Gluon shadowing

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Valparaiso

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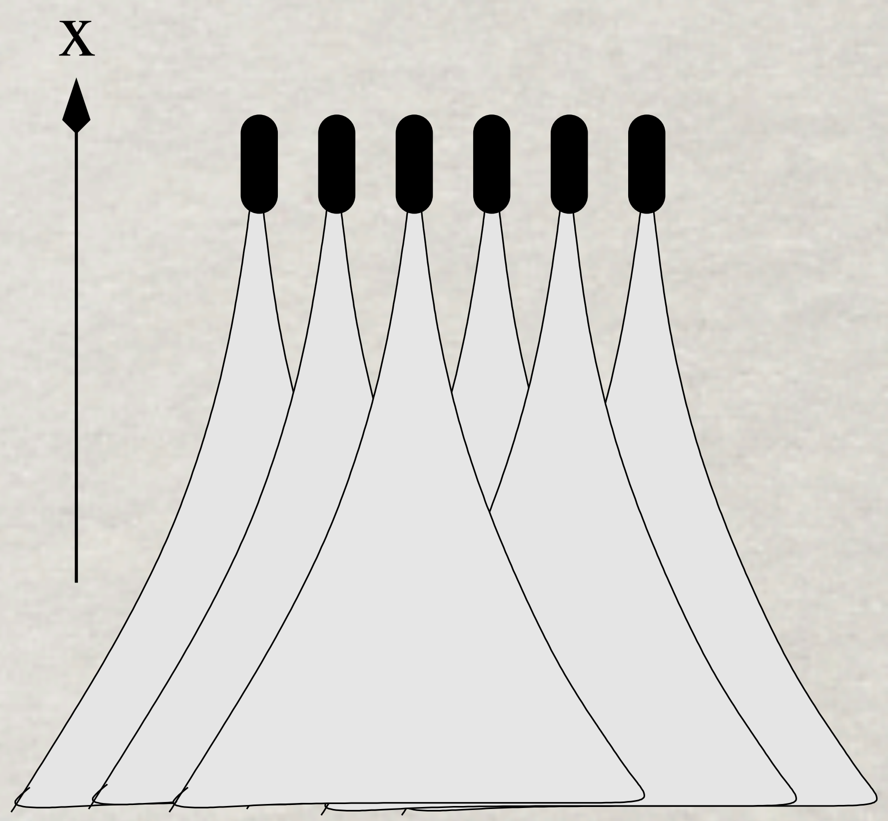
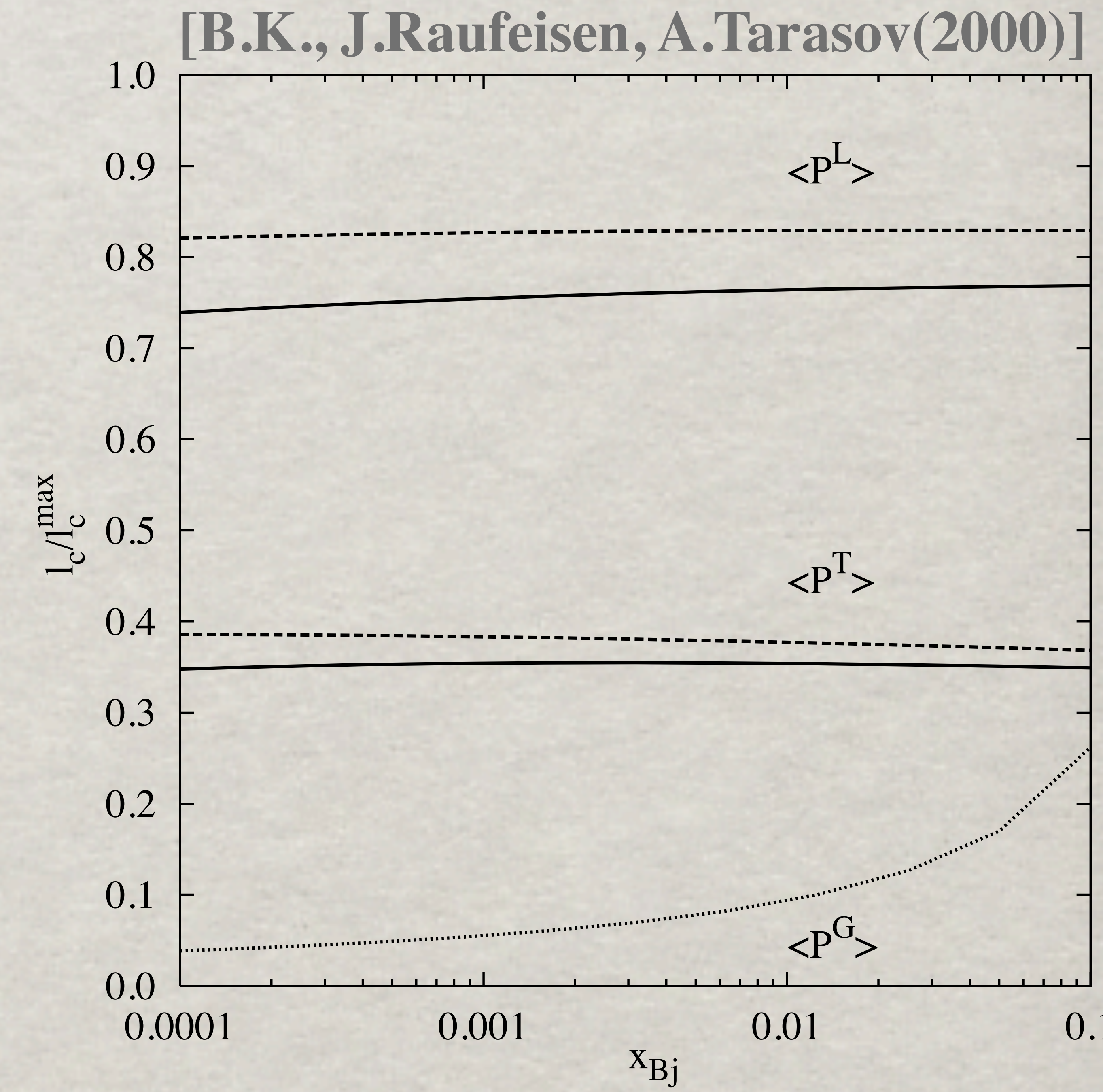
Why is less glue in nuclei?
Why shadowing?



A Lorentz-boosted nucleus looks like a pancake, as well as the bound nucleons. So the nucleons are still well separated. However, parton at small $x < (m_N R_A)^{-1}$ are less contracted and overlap in the longitudinal directions. Then they can fuse reducing parton density at small **x**. This is how shadowing looks like in the infinite momentum frame [O.Kancheli (1973)].



Why shadowing?

The same phenomenon in the rest frame of the nucleus looks like coherent multiple interactions of the projectile fluctuations. These interactions shadow each other.

The parameter controlling shadowing is the coherence time of gluon radiation

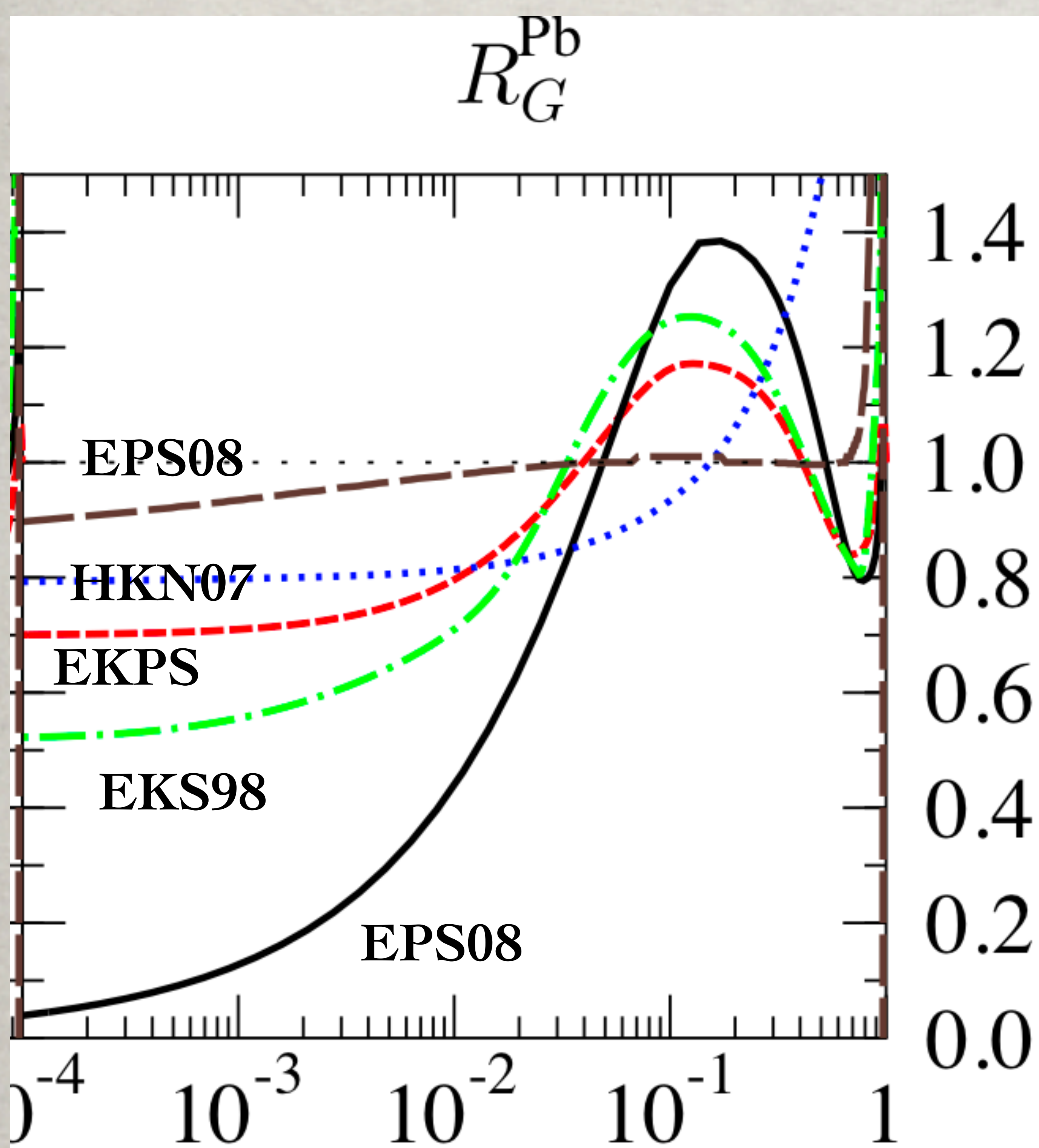
$$t_c = \frac{P}{x_{Bj} m_N}$$

Gluon shadowing, i.e. suppression of gluon radiation, can also be interpreted as Landau-Pomeranchuk effect.

