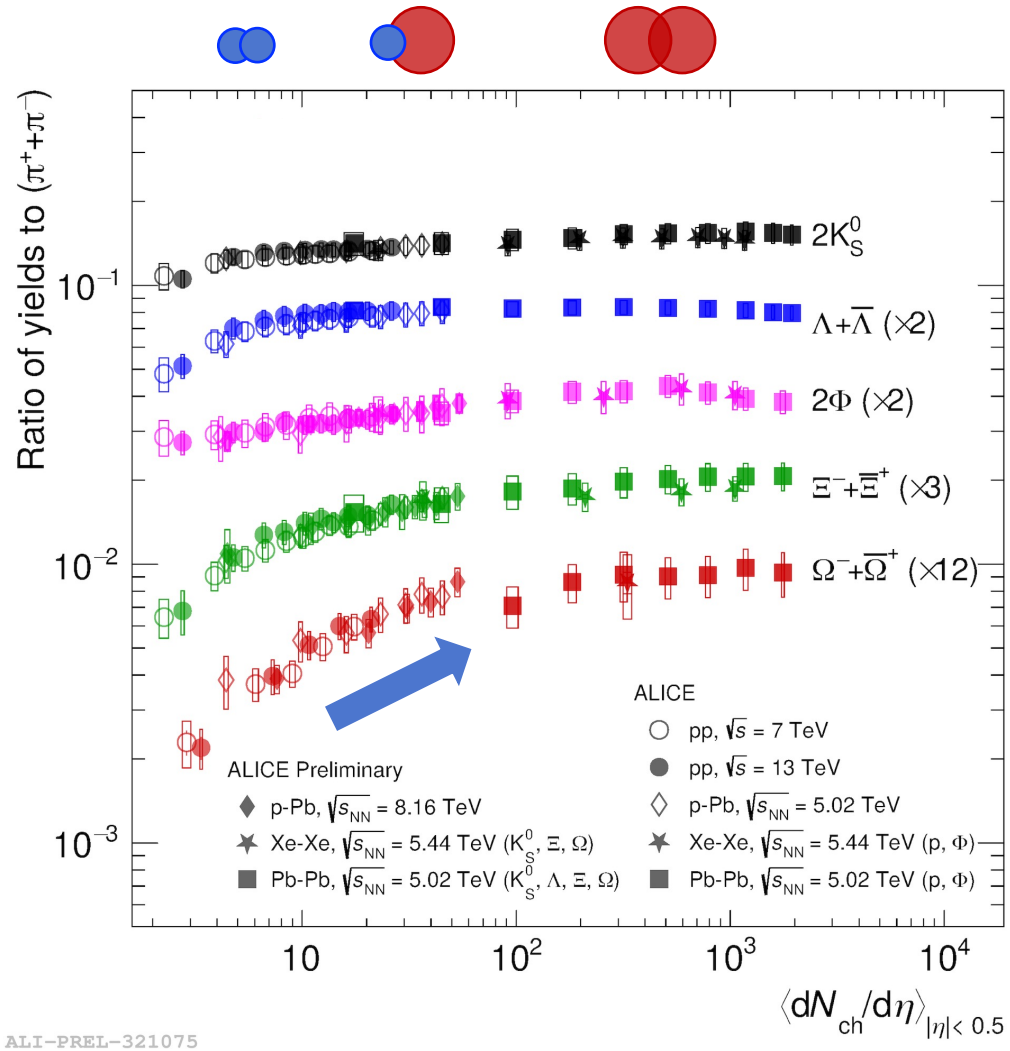
Strangeness production in jets and out of jets in small collision systems with ALICE

Chiara De Martin on behalf of the ALICE Collaboration

University and INFN - Trieste

LHCPhysics
Belgrade, 22 - 26 May 2023

Physics motivation

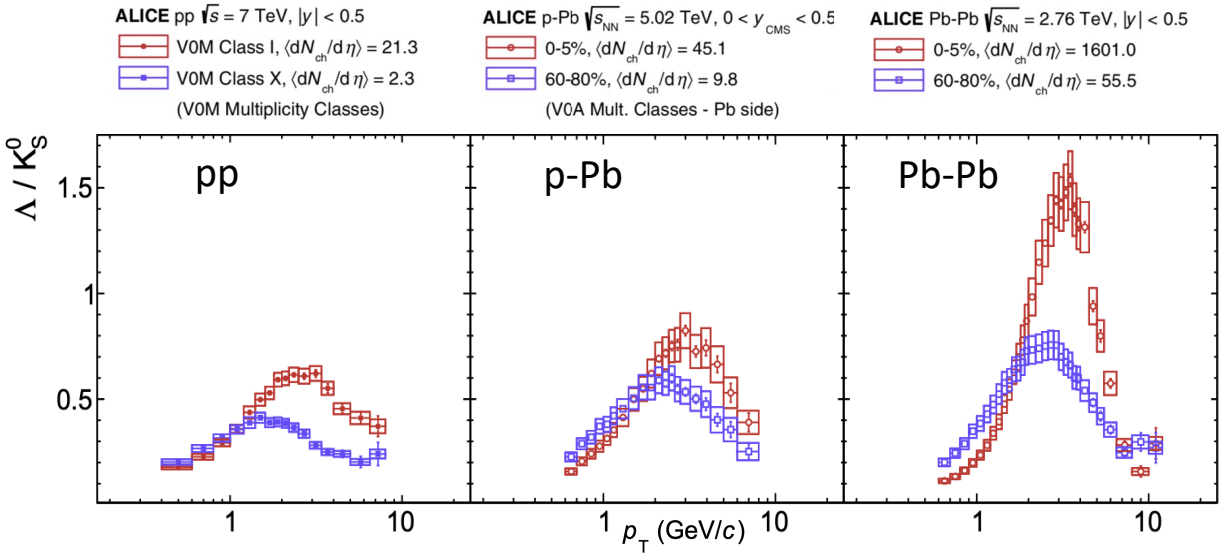


Strangeness enhancement:
The ratio between (multi-)strange hadron yields and pion yields is enhanced in heavy-ion collisions with respect to minimum bias pp collisions

- 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

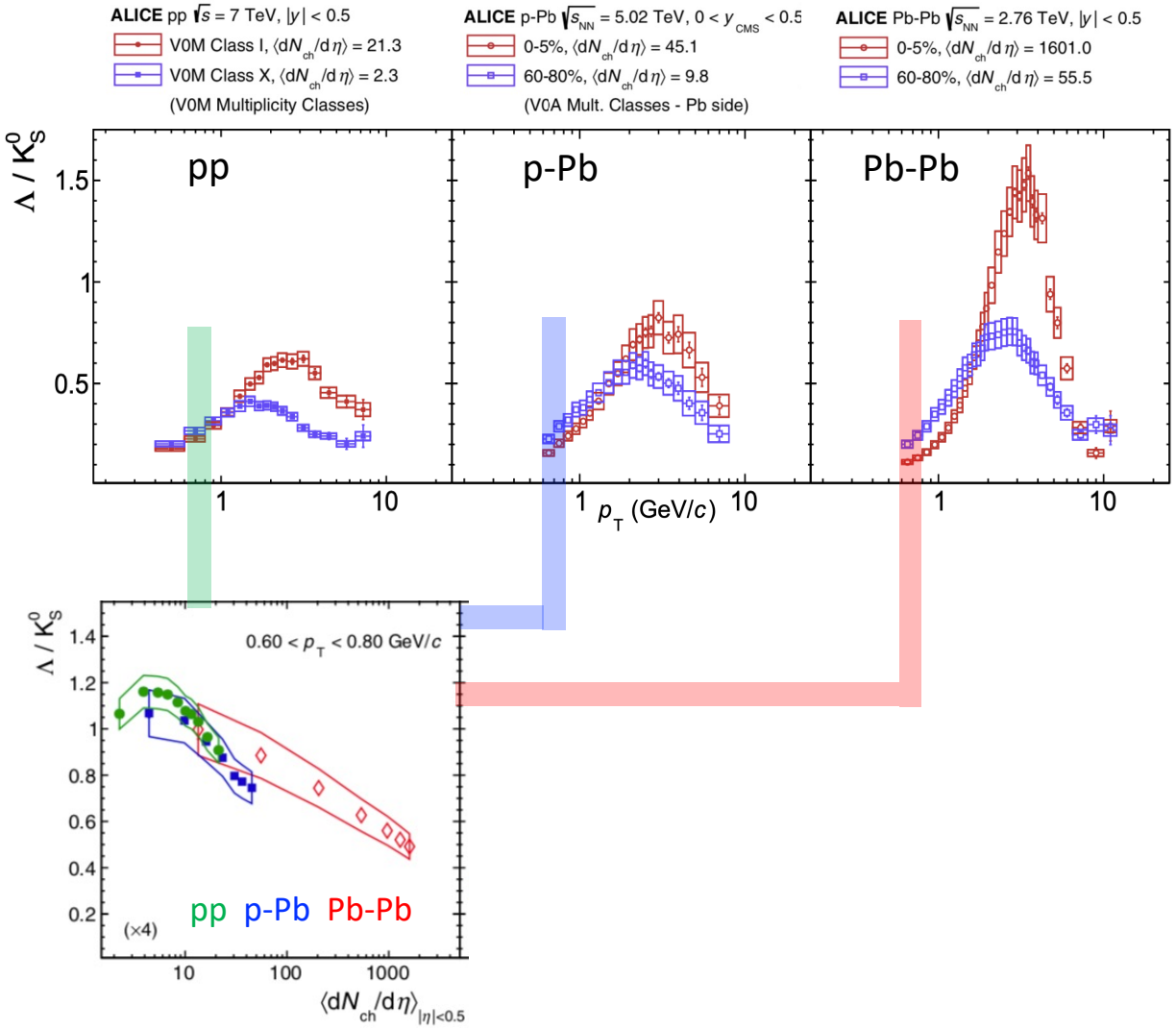


$\Lambda/\mathrm{K}^0_\mathrm{S}$ evolution with p_T:

- $\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio increases at p_T~3 GeV/c
- This effect is observed in different collision systems (pp, p-Pb, Pb-Pb)
- This effect is larger in collisions characterised by a larger multiplicity of charged particles

Phys. Rev. C 99, 024906 (2019)

Physics motivation



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- Smooth evolution with the multiplicity of charged particles across different collision systems

