



विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
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Recent results on two particle correlation measurements at LHC energy

Mintu Haldar
Bose Institute, Kolkata



Outline

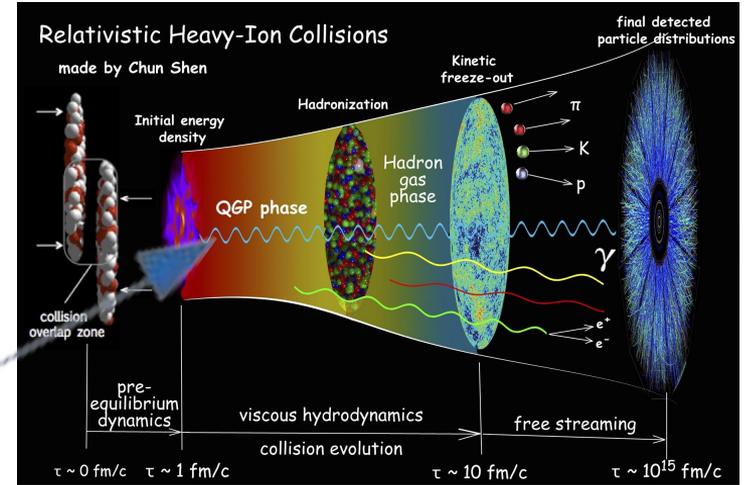
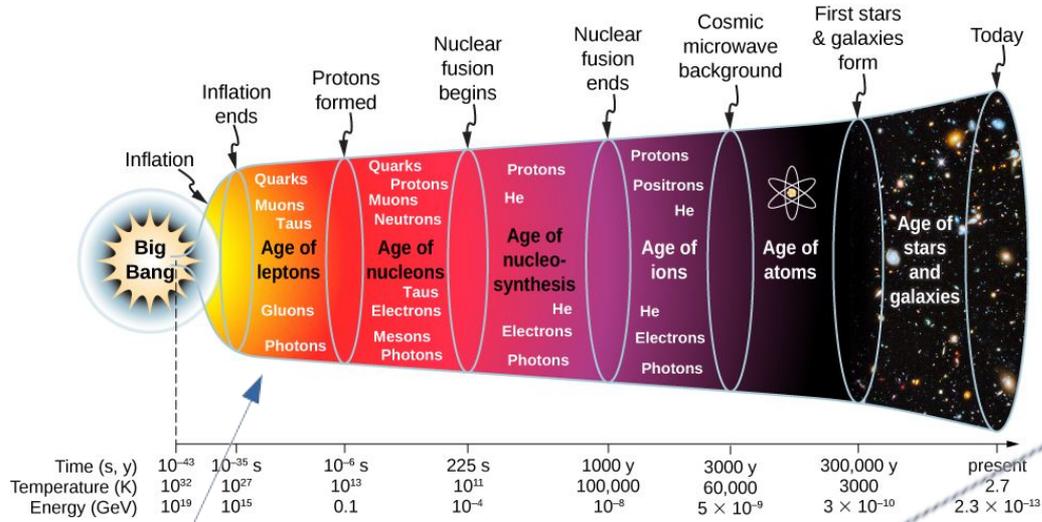
→ Introduction

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→ Results

→ Summary

Introduction



Quark Gluon Plasma (QGP):

