HADRON 2021

19th INTERNATIONAL CONFERENCE ON HADRON SPECTROSCOPY AND STRUCTURE

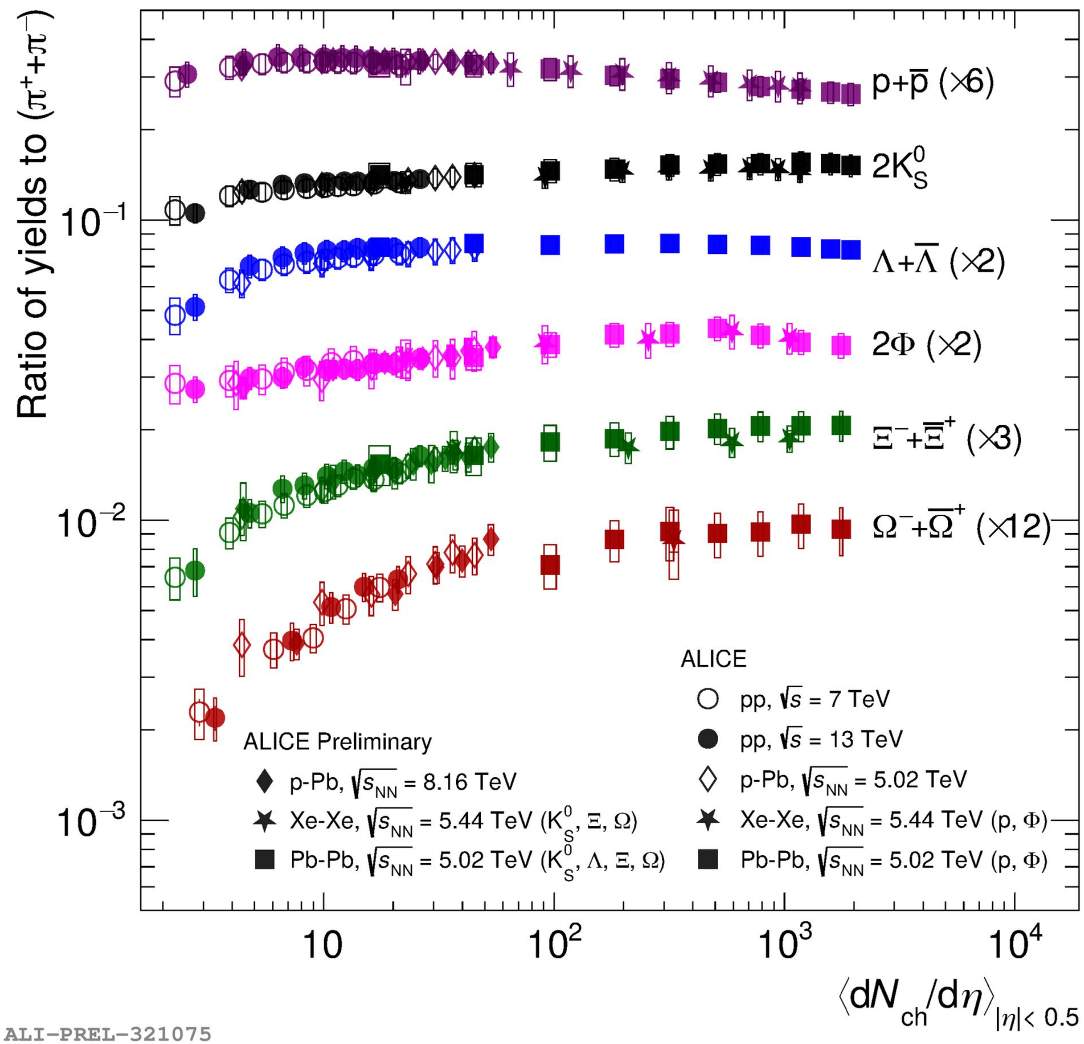
# Recent results on strange and multi-strange particle production with ALICE at the LHC


Presenter: Meenakshi Sharma
(on behalf of the ALICE Collaboration)

ALICE

UNIVERSITY OF JAMMU

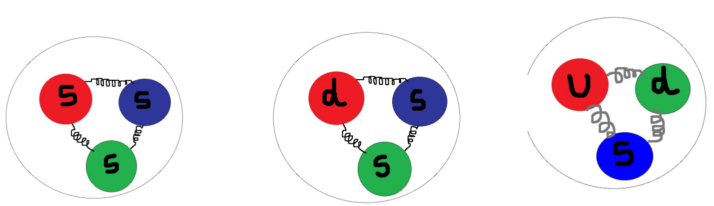
# Strangeness enhancement across multiplicity, collision energy and system size




ALICE has measured the ratio of strange to non-strange hadron yields ( h/π ) across multiplicities, collision systems and energies

- ➢ increases with multiplicity
- ➢ smoothly evolves across different collision systems
- ➢ no dependence on collision energy for similar multiplicities
- ➢ enhancement is larger for particles with larger strangeness content

**E(Ω) > E(Ξ) > E(Λ)**

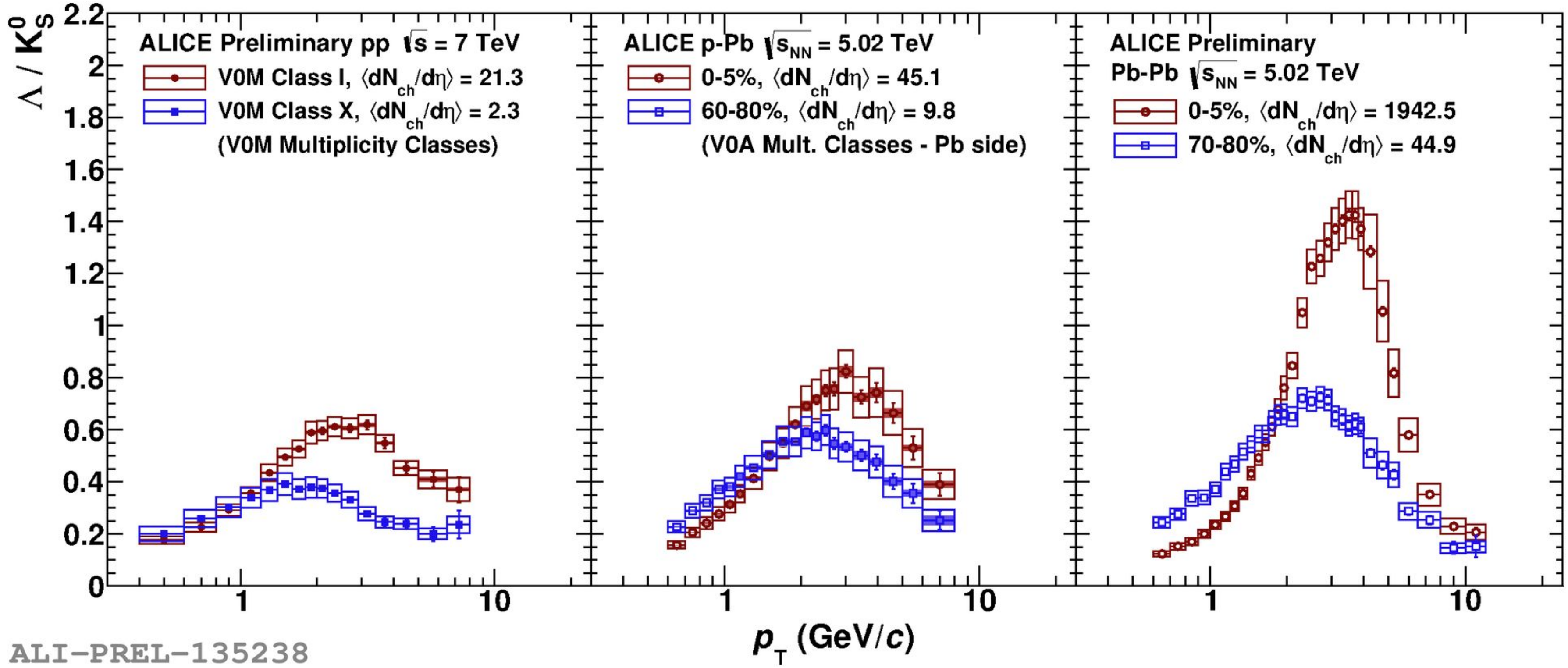


# Baryon Over Meson

Enhancement of $\Lambda/K^0_s$ at intermediate $p_T$ (~ 3 GeV)

