



# Novel Real-time Calibration and Alignment Procedure for LHCb Run II

Claire Prouve, on behalf of the LHCb collaboration

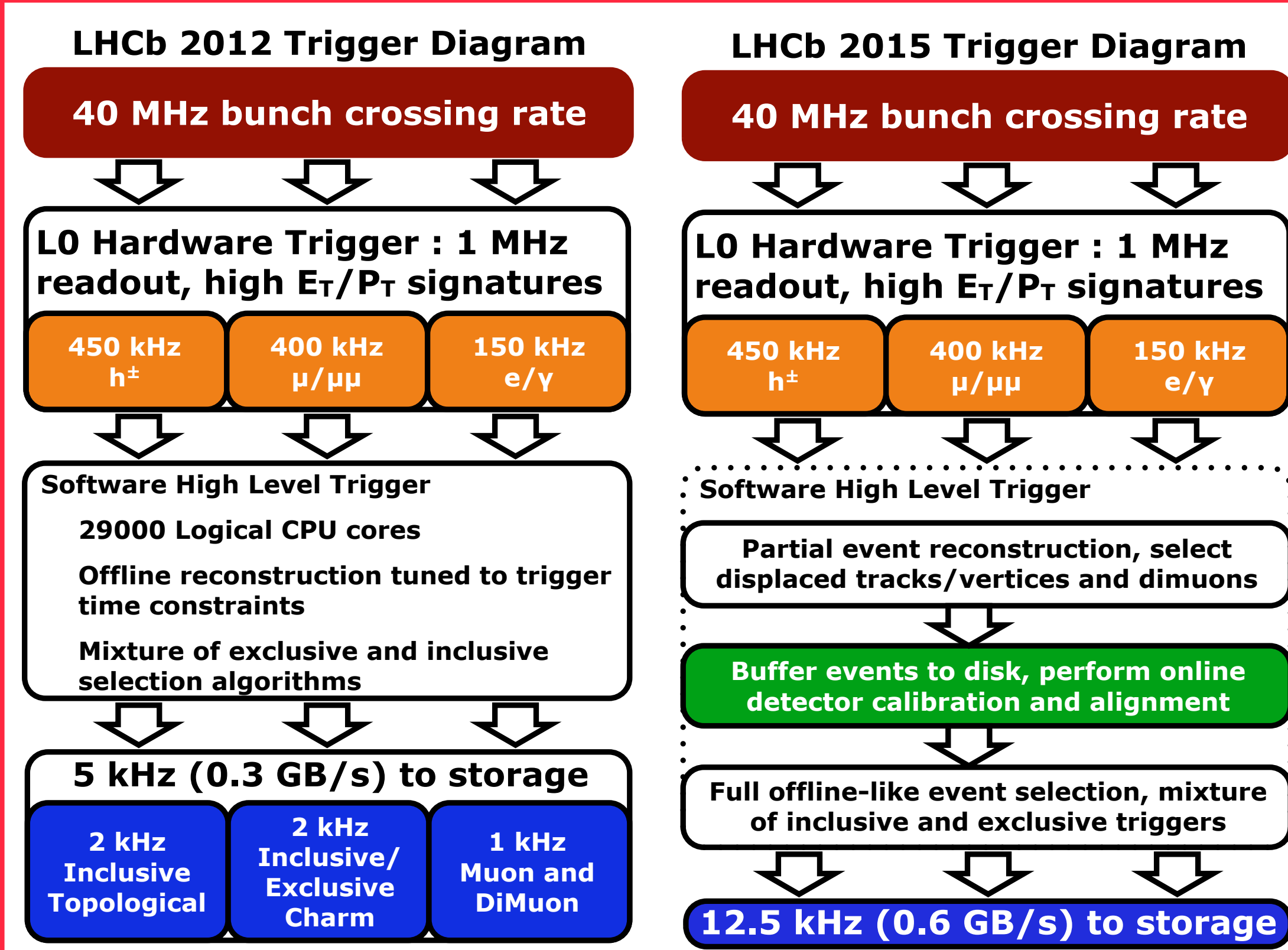
## New challenges in Run II

- Increase in energy:  $\sqrt{s} = 7(8) \text{ TeV} \Rightarrow 13 \text{ TeV}$
- 15% increase of inelastic collision rate
- 20% increase of multiplicity per collision
- 60% increase of  $\sigma_{b\bar{b}}$  and  $\sigma_{c\bar{c}}$
- Reduced bunch spacing:  $50 \text{ ns} \Rightarrow 25 \text{ ns}$

## Real Time Alignment and Calibration

- Particle identification useable in HLT2
- Overall improved HLT2 efficiency
- Stable quality of alignment
- No more differences between online and offline

