Sudakov resummation in CGC framework

Shu-yi Wei (魏树一) @ ECT*
swei@ectstar.eu

C. Marquet, S.Y. Wei, B.W. Xiao, arXiv:1909.08572
G. Giacalone, C. Marquet, M. Matas, S.Y. Wei, in preparation

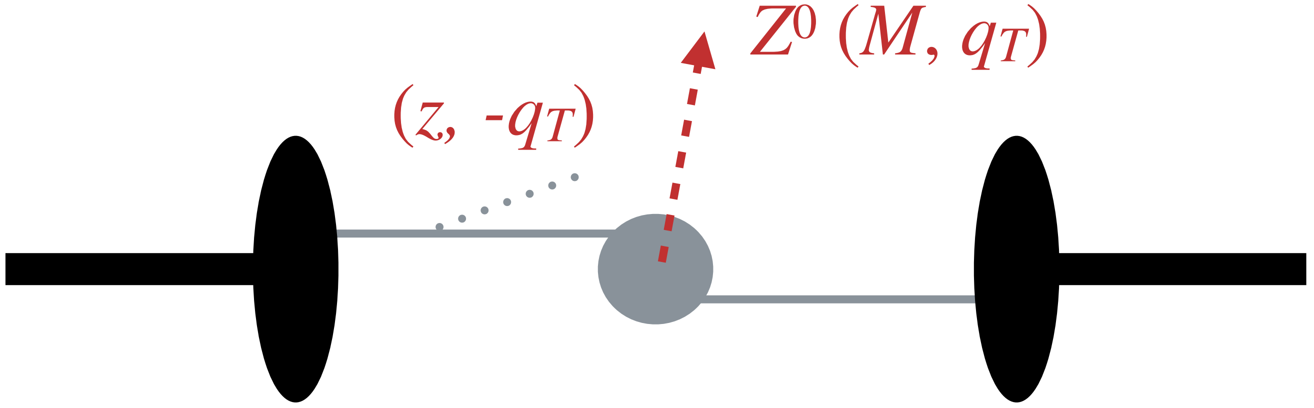
Contents

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

Introduction

Z^0-boson production in *pp* collisions

differential X at small q_T



☑ 0th order: $$\frac{d\sigma^{(0)}}{d^2q_T} \propto \delta^2(q_T)$$

☑ 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
$z \ll 1$, $q_T \ll M$

Sudakov resummation

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

next-to-leading logarithms

- ☑ Sudakov factor at NLL accuracy

