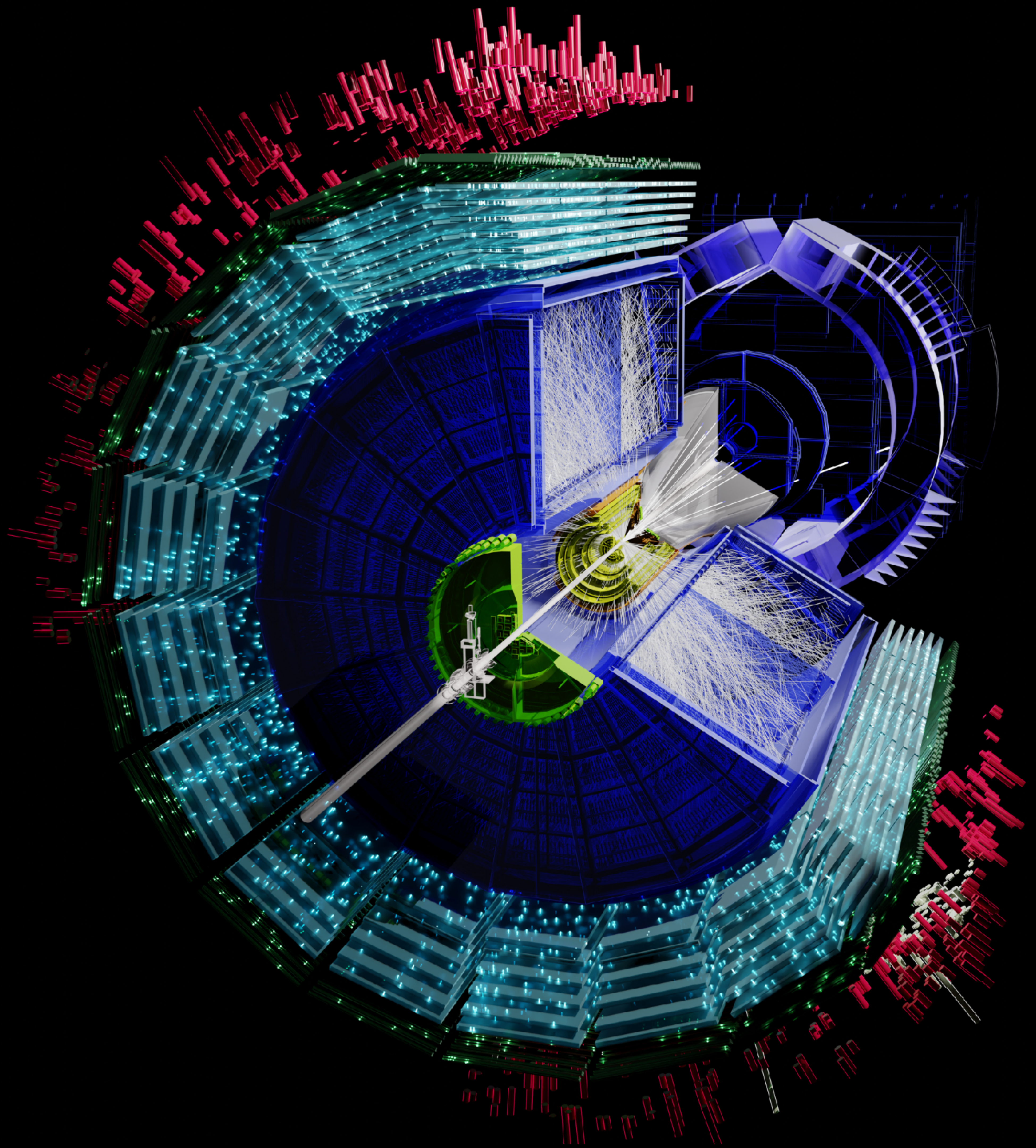
Particle identification in ALICE and LHCb

LHCP conference 2023 — Belgrade, Serbia

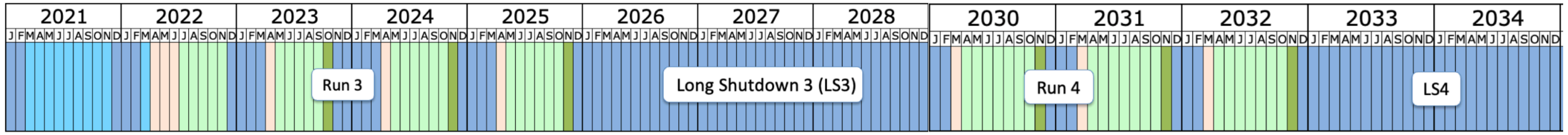


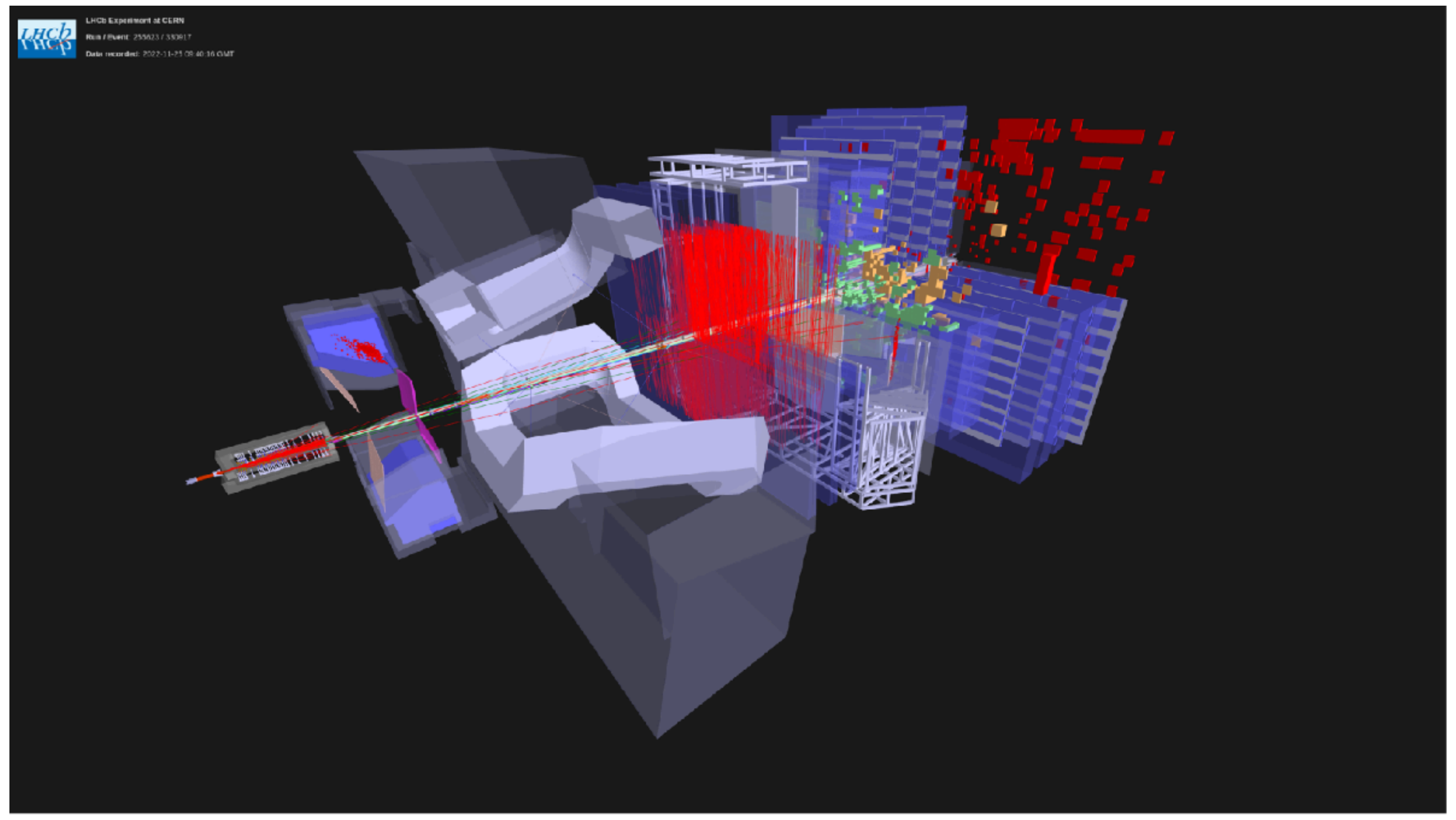
Christian Sonnabend on behalf of the
ALICE and LHCb collaborations

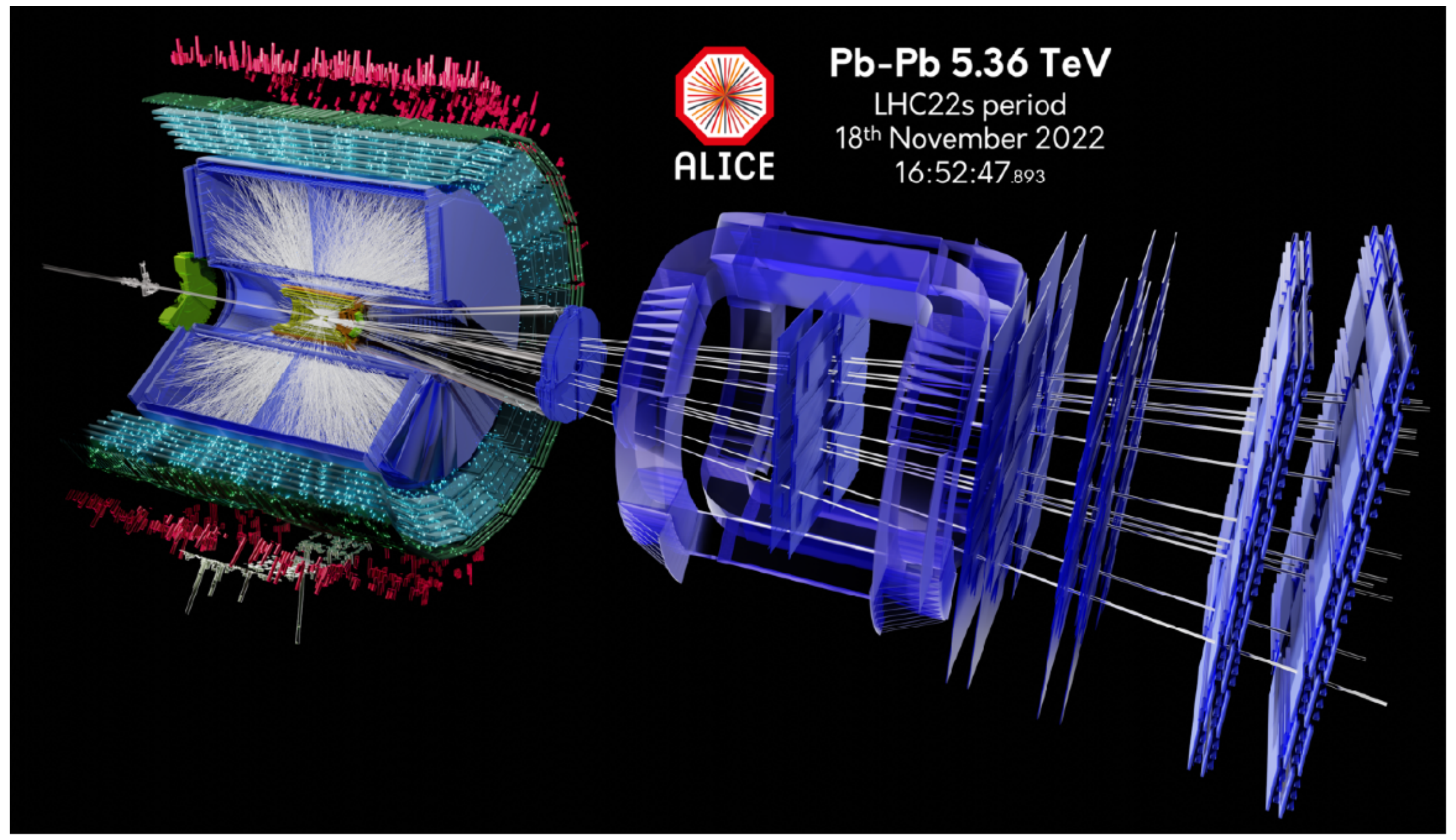
25.05.2023

Introduction

Run 3 is in full swing - new challenges and opportunities!