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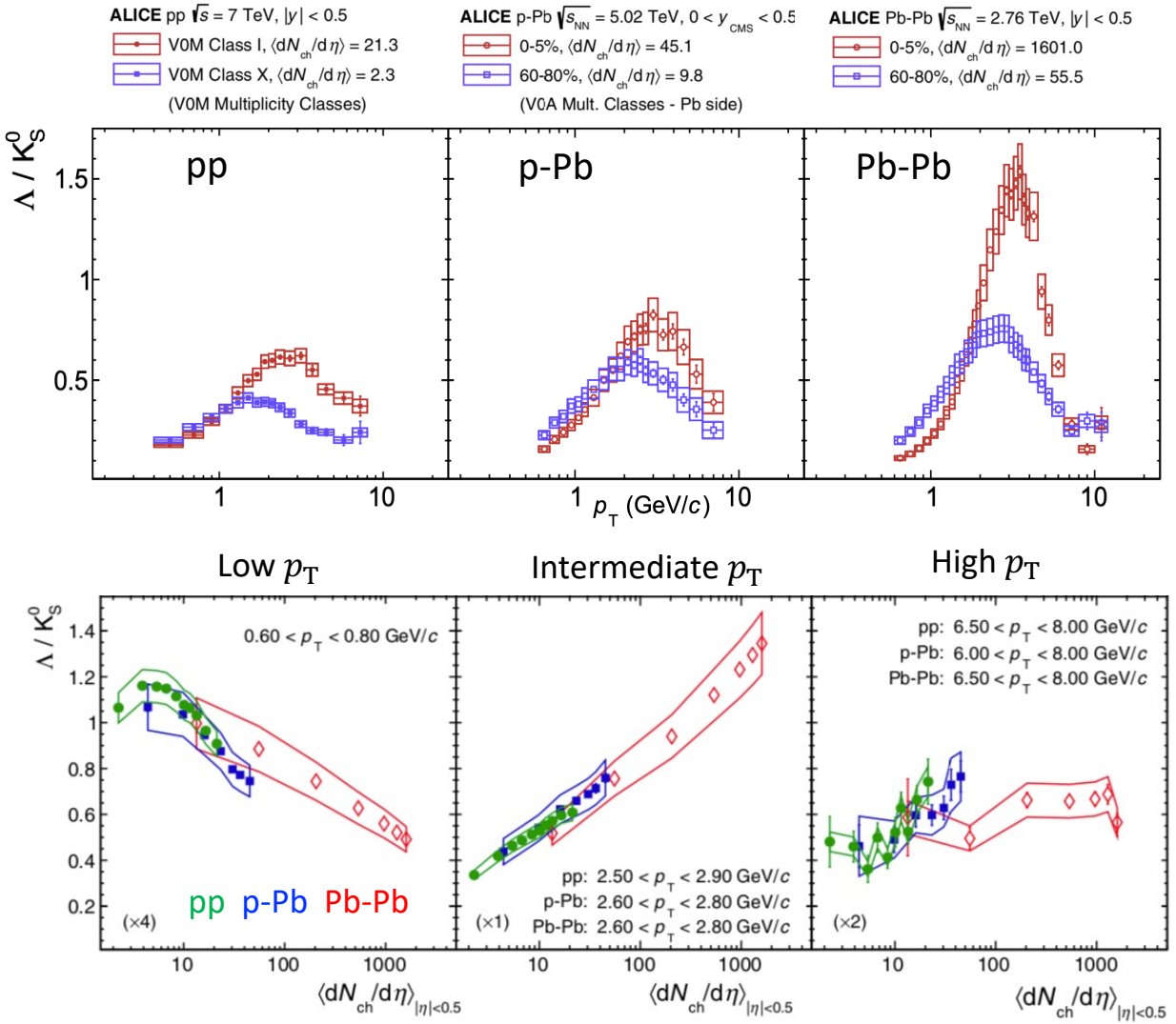

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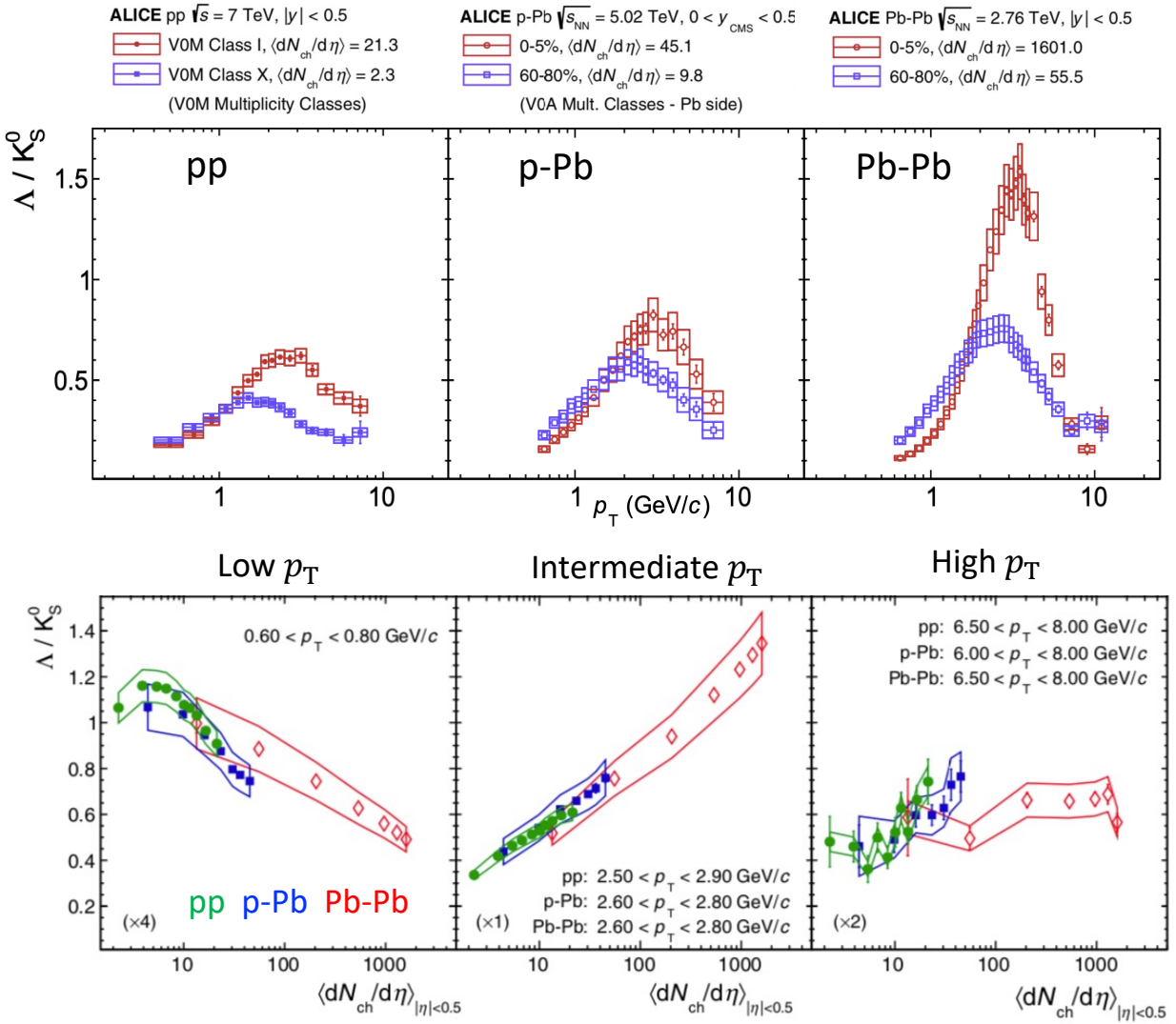

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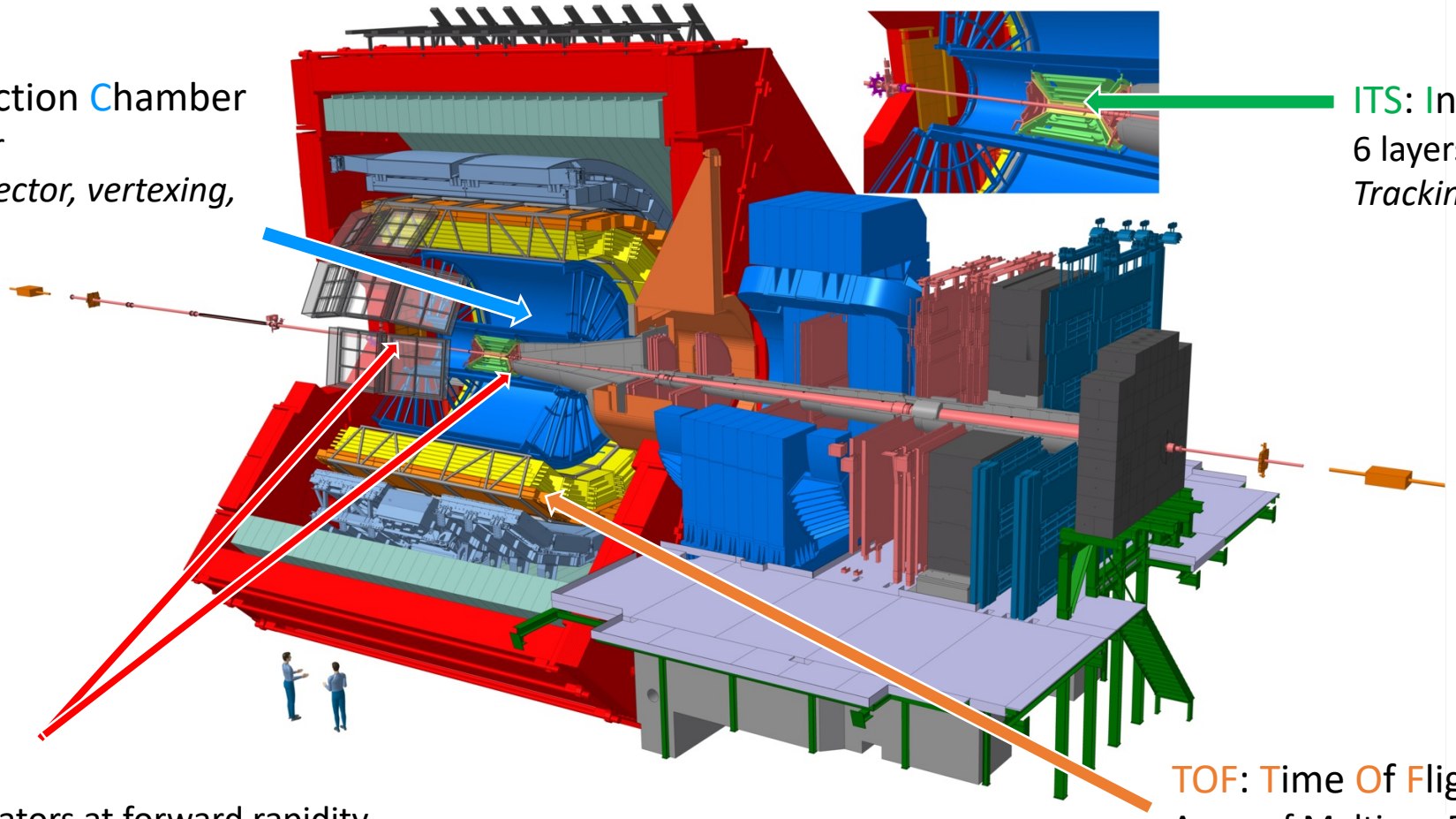
- This effect is observed in different collision systems (pp, p-Pb, Pb-Pb)
- This effect is larger in collisions characterised by a larger multiplicity of charged particles
- Smooth evolution with the multiplicity of charged particles across different collision systems

Are these phenomena related to hard processes, such as jets, to the underlying event, or to both?

