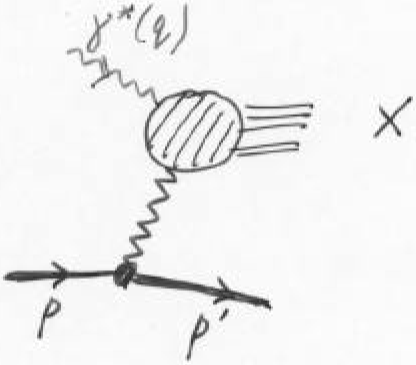
PHYSICS OF HARD DIFFRACTION

John Collins (Penn State)

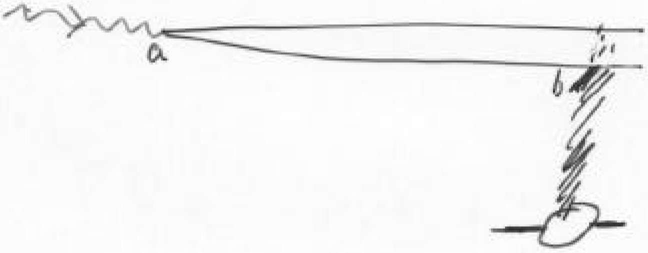
$\gamma^* p \longrightarrow X p$



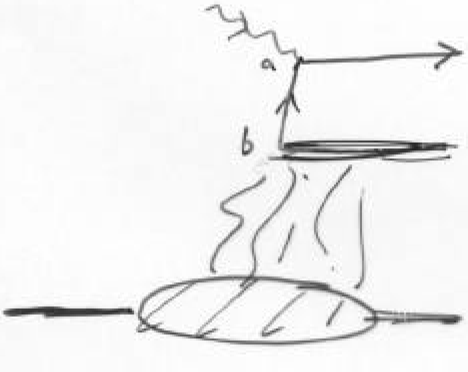
$x_{bj}, Q^2 \qquad x_{\mathbb{P}} \equiv \frac{p^+ - p'^+}{p^+},$

$\Rightarrow \beta \equiv x_{bj}/x_{\mathbb{P}}.$

2 views : 1. dipole/target rest frame



2. Conditional pdf



⊕ NLO...

$d\sigma = \int d\hat{\sigma} \times$ conditional pdf.

Issues:

- How compatible are the two views?
- How to translate?
- Advantages / disadvantages.
- Where does saturation show up?

Overview:

1. Pdf view — space-time
   — formulae
   — predictions

2. Dipole view — space-time & kinematics
   — diffraction
   — corrections?

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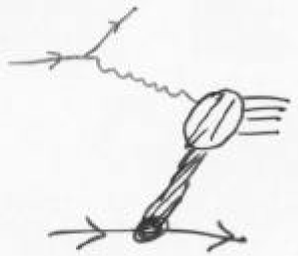
Breit frame

F. ex. $Q^2 = 20\,GeV^2$, $x_{I\!P} = 10^{-3}$, $\beta = 0.4$



] $M_x \simeq 5.5\,GeV$

L.O. hard sc. $\gamma^* q \to q$

In: $\;\gamma^*$ 2.2 GeV = Q/2 ← $\qquad$ p 5600 GeV ←

Out:

qk jet 2.2 GeV →

p′: 5600 − 5.6 GeV ← $\qquad$ $I\!P$ beam jet 3.4 GeV

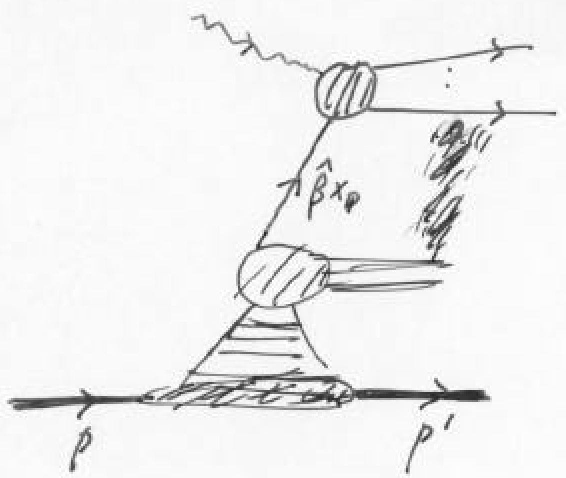
Distances 1. γ^*: $\frac{\hbar c}{Q} \simeq \frac{0.2}{4.5} \sim 0.04\,fm$.

