QCD, Trento, 2018

Dihadron angular correlation

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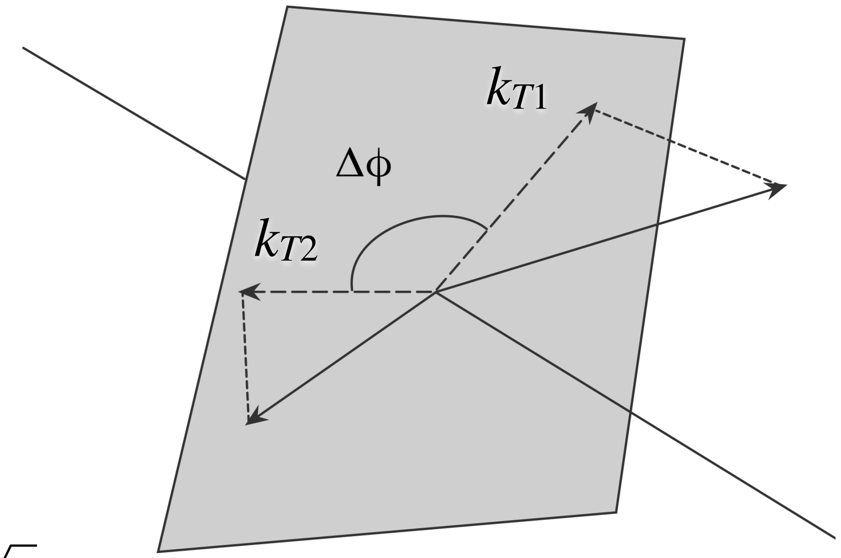
L. Chen, G.Y. Qin, S.Y. Wei, B.W. Xiao, H.Z. Zhang (arXiv:1607.01932)
A. Stasto, S.Y. Wei, B.W. Xiao, F. Yuan (arXiv: 1805.05712)

Contents

What is dihadron angular correlation?

azimuthal angular correlation

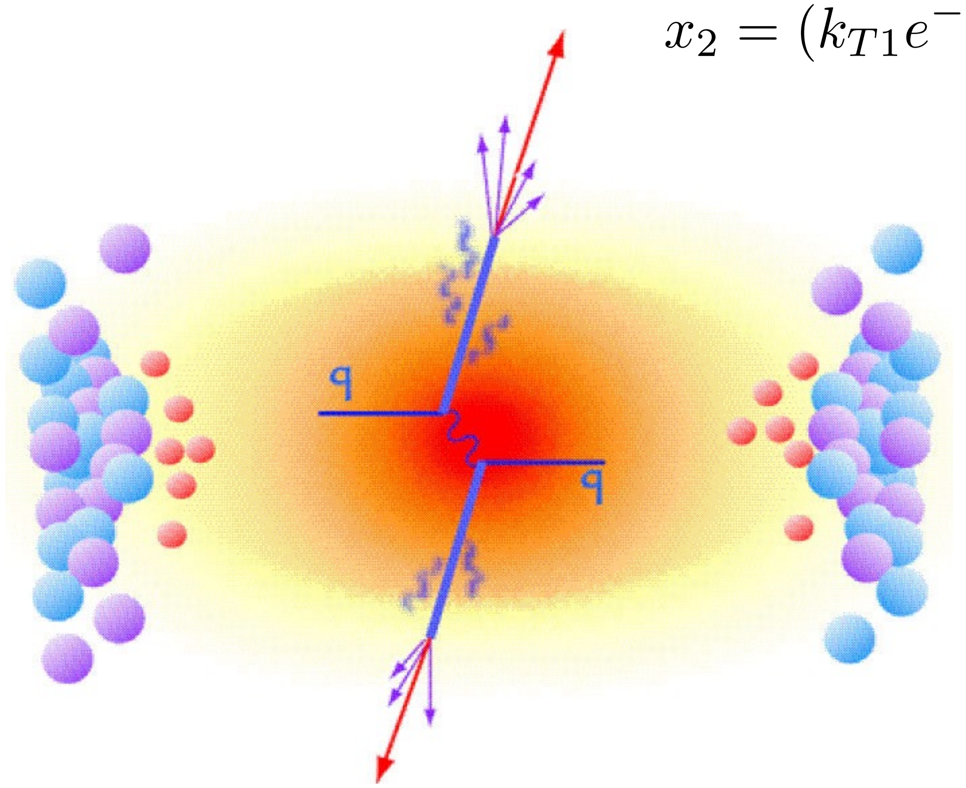
in the transverse plane

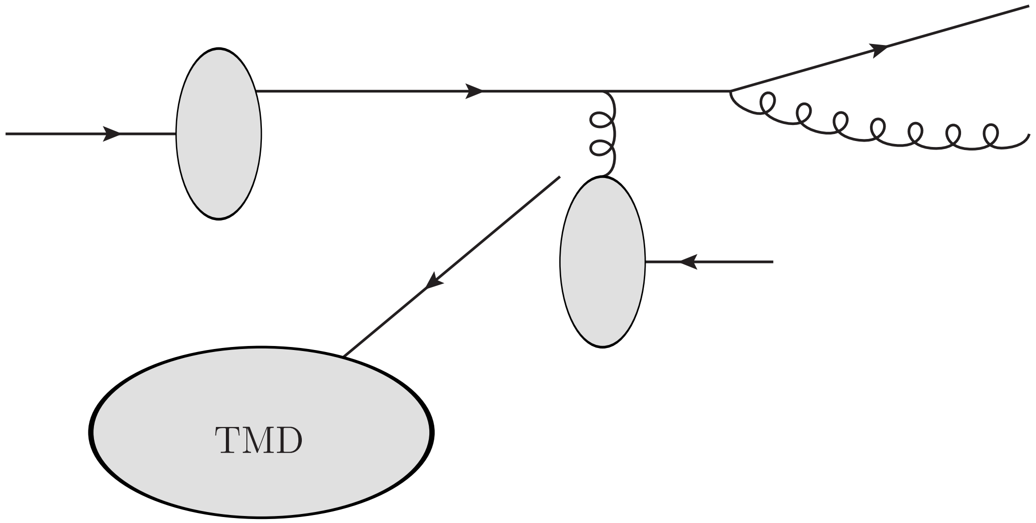


Why is it interesting?

