Very forward pA physics at LHC

Mark Strikman, PSU

pA@LHC, June 8, 2012

Outline

Color fluctuations in the nucleon and pA scattering

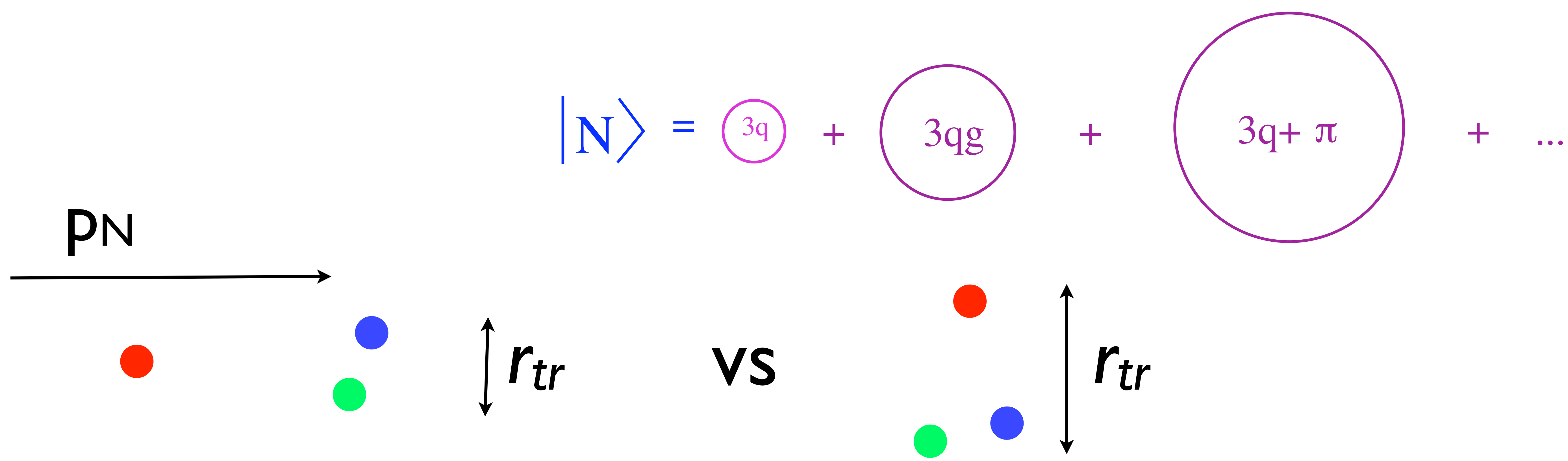
Nucleon fragmentation at $x_F > 0.2$ in pA

Ultraperipheral processes

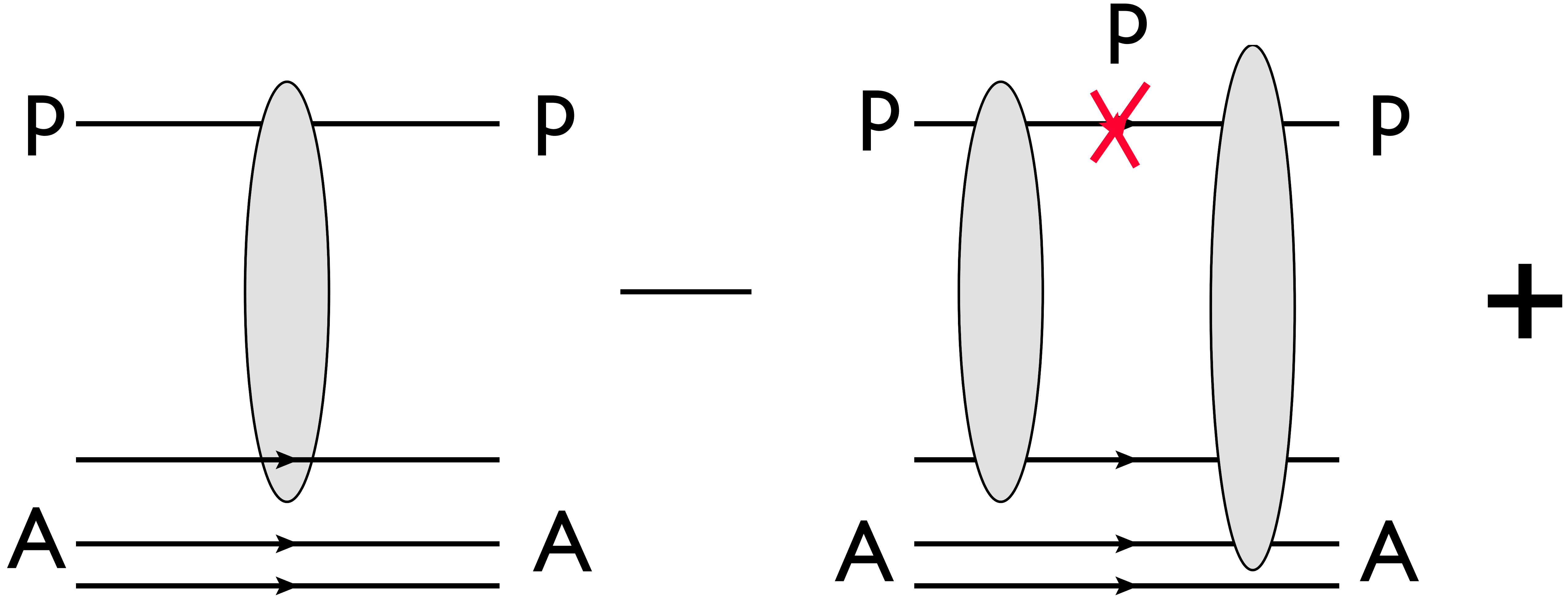
Multiparton interactions

Color fluctuations in the nucleon wave function & 3-dimensional mapping of the nucleon

Are there global fluctuations of the strength of interaction of a fast nucleon, for example due to fluctuations of the size /orientation

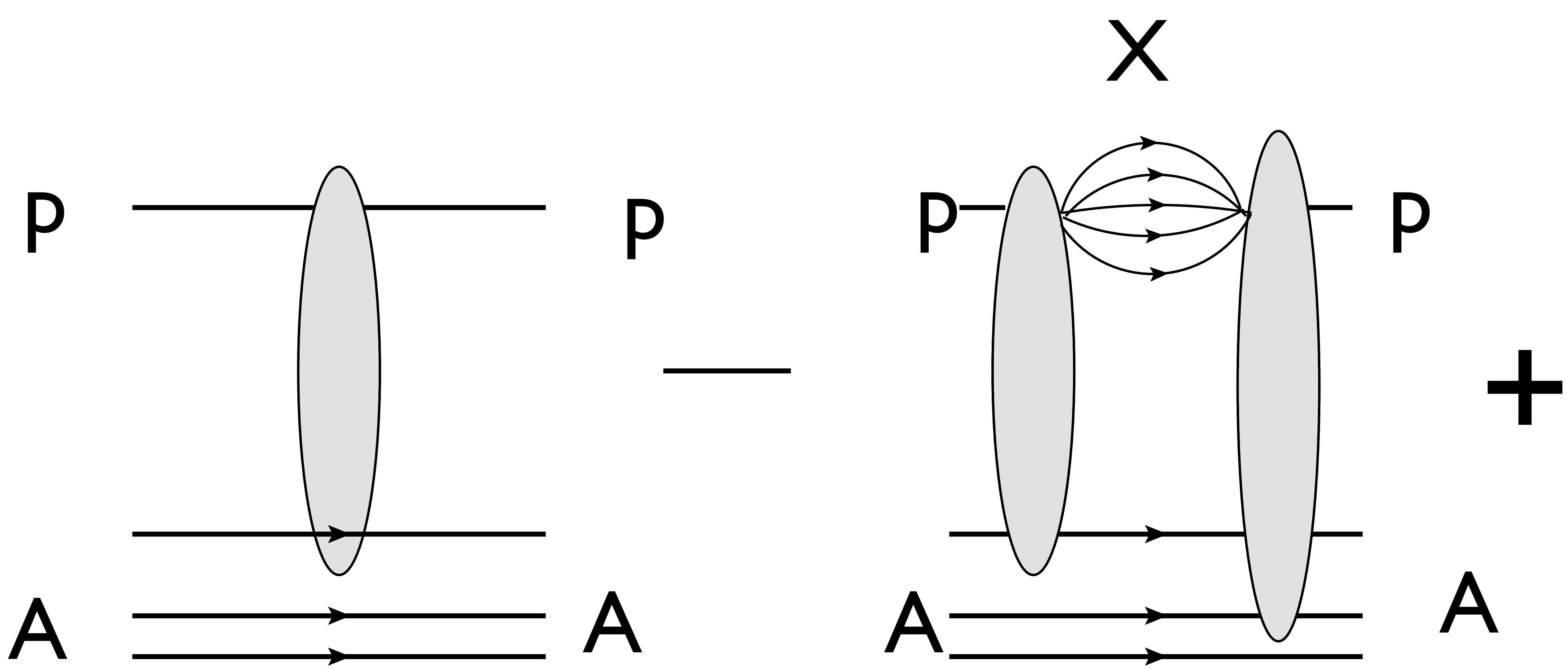


Due to a slow space-time evolution of the fast nucleon wave function one can treat the interaction as a superposition of interaction of configurations of different strength - Pomeranchuk & Feinberg, Good and Walker, Pumplin &Miettinen (in QCD this is reasonable for total cross sections and for diffraction at very small t)



Glauber model

in rescattering proton in intermediate state - zero at high energy
- AFS cancelation - no time for a proton to come together between nucleons



High energies = Gribov -Glauber

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 ~ 1.3 fm $\Rightarrow$

$2\langle b\rangle > r_{NN} \sim 1.7$ fm $\Rightarrow$

projectile proton can hit two nucleons at the same time.

Convenient picture of diffraction -

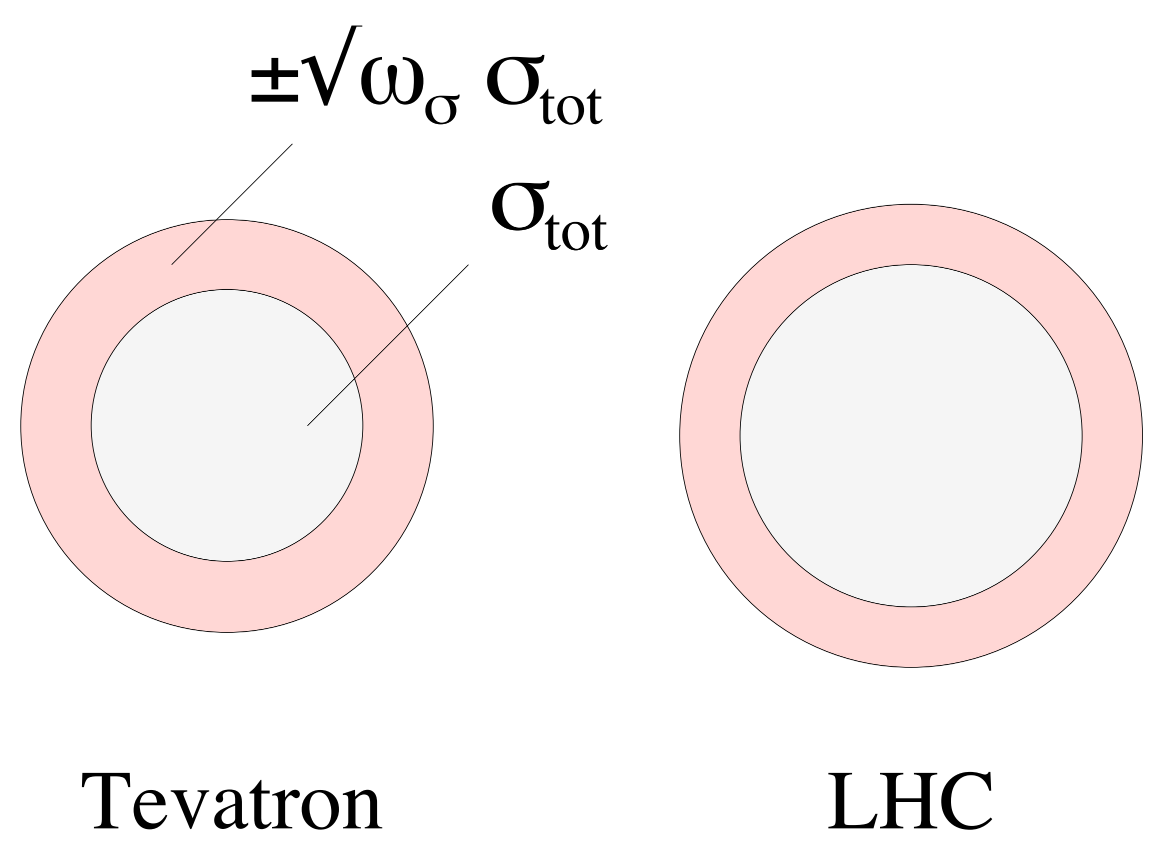
Good - Walker scattering eigen state formalism $\sigma_n |n\rangle = T|n\rangle$

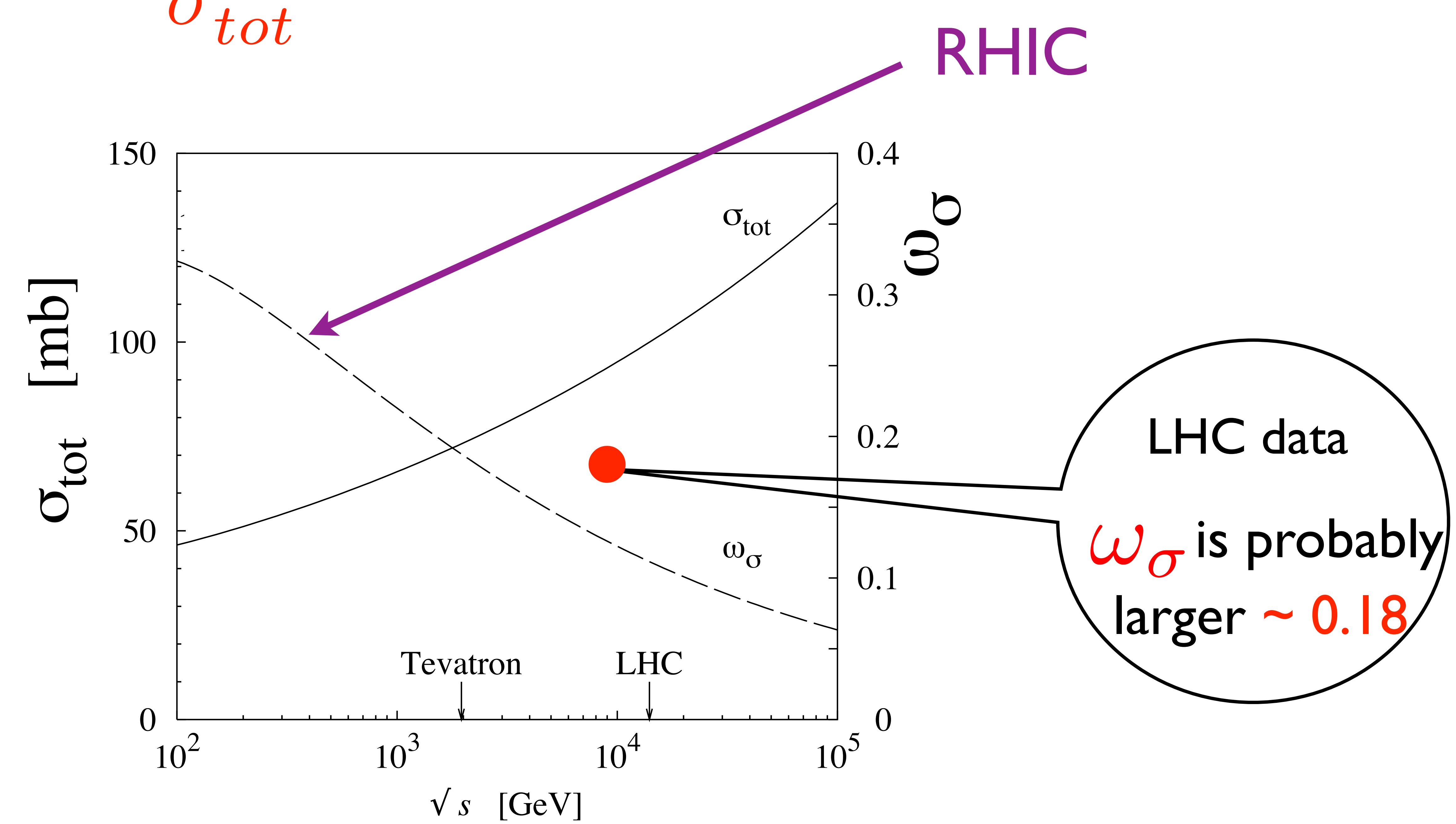
Useful quantity - $P(\sigma)$ -probability that nucleon interacts with cross section σ

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

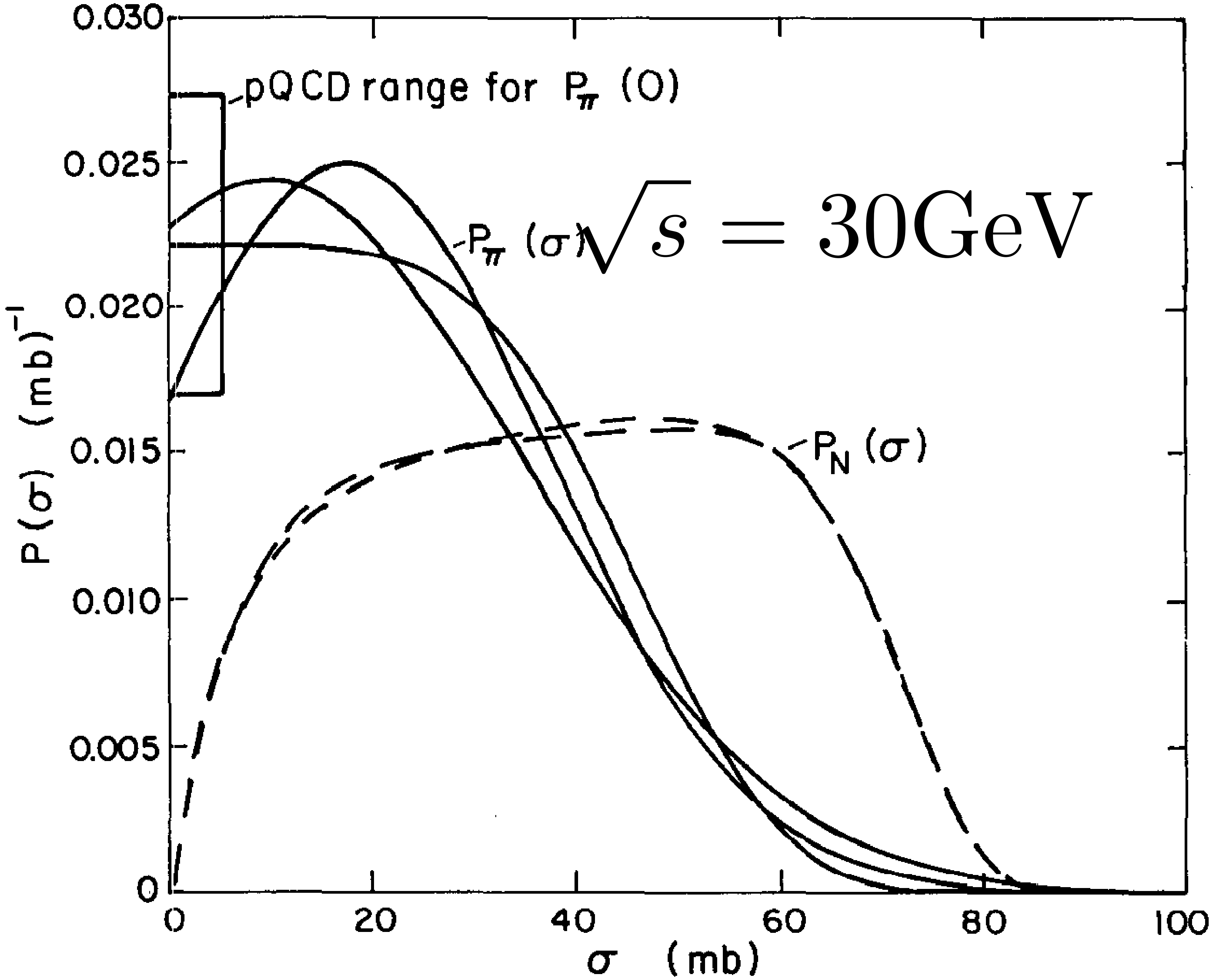
$$\left.\frac{\frac{d\sigma(pp\to X+p)}{dt}}{\frac{d\sigma(pp\to p+p)}{dt}}\right|_{t=0} = \frac{\int(\sigma-\sigma_{tot})^2 P(\sigma)d\sigma}{\sigma_{tot}^2} \equiv \omega_\sigma$$

