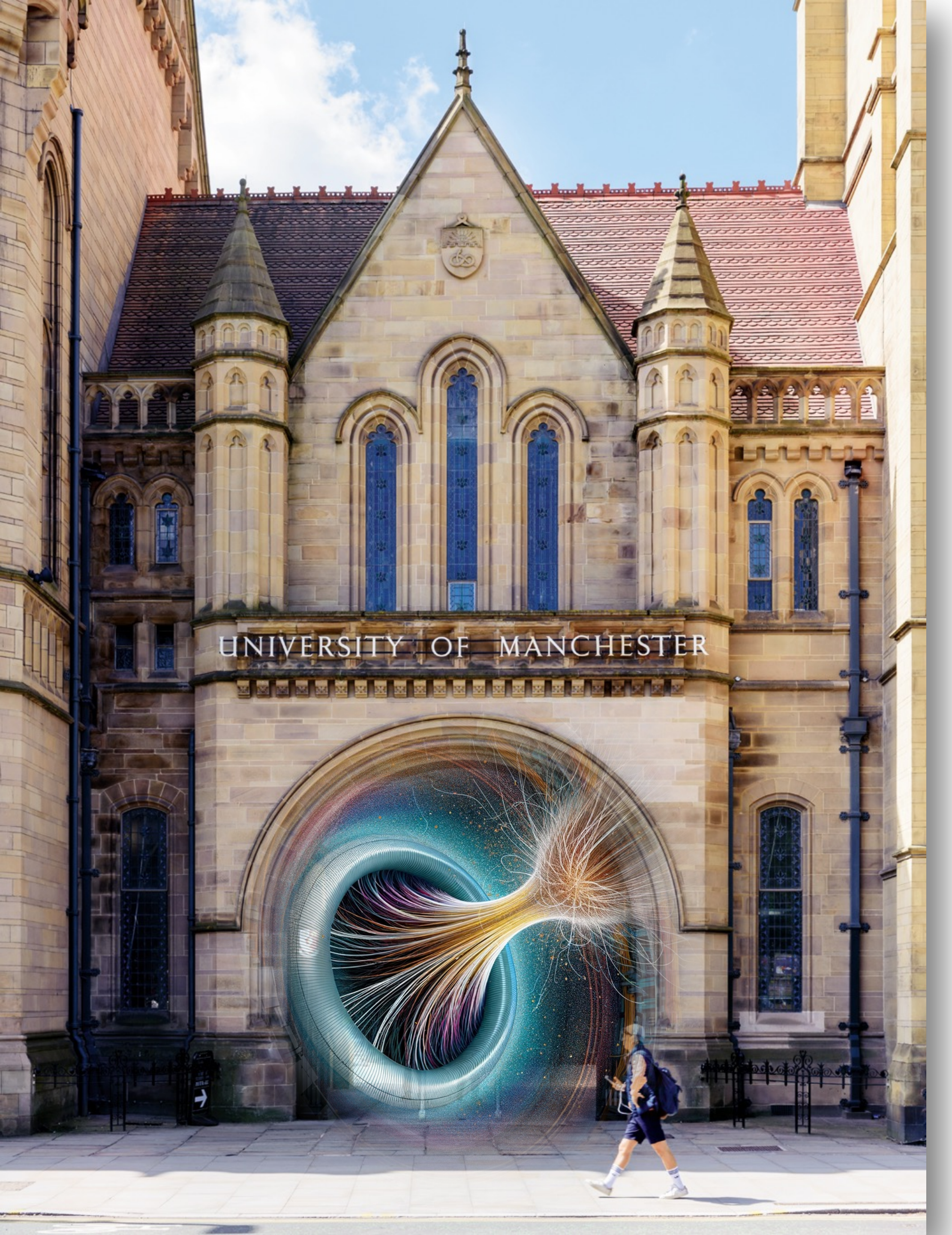

Probing the Mechanisms of Strangeness Enhancement in Small Systems with ALICE

MPI@LHC 2023

ALICE

LUND UNIVERSITY

Roman Nepeivoda* for the ALICE Collaboration
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Strangeness Enhancement Phenomenon

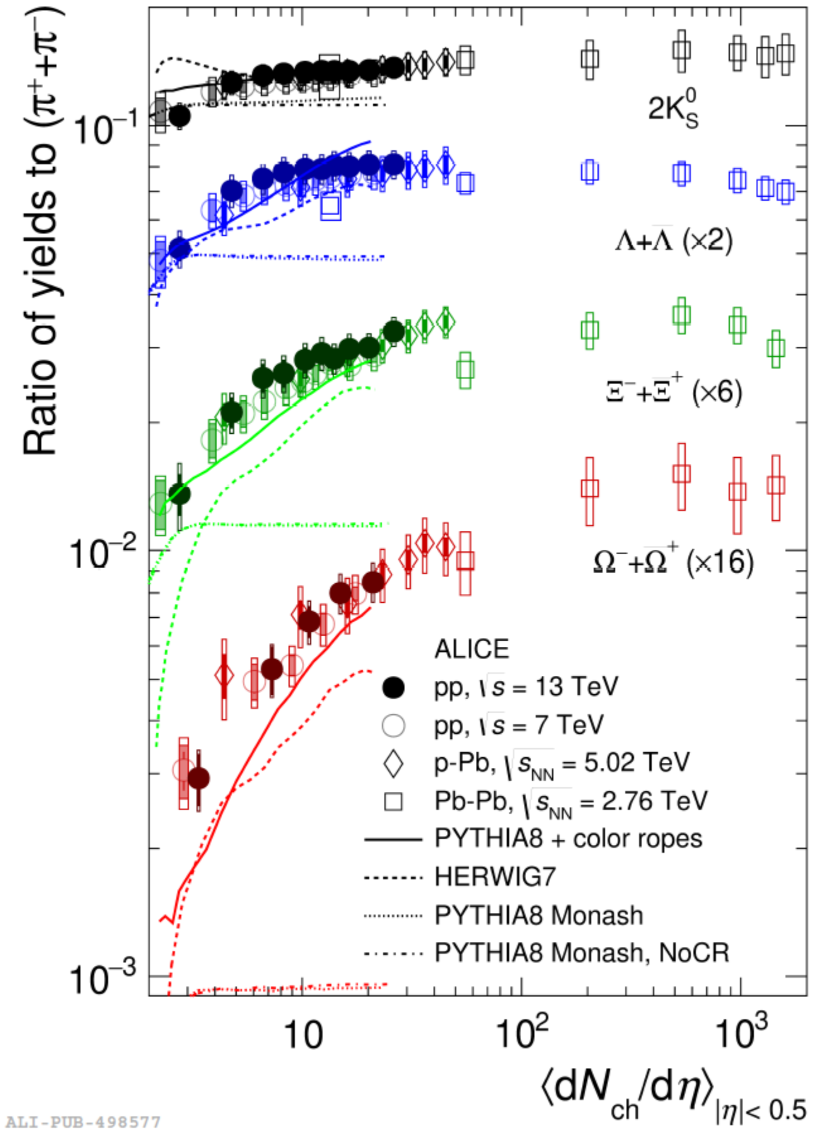
Strangeness as a signature of QGP

QGP → deconfinement → lower effective s quark mass → thermal $s\bar{s}$ production → more (multi)strange hadrons

Strangeness enhancement with particle multiplicity **independent** of collision system and energy

