



Strangeness enhancement in small collision systems at ALICE: Role of hard and soft processes

Ishaan Ahuja on behalf of the ALICE Collaboration

Pavol Jozef Šafárik University in Košice, Slovakia

Theory and Experiment in High Energy Physics #1

FMFI UK, Bratislava

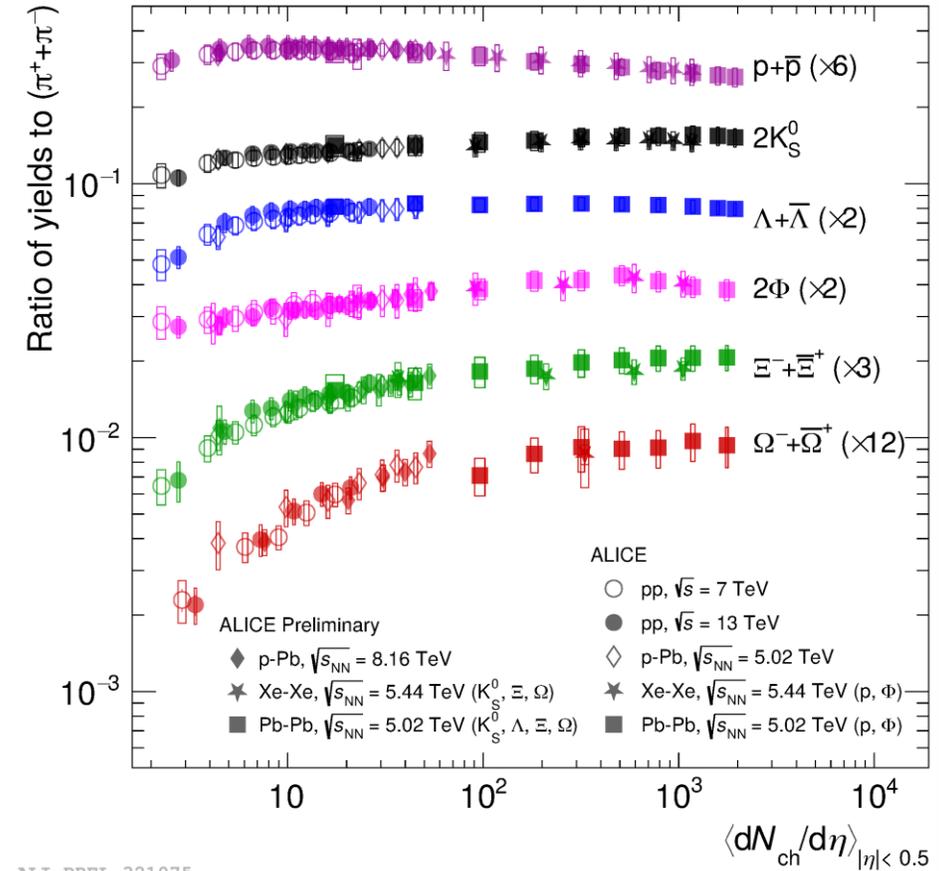
26-28 July 2023

Strangeness enhancement in small collisions



Strangeness enhancement in small collisions refers to an increase in strangeness production, observed through an increasing ratio of strange hadron yields over non-strange ones as a function of multiplicity.

- Steady progression with charged particle multiplicity spanning over multiple collision systems (pp, p-Pb & Pb-Pb)
- Independent of collision energy



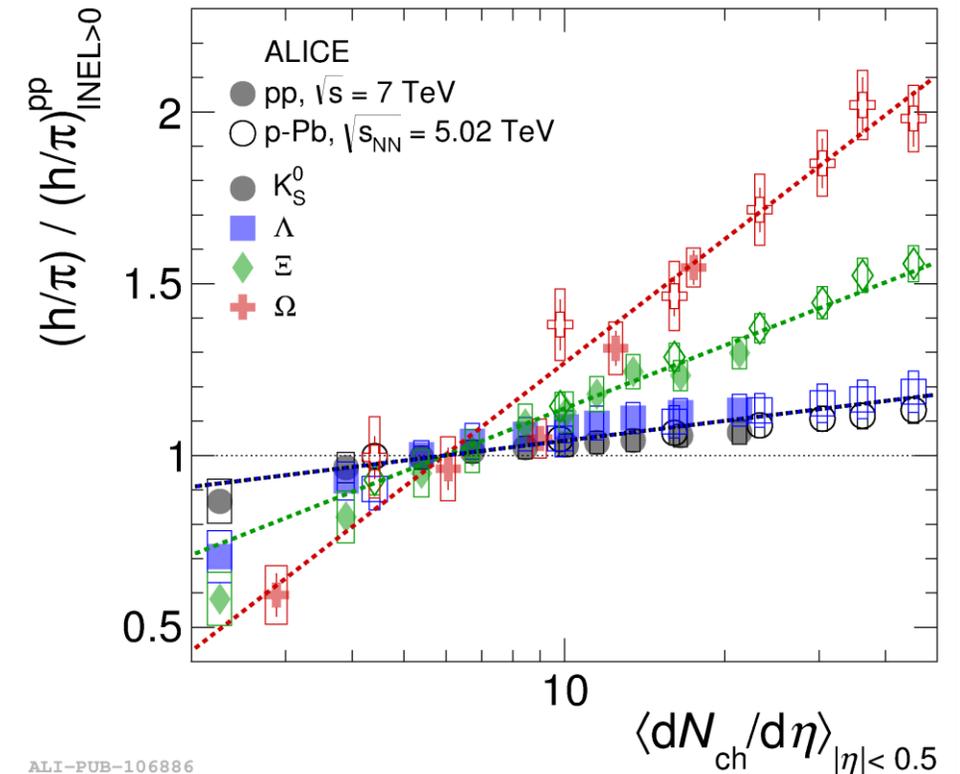
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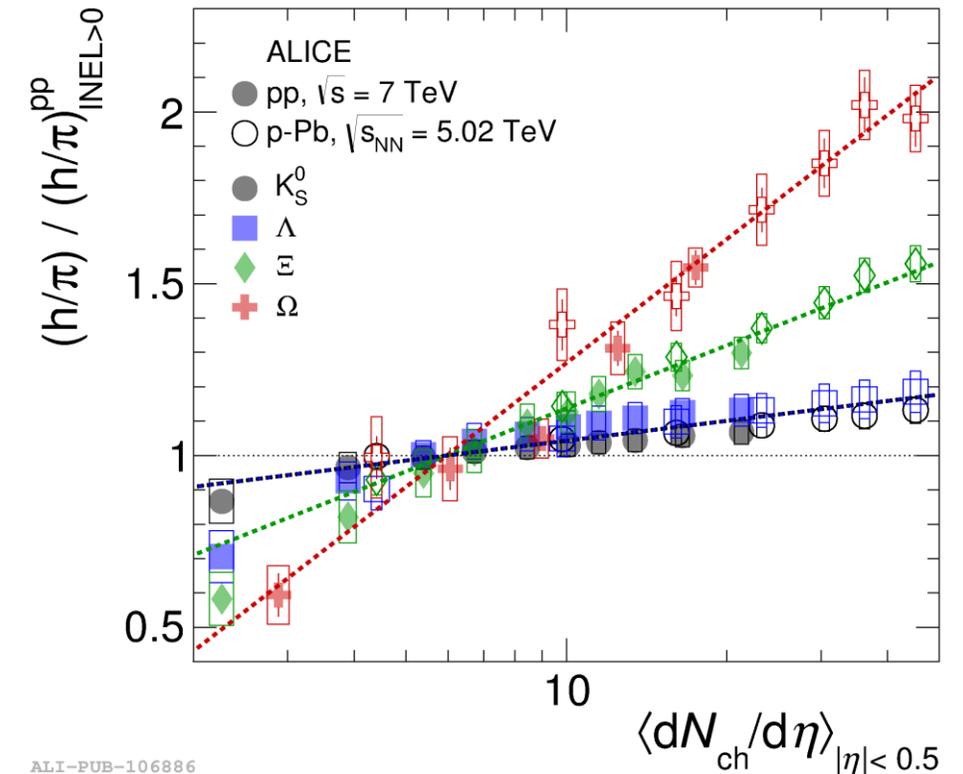
ALICE Collaboration, Nature Phys 13, 535–539 (2017)
ALICE Collaboration, Eur.Phys.J.C 80, 167 (2020)

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- Steady progression with charged particle multiplicity spanning over multiple collision systems (pp, p-Pb & Pb-Pb)
- Independent of collision energy
- Scales with particle strangeness content
- Relationship between strangeness enhancement and hard processes (jets) vs. soft (out-of-jet) processes?



