Some comments on medium-modified g-> c cbar

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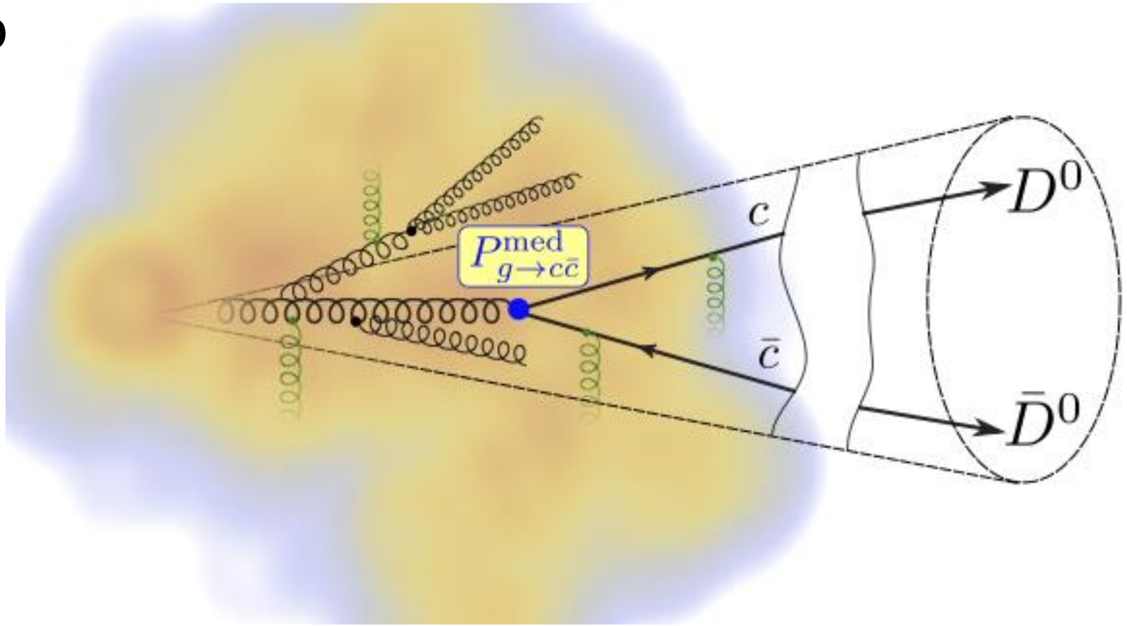
M. Attems, J. Brewer, G.M. Innocenti, A. Mazeliauskas, S. Park, W. v.d.Schee, U.A. Wiedemann, arXiv:2209.13600 and arXiv: 2203.11241

- I discuss the physics underlying small-angle D-Dbar correlations in heavy –ion collisions
- The calculations I present were done for D-Dbar correlations inside jets at the LHC and not at the SPS.
- So, primarily, I entertain you with a story from high-energy nuclear physics.
- However, while non-perturbative physics plays certainly a more prominent role at the SPS, I shall ask whether the calculation may provide qualitative guidance for fixed-target experiments, too



