

Study on the performance of the Particle Identification Detectors at LHCb after the LHC First Long Shutdown

Marianna Fontana on behalf of the LHCb collaboration

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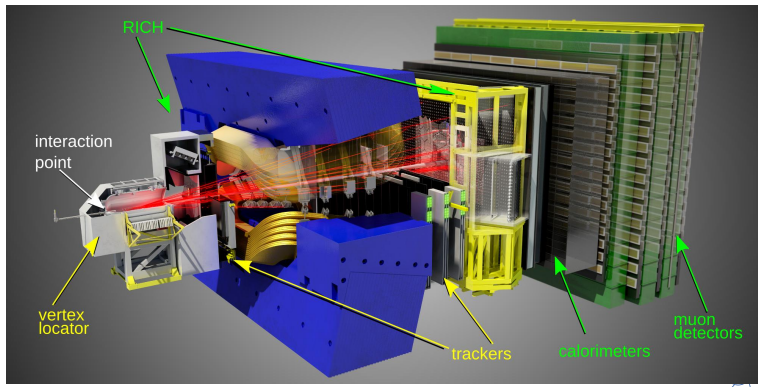


The LHCb experiment

- Single arm forward spectrometer
- Optimized for b - and c -physics
- Good vertex resolution and tracking
- Excellent particle identification (RICH, CALO, MUON)
- Fast, efficient and flexible high bandwidth trigger system [See E. Michielin poster]

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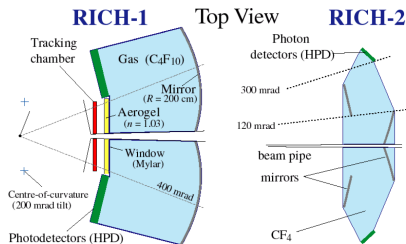


The PID detectors: RICH

See M. Fiorini talk

- Need to identify heavy flavour decays from huge hadronic background
- Good $\pi/K/p$ separation on a wide momentum range
- Usage of 2 separate detectors and 2 different radiators:

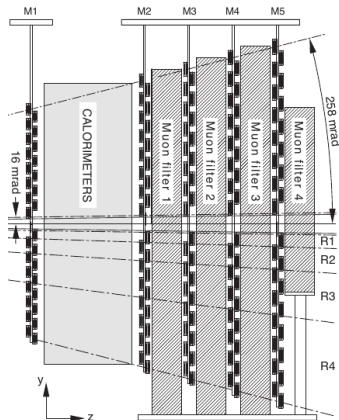
- RICH1 covering low p (2-60 GeV/c) region, using C_4F_{10} radiator
- During LS1 the aerogel has been removed from RICH1
- RICH2 covers higher momenta (15-100 GeV/c) with CF_4 radiator



- The light rings are produced on an array of HPD located outside the LHCb acceptance (usage of spherical and flat mirrors)
- Combine photon rings and track momentum information
- Log likelihood recomputed for the mass hypothesis of all charged particles

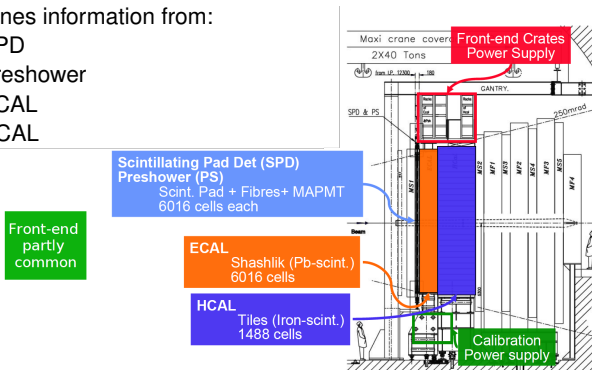
The PID detectors: MUON

- 5 tracking stations interspersed with hadron absorbers ($\sim 23\lambda$)
 - M1 before the calorimeter
- Technology
 - MWPC
 - 3-GEM in M1 (inner region)
- Identification based on
 - Track extrapolation to the μ -system
 - Look for hits in the μ stations around the extrapolated track
 - Calculate probability from hit distribution in μ -stations



The PID detectors: CALO

- Calorimeter system identifies electrons/photons/ π^0 and hadrons
- It combines information from:
 - SPD
 - Preshower
 - ECAL
 - HCAL



- Photon PID based on 2D PDF $\rightarrow \Delta LL$ method
 - Energy: total cluster energy in the ECAL and reconstructed energy deposit in the PS
 - Direction: from the interaction point and the energy-weighted position of the photon candidate

