Rapidity gap survival in double Pomeron processes at LHC and onset of the black disk regime

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Outline

Introduction: up to what p_t parton interactions are black

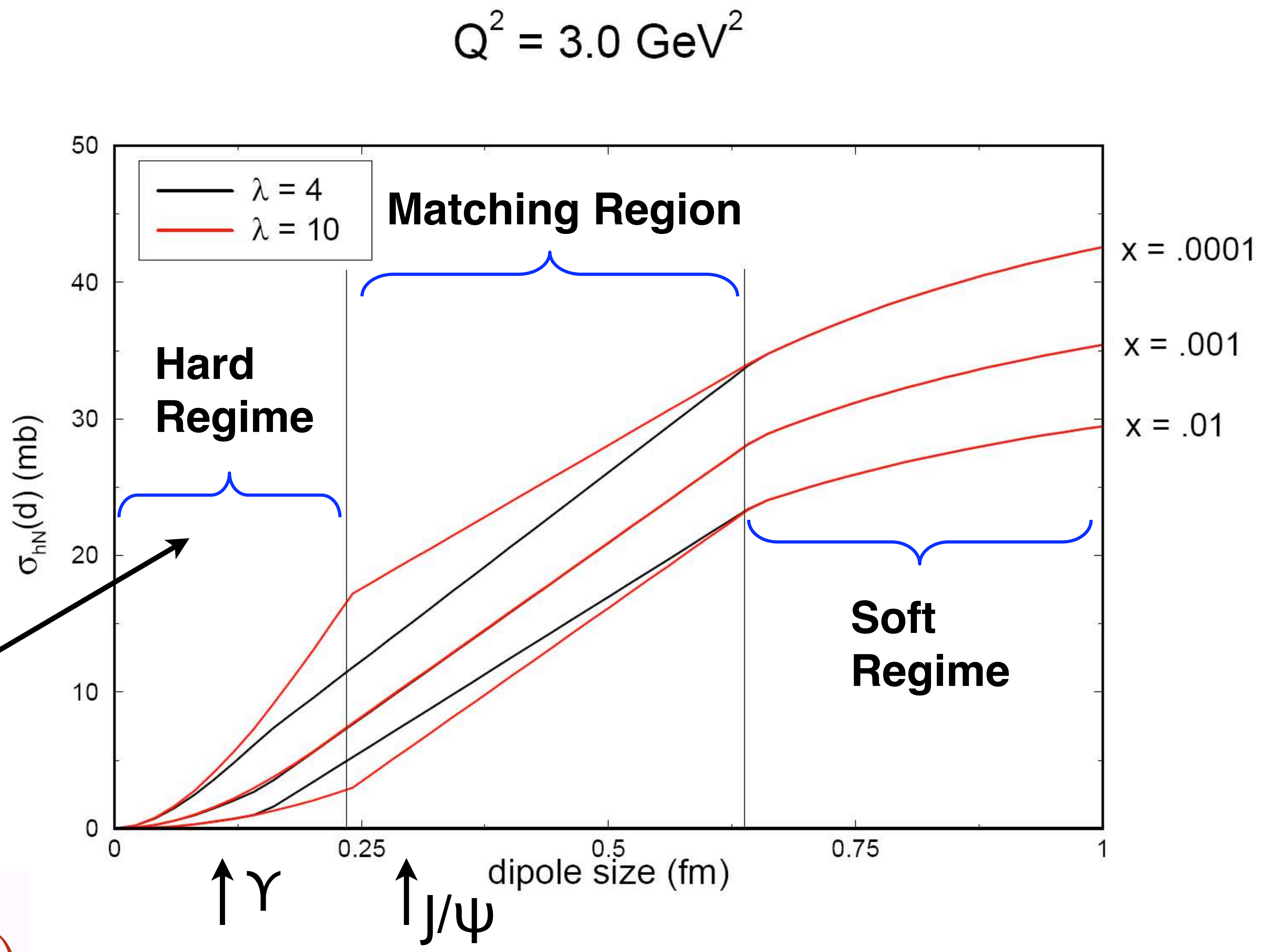
Gap survival in mean field approximation

Strong suppression of gap survival due to onset of black regime

New high energy QCD regime: regime of complete absorption for small α_s: limit - fixed Q & large energies -black disk regime (BDR)

Evidence for proximity to BDR at HERA

studies of the "quark-antiquark dipole"(transverse size d) - nucleon cross section based pQCD and HERA data



$$\sigma_{inel} = \frac{\pi^2}{3} F^2 d^2 \alpha_s(\lambda/d^2) x G_T(x.\lambda/d^2)$$

Frankfurt et al 2000-2001

F^2 Casimir operator of color SU(3) Baym et al 93

Provided a reasonable prediction for σ_L

F^2(quark) =4/3 F^2 (gluon)=3

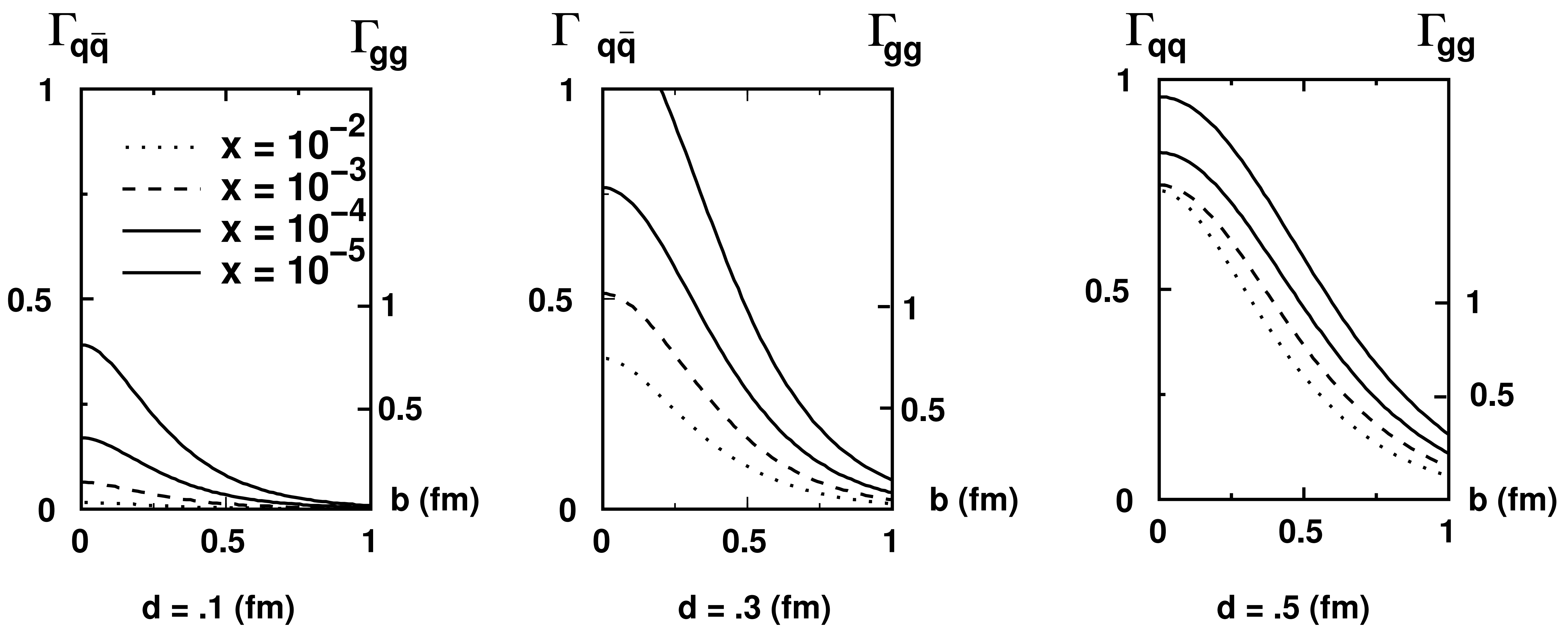
Combine with: analysis of exclusive hard processes
(t-dependence of the dipole - nucleon scattering)

determine impact factors for elastic $q\bar{q} - N\, scattering$

$$\Gamma_h(s,b) = \frac{1}{2is}\frac{1}{(2\pi)^2}\int d^2\vec{q}\, e^{i\vec{q}\vec{b}} A_{hN}(s,t)$$

