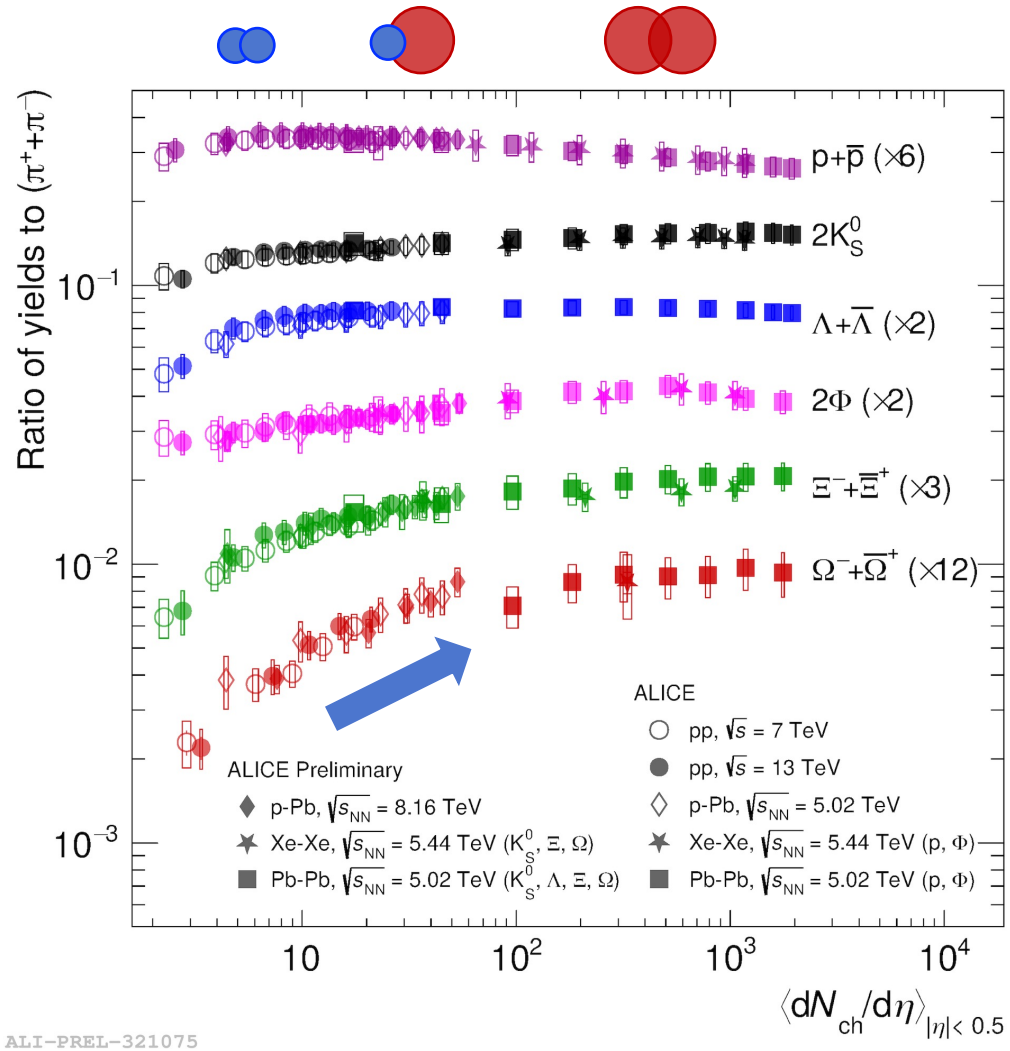
Strange hadron production in and out of jets in proton-proton collisions with ALICE

Chiara De Martin on behalf of the ALICE Collaboration

University and INFN - Trieste

Physics motivation

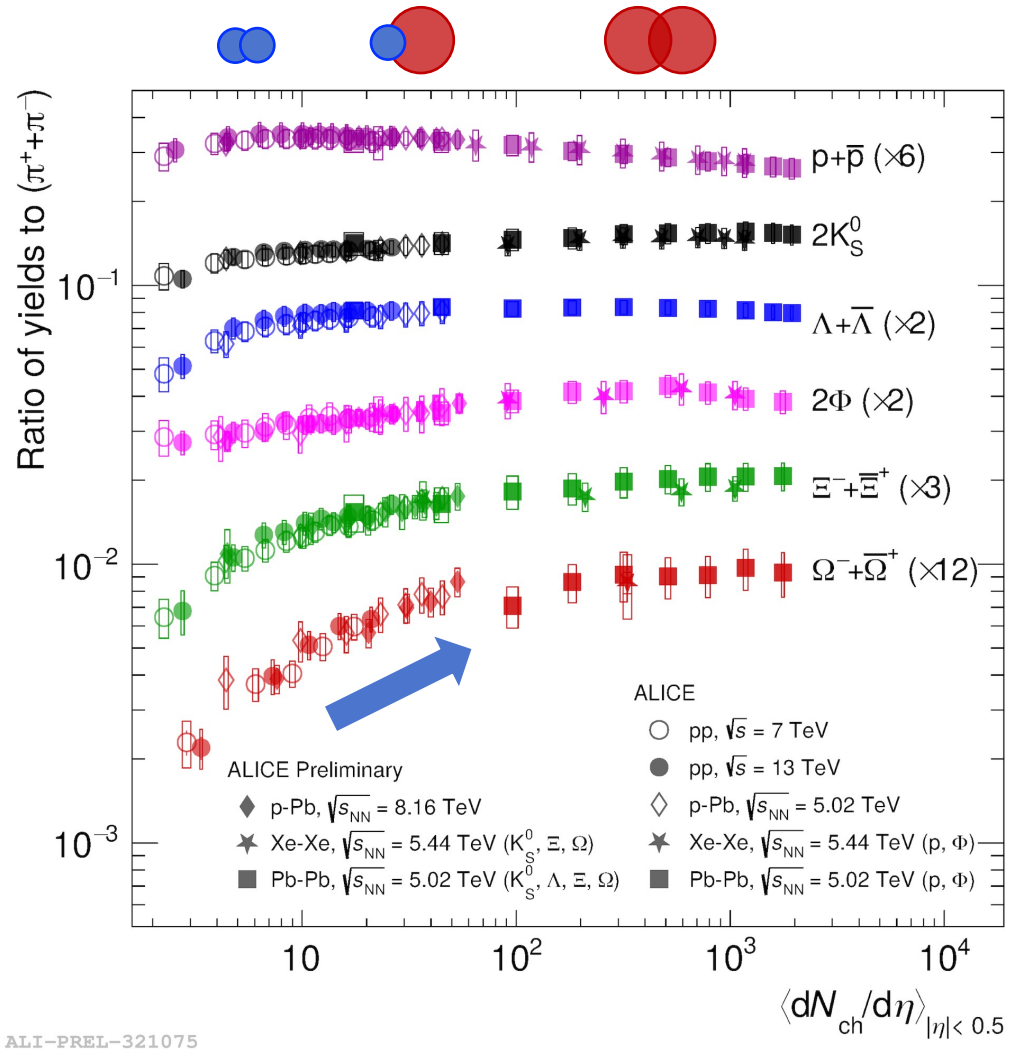


Strangeness enhancement:
The ratio between (multi-)strange hadron yields and pion yields is enhanced in heavy-ion collisions with respect to minimum bias pp collisions

- Smooth evolution with the multiplicity of charged particles across different collision systems (pp, p-Pb, Pb-Pb)
- No dependence on the collision energy at the LHC
- The enhancement is larger for particles with larger strangeness content ($\Omega > \Xi > \Lambda \sim K^0_S$)

