Performance of the upgraded LHCb detector in Run 3

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Introduction

- LHCb Run 1 and Run 2: huge success!
- The majority of measurements is statistically limited

  → LHCb Upgrade I: 5x instantaneous luminosity
- Improve physics performance, despite the more challenging environment

  ➢ Completely new tracking and trigger system
- This presentation: overview of detector status and performance

  - Commissioning of UT, M. Artuso
  - LHCb Muon detector, A. Contu
  - Real-time alignment and calibration performance, Z. Xu
  - Results with LHCb's 30MHz software trigger, L. Calefice
  - SMOG: a high-density gas target experiment at LHCb, C. Lucarelli
  - The LHCb RICH upgrade, G. Cavallero
  - The LHCb SciFi tracker, U. De Freitas
  - The LHCb VELO detector. M.D. Galati

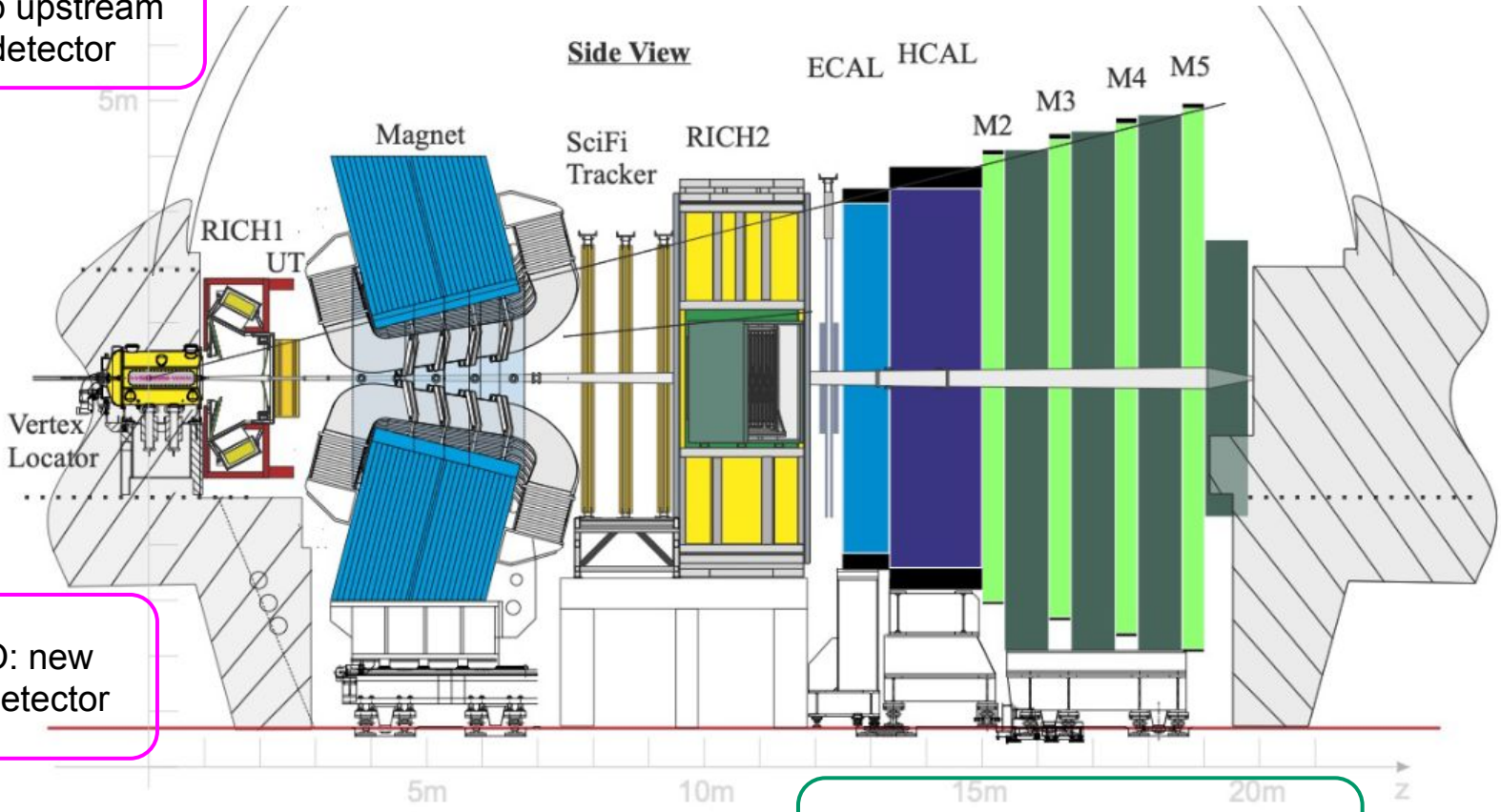
LHCb in Run 3

JINST 19P05065

SciFi: new scintillating fibres downstream detector

RICH: new mechanics, optics, photodetectors

UT: new silicon strip upstream detector

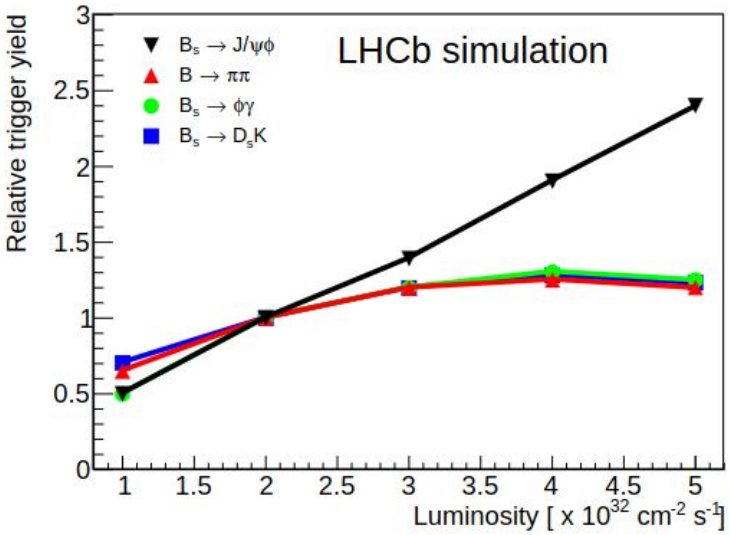


VELO: new pixel detector

New frontend electronics and new DAQ for all sub-detectors!

Trigger system

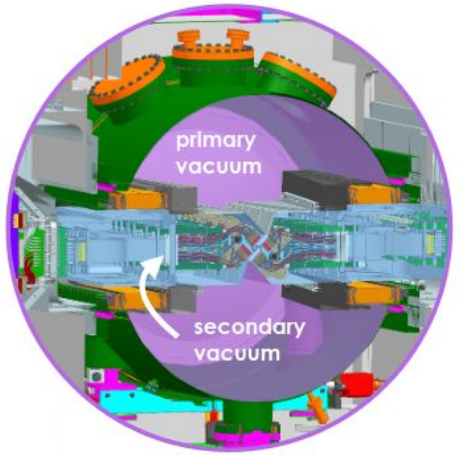
- Trigger strategy in Run 1 + Run 2:
  - Hardware trigger (L0), followed by a software trigger
- Higher instantaneous luminosity
  - Tight p_T and E_T cuts saturate hadronic channels → L0 trigger removed
  - Software trigger process events at the full LHC collision rate
  - → room for improving trigger efficiency w.r.t. Run 2



