Charged-particle beauty-jet measurement with the impact parameter method in pp collisions in Run3

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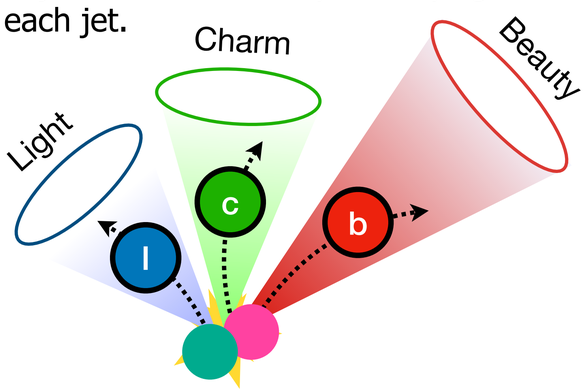
Why heavy-flavor jets?

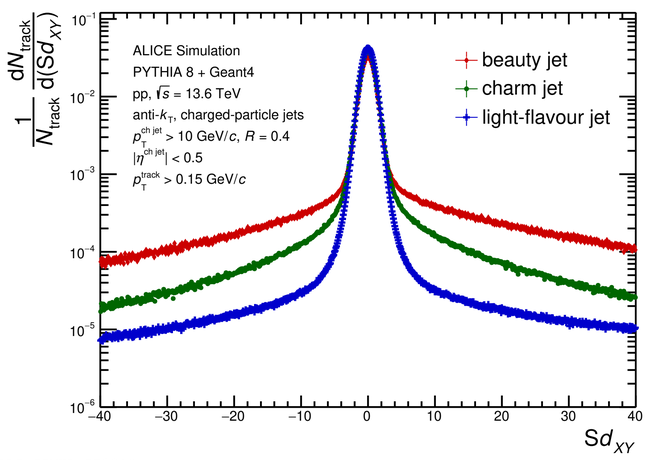
- Heavy quarks are produced in the early stages of the collisions, before the formation of the quark-gluon plasma (QGP)
- Heavy-flavor jets serve as excellent probes for studying QGP, as they interact with the medium after the collision.
- The cross section of heavy-flavor jets can be calculated using perturbative QCD (pQCD).
- Heavy-flavor jets can study mass and flavor dependent in-medium parton energy loss mechanisms.

Jet classification

- Monte Carlo simulations are performed using PYTHIA 8 with Geant4.
- The anti-k_{T} algorithm is used to reconstruct jets with $R = 0.4$.
- Heavy-flavor jets are classified by identifying the originating parton for each jet.

