Particle identification performance of the LHCb experiment in Run 2

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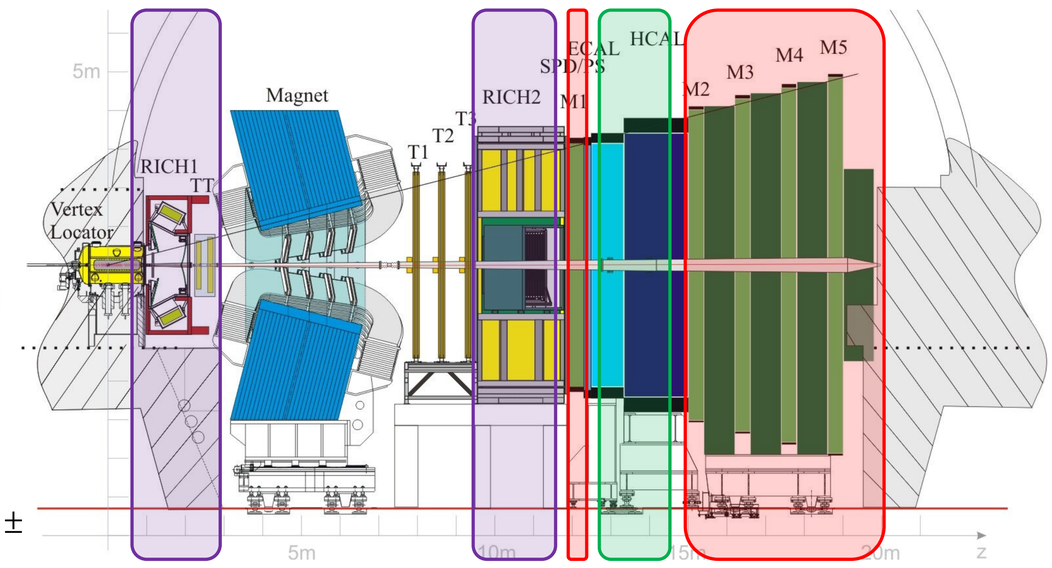
Introduction

- In a flavour physics experiment one of the major requirements is the ability to **distinguish** between electrons, muons, pions, kaons and protons traversing the detector through Particle IDentification (PID). PID also plays a crucial role in **tagging** the flavour of neutral mesons at production.

