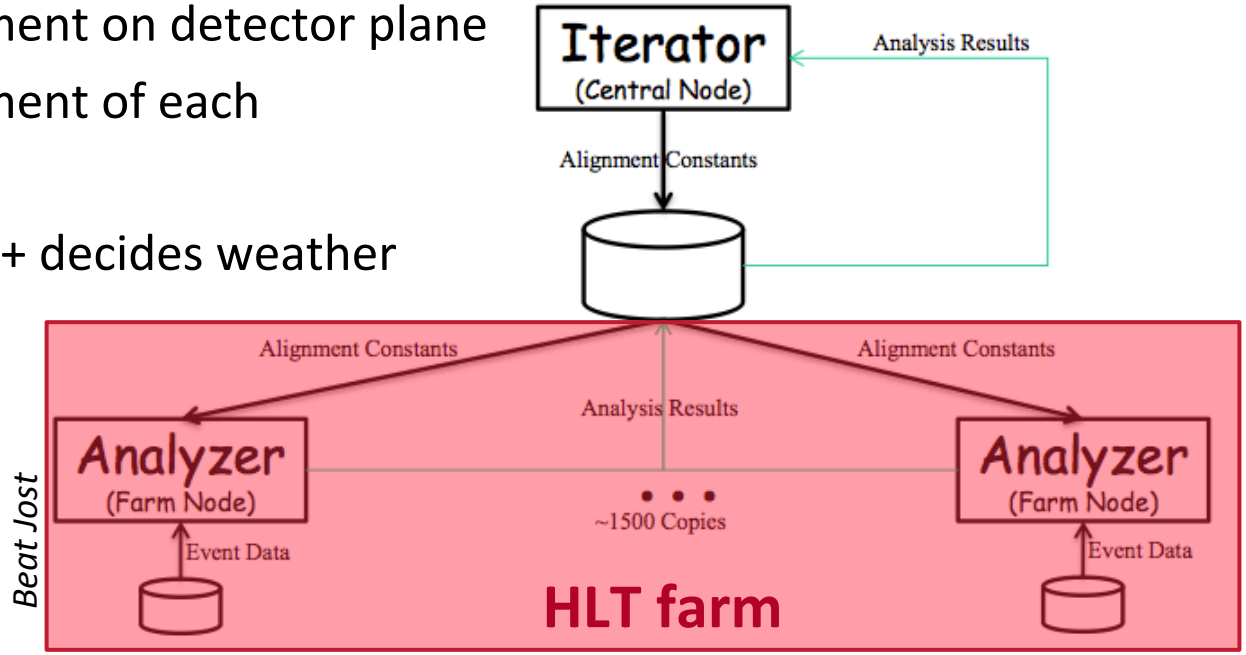
**Run II:**

- **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