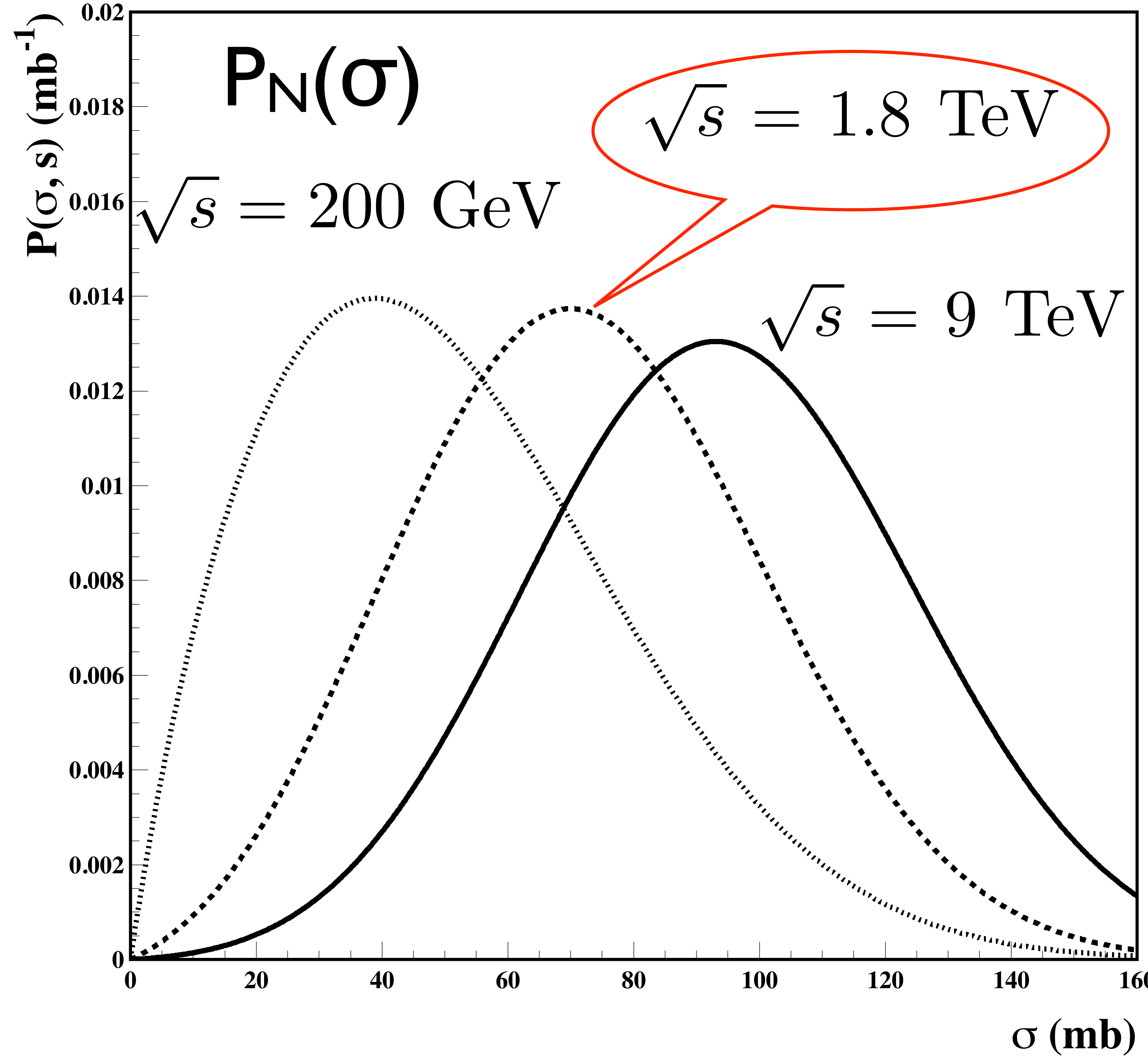
variance



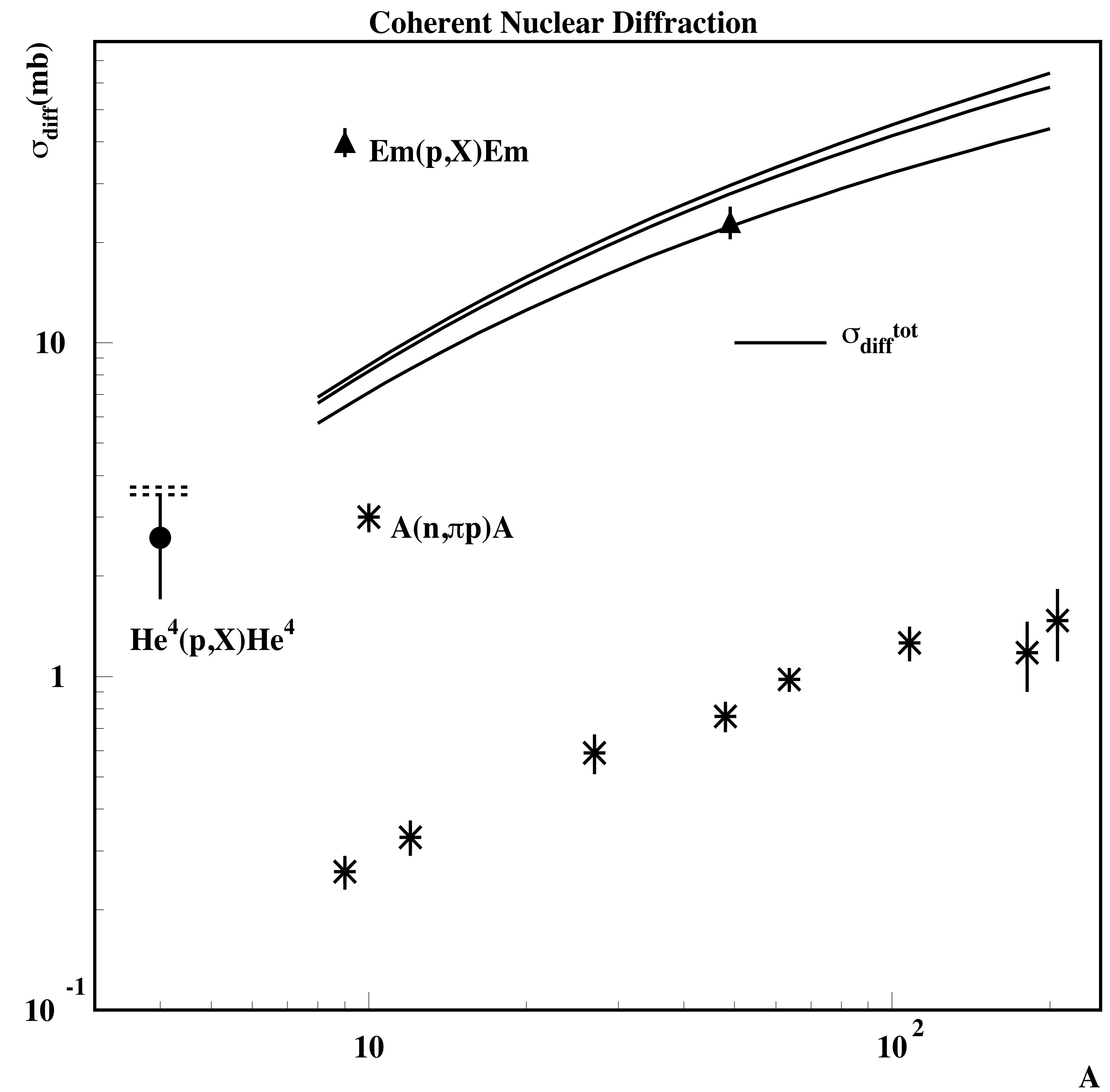


Both small and large configurations grow a periphery - still there is a correlation between σ and parton distributions -smaller σ, harder quark distribution





$P_N(\sigma)$ 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.

Fluctuations in the number of interactions even at small b given by variance of P(σ0.

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

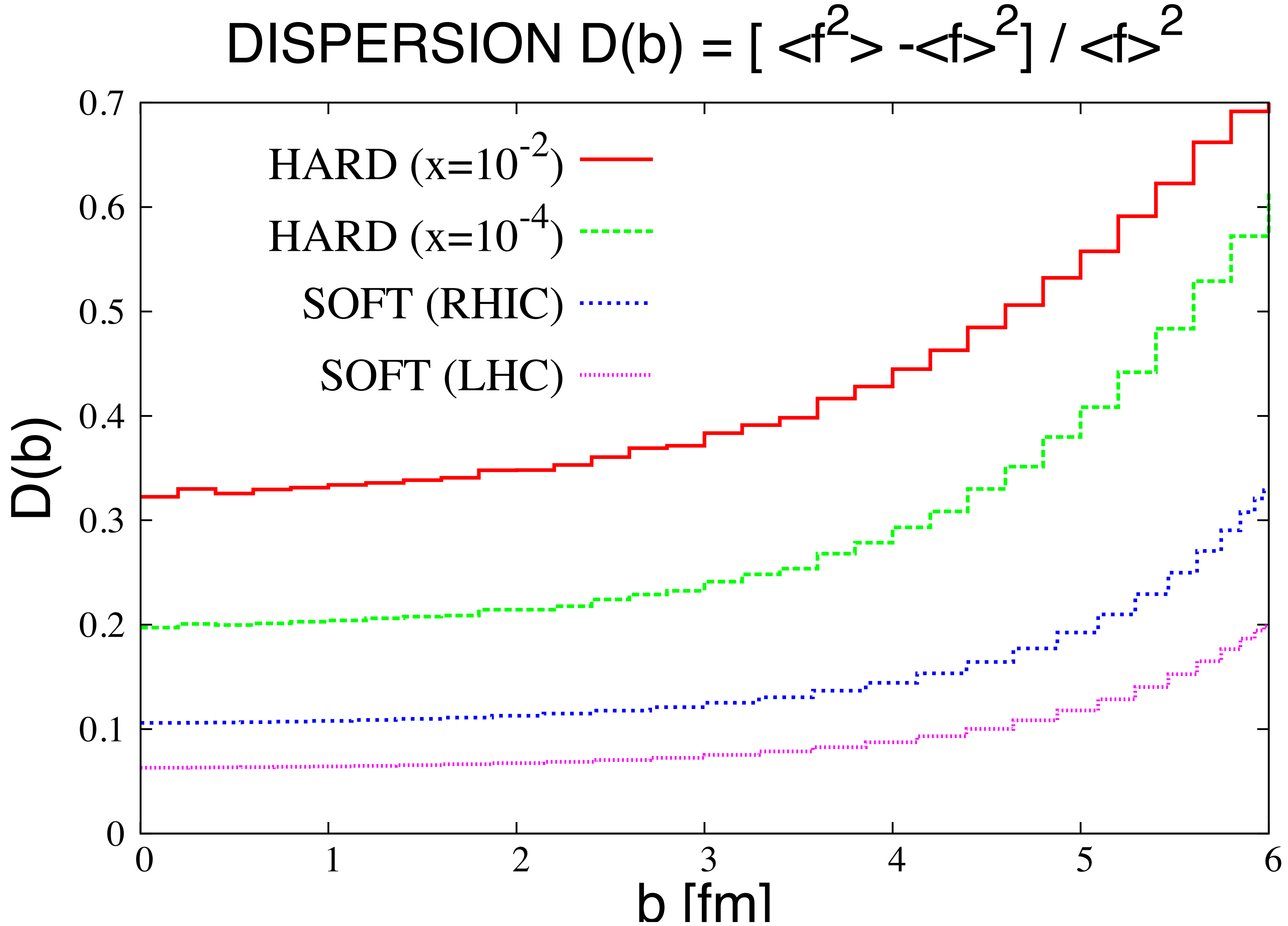
number of wounded nucleons at small b differs by a factor of 3 !!!

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

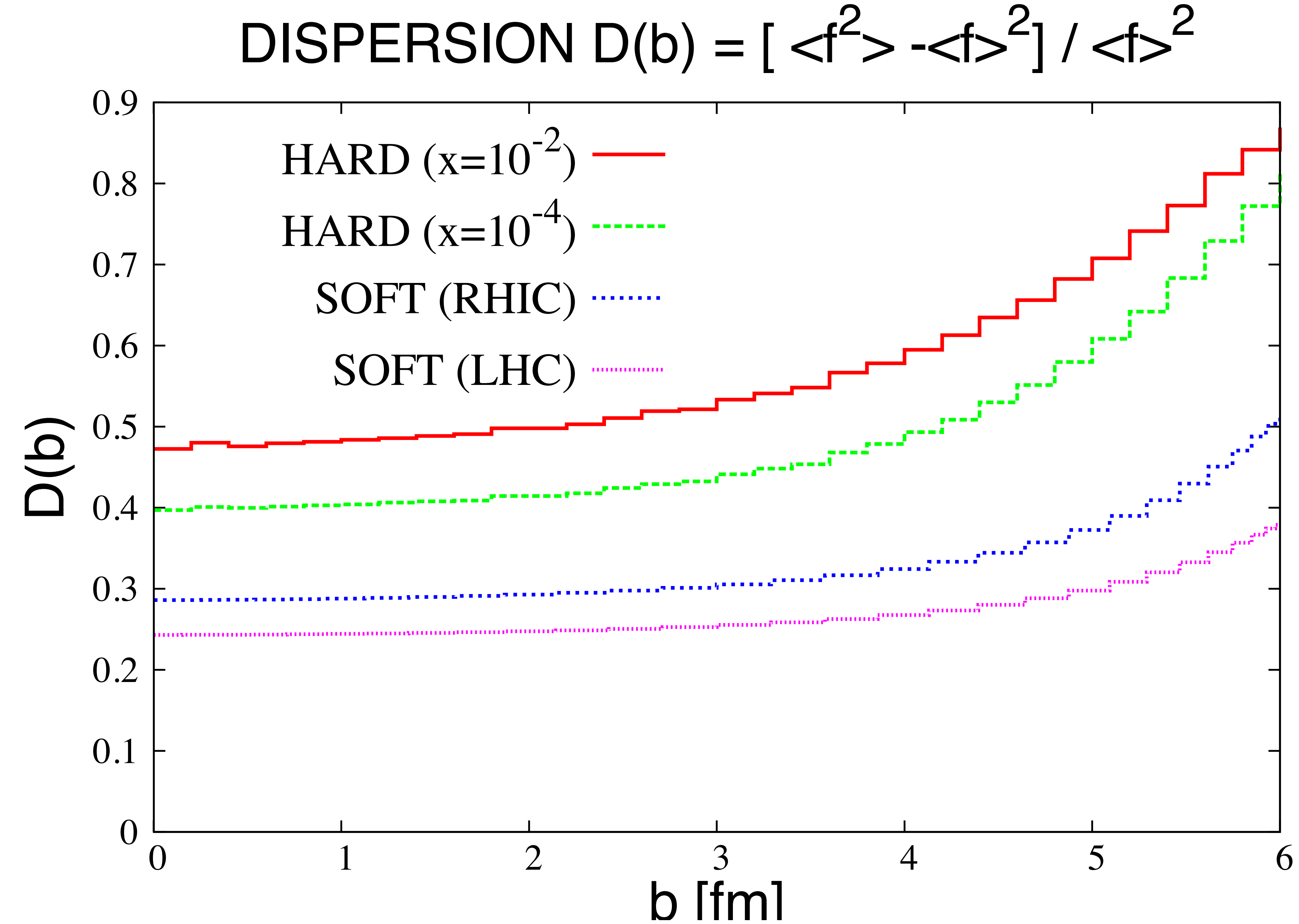
color fluctuations lead to addition dispersion as compared to geometrical model

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

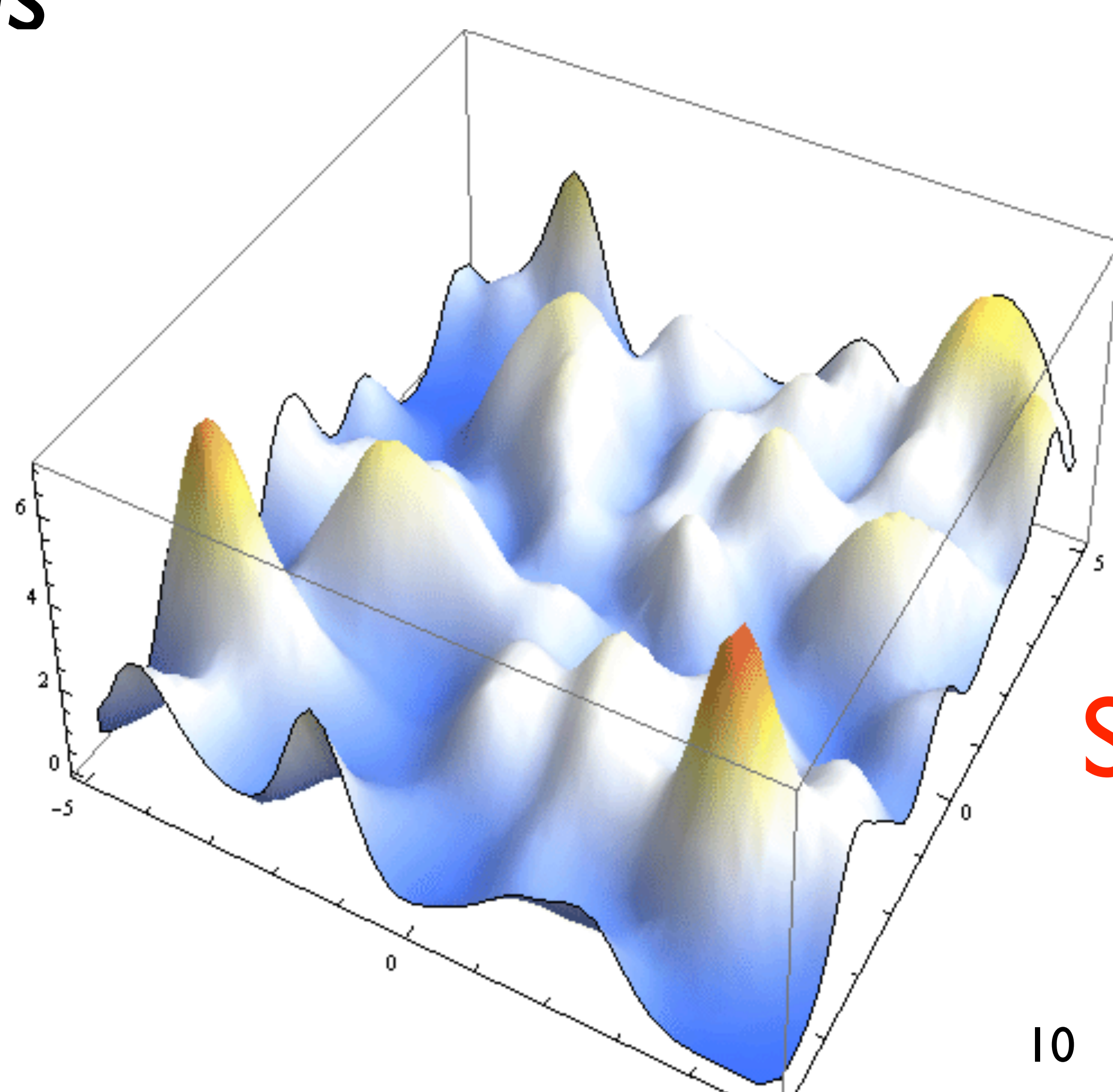
$\Delta\omega = 2\ \omega_\sigma$ in AA



effect of fluctuations of the number of nucleons



nucleon color fluctuations + fluctuations of the number of nucleons



Snapshot of transverse distribution of gluons

Alvioli & MS

Correlation between the hard and soft components of the pA interaction.

Most promising case (of relevance for discussion of forward physics in central pA collisions)

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: σ_{eff}.

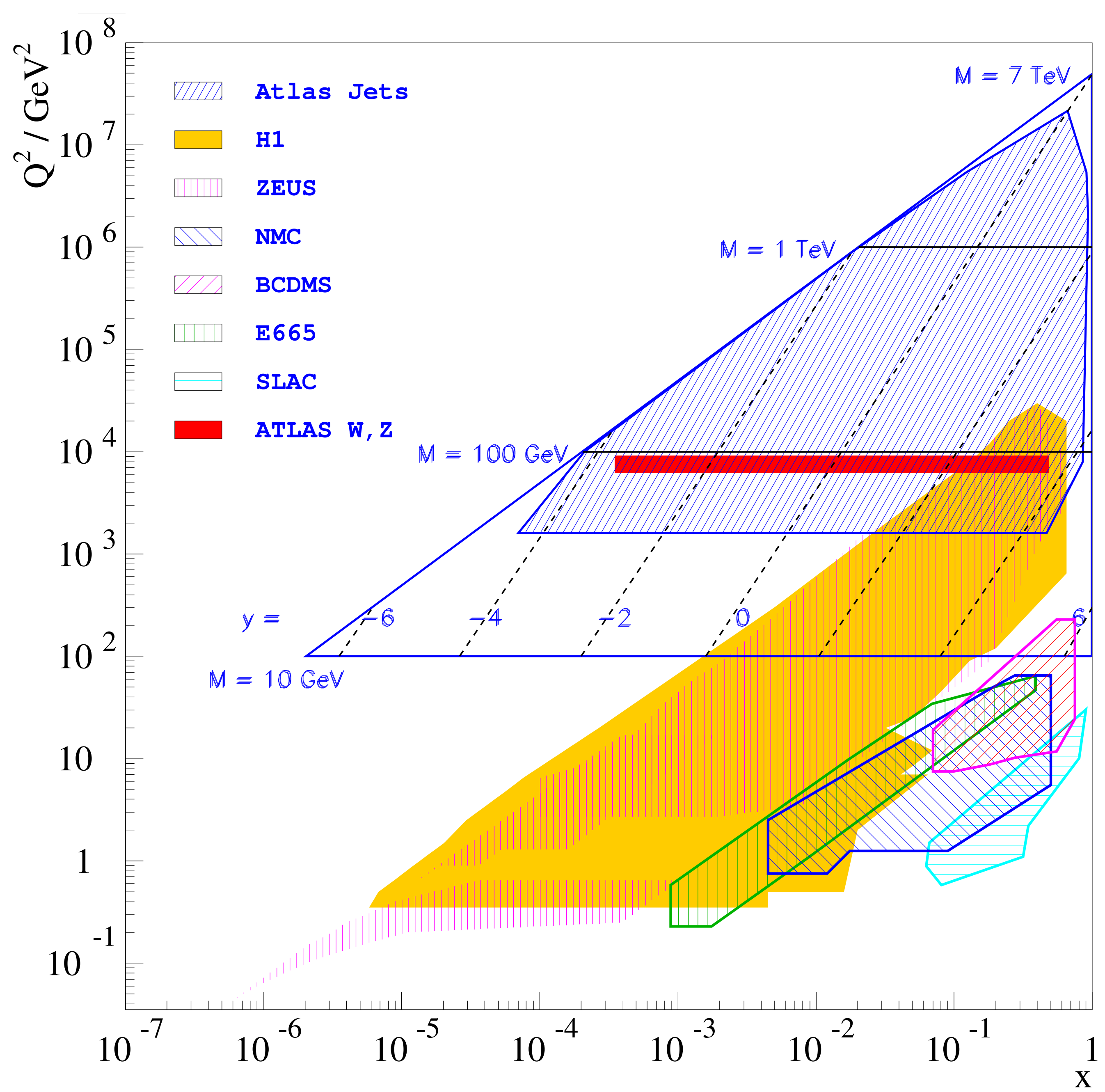
Idea:

Use the hard trigger to determine x_p and soft hadrons to measure overall strength of interaction σ_{eff} of configuration in the proton with given x_p FS83

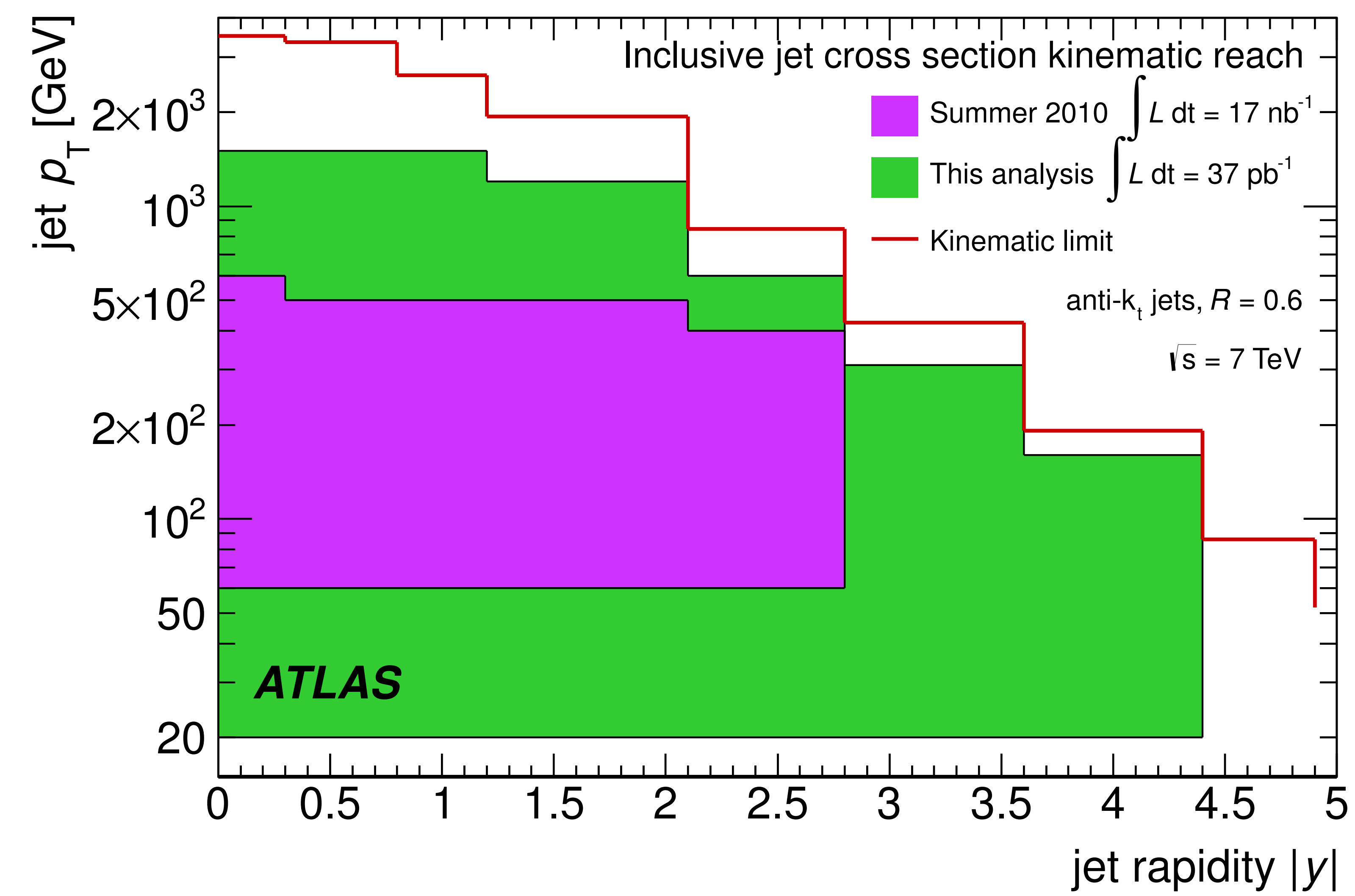
LHC - jets with large p_t - -- no nuclear shadowing effects

Inclusive jet/dijet cross section measurements

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



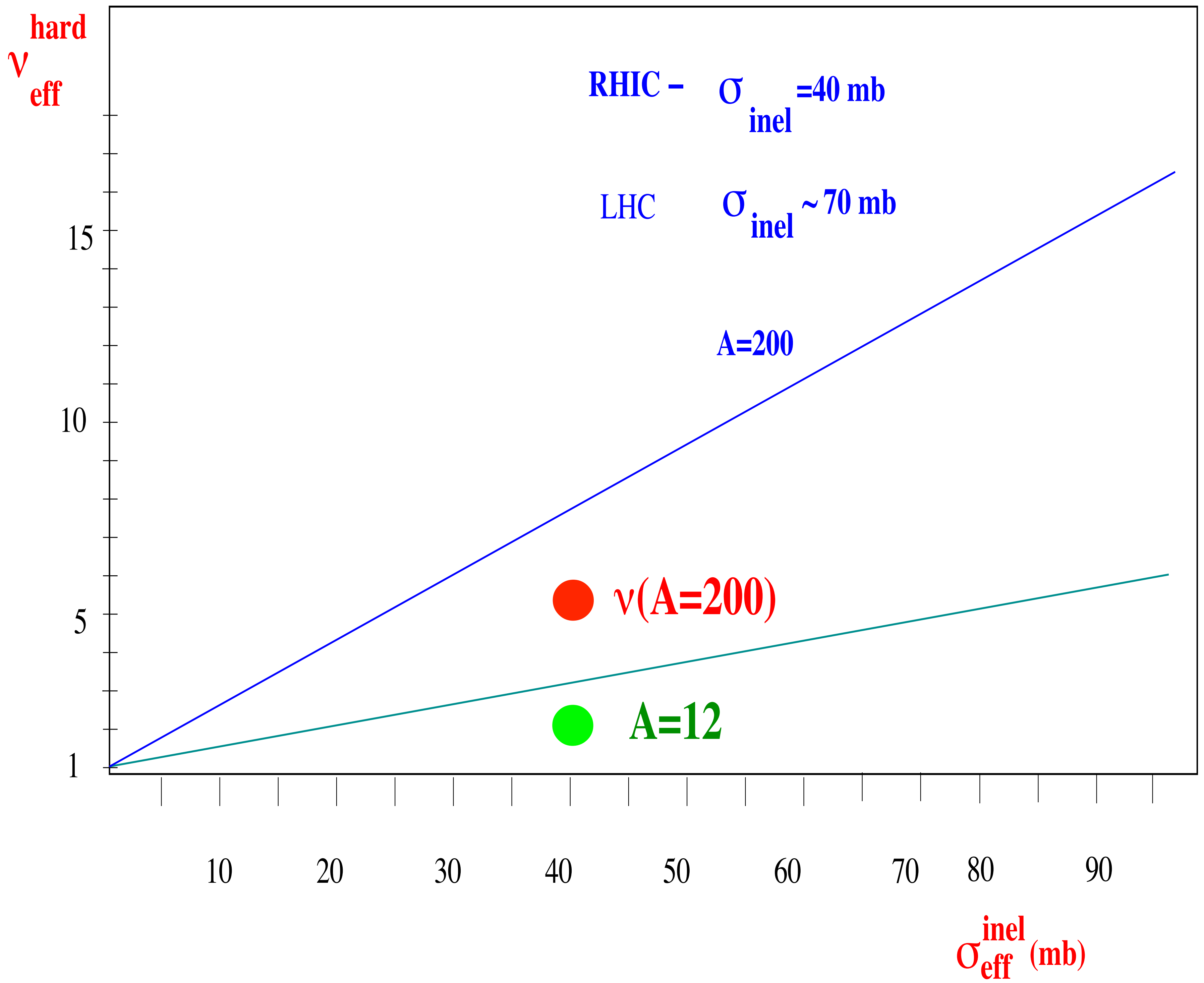
$7 \cdot 10^{-5} < x < 0.9$
$Q^2 > 2 \cdot 10^7$ GeV^2



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

Next slides: results for inclusive jet measurement, R=0.6
from [ATLAS arXiv 1112.6297, To be published by PRD]

$\nu(x,A) = 1 + \sigma_{eff}(x)\frac{A-1}{A^2}\int T^2(b)\ d^2b$ 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 $p + A \rightarrow jet_1$ (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 - $\sigma_{eff} > \sigma_{inel}$???

Side remark: nucleus quark pdf, $xq_A(x,Q^2)$ can be measured at large x if resolution in energy of the jet is good enough

$$xq_{Pb}(x,Q^2)/xq_N(x,Q^2) > 3 \text{ for } Q^2= 10^5 \text{ at } x=0.9$$

Expectation: $xq_A(x,Q^2) \propto \exp(- 10\, x)$ for $x > 0.8$

Analysis of dipole - nucleon - nucleus scattering in impact parameter space

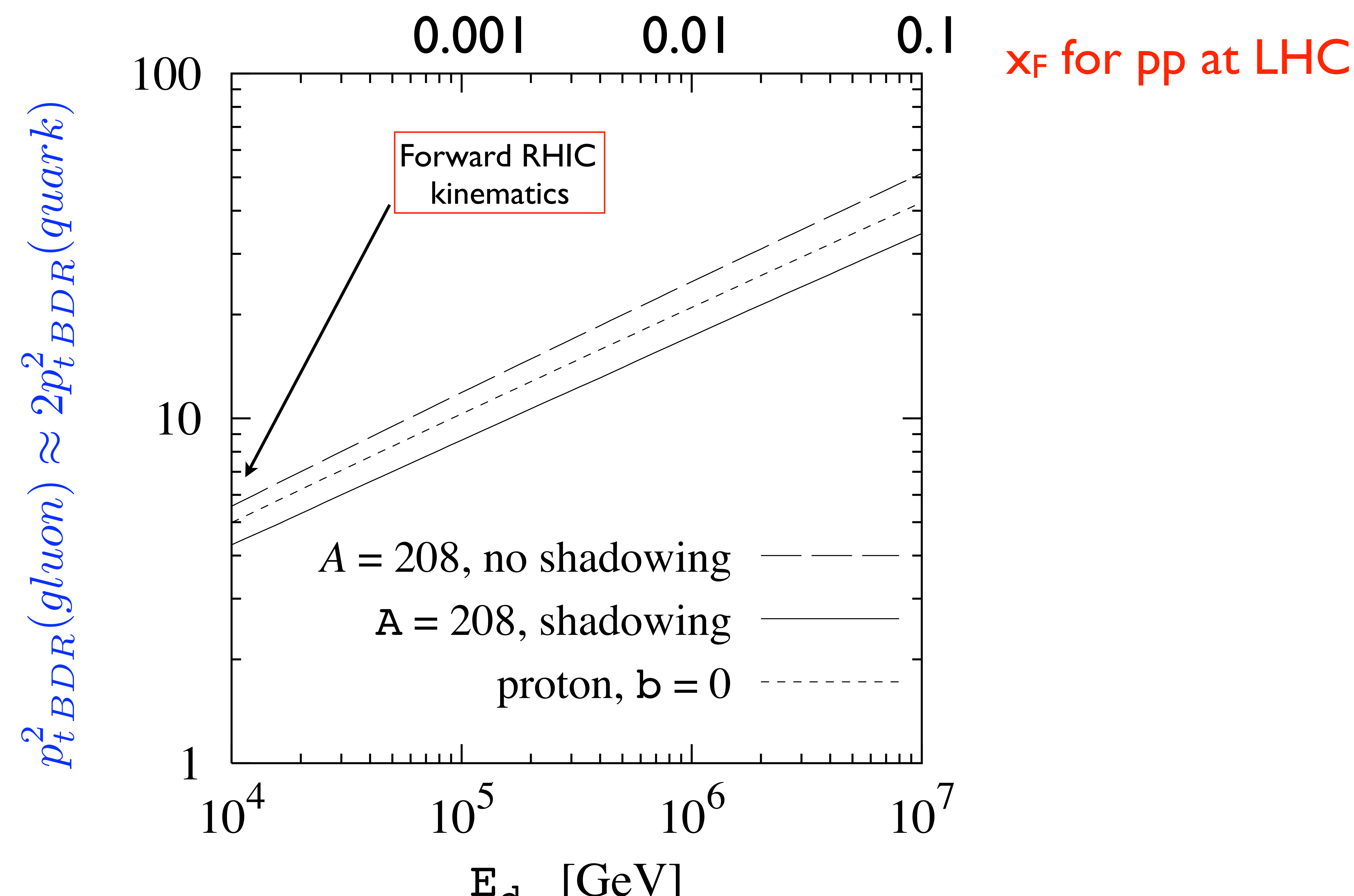
Large nonlinear effects at the LHC in wide range of rapidities down to y~0

in proton (A) - proton (A) collisions a parton with given x_R resolves partons in another nucleon with $x_2 = 4p_\perp^2/x_R s$

$$x_R = 0.01, p_\perp = 2GeV/c \Rightarrow x_2 \sim 8 \times 10^{-6}$$

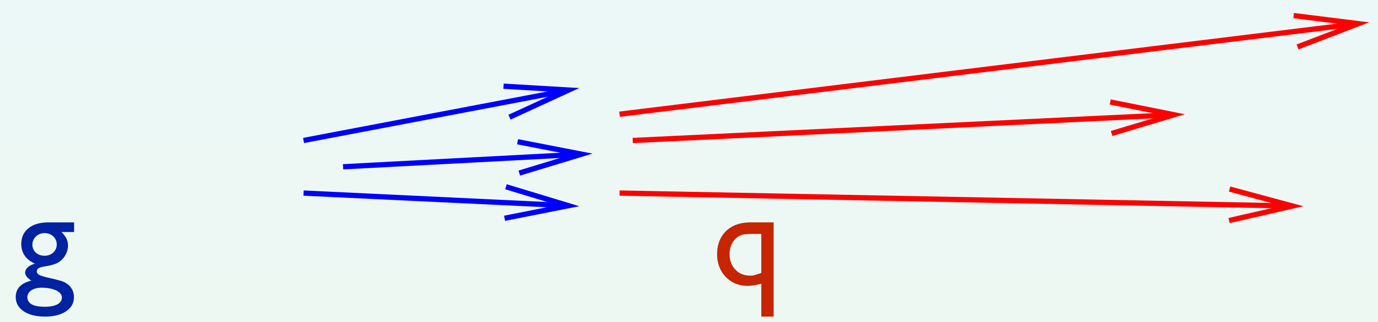
Onset of BDR for interaction of a small dipole - break down of LT pQCD approximation - natural definition of boundary: $\Gamma_{dip}(b) = 1/2$ - corresponds the probability for dipole to pass through the target at given b without interaction:

$$|1-\Gamma_{dip}(b)|^2 < 1/4 \quad \Rightarrow \quad p_{t\,BDR} \sim \frac{\pi}{2d_{BDR}}$$

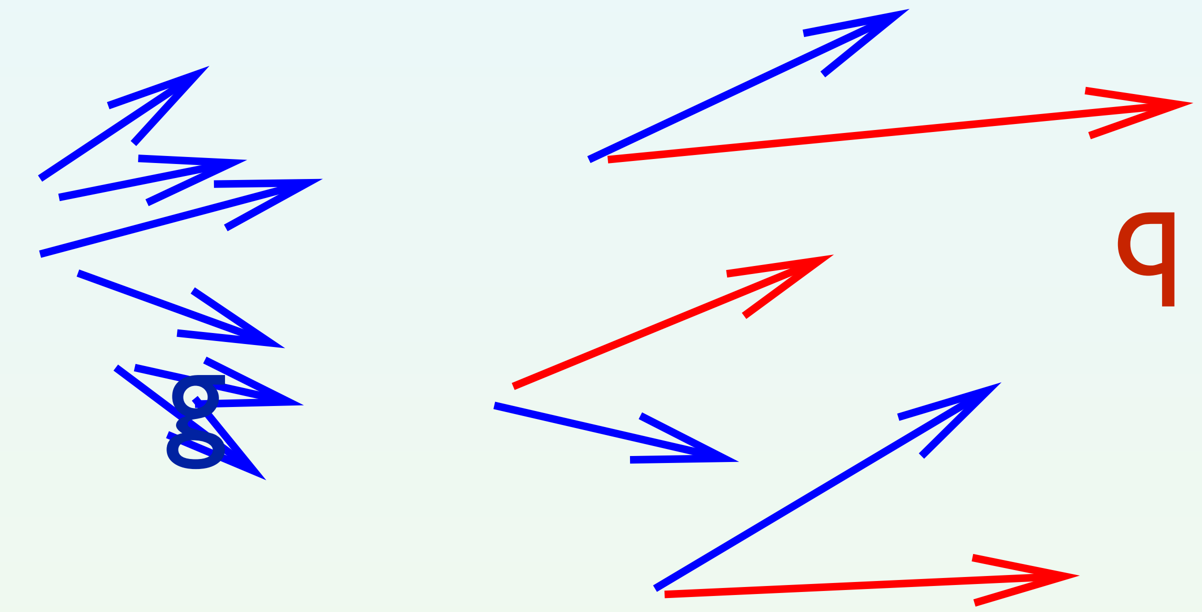


Warning - estimate assumes $x^{-\omega}$ regime for all x- may overestimate $p_{t\,BDR}$ for parton energies (in nucleus rest frame) $E_d > 10^5$ GeV - better to use double log approximation

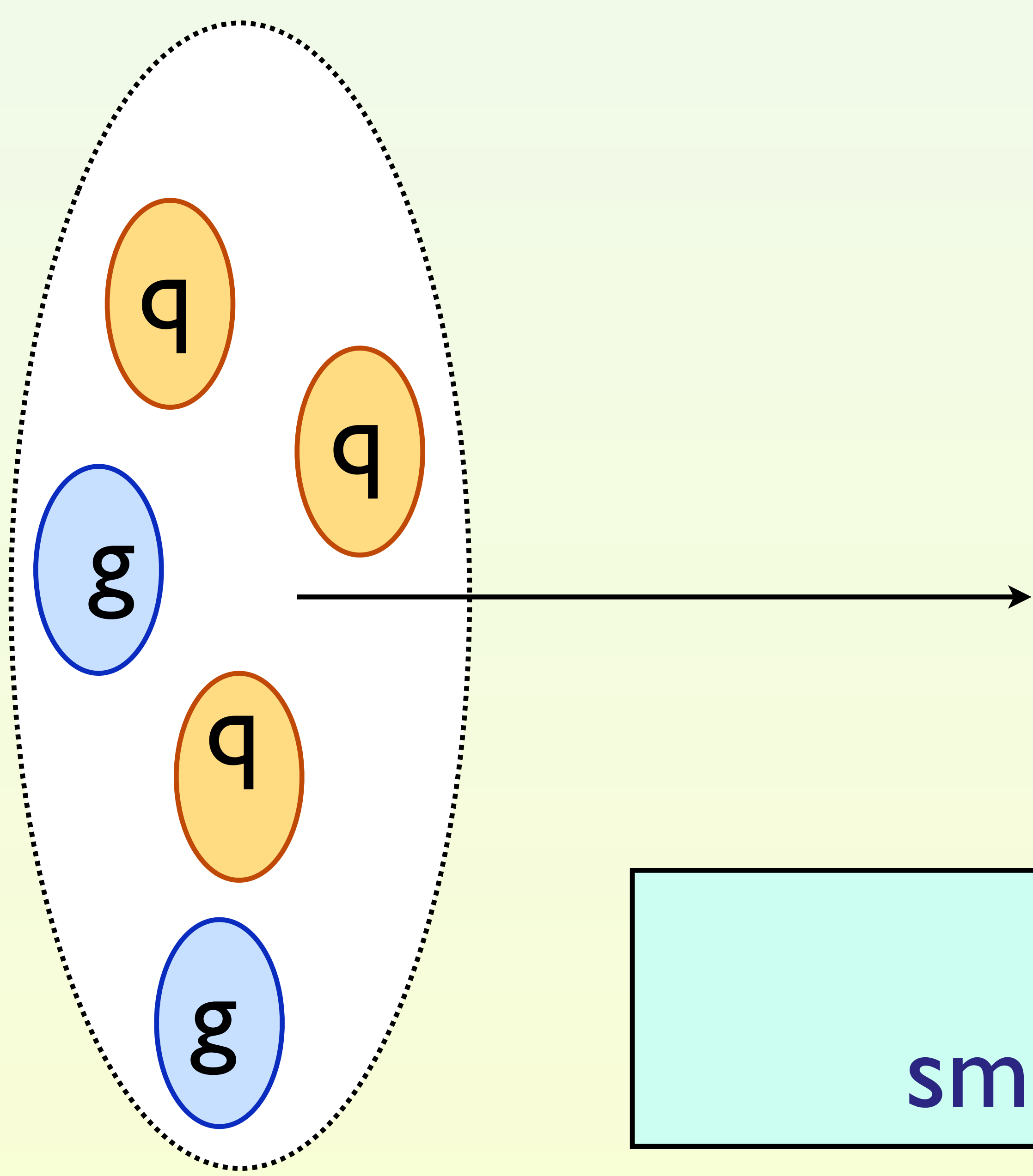
Leading hadron production in the central pA(pp) collisions

