



**RICH 2016**

*9th International Workshop on Ring Imaging Cherenkov Detectors, Bled, Slovenia, Sept 5-9 2016*

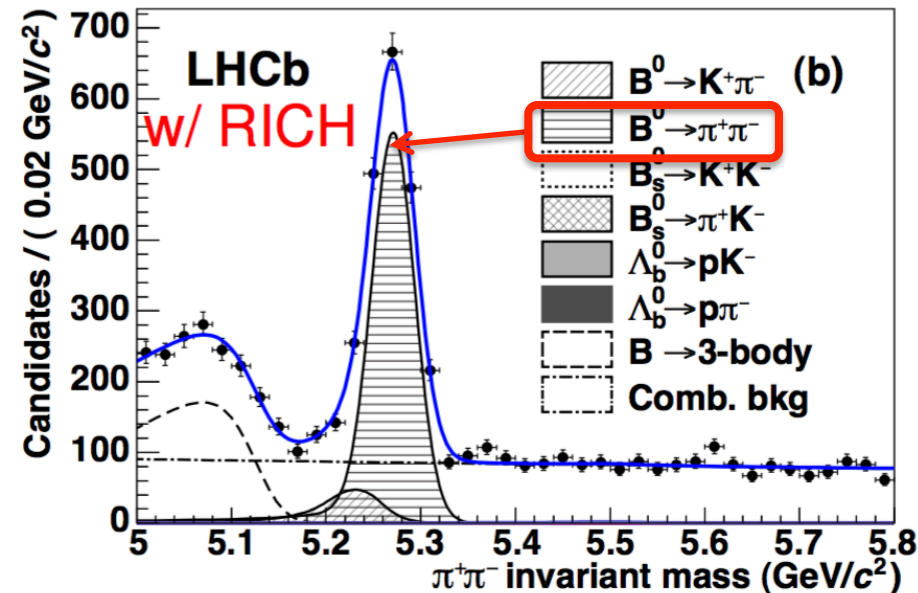
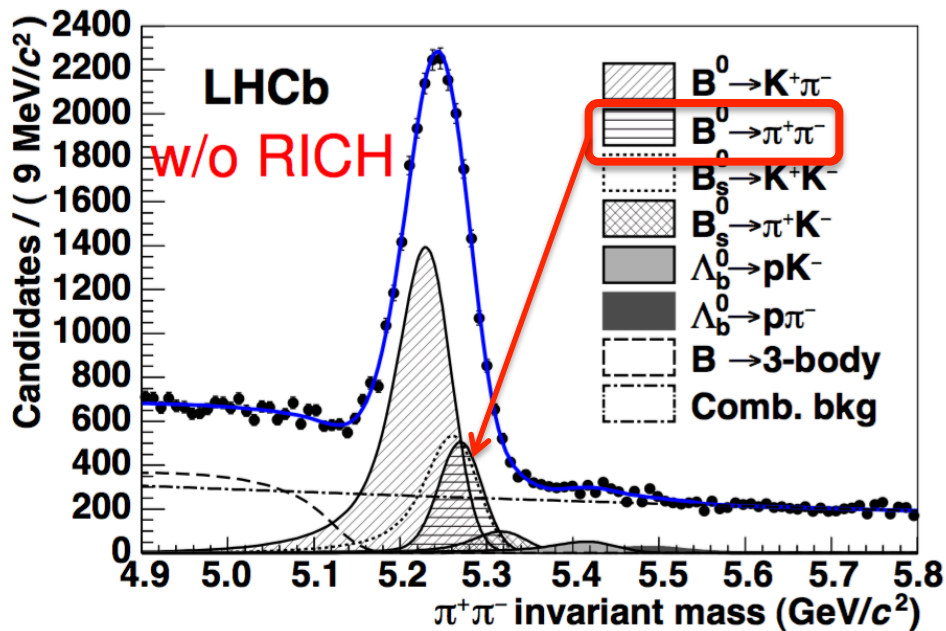
# Real-time calibration and alignment of the LHCb RICH detectors

Jibo HE (UCAS)

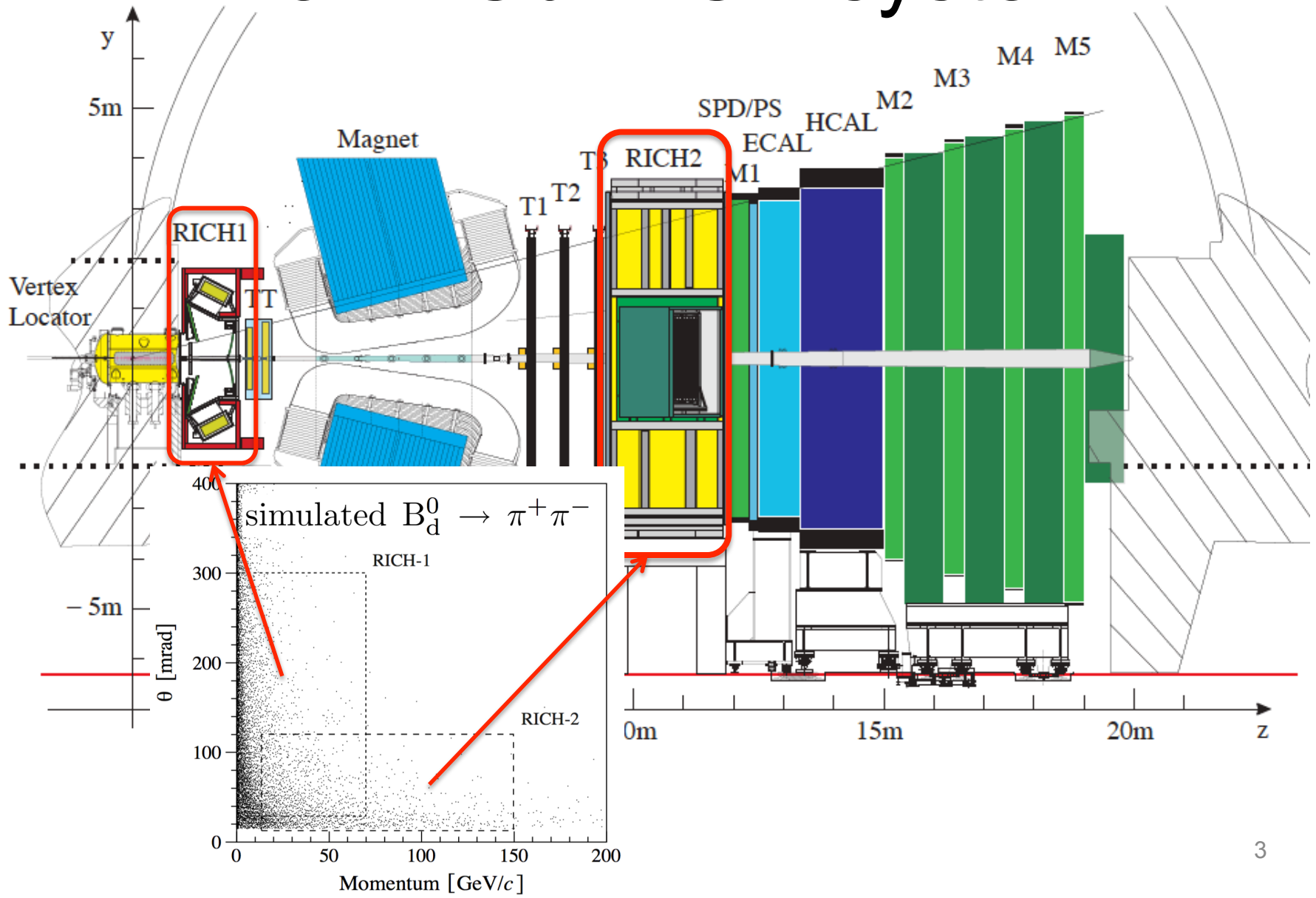
on behalf of the LHCb-RICH collaboration

# Importance of hadron PID for LHCb

- Goal: search for New Physics by studying CP violation & rare decays in  $b/c$ -hadrons
- Excellent PID is essential



