

QPT 2019

Enshi, China

IOPP
Institute of Particle Physics



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

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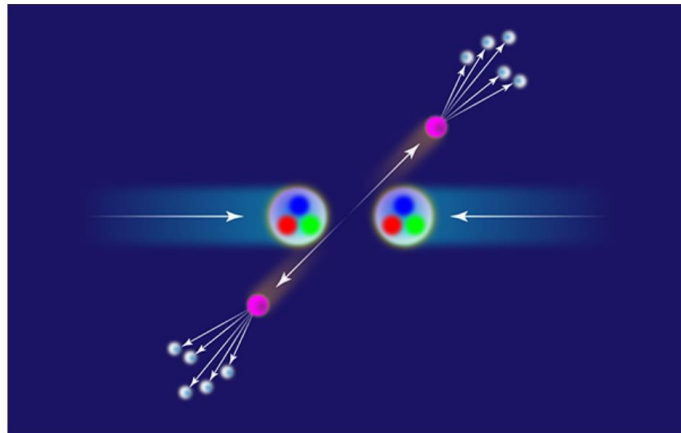
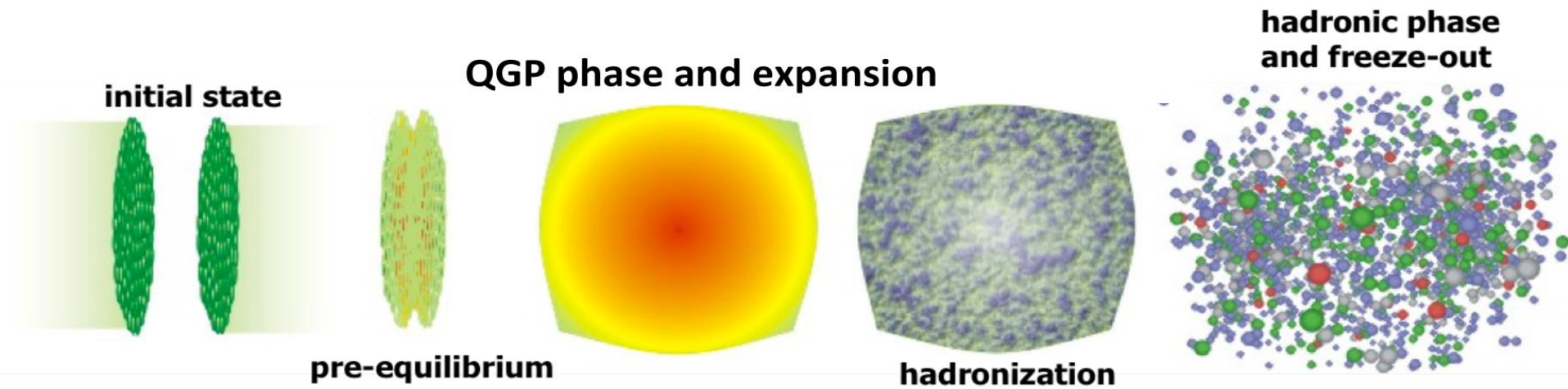
Based on [[arXiv :1906.01499](#)]

QPT2019, Enshi

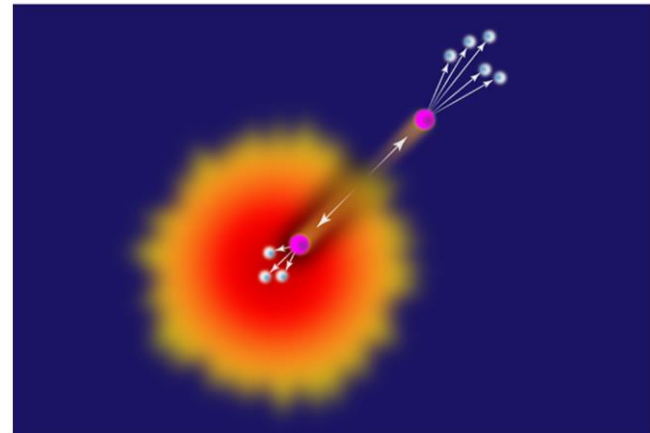
**Key Laboratory of Quark & Lepton Physics (MOE) and Institute of Particle Physics
CCNU**

Introduction

Jet quenching at high-energy heavy-ion collisions



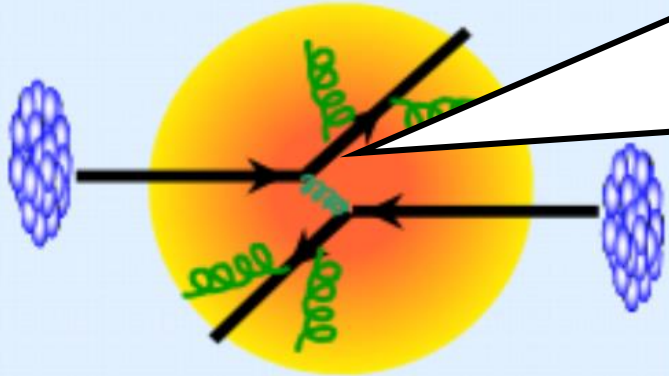
$p+p$



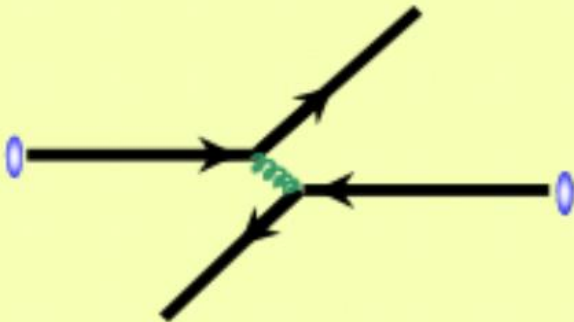
$A+A$

In-Medium Energy Loss

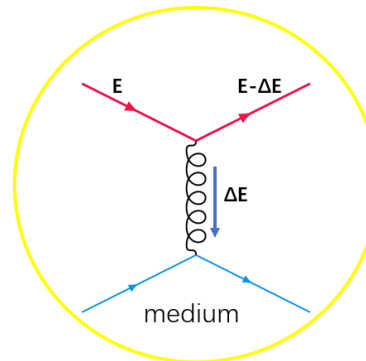
PbPb measurement



pp reference

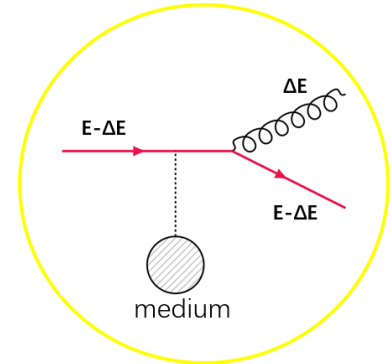


Collisional



+

Radiative



“Dead cone effect” :

