Theory of leading twist shadowing phenomena : predictions and uncertainty estimates.

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Leading twist nuclear shadowing phenomena in hard processes with nuclei

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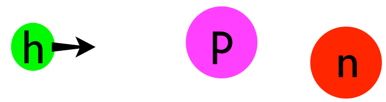
Outline

- Brief historical Introduction
- Theory of leading twist (DGLAP) nuclear shadowing
- Predictions for nuclear pdfs & diffractive pdfs, other final states
- Best Signal for onset of black disk regime

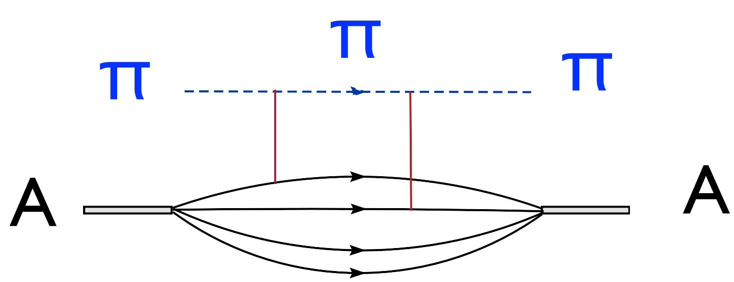
Nuclear shadowing in DIS - is this obvious?



$\Rightarrow \quad \sigma_{h^2H} < \sigma_{hp} + \sigma_{hn}$

$\sigma_{e^2H}(x,Q^2) < \sigma_{ep}(x,Q^2) + \sigma_{en}(x,Q^2)$ in DIS???

Glauber model: interaction of the projectile with nucleons via potential



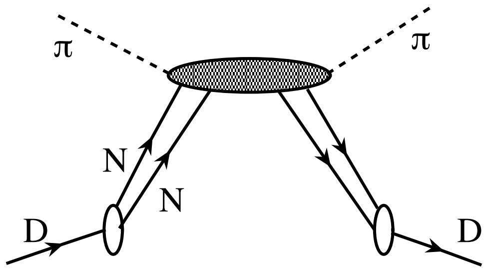
The diagrams consider by Glauber in QM treatment of hA scattering are exactly zero at $E_h >> m_h$ (Mandelstam & Gribov proof of the cancelation of AFS diagrams).

Physics: no time for pion to go back to pion during a short time between the interactions.

Key observations of sixties (Gribov) relevant for description of nuclear shadowing in DIS

✔ Nuclear shadowing in high energy hadron - nucleus scattering

Though the diagrams consider by Glauber are exactly zero at $E_h >> m_h$, the answer for double scattering



shadowing correction

is expressed through the diffractive cross section (elastic + inelastic) at t~0. For triple,... rescattering the answer is related to the low t diffraction but cannot be obtained in a model independent way

Theoretical accuracy of the approach - nonnucleonic degrees of freedom - pions, off-mass-shell effects. Empirically Glauber for E_p=1 GeV, Gribov-Glauber for $E_p \leq$ 500 GeV works with accuracy of better than 5% **including photon - nucleus scattering**.

Natural explanation in the Gribov space-time picture of high energy scattering - (photon) hadron fluctuates into different configurations well before the collisions - they are frozen during the collision. Sum over these configurations = elastic + inelastic diffraction. Though inelastic shadowing effects are a rather small correction of total cross section - presence of the fluctuations of the strength of NN interaction leads to significant fluctuations in inelastic pA, AA collisions (Baym, LF, MS,.. 92) - still not taken into account in MC generators.

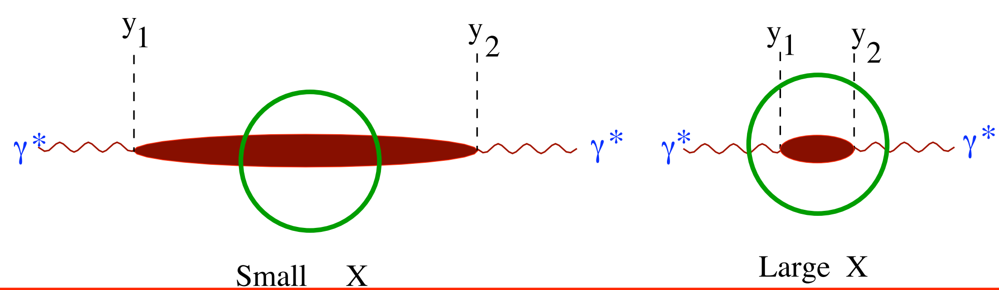
✔ Large longitudinal distance dominate the small x DIS

Gribov, Ioffe, Pomeranchuk 65, Ioffe 68, Gribov 69

Follows from the analysis of the representation of the forward Compton scattering amplitude expressed as a Fourier transform of the matrix element of the commutator of two electromagnetic (weak) current operators:

$$Im A_{\mu\nu}^{\gamma^* N}(q^2, 2qp) = \frac{1}{\pi}\int \exp^{iq(y_2-y_1)} \langle p|\left[j_\mu(y_2), j_\nu(y_1)\right]|p\rangle\, d^4(y_2-y_1)$$

y_1 and y_2 are the points where γ^* is absorbed and emitted.



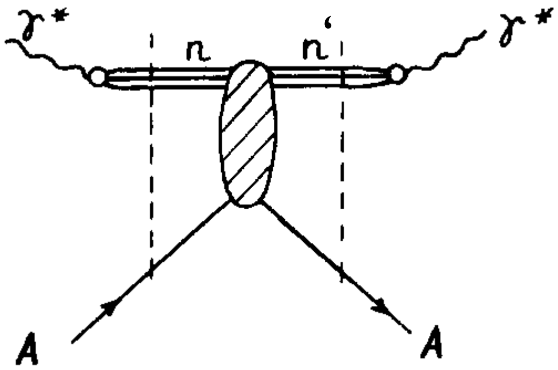
full shadowing

In the nucleus rest frame for z component of y_2-y_1 ≡ z ~ $\boxed{\dfrac{1}{2m_N x}}$ >> 2 R_A

Scaling violation for small x ⇒z= λ_s /2mNx, with λ_s << 1 at large Q^2

Kovchegov & MS, Blok & Frankfurt

✔ Nuclear shadowing in the limit of $q_0 \to \infty$, fixed Q^2:
relation to the photon polarization operator & Gribov paradox



For large q_0 & $A >> 1$ all hadronic configurations |n> in γ^* interact with black disk strength $\sigma_{tot}=2\pi RA^2$

➠ only diagonal transitions n=n' survive

$$F_{2A}(\gamma^* A) \propto \frac{Q^2}{Q_0^2} \ln(2R_A m_N/x) 2\pi R_A^2$$

Gross violation of Bjorken scaling - Gribov paradox (Bj)

➠ Parton model solution - aligned jet model - Bj

➠ QCD aligned jet model - color screening and color transparency - LF & MS 85

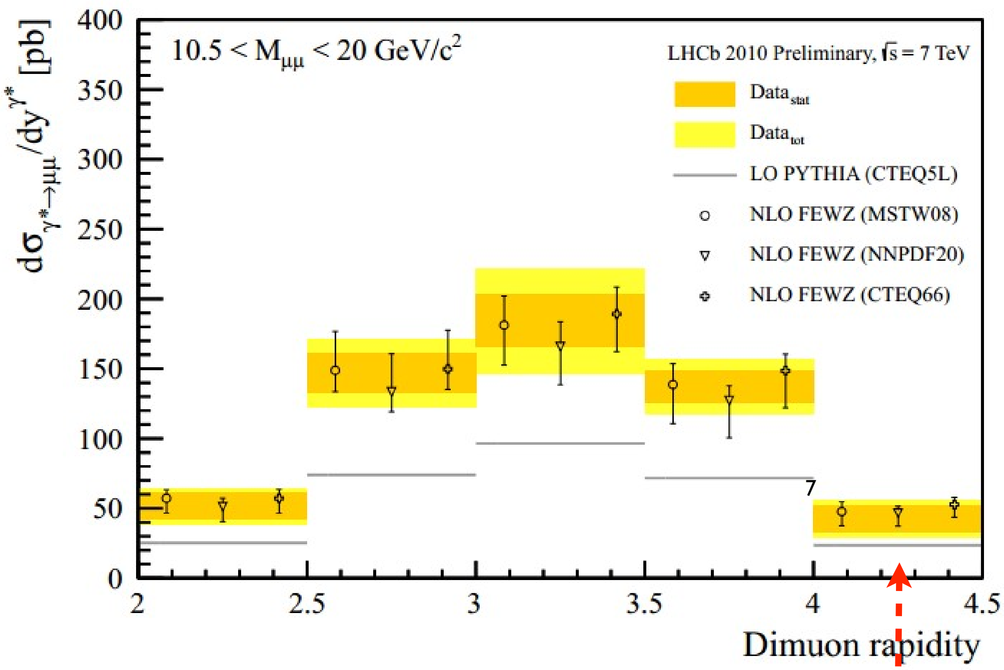
⇓

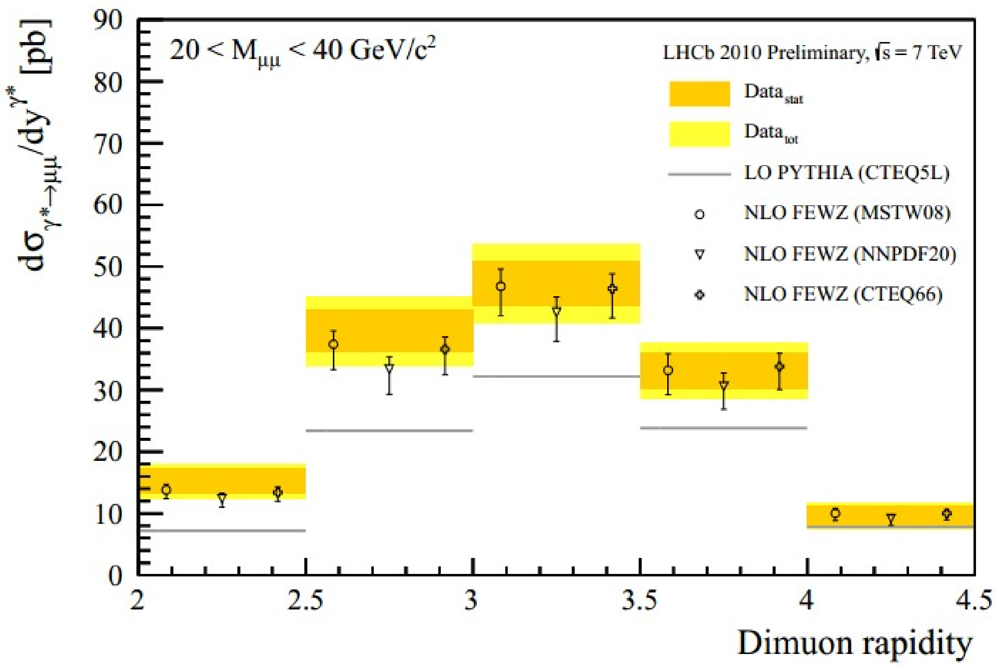
Onset of the Gribov regime is likely in QCD though at much smaller x

QCD aligned jet model predicted correct magnitude of shadowing, diffraction at HERA, as well the slow energy dependence of diffraction in DIS.