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The ALICE detector

TPC: Time Projection Chamber

3-D particle tracking through gas ionisation

Main tracking detector, PID, momentum measurement

ITS: Inner Tracking System

Innermost, 6 layered silicone-based detector

Tracking, triggering, vertexing

V0 detector

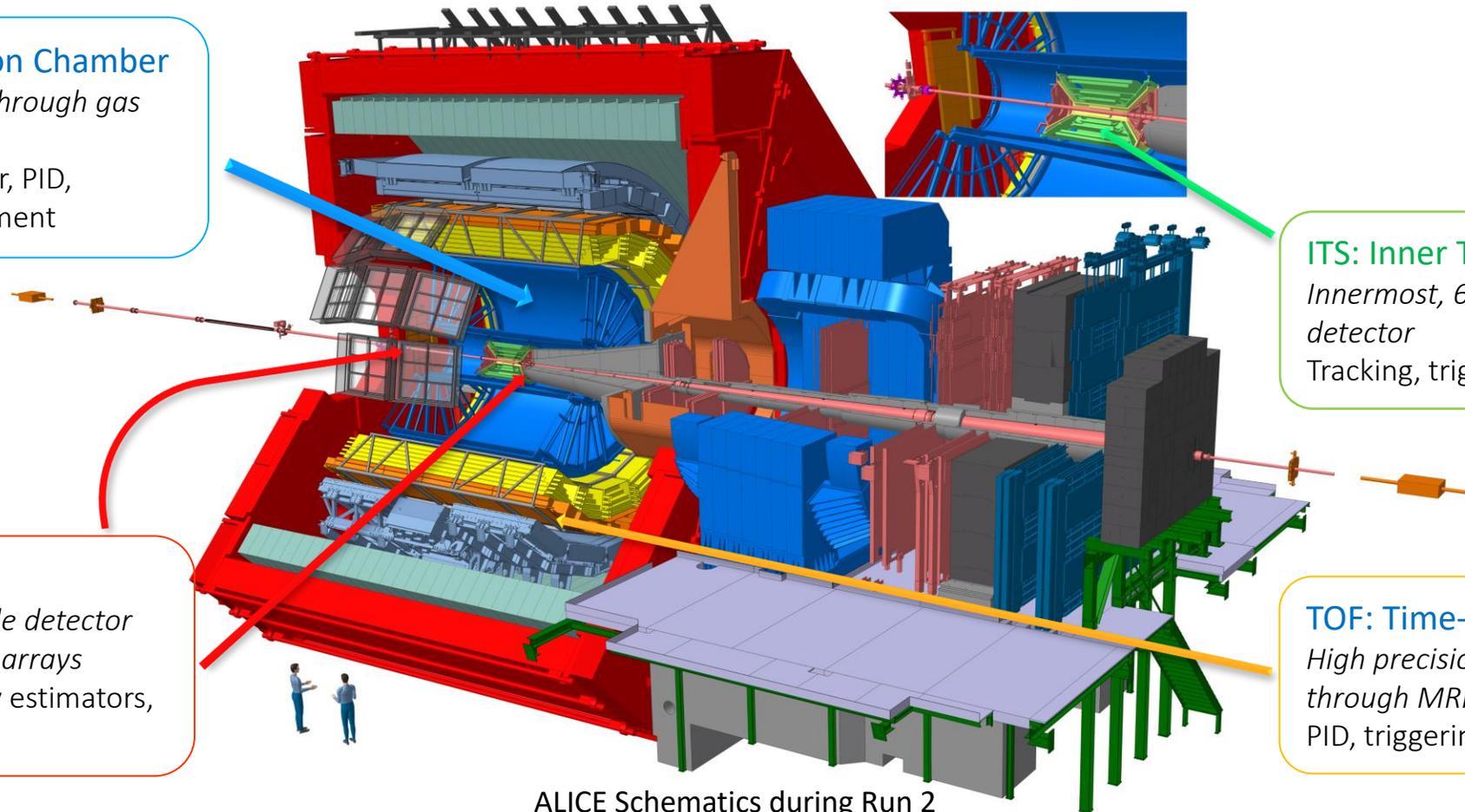
VOA & VOC: small angle detector based on scintillators' arrays

Triggering, multiplicity estimators, background rejection

TOF: Time-Of-Flight detector

High precision time tracking through MRPCs

PID, triggering



ALICE Schematics during Run 2

Two-particle angular correlations

Method of studying strange hadron production w.r.t. jet axis: angular correlations ($\Delta\varphi, \Delta\eta$) can be used to distinguish between hard (in-jet) and soft (out-of-jet) processes

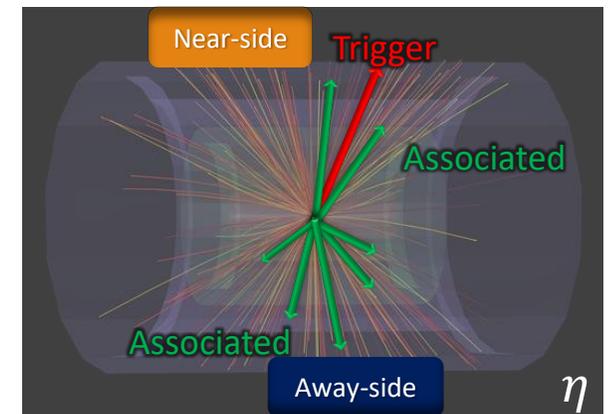
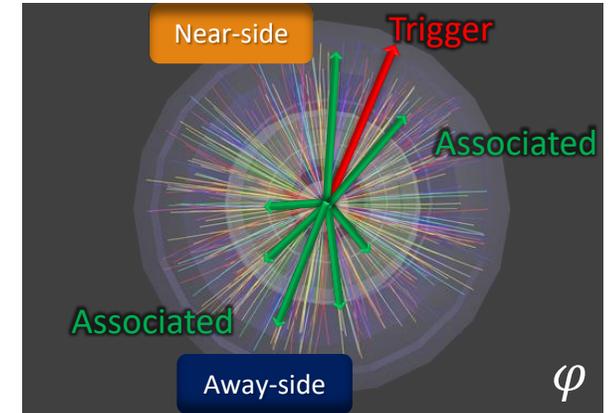
1. **Trigger** particle (jet axis proxy) selection: highest p_T charged hadron with $p_T > 3$ GeV/c
2. **Associated** particles: identified strange hadrons
3. Angular correlation constructed using angular differences between **trigger** and **associated** particles:

$$\Delta\varphi = \varphi_{\text{trig}} - \varphi_{\text{assoc}}$$

$$\Delta\eta = \eta_{\text{trig}} - \eta_{\text{assoc}}$$

where φ : Azimuthal angle;
 $\eta = -\ln(\tan(\frac{\theta}{2}))$;
 θ : Polar angle

