Diffractive cross sections and PDFs

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On behalf of H1 & ZEUS collaborations

New Trends in HERA Physics 2008
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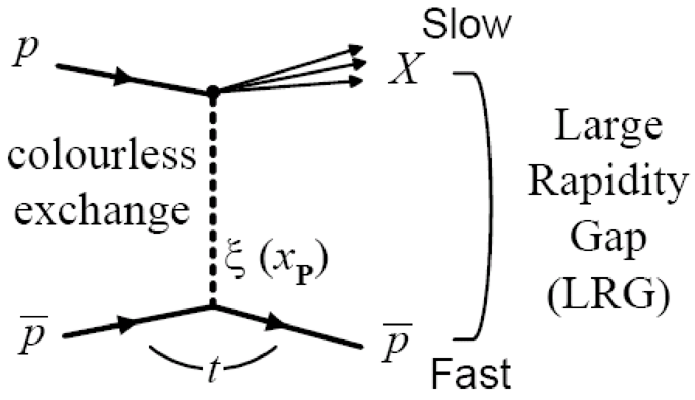
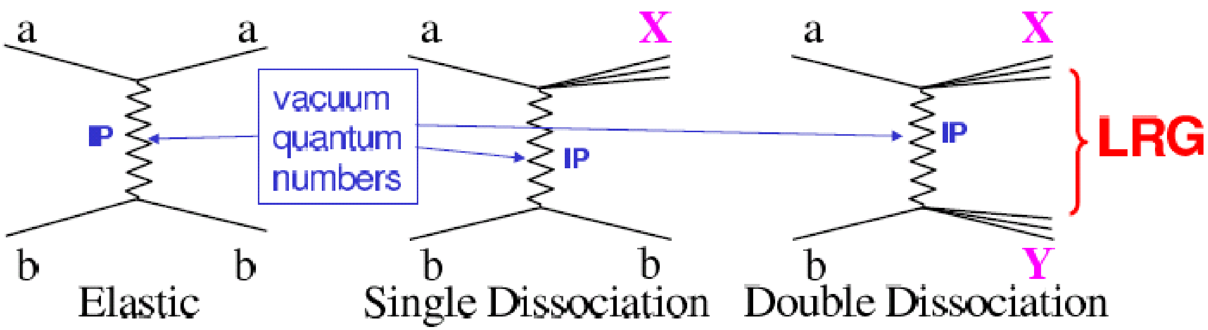
Definition of hadronic diffraction

Diffraction in particle physics @ large Energy (s >> t)



- The proton is left intact or quasi-intact
- Large Rapidity Gap (LRG)
- Vacuum Quantum Number exchange [no colour flow] == Pomeron (IP)

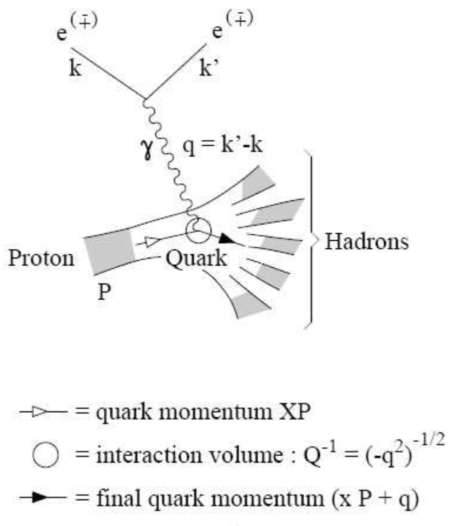


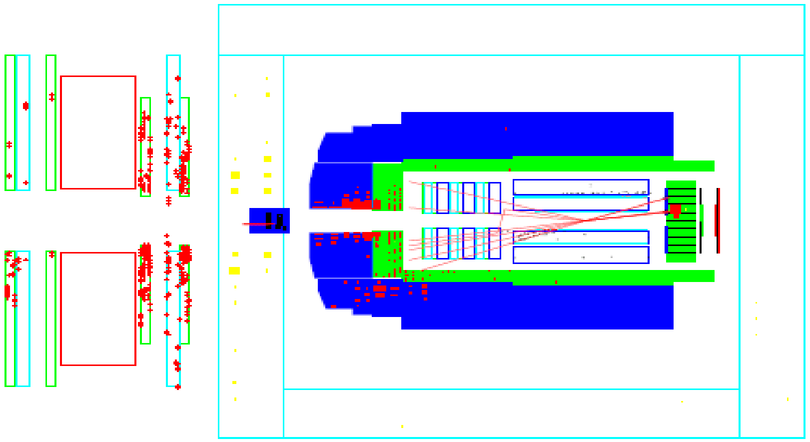
Diffraction : *generalisation* of elastic scattering

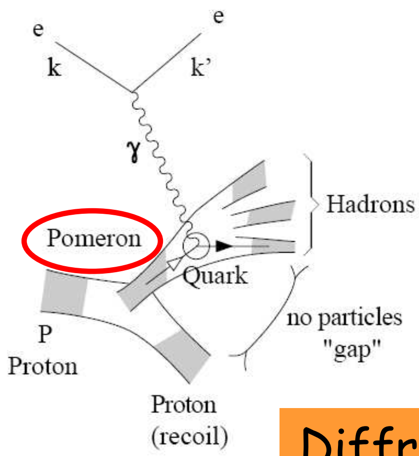
What does it give for real events @ HERA?

