

Medium-enhanced $c\bar{c}$ radiation

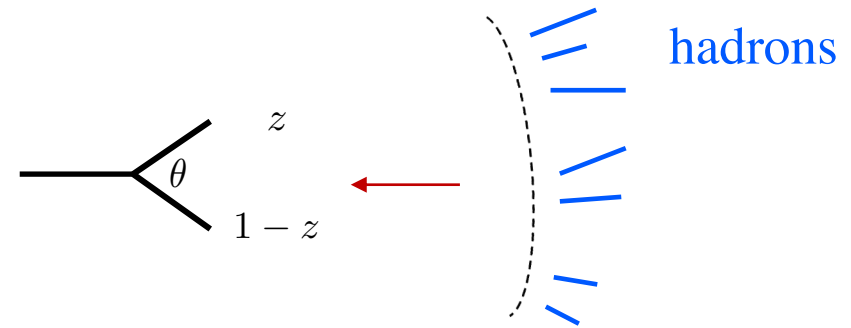
Jasmine Brewer



In collaboration with Maximilian Attems, Gian Michele Innocenti, Aleksas Mazeliauskas, Sohyun Park, Wilke van der Schee, and Urs Wiedemann

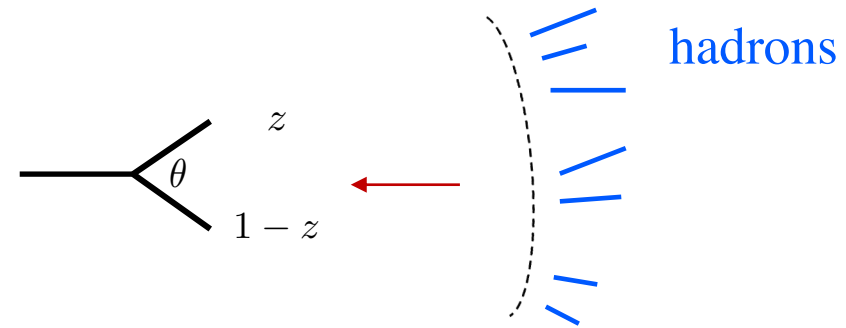
Building up a picture of a medium-modified jet from phenomenology

- **Hadrons to splittings**



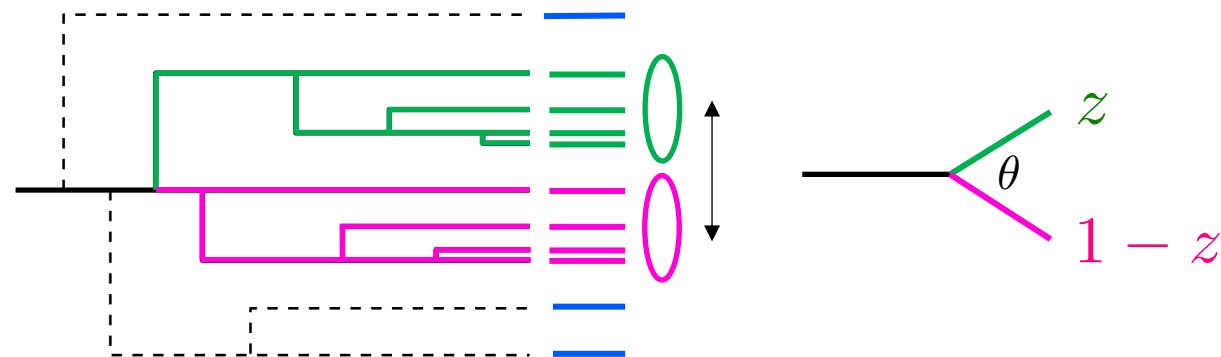
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- **Hadrons to splittings**



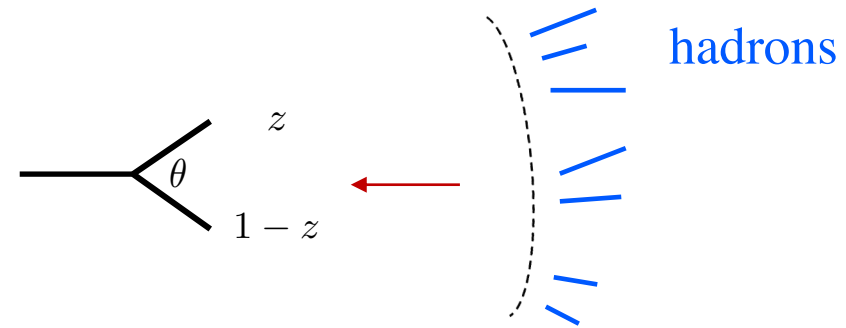
Jet substructure:

Use angular ordering of QCD to reconstruct emission history of shower from hadrons