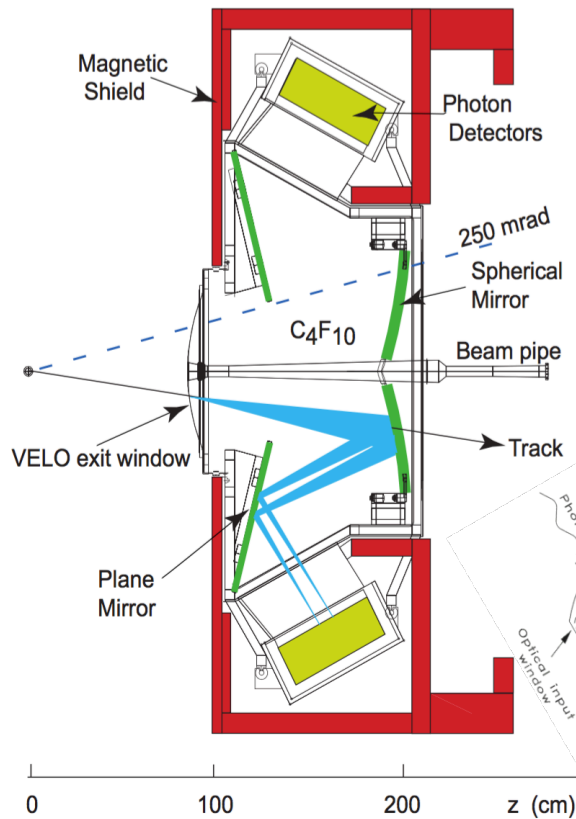
# The LHCb RICH system



# The LHCb RICH system

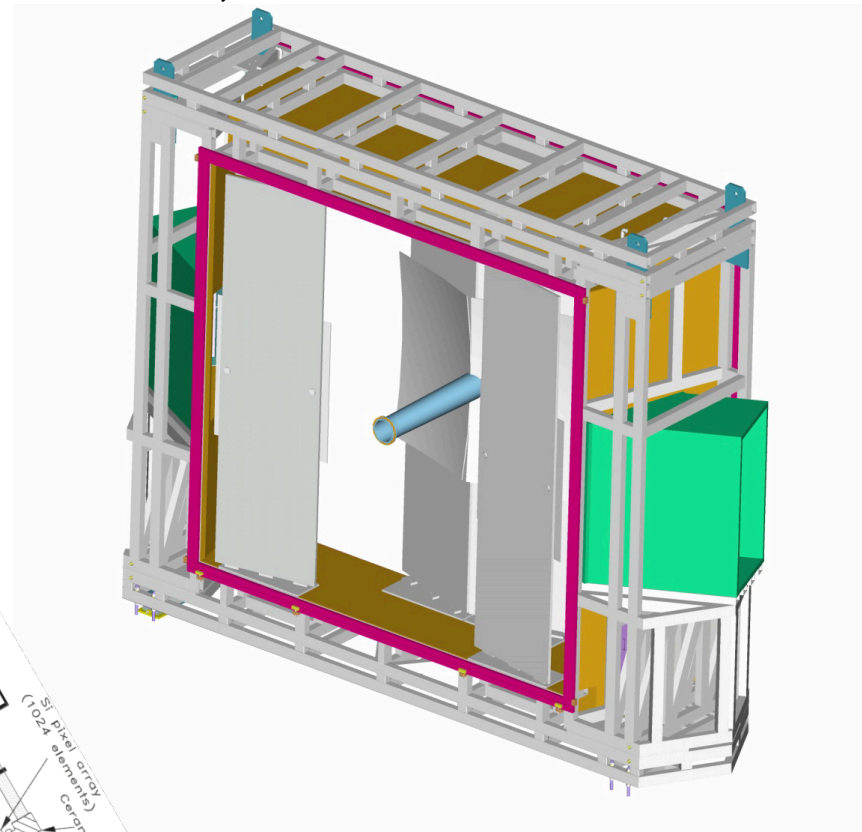
- **RICH1 (25-300 mrad)**

$C_4F_{10}$ ,  $n \sim 1.0014$ , up to 60 GeV

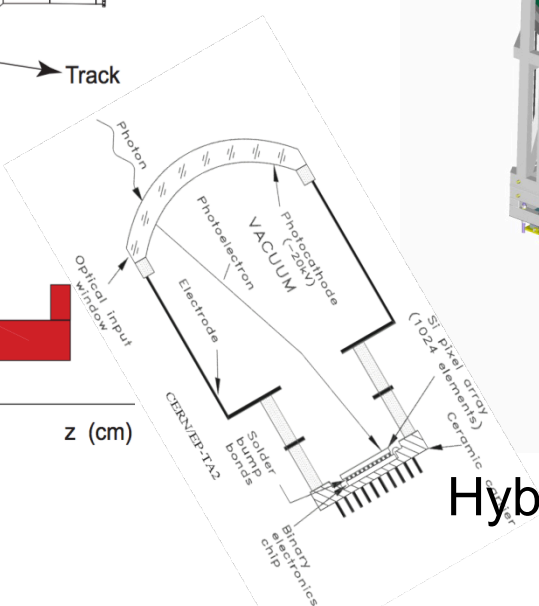


- **RICH2 (15-120 mrad)**

$CF_4$ ,  $n \sim 1.0005$ , up to  $\sim 100$  GeV

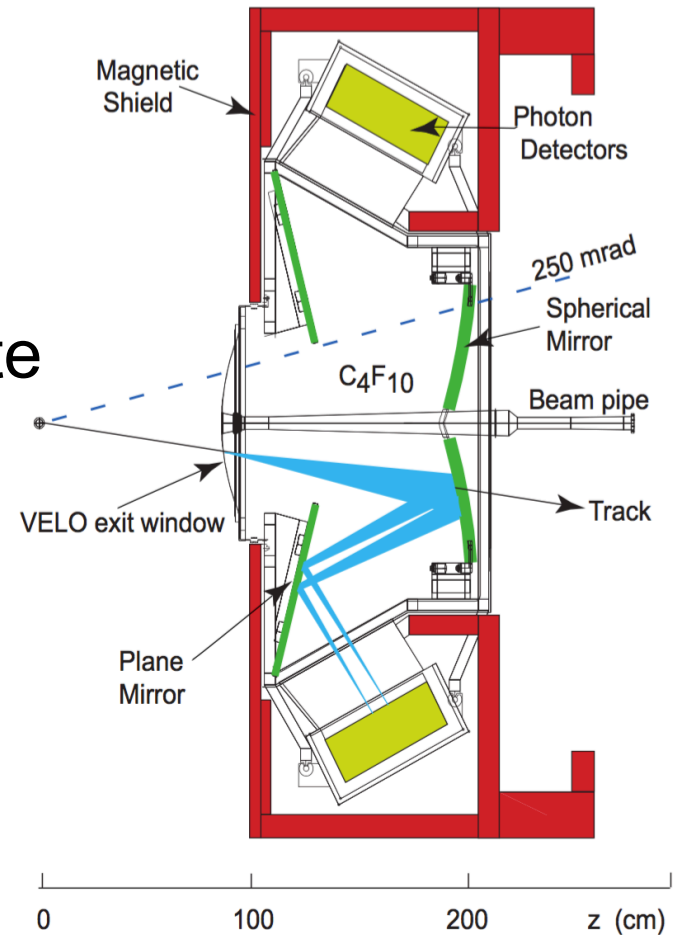


Hybrid Photon Detector (HPD)



# RICH reconstruction in nutshell

- HPD hit  $\rightarrow$  spatial position
  - Decode raw data
- Select tracks and reconstruct photon candidates, then calculate Cherenkov angle
- Determine PIDs with Global likelihood
  - Compare the **observed Cherenkov angles** with the **expected** under different PID hypothesis, and maximize the likelihood



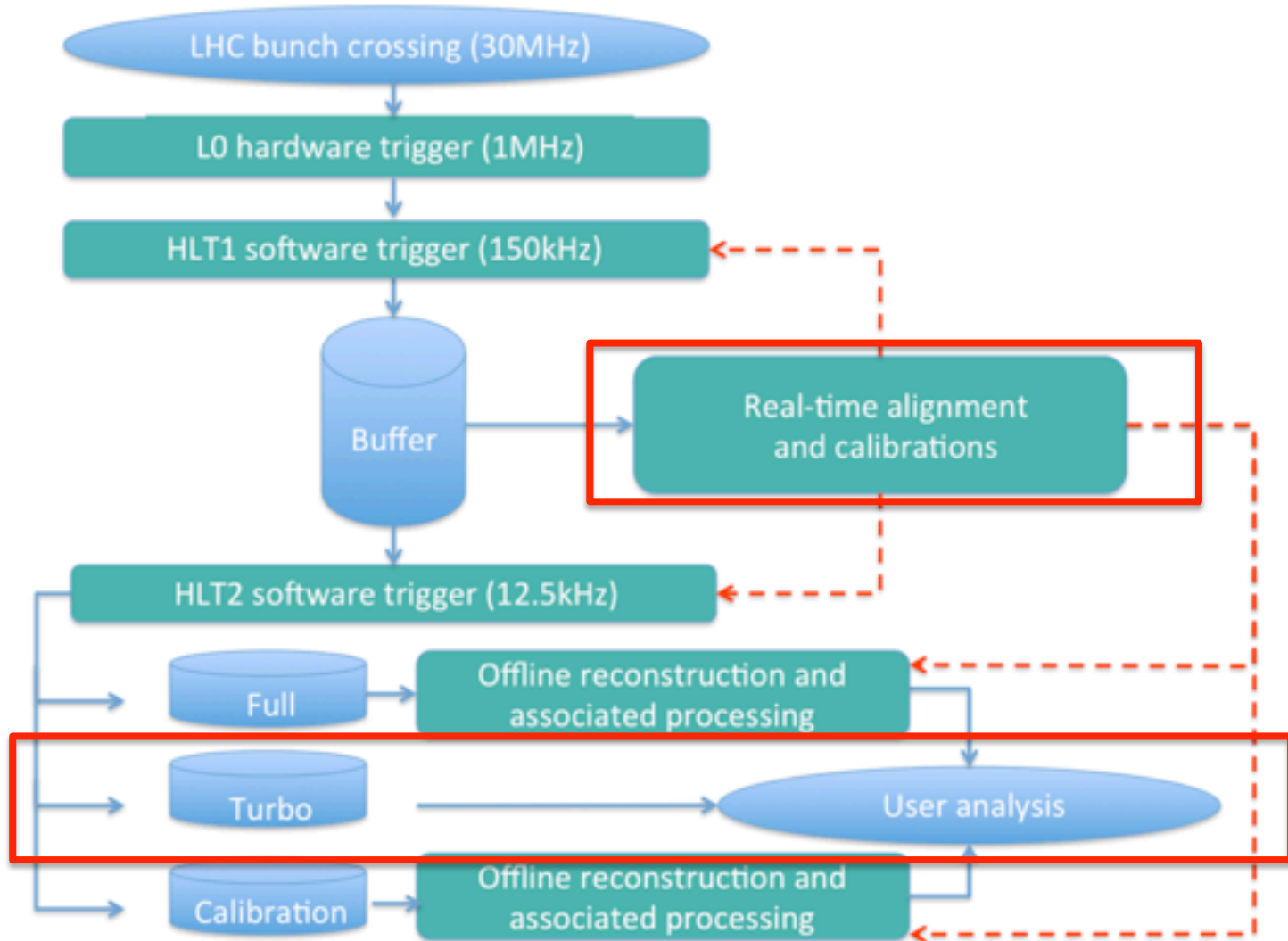
# Key points to have excellent PID

- Cherenkov angle
  - RICH mirrors / detector planes alignment
  - Tracking system alignment
  - HPD image calibration
  - Refractive index (Cherenkov angle)
- Number of photons
  - Refractive index
- These are **time-dependent!**

# Why real-time calib./align.?

- Maximize physics output
  - From Run-I to Run-II, 7/8 TeV  $\rightarrow$  13 TeV
  - After upgrade,  $>4$  times higher luminosity & hardware trigger removed
- Make trigger more selective & use trigger output for analysis directly
  - Need to have offline quality reconstruction
  - Alignment/calibration are time-dependent
  - $\rightarrow$  real-time calibration and alignment

