H1 2006 Diffractive Parton Densities: Updates and Practicalities

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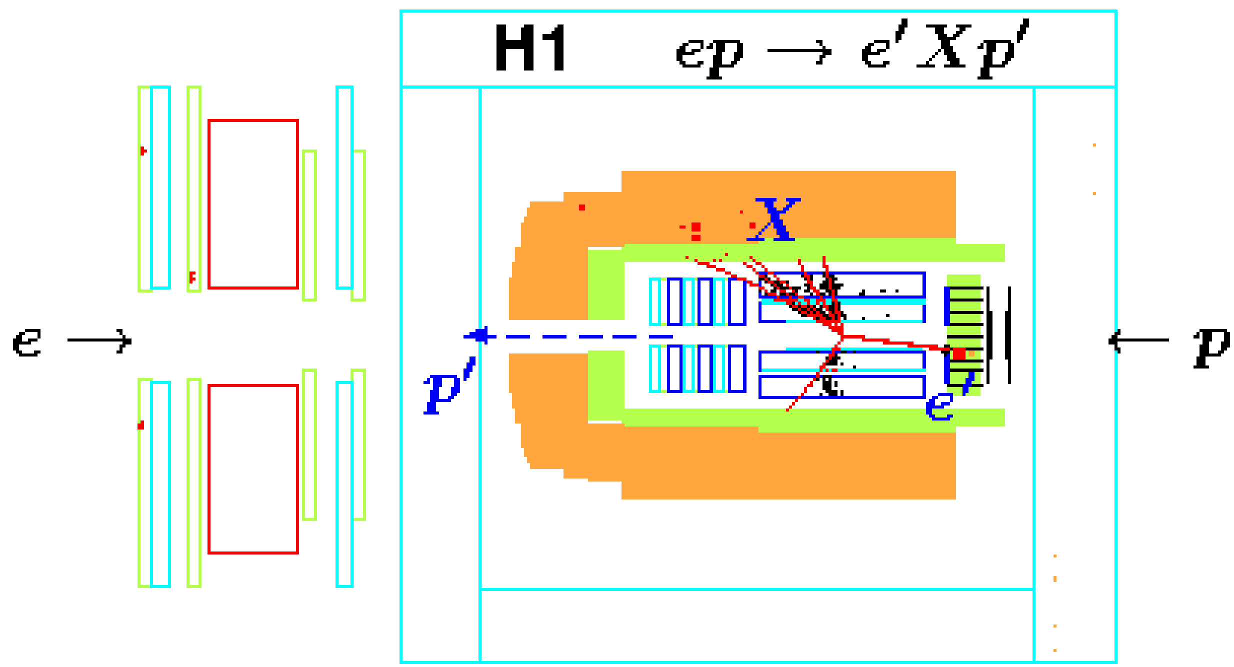
HERA-LHC
workshop
14 / 3 / 07



Contents

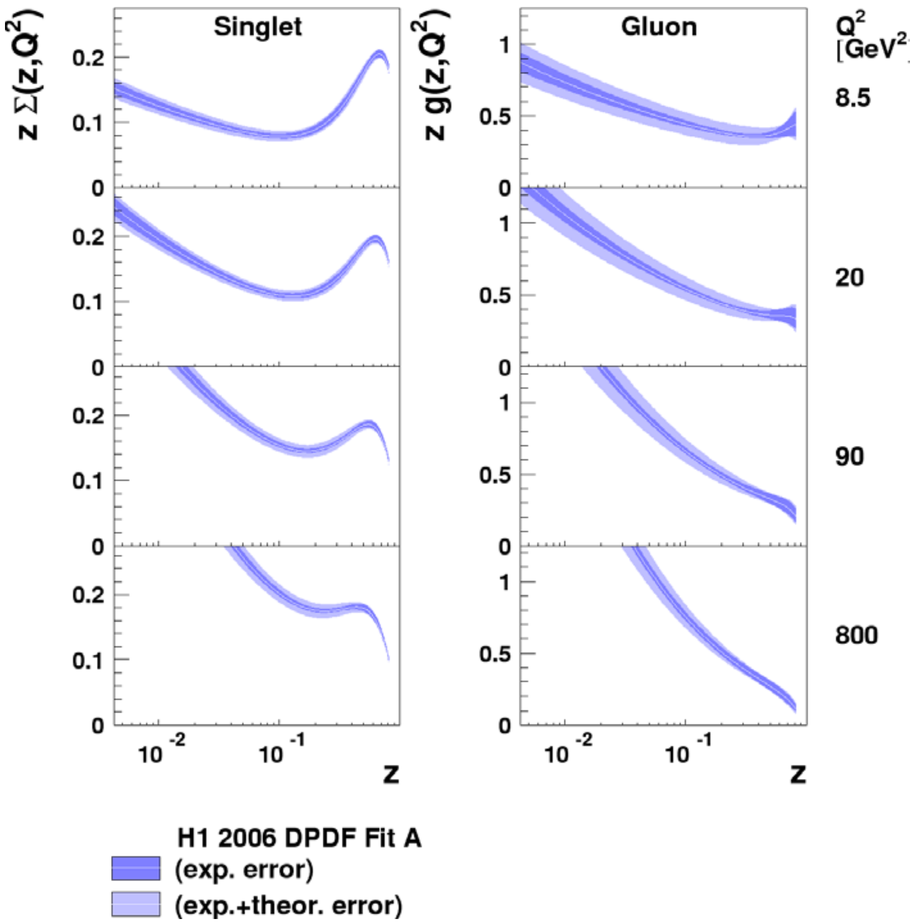
• Reminder of the measurements and QCD fits (hep-ex/0606003, hep-ex/0606004)

• Why is the high z gluon so poorly known?

• Applications of the DPDFs at HERA, the LHC and elsewhere

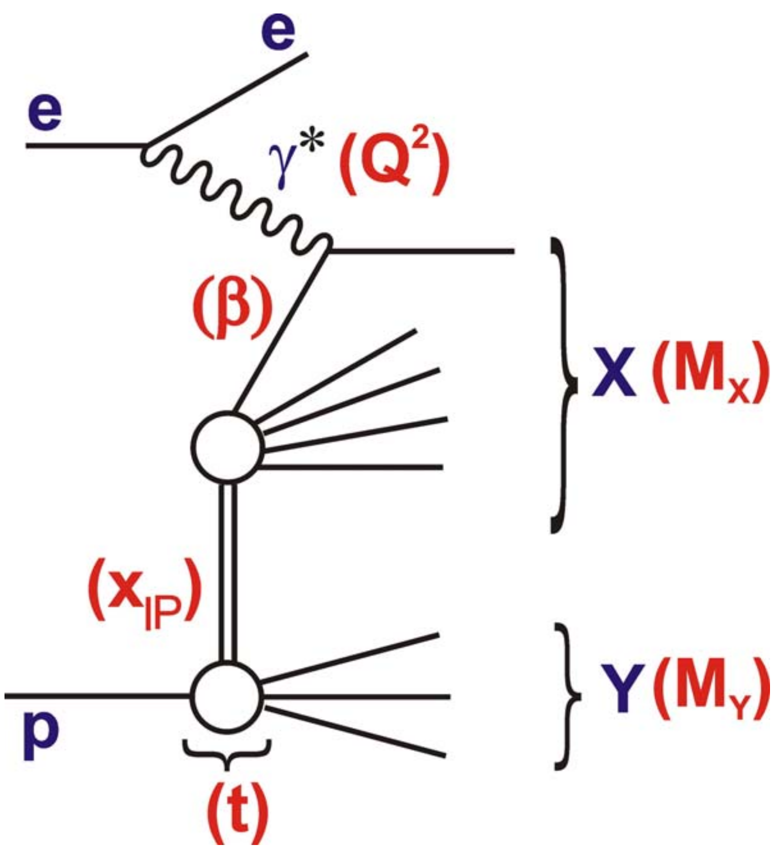
• How to get hold of the fit output and use it

• Some variations of the fits – massless charm, LO version …



Kinematics & Observables

Most generally $ep \rightarrow eXY$ ...



x = momentum fraction q/p

Q^2 = $|\gamma^*$ 4-momentum squared$|$

t = squared 4-momentum transfer at proton vertex

x_{IP} = fractional momentum loss of proton (momentum fraction IP/p)

β = x / x_{IP} (momentum fraction q / IP)

