Charm production in the dipole approach

Introduction

Charm structure function

Charm pt distribution in eA

Charm production in pp and pA

Summary

(focus on saturation effects)

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IFUSP / BRAZIL

Introduction

Why charm ?

- Heavy enough for perturbative QCD
- Light enough to be abundant
- more important at low x $F_2^c \cong 0.25\ F_2$
- $m_c \sim Q_s$ saturation effects ?

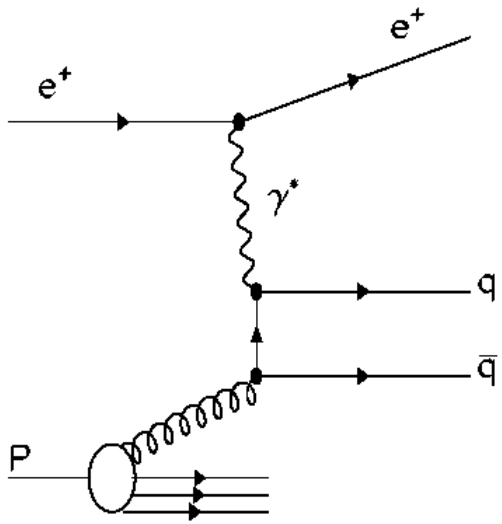
How to calculate ?

- Collinear factorization + DGLAP evolution
- KT factorization + unintegrated gluon densities — Zotov´s talk
- Color dipole + dipole cross section

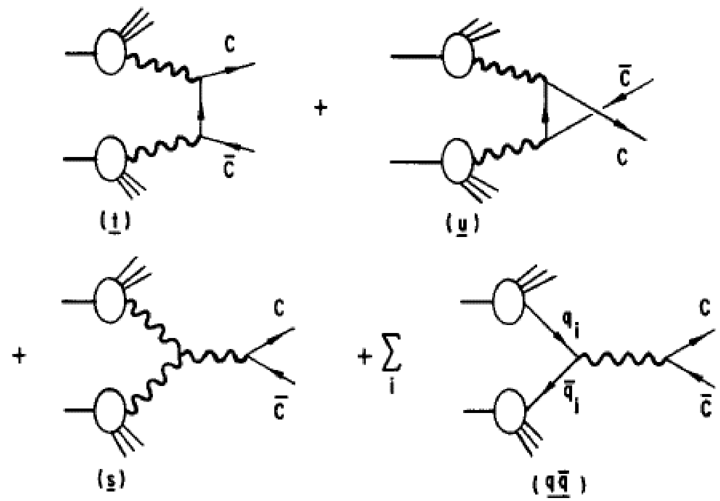
Dipoles: easy inclusion of saturation effects

Nikolaev, Zakharov (1991),
A. Müller (1994)

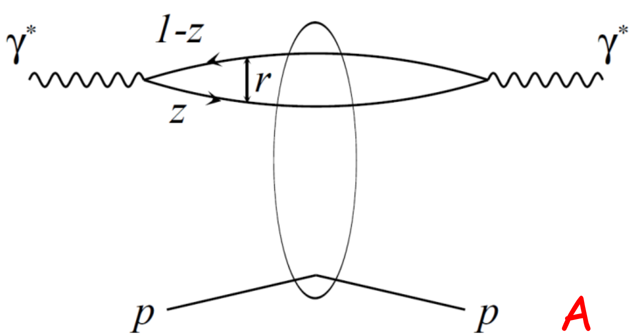
ep: boson-gluon fusion



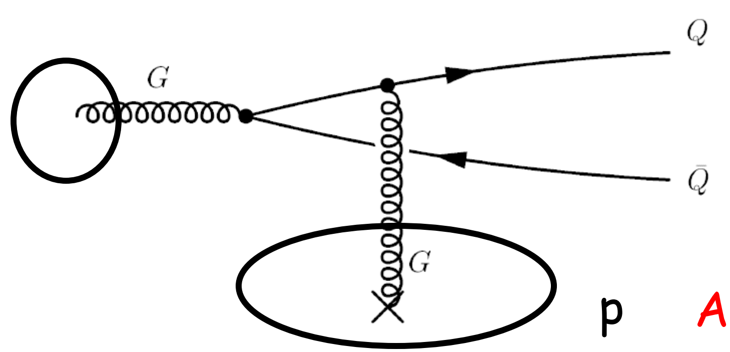
pp: gluon-gluon fusion



color (singlet) dipole



color (octet) dipole



Charm structure function in eA

$$F_2^A(x,Q^2) = \frac{Q^2}{4\pi^2\alpha_{em}}(\sigma_T + \sigma_L)$$

Albacete´s talk

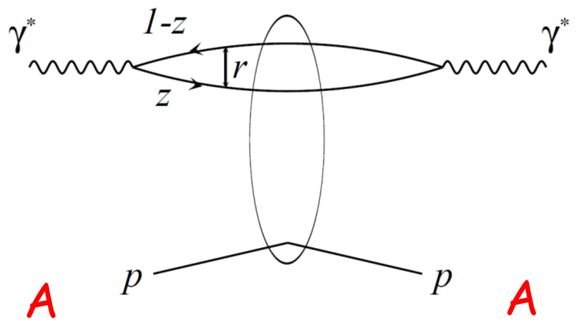
Stasto´s talk

$$\sigma_{T,L} = \int d^2r\, d\alpha\; |\Psi_{T,L}(r,\alpha,Q^2)|^2\; \sigma_{dA}(x,r)$$

$$\sigma_{dA}(x,r) = 2\int d^2b\; N_A(x,r,b)$$

$$N_A(x,r,b) = 1 - \exp\left[-\frac{1}{2}\sigma_{dp}(x,r)\, T_A(b)\right]$$

Armesto (2002)



QCD input: in the dipole – proton cross section !

Dipole – proton cross section

Golec-Biernat - Wüsthoff	GBW	(1998)
Bartels – Golec-Biernat - Kowalski	BGK	(2002)
Kowalski - Teaney	IPsat	(2003)
Iancu – Itakura - Munier	IIM	(2004)
Kharzeev - Kovchegov -Tuchin	KKT	(2004)
Kowalski - Motyka - Watt	bCGC	(2006)
Dumitru - Hayashigaki – Jalilian-Marian	DHJ	(2006)
Gonçalves – Kugeratski – Machado – Navarra	GKMN	(2006)
Marquet - Peshanski - Soyez	MPS	(2007)
Boer - Utermann - Wessels	BUW	(2008)
Albacete – Armesto – Milhano - Salgado	rcBK	(2009)

(and others...sorry for omissions)

Linear limit with dipoles

dp

GBW $\quad N(x,r) = 1-\exp\{-\frac{1}{4}(r^2 Q_s^2)\} \xrightarrow{r\to 0} N(x,r) \cong \frac{1}{4}(r^2 Q_s^2)$

KKT $\quad N(x,r) = 1-\exp\{-\frac{1}{4}(r^2 Q_s^2)^{\gamma}\} \longrightarrow N(x,r) \cong \frac{1}{4}(r^2 Q_s^2)^{\gamma}$

IIM $\quad N(x,r) = \begin{cases} N_0\left(\frac{r\,Q_s}{2}\right)^{2\gamma_{eff}} & r\,Q_s < 2 \quad \text{linear} \\ 1-\exp[-a\ln^2(b\,r\,Q_s)] & r\,Q_s > 2 \quad \text{saturation} \end{cases}$

full

rcBK (all numerical)

dA

Mixed description: $\sigma_{dA}(x,r^2) = \frac{\pi^2}{3} r^2 \alpha_s \, x \, g_A(x,Q^2)$

$$x\, g_A(x,Q^2) = A\, x\, g_N(x,Q^2)$$

g_N from GRV98

Color transparency (CT)

$$x\, g_A(x,Q^2) = A\, R_g(x,Q^2)\, x\, g_N(x,Q^2)$$

R_g from EKS98

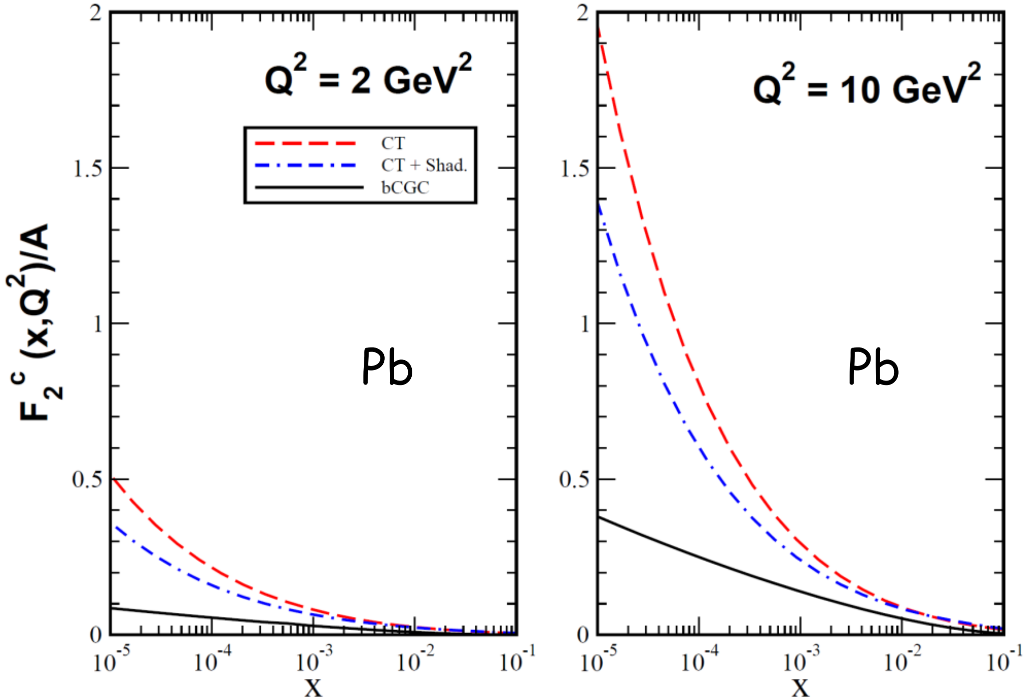
Color transparency
+ Shadowing (CT + Shad)

Linear - p:

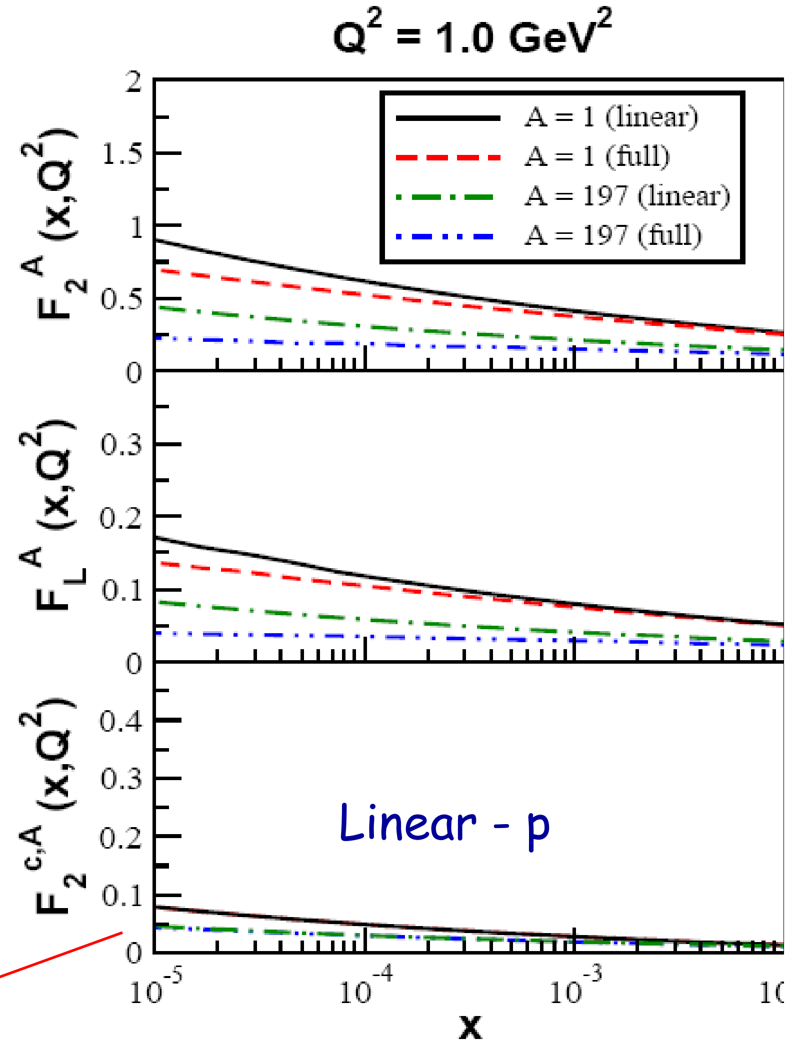
$$N_A(x,r,b) = 1 - \exp\left[-\frac{1}{2} \sigma_{dp}(x,r)\, T_A(b) \right]$$

σ_{dp} = linear

Charm structure function in eA



Gonçalves, Kugerastski, Navarra (2010)

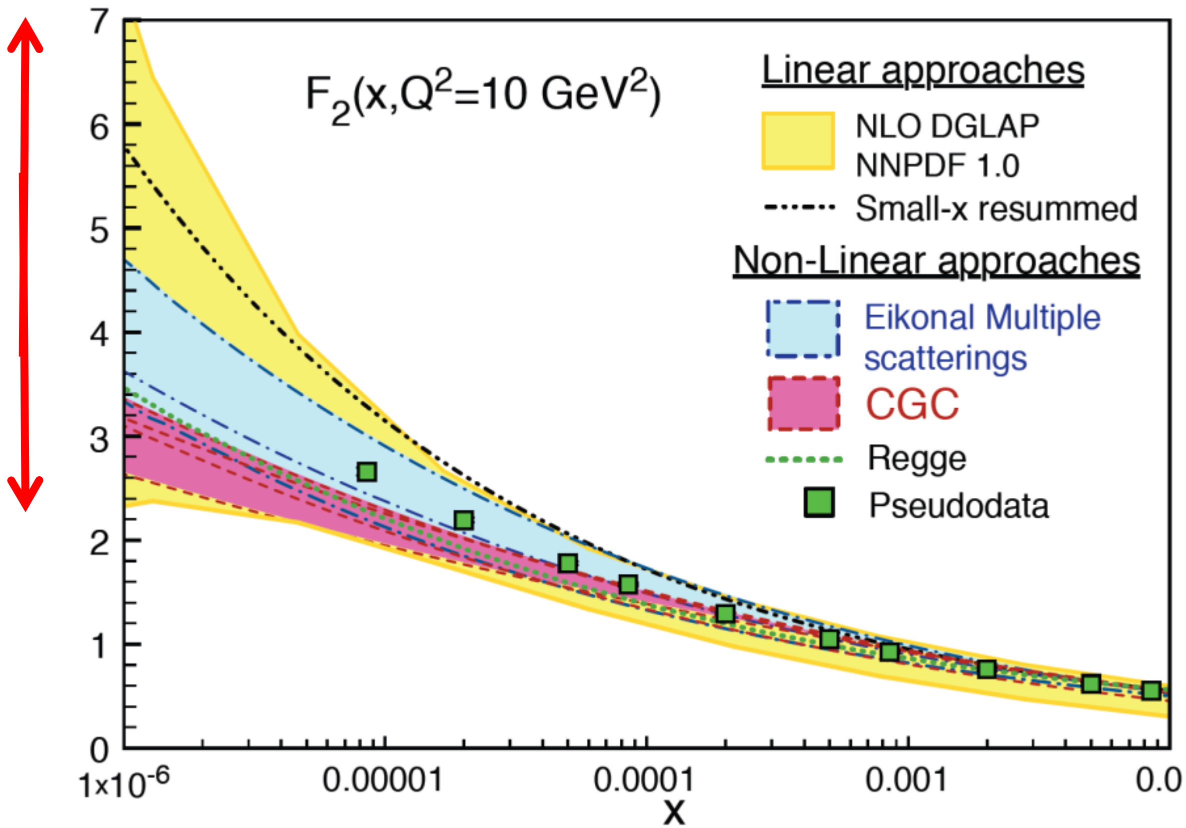


Gonçalves, Kugerastski, Navarra (2005)

Saturation: reduction by a factor 3 to 4 at $x = 10^{-5}$

Almost no reduction

Linear limit without dipoles



Saturation: reduction by a factor ~ 2

Stasto´s talk

Linear limit without dipoles

Collinear factorization approach:

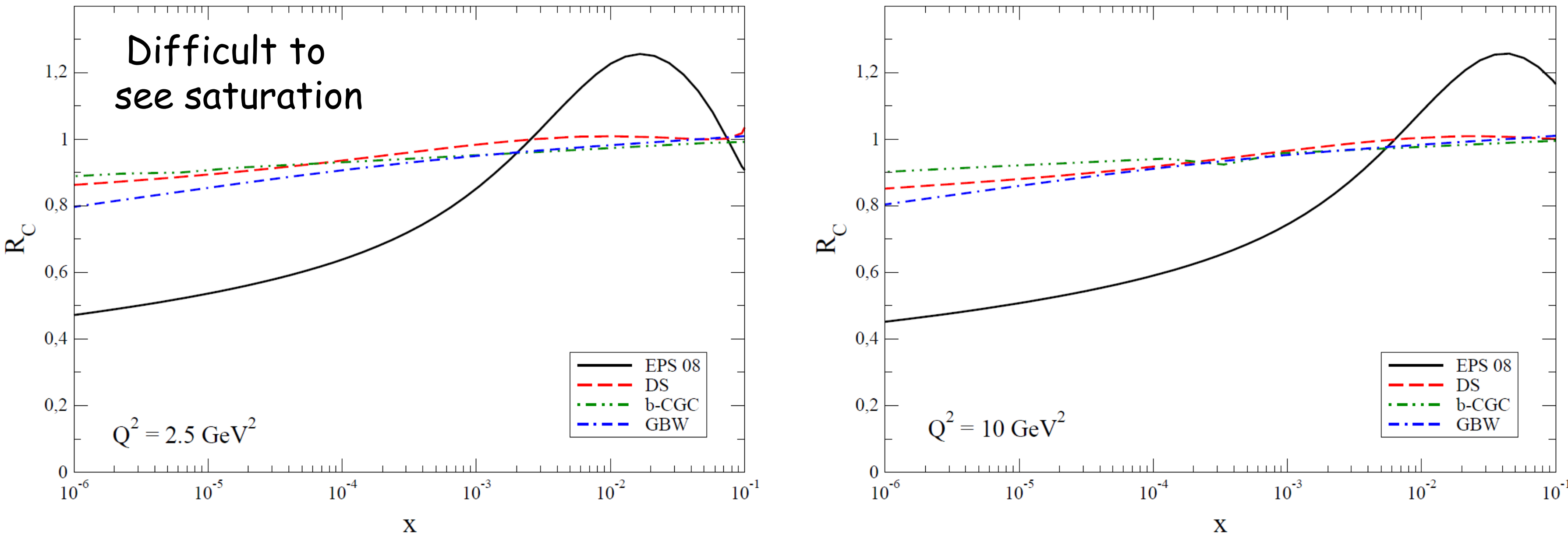
$$R_c = \frac{F_2^{cA}}{A\,F_2^{cp}}$$

$$\frac{1}{x} F_2^c(x, Q^2, m_c) = e_c^2 \frac{\alpha_s(\mu^2)}{2\pi} \int_{ax}^{1} \frac{dy}{y} C\left(\frac{x}{y}, \xi\right) g(x, \mu^2)$$

$C(z,\xi) =$ Coefficient function from pQCD

$$x\, g_A(x, Q^2) = \begin{cases} \text{DS: de Florian, Sassot (2004)} \\ \text{EPS: Eskola, Paukkunen, Salgado (2008)} \end{cases}$$

Cazaroto, Gonçalves, Carvalho, Navarra (2009)



eA

Heavy quark pt distribution

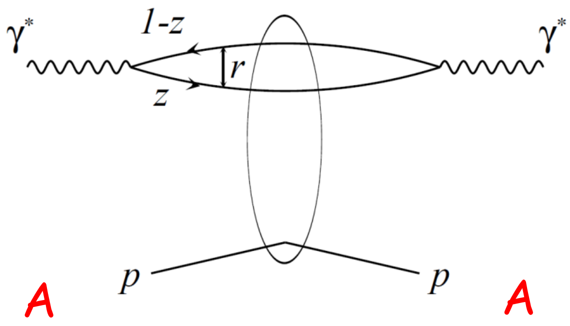
$$\frac{d\sigma(\gamma^* A \to Q\,X)}{d^2 p_Q^\perp} = \frac{6e_Q^2 \alpha_{em}}{(2\pi)^2} \int d\alpha \left\{ \left[m_Q^2 + 4Q^2\alpha^2(1-\alpha)^2 \right] \left[\frac{I_1}{p_Q^{\perp 2} + \epsilon^2} - \frac{I_2}{4\epsilon} \right] + \left[\alpha^2 + (1-\alpha)^2 \right] \left[\frac{p_Q^\perp \epsilon I_3}{p_Q^{\perp 2} + \epsilon^2} - \frac{I_1}{2} + \frac{\epsilon I_2}{4} \right] \right\}$$

$$I_1 = \int dr\, r\, J_0(p_Q^\perp r)\, K_0(\epsilon r)\, \sigma_{dA}(\boldsymbol{r})$$

$$I_2 = \int dr\, r^2\, J_0(p_Q^\perp r)\, K_1(\epsilon r)\, \sigma_{dA}(\boldsymbol{r})$$

$$I_3 = \int dr\, r\, J_1(p_Q^\perp r)\, K_1(\epsilon r)\, \sigma_{dA}(\boldsymbol{r})$$

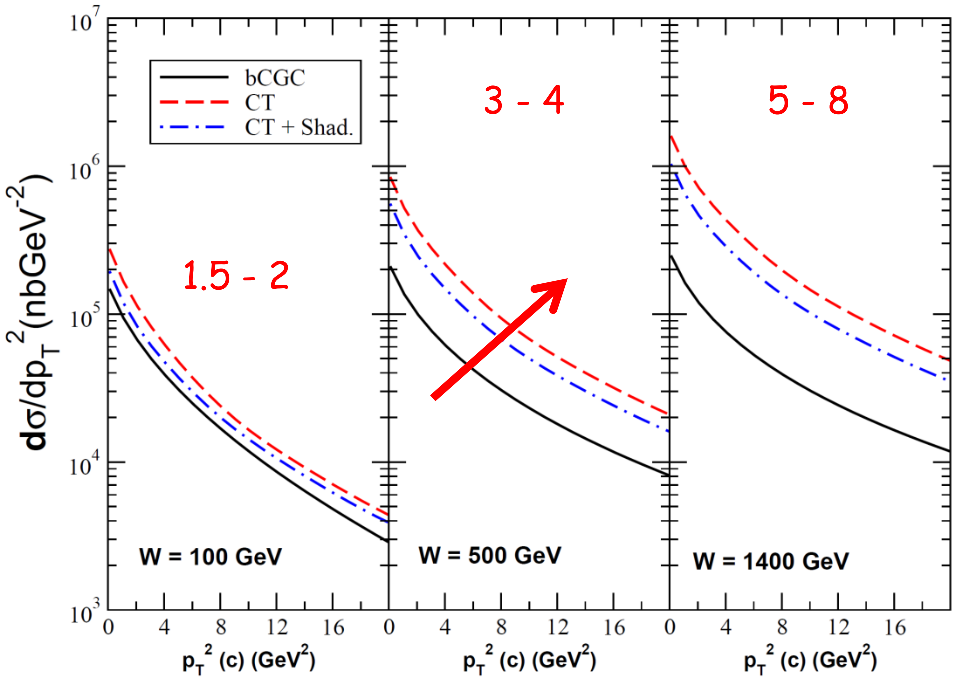
Flöter, Kopeliovich, Pirner, Raufeisen (2007)



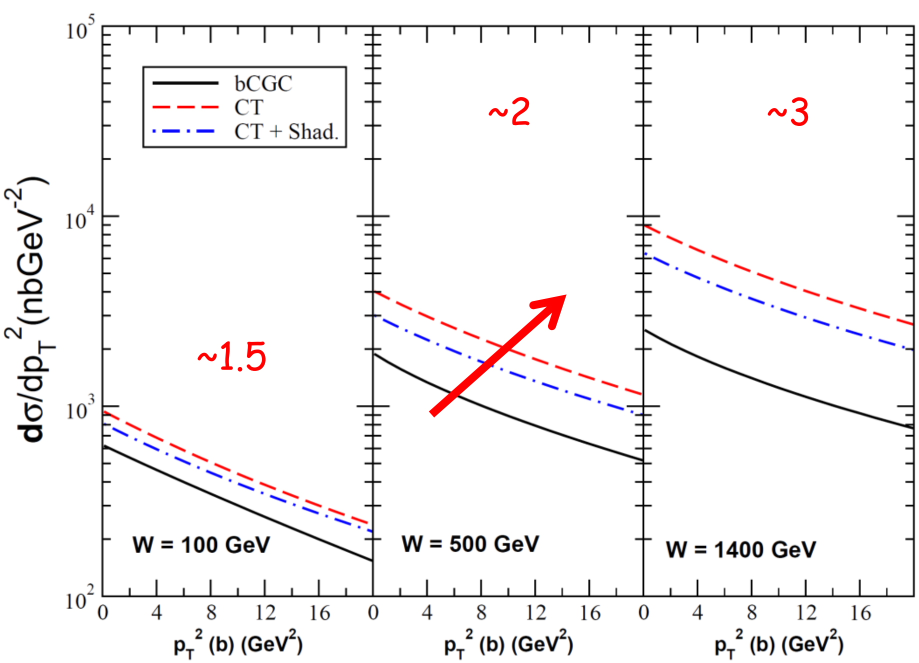
$$\epsilon = \alpha(1-\alpha)Q^2 + m^2$$

eA

$Q^2 = 2 \ GeV^2$



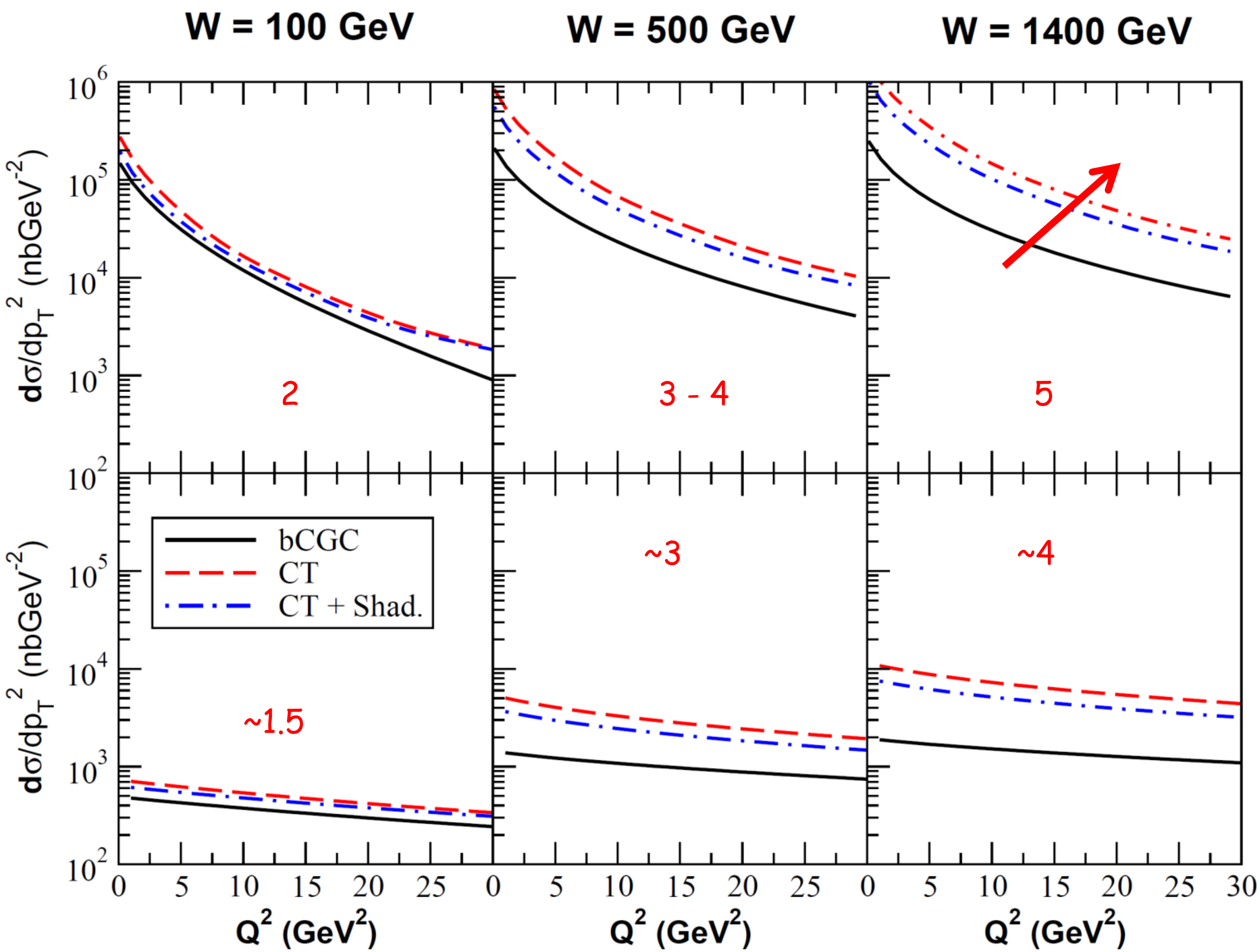
charm



bottom

Gonçalves, Kugerastski, Navarra (2010)

eA



charm

bottom

Gonçalves, Kugerastski, Navarra (2010)

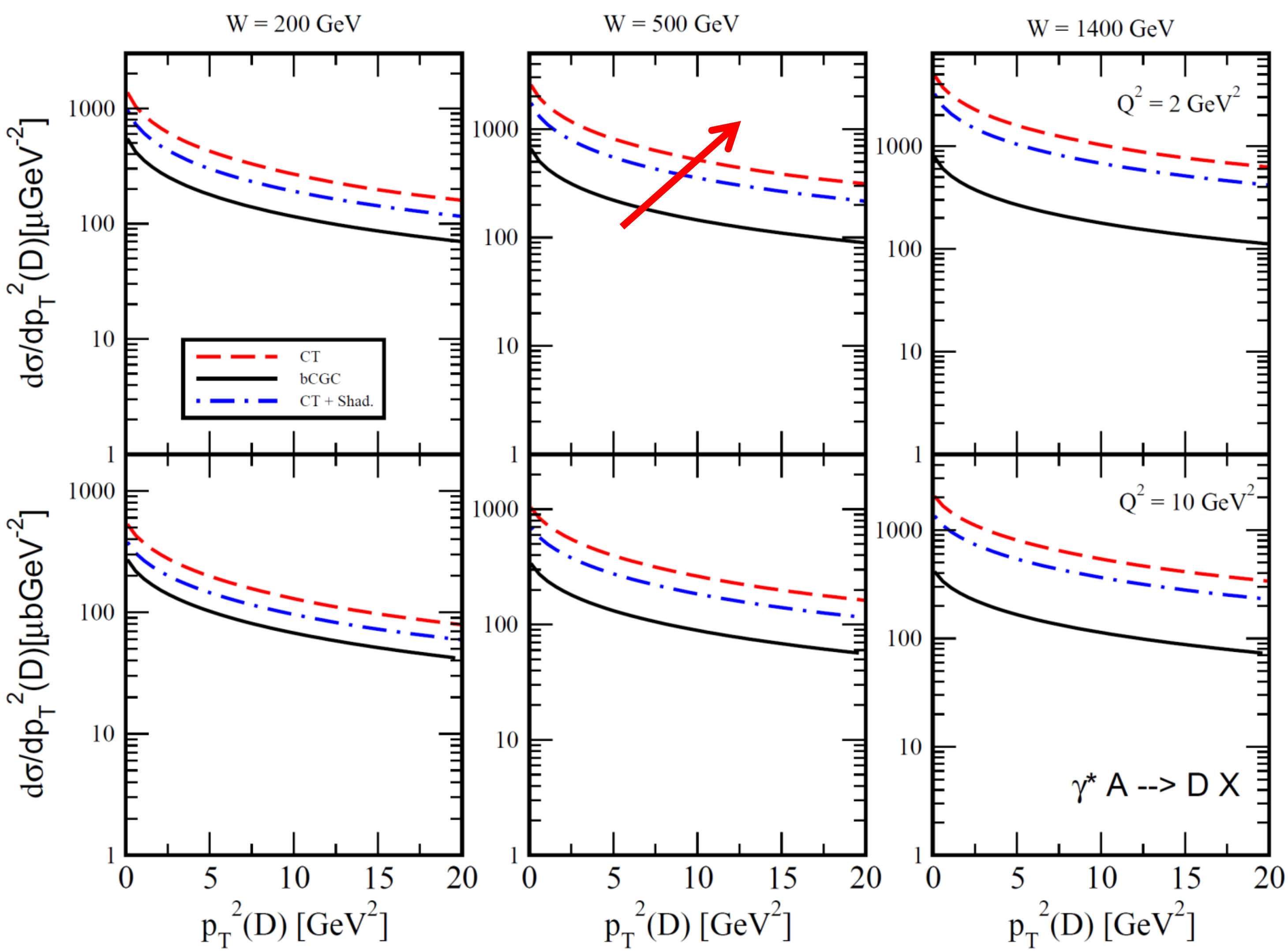
$p_T^2 = 4 \ GeV^2$

eA

D meson pt distribution

$$\frac{d\sigma(\gamma^* A \to DX)}{dz\, d^2 p_D^\perp} = \int \frac{dp_c^\perp\, d\alpha}{\alpha} \frac{d\sigma(\gamma^* A \to cX)}{d^2 p_c^\perp\, d\alpha} D_D^c\left(\frac{z}{\alpha}\right) \delta\left(p_D^\perp - \frac{z}{\alpha} p_c^\perp\right)$$

Peterson fragment.