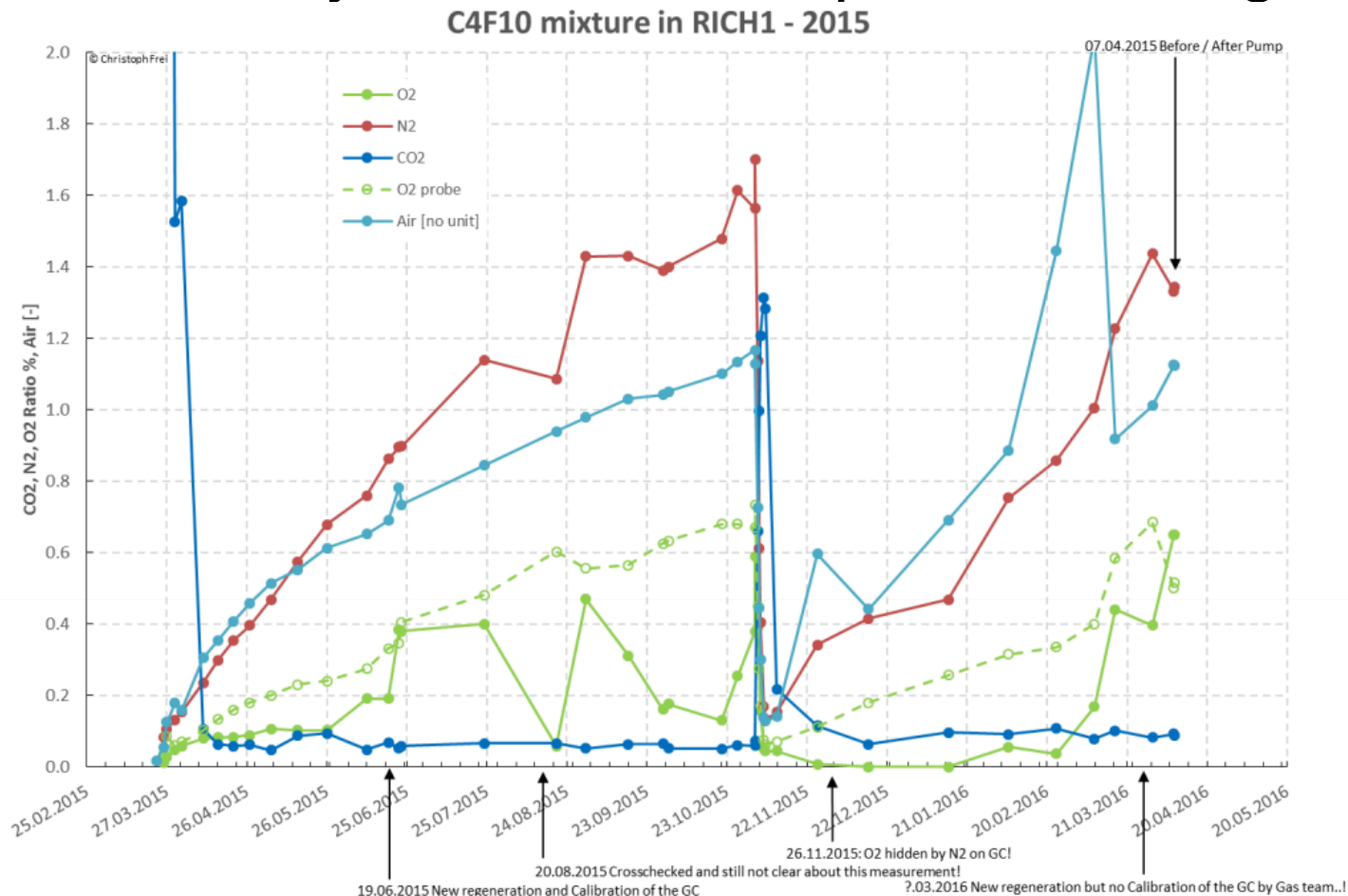
# New dataflow





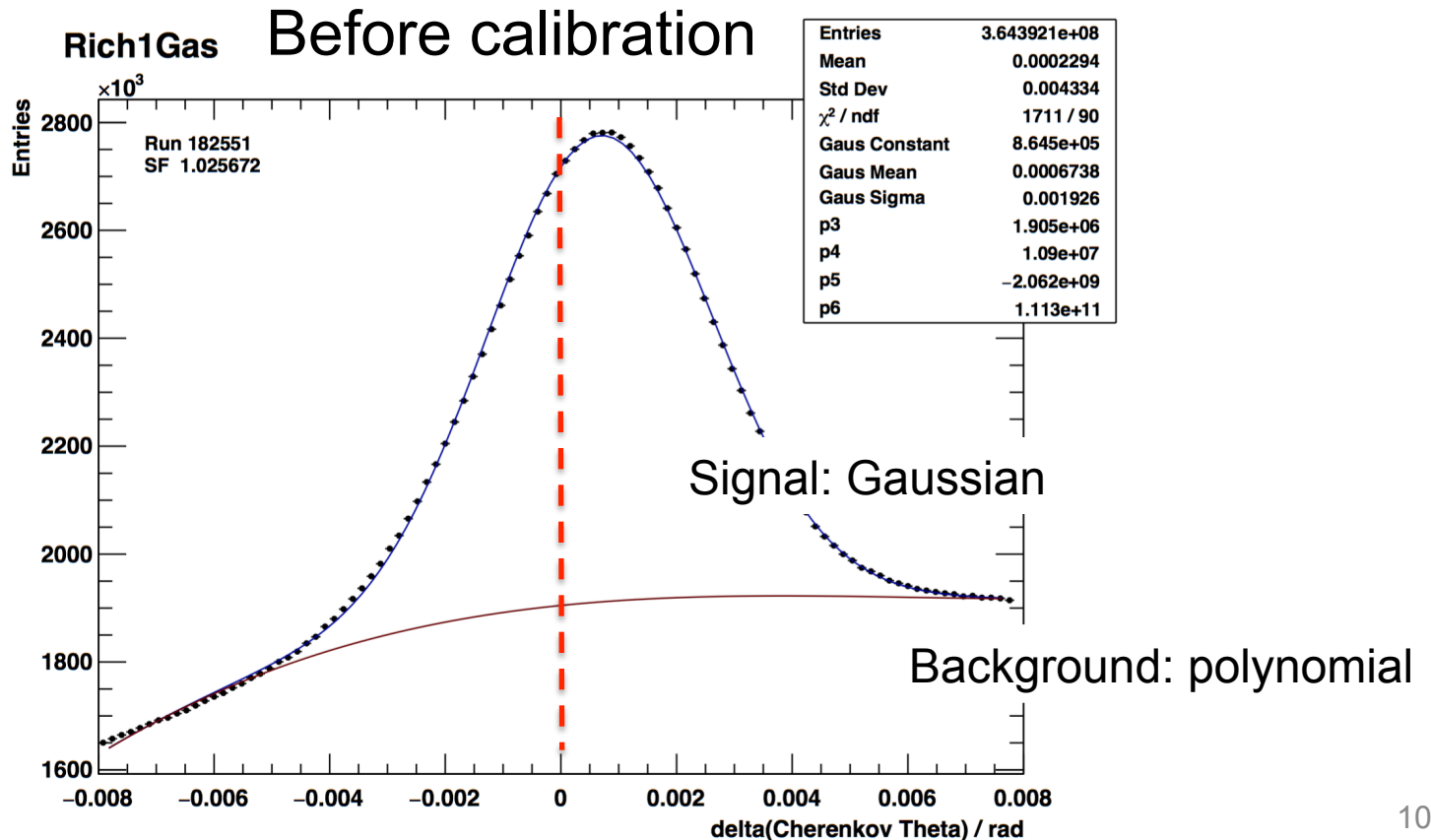
# Refractive index calibration

- Gas components, temperature, pressure
- Monitored by hardware, not precise enough



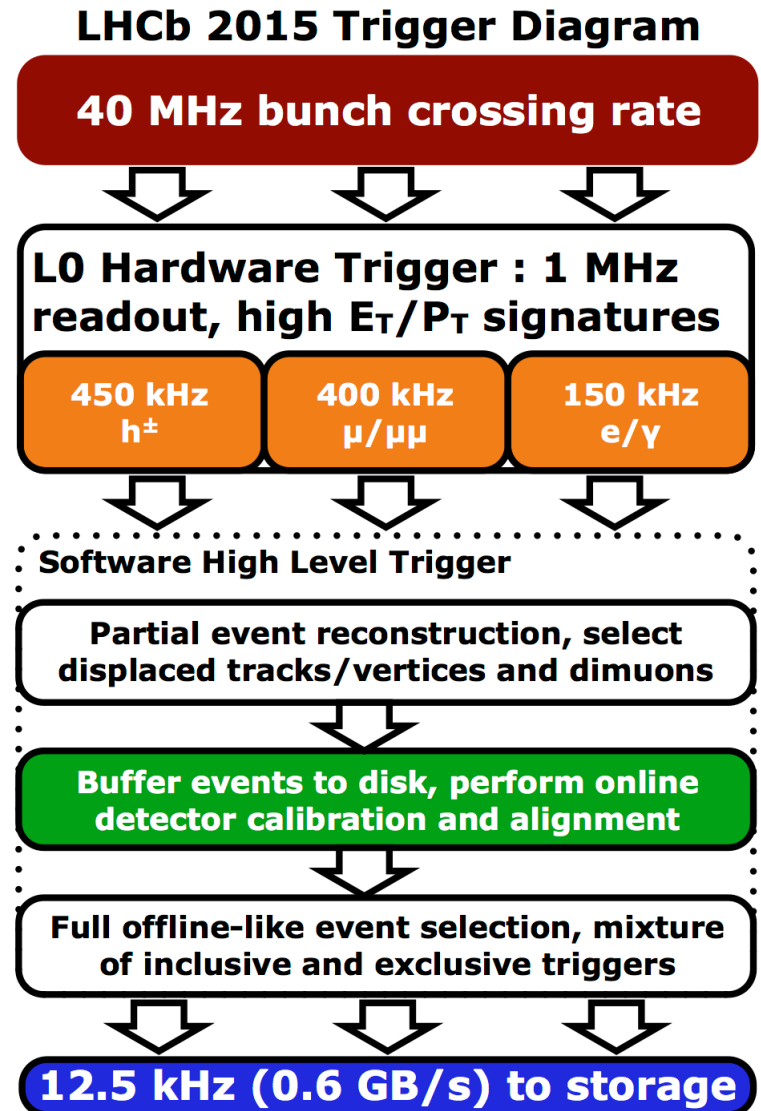
# Refractive index calibration (cont.)

- Difference between reconstructed and expected Cherenkov angle  $\rightarrow$  scale factor

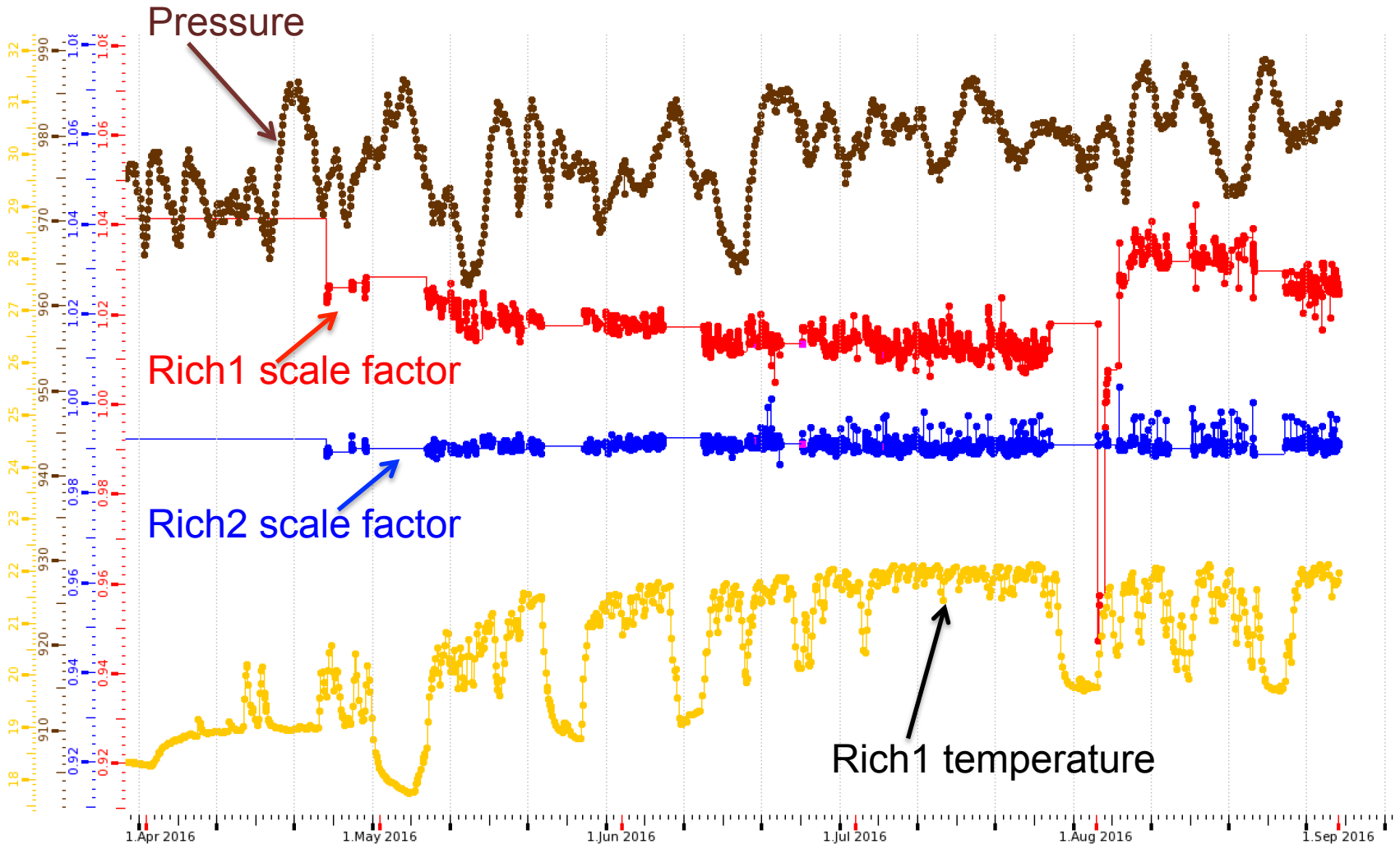


# Refractive index calibration: how?

- Run-by-run
- Run reconstruction on ~50 Hz HLT1 outputs
- Fit and publish constants
- In case of problem, use constants of previous run
- Fast & automatically



