Study of the strangeness production mechanism in small systems through Ξ−hadron correlations in pp collisions at 13 TeV

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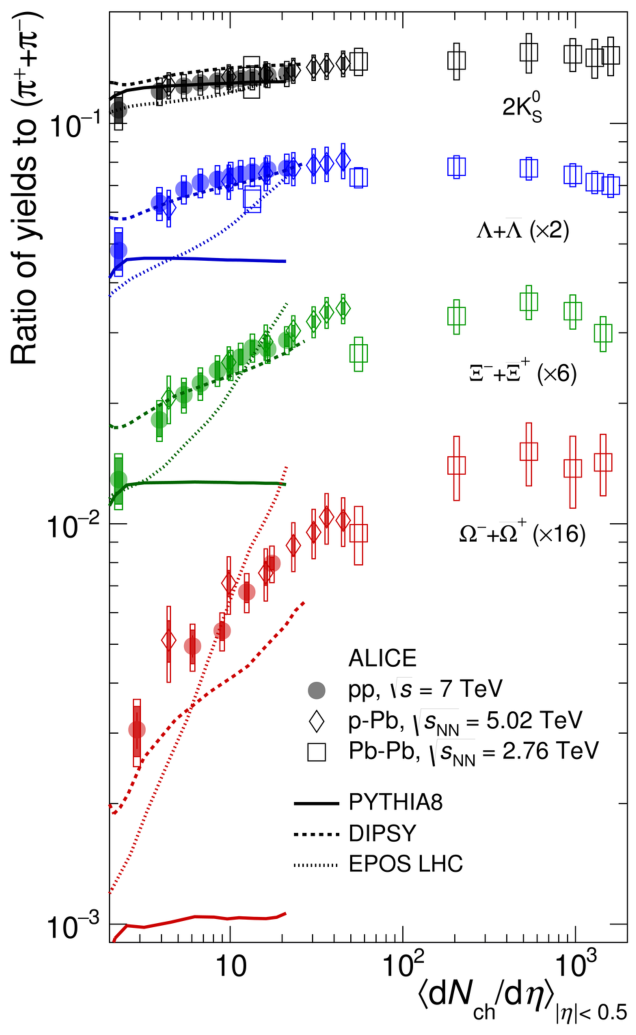
Introduction

Strangeness enhancement in small systems is not yet well understood. In this work, Ξ baryon (= *ssd*) correlations are used as a tool to get further insights into the origin.

- Strangeness is conserved in strong interactions, so each *s* quark must be balanced by an $\bar{s}$ quark.
- Angular correlations tell us how this balance is distributed within the event.
- $s\bar{s}$ correlations are studied through opposite-quantum number (OS) $\Xi-\mathrm{K}$ correlations. To remove jet-like correlations and the underlying event, same-quantum number (SS) $\Xi-\mathrm{K}$ correlations can be subtracted.
- To disentangle charge balance effects, a comparison is done to $\Xi-\pi$ correlations.



Right: Yields of various strange baryons as a function of multiplicity [1].

Method

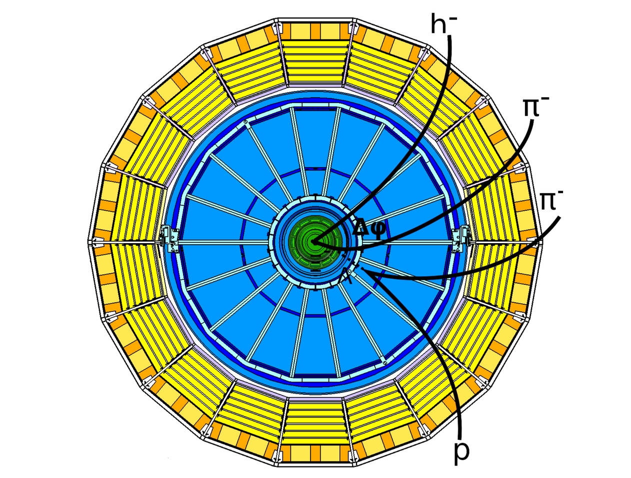
The measured observable is per-trigger yields, i.e.

