

# Quantifying the role of strangeness in baryon production mechanisms through angular correlations in pp collisions at $\sqrt{s} = 13.6$ TeV with ALICE



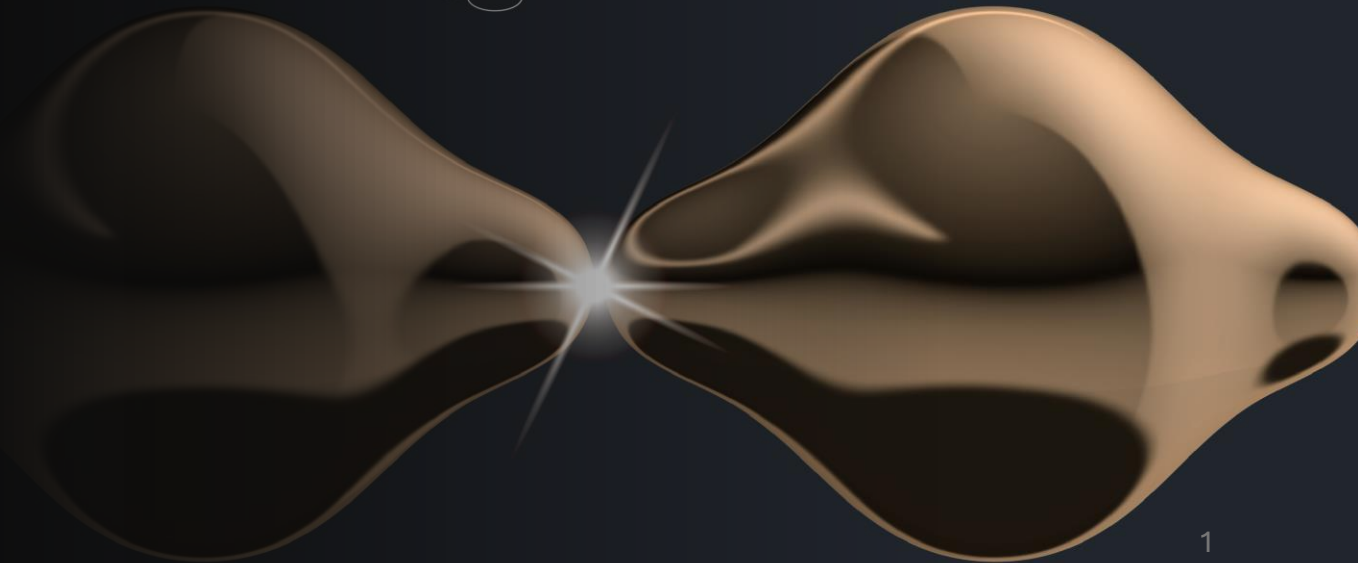
Shirajum Monira for the ALICE Collaboration

*<sup>1</sup>Warsaw University of Technology*

*Initial Stages 2025 at Taipei, Taiwan*

*10 September 2025*

 INITIAL STAGES 2025



# Two-particle angular correlation

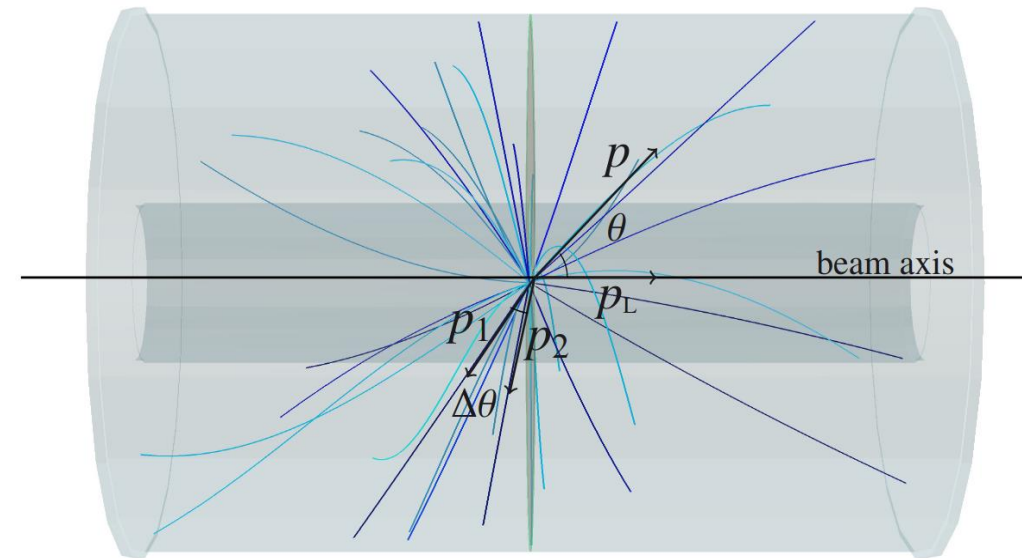
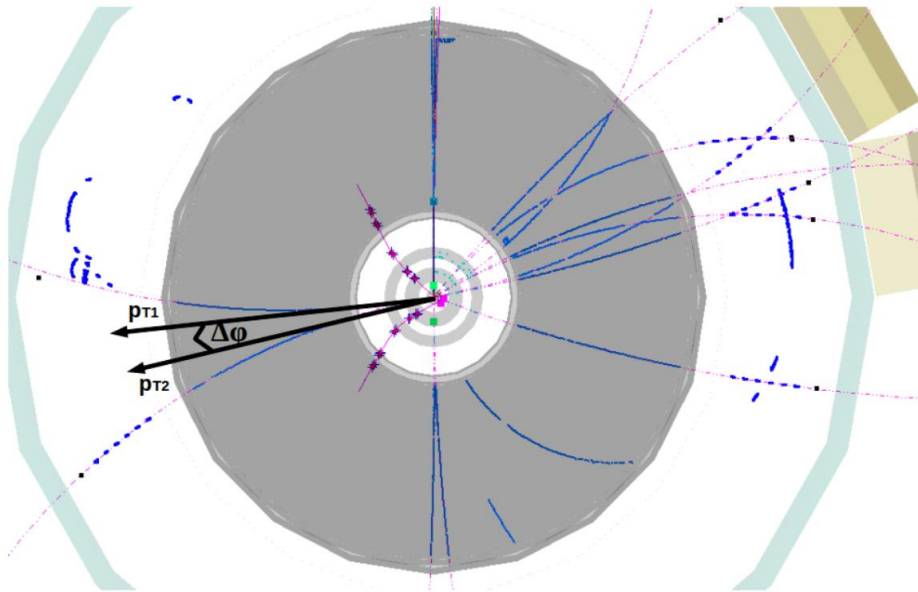
- Gives access to particle distribution in space
- Used to study a range of correlation sources
- Likelihood of observing a pair of particles as a function of  $\Delta\eta$  and  $\Delta\varphi$

Difference in pseudorapidity  $\left\{ \begin{array}{l} \Delta\eta = \eta_1 - \eta_2 \\ \Delta\varphi = \varphi_1 - \varphi_2 \end{array} \right\}$