"Ordinary" Deep-Inelastic

PDFs



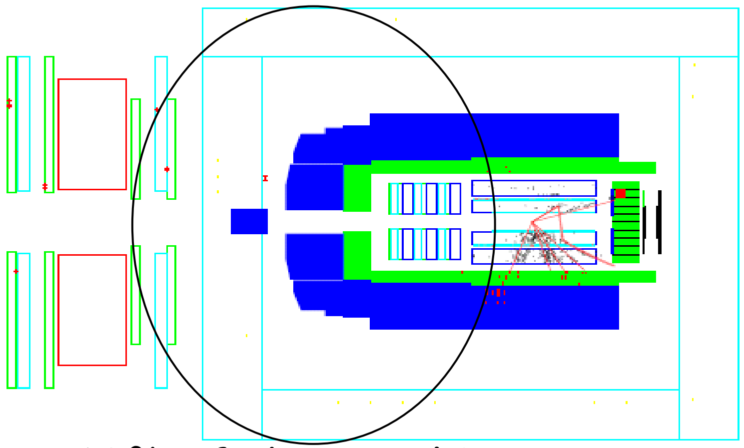




Diffractive PDFs

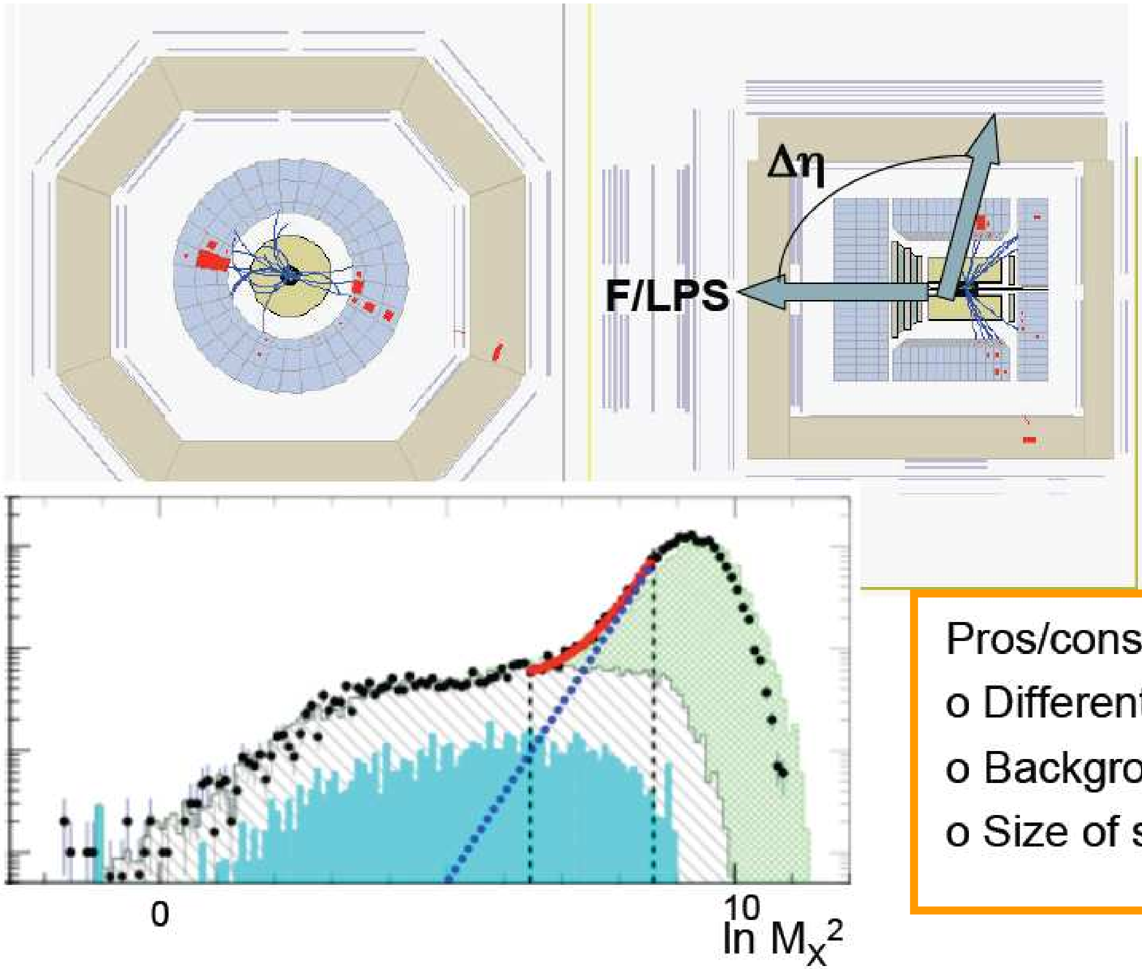
"Diffractive" Deep-Inelastic

The Pomeron as a composite object



~ 10% of the total DIS events

Experimental signatures of diffraction



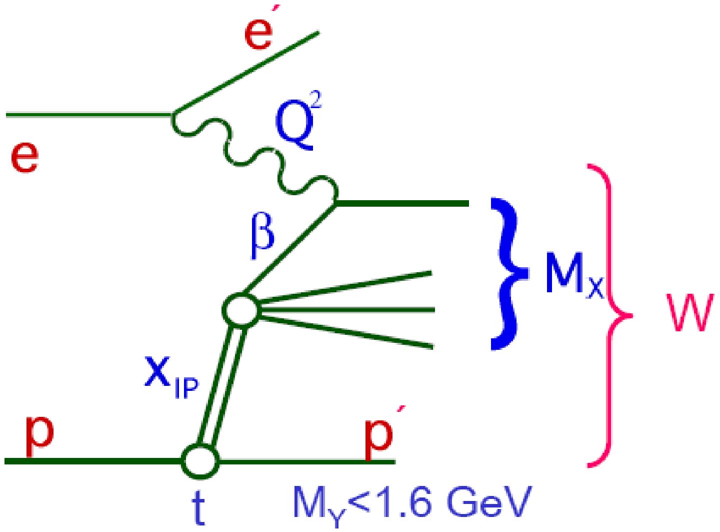
Forward Leading protons
The cleanest but restricted kinematics…

Large Rapidity Gap events

Mx method

Pros/cons:
- o Different kinematic regions
- o Background contributions
- o Size of sample

Kinematics & diffractive cross sections



Standard DIS kinematic variables : Q^2, x, W

$x_{IP} = 1 - p'^{+}/p^{+}$: fraction of the longitudinal momentum lost by the proton (below a few%)

$\beta = x/x_{IP}$: *fraction of the IP momentum carried by the struck quark in the diffractive exch.*

Important formula : $\beta \approx Q^2 / (Q^2 + M_X^2)$

The same formulae as for F2 are written except that we deal with diffractive events…

$$\frac{d^3\sigma}{d\beta dQ^2 dx_{IP}} = \frac{4\pi\alpha^2}{\beta Q^4}(1 - y + \frac{y^2}{2})\sigma_r^{D(3)}(\beta, Q^2, x_{IP})$$

$$\sigma_r^{D(3)} = F_2^{D(3)} - \frac{y^2}{2(1 - y + y^2/2)} F_L^{D(3)}$$

Why studying diffraction?

A few points for inclusive diffraction:

- Significant fraction of the inclusive DIS cross section
  It deserves a specific analysis…

- long standing pb of the IP structure (specific PDFs?, no PDFs al all? Something else…)

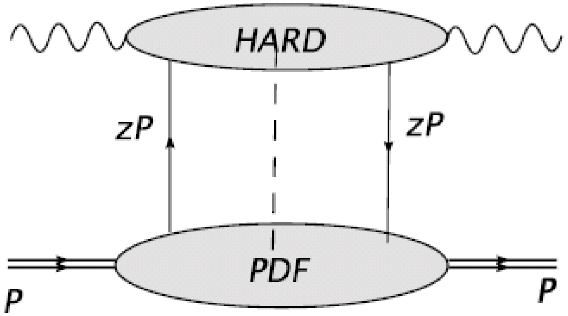
- Modeling diffraction => saturation effects in the nucleon
  More sensitivity for diffraction than for standard DIS

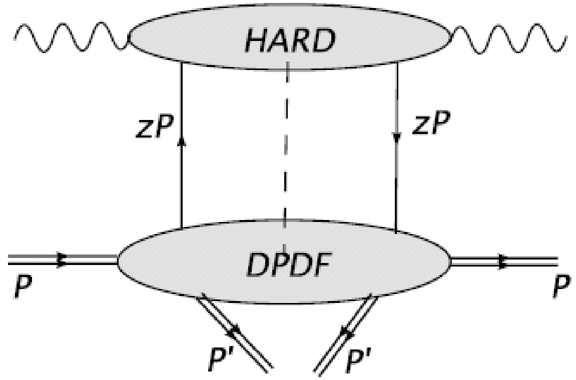
- Higgs @ LHC

Not covered here: inclusive + exclusive diffraction provide a view of the (real) structure of the proton… not only in momentum but in space!

Has diffraction something to do with pQCD?

Let's compare DIS and Diff DIS from a pQCD point of view…
First look at the long standing pb of the IP structure?!





$$f_a^D(z,\mu^2,x_{I\!P},t) = \sum_X \int dy_- \, e^{-izP^+y^-} \langle P\,|\overline{\psi_a}(y_-)\gamma^+ \underbrace{|P'X\rangle\langle P'X|}\psi_a(0)|\,P\rangle$$

dPDFs (β,Q^2) would follow the DGLAP QCD evolution eq. // standard PDFs

QCD factorisation for diffractive events

PHYSICAL REVIEW D VOLUME 57, NUMBER 5 1 MARCH 1998

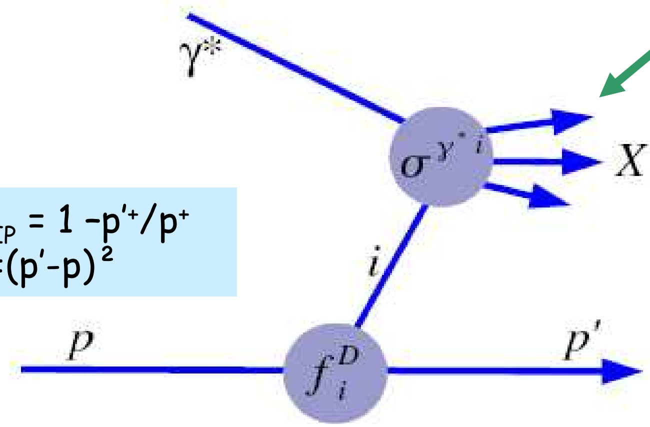
Proof of factorization for diffractive hard scattering

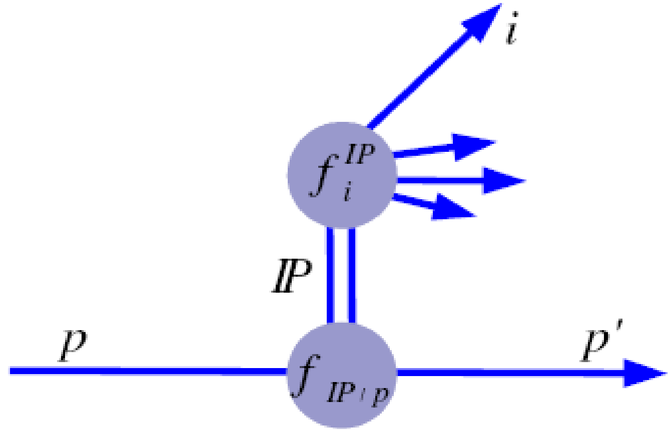
John C. Collins*
Penn State University, 104 Davey Lab, University Park, Pennsylvania 16802
(Received 14 October 1997; published 6 February 1998)

A proof is given that hard-scattering factorization is valid for deep-inelastic processes which are diffractive or which have some other condition imposed on the final state in the target fragmentation region.
[S0556-2821(98)00507-4]
PACS number(s): 13.85.Ni, 12.38.Aw, 13.60.−r

More on diffractive events in pQCD...

