Diffractive Higgs Production at LHC

a case study

QCD@work Lecce - June, 18th 2012

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may diffractive Higgs production represent a viable alternative method for the Higgs search ?

is it worth trying?

aim of this talk is simply to introduce some of the issues about these questions

outlook and a few crucial questions

Let us define Diffractive Higgs Production

see the approach of
Khoze Martin Ryskin and collaborators
and of Forshaw (hep-ph/0611074)

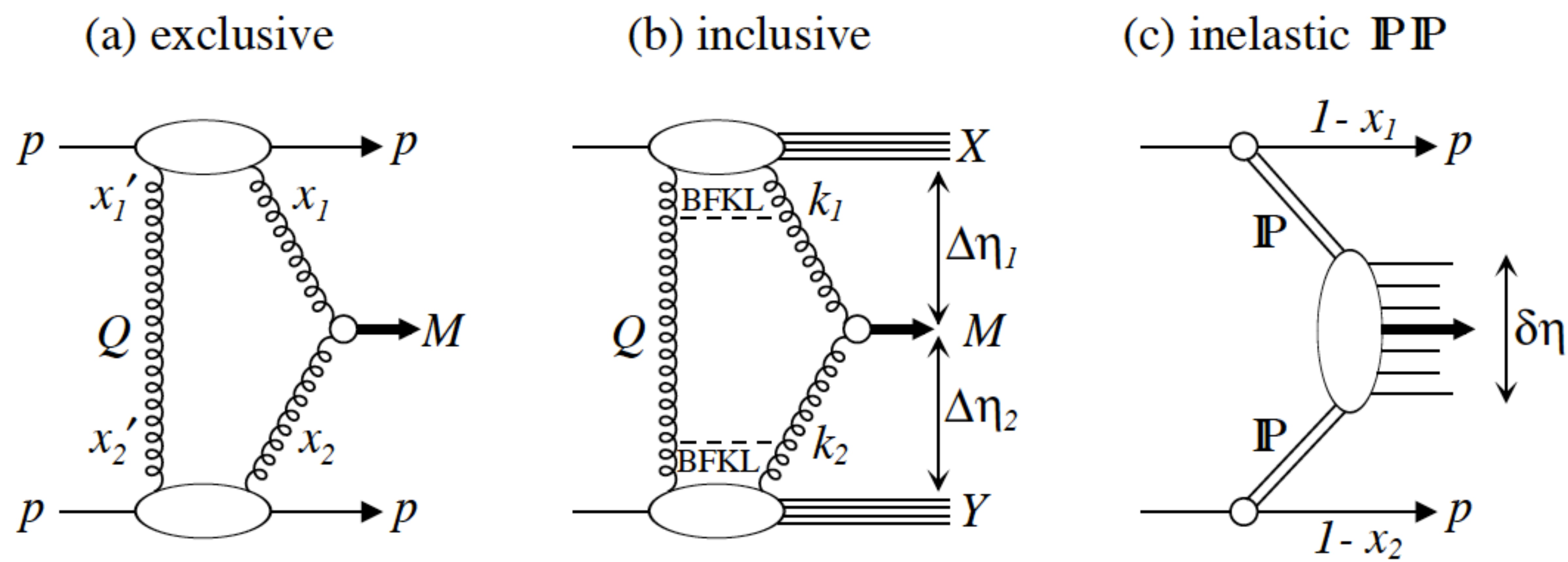


Figure 1: Different mechanisms for the double-diffractive production of a system of mass M in high energy proton-proton collisions.

where M could be the Higgs boson, a couple of jets a $b\bar{b}$ $t\bar{t}$

for example when applied to a well defined channel

i.e. bb

Khoze Martin Ryskin hep-ph/011107
Forshaw hep-ph/0611074

M is s given by an hard exclusive process

For $H \to b\bar{b}$, the signal-to-QCD background ratio is

$$\frac{S(gg^{PP} \to b\bar{b})}{B(gg^{PP} \to gg)} \simeq 4.3 \times 10^{-3}\, \mathrm{Br}(H \to b\bar{b}) \left(\frac{M}{100\text{ GeV}}\right)^3 \left(\frac{250\text{ MeV}}{\Delta M}\right), \tag{56}$$

which is very small [2]. Fortunately, if we tag the b and $\bar{b}$ jets to reject the gg events, we can strongly suppress the QCD background. Recall that the $gg^{PP} \to b\bar{b}$ QCD background process is suppressed by colour and spin factors, and by the $J_z = 0$ selection rule. In this way the background is suppressed by an extra factor

$$\frac{m_b^2}{M_H^2} \frac{1}{4} \frac{1}{27} \lesssim 2 \times 10^{-5}. \tag{57}$$

However the full suppression is only true in the Born approximation. Recall that large angle gluon radiation in the final state violates the $J_z = 0$ selection rule [36], so in the $b\bar{b}$ QCD background the suppression factor m_b^2/M_H^2 is replaced by α_S/π. The final result for the $H \to b\bar{b}$ signal-to-background ratio is therefore

$$\frac{S(gg^{PP} \to H \to b\bar{b})}{B(gg^{PP} \to b\bar{b})} \gtrsim 15 \left(\frac{250\text{ MeV}}{\Delta M}\right), \tag{58}$$

for a Higgs boson of mass $M_H = 120$ GeV.

(a) exclusive

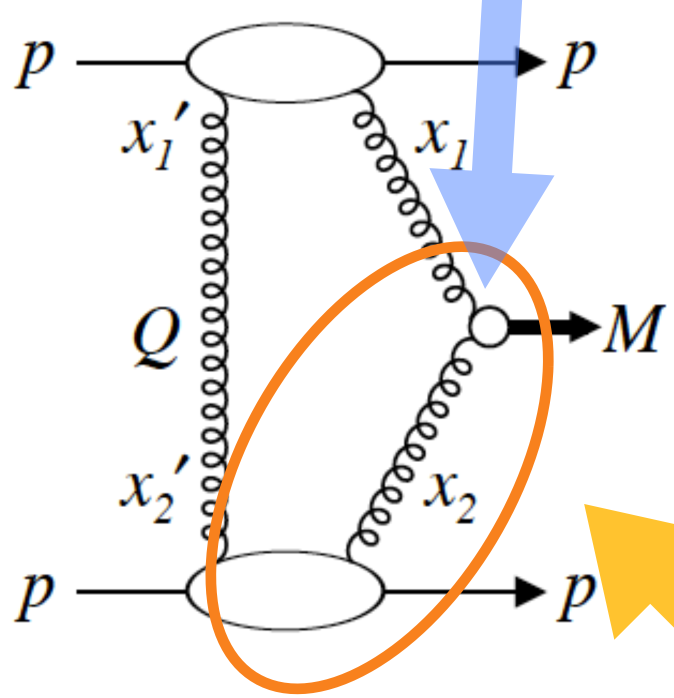


Figure 1: Different mechanisms for the double-diffractive production of a system of mass M in high energy proton-proton collisions.

here, according to Khoze et collab., a strong (Sudakov) suppression takes place

as from Khoze et al.
hep-ph/0002072

$$\mathcal{M}(pp \to p + H + p) \;=\; A\pi^3 \int \frac{dQ_T^2}{Q_T^4}\, e^{-S(Q_T^2, M_H^2)}\, f(x_1, Q_T^2)\, f(x_2, Q_T^2),$$

$$S(Q_T^2, M_H^2) \;=\; \int_{Q_T^2}^{M_H^2/4} \frac{C_A \alpha_S(p_T^2)}{\pi} \frac{dE}{E} \frac{dp_T^2}{p_T^2}.$$

Sudakov form factor

$$\mathcal{M}(pp \to p + H + p) \;=\; A\pi^3 \int \frac{dQ_T^2}{Q_T^4}\, f_g(x_1, x_1', Q_T^2, M_H^2/4)\; f_g(x_2, x_2', Q_T^2, M_H^2/4)$$

$$f_g(x, x, Q_T^2, \mu^2) \;=\; \frac{\partial}{\partial \ln Q_T^2}\, \left[T(Q_T, \mu)\, xg(x, Q_T^2) \right],$$

from Dokshitzer Dyakonov Troyan (DDT)

$$T(Q_T, \mu) \;=\; \exp\left(- \int_{Q_T^2}^{\mu^2} \frac{\alpha_S(k_t^2)}{2\pi} \frac{dk_t^2}{k_t^2} \int \left[zP_{gg}(z) \;+\; \sum_q P_{qg} \right] dz \right).$$

Sudakov-like form factor

$$f_g(x, x', Q_T^2, M_H^2/4) \;=\; R_g\, \frac{\partial}{\partial \ln Q_T^2}\, \left[\sqrt{T(Q_T, M_H/2)}\, xg(x, Q_T^2) \right]$$

Summary (from Khoze et al.)

We have calculated the cross sections for exclusive and inclusive double diffractive Higgs boson, and also dijet, production in the central region, at both LHC and Tevatron energies. That is

$$\begin{aligned} pp &\rightarrow p + (H \text{ or } jj) + p \\ pp &\rightarrow X + (H \text{ or } jj) + Y \end{aligned} \qquad (38)$$

where + denotes a rapidity gap. These processes are driven by 'asymmetric' two gluon exchange, with the colour screening gluon being comparatively soft, but still in the perturbative QCD domain.

driven by the same S_{spec} factor in the same kinematic region. Unfortunately even our most optimistic predictions for the Higgs process are considerably smaller than previous estimates, and would make the process hard to observe at the Tevatron and the LHC.

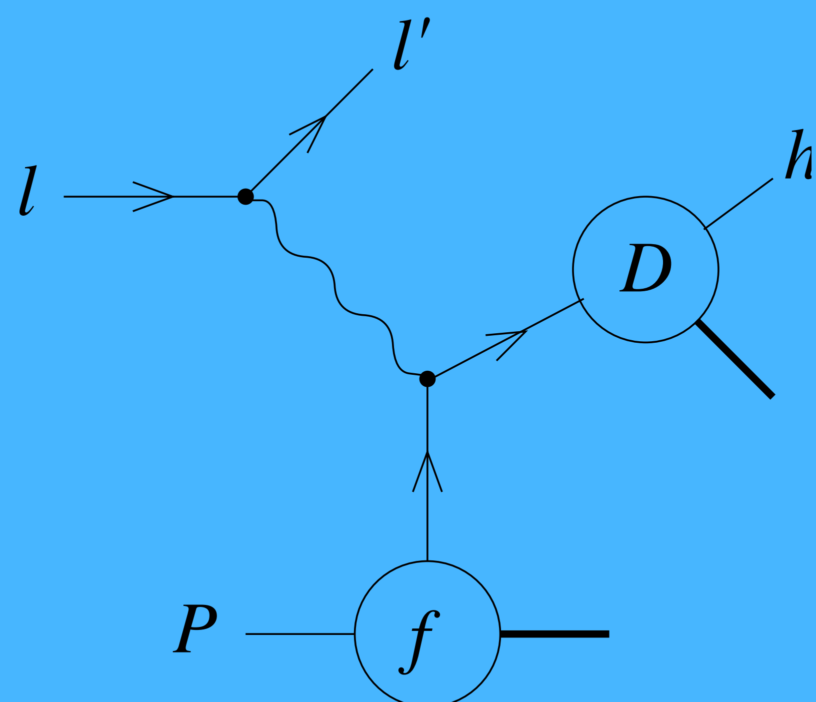
Let us follow a different approach

i.e. the one of the Fracture Functions to describe diffraction

or in other words
the usual approach we use to transfer the long distance non-perturbative effects from one process (once measured and parametrized) to another one

Let us give a closer look to Fracture Functions
as, for example, in the Deep Inelastic Scattering (DIS)
case where FF were initially defined

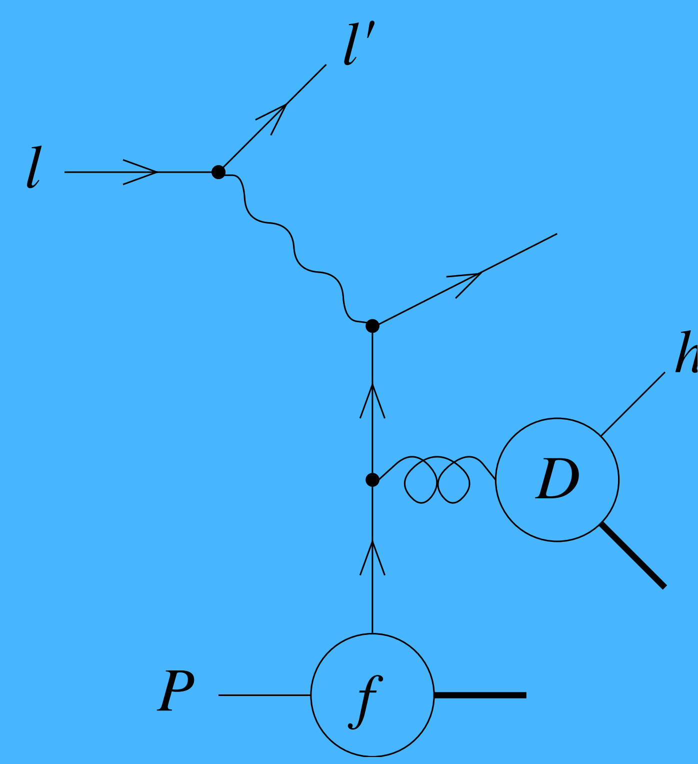
Semi Inclusive Deep Inelastic Scattering
Current Fragmentation

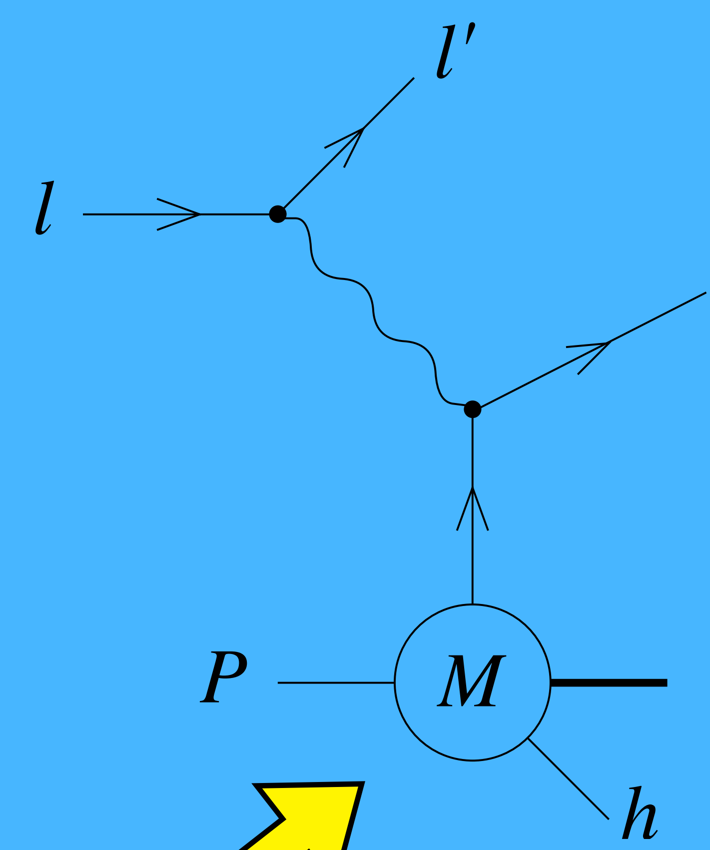


$$\sigma_C = \int \frac{dx'}{x'}\frac{dz'}{z'} F_P^i(x', Q^2)\,\hat{\sigma}_{ij}(x/x', z_h/z', Q^2)\,D_h^j(z', Q^2)$$

Hadrons may also come from elsewhere !