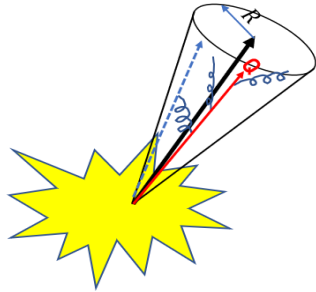
$$\frac{dP_{Q \rightarrow Qg}}{dx dk_{\perp}^2} = \left(\frac{1}{1 + x^2 \theta_0^2} \right)^4 \frac{dP_{q \rightarrow qg}}{dx dk_{\perp}^2}$$

where $\theta_0 \equiv \frac{M}{k_{\perp}}$

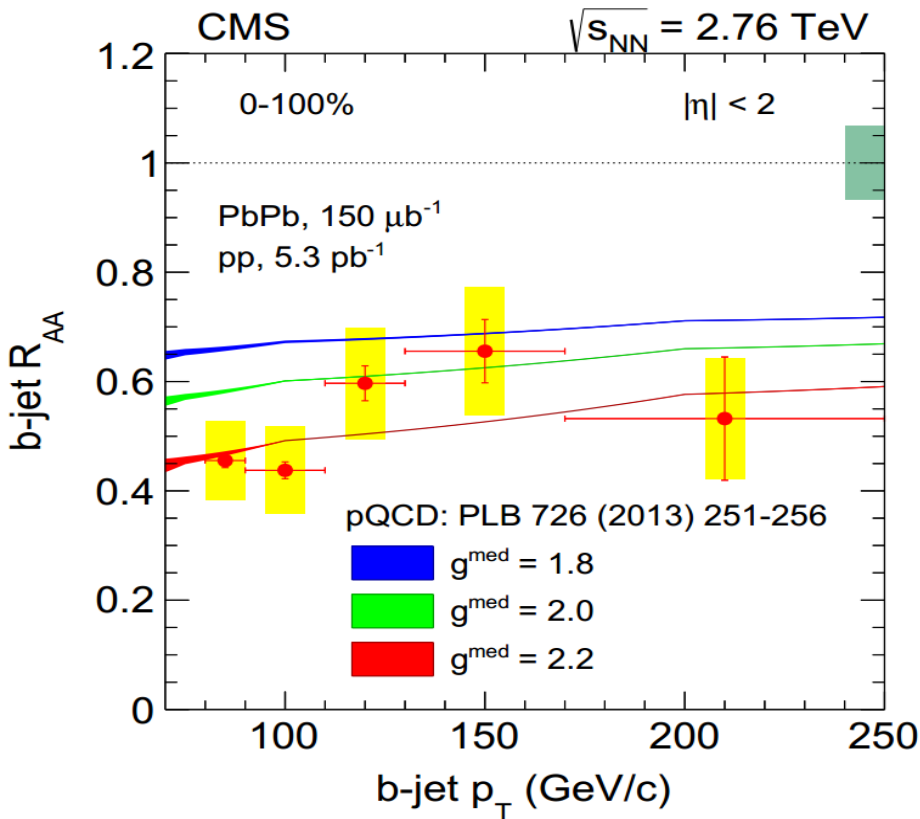


$$\Delta E_b < \Delta E_c < \Delta E_q < \Delta E_g$$

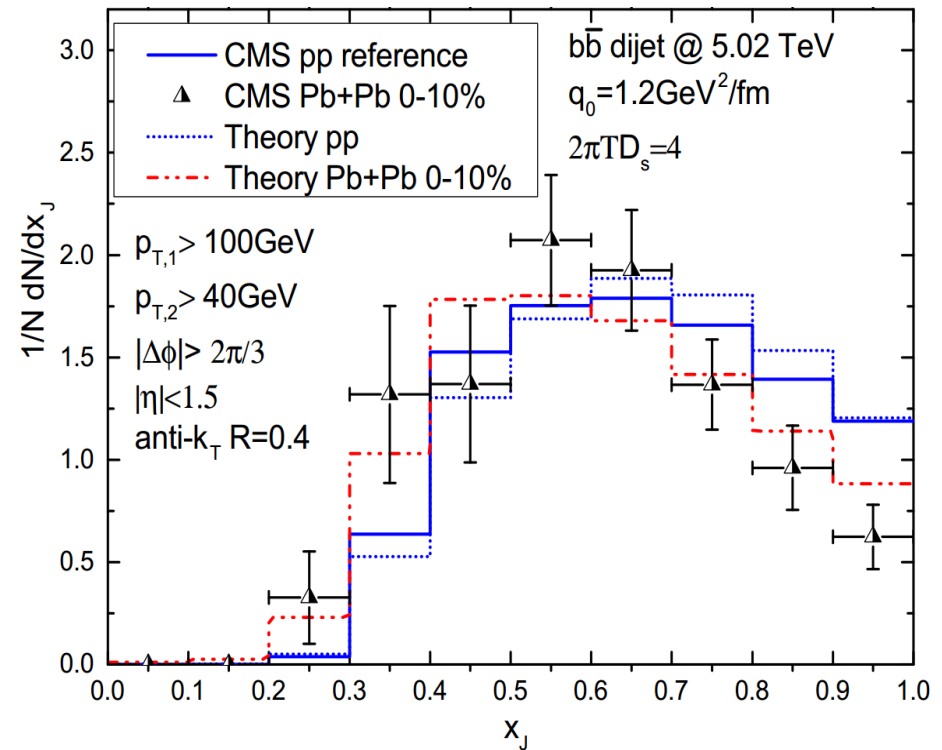
Heavy flavor jet



Heavy flavor jet—heavy quark (HQ) inside the jet cone with the jet radius parameter R .



