The role of the underlying event in the charm-baryon enhancement observed in pp collisions at LHC energies

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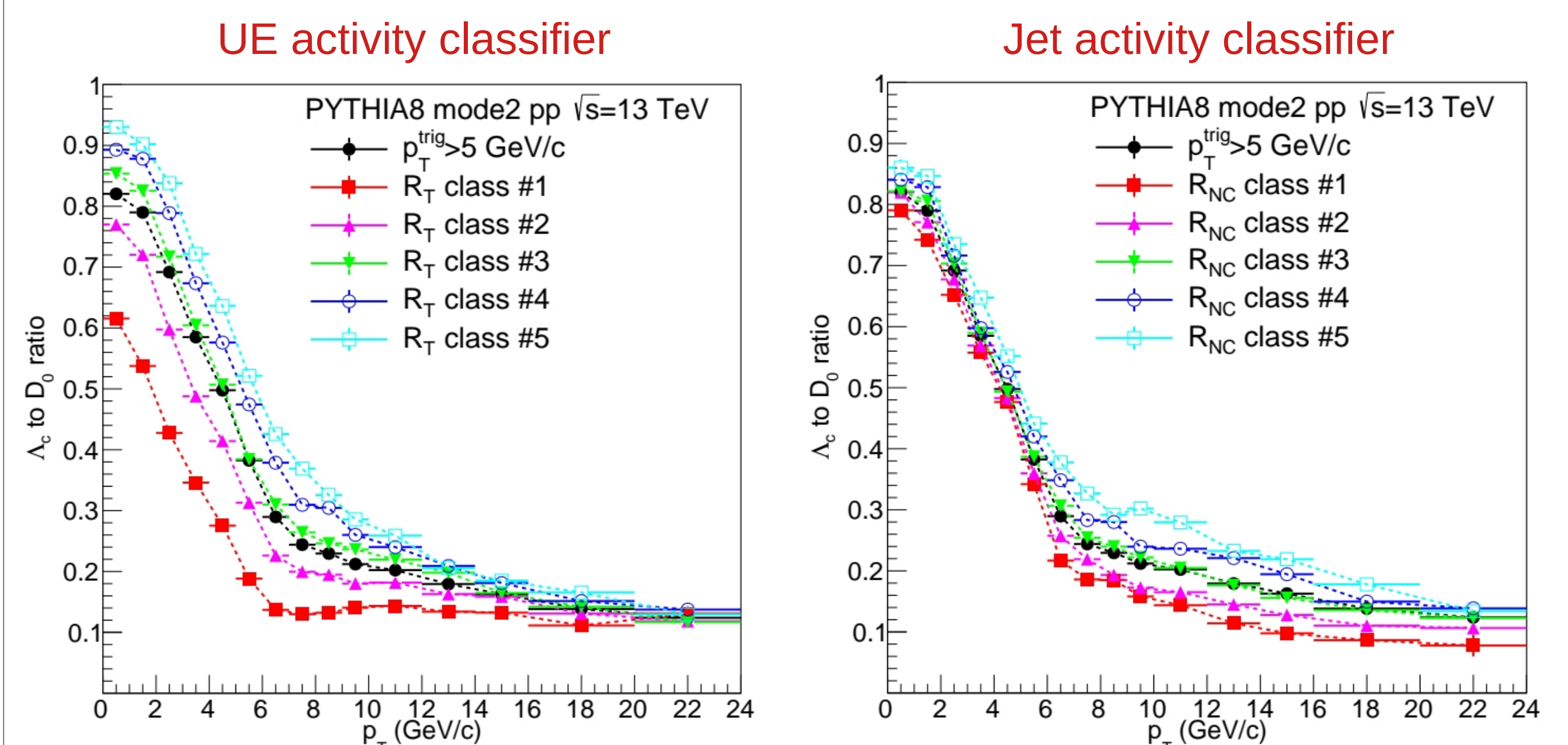
Production of heavy-flavor baryons