$$\frac{1}{N_{\text{trig}}}\frac{\mathrm{d}^2N}{\mathrm{d}\Delta\varphi\mathrm{d}\Delta y}.$$

In practice, this is measured as

$$\frac{\mathrm{d}^2N}{\mathrm{d}\Delta\varphi\mathrm{d}\Delta y}=\frac{1}{B(0,0)}\frac{S(\Delta y,\Delta\varphi)}{B(\Delta y,\Delta\varphi)},$$

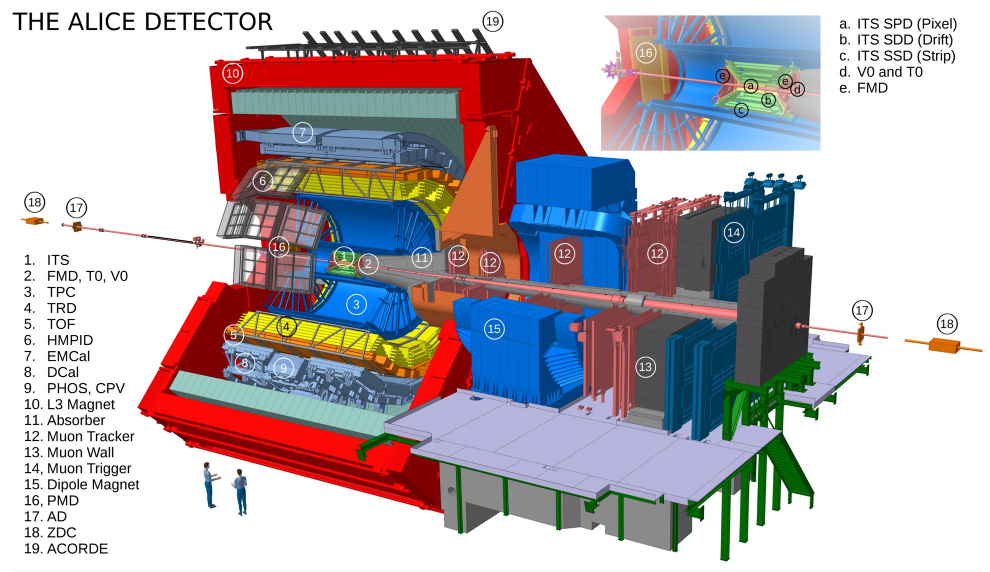
where $S(\Delta y,\Delta\varphi)$ and $B(\Delta y,\Delta\varphi)$ are trigger-associated pair yields in the same event and different but similar events, respectively. This is done to correct for detector efficiency and acceptance limitations.



Schematic view of a measurement of the angular distance between a Ξ^- and an h^-.

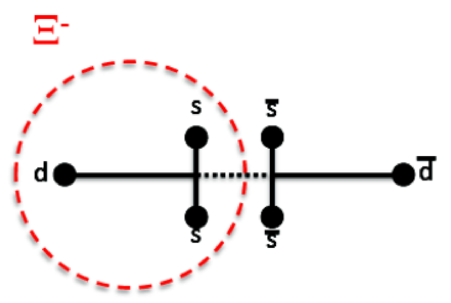
Pions, kaons and protons are identified by the ITS, TPC, and TOF subdetectors of ALICE. The Ξ baryon is identified from its primary decay channel