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

Physics motivation



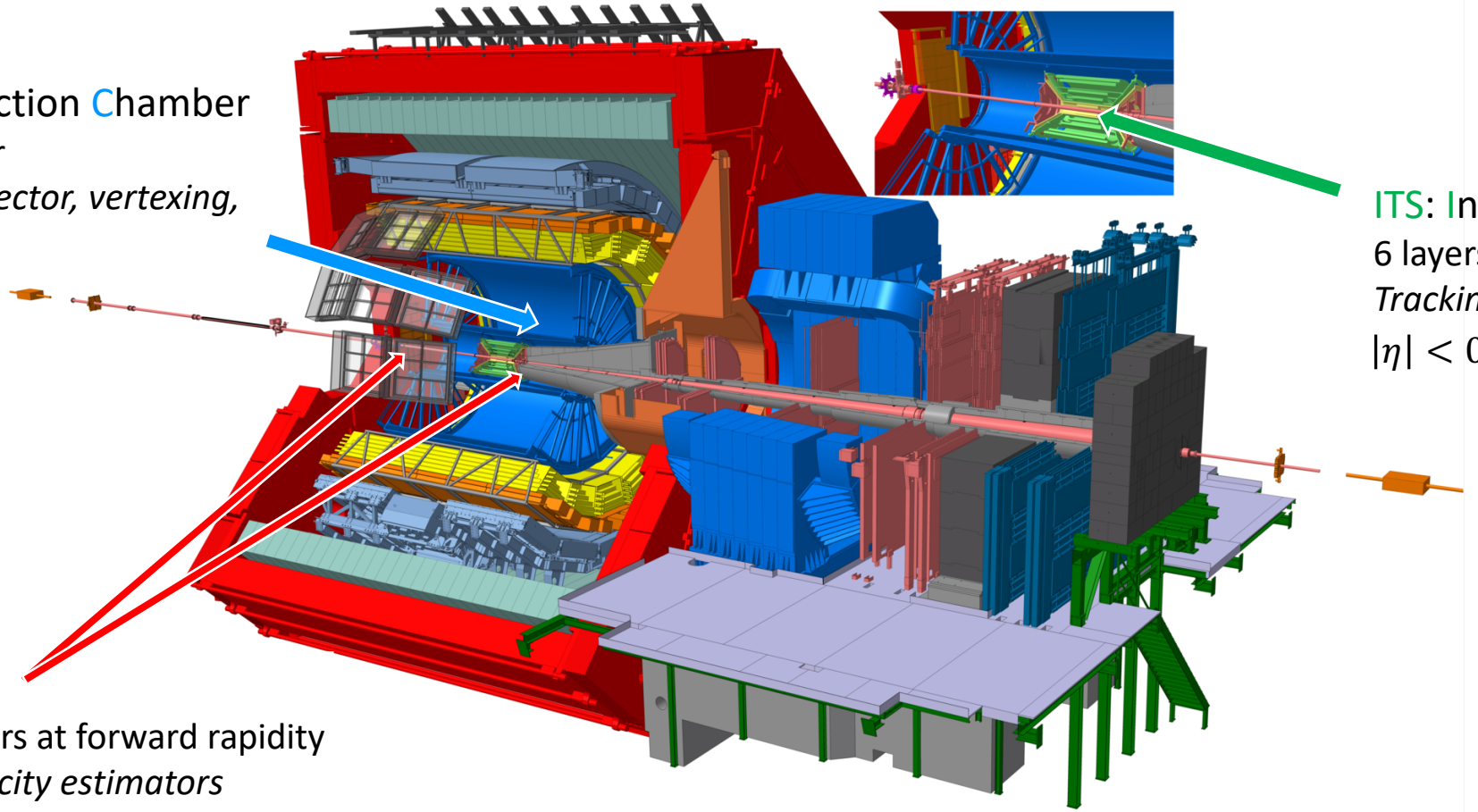
Strangeness enhancement:
The ratio between (multi-)strange hadron yields and pion yields is enhanced in heavy-ion collisions with respect to minimum bias pp collisions

- Is strangeness enhancement in pp collisions related to hard processes, such as jets, to out-of-jet processes, or to both?

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

ALICE at the LHC

TPC: Time Projection Chamber
Gas-filled detector
Main tracking detector, vertexing, PID (dE/dx)
$|\eta| < 0.9$



ITS: Inner Tracking System
6 layers of silicon detectors
Tracking, triggering, vertexing
$|\eta| < 0.9$

V0A and V0C
Arrays of scintillators at forward rapidity
Triggering, multiplicity estimators
V0A: $2.8 < \eta < 0.9$
V0C: $-3.7 < \eta < -1.7$

Correlations of high-p_{T} charged hadrons with strange particles

The angular correlation method:

1. Selection of the trigger particle (~jet axis): the charged primary particle with the highest p_{T} and $p_{\mathrm{T}} > 3$ GeV/c

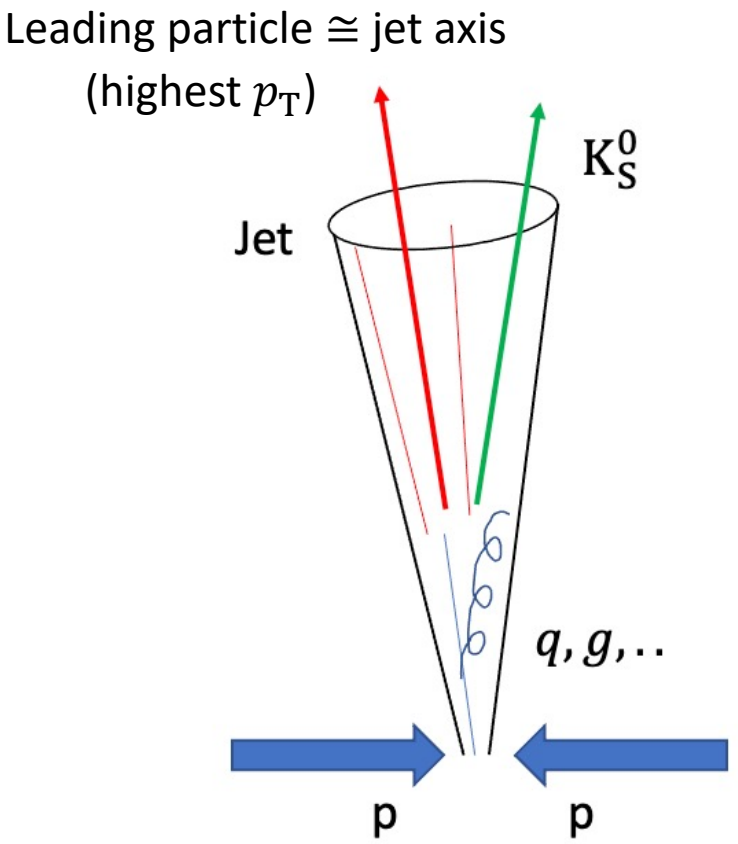
2. Identification of strange hadrons (associated particles)

3. Angular correlation between trigger and associated particles is calculated

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

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

φ: azimuthal angle
η = - ln (tan(θ/2))
θ: polar angle



Correlations of high-p_{T} charged hadrons with strange particles

The angular correlation method:

1. Selection of the trigger particle (~jet axis): the charged primary particle with the highest p_{T} and $p_{\mathrm{T}} > 3$ GeV/c

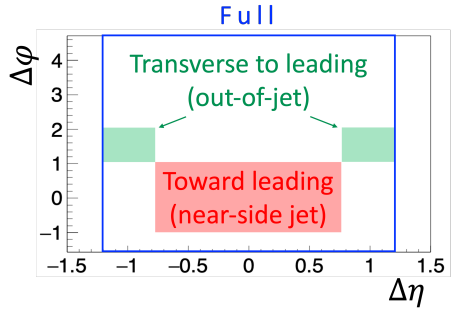
2. Identification of strange hadrons (associated particles)

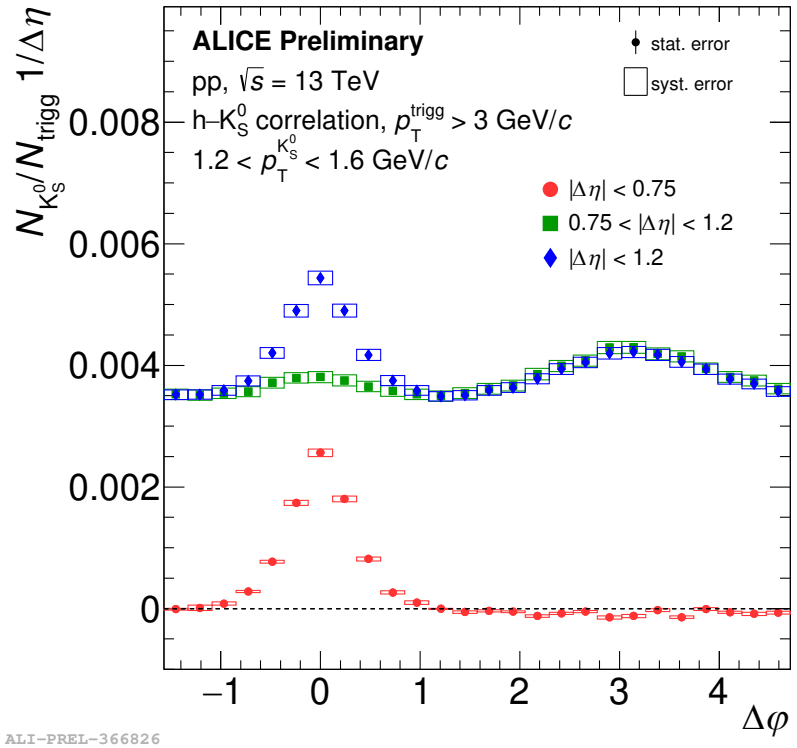
3. Angular correlation between trigger and associated particles is calculated

