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

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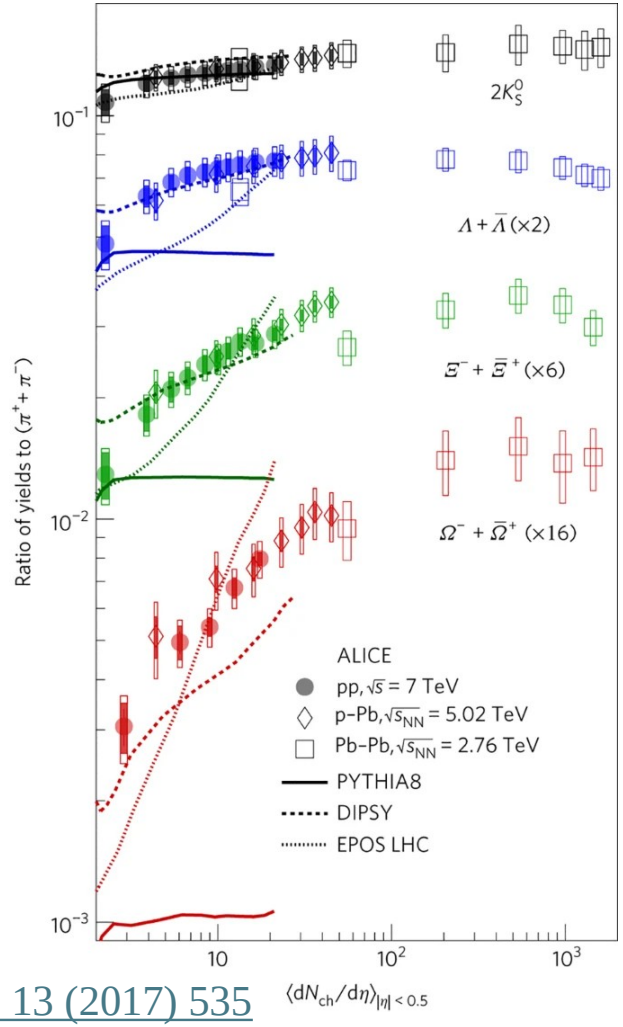
Signatures of QGP

- Collective flow
  - Large systems: hydrodynamic evolution of the QGP
  - Small systems: also observed at LHC
- Strangeness enhancement
  - Governed by event multiplicity
  - pp trend continued in p-Pb and Pb-Pb
- Is there QGP in small collisional systems?
  - No definitive answer yet
  - Vacuum-QCD effects are at play: MPI, CR, minijets



