Exploring the time axis within medium-modified jets

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Based on ongoing work with Liliana Apolinario [a] and Korinna Zapp [b]

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[b] *Department of Astronomy and Theoretical Physics, Lund University*

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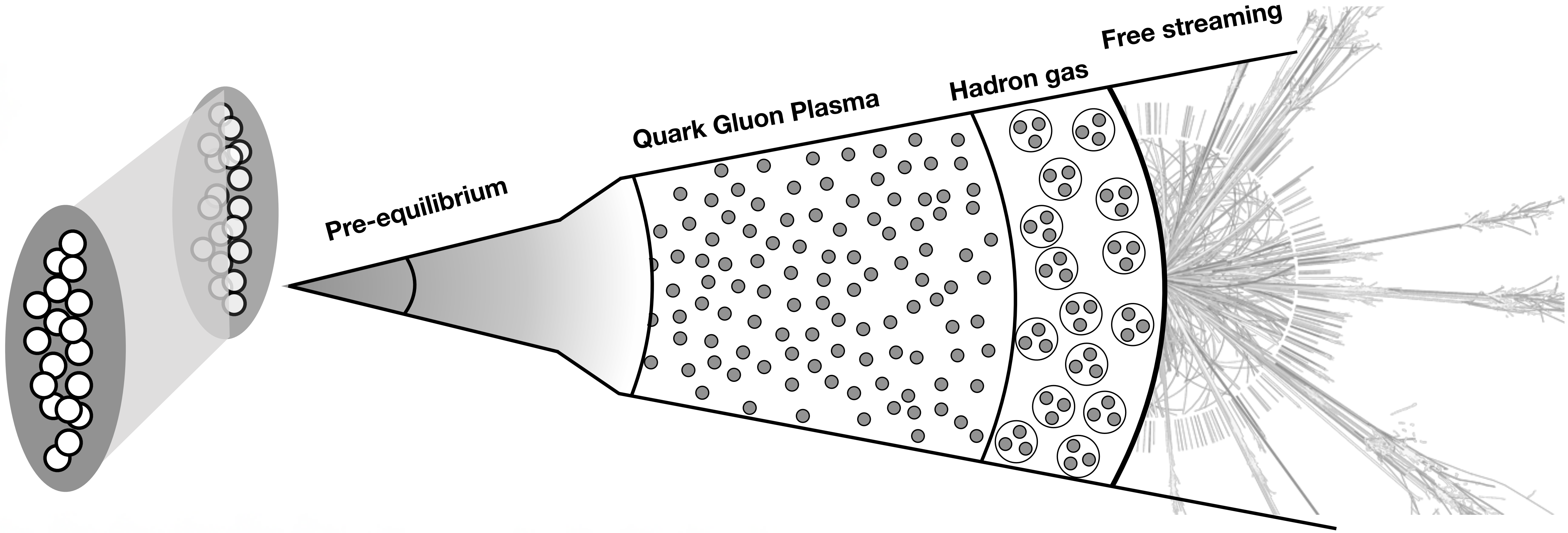

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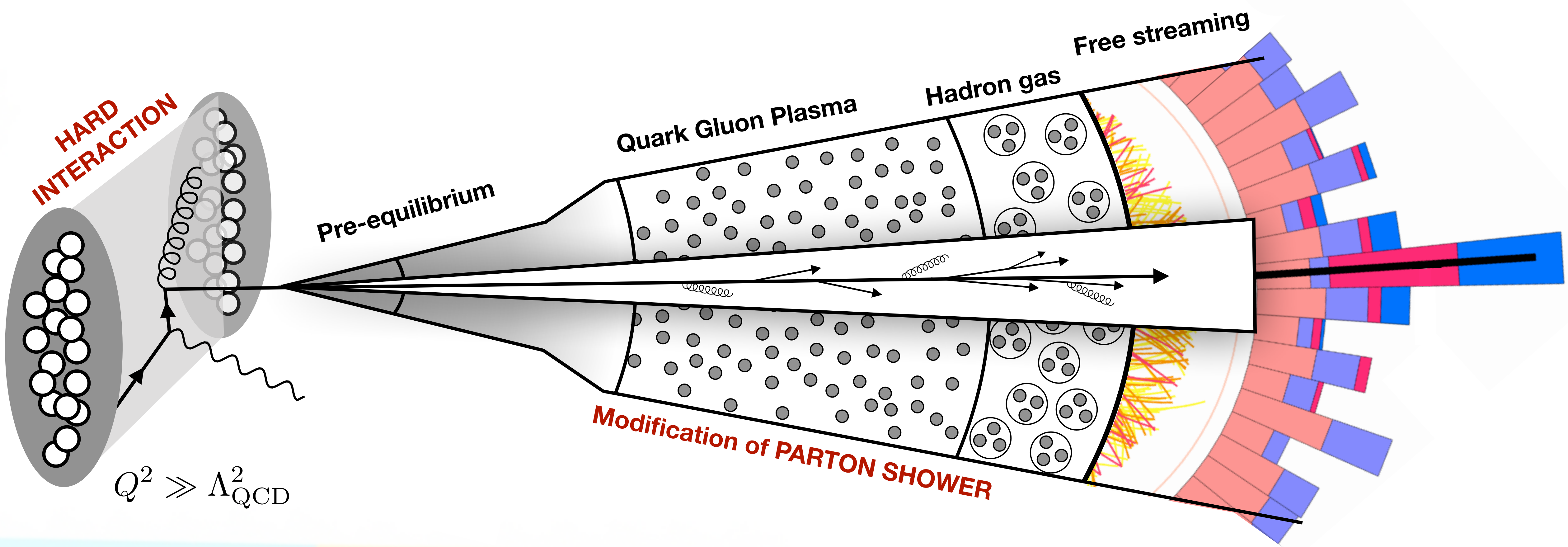

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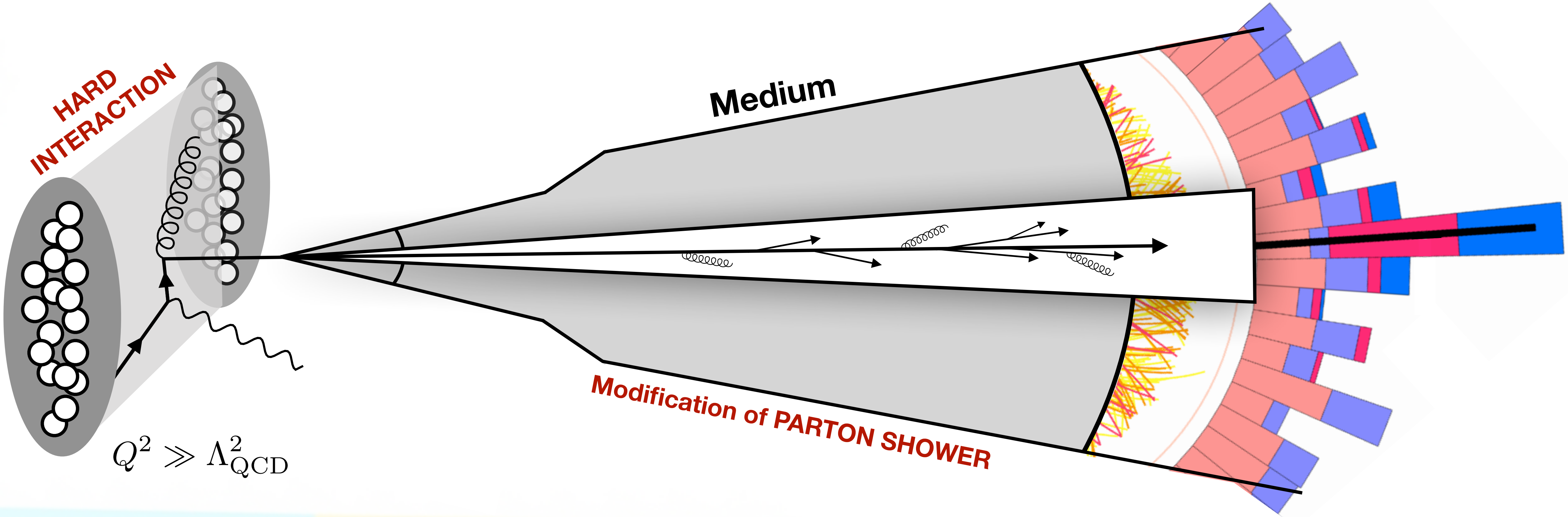

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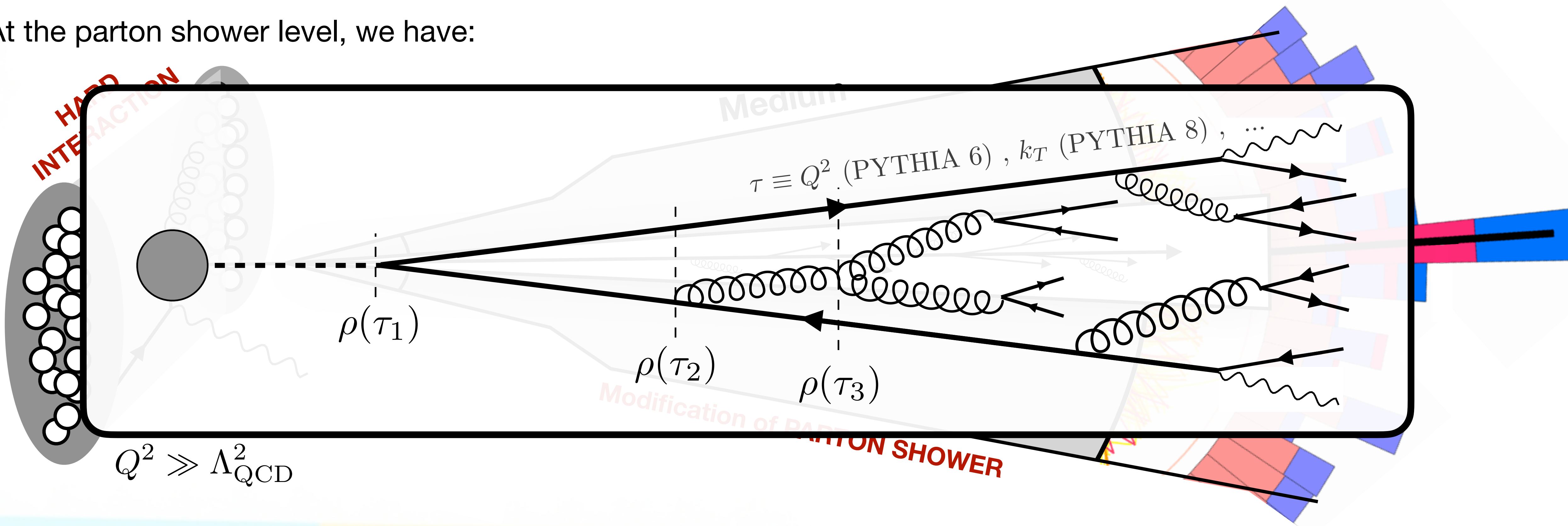

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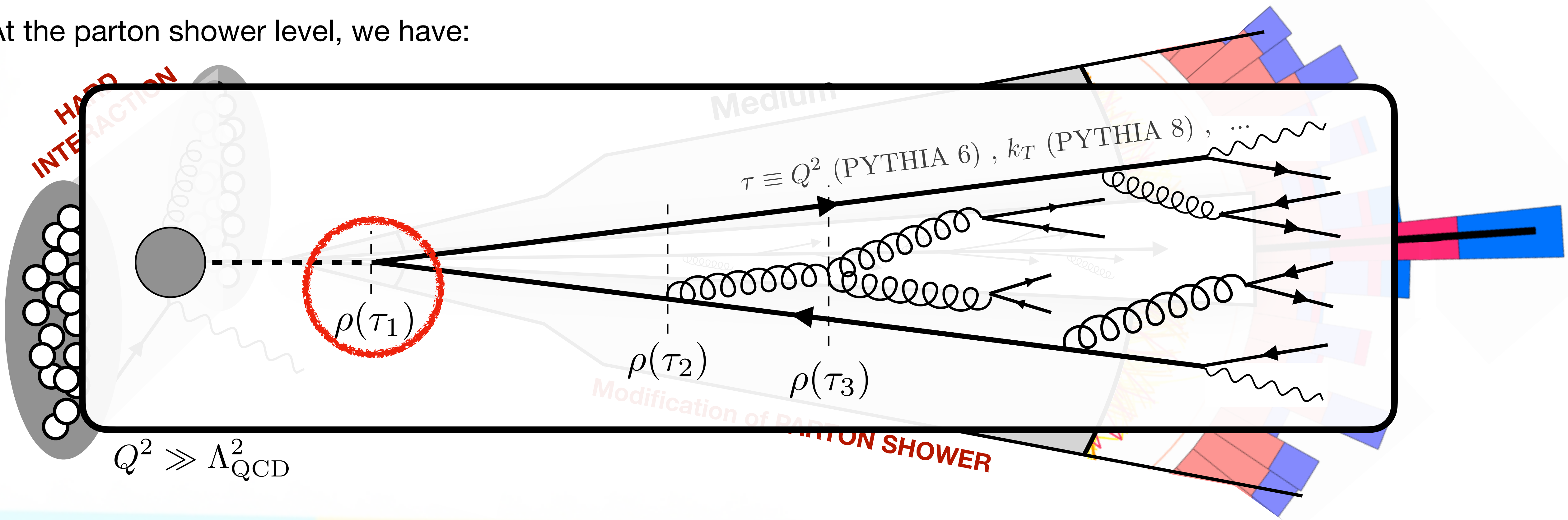

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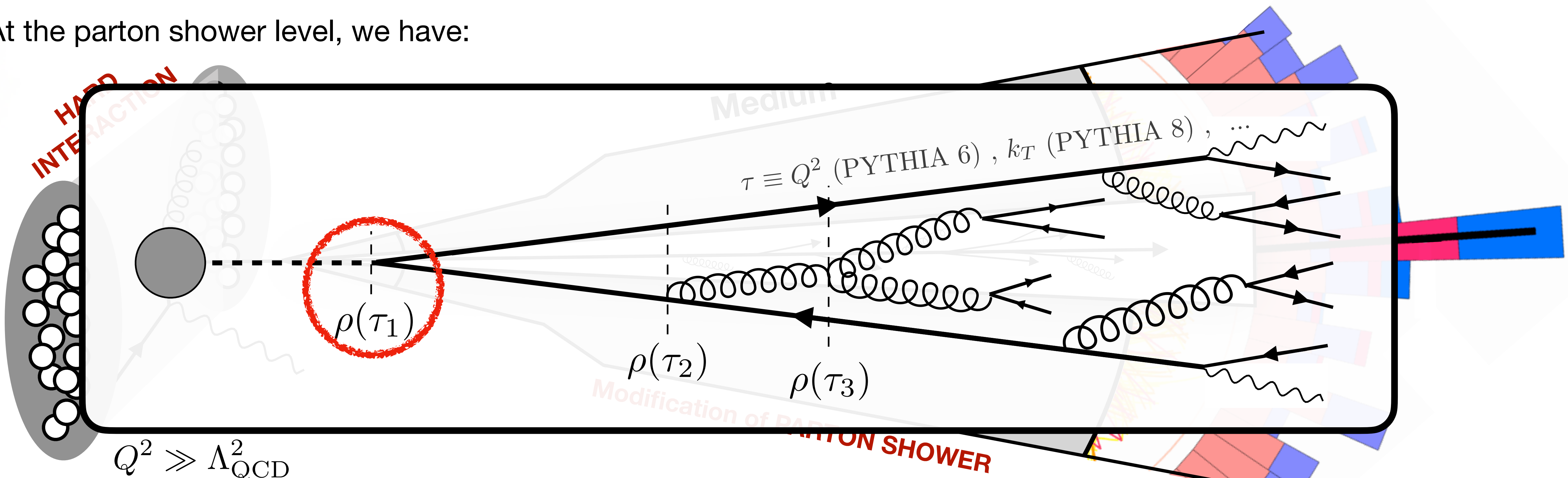

