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高能核物理大会

Diffusion of charm quarks in jets in high-energy heavy-ion collisions

王洒

In collaboration with Wei Dai, Ben-Wei Zhang, Enke Wang

Based on [arXiv :1906.01499]

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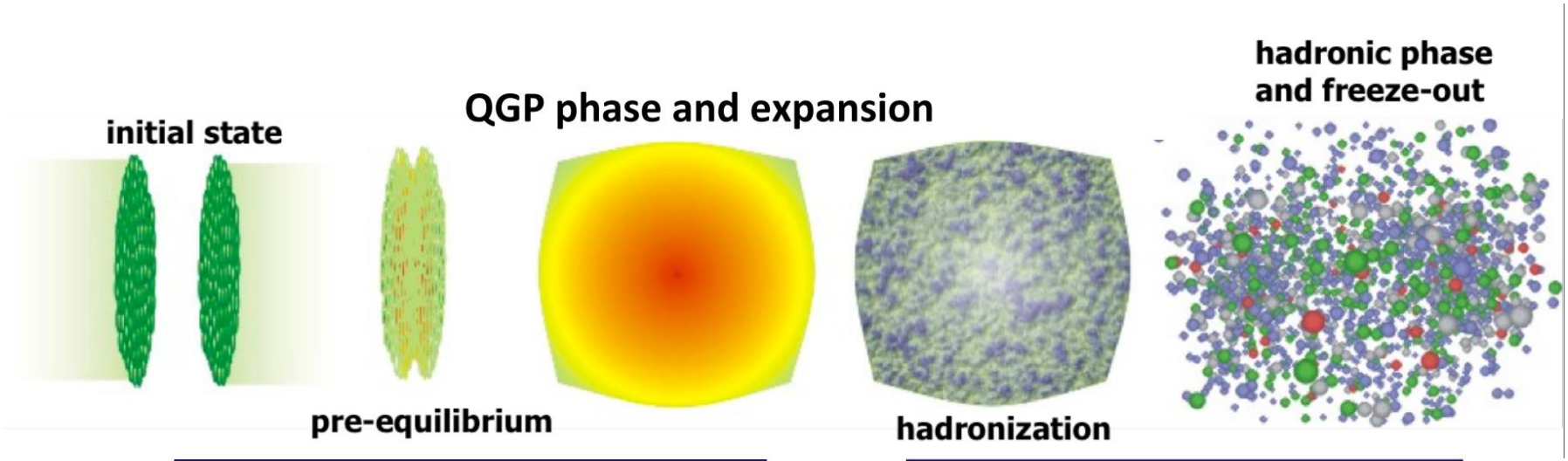
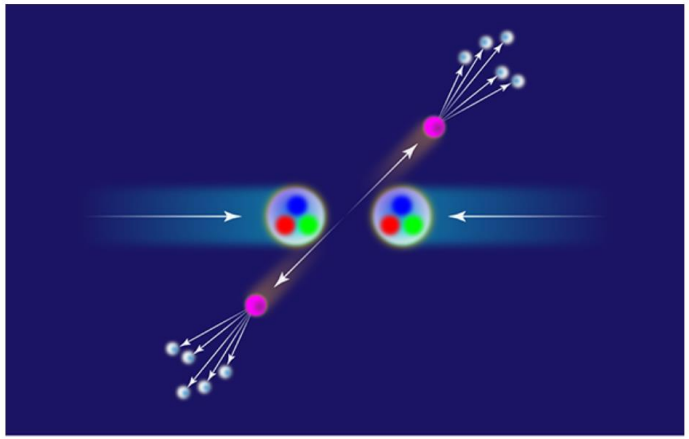
Key Laboratory of Quark & Lepton Physics (MOE) and Institute of Particle Physics

CCNU

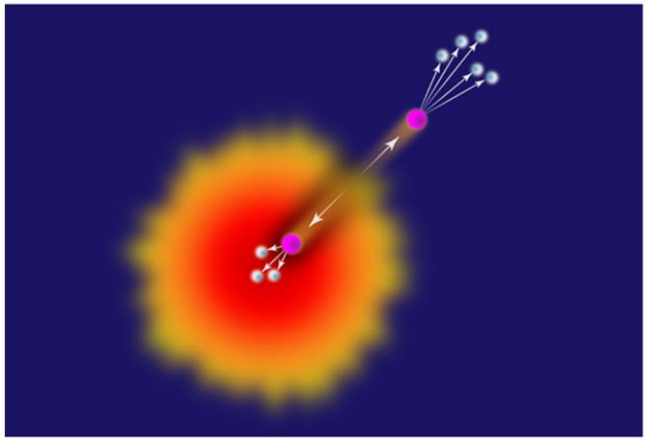
Introduction

Jet quenching at high-energy heavy-ion collisions





p+p



Pb+Pb

Why heavy flavor ?

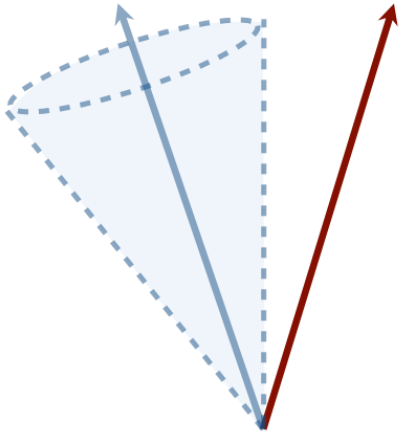
- Heavy quarks with large mass (M_c=1.5 GeV, M_b=4.75 GeV), produced at very early stage in the initial hard scattering in HIC, witness the entire QGP evolution.

- Negligible thermal creation and small Cold Nuclear Matter (CNM) effects on the heavy flavor production.

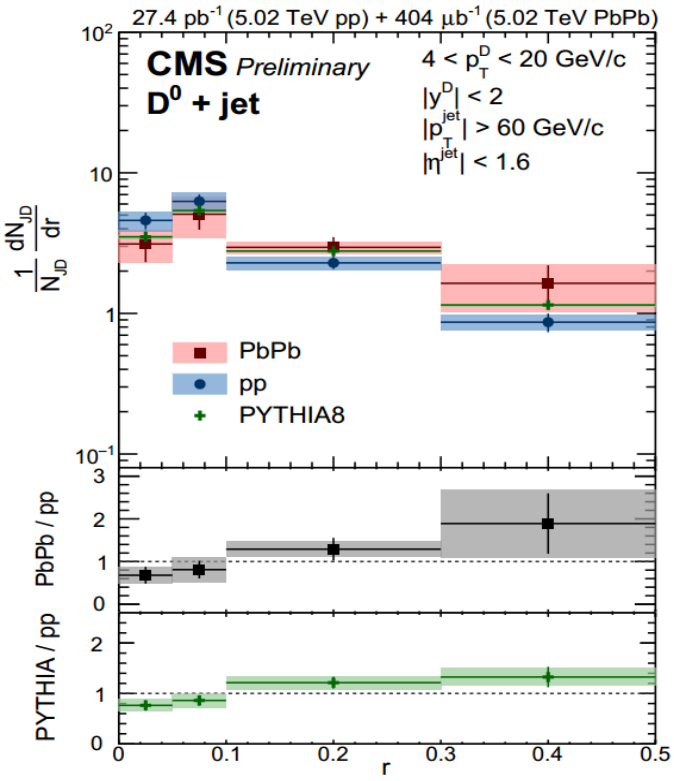
- Ideal hard probes to the properties of QGP, while strongly interact with the medium during their in-medium propagation.

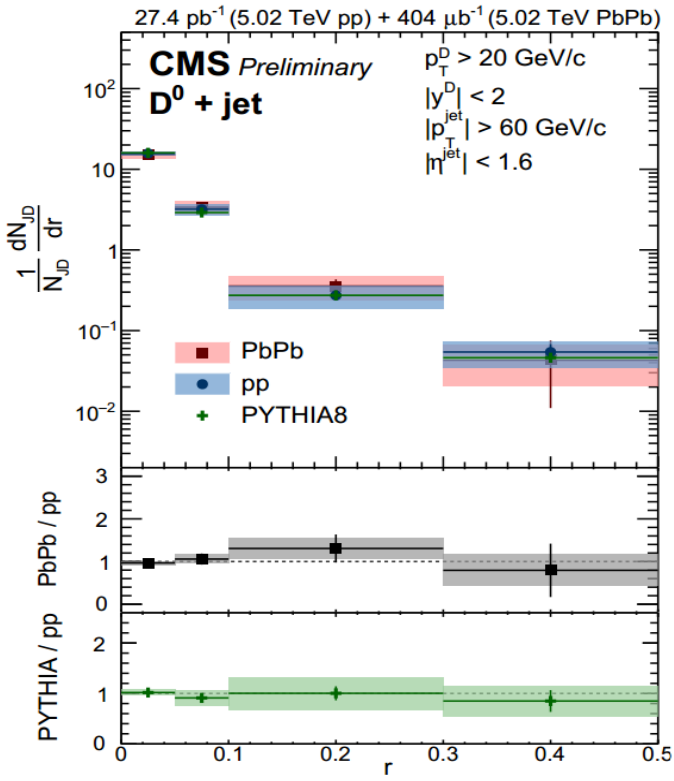
- Mass hierarchy of jet quenching $\Delta E_b < \Delta E_c < \Delta E_q < \Delta E_g$.