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

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

- ☑ b^* prescription: perturbative + non-perturbative

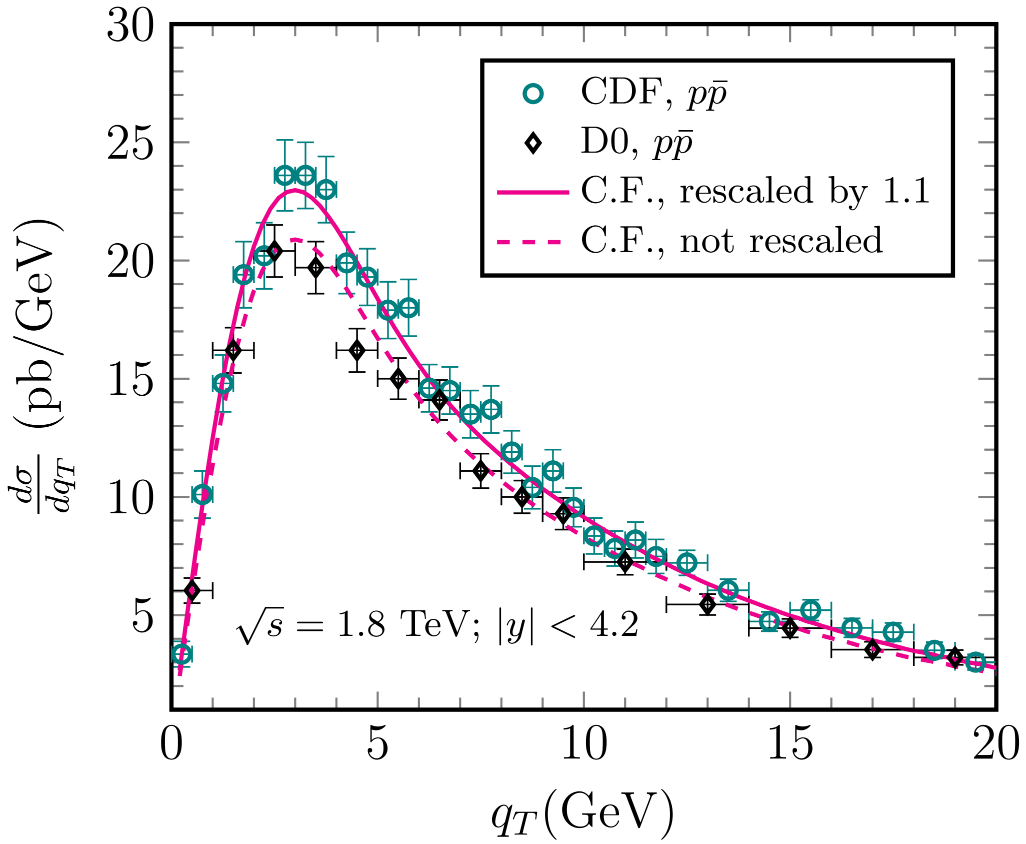
$$\mu_b > 2e^{-\gamma_E}/b_{\rm max}$$

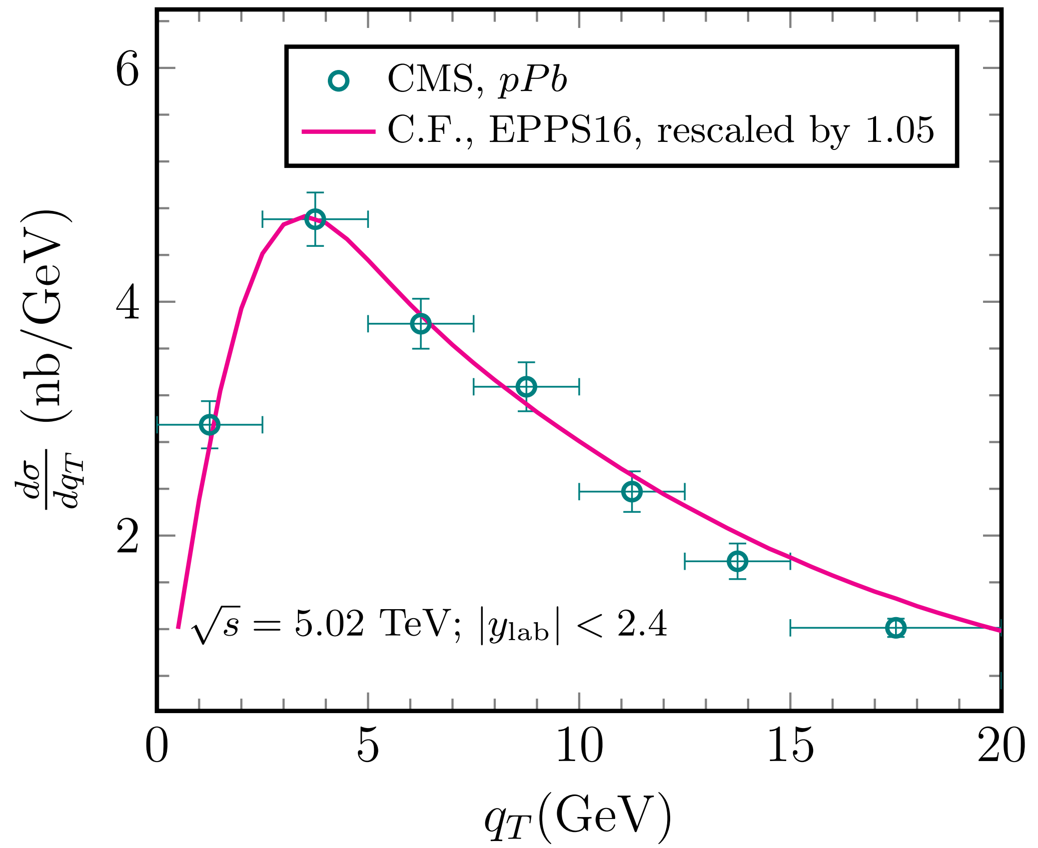
Collins, Soper, Sterman, 1985

Sudakov resummation

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

Some numerical results





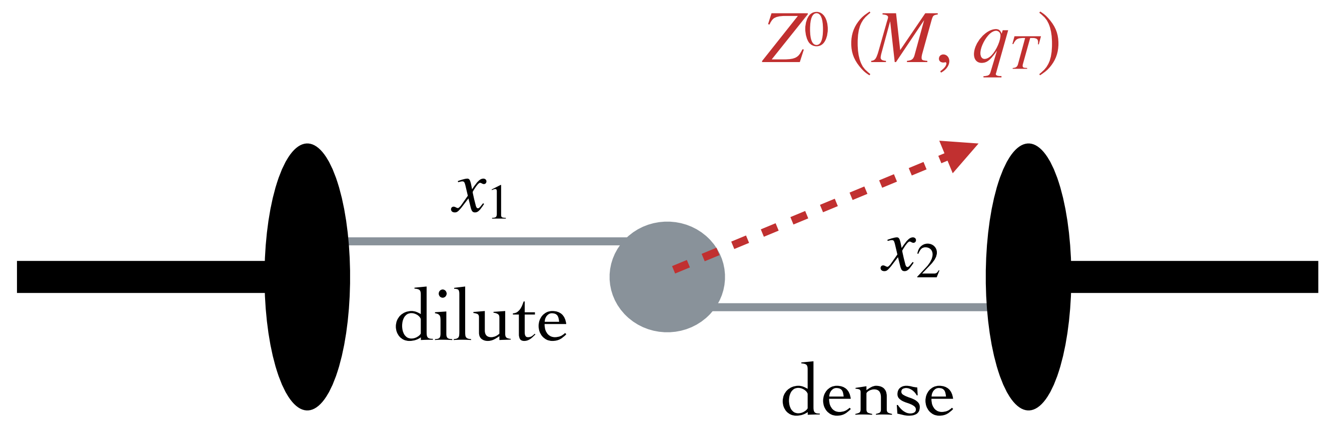
Collins, Soper, Sterman, 1985

Introduction: CGC + Sudakov

Dilute-dense factorization

forward rapidity

$x_1 \gg x_2$



Quark density in CGC framework
(saturation, TMD...)