★ First clean tests of nuclear shadowing at large virtualities are likely to come from the pA run at LHC in February 2013 and from ultraperipheral collisions in AA

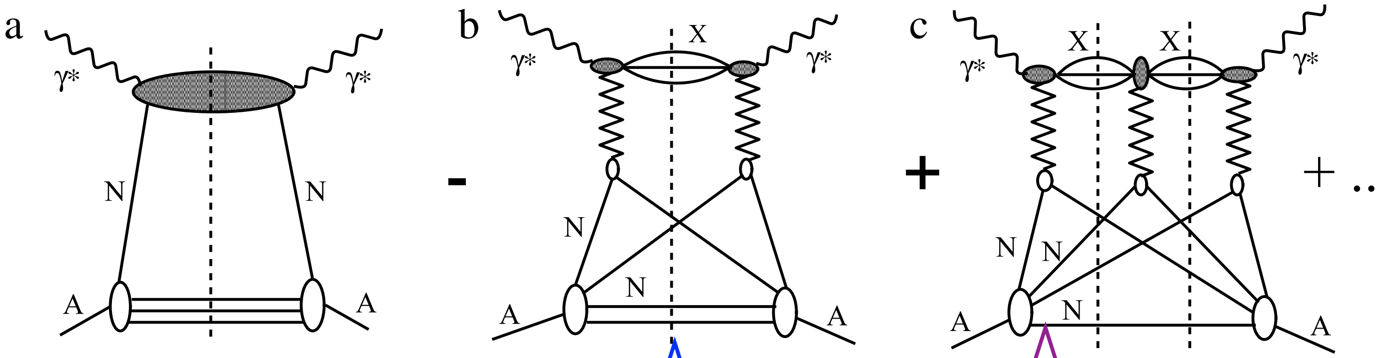
Low Mass Drell-Yan Production





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

The Gribov theory of nuclear shadowing relates shadowing in $\gamma^* A$ and diffraction in the elementary process: $\gamma^*+N \rightarrow X+N$.

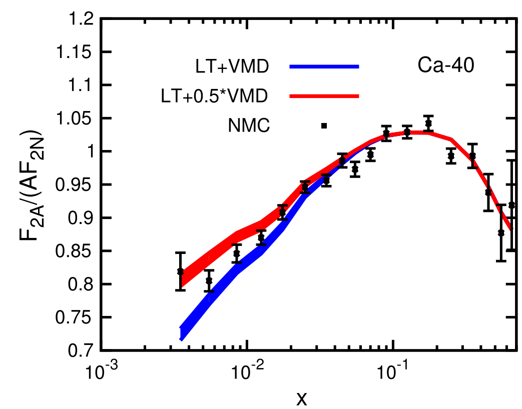


model independent

model dependent but universal (~ same for different A)

four fold rescattering a small correction for $x > 10^{-3}$

Before HERA one had to model ep diffraction to calculate shadowing for $\sigma_{\gamma^* A}$ (FS88-89, Kwiecinski89, Brodsky & Liu 90, Nikolaev & Zakharov 91). More recently several groups (Capella et al) used the HERA diffractive data as input to obtain a reasonable description of the NMC data (however this analysis made several simplifying assumptions). Also the diffractive data were used to describe shadowing in γA scattering without free parameters.



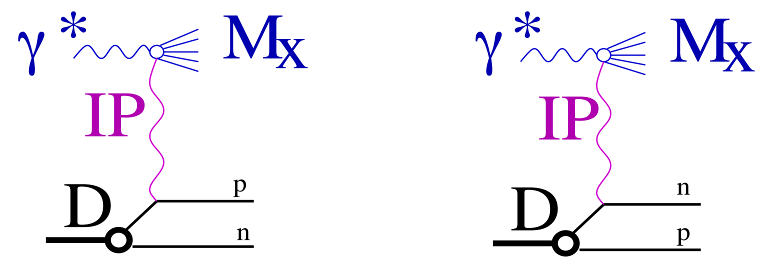
Does not allow to calculate gluon pdfs and hence quark pdfs

Connection between nuclear shadowing and diffraction - nuclear rest frame

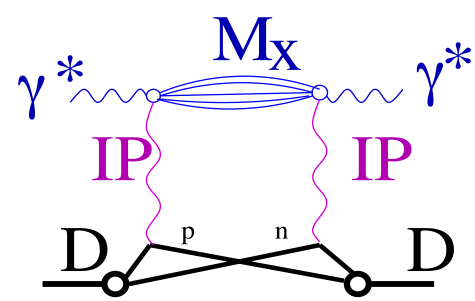
Qualitatively, the connection is due to a possibility of small t to the nucleon at small x: $-t_{min} = x^2 m_N^2 (1 + M_{dif}^2/Q^2)^2$

If $\sqrt{t} \leq$ "average momentum of nucleon in the nucleus" → large shadowing /interference

Deuteron example -amplitudes of diffractive scattering off proton and off neutron interfere



$\Downarrow$



Double scattering diagram for the $\gamma^* D$ scattering

$$\frac{d\sigma^{\gamma^*+D\to M_X+(pn)}}{dt\, dM_X^2} = \frac{d\sigma^{\gamma^*+N\to M_X+(pn)}}{dt\, dM_X^2}(2+2F_D(4t))$$

$F_D(t)$ is the deuteron form factor.

For $t=0$ - 100% constructive interference - (pn) system is D. Coherence dies out at large t.

Integrate over t, M_X ➨ positive correction to the impulse approximation. Coincides with the Gribov shadowing correction to the total cross section (up to small corrections due to the real part of the amplitude).

However the sign is opposite !!!

Explanation is unitarity - Abramovskii, Gribov, Kancheli cutting rules (AGK) - with some technical differences due to scattering off nuclei - Bertocchi & Treleani

➡ Using AGK cutting rules we re-derived original Gribov result for nuclear shadowing extending it to include the real part effects. This approach does not require separation of diffraction into leading twist and higher twist contributions. *It is essentially a consequence of unitarity and many nucleon approximation for the nucleus. Same is true for interactions with N>2 nucleons.*

➡ *Gives relations term by term for contribution of j-nucleon interactions to nuclear shadowing and to diffraction.*

Summary - Diffractive phenomena - inclusive diffraction and measurement of diffractive pdf's

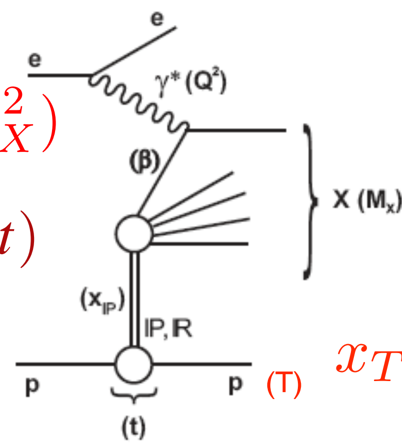
Collins factorization theorem: consider hard processes like

$$\gamma^* + T \to X + T(T'), \quad \gamma^* + T \to \ jet_1 \ + \ jet_2 + X + T(T')$$

one can define fracture (Trentadue &Veneziano) parton distributions

$$\beta \equiv x/x_{I\!P} = Q^2/(Q^2 + M_X^2)$$

$$f_j^D(\frac{x}{x_{I\!P}}, Q^2, x_{I\!P}, t)$$



(T) $x_{T_f} = 1 - x_{I\!P}$

Theorem:

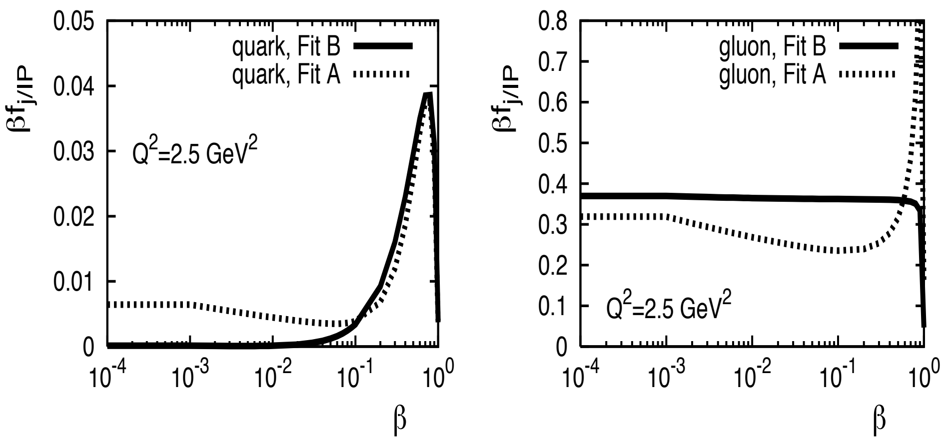
For fixed $x_{I\!P}, \ t$ universal fracture pdf + the evolution is the same as for normal pdf's