$x_{IP} = 1 - p'^{+}/p^{+}$
$t = (p'-p)^2$





$$f_{IP}(x_{IP}) = \int_{t_{cut}}^{t_{min}} e^{B_{IP} t} / (x_{IP}^{2\alpha_{IP}(t)-1})\, dt$$

QCD (Collins) factorisation at fixed x_{IP} & t

$$d\sigma_{\text{parton } i}(ep \to eXY) = f_i^D(x, Q^2, x_{IP}, t) \otimes d\hat{\sigma}^{ei}(x, Q^2)$$

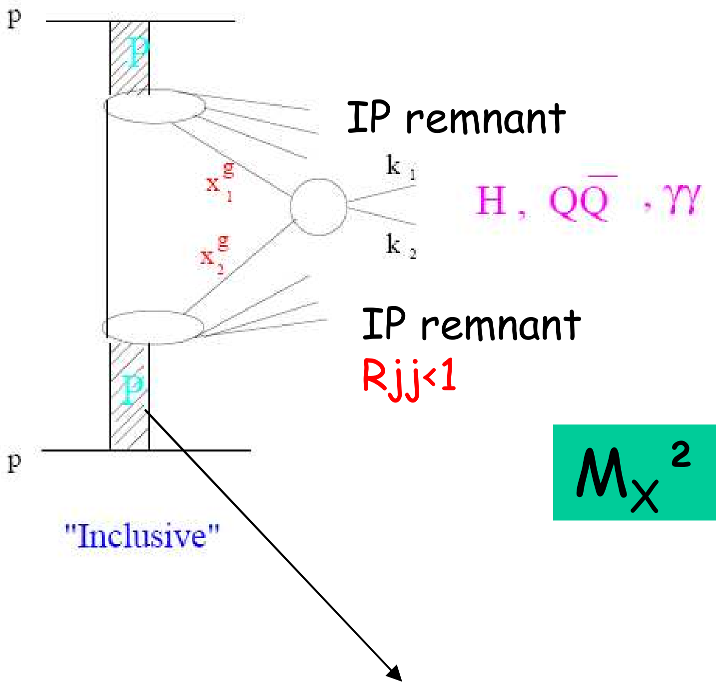
Proton vertex factorisation of the x_{IP} dependence (**hypothesis not rooted in QCD**)

$$f_i^D(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{IP}$$

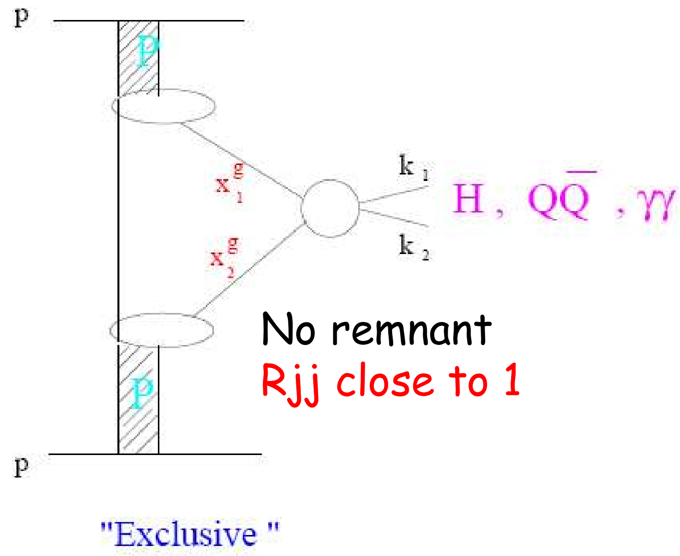
dPDFs

Higgs and diffraction @ LHC

2 protons tagged on both sides (double diffractive event)
+ measurement of their energy loss $\xi_{1,2}$



$$M_X{}^2 = s\,\xi_1\xi_2$$



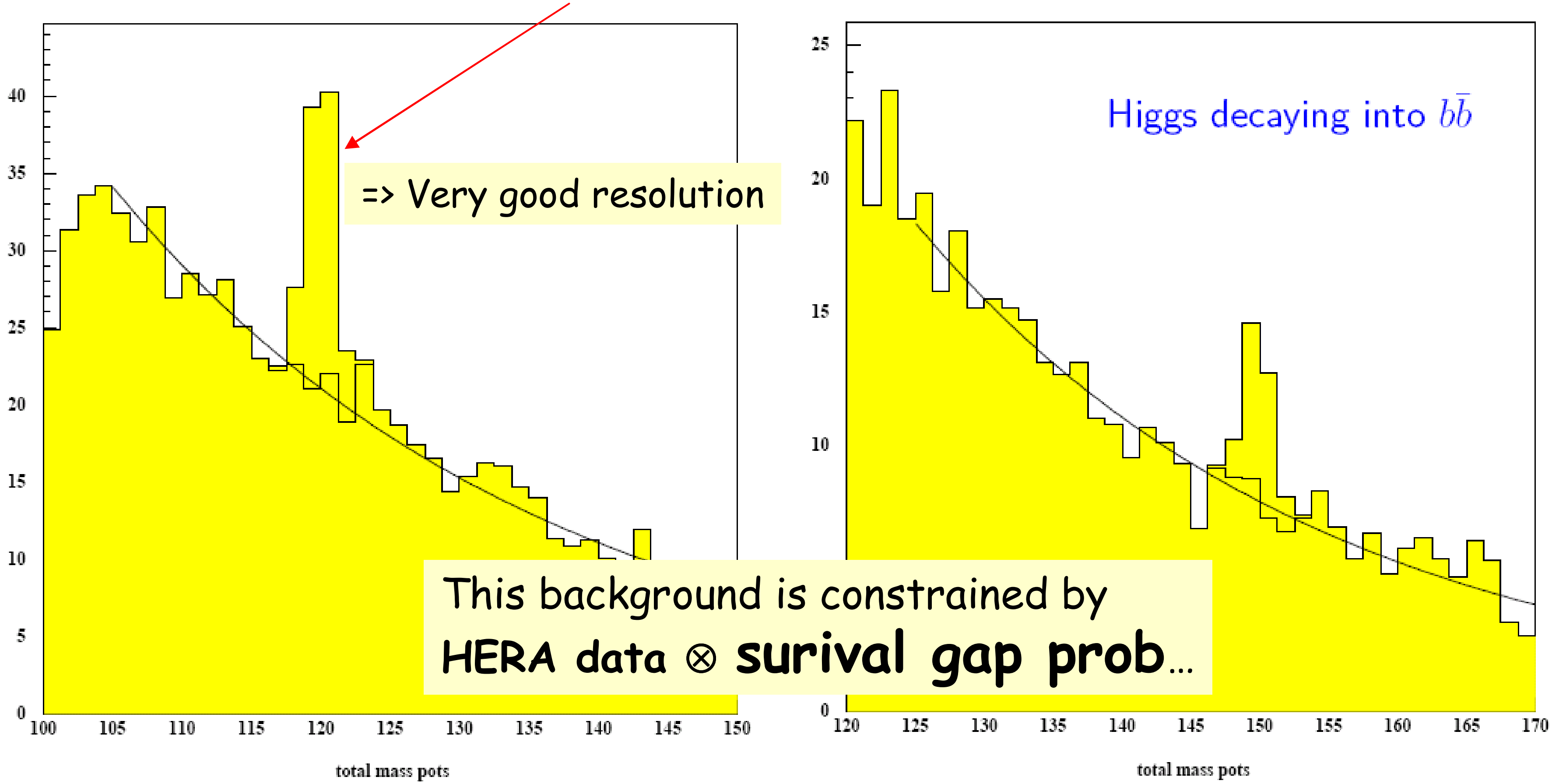
$$R_{jj} = \frac{M_{jj}}{M_X}$$

Diffractive PDFs enter here ⊗ surival gap prob:
events with IP remnants are may be a huge background to the exclusive (central) production of a heavy object like a Higgs…

Exclusive Higgs production @ LHC

After the hints from the TeV, let's come back on the Higgs exclusive production @ LHC : **simul for a 120 & 150 GeV mass Higgs!**

Measurement of the mass from : $M_X^2 = s\,\xi_1\xi_2$



Signal and background for different Higgs masses for 100 fb^{-1}

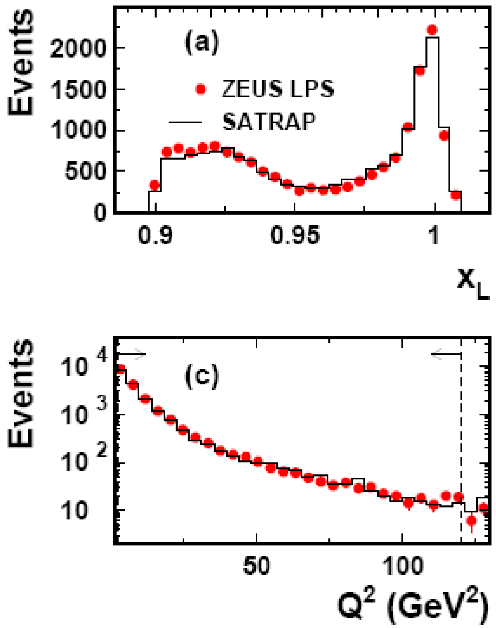
First of all, we need to have **good measurements**
& then to check if these measurements are
described by calculations based on diffractive PDFs…