Heavy flavor production –the perturbative picture

- ❑ Cross section*

$$d\sigma = \text{pdf} \otimes \text{Hard} \otimes \text{Frag}$$

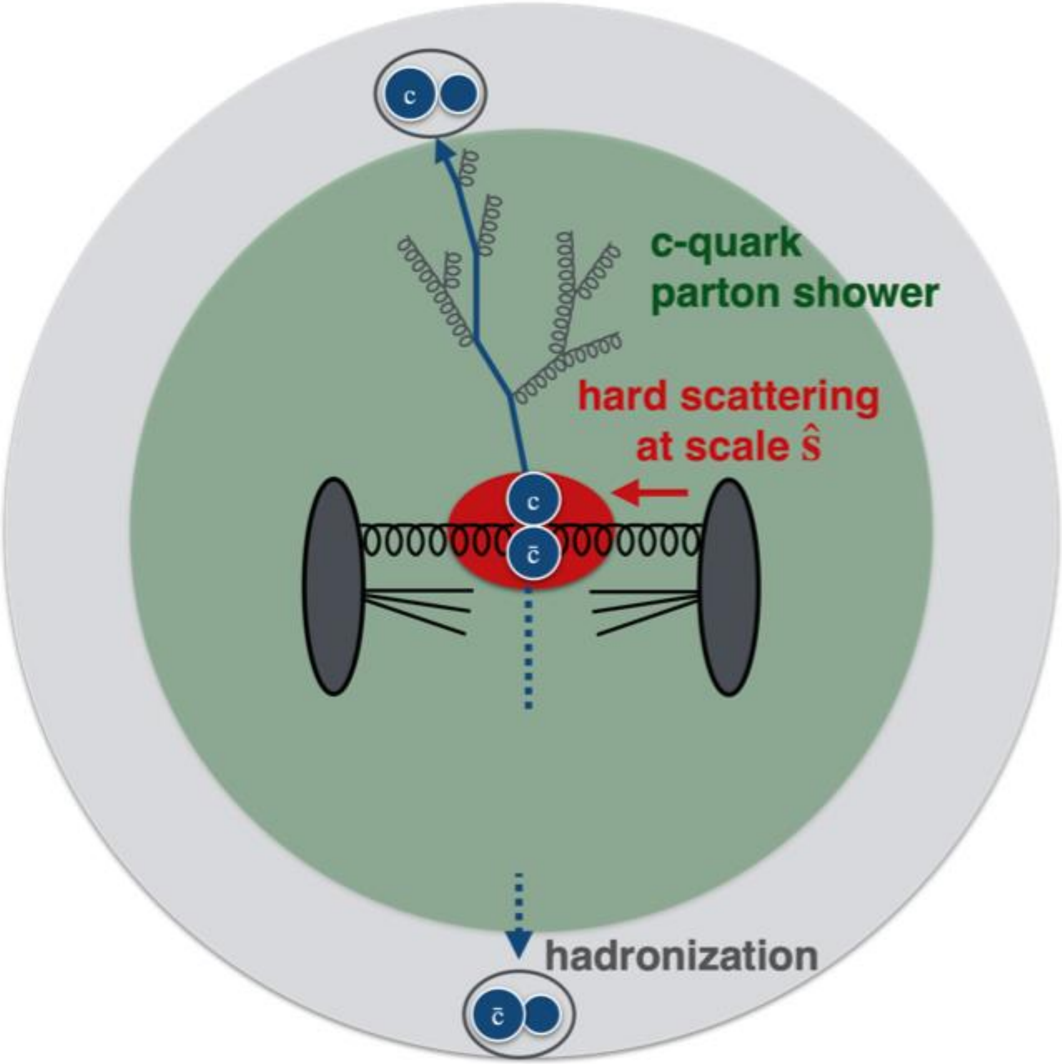
- ❑ Hard production is <u>short distance,</u>

$$\hat{s} \sim Q^2_{c\bar{c}} \gg 4m_c^2 \gg T\,, Q_s$$

yield unaffected by QCD medium.

- ❑ c -> cg in parton shower is <u>long distance,</u> can be affected by QCD medium**

- ➢ "parton energy loss" $C_{c \to cg}$
- ➢ "momentum broadening"



* M. Cacciari et al, JHEP 10 (2012) 137
**Y.L. Dokshitzer and D. Kharzeev, Phys. Lett. B 519 (2001), 199

