QCD fits in diffractive DIS revisited

Federico Alberto Ceccopieri

Université de Liège

Belgium

International Workshop on Deep-Inelastic Scattering
and Related Subjects
26-30 March 2012, Bonn, Germany

Work in collaboration with L.Favart

Diffractive parton distributions

- Diffractive PDF's are essential ingredients for the description of hard diffractive processes
- DPDF's evolution is known (Trentadue, Veneziano '94)
- DPDF's factorization has been demonstrated in DDIS (Grazzini & al. '98, Collins '98)
- Once extracted from DDIS data they allow factorization tests in

- diffractive dijet production in DIS
- diffractive dijet photoproduction
- single and double diffractive hard processes in hadron-hadron collisions

- A more flexible and less model dependent pQCD-approach has been designed to exploit the improved quality of forthcoming data
- Results of a benchmark study on H1 LRG06 data (EPJ 2006)

Data and Observable

- Data set : H1 LRG06 (diffrative selection by large rapidity gap method)
- Kinematic variables

$$\beta = \frac{Q^2}{Q^2 + M_X^2}; \quad x_{I\!P} = \frac{x_B}{\beta}; \quad y = \frac{Q^2}{s x_B}$$

- Kinematic coverage @ $\sqrt{s}$=318 GeV :

$$3.5 \leq Q^2 \leq 1600 \text{ GeV}^2 \quad 3 \cdot 10^{-4} \leq x_{I\!P} \leq 3 \cdot 10^{-2} \quad 10^{-3} \leq \beta \leq 0.8$$

- Observable:

$$\sigma_r^{D(3)}(\beta, Q^2, x_{I\!P}) = F_2^{D(3)}(\beta, Q^2, x_{I\!P}) - \frac{y^2}{1 + (1-y)^2} F_L^{D(3)}(\beta, Q^2, x_{I\!P})$$

- Measuraments integrated over $|t| \leq 1$ GeV^2, $M_Y < 1.6$ GeV $\rightarrow$ DPDF's definition

Theory

- Evolution and convolution performed with $\mathrm{QCDNUM17}$ package (M.Botje 2011)
- Fixed Flavour Number Scheme with $n_f = 3$, evolution @NLL
- Heavy Quarks in G(eneral) M(assive) scheme: NLO massive coefficients from `HQSTFUN`
- Coupling @NLO : $\alpha_s^{(n_f=3)}(M_Z^2) = 0.107 \leftrightarrow \alpha_s^{(n_f=5)}(M_Z^2) = 0.118$
- $m_c = 1.4$ GeV, $m_b = 4.5$ GeV
- $\mu_F^2 = \mu_R^2 = Q^2$

The new method

- Widely used Regge-inspired approach + vertex factorisation:

$$F_i^D(\beta, Q^2, x_{I\!P}, t) = f_{I\!P/P}(x_{I\!P}, t)\; F_i^{I\!P}(\beta, Q^2) + f_{I\!R/P}(x_{I\!P}, t)\; F_i^{I\!R}(\beta, Q^2) + \ldots$$

- Factorization theorem holds at fixed $x_{I\!P}$ and t
- DPDF's parametrize the parton content of the incoming proton under the condition that it is quasi elastically scattered with a given $x_{I\!P}$ and t
- Basic new assumption : for each $x_{I\!P}$ one has (in principle) different DPDF's
- Perform QCD-fits at fixed $x_{I\!P}$ with a common initial condition at Q_0^2

$$\Sigma(\beta, Q_0^2) = A_q\, \beta^{B_q}\, (1-\beta)^{C_q}\, e^{\frac{-0.01}{1-\beta}}$$

$$g(\beta, Q_0^2) = A_g\, e^{\frac{-0.01}{1-\beta}}$$

- 4 free parameters, inspired by H1 FitB parametrization

Fixed $x_{I\!P}$-fits: results

- Same cuts as in H1 LRG '06 paper
- $M_X^2 \geq 4$ GeV^2, $Q^2_{\text{min}} \geq 8.5$ GeV^2, 190 points after cuts (out of 276)