Gonçalves, Kugerastski, Navarra (2010)

Charm production in pA collisions

Kopeliovich, Tarasov (2002)

$$\frac{d\sigma\{p\,p \to Q\overline{Q}\,X\}}{d\,y} = x_1 G(x_1,\mu^2)\;\sigma\{g\,p \to Q\overline{Q}\,X\}$$

$$\sigma\{g\,N \to Q\overline{Q}\,X\} = \int_0^1 d\alpha \int_0^1 d^2\rho\,|\Psi_{g\to Q\overline{Q}}(\alpha,\rho)|^2\,\sigma_{gq\bar{q}}(\alpha,\rho)$$

$$|\Psi_{g\to Q\overline{Q}}(\alpha,\rho)|^2 = \frac{\alpha_s(\mu^2)}{(2\pi)^2}\{m_Q^2 K_0^2(m_Q\rho) + (\alpha^2+\overline{\alpha}^2)\,m_Q^2 K_1^2(m_Q\rho)\}$$

$$\sigma_{gq\bar{q}}(\alpha,\rho) = \frac{9}{8}[\sigma_{dp}(\alpha\rho) + \sigma_{dp}(\overline{\alpha}\rho)] - \frac{1}{8}\sigma_{dp}(\rho)$$

$$x_1 = \frac{2\,m_Q\,e^{y}}{\sqrt{s}}$$

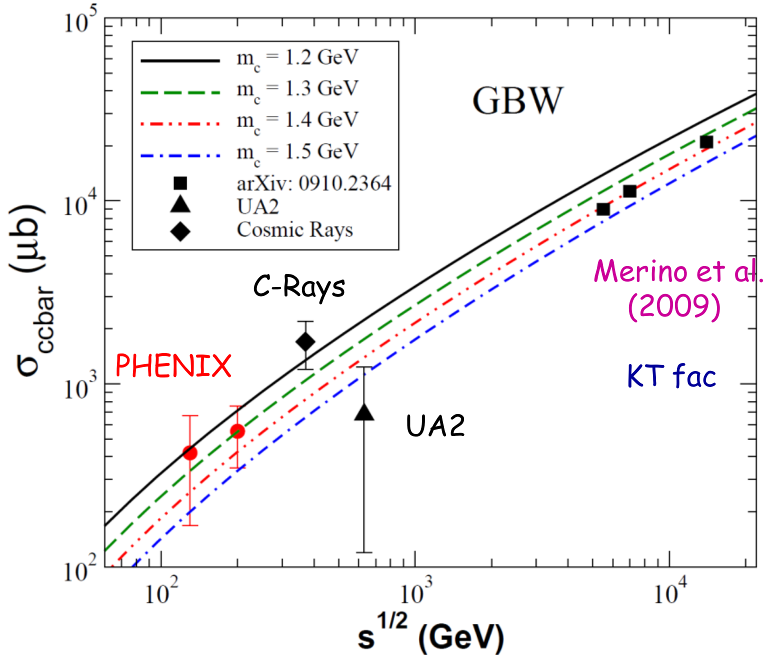
$$\sigma\{p\,p \to Q\overline{Q}\,X\} = 2\int_0^{\ln(\sqrt{s}/2m_Q)} d\,y\;x_1 G(x_1,\mu^2)\;\sigma\{g\,p \to Q\overline{Q}\,X\}$$

$$x_2 = \frac{2\,m_Q\,e^{-y}}{\sqrt{s}}$$

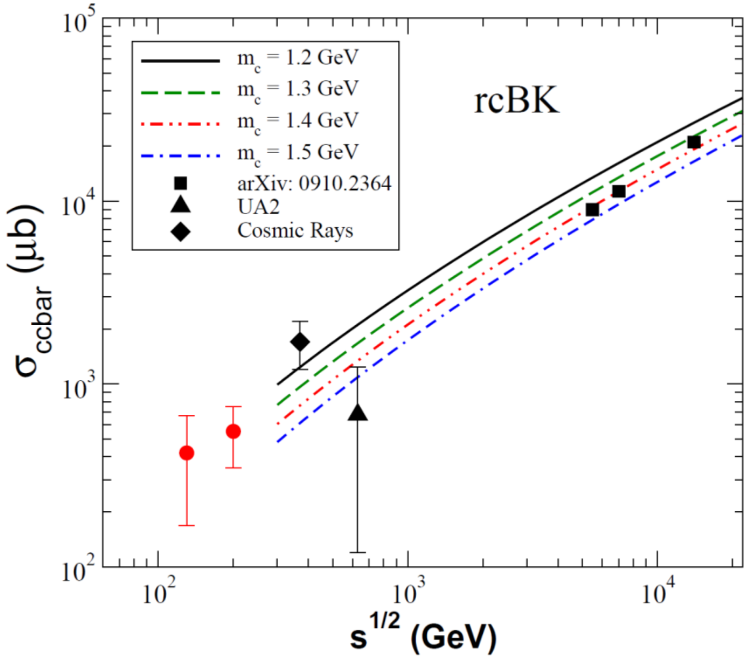
$G(x_1) =$ GRV 98 $\qquad \mu^2 = m_c^2$

$$y = \frac{1}{2}\ln\left(\frac{x_1}{x_2}\right)$$

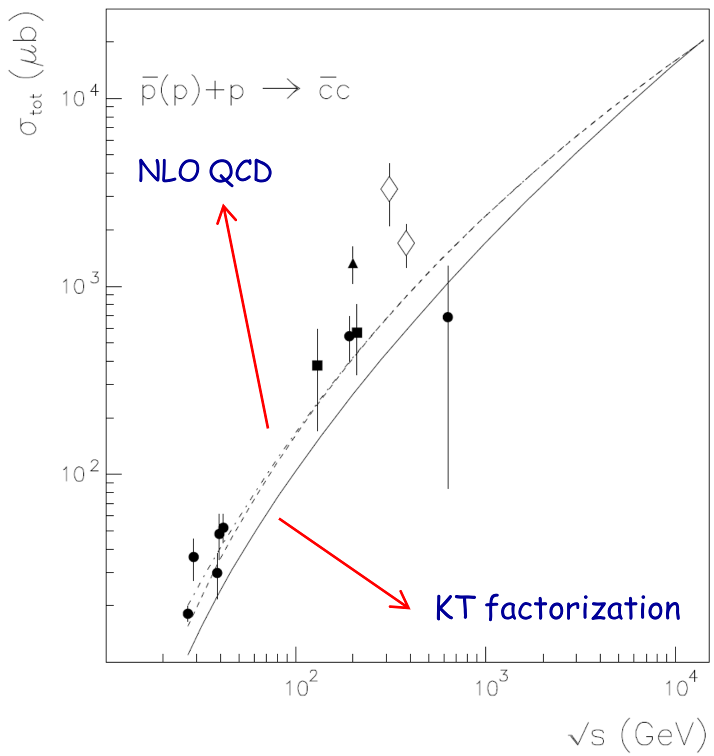
pp



C-Rays
nucl-ex/0607015



Cazaroto,
Gonçalves,
Navarra
in progress



Merino, Pajares, Ryzhinskiy,
Shabelski, Shuvaev,
arXiv:0910.2364

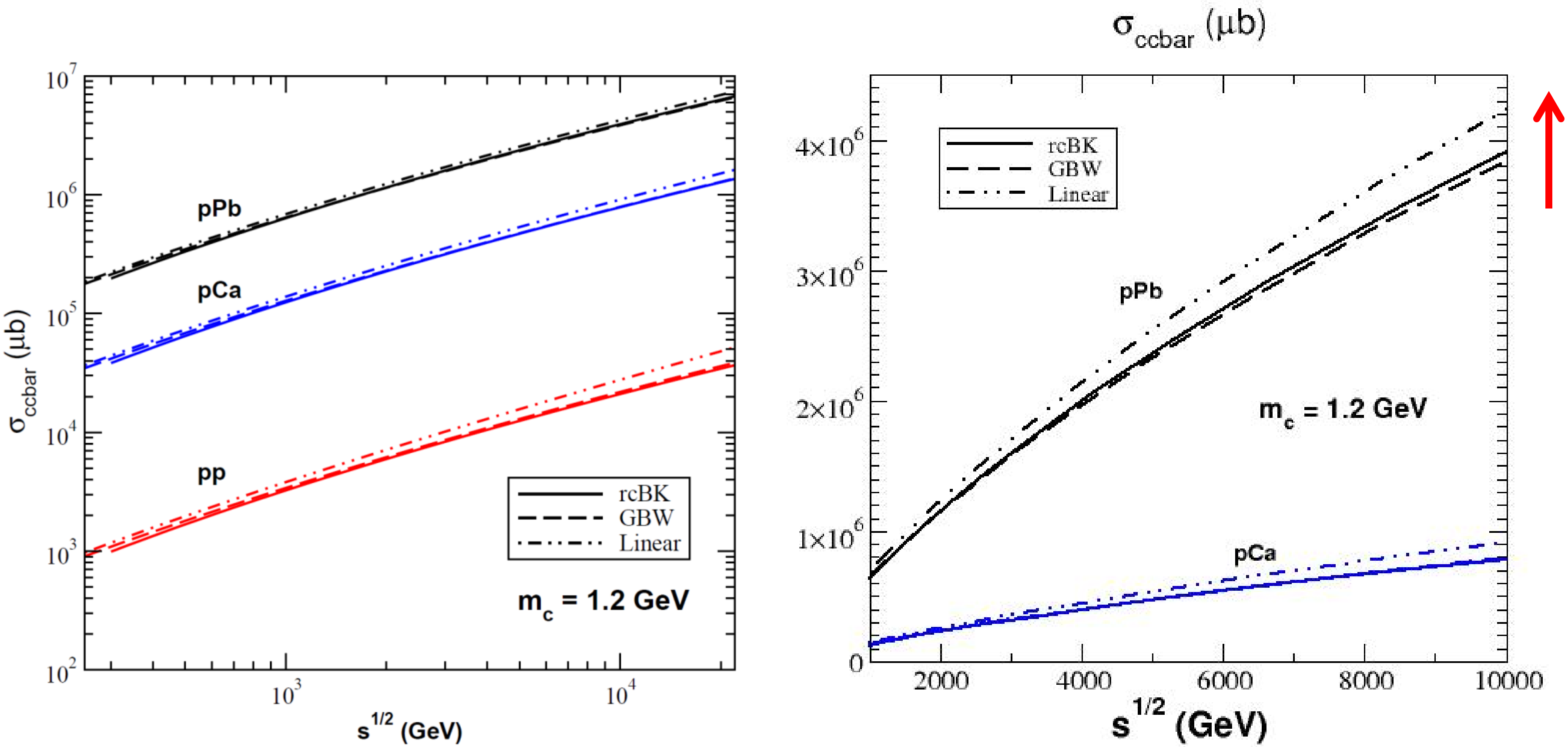
pA

Total cross section

linear p

$$\sigma_{dA} = 2\pi \int_0^{R_A} d\,b\,b\,[\,2\,(\,1 - \exp\,[\,-\frac{1}{2}\sigma_{dp}\,T_A(b)\,]\,)\,]$$

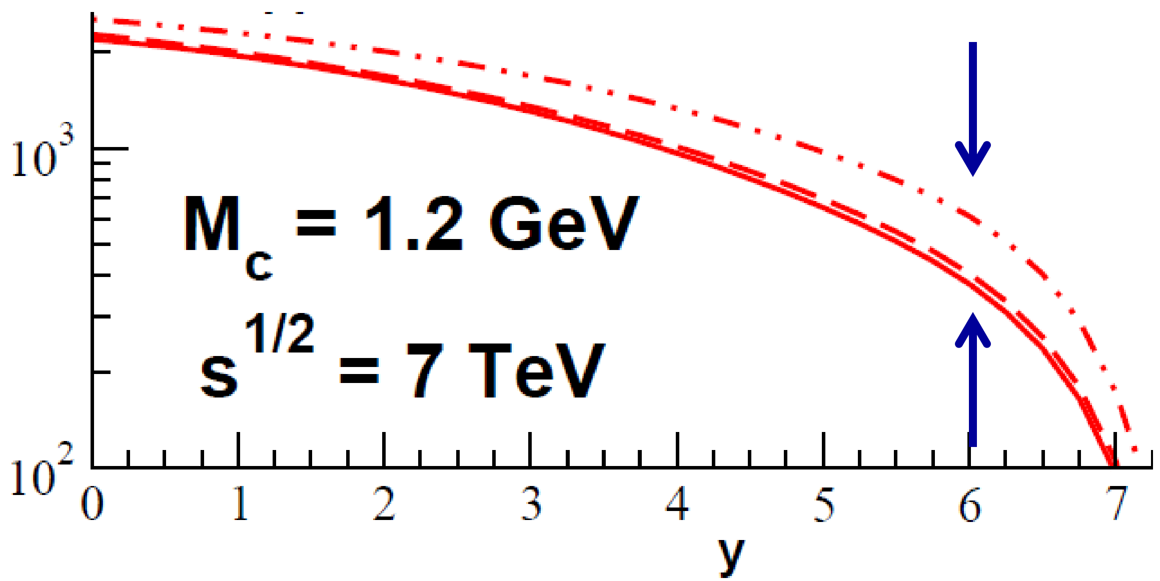
$$\sigma_{dp} = \frac{\sigma_0}{4} Q_s^2 \rho^2$$



Saturation: reduction by 10 % with x going down to $x_2 = 10^{-6}$

Rapidity distribution

$$\frac{d\,\sigma\{p\;p \to Q\bar{Q}\;X\}}{d\;y}$$



Saturation: reduction by 1.7 at y = 6

Summary

Well established dipole model for charm production in ep, eA, pp and pA

Different ways to estimate the linear predictions in eA and pA:

- CT (overestimates linear regime)
- CT+Shad
- Linear p (underestimates linear regime)

F2c: almost no suppression with (linear-p)

F2c: large suppression factors (3 – 4) with (CT , CT+Shad)

Rc: no sign of saturation

F2c: large suppression factors (2) in other approaches

eA @ 1TeV: large suppression factors (1.5 – 8) in dN/d pt (CT , CT+Shad)

Dipole models reproduce well the data on $\sigma\,(p+p \rightarrow Q\,\overline{Q} + X)$

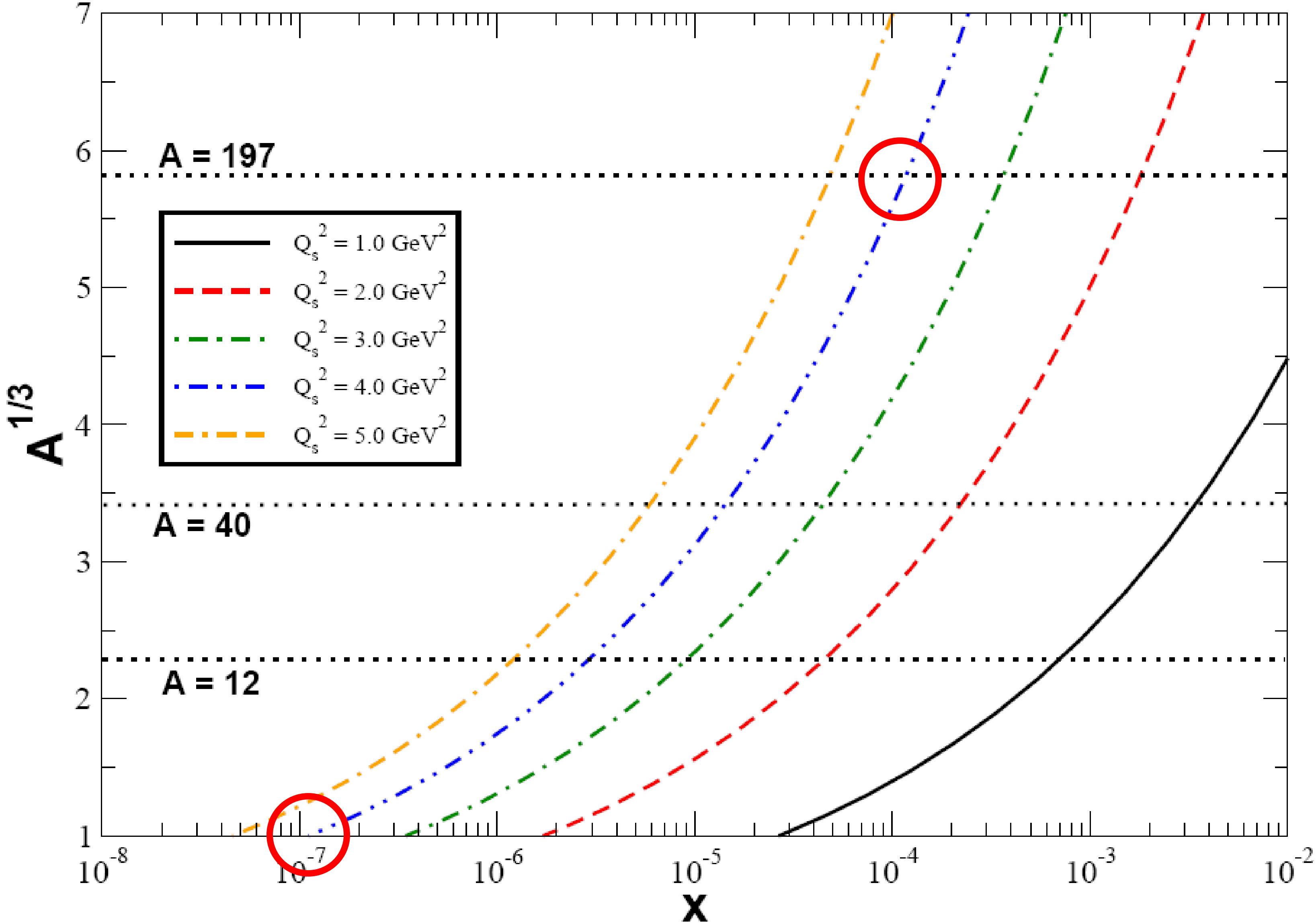
pA @ 10 TeV: reduction by 10 % (or 1.1) in the total cross section (linear-p)

pA @ 10 TeV: reduction by 1.7 in dN/dy at large y (linear-p)