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

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

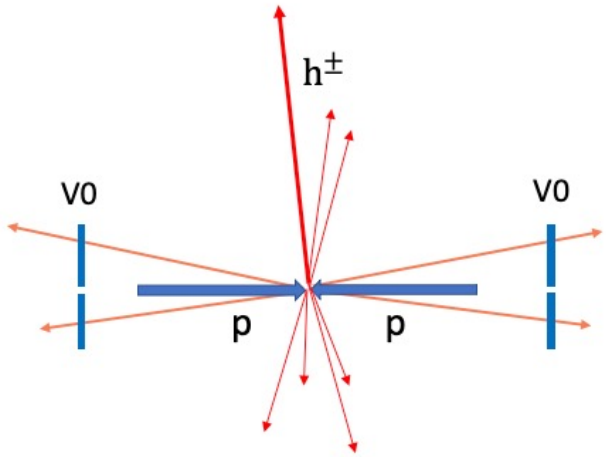
φ: azimuthal angle
η = - ln (tan(θ/2))
θ: polar angle



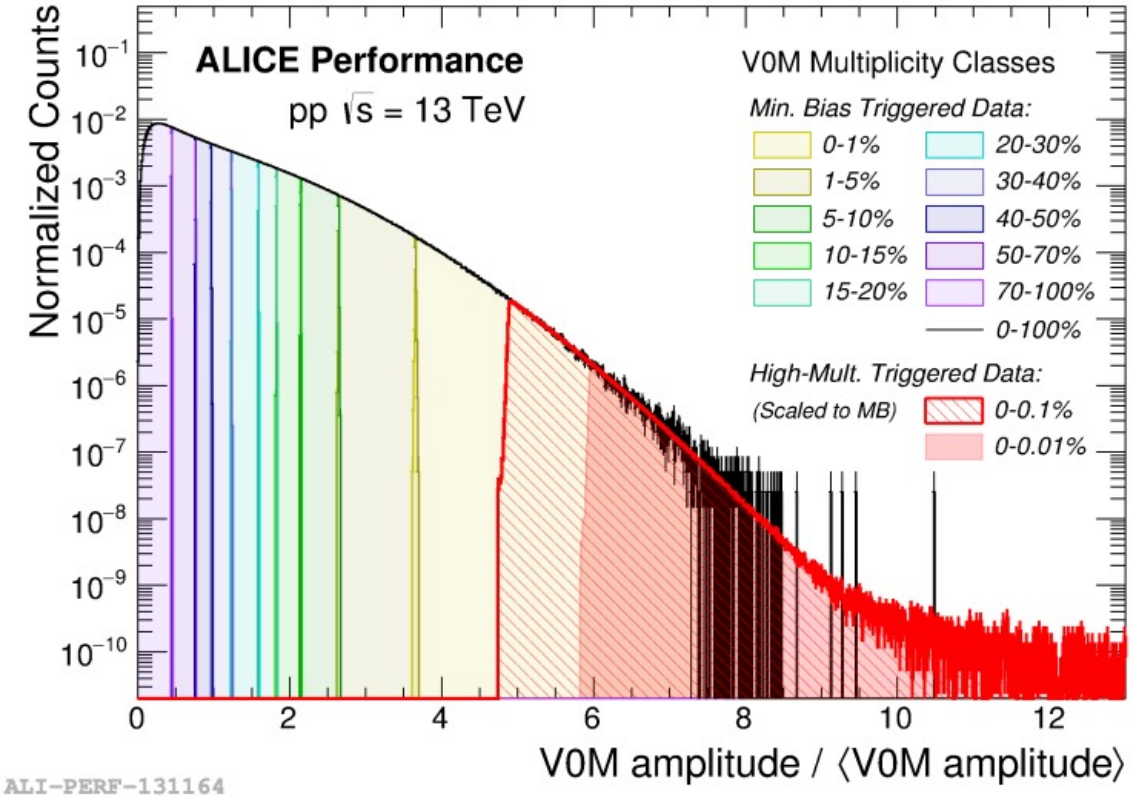


Event classification according to charged particle multiplicity

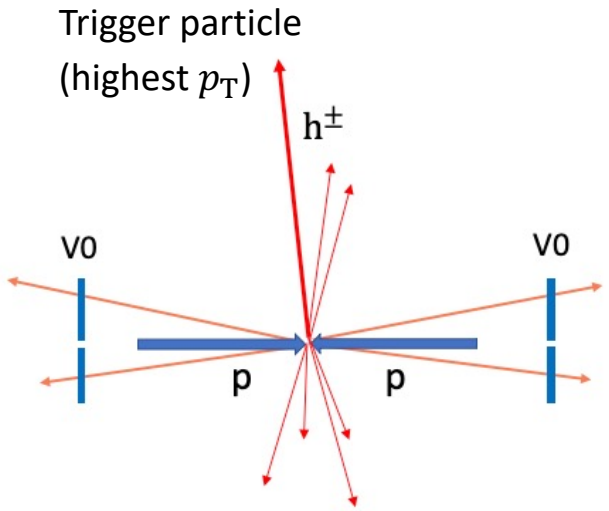
The analysis is performed in multiplicity classes based on the signal amplitude in the V0 detectors



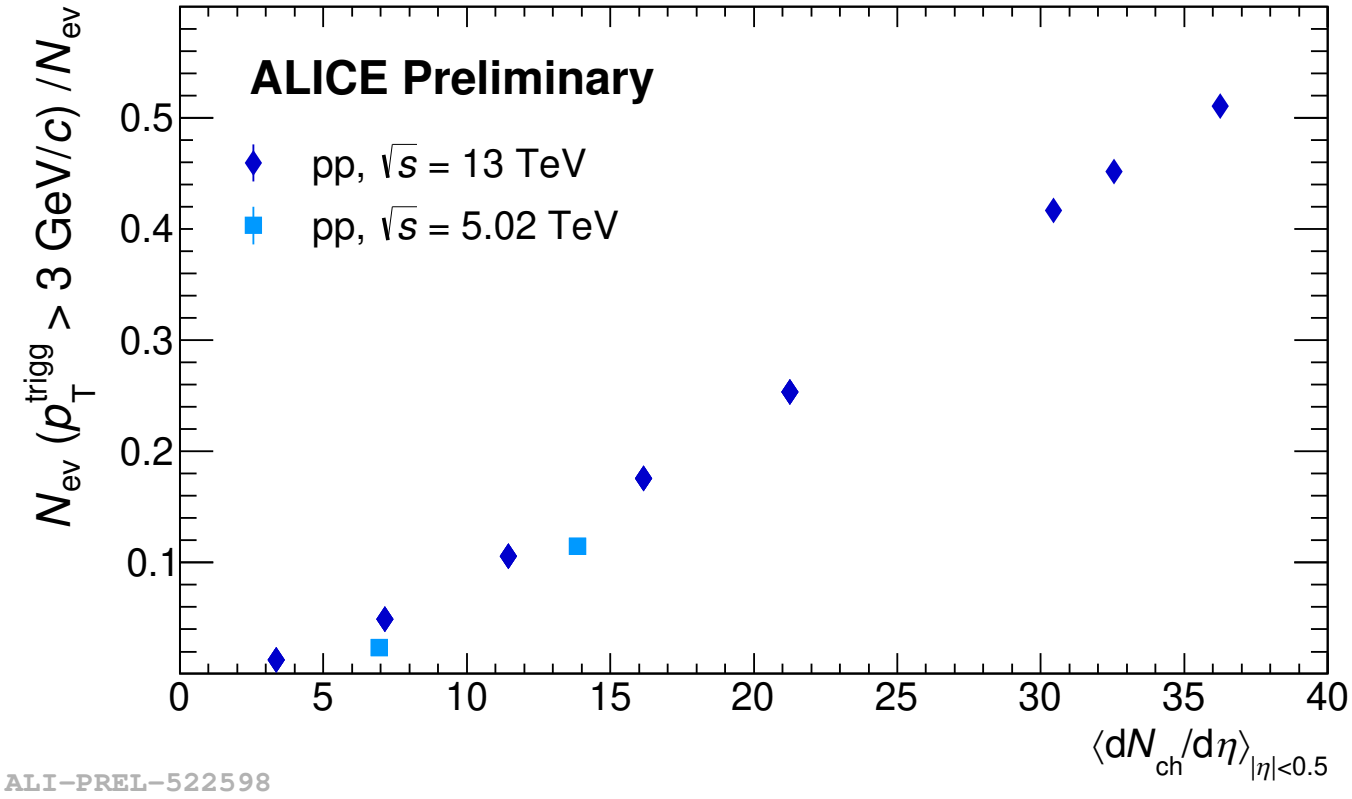
Large activity in the V0 → large average number of charged particles produced at midrapidity



