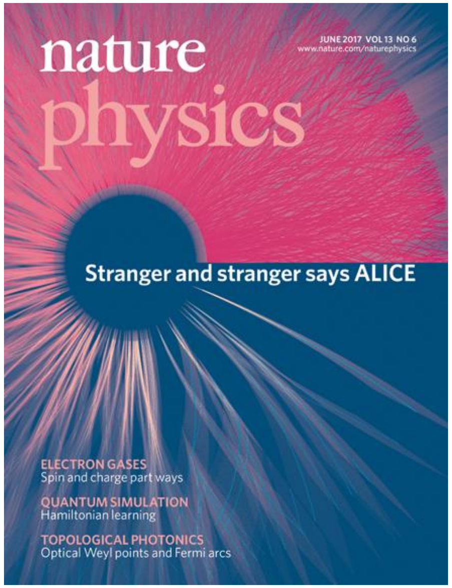
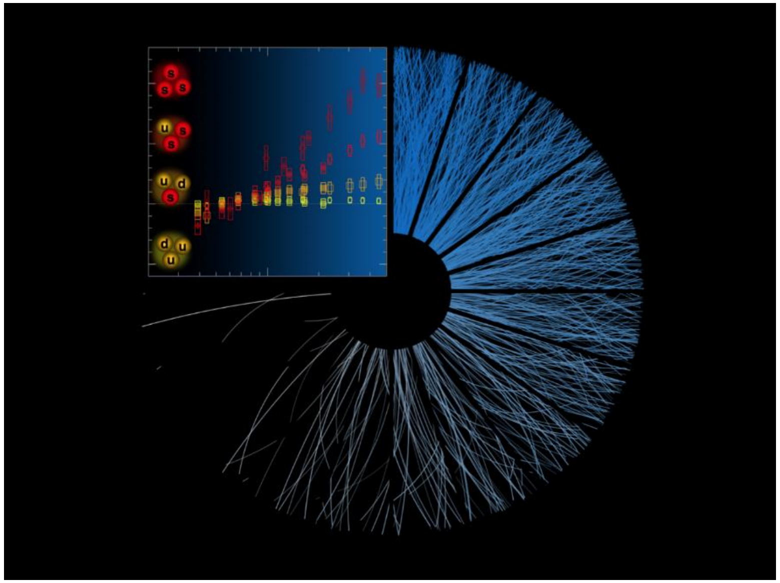



# QCD short talk ALICE

Peter Christiansen
Lund University



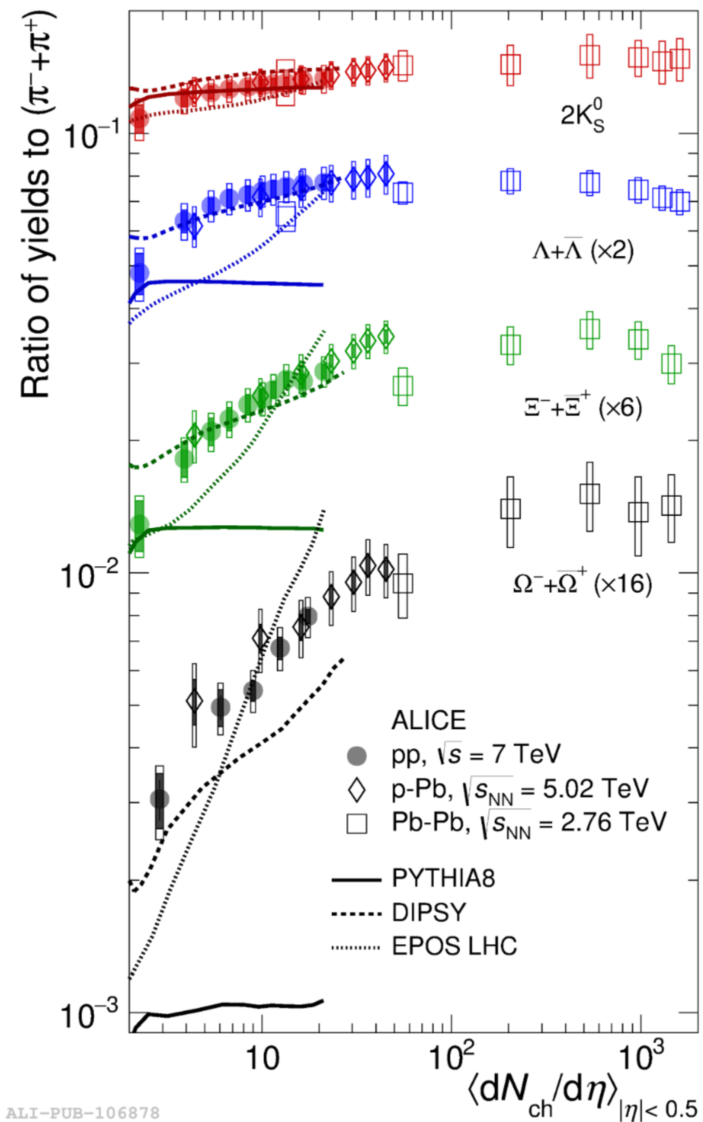
# Strangeness production in small systems - from revolution to resolution

Peter Christiansen
Lund University

ALICE

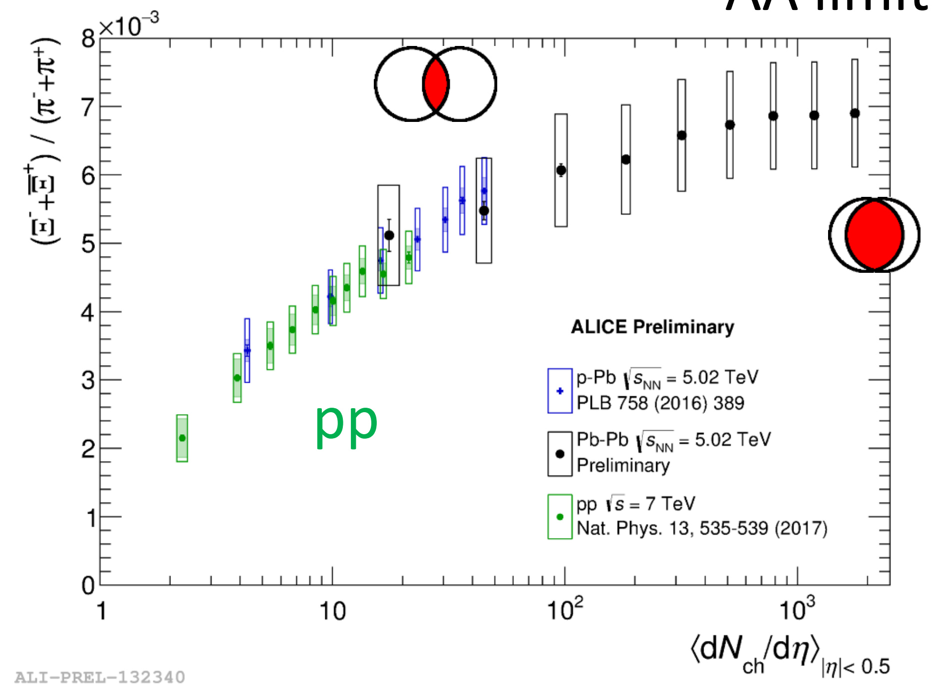
# Focus mainly on Ξ in this presentation