Radial profile of D meson in jets



$$r = \sqrt{(\Delta\phi_{JD})^2 + (\Delta\eta_{JD})^2}$$





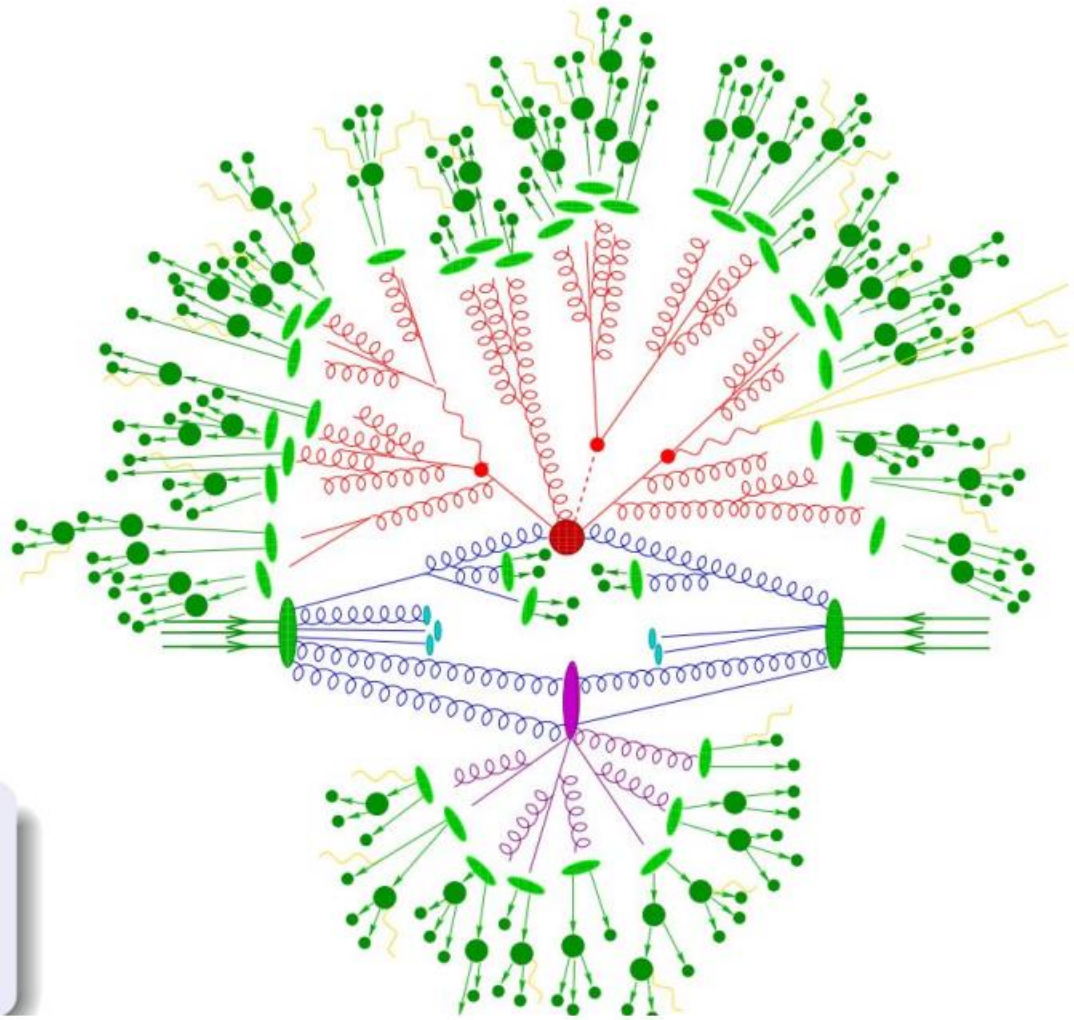
CMS-PAS-HIN-18-007

- The recent CMS measurements provide a new perspective to study the interaction mechanisms between heavy quarks and the medium in the nucleus-nucleus collisions

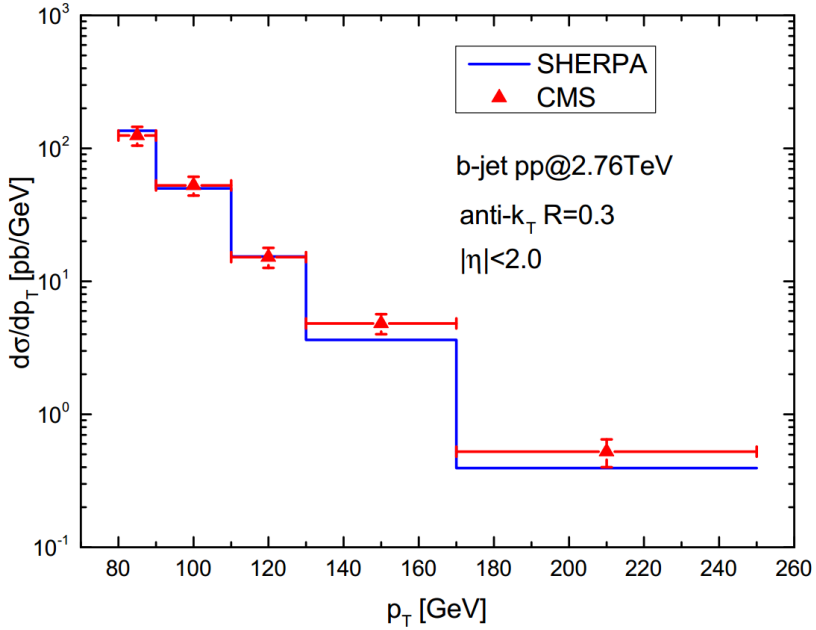
NLO+PS MC event generator ---- SHERPA

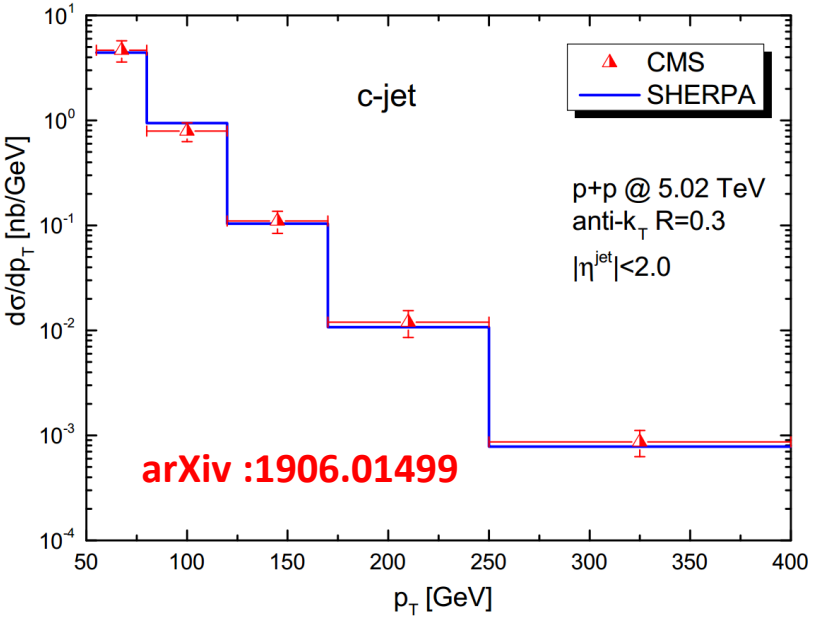
- Initial state parton shower (QCD)
- Underlying event
- Signal process
- Final state parton shower (QCD)
- Fragmentation
- Hadron decays
- QED radiation

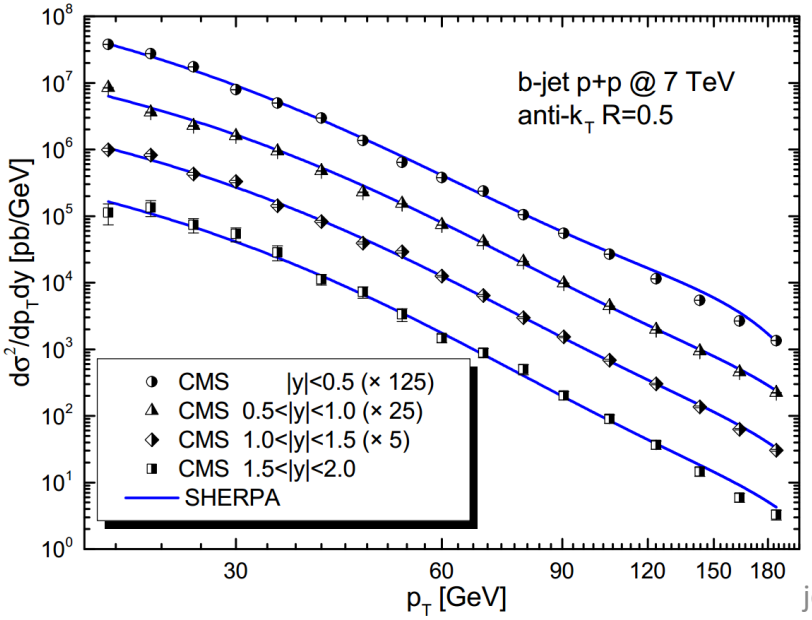
SHERPA is the framework steering these event phases.