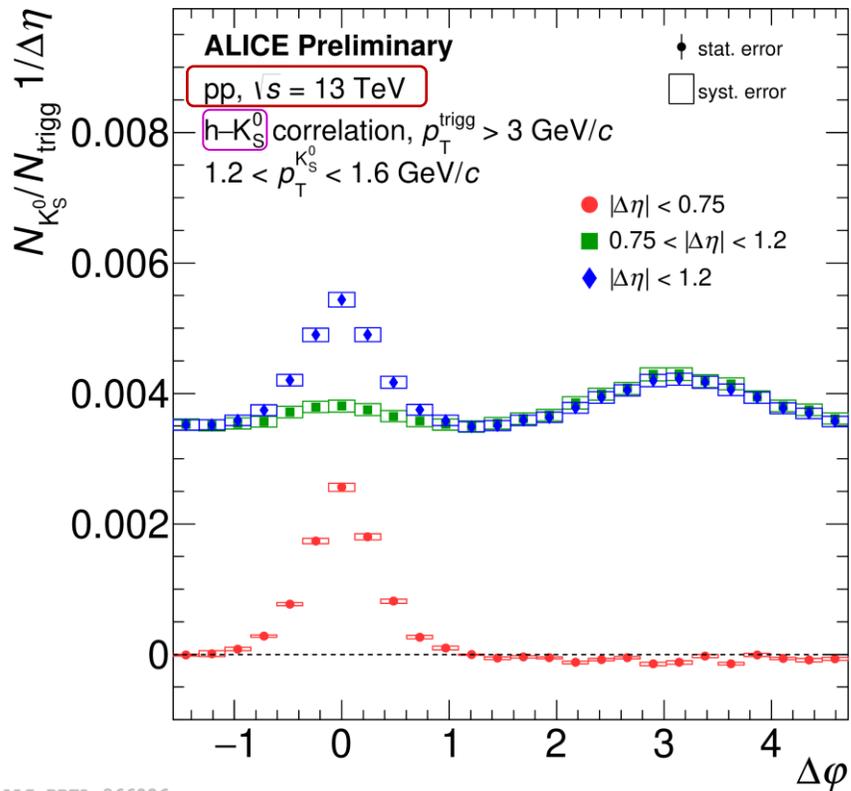
4. Per-trigger yield of **associated** particles corrected for **trigger** and **associated** particle reconstruction efficiencies, pair detector acceptance, contamination from non-primary particles, etc.