Semi Inclusive Deep Inelastic Scattering
Target Fragmentation





Fracture Function

$$\sigma_T = \int \frac{dx'}{x'} M^i_{Ph'}(x', z_h, Q^2)\, \hat{\sigma}_i(x/x', Q^2)$$

$L.T.\ G.Veneziano, Phys.Lett.B323(1994)201.$

Fracture Functions = Fragmentation + structure

Properties:

- Do not depend on the arbitrary choosen scale Q_0^2 i.e.

$$\frac{\partial}{\partial Q_0^2} M_{p,h}^j(x,z,Q^2) \;=\; 0$$

- Both $D_l^h(x,Q^2)$ and $F_p^i(x,Q^2)$ satisfy the usual Altarelli Parisi evolution equations and $\sum_h \int_0^1 \; dz \; z \; D_l^h(x,Q^2) = 1$ and $\sum_i \int_0^1 \; dx \; x \; F_p^i(x,Q^2) = 1$ with

$$\sum_i \int_0^1 du \; u \; P_i^j(u) \;=\; 0 \tag{8}$$

$M_{p,h}^j(x,z,Q^2)$ satisfies the momentum sum rule:

$$\sum_h \int_0^1 dz \; z \; M_{p,h}^j(x,z,Q^2) \;=\; (1-x) \; F_p^j(x,Q^2)$$

accounting for the s-channel unitarity constraint.

The combination of the Fracture Function with the target-Fragmentation evolution
gives the evolution equation:

$$\frac{\partial}{\partial \log Q^2} M_{i,h/p}\left(\xi, \zeta, Q^2\right) = \frac{\alpha_s(Q^2)}{2\pi} \int_{\xi/(1-\zeta)}^{1} \frac{du}{u} \, P_j^i(u) \, M_{j,h/N}\left(\frac{\xi}{u}, \zeta, Q^2\right)$$
$$+ \frac{\alpha_s(Q^2)}{2\pi} \int_{\xi}^{\xi/(\xi+\zeta)} \frac{du}{\xi(1-u)} \, \hat{P}_j^{i,l}(u) \, f_{j/p}\left(\frac{\xi}{u}, Q^2\right) \, D_{h/l}\left(\frac{\zeta u}{\xi(1-u)}, Q^2\right)$$

Homogeneus (usual Altarelli Parisi type) term + Inhomogeneus term

Several properties:

1) Fracture Functions satisfy unitarity

$$\sum_h \int_0^1 dz\, z\, M^j_{p,h}(x,z;\mu^2) = (1-x) \cdot F^j_p(x,\mu^2).$$

2) Fracture Functions factorize

*M.Grazzini, L.Trentadue and G.Veneziano, Nucl.Phys.B*519(1998)394
*J.Collins, Phys.Rev.D*57(1998)3051

3) Extended $M(x,z,t,Q^2)$-Fracture Functions satisfy Gribov-Lipatov-Altarelli-Parisi type evolution equations

$$Q^2 \frac{\partial}{\partial Q^2} \mathcal{M}^j_{A,A'}(x,z,t,Q^2) = \frac{\alpha_S(Q^2)}{2\pi} \int_{\frac{x}{1-z}}^1 \frac{du}{u} P^j_i(u) \mathcal{M}^i_{A,A'}(x/u,z,t,Q^2)$$

Applications:

Diffraction:

$$e^-(k) + A(P) \to e^-(k') + A(P') + X$$

- According to the Ingelman-Schlein model,

[G.Ingelman and P.Schlein, Phys.Lett. **B152** (1985) 256.]

the diffractive structure function $F_2^{diff}(x, Q^2)$ is

$$F_2^{diff}(x, Q^2) = \sum_a \int d\xi \frac{df_{a/P}^{diff}(\xi, \mu, x_P, t)}{dx_P dt} \hat{\sigma}(\frac{x}{\xi}, Q^2, \mu)$$

But

$$\int_0^\infty d|t| \frac{df_{a/P}^{diff}(\xi, \mu, x_P, t)}{dx_P dt} = M_{AA}(\xi, \mu, z = 1 - x_P)$$

- Analyzing $F_2^{D(3)}(\beta, \mu, x_P)$, H1 collaboration at HERA observed a possible Q^2 dependence of the diffractive distributions

$$\Downarrow$$

A logarithmic dependence on Q^2 is implicitely contained in fracture functions!

DESY 05-011
January 2005

Study of deep inelastic inclusive and diffractive scattering with the ZEUS forward plug calorimeter

ZEUS Collaboration

steeper with increasing Q^2. The latter observation excludes the description of diffractive deep inelastic scattering in terms of the exchange of a single Pomeron. The ratio of diffractive to total cross section is constant as a function of W, in contradiction to the expectation of Regge phenomenology combined with a naive extension of the optical theorem to $\gamma^* p$ scattering. Above M_X of 8 GeV, the ratio is flat with Q^2, indicating a leading-twist behaviour of the diffractive cross section. The data are also presented in terms of the diffractive structure function, $F_2^{D(3)}(\beta, x_{I\!P}, Q^2)$, of the proton. For fixed β, the Q^2 dependence of $x_{I\!P} F_2^{D(3)}$ changes with $x_{I\!P}$ in violation of Regge factorisation. For fixed $x_{I\!P}$, $x_{I\!P} F_2^{D(3)}$ rises as $\beta \to 0$, the rise accelerating with increasing Q^2. These positive scaling violations suggest substantial contributions of perturbative effects in the diffractive DIS cross section.

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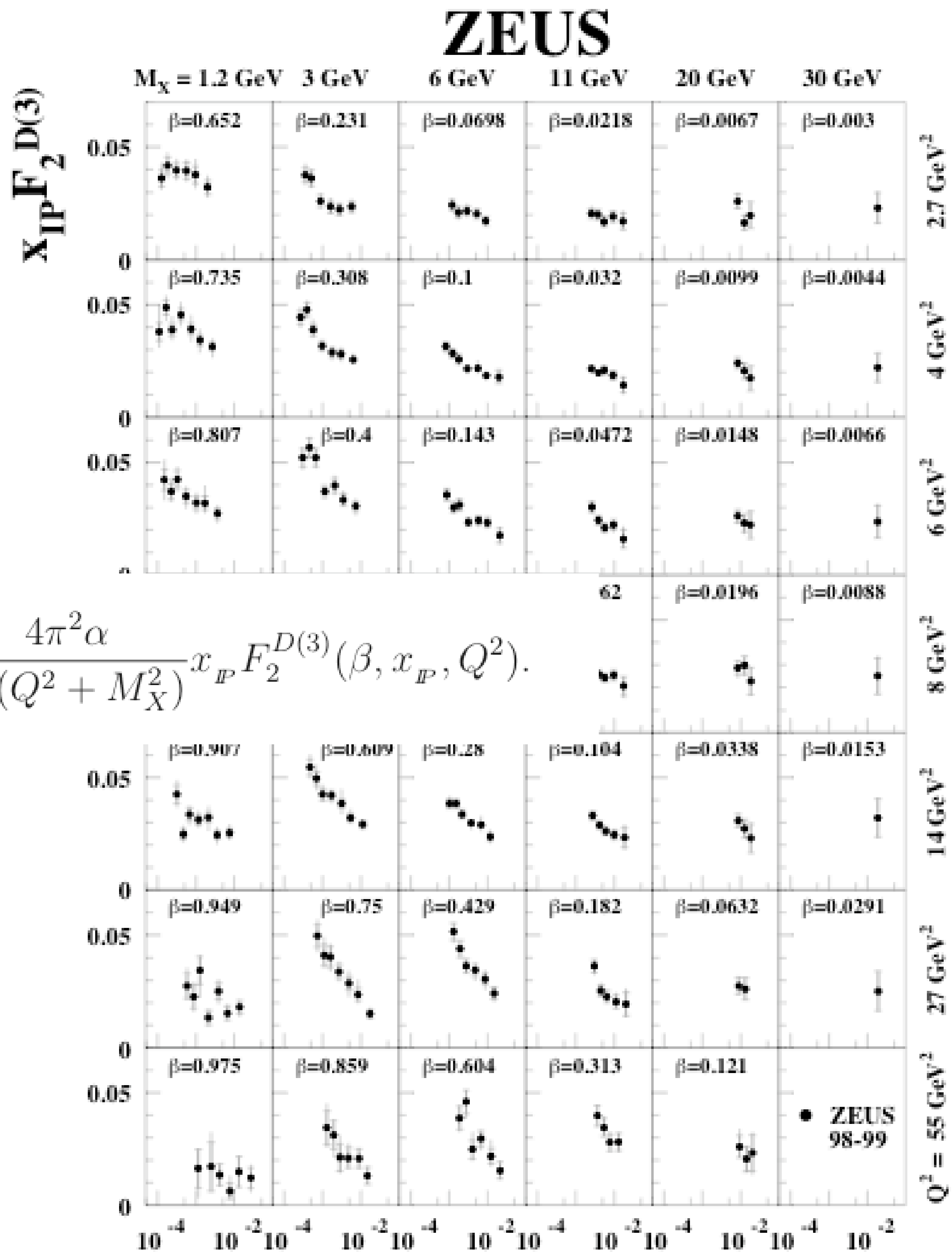


$$\frac{1}{2M_X}\frac{d\sigma^{\text{diff}}_{\gamma^* p\to XN}(M_X,W,Q^2)}{dM_X} = \frac{4\pi^2\alpha}{Q^2(Q^2+M_X^2)}x_{_{I\!P}}F_2^{D(3)}(\beta,x_{_{I\!P}},Q^2).$$

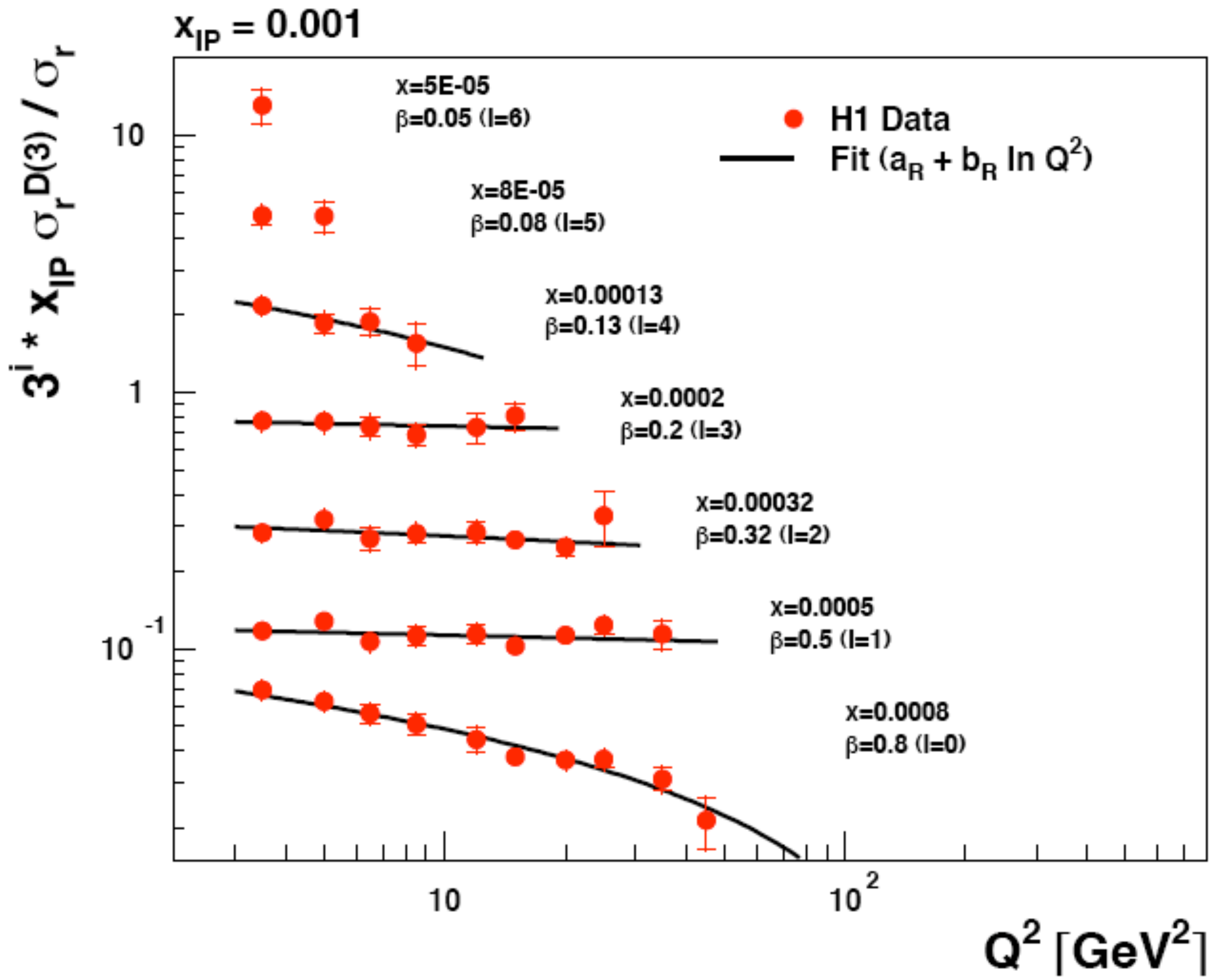


Fig. 14. As Fig.13 with $x_{I\!P} = 0.001$. From Ref.[38]