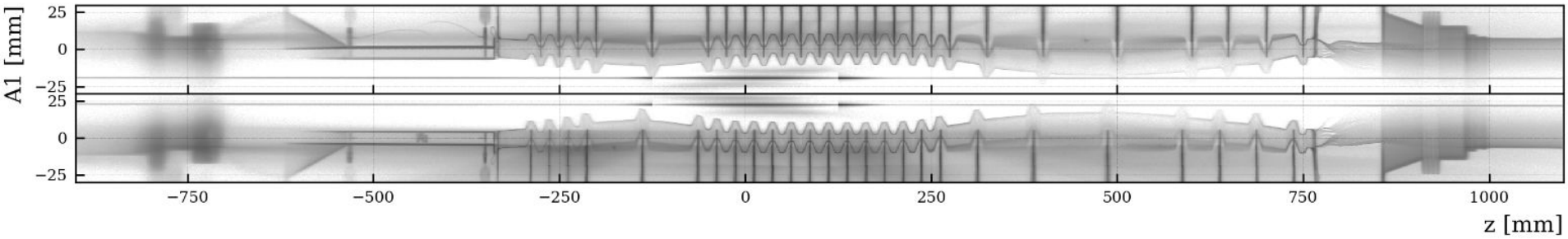
JINST 19P05065

Data-taking

- **2022**
  - all detectors installed but UT
  - local commissioning of subdetectors
  - global commissioning of trigger, alignment and calibration
  - VELO routinely closed in the last couple of months

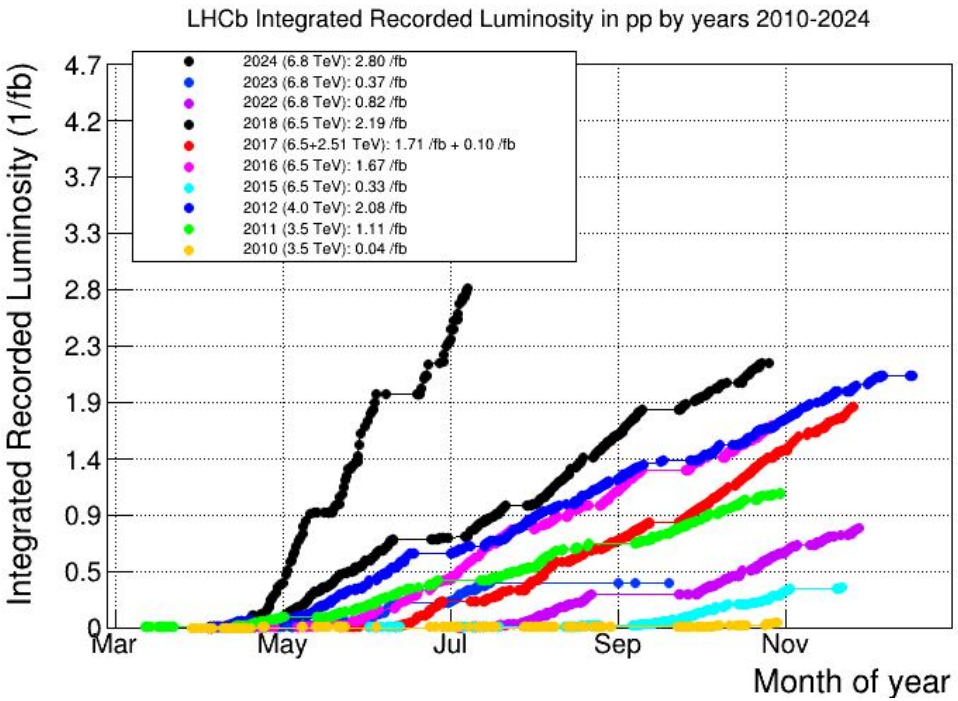


- **2023**
  - LHC vacuum incident in the VELO in Jan: operated with VELO gap of 49 mm
  - UT completed installation
  - collected data during ion run

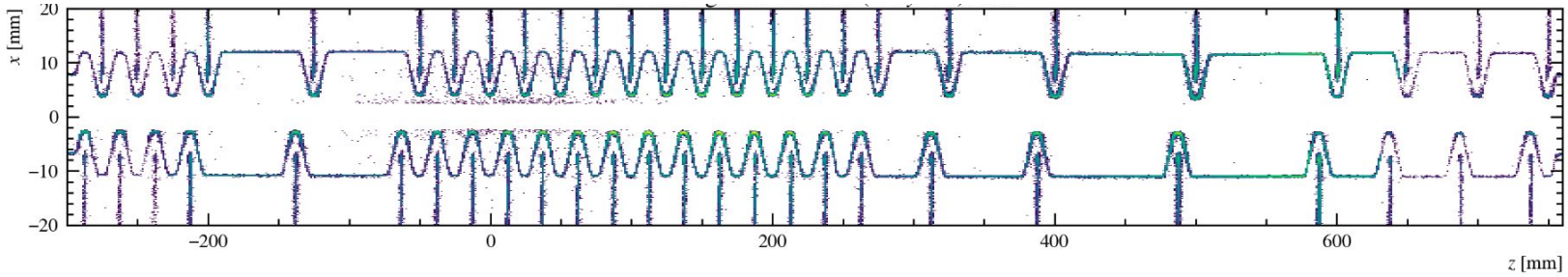


Data-taking (2)

- **2024**
  - VELO RF-box replaced
  - UT included in global data-taking after June TS
  - Currently collecting pp data



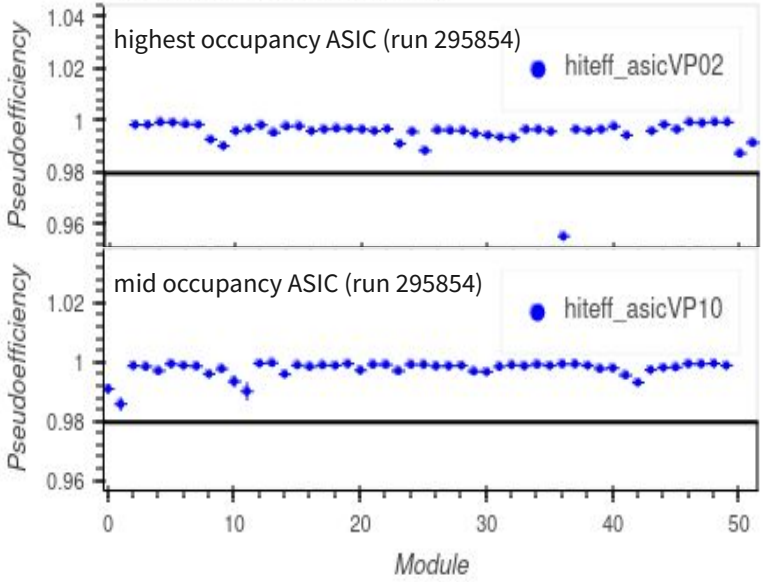
Selfie of the new RF-box and VELO modules with reconstructed hadronic interaction vertices