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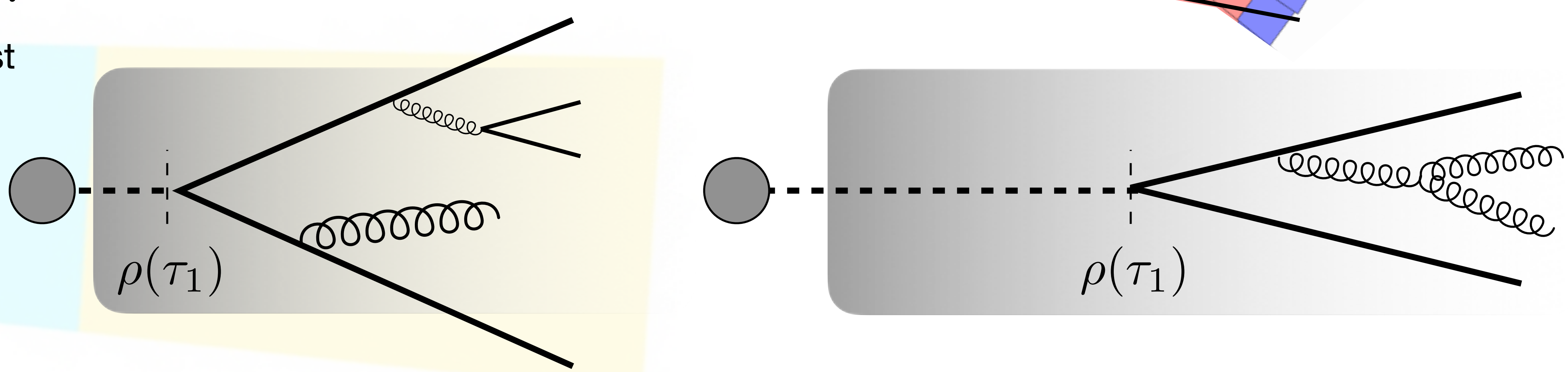

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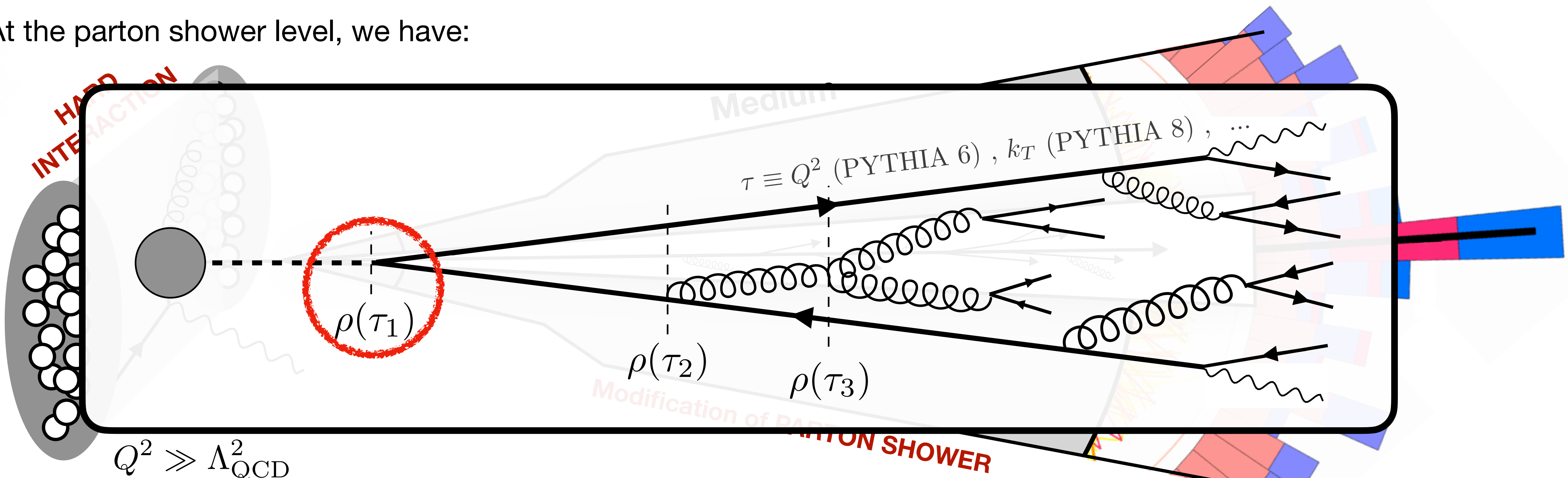

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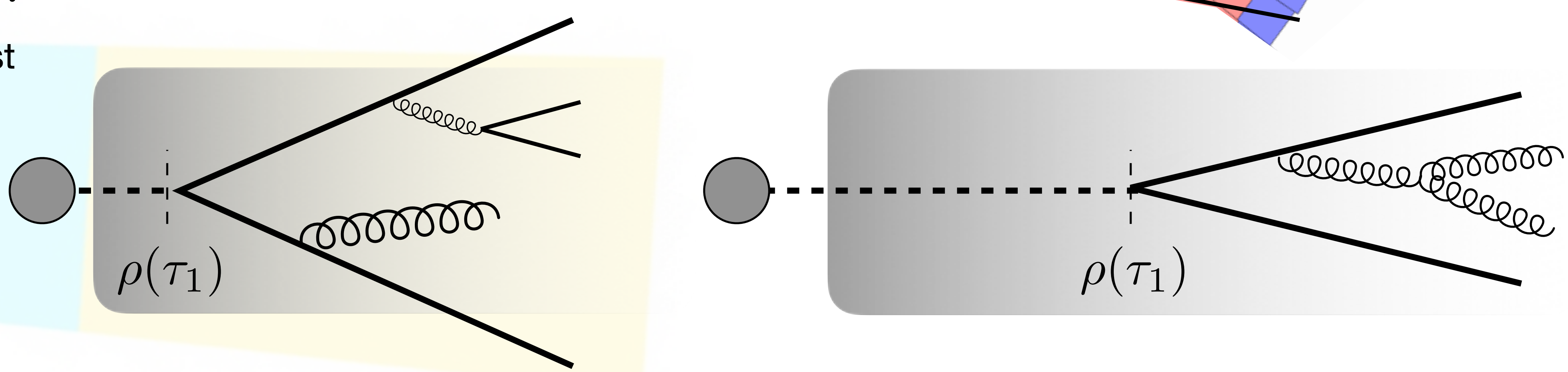

- *BUT how can we access this information?*

Jet clustering

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- *So, how do we make a jet?*

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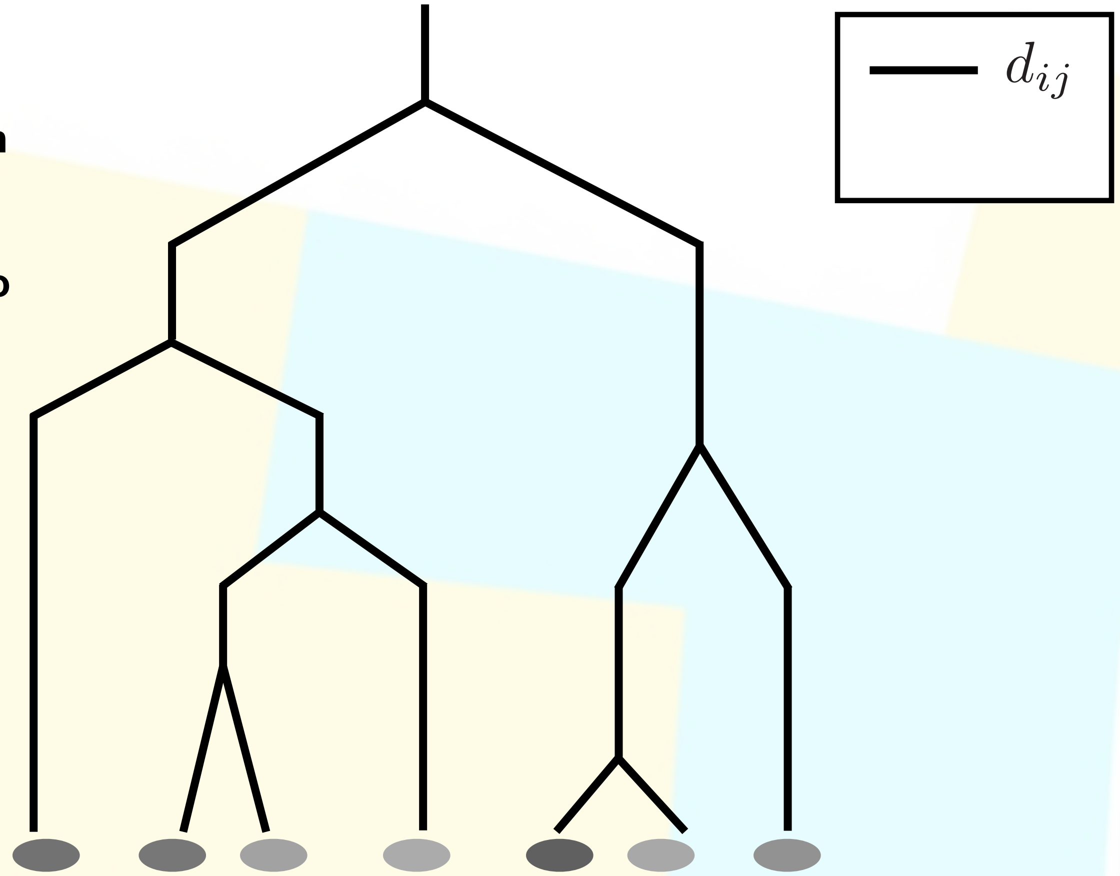
Sequential combination of particles ordered according to some user-defined distance measure d_{ij}



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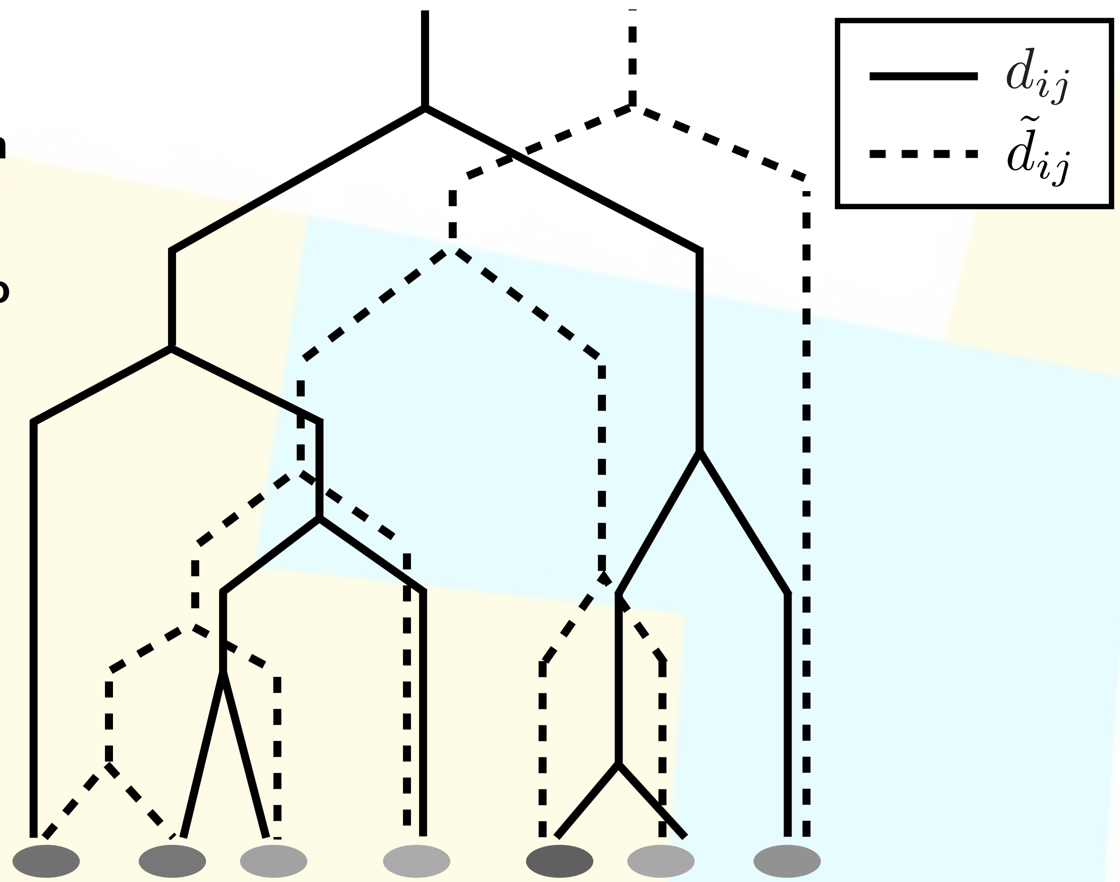

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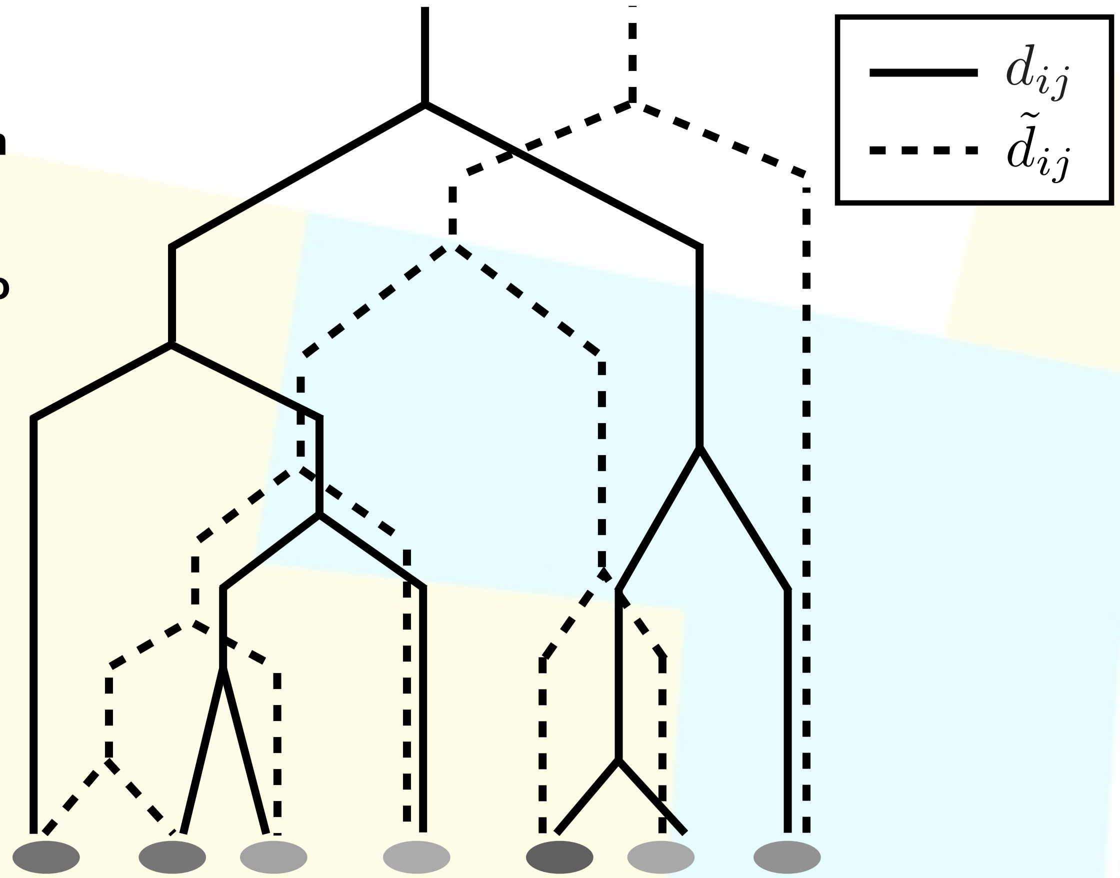