… spatio-temporal embedding of parton shower …

Collinear limit

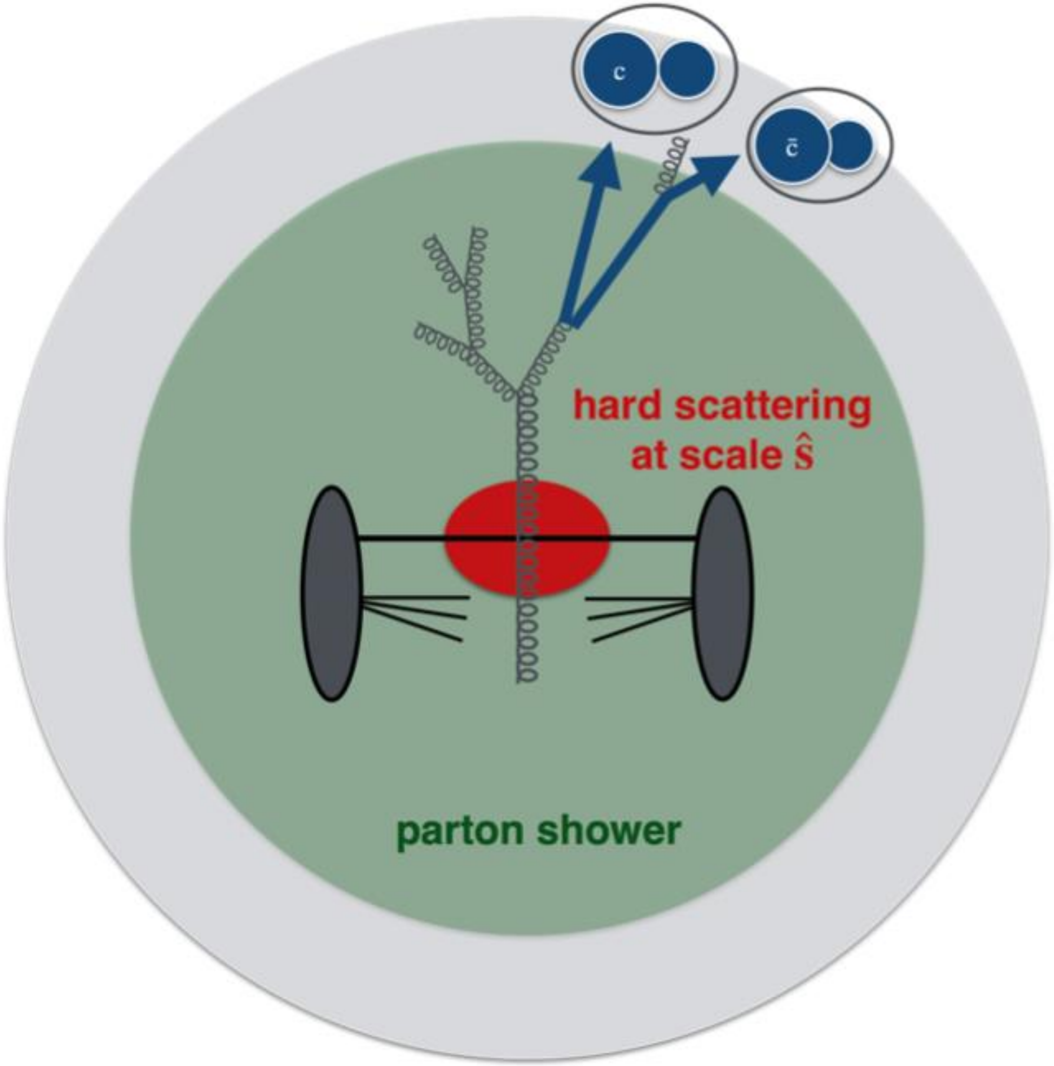
$$\hat{\sigma}^{gg\to c\bar{c}X}\Big|_{Q^2_{c\bar{c}}\ll\hat{s}} \longrightarrow \hat{\sigma}^{gg\to gX}\,\frac{\alpha_s}{2\pi}\,\frac{1}{Q^2_{c\bar{c}}}\,P_{g\to c\bar{c}}$$

- ❑ g -> c cbar is long-distance.
  Formation time is **boosted***

$$\tau_{g\to c\bar{c}} \sim \frac{1}{Q_{c\bar{c}}}\,\frac{E_g}{Q_{c\bar{c}}}$$

- ❑ g-> c cbar medium-modified if boosted sufficiently

- ➢ medium-enhancement c-cbar yield in jets
- ➢ momentum broadening of c-cbar pair …