Phys. Rev. C 99, 024906 (2019)

ALICE at the LHC

TPC: Time Projection Chamber
Gas-filled detector
Main tracking detector, vertexing, PID (dE/dx)



ITS: Inner Tracking System
6 layers of silicon detectors
Tracking, triggering, vertexing

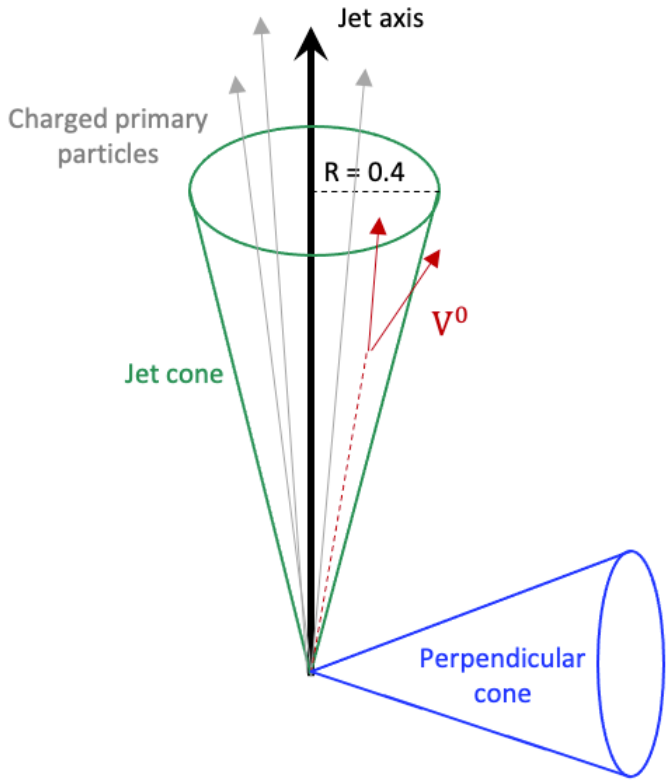
V0A and V0C
Arrays of scintillators at forward rapidity
Triggering, multiplicity estimators

TOF: Time Of Flight
Array of Multigap Resistive Plate Chambers
PID, out-of-bunch pile-up rejection

Strange particle production in and out of jets using jet finder algorithm

Strange particle production in and out of jets using jet finder algorithm

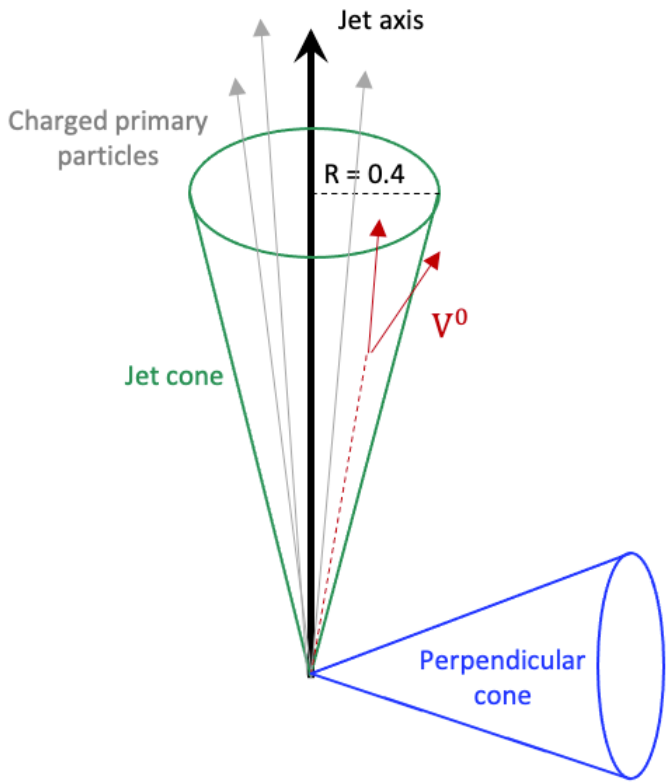
Jet finder algorithm: anti-k_{T}

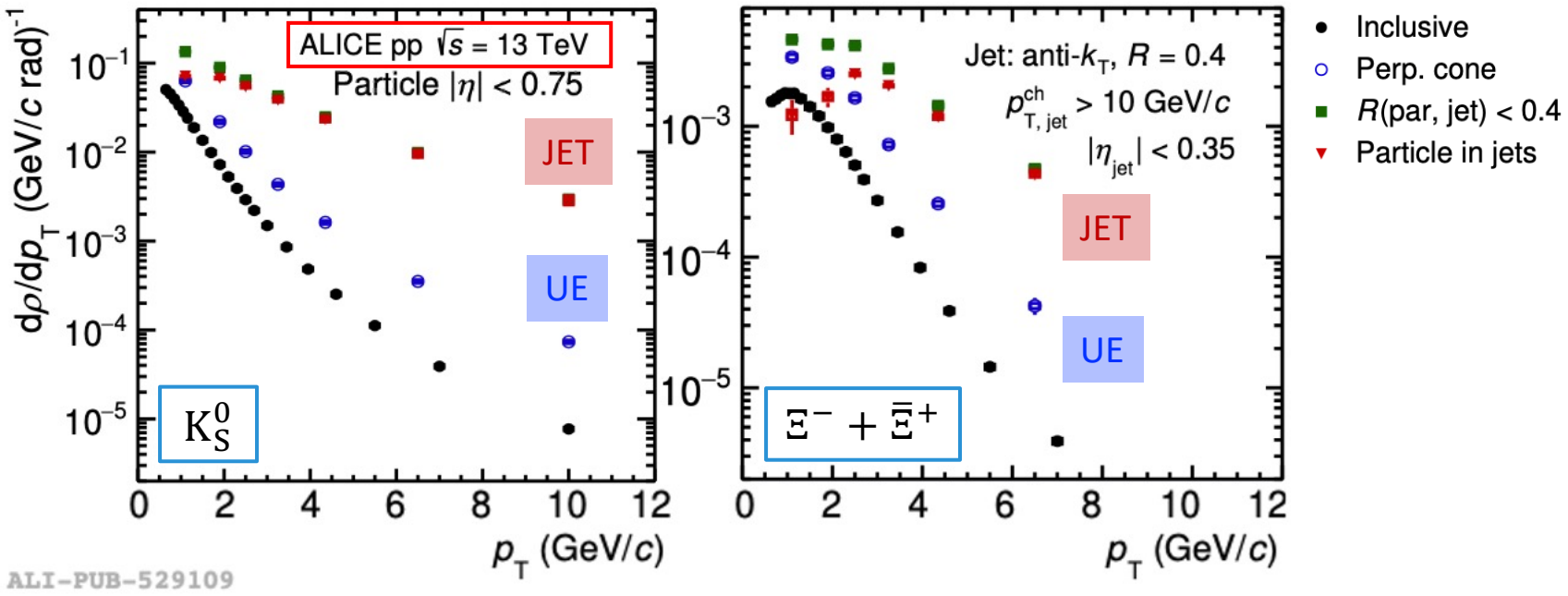


- Jet cone (JC) : R(strange hadron, jet) < 0.4
- Underlying Event (UE):
  strange hadrons in perpendicular cone
- In jet production (JE) = JC - UE

Strange particle production in and out of jets using jet finder algorithm

Jet finder algorithm: anti-k_T



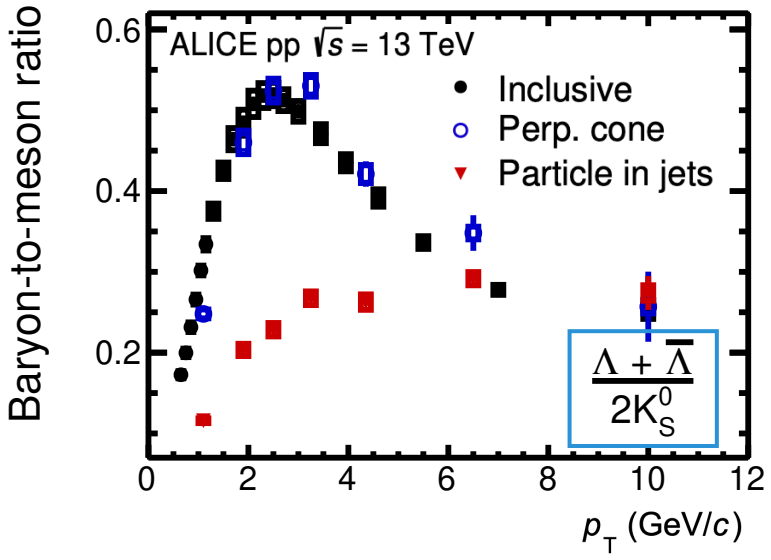


- Jet cone (JC) : R(strange hadron, jet) < 0.4
- Underlying Event (UE): strange hadrons in perpendicular cone
- In jet production (JE) = JC - UE

- The spectra of K^0_S and $\Xi^{\pm}$ in jets are harder than in the UE
- The same is observed for Λ and $\Omega^{\pm}$
- Similar results in p-Pb collisions

Phys. Lett. B 827, 136984 (2022)
arXiv:2211.08936 (2022)

Λ/K^0_S and Ξ/Λ ratios in and out of jets



Λ/K^0_S (baryon/meson) $|S|$=1

- The inclusive and UE ratios show a peak at $p_T \sim 3$ GeV/c
- The enhancement is not present within jets
- The same is observed in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
- Similar results shown by Ξ/K^0_S and Ω/K^0_S

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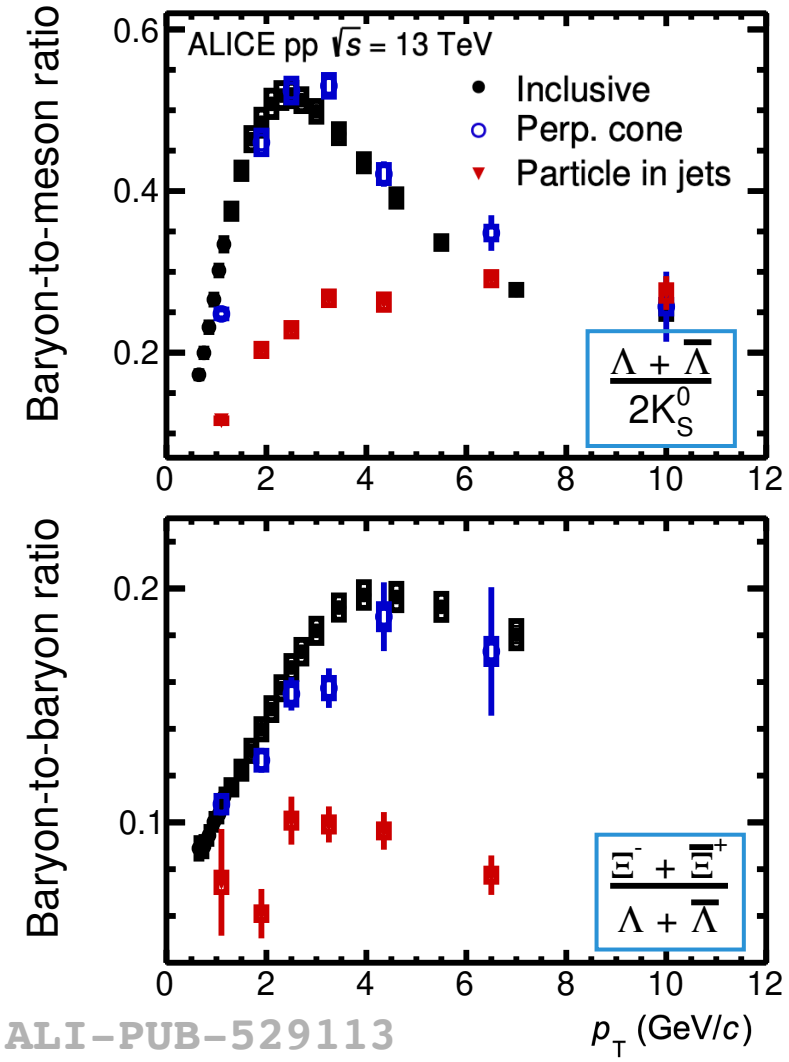