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- We use the **generalized** k_t **algorithm**

$$d_{ij} = \min(p_{t,i}^{2p}, p_{t,j}^{2p})\frac{\Delta R_{ij}^2}{R^2} \text{ , with } \Delta R_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$

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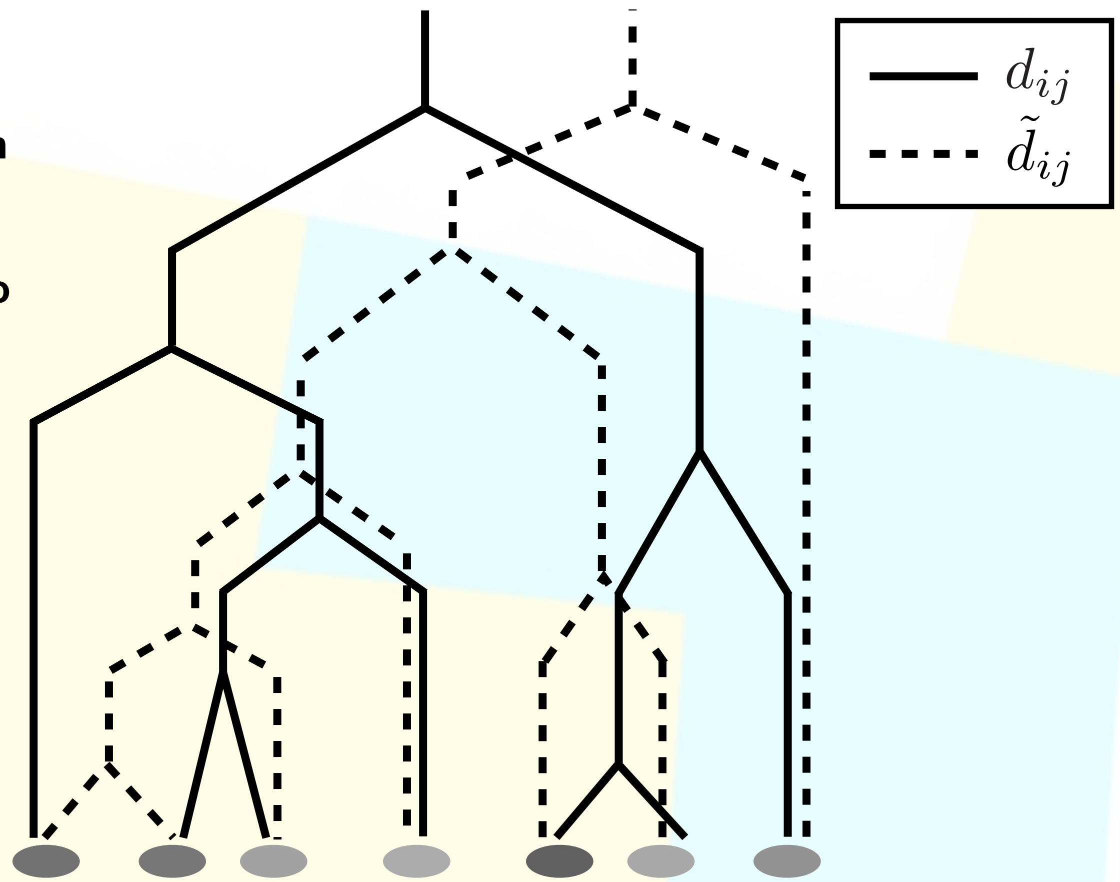

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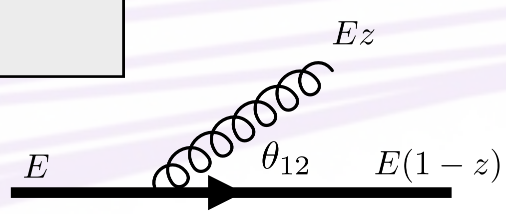
- We propose using $p = 0.5$. With this setup:

(High energy limit)

$$d_{ij} \sim p_{T,i}\theta^2 \sim \frac{1}{\tau_{\text{form}}}\ , \text{ with } \tau_{\text{form}} \approx \frac{E}{Q^2} \approx \frac{1}{2Ez(1-z)(1-\cos\theta_{12})}$$



Jet clustering

- We want to extract information from the internal structure of jets
- *So, how do we make a jet?* Can we relate them to parton showers?

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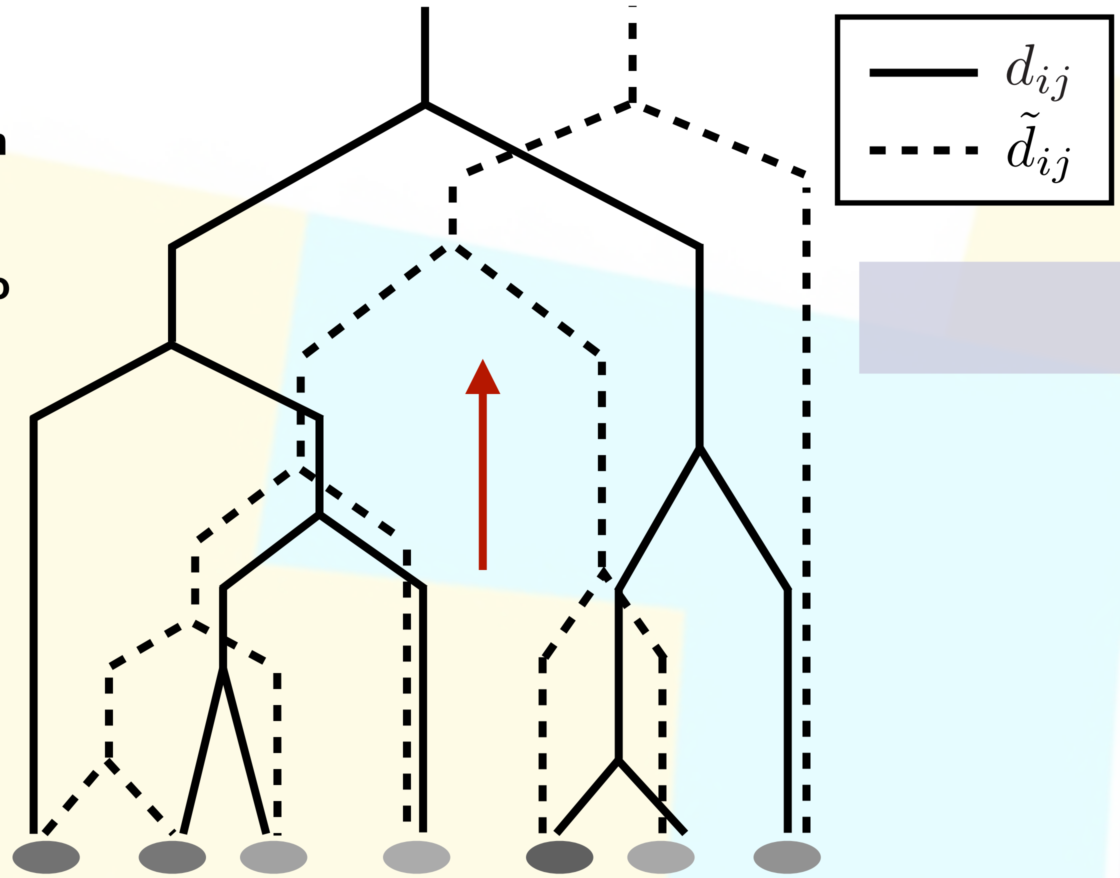

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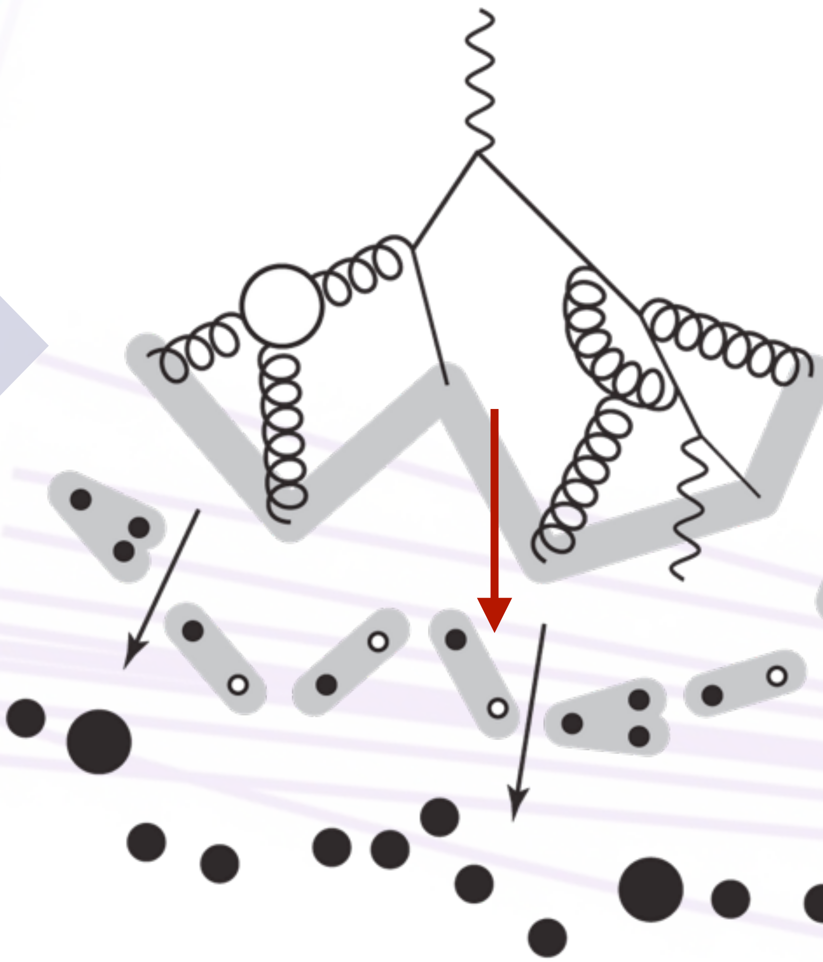

Sequential emission of particles controlled by QCD evolution over virtuality or momentum scales

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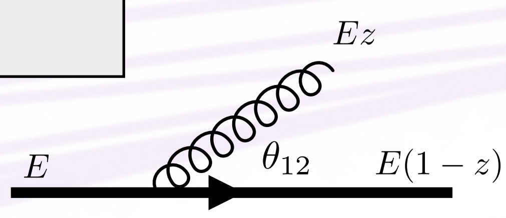

- We can use the clustering history of the jet to reconstruct the parton shower splitting by splitting

Jet unclustering with the τ-algorithm

L. Apolinário, A.Cordeiro, K. Zapp, Eur. Phys. J. C 81 (2021) 6, 561

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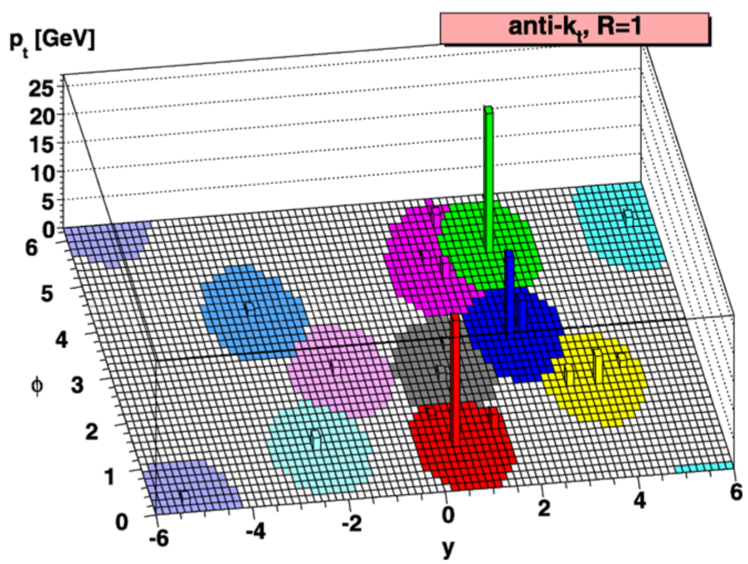

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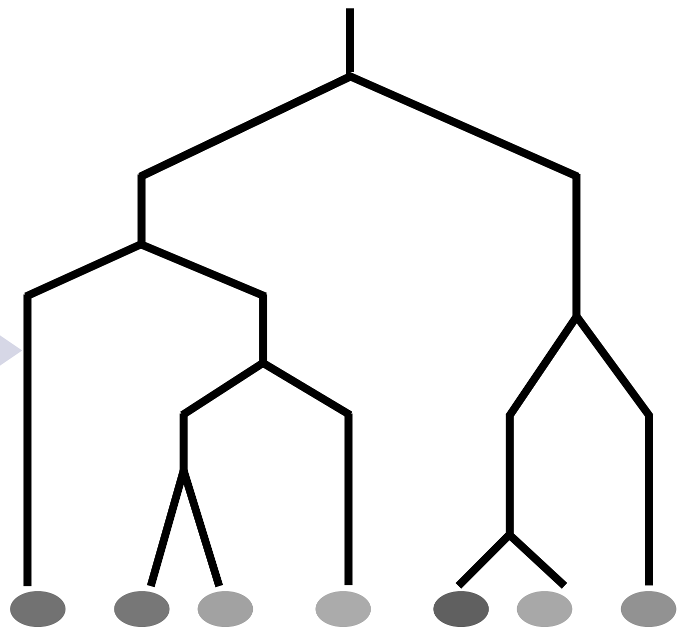

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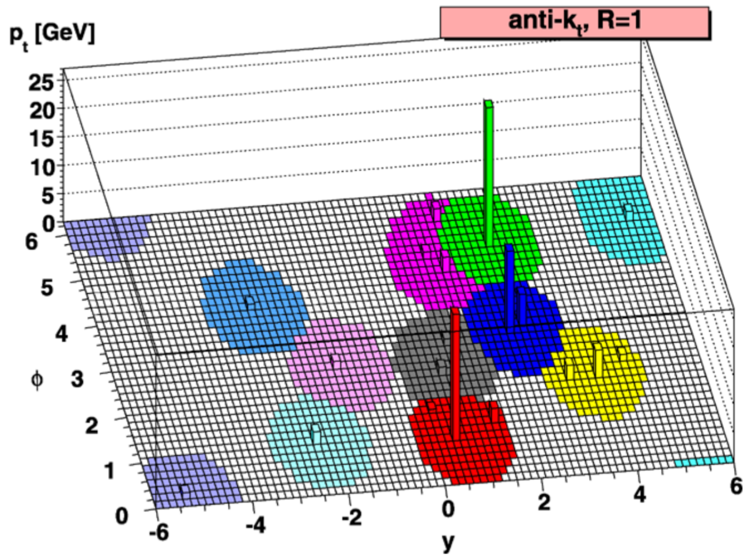