Nature Physics 13 (2017) 535



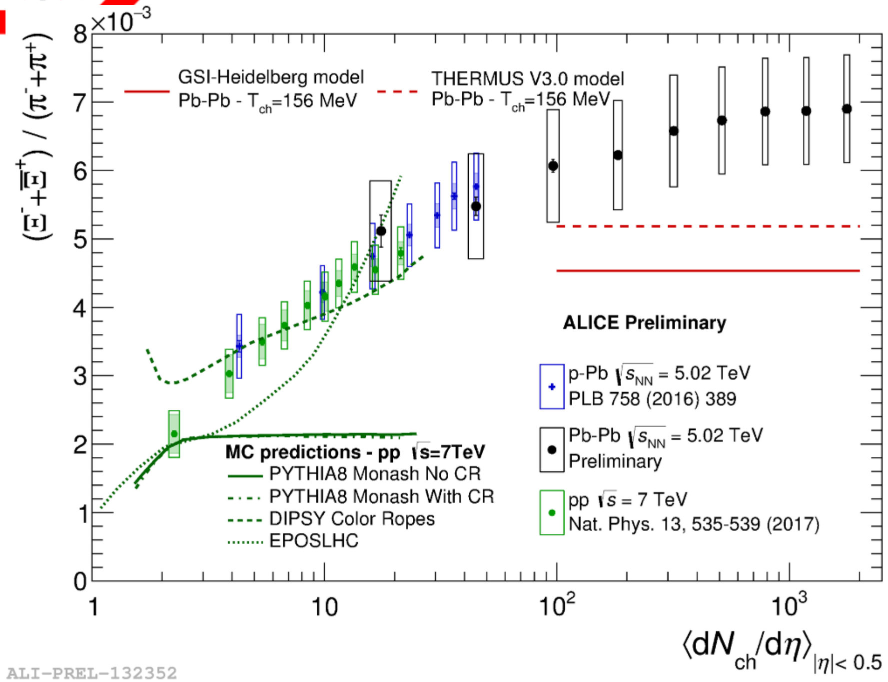

$$\frac{(ssd + \bar{s}\bar{s}\bar{d})}{(\bar{u}d + u\bar{d})}$$

AA limit




Importantly, even in pp collisions we see a large change

# What do the models say?



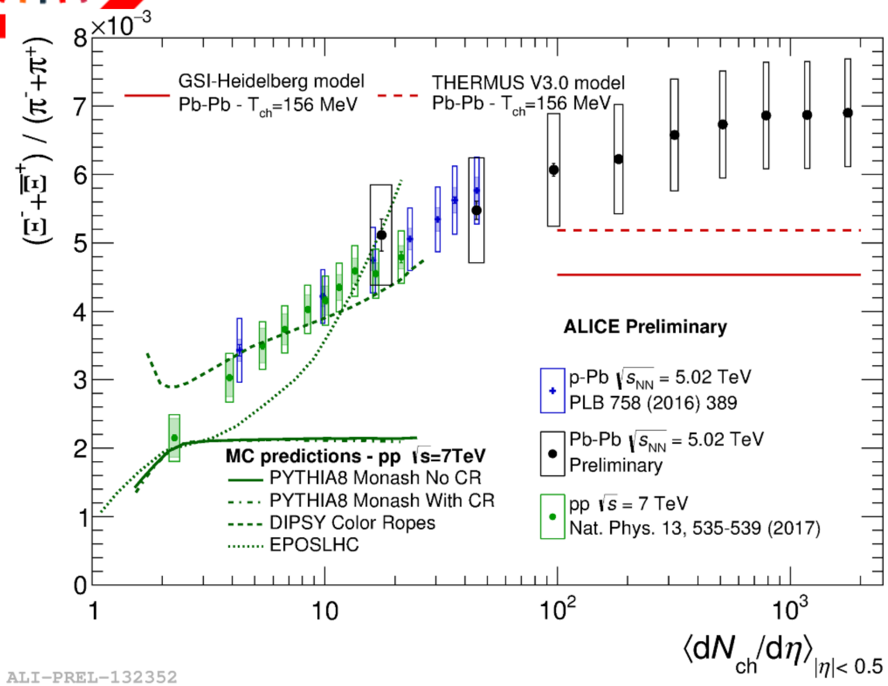

PYTHIA:
pp
$\sim \sum_{N_{MPI}}$ parton−parton interactions

predicts "more of the same" as one could expect from asymptotic freedom.

The revolution is that this is wrong!

Strangeness: from revolution to resolution (P. Christiansen)

# What do the models say?




PYTHIA:
pp
$\sim \sum_{N_{MPI}}$ parton−parton interactions

predicts "more of the same" as one could expect from asymptotic freedom.

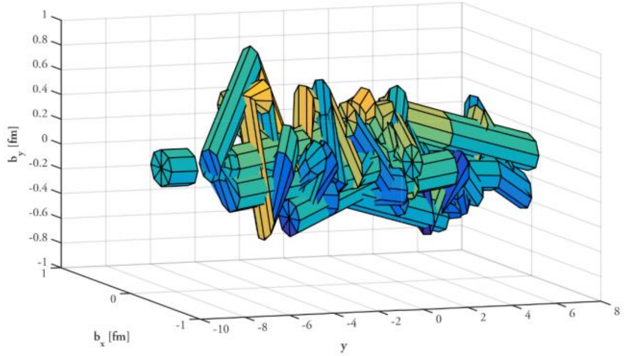
The revolution is that this is wrong!

- DIPSY/Angantyr: "Microscopic extension of PYTHIA"
  2+ strings can merge into 1 rope → Increases string/rope tension
  → Enhances production of the heavier strange quarks

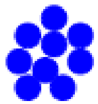
- EPOS LHC (and EPOS 3): introduces QGP phase (a la GSI-Heidelberg and THERMUS models). Rise is interplay between corona ("PYTHIA" like) and QGP-like core.

# How to make progress?

Microscopic vs Macroscopic



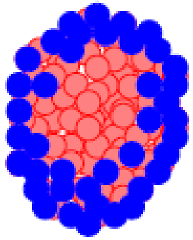
Picture from C. Bierlich
(string radii ~3.5 times too small!)



Low mult pp

corona
core

High mult pp



Pictures from K. Werner

- New more differential measurements:
  - $R_T$: a tool that can control the Underlying Event (UE)
  - Separate production into jet-like and UE
  - Ξ-hadron correlations to trace balancing quantum numbers

# Introduction to $R_T$

Idea: Martin, Skands, Farrington, Eur. Phys. J. C76 (2016), 1

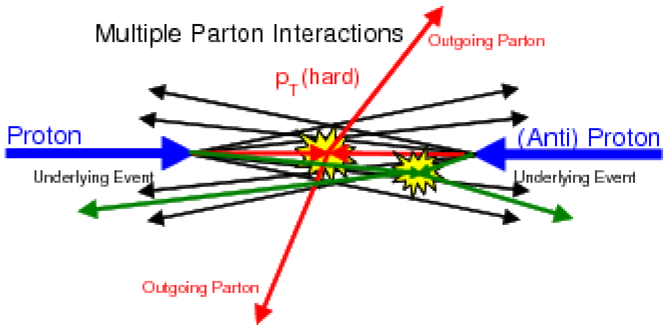
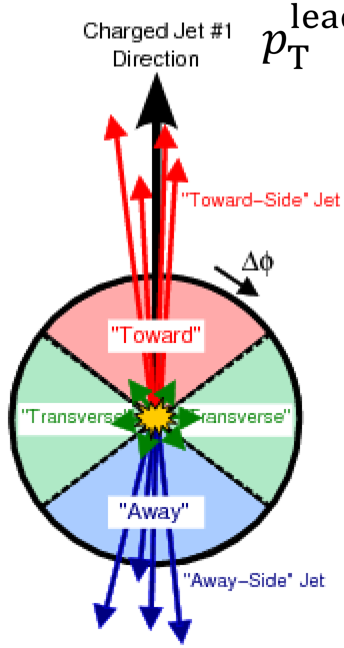
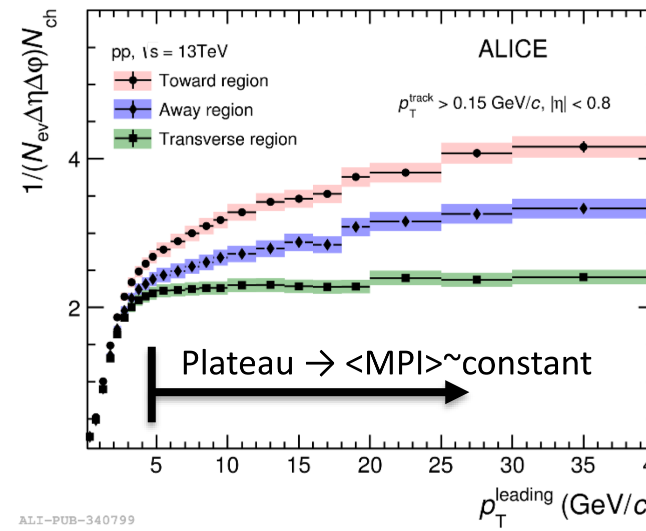



Figure from Eur. Phys. J. C62 (2009), 237

$p_T^{\mathrm{leading}} / p_T^{\mathrm{trigg}}$




arXiv:1910.14400



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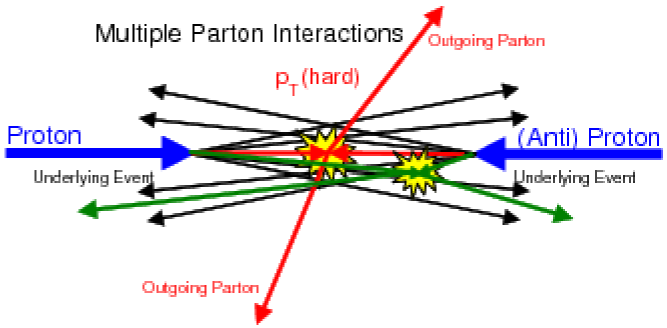
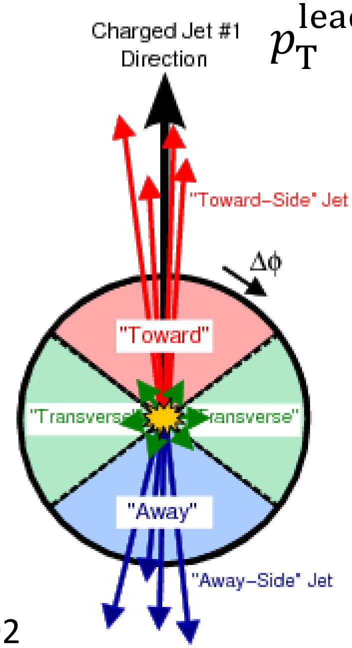