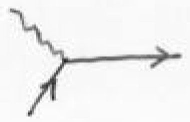
2. Struck qk up to boost × 1 fm

$= \frac{2.2}{0.3} \times 1\,fm \sim 7\,fm$

3. Proton boost × 1 fm ∼ 5000 fm.

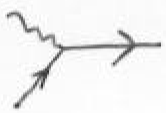
General structure of factorization



$\Big\} =$  + NLO + ...

$\Longrightarrow$ (non-trivial) $\quad d\sigma = \sum_i \int_\beta^1 d\hat{\beta} \quad d\hat{\sigma}_i \quad f_i(\hat{\beta}, \mu \sim Q, x_{I\!P}, t) + p\ell$

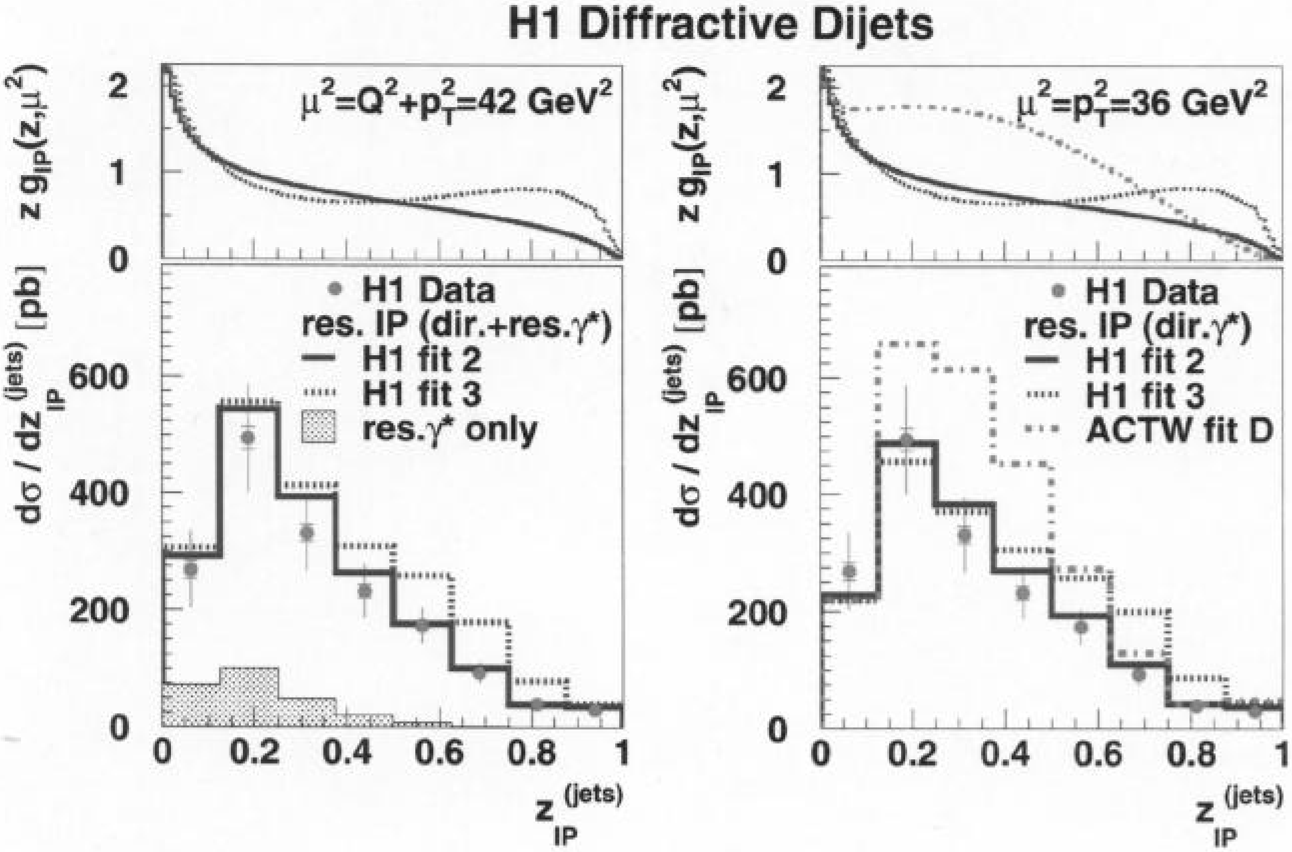
$$\frac{df}{d\ln\mu} = \text{DGLAP} \otimes f$$