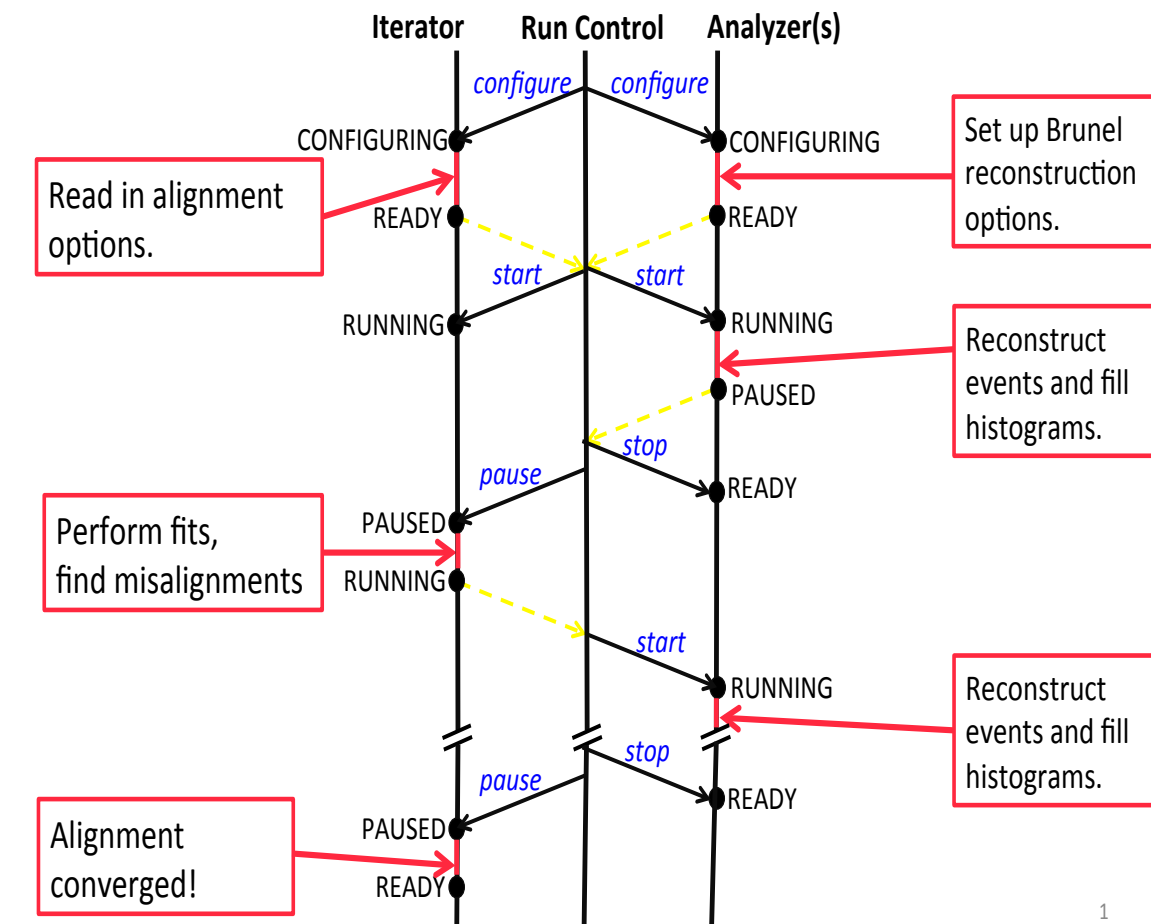
## LHCb Trigger Schemes



## Alignment Farm and Framework

- Alignments performed for each fill
- HLT1 line for each task
- Event reconstruction parallelised on *analysers* (1700 nodes), computing of alignment constants by *iterator* (1 node)
- Steered by the run control using a Finite State Machine
- VELO, Tracker & calibrations: automatic update of the constants if they differ by a given value
- RICH alignment & Muon System: monitoring mode

### Example of alignment sequence



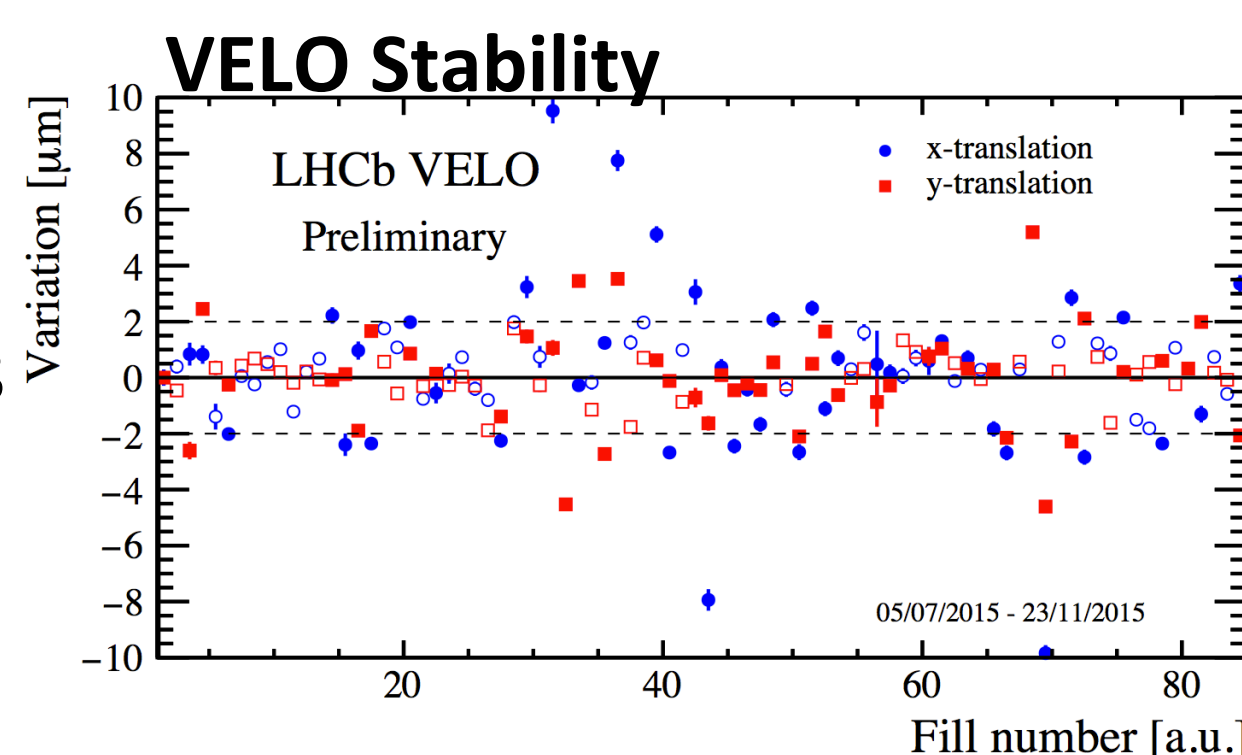
## Tracker Alignment: VELO, Tracker, Muon System

### Position of the tracking elements in x and y

- Minimisation of residual of Kalman track fit using additional constraints

$$\alpha = \alpha_0 - \left( \frac{d^2 \chi^2}{d\alpha^2} \right)^{-1} \bigg|_{\alpha_0} \frac{d\chi^2}{d\alpha} \bigg|_{\alpha_0}$$

- Independent alignments:
  - VELO & Tracker: updated every  $O(1)$  fills
  - Tracker: updated every  $O(1)$  weeks
  - Muon system: updated  $O(1)$  per year
  - ~7 minutes for each task