Difference in azimuthal angle

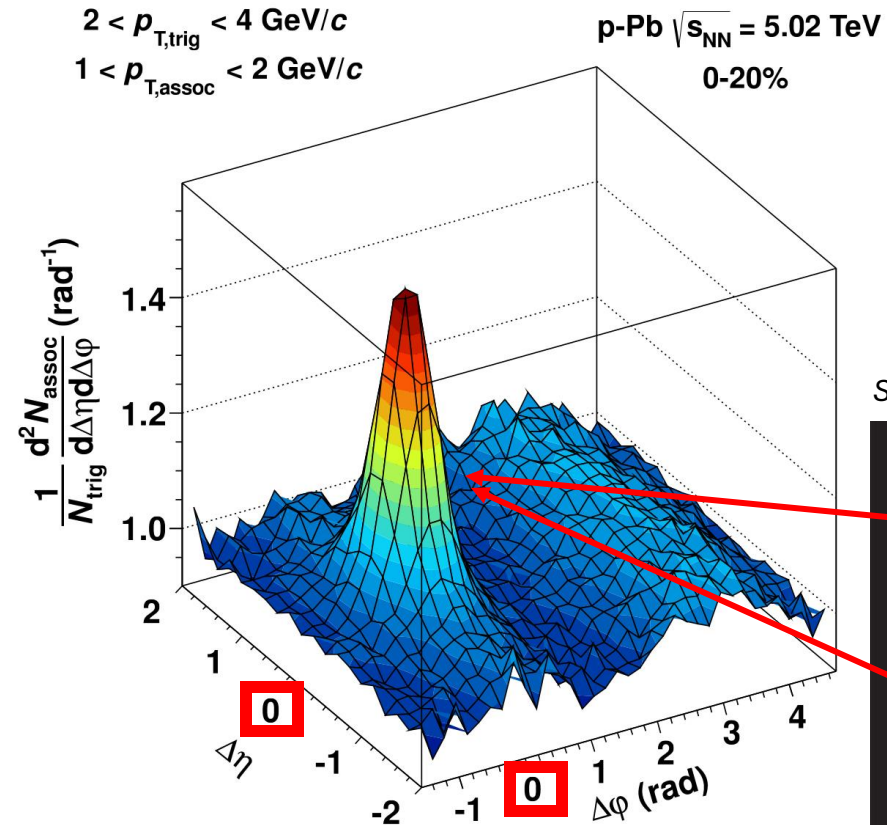
Pseudorapidity is defined as  $\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$

A. Zaborowska, CERN-THESIS-2014-401  
M. A. Janik, CERN-THESIS-2014-339

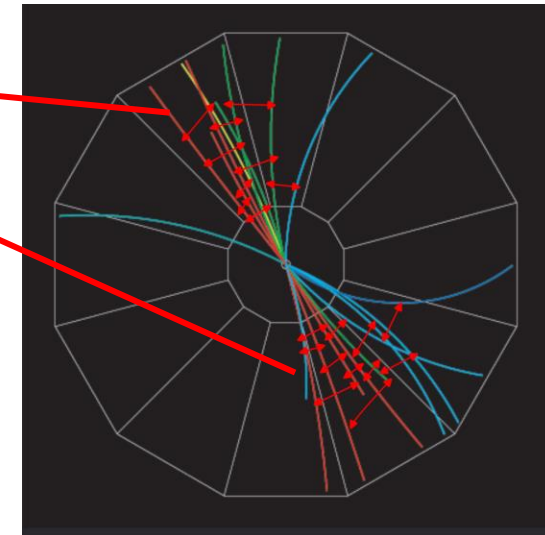


# Features of correlation functions

- Enables study of different physics mechanisms simultaneously
- During parton shower, highly energetic partons are emitted in the same direction (jet)  $\rightarrow$  peak at  $\Delta\eta\Delta\phi \approx (0, 0)$
- At  $\Delta\phi \approx \pi$ , away side-ridge comes from back-to-back jet correlations



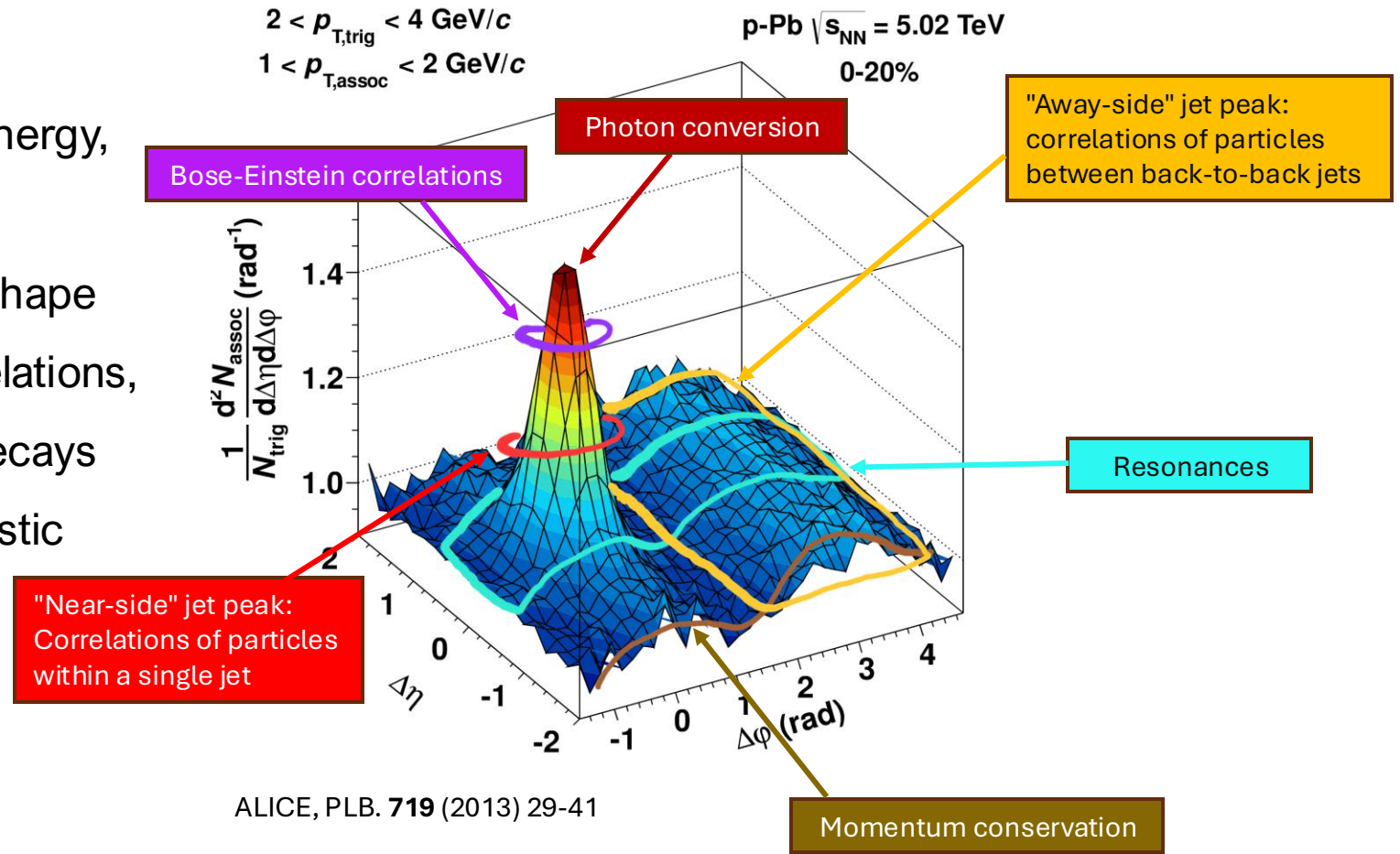
STAR event view (for demonstration)