$\hat{\sigma}(LO)$ from  $\quad (\hat{\beta} = \beta)$

$\hat{\sigma}(NLO)$ from  & c. with subtraction,

Fit conditional pdfs. Predict other hard diffractive cross sections

[H1 Collab., C. Adloff et al., Eur. Phys. J. C20 (2001) 29]



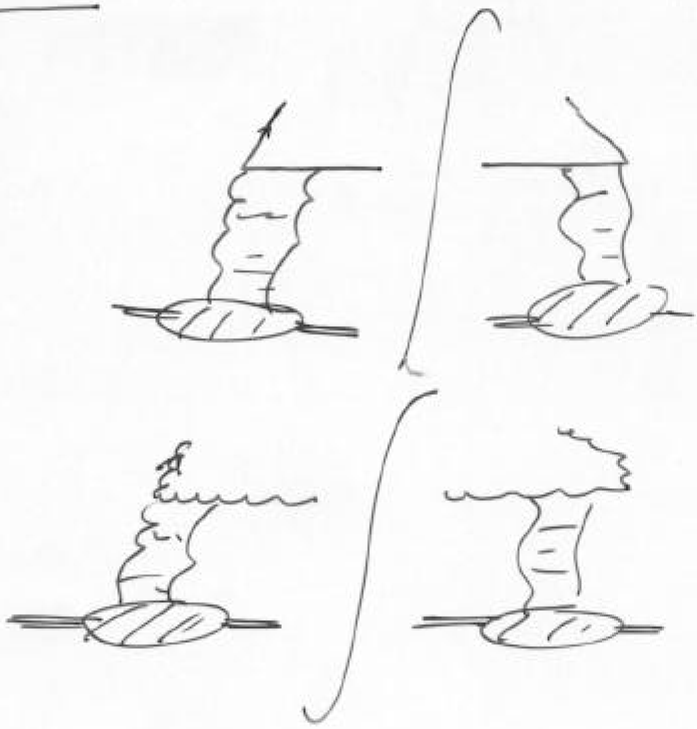
Fit conditional pdfs ~~to~~ diffractive DIS
(maybe diffractive photo production of jets)

Predict DDIS to jets.

Similarly predict DDIS to charm.