Figure from Eur. Phys. J. C62 (2009), 237

$p_T^{leading} / p_T^{trigg}$

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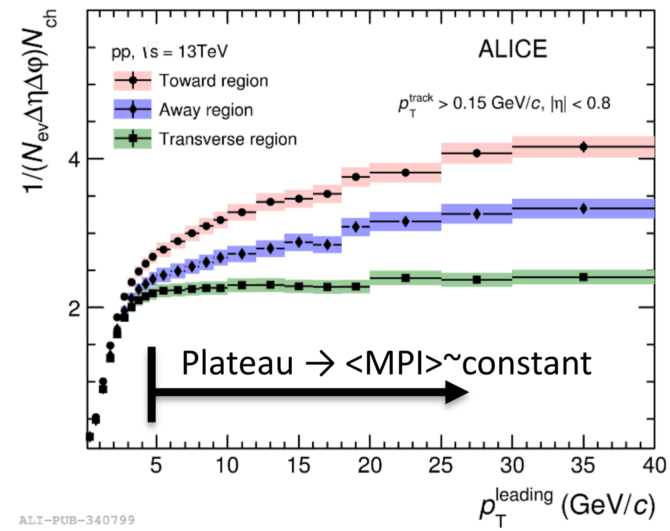
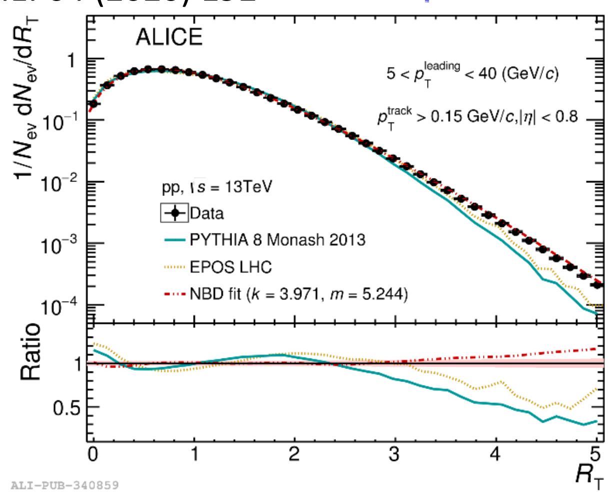



JHEP04 (2020) 192

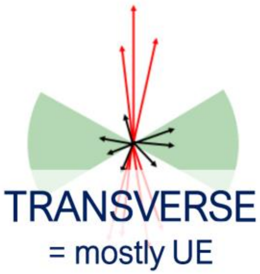


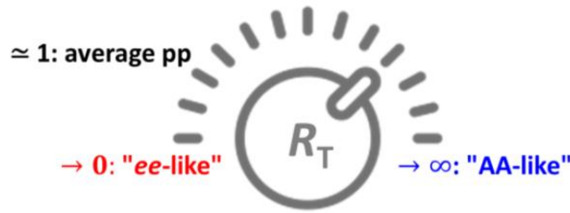

Gives some control over the UE

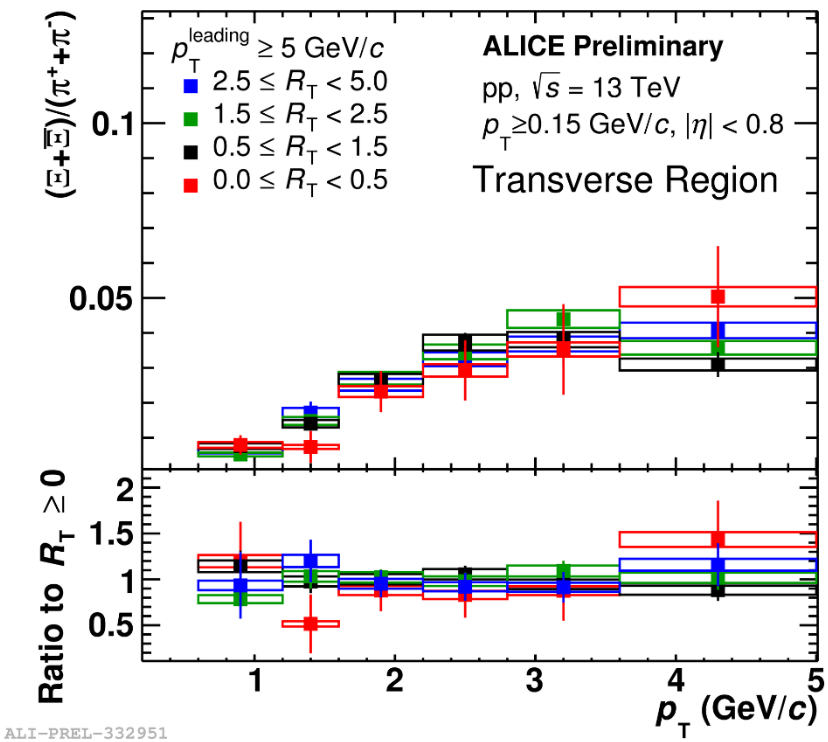

Define:

$$R_T = \frac{N_{ch}^{Transverse}}{\langle N_{ch}^{Transverse} \rangle}$$

# $\Xi$-to-$\pi$ ratios vs $R_T$

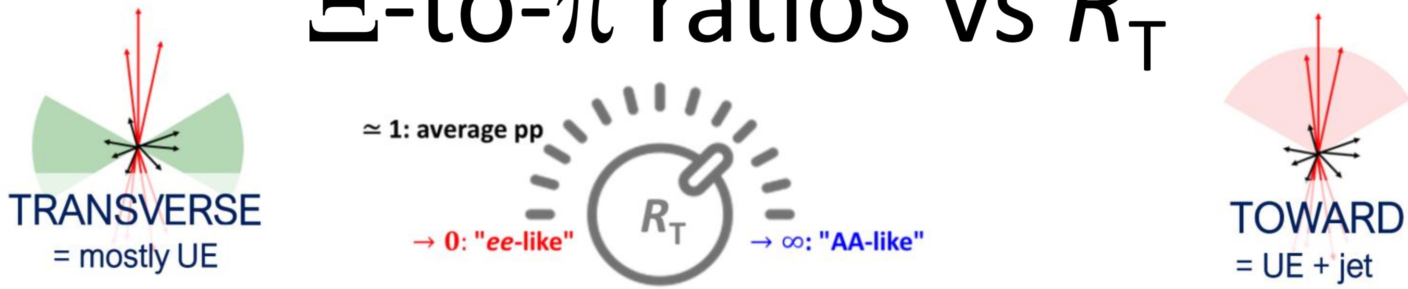


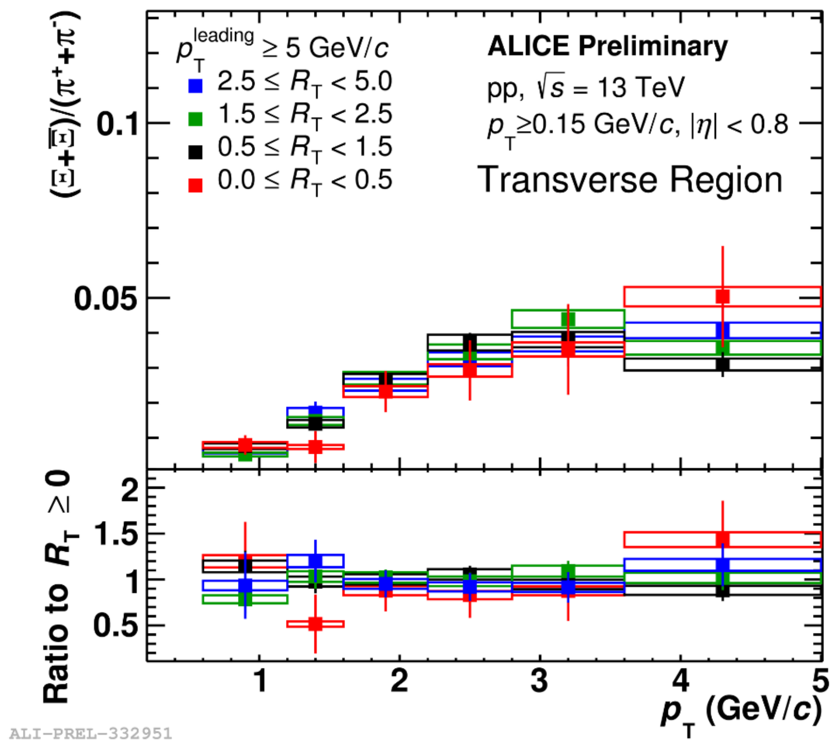



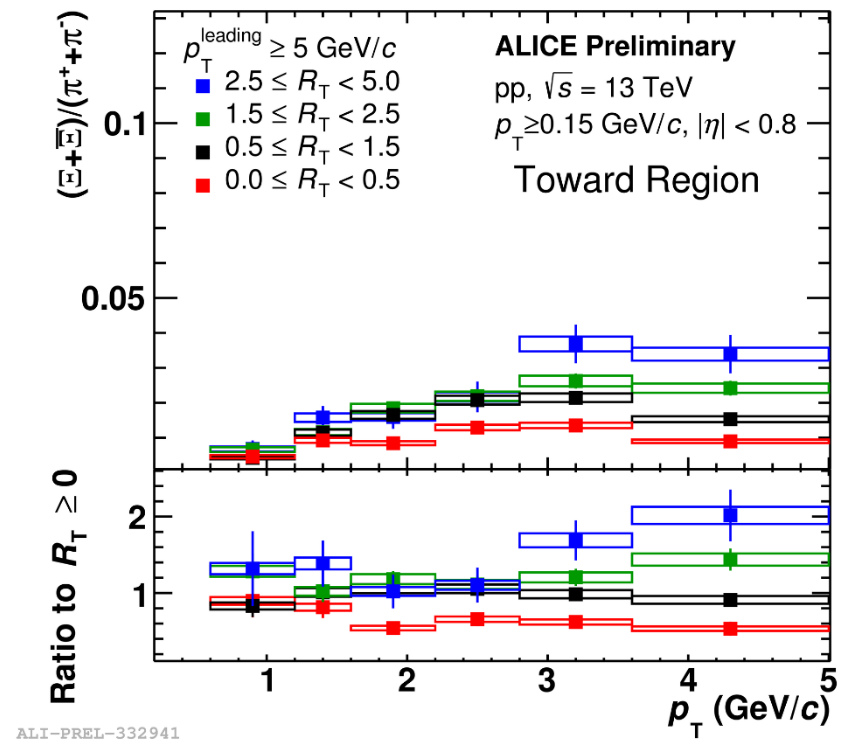




Transverse: the $\Xi$-to-$\pi$ ratio shows little or no dependence on $R_T$. Why not?

