

# RICH Detector Alignment at LHCb with 2009 Collision Data

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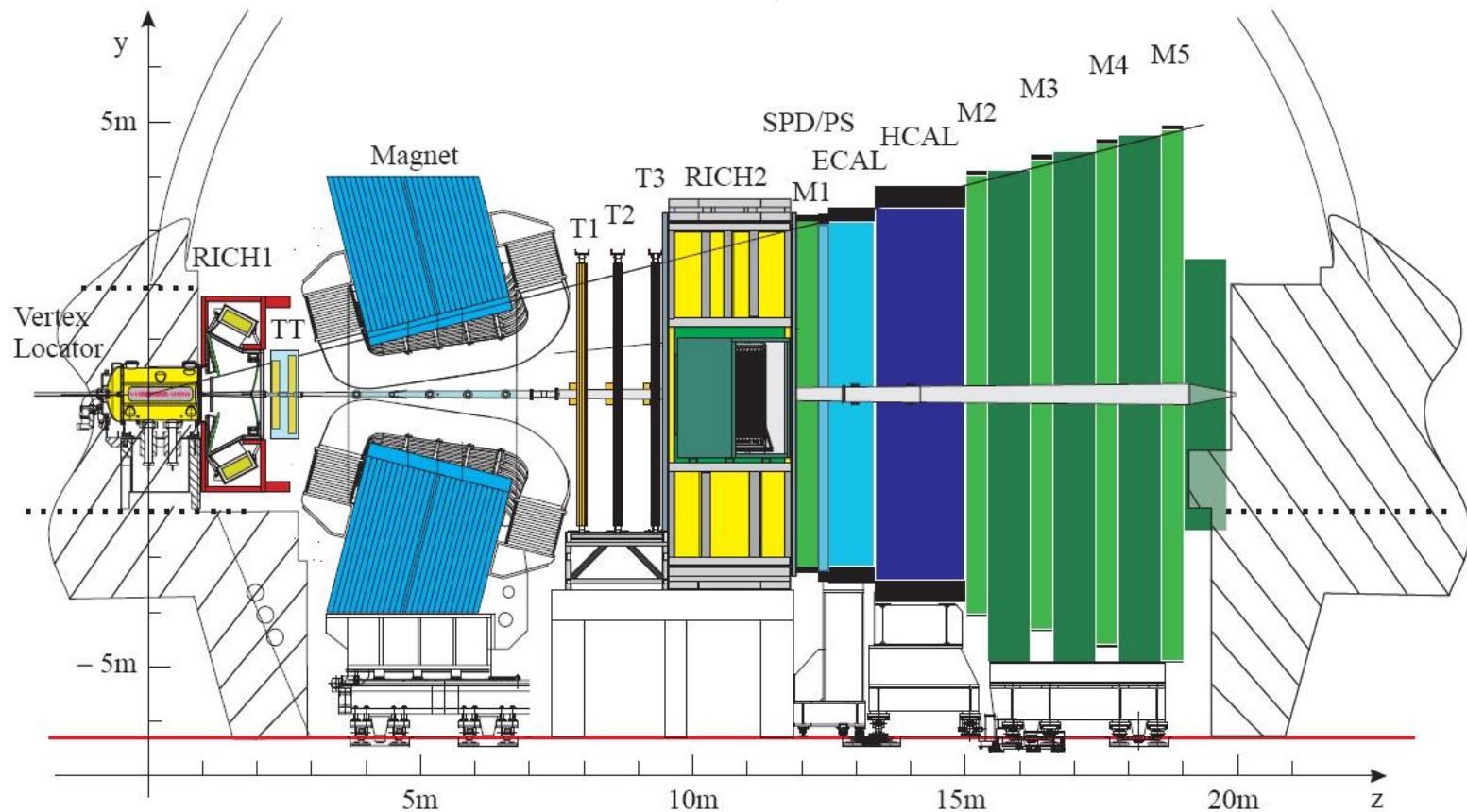
IoP 2010 at University College London

# Contents

- **Introduction to LHCb & its RICH detectors,**
- Misalignments of the RICH in theory & in practice,
- **A walkthrough of RICH alignment & latest results,**
- RICH PID performance,
- **Summary.**

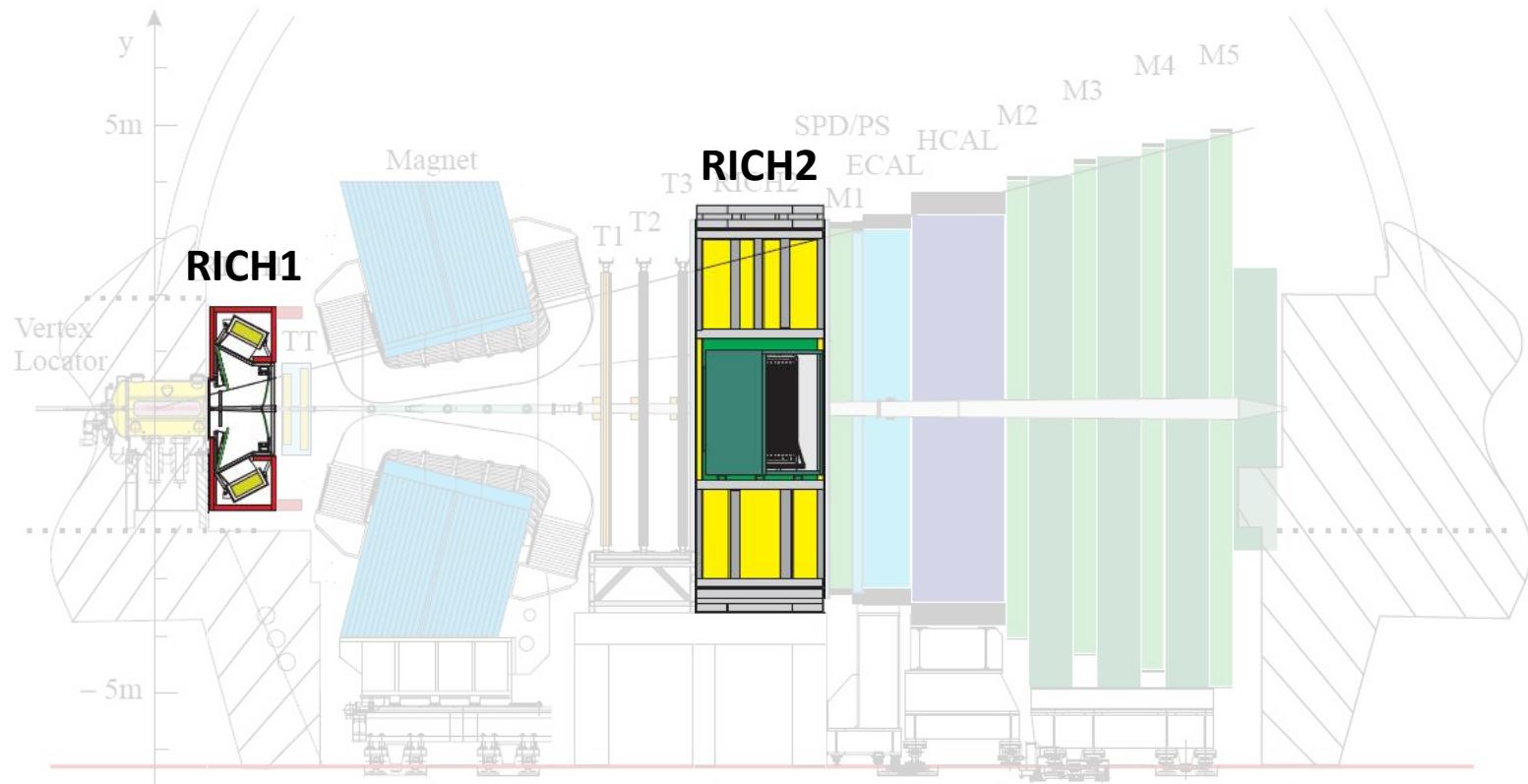
# The LHCb Experiment

A forward detector ( $2 < \eta < 5$ ) for precision measurement of CP violation and rare B-decays:



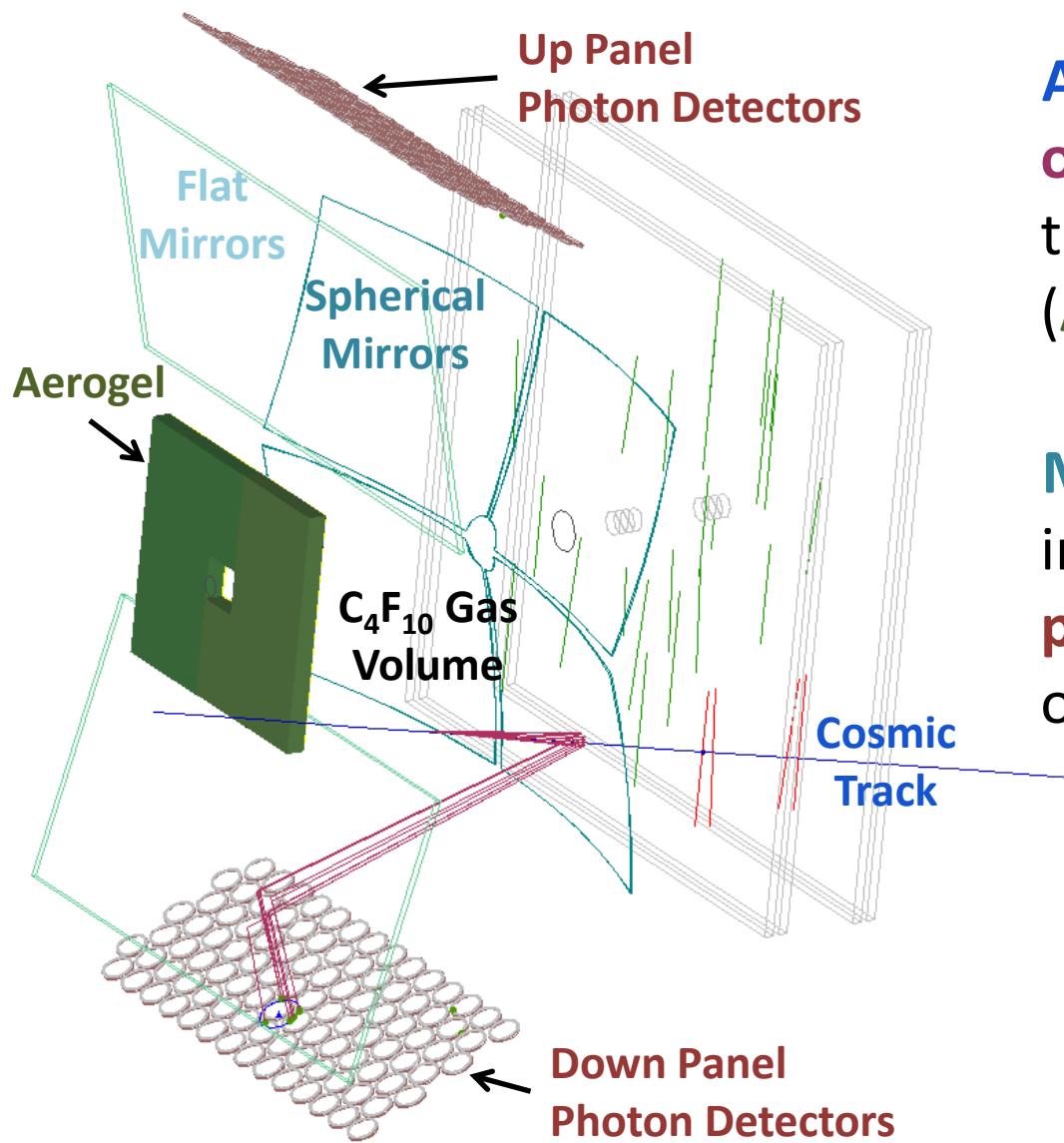
# The LHCb RICH Detectors

A forward detector ( $2 < \eta < 5$ ) for precision measurement of CP violation and rare B-decays:



2 RICH detectors distinguish charged particles by mass over a momentum range of 2 to  $\sim 100$  GeV/c.

# RICH1 in Detail



A charged track emits a cone of Cherenkov light on passing through the radiators (Aerogel &  $C_4F_{10}$  Gas),

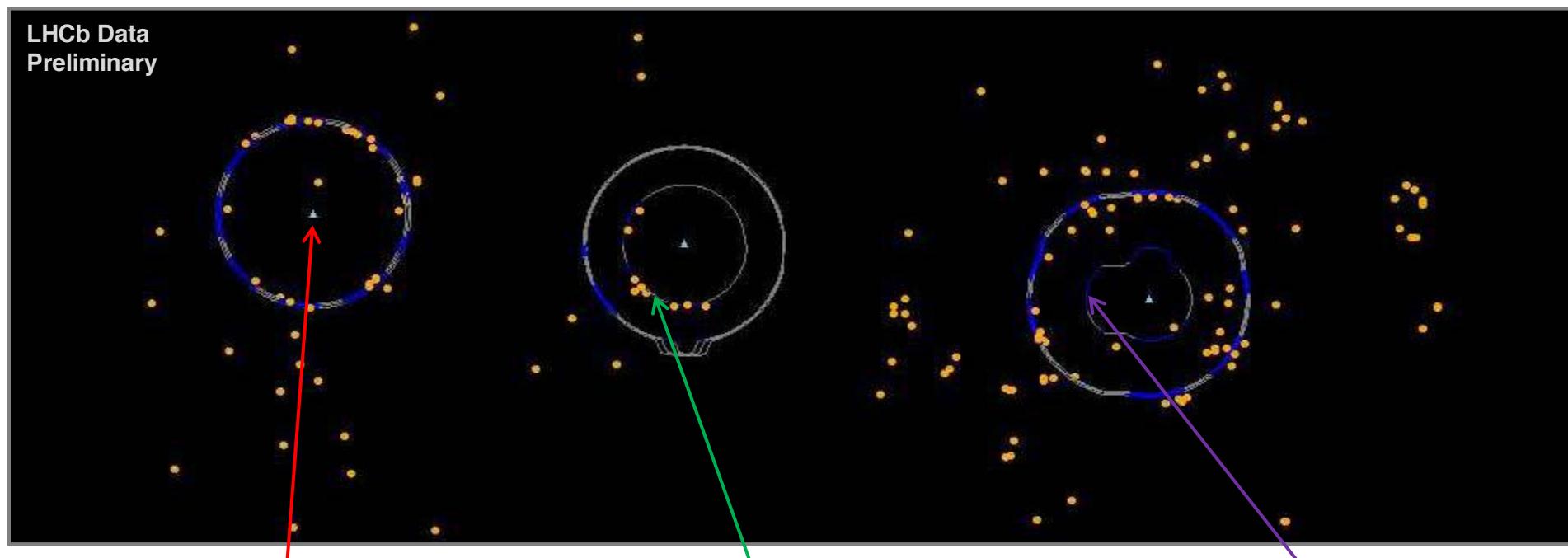
Mirrors focus these cones into rings on 2 banks of photon detectors positioned out of LHCb acceptance.

*Cosmic event display provided by S. Koblitz (CERN)*

# RICH1 Particle Identification

An event display from real data show “rings” projected on to the photon detector plane:

**Detector acceptance**



Saturated track:  
particle hypotheses  
indistinguishable

Photons clearly  
favour the Kaon  
ring hypothesis

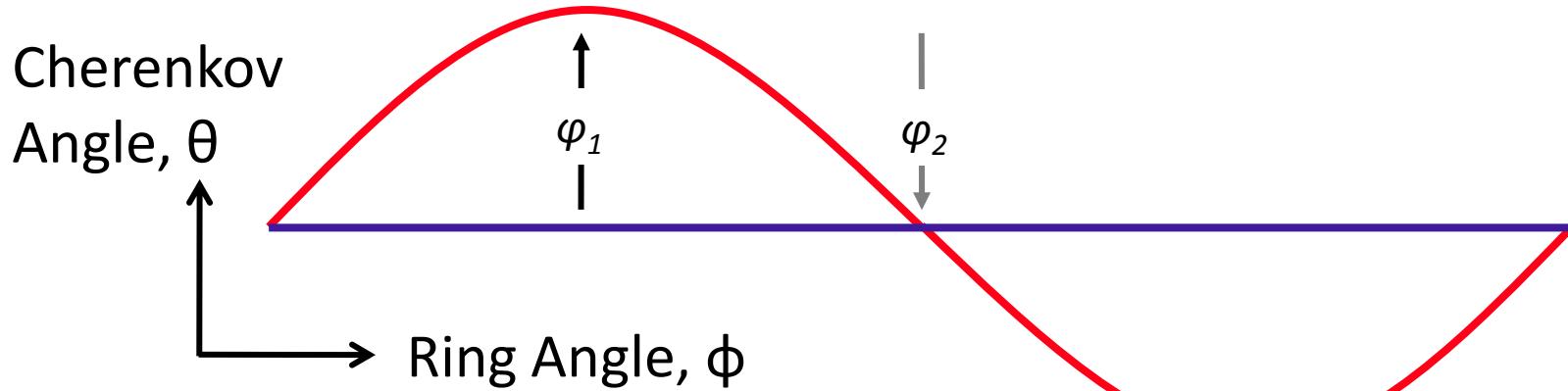
Ring distortions due to  
detector geometry

# RICH Misalignments

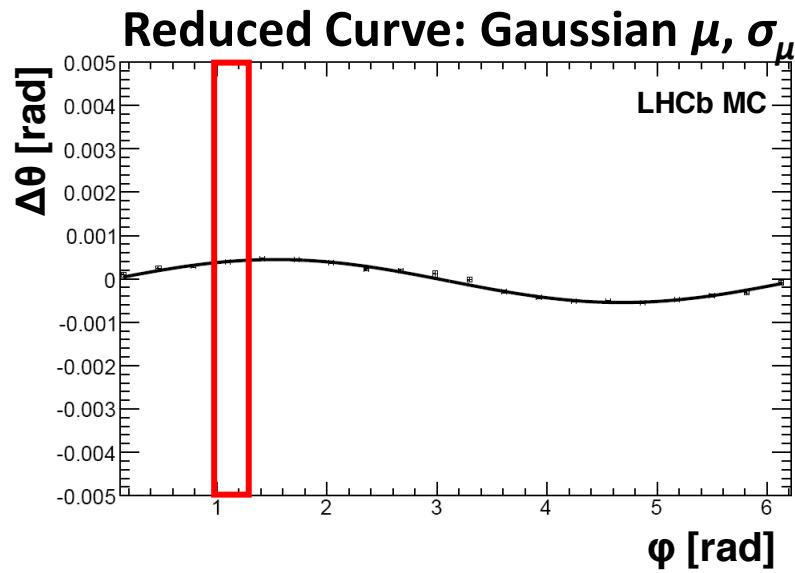
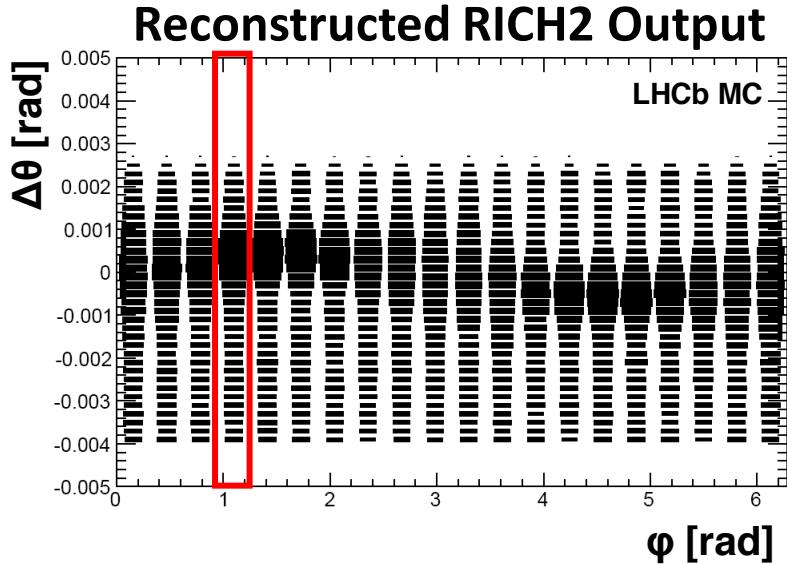
Misalignment is observed relative to tracking:



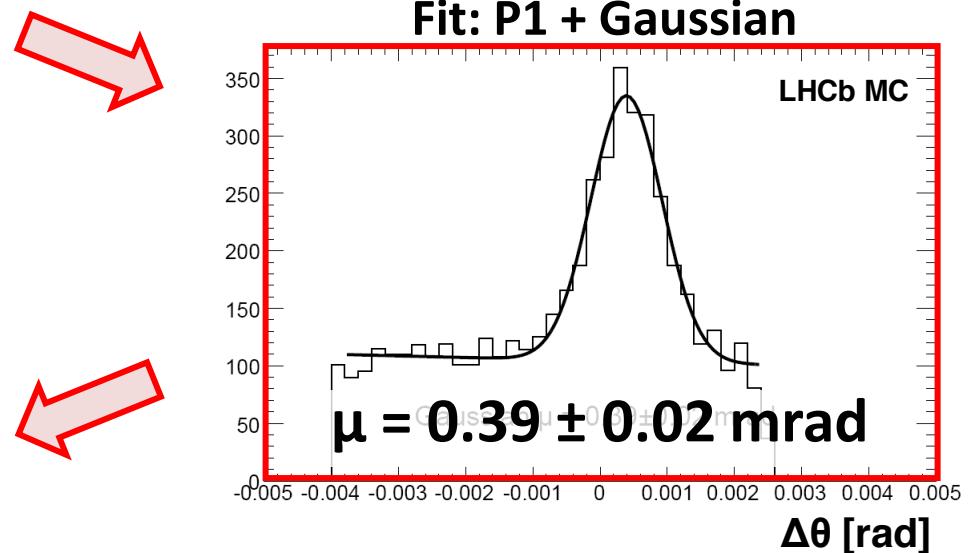
Seen as a distribution  $\Delta\theta = A\sin\varphi + B\cos\varphi$ :



# Fitting Procedure



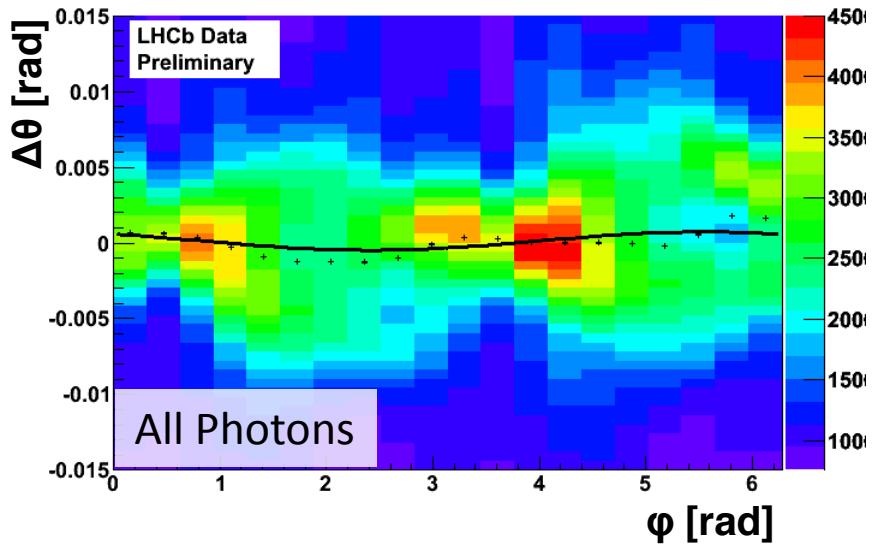
RICH output is split into bins of  $\varphi$  then fitted with Gaussian peak on a straight-line background,



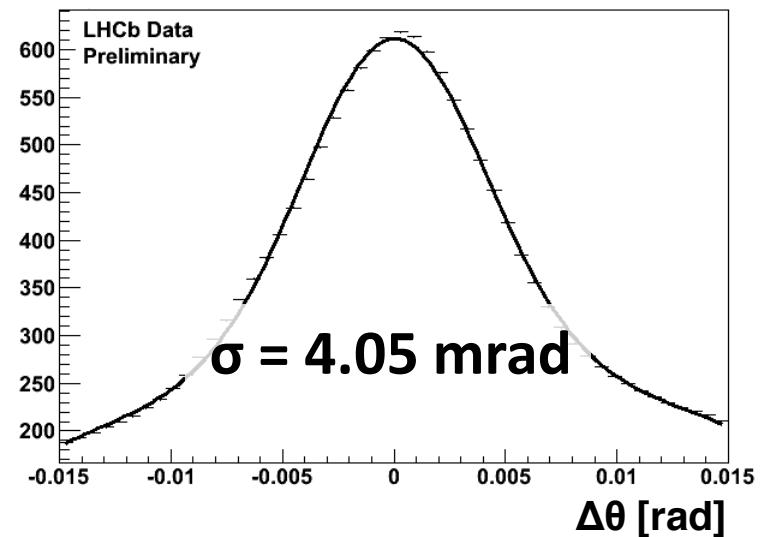
LHCb output re-plotted using Gaussian  $\mu$  and fitted with:

$$\Delta\theta = A\sin\varphi + B\cos\varphi$$

# Real Data from RICH1



**Total Resolution**

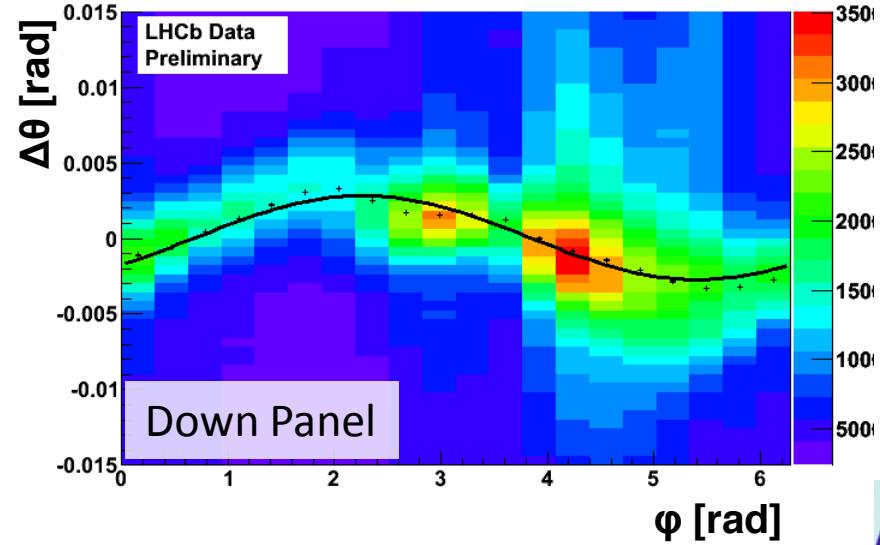
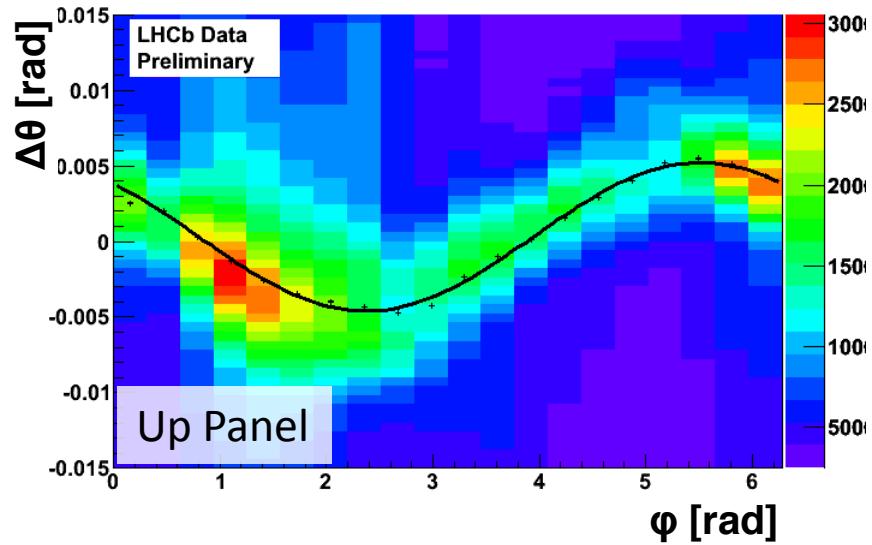
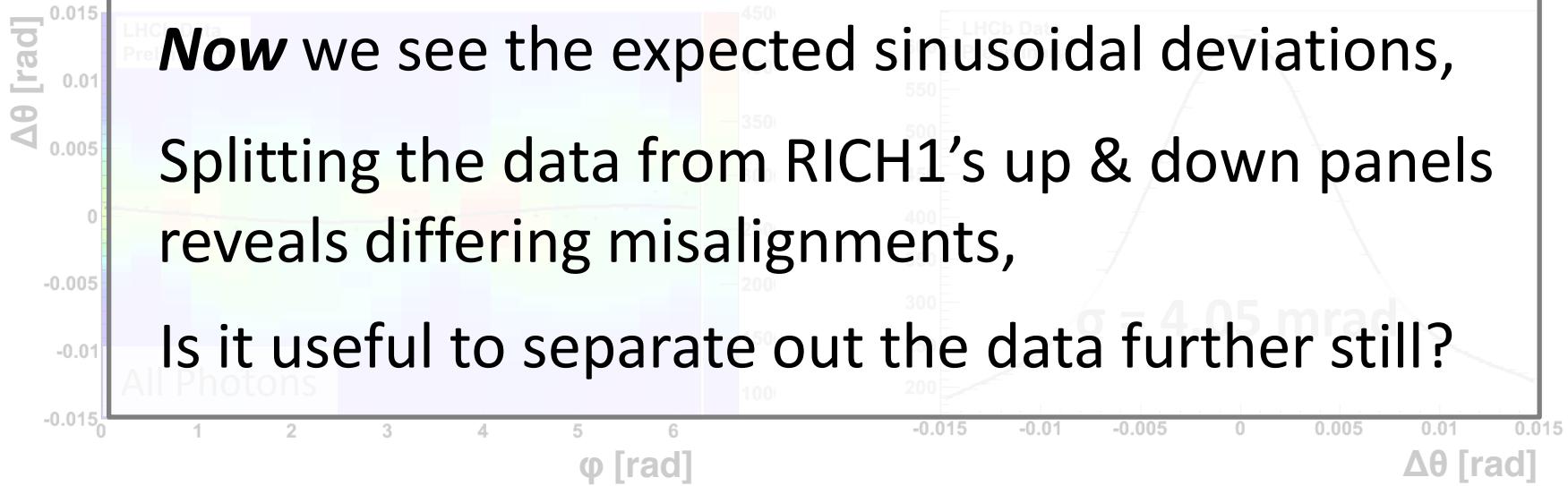


