Rapidity gap dynamics: color fluctuations vs knockout mechanism

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Selected topics in diffraction with protons and nuclei: past, present, and future

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To describe soft diffraction Good and Walker assumed that the state of an energetic incident hadron $|\Psi\rangle$

$$|\Psi\rangle = \sum_k c_k|\Psi_k\rangle \ ,$$

$$\mathrm{Im}T|\Psi_k\rangle = t_k|\Psi_k\rangle \ ,$$

$$\sum_k |c_k|^2 = 1 \ .$$

$|\Psi_k\rangle$ interact with the target with different cross sections σ and orthogonal

$$\left(\frac{d\sigma}{dt}\right)^{\mathrm{diff}}_{t=0} = \frac{1}{16\pi}\sum_k |\langle\Psi_k|\mathrm{Im}T|\Psi\rangle|^2 = \frac{1}{16\pi}\sum_k |c_k|^2 t_k^2 \equiv \frac{1}{16\pi}\langle\sigma^2\rangle$$

$$\left(\frac{d\sigma}{dt}\right)^{\mathrm{el}}_{t=0} = \frac{1}{16\pi}|\langle\Psi|\mathrm{Im}T|\Psi\rangle|^2 = \frac{1}{16\pi}\Big(\sum |c_k|^2 t_k\Big)^2 \equiv \frac{1}{16\pi}\langle\sigma\rangle^2$$

Inelastic diffractions is related to fluctuations of cross section

Problem GOOD & WALKER LOGIC TO BE APPLICABLE FOR A RNGE OF T , IT ISN NECESARY TO HAVE THE SAMEEIGENSTATES FOR DIFFERENT T. I

Doubtful In pQCD DIPOLES OFf DIFFERENT SIZE ARE EIGENSTATES FOR T=0, BUT NOT FOR FINITE T.

Nonperturbative example — deuteron +p —> d+p & pn +p.

Impulse approximation
No fluctuations

the condition of orthogonality of the wave functions of the continuum and bound states leads to

$$\left.\frac{d\sigma(D+h\to\,"pn"+h)}{dt}\right|_{t=0} = 0\,,$$

Consistent with GW

But contrary to GW expectations at finite t

$$\left.\frac{d\sigma(D+h\to\,"pn"+h)}{dt}\right|_{\rm incoh} = 2\frac{d\sigma(N+h\to N+h)}{dt}(1-F_D^2(4t))$$
$$\frac{d\sigma(D+h\to D+h)}{dt} = 4\frac{d\sigma(N+h\to N+h)}{dt}F_D^2(t)\,,$$

Recently renewed interest to Inelastic diffraction in γ +p (A)→ J/ψ (leading dijet) + gap + Y

Rapidity gap In particular it was suggested by Heikki Mäntysaari, Björn Schenke that the data at $-t < 2$ GeV^2 are dominated by color fluctuations. Hot spots, etc.

Prompted us to look again on these processes - interplay of different mechanisms which relative role depends on t.

Inelastic diffraction in $\gamma + p\ (A) \to J/\psi$ (leading dijet) + gap + Y

Three regimes

- **t=0** - color fluctuations in nucleons variance of

$$\sigma_{diff}/\sigma_{el} =$$ variance of gluon density at given x (color fluctuations)

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- **$-t > 0.3 \div 0.5$ GeV^2** elastic scattering of a small dipole off gluons & quarks

for smaller t this mechanism is suppressed by factor

$$R = 1 - \left(\frac{1}{1 - t/M^2}\right)^4$$

$M^2 = 1$ GeV^2

- **$0.1 < -t < 0.3 \div 0.5$ GeV^2** interplay of these two mechanisms

plus spinflip

t=0 Processes where is coupled to two gluon ladder

Logic is a combination of QCD factorization theorem fir exclusive processe and Good Walker s

$$G\left(x,Q^2\right)=\sum_n |a_n|^2\, G\left(x,Q^2|n\right)\equiv\langle G\rangle$$

$$\left.\frac{\mathrm{d}\sigma_{elastic}}{\mathrm{d}t}\right|_{t=0}\propto\left[\sum\nolimits_n |a_n|^2\, G\left(x,Q^2|n\right)\right]^2\equiv\langle G\rangle^2$$

$$\left.\frac{\mathrm{d}\sigma_{diffractive}}{\mathrm{d}t}\right|\propto\sum\nolimits_n |a_n|^2\left[G\left(x,Q^2|n\right)\right]^2\equiv\langle G^2\rangle$$

$$\omega_g\equiv\frac{\langle G^2\rangle-\langle G\rangle^2}{\langle G\rangle^2}=\left[\frac{\mathrm{d}\sigma_{inelastic}}{\mathrm{d}t}\Big/\frac{\mathrm{d}\sigma_{elastic}}{\mathrm{d}t}\right]_{t=0}$$

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~ 0.15 — 0.2

Perturbative Pomeron: what is energy dependence cross section in vacuum channel ?