# Ξ-to-π ratios vs $R_T$

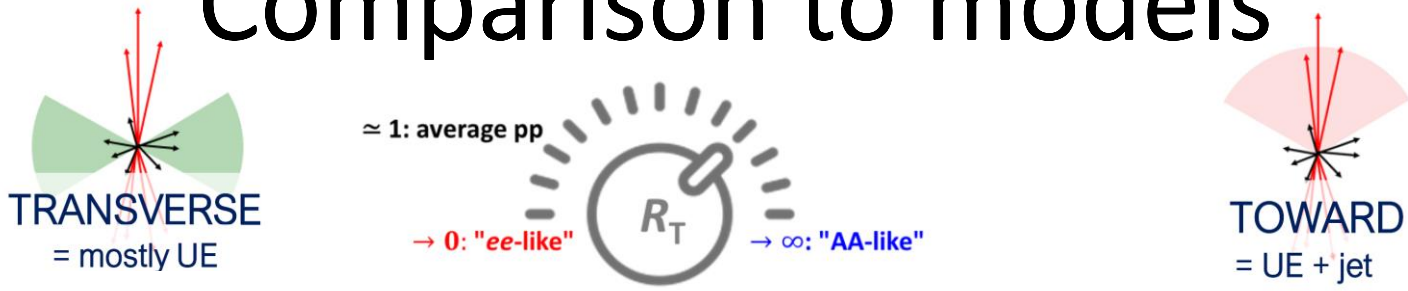


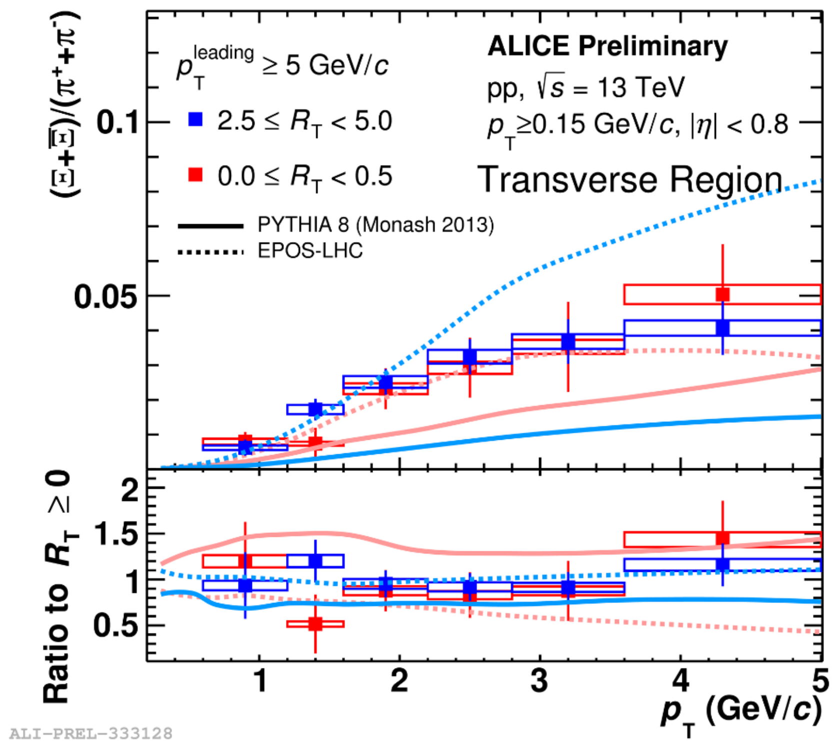



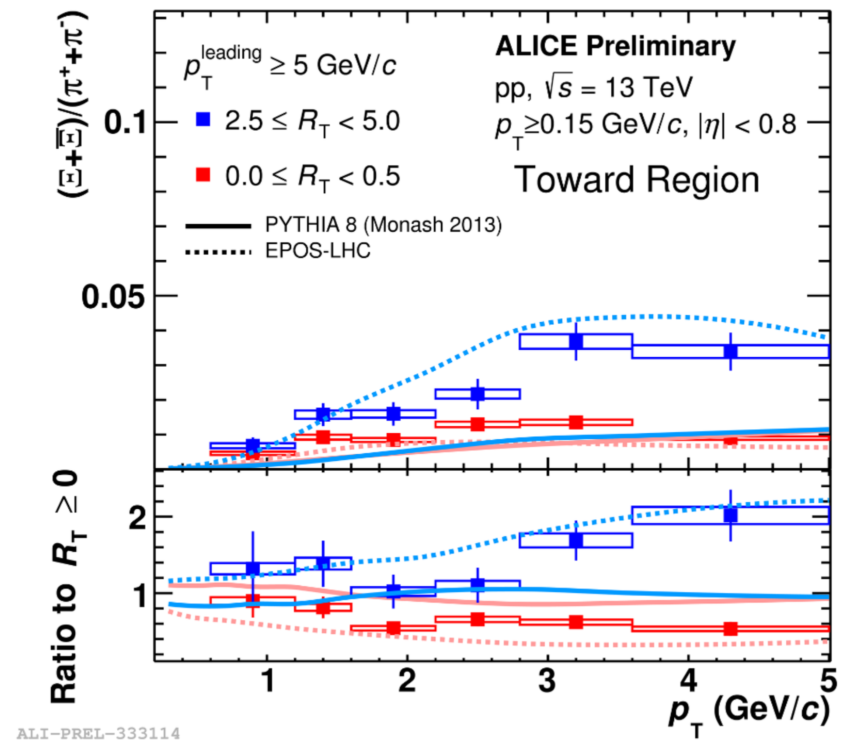




Transverse: the Ξ-to-π ratio shows little or no dependence on $R_T$. Why not?
Toward: the Ξ-to-π ratio increases with increasing $R_T$, approaching the “Transverse” value.

# Comparison to models

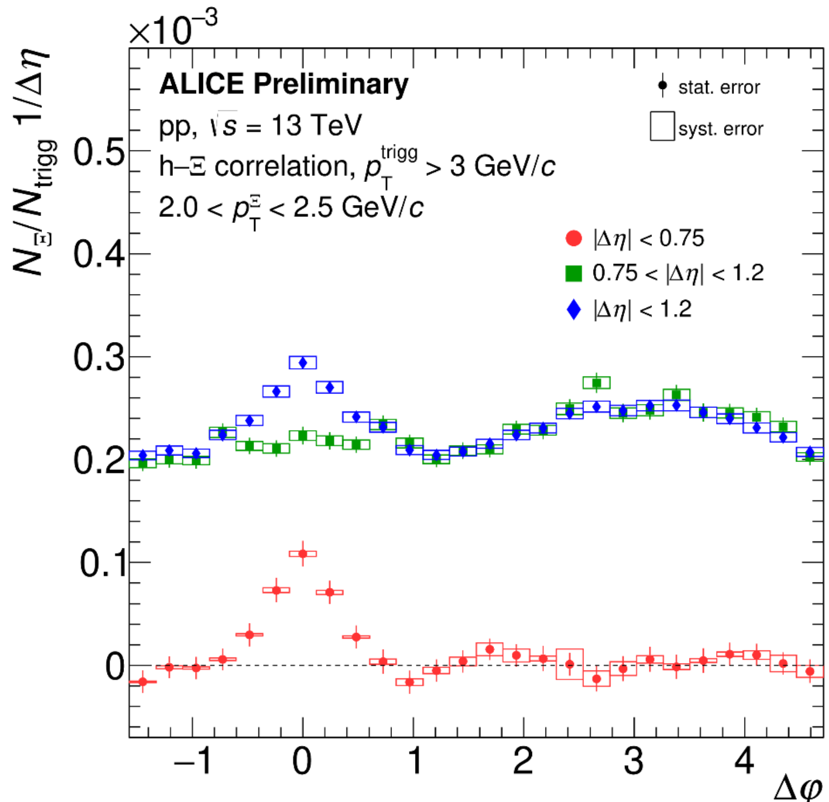



PYTHIA describes well low $R_T$ Toward region (ee-like), but does not describe other regions (as expected). EPOS describes well Toward region but predicts a significant increase for transverse that is not observed.