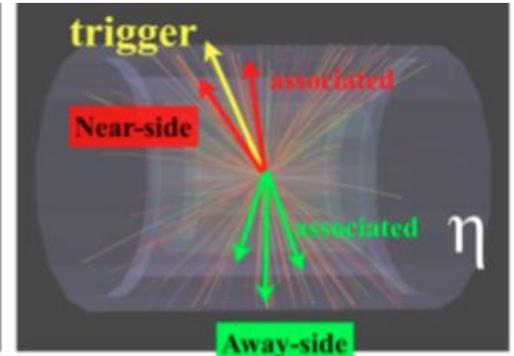
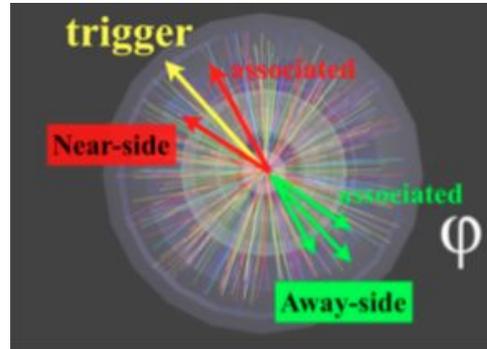
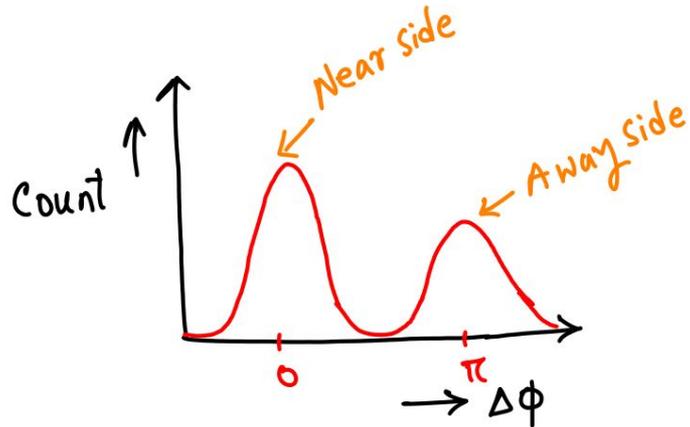
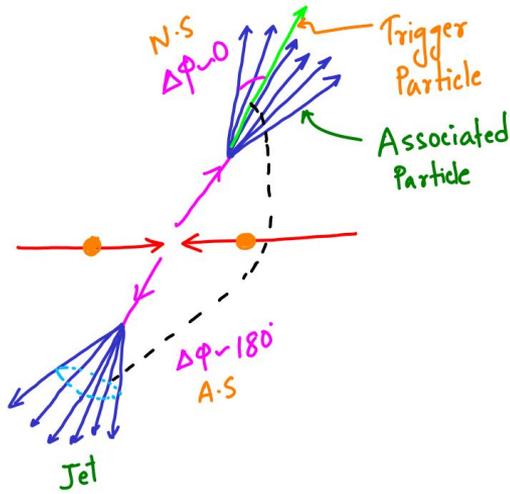
- ❖ Deconfined state of quarks and gluons
- ❖ Thermally equilibrated state of matter

Motivation

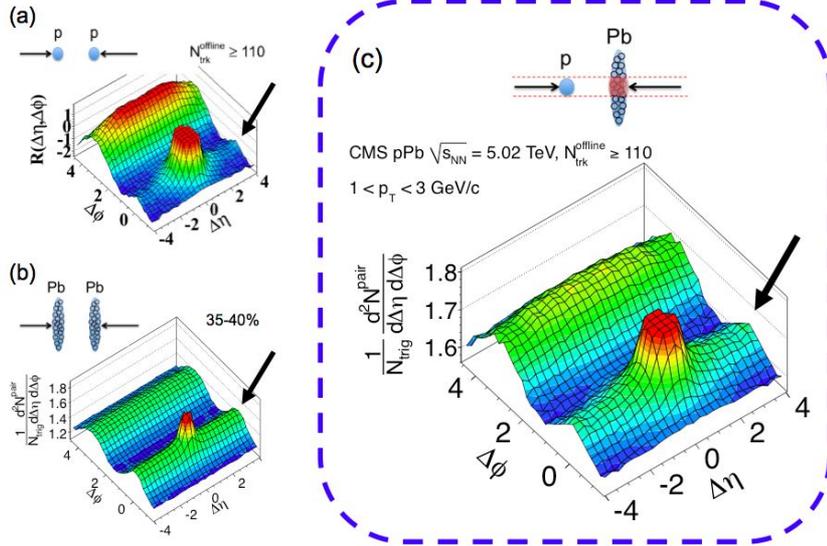
Correlation function is defined as the distribution of relative azimuthal angle and relative pseudorapidity between the trigger and associated particles