Measure semi-inclusive cross section for $ep \rightarrow eXY$,

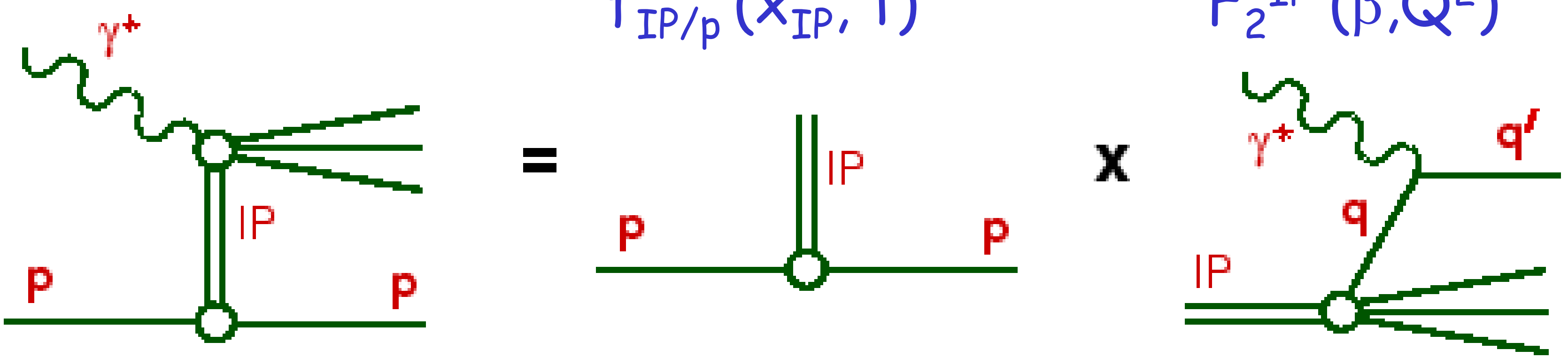
$\sigma_r^{D(3)}(\beta, Q^2, x_{IP}) \sim F_2^{D(3)}$,integrated over $M_Y < 1.6$GeV and $|t| < 1\text{GeV}^2$

Fit Framework: Proton Vertex Factorisation

Factorise x_{IP}, t dependences into a `flux factor'

MEASUREMENT = IP FLUX x IP STRUCTURE

$f_{IP/p}(x_{IP}, t)$ $F_2^{IP}(\beta, Q^2)$



'Flux' treatment from Regge theory …

$$f_{IP/p}(x_{IP}, t) = \frac{e^{B_{IP} t}}{x_{IP}^{2\alpha_{IP}(t)-1}} \qquad \alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP}\, t$$

$F_2^{IP}(\beta, Q^2)$ sensitive to diffractive quark and gluon densities

Secondary (IR) trajectory exchange similarly defined

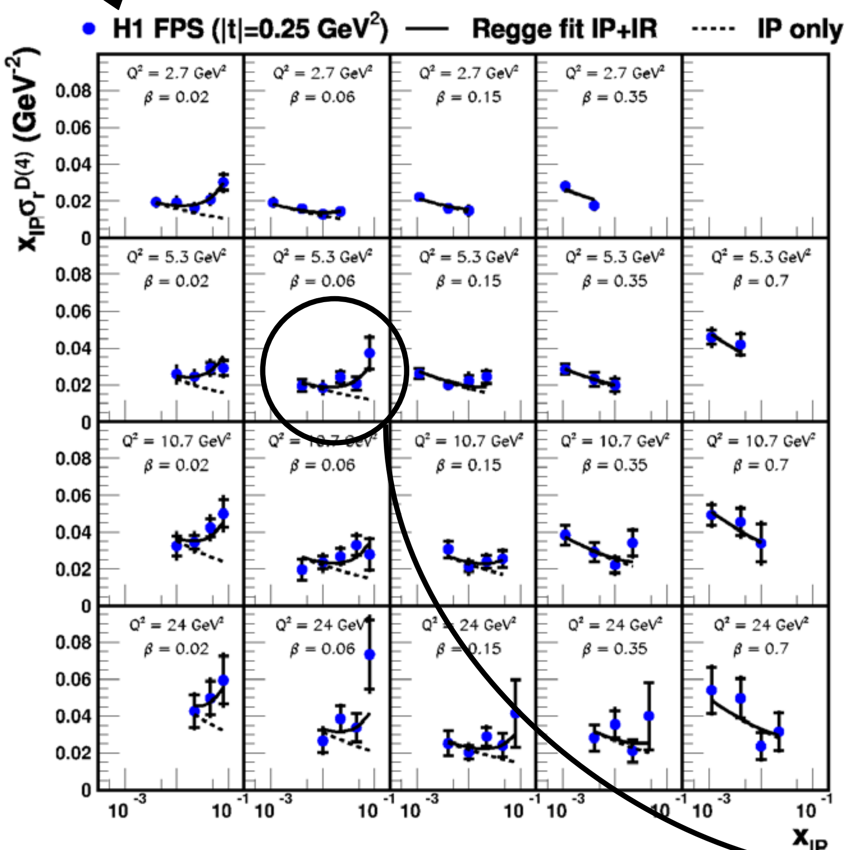
Data Overview

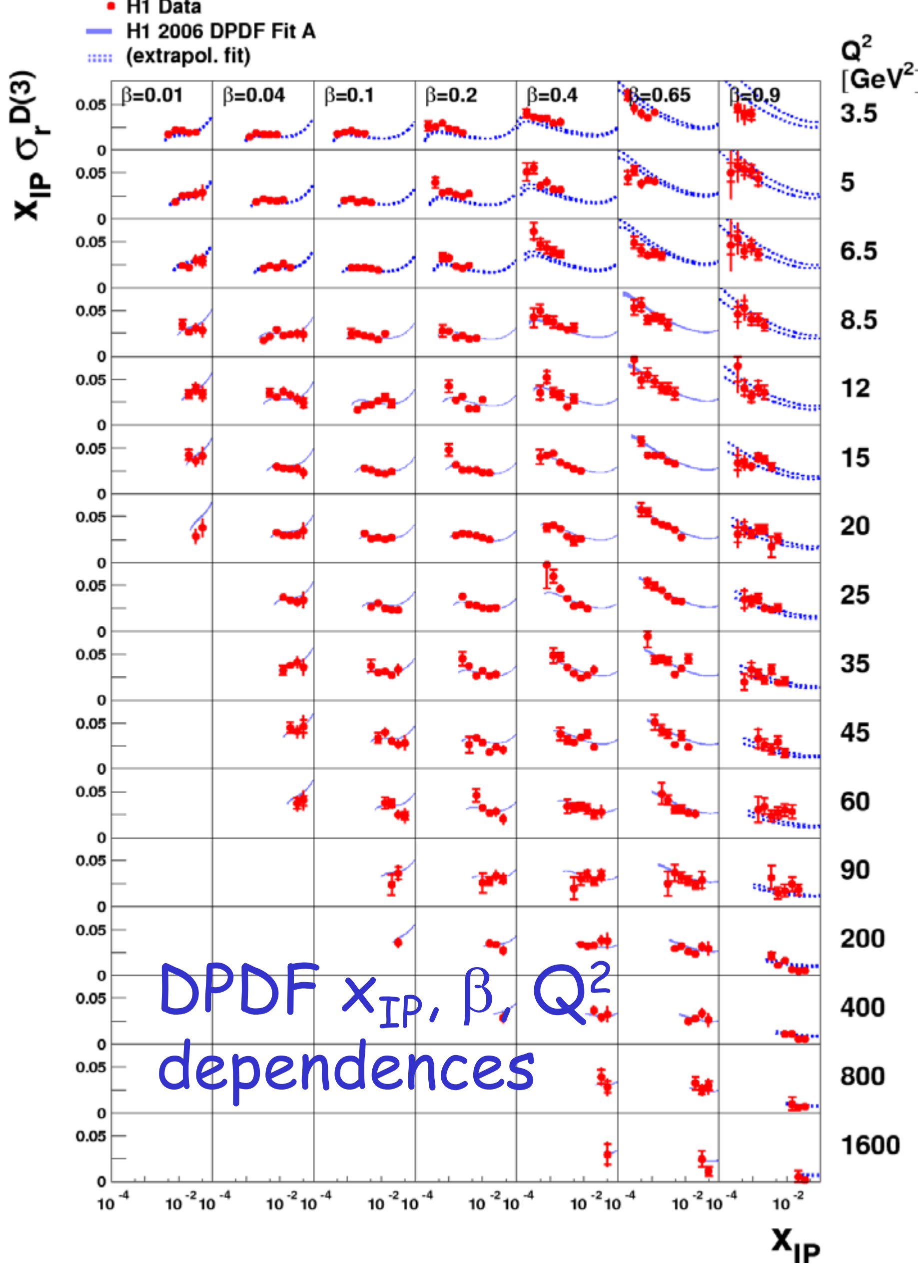
LRG: $M_Y < 1.6$ GeV →

$$3.5 \le Q^2 \le 1600 \text{ GeV}^2$$

FPS: Y=p

$$2.7 \le Q^2 \le 24 \text{ GeV}^2$$

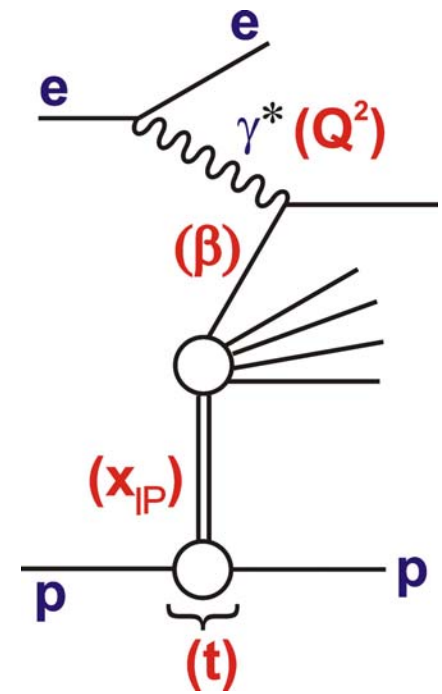




DPDF x_{IP}, β, Q^2 dependences

DPDF t dependence & best constraints on IR component

Extracting the Quarks and Gluons



- Fit LRG data with fixed x_{IP} binning

- Parameterise β and Q^2 dependences at starting scale Q_0^2 for QCD evolution (optimise Q_0^2 w.r.t. χ^2)

- Evolve to higher Q^2 using NLO DGLAP equations (massive charm, $\alpha_s(M_z^2)=0.118$)

- Use proton vertex factorisation with $\alpha_{IP}(t)$ from FPS and LRG data to relate data from different x_{IP} values with complementary β, Q^2 coverage.

