Looking forward in pA@LHC

Mark Strikman, PSU

Forward physics at RHIC,
July 30, 2012

Summary of some of the discussions at the workshop pA@LHC, CERN, June 4 - 7

Main emphasize: Forward physics - LHC vs RHIC

what issues can be best studied at LHC

what issues can be best studied at RHIC

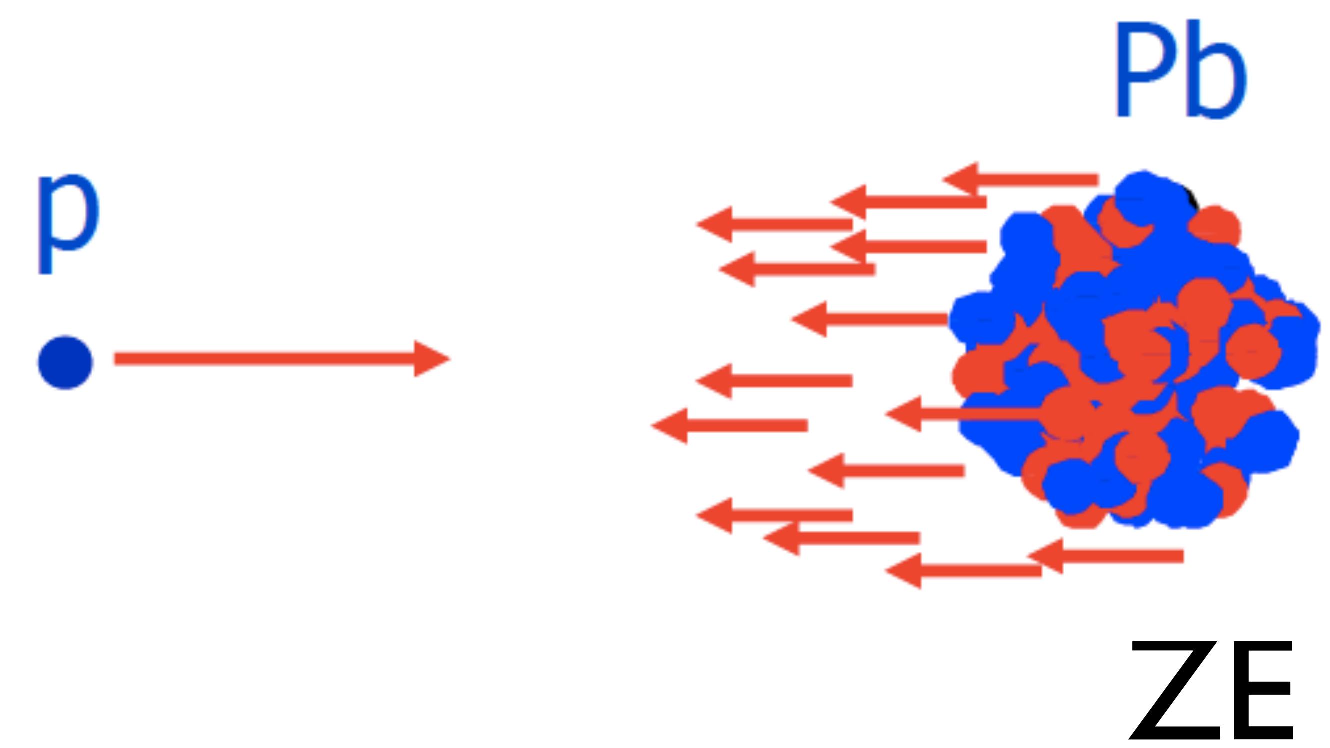
where one can gain from coordinated studies

will talk little on the results presented at pA@LHC by speakers who will also speak at this meeting.

will not talk about benchmark measurements which are mostly for central rapidities.

MACHINE

Collision energy:



Beam energy at LHC: E_p=3.5 TeV (or 4 TeV)
E_A=1.38 TeV

$$\sqrt{s_{pN}} = 4.4\,TeV$$

SCHEDULE

- Feasibility Run - I : (2011-Oct 31)
  Stored Pb bunches in presence of many proton bunches – OK
- Feasibility Run – II: 2012 (Aug/Sep)
- 1st Physics Run: March 2013

Target p-Pb performance in 2012 (ATLAS/CMS)

Main choice:	**Units**	**200 ns**		**100 ns**	
Beam energy/(Z TeV)	*Z* TeV	3.5	4	3.5	4
Colliding bunches		356	356	550	550
β^*	m	0.7	0.6	0.7	0.6
Emittance protons	μm	3.75	3.75	3.75	3.75
Emittance Pb	μm	1.5	1.5	1.5	1.5
Pb/bunch	10^8	1.2	1.2	0.8	0.8
p/bunch	10^{10}	1.15	1.15	1.15	1.15
Initial Luminosity L_0	10^{28} cm^{-2} s^{-1}	**6.2**	**8.3**	**6.4**	**8.5**
Operating days		**22**	**24**	**22**	**24**
Difficulty (subjective)		**0.9**	**1**	**0.9**	**1**
Integrated luminosity	nb^{-1}	**15.4**	**22.4**	**15.9**	**23.1**
Nucleon-nucleon	pb^{-1}	**3.2**	**4.7**	**3.3**	**4.8**

Integrated luminosity by scaling from 2011 (c.f. ~7 pb^{-1} NN in Pb-Pb)
Average Pb bunch intensities from best 2011 experience.
Proton bunch intensities conservative, another factor 10 **???**
Proton emittance conservative, another factor 1.37 **?**
Untested moving encounter effects, possible reduction factor 0.1 **??**

All 6 detectors plan to take pA data

only ALICE , ATLAS, CMS took AA data

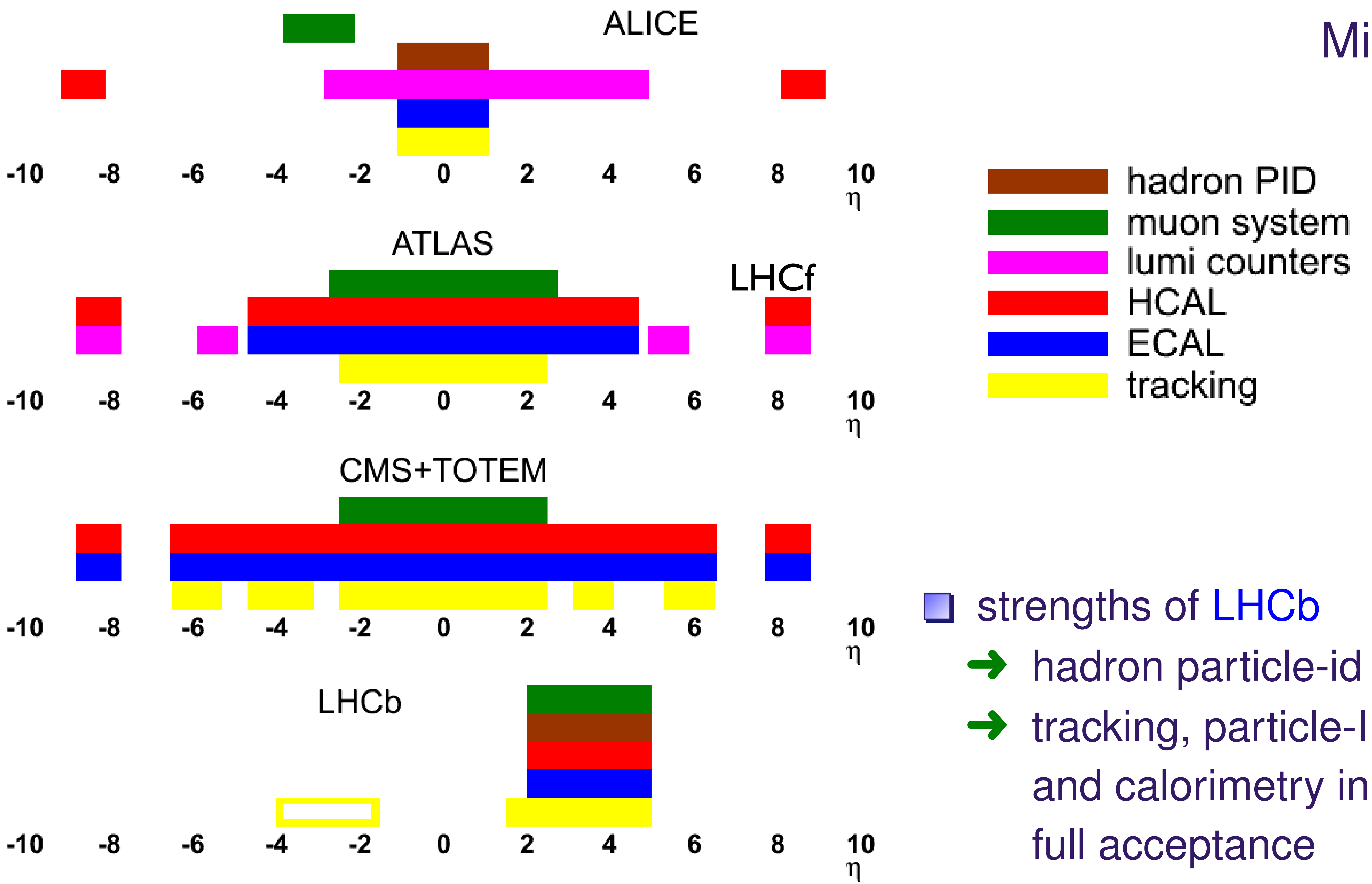
LHCb, LHCf, TOTEM acceptance at larger rapidities than ATLAS and CMS important for forward physics

aim to exchange event information with ATLAS CMS

Details on detectors - David D'Entrria talk - just one slide

Comparison of Angular Coverage

Michael Schmelling



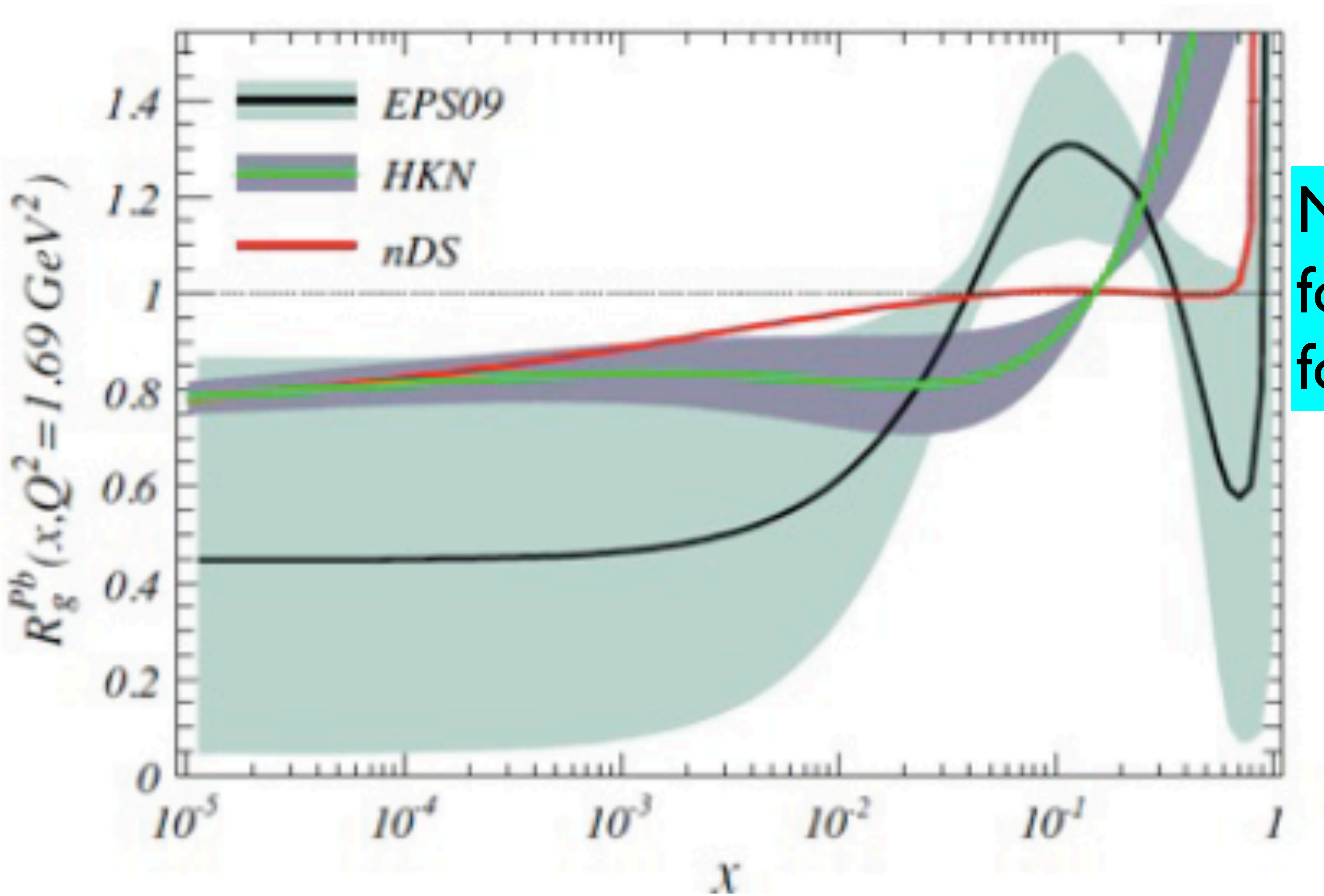
- strengths of LHCb
  - ➜ hadron particle-id
  - ➜ tracking, particle-ID and calorimetry in full acceptance

Nuclear pdfs

Juan Rojo descibed plans to perform extraction of nuclear pdfs using only LHC data (dijets, Z,W, γ') from AA and pA. Similar to pp program.

Problems - no corresponding data base for eA as for ep

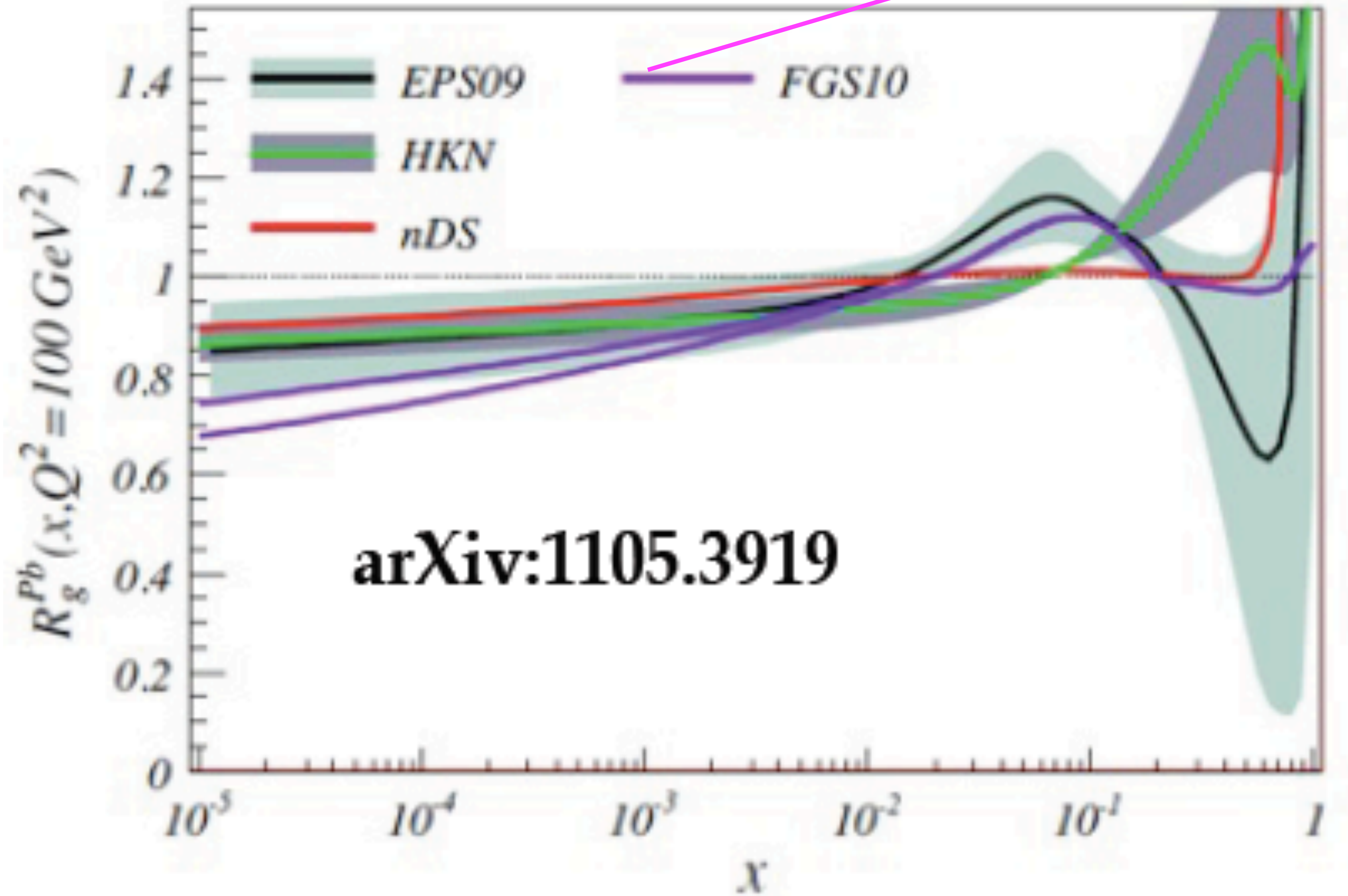
Main interest: the ratios nuclear pdf/nucleon pdf at moderate Q^2. Expected very small (few %) deviations from one for $Q^2 \sim 10^4$ GeV^2. Instability of backward evolution.



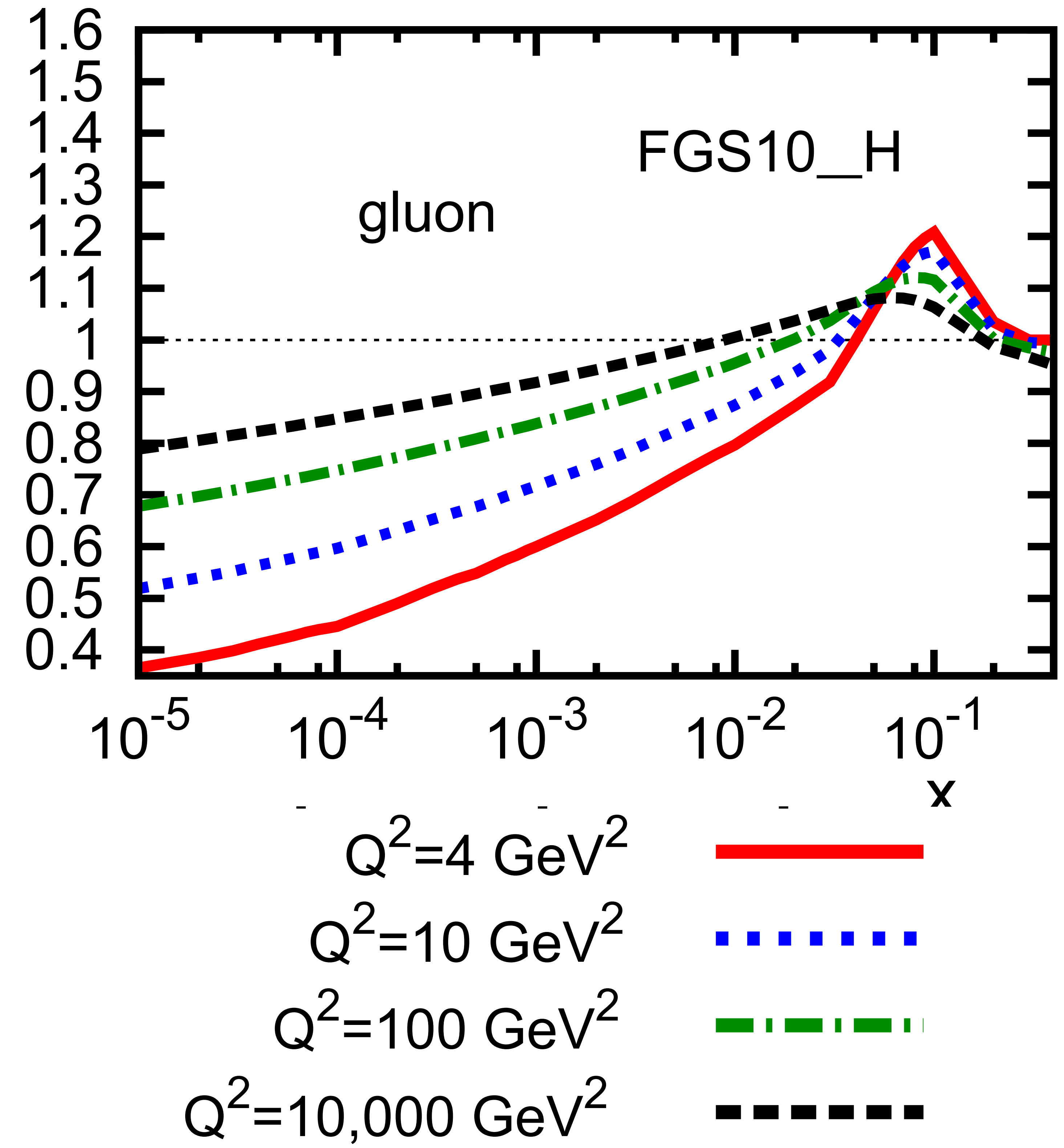
No data on $F_{2A}(x < 10^{-2})$ for $Q^2 \geq 4$ GeV^2. Gluons for x<0.05.

RHIC forward data are not in the LT kinematics

Parametrizations based on fitting the data with no theory input - uncertainty at normalization point even begger than in the plot.



Prediction of the LT theory of nuclear shadowing based on factorization theorem for diffraction and AGK



Strong reduction of nuclear shadowing at fixed x due to the DGLAP flow of partons from larger x

Another challenge:determine nuclear diagonal generalized parton distributions ≡ b dependent npdfs

Ilkka Helenius
In collaboration with
Kari J. Eskola, Heli Honkanen, and Carlos A. Salgado

Nuclear modifications with spatial dependence

- We replace

$$R_i^A(x,Q^2) \rightarrow r_i^A(x,Q^2,\mathbf{s}),$$

where $\mathbf{s}$ = the transverse position of the nucleon

- Definition

$$R_i^A(x,Q^2) \equiv \frac{1}{A}\int d^2\mathbf{s}\, T_A(\mathbf{s}) r_i^A(x,Q^2,\mathbf{s}),$$

where $R_i^A(x,Q^2)$ from EKS98 or EPS09 (= data!)