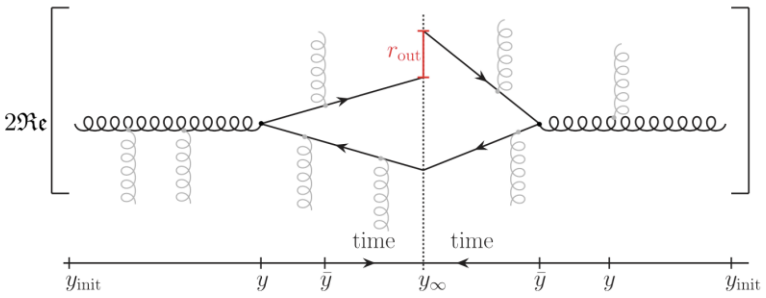


* M. Attems et al, 2203.11241

What we know about g-> c cbar ...

Medium-modified g-> c cbar splitting function* in Baier-Dokshitzer-Mueller-Peigné-Schiff / Zakharov formalism

(many other recent developments**)



$$\left(\frac{1}{Q^2}P_{g\to c\bar{c}}\right)^{\rm tot} \equiv \left(\frac{1}{Q^2}P_{g\to c\bar{c}}\right)^{\rm vac} + \left(\frac{1}{Q^2}P_{g\to c\bar{c}}\right)^{\rm med}$$

$$= 2\,\mathfrak{Re}\,\frac{1}{4E_g^2}\int_{t_{\rm init}}^{t_\infty} dt \int_t^{t_\infty} d\bar{t}\, \exp\left[i\frac{m_c^2}{2E_g z(1-z)}(t-\bar{t}) - \epsilon|t| - \epsilon|\bar{t}|\right]\int d\mathbf{r}_{\rm out}$$

$$\times \exp\left[-\frac{1}{2}\int_{\bar{t}}^{\infty} d\xi\, n(\xi)\,\sigma_3(\mathbf{r}_{\rm out}, z)\right]\exp\left[-i\,\boldsymbol{\kappa}\cdot\mathbf{r}_{\rm out}\right]$$

$$\times\left[\left(m_c^2 + \frac{\partial}{\partial \mathbf{r}_{\rm in}}\cdot\frac{\partial}{\partial \mathbf{r}_{\rm out}}\right)\frac{z^2+(1-z)^2}{z(1-z)} + 2m_c^2\right]\mathcal{K}\left[\mathbf{r}_{\rm in}=0, t; \mathbf{r}_{\rm out}, \bar{t}\right].$$

$$\sigma_3(\mathbf{r}, z) \equiv -\frac{1}{2N_c}\sigma(\mathbf{r}) + \frac{N_c}{2}\sigma(z\mathbf{r}) + \frac{N_c}{2}\sigma((1-z)\mathbf{r}).$$

- ❑ Confirms **formation time** estimate

$$\tau_{g\to c\bar{c}} = \frac{2}{Q}\frac{E_g}{Q}$$

- ❑ Sensitive to **color field strength of medium**

$$\hat{q} \equiv \frac{\langle \mathbf{q}^2\rangle_{\rm med}}{\lambda_{\rm mfp}}$$

- ❑ Numerically sizeable for

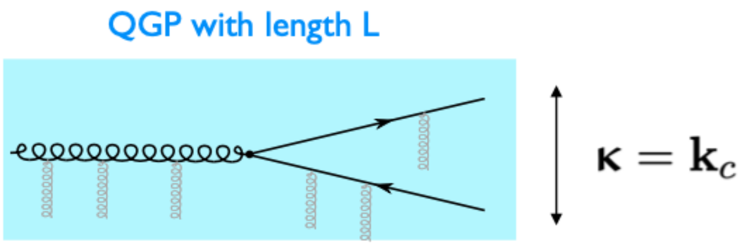
$$\langle \mathbf{q}^2\rangle_{\rm med} = \int_{\tau_i}^{\tau_f} d\tau\,\hat{q}(\tau) \sim \mathcal{O}(m_c^2)$$