- Exclude data with $M_X < 2$ GeV or $\beta > 0.8$ (higher twist region) and with $Q^2 < 8.5$ GeV^2 (NLO insufficient?)

Free Parameters of H1 2006 DPDF Fit

5 free parameters for singlet quark $z\Sigma(z,Q_0^2)$, gluon $zg(z,Q_0^2)$ densities, where z is parton momentum fraction (= β for quarks at lowest order, otherwise $>\beta$)

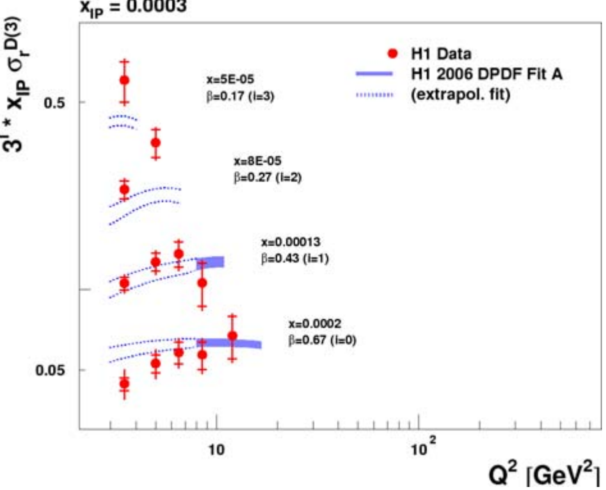
$$z\Sigma(z,Q_0^2) = A_q z^{B_q}(1-z)^{C_q}$$

$$zg(z,Q_0^2) = A_g (1-z)^{C_g}$$

(gluon insensitive to B_g)

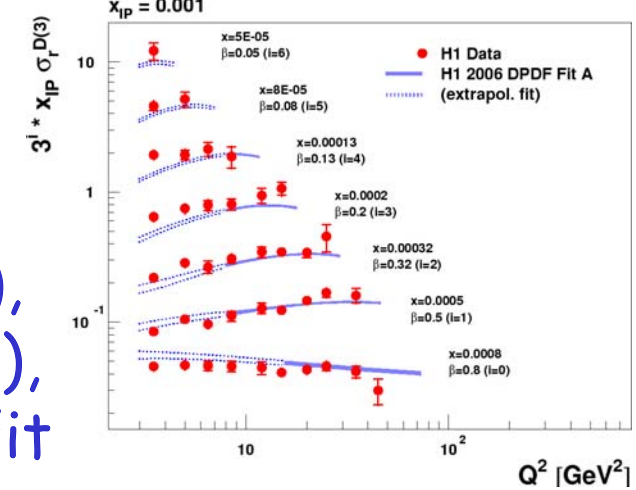
- 1 free parameter $\alpha_{IP}(0)$ describes x_{IP} dependence via flux factor

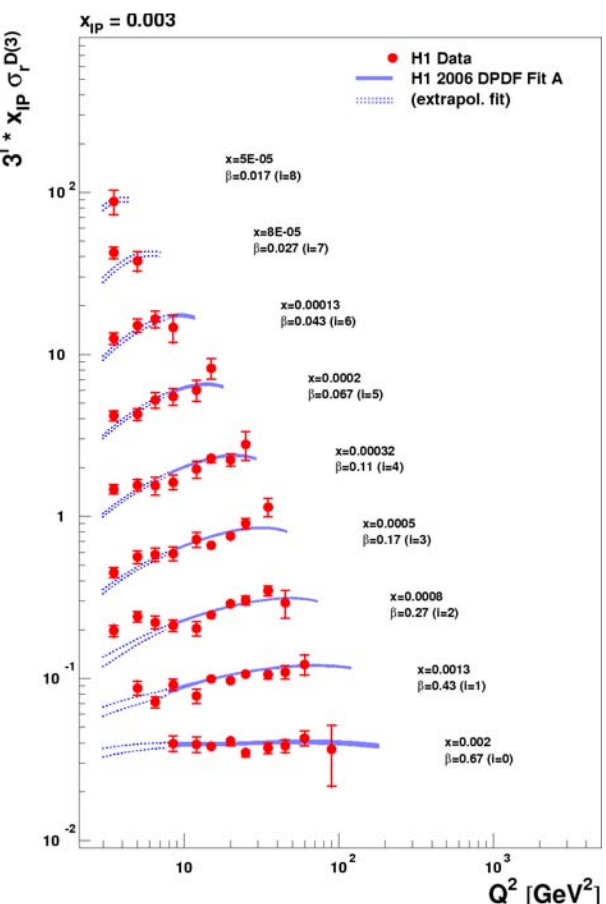
- 1 free parameter describes normalisation of sub-leading IR, which is otherwise treated as a π^0

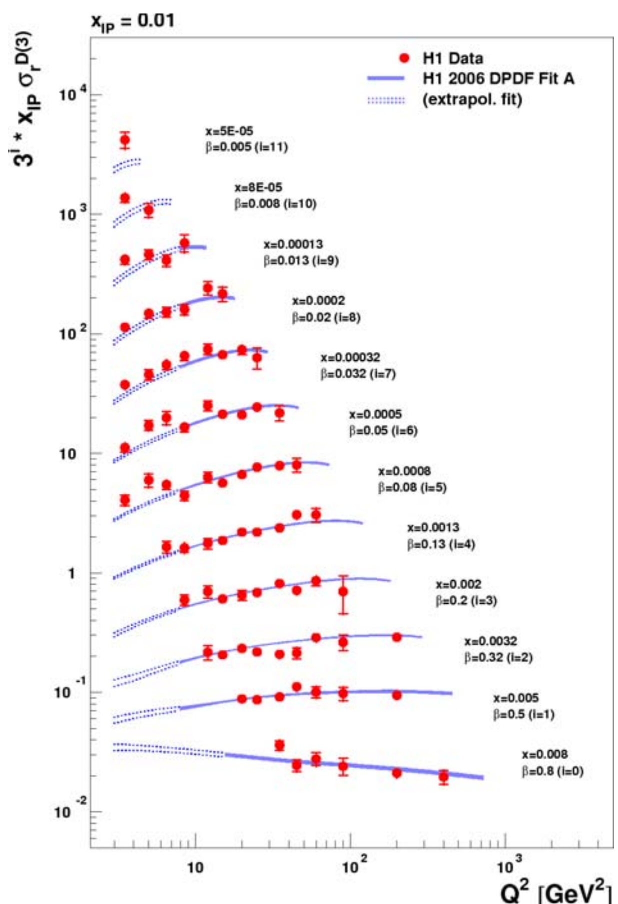


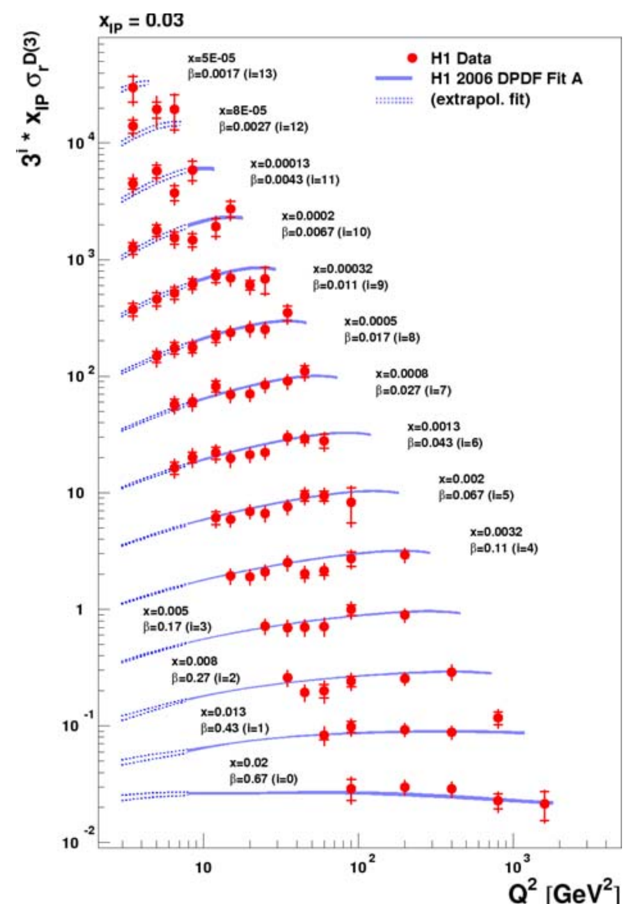
Data Fitted

In best regions, precision ~5% (stat), 5% (syst), 6% (norm), …well described by fit