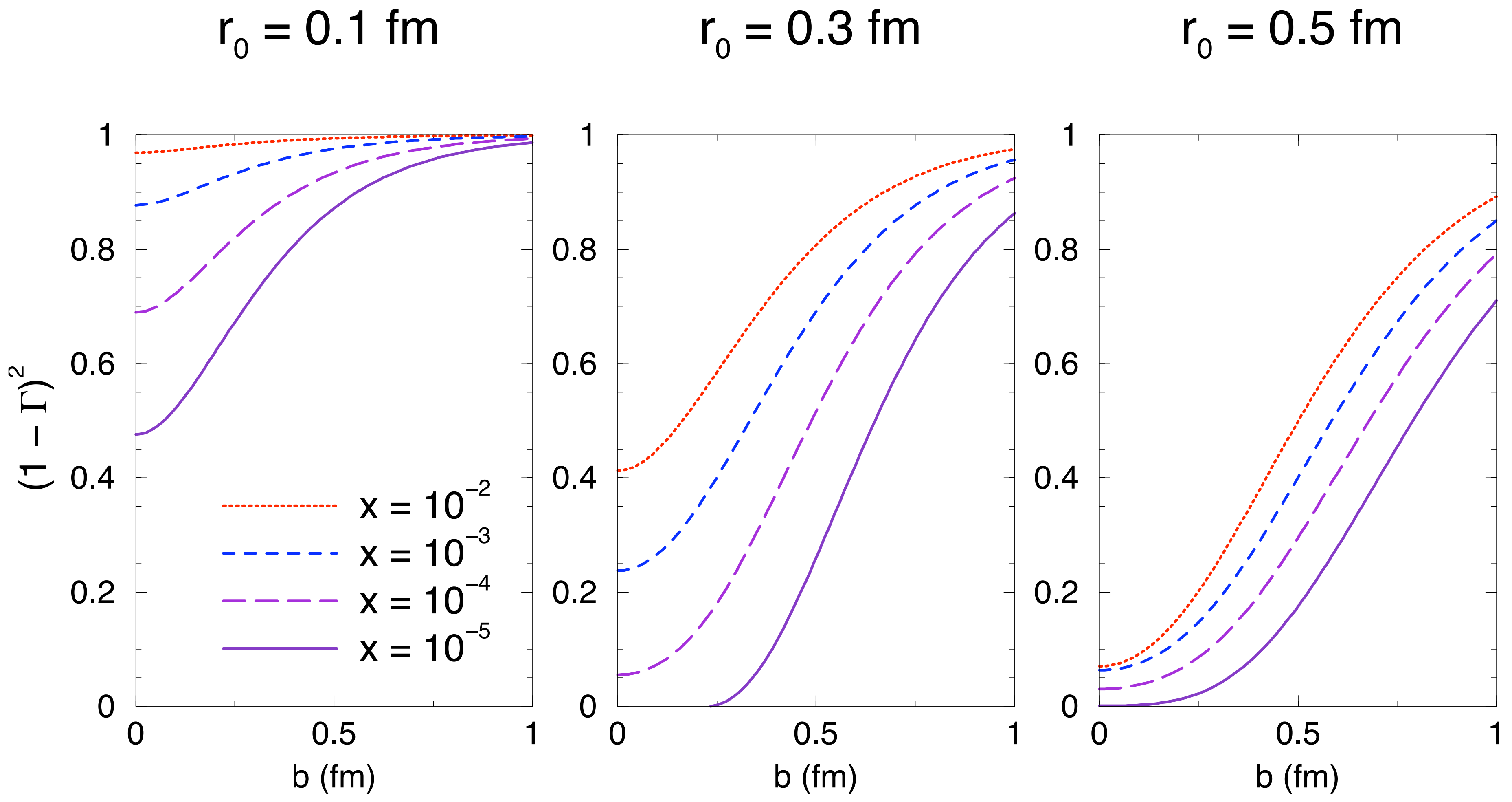
$\Gamma = 1$ *corresponds to regime of complete absorption - BDR*

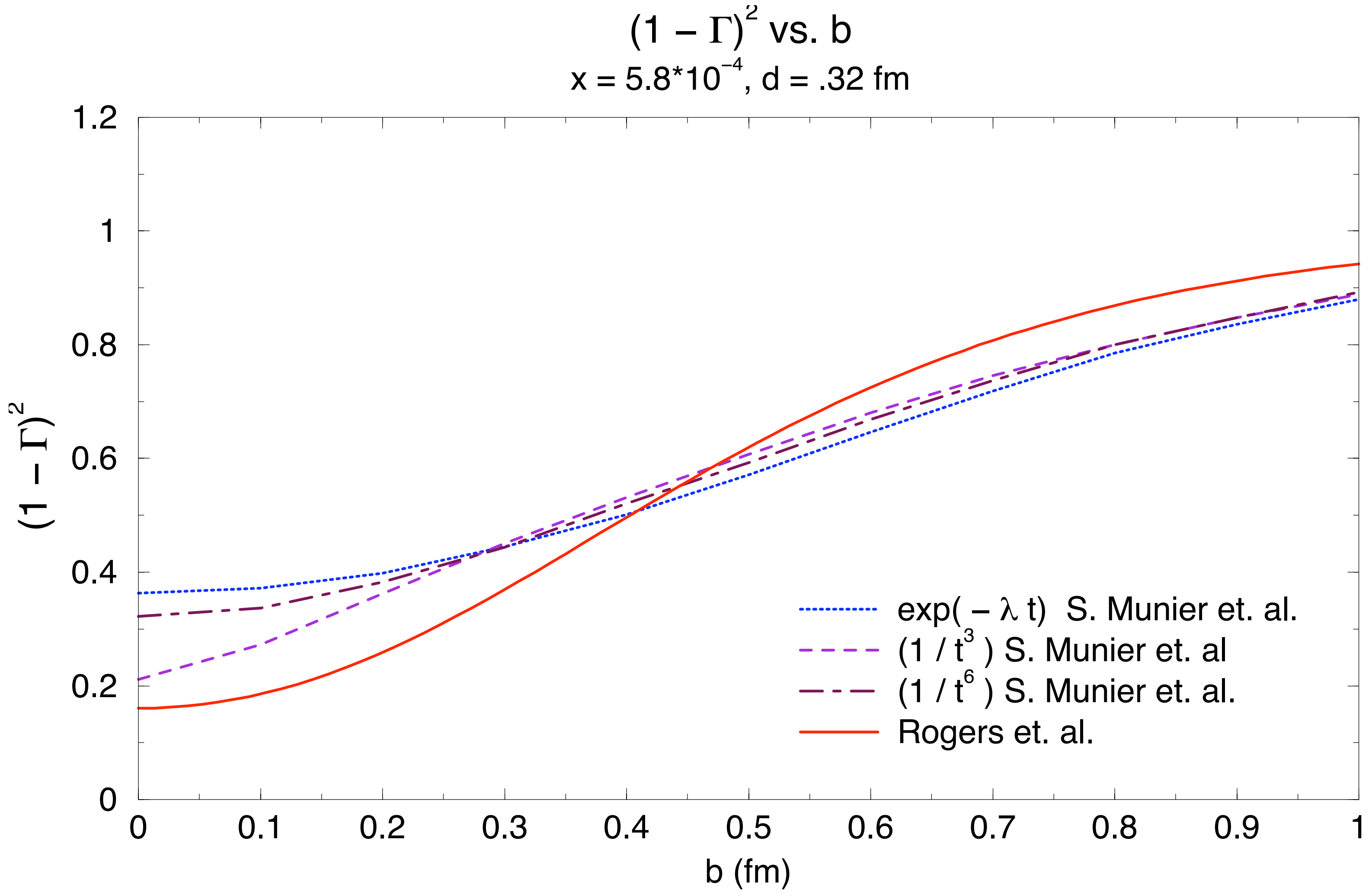
T.Rogers et al



In the case gg-N scattering we assume pQCD relation

$$\Gamma_{gg} = \frac{9}{4}\Gamma_{q\bar{q}}$$





$|1-\Gamma(b)|^2$ -
probability not to interact at given b

gg -N interaction seems close to BDR for $Q^2 \sim 4$ GeV^2, $x \sim 10^{-4}$ ⇒ Large probability of diffraction in gluon channel

for $Q^2 \sim 4$ GeV^2, $x \sim 10^{-3}$ gg - Pb interaction at b=0 is deep in BDR
$q\bar{q}$ - Pb interaction in BDR

for these x nuclear gluon shadowing effect is rather small

Forward partons with p_t less than BDR scale should loose energy and p_t distribution should broaden