Events with trigger particle vs charged particle multiplicity

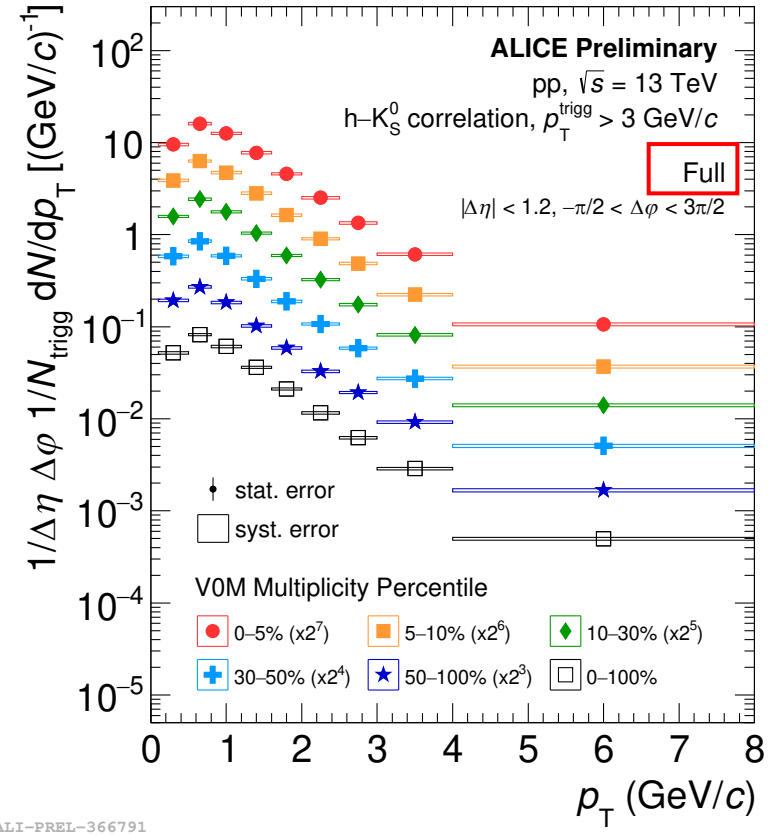


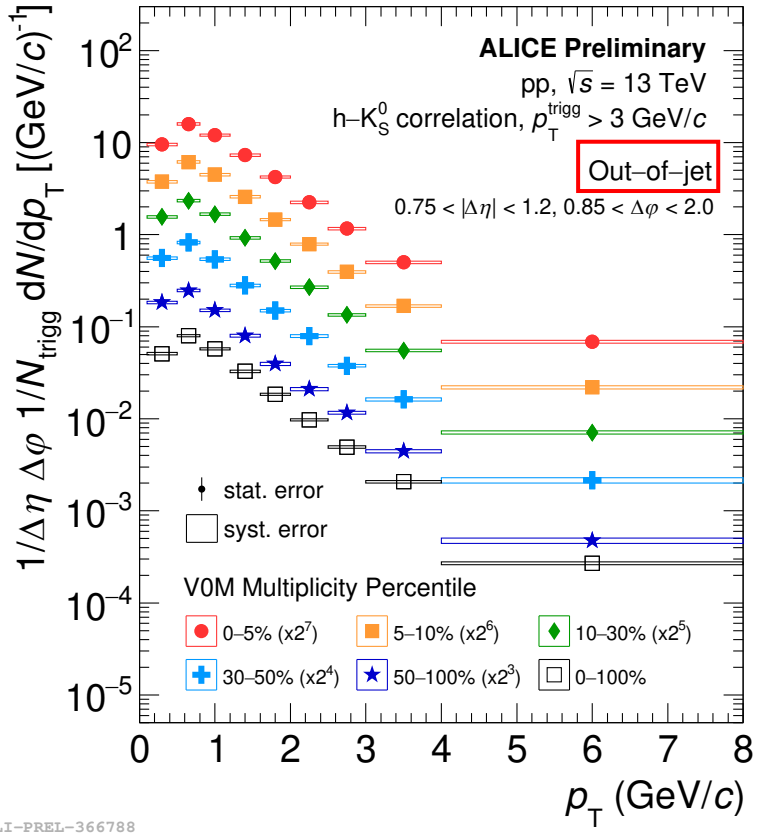
Large activity in the V0 → large average number of charged particles produced at midrapidity

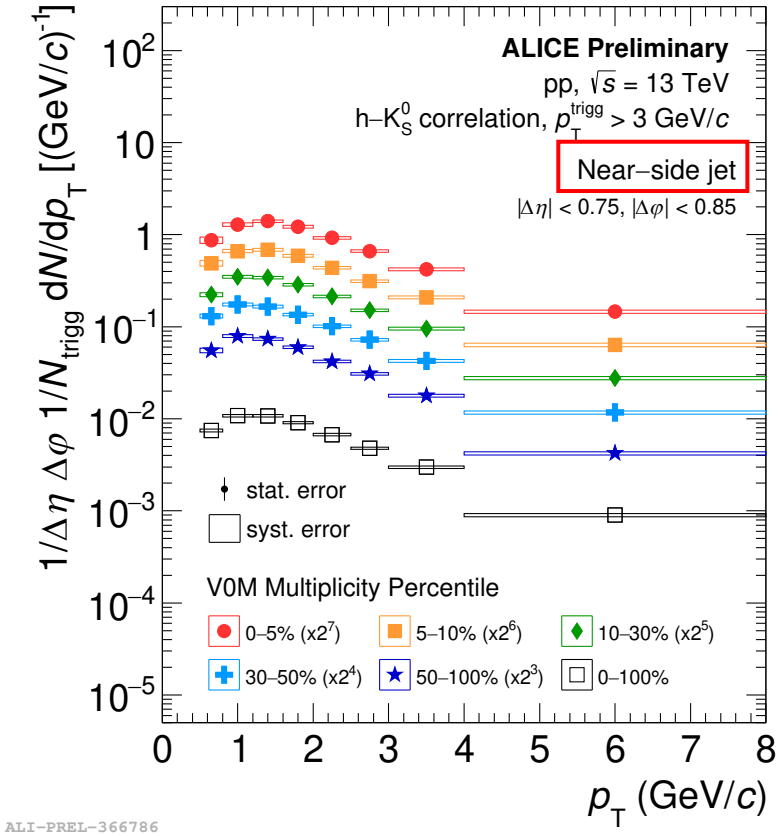


The fraction of events with a trigger particle with $p_T > 3$ GeV/c **increases with the multiplicity** of charged particles and **is larger at higher centre-of-mass energy**