# Correlations: Studying jet-like and UE production

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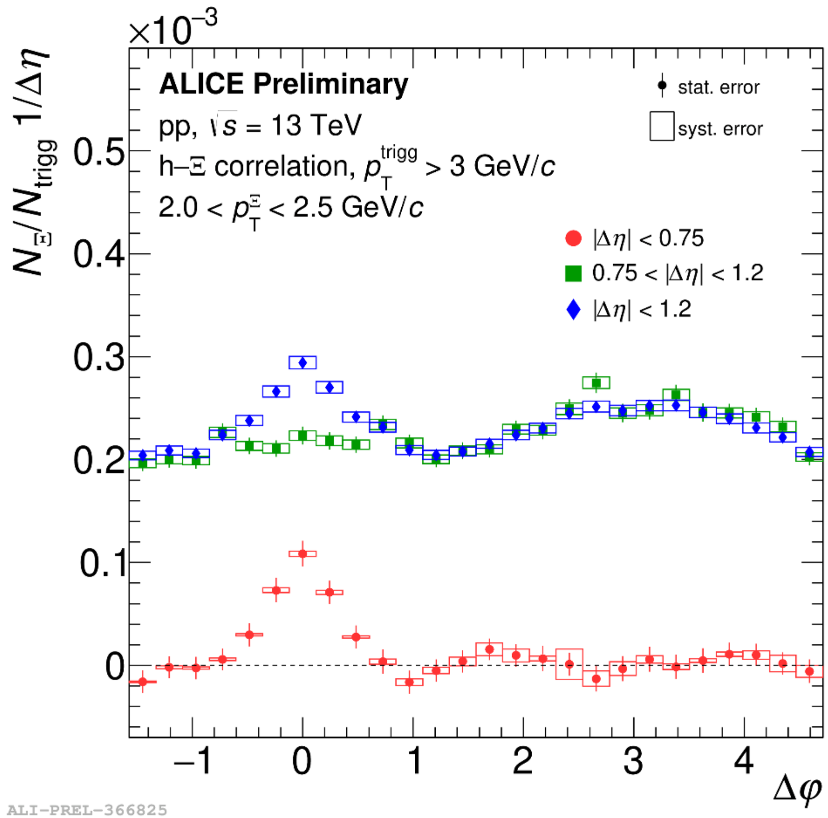
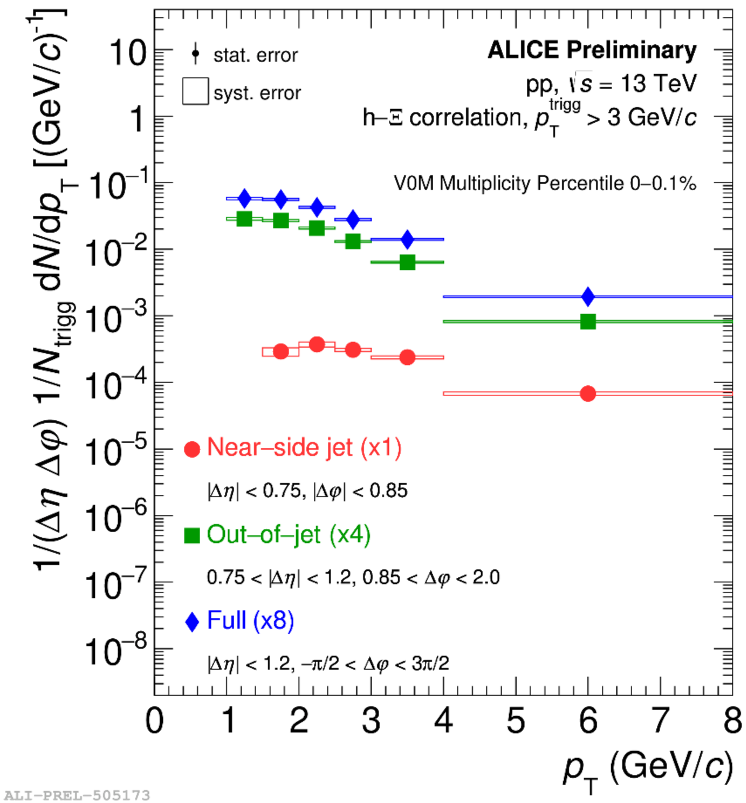
# Correlations: Studying jet-like and UE production

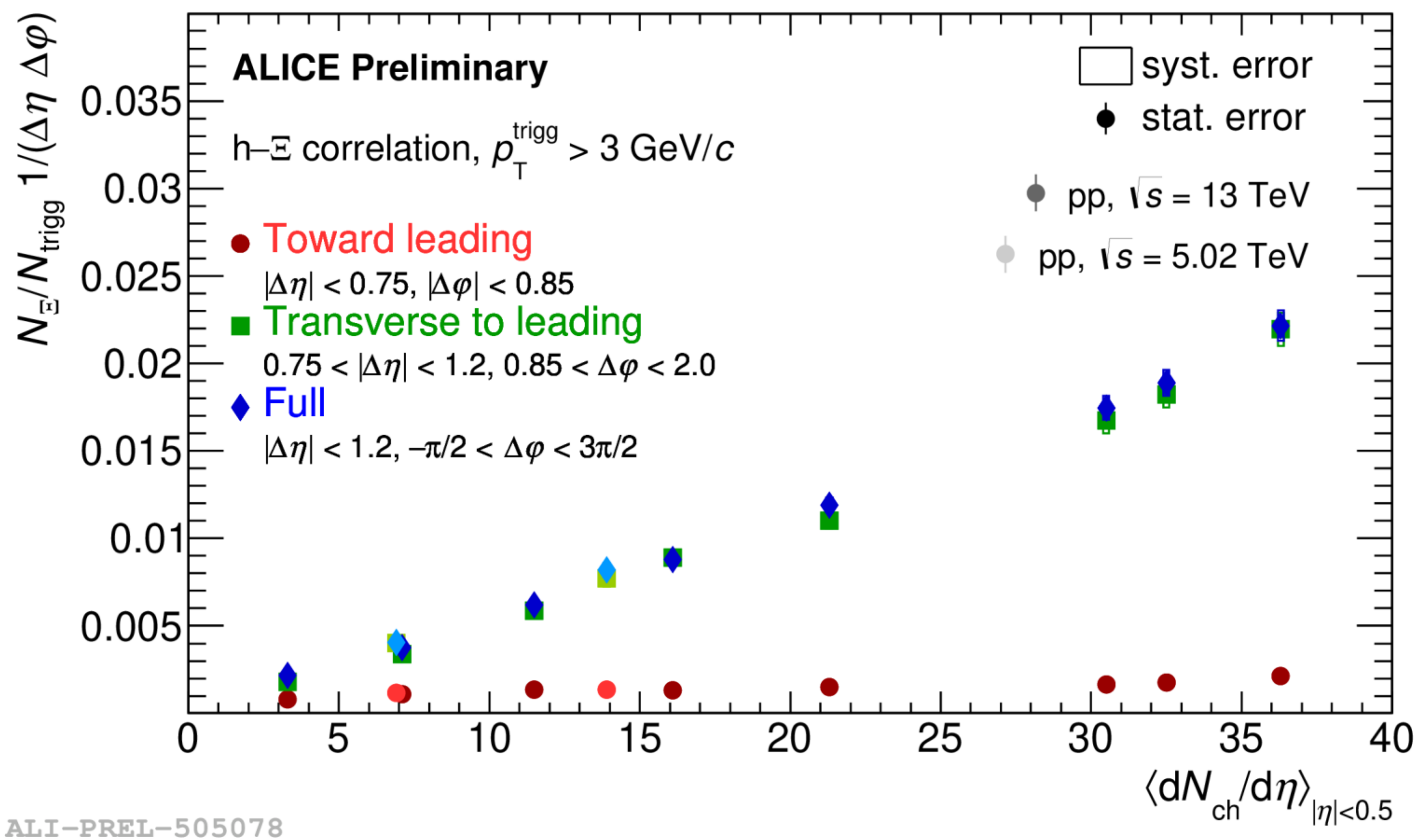



- Note that the $p_{\mathrm{T}}^{\mathrm{trigg}}$ requirement is lower and the angular regions are slightly different than for $R_{\mathrm{T}}$
- The jet-like spectra are much harder than for the UE/bulk

# Yields in jet-like and UE regions






- The bulk production is dominated by the UE production
  - The strangeness enhancement is a soft MPI-like effect

