

Low-x, Nicosia, Cyprus

Sudakov resummation in CGC framework



Shu-yi Wei (魏树一)

CPHT, Ecole Polytechnique

C. Marquet, S.Y. Wei & B.W. Xiao, to appear
G. Giacalone, C. Marquet, M. Matas, S.Y. Wei, in preparation

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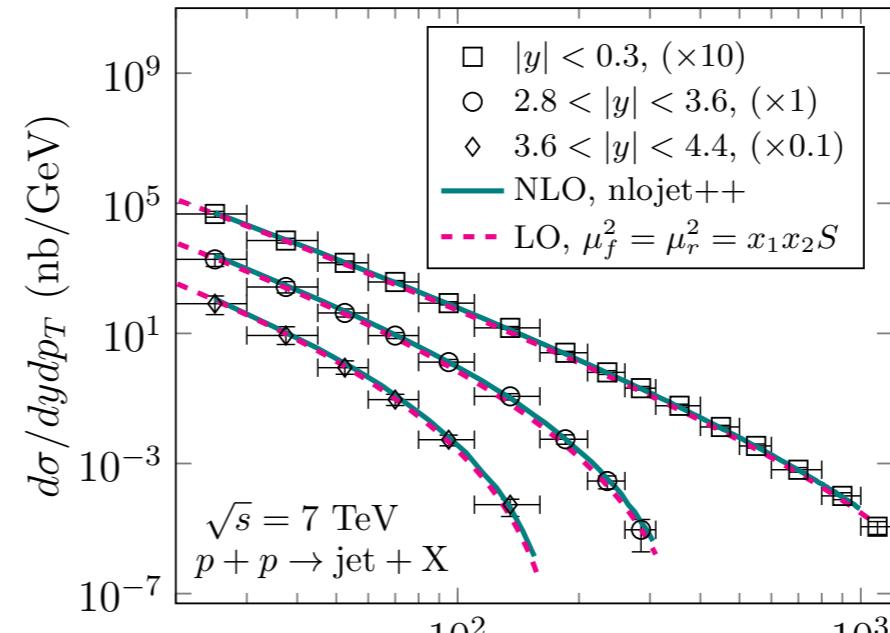
- Introduction of Sudakov resummation
- CGC + Sudakov resummation
- Numerical Results (Z^0 -boson and dijet)
- Summary

Introduction: Sudakov resum in C.F.

Perturbative Expansion vs Resummation

inclusive jet cross section

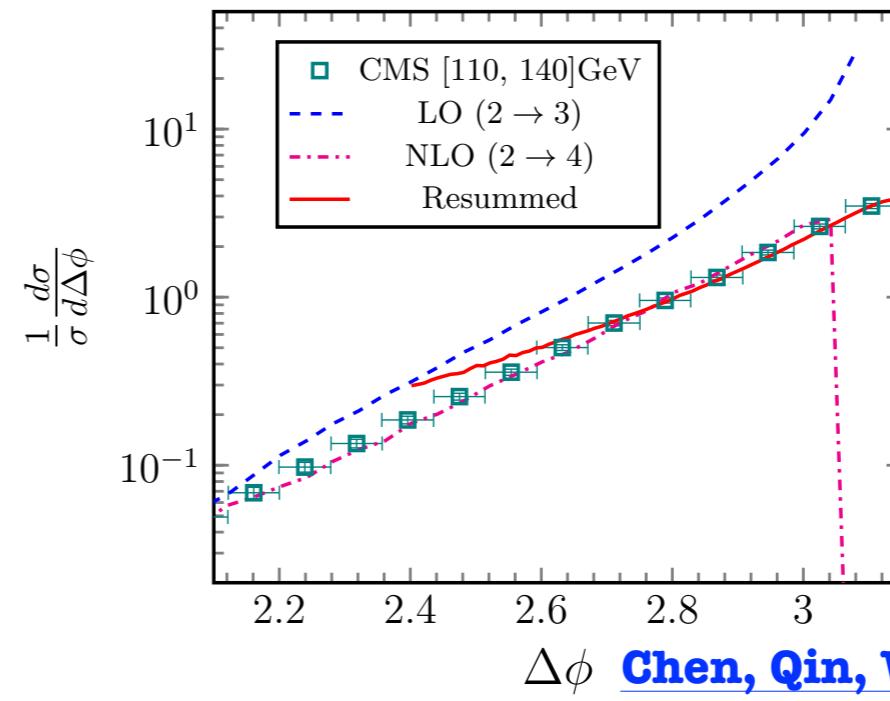
$$Q \sim p_T$$



Jia, Wei, Xiao, Yuan, to appear

dijet angular correlation

$$Q \sim p_T \gg q_T$$

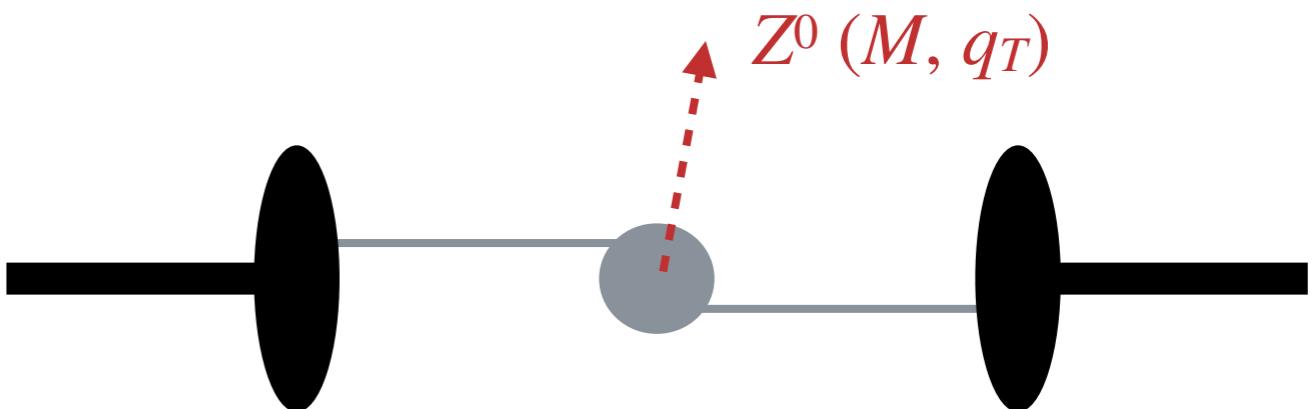


Chen, Qin, Wei, Xiao, Zhang, 2016

Introduction: Sudakov resum in C.F.

Z^0 -boson production in pp collisions

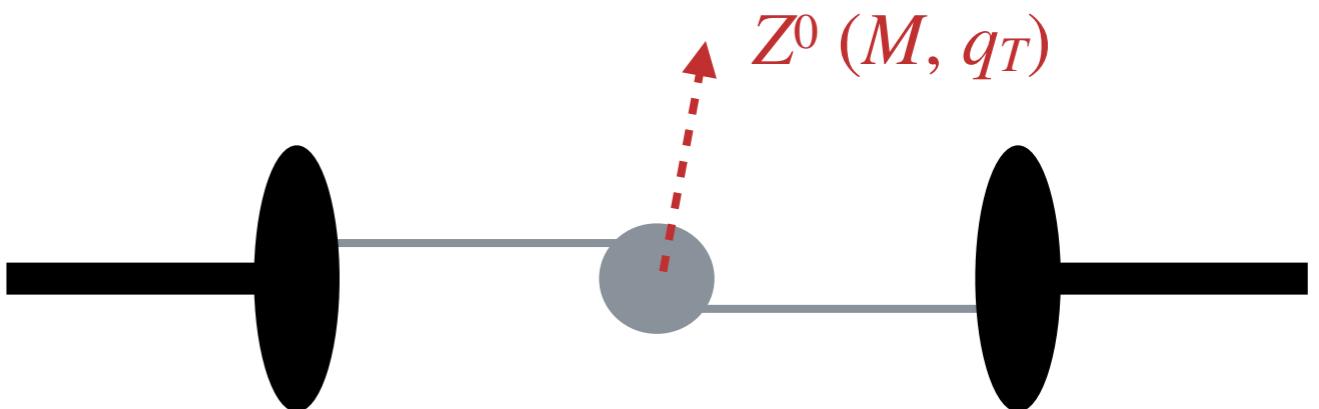
differential cross section
at small q_T



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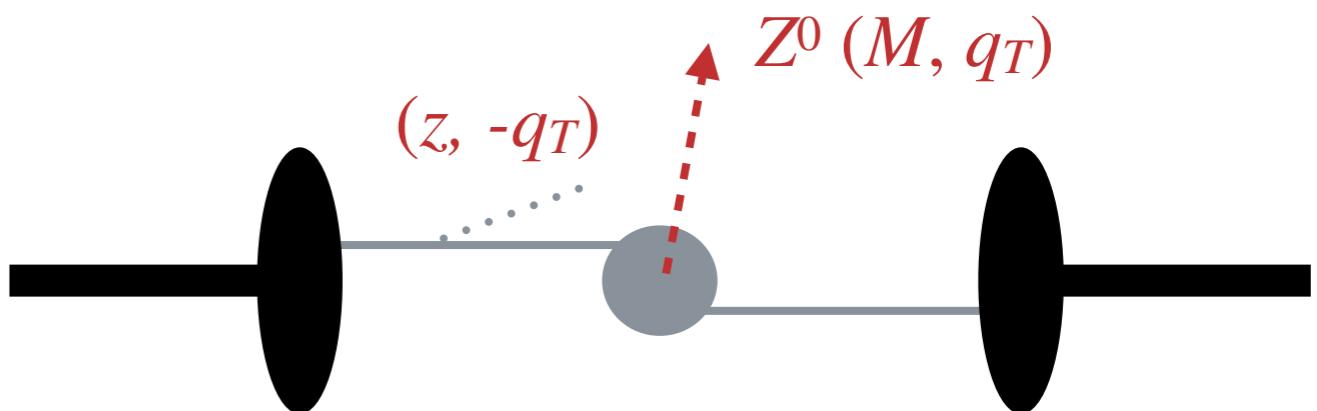
0th order:

$$\frac{d\sigma^{(0)}}{d^2 q_T} \propto \delta^2(q_T)$$

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0th order:

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leading order:

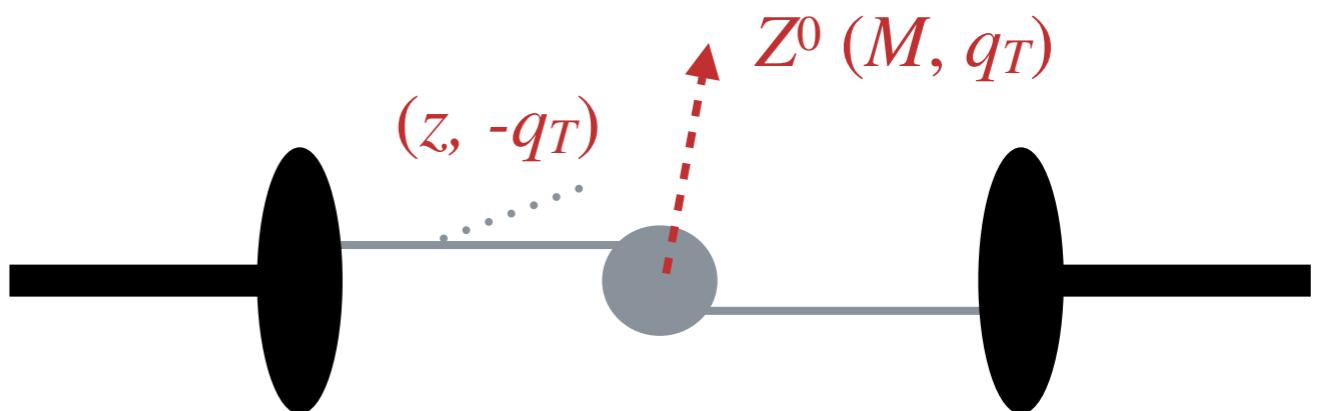
$$\frac{d\sigma^{(1)}}{d^2q_T} \propto \frac{\alpha_s}{q_T^2} \ln \frac{M^2}{q_T^2}$$

leading logarithm
 $z \ll 1, q_T \ll M$

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0th order:

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leading order:

$$\frac{d\sigma^{(1)}}{d^2q_T} \propto \frac{\alpha_s}{q_T^2} \ln \frac{M^2}{q_T^2}$$

higher order:

$$\frac{d\sigma^{(n)}}{d^2q_T} \propto \frac{\alpha_s^n}{q_T^2} \ln^{2n-1} \frac{M^2}{q_T^2}$$

leading logarithm
 $z \ll 1, q_T \ll M$

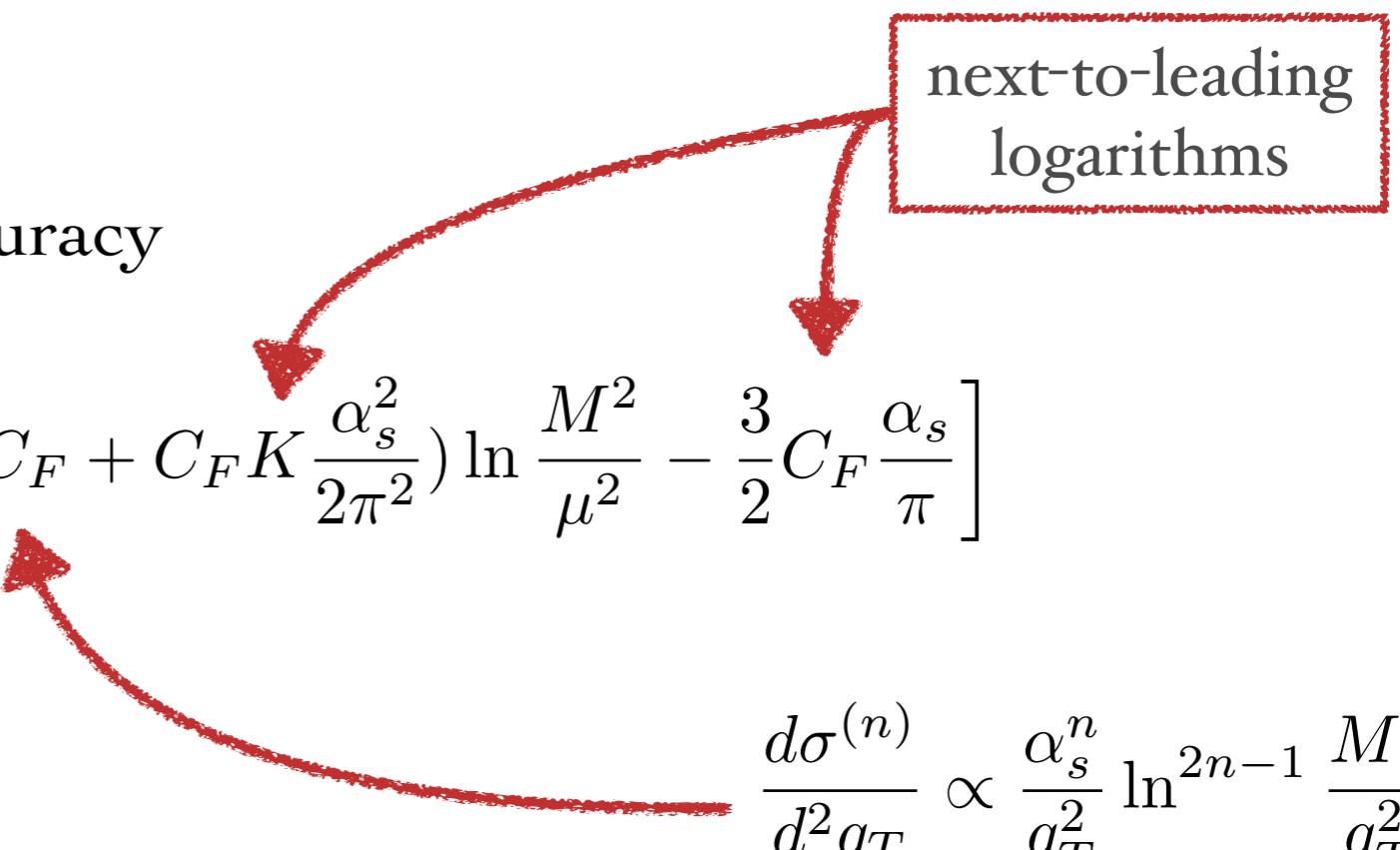
Introduction: Sudakov resum in C.F.

Sudakov resummation

$$\frac{d\sigma}{dydq_T^2} = \sigma_0 \int \frac{d^2 b_\perp}{(2\pi)^2} e^{-i\vec{q}_T \cdot \vec{b}_\perp} e^{-S_{\text{sud}}} Q_{ij}^2 \sum f_i(x_1, \mu_b) f_j(x_2, \mu_b)$$

- Sudakov factor at NLL accuracy

$$S_{\text{sud}} = \int_{\mu_b^2}^{M^2} \frac{d\mu^2}{\mu^2} \left[\left(\frac{\alpha_s}{\pi} C_F + C_F K \frac{\alpha_s^2}{2\pi^2} \right) \ln \frac{M^2}{\mu^2} - \frac{3}{2} C_F \frac{\alpha_s}{\pi} \right]$$



- b^* prescription: perturbative + non-perturbative

[Collins, Soper, Sterman, 1985](#)

Introduction: Sudakov resum in C.F.