The PID strategy

LHCb-PUB-2016-020

- The majority of analyses in LHCb rely on particle identification
- The performance are measured with a data-driven method, since PID variables are poorly reproduced in MC
- The information obtained from sub-detectors is combined to provide a single set of more powerful variables:
 - 1 **ΔLL** : the likelihood information produced by each sub-system is added linearly, to form a set of combined likelihoods
 - 2 **ProbNN**: they are built using multivariate techniques by combining tracking and PID information from each sub-system into a single probability value for each particle hypothesis
- In Run 1 the calibration samples were produced with offline selections \rightarrow lack of statistics in some phase-space regions
- In Run 2 the strategy has been completely renewed:
 - Select the calibration samples directly in the high level trigger [See B. Sciascia talk]
 - Larger statistics to have smaller statistical uncertainty
 - Systematic studies possible, including those with detector low-level information

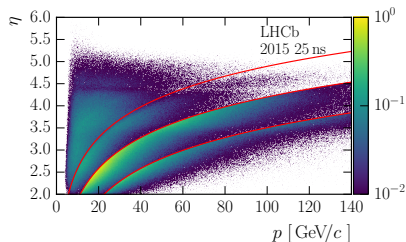
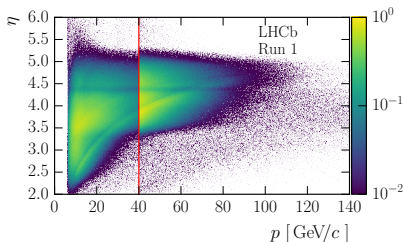
Calibration samples

LHCb-PUB-2016-005

- Pure samples of known-ID particles have to be collected
- There is a main line (red) 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	—	$J/\psi \rightarrow e^+e^-$
μ^\pm	$D_s^+ \rightarrow \mu^+ \mu^- \pi^+$	$J/\psi \rightarrow \mu^+ \mu^-$
π^\pm	$K_S^0 \rightarrow \pi^+ \pi^-$	$D^* \rightarrow D^0(K^- \pi^+) \pi^+$
K^\pm	$D_s^+ \rightarrow K^+ K^- \pi^+$	$D^* \rightarrow D^0(K^- \pi^+) \pi^+$
p^\pm	$\Lambda^0 \rightarrow p \pi^-$	$\Lambda^0 \rightarrow p \pi^-, \Lambda_c^+ \rightarrow p K^- \pi^+$

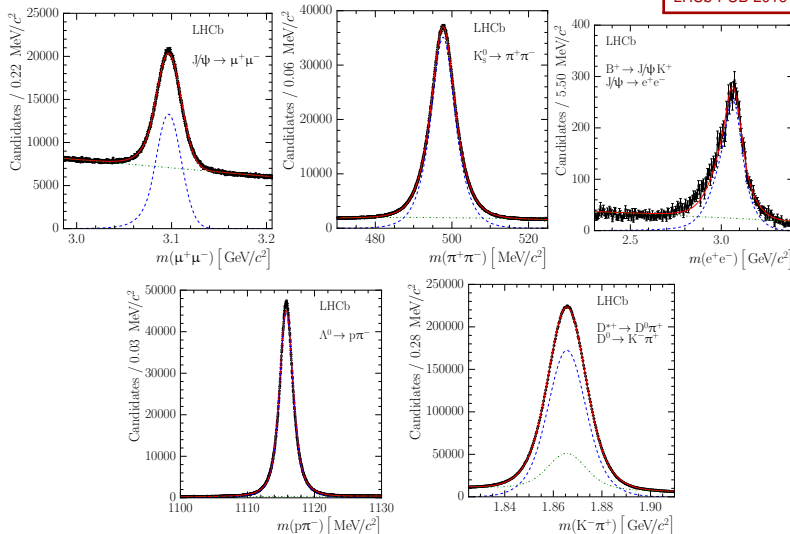
- New selections designed to improve the kinematic coverage



- The final samples are background subtracted

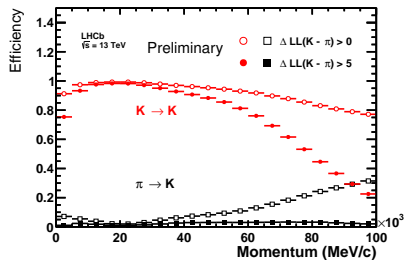
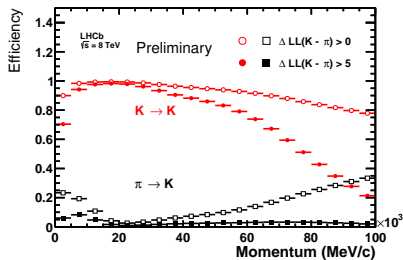
The PID calibration samples