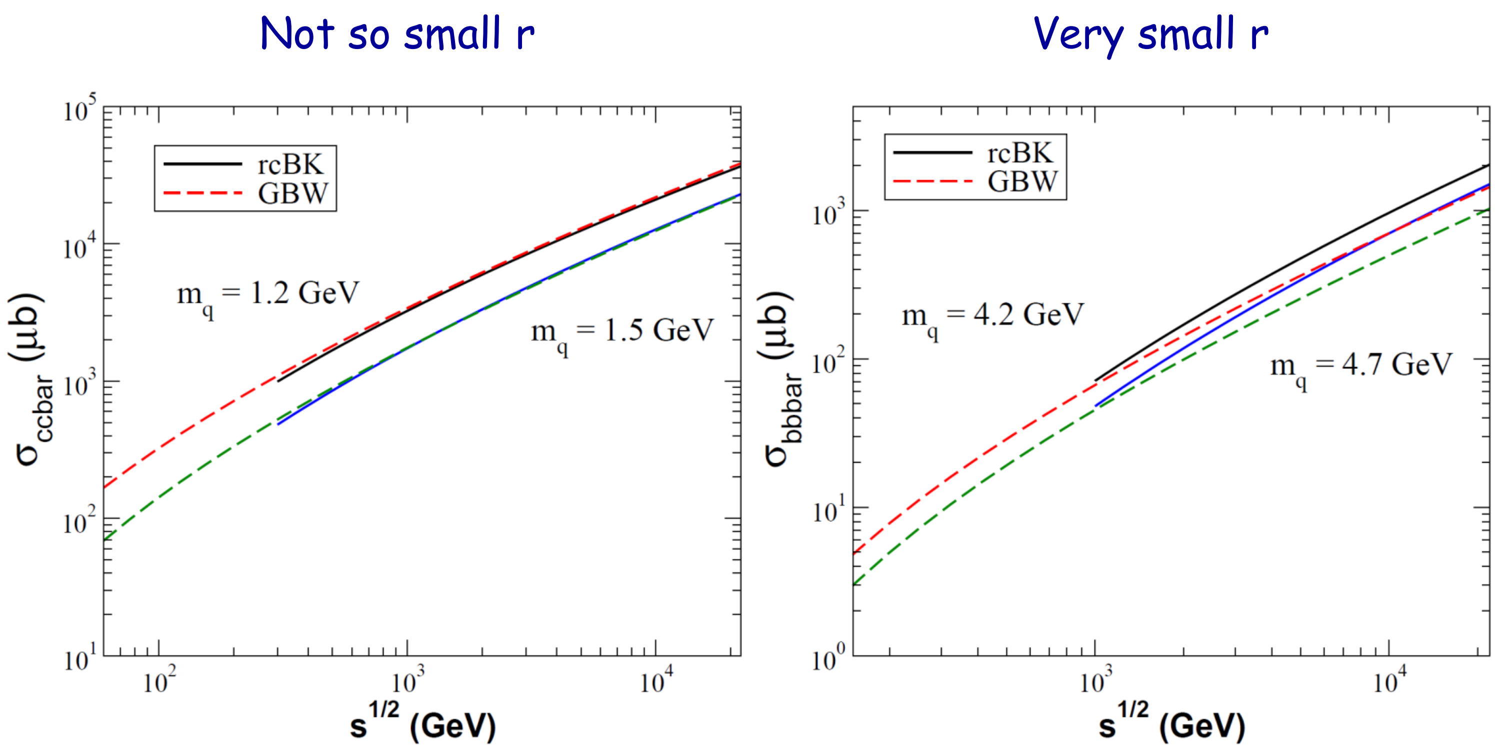
$$Q_s^2 = A^{1/3} Q_0^2 \left(\frac{x_0}{x} \right)^{\lambda}$$

$Q_0^2 = 1.0 \quad GeV^2$ $\qquad \lambda = 0.253$

$x_0 = 0.267 \times 10^{-4}$



pp



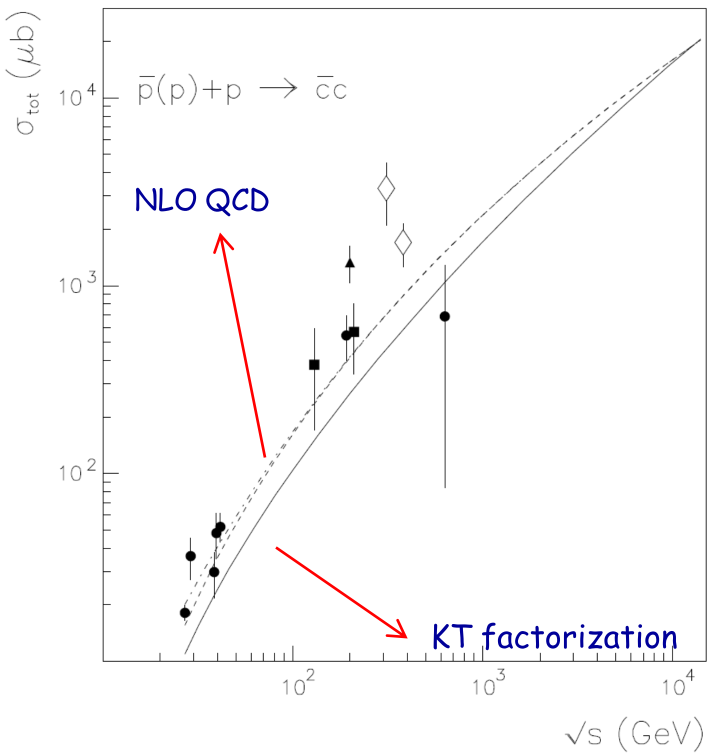
GBW $N(x,r) = 1 - \exp\{-\frac{1}{4}(r^2 Q_s^2)\}$ $\xrightarrow{r \to 0}$ $N(x,r) \cong \frac{1}{4}(r^2 Q_s^2)$

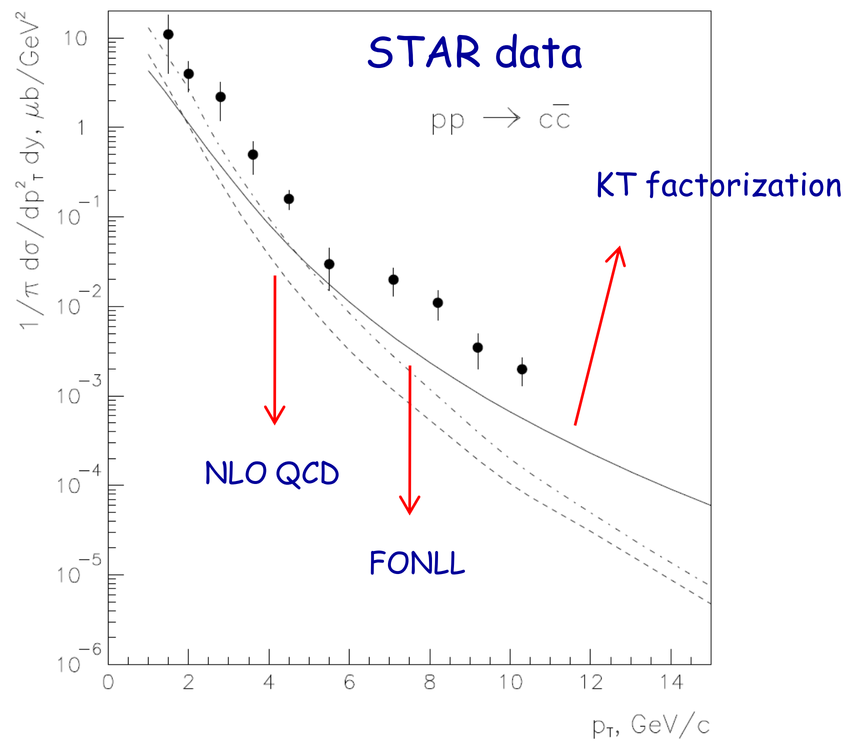
rcBK (?) $N(x,r) = 1 - \exp\{-\frac{1}{4}(r^2 Q_s^2)^{\gamma}\}$ $\longrightarrow$ $N(x,r) \cong \frac{1}{4}(r^2 Q_s^2)^{\gamma}$

Discussion

On charm production in pp and AA :

Merino,Pajares,Ryzhinskiy,
Shabelski,Shuvaev,
arXiv:0910.2364

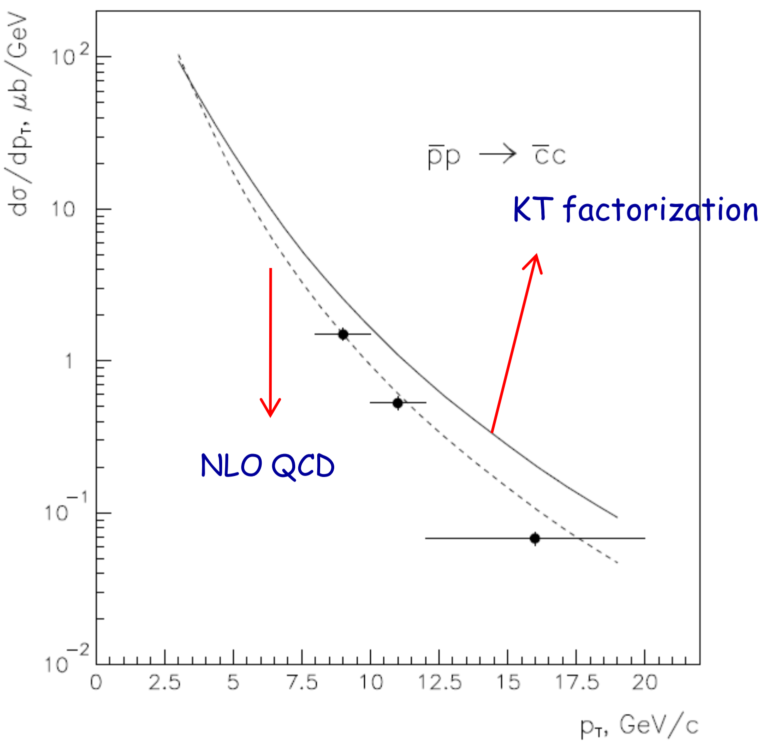


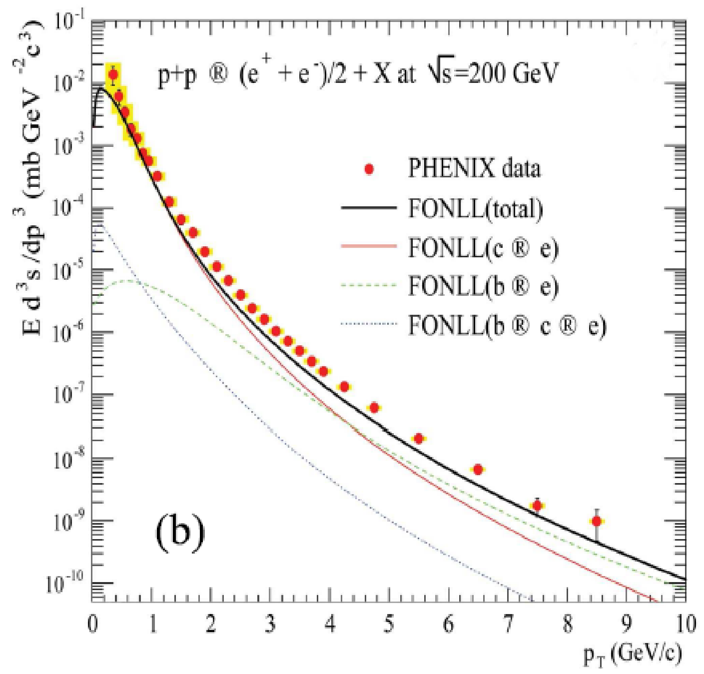


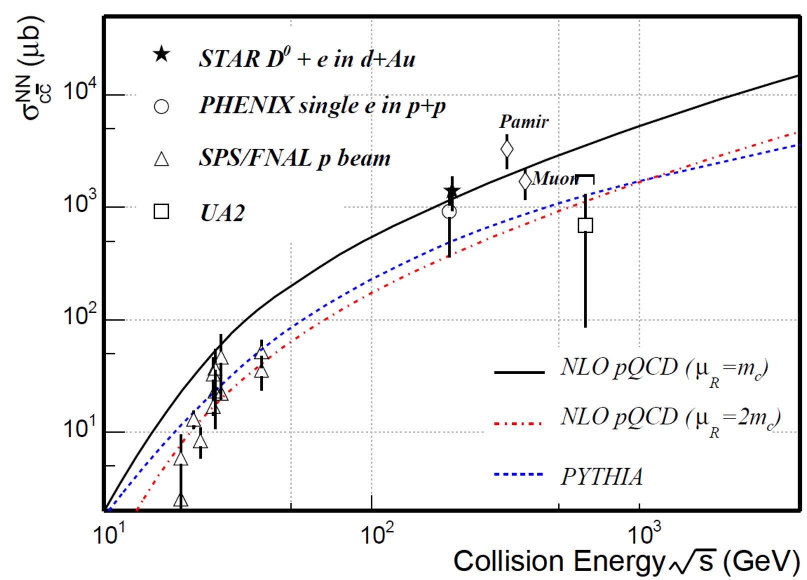
Will we have data on total cross section from Tevatron?

Disagreement between PHENIX and STAR is gone ?

Tevatron data





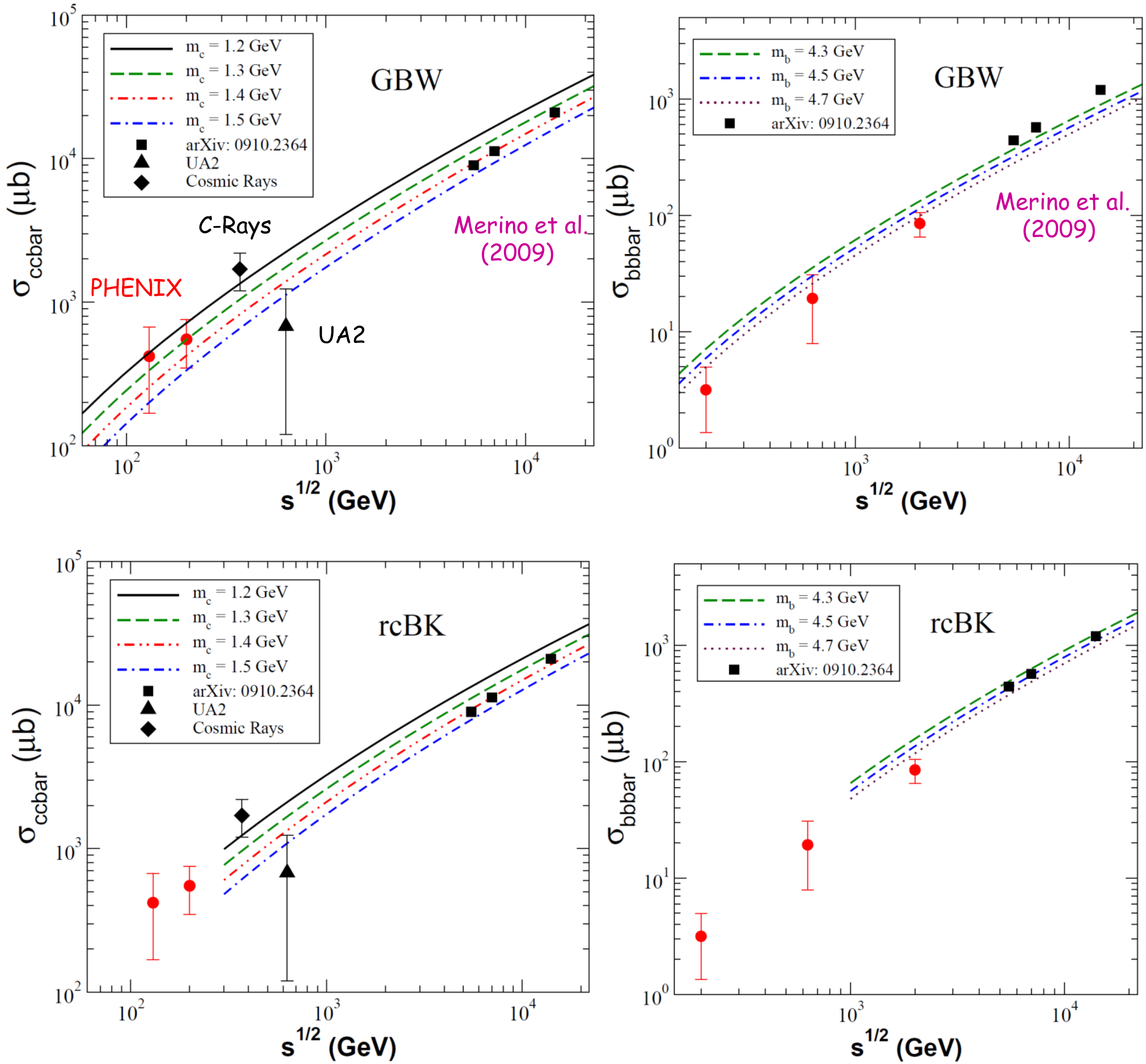


Fragmentation ?