NLO+PS MC event generator ---- SHERPA

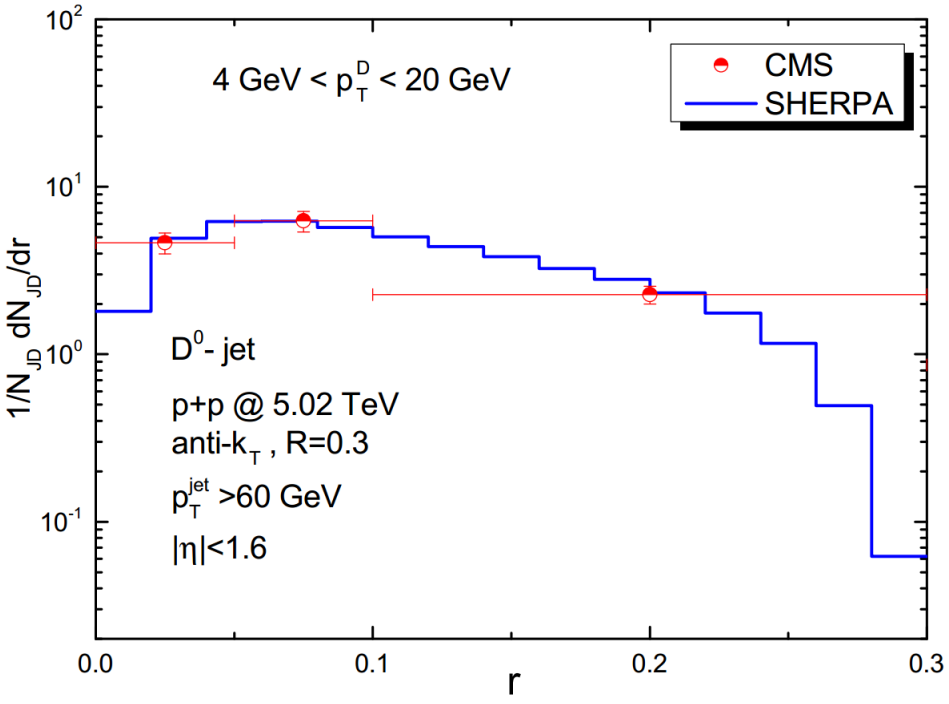


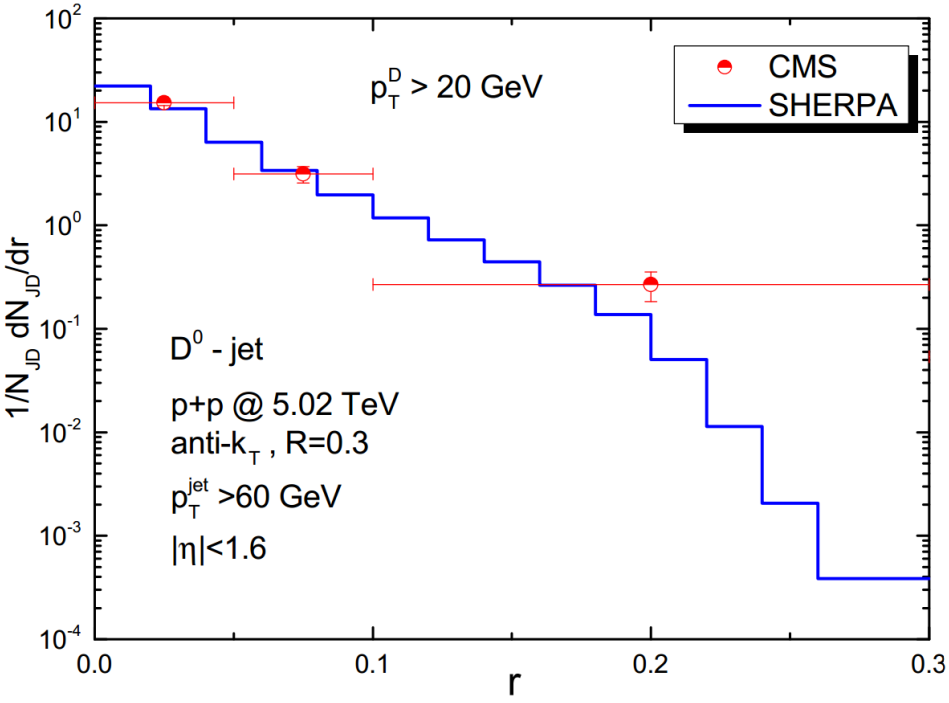




- Heavy flavor jet is defined as a jet containing heavy quarks inside the jet cone.
- SHERPA could well describe the heavy flavor jet production in p+p collisions at 2.76 TeV, 5.02 TeV and 7 TeV.