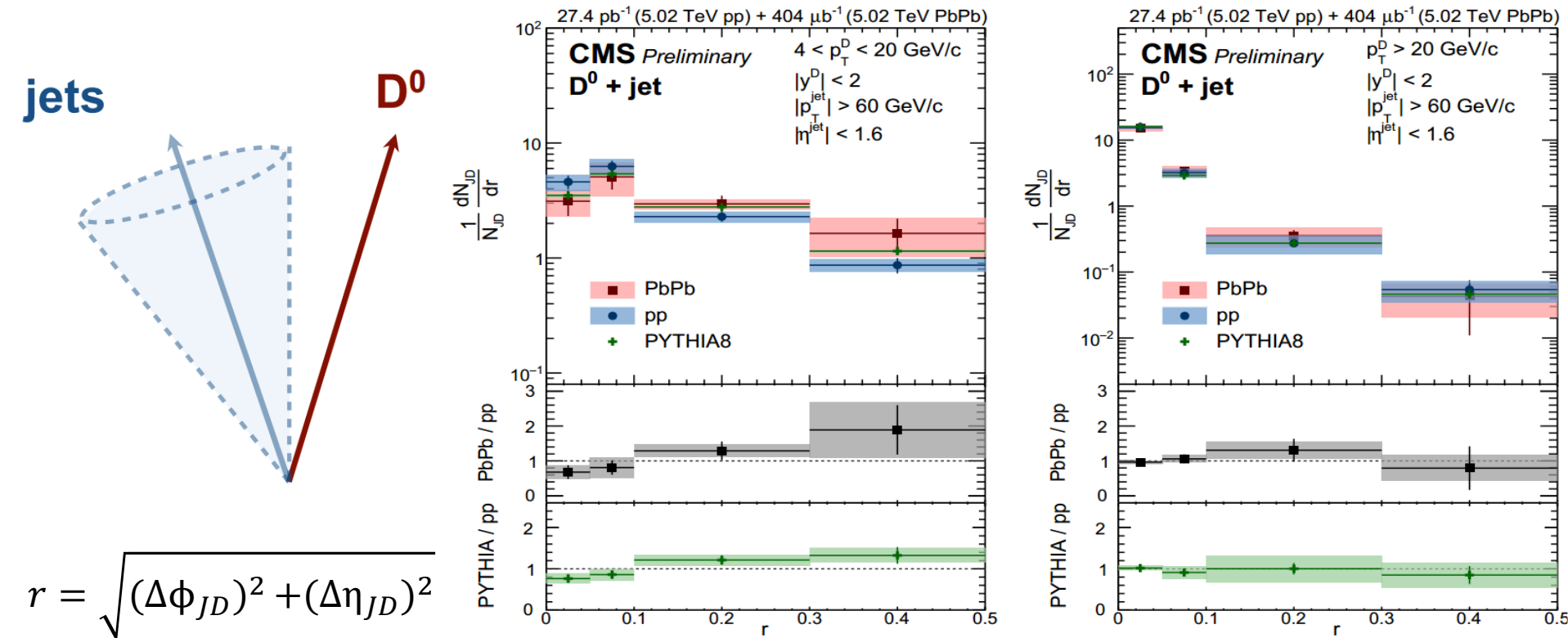
CMS collaboration, [PRL 113\(2014\)132301](#)