h – K_S^0 and h – Ξ angular correlations

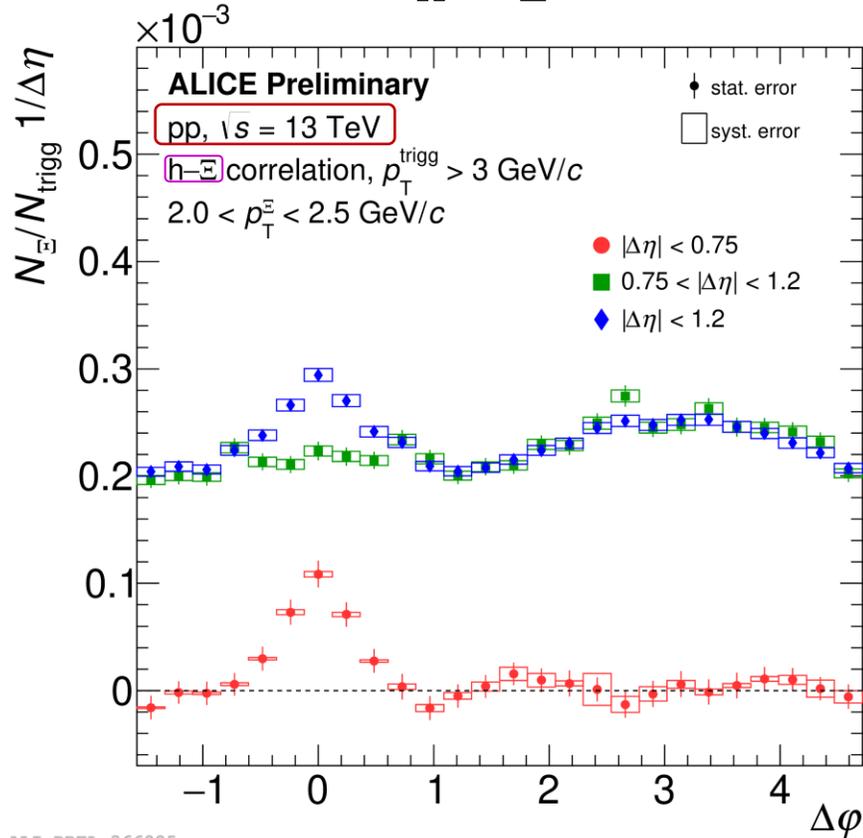


h – K_S^0

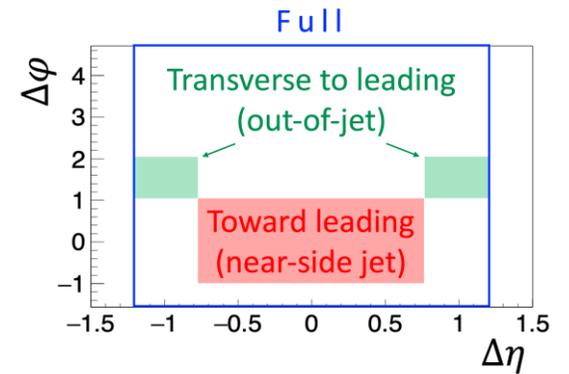


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h – Ξ

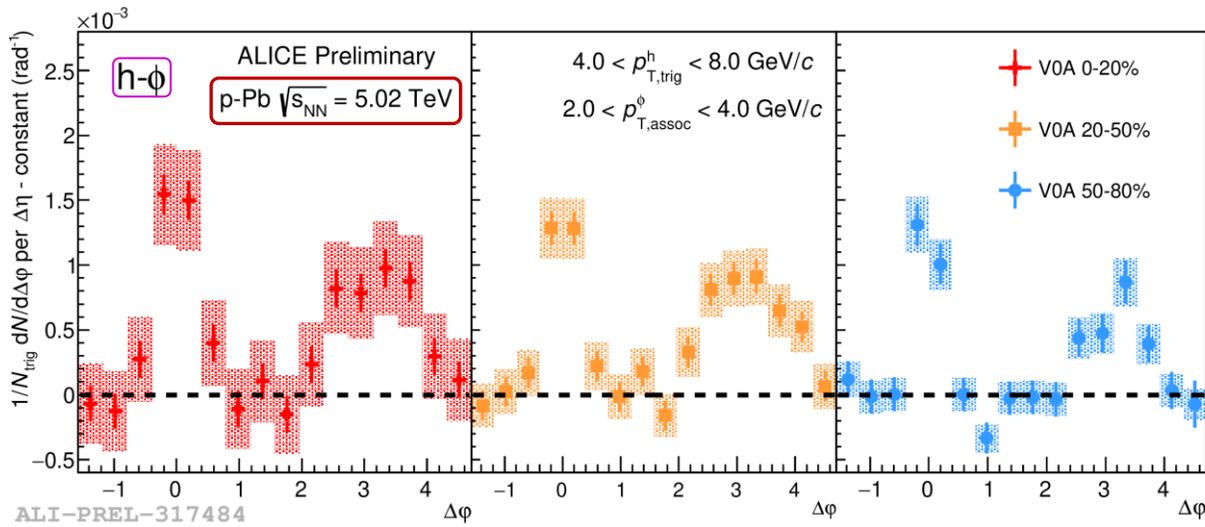


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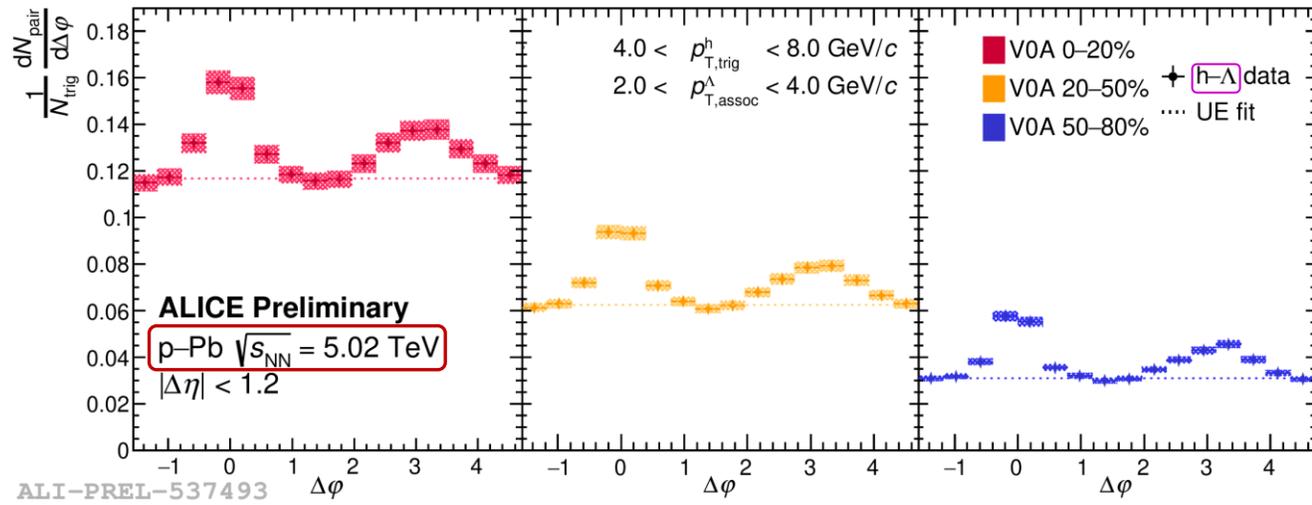
h – ϕ and h – Λ angular correlations

h – ϕ



- $2.0 < p_{T, \text{assoc}} < 4.0$ GeV/c
- Underlying event subtracted from correlation

h – Λ



- $2.0 < p_{T, \text{assoc}} < 4.0$ GeV/c

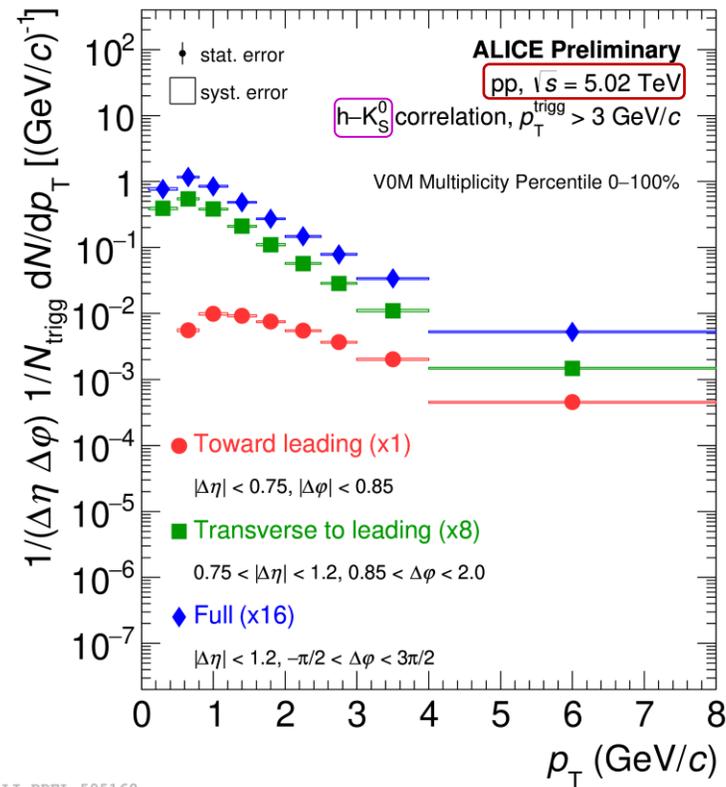
Transverse momentum (p_T) spectra

Strange hadrons: K_S^0, Ξ^\pm

pp collisions at $\sqrt{s} = 5.02$ TeV

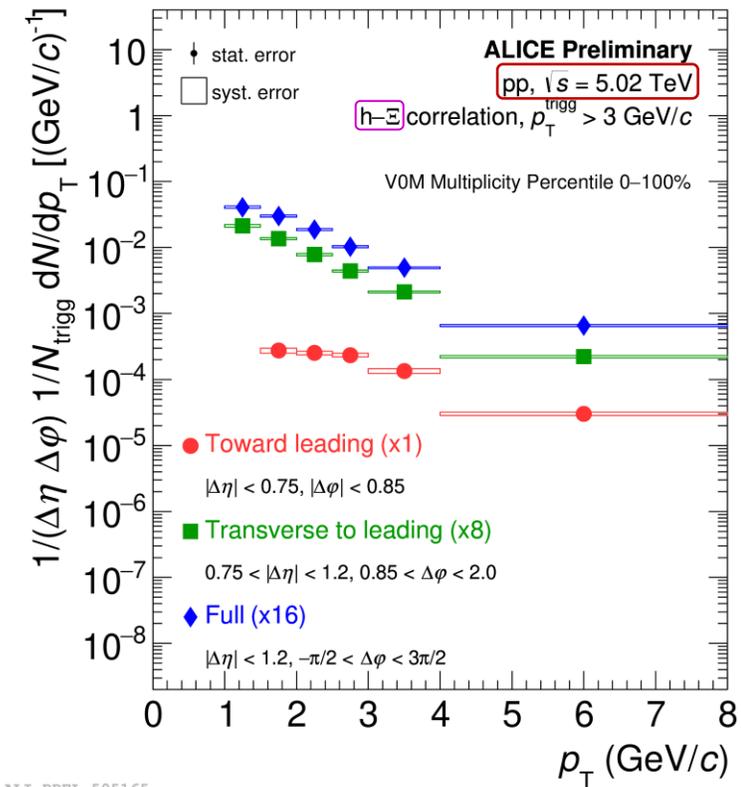
- In-jet spectra **harder** than out-of-jet contribution
- Valid across different multiplicity classes and energies

$h - K_S^0$



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$h - \Xi$



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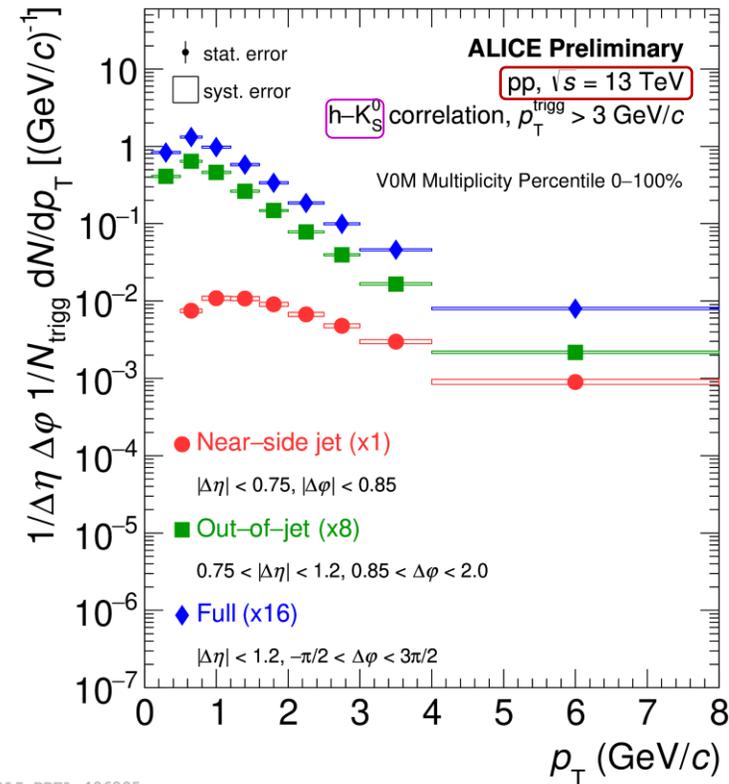
Transverse momentum (p_T) spectra