Without alignment, real data shows less than optimal resolution in RICH1 – we expected  $\sigma = 1.6$  mrad!

The  $\Delta\theta$  vs.  $\varphi$  alignment plot was not very helpful.  
Where is the expected sinusoidal deviation?

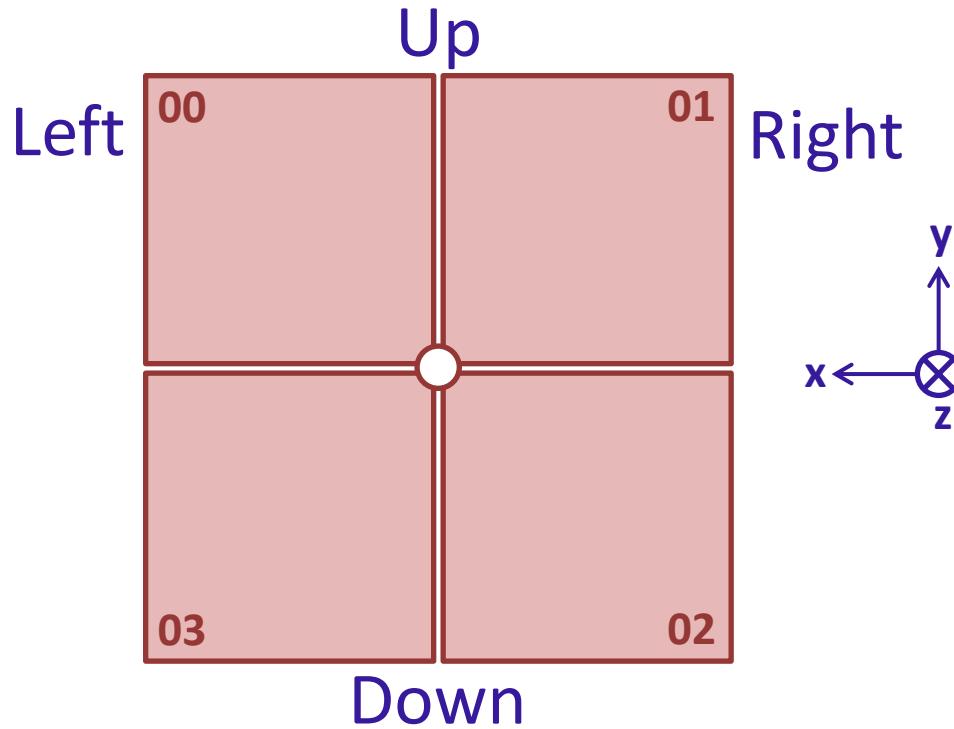
# Real Data from RICH1

**Now we see the expected sinusoidal deviations,  
Splitting the data from RICH1's up & down panels  
reveals differing misalignments,  
Is it useful to separate out the data further still?**

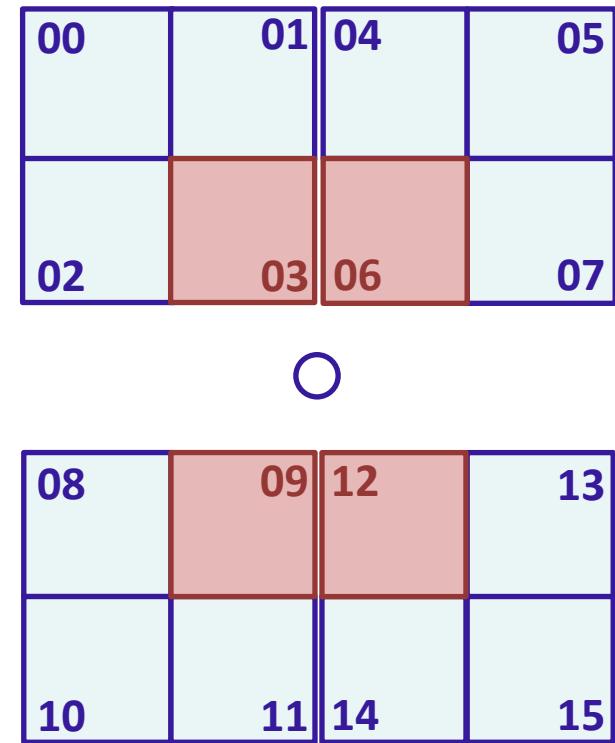


# RICH1 Mirror Configuration

## Spherical Mirrors

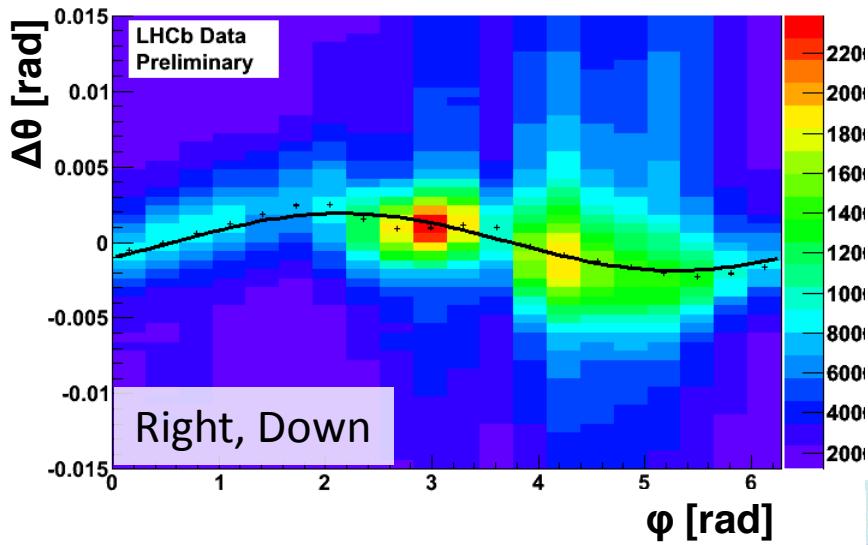
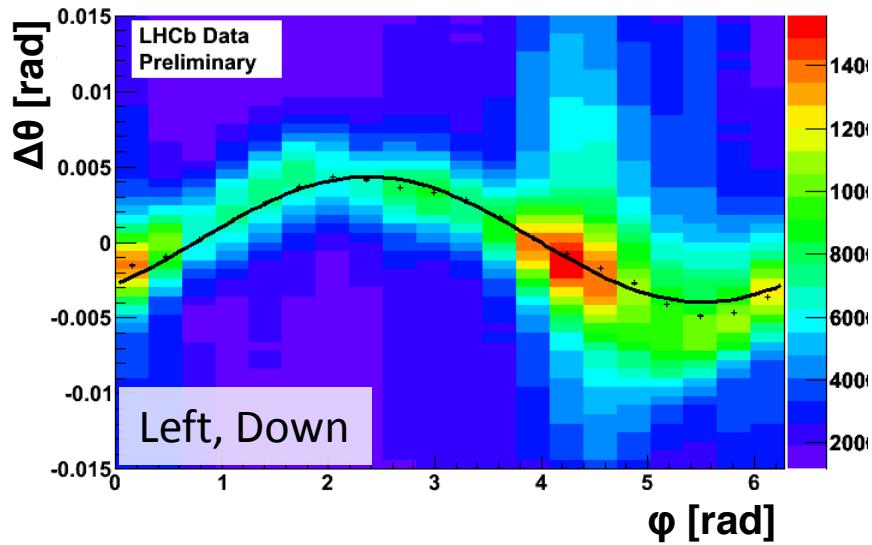
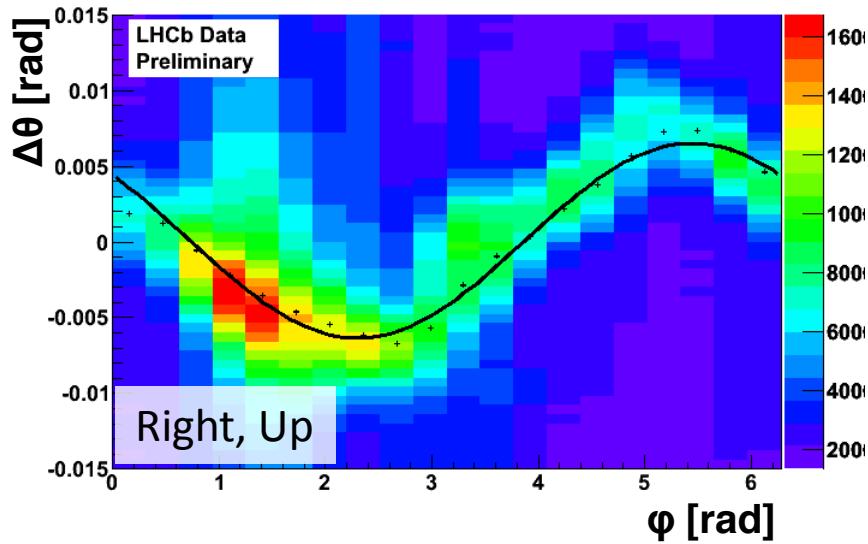
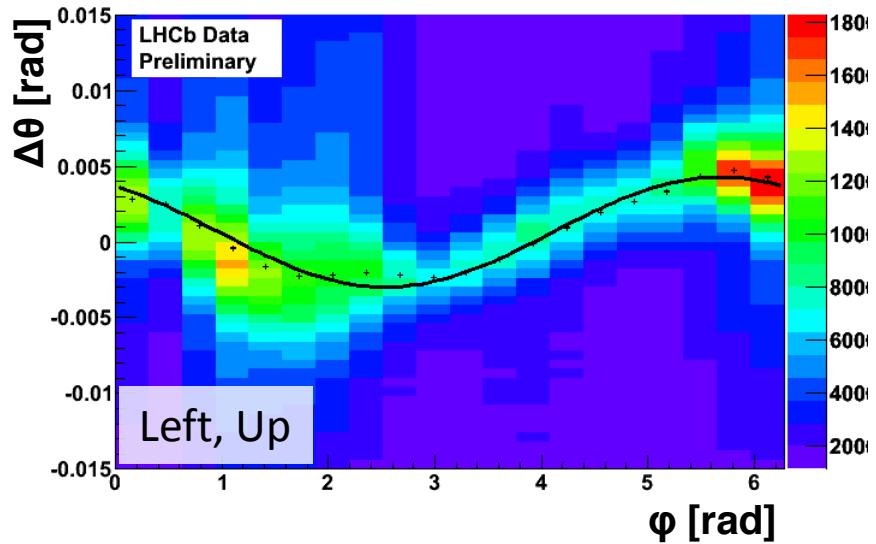


