Low X Meeting 2012

Institute of Physics

Nuclear Effects in Heavy Quark Production in pA Collisions

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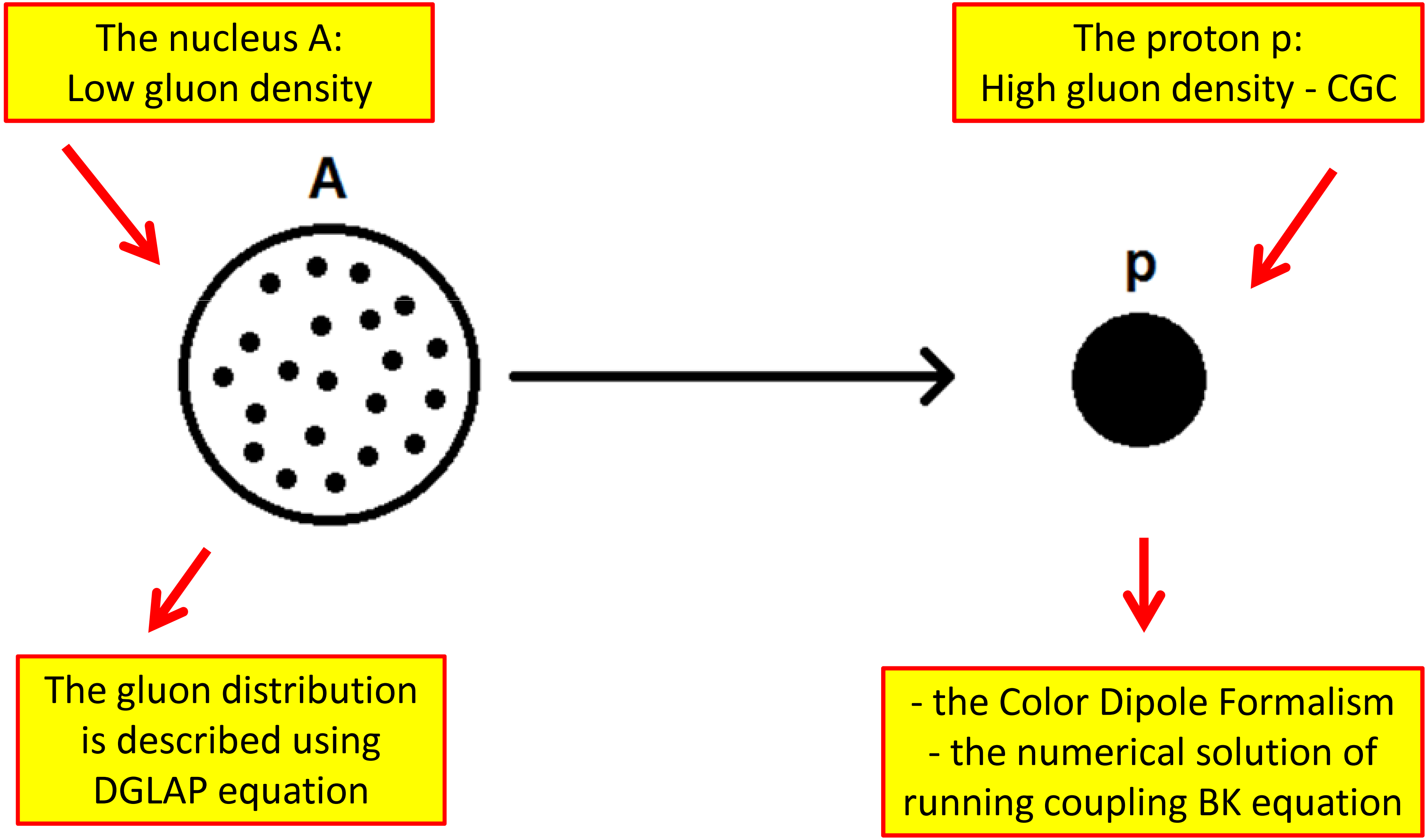
Introduction

A brief introduction to the nuclear shadowing effect in proton-nucleus processes

Proton-nucleus collisions

In the proton frame:



The nucleus A:
Low gluon density

The proton p:
High gluon density - CGC

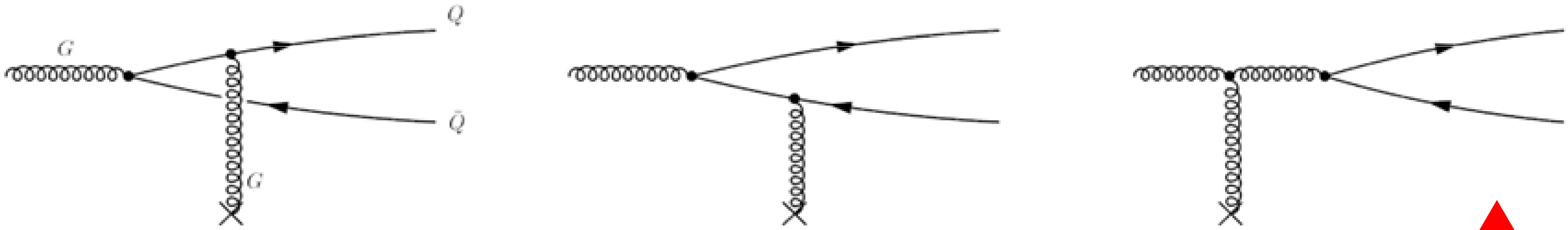
The gluon distribution
is described using
DGLAP equation

- the Color Dipole Formalism
- the numerical solution of
running coupling BK equation

Proton-nucleus collisions

In the Color Dipole Formalism:

The projectile emits a gluon that fluctuates in a (color octet) pair quark-antiquark



