PID calibration with 2024 data

LHCb UK meeting 2025

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PID calibration at LHCb

- Simulating PID is difficult
  - Sensitive to alignments, conditions and decay kinematics

- Require precise reconstruction efficiencies - e.g. charge asymmetries

- Use data samples to determine efficiencies
  - Large yields
  - High purity
  - Easy to reconstruct without using PID

Particle	Sample
p	$\Lambda^0 \to p\pi^-$
K/π	$D^{*+} \to D^0(\to K^-\pi^+)\pi^+$
μ	$J/\psi \to \mu^+\mu^-$
e	$B^+ \to J/\psi(\to e^+e^-)K^+$

Efficiencies

- Efficiencies in the calibration samples calculated using per-event signal weights (sWeights) determined through fits

$$\epsilon = \frac{N_{sig}(\text{after PID selection})}{N_{sig}(\text{before PID selection})} = \frac{\sum_i s_i}{\sum_j s_j}$$

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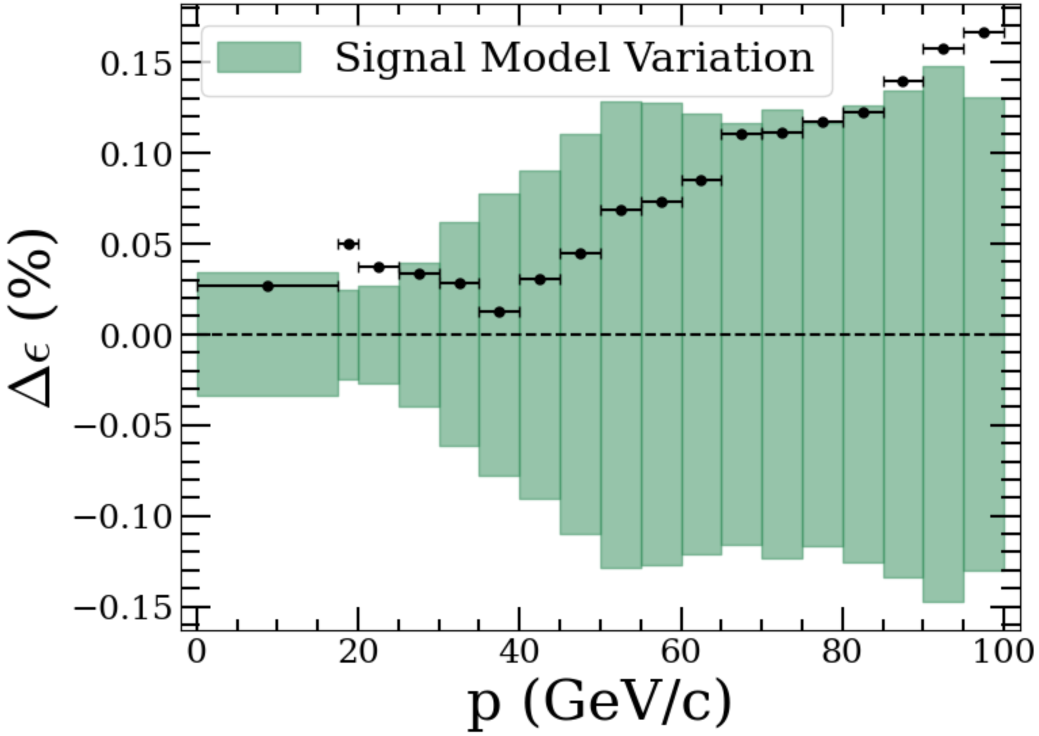
- sWeight agrees with F+C within fit model variations (around 0.1%)



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- An analyst's sample will be kinematically different from the calibration sample

User-defined kinematic binning (typically p, η, occupancy)