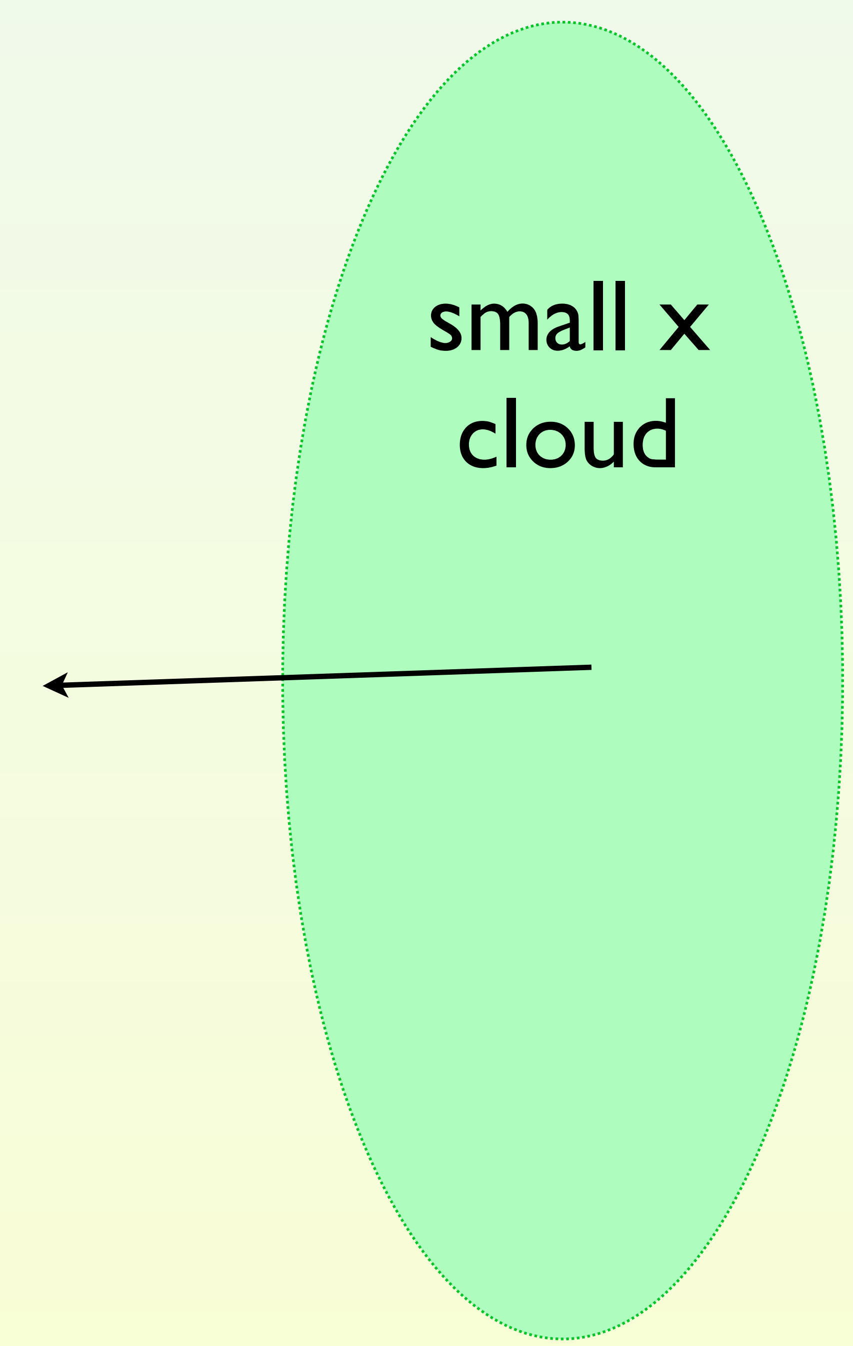


fast partons in a nucleon before collisions



fast partons in a nucleon after central collisions





Large x partons burn
small holes in the small x cloud

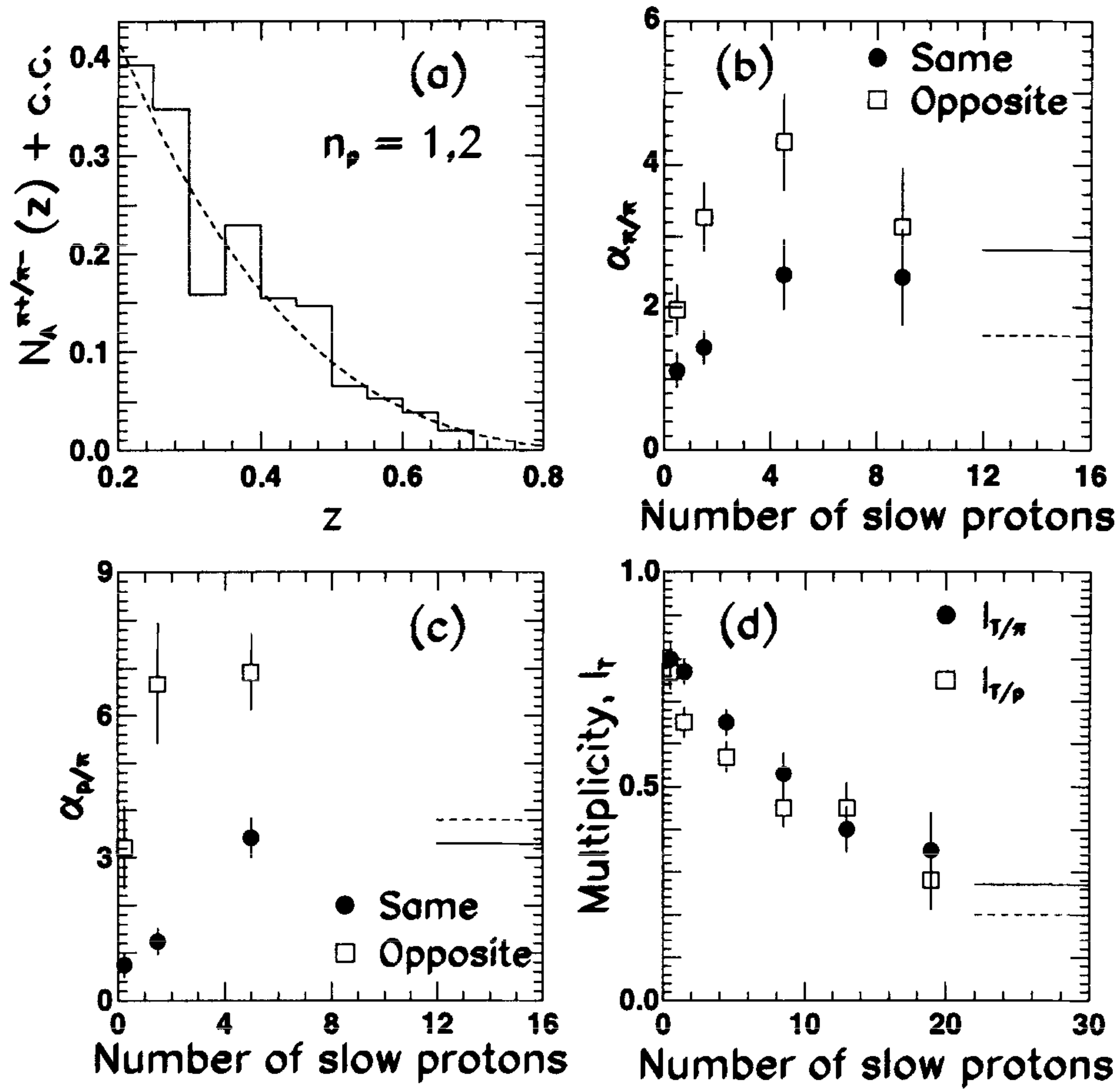
The leading particle spectrum will be strongly suppressed compared to minimal bias events since each parton fragments independently and splits into a couple of partons with comparable energies. The especially pronounced suppression for nucleons: for $z \geq 0.1$ the differential multiplicity of pions 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



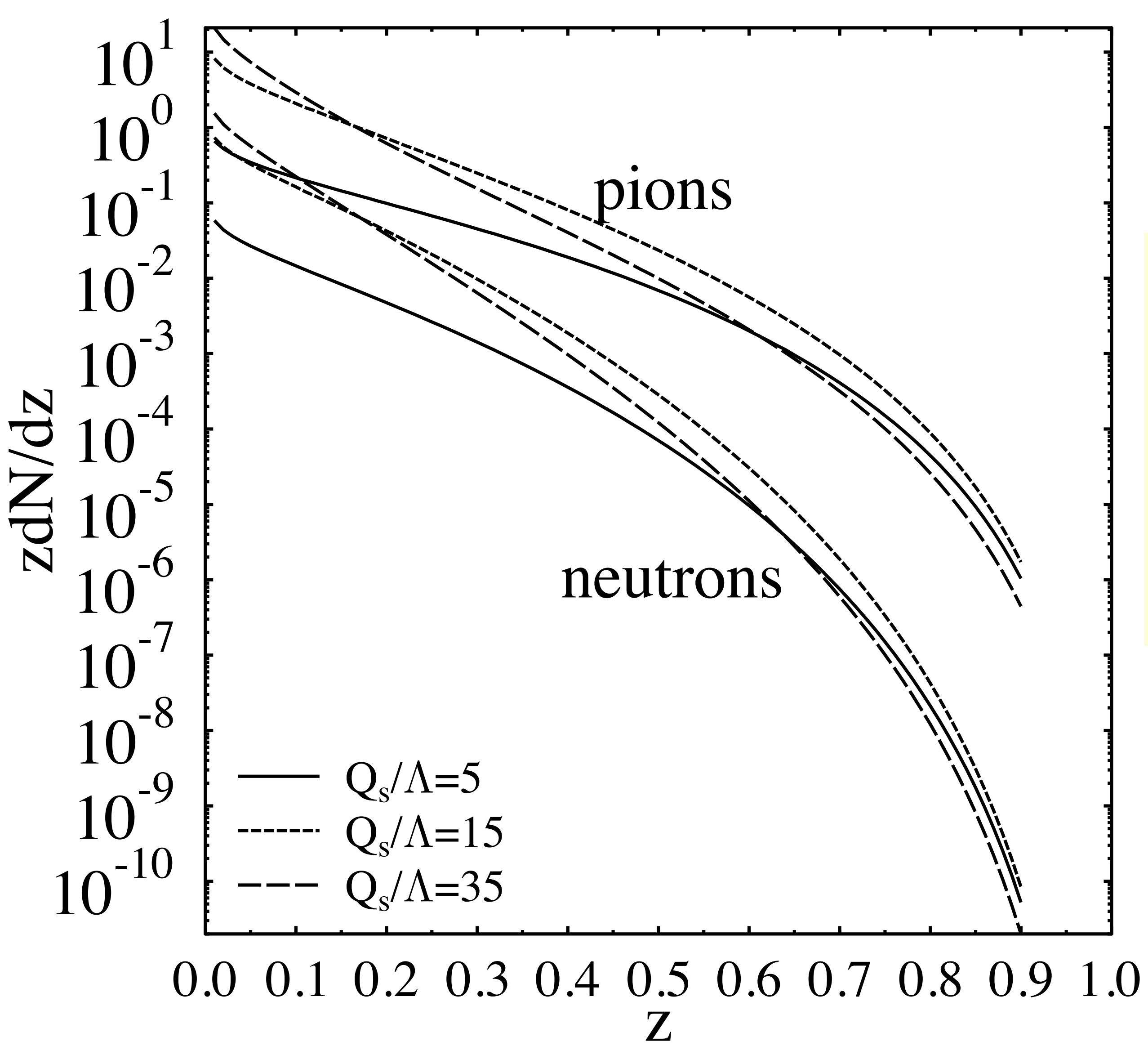
$$\frac{dN}{dz} \propto (1-z)^{\alpha}$$

Fig. 2. Experimental results for h–A collisions at 100 GeV/c: (a) Differential multiplicity for $\pi^- A \to \pi^+$ combined with $\pi^+ A \to \pi^-$ for events with $n_p = 1, 2$ (n_p is the number of slow protons). The dashed curve is a fit to the form $(1-z)^{\alpha}$; (b) Leading exponent α for $\pi A \to \pi$, solid circles (open boxes) when the produced π has the same (opposite) charge to that of the beam projectile; the horizontal lines on the right are the theoretical limits from QGSM fragmentation functions to the same (dashed) and opposite (solid) charge leading particle; (c) Leading exponent α for $\pi A \to p(\bar{p})$, the horizontal lines on the right are the theoretical results from EMC fragmentation functions to like (dashed) and opposite (solid) charge leading particle; (d) The integrated multiplicity of hadrons with $z_m > 0.2$ for $\pi^{\pm}$ (solid circles) and proton (open boxes) beam projectiles as a function of n_p. The horizontal lines on the right of the figure are the theoretical asymptotic limits for π (dashed) and proton (solid) projectiles.

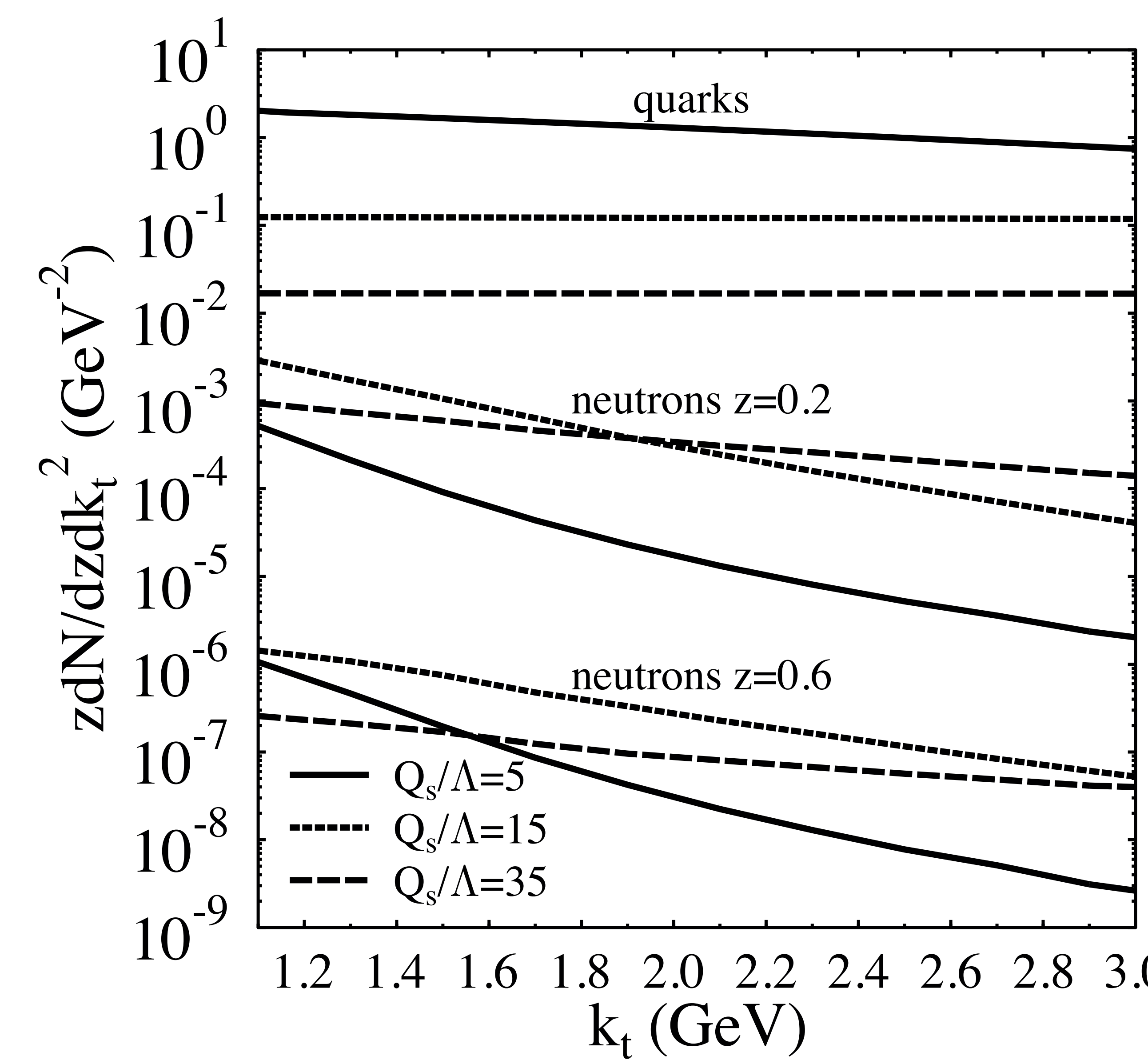
Simple model of p_t broadening - eikonal rescattering model with saturation (Boer, Dumitru 2003), effective energy losses (discussed later) are neglected

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

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



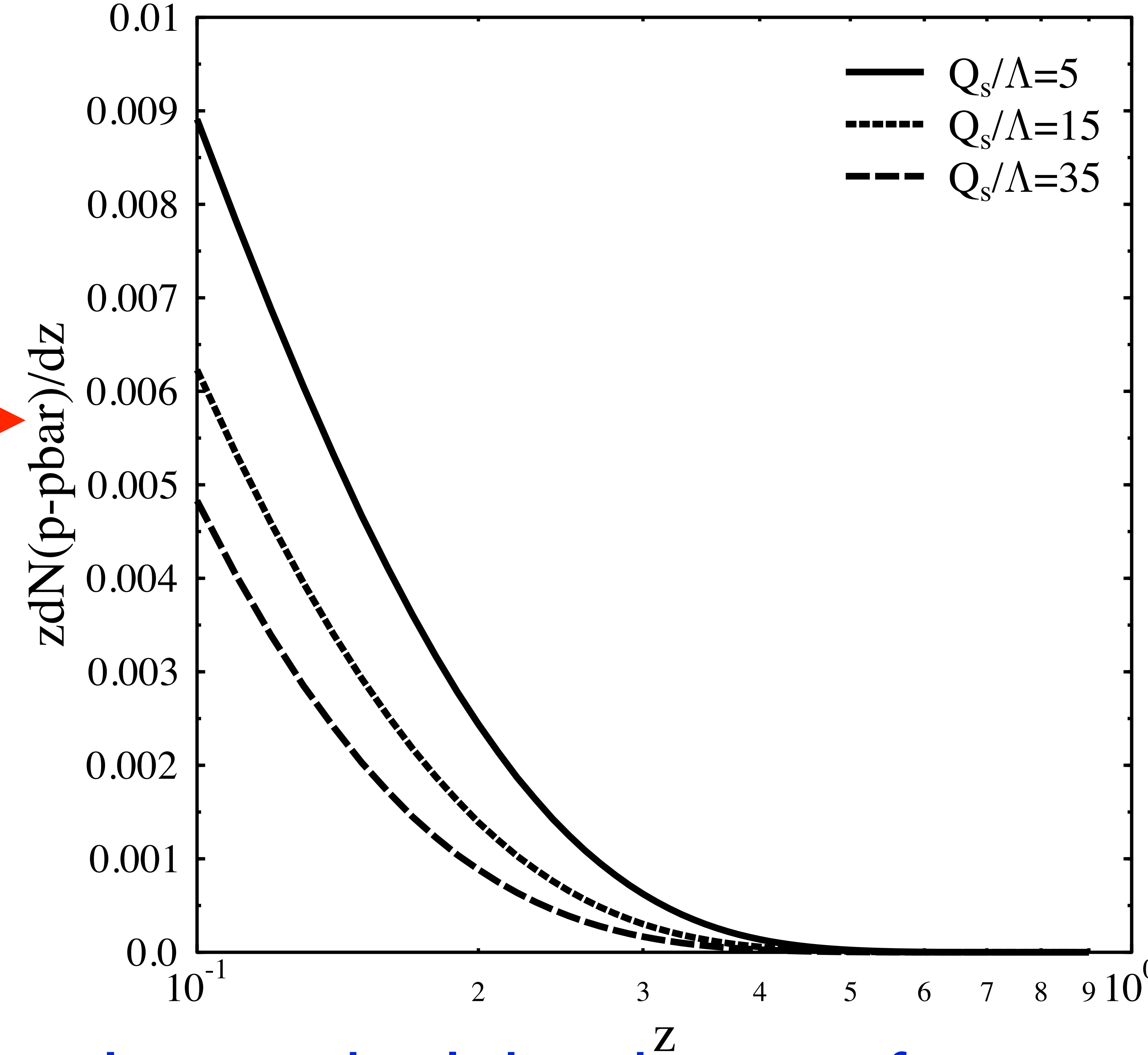
Steep fall with z, strong E_{inc} dependence



Weak p_t dependence, becomes weaker with increase if 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

Longitudinal distribution of net protons

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: $x_F > 0.75$ broad range of p_t can check both suppression and p_t broadening

neutrons from ZDC; other forward detectors?