A gluon from target is absorbed and the pair becomes a color singlet

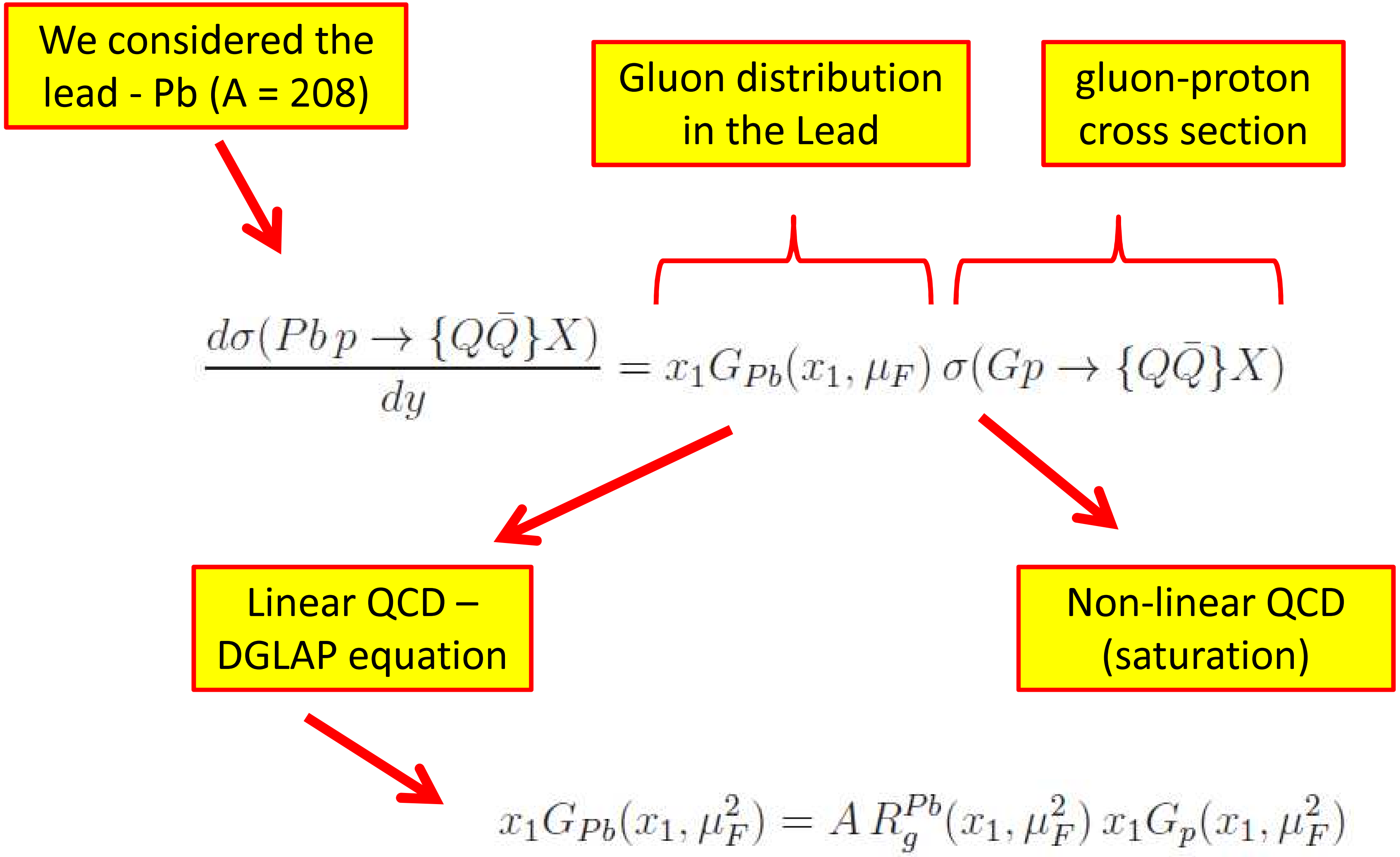
We are interested in heavy quarks – charm or bottom

Reference:

J. Raufeisen and J. Peng, Phys. Rev. D **67,** 054008 (2003).

Proton-nucleus collisions

The rapidity distribution of the cross section



We considered the lead - Pb (A = 208)

$$\frac{d\sigma(Pb\,p \to \{Q\bar{Q}\}X)}{dy} = \overbrace{x_1 G_{Pb}(x_1,\mu_F)}^{\text{Gluon distribution in the Lead}}\,\overbrace{\sigma(Gp \to \{Q\bar{Q}\}X)}^{\text{gluon-proton cross section}}$$

Linear QCD – DGLAP equation

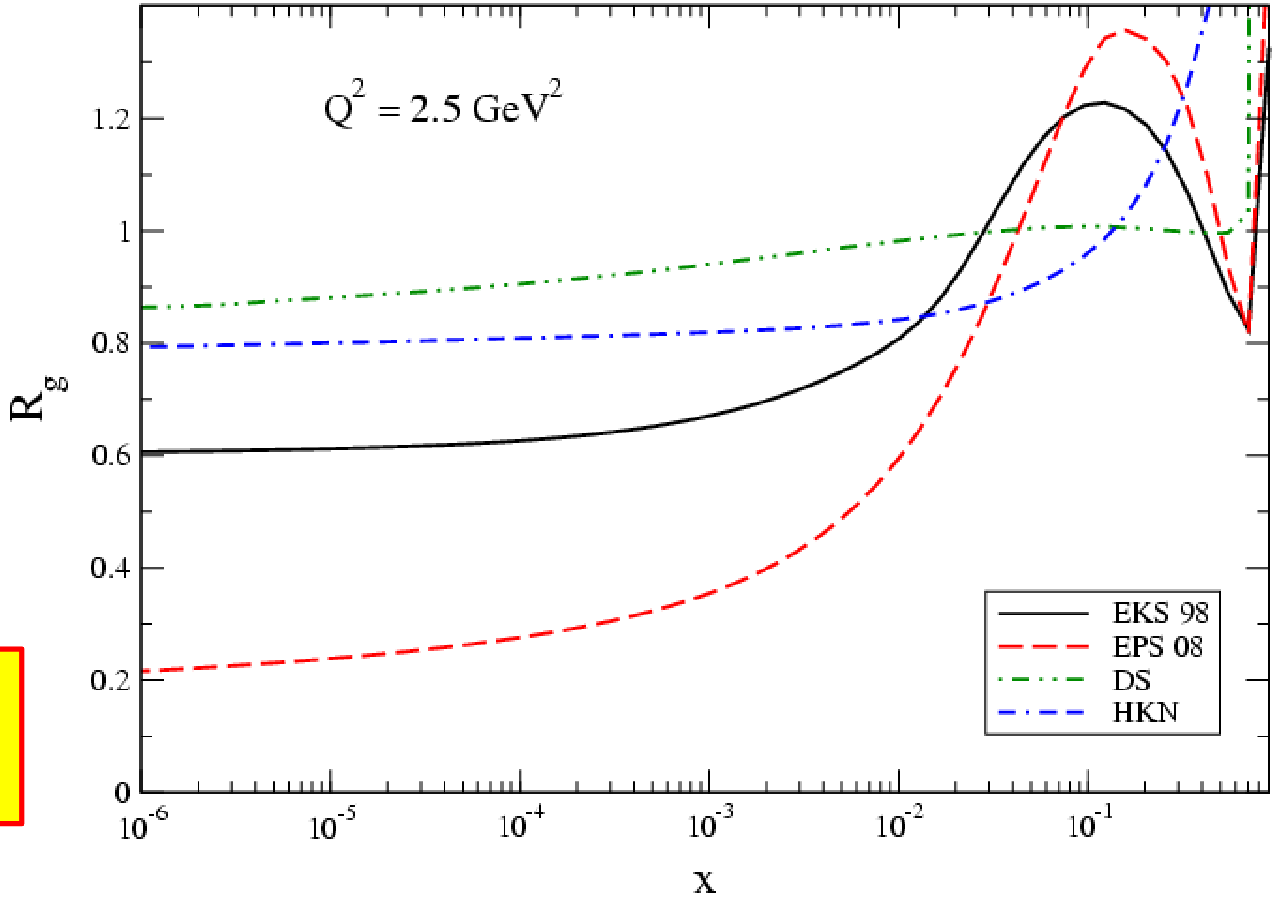
Non-linear QCD (saturation)