D^0 radial profile in jets in p+p collisions



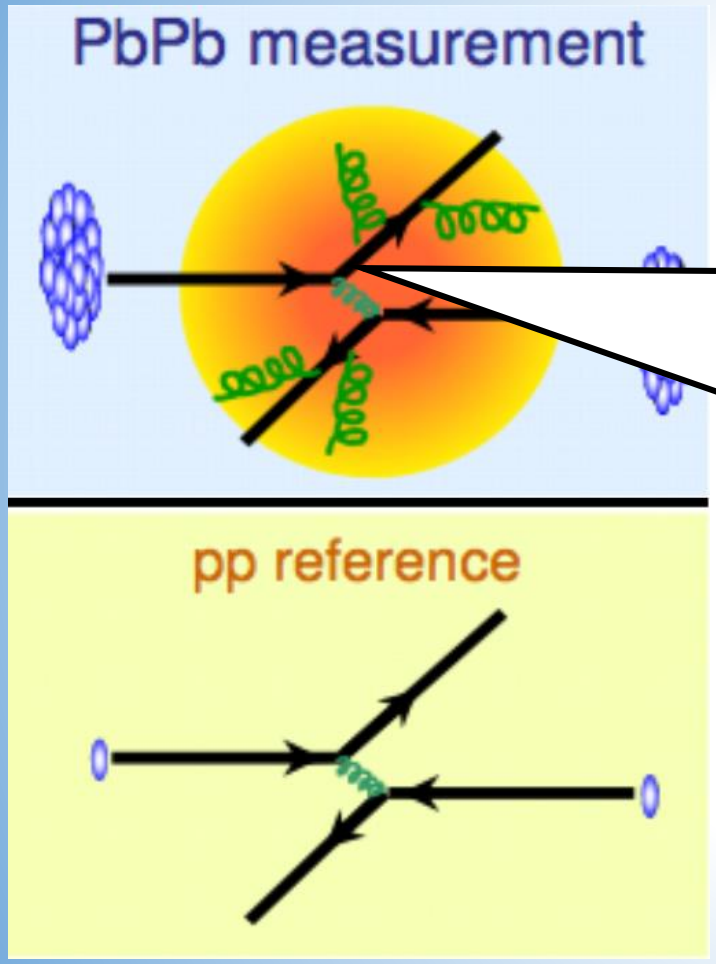


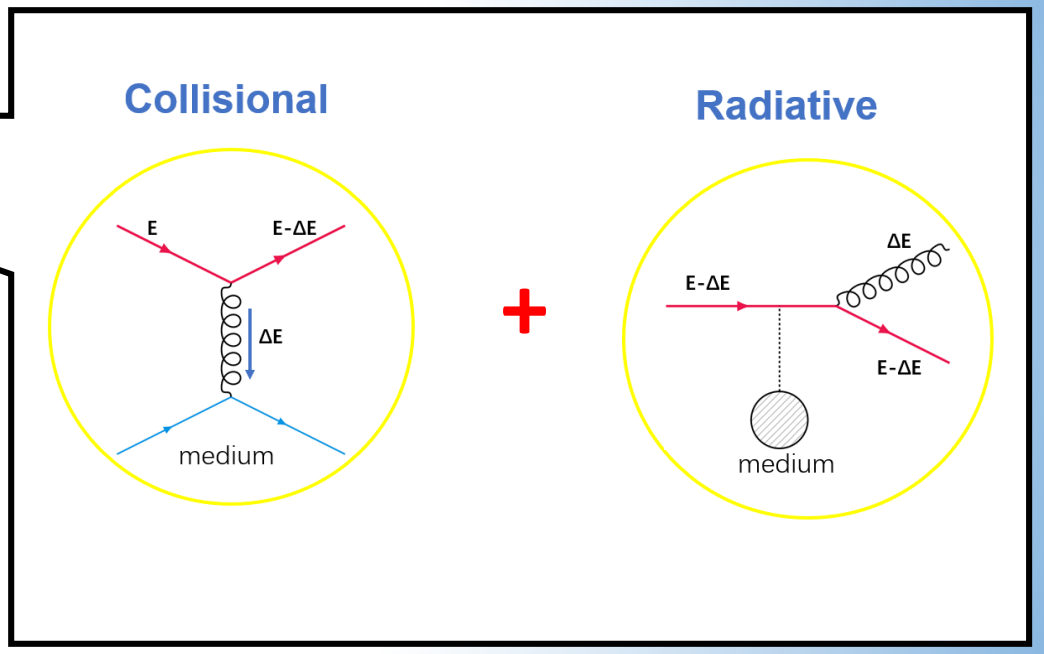
$$r = \sqrt{(\Delta\phi_{JD})^2 + (\Delta\eta_{JD})^2}$$

arXiv :1906.01499

- SHERPA provides a good description to the CMS measurements in p+p collision.
- Different shape of the radial distribution in jets for low p_T and high p_T D meson.

In-Medium Energy Loss





In-Medium E-loss: Radiative

- The medium-induced radiative energy loss of final-state patons is described by the Higher-Twist scheme [X.-F. Guo and X.-N. Wang, Phys. Rev. Lett. 85, 3591(2000);B.-W. Zhang, E. Wang, and X.-N. Wang, Phys. Rev.Lett. 93, 072301 (2004);A. Majumder, Phys. Rev. D85, 014023 (2012).]

$$\frac{dN_g}{dxdk_\perp^2 dt} = \frac{2\alpha_s C_A P(x)\hat{q}}{\pi k_\perp^4} \sin^2\left(\frac{t-t_i}{2\tau_f}\right)\left(\frac{k_\perp^2}{k_\perp^2 + x^2 M^2}\right)^4$$

- $\hat{q}$ is QGP transport coefficient[X.F.Chen, C.Greiner, E.Wang, X.N.Wang and Z.Xu,Phys.Rev.C 81(2010)064908]:

$$\hat{q}(\tau, r) = q_0 \frac{\rho^{QGP}(\tau, r)}{\rho^{QGP}(\tau_0, 0)} \frac{p^\mu u_\mu}{p^0}$$

- q_0 is fixed at 1.2 GeV^2/fm in our simulation.[G.Y.Ma, W.Dai, B.W Zhang,E.Wang, EPJC 79(2019)no.6,518]

In-Medium E-loss: Collisional

- For heavy quark, the discrete Langevin transport equations are used to describe the propagating of heavy quarks in the QGP. [Eur. Phys. J. C 71, 1666 (2011); Physical Review C, 2009, 79(5): 054907.]:

$$\vec{x}(t+\Delta t) = \vec{x}(t) + \frac{\vec{p}(t)}{E}\Delta t$$
$$\vec{p}(t+\Delta t) = \vec{p}(t) - \Gamma(p)\vec{p}\Delta t + \vec{\xi}(t)\Delta t$$

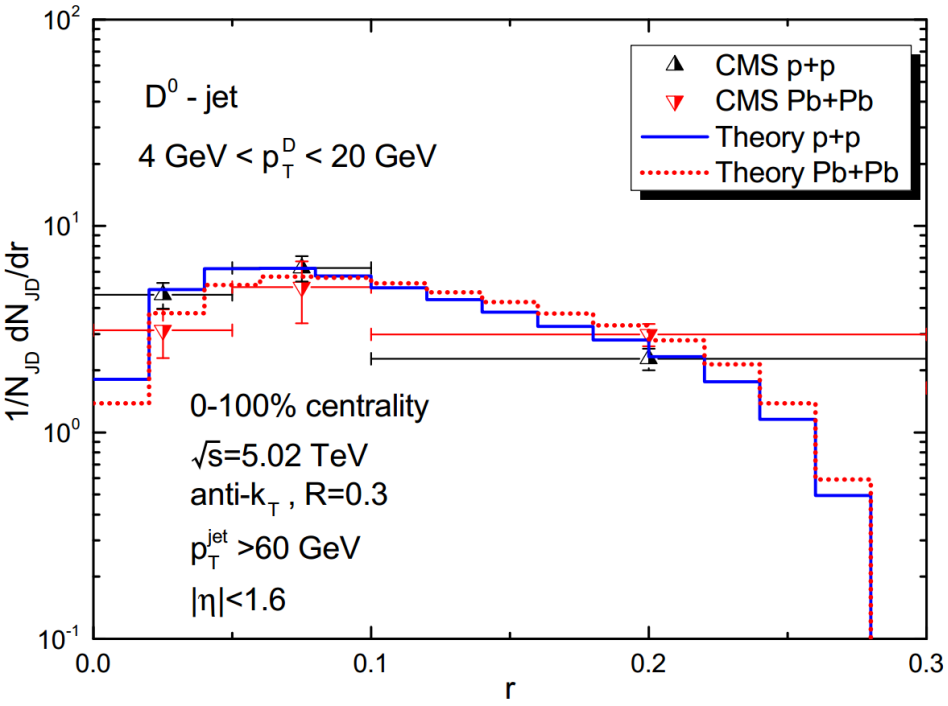
The Fluctuation-Dissipation Theorem:$\kappa = 2ET\Gamma = \frac{2T^2}{D_s}$. Based on the Lattice calculation[arXiv:1508.04543 [hep-lat]], D_s is fixed as $2\pi TD_s = 4$.

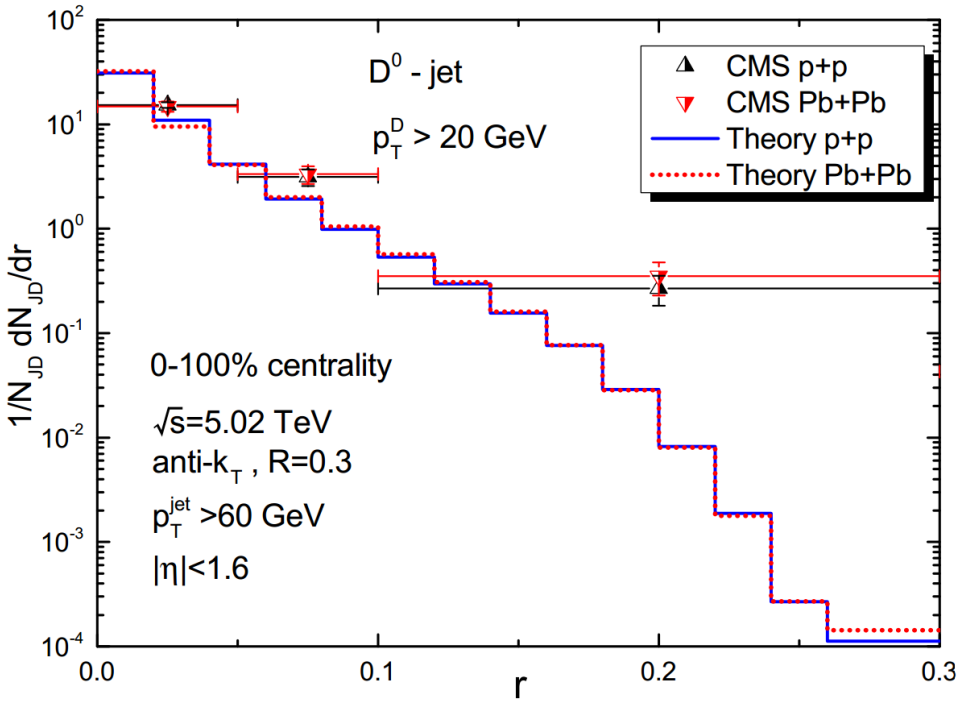
- For light partons, the collisional energy loss is described by Hard Thermal Loop calculation.[J.D. Bjorken, Fermilab preprint PUB-82/59-THY; Markus H.Thoma Physics Letters B 273 (1991)128-132; R.B.Neufeld PRD 83 (2011) 065012]

$$\frac{dE}{dz} = \frac{\alpha_s C_i m_D^2}{2} ln \frac{\sqrt{ET}}{m_D}$$

- The smooth iEBE-VISHNU hydro[Comput.Phys.Commun.199(2016) 61] has been used for the medium evolution.