$$C(\Delta\phi, \Delta\eta) = \frac{1}{N_{\text{trigger}}} \frac{d^2 N_{\text{asso}}}{d\Delta\phi d\Delta\eta}$$

$$\Delta\phi = \phi_{\text{trig}} - \phi_{\text{asso}}, \Delta\eta = \eta_{\text{trig}} - \eta_{\text{asso}}$$



Two-particle correlation: a tool to probe medium properties

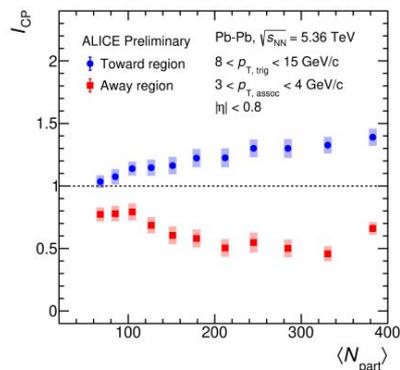


- For **pp** : Shows the “ridge” in high-multiplicity events, unexpected for such a small system
- For **Pb–Pb**: Ridge is well-known, explained by **collective flow** (hydrodynamics)
- For **p–Pb**: Ridge is also seen — **similar to heavy-ion collisions**
- Indicates possible **collective behavior** or **initial-state effects**

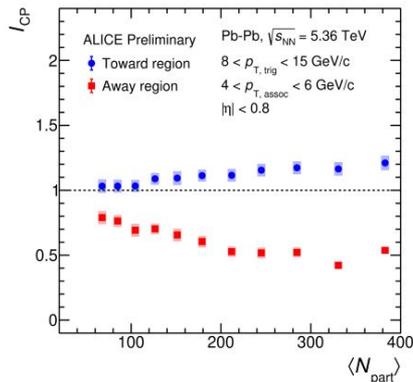
There is a two sets of two-particle correlation-

- Short-range jet-like correlation ($|\Delta\eta| < 1$)
 - Near-side peak at $(\Delta\eta=0, \Delta\phi=0)$
 - Away-side peak at $(\Delta\phi=\pi)$ broader peak from the back to back recoil jet
 - **Origin:** pQCD (jets + momentum conservation), dominant at high p_T
- Long-range ridge-structure correlation ($|\Delta\eta| > 2$)
 - Near-side ridge: enhancement around $\Delta\phi=0$, extended over $|\Delta\eta| > 2$
 - Away-side ridge: modulation at $\Delta\phi=\pi$, also extended in $\Delta\eta$
 - Signal collectivity and possible medium effects

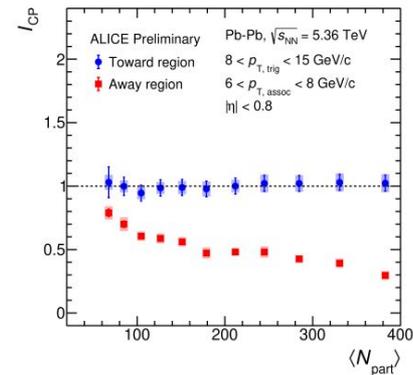
Jet modification using Two-particle correlation



ALI-PREL-577163



ALI-PREL-577174



ALI-PREL-577168

→ Toward region (blue):

- ◆ $I_{CP} \sim 1$ across all centralities and all $p_{T, \text{asso}}$ bins
- ◆ The near-side jet yield is **not significantly modified** from peripheral to central collisions