Test

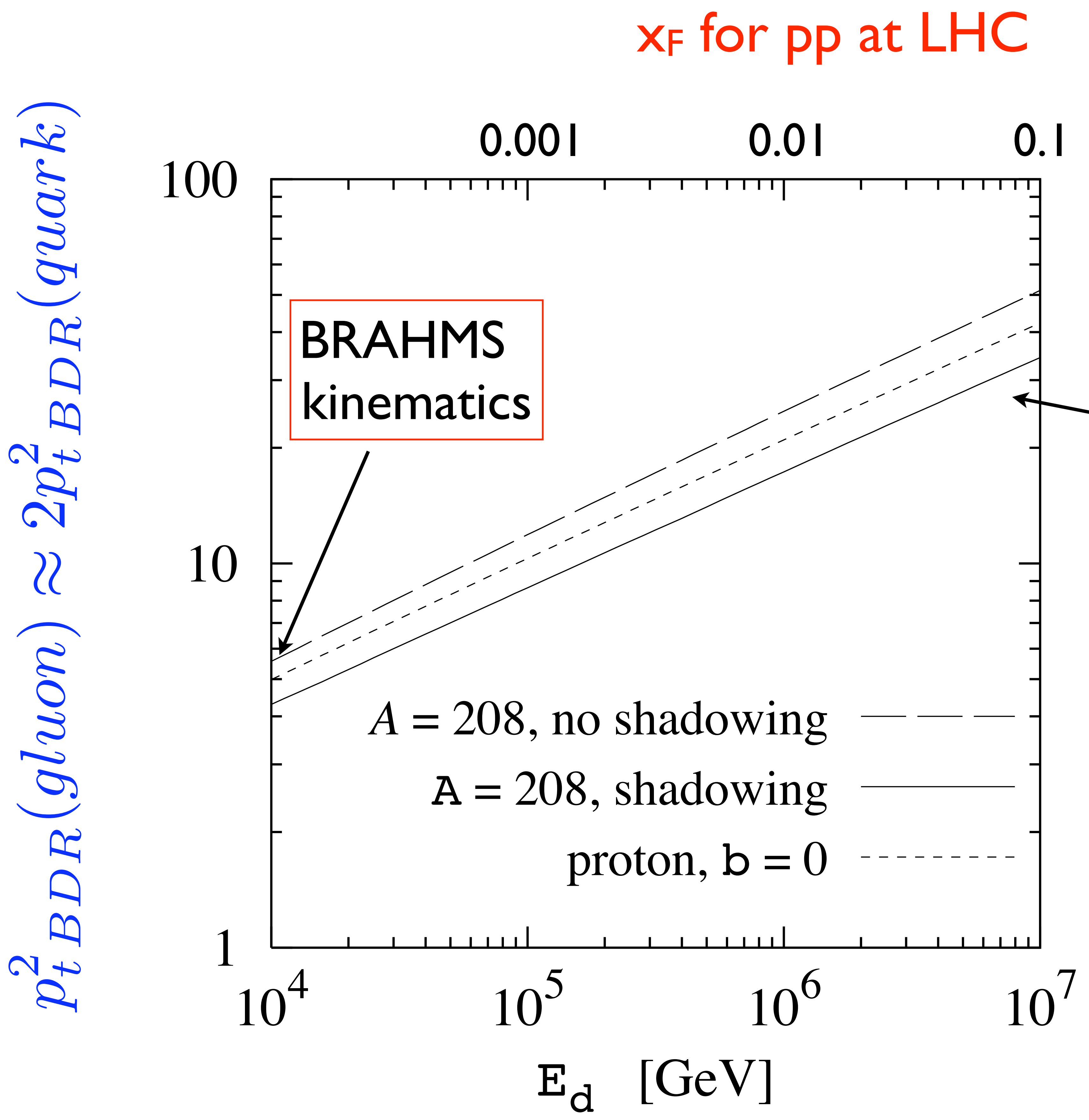
Suppression of the leading hadron production in pA scattering at large p_t comparable to the scale of Black disk regime at given energy (FS 01-06) ⇒ Natural explanation of the BRAHMS result at RHIC, the only one consistent with the STAR data on correlations

In high energy pp collisions at small b no partons with p_t < few GeV can survive

Gluon densities at small x in heavy nuclei at b=0 and in the proton at b=0 are similar ⇒ In high energy pp collisions at small b no partons with p_t < few GeV can survive

$$p_{t\,BDR} \sim \frac{\pi}{2d}$$

where d is the minimal size of the gg ($q\bar{q}$) dipole for which $\Gamma(b=0) \geq 1$ in LT



Gluon densities in nuclei and proton at b=0 are very similar!!!!

Difference is in the spread in b

Gap suppression for pp → p+ H + p

(a) How black in pp interactions at LHC

Frankfurt, Hyde, MS, Weiss 06

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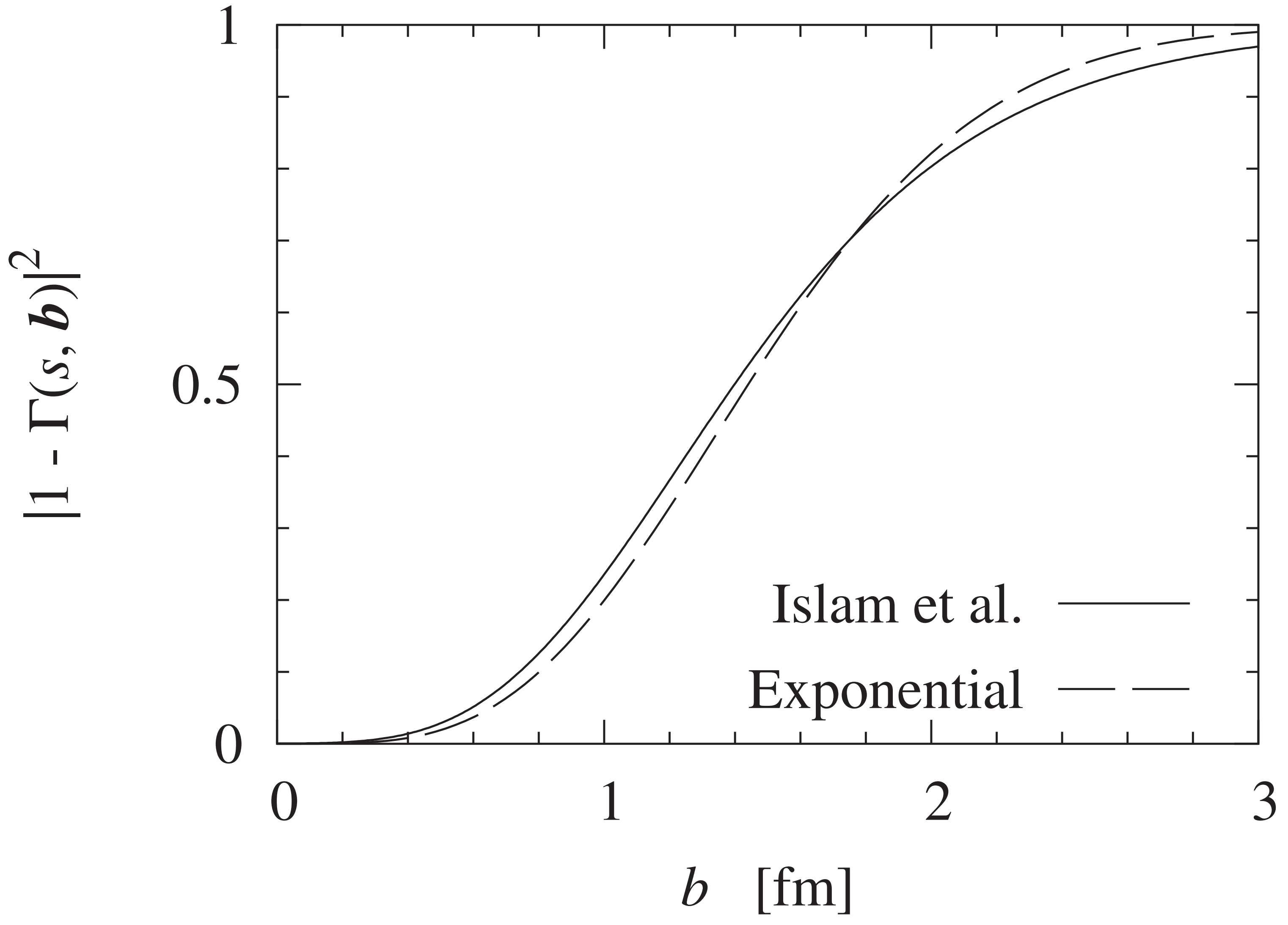
$$T_{\rm el}(s, t = -\boldsymbol{\Delta}_\perp^2) = \frac{is}{4\pi} \int d^2b e^{-i(\boldsymbol{\Delta}_\perp \boldsymbol{b})} \Gamma(s, \boldsymbol{b}),$$

$$\left.\begin{matrix} \sigma_{\rm el}(s) \\ \sigma_{\rm tot}(s) \\ \sigma_{\rm inel}(s) \end{matrix}\right\} = \int d^2b \times \begin{cases} |\Gamma(s, \boldsymbol{b})|^2, \\ 2\,{\rm Re}\Gamma(s, \boldsymbol{b}), \\ [1 - |1 - \Gamma(s, \boldsymbol{b})|^2]. \end{cases}$$

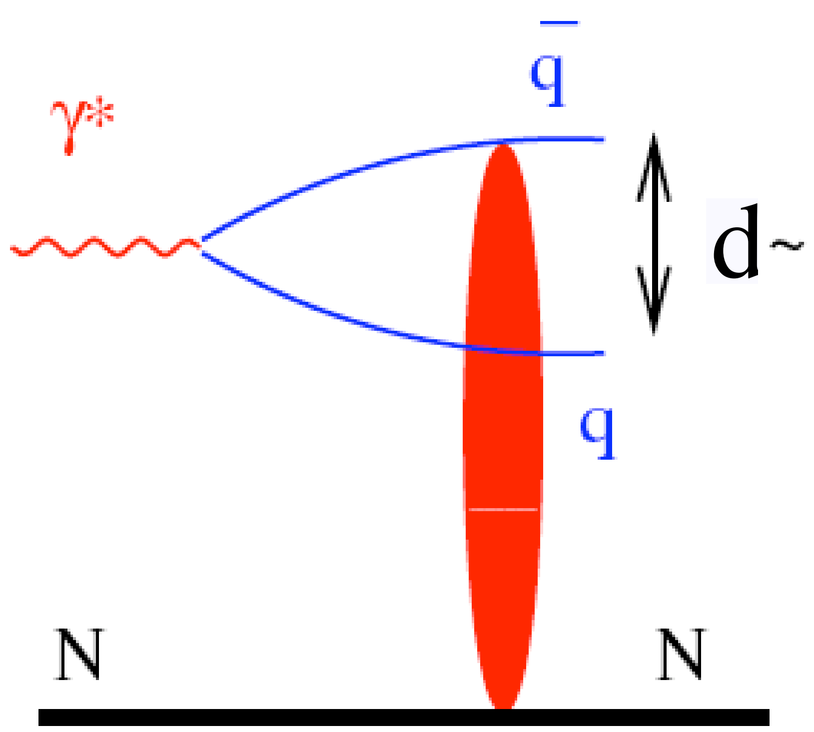


The probability distribution $|1 - \Gamma(s, \boldsymbol{b})|^2$ for no inelastic interaction, as a function of b, at the LHC energy (W=14TeV)as computed with different parametrizations of the pp elastic scattering amplitude. Solid line: parametrization of Islam et al ("diffractive part" only). Dashed line: exponential parametrization, withΓ(b=0) =1 (BLACK DISK LIMIT) and B=21.8 GeV^{-2}.