- Assumption: spatial dependence related to $T_A(\mathbf{s})$

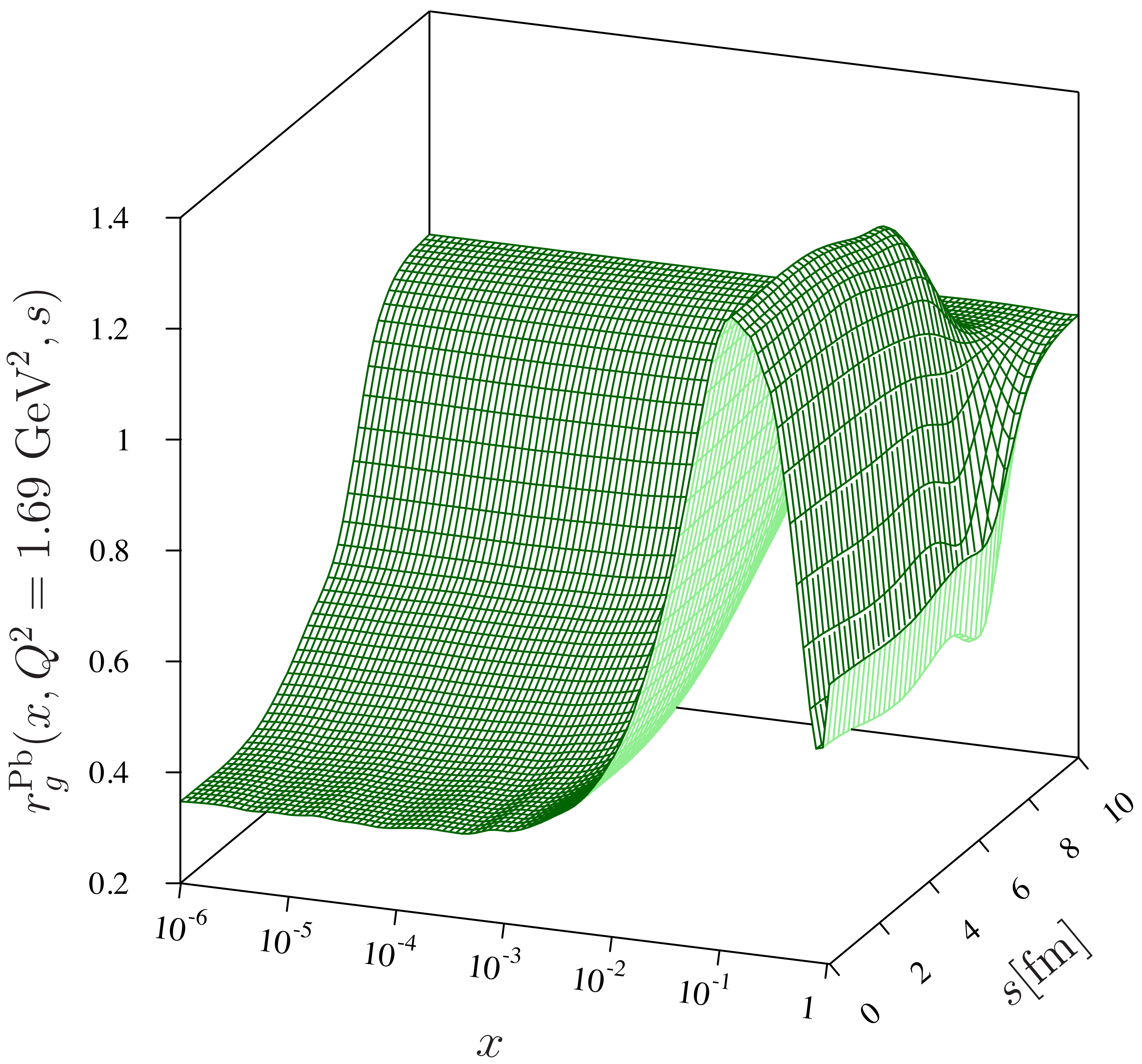
$$r_A(x,Q^2,\mathbf{s}) = 1 + c_1(x,Q^2)[T_A(\mathbf{s})] + c_2(x,Q^2)[T_A(\mathbf{s})]^2 + c_3(x,Q^2)[T_A(\mathbf{s})]^3 + c_4(x,Q^2)[T_A(\mathbf{s})]^4$$

Important: No A dependence in the fit parameters $c_j(x,Q^2)$ (unlike some earlier analyses with only one fit parameter)

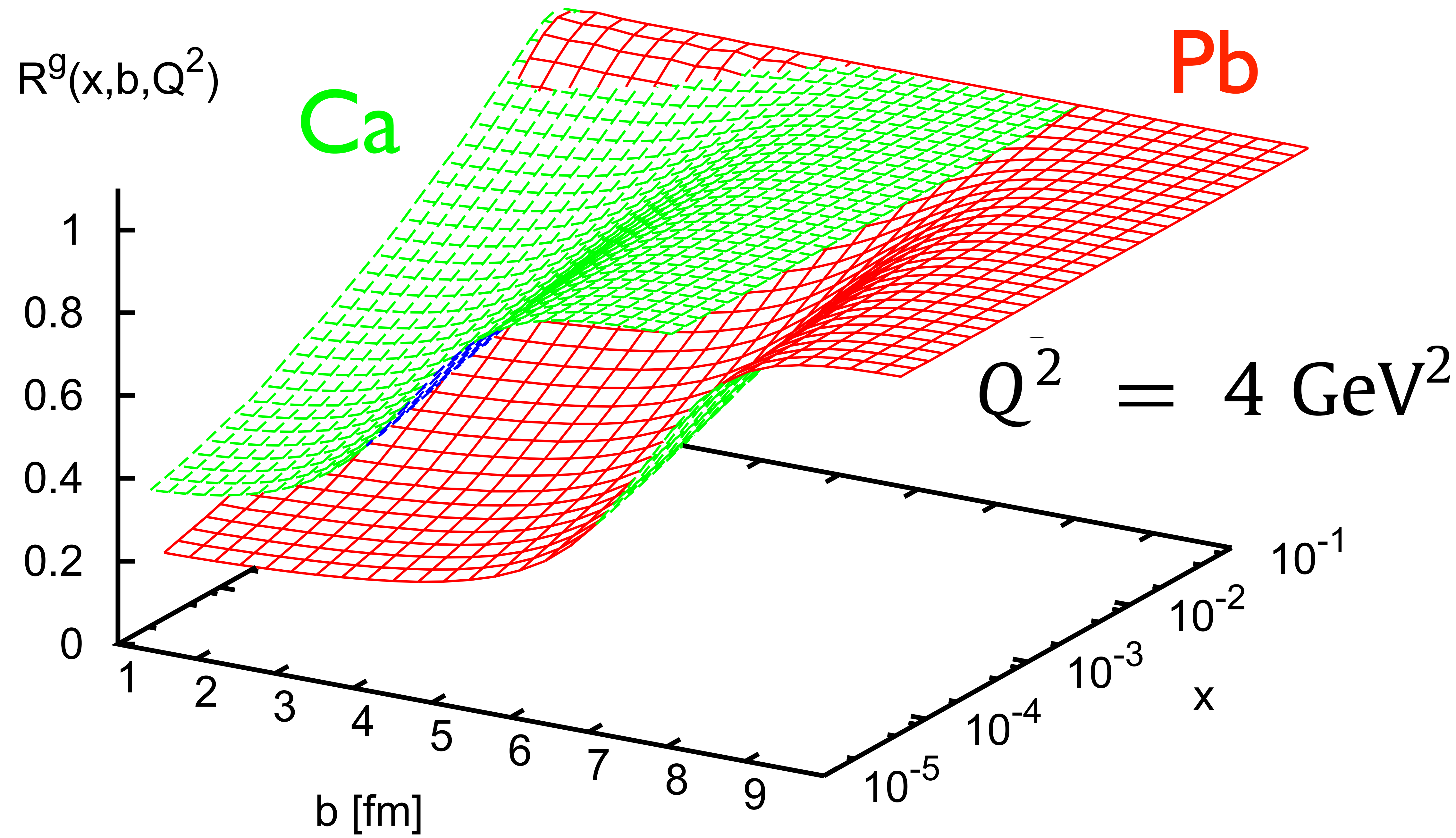
Series in powers of T is reasonably strength of interaction is small - otherwise convergence is poor. - example
1-exp(-1) -ok
1-exp(-2.5) -bad

expression not valid for x >10^{-2}-due to finite coherence length, EMC effect, etc

Spatial Dependence of Nuclear Modifications



Helenius et al fit to EKS09

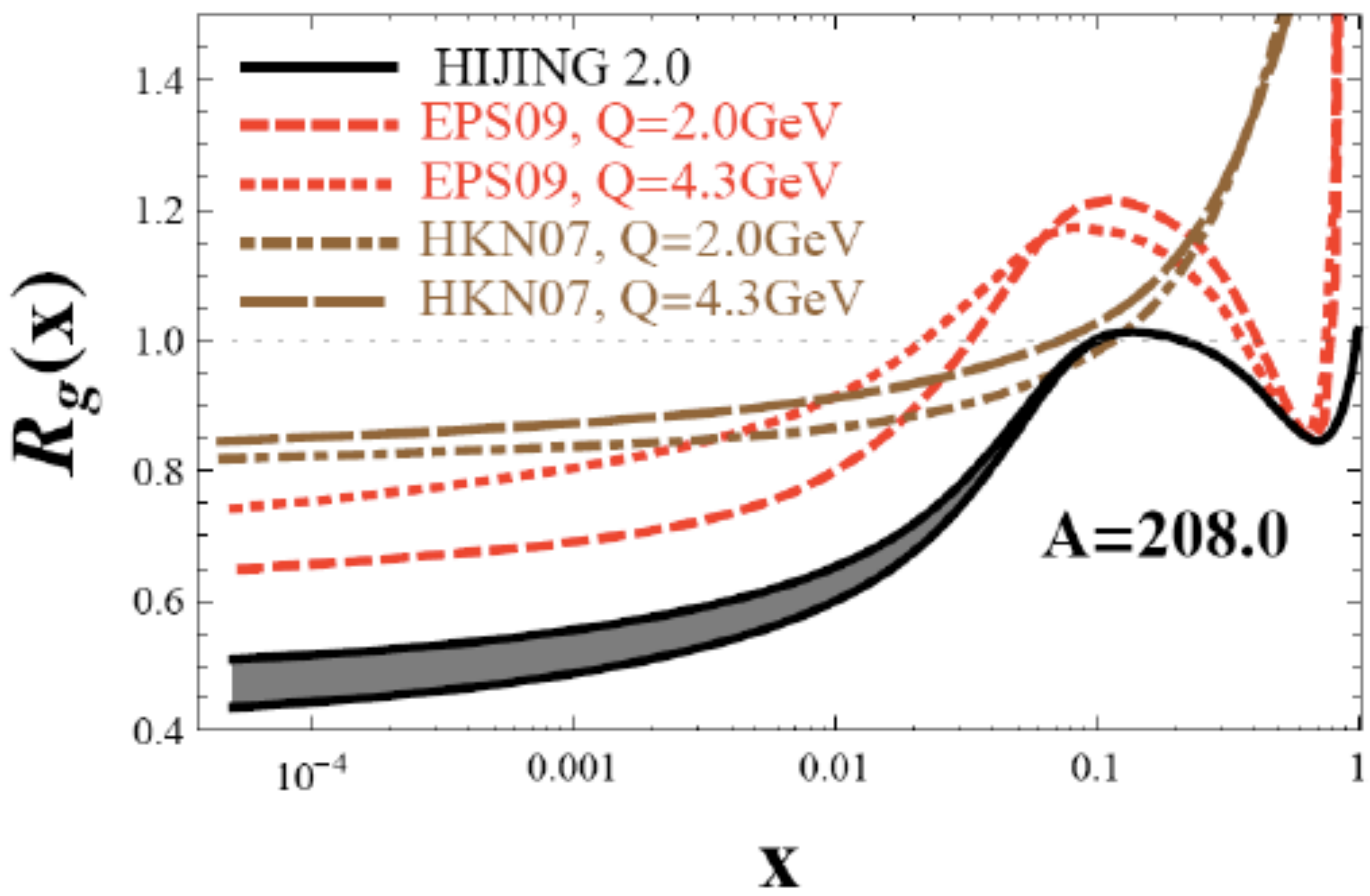


Frankfurt, Guzey, MS - calculation in LT theory

Several features similar

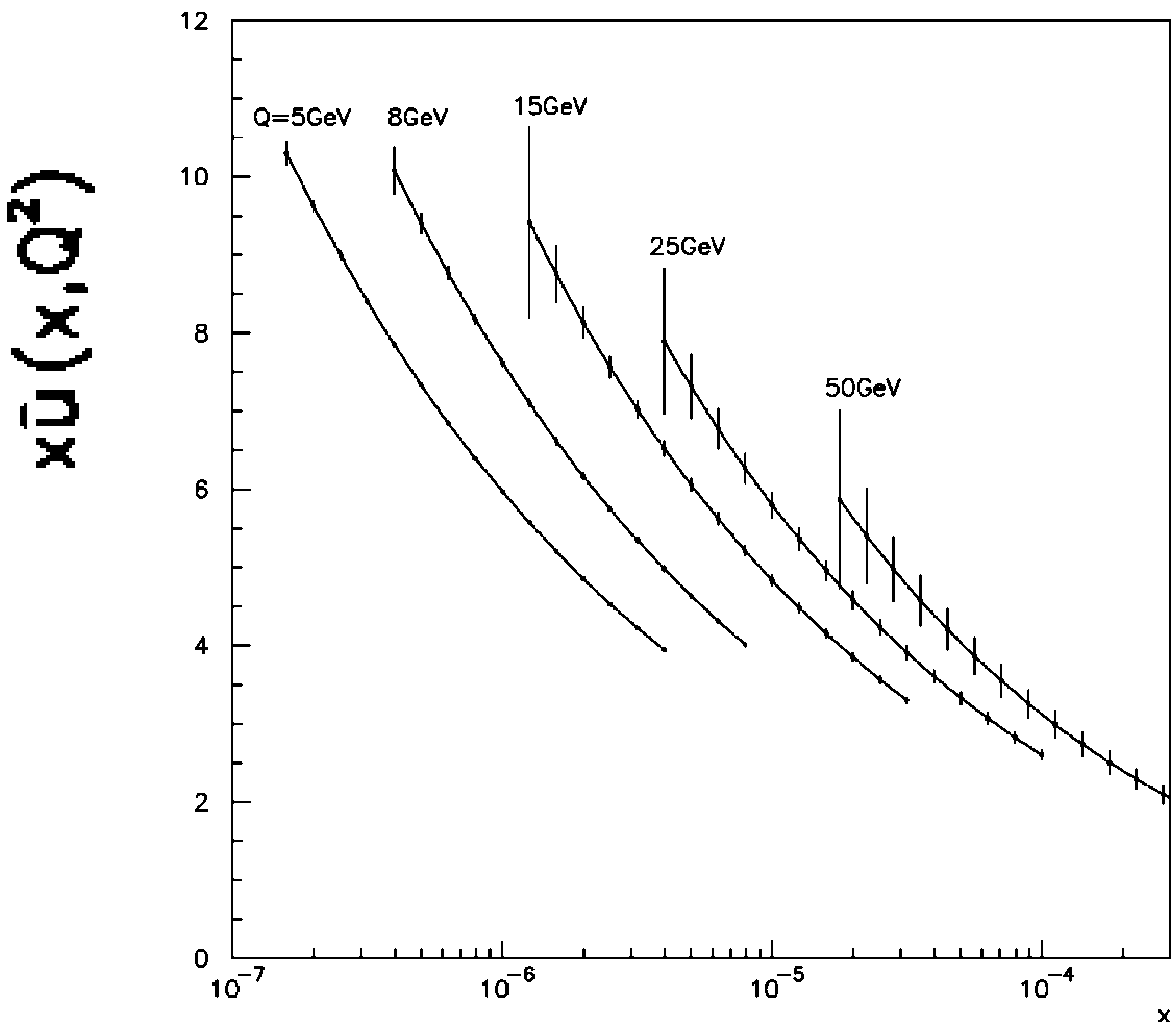
Measurement of npdfs

Most interesting - small x: LT shadowing, new physics at very small x, etc



Relevant for MC models of generic AA collisions. HIJING uses gluon shadowing to fit RHIC data (X.N.Wang). No scaling violation & violation of the momentum sum rule

Main challenge for measurements is not the counting rate but angular acceptance (plus for jets dealing with pedestal and other backgrounds)

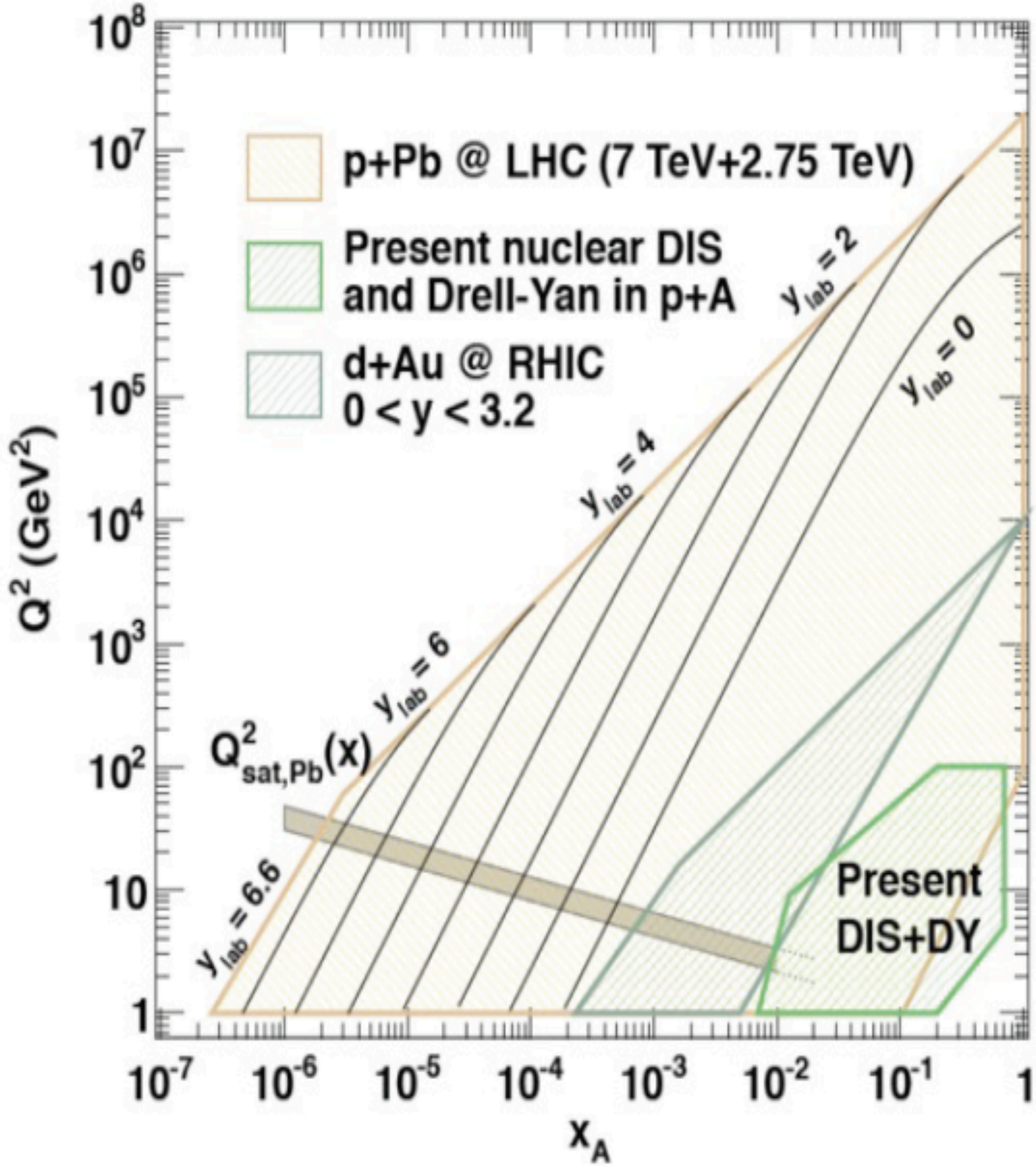


Full acceptance detector FELIX.

The u antiquark momentum distribution with error bars calculated from the Drell-Yan cross section and a data sample corresponding to an integrated luminosity of 100 pb^{-1}

Alvero, Collins, MS, Whitmore 94

for minimal lumi of the pA run errors are 4 times larger



p+Pb @ LHC (7 TeV+2.75 TeV)
Present nuclear DIS
and Drell-Yan in p+A
d+Au @ RHIC
0 < y < 3.2
$y_{lab} = 2$
$y_{lab} = 0$
$y_{lab} = 4$
$y_{lab} = 6$
$Q^2_{sat,Pb}(x)$
$y_{lab} = 6.6$
Present
DIS+DY
Q^2 (GeV^2)
x_A
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1

LHCb is sensitive to
low-x and a high-x parton collisions.