$$x_1 = (k_{T1}e^{+y_1} + k_{T2}e^{+y_2})/\sqrt{s}$$

$$x_2 = (k_{T1}e^{-y_1} + k_{T2}e^{-y_2})/\sqrt{s}$$





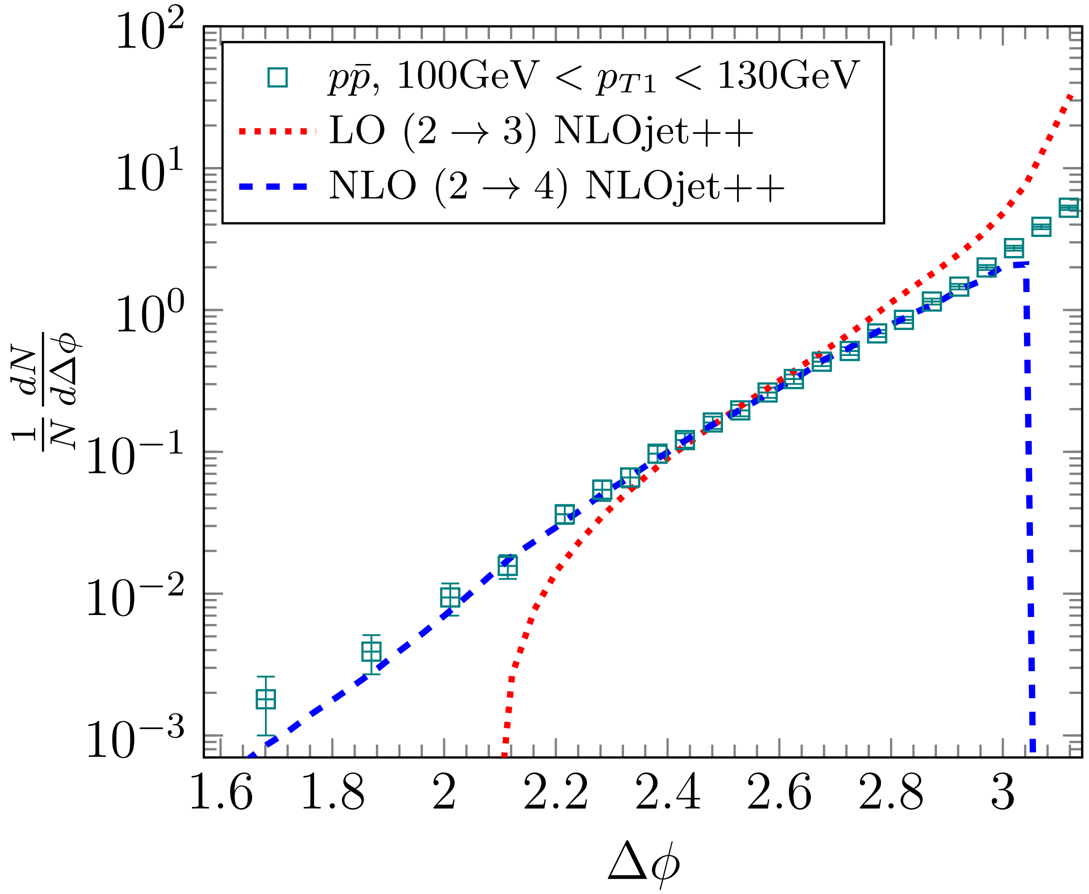
Middle Rapidity: jet-medium interaction

collinear factorization

Forward Rapidity: small-x physics

dilute-dense factorization

Dijet angular correlation in *pp* with perturbative expansion approach



$2 \to 3$ $\quad$ $2 \to 3/4$

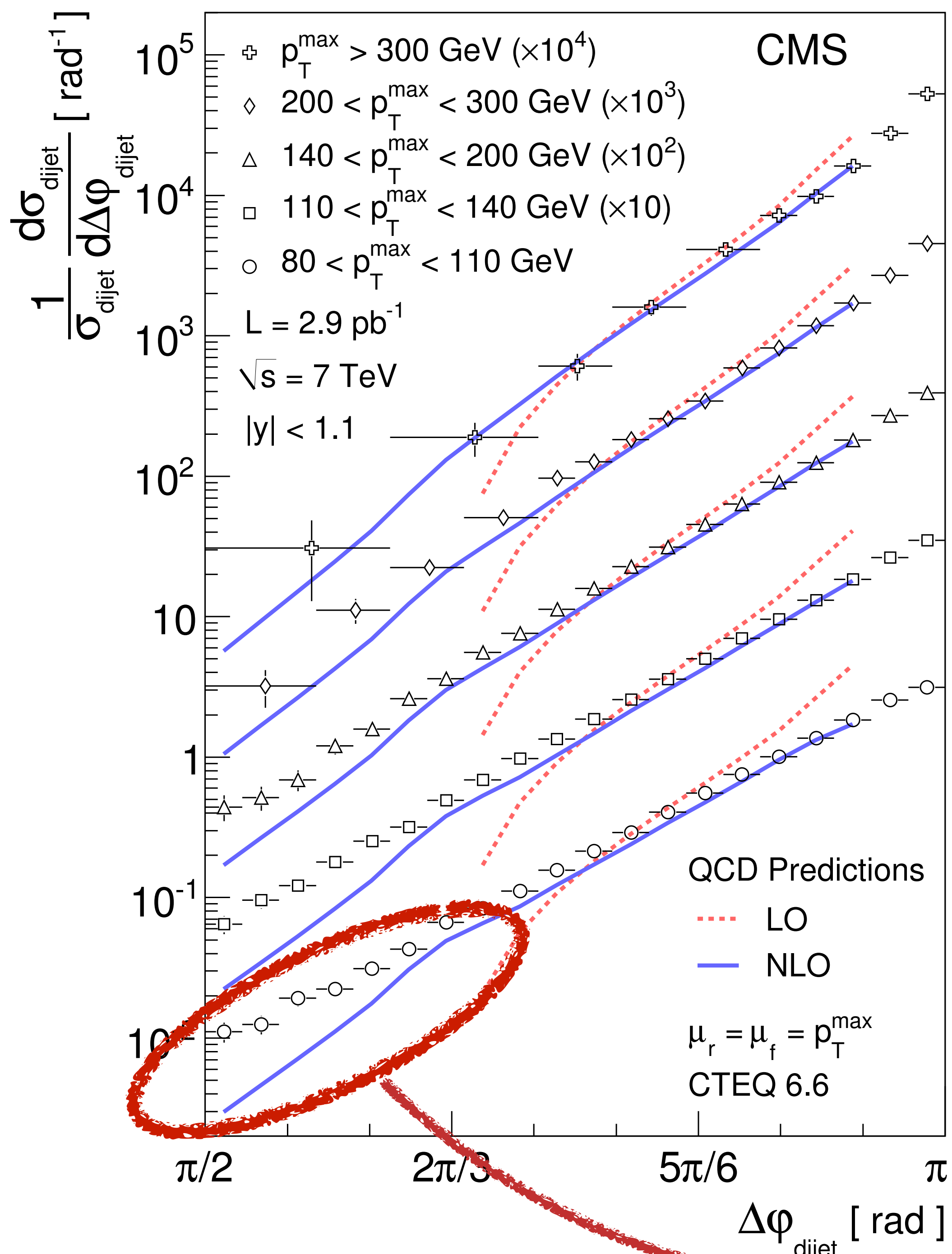
$$\frac{1}{N}\frac{dN}{d\Delta\phi} \leftrightarrow \frac{1}{\sigma_{\rm LO}}\frac{d\sigma_{\rm LO}}{d\Delta\phi} \leftrightarrow \frac{1}{\sigma_{\rm NLO}}\frac{d\sigma_{\rm NLO}}{d\Delta\phi}$$

$2 \to 2$ $\quad$ $2 \to 2/3$

D0 @ 1.96 TeV: PRL 94, 221801 (2005)

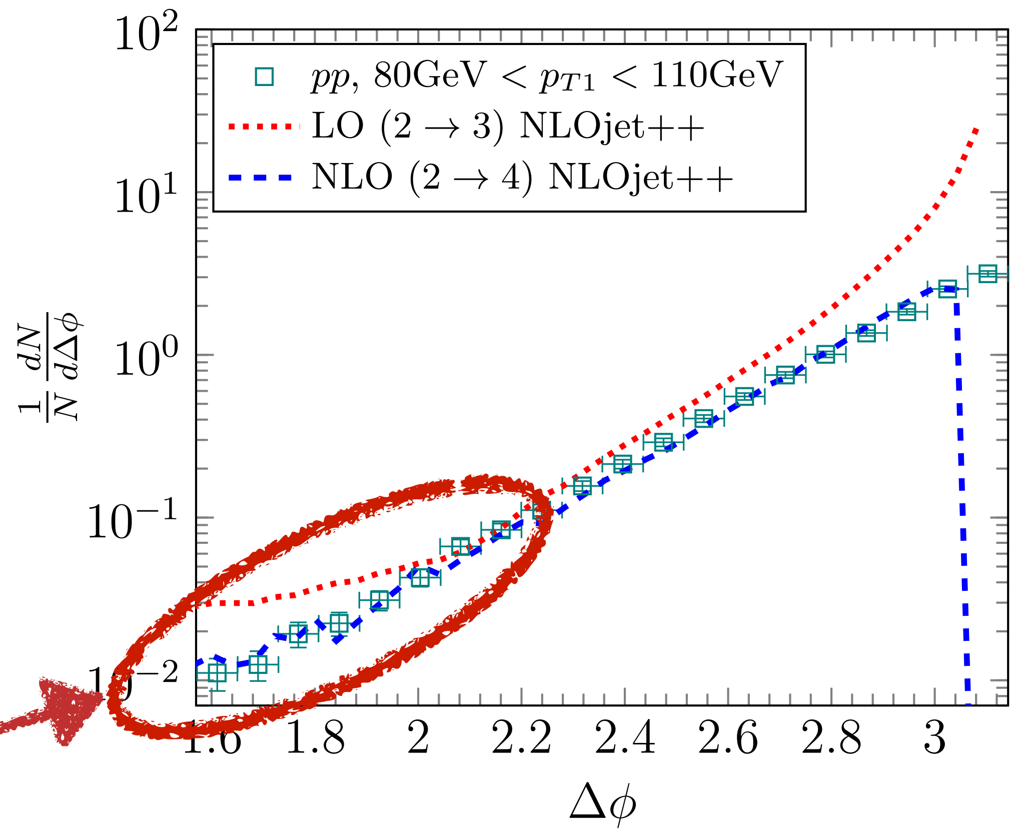
☑ NLO calculation can describe the experimental data very well.

Dijet angular correlation in *pp* with perturbative expansion approach



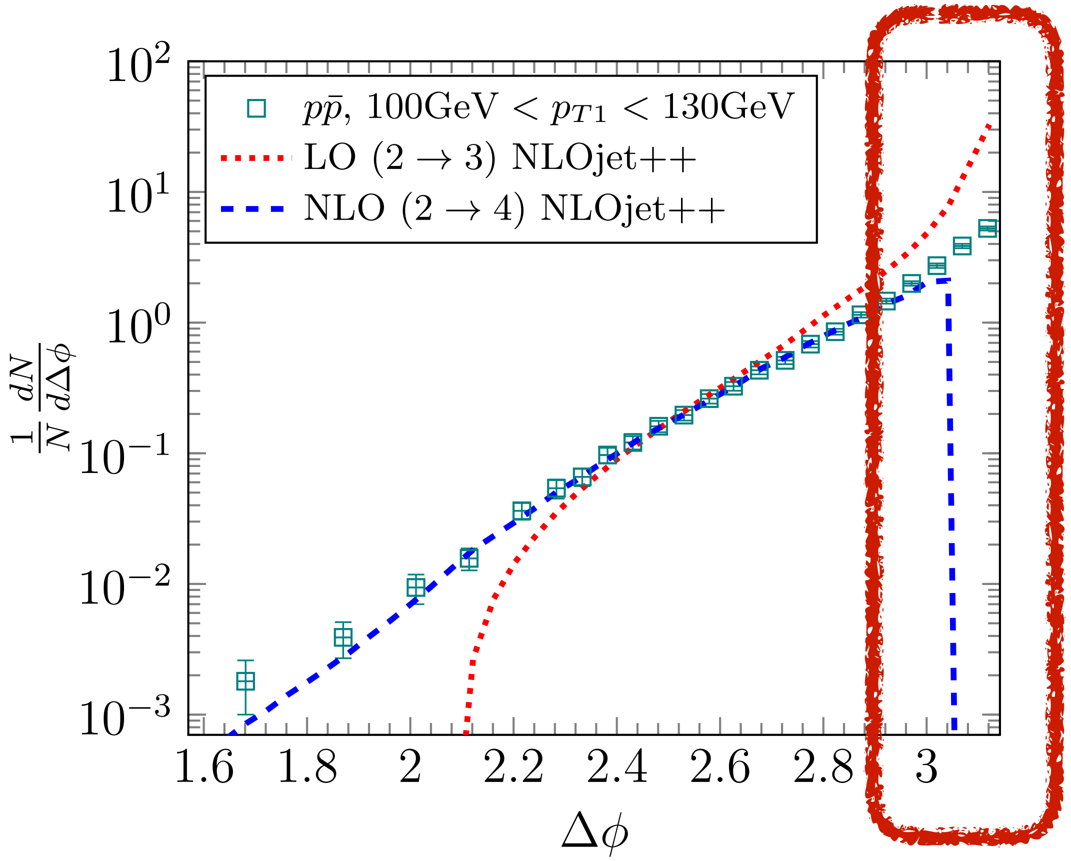
- ☑ Find leading and sub-leading jets
- ☑ Only keep the events with |y|<1.1

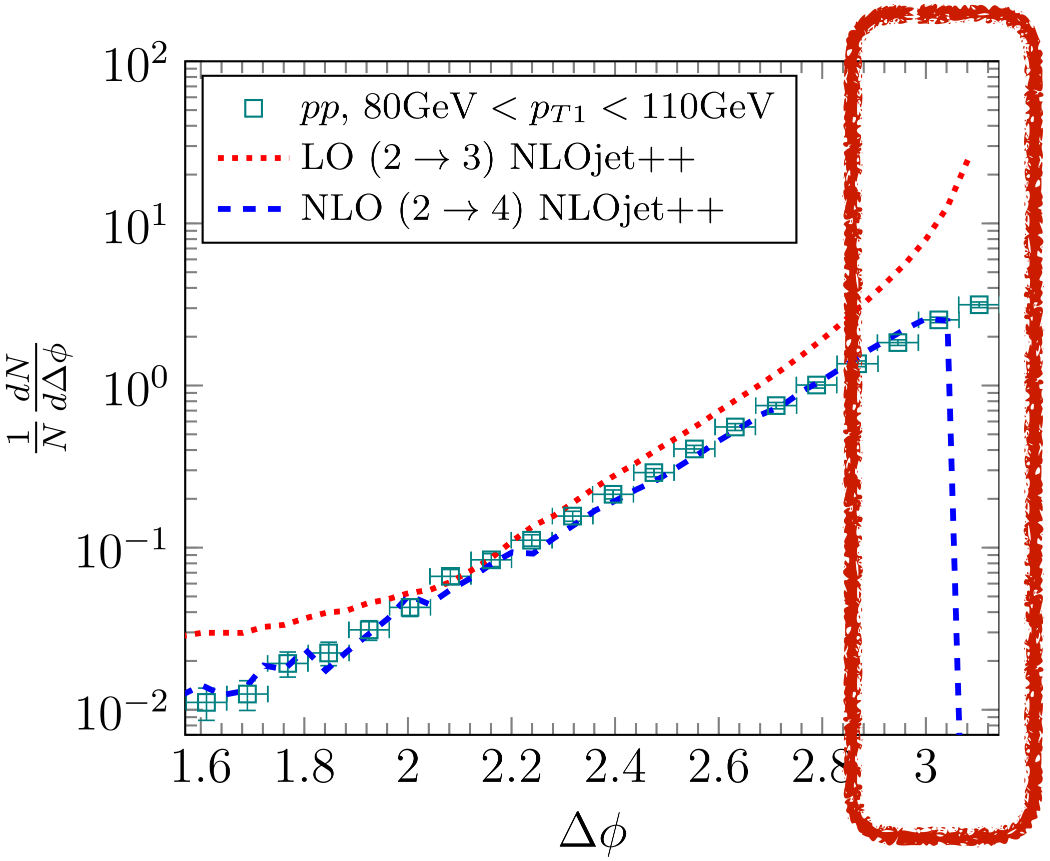
- ☑ Find (sub-)leading jets that you can observe
- ☑ Only keep the events with |y|<1.1