interaction between **MPI systems?**

core-corona approach down to **pp systems?**

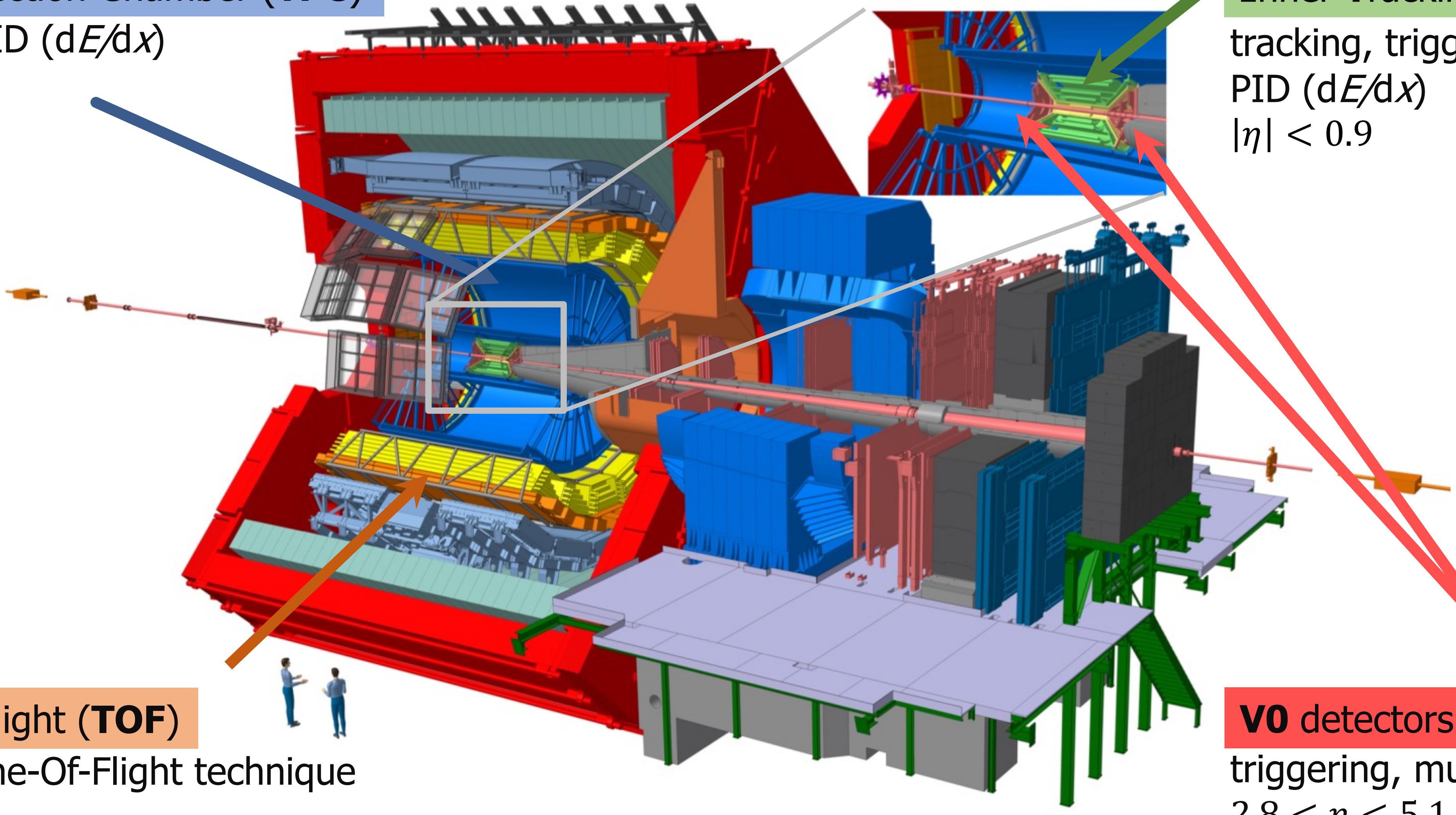


Eur. Phys. J. C 80, 693 (2020)

The ALICE Detector: A Window into High-Energy Collisions

Time **P**rojection **C**hamber (**TPC**)
tracking, PID (dE/dx)
$|\eta| < 0.9$

Inner **T**racking **S**ystem (**ITS**)
tracking, triggering, vertexing, PID (dE/dx)
$|\eta| < 0.9$



Time **O**f **F**light (**TOF**)
PID via Time-Of-Flight technique
$|\eta| < 0.9$

V0 detectors (**V0A** & **V0C**)
triggering, multiplicity estimator
$2.8 < \eta < 5.1$ (V0A)
$-3.7 < \eta < -1.7$ (V0C)

Analysis methodology

- Different **underlying assumptions** of qualitatively very different production scenarios **are tested** by investigating the angular correlations between the multi-strange baryon $\Xi^-(\overline{\Xi}^+)$ and other identified hadrons

- Per-trigger yield of associated identified hadrons with respect to the **trigger Ξ**

$$S(\Delta y, \Delta\varphi) = \frac{1}{N_{\text{trig}}} \frac{d^2 N_{\text{pairs}}^{\text{sig}}}{\text{d}\Delta y \text{d}\Delta\varphi}$$

$$B(\Delta y, \Delta\varphi) = \alpha \frac{d^2 N_{\text{pairs}}^{\text{mixed}}}{\text{d}\Delta y \text{d}\Delta\varphi}$$

$$Y(\Delta y, \Delta\varphi) = \frac{S(\Delta y, \Delta\varphi)}{B(\Delta y, \Delta\varphi)}$$

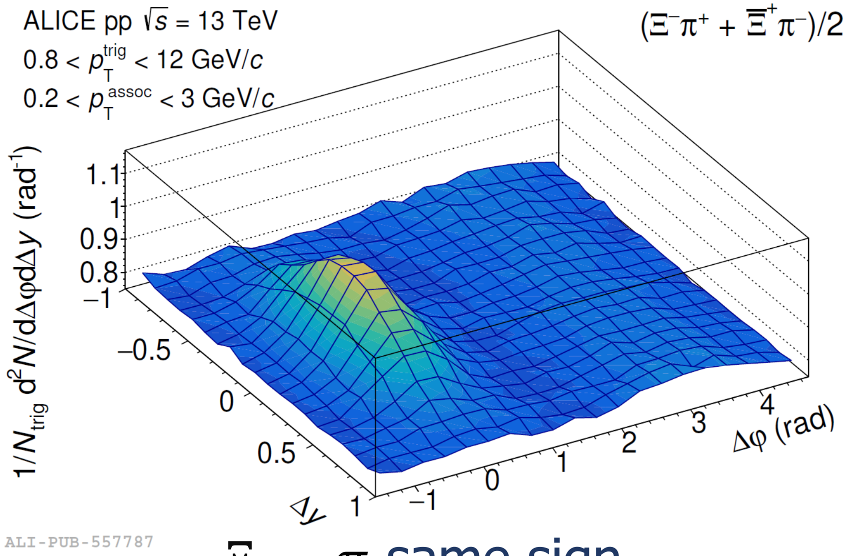
$\Xi^-\ (dss)$ $\Xi^+\ (\overline{dss})$
$\text{K}^-\ (s\bar{u})$ $\text{K}^+\ (u\bar{s})$
$\Lambda\ (uds)$ $\overline{\Lambda}\ (\overline{uds})$

$\pi^-\ (d\bar{u})$ $\pi^+\ (u\bar{d})$
$p\ (uud)$ $\bar{p}\ (\overline{uud})$

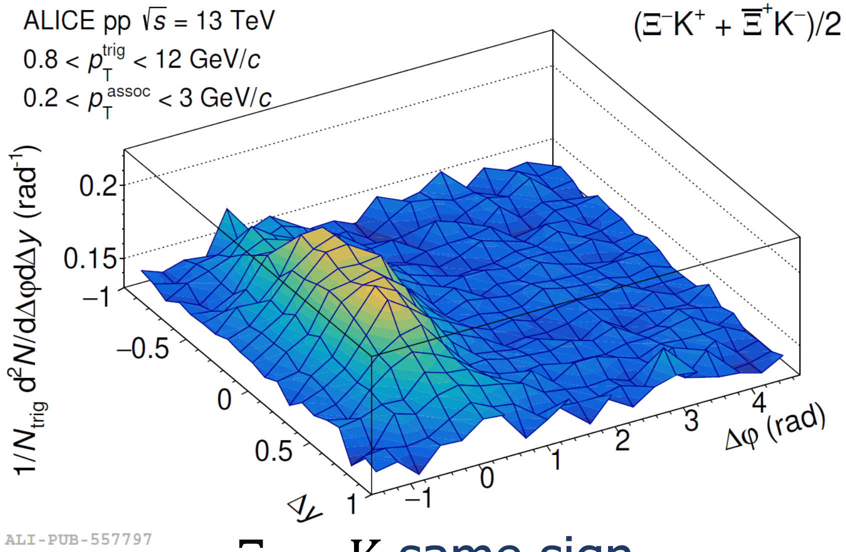
$\Delta y = y_{\text{assoc}} - y_{\text{trig}}$	difference in rapidity
$\Delta\varphi = \varphi_{\text{assoc}} - \varphi_{\text{trig}}$	relative azimuthal angle between the trigger and associated particles
$N_{\text{pairs}}^{\text{sig}}\ (N_{\text{pairs}}^{\text{mixed}})$	number of trigger-associated particle pairs in the same event (in different events)
N_{trig}	number of trigger particles

