arXiv:2203.11241 see talk by Sohyun Park, Wed, 8:40

The medium-modified $g \to c\bar{c}$ splitting function in the BDMPS-Z formalism

arXiv:2206.xxxxx this "poster"

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

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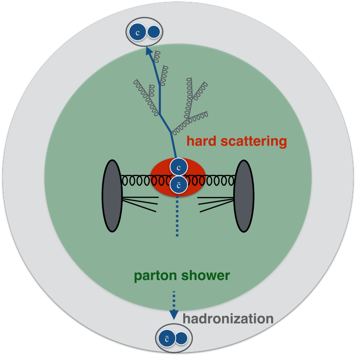
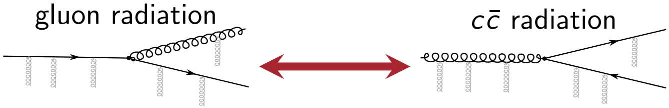
We show that the very same Baier-Dokshitzer-Mueller-Peigné-Schiff – Zakharov (BDMPS-Z) parton energy loss formalism that predicts a medium-induced depletion of high-p_T single inclusive charm spectra results in a medium-enhanced $c\bar{c}$-pair production within high-p_T jets.

Heavy quark production and energy loss in high-energy collisions

- Heavy quarks $m_{c,b} \gg \Lambda_{QCD}$
  $\Longrightarrow$ *short-distance perturbative production.*
- Scattering with Quark Gluon Plasma
  $\Longrightarrow$ *long-distance gluon radiation $c \to cg$*
- Observed modification of p_T spectra
  $\Longrightarrow$ *heavy flavour quenching*



New effect: interaction with the medium modifies $g \to c\bar{c}$ splitting rate!

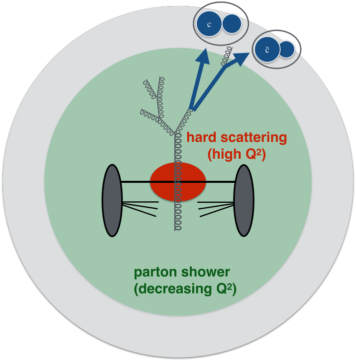


Colinear splitting $g \to c\bar{c}$ in parton shower

- Factorization in the colinear limit

$$\sigma^{gg\to c\bar{c}X} = \underbrace{\sigma^{gg\to gg}}_{\text{hard gluons}} \otimes \frac{\alpha_s}{2\pi}\frac{1}{Q^2} \underbrace{P_{g\to c\bar{c}}}_{\text{splitting function}}$$

- Formation time $t_{\text{form}} \sim \frac{E_g}{Q^2}$
  $\Longrightarrow$ *boosted pairs are produced late*
- Interaction with the medium changes *the number of charmed hadrons*.



Modification of $\frac{1}{Q^2}P_{g\to c\bar{c}}$ calculable in the perturbative BDMPS-Z framework.

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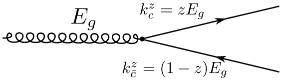
$g \to c\bar{c}$ splitting function: $P_{g\to c\bar{c}}$

- In vacuum, e.g., Pythia shower,



$$\left(\frac{1}{Q^2} P_{g\to c\,\bar{c}}\right)^{\text{vac}} = \frac{1}{Q^4 z(1-z)}(m_c^2 + \boldsymbol{\kappa}^2[z^2+(1-z)^2])$$

where $\boldsymbol{\kappa} = \frac{1}{2}(\mathbf{k}_c - \mathbf{k}_{\bar{c}})$

- In medium $P_{g\to c\bar{c}}$ is modified

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$$\left(\frac{1}{Q^2} P_{g\to c\,\bar{c}}\right)^{\text{tot}} = 2\,\mathfrak{Re}\,\frac{1}{4\,E_g^2 z(1-z)} \int_{t_{\text{init}}}^{t_\infty} dt \int_{t}^{t_\infty} d\bar{t}\, e^{i\frac{m_c^2}{2E_g z(1-z)}(t-\bar{t})} \int d\mathbf{r}_{\text{out}}$$