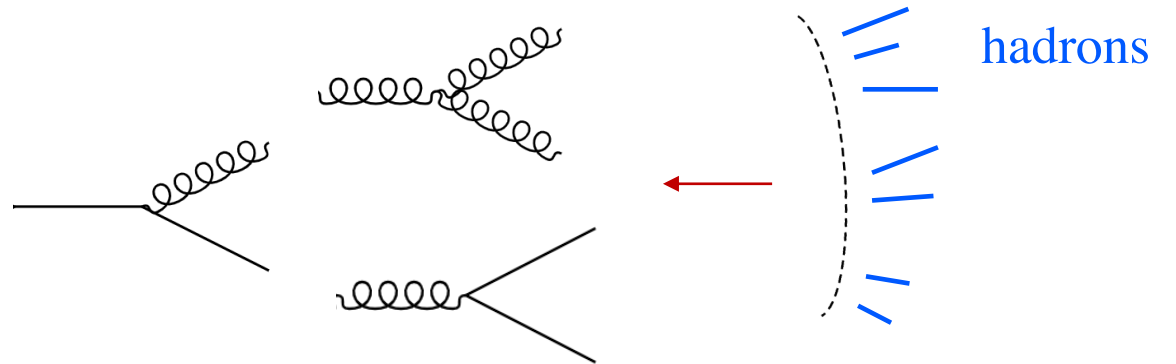


Building up a picture of a medium-modified jet from phenomenology

- Hadrons to splittings

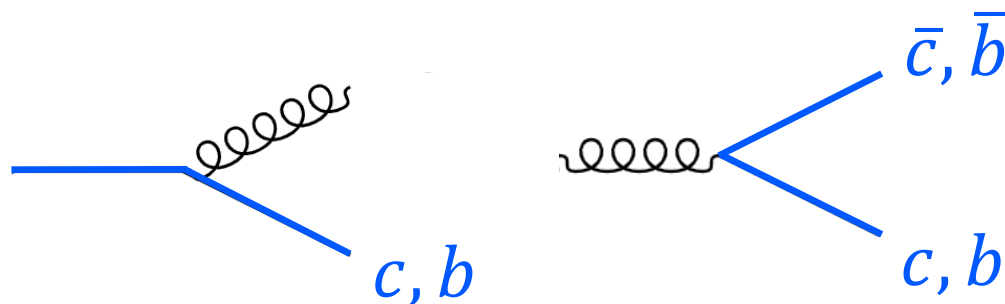


- Flavor-dependence of splittings



Accessing heavy flavor splitting functions

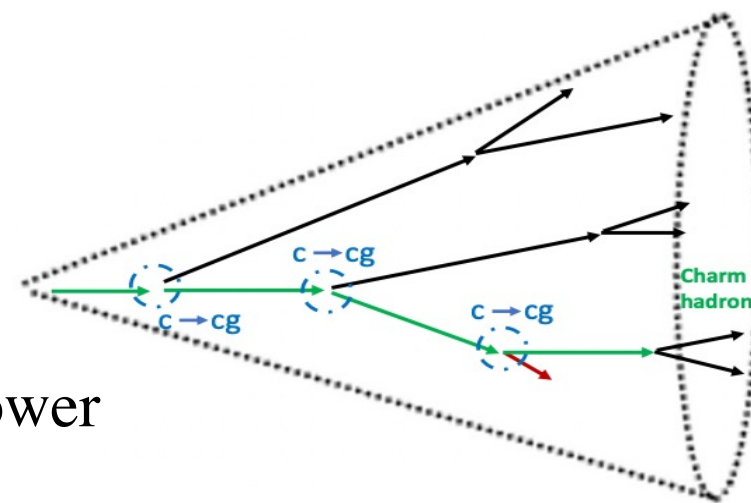
Heavy flavor splittings:



Advantages:

- Heavy flavor is preserved in the shower and not produced at hadronization
- Access late (more modified) splittings in the shower
- At high energies, access light flavor splittings

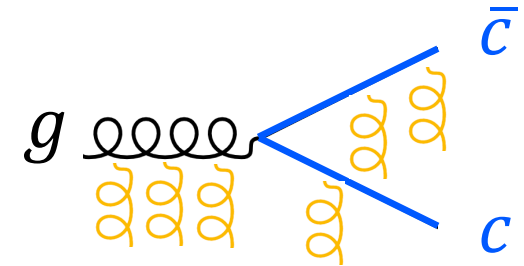
Used in ALICE [2106.05713]



Focus of this talk: phenomenology of $g \rightarrow c\bar{c}$

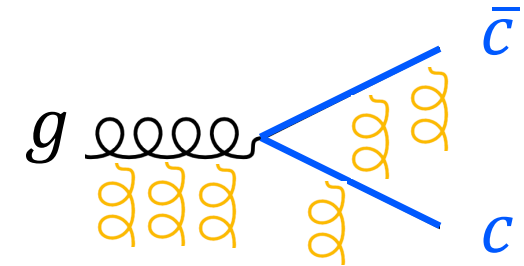
Unique features of the modification of $g \rightarrow c\bar{c}$

Signature of momentum broadening of $c\bar{c}$ pair

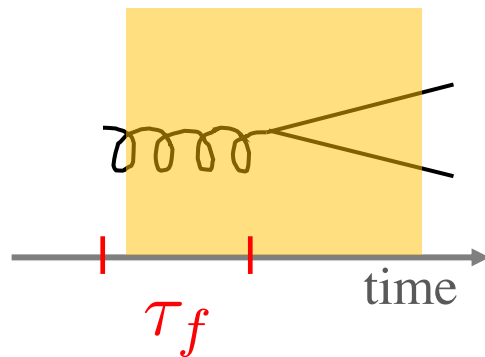


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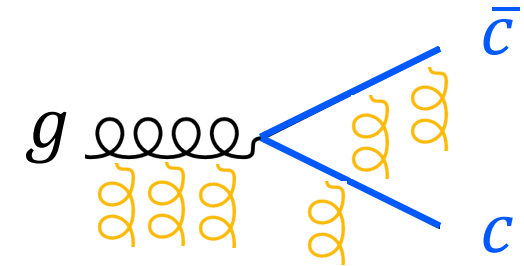


Gluons have a “lifetime” $\tau_f \sim \frac{2E_g}{Q^2}$ depending on their energy



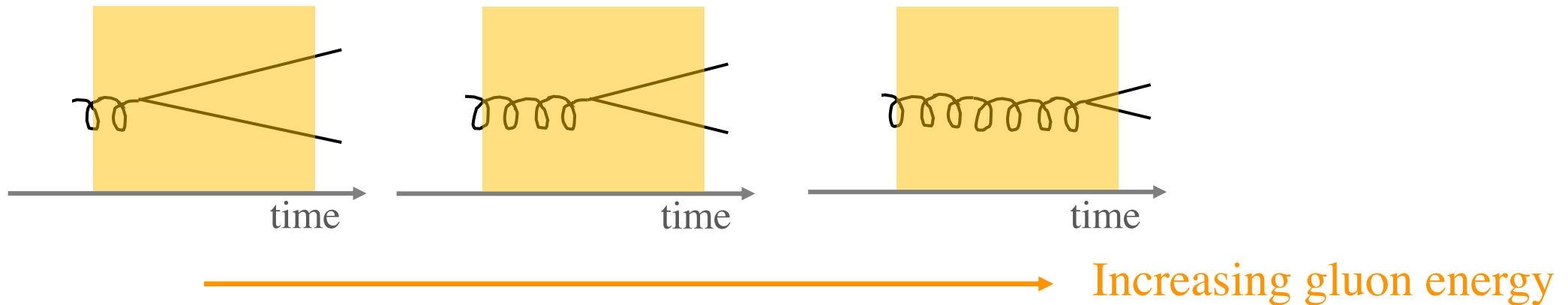
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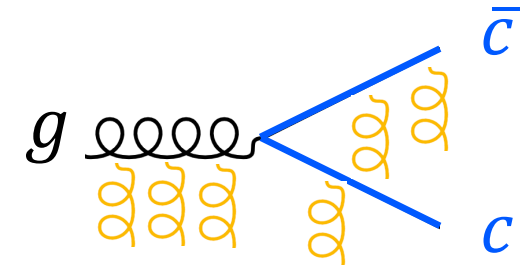
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- Access modification of $c\bar{c}$ pair at later times in the QGP