Multiplicity-integrated correlation functions

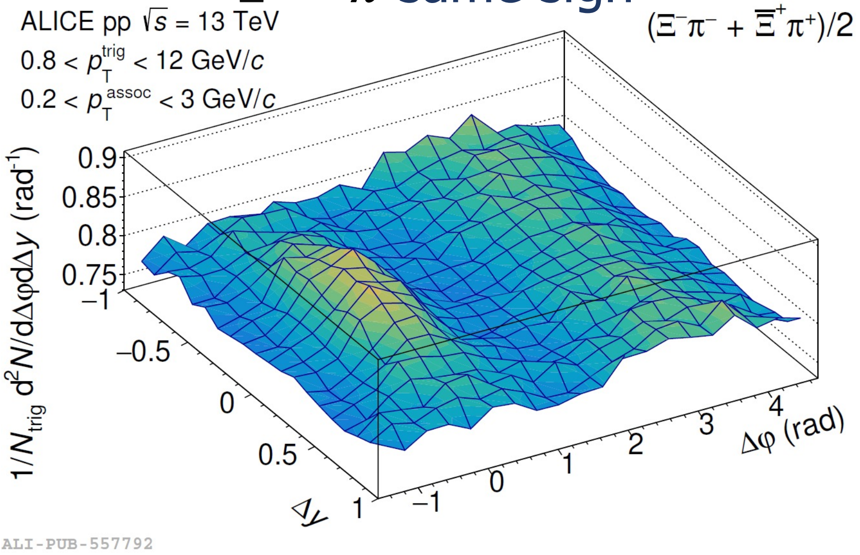
$\Xi - \pi$ opposite sign



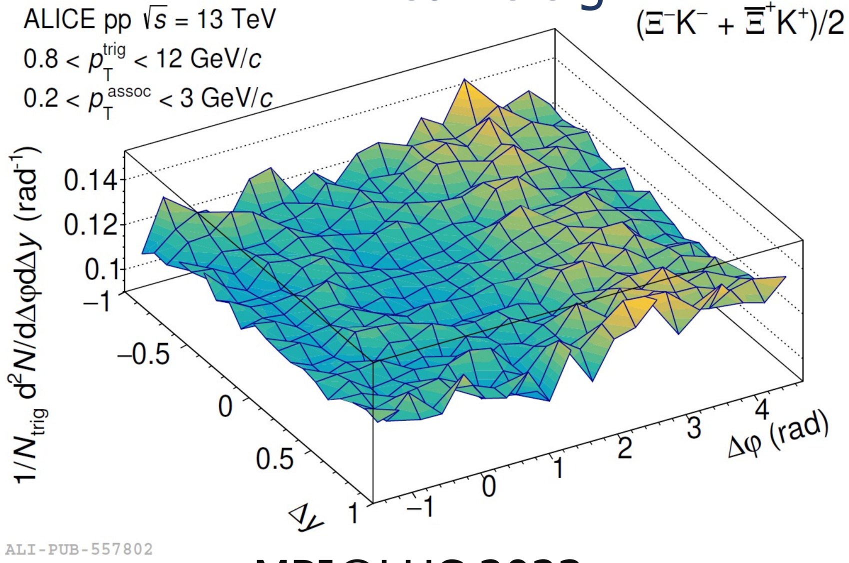
$\Xi - \mathrm{K}$ opposite sign



$\Xi - \pi$ same sign



$\Xi - \mathrm{K}$ same sign

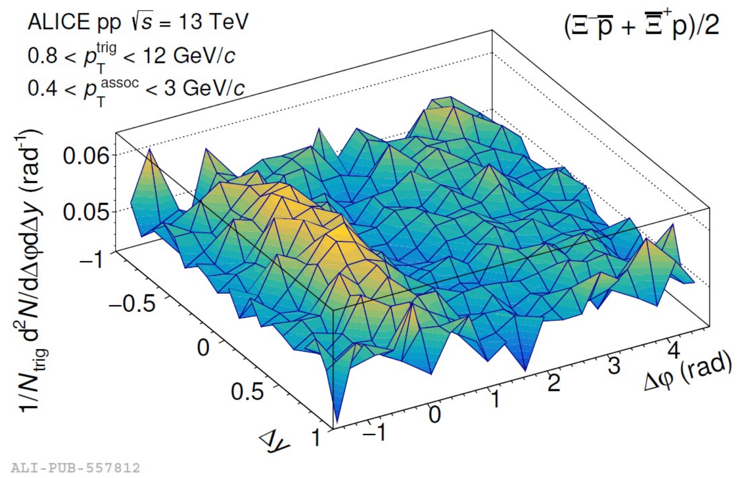


- **Flat pedestal** represents **underlying event (UE)** activity not correlated to the Ξ^- production
- **Near-side** and **away-side** peaks localized around $(\Delta y, \Delta\varphi) = (0, 0)$ and $\Delta\varphi = \pi$ attributed to the production within **the same** and **back-to-back (mini)jets**
- In opposite-sign (**OS**) correlations, near-side peak is enhanced due to the production of $q\bar{q}$ pair ($\bar{d}d$ and $\bar{s}s$)
- In same-sign (**SS**) correlations, near side peak for $\Xi - \mathrm{K}$ is suppressed demonstrating the difficulty of producing three strange quarks within the same (mini)jet

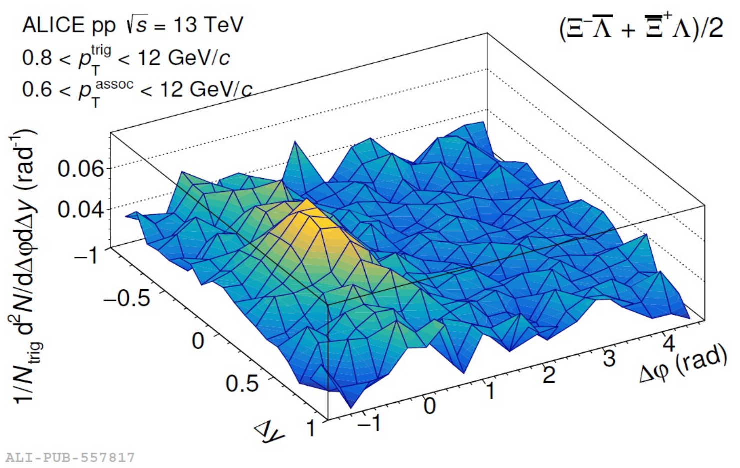
$$\Xi^-\ (dss)\quad \Xi^+\ (\overline{dss})$$
$$\mathrm{K}^-\ (s\bar{u})\quad \mathrm{K}^+\ (u\bar{s})$$
$$\pi^-\ (d\bar{u})\quad \pi^+\ (u\bar{d})$$