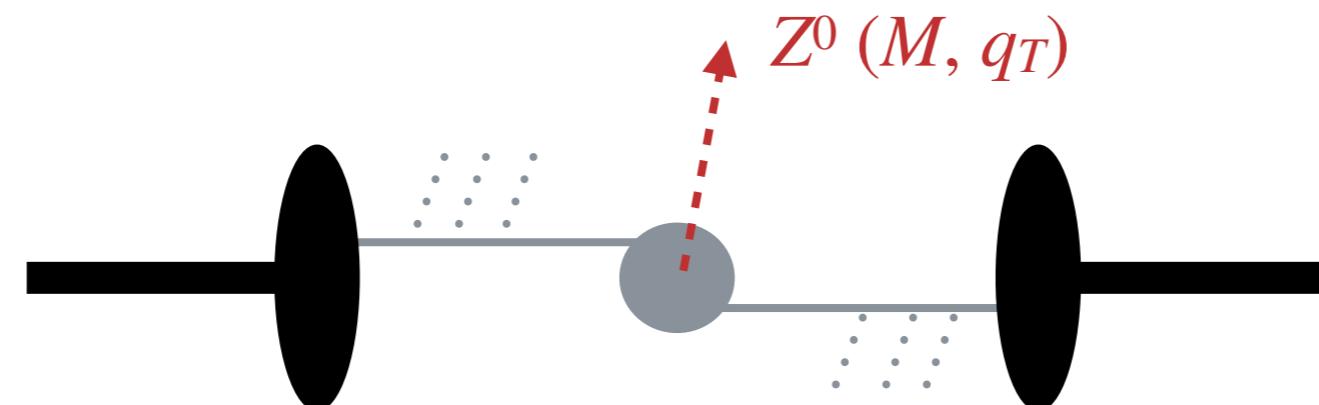
Sudakov resummation

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Physical Interpretation

$z \ll 1, q_T \ll M$

multiple soft gluon radiations
(parton shower)



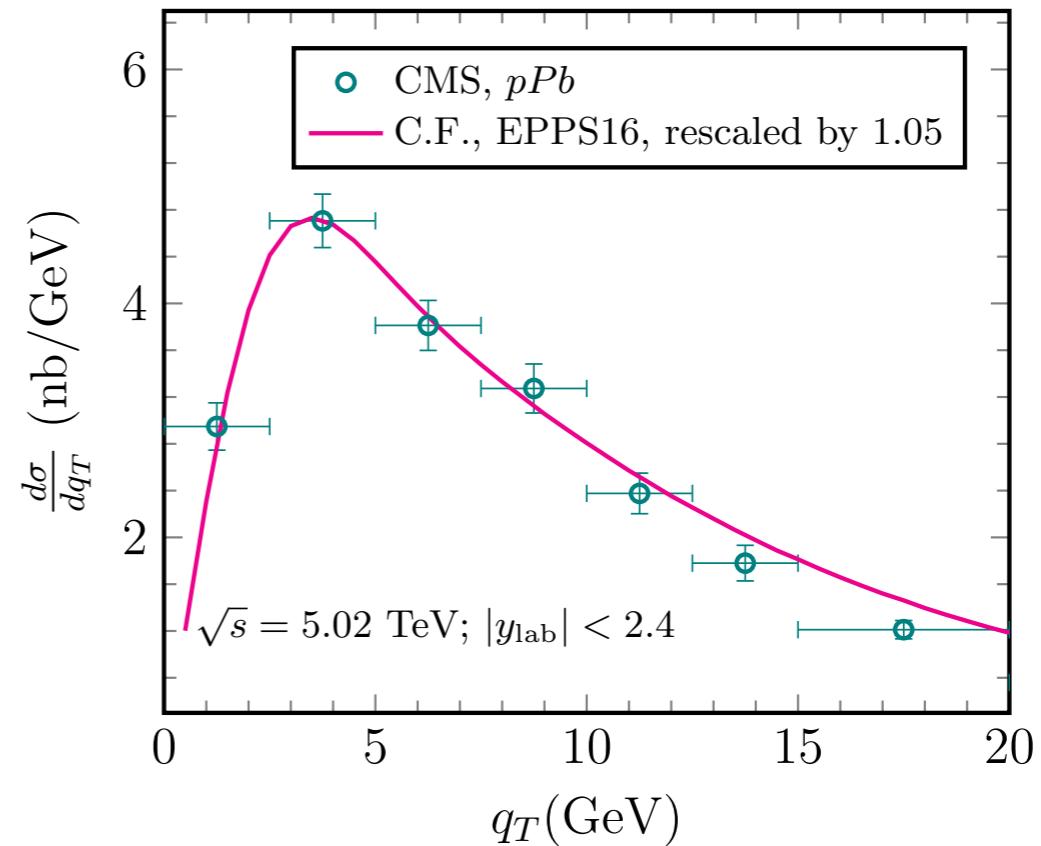
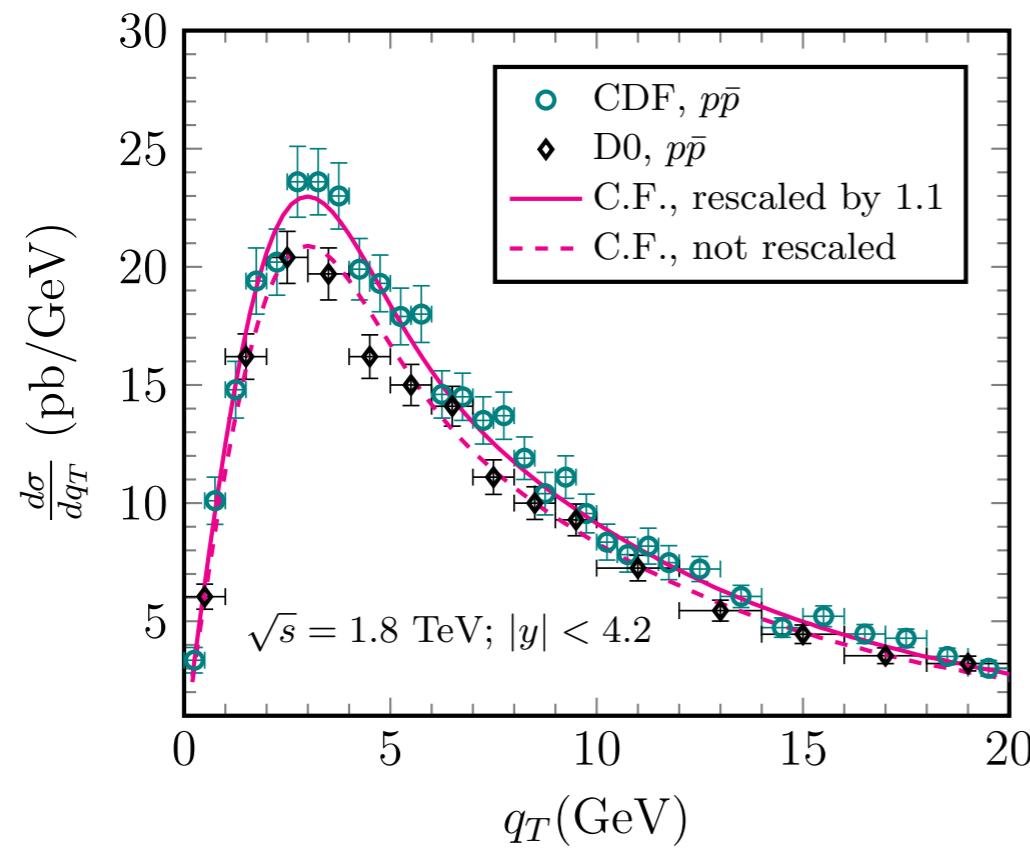
[Collins, Soper, Sterman, 1985](#)

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Sudakov resummation

$$\frac{d\sigma}{dydq_T^2} = \sigma_0 \int \frac{d^2 b_\perp}{(2\pi)^2} e^{-i\vec{q}_T \cdot \vec{b}_\perp} e^{-S_{\text{sud}}} Q_{ij}^2 \sum f_i(x_1, \mu_b) f_j(x_2, \mu_b)$$