CMS @ 7TeV, arXiv:1101.5029

Dijet angular correlation in *pp* with perturbative expansion approach





Perturbative Expansion	Resummation
$\sigma_0 \sum_{i=0}^{n} \Big((\alpha_s \text{Log})^i + \alpha_s^i C_i \Big)$	$\sigma_0 \sum_{i=0}^{n} \Big((\alpha_s \text{Log})^i \Big) + \sigma_0 \sum_{n+1}^{\infty} \Big((\alpha_s \text{Log})^i \Big)$

- ☑ Perturbative Expansion: α_s is small
- ☑ Resummation: large logs

Introduction

Dijet angular correlation in *pp* with Resummation approach

Perturbative Expansion

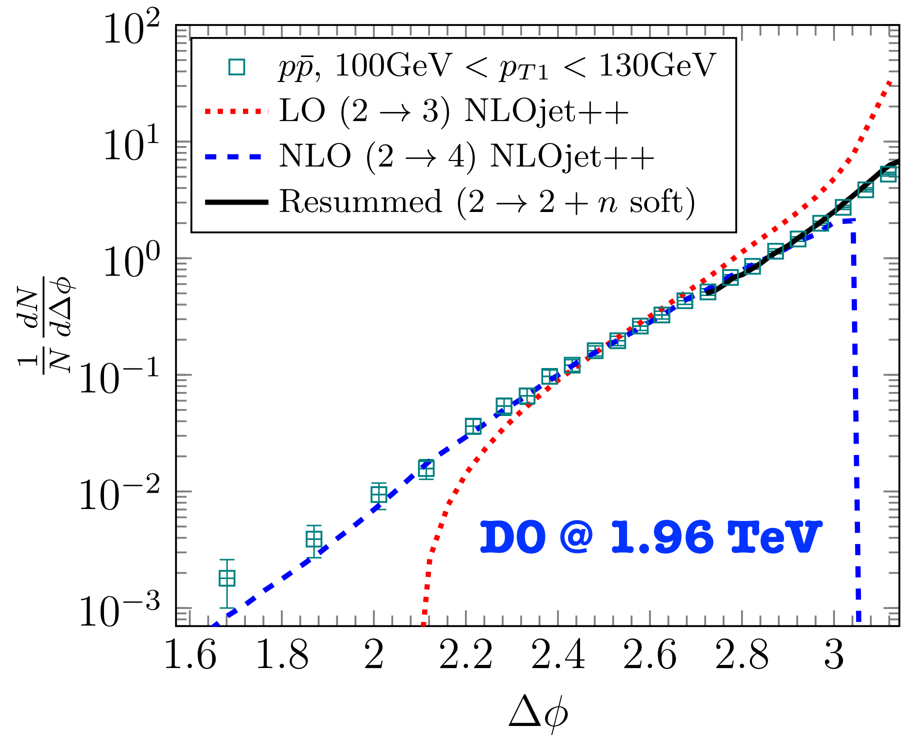
paradigm shift

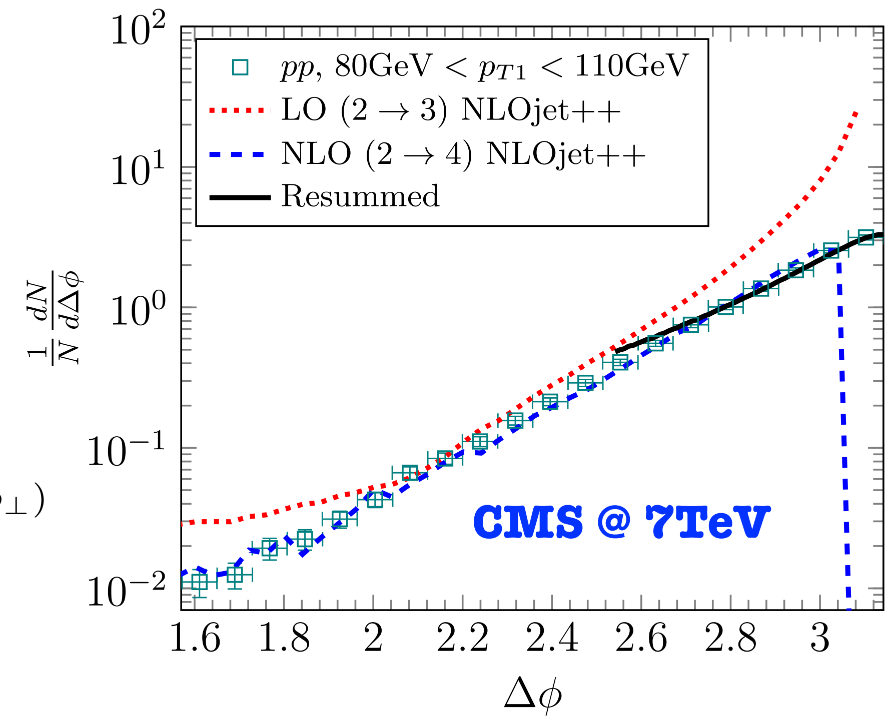
large logarithms

$$(\alpha_s \ln^2 \frac{p_T^2}{q_\perp^2})^n$$

Sudakov Resummation

$2 \rightarrow 2 + n$ Soft gluon radiations (parton shower)





$$\frac{d\sigma}{dy_1 dy_2 dk_{1\perp}^2 d^2k_{2\perp}} = \sum_{ab} \int \frac{d^2 b_\perp}{(2\pi)^2} e^{-i\vec{q}_\perp \vec{b}_\perp} x_1 f_a(x_1, \mu_b) x_2 f_b(x_2, \mu_b) \frac{1}{\pi} \frac{d\sigma}{dt} e^{-S(Q^2, b_\perp)}$$

NLL resummation

Sun, Yuan, Yuan, PRL113 (2014), PRD92 (2015)

Dijet angular correlation in *pp* with Resummation approach

$$S^i(Q,b) = \int_{\mu_b^2}^{Q^2} \frac{d\mu^2}{\mu^2}\left[A_i \frac{\alpha_s}{2\pi}\ln\left(\frac{Q^2}{\mu^2}\right) + B_i \frac{\alpha_s}{\pi}\right]$$

b*-prescription

$$\mu_b = c_0/b$$

$$\mu_b = c_0/b^* \qquad b^* = b/\sqrt{1+b^2/b_{\max}^2}$$

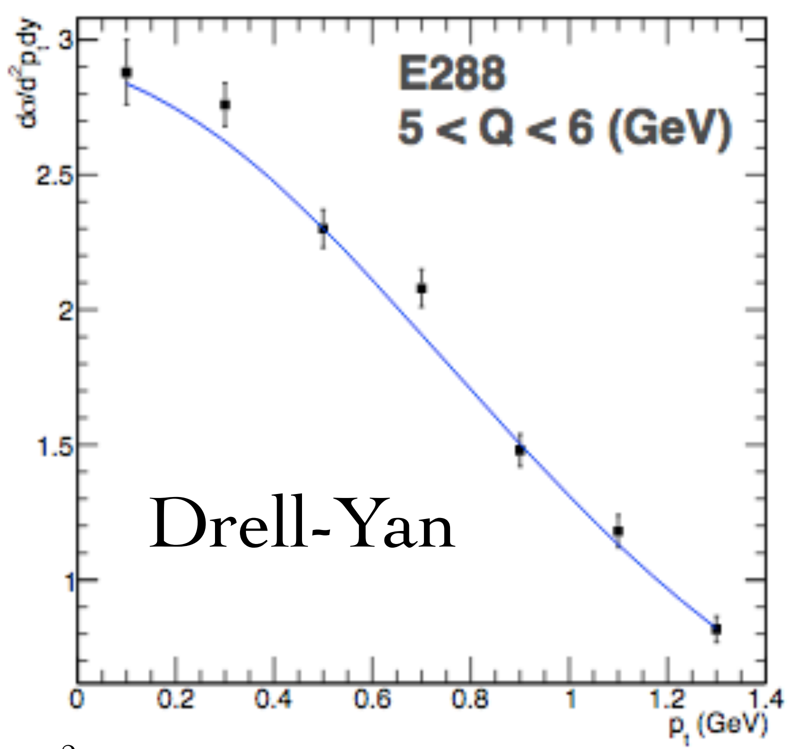
$$S(Q,b) = S_{\text{perturbative}}(Q,b) + S_{\text{non-perturbative}}(Q,b)$$