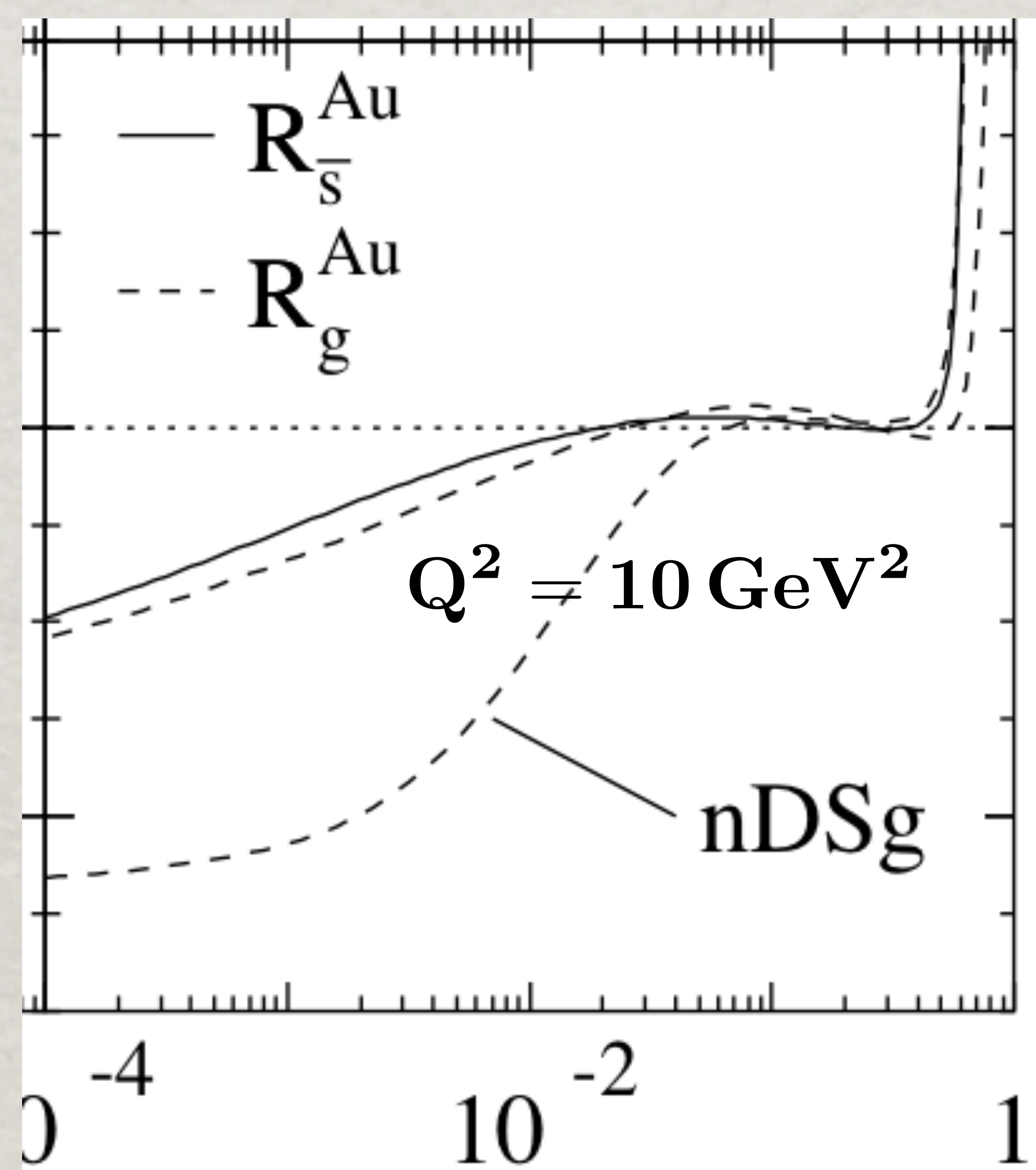
Gluon shadowing from DIS

DIS does not probe directly the gluon PDF. It comes via the DGLAP evolution from the Q^2 dependence of $F_2(x, Q^2)$.

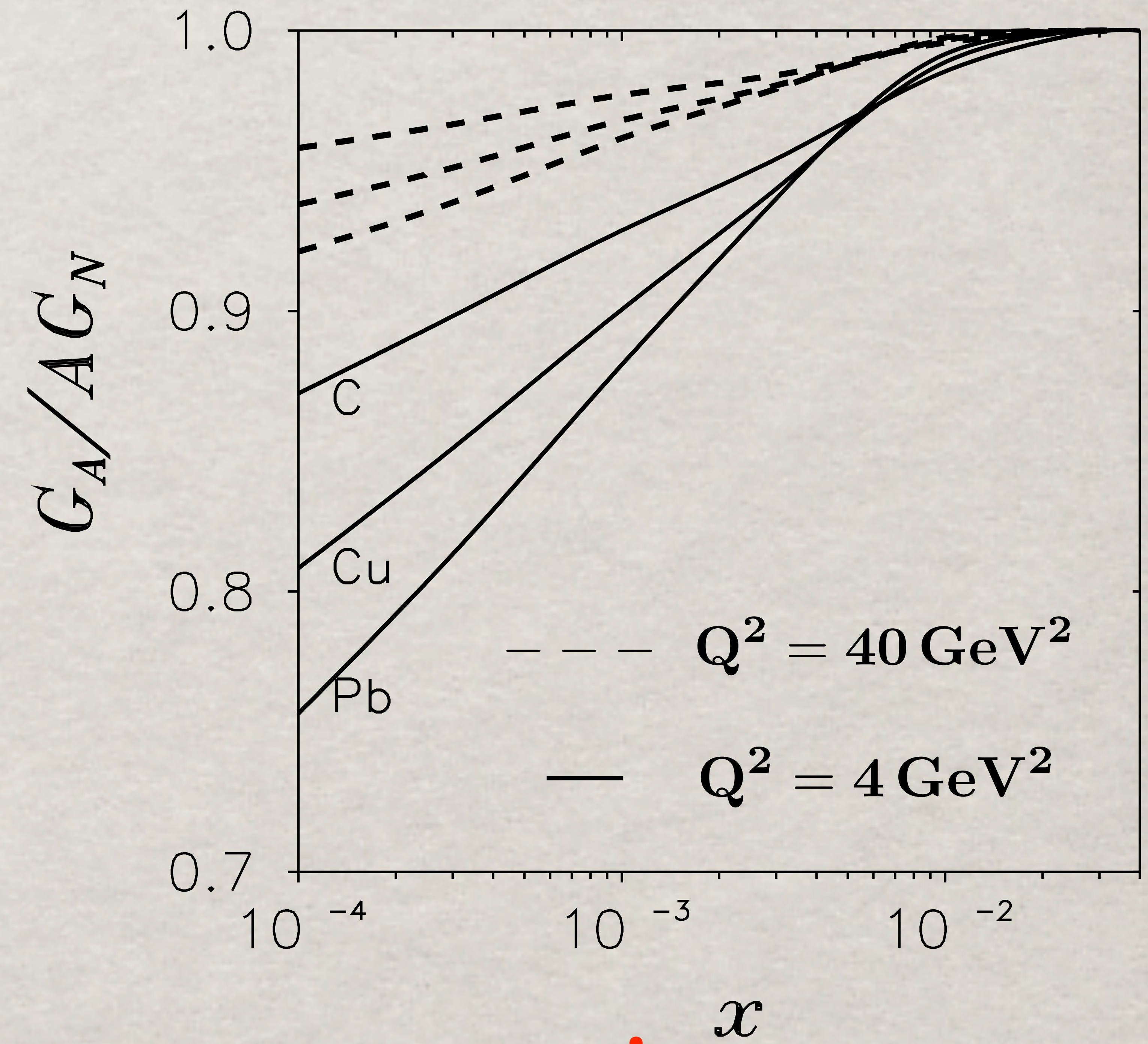
So far only the NMC experiment managed to detect a variation of the nuclear PDF with Q^2



D.de Florian, R.Sassot(2004)



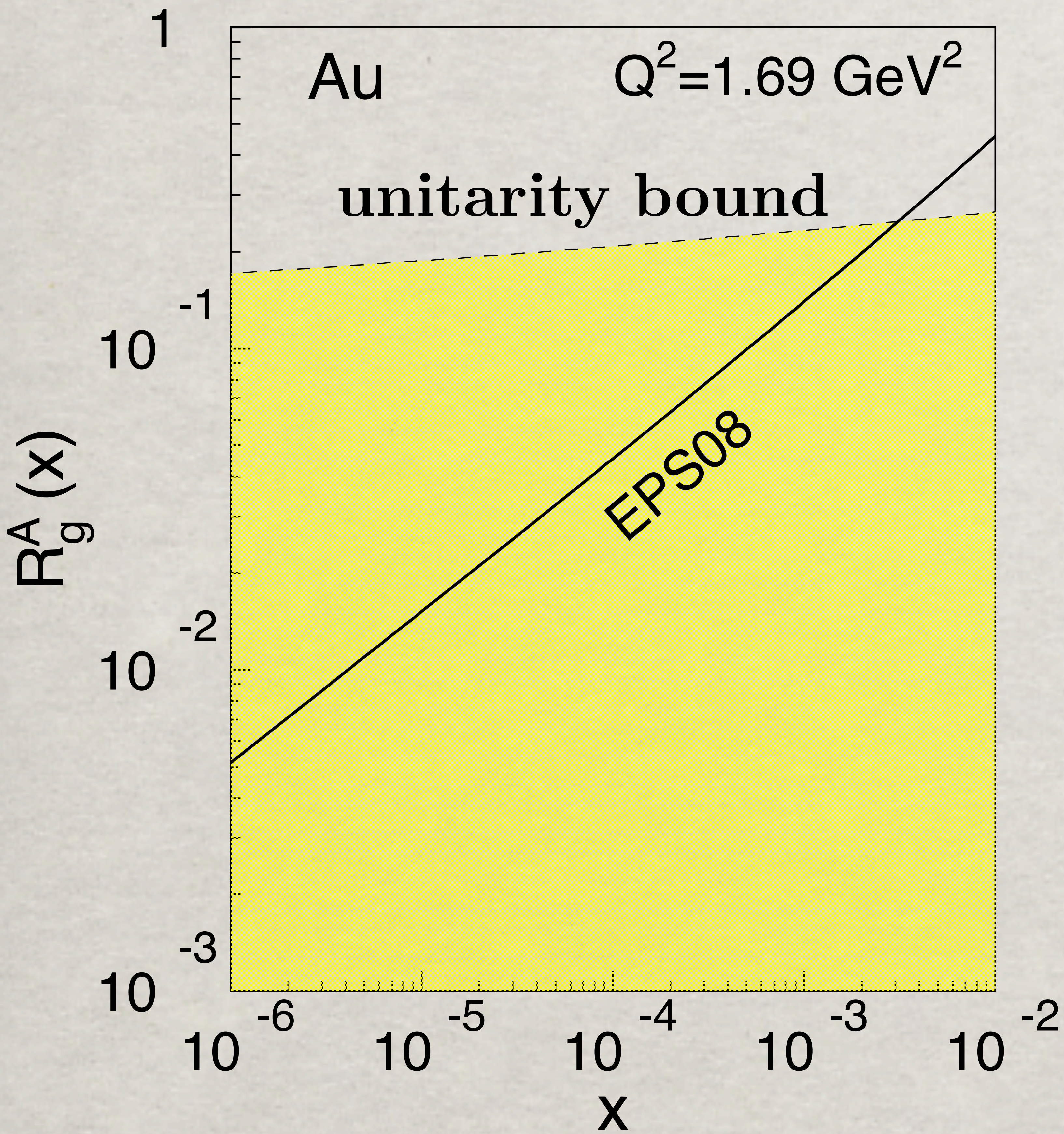
B.K., A.Schafer, A.Tarasov(1999)