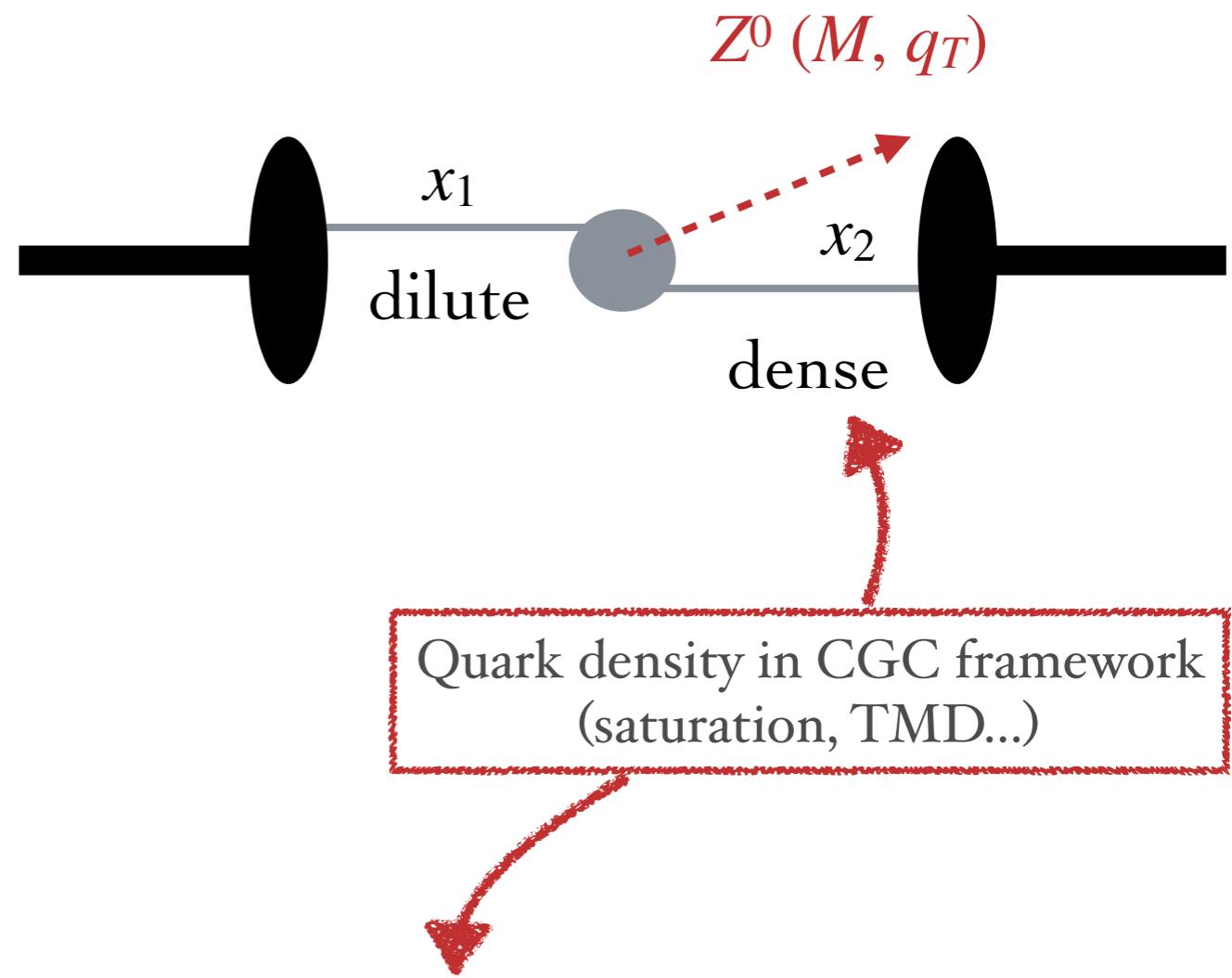
Some numerical results



[Collins, Soper, Sterman, 1985](#)

Dilute-dense factorization

$$x_1 \gg x_2$$



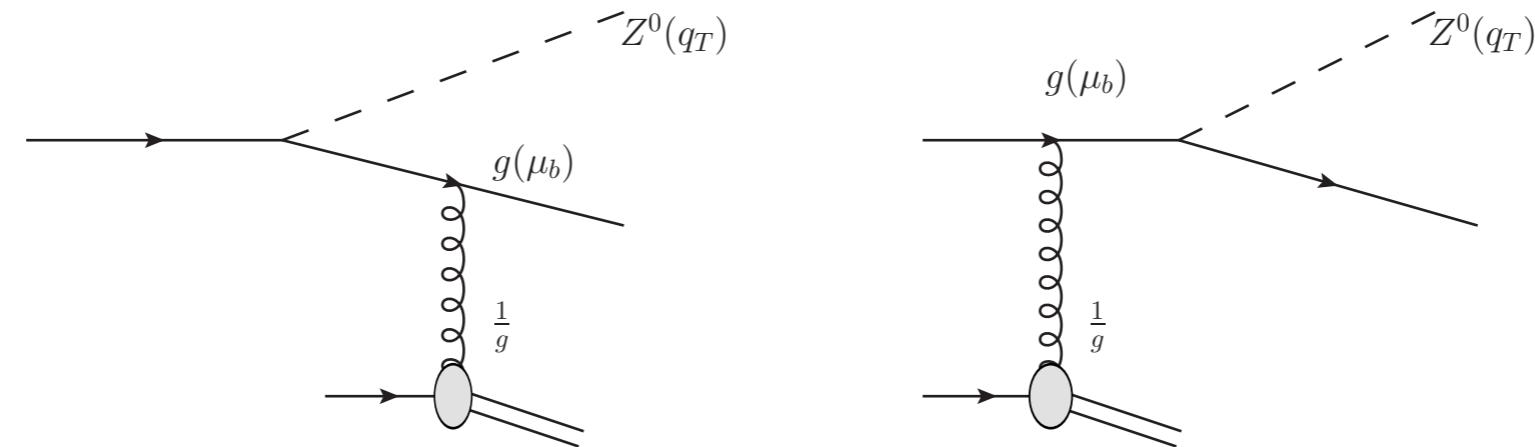
Leading order cross section

$$\frac{d\sigma}{dy dq_T^2} = \sigma_0 Q_{ij}^2 \sum f_i(x_1) \mathcal{F}_j(x_2, q_T)$$

$q_T \sim$ saturation scale
parton shower is missing

[Mueller, 1999;](#)
[Marquet, Xiao, Yuan, 2009;](#)
[Gelis, Jalilian-Marian, 2002, 2003;](#)
.....

Quark density at small- x



Leading order cross section

$$\frac{d\sigma}{dy dq_T^2} = \sigma_0 Q_{ij}^2 \sum f_i(x_1) \mathcal{F}_j(x_2, q_T)$$

$q_T \sim$ saturation scale
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Quark density in CGC framework
(saturation, TMD...)



[Mueller, 1999;](#)
[Marquet, Xiao, Yuan, 2009;](#)
[Gelis, Jalilian-Marian, 2002, 2003;](#)
.....

CGC + Sudakov resummation Mueller, Xiao, Yuan, 2013

- One-loop calculation
- Sudakov resummation & small-x resummation factorize

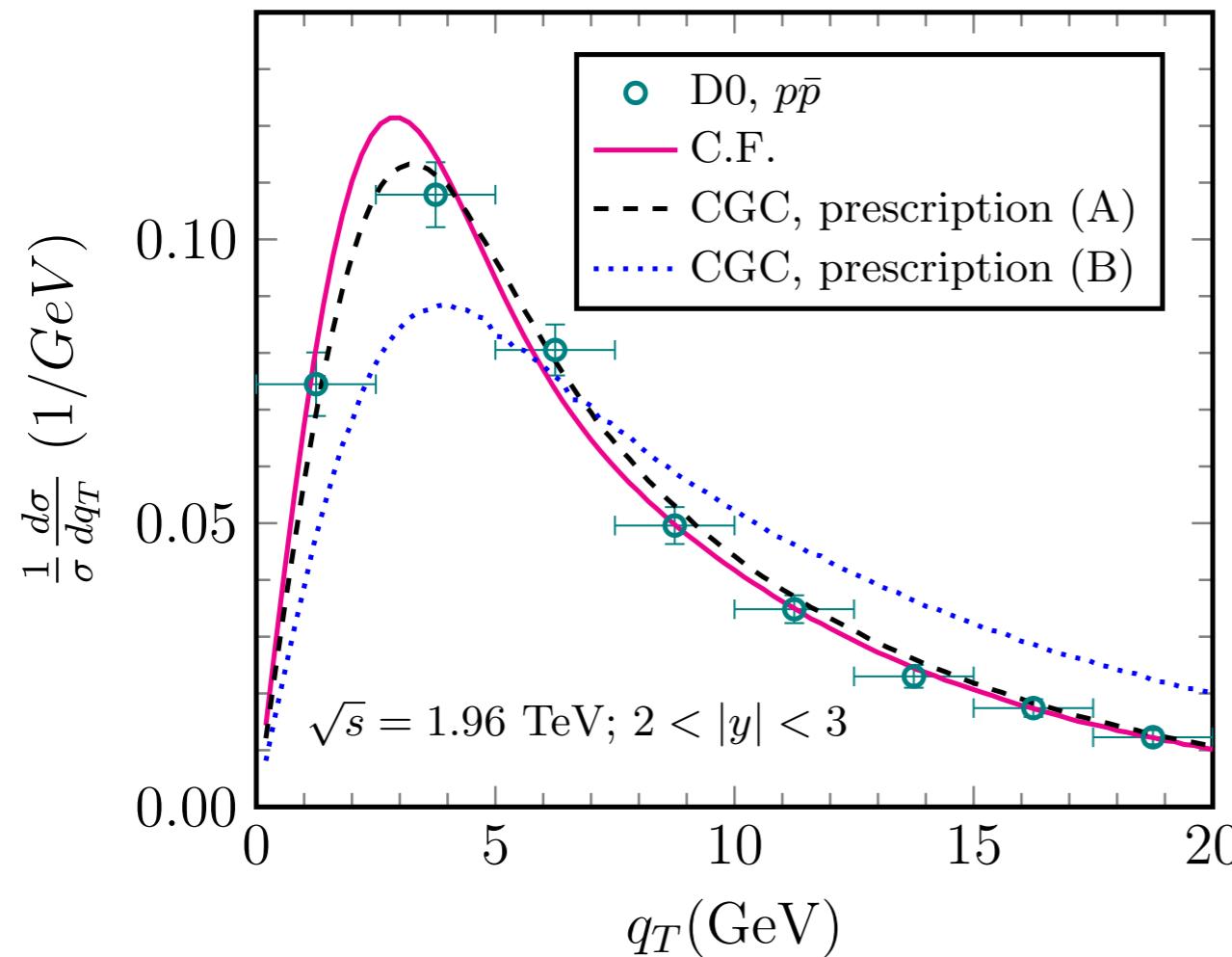
$$\frac{d\sigma}{dydq_T^2} = \sigma_0 \int \frac{d^2 b_\perp}{(2\pi)^2} e^{-i\vec{q}_T \cdot \vec{b}_\perp} e^{-S'_{\text{sud}}} Q_{ij}^2 \sum f_i(x_1) \mathcal{F}_j(x_2, b_\perp)$$

