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RICH Detector Alignment at LHCb with 2009 Collision Data

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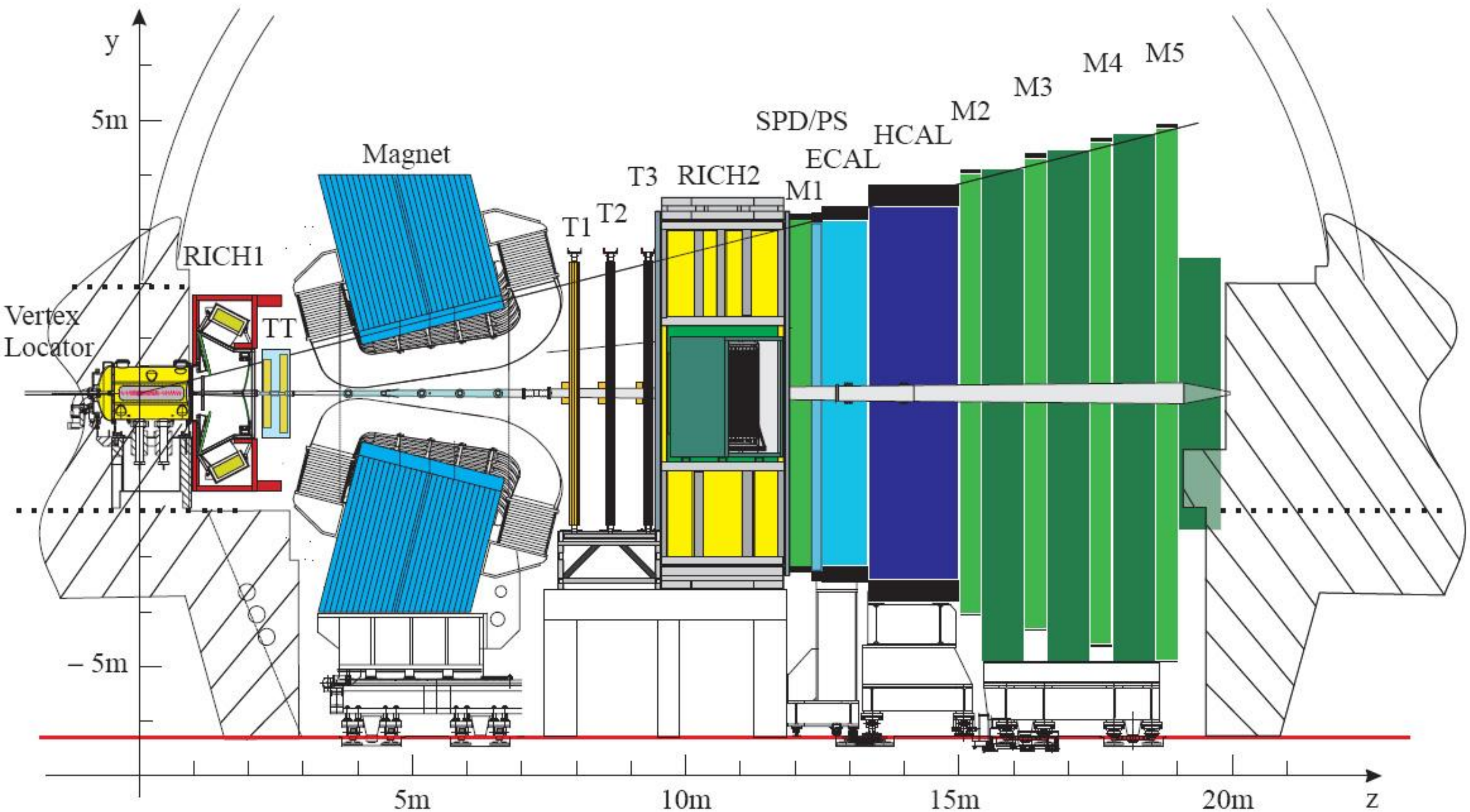
- **Introduction to LHCb & its RICH detectors,**
- Misalignments of the RICH in theory & in practice,
- **A walkthrough of RICH alignment & latest results,**
- RICH particle identification (PID) performance,
- **Summary.**