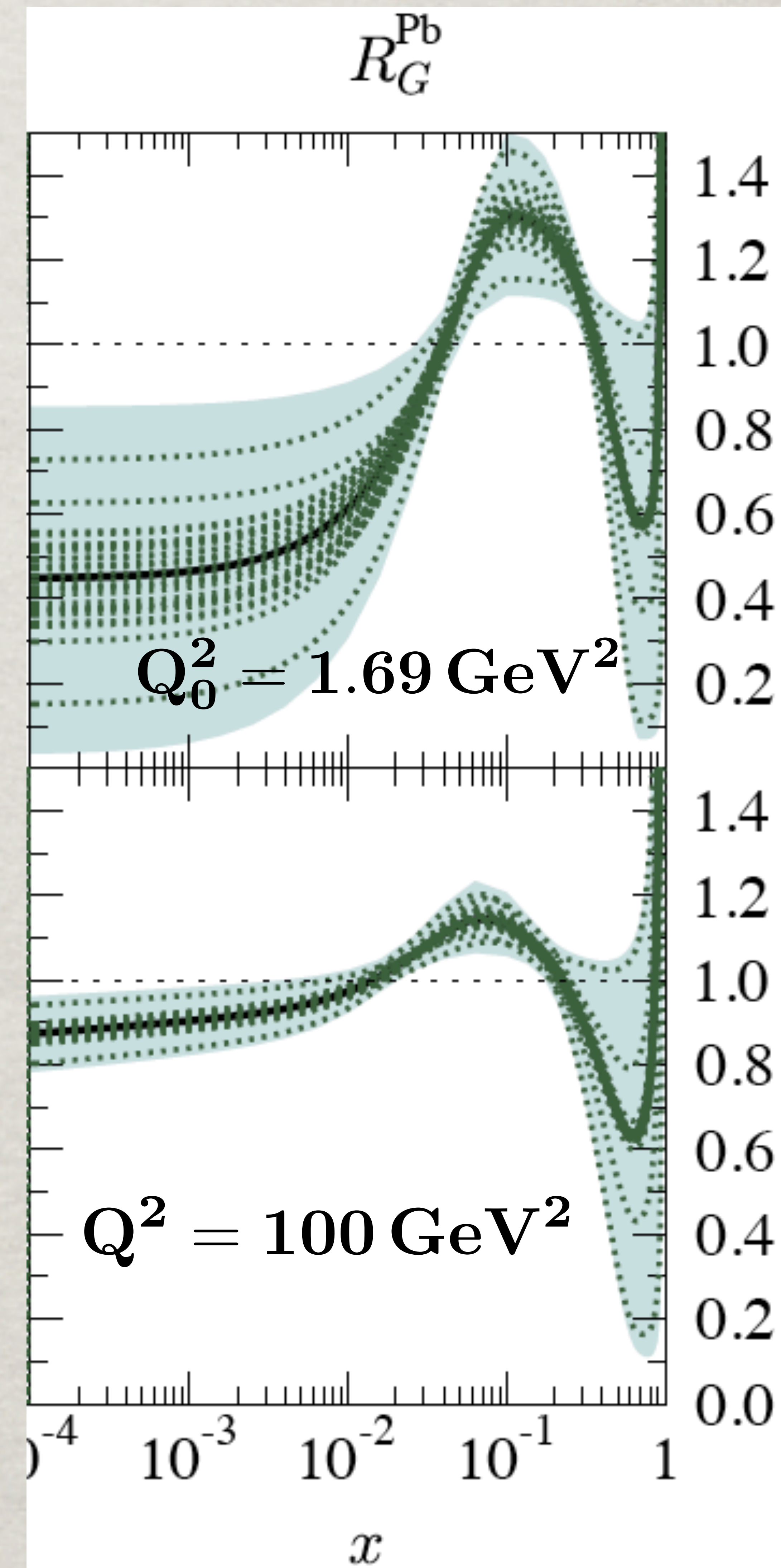
¡ A dramatic controversy with the magnitude of gluon shadowing !

Gluon shadowing from hadronic data

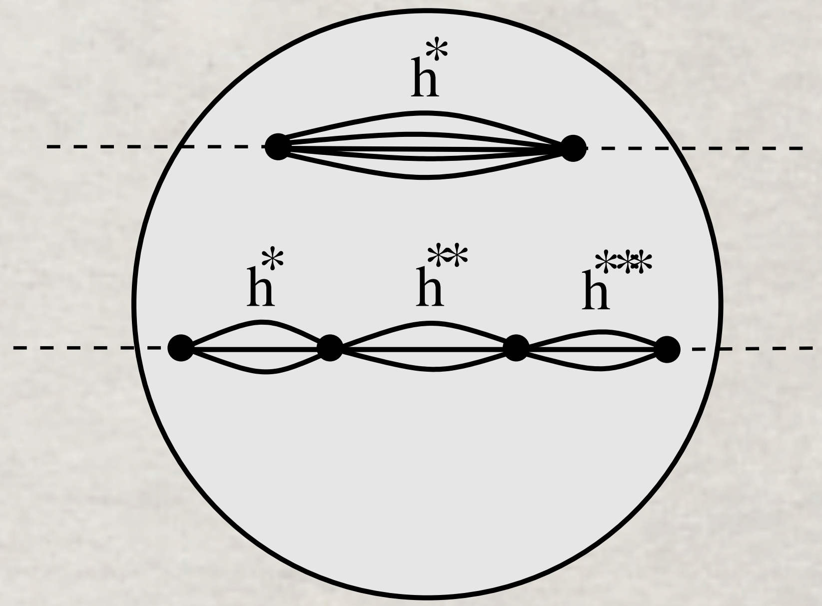
B.K., E.Levin, I.Potashnikova, I.Schmidt (2009)



EPS09

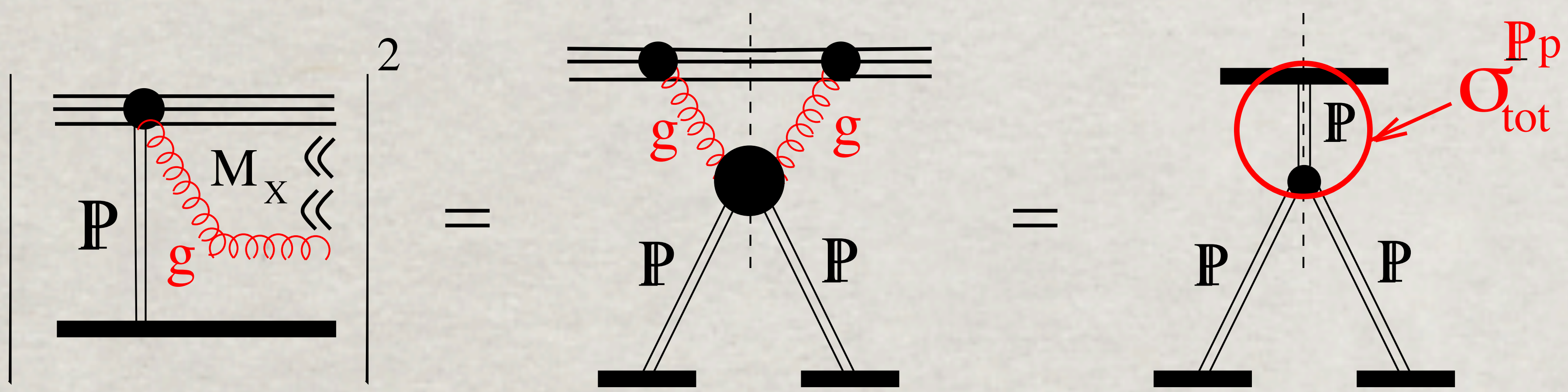


Weak gluon shadowing



Gluon shadowing and the Gribov inelastic corrections:

The triple-Pomeron term in diffraction, h->h*, correspond to gluon shadowing.



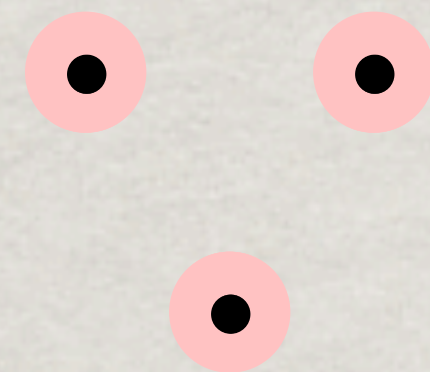
expected: $\sigma_{\mathbf{tot}}^{\mathbf{Pp}} \sim 50\,\mathrm{mb}$

measured: $\sigma_{\mathbf{tot}}^{\mathbf{Pp}} \lesssim 2\,\mathrm{mb}$!!!

Smallness of the diffractive cross section means weakness of gluon shadowing.

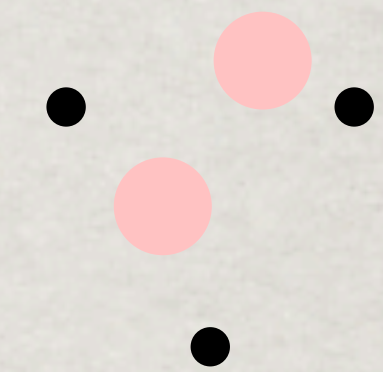
In terms of pQCD this shows a suppression of diffractive gluon radiation, which can only be related to smallness of gluonic dipoles.

Two-scale hadronic structure



B.K., A.Schafer, A.Tarasov(1999):

the valence quarks carry small size gluon clouds, $r_0 \approx 0.3\mathrm{fm}$



Shuryak & Zakhed (2004):

gluonic spots of small size, $r_0 \approx 0.3\mathrm{fm}$ are floating in the proton.