Two α_s

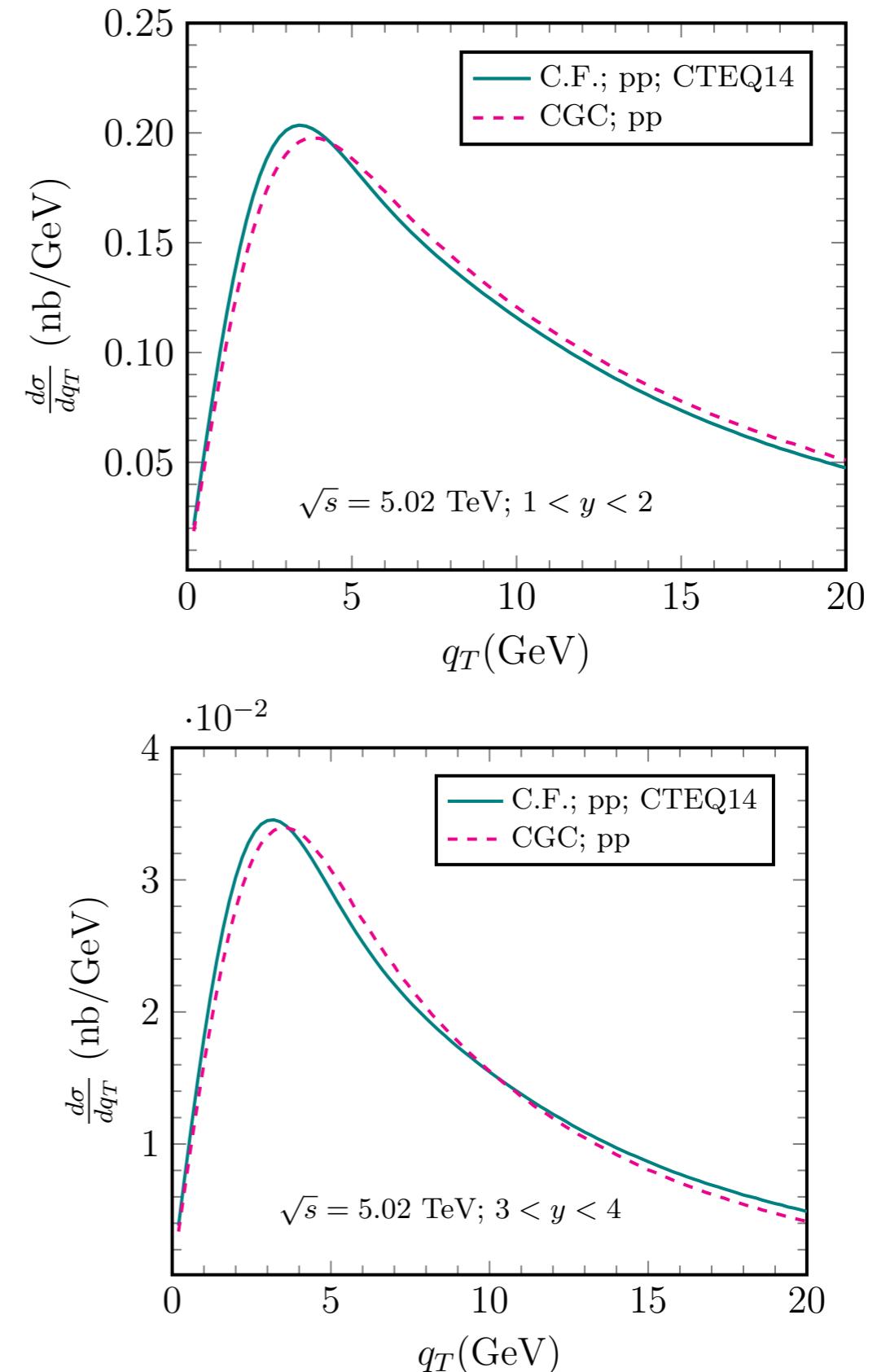
$$x_2 \mathcal{F}(x_2, b) = \frac{\alpha_s M_Z^2 N_C}{8\pi^4 \alpha_s} \int dz d^2 b_1 d^2 R_\perp \frac{\vec{b}_1 \cdot \vec{b}_2}{|\vec{b}_1| |\vec{b}_2|} \epsilon_f^2 K_1(\epsilon_f |\vec{b}_1|) K_1(\epsilon_f |\vec{b}_2|) \frac{1 + (1-z)^2}{z} [\mathcal{N}(x_2, z|b_1|) + \mathcal{N}(x_2, z|b_2|) - \mathcal{N}(x_2, z|b|)]$$