Multiplicity-integrated correlation functions

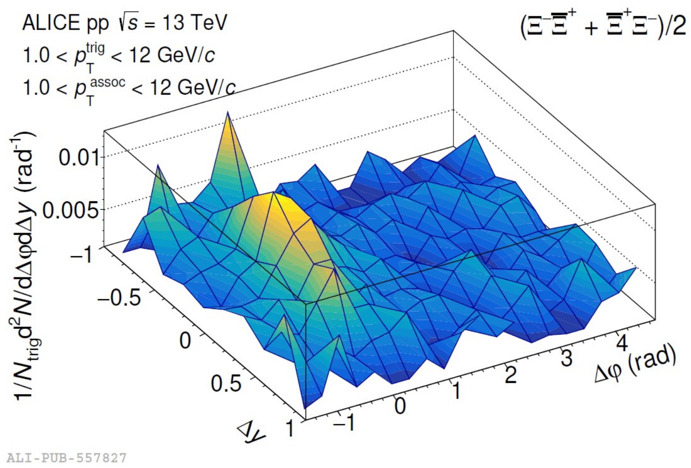
$\Xi - p$ opposite B



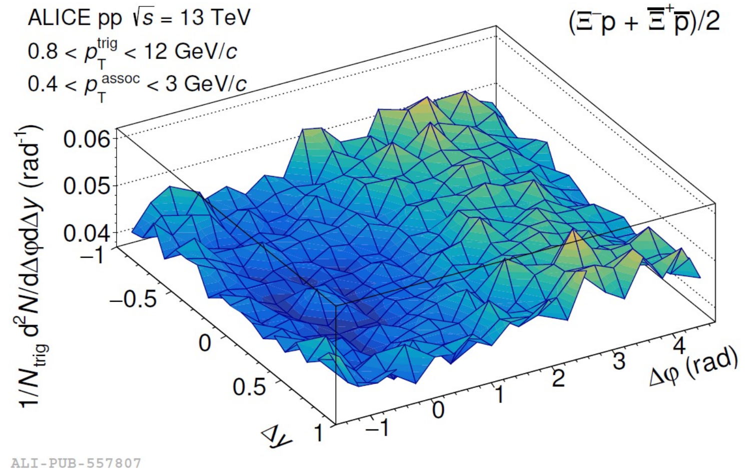
$\Xi - \Lambda$ opposite B



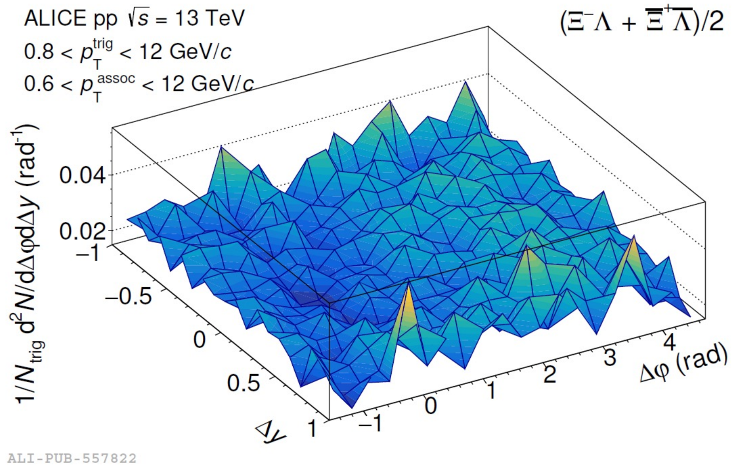
$\Xi - \Xi$ opposite B



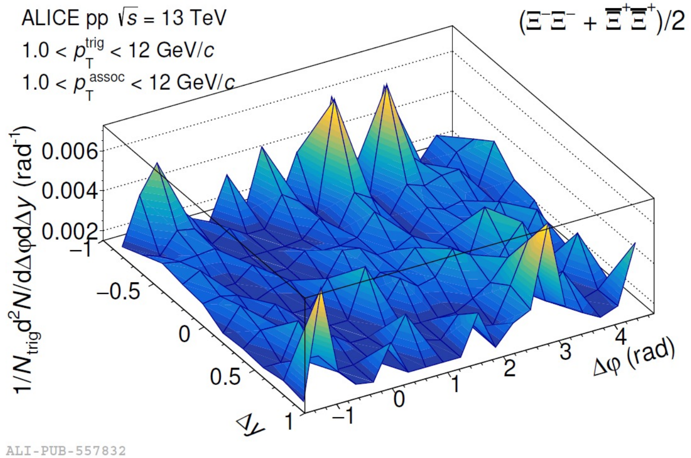
$\Xi - p$ same B



$\Xi - \Lambda$ same B



$\Xi - \Xi$ same B



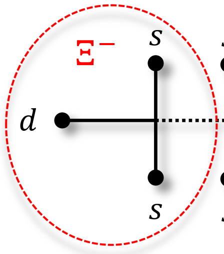
Explanation for the strangeness enhancement

PYTHIA 8

Monash

Includes color reconnection mechanism

Individual MPI systems may be color-connected

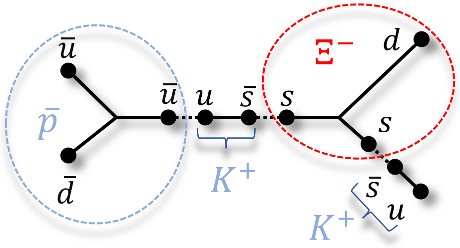


[Phys. Rev. Lett. 111(4), 042001](#)

Junctions

Allows more possibilities for balancing the strange number

$\Xi^-(\bar{\Xi}^+)$ could be balanced by the $\bar{p}(p)$ and $2K^+(2K^-)$

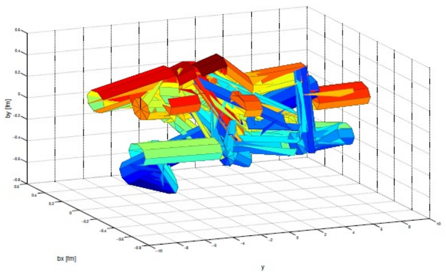


[Phys. Rev. D, 92(9), 094010](#)

Ropes

Allows strings to fuse together in high-density regions

Increased string tension leads to the enhanced production of strange quarks



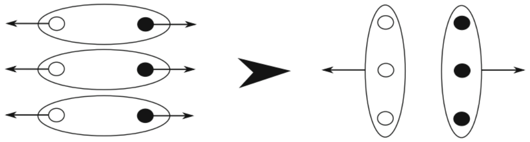
[Journal of High Energy Phys., 2015(3), 1-49](#)

HERWIG

Parton showers are generated via string breaking

Cluster hadronization mechanism is introduced

Own colour reconnection model where 3 mesons can recombine to a baryon and an anti-baryon



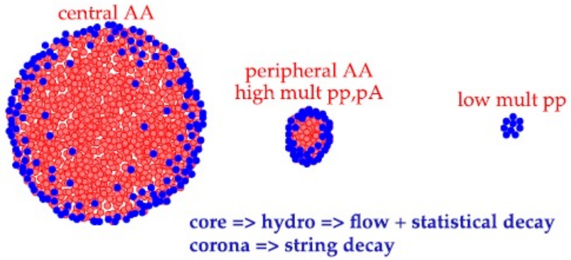
[Eur. Phys. J., C 76 (2016), 196](#)

[Eur. Phys. J. C 78 (2018), 99](#)

EPOS-LHC

Core-corona model where strangeness is dominantly produced in the core, which is assumed to be thermal (grand canonical)

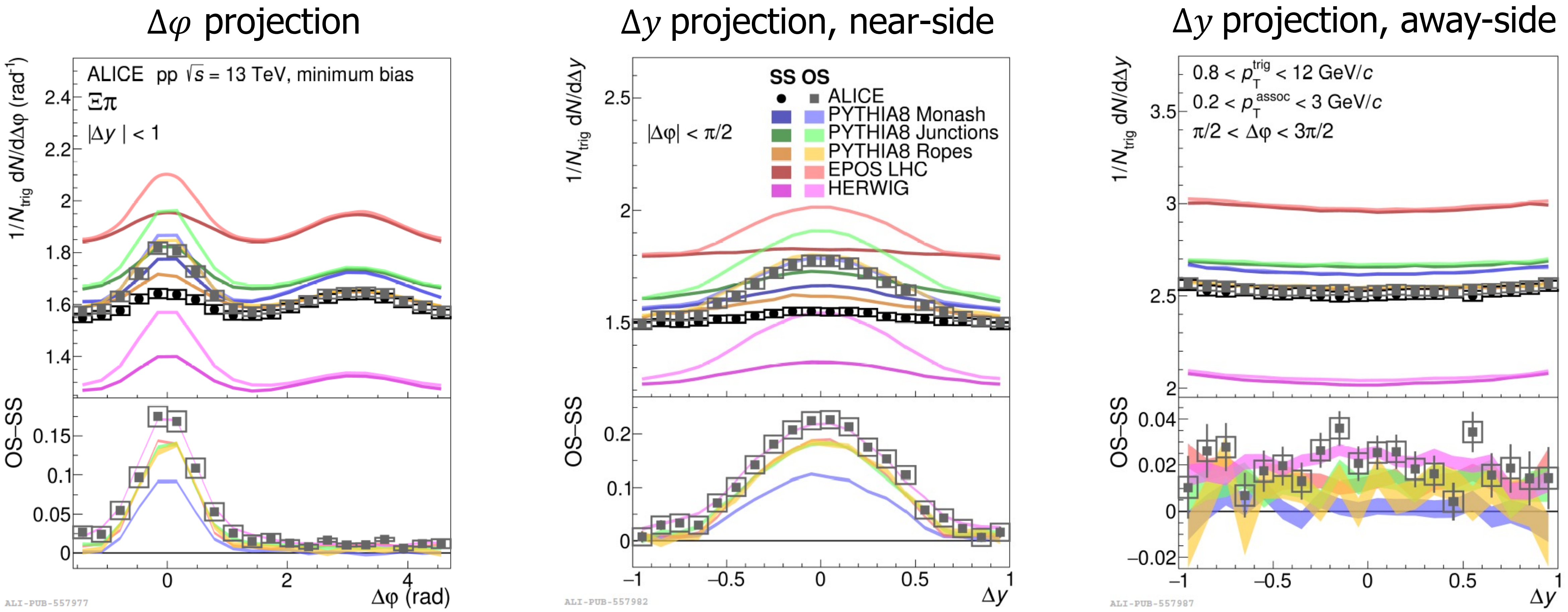
More long-ranged correlations



[Phys. Rev. C 92, (2015), 034906](#)

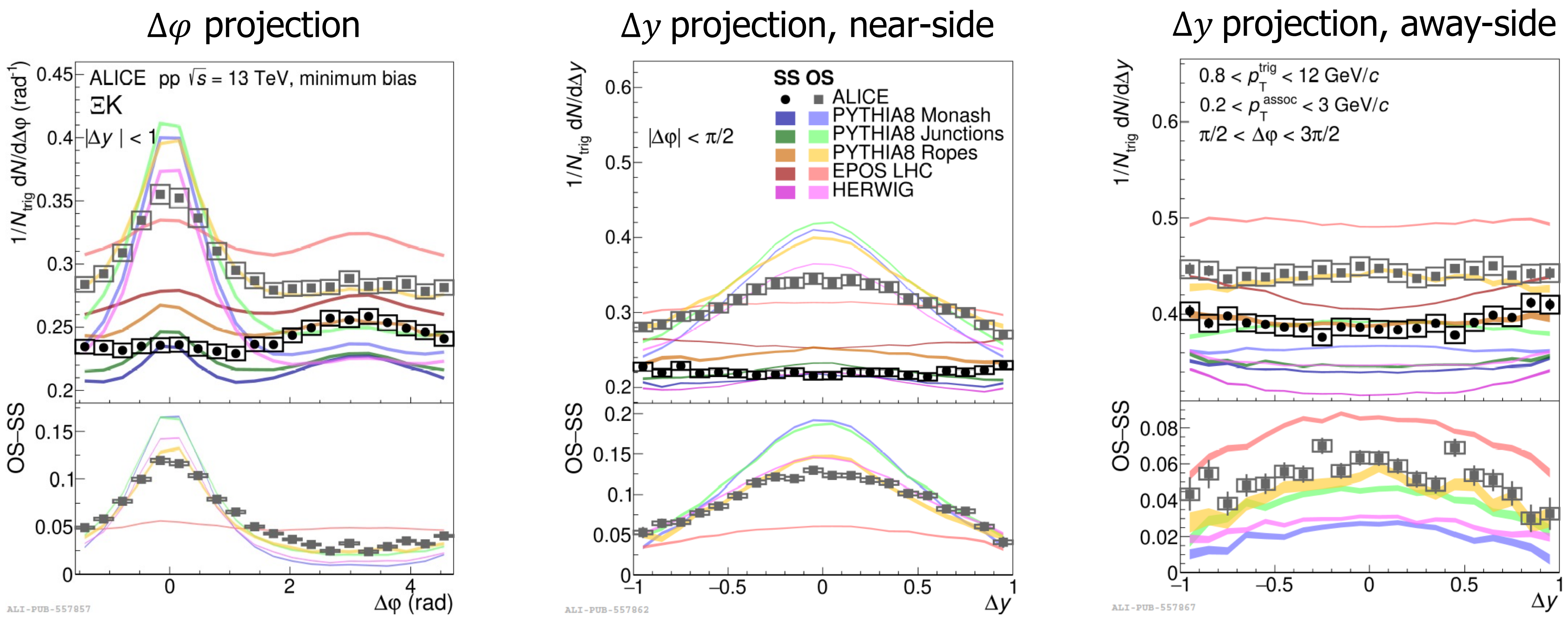
[arXiv:2203.11601](#)