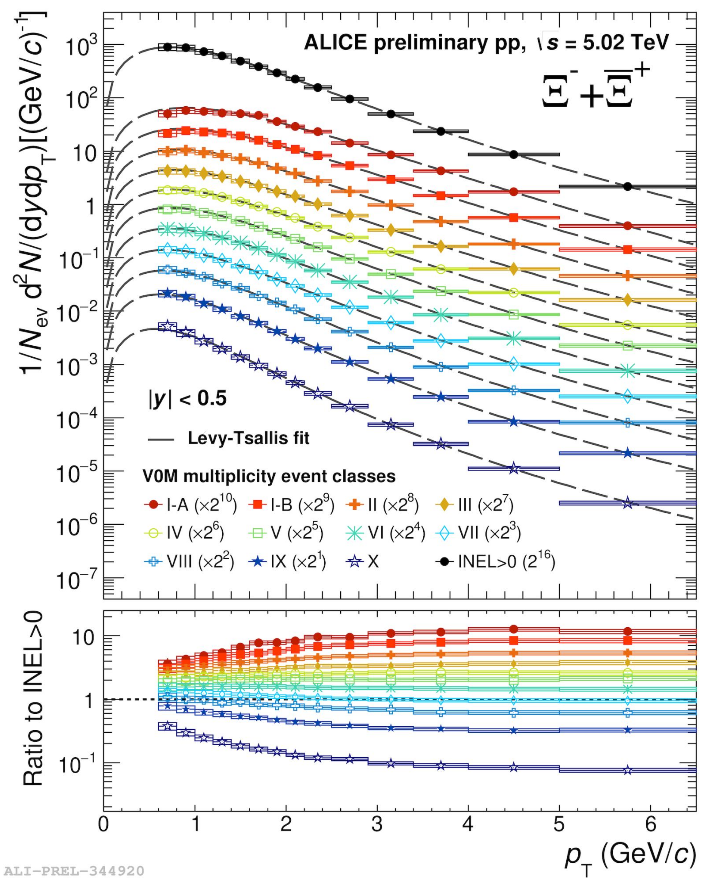
- ❖ Similar behaviour observed in different collision systems (pp, p-Pb and Pb-Pb) and also in p/π ratio
- ❖ Larger effect in collisions characterised by a larger charged particle multiplicity

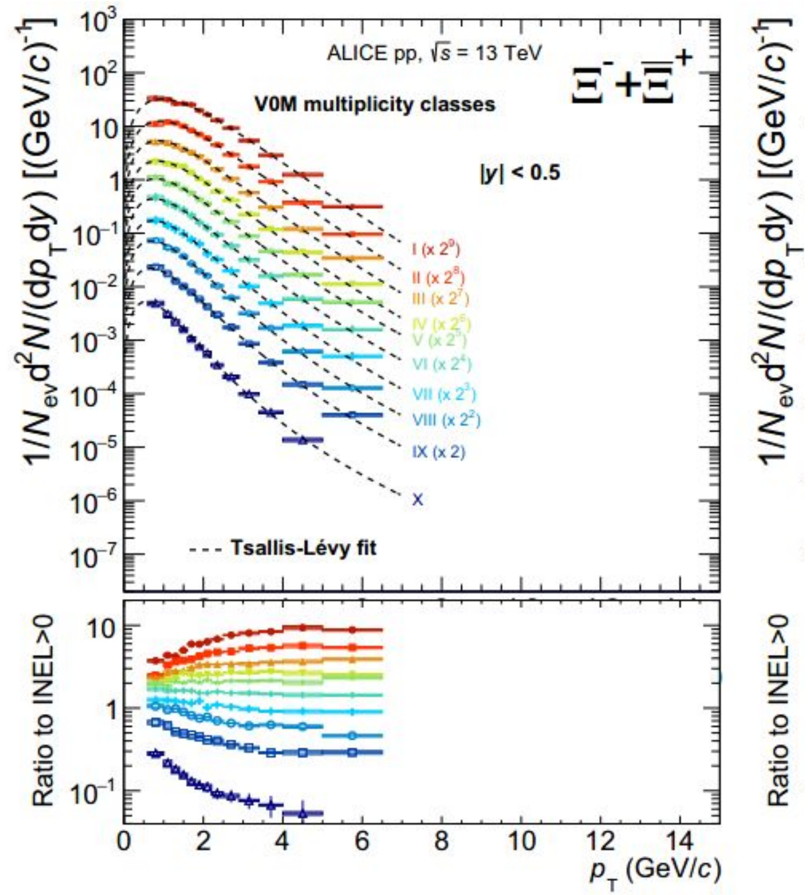
*Hints of collective phenomena in small systems?*




ALICE Collaboration, Phys. Rev. C 99, 024906 (2019)

# $p_T$ differential yield of strange particles




ALICE Collaboration, Eur. Phys. J. C80, 167 (2020)

- Clear evolution of particle spectra with multiplicity
- Spectra harden towards higher multiplicity as observed in p-Pb and Pb-Pb