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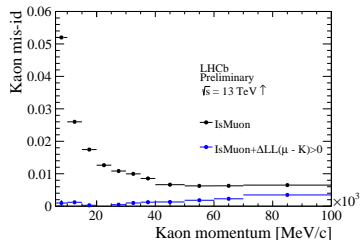
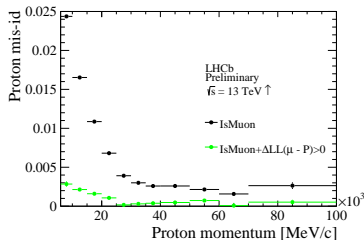
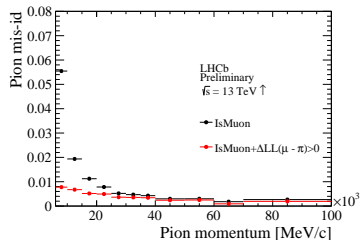
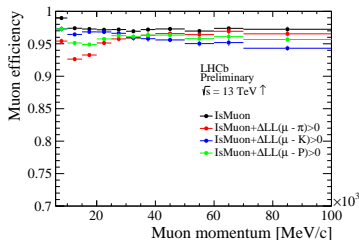
The RICH performance

- PID performance better than Run 1
- Better background rejection at low momentum, due to RICH1 changes in LS1



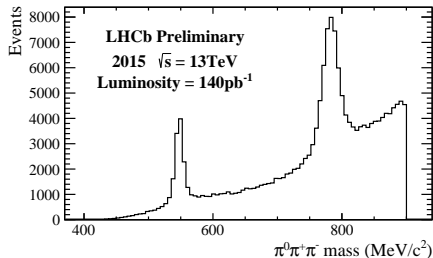
The MUON performance

- Integrated efficiency over the full spectrum $\varepsilon(\mu) \sim 95\%$
- Mis-id hadron rates: $\varepsilon(p, \pi, K \rightarrow \mu) < 1\%$ over most of the kinematic range



The CALO performance

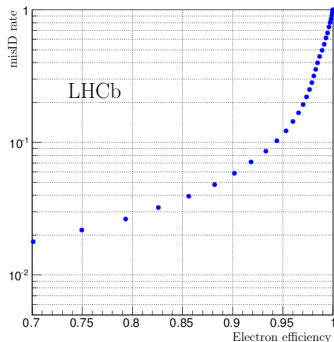
- Capability to work with neutral objects:
expected π^0 resolution: $< 9 \text{ MeV}/c^2$



Example of $\pi^0 \pi \pi$ decay, where $\pi^0 \rightarrow \gamma \gamma$, selected in CEP lines.

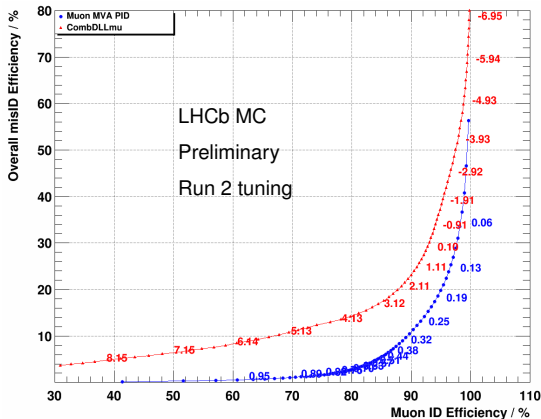
- Expected electron ID not different from Run 1:
5.5% misID rate for 90% efficiency

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The ProbNN performance

- In Run 2 the MVA PID algo are used at trigger level
- In MC MVA algo perform by far better than DLL
- Both ProbNN and DLL remain useful in data



Performance on top of IsMuon

Conclusion

- Only slight modifications on PID detectors during LS1 in LHCb
- For Run 2 a new procedure has been introduced to select the PID calibration samples directly at trigger level
- The selection of the samples have improved the purity, leading to lower statistical uncertainties and better performance
- Better tunings of the global PID algorithms have been implemented
- The improvements open the door to a large number of PID-related studies, which will result in a better understanding of the systematic effects related to the detector
- All these features pave also the way for an improved PID performance for the LHCb upgrade

Backup