If STAR was right enhanced production might have non-pert. origin: strong fields

Should we prefer KT factorization?

pp



Cazaroto,
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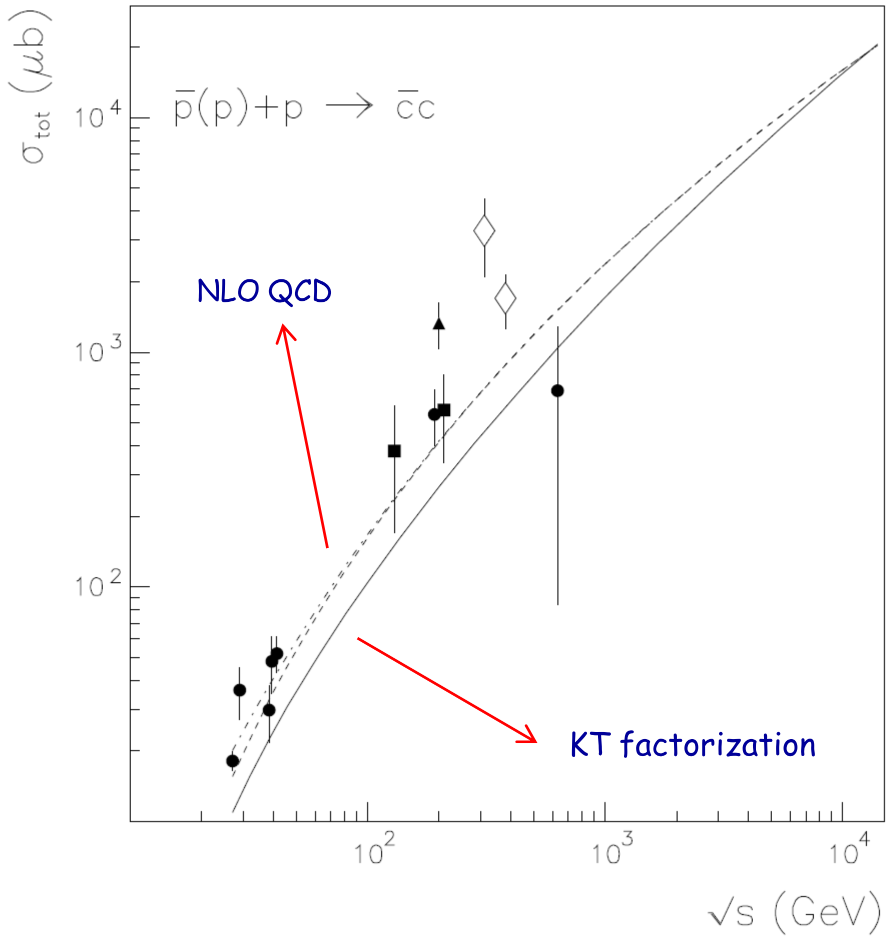
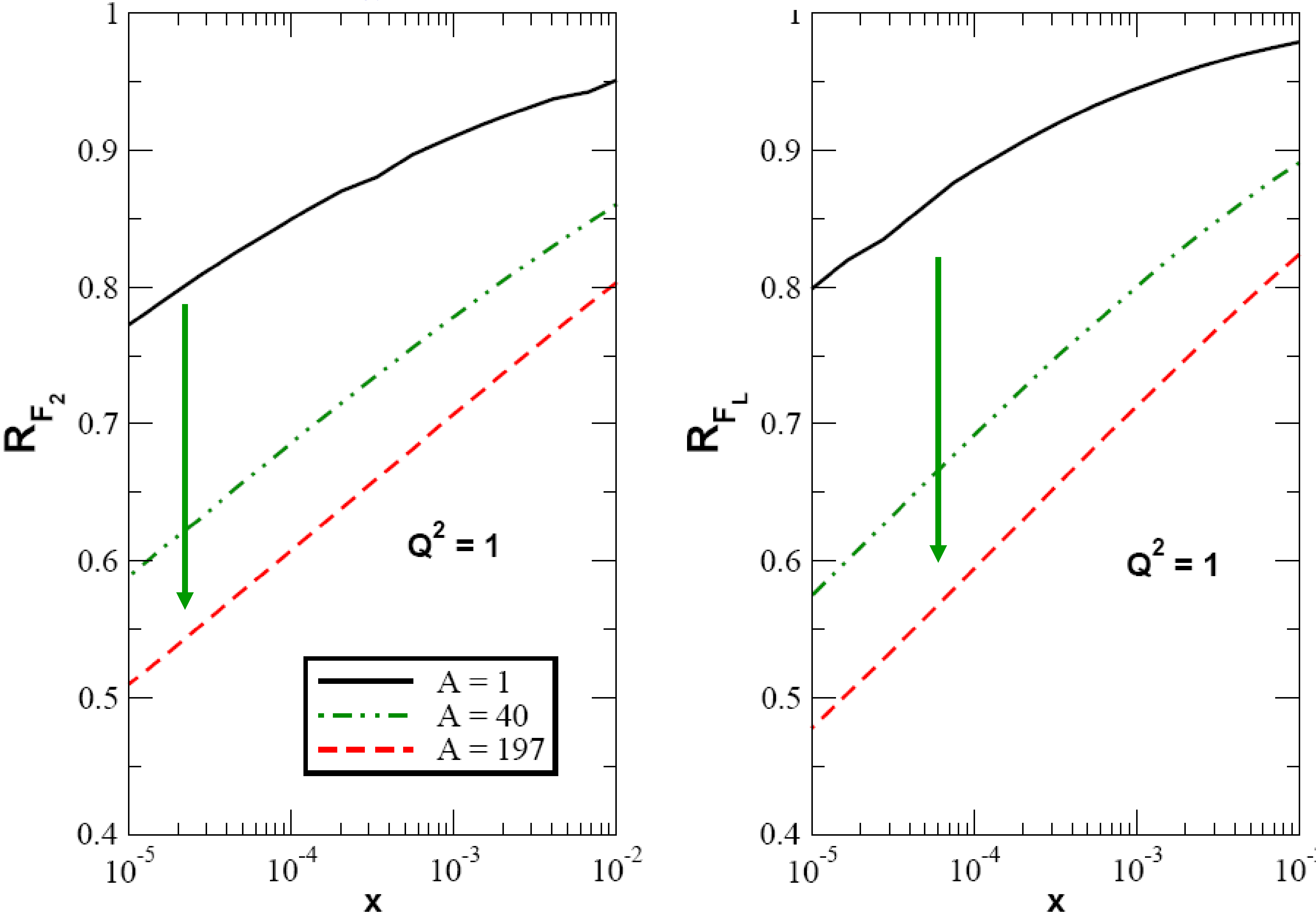
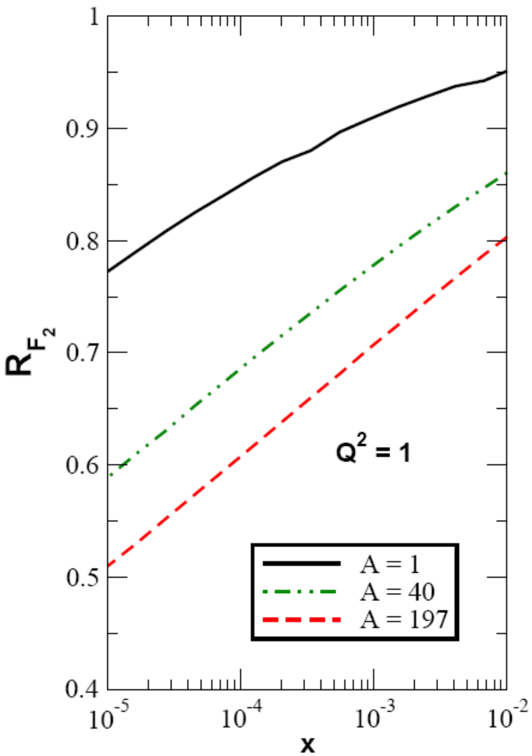


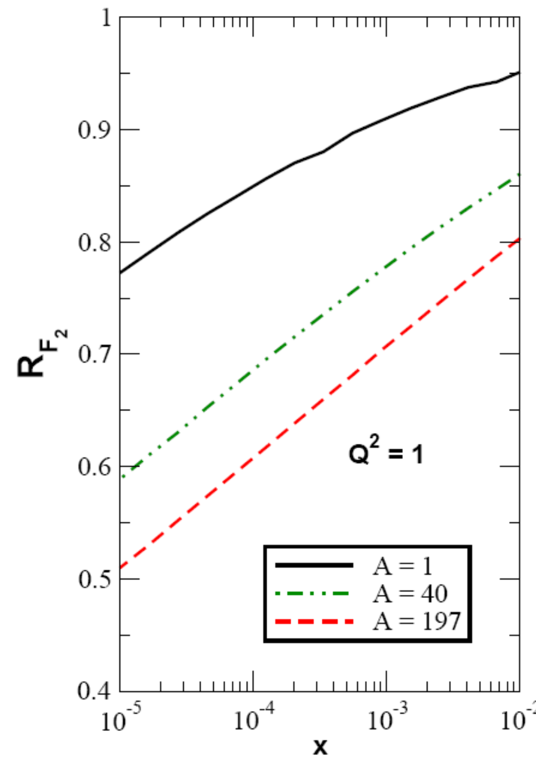
Merino,Pajares,Ryzhinskiy,
Shabelski,Shuvaev,
arXiv:0910.2364

F_2 R = full / linear





1
0.9
0.8
0.7
0.6
0.5
0.4
R_{F_2}
$Q^2 = 1$
A = 1
A = 40
A = 197
10^{-5}
10^{-4}
10^{-3}
10^{-2}
x



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R_{F_2}
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A = 1
A = 40
A = 197
10^{-5}
10^{-4}
10^{-3}
10^{-2}
x

Charm structure function in the KLN model

$$\frac{1}{x} F_2^c(x, Q^2, m_c) = e_c^2 \frac{\alpha_s(\mu^2)}{2\pi} \int_{ax}^{1} \frac{dy}{y} C(\frac{x}{y}, \xi)\, g(x, \mu^2)$$

Glück, Reya, Stratmann (1994)

Glück, Reya, Vogt (1995)

$C(z, \xi) =$ Coefficient function from pQCD

$$a = 1 + \frac{m_c^2}{Q^2} \qquad \mu^2 = 4 m_c^2 \qquad \mu^2 = 4 m_c^2 + Q^2 \qquad m_c = 1.2\ GeV$$

$$x\, g(x, \mu^2) = \begin{cases} \frac{\kappa_0}{\alpha_s(Q_s^2)} S\, Q^2\, (1-x)^4 & Q^2 < Q_s^2 \quad \text{saturation} \\ \frac{\kappa_0}{\alpha_s(Q_s^2)} S\, Q_s^2\, (1-x)^4 & Q^2 > Q_s^2 \quad \text{linear} \end{cases}$$

$$Q_s^2 = Q_0^2 \left(\frac{x_0}{x}\right)^{\lambda} \qquad S = \pi R^2$$

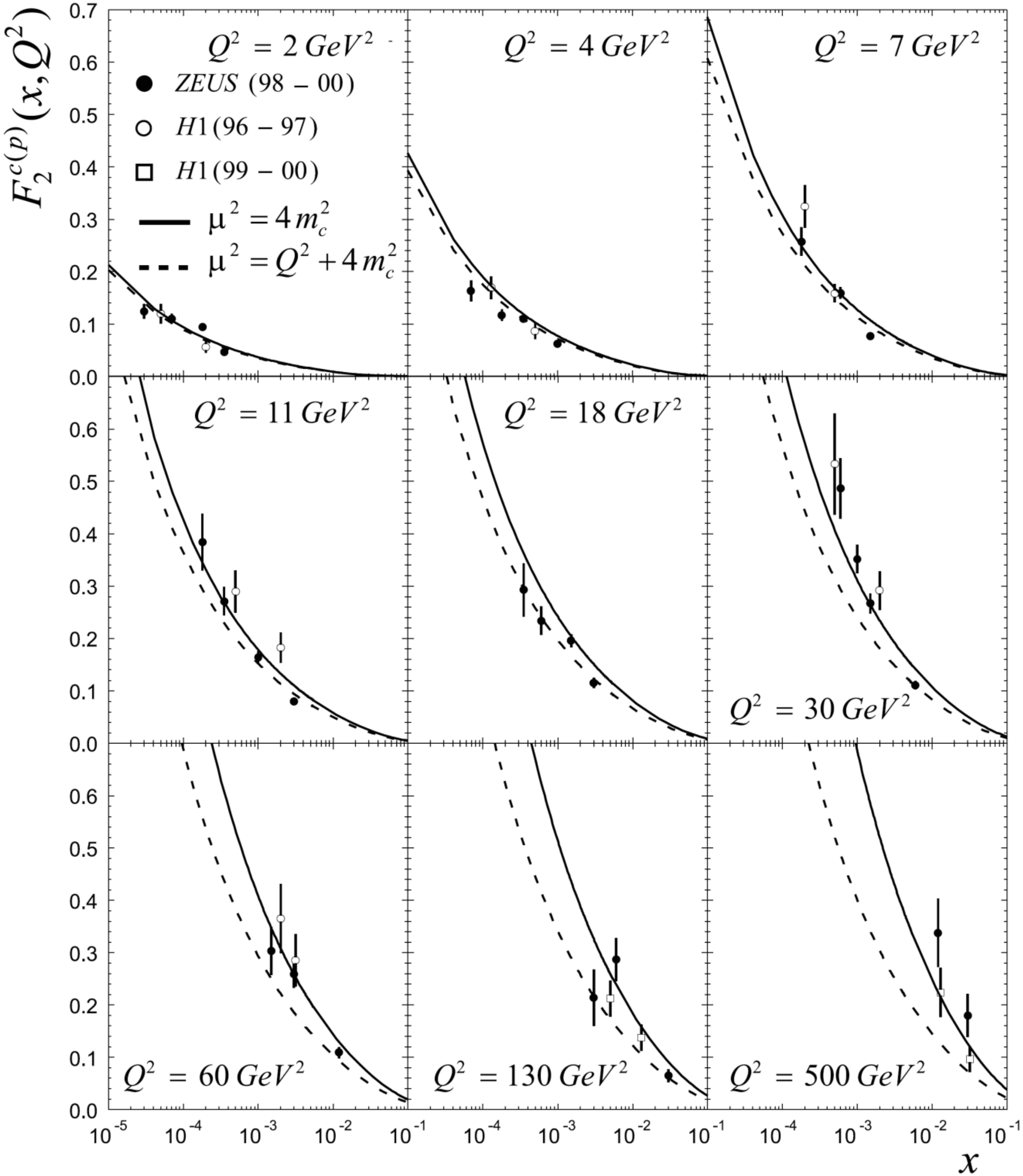
Kharzeev, Levin, Nardi (2001)

ep

$Q_0^2 = 0.34 \quad GeV^2$

$x_0 = 3 \times 10^{-3}$

$\lambda = 0.25$

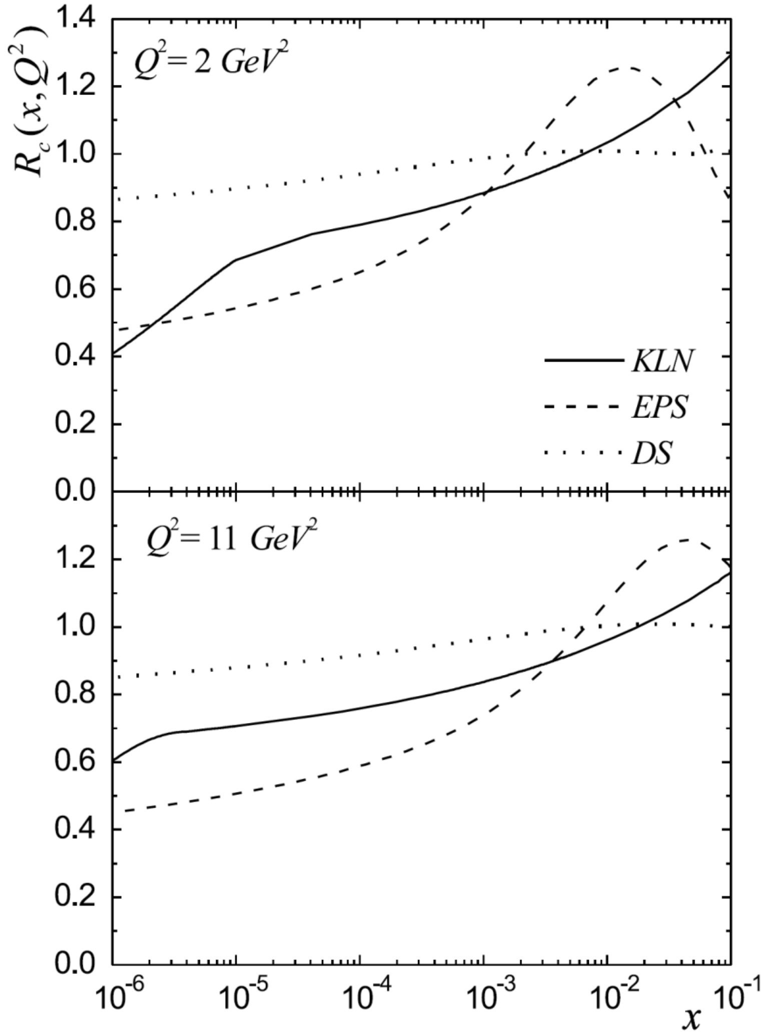


Carvalho, Durães
Navarra, Szpigel
(2009)

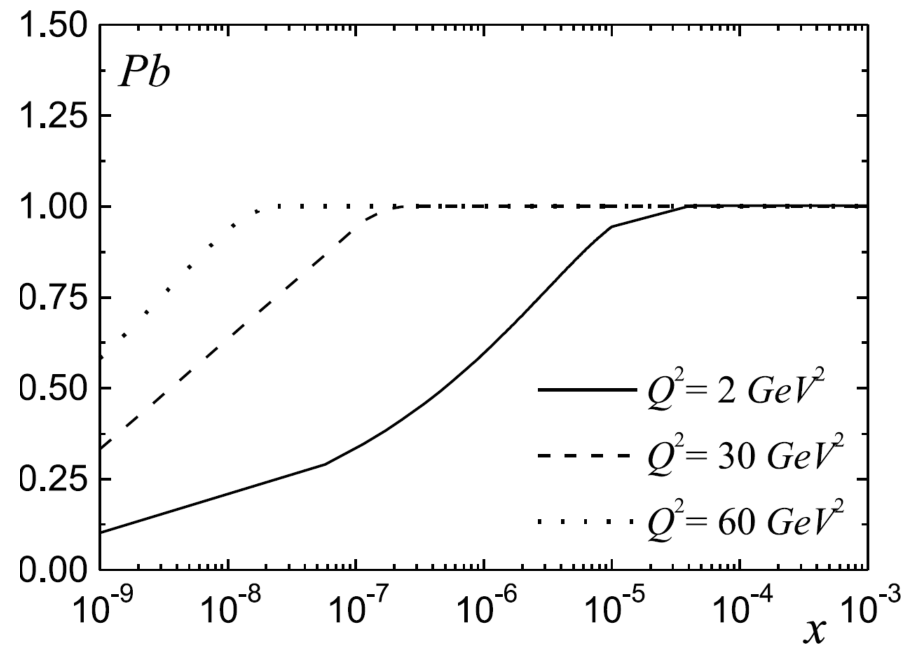
eA

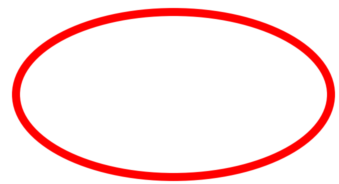
$$R_c = \frac{F_2^{cA}}{A\,F_2^{cp}}$$

$$\begin{cases} g(x,\mu^2) \to g^A(x,\mu^2) \\ S \to S^A = A^{2/3}\,S \\ Q_s^2 \to Q_s^{2A} = A^{1/3}\,Q_s^2 \end{cases}$$



$$R_{FL} = \frac{full}{linear}$$





Charm production in pA collisions

Kopeliovich, Tarasov (2002)

$$\sigma(GN \to \{Q\bar{Q}\}X) = \int_0^1 d\alpha \int d^2\rho \, |\Psi_{G\to Q\bar{Q}}(\alpha,\rho)|^2 \; \sigma_{q\bar{q}G}(\alpha,\rho)$$

$$\sigma_{q\bar{q}G}(\alpha,\rho) = \frac{9}{8}[\sigma_{q\bar{q}}(\alpha\rho) + \sigma_{q\bar{q}}(\bar{\alpha}\rho)] - \frac{1}{8}\sigma_{q\bar{q}}(\rho)$$

$$|\Psi_{G\to Q\bar{Q}}(\alpha,\rho)|^2 = \frac{\alpha_S(\mu_R)}{(2\pi)^2}\{m_Q^2 K_0(m_Q\rho_1)K_0(m_Q\rho_2) + [\alpha^2 + \bar{\alpha}^2]m_Q^2 \frac{\vec{\rho}_1 . \vec{\rho}_2}{\rho_1\rho_2} K_1(m_Q\rho_1)K_1(m_Q\rho_2)\}$$

$$\frac{d\sigma(pp \to \{Q\bar{Q}\}X)}{dy} = x_1 G(x_1,\mu_F^2)\,\sigma(GN \to \{Q\bar{Q}\}X)$$

$$\sigma_{tot}(pp \to \{Q\bar{Q}\}X) = 2\int_0^{-ln(2m_Q/\sqrt{s})} dy x_1\, G(x_1,\mu_F)\,\sigma(GN \to \{Q\bar{Q}\}X)$$