Hit efficiencies

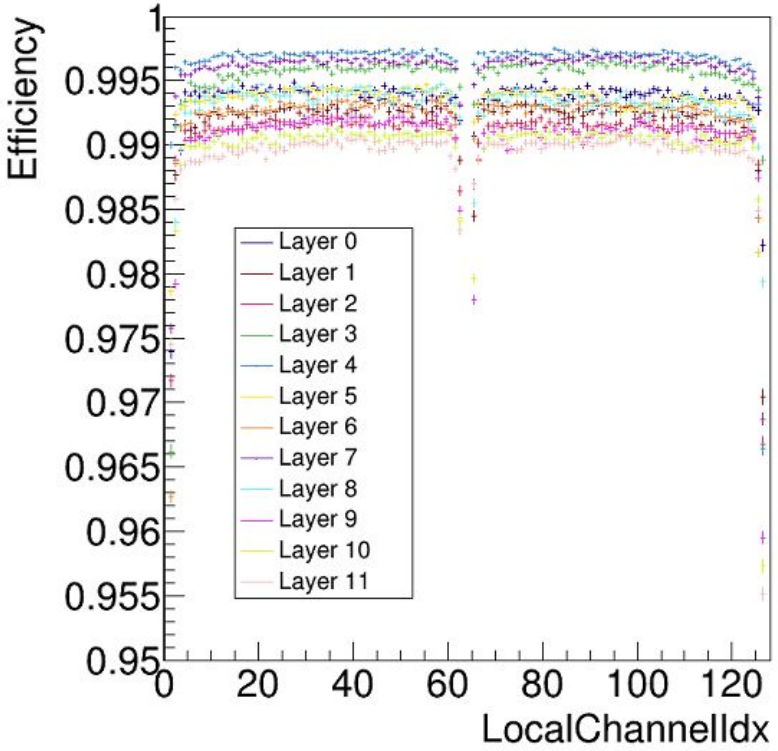
VELO

Biased hit efficiencies in online monitoring



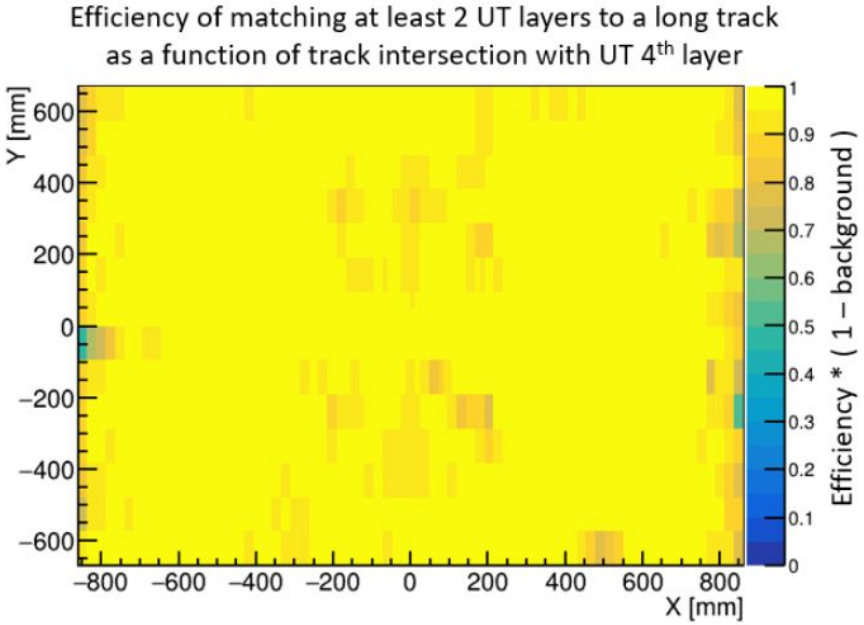
SciFi

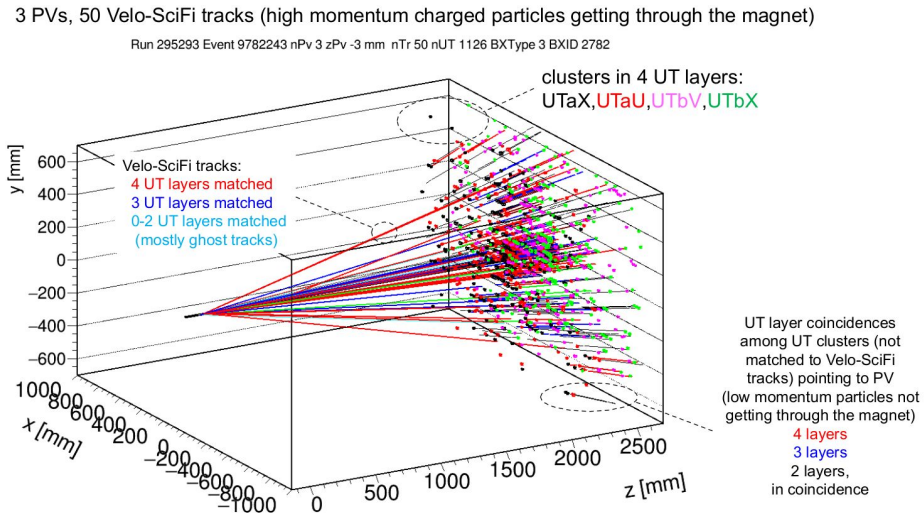
LHCb-FIGURE-2024-016



- Hit efficiency for VELO and SciFi approaching design specification

UT tracking efficiency



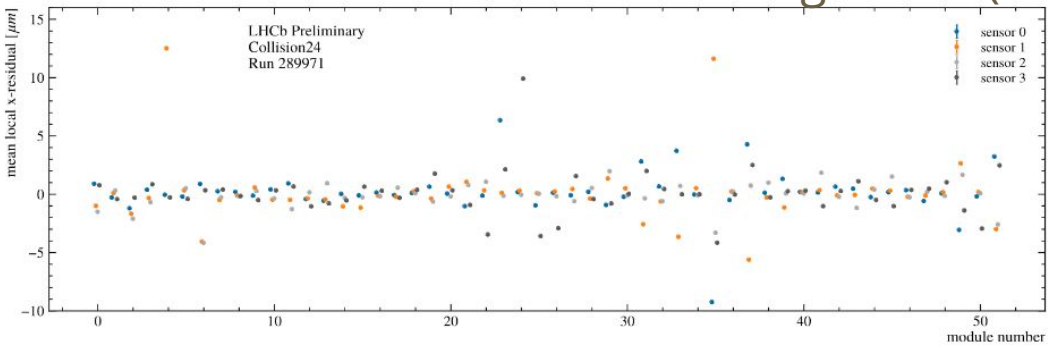


- UT efficiency on VELO-SciFi tracks is higher than 99%

Alignment

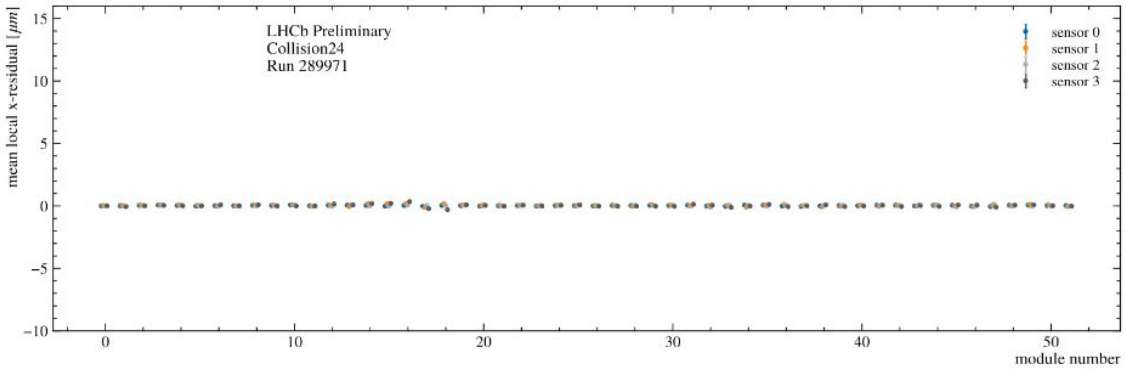
- To achieve best performance: essential to spatially align and calibrate the detector!
  - ➢ Detectors have been moved (VELO re-installed) between 2023 and 2024 → evaluate again spatial alignment of detector elements

with 2022 modules and sensors alignment (VELO)