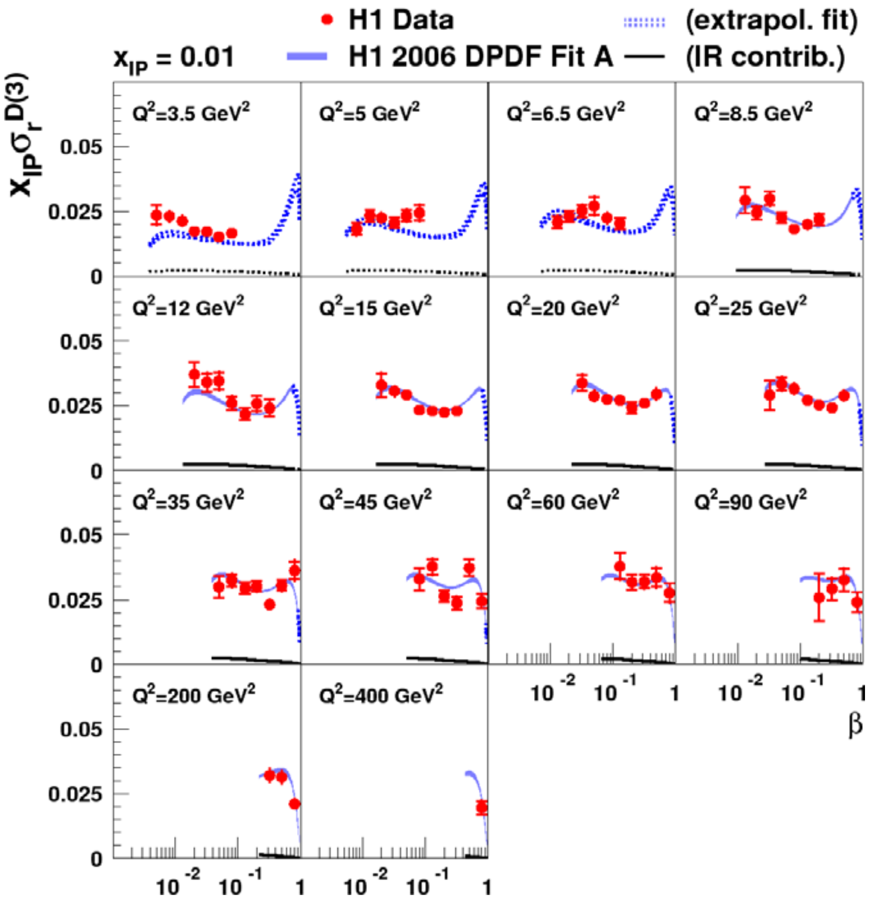


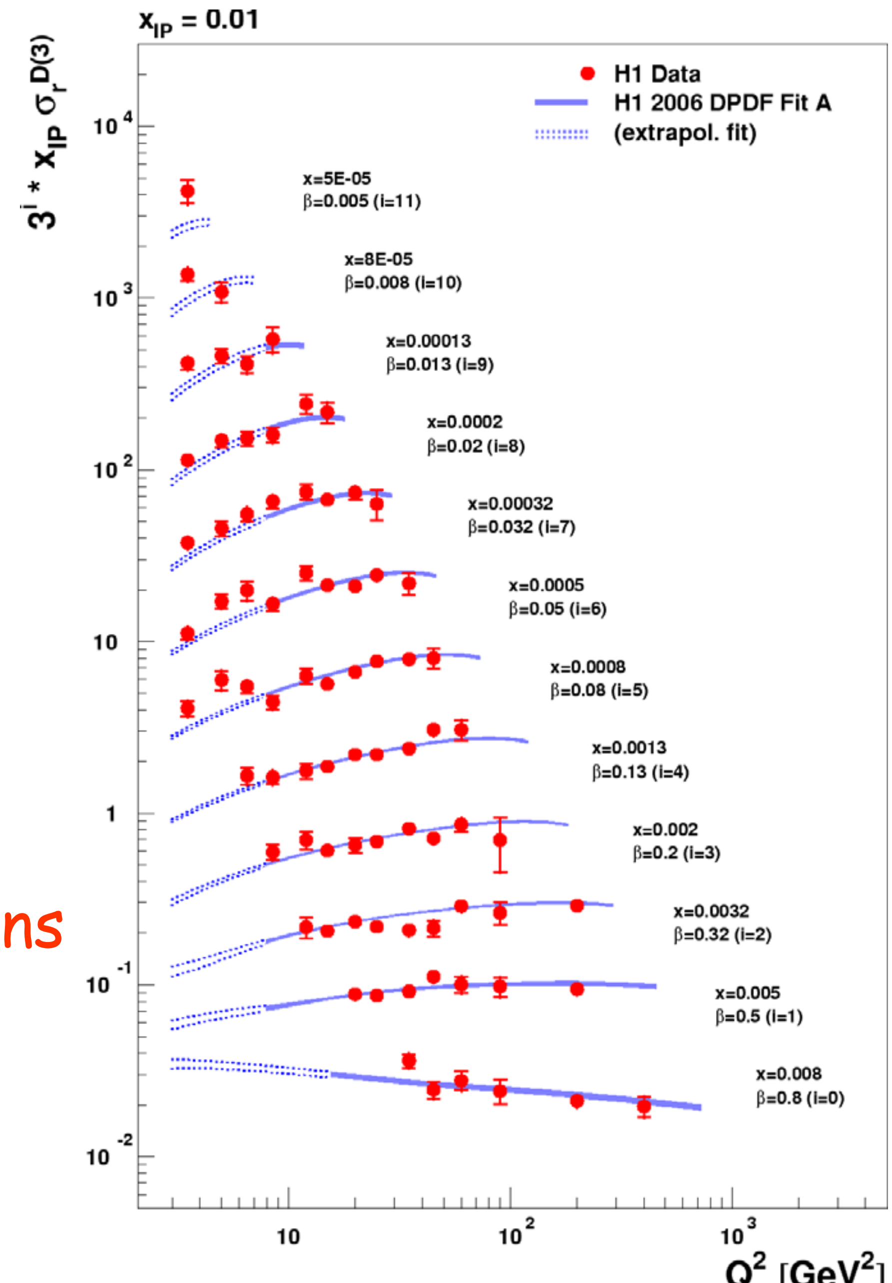






Focus on $x_{IP} = 0.01$





- Reduced cross section constrains quark density
- ln Q^2 dependence constrains gluon density