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Ξ/Λ (baryons with different strangeness content: $|S|$=2/$|S|$=1)

- The UE ratio is consistent with the inclusive one
- The ratio in jets is rather flat with p_T and is suppressed with respect to the inclusive one

Phys. Lett. B 827, 136984 (2022)
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Angular correlations for in- and out-of-jet strange hadron production vs $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle_{|\eta|<0.5}$

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 $p_{\mathrm{T}} > 3 - 4$ GeV/c

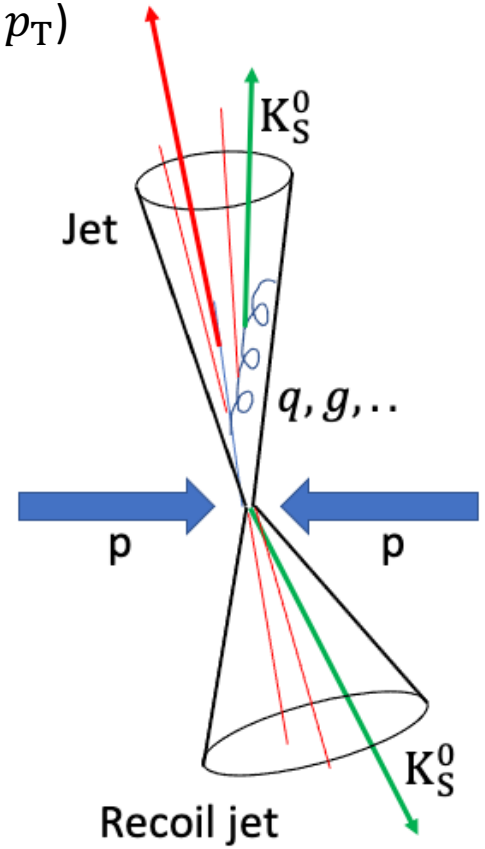
2. Identification of strange hadrons (associated particles)

3. Angular correlation between trigger and associated particles is calculated

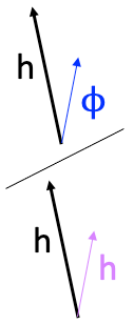
$$\Delta\varphi = \varphi_{\mathrm{trigg}} - \varphi_{\mathrm{assoc}}$$
$$\Delta\eta = \eta_{\mathrm{trigg}} - \eta_{\mathrm{assoc}}$$

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

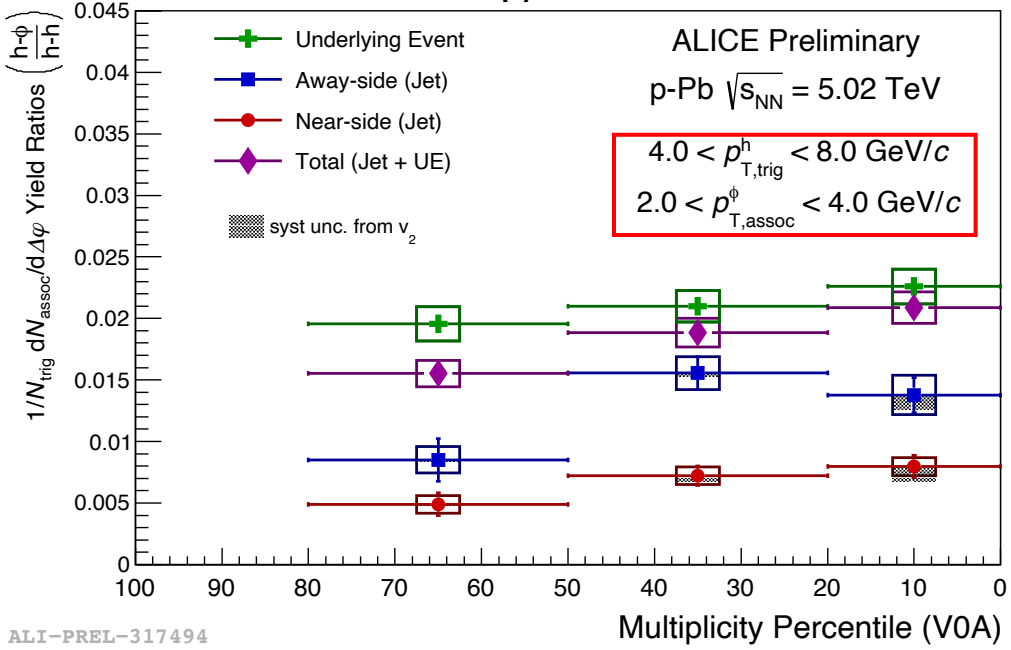
Leading particle ≅ jet axis (highest p_{T})



h – ϕ/h – h and h – Λ/h – h yield ratios vs multiplicity in p-Pb collisions



ϕ/h



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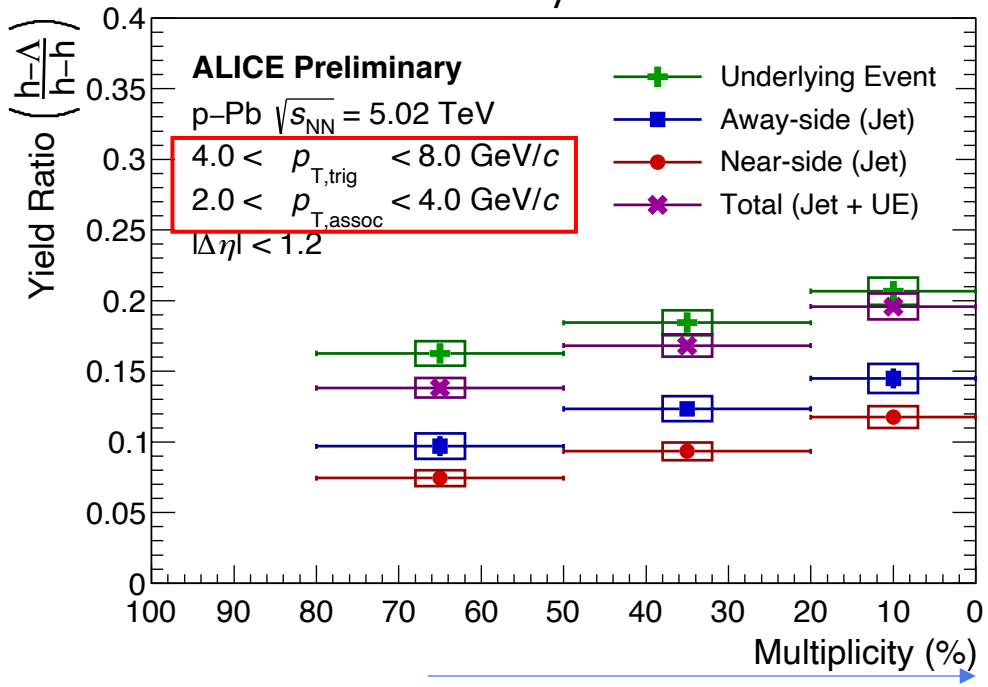
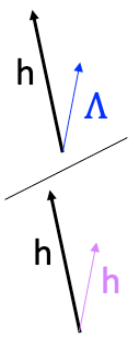
Increasing multiplicity

Λ/h

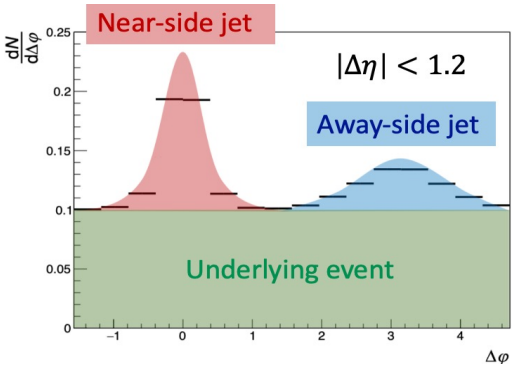




NEW!

ALI-PREL-542464

Increasing multiplicity

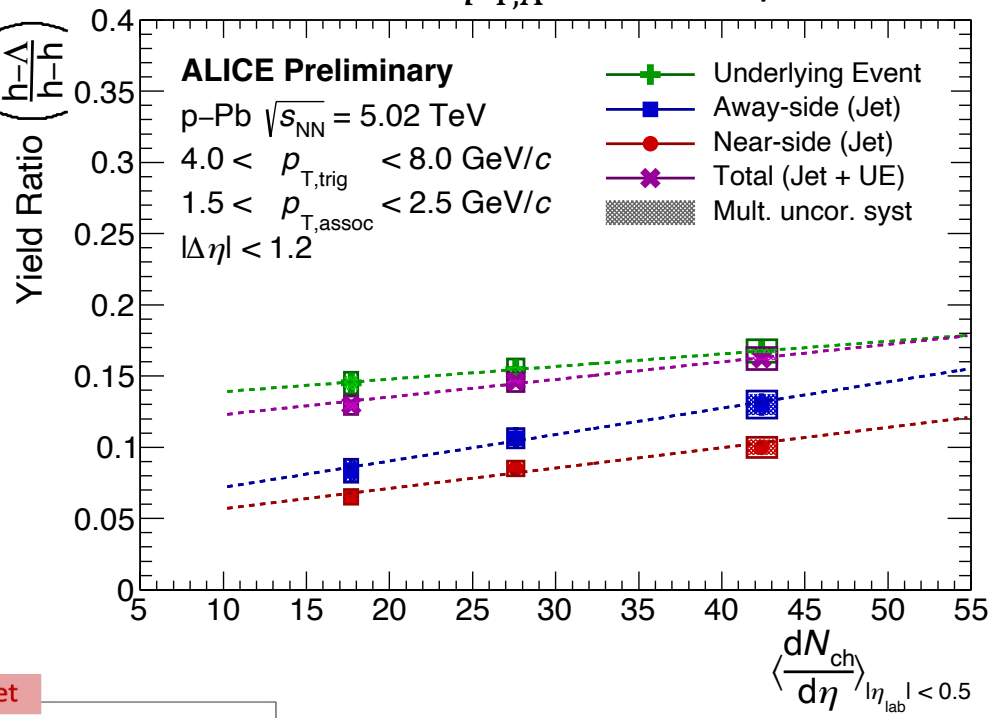


- The underlying event (UE) ratio is systematically larger in all multiplicity intervals
- The jet-like production is smaller than the UE and total production, with the near-side jet ratio smaller than the away-side one