Efficiency in calibration sample

$$\bar{\epsilon} = \frac{\sum_i \epsilon_i w_i C_i}{\sum_i w_i C_i}$$

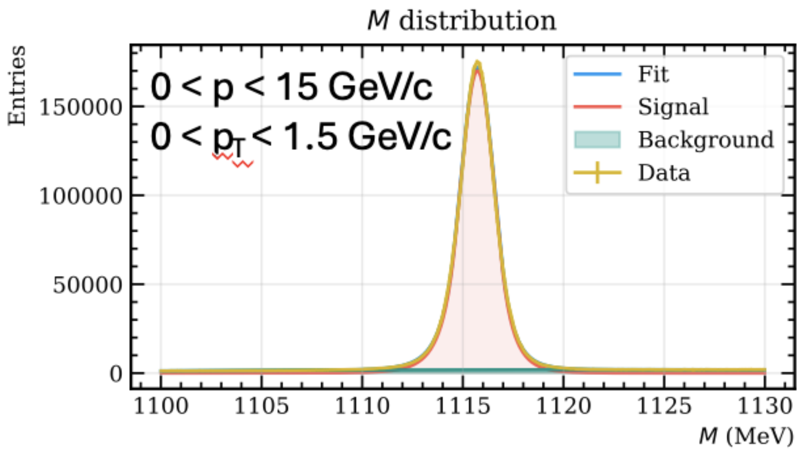
Calibration sample yield

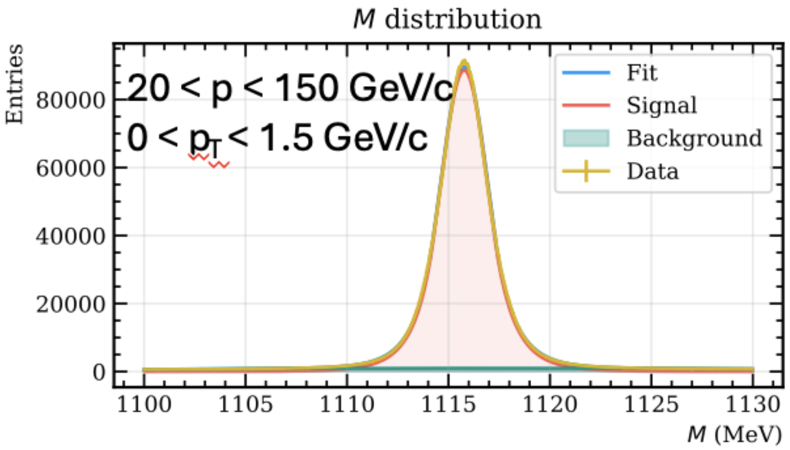
Kinematic weight

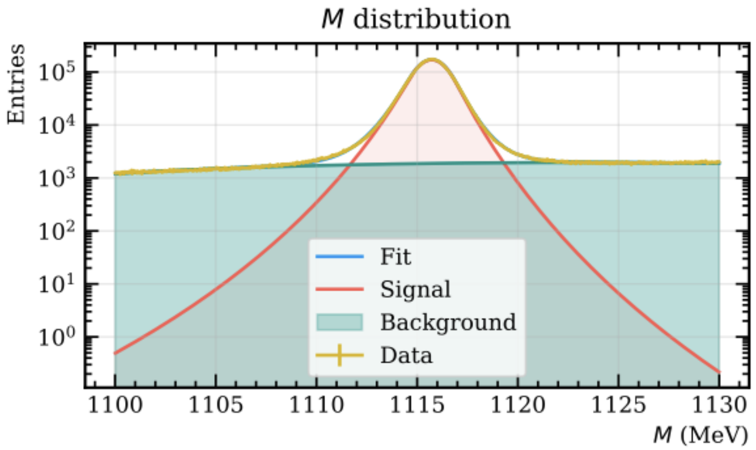
- Performed using PIDCalib2 package

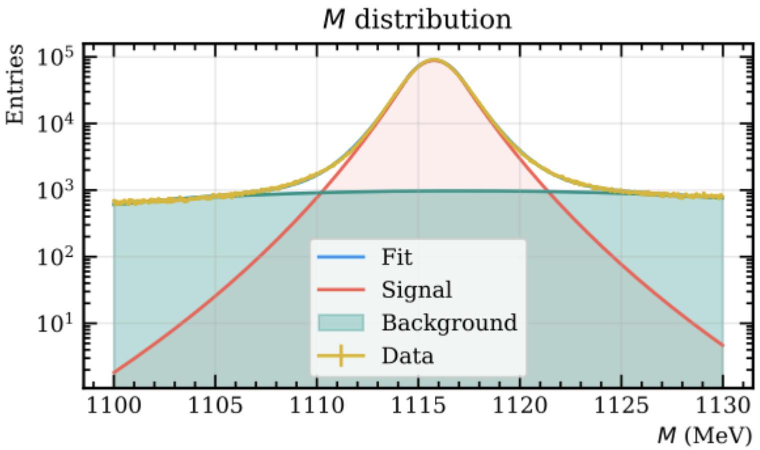
Example fits: $\Lambda^0 \rightarrow p\pi^-$