ALICE, PLB. 719 (2013) 29-41

# Features of correlation functions

- Baseline: global conservations of energy, momentum, baryon number, etc.
- Baseline results in a  $-\cos(\Delta\varphi)$  like shape
- Other sources: Bose-Einstein correlations, mini-jets, elliptic flow, resonance decays
- Each source produces a characteristic distribution in the  $\Delta\eta\Delta\varphi$  space
- Final shape: contributions from all correlation sources

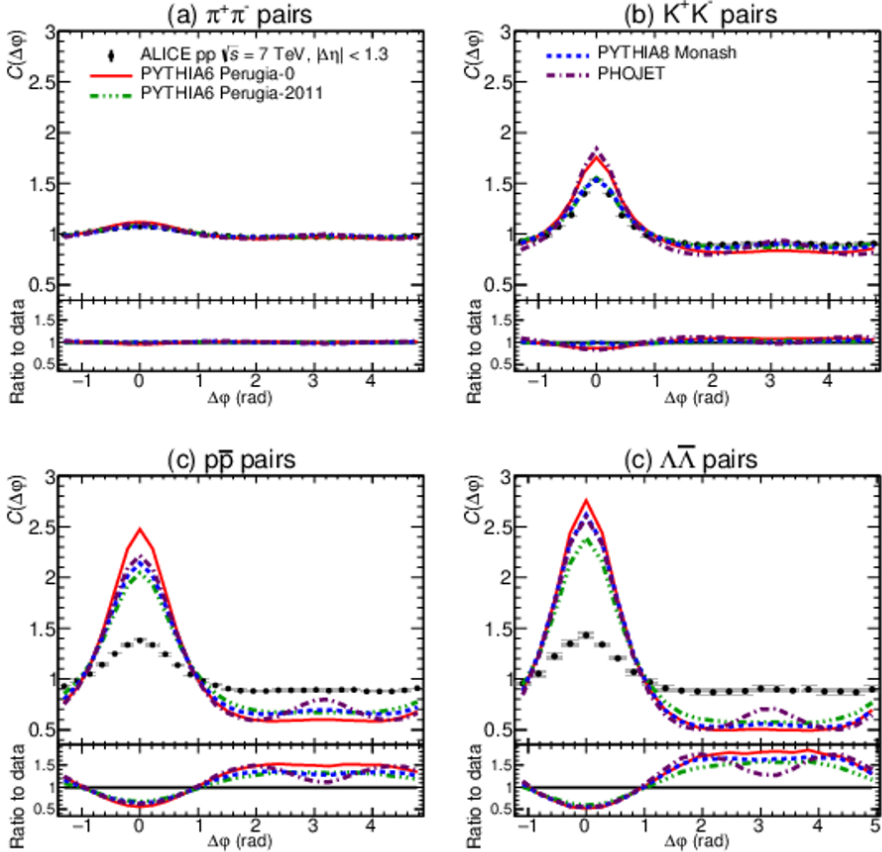


# Motivation

'Insight into particle production mechanisms via angular correlations of identified particles in pp collisions at  $\sqrt{s} = 7$  TeV'

Unlike-sign

ALICE Eur. Phys. J. C77 (2017) 569



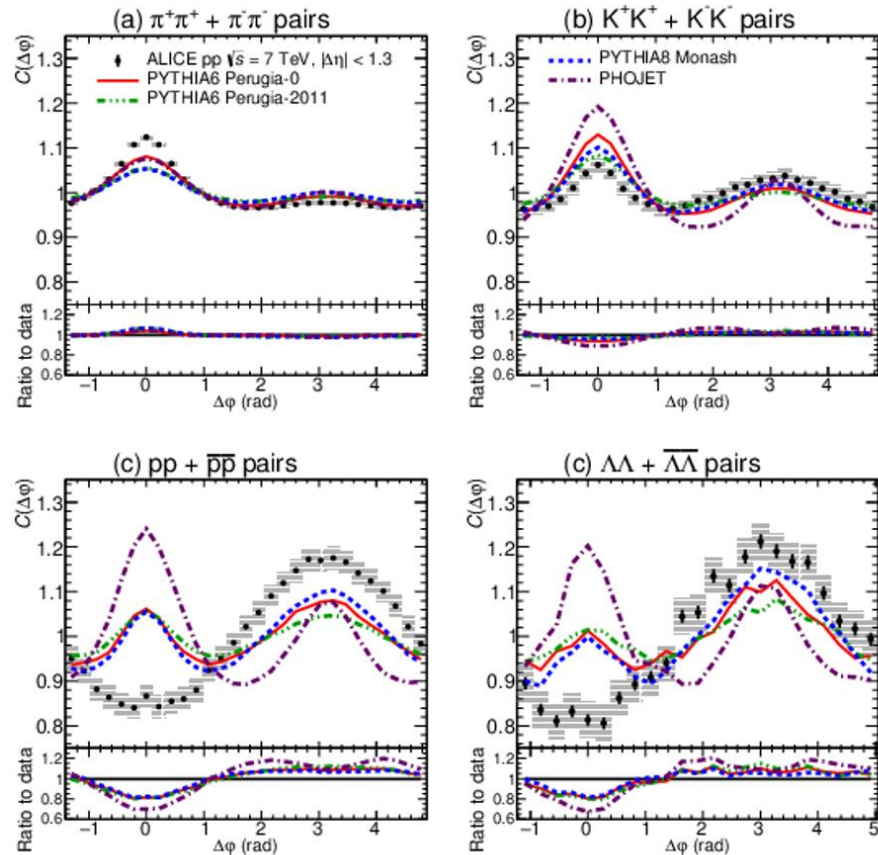
- Run 1: studied all combinations of  $p$ ,  $\pi$ ,  $K$  and  $\Lambda$
- **Meson** and **baryon** particle/anti-particle pairs: a distinct near-side peak
- Only magnitude and width of the peak was observed to differ
- Well reproduced by the Monte Carlo

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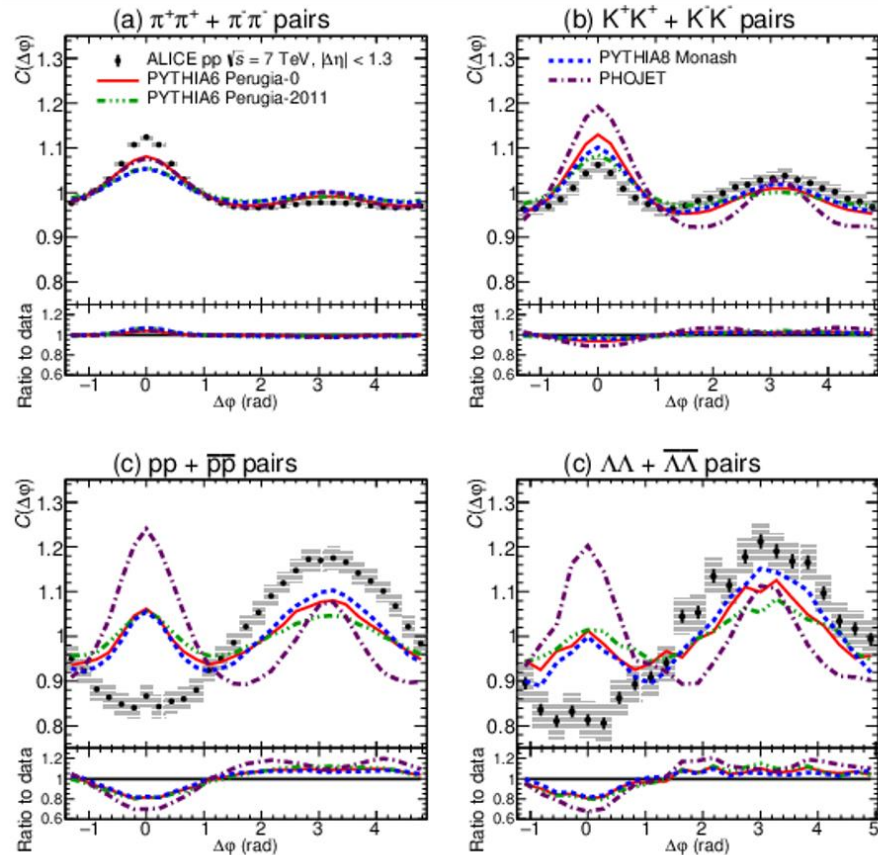
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- **Meson** same-sign pairs: a distinct near-side peak
- **Baryons** with the same baryon number: **a near-side depression instead of the peak!**
- MC models fail to reproduce this effect