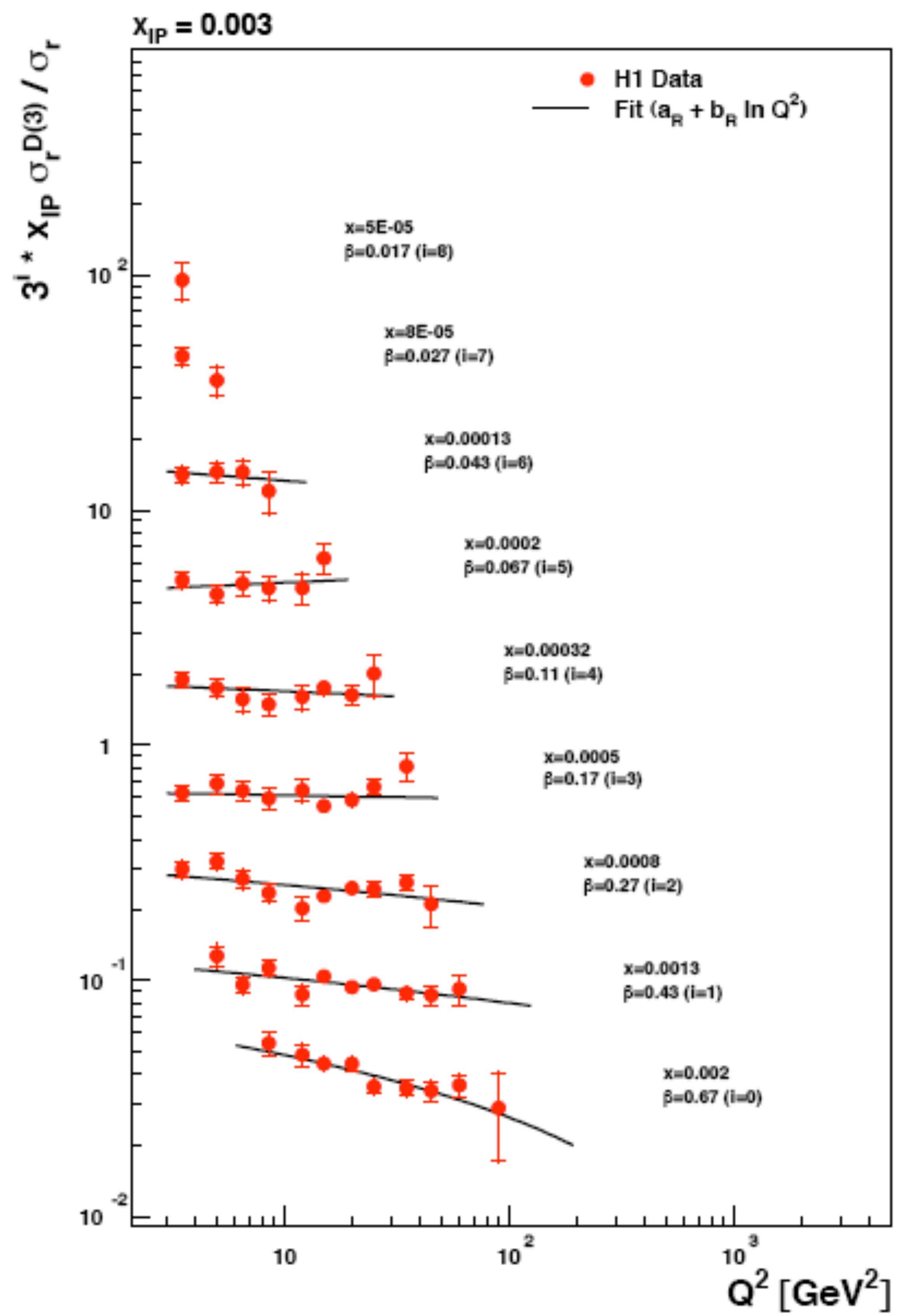
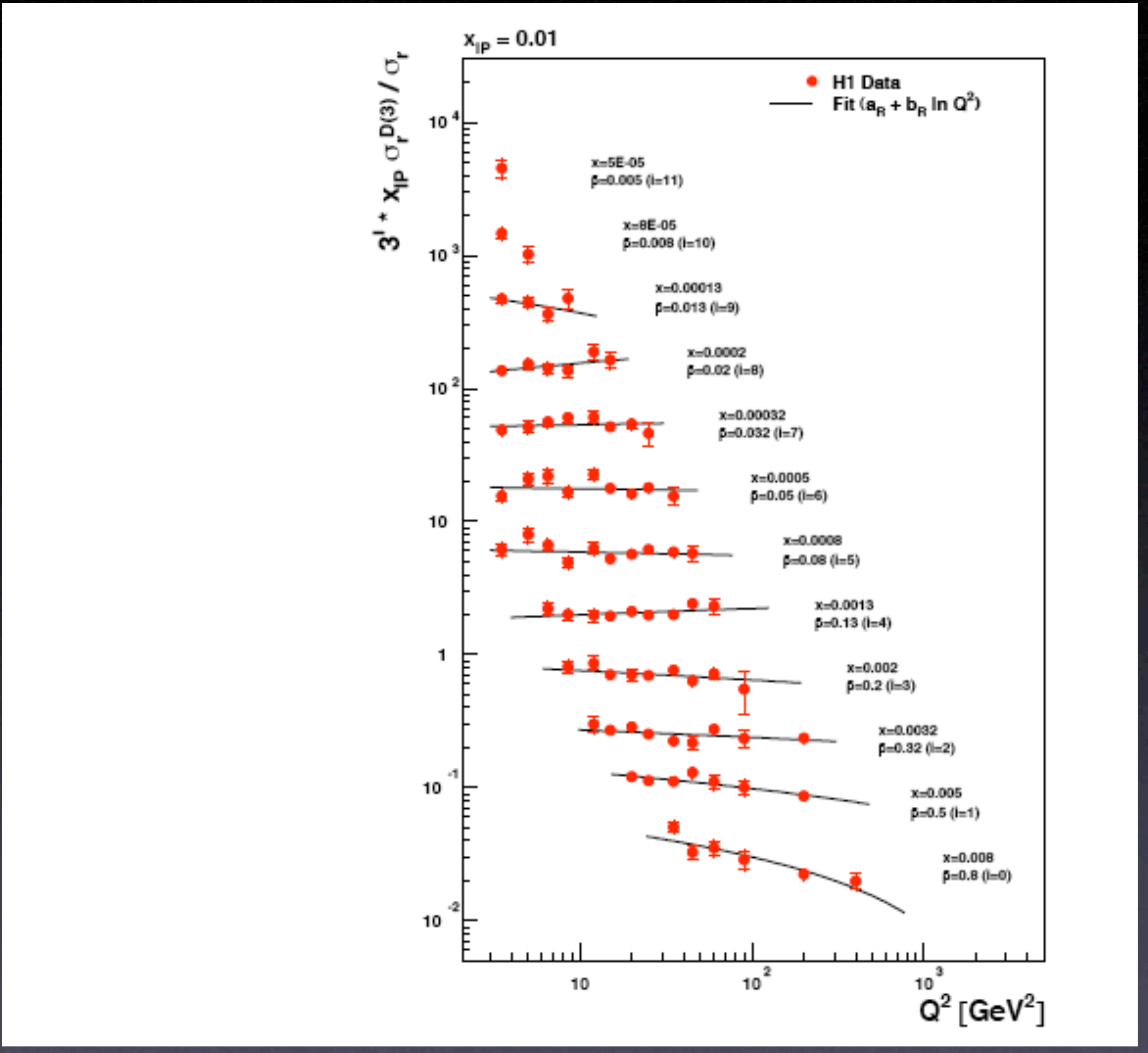


Fig. 15. As Fig.13 with $x_{IP} = 0.003$. From Ref.[38]



x_IP = 0.01
H1 Data
Fit (a_R + b_R ln Q²)
x=5E-05 β=0.005 (i=11)
x=8E-05 β=0.008 (i=10)
x=0.00013 β=0.013 (i=9)
x=0.0002 β=0.02 (i=8)
x=0.00032 β=0.032 (i=7)
x=0.0005 β=0.05 (i=6)
x=0.0008 β=0.08 (i=5)
x=0.0013 β=0.13 (i=4)
x=0.002 β=0.2 (i=3)
x=0.0032 β=0.32 (i=2)
x=0.005 β=0.5 (i=1)
x=0.008 β=0.8 (i=0)
Q² [GeV²]

Next-to-leading Fracture Functions

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Next to leading order evolution of SIDIS processes in the forward region*

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We compute the order α_s^2 quark initiated corrections to semi-inclusive deep inelastic scattering extending the approach developed recently for the gluon contributions. With these corrections we complete the order α_s^2 QCD description of these processes, verifying explicitly the factorization of collinear singularities. We also obtain the corresponding NLO evolution kernels, relevant for the scale dependence of fracture functions. We compare the non-homogeneous evolution effects driven by these kernels with those obtained at leading order accuracy and discuss their phenomenological implications.

PACS numbers: 12.38.Bx, 13.85.Ni
Keywords: Semi-Inclusive DIS; perturbative QCD; Fracture functions

$$
\frac{\partial\, M^r_{i,h/P}(\xi,\zeta,M^2)}{\partial \log M^2} = \frac{\alpha_s(M^2)}{2\pi} \int_{\frac{\xi}{1-\zeta}}^{1} \frac{du}{u} \left[P^{(0)}_{i\leftarrow j}(u) + \frac{\alpha_s(M^2)}{2\pi} P^{(1)}_{i\leftarrow j}(u) \right] M^r_{j,h/P}\left(\frac{\xi}{u},\zeta,M^2\right)
$$
$$
+ \frac{\alpha_s(M^2)}{2\pi} \frac{1}{\xi} \int_{\xi}^{\frac{\xi}{\xi+\zeta}} \frac{du}{u} \int_{\frac{\zeta}{\xi}}^{\frac{1-u}{u}} \frac{dv}{v} \left[\hat{P}^{(0)}_{ki\leftarrow j}(u,v) + \frac{\alpha_s(M^2)}{2\pi} P^{(1)}_{ki\leftarrow j}(u,v) \right] f^r_{j/P}\left(\frac{\xi}{u},M^2\right) D^r_{h/k}\left(\frac{\zeta}{\xi\, v},M^2\right) ,
$$

Recently (2012)
the H1 collaboration

DESY 12-041
March 2012

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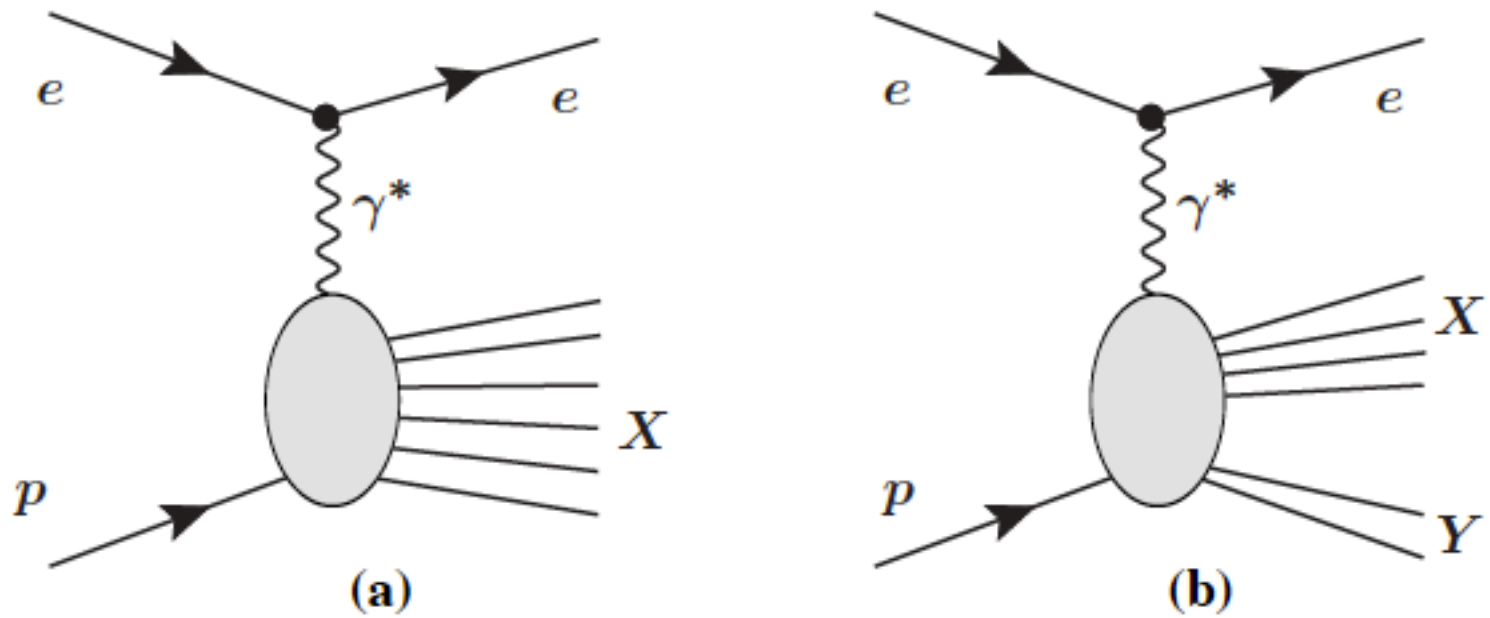
Inclusive Measurement of Diffractive Deep-Inelastic Scattering at HERA

H1 Collaboratio

Abstract

The diffractive process $ep \rightarrow eXY$, where Y (tation with $M_Y < 1.6$ GeV, is studied with the H1 restricted to the phase space region of the photon virtuality $3 \leq Q^2 \leq 1600$ GeV^2, the square of the four-momentum transfer at the proton vertex $|t| < 1.0$ GeV^2 and the longitudinal momentum fraction of the incident proton carried by the colourless exchange $x_{I\!P} < 0.05$. Triple differential cross sections are measured as a function of $x_{I\!P}$, Q^2 and $\beta = x/x_{I\!P}$ where x is the Bjorken scaling variable. These measurements are made after selecting diffractive events by demanding a large empty rapidity interval separating the final state hadronic systems X and Y. High statistics measurements covering the data taking periods 1999-2000 and 2004-2007 are combined with previously published results in order to provide a single set of diffractive cross sections from the H1 experiment using the large rapidity gap selection method. The combined data represent a factor between three and thirty increase in statistics with respect to the previously published results. The measurements are compared with predictions from NLO QCD calculations based on diffractive parton densities and from a dipole model. The proton vertex factorisation hypothesis is tested.



$$ep \to epX$$

p

Figure 1: Inclusive (a) and diffractive (b) deep inelastic scattering.

The study and interpretation of diffraction at HERA provides essential inputs for the understanding of quantum chromodynamics (QCD) at high parton densities. The sensitivity of the diffractive cross section to the gluon density at low values of Bjorken x can explain the high rate of diffractive events. Diffractive reactions may therefore be well suited to search for saturation effects in the proton structure when x reaches sufficiently small values [16].

$$\frac{\mathrm{d}^3\sigma^{ep\to eXY}}{\mathrm{d}Q^2\,\mathrm{d}\beta\,\mathrm{d}x_{I\!P}} = \frac{4\pi\alpha_{\mathrm{em}}^2}{\beta Q^4}\left[\left(1-y+\frac{y^2}{2}\right)F_2^{D(3)}(\beta,Q^2,x_{I\!P}) - \frac{y^2}{2}F_L^{D(3)}(\beta,Q^2,x_{I\!P})\right],$$

$$\begin{aligned}\sigma_r^{D(3)}(Q^2,\beta,x_{I\!P}) &= \frac{\beta Q^4}{4\pi\alpha_{em}^2}\,\frac{1}{(1-y+\frac{y^2}{2})}\,\frac{\mathrm{d}^3\sigma^{ep\to eXY}}{\mathrm{d}Q^2\,\mathrm{d}\beta\,\mathrm{d}x_{I\!P}}\\ &= F_2^{D(3)} - \frac{y^2}{1+(1-y)^2}F_L^{D(3)}\ .\end{aligned}$$

$$\beta = \frac{Q^2}{Q^2+M_X^2}; \qquad x_{I\!P} = \frac{x}{\beta}\ .$$

$$\sigma_r^{D(3)}(Q^2,\beta,x_{\mathcal{P}})$$

$$ep \to epX \quad M_X \le 1.6\ GeV \quad t \le 1GeV$$

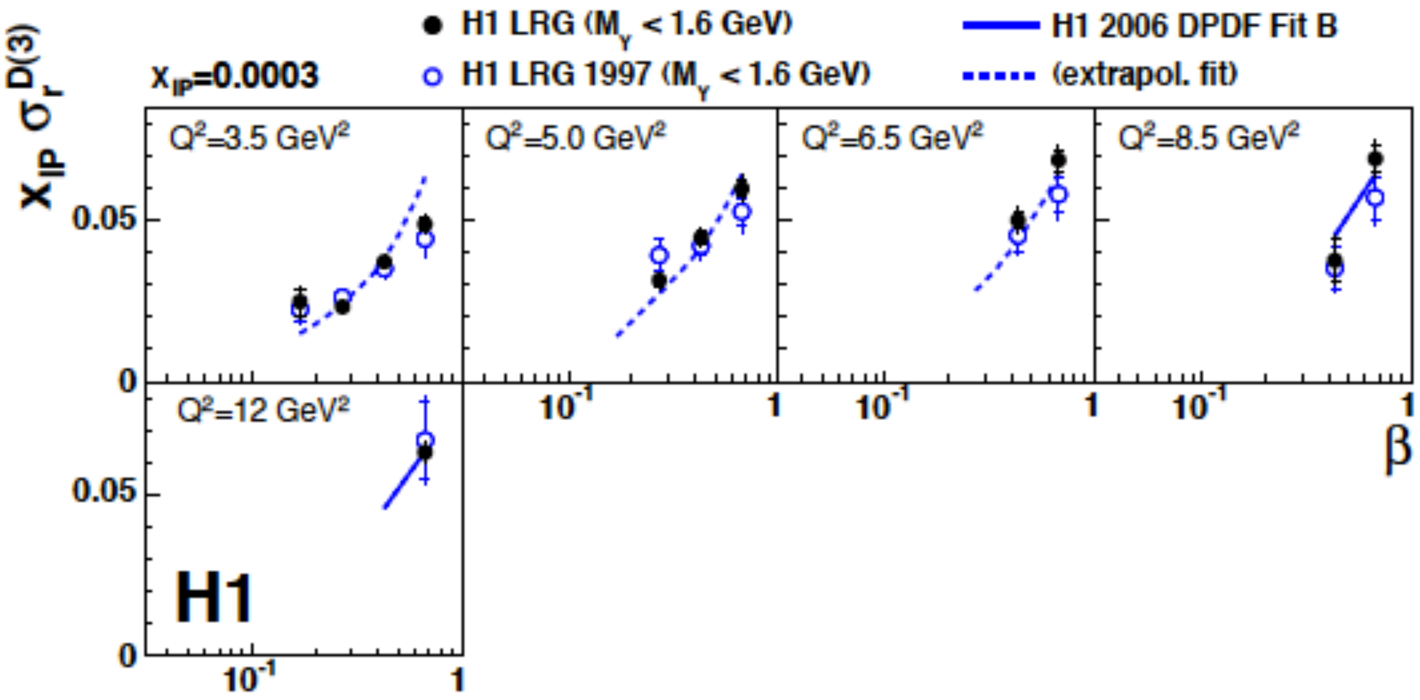


Figure 3: The β dependence of the reduced diffractive cross section, multiplied by $x_{I\!P}$, at a fixed value of $x_{I\!P} = 0.0003$, resulting from the combination of all data samples. Previously published H1 measurements [10] are also displayed as open points. The inner and outer error bars on the data points represent the statistical and total uncertainties, respectively. Overall normalisation uncertainties of 4% and 6.2% on the combined and previous data, respectively, are not shown. Predictions from the H1 2006 DPDF Fit B [10] are represented by a curve in kinematic regions used to determine the DPDFs and by a dashed line in regions which were excluded from the fit (see section 4.3).