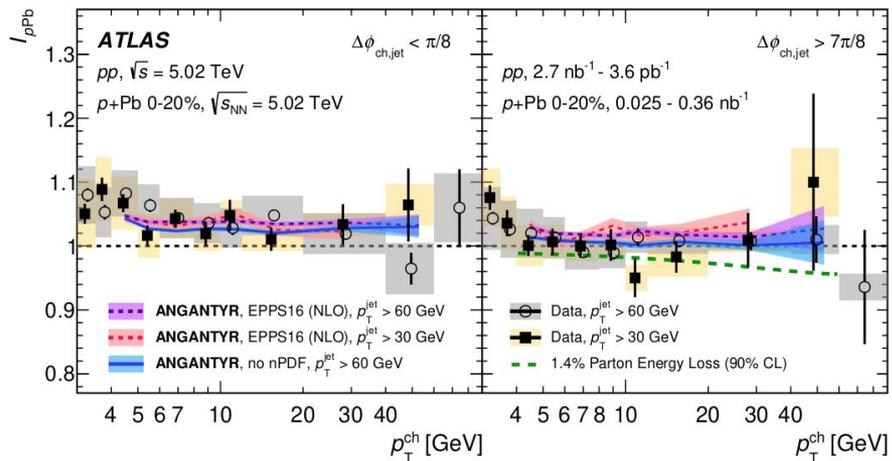
→ Away region (red):

- ◆ $I_{CP} < 1$, decreasing with centrality (higher $\langle N_{\text{part}} \rangle$)
- ◆ Stronger suppression for higher centralities (especially at larger $p_{T, \text{asso}}$)
- ◆ The away-side jet suffers **energy loss in the QGP**, leading to suppressed yields in central Pb–Pb relative to peripheral

→ jet quenching in Pb–Pb collisions

→ Away-side jets are strongly suppressed with increasing centrality, consistent with parton energy loss in the quark–gluon plasma (QGP)

Jet-associated particle yields in p-Pb vs pp (ATLAS)



- ★ Data agrees with ANGANTYR (both with and without nuclear PDFs)
- ★ **No significant nuclear modification** is observed
- ★ This indicates that **cold nuclear matter effects are small**

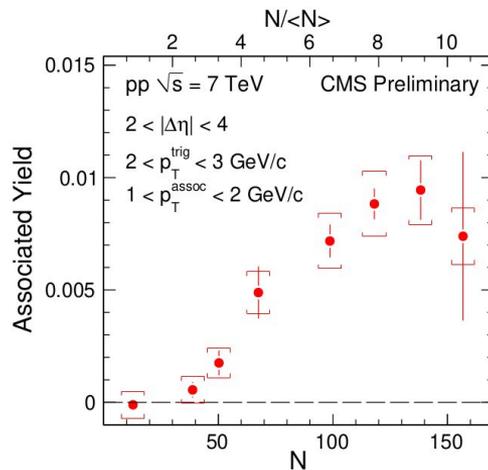
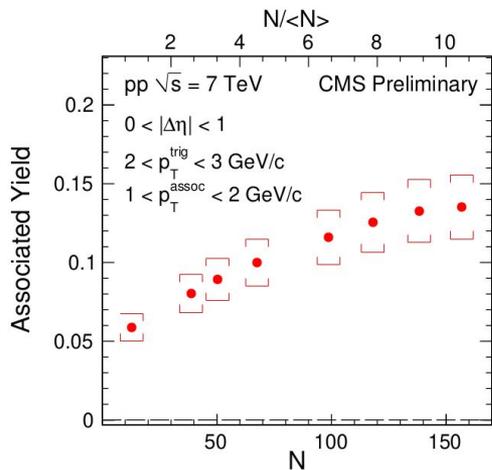
→ Near-side (left panel):

- ◆ $I_{pPb} \approx 1$ across the whole p_T^{ch} range
- ◆ No significant modification of near-side jet fragmentation in p+Pb compared to pp

→ Away-side (right panel):

- ◆ I_{pPb} is also close to unity within uncertainties
- ◆ Slight downward trend at higher p_T^{ch} , but consistent with models
- ◆ No strong evidence of suppression or energy loss effects