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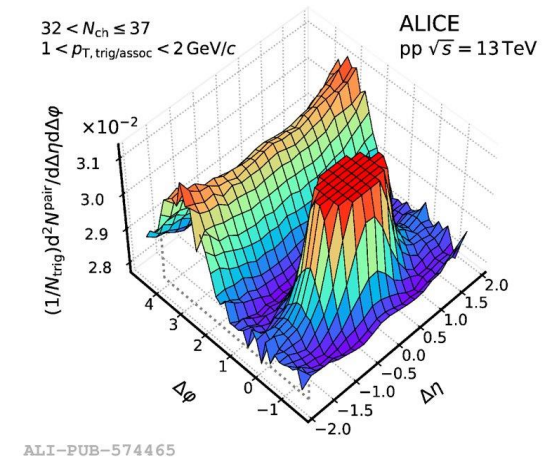
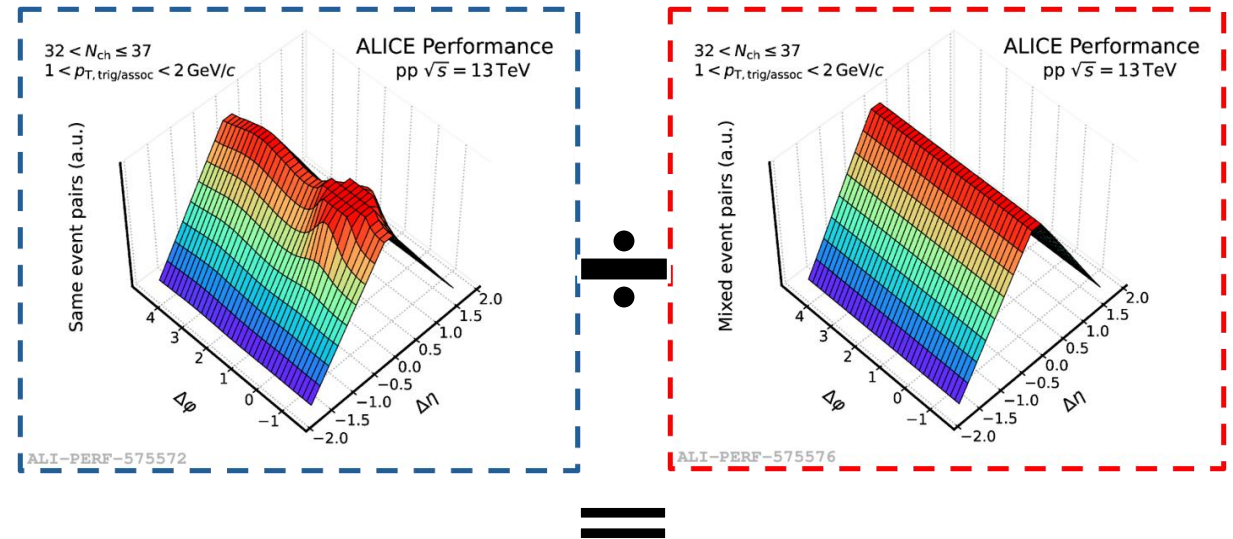


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- **Meson** same-sign pairs: a distinct near-side peak
- **Baryons** with the same baryon number: **a near-side depression instead of the peak!**
- MC models fail to reproduce this effect
- **Does anti-correlation structure appear in other baryons?**
- **Does strangeness affect this anti-correlation effect? If yes, to what extent?**

# Methodology

- Use event-mixing technique to correct for pair acceptance effects
- Same-event distribution: pair of particles coming from the same-event
- Mixed-event distribution: each particle of the pair comes from a different event
- Final correlation: **same-event** pair distribution normalized by the **mixed-event** distribution

$$C(\Delta\eta, \Delta\phi) = \frac{N_{\text{pairs}}^{\text{mixed}} S(\Delta\eta, \Delta\phi)}{N_{\text{pairs}}^{\text{same}} B(\Delta\eta, \Delta\phi)}$$



# Analysis details

Data: pp  $\sqrt{s} = 13.6$  TeV recorded in 2022 & 2023

## Event Selection

- Minimum bias (0 –100%)
- **59.7B** accepted events for V0s
- **227B** accepted events for Cascades

## Track Selection (Protons)

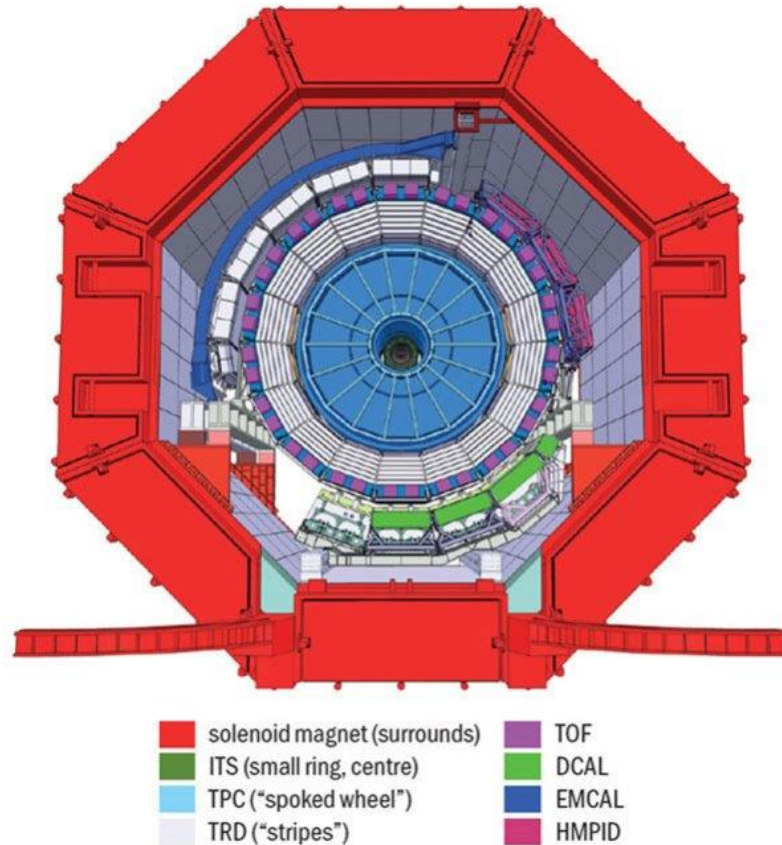
- $0.5 < p_T < 4.0$  GeV/c
- $|\eta| \leq 0.8$