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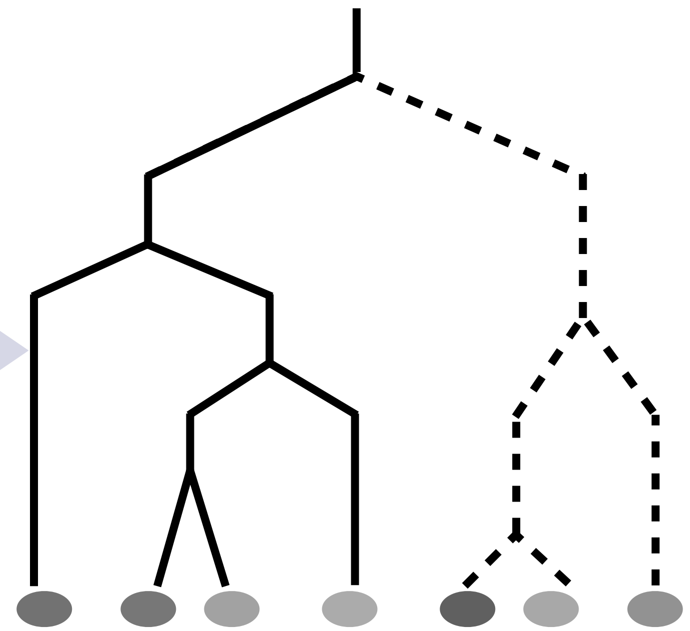

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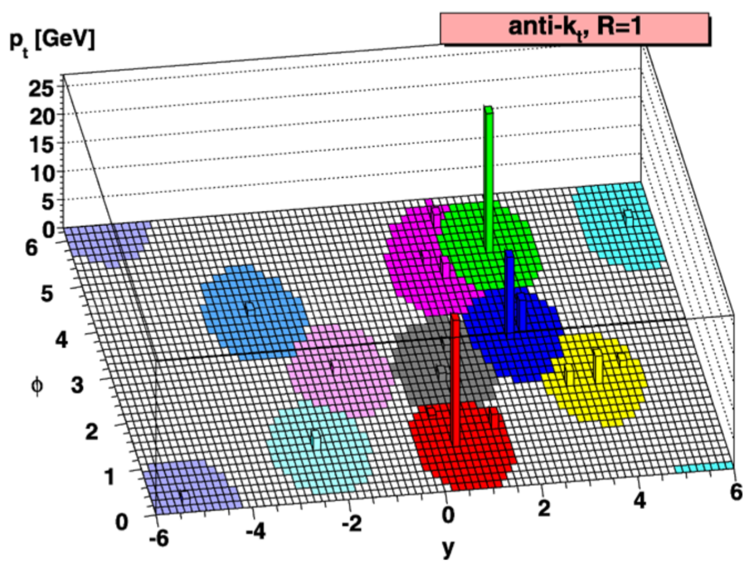

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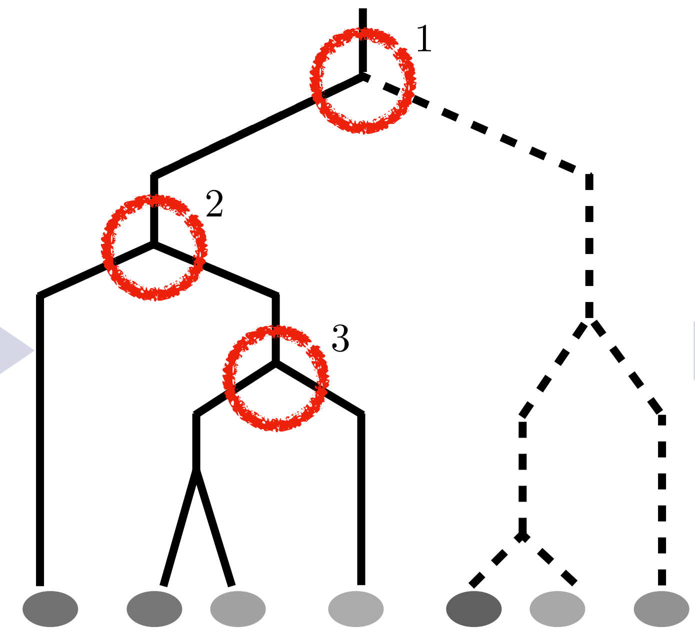

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Compute splitting times along leading branch

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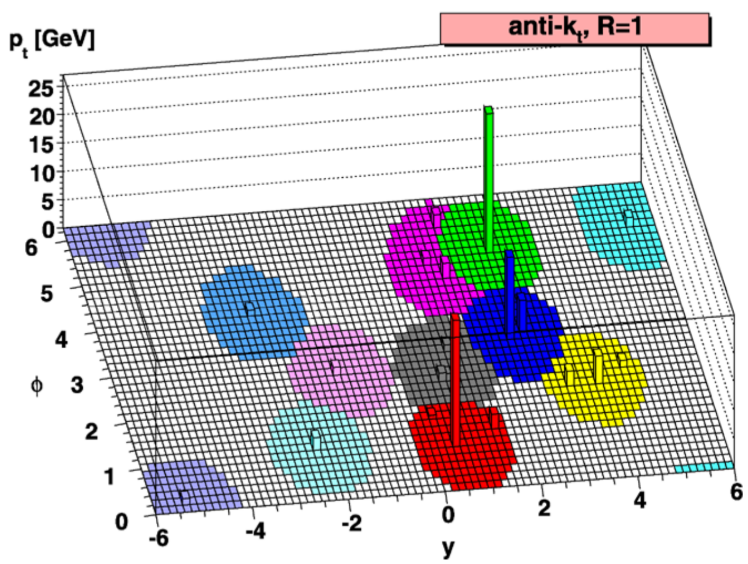

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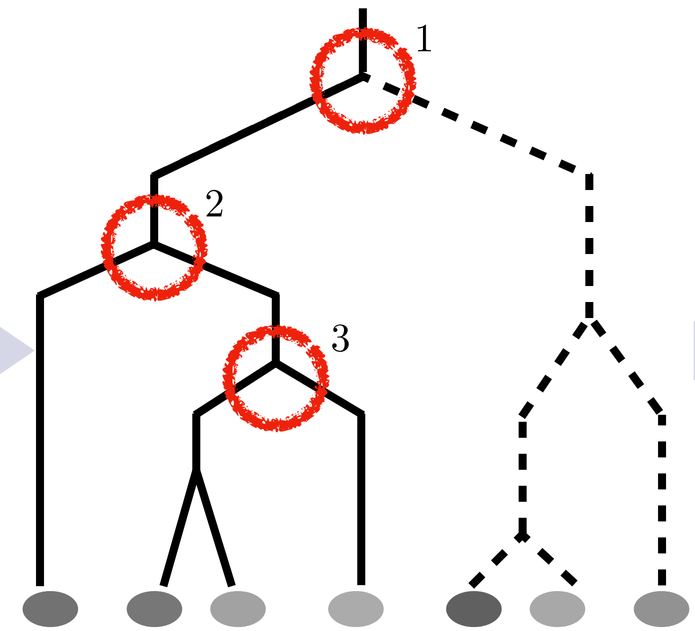

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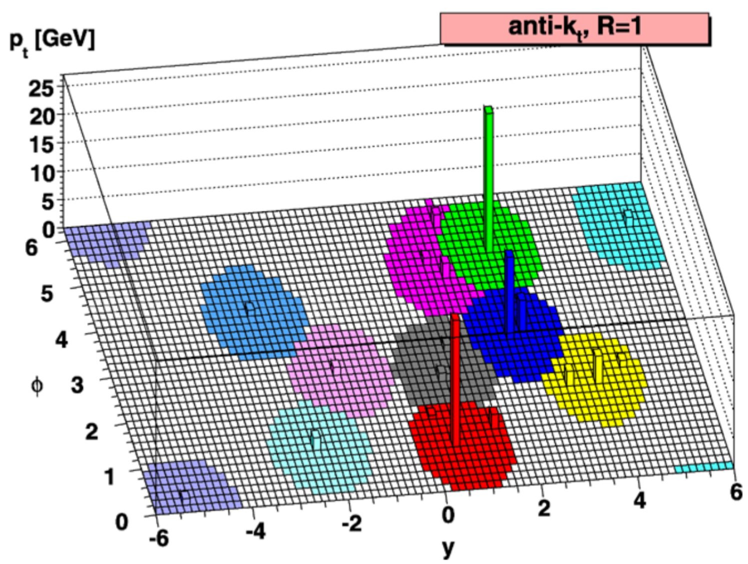

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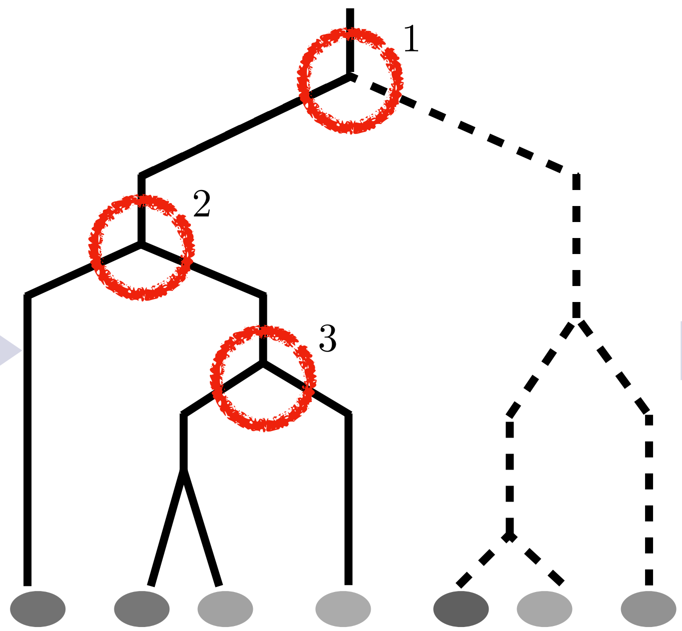

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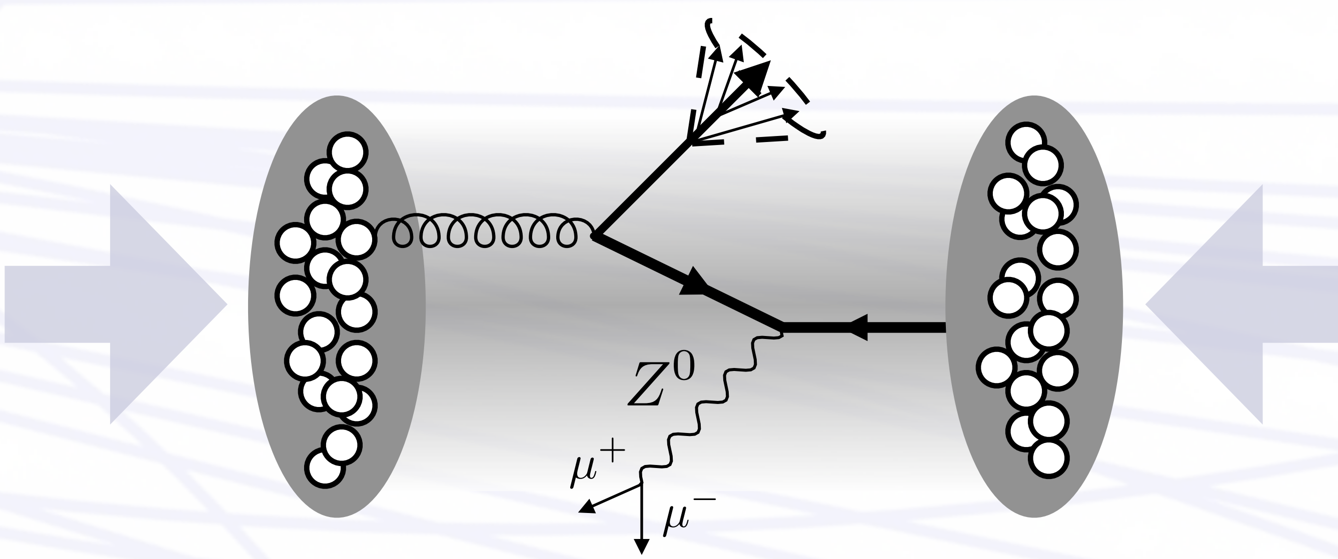
- We focus our study on **Z-jet events**: a clean and well calibrated environment for energy loss studies



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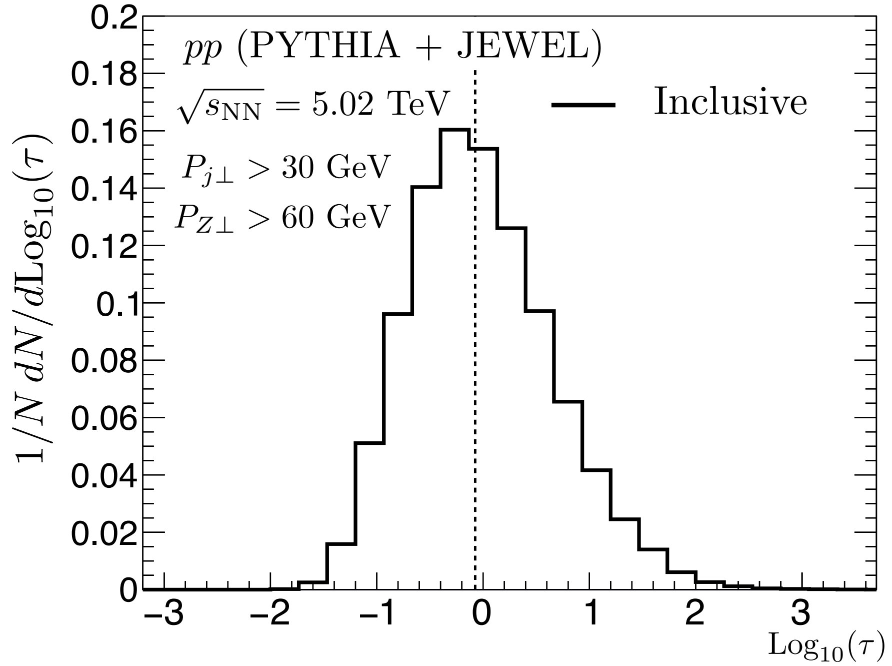

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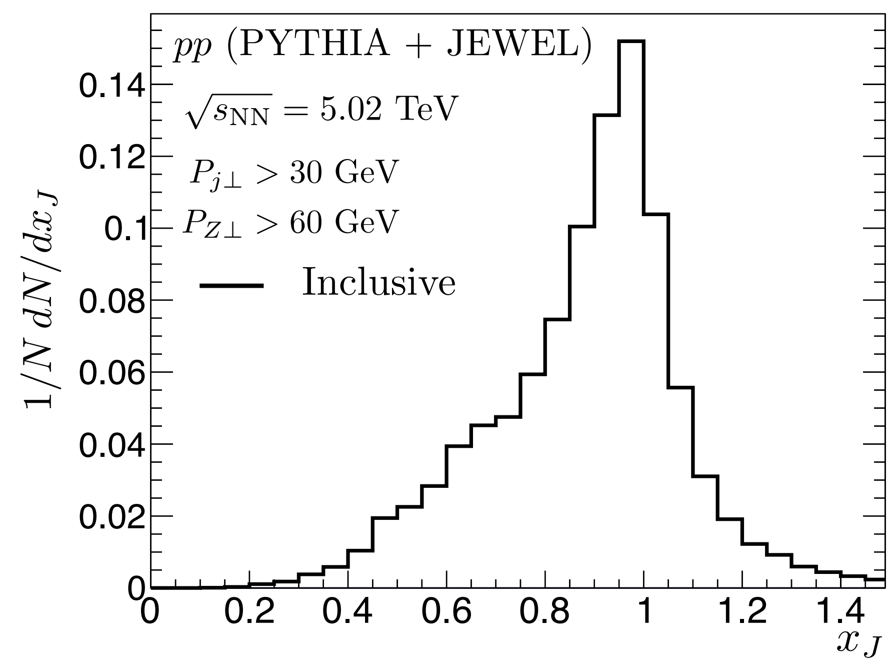