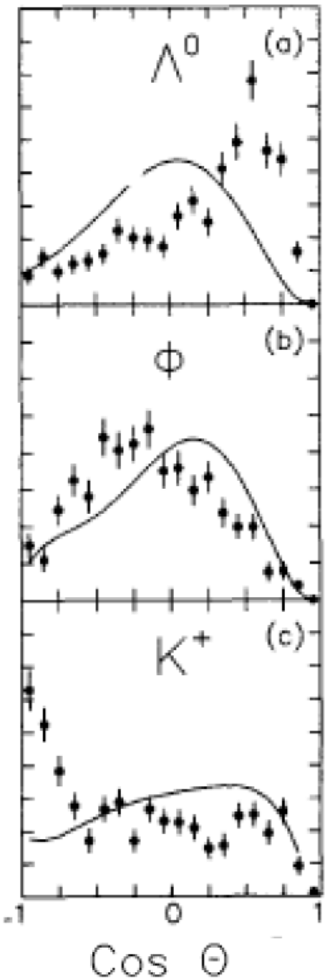
# Strangeness “balance”: an old idea

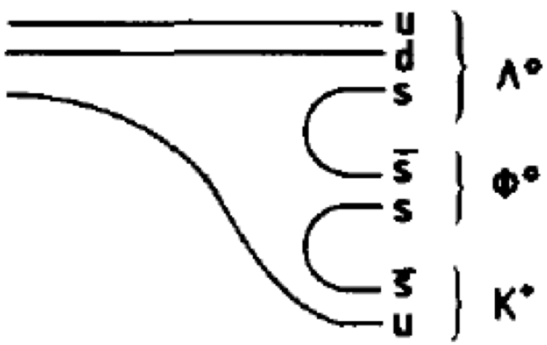


Phys.Lett. 163B (1985), 267

**EVIDENCE FOR POMERON SINGLE-QUARK INTERACTIONS IN PROTON DIFFRACTION AT THE ISR**

R608 Collaboration

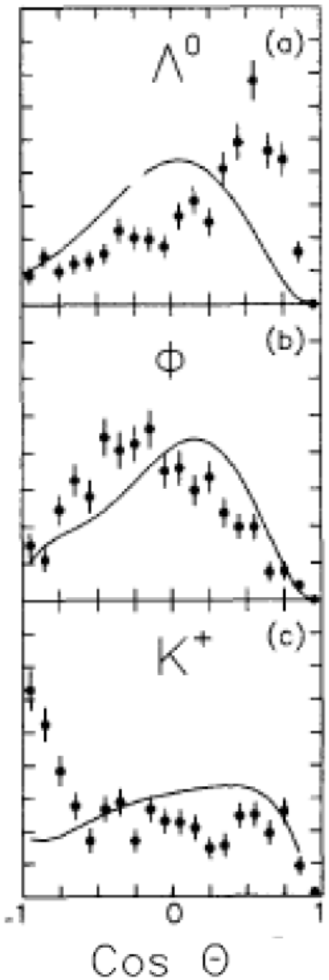



Solid lines are calculations for isoptropic phasespace

# Strangeness "balance": an old idea

Phys.Lett. 163B (1985), 267

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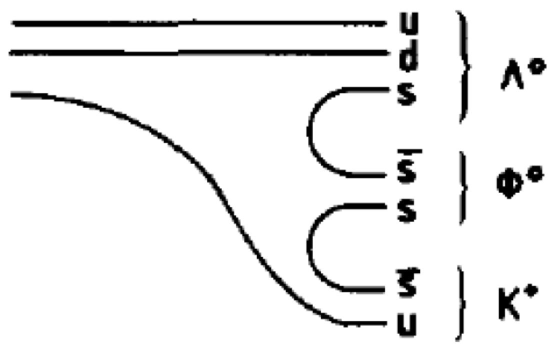


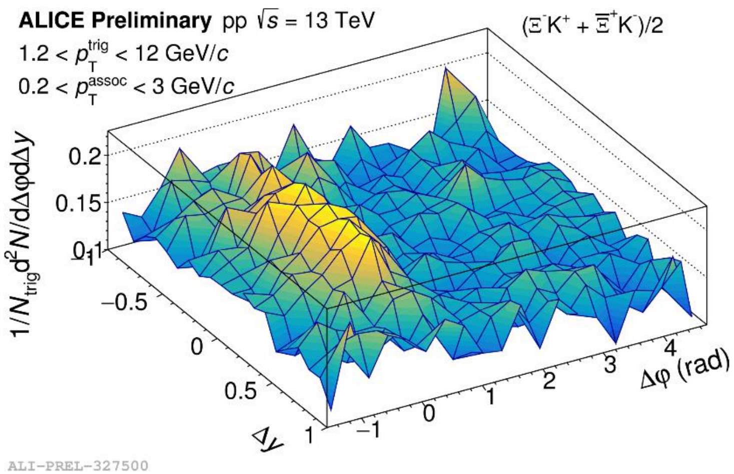

In pp collisions we can ask the questions:
Where is the anti-strangeness (strangeness) associated with production of $\Xi^-/ssd$ ($\Xi^+/\bar{s}\bar{s}\bar{d}$) recovered?

PYTHIA/Angantyr: expect strangeness to be recovered locally (as shown to the left).

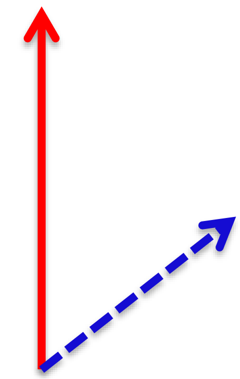
EPOS LHC: expect strangeness enhancement to be associated with a grand canonical (global) reservoir. Microscopic picture?

# Example:
# Ξ-K correlation functions

Opposite sign (OS), e.g., $\Xi^{-}/ssd$ – $K^{+}/\bar{s}d$




Trigger on : $\Xi\ (ssd)$



Measure where the anti-strangeness (baryon number, charge) that balances the strangeness ends up:
$K^{+}\ (u\bar{s}), \bar{p}\ (\bar{u}\bar{u}\bar{d}), \bar{\Lambda}\ (\bar{u}\bar{d}\bar{s}), \bar{\Xi}\ (\bar{s}\bar{s}\bar{d})$

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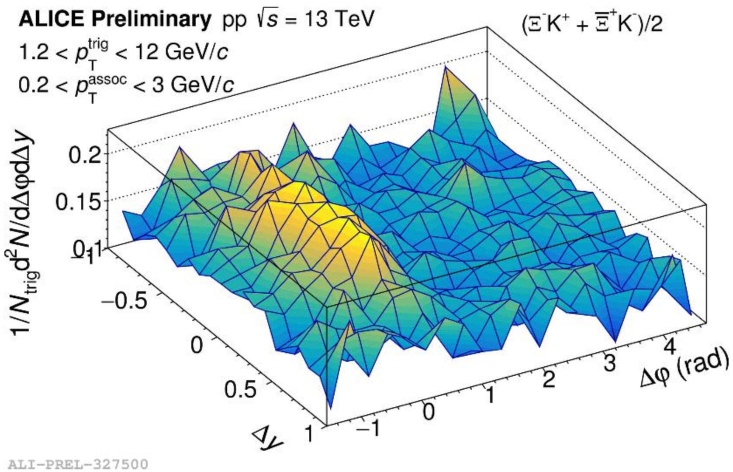
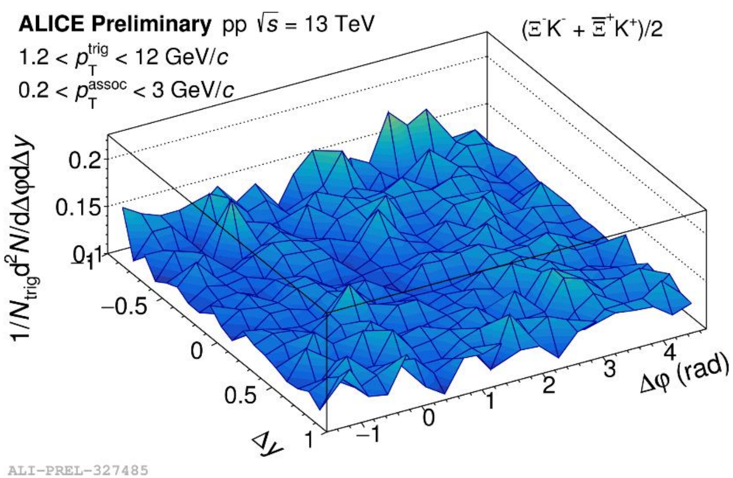
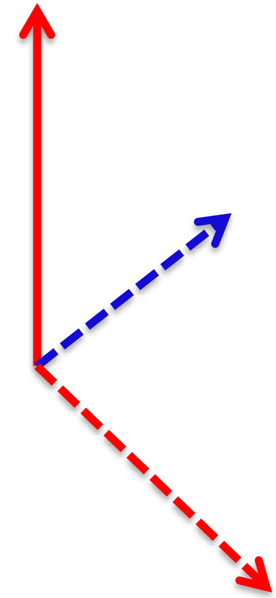



Same sign (SS), e.g., $\Xi^{-}/ssd$ – $K^{-}/\bar{d}s$




Trigger on : $\Xi\ (ssd)$

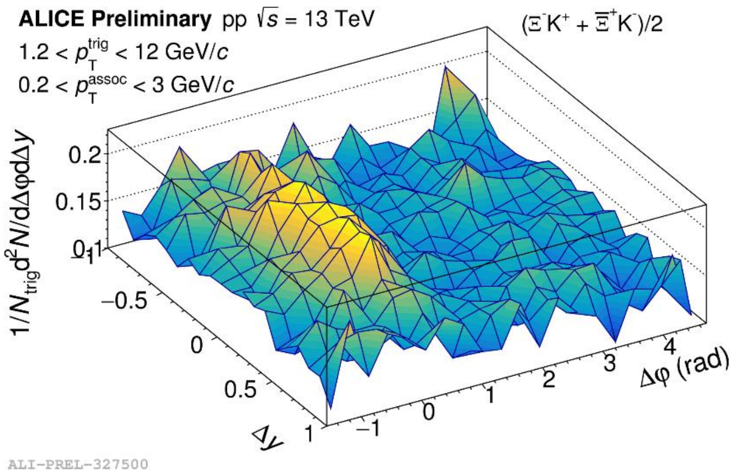


Measure where the anti-strangeness (baryon number, charge) that balances the strangeness ends up:
$K^{+}\ (u\bar{s}), \bar{p}\ (\bar{u}\bar{u}\bar{d}), \bar{\Lambda}\ (\bar{u}\bar{d}\bar{s}), \bar{\Xi}\ (\bar{s}\bar{s}\bar{d})$

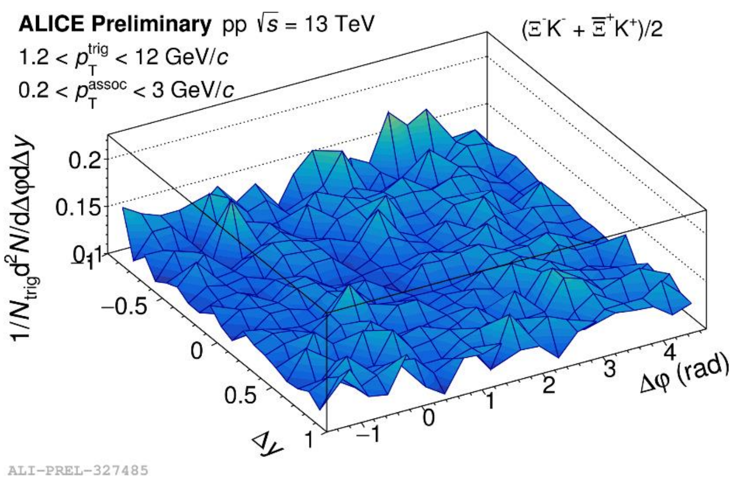
Subtract the uncorrelated production via the same-quantum-number correlations:
$K^{-}\ (s\bar{u}),\ p\ (uud), \Lambda\ (uds),\ \Xi\ (ssd)$