## V0 Vertex Selection

- $0.16 < p_T < 4.0$  GeV/c
- $|\eta| \leq 0.8$

## Cascade Selection

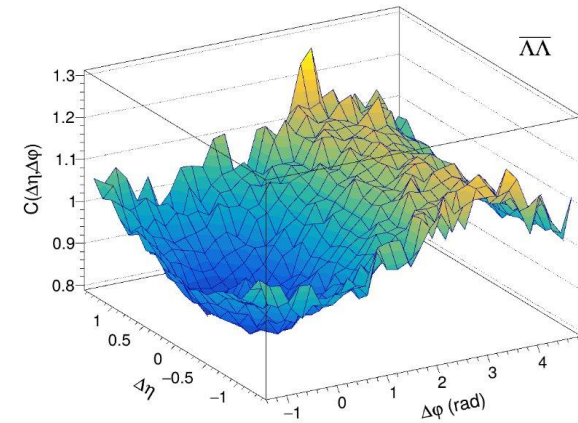
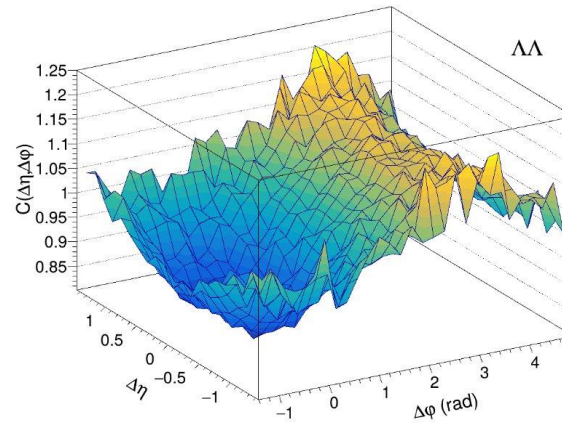
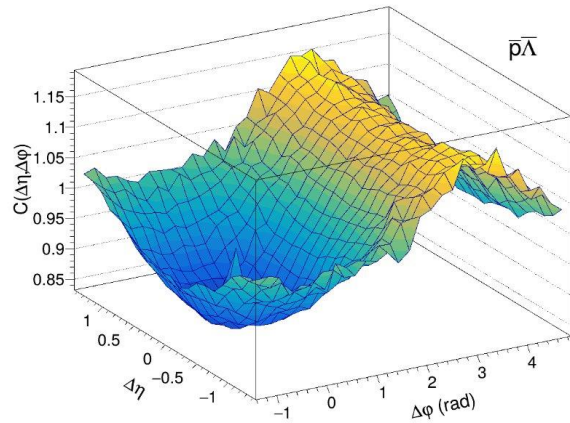
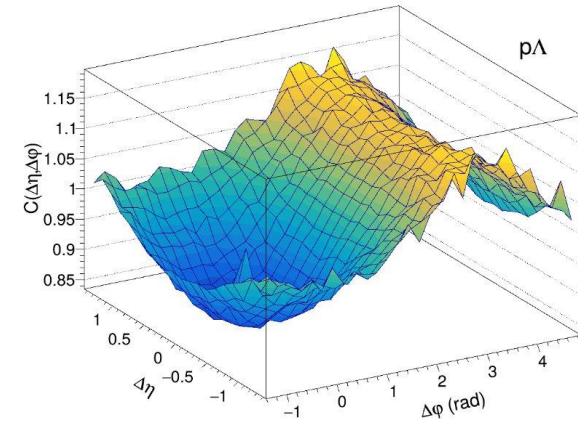
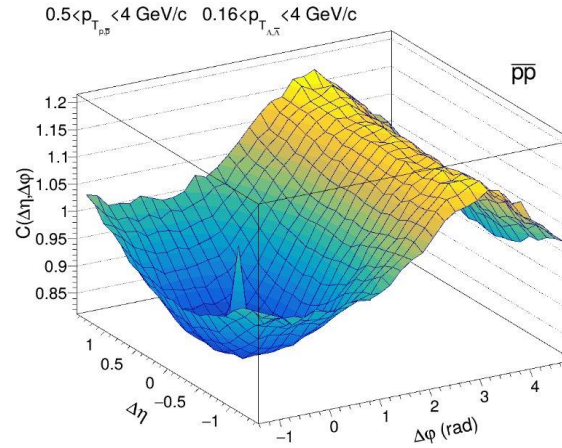
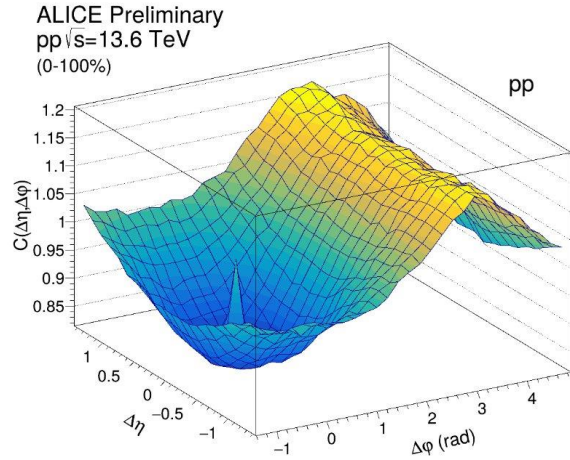
- $0.9 < p_T < 4.0$  GeV/c
- $|\eta| \leq 0.8$
- Competing mass rejection



Tracking: **TPC+ITS**  
 Particle Identification: **TOF**

# p $\Lambda$ correlation results

Prominent near-side depression instead of the peak, combined with an away-side ridge!