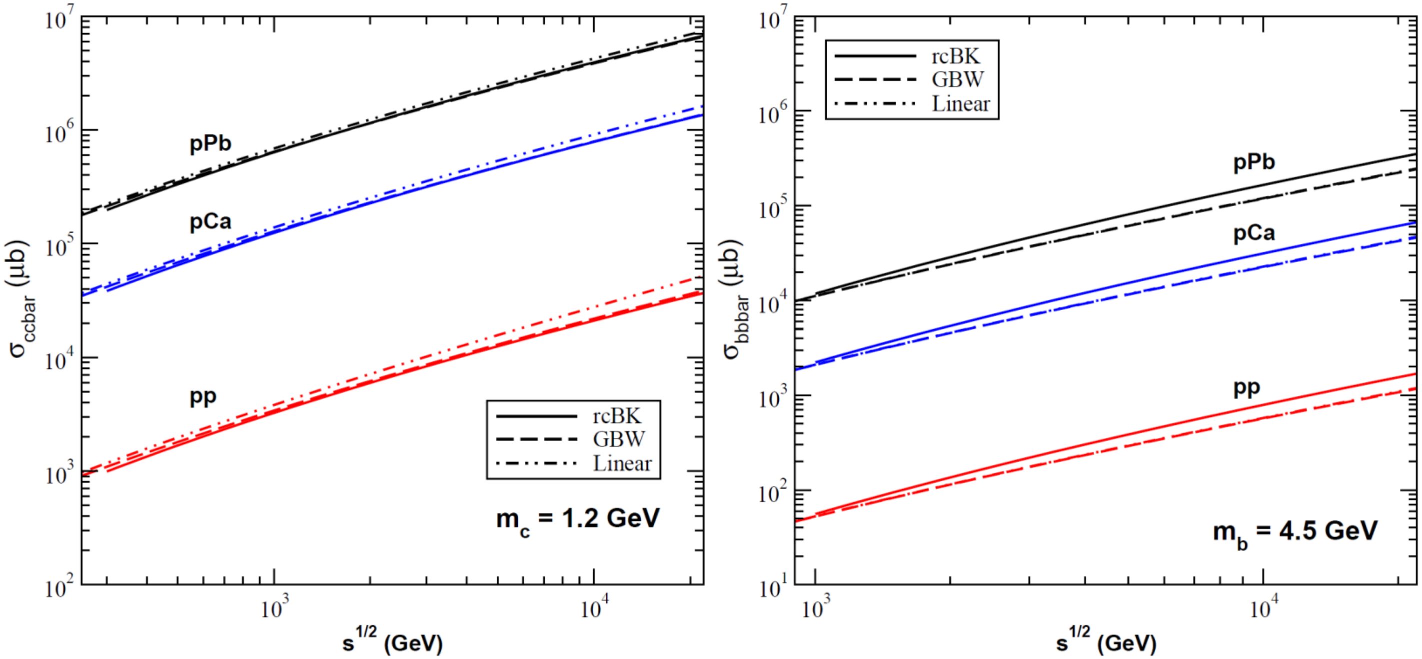
$$x_1 = \frac{2m_Q\, e^{y}}{\sqrt{s}}$$

$$x_2 = \frac{2m_Q\, e^{-y}}{\sqrt{s}}$$

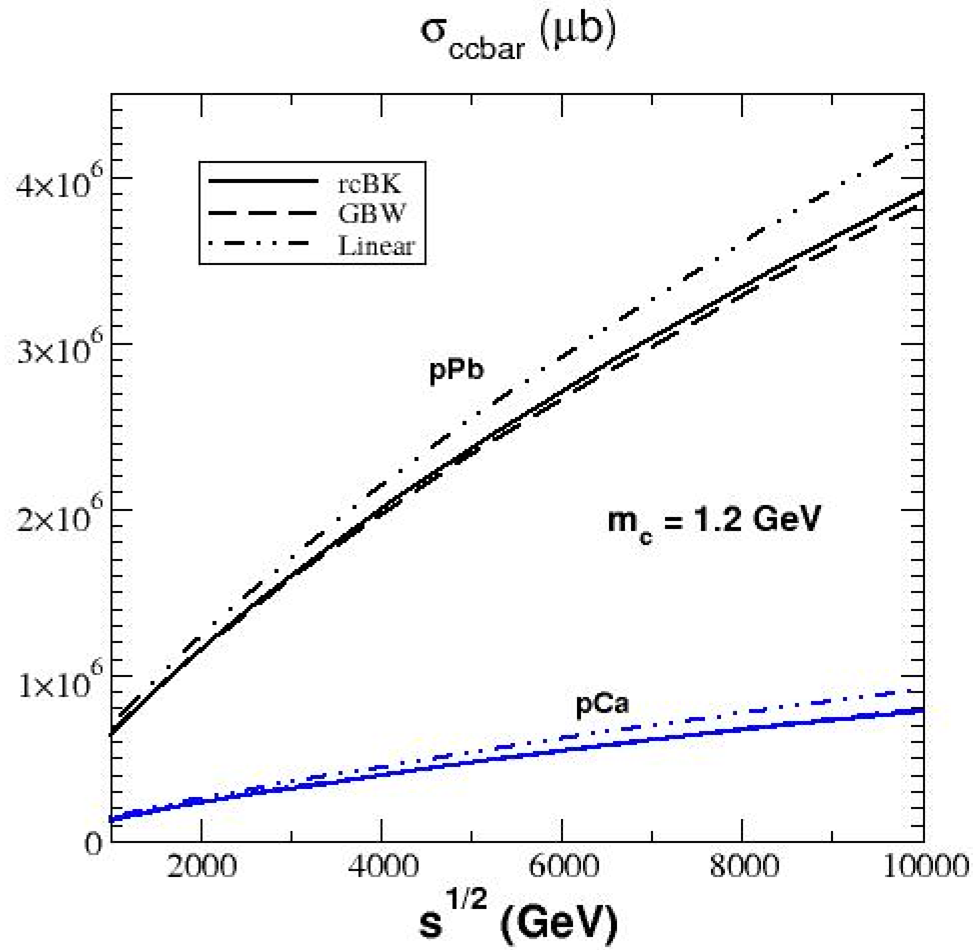
$$y = 1/2\, ln(x_1/x_2)$$

$$\sigma_{q\bar{q}-A} = 2\pi \int_0^{R_A} dbb\left[2\left(1 - e^{-\frac{1}{2}\sigma_{q\bar{q}}T_A(b)}\right)\right]$$

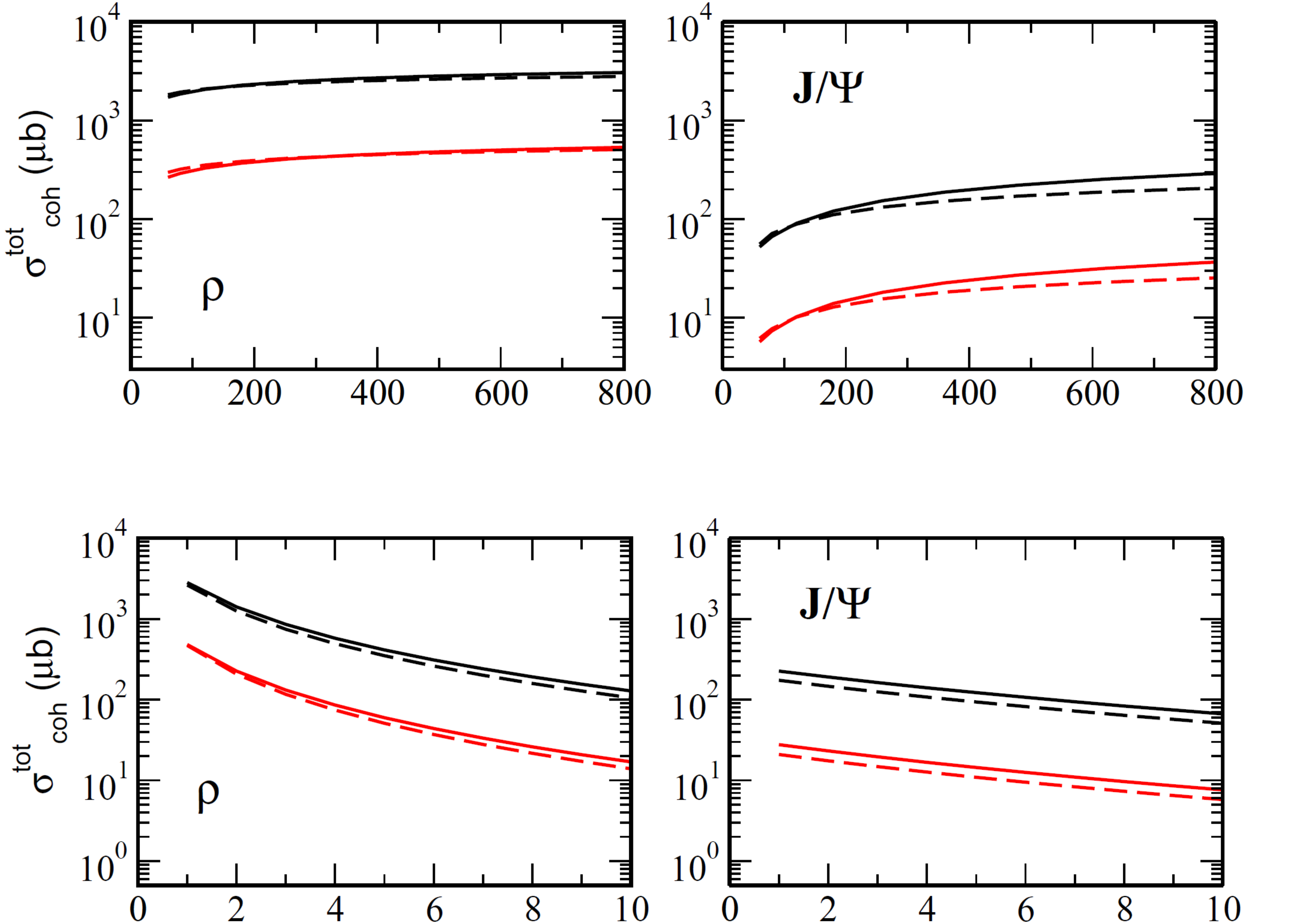
Back ups



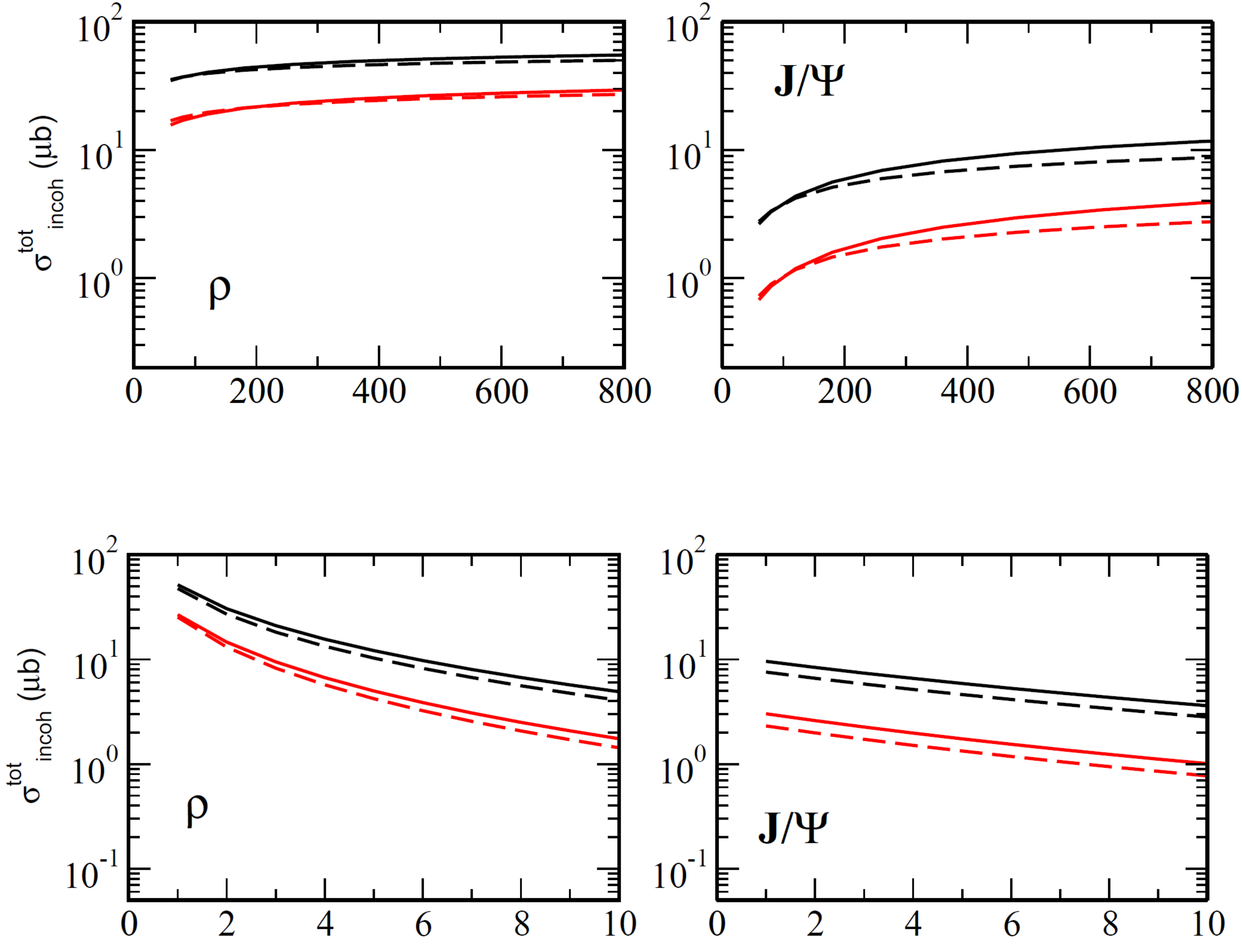
10^7
10^6
10^5
10^4
10^3
10^2
σ_{ccbar} (μb)
pPb
pCa
pp
rcBK
GBW
Linear
m_c = 1.2 GeV
10^3
10^4
$s^{1/2}$ (GeV)
10^7
10^6
10^5
10^4
10^3
10^2
10^1
σ_{bbbar} (μb)
rcBK
GBW
Linear
pPb
pCa
pp
m_b = 4.5 GeV
10^3
10^4
$s^{1/2}$ (GeV)



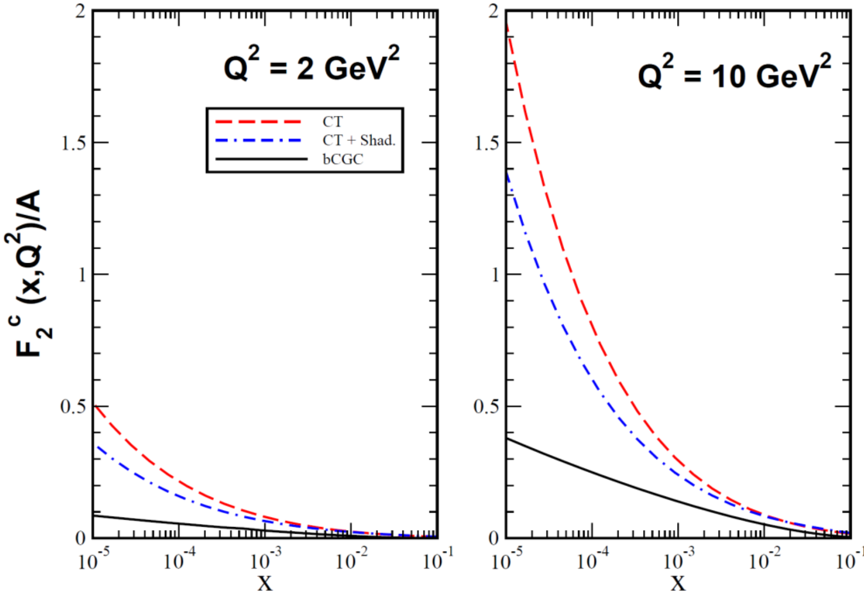
σ ccbar (μb)
rcBK
GBW
Linear
pPb
pCa
m c = 1.2 GeV
4×10^6
3×10^6
2×10^6
1×10^6
0
2000
4000
6000
8000
10000
s^1/2 (GeV)