*Theorem is violated in dipole model of γ*N diffraction in several ways*

HERA: Good consistency between H1 and ZEUS three sets of measurements

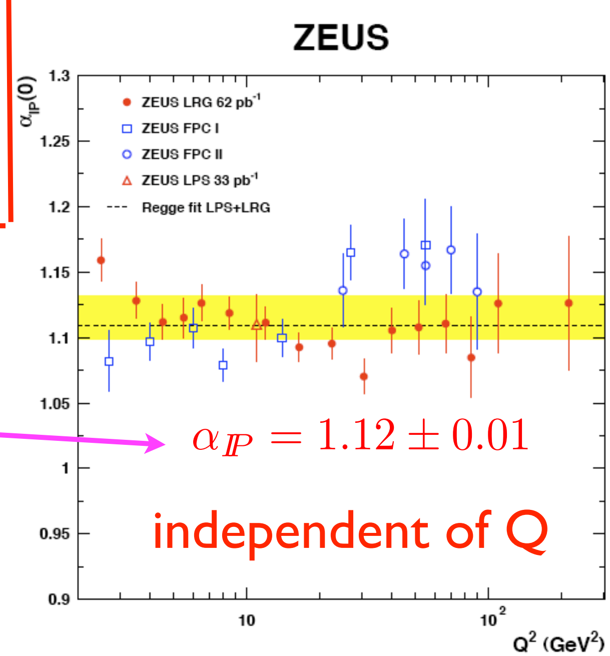
- ☞ *Measurements of $F_2^{D(4)}$*
- ☞ *Measurements of dijet production*
- ☞ *Diffractive charm production*

DGLAP describes totality of the data well several crosschecks - Collins factorization theorem valid for discussed Q^2,x range



gluon dPDF >> quark dPDF

The quark and gluon diffractive PDFs at Q^2 =2.5 GeV^2 as a function of β



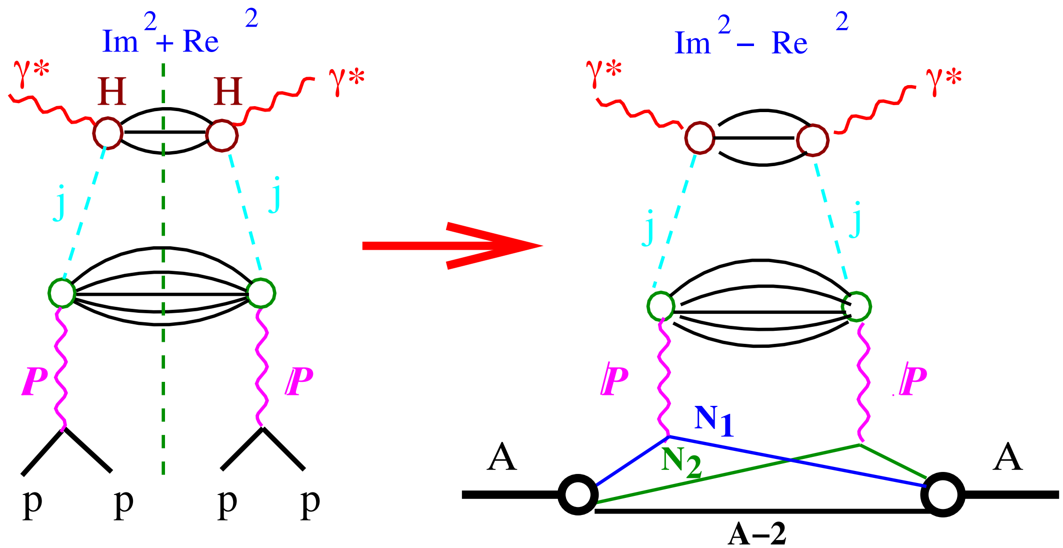
Current fits to soft hadron - hadron interactions find $\alpha_{IP}(0)$=1.09 - 1.10

☛Diffraction at HERA is mostly due to the interaction of hadron size components of γ^* not small dipoles. Confirms QCD aligned jet logic for x > 10^{-4}

Theoretical expectations for shadowing in the LT limit

Combining Gribov theory of shadowing and pQCD factorization theorem for diffraction in DIS allows to calculate LT shadowing for all parton densities (FS98) (instead of calculating F_{2A} only)

Theorem: In the low thickness limit the leading twist nuclear shadowing is unambiguously expressed through the nucleon diffractive parton densities $f_j^D(\frac{x}{x_{I\!P}}, Q^2, x_{I\!P}, t)$:



Hard diffraction
off parton "j"

Leading twist contribution
to the nuclear shadowing for
structure function $f_j(x,Q^2)$

Theorem: in the low thickness limit (or for x>0.005)

$$\mathrm{f}_{j/A}(x,Q^2)/A = f_{j/N}(x,Q^2) - \frac{1}{2+2\eta^2}\int d^2b \int_{-\infty}^{\infty} dz_1 \int_{z_1}^{\infty} dz_2 \int_x^{x_0} dx_{I\!P} \cdot$$

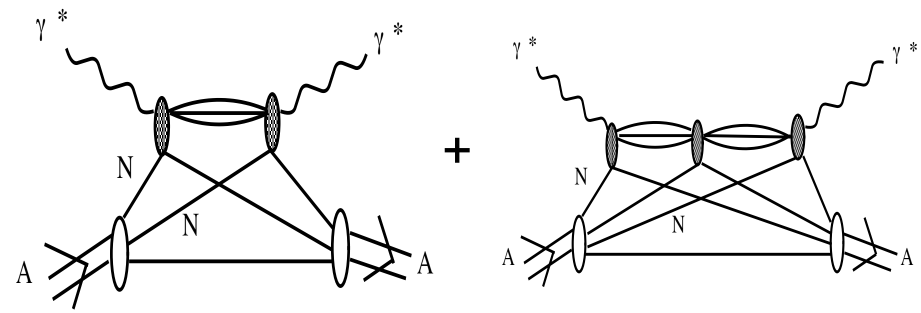
$$\cdot f_{j/N}^D\left(\beta,Q^2,x_{I\!P},t\right)\Big|_{k_t^2=0}\ \rho_A(b,z_1)\ \rho_A(b,z_2)\mathrm{Re}\left[(1-i\eta)^2\exp(ix_{I\!P}m_N(z_1-z_2))\right],$$

where $f_{j/A}(x,Q^2), f_{j/N}(x,Q^2)$ are nucleus(nucleon) pdf's,

$\eta = ReA^{diff}/ImA^{diff} \approx 0.174,\ \rho_A(r)$ nuclear matter density.

$x_0(quarks) \sim 0.1,\ x_0(gluons) \sim 0.03$

Including higher order terms



+ ....

Color fluctuation approximation: Amplitude to interact with j nucleons $\sim\sigma^j$

$$
\begin{aligned}
xf_{j/A}(x,Q^2) &= \frac{xf_{j/N}(x,Q^2)}{\langle\sigma\rangle_j} 2\,\Re e \int d^2b \left\langle \left(1 - e^{-\frac{A}{2}(1-i\eta)\sigma T_A(b)}\right)\right\rangle_j \\
&= Axf_{j/N}(x,Q^2) - xf_{j/N}(x,Q^2)\frac{A^2\langle\sigma^2\rangle_j}{4\langle\sigma\rangle_j}\Re e(1-i\eta)^2 \int d^2b\, T_A^2(b) \\
&- xf_{j/N}(x,Q^2) 2\Re e \int d^2b \frac{\sum_{k=3}^{\infty}(-\frac{A}{2}(1-i\eta)T_A(b))^k \langle\sigma^k\rangle_j}{k!\,\langle\sigma\rangle_j},
\end{aligned}
$$

does not depend on f_j

$\langle \cdots \rangle_j$ integral over σ with weight $P_j(\sigma)$ - probability for the probe to be in configuration which interacts with cross section σ;

$$\langle \sigma^k \rangle_j = \int_0^\infty d\sigma P_j(\sigma)\sigma^k$$

For intermediate x one needs also to keep finite coherence length factor $e^{i(z_1 - xz_2)m_N x_{I\!P}}$

Fluctuations with small σ are significant only for $<\sigma>$, $<\sigma^2>$

$<\sigma^k>$ for k> 2 dominated by soft fluctuations. $\alpha_{IP}(0)=1.1$ - proof that soft dynamics dominates already for $<\sigma^2>$

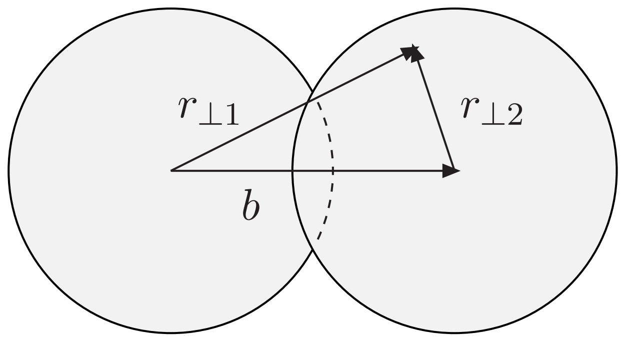
$<\sigma^k>/<\sigma^2>$ can be modeled based on soft physics - effects of dispersion in this case known to be small (we did a numerical study for our case where these effects are larger due to presence of small configurations).

Fluctuation approximation for Q_0^2:

$$x f_{j/A}(x,Q^2) = A x f_{j/N}(x,Q^2)$$
$$- x f_{j/N}(x,Q^2) 8\pi A(A-1)\,\Re e \frac{(1-i\eta)^2}{1+\eta^2} B_{\rm diff} \int\limits_x^{0.1} dx_{I\!P} \beta f_j^{D(3)}(\beta,Q^2,x_{I\!P})$$
$$\times \int d^2b \int\limits_{-\infty}^{\infty} dz_1 \int\limits_{z_1}^{\infty} dz_2 \rho_A(\vec{b},z_1)\rho_A(\vec{b},z_2) e^{i(z_1-z_2)x_{I\!P}m_N} e^{-\frac{A}{2}(1-i\eta)\sigma_{\rm soft}(x,Q^2)\int_{z_1}^{z_2} dz' \rho_A(\vec{b},z')}$$

where $\sigma_{soft}(x,Q_0^2) \equiv \left\langle \sigma^3 \right\rangle_j / \left\langle \sigma^2 \right\rangle_j$ is the only parameter (weakly dependent on x) which can be estimated semiquantitatively.