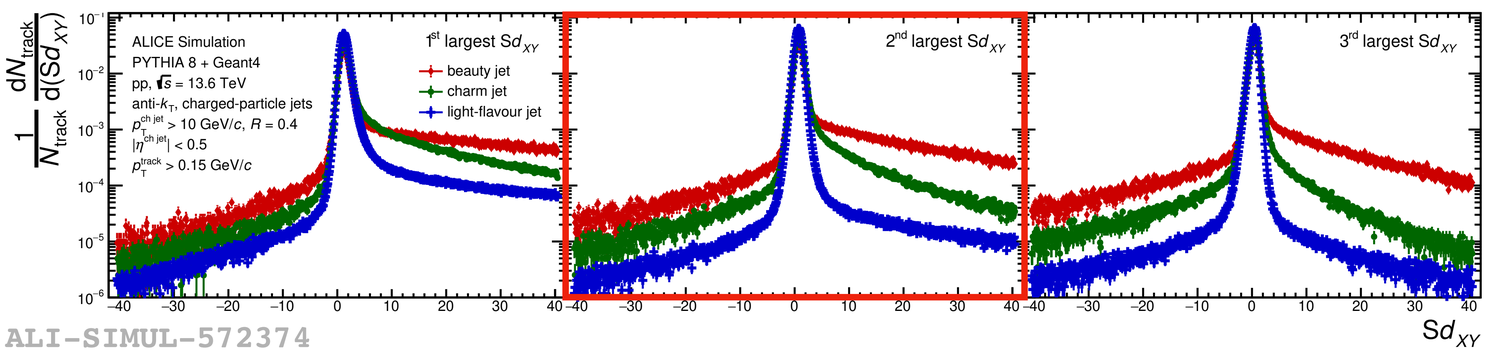


b-jet candidate selection



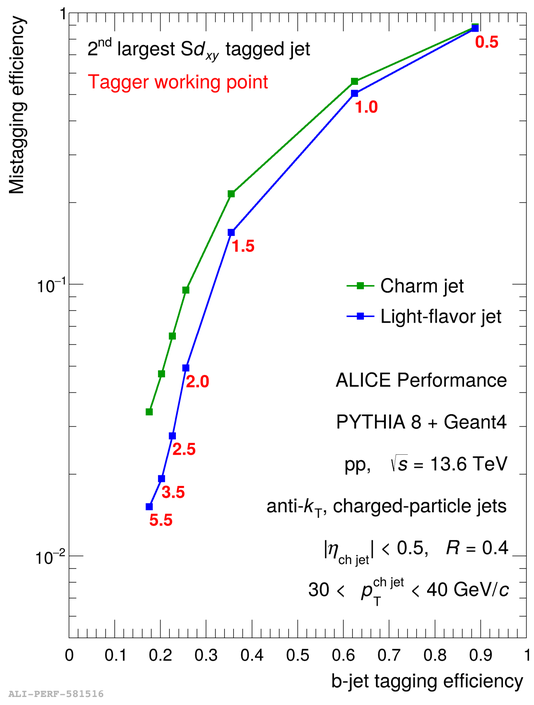
- Impact parameter :
  - Distance of closest approach of jet constituents to primary vertex.
- b-jet candidate selection with IP method :
  - Signed impact parameter significance ($Sd_{xy} = \delta \cdot d_{xy}/\sigma_{xy}$)
  - δ : The sign of the impact parameter is determined by the dot product of the jet and IP vector.
  - d_{xy} : 2D impact parameter on transverse plane
  - σ_{xy} : uncertainty of d_{xy}

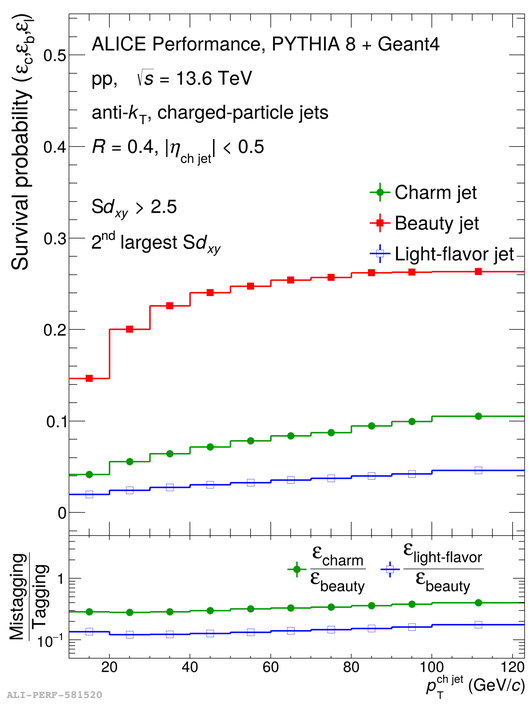
Track counting method



- Sd_{xy} of the tracks inside the jet are sorted in descending order.
- Each flavor can be effectively distinguished in the positive region.
- b-jets are tagged by the 2^{nd} largest Sd_{xy} greater than a threshold parameter (tagger working point).

b-jet tagging efficiency





- Tagging efficiency is defined as $\epsilon_{\mathrm{flavor}} = \dfrac{N_{\mathrm{flavor}}^{\mathrm{Tagged}}}{N_{\mathrm{flavor}}^{\mathrm{Total}}}$
- The tagger working point is set to 2.5, consistent with the setting used in the Run 2 analysis[1].
- Smaller ratio of mistagging to tagging efficiency indicates the stronger separation power of the tagger.