- Fit in regions of proton (p, pt) to determine more accurate sWeights



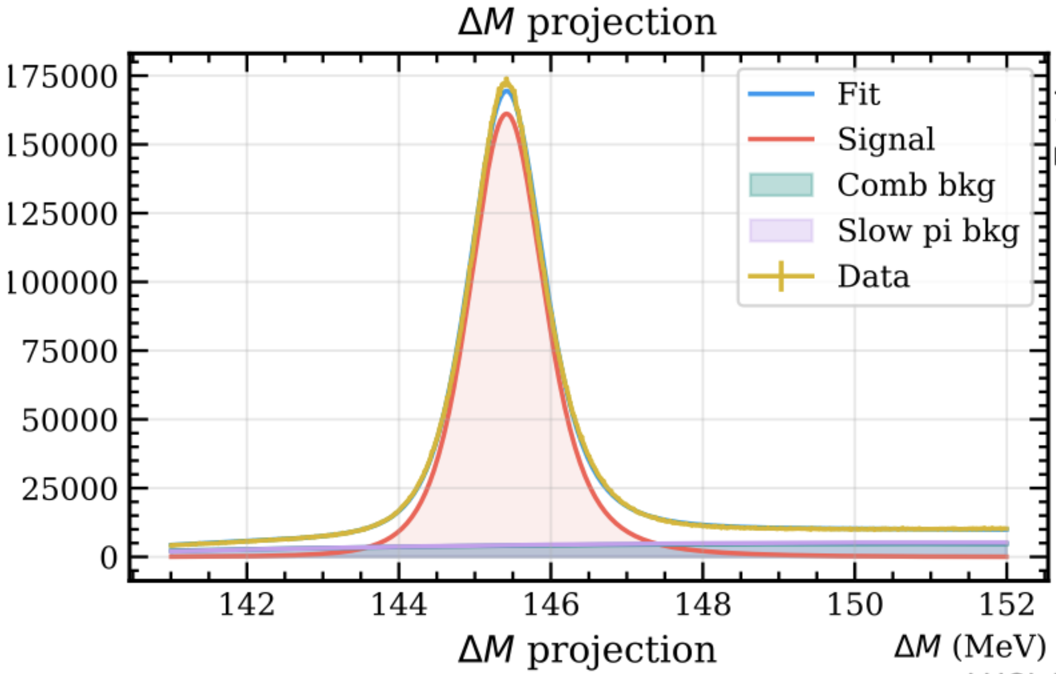


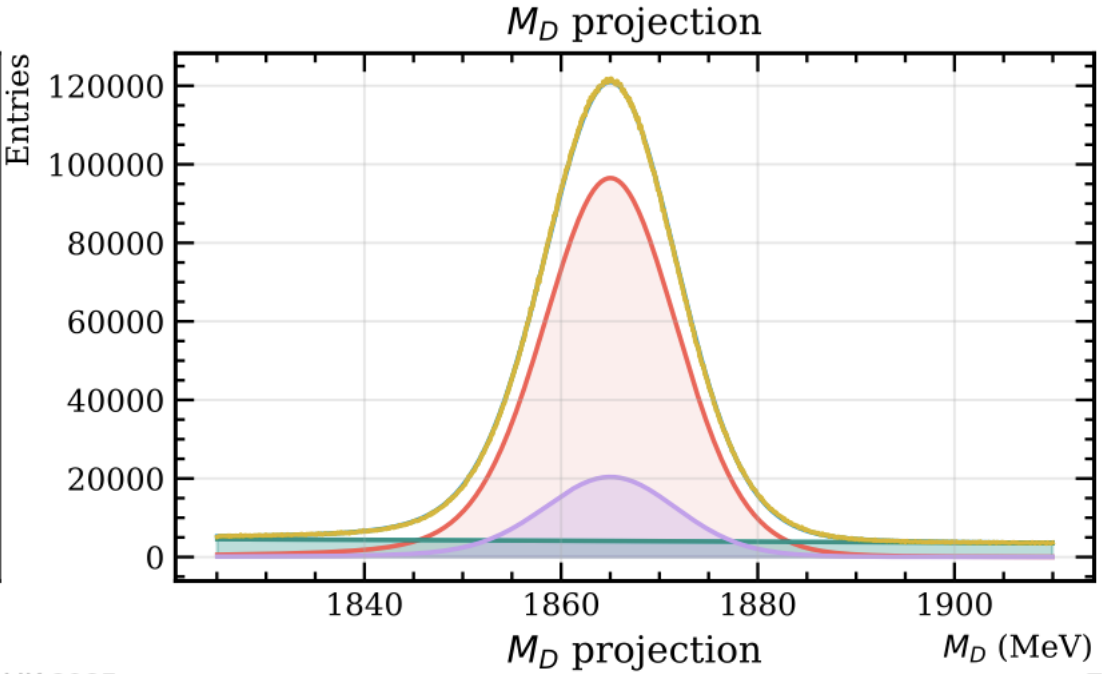




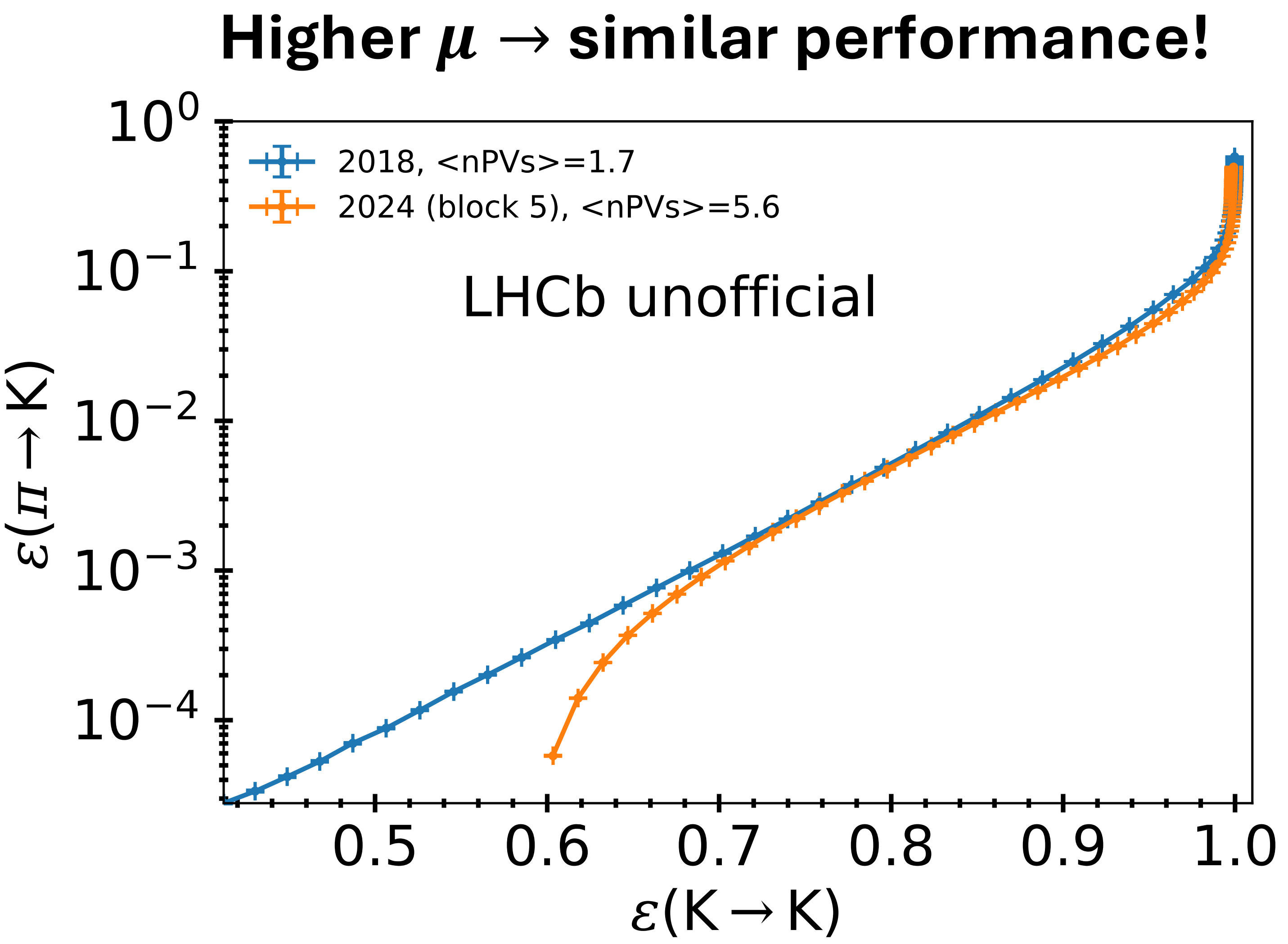
Example fits: $D^{*+} \to D^0(\to \boldsymbol{K^-\pi^+})\pi^+$

- 2D fit to account for background from real D decays with random companion pion
- **Small** multibody background is work in progress