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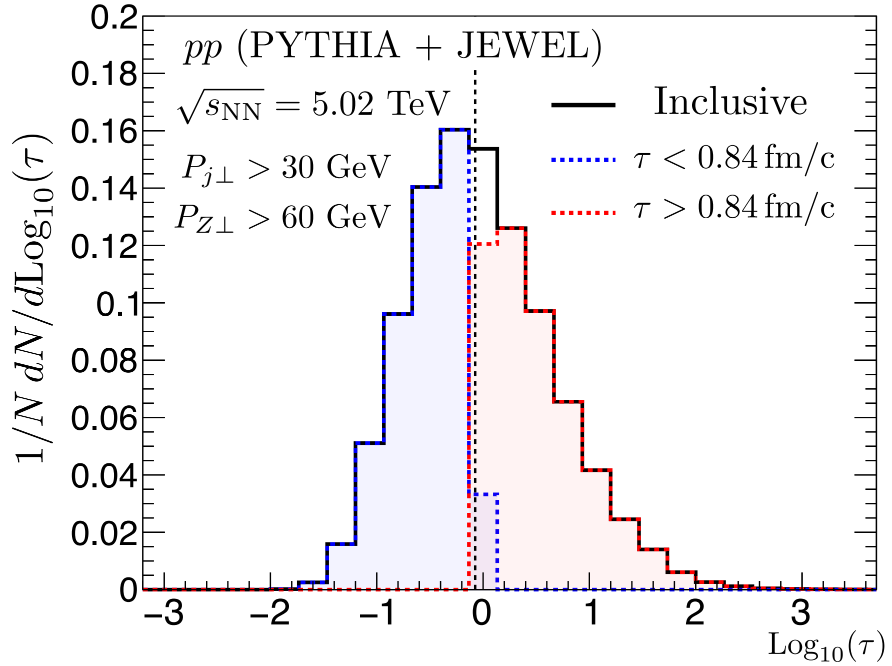

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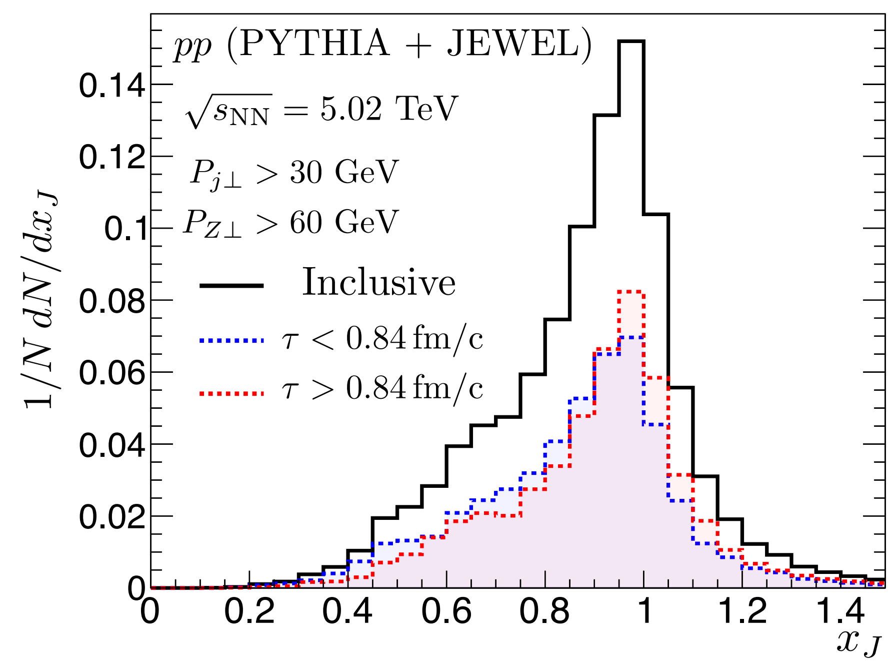

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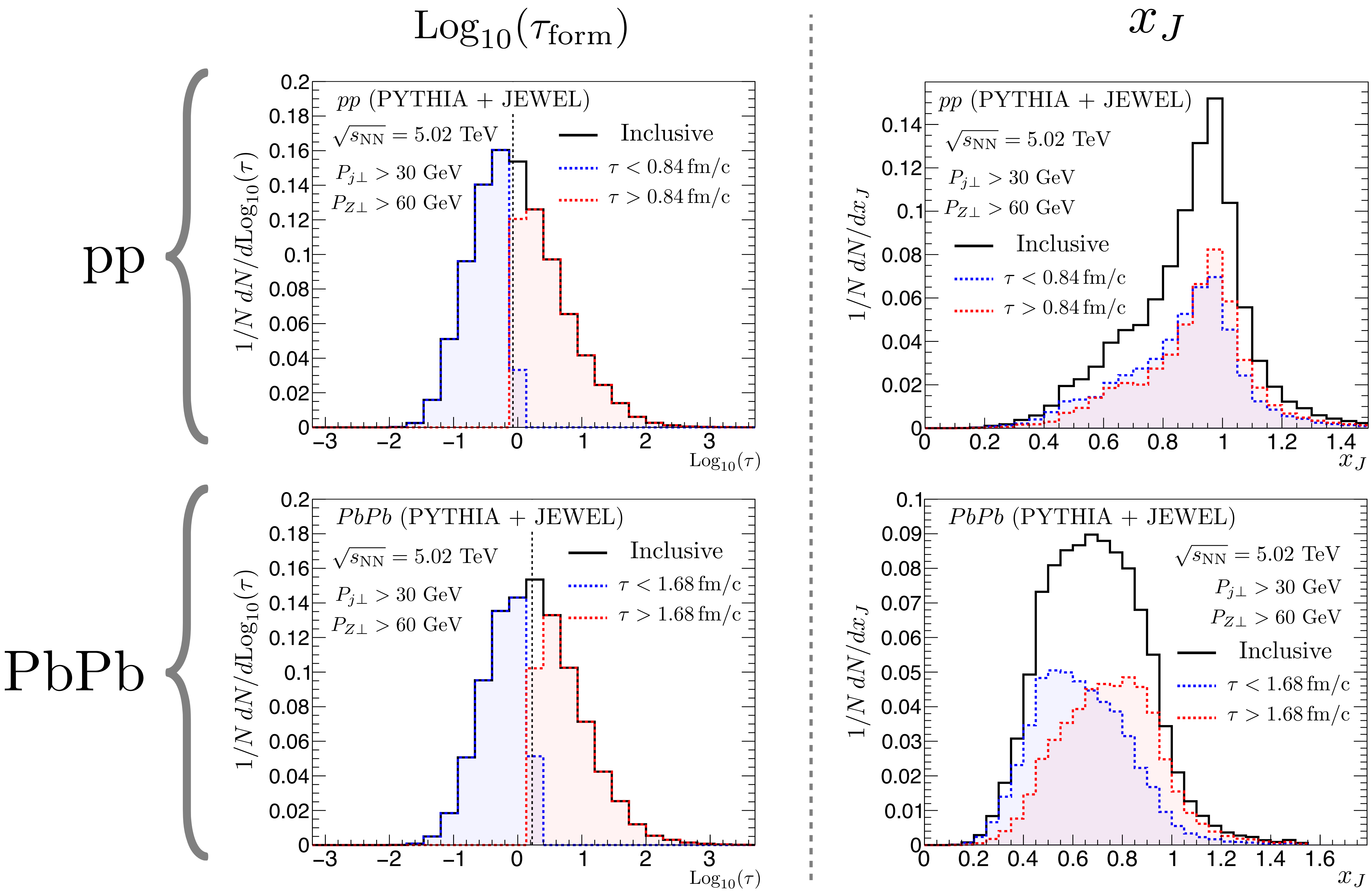
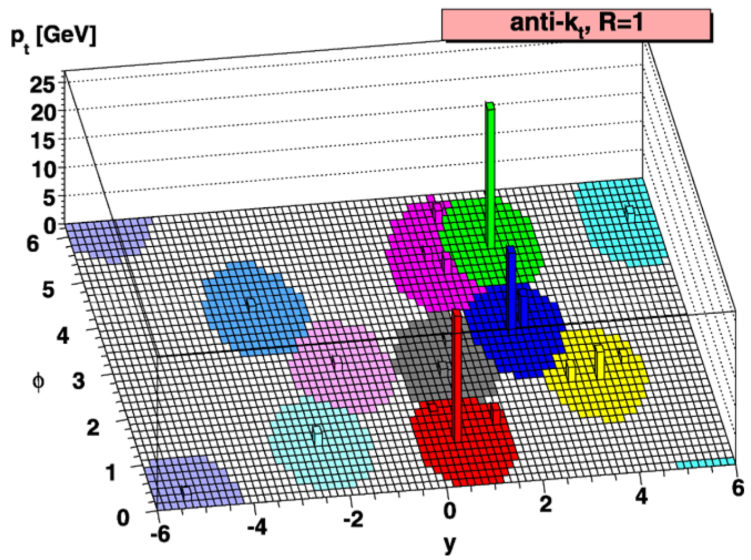


- Our early/late jet selection on $\tau_{\rm form}$ allows to evaluate ΔE

$\tau_{\rm form}$ or ΔR ?

- This feature is not unique to $\tau_{\rm form}$: a similar selection can be made using ΔR



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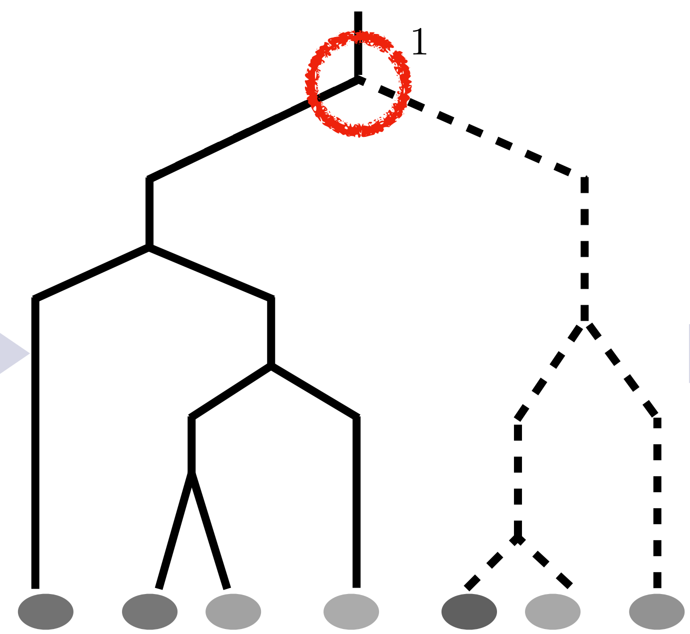

Re-cluster jets with τ-algorithm (p=0.5)
(+ apply SoftDrop)

$$(\Delta R^{\rm Uncluster})_1$$

Compute opening angle of first splitting

$$\tau_{\rm form} \approx \frac{1}{2Ez(1-z)(1-\cos\theta_{12})} \approx \frac{1}{zE\Delta R^2} \sim \frac{1}{z_{\rm cut}p_{\perp \rm min}\Delta R^2}$$

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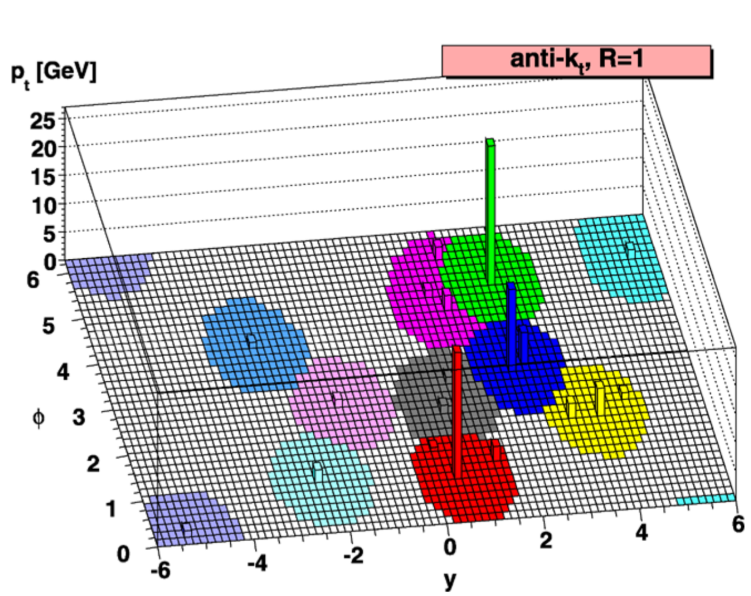

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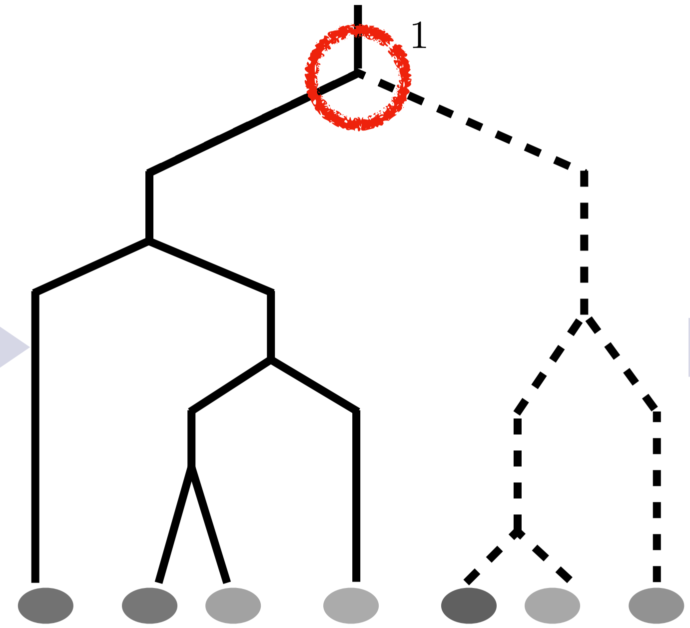

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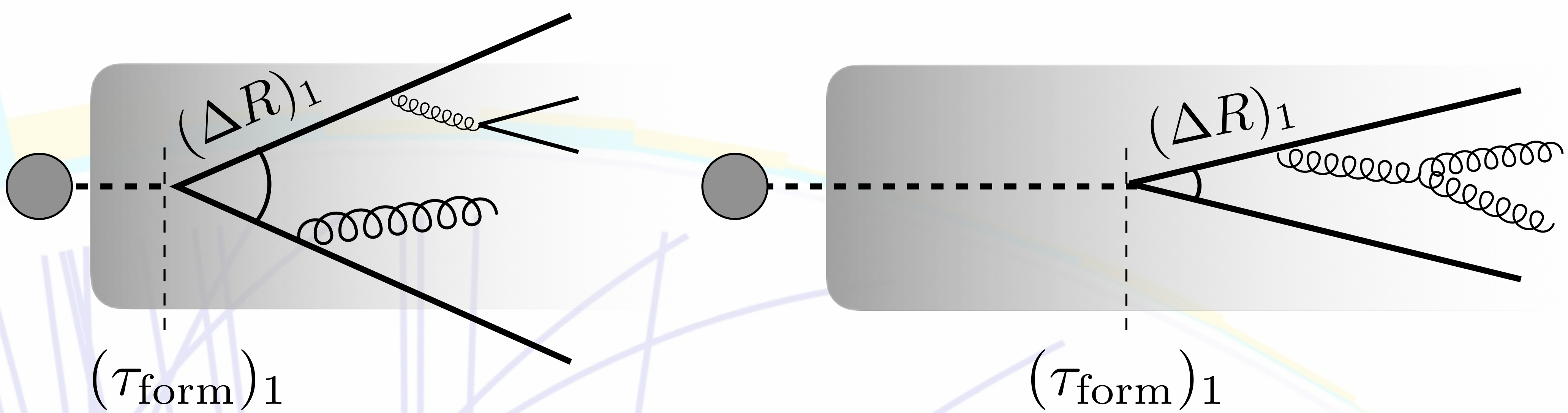