Multiplicity Dependence of Near-Side Associated Yield in pp Collisions

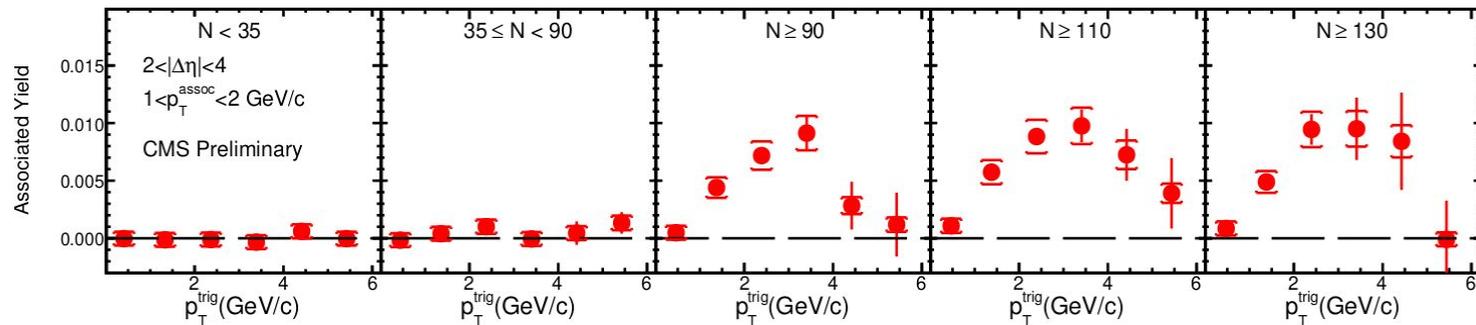


Short-range jet region ($0 < |\Delta\eta| < 1$)

Long-range ridge region ($2 < |\Delta\eta| < 4$)

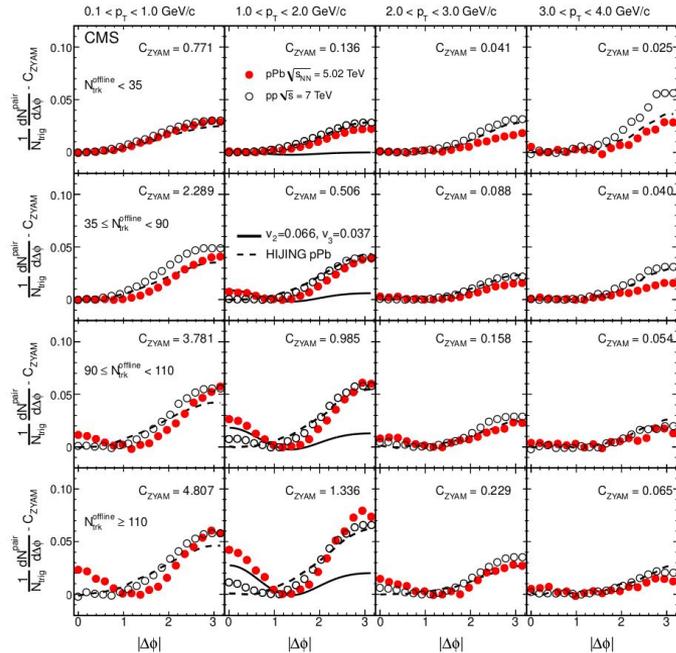
- ★ **Short-range (left panel):**
 - The associated yield increases steadily with multiplicity
 - This is expected: more particles \rightarrow stronger jet-like correlations
 - Jet fragmentation dominates this region
- ★ **Long-range (right panel):**
 - At low multiplicity, yield is nearly zero (no ridge)
 - Above $N \geq 50$, a clear non-zero associated yield appears
 - Yield grows with multiplicity, peaking around $N \sim 120-130$
 - This is the **ridge signal** (long-range near-side correlation), not explained by jets alone