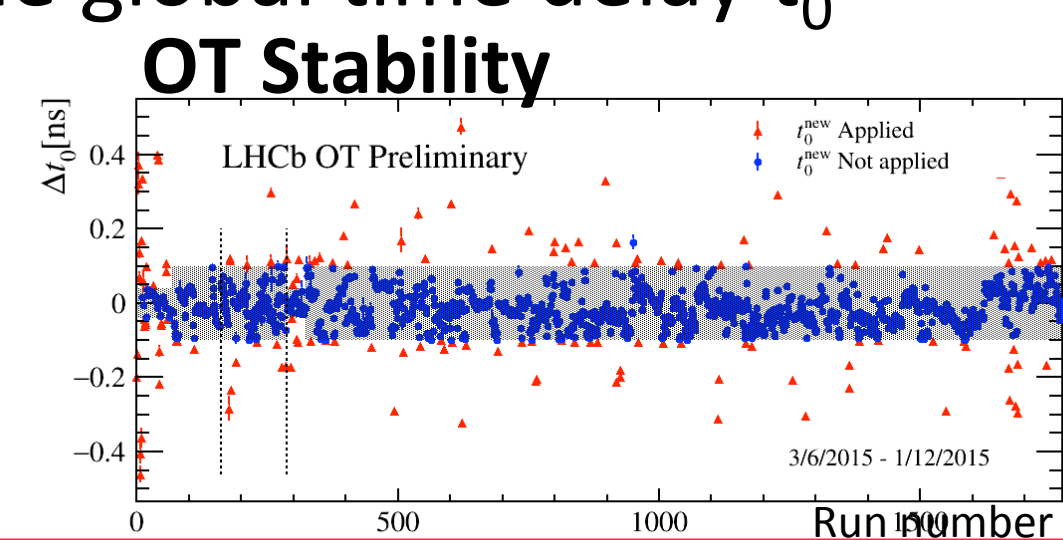
## Outer Tracker Calibration

### Global time alignment for all modules

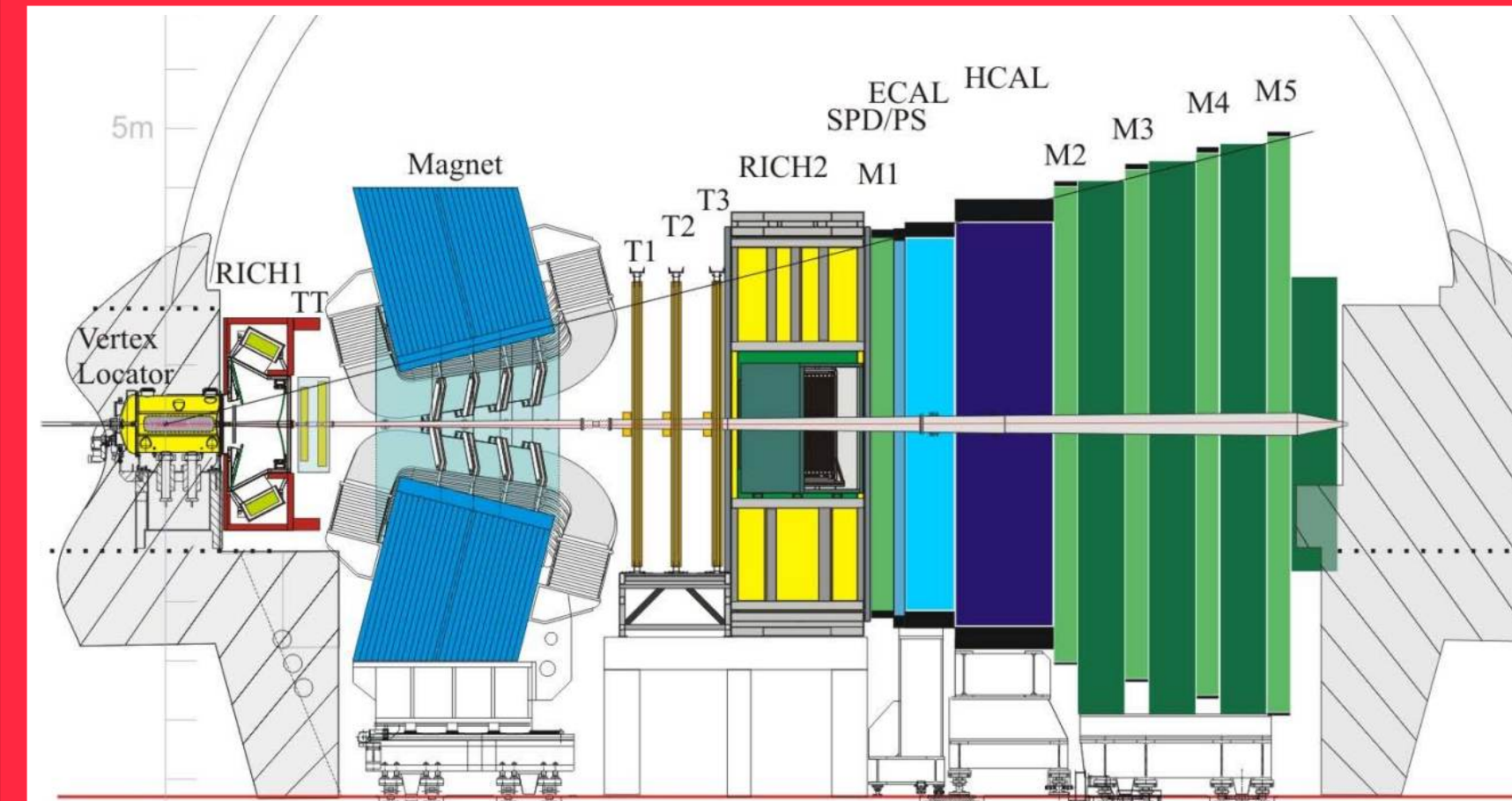
- Fit the residual of the drift time to extract the global time delay  $t_0$  caused by readout electronics

$$t_{\text{meas}} = t_0 + t_{\text{flight}} + t_{\text{drift}} + t_{\text{prop}}$$