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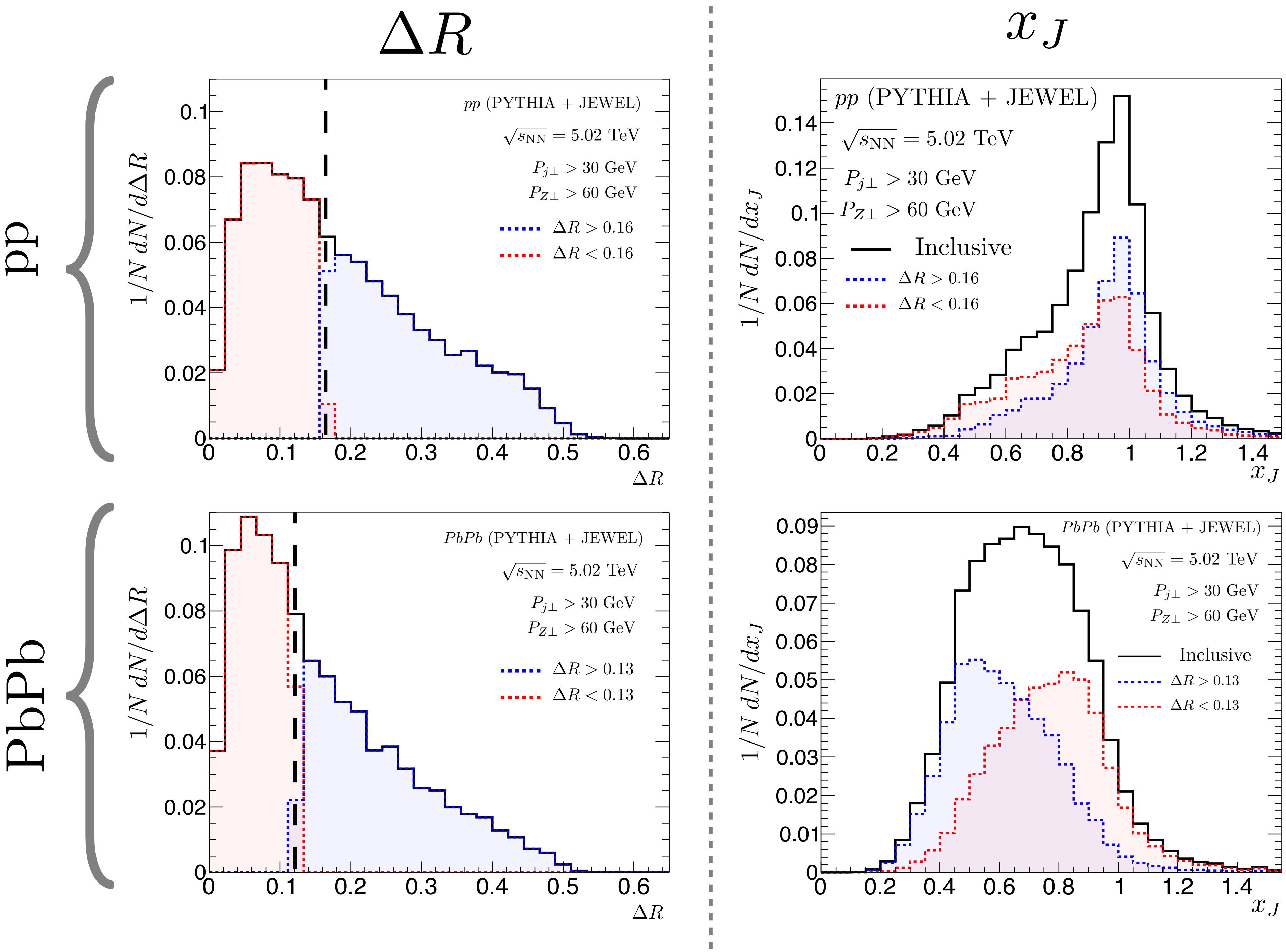

Energy loss in an evolving QCD medium (revisited)

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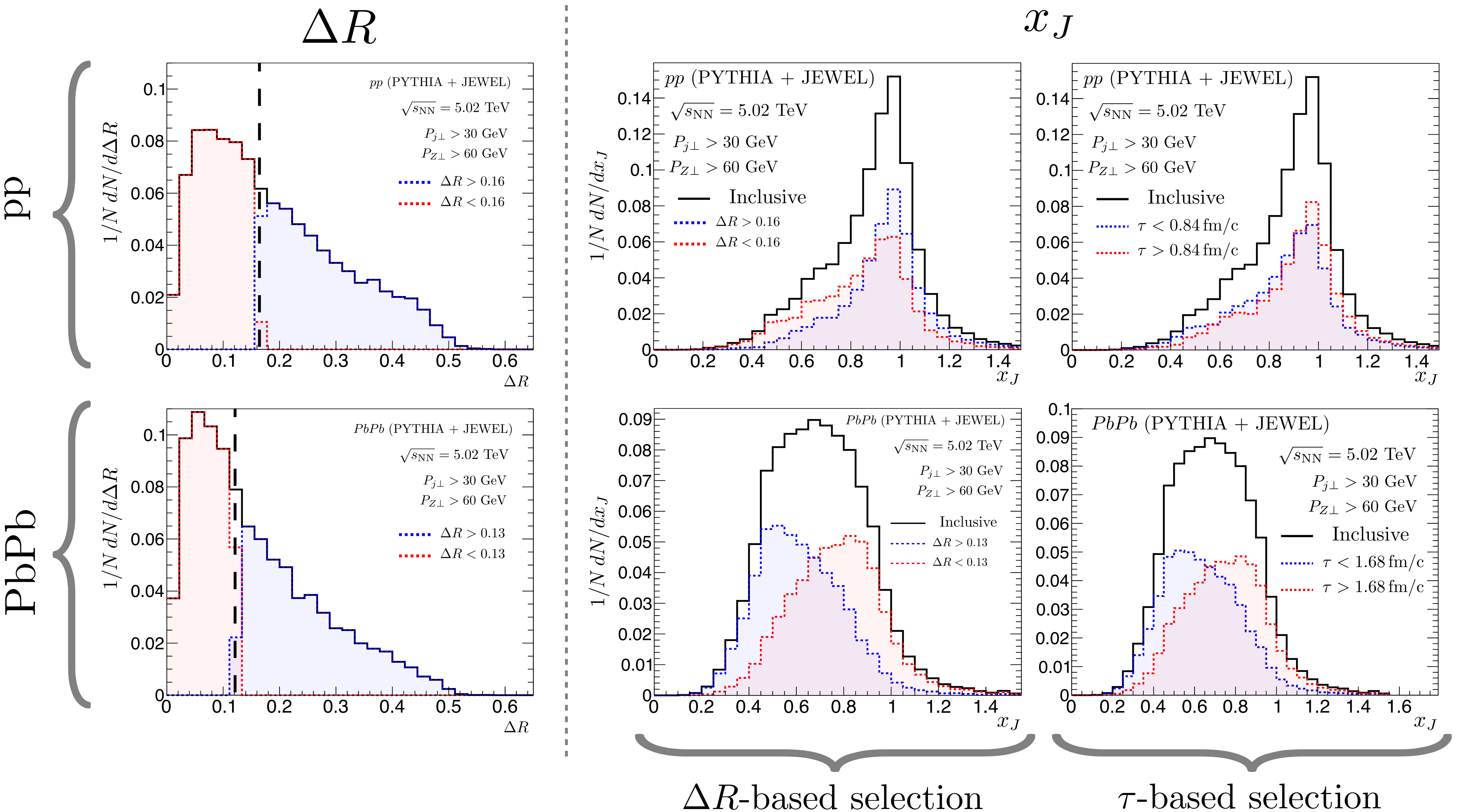
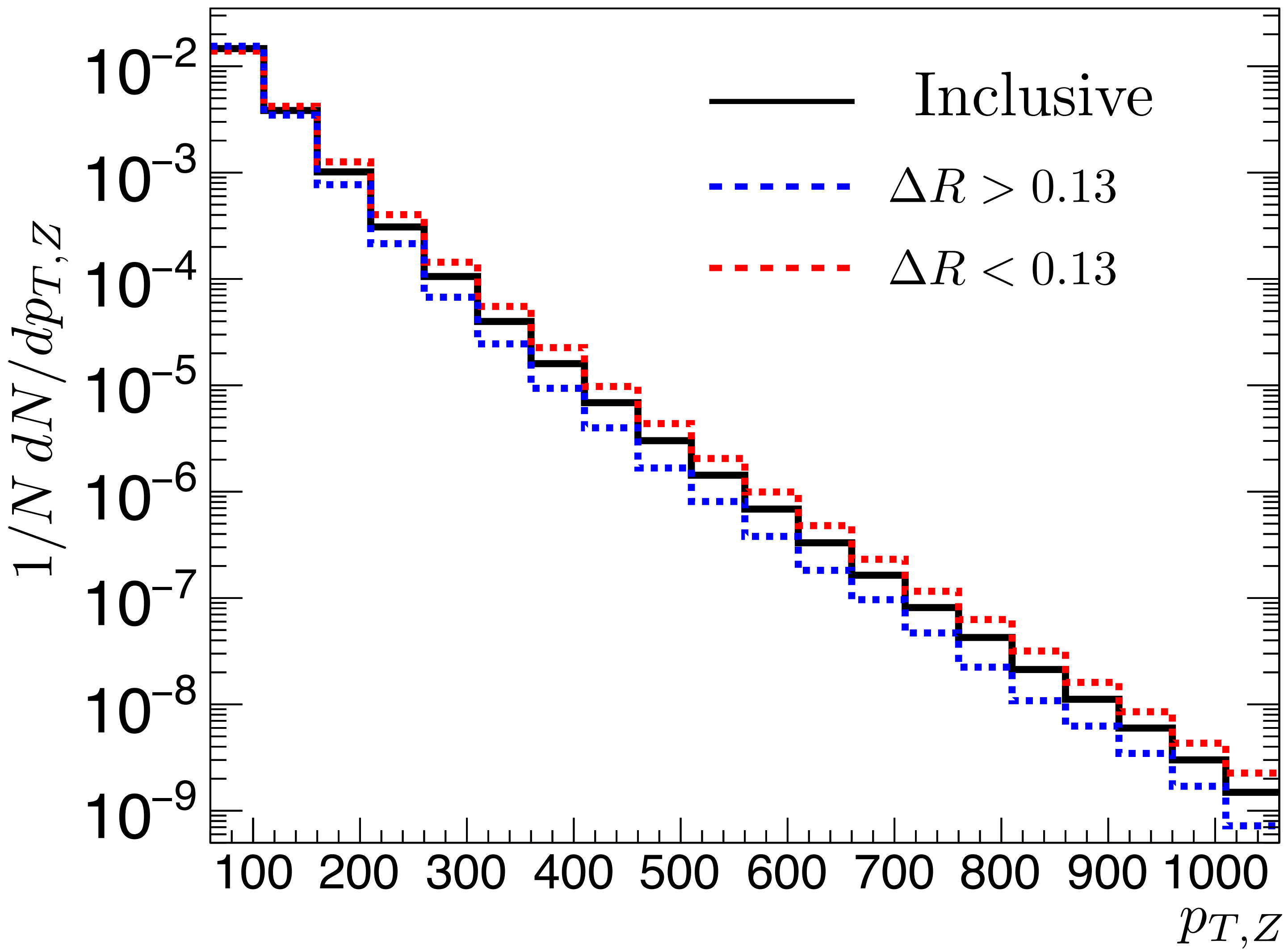


- **Same jet selection as with** $\tau_{\rm form}$ **?**

$\tau_{\rm form}$ or ΔR : bias comparison

- **But** selecting in terms of $\tau_{\rm form}$ minimizes the distorsion of the initial p_t spectra of our samples
- **This is essential to compute ΔE!**



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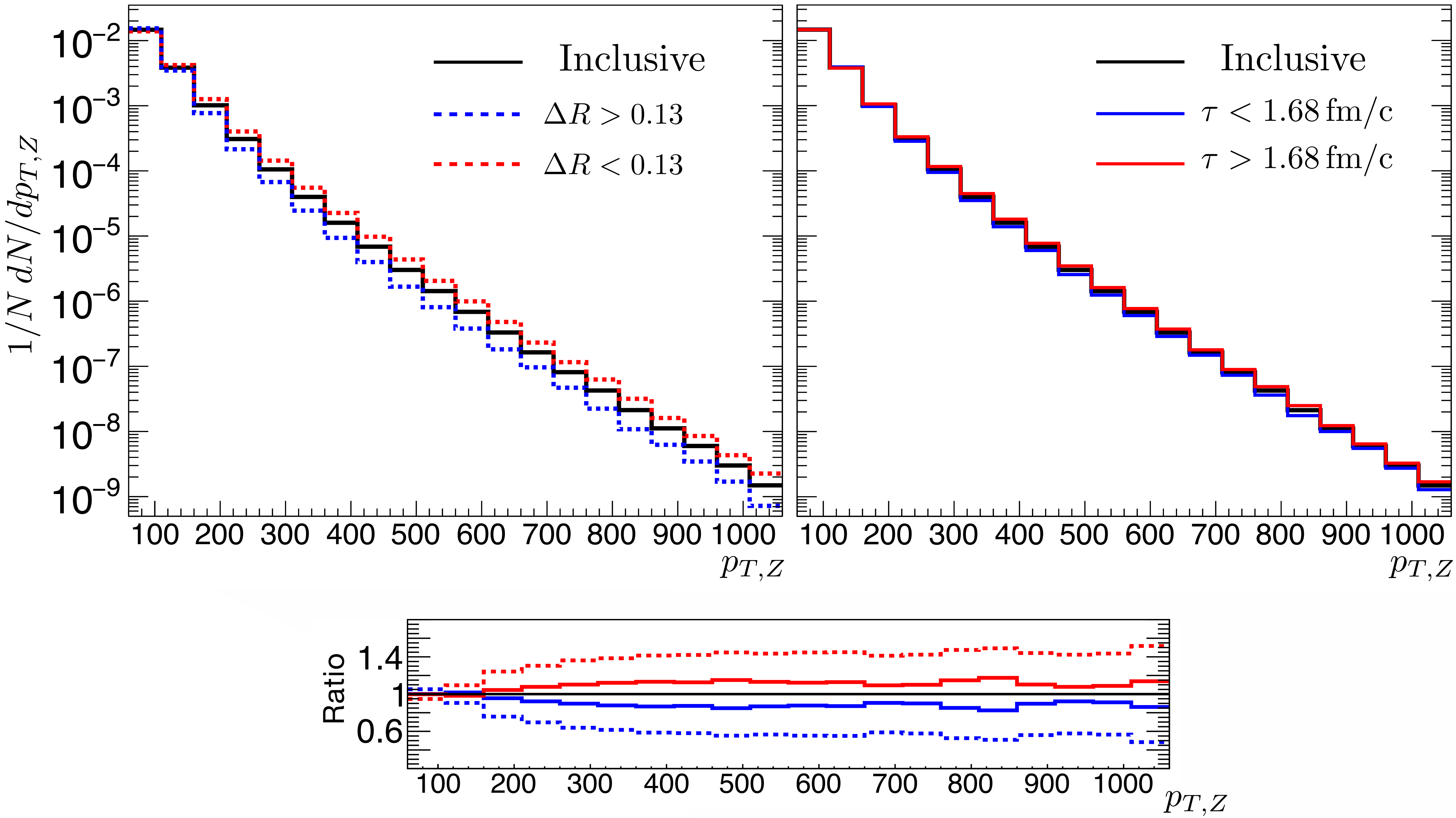