Strange hadrons: K_S^0, Ξ^\pm

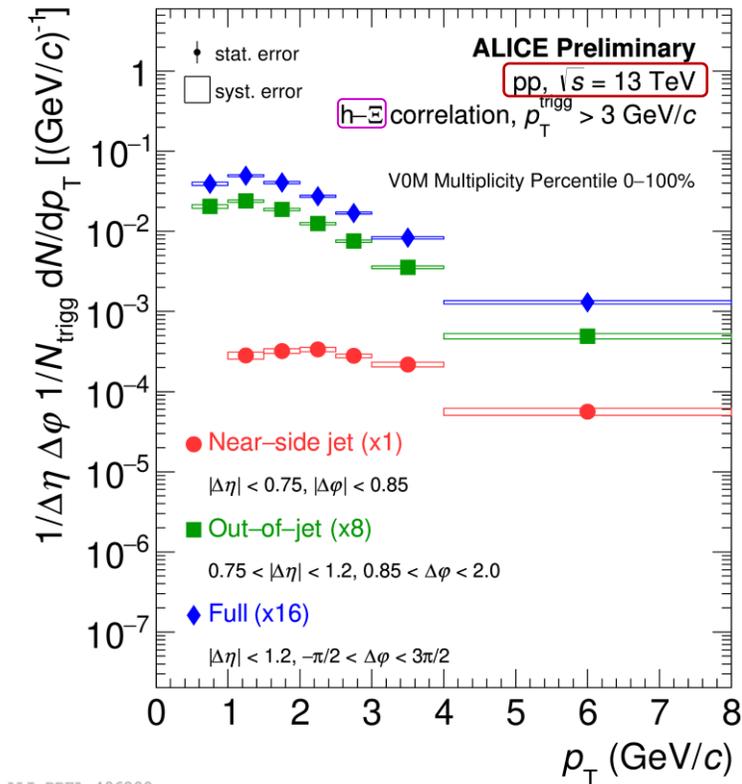
Same behaviour at higher energies: $\sqrt{s} = 13$ TeV

- In-jet spectra **harder** than out-of-jet contribution
- Valid across different multiplicity classes and energies