$x_{I\!P}$	χ^2	# Fitted points after cuts	# Total points
0.0003	-	3	12
0.0010	1.23	19	40
0.0030	1.01	39	59
0.0100	1.08	61	80
0.0300	0.63	68	85

- Almost good overall description despite only statistical errors are used

$x_{I\!P}$-dependence of input distributions

- A generalisation of the initial condition to include the $x_{I\!P}$-dependence is needed
- $x_{I\!P}$-dependence fully contained in parameters

$$\begin{aligned} \Sigma(\beta, x_{I\!P}, Q_0^2) &= A_q(x_{I\!P})\, \beta^{B_q(x_{I\!P})}\, (1-\beta)^{C_q(x_{I\!P})}\, e^{\frac{-0.01}{1-\beta}} \\ g(\beta, x_{I\!P}, Q_0^2) &= A_g(x_{I\!P})\, e^{\frac{-0.01}{1-\beta}} \end{aligned}$$

- $x_{I\!P}$-dependence is however controlled by non-perturbative dynamics
- ..get inspiration from fixed $x_{I\!P}$-fits

$x_{I\!P}$-dependence of input distributions

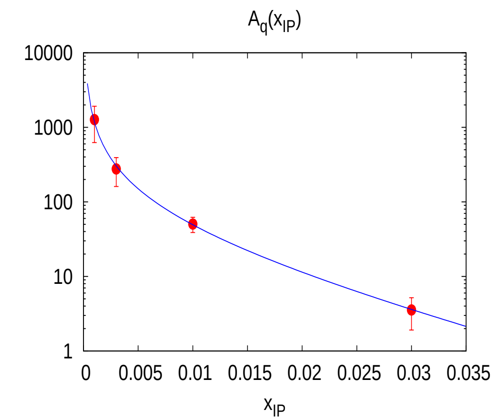
- The NP dependence of DPDF parameters on $x_{I\!P}$ is inferred by fixed $x_{I\!P}$-fits

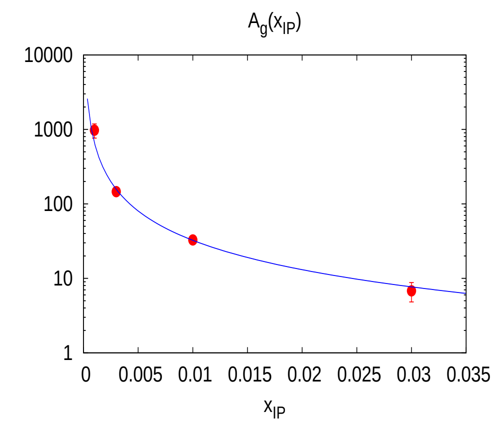
- The singlet and gluon normalizations are parametrized as follows:

- $A_q(x_{I\!P}) = A_{q,0} \cdot (x_{I\!P})^{A_{q,1}} \cdot (1 - x_{I\!P})^{A_{q,2}}$

- $A_g(x_{I\!P}) = A_{g,0} \cdot (x_{I\!P})^{A_{g,1}}$

- Distinct powers for singlet and gluons (different w.r.t. to fluxes)



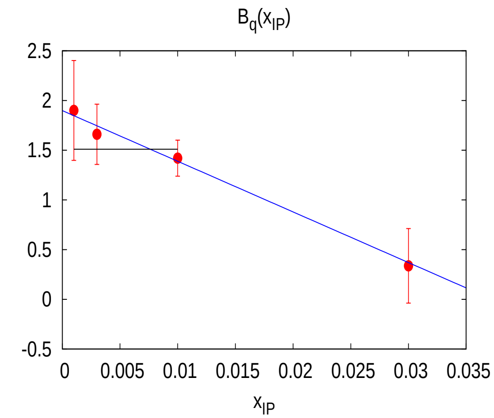


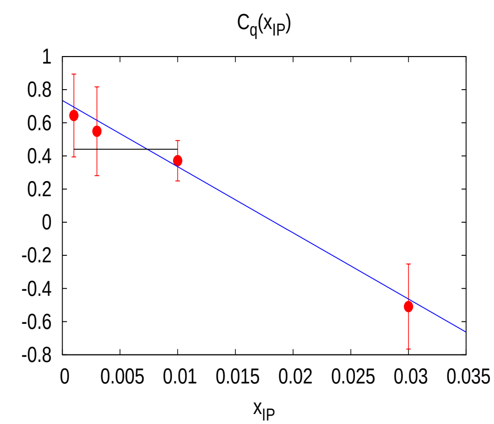
$x_{I\!P}$-dependence of input distributions