- Updated every  $O(10)$  runs

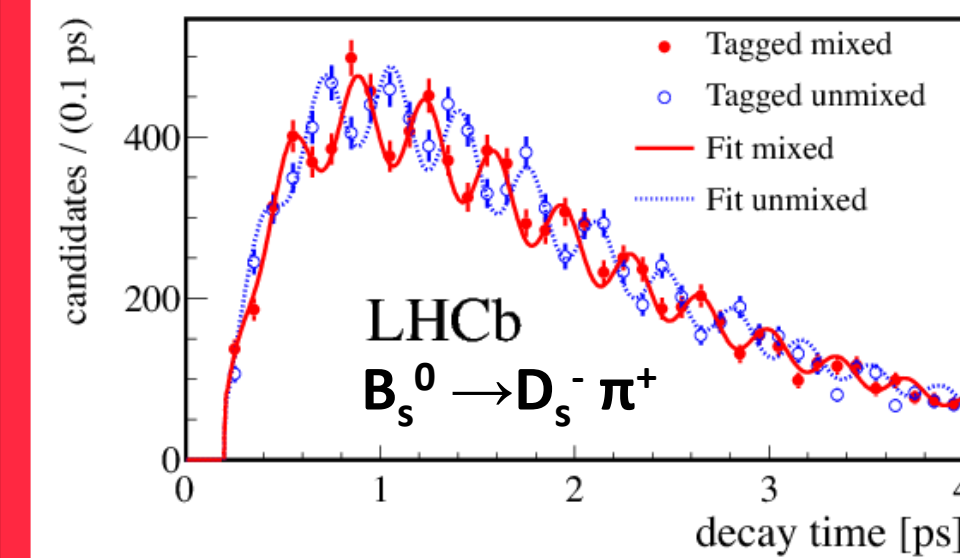


## The LHCb Detector

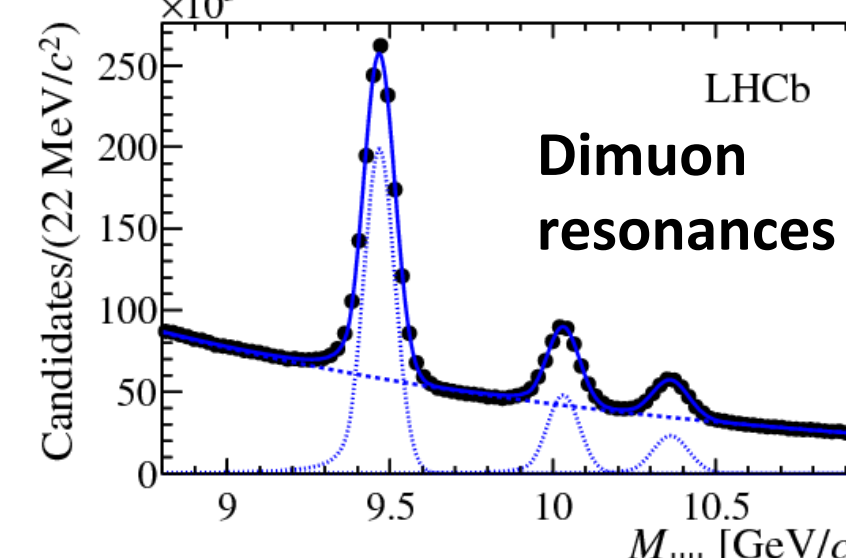


$2.4 \cdot 10^{12}$  B hadrons in LHCb detector acceptance in 2011 + 2012

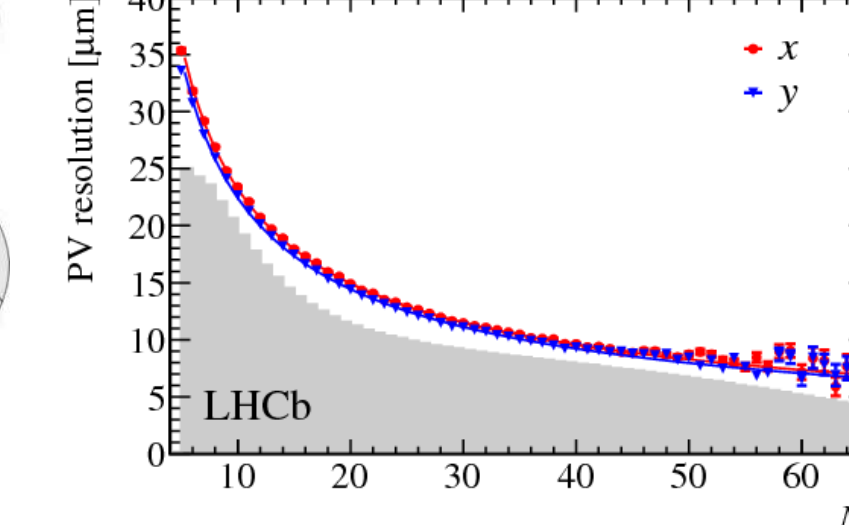
### Decay-time resolution



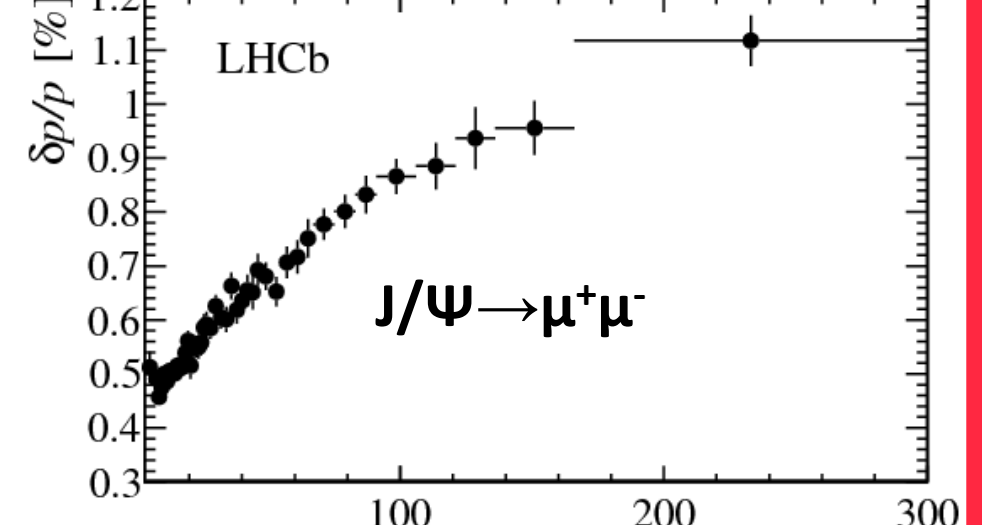
### Mass resolution



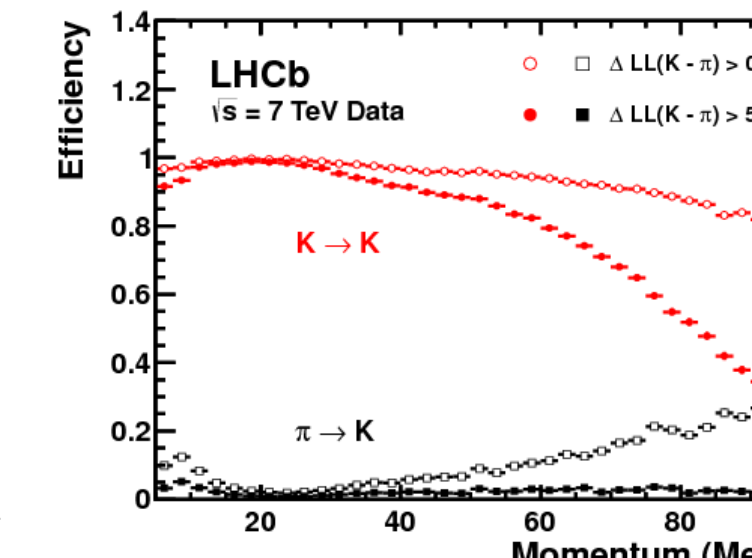
### Vertex resolution



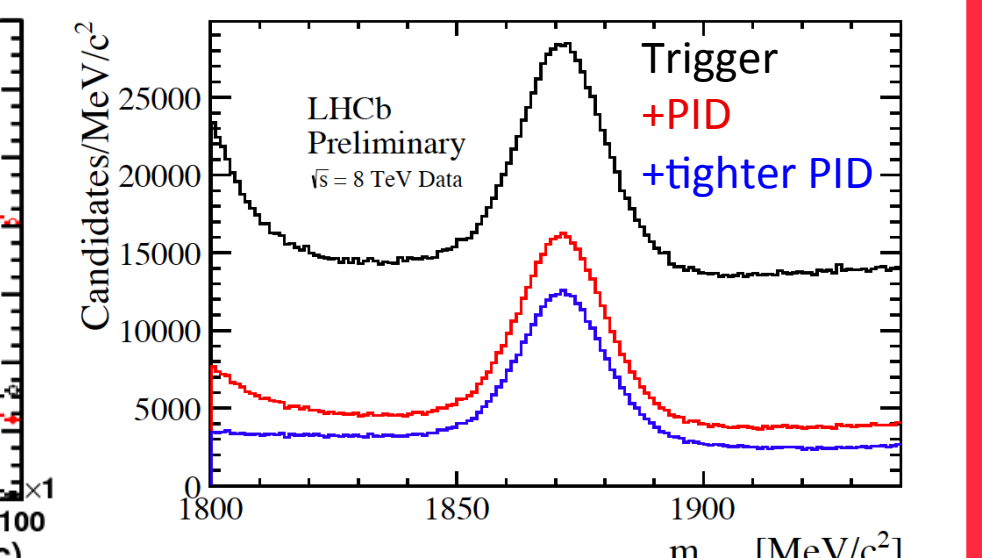
