Performance of the LHCb RICH detectors during the LHC Run II

Antonis Papanestis
STFC – RAL
On behalf of the
LHCb RICH Collaboration

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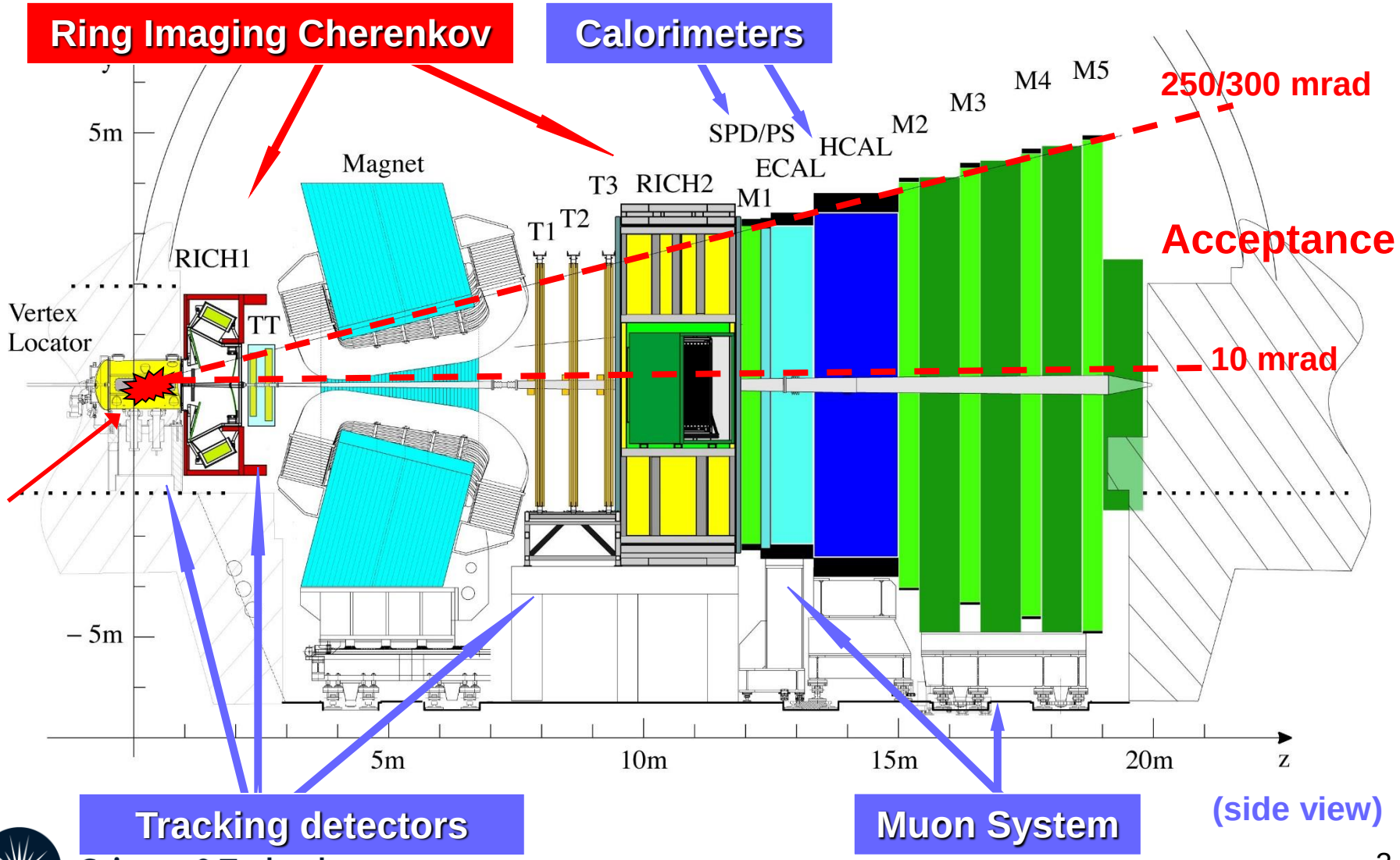
Outline

- Brief description of the detectors
- Changes between Run I and Run II
  - LHCb changes
  - RICH changes
- Performance in Run II
  - Cherenkov angle resolutions
  - PID performance
  - Comparison with Run I

LHCb experiment



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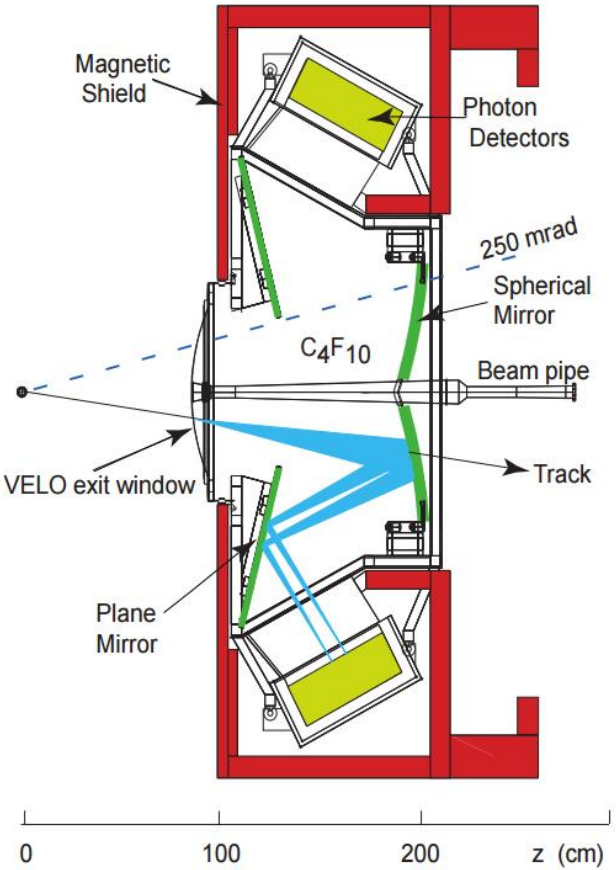
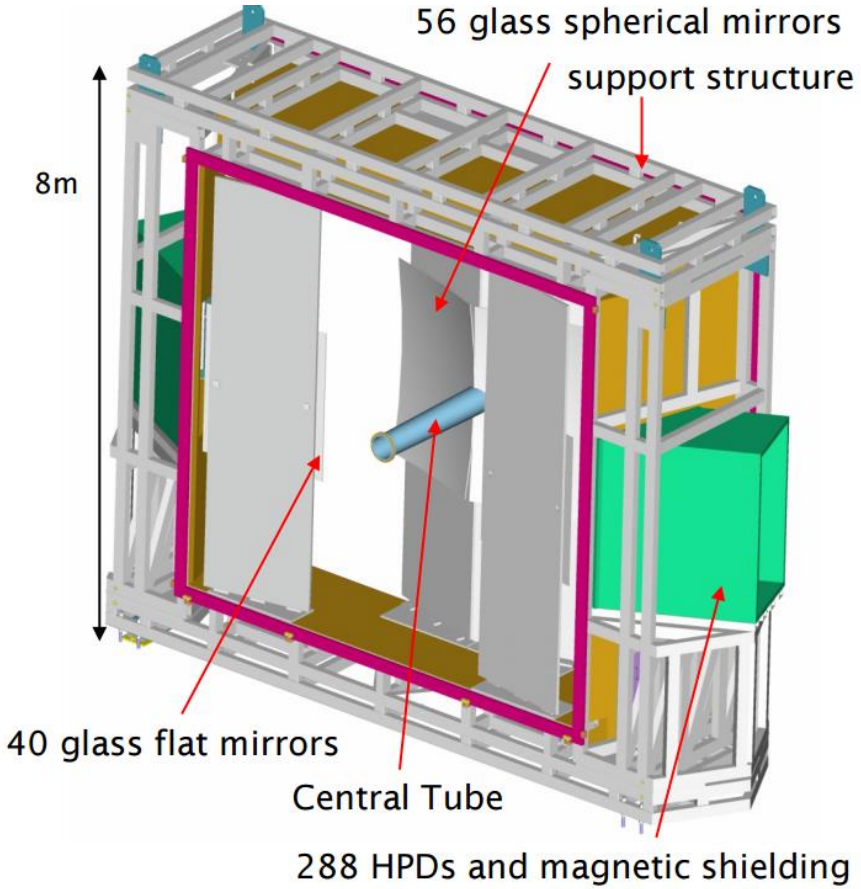
LHCb RICH Detectors