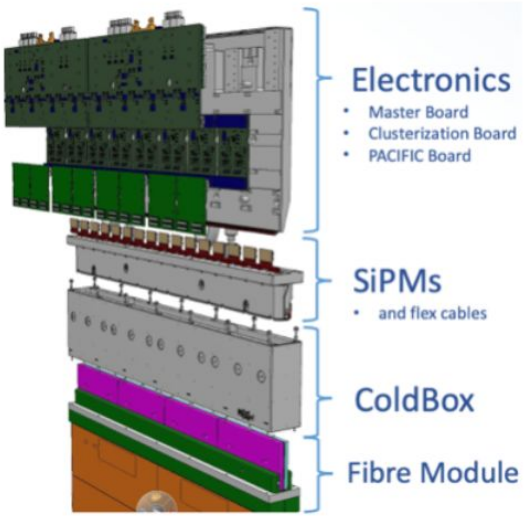
LHCb-FIGURE-2024-009

after new modules and sensors alignment (VELO)

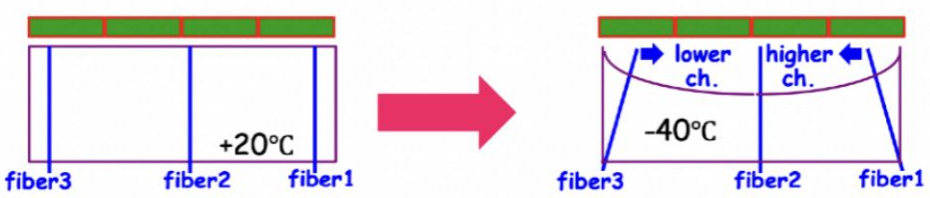


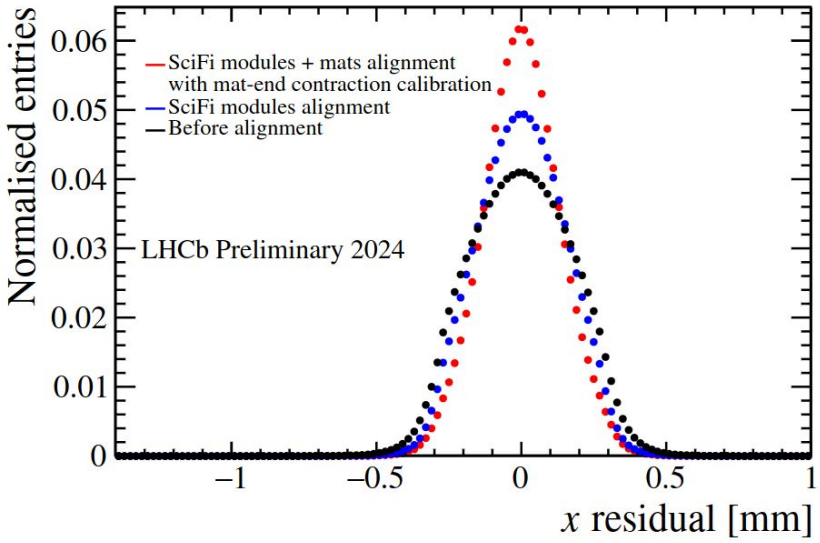
Alignment (2)

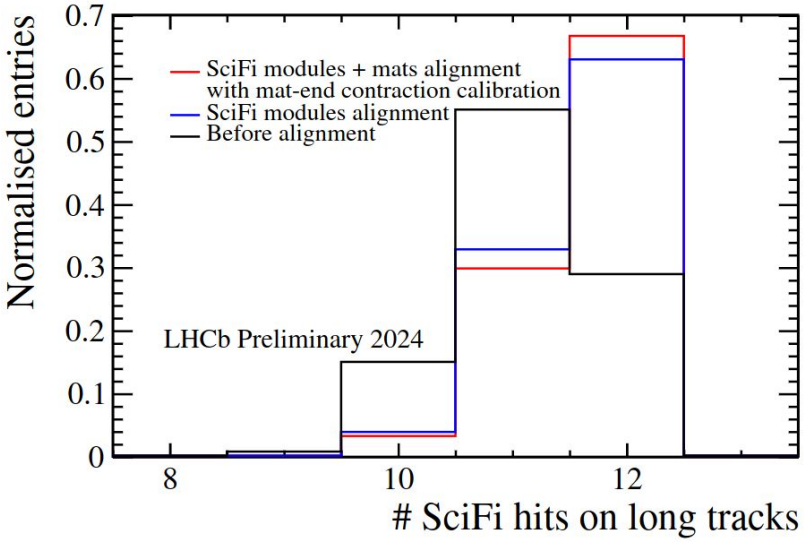
- Still room for improving SciFi alignment , but large progress made in the first weeks of data-taking



LHCb-FIGURE-2024-009



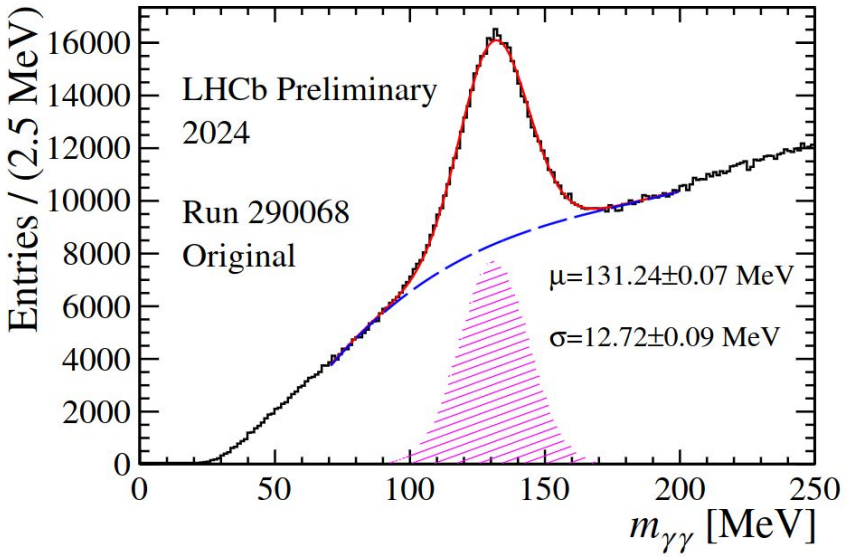


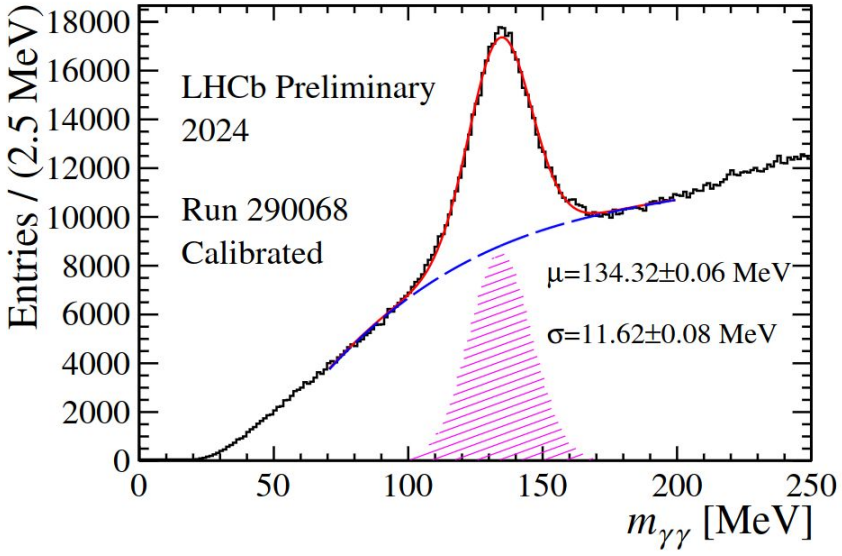


Calibration of electromagnetic calorimeter

- Calibrate each of the 6016 cells of the electromagnetic calorimeter via an iterative process
  - Measure neutral pion invariant mass in all the cells and apply calibration to match PDG value