D^0 radial profile in jets in pp and PbPb





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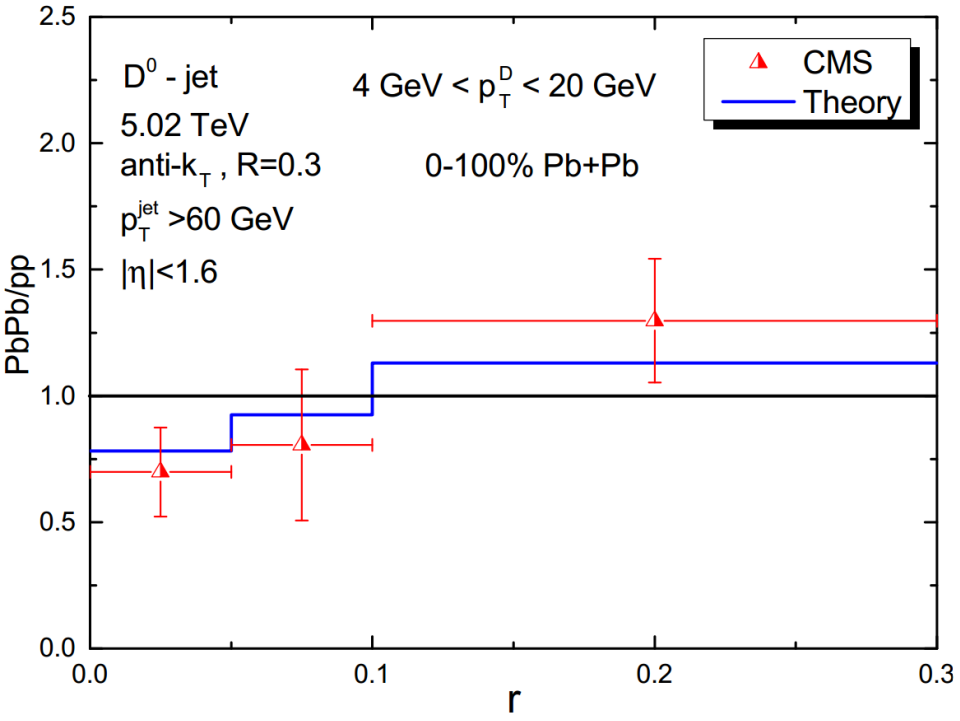
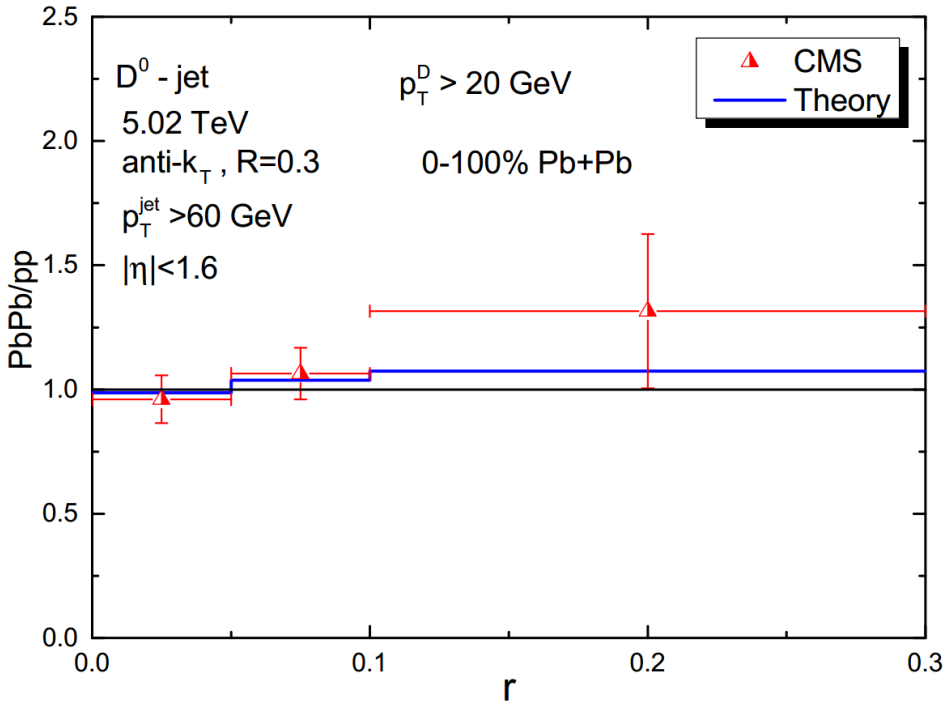
- Our simulations can fairly describe the data of D meson radial distribution in $jets$ measured by CMS collaboration, both in p+p and Pb+Pb collision.
- For low p_T D meson, a significant modification was observed in Pb+Pb collision relative to the pp baseline.

Medium modification





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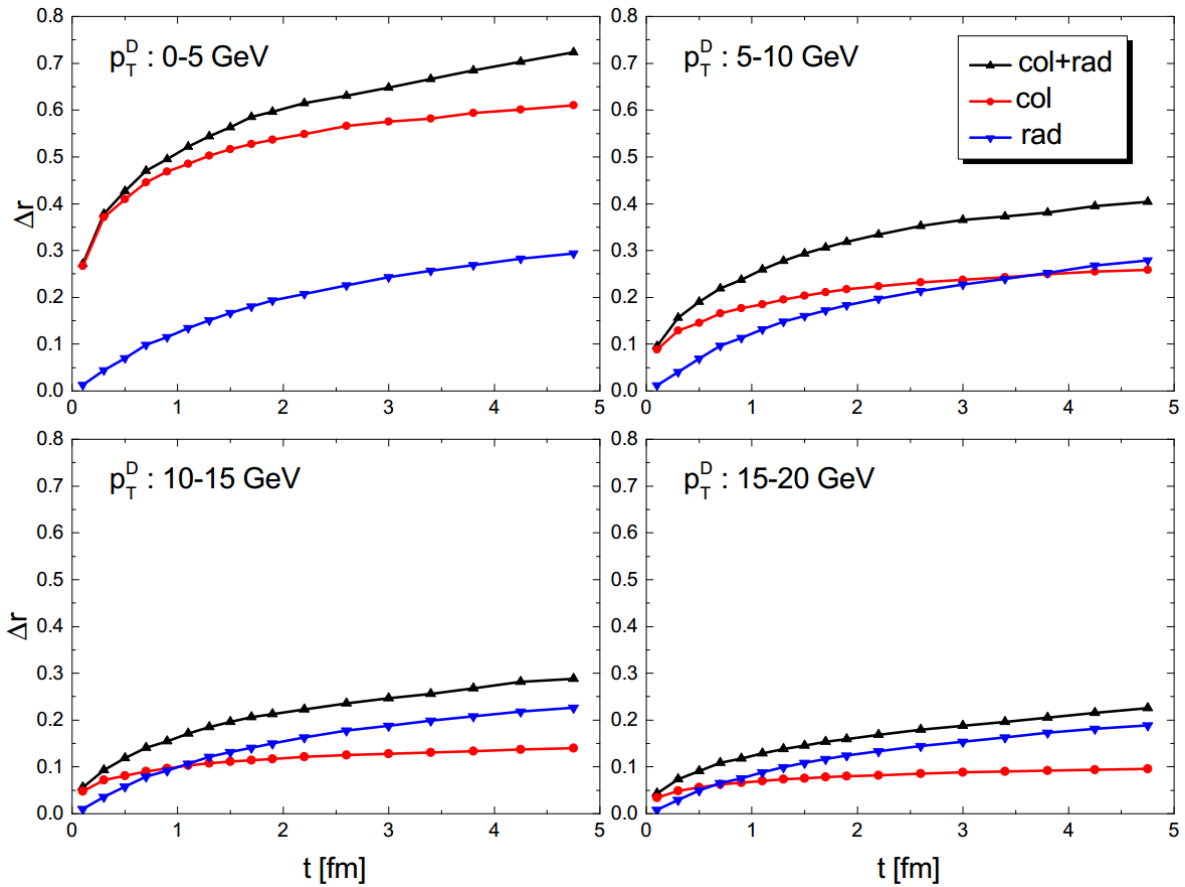
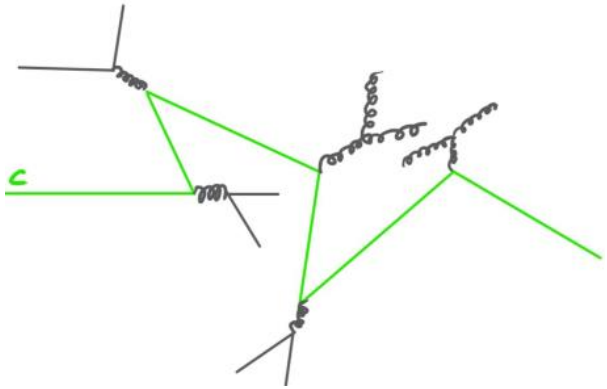
- A significant modification is observed in the low D meson p_T.
- Suppression in small r region(close to the jet axis) and enhancement in larger r region for 4-20GeV indicates that D mesons diffuse to larger radius region due to the in-medium interactions.
- No significant modification for the high p_T D meson.