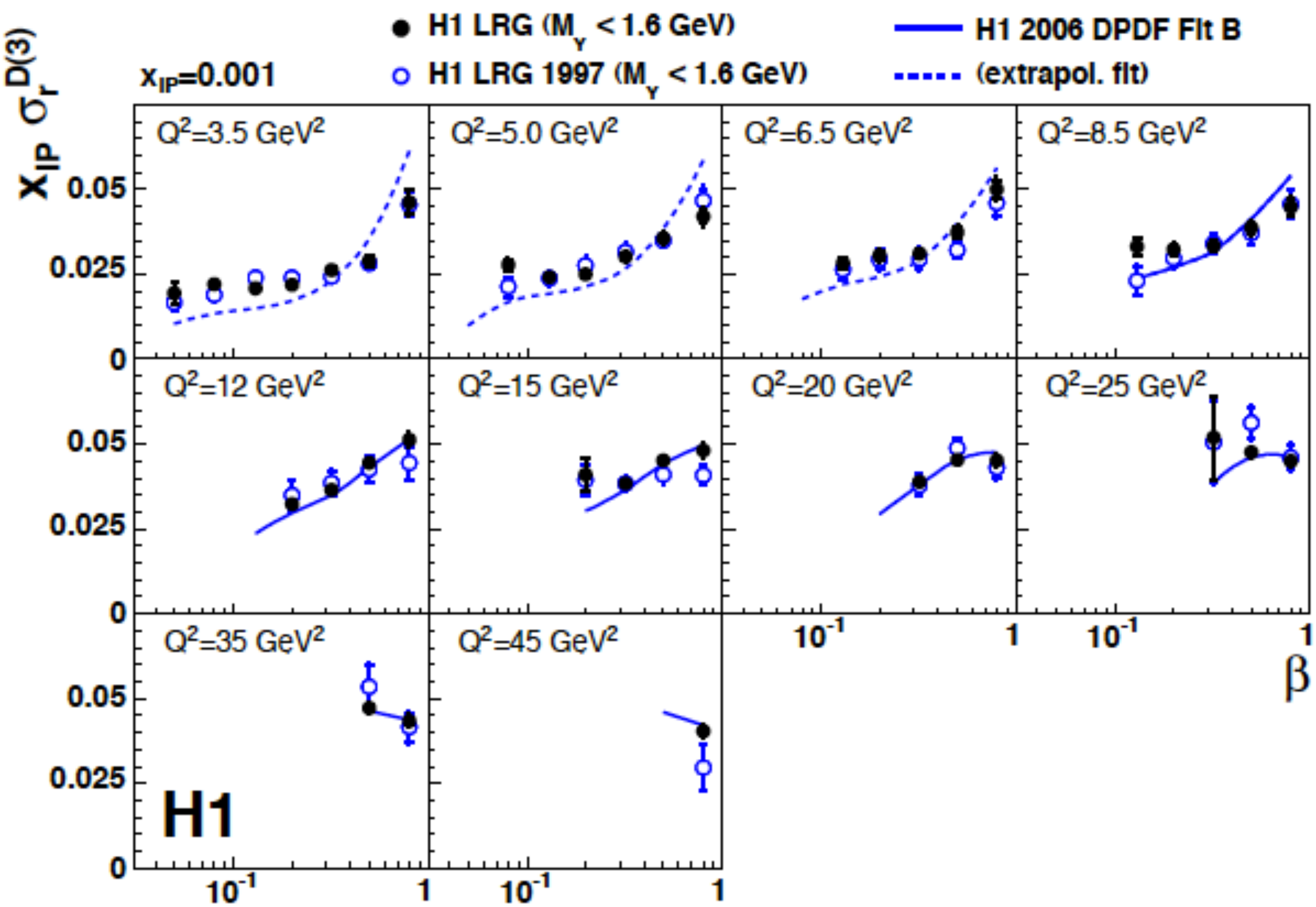


Figure 4: The β dependence of the reduced diffractive cross section, multiplied by $x_{I\!P}$, at a fixed value of $x_{I\!P} = 0.001$, resulting from the combination of all data samples. Details are explained in the caption of figure 3.

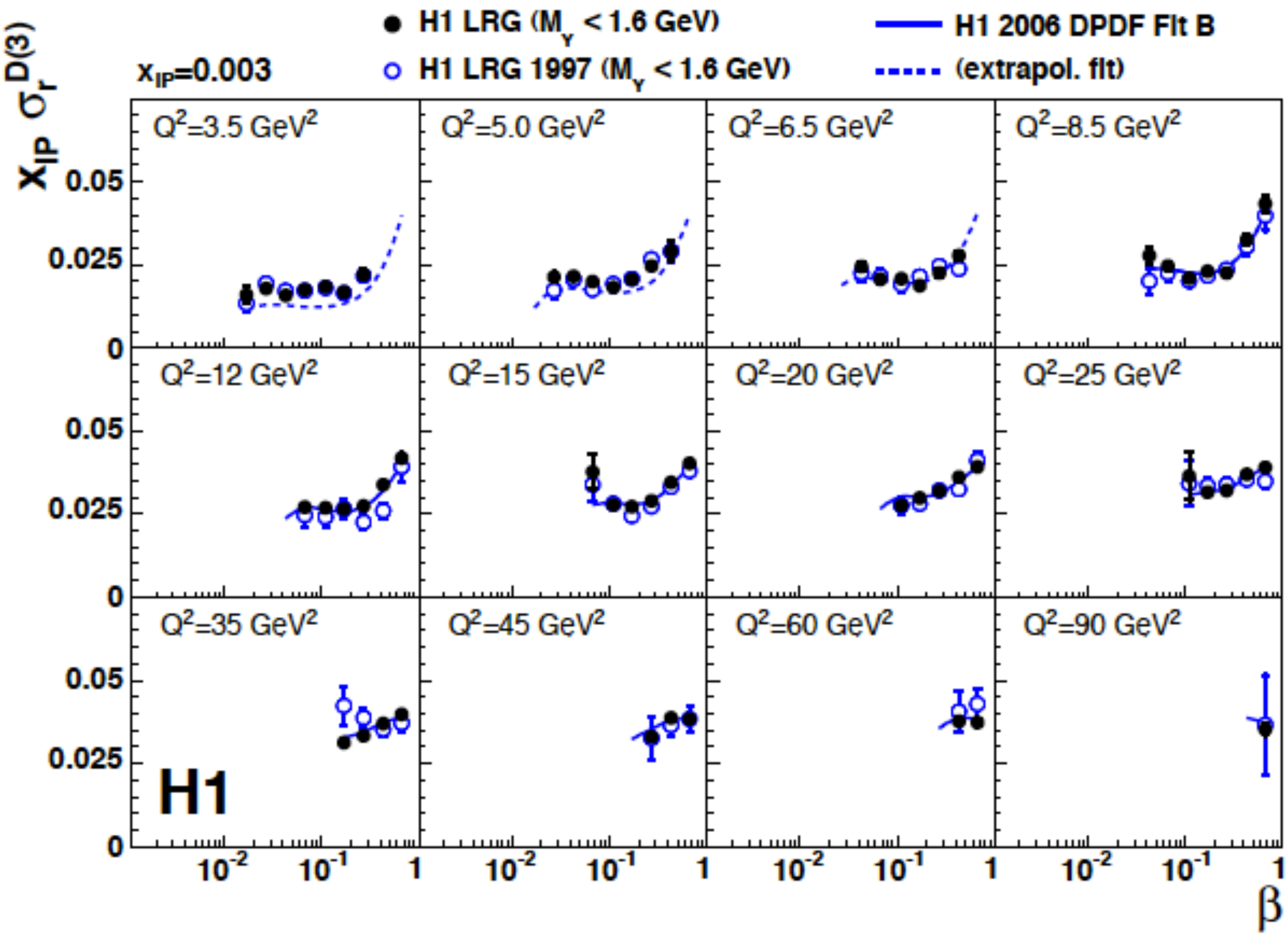


Figure 5: The β dependence of the reduced diffractive cross section, multiplied by $x_{I\!P}$, at a fixed value of $x_{I\!P} = 0.003$, resulting from the combination of all data samples. Details are explained in the caption of figure 3.

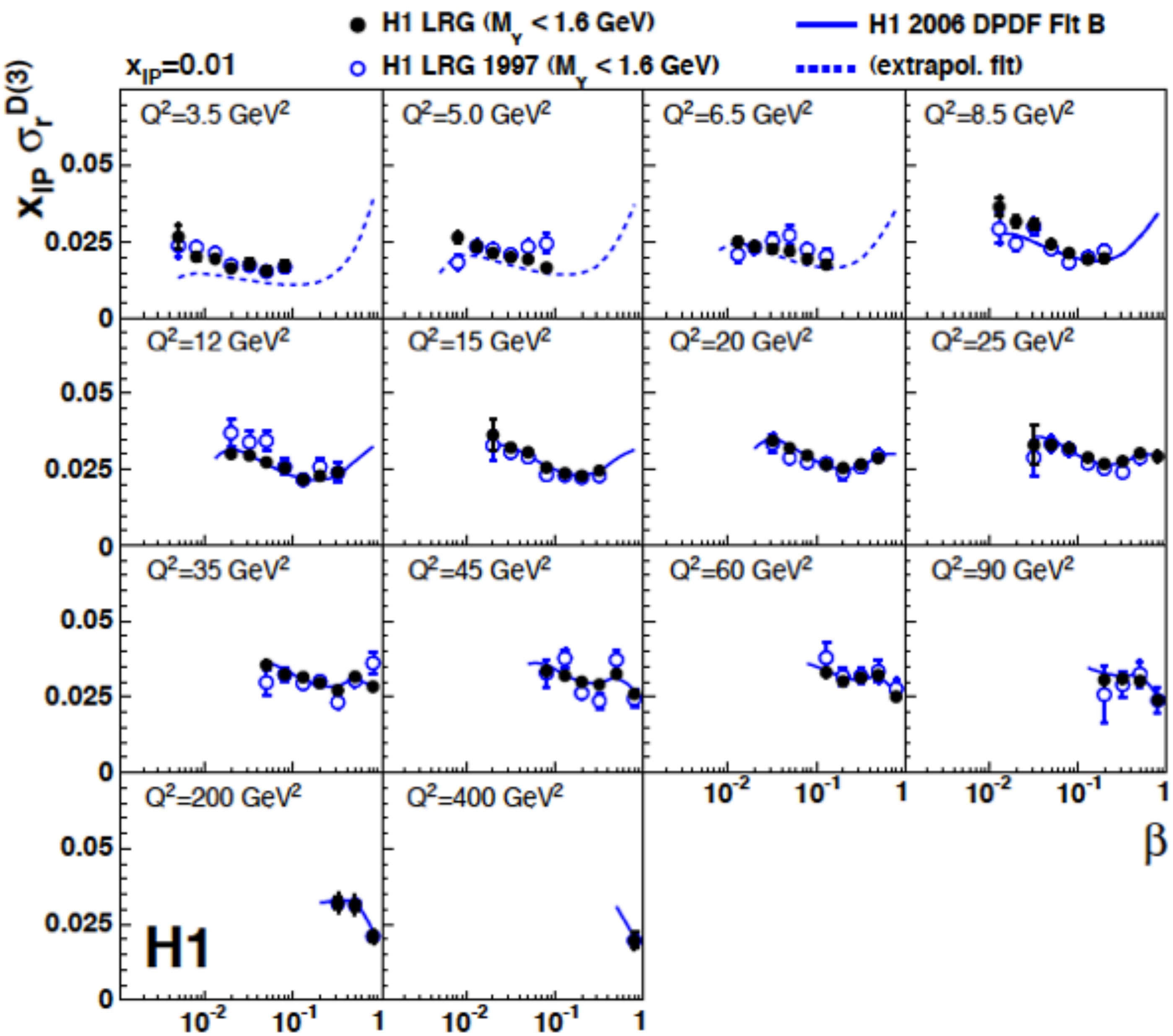


Figure 6: The β dependence of the reduced diffractive cross section, multiplied by $x_{I\!P}$, at a fixed value of $x_{I\!P} = 0.01$, resulting from the combination of all data samples. Details are explained in the caption of figure 3.

