Event-activity-dependent beauty-baryon enhancement in simulations with color junctions

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1. Heavy-flavor production

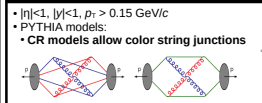
- Total cross section of the process calculated by the factorization theorem:

$$\sigma_{h_1+h_2} = f_{i/h_1}(x_1,Q^2) \otimes f_{j/h_2}(x_2,Q^2) \otimes \sigma_{i+j\to k\bar{k}} \otimes D_{h=k\bar{k}}(z_h,Q^2)$$

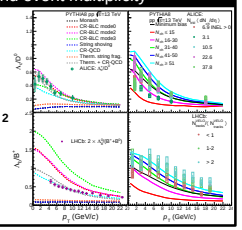
- **Parton distribution functions (PDFs)**
- **Partonic hard scattering cross section**
- **Fragmentation function**
  - The fragmentation function is traditionally assumed to be universal among different collisional systems
  - It is often computed from e^+e^- collisions
  - However the Λ_b^0/B^+ and Λ_c^+/D^0 yield ratios:
    - Do **not** show enhancement in e^+e^- collisions
    - Show a multiplicity dependent **enhancement in mid-p_T regime** in pp collisions [1, 2]
  - **Possible explanation:** Color Reconnection Beyond Leading Color (CR-BLC) [3]

2. PYTHIA models and event multiplicity

- $|\eta|<1$, $|y|<1$, $p_T > 0.15$ GeV/c
- PYTHIA models:
  - **CR models allow color string junctions**



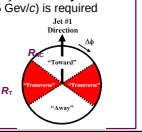
  - Charm: best described by **CR-BLC mode 2**
  - Beauty: best described by **CR-QCD**
- Detailed event-activity-dependent studies reveal information about the source of the enhancement [4]
- Event multiplicity: N_{ch}
  - Number of final state charged hadrons
  - N_{ch} dependent enhancement



3. Event classifiers

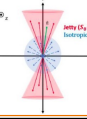
- **Transverse event activity: R_T**
  - Represents the **underlying event** (UE)
- **Near-side jet-cone activity: R_{NC}**
  - Represents the activity within the **jet**
- Trigger hadron ($p_T > 5$ GeV/c) is required

$$R_T = \frac{N_{trans}}{\langle N_{trans}\rangle} \qquad R_{NC} = \frac{N_{cone}}{\langle N_{cone}\rangle}$$



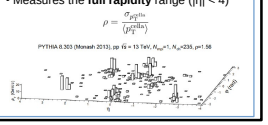
- **Transverse spherocity: S_0**
  - Measures if the event is jetty or isotropic
  - Trigger hadron is **not** required
  - Concentrates on the **midrapidity**

$$S_0 = \frac{\pi^2}{4}\left(\frac{\sum_i |\vec{p}_{T_i} \times \vec{n}|}{\sum_i |\vec{p}_{T_i}|}\right)^2$$



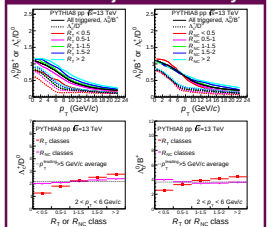
- **Flattenicity: ρ**
  - Measures if the event is "hedgehog-like" or jetty
  - Trigger hadron is **not** required
  - Measures the **full rapidity** range ($|\eta| < 4$)

$$\rho = \frac{\sigma_{p_T^{\mathrm{leading}}}}{\langle p_T^{\mathrm{leading}}\rangle}$$



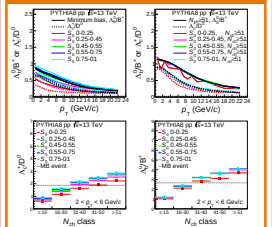
4. Results

Transverse event activity and Near-side jet-cone activity



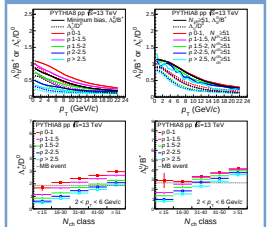
- The enhancement is stronger when the R_T is higher, but it does not depend on the R_{NC}.

Transverse spherocity



The enhancement is stronger when the transverse spherocity is higher.

Flattenicity



The enhancement is stronger when the flattenicity is lower.