W. Dai S. Wang B-W. Zhang E. Wang, [arXiv: 1806.06332](#)

Talk by W.Dai tomorrow

Radial profile of D meson in jets



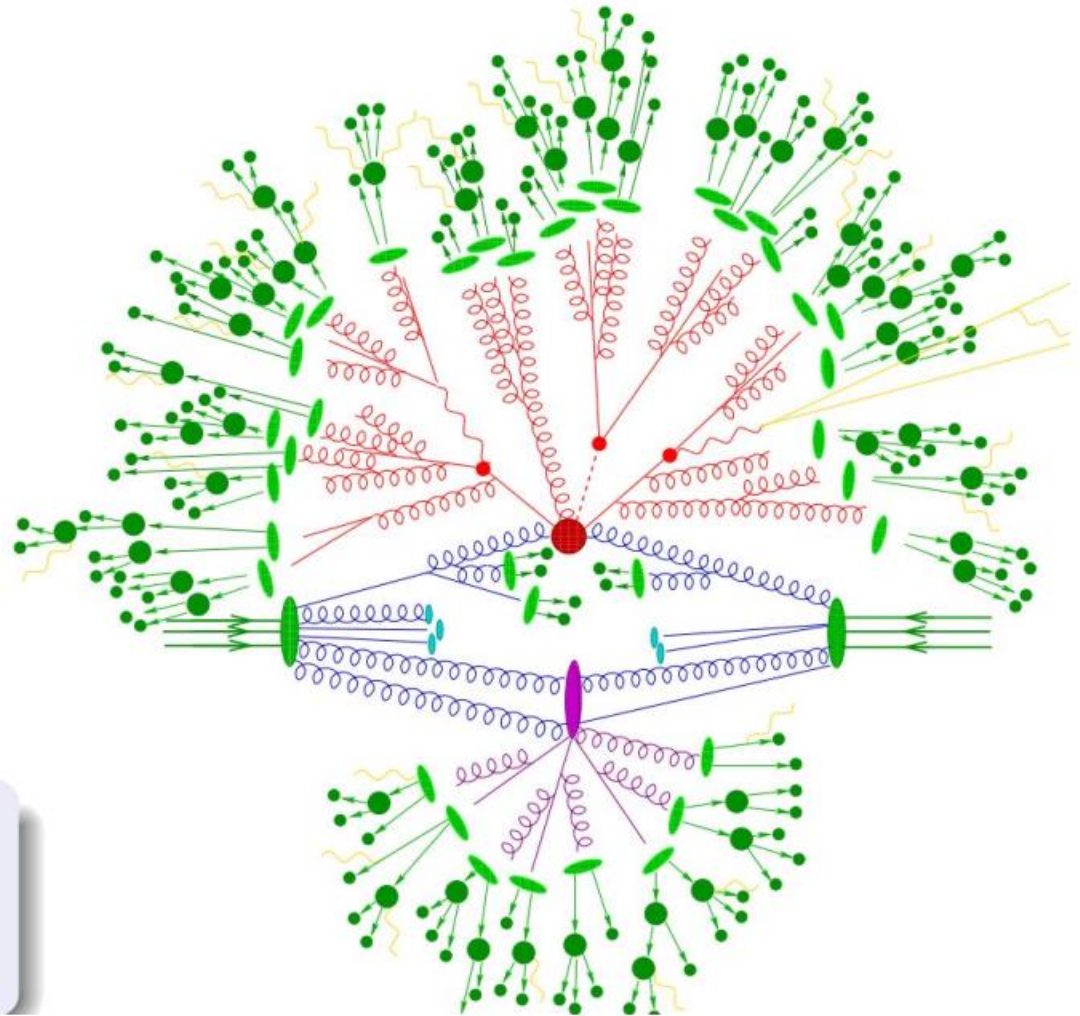
CMS-PAS-HIN-18-007

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

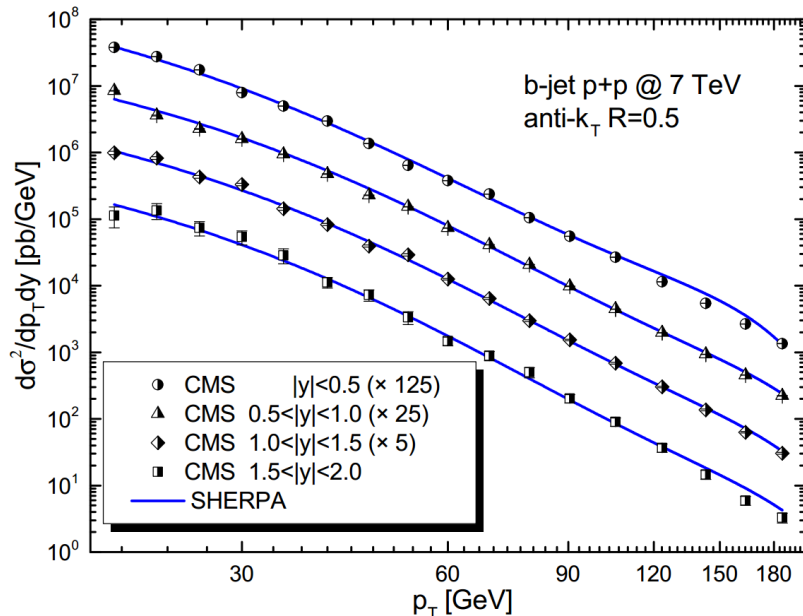
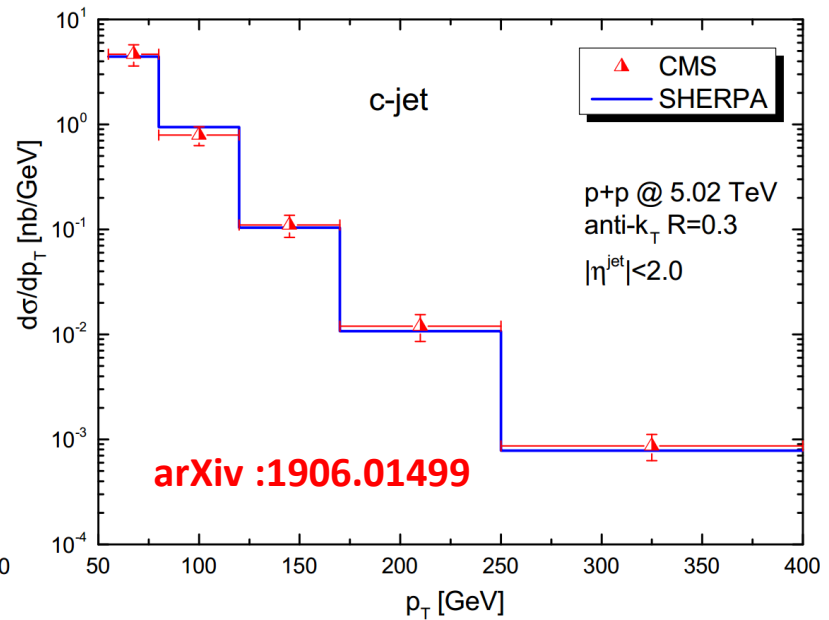
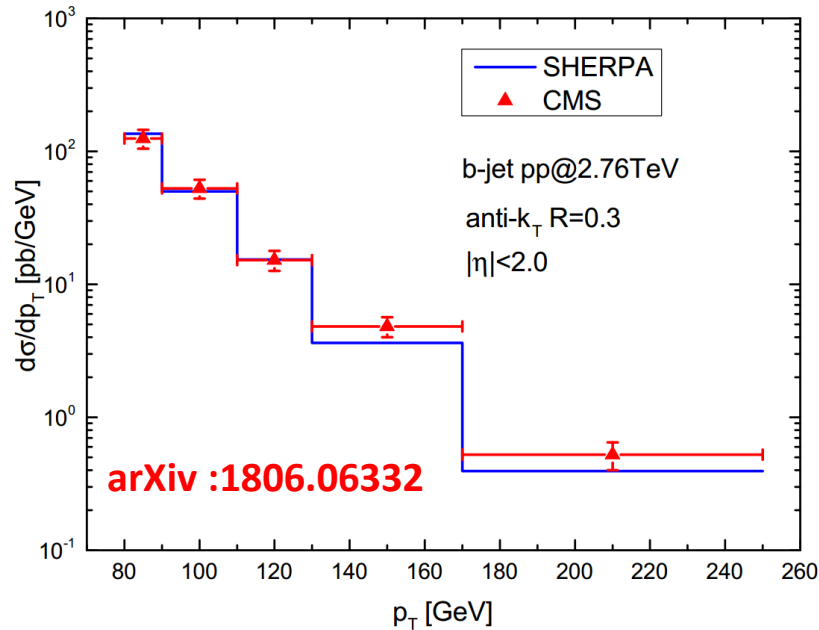
NLO+PS MC event generator ---- SHERPA

- 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.

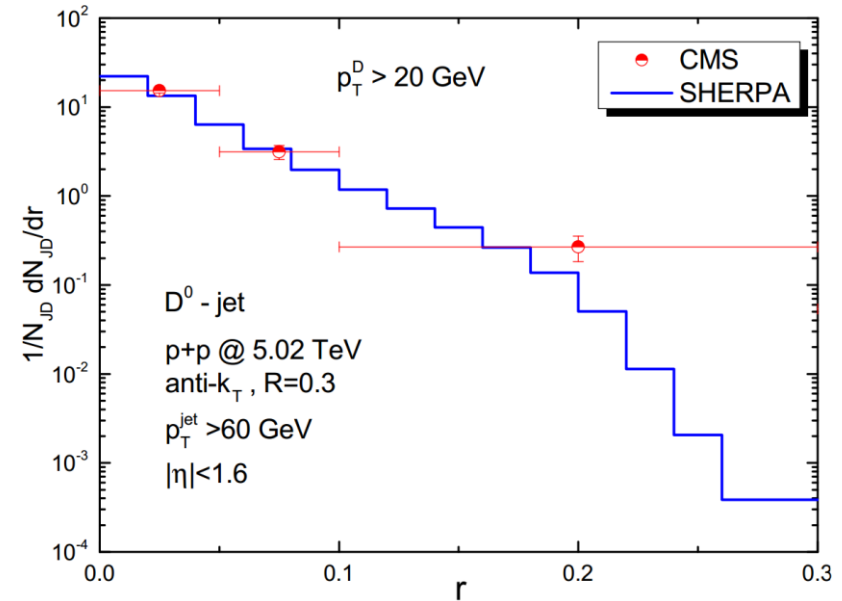
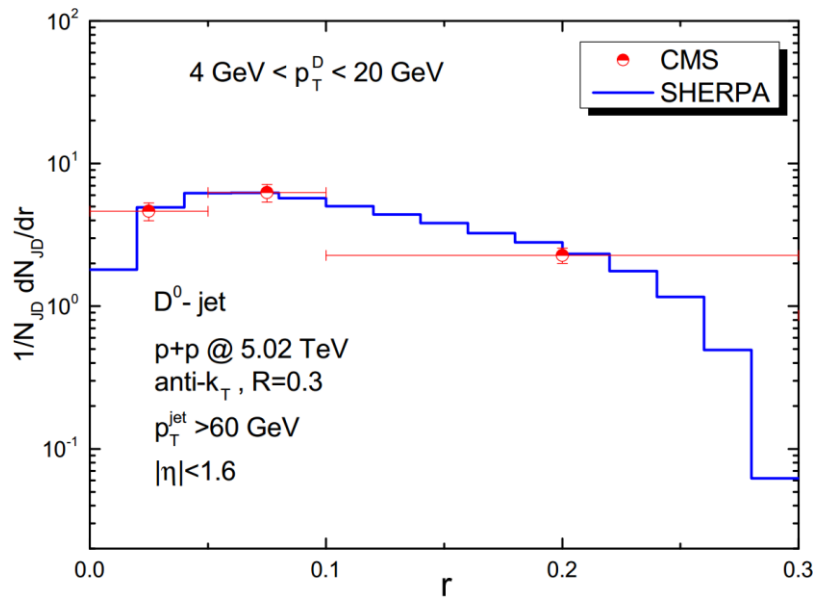


NLO+PS MC event generator ---- SHERPA



➤ SHERPA can 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 E-loss: Radiative

- The medium-induced radiative energy loss of final-state partons 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).]