## Flat Mirrors



The **central flat mirrors** see >99% all selected photons.

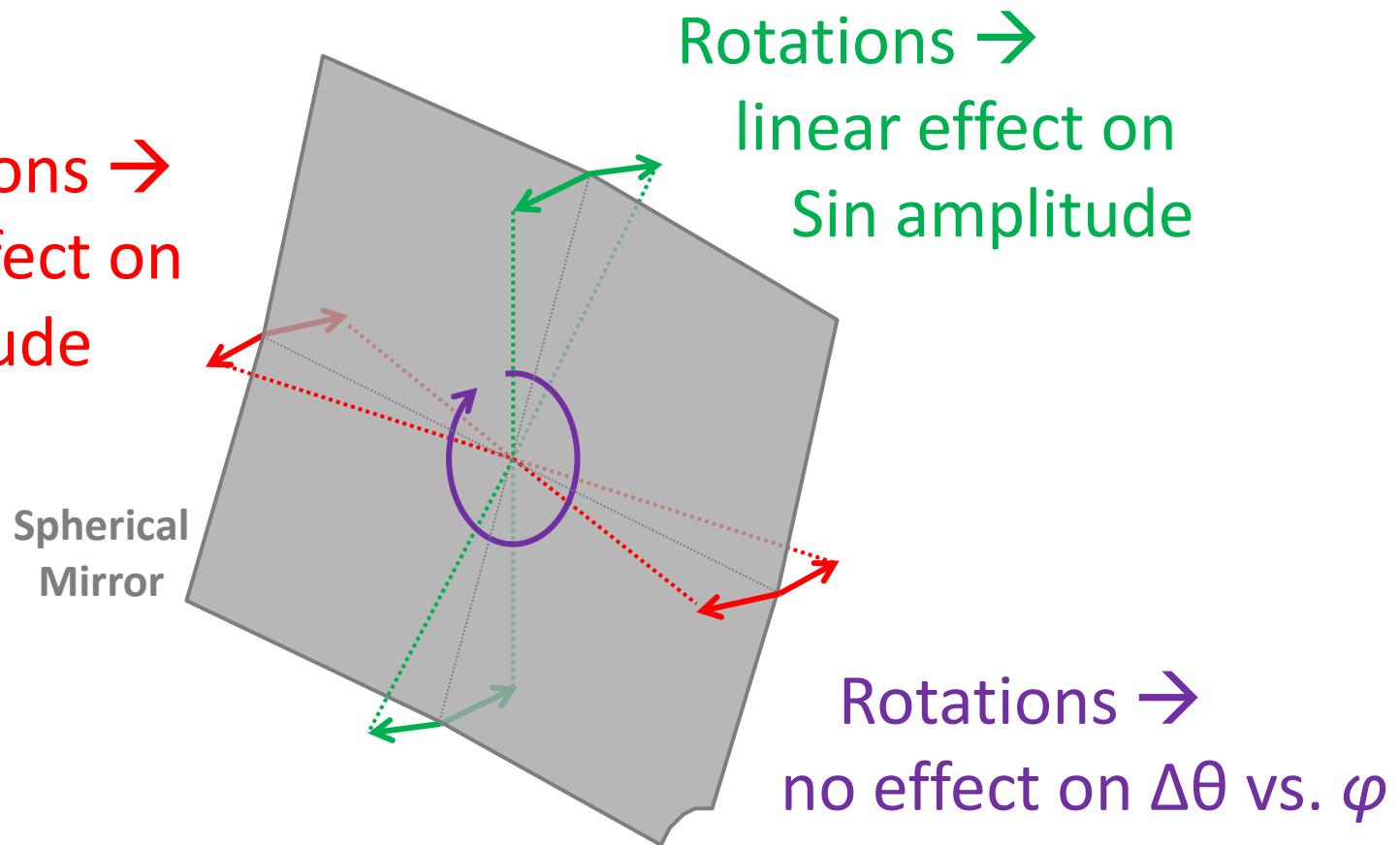
# RICH1 Misalignments by Quadrant



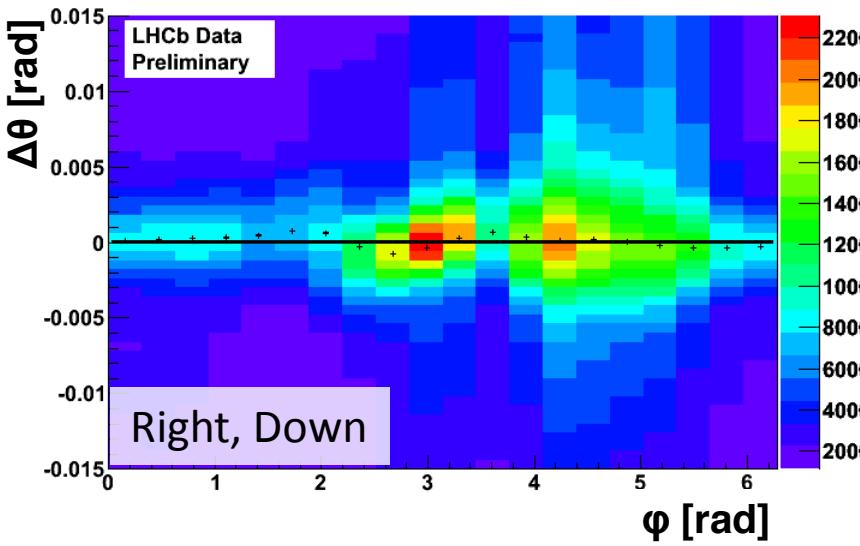
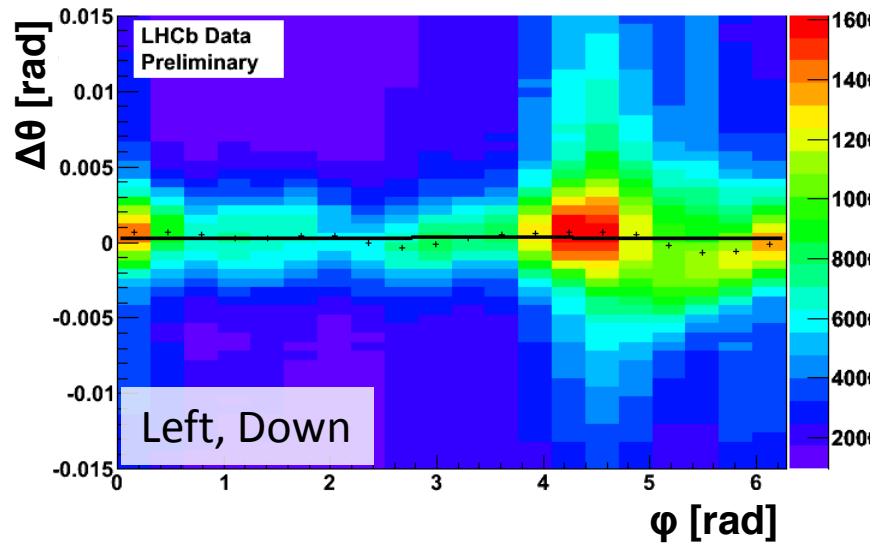
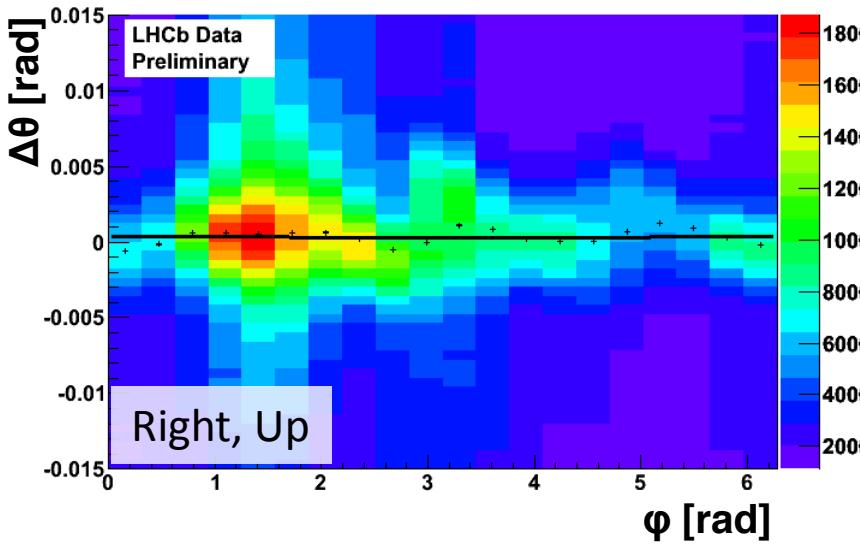
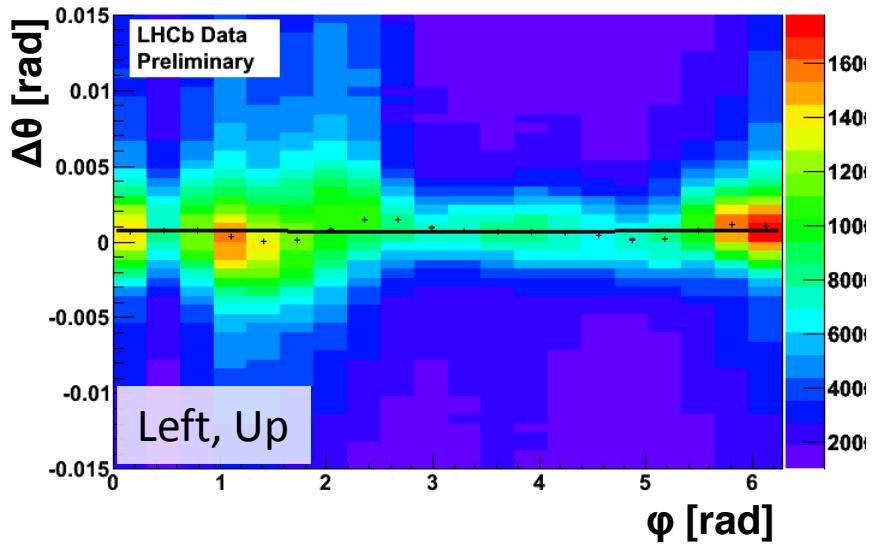
# Aligning RICH1 Spherical Mirrors