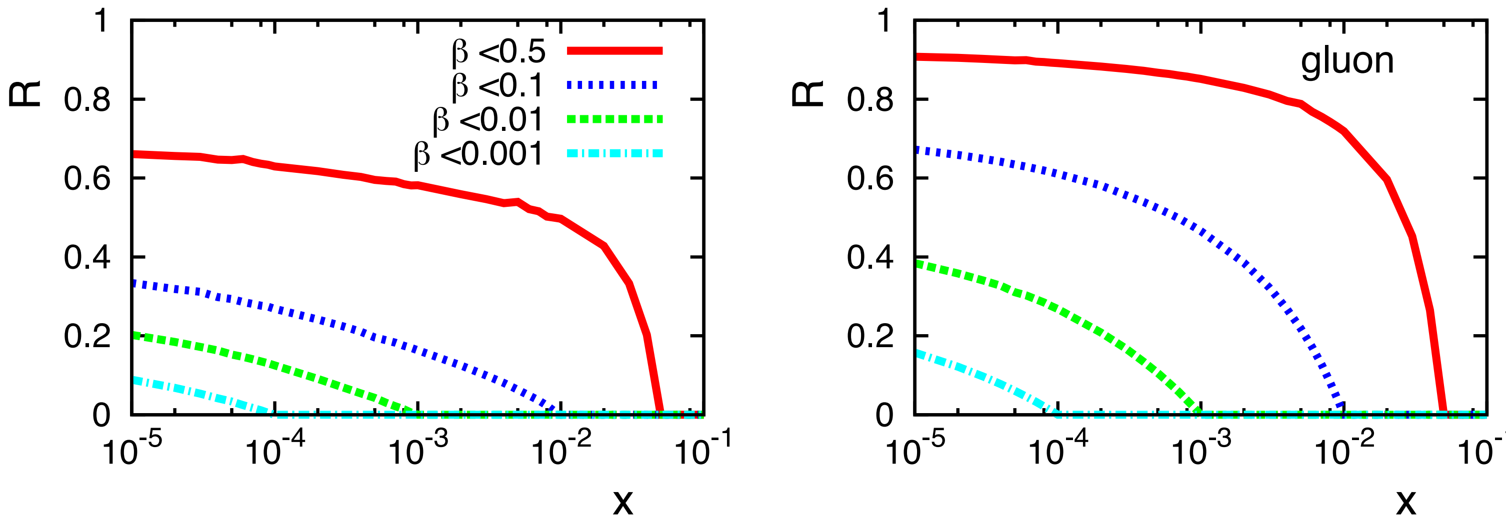
Key element of the logic - nucleus is a system of color singlet clusters - nucleons which are weakly deformed in nuclei - checked by success of the Gribov-Glauber theory of soft hA interactions - σ_{tot} (hA) to few %.



. Geometry of the parton overlap in the transverse plane.

A transverse slice of the wave function of a heavy nucleus for x ~ 5×10^{-3} looks like a system of colorless (white) clusters with some clusters (~ 30%) built of two rather than of one nucleon, with a gradual increase of the number of two-nucleon, three-nucleon, etc. clusters with decreasing x.

In our derivations, the global and local color neutrality are satisfied at every step. This is very different from the approaches where the nucleus is initially built from free quarks and one tries to implement the color neutrality at a later stage.

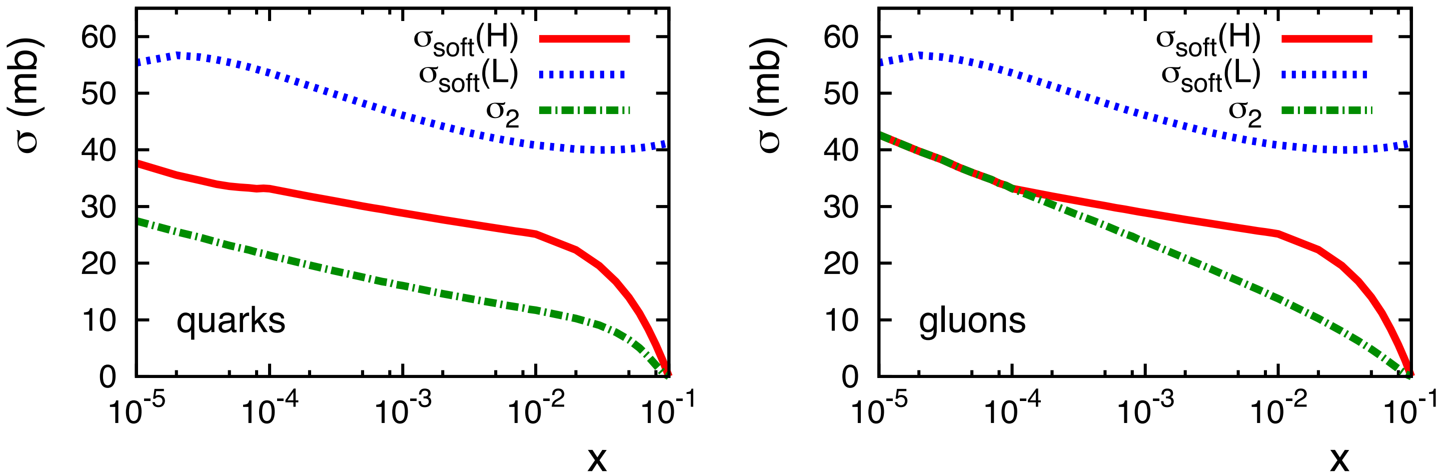


Contributions of different $\beta = Q^2/(Q^2+M^2)$ to shadowing. $M^2 \sim Q^2$ dominate in a wide x range

Confer: BFKL for $\mathbb{P}\mathbb{P}\mathbb{P}$ requires large rapidity interval for diffraction $\ln(1/\beta) > 3 \div 4$

Also $\alpha_{\mathbb{P}} = 1.3 \div 1.5$ rather than $\alpha_{\mathbb{P}} = 1.11$

Balitski - Kovchegov eq. - even higher energies



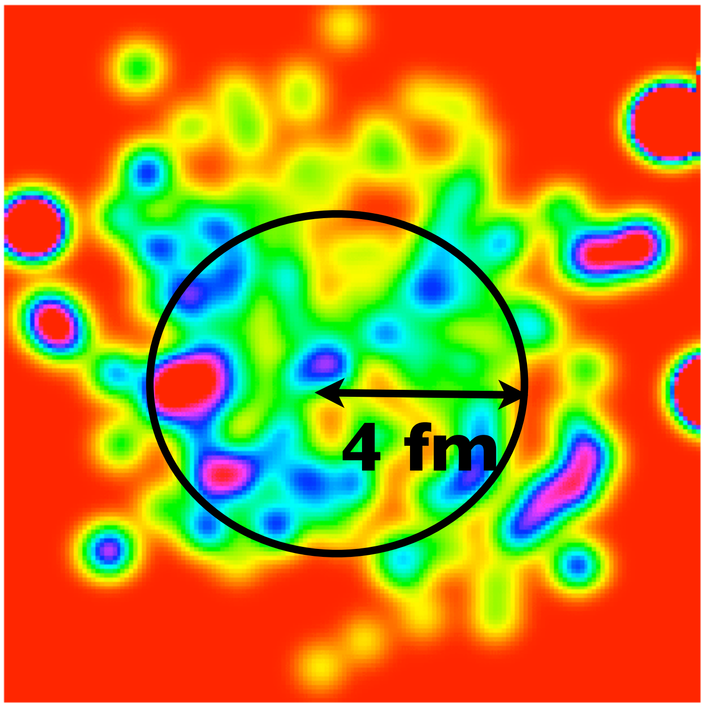
The cross sections $\sigma^{j(H)}_{(soft)}$, $\sigma^{j(L)}_{(soft)}$, and $\sigma^{j}_{2}(x,Q^2)$ as functions of Bjorken x at fixed Q^2_0= 4 GeV^2. The left panel corresponds to the ū-quark; the right panel corresponds to gluons.

The cross sections $$\sigma_{soft}(x,Q_0^2) \equiv \sigma_3 \equiv \left\langle \sigma^3 \right\rangle_j / \left\langle \sigma^2 \right\rangle_j$$

and $$\sigma_2 \equiv \left\langle \sigma^2 \right\rangle_j / \left\langle \sigma \right\rangle_j$$

Note that the strength of interaction is large but thickness of the realistic nuclei is pretty low. So number of interactions is rather small and fluctuations are large

Fluctuations of gluon density in lead on event by event basis (Alvioli and MS 09)



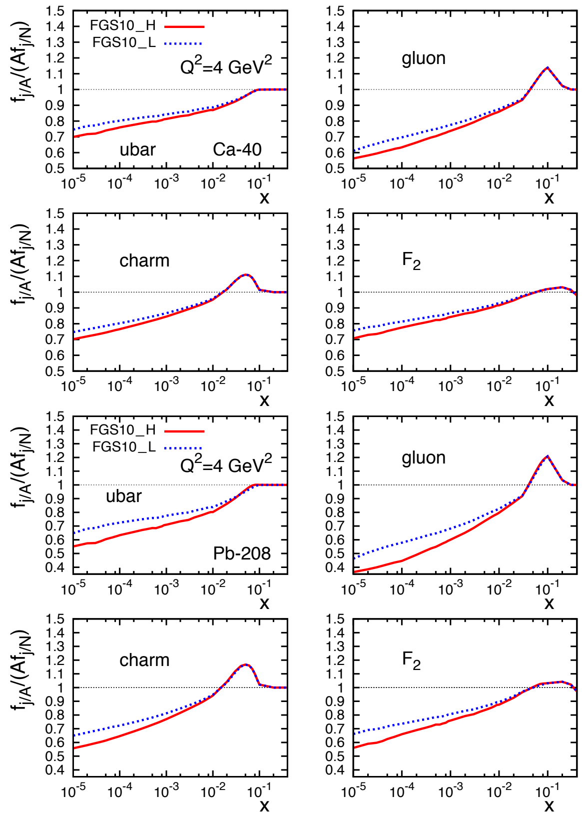
yellow < 1
1 green <2
2 <cyan < 3
3 <blue <4
4< magenta < 5
5< red

Heavy nuclei are not large enough to suppress fluctuations - A=200 nucleus for gluons is like a *thin slice of Swiss cheese*.