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

Ultraperipheral Collisions ≡ UPC

Based on our study

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Physics Reports 458 (2008) 1–171

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The physics of ultraperipheral collisions at the LHC

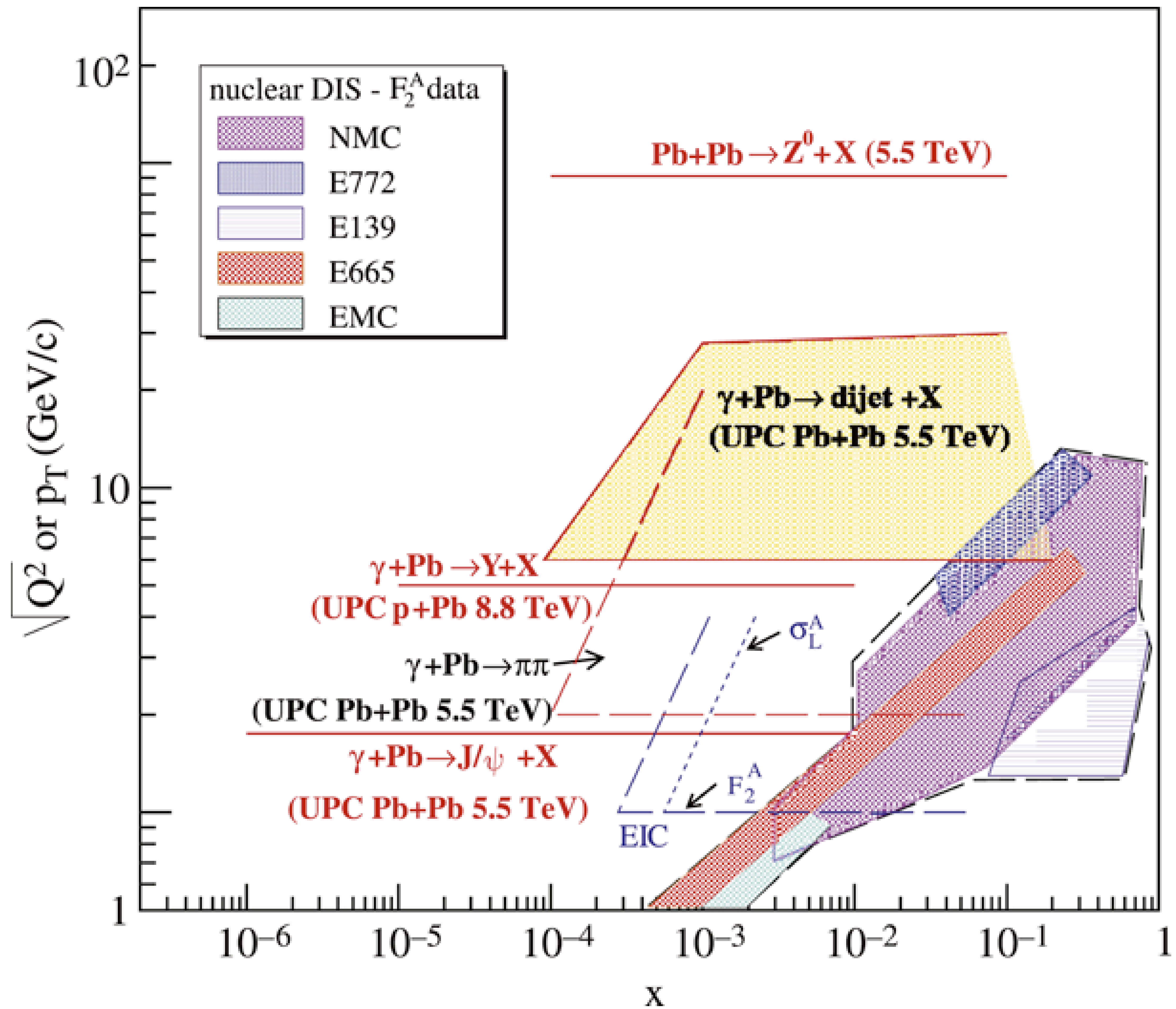
A.J. Baltz[a], G. Baur[b], D. d'Enterria[c], L. Frankfurt[d], F. Gelis[e], V. Guzey[f,w], K. Hencken[g,h,1], Yu. Kharlov[i], M. Klasen[j], S.R. Klein[k], V. Nikulin[l], J. Nystrand[m], I.A. Pshenichnov[n,o], S. Sadovsky[i], E. Scapparone[p], J. Seger[q], M. Strikman[r,*,1], M. Tverskoy[l], R. Vogt[k,s,t,1],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

Trigger: One or both nuclei remain intact

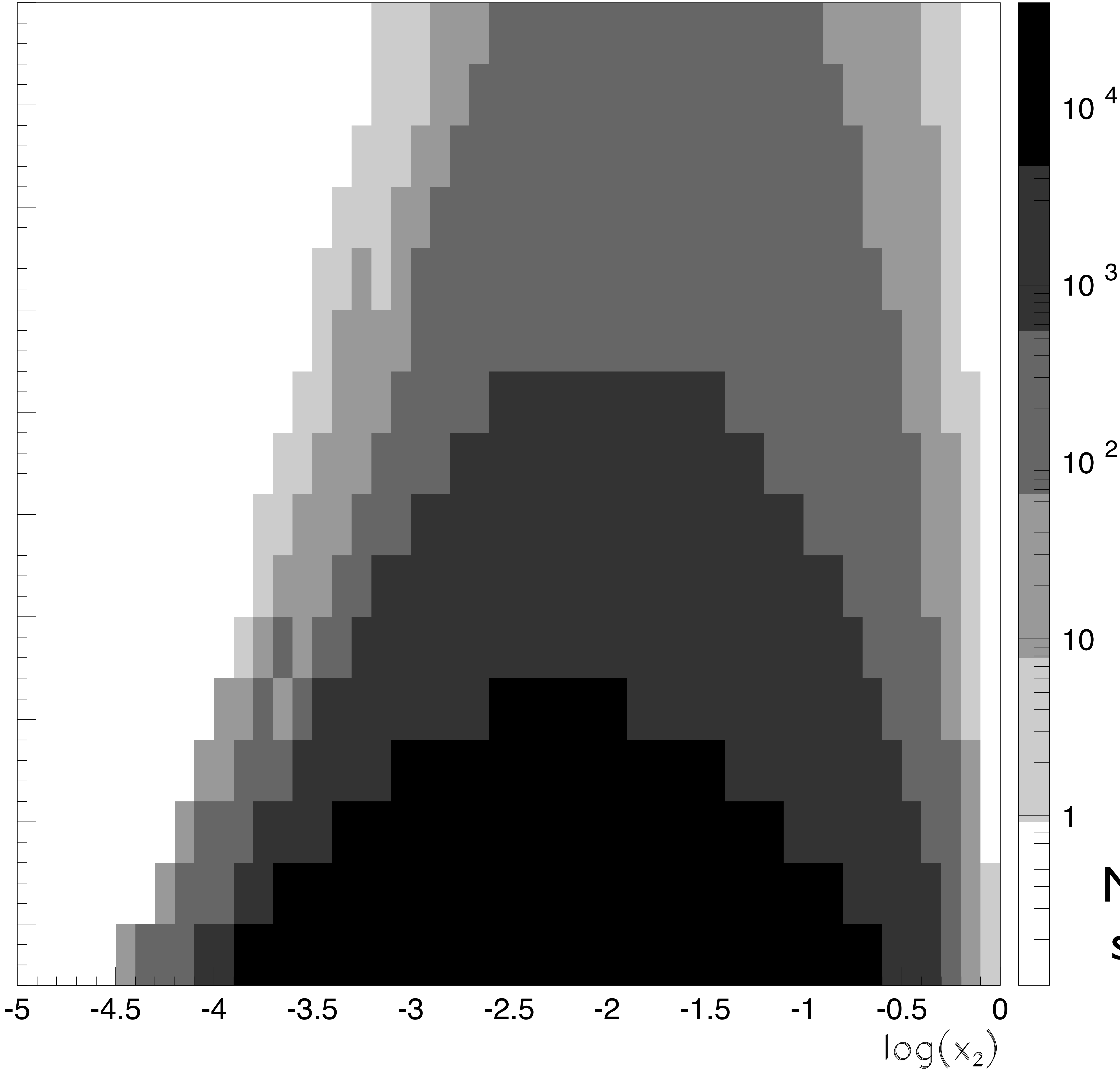
Breakup of nuclei due to the Coulomb excitations are allowed (emission of few soft (in the nucleus rest frame) neutrons. Contribution of strong interactions due to nucleus-nucleus scattering at $b \sim 2R_A$ is a small correction (weak A-dependence & small probability of diffraction). One can also study asymmetric UPC - $pA, \& AA$

Counting rates are large up to

$$s^{\gamma A}_{eff}(LHC) \sim (1TeV)^2, \sim 10 s_{max,\ HERA}(\gamma p)$$



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.



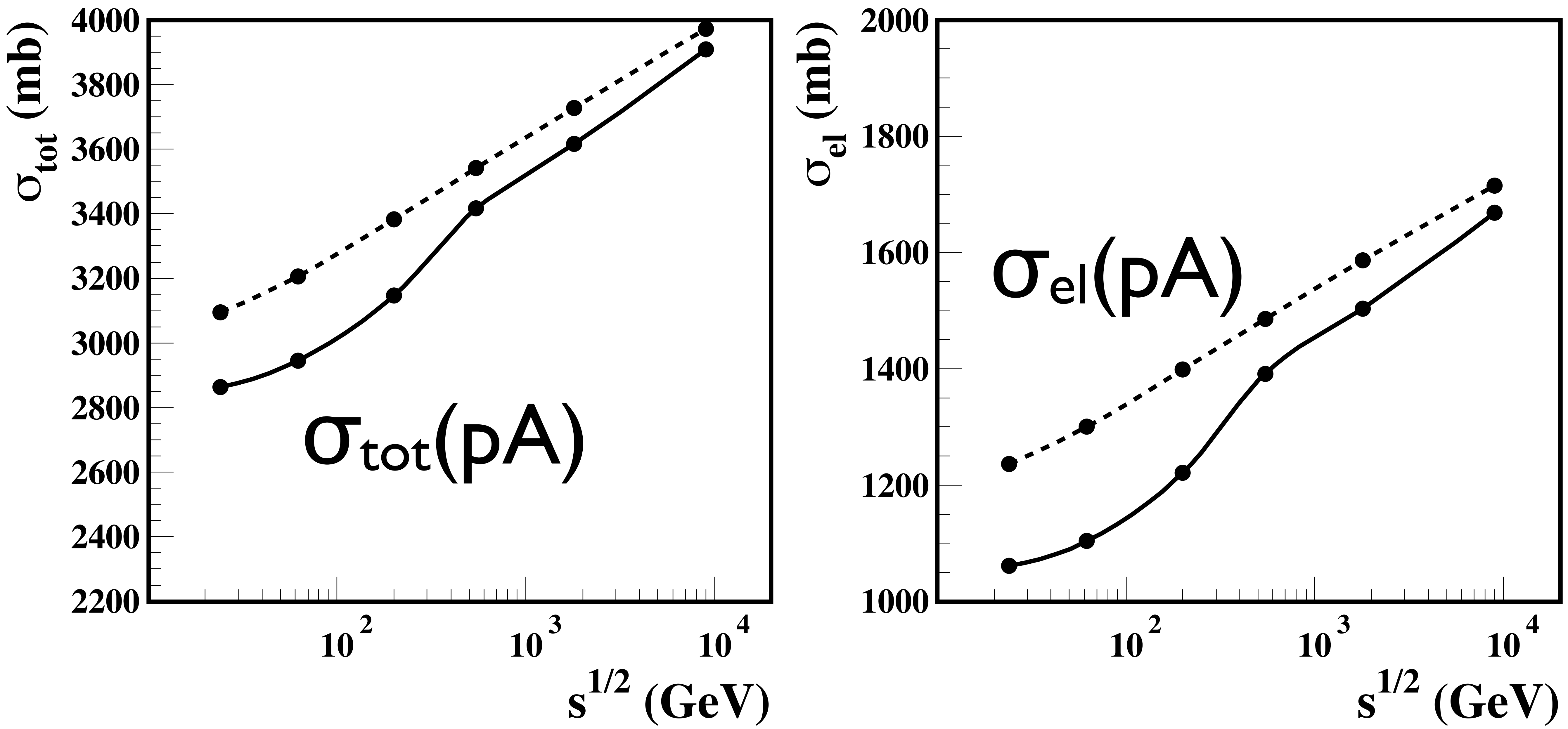
Expected rate of b-jet photoproduction for a 1 month LHC Pb+Pb run at 7.4×10^{29} $cm^{-2}s^{-1}$.

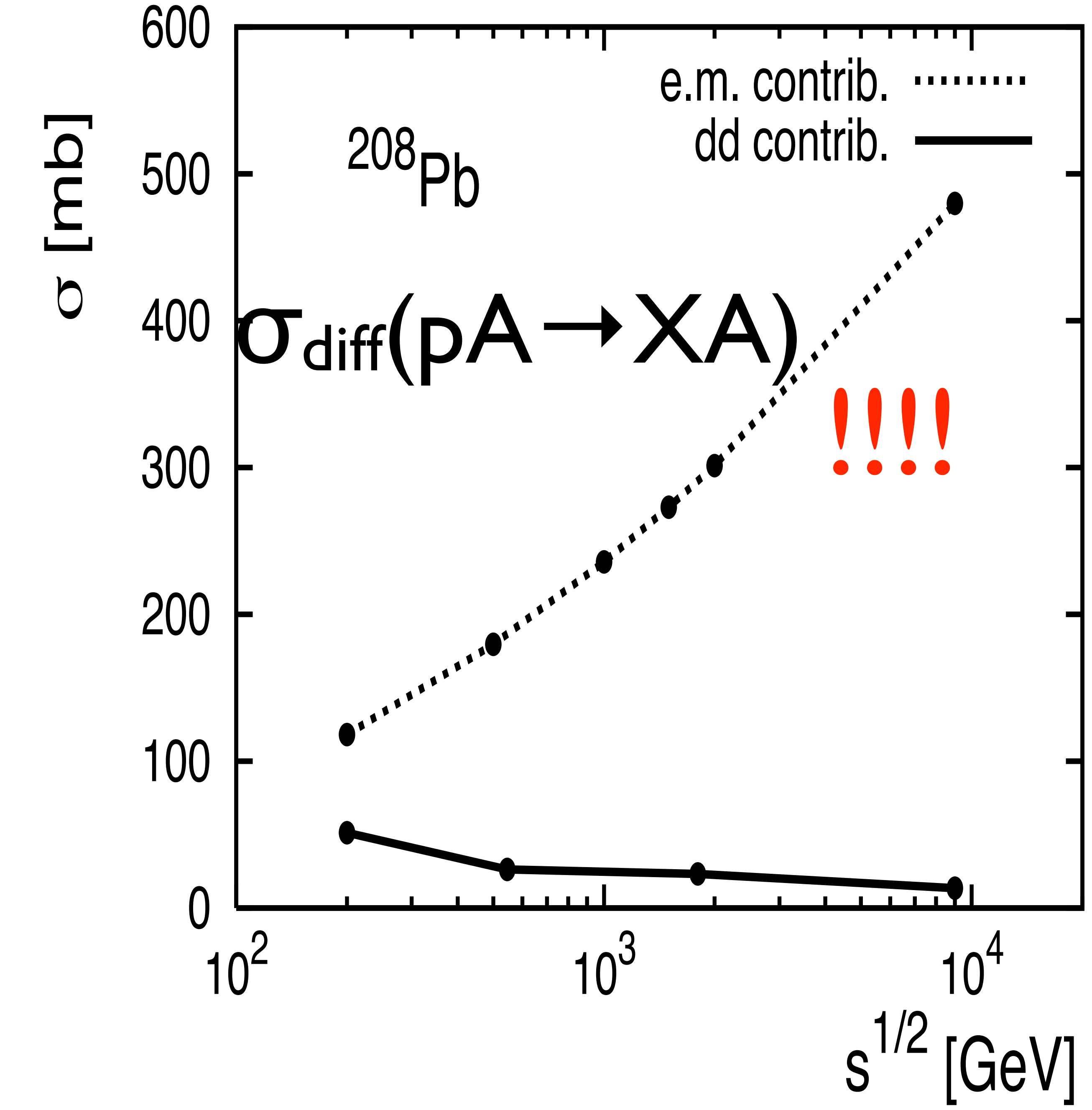
Many more interesting questions to study - like inclusive leading pion A-dependence as a function of p_t, associated multiplicity at different rapidities,...

R.Vogt, S.White, MS

Color fluctuations/inelastic shadowing

Guzey & MS





⇒ E.M. interaction dominates by far in diffraction - huge cross section

true for hard diffraction as well (Guzey, MS)

⇒ Many interesting γp processes can be studies in UPC pA.

Photon fragments in the central detector hence one can study many small x phenomena at much smaller virtualities than in pp and still x down to 10^{-4}.

Possible to compare suppression of the leading pion production in the process

$$\gamma + g \to q\bar{q}$$

for same W range (and somewhat higher) as at RHIC discussed in many talks.

Reminder: Single pion forward RHIC data - suppression of dominant 2 → 2 process with $x_A=10^{-2}$ (factor of 4 -- 5 for central collisions) requires effective fractional energy losses - postselection in the BDR. Compare Arneo and Kovner's talks.

Expected suppression of $R_{\gamma A}$ is smaller than for R_{pA} but still significant.

Need measurements in pA and AA.

Observables:

- $W_{\gamma N}$ dependence
- x_F and p_t dependence for single pion
- two pion correlations

Studies of exclusive photoproduction processes in pA UPC:

Hard physics:

- Onium production
- Diffraction into two, three jets

Soft & Hard(?) (Pomeron) physics:

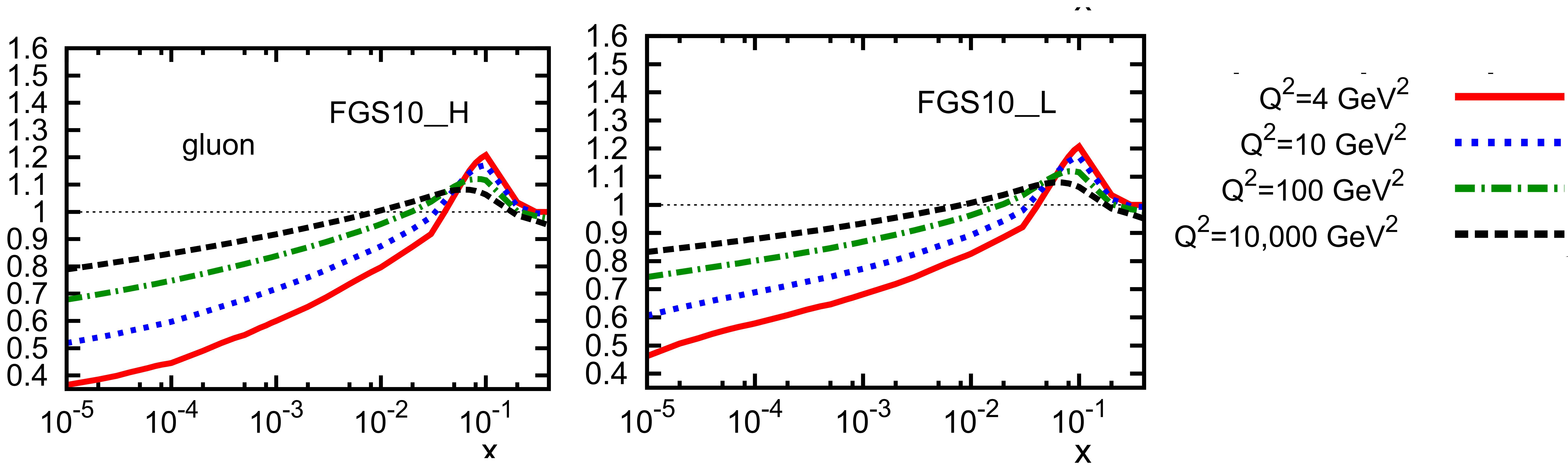
- Energy and t dependence of production of ρ,φ-mesons

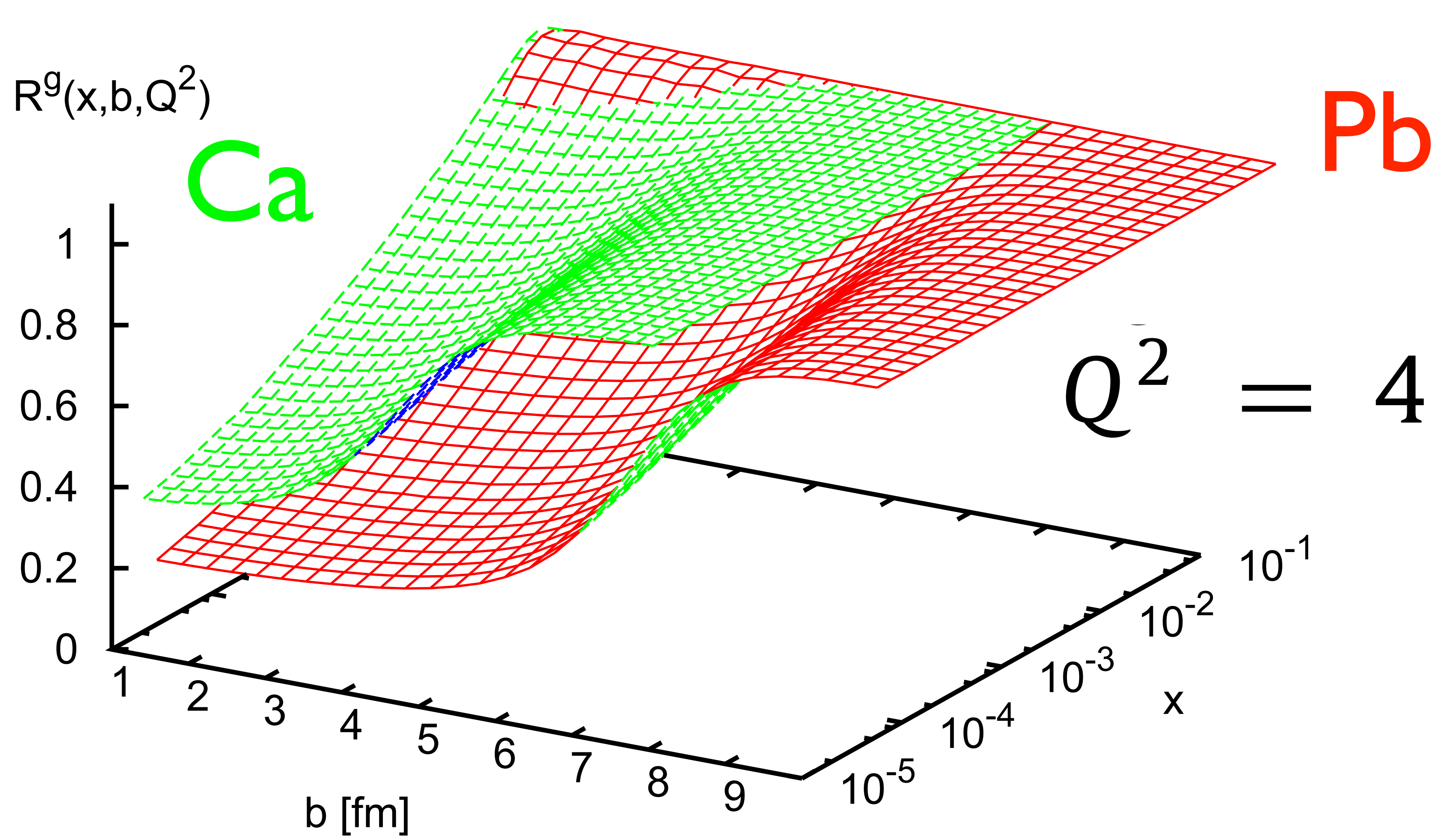
$$\frac{\mathrm{d}\sigma_{pA\to pAV}}{\mathrm{d}y\mathrm{d}t} = \frac{\mathrm{d}N_\gamma^Z(y)}{\mathrm{d}k}\frac{\mathrm{d}\sigma_{\gamma p\to Vp}(y)}{\mathrm{d}t} + \frac{\mathrm{d}N_\gamma^p(-y)}{\mathrm{d}k}\frac{\mathrm{d}\sigma_{\gamma A\to VA}(-y)}{\mathrm{d}t},$$