Comparison to Monte Carlo models ($\Xi - \pi$)



- The overall magnitude of the UE is well described by the PYTHIA 8 tunes but not the EPOS-LHC and HERWIG
- Overestimation of the UE in EPOS-LHC could be dictated by the Ξ production in mainly higher-than-average multiplicity events

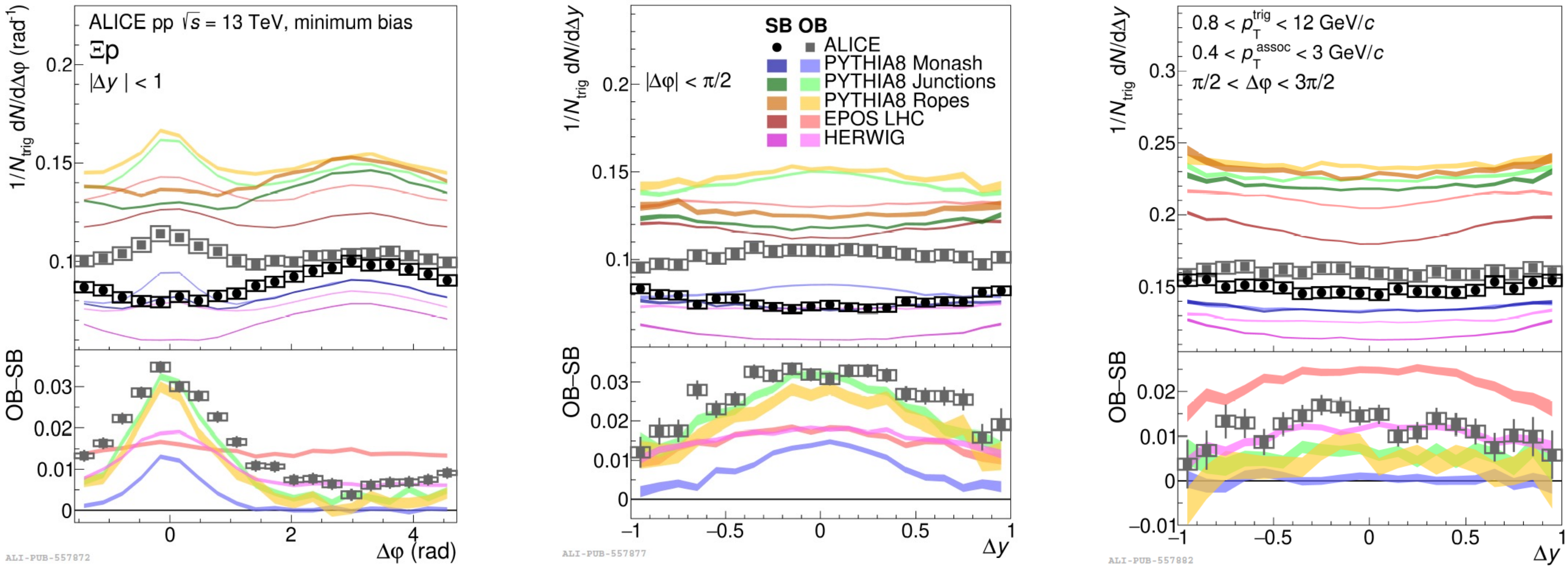
Comparison to Monte Carlo models (Ξ — K)



- PYTHIA 8 tunes tend to predict more significant near-side peaks than are observed in data indicating that strangeness is overproduced in (mini)jet fragmentation in the corresponding models
- The width of the near-side peak in data is larger comparing to the PYTHIA 8 predictions suggesting more considerable quark diffusion than the one anticipated by the models

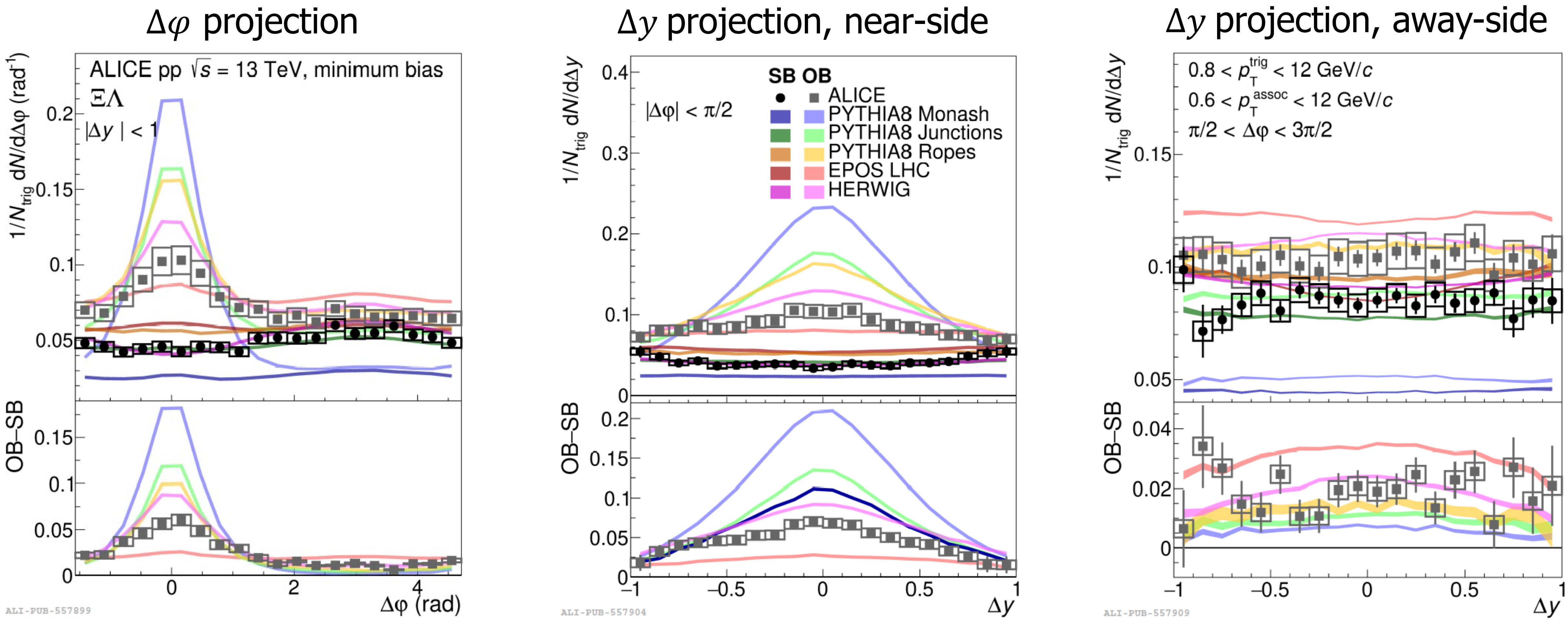
Comparison to Monte Carlo models ($\Xi - p$)