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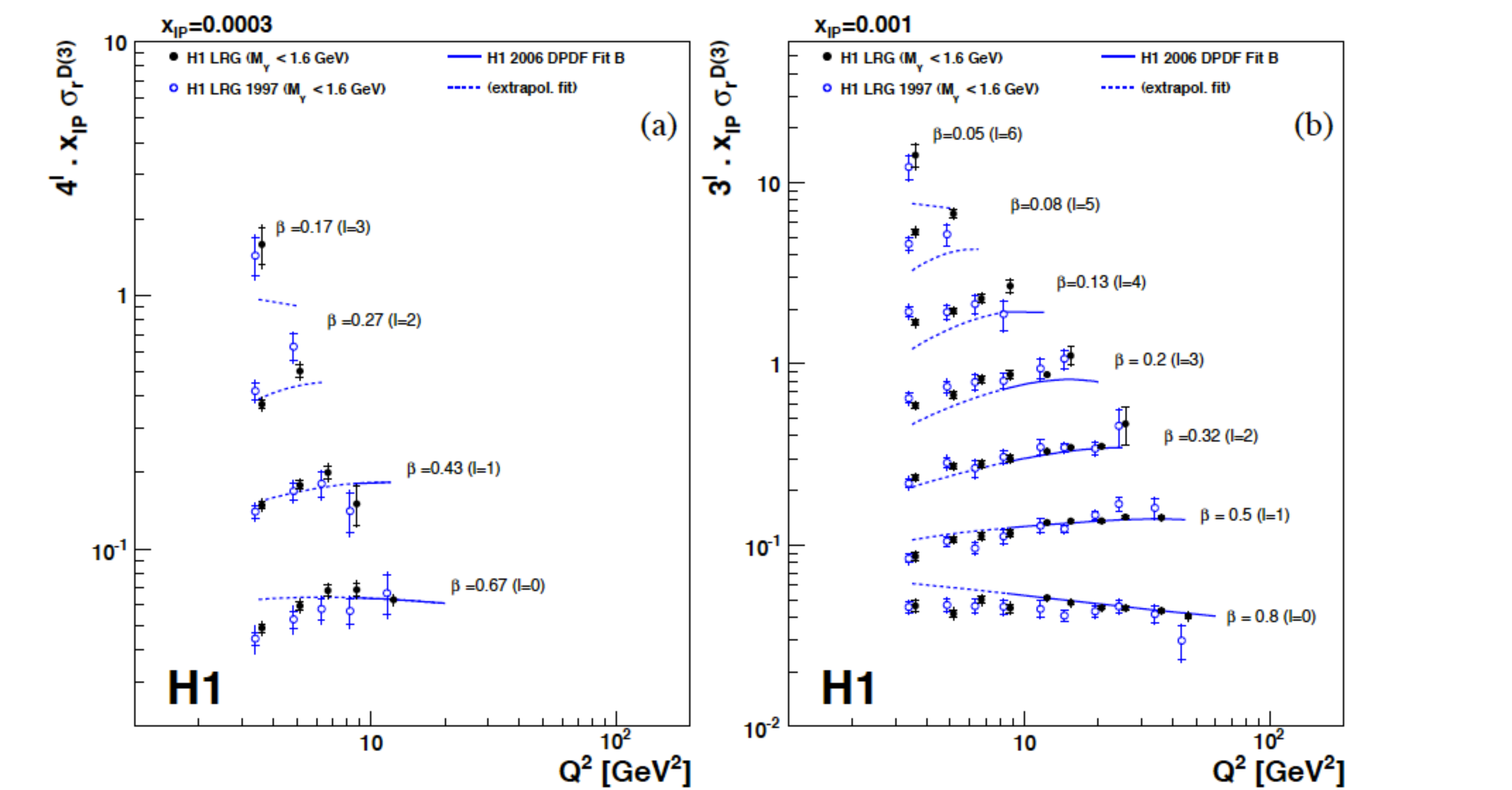
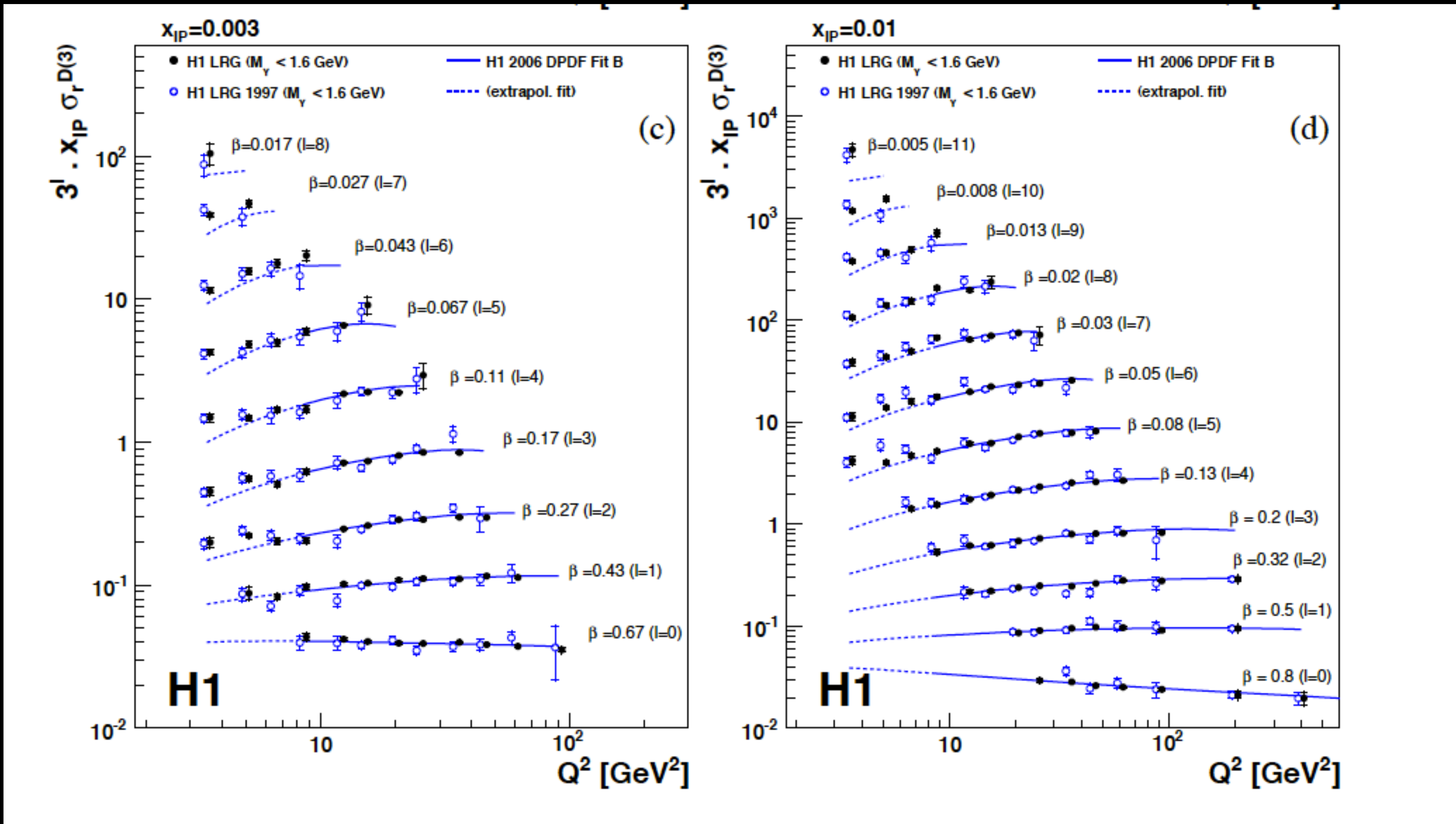
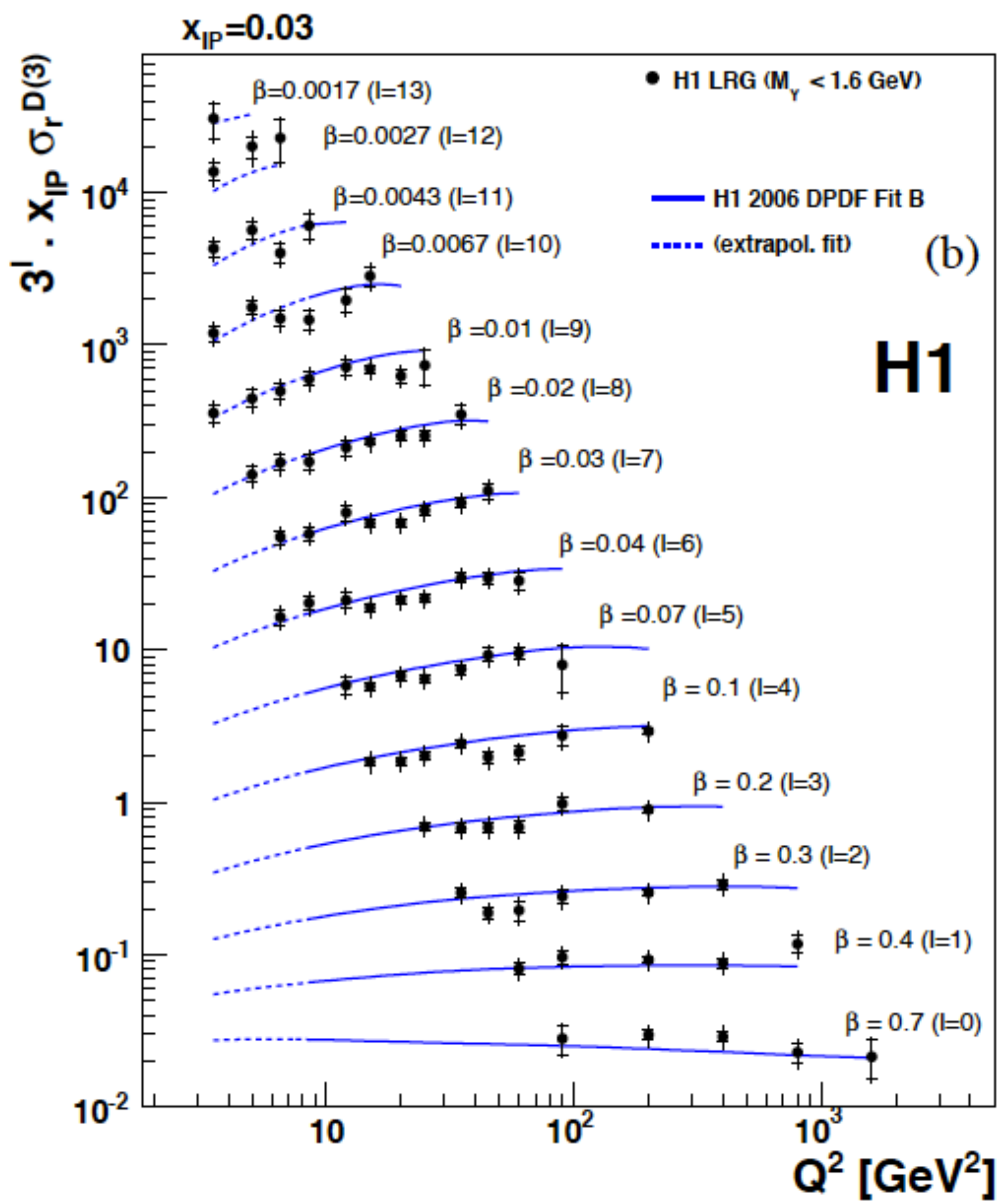


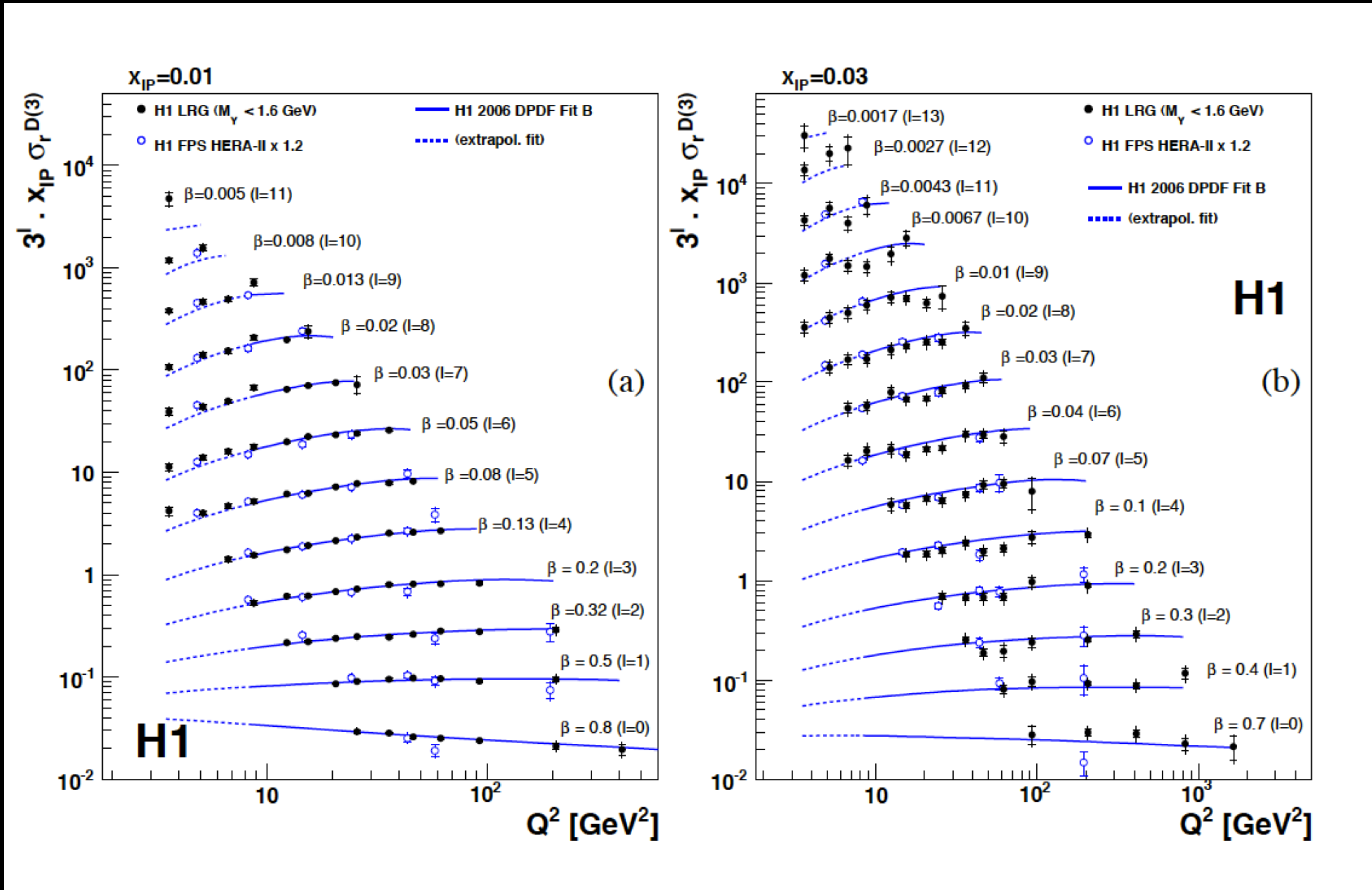
x_{IP}=0.0003
$4^l \cdot x_{IP}\,\sigma_r^{D(3)}$
H1 LRG (M_Y < 1.6 GeV)
H1 LRG 1997 (M_Y < 1.6 GeV)
H1 2006 DPDF Fit B
(extrapol. fit)
(a)
β =0.17 (l=3)
β =0.27 (l=2)
β =0.43 (l=1)
β =0.67 (l=0)
H1
Q^2 [GeV^2]
x_{IP}=0.001
$3^l \cdot x_{IP}\,\sigma_r^{D(3)}$
H1 LRG (M_Y < 1.6 GeV)
H1 LRG 1997 (M_Y < 1.6 GeV)
H1 2006 DPDF Fit B
(extrapol. fit)
(b)
β=0.05 (l=6)
β=0.08 (l=5)
β=0.13 (l=4)
β = 0.2 (l=3)
β =0.32 (l=2)
β = 0.5 (l=1)
β = 0.8 (l=0)
H1
Q^2 [GeV^2]



x_{IP}=0.003
x_{IP}=0.01
H1 LRG (M_Y < 1.6 GeV)
H1 LRG 1997 (M_Y < 1.6 GeV)
H1 2006 DPDF Fit B
(extrapol. fit)
(c)
(d)
$3^l \cdot x_{IP} \sigma_r^{D(3)}$
β=0.017 (l=8)
β=0.027 (l=7)
β=0.043 (l=6)
β=0.067 (l=5)
β =0.11 (l=4)
β =0.17 (l=3)
β =0.27 (l=2)
β =0.43 (l=1)
β =0.67 (l=0)
β=0.005 (l=11)
β=0.008 (l=10)
β=0.013 (l=9)
β=0.02 (l=8)
β =0.03 (l=7)
β =0.05 (l=6)
β =0.08 (l=5)
β =0.13 (l=4)
β = 0.2 (l=3)
β =0.32 (l=2)
β = 0.5 (l=1)
β = 0.8 (l=0)
H1
Q^2 [GeV^2]