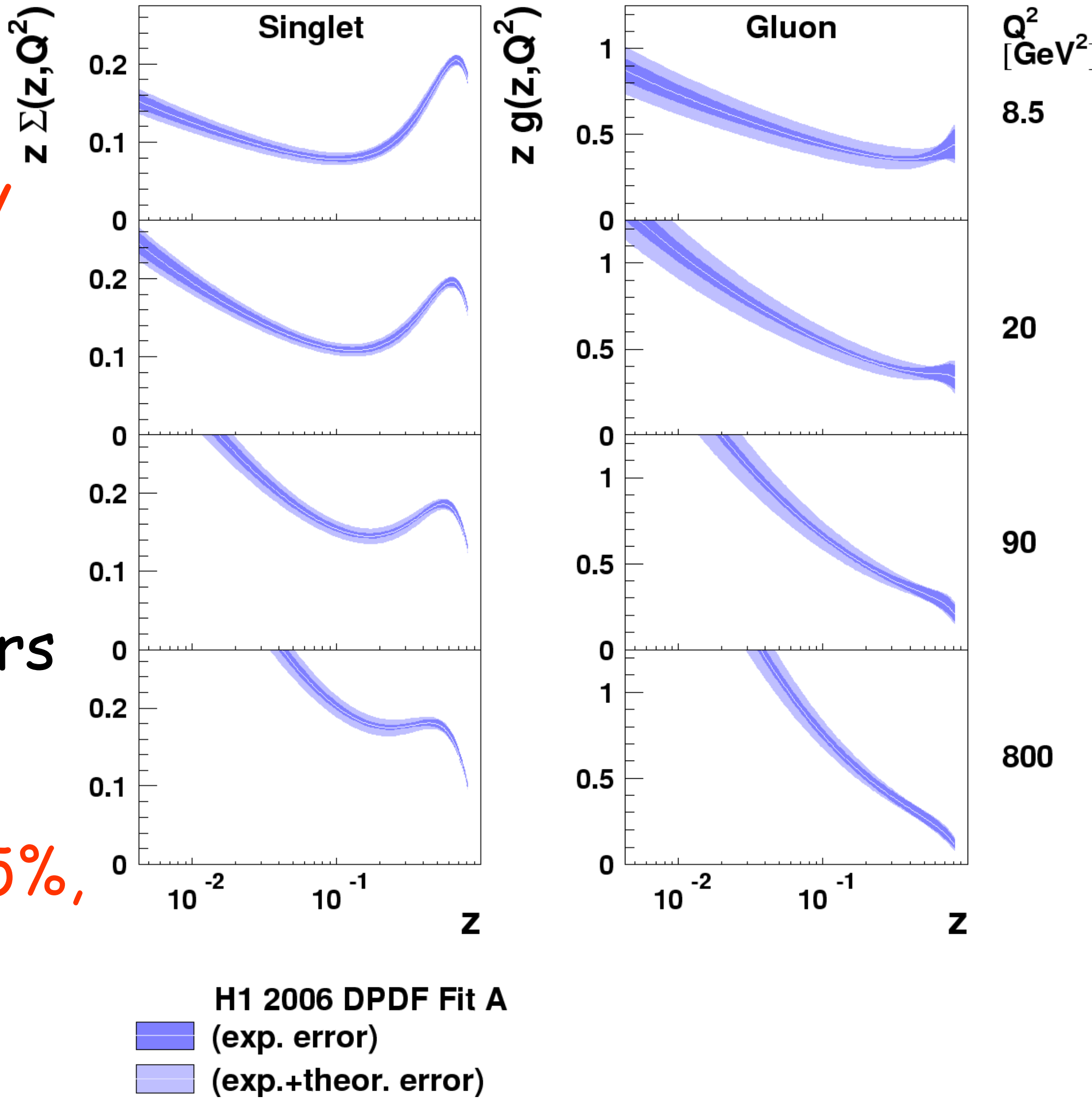
'H1 2006 DPDF Fit A' (log z scale)

χ^2 ~158 / 183 d.o.f.

- Experimental uncertainty obtained by propagating errors on data through χ^2 minimisation procedure

- Theoretical uncertainty by varying fixed parameters of fit and Q^2_0 (s.t. $\Delta\chi^2 = 1$)

- Singlet constrained to ~5%, gluon to ~15% at low z, growing a lot at high z

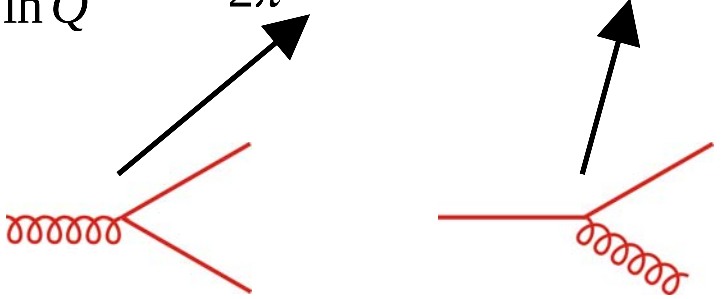


$$\alpha_{IP}(0) = 1.118 \pm 0.008\ (\text{exp.})\ ^{+0.029}_{-0.010}\ (\text{theory})$$

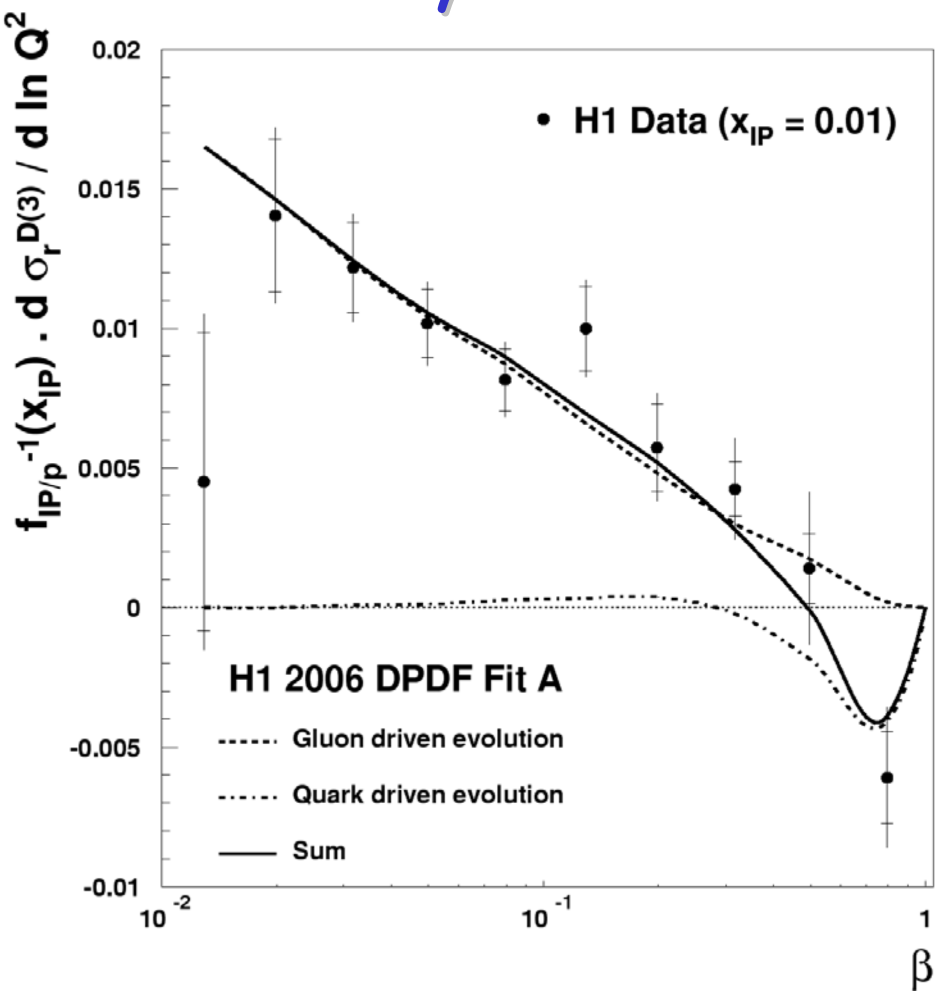
$$\alpha'_{IP} = 0.06^{+0.19}_{-0.06}\ \text{GeV}^{-2}$$

What the Q^2 Dependence Really Constrains

$$\frac{d\sigma_r^D}{d\ln Q^2} \sim \frac{\alpha_s}{2\pi}\left[P_{qg}\otimes g \;+\; P_{qq}\otimes q\right]$$



Extract $d\sigma_r^D/d\ln Q^2$ by fitting data at fixed x, x_{IP}



- Low β evolution driven by $g \to q\bar{q}$ … strong sensitivity to gluon
- High β, relative error on derivative grows, $q \to qg$ contribution to evolution becomes dominant … sensitivity to gluon is lost!

`Fit A' and `Fit B' DPDFs (linear z scale)