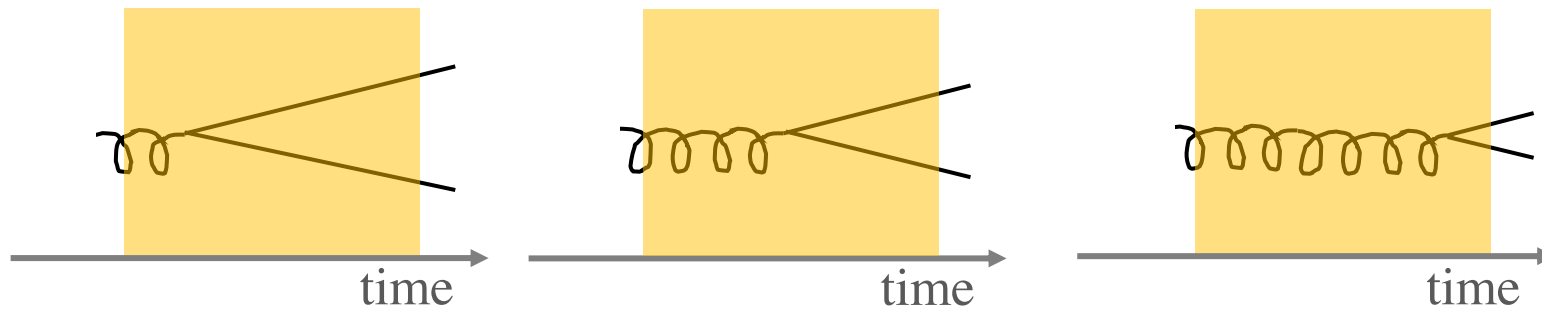
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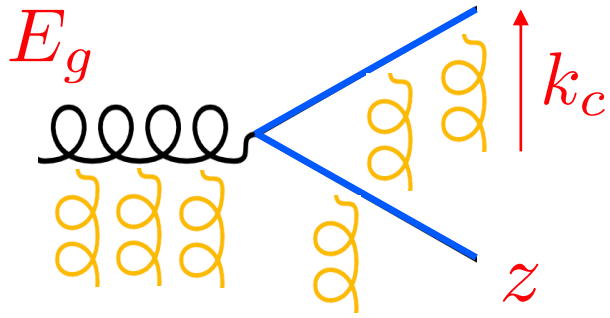
- Access modification of $c\bar{c}$ pair at later times in the QGP



$\sim 1 - 6$ fm delay for
20 – 100 GeV gluons

Increasing gluon energy

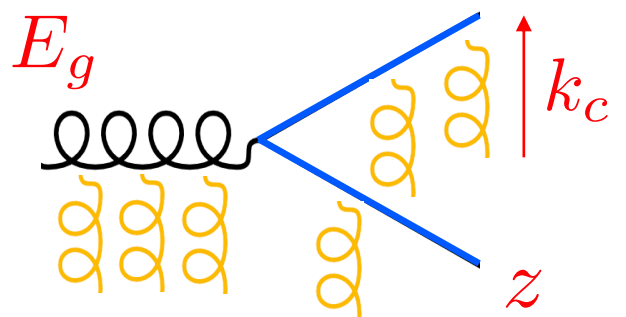
Modification of the $g \rightarrow c\bar{c}$ splitting function



$$P_{g \rightarrow c\bar{c}}(E_g, k_c^2, z) = P_{g \rightarrow c\bar{c}}^{\text{vac}}(k_c^2, z) + P_{g \rightarrow c\bar{c}}^{\text{med}}(E_g, k_c^2, z)$$

Resum arbitrarily-many soft gluon interactions
with a medium of length L

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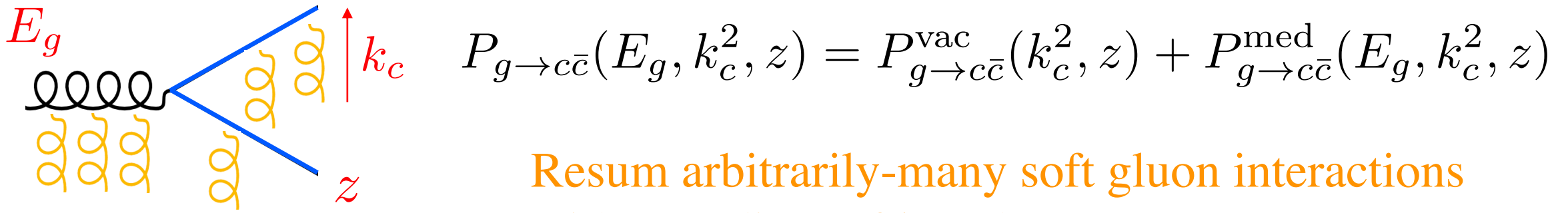
Resum arbitrarily-many soft gluon interactions with a medium of length L

Results of the calculation:

- Depletion at small k_c^2

broadening

Modification of the $g \rightarrow c\bar{c}$ splitting function



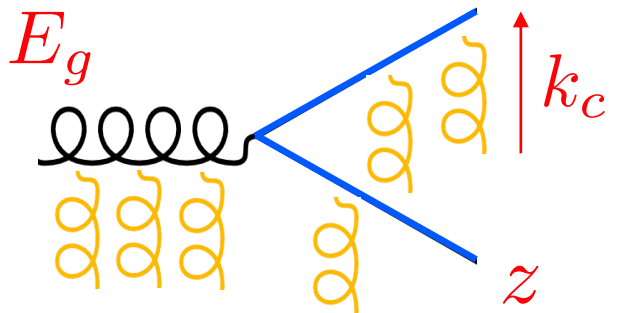
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Resum arbitrarily-many soft gluon interactions with a medium of length L