Problem for the study - two large parameters ln Q^2, and ln $1/x$.

DIS - both parameters enter (DGLAP); BGKL - only ln $1/x$ (scattering of two small dipoles)

BFKL elastic amplitude $f(s) = (s/s_0)^{1+\omega_P}$

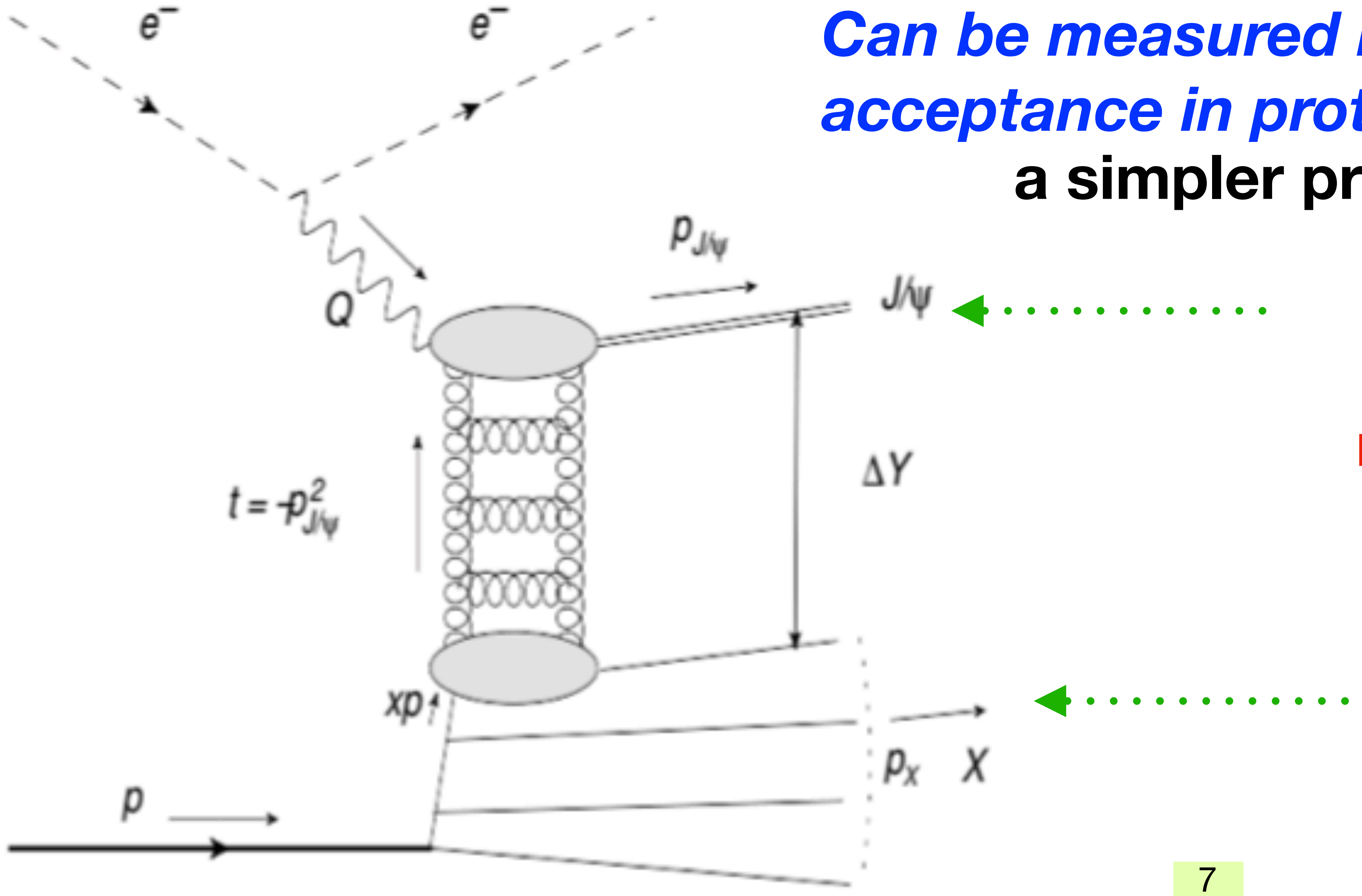
$$\omega_{/P} = a_1\alpha_S - a_2\alpha_S^2 + \ldots$$

