Exploring strangeness enhancement feature in proton-proton collisions at the LHC with event shape classifiers

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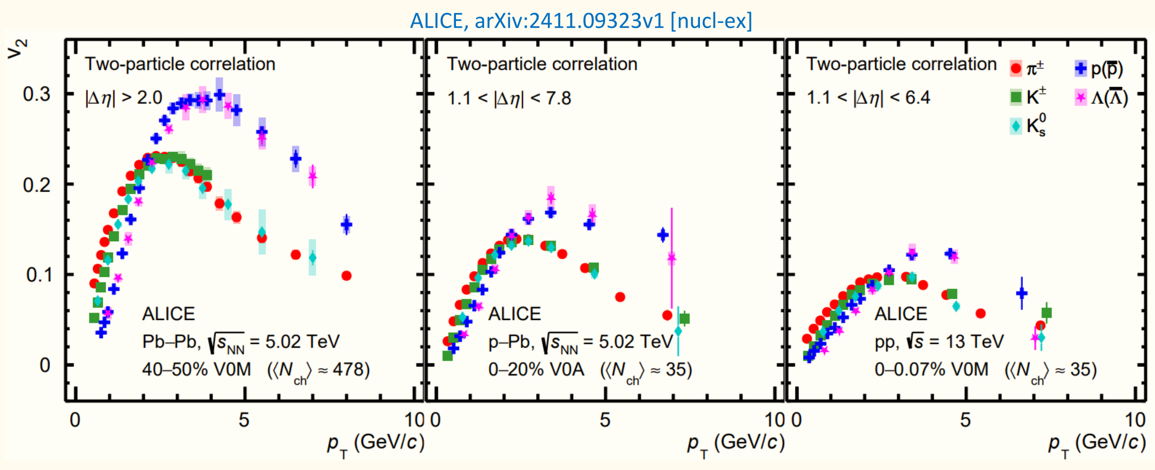
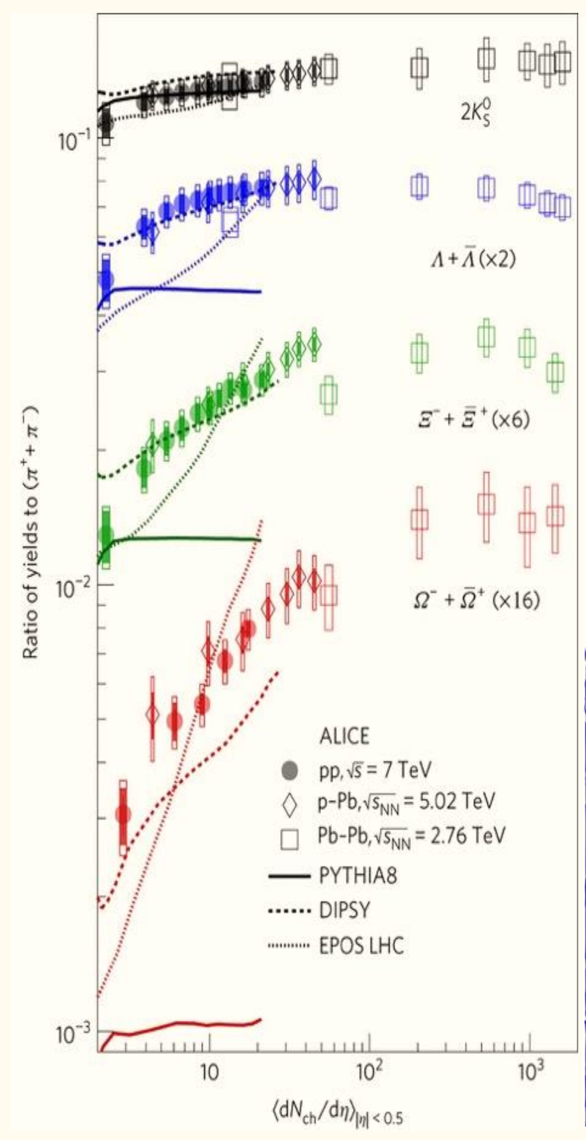
Motivation and goals