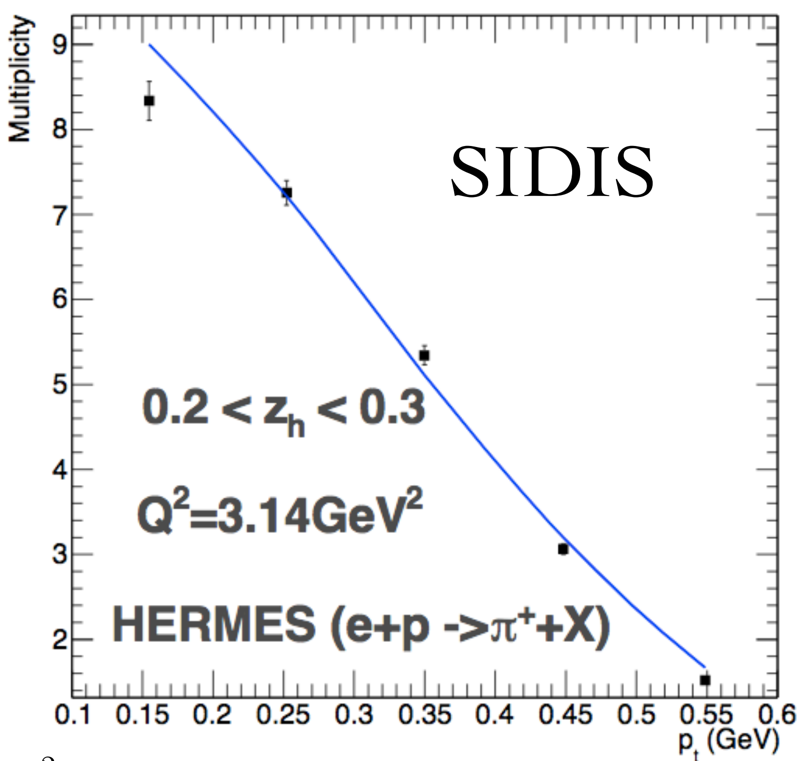
double logs and single logs

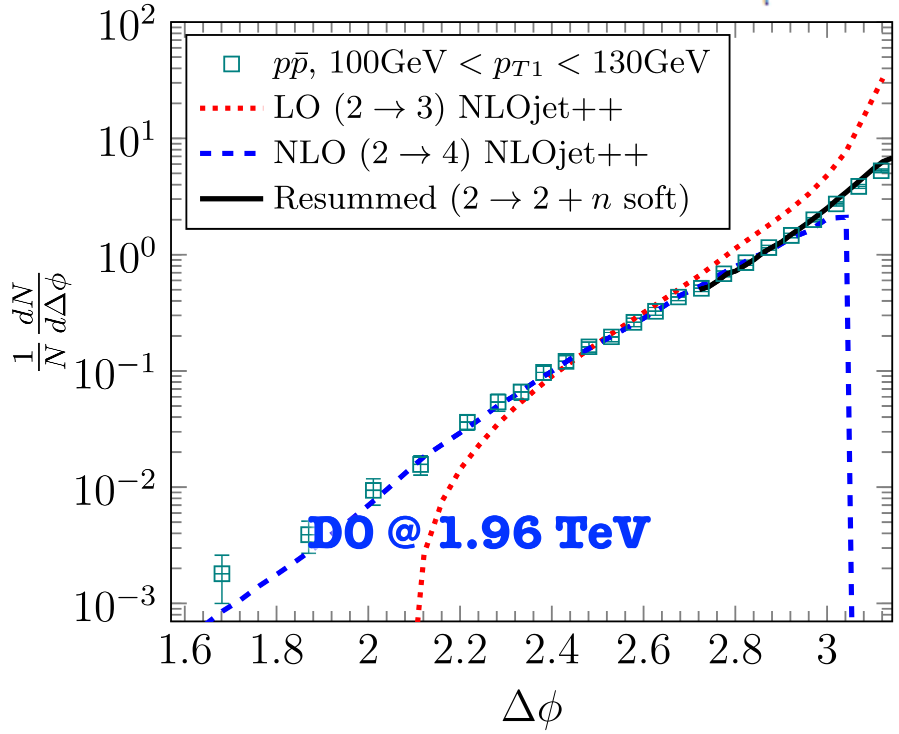
Universal / Gaussian form / Extracted from experiments

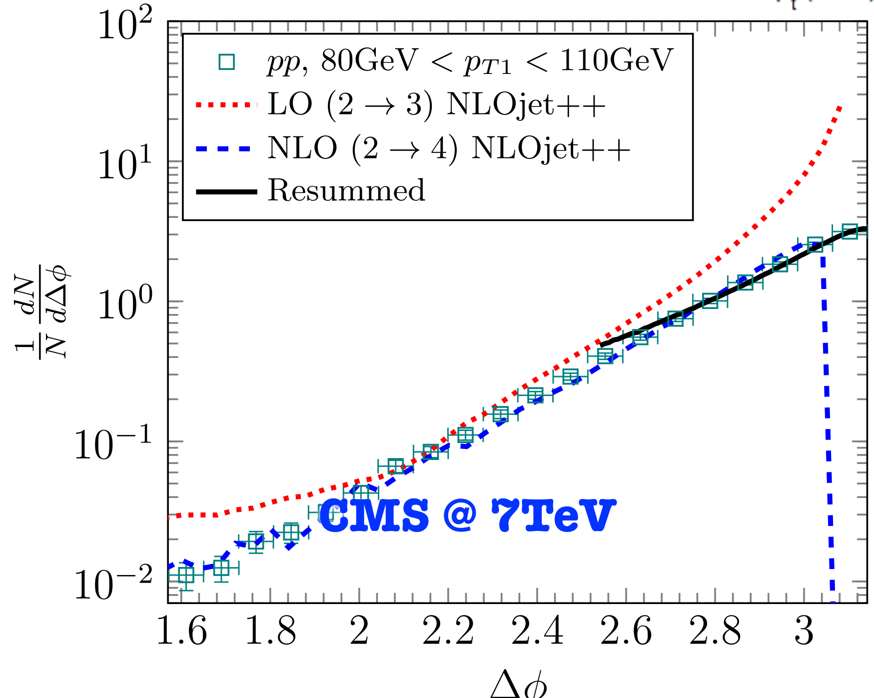
Sudakov Factor

$$S^i(Q,b) = \int_{\mu_b^2}^{Q^2} \frac{d\mu^2}{\mu^2}\left[A_i \frac{\alpha_s}{2\pi}\ln\left(\frac{Q^2}{\mu^2}\right) + B_i\frac{\alpha_s}{\pi}\right]$$









Sun, Isaacson, Yuan, Yuan (1406.3073)

Dihadron production in *pp* collisions

p + p -> h_1 + h_2 + X

$$\frac{d\sigma}{d\Delta\phi} = \sum_{\text{all channels}} \int p_T^{h_1} dp_T^{h_1} \int p_T^{h_2} dp_T^{h_2} \int \frac{dz_c}{z_c^2} \int \frac{dz_d}{z_d^2} \int \frac{d^2b}{2\pi} e^{-i\vec{q}_\perp \cdot \vec{b}} e^{-S(Q,b)}$$

$$x_a f_a(x_a, \mu_b) x_b f_b(x_b, \mu_b) \frac{1}{\pi} \frac{d\sigma_{ab\to cd}}{d\hat{t}} D_c(z_c, \mu_b) D_d(z_d, \mu_b)$$

non-perturbative part
is not universal

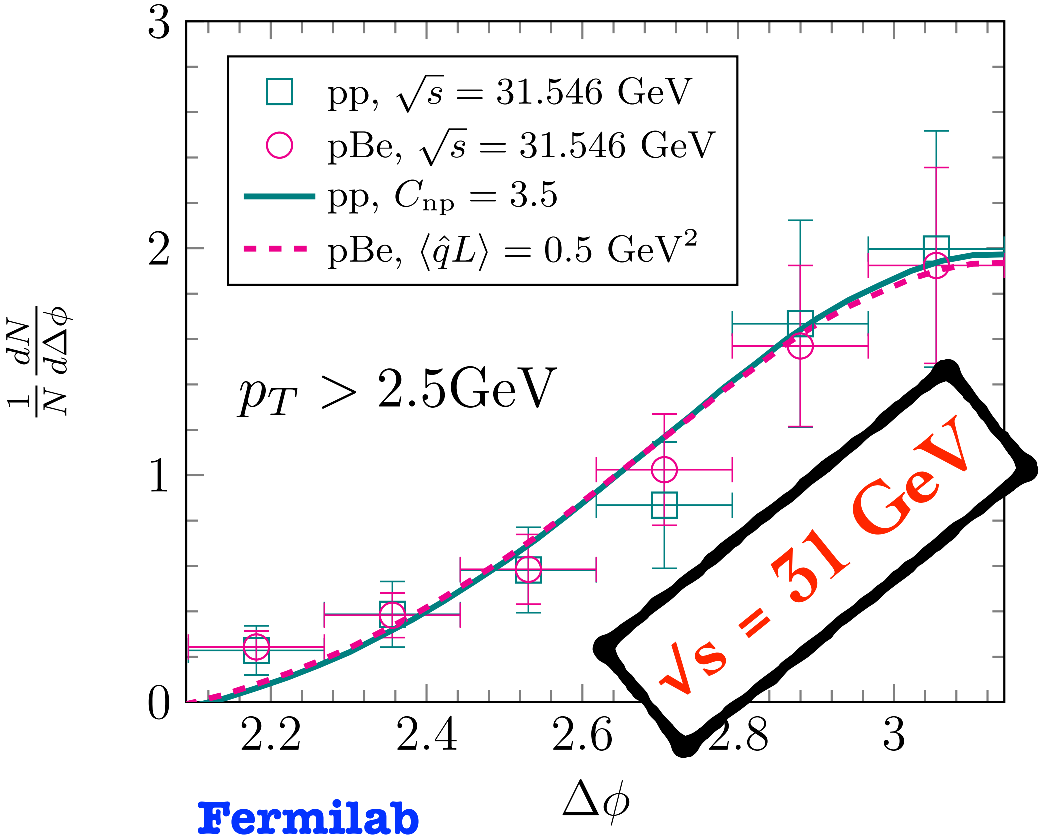
Global universality is gone.

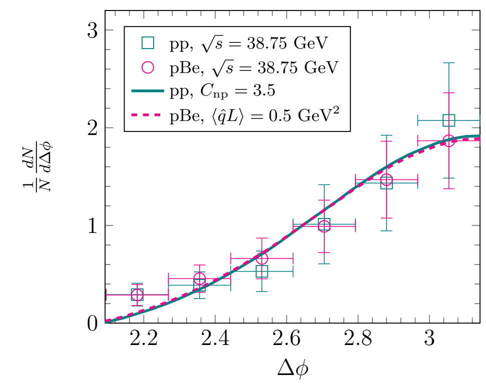
Try to find some local universality.

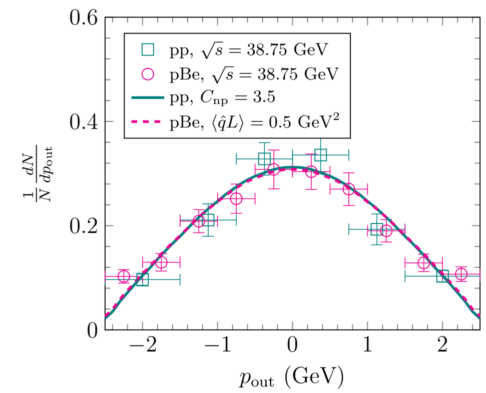
Collins, Qiu, PRD 75, 2007
Rogers, Mulders, PRD81, 2010

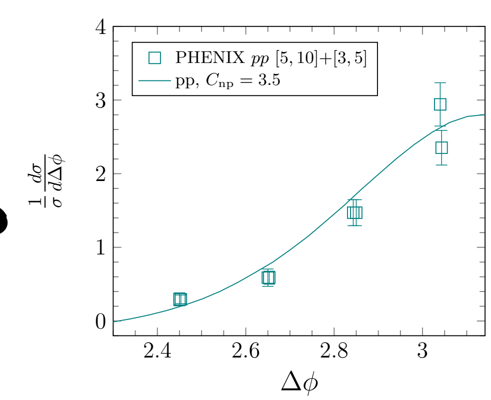
Hope we could find an universal parameterization for Dihadron production at different CMEs and different p_T ranges.