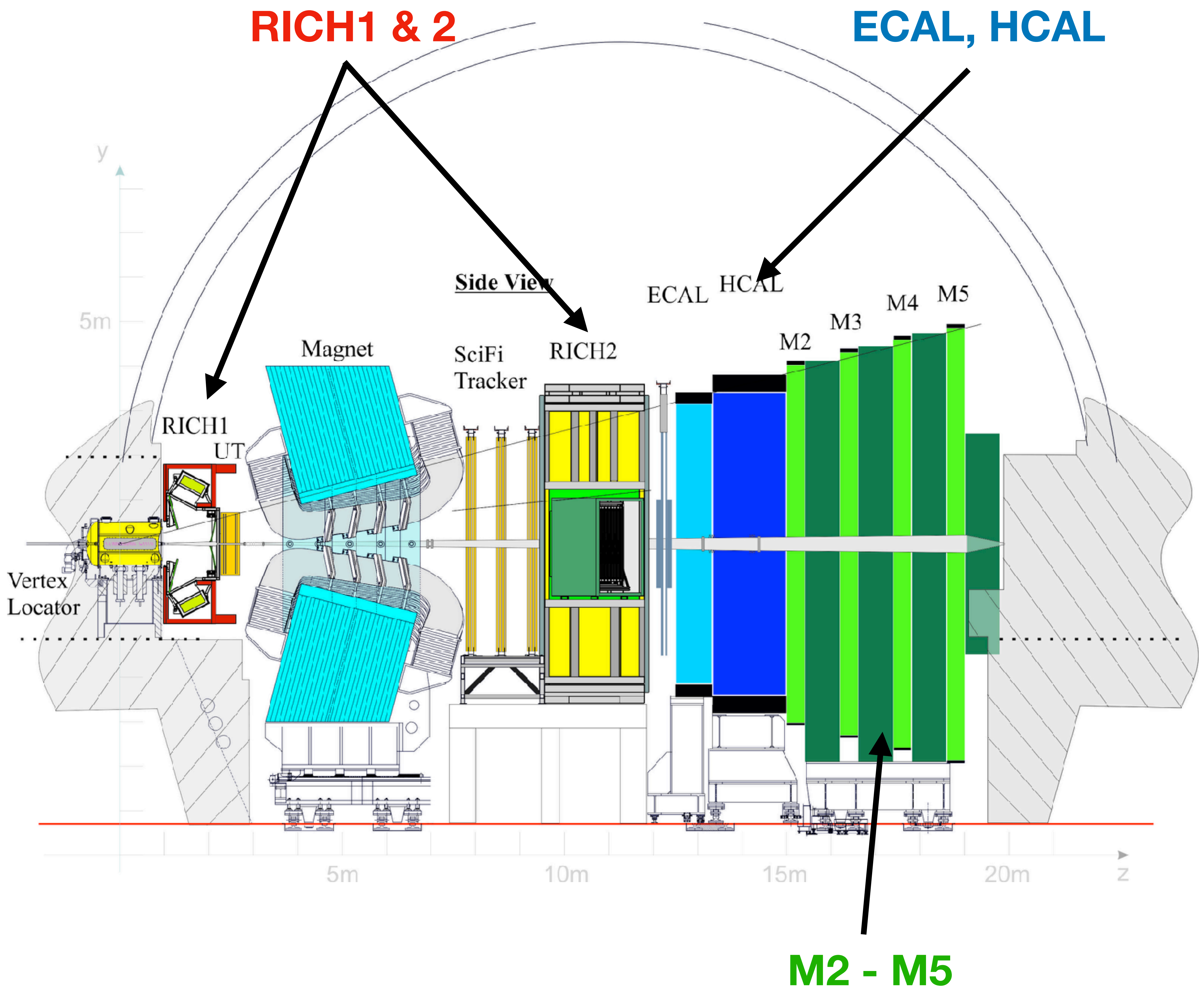


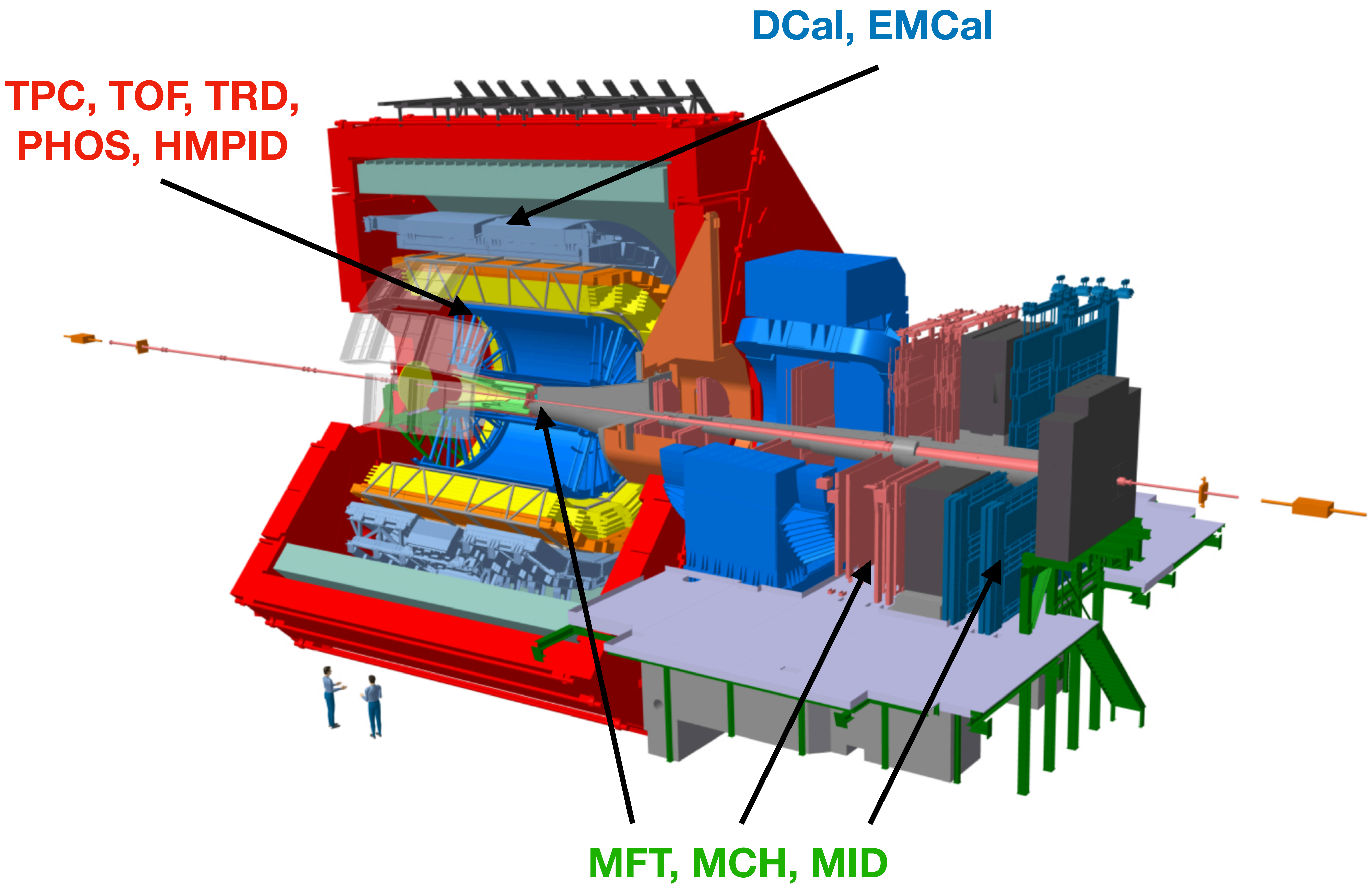


- Major upgrades during LS2 for ALICE and LHCb, in particular for PID detectors
  - Completely new sensors and readout chain in RICH detectors of LHCb
  - New TPC readout in ALICE - GEMs replace the MWPCs
  - Replacing hardware triggers with software triggering — minimum bias data collection!
- Goals until LS4: ALICE — 200 pb^{-1} pp and 13 nb^{-1} Pb-Pb | LHCb — 50 fb^{-1} pp and 1 nb^{-1} in Pb-Pb
- New algorithms to cope with higher luminosities and data rates

1) LHCb event display: https://cds.cern.ch/images/LHCb-PHO-GEN-2022-004-1
2) ALICE event display: https://cds.cern.ch/record/2841865?ln=en

Run 3 PID-detectors in ALICE and LHCb



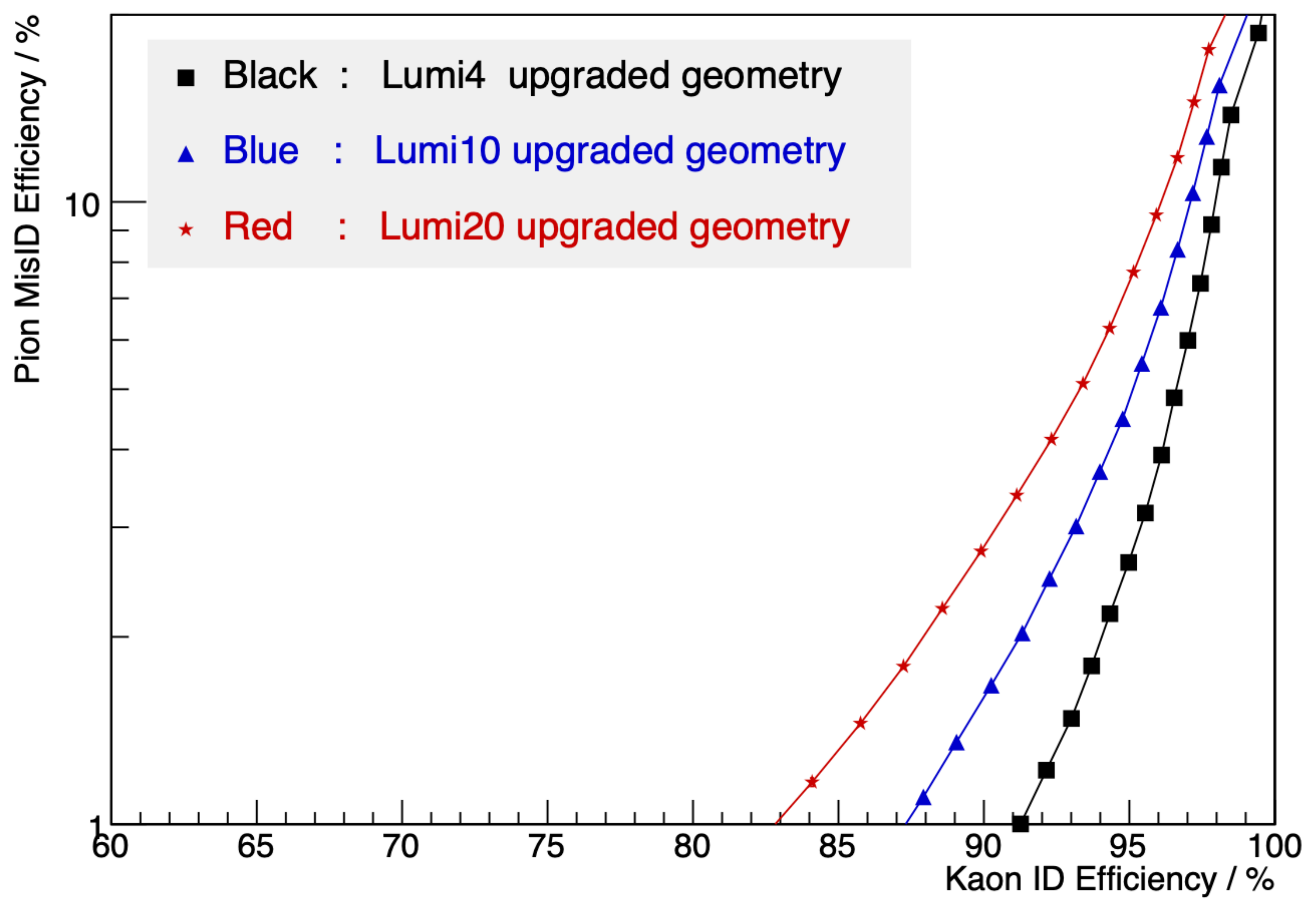


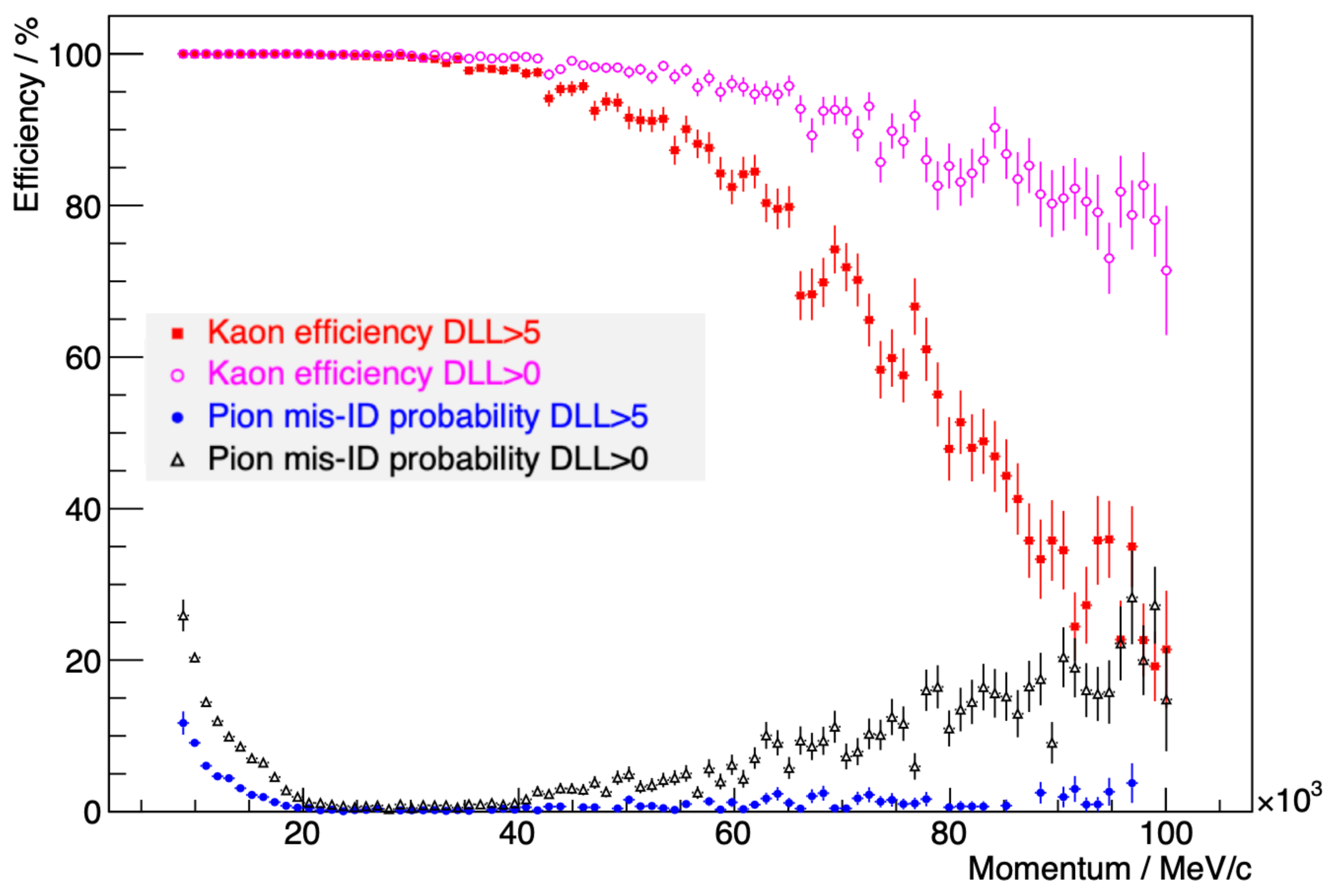
1) LHCb schematic: https://cds.cern.ch/record/1087860
2) ALICE schematic: https://cds.cern.ch/record/2263642