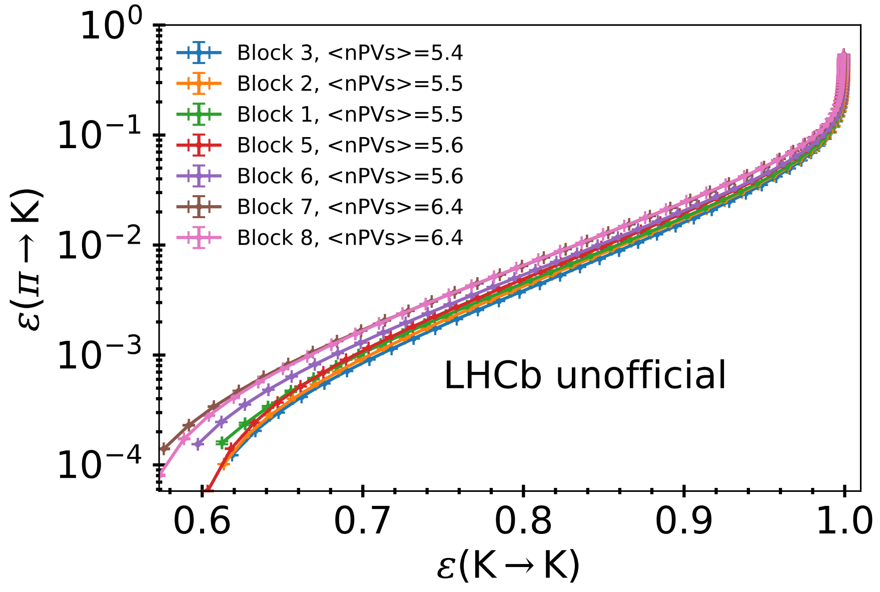
2018 vs now

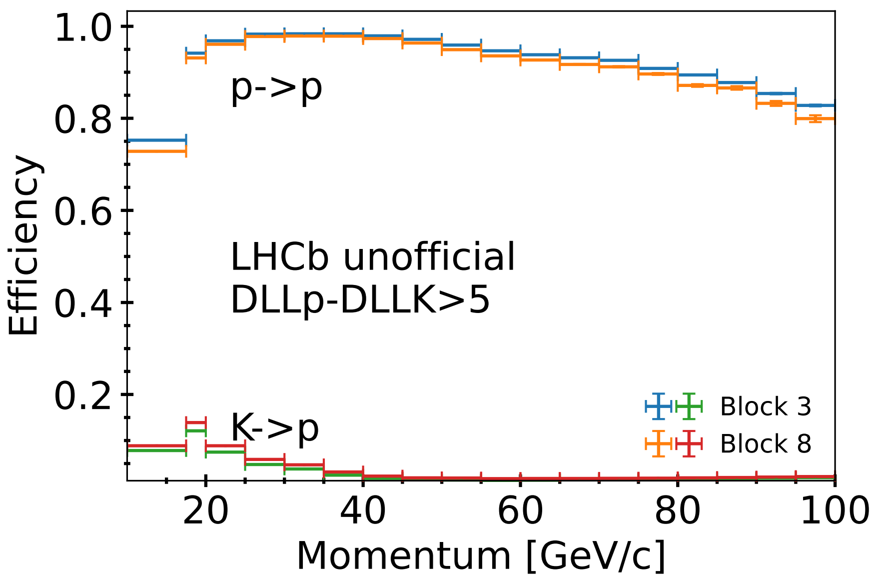


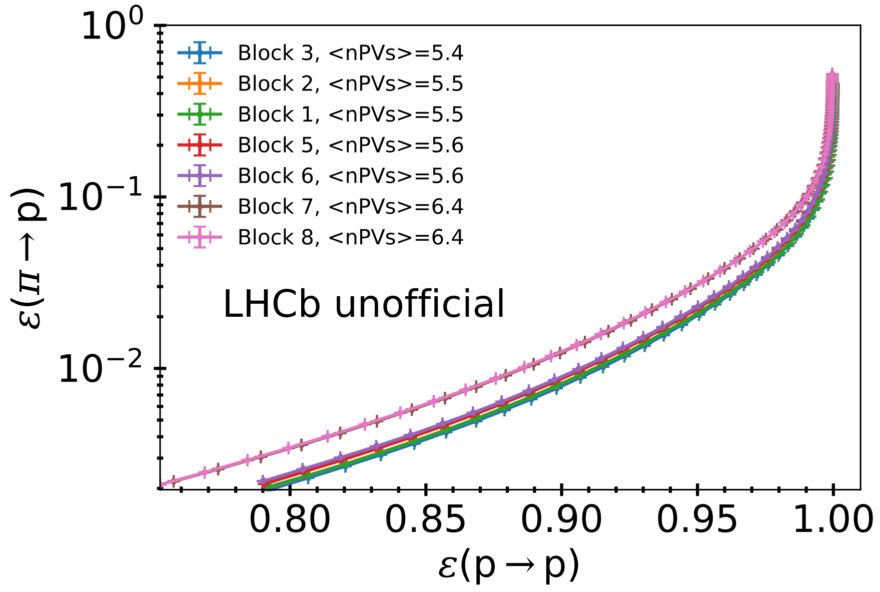
Higher $\mu \rightarrow$ similar performance!
2018, <nPVs>=1.7
2024 (block 5), <nPVs>=5.6
LHCb unofficial
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\varepsilon(\pi \rightarrow \mathrm{K})$
0.5
0.6
0.7
0.8
0.9
1.0
$\varepsilon(\mathrm{K} \rightarrow \mathrm{K})$