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

- \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 $1.2 \text{ GeV}^2/\text{fm}$ 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](#).]:

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

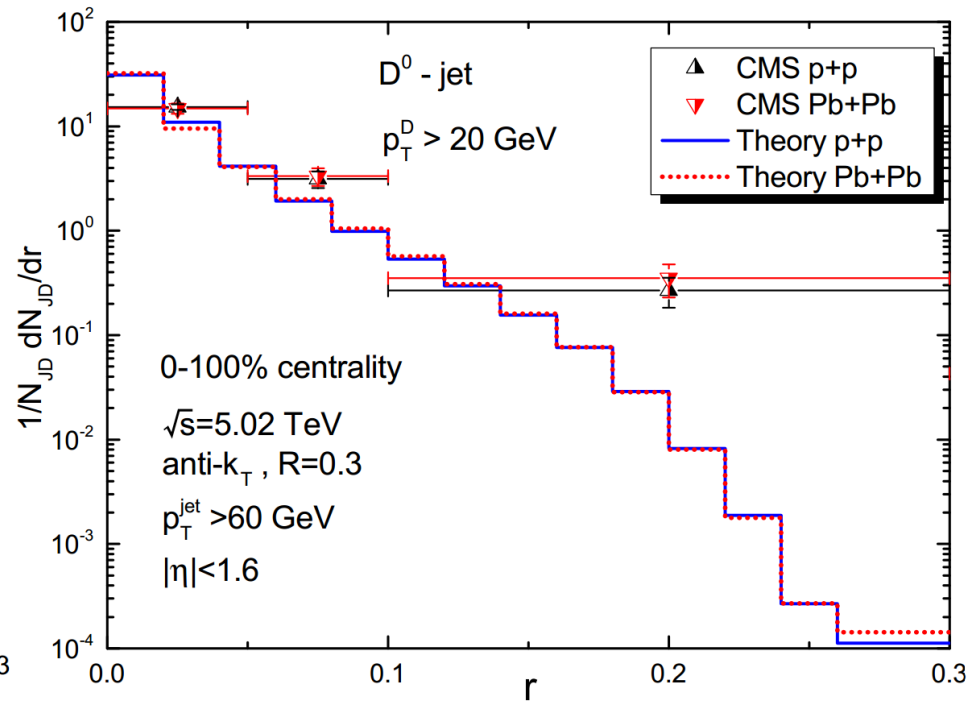
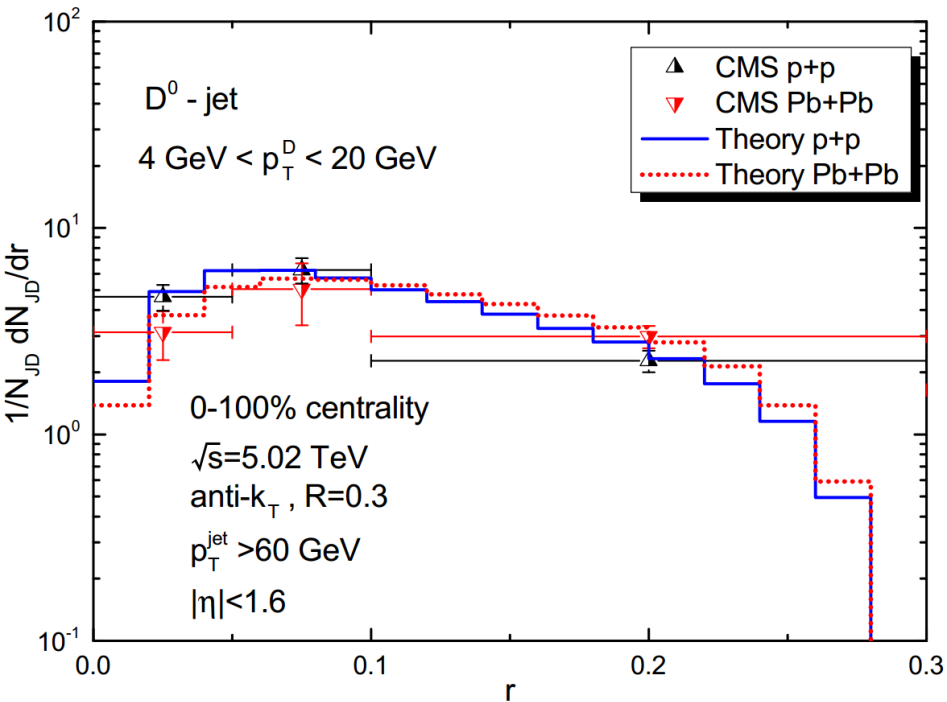
The Fluctuation-Dissipation Theorem: $\kappa = 2ET\Gamma = \frac{2T^2}{D_s}$. Based on the Lattice calculation [[arXiv:1508.04543 \[hep-lat\]](#)], D_s is fixed as $2\pi TD_s = 4$.

- 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.

