technische universität dortmund

FSP LHCb
Erforschung von Universum und Materie

SFB1491

LHCb

Early measurement of V^0 production cross-section ratios at LHCb

Johannes Albrecht[1],
Noah Behling[1],
Lukas Calefice[2],
Hans Dembinski[1],
Biljana Mitreska[1]

[1] TU Dortmund

[2] Universitat de Barcelona / ICCUB

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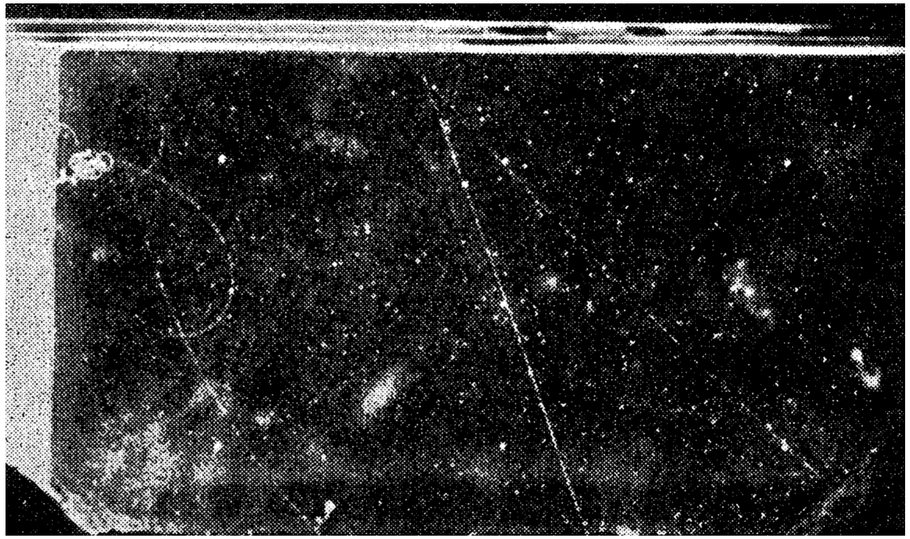
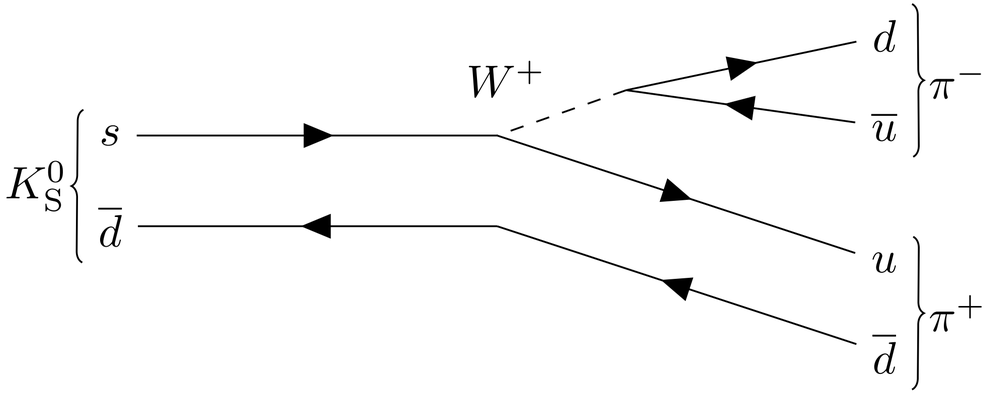
V^0 hadrons

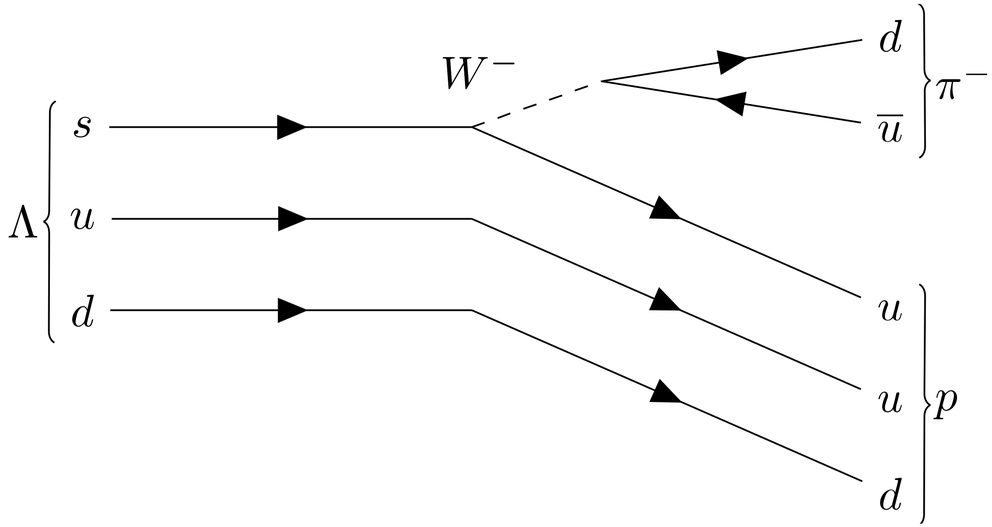
- Long-lived neutral particles weakly decaying into two charged hadrons
- Displaced decay topology
  - $\tau(K^0_S/\Lambda^0) \approx 0.9\,/\,2.6 \times 10^{-10}\,\mathrm{s})$ vs. $\tau(B^0) \approx \mathcal{O}(10^{-12}\,\mathrm{s})$
- Huge cross-sections ($\mathcal{O}(1\,\mathrm{b})$ vs. $\sigma(b) \approx \mathcal{O}(100\,\mu\mathrm{b})$)
  - $K^0_S \to \pi^+\pi^-$ $(\Gamma_i/\Gamma \approx 69.2\,\%)$
  - $\Lambda^0 \to p\pi^- + \overline{\Lambda}^0 \to \bar{p}\pi^+$ $(\Gamma_i/\Gamma \approx 63.9\,\%)$
- Small phase space, soft p, p_T spectra

  → Lower reconstruction efficiency than b, c



R. B. Leighton, S. D. Wanlass, and C. D. Anderson, The decay of V^0 particles, Phys. Rev. 89, 148 (1953).





Why strangeness → Two motivations

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1. Detector commissioning (short-term)