Sizes of pdfs

Simple model



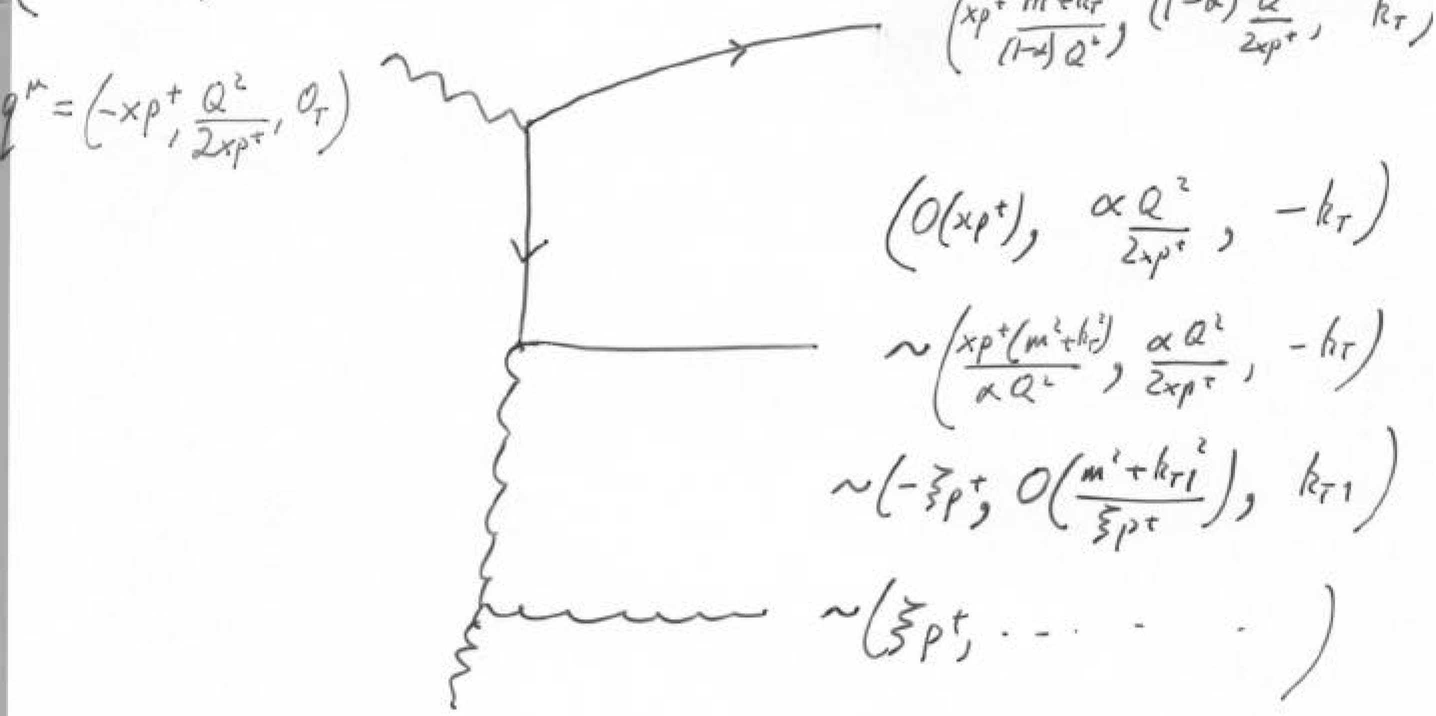
$\Rightarrow$ conditional (diffractive) gluon density larger than quark.

("Pomeron is like a glueball")

$\Rightarrow$ $\left.\begin{matrix} f_g \times \alpha_s \\ NLO \end{matrix}\right\}$ not small c.w. $\left\{\begin{matrix} f_q \\ LO \end{matrix}\right.$!

Target rest frame

$(t - T)$

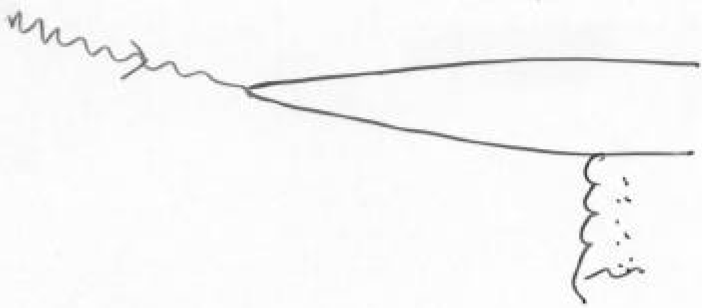


$p^+ = M/\sqrt{2}$; $E_{\gamma^*} \simeq 3\times 10^4\,\text{GeV}$ $\left(\begin{matrix} Q = 4.5\,\text{GeV} \\ x_P = 10^{-3}, \ \beta = 0.4 \end{matrix}\right)$

Lifetime $\sim \dfrac{k^-}{\text{virtuality}}$ (k^- large)

Transverse size $\sim 1/\sqrt{k_T^2 + m^2}$.

$\frac{1}{Q} \times \left(\frac{Q^2/xp^+}{Q}\right)$



$\longleftrightarrow$ $\frac{1}{xm}$ $\longleftrightarrow$ $\frac{1}{xm}$ $\leftrightarrow$ $\frac{1}{\xi m} \ll \frac{1}{xm}$ if strong ordering "in x"

Same conditions

$\frac{1}{xm} \sim$ few hundred fm

Highly boosted from γ^* frame $\frac{E_{\gamma^*}}{Q} = \frac{3 \times 10^4}{2 \cdot 2}$.