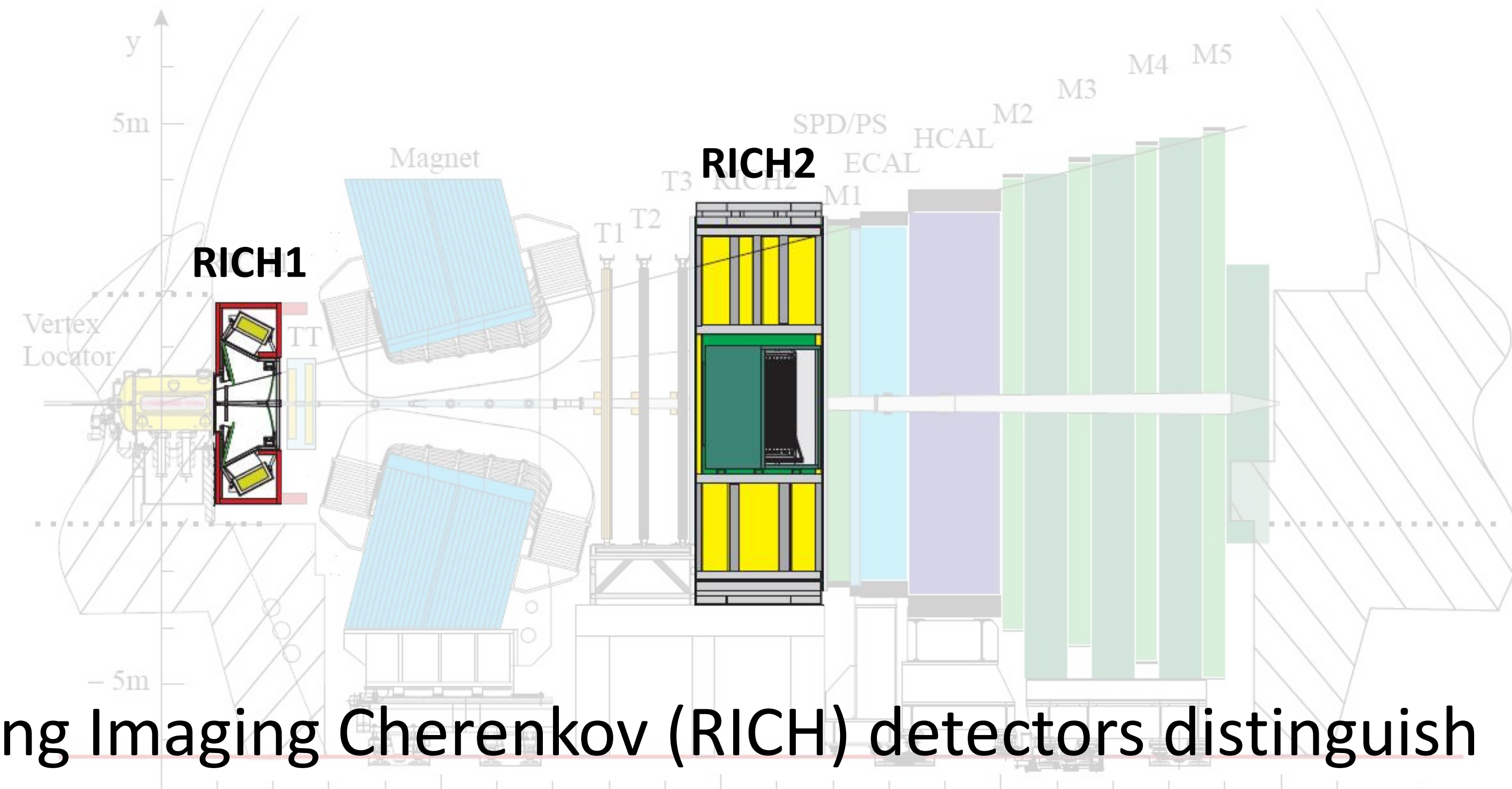
The LHCb Experiment

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



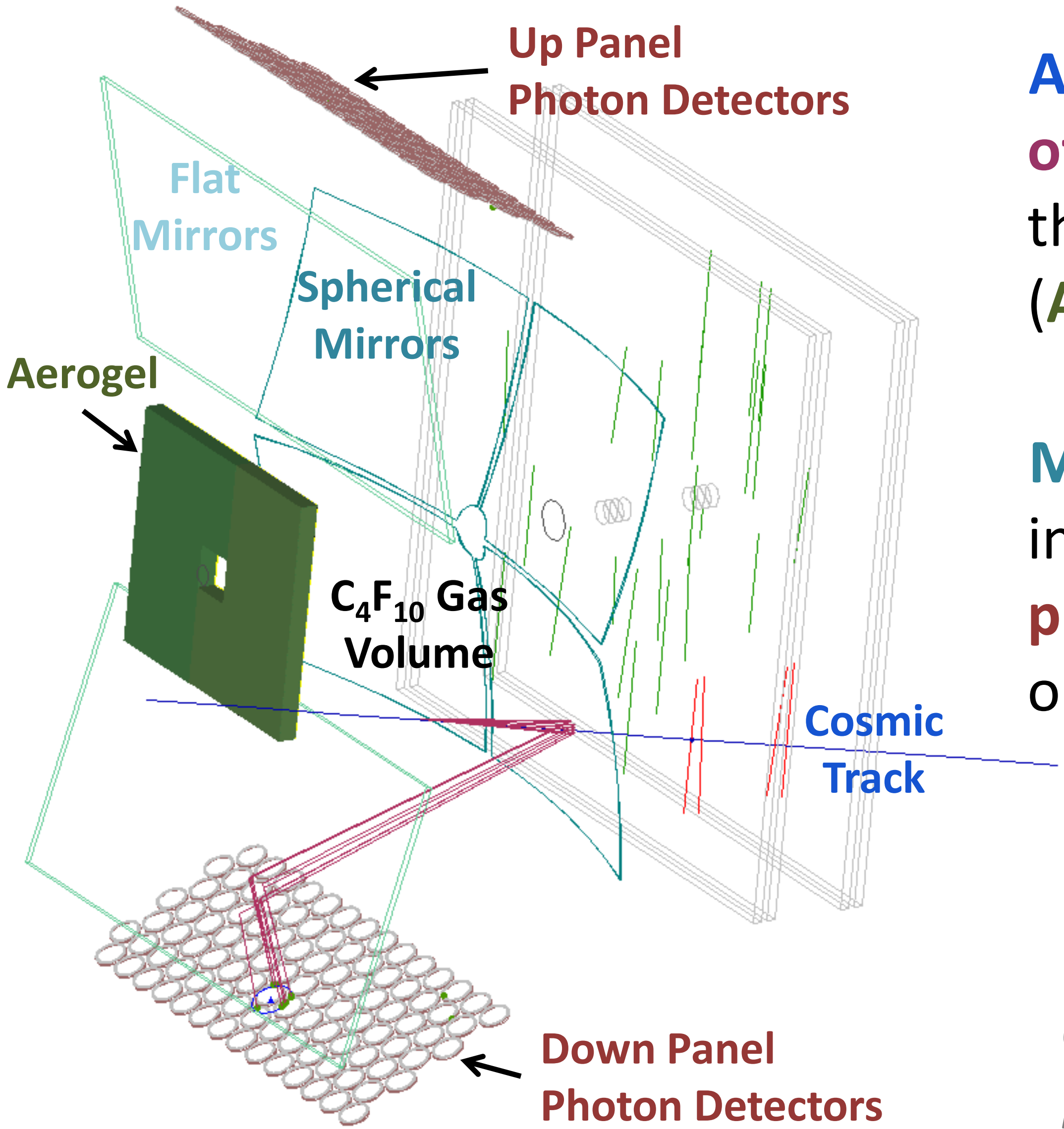
The LHCb RICH Detectors

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



2 Ring Imaging Cherenkov (RICH) detectors distinguish charged particles by mass over a momentum range of 2 to ~100 GeV/c.

RICH1 in Detail



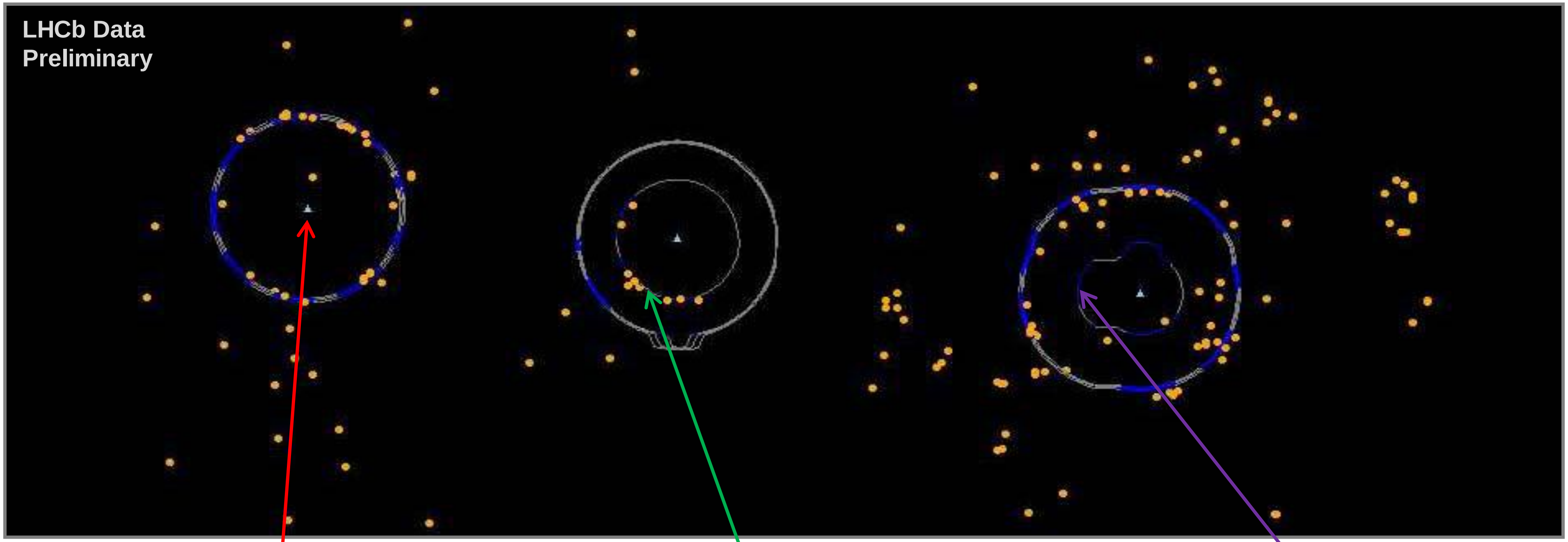
A charged track emits a **cone of Cherenkov light** on passing through the radiators (**Aerogel** & **C_4F_{10} Gas**),

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

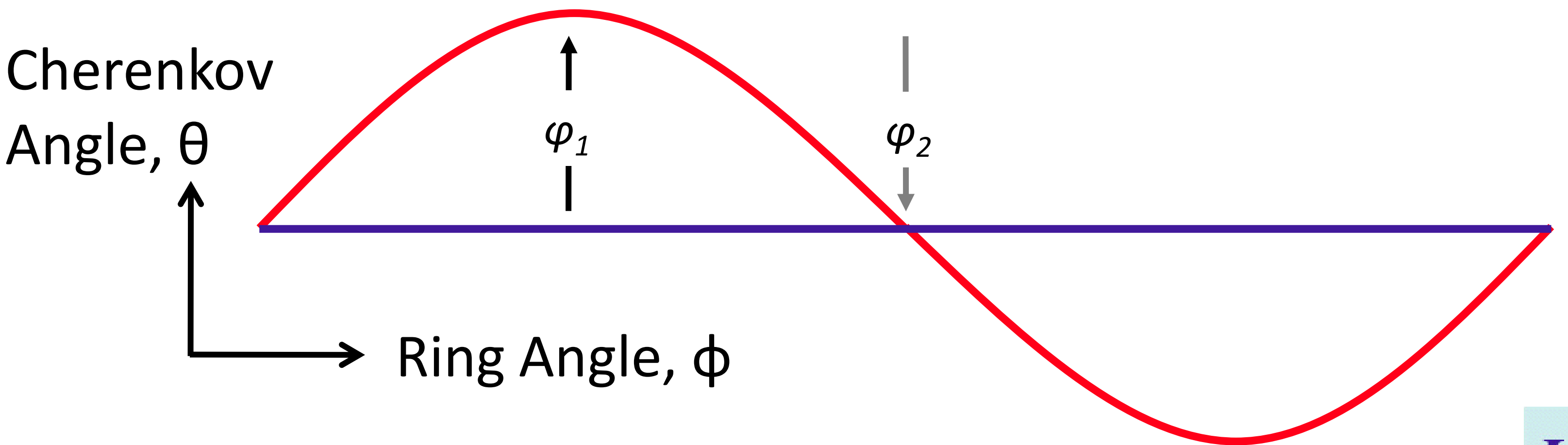
An event display from real data show "rings" projected on to the photon detector plane:



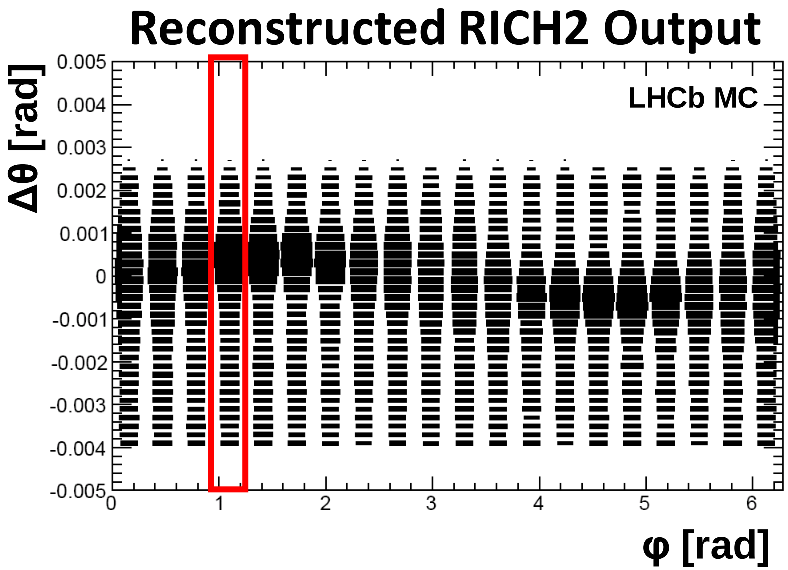
RICH Misalignments

Misalignment is observed relative to tracking:

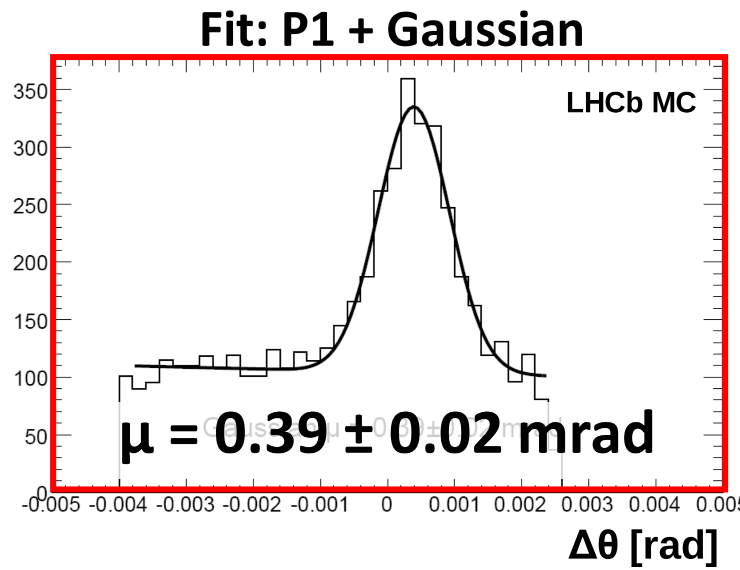
Seen as a distribution $\mathbf{\Delta\theta = A\sin\varphi + B\cos\varphi}$:

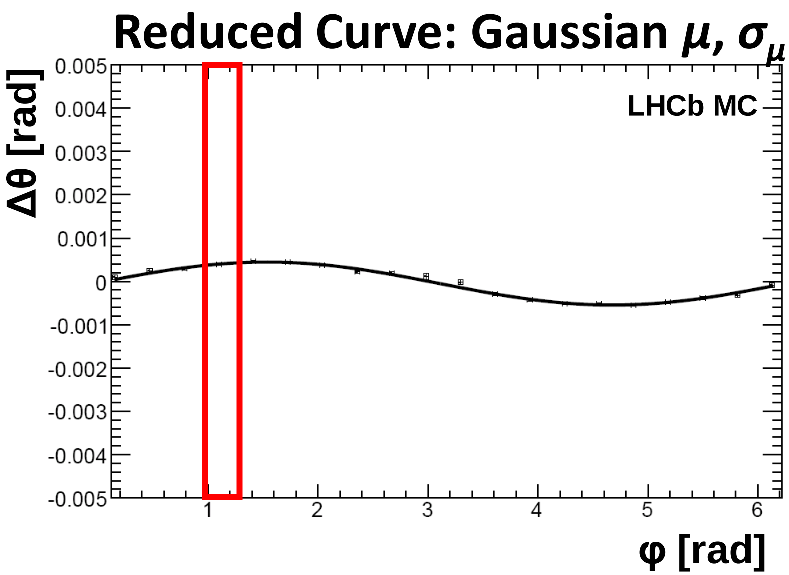


Fitting Procedure



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

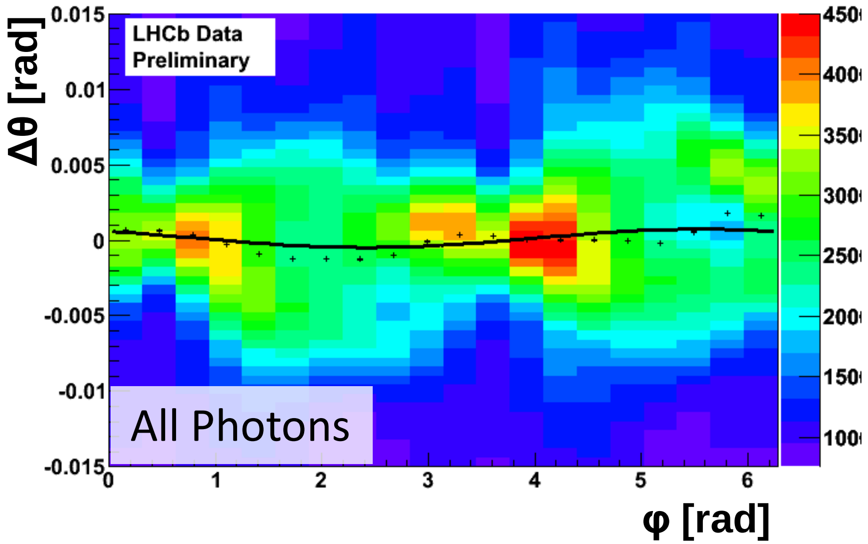




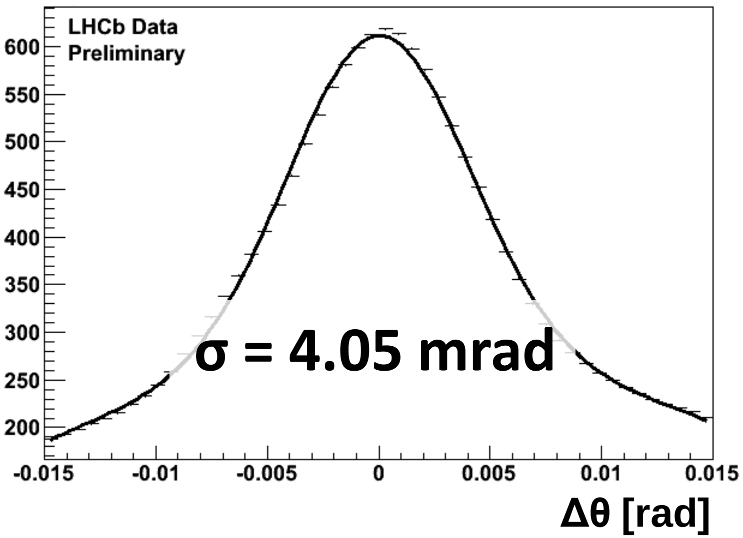
LHCb output re-plotted using Gaussian μ and fitted with:

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

Real Data from RICH1



Total Resolution



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

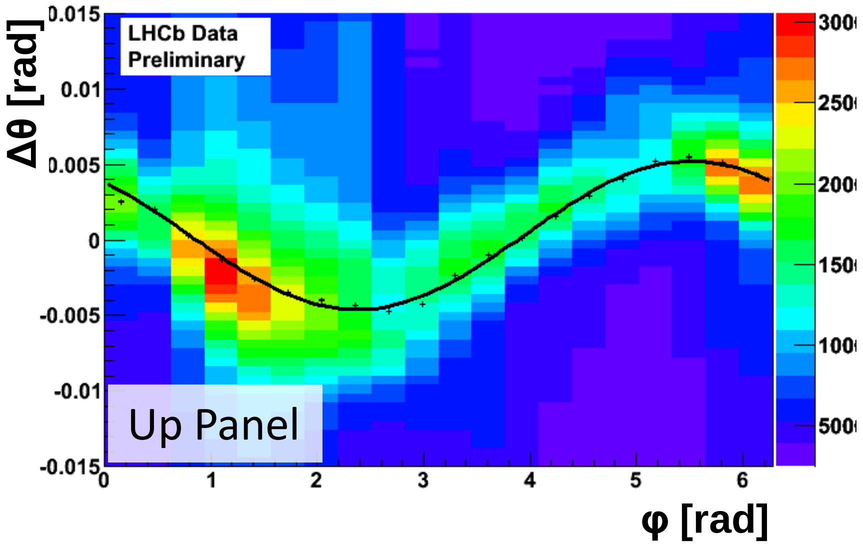
The Δθ vs. *φ* alignment plot was not very helpful. Where is the expected sinusoidal deviation?