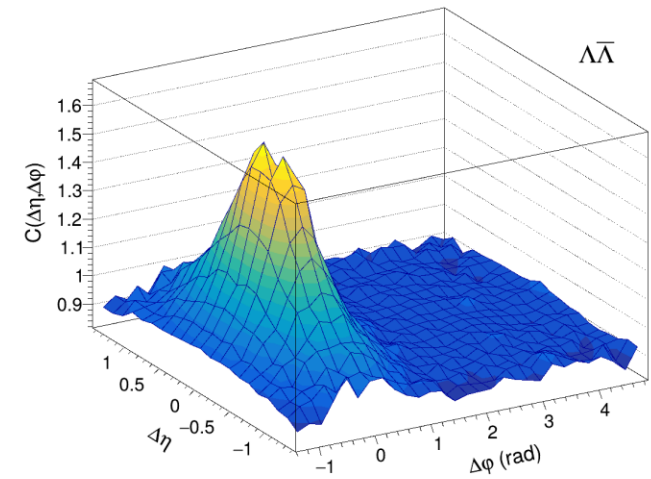
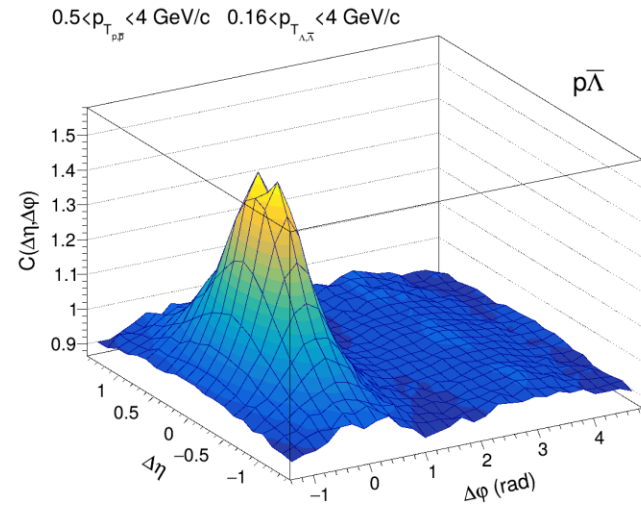
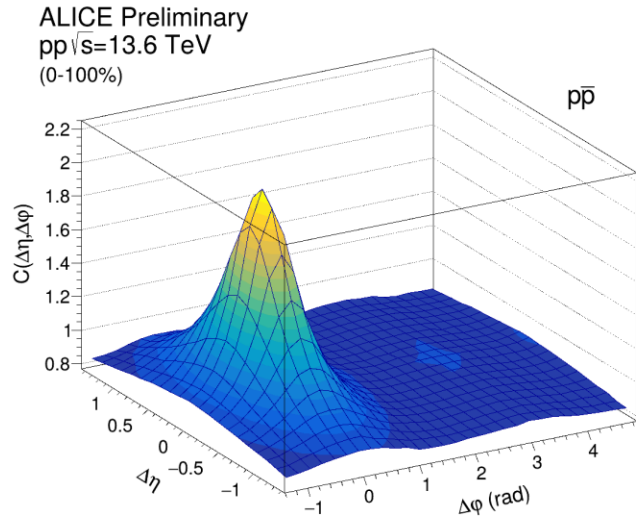


New Run 3

ALI-PREL-587437

# p $\Lambda$ correlation results

A distinct near-side peak combined with a weak away-side structure!

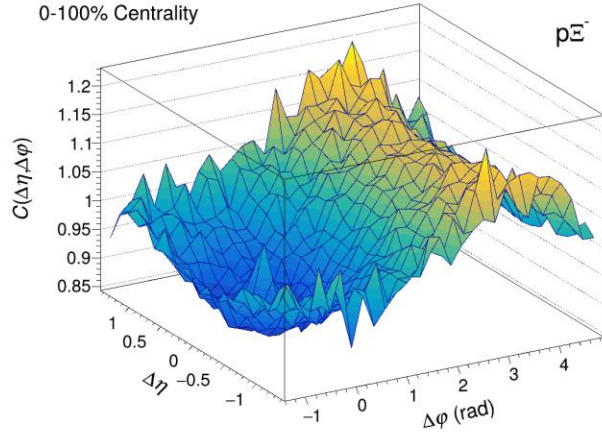


ALI-PREL-587442

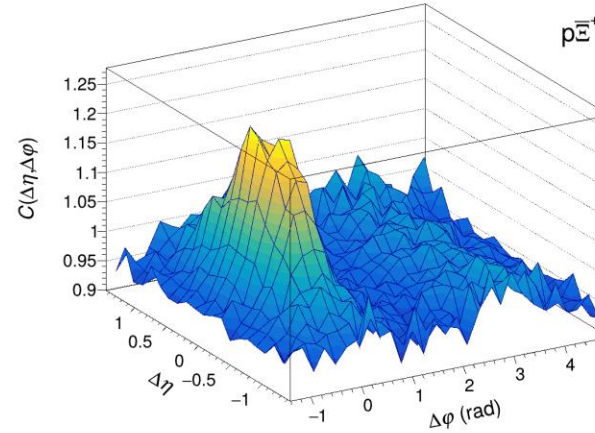
New Run 3

# $p\Xi$ correlation results

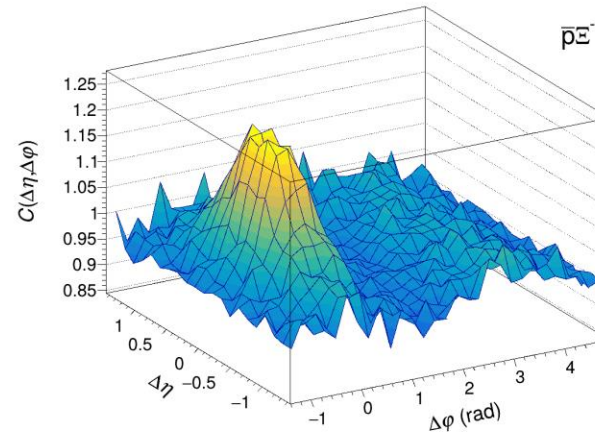
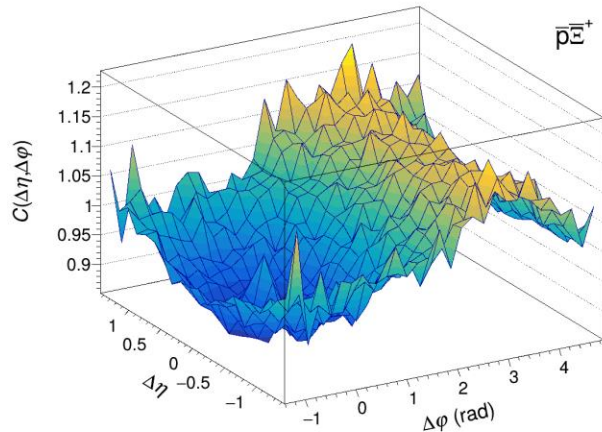
ALICE Preliminary  
 $pp\sqrt{s}=13.6$  TeV  
 0-100% Centrality