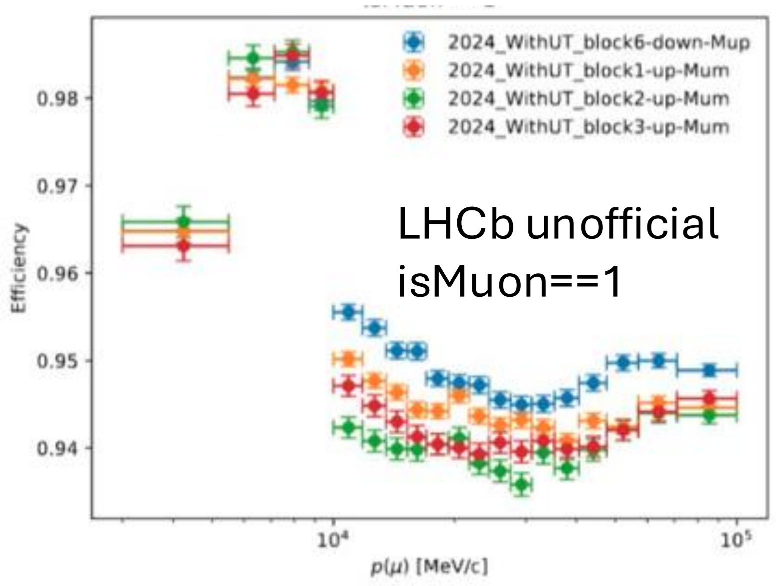
2024 performance

Blocks 1-8 excl. 4 available in PIDCalib2 for p, K, π and μ







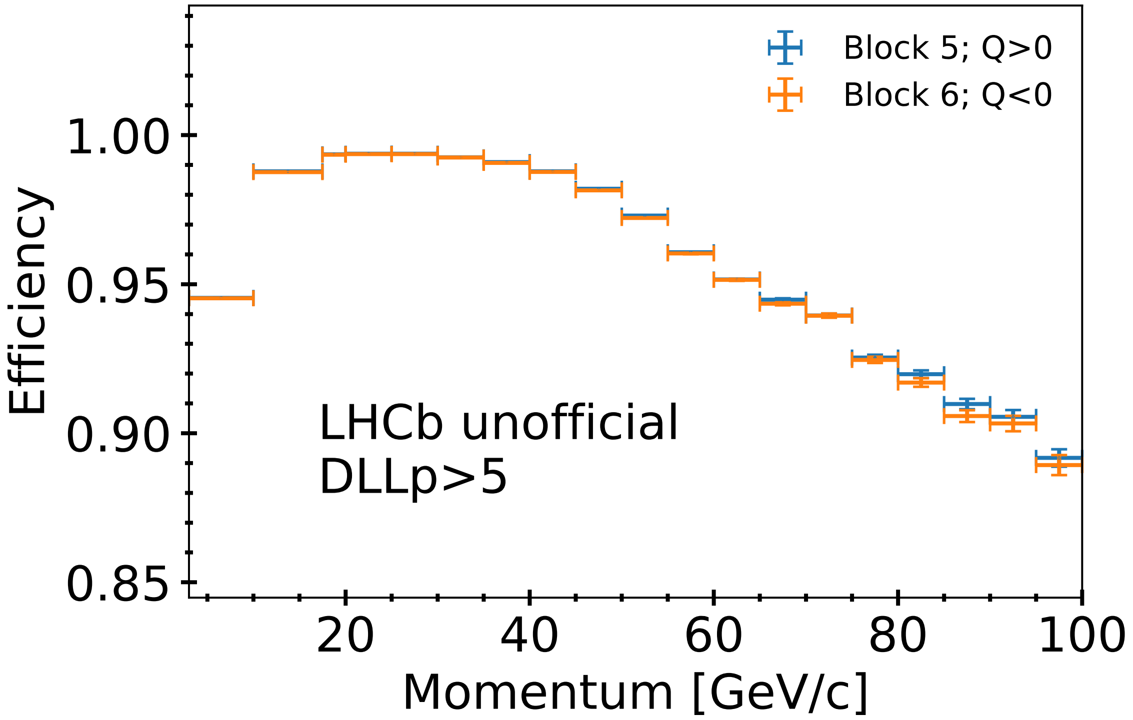


Charge studies

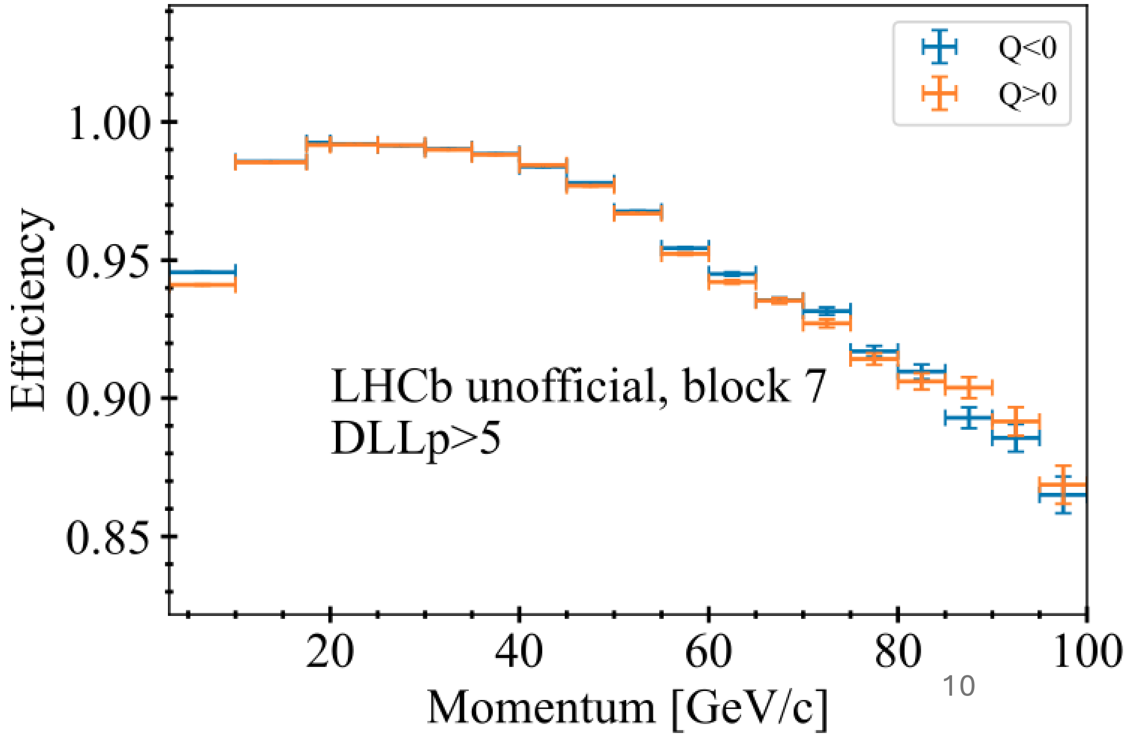
Proton fits split by charge so can study asymmetries