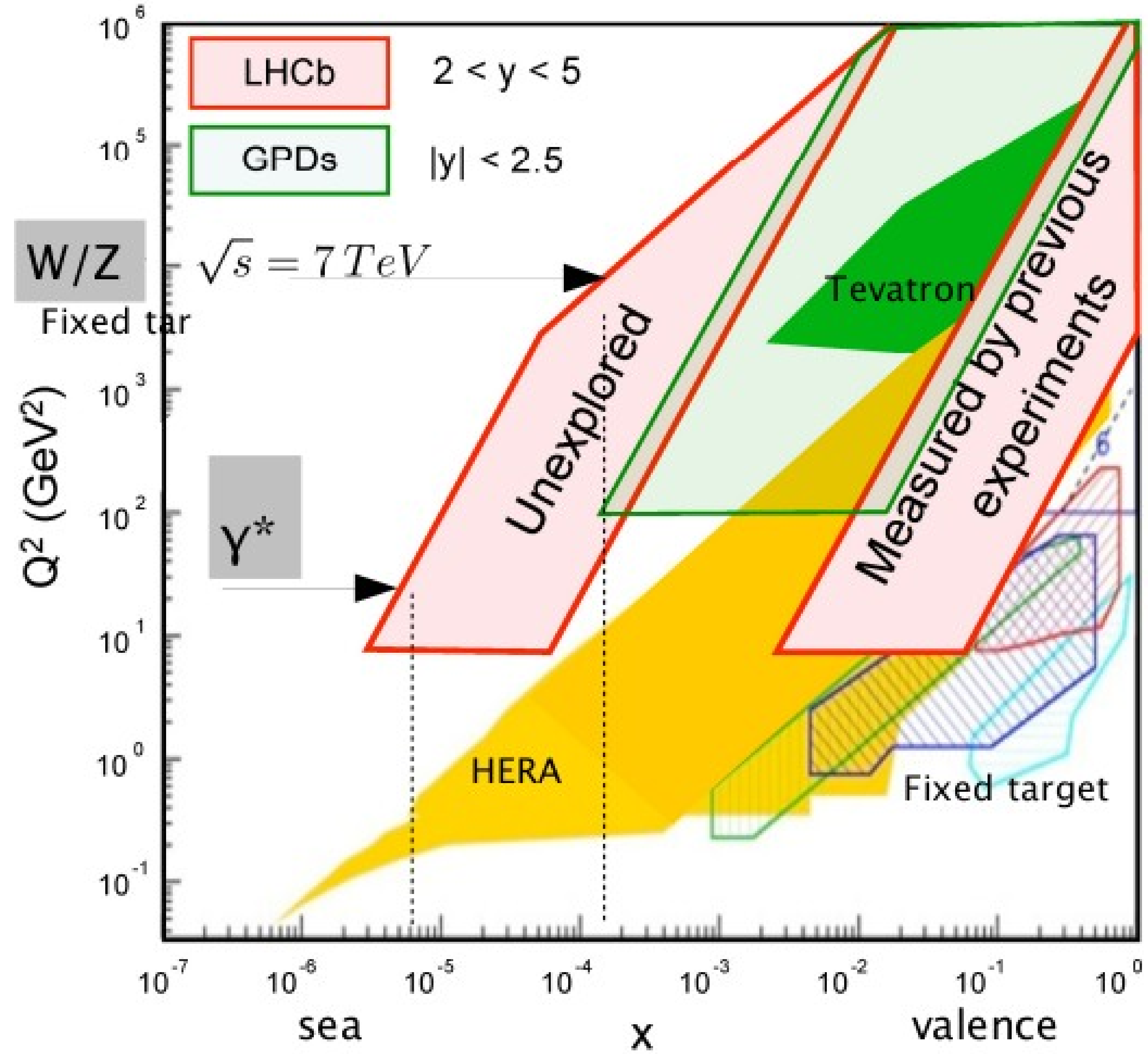
Two different regions are probed
→ inputs for PDF fits

- W/Z measurements probe

  $Q^2 = 10'000\ GeV^2$, $x = 1.7\cdot10^{-4}$

- Low mass Drell–Yan (γ^*)

  $Q^2 = 25\ GeV^2$, $x = 8\cdot10^{-6}$

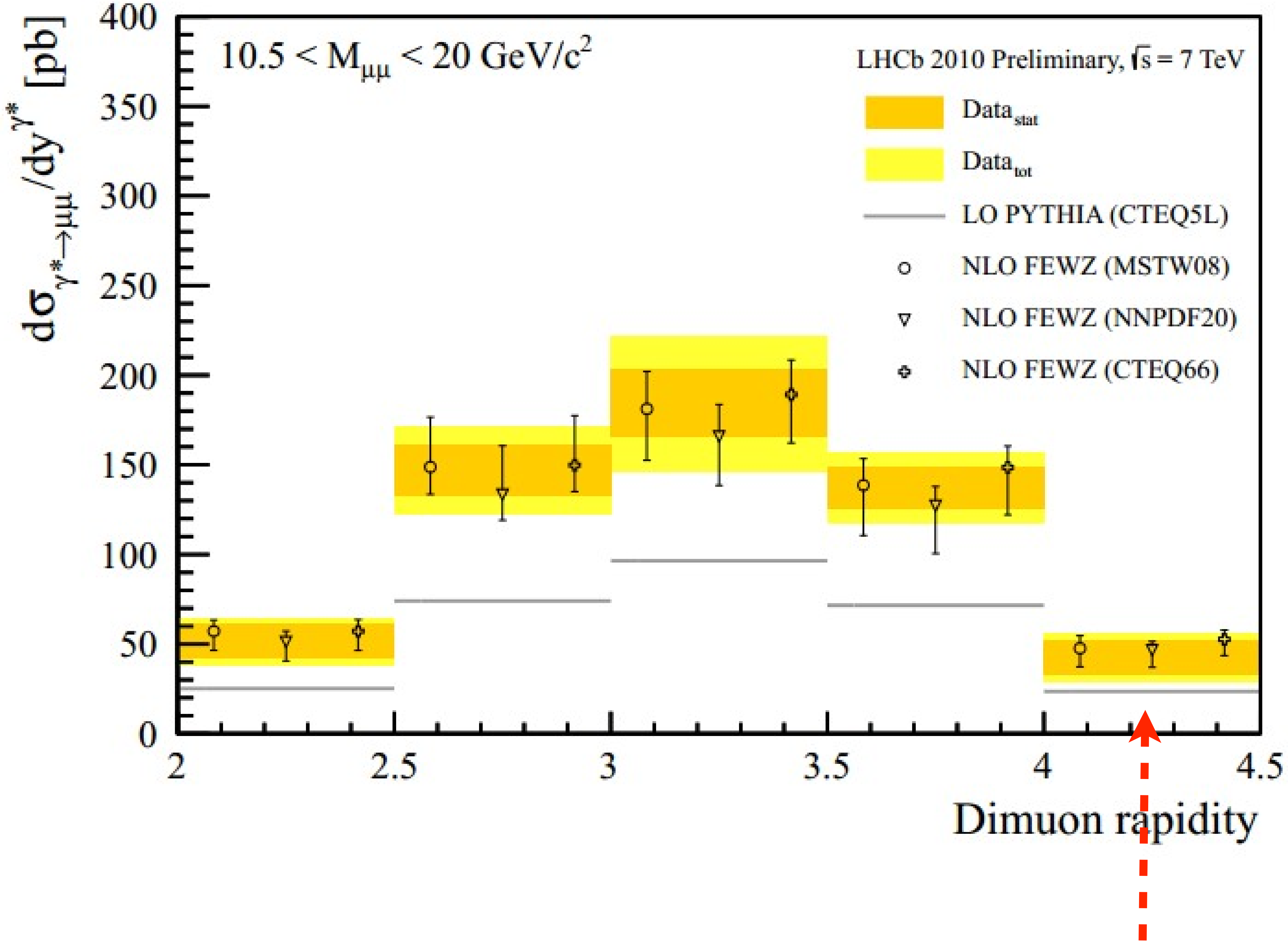


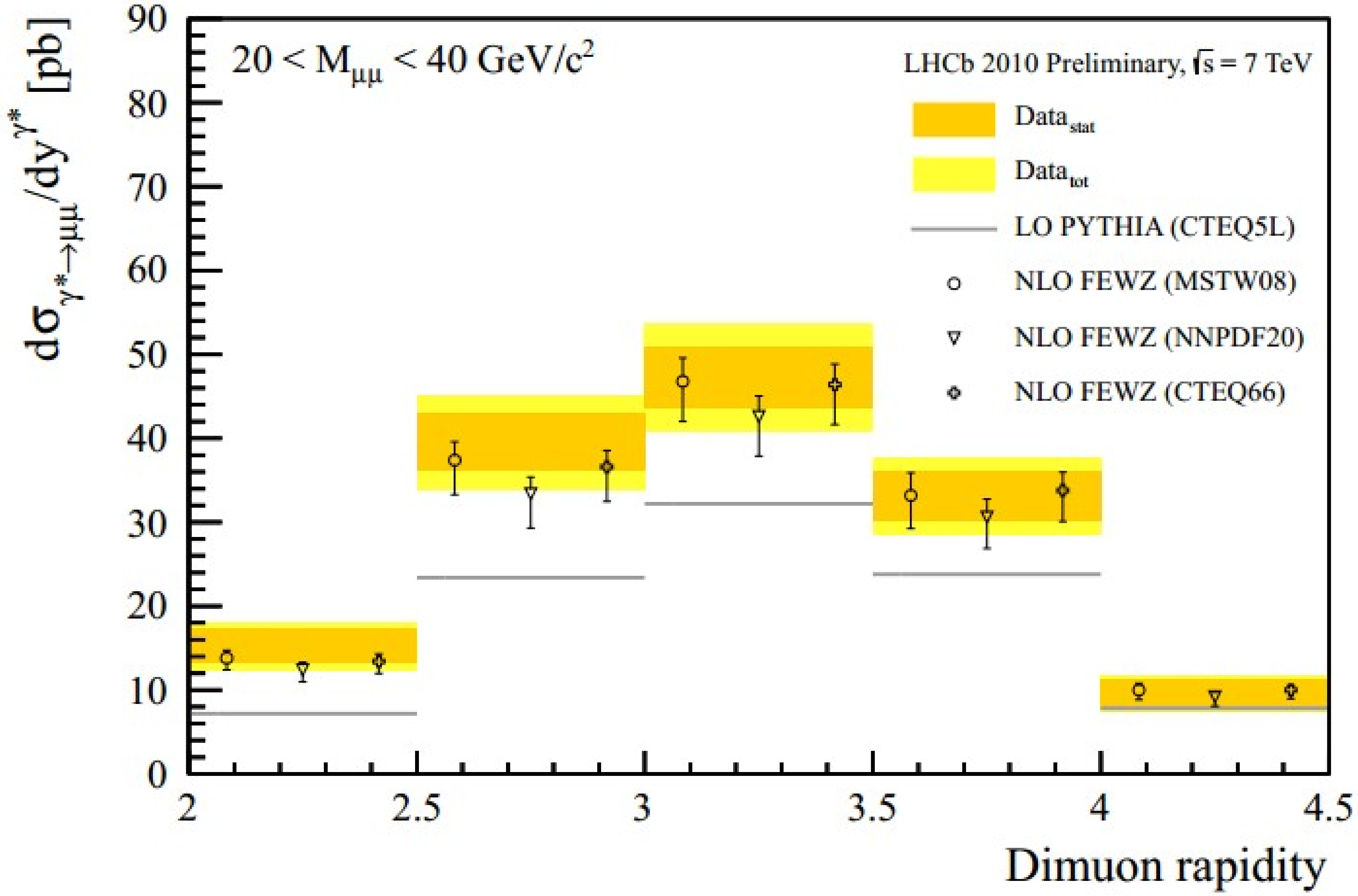
Strength of LHCb - ability to measure c-quark and b-quark contributions to dileptons at forward rapidities and separate them from DY. Hence measure DY as well as gluon pdf for similar x.

Low-x WS - 27-30 June

M. Rangel

Low Mass Drell-Yan Production





$$x = 3 \cdot 10^{-5}$$

Reaching small x at modest virtualities to observe nonlinear effects

- Use of differential cross sections -- DY
- Ultraperipheral AA collisions

DY: In the leading log approximation $$\frac{d\sigma^{l^+l^-}}{dy\,dM^2\,dp_t^2}$$

differential cross section at $p_t \sim 0$ is suppressed by the DDT form factor - a minimum

However exponentiating soft gluon radiation *in the impact parameter* space results in *flattening* of the spectrum in the $p_t \sim 0$ limit. Plateau for p_t < p_0

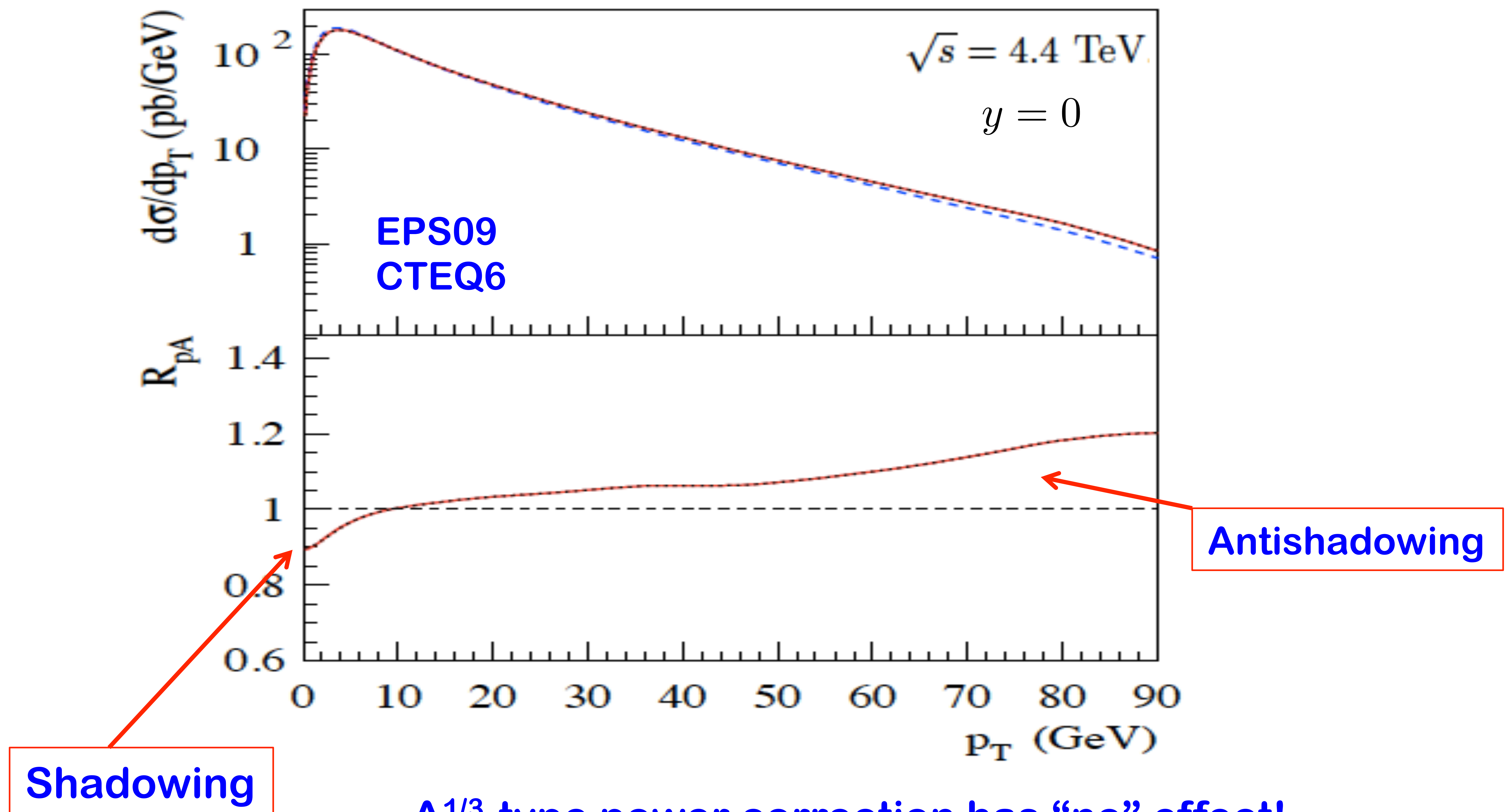
$$p_0^2 \propto \Lambda_{QCD}^2 \left(\frac{Q^2}{\Lambda_{QCD}^2}\right)^{\gamma}, \quad \gamma = \left(1 + \frac{\beta_2}{2\Sigma_C}\right)^{-1} \qquad \gamma_{q\bar{q}} = 0.372$$

Much smaller virtualities than $M^2(l^+l^-)$ can be probed in DY process !!

Predictions – pA @ LHC

J-W. Qiu

- "Cronin" effect for Z^0 production?



A factor of ~2 larger effect at moderate p_t with FGS10

$A^{1/3}$-type power correction has "no" effect!

Ultraperipheral Collisions ≡ UPC

Based on our study

Available online at www.sciencedirect.com

ScienceDirect

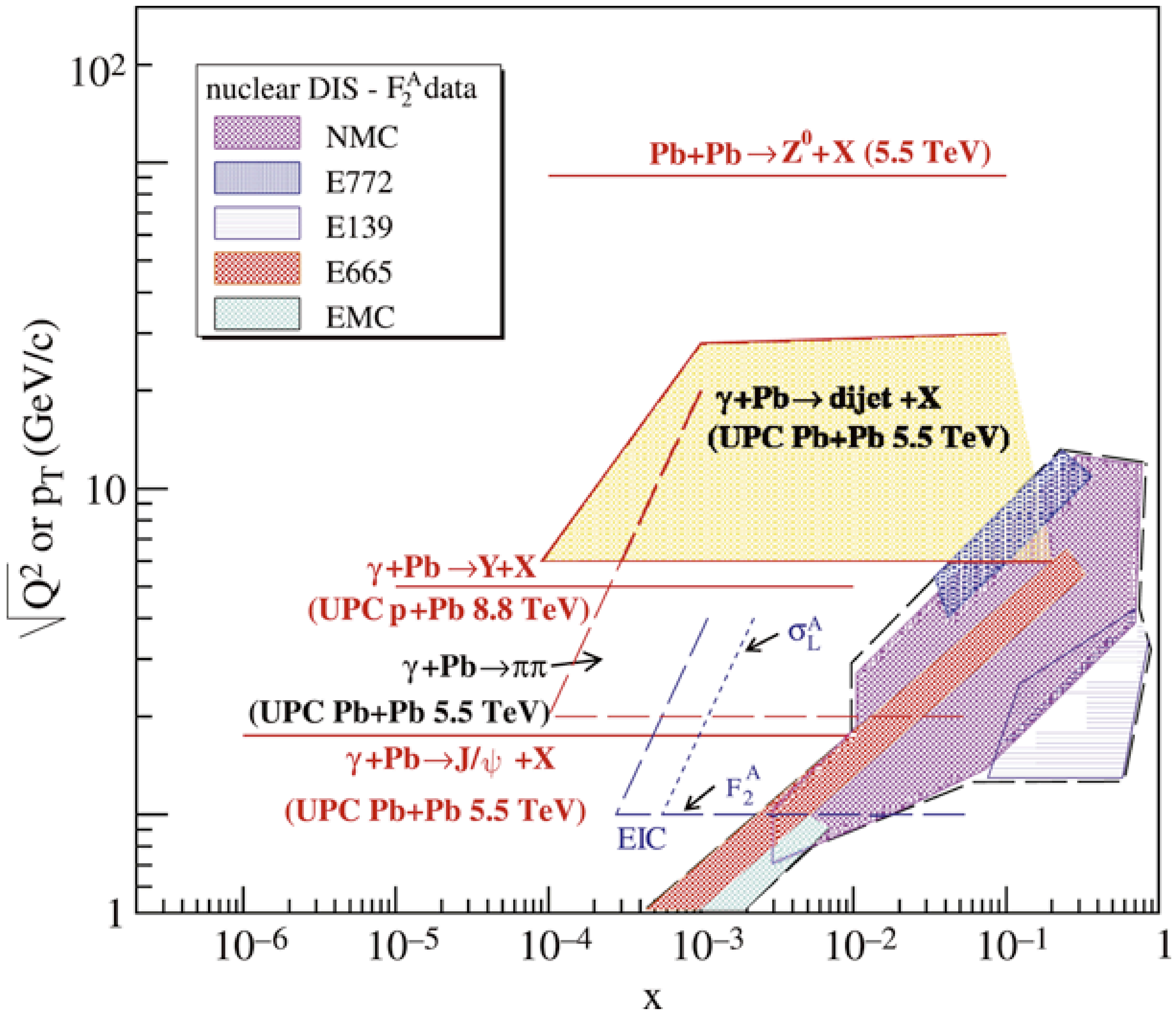
Physics Reports 458 (2008) 1–171

PHYSICS REPORTS

www.elsevier.com/locate/physrep

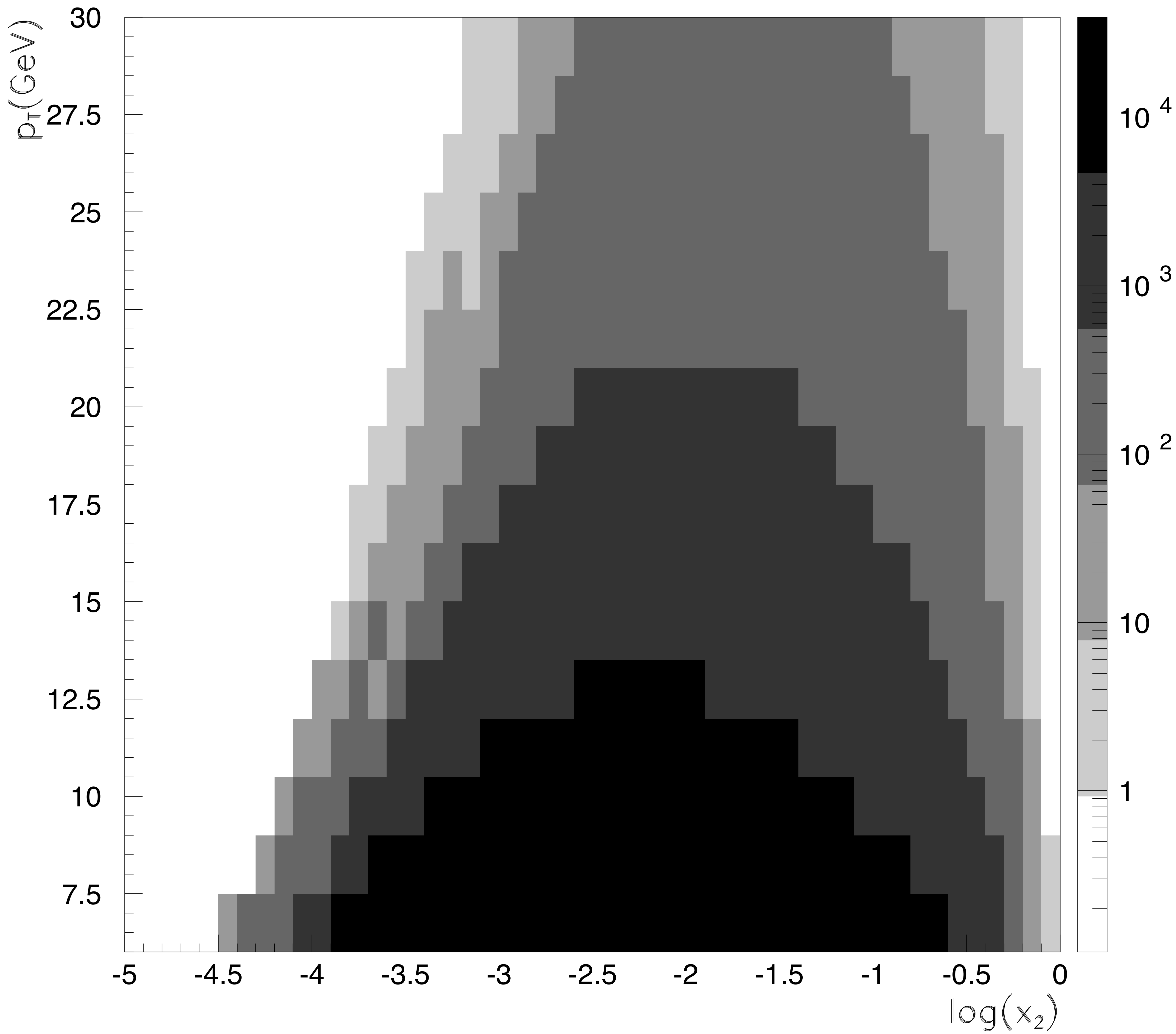
The physics of ultraperipheral collisions at the LHC

A.J. Baltz[a], G. Baur[b], D. d'Enterria[c], L. Frankfurt[d], F. Gelis[e], V. Guzey[f,w], K. Hencken[g,h,1], Yu. Kharlov[i], M. Klasen[j], S.R. Klein[k], V. Nikulin[l], J. Nystrand[m], I.A. Pshenichnov[n,o], S. Sadovsky[i], E. Scapparone[p], J. Seger[q], M. Strikman[r,*,1], M. Tverskoy[l], R. Vogt[k,s,t,1], S.N. White[a], U.A. Wiedemann[u], P. Yepes[v,1], M. Zhalov[l]



The kinematic range in which UPCs at the LHC can probe gluons in protons and nuclei in quarkonium production, dijet and dihadron production. The Q value for typical gluon virtuality in exclusive quarkonium photoproduction is shown for J /ψ and Υ . The transverse momentum of the jet or leading pion sets the scale for dijet and π π production respectively. For comparison, the kinematic ranges for J /ψ at RHIC, F_{2A} ,$\sigma_L{}^A$ and Z^0 hadroproduction at the LHC are also shown.