- ✓ Measurements at the LHC have revealed that **small collision systems** exhibit **collective-like behavior**, as seen in heavy-ion collisions
- ✓ The origin of the QGP-like behavior in small systems is still unclear. One of the explanations is multiple parton interactions (MPI) based picture
- ✓ Event selections based only on multiplicity have shown significant bias towards hard pp collisions
- ✓ Event shape observables have shown a significant correlation with MPI
  - ➢ **Relative transverse activity classifier (R_T)**
  - ➢ **Transverse spherocity (S_0)**
  - ➢ **Charged-particle flattenicity (ρ_{ch})**

These global observables can distinguish soft and hard collisions from average ones

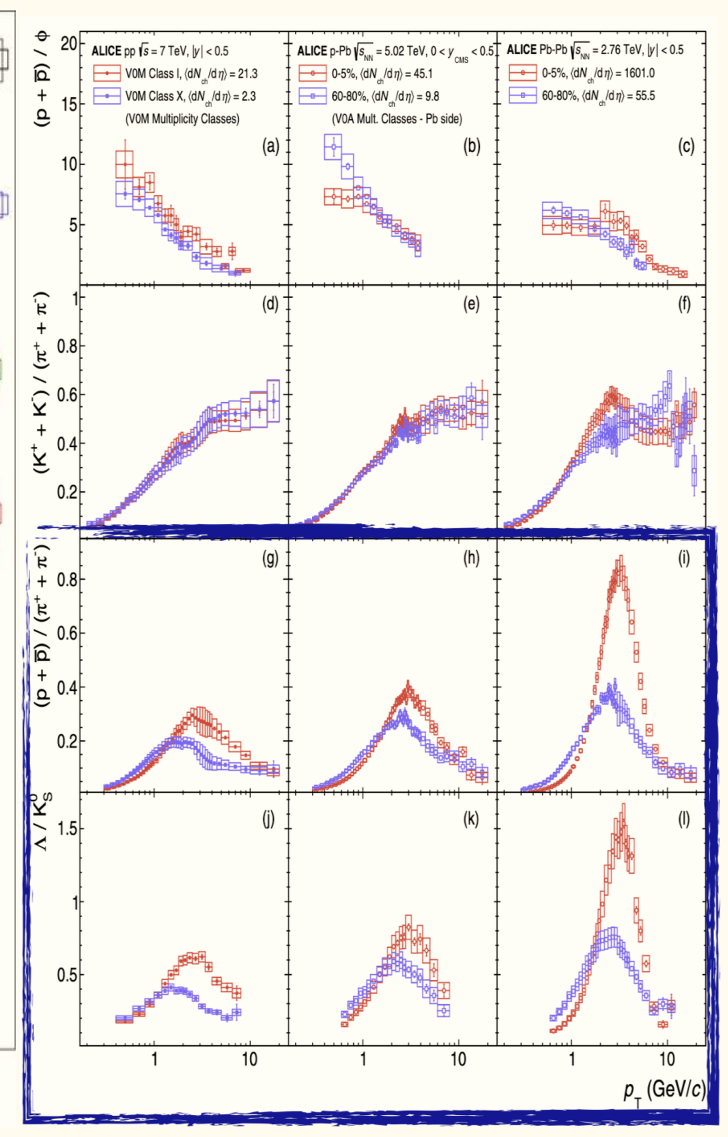


Partonic collectivity in pp and p-pb : Mass ordering in low p_T, and baryon-meson separation at intermediate p_T



Strangeness enhancement in high multiplicity pp collisions are similar to Pb-Pb collisions

ALICE, Nature Physics 13, 535 (2017)