leading log $\omega_{/P}$ ~ 0.5 ÷ 0.8 , NLO ~ 0.1, resummation ~0.25

Main reason for small values of $\omega_{/P}$ energy conservation

Promising direction: Rapidity gaps at large t for J/psi production - squeezing from both ends. Can be measured in UPC (pA) if good acceptance in proton region

a simpler process than Mueller and Tung dijet

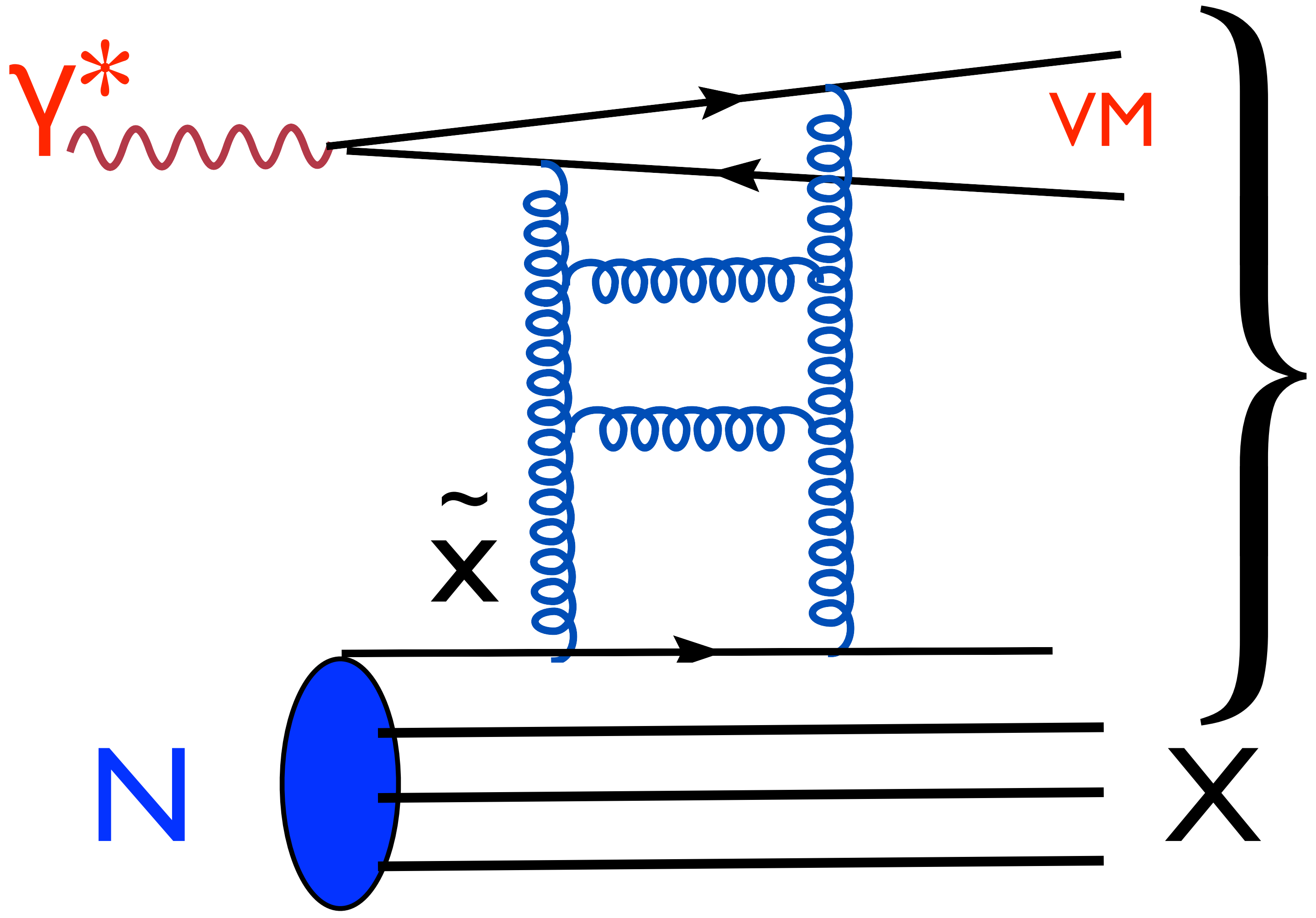


rapidity gap

Parton knockout. mechaanism

fixed x

elementary reaction scattering of projectile off a parton of the target at large t belongs to a class of reactions with hard white exchange in t-channel



$$s' = \tilde{x} W^2_{\gamma p},$$

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

FS 89, FS95,

Mueller & Tung 91

Forshaw & Ryskin 95

best way to measure of the strength of inelastic interactions of small dipole in the processes initiated by elastic small dipole - parton scattering. In HI via UPC feasible for at $[s']^{1/2}$=20 GeV - 100 GeV at the LHC