Z⁰-boson production in forward $pp(A)$ collisions

Self-normalized data from D0

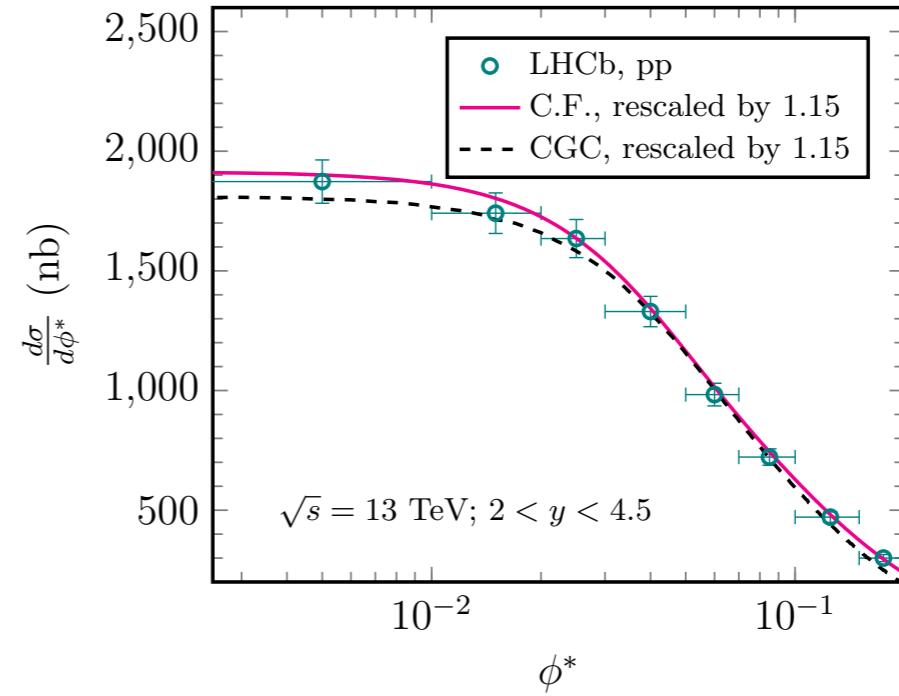
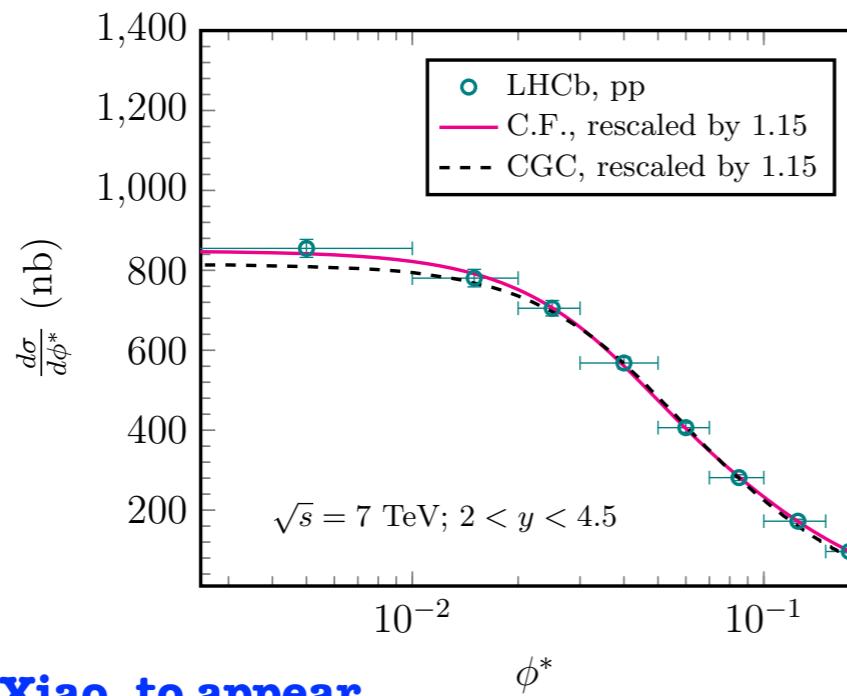
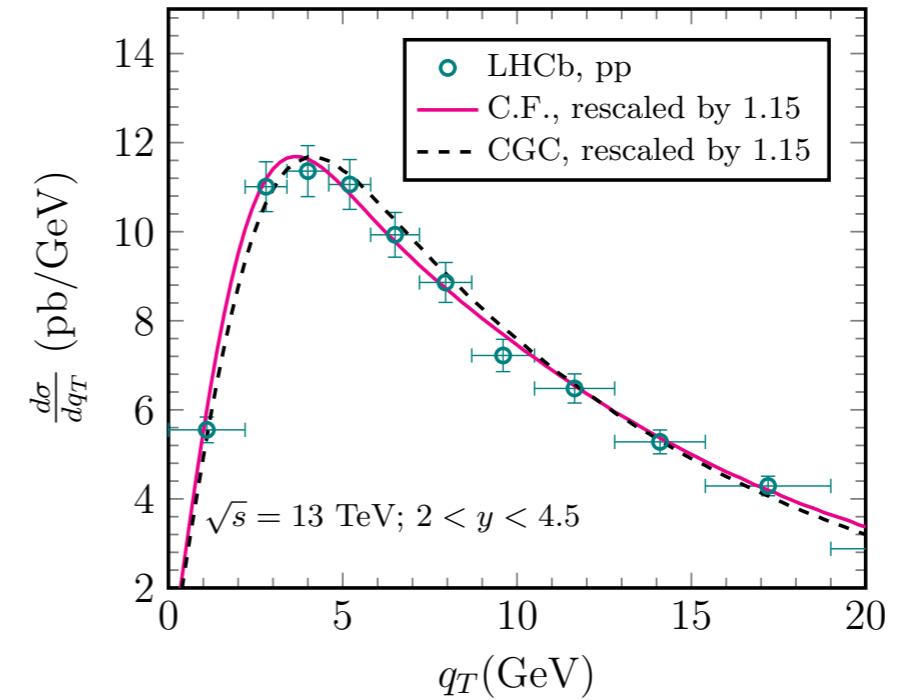
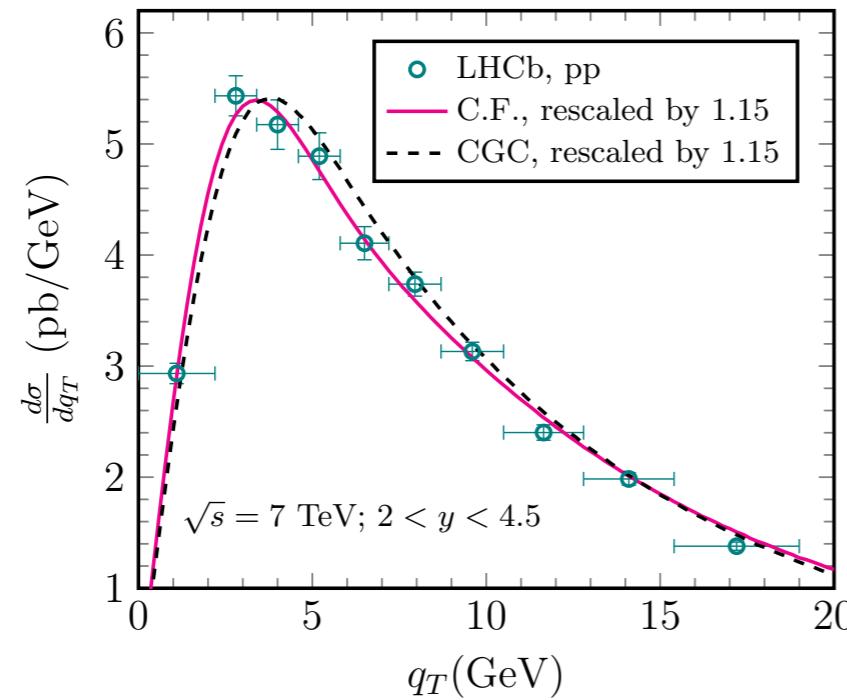