**Hints of collective phenomena in small systems ?**

# ALICE at the LHC

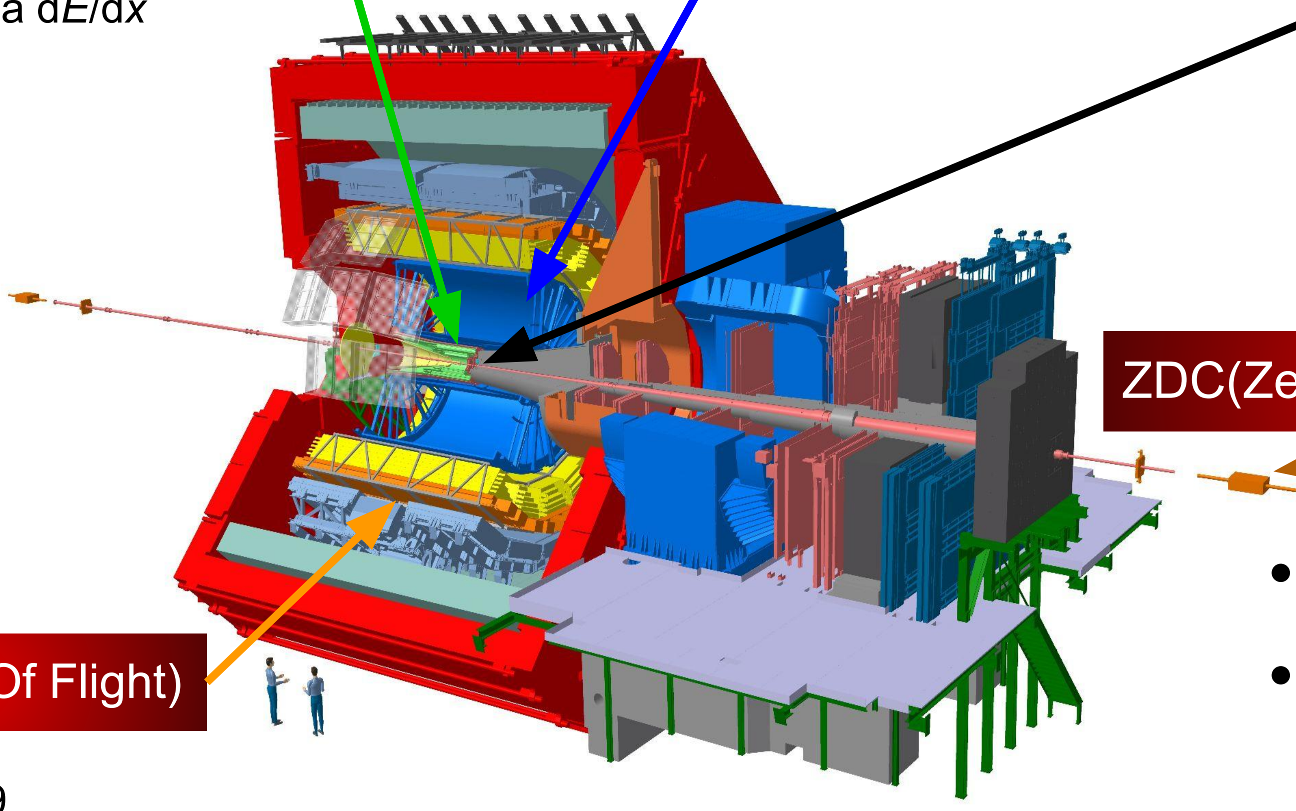
ALICE

## ITS (Inner Tracking System) and TPC (Time Projection Chamber)

- $|\eta| < 0.9$
- Tracking and vertexing
- PID via d$E$/dx

## V0

- $2.8 < \eta < 5.1$ (V0A), $-3.7 < \eta < -1.7$ (V0C)
- Multiplicity percentile classes based on the V0 signal amplitude



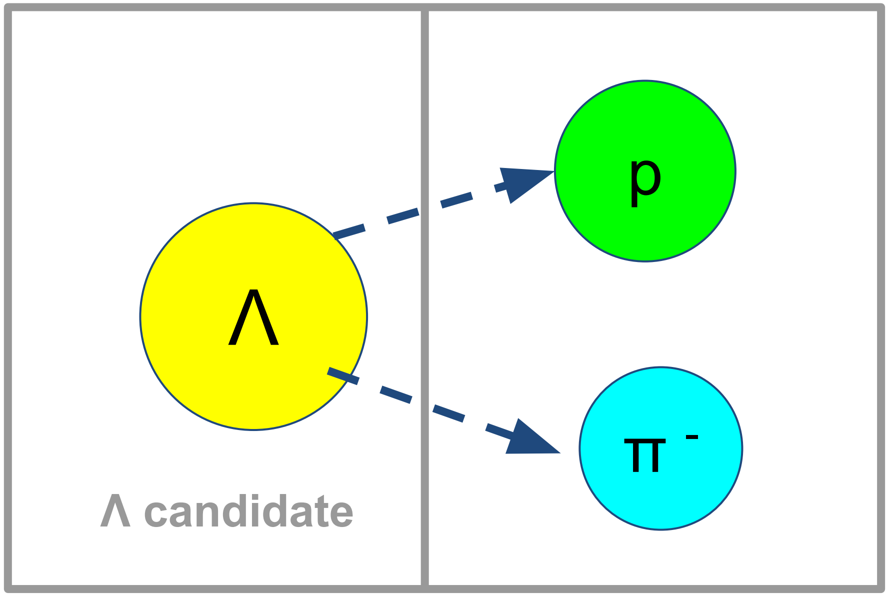
## ZDC(Zero Degree Calorimeter)

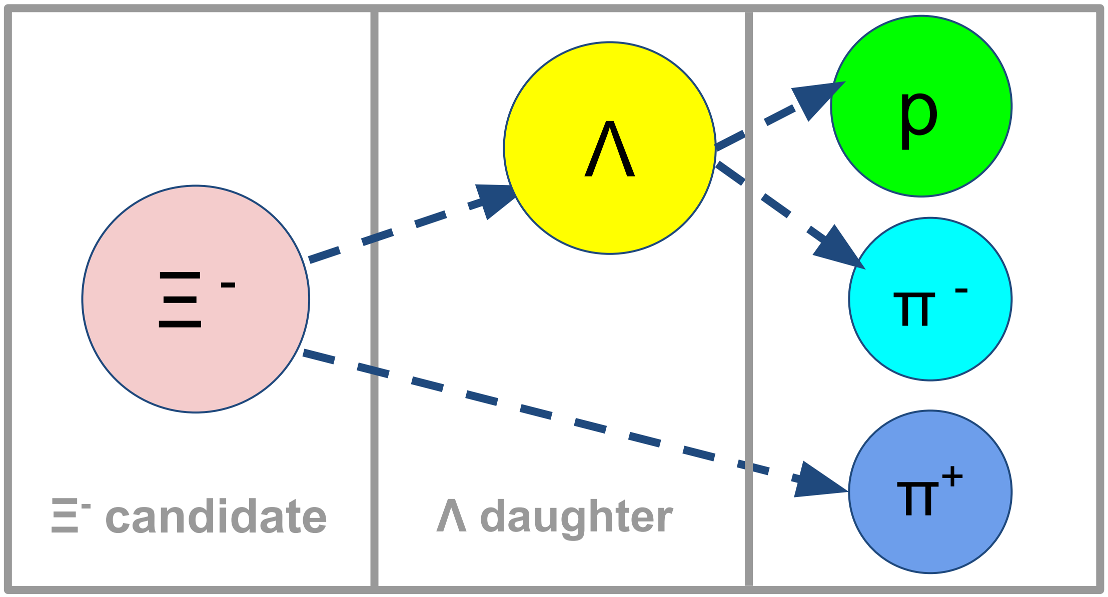
- $|\eta| > 8.8$ (ZN), $6.5 < |\eta| < 7.4$ (ZP)
- Energy percentile classes based on the energy deposits of forward emitted particles

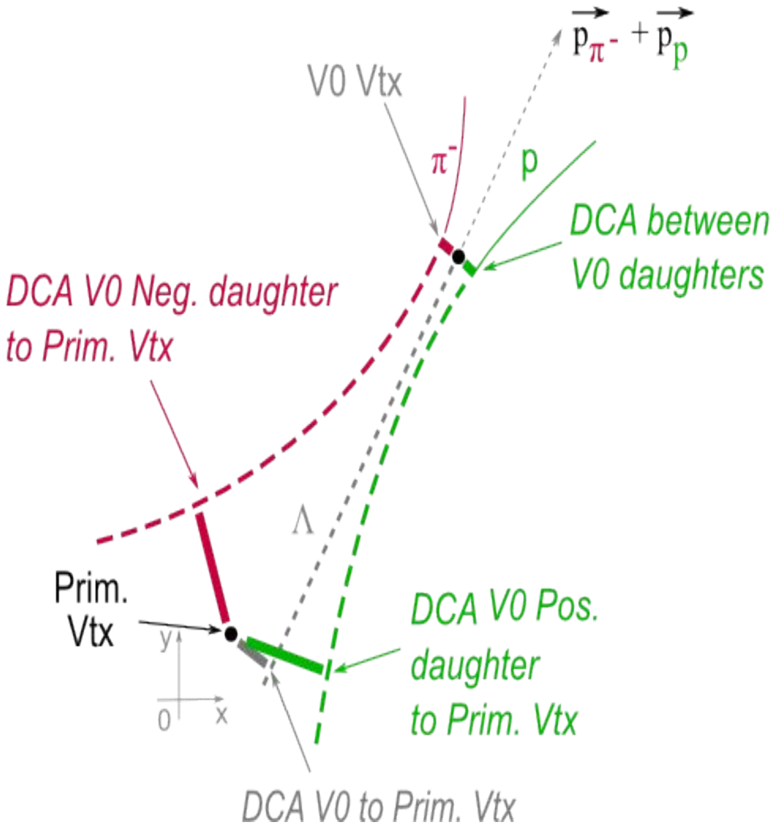
## TOF(Time Of Flight)