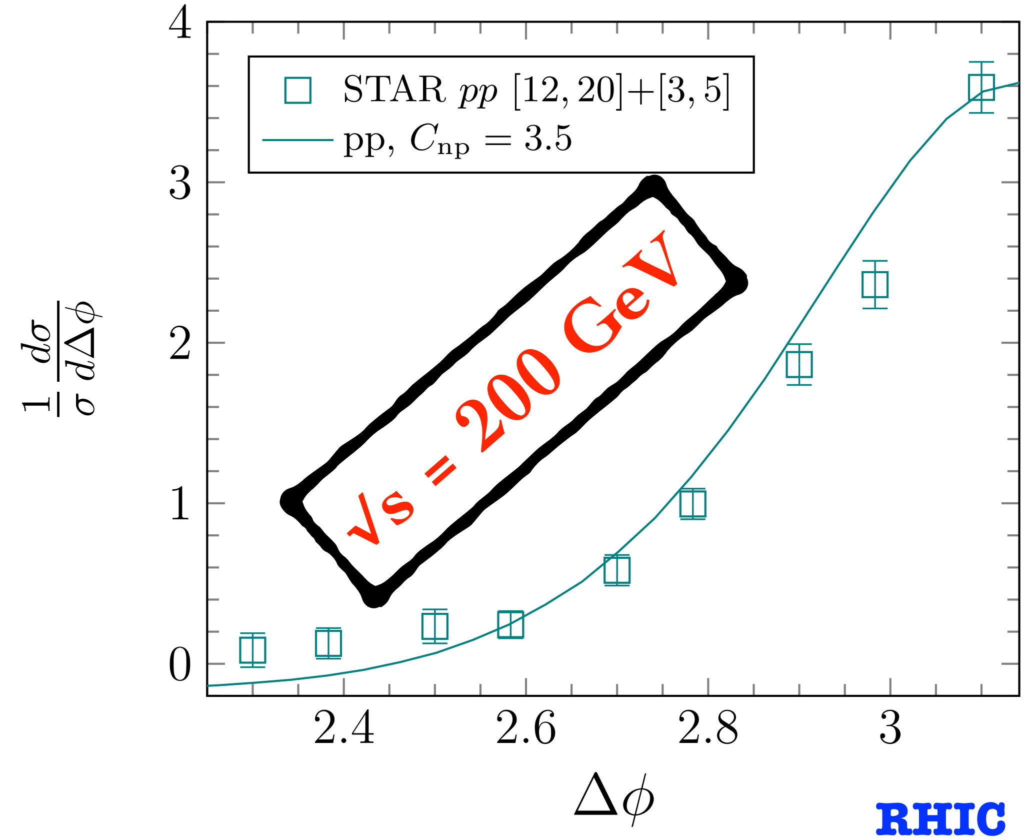
Dihadron angular correlation in the middle rapidity





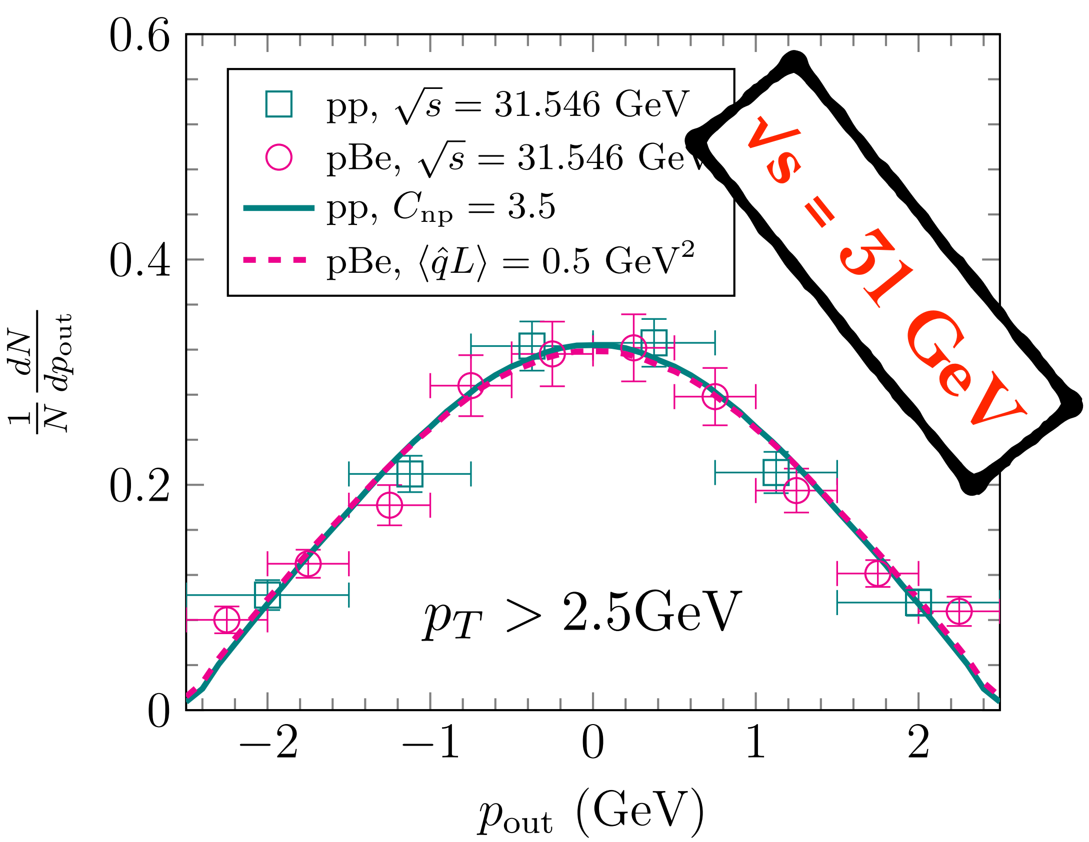


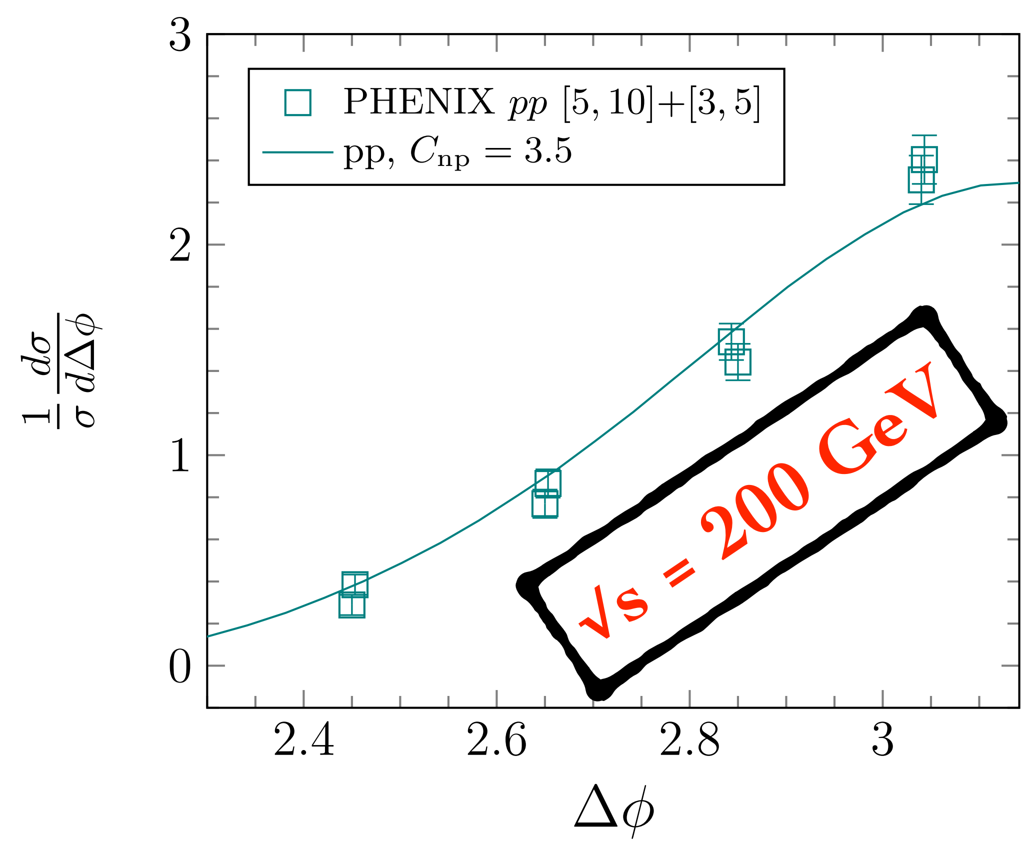




Fermilab

RHIC



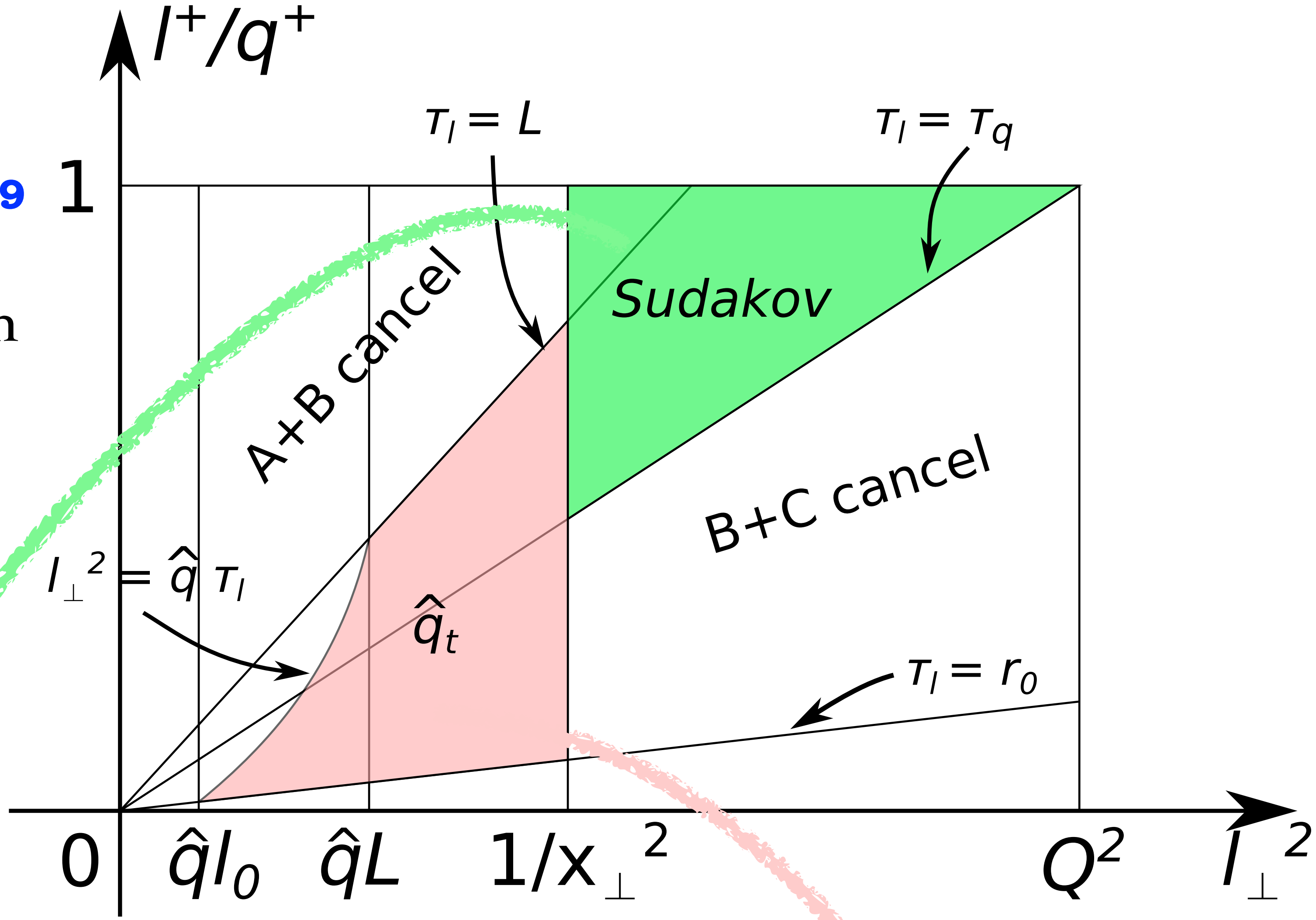


Dihadron angular correlation in the middle rapidity

From *pp* to *AA*

Mueller, Wu, Xiao, Yuan, arXiv:1608.07339

Considering one gluon radiation in the large medium, Medium Induced Radiation and Vacuum Parton Shower can be separated.



