PID strategy and performance at LHCb in Run 2

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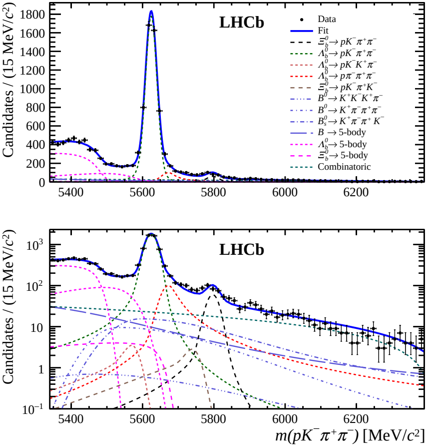
on behalf of the LHCb collaboration

Outline

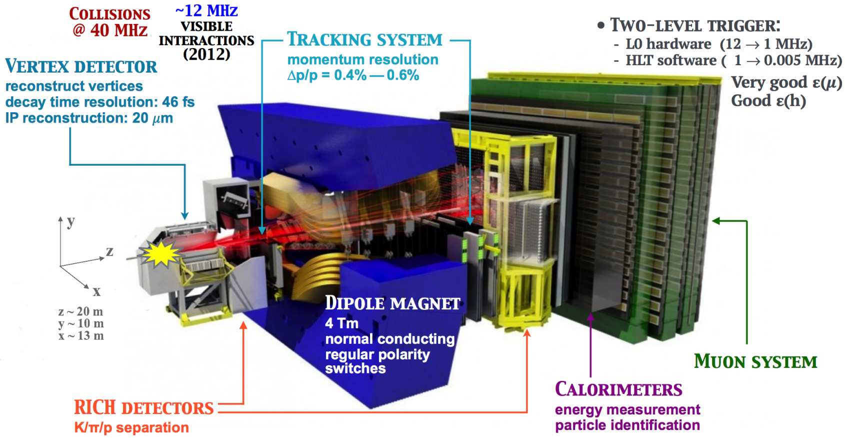
- Particle Identification at LHCb
- Computing strategy
- Calibration samples
- Performance

Particle Identification (PID) at LHCb

- LHCb is a heavy flavour physics experiment
- PID is crucial to study exclusive final states
- Recent example in JHEP02(2018)098:

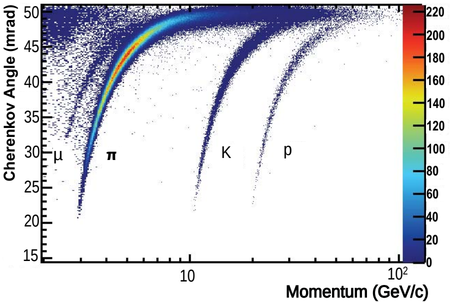


The LHCb detector [JINST3 (2008) S08005]



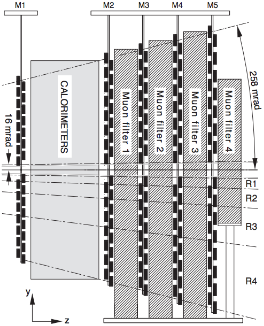
RICH detectors

- Two Ring Image Cherenkov Detecors (RICH)
  - RICH 1 based on $\mathrm{C_4F_{10}}$ separates particles with *p* in [2, 60] GeV/c
  - RICH 2 based on $\mathrm{CF_4}$ separates particles with *p* in [15, 100] GeV/c
- Combine light rings and momentum to build log(Likelihood) distributions
- Crucial for π, K, p separation



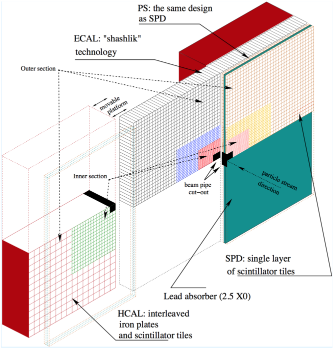
Muon chambers

- Five tracking stations alternated with hadron absorbers at the end of the detector (M1 before calorimeters)
  - based on MWPC technology
  - 3-GEM in inner region of M1
- Track extrapolation and matching to hits in muon chambers
- Crucial for μ identification, also at trigger level



Calorimeters

- Scintillating Pad Detector (SPD), Preshower (PS), Electromagnetic (ECAL) and Hadronic (HCAL) calorimeters