Cross check: opposite charge & opposite magnet polarity

Efficiencies stable across blocks for tracks on each half of the detector

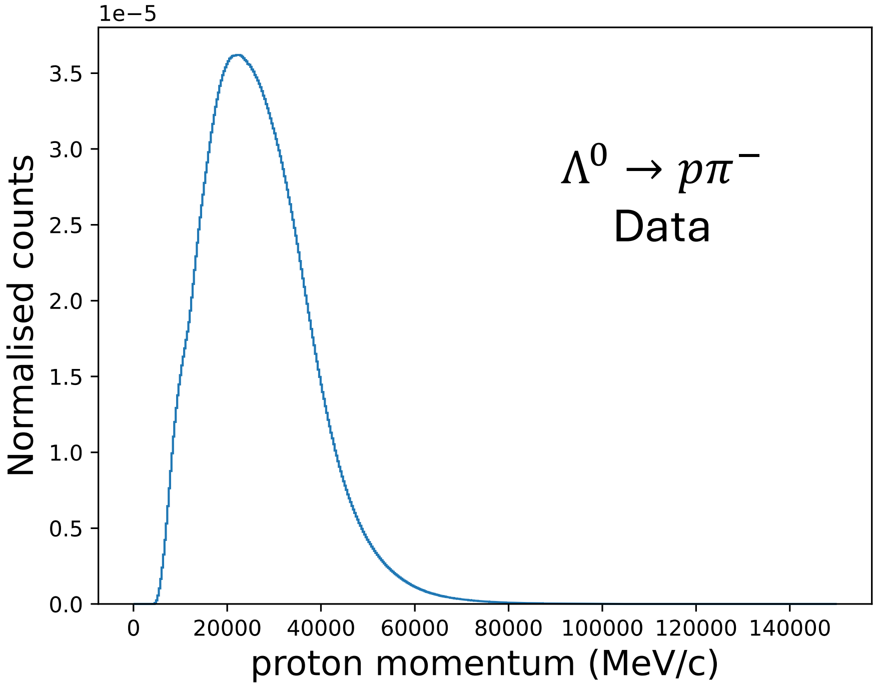


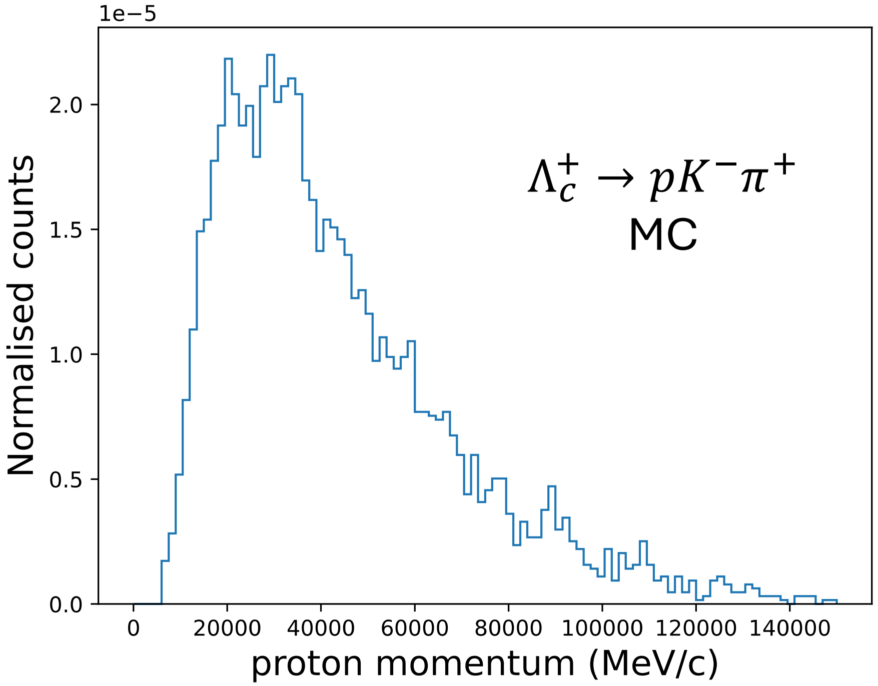
Minor asymmetries between left/right halves of the detector



Secondary proton sample: inclusive $\Lambda_c^+ \to pK^-\pi^+$

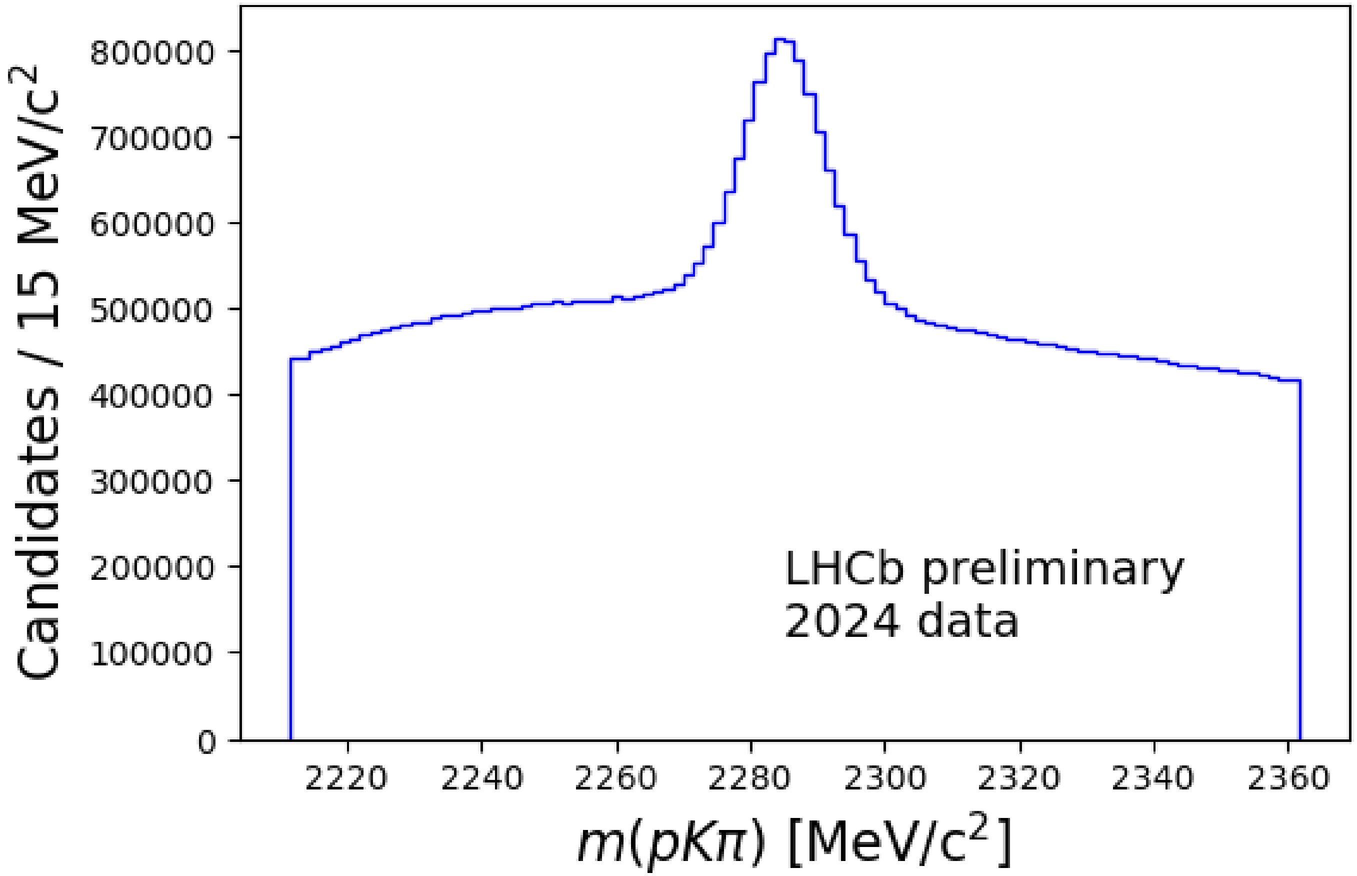
1. Reduced coverage of **high momentum protons** in the Λ^0 sample (lower than Run 2)
2. **ProbNN variables** trained on properties of heavy flavour decays so efficiencies from Λ^0 sample can be biased