Warning - in case of exclusive processes with J /ψ - connection between nuclear shadowing in diagonal and off diagonal kinematics needs further theoretical investigation



Expected rate of b-jet photoproduction for a 1 month LHC Pb+Pb run at 7.4×10^{29} $cm^{-2}s^{-1}$. including acceptance of ATLAS

Many more interesting questions to study - like inclusive leading pion A-dependence as a function of p_t, associated multiplicity at different rapidities,...

R.Vogt, S.White, MS

Parton propagation through cold media.

RHIC - suppression of forward pion & dipion production:
definitely breakdown of pQCD in the kinematics where it works for pp

Explanations:

$2 \rightarrow 2$ mechanism with fractional energy losses near black regime and small effect of p_t broadening effect

$2 \rightarrow 1$ mechanism with p_t broadening and A-dependent splitting of "1"

For single forward pion production $2 \rightarrow 2$ appears to dominate (correlation data)

For forward double pion production double parton scattering complicates interpretation.
Additional complications: soft and hard color fluctuations (will discuss later)

LHC pA: acceptance for reasonably large p_t only for rapidities corresponding to rather small x in the proton

➠ sensitivity only to relatively large energy losses, large sensitivity to gluon shadowing, and to p_t broadening.

Acceptance over large range of y (CMS & ATLAS)

➠ Ability to look for correlation of forward hadron with $y= -4 \div 0$ hadrons / minijets corresponding to $x_A > 0.01$ where nuclear shadowing is absent (allows to distinguish $2 \to 1$ and $2 \to 2$)

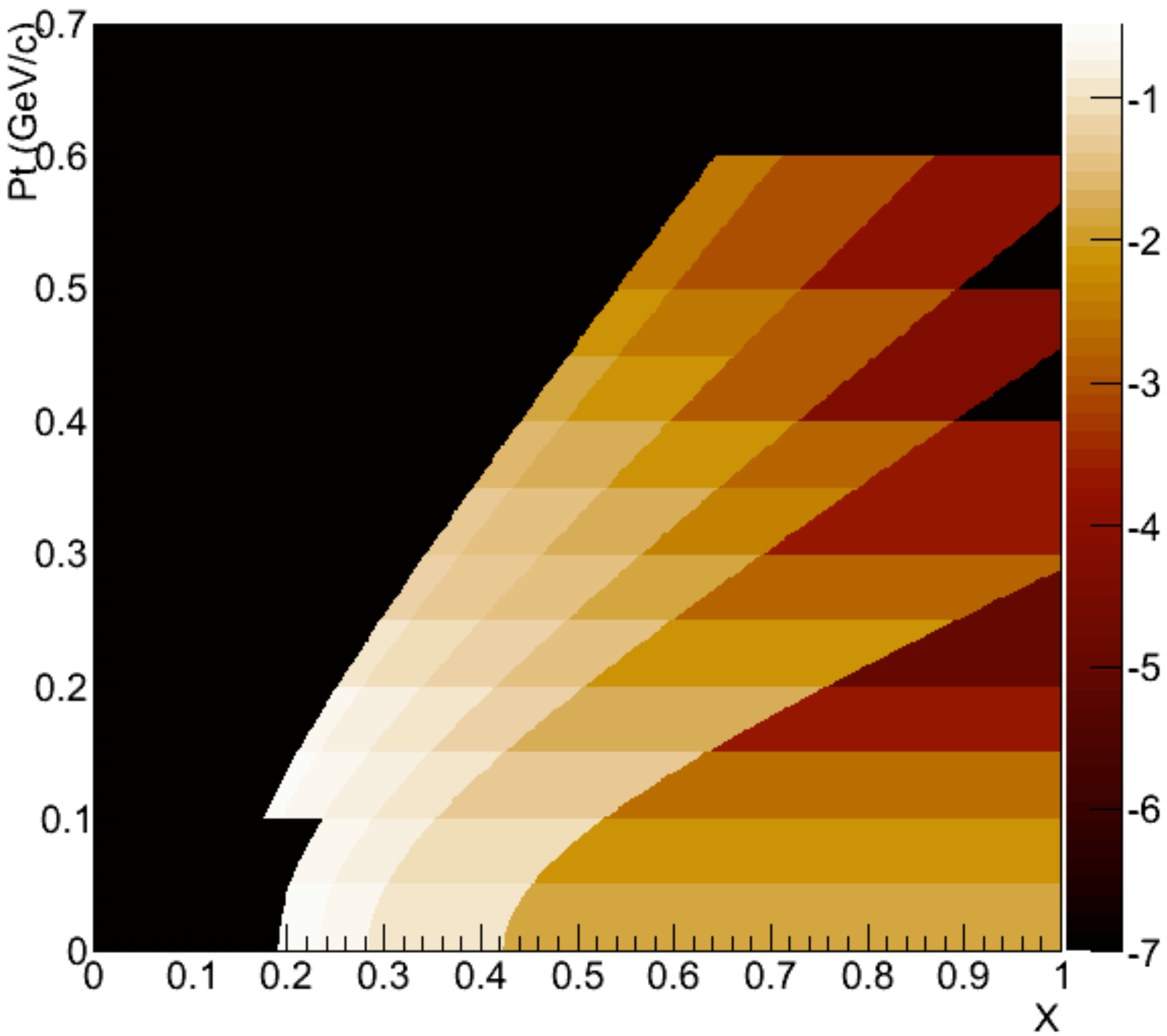
➠ UPC (γA) forward pion production (within tracking acceptance of CMS& ATLAS) about the same kinematics as at RHIC for $y \sim 4$ - high sensitivity to fractional energy losses.

Very forward hadron production ($x_F > 0.3$ moderate p_t)

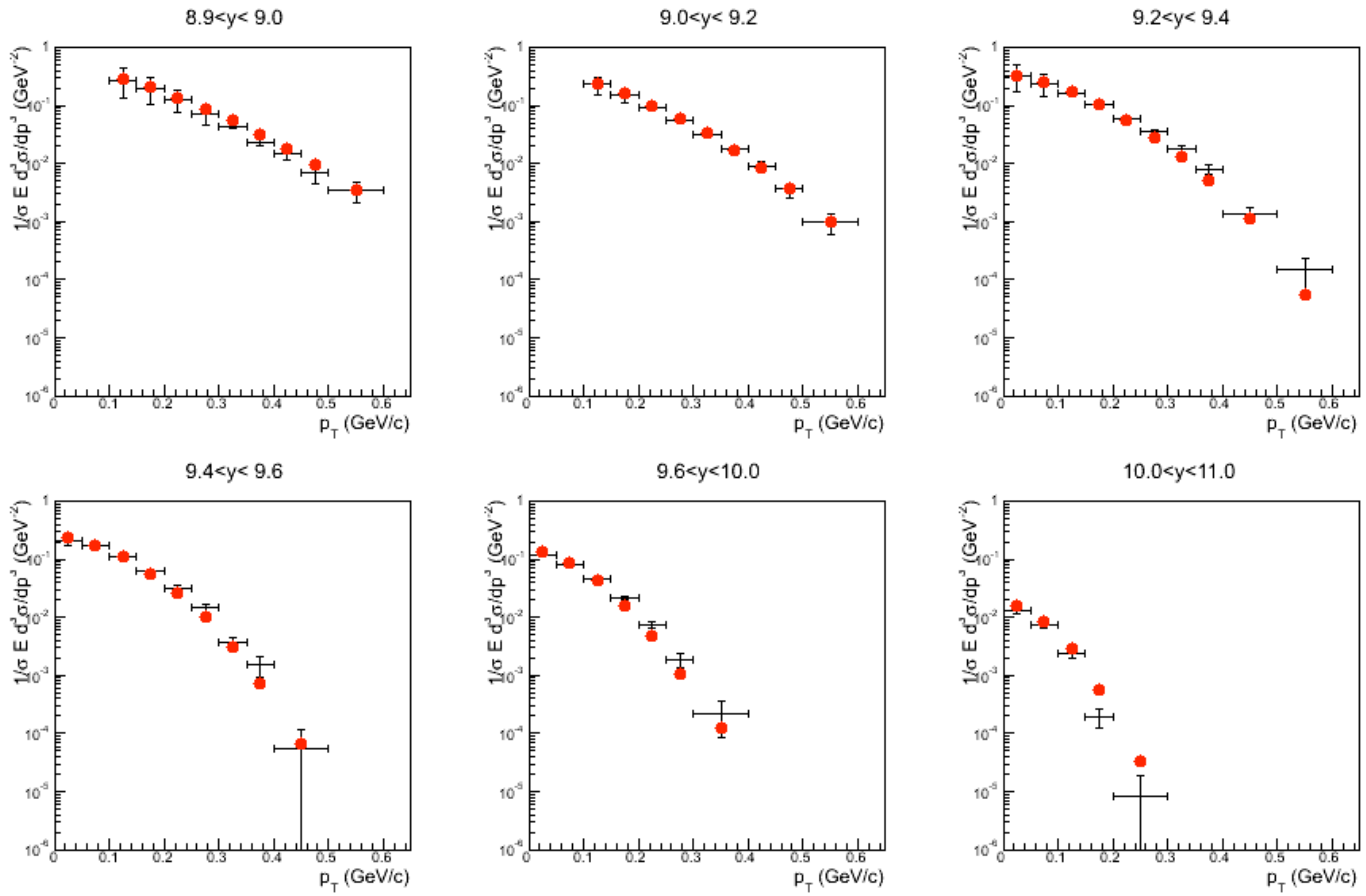
First data on pp $\rightarrow \pi^0$+X from LHCf

Data on pp $\rightarrow$n+X are coming from LHCf and other LHC experiments

Currently no forward low p_t production is available from RHIC,

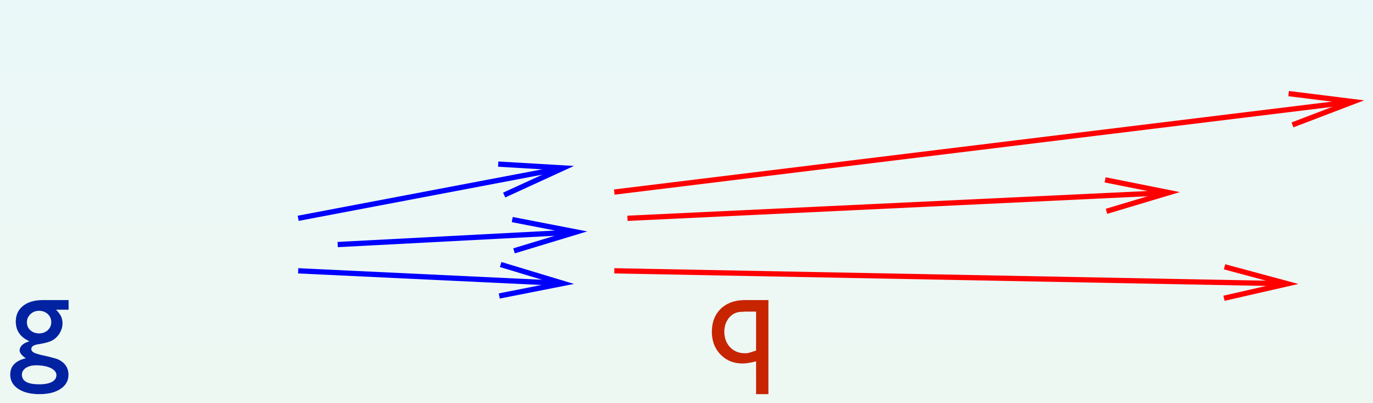


LHCf range

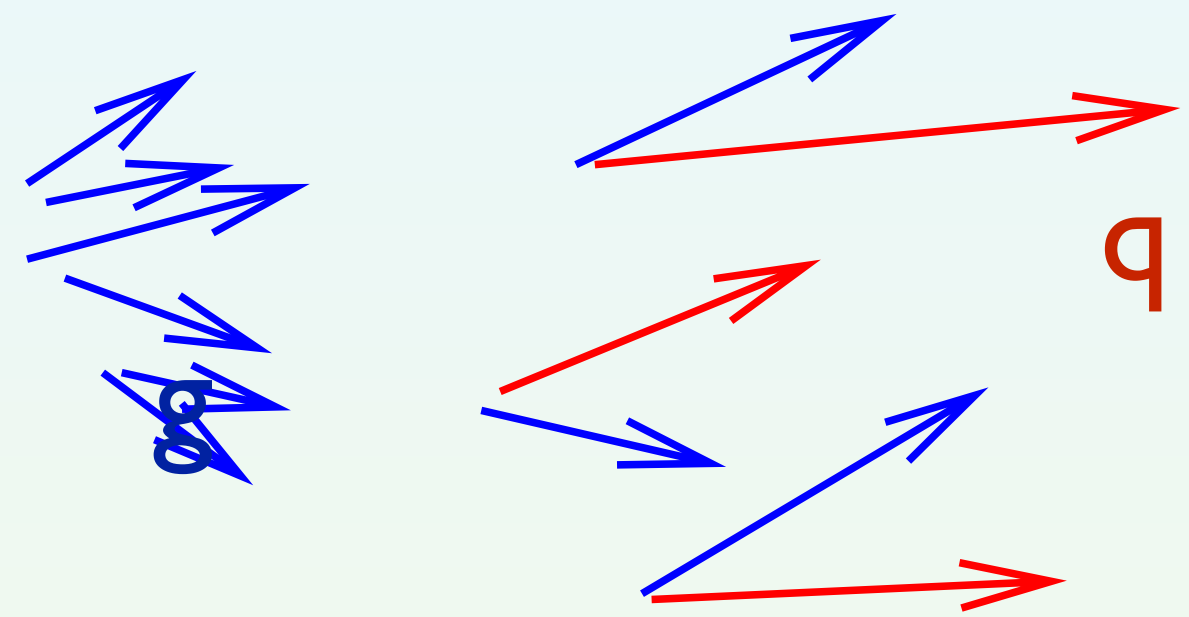


LHCf pp $\rightarrow \pi^0$+X data

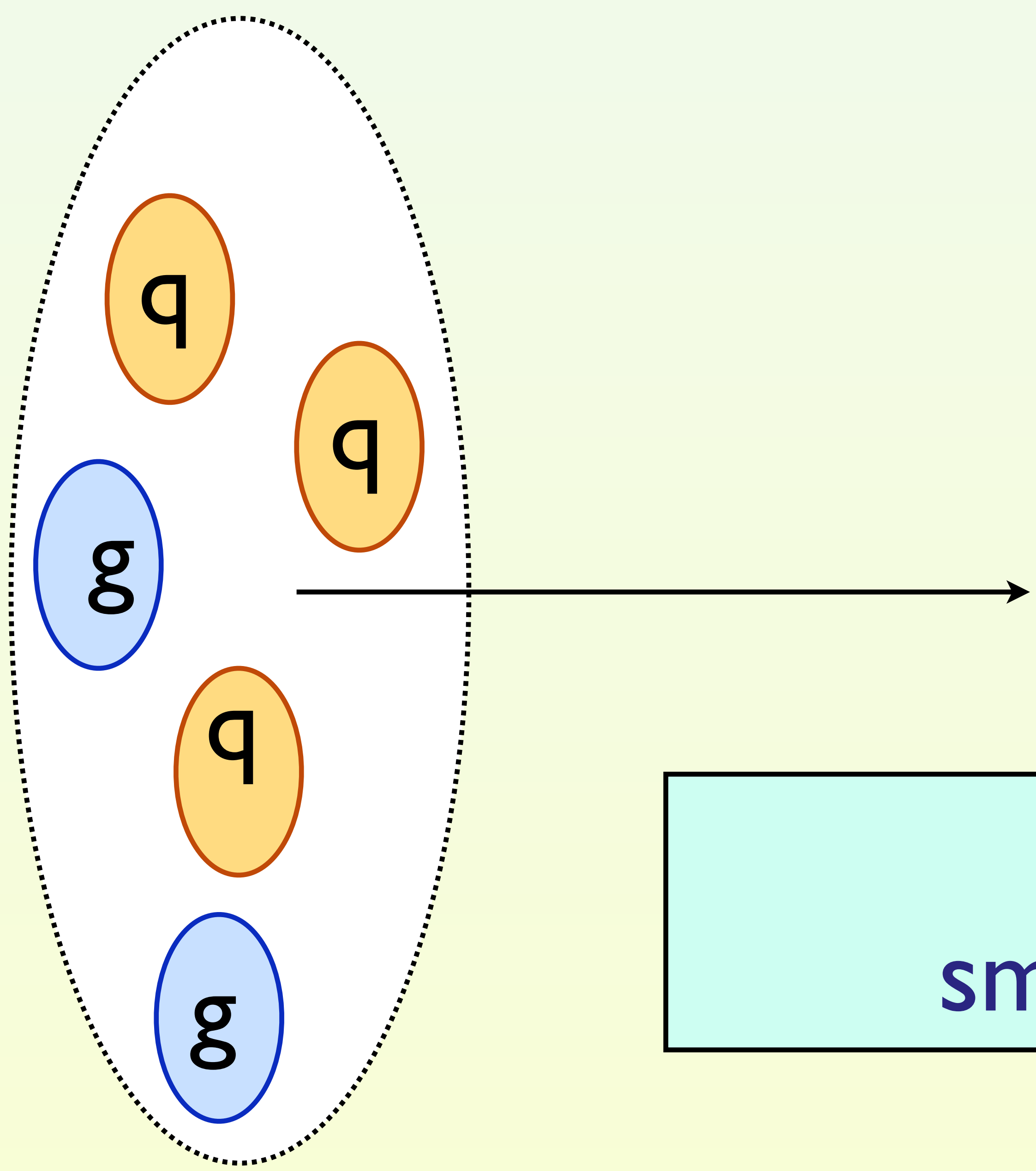
Leading hadron production in the central pA(pp) collisions



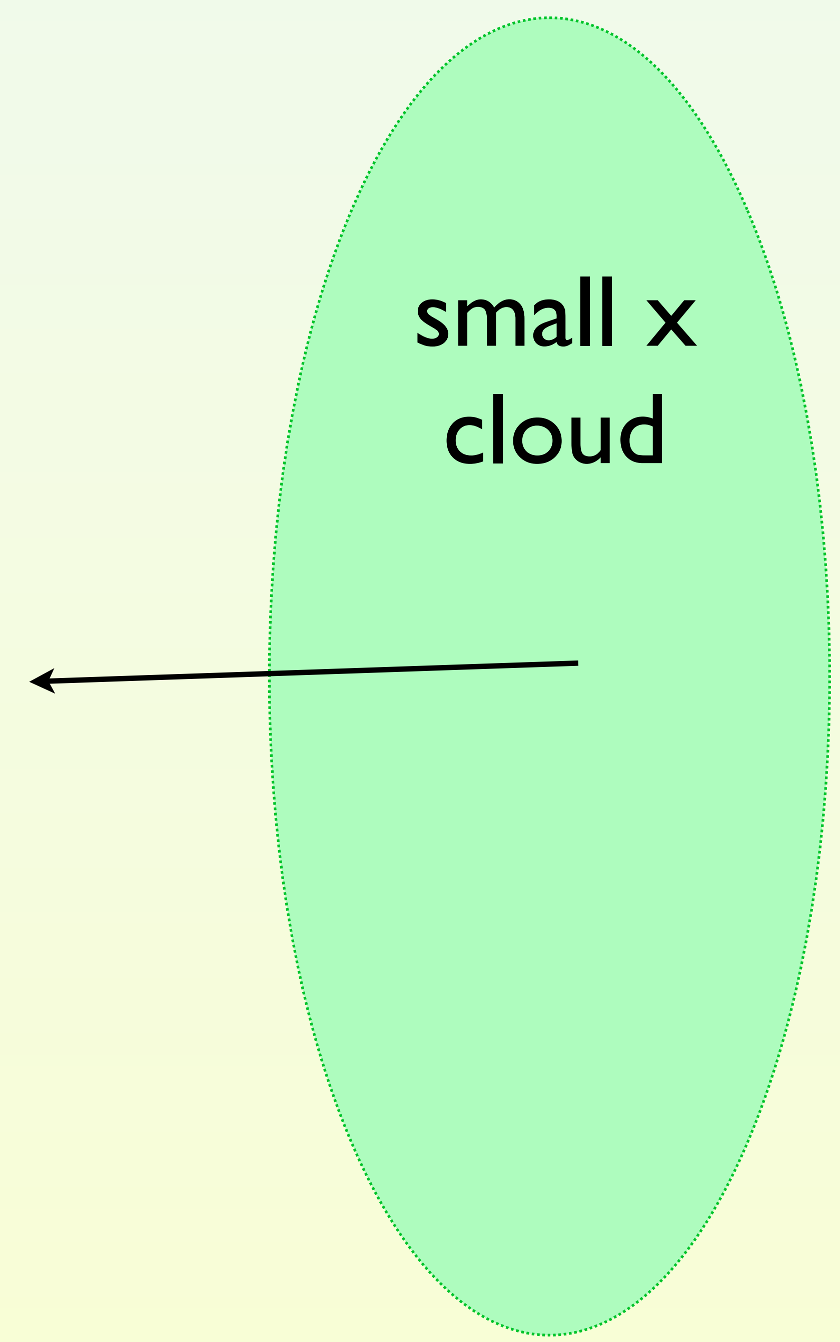
fast partons in a nucleon before collisions



fast partons in a nucleon after central collisions:
large p_t (determined by black limit) and splitting