$0.5 < p_{T,p} < 4$  GeV/c  $0.9 < p_{T,\Xi} < 4$  GeV/c



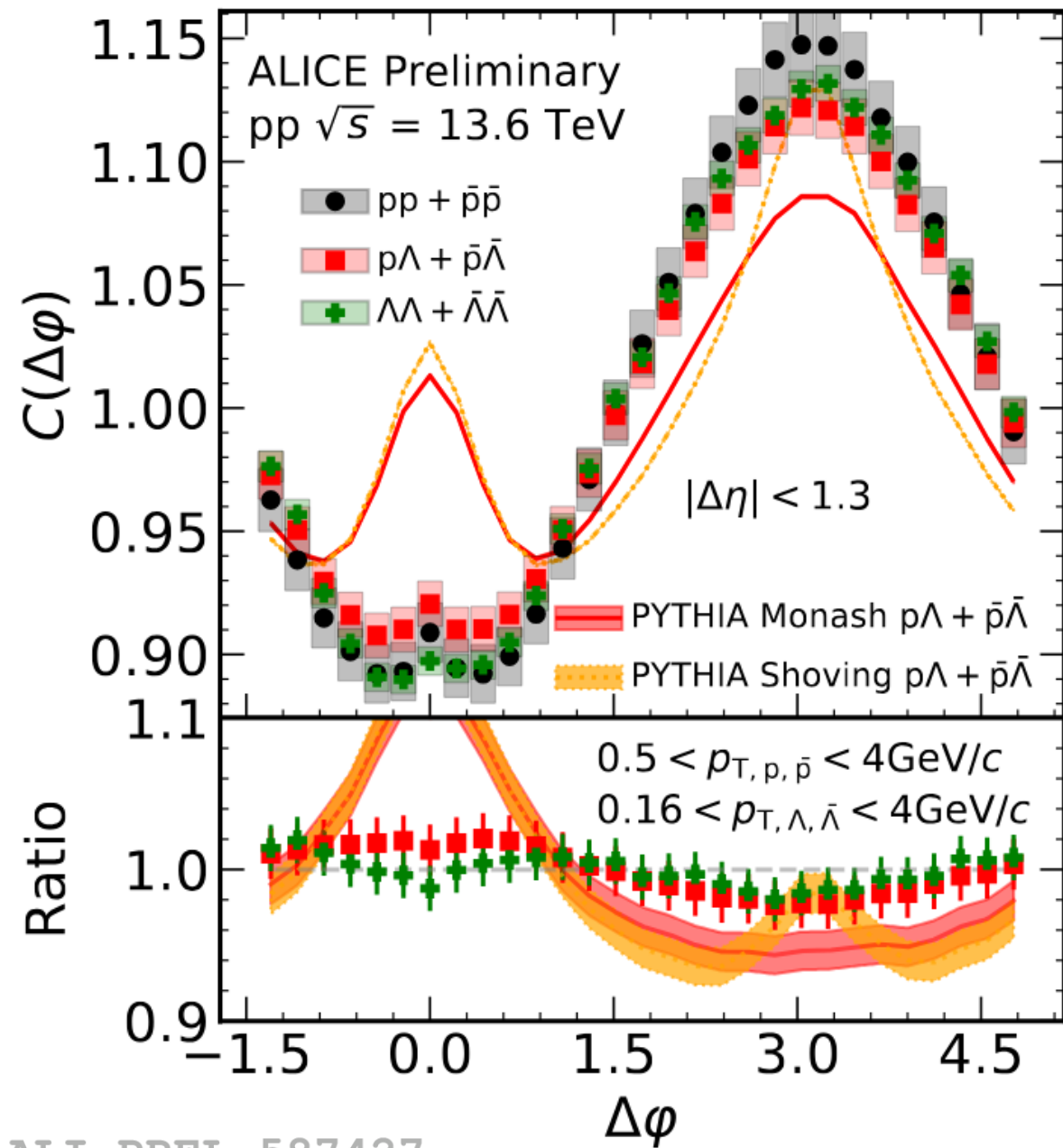
New Run 3



- A strong anti-correlation structure at the near-side region persists for  $p\Xi$  pairs with the same baryon number
- Pairs with non-identical baryon number show a distinct peak at the near side

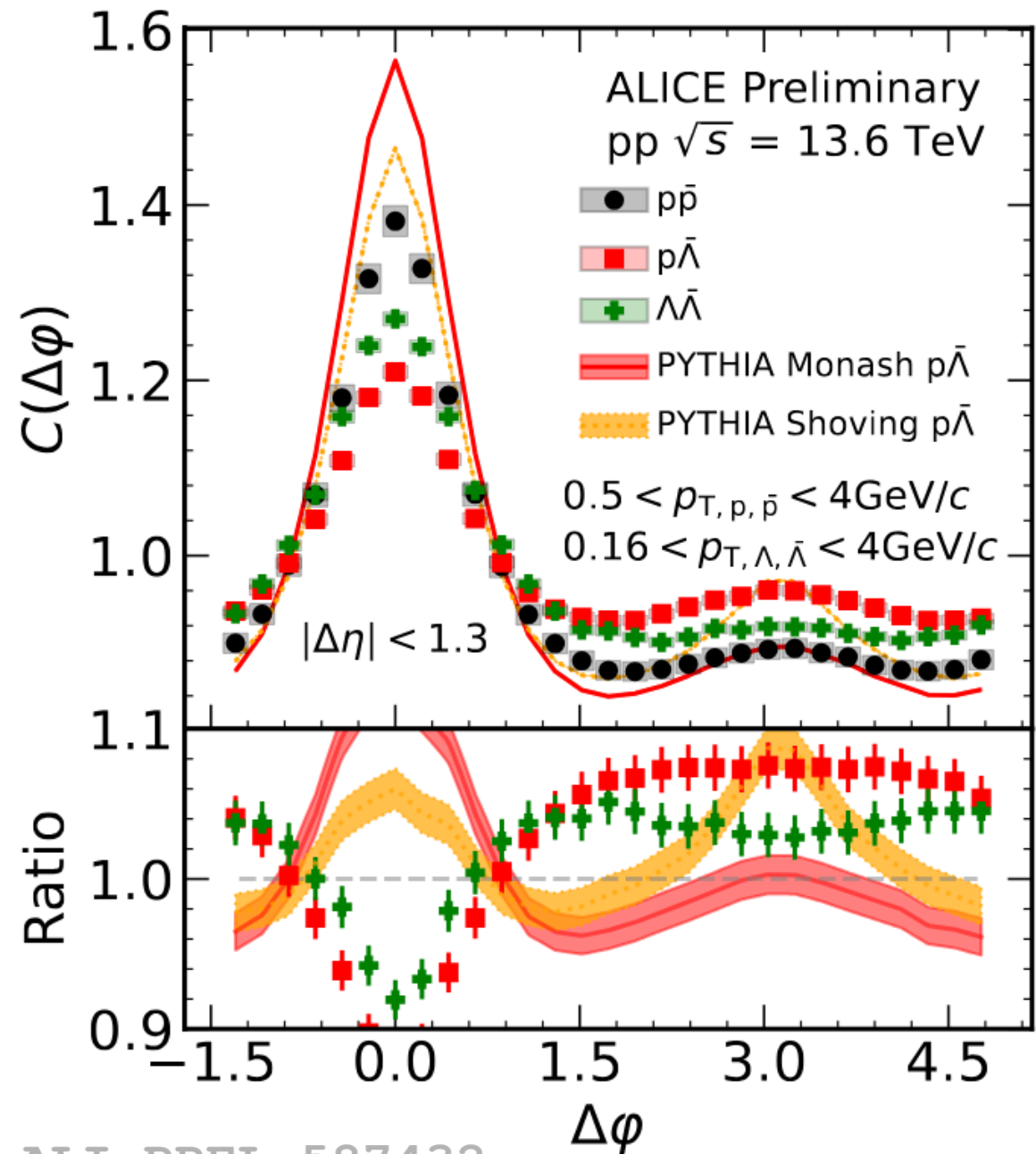
## $\Delta\eta$ projections for same-sign $p\Lambda$ and $\Lambda\Lambda$ pairs

- Different pairs show compatibility within uncertainty
- Consistent results with the Run 1 published data [ALICE Eur. Phys. J. C77 (2017) 569] with improved statistical uncertainty
- Anti-correlation in (0,0) - probability of producing two baryons close in phase space is lower than in other directions!
- PYTHIA models predict a positive correlation in the near-side region and fail to capture the dependence on  $\Delta\varphi$