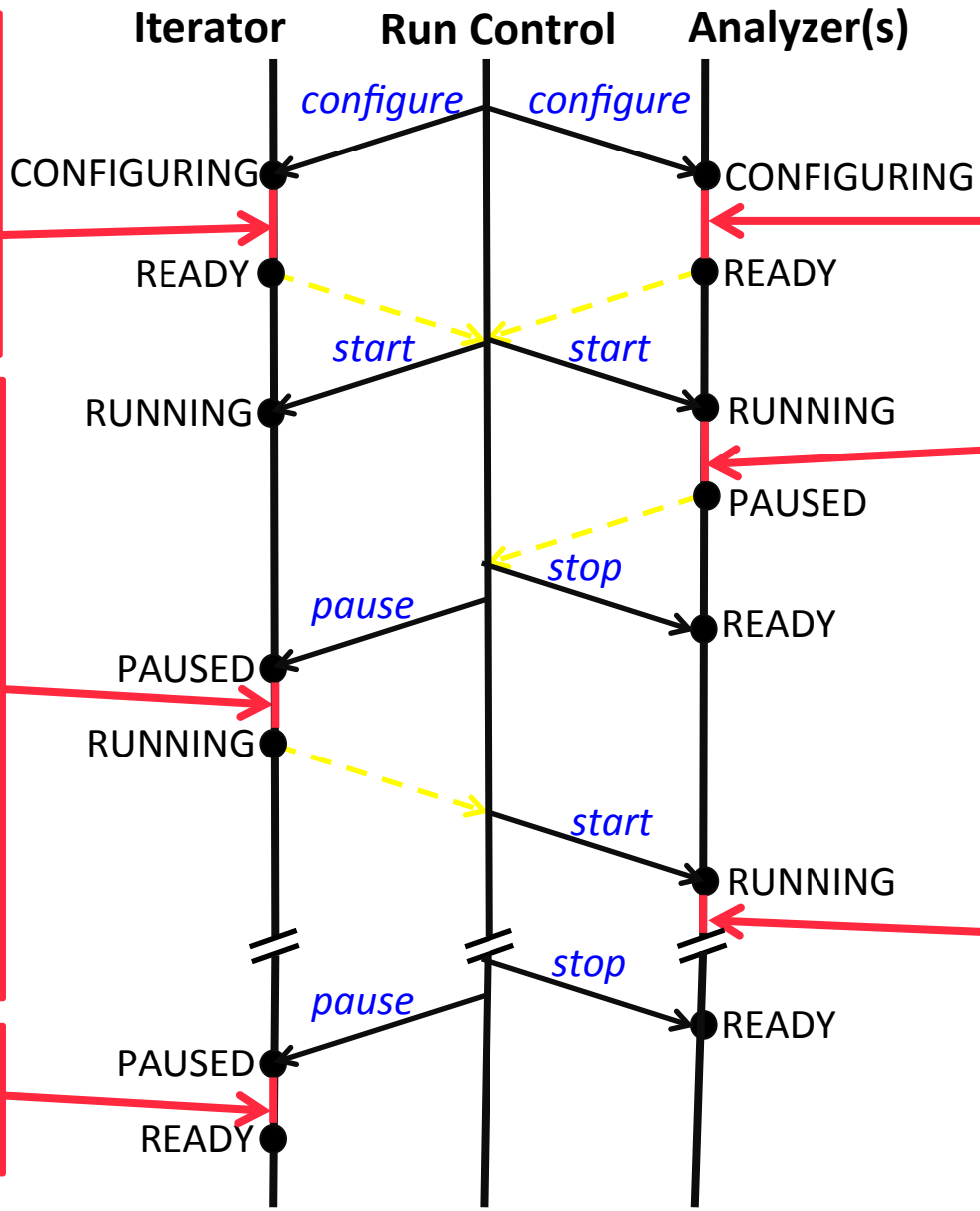
# Finite State Machine

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.