prescription (B): two α_s cancel



Z⁰-boson production in forward $pp(A)$ collisions

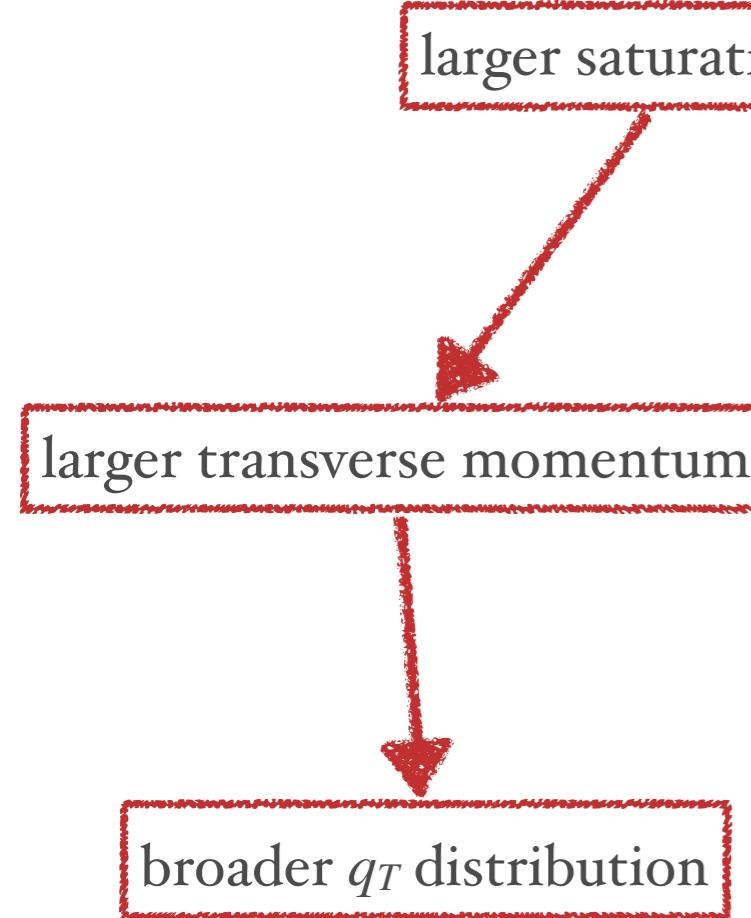
Absolute cross section from LHCb



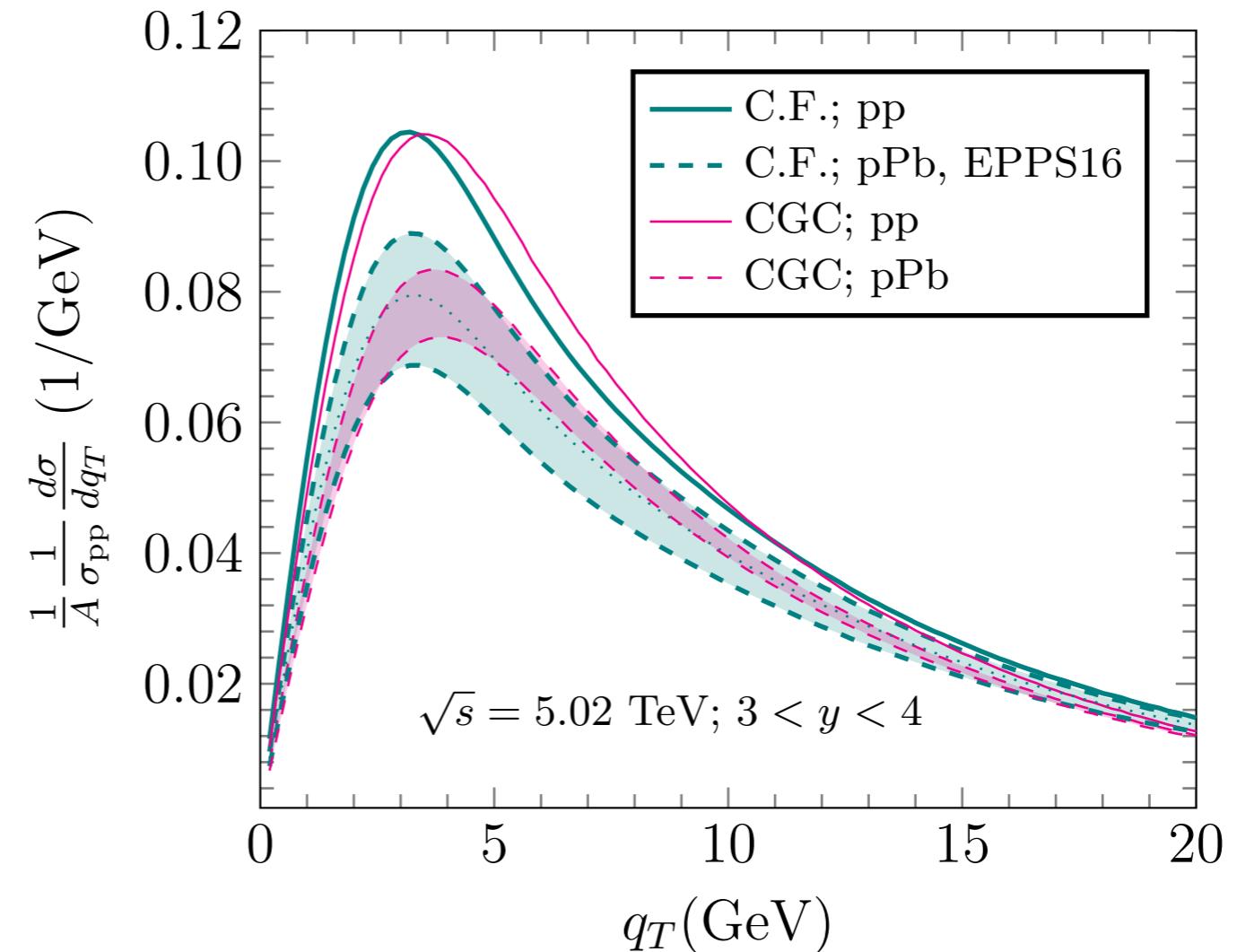
Marquet, Wei, Xiao, to appear

Z^0 -boson production in forward $pp(A)$ collisions

From pp to pA collisions



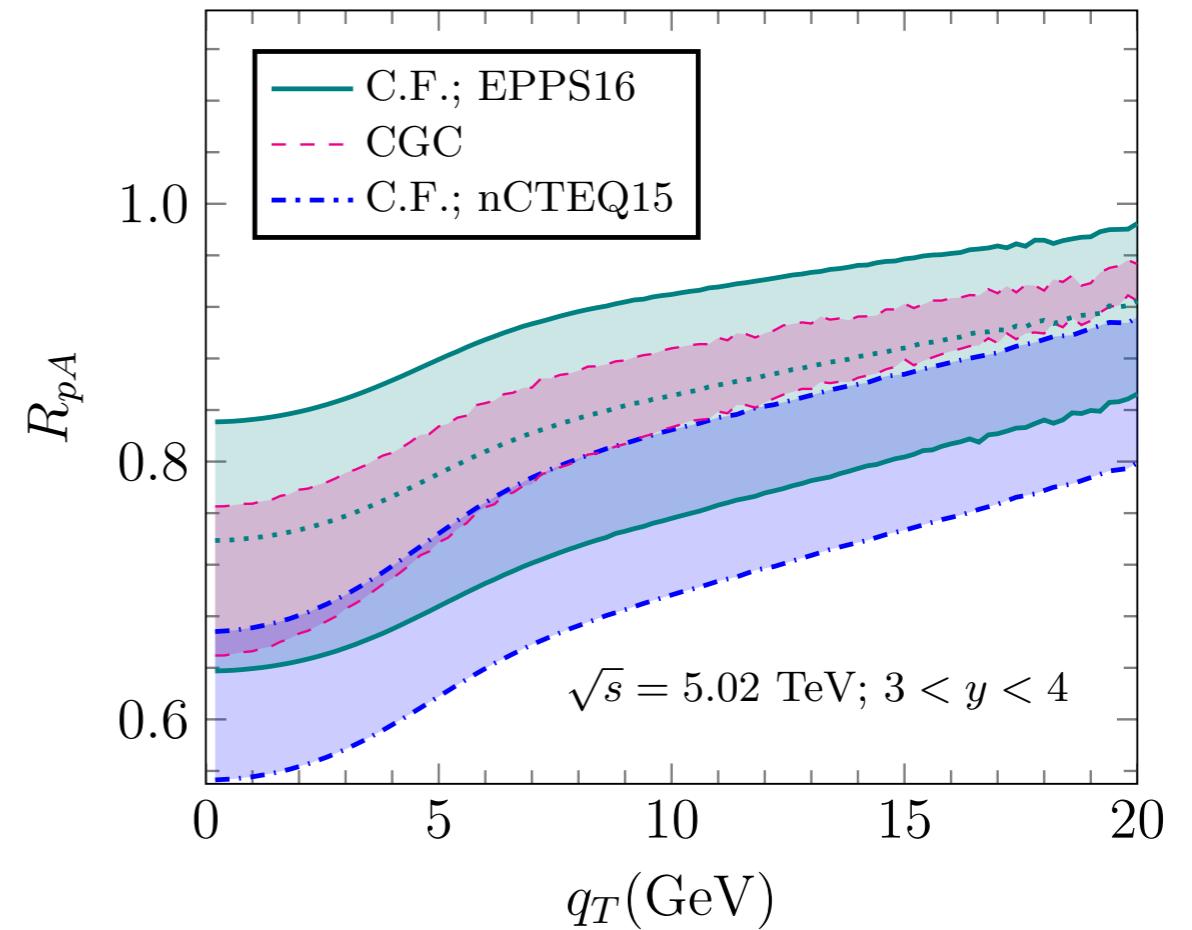
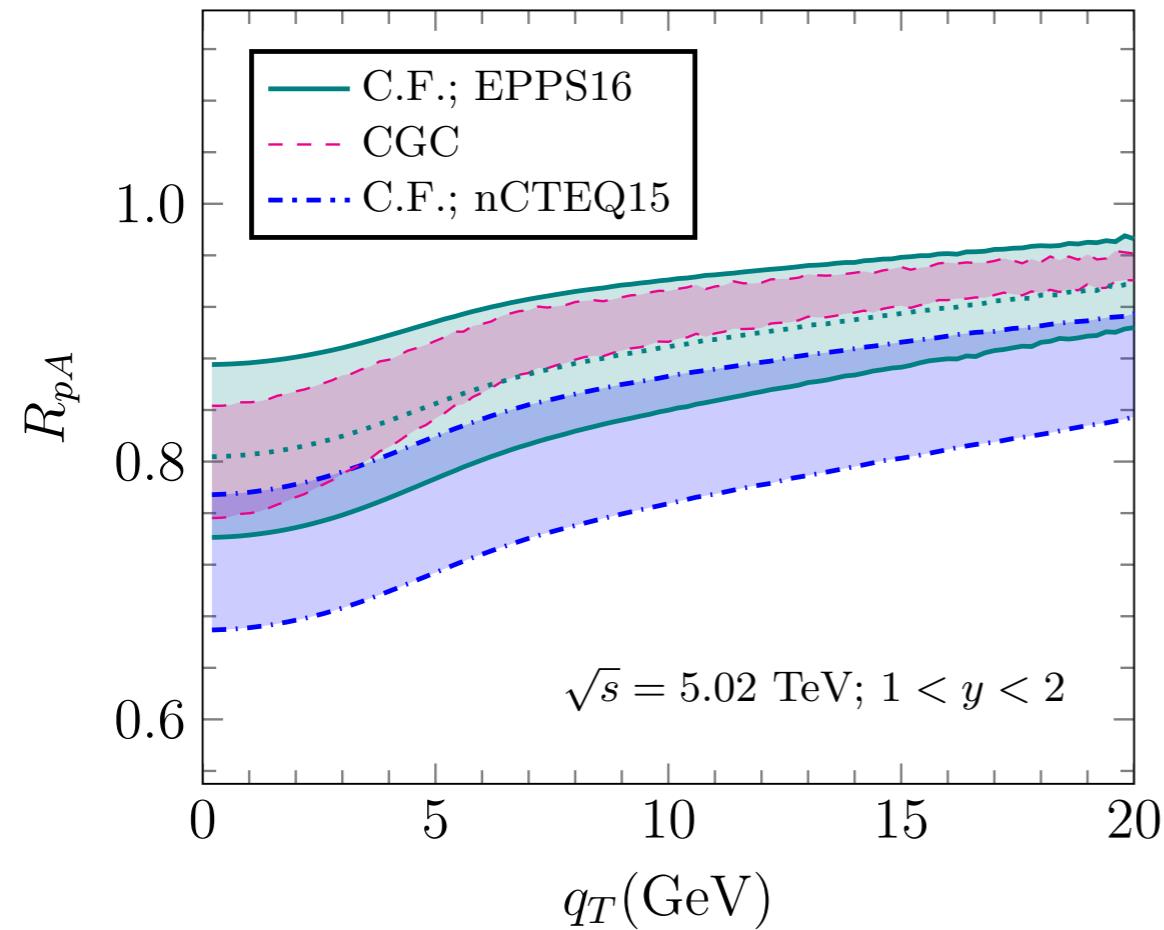
$$Q_{sA}^2 = 2(3)Q_{sp}^2$$