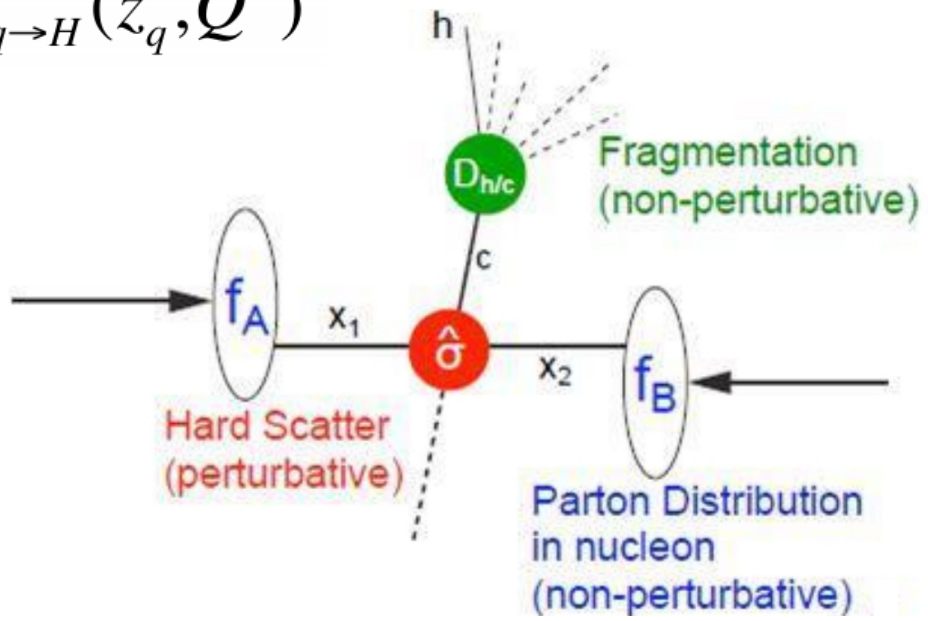
Nature Phys. 13 (2017) 535

Heavy-flavor production

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

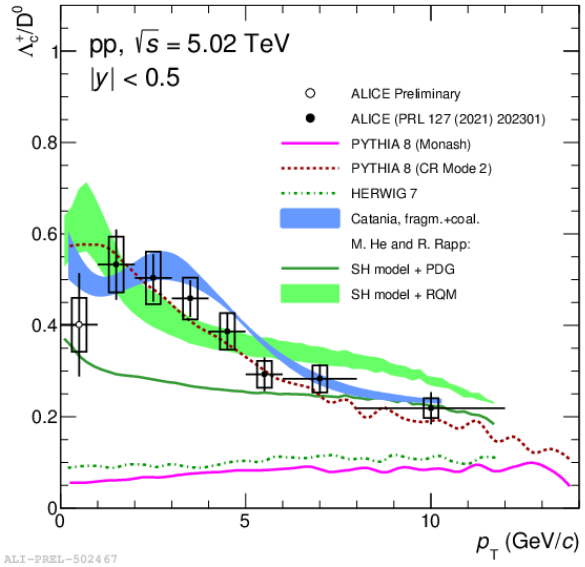
$$\sigma_{hh\to H} = f_a(x_1,Q^2) \otimes f_b(x_2,Q^2) \otimes \sigma_{ab\to q\bar{q}} \otimes D_{q\to H}(z_q,Q^2)$$

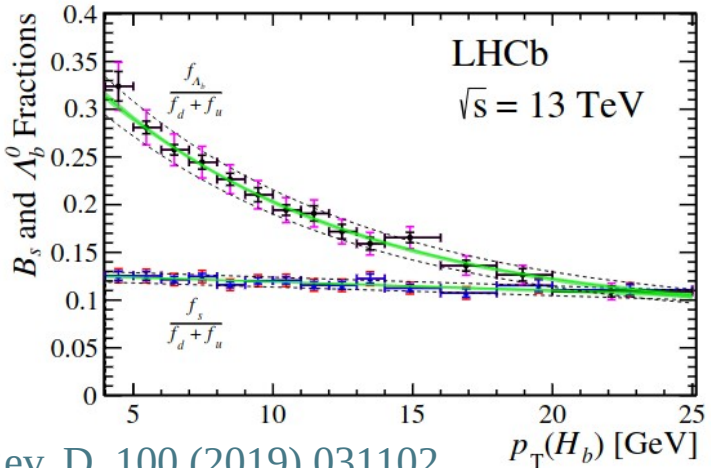
- Fragmentation function (D_{qH})
  - Traditionally assumed to be universal across different collisional systems
  - Assumption works for D-mesons



Heavy-flavor baryon enhancement

- FF from e^+e^- collision: underestimates HF baryon production in pp collisions
- **Fragmentation is not universal!**
- Beauty shows similar trends