$$x_1 G_{Pb}(x_1,\mu_F^2) = A\,R_g^{Pb}(x_1,\mu_F^2)\,x_1 G_p(x_1,\mu_F^2)$$

The nuclear shadowing effect

$R_g < 1$ – shadowing
$R_g > 1$ – antishadowing

$$R_g = \frac{xg_{Pb}}{Axg_p}$$



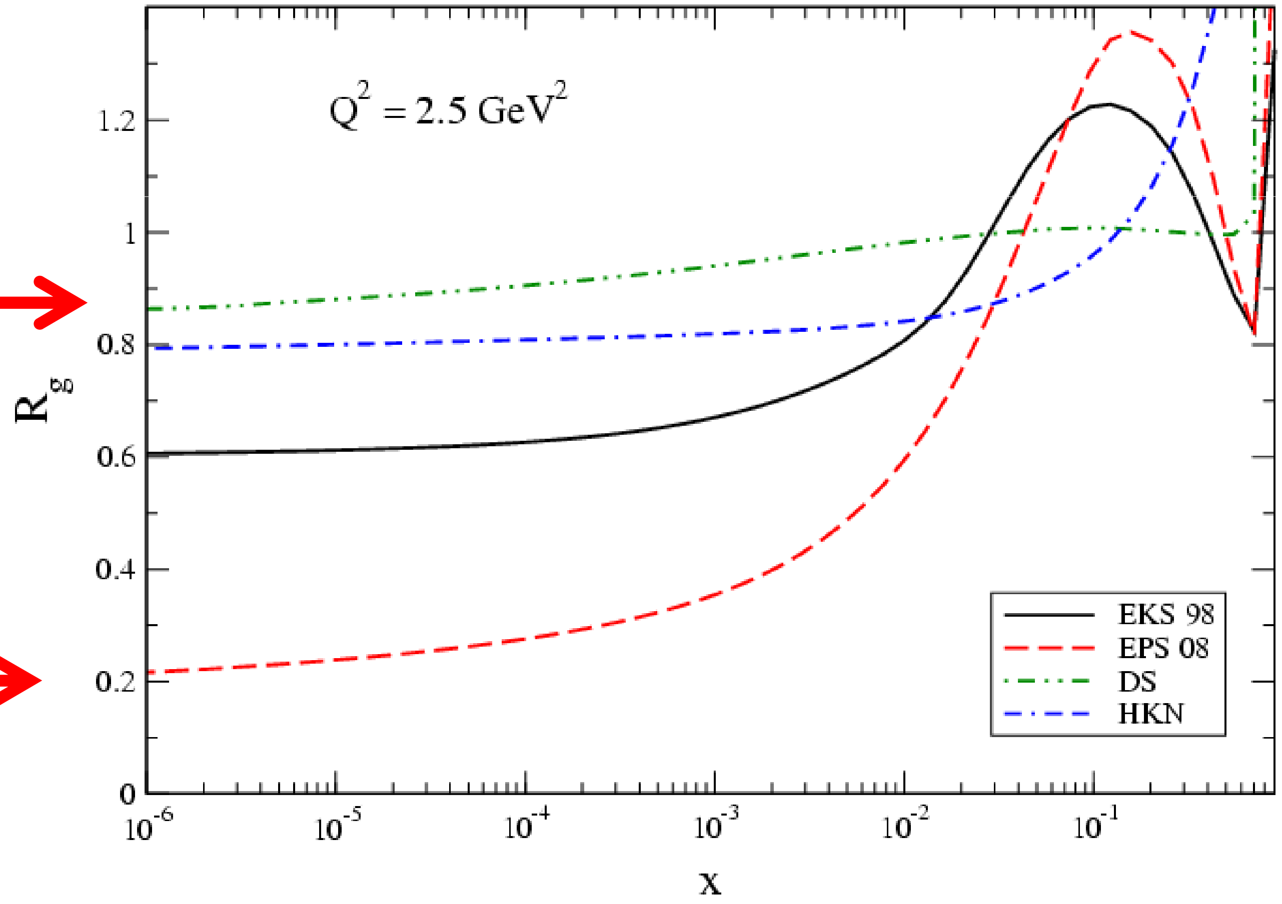
Great uncertainty in the magnitude of R_g

The nuclear shadowing effect

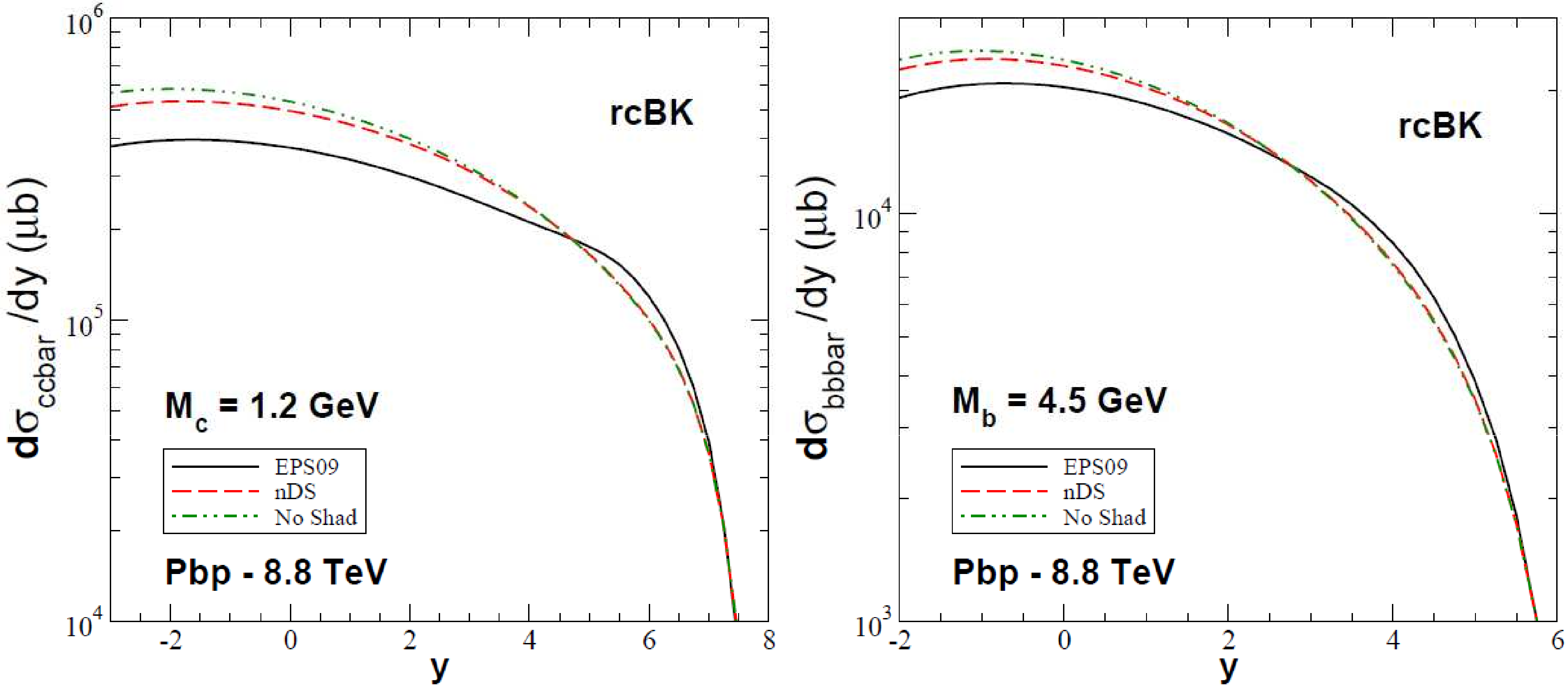
We choose the extreme cases, but substituting **EPS08** with **EPS09**