Leading order cross section

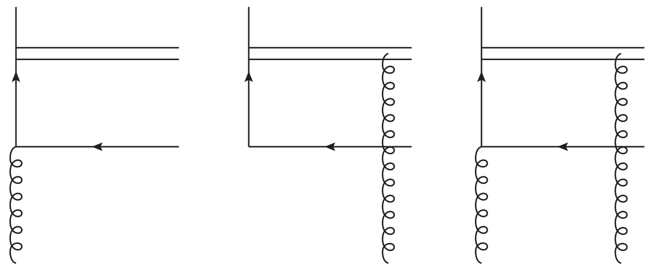
$$\frac{d\sigma}{dy dq_T^2} = \sigma_0 Q_{ij}^2 \sum f_i(x_1) \mathcal{F}_j(x_2, q_T)$$

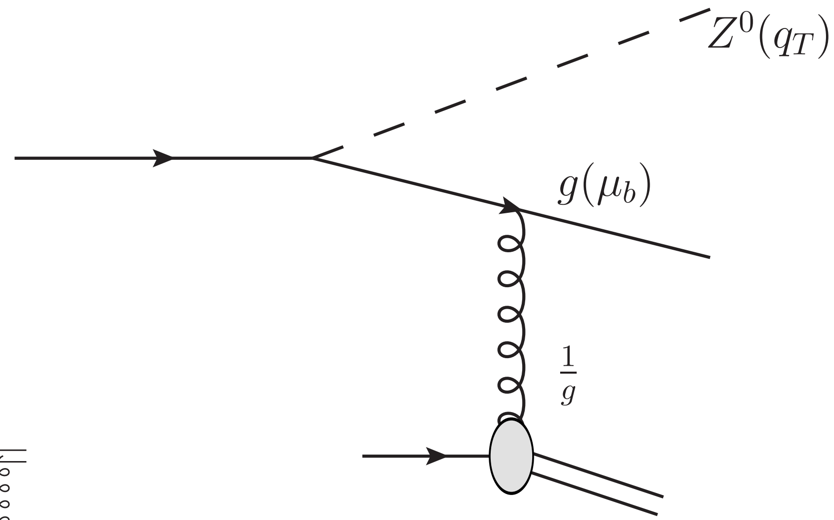
$q_T \sim$ saturation scale
parton shower is missing

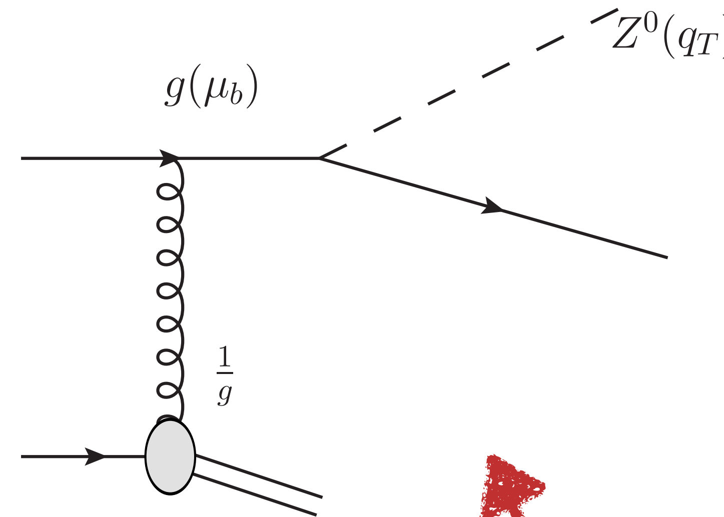
Mueller, 1999;
Marquet, Xiao, Yuan, 2009;
Gelis, Jalilian-Marian, 2002, 2003;
……

Introduction: CGC + Sudakov

Quark density at small-x







Quark density in CGC framework
(saturation, TMD...)