hot medium

$$S_{AA}(Q,b) = S_{pp}(Q,b) + \frac{1}{2}\frac{\langle \hat{q}L\rangle b^2}{4}$$

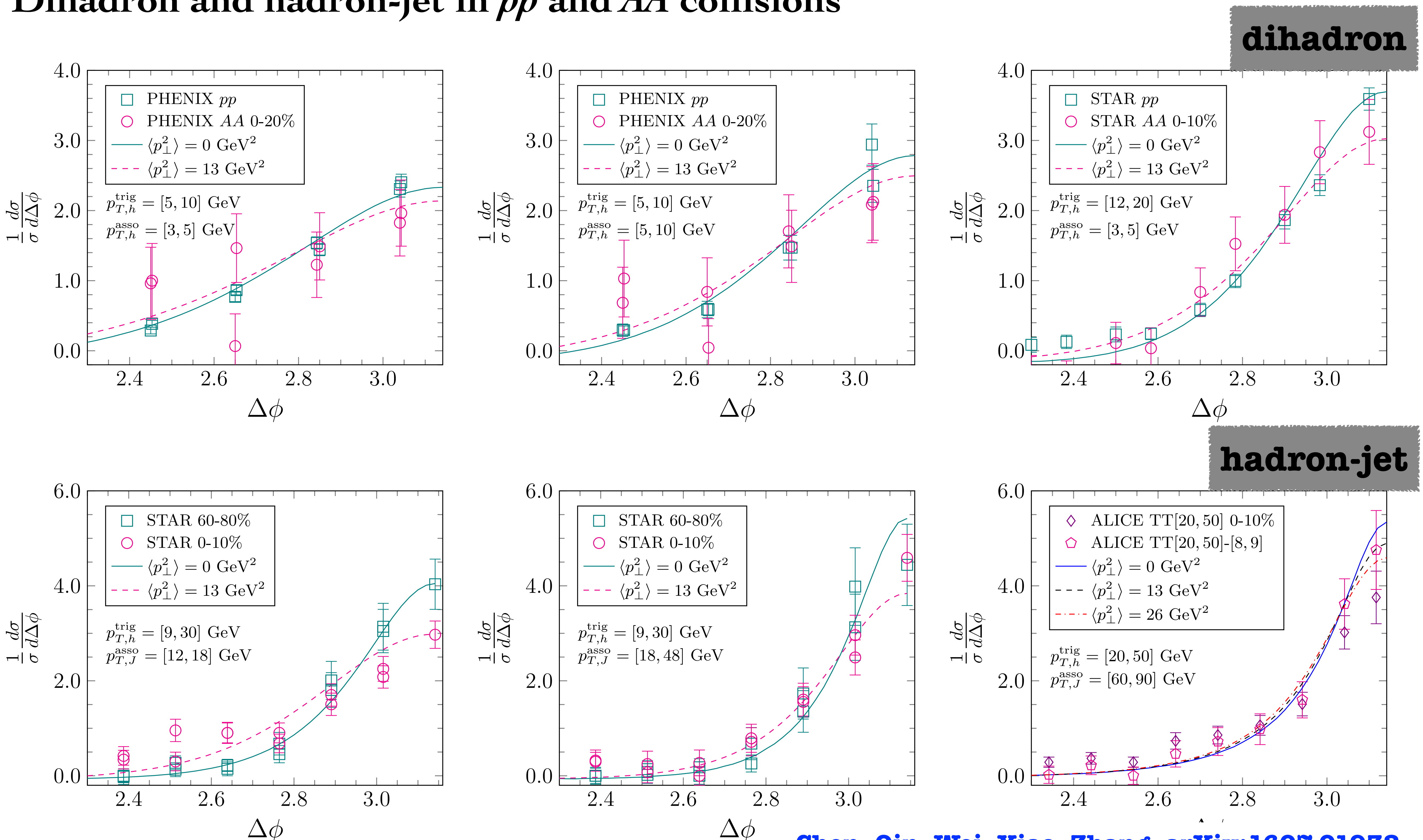
Vacuum parton shower

k_T broadening

Multiple scattering

Medium induced radiation

Dihadron and hadron-jet in *pp* and *AA* collisions

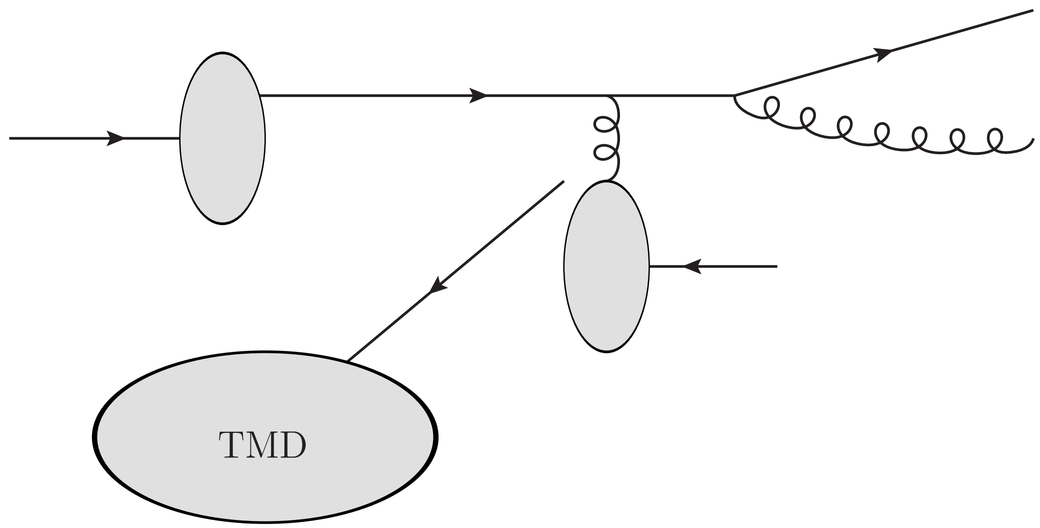


Chen, Qin, Wei, Xiao, Zhang, arXiv:1607.01932

Forward dihadron angular correlation in *pp* and *pA* collisions

rcBK: Albacete, Giacalone, Marquet, Matas, 1805.05711

$$\mathcal{F}_{qg}^{(a)}(x, q_\perp) = \int \frac{d^2b}{(2\pi)^2} \mathcal{F}_{qg}^{(a)}(x, b_\perp) e^{-iq_\perp b_\perp}$$

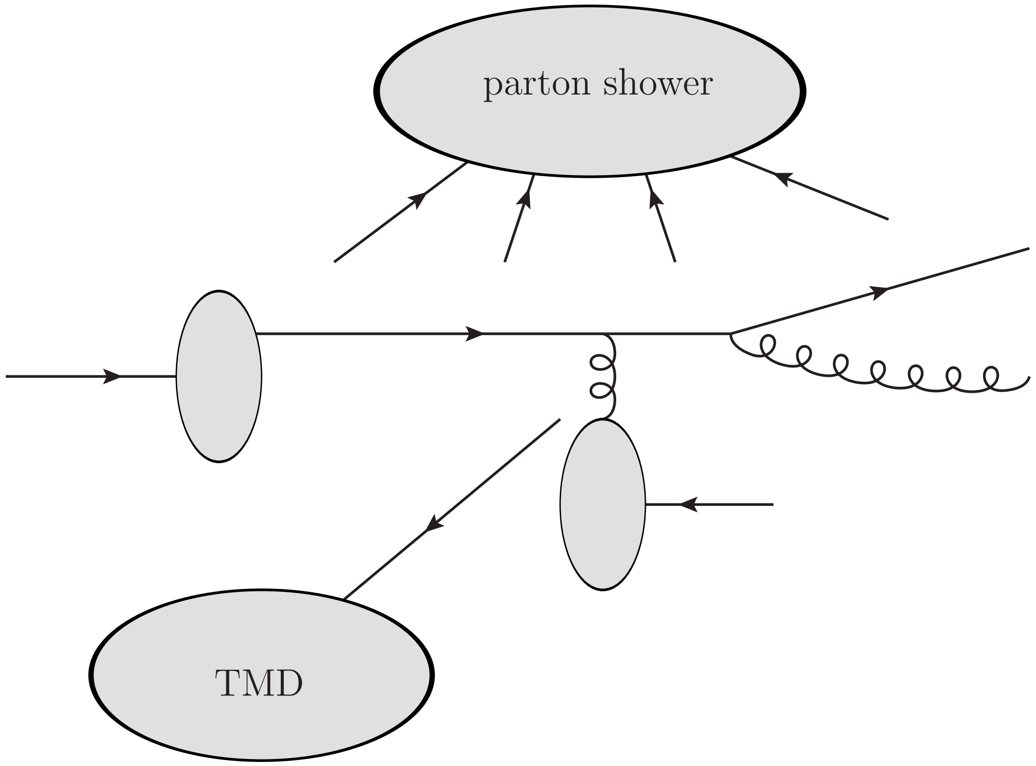


$$\frac{d\sigma^{qg\to gq \to h_1 h_2}}{dy_1 dy_2 d^2p_{1\perp} d^2p_{2\perp}} = \int \frac{dz_1}{z_1^2} \int \frac{dz_2}{z_2^2} \Big\{ D_{h/g}(z_1) D_{h/q}(z_2) x q(x) H_{qg} \left[(1-z)^2 \mathcal{F}_{qg}^{(a)}(x_g, q_\perp) + \mathcal{F}_{qg}^{(b)}(x_g, q_\perp) \right] + [1 \leftrightarrow 2] \Big\}$$