Near-side jet, out-of-jet and full p_{T} spectra of $\mathrm{K}^0_{\mathrm{S}}$

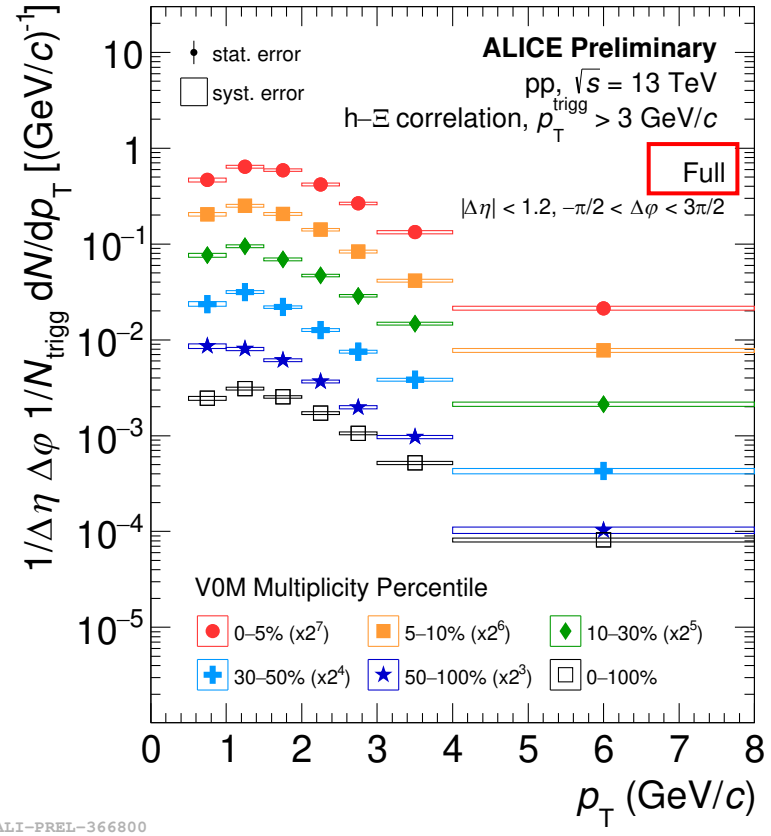


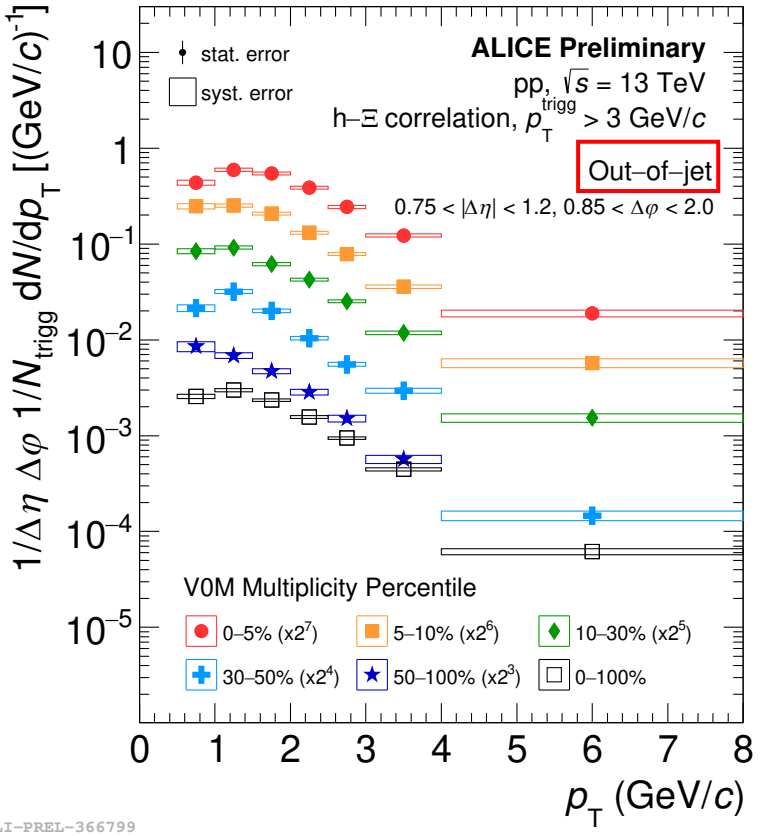


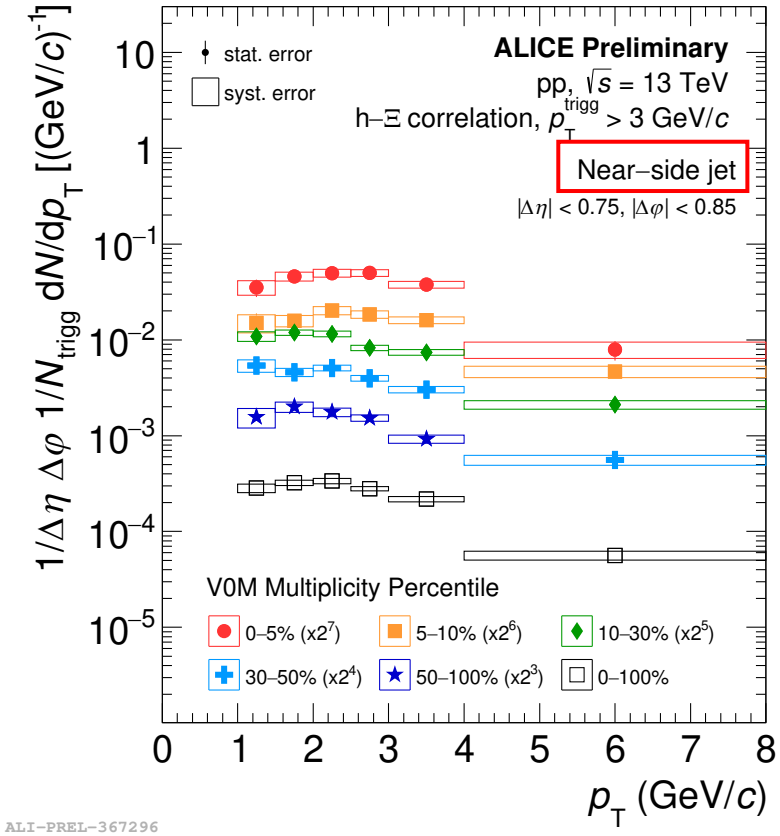


Spectra of $\mathrm{K}^0_{\mathrm{S}}$ produced in jets are harder than spectra of $\mathrm{K}^0_{\mathrm{S}}$ produced out of jets

Near-side jet, out-of-jet and full p_{T} spectra of $\Xi^{\pm}$

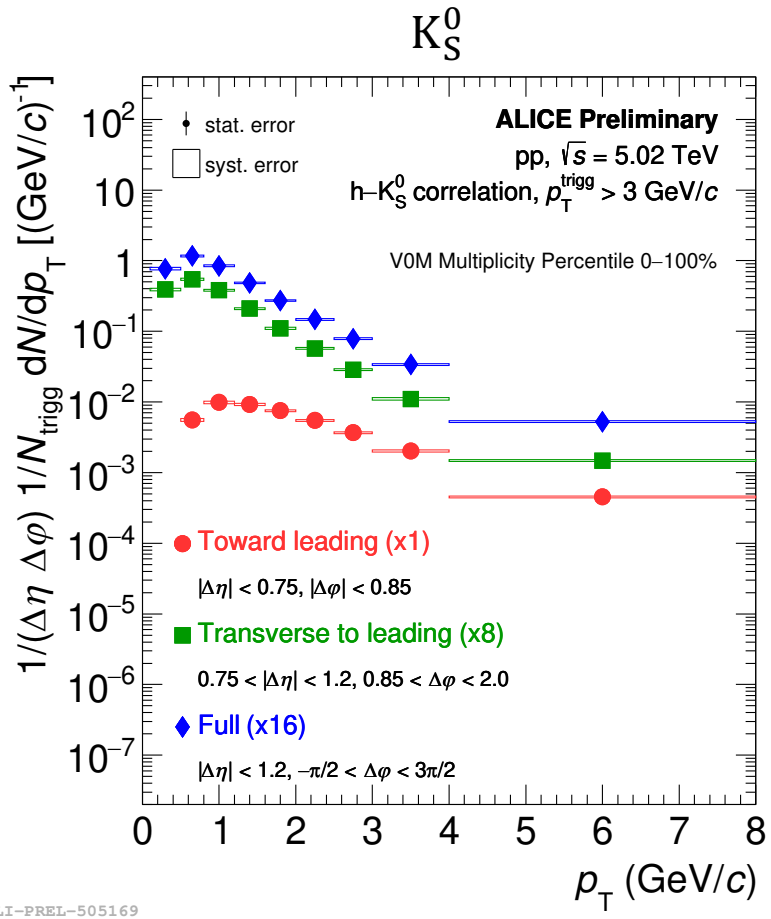


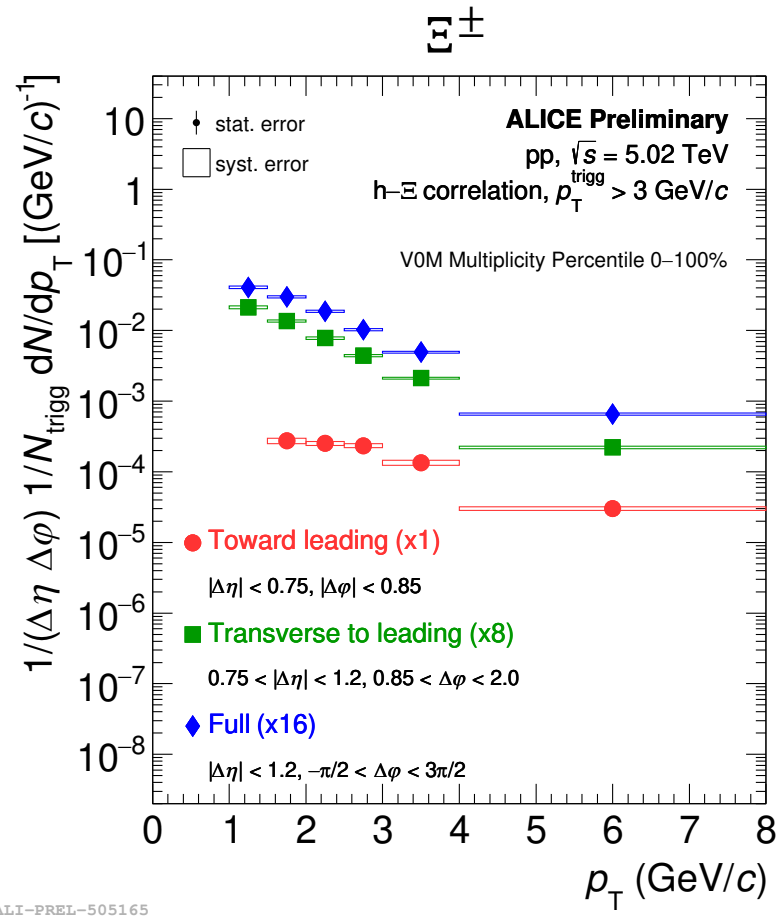




Spectra of $\Xi^{\pm}$ produced in jets are harder than spectra of $\Xi^{\pm}$ produced out of jets