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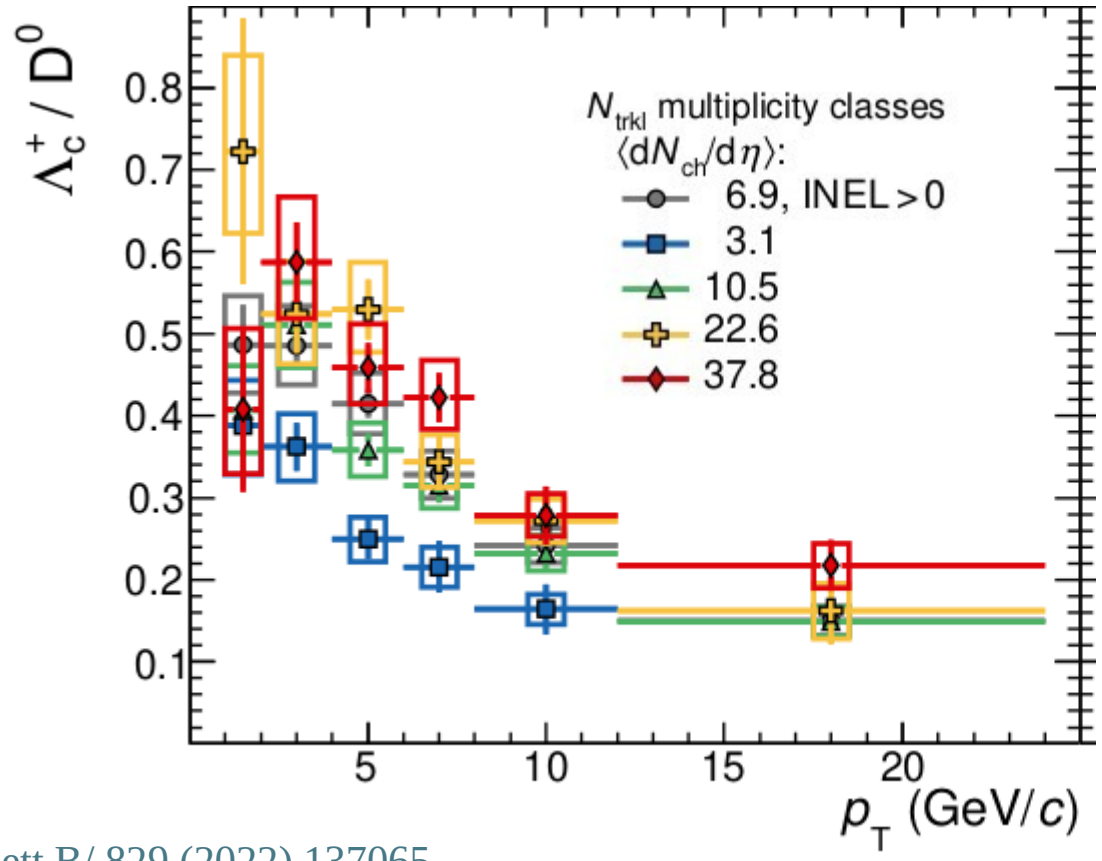
- Possible explanations:
  - Quark coalescence
  - Undiscovered excited charm-baryon states
  - **Color reconnection beyond leading color approximation**

Multiplicity-dependent ehancement

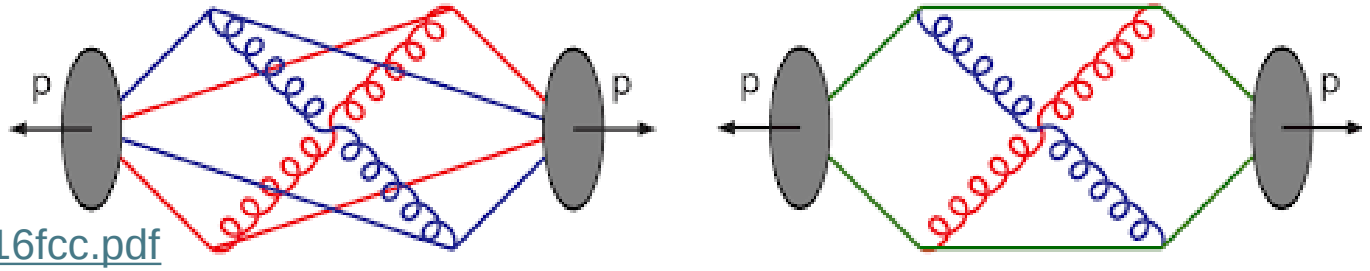
- The ALICE experiment found that the mid-p_T Λ_c^+/D_0 enhancement is multiplicity dependent



Phys.Lett.B/ 829 (2022) 137065

PYTHIA models

- Monash 2013
  - Fragmentation function based on e^+e^- collisions
- Color reconnection beyond leading color approximation
  - **Allows color string junctions**
  - Time dilation using the boost factor derived from the final-state dipole mass
  - Causal connections among all dipoles
  - CR-QCD: default PYTHIA settings for this model
  - CR-BLC mode 2: further tuned for bulk observables [JHEP 08 (2015) 003]