- $|\eta| < 0.9$
- PID via Time-Of-Flight technique

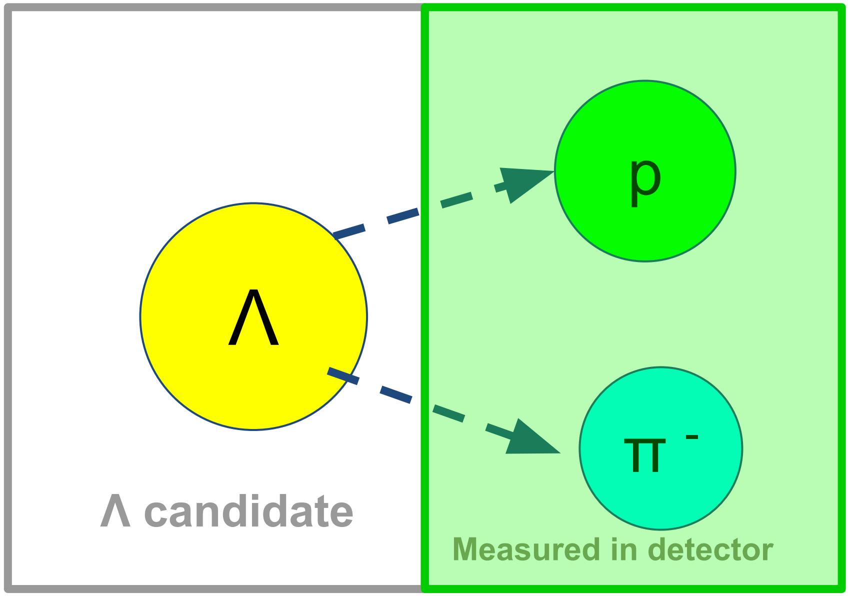
# Strange particle identification in ALICE

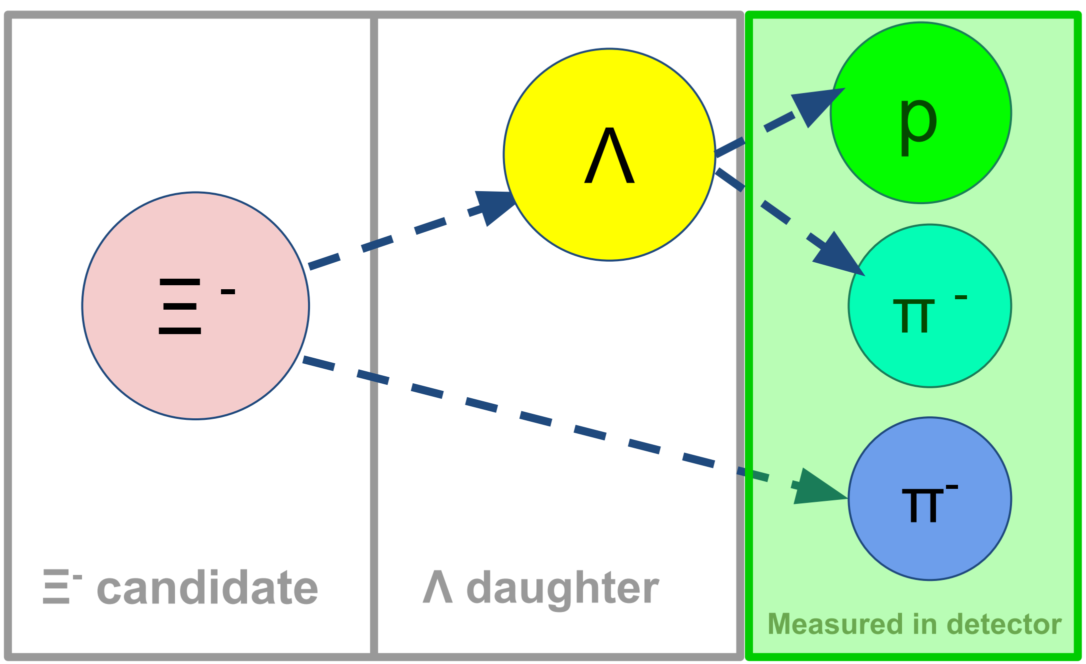


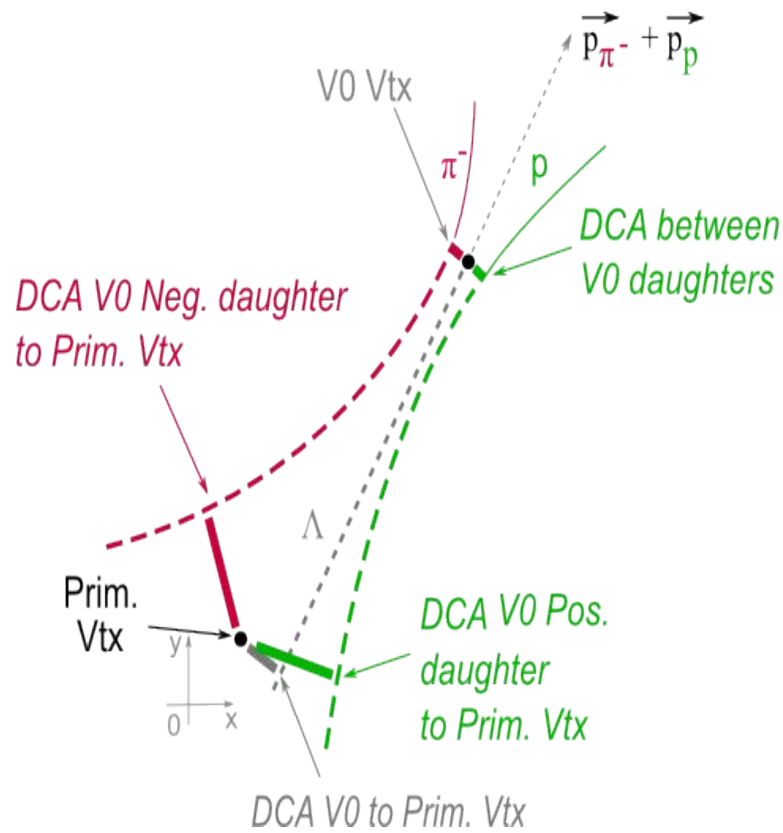



# Strange particle identification at ALICE



# Investigating the strange particle production in pp

ALICE

Recent studies have been performed in small systems to investigate the strange hadron production mechanism:

- **Angular correlations for in-jet and out-of-jet studies of strange hadron production**

*Is strangeness enhancement in pp related to soft particle production or to hard processes, such as jets?*

- **Multi-differential studies of strange hadron production to disentangle initial and final state effects**

*Is strangeness enhancement in pp related exclusively to final state physics or to the available initial energy or both ?*