Large x partons burn
small holes in the small x cloud



Expectation: The leading particle spectrum should be strongly suppressed in the central pA collisions as compared to minimal bias pp collisions since each leading parton gets large transverse momentum and hence fragments independently and may also split into a couple of partons with comparable energies. The especially pronounced suppression for nucleons: for $z \geq 0.1$ the differential multiplicity of pions should exceed that of nucleons. This model neglects additional suppression due to finite fractional energy losses in BDR

$$\frac{1}{N}\left(\frac{dN}{dz}\right)^{pA\to h+X} = \sum_{a=q,g}\int dx\, x f_a^{(p)}(x, Q^2_{\rm eff}) D_{h/a}(z/x, Q^2_{\rm eff})$$

The limiting curve of leading particles from hadron-nucleus collisions at infinite A

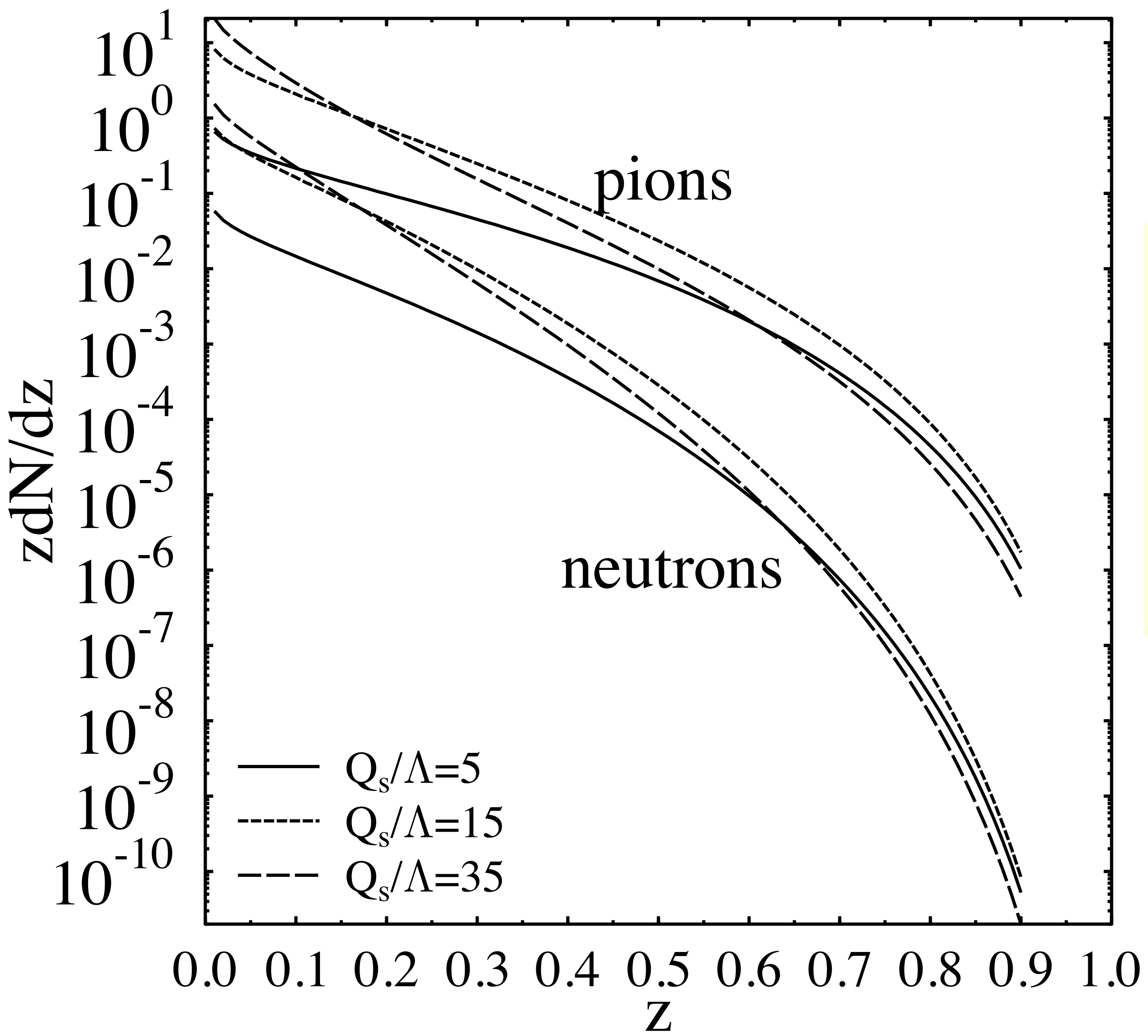
A. Berera[a,1], M. Strikman[a], W.S. Toothacker[b], W.D. Walker[c], J.J. Whitmore[a]

Physics Letters B 403 (1997) 1–7

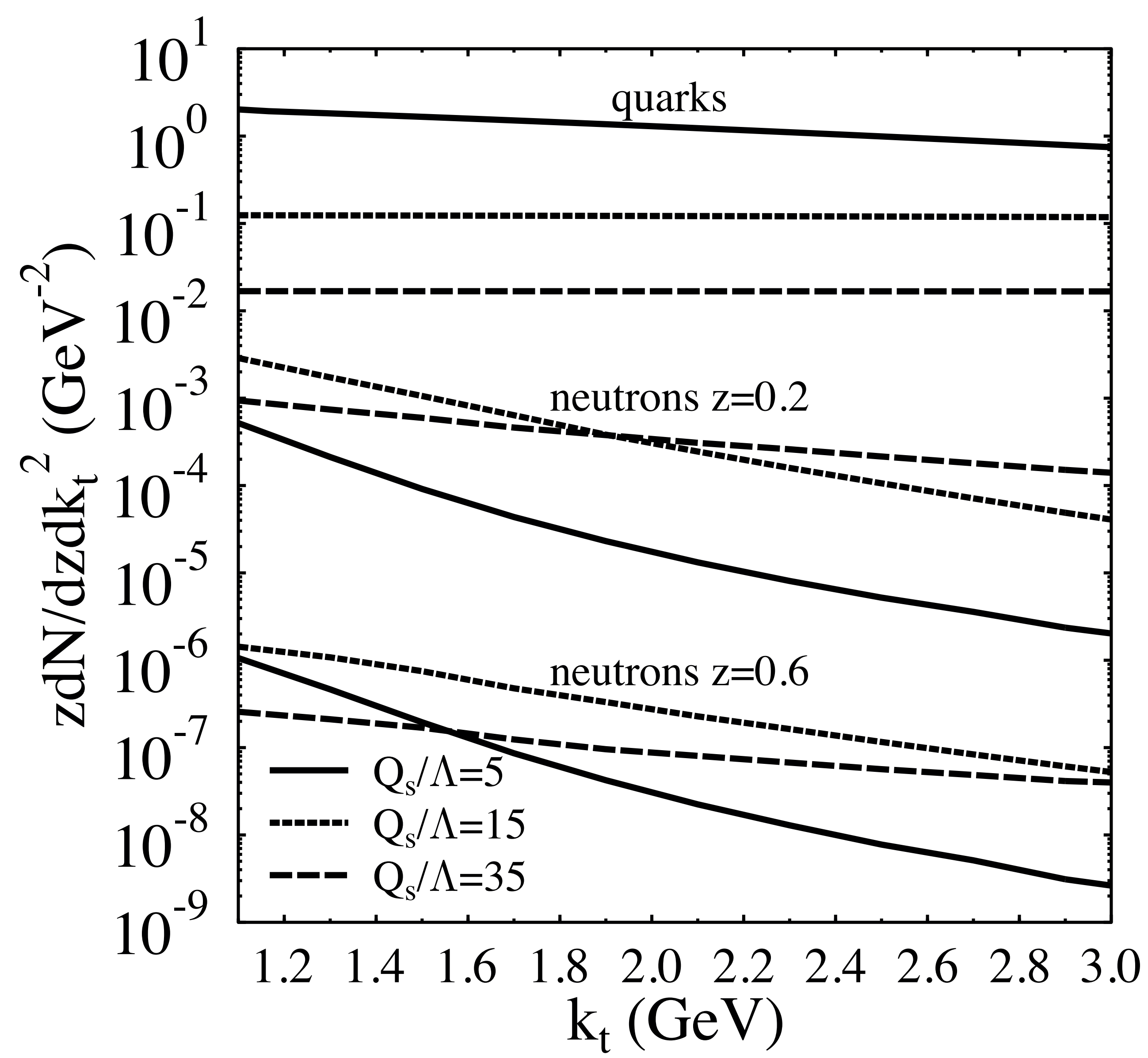
Simple model of p_t broadening - eikonal rescattering model with saturation (Boer, Dumitru 2003), effective energy losses (mentioned before) are neglected

$$C(k_t) \sim \frac{1}{Q_s^2 \log \frac{Q_s}{\Lambda_{QCD}}} \exp(-\frac{\pi k_t^2}{Q_s^2 \log \frac{Q_s}{\Lambda_{QCD}}}) .$$

Quark gets a transverse momentum of the order Q_s but does not loose significant energy. Use of the convolution formula for fixed transverse momentum of the produced hadron using $C(k_t)$ -
Dumitru, Gerland, MS -PRL03. Other calculations with similar logic -Gelis, Stasto, Venugopalan (06)



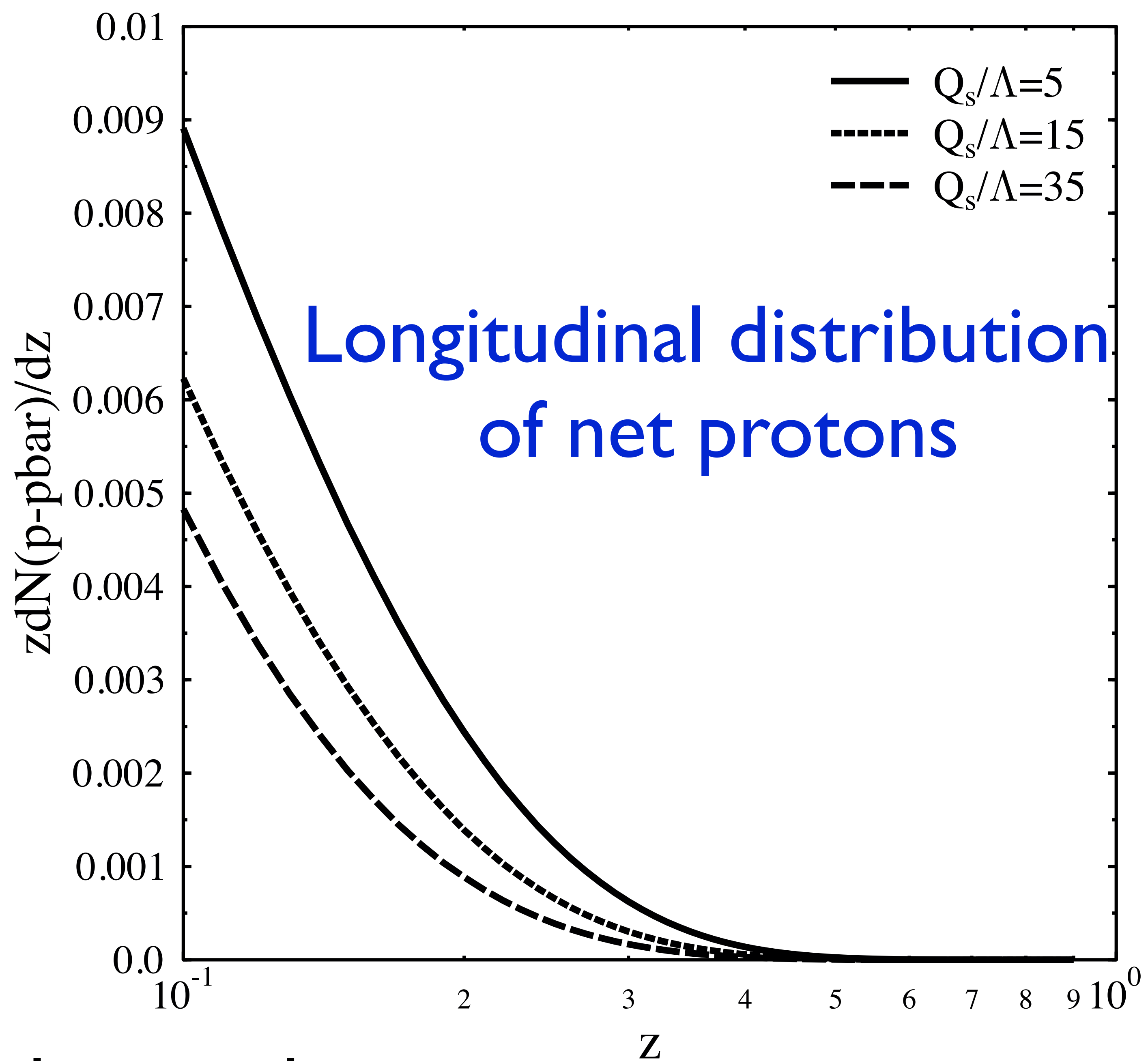
Steep fall with z, strong E_{inc} dependence



Weak p_t dependence, becomes weaker with increase of E_{inc}

Longitudinal (integrated over p_t) and transverse distributions in Color Glass Condensate (CGC) model for central pA collisions. Spectra for central pp - the same trends.

Very few forward baryons in central collisions!!!



Large flow of energy to central rapidities
- obvious implications for AA

Warnings: Parton carrying a fraction y of the quark momentum carries $y\, p_t$ part of the quark's transverse momentum. Condition for independent fragmentation $y\, p_t > 1/r_N \sim .3 - 0.5$ GeV/c

For RHIC (LHC) independent fragmentation is probably safe for $z > 0.2$ (0.1)

➠ Photon - proton contribution has to be subtracted!!! Very large - discuss later

Experimental prospects:

TOTEM: $x_F \geq 0.8$ broad range of p_t can check both suppression and p_t broadening

neutrons from ZDC (CMS, ALICE, LHCf); π^0+ (LHCf) -large z , moderate p_t

RHIC: need pA run preferably at different energies and for several nuclei to avoid model dependent procedure for determining centrality of collision.

Warning: Color fluctuations in nucleon and nucleon density in nucleus may reduce the suppression

How to determine centrality of pA collisions (discussion session)

Number of neutrons in ZDC - very different geometry of nucleus heating in pA and AA collisions, sensitivity to the contribution of low energy cascades? !

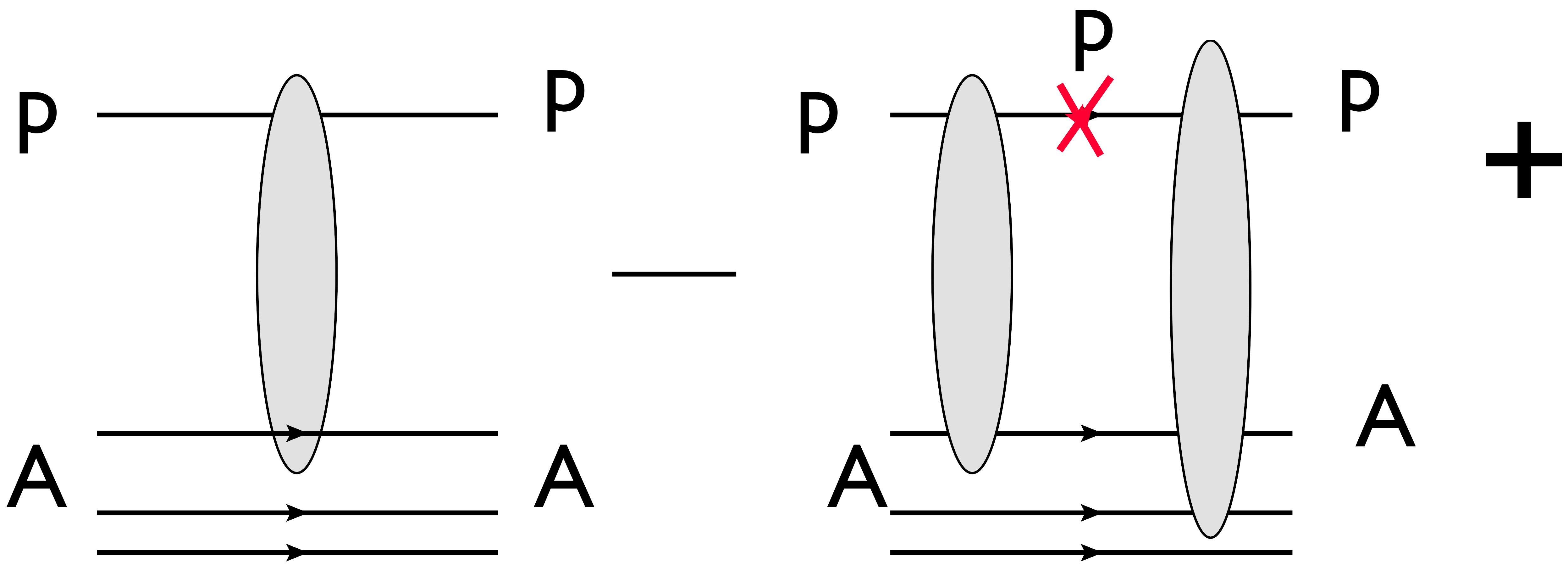
Central hadron multiplicity ∝ number of collisions in Glauber model - how reliable is the model? Role of hard contributions?

Jet production in the region where LT works and shadowing is small — Low rate

need for cross calibration of different methods, tests of Glauber approximation

Gribov - Glauber color fluctuations

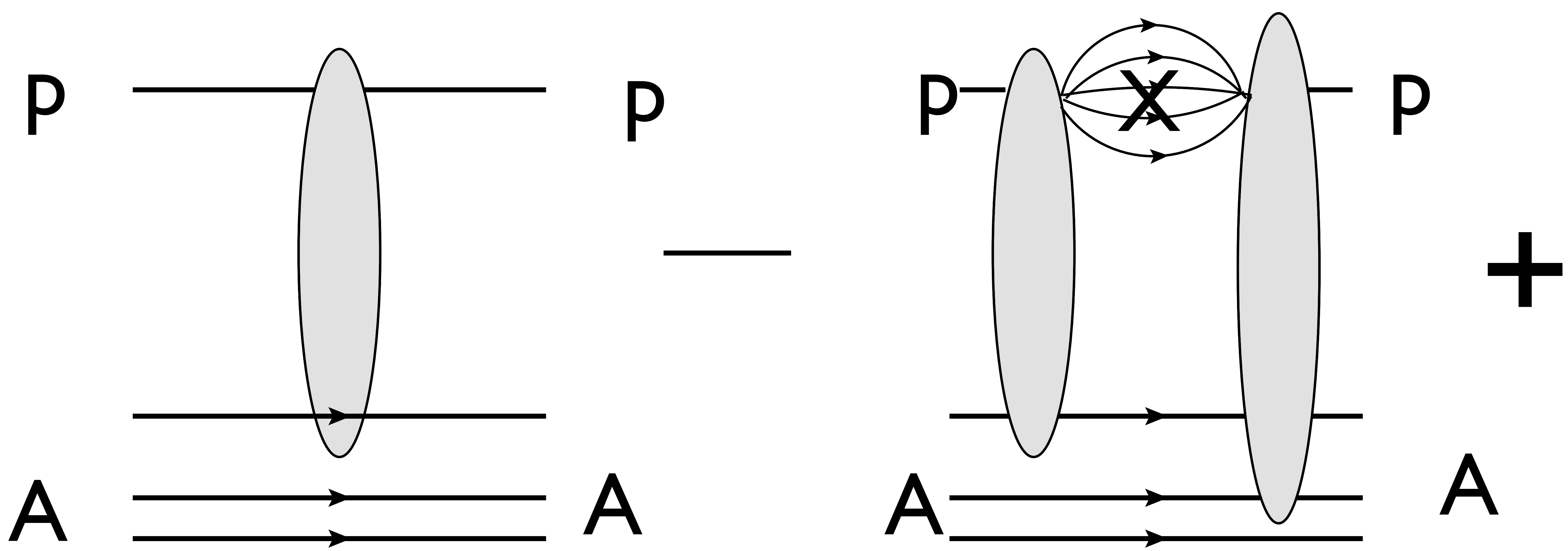
Space time picture of soft high energy hA scattering (Gribov - Glauber model) is qualitatively different Glauber QM model



Glauber model

in rescattering diagrams proton in intermediate state - zero at high energy

- cancelation of AFS diagrams (Mandelstam & Gribov)- no time for a proton to come together between collisions with two nucleons



High energies = Gribov -Glauber model

X= set of intermediate states the same as in pN diffraction

$$\sigma_2 \propto \int dt F_A^2(t) \frac{d\sigma(p+p\to p+X(p+\ inel\ diff))}{dt}$$

Potential problem for Gribov- Glauber approximation:
average impact factor <b> at LHC for inelastic collisions ~ 1.3 fm

$\Rightarrow$ 2<b> > r_{NN} ~ 1.7 fm $\Rightarrow$

projectile proton can hit two nucleons at the same light-cone time.