LHCb-FIGURE-2024-009

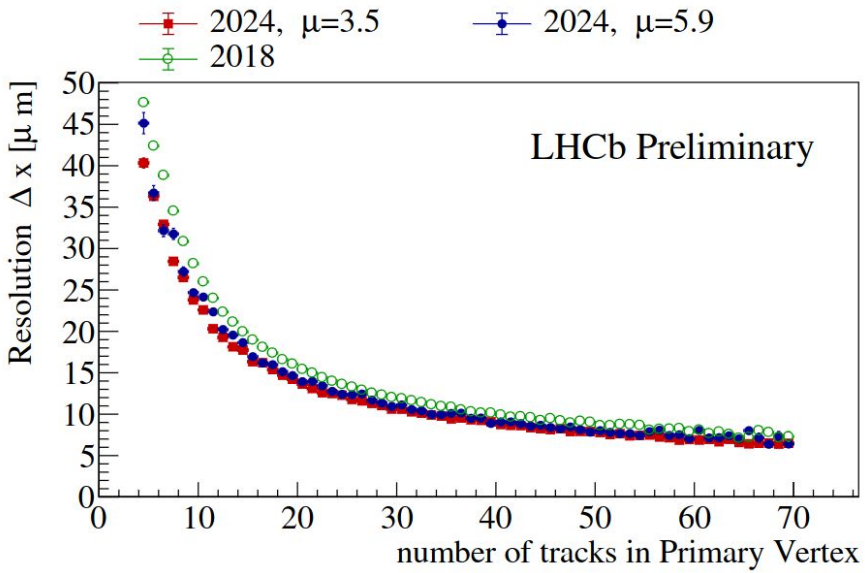


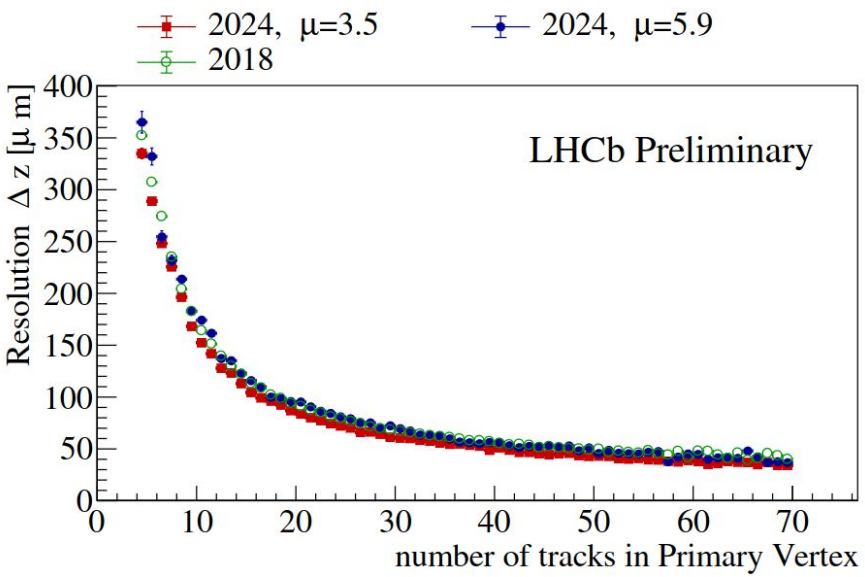


PV resolution

- Performance better than Run 2 and stable when varying the average number of visible pp interactions per bunch crossing (μ)
  - ➢ μ=5 → ~ nominal luminosity

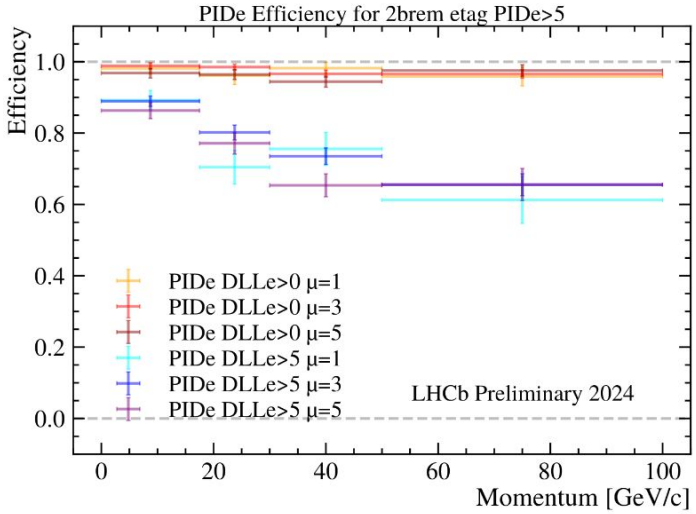
LHCb-FIGURE-2024-011





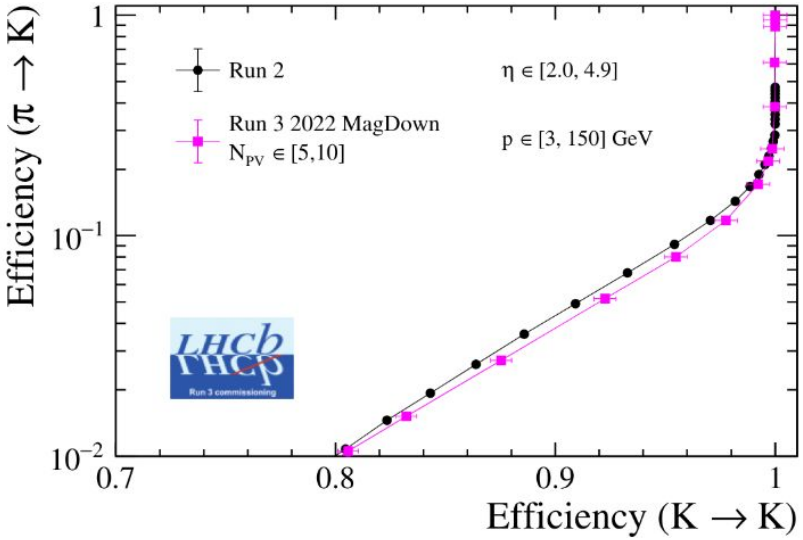
PID performance

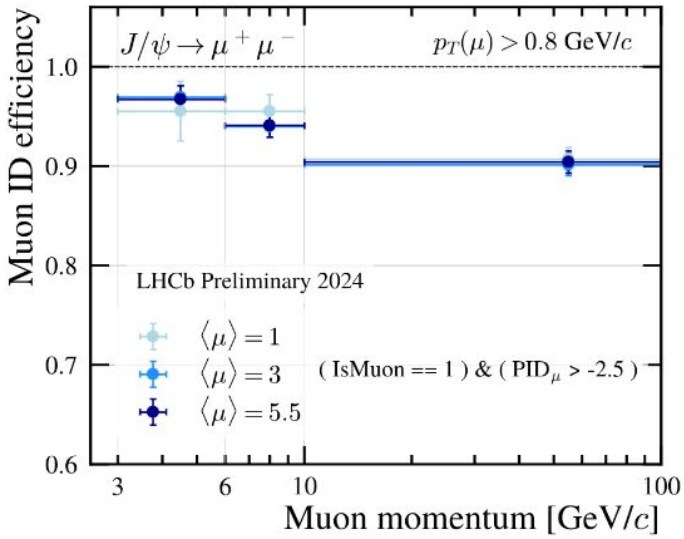
- Particle identification by combining information from different subdetectors
  - ➢ Difference in log-likelihood between different hypothesis
- Good stability as a function of μ!