Dominguez, Xiao, Yuan, PRL106, 2011
Dominguez, Marquet, Xiao, Yuan, PRD83, 2011

Forward dihadron angular correlation in *pp* and *pA* collisions

rcBK: Albacete, Giacalone, Marquet, Matas, 1805.05711



$$\mathcal{F}_{qg}^{(a)}(x, q_\perp) = \int \frac{d^2b}{(2\pi)^2} \mathcal{F}_{qg}^{(a)}(x, b_\perp) e^{-iq_\perp b_\perp}$$

↓

$$\mathcal{F}_{qg}^{(a)}(x, q_\perp) = \int \frac{d^2b}{(2\pi)^2} \mathcal{F}_{qg}^{(a)}(x, b_\perp) e^{-S_{\text{sudakov}}} e^{-iq_\perp b_\perp}$$

Mueller, Xiao, Yuan, PRL110, 2013
Sudakov resummation in small-x framework for higgs production

$$\frac{d\sigma^{qg\to gq\to h_1 h_2}}{dy_1 dy_2 d^2p_{1\perp} d^2p_{2\perp}} = \int \frac{dz_1}{z_1^2} \int \frac{dz_2}{z_2^2} \left\{ D_{h/g}(z_1) D_{h/q}(z_2) xq(x) H_{qg} \left[(1-z)^2 \mathcal{F}_{qg}^{(a)}(x_g, q_\perp) + \mathcal{F}_{qg}^{(b)}(x_g, q_\perp) \right] + [1 \leftrightarrow 2] \right\}$$

Dominguez, Xiao, Yuan, PRL106, 2011
Dominguez, Marquet, Xiao, Yuan, PRD83, 2011

Unintegrated gluon distributions

$$S_{x_g}(b_\perp) = \exp\left(-\frac{1}{4}Q_s^2 b_\perp^2\right)$$

$$\mathcal{F}_{qg}^{(a)}(x_g, b_\perp) = \frac{-N_c S_\perp}{2\pi^2\alpha_s}\nabla_{b_\perp}^2 S_{x_g}(b_\perp),$$

$$\mathcal{F}_{qg}^{(b)}(x_g, b_\perp) = \frac{C_F S_\perp}{2\pi^2\alpha_s}\frac{\nabla_{b_\perp}^2 \ln \tilde{S}_{x_g}(b_\perp)}{\ln \tilde{S}_{x_g}(b_\perp)}\left[1 - \tilde{S}_{x_g}(b_\perp)\right] S_{x_g}(b_\perp).$$

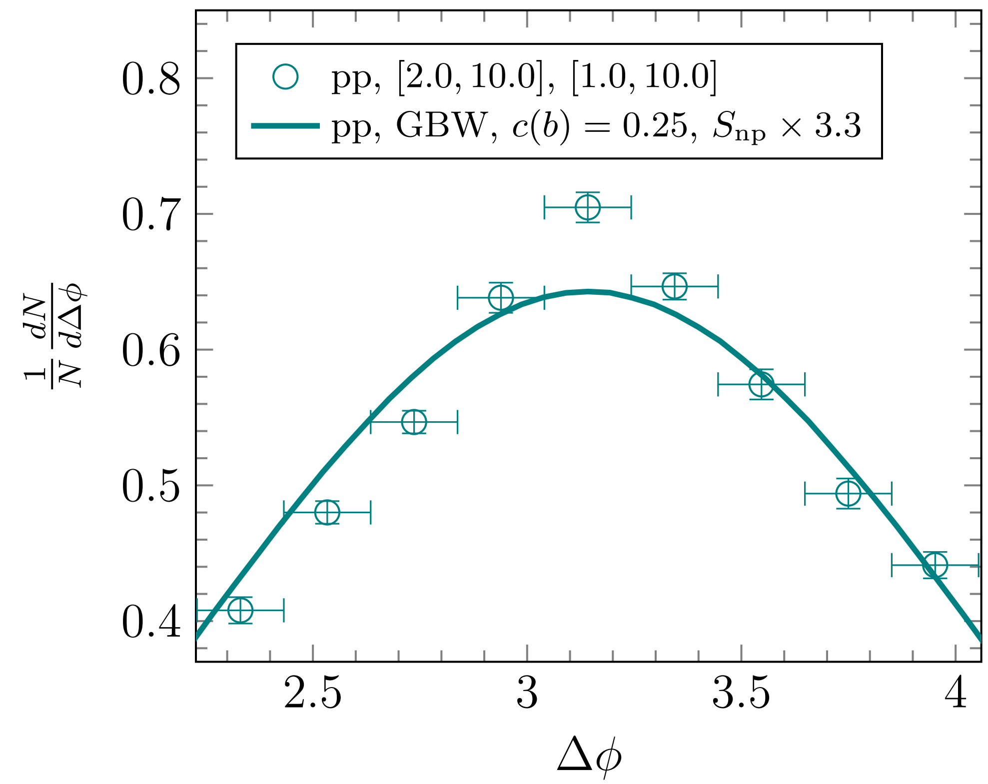
$$\mathcal{F}_{gg}^{(a)}(x_g, b_\perp) = \frac{-N_c S_\perp}{2\pi^2\alpha_s} S_{x_g}(b_\perp)\left[\nabla_{b_\perp}^2 S_{x_g}(b_\perp)\right],$$

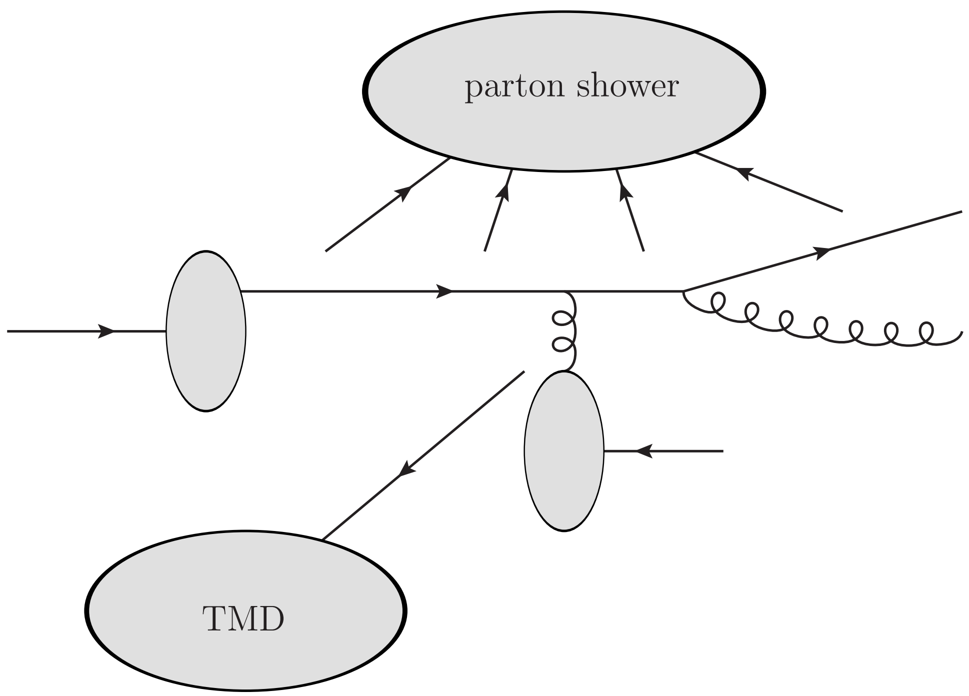
$$\mathcal{F}_{gg}^{(b)}(x_g, b_\perp) = \frac{N_c S_\perp}{2\pi^2\alpha_s}\left[\nabla_{b_\perp} S_{x_g}(b_\perp)\right]\cdot\left[\nabla_{b_\perp} S_{x_g}(b_\perp)\right],$$

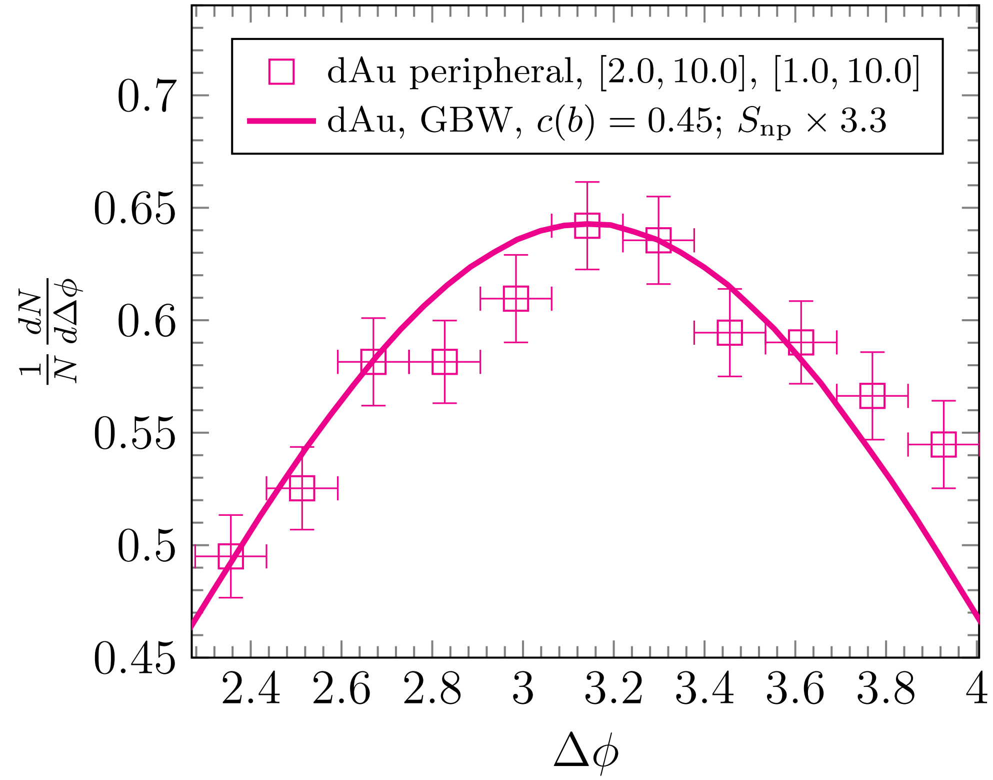
$$\mathcal{F}_{gg}^{(c)}(x_g, b_\perp) = \frac{C_F S_\perp}{2\pi^2\alpha_s}\frac{\left[\nabla_{b_\perp}^2 \ln \tilde{S}_{x_g}(b_\perp)\right]}{\ln \tilde{S}_{x_g}(b_\perp)}\left[1 - \tilde{S}_{x_g}(b_\perp)\right] S_{x_g}(b_\perp) S_{x_g}(b_\perp).$$