RICH-1 (25-300 mrad)

4 m^3 C_4F_{10} n = 1.0014, up to 60 GeV



RICH-2 (15-120 mrad)

100 m^3 CF_4 n = 1.0005, up to ~100 GeV

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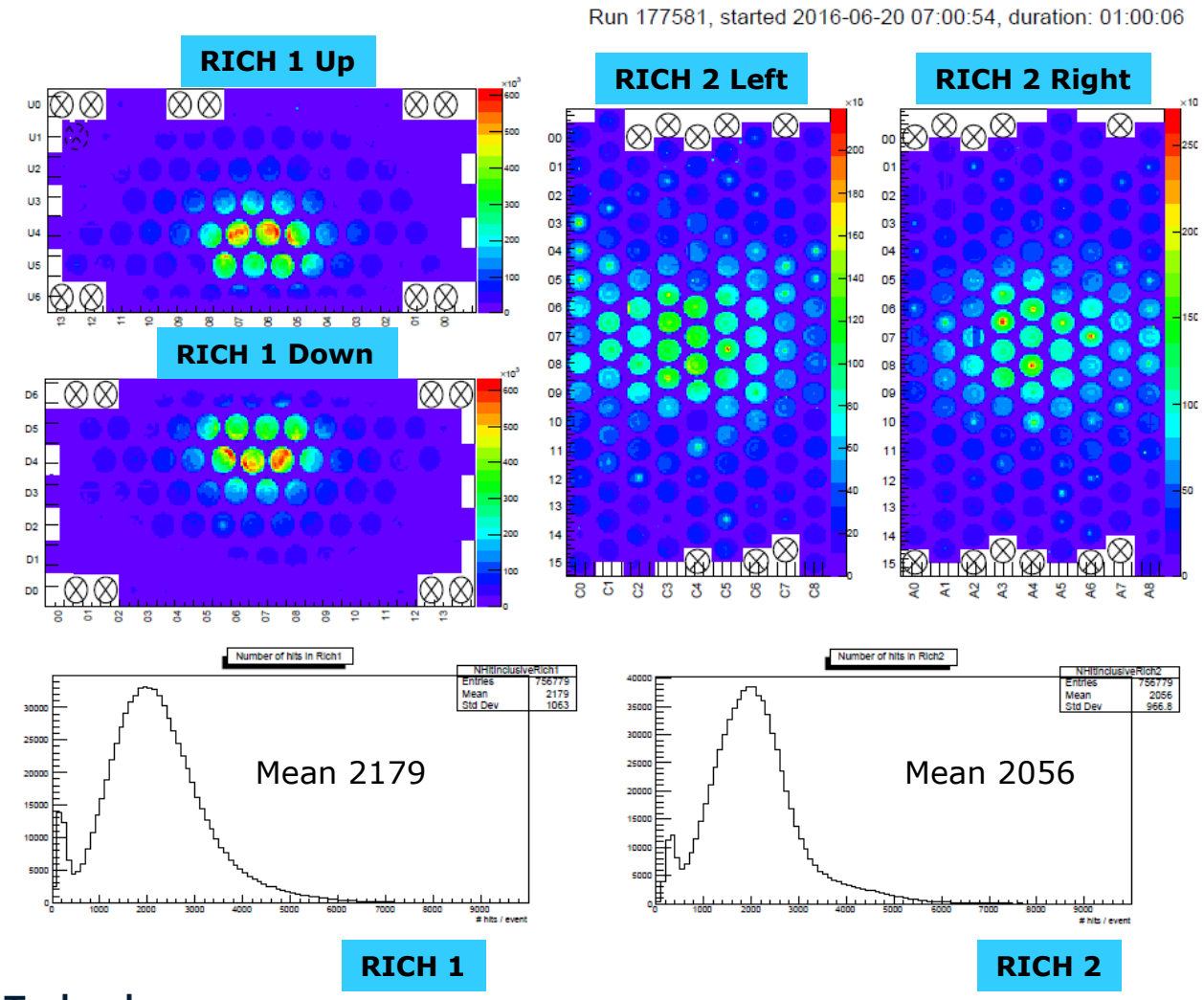
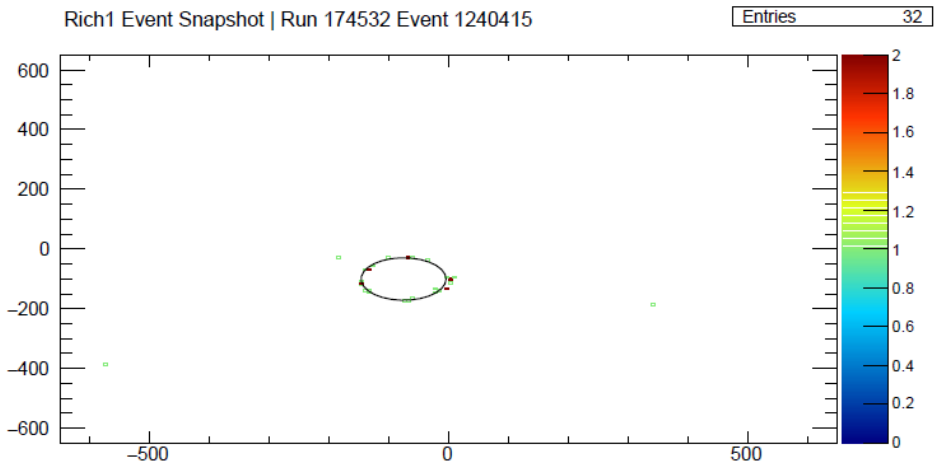
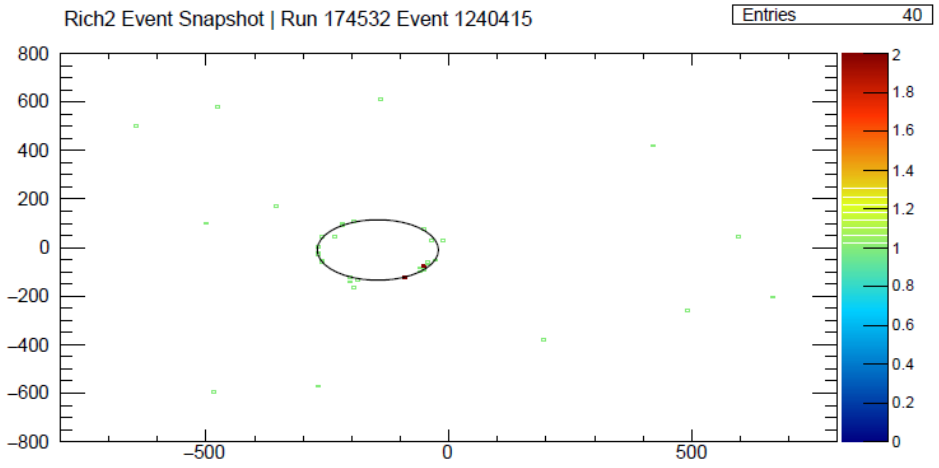
RICH Hitmap


Run 177581, started 2016-06-20 07:00:54, duration: 01:00:06
RICH 1 Up
RICH 1 Down
RICH 2 Left
RICH 2 Right
Number of hits in Rich1
Mean 2179
Number of hits in Rich2
Mean 2056
RICH 1
RICH 2