$$\Xi^-\to\pi^-+\Lambda^0,$$
$$\Lambda^0\to\pi^-+\mathrm{p}.$$



PYTHIA

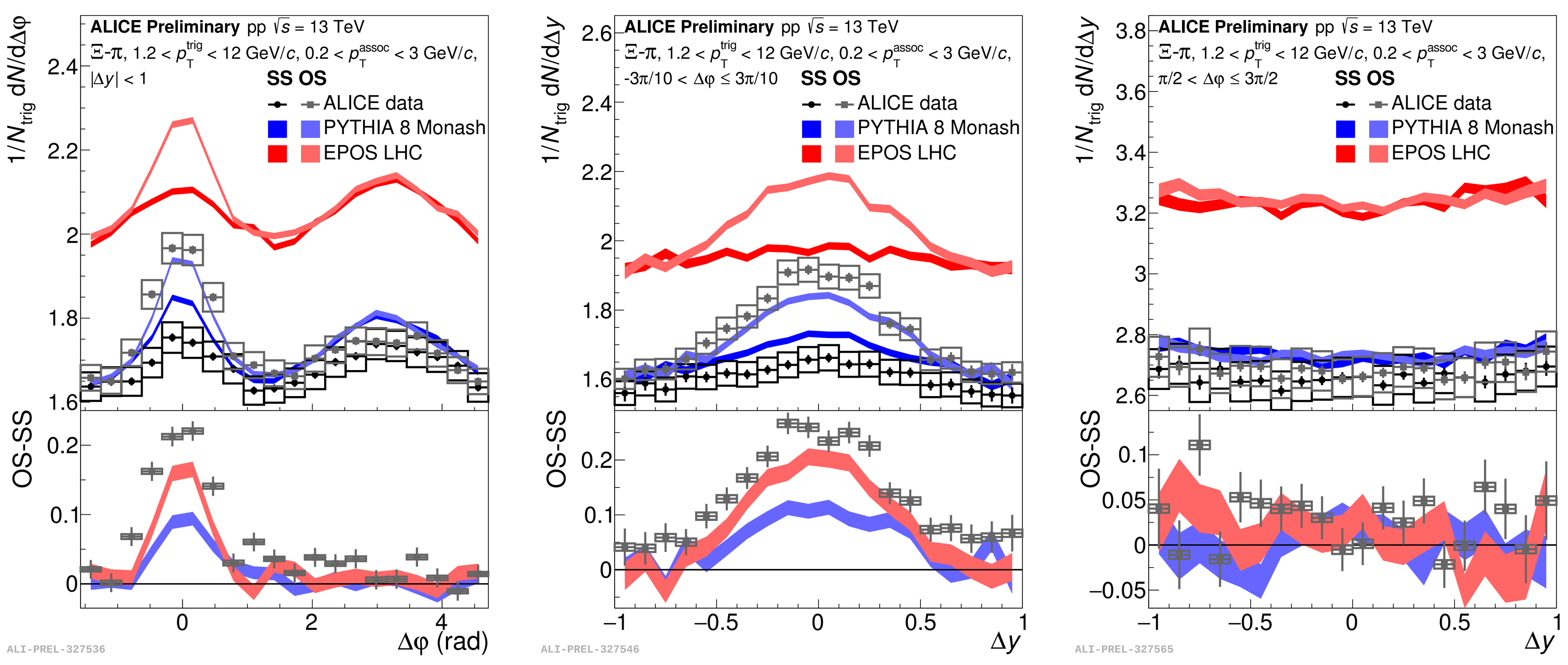
PYTHIA is an event generator based on string fragmentation. In this framework, hadrons are formed through breakings of colour strings built up after the collision, forming $q\bar{q}$ pairs. Multistrange hadron yields are underestimated in PYTHIA.



Ξ production in PYTHIA.