Results of the calculation:

- Depletion at small k_c^2 broadening
- Less modification with increasing E_g formation-time dependence

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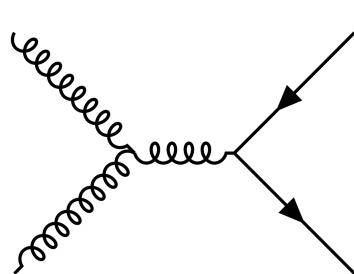
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Results of the calculation:

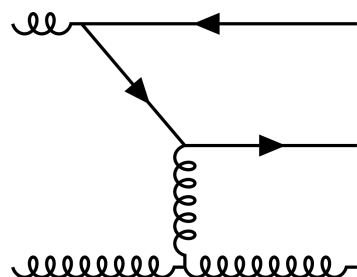
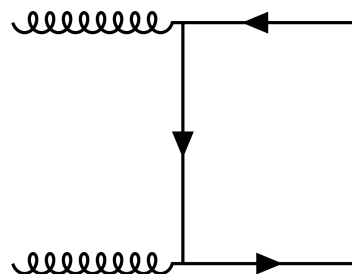
- Depletion at small k_c^2 broadening
- Less modification with increasing E_g formation-time dependence
- Medium-enhanced rate of $c\bar{c}$ production! gluons promoted above threshold

Phenomenologically accessing the $g \rightarrow c\bar{c}$ splitting in jets

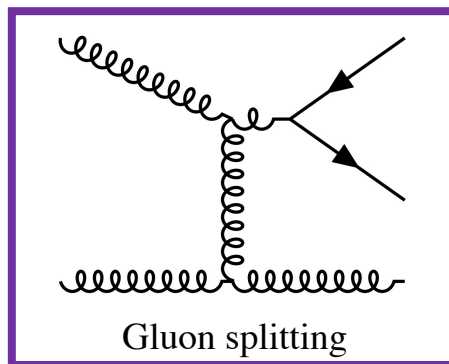
Leading processes for heavy quark production



Flavor creation

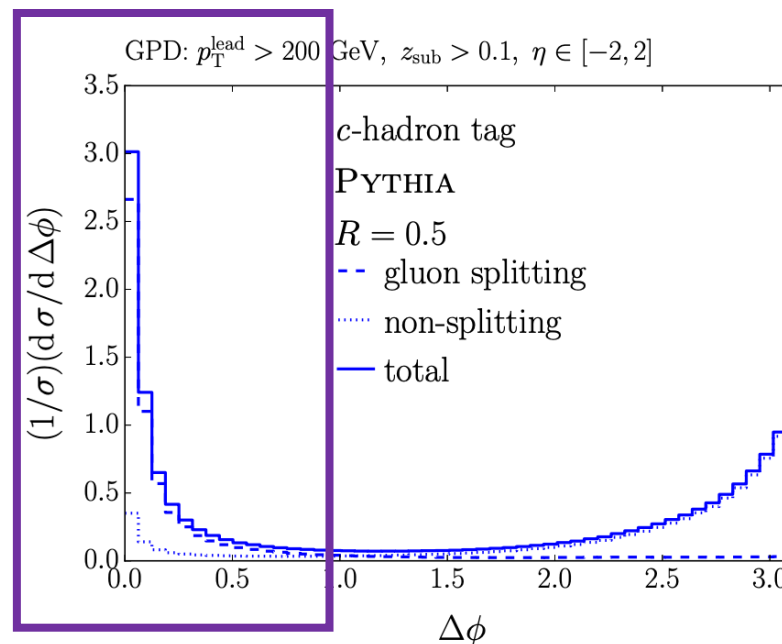
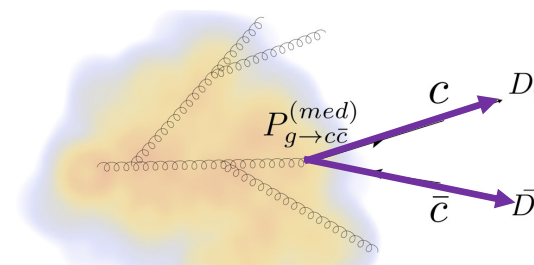


Flavor excitation



Gluon splitting

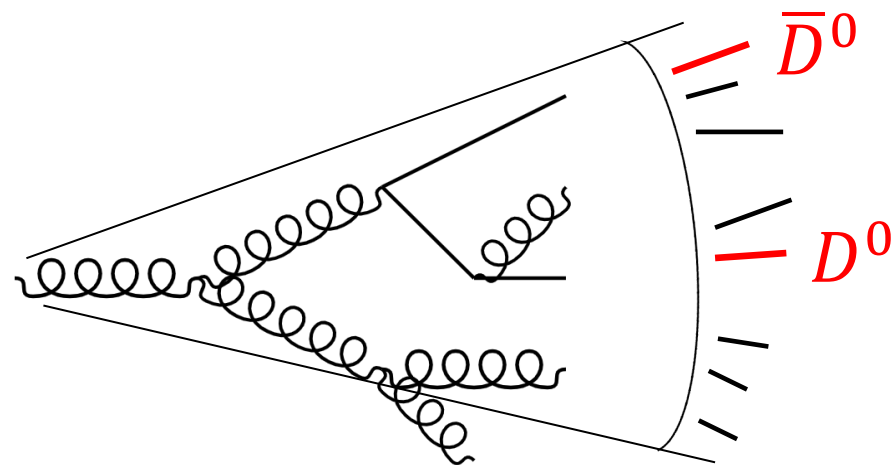
(approximately) collinear



Gluon splitting

Non-gluon-splitting

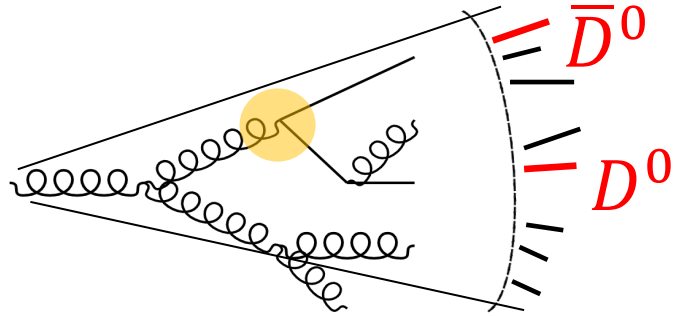
Phenomenologically accessing the $g \rightarrow c\bar{c}$ splitting in jets