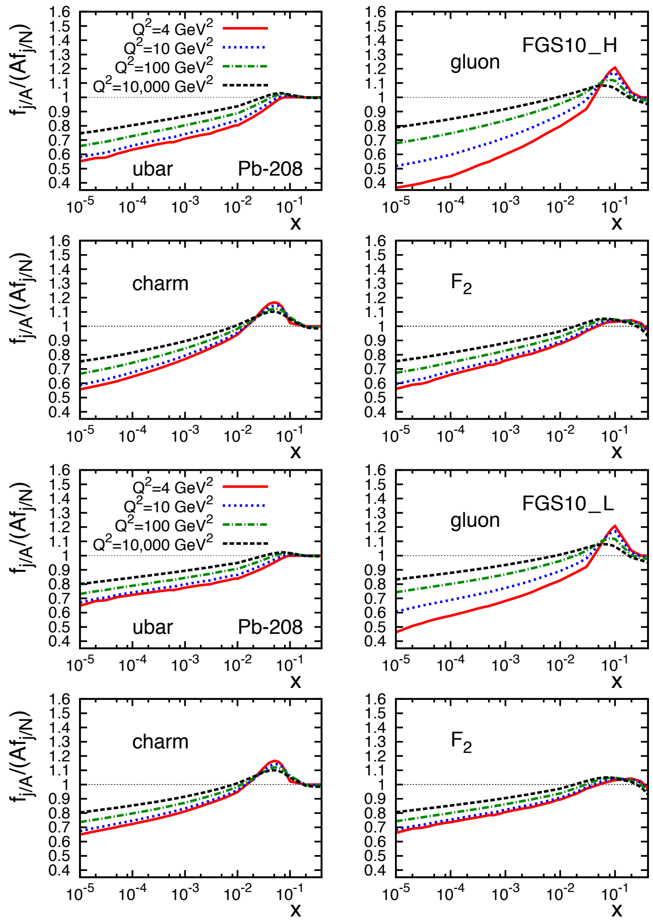
Far from the A $\rightarrow\infty$ limit.

Numerical studies impose antishadowing to satisfy the sum rules for baryon charge and momentum (LF + MS + Liuti 90) - sensitivity to model of fluctuations is weak. At the moment uncertainty from HERA measurements is comparable.

NLO pdfs - as diffractive pdfs are NLO



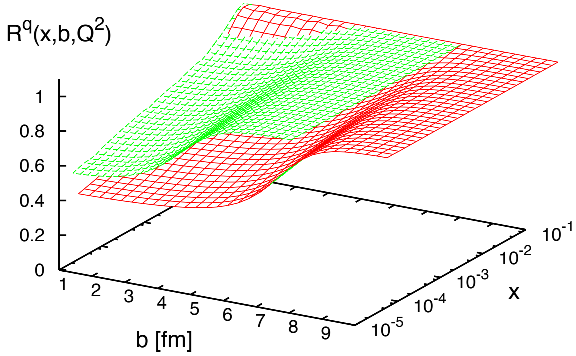
Predictions for nuclear shadowing at the input scale $Q_0^2 = 4$ GeV^2. The ratios R_j ($\bar{u}$ and c quarks and gluons) and R_{F_2} as functions of Bjorken x at $Q^2 = 4$. The four upper panels are for ^{40}Ca; the four lower panels are for ^{208}Pb. Two sets of curves correspond to models FGS10_H and FGS10_L

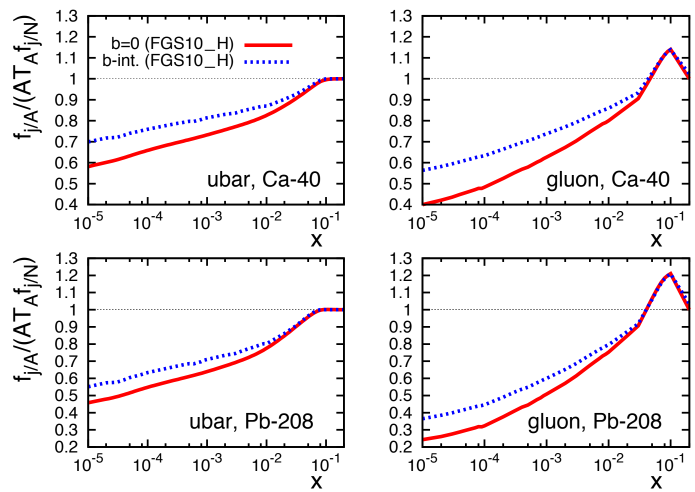


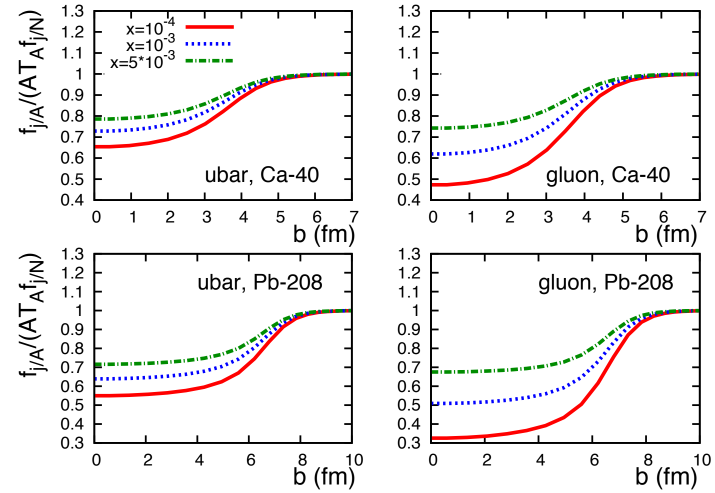
Prediction for nuclear PDFs and structure functions for ^{208}Pb. The ratios R_j ($\bar{u}$ and c quarks and gluons) and R_{F_2} as functions of Bjorken x at $Q^2 = 4$, 10, 100 and 10,000 GeV^2. The four upper panels correspond to FGS10_H; the four lower panels correspond to FGS10_L.

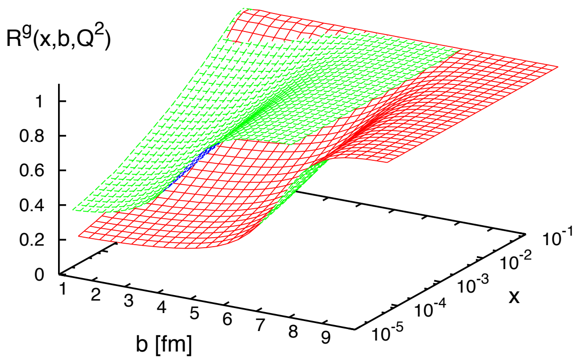
Nuclear diagonal generalized parton distributions.

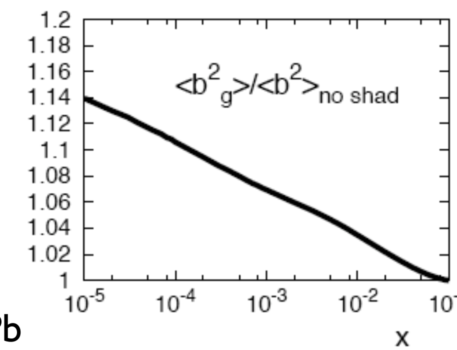
Shadowing strongly depends on the impact parameter, b, - one can formally introduce nuclear diagonal generalized parton distributions. In LT theory - one just needs to remove integral over b.





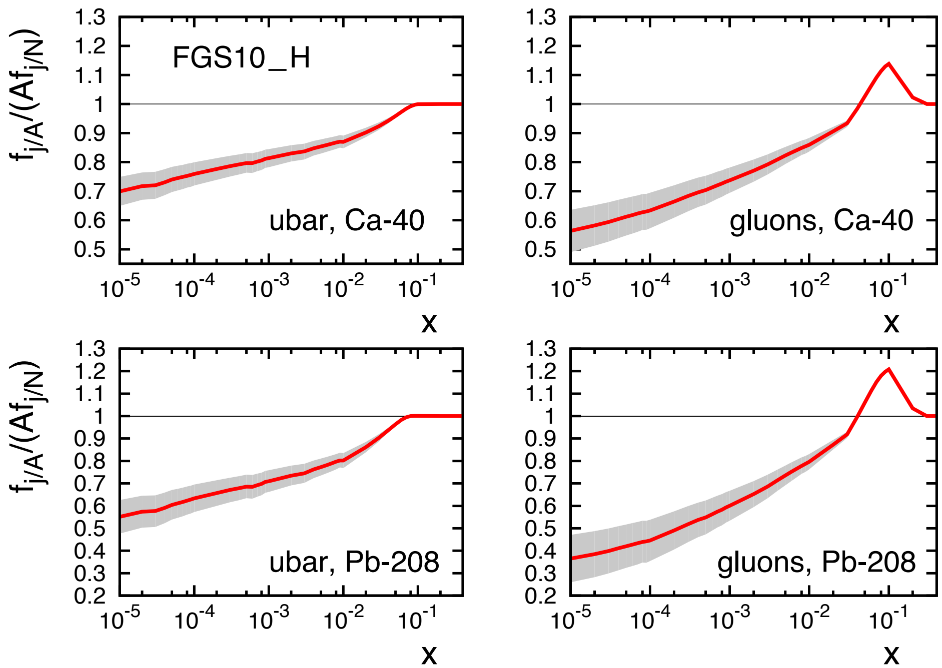






Impact parameter dependence of nuclear shadowing for ^{40}Ca (upper green surfaces) and ^{208}Pb (lower red surfaces). The graphs show the ratio $R_j(x,b,Q^2)$ as a function of x and the impact parameter |b| at $Q^2 = 4$ GeV^2. The top panel corresponds to $\bar{u}$-quarks; the bottom panel corresponds to gluons. For the evaluation of nuclear shadowing, model FGS10 H was used.