$$\times\, e^{-\frac{1}{2}\int_{\bar{t}}^{\infty} d\xi\, n(\xi)\,\sigma_3(\mathbf{r}_{\text{out}},z)}\, e^{-i\,\boldsymbol{\kappa}\cdot\mathbf{r}_{\text{out}}} \left[m_c^2 + \frac{\partial}{\partial \mathbf{r}_{\text{in}}} \cdot \frac{\partial}{\partial \mathbf{r}_{\text{out}}}[z^2+(1-z)^2]\right] \mathcal{K}\,[\mathbf{r}_{\text{in}}, t; \mathbf{r}_{\text{out}}, \bar{t}]$$

- In multiple soft scattering approximation

$$n(\xi)\sigma_3(\mathbf{r}_{\text{out}}, z) = \frac{1}{2}\hat{\bar{q}}(C_F - N_c z(1-z))\mathbf{r}_{\text{out}}^2, \quad C_F = \frac{4}{3}$$

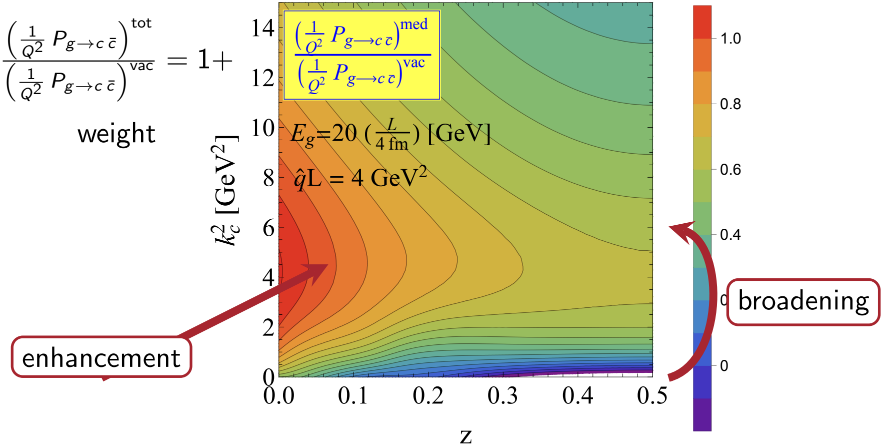
Various model estimates $1\ \text{GeV}^2 \lesssim C_F\hat{\bar{q}}L \lesssim 8\ \text{GeV}^2$

Broadening and enhancement of $c\bar{c}$ pairs

We observe enhancement of the splitting function over wide phase-space.

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

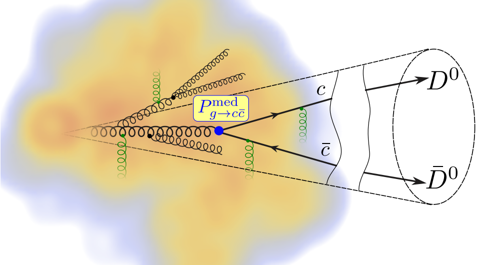
weight



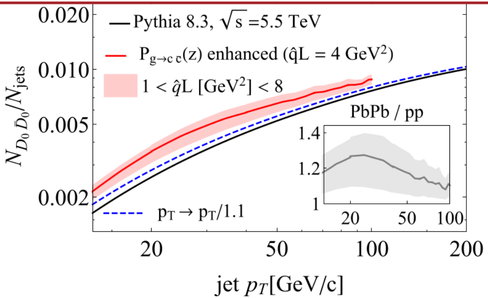
Idea: reweight vacuum shower (Pythia) with medium modified splitting functions.