$h - K_S^0$



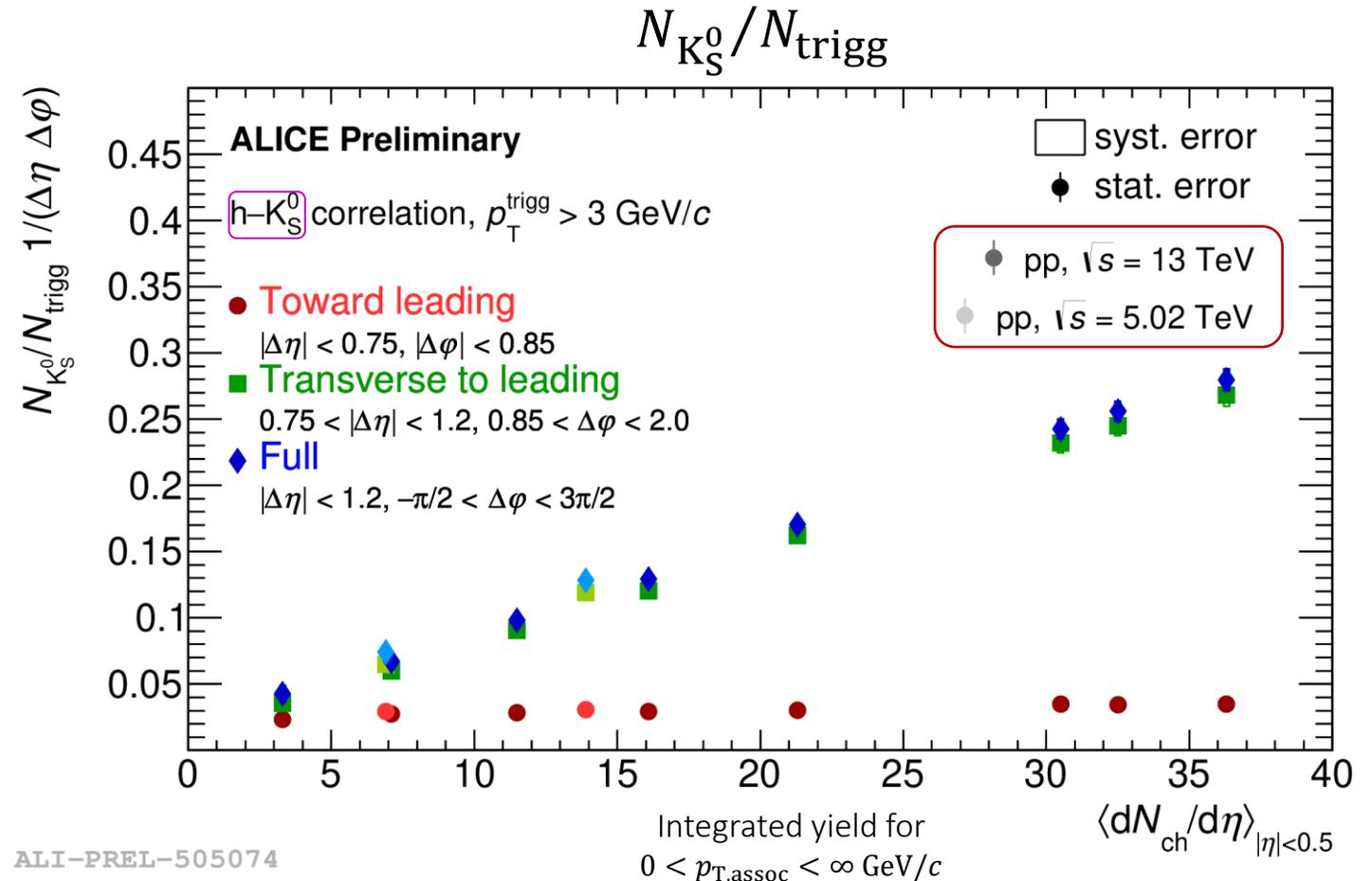
$h - \Xi$



Strange hadron yields vs. multiplicity

Strange hadron: K_S^0

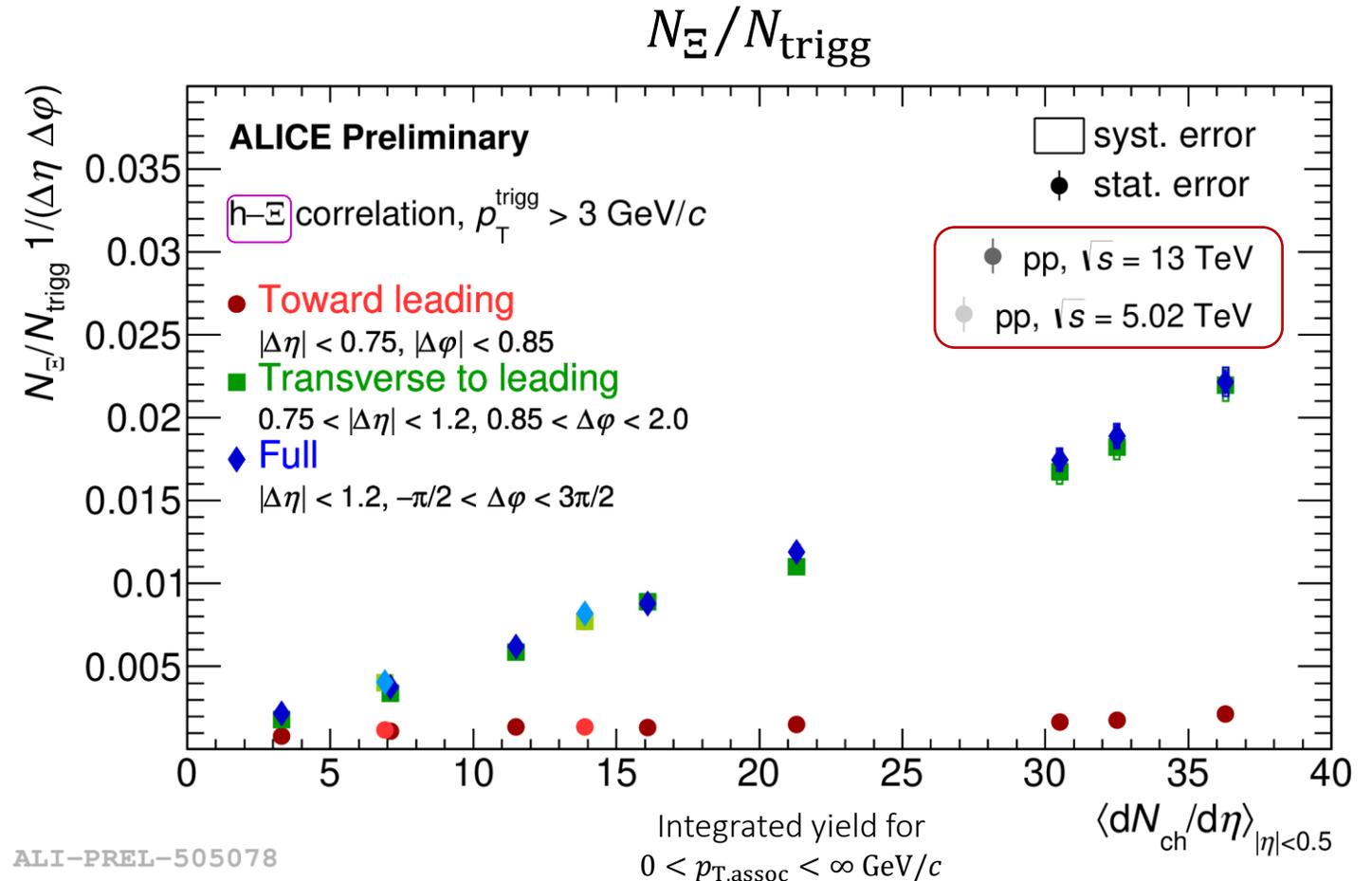
- Near-side jet yield flatter
- Out-of-jet yield and full yield rise as a function of multiplicity \Rightarrow soft processes as a dominant contributor to the strangeness enhancement?
- Out-of-jet contribution relative to near-side jet increases with multiplicity
- Valid across different centre-of-mass energies



Strange hadron yields vs. multiplicity

Strange hadron: Ξ^\pm

- Near-side jet yield flatter
- Out-of-jet yield and full yield rise as a function of multiplicity \Rightarrow soft processes as a dominant contributor to the strangeness enhancement?
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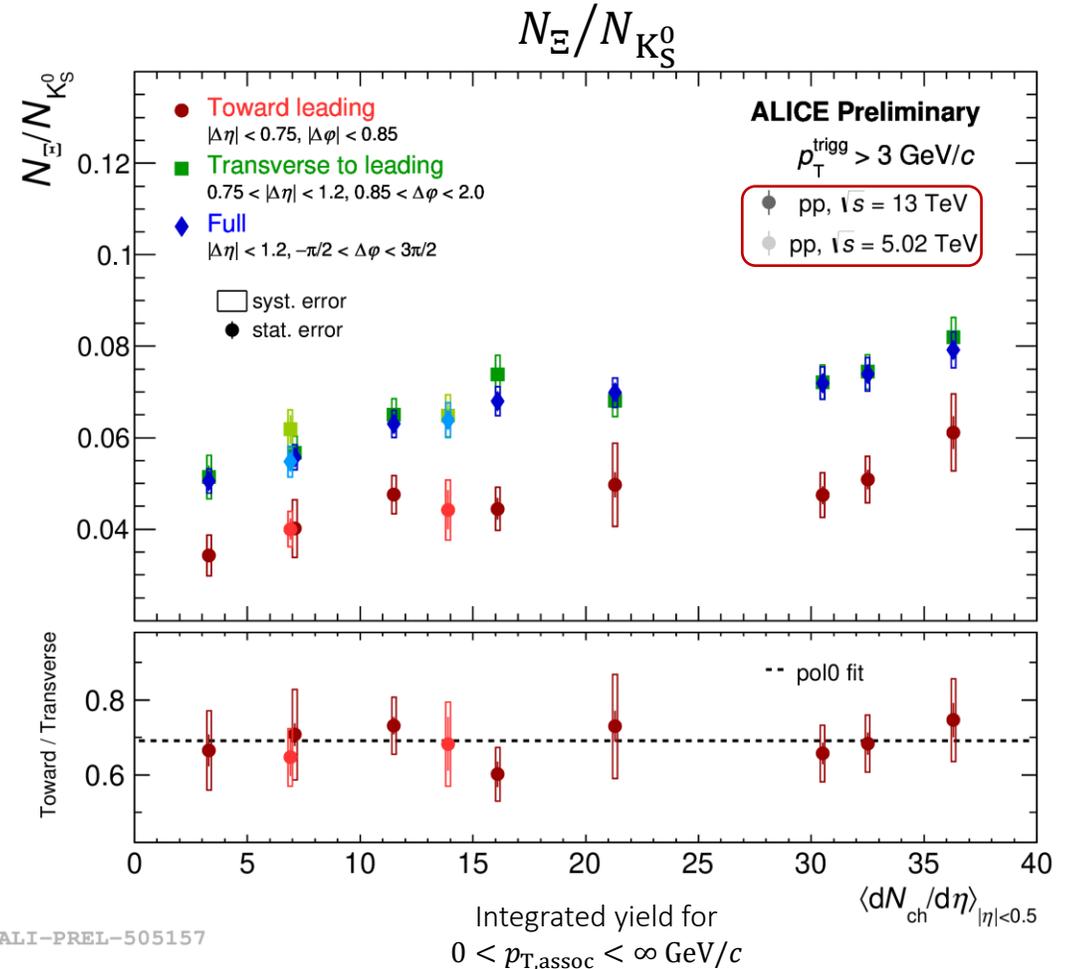


Per-trigger E^\pm/K_S^0 yield ratio vs. multiplicity



Per-trigger yield ratio: $\frac{N_E}{N_{K_S^0}}$

- No centre-of-mass energy dependence
- **Out-of-jet** yield ratio and **full** yield ratio **increase** with multiplicity
- **Near-side jet** yield ratio also **increases** with multiplicity
- **Near-side jet** yield ratio **smaller** than **out-of-jet** yield ratio