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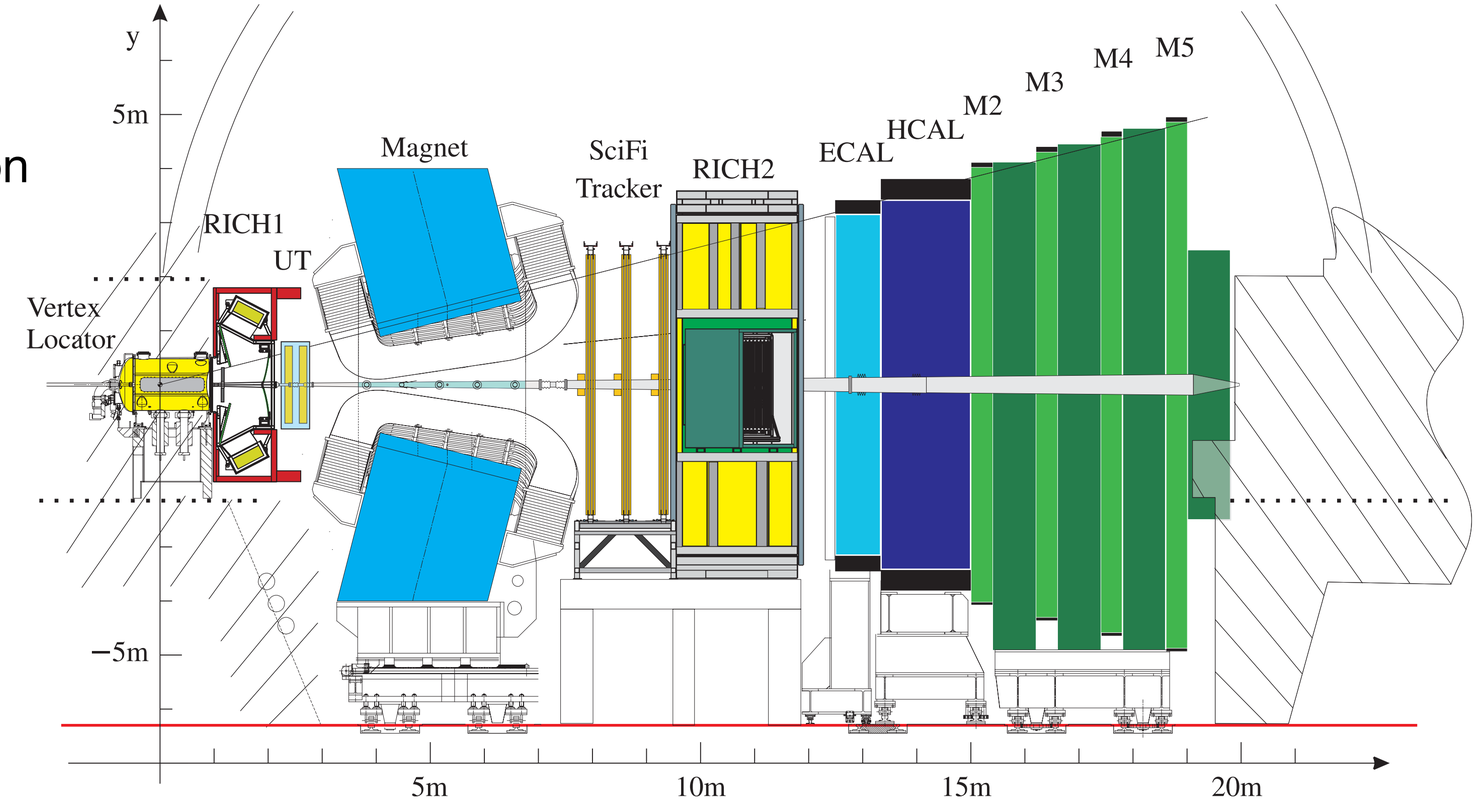
- 5x higher $\mathscr{L}$ in Run 3
- Major upgrades of hard- and software

→ V^0 measurement allows unbiased evaluation of detector performance, especially the tracking

→ Also analyse Run 2 data for comparison



P. Fernandez Declara, D.H. Perez Campora, J. Garcia-Blas, D. Vom Bruch, J.D. Garcia, N. Neufeld, IEEE Access 7, 91612 (2019).

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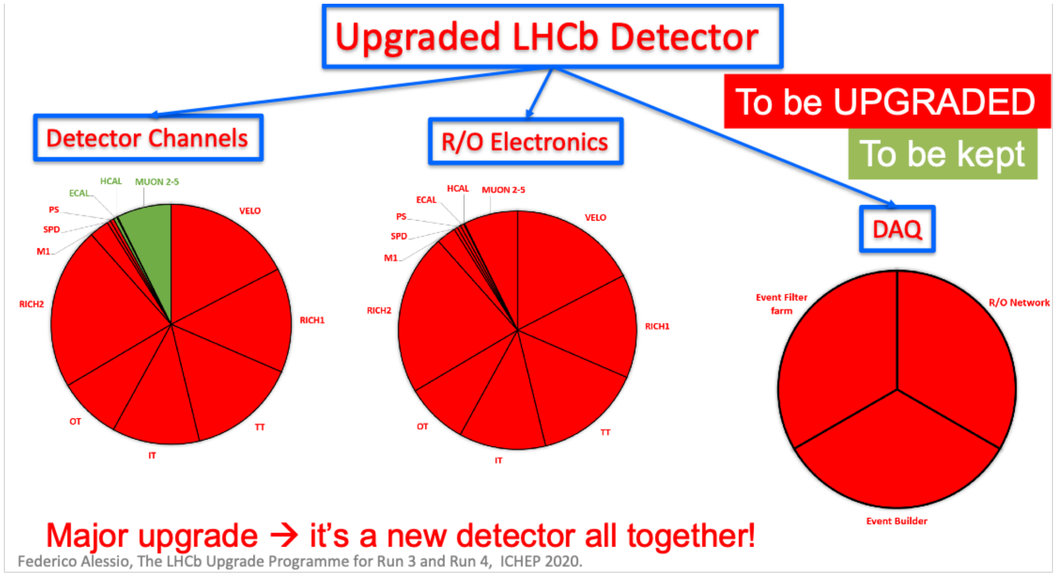