LHCb-FIGURE-2024-010

LHCb-FIGURE-2023-019

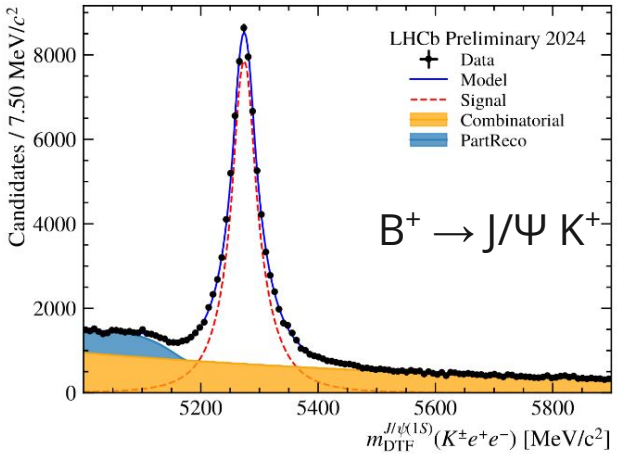


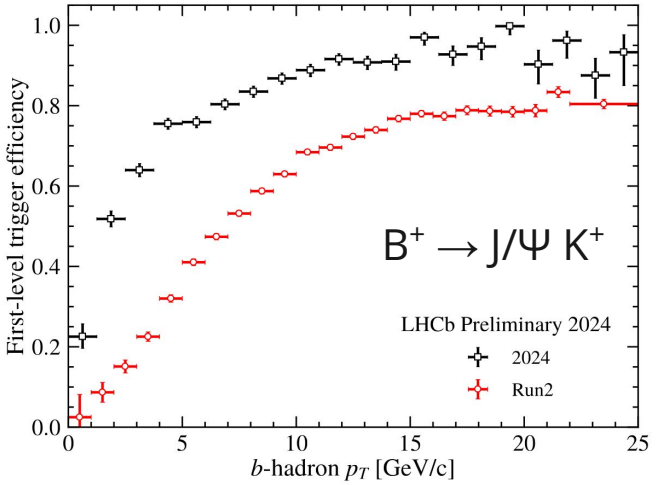


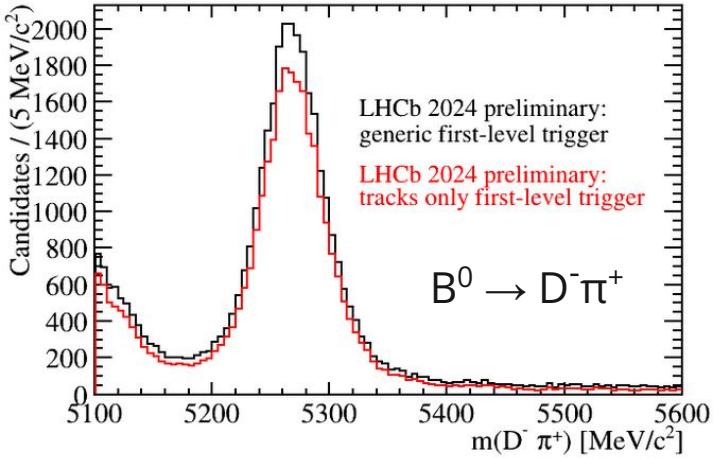
Trigger efficiency in 2024 data

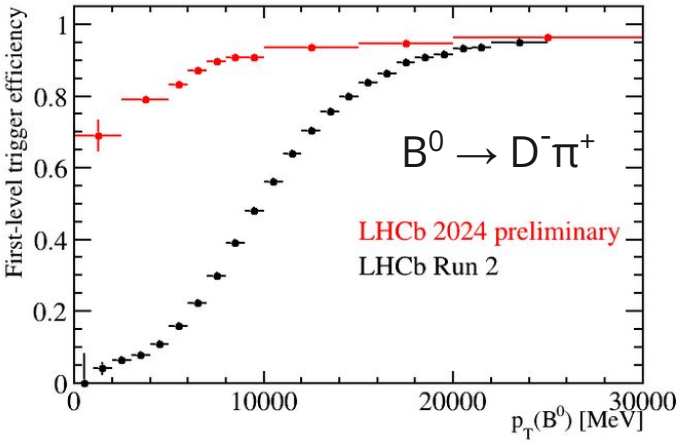
LHCb-FIGURE-2024-007
LHCb-FIGURE-2024-014

- Removal of hardware trigger improved the efficiency in selecting hadronic decays and when electrons are present in the final state!





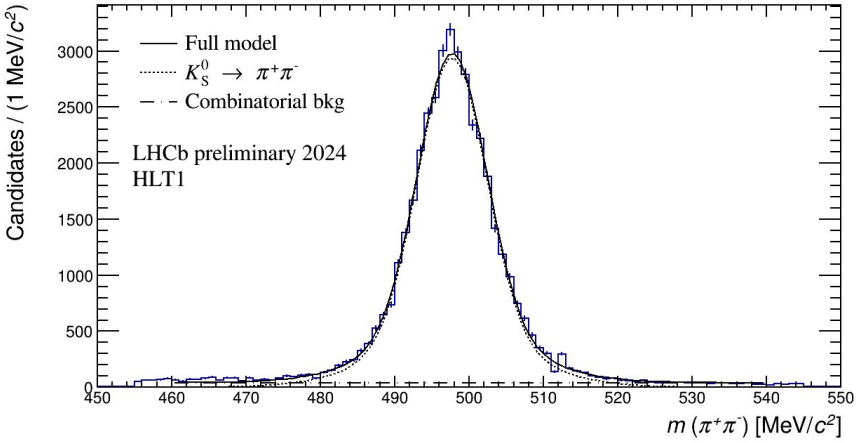


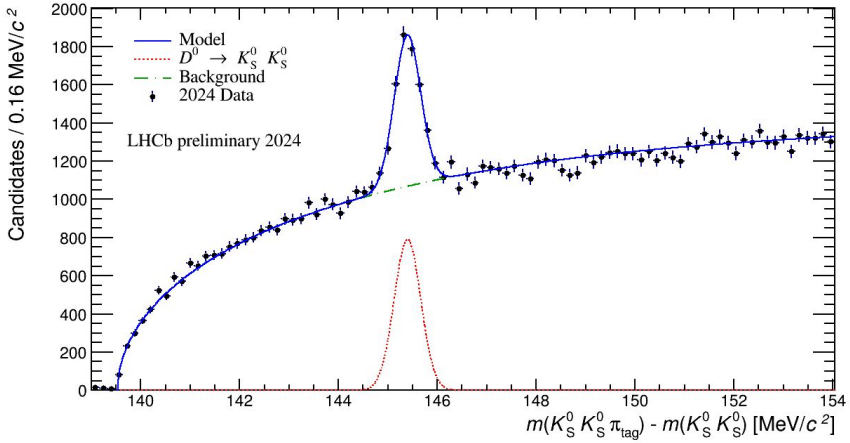


New opportunities with software trigger

LHCb-FIGURE-2024-008
LHCb-FIGURE-2024-013

- Software trigger → flexibility in design selections
  - ➢ K_S^0 candidates reconstructed directly at the first level of the trigger!
  - ➢ Dedicated selections to collect single K_S^0 and pairs of K_S^0 → increase efficiency in selecting decays like $D^0 \rightarrow K_S^0 K_S^0$