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 ~ saturation scale
parton shower is missing

Mueller, 1999;
Marquet, Xiao, Yuan, 2009;
Gelis, Jalilian-Marian, 2002, 2003;
……

Introduction: CGC + Sudakov

CGC + Sudakov resummation Mueller, Xiao, Yuan, 2013

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

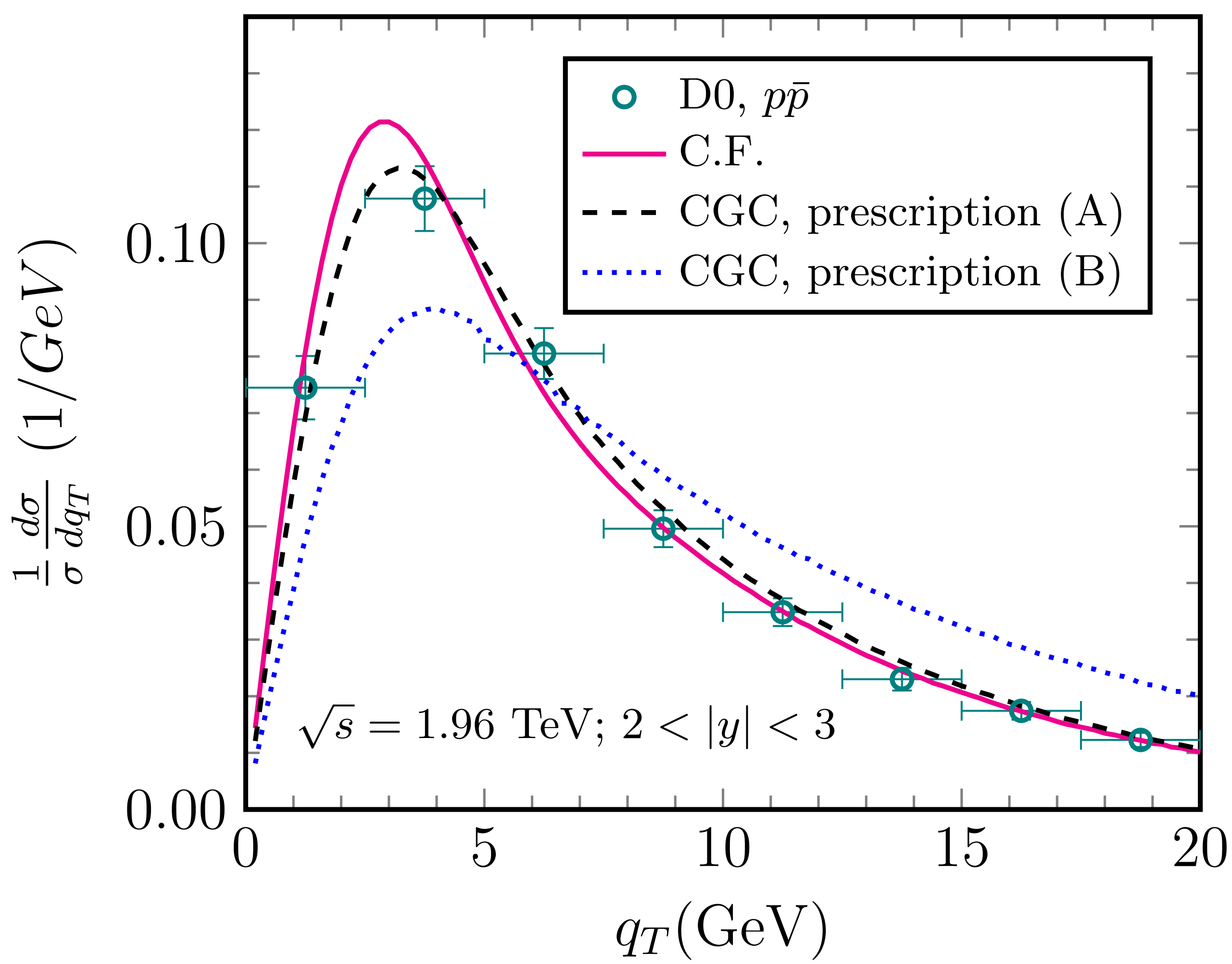
$$\frac{d\sigma}{dydq_T^2} = \sigma_0 \int \frac{d^2b_\perp}{(2\pi)^2} e^{-i\vec{q}_T\cdot\vec{b}_\perp} e^{-S'_{\rm sud}} Q_{ij}^2 \sum f_i(x_1)\mathcal{F}_j(x_2, b_\perp)$$