Small gluonic spots ==> weak gluon shadowing:

$$\left.\frac{G_A(x)}{AG_N(x)}\right|_{x\ll 1} = \frac{2}{\langle\sigma_{GG}(r)\rangle}\int d^2b\left[1-\left\langle e^{-\frac{1}{2}\sigma_{GG}(r)T_A(b)}\right\rangle\right] = 1-\frac{3C}{8}\,r_0^2\,\rho_A R_A + \ldots \approx 0.8$$

Even if small-x gluons overlap in the longitudinal direction, they can miss each other in transverse plane, if they are located within small spots. Indeed, for a heavy nucleus (lead) the mean number of gluonic spots overlapping with a given one is,

$$\langle n\rangle = \frac{3\pi}{4}\,r_0^2\,\langle T_A\rangle = \pi\,r_0^2\,\rho_A\,R_A = 0.3$$

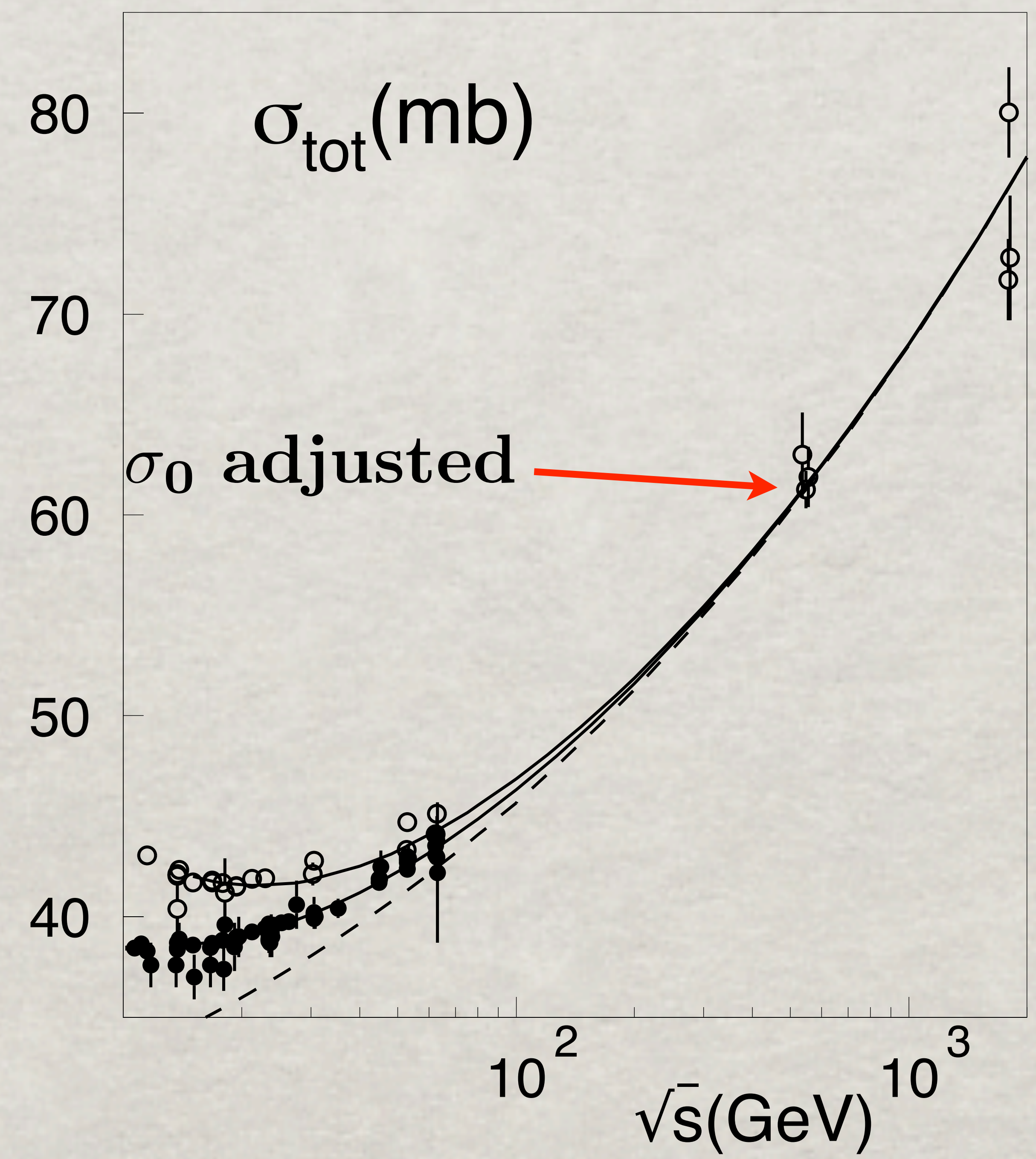
Evidences for two-scales

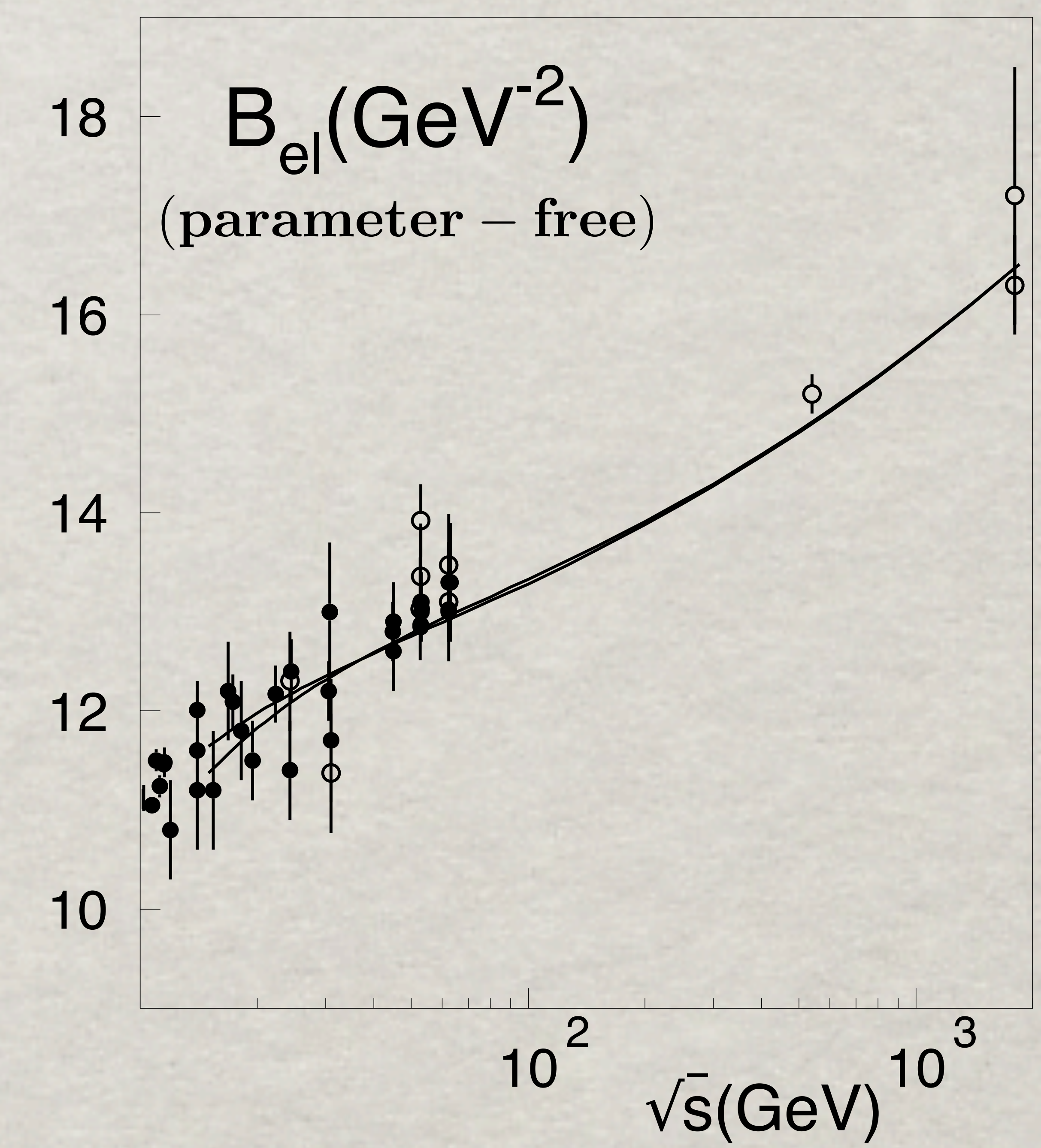
As far as gluon radiation is suppressed, hadronic cross sections should rise slowly with energy. Indeed, the observed energy dependence of the total pp cross section is well described [B.K., I.Potashnikova, E.Predazzi, B.Povh, PRL 85(2000)507]