$\Delta\varphi$ projection | Δy projection, near-side | Δy projection, away-side



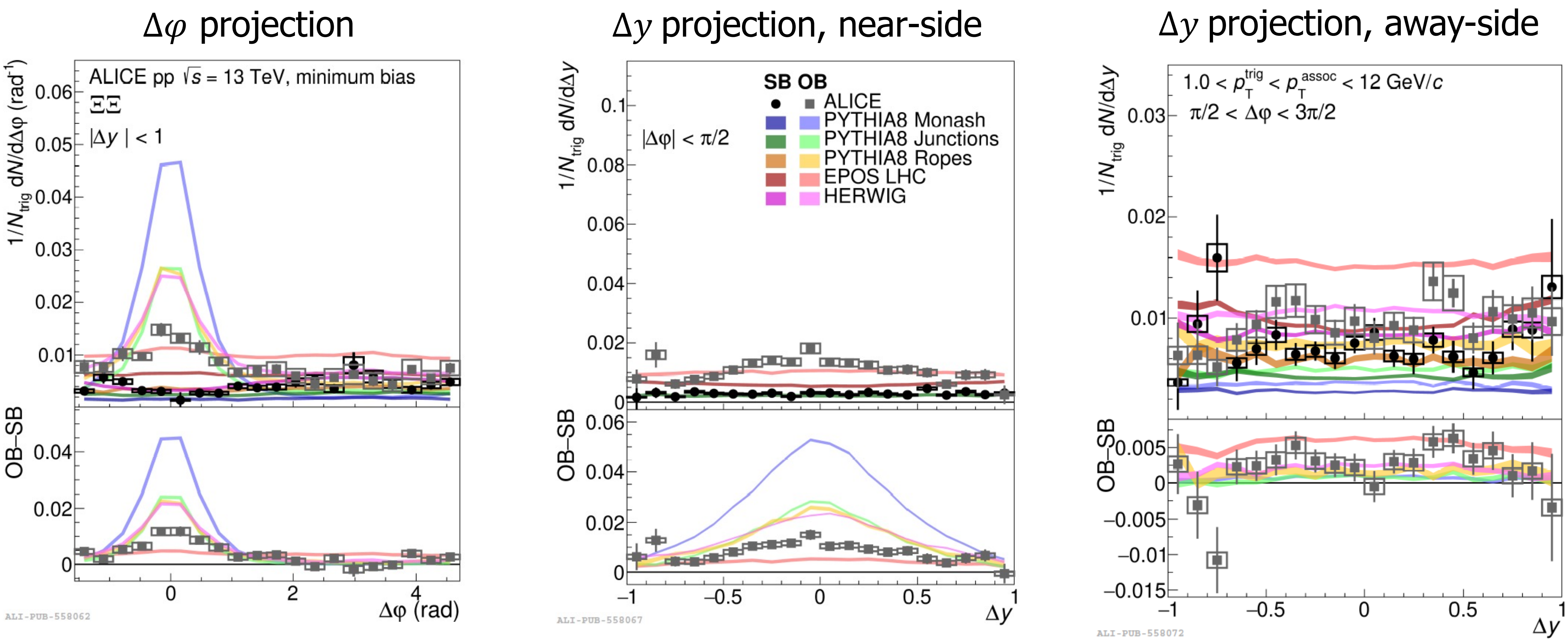
- OB-SB difference in data is described by the rope and junction models in PYTHIA 8 after the introduction of the junction mechanism unlike the results provided by the Monash tune
- The near-side peak is also observed to be broader in Ξ −baryon correlations than in Ξ −meson ones, which may indicate the early decoupling and diffusion of baryon number

Comparison to Monte Carlo models (Ξ — Λ)



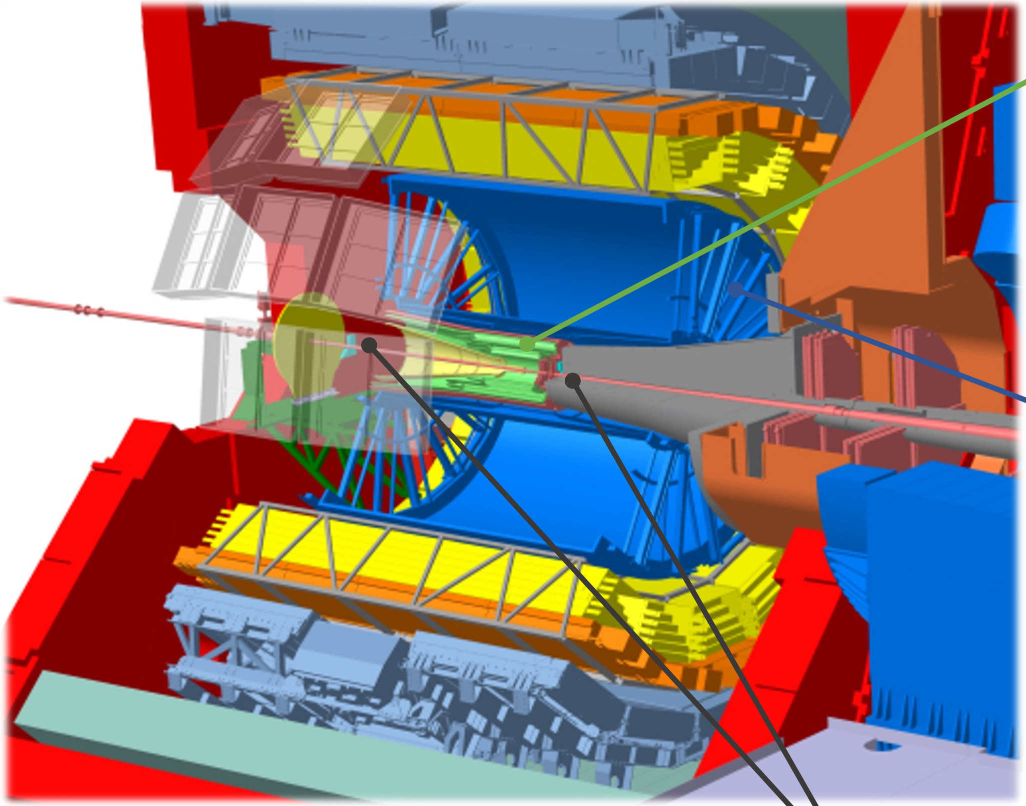
- Similar difference between data and PYTHIA as in Ξ — K correlations
- Junction model reduces the peak amplitude favoring junction/rope baryon production mechanism over the diquark breaking while still overpredicting the strength of the OB-SB correlation significantly

Comparison to Monte Carlo models (Ξ — Ξ)



- Similar difference between data and other models as in Ξ — Λ correlation
- PYHTIA 8 and HERWIG tend to overpredict the OB near-side ridge
- Near-side dip in the same-baryon-number correlations demonstrates the difficulty of producing multiple baryons (or multiple antibaryons) close in phase space

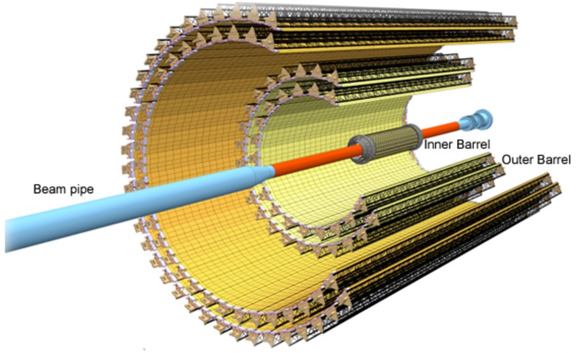
The ALICE Detector in Run 3



ITS upgrade

NIM 1032, 166632 (2022)

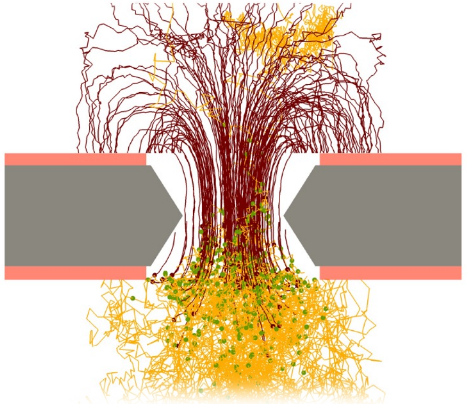
- 7 layers of silicon pixel detectors with reduced material budget
- First detection layer closer to IP + new beam pipe (ITS L0 at 22 mm)



TPC upgrade

JINST 16, P03022 (2021)

- MWPCs replaced with GEMs
- Continuous readout up to 50 kHz Pb-Pb interaction rate (x50 wrt Run 2)



New O² framework

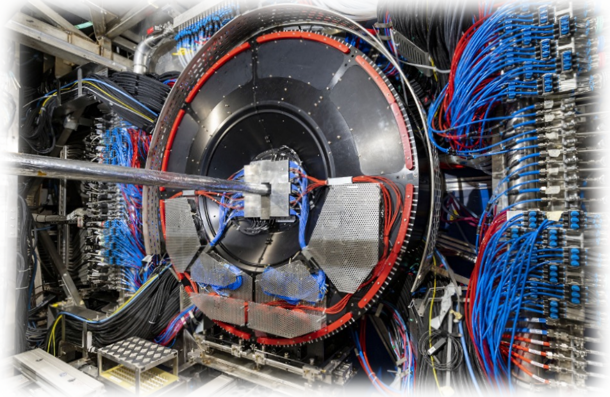
CERN-LHCC-2015-006, ALICE-TDR-019

- One common Online Offline (O^2) computing system
- Faster online and offline processing
- Increased data volume x100 wrt Run 2