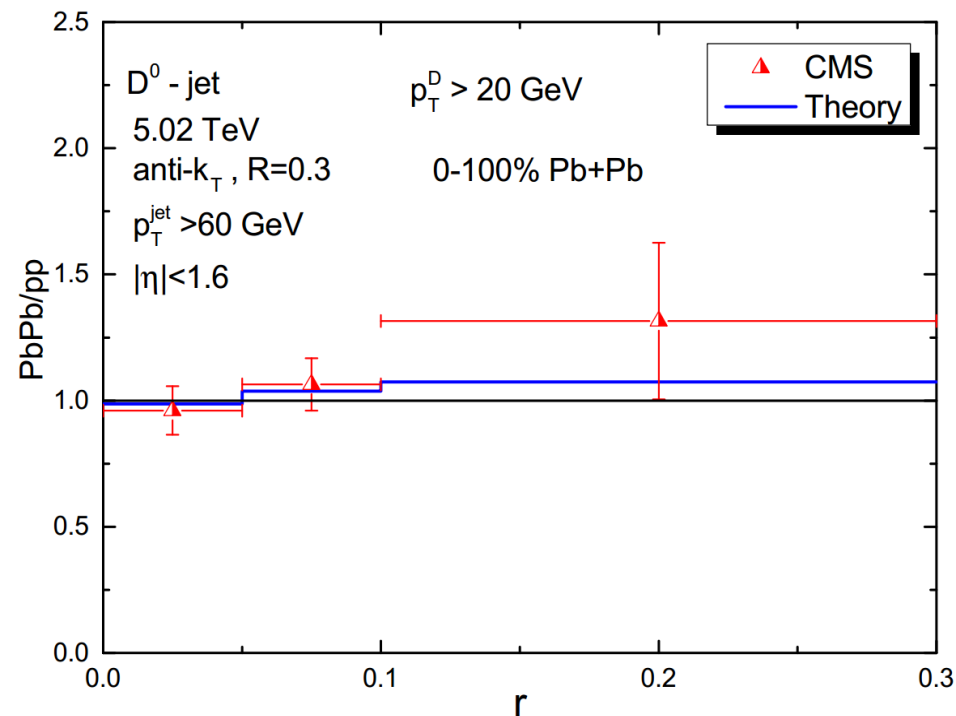
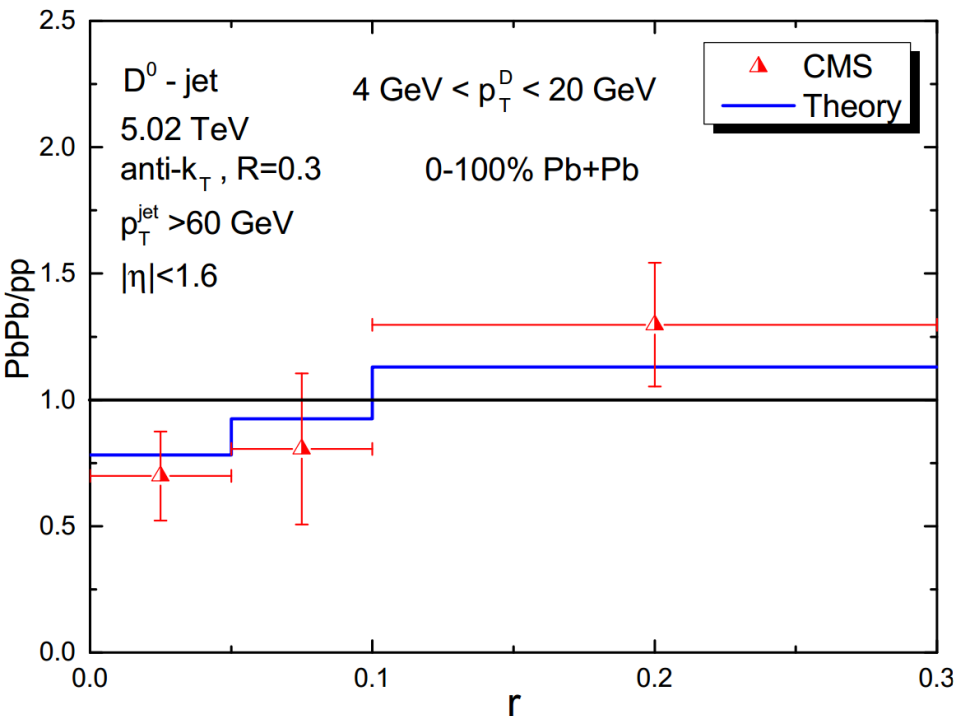
D^0 radial profile in jets in pp and PbPb



arXiv :1906.01499

- 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 collisions.
- For low p_T D meson, a significant modification was observed in Pb+Pb collisions relative to the pp baseline.

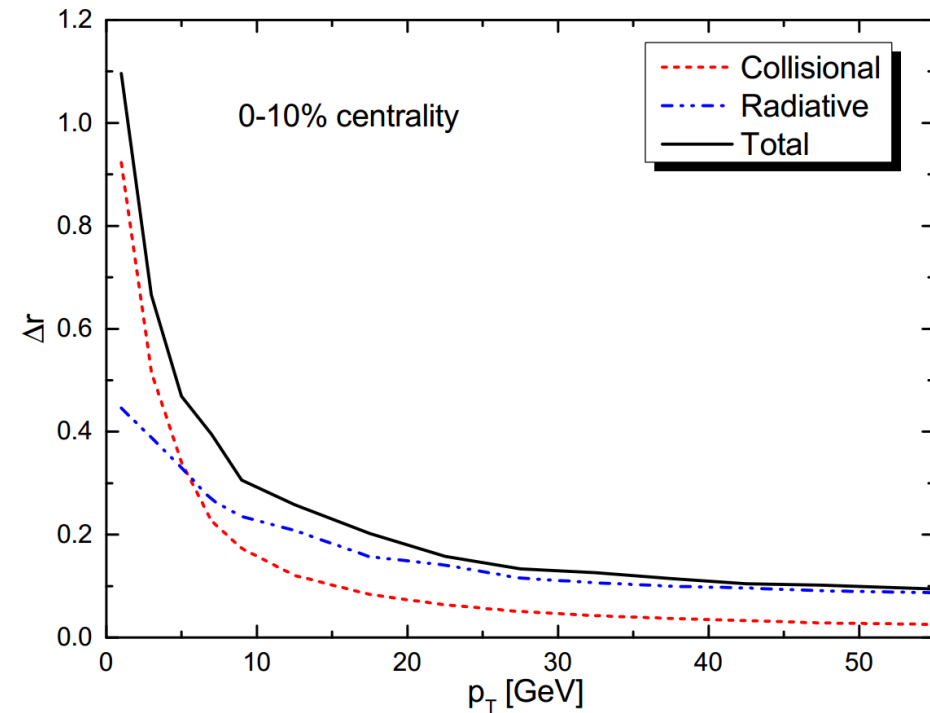
Medium modification



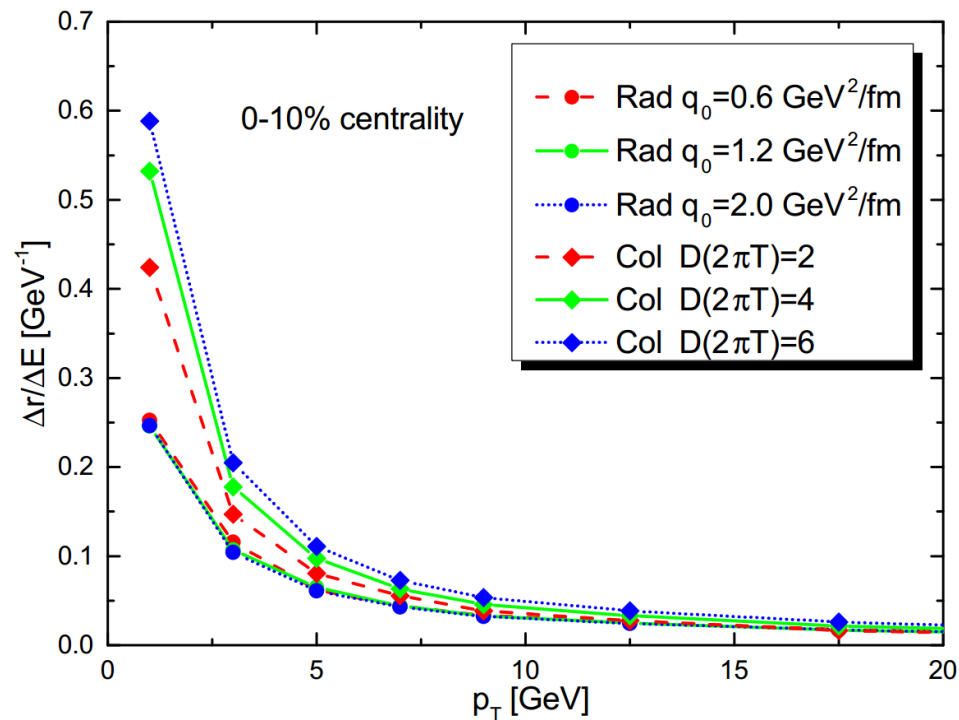
arXiv :1906.01499

- 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 4-20 GeV 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.