Particle identification in LHCb

RICH - Ring Imaging Cherenkov Detector

- Release of Cherenkov radiation when charged particles pass C_4F_{10} (RICH1) & CF_4 (RICH2)
- Focusing radiation using mirror system and detection using multianode photomultipliers (MaPMT)
- Ultimate physics performance: separation between charged hadron species ($\pi^{\pm}$, $K^{\pm}$, p$^{\pm}$, etc.) — purity vs. efficiency



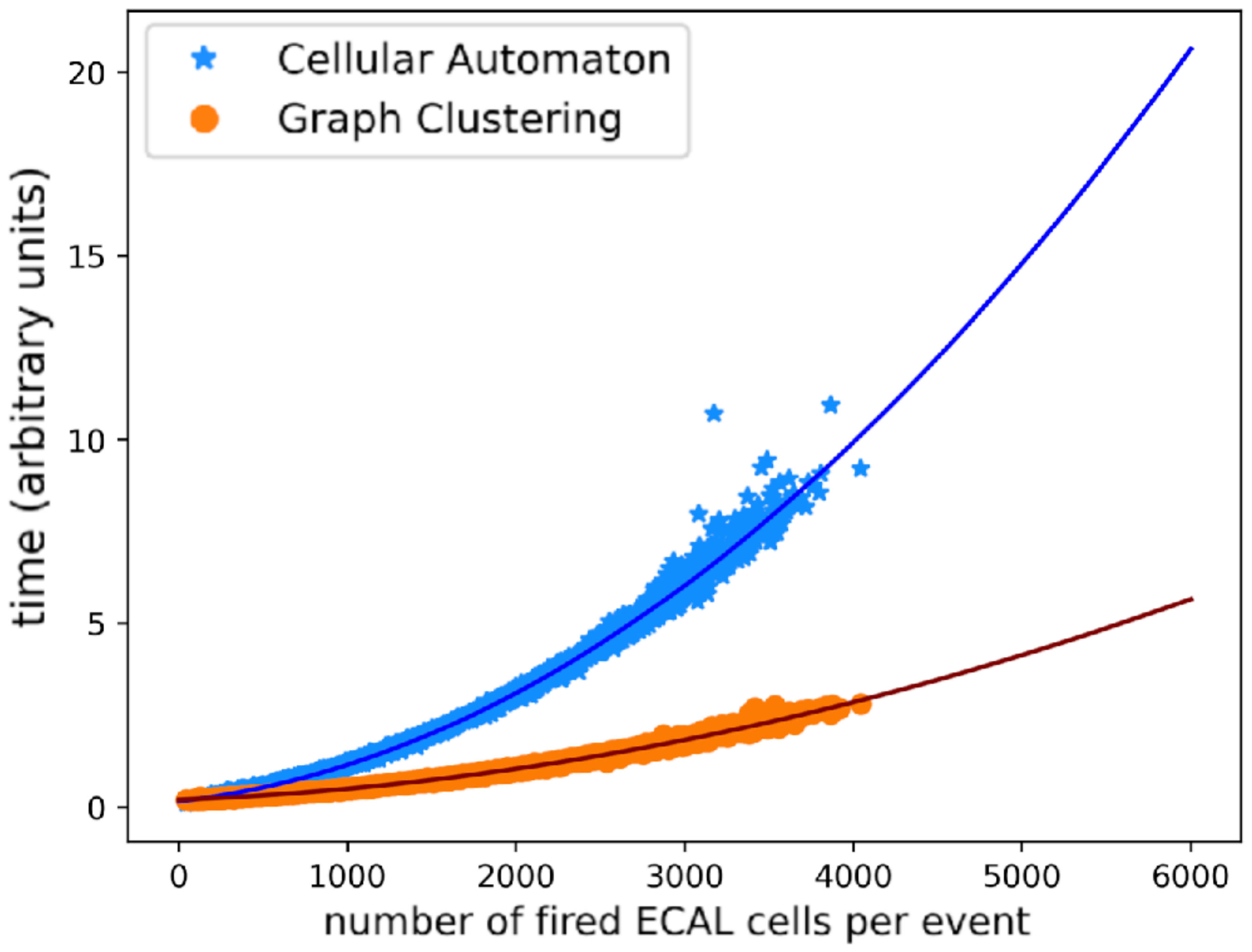


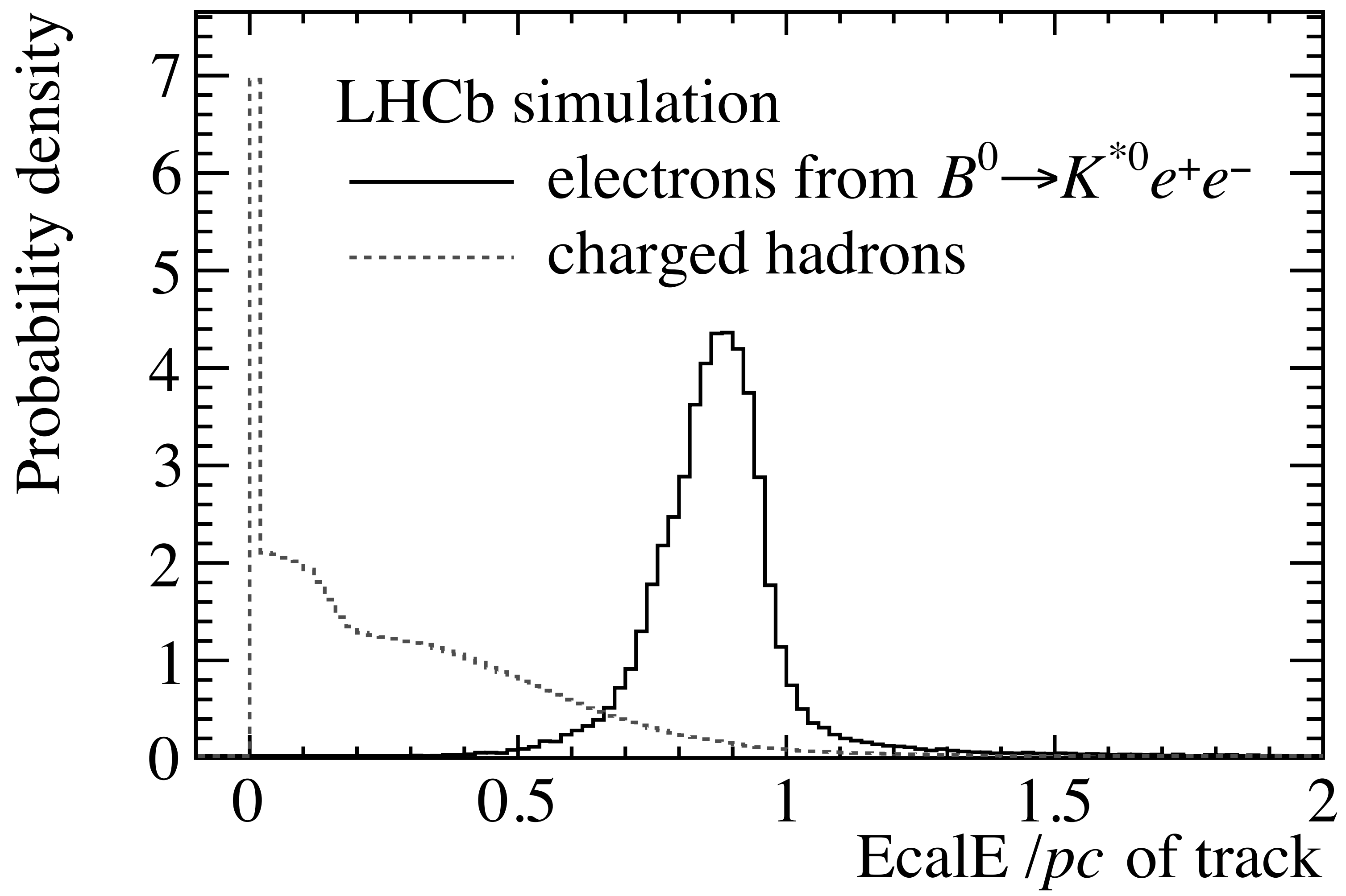
1) & 2) PID performance of upgraded geometry: https://cds.cern.ch/record/1624074/files/LHCB-TDR-014.pdf

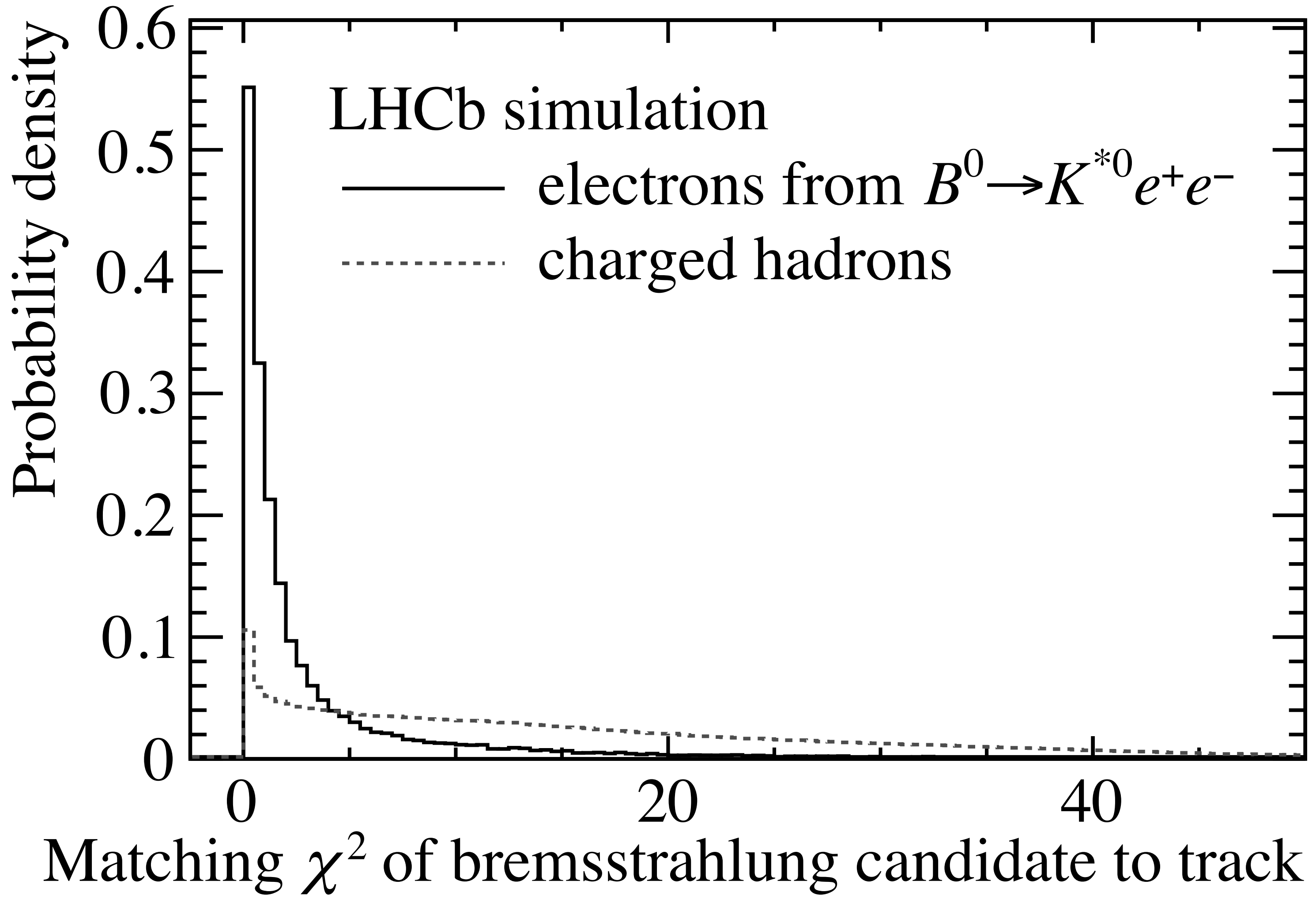
Particle identification in LHCb

Calorimeters (ECAL & HCAL)