Single track event





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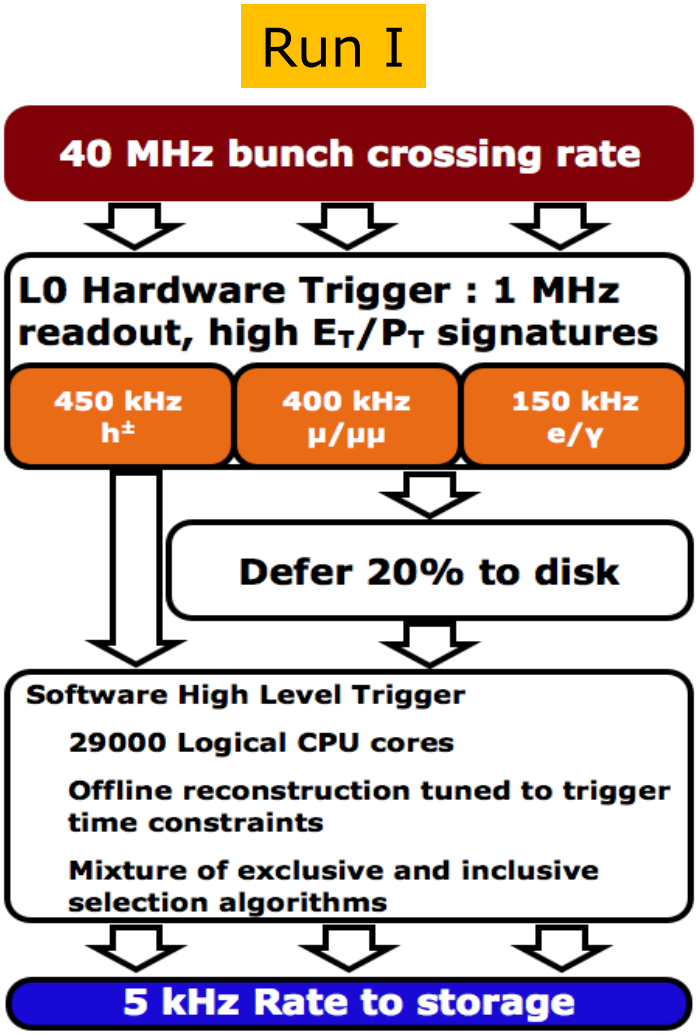
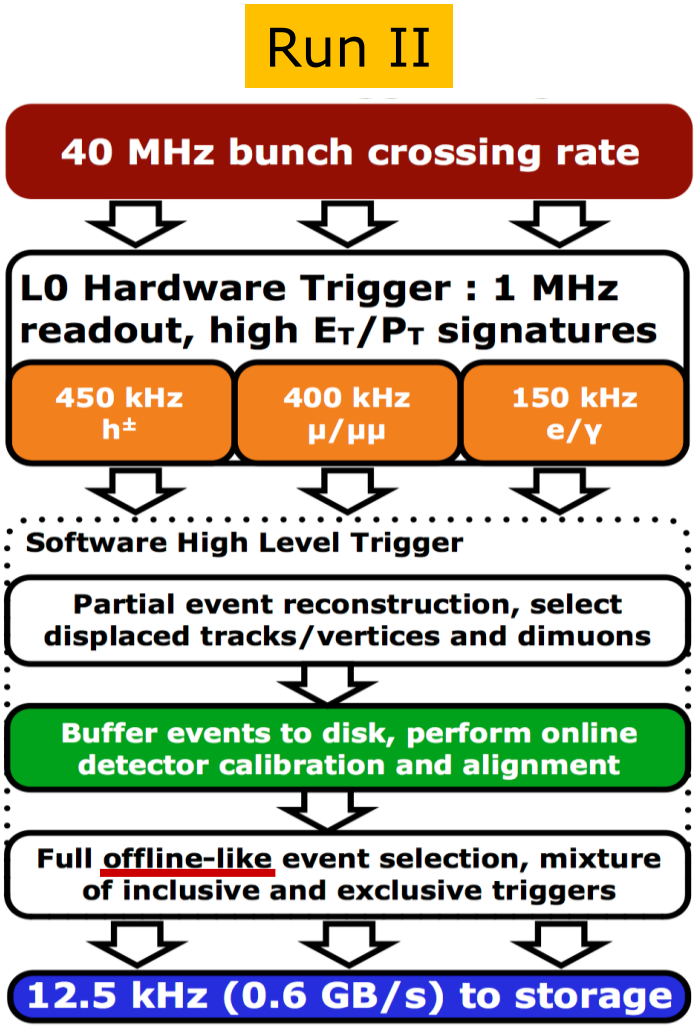
New LHCb Trigger





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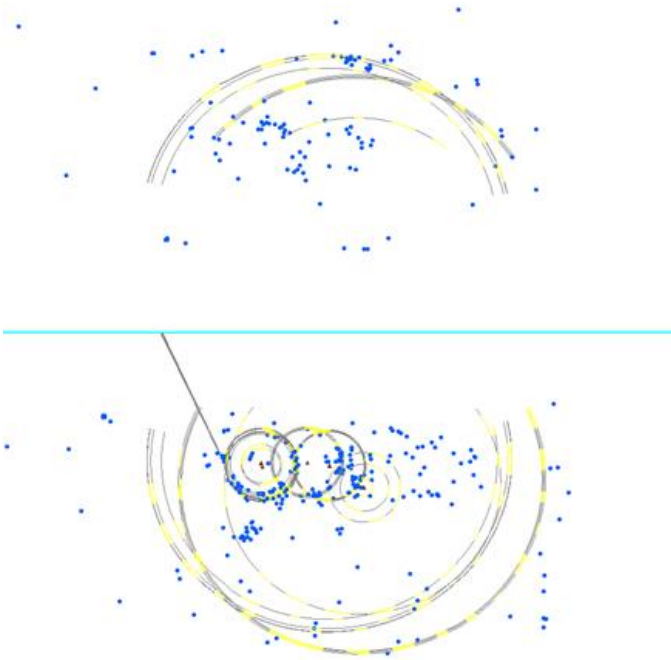
Consequences of the new trigger strategy

- RICH information in HLT2
  - Limited time for RICH decision
  - Needed to speed up the procedure
  - Aerogel rings very big
    - Many photons, many track/photon combinations
  - Need for 100% compatibility between online/offline on track by track basis, not average, likelihood values
- Aerogel geometry not well matched to new trigger requirements
- Aerogel performance impaired by running conditions:
  - Many tracks, high background
- Need to optimise performance/time
- Space behind the aerogel container for a longer gas radiator



Example rings in RICH1 from Run I

Real-time calibration and alignment of the LHCb RICH detectors
Jibo He, Tuesday 16:35

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Changes in the RICH detectors

- Challenge: make an excellent RICH detector even better

- Removal of aerogel
- Better tuning of photon detectors, giving 2-3% better photon yield
- New vacuum treatment for HPDs
  - Better vacuum quality
  - No aging (so far)
- Liquefying stage in C_4F_{10} recirculation
  - Allows to remove air periodically
  - Used mainly during LHC Technical Stops
- Better control of CO_2 in RICH2
  - For reduced CF_4 scintillation

