Investigating strangeness production in pp collisions as a function of charged-particle multiplicity and effective energy with ALICE

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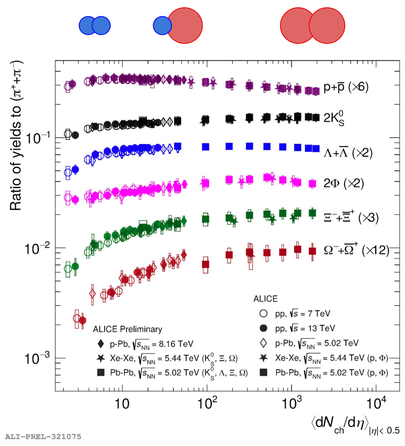
Physics motivation



Strangeness enhancement was one of the first proposed signatures of **QGP** formation

ALICE observed that the ratio of strange to non-strange hadron yields (h/π):

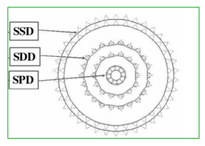
- **increases with** midrapidity **multiplicity**
- **smoothly evolves across** collision **systems**
- shows a **larger enhancement** for particles with larger **strangeness content**

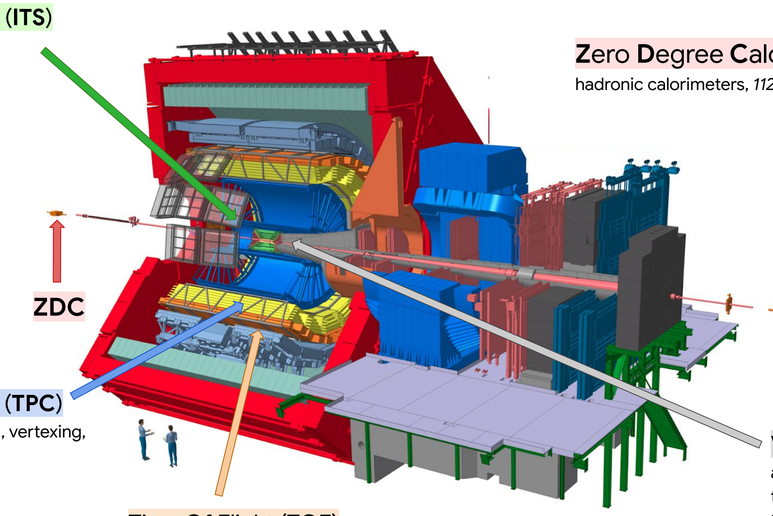
Does strangeness production depend only on final state particle multiplicity, or **is it also correlated to the initial stage**?

Nature Phys 13, 535-539 (2017)
Eur. Phys. J. C 80, 167 (2020)

ALICE at the LHC

Inner Tracking System (ITS)
six layers of silicon detectors (SPD, SDD, SSD), tracking, triggering, vertexing





Zero Degree Calorimeters (ZDC)
hadronic calorimeters, *112.5* m from the IP, $|\eta| > 8.8$ (ZN), $6.5 < |\eta| < 7.4$ (ZP*))

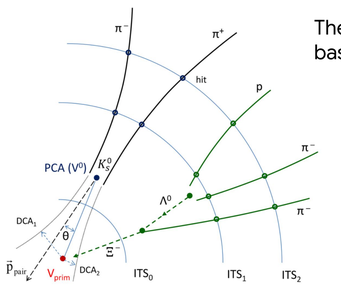
Time Projection Chamber (TPC)
main tracking detector (gas-filled), vertexing, PID (dE/dx)

Time Of Flight (TOF)
PID via Time-Of-Flight technique

V0 detectors (V0A and V0C)
arrays of scintillators at forward rapidity, triggering, multiplicity estimators
$2.8 < \eta < 5.1$ (V0A), $-3.7 < \eta < -1.7$ (V0C)

*considering LHC beam optics ZP acceptance for protons is $7.0 < |\eta| < 8.7$

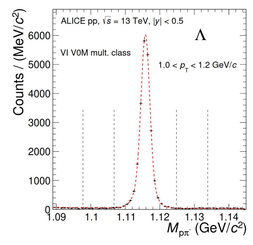
Strange hadron PID

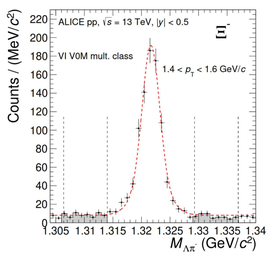


The identification of (multi-)strange baryons is based on kinematical and topological criteria

V^0 → neutral particle decaying weakly into a pair of charged particles (V-shaped)

Cascade → charged particle decaying weakly into a V^0 + charged particle





$$\Lambda\,(\bar{\Lambda}) \rightarrow p\,(\bar{p}) + \pi^-\,(\pi^+) \quad \text{B.R.} = (63.9 \pm 0.5)\,\%$$
$$\Xi^-\,(\bar{\Xi}^+) \rightarrow \Lambda\,(\bar{\Lambda}) + \pi^-\,(\pi^+) \quad \text{B.R.} = (99.887 \pm 0.035)\,\%$$
$$\Omega^-\,(\bar{\Omega}^+) \rightarrow \Lambda\,(\bar{\Lambda}) + K^-\,(K^+) \quad \text{B.R.} = (67.8 \pm 0.7)\,\%$$