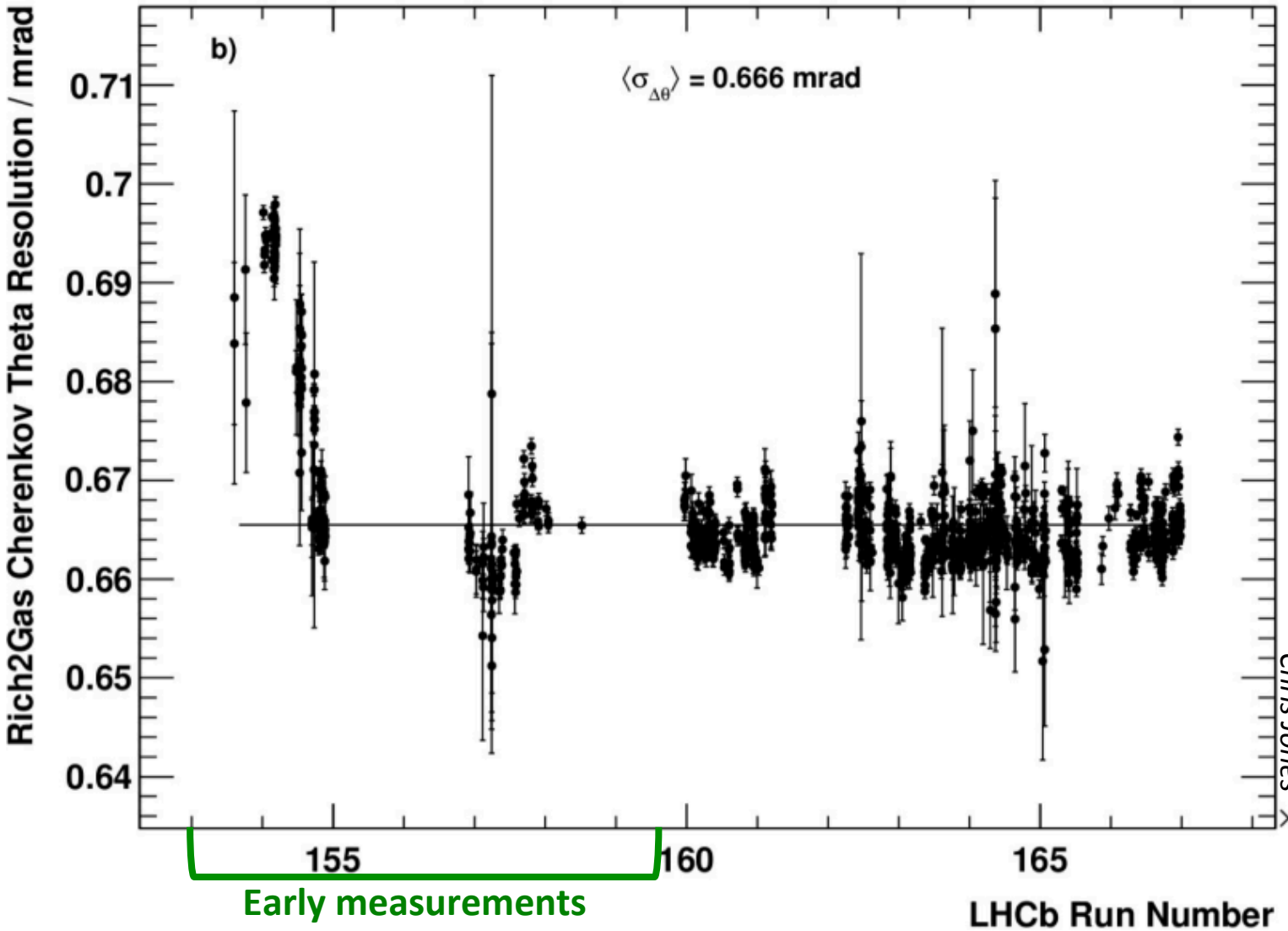
Reconstruct events and fill histograms.

Reconstruct events and fill histograms.