Summary, future prospects

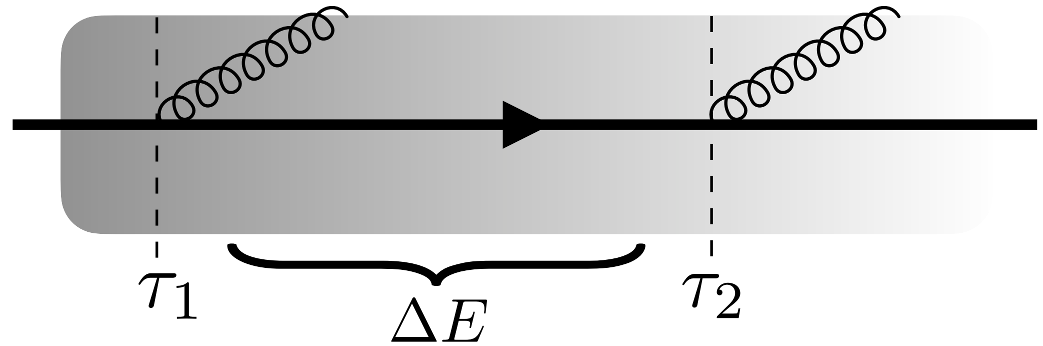
- We use the tau-algorithm to extract the formation time corresponding to the first splitting of the parton showers
- This information allows to classify jets according to sensitivity to medium interactions
- We checked that $\tau_{\rm form}(p_{T,i}, \Delta E)$ (unlike $\Delta R(p_{T,i}, \Delta E)$)

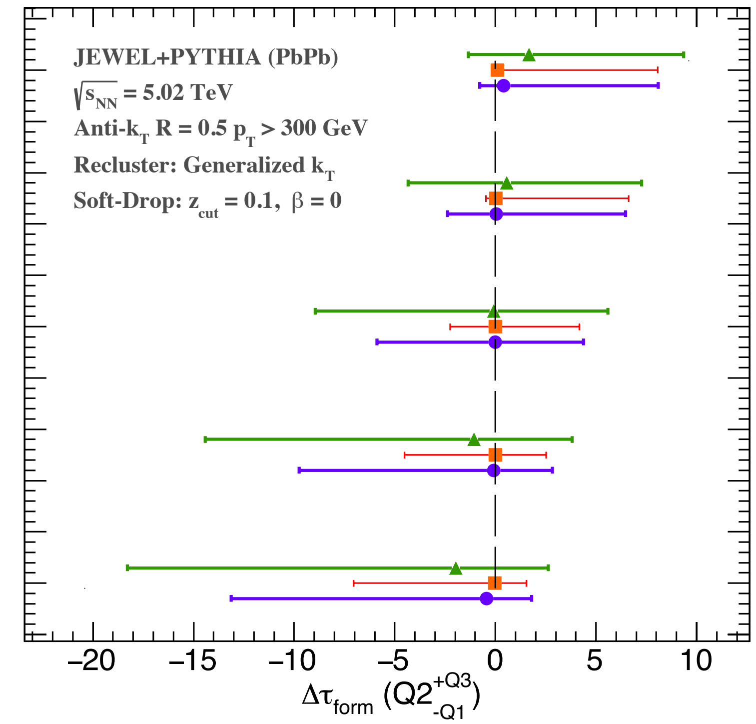
- To-do list:
  - ➡ Include medium response (JEWEL 2.4.0 available!)
  - ➡ Check performance of $\tau_{\rm form}$ -based binning with other jet substructure observables (for example, z_g, jet radial profile, etc.)
  - ➡ Can we make the association $\tau_{\rm form} \longrightarrow \tau_{\rm medium}$?
  - ➡ Can we use subsequent splittings of the shower to make differential measurements?
  - ➡ …

TO APPEAR SOON IN ARXIV!

Back-up: With regard to the second splitting

- Necessary in order to relate **energy loss to path length within the medium**

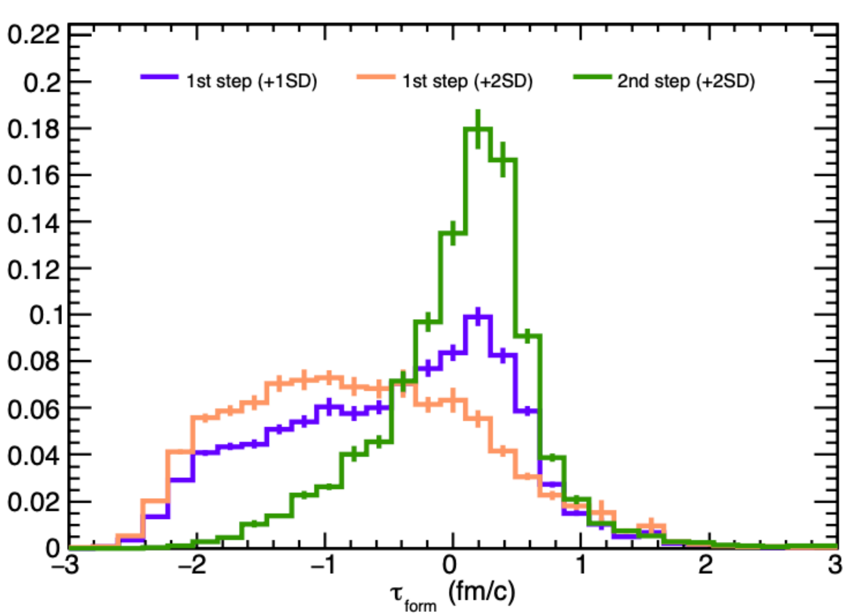


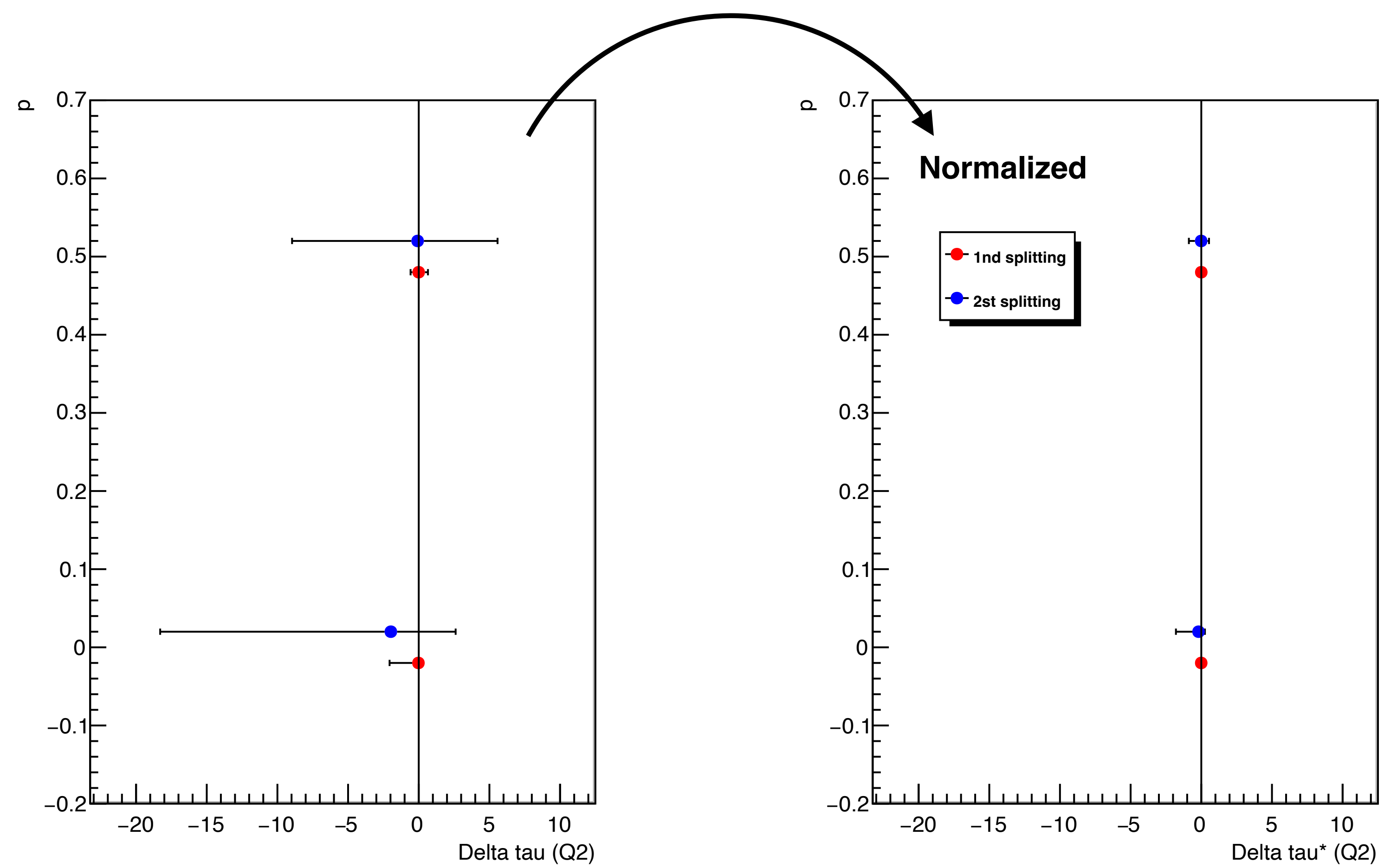


- But the IQR for the second step is significantly larger
  - ✳ However, so is τ_{form}!
  - ✳ How about using the *relative* IQR?

  This seems to do the trick, but…

- By looking at jets with at least two splittings, we are introducing new biases





Back-up: Effectiveness of proxy

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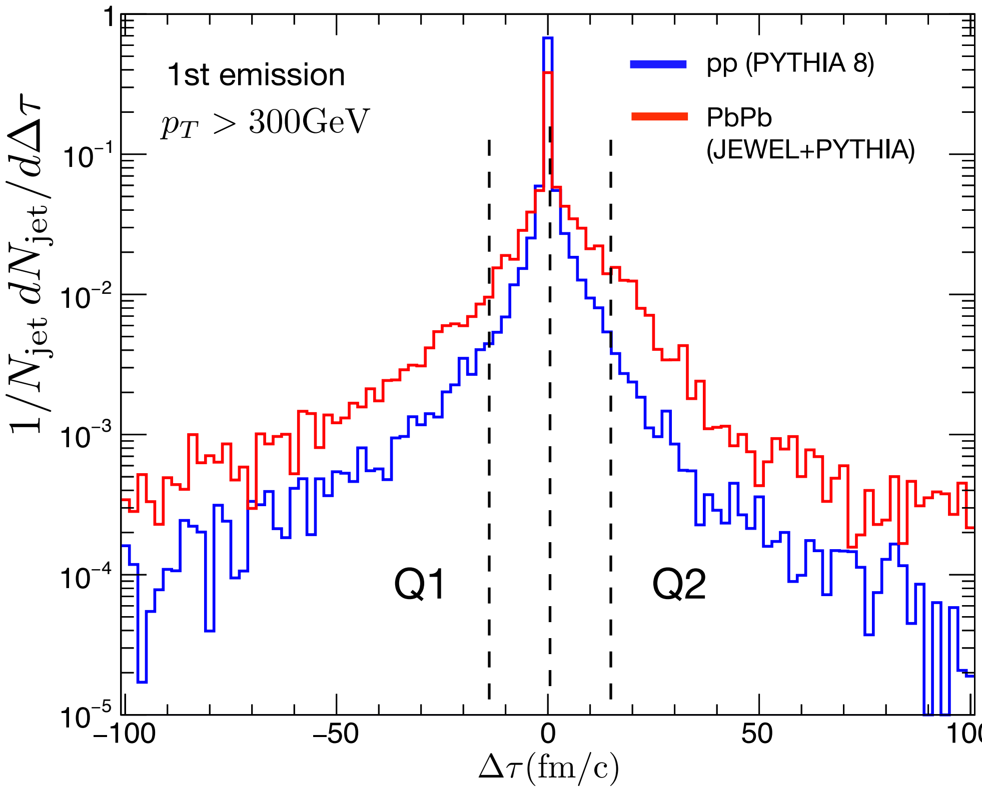
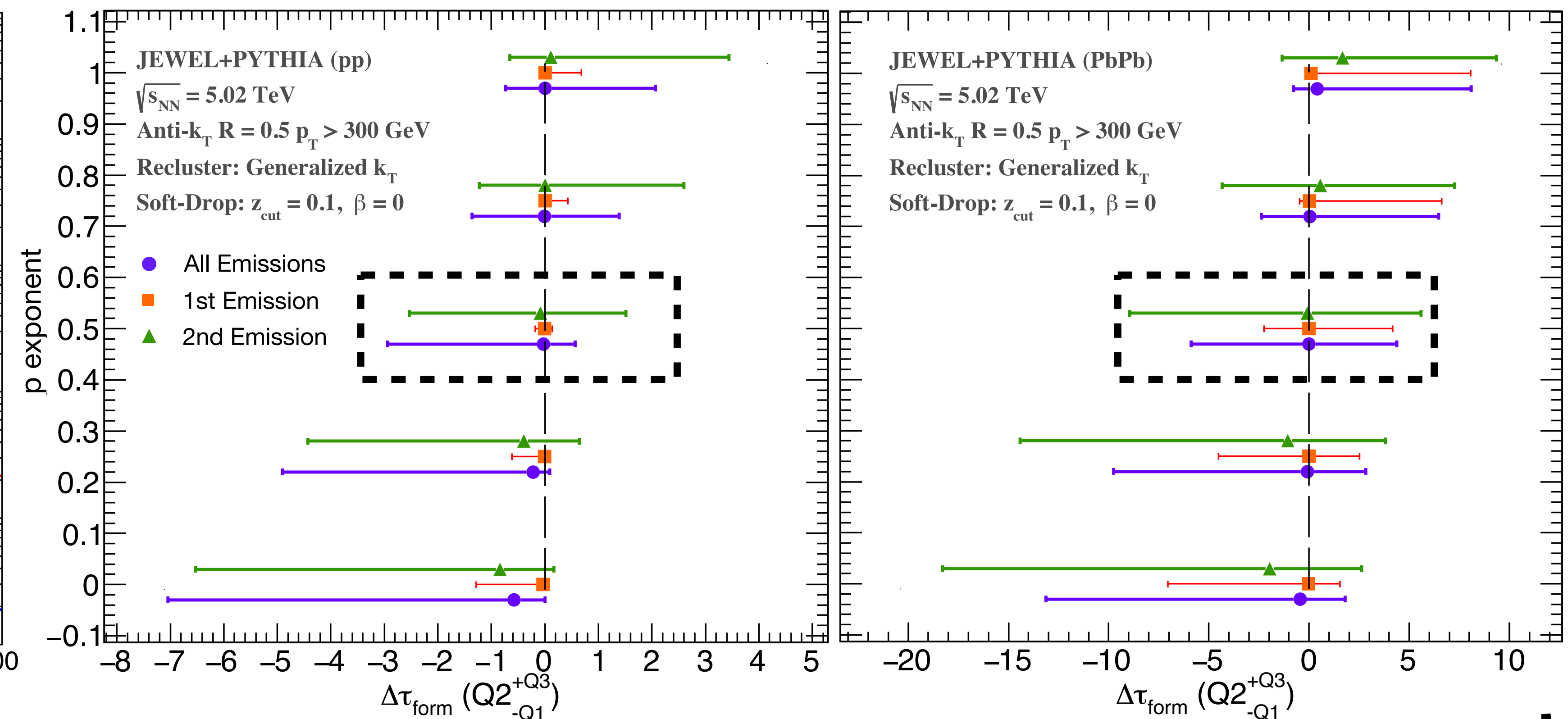
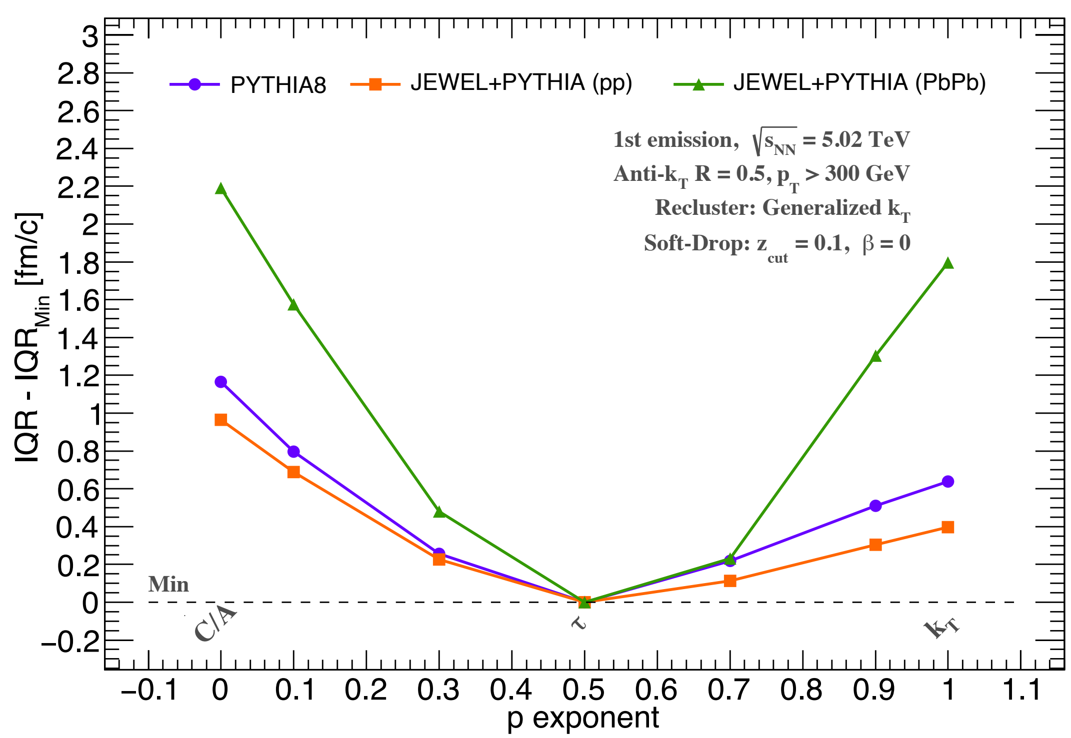
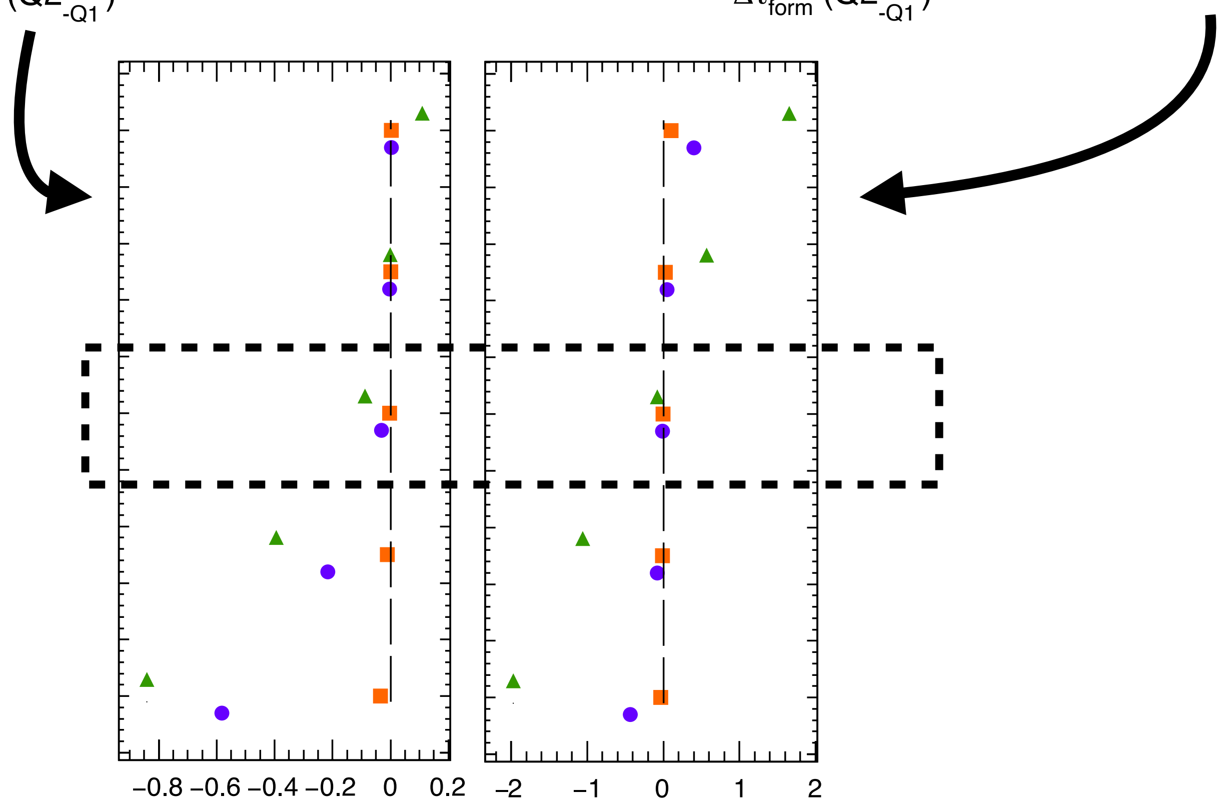
- We want to quantify the correlation between the values of $\tau_{\rm form}$ obtained through unclustering and those extracted from MonteCarlo-generated **di-jet events**. We look at $\Delta\tau = \tau_{\rm form}^{\rm MC} - \tau_{\rm form}^{\rm Unclustering}$ distributions:





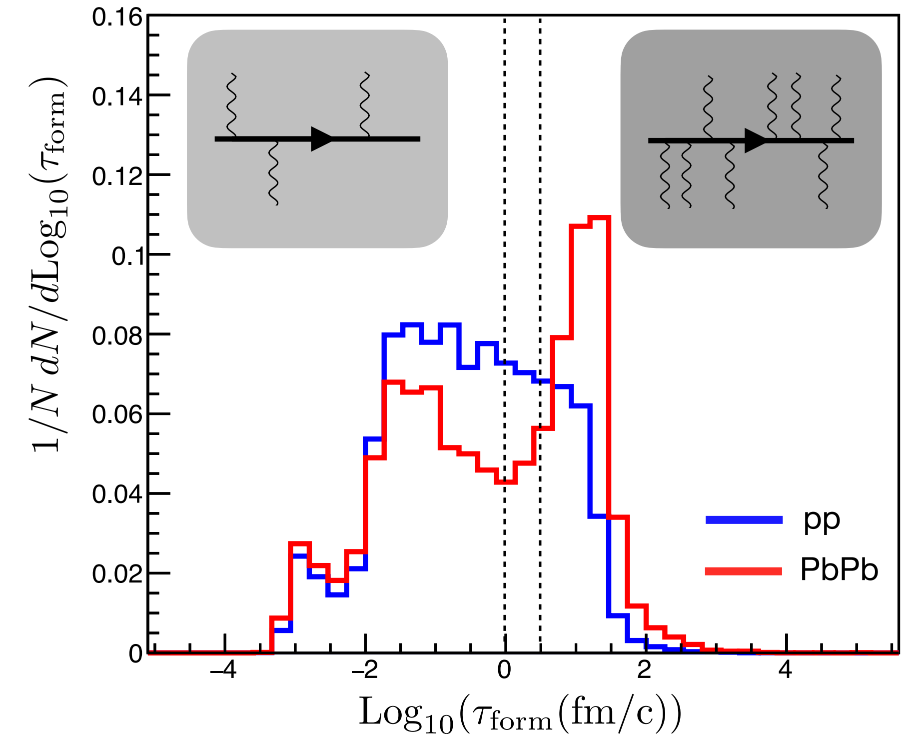
- We compare for different algorithms and different parton showers:



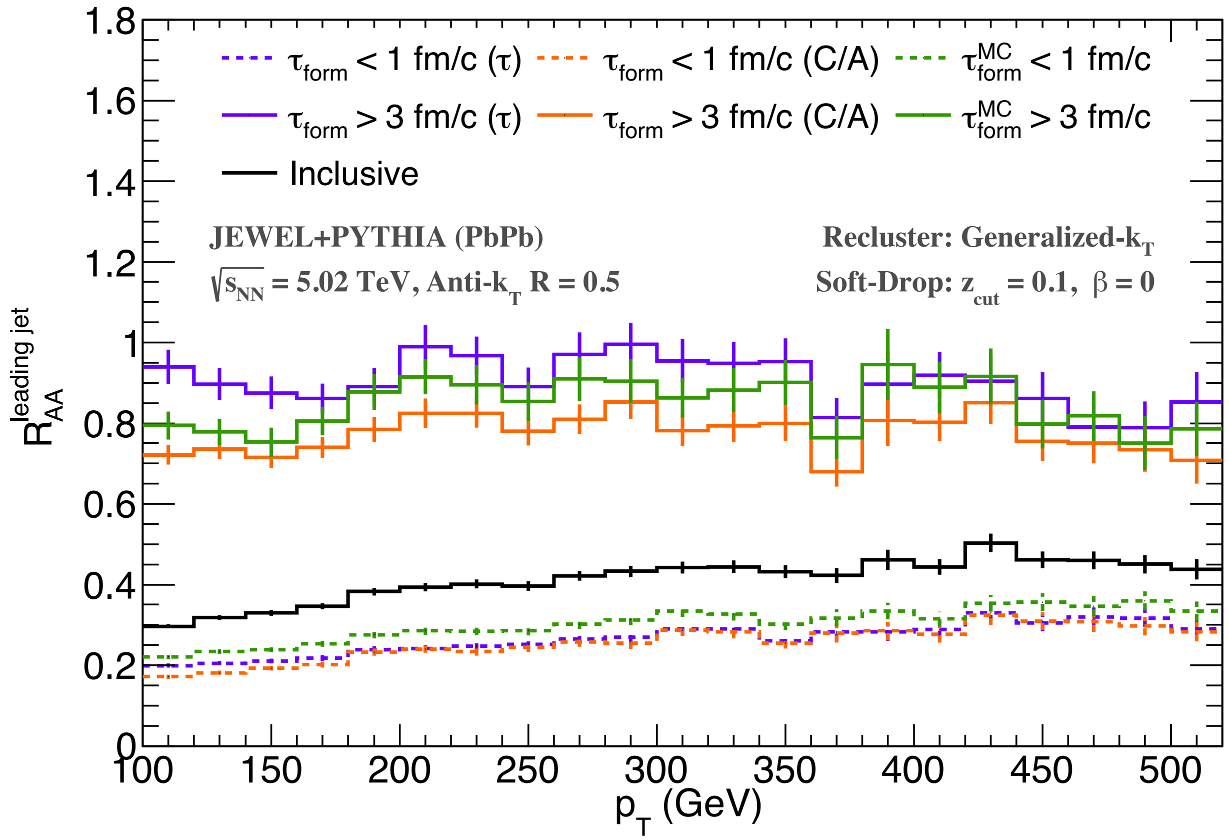


Back-up: The τ -algorithm applied to jet selection (more)

- We define two populations according to the value of $\tau_{\text{form}}^{\text{Unclustering}}$ for the first splitting:
  - ✳ **Early jets** (first 1 fm/c) ⟶ **Strongly modified**
  - ✳ **Late jets** (after 3 fm/c) ⟶ **Weakly modified**



- We compute the **nuclear modification factor** for each population:



⟶ **Weakly modified**

⟶ **Strongly modified**

$$R_{\text{AB}} = \frac{1}{\langle N_{\text{coll}} \rangle} \frac{dN/dp_T|_{\text{A+B}}}{dN/dp_T|_{\text{p+p}}}$$

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Back-up: What about the dispersion of the distributions?

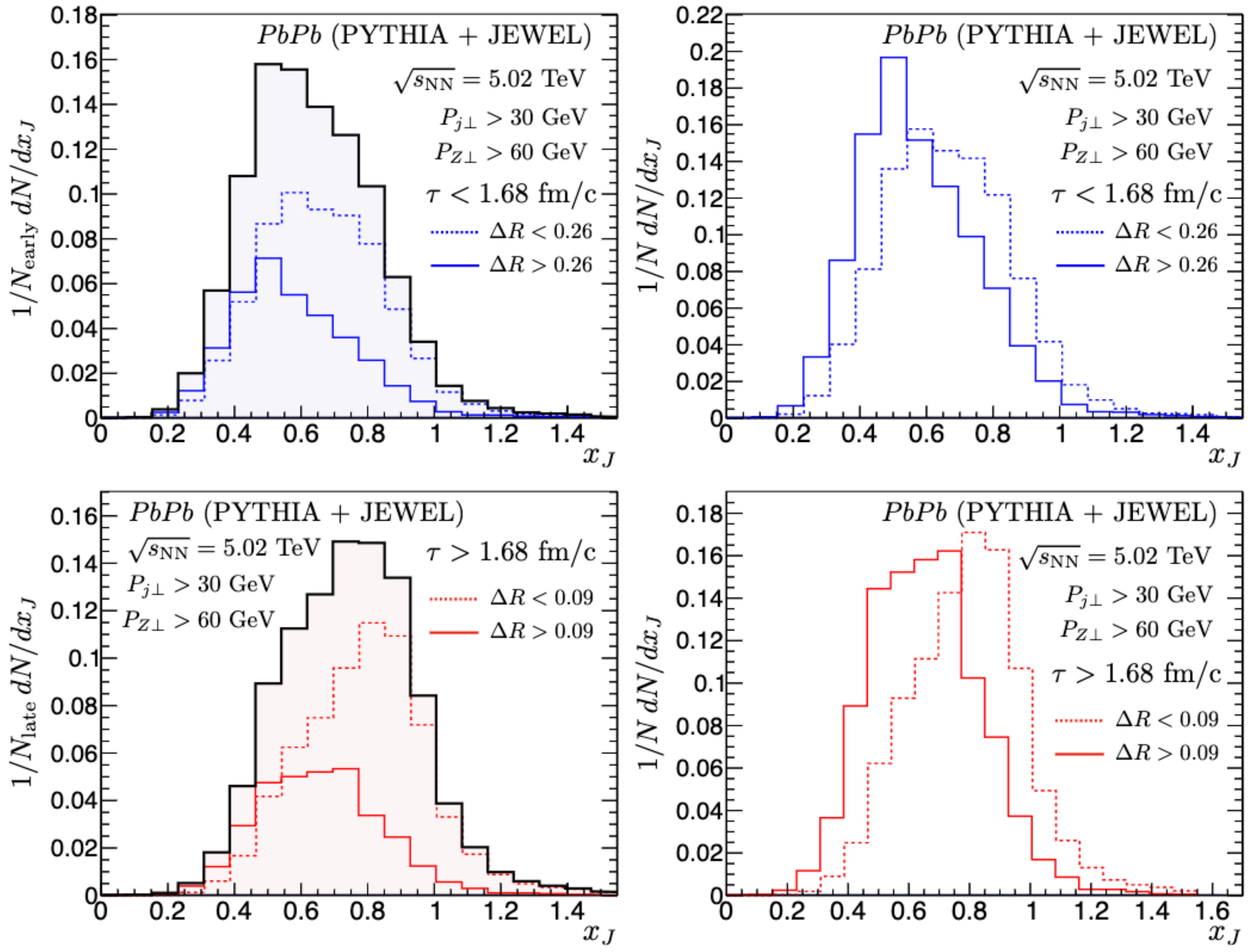

FIG. 2: Comparison of x_{jZ} distributions for narrow (full colored lines) and wide (dashed lines) subsamples taken from the early (top) and late (bottom) PbPb jet selections. The distributions in the left panels are normalized to the size of the corresponding parent jet samples, represented as full black lines above color-shaded areas (note that these same distributions were shown previously in the left bottom plot of Fig. 1). In the right panels we display the narrow and wide subsamples only, each normalized to unity.