- The NP dependence of DPDF parameters on $x_{I\!P}$ is inferred by fixed $x_{I\!P}$-fits

- The singlet shape-modulation parameters are parametrized as follows:

- $B_q(x_{I\!P}) = B_{q,0} + B_{q,1} \cdot (x_{I\!P})$
- $C_q(x_{I\!P}) = C_{q,0} + C_{q,1} \cdot (x_{I\!P})$
- Black line : Regge inspired (pomeron only)
- H1 FPS and Tevatron go up to 0.1 in $x_{I\!P}$...





Combined-$x_{I\!P}$ fit : results (1)

- $M_X^2 > 4$ GeV^2, $Q^2_{\text{min}} \geq 8.5$ GeV^2, 190 points
- In combined-$x_{I\!P}$ fit, systematics errors taken into account (Pascaud and Zomer LAL-95-05)
- Systematics parameters (21) are fitted along with theory parameters (9)

$x_{I\!P}$	partial χ^2 in the combined fit	χ^2 for fixed $x_{I\!P}$ fits	Points after cuts
0.0003	3.1	-	3
0.0010	26.2	18.4	19
0.0030	38.9	35.4	39
0.0100	58.6	61.8	61
0.0300	36.4	40.2	68

- Good description in most of the bins

Combined-$x_{I\!P}$ fit : results (2)

- Best $\chi^2 = 165.8$ for 9 free parameters, $\chi^2/d.o.f. = 0.92$
- $x_{I\!P}$-combination costs $\Delta\chi^2 = +5$ units
- Comparable quality with respect to H1 published pQCD fits

- Same power controlling the $x_{I\!P}$-dependence of singlet and gluon normalization:

  $A_{q,1} = A_{g,1} \rightarrow \chi^2$=171.0

- $A_{q,1} = A_{g,1}$ & no shaping for the singlet:

  $B_{q,1} = C_{q,1} = 0 \rightarrow \chi^2$=187.6

Study of the stability of the fit

- Restrict the phase space to $Q^2_{\text{min}} \geq 8.5$ GeV^2 and $y < 0.5$

▶ Both χ^2's and parameters unchanged :

$\rightarrow$ consistent. Same conclusion as the recent F_L^D analysis by H1 (EPJ 2012)

- Relax the cut on Q^2_{min} and keep $0 < y < 1$

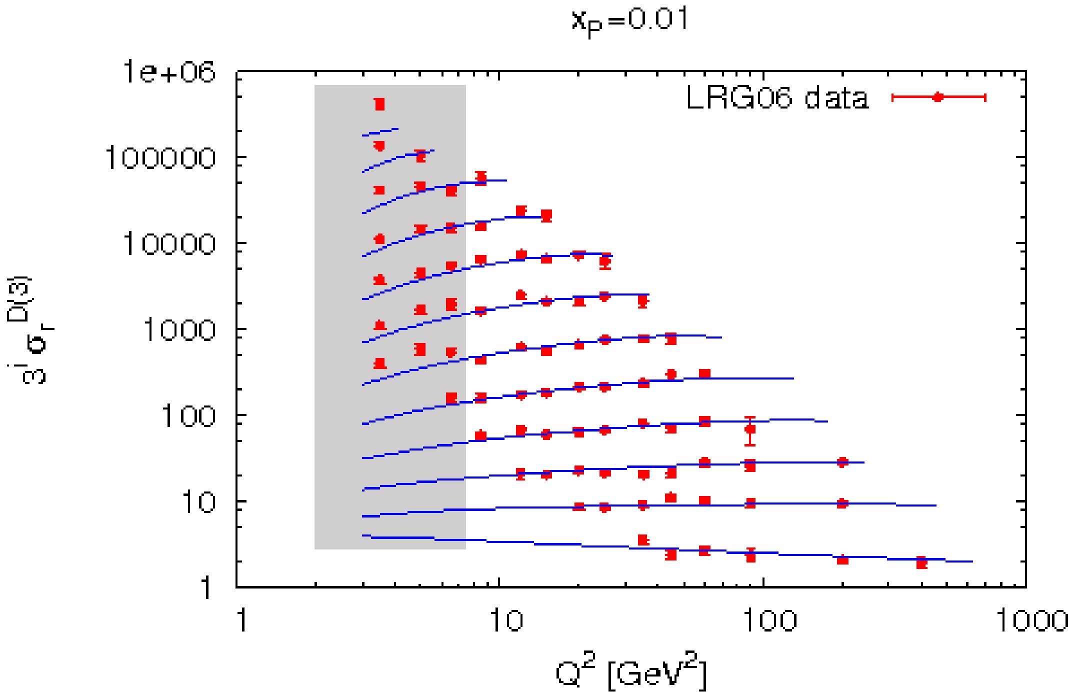
▶ χ^2's deteriorate and parameters are strongly affected