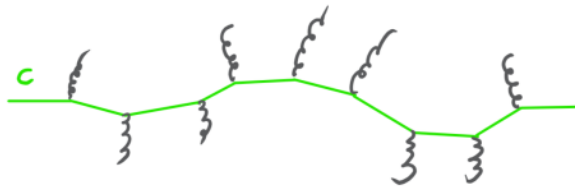
Angular diffusion of charm quark in QGP



Collisional mechanism



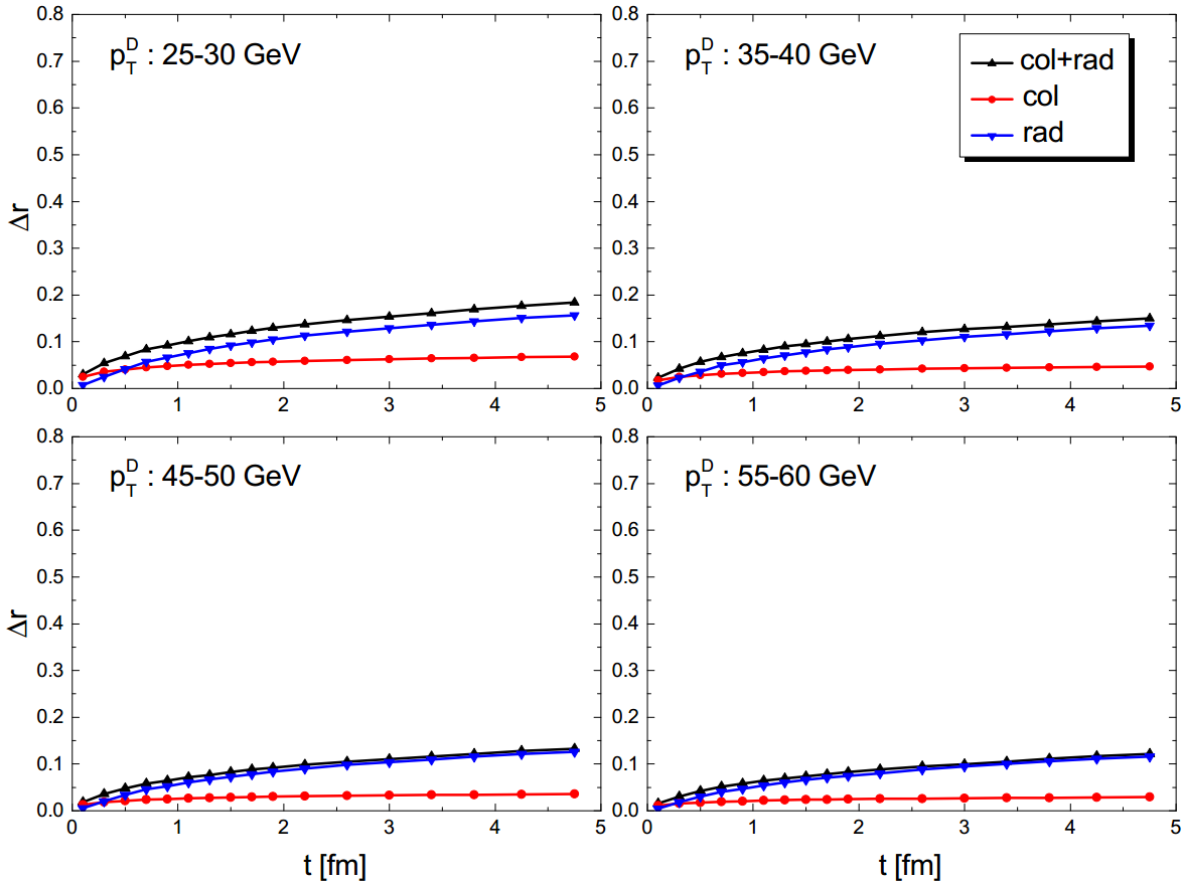
Radiative mechanism



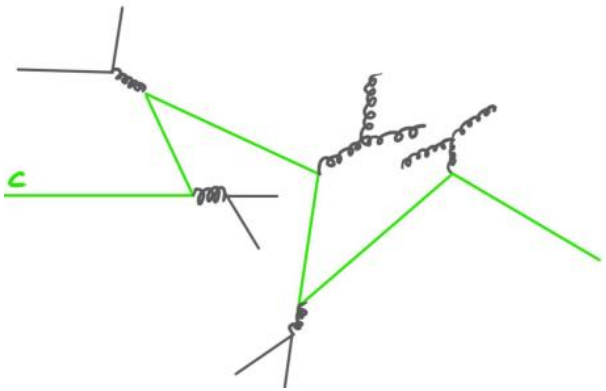
$$\Delta r = \sqrt{(\Delta\phi_c)^2 + (\Delta\eta_c)^2}$$

- Angular diffusion increases with propagating time in the QGP.
- At very low p_T (0 - 5GeV), angular diffusion mostly caused by Langevin mechanism (collisional), while high p_T by gluon radiation.