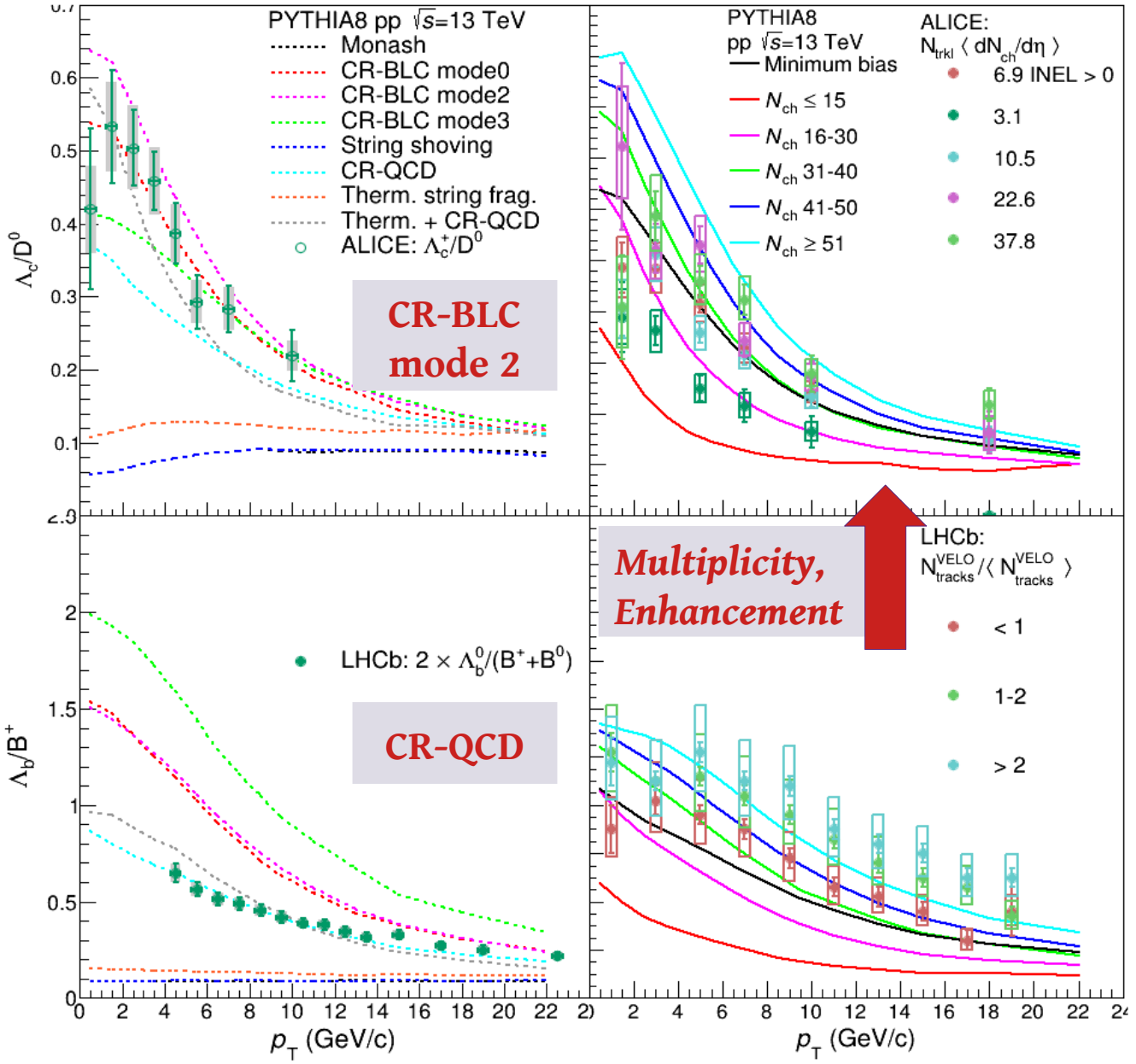


https://pythia.org/download/talks/SjostrandCern16fcc.pdf

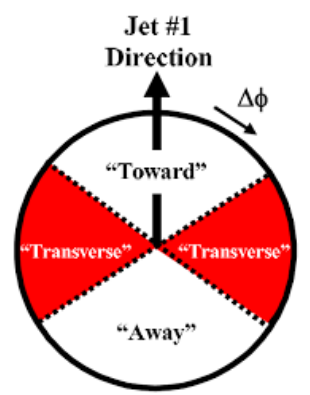
Event multiplicity

- N_{CH}
- $|\eta|<1$, $|y|<1$
- $p_T>0.15$ GeV/c

- N_{CH} dependent enhancement
- **Charm: best described by CR-BLC mode 2**
- **Beauty: best described by CR-QCD**