Eur. Phys. J. C 80, 167 (2020)

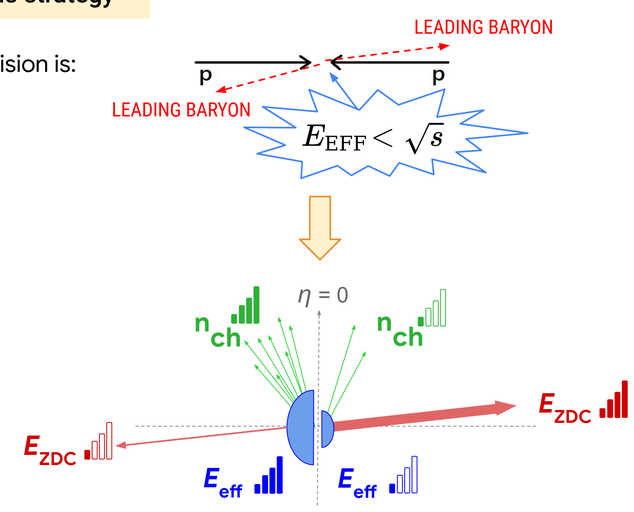
Analysis strategy

The **charged-particle multiplicity** produced in a pp collision is:

- characteristic of the **hadronic final** state
- strongly correlated to the **initial effective energy**

EFFECTIVE ENERGY
energy available for particle production in the **initial stages** of the pp collision

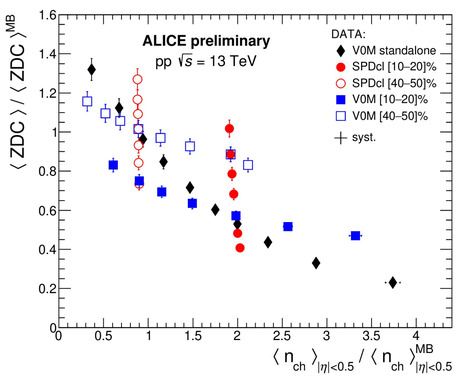
$E_{EFF} < \sqrt{s}$ due to **leading baryon effect**: high probability to emit forward baryons with a high longitudinal momentum



A. Akindinov et al., Eur. Phys. J. C 50, 341-352 (2007)

Event classes

The **forward energy decreases with** increasing particle **multiplicity** produced at **midrapidity**



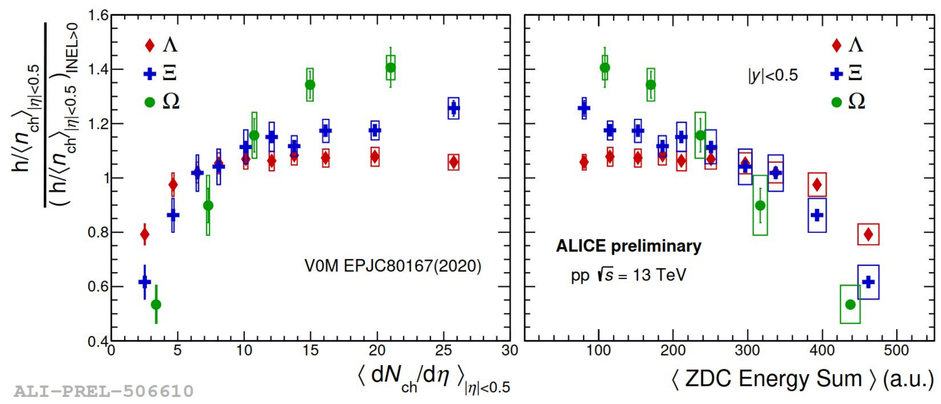
Single differential V0 classes

Fixed multiplicity at midrapidity + different energy in the ZDC

ZDC energy constrained in a small range + different multiplicity

ALICE Collaboration, arxiv.org/2107.10757

Single-differential results



Strangeness production per charged particle:

- **increases** with **midrapidity multiplicity** (left)
- is **anti-correlated** with the **ZDC energy** (right)