- Same results with no cut on Q^2_{min} and $y < 0.5$
- Situation does not improve even with more flexible inputs (!)

$\rightarrow$ consistent with H1 analysis (EPJ 2006)

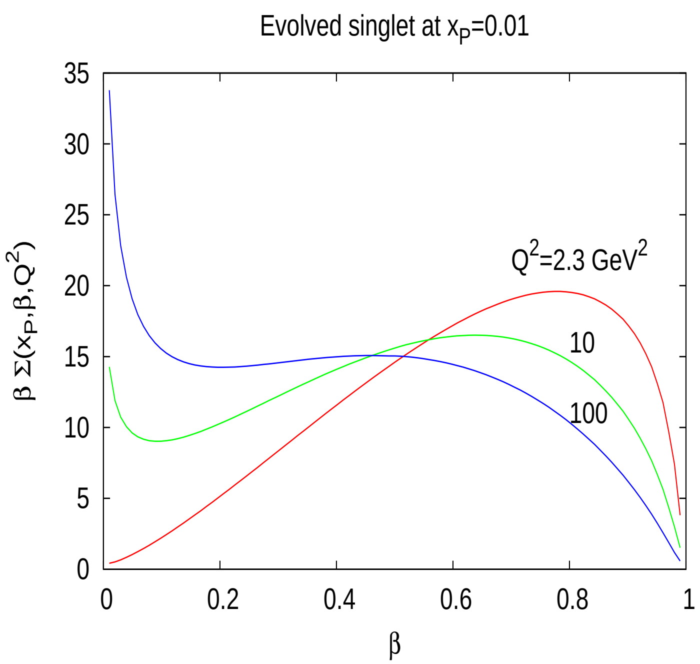
Reduced cross-sections at $x_{I\!P} = 0.01$

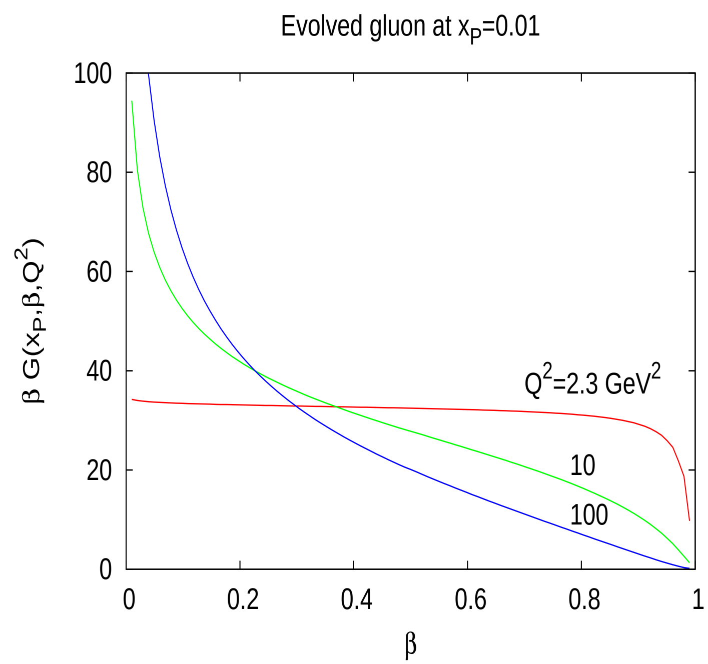
- The grey area indicates the cut $Q^2_{\text{min}} \geq 8.5$ GeV^2