$$\sigma_{tot} = \sigma_0 + \sigma_1 \left(\frac{s}{s_0}\right)^{\Delta}$$

$$\Delta = \frac{4\alpha_s}{3\pi} = 0.17$$

$$\sigma_1 = \frac{27}{4} C\, r_0^2$$





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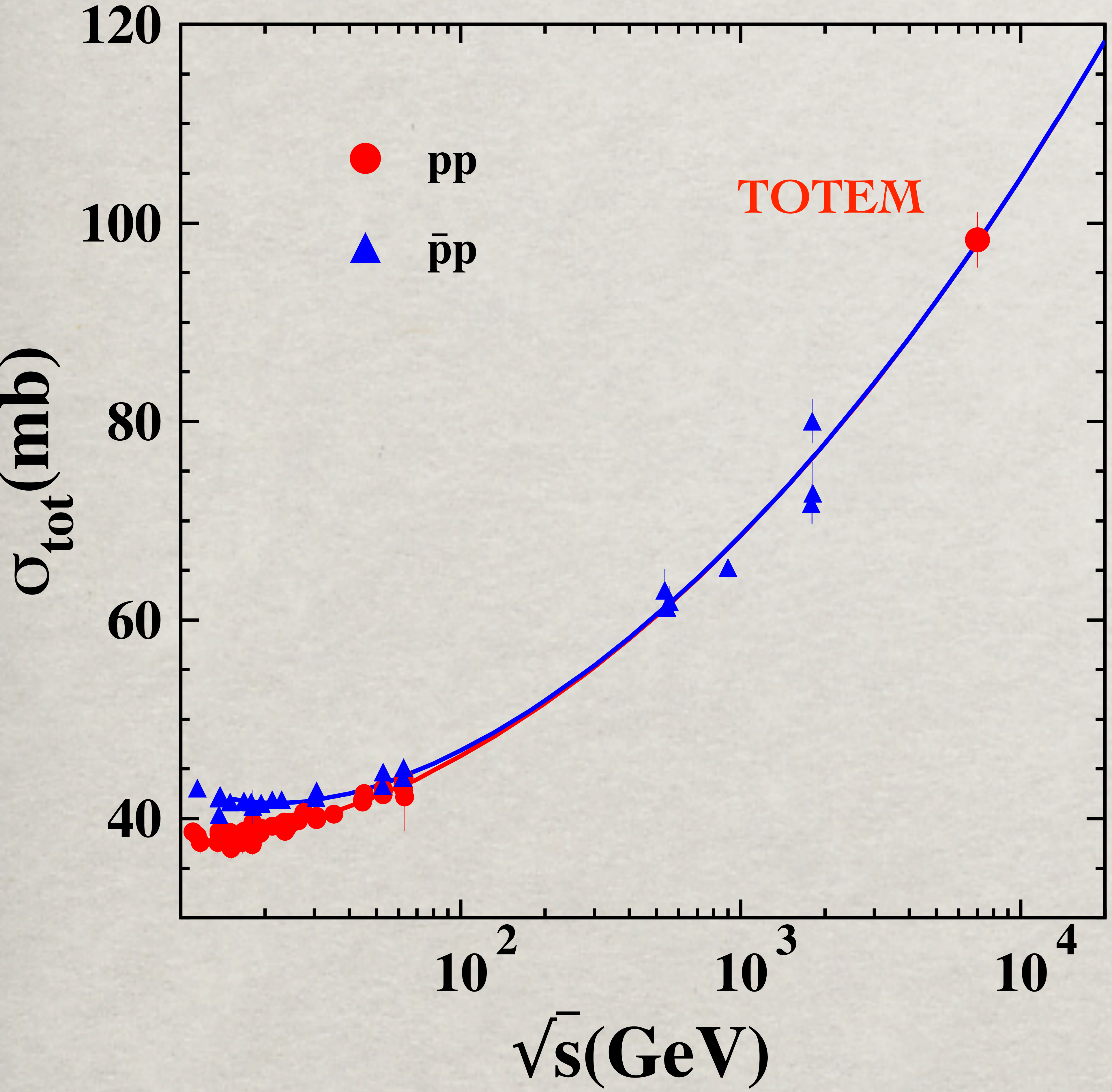
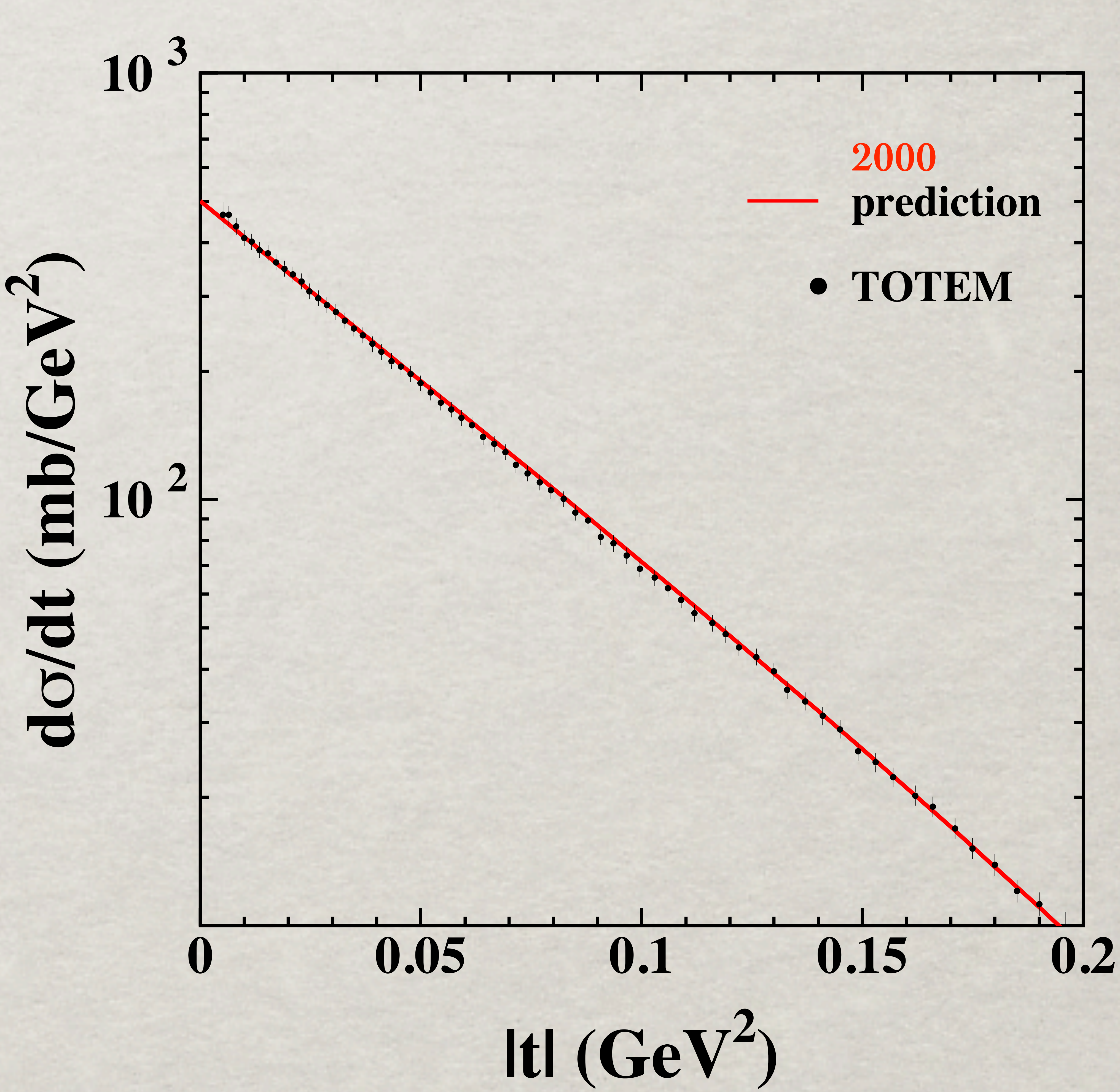
Evidences for two-scales

B.K., I.Potashnikova, B.Povh D86(2012)051502]





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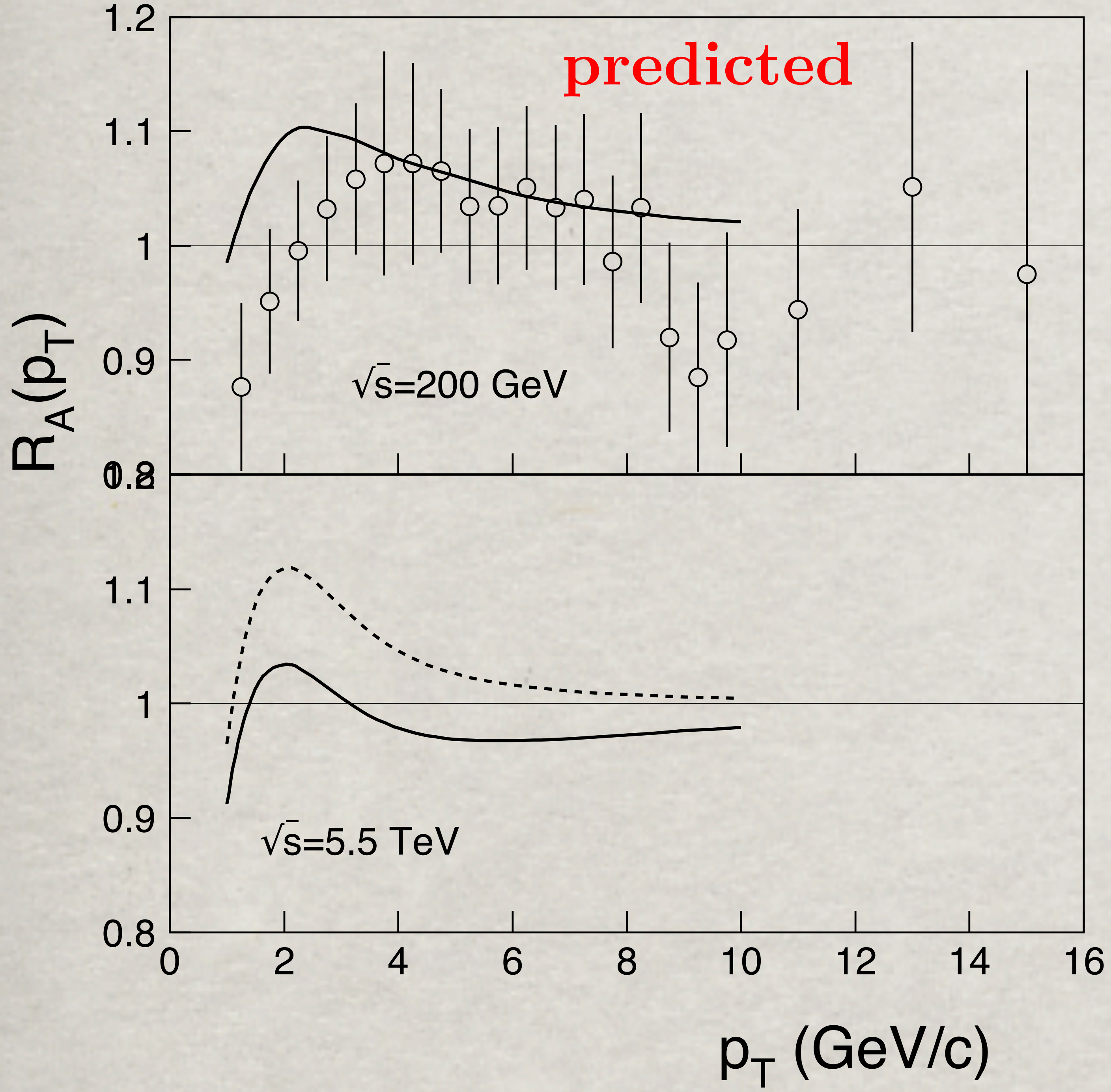
Cronin effect: predicted and observed

B.K., J.Nemchik, A.Schafer, A.Tarasov, PRL 88(2002)232303:



The Cronin enhancement at fixed target experiments was huge, nearly factor 2. The predicted weak effect of 10% for RHIC was nontrivial. It is a direct consequence of existence of the short length-scale for gluons.

Some of the Color Glass Condensate models traditionally exaggerate the magnitude of coherence effects.

CGC:

D.Kharzeev, E.Levin,L.McLerran, PL B561(2003)93:

to decrease as $(N_{part}^{Au})^{-1/2}$. In 15% most central dAu events, where $N_{part}^{Au} \simeq 12$ [53], we therefore expect to see the normalized yield of $(6/12)^{1/2} \simeq 0.7$, corresponding to $\simeq$ 30% suppression of high p_t particles[†]. The scaling of semi–hard processes in dAu collisions with centrality at RHIC energy can thus expected to be drastically different from that observed previously at fixed target energies, where at high p_t the yields of particles were proportional to the number of collisions.