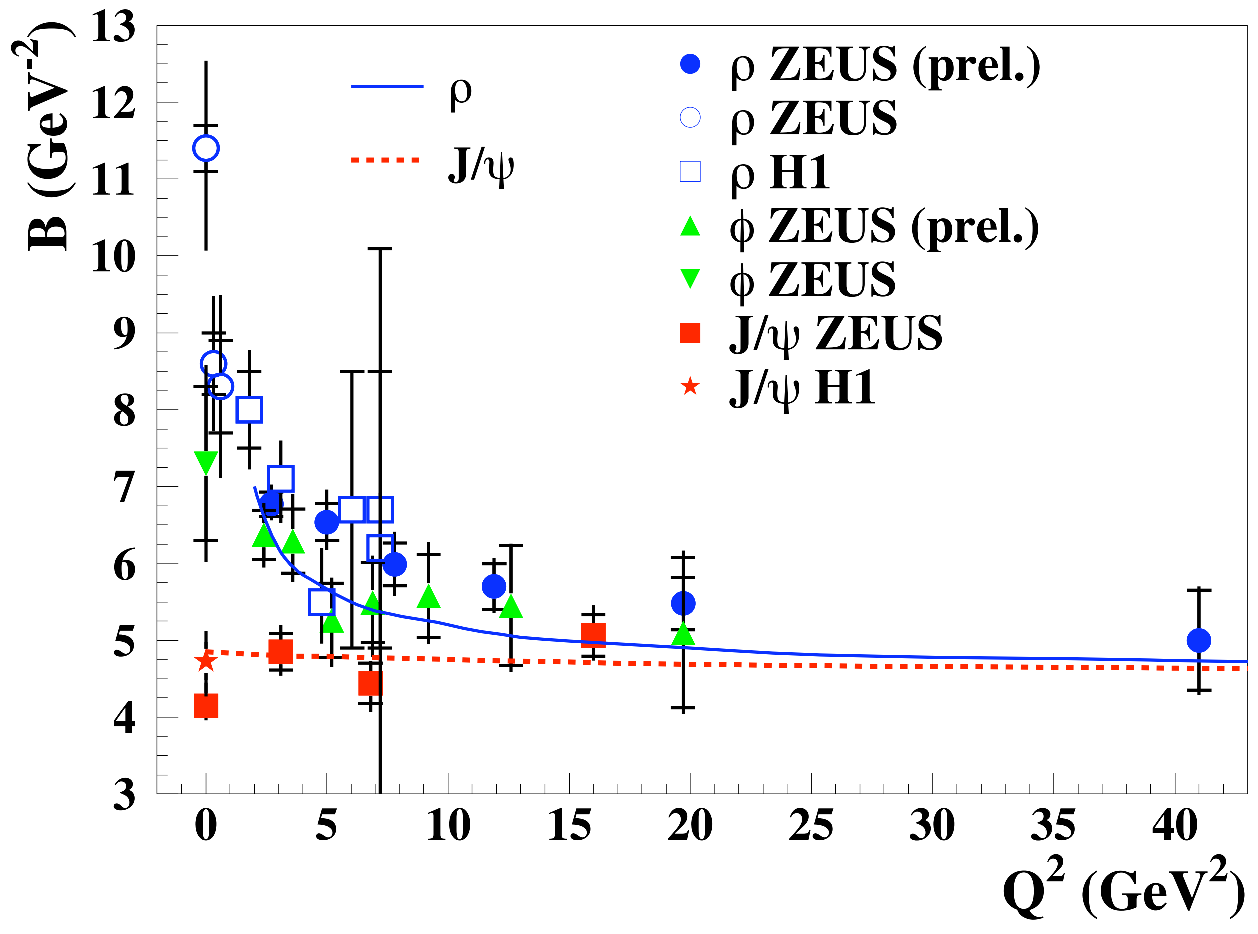
In LT in pQCD t-distribution of exclusive VM production measures transverse distribution of gluons given by the Fourier transform of the two gluon form factor $F_g(x,t)$

$$d\sigma/dt \propto F^2_g(x,t)$$

Onset of universal regime FKS[Frankfurt,Koepf, MS] 97.



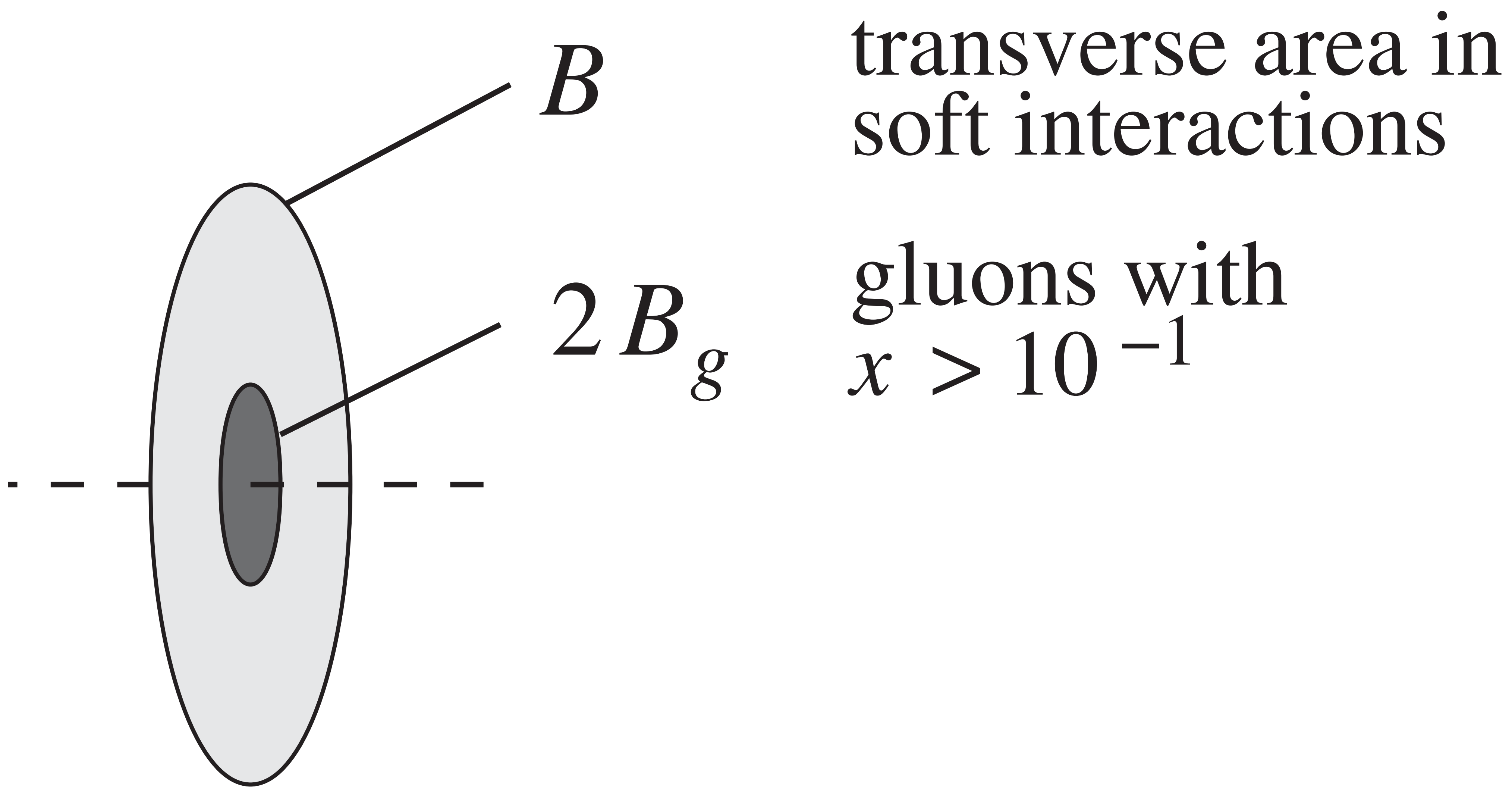
$$d \sim r_T \propto \frac{1}{Q}\left(\frac{1}{m_c}\right) \ll r_N$$