# Performance in Run II

# Performance – RICH2

## RICH2 Cherenkov Resolution Stability : 2015



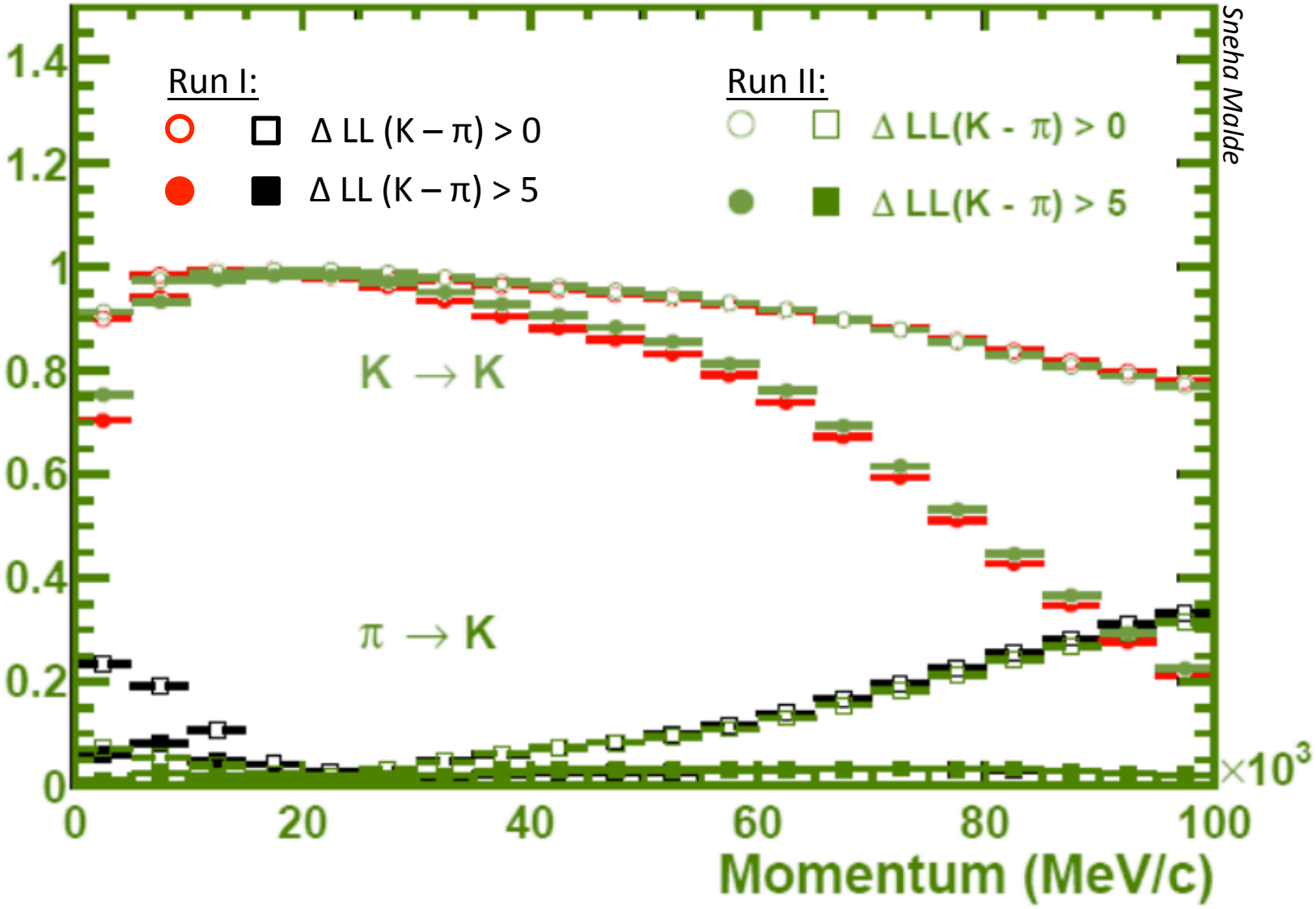

Run I:
$\langle\sigma_{\Delta\theta}\rangle$ ~ 0.665 mrad

**Run II average:**
**$\langle\sigma_{\Delta\theta}\rangle$ ~ 0.666 mrad**

# Performance – RICH1

Waiting for news from Chris.