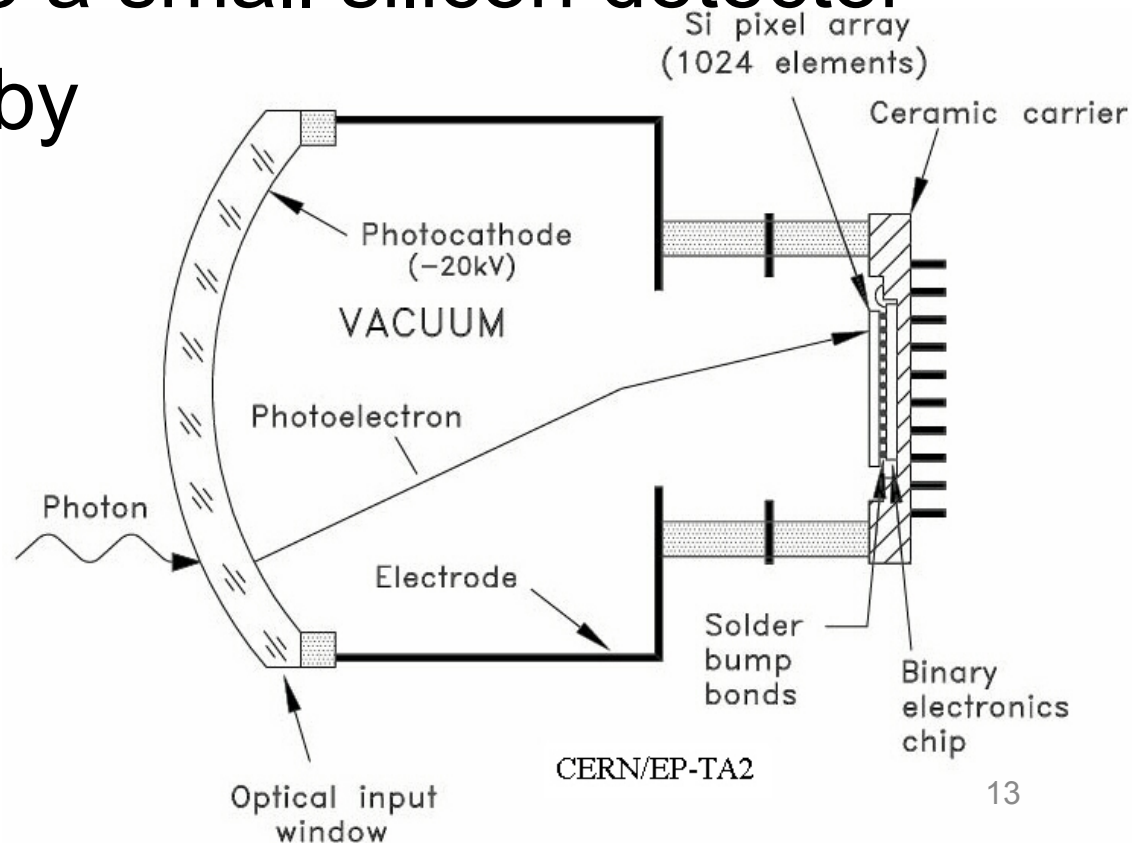
# Monitoring: trend



01/09/2016 03:06:18 .235	<input checked="" type="checkbox"/> R1ECS_Rich1RefIndexScaleFactor	1.02	<input checked="" type="checkbox"/> R1DCS2.AnalogDigital/Rich1CondDBPressure.value	983.94
	<input checked="" type="checkbox"/> R1ECS_Rich2RefIndexScaleFactor	0.99	<input checked="" type="checkbox"/> R1DCS2.AnalogDigital/Rich1CondDBTemperature.value	21.97

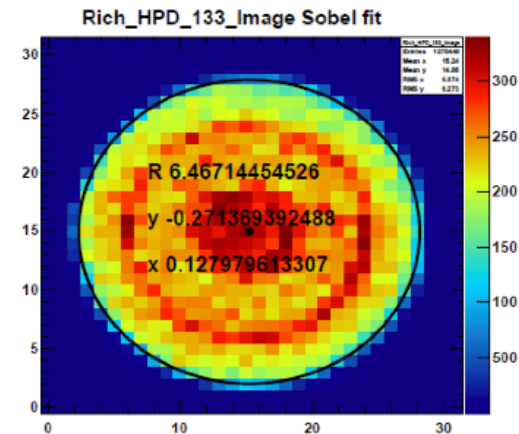
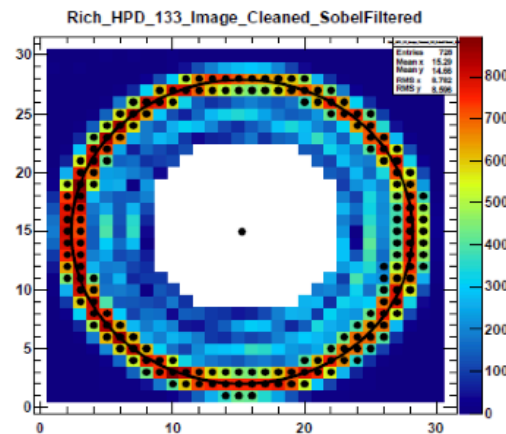
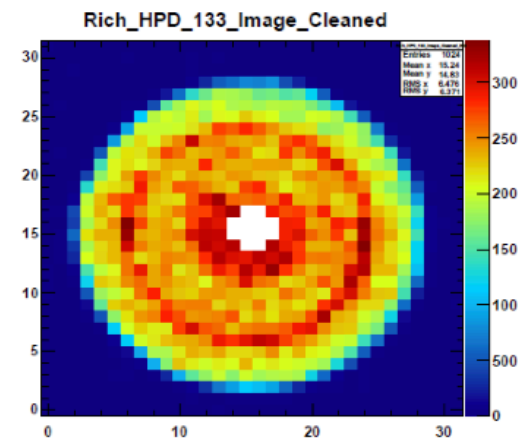
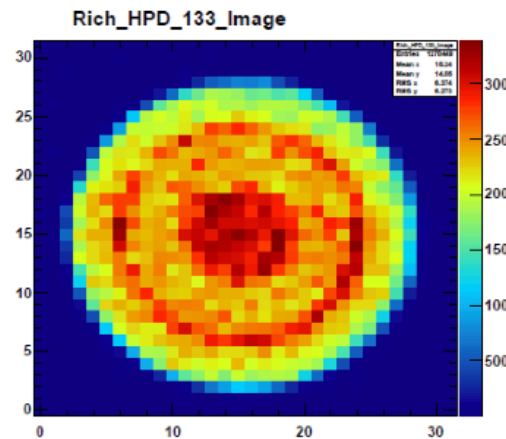
# Pixel hybrid photon detector (HPD)

- Electrostatically focused tube
- Photon-cathode image **de-magnified** by a factor of  $\sim 5$  onto a small silicon detector
- Image affected by
  - Electric fields
  - Magnetic fields

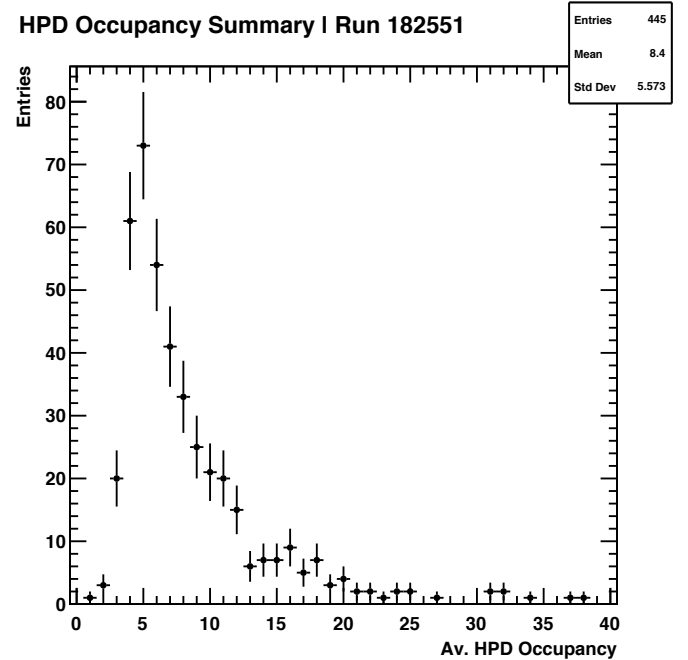
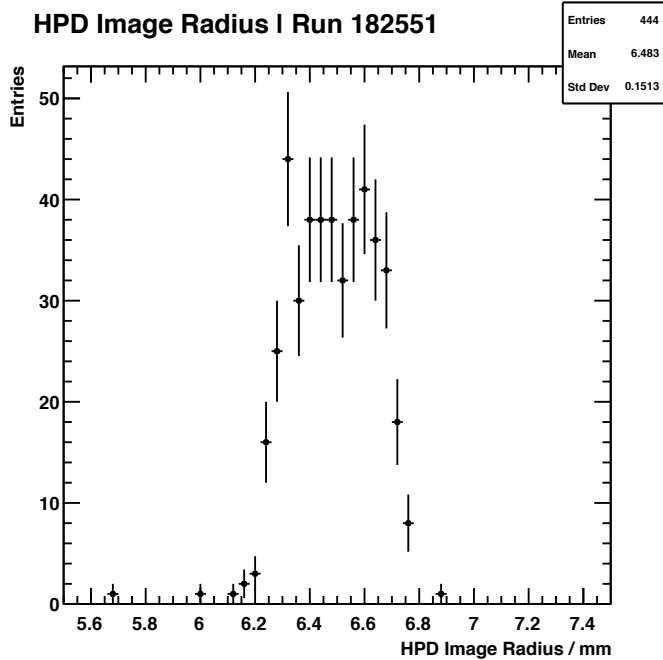
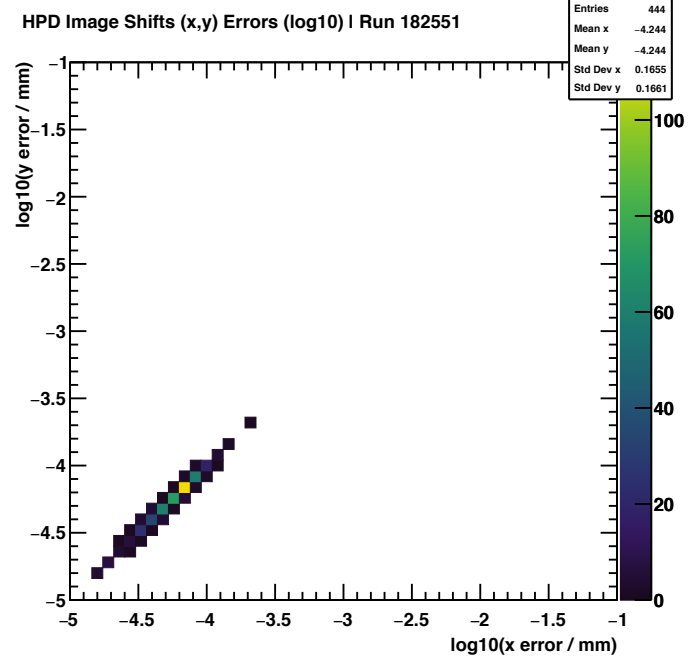
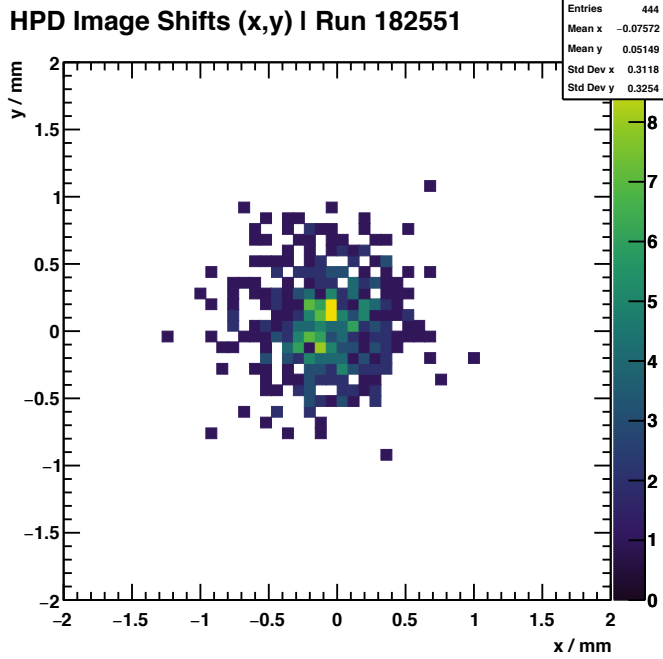