where the rapidity of the produced vector meson is

$$y = \frac{1}{2}\ln\frac{E_V - p_{z\,V}}{E_V + p_{z\,V}}.$$

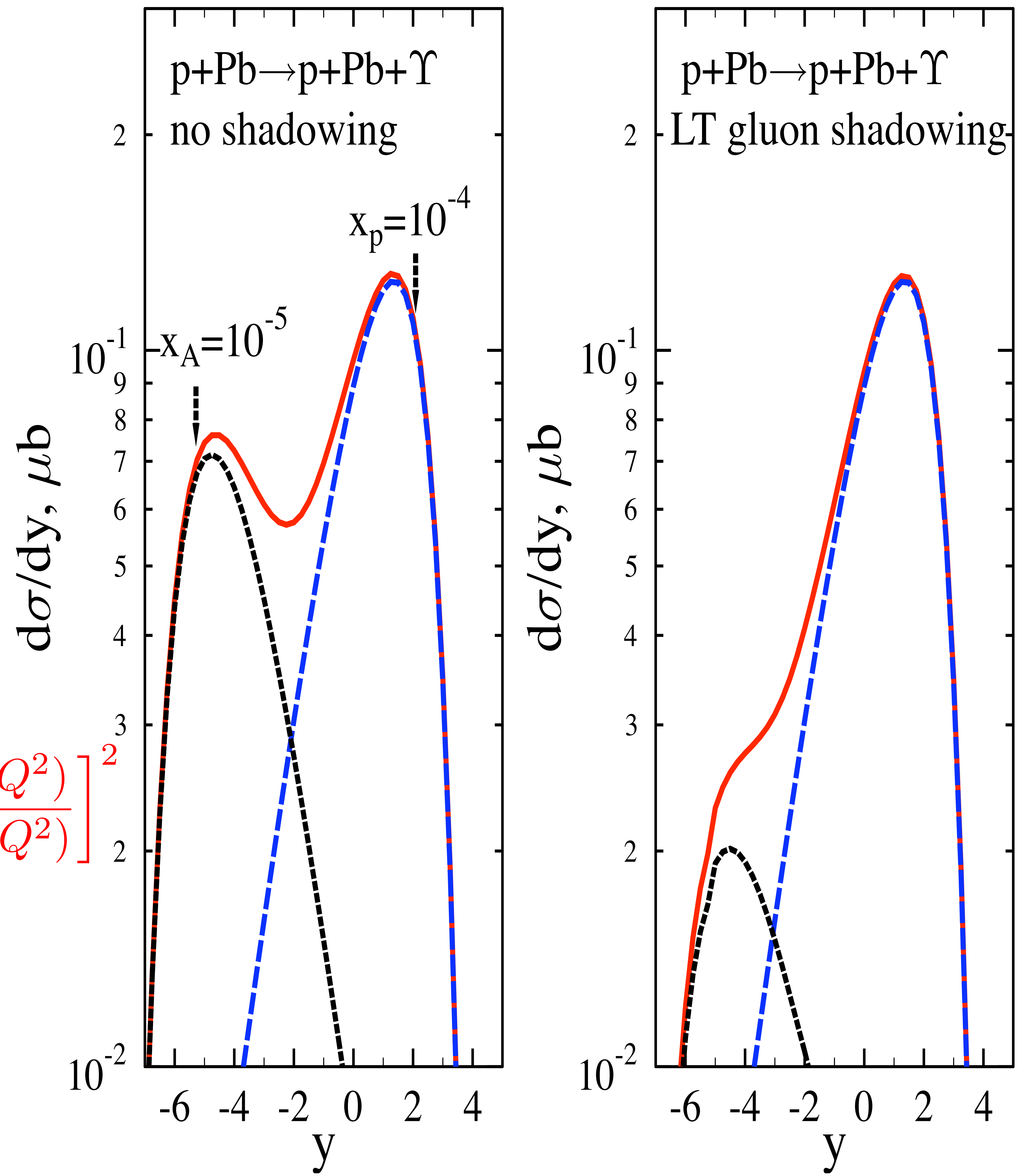
Predictions for LT nuclear shadowing based on QCD factorization theorem for diffraction and AGK. FGS10_H and FGS10_L reflect uncertainties in diffractive pdfs from HERA. Guzey et al. Phys.Rep. 2012





$Q^2 = 4\ GeV^2$

$$\frac{d\sigma}{dt} \propto \left[\frac{G_A(x,Q^2)}{G_N(x,Q^2)}\right]^2$$

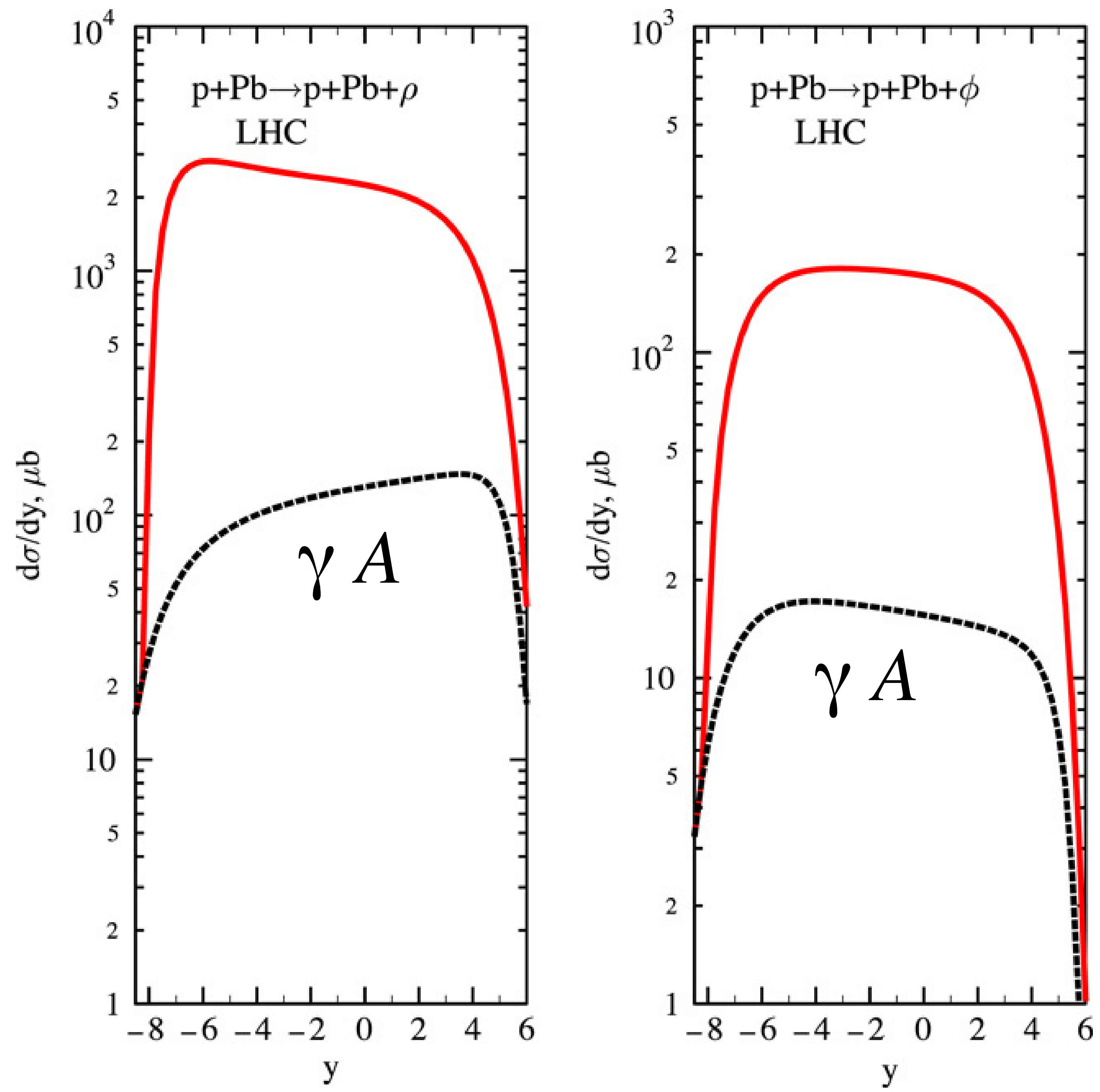


Zhalov & MS 05

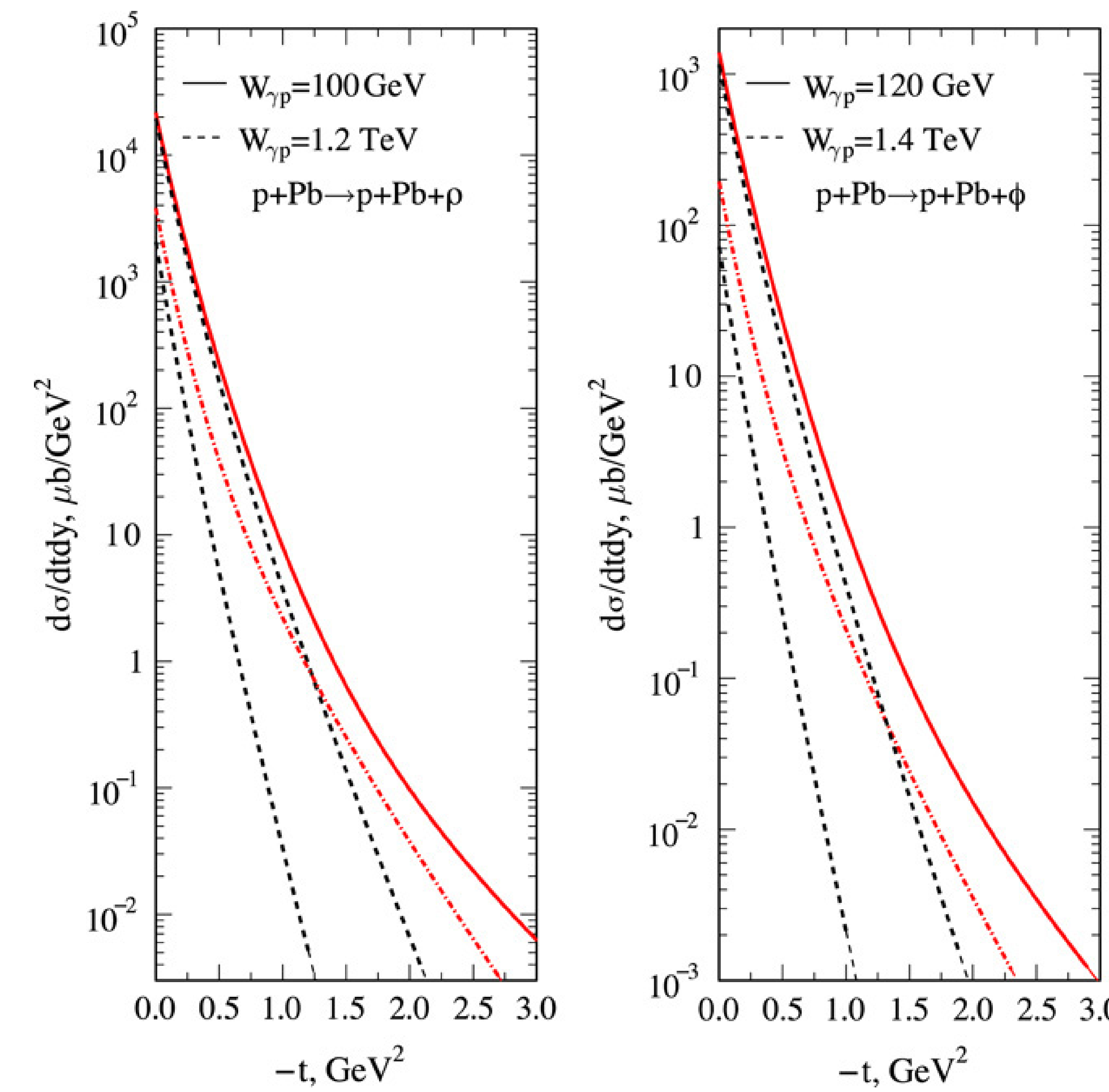
Sufficient to check pQCD prediction of $\sigma \sim W^{1.6}$ for Upsilon production, determination of the t-slope provided protons could be detected) and measure nuclear shadowing at Q^2=40 GeV^2 If proton is not detected - still energy dependence for fixed missing mass should be similar.

Production of ϒ's in pA collisions : coherent γ+A →V+A is shown by black lines, and γ+p →V+p by blue lines.

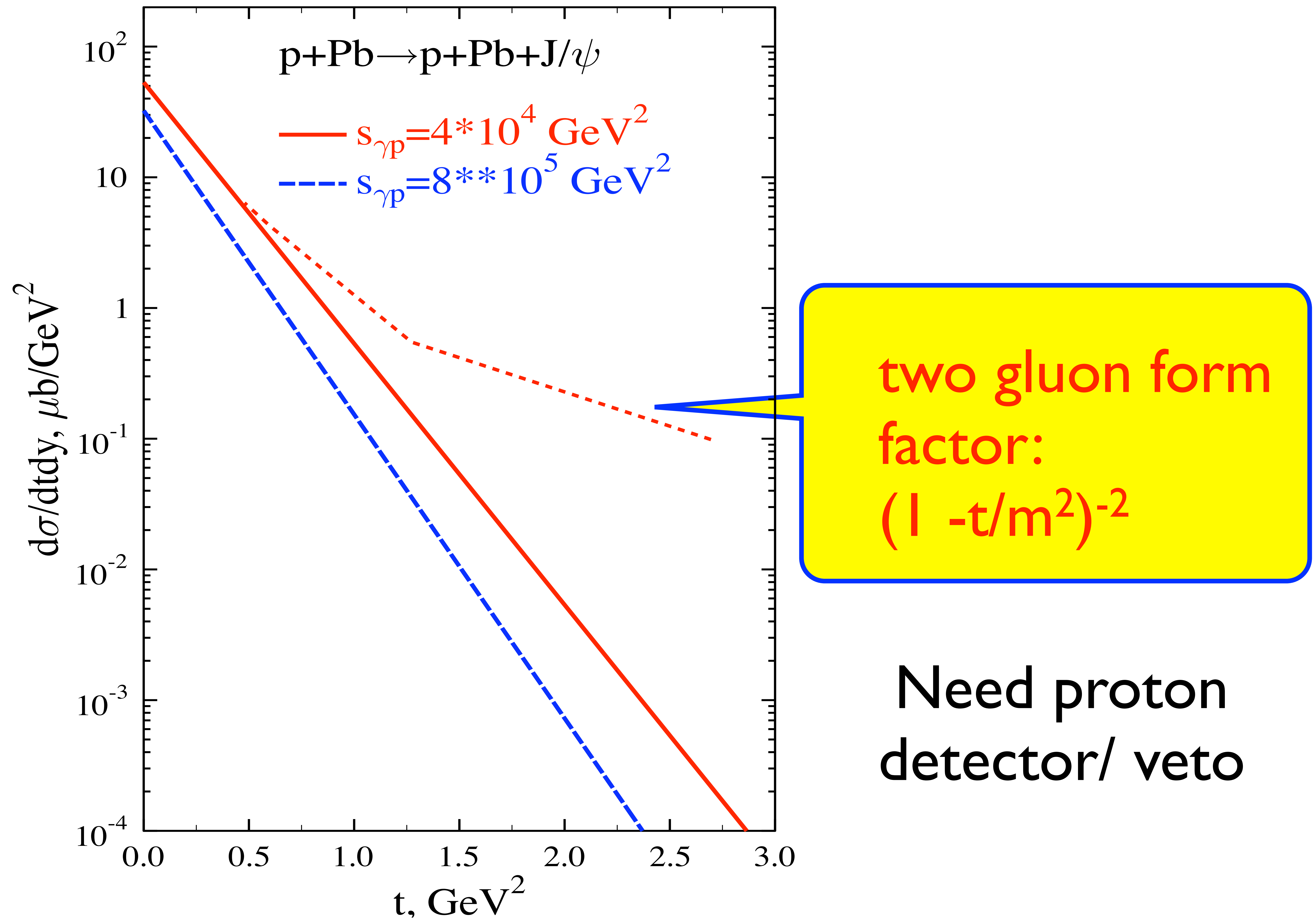
Issues: Universal soft Pomeron? - energy dependence, α' much smaller than pp, rapidity gaps - from soft to hard regime, minimum in dσ/dt like in pp? Experimental problem - detecting proton (TOTEM only at -t > 3 GeV2 - still rates large enough and very interesting to see whether process becomes hard - power law t-dependence). Energy dependence at fixed gap - α' at large t - is α(t) const?



The ϱ⁰ and ϕ rapidity distributions in *pPb* UPCs at the LHC.



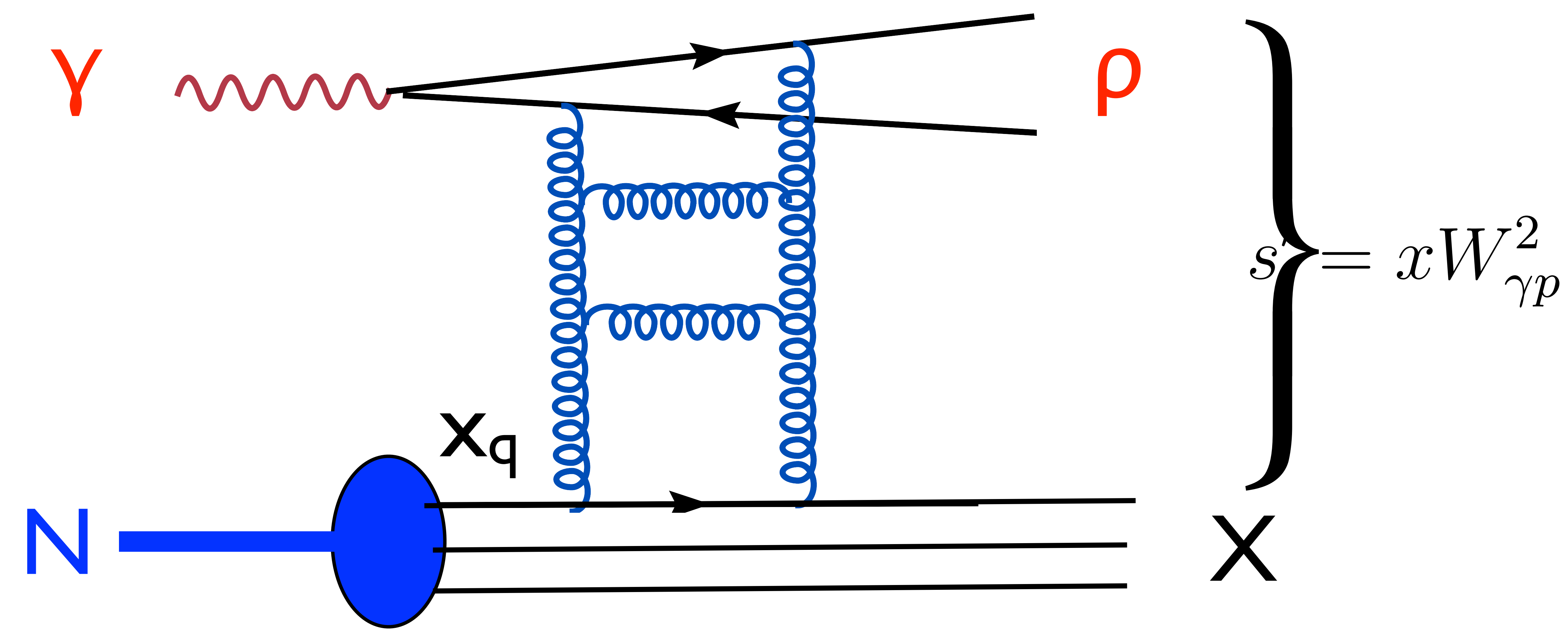
The ϱ⁰ and ϕ t distributions in pPb UPCs. The solid- and long-dashed lines are the results of calculation using model of Landshoff (soft + hard) for two different values of Wγ p. The short-dashed lines are the soft contribution from hard term.



Need proton detector/ veto

Momentum transfer distribution for J/ψ photoproduction in pA at LHC

Rapidity gap processes at large $t=(p_\rho-p_\gamma)^2$: from HERA to LHC



Elementary reaction - scattering of a hadron (γ, γ*) off a parton of the target at large $t=(p_\gamma-p_V)^2$

FS 89 (large t pp→p +gap + jet), FS95

Mueller & Tung 91

Forshaw & Ryskin 95

$$x = \frac{-t}{(-t + M_X^2 - m_N^2)}$$

The rapidity gap between the produced vector meson and knocked out parton (roughly corresponding to the leading edge of the rapidity range filled by the hadronic system X) is related to $W_{\gamma p}$ and t (for large t, $W_{\gamma p}$ as

$$y_r = \ln \frac{xW_{\gamma p}^2}{\sqrt{(-t)(m_V^2 - t)}}$$

The choice of large t ensures two important simplifications. First, *the parton ladder mediating quasielastic scattering is attached to the projectile via two gluons*. Second is that *attachment of the ladder to two partons of the target is strongly suppressed*. Also the transverse size $d_{q\bar{q}} \propto 1/\sqrt{-t}$

$$\frac{d\sigma_{\gamma+p\to V+X}}{dtdx} = \frac{d\sigma_{\gamma+quark\to V+quark}}{dt}\left[\frac{81}{16}g_p(x,t) + \sum_i (q_p^i(x,t) + \bar{q}_p^i(x,t))\right]$$

$$\frac{d\sigma_{N+q(g)\to N+q(g)}}{dt} \propto \frac{1}{t^6} \qquad \frac{d\sigma_{\gamma+q(g)\to V+q(g)}}{dt} \propto \frac{1}{t^4}$$

Energy dependence of $f_q(s',t) \propto [s']^{\delta(t)}$

$\delta(-t >> 1\ \mathrm{GeV}^2)$?