How do we compare mirror misalignment to our function:  
 $\Delta\theta = A\sin\varphi + B\cos\varphi$  ?

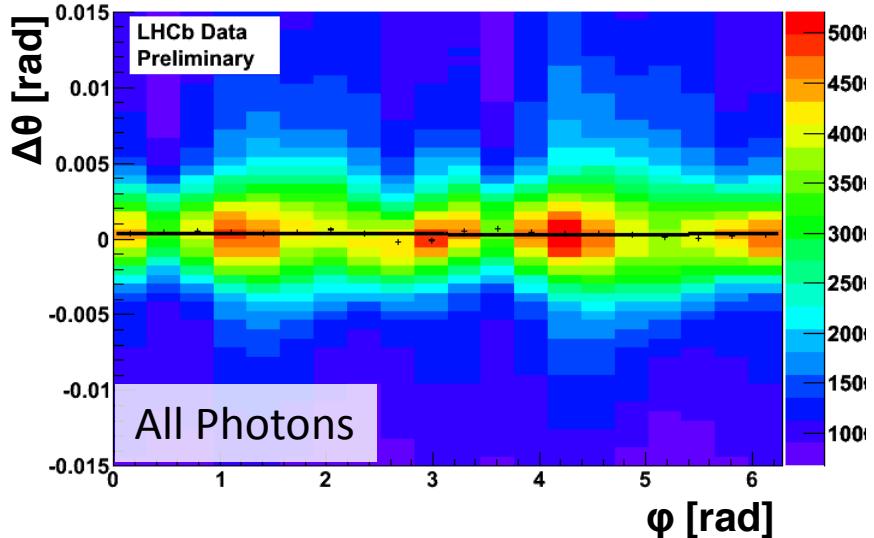
Rotations →  
 linear effect on  
 Cos amplitude



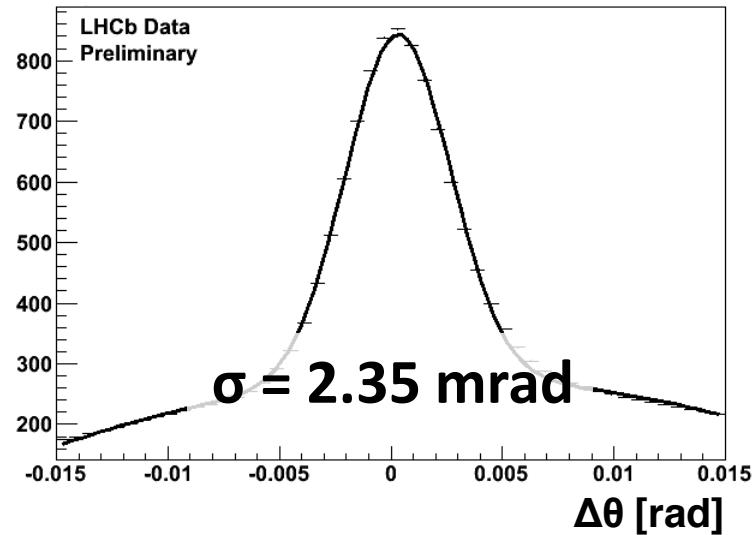
# RICH1 Spherical Mirrors Aligned



# Aligned Resolution RICH1



## Total Resolution



The latest MC production with data-like configuration:  
 $\sigma = 1.57 \text{ mrad}$ .

Corrections expected from survey:  
 $< 2 \text{ mrad}$ .

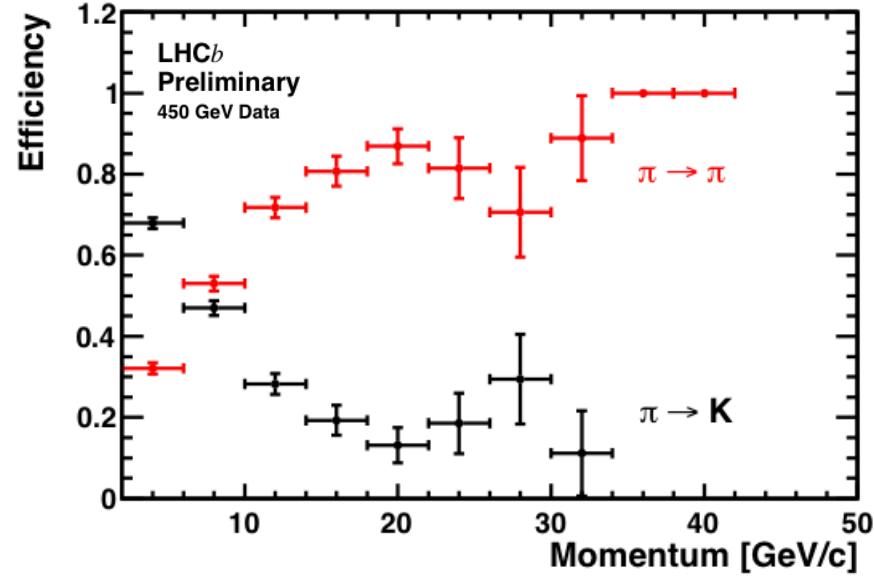
Correction	A, Up	C, Up
Local Ry	-1.45 mrad	-1.87 mrad
Local Rz	+1.22 mrad	+2.88 mrad
A, Down	C, Down	
+1.34 mrad	+0.43 mrad	
-1.78 mrad	-0.88 mrad	

# RICH Performance Improvement

The performance of the RICH system is measured by its efficiency at separating between charged particle species, e.g.  $\pi$  vs.  $K$ :