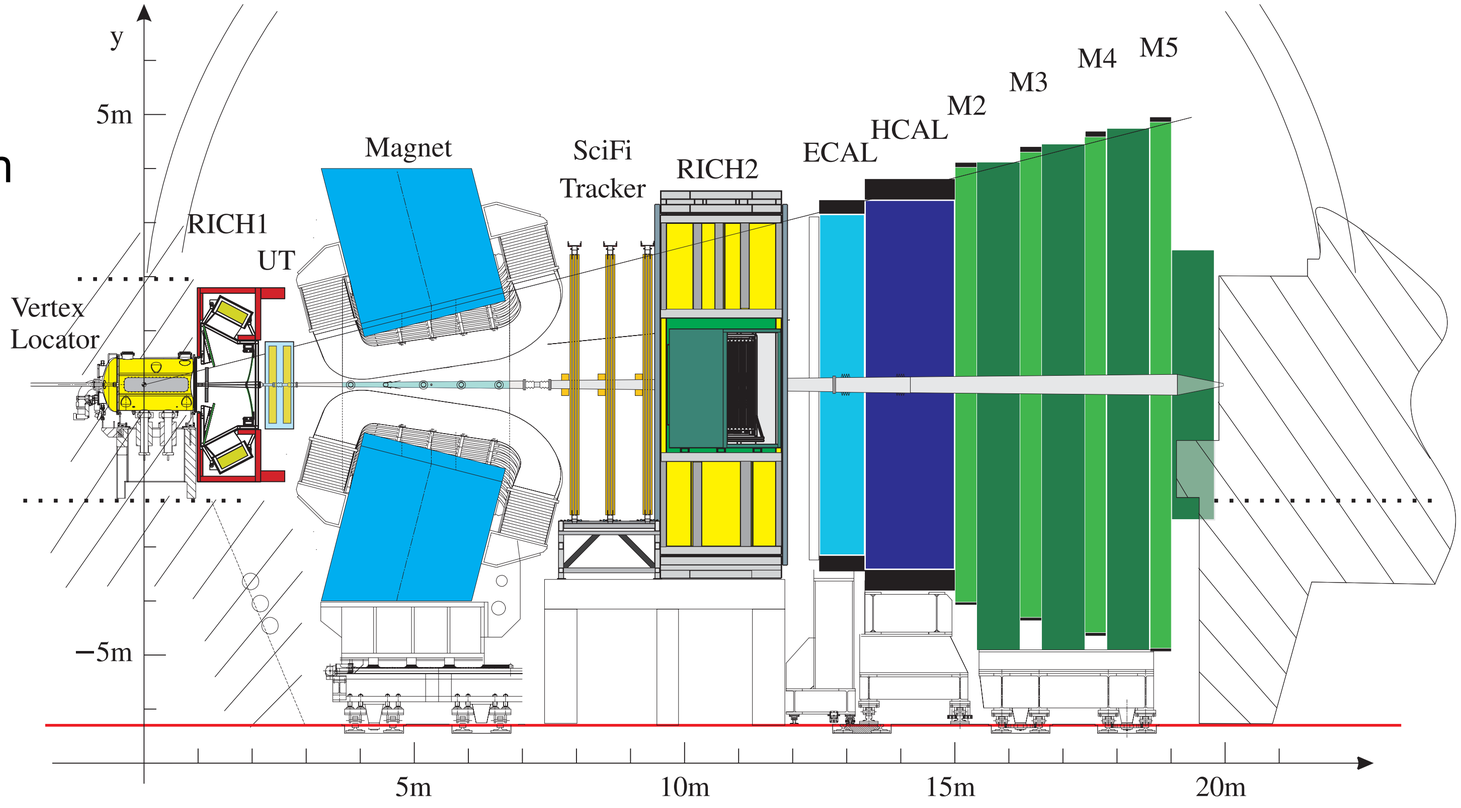

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1. Detector commissioning (short-term)
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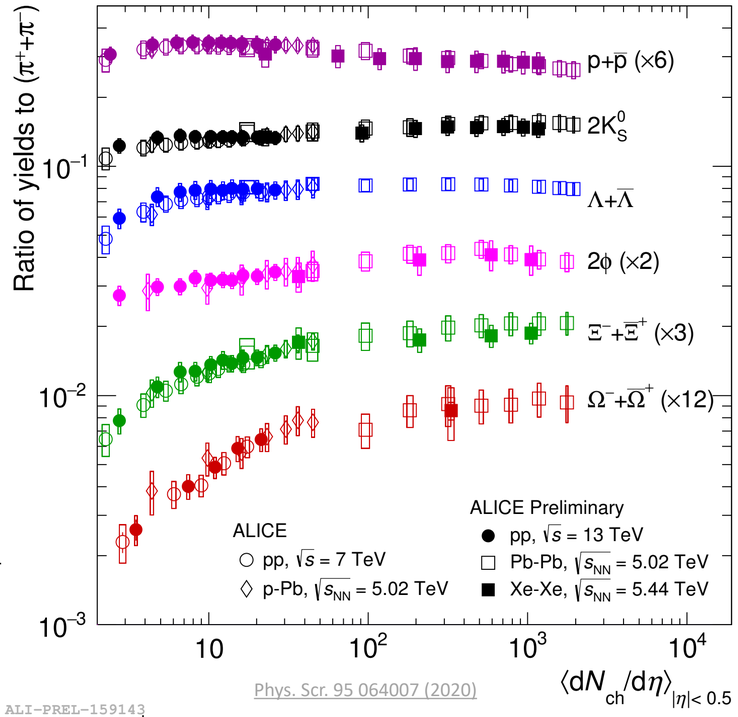
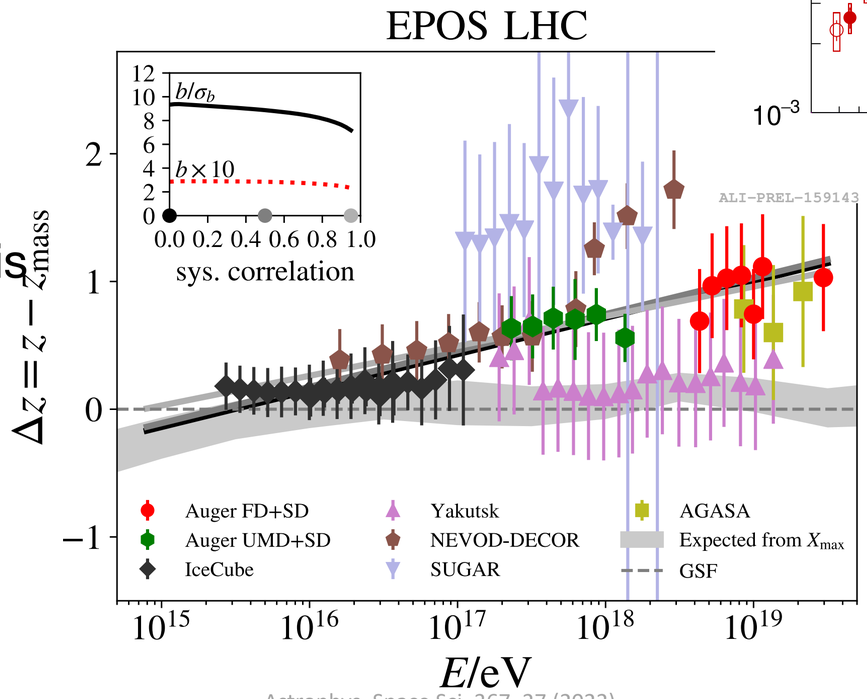
- Strange hadron production → non-perturbative QCD
- Enhancement of strange-hadron production in high-multiplicity events observed by ALICE [Nature Phys. 13 (2017) 535-539]
- Possible solution of “muon puzzle” in astroparticle physics
- Muon number also sensitive to meson-to-baryon-ratio

→ LHCb offers unique environment to test this



[Phys. Scr. 95 064007 (2020)]



[Astrophys. Space Sci. 367, 27 (2022)]

V^0 cross-section ratios

Cancels in ratios

>1M V^0 decays from few minutes of data taking in nominal conditions + good background rejection

No trigger efficiencies

$$R(\bar{\Lambda}^0, K^0_S) = \frac{\sigma(pp \to \bar{\Lambda}^0 X)}{\sigma(pp \to K^0_S X)} = \frac{\mathscr{L}\, N(\bar{\Lambda}^0 \to \bar{p}\pi^+)\, \varepsilon_{K^0_S \to \pi^+\pi^-}\, \mathscr{B}(K^0_S \to \pi^+\pi^-)}{\mathscr{L}\, N(K^0_S \to \pi^+\pi^-)\, \varepsilon_{\bar{\Lambda}^0 \to \bar{p}\pi^+}\, \mathscr{B}(\bar{\Lambda}^0 \to \bar{p}\pi^+)}$$