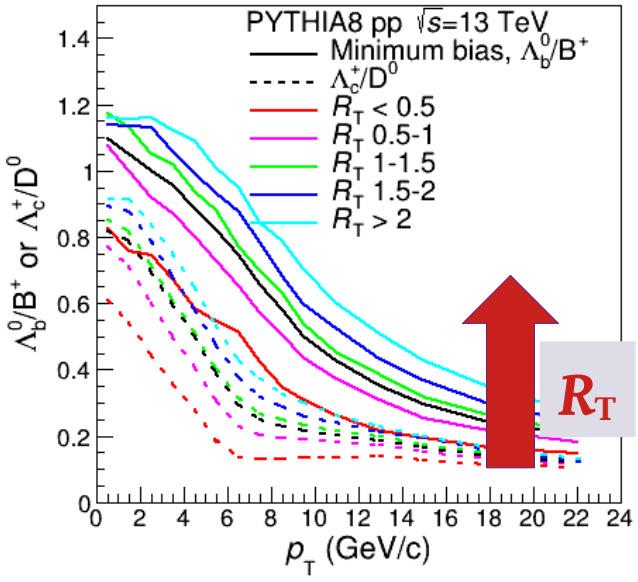
Transverse event activity and near-side jet-cone activity

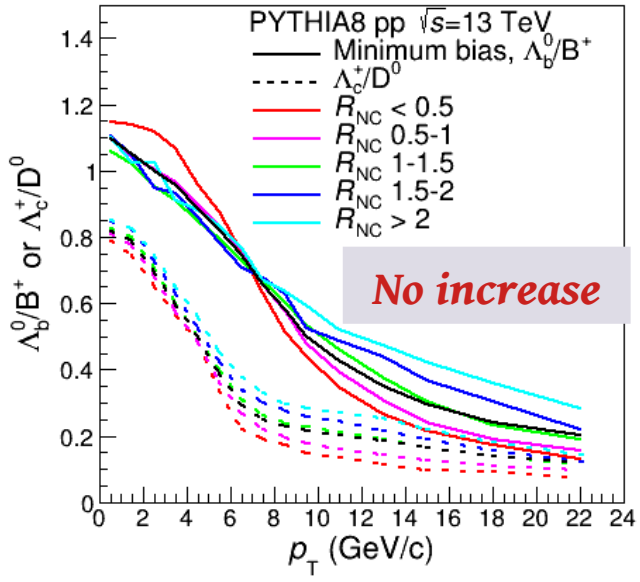


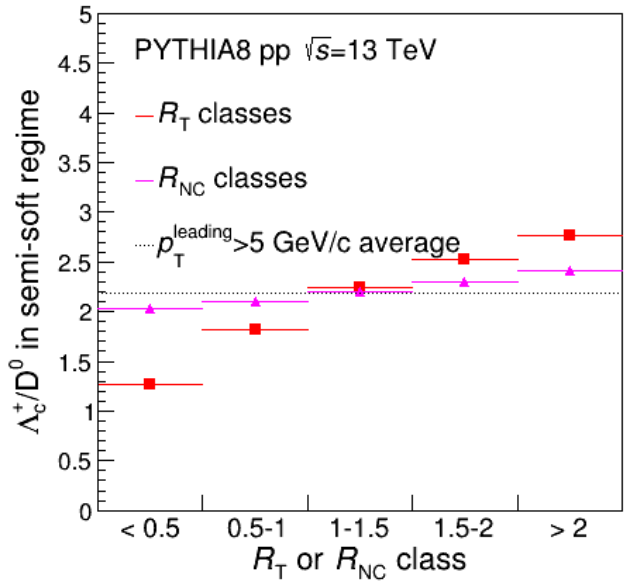
$$R_{\mathrm{T}} = \frac{N_{\mathrm{trans}}}{\langle N_{\mathrm{trans}} \rangle}$$

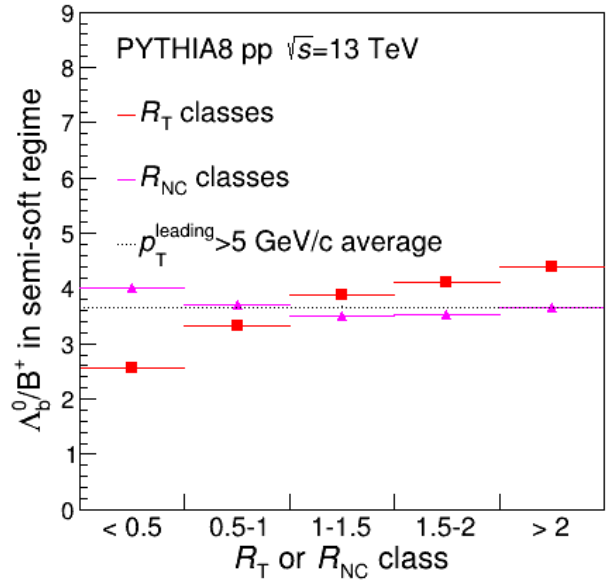
$$R_{\mathrm{NC}} = \frac{N_{\mathrm{cone}}}{\langle N_{\mathrm{cone}} \rangle}$$