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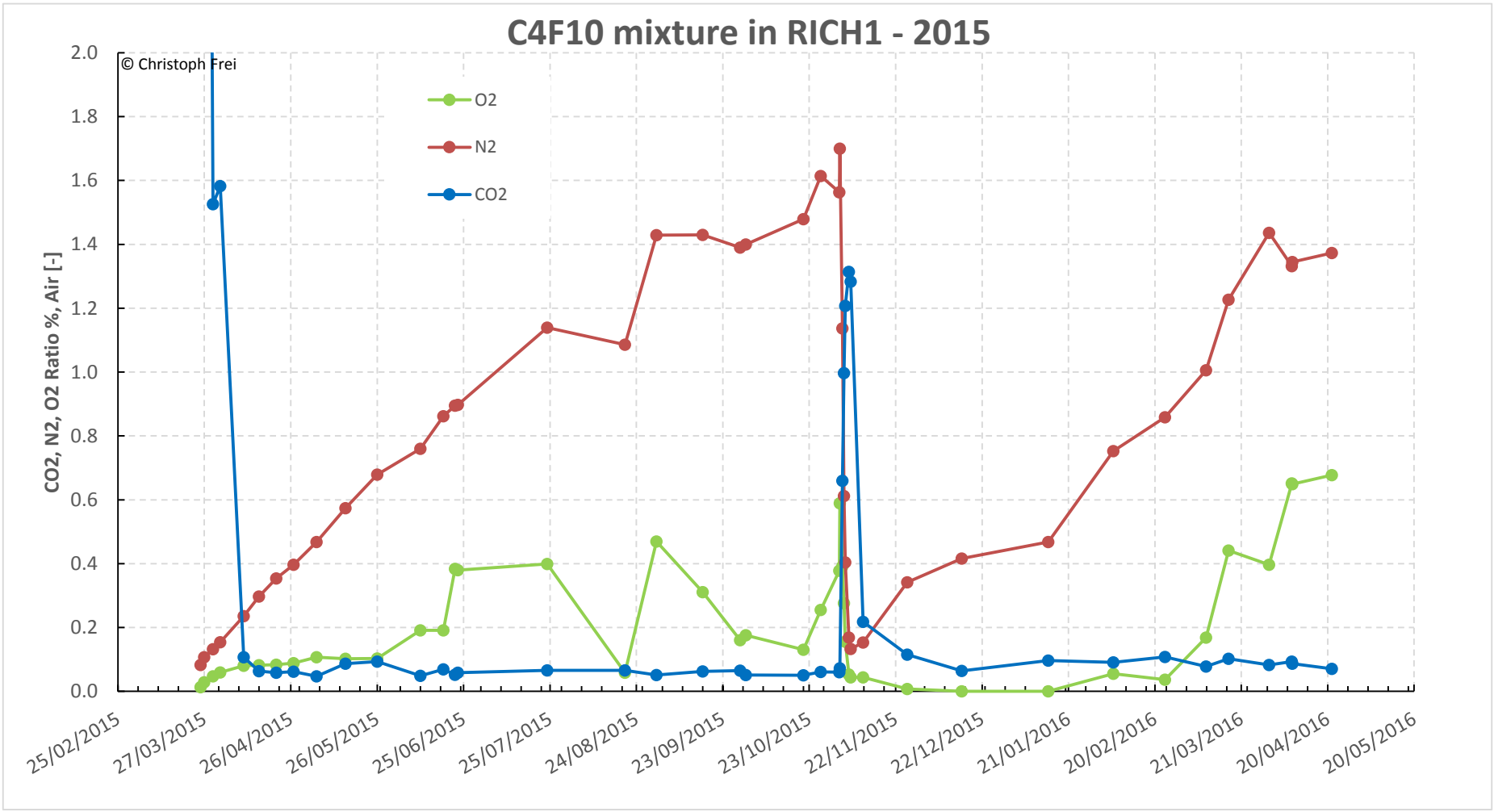
RICH1 C_4F_{10} purity



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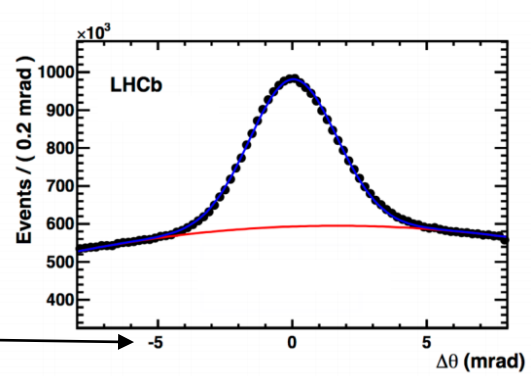
Cherenkov Angle Resolutions

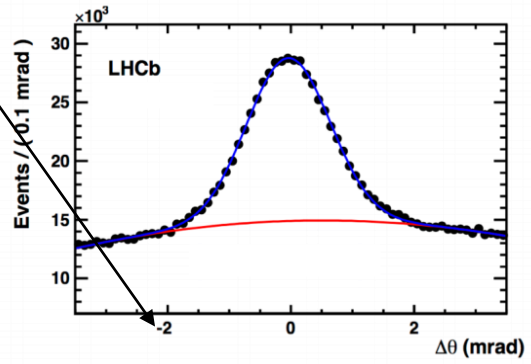
Example resolution curve

RICH1

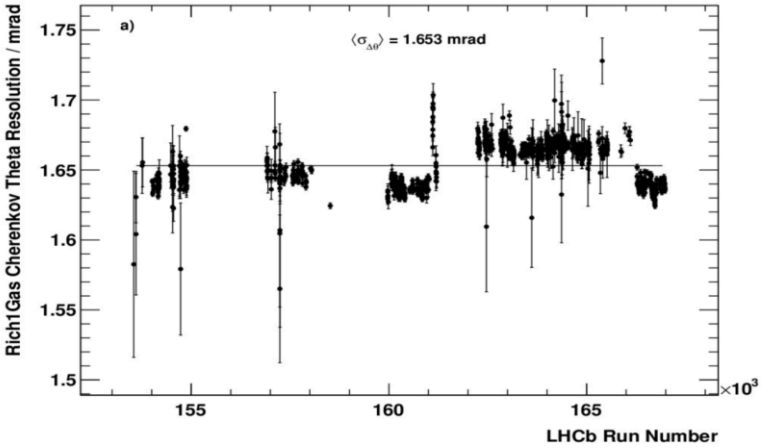
Different scale

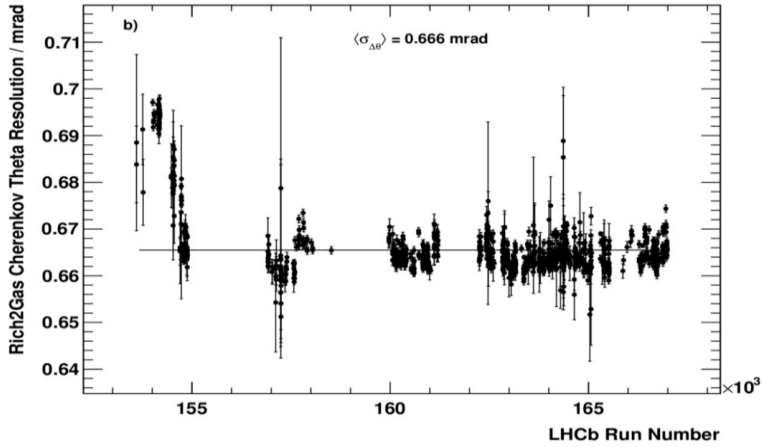


RICH2



Stability over time (2015)