### Momentum resolution



### PID efficiency



### PID impact D+ → π+ π+

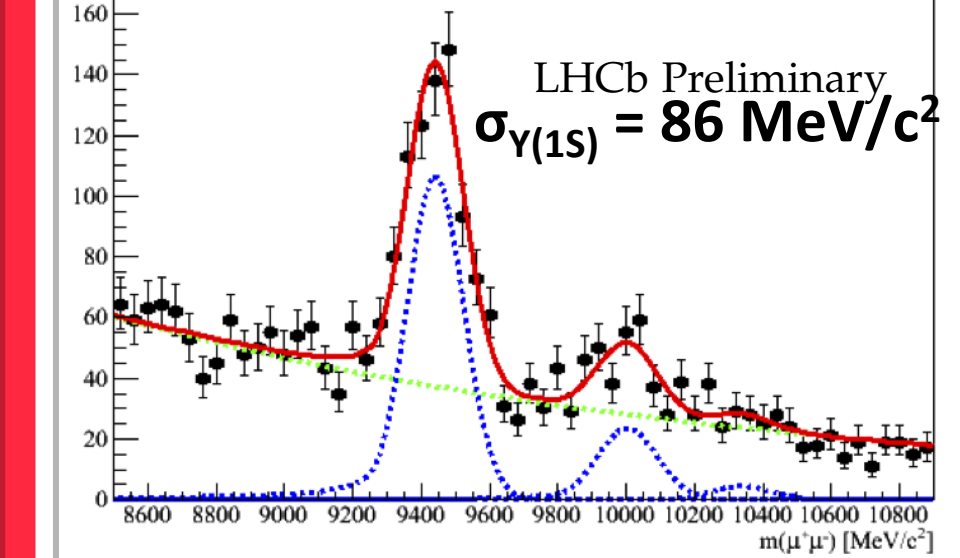


References:

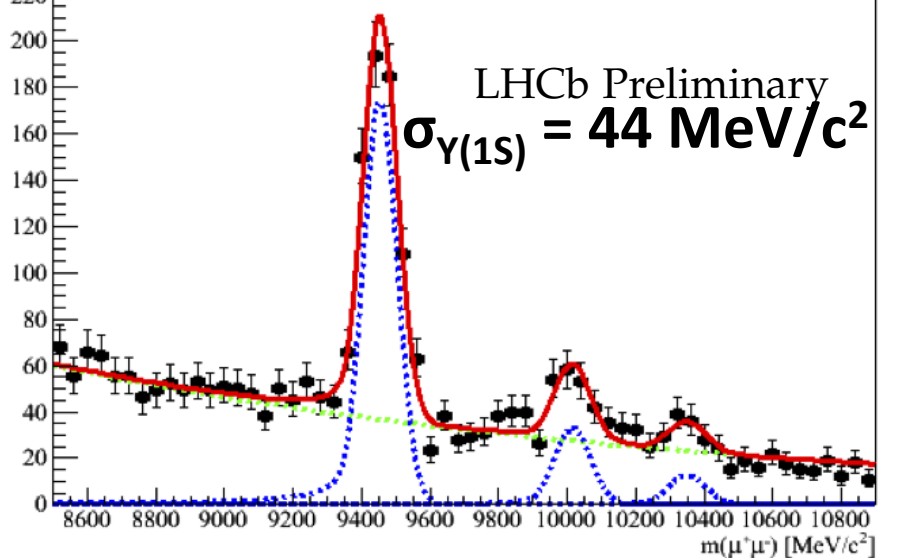
- [1] R. Aaij et al., Int.J.Mod.Phys. A30, 1530022 (2015). [2] R. Aaij et al., JINST 9, 09007 (2014). [3] J. Amoraa et al., Nucl.Instrum.Meth. A712, 48 (2013). [4] M. Adinolfi et al., Eur.Phys.J. C73, 2431 (2013). [5] W. Hulsbergen, Nucl.Instrum.Meth. A600, 471 (2009). [6] R. Arink et al., LHCb-DP-2013-003.