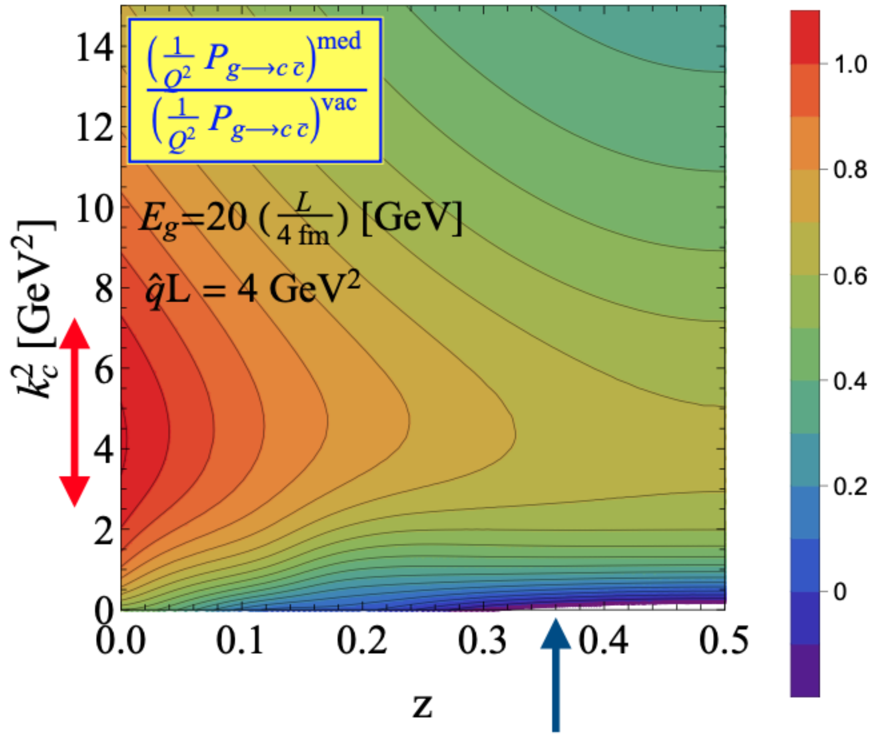
- ❑ Geometrically enhanced power-correction

$$P^{\rm med}_{g\to q\bar{q}} \sim \mathcal{O}\left(\frac{\langle \mathbf{q}^2\rangle_{\rm med}}{Q^2}\right)$$

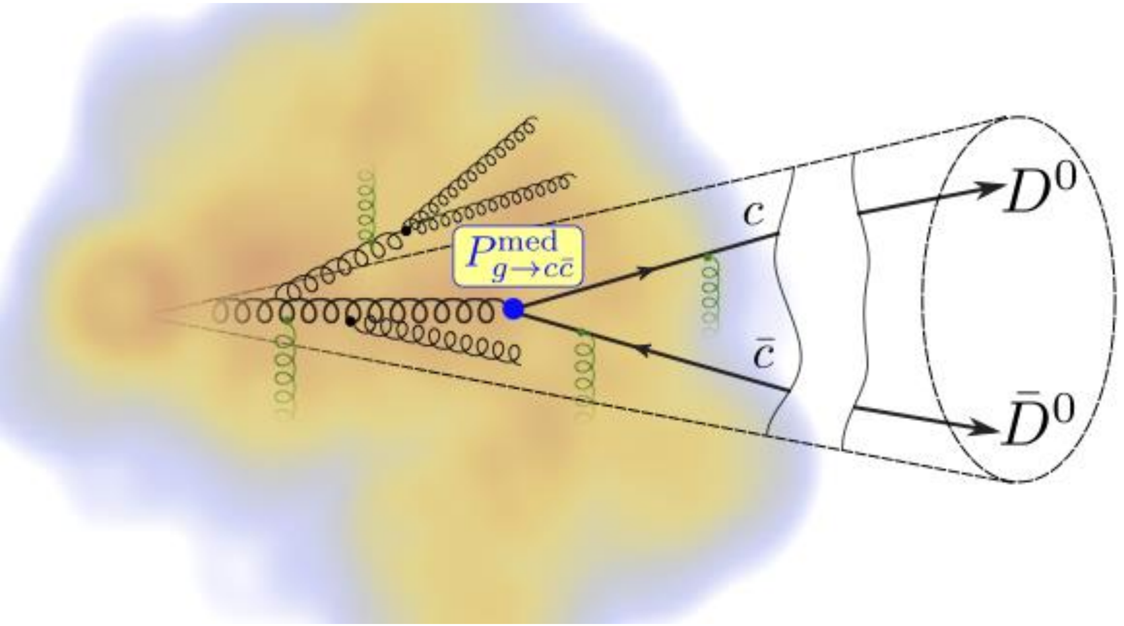
*M. Attems et al, 2203.11241v2 ** L. Apolinario et al, 1407.0599, F. Dominguez et al., 1907.03653, Isaksen et al., 2107.02542, 2206.02811
Z.B. Kang et al. 1610.02043, S. Caron-Huot&Gale, 1006.2379