Convenient picture of diffraction -

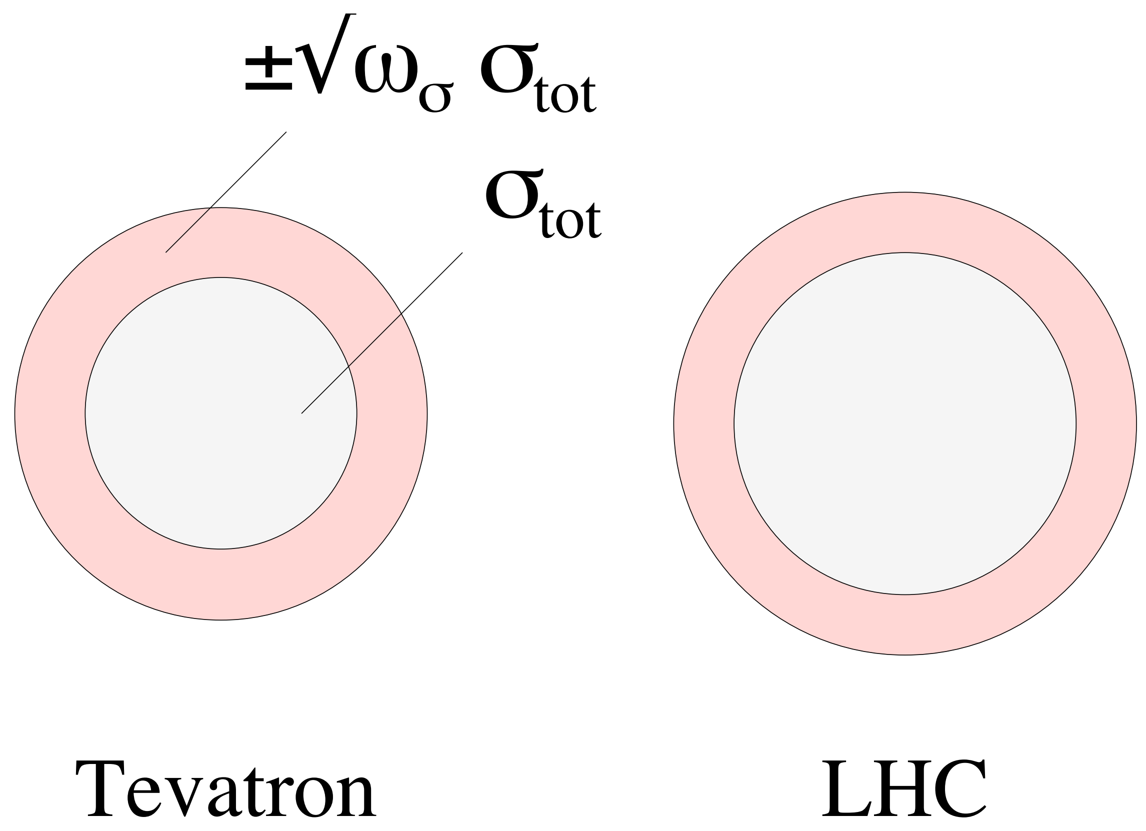
Good - Walker scattering eigen state formalism $\sigma_n |n\rangle = T|n\rangle$

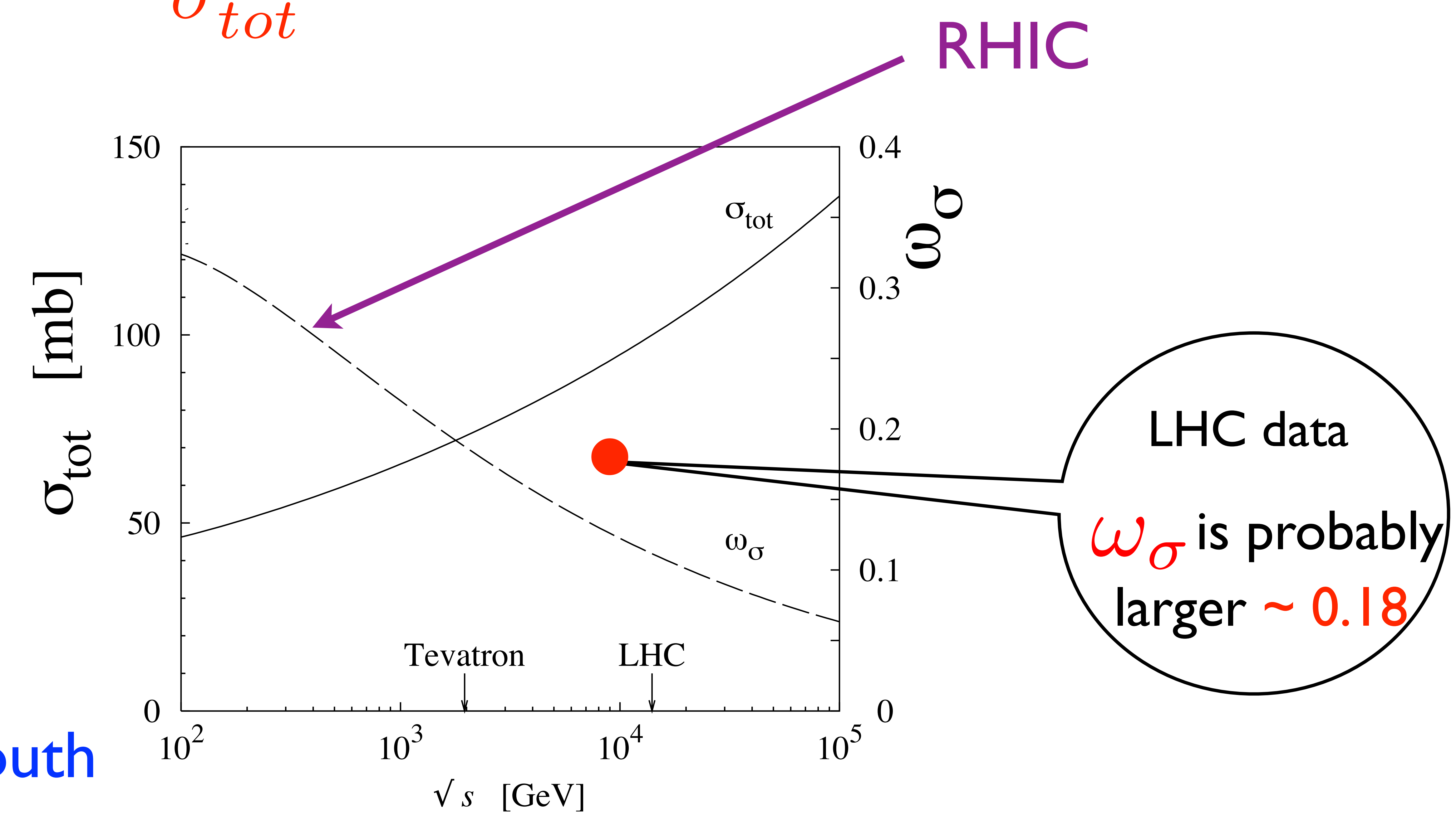
Allows a probabilistic formulation of inelastic shadowing in the Gribov-Glauber model, calculation of total, elastic, diffractive cross pA cross sections

Useful quantity - P(σ) -probability that nucleon interacts with cross section σ

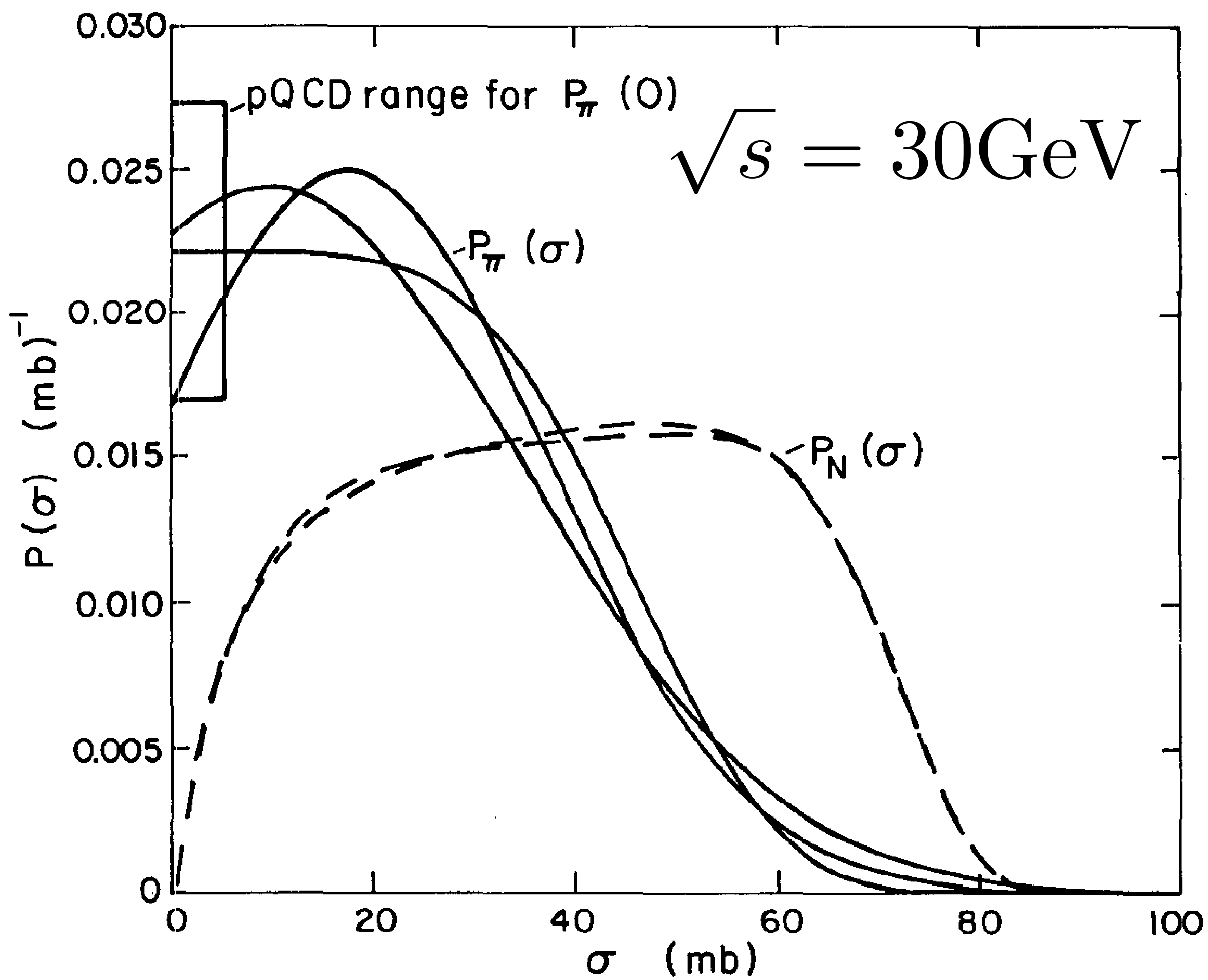
If there were no fluctuations of strength - there will be no inelastic diffraction at t=0:

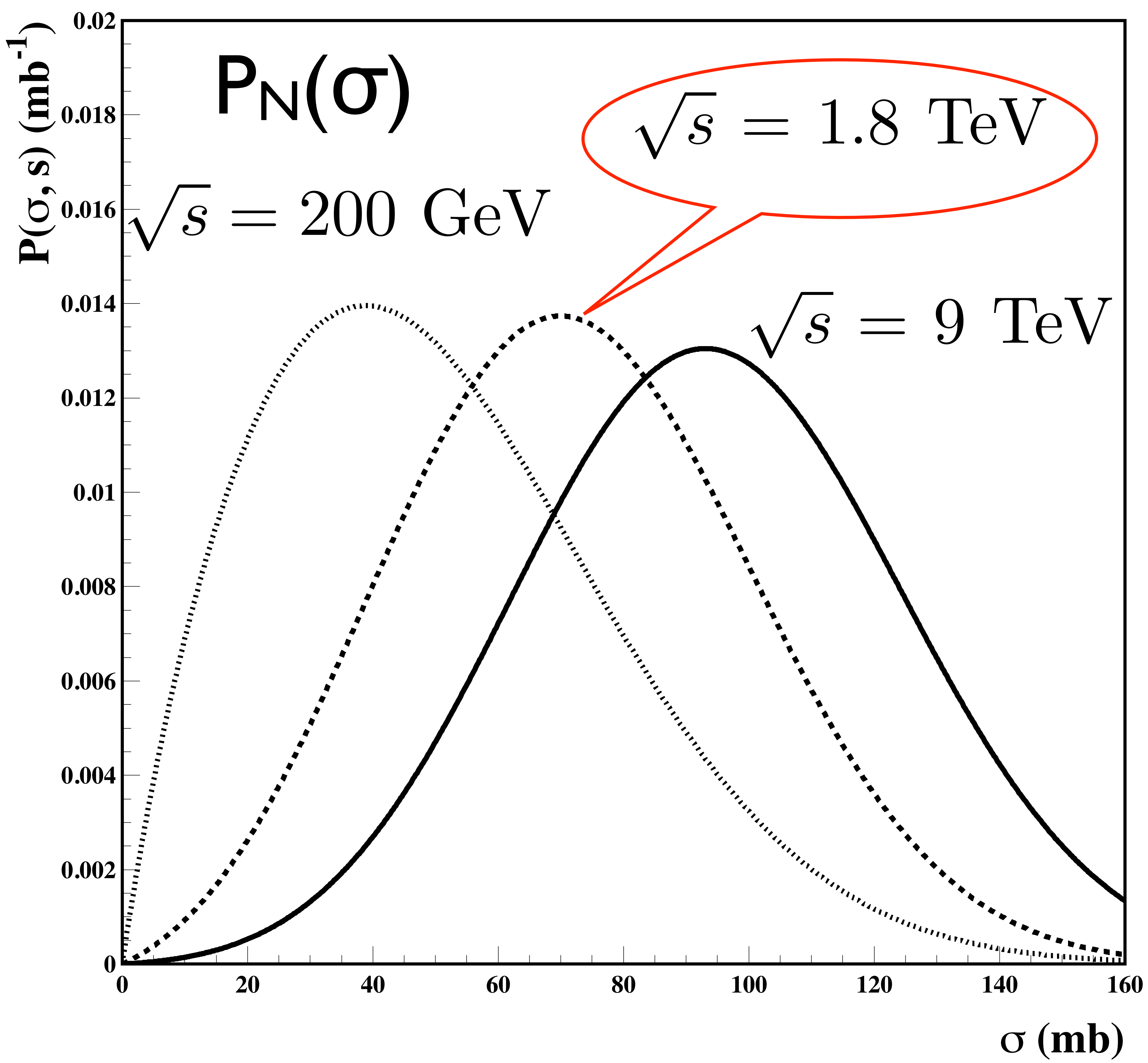
$$\left.\frac{\frac{d\sigma(pp\to X+p)}{dt}}{\frac{d\sigma(pp\to p+p)}{dt}}\right|_{t=0} = \frac{\int(\sigma-\sigma_{tot})^2 P(\sigma)d\sigma}{\sigma_{tot}^2} \equiv \omega_\sigma$$ variance





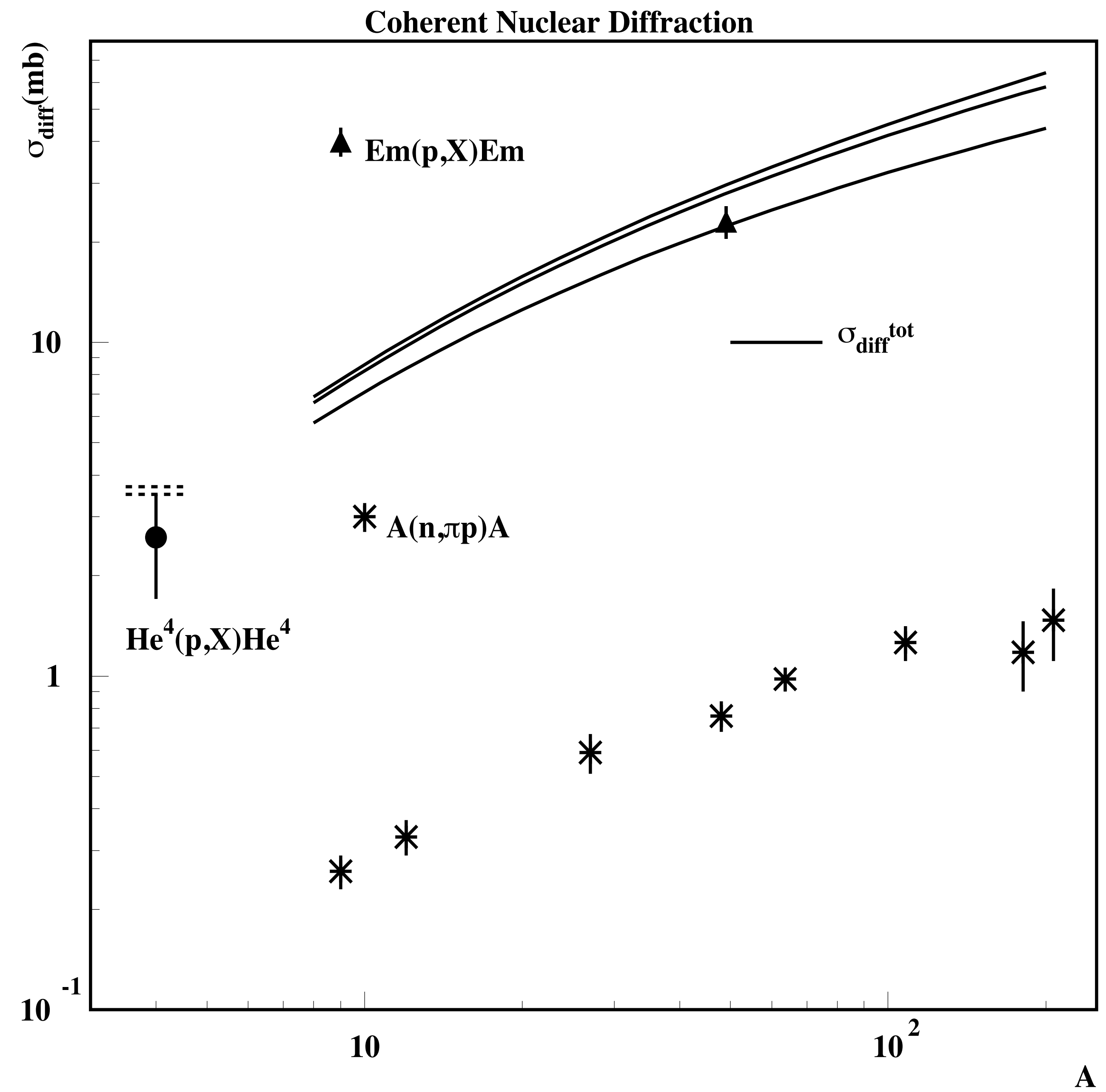
Both small and large configurations lead to grouth of periphery - still there is a correlation between σ and parton distributions -smaller σ, harder quark and gluon distributions





$P_N(\sigma)$ extracted from pp,pd diffraction Baym et al 93.

$P_\pi(\sigma)$ is also shown



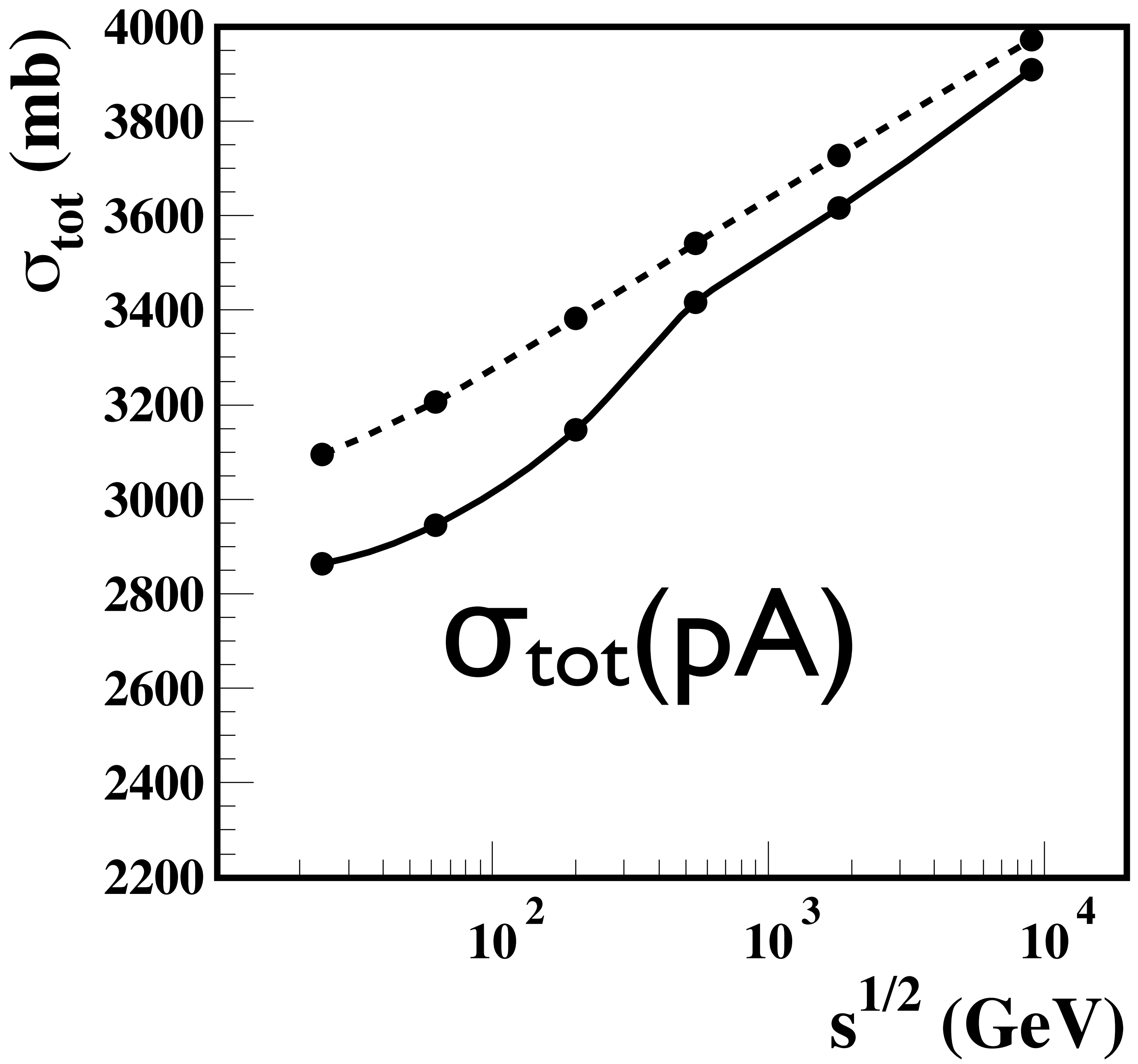
The inelastic small t coherent diffraction off nuclei provides one of the most stringent tests of the presence of the fluctuations of the strength of the interaction in NN interactions. The answer is expressed through $P(\sigma)$ - probability distribution for interaction with the strength σ. (Miller &FS 93)