The choice of large t ensures several important simplifications:

✳ *the parton ladder mediating quasielastic scattering is attached to the projectile via two gluons.*

✳✳ *attachment of the ladder to two partons of the target is strongly suppressed.*

✳✳✳ *small transverse size* $d_{q\bar{q}} \propto 1/\sqrt{-t} \sim 0.15 \mathrm{fm\ for} J/\psi \mathrm{\ for} -t \sim m^2_{J/\psi}$

$$\frac{d\sigma_{\gamma+p\to V+X}}{dt d\tilde{x}} =$$

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

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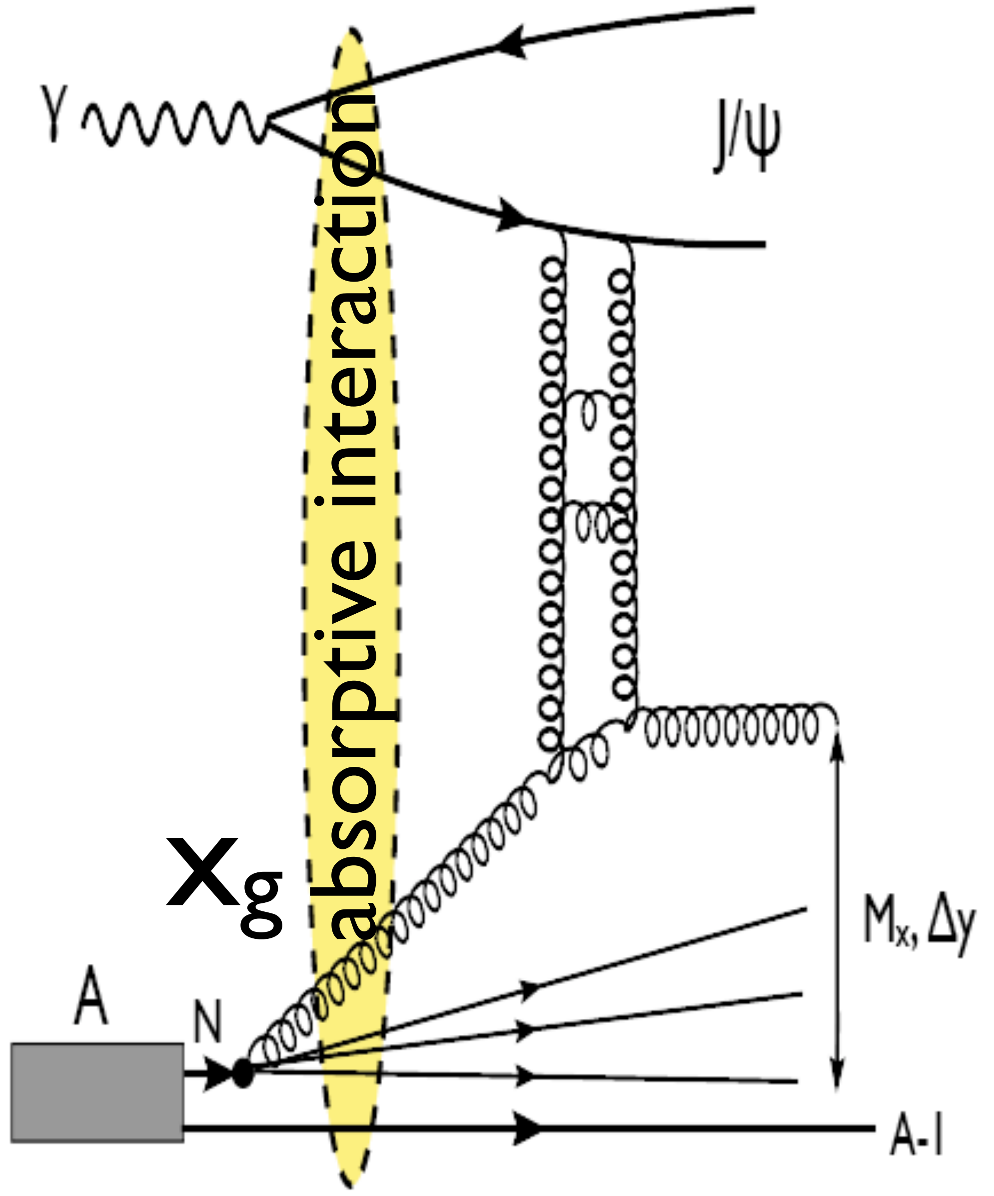
$\exp(2\omega_{IP}\ \Delta Y)$

resummation predicts a huge effect - between ΔY =2 and ΔY =4 σ is expected to increase by a factor of 3 !!!