Weaker shadowing

Stronger shadowing



Results



negative y = low x_1 →

$$x_1 = \left(\frac{m_Q}{\sqrt{s}}\right)e^{+y}$$

Results

The more interesting observable is the ratio

$$\frac{(d\sigma/dy)_{Shad}}{(d\sigma/dy)_{No\ Shad}} = \frac{A\, R_g^{Pb}\ x_1 G_p\ \sigma}{A\, x_1 G_p\ \sigma} = R_g^{Pb}(x_1, \mu_F)$$

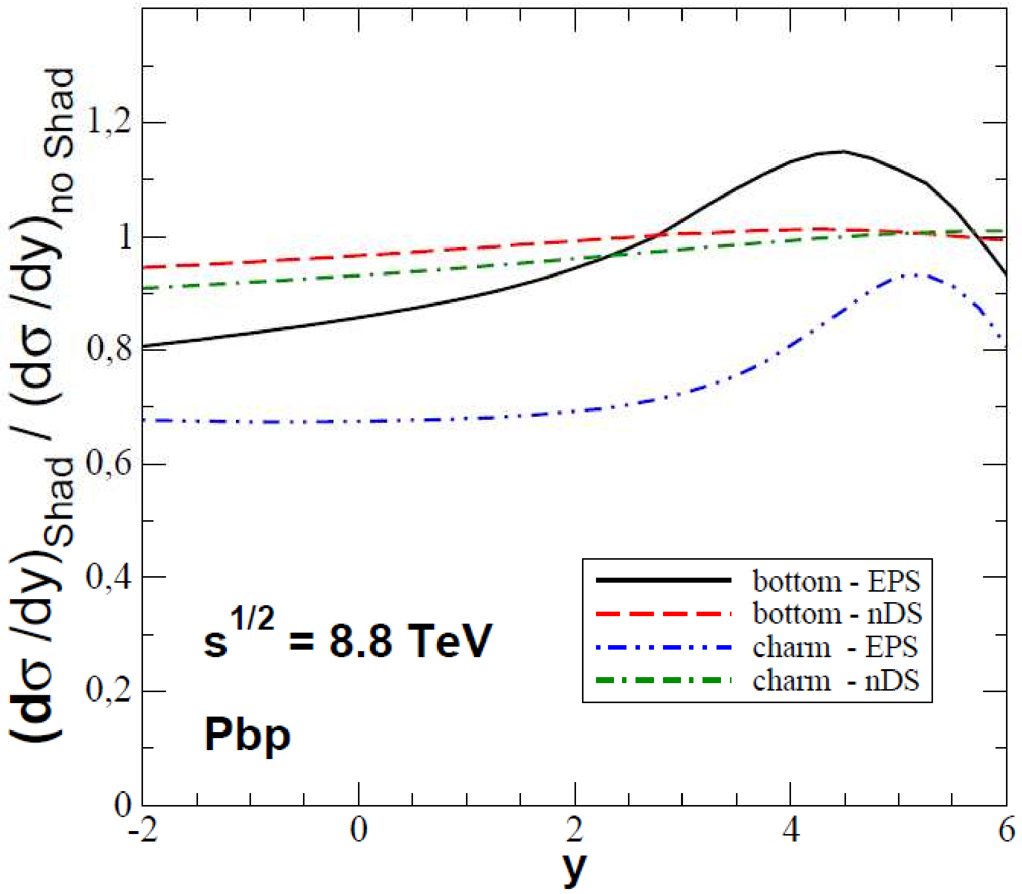
It is just the nuclear modification factor

Results

$$R_g^{Pb}(x_1, \mu_F) \longrightarrow$$

$$\mu_F = m_c$$

$$\mu_F = m_b$$



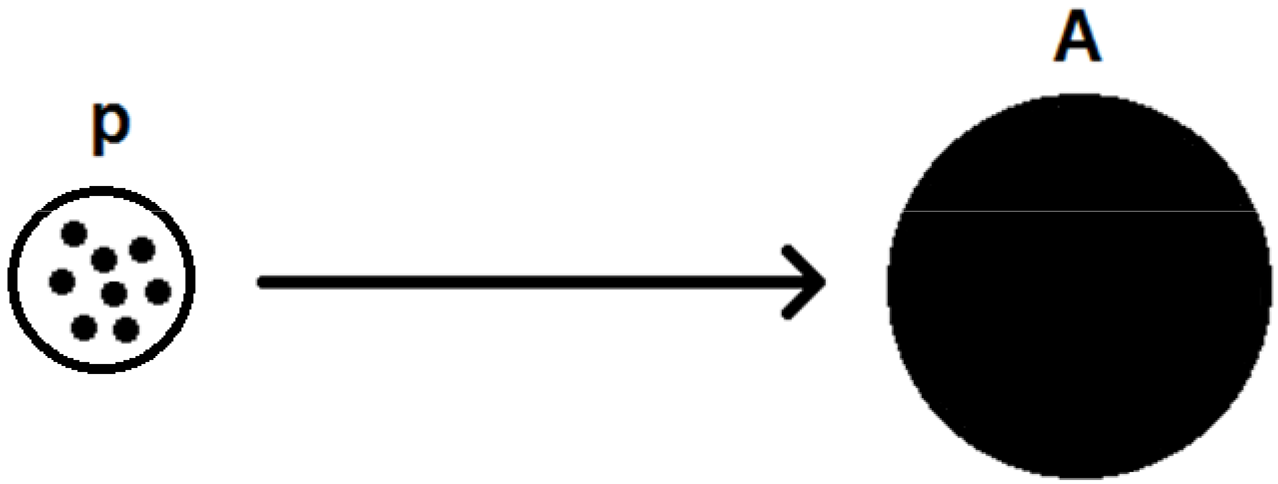
- Charm production can give us information about the magnitude of the nuclear shadowing effect
- Bottom production can be useful to determine the magnitude of antishadowing