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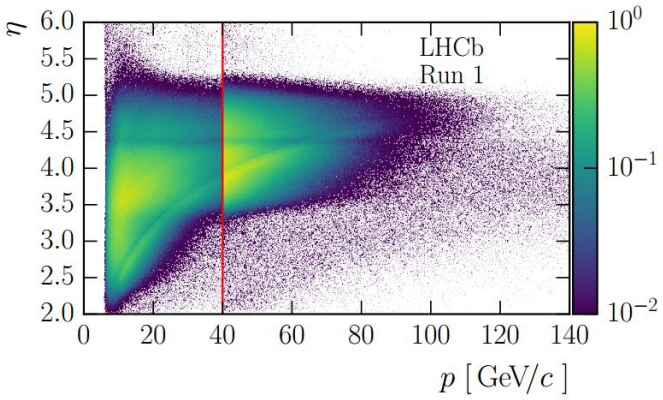
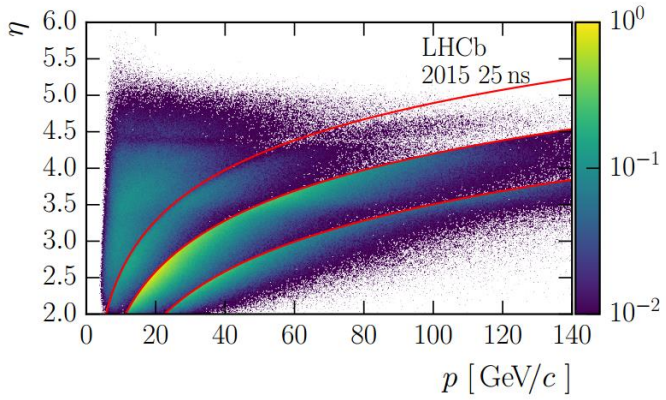
Calibration sample

- Collect pure samples of known-ID particles
- There is a main trigger line for each particle and possibly another one for cross-checks and systematic studies

Species	Low $p - p_T$	High p and p_T
$e^{\pm}$	—	$J/\psi \to e^+e^-$
$\mu^{\pm}$	$D_s^+ \to \mu^+\mu^-\pi^+$	$J/\psi \to \mu^+\mu^-$
$\pi^{\pm}$	$K_S^0 \to \pi^+\pi^-$	$D^* \to D^0(K^-\pi^+)\pi^+$
$K^{\pm}$	$D_s^+ \to K^+K^-\pi^+$	$D^* \to D^0(K^-\pi^+)\pi^+$
$p^{\pm}$	$\Lambda^0 \to p\pi^-$	$\Lambda^0 \to p\pi^-$, $\Lambda_c^+ \to pK^-\pi^+$





New selections designed to improve the kinematic coverage

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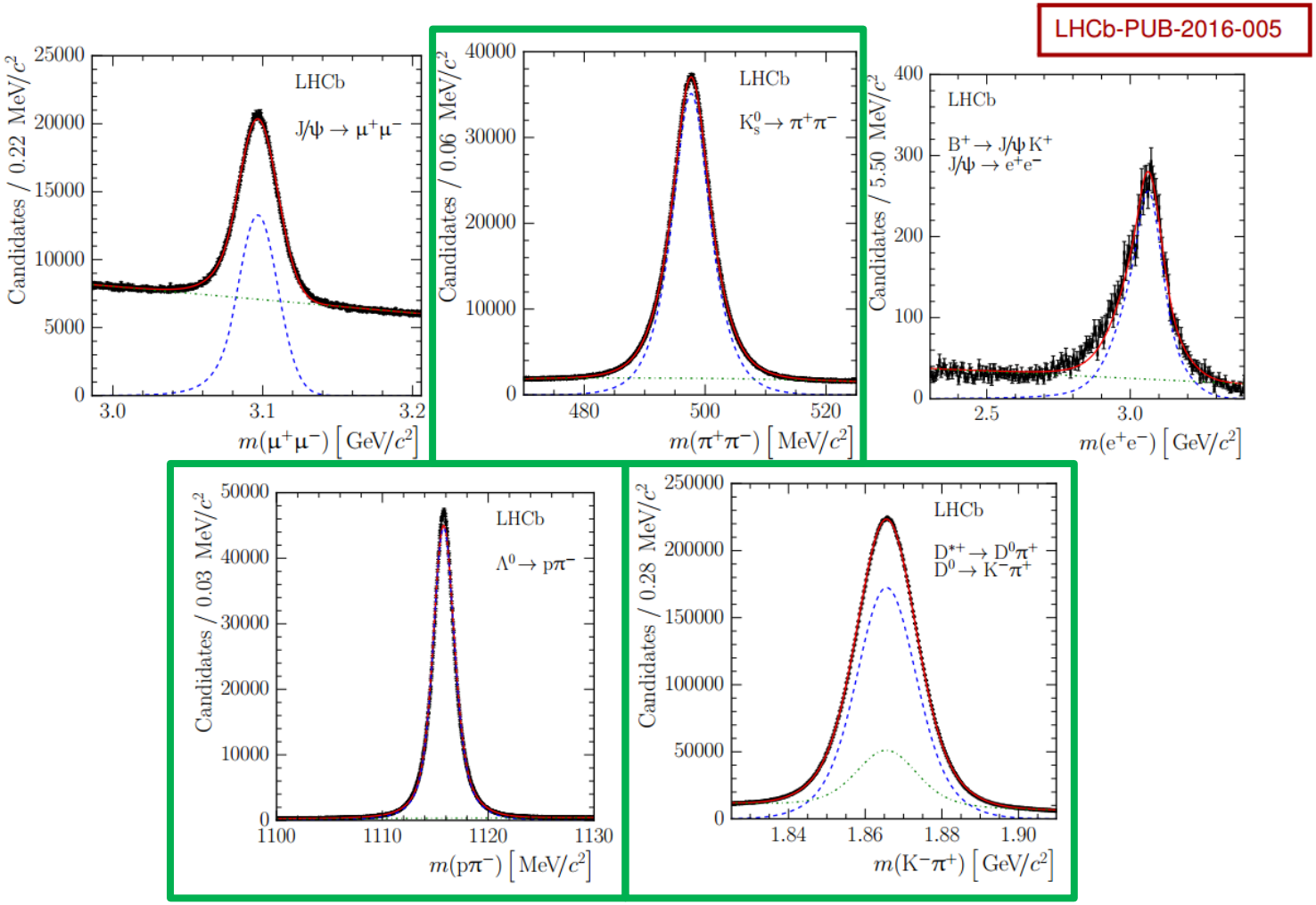
Mass distributions of PID samples



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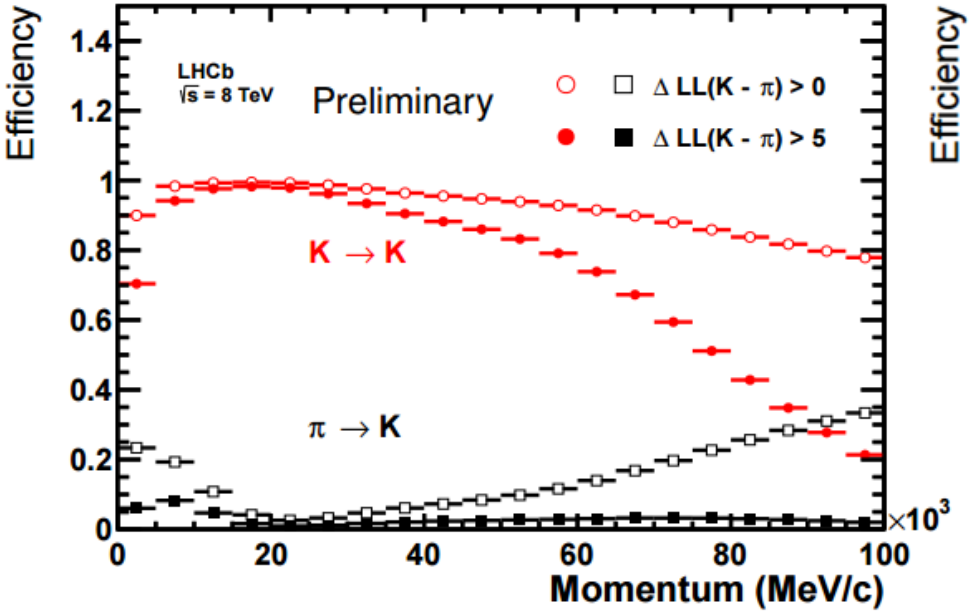
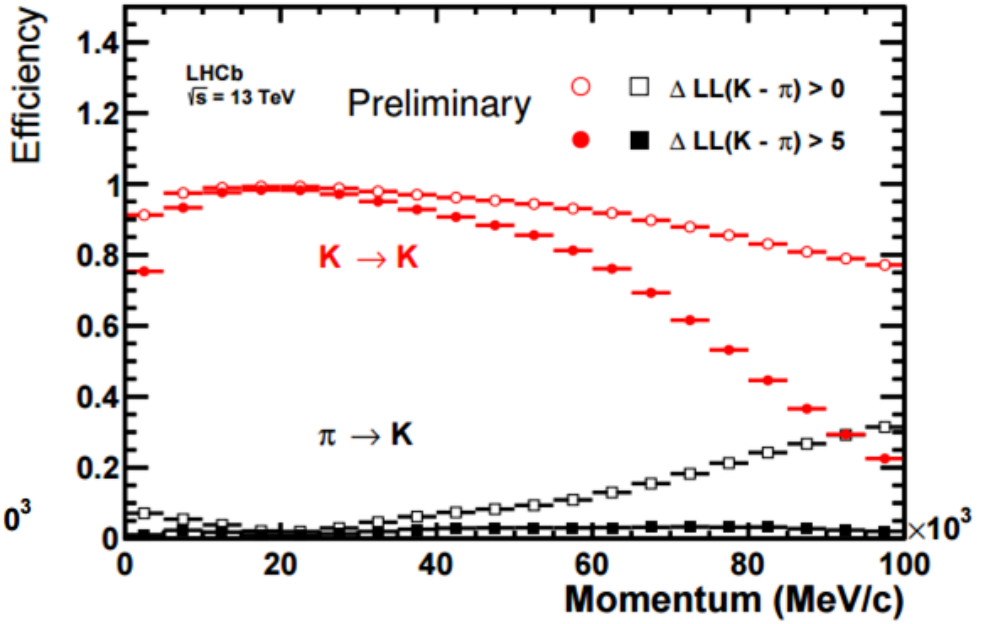
RICH PID performance