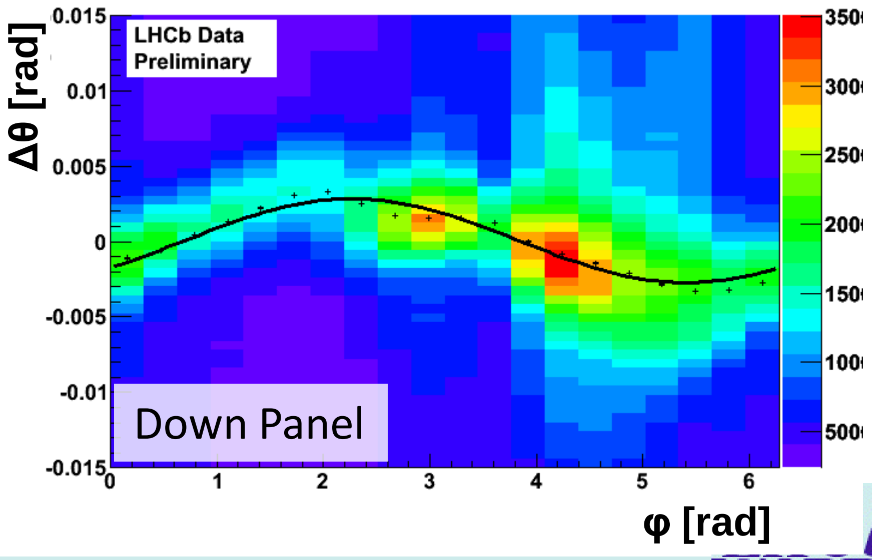
Real Data from RICH1

Now we see the expected sinusoidal deviations,

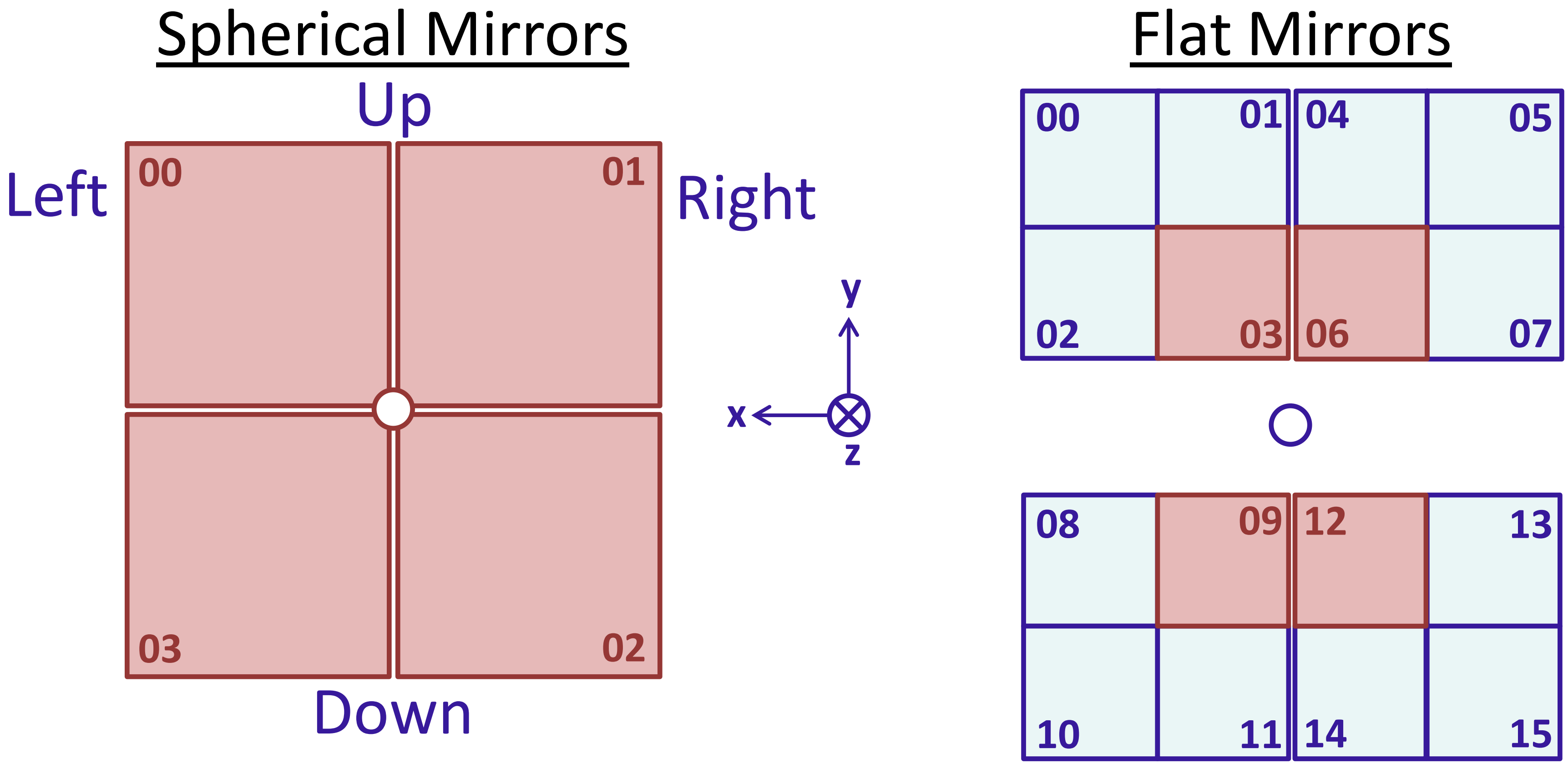
Splitting the data from RICH1's up & down panels reveals differing misalignments,

Is it useful to separate out the data further still?