Singlet and gluon Q^2-evolution at $x_{I\!P} = 0.01$

- Evolution at high Q^2 washes away any structure at high β

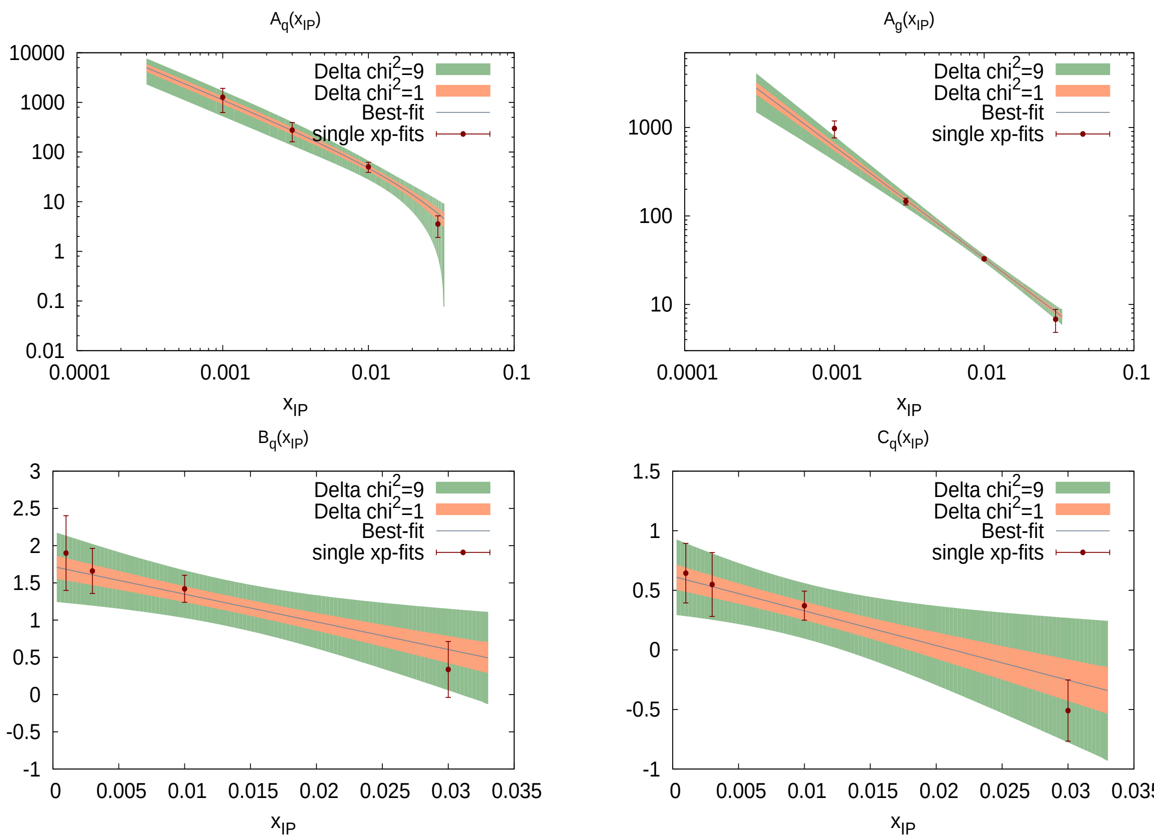




- However the initial condition at $Q_0^2 = 2.3$ GeV^2 is far in the unmeasured region