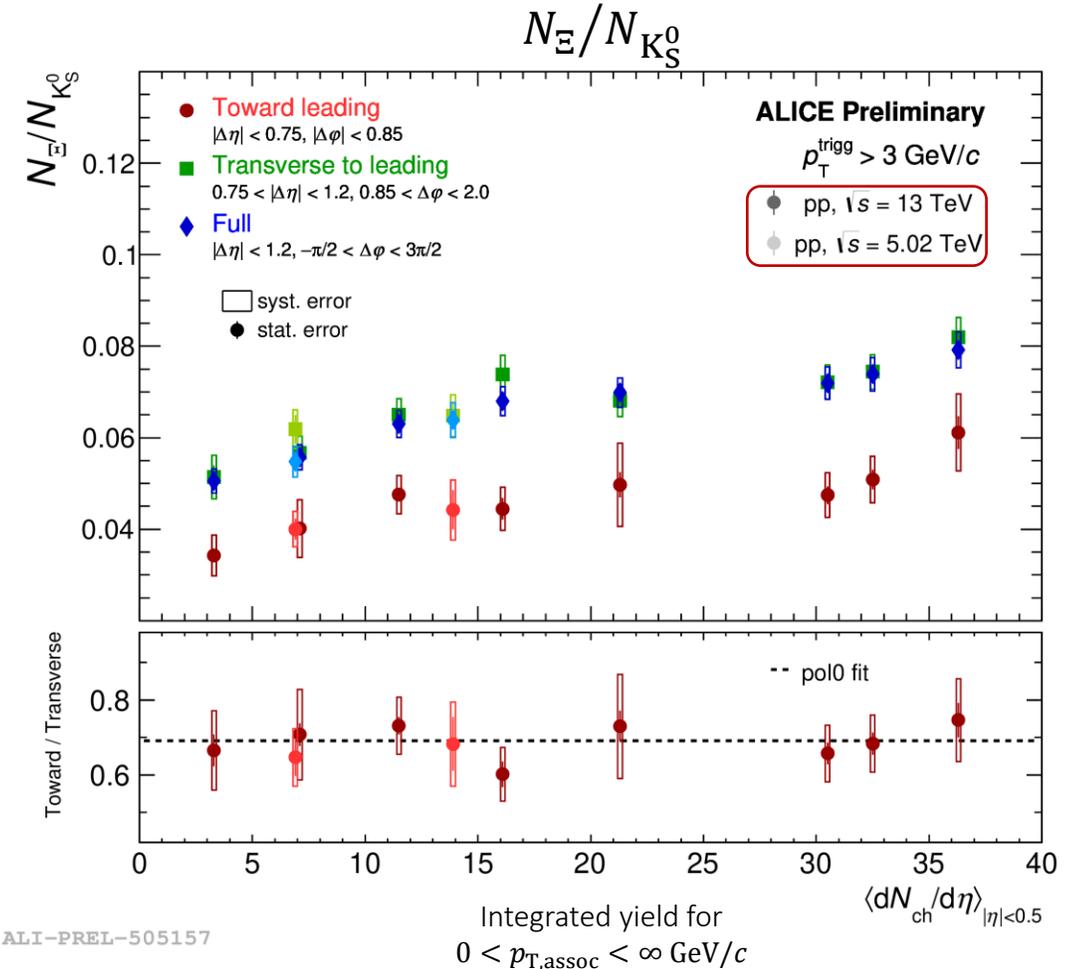


Per-trigger Ξ^{\pm}/K_S^0 yield ratio vs. multiplicity



Per-trigger yield ratio: $\frac{N_{\Xi}}{N_{K_S^0}}$

- Higher values of **out-of-jet** yield ratio indicate a **dominant contribution** to the Ξ^{\pm}/K_S^0 **full** yield ratio
- **Near-side jet** yield ratio and **out-of-jet** yield ratio show a compatible increase with multiplicity

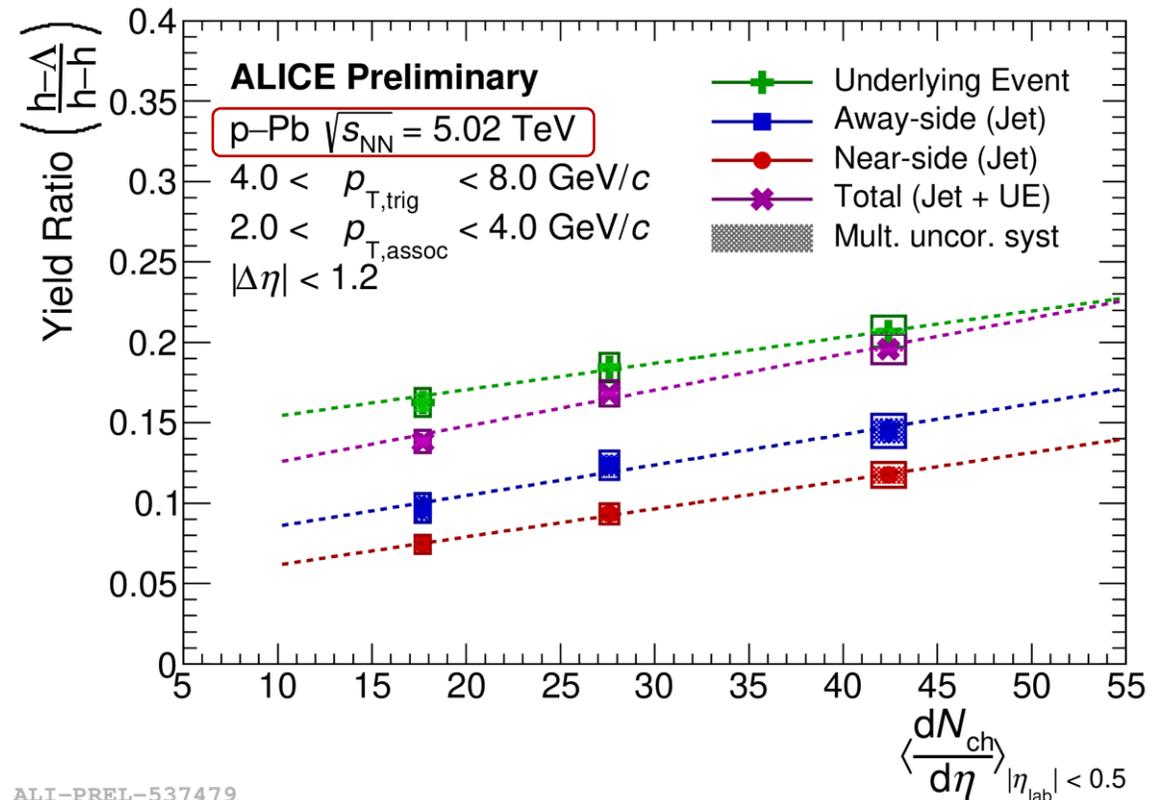


Per-trigger $\frac{h-\Delta}{h-h}$ yield ratio vs. multiplicity



Per-trigger yield ratio: $\frac{h-\Delta}{h-h}$

- Out-of-jet (UE) yield ratio and total yield ratio increase with multiplicity
- Near-side jet yield ratio also increases with multiplicity
- Near-side jet yield ratio smaller than out-of-jet (UE) yield ratio
- Higher values of out-of-jet (UE) yield ratio indicate a dominant contribution to the total (Jet + UE) yield ratio