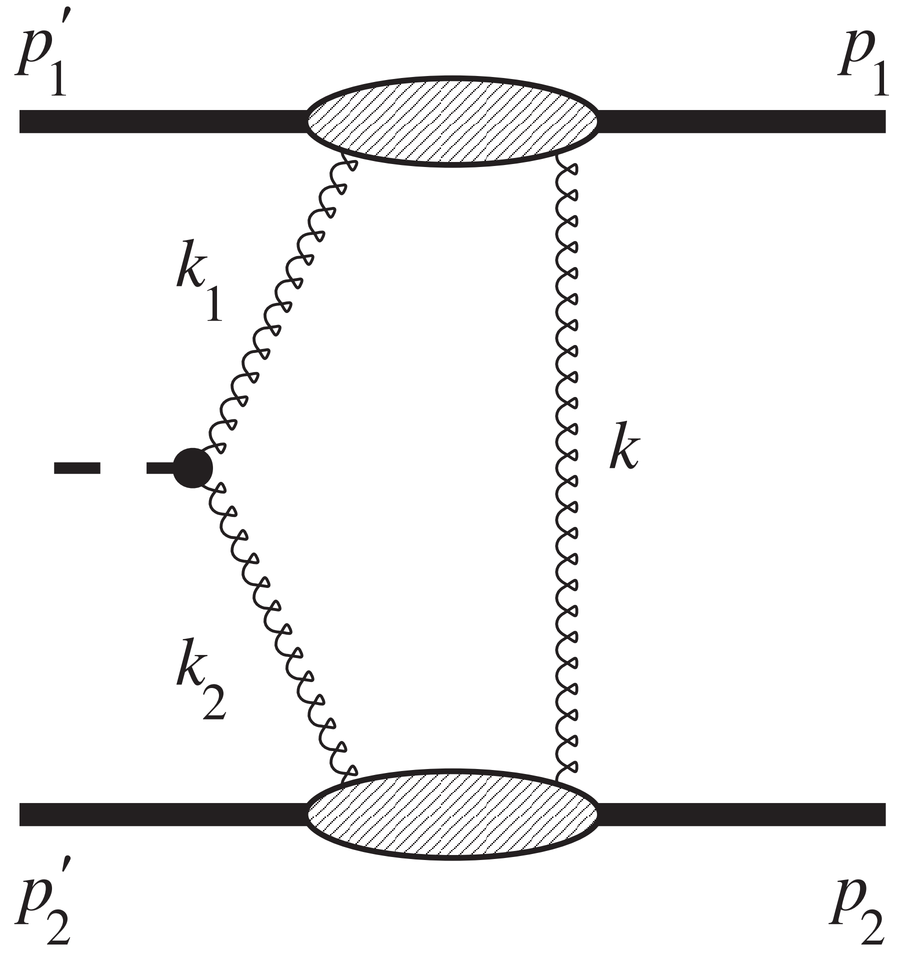


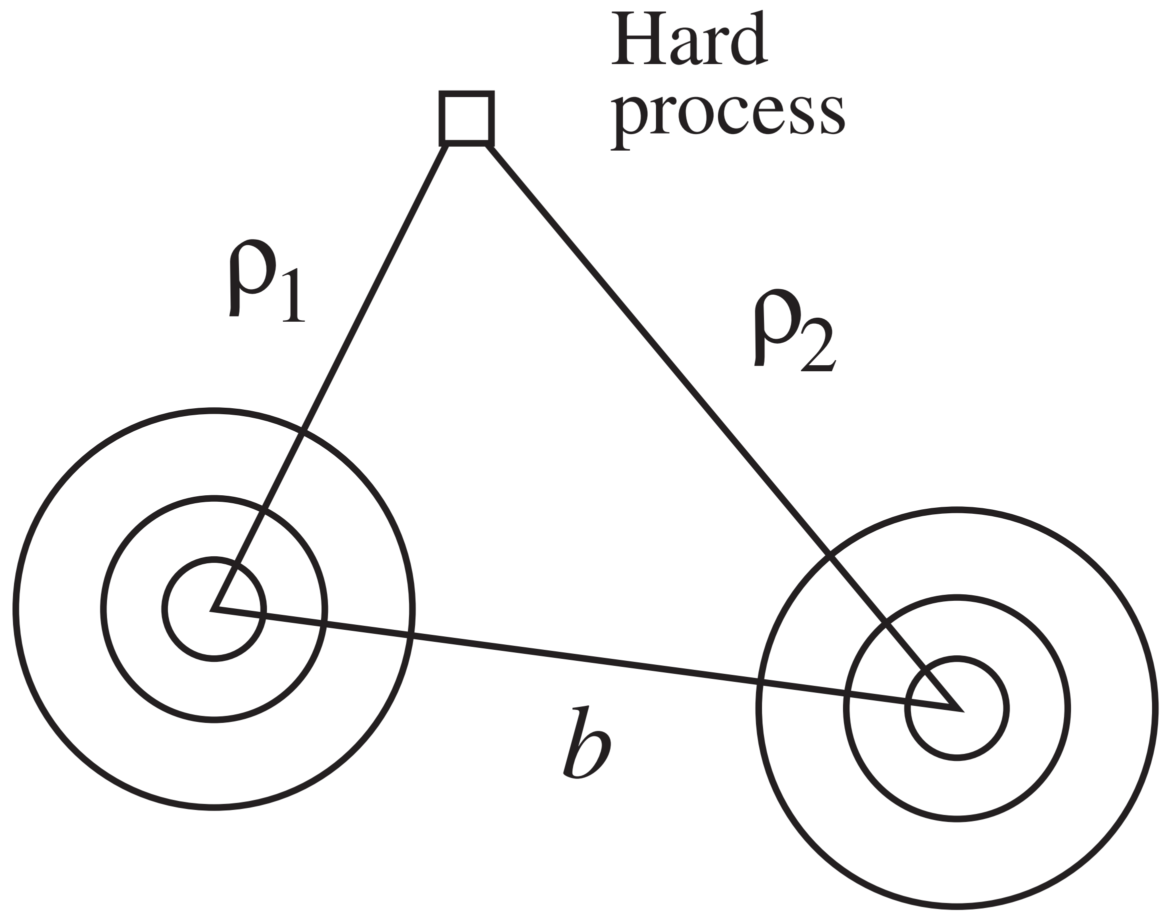
Convergence of the t-slopes, B ($\frac{d\sigma}{dt} = A\exp(Bt)$), of ρ-meson electroproduction to the slope of J/psi photo(electro)production.

Transverse distribution of gluons can be extracted from $\gamma + p \to J/\psi + N$

A crucial observation is that the transverse area occupied by partons with x > 0.05 is much smaller than the transverse area associated with the proton in soft interactions







Assuming no correlation between hard and soft interaction in impact parameter space we derive expression for the amplitude of the process:

$$T_{\mathrm{diff}}(\boldsymbol{p}'_{1\perp}, \boldsymbol{p}'_{2\perp}) = \int d^2b \int d\rho_1 \int d\rho_2 \delta^{(2)}(\boldsymbol{b} - \boldsymbol{\rho}_1 + \boldsymbol{\rho}_2)\; e^{-i(\boldsymbol{p}'_{1\perp}\boldsymbol{\rho}_1)-i(\boldsymbol{p}'_{2\perp}\boldsymbol{\rho}_2)} \boldsymbol{\kappa} F_g(x_1, \xi_1, \boldsymbol{\rho}_1; Q^2) \times F_g(x_2, \xi_2, \boldsymbol{\rho}_2; Q^2)[1 - \Gamma(s, \boldsymbol{b})]$$

where $\kappa \equiv \kappa(s, \xi_1, \xi_2)$ represents the symbolic result for the absolute normalization of amplitude of the hard scattering process

Focus on the total suppression due to soft interactions

$$S^2 \equiv \frac{\sigma_{\mathrm{diff}}(\mathrm{physical})}{\sigma_{\mathrm{diff}}(\mathrm{no\ soft\ interactions})}$$

It is convenient to introduce a normalized impact parameter distribution

$$P_{\rm hard}(\boldsymbol{b}) \equiv \int d^2\rho_1 \int d^2\rho_2 \delta^{(2)}(\boldsymbol{b}+\boldsymbol{\rho}_1-\boldsymbol{\rho}_2)\ \frac{F_g^2(\boldsymbol{\rho}_1)}{[\int d^2\rho_1' F_g^2(\boldsymbol{\rho}_1')]}\,\frac{F_g^2(\boldsymbol{\rho}_2)}{[\int d^2\rho_2' F_g^2(\boldsymbol{\rho}_2')]}$$

which satisfies $\int d^2 b P_{\rm hard}(\boldsymbol{b}) = 1.$

In our approach one does not need to model effects of multiPomeron exchanges, etc.