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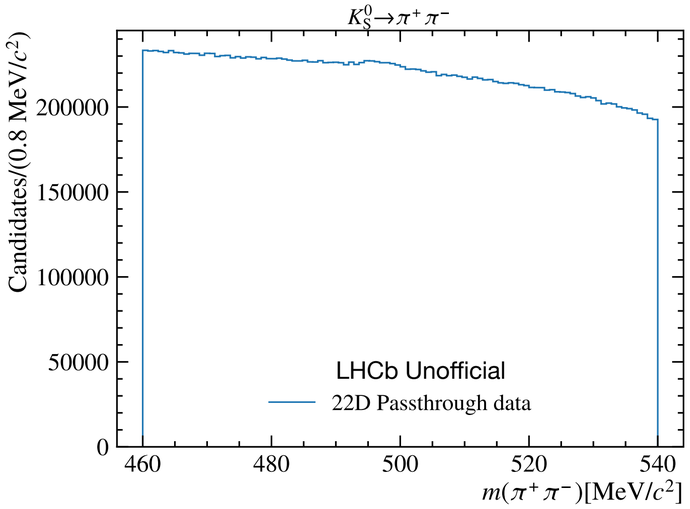
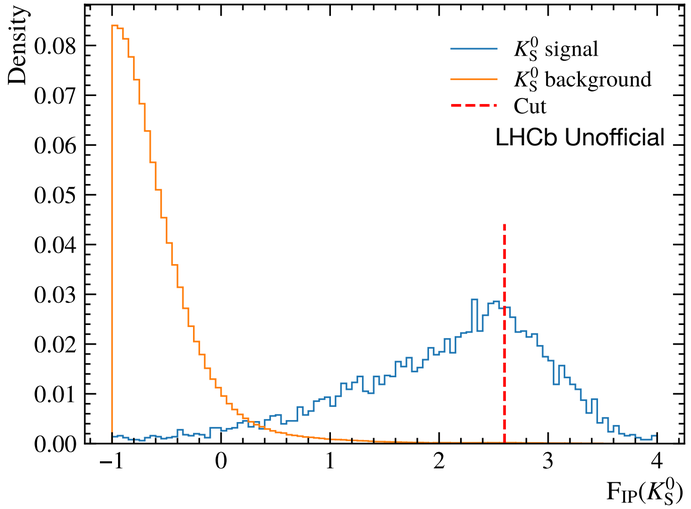
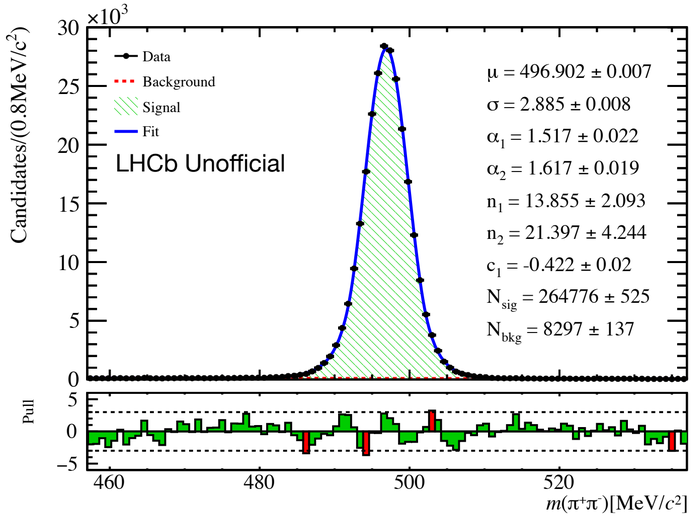
V^0 candidates



- Data recorded in $90\,\mathrm{s}$ ($78\,\mathrm{nb}^{-1}$)
- Pairs of tracks leaving hits in VELO + SciFi and forming vertex



- Cut optimised in Run 2 analysis
- $\mathcal{F}_{\mathrm{IP}}(K^0_S/\Lambda^0) > 2.6/1.5$
- Additional cut $\mathrm{IP}(\Lambda^0) < 0.13\,\mathrm{mm}$ to suppress hyperon (Ξ^0, Ξ^-) contributions