Similar features of **baryon-to-meson ratios** in pp, p-Pb and Pb-Pb collisions

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

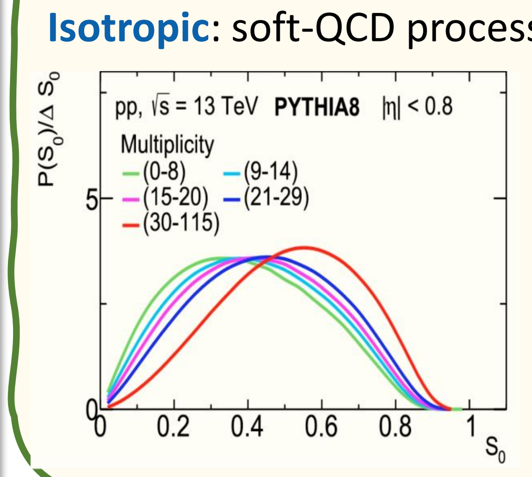
Transverse spherocity (S_0)

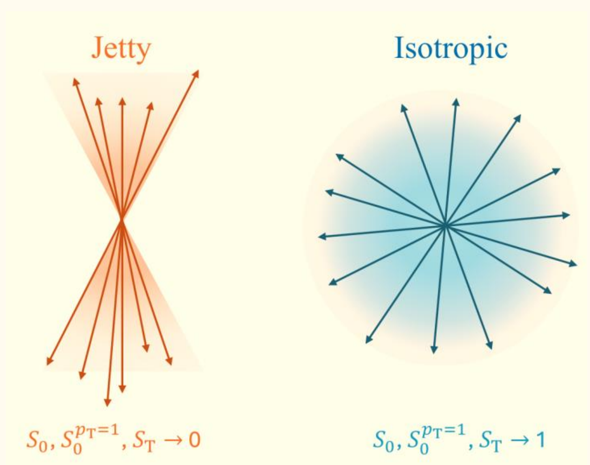
Transverse Spherocity distinguishes hard and soft processes

$$S_0 = \frac{\pi^2}{4} \min_{\hat{n}=(n_x,n_y,0)} \left(\frac{\sum_i |\vec{p}_{T i} \times \hat{n}|}{\sum_i p_{T i}} \right)^2$$

Jetty: Back-to-back structure, hard-QCD

Isotropic: soft-QCD process

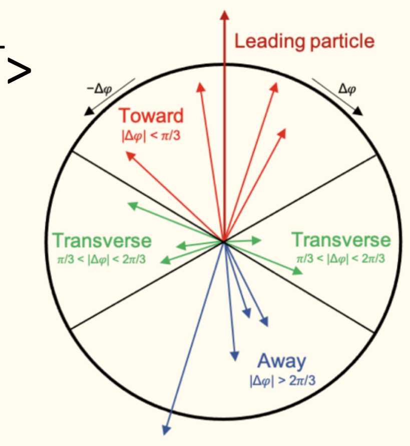




Relative transverse activity classifier (R_T)

- ✓ $R_T \to 0$: Events with less UE (dominated by jets)
- ✓ **Higher R_T** → Higher UE contribution
- ✓ To reduce the contribution from ISR and FSR, Transverse region is further sub-divided

$$R_T = N_{ch}^T / \langle N_{ch}^T \rangle$$



Charged-particle Flattenicity (ρ_{ch})

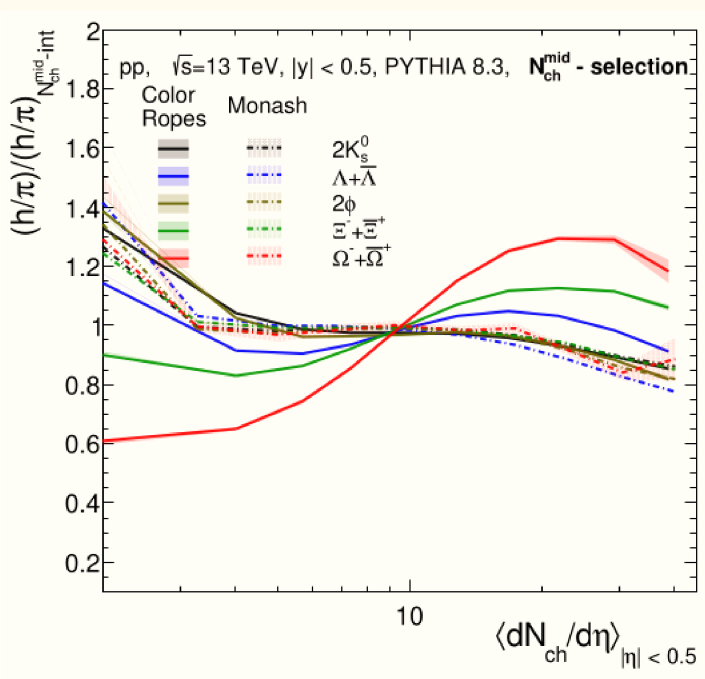
Motivation: Search for observable highly sensitive to SOFT particle production (MPI) and CR effects without introducing a bias toward HARD production