if EIC would have a detector with high acceptance in the nucleon fragmentation region. Ar LHC much larger ΔY can be reached —> even larger effect

F& S & Zhalov - PRL 2009

$\gamma + A \to J/\psi$ + gap + Y



$$s' = \tilde{x} W_{\gamma N}^2$$

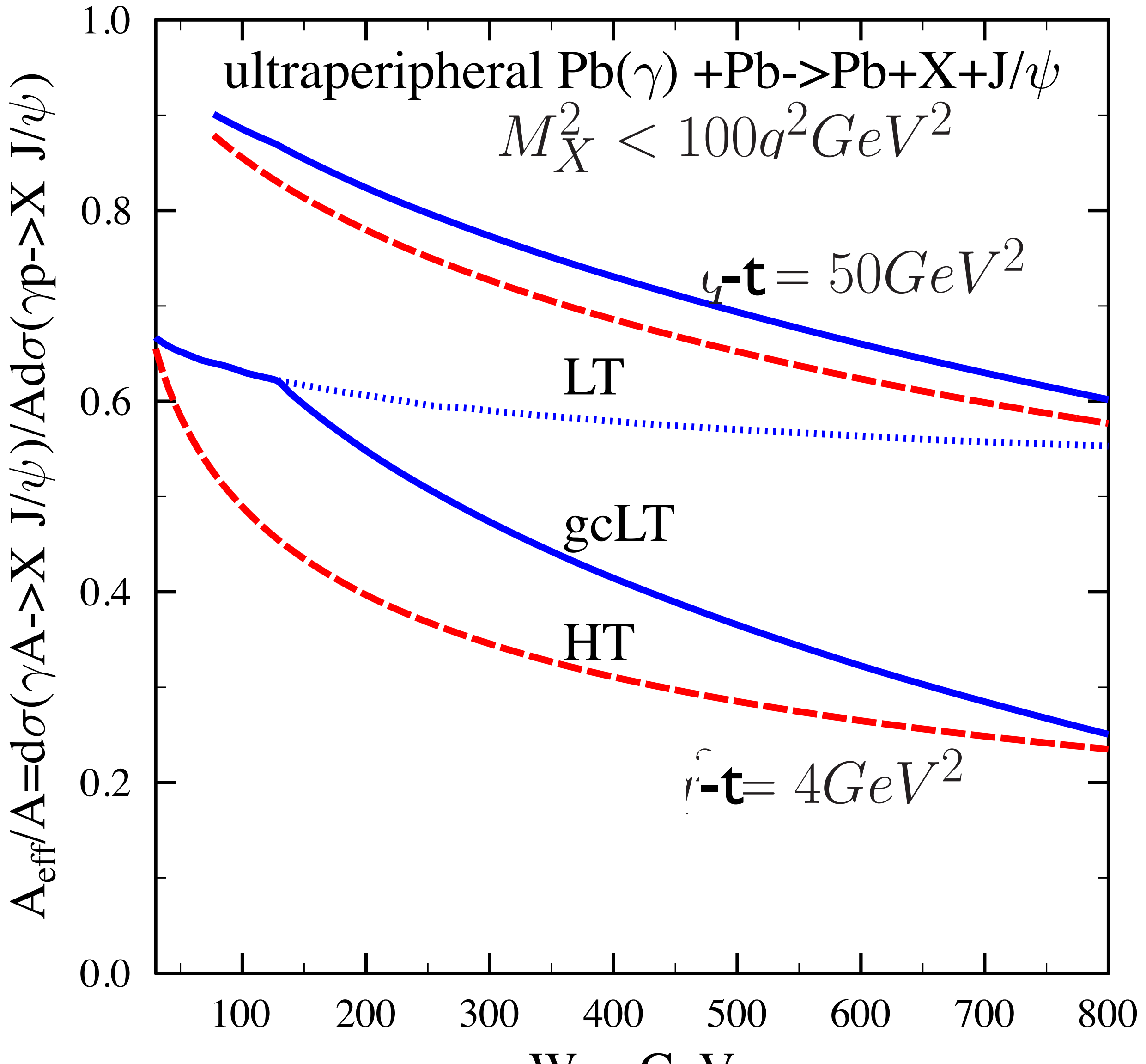
Complementary to coherent J/ψ.