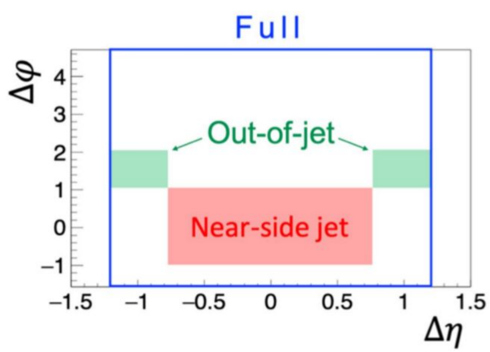
# Angular correlation: in-jet and out-of jet studies

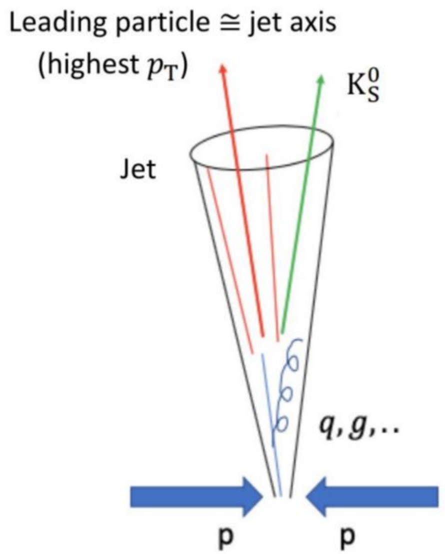
ALICE

- Angular correlation between trigger and associated particles:

$$\Delta\varphi = \varphi_{Trigg} - \varphi_{Assoc}$$

$$\Delta\eta = \eta_{Trigg} - \eta_{Assoc}$$



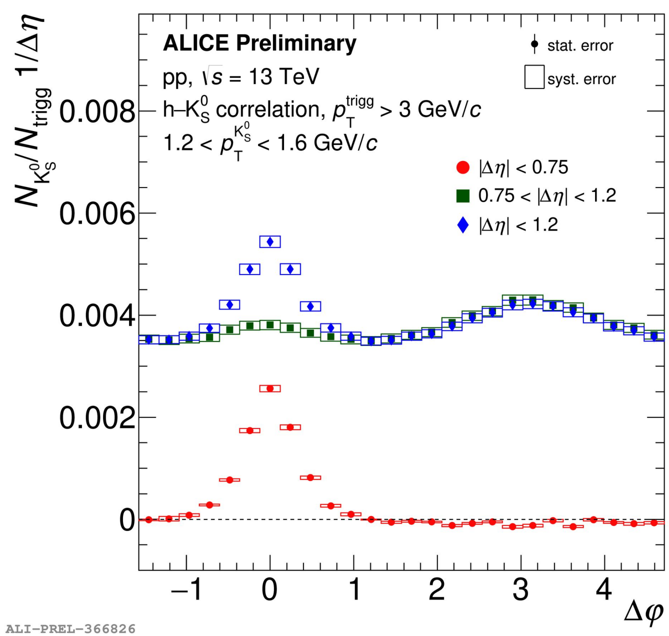




- Selection of the trigger particle as a proxy for the jet axis:

the charged primary particle with the highest $p_T$ ( $p_T$ > 3 GeV/c)

- Strange hadron identification (associated particles)

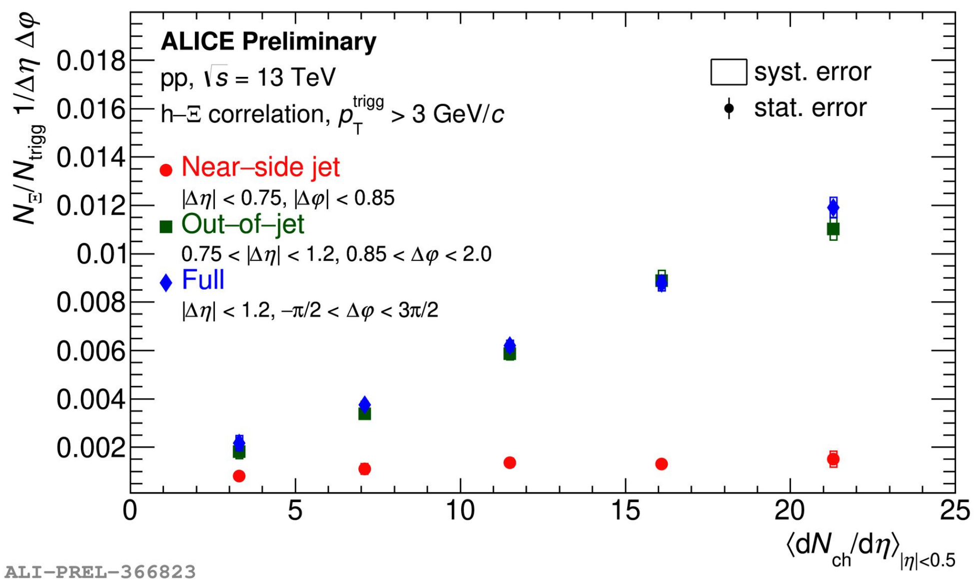
The near-side-jet contribution is obtained subtracting the full and out-of-jet yields in the selected Δφ-Δη region

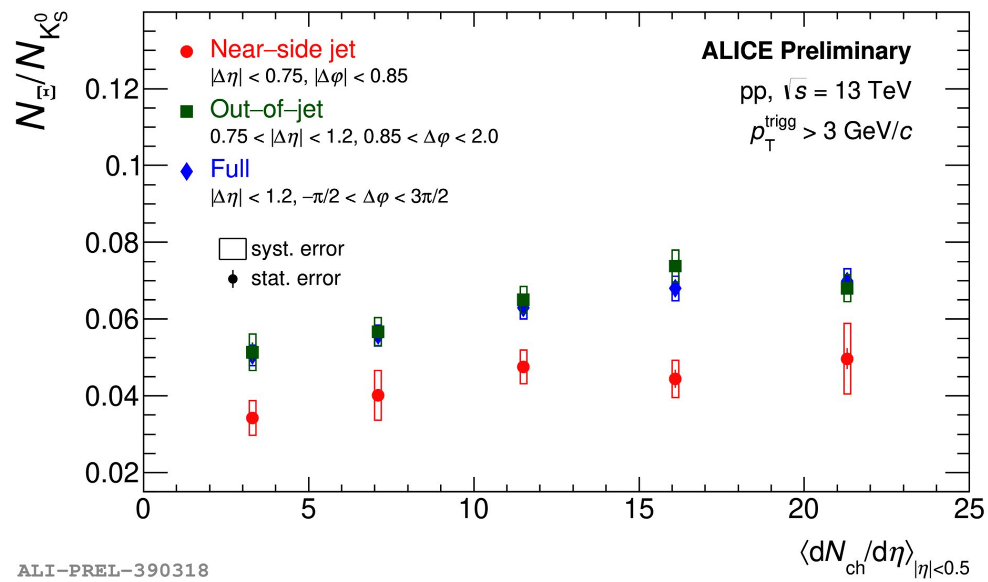


# Angular correlation: in-jet and out-of jet studies

ALICE

- Full and out-of-jet yields increase with multiplicity
- Near-side-jet yields have very small dependence on multiplicity
- The out-of-jet $\Xi/K^0_s$ yield ratio increases with multiplicity
- The near-side-jet $\Xi/K^0_s$ yield ratio shows a hint of increase with multiplicity