High-purity sample of showers
including $g \rightarrow c\bar{c}$ splitting

Expected experimental sensitivity already in Run 3/4

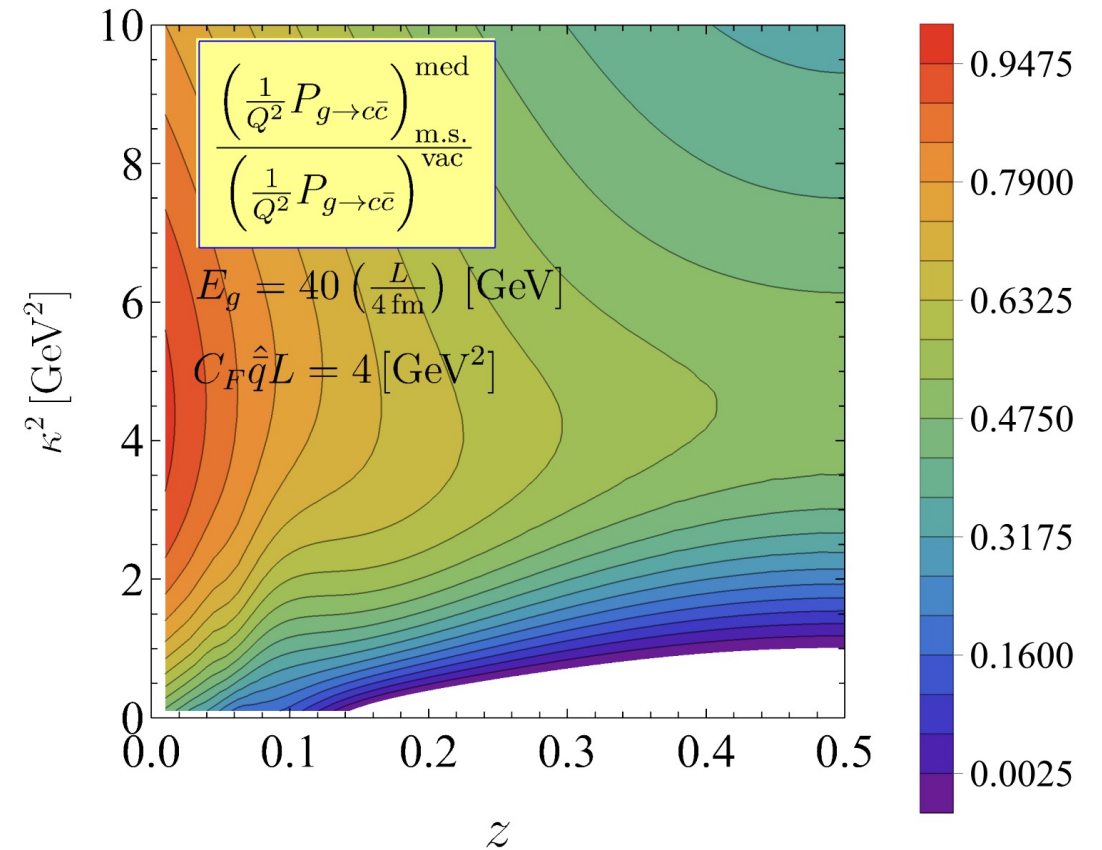
Observing $g \rightarrow c\bar{c}$ enhancement in jets



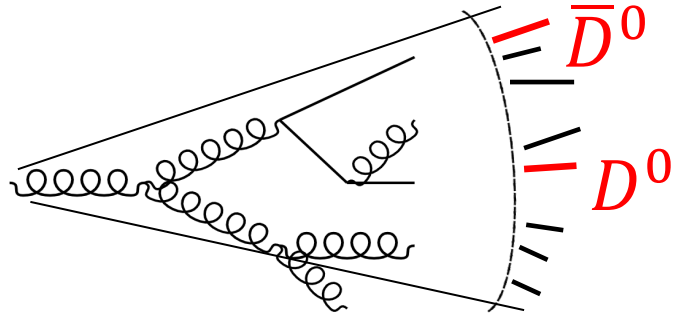
Get kinematics of $g \rightarrow c\bar{c}$

Reweight each splitting by

$$w_{g \rightarrow c\bar{c}}^{med}(E_g, k_c^2, z) = 1 + \frac{\left(\frac{1}{Q^2} P_{g \rightarrow c\bar{c}}\right)^{med}(E_g, k_c^2, z)}{\left(\frac{1}{Q^2} P_{g \rightarrow c\bar{c}}\right)^{vac}(k_c^2, z)}$$