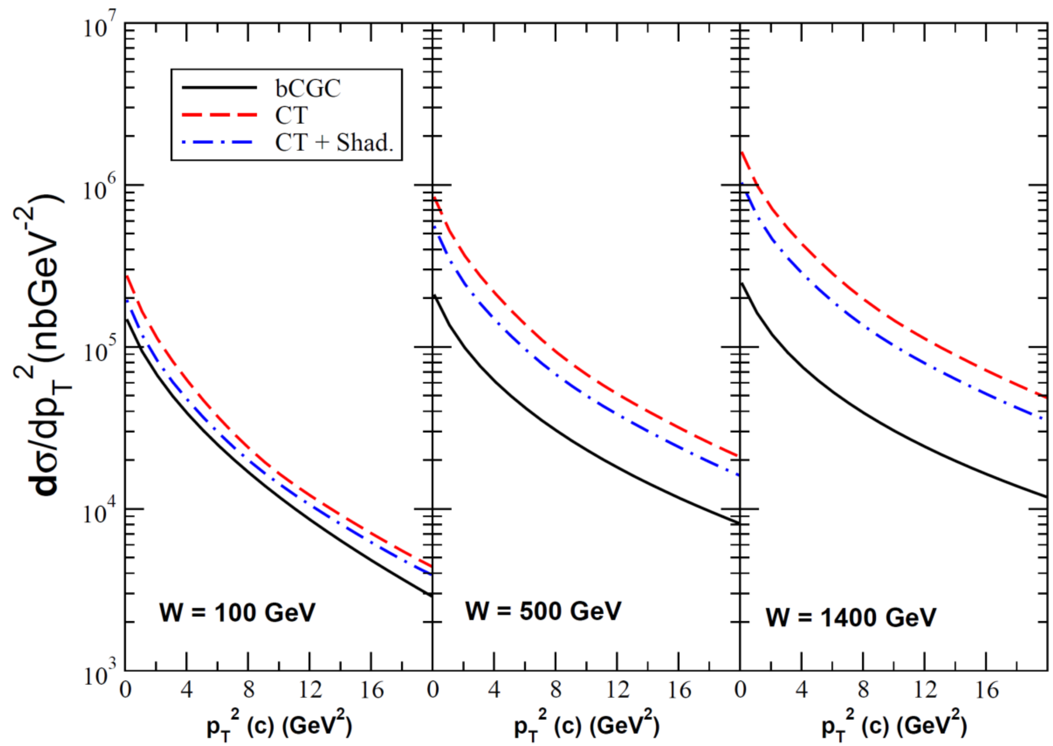
σ^{tot}_{coh} (μb)
ρ
J/Ψ
ρ
J/Ψ
10^0
10^1
10^2
10^3
10^4
0
200
400
600
800
2
4
6
8
10



σ^{tot}_{incoh} (μb)
ρ
J/Ψ
10^2
10^1
10^0
10^{-1}
0
200
400
600
800
2
4
6
8
10



$Q^2 = 2\ GeV^2$
$Q^2 = 10\ GeV^2$
CT
CT + Shad.
bCGC
$F_2^c(x,Q^2)/A$
x



bCGC
CT
CT + Shad.
$d\sigma/dp_T^2 (nbGeV^{-2})$
W = 100 GeV
W = 500 GeV
W = 1400 GeV
p_T^2 (c) (GeV^2)
p_T^2 (c) (GeV^2)
p_T^2 (c) (GeV^2)

Introduction

NLO collinear factorization

[1] P. Nason, S. Dawson and R. K. Ellis, Nucl. Phys. B **303**, 607 (1988).
[2] G. Altarelli, M. Diemoz, G. Martinelli and P. Nason, Nucl. Phys. B **308**, 724 (1988).
[3] P. Nason, S. Dawson and R. K. Ellis, Nucl. Phys. B **327**, 49 (1989) [Erratum-ibid. B **335**, 260 (1990)].
[4] W. Beenakker, H. Kuijf, W. L. van Neerven and J. Smith, Phys. Rev. D **40**, 54 (1989).

Fixed Order plus Next to Leading Log (FONLL)

[5] M. Cacciari, M. Greco and P. Nason, JHEP **9805**, 007 (1998) [arXiv:hep-ph/9803400].

KT factorization

[6] S. Catani, M. Ciafaloni and F. Hautmann, Phys. Lett. B **242**, 97 (1990).
[7] S. Catani, M. Ciafaloni and F. Hautmann, Nucl. Phys. B **366**, 135 (1991).
[8] J. C. Collins and R. K. Ellis, Nucl. Phys. B **360**, 3 (1991).
[9] G. Marchesini and B. R. Webber, Nucl. Phys. B **310**, 461 (1988).

[10] G. Marchesini and B. R. Webber, Nucl. Phys. B **386**, 215 (1992).
[11] P. Hagler, R. Kirschner, A. Schafer, L. Szymanowski and O. Teryaev, Phys. Rev. D **62**, 071502 (2000) [arXiv:hep-ph/0002077].
[12] L. V. Gribov, E. M. Levin and M. G. Ryskin, Phys. Rept. **100**, 1 (1983).
[13] E. M. Levin and M. G. Ryskin, Phys. Rept. **189**, 267 (1990).
[14] E. M. Levin, M. G. Ryskin, Yu. M. Shabelski and A. G. Shuvaev, Sov. J. Nucl. Phys. **53**, 657 (1991) [Yad. Fiz. **53**, 1059 (1991)].
[15] E. M. Levin, M. G. Ryskin, Yu. M. Shabelski and A. G. Shuvaev, Sov. J. Nucl. Phys. **54**, 867 (1991) [Yad. Fiz. **54**, 1420 (1991)].
[16] Yu. M. Shabelski, Surveys High Energ. Phys. **14**, 357 (2000).
[17] M. G. Ryskin, A. G. Shuvaev and Yu. M. Shabelski, Phys. Atom. Nucl. **64**, 120 (2001) [Yad. Fiz. **64**, 123 (2001)] [arXiv:hep-ph/9907507].
[18] M. G. Ryskin, A. G. Shuvaev and Yu. M. Shabelski, Phys. Atom. Nucl. **64**, 1995 (2001) [Yad. Fiz. **64**, 2080 (2001)] [arXiv:hep-ph/0007238].
[19] Yu. M. Shabelski and A. G. Shuvaev, Phys. Atom. Nucl. **69**, 314 (2006) [arXiv:hep-ph/0406157].

Color dipole formalism

[23] J. Raufeisen and J. C. Peng, Phys. Rev. D **67**, 054008 (2003) [arXiv:hep-ph/0211422].

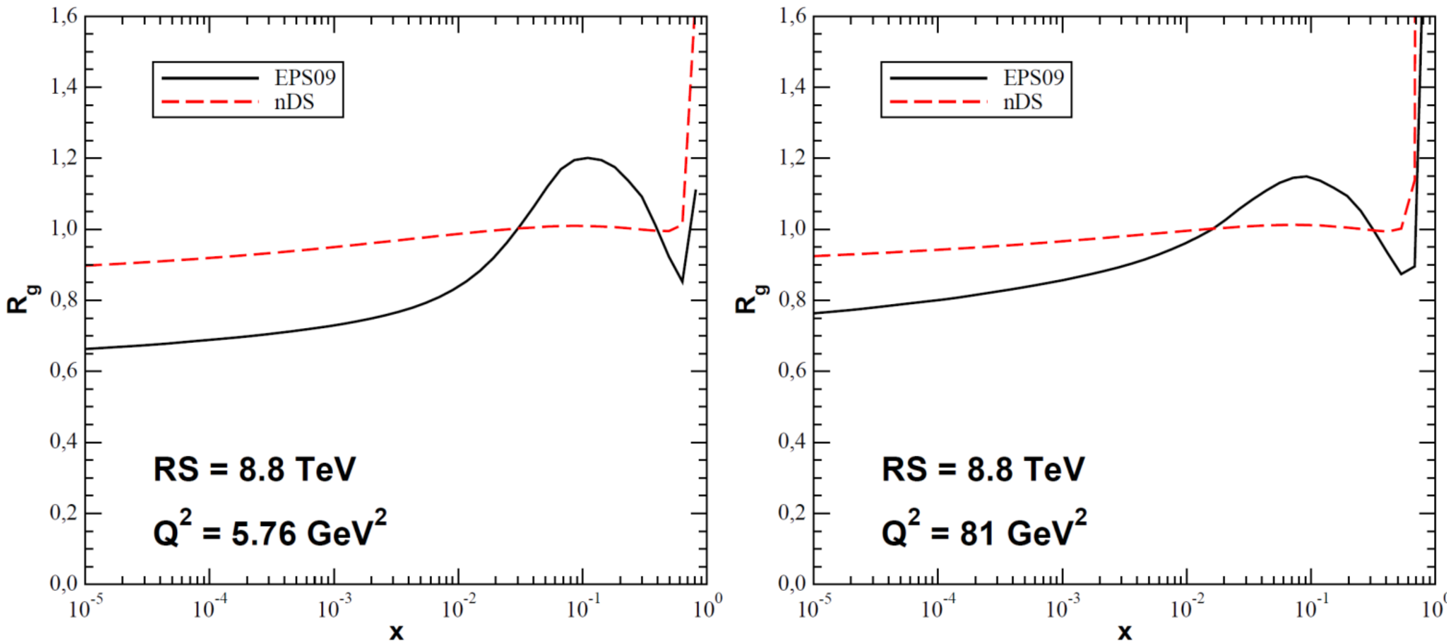
$$F_2^A(x,Q^2) \;=\; \frac{Q^2}{4\pi^2\alpha_{em}}\,\sigma_{tot}(x,Q^2)$$

$$\sigma_{tot} = \sigma_T + \sigma_L \;\; \text{and} \;\; \sigma_{T,L} \;=\; \int d^2\boldsymbol{r}\,dz\,|\Psi_{T,L}(\boldsymbol{r},z,Q^2)|^2\;\sigma_{dA}(x,\boldsymbol{r})$$

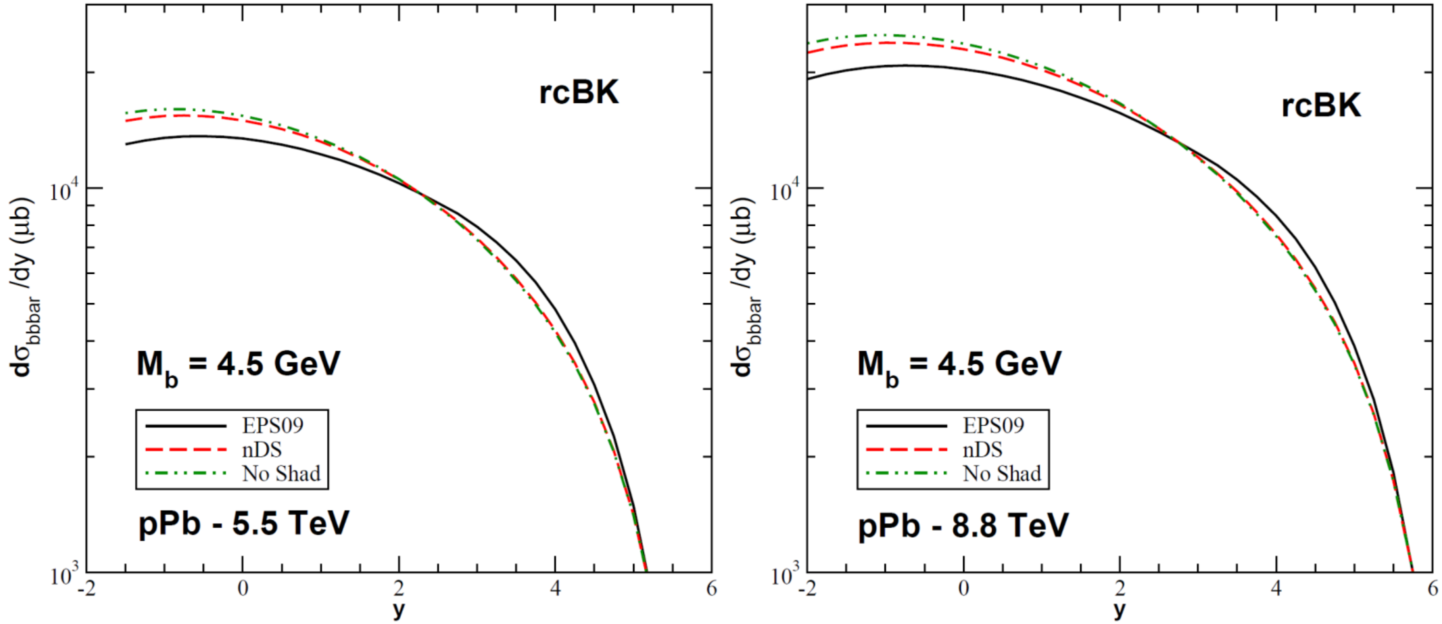
$$D_Q^h(z^*) \;=\; \frac{n(h)}{z^*[1-\frac{1}{z^*}-\frac{\epsilon_Q}{1-z^*}]^2}$$

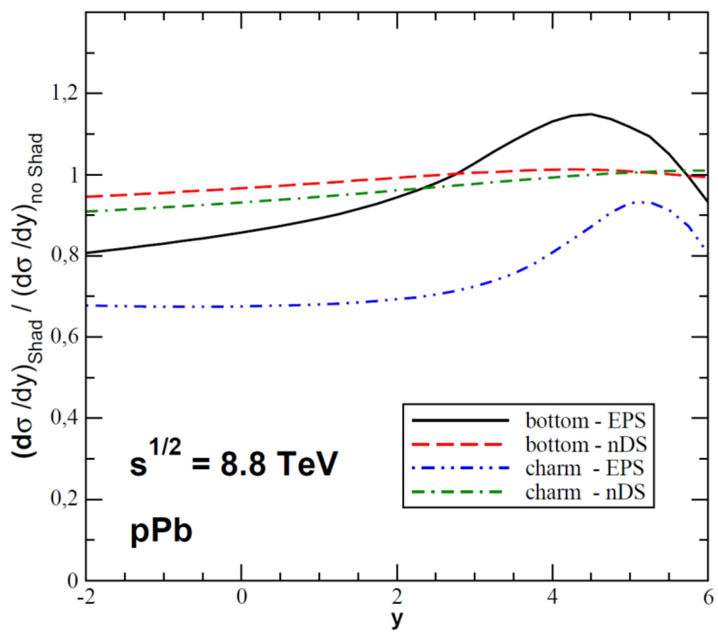
$$\sigma_{dp}^{bCGC}(x,\boldsymbol{r}^2) \equiv \int d^2\bar{\boldsymbol{b}}\,\frac{d\sigma_{dp}}{d^2\bar{\boldsymbol{b}}}$$

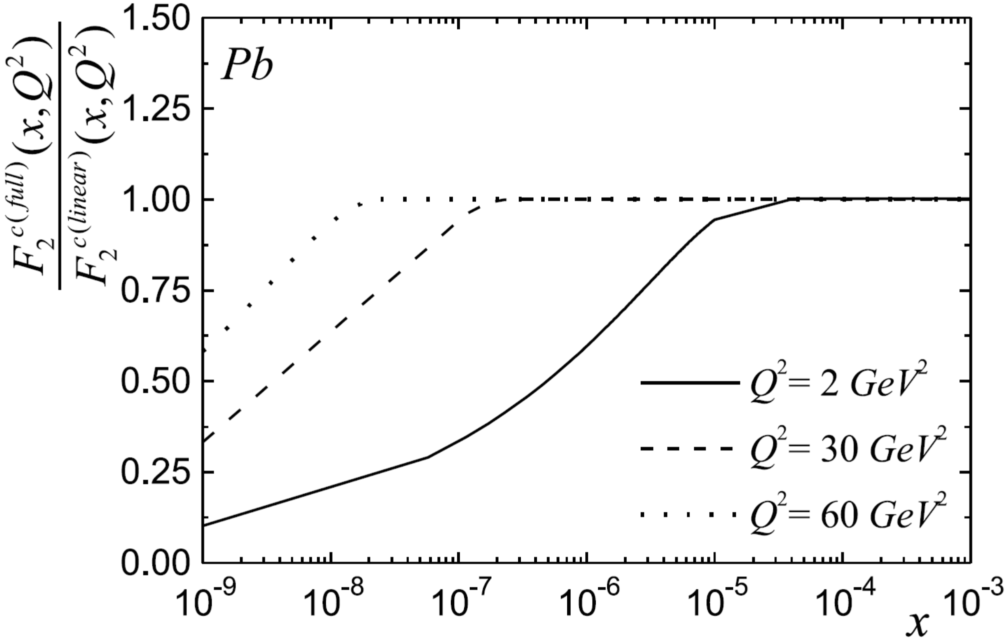
$$\frac{d\sigma_{dp}}{d^2\bar{\boldsymbol{b}}} = 2\,\mathcal{N}^p(x,\boldsymbol{r},\bar{\boldsymbol{b}}) = 2\times\begin{cases}\mathcal{N}_0\,\left(\frac{r\,Q_s}{2}\right)^{2\left(\gamma_s+\frac{\ln(2/rQ_s)}{\kappa\,\lambda\,Y}\right)} & rQ_s\le 2\\ 1-\exp\left[-a\,\ln^2(b\,r\,Q_s)\right] & rQ_s>2\end{cases}$$



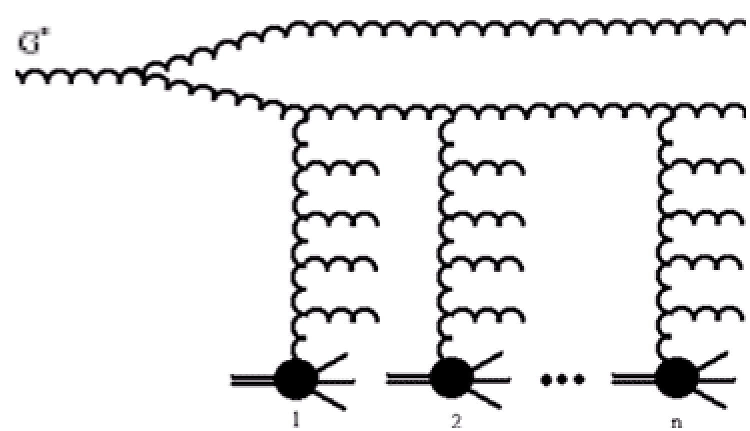
EPS09
nDS
RS = 8.8 TeV
Q2 = 5.76 GeV2
Rg
x
EPS09
nDS
RS = 8.8 TeV
Q2 = 81 GeV2
Rg
x


rcBK
$d\sigma_{bbbar}/dy$ (μb)
M_b = 4.5 GeV
EPS09
nDS
No Shad
pPb - 5.5 TeV
y
rcBK
$d\sigma_{bbbar}/dy$ (μb)
M_b = 4.5 GeV
EPS09
nDS
No Shad
pPb - 8.8 TeV
y