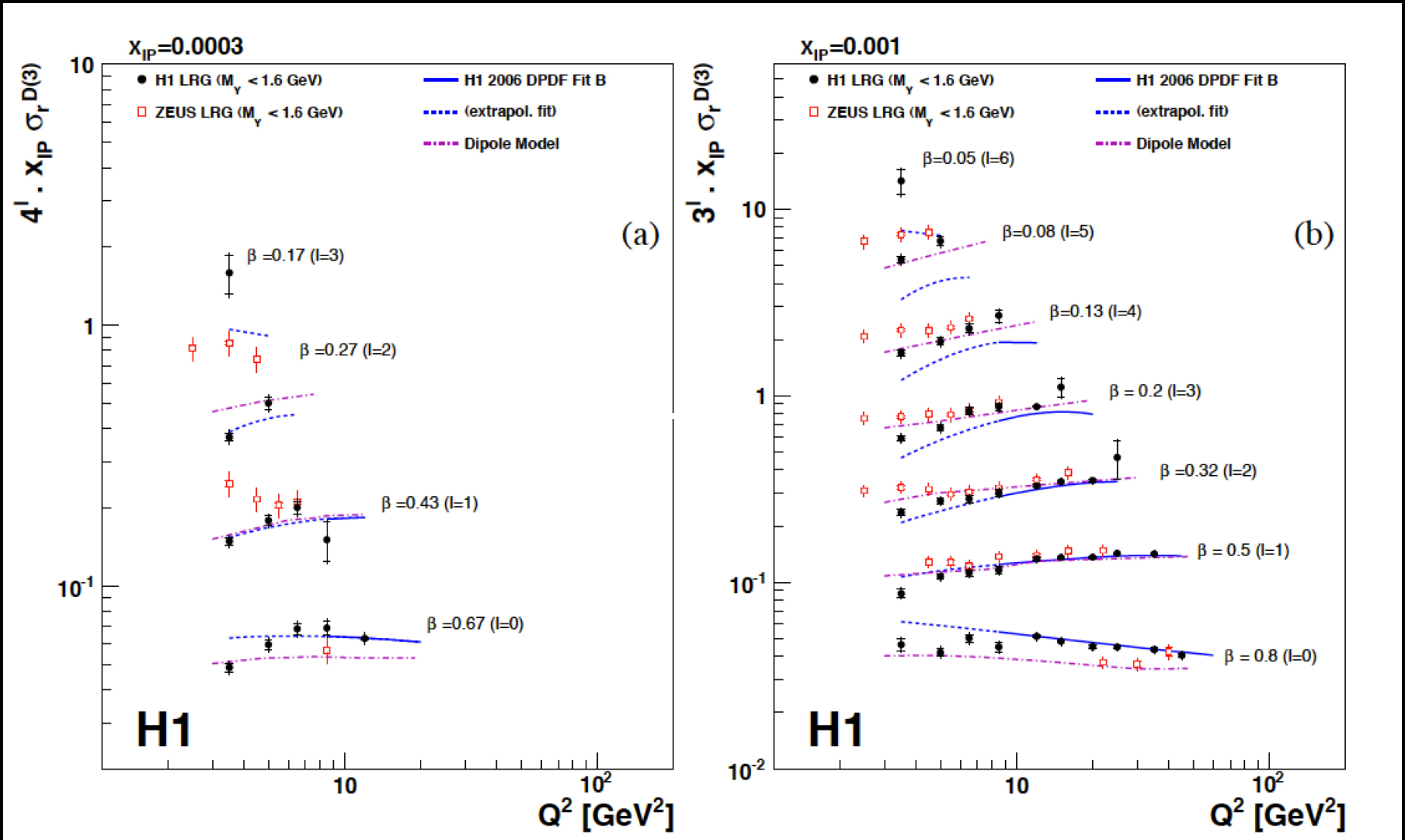


x_{IP}=0.03
$3^l \cdot x_{IP}\,\sigma_r^{D(3)}$
H1 LRG (M_Y < 1.6 GeV)
H1 2006 DPDF Fit B
(extrapol. fit)
(b)
H1
β=0.0017 (l=13)
β=0.0027 (l=12)
β=0.0043 (l=11)
β=0.0067 (l=10)
β =0.01 (l=9)
β =0.02 (l=8)
β =0.03 (l=7)
β =0.04 (l=6)
β =0.07 (l=5)
β = 0.1 (l=4)
β = 0.2 (l=3)
β = 0.3 (l=2)
β = 0.4 (l=1)
β = 0.7 (l=0)
Q^2 [GeV^2]

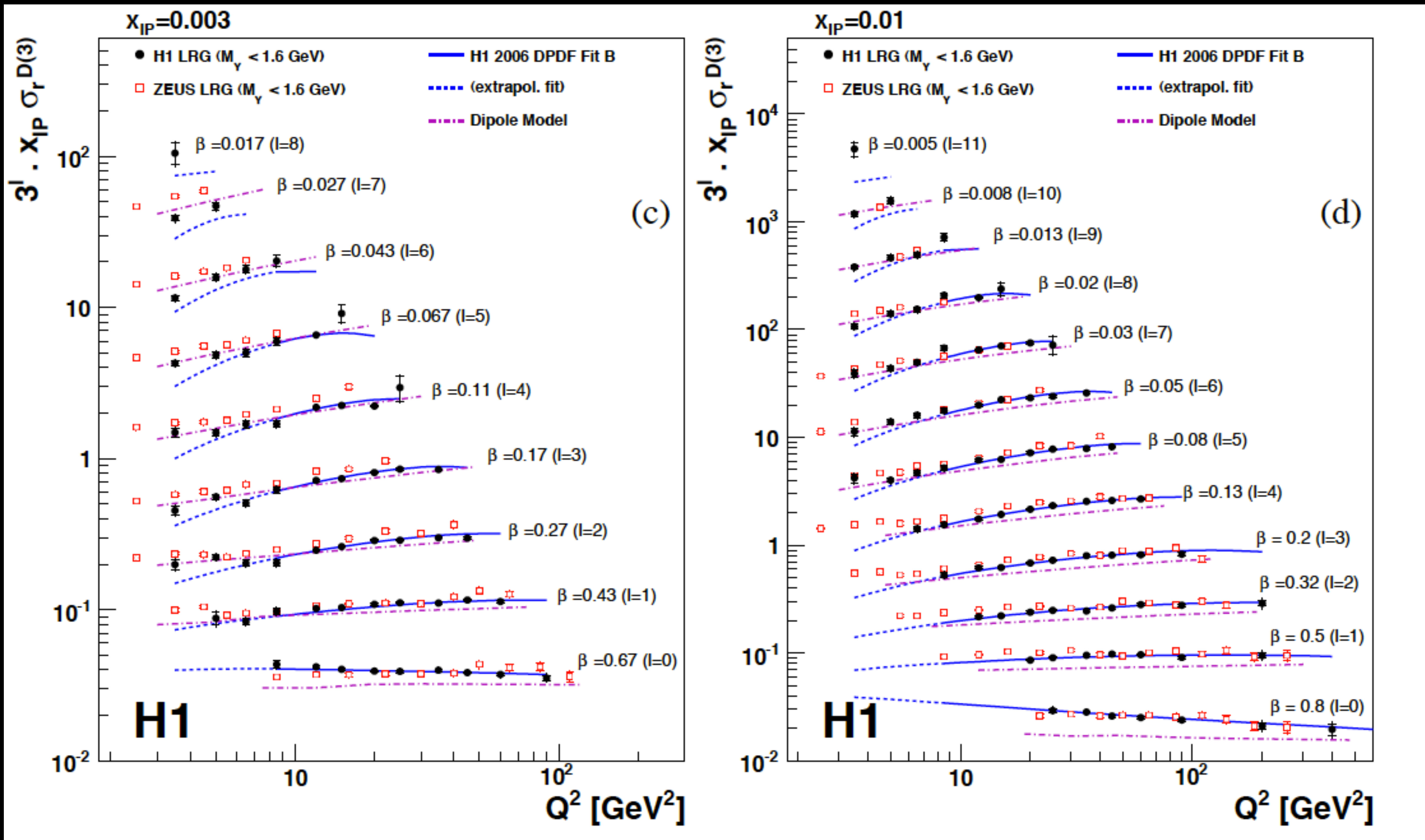


x_{IP}=0.01
H1 LRG (M_Y < 1.6 GeV)
H1 FPS HERA-II x 1.2
H1 2006 DPDF Fit B
(extrapol. fit)
β=0.005 (I=11)
β=0.008 (I=10)
β=0.013 (I=9)
β =0.02 (I=8)
β =0.03 (I=7)
β =0.05 (I=6)
β =0.08 (I=5)
β =0.13 (I=4)
β = 0.2 (I=3)
β =0.32 (I=2)
β = 0.5 (I=1)
β = 0.8 (I=0)
(a)
H1
x_{IP}=0.03
β=0.0017 (I=13)
β=0.0027 (I=12)
β=0.0043 (I=11)
β=0.0067 (I=10)
β=0.01 (I=9)
β =0.02 (I=8)
β =0.03 (I=7)
β =0.04 (I=6)
β =0.07 (I=5)
β = 0.1 (I=4)
β = 0.2 (I=3)
β = 0.3 (I=2)
β = 0.4 (I=1)
β = 0.7 (I=0)
(b)
H1
$3^I \cdot x_{IP} \sigma_r^{D(3)}$
Q^2 [GeV^2]

Comparison with ZEUS data



the normalization issue



x_{IP}=0.003
$3^l \cdot x_{IP}\, \sigma_r^{D(3)}$
H1 LRG (M_Y < 1.6 GeV)
ZEUS LRG (M_Y < 1.6 GeV)
H1 2006 DPDF Fit B
(extrapol. fit)
Dipole Model
β =0.017 (l=8)
β =0.027 (l=7)
β =0.043 (l=6)
β =0.067 (l=5)
β =0.11 (l=4)
β =0.17 (l=3)
β =0.27 (l=2)
β =0.43 (l=1)
β =0.67 (l=0)
(c)
H1
Q^2 [GeV^2]
x_{IP}=0.01
β =0.005 (l=11)
β =0.008 (l=10)
β =0.013 (l=9)
β =0.02 (l=8)
β =0.03 (l=7)
β =0.05 (l=6)
β =0.08 (l=5)
β =0.13 (l=4)
β = 0.2 (l=3)
β =0.32 (l=2)
β = 0.5 (l=1)
β = 0.8 (l=0)
(d)

Some time ago

4 January 1996

PHYSICS LETTERS B

ELSEVIER

Physics Letters B 365 (1996) 302–308

Estimating diffractive Higgs boson production at LHC from HERA data

D. Graudenz [1,2], G. Veneziano [3]

Theoretical Physics Division, CERN, CH-1211 Geneva 23, Switzerland

Received 1 September 1995
Editor: R. Gatto

Diffractive Higgs

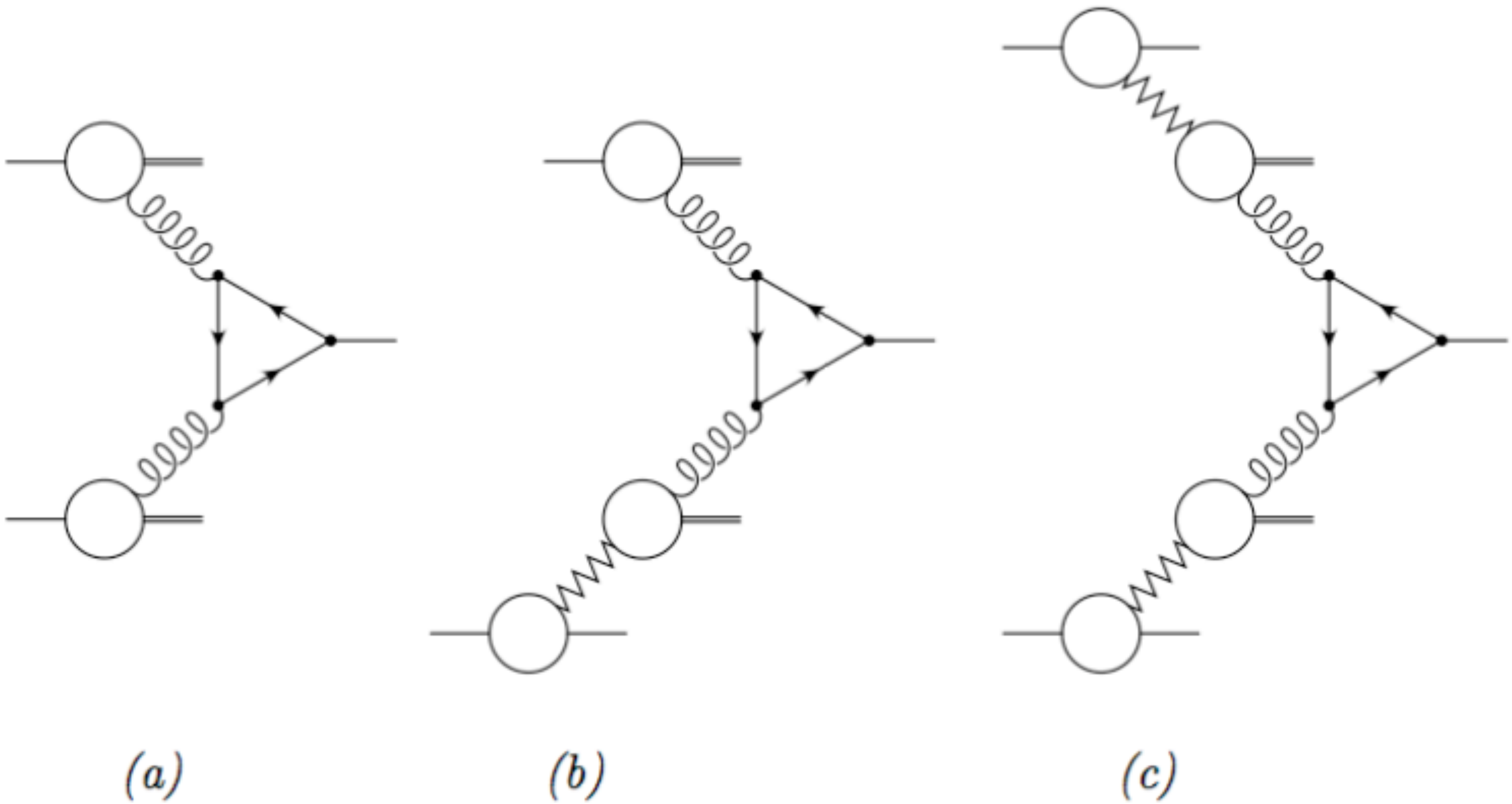


Fig. 1. *Generic diagrams for the total Higgs boson production cross section (a), the single diffractive case (b) and the double diffractive case (c). The quark in the triangle loop is the top quark. Single lines stand for the incident proton and leading outgoing proton, and double lines for the fragments of the proton and Pomeron.*

D. Graudenz, G. Veneziano, Phys. Lett. B365 (1996) 302

Higgs production via gluon fusion

see Graudenz Veneziano

$$\sigma = \int_{\tau_H}^{1} \frac{\mathrm{d}\xi}{\xi}\, g_1(\xi,\mu^2)\, g_2\left(\frac{\tau_H}{\xi},\mu^2\right)\, \tau_H\, \sigma_0\left(\frac{m_H^2}{m_{\mathrm{top}}^2}\right).$$