Marquet, Wei, Xiao, to appear

Z^0 -boson production in forward $pp(A)$ collisions

From pp to pA collisions



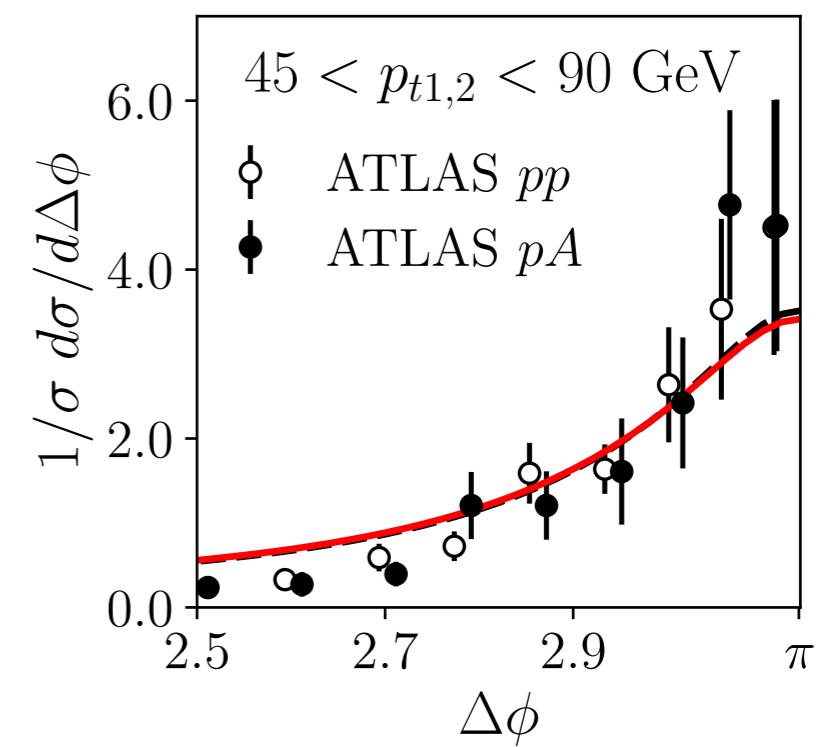
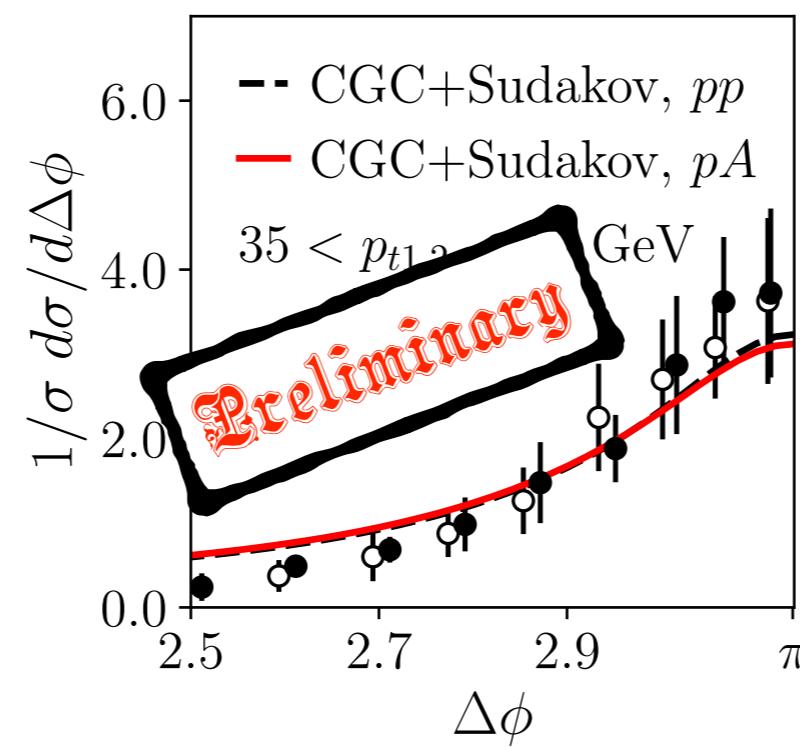
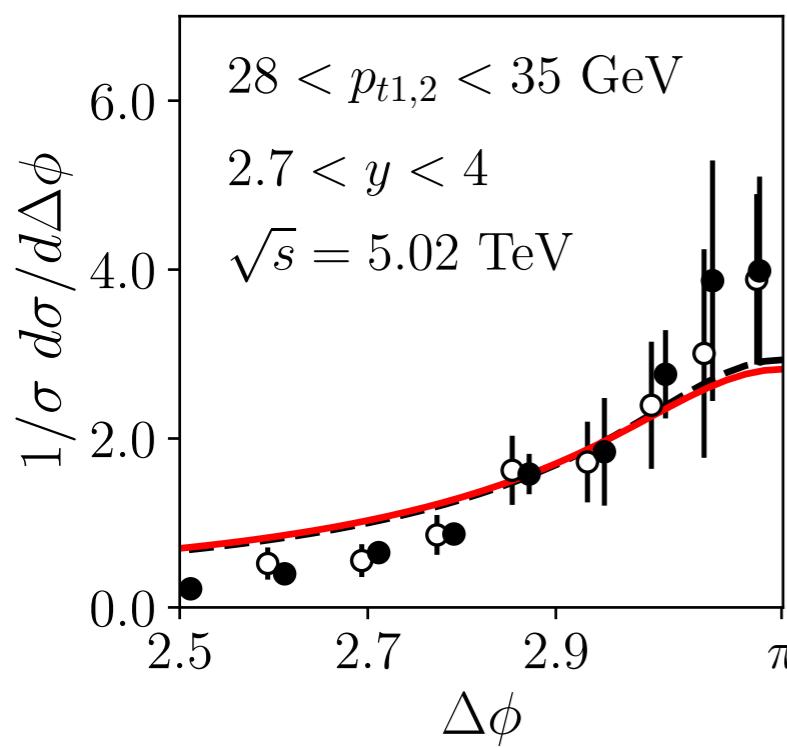
- CGC agrees with EPPS16, a smaller error band.
- Rapidity dependence of R_{pA} .

Dijet production in forward $pp(A)$ collisions

Same framework

Experimental data: dijet cross section normalized by trigger jet cross section.

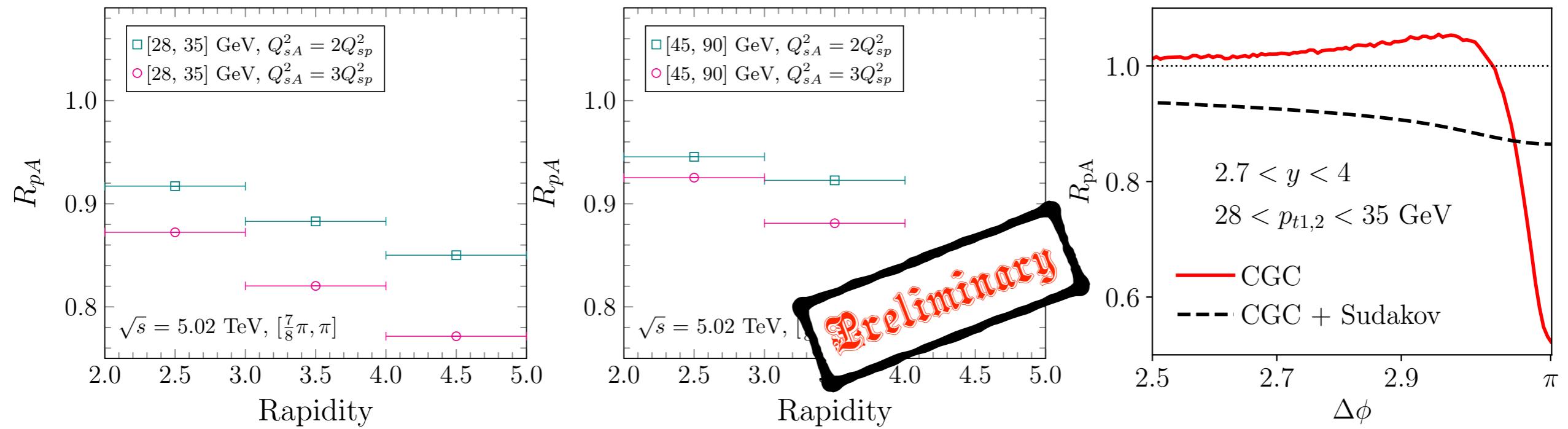
ATLAS, 1901.10440



Giacalone, Marquet, Matas, Wei, in preparation

Dijet production in forward $pp(A)$ collisions

Nuclear Modification factor R_{pA}



Giacalone, Marquet, Matas, Wei, in preparation

Summary

- Sudakov resummation is important for these processes.
- CGC can predict the nuclear suppression factor.
- We have numerical results.

Thanks for your attention!

The End