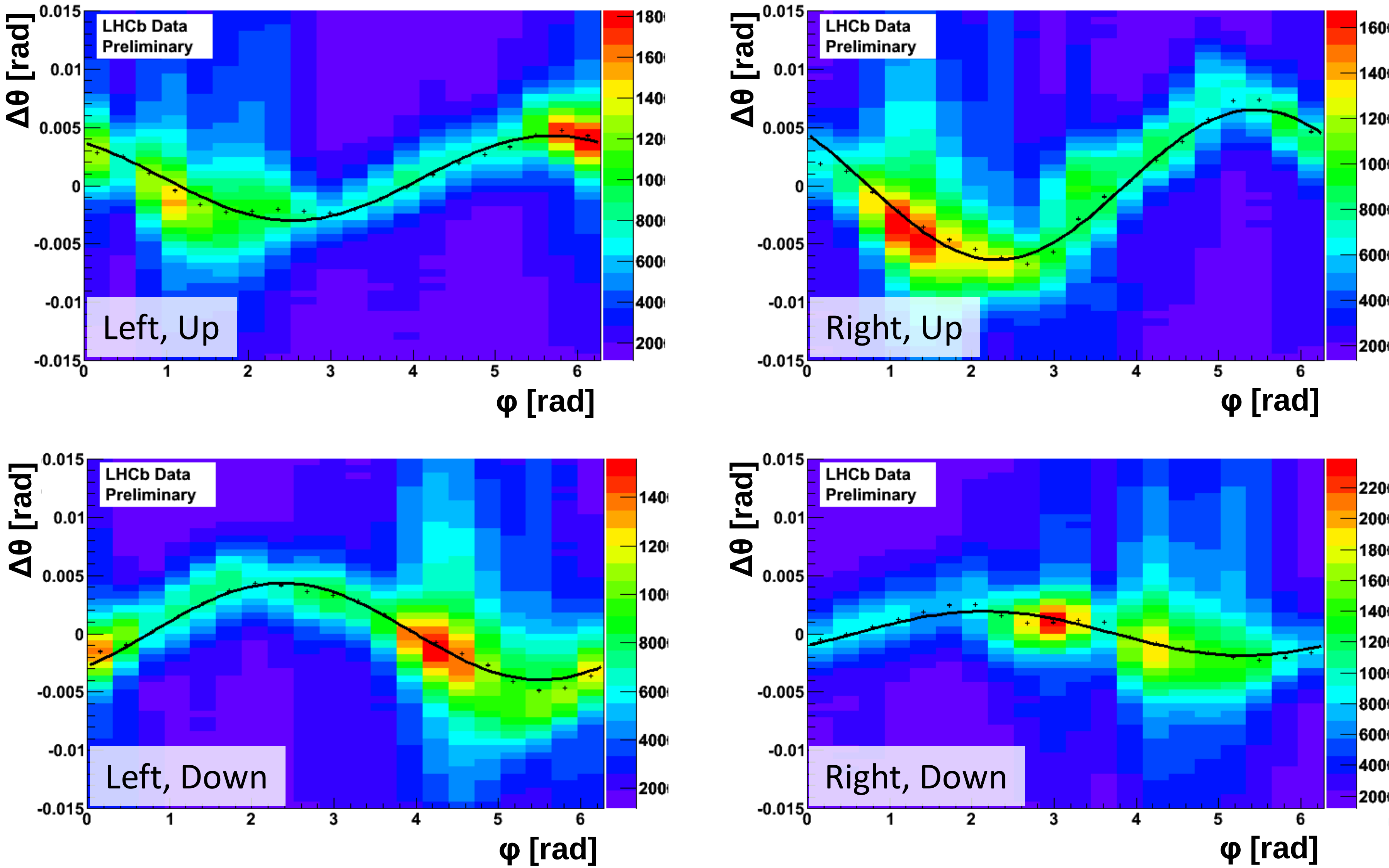


RICH1 Mirror Configuration



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

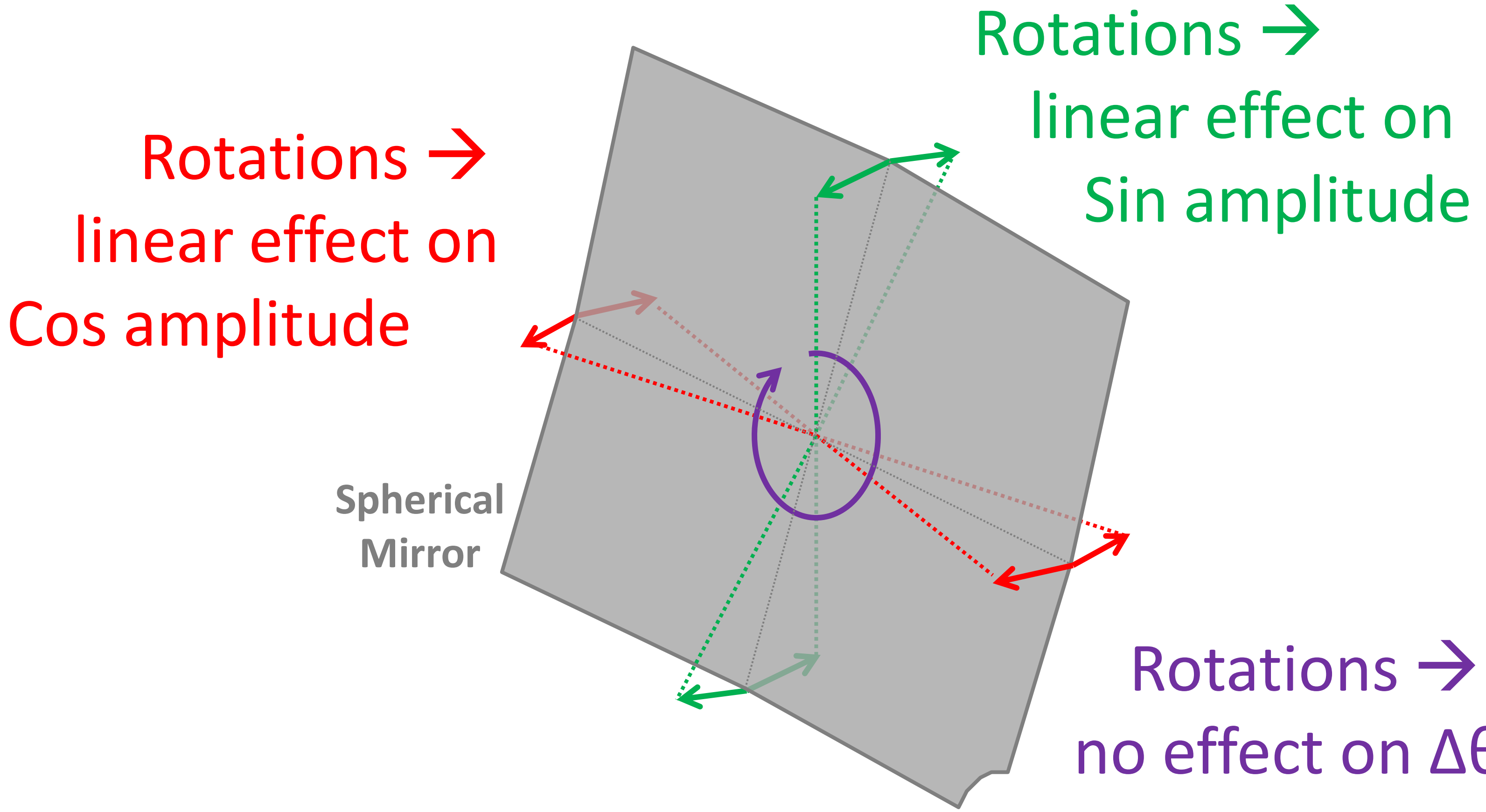
RICH1 Misalignments by Quadrant



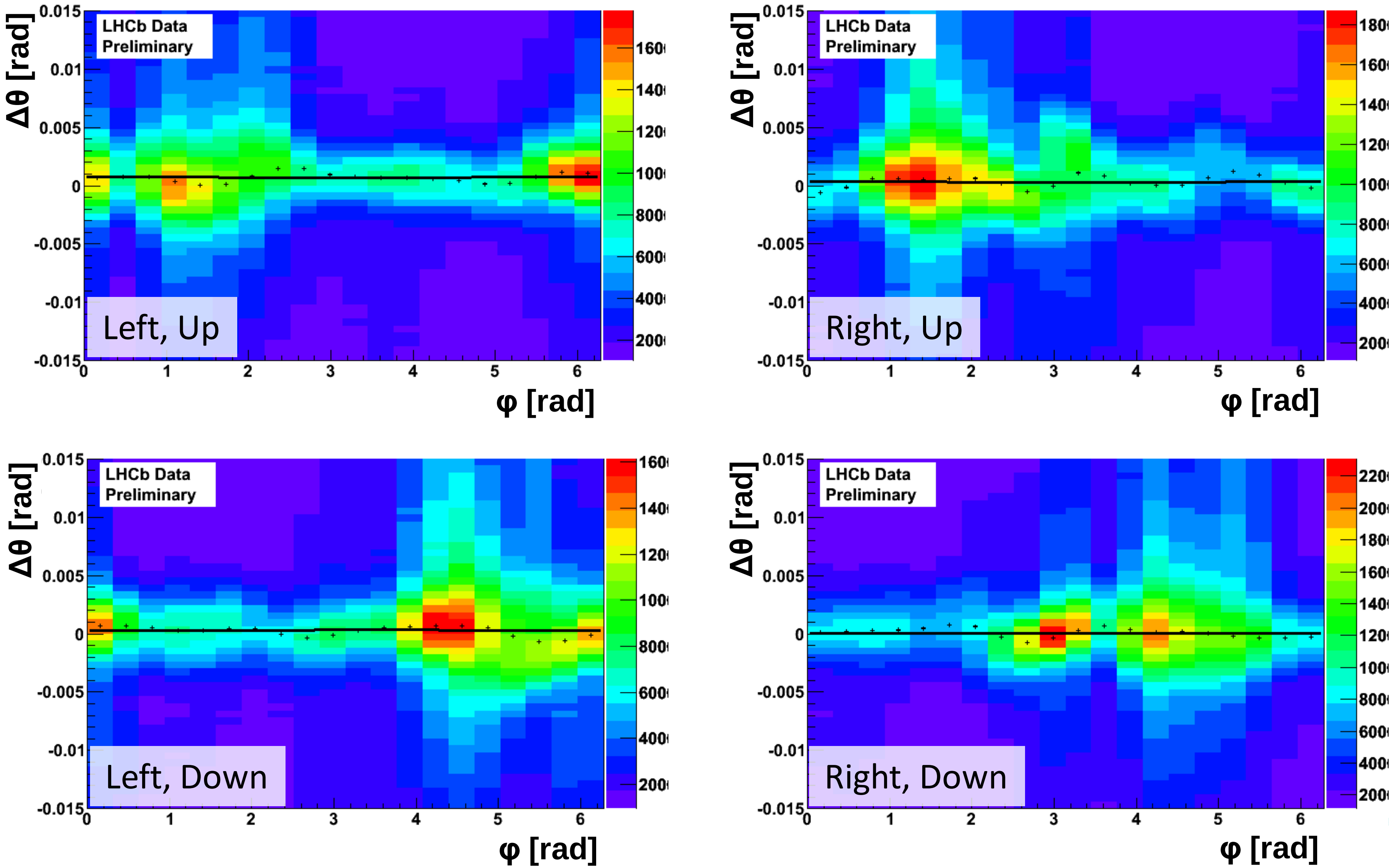
Aligning RICH1 Spherical Mirrors

How do we compare mirror misalignment to our function:

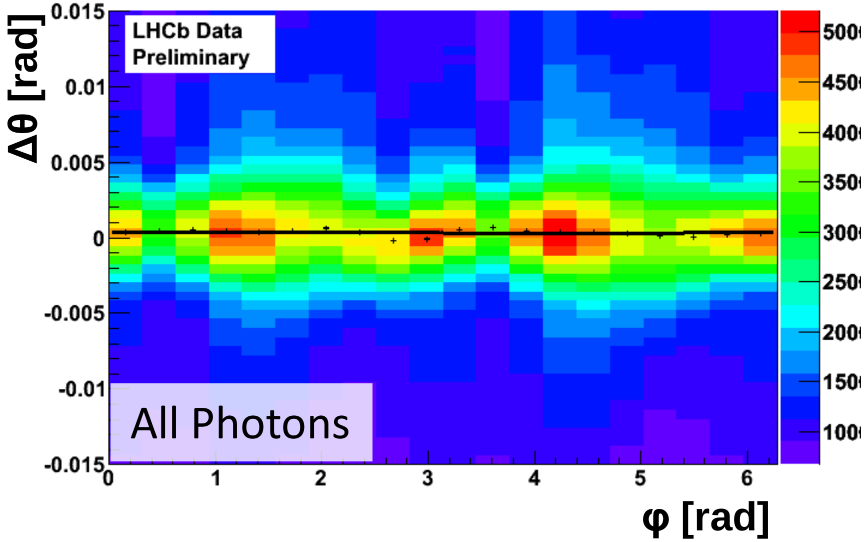
$\boldsymbol{\Delta\theta = A\sin\varphi + B\cos\varphi}$?



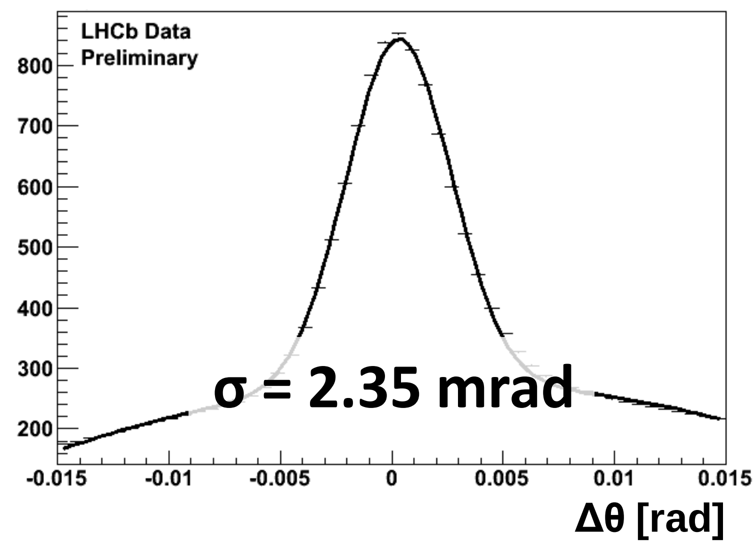
RICH1 Spherical Mirrors Aligned



Aligned Resolution RICH1



Total Resolution



MC production with data-like configuration: **σ = 1.57 mrad**

Next stage:
Align individual photon detectors.

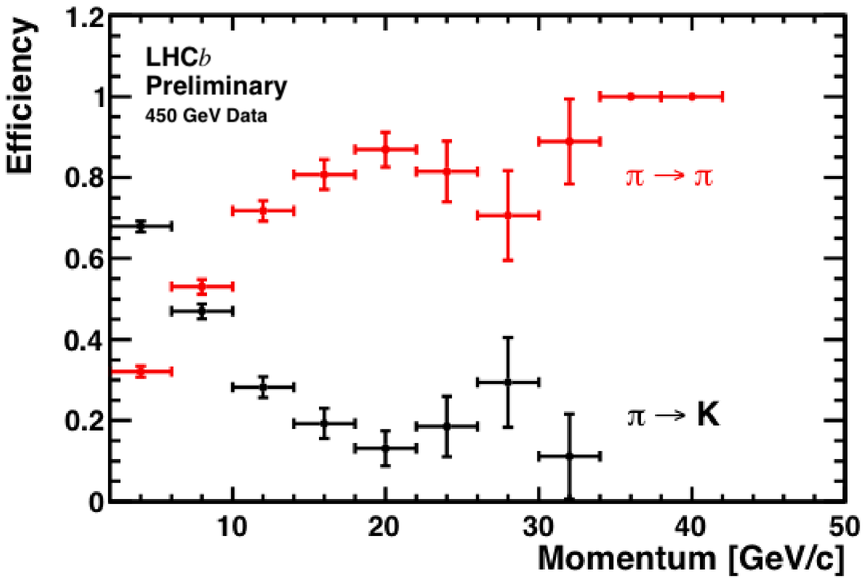
Correction	A, Up	C, Up
Local Ry	-1.45 mrad	-1.87 mrad
Local Rz	+1.22 mrad	+2.88 mrad
	A, Down	**C, Down**
	+1.34 mrad	+0.43 mrad
	-1.78 mrad	-0.88 mrad

Corrections expected from survey: ***< 2 mrad***

RICH Performance Improvement

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

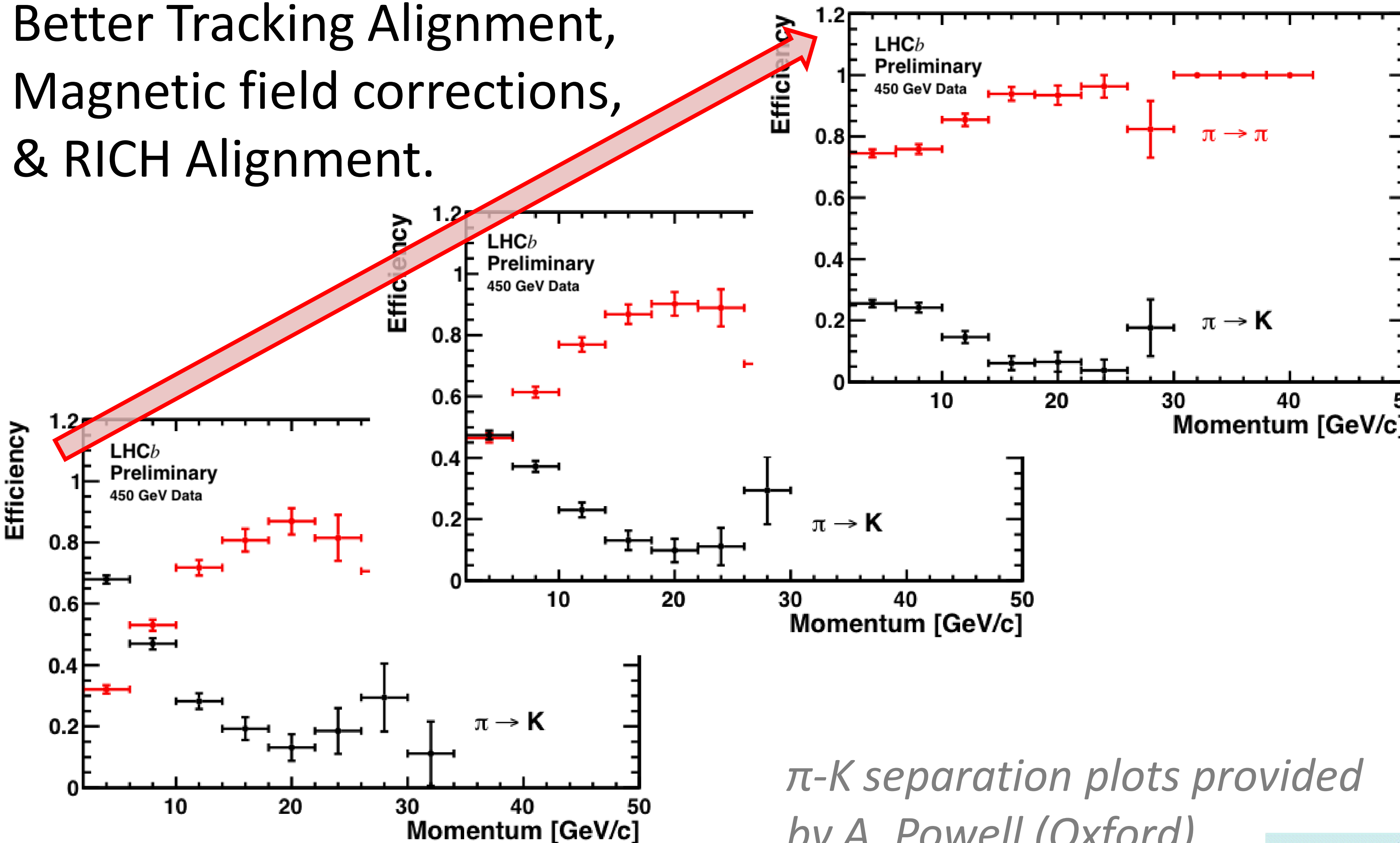
This example plot shows the efficiency of **π identification** & **misidentification as a K** (*considering only these two possible hypotheses*) for known π selected from K_S decays in data.