- 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
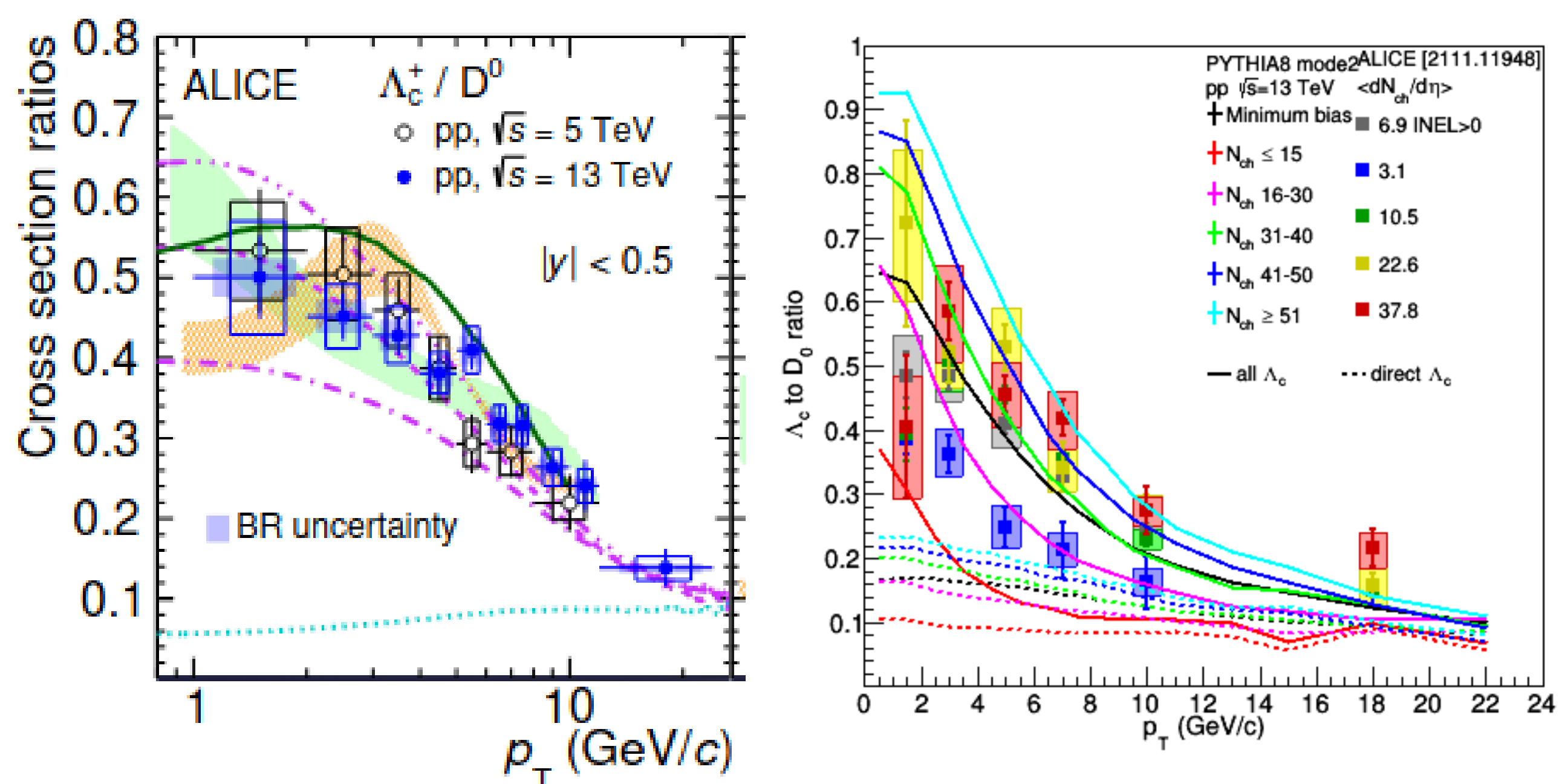
- Significant enhancement in the Λ_C/D^0 ratio in the low p_T (2-8 GeV/c) range compared to e^+e^- predictions [1]: **no universality!