- Combine information into Multi-variate tools
- Provide energy and position for neutral objects and triggers for e/γ
- Crucial for e, γ and π^0 separation

PID strategy [LHCb-DP-2018-001]

- Two types of variables from combination of charged PID information
  - $\mathrm{DLL}_{X\pi}$: log likelihood difference betwen X and π hypothesis
  - ProbNNX: output of neural networks (NN) trained to identify X including also tracking information

- Dedicated tools for neutral objects based on NN: isNotE, isNotH

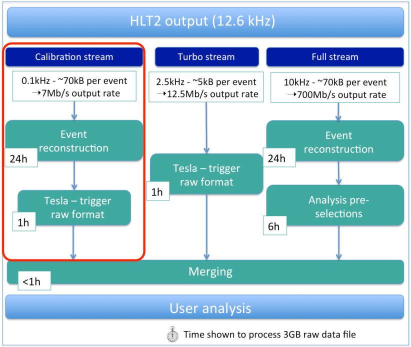
- Exploitaiton of state-of-the-art classifiers under development

- Calibration from data-driven techniques since PID not perfectly reproduced in simulation

See A. Poluektov's talk for details on latest techniques

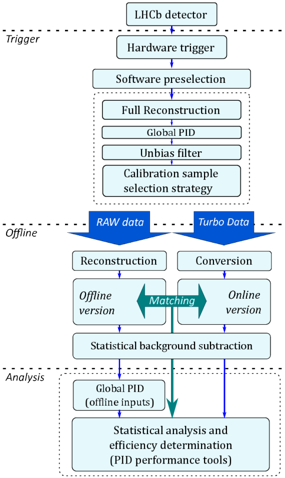
Computing strategy: TurboCalib

- In Run 2, offline quality reconstruction is achieved in the Trigger
  - Details in M. Whitehead's talk



- Calibration samples in the Turbo Calibration (TurboCalib) stream
  - Large statistic samples → required precision for analysis
  - Computation of both offline and online PID variables
  - Raw event information available → exploit offline re-calibrations and new tunnings

Computing strategy: Working Group productions



- TurboCalib samples processed centrally and provided to analysts as ROOT files:
  - Large resource optimisation wrt do-it-yourself approach
  - Gain control on systematic uncertainties
- Several steps to provide information needed by analyses:
  - Matching of online and offline candidates
  - Invariant mass fits
  - Background subtraction using sWeights
- Raw event information also available for particular studies (e.g. Upgrade, new PID variables)

Calibration samples: charged species [LHCb-DP-2018-001]

Species	Soft	Hard
e	$B^+ \to K^+[e^+e^-]_{J/\psi}$	
μ	$B^+ \to K^+[\mu^+\mu^-]_{J/\psi}$	$J/\psi \to \mu^+\mu^-$
π	$K^0_S \to \pi^+\pi^-$	$D^{*+} \to [K^-\pi^+]_{D^0}\pi^+$
K	$D_s^+ \to [K^+K^-]_\phi\pi^+$	$D^{*+} \to [K^-\pi^+]_{D^0}\pi^+$
p	$\Lambda \to p\pi^-$	$\Lambda \to p\pi^-$, $\Lambda_c^+ \to pK^-\pi^+$

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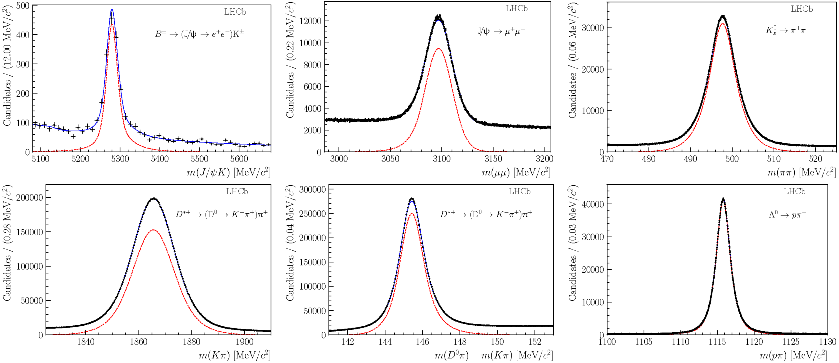
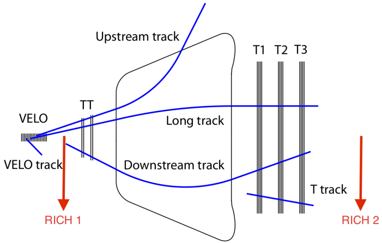
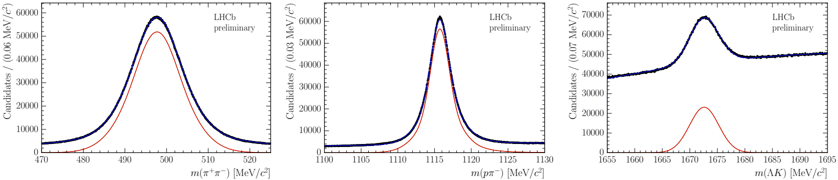