assuming factorization

with a more undefined set
of
Parton Distribution Functions

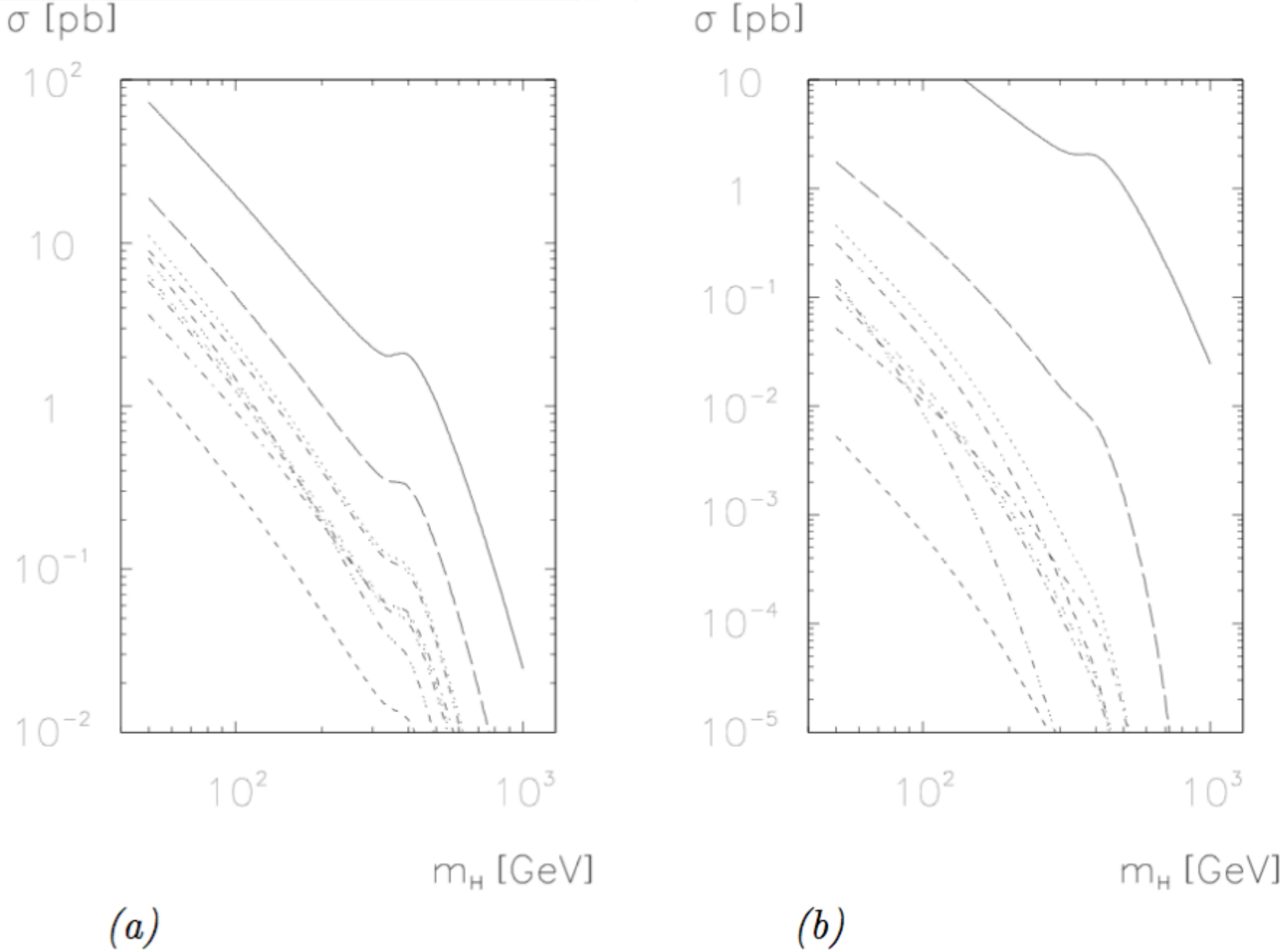
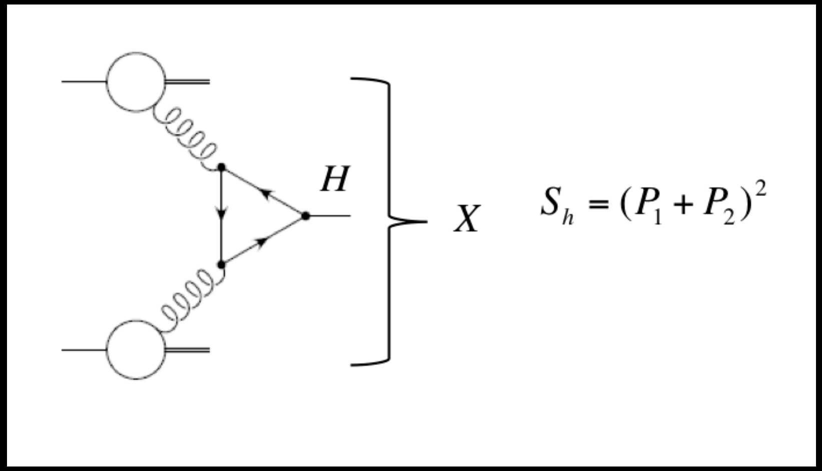
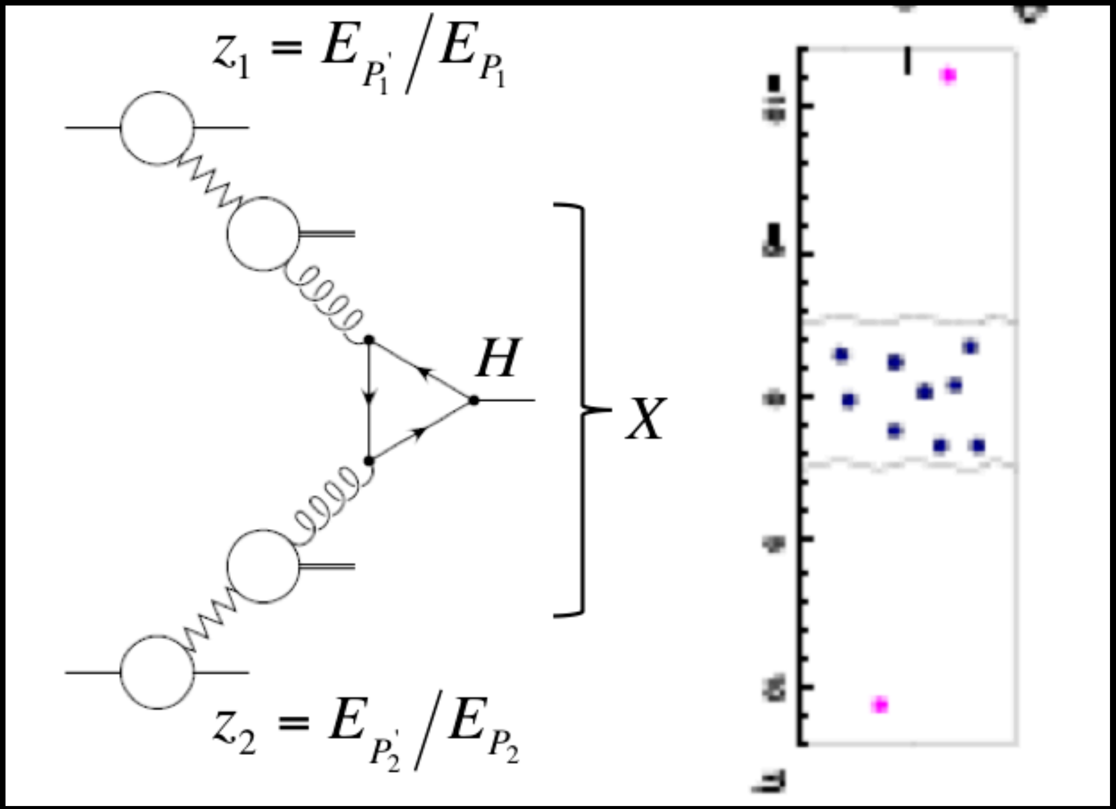
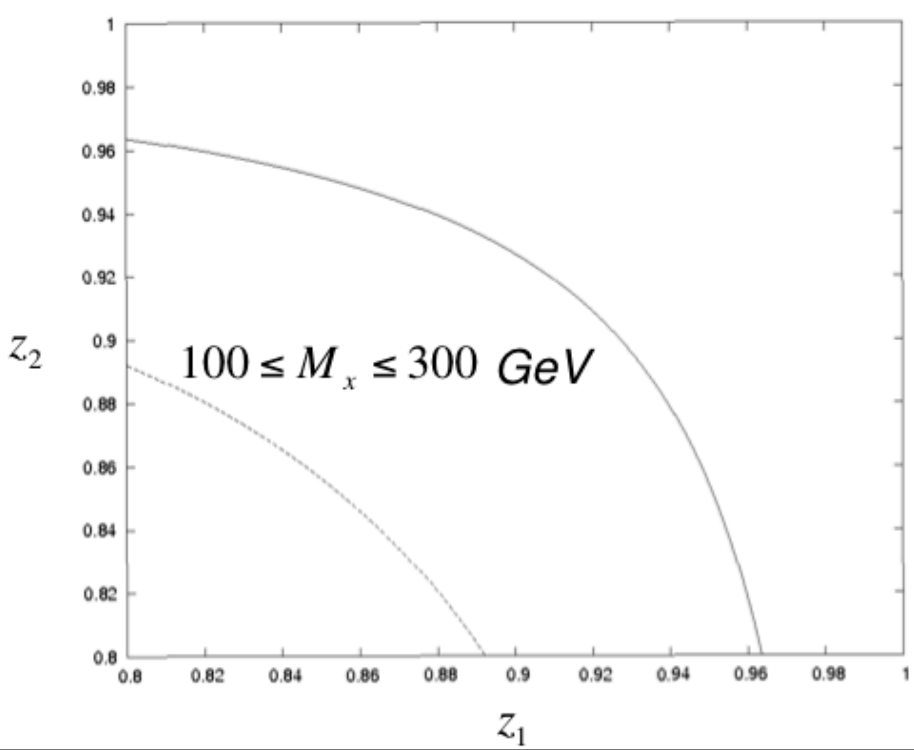


Fig. 3. *Dependence of the single diffractive (a) and double diffractive (b) Higgs boson production cross section on the Higgs boson mass. The full line is the total cross section* $pp \rightarrow gg+X \rightarrow H+X$. *The other line types related to various gluon densities of the Pomeron are defined in Tab. 1.*







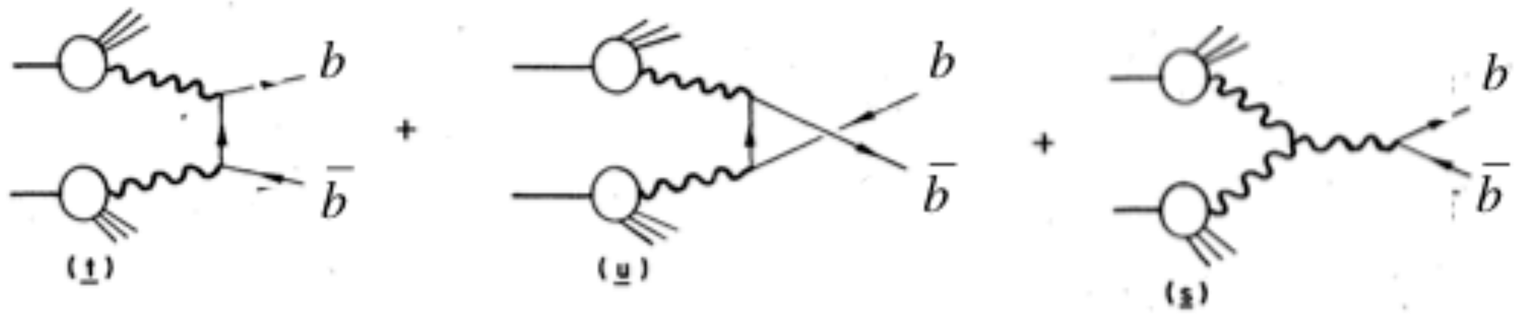
$$M_X^2 = S_h (1 - z_1)(1 - z_2)$$

$$S_h = (P_1 + P_2)^2$$

D.Graudenz, G.Veneziano hep-ph/9508401

- Consider the QCD Background to the Signal $H \to b + \bar{b}$ in the inclusive channel:

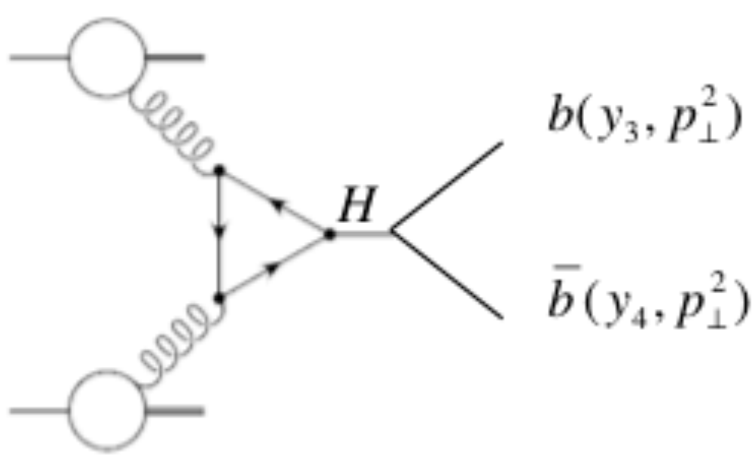
B:



$$\begin{cases} y_i = \dfrac{1}{2}\ln\dfrac{E_i + p_{z,i}}{E_i - p_{z,i}}, \quad i = 3,4 \\ m_T^2 = m_b^2 + p_\perp^2 \\ \hat{s} = 2m_T^2(1+\cosh(y_3 - y_4)) \end{cases}$$

$$\frac{d\sigma}{dy_3 dy_4 d^2 p_\perp} = \frac{1}{16\pi^2 \hat{s}} x_1 g(x_1,\hat{s}) x_2 g(x_2,\hat{s}) \overline{\Sigma}\left|M(gg \to b\bar{b})\right|^2$$

S:



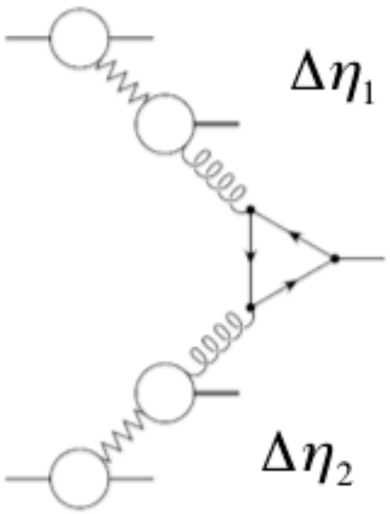
$$R(y_3, y_4, p_\perp^2, m_b^2, m_H^2, m_t^2) = \frac{\overline{\Sigma}\left|M(gg \to H \to b\bar{b})\right|^2}{\overline{\Sigma}\left|M(gg \to b\bar{b})\right|^2}$$

$$\frac{d\sigma}{dy_3 dy_4 d^2 p_\perp} = \frac{1}{16\pi^2 \hat{s}} x_1 g(x_1,\hat{s}) x_2 g(x_2,\hat{s}) \overline{\Sigma}\left|M(gg \to H \to b\bar{b})\right|^2$$

✓The **same ratio** could be formed also in the **diffractive** case, avoiding issues related to factorization (at LO).

✘ the S/B depends on the same matrix elements ratio both in inclusive and in diffractive cases!

The diffractive cross-sections:



$$d\sigma^{(PP\to HX)} \approx \int_{\frac{\tau}{1-z_2}}^{1-z_1} dx_1 \int_{\frac{\tau}{x_1}}^{1-z_2} dx_2 M^{g}_{P_1'/P_1}(x_1,z_1) M^{g}_{P_2'/P_2}(x_2,z_2) d\hat{\sigma}^{(gg\to HX)}$$

- Same $d\hat{\sigma}$ as in the inclusive case.

- The fracture function $M^{g}_{P'/P}$ gives the conditional probability of finding a gluon in the incoming proton P while an outgoing proton P' is measured.

- If protons are not tagged, use LRG method : $\Delta\eta \approx -\ln(1-z)$ (see e.g. J.Collins hep-ph/9705393)

✘ However factorization is violated when DPDF ($M^{g}_{P'/P}$) extracted from HERA are used to reproduce Tevatron diffractive data.

in the pp interaction case

Drell-Yan

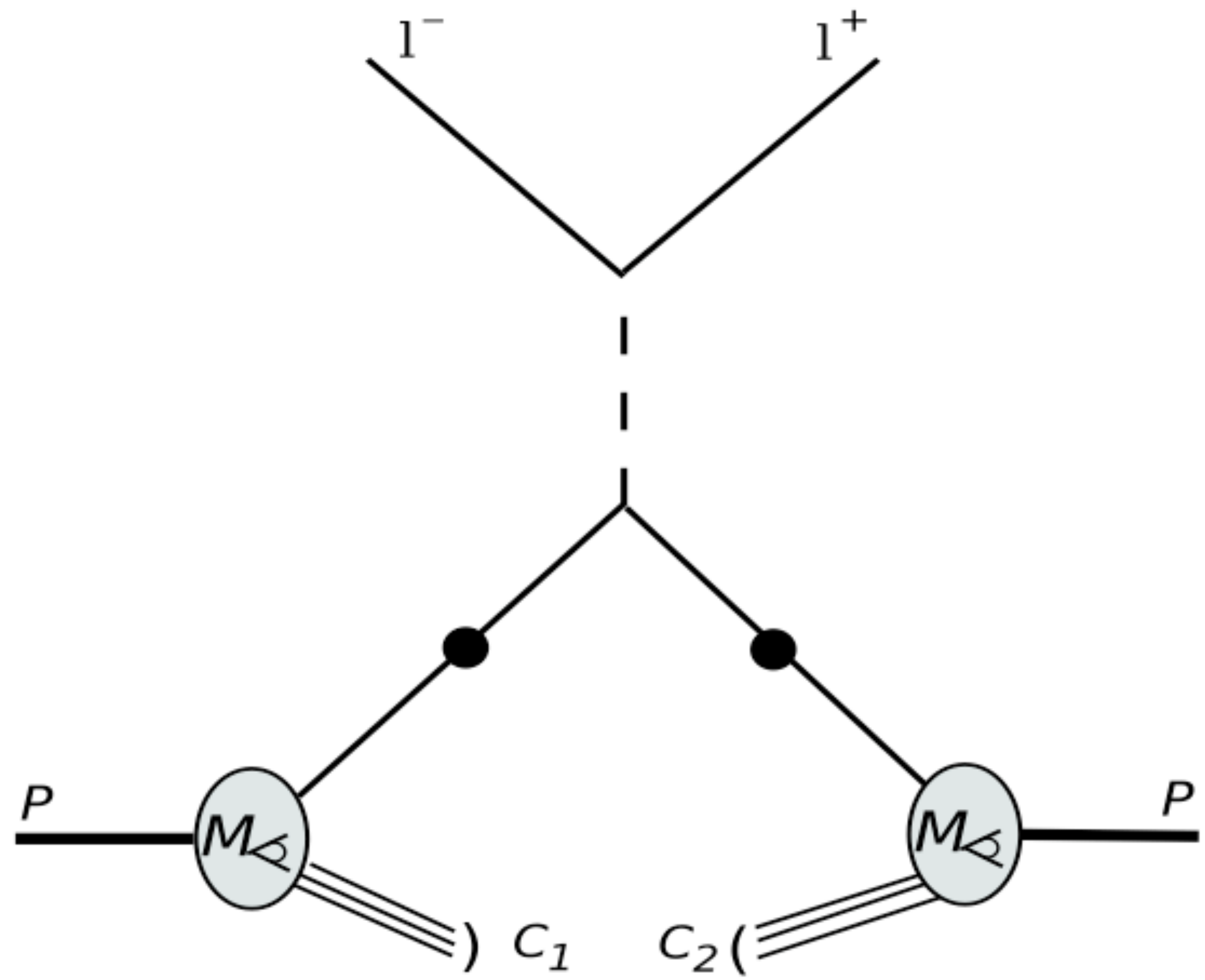
the factorization takes place

semi-inclusive

Drell-Yan

and factorization

$$p + p \to C_1 + C_2 + \gamma^*_{\hookrightarrow\ l^+l^-} + X \,.$$



$$\frac{d\sigma^{DY}}{dt_1 dt_2 dQ^2 dz_1 dz_2} = \sum_{i,j=q,\bar{q}} \int\int dx_1 dx_2 \Big(\mathcal{M}^i_{\triangleleft}(x_1, Q^2, z_1, t_1)\mathcal{M}^j_{\triangleleft}(x_2, Q^2, z_2, t_2) + i \leftrightarrow j\Big)\ \delta(s - x_1 x_2 Q^2)\,,$$

can be used to measure the strenght of the factorization breaking in semi-inclusive hadron hadron collisions

factorization properties of the cross sections can be connected with the observed forward radiation pattern

However

several issues have still to be considered

The assumption of factorization picture. Factorization may break down for certain diffractive processes and thus the expression of the cross section as a convolution of parton densities with a mass-factorized parton-level scattering cross section ceases to be valid in principle (even if a good approximation in practice).