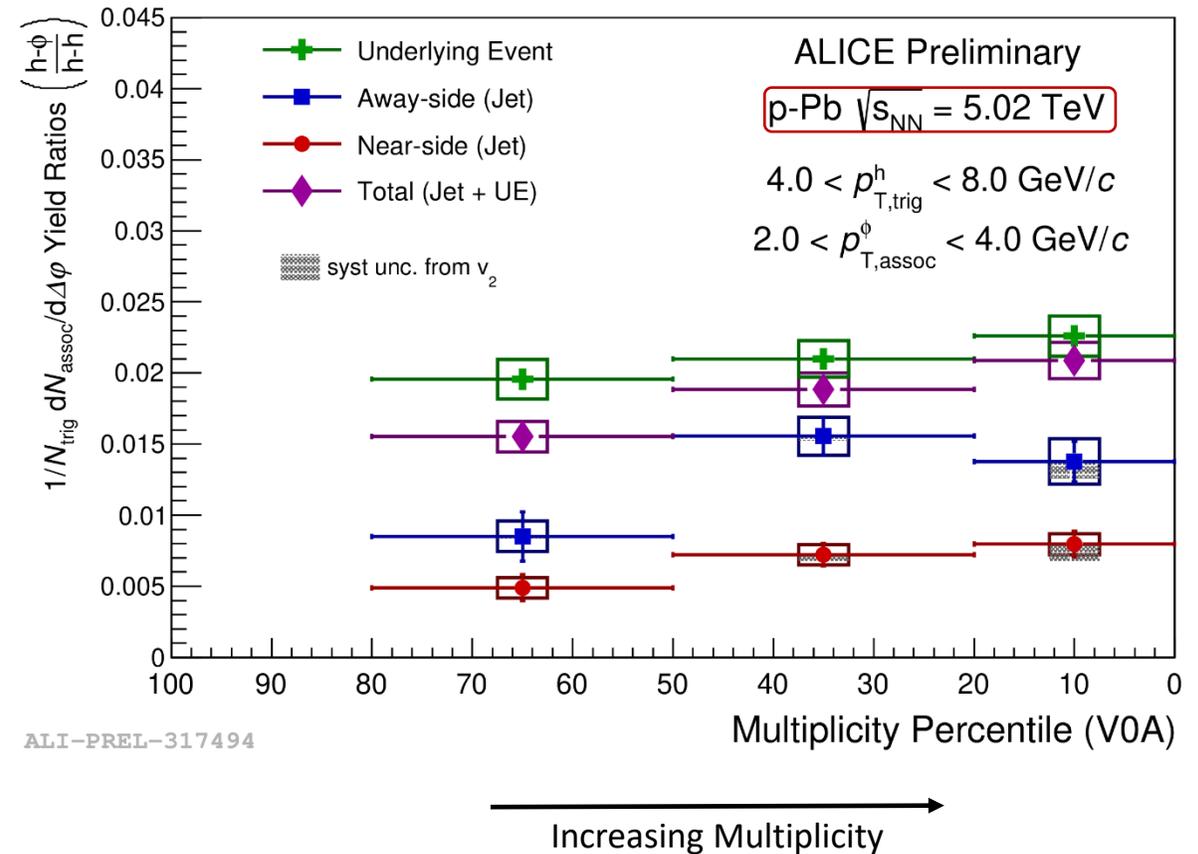


Per-trigger $\frac{h-\phi}{h-h}$ yield ratio vs. multiplicity



Per-trigger yield ratio: $\frac{h-\phi}{h-h}$

- **Out-of-jet (UE)** yield ratio and **total** yield ratio increase with multiplicity
- **Near-side jet** yield ratio also increases with multiplicity
- **Near-side jet** yield ratio **smaller** than **out-of-jet (UE)** yield ratio
- Higher values of **out-of-jet (UE)** yield ratio indicate a **dominant contribution** to the **total (Jet + UE)** yield ratio



ALI-PREL-317494

Summary

- Harder p_T spectra for strange hadrons in jets than in out-of-jet events or full sample
- No centre-of-mass energy dependence or collision system dependence for strangeness enhancement studied via two-particle correlations
- Per-trigger yield ratios indicate strangeness enhancement dependent on charged particle multiplicity
- Hard (in-jet) and soft (out-of-jet) processes' yield ratios show a compatible multiplicity dependence
- Soft (out-of-jet) processes have a dominant contribution towards strange particle production

An aerial photograph of Bratislava, Slovakia, featuring the prominent Bratislava Castle (Bratislavský hrad) with its white walls and red-tiled roof. The castle is situated on a hill overlooking the Danube River, which flows through the city. The scene is captured during the golden hour, with warm sunlight casting long shadows and illuminating the buildings and trees. In the background, the city's residential areas and distant hills are visible under a sky with soft, wispy clouds. A small orange rectangular graphic is located in the top-left corner of the image.

Thank you for
your attention!



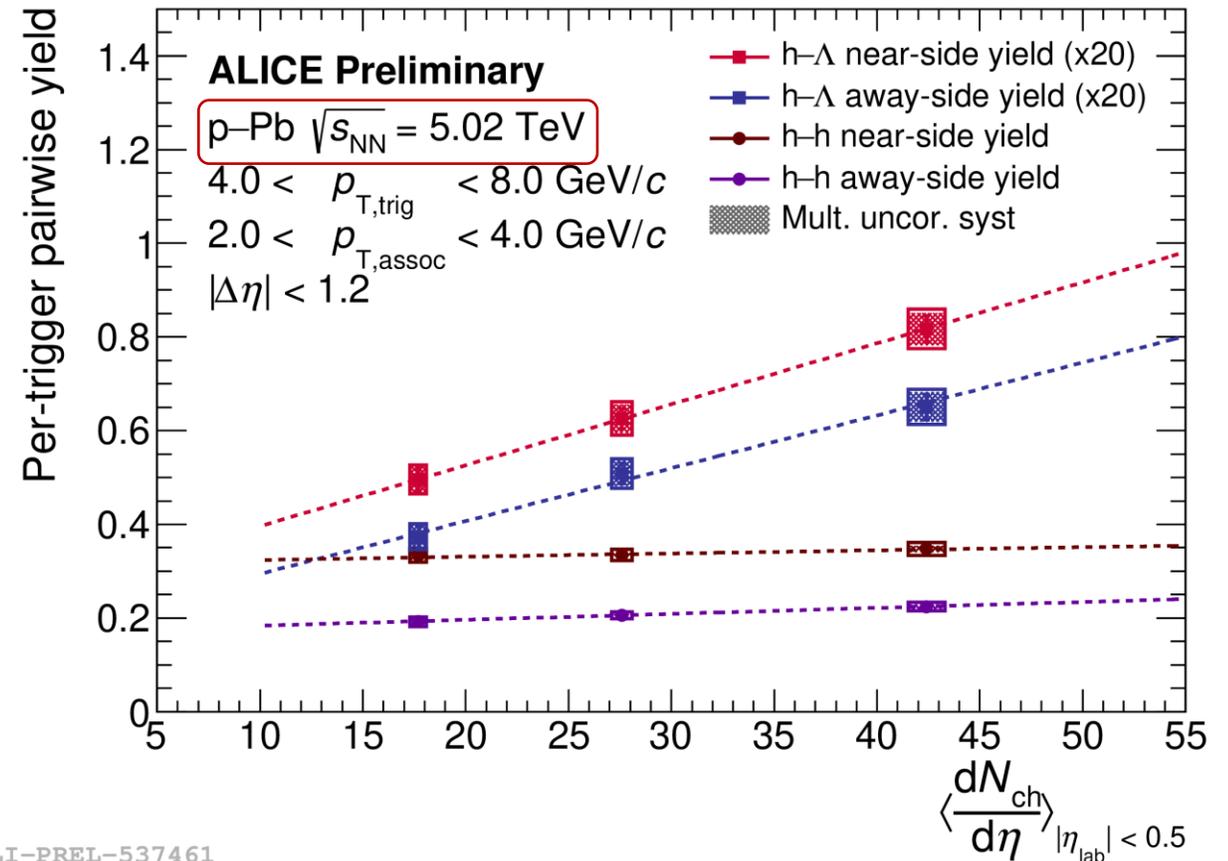
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BACKUP SLIDES

Per-trigger $h - \Lambda$ and $h - h$ yields in p-Pb



- Multiplicity dependent $h - \Lambda$ **near-side jet** yield
- Increased contribution as a function of increasing multiplicity, in contrast to di-hadron yield.



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