**
- **PYTHIA Color-reconnection beyond leading color** (CR-BLC)[2,3] describes the multiplicity dependence.
- **Multiplicity dependence**: connected to the event activity. 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**.
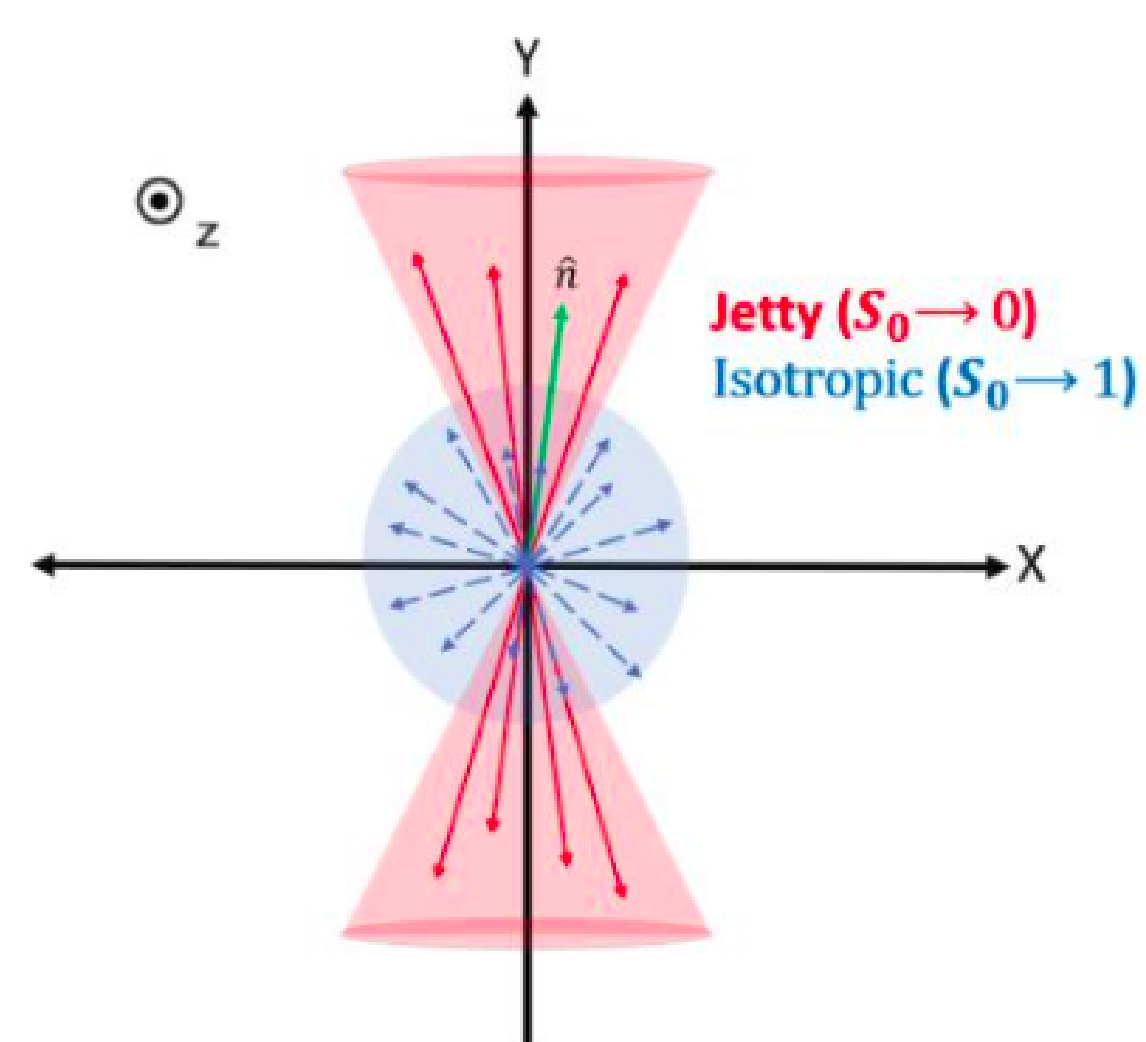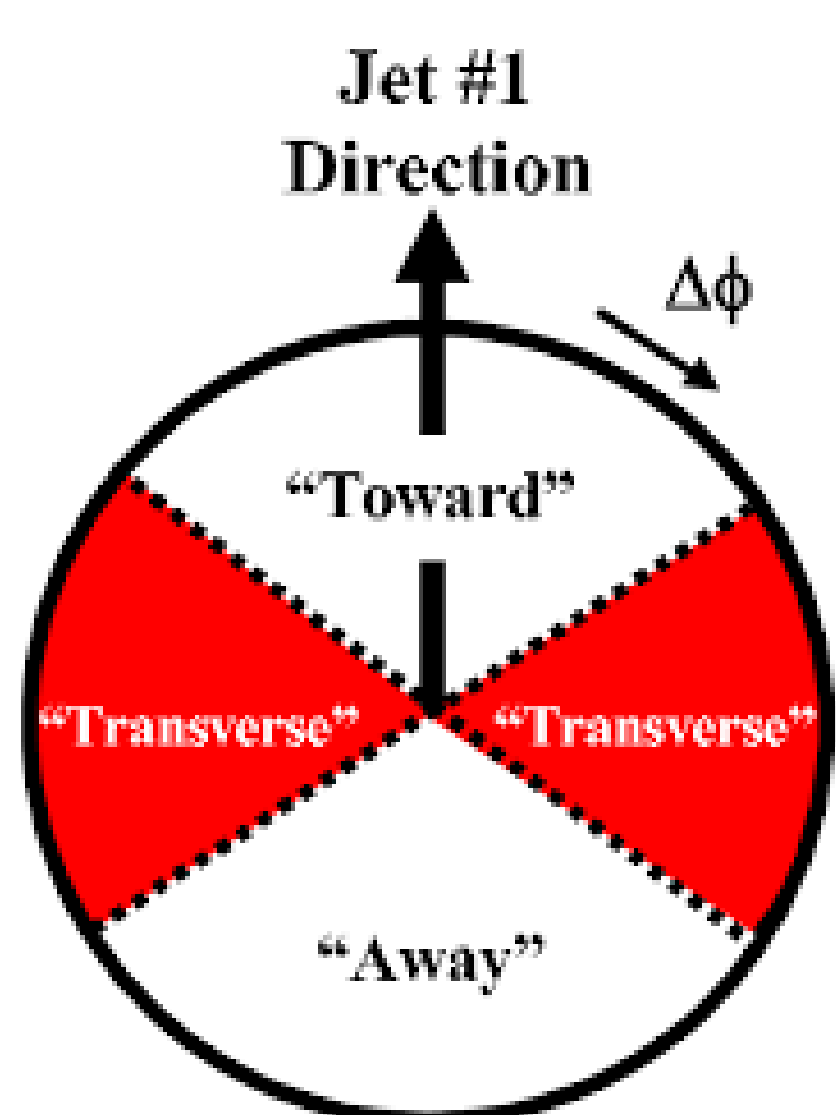
Classifying event based on jettyness and underlying event activity