- R_{T}: transverse event activity
  - **Represents the underlying event (UE)**
  - Connected to MPI
- R_{NC}: near-side jet-cone activity
  - **Activity within the jet**
- Trigger hadron is required
- **The enhancement is dependent on the UE**

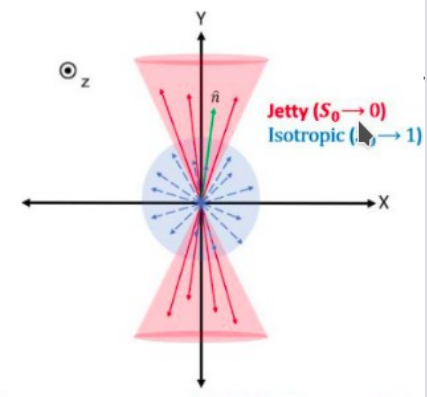






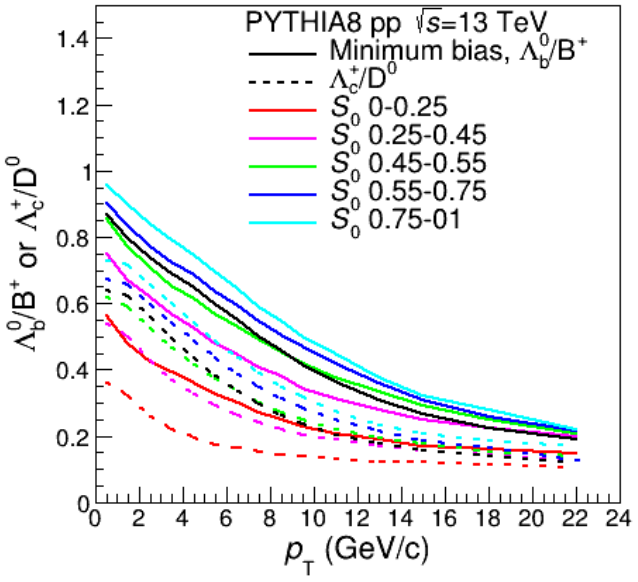


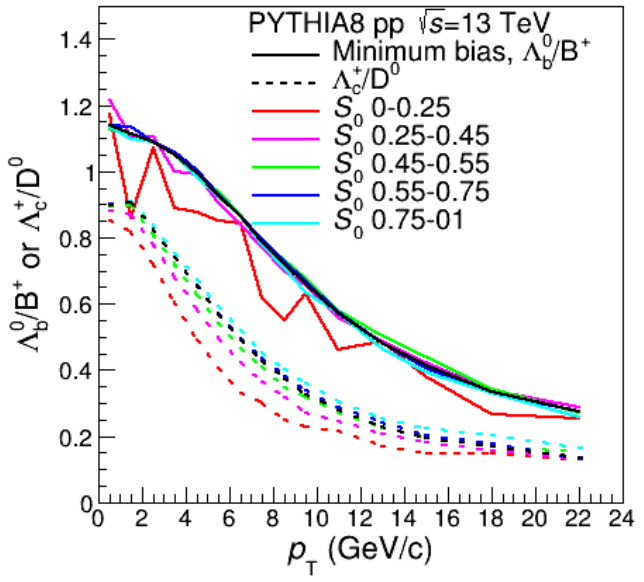
Transverse spherocity

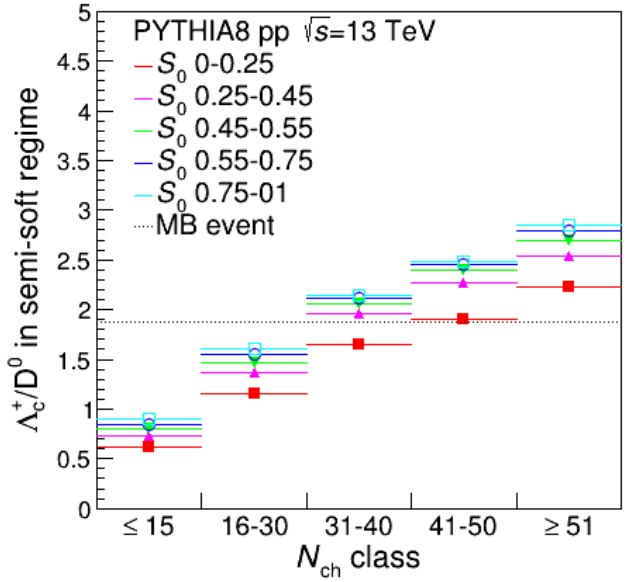


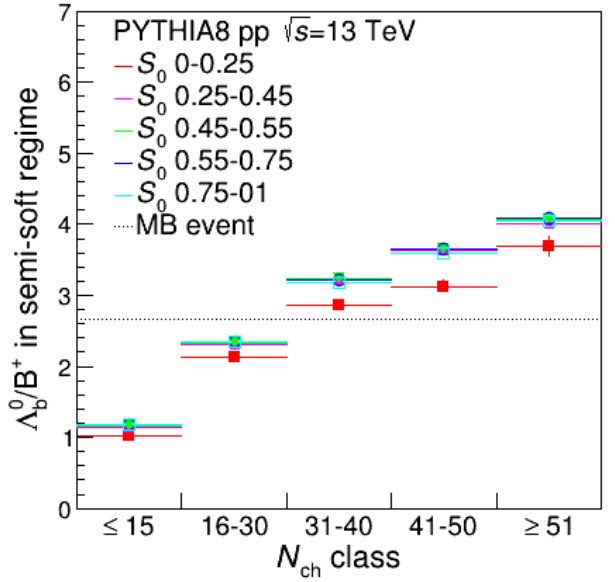
$$S_0 = \frac{\pi^2}{4}\left(\frac{\Sigma_i |\vec{p_{T_i}} \times \vec{n}|}{\Sigma_i \vec{p_{T_i}}}\right)^2$$

- Measures if the event is jetty or isotropic
- No need for trigger hadron
- Only midrapidity