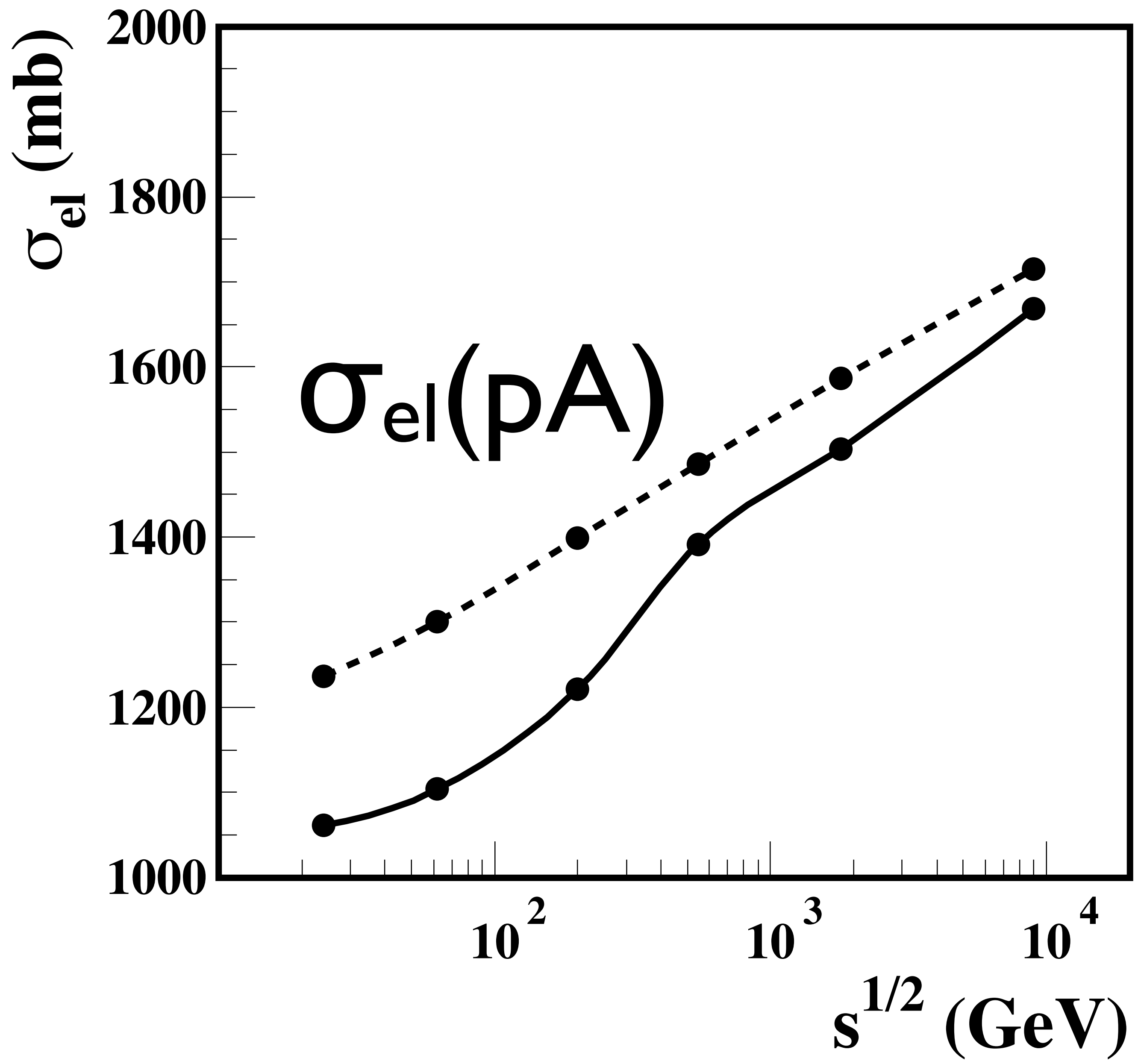
$$\sigma^{hA}_{diff} = \int d^2b\left(\int d\sigma P_h(\sigma)|\langle h|F^2(\sigma,b)|h\rangle| - \left(\int d\sigma P(\sigma)|\langle h|F(\sigma,b)|h\rangle|\right)^2 \right).$$

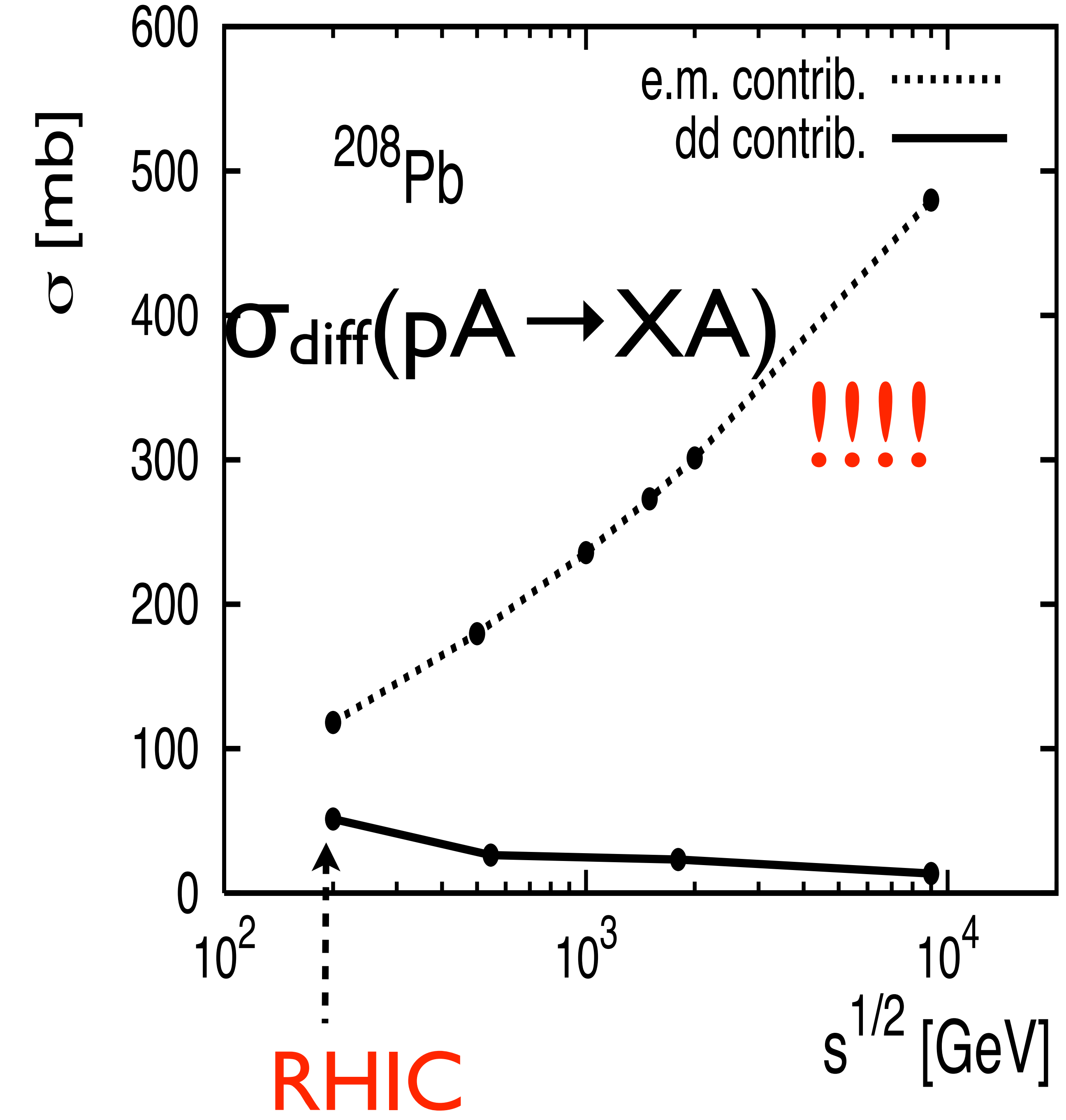
Here $F(\sigma,b) = 1 - e^{-\sigma T(b)/2}$, $T(b) = \int_{-\infty}^{\infty} \rho_A(b,z)dz$, and $\rho_A(b,z)$ is the nuclear density.

Color fluctuations/inelastic shadowing

Guzey & MS







⇒ E.M. interaction dominates by far in diffraction at LHC- huge cross section true for hard diffraction as well (Guzey, MS)

⇒ inelastic diffraction can be measured at RHIC - important check of the picture

⇒ Many interesting γp processes can be studies in UPC pA at LHC

Fluctuations in the number of interactions even at small b given by variance of P(σ).

Simple illustration - two component model ≡ quasieikonal approximation:

$$P(\sigma) = \frac{1}{2}\delta(\sigma - \sigma_{tot}(1-\sqrt{\omega_\sigma})) + \frac{1}{2}\delta(\sigma - \sigma_{tot}(1-\sqrt{\omega_\sigma}))$$

RHIC $\sigma_1 = 25\,mb,\ \sigma_2 = 75\,mb$

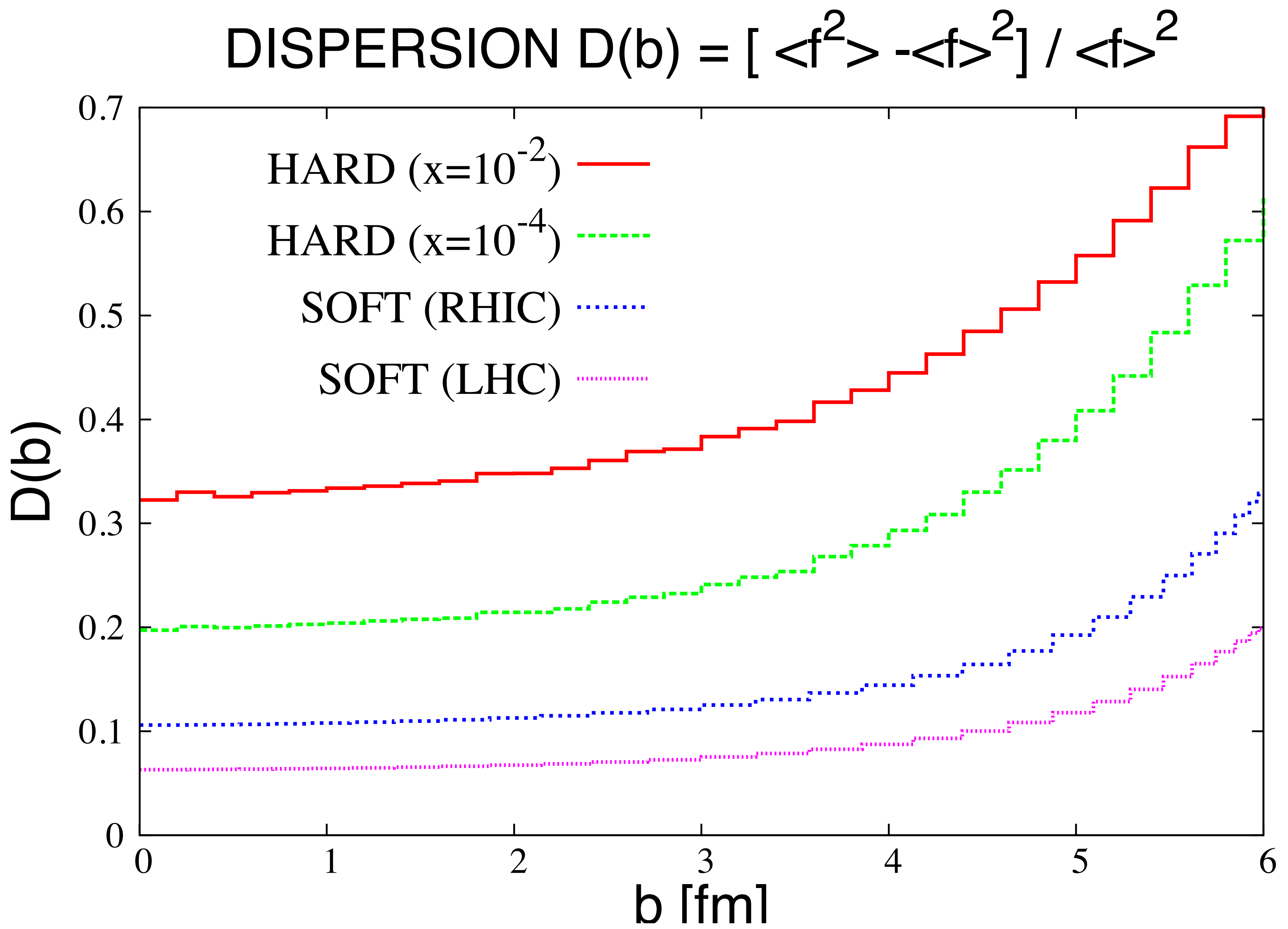
LHC $\sigma_1 = 60\,mb,\ \sigma_2 = 140\,mb$

number of wounded nucleons at small b differs for two components by a factor of ≥3 !!!

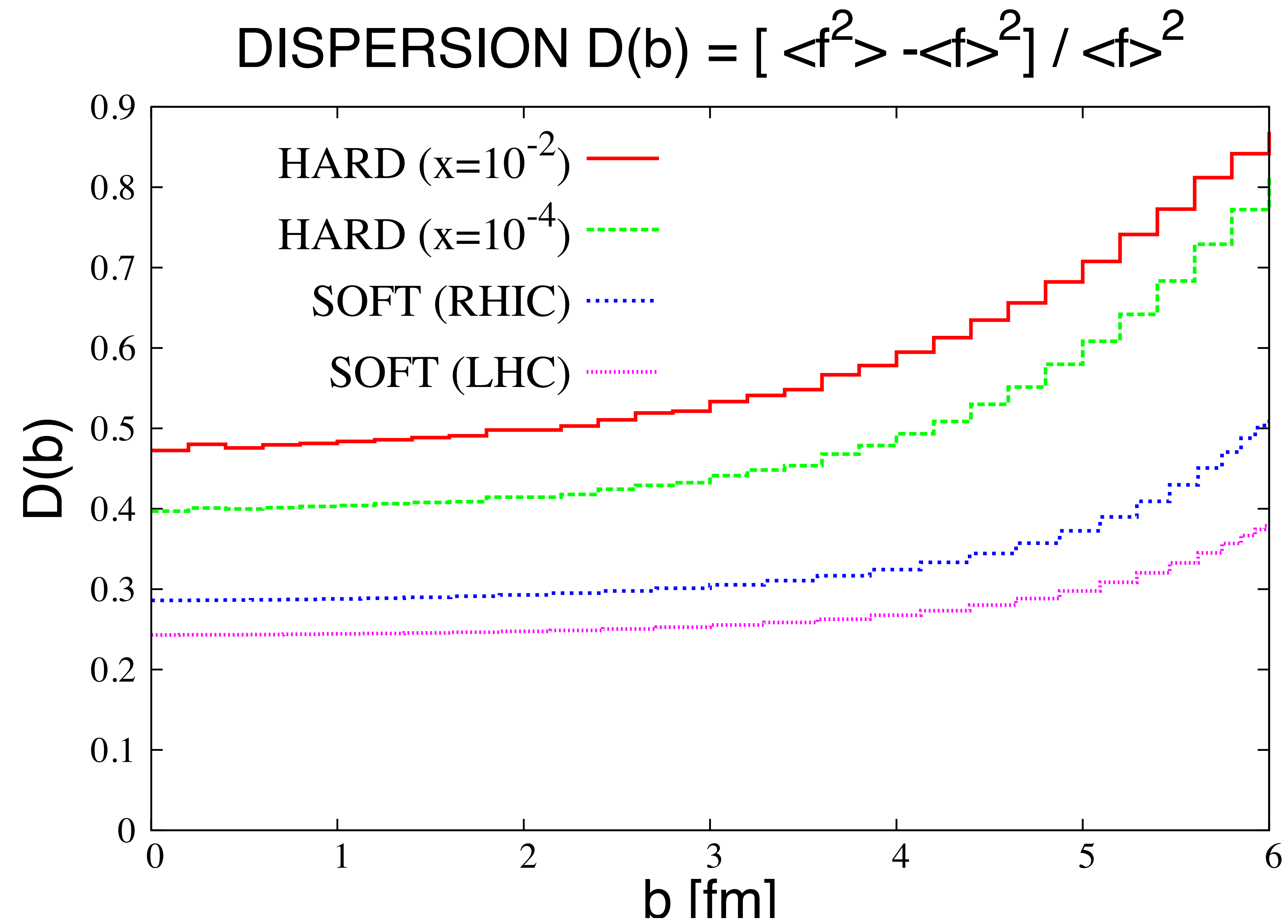
color fluctuations lead to addition dispersion as compared to geometrical model

$\Delta\omega = \omega_\sigma$ in pA

$\Delta\omega = 2\ \omega_\sigma$ in AA

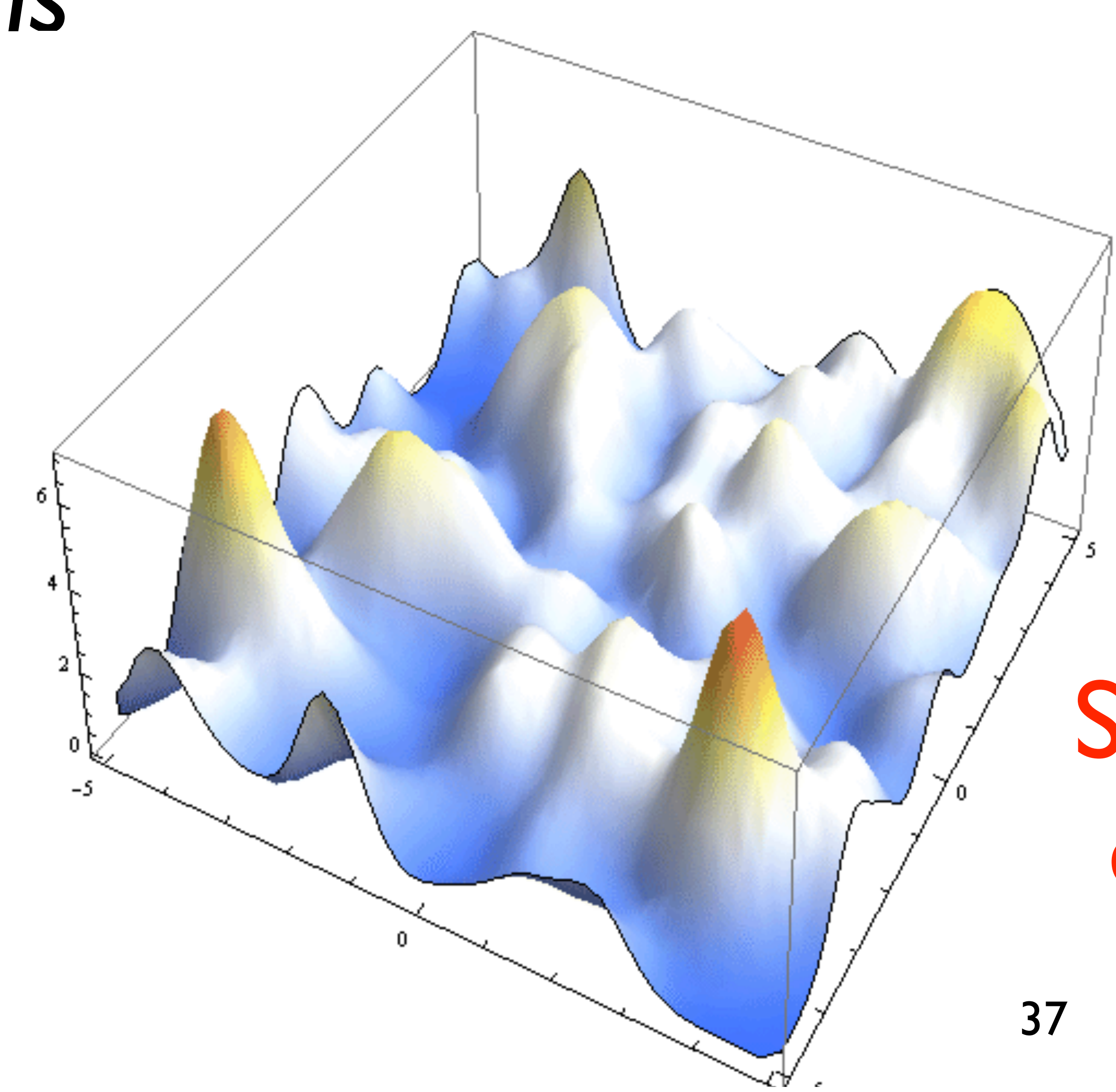


effect of fluctuations of the number of nucleons



nucleon color fluctuations + fluctuations of the number of nucleons

Alvioli & MS



Snapshot of transverse distribution of gluons

Expectation: configurations with larger σ □ softer x distribution

configurations with smaller σ □ harder x distribution

The presence of a parton with large x>0.6 requires three quarks to exchange rather large momenta, one may expect that these configurations have a smaller transverse size (+ few gluons & sea quarks at low Q scale) and hence interact with the target with a smaller effective cross section: $\sigma < \sigma^{inel}(NN)$

RHIC: tests are difficult as one needs a process which has inclusive cross section linear in A at large x: Single pion production at very large p_t?

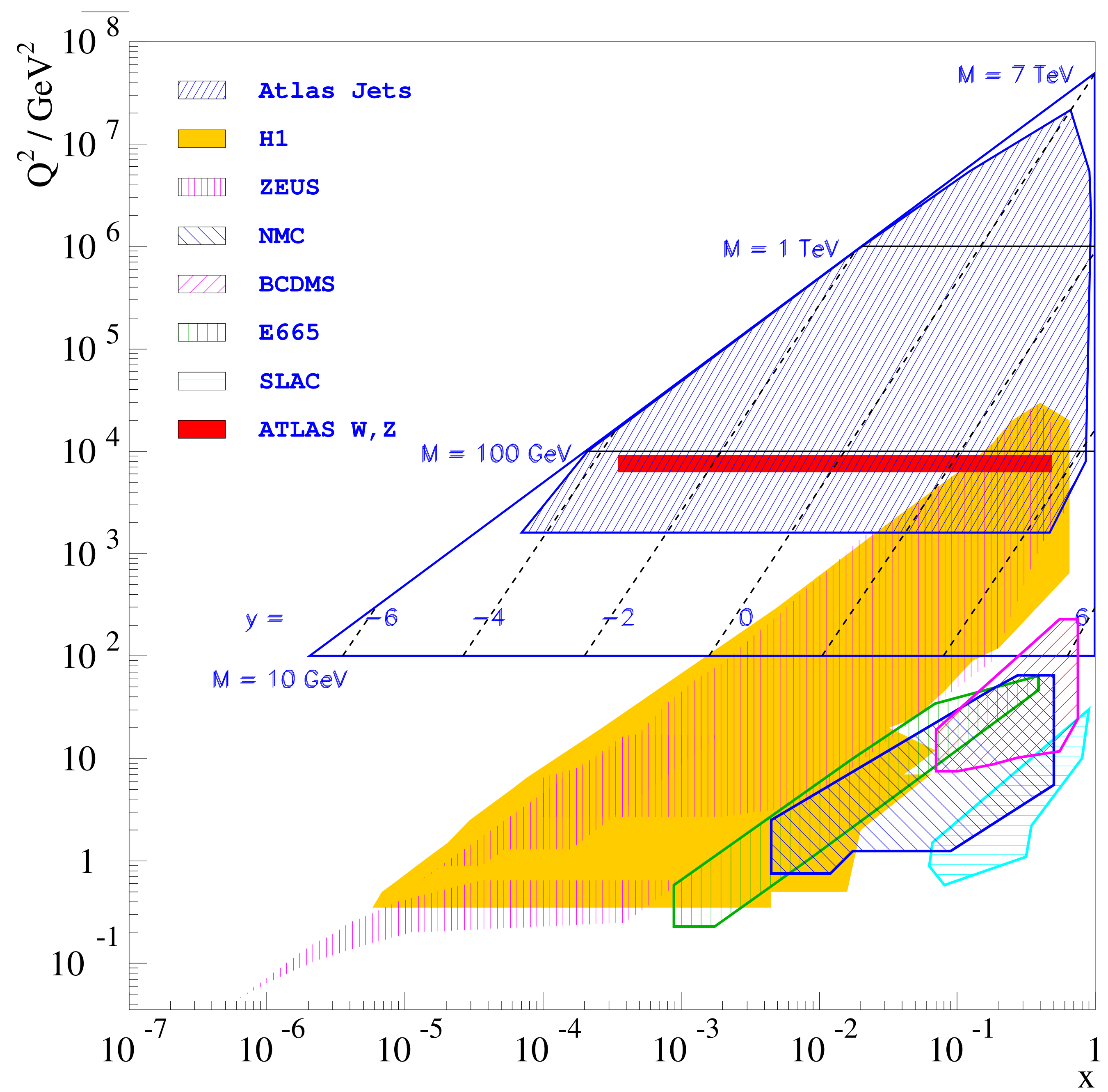
For current dA runs the color fluctuation effect would lead to additional suppression of pion yield for central collisions due to adopted procedure of definition of centrality.

