Event activity dependence of charm baryon production at LHC energies

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Production of heavy-flavor baryons

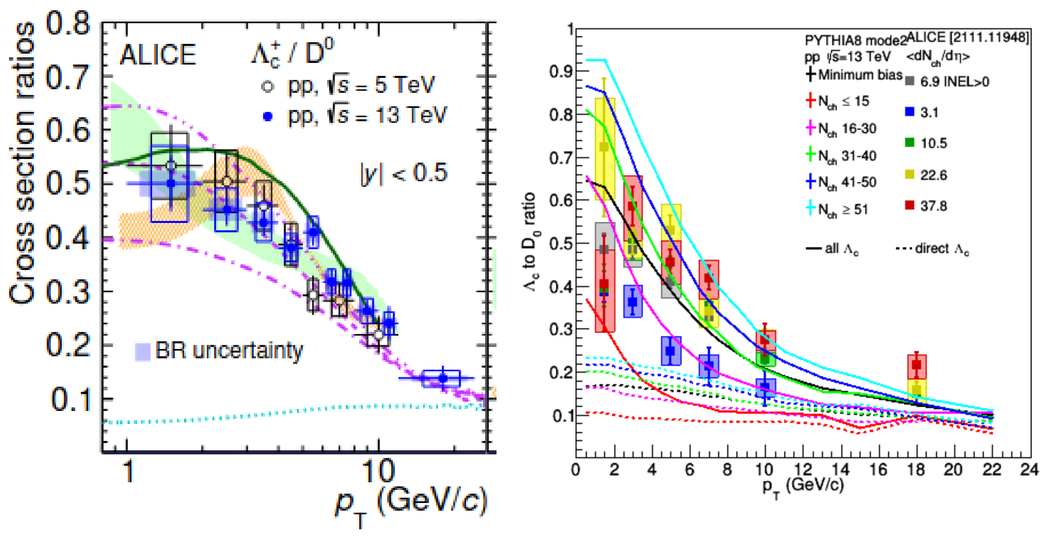
- Heavy-flavor production is usually described with the factorization approach, where **incoming hadron PDFs**, **hard parton-parton scattering** and **fragmentation** are independent:

$$d\sigma^{hard}_{AB\to C} = \sum_{a,b} f_{a/A}(x_a, Q^2) \otimes f_{b/B}(x_b, Q^2) \otimes d\sigma^{hard}_{ab\to c}(x_a, x_b, Q^2) \otimes D_{c\to C}(z, Q^2)$$

Parton Distribution Function (PDF) | Partonic hard scattering cross-section | Fragmentation Function (FF)

- Traditional assumption: fragmentation functions are **universal** for different collision systems.
  - **FF** often determined from e+e- (or e-p) collisions, where **PDF** plays no (or less important) role.
- Recent experimental results (ALICE, CMS, LHCb) on charmed-baryon production **do not support** this assumption! [1]

Event activity dependence of Λ_c/D^0 enhancement



- Significant enhancement in the Λ_C/D^0 ratio in the low p_T (2-8 GeV/c) range compared to e^+e^- predictions [1]: **no universality!**
- **PYTHIA Color-reconnection beyond leading color** (CR-BLC)[2,3] describes the multiplicity dependence.
- **Multiplicity dependence**: connected to the event activity. Needs to be better understood!
- p_T dependence may be sensitive to baryon type: trend differs for Σ_C although it only **differs** from Λ_C **in isospin**.

Classifying event based on jettyness and underlying event activity

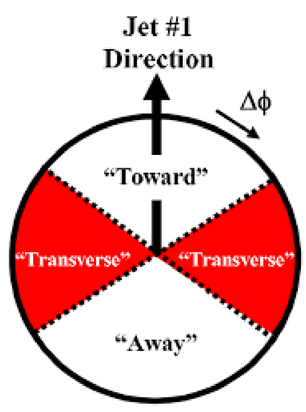
- Events with $p_T > 5$ GeV/c trigger hadron:

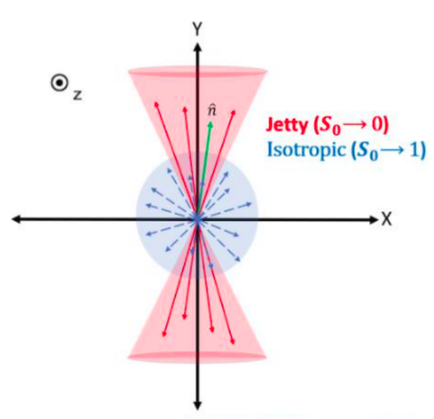
  - **R_T**: underlying event (UE) activity classifier $R_T = \frac{N_{CH}^{transverse}}{\langle N_{CH}^{transverse} \rangle}$ $\frac{\pi}{3} < |\Delta\phi| < \frac{2\pi}{3}$

  - **R_{NC}**: jet region activity classifier $R_{NC} = \frac{N_{CH}^{near-side\ cone}}{\langle N_{CH}^{near-side\ cone} \rangle}$ $\sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} < 0.5$

- **S_0**: spherocity (how isotropic the event is) $S_0 = \frac{\pi^2}{4} \times \min_{\hat{n}=(n_x,n_y,0)} \left(\frac{\Sigma_i |\vec{p}_{T_i} \times \hat{n}|}{\Sigma_i \vec{p}_{T_i}} \right)^2$