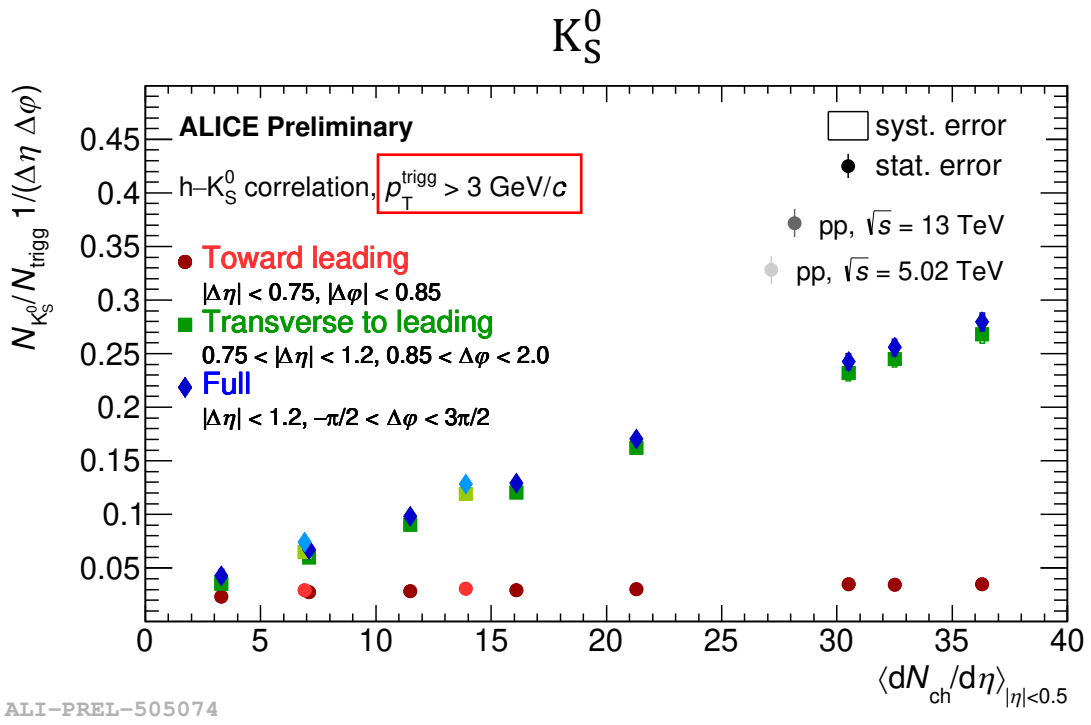
Near-side jet, out-of-jet and full p_T spectra of K^0_S and $\Xi^{\pm}$

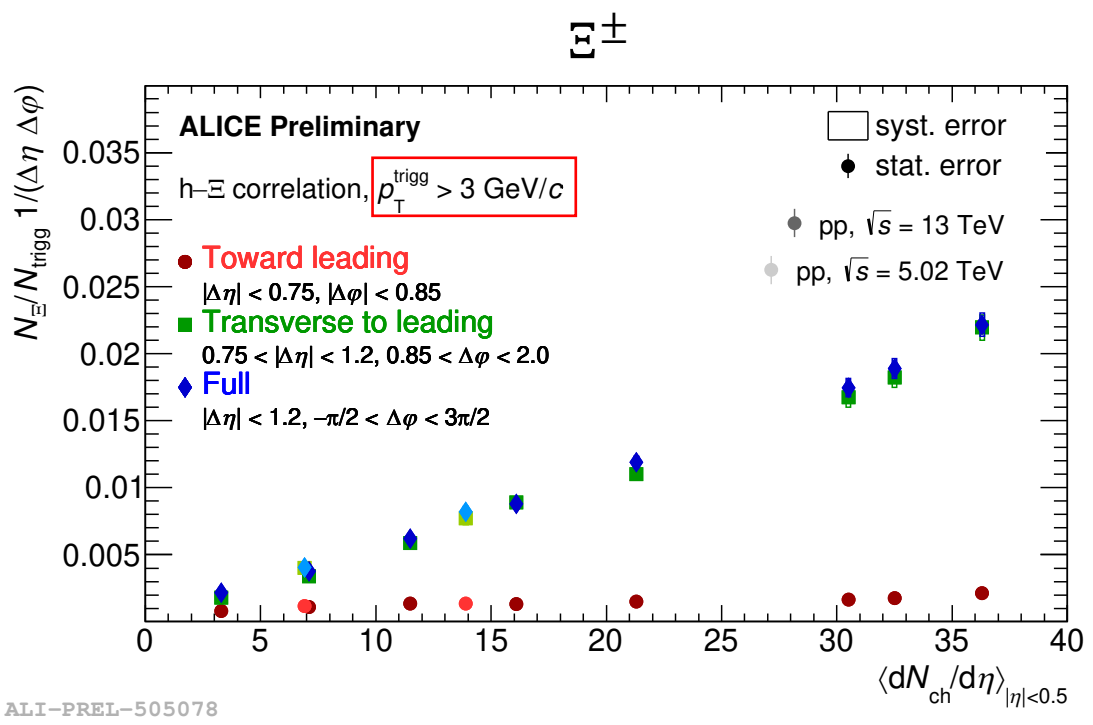




- Spectra of K^0_S ($\Xi^{\pm}$) produced in jets are harder than spectra of K^0_S ($\Xi^{\pm}$) produced out of jets
- Same feature observed in different V0M multiplicity classes and different centre-of-mass energies

Near-side jet, out-of-jet and full yields of strange hadrons vs multiplicity

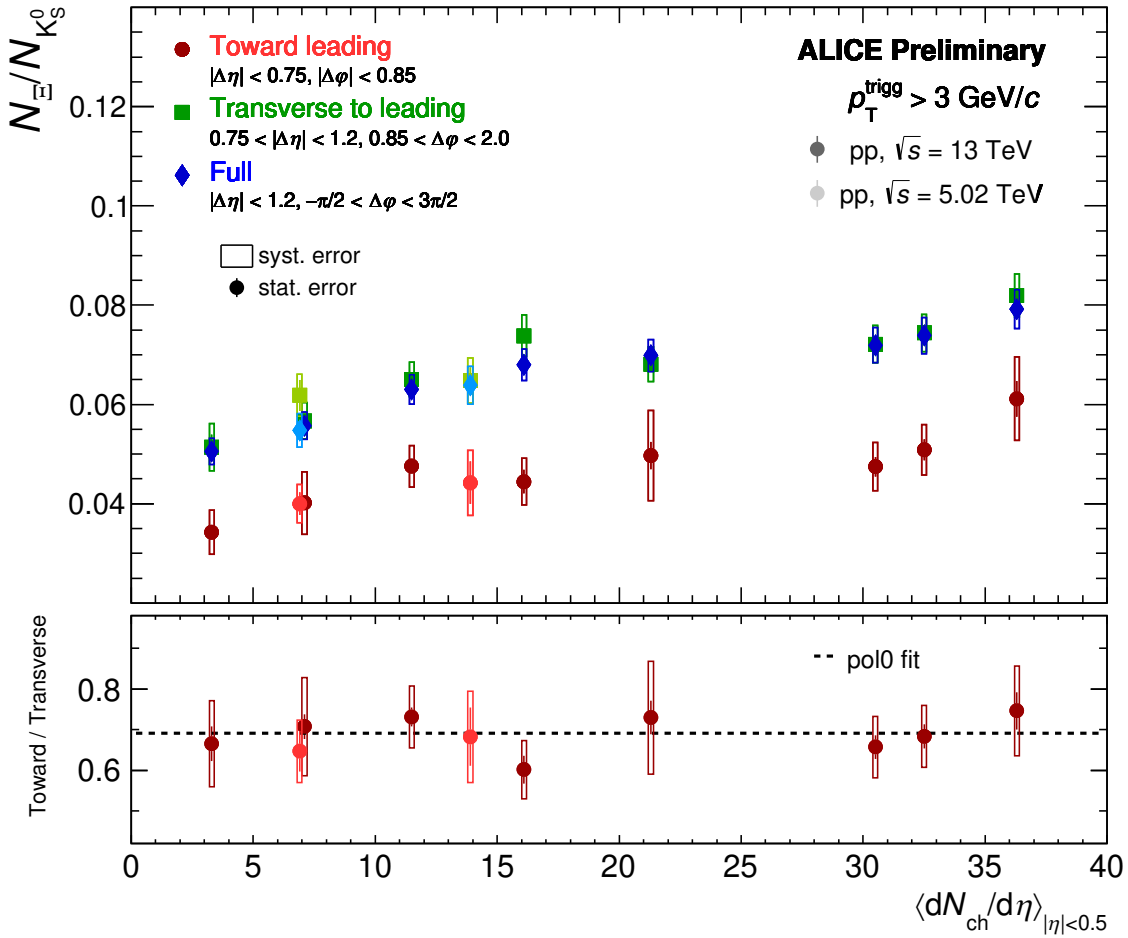




- Both the full yield and the out-of-jet yield increase with the multiplicity
- Very mild to no evolution with multiplicity of the near-side-jet yield
- The yields show no dependence on the centre-of-mass energy