- Identification of hadrons (HCAL), electrons and photons (ECAL)
- New graph-based clustering for Run 3: match performance of cellular automaton but much more efficient
- Neural network based classification for photon identification
- For Run 3 calorimeter PID is running in first level triggering





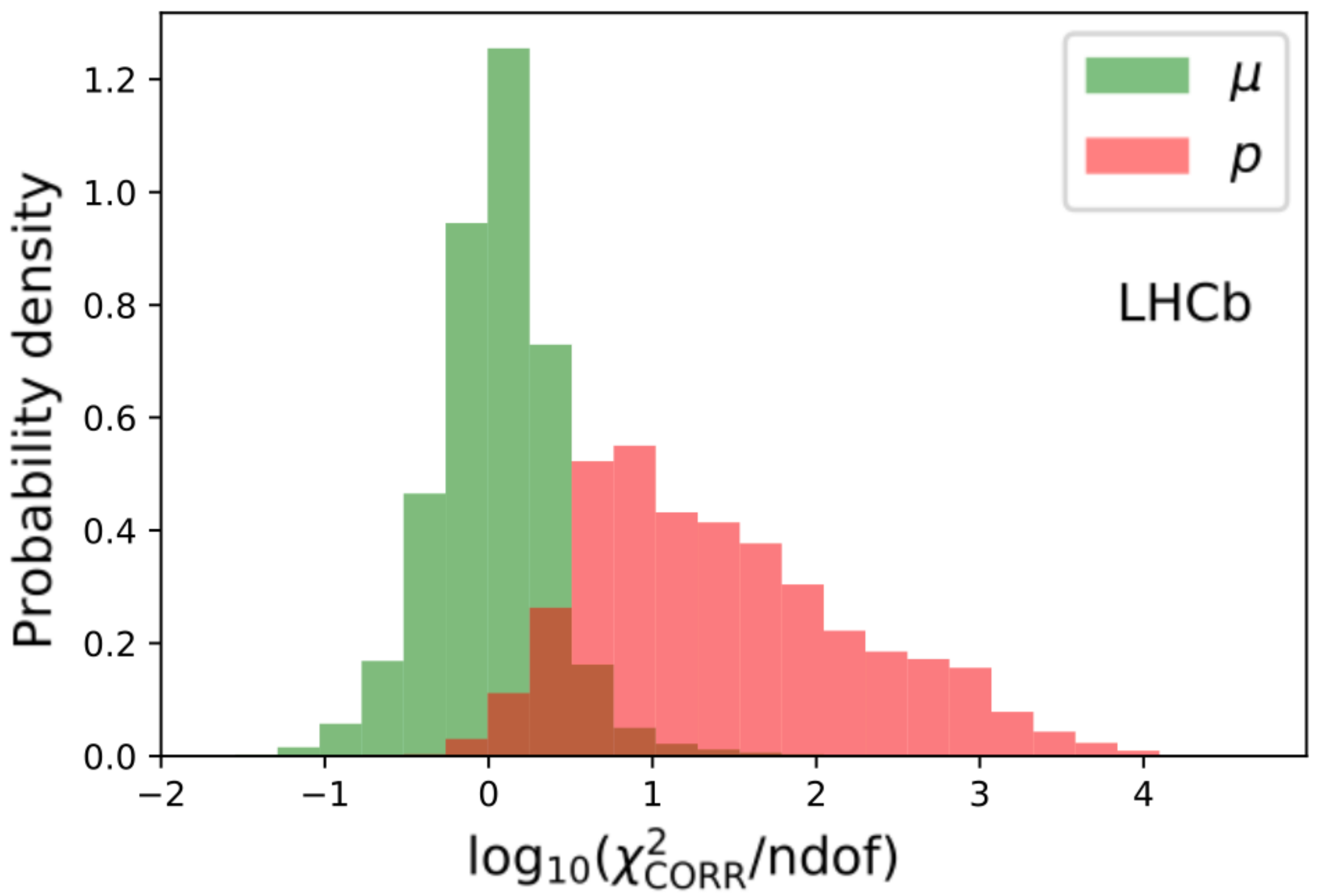


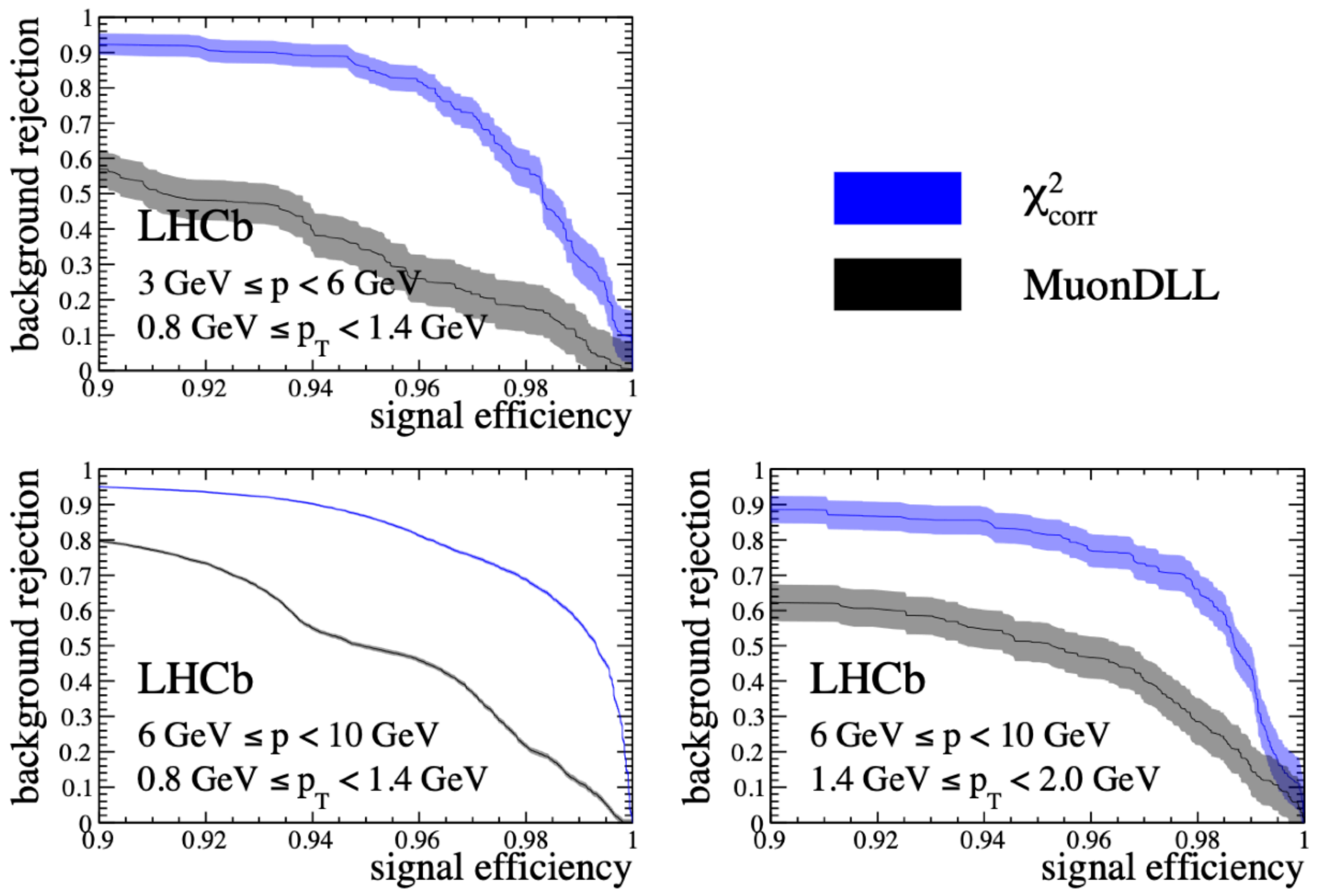
1) Graph based clustering: https://doi.org/10.1140/epjc/s10052-023-11332-1
2) & 3) Electron identification: https://cds.cern.ch/record/2773174

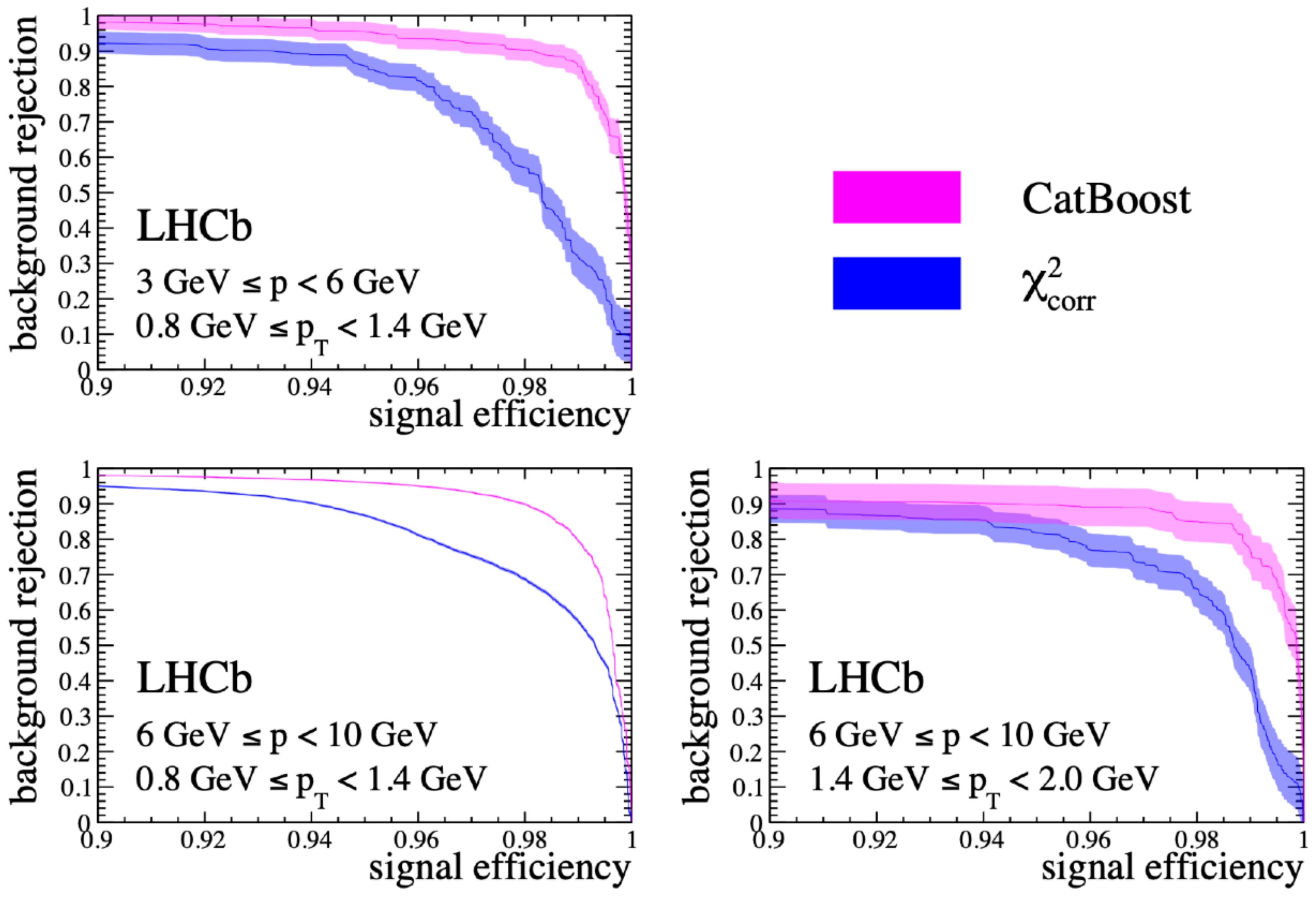
Particle identification in LHCb

Muon detectors

- 80 cm thick iron absorbers interleaved with sensitive readout panels (M2-M5)
- Run 3 readout upgrade allows to run with the full event rate — no hardware triggering
- Novel algorithms in Run 3 for HLT1 (χ^2_{corr}) and HLT2 (CatBoost) for purification of muon identification