- **ρ**: flatenicity $\rho = \sigma_{p_T}^{cell} / \langle p_T^{cell} \rangle$





Charmed-baryon enhancement classified by spherocity and flatenicity

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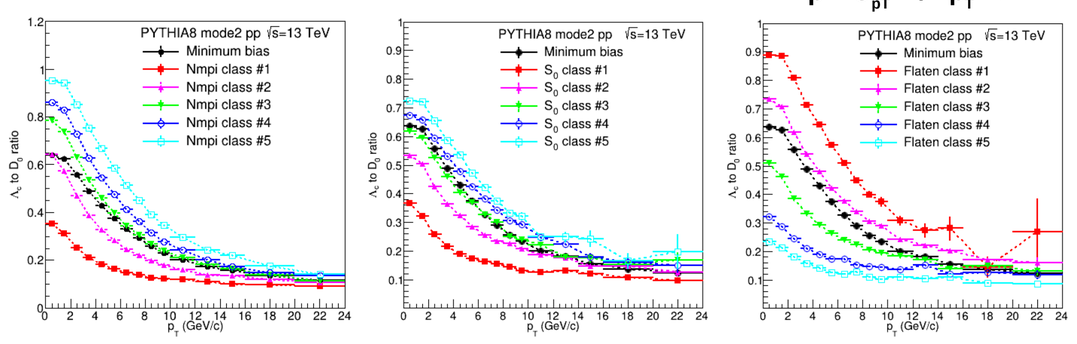
Λ_c(qqc), I = 0

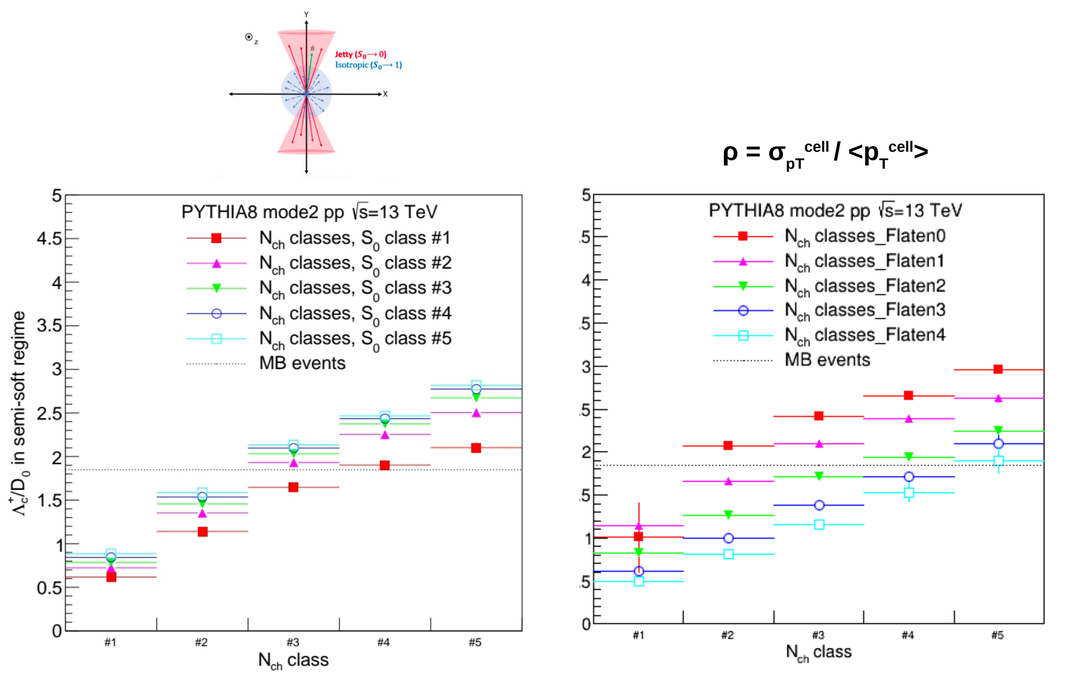
$S_0 = \frac{\pi^2}{4} \times \min_{\hat{n}=(n_x,n_y,0)} \left(\frac{\Sigma_i |\vec{p}_{T_i} \times \hat{n}|}{\Sigma_i \vec{p}_{T_i}} \right)^2$

Flatenicity: A. Ortiz, G. Paic, arXiv:2204.13733

$\rho = \sigma_{p_T}^{cell} / \langle p_T^{cell} \rangle$



- The Λ_C/D^0 enhancement depends on the MPI in the lower p_T region.
- Spherocity allows decribing the enhancement in events without a leading trigger hadron.
- **Flatenicity pulls apart the distributions much more than spherocity.**



- **Spherocity S_0** in **minimum-bias events**:
  - Λ_C/D^0 enhancement is more prominent in spherical (UE-dominated) than jetty events
- **Flatenicity ρ** in **minimum-bias events**:
  - Λ_C/D^0 enhancement decreases with flatenicity, and **contrary to spherocity** the enhancement is sensitive to it in every N_{ch} classes

- **CR-BLC model links the enhancement to the UE:**
  - discrimination power in data from the upcoming LHC Run3.
- **Flatenicity could be a better quantity to describe the MPI and the enhancement!**

Summary

- Λ_C/D^0 ratios: **universality** of fragmentation functions is **broken**. Does the factorization approach work?
- **Discrimination power** of differential measurements that focus on event activity in the jet and/or the underlying event region.
- **Flatenicity** is sensitive to the ΛC/D0 enhancement regardless of the multiplicity class, therefore can be a better descriptor than spherocity.

[1] ALICE Coll., "Measurement of prompt D0, Lambda_c+, and Sigma_c{0,++}(2455) production in pp collisions at sqrt(s) = 13$ TeV", arXiv:2106.08278
[2] Christiansen, J.R., Skands, P.Z. "String formation beyond leading colour", J. High Energ. Phys. 2015, 3 (2015)
[3] T. Sjöstrand et al., "An introduction to PYTHIA 8.2", Comput. Phys. Commun. 191 (2015) 159-177, arXiv:1410.3012