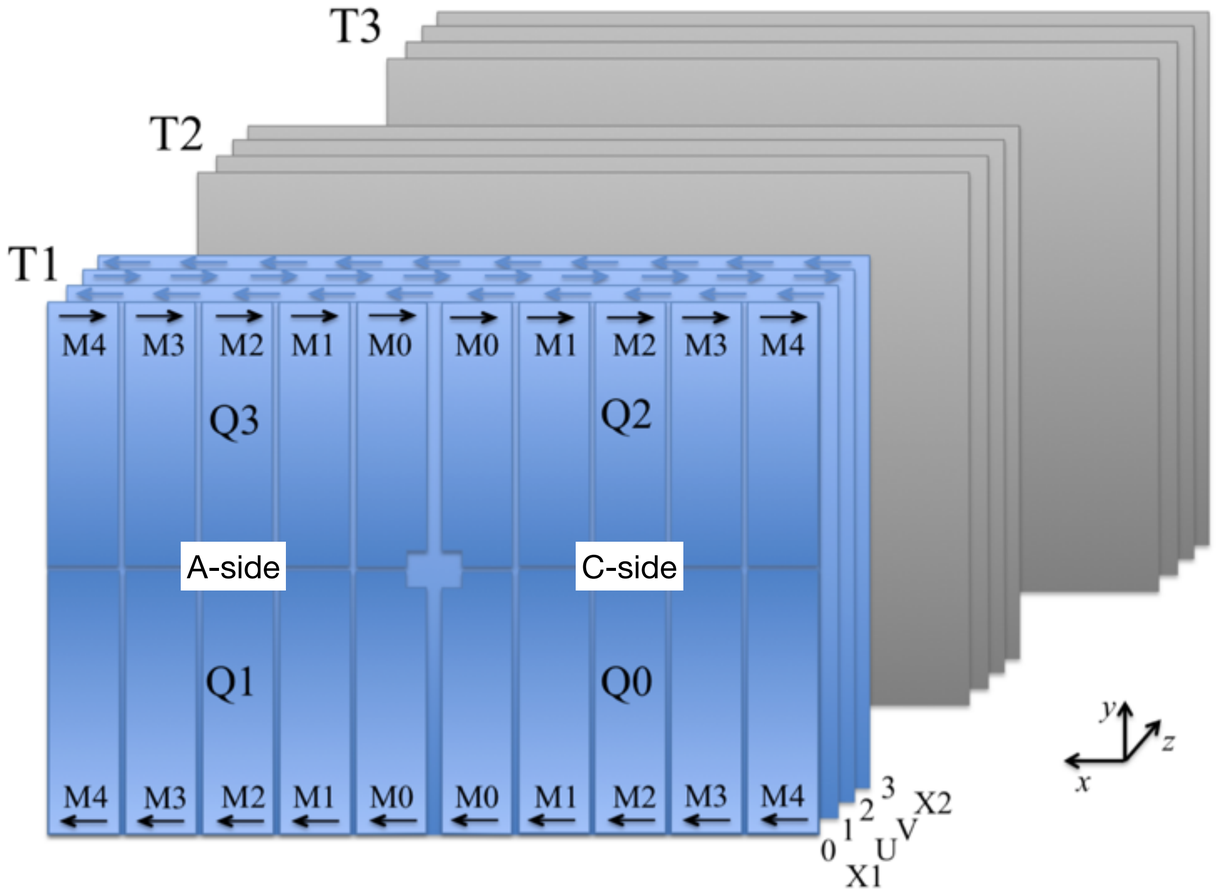


- Signal yield + mass resolution highly dependent on spatial detector alignment

$$\mathcal{F}_{\mathrm{IP}}(V^0 \to h^+h^{(\prime)-}) = \log_{10}(\mathrm{IP}(h^+)) + \log_{10}(\mathrm{IP}(h^{(\prime)-})) - \log_{10}(\mathrm{IP}(V^0))$$

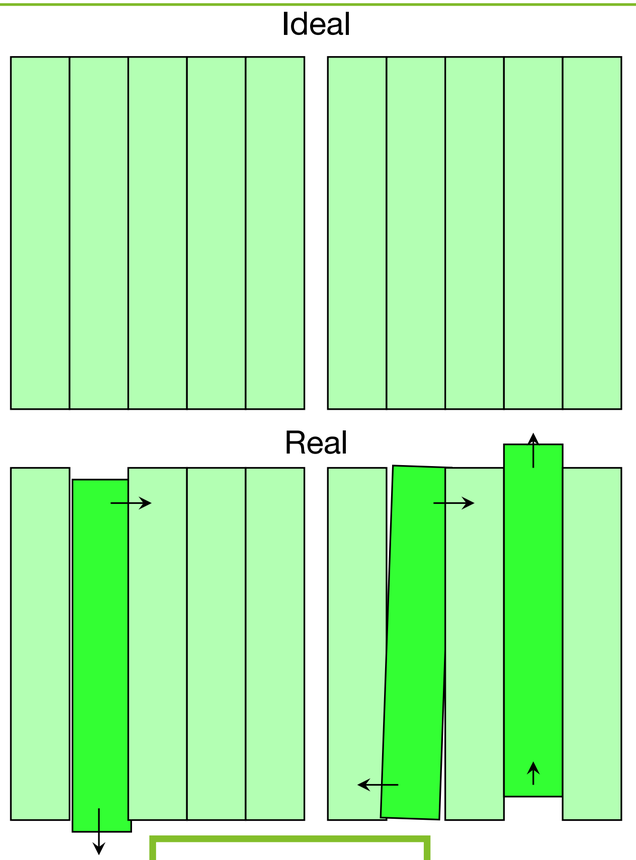
SciFi Tracker

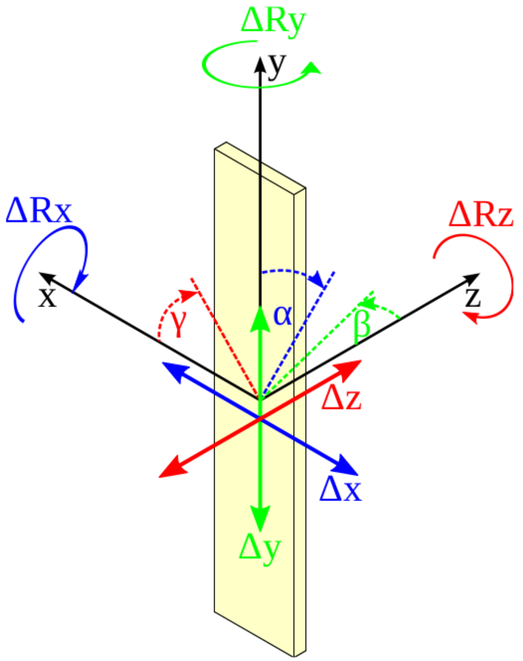
- 3 tracking stations
- 4 layers per station
  → U, V rotated by $\mp$ 5°
- Divided into 4 quarters in x-y-plane
  → A- ($x > 0$) and C-side ($x < 0$)
  → Top ($y > 0$) and bottom half ($y < 0$)
- Each side persists of 5 modules (6 for T3) with 2x4 fibre mats each separated by a mirror at $y = 0$



SciFi Spatial Alignment

- Real detector does not resemble ideal detector perfectly
  - → Need to find translations and rotations of detector elements from ideal position (applies to all subdetectors)





V7

- SciFi v2 half-module alignment $(\Delta x, \Delta Rz)$

V10

- SciFi v3 half-module alignment $(\Delta x, \Delta z, \Delta Rz)$
- SciFi mat alignment $(\Delta x, \Delta z)$