NEW Fast Interaction Trigger (FIT)

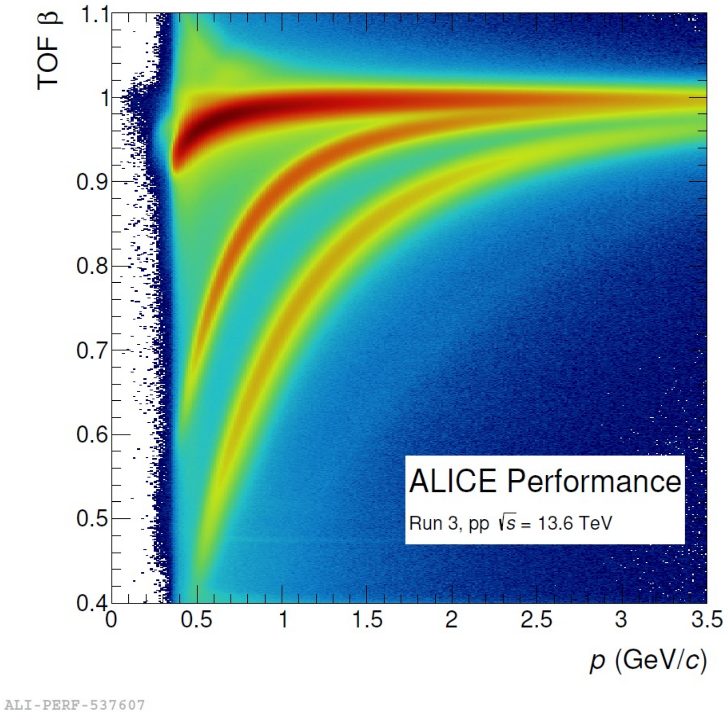
NIM 1039, 167021 (2022)

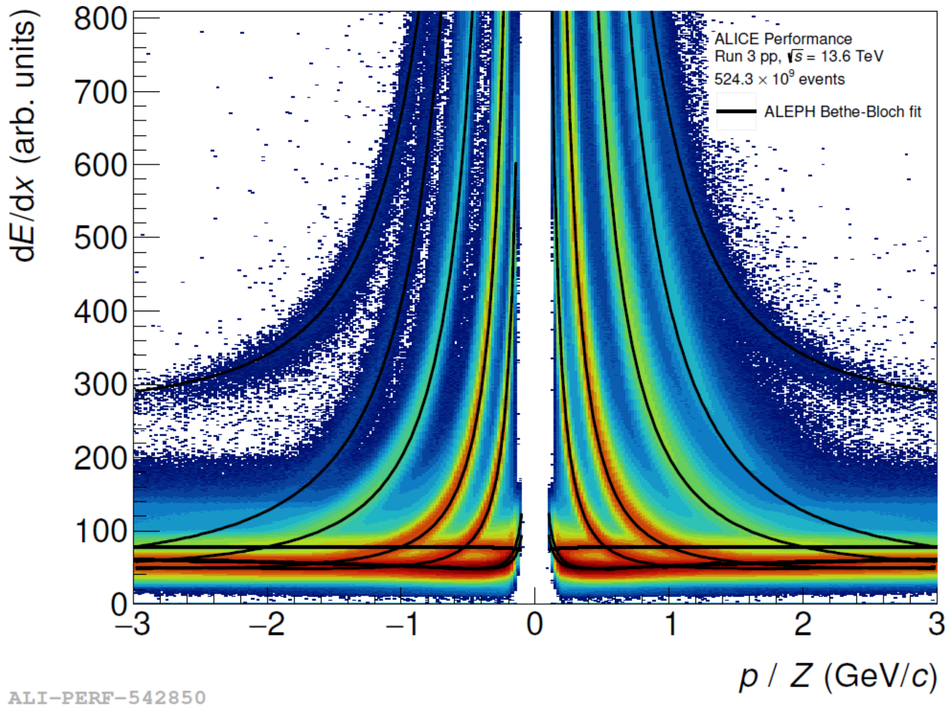
- 4 arrays of Cherenkov detectors and scintillators
- Triggering, collision time, centrality estimation

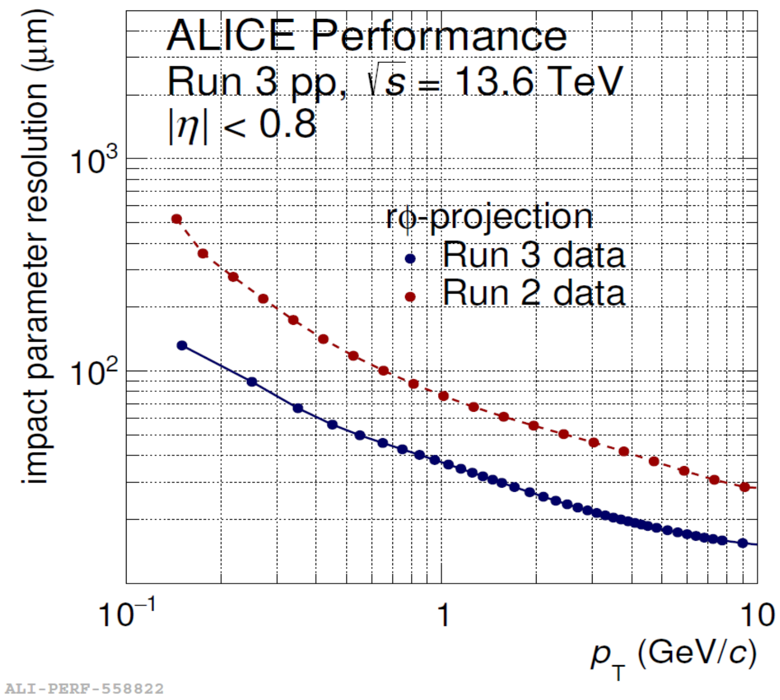


Performance of the ALICE detector in Run 3

The LHC Run 3 started in 2022, so far ALICE collected almost **x1000** events wrt Run 2 in pp data taking at **~500 kHz** in continuous readout