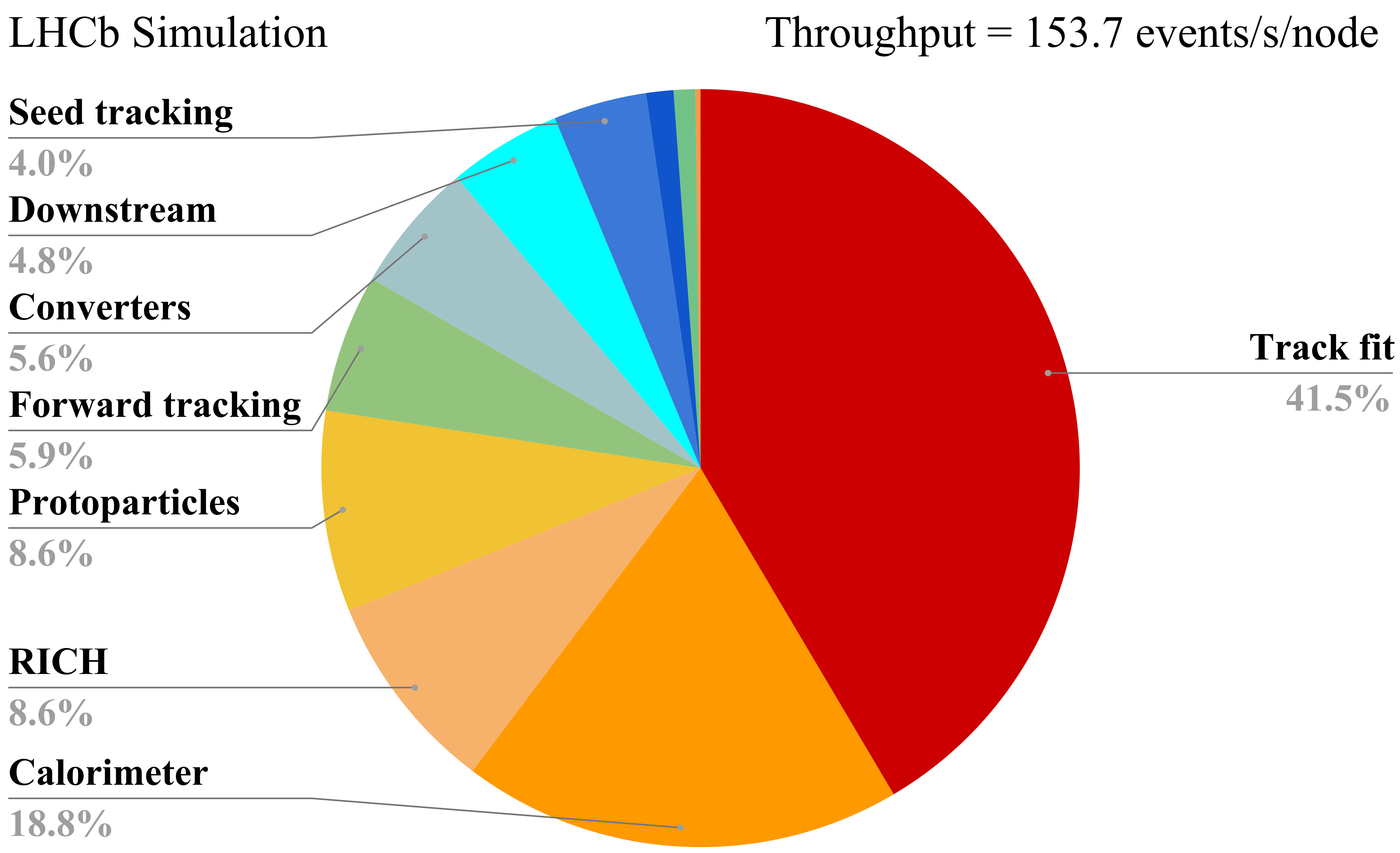




1) - 3) Performance HLT1 and 2: https://doi.org/10.1088/1748-0221/15/12/T12005

Reconstruction in LHCb

Computing throughput — HLT2 reconstruction

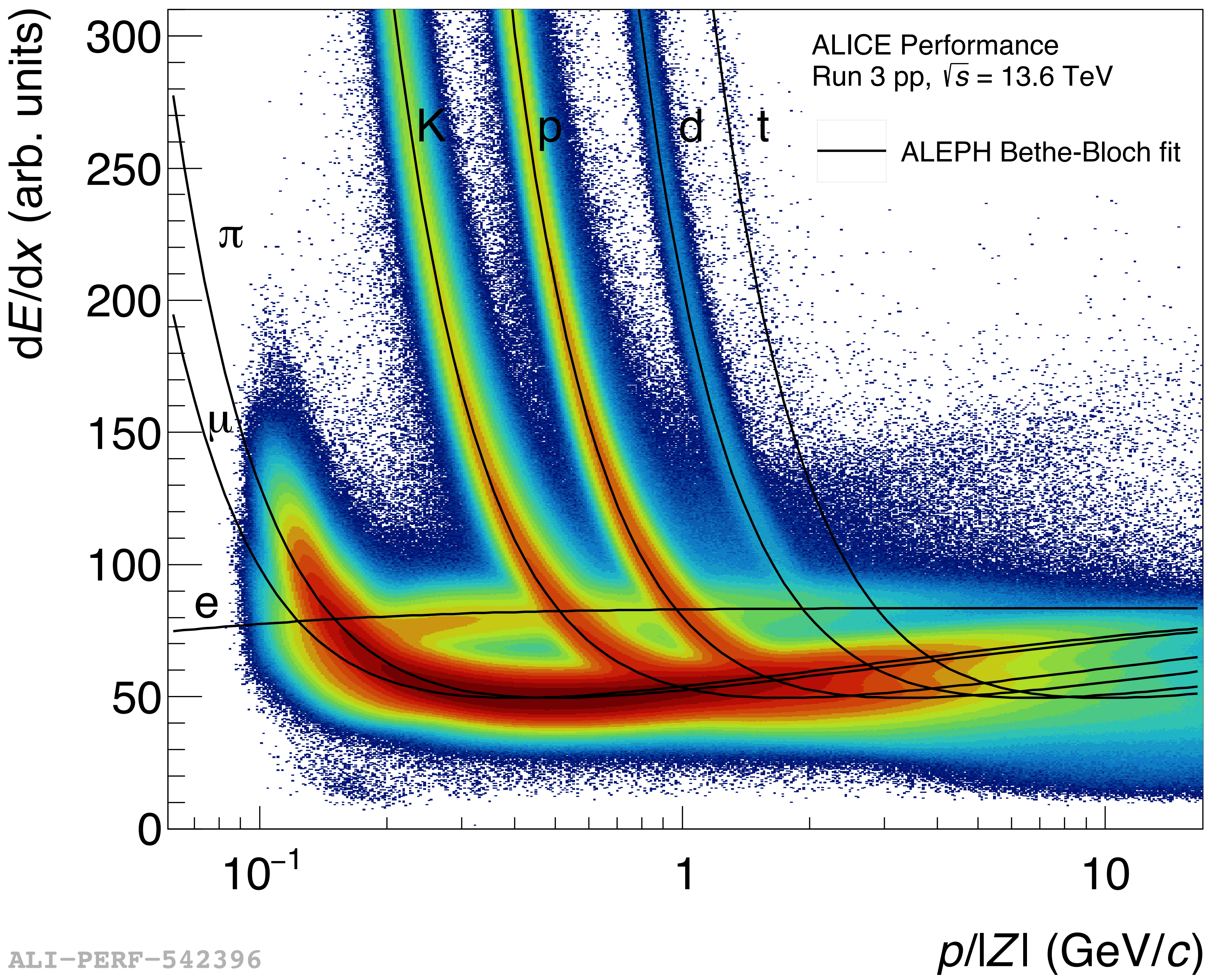


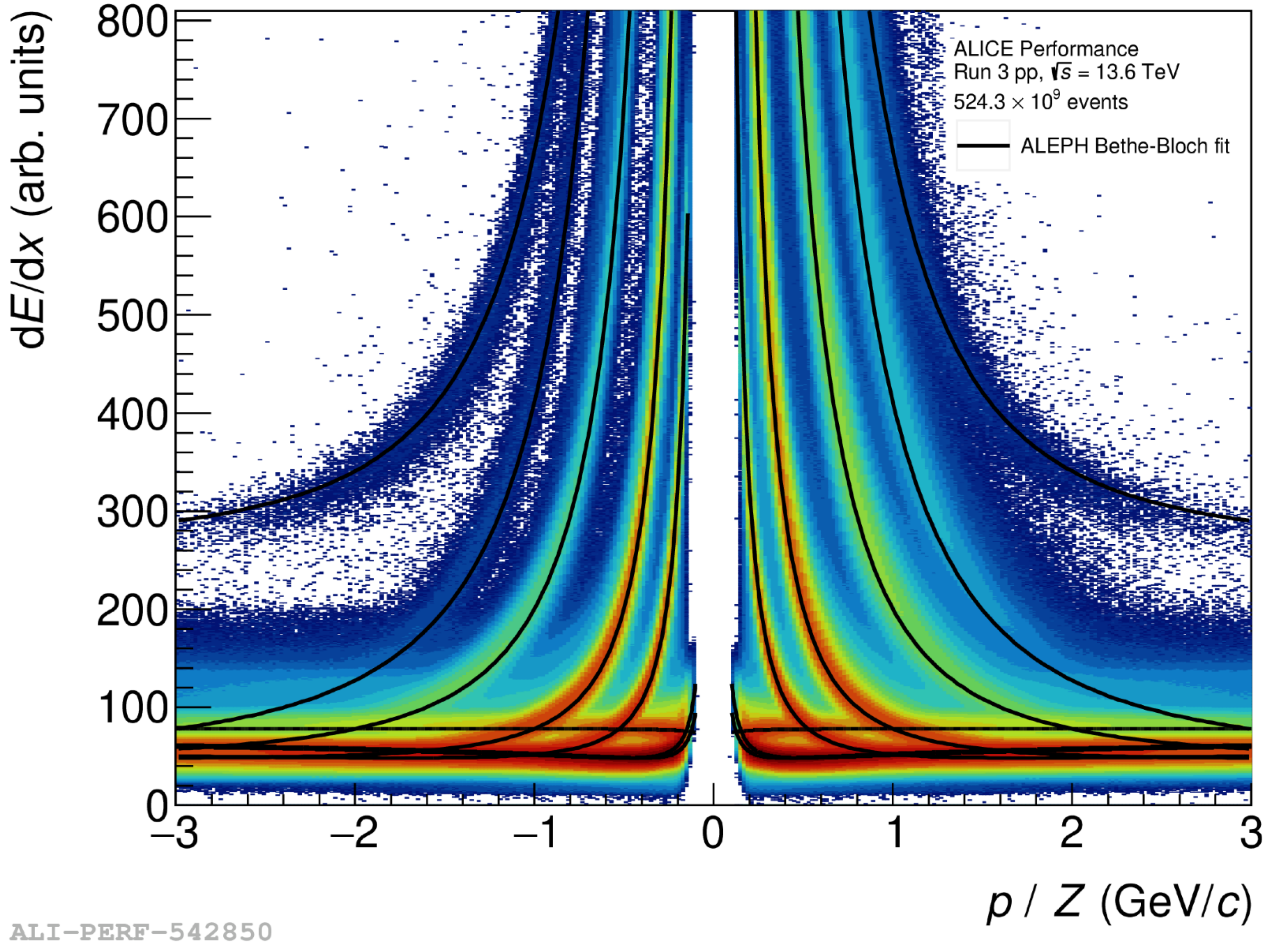
1) Performance graph: https://cds.cern.ch/record/2773174

Particle identification in ALICE

TPC - Time projection chamber

- Gaseous detector ($Ne\text{-}CO_2\text{-}N_2$, 90-10-5 gas mixture), collects 97.5% of all raw data in ALICE
- PID via specific energy loss per unit distance dE/dx — Bethe-Bloch with secondary corrections
- Run 3: GEM-based readout —> 50 kHz readout rate, raw-data stream of up to 3.5 TB/s