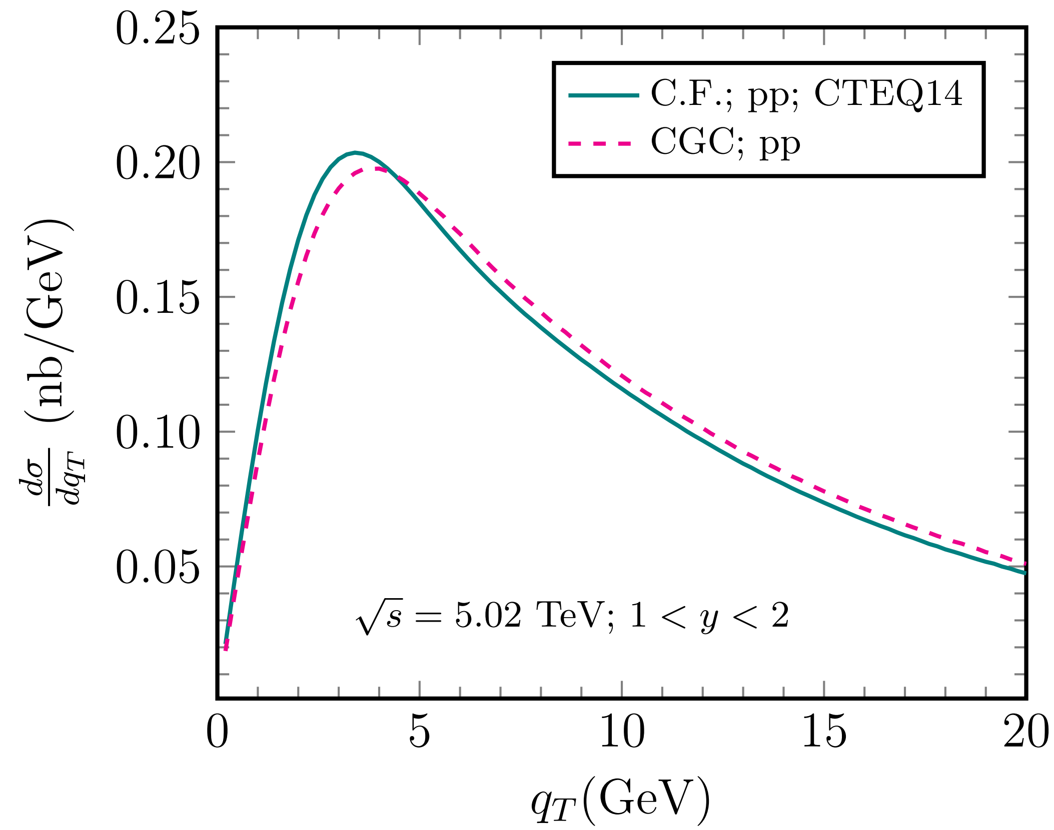
A tale of two α_s

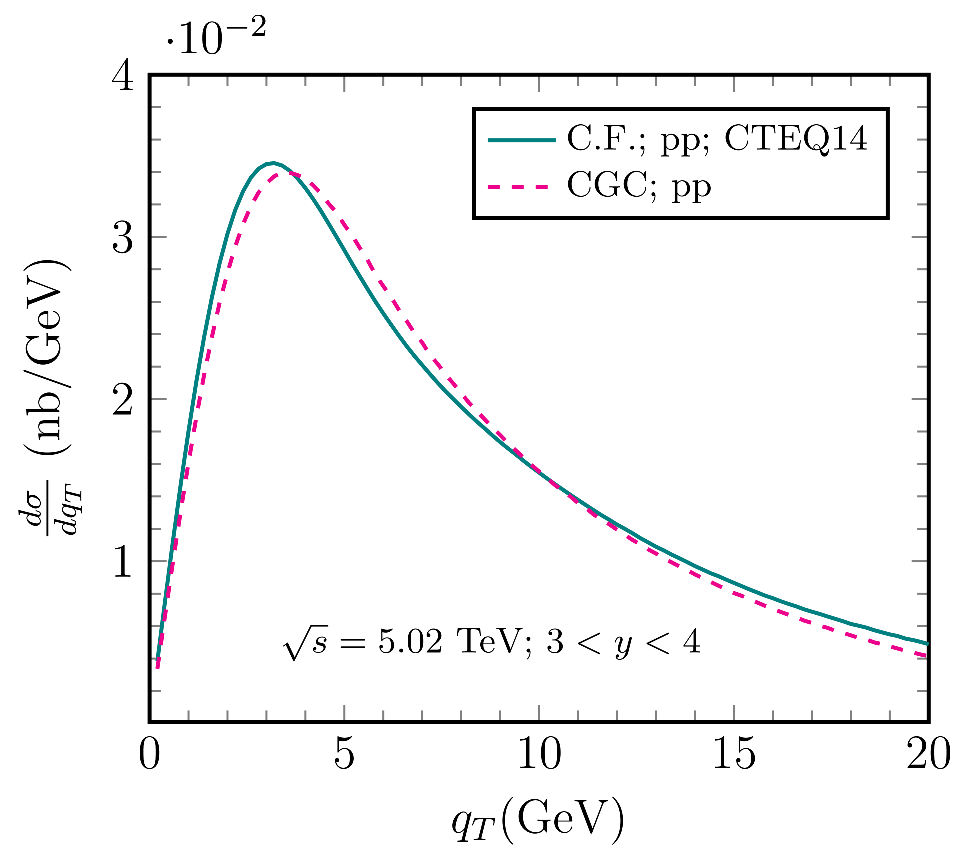
$$x_2\mathcal{F}(x_2,b) = \frac{\alpha_s M_Z^2 N_C}{8\pi^4\alpha_s} \int dz d^2b_1 d^2R_\perp \frac{\vec{b}_1\cdot\vec{b}_2}{|\vec{b}_1||\vec{b}_2|} \epsilon_f^2 K_1(\epsilon_f|\vec{b}_1|)K_1(\epsilon_f|\vec{b}_2|)\frac{1+(1-z)^2}{z}$$
$$[\mathcal{N}(x_2,z|b_1|)+\mathcal{N}(x_2,z|b_2|)-\mathcal{N}(x_2,z|b|)]$$