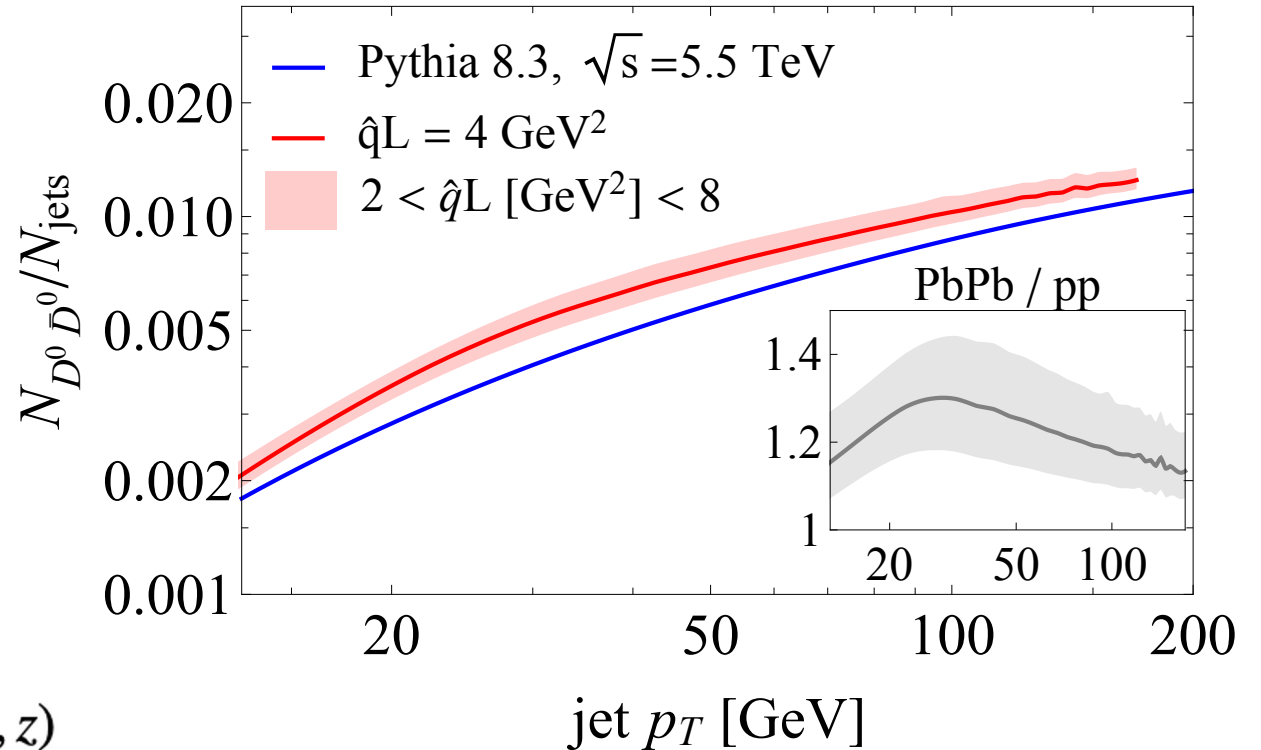
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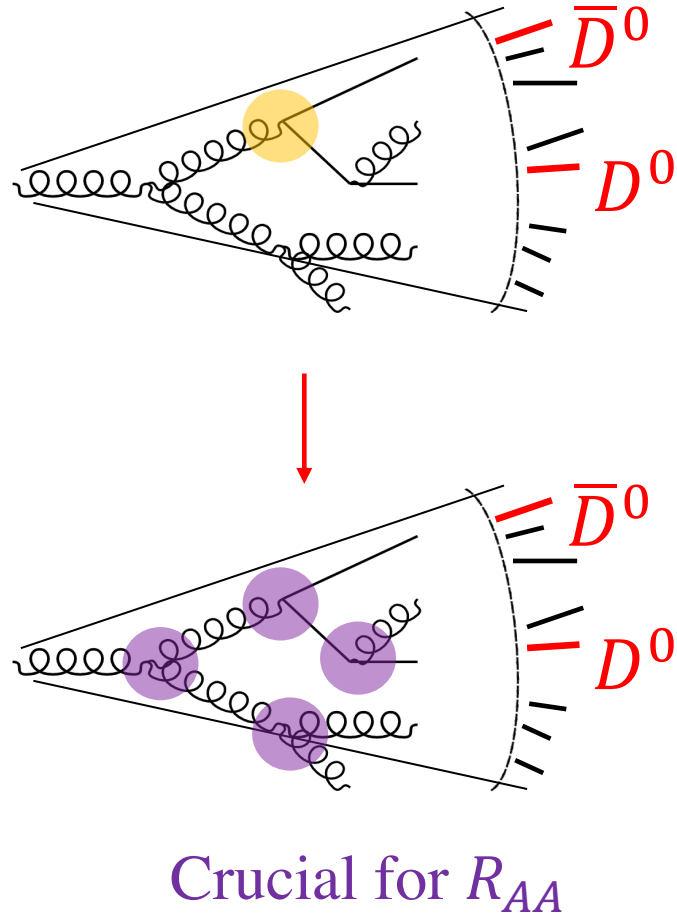
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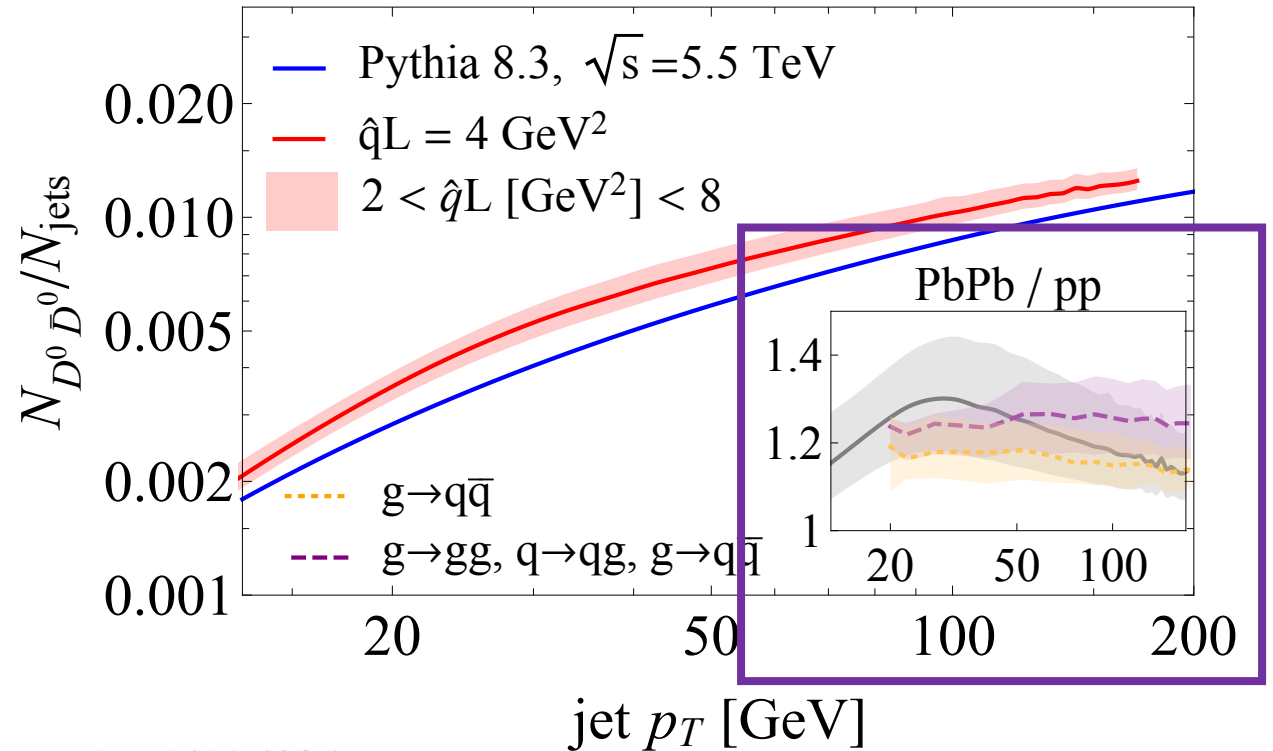
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$N_{D\bar{D}}/N_{\text{jets}}$ is dominantly sensitive to enhancement of $g \rightarrow c\bar{c}$ splittings