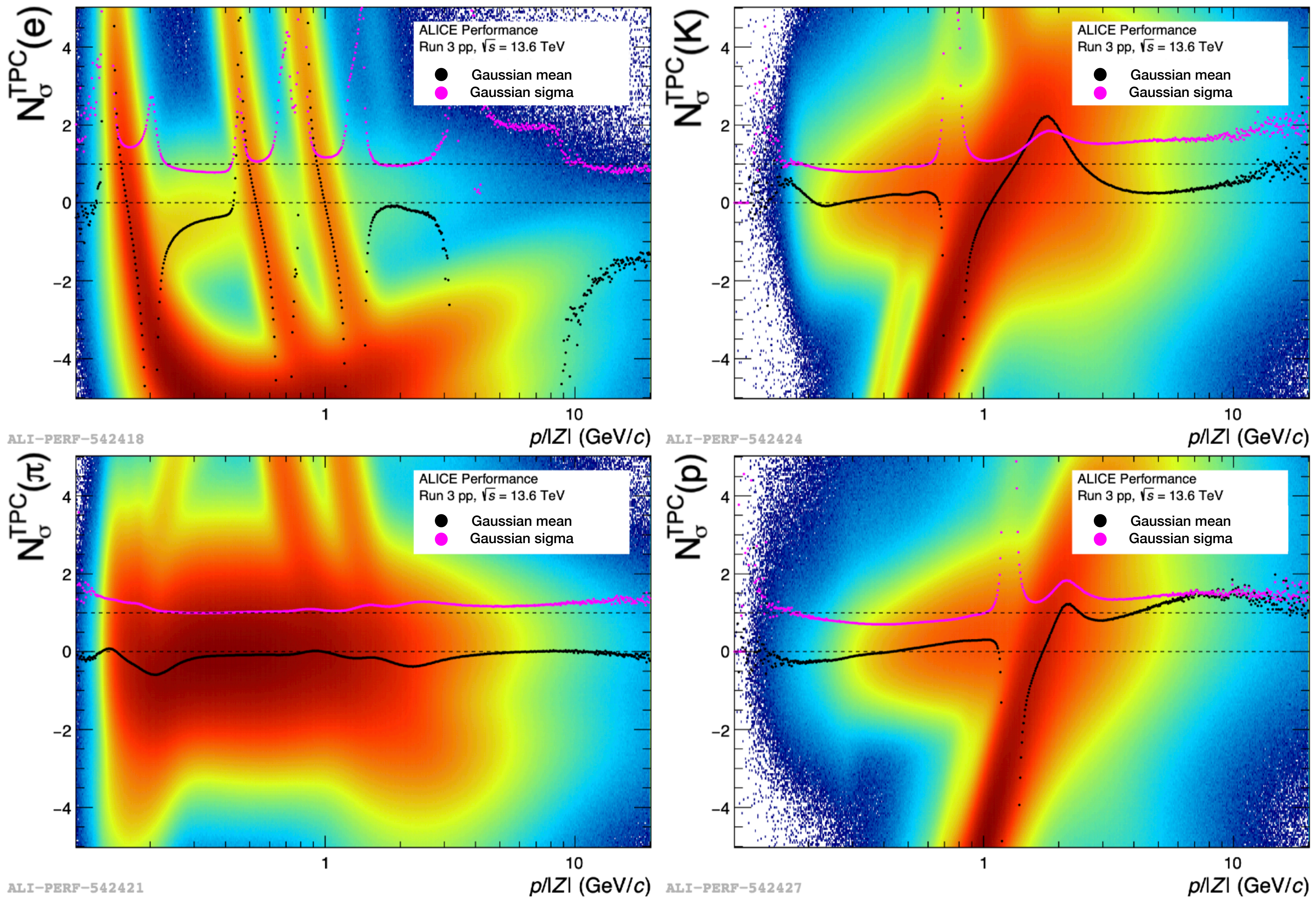


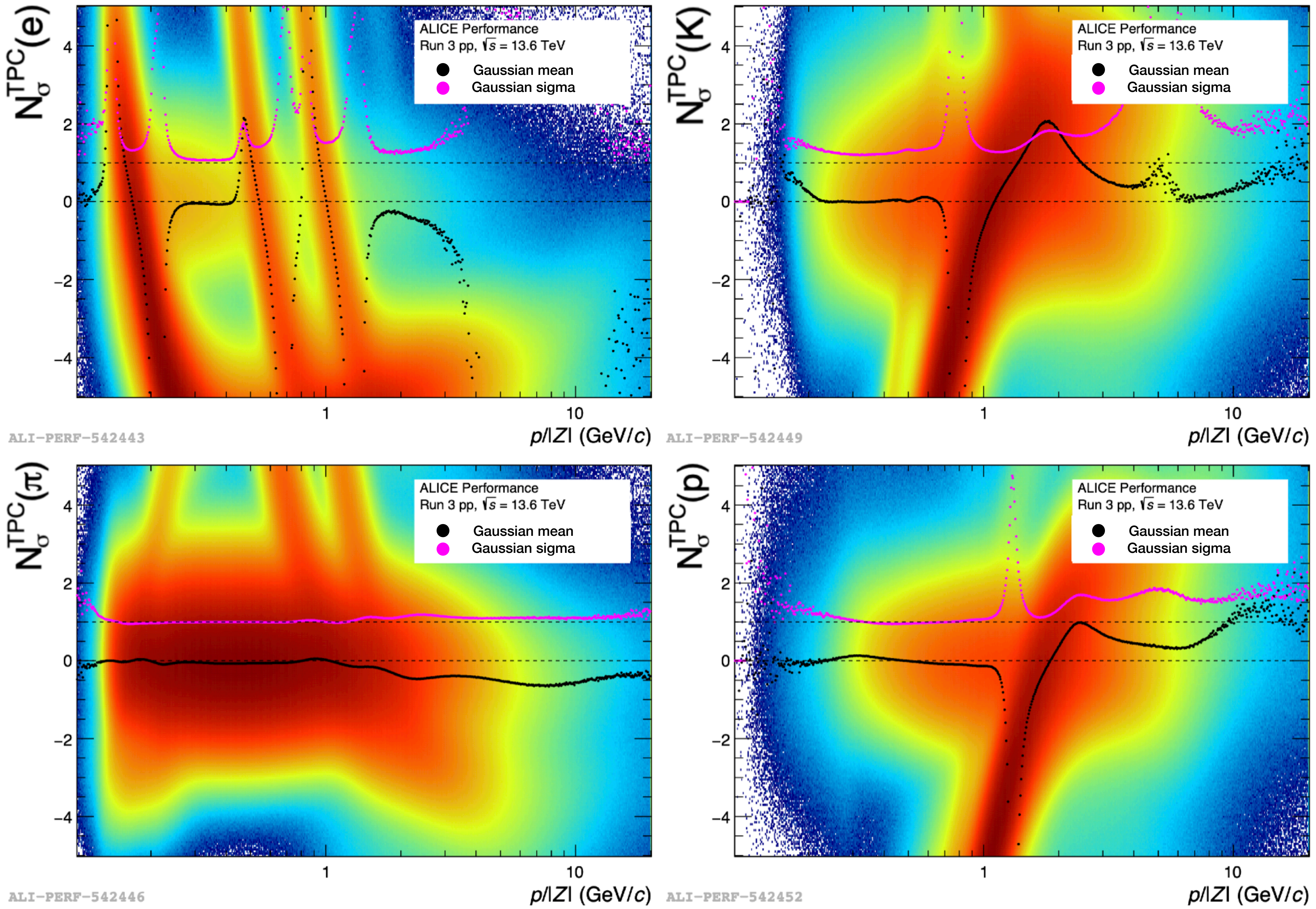


Particle identification in ALICE

TPC - Time projection chamber

- Novel PID procedure in Run 3
  - Hyperparameter optimisation for initial fit of Bethe-Bloch — a priori PID information not needed
  - Neural network corrections for secondary effects and sigma estimation
  - Fully data-driven 6D corrections and sigma estimation (Run 3)





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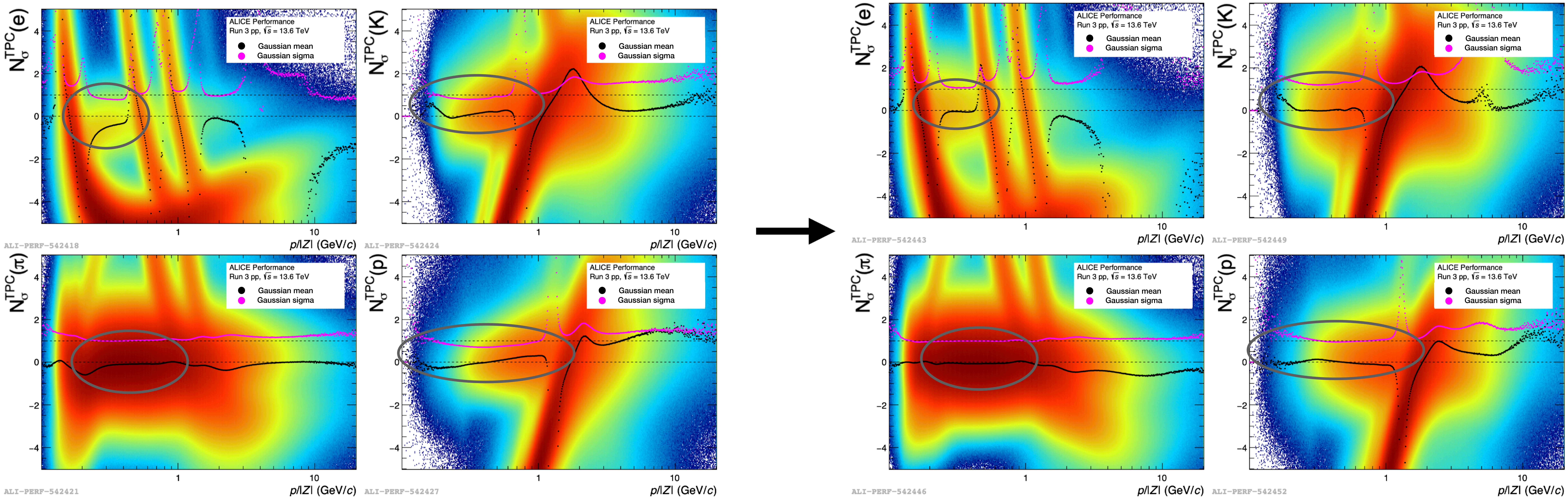
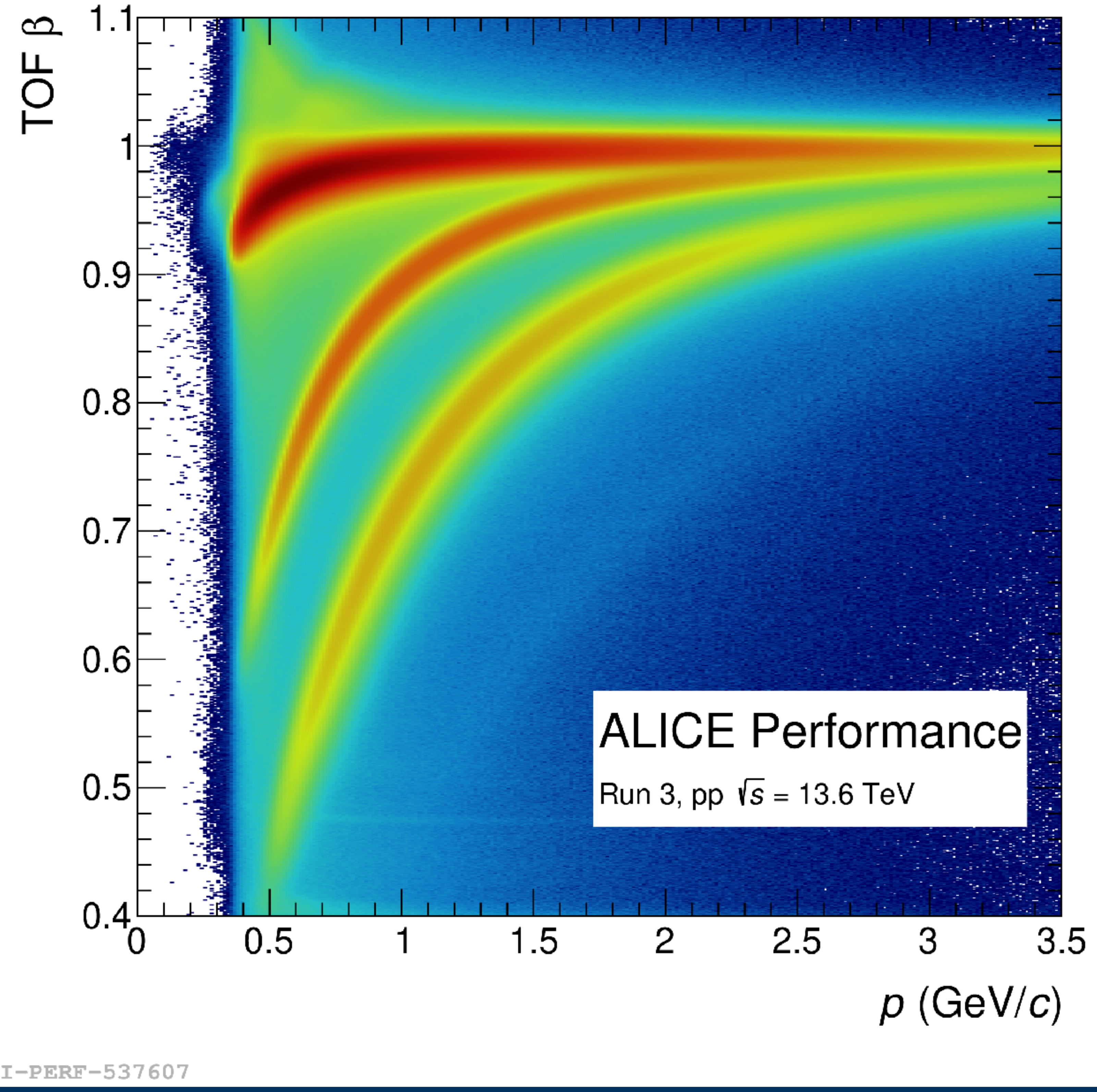
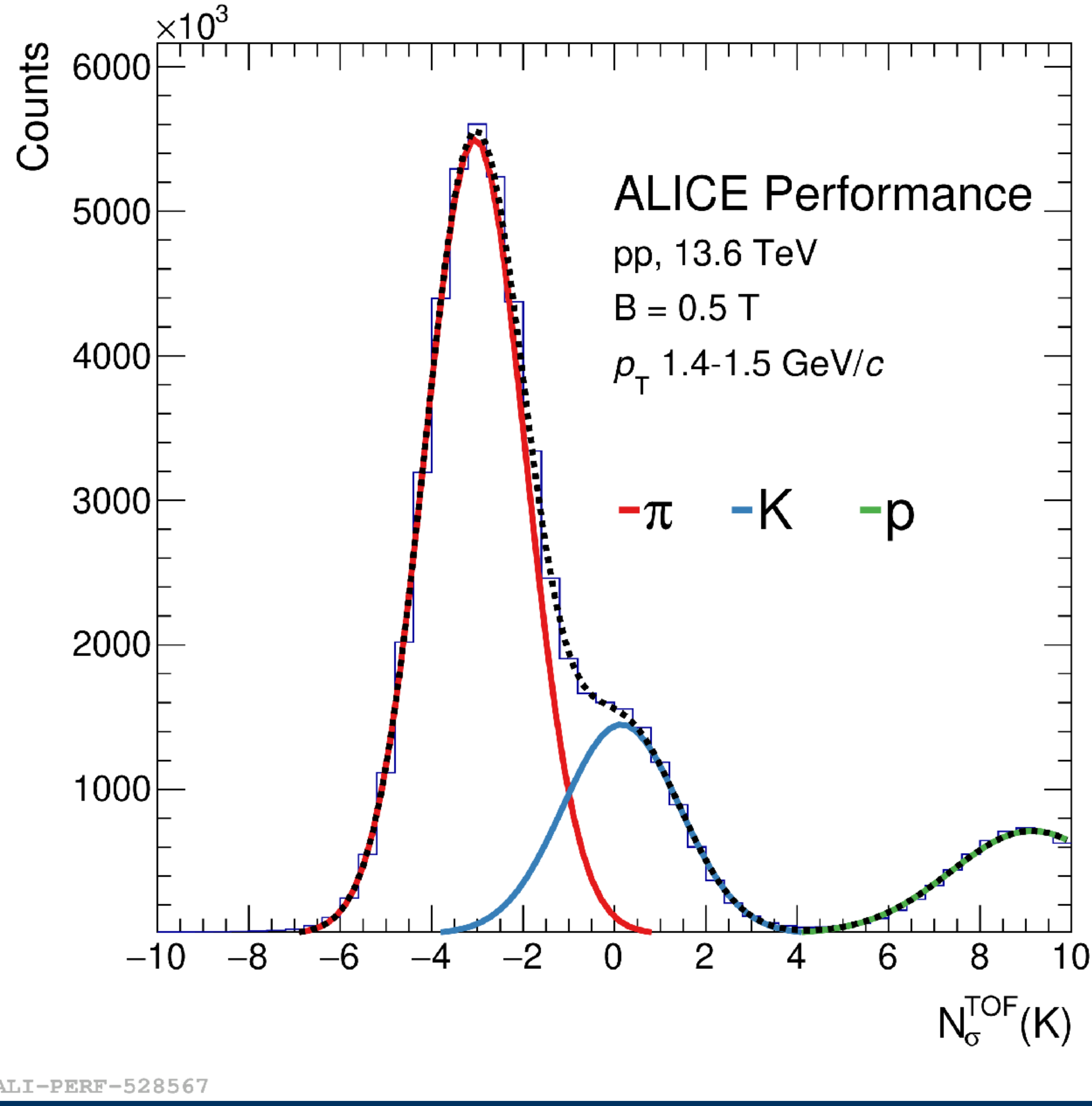