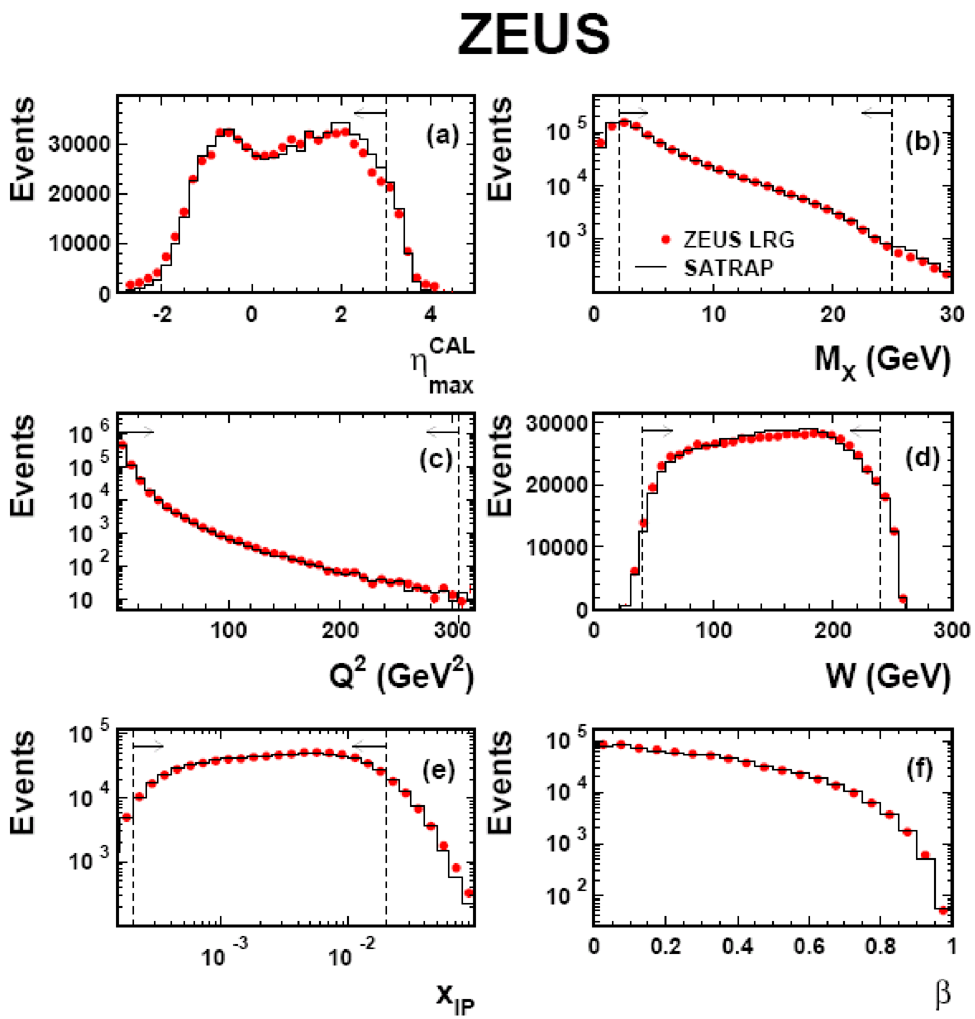
Step 1:
Measurements at HERA

Diffractive cross sections (latest analysis)

Latest ZEUS data on **LRG sample:**
from 2.5 GeV² till 300 GeV²
(last bin @ 225 GeV²)

& on the **LPS sample:**
2.5 GeV² - 120 GeV²
(last bin @ 40 GeV²)



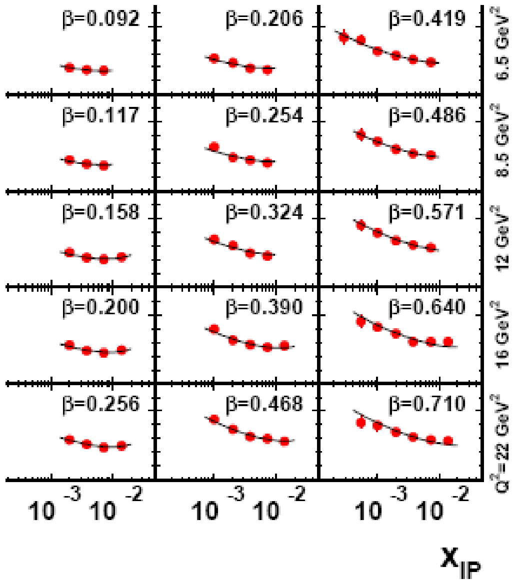


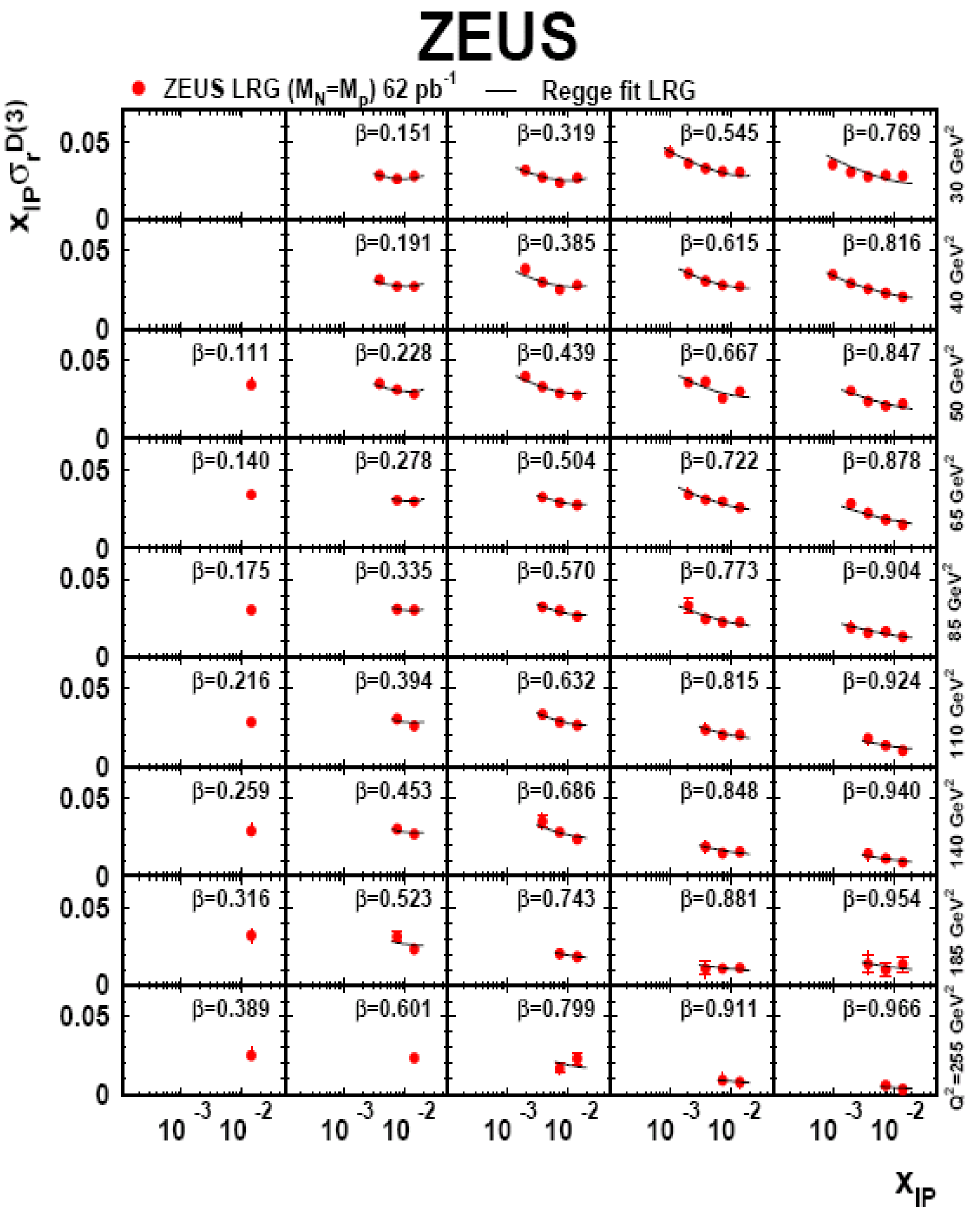
Diffractive cross sections (latest analysis LRG ZEUS)