- Tracks dipole though ~ 10 fm of nuclear matter
- Allows to measure dipole size as a function of q^2
- Can reach maximal W of LHeC

Estimate of dipole size for $q^2=0$

$$d^2(-t)/d^2(0) \approx (1 - t/4m_c^2)^{-1}$$

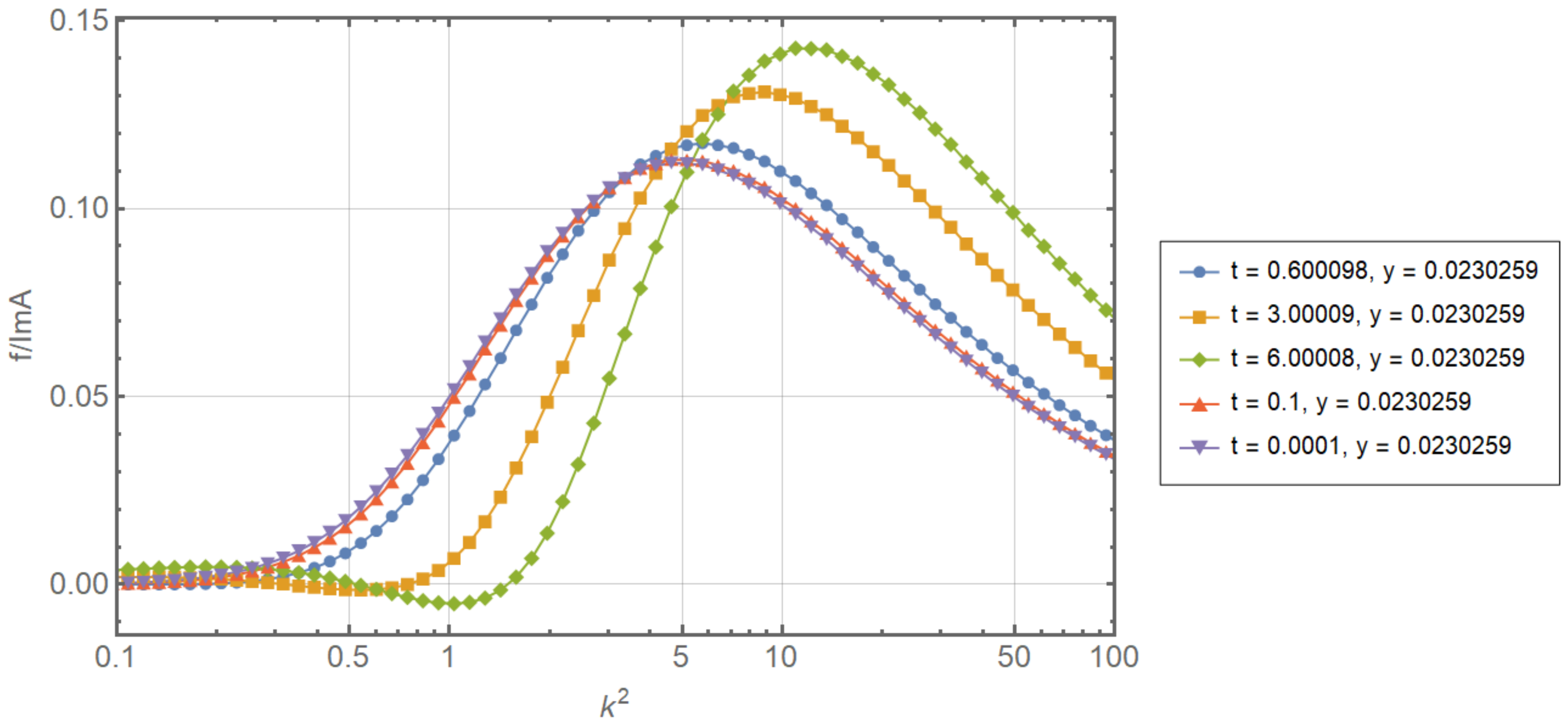
$$(d_0 = .25\text{fm}, m_c = 1.5\,GeV)$$



Significant absorption is expected in the leading twist and higher twist models of dipole interaction. One can select x_g both in the LT shadowing region and above 0.01

Large t data described well by pQCD. Iwe it crazy to go ti t~0?