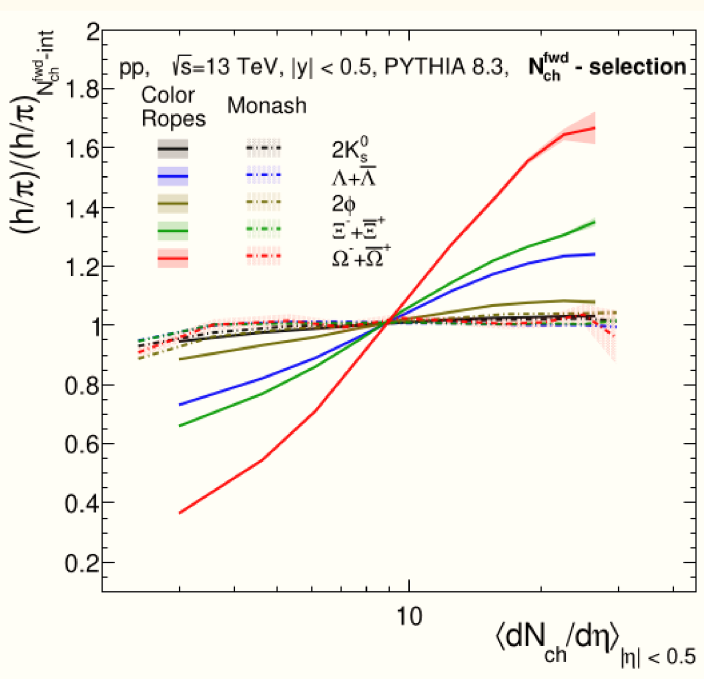
$$\rho_{nch} = \frac{\sqrt{\sum_i (N_{ch}^{cell,i} - \langle N_{ch}^{cell} \rangle)^2 / N_{cell}^2}}{\langle N_{ch}^{cell} \rangle}$$

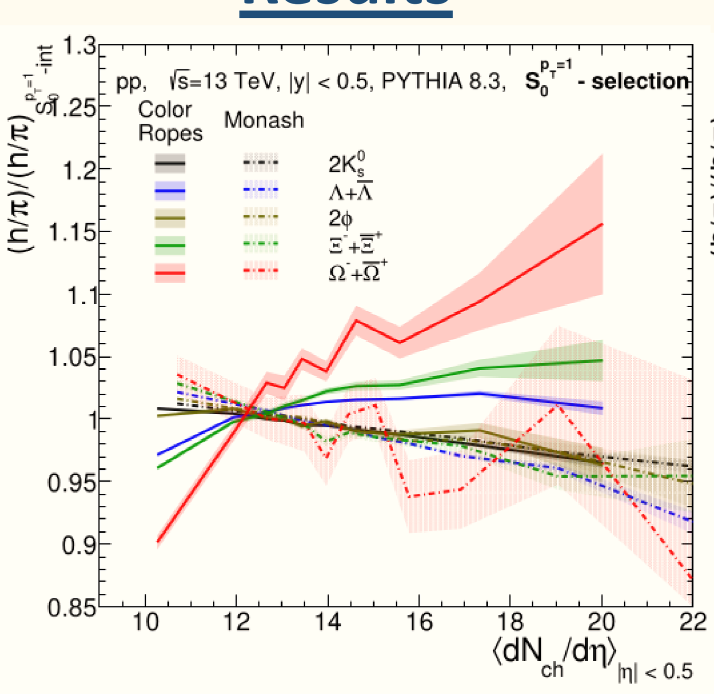
N_{ch}^{cell} = charged-particle multiplicity per cell

