The color dipole formalism

description of

- inclusive DIS: F_2, $F_2^{c\bar{c}}$, F_L
- inclusive diffraction: F_2^D, F_L^D
  diffract. $q\bar{q}$ state simple, $q\bar{q}g$ more complicated
- exclusive channels: DVCS, $J/\Psi, \Upsilon$, ρ, ϕ, ω

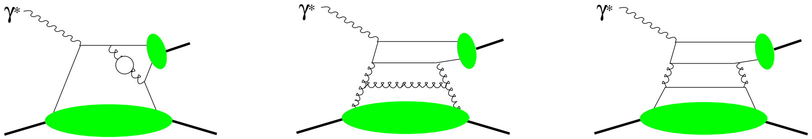
with same non-perturbative input: dipole scatt. amp. $N(x, r, b)$

but: formalism essentially at LO

- $\gamma^* \to q\bar{q}$, but not $\gamma^* \to q\bar{q}g$ in general
- x dependence of σ_{dip} in principle from theory (BFKL, BK, ...)
  in practice fitted to data
- appropriate energy variable of σ_{dip}: x_B, W^2, ...?
- skewness factor in dipole formalism?

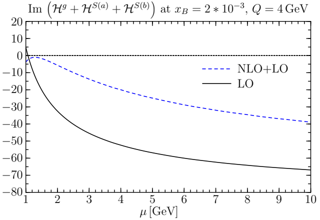
outstanding task: cast NLO BFKL into dipole form

Exclusive vector meson production



- all-order factorization proof J Collins, L Frankfurt, M Strikman '96
  in collinear (DGLAP) factorization framework

Exclusive vector meson production



amplitude at LO and NLO
$x_B = 2 \times 10^{-3}$
$Q^2 = 16\,\mathrm{GeV}^2$

- huge NLO corrections D Ivanov et al '04; MD and W Kugler '07
- large $\log 1/x$ terms in coefficient fct (much larger than for F_L)
- high-energy resummation seems to recover perturb. stability
  D Ivanov et al, in progress, using method of Catani, Hautman '94
  see http://gpd.gla.ac.uk/gpd2008/programme_full.php
- good description of data also in dipole formulation
  but no NLO evaluation available

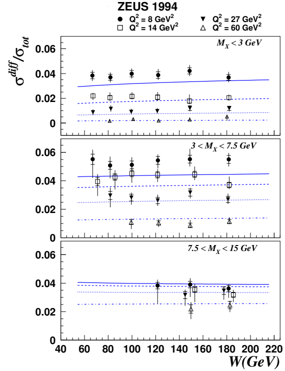
Evidence for saturation effects at HERA ?

- overall successful dipole models with and without saturation in σ_{dip} e.g. Forshaw, Sandapen, Shaw '06

  NB: at very low Q^2 become sensitive to non-perturb. effects in γ^* wave function $\to$ stronger model dependence

- saturation provides natural explanation why F_2^D/F_2 flat in x (at given Q^2, β)
- how to go further?
  - increased kinematic coverage? higher precision?
  - predict deviations from flat F_2^D/F_2?
  - full calculation for $q\bar{q}g$ final state?

K Golec-Biernat, M Wüsthoff '99 $\to$



Geometric scaling

- seen in wide kinematical range of HERA data
- naturally emerges in dipole formulation for deeply saturated regime $1/x \to \infty$ at fixed Q^2

  but also find approx. scaling from BFKL and DGLAP eqs. under certain conditions

  Iancu, Itakura, McLerran '02; Kwieciński, Staśto '02
  Avsar, Gustafson '07, Caola, Forte '08

  NB: even $\sigma_{\text{tot}} = \sigma_0 \, x^{-\lambda} \, Q^{2(1-\gamma)}$ satisfies geom. scaling
- if want to probe saturation then should restrict to x, Q^2 where expect nonlin. effects

  $\rightsquigarrow$ low Q^2 but at very low Q^2 uncertainties from γ^* wave fct.
- for precision should subtract charm contrib'n from F_2, which does not scale except if $Q^2 \to Q^2 + n m_c^2$ with $n \gtrsim 4$

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- if want to probe saturation need change in paradigm?
  (approx.) geometric scaling
  $\longrightarrow$ deviations from geometric scaling
  - should be different in linear and nonlinear regimes
    can theory quantify this sufficiently?
  - can HERA data distinguish?
    $\rightsquigarrow$ kinematic lever arm, precision of data