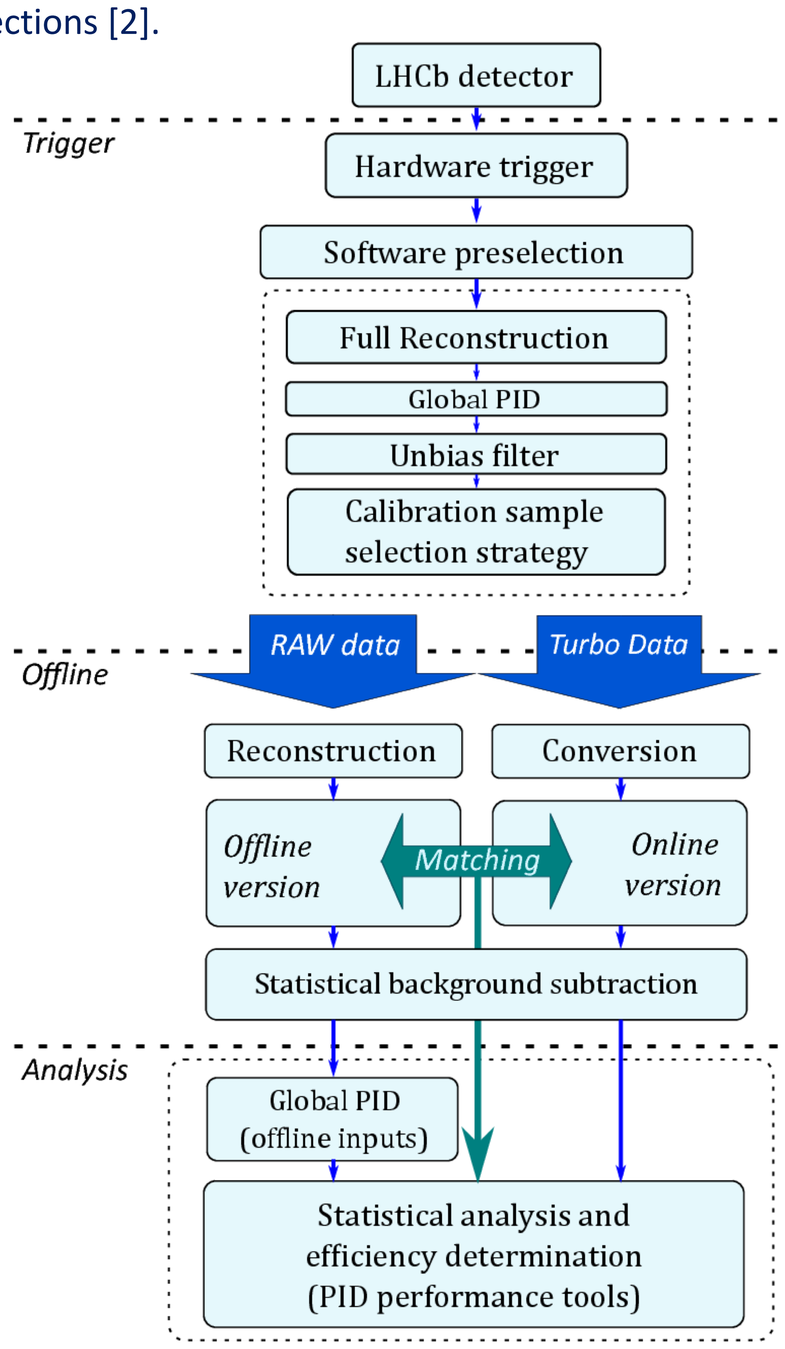
- At LHCb [1], 3 groups of sub-detectors provide the PID:
  - **Ring Imaging Cherenkov (RICH):** Consists of 2 detectors (RICH1 and RICH2) and provides PID for $K^{\pm}, \pi^{\pm}$ and protons.
  - **Calorimeters (CALO):** Consists of Scintillation Pad Detector (SPD), Pre-Shower detector (PS), Electromagnetic CALO (ECAL) and Hadronic CALO (HCAL) and provides PID for e^{-}, γ and neutral hadrons.
  - **Muon chamber:** Consists of 5 tracking stations (M1-M5) and provides PID for $\mu^{\pm}$ with high purity.



The PID information from these sub-detectors are combined into **global PID variables** which are available for use in physics analysis.

Data selection and processing

- The LHCb trigger has a heterogeneous configuration with different output data formats for different groups of trigger selections [2].



- Calibration samples combine information from online and offline reconstruction to allow full offline reprocessing if required.
- A dedicated data format **TurboCalib** was developed to achieve this [3].
- Measurement of selection efficiencies in samples enabled through subtraction of residual background with the **$_s\mathcal{P}$lot** technique [4].
- Samples are made available to analysts via **CERN EOS** and the **PIDCalib** package [5].

Calibration samples

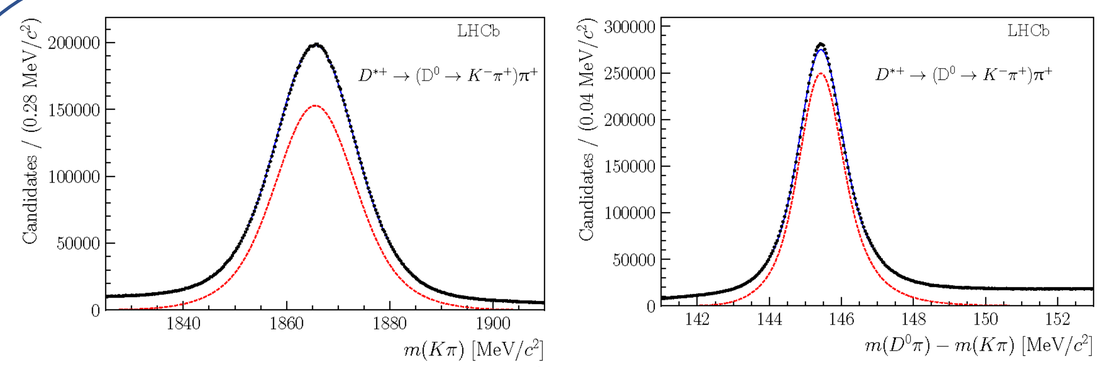
Calibration data are obtained through a real-time selection based on the online reconstruction with no requirements on PID variables. The samples:

- Are completely reconstructed final states composed of charged particles only as they are selected with high purity.
- Are low-multiplicity modes with large branching fractions.
- Use tag and probe method (e.g. $J/\psi \to \mu^+\mu^-$)

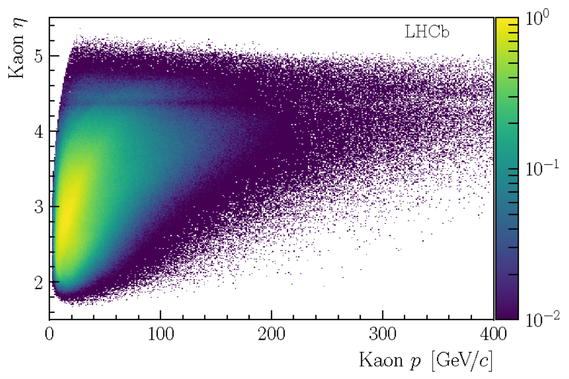
Calibration modes and selections are chosen which maximise the kinematic range available.

Species	Soft (low p and p_T)	Hard (high p and p_T)
$e^{\pm}$	$B^+ \to (J/\psi \to e^+e^-)K^+$	
$\mu^{\pm}$	$B^+ \to (J/\psi \to \mu^+\mu^-)K^+$	$J/\psi \to \mu^+\mu^-$
$\pi^{\pm}$	$K_S^0 \to \pi^+\pi^-$	$D^{*+} \to (D^0 \to K^-\pi^+)\pi^+$
$K^{\pm}$	$D_s^+ \to (\phi \to K^+K^-)\pi^+$	$D^{*+} \to (D^0 \to K^-\pi^+)\pi^+$
$p, \bar{p}$	$\Lambda^0 \to p\pi^-$	$\Lambda^0 \to p\pi^-; \Lambda_c^+ \to pK^-\pi^+$

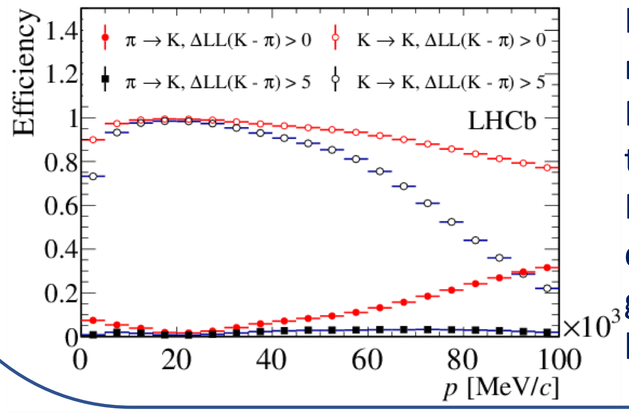
PID Performance



Invariant mass distributions of $D^{*+} \to (D^0 \to K^-\pi^+)\pi^+$ with 2017 data [2].



Background-subtracted distributions of calibration samples for kaons as a function of track pseudorapidity η and momentum p for 2017 data [2].



Kaon efficiency and pion mis-ID rate measured using 2017 MagDown data as function of track momentum.
Results are shown for two different requirements on the global PID variable delta log-likelihood, $\Delta\mathrm{LL}(K-\pi)$ [1].

References
[1] LHCb collaboration, R. Aaij. *et al, Design and performance of the LHCb trigger and full real-time reconstruction in Run 2 of the LHC*, JINST 14 (2019) P04013
[2] LHCb collaboration, R. *Aaij et al., Selection and processing of calibration samples to measure the particle identification performance of the LHCb experiment in Run 2*, LHCb-DP-2018-001, arXiv: 1803.00824
[3] L. Anderlini *et al.*, *Computing strategy for PID calibration samples for LHCb Run 2*, Tech. Rep. LHCb-PUB-2016-020, CERN, Geneva, Jul,2016.
[4] M. Pivk and F. R. Le Diberder, *sPlot: A statistical tool to unfold data distributions*, Nucl. Instrum. Meth. **A555** (2005) 356, arXiv:physics/0402083
[5] L. Anderlini *et al.*, *The PIDCalib package*, Tech. Rep. LHCb-PUB-2016-021, CERN, Geneva, Jul, 2016