π-K separation plot provided by A. Powell (Oxford)

RICH Performance Improvement

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

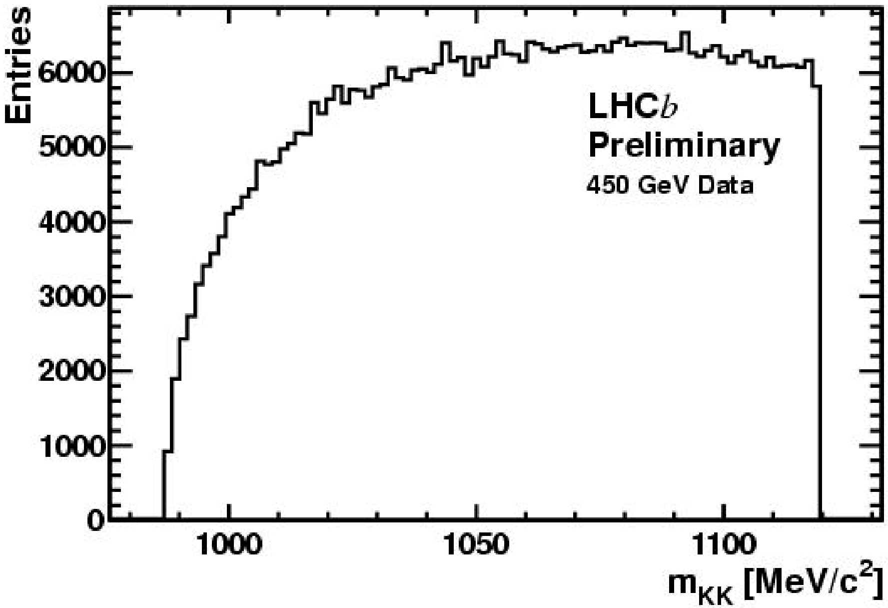


π-K separation plots provided by A. Powell (Oxford)

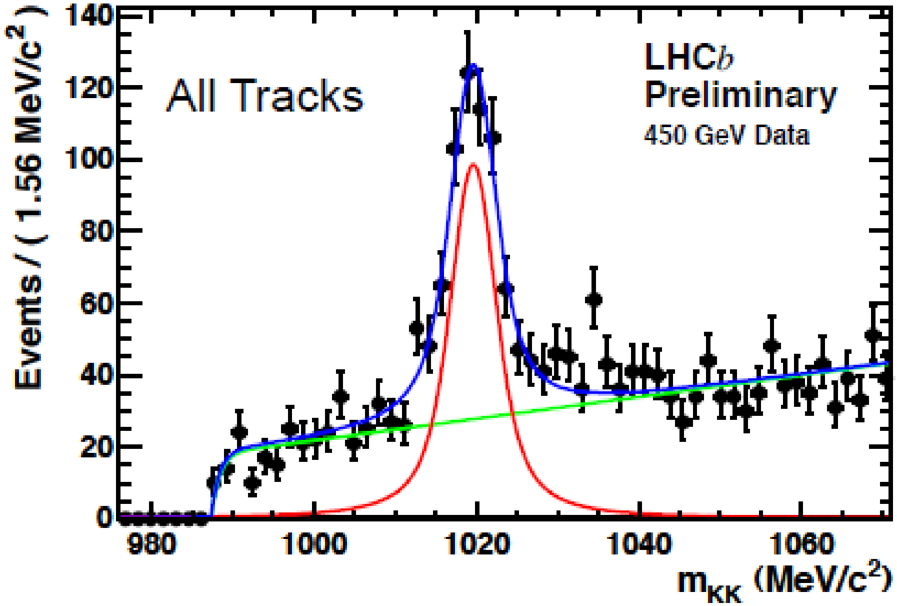
RICH Performance Improvement

With RICH improvements, LHCb can now find ϕ -> KK :

Track-based Selection



Added K-PID Cut from RICH



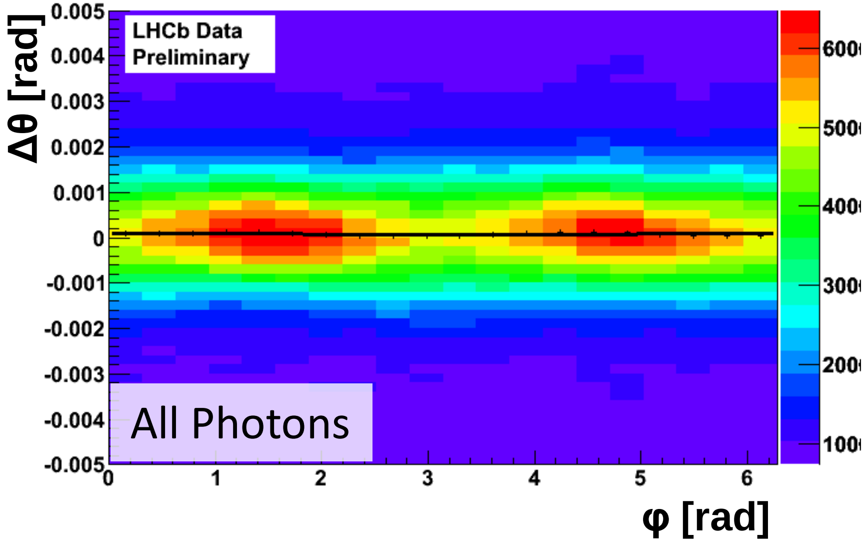
ϕ -> KK selection plots provided by A. Powell (Oxford)

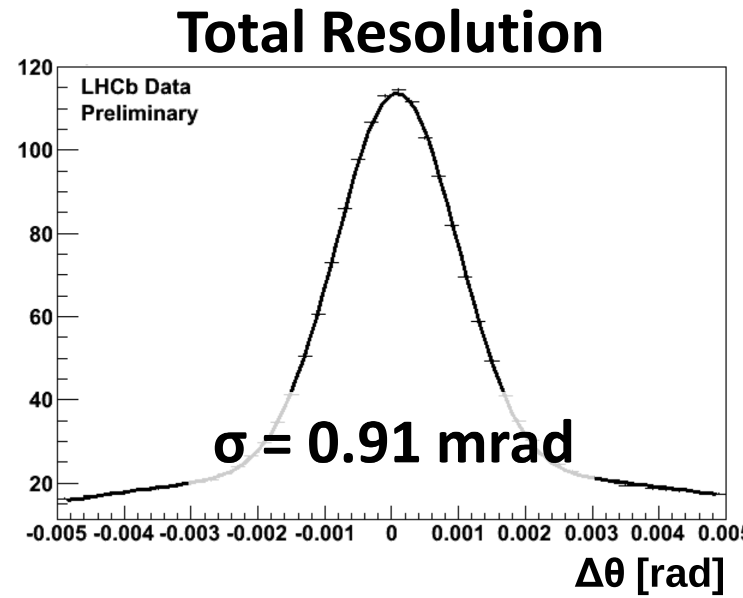
Summary

- **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





MC production with data-like configuration: **σ = 0.67 mrad**

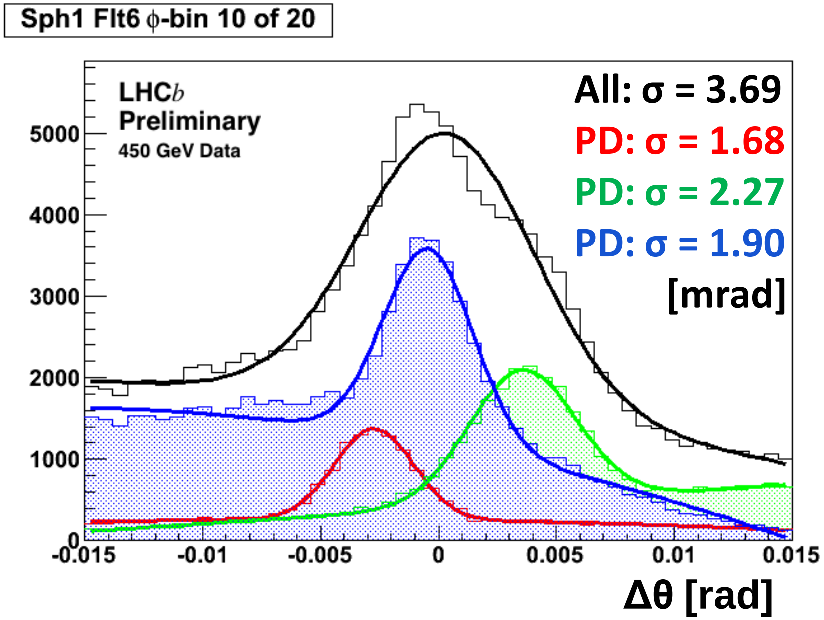
Next stage:
Align individual mirrors.