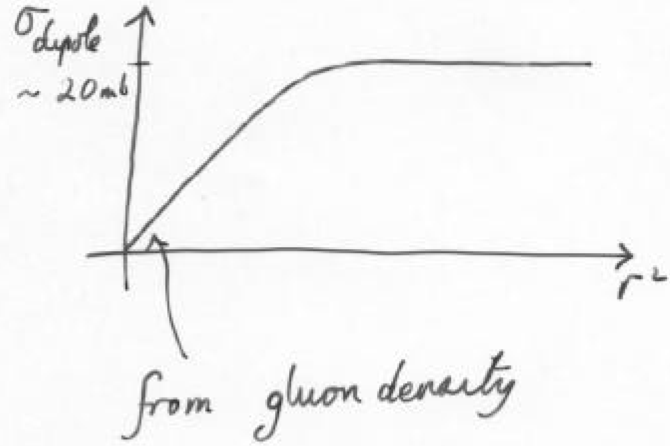
Same time for

low k_T	high k_T
large size	small size
to 1 fm	~~to~~ $1/Q$

Basic dipole phenomenology

Inclusive DIS

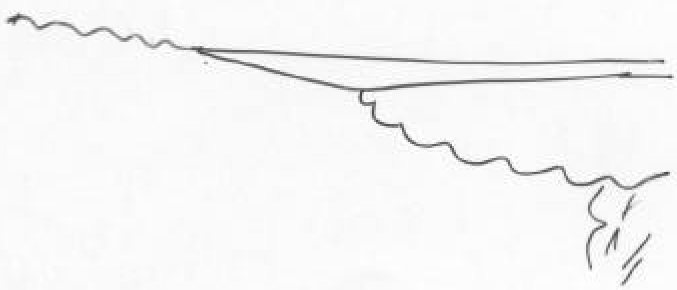
$$\sigma = \int d\alpha \int d^2 r \, \left| \psi_{q\bar{q} \leftrightarrow \gamma^*}(\alpha, r_T) \right|^2 \sigma_{tot,dipole}(r, x)$$



Will predict DDIS. (later)

Corrections to simple dipole

Evolution in k_T w/o strong "x-ordering"



$\Rightarrow$ octet dipole term.

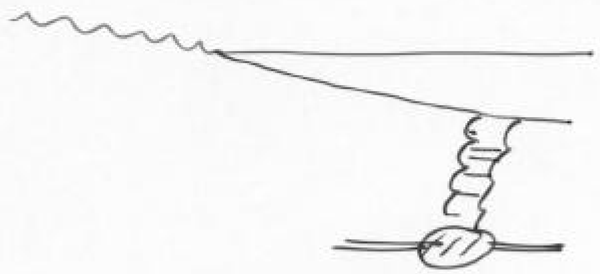
$\Rightarrow$? Systematics of combining terms? $\Leftarrow$

Pure $O(\alpha_s)$ correction w/o log enhancement

$\Rightarrow$ 3 body term, ...

(e.g. Bartels, Colferai, Gieseke & a

Diffraction & dipole model



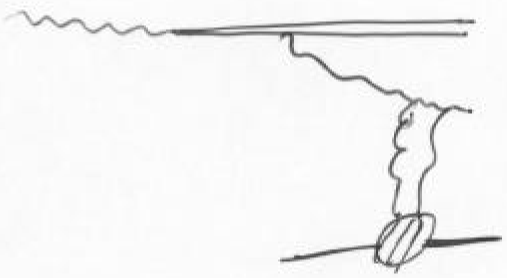
- Amplitude $= \int$ photon w.f. $\times$ $\mathcal{M}_{\text{elastic dipole}}(r)$

- Large k_T (small dipole) disfavored ("higher twist")

- Optical thm $\sigma_{tot} = \text{coeff} \times \text{disc}\, \mathcal{M}_{\text{forward}}$

$$\left.\frac{d\sigma_{diff}}{dt}\right|_{t=0} = \text{coeff} \times \int d\alpha \int d^2 r\, |\psi(\alpha, r)|^2\, \sigma_{\text{dipole, tot}}(r)$$