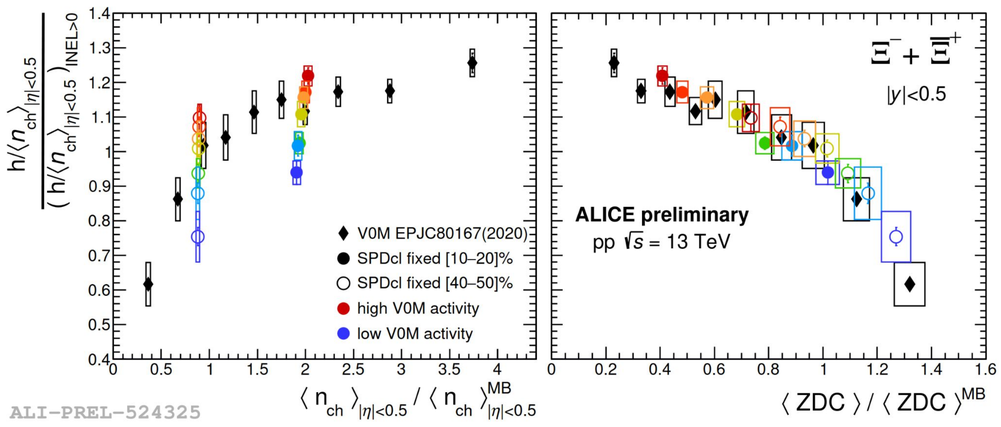
Can we **disentangle** the dependence on effective energy and multiplicity?

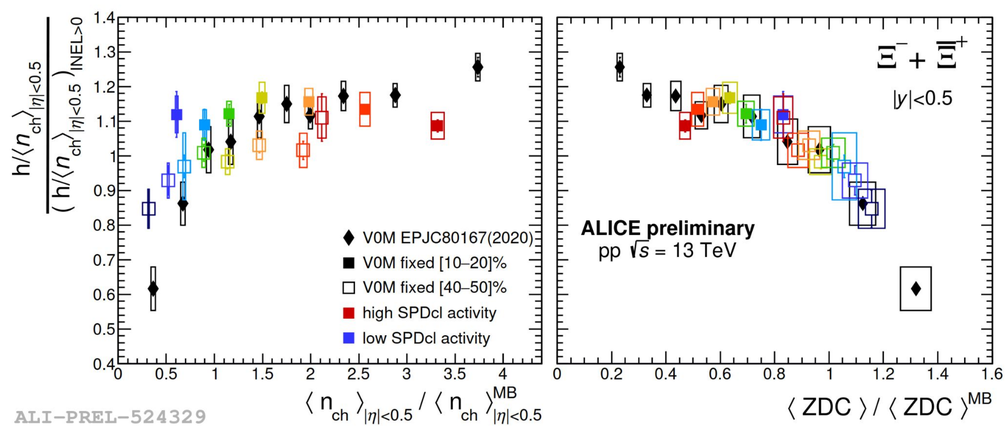
Double-differential results

In events with the fixed multiplicity:

- **increase** in Ξ production per charged particle is observed for **decreasing forward energy** (ZDC)
- scaling trends with ZDC energy are **compatible within uncertainties**

Strangeness enhancement in pp collisions is **observed at fixed** final state **multiplicity**





In events with ZDC energy constrained in a small range:

- strangeness **enhancement with multiplicity is reduced** (left)
- scaling **trends** are **compatible** within uncertainties (right)

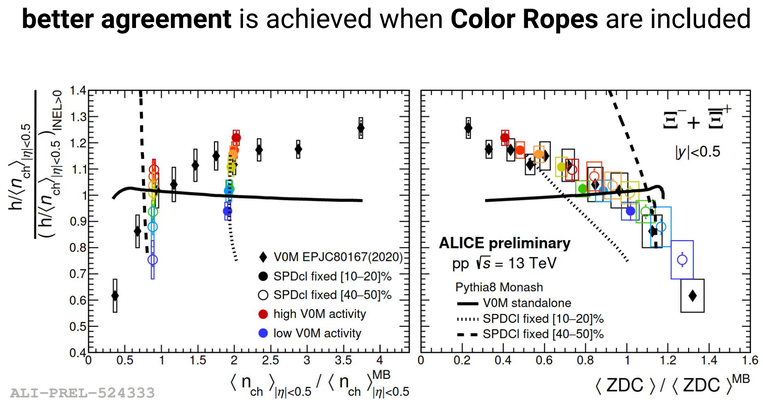
Strangeness enhancement in pp collisions is **correlated with the effective energy**

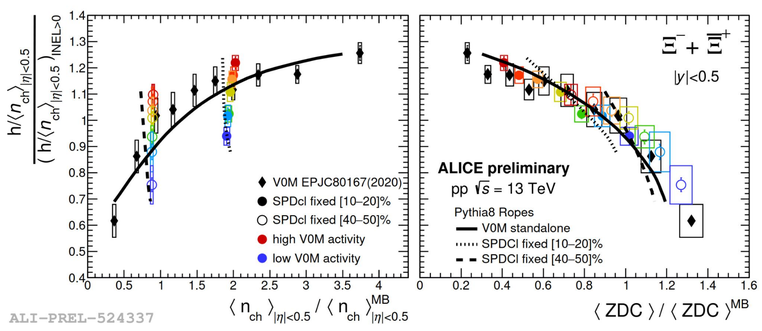
Summary

Strangeness enhancement in pp collisions:

- is **observed** at **fixed midrapidity multiplicity**
- shows a **strong correlation with the effective energy**, which reflects the initial stage of the collision

The **Pythia Monash** tune **fails to** reproduce the results, a **better agreement** is achieved when **Color Ropes** are included





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