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

Corrections expected from survey: ***< 2 mrad*** *or* ***< 3 mm***

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

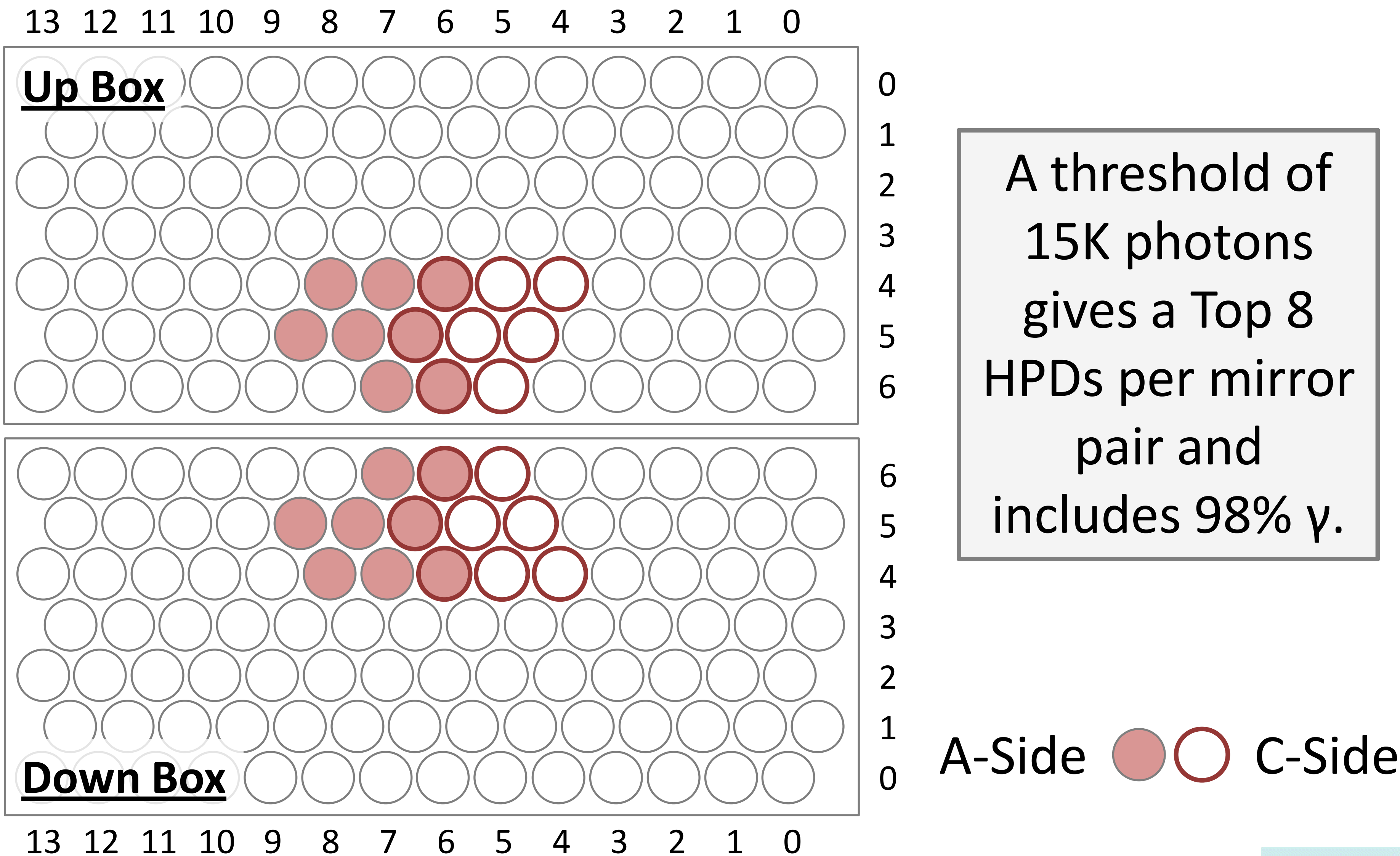


The key may already be found:

Mirror-aligned RICH1 data shows a misalignment between photon detectors (*in one φ-bin*).

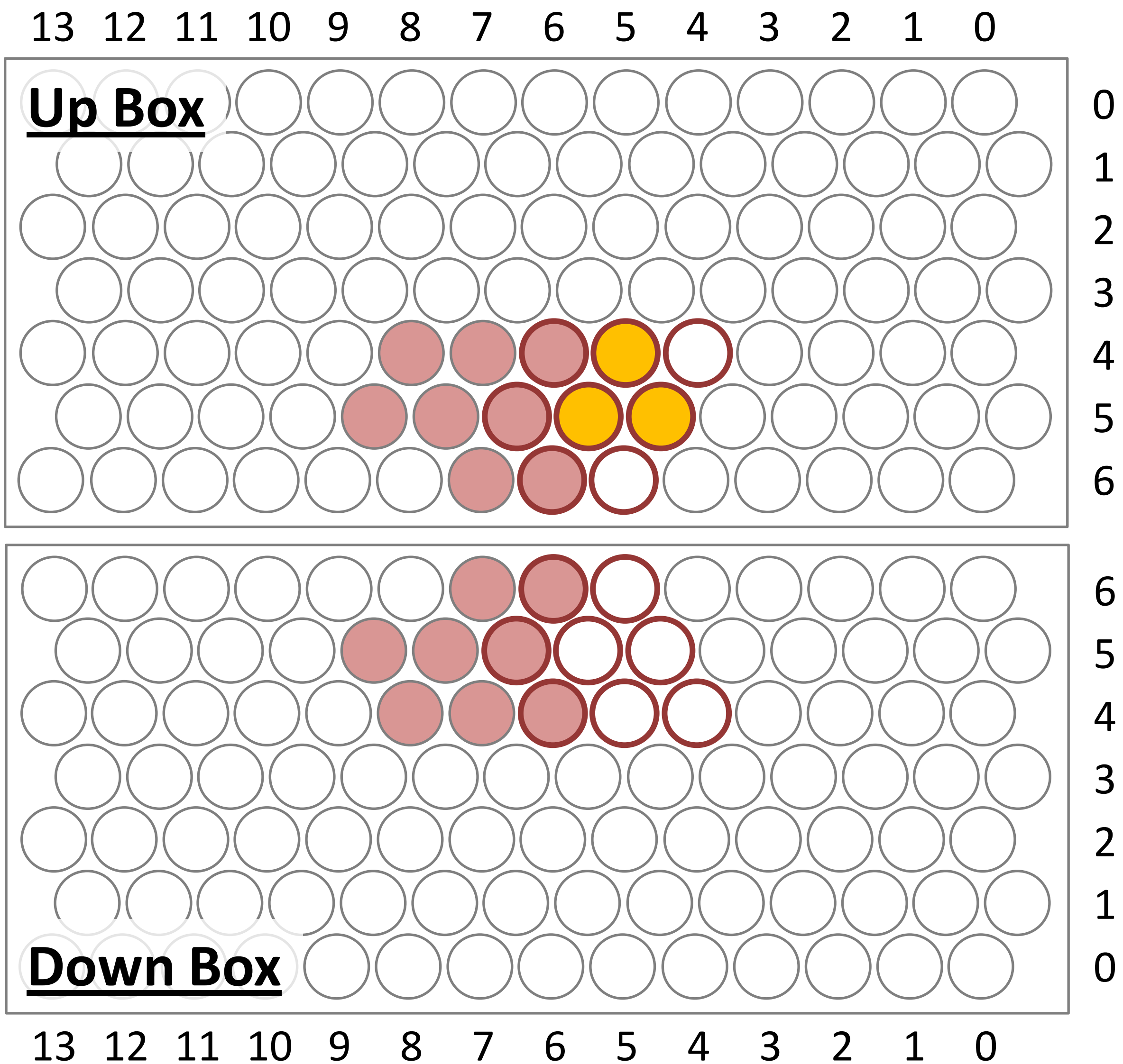
The RICH group expects improved alignment with more data.

Which HPDs Do We See?



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

Which HPDs Do We See?



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

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A-Side C-Side

Multiple Peaks in φ-bins