Lage kin coverage in Q^2, x_{IP} & β

+

precision data



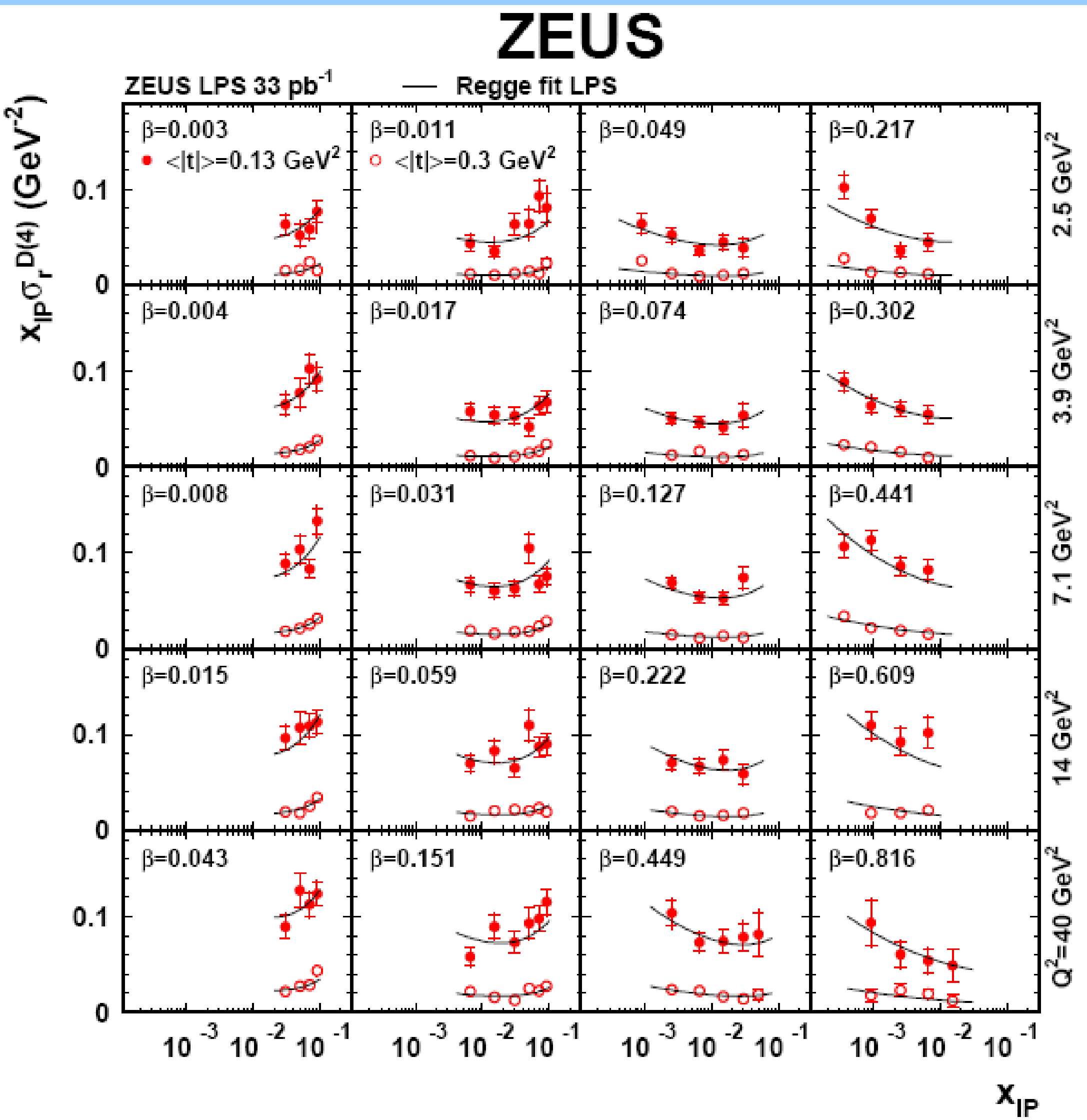


Diffractive cross sections (latest analysis LPS ZEUS)

Note that 2 bins
of <t> have been
measured over
the all kin phase space
(**first time measurement**)

=>

Important experimental
result when extracting
parameters for the
IP trajectory from data…
(see later)
First look: similar x_{IP}
dependence for the 2 bins…



Diffractive cross sections (latest analysis LPS/LRG)

In LPS we expect a clean sample with no proton-diss background as the scattered proton is detected…

=>

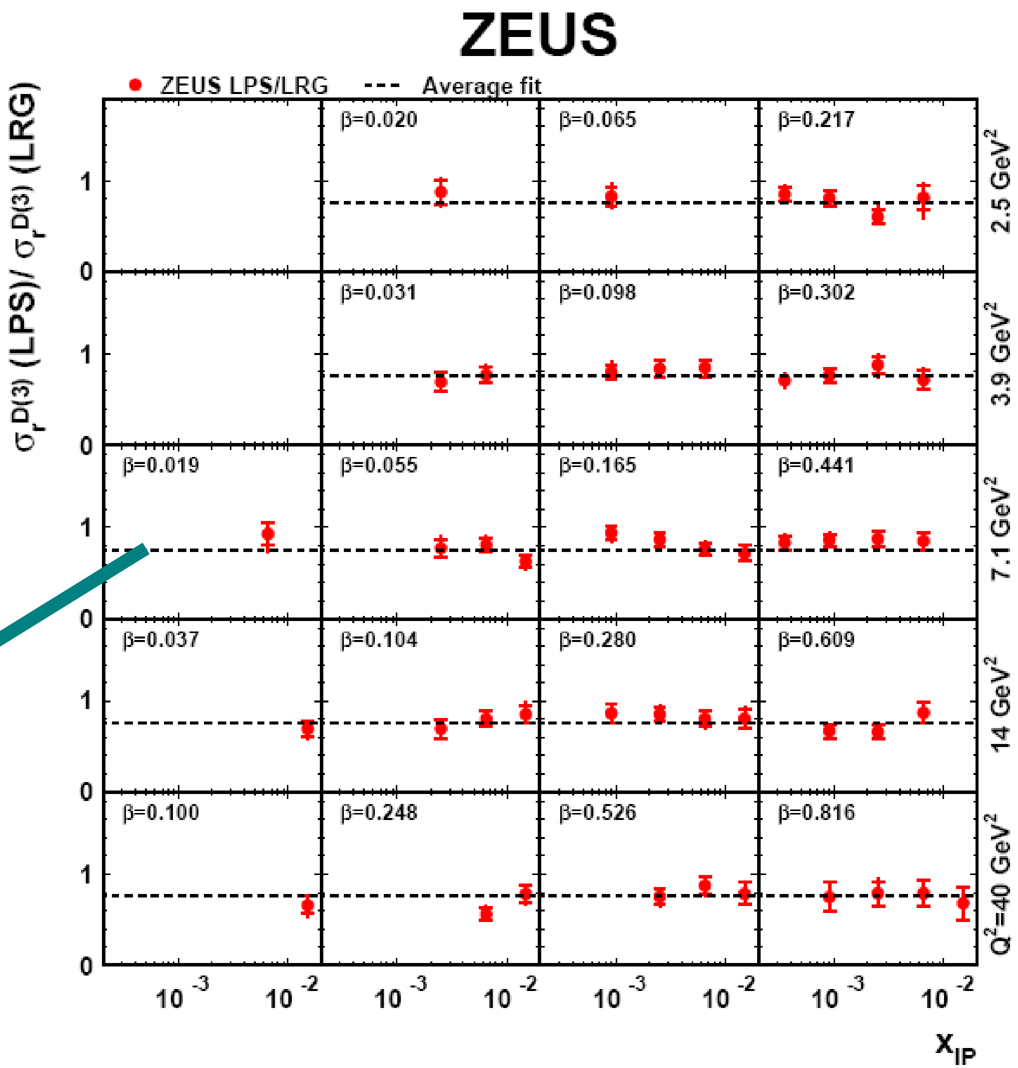
LRG/LPS gives the fraction of pdiss events in the LRG sample.

Result:

The LRG sample contains a significant fraction of pdiss ~24%...