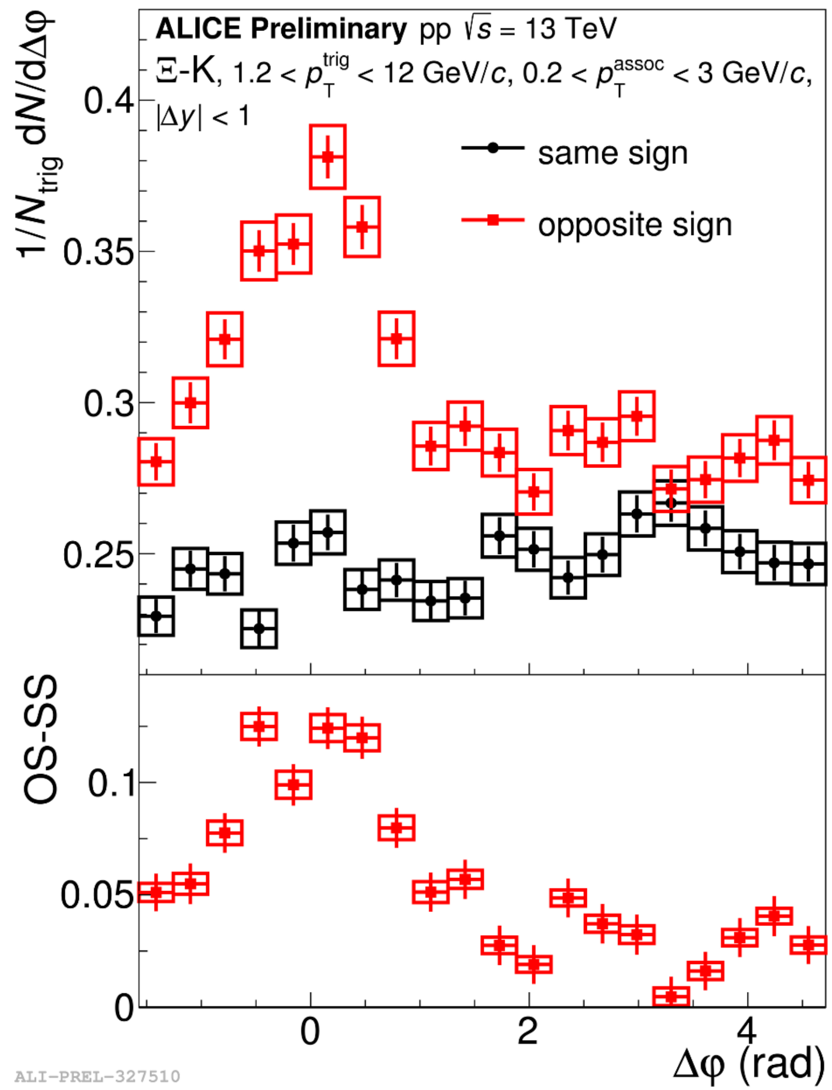
# Example:
# Ξ-K correlation functions

Opposite sign (OS), e.g., $\Xi^{-}/ssd - K^{+}/\bar{s}d$

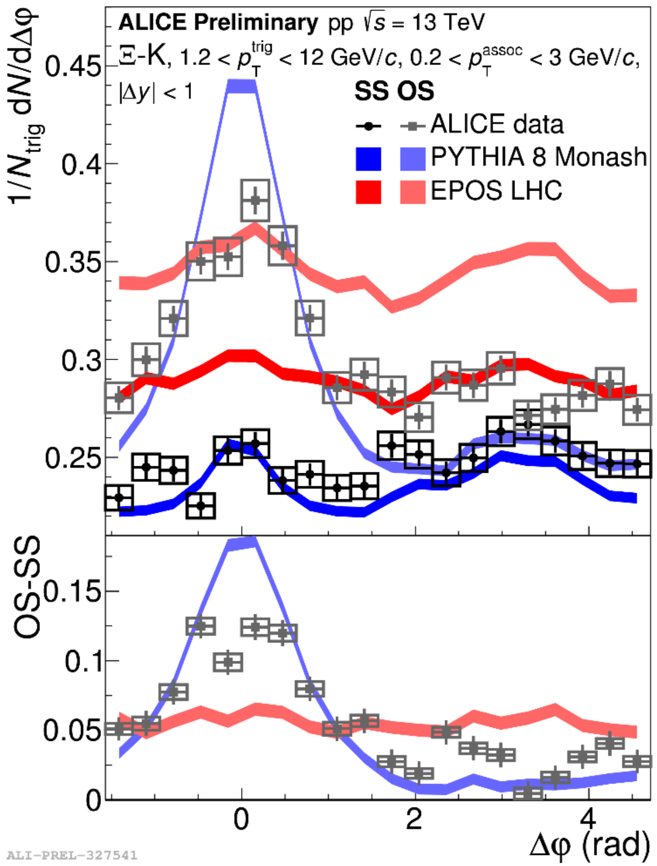


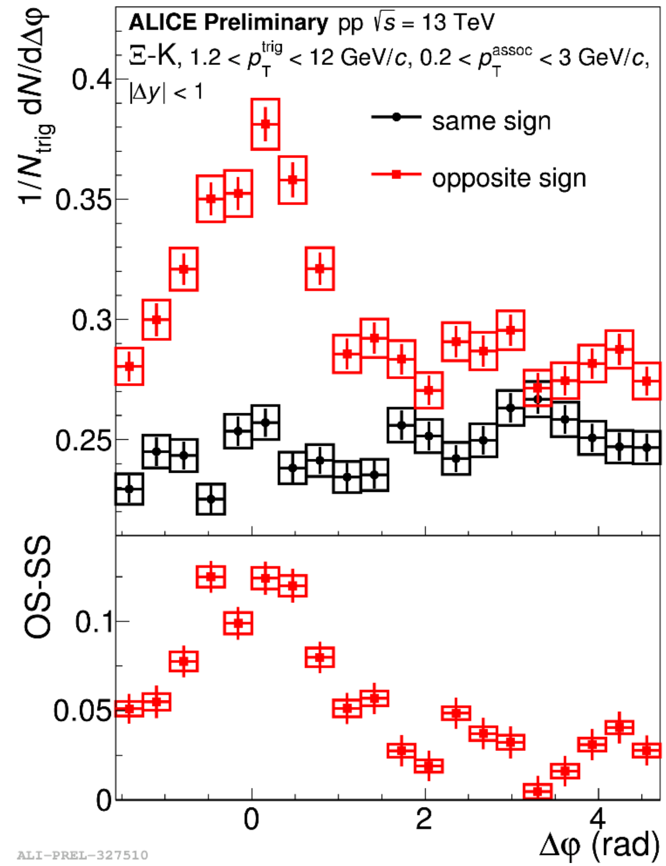

Same sign (SS), e.g., $\Xi^{-}/ssd - K^{-}/\bar{d}s$



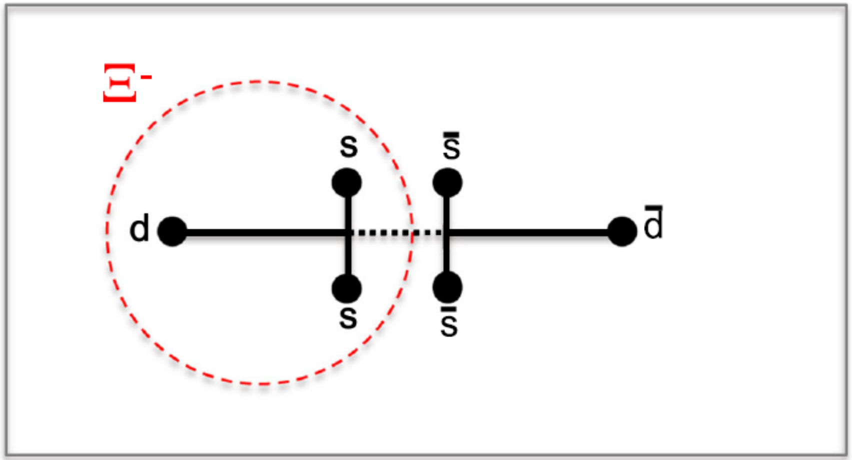
# Example: Ξ-K correlation functions



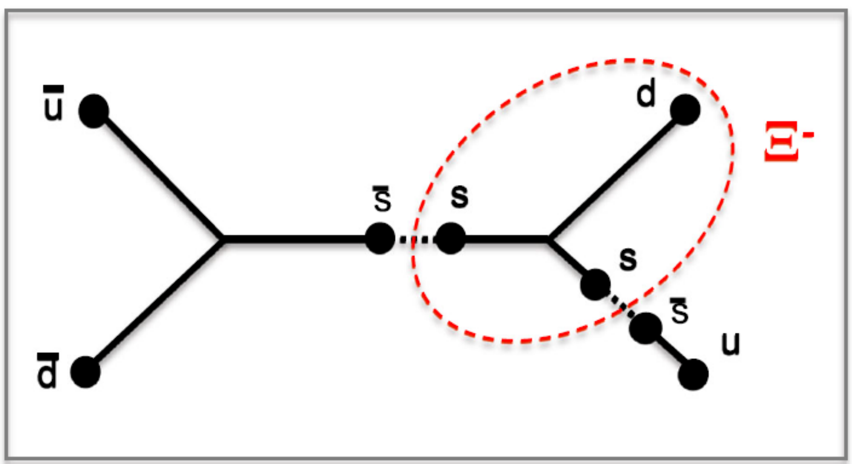




- PYTHIA does a good job of the SS (UE) correlations, but OS are too strong and away side decorrelations are too weak
- EPOS LHC: in general worse job and too strong strangeness decorrelation

# What can we learn from baryons?




Normal Lund string:
Ξ almost never balanced by antiproton but instead typically by antistrange baryons and even anti-Ξ!