Particle identification in ALICE

TOF - Time-of-flight detector

- 3.7 meters from IP, 1593 strips multigap resistive plate chambers, 141 m^2 and -0.9 < η < 0.9 of coverage
- Particle identification using particle velocity and measured momentum
- Requires event time, particle arrival time at TOF, track path length

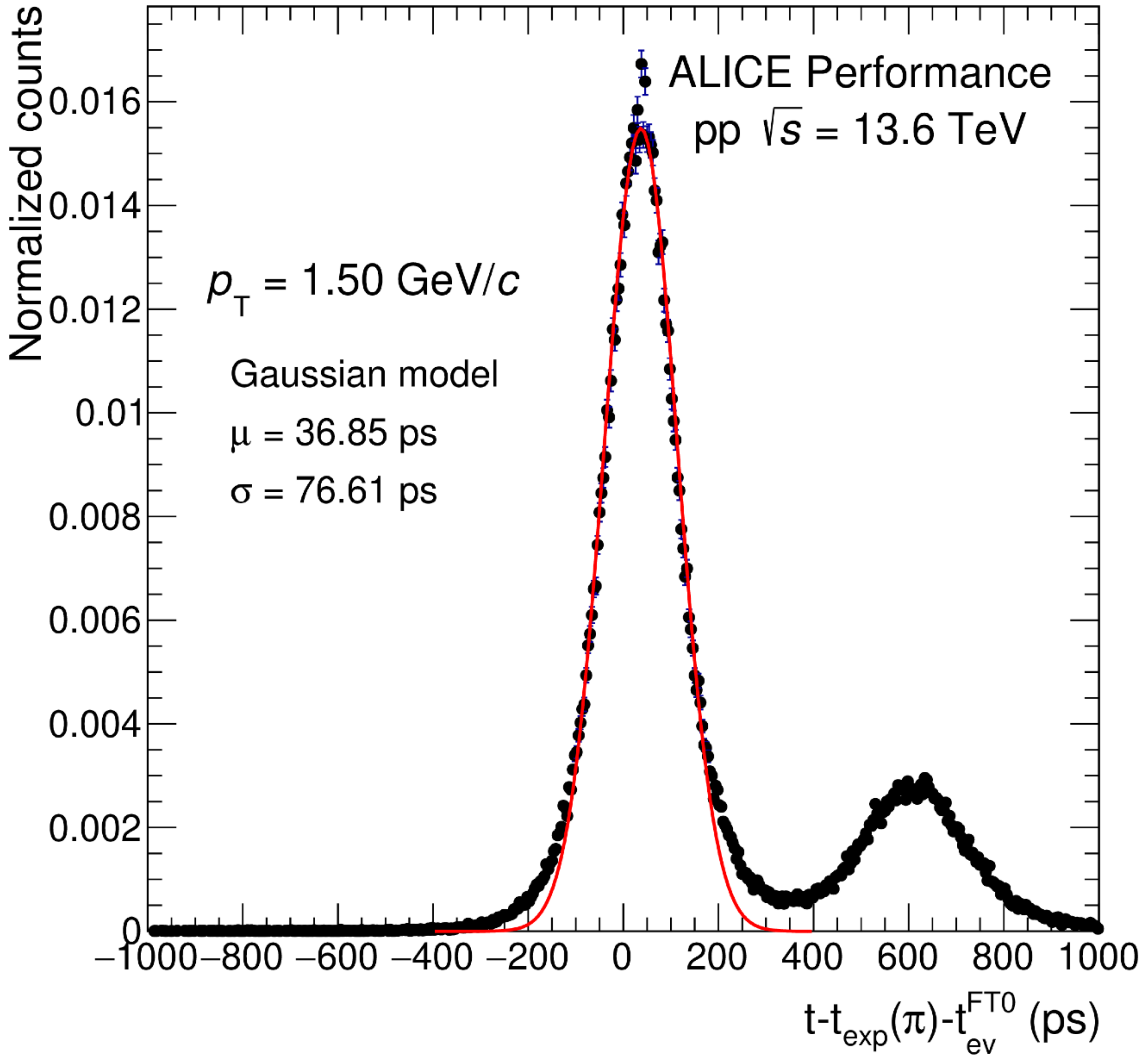




Particle identification in ALICE

TOF - Time-of-flight detector

- Event time computed by forward detectors FT0 and TOF itself
- Comparison with FT0 detector — nominal performance of the ALICE TOF detector



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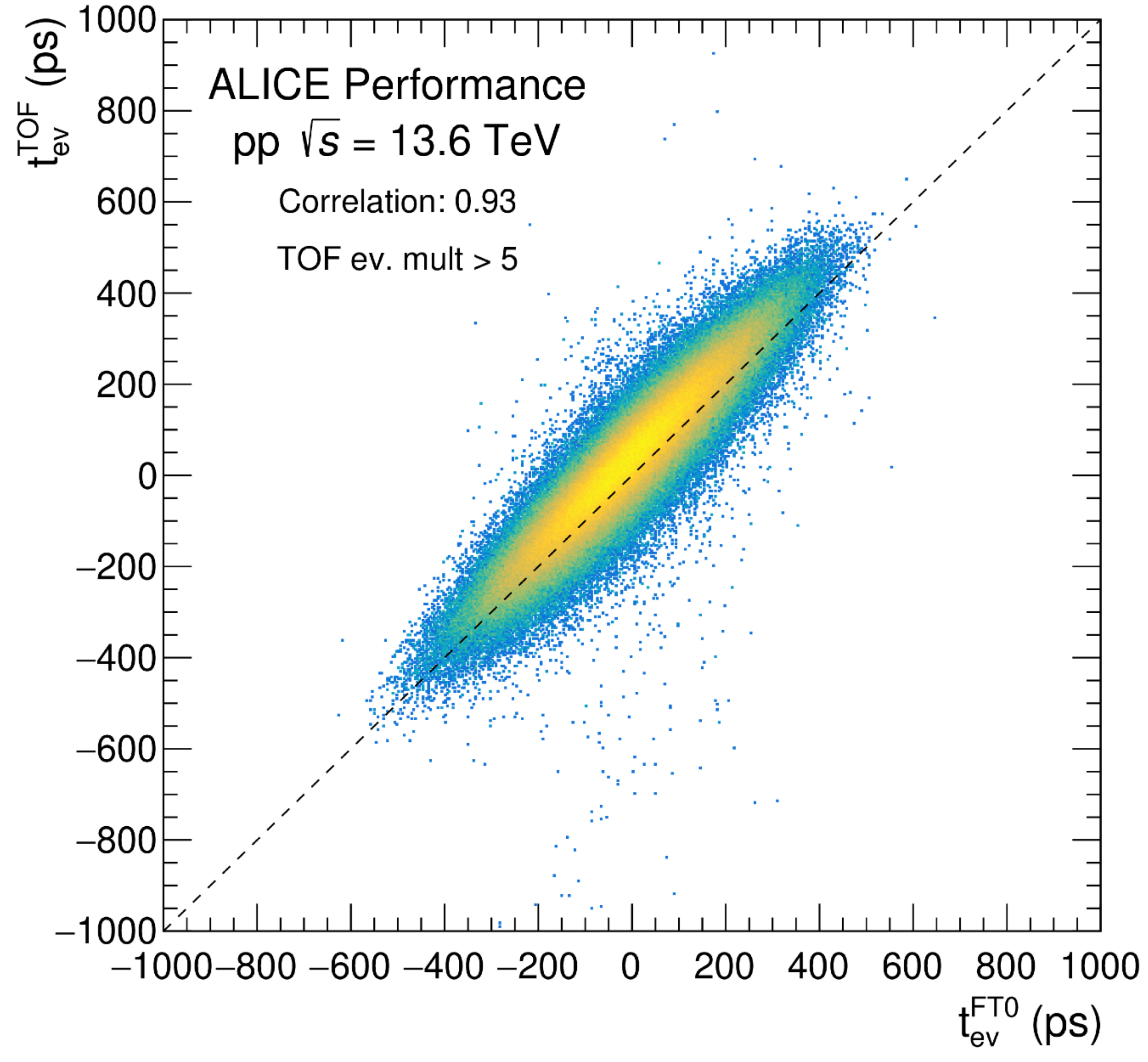