Saturation

We also analyzed saturation effects in proton-nucleus collisions

Proton-nucleus collisions

In the nucleus frame:



The proton p:
Low gluon density

The nucleus A:
High gluon density - CGC

The gluon distribution
is described using
DGLAP equation

- the Color Dipole Formalism
- several models to describe
dipole-nucleus cross section

Models:

dipole-proton cross section

CT →

$$\sigma_{q\bar{q}}(x,\rho^2) = \frac{\pi^2}{3}\rho^2\alpha_s x G_{h_2}(x, 10/\rho^2)$$

GBW →

$$\mathcal{N}(x,\rho) = 1 - \exp\left[-\frac{1}{4}(\rho^2 Q_s^2)\right]$$

rcBK → Numerical solution of running coupling BK equation

Nuclear generalization

CT
(EPS09 / DS) →

$$xG_A(x,Q^2) = A.R_g(x,Q^2).xG_N(x,Q^2)$$

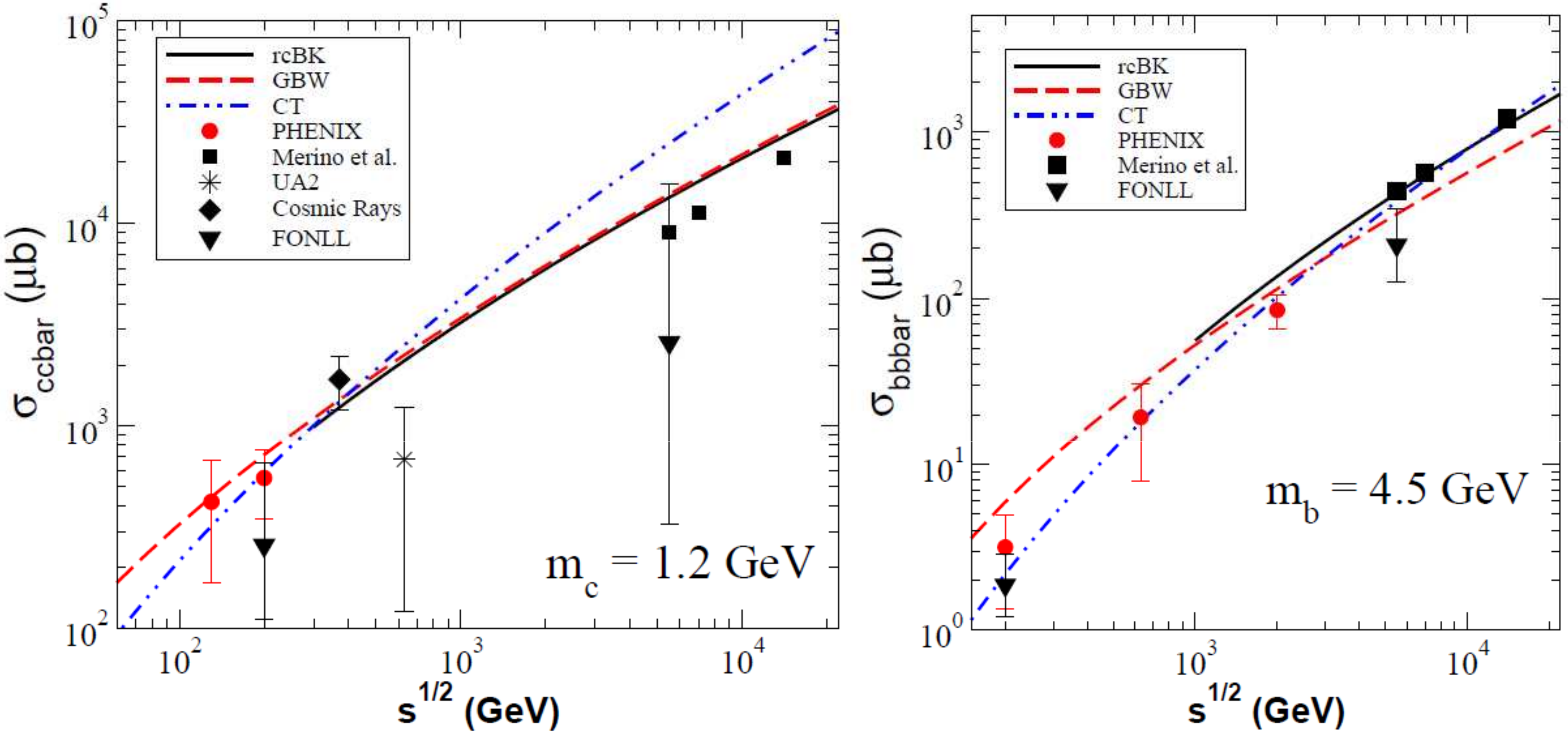
Glauber-Mueller
(GBW / rcBK) →

$$\mathcal{N}^A(x,\boldsymbol{r},\boldsymbol{b}) = 1 - \exp\left[-\frac{1}{2}AT_A(\boldsymbol{b})\sigma^p_{\mathrm{dip}}(x,\boldsymbol{r}^2)\right]$$