At smaller x, or for photon trigger study of correlation between hard and soft components of pA interaction is promising way to probe nucleon structure FS83

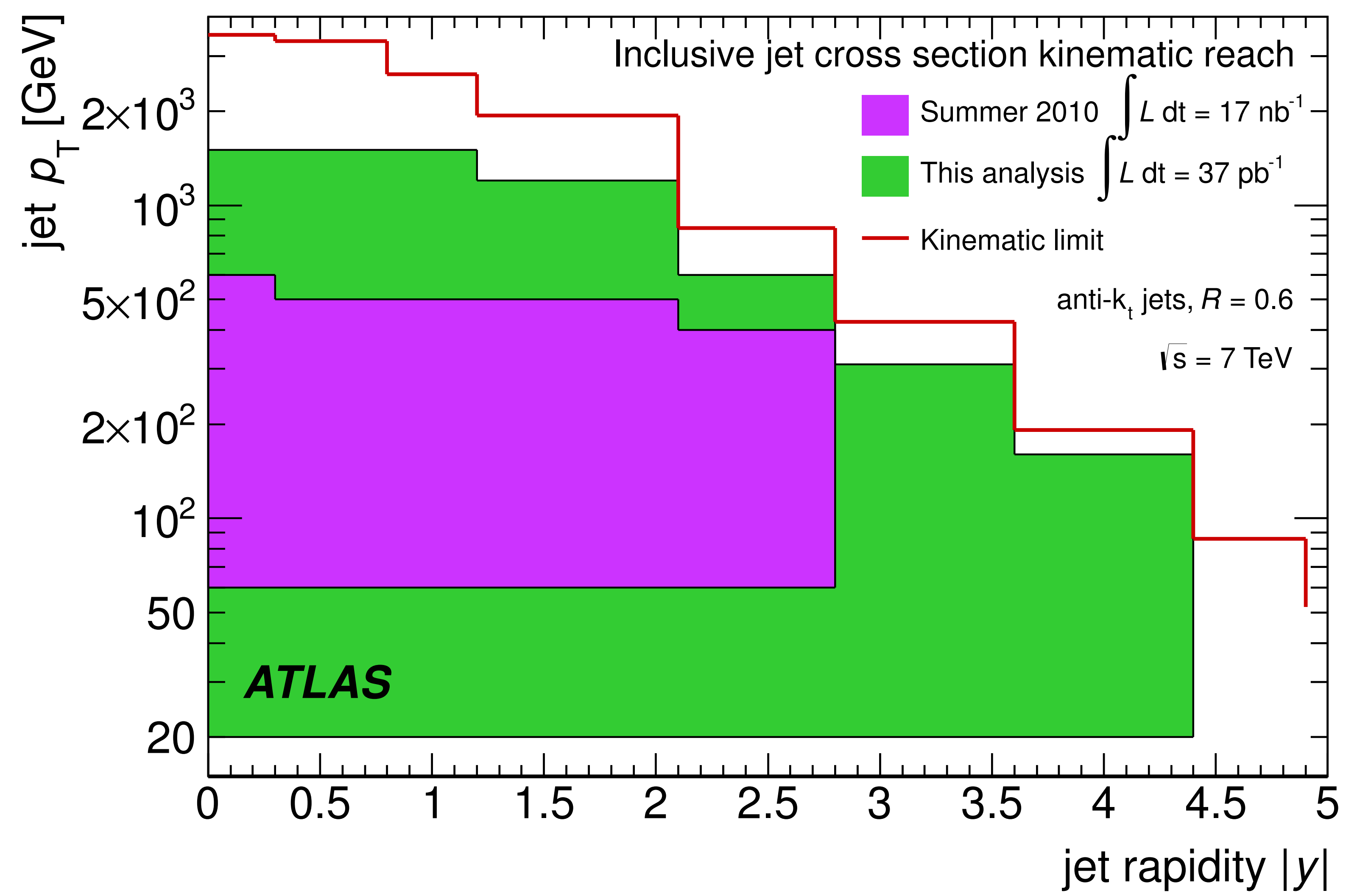
LHC - jets with large p_t - -- no nuclear shadowing effects

Inclusive jet/dijet cross section measurements

Using full 2010 dataset (**37 pb**$^{-1}$)
$\rightarrow$ probe perturbative QCD in new kinematic regime



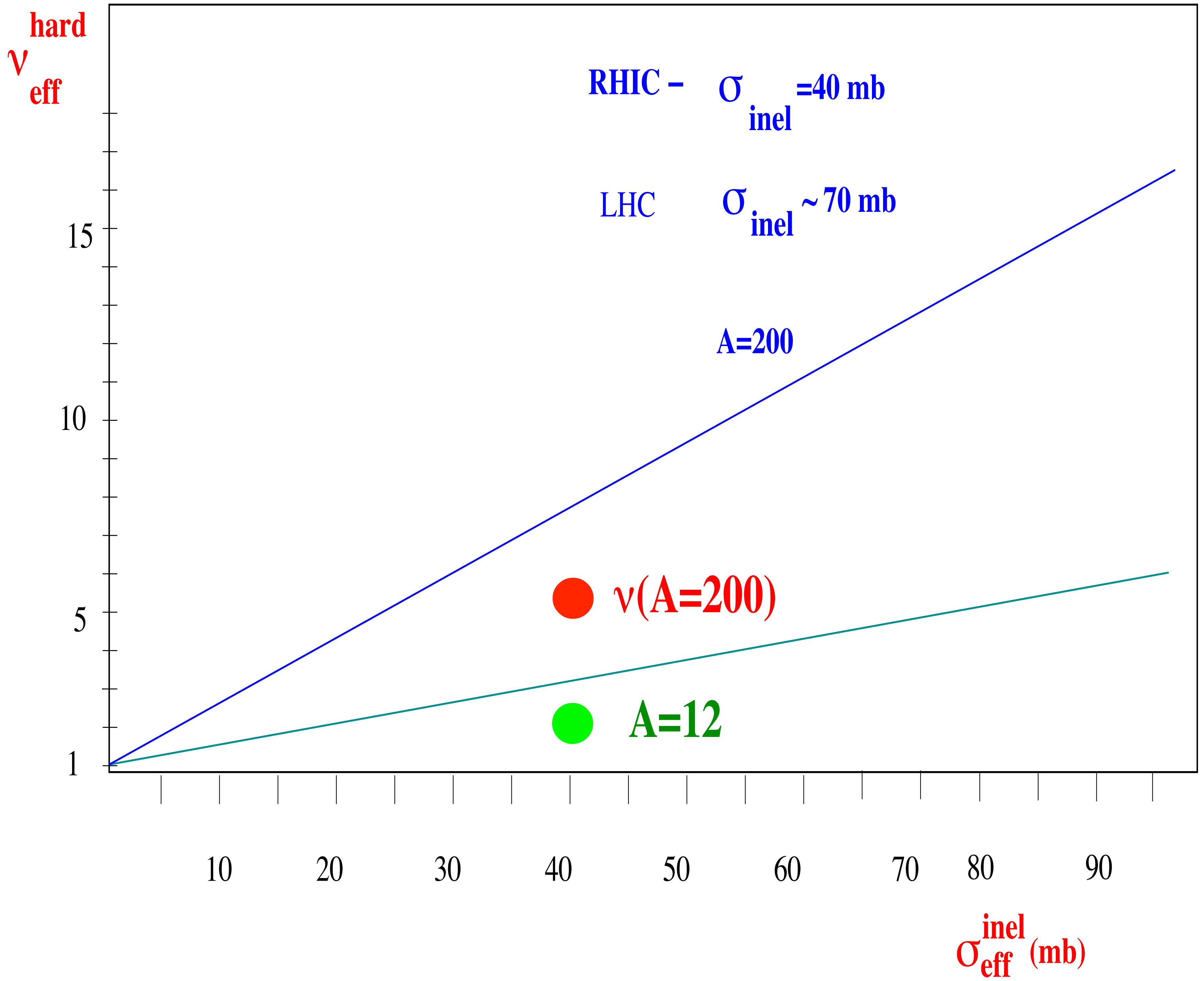
$7 \cdot 10^{-5} < x < 0.9$
$Q^2 > 2 \cdot 10^7$ GeV^2



20 GeV$<p_T^{jet}<$1.5 TeV
70 GeV $< m_{12} <$ 5 TeV
$|y| <$4.4

A lot of events at x> 0.6 at large p_t !!!

$$\nu(x,A) = 1 + \sigma_{eff}(x)\frac{A-1}{A^2}\int T^2(b)\ d^2b$$ number of wounded nucleons > ν(A)



Dependence of the number of inelastic interactions with the target on the transverse size of the probed configuration for a hard trigger like p +A→jet$_1$ (forward x) + (jet$_2$) + X reaction

Significant reduction of ν(x,A) for x≳0.6(based on suppression of the sea at large x and also the analysis of the EMC effect)

Expectation:

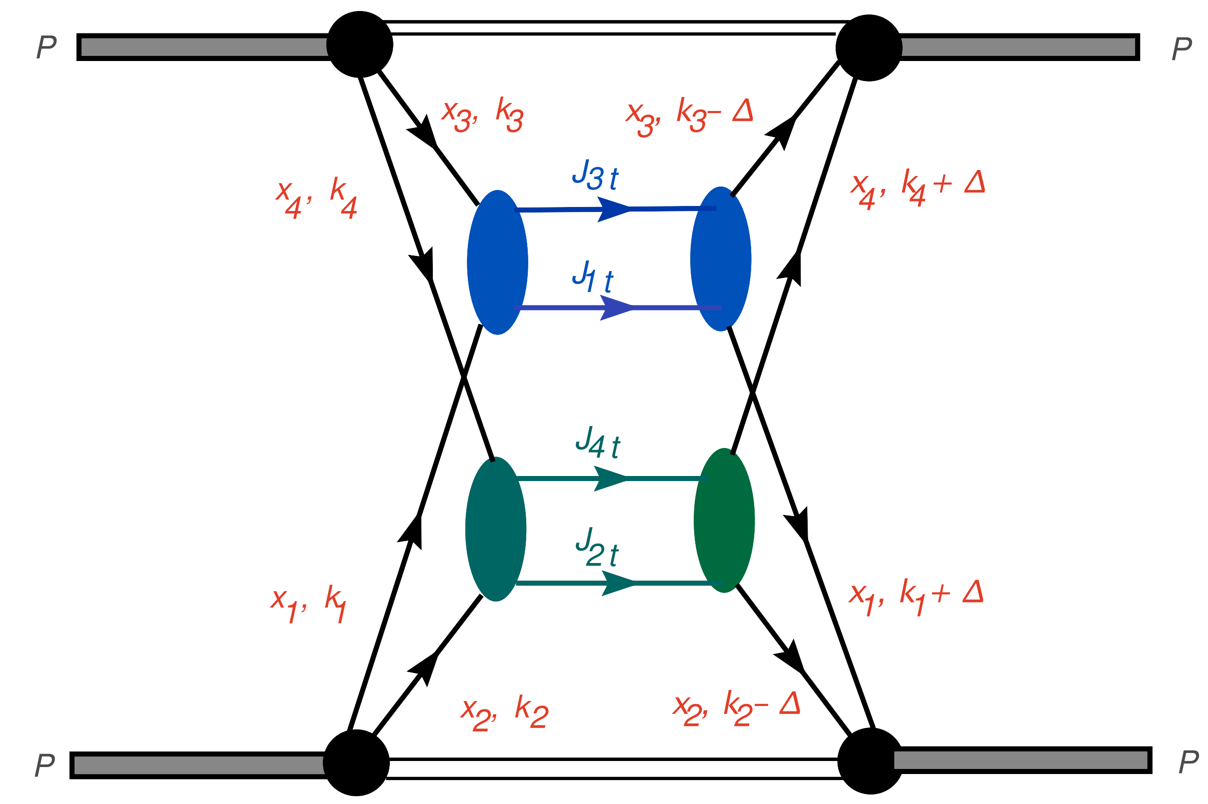
σ_{incl} (pA) = A σ_{incl} (pN)

σ_{cental} (pA) <<T_A(b=0) σ_{incl} (pN)

mimics absorption for $p_t \gtrsim$ 100 GeV/c

Small x trigger - $\sigma_{eff} > \sigma_{inel}$???

Multiparton interactions in pA.--- probing parton correlations in nucleons - maybe feasible at LHC (4 jets) . Two forward pions at RHIC (Vogelsang, MS)



Experimentally one measures the ratio

$$\frac{\frac{d\sigma(p+\bar{p}\to jet_1+jet_2+jet_3+\gamma)}{d\Omega_{1,2,3,4}}}{\frac{d\sigma(p+\bar{p}\to jet_1+jet_2)}{d\Omega_{1,2}} \cdot \frac{d\sigma(p+\bar{p}\to jet_3+\gamma)}{d\Omega_{3,4}}} = \frac{f(x_1,x_3)f(x_2,x_4)}{Sf(x_1)f(x_2)f(x_3)f(x_4)}$$

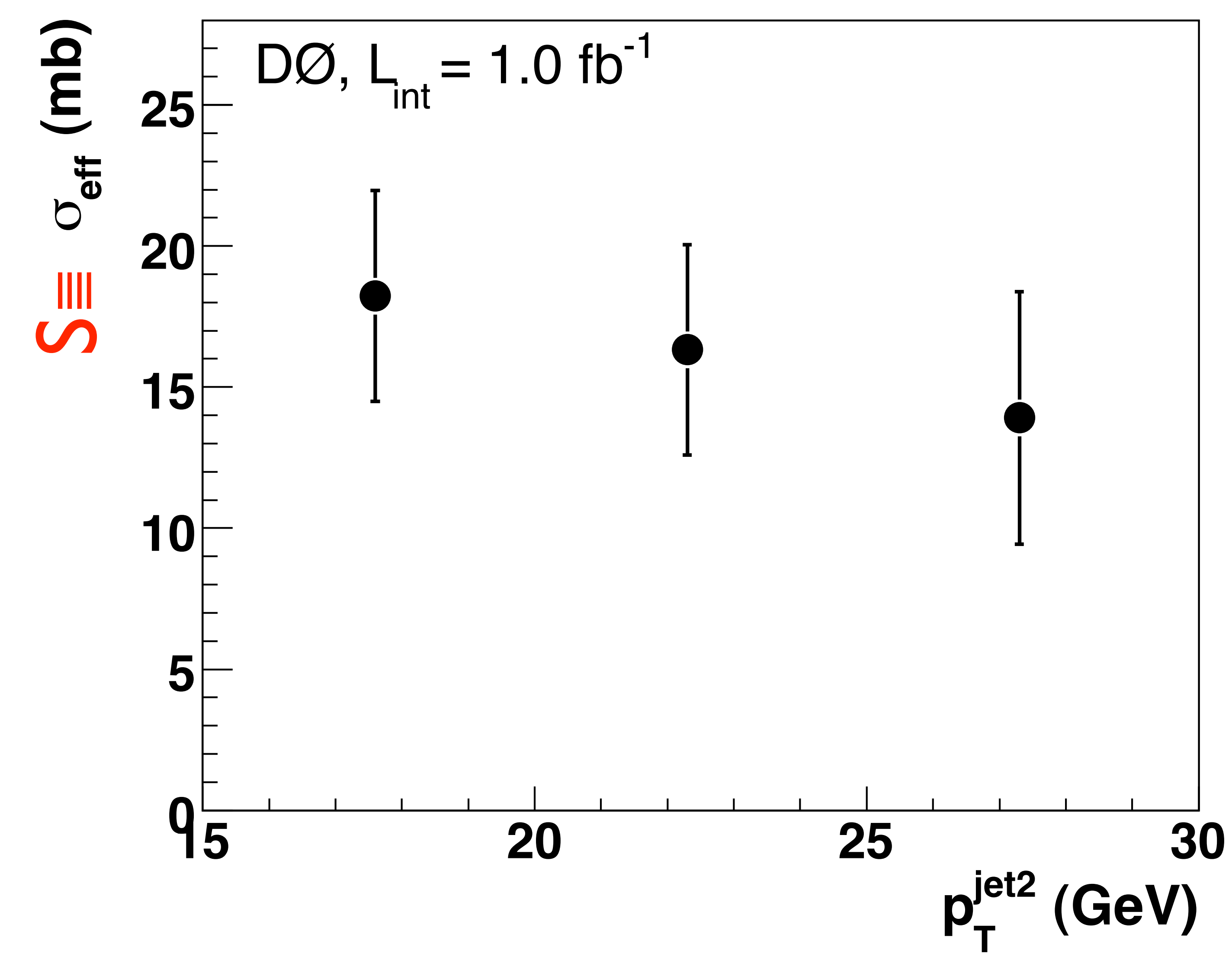
where $f(x_1,x_3), f(x_2,x_4)$ longitudinal light-cone double parton densities and

S is ``transverse correlation area". One selects kinematics where 2 →4 contribution is small

CDF observed the effect in a restricted x-range: two balanced jets, and jet + photon and found

$$S = 14.5 \pm 1.7^{+\,1.7}_{-\,2.3}\ mb$$

No dependence of S on x_i was observed.



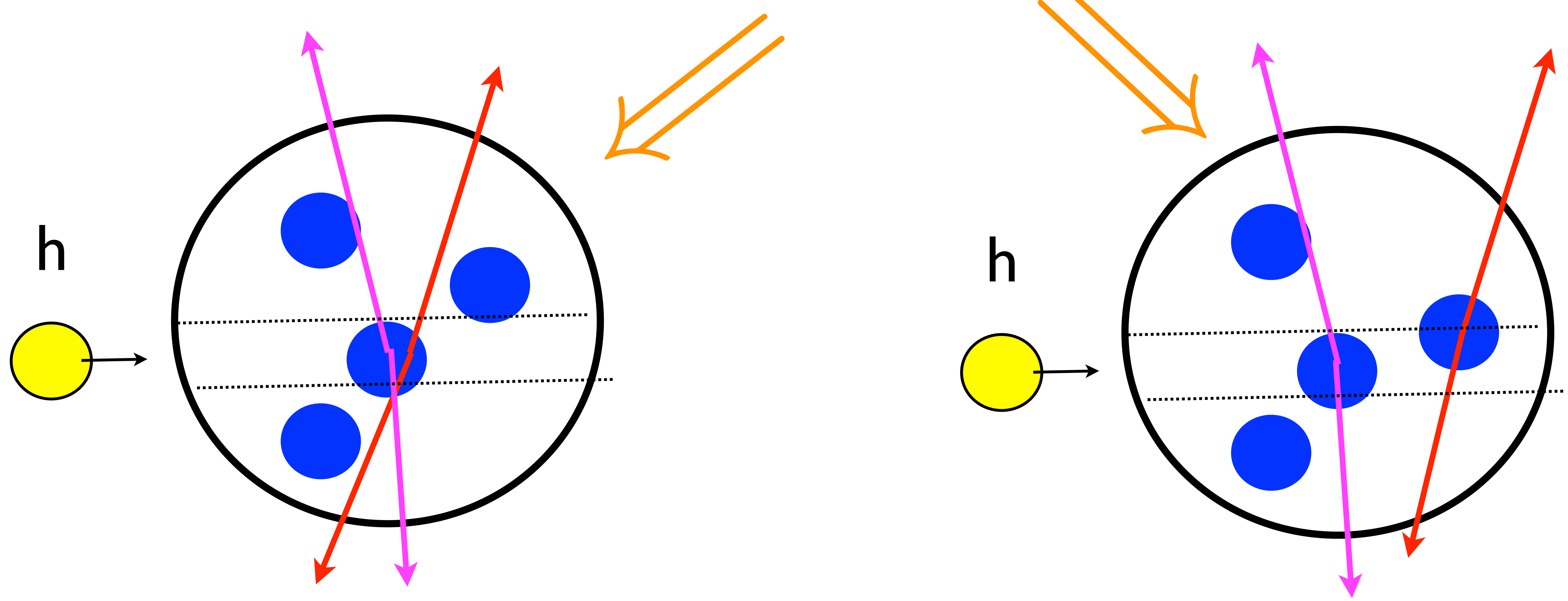
A naive expectation (based on r_N=0.8 fm) is S~ 55 mb. Gluon radius is smaller --- S~ 35 mb. So S~ 15mb indicate presence of significant correlations between partons in the nucleon. Is it transverse plane correlation or correlation of x's ?

Similar results from D0.

Multiparton interactions in proton - nucleus collisions

MS & Treleani 95 - PRL 2002

$$\sigma = \sigma_1 \cdot A + \sigma_2$$



$$R \equiv \frac{\sigma_2}{\sigma_1 \cdot A} \approx \frac{(A-1)}{A^2} \cdot \sigma_{eff} \int T^2(b)\ d^2b \approx 0.68 \cdot \left(\frac{A}{12}\right)^{0.39}\Big|_{A \geq 12, \sigma_{eff} \sim 14mb}$$

$$T(b) = \int_{-\infty}^{\infty} dz \rho_A(z,b), \int T(b) d^2b = A.$$

"Antishadowing effect": For A=200, and σ_{eff}=14 mb $\quad \frac{\sigma_{pA}}{\sigma_{pp}} \approx 3$ $\quad$ linear in σ_{eff} !!

Measurement of R allows to separate longitudinal and transverse correlations of partons as it measures $R=f(x_1,x_2)/f(x_1)f(x_2)$ - Blok, Dokshitzer, Frankfurt, MS R-1.2

Conclusions

pA@LHC will provide important information on high density small x physics in variety of pA channels complementary to

$\gamma A/\gamma p$. Clear path to probing nonlinear effects at moderate p_t and x at least down to 10^{-4}

Forward region -- critical tests of p_t broadening, energy losses, looking for $2 \rightarrow 1$ mechanism of pion/jet production.

Very forward region -- critical tests of the onset of black regime
Very important to have pA RHIC vs LHC comparison

Effects of color fluctuations can be studied with large x_p trigger

Multiparton interactions - need for high lumi