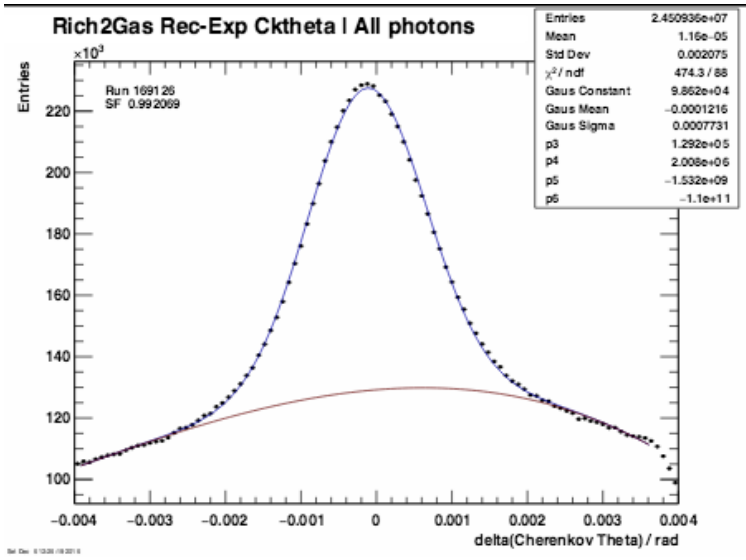
# PID Performance



# Maintenance and operation

# Calibrations

**Online calibrations at the end of each run.**

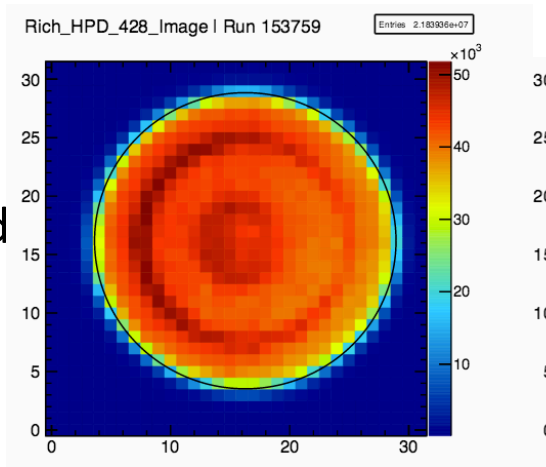


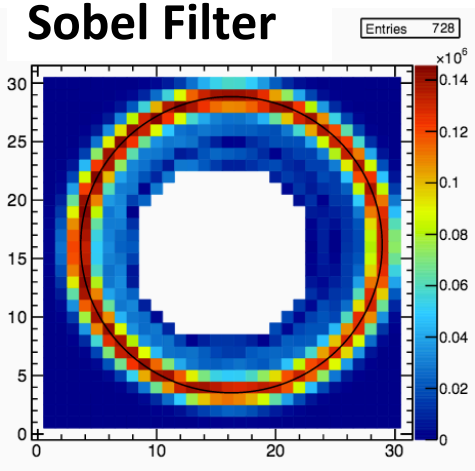

## Refractive Index Calibration:

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

## HPD images calibration:

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