Medium-induced charm meson production inside jets

- Consider the fraction of jets with $D^0, \bar{D}^0$ pairs $\Rightarrow$ *contains $g \to c\bar{c}$ splitting.*
- Reweight each $g \to c\bar{c}$ splitting $\Rightarrow$ *explore range of $\hat{q}$ values for for PbPb*.
- Compare with the unmodified pp fraction.



Fraction of $D^0\bar{D}^0$ tagged jets w/out modification



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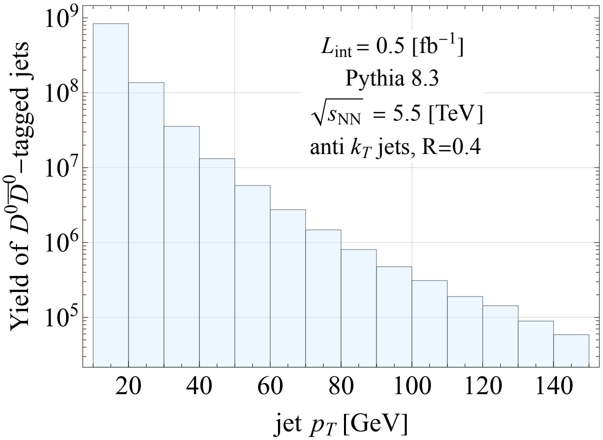
10-40% enhancement of $D^0\bar{D}^0$ tagged jets $\Rightarrow$ novel test of BDMPS-Z picture.

Backup

Statistics estimates of $D^0\bar{D}^0$ tagged jets

Expected PbPb luminosity $\mathcal{L} = 10\,\mathrm{nb}^{-1} \implies$ equivalent $\mathcal{L}_{pp} = 0.1\,\mathrm{fb}^{-1}$



At $p_T \sim 80$ GeV expect to measure $\mathcal{O}(1000)$ $D^0\bar{D}^0$ jets via $K^-\pi^+$ channel.

Effect of enhanced gluon radiation to $c\bar{c}$ splitting

Gluon no-splitting probability given by Sudakov factor:

$$S^{\text{tot}}_{g\to\text{All}} \quad = \quad \exp\left[-\frac{\alpha_s}{2\pi}\int \frac{dQ^2}{Q^2}\,dz\,\left(P^{\text{vac}}_{g\to c\bar{c}} + P^{\text{med}}_{g\to c\bar{c}} + P^{\text{vac}}_{g\to X} + P^{\text{med}}_{g\to X}\right)\right] = S^{\text{tot}}_{g\to c\bar{c}}\, S^{\text{tot}}_{g\to X}\,,$$

Probability (to split into $c\bar{c}$) & (**not** to split in anything else):

$$\frac{\left(1 - S^{\text{tot}}_{g\to c\bar{c}}\right)\, S^{\text{tot}}_{g\to X}}{\left(1 - S^{\text{vac}}_{g\to c\bar{c}}\right)\, S^{\text{vac}}_{g\to X}} = \frac{\int \frac{dQ^2}{Q^2} dz \left(P^{\mathrm{vac}}_{g\to c\bar{c}} + P^{\mathrm{med}}_{g\to c\bar{c}}\right)}{\int \frac{dQ^2}{Q^2} dz P^{\mathrm{vac}}_{g\to c\bar{c}}} \exp\left[-\frac{\alpha_s}{2\pi}\int\frac{dQ^2}{Q^2} dz P^{\mathrm{med}}_{g\to X}\right].$$

However relative probability (**not** to split in anything else) is suppressed by α_S

$$\exp\left[-\frac{\alpha_s}{2\pi}\int\frac{dQ^2}{Q^2} dz P^{\mathrm{med}}_{g\to X}\right] \sim e^{-\frac{\alpha_s}{2\pi}\#\left(\frac{\hat{q}L}{Q_c^2} - \frac{\hat{q}L}{Q_h^2}\right)} = 1 - \mathcal{O}(\alpha_s)\,.$$

While medium enhancement probability (to split into $c\bar{c}$) is not suppressed.