Soft QCD $\delta<-0.5$

Two gluon exchange $\delta=0$

DGLAP / resummed BFKL for t=0 $\delta=0.2$ -- 0.3

subtle points in BFKL analysis for t away from 0

Our calculation in the double log approximation describes t dependence of δ

We analyzed the rho-meson data using a fit

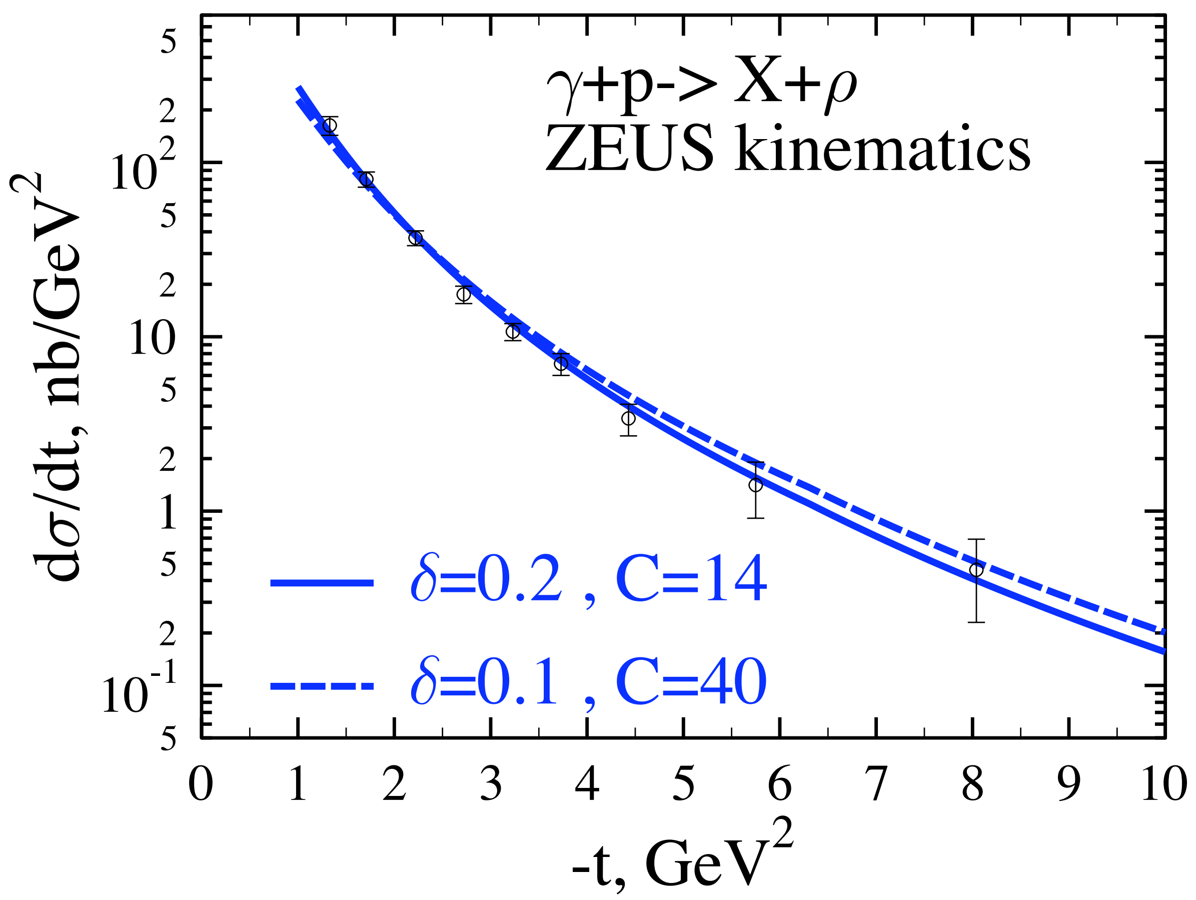
$$\frac{d\sigma_{\gamma+p\to\rho+X}}{dt} = \frac{C}{(1-t/t_0)^4}\left(\frac{s}{{m_V}^2-t}\right)^{2\delta(t)} I(x_{min},t)$$

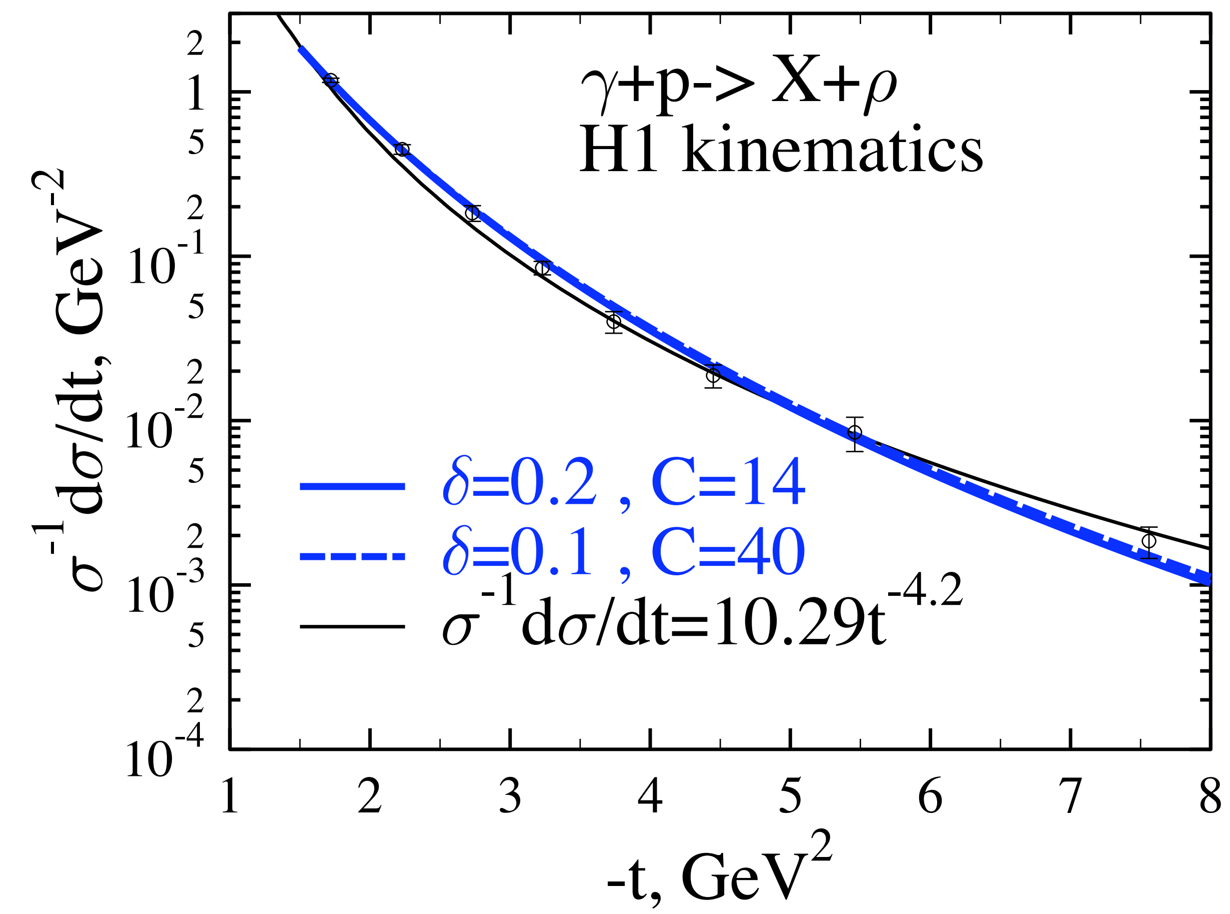
$$I(x_{min},t) = \int_{x_{min}}^{1} x^{2\delta(t)}\left[\frac{81}{16}g_p(x,t) + \sum_i [q_p^i(x,t) + \bar{q}_p^i(x,t)\right] dx$$

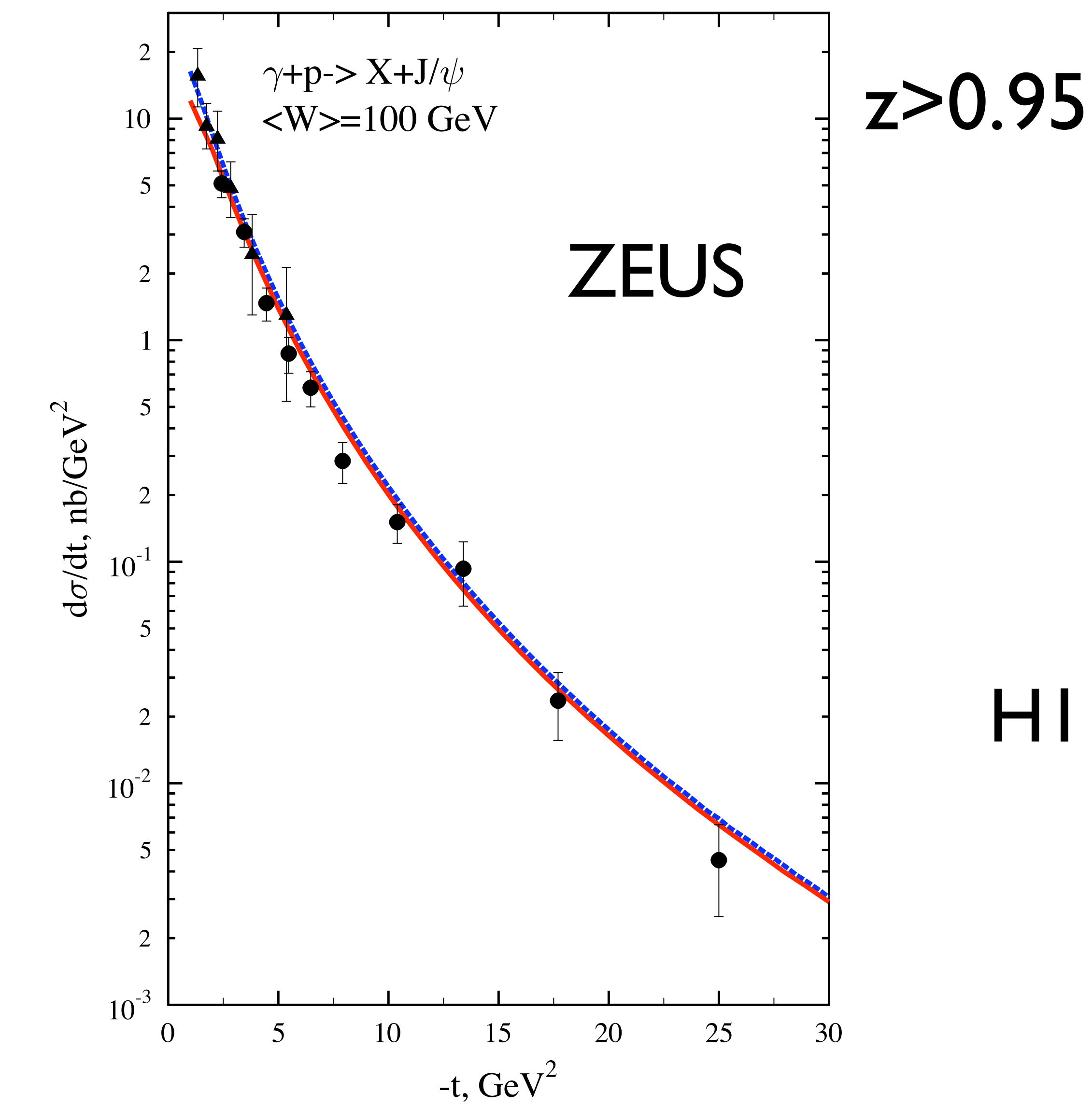
$t_0 \sim 1$ GeV^2, δ=0.1 -0.2 is consistent with the data at large t

For J/ψ we changed

$$\frac{1}{(1-t/t_0)^4} \to \frac{1}{(1-t/t_0)(1-t/m_{J/\psi}^2)^3}$$



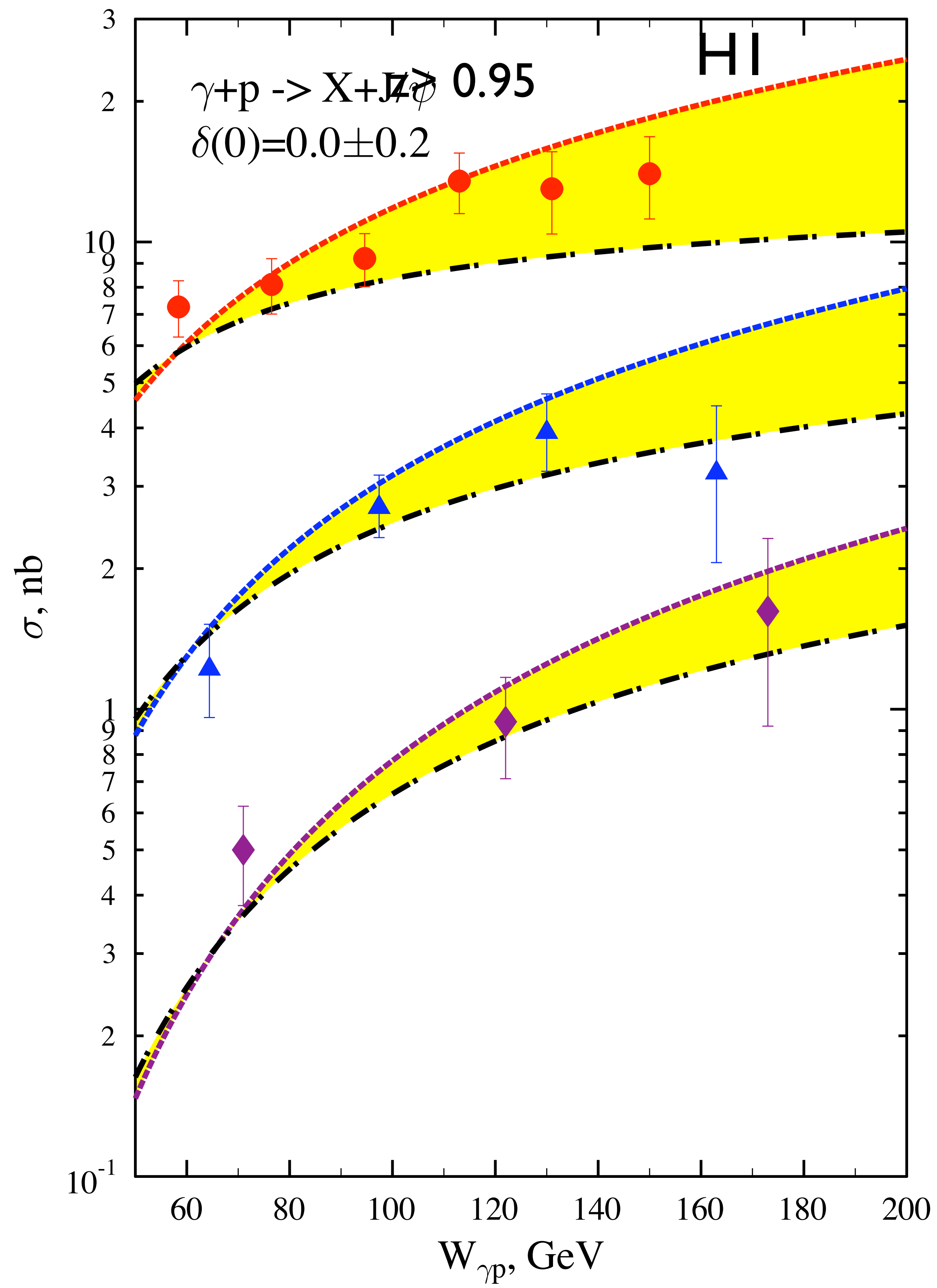


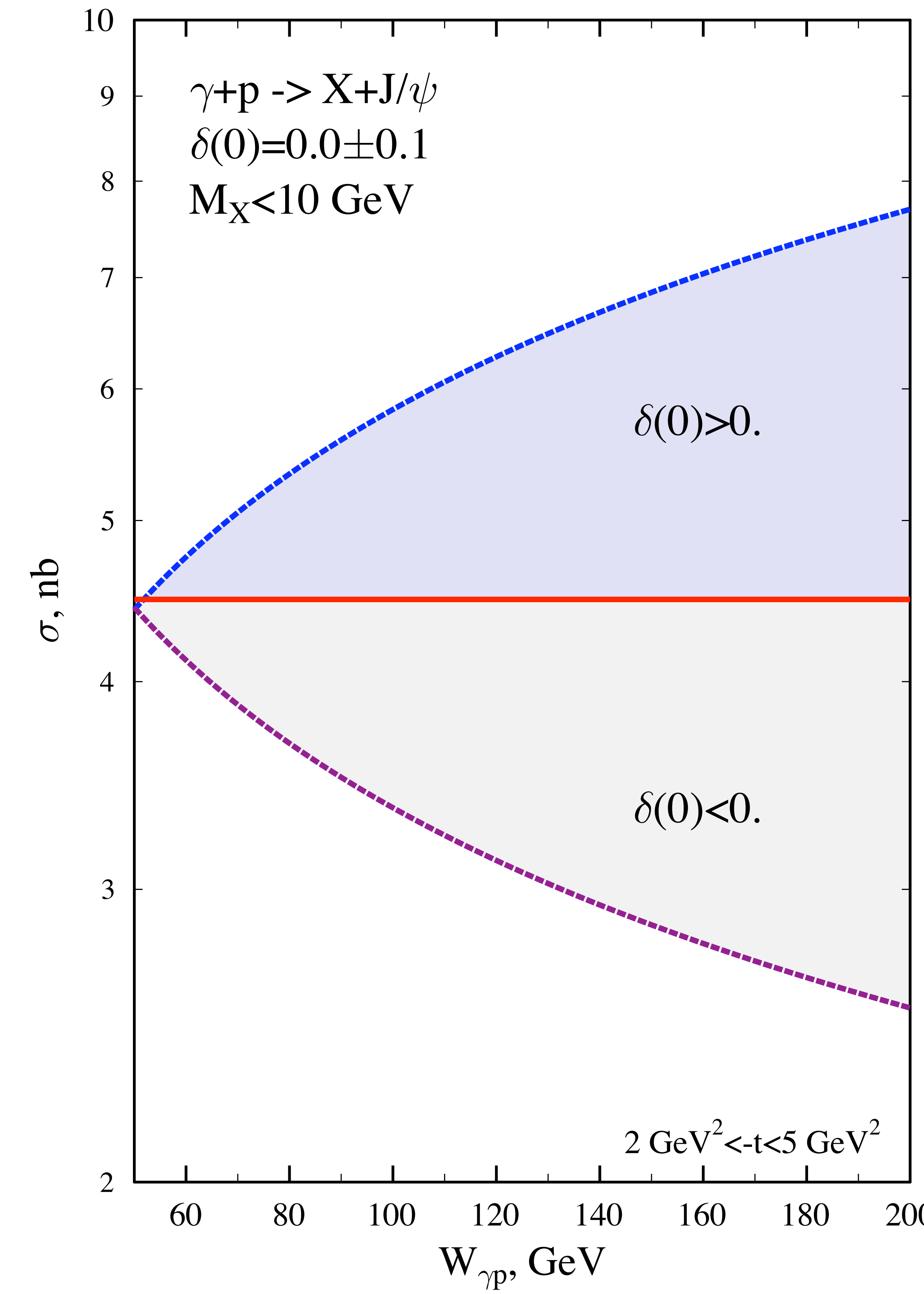


Description of ZEUS and H1 data for t-dependence of the large t and rapidity gap cross section. ZEUS data were taken at average $W_{\gamma p}$=100 GeV with fixed cut M_X < 25 GeV and additional restriction 0.01 <x< 1. The H1 data were taken at average $W_{\gamma p}$=85 GeV and cut M_X < 5 GeV.

Sensitivity to the energy dependence is weak.

t-dependence of J/ψ production is consistent with dominance of hard dynamics





Study of the VM production with gaps is mostly sensitive to gluon pdfs if the cut is on z_{min} or M_X^2/W^2 is made. Sensitivity to the energy dependence of dipole - parton amplitude $f(s',t) \propto s'^{\delta}$ is minor. On the contrary if the cut on $M_X <$ const is made, sensitivity to the value of δ is very high.

Analyses with z cut, M^2_X/s < const cuts are good for study of the dominance of the mechanism of scattering off single partons. However they correspond to rapidity interval between VM and jet which are typically of the order $\Delta y = 2 - 3$.