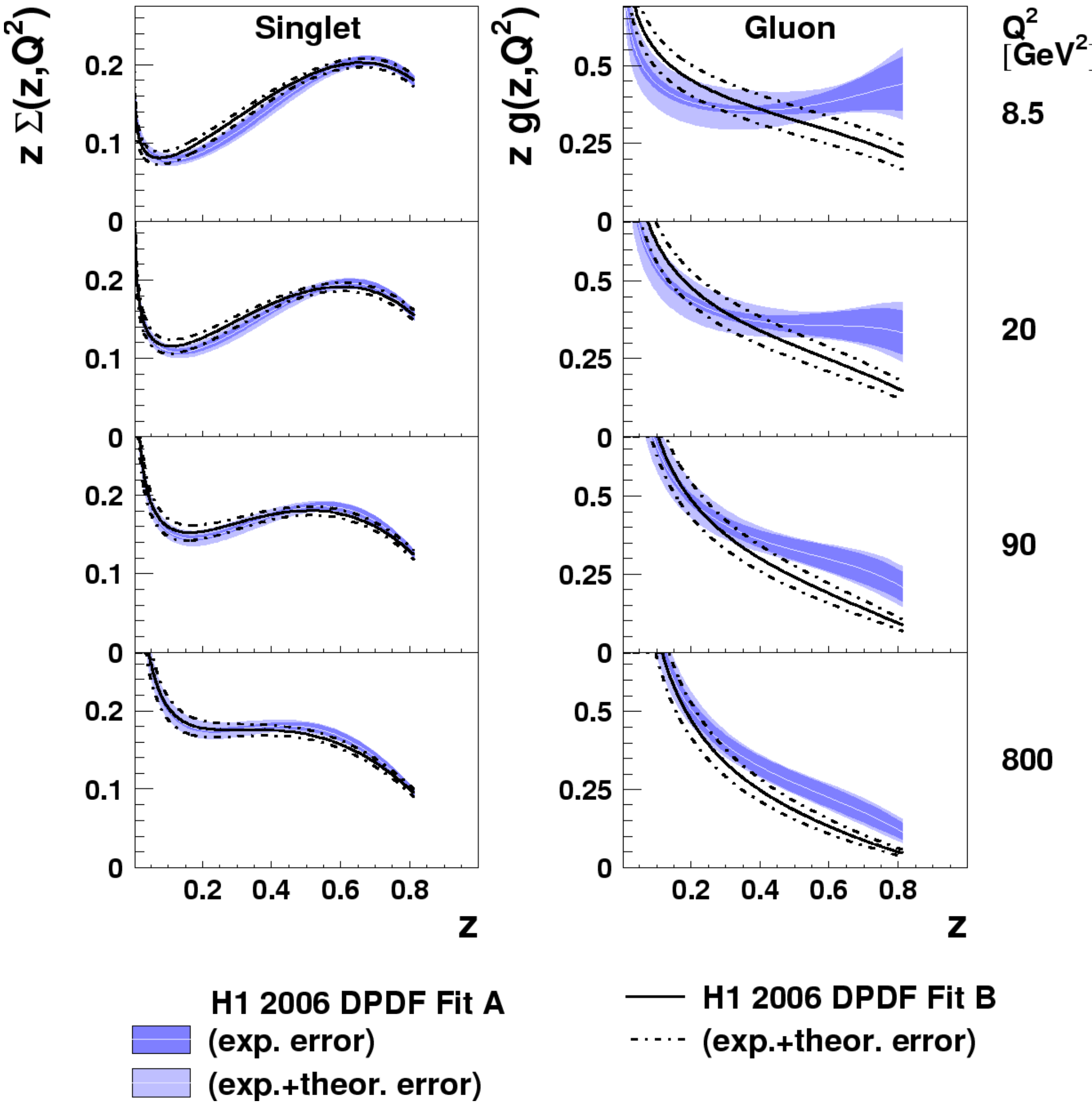
- Lack of sensitivity to high z gluon confirmed by dropping (high z) C_g parameter, so gluon is a constant at starting scale!

•Fit B

χ^2 ~164 / 184 d.o.f.

- Quarks very stable
- Gluon similar at low z
- Substantial change to gluon at high z

NB: no statement for z > 0.8 (data not fitted!!!)



"HERA and the LHC" (& elsewhere)

DPDFs well tested inside H1 … see talks by Roger Wolf and Matthias Mozer:

- Describe jets and charm in DIS well
- Ongoing work to improve high z gluon with DIS jets (crucial for LHC applications)
- Factorisation breaking in photoproduction established

Beyond HERA?…

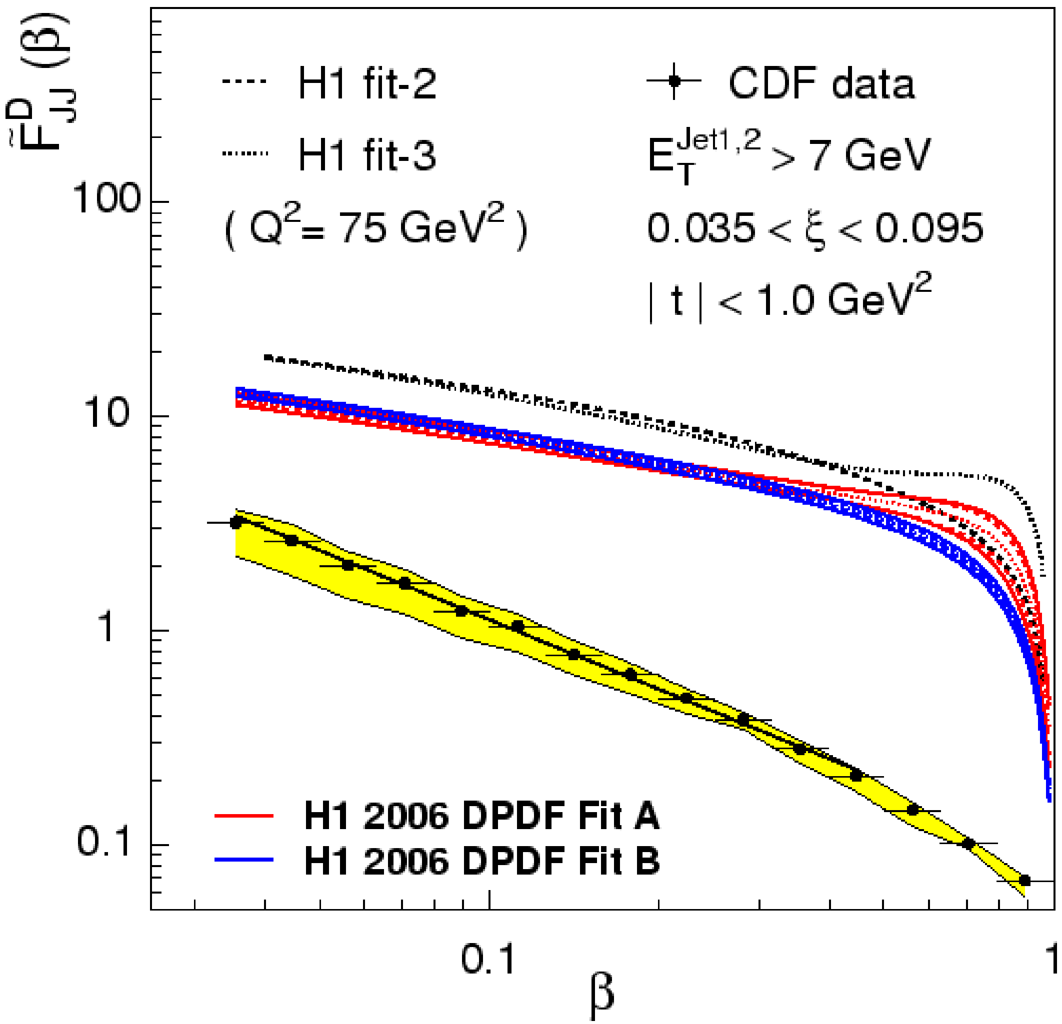
DPDFs available for public use, including full information to propagate error bands to arbitrary application

Small complication in that partons correspond to $M_Y < 1.6$ GeV

→ larger than the case of intact protons by a (universal?) factor …

$$\frac{\sigma(M_Y < 1.6 \text{ GeV})}{\sigma(Y = p)} = 1.23 \pm 0.03 \text{ (stat.)} \pm 0.16 \text{ (syst.)}$$

Example Comparison with Tevatron: CDF Jets



- Fit A and fit B predictions in good agreement at low β.
- ~30% lower than earlier predictions, because gluon smaller and meson smaller.
- Basic conclusion of large factorisation breaking holds
- Reassess gap survival factors?
- High β still problematic

Using the Parton Densities

http://www-h1.desy.de/h1/www/publications/htmlsplit/DESY-06-049.long.html

DESY-06-049

Measurement and QCD Analysis of the Diffractive Deep-Inelastic Scattering Cross Section at HERA

hep-ex/0606004
H1-155

Reference	H1 Collab., A. Aktas et al., Eur. Phys. J. C48 (2006) 715-748 , 06/06
Figures	(1a) (1b) (2a) (2b) (3a) (3b) (4a) (4b) (5a) (5b) (6a) (6b) (7a) (7b) (8) (9a) (9b) (10) (11) (12) (13) (14) (15) (16a) (16b) (16c) (17a) (17b) (18) (19)
Links	back to overview Abstract from hep-ex pdf version
Comments	Tables for the Diffractive Reduced Cross Sections, results of the fits and fortran paramterisations of the diffractive PDFs and the flux factors.

- Follow link under `Comments' for code to generate the DPDFs, structure functions etc.
- Update with additional tools imminent

Tools Available

Code is provided for …

- Pomeron parton densities (DPDFs from fit A or B)
- Pomeron, Meson Flux factors (fixed t or t-integrated)
- Pomeron, Meson structure functions (F_2^D, F_L^D, F_2^c)

Multiple sets of `eigenvector' DPDFs, corresponding to a diagonalisation of the covariance matrix between the different fit parameters.

Similar sets of parton densities corresponding to the theoretical uncertainties

… i.e. to evaluate uncertainty due to the DPDFs on an arbitrary prediction, just go through the full set and add deviations from central result in quadrature.