Discriminator for b-jet tagging

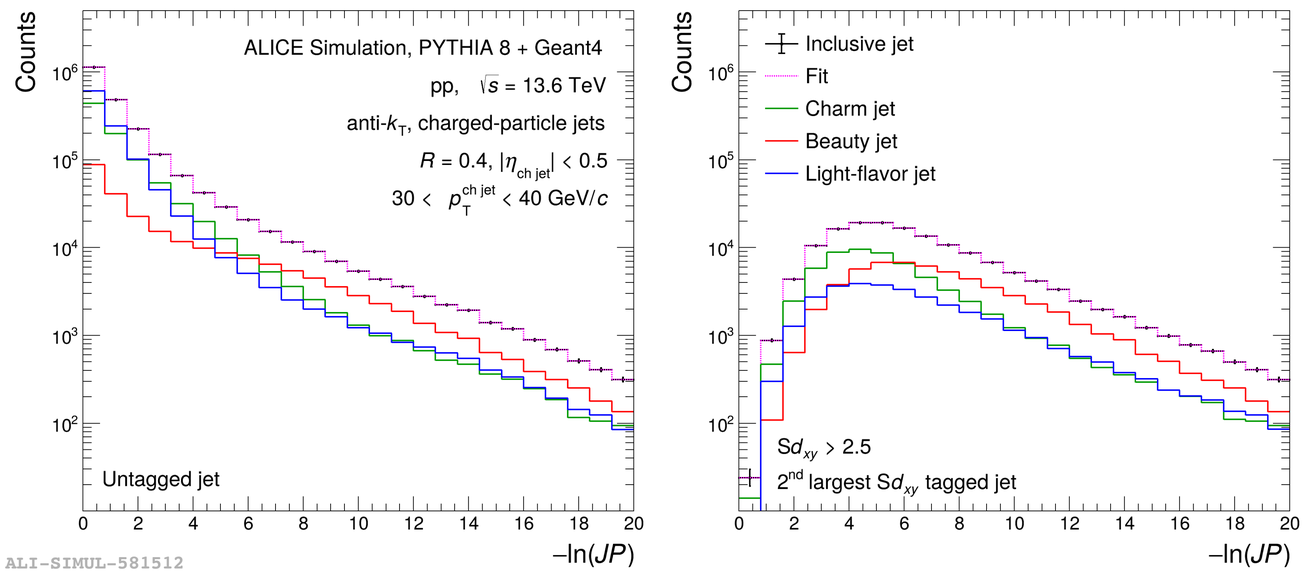
- The impact parameter distribution is used as an input for the jet probability algorithm, which will be employed to calculate the efficiency and purity of b-jet tagging.
- Jet probability serves as a discriminator to distinguish the flavor of jets.

Track probability

- $P_{\mathrm{track}}(x) = \dfrac{\int_{-\infty}^{|x|} R(s)ds}{\int_{-\infty}^{0} R(s)ds}$, $R(s)$ is a resolution function from negative side of Sd_{xy} distribution.

Jet Probability

- $JP = \prod \times \sum_{k=0}^{N_{\mathrm{trk}}-1} \dfrac{(-\log\prod)^k}{k!}$, $\prod = \prod_{k=1}^{N_{\mathrm{trk}}} P_{\mathrm{track}}$
- The probability that the constituents of a jet originate from a secondary vertex.



- The -ln(JP) distribution on tagged jets enables clear separation between flavors.

Conclusion

- Performance evaluation of heavy-flavor jets in Run 3 using Monte Carlo simulations.
- The Sd_{xy} distribution shows clear flavor separation following the application of the track counting method.
- Examined the efficiency and jet probability.

Outlook

- Optimize the tagger working point to improve flavor identification while maintaining high b-jet purity.
- Based on the extensive Run 3 data, detailed studies on heavy-flavor jets, including fragmentation functions and correlations, are now possible advancing beyond the limitations of Run 1 and Run 2.
- Future plans include applying heavy-flavor tagging in heavy-ion collisions.

[1] ALICE Collaboration, "Measurement of inclusive charged-particle b-jet production in pp and p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02\,\mathrm{TeV}$", Journal of High Energy Physics, vol. 2024, article no. 41, 2024.