Optimal way to study BFKL dynamics is to keep
M^2_X < const and vary W

Was practically impossible at HERA --- natural at LHC

At LHC one can energy dependence of elastic $\bar{q}q$ - parton scattering at W'=20 GeV - 400 GeV

$$\sigma_{el}(q\bar{q} - q(g)(W' = 400GeV)/\sigma_{el}(q\bar{q} - q(g)(W' = 20GeV) \sim 10\,!!!$$

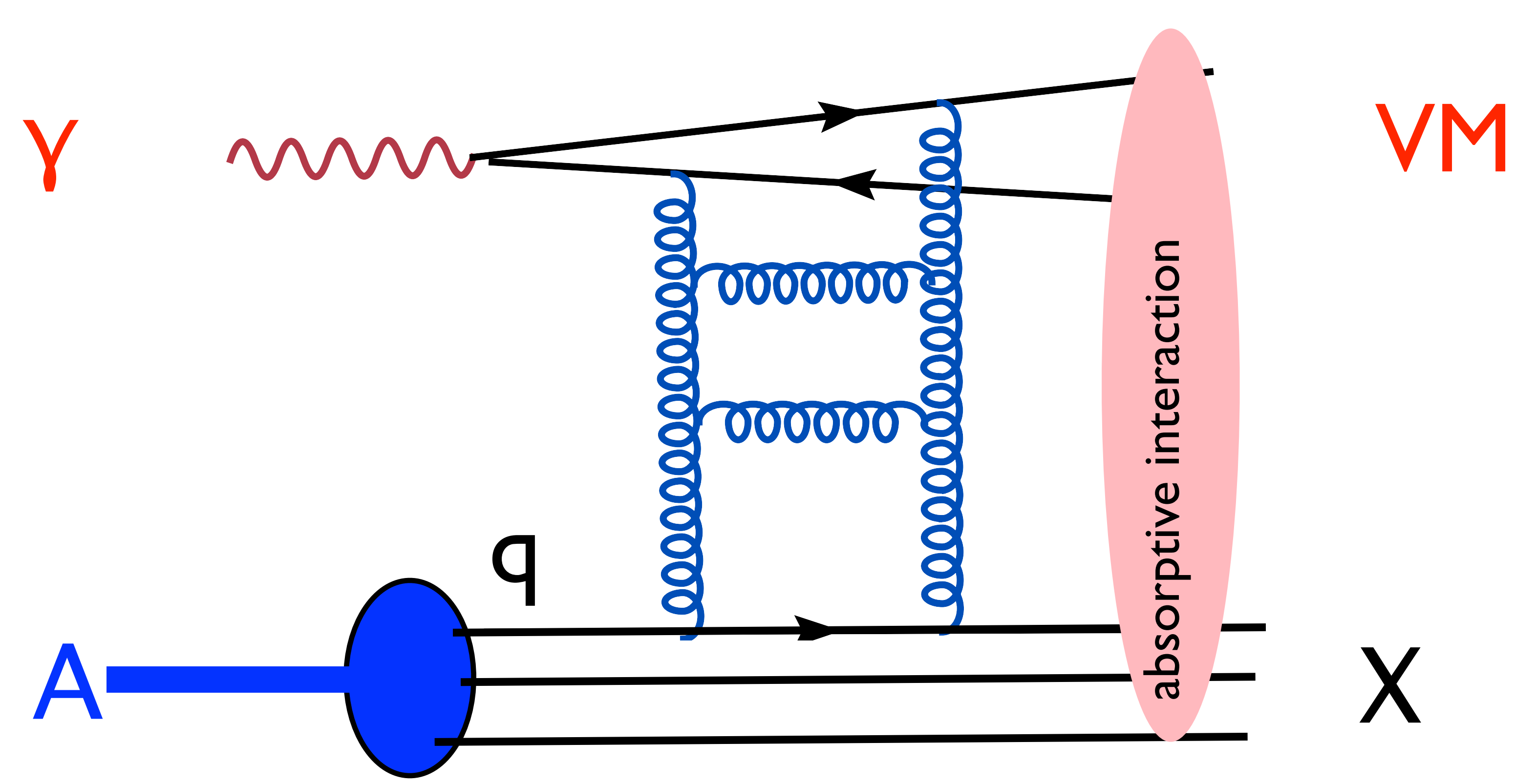
if δ=0.2

γ + p → ρ (J/ψ) + gap + X is necessary also as a reference point to

FS & Zhalov 06

- γ + A → ρ (J/ψ) + gap + X   UPC LHC

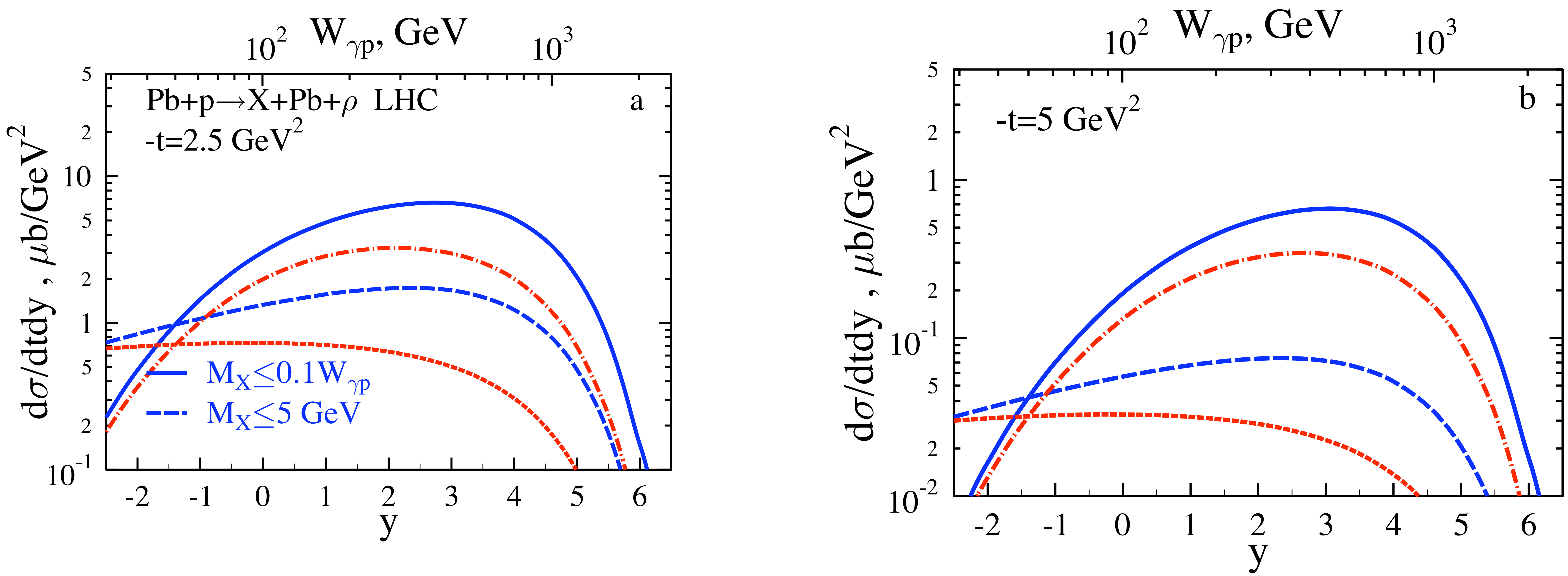
measure of the strength of inelastic interactions of small dipole in the processes initiated by BFKL elastic qq - parton scattering at $\bar{W}$=30 GeV - 1 TeV



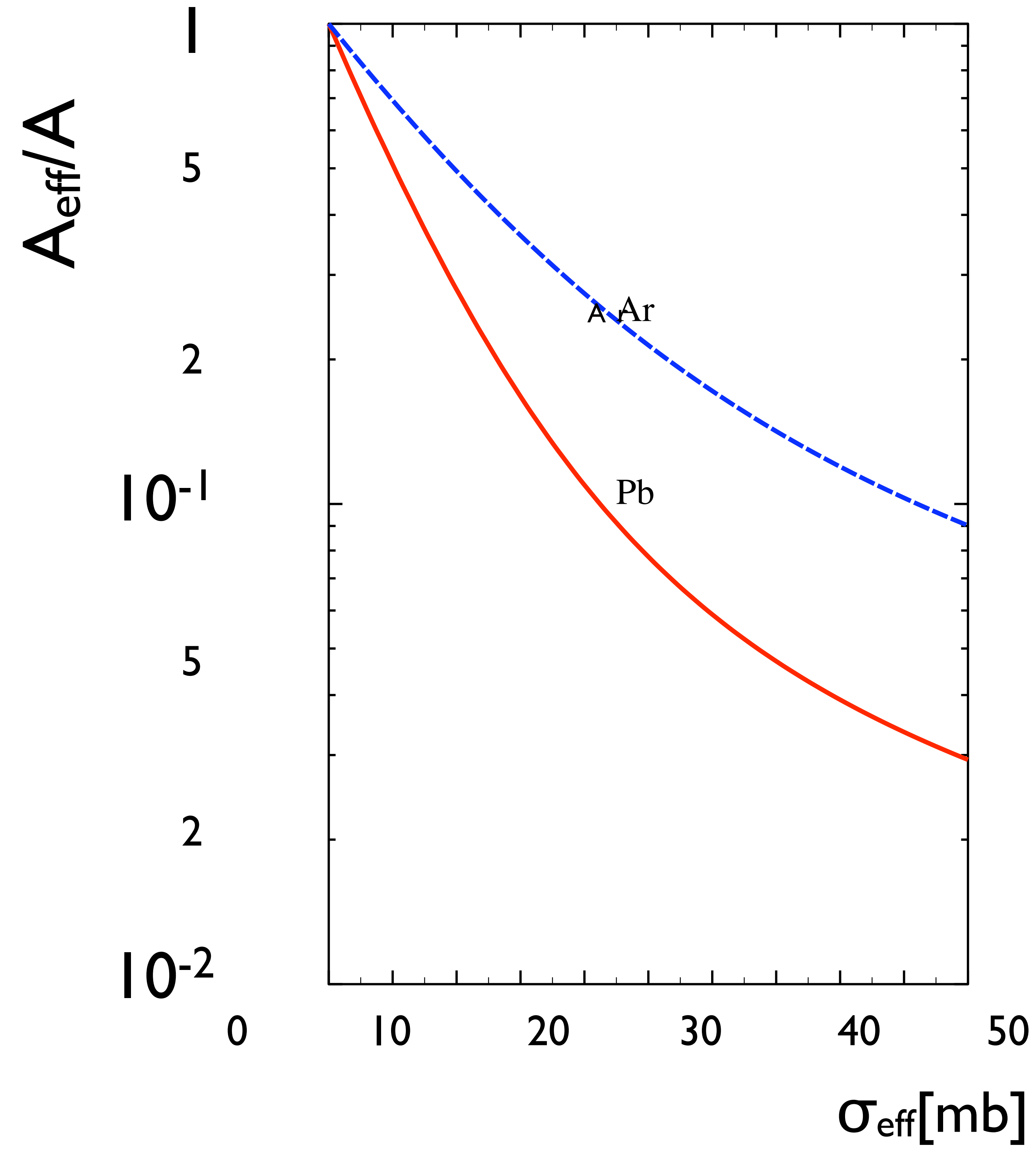
Advantages: trigger on hadron production in a rapidity interval close to one of the nuclei

no ambiguity which of the nuclei emitted photon - Large W are possible, better VM acceptance for large t.

Used our fit to estimate the rates in p A scattering



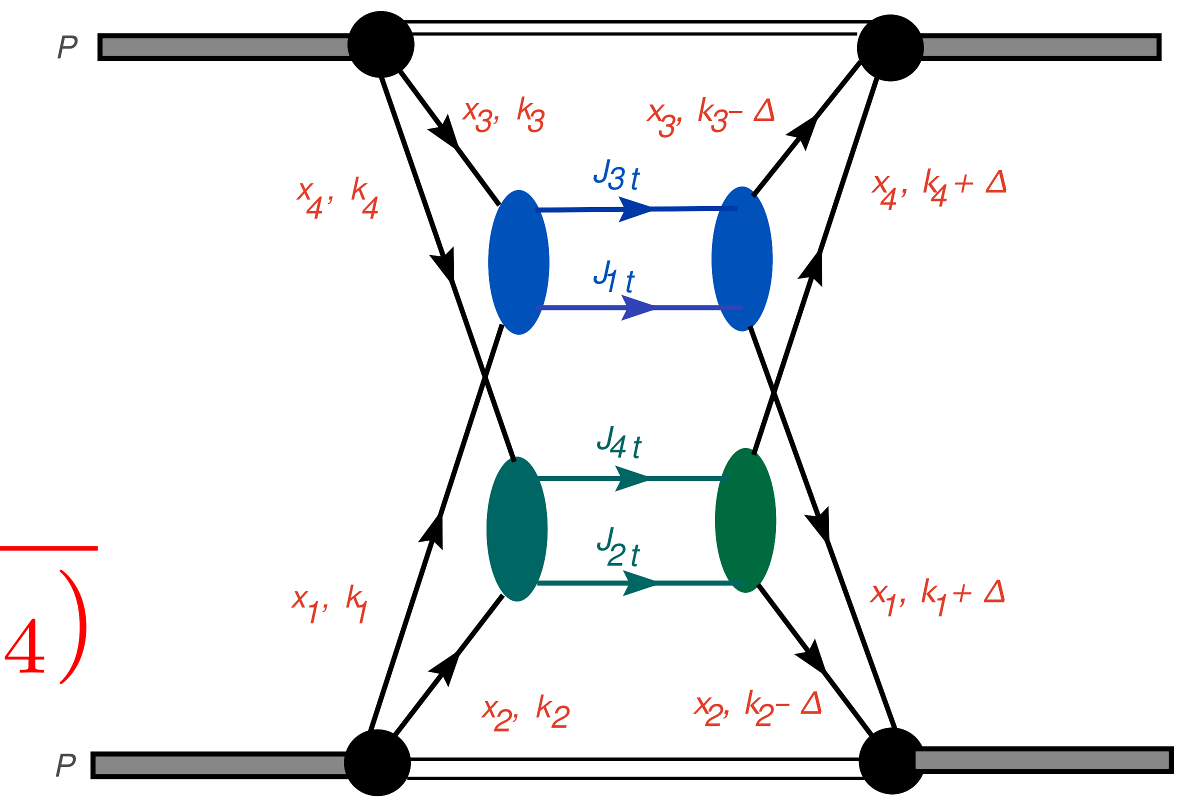
Rapidity distribution for the large t and rapidity gap cross section of ρ meson photoproduction in ultraperipheral proton-lead collisions in kinematics of LHC. Notation is the same as in previous figure. The corresponding counting rates can be easy estimated using the value of luminosity of pPb colisions $L = 10^{-1}\,\mu b^{-1} sec^{-1}$.



Strong sensitivity of A_{eff}/A to the strength of inelastic $q\bar{q}$-N interactions

Complementary to quasielastic process - no small x partons in the nucleus are involved on the trigger level

Multiparton interactions in pA.--- probing parton correlations in nucleons



Experimentally one measures the ratio

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

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

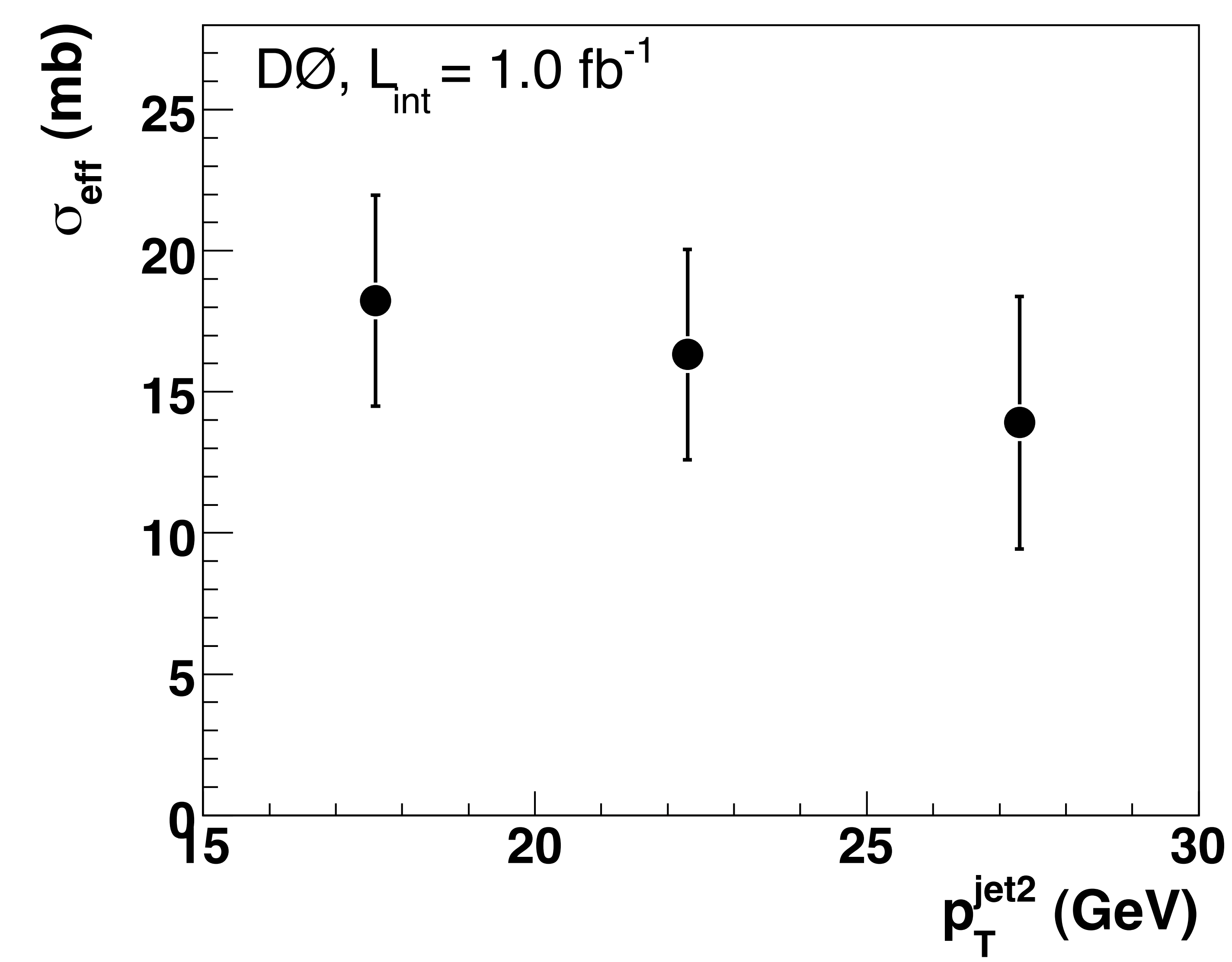
πR^2_{int} is ``transverse correlation area". One selects kinematics where $2 \to 4$ contribution is small

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

$$\pi R^2_{int} = 14.5 \pm 1.7^{+\ 1.7}_{-\ 2.3}\ mb$$

No dependence of πR^2_{int} on x_i was observed.

A naive expectation (based on r_N=0.8 fm) is $\pi R^2_{int} \sim 55$ mb.
Gluon radius is smaller --- $\pi R^2_{int} \sim 35$ mb indicating high degree of correlations between partons in the nucleon. Is it in the transverse plane or it is correlation of x's ?

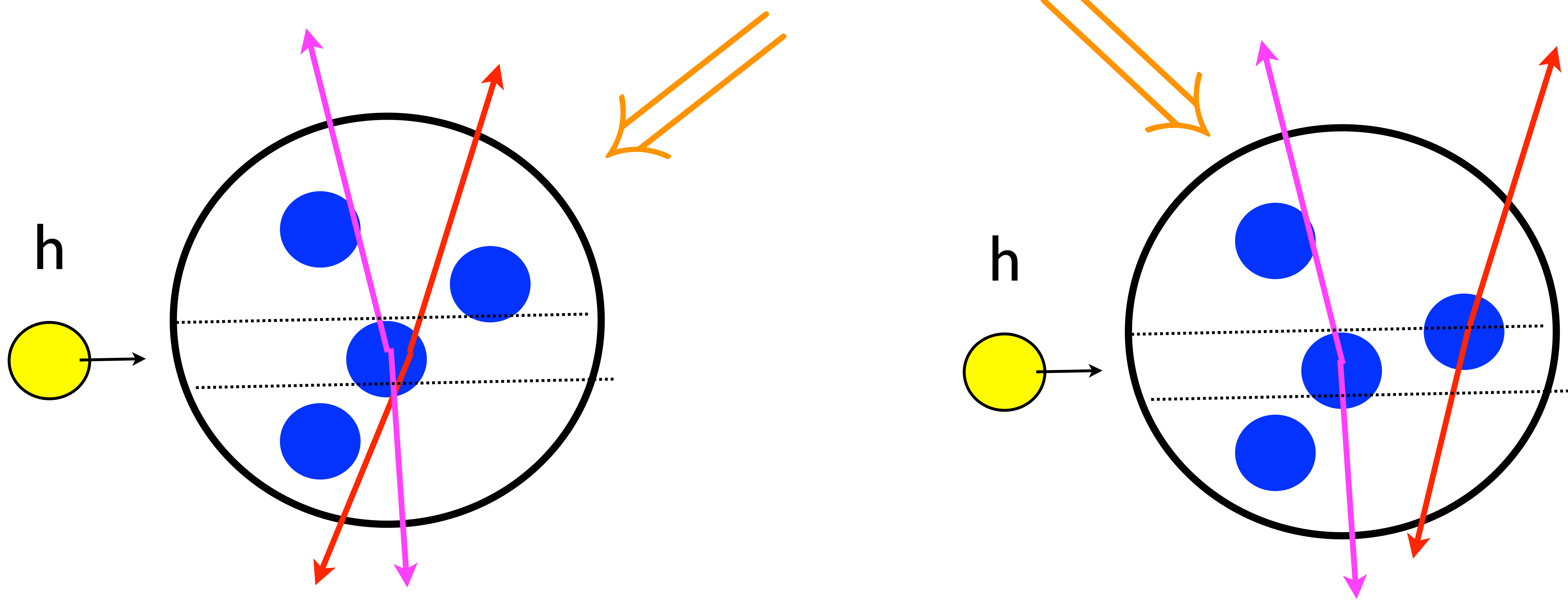


Similar results from D0.

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 $\quad \frac{\sigma_{pA}}{\sigma_{pp}} \approx 3$

linear in σ_{eff} !!

Measurement of R allows to separate longitudinal and transverse correlations of partons as it measures $f(x_1,x_2)/f(x_1)f(x_2)$

Conclusions

Glauber model for number of wounded nucleons is too simplistic

Effects of color fluctuations can be studied with large x_p trigger

Very forward region -- critical tests of the onset of black regime

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

γp is critical for this program + possibility to address many pQCD/Pomeron problems

Multiparton interactions - need for high lumi