ALI-PREL-587427

New Run 3



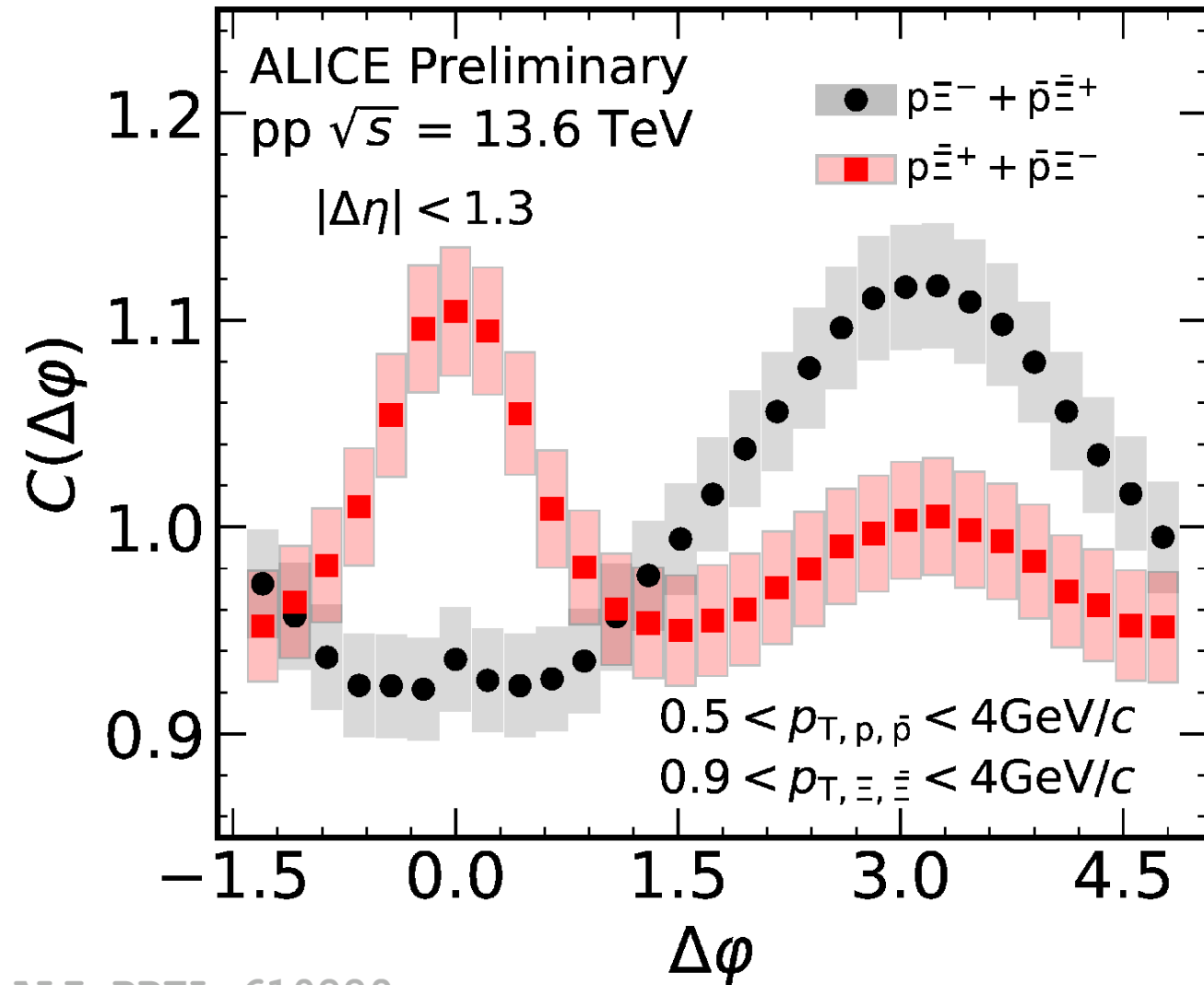
## $\Delta\eta$ projections for unlike-sign $p\bar{\Lambda}$ and $\Lambda\bar{\Lambda}$ pairs

- Distinct near-side peaks suggest significant mini-jet contributions
- Different pairs differ in magnitude and width
  - Proton–anti-proton largest in the near-side and lowest in the away-side
  - Proton–anti-lambda lowest in the near-side and highest in the away-side
- PYTHIA models reproduce the general shape of the correlation functions; however, the magnitude is over- or underestimated.

New Run 3

## $\Delta\eta$ projections for $p\Xi$ pairs

- Distinct near-side peak for pairs with opposite baryon number
- Strong anti-correlation observed for p and  $\Xi$  (dss) pairs with the same baryon number
- Previous Run 2 results [*JHEP* 09 (2024) 102] – anti-correlation visible for both high and low multiplicities (not comparable to Run 3 results)



ALI-PREL-610229

# Conclusion

- Anti-correlation persists in heavier baryon-baryon and anti-baryon-anti-baryon pairs
- New precision results indicate that
  - jet fragmentation may not be the dominant mechanism in baryon production
  - the mechanism(s) which would produce a peak dominated by effects associated with mini-jets are either not present or produce a very different correlation shape
  - Combination of energy and baryon-number conservation is not enough to explain this anti-correlation structure
- While some aspects of the experimental data are described quantitatively, no model can reproduce all features of the data
  - string melting version of a multi-phase transport (AMPT) model with improved quark coalescence [*Phys. Rev. C* 98, no.3, 034912 (2018), *Phys. Lett. B* 829, 137063 (2022)]

# Summary

- Angular correlations for all combinations of p,  $\Lambda$  and  $\Xi$  pairs are measured in Run 3 pp collisions at  $\sqrt{s} = 13.6$  TeV
- New precision results confirm existence of a clear anti-correlation structure for heavier baryon pairs with the same baryon number
- Work-in-progress to extend the correlation measurements for  $\Omega$

**Thank you!**

Backup

# Selection Cuts

Data: pp  $\sqrt{s} = 13.6$  TeV recorded in 2022 and 2023

Trigger: sel8,

## Event Selection

- Minimum bias (0 –100%)
- $|V_z| < 10$  cm

## Track Selection

- Protons
  - Global track cuts
    - $0.5 < p_T < 4.0$  GeV/c
    - $|\eta| \leq 0.8$
    - DCAxy < 0.1 cm
    - DCAz < 0.2 cm
  - Sigma < 3 (TPC, TOF when  $p > 0.75$  GeV/c)
  - Number of TPC clusters 80
  - Number of crossed TPC rows 80
  - Number of ITS clusters 6

## Cascade Child Selection

- $\Xi (\Lambda, \pi), \Omega (\Lambda, K)$ 
  - Sigma < 3 (TPC)
  - $|\eta| \leq 0.8$
  - Has TOF check option added
  - Number of TPC clusters 70
  - Same selection cuts as the track particle

## Cascade Selection

- Cascade candidate ( $\Xi, \Omega$ )
  - $0.9 < p_T < 4.0$  GeV/c
  - $|\eta| \leq 0.8$
  - DCA between cascade daughters < 1.6 cm
  - DCA of positive daughter to PV > 0.04 cm
  - DCA of negative daughter to PV > 0.04 cm
  - DCA of bachelor track to PV > 0.05 cm
  - DCA of V0 to PV > 0.01 cm
  - DCA between V0 daughters < 1.6 cm
  - Cascade Cosine of Pointing Angle  $\geq 0.99$
  - Cascade transverse radius > 0.7 cm
  - Cascade invariant mass cut for  $\Xi$   $1.315 < m_{inv} < 1.328$  GeV/c<sup>2</sup>
  - Mass rejection window for  $\Omega$   $1.64 < m_{inv} < 1.71$  GeV/c<sup>2</sup>
  - Cascade invariant mass cut for  $\Omega$   $1.666 < m_{inv} < 1.678$  GeV/c<sup>2</sup>
  - Mass rejection window for  $\Xi$   $1.29 < m_{inv} < 1.35$  GeV/c<sup>2</sup>