CGC
(GBW) →

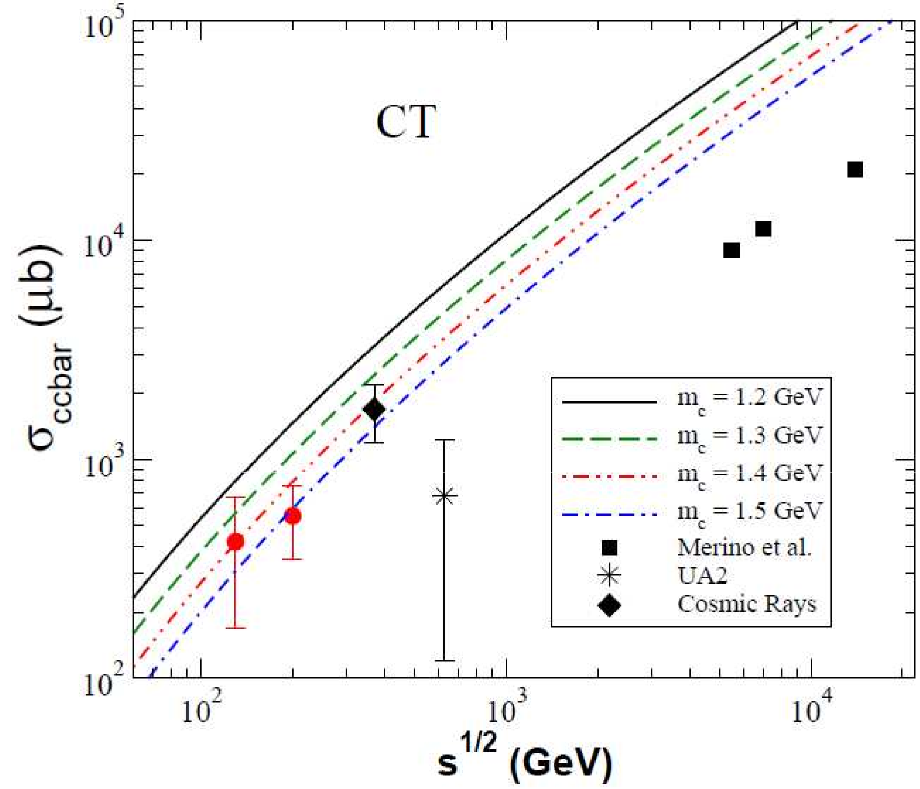
$$\sigma^A_{q\bar{q}G}(\alpha,\rho) = \int d^2\boldsymbol{b}\left\{\frac{9}{8}\left[1-\exp\left[\left(-\sigma_{q\bar{q}}(\alpha\rho)-\sigma_{q\bar{q}}(\bar{\alpha}\rho)\right)T_A(\boldsymbol{b})\right]\right]\right.$$
$$\left.-\frac{1}{8}\left[1-\exp\left(-\sigma_{q\bar{q}}(\rho)T_A(\boldsymbol{b})\right)\right]\right\}$$