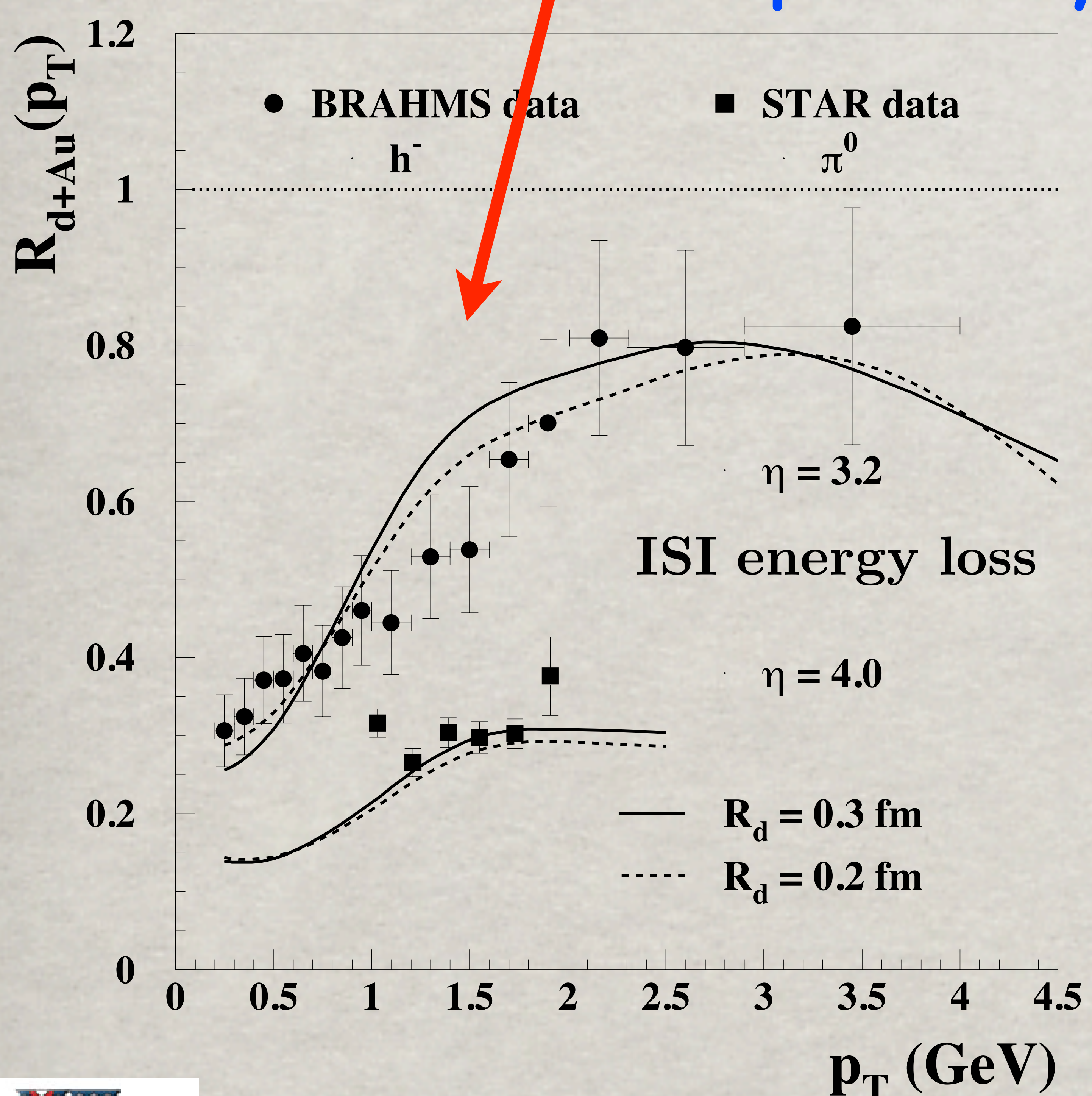
[†]Numerical calculations according to the formulae given above give somewhat smaller, but close, $\simeq$ 25% suppression effect.

Toward the kinematic bound

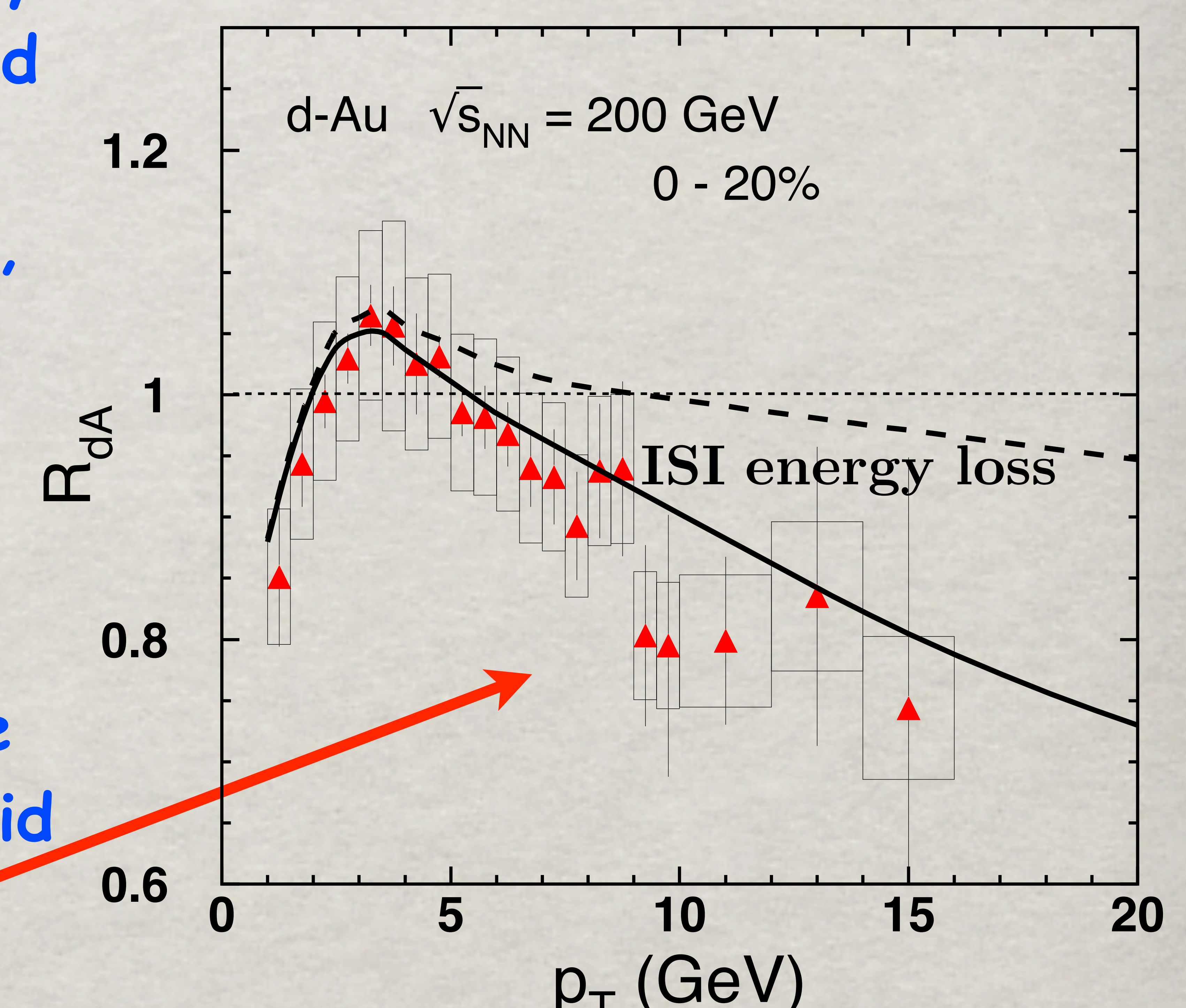
Smallest x2 are reached at forward rapidities. This is why it was tempting to interpret the suppression observed at forward rapidities by BRAHMS and STAR, as a result of coherence, CGC [D.Kharzeev, Yu.Kovchegov, K.Tuchin (2003)]

Initial-state energy loss suppresses particle production toward the kinematic limit x1->1 [B.K., J.Nemchik, I.Potashnikova, I.Schmidt (2005)]

A possibility to settle this controversy would be to go to higher energies and check with the nuclear effects at the same x2, but further away from the kinematic limit (see LHC data below).



One also approaches the kinematic limit at the mid rapidity, but high pT.