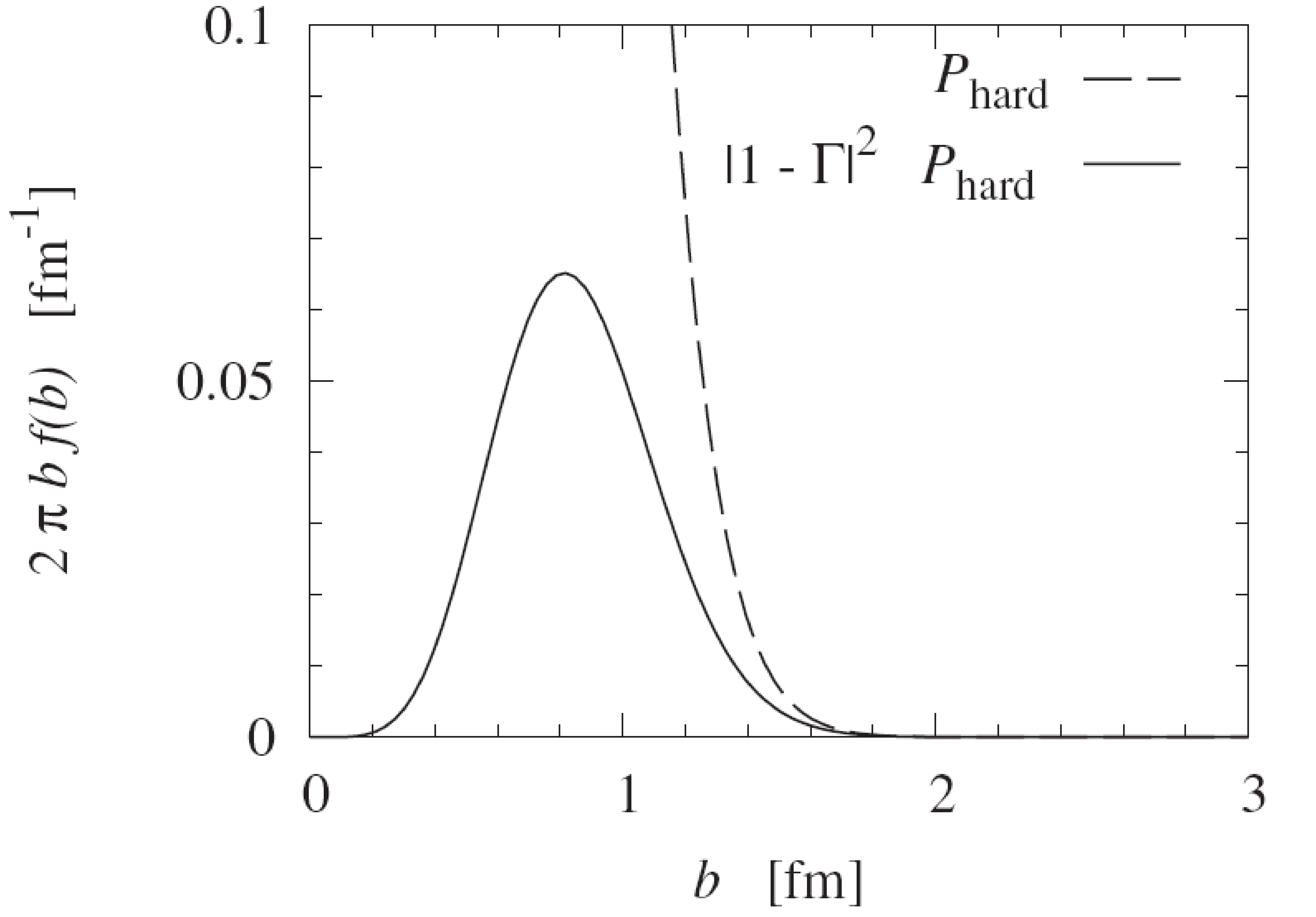
$$S^2 = \int d^2 b P_{\rm hard}(\boldsymbol{b})|1-\Gamma(\boldsymbol{b})|^2.$$

We find that structure of diffraction in pp scattering at LHC and in GDPs relevant for the Higgs production is very different:

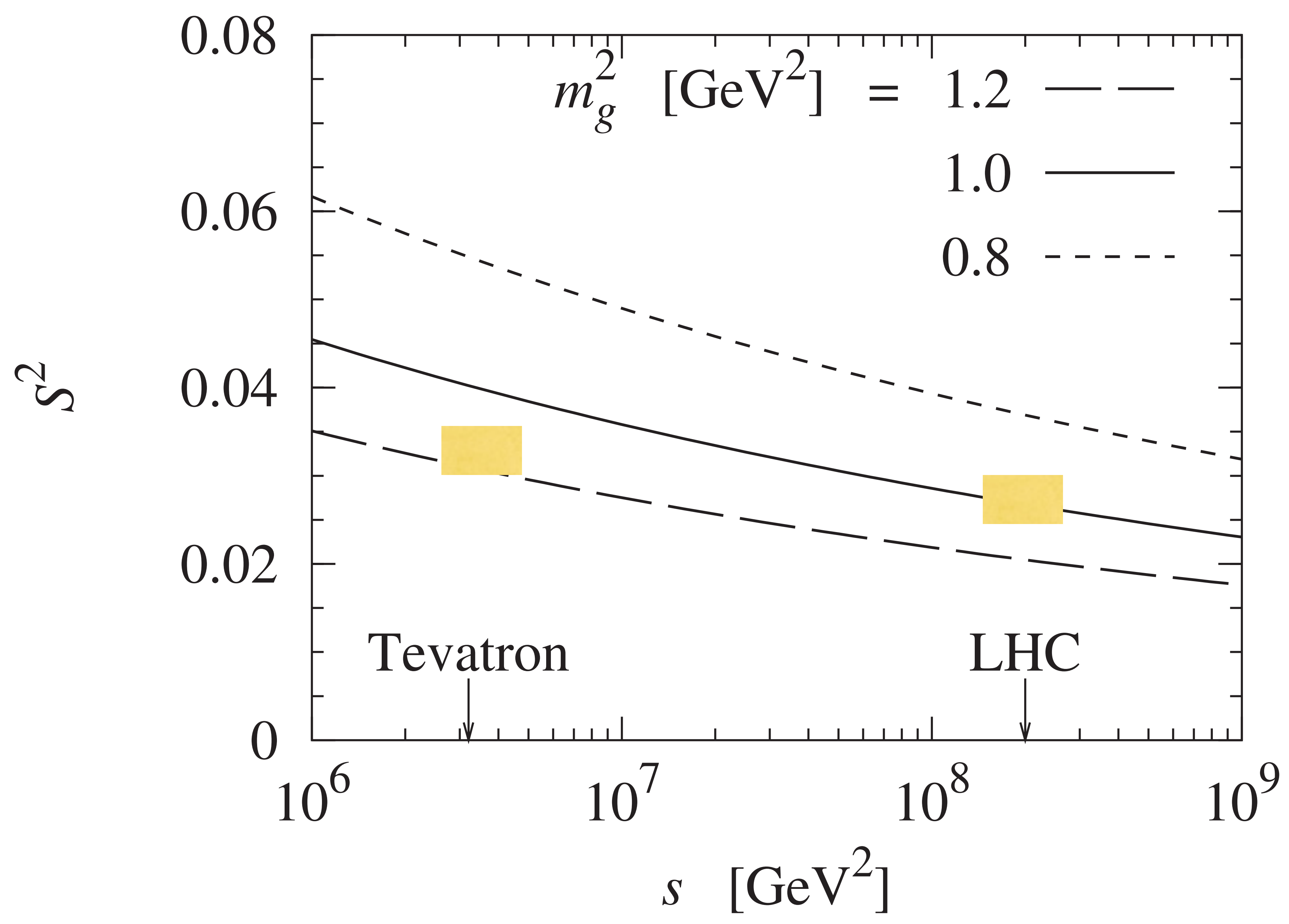
$10^{-8} \le x_{I\!P} \le 0.1$ generic pp diffraction vs $10^{-2} \le x_{I\!P} \le 0.1$ for GDPs

Overall we find effects of inelastic intermediate states are very small.

Model of Durham group for diffraction which found large suppression due to inleastic diffraction neglected this effect, used Good-Walker model which violates Pumplin limit and neglected dominance of spin flip away from t=0.



The integrand (impact factor distribution) in the RGS probability for Higgs boson production at the LHC energy. Dashed line: b distribution of the hard two-gluon exchange, $P_{hard}(b)$ evaluated with exponential parametrization of the two-gluon form factor with B_g=3.24 GeV^{-2}. Solid line: the product $P_{hard}(b)|1-\Gamma(b)|^2$. Vanishing of $|1-\Gamma(b)|^2$ strongly suppresses the contribution of the small impact parameters. RGS probability, S^2 is given by the area under the solid curve. Note that mediane of the distribution is at b~0.8 fm.