… testing g-> c cbar …

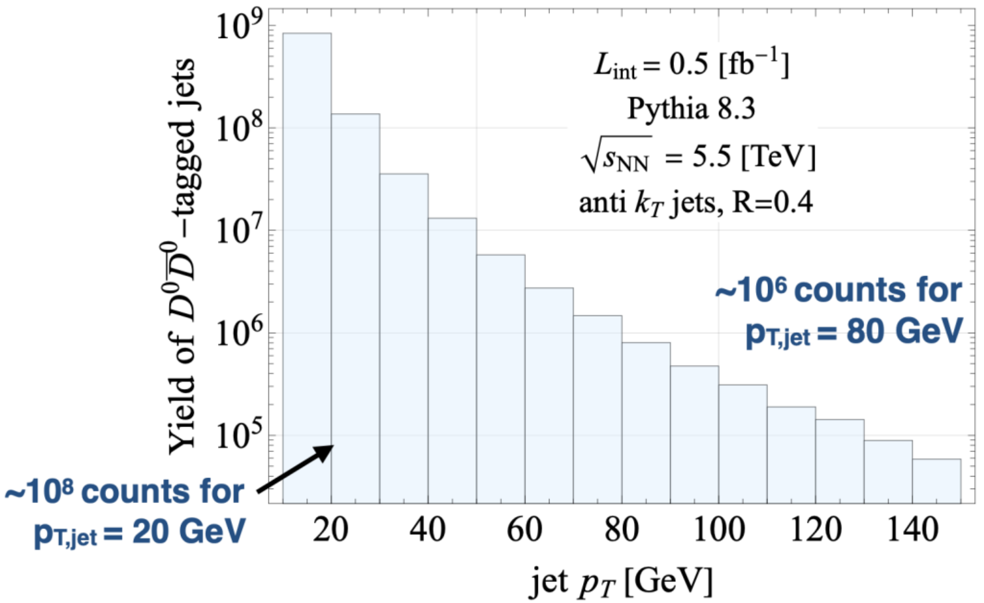




$$Q^2_{c\bar{c}} \simeq \frac{m_c^2 + k_c^2}{z(1-z)}$$

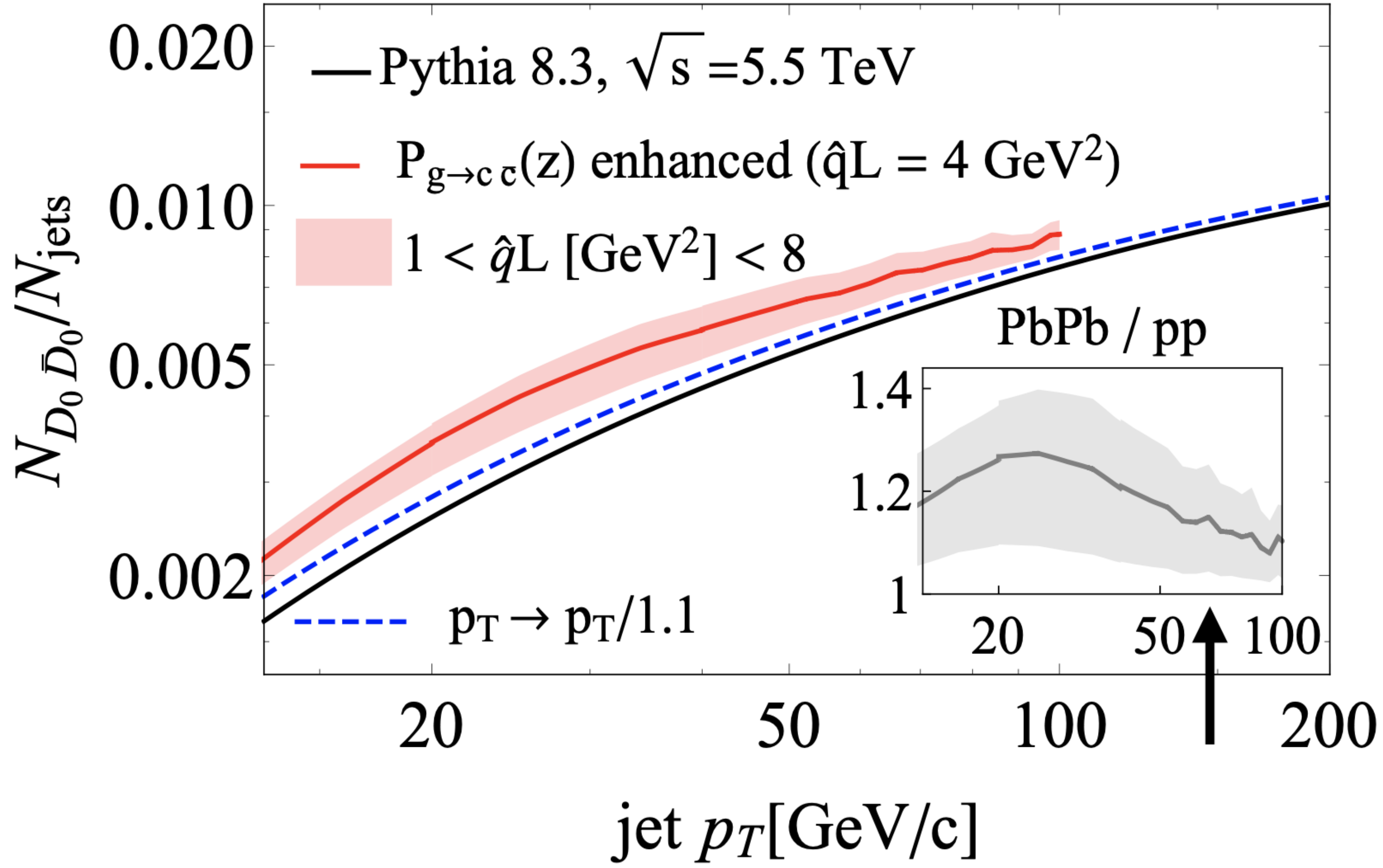


L_{int} = 0.5 fb^{-1} pp ~ 10 nb^{-1} PbPb (no quenching)



*M. Attems et al, 2203.11241 & in preparation

An observable sensitive to enhanced g->ccbar in jets



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How could a similar picture apply to fixed target experiments?

- Sit the fixed-target rest frame:
- Large-x gluons from the projectile proton or projectile nucleus are significantly boosted w.r.t. this rest frame.
- With small probability, these gluons fluctuate into a c cbar and interact with the strong field of the target nucleus.
- On general grounds, one expects enhanced spltting (gluons are lifted above the ccbar mass threshold) and transverse momentum broadening.

THE END

(but time for questions)