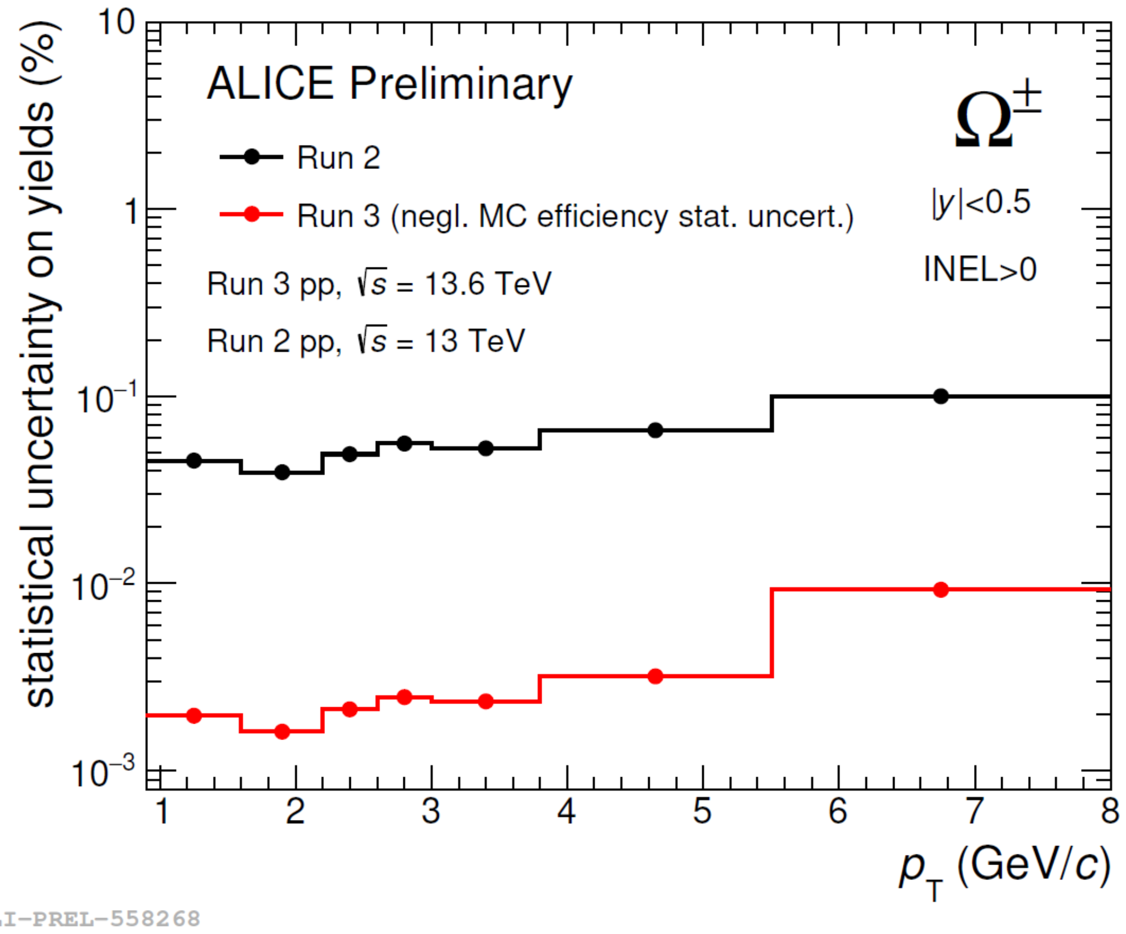


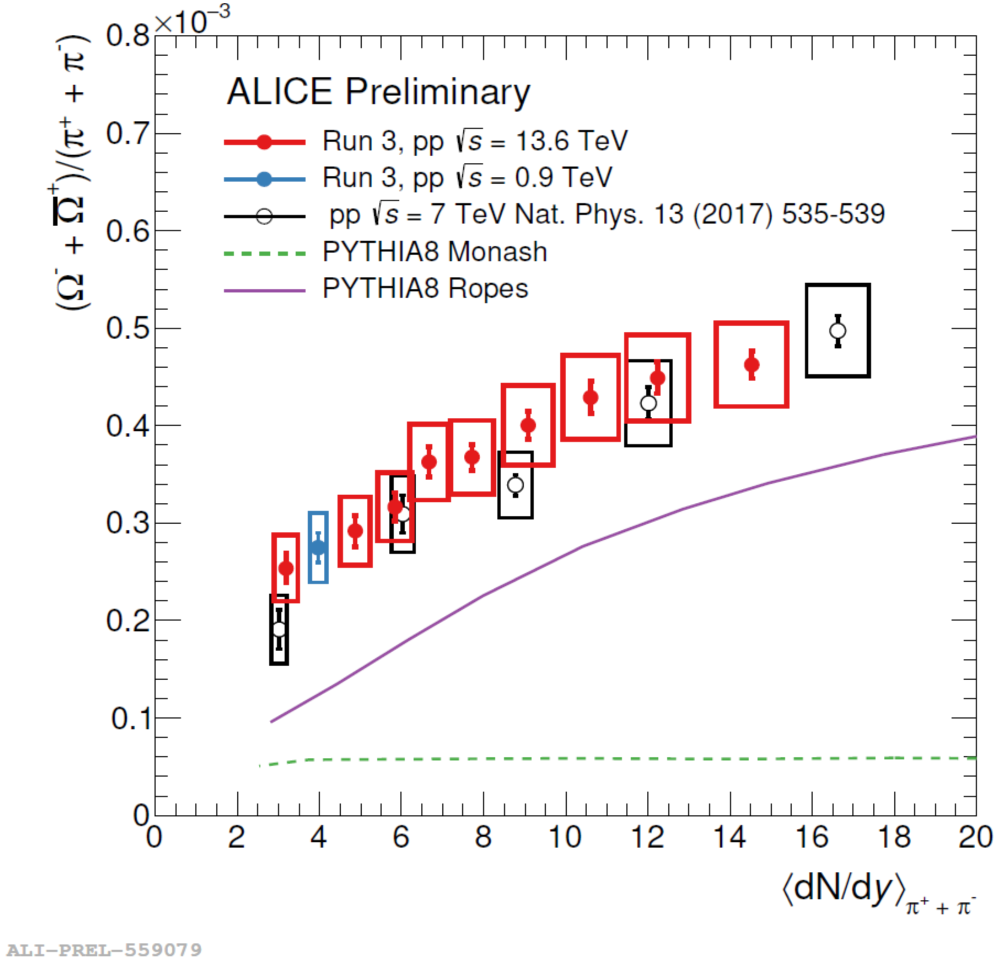




- Extend our studies further to higher multiplicities
- Increase our precision on existing studies
- Conduct studies on rare species (stay tuned for Ω — hadron correlations)

Ω/π ratio vs multiplicity



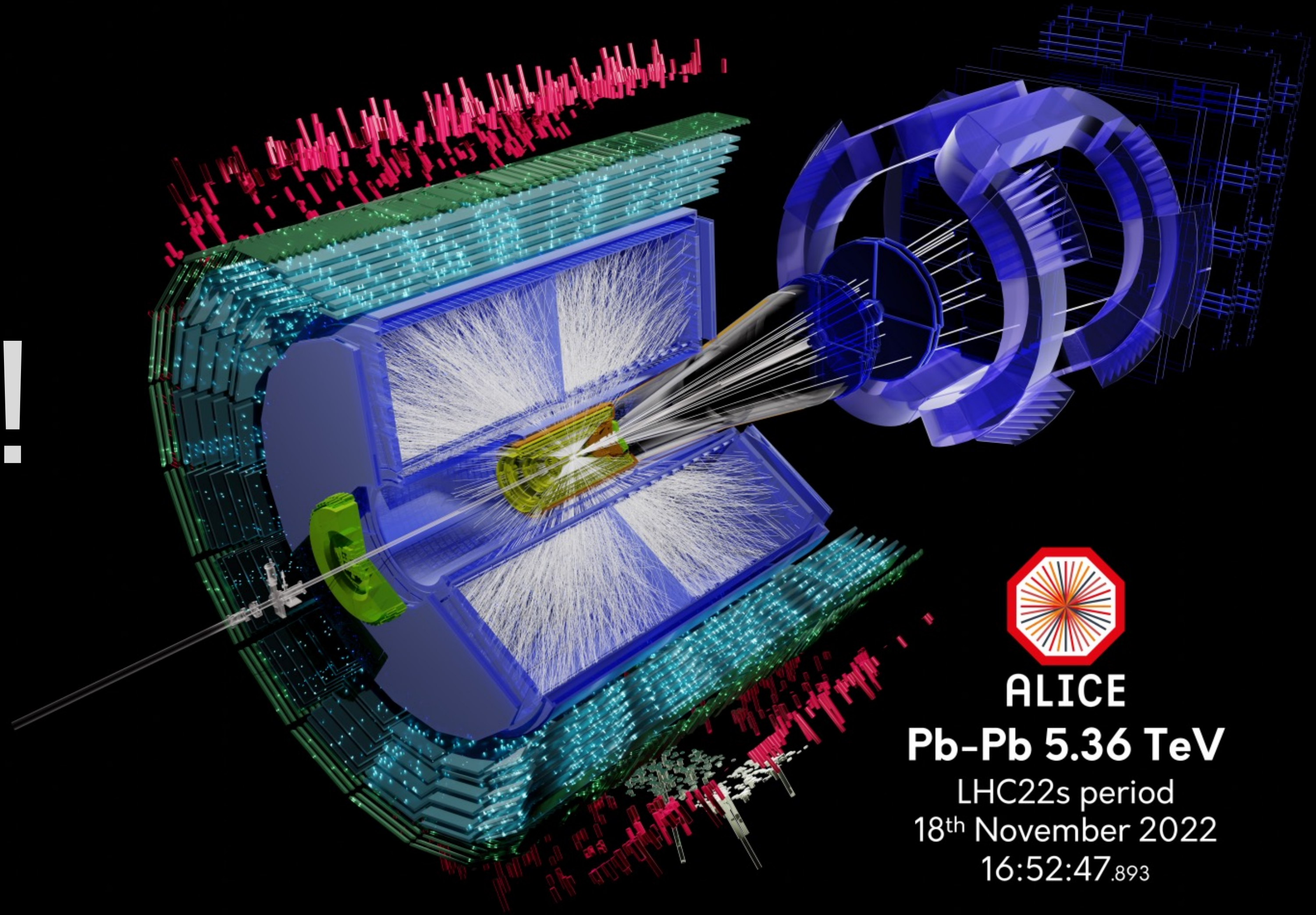


- Unprecedented multiplicity differential study of Ω/π production in pp collisions at $\sqrt{s}$ = **13.6 TeV**
- First Ω yield measured in INEL>0 pp collisions at $\sqrt{s}$ = **900 GeV** at the LHC

Summary

- **Strangeness enhancement** phenomenon **is examined** via the microscopic balance of baryon number, charge and strangeness
- **The results are compared with the predictions** from the string-breaking model PYTHIA 8, including tunes with baryon junctions and rope hadronization enabled, the cluster hadronization model HERWIG 7, and the core–corona model EPOS-LHC
- **None** of the aforementioned models **is able to describe** both qualitative and quantitative features of the **experimental data**
- Nevertheless, these **results can be used to further refine and tune models** of strangeness and baryon number production in hadronic collisions
- First measurement of $\Omega^{\pm} - \mathrm{to} - \pi^{\pm}$ ratio in pp at $\sqrt{s} = 13.6$ TeV: **unprecedented multiplicity differential study**
- **Extension** of the $\Omega^{\pm} - \mathrm{to} - \pi^{\pm}$ ratio to the lowest collision energy (900 GeV) available at the LHC

Thank you!



ALICE

Pb-Pb 5.36 TeV

LHC22s period

18th November 2022

16:52:47.893