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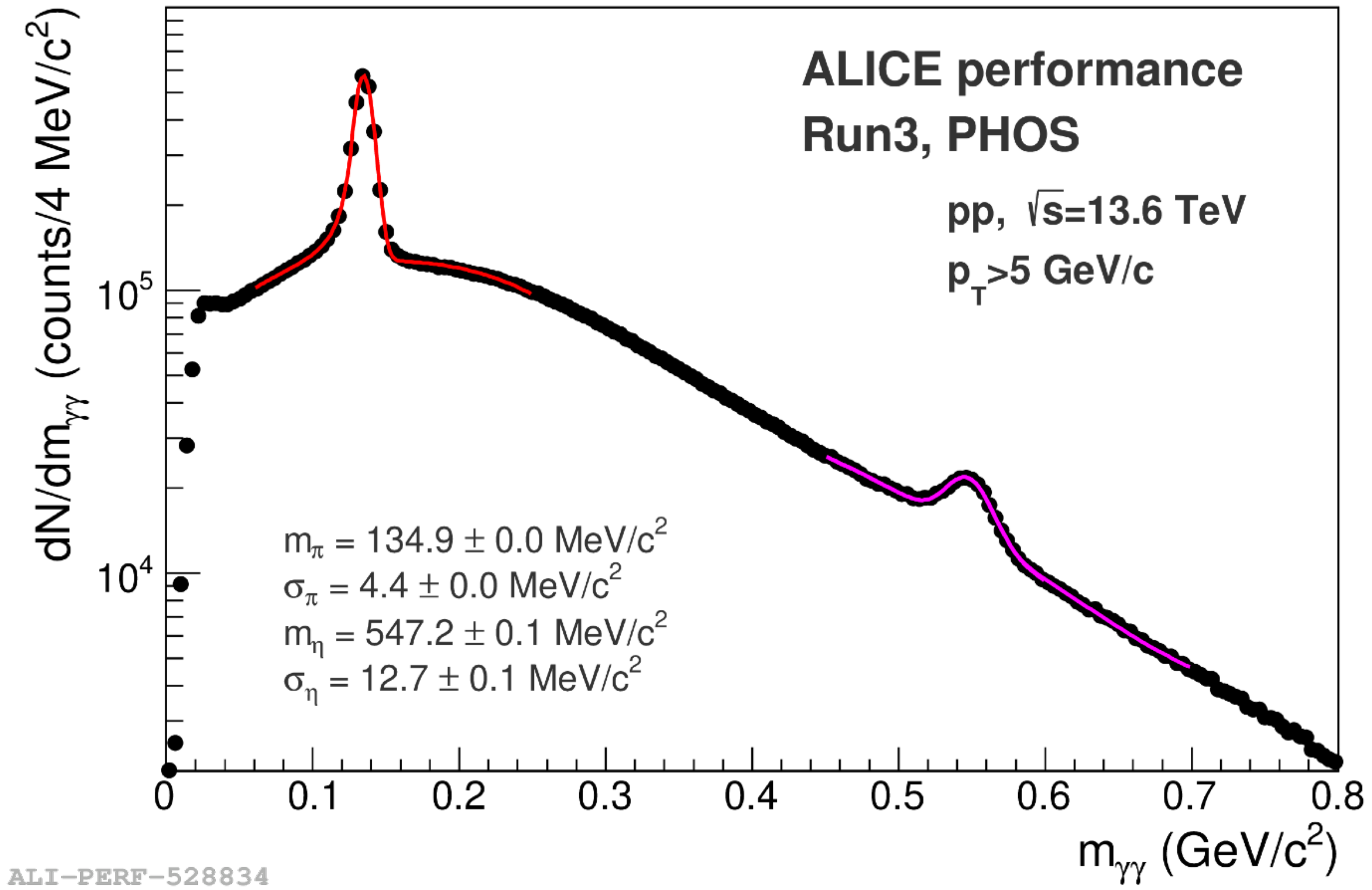
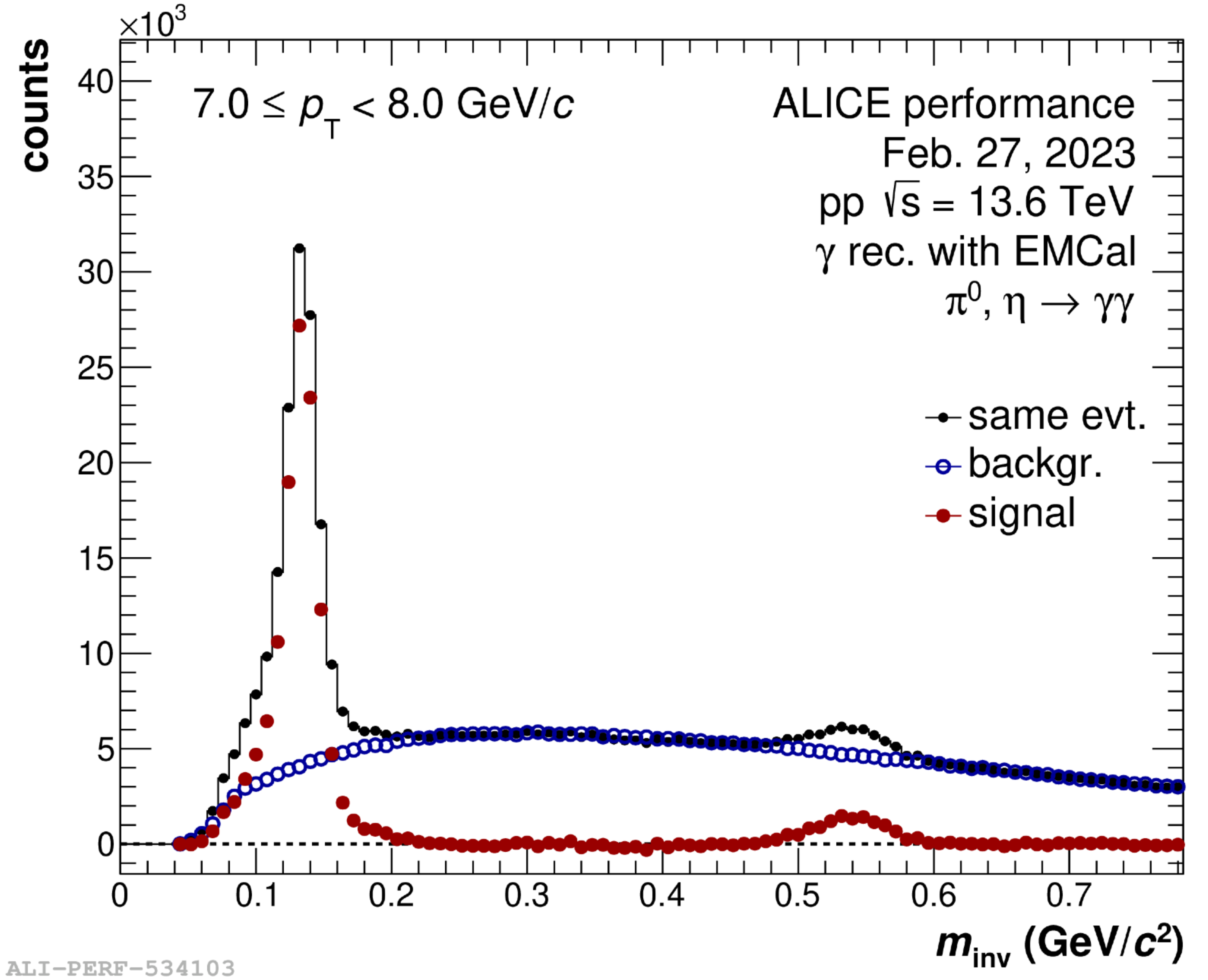
Particle identification in ALICE

Specialized detector systems

- **TRD**
  - Electron PID for $\gamma > 1000$ by transition radiation, Xe-CO_2 mixture, excellent tracking capabilities
- **PHOS, EMCal, DCal** — Calorimetry
  - Electromagnetic and di-jet identification
- **HMPID**
  - RICH with liquid C_6F_{14}, used for high momentum PID

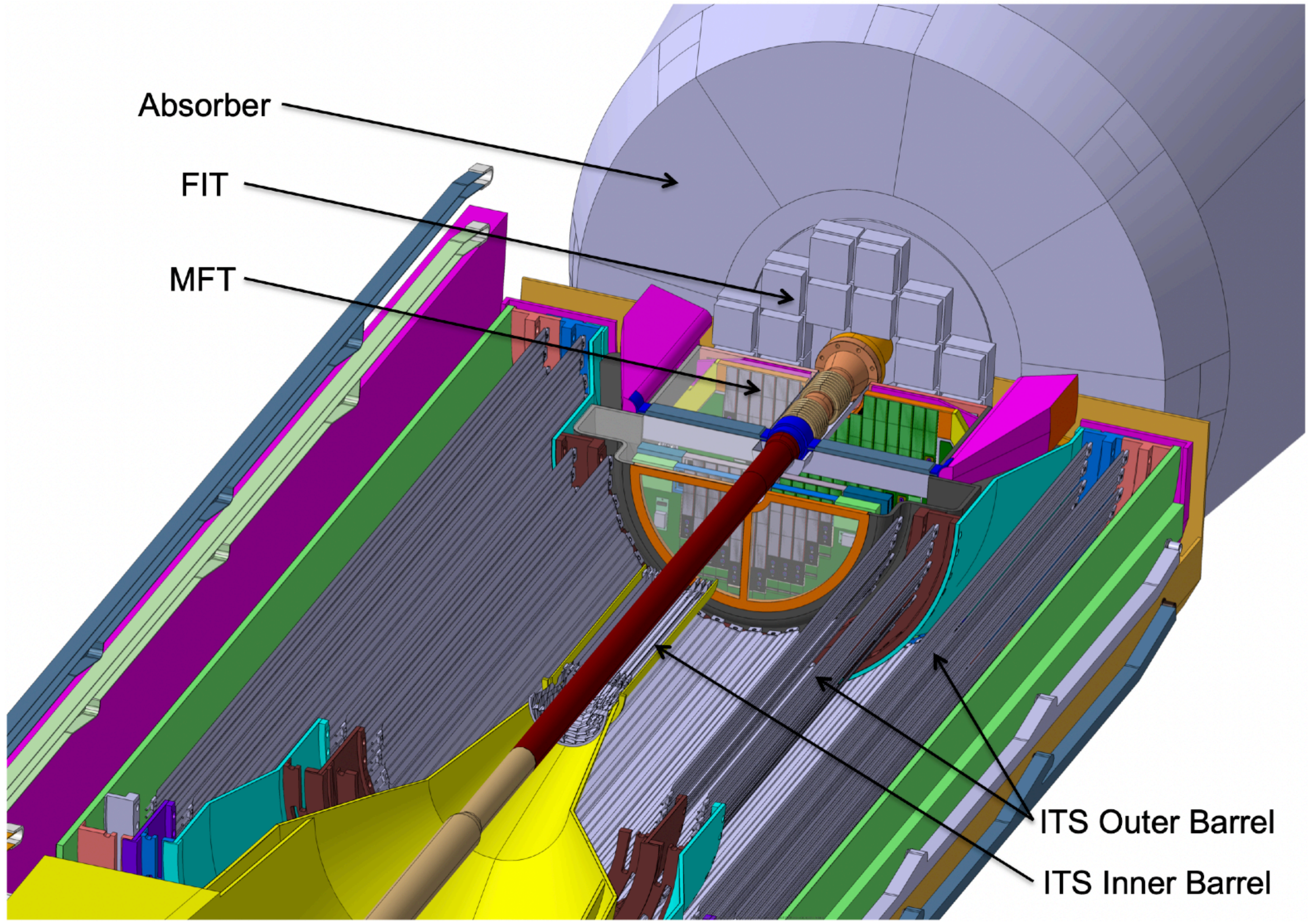




Particle identification in ALICE

Specialized detector systems

- **MFT, MCH, MID**
  - Muon identification at forward rapidity
  - MFT new in Run 3
  - Precision vertexing using ALPIDE MAPS silicon sensors
- **ITS**
  - Run 3: purely silicon pixels (ALPIDE MAPS)
  - Ongoing feasibility studies for PID
  - Excellent vertex resolution
- **FIT** — new in Run 3!
  - Event multiplicity, centrality, reaction plane
  - Determination of collision time with ~20 ps precision



1) Muon forward tracker - TDR: https://cds.cern.ch/record/1981898

Conclusion

LHCb

- New algorithmic and hardware implementations for calorimeters and muon system
- PID efficiency is expected to match Run 2 and improve with higher statistics

ALICE

- New TPC readout and PID corrections will bring strong improvements compared to Run 2
- High precision of interaction vertex (space and time: ITS and FIT) will strongly enhance tracking

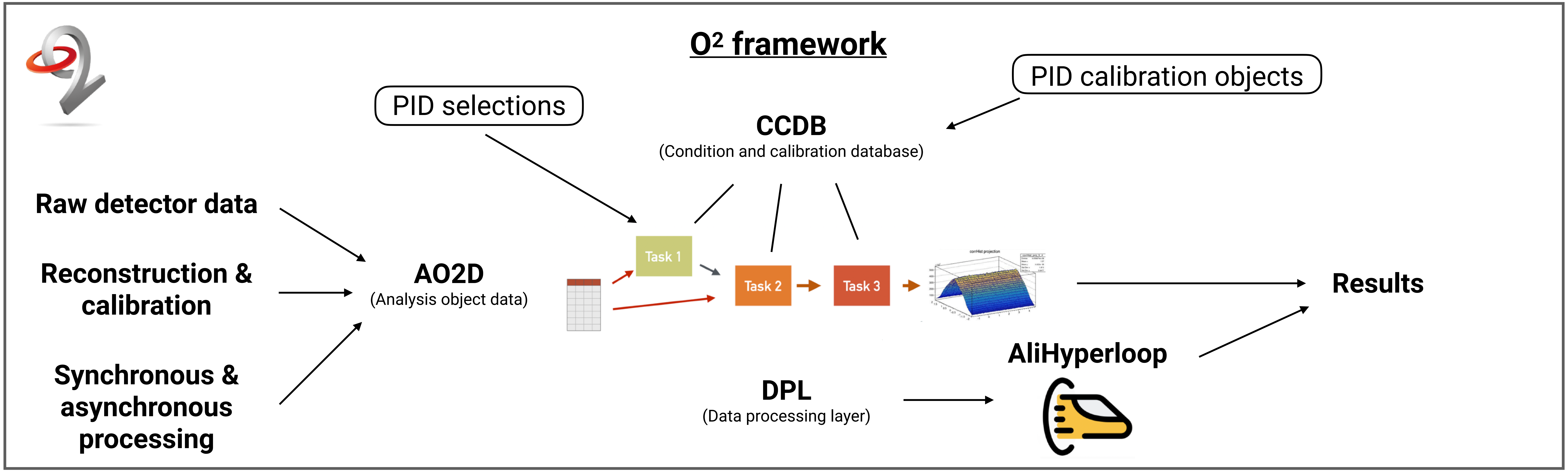
Thank you

BACKUP

Data processing for PID in ALICE

Computing

- Completely new software framework — Combine detector operation, data processing and physics analysis
- Purely software triggering, online (synchronous) and offline (asynchronous) processing — O[2]
- Processing and compression of several events in timeframes (TF), PID selections in DPL



1) ALICE O2 TDR: https://cds.cern.ch/record/2011297/files/ALICE-TDR-019.pdf
2) CHEP talk — David Rohr, Giulio Eulisse: https://indico.jlab.org/event/459/contributions/12432/attachments/9414/14116/alice_o2_gpu_eulisse_rohr.pdf

TOF event time determination - Run 2 and Run 3

Event time determination

- Iterative procedure described in EPJP 132 (2017) 99