## Performance and Impact on Physics

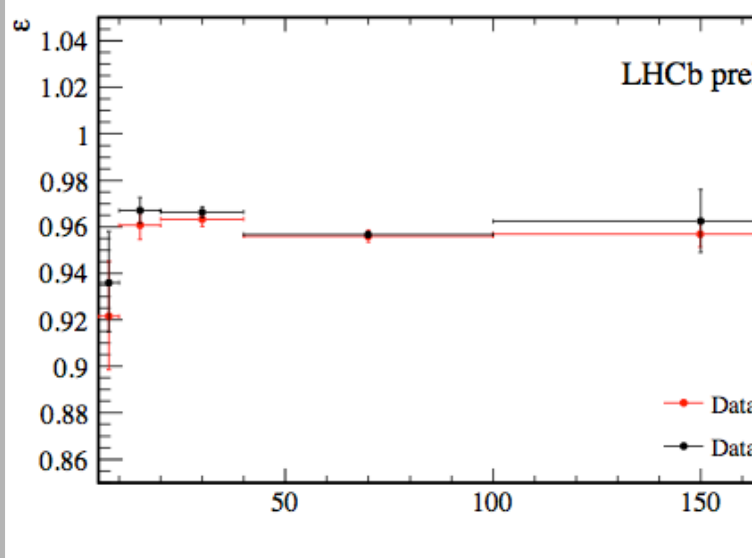
### First alignment



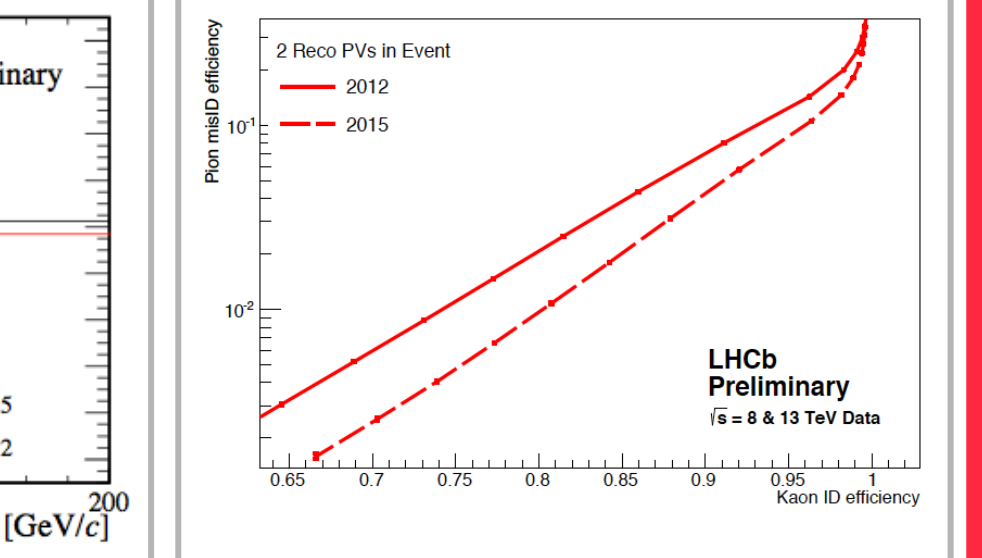
### Improved alignment



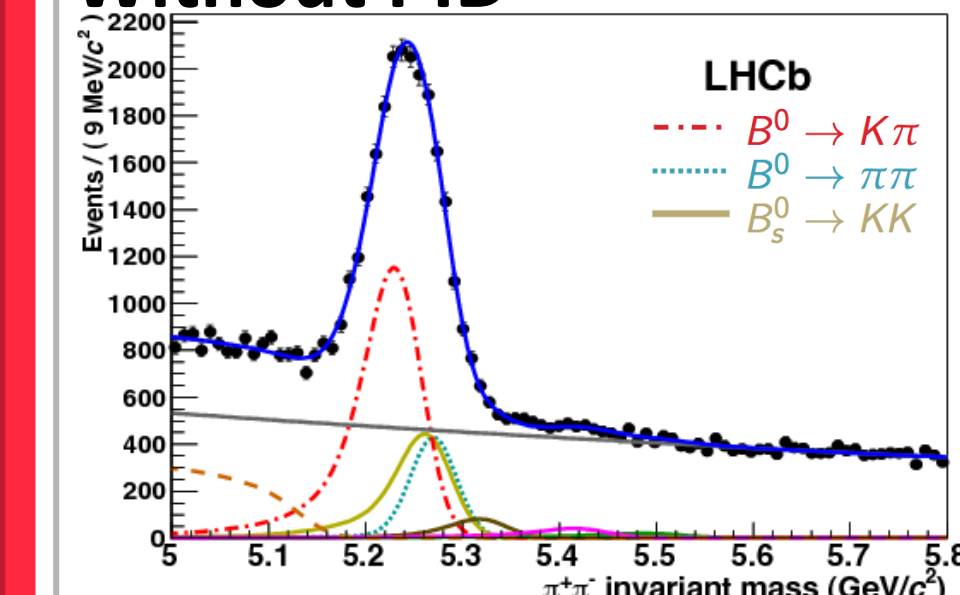