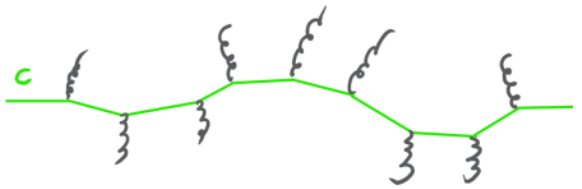
Angular diffusion of charm quark in QGP



Collisional mechanism



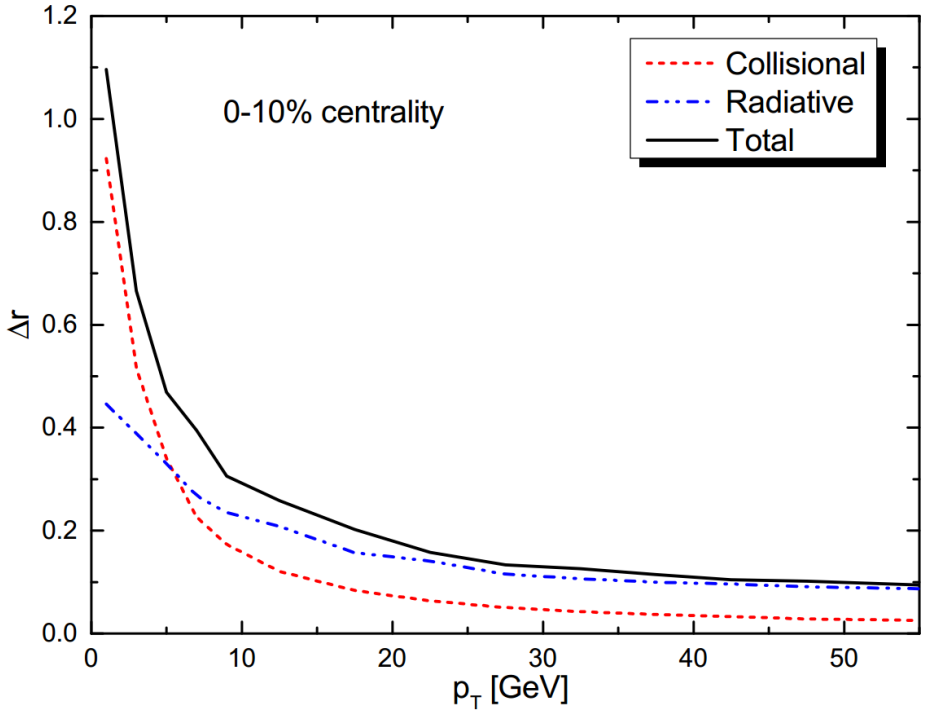
Radiative mechanism

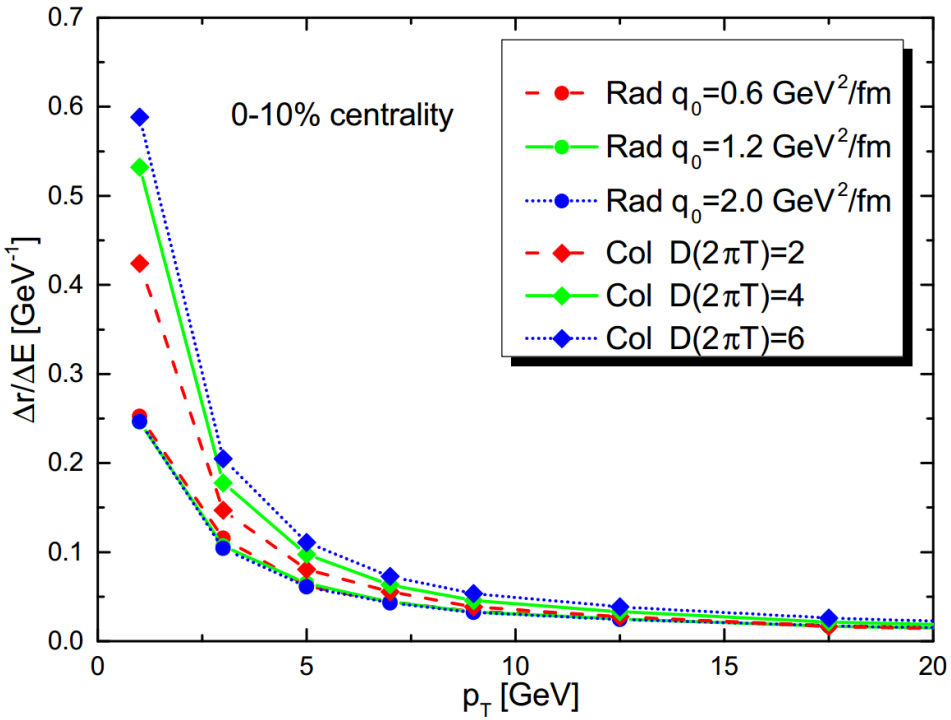


$$\Delta r = \sqrt{(\Delta\phi_c)^2 + (\Delta\eta_c)^2}$$

- The none-zero Δr due to the radiative mechanism exists even at p_T >60 GeV and dominates the total angular diffusion effect.

Radiative & Collisional





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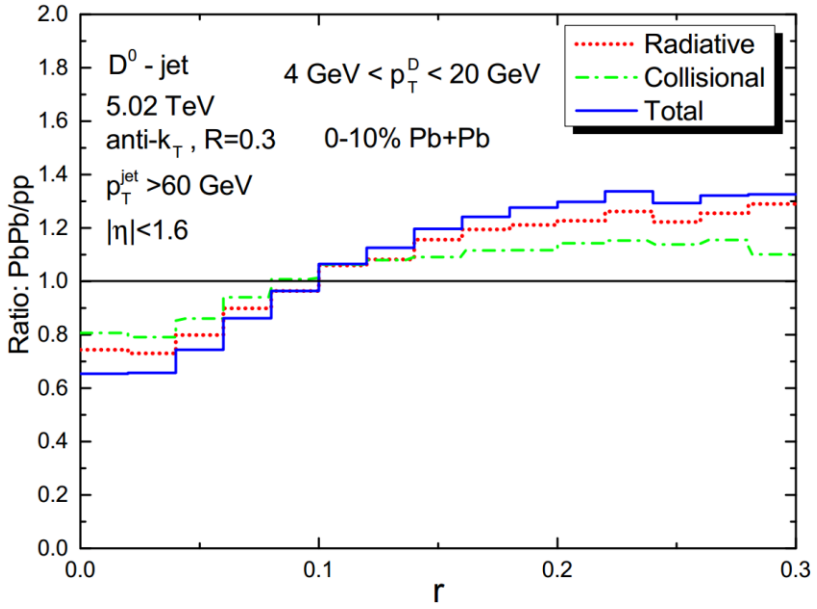
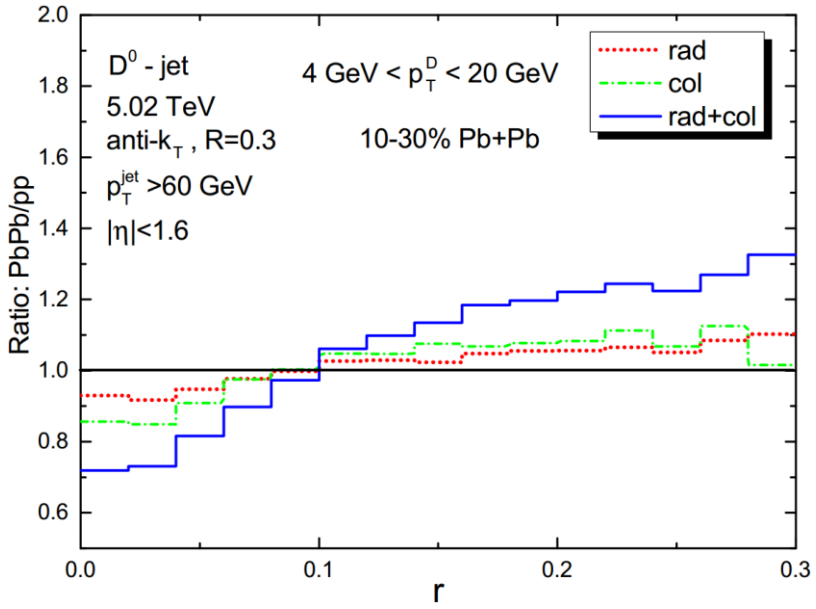
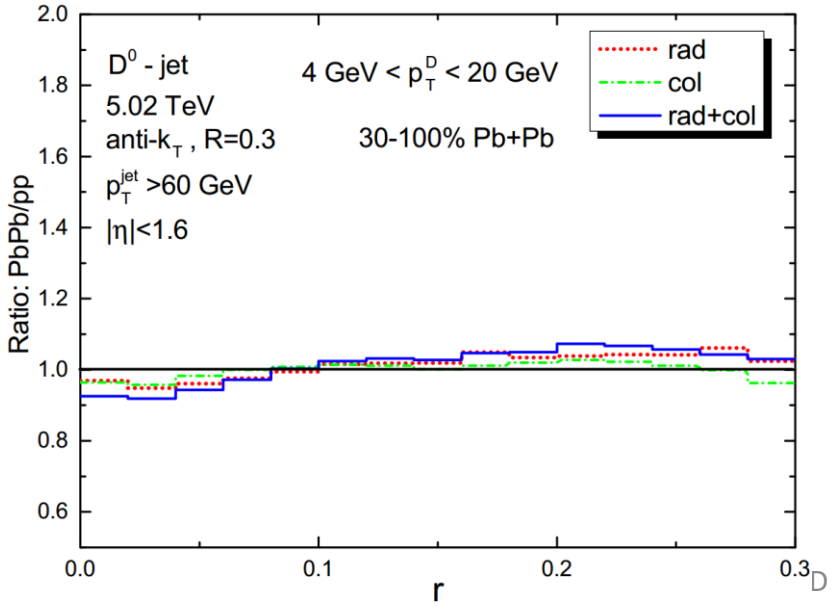
- The total diffusion effects decrease with increasing p_T.
- The ratio $\Delta r/\Delta E$ is sensitive for the parameter Ds in collisional mechanism but not sensitive to $\hat{q}_0$, which may indicate an essential difference between elastic and inelastic interaction.