# HPD image calibration: how?

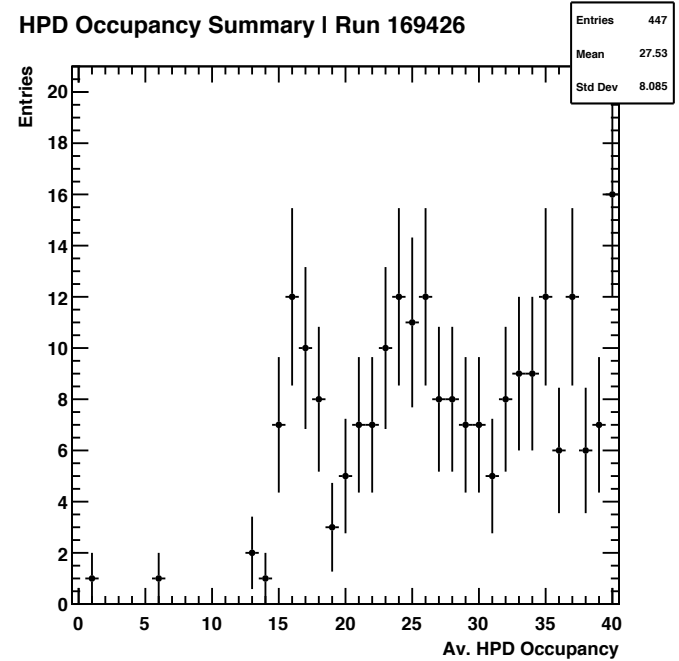
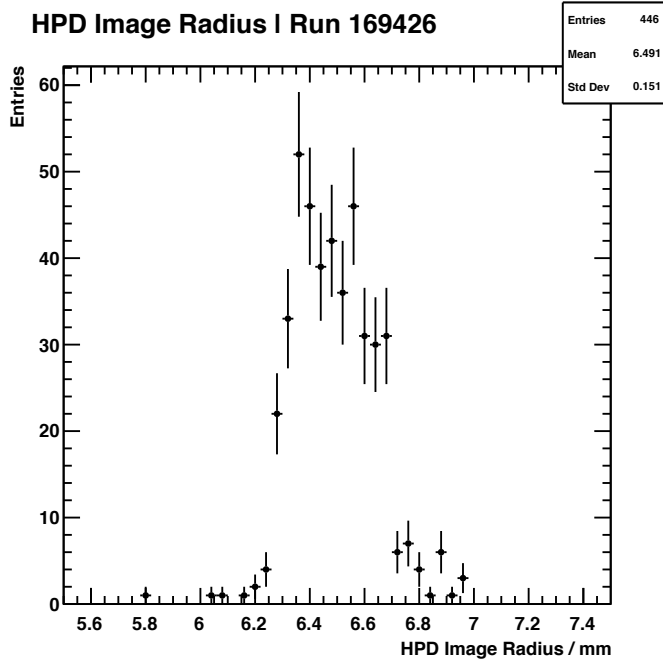
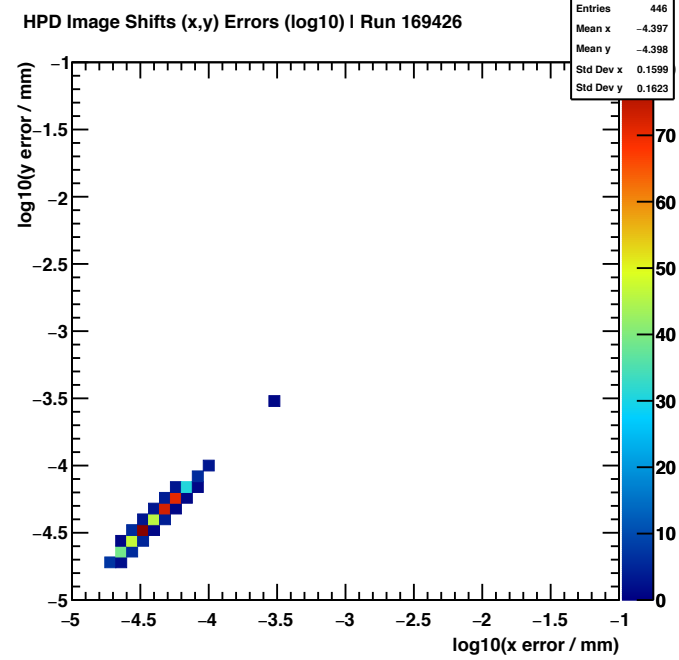
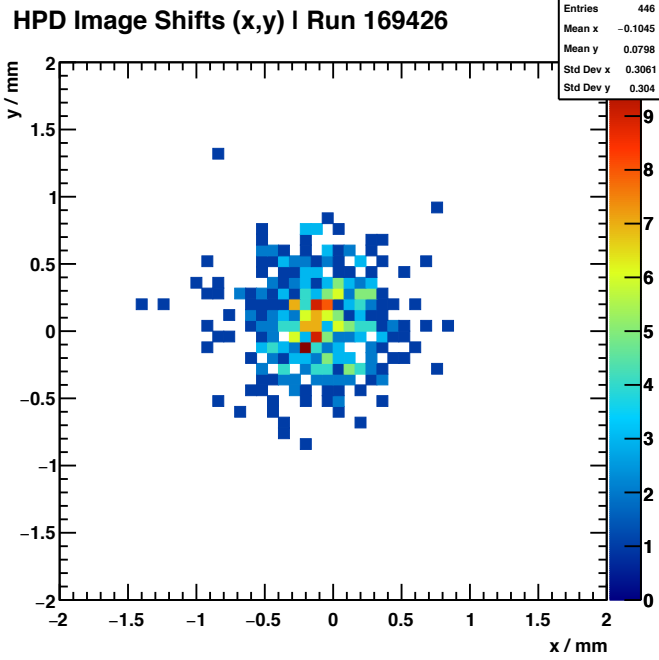
- Run-by-run, only need to decode raw data, process  $>500$  Hz
- Procedure
  - Accumulate
  - Clean
  - Sobel filtered
  - Fit



# pp collisions

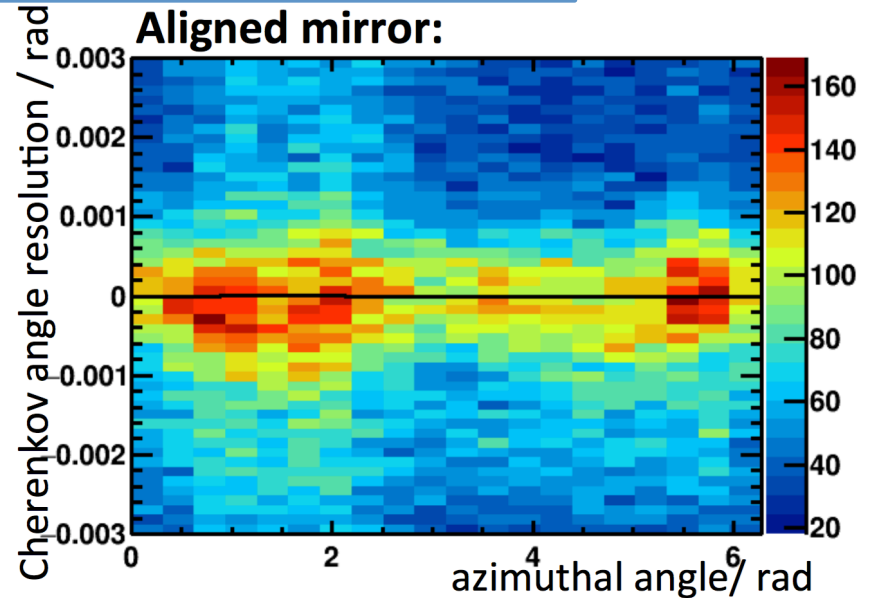
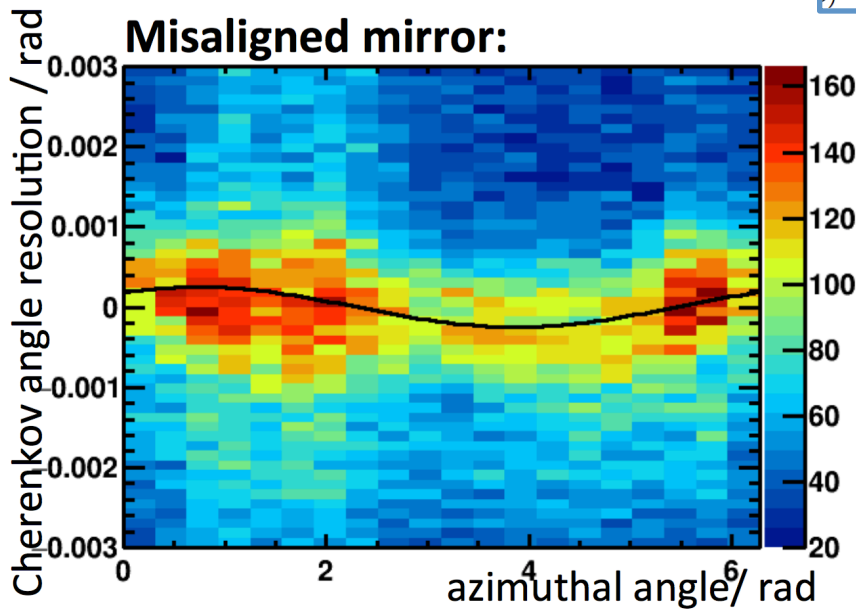
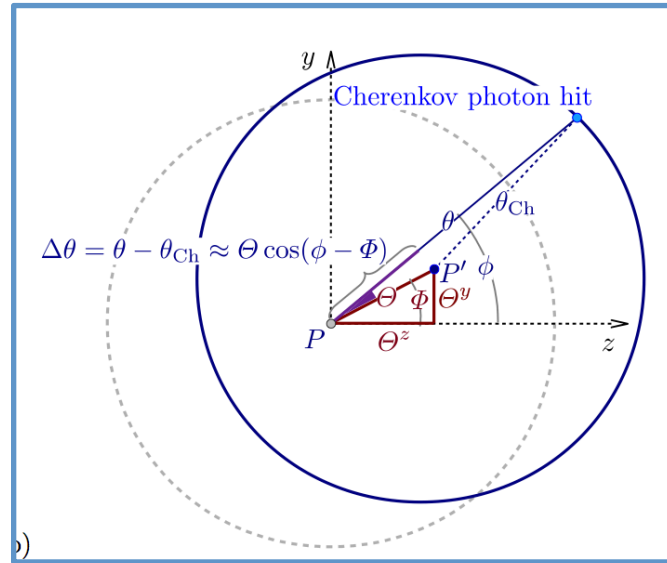
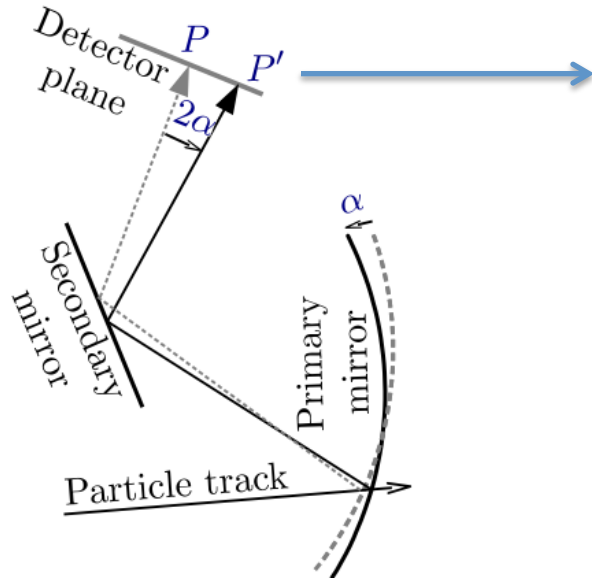