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

Self-normalized data from D0





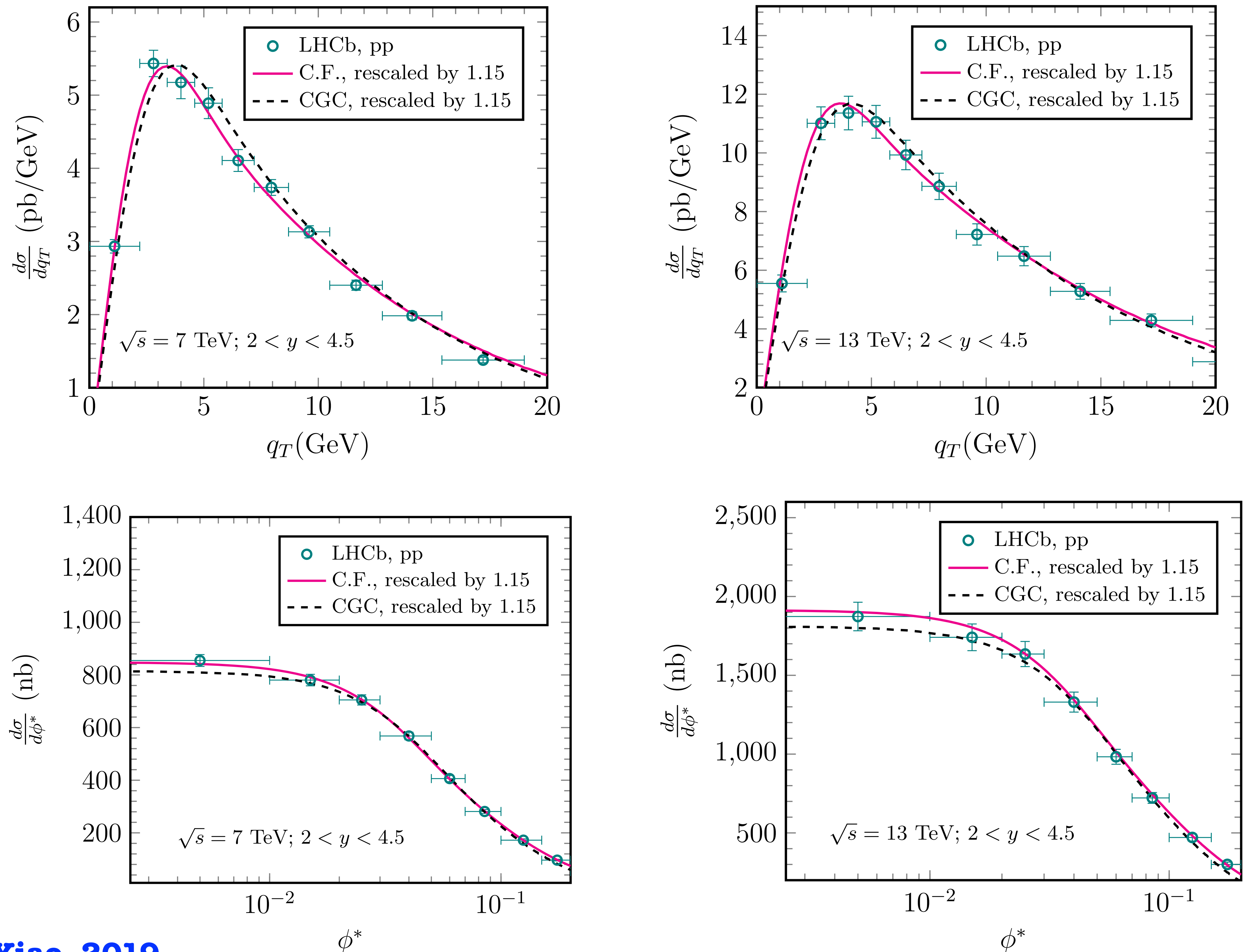


☑ prescription (B): two α_s cancel

Marquet, Wei, Xiao, 2019

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

Absolute cross section from LHCb



Marquet, Wei, Xiao, 2019

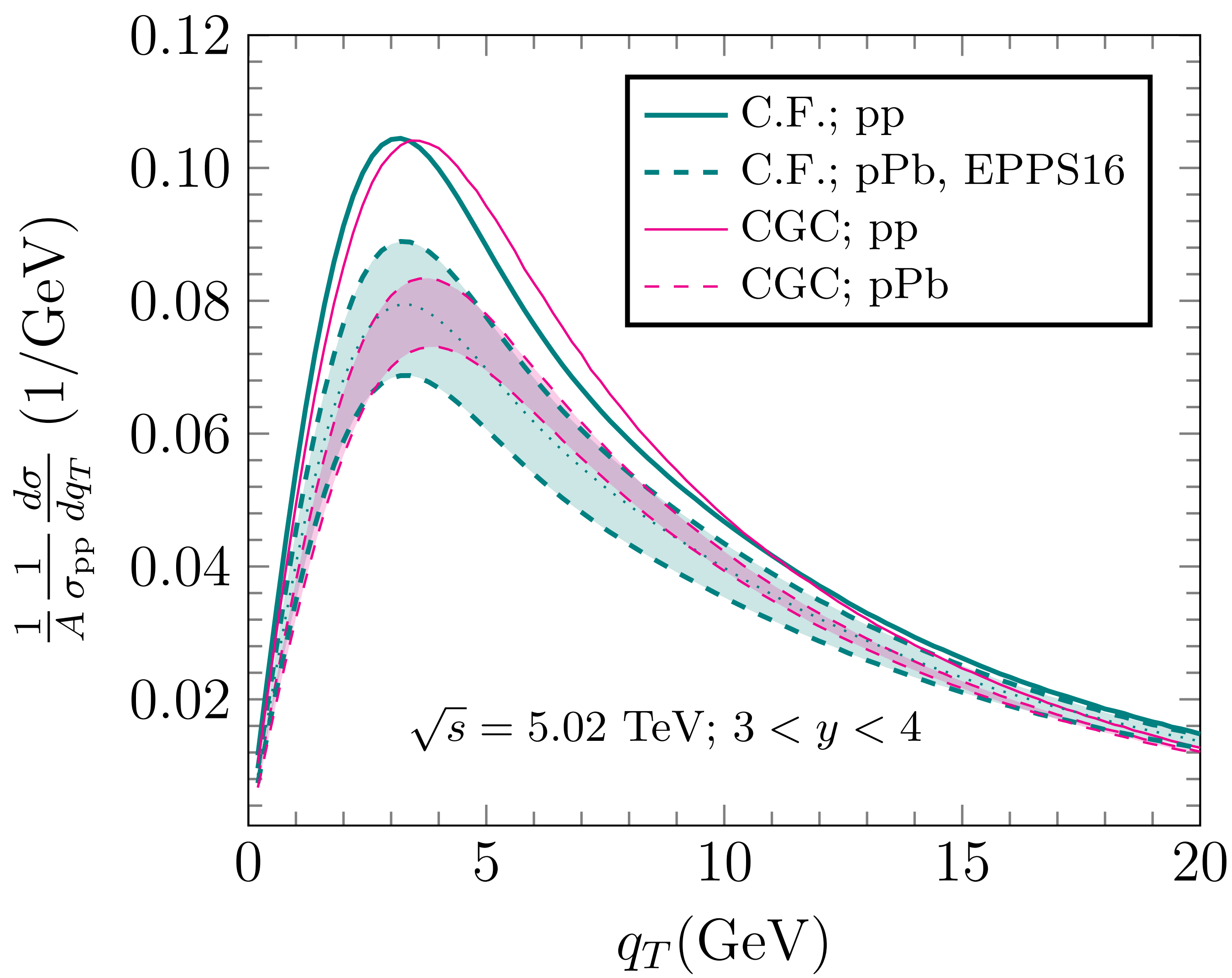
Z^0-boson production in forward $pp(A)$ collisions