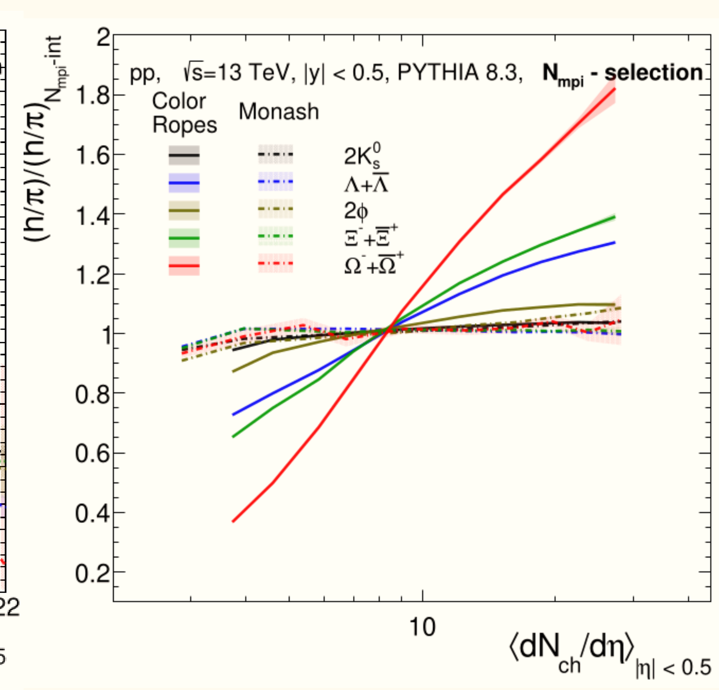
A. Ortiz, Phys. Rev. D 107, 076012 (2023)