Error Decomposition

Description	Fit A index	Fit B index
central fit	0	0
eigen1+	1	1
eigen1-	2	2
eigen2+	3	3
eigen2-	4	4
eigen3+	5	5
eigen3-	6	6
eigen4+	7	7
eigen4-	8	8
eigen5+	9	9
eigen5-	10	10
eigen6+	11	11
eigen6-	12	12
eigen7+	13	13
eigen7-	14	14
eigen8+	15	-
eigen8-	16	-

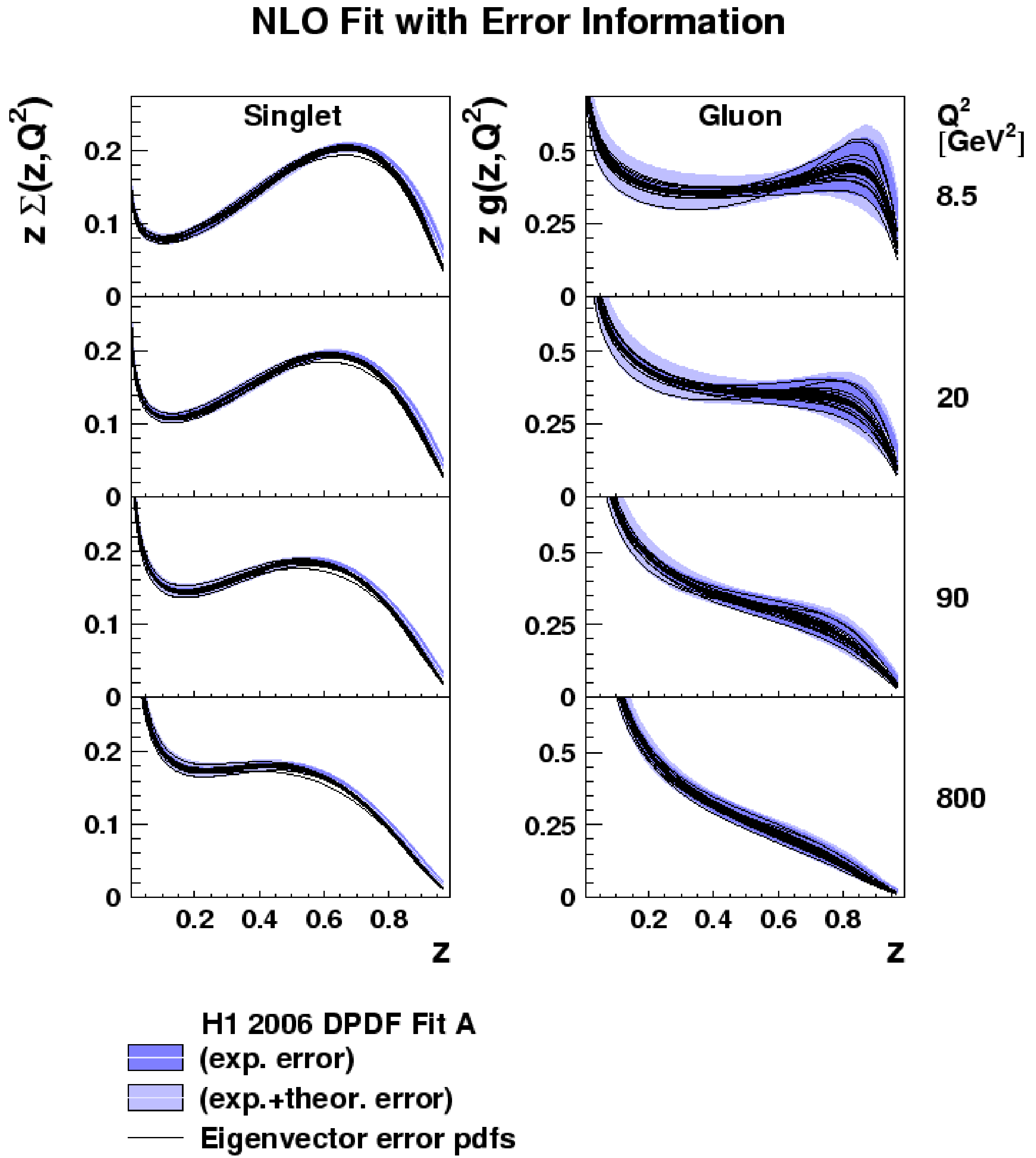
(`Experimental' errors due to PDF param'n, $\alpha_{IP}(0)$, IR norm, in pairs and diagonalised)

Description	Fit A index	Fit B index
lambda-qcd-	17	15
lambda-qcd+	18	16
mc-	19	17
mc+	20	18
mb-	21	19
mb+	22	20
B0pom -	23	21
B0pom +	24	22
alpha'B0-pom -	25	23
alpha'B0-pom +	26	24
alpha'-mes -	27	25
alpha'-mes +	28	26
alpha'B0-mes -	29	27
alpha'B0-mes +	30	28
Q02 -	31	29
Q02 +	32	30

(Theoretical errors)

All Error Sets Superimposed

Added in quadrature, the various error sets form the bands shown



Variations on the Theme

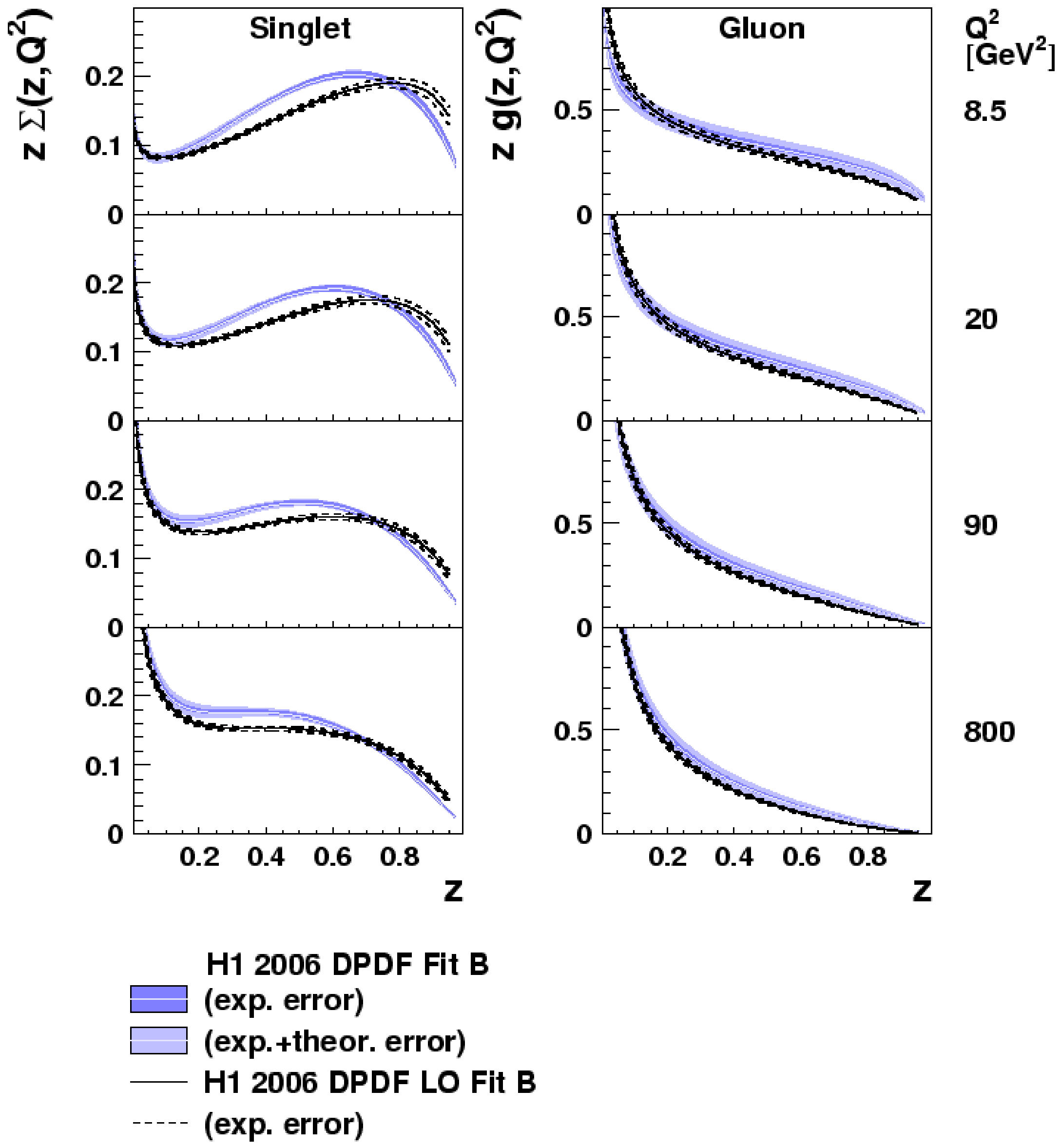
In addition to the basic DPDFs provided, alternative versions should be available soon…

- Fits using LO DGLAP
  - … restricted to $y<0.45$ to avoid large F_L^D influence.
  - … following MRST and CTeQ, increase strong coupling in LO version → $\Lambda=0.22$ GeV … $\alpha_s(M_z^2)=0.130$
  - … otherwise identical method