Calibration samples: charged species

- Long-lived particles (Λ, K^0_S) decay mostly outside the VELO
- Downstream tracks might not have information from RICH 1
- Dedicated calibration samples included in TurboCalib since 2017 data-taking

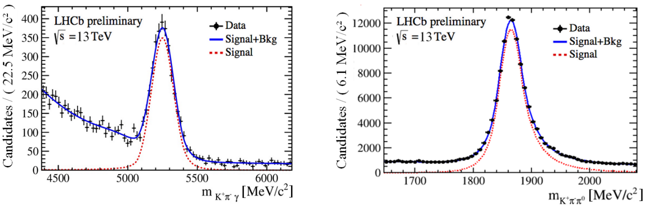




Calibration samples: neutral objects

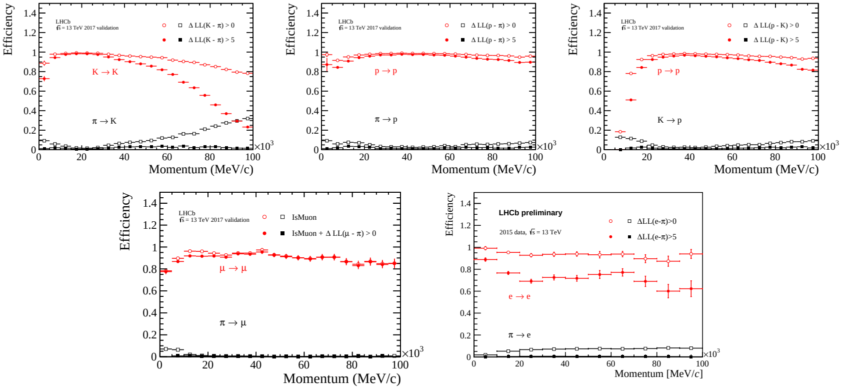
- Calibration samples for neutral objects also included in TurboCalib stream since 2017 data-taking

Species	**Soft**	**Hard**
γ	$D^+ \to [\rho^0\gamma]_{\eta'}\pi^+$, $D_s^{*+} \to D_s^+\gamma$, $\eta \to \mu^+\mu^-\gamma$	$B^0 \to K^{*0}\gamma$
π^0	$D^0 \to K^+\pi^-\pi^0$ (resolved)	$D^0 \to K^+\pi^-\pi^0$ (merged)

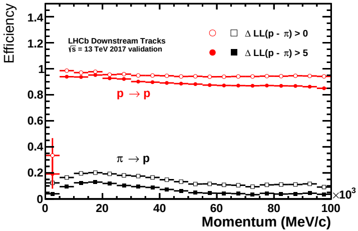


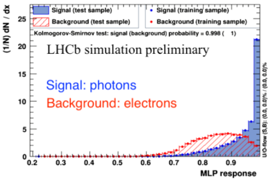
Performance: charged species

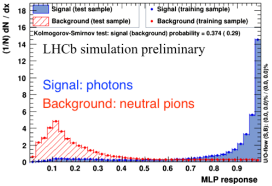
- Excellent separation in wide momentum range



- Good results also for downstream tracks and neutral objects







Summary

- Excellent PID performance is key for outstanding flavour physics results at LHCb
- PID from combined information of dedicated sub-detectors:
  - RICH 1 and RICH 2
  - Muon chambers
  - Calorimeters
- New computing strategy developed for Run 2 exploiting the Turbo model for calibration (TurboCalib)
- Calibration samples covering full analysis phase-space provided
  - Samples for downstream tracks and neutral objects recently included
- Excellent performance achieved in Run 2, laying the foundations for the LHCb upgrade

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THANK YOU!

BACK-UP

Performance: charged species

- Excellent separation in wide momentum range