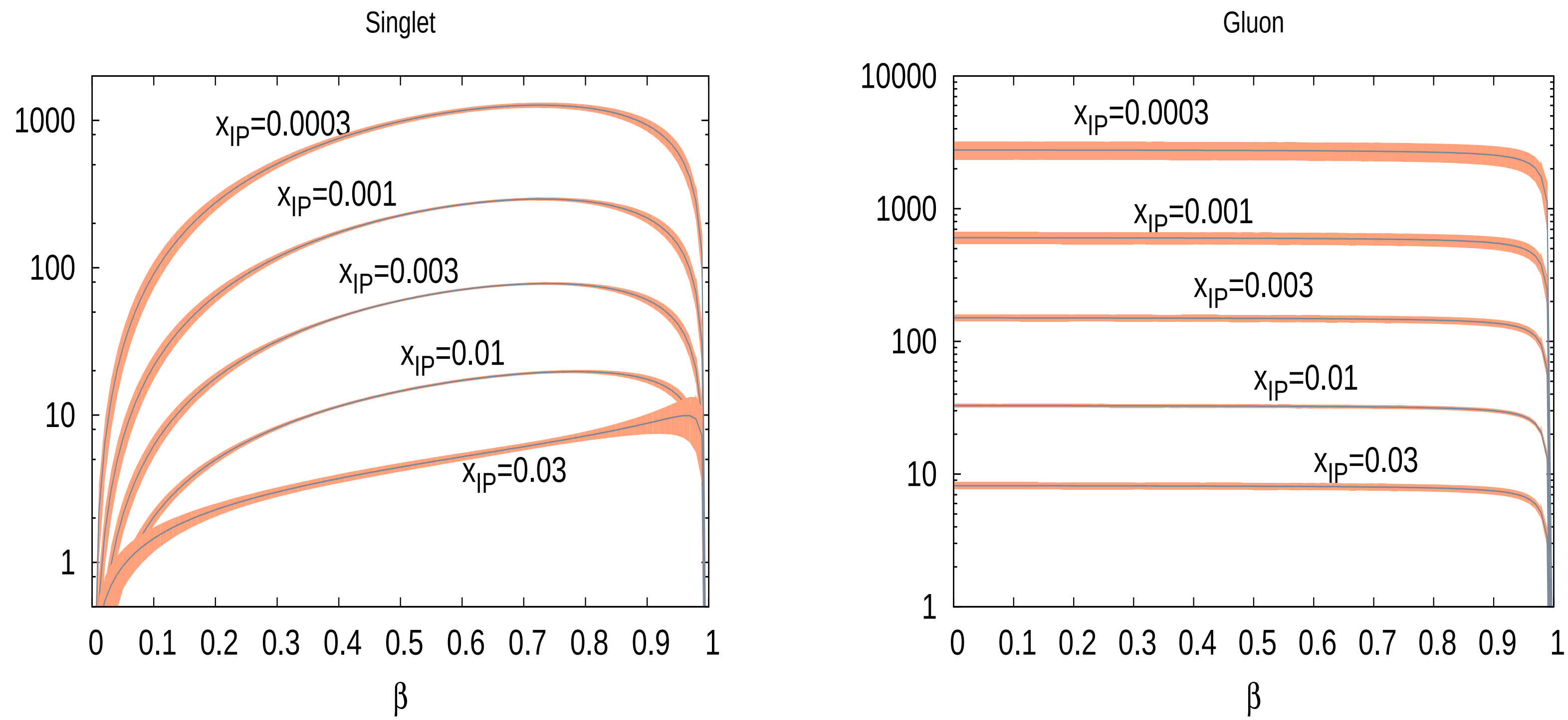
Parameters check

- Comparison of parameters from fixed-$x_{I\!P}$ fits and combined-fit



DPDF's vs β at $Q_0^2 = 2.3$ GeV^2 for different $x_{I\!P}$

- The singlet slightly evolves with $x_{I\!P}$ (initial conjecture)



Conclusions

- The new method offers flexibility in the choice of the input distributions : surface in $(\beta, x_{I\!P})$ properly interfaced with pQCD
- Singlet β-shape slightly evolves in $x_{I\!P}$
- $x_{I\!P}$-combined fit is possible (important for $x_{I\!P}$-integrated cross-sections, *i.e.* jet CS, portability of the code..)
- Quality of the fit comparable with respect to pQCD+Regge-inspired fit by H1 on the same data
- The approach can be extended to treat the t-dependence of the cross-section
- The precision of forthcoming data will further tests these ideas