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

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

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

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

Charmed-baryon enhancement in jetty and isotropic events

UE activity classifier | Jet activity classifier

- We studied the Λ_C/D^0 ratio with several different event classifiers.

  Z.V., R.V., J. Phys. G: Nucl. Part. Phys. 49 (2022) 075005 (arXiv:2111.00060)

- **Significant difference** is observable **in case of R_T** (UE classification).

- **No significant difference** when classified **by R_{NC} classes** (jet activity).
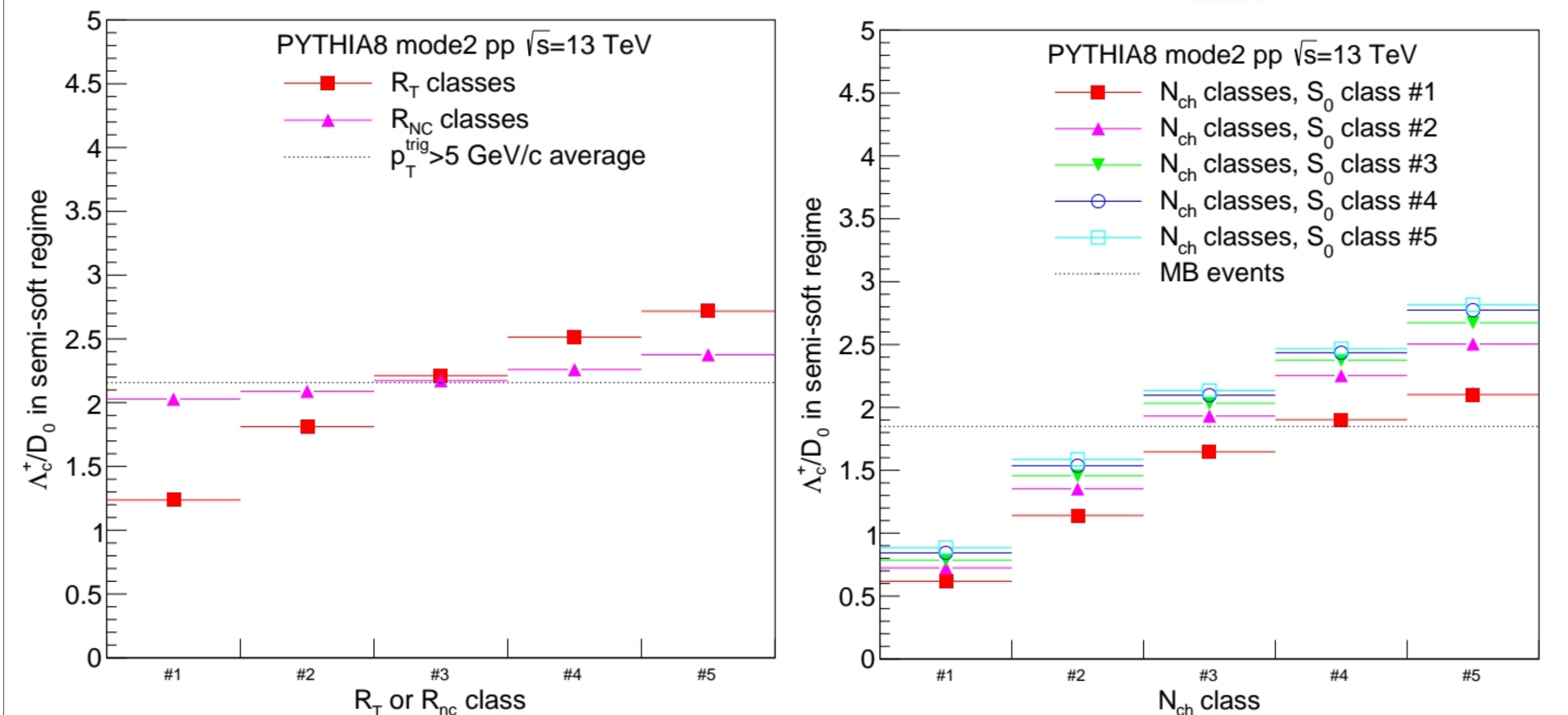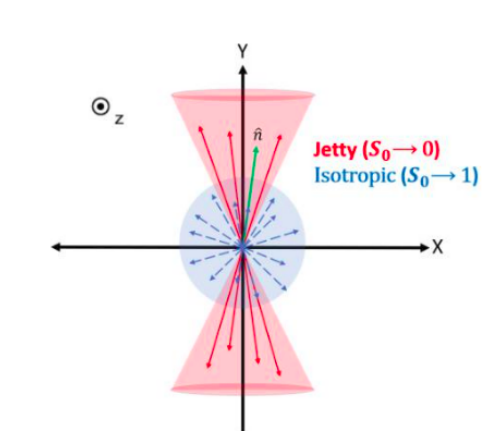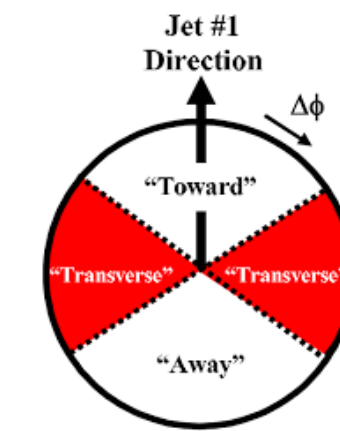
- R_T vs. R_{NC} in **triggered events** (hadron with $p_T > 5$ GeV/c)

- Λ_C/D^0 enhancement depends on UE activity, almost independent on activity within jet

- Spherocity in **min-bias events**

- Λ_C/D^0 enhancement is more prominent in spherical (UE-dominated) than jetty events

- **CR-BLC model links the enhancement to the UE:** Discrimination power in data from the upcoming LHC Run3!

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.

- Measurements with different heavy-flavor baryons: more **constraints on models**. Explore the connection to strange-baryon enhancement.

[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