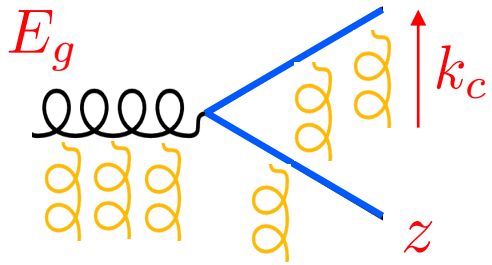


Enhancement of $N_{D\bar{D}}/N_{\text{jets}}$ is generated by modification of $g \rightarrow c\bar{c}$

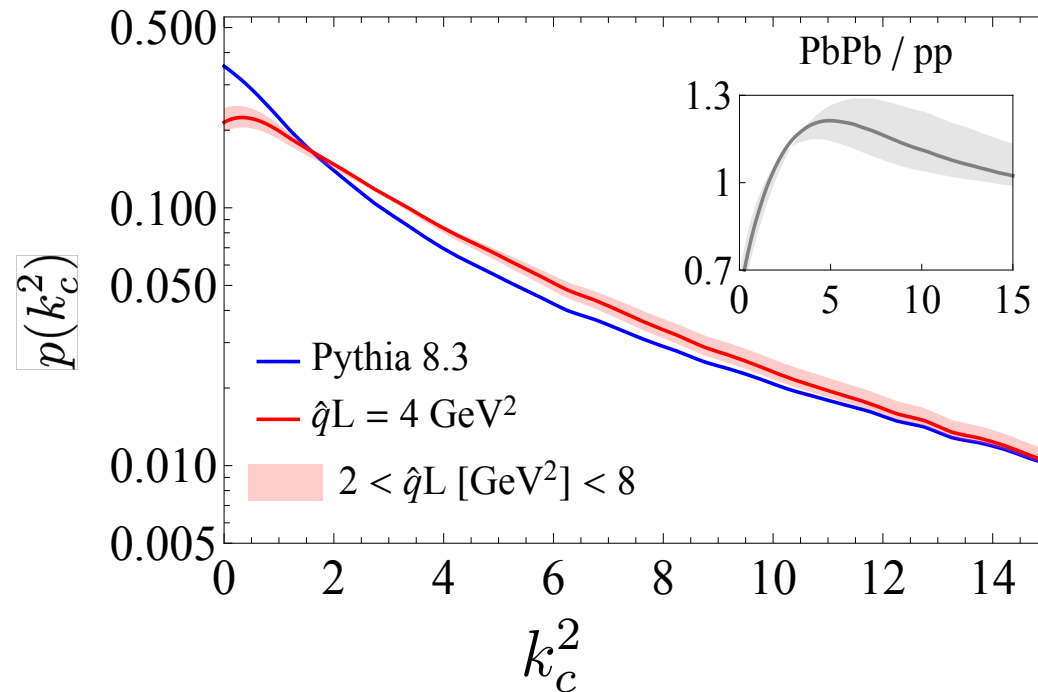


Modified all splittings in simple dipole shower Hoeche [1411.4085]