Centrality dependence

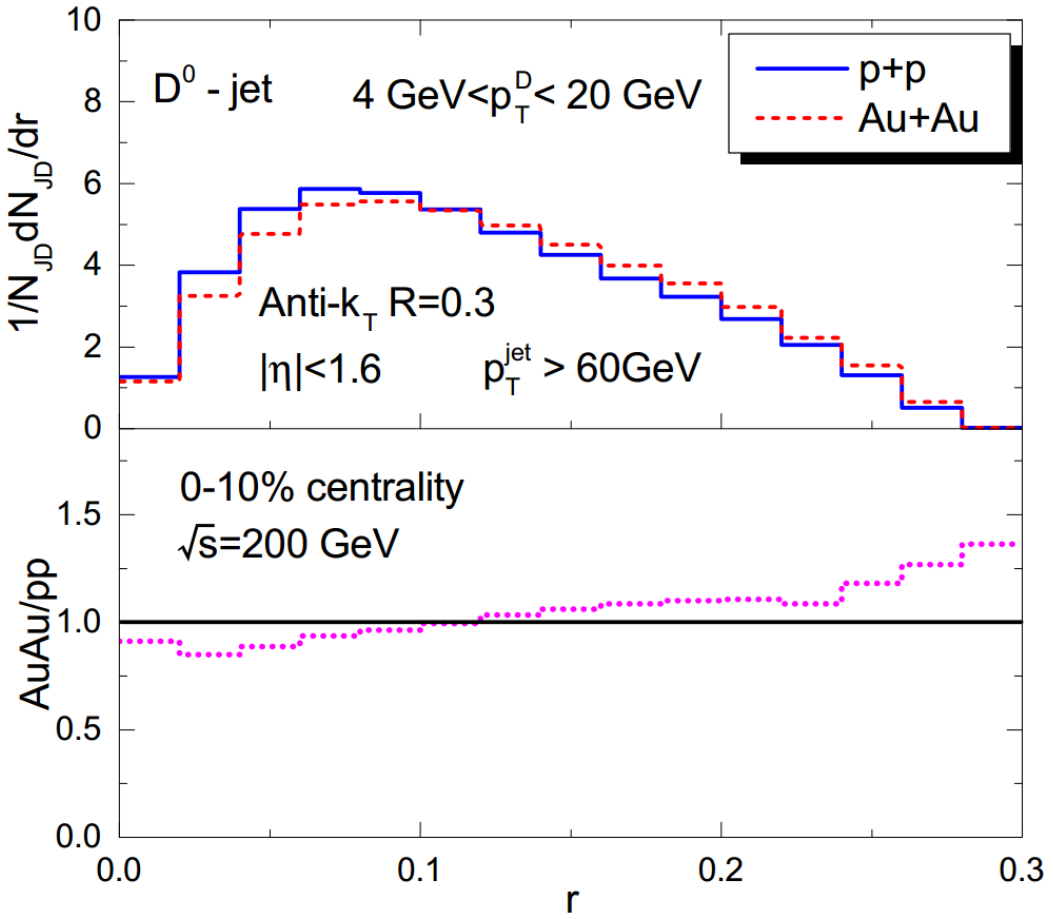






- Total diffusion effects of D meson are strongly dependent on the collision centrality.
- Radiative mechanism seems more sensitive to the centrality than collisional mechanism, from 0-10% to 10%-30%.

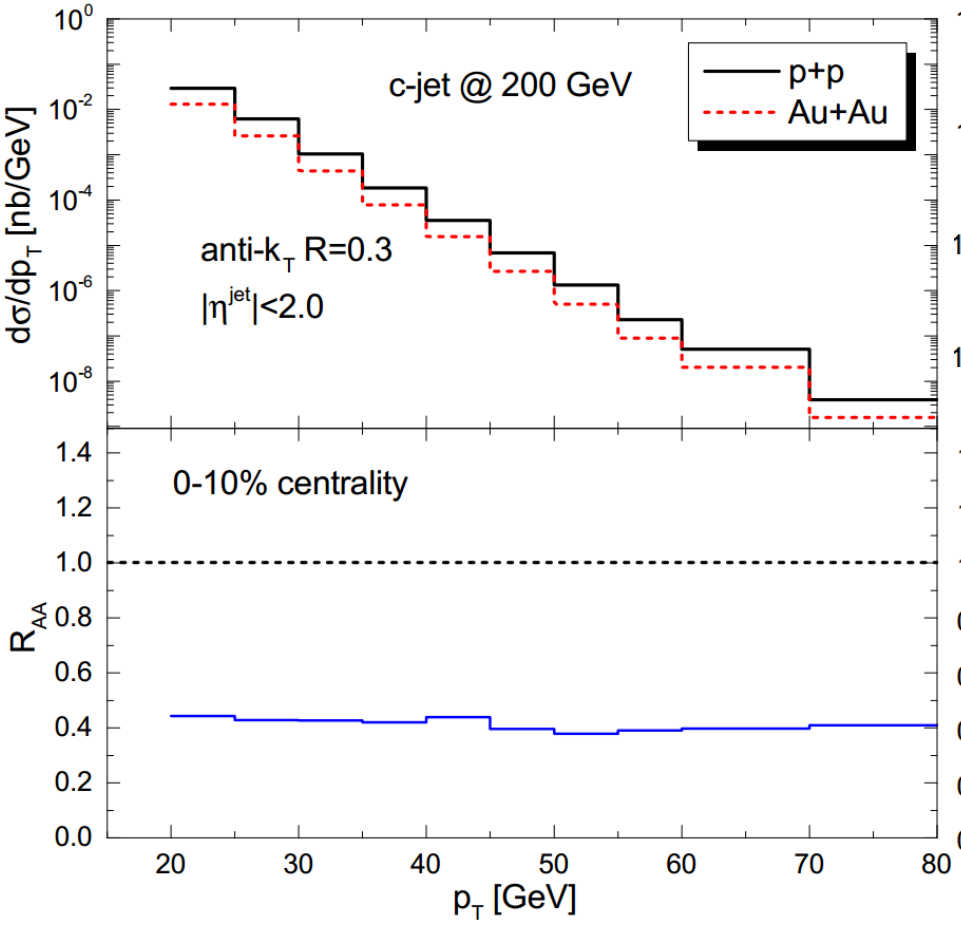
D^0 radial diffusion in jets at the RHIC

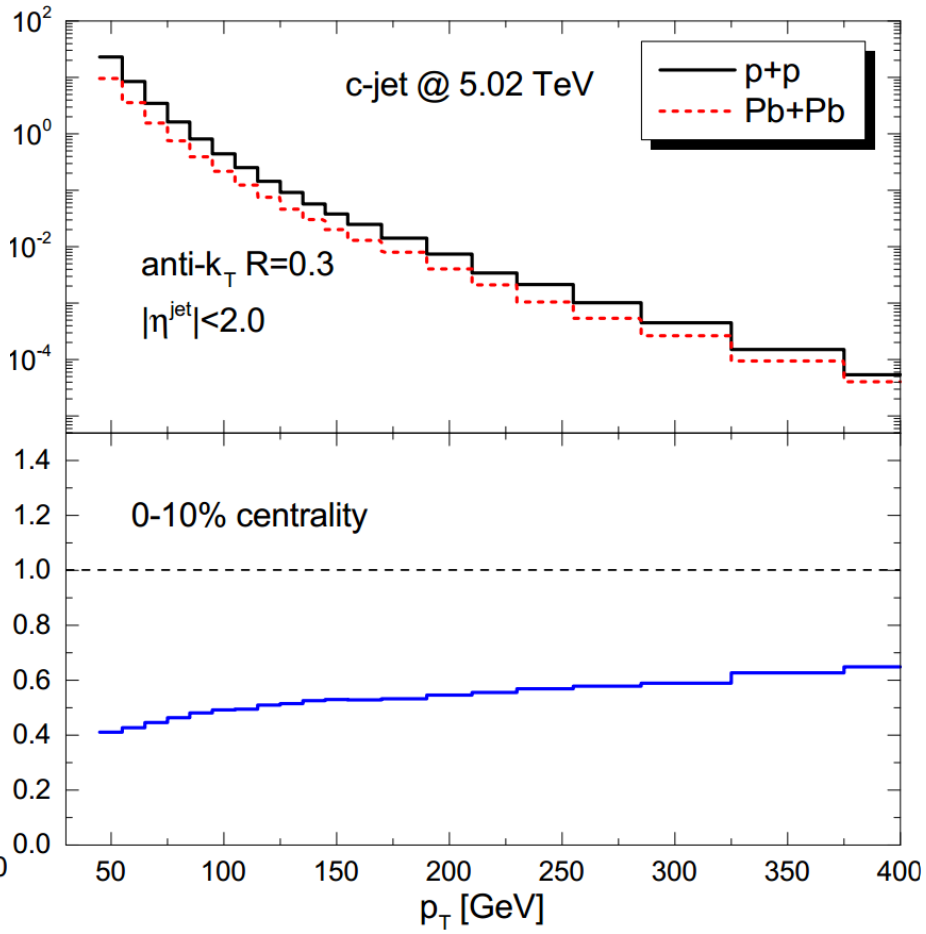


arXiv :1906.01499

- In central Au+Au collision at 200 GeV, weaker modification is observed than that in Pb+Pb collisions at 5.02 TeV.
- Mainly because the lower temperature of the QGP formed in Au+Au collisions than Pb+Pb collisions.

c-jet R_{AA}





$$R_{\mathrm{AA}}(p_T) = \frac{1}{N_{\mathrm{coll}}} \frac{d^2 N_{\mathrm{AA}}/(dp_{\mathrm{T}} dy)}{d^2 N_{pp}/(dp_{\mathrm{T}} dy)}$$

arXiv :1906.01499

➢ Predicted nuclear modification factors of c-jet at the RHIC and the LHC.

Summary

- We present the first theoretical calculation of the radial distribution of a D meson in jets , which are well consistent with recent CMS data, both for p+p and Pb+Pb collision.
- We estimate the net effect on the charm diffusion from collisional and radiative mechanisms and demonstrate the p_T dependence of this effect.
- The ratio $\Delta r/\Delta E$ is sensitive for the diffusion coefficient D_S in collisional mechanism but not sensitive to $\hat{q}$, which indicates an essential difference between elastic and inelastic interaction.
- The nuclear modification factor R_{AA} both at the RHIC and the LHC are predicted.

Thanks for your attention !