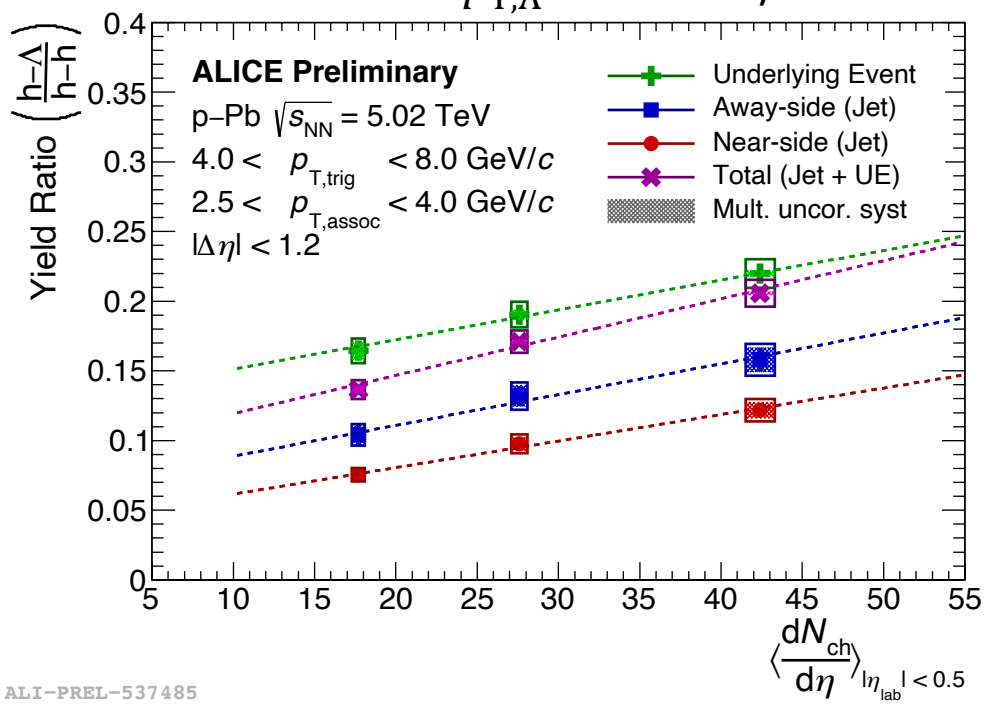
h − Λ/h − h yield ratios vs multiplicity in p-Pb collisions

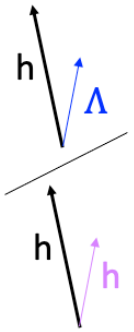
NEW!

$1.5 < p_{T,\Lambda} < 2.5$ GeV/c



$2.5 < p_{T,\Lambda} < 4.0$ GeV/c





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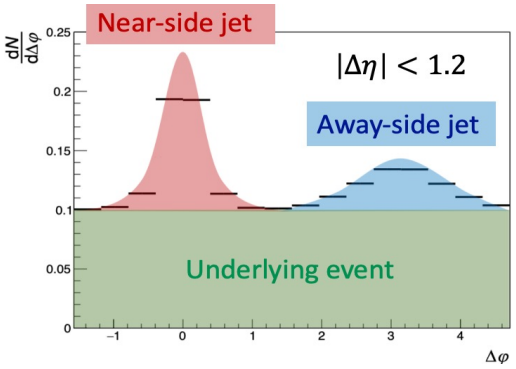
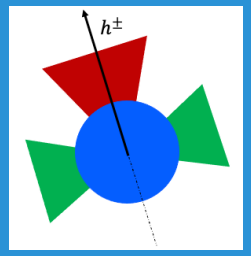
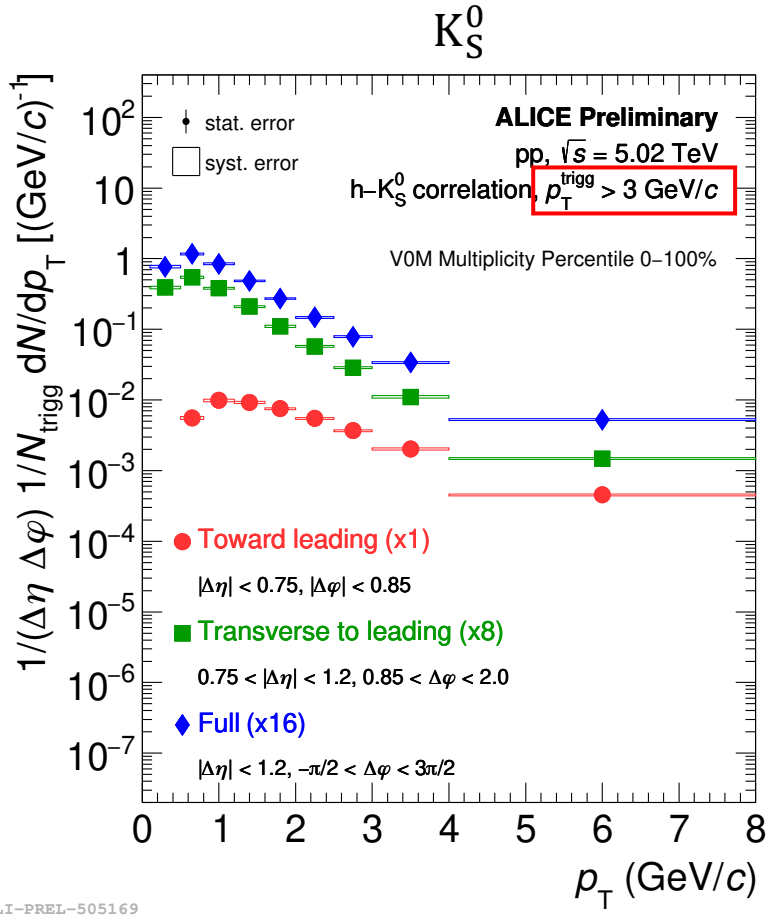


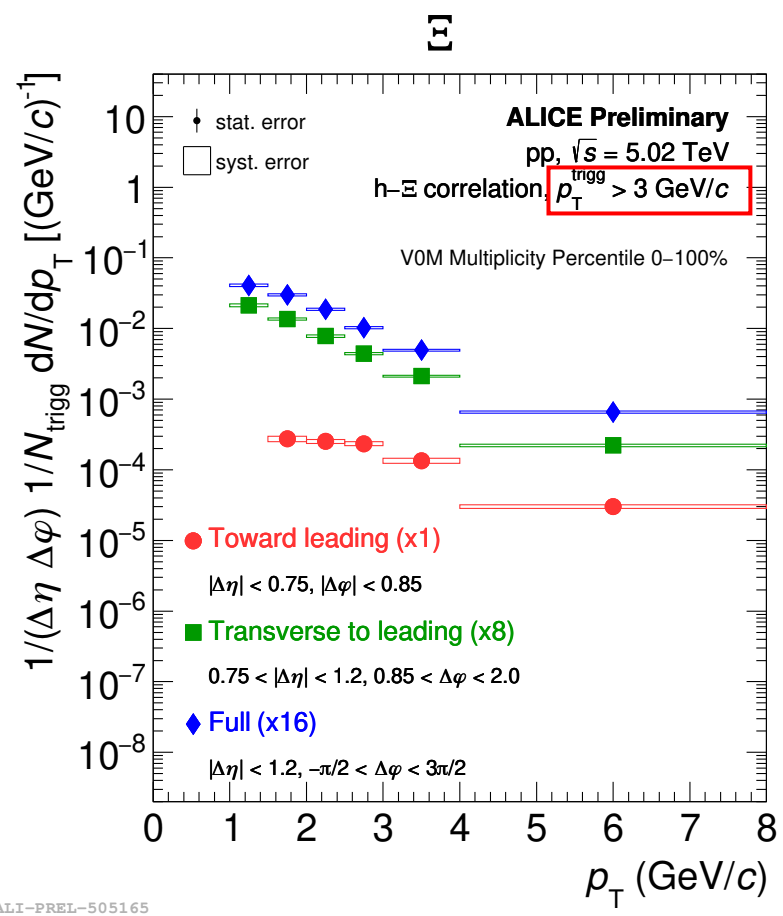
- The underlying event, the near-side and the away-side ratios **increase with multiplicity** in both p_T intervals
- The increase is systematically larger in the higher associated p_T interval

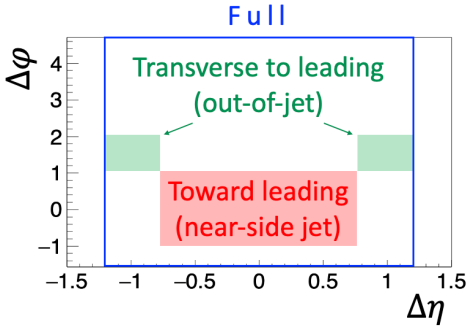


Toward, transverse-to-leading and full p_{T} spectra of $\mathrm{K}^0_{\mathrm{S}}$ and Ξ in pp collisions

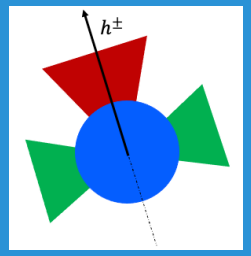
ALICE





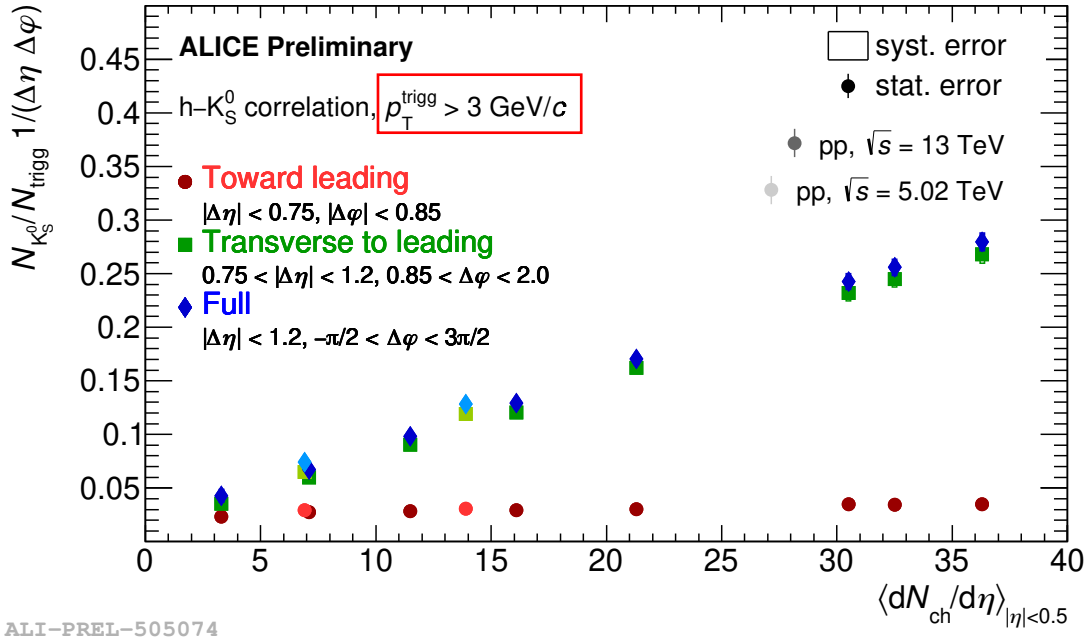


- Toward-leading spectra of $\mathrm{K}^0_{\mathrm{S}}$ (Ξ) are harder than transverse-to-leading spectra of $\mathrm{K}^0_{\mathrm{S}}$ (Ξ)
- Same feature observed in different multiplicity classes and different centre-of-mass energies