This issue may be studied with paradigmatic processes at high-energy colliders

F. Ceccopieri, L.T., Phys. Lett. B668 (2008) 319

In the mass range of 90 GeV < mH < 130 GeV the single diffractive cross section is between 25% and 10% of the total cross section

The double diffractive cross section is less than about 0.1 pb double diffractive exclusive is about 3 fb (hep-ph/0111078)

Crucial issues are also here :

- The determination of the gluon content of the "exchanged Pomerons" (leading proton tag via Fracture Function approach)

- The accuracy of the determination of the diffractive parton distributions F2 D(3) gluon densities at large scales are not very well constrained by the analysis of F2D(3) at small scales, because it contributes to $O(\alpha s)$ only and because of the large evolution span.

Additional constraints by studying heavy quark and jet production at HERA and possibly at the Tevatron may improve the situation.

A new Method

inspired by the factorization theorem

F.A.Ceccopieri L. Favart (DIS 2012)

for quarks and gluons

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

at a given scale Q_0

instead of using a " Regge Model " parametrization

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

this makes the parametrization of the kind used for the usual (non diffractive) parton distributions

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

with

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

The gluon normalisation is compatible with a single inverse power behaviour of the type:

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

The coefficients B_q and C_q which control the β-shape of the singlet distribution are well described by:

$$\begin{aligned} B_q(x_{I\!P}) &= B_{q,0} + B_{q,1}\, x_{I\!P}\,, \\ C_q(x_{I\!P}) &= C_{q,0} + C_{q,1}\, x_{I\!P}\,. \end{aligned}$$

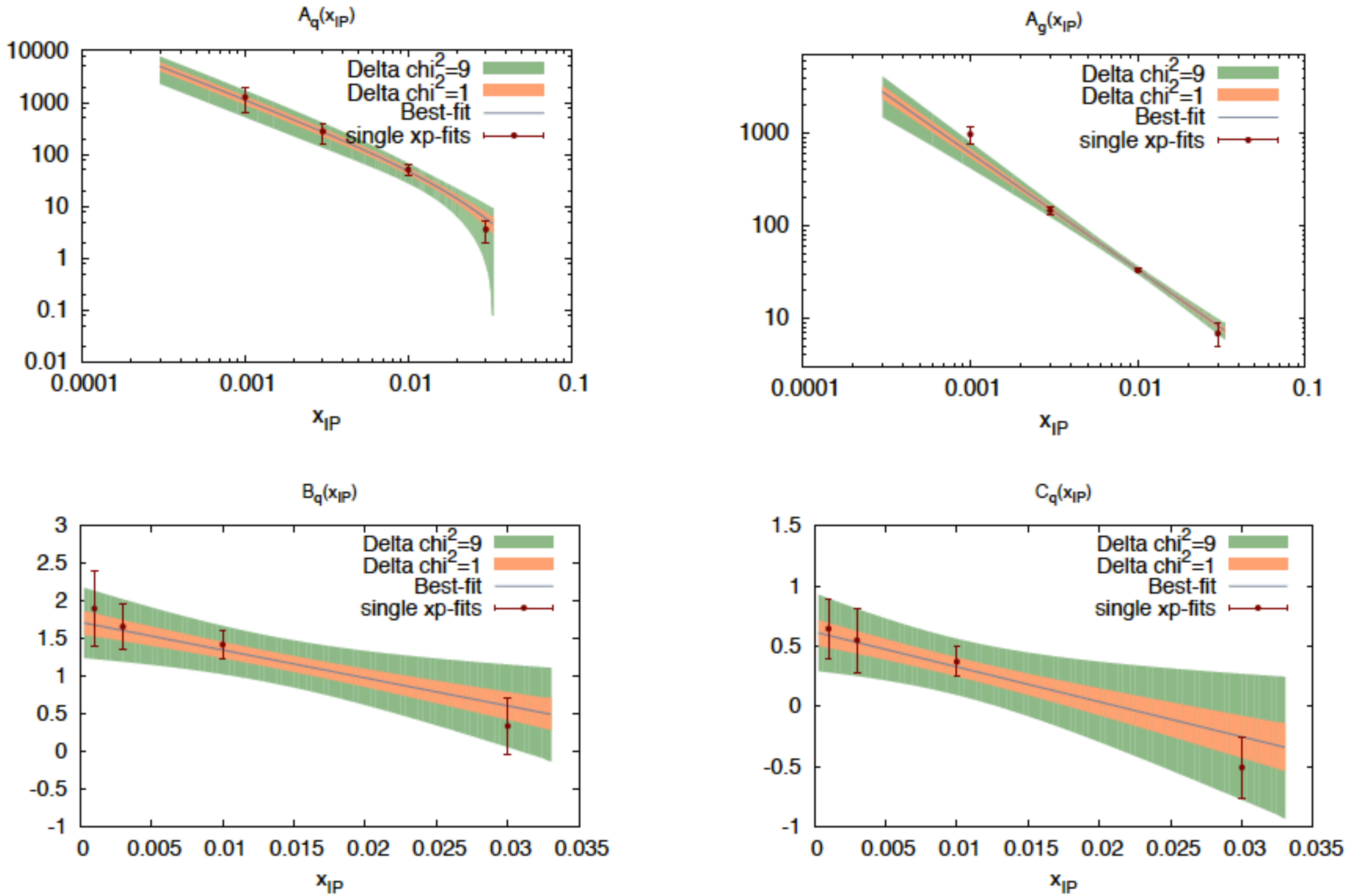


Figure 1: Parameters as a function of $x_{I\!P}$. Red dots are the results from pQCD fits at fixed $x_{I\!P}$. The grey line are best-fit prediction from $x_{I\!P}$-combined fit. The bands represent the propagation of experimental uncertainties by using the Hessian method [10].

Diffraction doesn’t mean Higgs only

S.Giani (december 2011 CERN Talk)

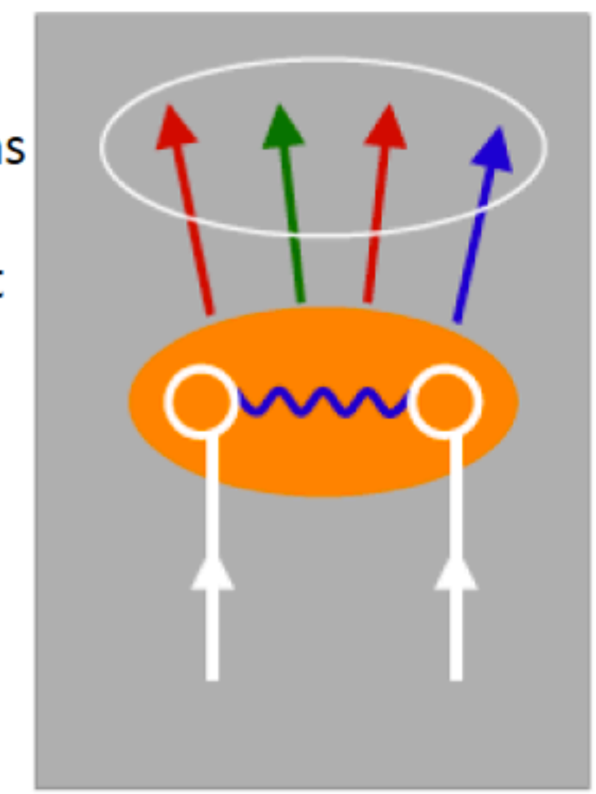
pp Interactions

Non-diffractive

Colour exchange

dN / d Δη = exp (-Δη)

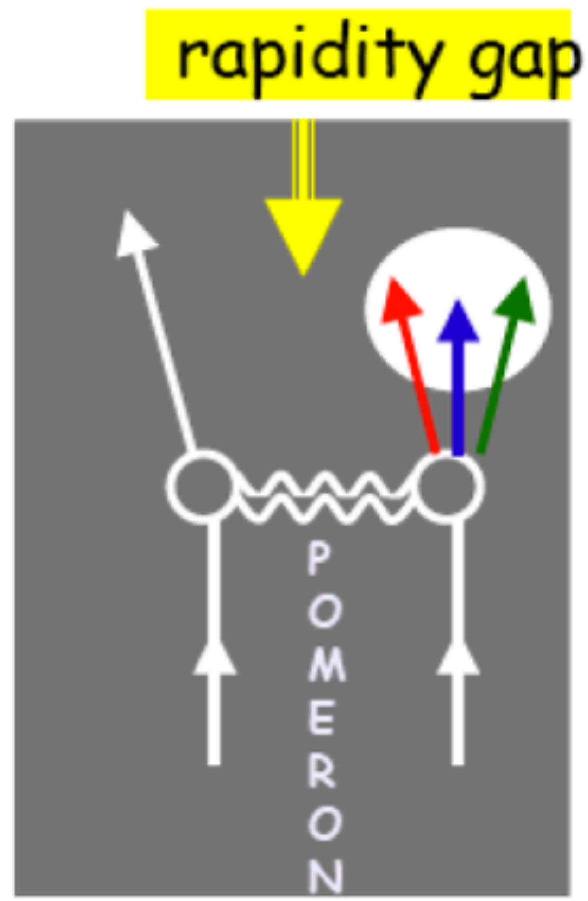
Incident hadrons acquire colour and break apart



Diffractive

Colourless exchange with vacuum quantum numbers

dN / d Δη = const

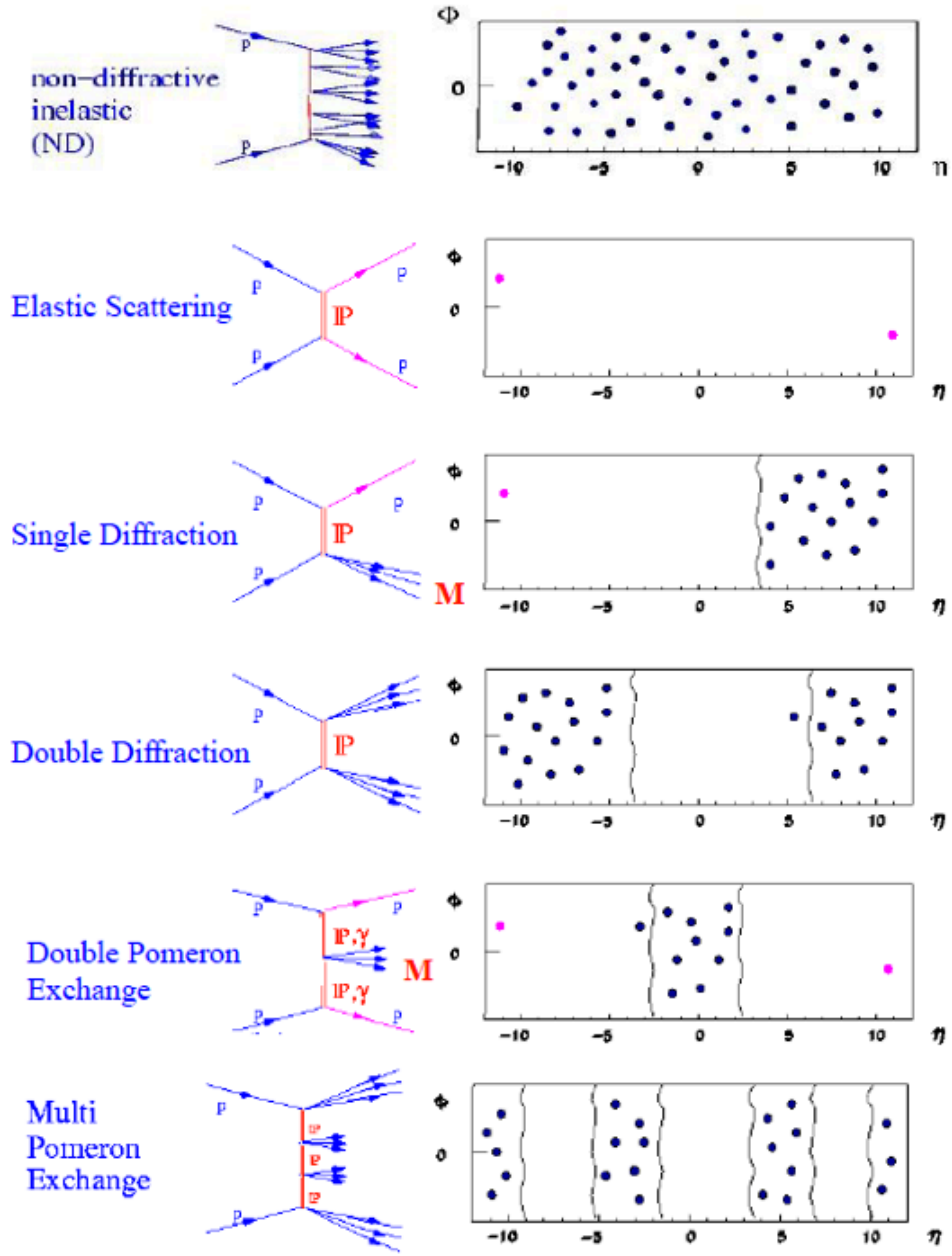


Incident hadrons retain their quantum numbers remaining colourless

GOAL: understand the QCD nature of the diffractive exchange

Inelastic and Diffractive Processes ($\eta = -\ln \mathrm{tg}\, \theta/2$)

All the drawings show soft interactions.
In case of hard interactions there should be jets,
which fall in the same rapidity intervals.



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Measure σ (M,ξ,t)

Diffractive scattering is a unique laboratory of confinement & QCD:
A hard scale + hadrons which remain intact in the scattering process.

Conclusions

Diffractive parton distributions as Diffractive Fracture Functions
from DIS should be used in pp modulo factorization

Once the perturbative evolution equations up to LHC energies
(and a suitable parametrization) have been applied
a sizeable estimate within the pQCD framework can be possibly drawn
for diffractive Higgs production processes