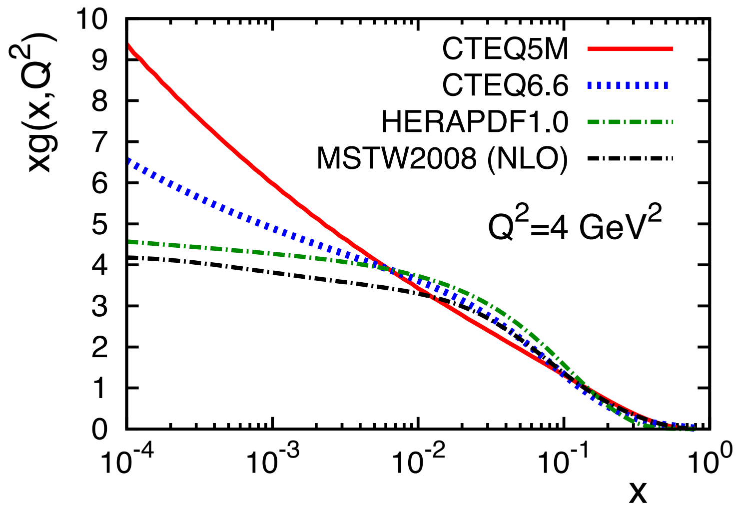
Numerical uncertainties due to diffractive and pdf inputs.

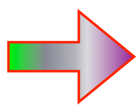


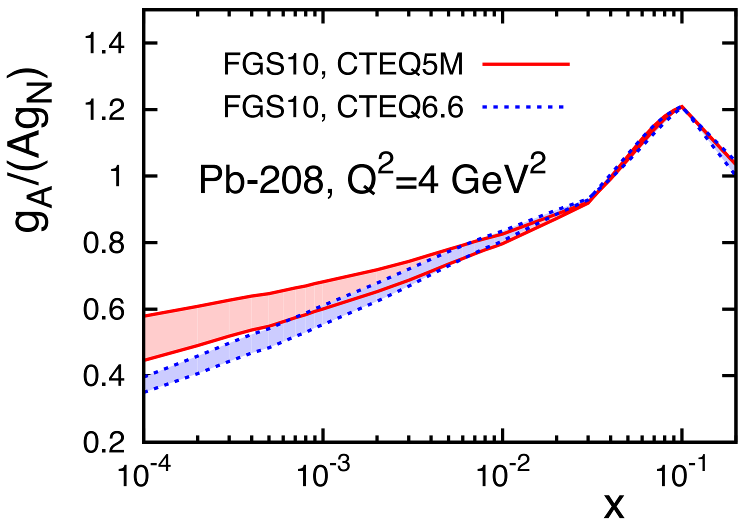
Nuclear PDFs calculated with our standard choice B_{diff} = 6 GeV^{-2} (solid curves) and with B_{diff} = 5 GeV^{-2} and B_{diff} = 7 GeV^{-2} that correspond to the upper and lower boundaries of the shaded areas, respectively. All curves correspond to model FGS10 H and Q^2_0 = 4 GeV^2.

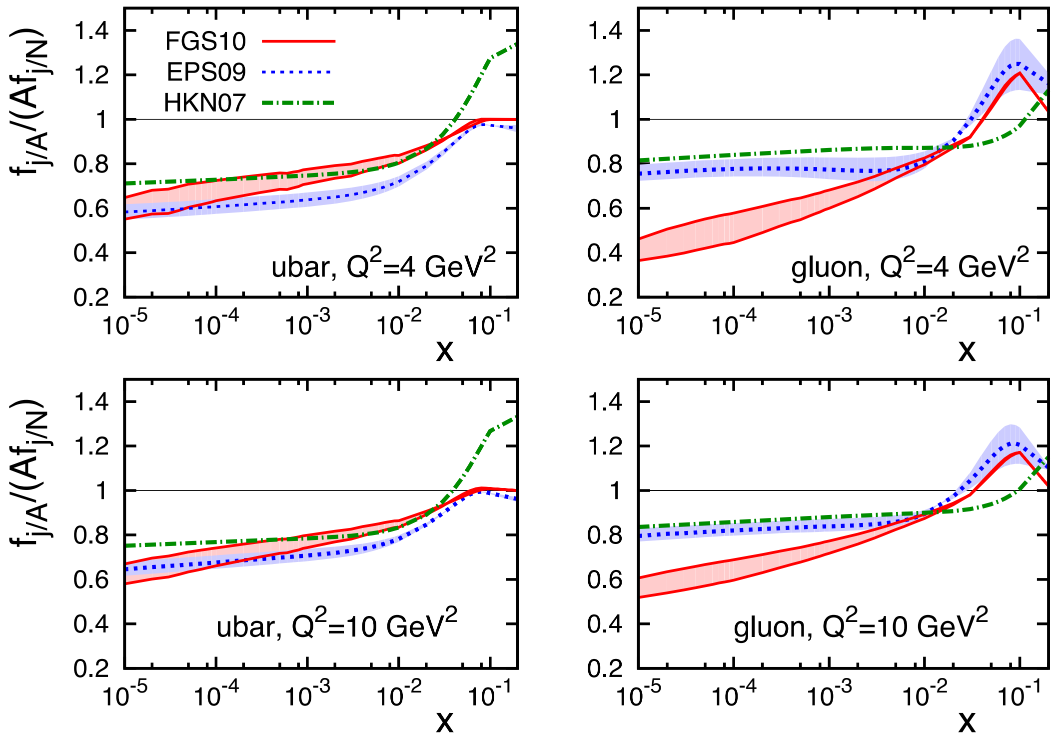
Nucleon pdf uncertainty - gluons at $x \sim 10^{-4}$ and Q^2=4 GeV^2

corresponding uncertainty for (anti)quarks at $x \sim 10^{-4}$ is negligible









Comparison of predictions of the leading twist theory of nuclear shadowing [the area bound by the two solid curves corresponding to models FGS10 H (lower boundary) and FGS10 L (upper boundary)], the EPS09 fit (dotted curves and the corresponding shaded error bands), and the HKN07 fit (dot-dashed curves). The NLO $f_{j/A}(x, Q^2)/[Af_{j/N}(x, Q^2)]$ ratios for the $\bar{u}$-quark and gluon distributions in ^{208}Pb are plotted as functions of x at Q^2 = 4 GeV^2 (upper panels) and Q^2 = 10 GeV^2 (lower panels).

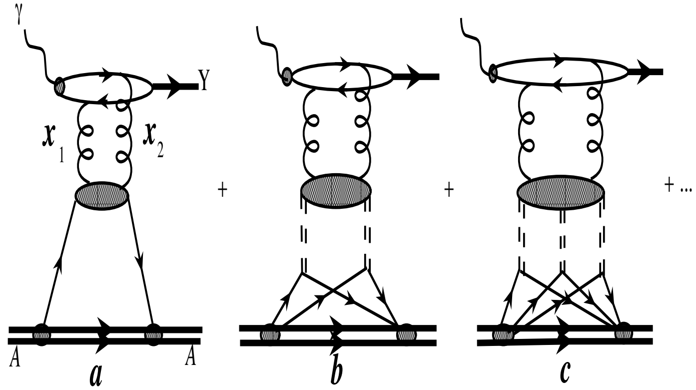
Examples of other nuclear shadowing phenomena

Exclusive vector meson production in DIS (onium in photoproduction)

The leading twist prediction (neglecting small t dependence of shadowing)

$$\sigma_{\gamma A\to VA}(s) = \frac{d\sigma_{\gamma N\to VN}(s,t_{min})}{dt}\left[\frac{G_A(x_1,x_2,Q^2_{eff},t=0)}{AG_N(x_x,x_2,Q^2_{eff},t=0)}\right]^2 \int\limits_{-\infty}^{t_{min}} dt \left|\int d^2b dz e^{i\vec{q}_t\cdot\vec{b}} e^{iq_l z}\rho(\vec{b},z)\right|^2.$$

$$where\ x = x_1 - x_2 = m_V^2/W_{\gamma N}^2$$



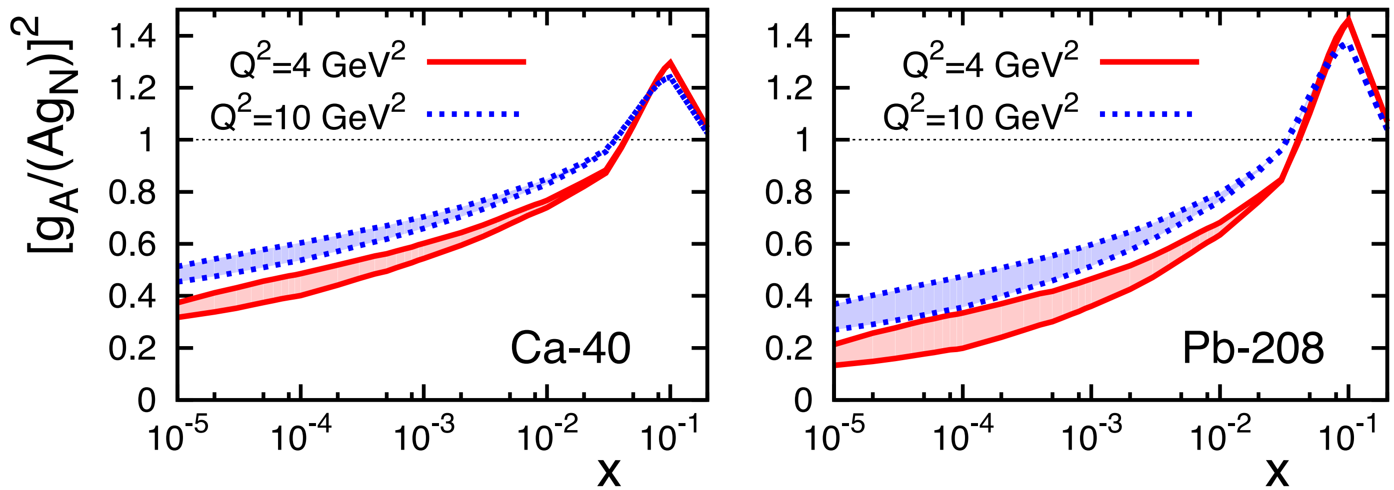
High energy quarkonium photoproduction in the leading twist approximation.