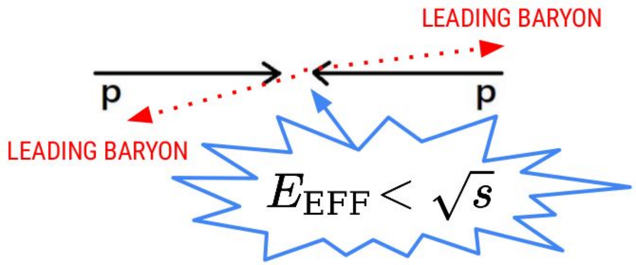




**Out-of-jet processes are the dominant contribution to the full yield ratio**

# Effective energy

**Effective energy** : Fraction of the initial energy spent in the hadronization process.

Effective energy < Initial energy



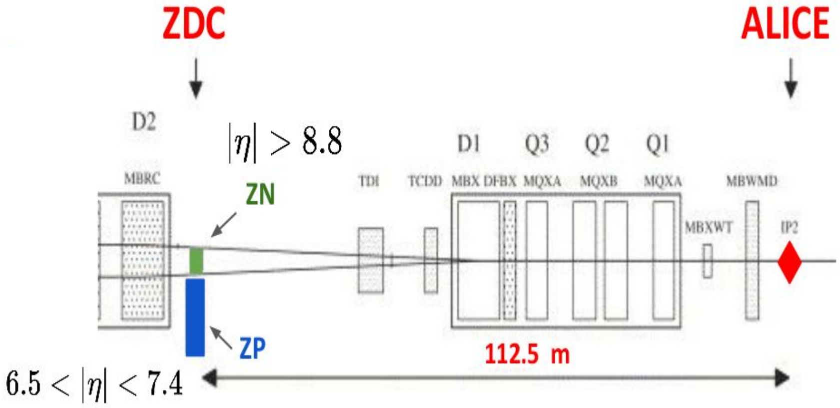

**Leading Effect**

**"Leading"** particle is the one carrying away a considerable fraction of the total available energy.

*Leading effect ⟶ high probability to emit baryons in the forward direction with high longitudinal momentum*

In ALICE, **ZDC** (Zero Degree Calorimeter) is used to reconstruct the energy of leading nucleons and define the effective energy classes.

$$E_{EFF} = \sqrt{s} - E_{|\eta|>8}$$

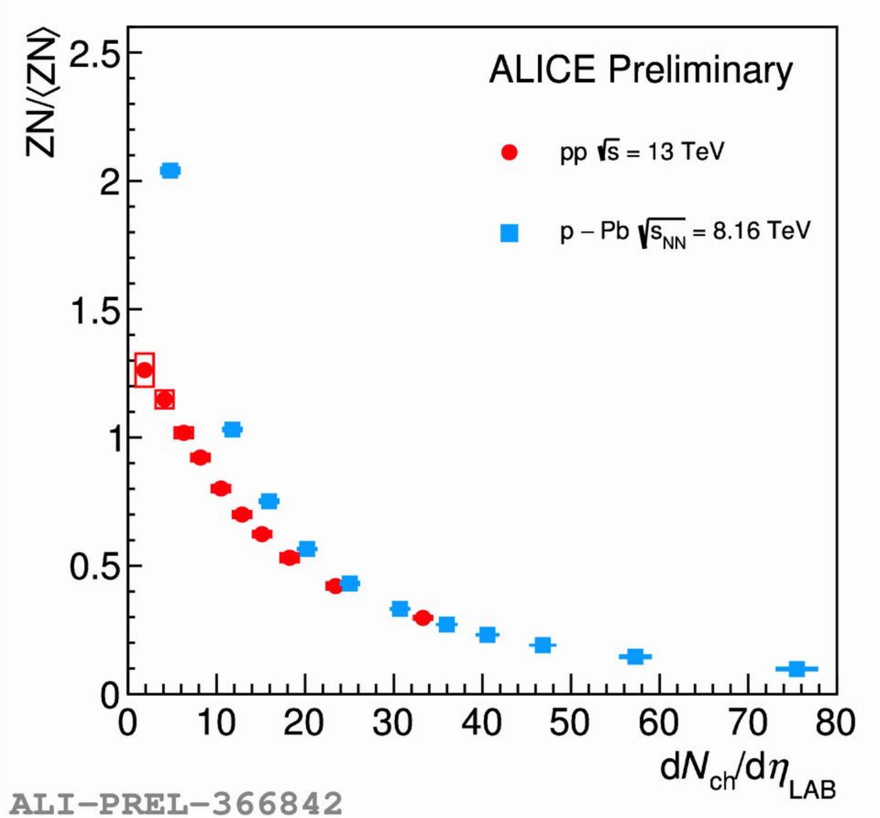


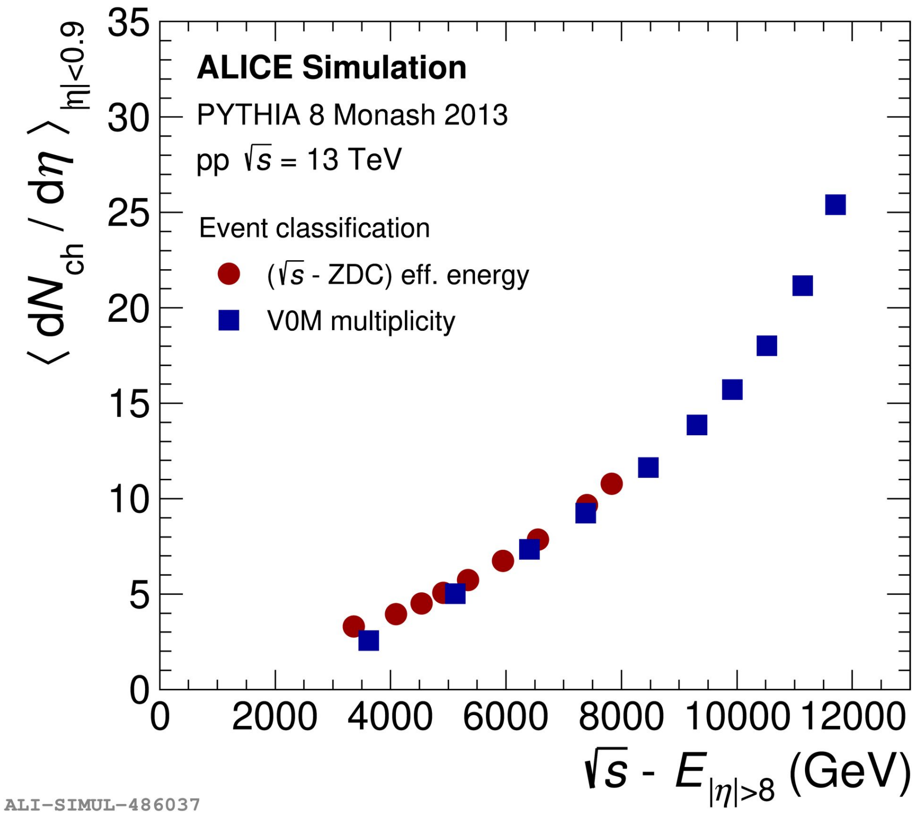
# Effective energy and multiplicity are correlated

Both Monte Carlo simulation and data confirm

***effective energy and multiplicity are correlated***

- data show forward energy decreases with increasing particle multiplicity at midrapidity
- simulation shows that V0 and ZDC based event classes have sensitivity to multiplicity and effective energy