We calculated distribution in the two gluon ladder over   transverse momenta of gluons



Conclusion: momenta typically above 1 GeV/c: k

Two contributions - two gluons are attached to the same parton or to two different partons.

No suppression

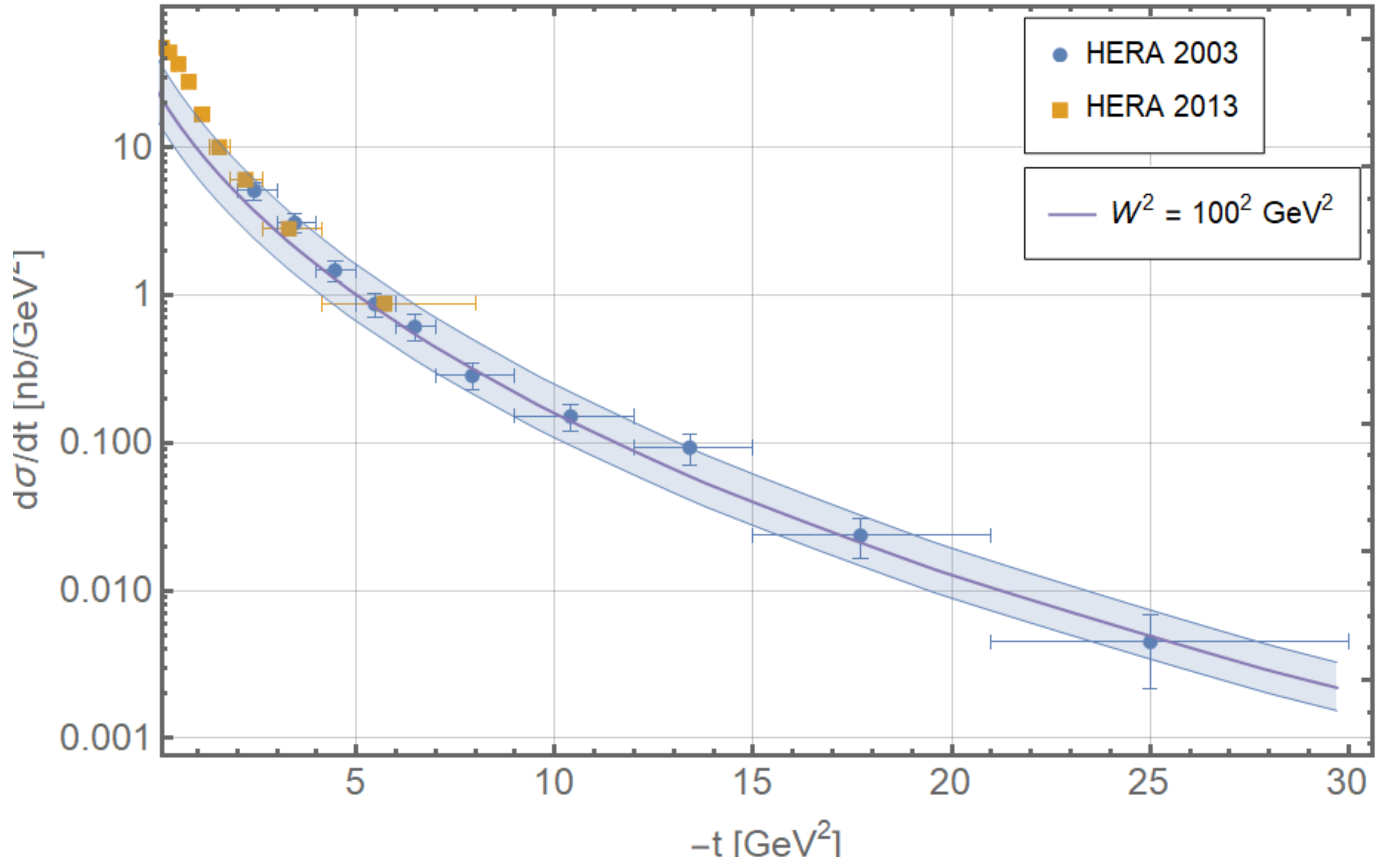
Large suppression. $F_N^4(k^2)$

For t—> 0 attachment to the same partons leads to cross section which is strongly suppressed - only elastic term survives (like in the deuteron example, logic similar to GW.)