Ridge strength as a function of $p_{T,\text{trig}}$



- ❖ **Correlation region:** Long-range ($2 < |\Delta\eta| < 4$) to avoid jet contributions
- ❖ **Low multiplicity ($N < 35$):**
 - The associated yield is essentially zero → no significant long-range correlation in low-multiplicity events
- ❖ **Intermediate multiplicity ($35 \leq N < 90$):**
 - A small ridge-like correlation begins to appear at intermediate $p_{T,\text{trig}}$
- ❖ **High multiplicity ($N \geq 90, 110, 130$):**
 - A **clear ridge structure** emerges: associated yield is significantly above zero
 - Maximum correlation observed when $p_{T,\text{trig}} \sim 2\text{--}3 \text{ GeV/c}$

Multiplicity and p_T Dependence of Near-Side Ridge

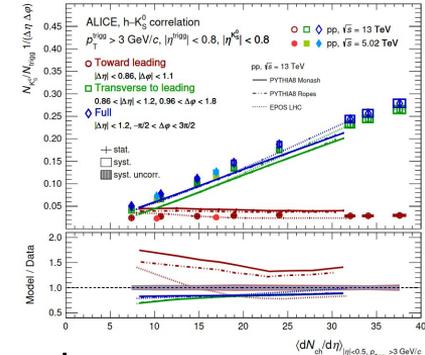
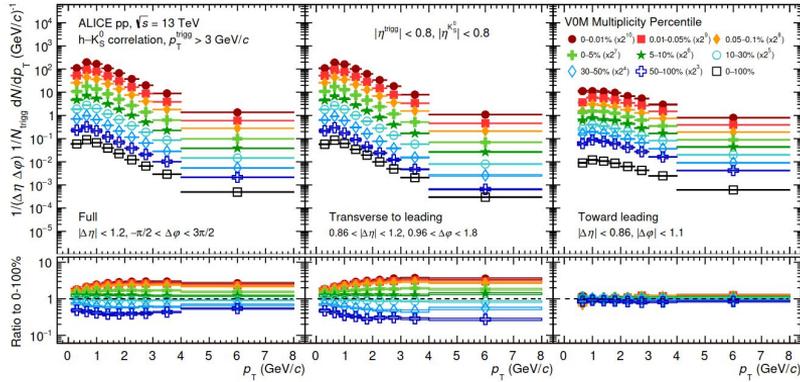


$2 < |\Delta\eta| < 4$

- ★ Event in small systems like p-Pb, under high multiplicity conditions **collective effects or QGP-like behavior may be present**

- A clear evolution of the $\Delta\Phi$ correlation function as a function of both p_T and N_T^{offline} is observed
- **Low multiplicity:**
 - Correlation function \rightarrow **minimum at $\Delta\Phi=0$** and **maximum at $\Delta\Phi=\pi$**
 - Dominated by **momentum conservation + back-to-back jets** (stronger at higher p_T)
- **Intermediate to high multiplicity:**
 - Emergence of long-range **near-side ridge** ($\Delta\Phi=0$ and large $|\Delta\eta|$)
 - Ridge stronger in **p-Pb than pp**, especially at high multiplicity
 - Near-side yield largest at **$1 < p_T < 2$ GeV/c**, increases with multiplicity
- **Comparison with models:**
 - **HIJING** (jet-only) fails to describe ridge
 - **Fourier fit (v_2, v_3)** \rightarrow collective flow-like behavior

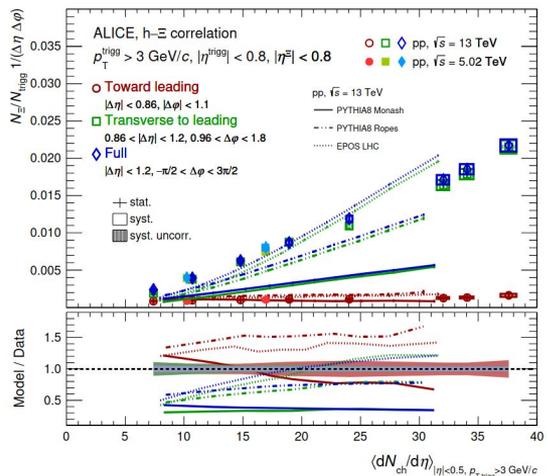
Strangeness Enhancement in pp Collisions via $h-K_s^0$ Correlations