Purity problem

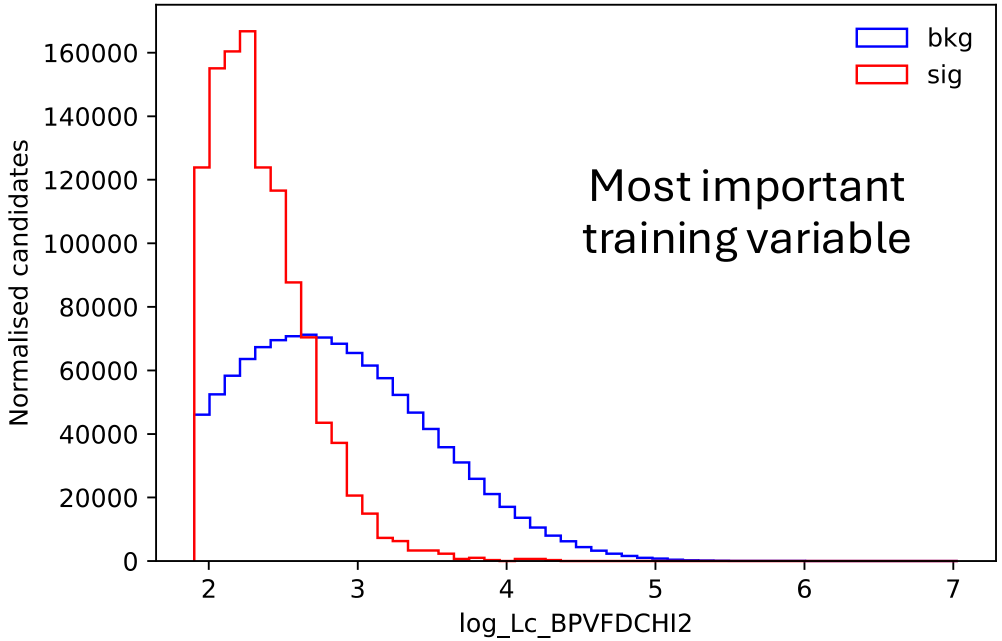
Purity in the Λ_c^+ sample is low

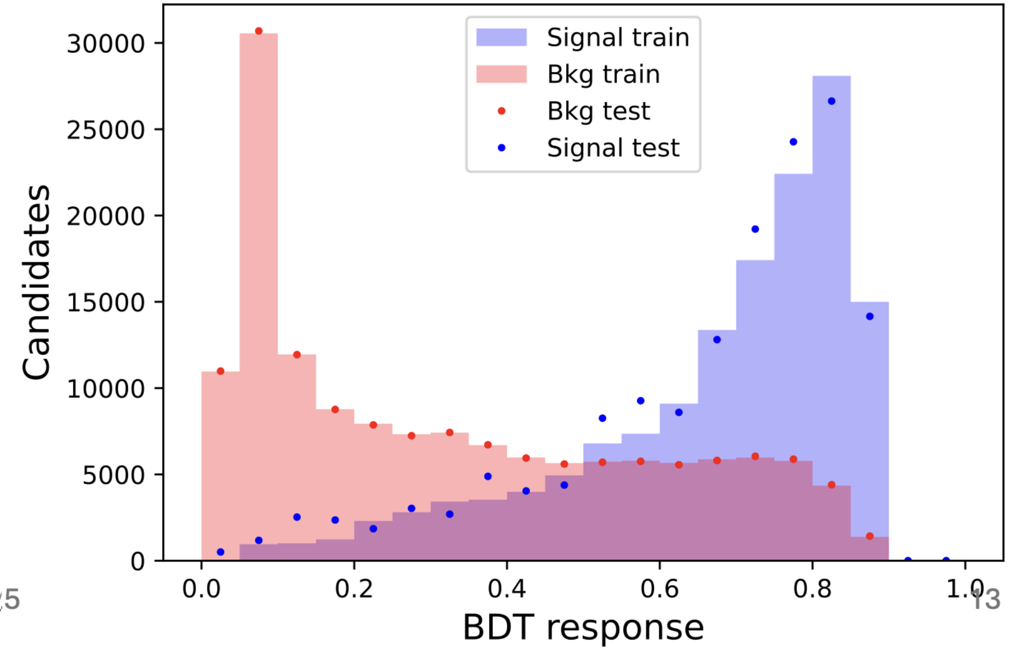


BDT training and response

- Trained on truth matched MC for signal (~4K events) and mass sideband (m<2225 or m>2345 MeV/c^2) in 2024 data for bkg