Comparison between:

Run I



Run II (2015)



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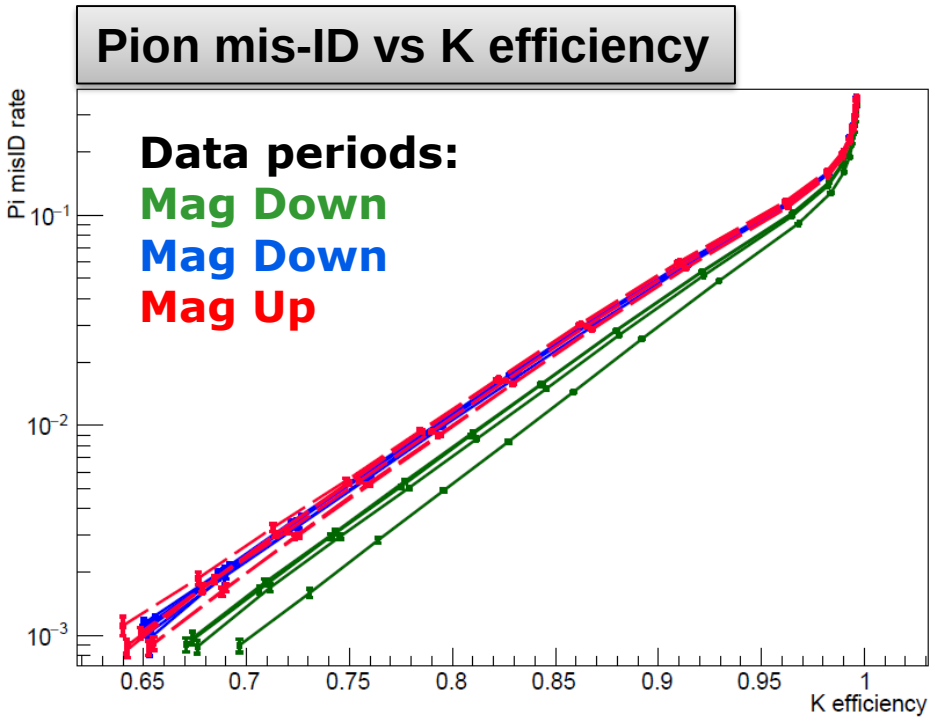
PID variations in 2015

- Every line represents PID performance in a different period in 2015
  - Periods follow big changes in data-taking
- There is a clear structure that coincides with changes in the trigger
- Detector studies show no change in detector performance
- Different mixture of events results in different PID performance



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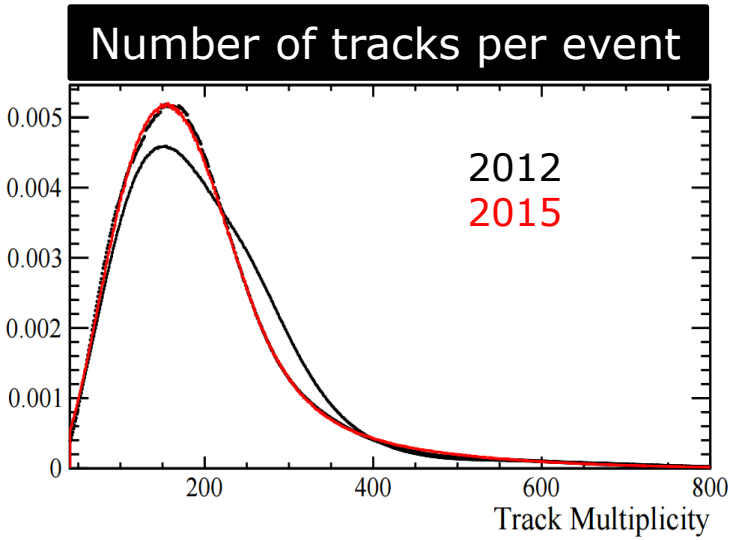
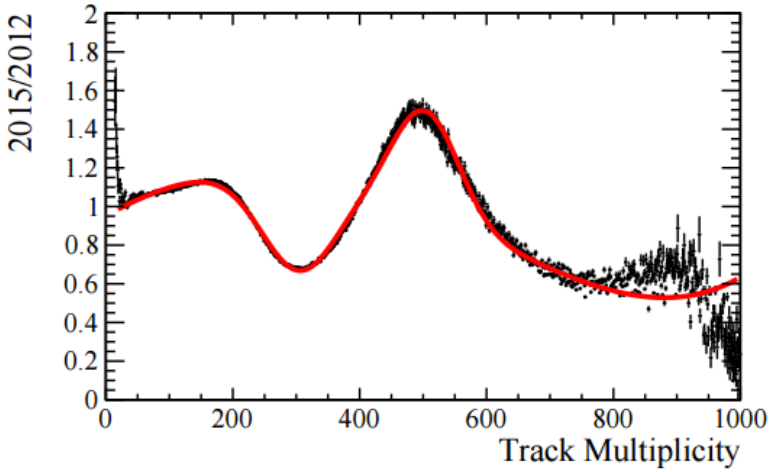
Equalising conditions for Run I/II

- Main factors affecting PID:
  - Momentum
  - Pt or η
  - Number of tracks
- Differences Run I→II
  - Higher beam energy
  - Smaller number of primary interactions
  - Different thresholds for trigger
- A re-weighting method is used to equalise the track distribution
- PID is studied in terms of momentum and η
- RICH2 covers η>2.6