$(d\sigma/dy)_{Shad} / (d\sigma/dy)_{no\ Shad}$
bottom - EPS
bottom - nDS
charm - EPS
charm - nDS
$s^{1/2}$ = 8.8 TeV
pPb
y

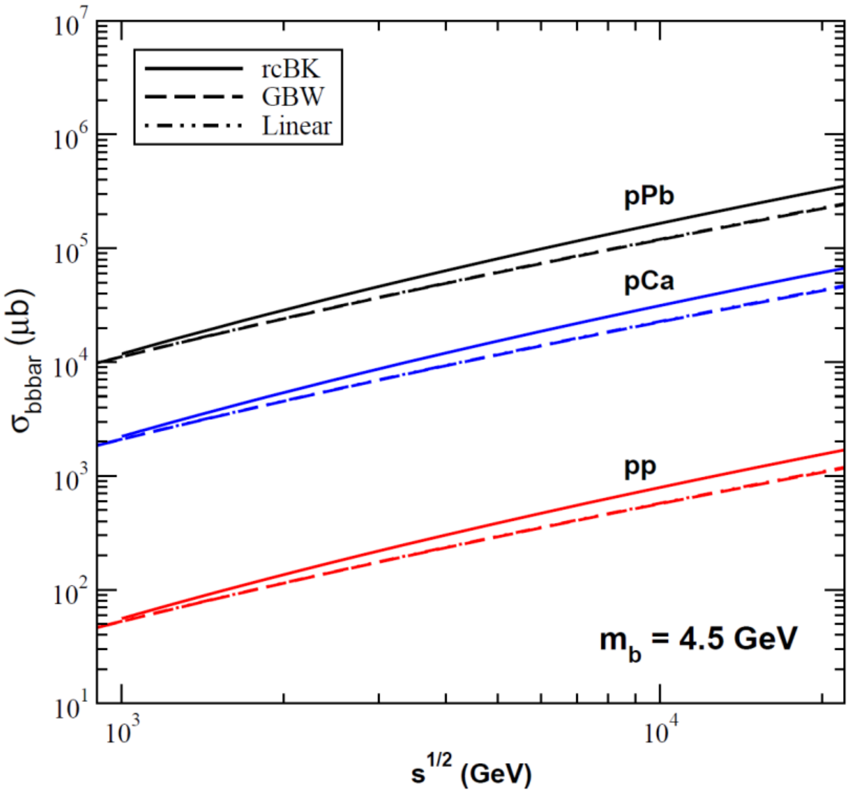


Pb
$\frac{F_2^{c(full)}(x,Q^2)}{F_2^{c(linear)}(x,Q^2)}$
1.50
1.25
1.00
0.75
0.50
0.25
0.00
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3}
x
Q^2= 2 GeV^2
Q^2= 30 GeV^2
Q^2= 60 GeV^2

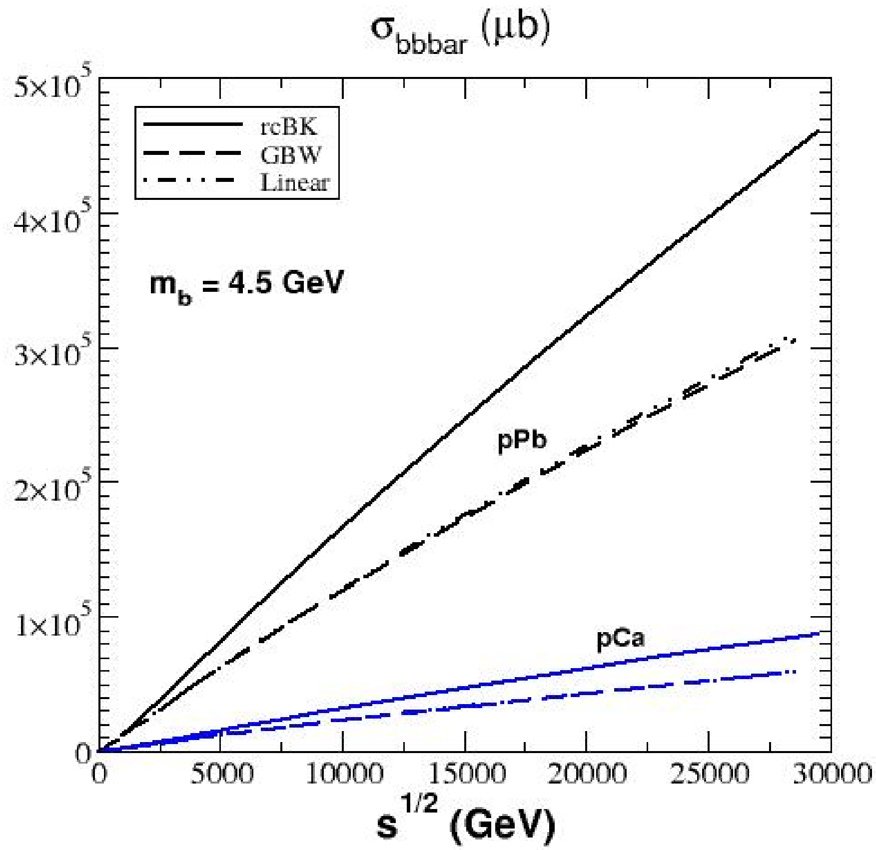


G*
1
2
n

pA



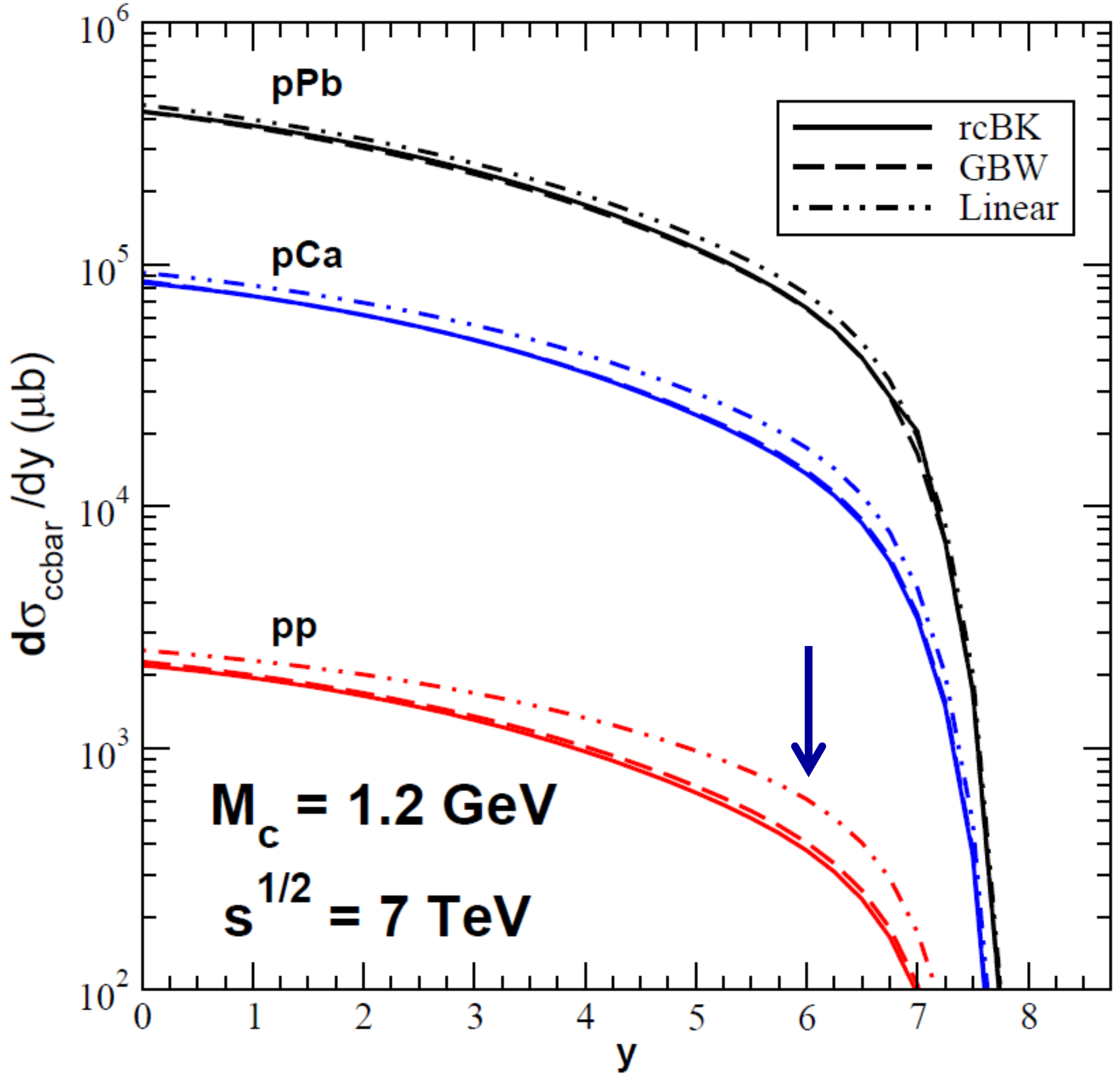
rcBK
GBW
Linear
pPb
pCa
pp
m_b = 4.5 GeV
σ_{bbbar} (μb)
$s^{1/2}$ (GeV)



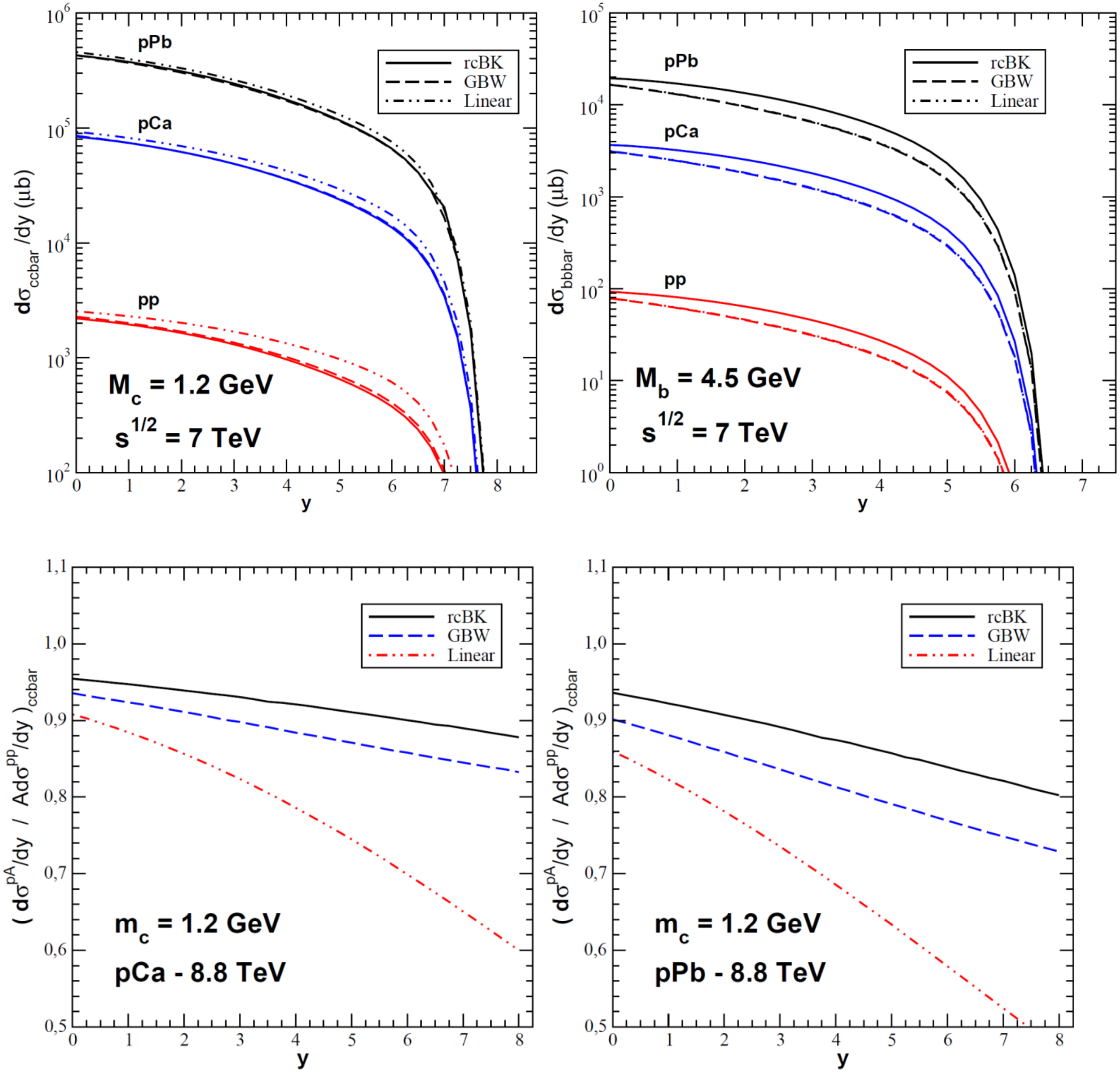
σ_{bbbar} (μb)
rcBK
GBW
Linear
m_b = 4.5 GeV
pPb
pCa
$s^{1/2}$ (GeV)

pA

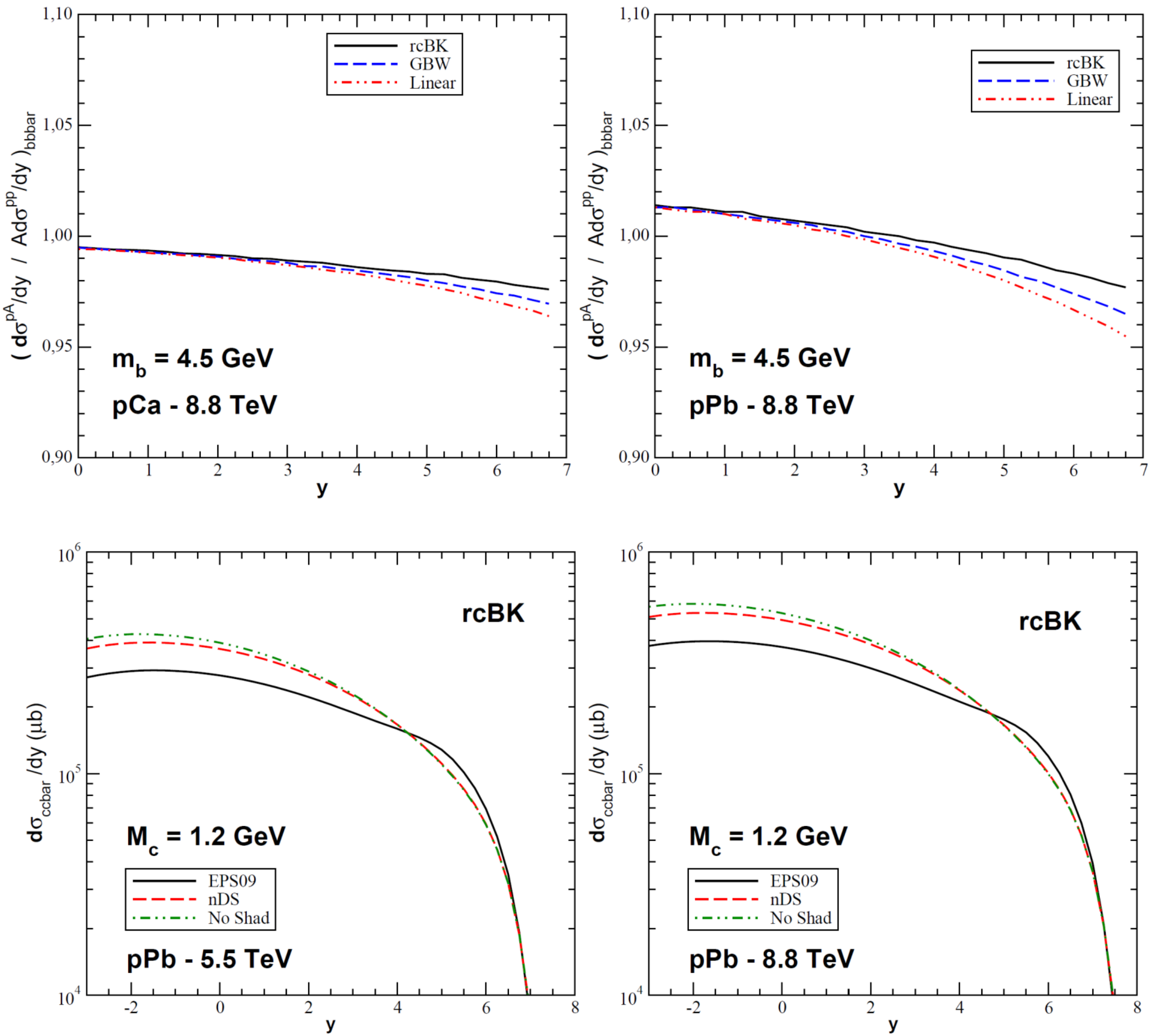
Rapidity distribution



Saturation: reduction by 1.7 at y = 6



pPb
pCa
pp
rcBK
GBW
Linear
M_c = 1.2 GeV
s^1/2 = 7 TeV
dσ_ccbar/dy (μb)
y
M_b = 4.5 GeV
s^1/2 = 7 TeV
dσ_bbbar/dy (μb)
m_c = 1.2 GeV
pCa - 8.8 TeV
pPb - 8.8 TeV
(dσ^pA/dy / Adσ^pp/dy)_ccbar


rcBK
GBW
Linear
(dσ^pA/dy / Adσ^pp/dy)_bbbar
m_b = 4.5 GeV
pCa - 8.8 TeV
pPb - 8.8 TeV
y
rcBK
dσ_ccbar/dy (μb)
M_c = 1.2 GeV
EPS09
nDS
No Shad
pPb - 5.5 TeV
pPb - 8.8 TeV