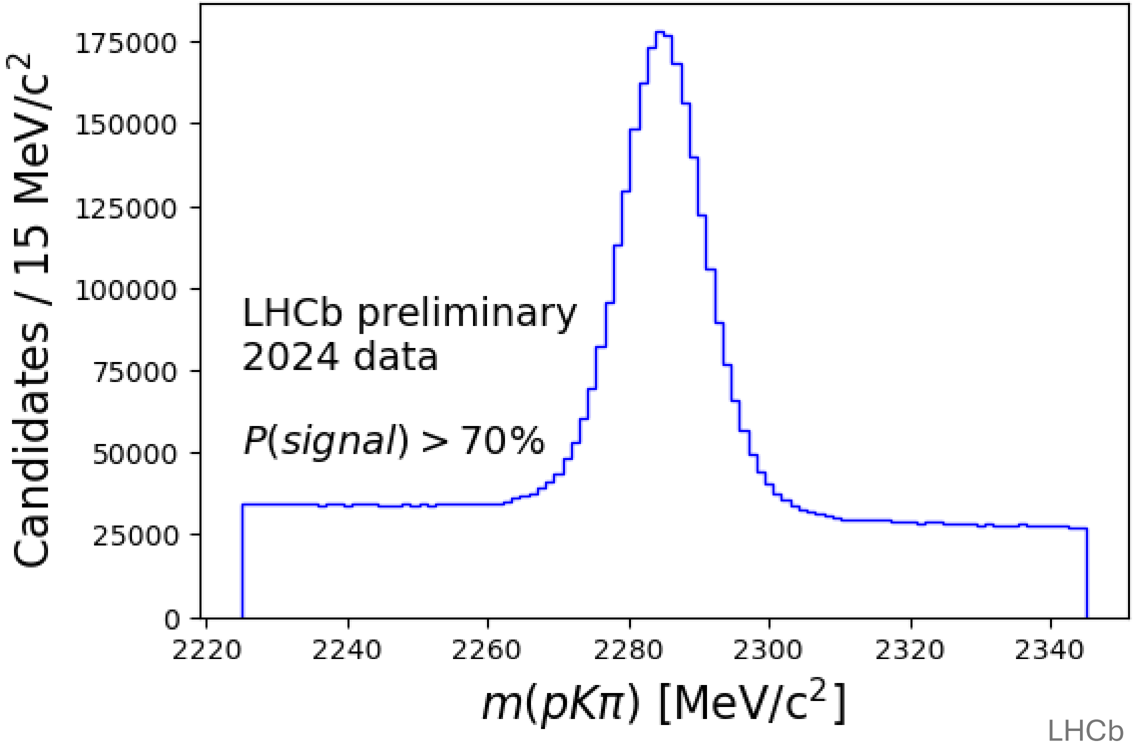
- Using **5 discriminating variables** with good agreement between sweighted data and MC, and are **not correlated with DLLp**

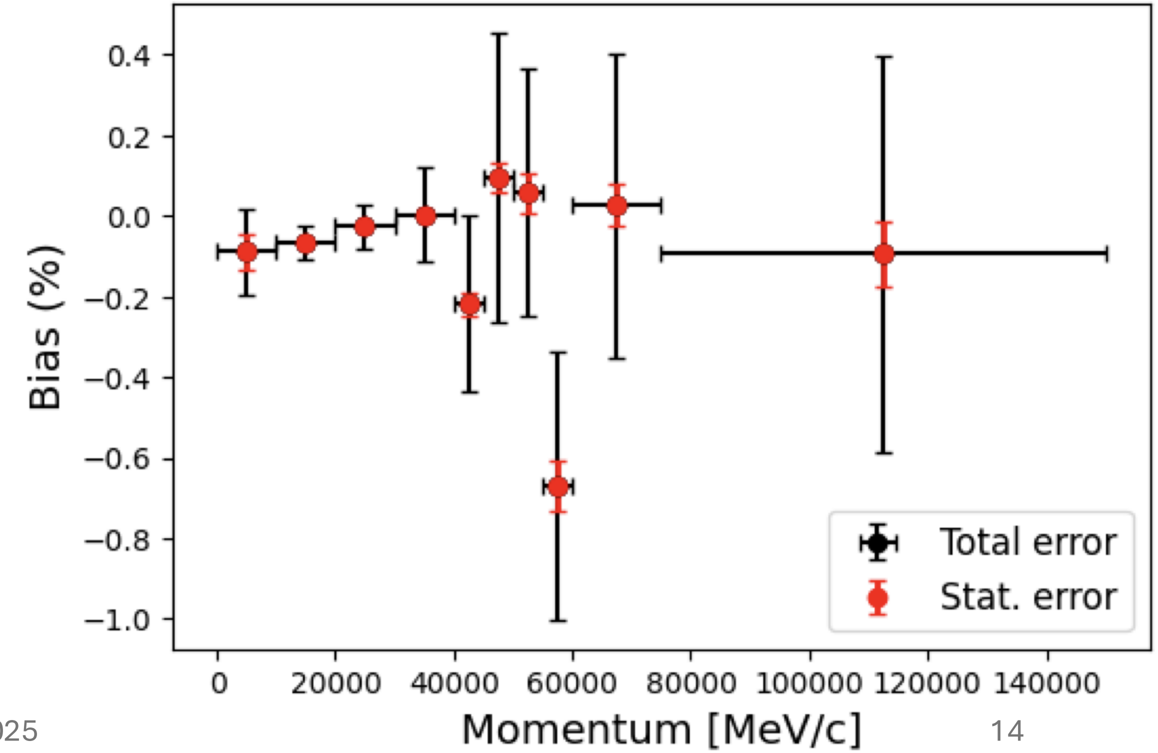




Performance on data

- Retains ~60% signal and removes ~85% background
- Efficiencies compared with/without BDT requirement agree – **no bias**





Summary

- PID performance is as expected
- Progression with PID calibration with 2024 data is good
    - Multibody background in the D^{*+} sample
    - Electron sample
    - Secondary proton sample

- ProbNN efficiency studies to be done

- Other PID work
    - Muons – Michele Atzeni
    - Electrons – Pol Vidrier
    - Downstream protons – Ying Liu