S^2(LHC)$_{\text{"uncorrelated approximation"}}$≈ 0.03 is very close to Durham number due to seemingly accidental compensation of two effects: no suppression due to diffractive channel, but a larger suppression due to more realistic transverse distribution of gluons

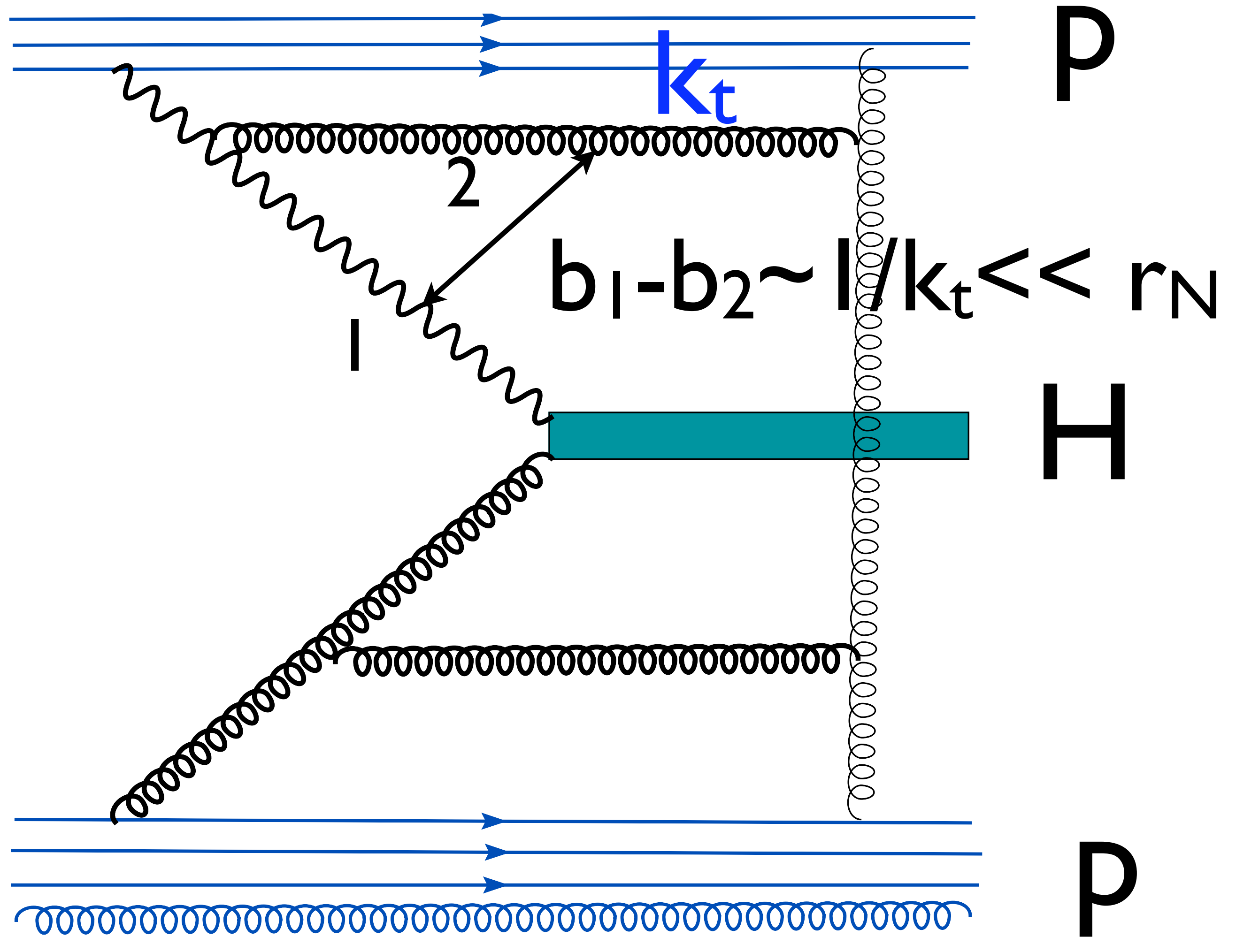
B_{2g} =3.24 GeV^{-2} vs B_{2g} =5 GeV^{-2}

ACCOUNT of CORRELATIONS between soft and hard interactions - HARD INTERACTIONS IN THE BLACK-DISK REGIME

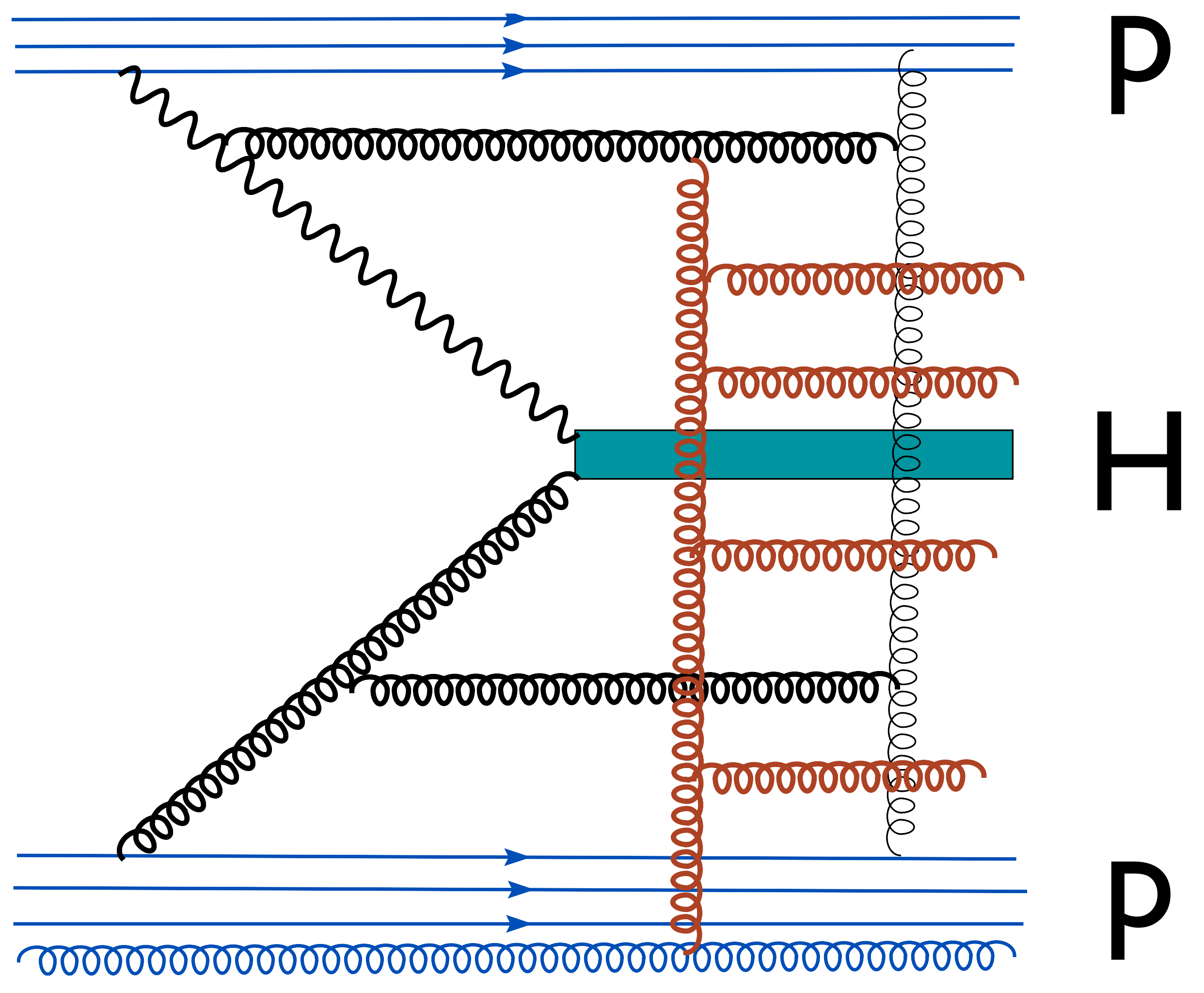
Modifications of the amplitude for double-gap diffraction resulting from hard interactions near the BDL.

(a) Absorption of parent partons of the gluon attached to the Higgs.
(b) Absorption of the hard gluons attached to the Higgs.
(c) Absorption due to local interactions within the partonic ladder.

we will consider only (a) which leads to a large suppression - other may lead to further suppression



Interactions of parton "2" with second nucleon are not included in soft factor $|1\text{-}\Gamma|^2$



Let us illustrate magnitude of these effects consider the interaction of gluon from the evolution of gluon gpd with the small x gluons in the second nucleon