Toward, transverse-to-leading and full yields of strange hadrons vs multiplicity

K^0_S



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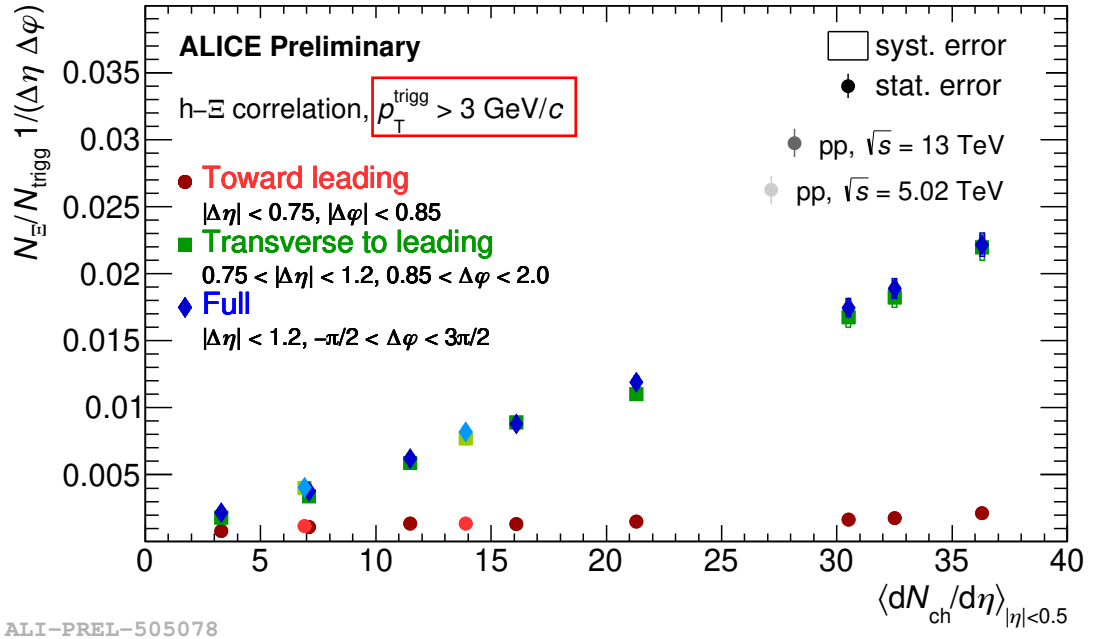
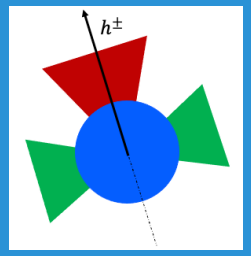
Ξ



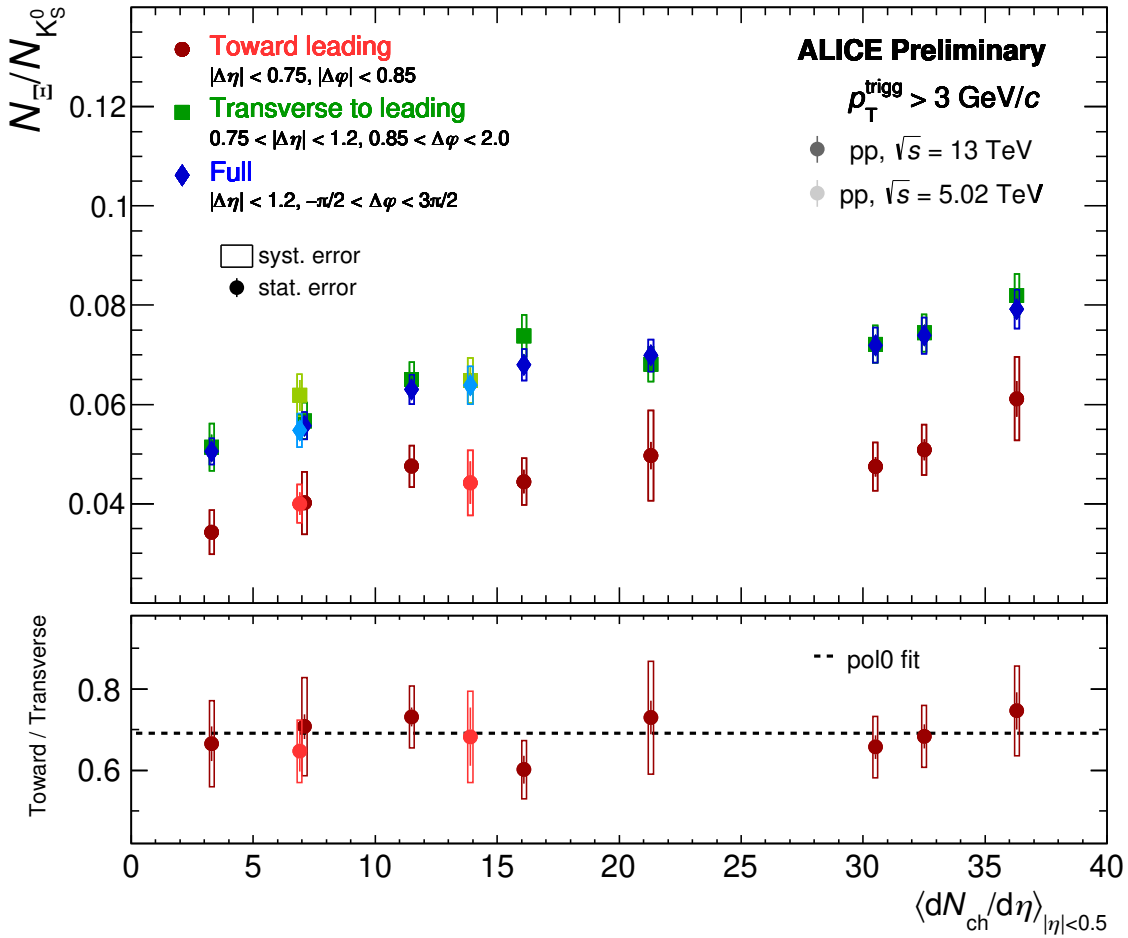
ALI-PREL-505078

- Both full and transverse-to-leading yields increase with the multiplicity
- Milder evolution with multiplicity of the toward-leading yield
- The yields show no dependence on the centre-of-mass energy

→ The contribution of transverse-to-leading wrt toward-leading production increases with multiplicity



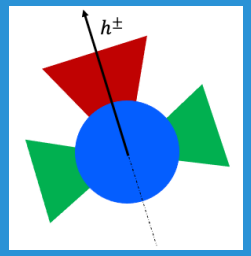
Strangeness enhancement in jets and out of jets



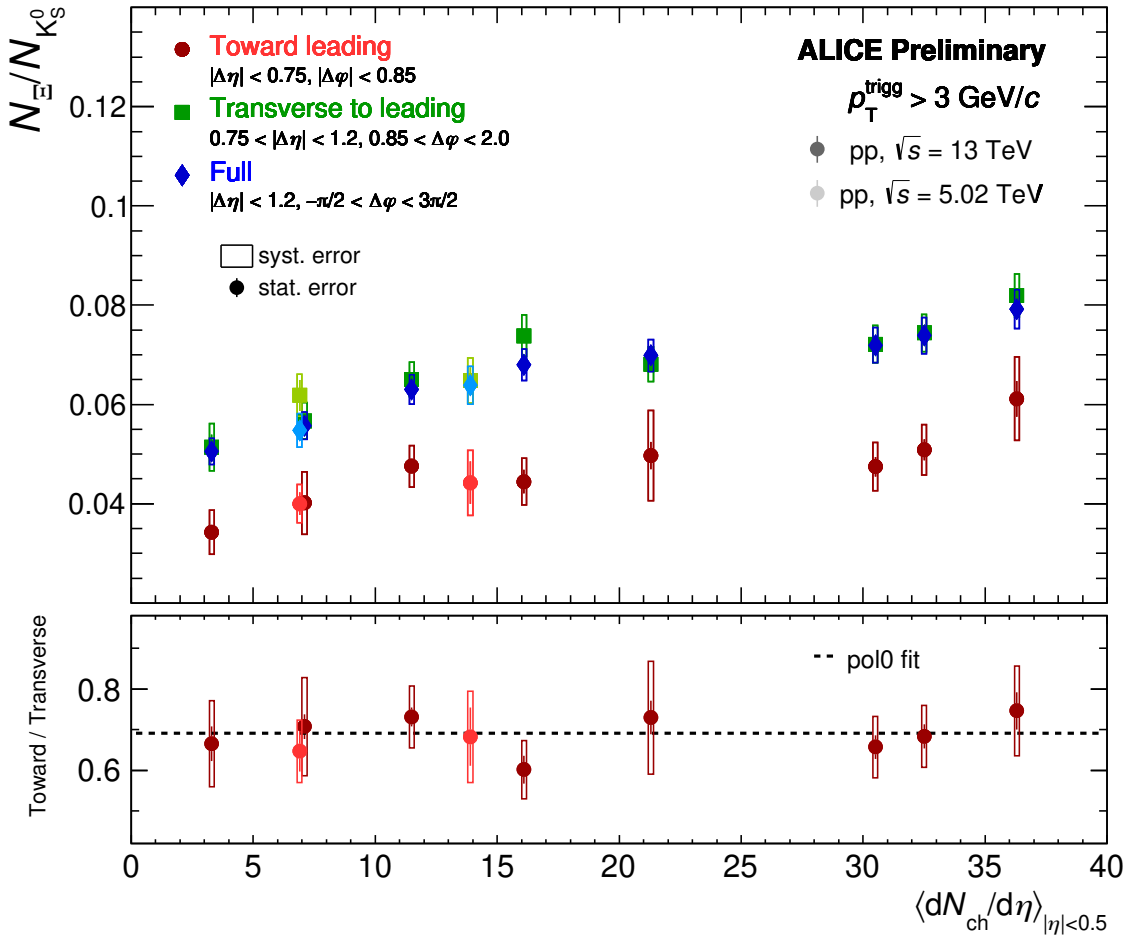
ALI-PREL-505157

- 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 transverse-to-leading Ξ/K^0_S yield ratio **increases with the multiplicity** and is compatible with the ratio of full yields
- The toward-leading yield **ratio increases with multiplicity** and is **smaller** than the transverse-to-leading one

- The toward-leading and transverse-to-leading Ξ/K^0_S yield ratios show **compatible increase** with multiplicity



Strangeness enhancement in jets and out of jets



ALI-PREL-505157

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

→ The Ξ/K^0_S production is favoured in transverse-to-leading processes wrt toward-leading processes

→ The toward-leading and transverse-to-leading Ξ/K^0_S yield ratios **increase with multiplicity** in a compatible way

Summary

- **Out-of-jet processes** give the **dominant contribution to strange particle production** in pp and p-Pb collisions
- The **baryon-over-meson enhancement** at intermediate p_{T} is related to **out-of-jet processes**
- **Strangeness enhancement** with multiplicity is observed both **in and out of jets**

Studies of strangeness production in pp collisions will profit from the large amount of data that ALICE is collecting during Run 3

→ e.g. x3000 increase of $\Omega^{\pm}$ for in- and out-of-jet analysis

Backup

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 $p_{\mathrm{T}} > 3 - 4$ GeV/c