But substantial octet dipole term

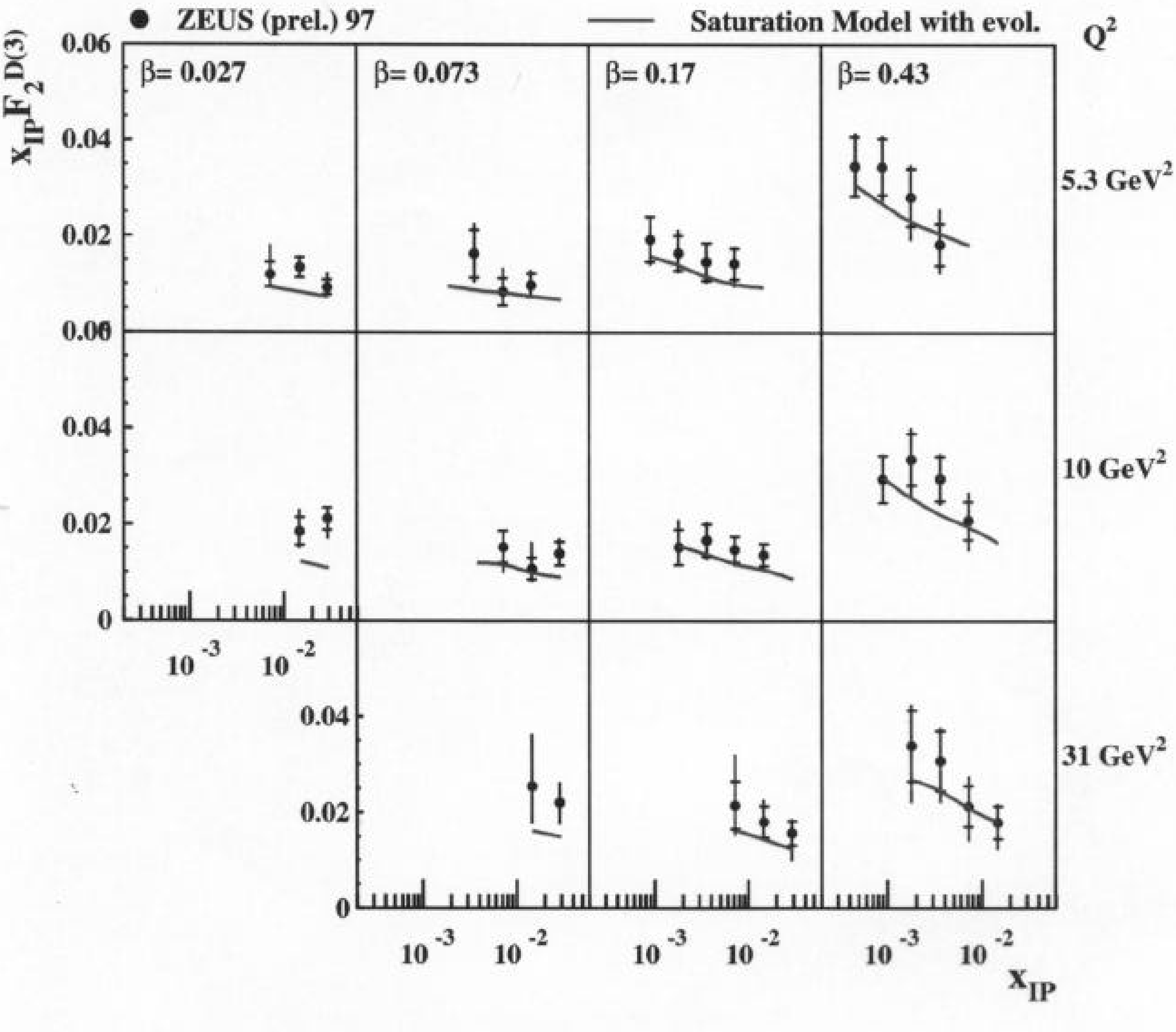


(Bartels, Golec-Biernat, Kowalski)

Use C_A instead of C_F in ladder-dipole coupling.

<u>Predict</u> diffractive D.I.S. from parameters fit elsewhere & pdfs & evolution
└ gluon, inclusive

[Bartels, Golec-Biernat, Kowalski, hep-ph/0203258 version 1]



Score card

Dipole

++ Connection: inclusive xsect. – diffractio
  – soft diffraction

\+ Unification of perturbative & non-perturba
physics

– Systematic corrections hard
[Definition of dipole xsect in itself?]

Should treat it as a model for pdfs
& conditional/diffractive pdfs

Pdf

-- Agnostic about non-perturbative physics

++ Systematic corrections — $\alpha_s(Q)$ expansio

\+ Can apply to many reactions (universality of pdfs).

\+ Explicit operator definition of pdfs.