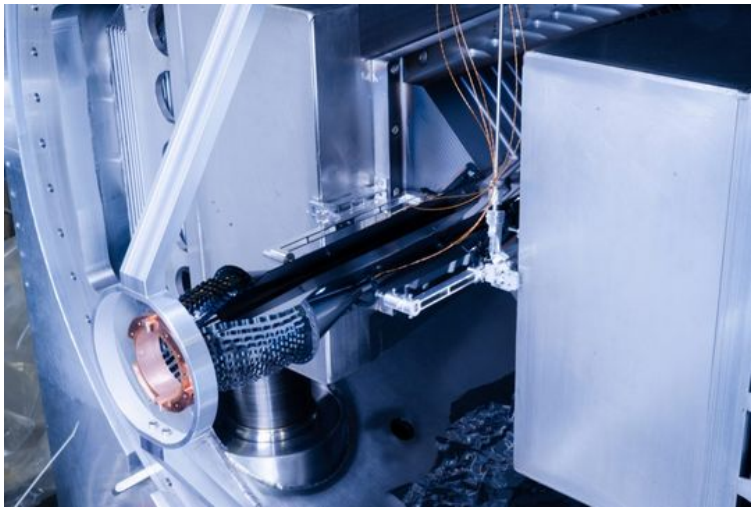


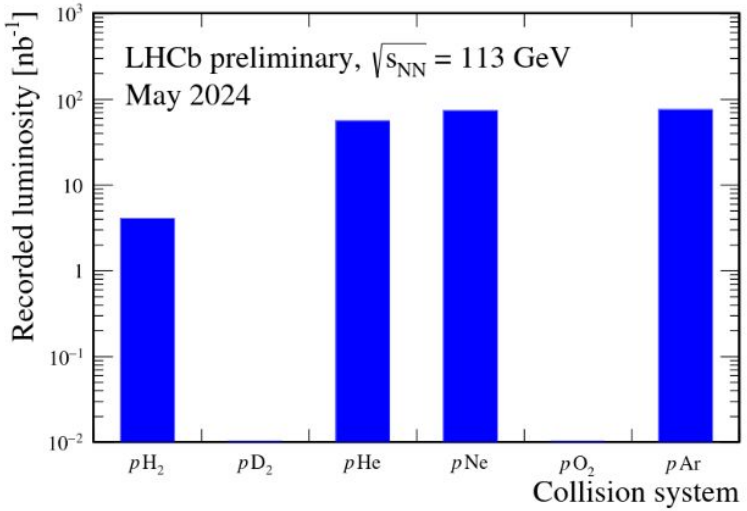


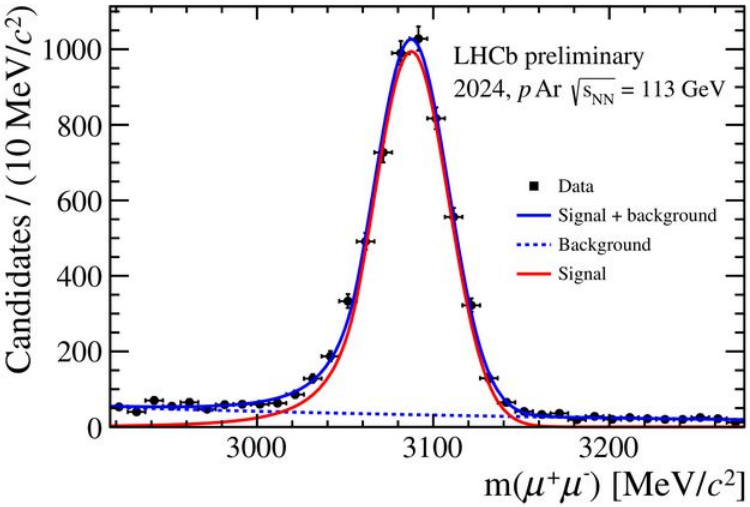
SMOG

LHCb-FIGURE-2024-005

- LHCb can inject gas into the beam pipe to act as a fixed target collision experiment
- Successfully collected samples in different fixed-target configurations!







Conclusions

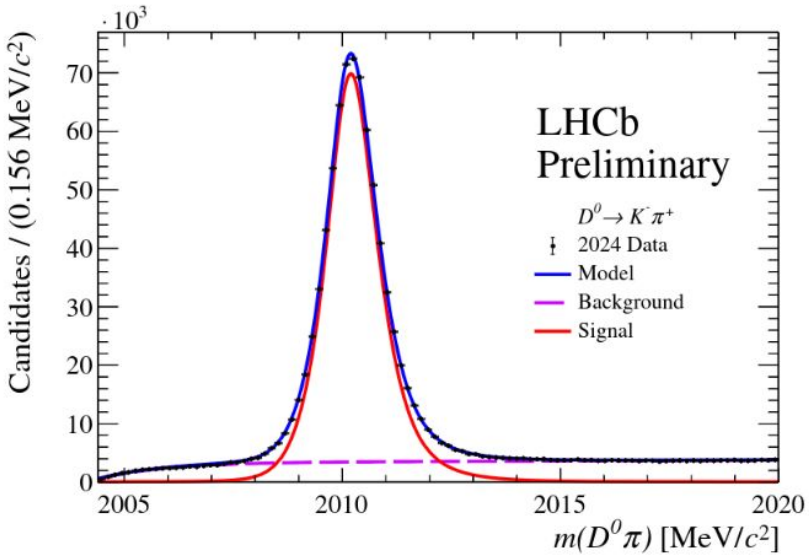
- Exploring the full potential of Upgrade I in 2024
  - VELO fully closed
  - UT commissioned and included in global data-taking
  - Detectors stably operating at nominal conditions
- Expected improvements of trigger efficiency for hadronic channels confirmed on data
- Still room for improving final performance, but huge progress made since the beginning of the 2024 data-taking

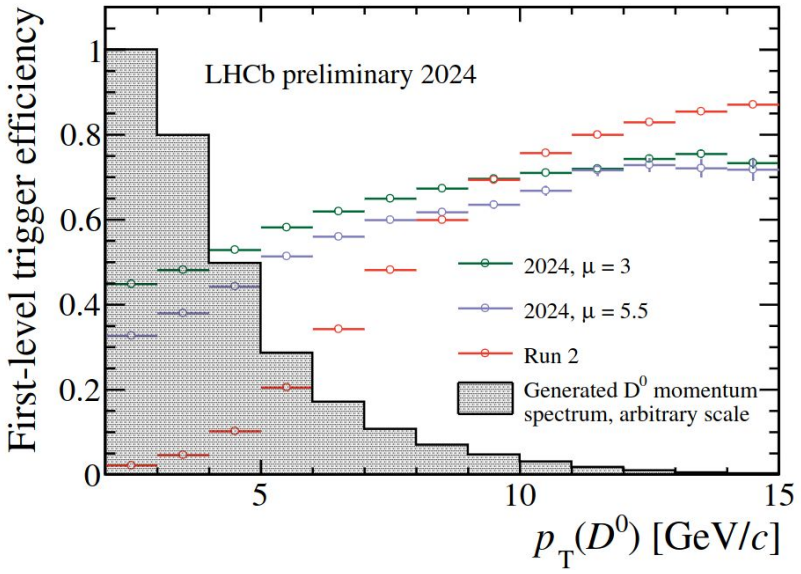
Backup slides

Charm decays in 2024 data

LHCb-FIGURE-2024-006

- Removal of hardware trigger improves the efficiency in selecting hadronic charm decays!