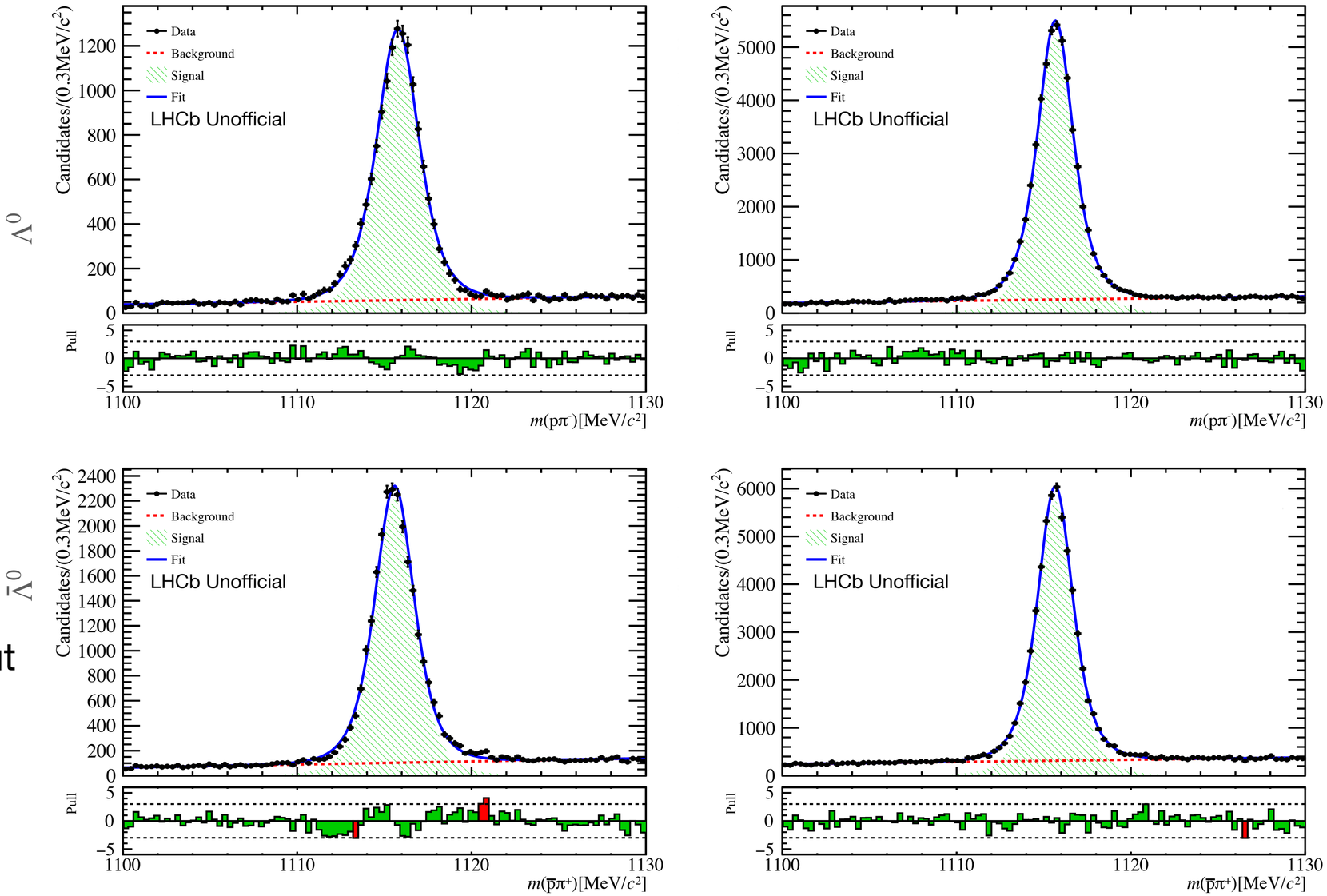
Impact of spatial alignment: V7 vs. V10

- Λ^0
  - → N_{sig} : 13582 → 49971
  - → σ : 1.262 → 1.07
  - → SciFi hits(p) : 11.04 → 11.33
  - → SciFi hits(π^-) : 10.18 → 10.92
- $\bar{\Lambda}^0$
  - → N_{sig} : 23187 → 53879
  - → σ : 1.18 → 1.055
  - → SciFi hits($\bar{p}$) : 10.82 → 11.12
  - → SciFi hits(π^+) : 10.79 → 11.06

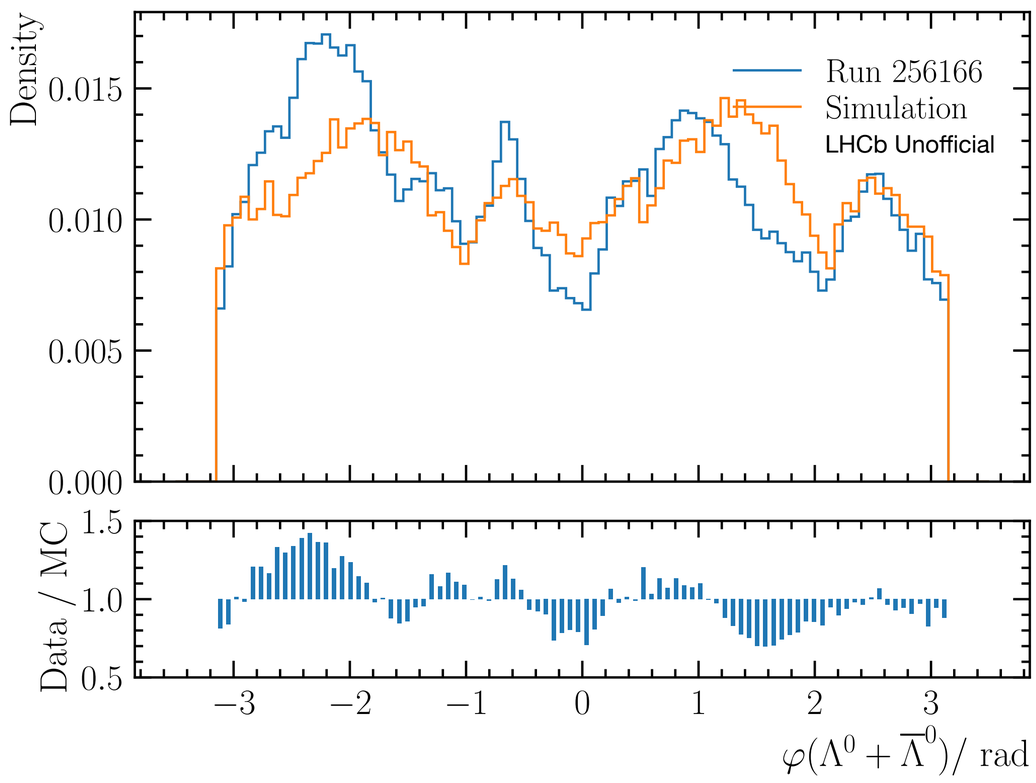
- Remaining charge asymmetries, but smaller
- No improvement found in further checks