This example plot shows the efficiency of  **$\pi$  identification**

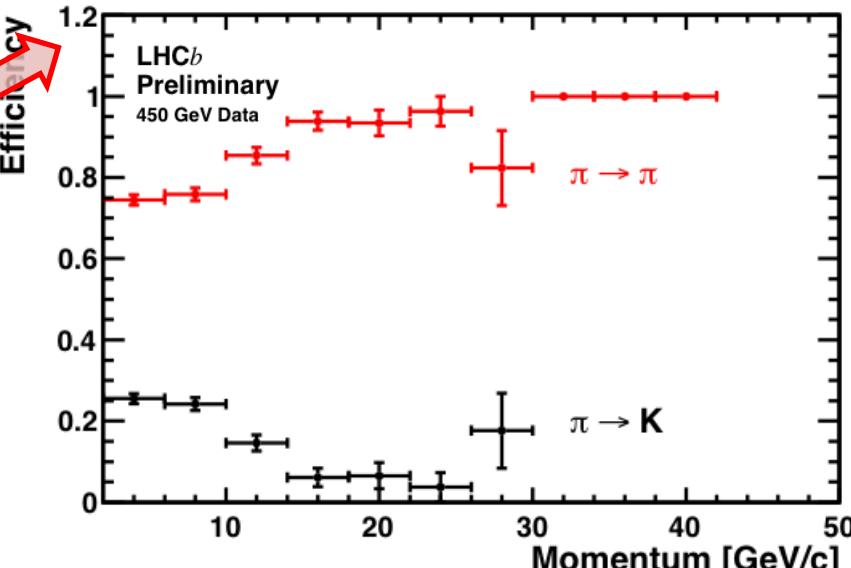
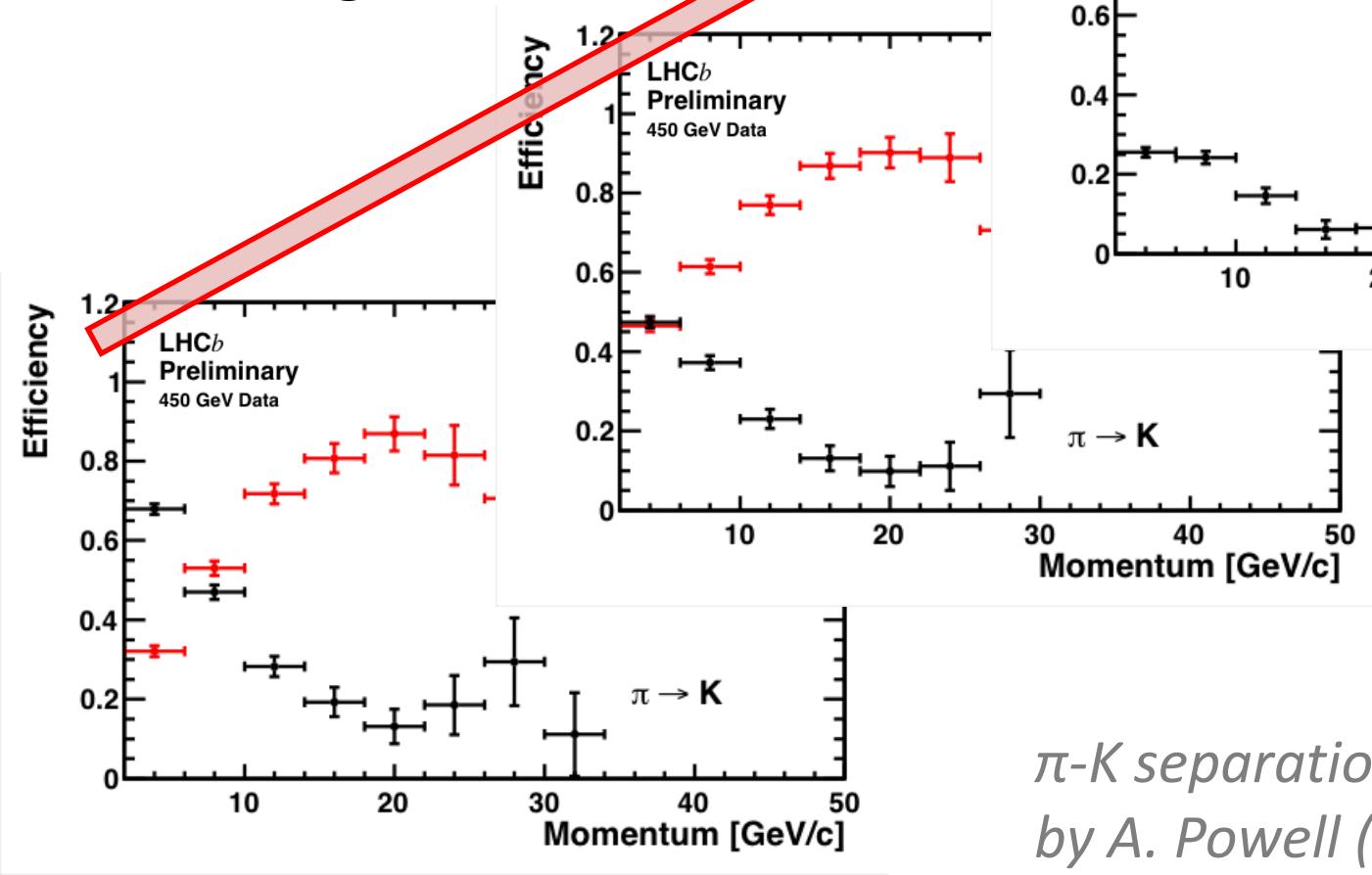
& misidentification as a  $K$   
(considering only these two possible hypotheses)  
for known  $\pi$  selected from  $K_S$  decays in data.



*$\pi$ -K separation plot provided  
by A. Powell (Oxford)*

# RICH Performance Improvement

Better Tracking Alignment,  
Magnetic field corrections,  
& RICH Alignment.



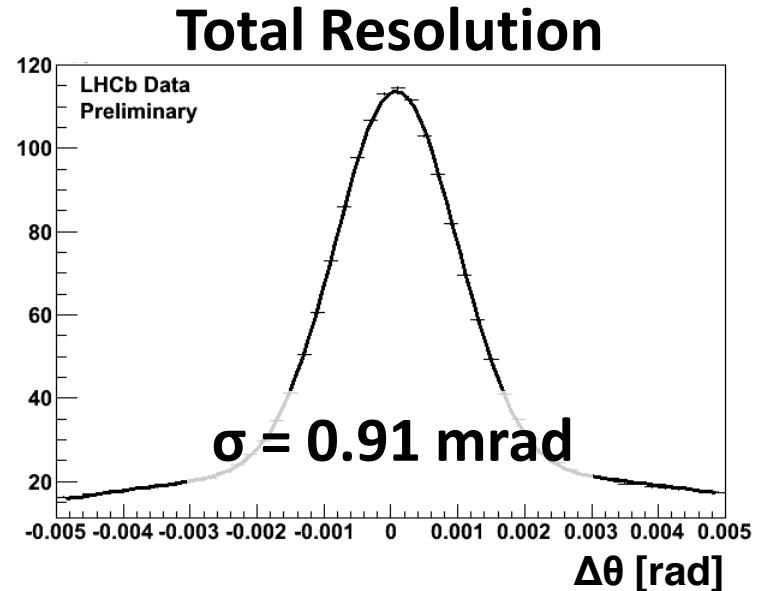
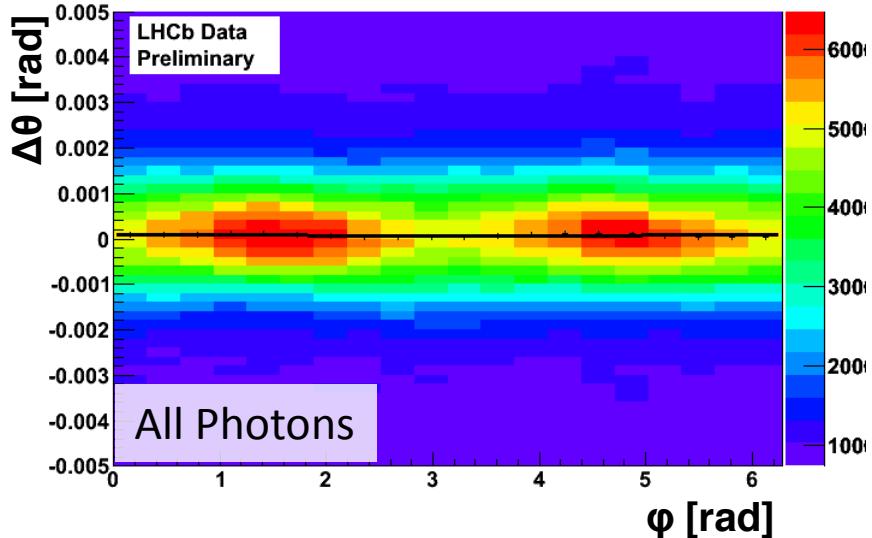
$\pi$ -K separation plots provided  
by A. Powell (Oxford)

# Summary

- LHCb finally took collision data last year,
- Fitting & alignment strategies developed on MC were successfully applied to real data,
- RICH alignment has greatly contributed to improved PID performance,
- There is still room for improvement and more work to be done,
- RICH improvements are just one example of our evolving understanding at LHCb,
- New data is just around the corner.

# Back up

# Aligned Resolution RICH2



The latest MC production with data-like configuration:  
 $\sigma = 0.67 \text{ mrad}$ .

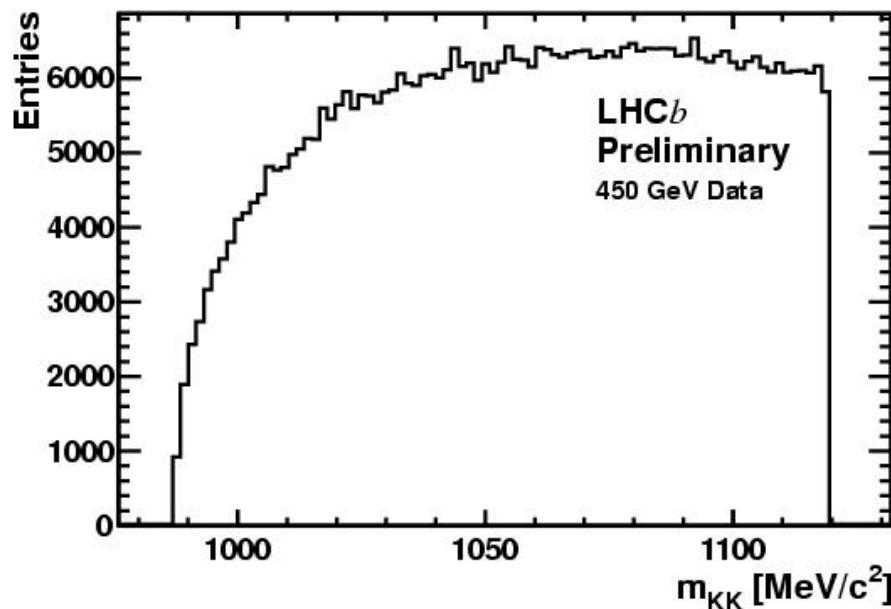
Corrections expected from survey:  
 $< 2 \text{ mrad}$  or  $< 3 \text{ mm}$ .