for small sizes dipoles - LT leads to much larger screening than eikonal. Compete for moderate Q^2 & M_{VM}

$$\Downarrow$$

$$\frac{G_A(x_1,x_2,Q^2_{eff},t=0)}{G_N(x_1,x_2,Q^2_{eff},t=0)} \approx \frac{G_A((x_1+x_2)/2,Q^2_{eff},t=0)}{G_N((x_1+x_2)/2,Q^2_{eff},t=0)}$$

$$\frac{(x_1+x_2)_{J/\psi}}{2} \approx x;\quad \frac{(x_1+x_2)_{\Upsilon}}{2} \approx x/2$$



The shaded bands reflect the theoretical uncertainty of our predictions.

factor > 2 shadowing effects for J/ψ for x< 10^{-2}
& for Υ for x< 10^{-4}

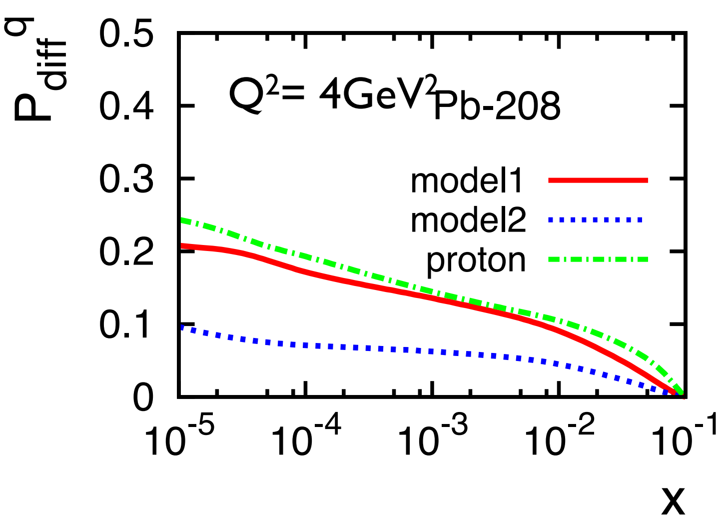
Warning: Nondiagonal effects require further studies

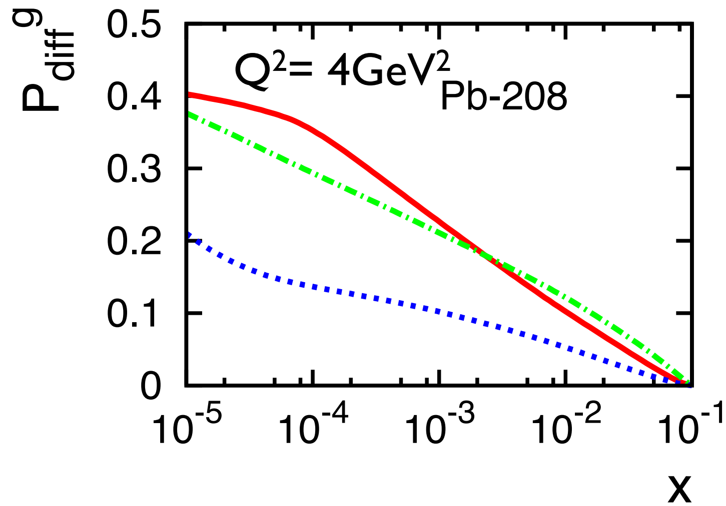
Nuclear Diffractive parton densities

Hard diffraction off nuclei: test of understanding of dynamics, importance of fluctuations, proximity to black disk limit, practical applications for ultraperipheral pA collisions

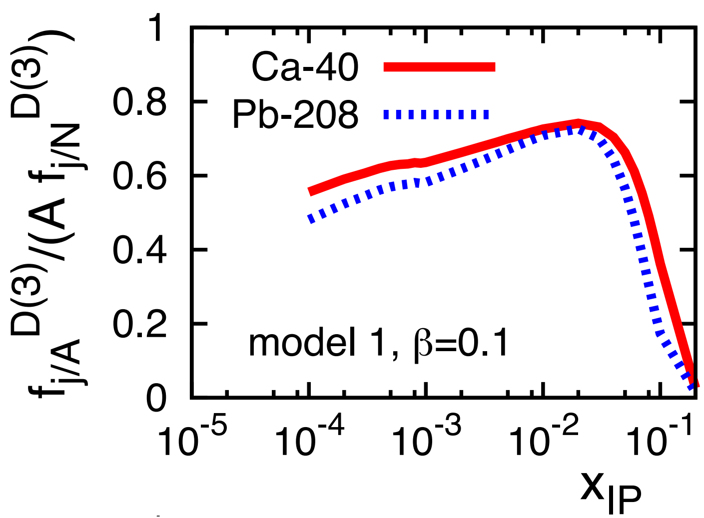
Nuclear diffractive pdfs were calculated by Guzey et al 03 in the same approximations as LT nuclear pdf's (quasieikonal) and recently in the fluctuation approximation (no model necessary for double rescattering). Difference between QE and fluctuation is the same as in inclusive case

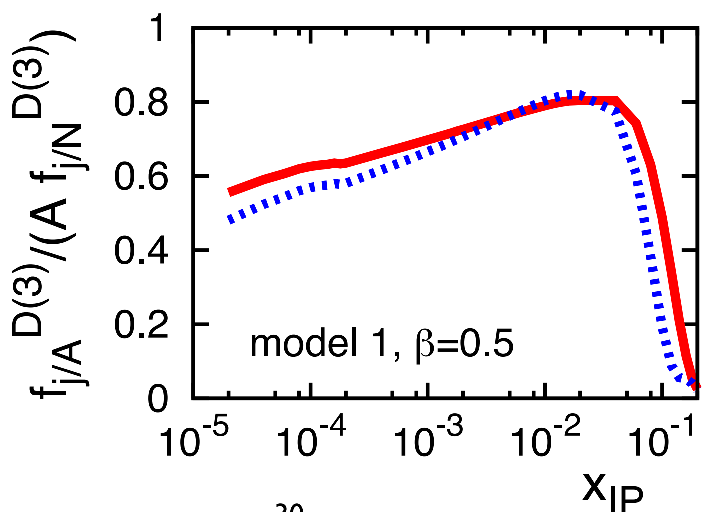
$$f_{j/A}^{D(3)}(x, Q_0^2, x_{\mathbb{P}}) = \frac{A^2}{4} 16\pi f_{j/N}^{D(4)}(x, Q_0^2, x_{\mathbb{P}}, t_{\min}) \times \int d^2b \left| \int_{-\infty}^{\infty} dz \exp\{i x_{\mathbb{P}} m_N z\} \exp\left\{\sigma_{\text{soft}}^{j} \frac{A}{2}(1 - i\eta) \int_z^{\infty} dz' \rho_A(b, z')\right\} \rho_A(b, z)\right|^2 .$$





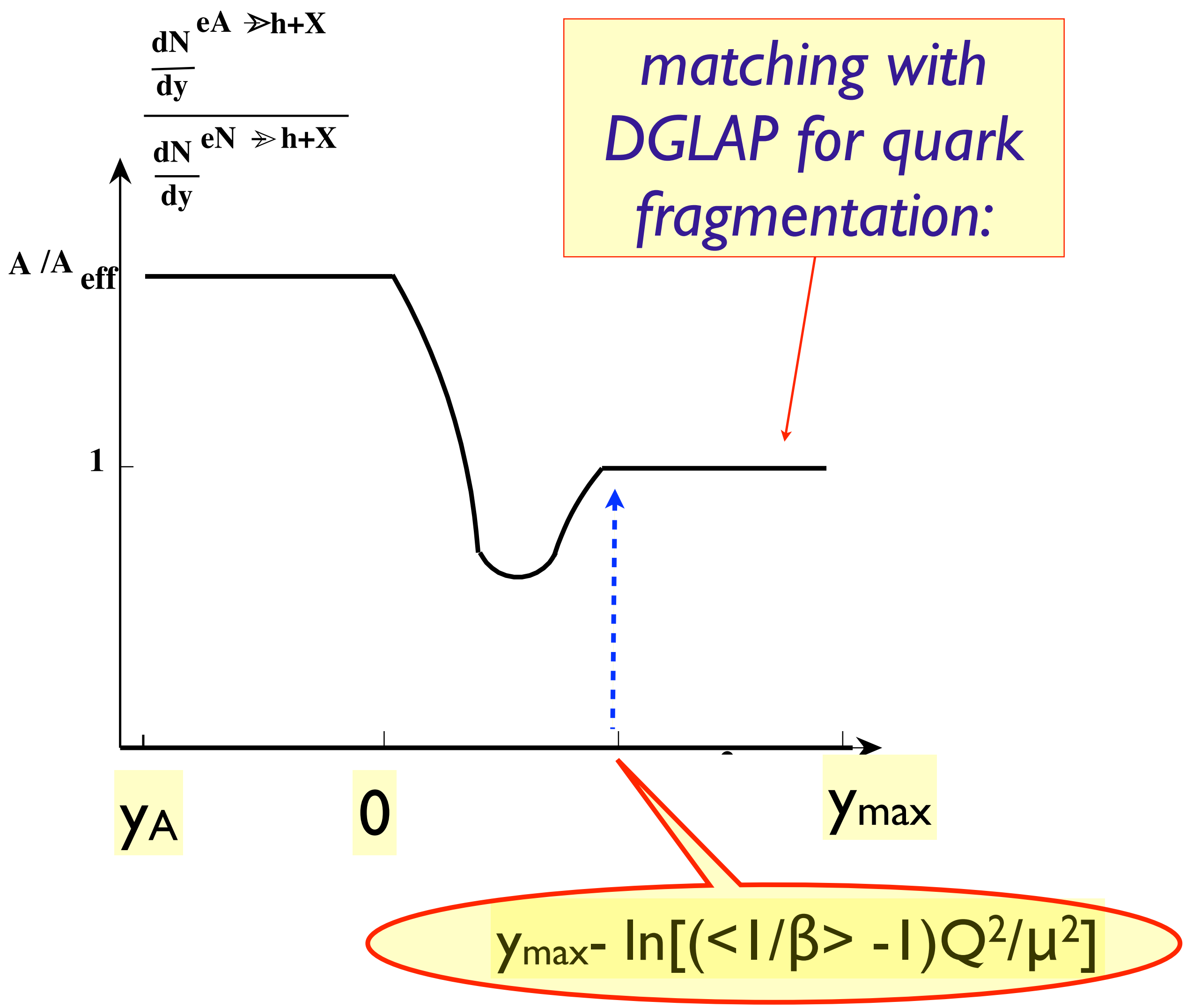
Much larger sensitivity to higher order effects - color fluctuations - large diffraction up to very large Q - will be possible to check soon in ultraperipheral AA collisions at the LHC