# PbPb collisions





# Mirror alignment

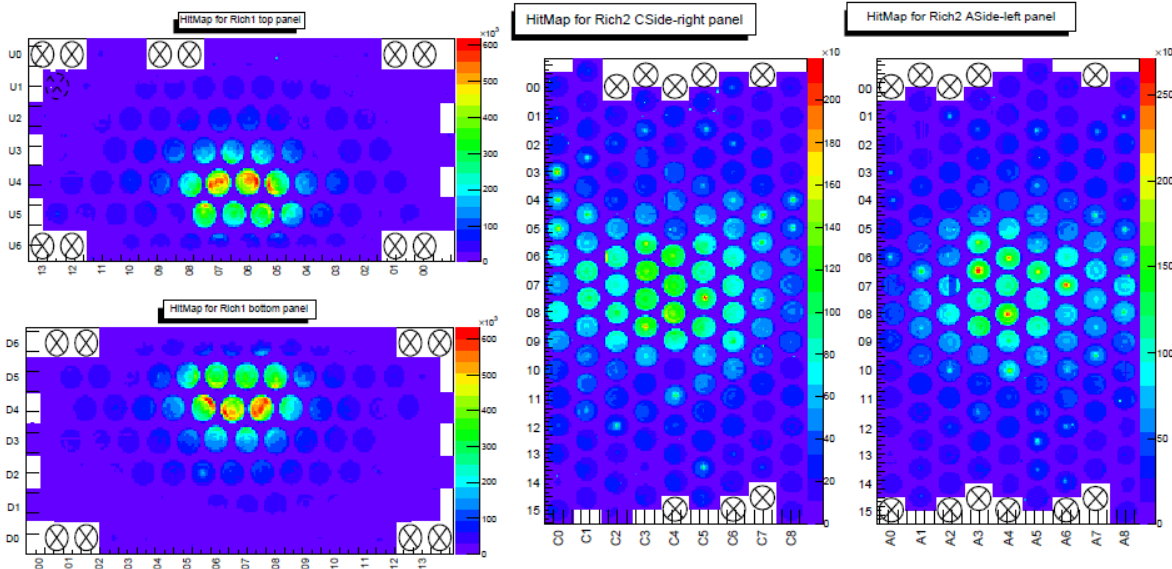


# To speed up mirror alignment...

- 116 mirrors to align...
- Dedicated trigger (online selection) to populate mirror pairs at the edge

/RICH/Default

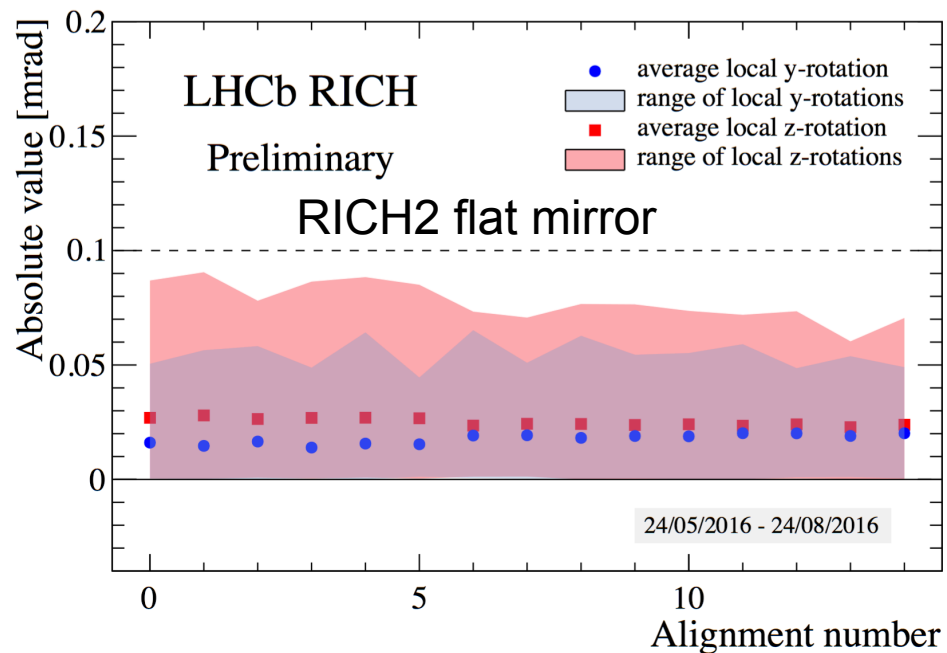
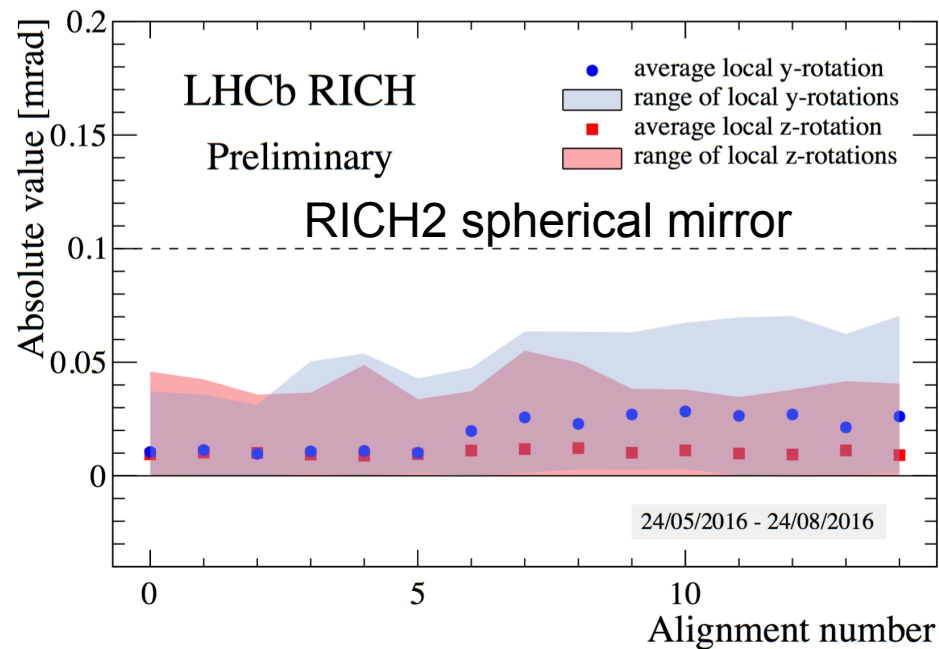
Run 177581, started 2016-06-20 07:00:54, duration: 01:00:06



- Dedicated framework to use HLT farm (~1800 nodes) to do alignment, as for Velo/tracker/...

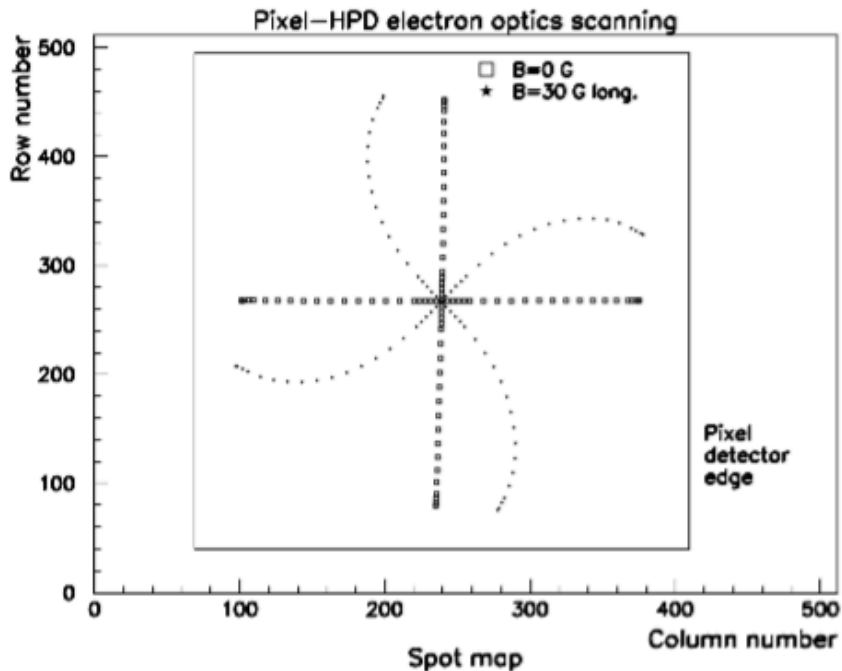
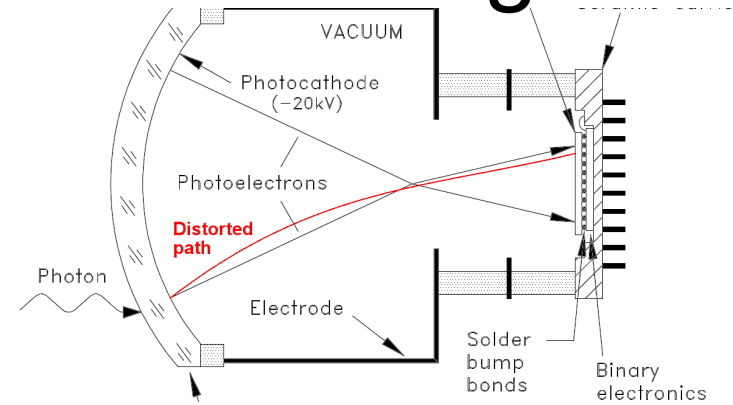
# Mirror alignment

- Monitored automatically fill-by-fill, following the Velo  $\rightarrow$  Tracker  $\rightarrow$  Rich1  $\rightarrow$  Rich2