→ The contribution of out-of-jet production relative to near-side jet production increases with multiplicity

Strangeness enhancement in jets and out of jets

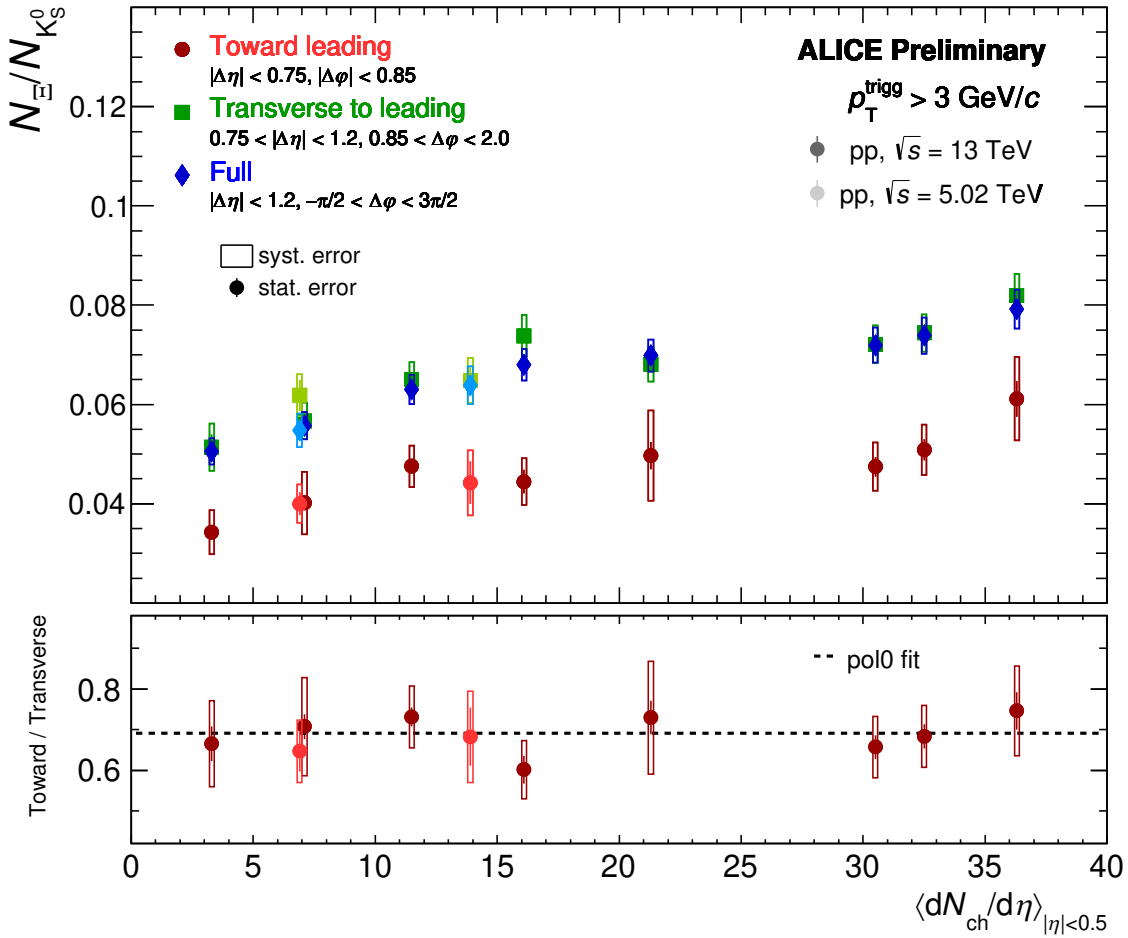


ALI-PREL-505157

- The strangeness enhancement in the ratio of full yields is attributed to the larger strangeness content of Ξ ($|S| = 2$) with respect to K^0_S ($|S| = 1$)
- The out-of-jet Ξ/K^0_S yield ratio **increases with the multiplicity** and is compatible with the ratio of full yields
- The near-side jet yield ratio is **smaller** than the out-of-jet one

- The near-side jet and out-of-jet Ξ/K^0_S yield ratios show **compatible increase** with multiplicity

Strangeness enhancement in jets and out of jets



→ Out-of-jet processes give the **dominant contribution** to the Ξ/K^0_S full yield ratio in pp collisions

→ The near-side jet and out-of-jet Ξ/K^0_S yield ratios show **compatible increase with multiplicity**

Summary

Is strange hadron production in pp collisions dominated by out-of-jet processes or by hard interactions?

- The K^0_S and Ξ out-of-jet yields increase with multiplicity, while the near-side jet yields show a milder evolution with multiplicity
- The out-of-jet $\Xi/\mathrm{K}^0_\mathrm{S}$ ratio increases with multiplicity and represents the dominant contribution to the full yield ratio

→ Out-of-jet processes give the dominant contribution to strange particle production and strangeness enhancement with multiplicity is observed in out-of-jet processes

Summary

Is strange hadron production in pp collisions dominated by out-of-jet processes or by hard interactions?

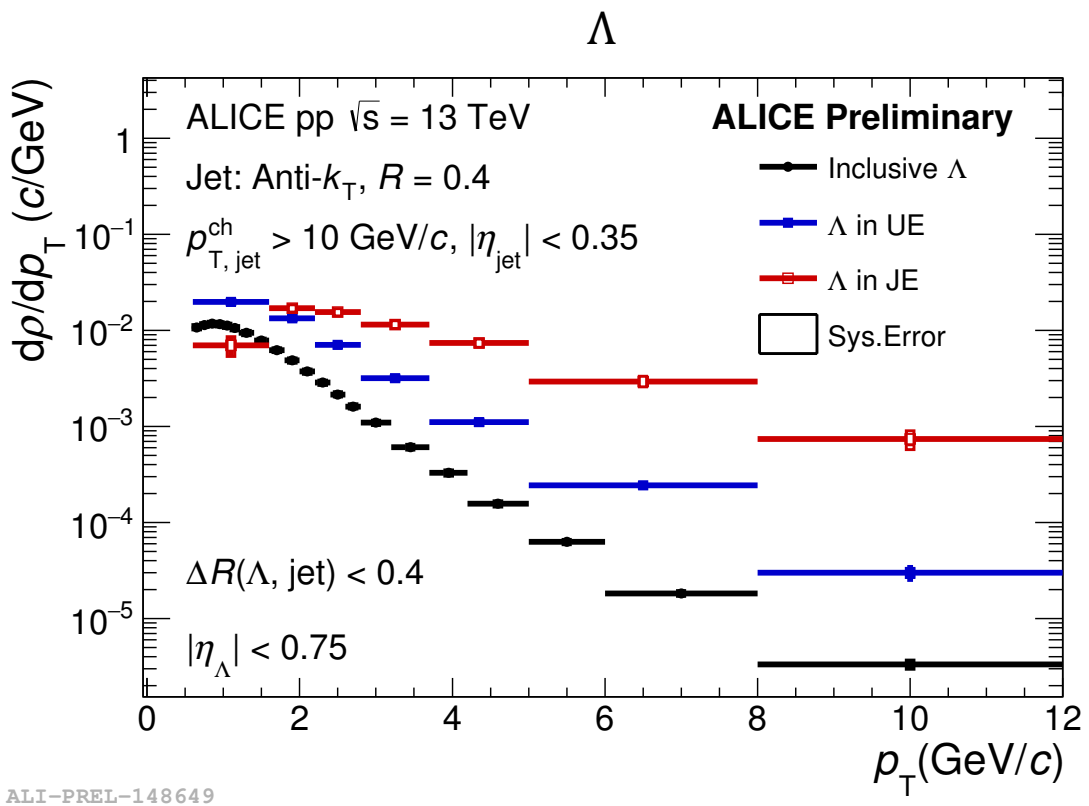
- The K^0_S and Ξ out-of-jet yields increase with multiplicity, while the near-side jet yields show a milder evolution with multiplicity
- The out-of-jet $\Xi/\mathrm{K}^0_\mathrm{S}$ ratio increases with multiplicity and represents the dominant contribution to the full yield ratio