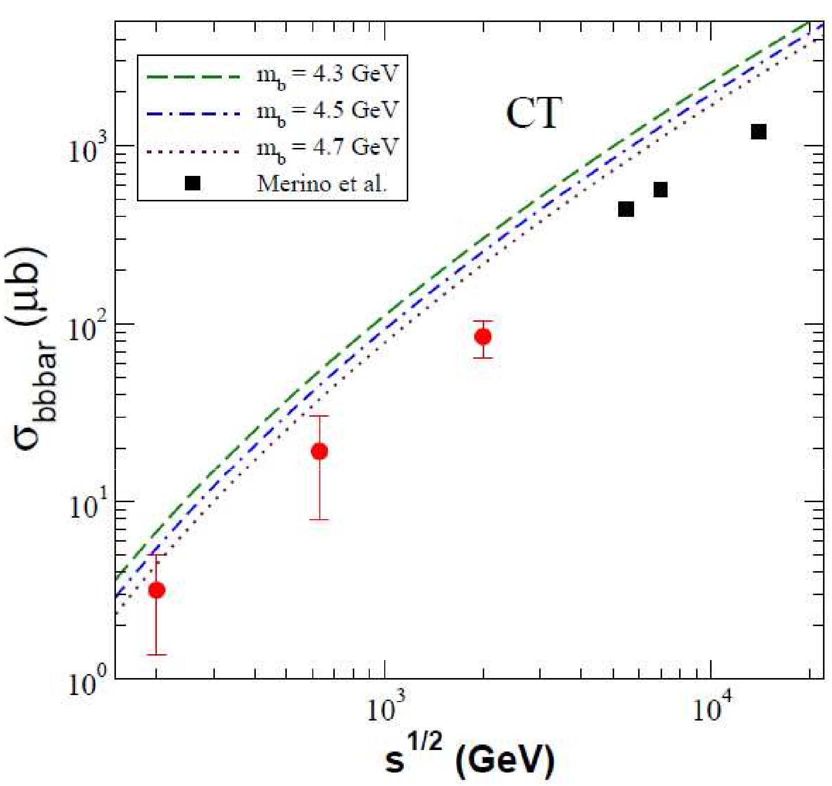
Results



First we fitted the existing data on pp collisions

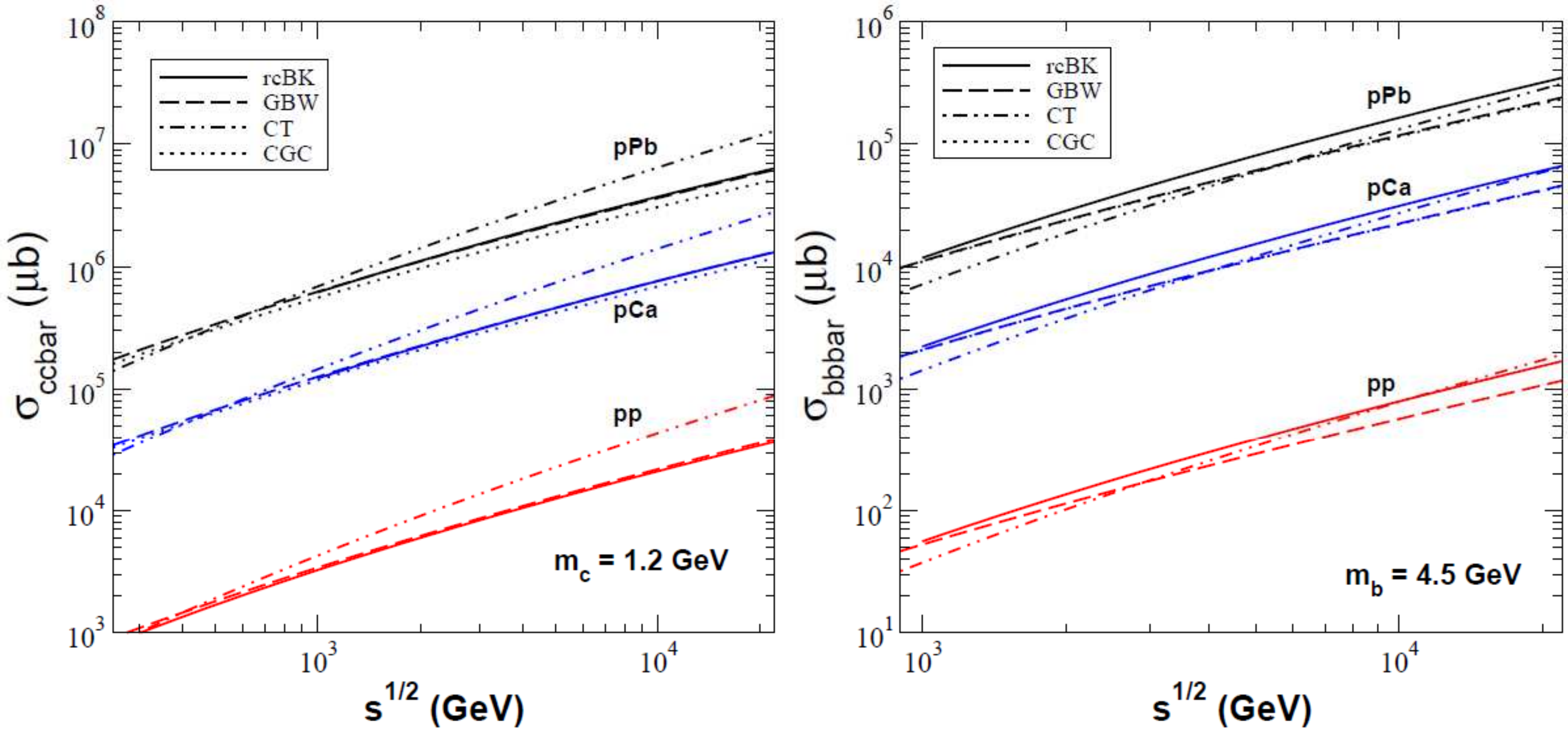
Results





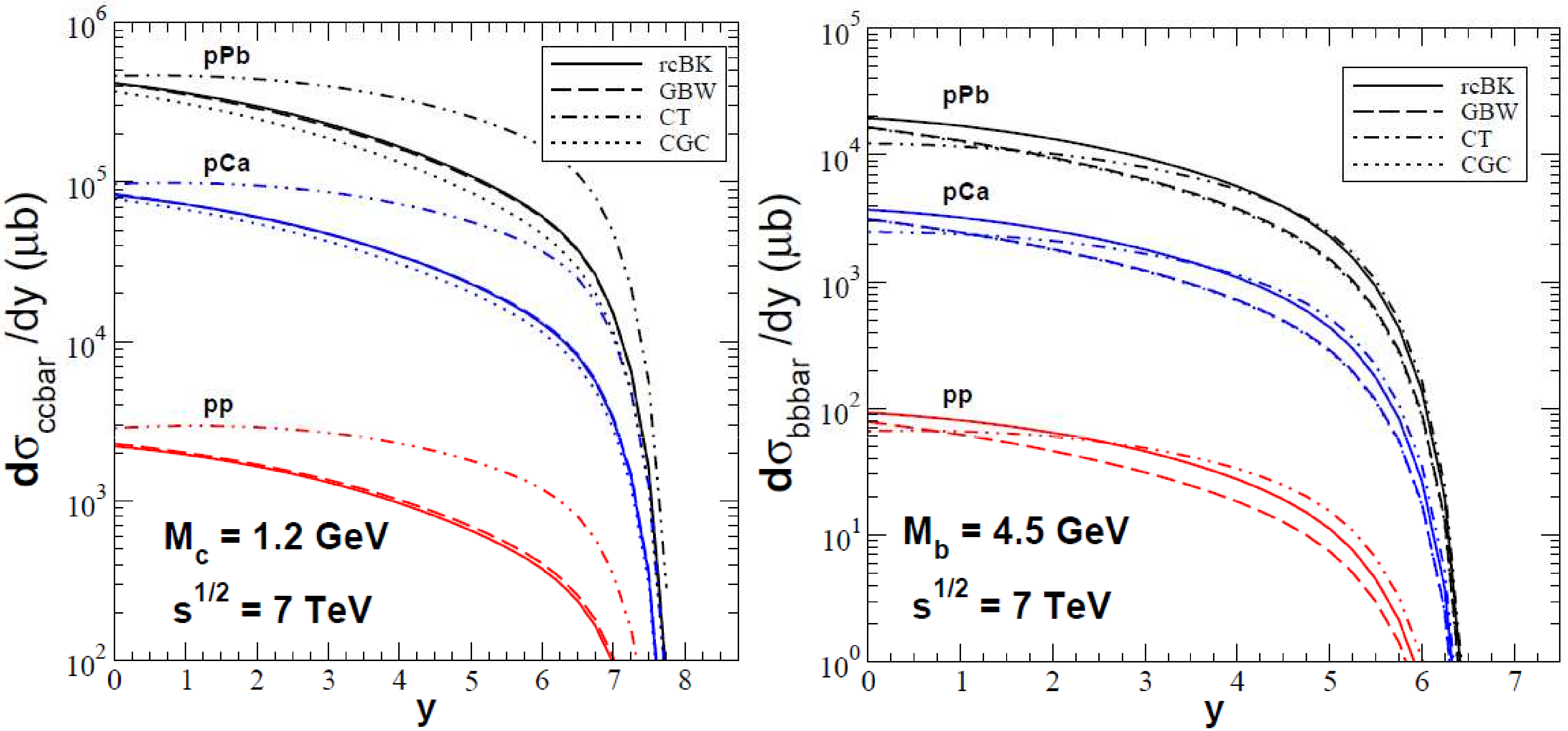
We fixed:
m_c = 1.2 GeV
m_b = 4.5 GeV

Results



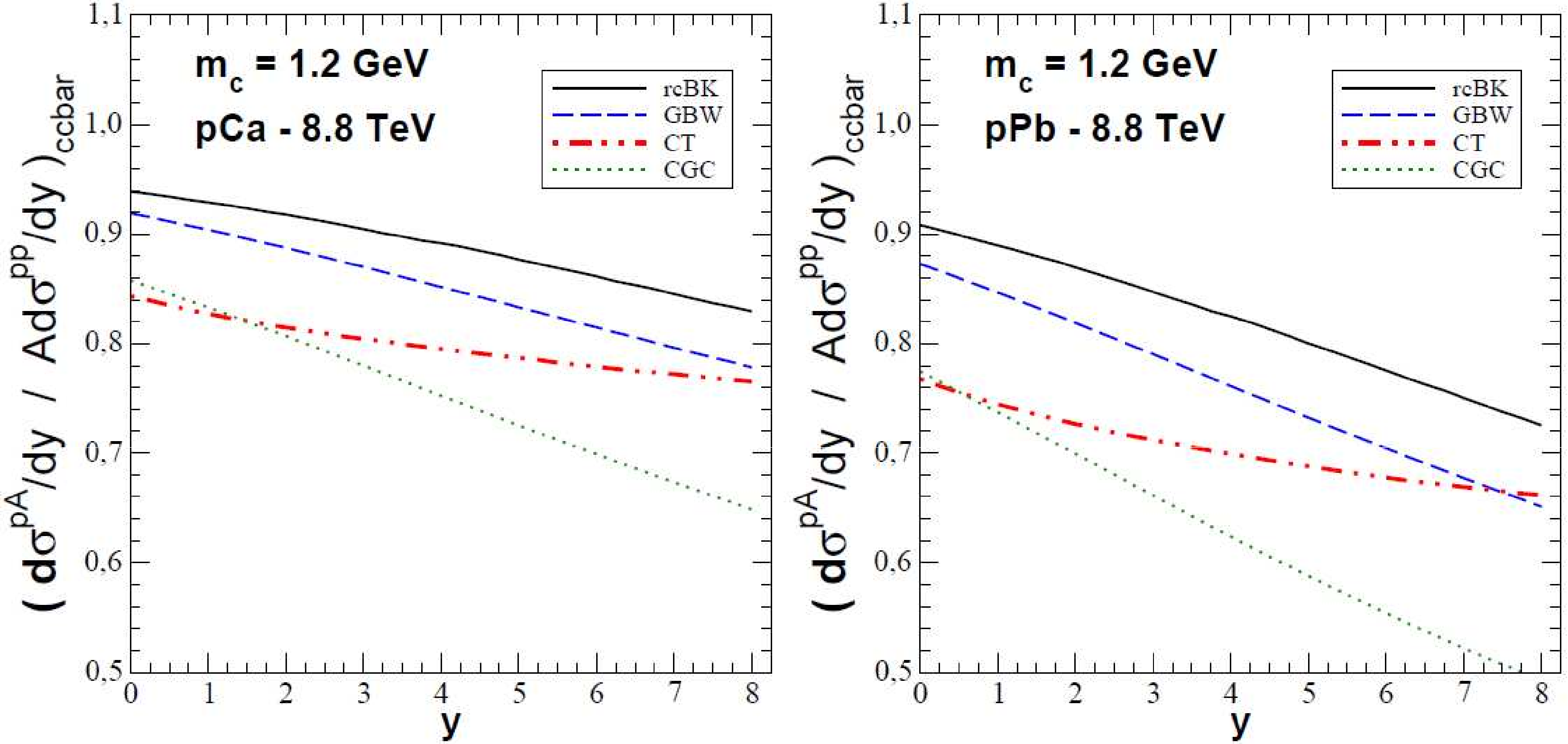
- At high energies, charm production is sensitive to saturation effects
- The same is not true with bottom production

Results



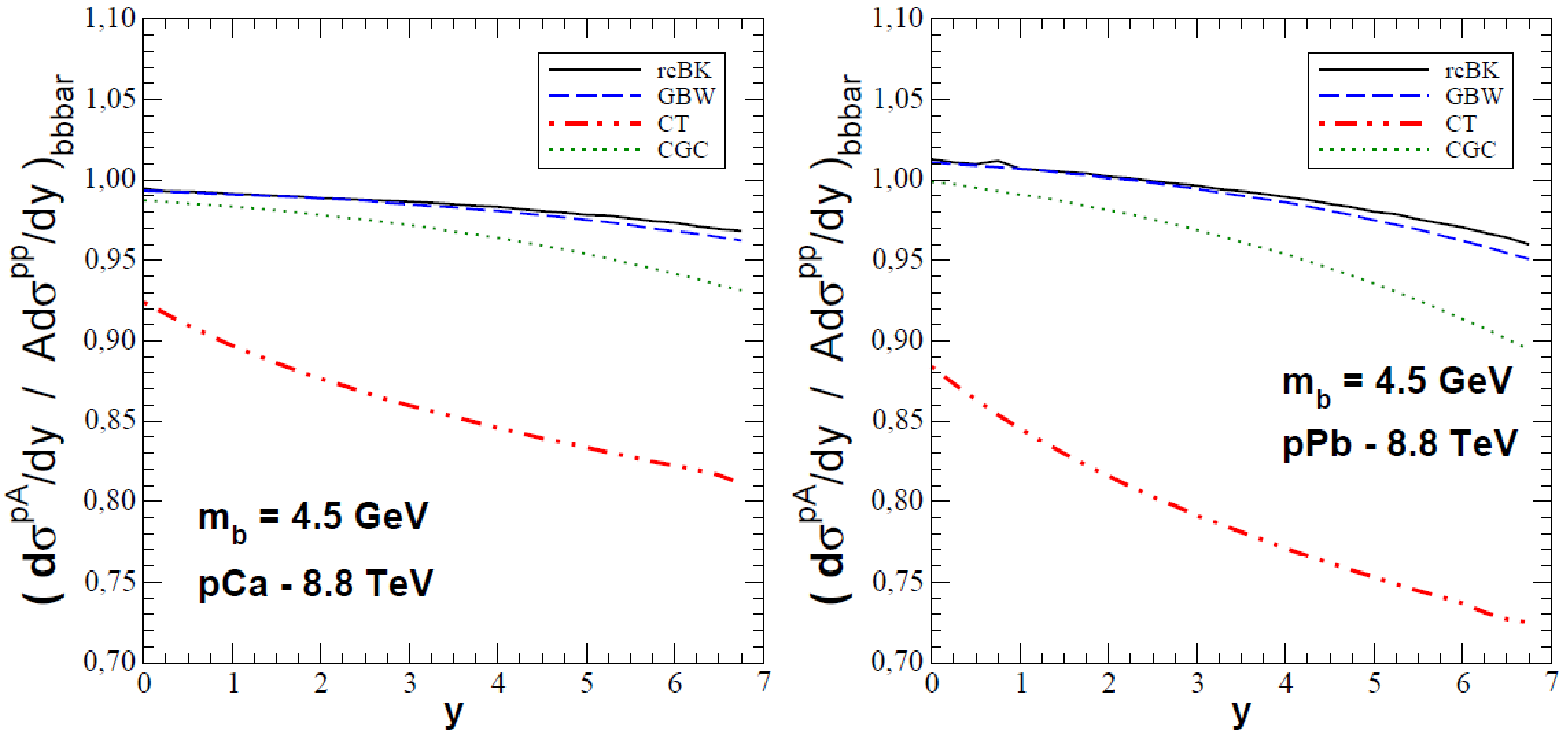
- At high Y, charm production is sensitive to saturation effects
- The same is not true with bottom production

Results



- This observable will be useful to determine, between Glauber-Mueller and Marquet models, which one describe better the saturation in a nucleus

Results



- Once EPS09 is confirmed by other observable, this observable of bottom production will be useful to detect saturation effects

Summary

- ☐ Our calculation was made in the energy of Large Hadron Collider - LHC

- ☐ The charm production is the most sensitive to shadowing effect as well as to saturation effect

- ☐ Only bottom production indicates the presence of antishadowing

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E.R. Cazaroto, V.P. Gonçalves, F.S. Navarra, Nucl. Phys. A 872 (2011) 196

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The End