From *pp* to *pA* collisions

larger saturation scale → smaller per nucleon density → $R_{pA} < 1$

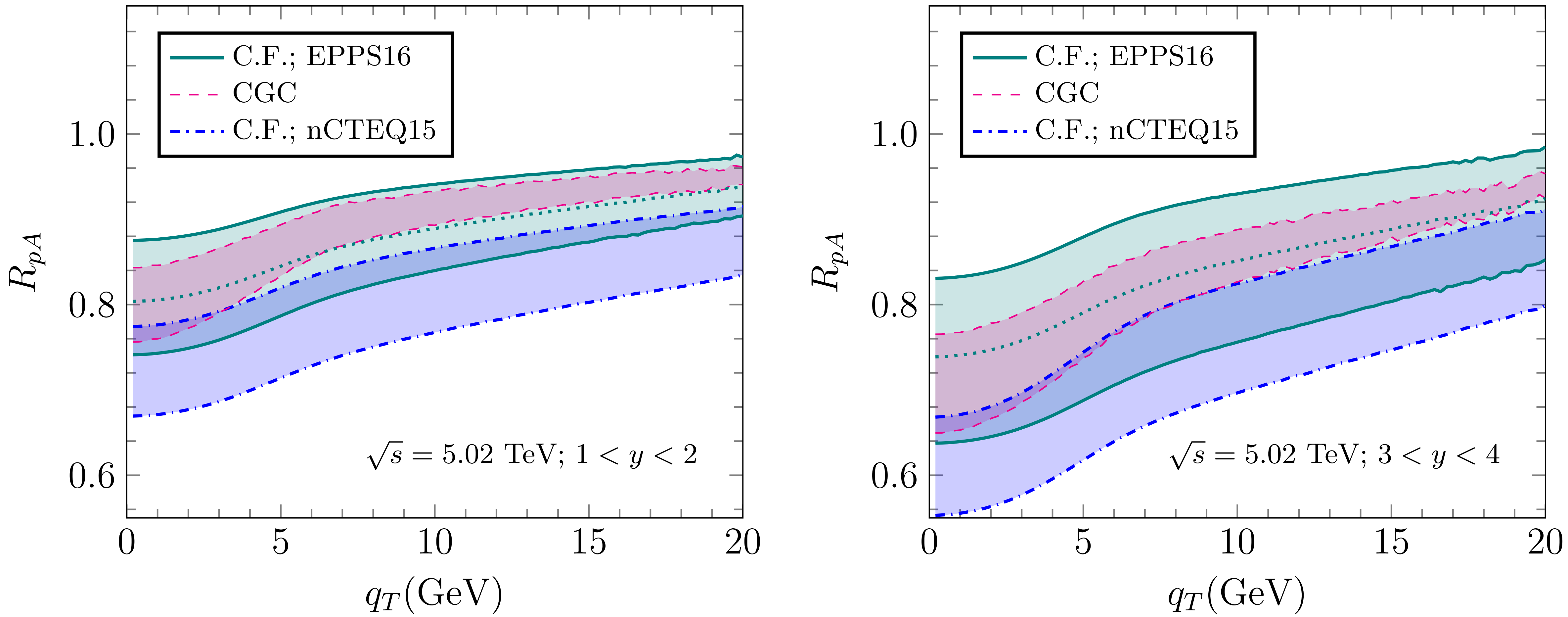
larger saturation scale → larger transverse momentum → broader q_T distribution

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



Marquet, Wei, Xiao, 2019

From *pp* to *pA* collisions



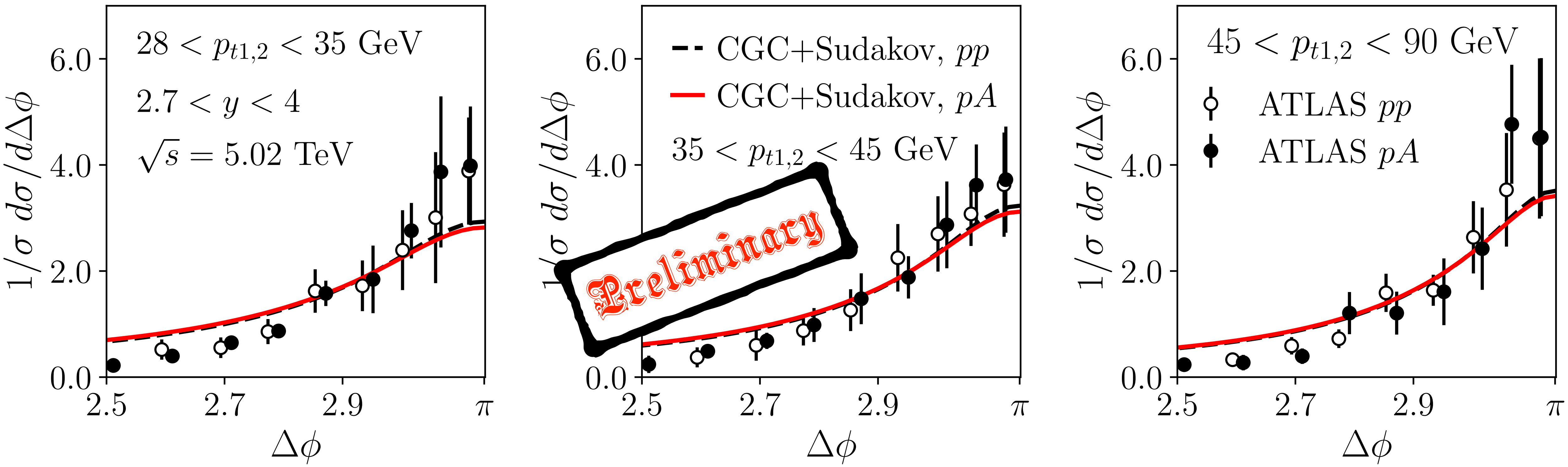
- ☑ CGC agrees with EPPS16, a smaller error band.
- ☑ Rapidity dependence of R_{pA}.