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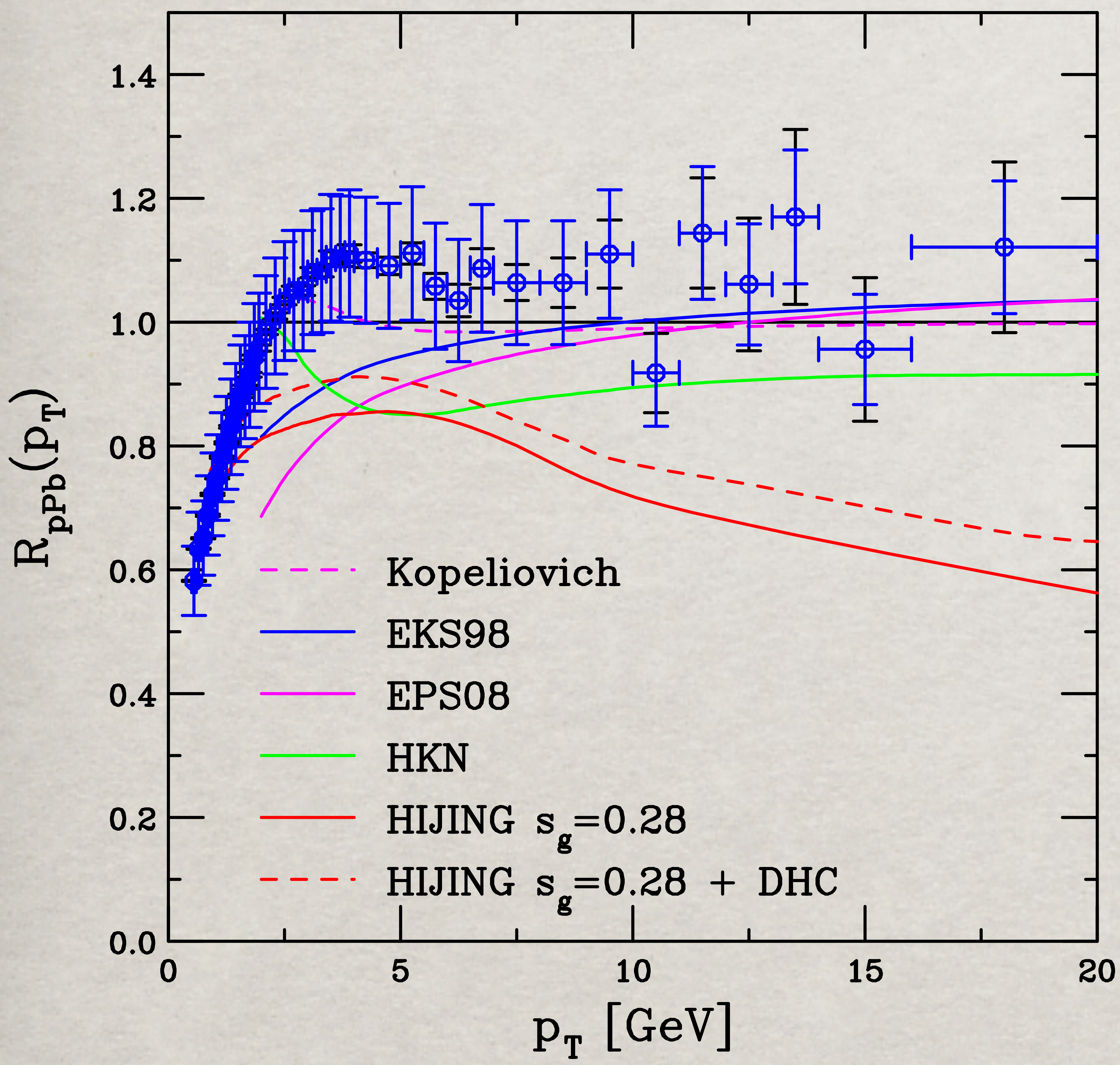
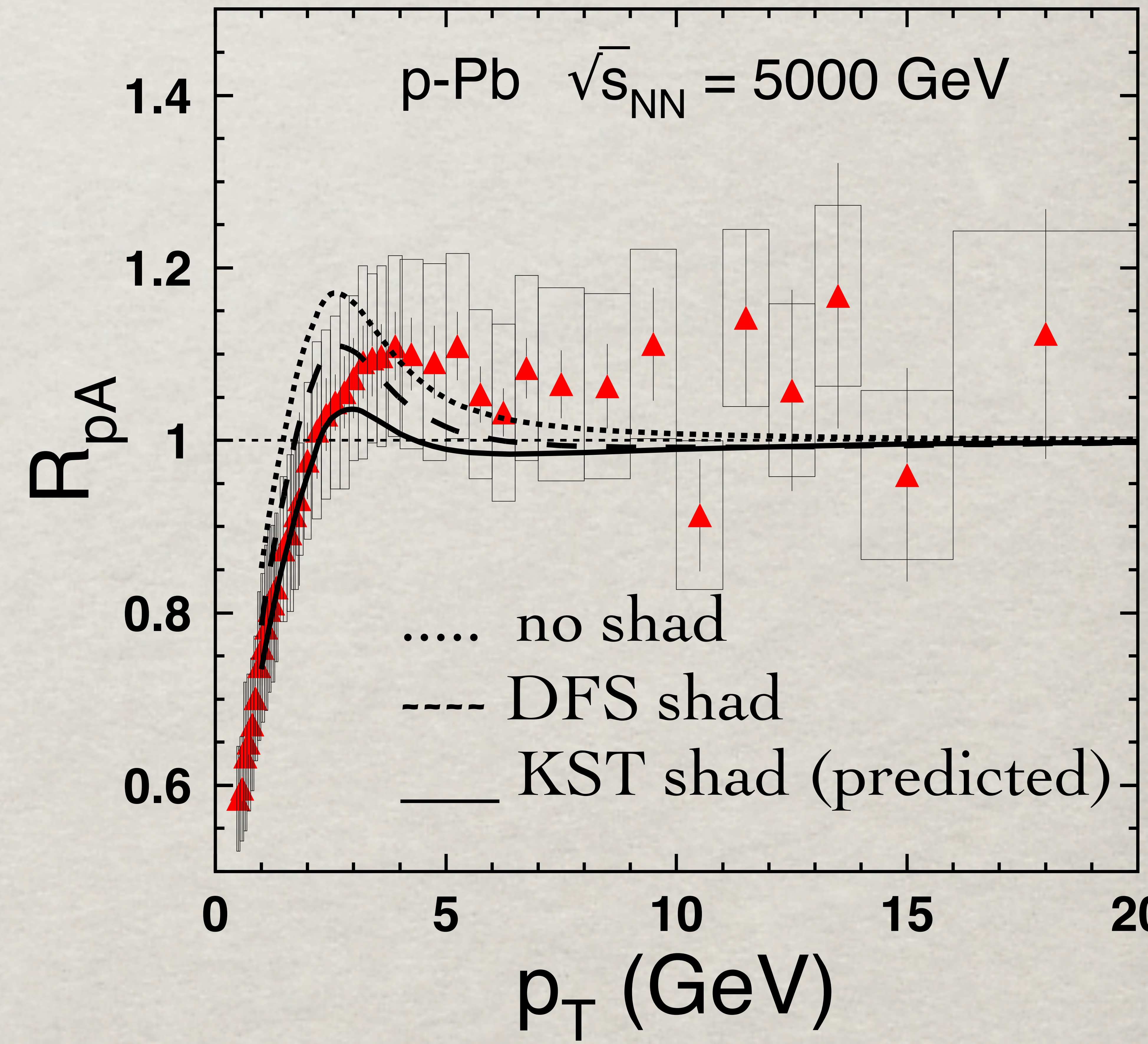
At last LHC...

R.Vogt et al, arXiv: 1301.3395



The only successful prediction

B.K., J.Nemchik, A.Schafer, A.Tarasov, PRL 88(2002)232303:



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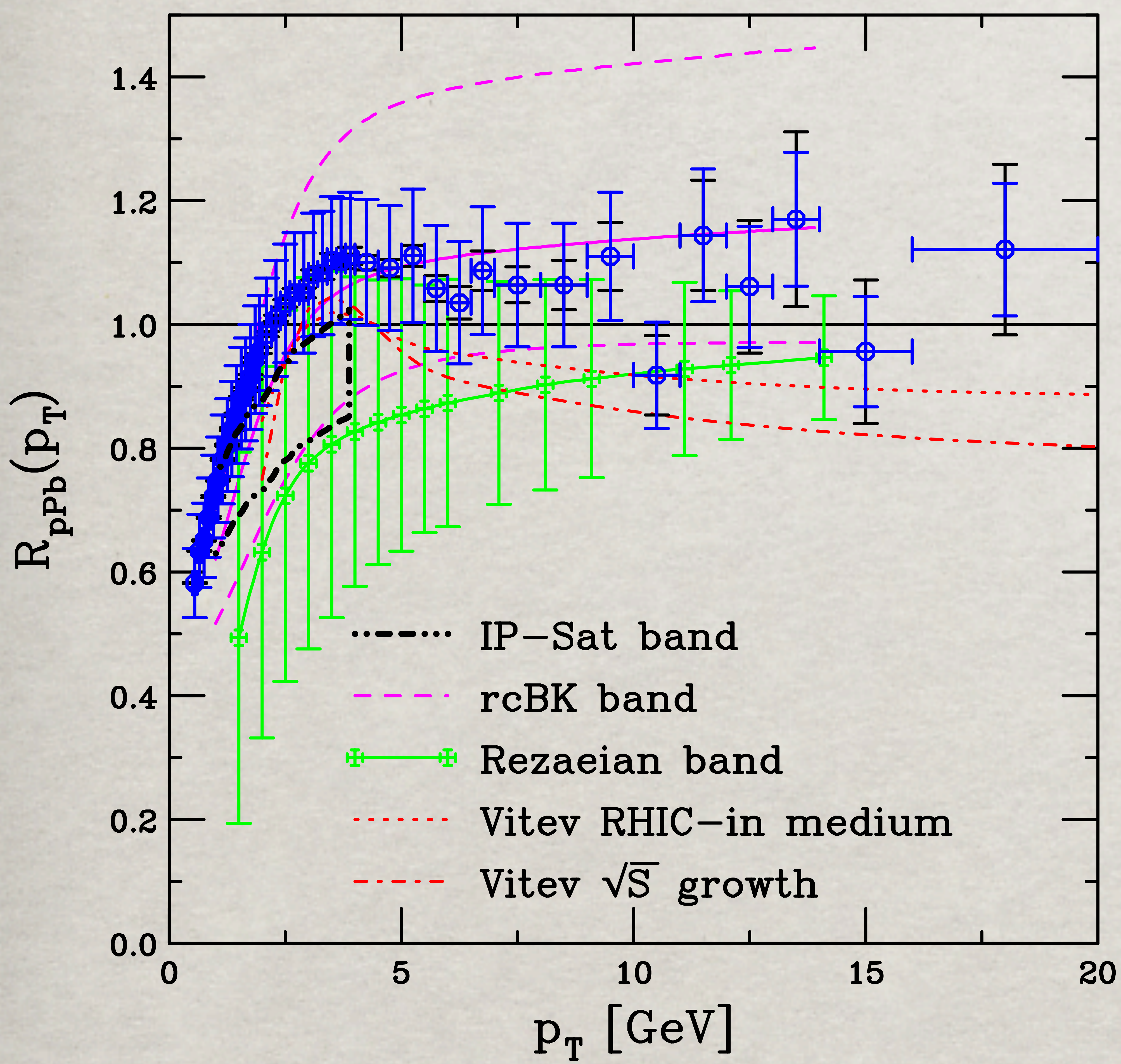
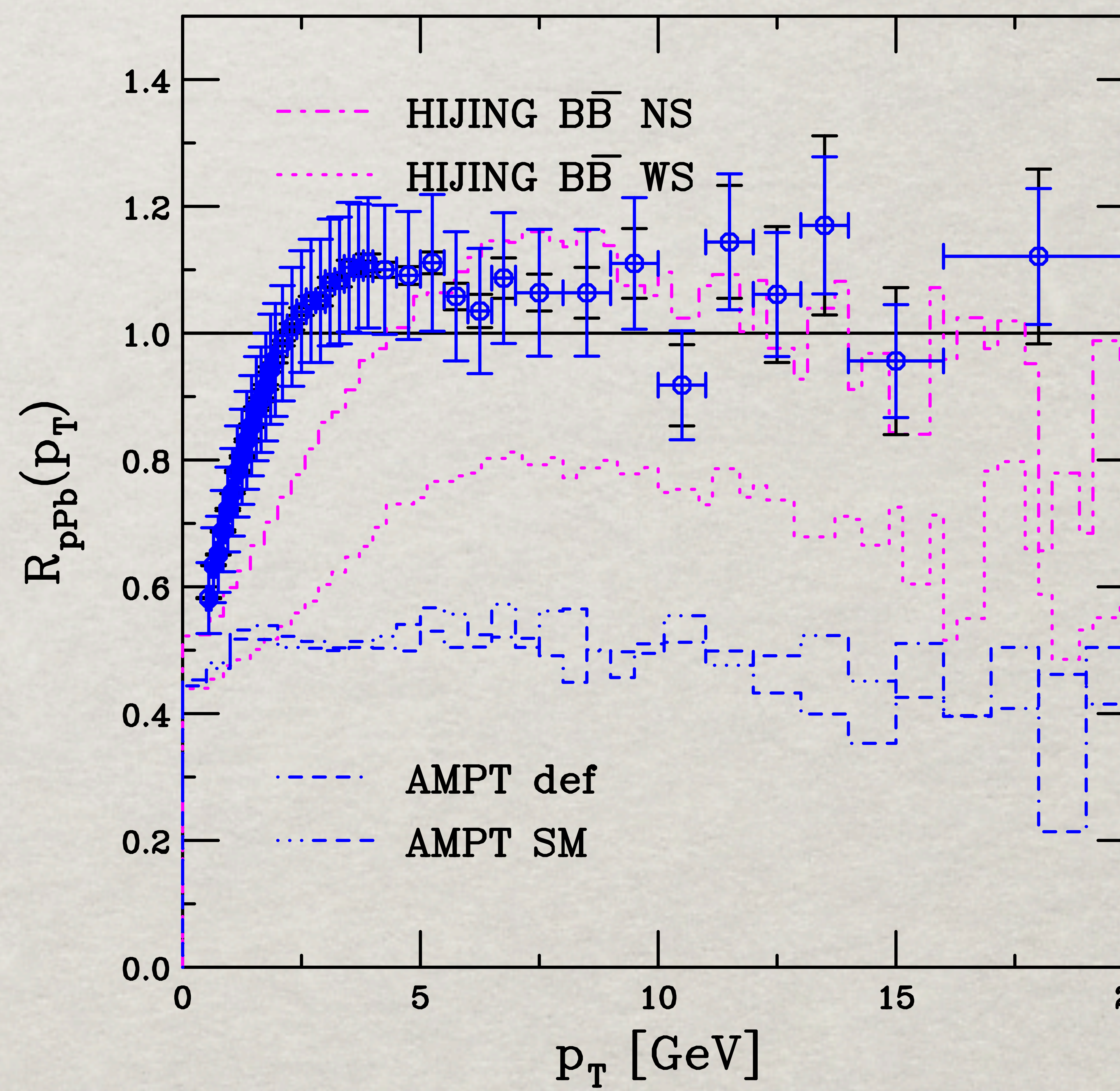
At last LHC...