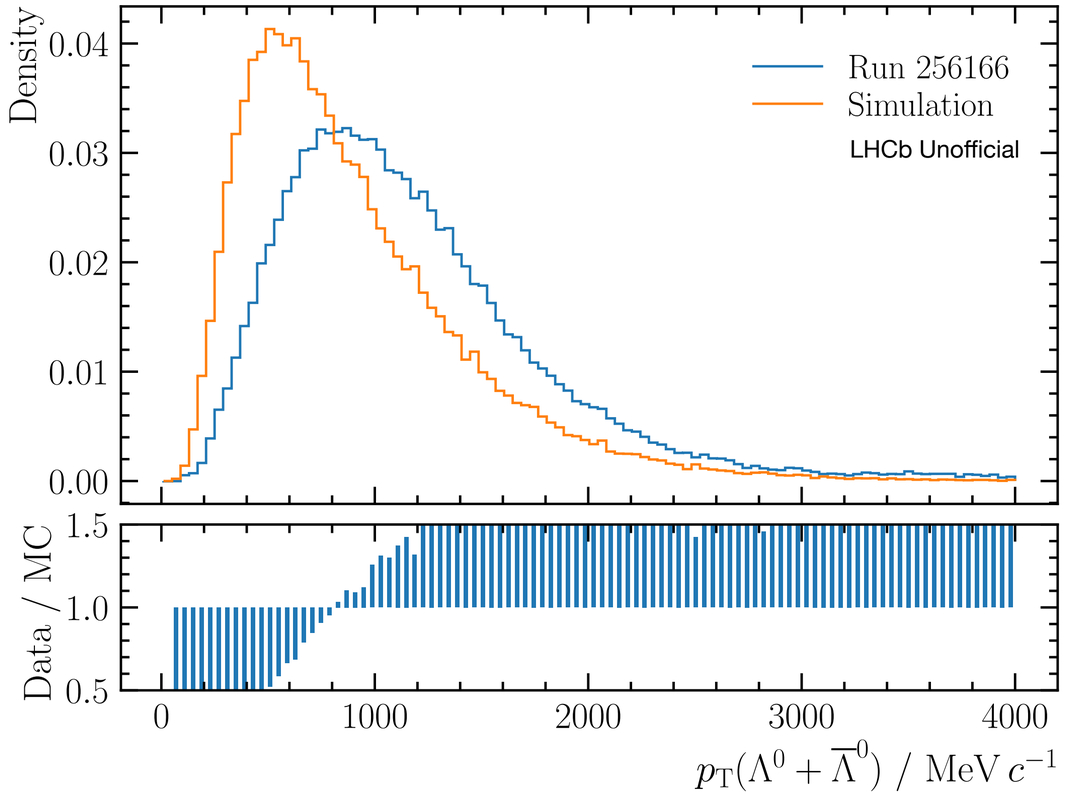
Alignment V7

Alignment V10



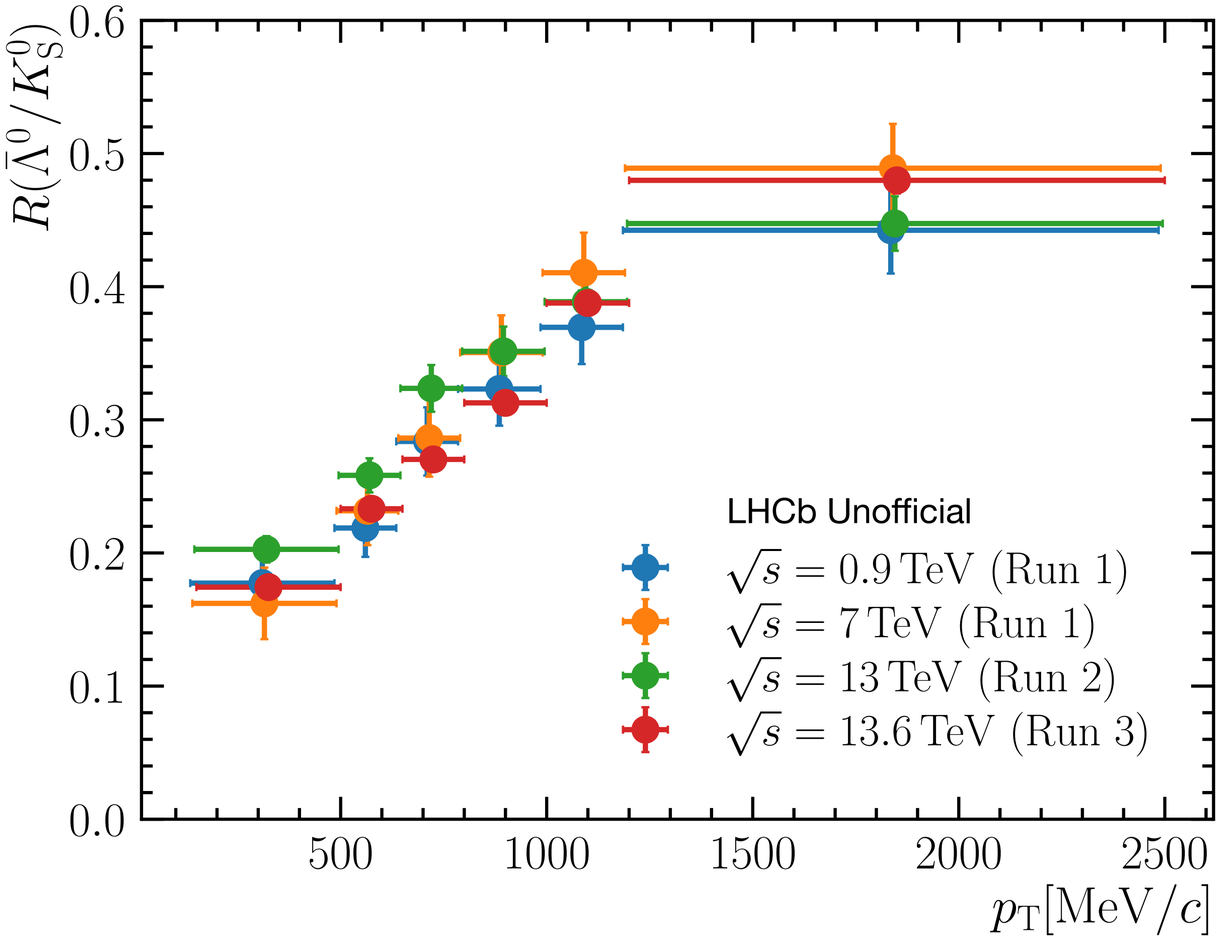
Agreement between data and MC

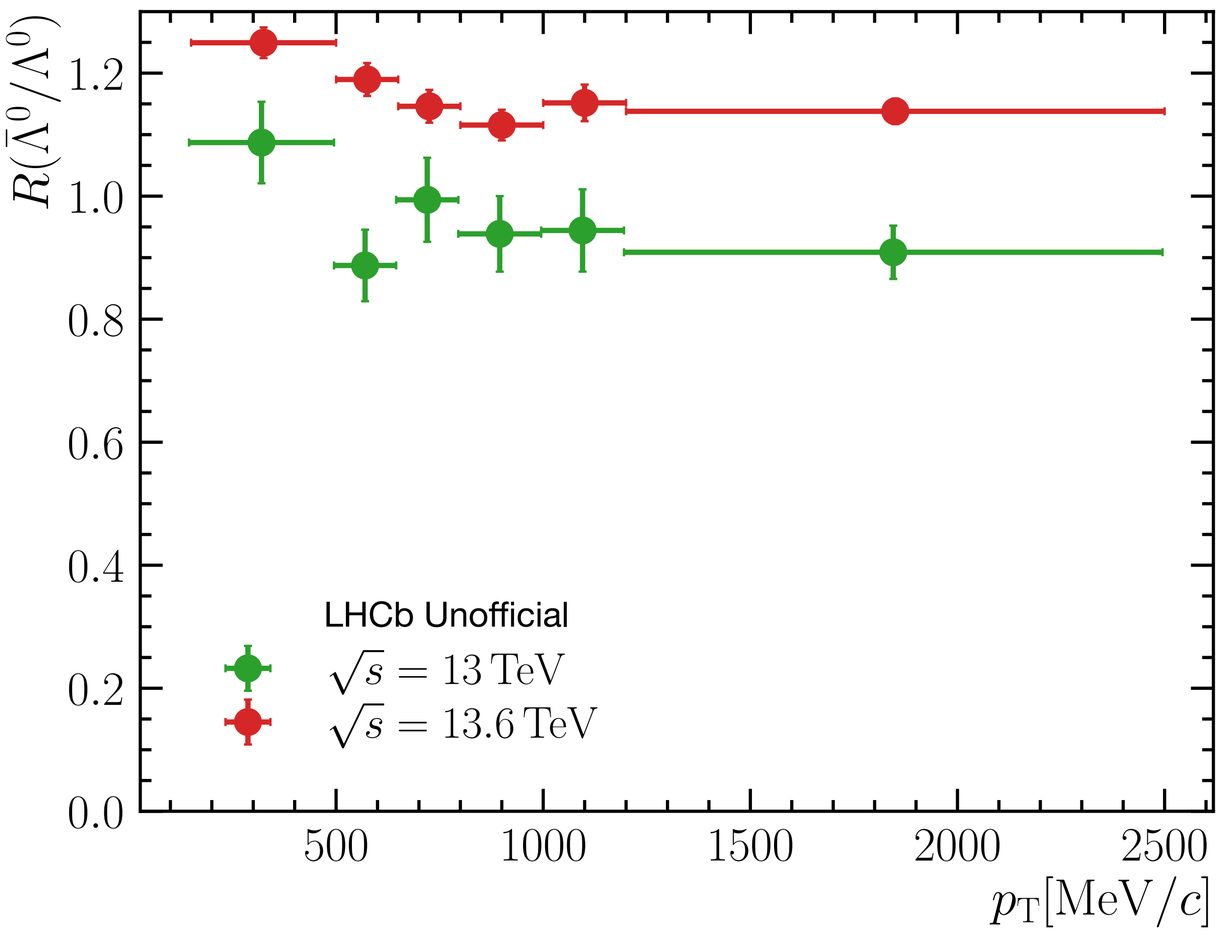




- Disagreement between data and simulation in key variables
- Not fully clear whether only due to detector misalignments
- Efficiencies estimated on simulation
- Corrections to reconstruction and tracking efficiencies in the works

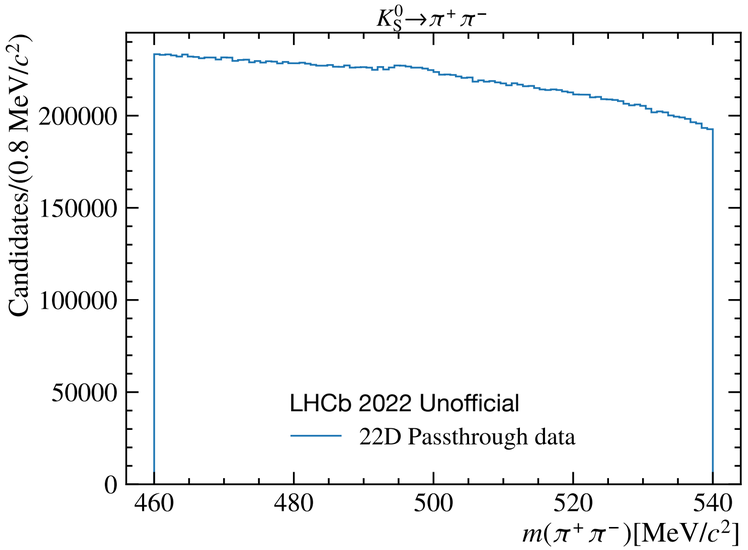
Preliminary ratio comparison

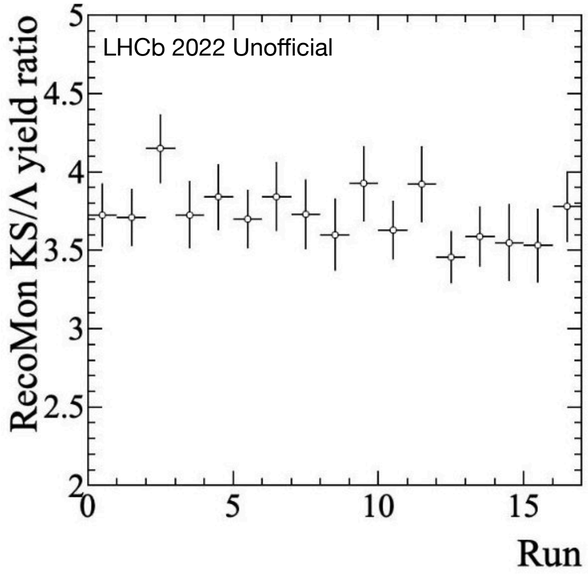




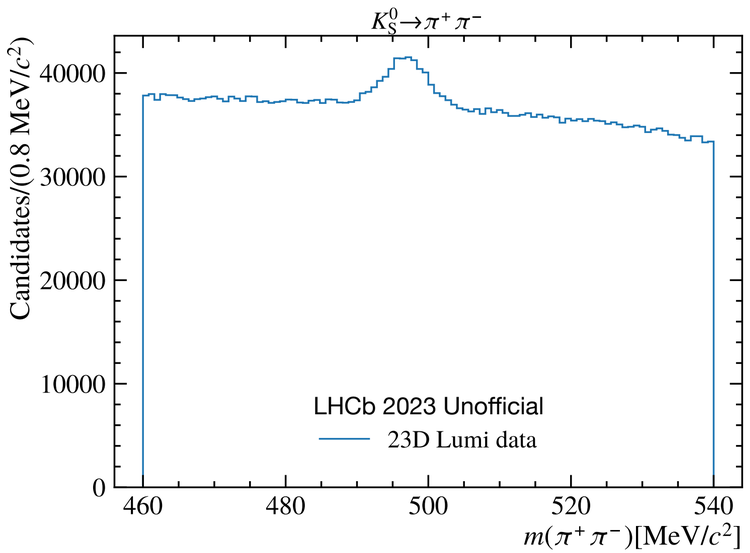
Prospects for 23 data

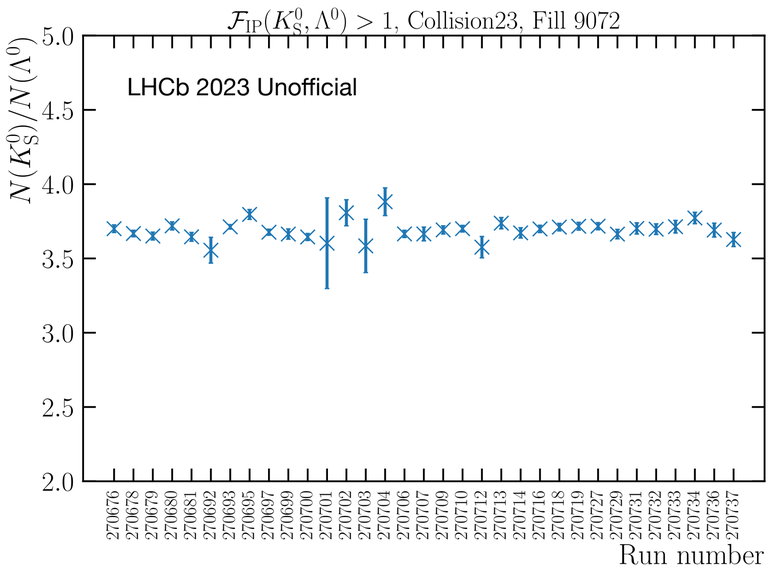
2022





2023





Summary

- V^0 production cross-section ratios contribute to validation of the LHCb Upgrade I detector paving the way towards stable physics programme in Run 3
  - → Presented current status of one of the first Run 3 measurements
  - → Crucial for precision measurements by LHCb in Run 3 contributing to F4
- Emphasis on future measurements of strangeness enhancement in intersection of particle and astroparticle physics
  - → Baryon-meson-ratio measurement in the forward region as input for generator tunings of atmospheric showers
  - → Possible solution to muon puzzle

Thanks for your attention!