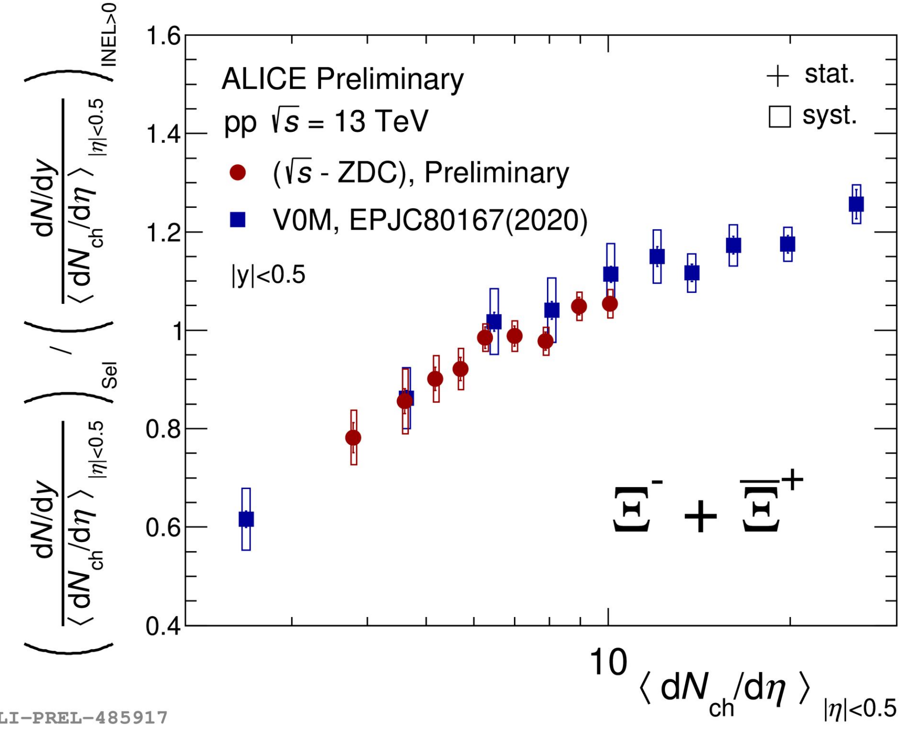



# Strangeness production in multiplicity and energy classes

ALICE

➢ (self-normalized) ratio of yields to the average charged particle multiplicity (in INEL>0) with multiplicity selected through V0 and ZDC

- strange particle production increases with multiplicity independent of the estimator used to classify events
- clear correlation among V0 and ZDC based event classes




★ Standalone analyses are not able to disentangle initial and final state effects
★ Combined classes could help to discriminate

# Strangeness production in combined classes

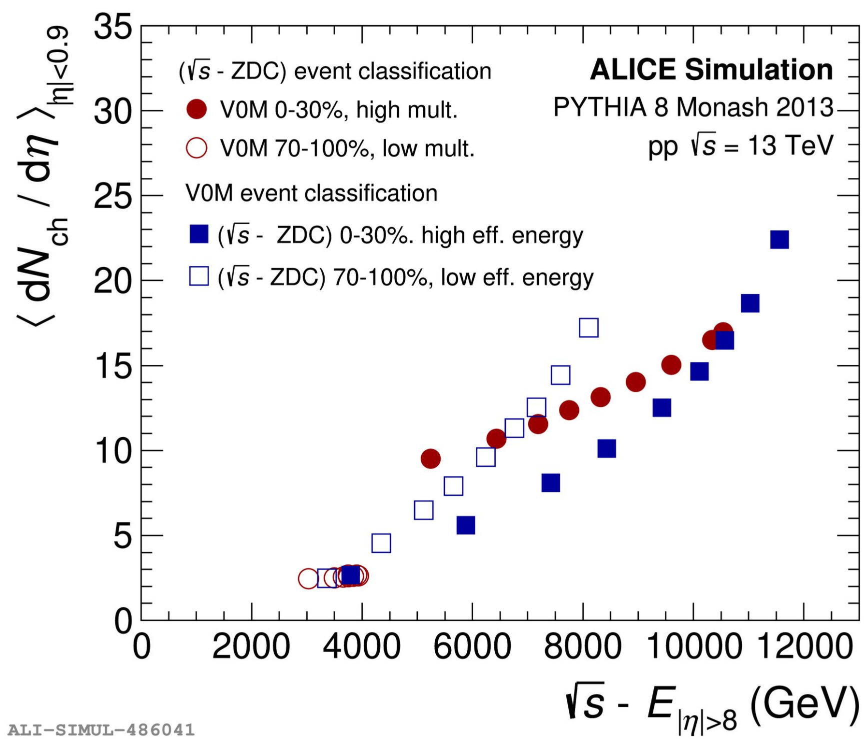
ALICE

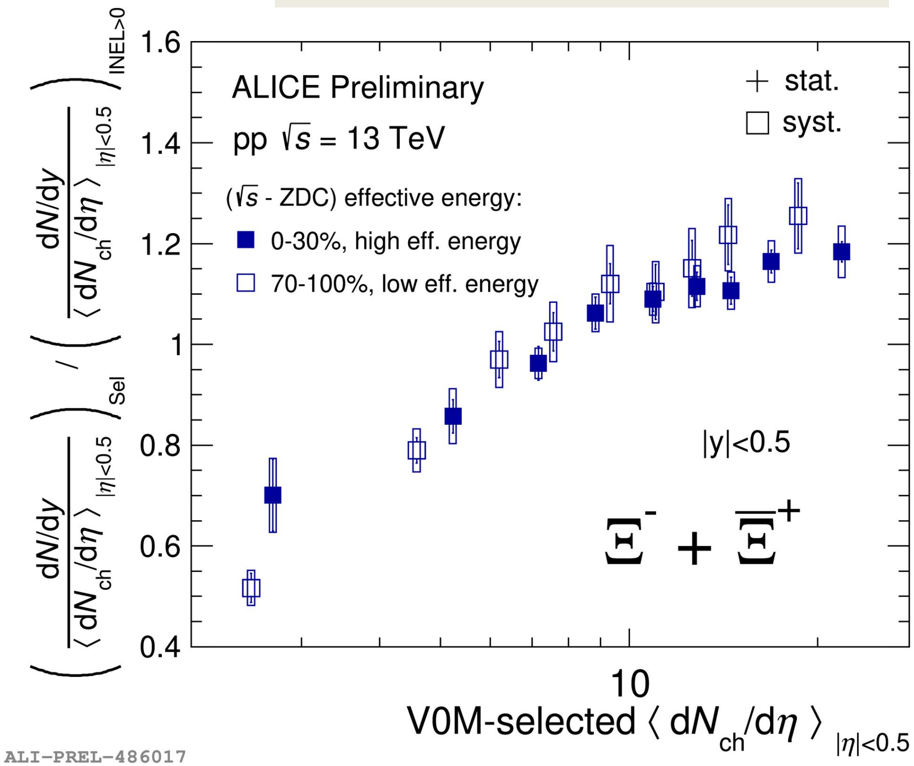
- ➢ Low multiplicity events correspond, on average, to events with significant energy released in the ZDCs **(lower energy available for particle production)**
- ➢ High multiplicity events correspond to events with a zero signal in the ZDCs **(high energy available for particle production)**

Definition of multiplicity and effective energy combined selections:

- ■ High effective energy → ($\sqrt{s}$ -ZDC) 0-30%
- □ Low effective energy → ($\sqrt{s}$ -ZDC) 70-100%