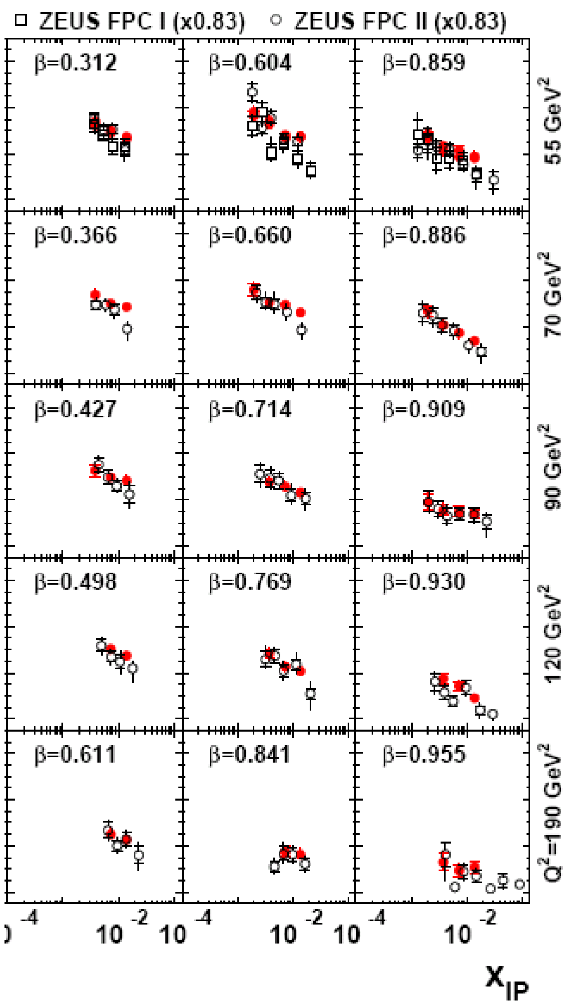
almost independent of the kinematics

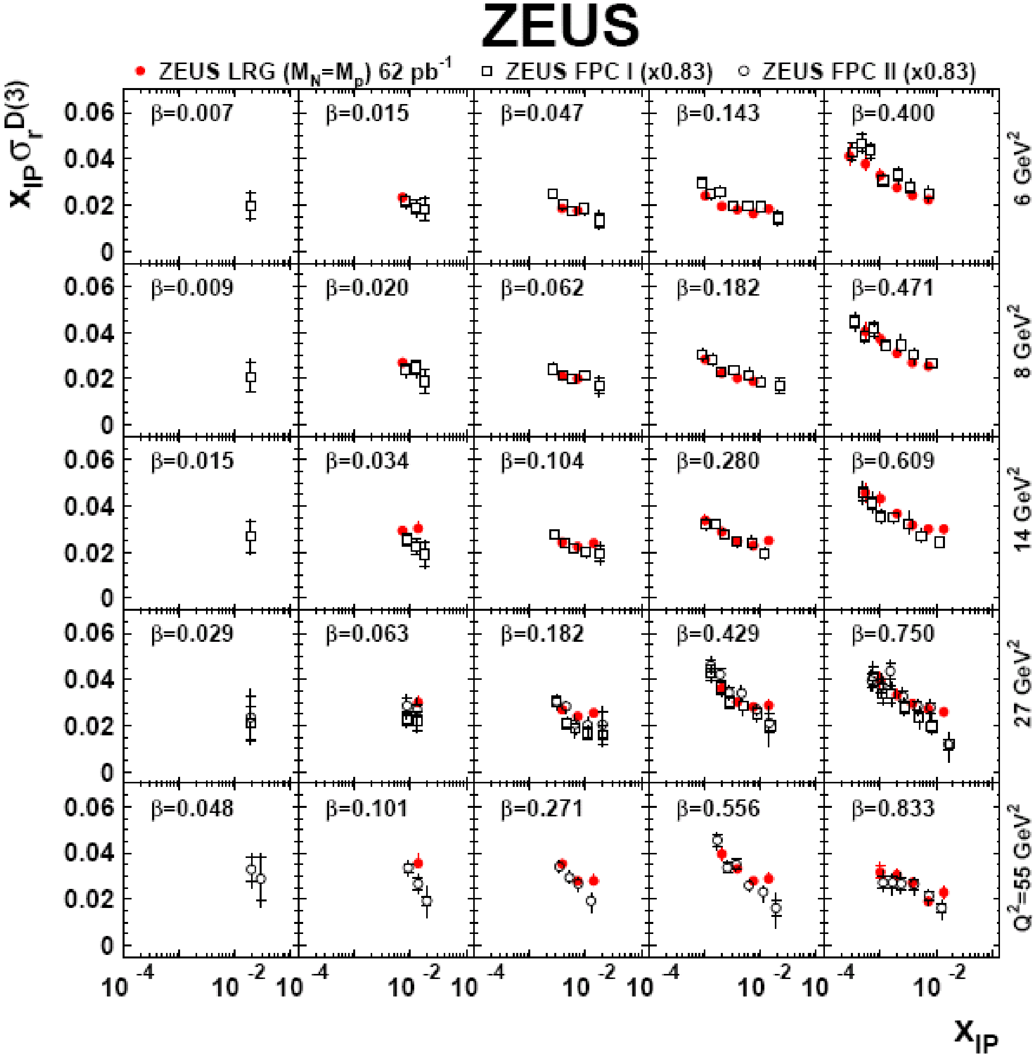
// H1 result…



The long standing problem of LRG versus Mx samples

Good agreement // preliminary result of H1 in 2006…



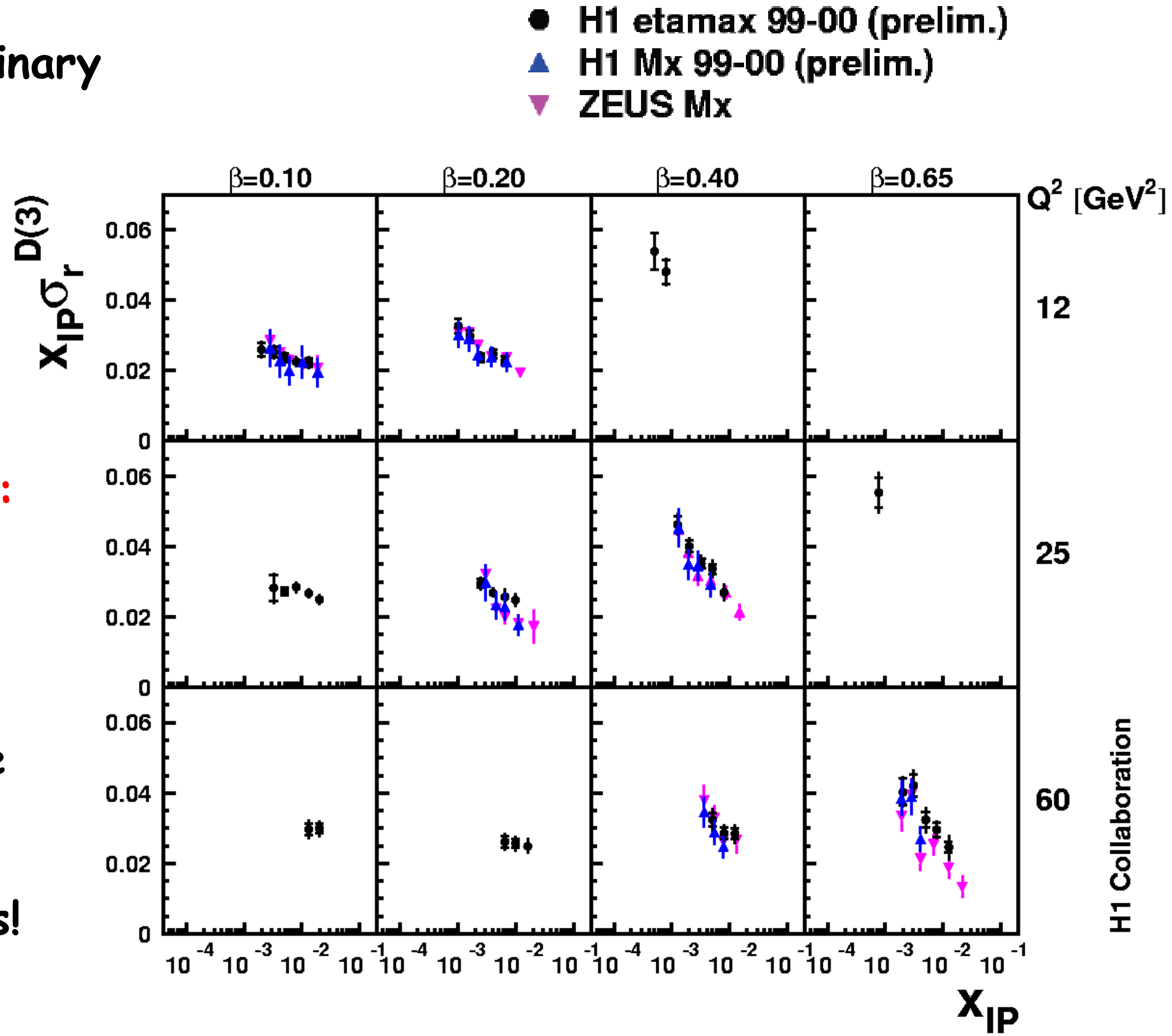


The long standing problem of LRG versus Mx samples

Reminder of the preliminary result of H1 in 2006…

Same message in the last ZEUS publication on a large kin coverage: An important message for experimentalists…