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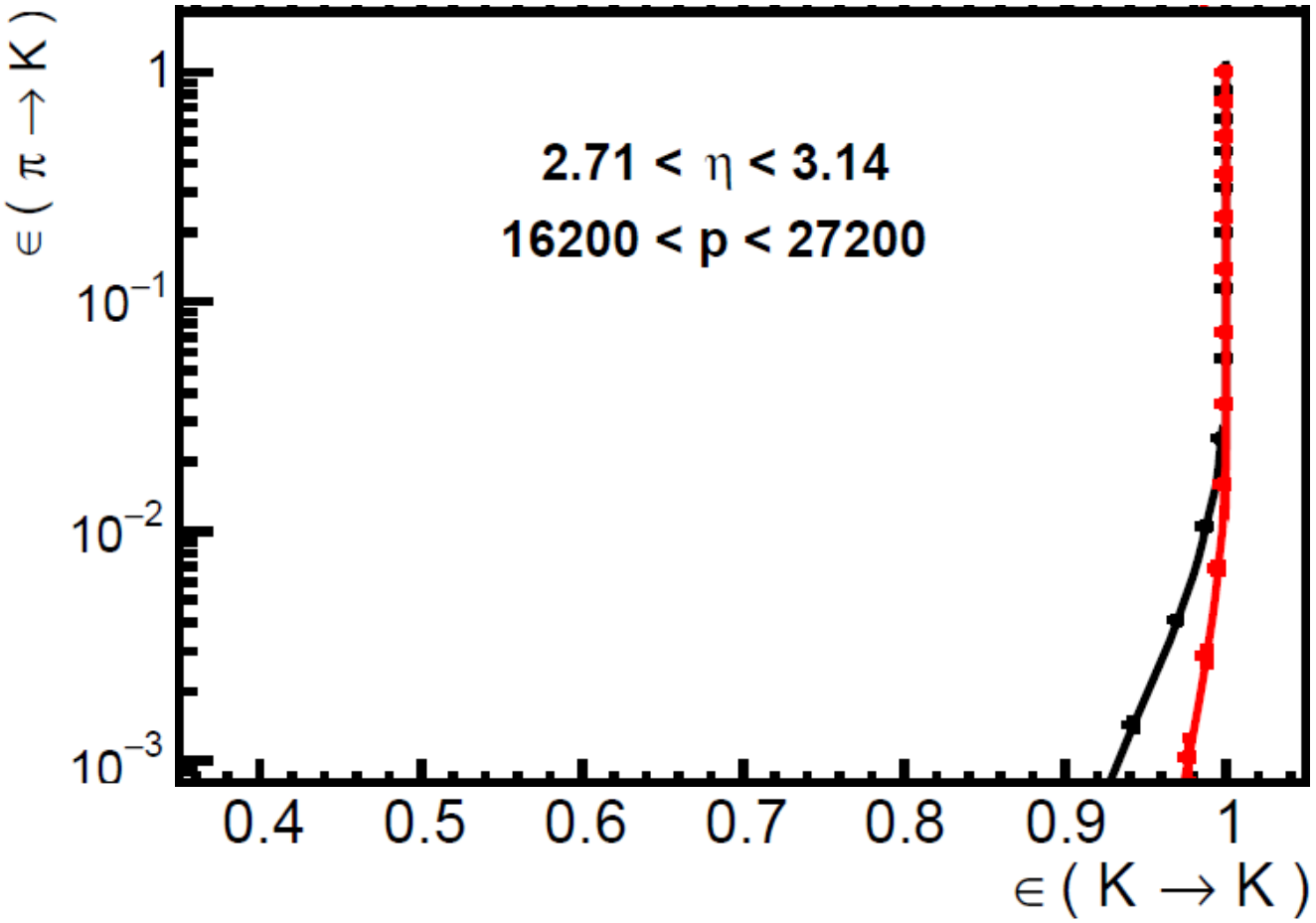
Example PID comparison 2012/2015



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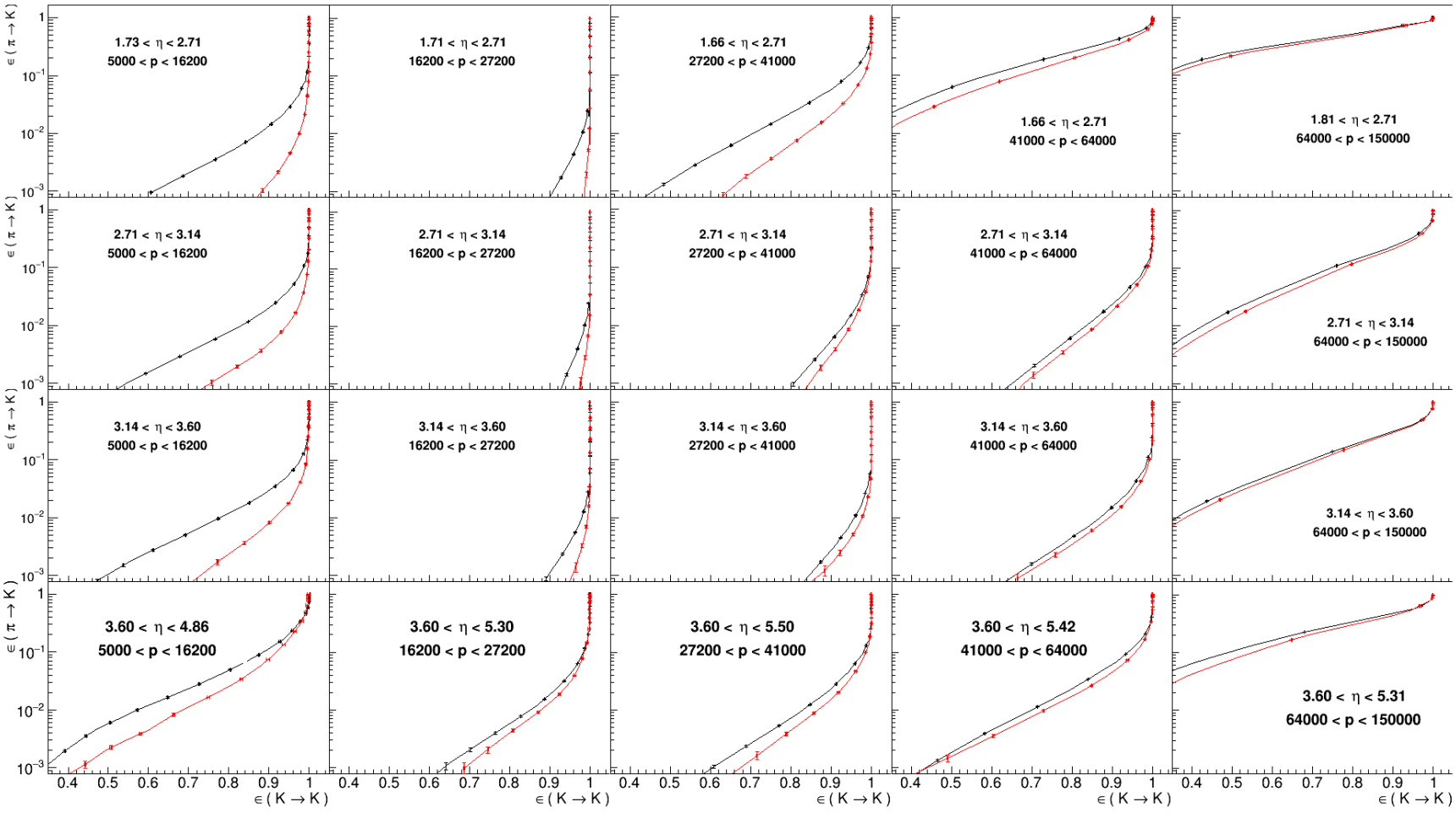
π/K PID 2012/2015