### Tracking efficiency



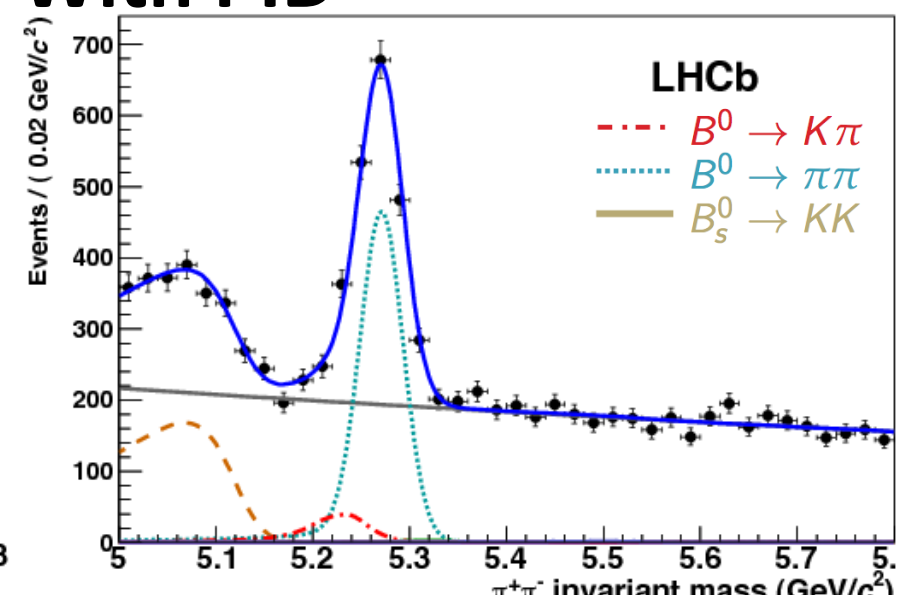
### PID efficiency



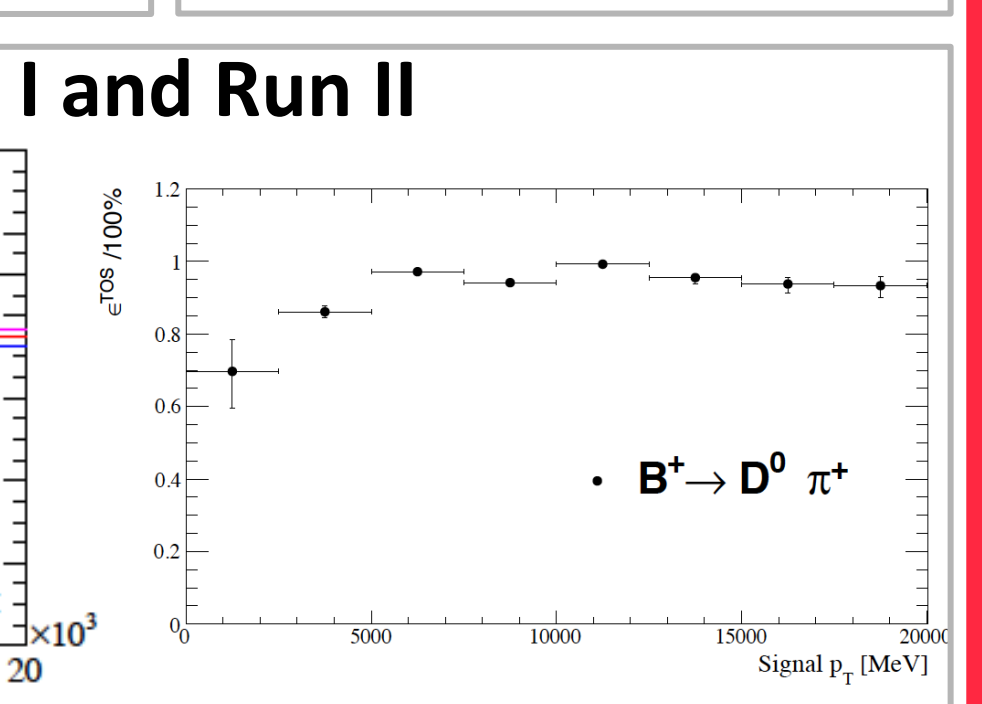
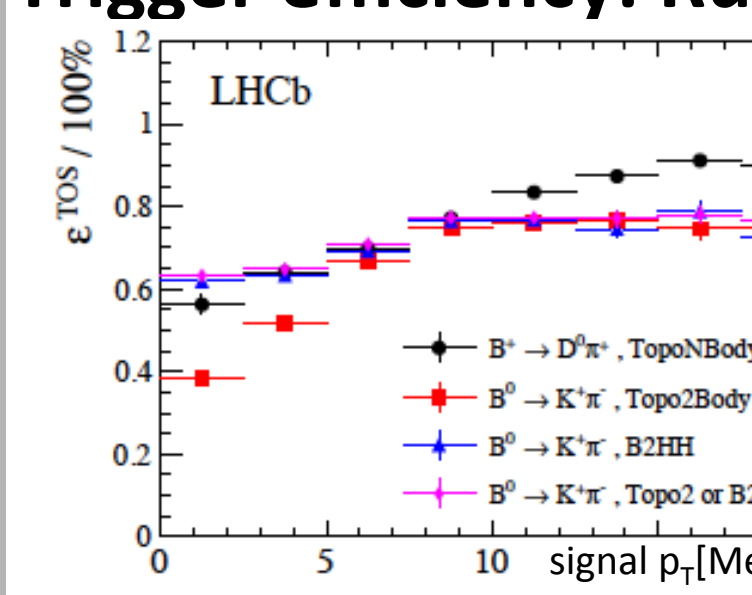
### Without PID