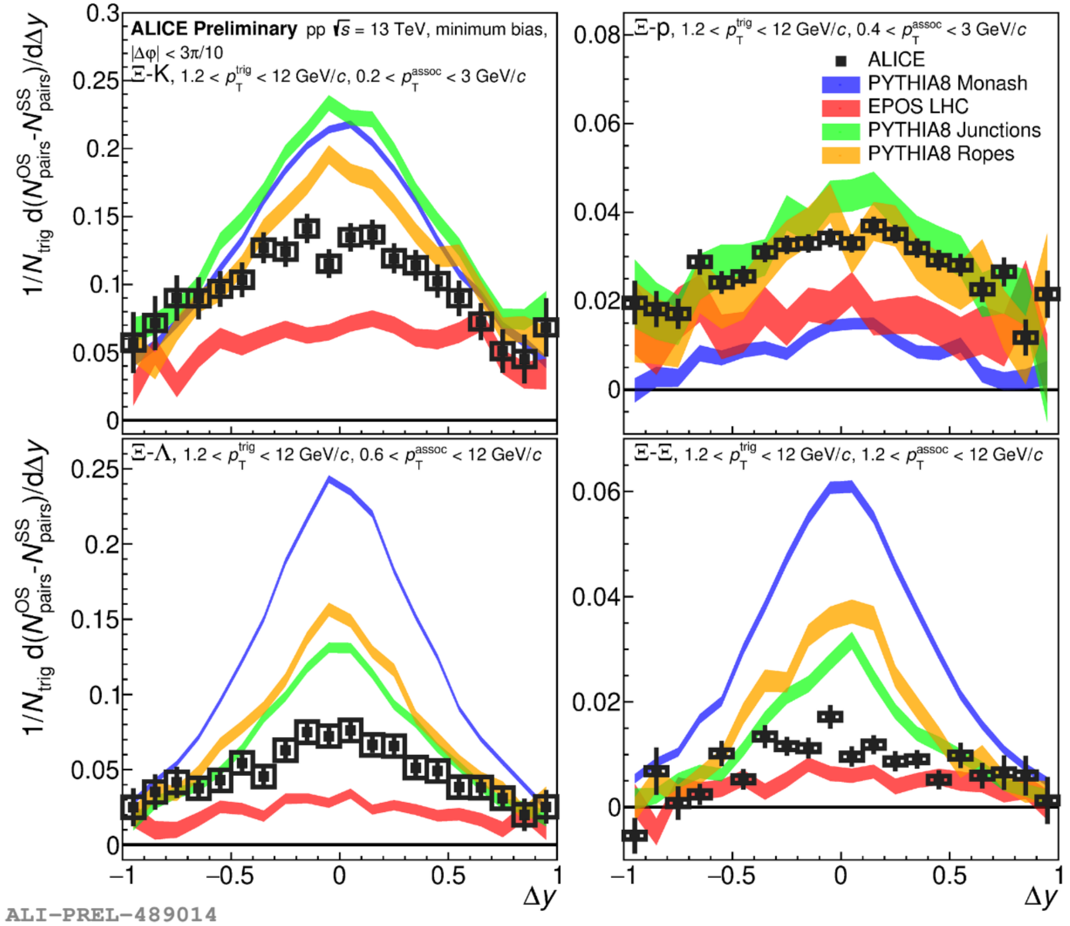

Junction:
Ξ balanced more by kaons and less by antistrange baryons. Broader correlations in rapidity.

Idea from CLASH workshop write up: J. Adolfsson et al, Eur. Phys. J. A 56 (2020) 11, 288, "QCD challenges from pp to A–A collisions"

# Results (near side)

Ξ-K

Ξ-p




Ξ-Λ

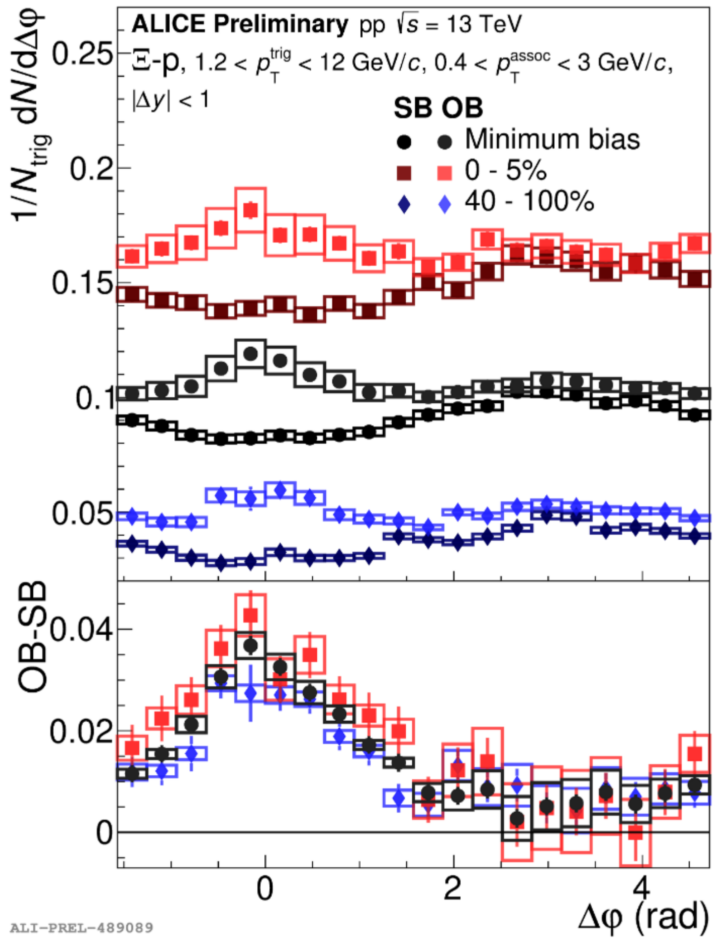
Ξ-Ξ

- Normal strings are disfavoured as main production mechanism
- Junctions describes well protons but not so well Λ and Ξ
  - In particular missing yield on away side (not shown)

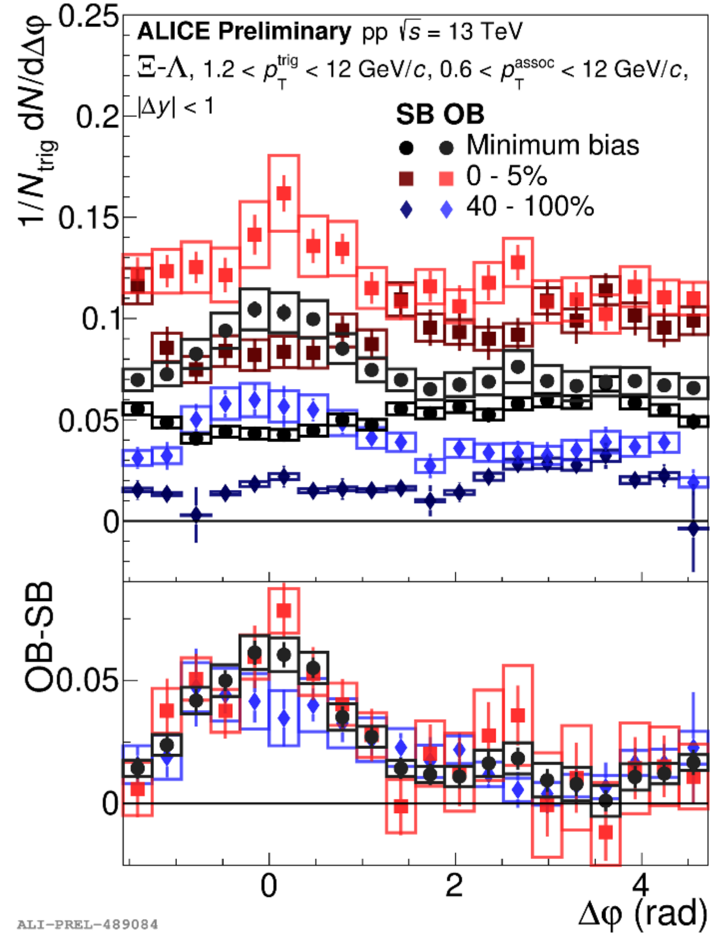
# Little or no multiplicity dependence



Ξ-p




Ξ-Λ




- No strong signals for change in production mechanism (?) or increasing diffusion/dissipation (thermalization)

# Conclusions

- Several interesting indications:
  - The *ee* limit is recovered in "Toward" region for low $R_T$
  - Bulk strangeness production is dominated by the UE production
  - Correlations can constrain production mechanism
- Puzzle: dynamics has no multiplicity dependence
  - $R_T$ independence of the $p_T$-dependent $\Xi$-to-$\pi$ in the UE
  - No indications that balance is multiplicity dependent: only one production mechanism (?).

Thank you!