↓ η

Momentum →

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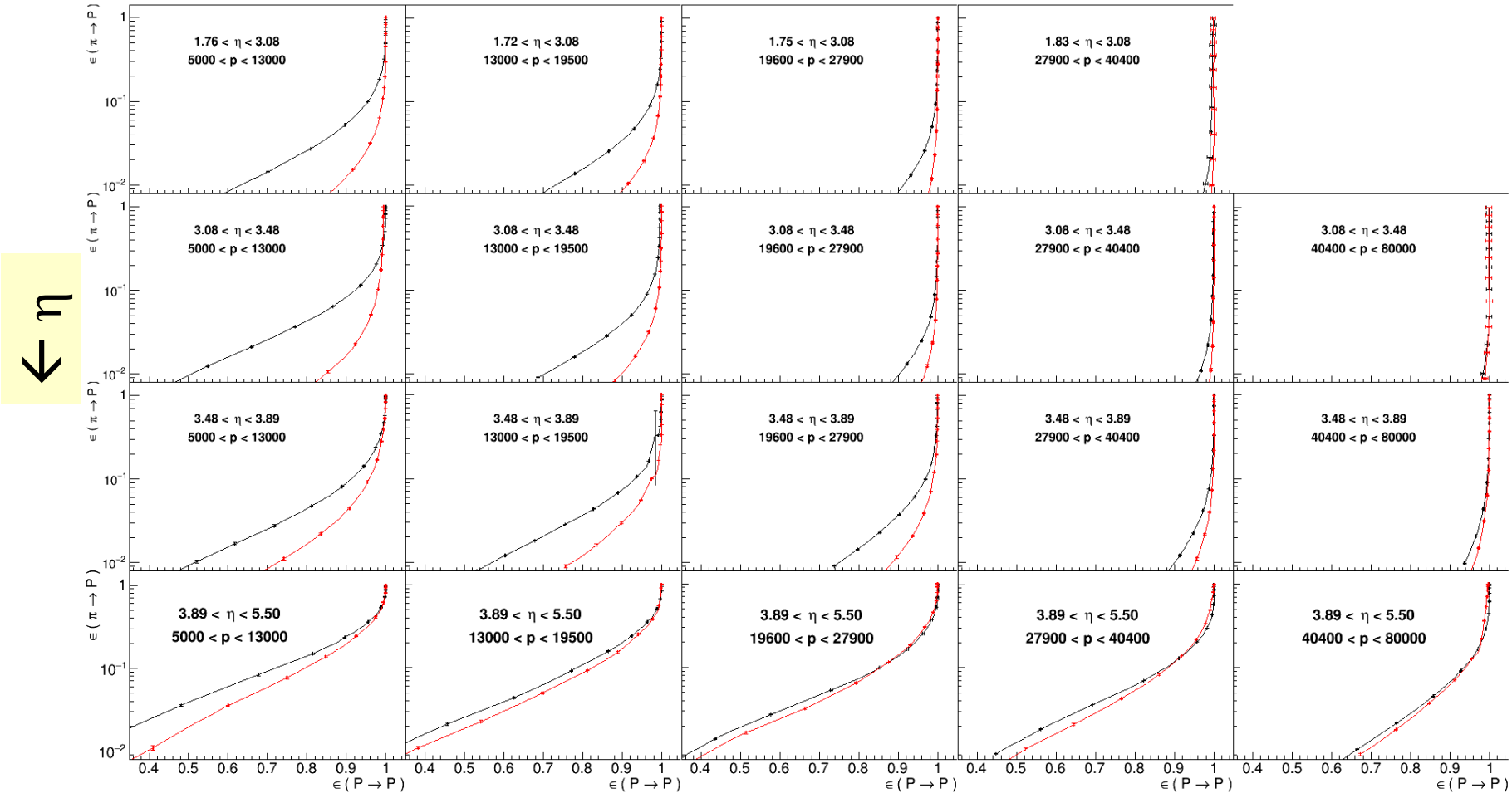
p/π PID 2012/2015



↓ η

Momentum →

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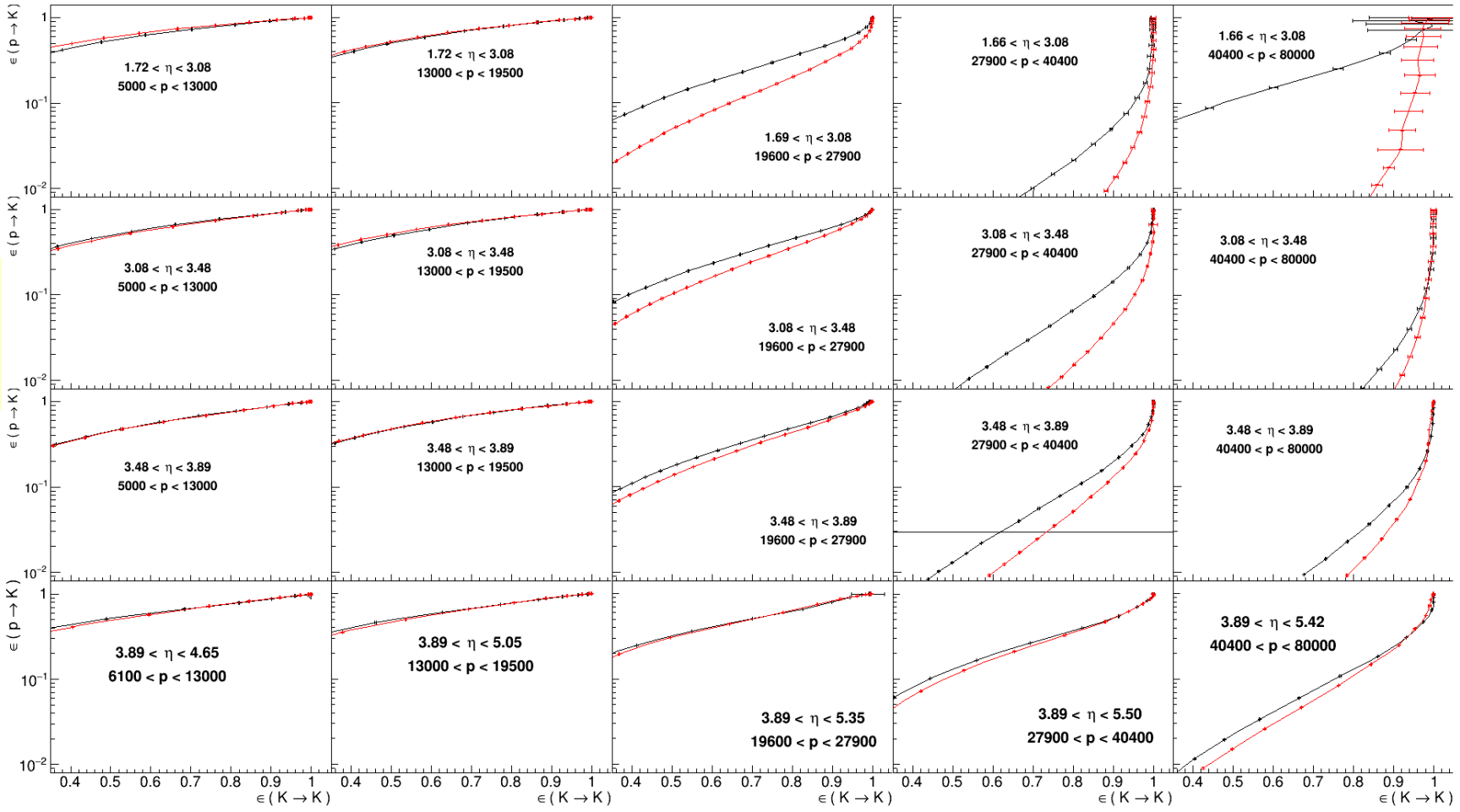
p/K PID 2012/2015



↓ η

Momentum →

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Summary

- The LHCb RICH detectors have been operational for 6 years, providing excellent hadron PID. The RICH is an essential part of the LHCb experiment.
  - The entire charm physics programme relies on RICH PID
- The LHC long shutdown gave us the opportunity to study their performance and find a new optimum within the new LHCb trigger strategy, and implement changes that improve PID
- The experience gained in the process gives us great confidence that the design choices for the LHCb RICH Upgrade will bring the expected improvements in performance