Results

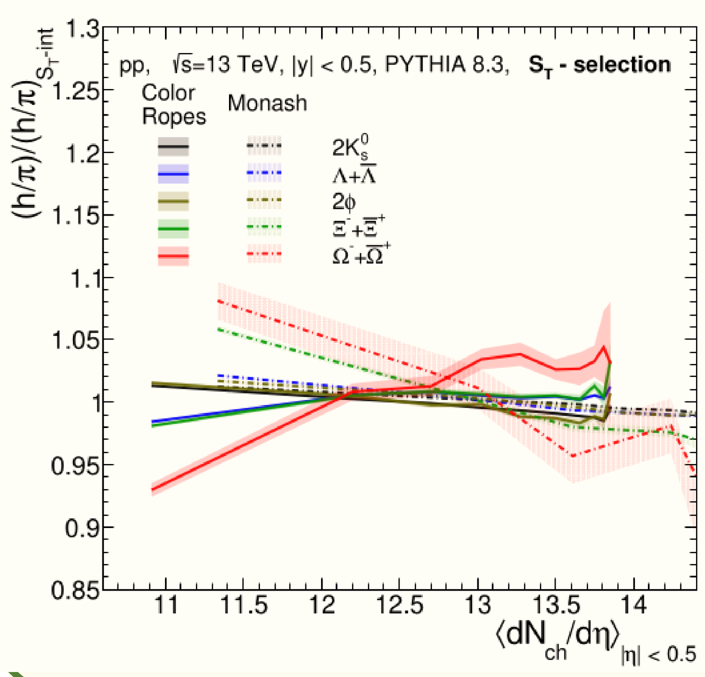


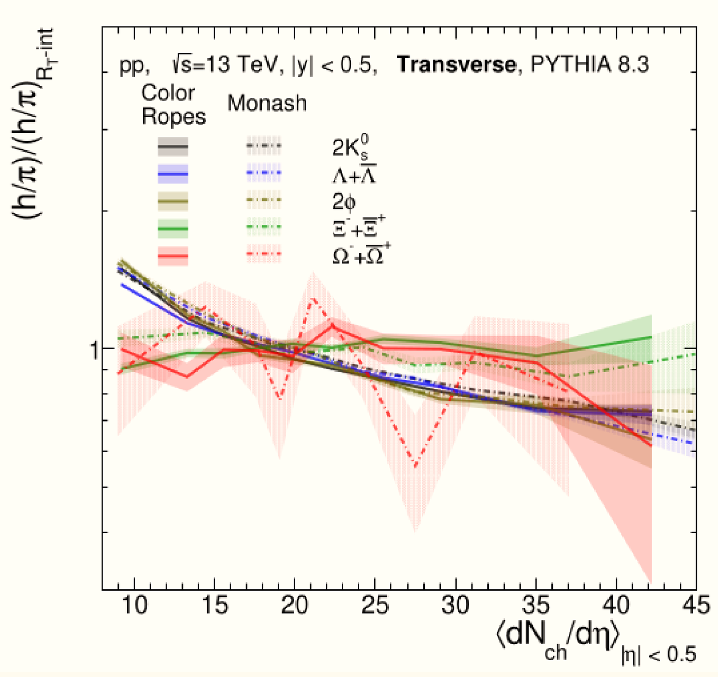


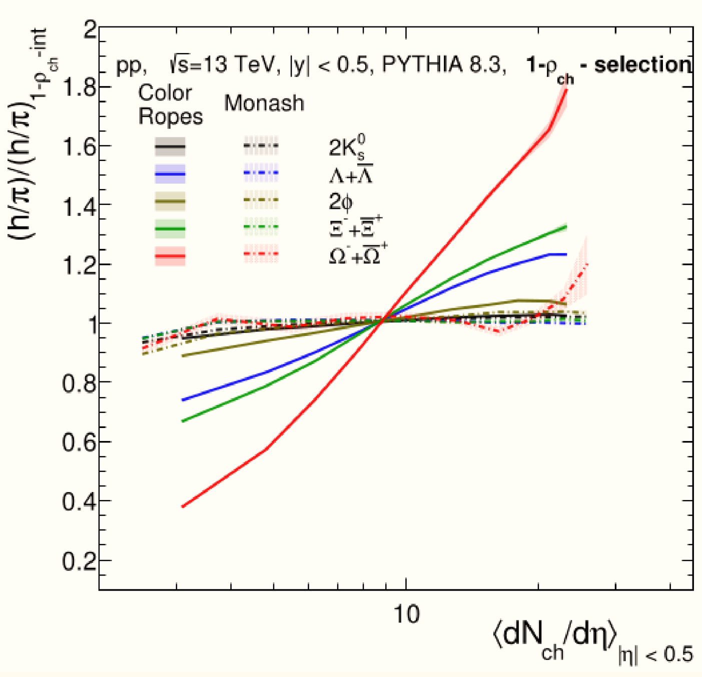




- ✓ A distinction in the self-normalised yield ratios to pions for the strange baryons having different numbers of valence strange quarks
- ✓ the increment of self-normalised yield ratios with $\langle dN_{ch}/d\eta \rangle$ for all event shapes is higher for Ω having three valence strange quarks as compared to Λ, having only one valence strange quark







- ✓ A close resemblance between the self normalised yield ratios to pions for the hidden strange meson, ϕ and K_S^0 possessing one valence strange quark
- ✓ The self-normalised yield ratios of ϕ and K_S^0 mesons to pions are observed to decrease with an increase in $\langle dN_{ch}/d\eta \rangle$ for the event shapes measured in the midrapidity which includes N_{ch}^{mid}, S_T, $S_0^{p_T=1}$, and R_T → Auto-correlation bias
- ✓ The self-normalised yield ratios to pions for the strange hadrons are all distinct for events selected with N_{ch}^{fwd} and $1-\rho_{ch}$, representing their sensitivity to probe the strangeness production

Summary

- ✓ Strangeness production as a function of $1-\rho_{ch}$ very closely mimics the event selection with N_{mpi} → Flattenicity is one of the best classifiers to study strangeness production at the LHC
- ✓ With larger statistics, one can perform multi-differential studies based on event-shape classifiers to study the final-state observables. Some of the event classifiers have similar coverage. Thus, one should be careful to use them for a specific study.
- ✓ See: **arXiv:2506.03782** for a review of event shape classifiers at the LHC