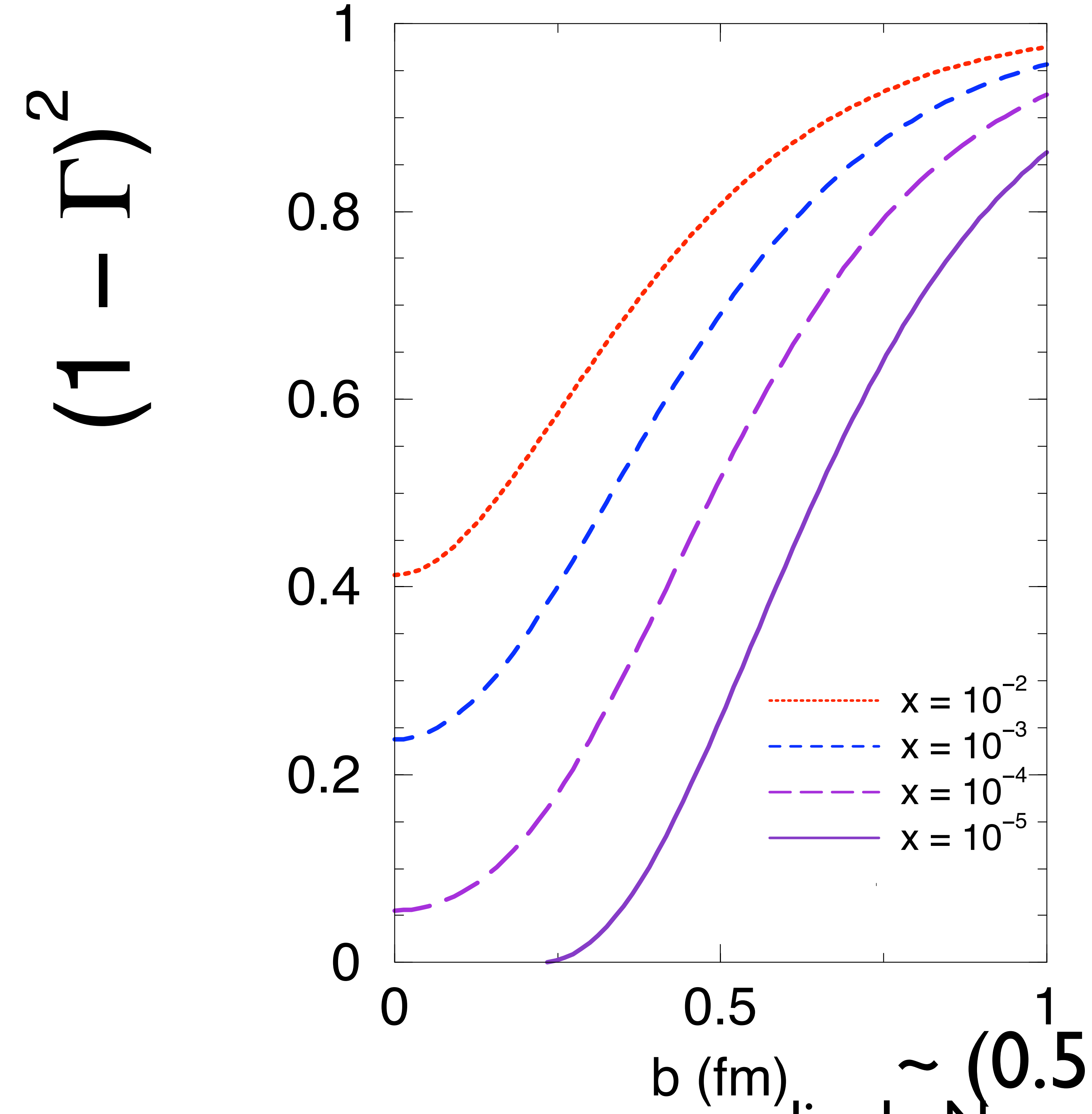
In gluon GDPs for diffractive Higgs production at LHC,

$Q^2 \sim 4$- 8 GeV^2, $x \sim 10^{-2}$

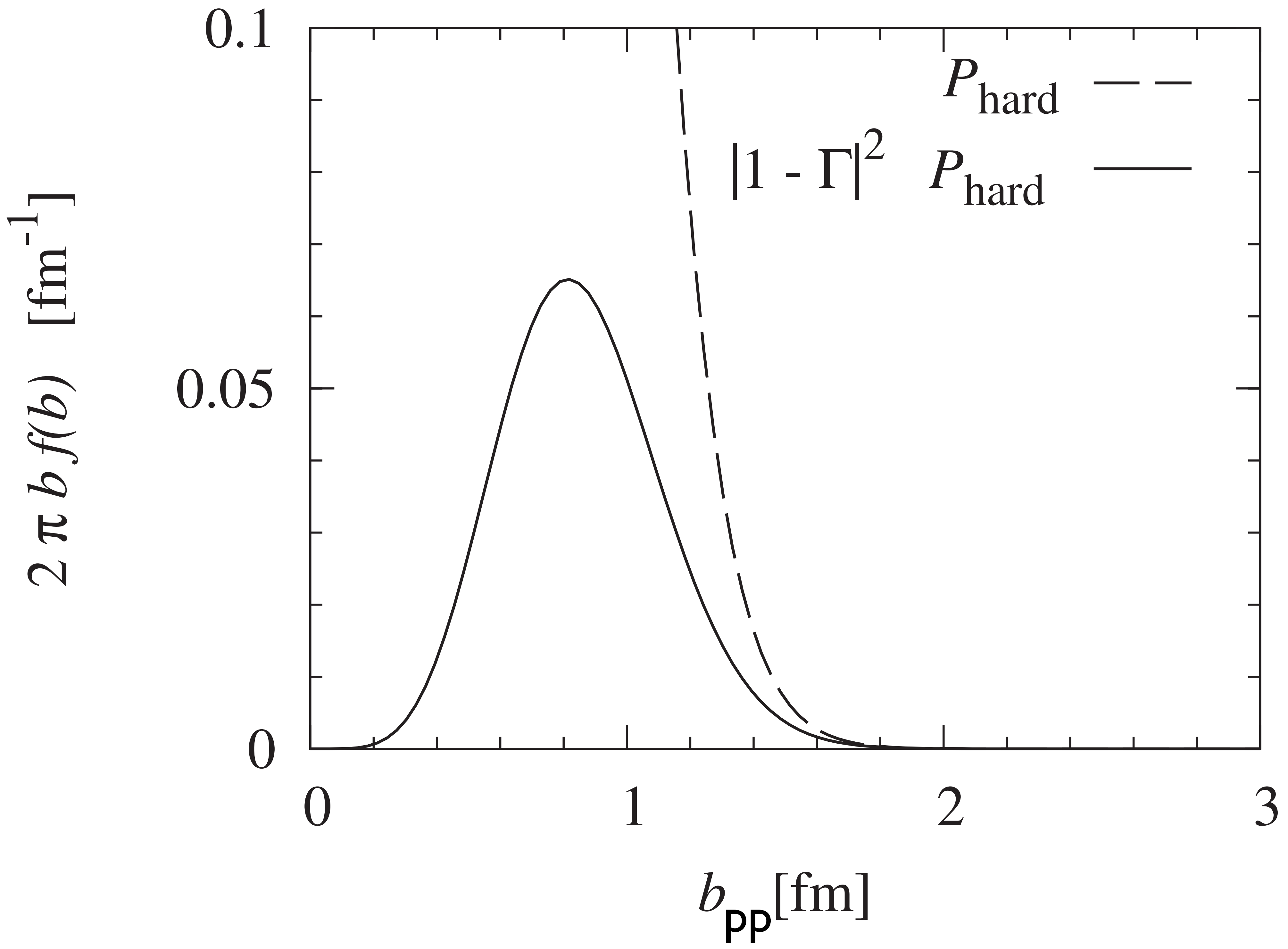
backward evolution - very high probability that these gluons originated from gluons at $x \sim 10^{-1}$ and $p_t \sim 1GeV/c$ - these gluons are present in the colliding nucleons and absorbed back into the final nucleon long after collisions provided they did not interact. These partons are close to the interacting partons and hence not included in the soft absorption factor.

Probability to survive - interaction of a dipole with size $d \sim \pi / 2p_t \sim .3$ fm at effective energy $s_{eff} \sim s_{LHC}/10$. $x_{eff} \sim 10^{-6} - 10^{-7}$!!!

$r_0 = 0.3$ fm



$b_{\text{dipole-N}} \sim (0.5\text{-}0.7)b_{pp}$



Extra suppression is roughly $|1-\Gamma_{\text{dipole N}}((0.5\text{-}0.7)b_{pp})|^4 \rightarrow$ for b_{pp} =0.8 fm suppression is by a factor > 10.

Overall would give suppression > a factor 5.

Only way out rare fluctuations where gluons were not emitted.

Let us estimate this contribution.

The probability to find a gluon at $x=10^{-2}$ at $Q^2=4$ GeV^2 which had the same x at a soft scale of $Q_0^2= 1$ GeV^2 is given by C $\delta(x-1)$ in the integral form of the evolution equation times the ratio of gluon pdfs at Q^2 and Q_0^2

$$C = \left[S_G(Q^2/Q_0^2)\right]^2 = \exp(-\frac{3\alpha_s}{\pi}\ln^2(Q^2/Q_0^2))$$

is the square of the gluon Sudakov form factor

Hence suppression factor for this contribution is

$$R = C^2\left[\frac{g_N(x_H,Q^2)}{g_N(x_H,Q_0^2)}\right]^2 \sim \frac{1}{10}$$

Suppression of exclusive Higgs production at LHC is very sensitive to onset of the black disk regime. Large suppression as compared to approximation of factorized soft and hard physics is likely to be large. Black disk regime effects should suppress S^2 by at least a factor of 3 at LHC (likely a factor of 4 -5). For Tevatron this effect is much smaller since effective x are a factor of 50 larger.

$$\boxed{S^2_{\,LHC}(\text{Higgs}) < 0.01}$$

Several other implications - in particular much more narrow t - distributions for protons since b is a factor > 40% larger.

Conclusion

Gap survival probability at LHC should be much smaller (<.01) than according to the models neglecting correlations of partons in transverse plane due to onset of black disk regime/ regime of high gluon fields

⇕

"No saturation without disintegration" Jonathan Mayhew, 1750