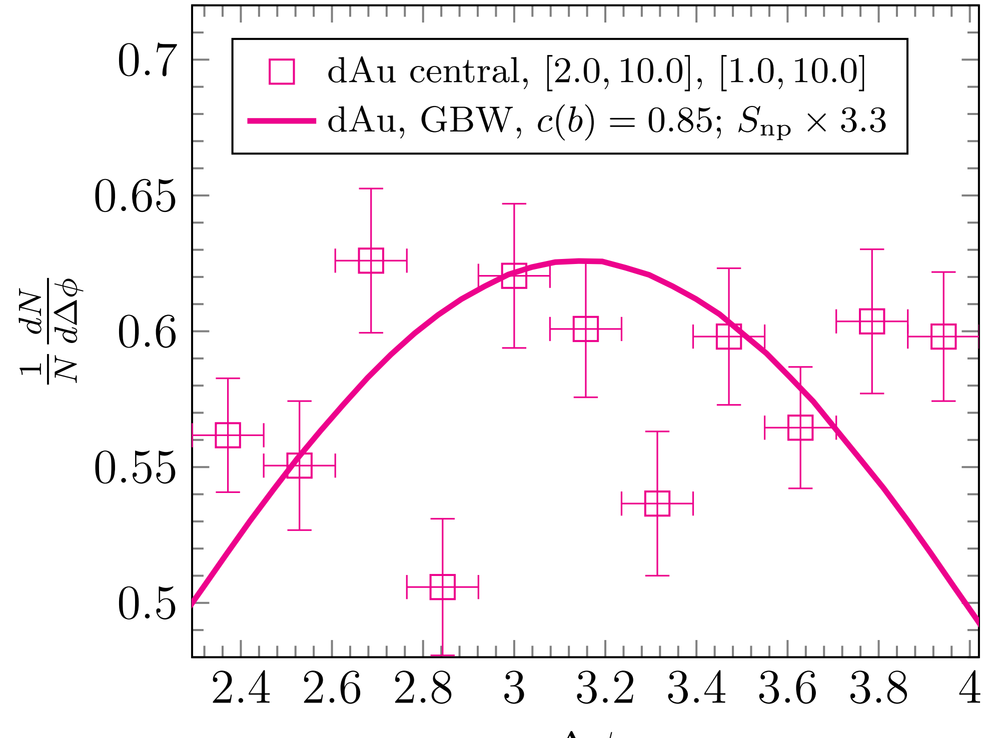
GBW model -> rcBK (together with Giuliano & Cyrille)

Forward dihadron angular correlation in *pp* and *pA* collisions Small-x & Sudakov





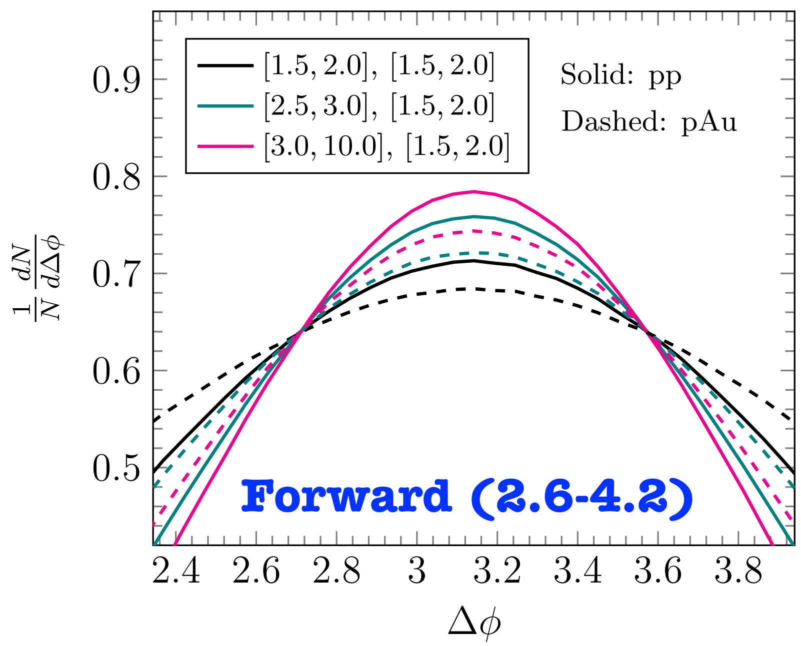


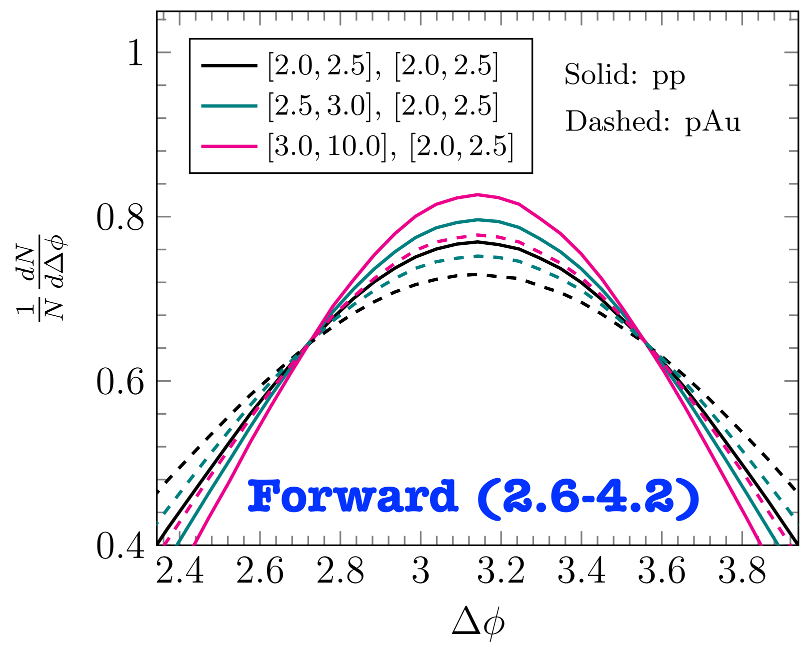


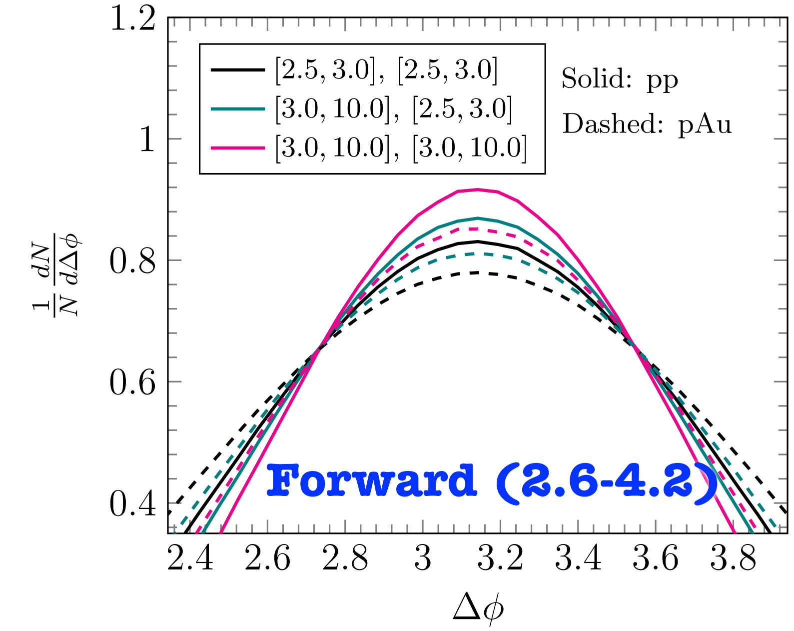
Stasto, Wei, Xiao, Yuan (1805.05712)

Forward dihadron angular correlation in *pp* and *pA* collisions

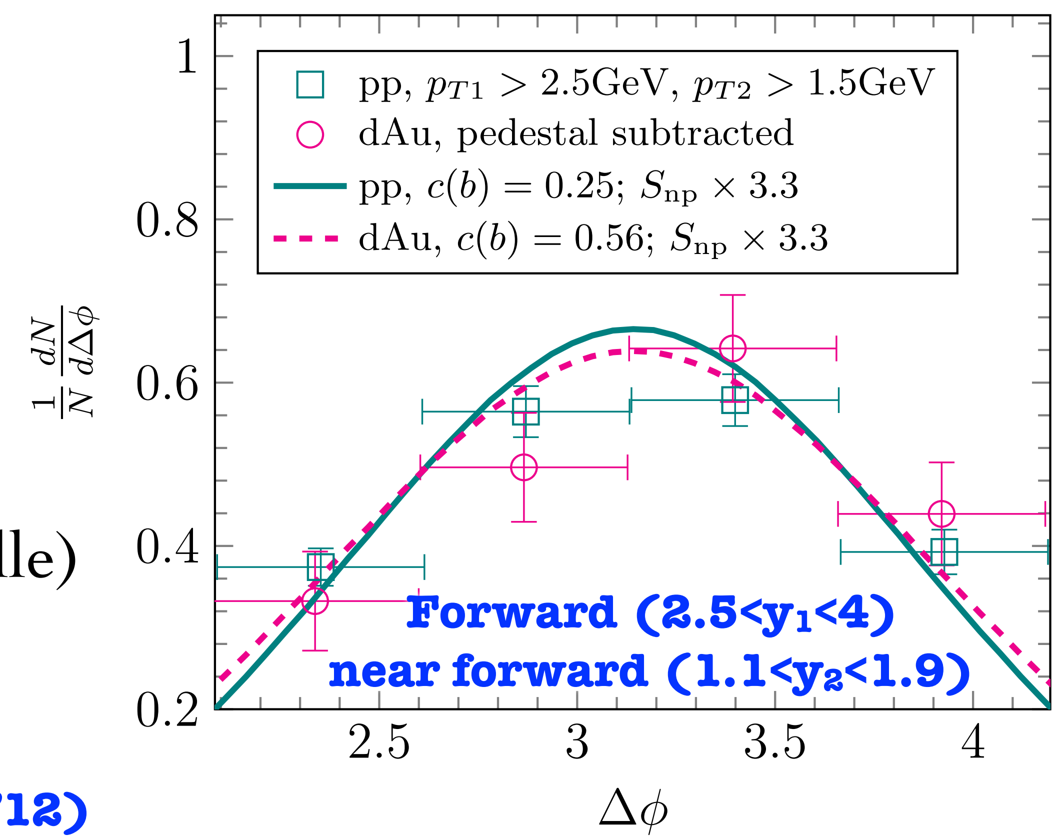
$\sqrt{s}$ = 200 GeV







- High p_T hadrons: Steeper curve
- pA: higher saturation scale, flatter curves.
- GBW model -> rcBK (together with Giuliano & Cyrille)



Stasto, Wei, Xiao, Yuan (1805.05712)

Summary

Dihadron angular correlation in the middle rapidity

- ☑ Dihadron, Dijet, Hadron-jet angular correlations in the middle rapidity can be described in the Sudakov resummation framework.
- ☑ The angular decorrelation can be used as a complementary method for the quantitative study of jet-medium interaction.

Dihadron angular correlation in the forward rapidity

- ☑ Dihadron angular correlation in the forward rapidity can be described in the hybrid formalism of Sudakov resummation and small-x.
- ☑ The angular correlations in pp and pA can be used to probe the small-x saturation physics.

Thank you very much for your attention!

The End