$\Xi-\pi$ correlation results

Projections onto $\Delta\varphi$ and Δy (near side and away side):

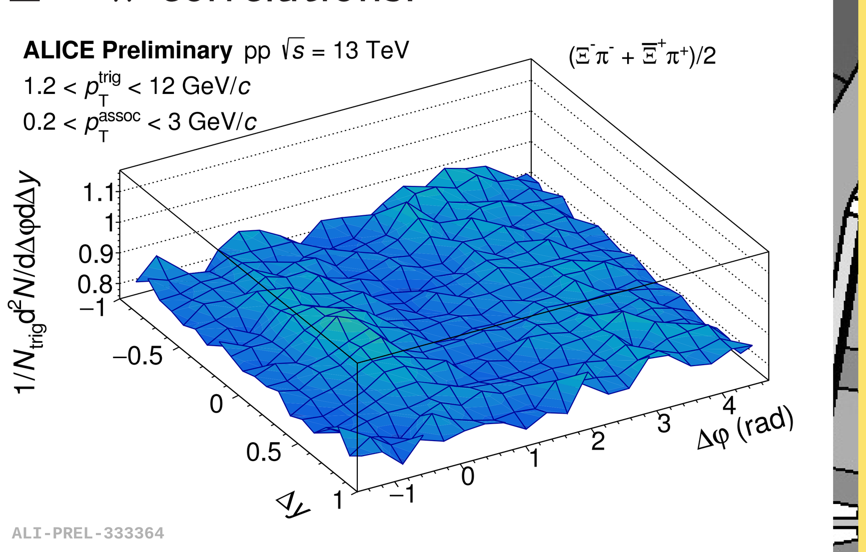


EPOS

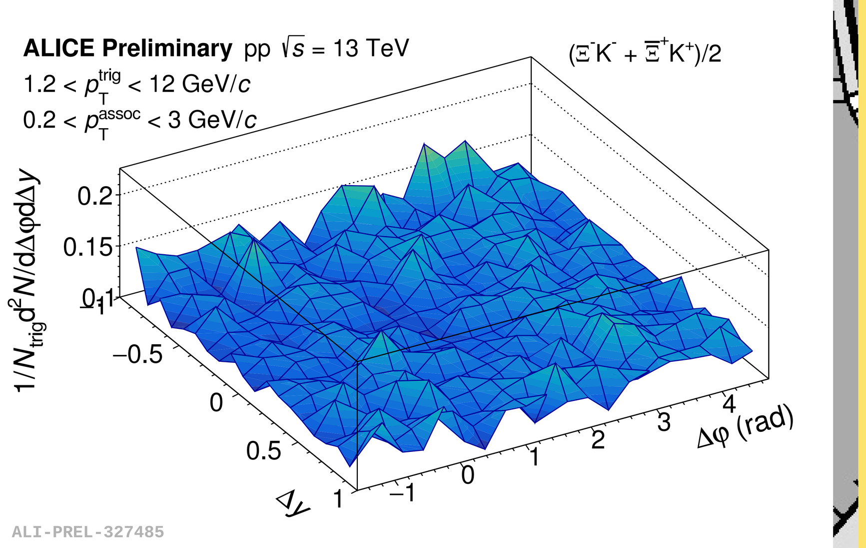
EPOS is an event generator based on a core-corona model, with a QGP-like core and a string-like corona. Hadrons are formed through string breakings, but in the initial stage, most strange quarks are produced thermally in the core. When increasing the system size, the core fraction increases, resulting in a smooth increase in strange particles.

Same-sign correlations

$\Xi-\pi$ correlations:



$\Xi-\mathrm{K}$ correlations:

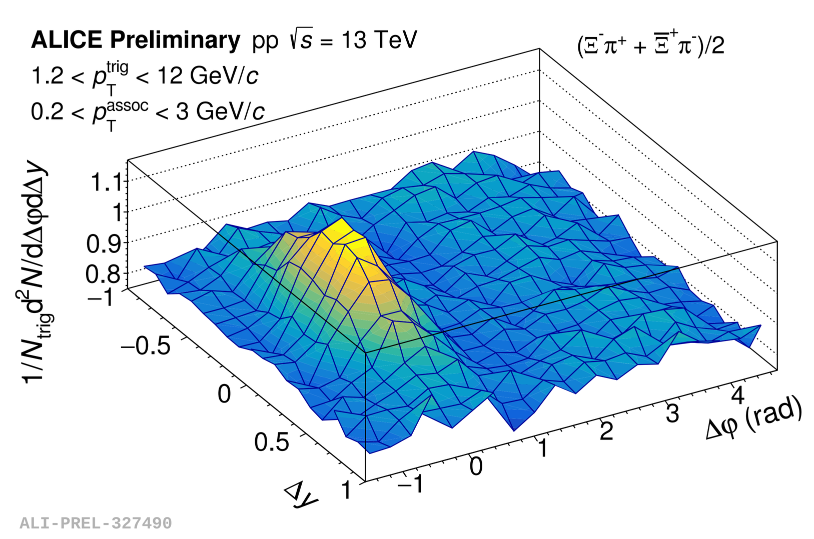


Conclusions

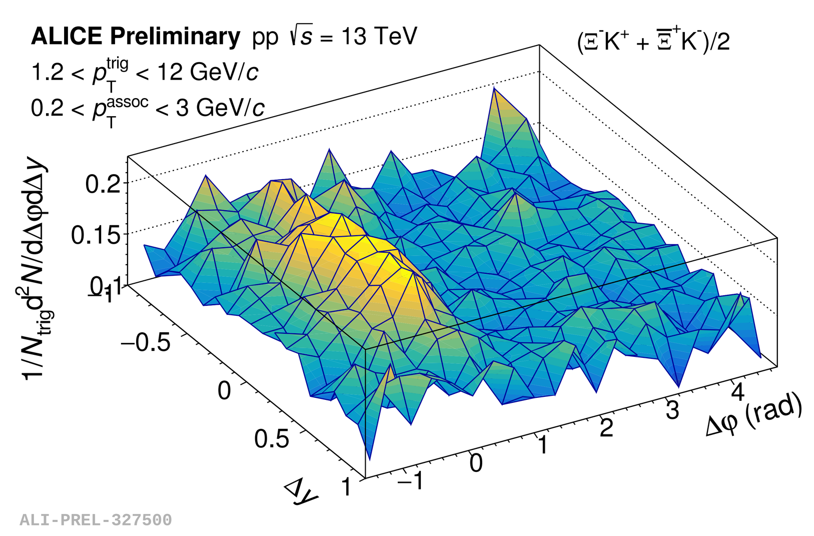
- SS correlations, sensitive to event activity, are very well described by PYTHIA, while EPOS overestimates it by ∼ 25% (this is however likely due to an overestimated multiplicity in Ξ-triggered events)
- OS $\Xi-\pi$ correlations are underestimated by both models, particularly PYTHIA, but the shape is qualitatively correct. The relative difference to SS is much smaller than for $\Xi-\mathrm{K}$ correlations, though, concluding that charge conservation effects have a minor impact on these.
- For OS-SS $\Xi-\mathrm{K}$ correlations, sensitive to the strangeness production mechanism, neither model describes the data well.
  - Qualitatively, PYTHIA is closer to data, but this is too much enhanced on the near side and too little on the away side. Moreover, the peak width is too narrow.
  - For EPOS, it is the other way round, but the near-side peak is nearly washed out, resulting in a very different shape than what is observed in data.
- **To summarise, theoretical advances are required to accurately describe Ξ − K correlations, and further the strangeness production mechanism. The wider near-side peak observed in data compared to PYTHIA indicates that these are related to collective effects.**

Opposite-sign correlations

$\Xi-\pi$ correlations:

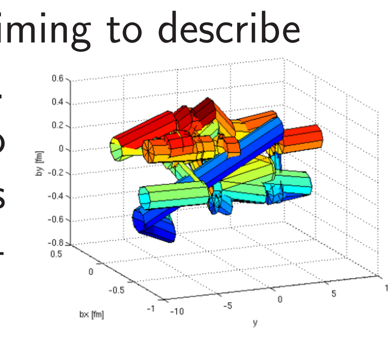


$\Xi-\mathrm{K}$ correlations:



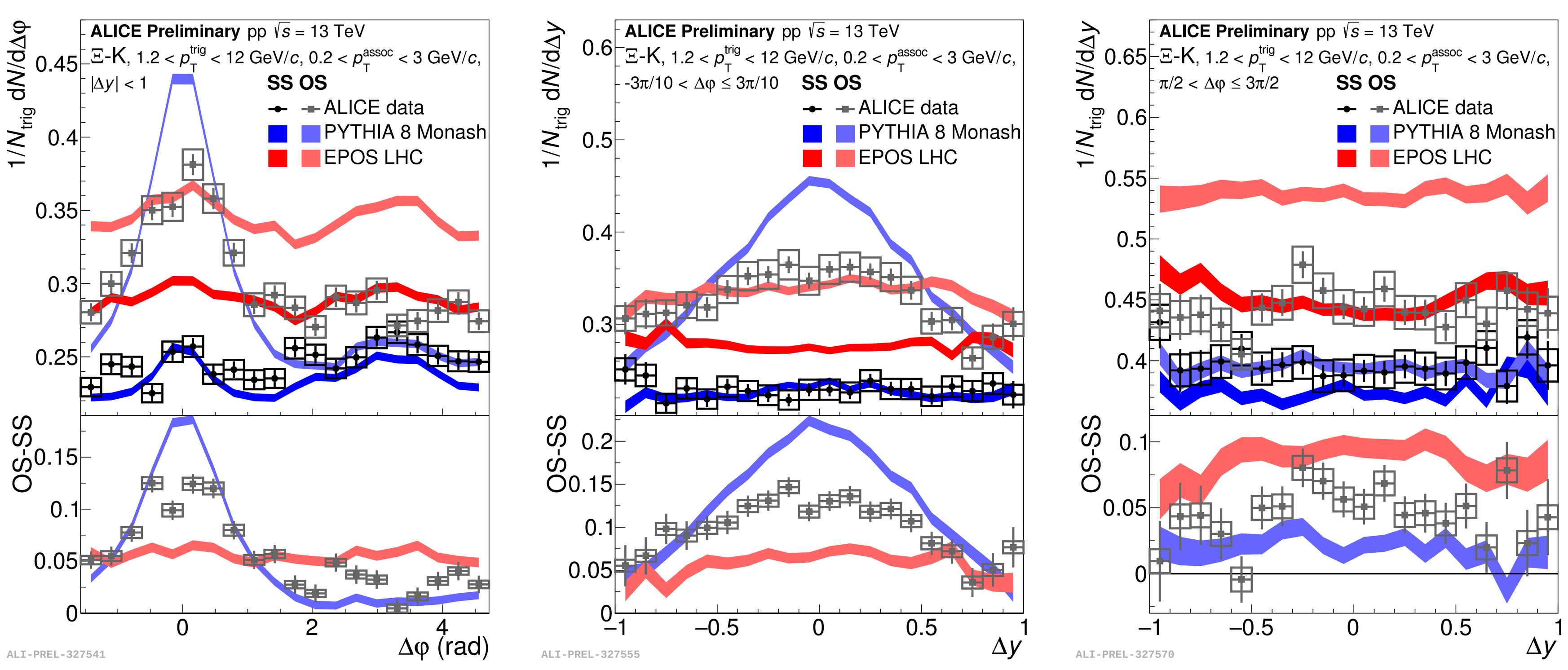
Ongoing theory development

While PYTHIA currently does not reproduce strangeness enhancement, the macroscopic model DIPSY does. This is based on rope hadronisation, i.e. string clustering into colour ropes. This is now incorporated in the Angantyr extension of PYTHIA, which is aiming to describe heavy-ion collisions. Work is ongoing to create a tune for this to enable comparisons to data.



Simulation of colour ropes [2].

$\Xi-\mathrm{K}$ correlation results



References

[1] ALICE Collaboration. *Nature Phys.* *13* 535-539. (2017).

[2] C. Bierlich. *QCD Challenges at the LHC: from pp to AA.* [Conference presentation]. Taxco, Mexico. (2016).