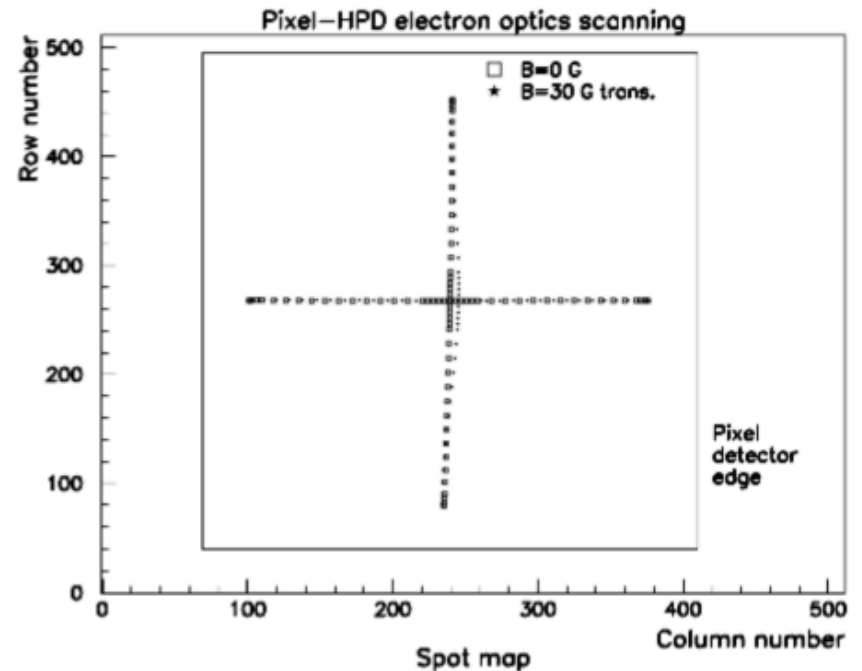


# Effects of magnetic field on HPD image

- Sensitive to longitudinal field



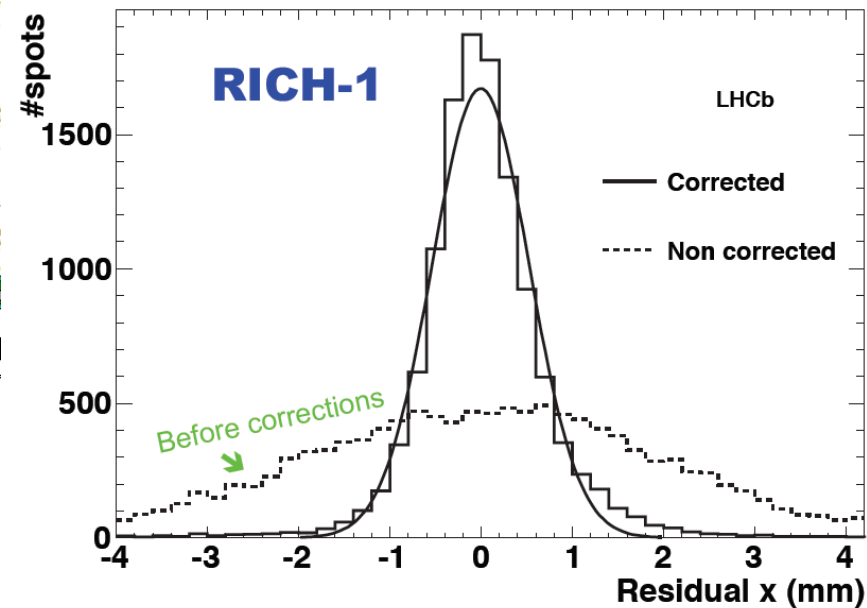
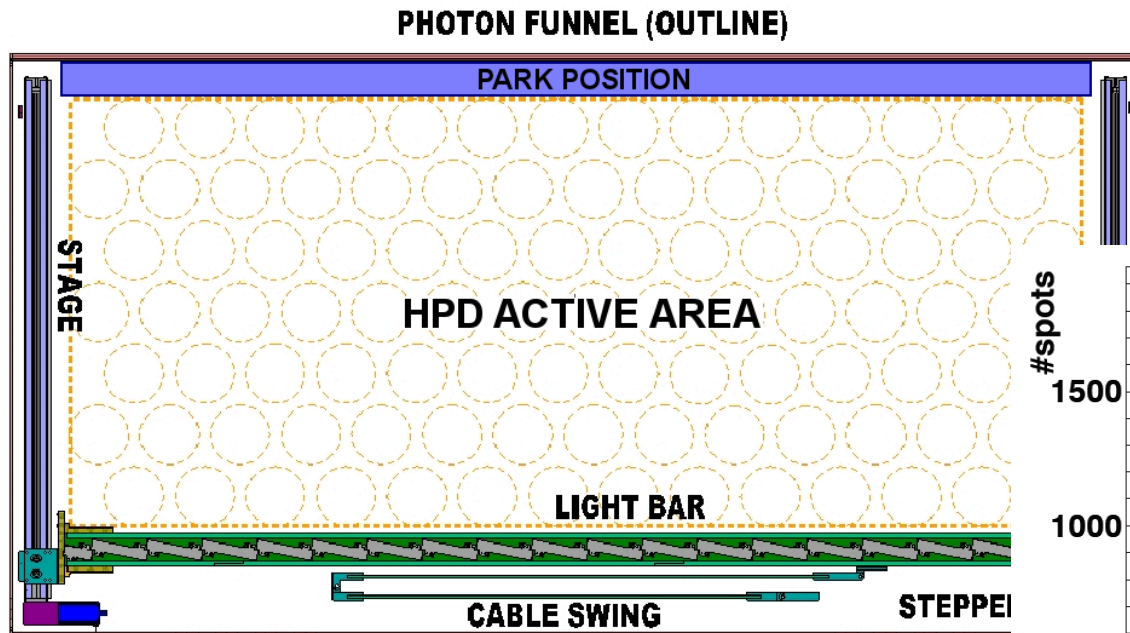
(a) Longitudinal field



(b) Transverse field

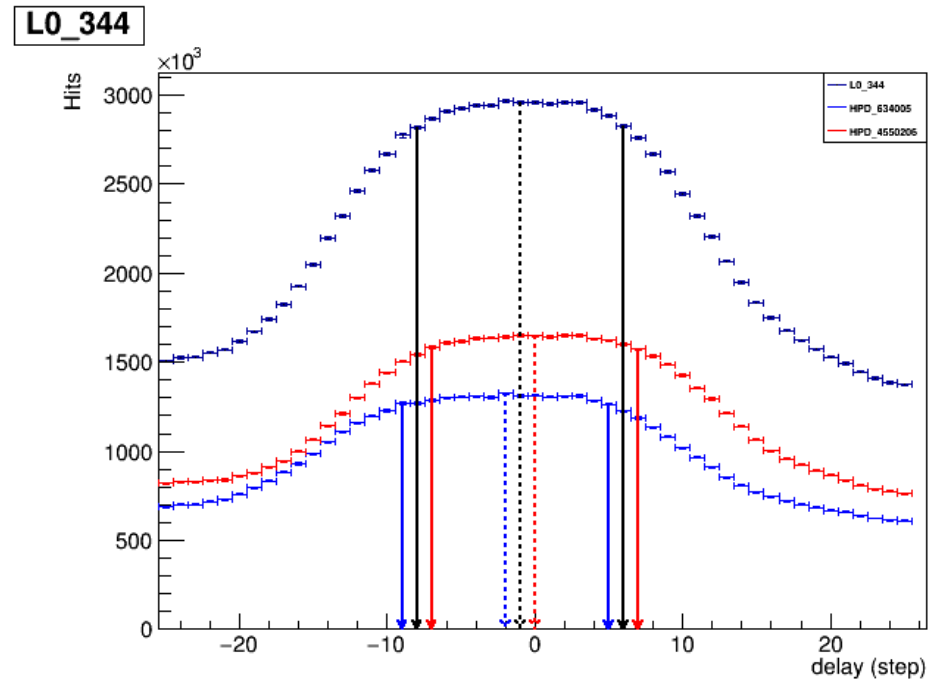
# Correction with the MDCS

- MDCS (Magnetic Distortion Correction System)



# Time alignment

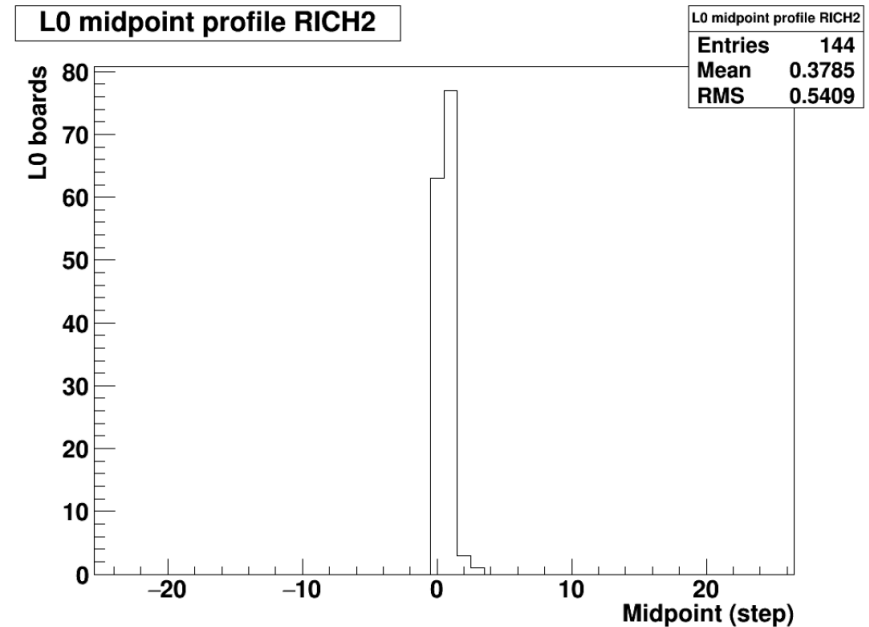
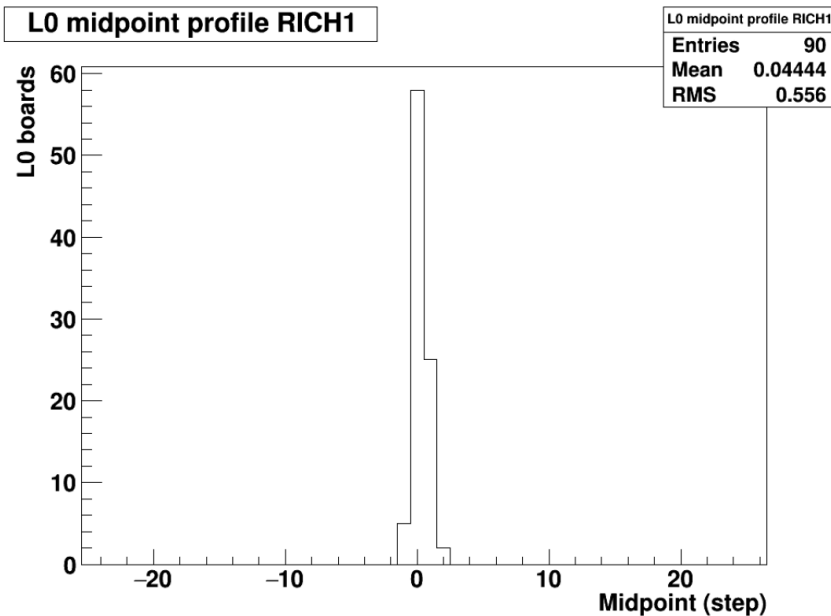
- Each HPD has different response time
- Done with timing scan data taken during physics collisions