Marquet, Wei, Xiao, 2019

Same framework

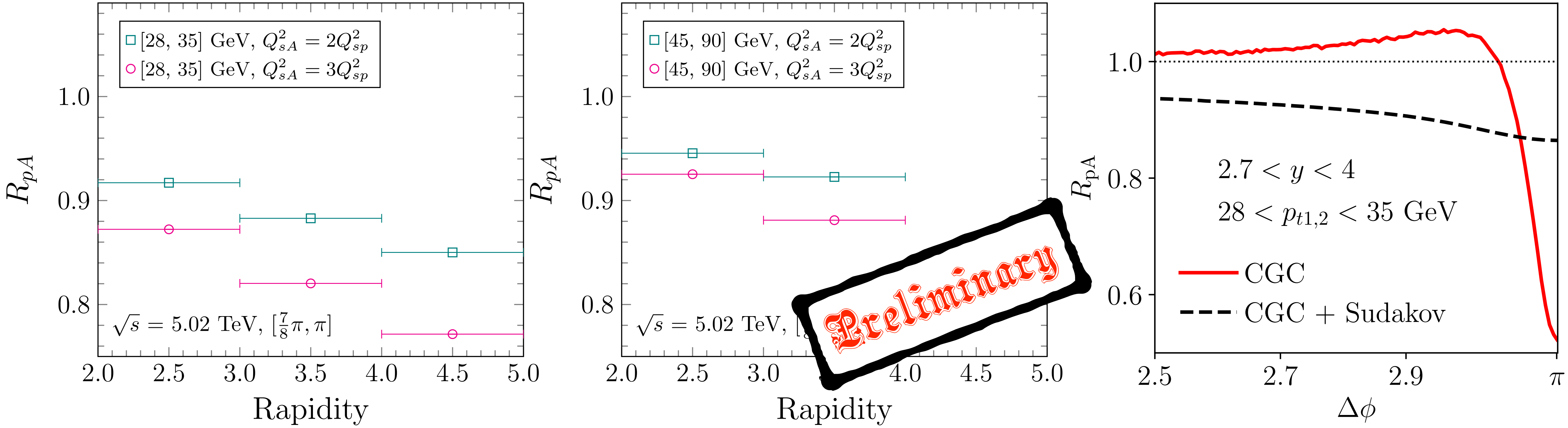
Experimental data: dijet cross section normalized by trigger jet cross section.

ATLAS, 1901.10440



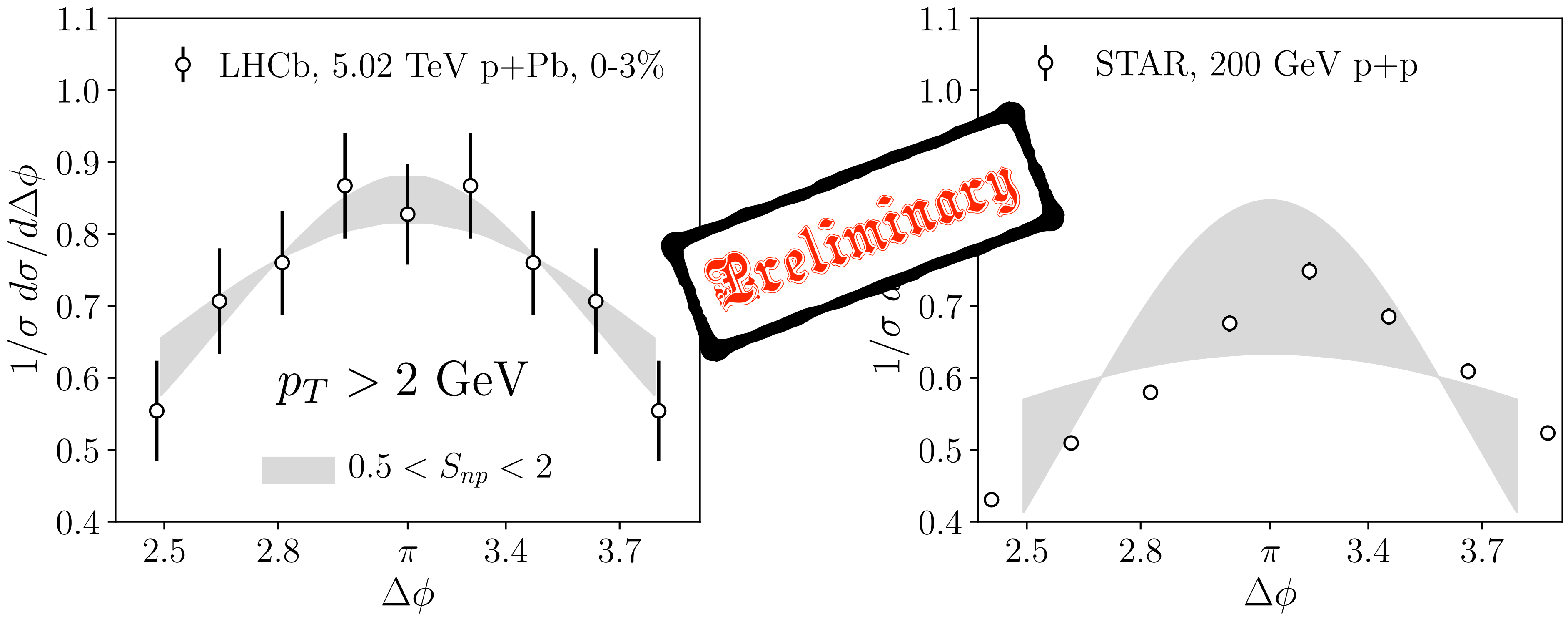
Giacalone, Marquet, Matas, Wei, in preparation

Nuclear Modification factor R_{pA}



Giacalone, Marquet, Matas, Wei, in preparation

From dijet to dihadron



Giacalone, Marquet, Matas, Wei, in preparation

Summary

☑ Motivation: Sudakov + CGC?

(1) To be able to describe the experimental data.

(2) To establish the baseline to study nuclear effect.

☑ Yes, we have some numerical results.

Thanks for your attention!

The End