2. Identification of strange hadrons (associated particles)

3. Angular correlation between trigger and associated particles is calculated

$$\Delta\varphi = \varphi_{trigg} - \varphi_{assoc}$$

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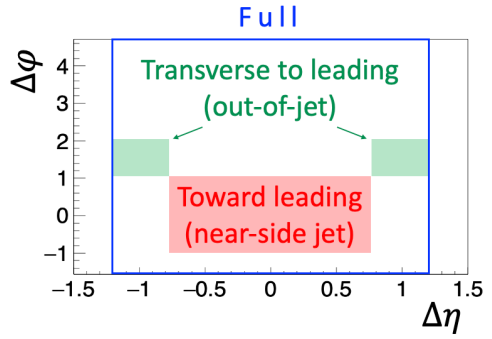
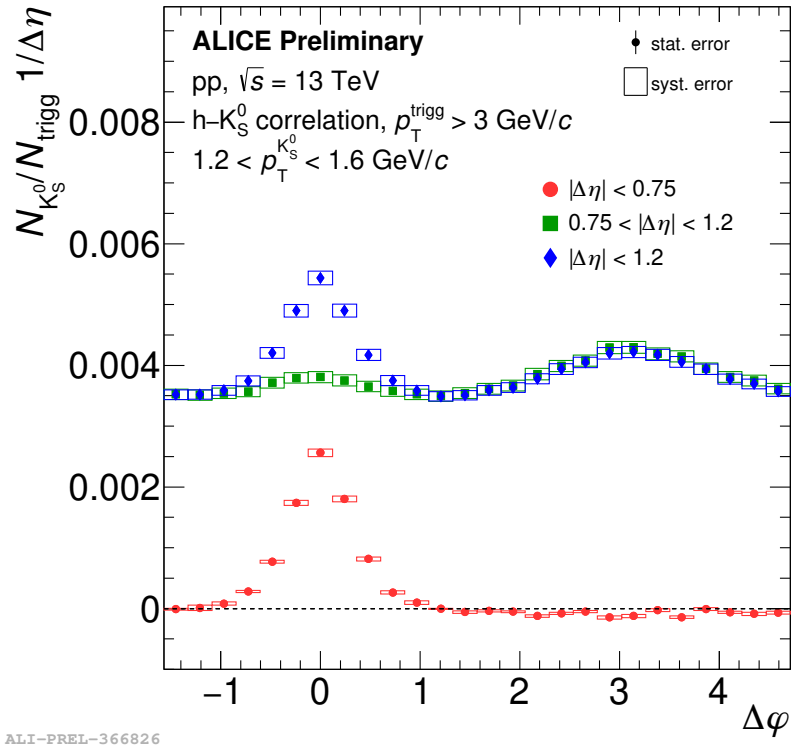
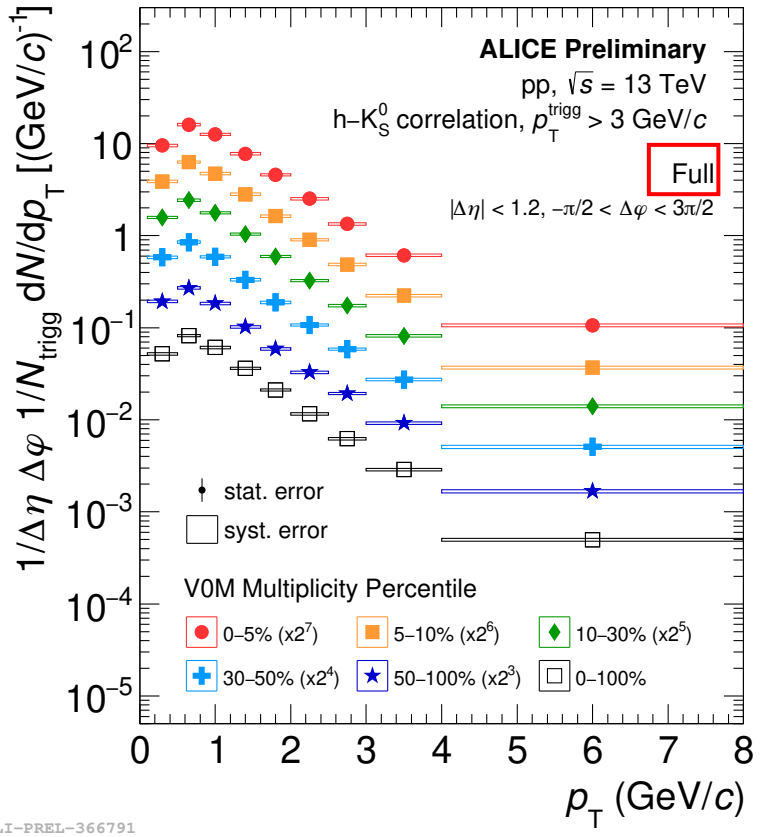




Toward, transverse-to-leading and full p_T spectra of K^0_S



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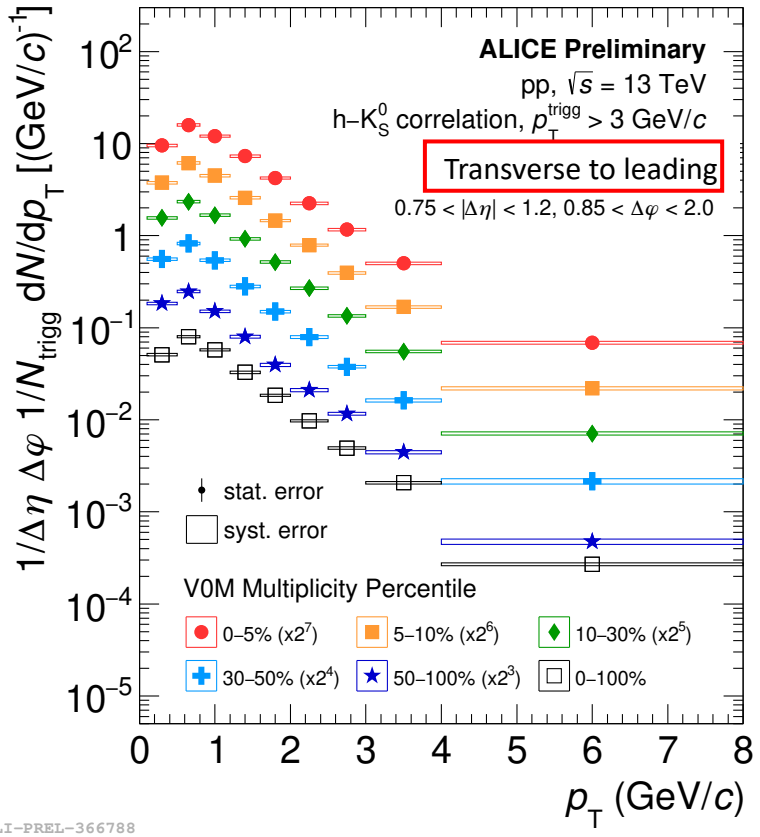

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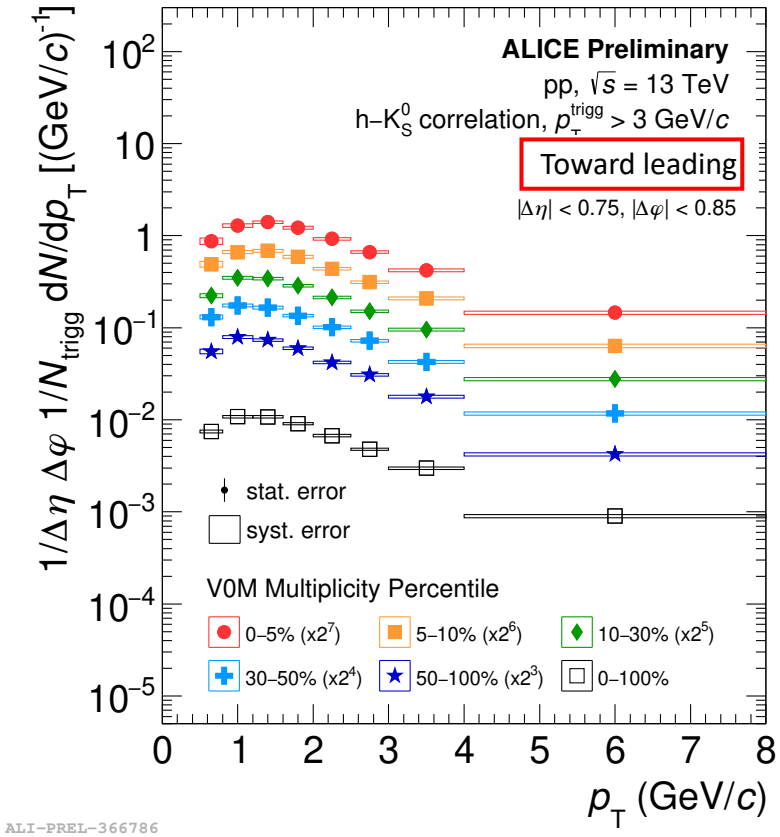
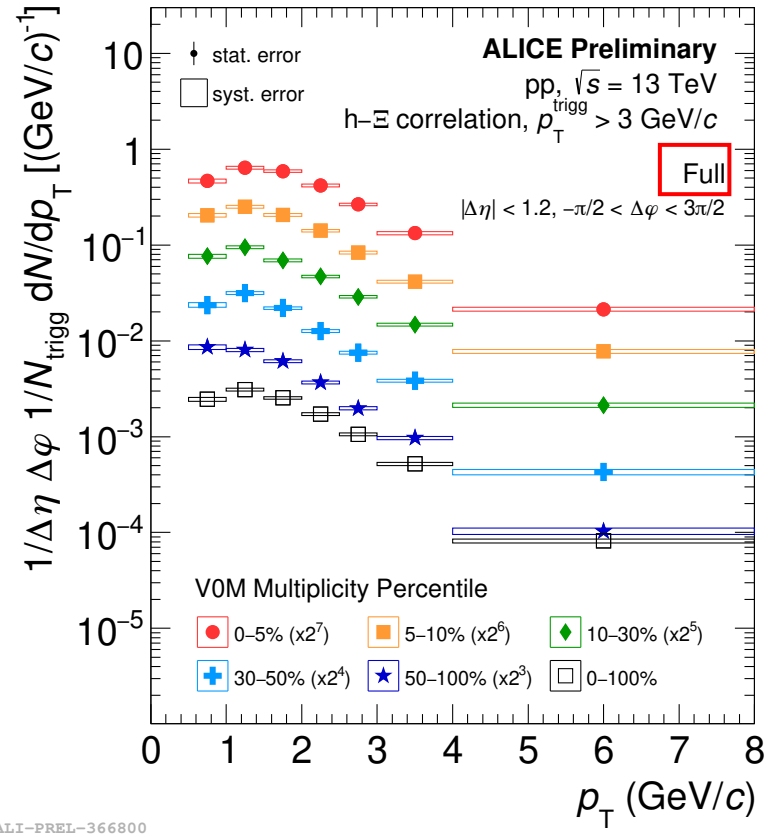
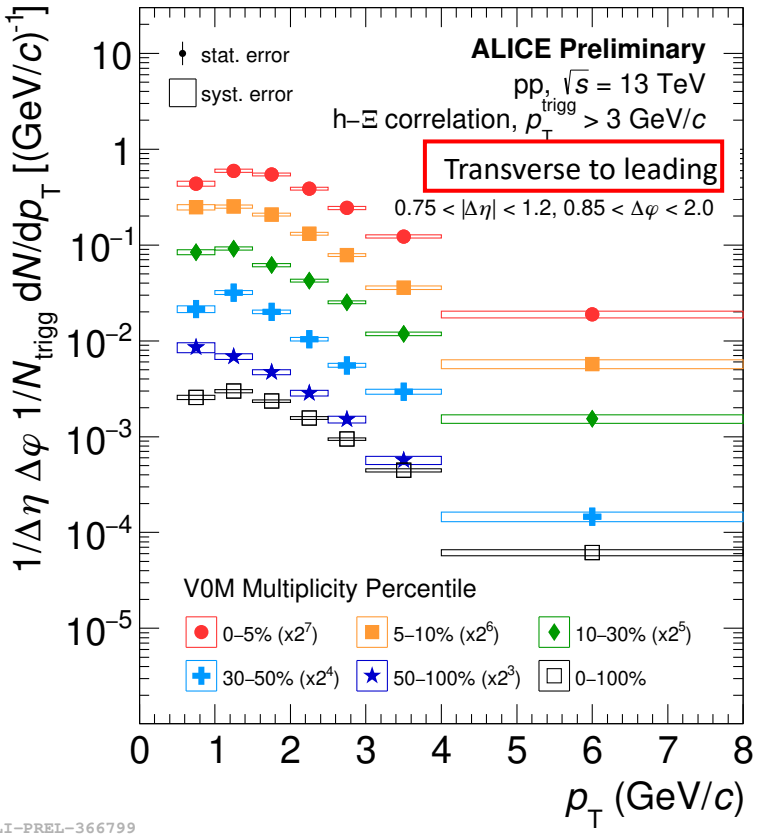