**Strangeness enhancement with multiplicity independent of the selection on effective energy**



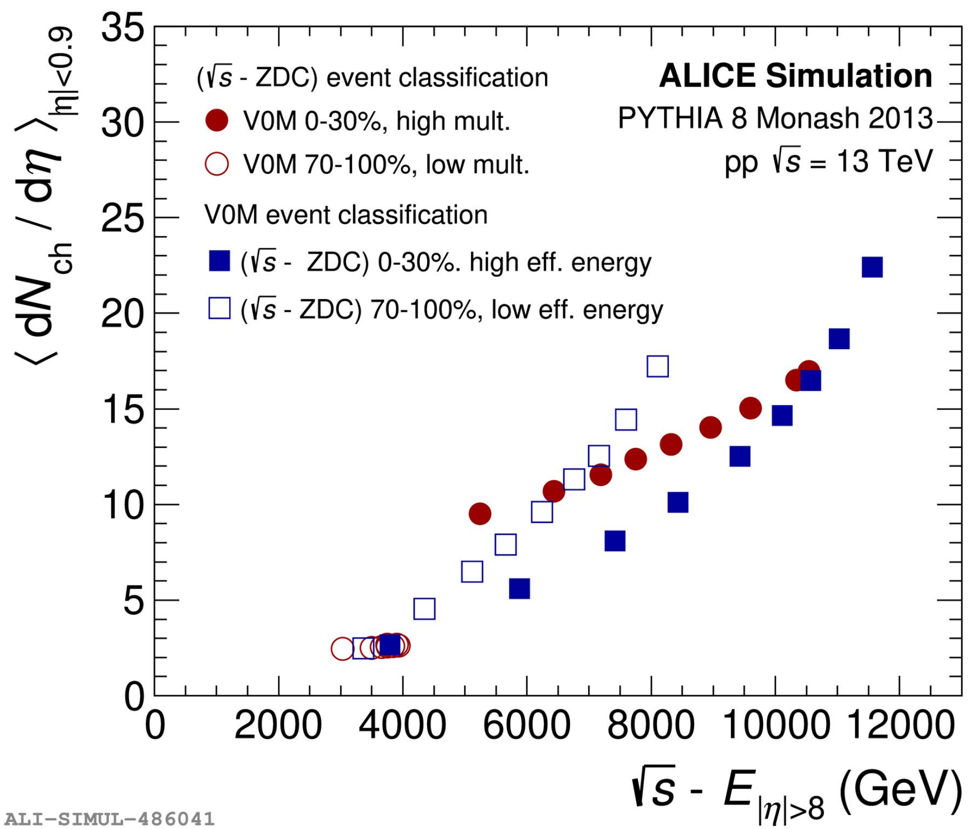
# Strangeness production in combined classes

ALICE

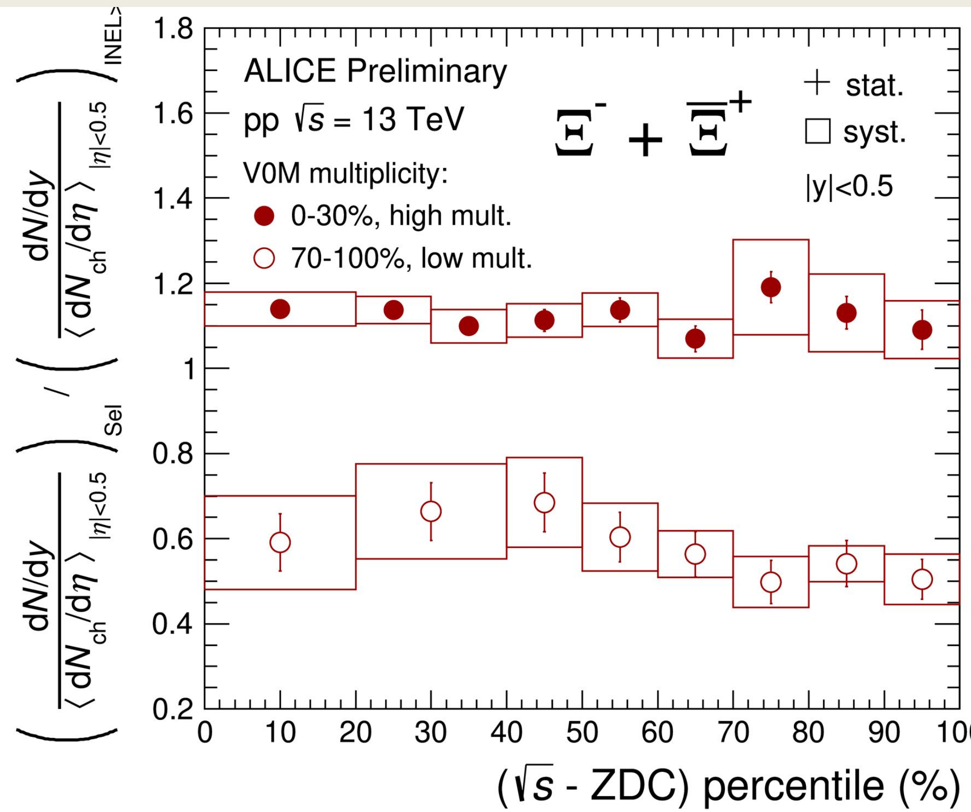
Ratio of Ξ yields over the average charged particle multiplicity (self-normalised to INEL>0) in effective energy classes fixing the multiplicity classifier to:

- High multiplicity → V0M 0-30 %
- Low multiplicity → V0M 70-100%

➔ **no significant evolution with effective energy**
➔ **final-state multiplicity is the dominant factor in strangeness enhancement**




ALI-SIMUL-486041




ALI-PREL-486025

# Summary

ALICE

➢ Studying the production of strange hadrons in and out of jets suggests **soft processes are the dominant contribution to strange particle production**

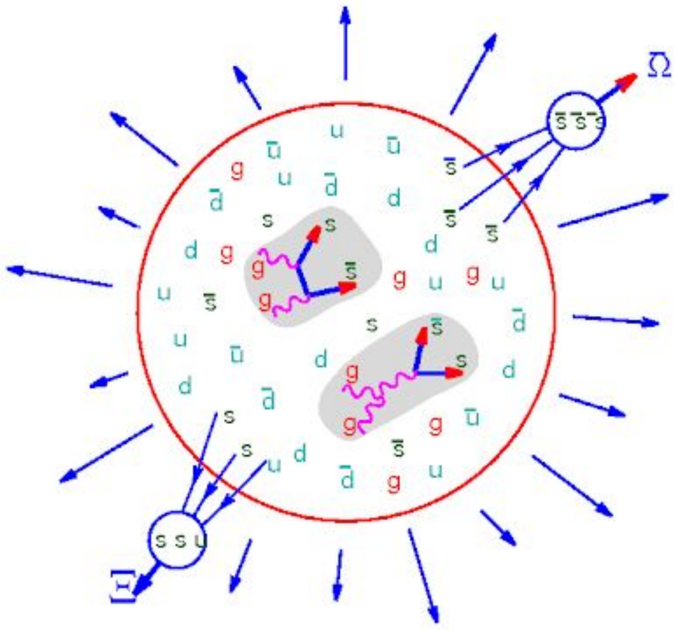
➢ Investigating strangeness production in multiplicity and effective energy combined selections:
   - **confirms the strong role of the final particle multiplicity in strangeness production**
   - **shows the effective energy plays no significant role in strangeness enhancement once multiplicity is selected**

*Thank you for your attention*

# Strangeness as a probe for QGP

ALICE

- Larger production cross-section in QGP compared to hadronic medium.
  - an enhancement is expected
    J. Rafelski and B. Muller, PRL. 48, 1066 (1982)




- s-quark mass ~ 100-150 MeV
  - can be thermalized in QGP medium
    **(T~200-300 MeV)**