Summary

- The universality of the fragmentation function is violated
- Beauty is best described by CR-QCD, charm is best described by CR-BLC mode 2
- CR models: heavy flavor (HF) baryon enhancement comes from the **underlying event**, not the jet
- Flattenicity is strongly related to multiparton interactions and free from biases caused by mid-rapidity jet production
- Using these methods on Run-3 data can reveal further information on the source of the HF-baryon enhancement and help test the validity of different models

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[2] Eötvös Lorand University
[3] Budapest University of Technology and Economics

[1] ALICE Coll., "Measurement of prompt D0, Lambda_c+, and Sigma_c(0,++)(2455) production in pp collisions at sqrt(s) = 13$ TeV", Phys.Rev.Lett. 128 (2022) 1, 012001
[2] LHCb Coll., "Enhanced Production of \ensuremath{\Lambda}b0 Baryons in High-Multiplicity pp Collisions at s=13\,\TeV", Phys. Rev. Lett. 132, 081901 (2024)
[3] Christiansen, J.R., Skands, P.Z. "String formation beyond leading colour", J. High Energ. Phys. 2015, 3 (2015)
[4] Varga, z., Vértesi, R., "The role of the underlying event in the enhancement in high-energy pp collisions", J. Phys. G. 49, 075005 (2022)

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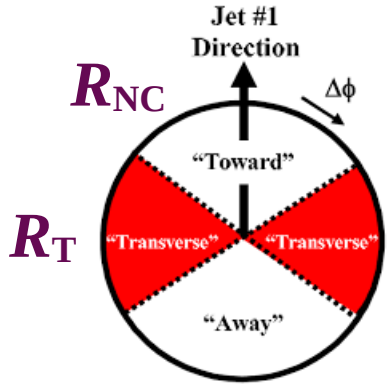

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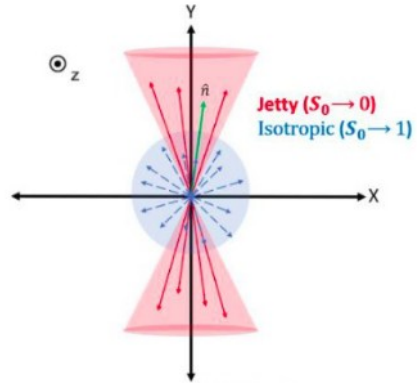

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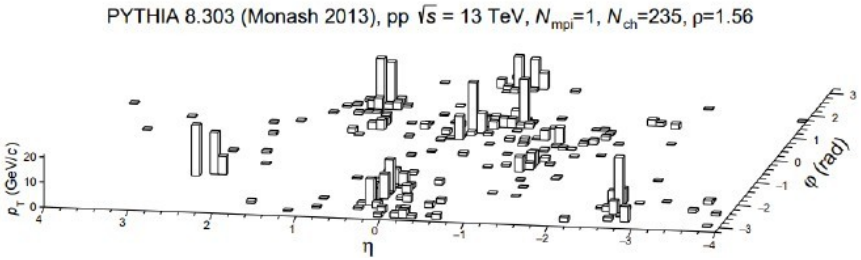
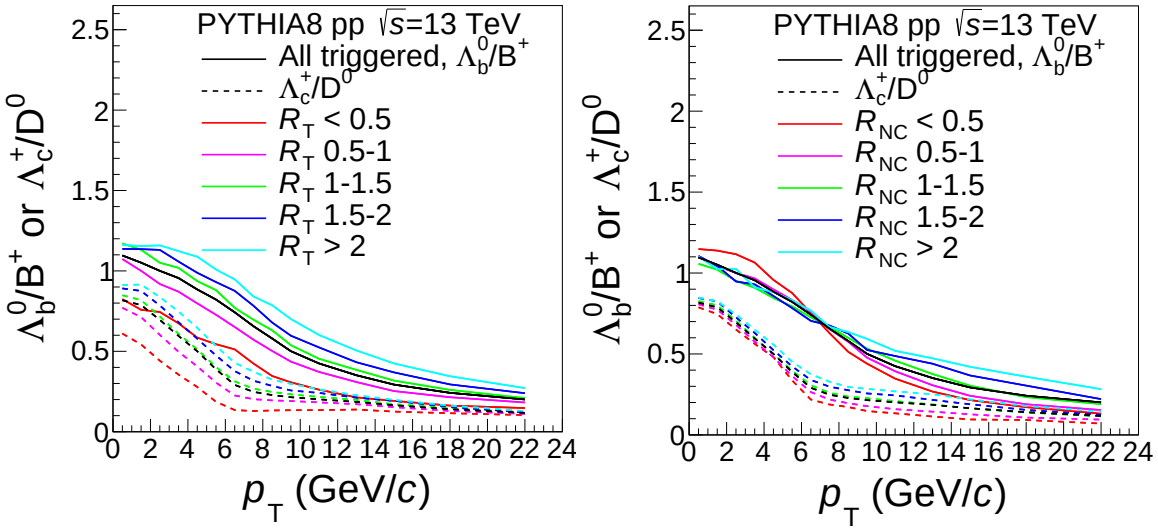


Results

R_T and R_{NC}:

- Activity of the jet ↑
  - Enhancement does not change
- Activity of the UE ↑
  - Enhancement ↑



Flattenicity:

- Isotropy ↑
  - Enhancement ↑

➔ **Heavy flavor baryon enhancement comes from the UE**