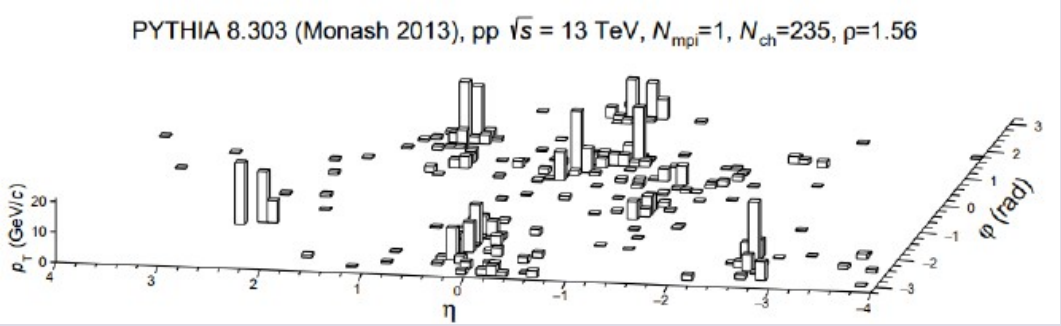






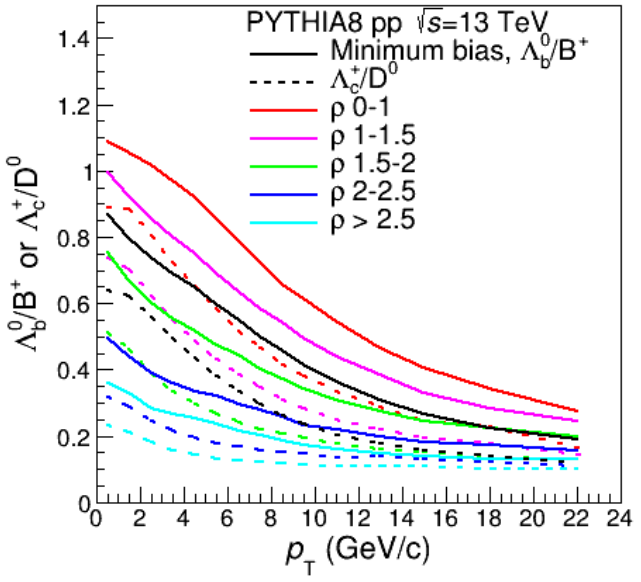


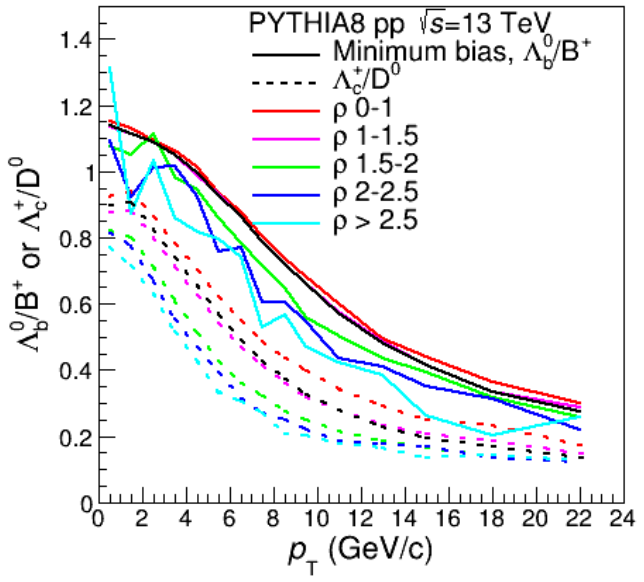
Flattenicity

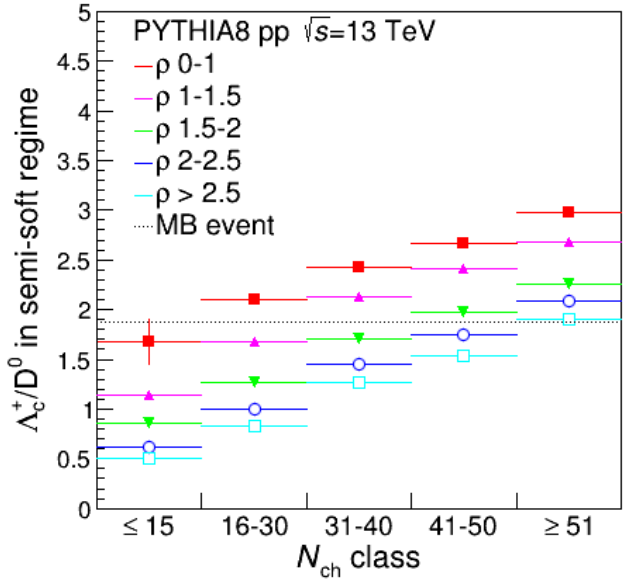


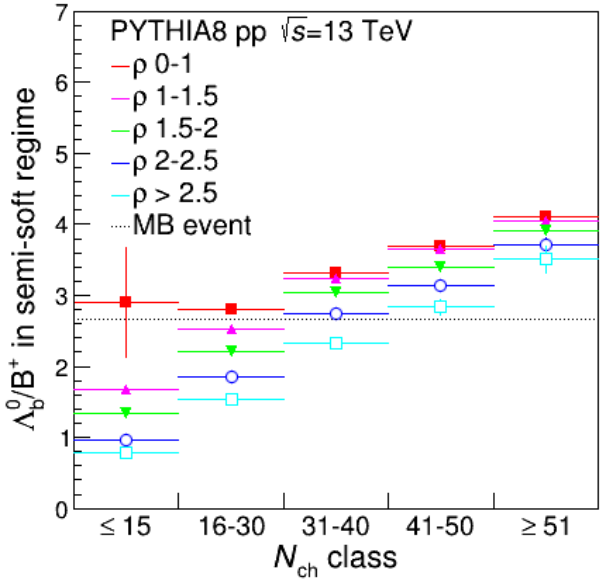
$$\rho = \frac{\sigma_{p_{\mathrm{T}}^{\mathrm{cella}}}}{\langle p_{\mathrm{T}}^{\mathrm{cella}} \rangle}$$

- Measures if the event is "hedgehog-like" or jetty
- No trigger hadron
- Full rapidity range $|\eta|<4$









Summary

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- The universality of fragmentation is violated
- Charmed and beauty baryons show similar enhancement trend
  - **Charm is best described by CR-BLC mode 2**
  - **Beauty is best described by CR-QCD**
- CR models: HF baryon enhancement comes from the underlying event, not the jet
- The proposed event-classifiers are sensitive to the production mechanisms
- Flattenicity
  - Strongly related to UE (MPI)
  - 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**

Thank you for your attention!

More PYTHIA models

- CR-BLC mode 0
  - Lacks time-dilation constraints
  - Controls CR by the invariant mass scale parameter
- CR-BLC mode 3
  - Time dilation
  - Requires only a single causal connection
- Thermodynamical string fragmentation
  - Gaussian suppression in mass and p_T is replaced by an exponential function
- Rope fragmentation with string shoving
  - Strings close in spacetime are allowed to repel each other