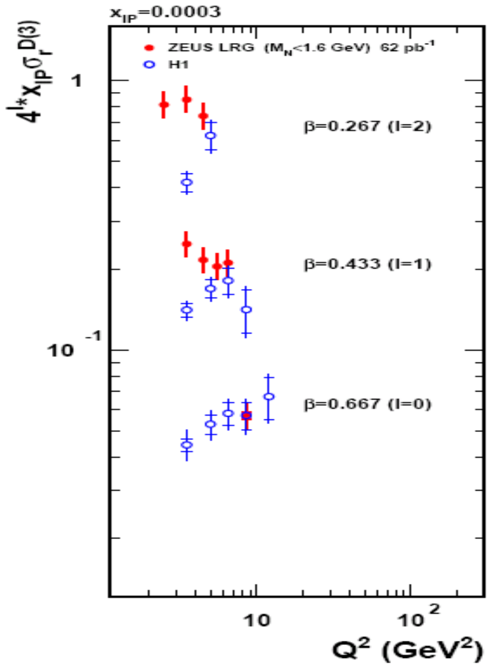
It shows the coherence of the analysis of diffraction using many experimental techniques!

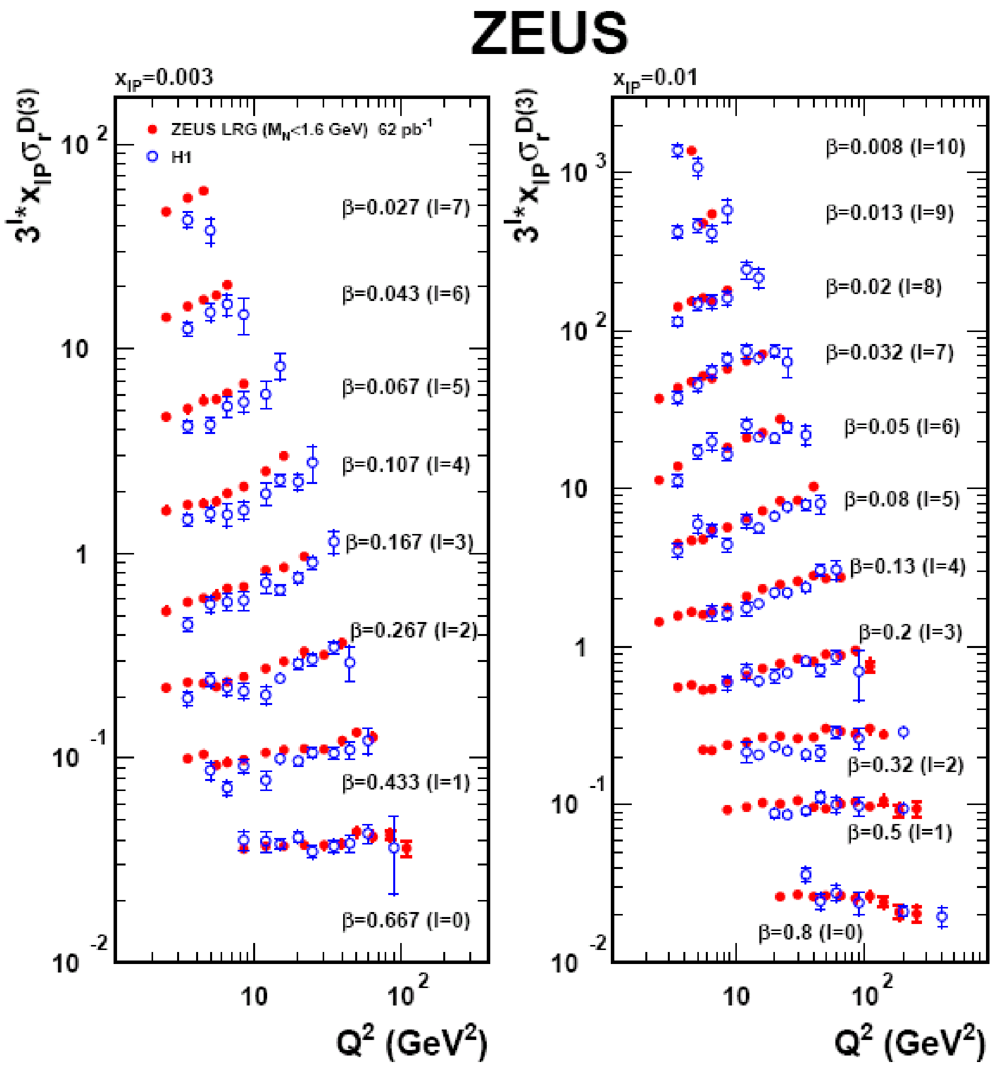


H1 LRG versus ZEUS LRG

Normalisation difference
Of ~13% covered by
Systematic errors on the
normalisations for each sample

Differences in shape @ low Q^2



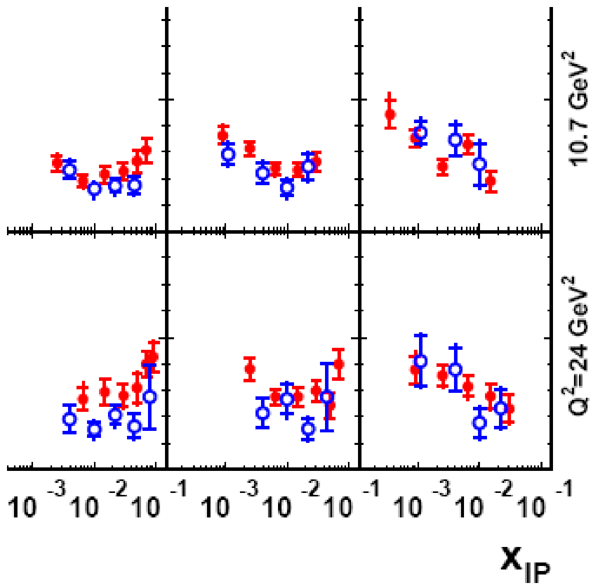


Data samples: some key points

Large wealth of data with the LRG method in reasonnable agreement
62 pb^{-1} for ZEUS and 10 pb^{-1} for H1
Some differences in normalisation
A larger statistics from H1 would give a new light on these comparisons… in progress…

Good comparison between Mx method and LRG samples: important experimental message of the last ZEUS publication // H1 preliminary result of 2006!

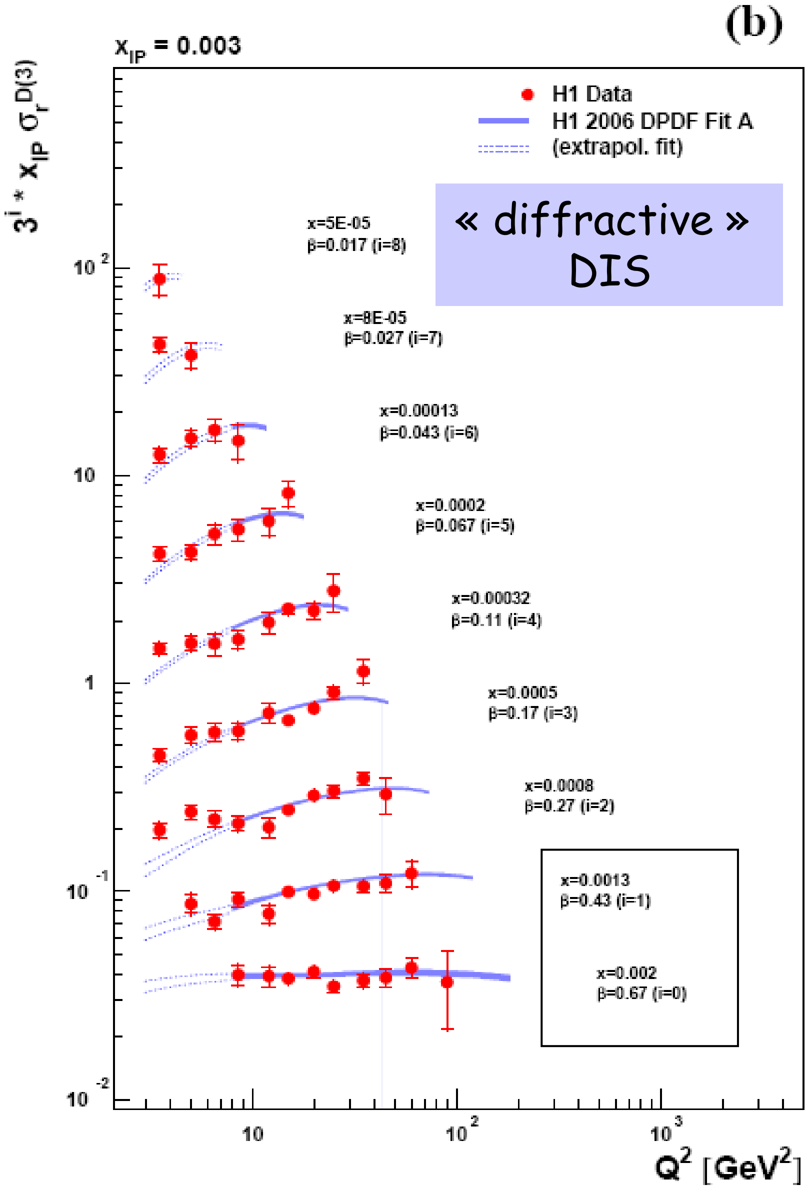
LPS data from ZEUS & FPS data from H1:
2 bins in t from ZEUS (33 pb^{-1})
Good agreement between H1 & ZEUS on this sample
LRG/L(F)PS from H1 & ZEUS in
good agreement also ~24%
(it gives the correction to move from M_Y<1.6 GeV to elastic)