Correction	RICH2	
Local Rx	-0.68 mrad	
Local Ry	1.27 mrad	
Correction	A	C
Local Tx	-3.16 mm	4.05 mrad
Local Ty	-0.90 mm	-0.72 mrad

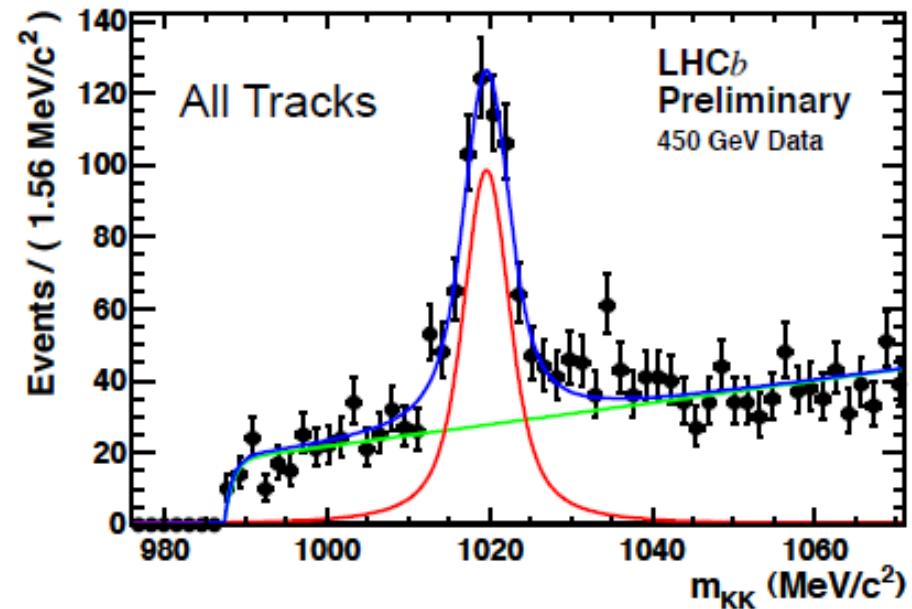
# RICH Performance Improvement

With RICH improvements, LHCb can now find  $\phi \rightarrow KK$ :

**Track-based Selection**



**Added K-PID Cut from RICH**

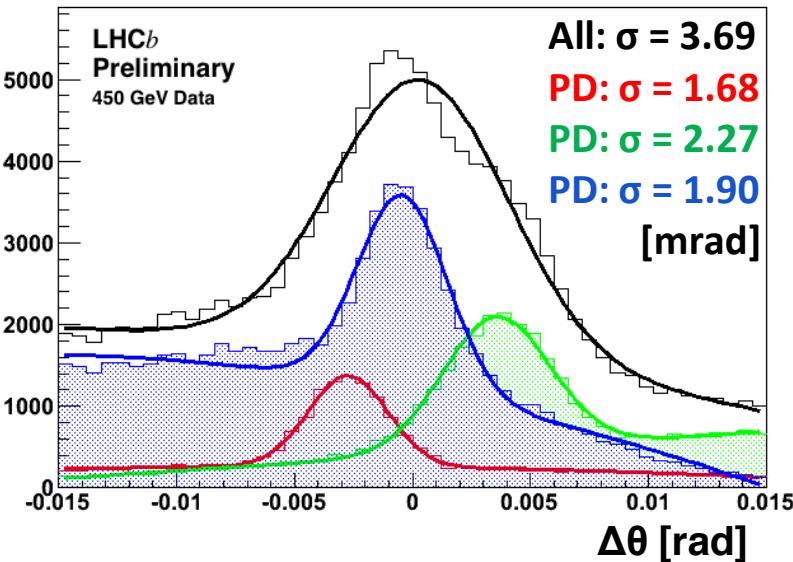


$\phi \rightarrow KK$  selection plots provided by A. Powell (Oxford)

# Where next?

Despite improvement from alignment, RICH resolution is far from MC prediction: **RICH1**  $2.35 > 1.57$  mrad  
**RICH2**  $0.91 > 0.67$  mrad

Sph1 Flt6  $\phi$ -bin 10 of 20



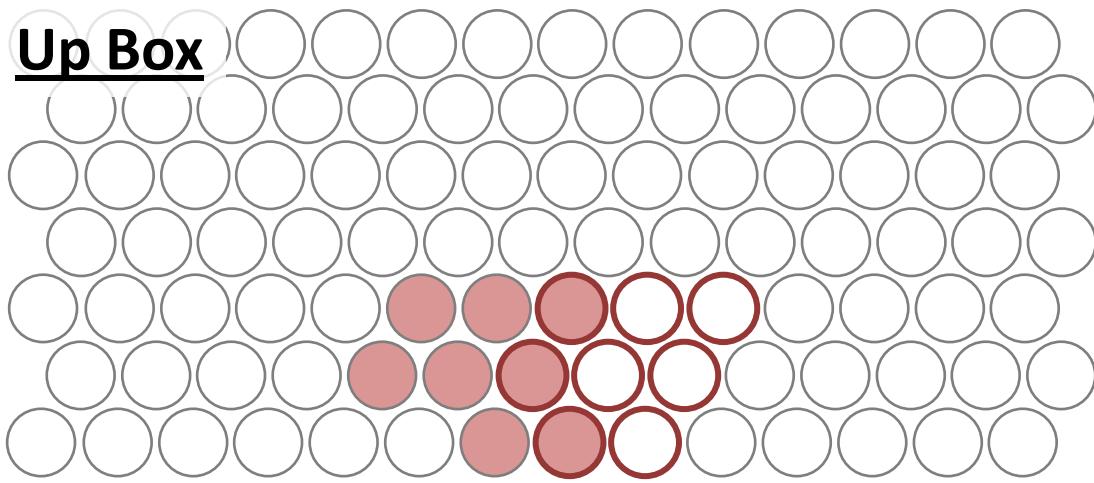
The key may already be found:  
Mirror-aligned RICH1 data shows a misalignment between photon detectors (*in one  $\varphi$ -bin*).

The RICH group expects improved alignment with more data.

# Which HPDs Do We See?

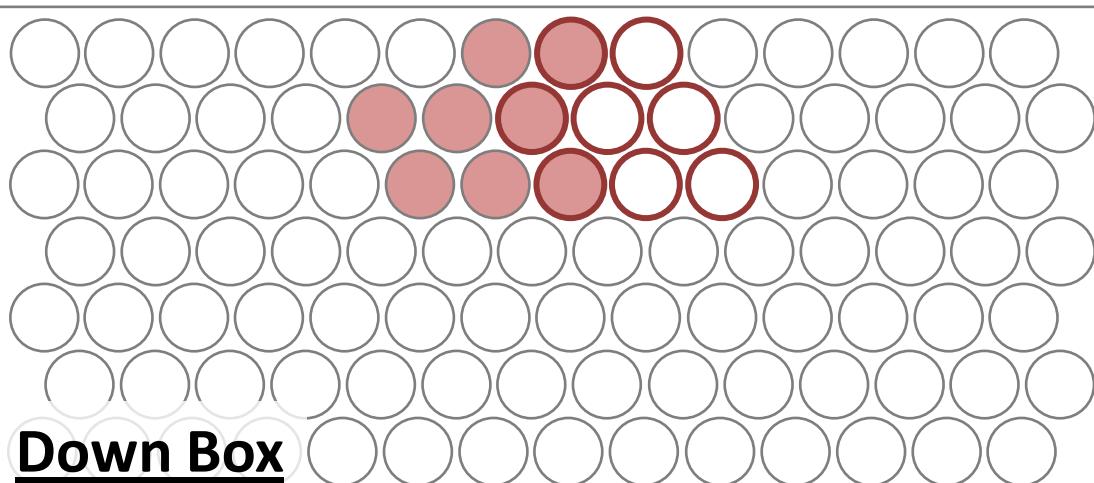
13 12 11 10 9 8 7 6 5 4 3 2 1 0

**Up Box**



0  
1  
2  
3  
4  
5  
6  
7  
6  
5  
4  
3  
2  
1  
0

**Down Box**



13 12 11 10 9 8 7 6 5 4 3 2 1 0

A threshold of 15K photons gives a Top 8 HPDs per mirror pair and includes 98%  $\gamma$ .

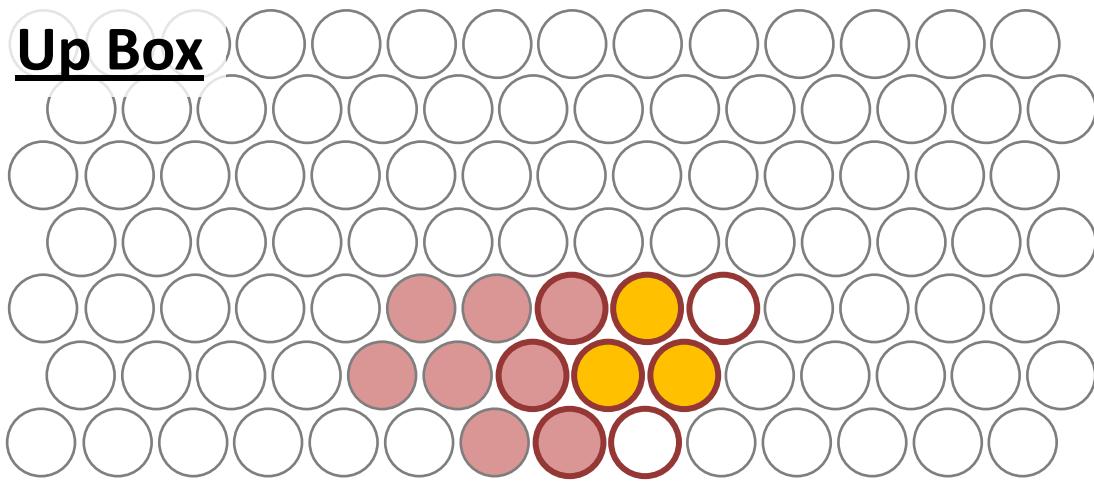
A-Side      C-Side



# Which HPDs Do We See?

13 12 11 10 9 8 7 6 5 4 3 2 1 0

**Up Box**



0  
1  
2  
3  
4  
5  
6  
5  
4  
3  
2  
1  
0

A threshold of 15K photons gives a Top 8 HPDs per mirror pair and includes 98%  $\gamma$ .

**Down Box**

13 12 11 10 9 8 7 6 5 4 3 2 1 0

A-Side C-Side

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C-Side

# Multiple Peaks in $\varphi$ -bins