### With PID



### Trigger efficiency: Run I and Run II

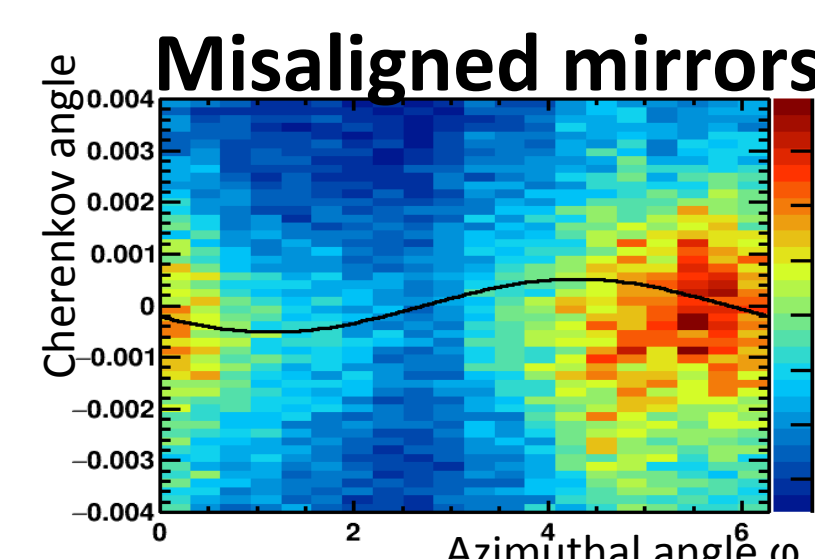


## RICH Mirror Alignment

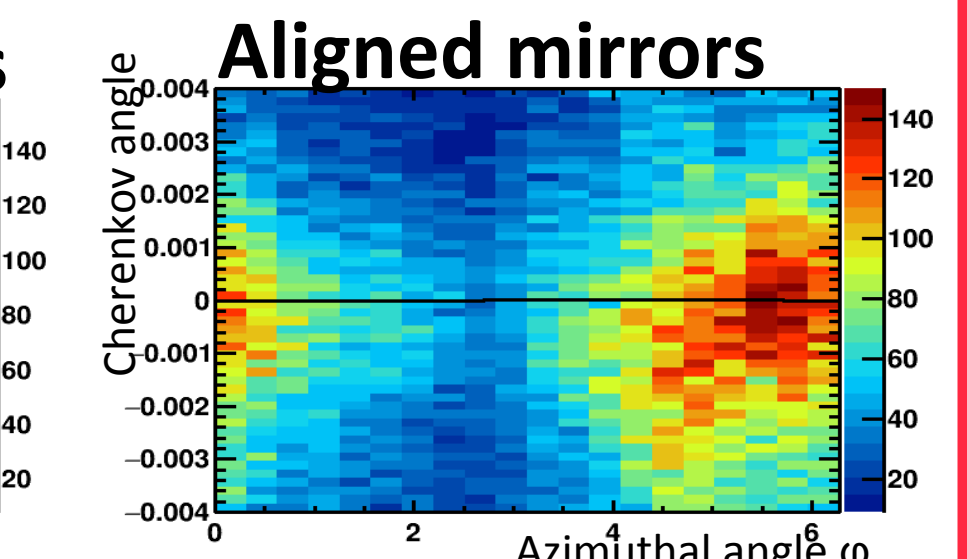
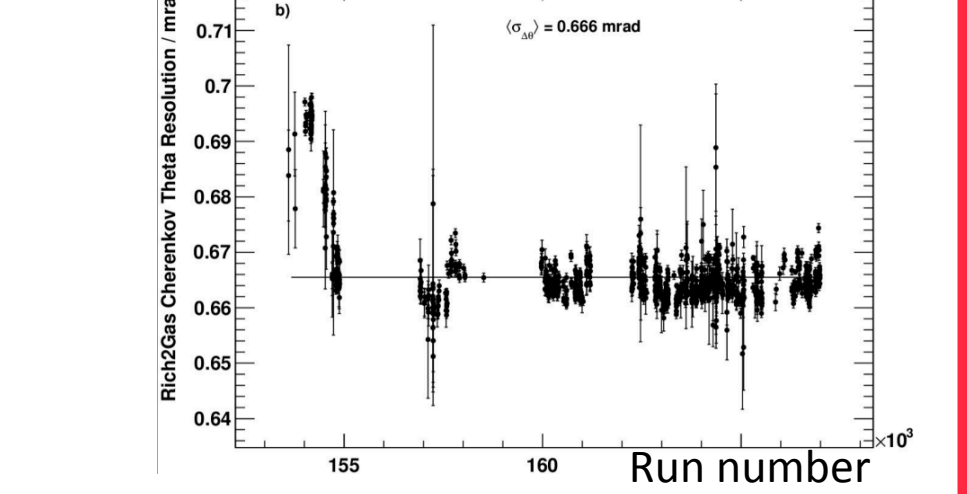
### Orientation of the RICH mirrors in x and y

- Fit the variation of the Cherenkov angle  $\Delta\theta$  as a function of the polar angle  $\varphi$  to extract the misalignments on the detector plane ( $\Theta_x, \Theta_y$ ):  $\Delta\theta = \Theta_x \sin\varphi + \Theta_y \cos\varphi$

- Monitoring mode, updated  $O(10)$  times a year
- ~30 minutes per task



### RICH1 Stability

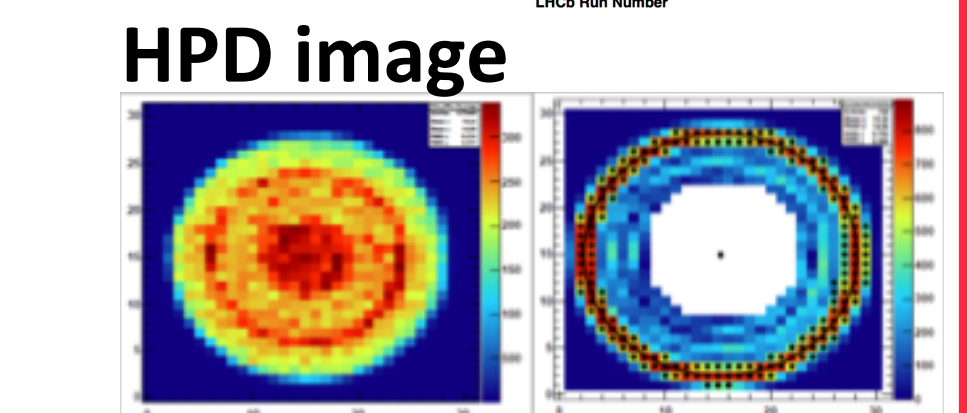
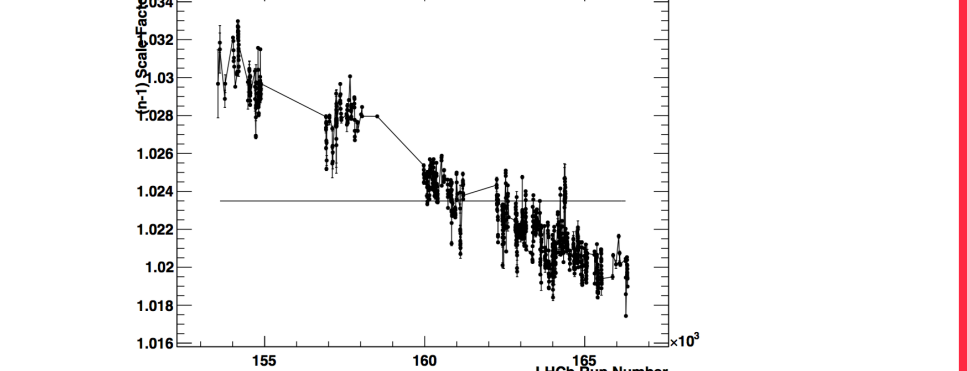


## RICH Calibration

- Refractive index calibration: Fit to the reconstructed-expected Cherenkov angle yields scale factor for the refractive index
- HPD image calibration: Sobel filter applied to each HPD and used to provide calibration

- Updated every run

### RICH1 scale factor



## Calorimeter Calibration

### Relative calibration for each cell

- Scale the High Voltage by factor  $\alpha$  to keep the gain stable by evaluating the variation of the occupancy
- LED monitoring system to detect ageing of the Photo Multiplier Tubes
- Updated per fill

### Calibrate to the neutral $\pi$ mass

- Fit the  $\pi^0$  mass distribution for each cell for  $\pi^0 \rightarrow \gamma\gamma$ , where one  $\gamma$  has its seed in the cell
- Run on the HLT-farm during TS

### LED average