Going forward: other unique signatures

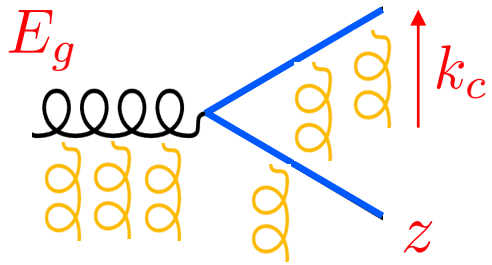


- **Broadening**

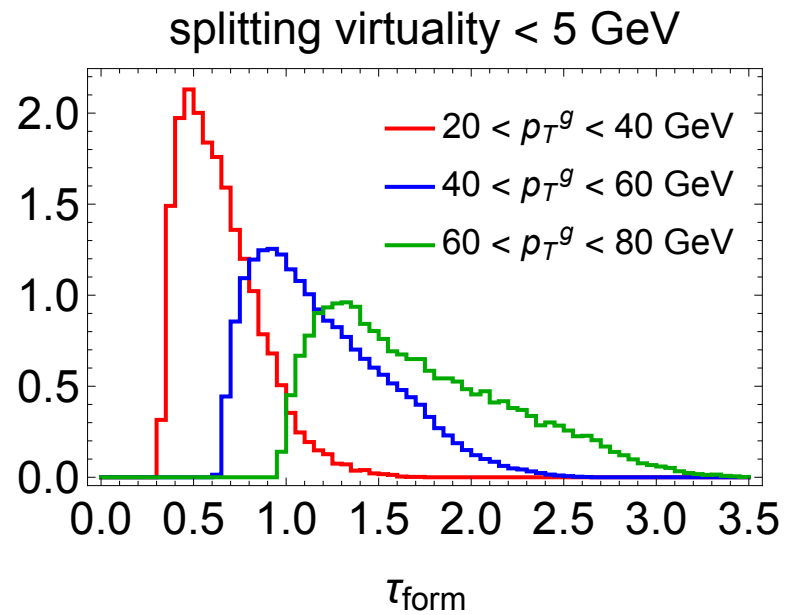


Can use jet substructure to access broadening at hadron-level

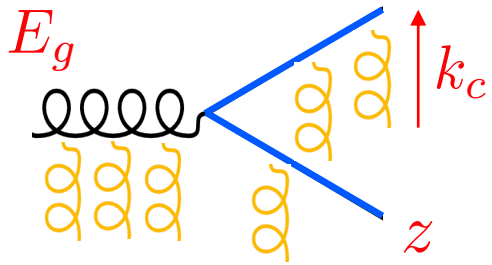
Going forward: other unique signatures



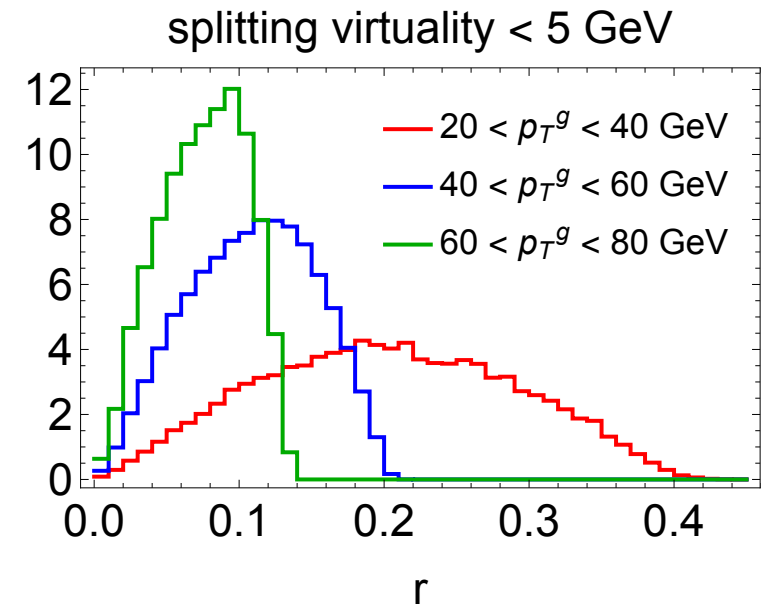
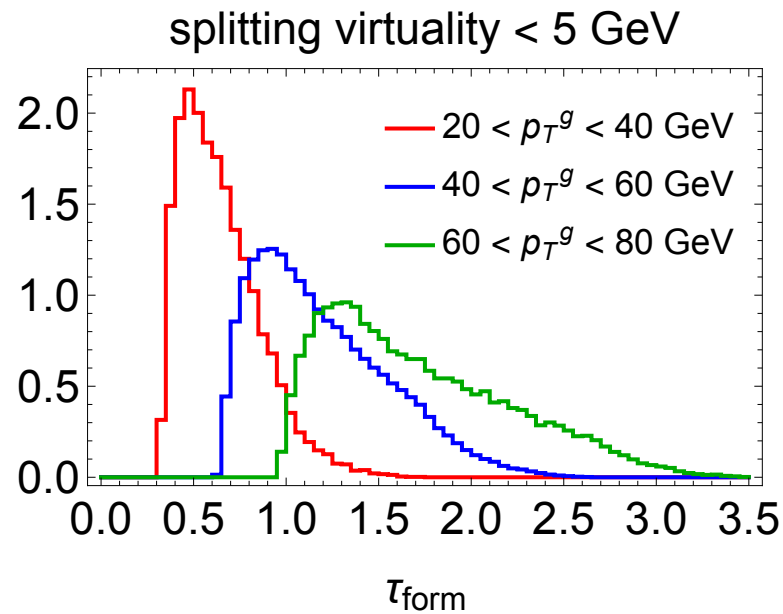
- Formation time dependence



Going forward: other unique signatures



- Formation time dependence



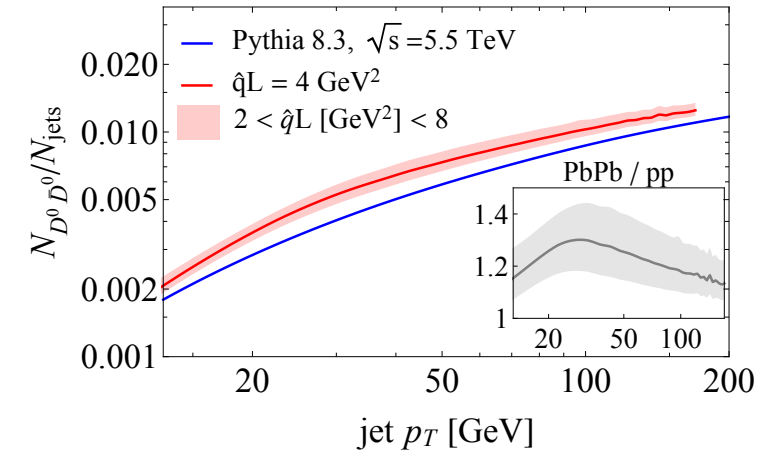
Ongoing: how to quantify modification differentially in formation time?

- Access delayed probe of QGP

A process with many exciting future avenues!

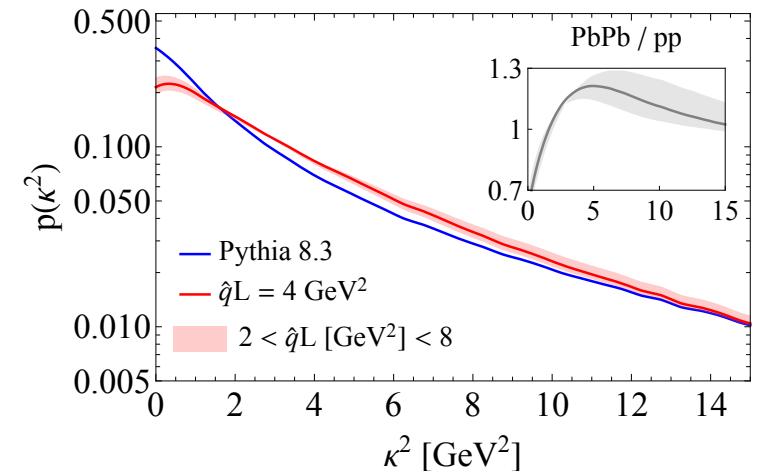
So far..

- Medium-enhanced rate of $c\bar{c}$ production



Outlook

- Broadening of $c\bar{c}$ pair from hadron level
- Formation time dependence of modification



Clean process with a lot of exciting physics opportunities!

$N_{D\bar{D}}/N_{\text{jets}}$ is dominantly sensitive to enhancement of $g \rightarrow c\bar{c}$ splittings

Modification of $g \rightarrow gg$ and $q \rightarrow qg$ splittings dominate jet energy loss

But enhancement of $N_{D\bar{D}}/N_{\text{jets}}$ is generated by modification of $g \rightarrow c\bar{c}$