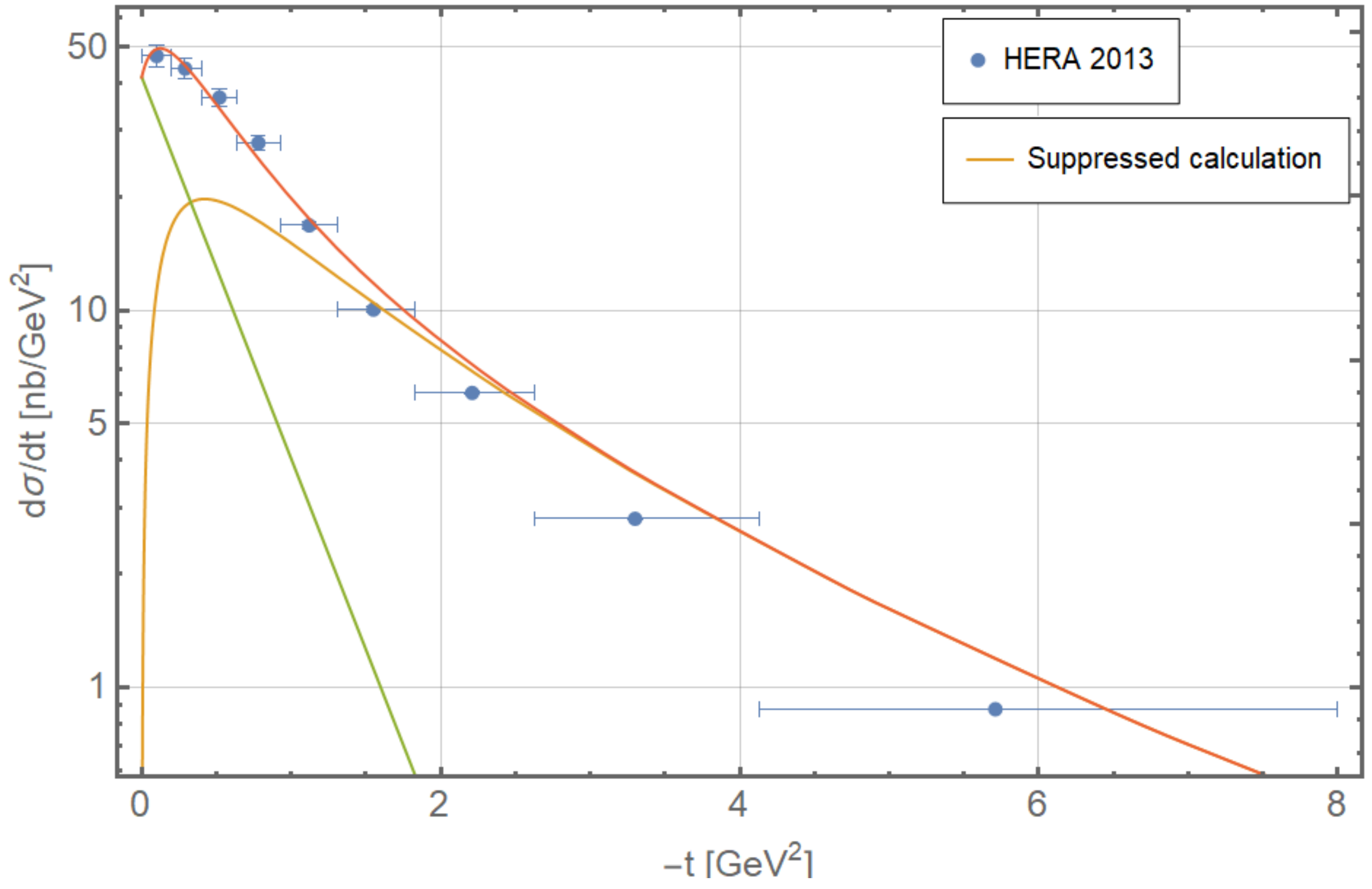
Suppression factor for each vertex - gluon form factor

$$R = 1 - \left(\frac{1}{1 - t/M^2}\right)^4$$

M ~ 1 GeV.



Large t calculation extrapolated to small t



Suppression included.

Overall no need for gluon hot spots.
Fluctuation cross section t-slope is comparable soft physics, in particular spin flip contribution

CONCLUSIONS

Gap physics with J/psi promising direction for studying in ultra peripheral collisions

NLO BFKL dynamics in a wide range of virtualities predicts fast energy dependence

t=0 inel/el tests onset of black regime

Good Walker model is justified (as a useful model for t close to 0)

Interesting nuclear effects

Easier to measure with improved rapidity acceptance of the LHC detectors