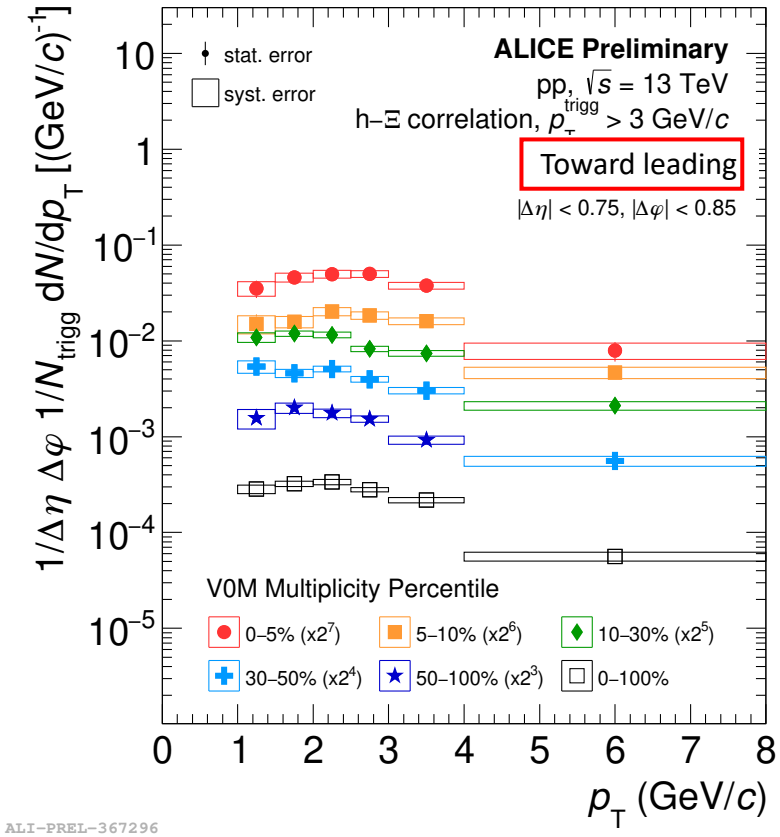
ALI-PREL-366786

Toward-leading spectra of K^0_S are harder than transverse-to-leading spectra of K^0_S

Toward, transverse-to-leading and full p_{T} spectra of $\Xi^{\pm}$

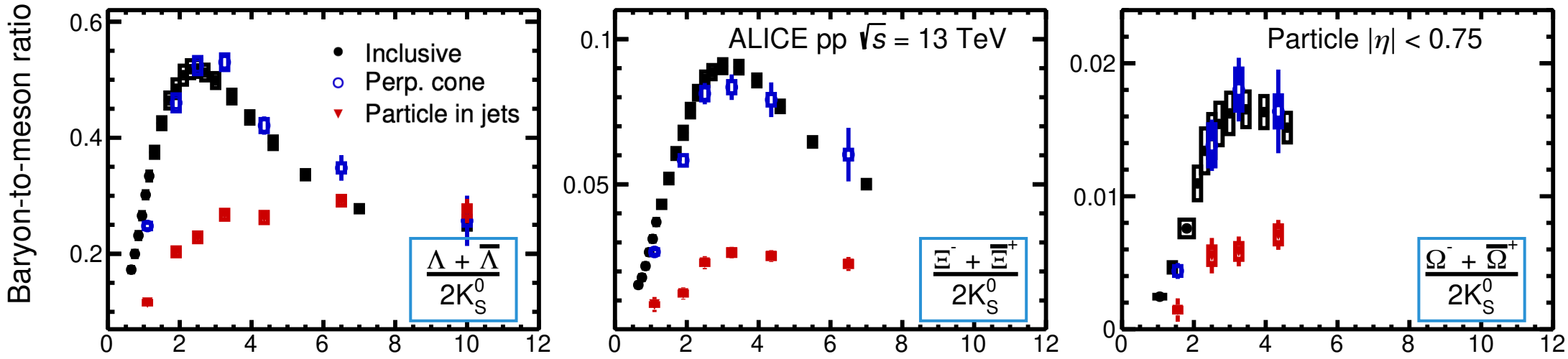






Toward-leading spectra of $\Xi^{\pm}$ are harder than transverse-to-leading spectra of $\Xi^{\pm}$

Baryon-to-meson ratio enhancement in and out of jets



- The inclusive and UE ratios show a peak at $p_{\mathrm{T}} \sim 3$ GeV/c
- The enhancement is **not present** within jets
- **The same** is observed for $\Lambda/\mathrm{K}^0_{\mathrm{S}}$ in **p-Pb collisions** at $\sqrt{s_{NN}} = 5.02$ TeV

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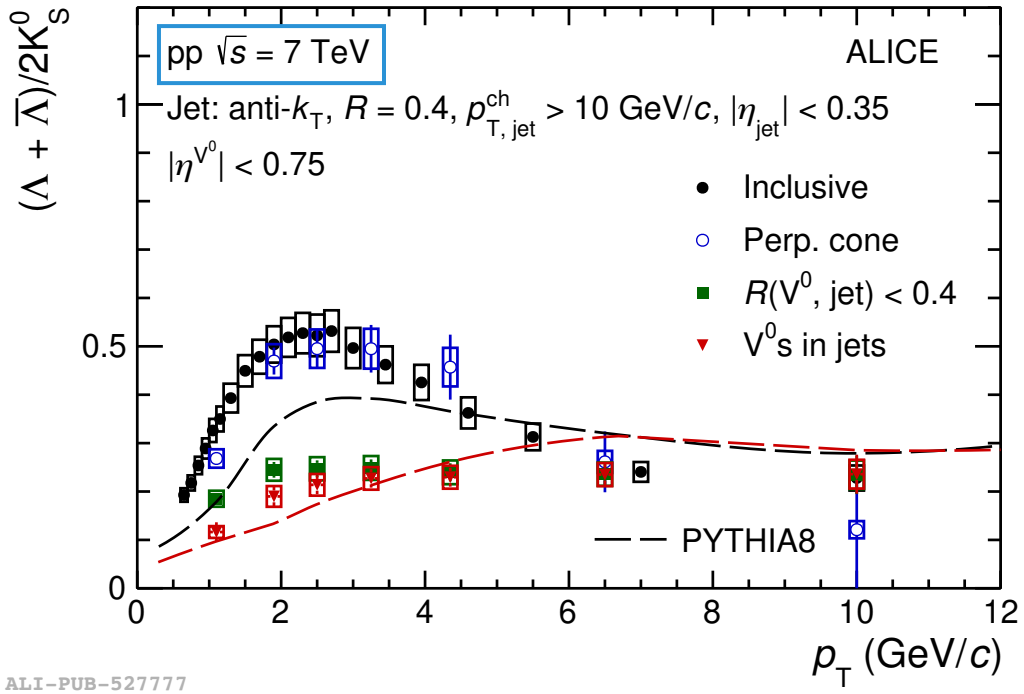
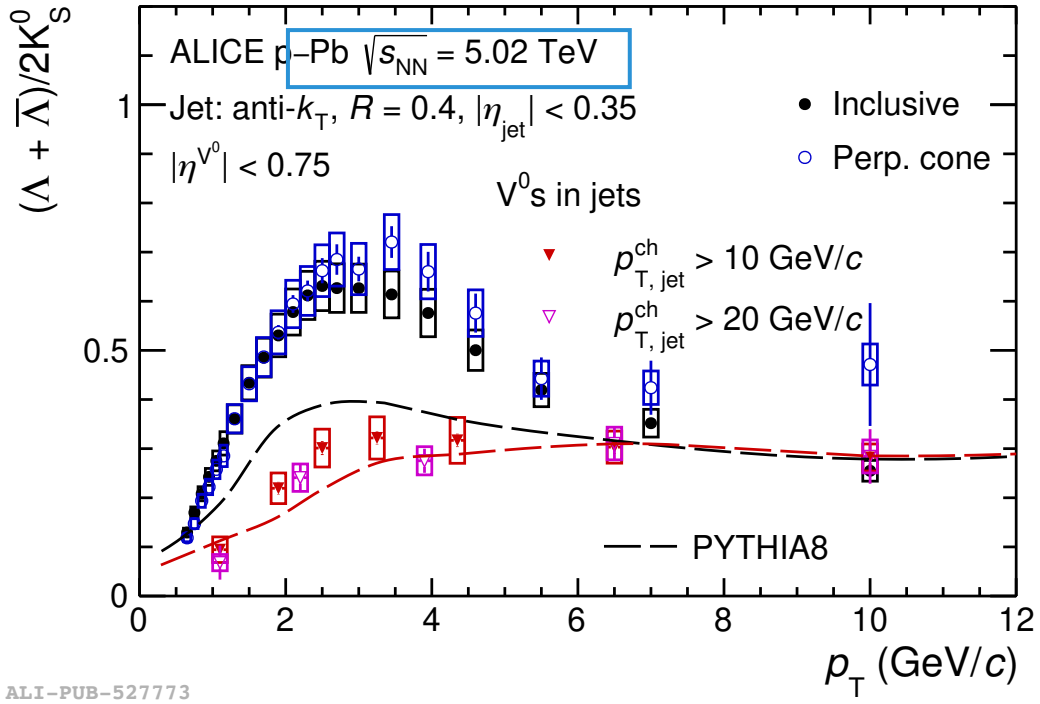
arXiv:2211.08936 (2022)

Λ/K^0_S in and out of jets in pp and p-Pb collisions





In both pp and p-Pb collisions:

- The inclusive and UE ratios show a peak at $p_T \sim 3$ GeV/c
- The enhancement is **not present** within jets

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