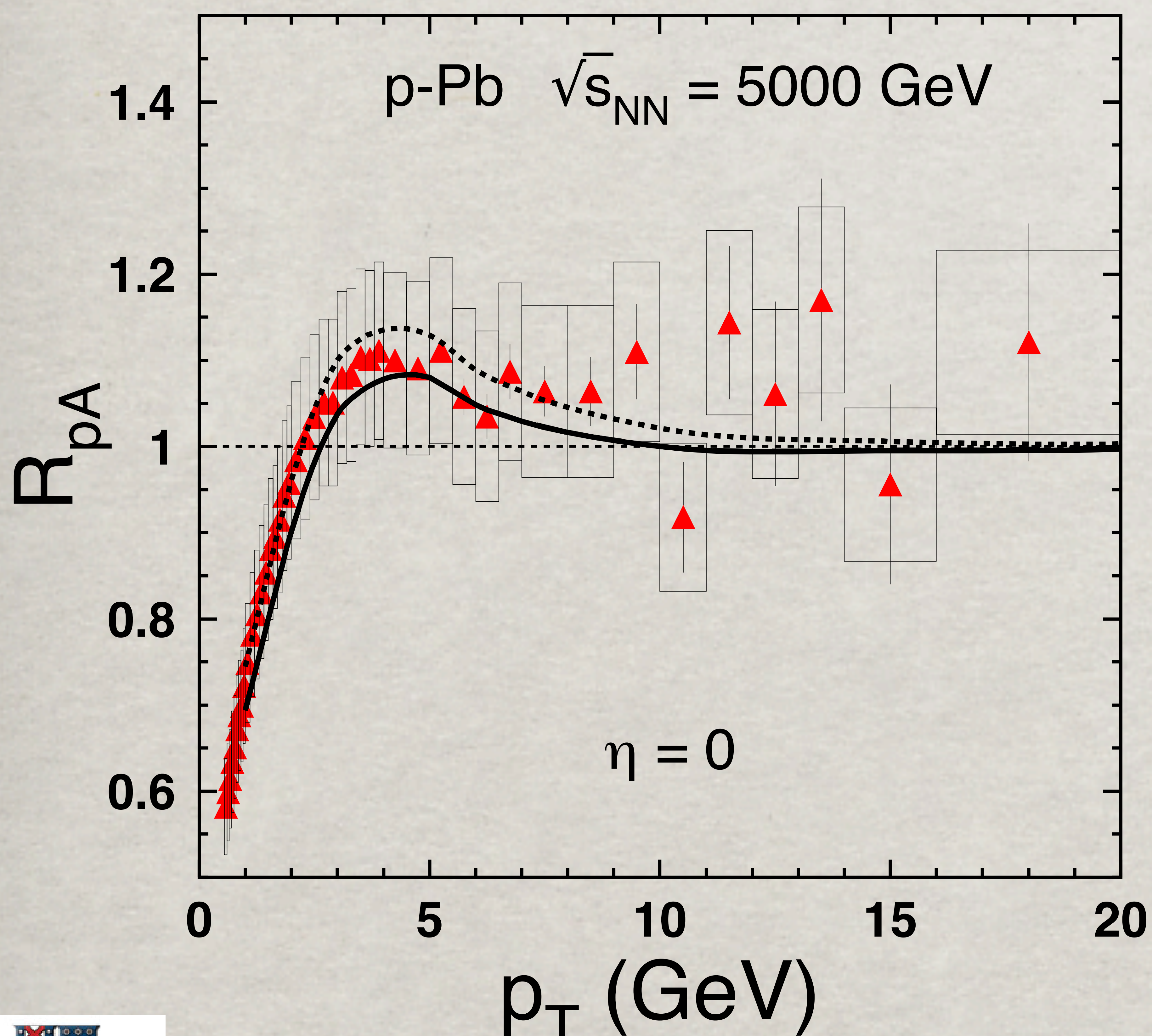
$R_{pPb}(p_T)$
p_T [GeV]
IP−Sat band
rcBK band
Rezaeian band
Vitev RHIC−in medium
Vitev √S growth



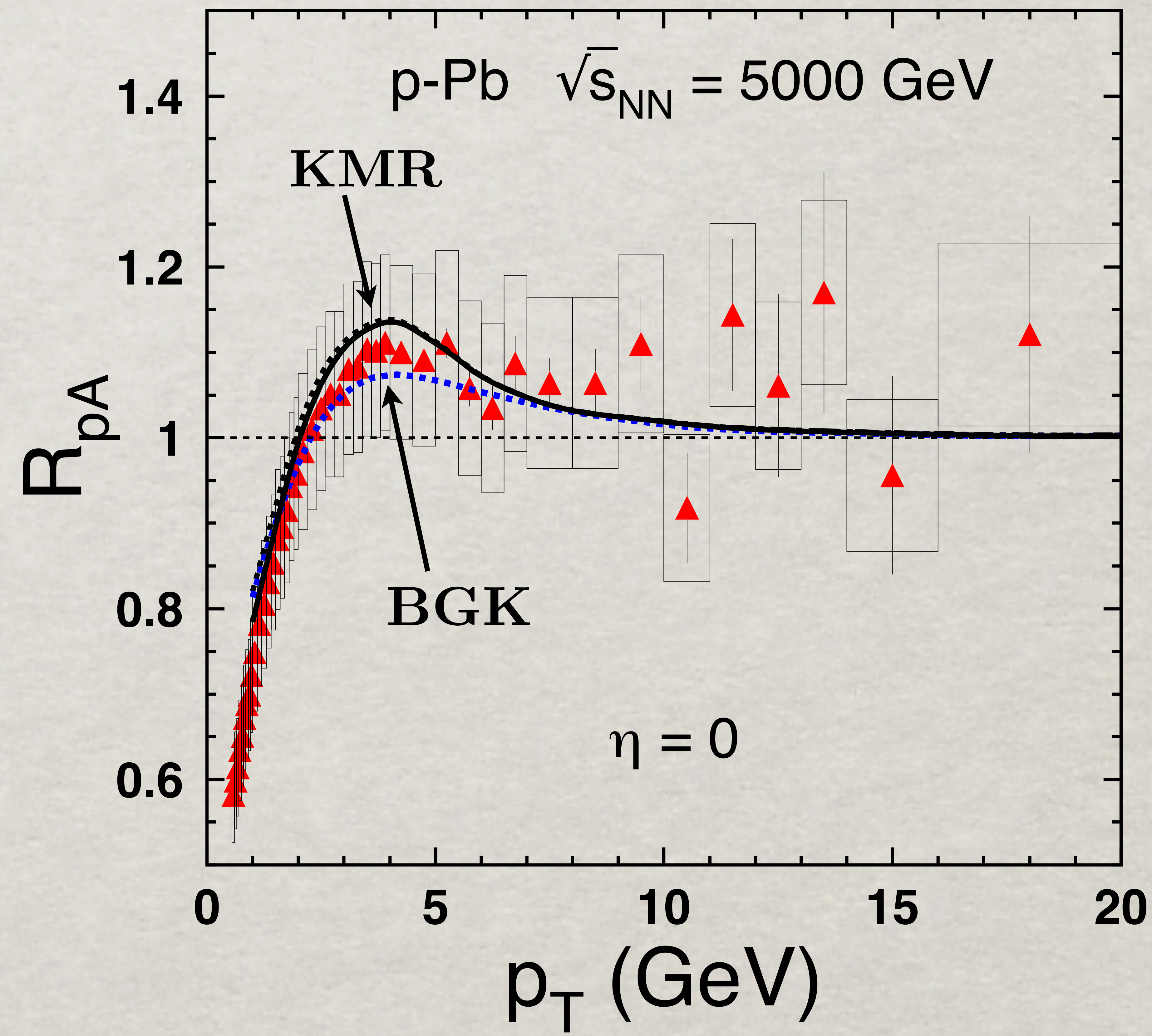
$R_{pPb}(p_T)$
p_T [GeV]
HIJING BB̄ NS
HIJING BB̄ WS
AMPT def
AMPT SM

Revisited and improved
A more realistic dipole cross section

Kimber-Martin-Ryskin unintegrated gluon PDF



Bartels-Golec-Biernat-Kowalski dipole cross section



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Summarizing,

pA data for the Cronin effect at LHC provide a strong support for the two-scale hadronic structure and weak gluon shadowing. Many popular models for coherent effects and results of global analyses are "ruled out".

Any judgment on gluon shadowing extracted from hadronic processes suffers of considerable model dependences.

We desperately need new precise measurements for the Q^2 of DIS on nuclei. Only this way we can settle the current dramatic controversy in available information on the magnitude of gluon shadowing (and CGC).