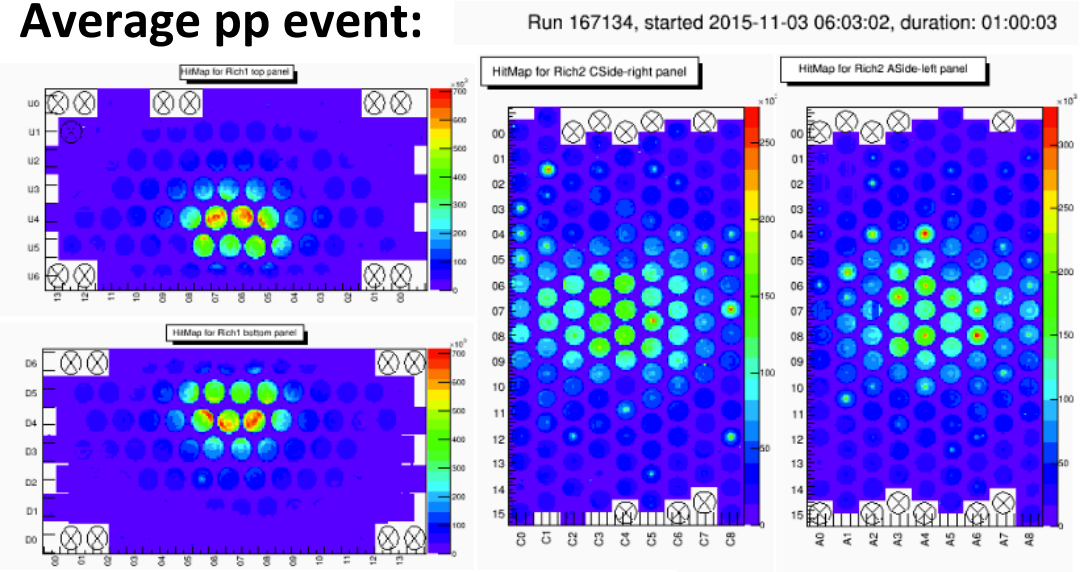


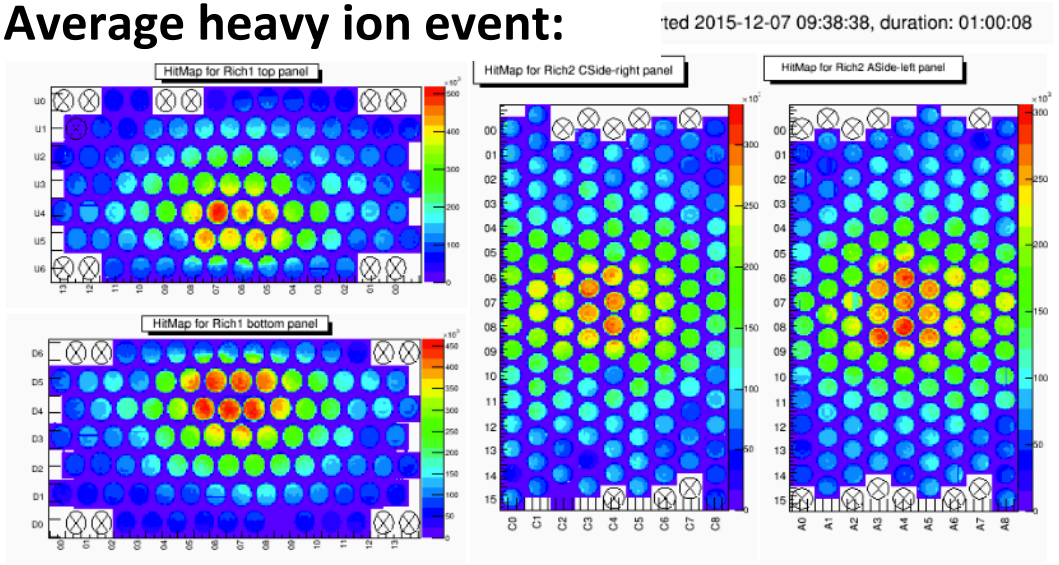
# Maintenance and Operation

- ~50% HPD 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 UKLO 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 can and will be run online for every fill
- RICH2 reached precision of Run I already

# Backup

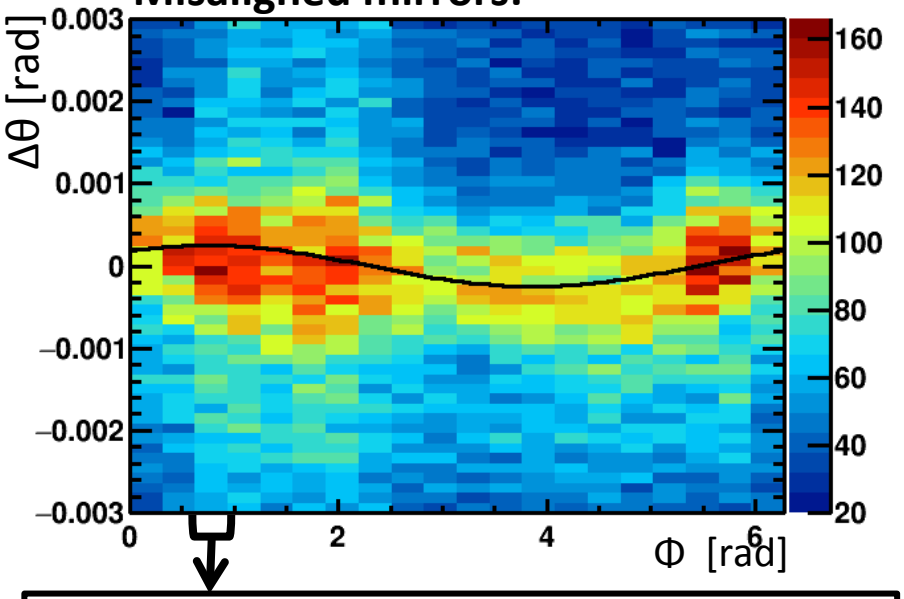
# Cherenkov angle resolution

Limiting factors to Cherenkov angle resolution:

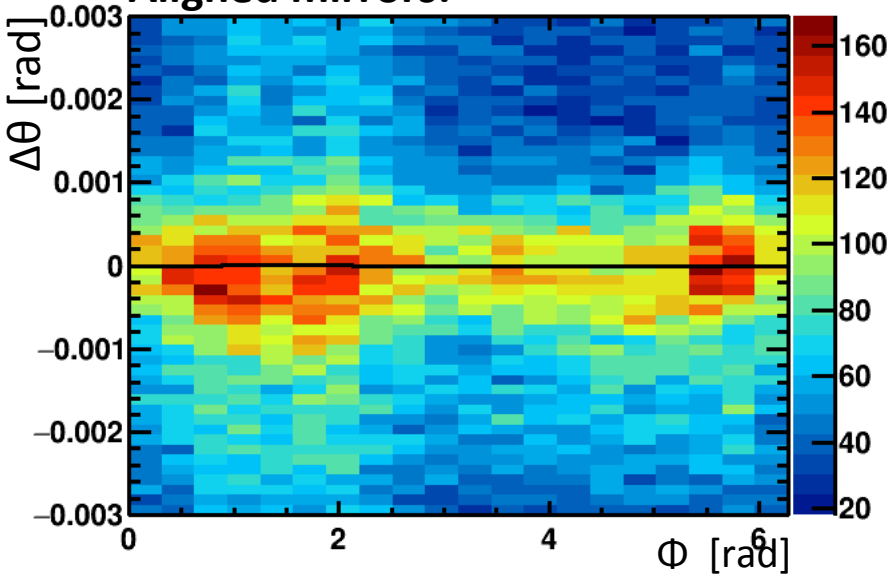
| | $\sigma$ [mrad] | | |
|---|---|---|---|
| | RICH1 | | RICH2 |
| | Aerogel | $C_4F_{10}$ | $CF_4$ |
| Emission point | 0.4 | 0.8 | 0.2 |
| Chromatic dispersion | 2.1 | 0.9 | 0.5 |
| Pixel size | 0.5 | 0.6 | 0.2 |
| Tracking | 0.4 | 0.4 | 0.4 |
| Total | 2.6 | 1.5 | 0.7 |

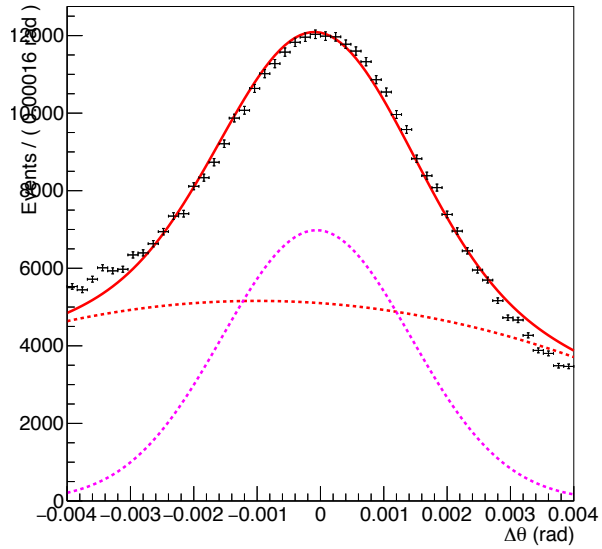
# Misalignment

**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 **&&** $\chi^2 < 2$ **&&** $2.59 < \eta < 2.97$
$(-2.69 < \Phi < -2.29)$ **||** $(-0.85 < \Phi < -0.45)$ **||**
$(0.45 < \Phi < 0.85)$ **||** $(2.29 < \Phi < 2.69)$

**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!**