Radiative & Collisional



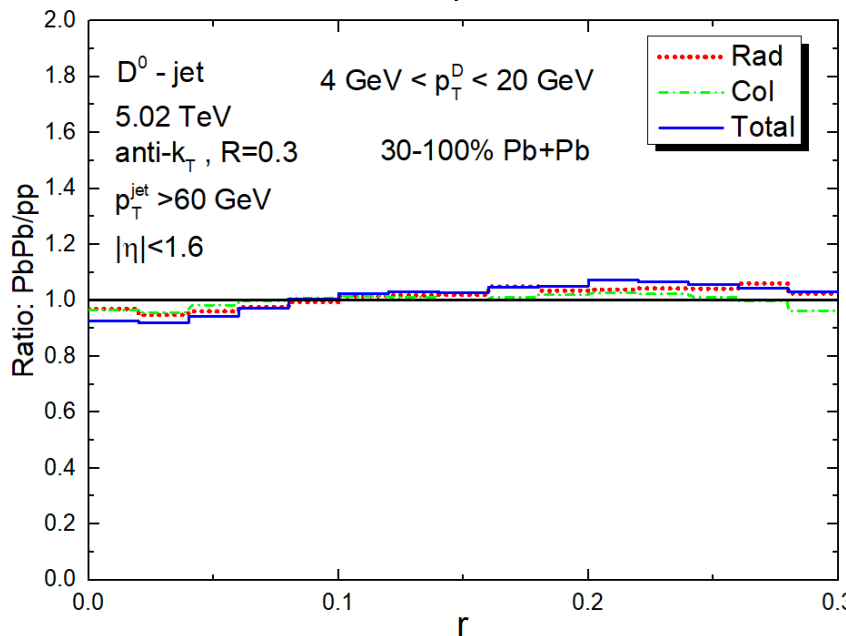
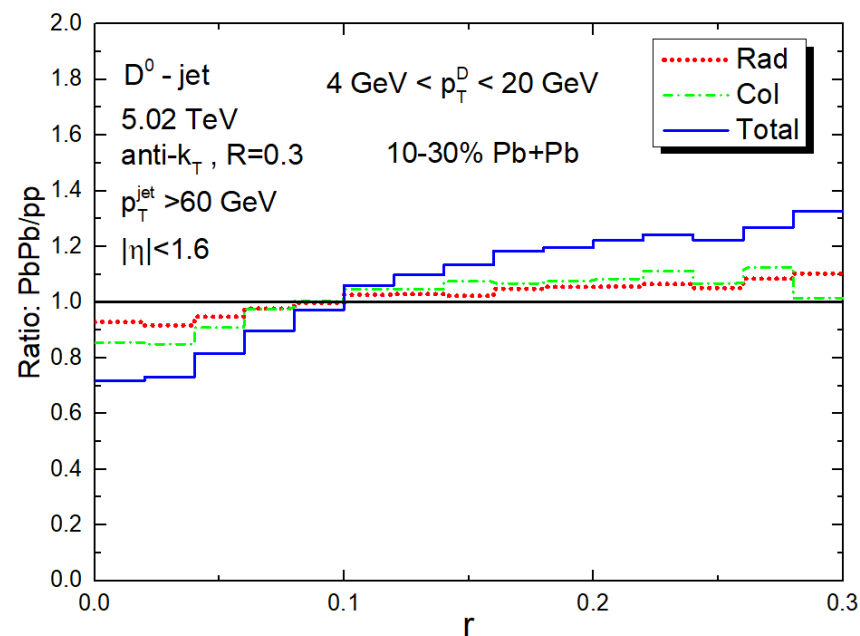
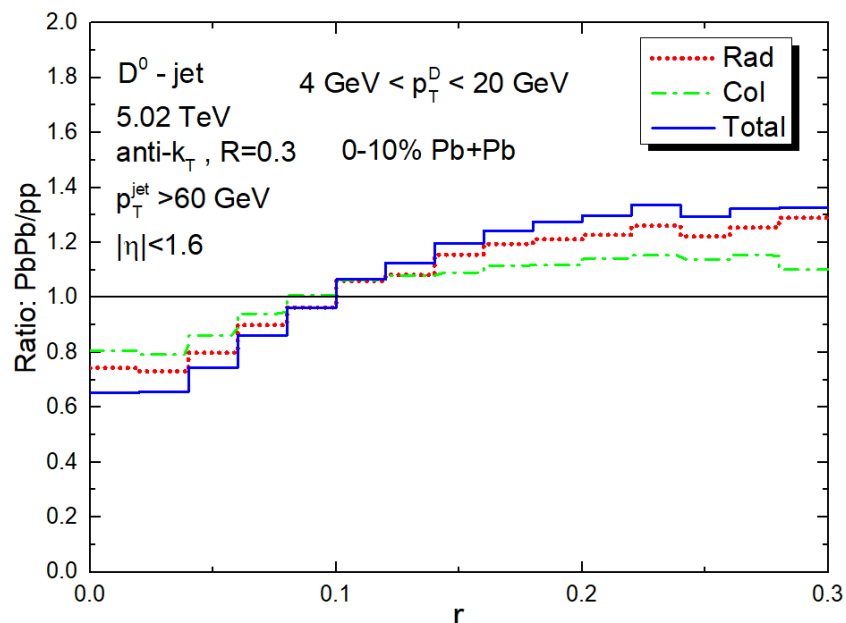
$$\Delta r = \sqrt{(\phi_c - \phi_c^0)^2 + (\eta_c - \eta_c^0)^2}$$