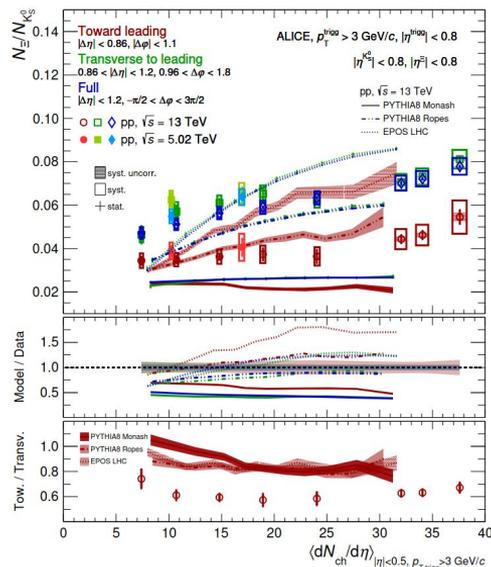
- **Yield of K_s^0** is strongly enhanced in HM pp events compared to low-multiplicity
- Enhancement most visible in the **transverse region** → isolates **underlying event** contributions (not jets)
- Strongest enhancement at **intermediate $p_T \sim 2-4$ GeV/c** → similar to heavy-ion collision trends
- Ratios relative to minimum-bias collisions (0-100%) show a clear **strangeness enhancement** with multiplicity
- **Transverse region:** largest enhancement → strong link between **strangeness production & underlying event**
- **Toward-leading region:** smaller enhancement → jet fragmentation plays a minor role

- ❖ **Multiplicity dependence:**
 - **Full and Transverse-to-leading**, yields increase strongly with event multiplicity.
 - **Toward-leading**, yield remains nearly flat with multiplicity → strangeness from jets does not scale with event activity.
- ❖ **Comparison between energies (13 vs 5.02 TeV):**
 - At the same multiplicity, the yields are similar between 13 TeV and 5.02 TeV.
 - This suggests that **strangeness production depends mainly on multiplicity, not collision energy.**
- ❖ **Ratio (Model/Data):**
 - Toward leading regions are close to 1 → models reproduce jet-related strangeness well.
 - Full and transverse regions deviate → standard PYTHIA fails, but Ropes and EPOS improve

Multiplicity Dependence of Strange Hadron Yields (Ξ , K_s^0)



- **Toward-leading:** Jet region → flat with multiplicity
- **Transverse-to-leading:** Underlying event → strong rise with multiplicity
- **Full:** Combination of both → strong rise with multiplicity
- Multiplicity dependence stronger than K_s^0 (multi-strange baryon effect)
- **Energy independence:** Similar behavior at 13 TeV and 5.02 TeV
- **PYTHIA8 Monash:** Underestimates yields
- **PYTHIA8 Ropes, EPOS-LHC:** Better agreement, include collective effects
- Strangeness enhancement is **driven by the underlying event**, not jets
- Collective/QGP-like dynamics may appear even in **small systems** (pp collisions)



- ❖ Ξ/K_s^0 ratio increases with charged-particle multiplicity
- ❖ **Toward region** shows **lower ratios**, suppressed by jet fragmentation effects
- ❖ **Transverse and full regions** show **higher ratios**, more sensitive to bulk/underlying event
- ❖ Models (PYTHIA8, EPOS) **overpredict absolute values**, but capture qualitative trend

Summary

- Short-range jet-like correlation and long-range ridge-like correlation in small systems
- Suppression of away-side yields as a function of multiplicity in Pb-Pb system
- No significant jet modification in small systems
- Strangeness enhancement in small systems

Acknowledgement

Dr. Sidharth Kumar Prasad

Thank you for your attention!