# Time alignment: results

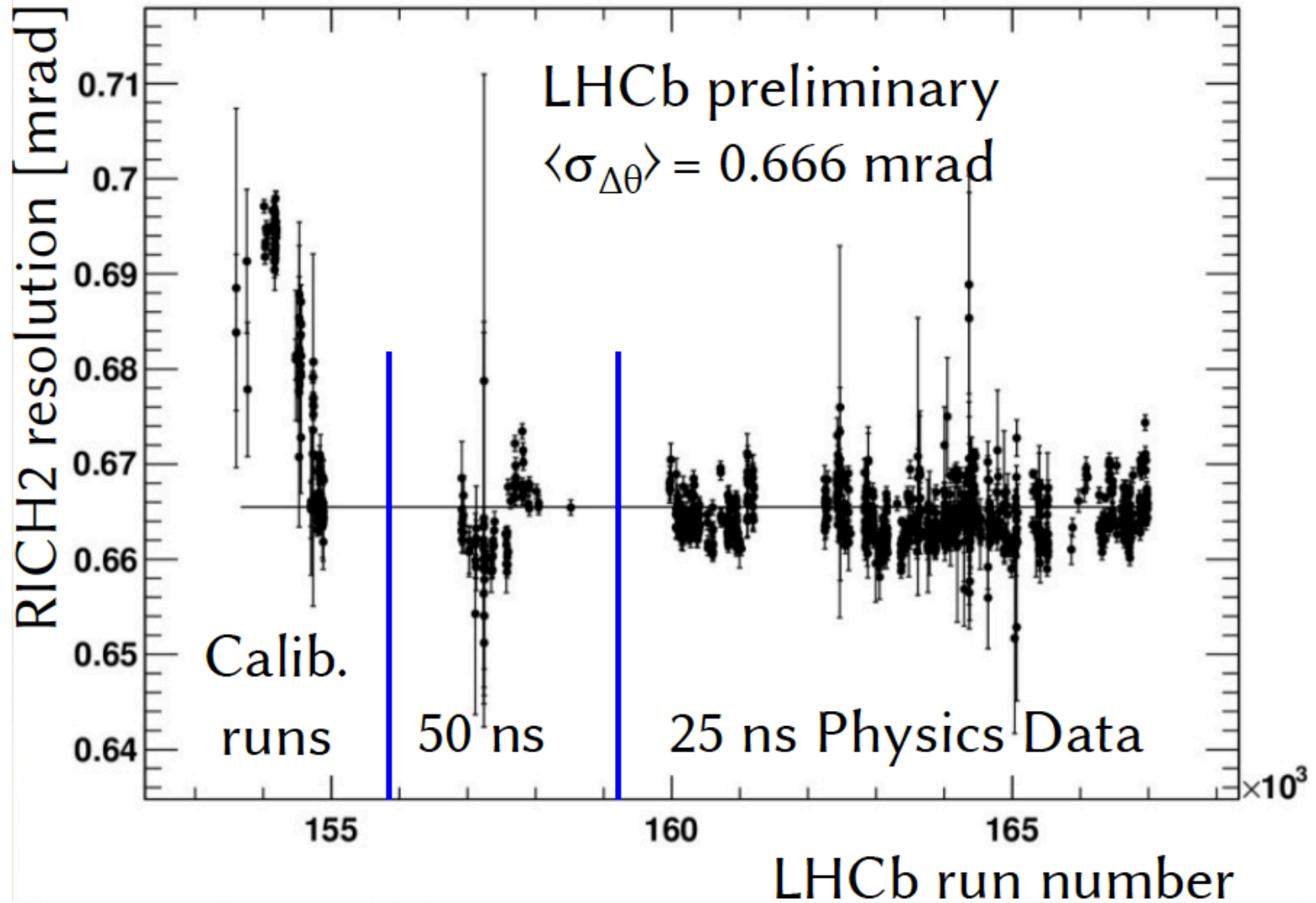
- RICH1 (ns)

- RICH2 (ns)



All HPDs are aligned to ns level!

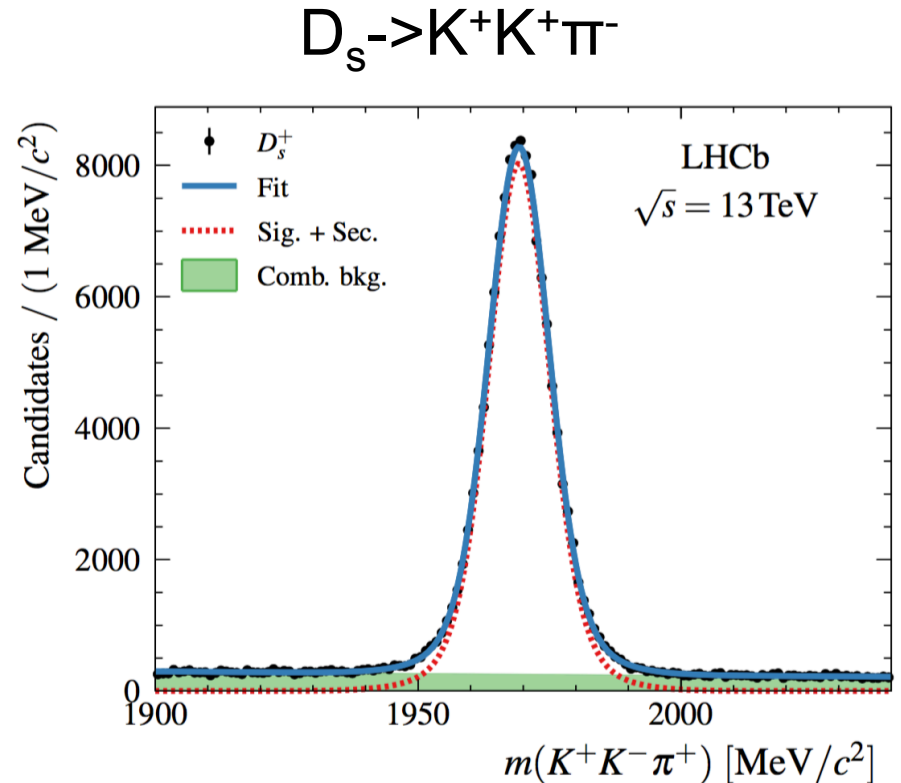
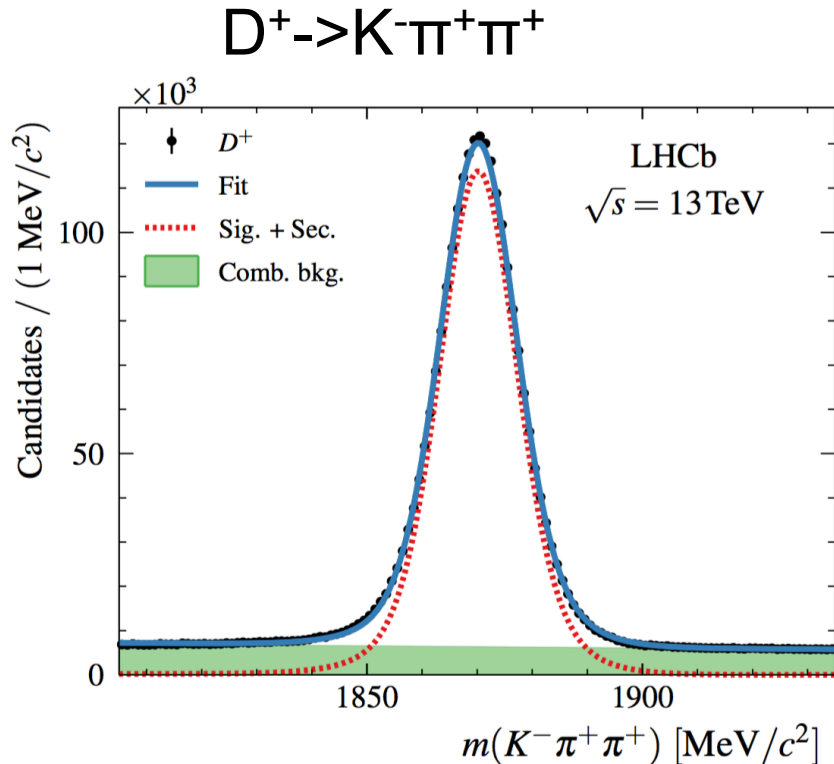
# Resolution stability: RICH2





# PID performance

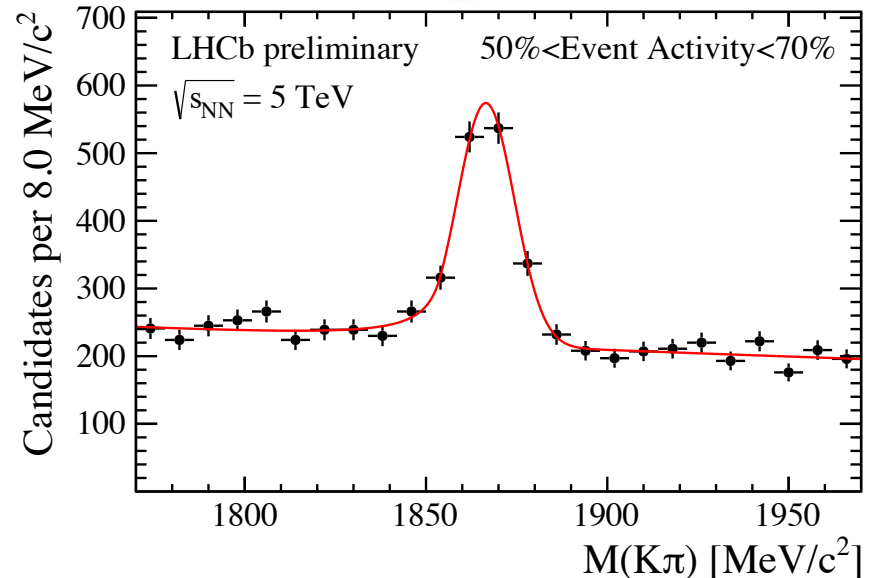
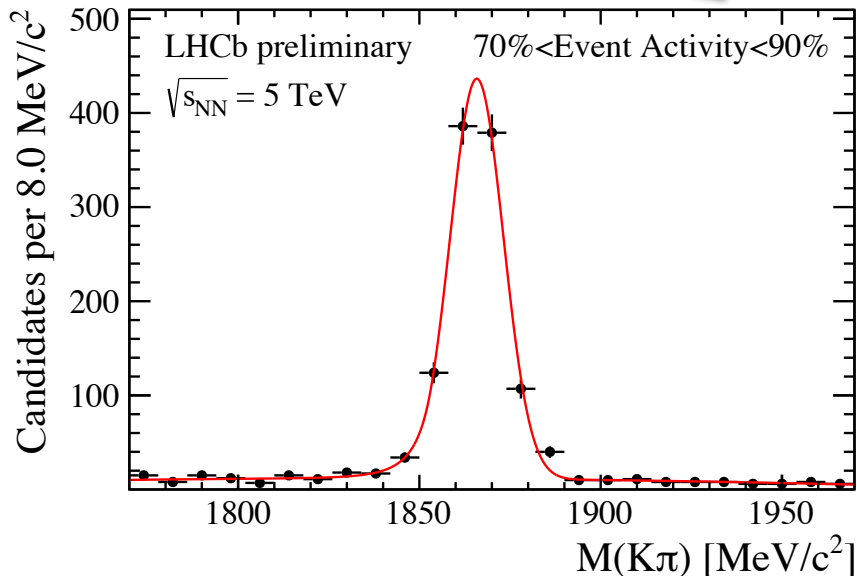
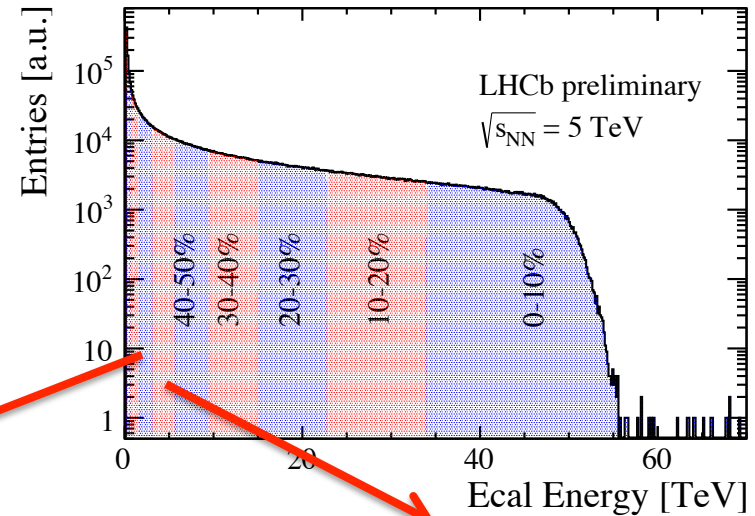
- See more in A. Papanetis's talk [Mon. 09h20]
- Analysis using trigger outputs directly



[LHCb, JHEP 03 (2016) 159]

# PID performance in PbPb collisions

- Works perfectly for less-busy events
- $D^0 \rightarrow K\pi$  in PbPb:



# Summary

- Novel real-time calibration and alignment of the RICHes:
  - Refractive index, run-by-run
  - HPD image, run-by-run
  - Mirror alignments, monitored fill-by-fill
- Works well for pp & PbPb collisions
- Provide excellent PID for the trigger & offline analysis, essential to achieve LHCb physics goal