arXiv :1906.01499

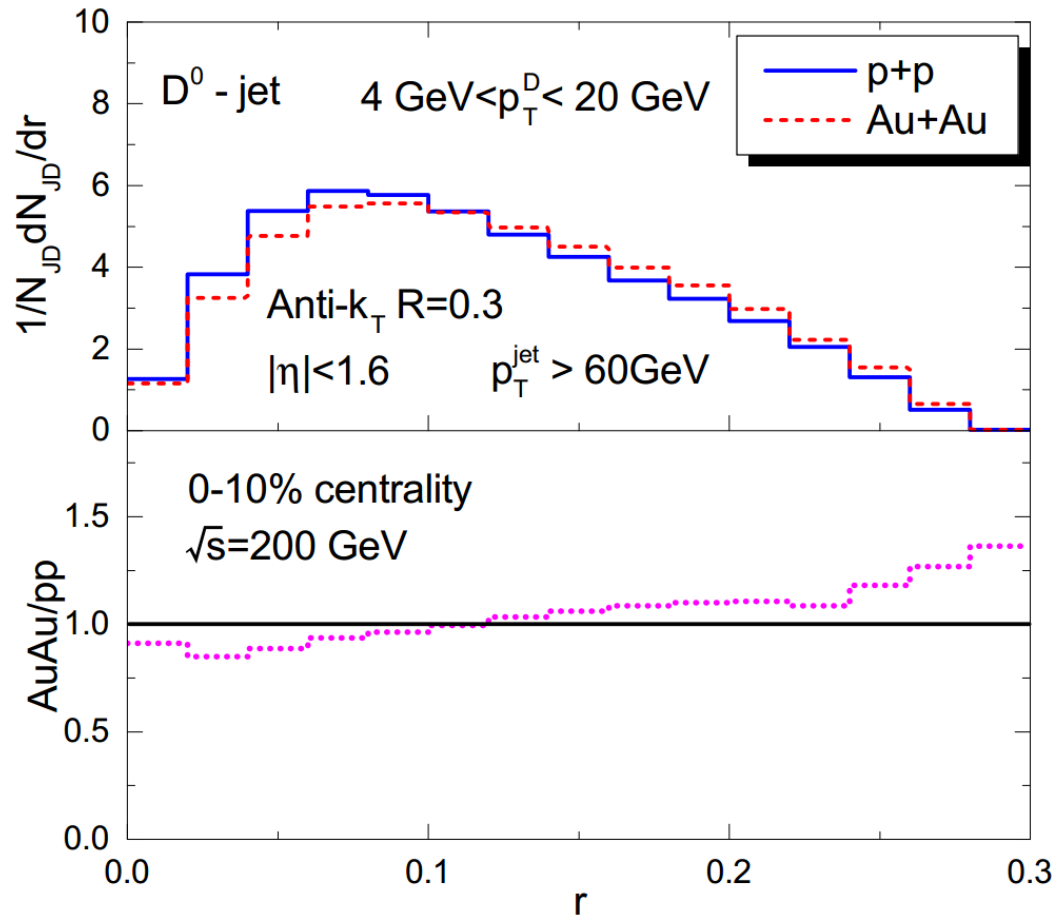
- The total diffusion effects decrease with increasing p_T .
- The ratio $\Delta r/\Delta E$ is sensitive for the parameter D_s in collisional mechanism but not sensitive to \hat{q}_0 , which may indicate an essential difference between elastic and inelastic interaction.

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%.

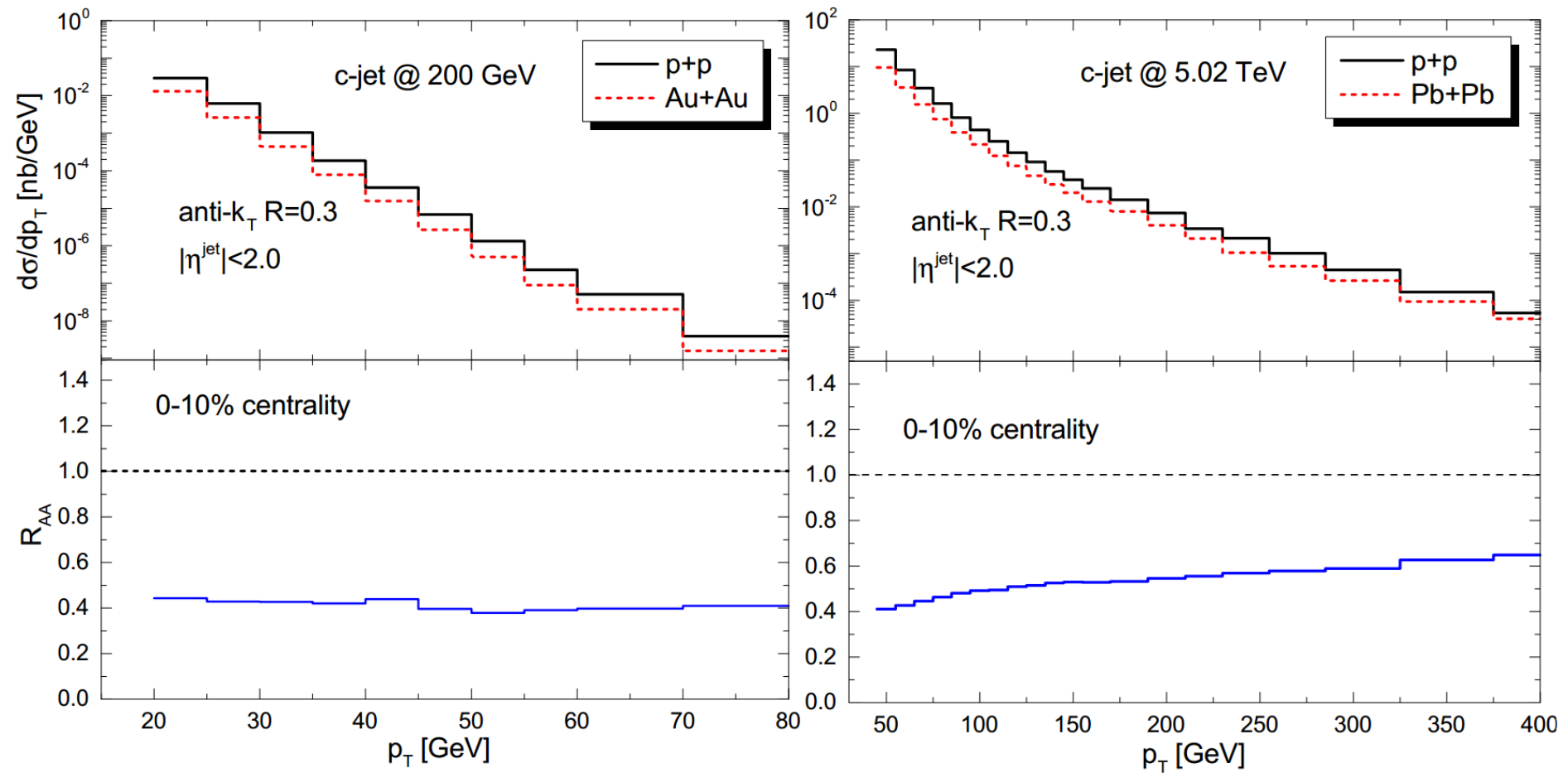
D^0 radial diffusion in jets at the RHIC



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}



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

arXiv :1906.01499

Summary

- We present the first theoretical calculation of the radial distribution of a D meson in jets .
- 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 to D_S but not \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 !