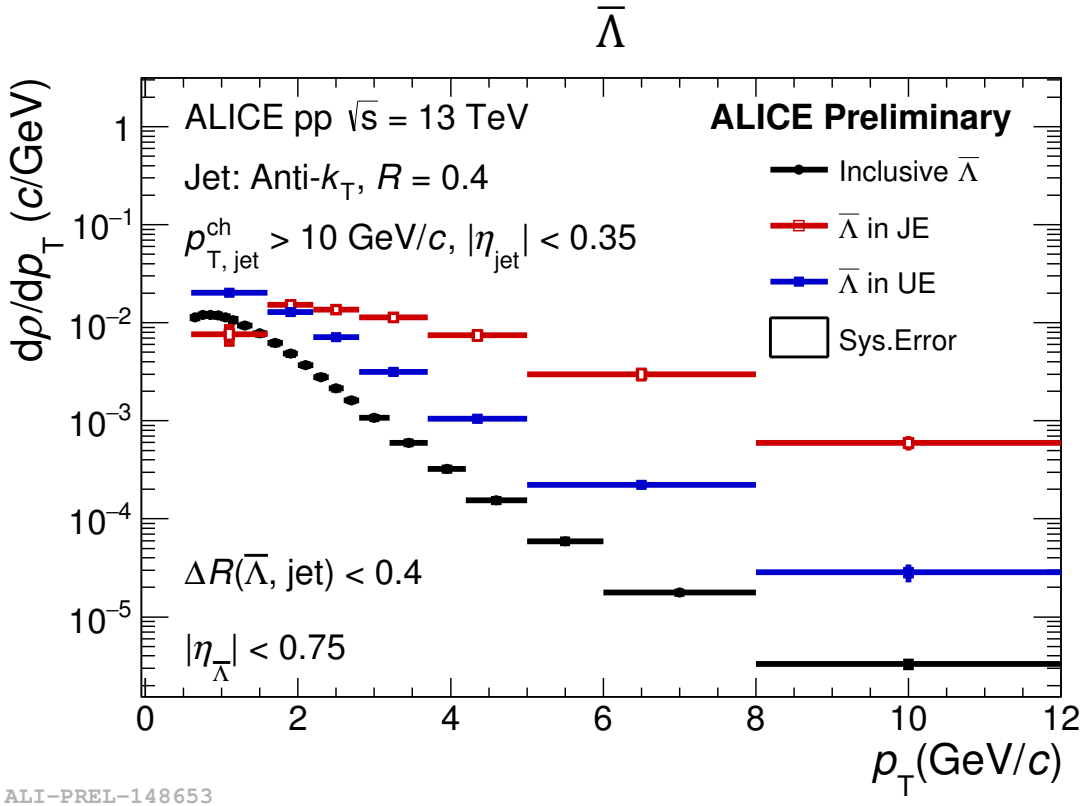
→ Out-of-jet processes give the dominant contribution to strange particle production and strangeness enhancement with multiplicity is observed in out-of-jet processes

Studies of strangeness production in pp collisions will profit from the large amount of data which will be collected during Run 3 (e.g. x3000 increase of $\Omega^{\pm}$ for in- and out-of-jet analysis)

Backup

Strange particle production in and out of jets

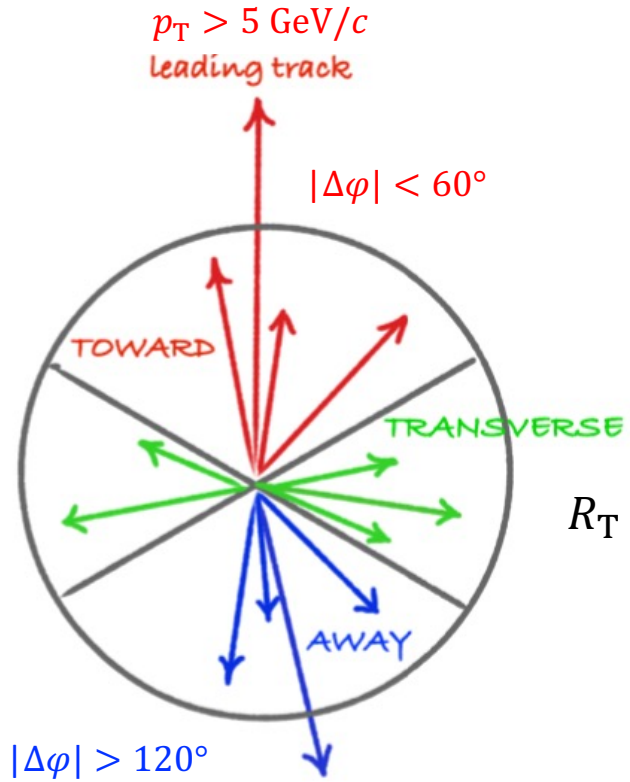




- The spectra of Λ and $\overline{\Lambda}$ in jets are harder than in the UE

R_{T} : particle production in the Underlying Event

R_{T} measures the multiplicity of tracks in a transverse region with respect to the leading track
i.e. the multiplicity related to the underlying event (UE)

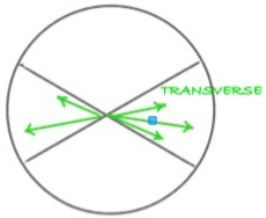


$$R_{\mathrm{T}} = \frac{N_T}{\langle N_T \rangle}$$

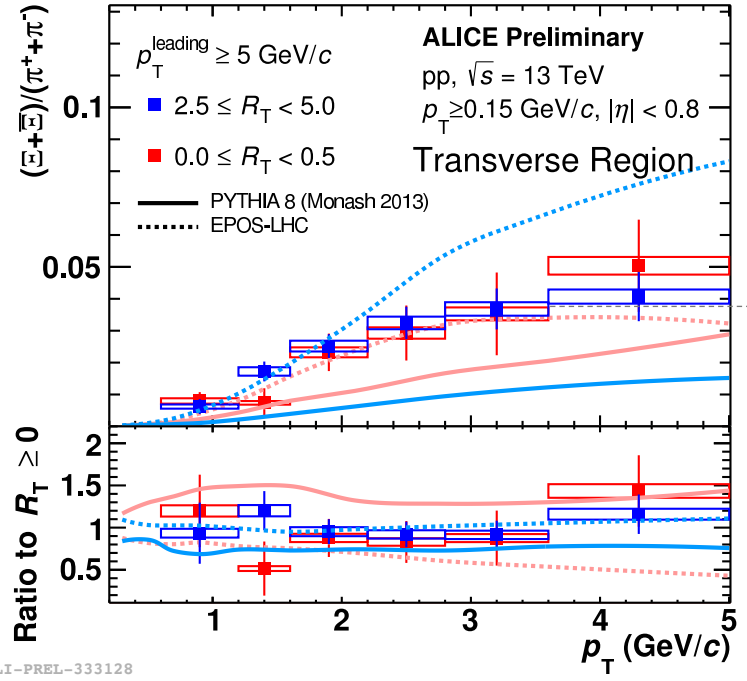
Topological classification of pp events:
Toward region (jet + UE)
Transverse region (UE)
Away region (recoiling jet + UE)

Studies of strange hadron production vs R_{T} in the different regions provide insight into strangeness enhancement

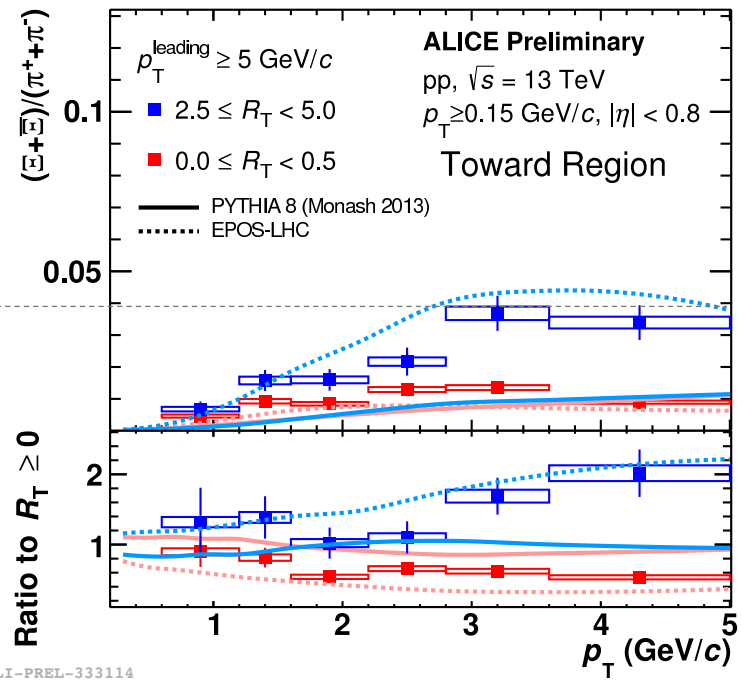
$\Xi^{\pm}$ production vs R_{T}

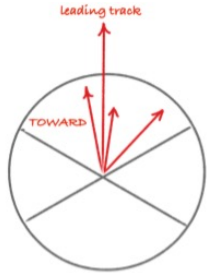


UE



Jet + UE





Ξ/π does not depend on R_{T} in the Transverse Region (UE)

Ξ/π increases with R_{T} in the Toward Region (Jet + UE), approaching the values of the Transverse Region

$\rightarrow \Xi/\pi$ higher in the UE than in the jet