- Fits using NLO DGLAP with massless charm
  - … useful for input to NLO programs? … in progress

- Combined inclusive + jets fit (Matthias Mozer's talk)

LO Partons (e.g. for fit B set-up)

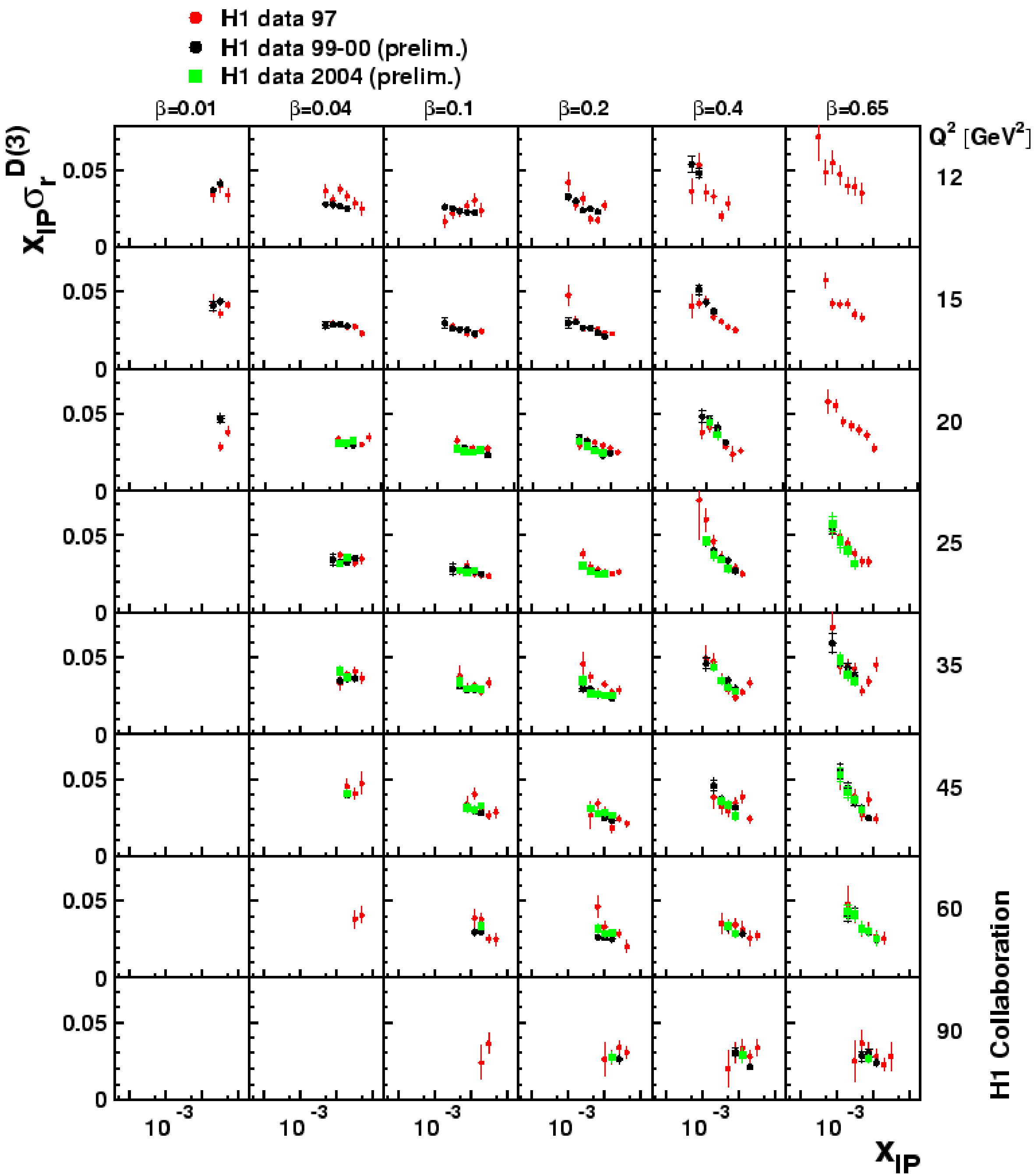


Similarly good description of data to NLO fits

χ^2 ~110 / 124 d.o.f.

With this choice of α_s, gluon similar to NLO version

Further Data Analysis in Progress



- New measurement using all available HERA-II data progressing well
- First preliminary results at DIS06
- Also large FPS and VFPS samples from HERA-II (Micha Kapishin)

Summary

• Tests and predictions using H1 2006 DPDF fits underway.

→Hard Scattering Factorisation working in DIS,

→Failing as expected in photoproduction, pp.

→ Ongoing work to improve high z gluon (crucial for LHC) through combined fits to inclusive and jet data

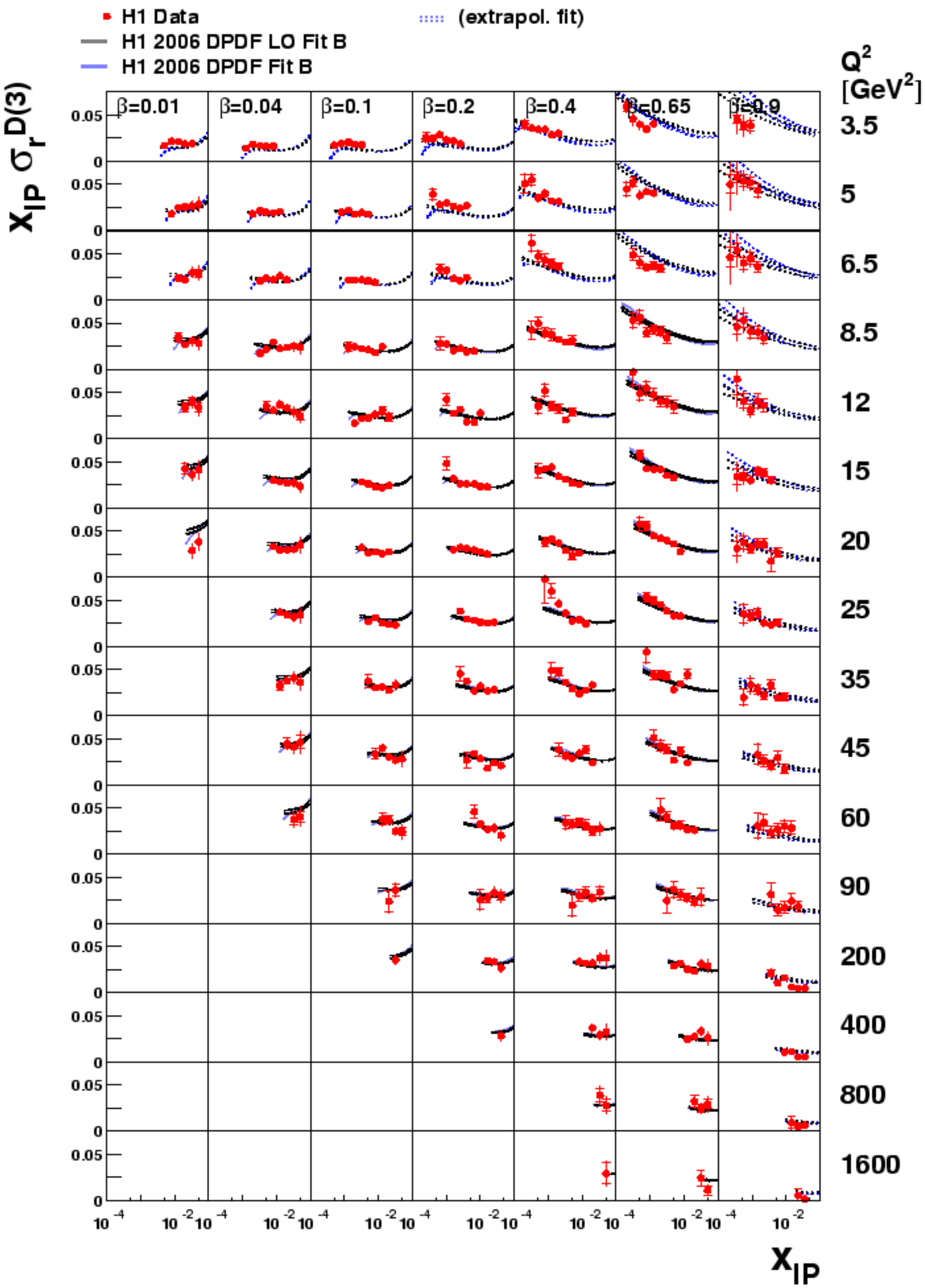
• Code available to implement DPDFs in Monte Carlos etc for applications at LHC and elsewhere.

→ Full error propagation now possible.

→ Contact PRN or FPS with questions / comments

• Ongoing work to produce LO partons, NLO partons with massless charm

→ Is there a big demand for this?



Description with LO Partons (e.g. for fit B)