$x_{I\!P}, \beta$ dependences are also calculated

Final non-diffractive states: DGLAP

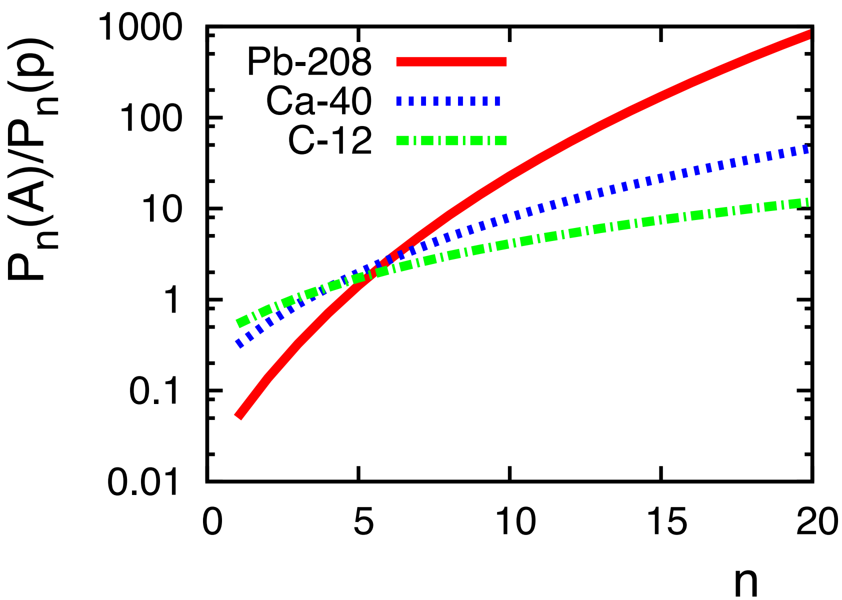


Distribution over multiplicity at central rapidities - very sensitive to presence of interactions with many nucleons.

$$p_j \equiv \frac{\sigma_j}{\sigma^{hA,\mathrm{inel}}_{\mathrm{summed}}} = \frac{\frac{A!}{(A-j)!j!}\int d^2b\,[x(b)]^j[1-x(b)]^{A-j}}{\int d^2b\,[1-(1-x(b))^A]}$$

the probability of the interaction with j nucleons

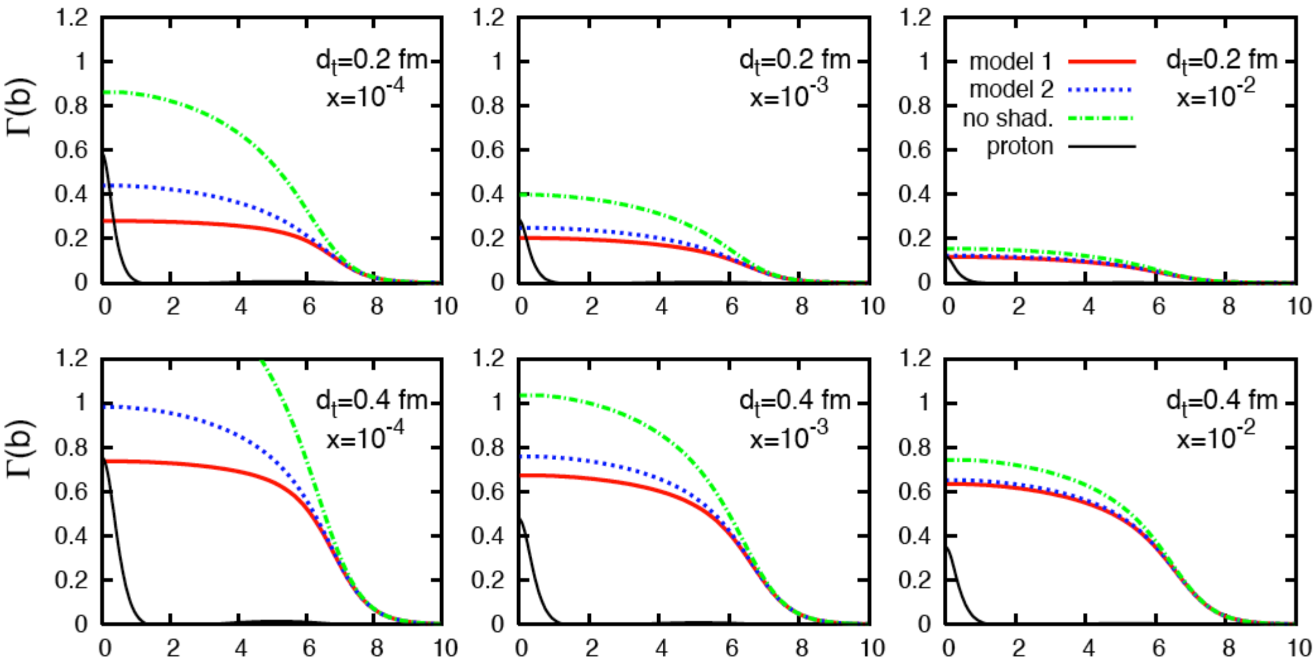
$$x(b) = \sigma_X^{\mathrm{inel}} T_A(b)$$



The A dependence of multiplicity distributions. The ratio of the nucleus to proton probabilities P_n^A/P_n as a function of the number of the produced particles n for the fixed pseudorapidity interval $1 \le \eta^* \le 2$, $Q^2 = 4$ GeV^2 and $x \sim 10^{-3}$.

Where DGLAP approximation breaks & non-linear(black disk?) regime (BDR) of strong absorption for configurations for small size configurations sets in. Note in the preQCD logic (Gribov 68) BDR for all configurations with $M^2/s < 1/2R_A m_N$.

Impact factor Γ(b) for quark - antiquark dipole p and dipole -Pb scattering



Update of Rogers et al 03

$$p_t \approx \frac{\pi}{2d}$$

$$p_t \approx 1.5\, GeV/c$$

$$p_t \approx 0.75\, GeV/c$$

Probability of inelastic interaction is $P_{in} = |1-\Gamma(b)|^2 \rightarrow P_{in} = 3/4$ for $\Gamma(b)=1/2$

Gluon densities in nuclei and proton at b=0 are rather similar. Difference at <b> is ~30% larger

Expectation for EIC I

LT should give a reasonable description for $Q^2 \geq 3$ GeV^2

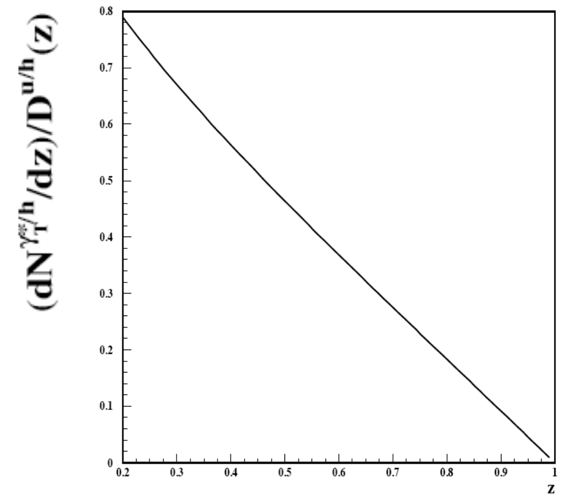
At lower Q^2 - significant HT effects are possible mostly due to the small mass diffractive contributions (ρ,ω,...) - but these effects would be accounted for in the Gribov - Glauber model for $\sigma_{\gamma^* A}$

Difficult to find a clean observable for onset of black disk regime. Our conclusion that the best tool is

Post selection effect in BDR - effective fractional energy losses

"Parton Propagation" for $p_t \leq p_t^{(BDR)}$

Gross scaling violation in BDR as compared to DGLAP -
can compare peripheral and central collisions and look for suppression



The total differential multiplicity normalized to the up quark fragmentation function as a function of z at Q^2=2 GeV^2.

Conclusions

☺ Theory provides essentially model independent predictions for LT shadowing effects in a wide range of x. LT is significant up to large virtualities for x<0.01.

☺ For small enough x and in a wide range of virtualities gluon shadowing remains larger than the quark shadowing.

☺ Future measurements of inclusive hard diffraction off nucleon at small t, nuclear shadowing and diffraction will provide stringent tests of the theory and allow to understand interplay of soft and hard dynamics.

☺ Transition from DGLAP region to black disk regime at $x \sim 10^{-4}$, $p_t \sim 1 \div 1.5$ GeV/c

☺ Post-selection leads to fractional energy losses in and near BDR

☺ RHIC data on forward pion production in dAu collisions are consistent with this scenario: strong suppression of the production at central impact parameters. No suppression of recoil jets for forward - central case.