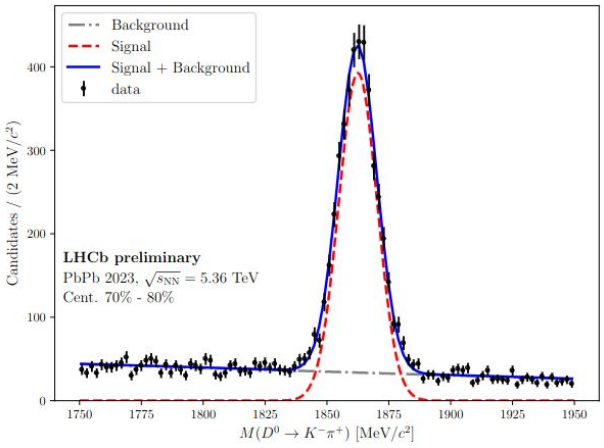


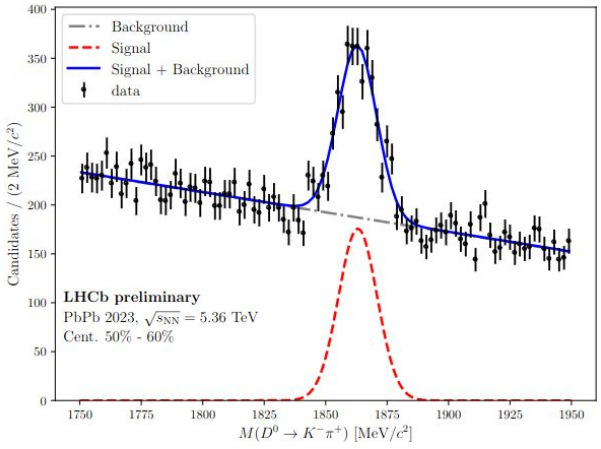


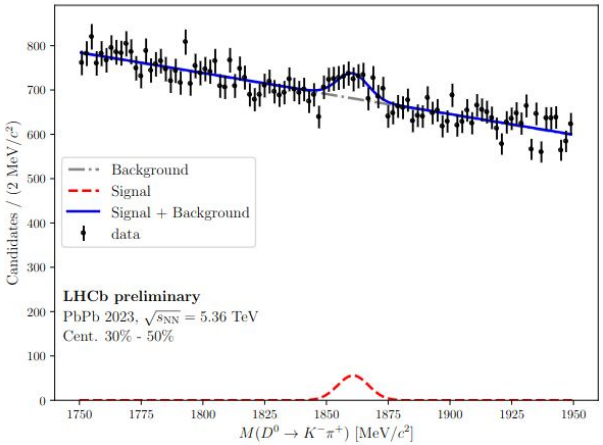
2023 PbPb data

- Goal for Run 3: take advantage of new tracking system (more granular detector) and reach 30% of centrality (VELO was saturating at ~70% in Run 2)
- Despite the challenging 2023 conditions signal events up to mid-central collisions are found
  - ➢ VELO in an open position and UT, crucial to reduce ghost rate, not included in the data-taking at the time

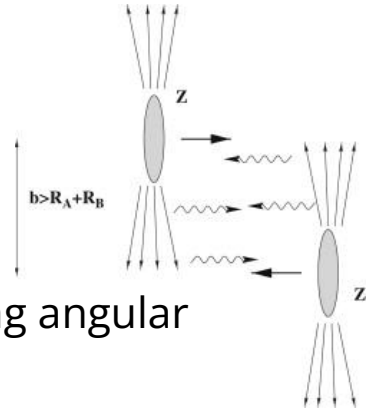
LHCb-FIGURE-2024-004





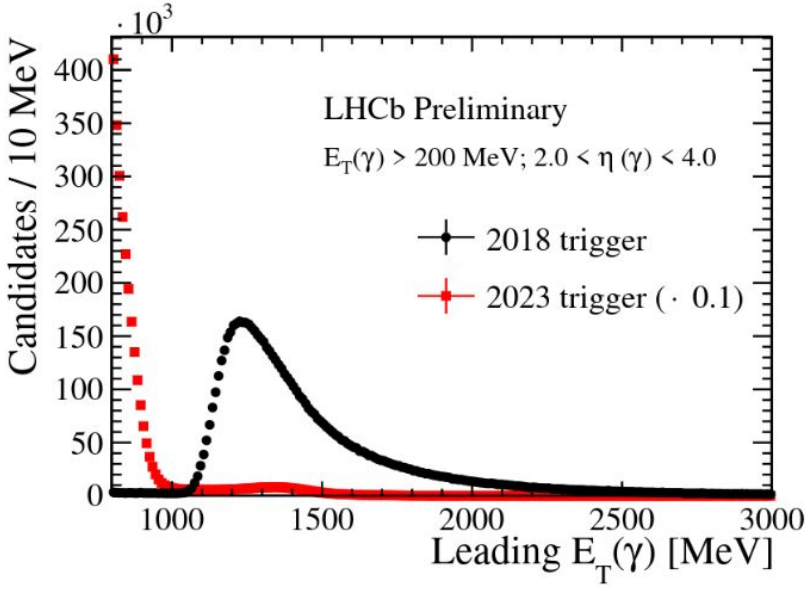


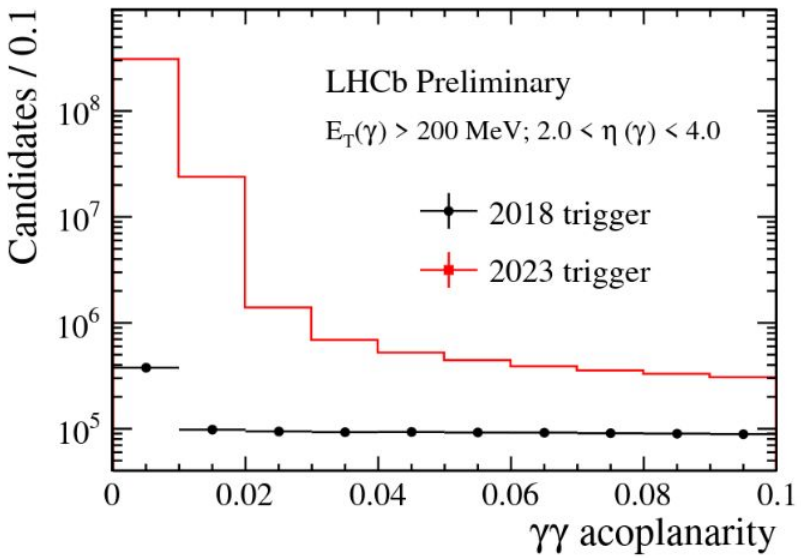
2023 PbPb data



- Ultraperipheral collisions: great laboratory for QCD studies
- How to identify them? Search for photon pair candidates, with strong angular correlation, in low multiplicity PbPb collisions

LHCb-FIGURE-2024-012





- Big improvement in trigger efficiency thanks to L0 removal!