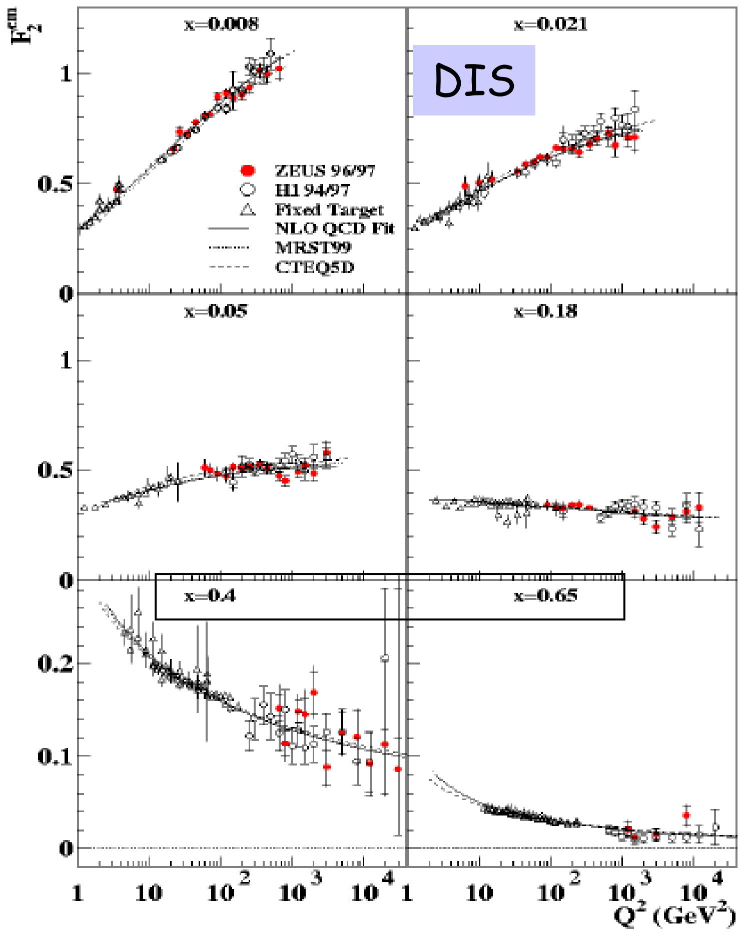


First of all, we need to have good measurements
& then to check if these measurements are
described by **calculations based on diffractive PDFs**…

Step2:
Compatibility with diffractive PDFs

First look





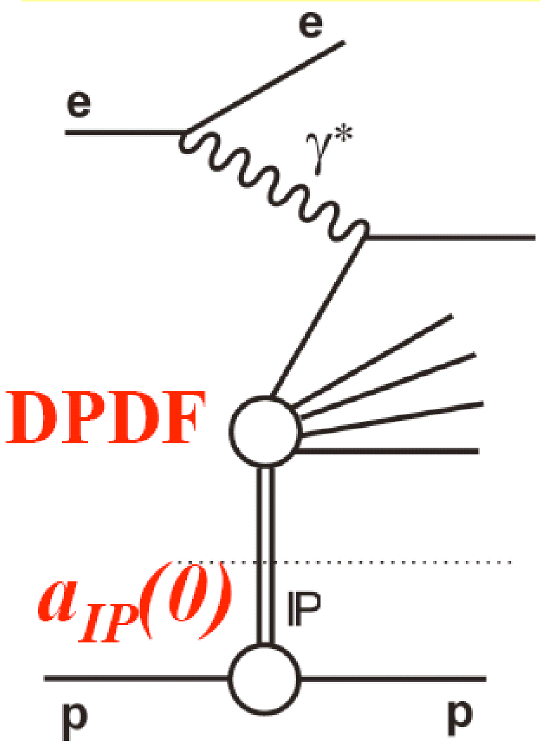
At large β values : scaling violations still >0 for diffraction, *<0 for standard DIS*

=> Large gluon content expected for DIFF

Diffractive QCD fits process

QCD fits are processed as for F2 and standard PDFs but with diffractive cross sections =>
parametrise the IP flux & factorise it (hypothesis)
Then, use the IP structure functions as F2 in the QCD fits…

$$f_i^D(x,Q^2,x_{IP},t) = f_{IP/p}(x_{IP},t)\cdot f_i^{IP}$$

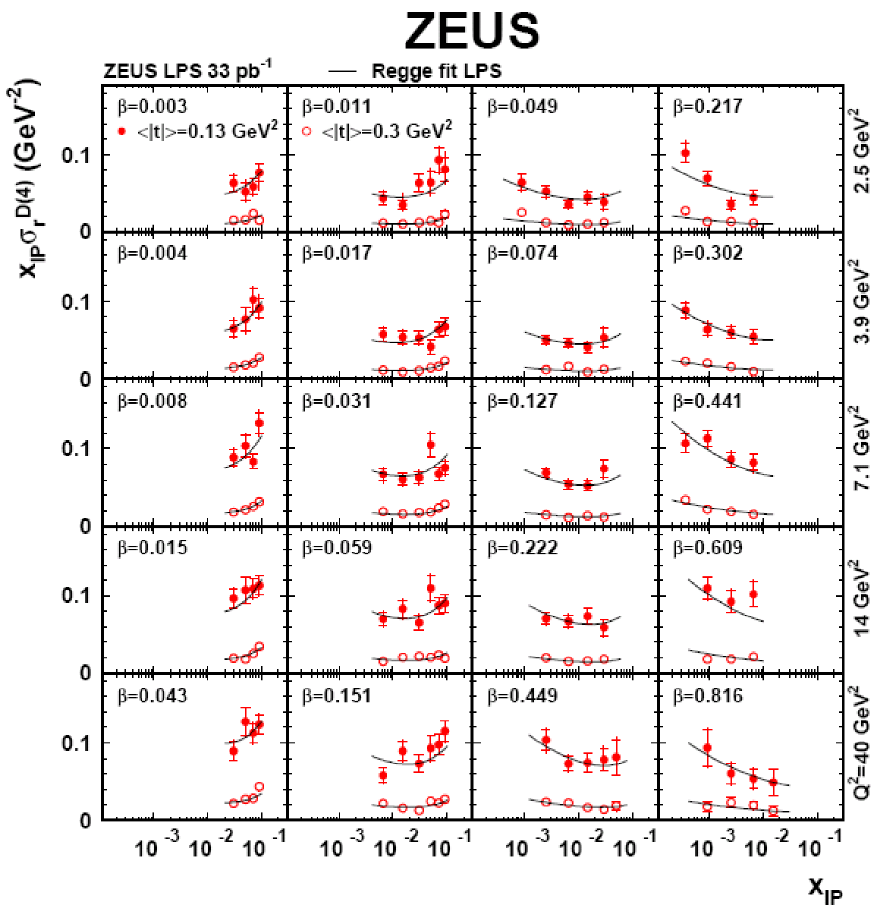


Note:
there are some technicalities…
@ large x_{IP} a subleading trajectory is needed for the LRG sample
(not for the Mx sample)

Concerning the IP flux

$$f_i^D(x,Q^2,x_{IP},t) = f_{IP/p}(x_{IP},t)\cdot f_i^{IP}$$

Using the last ZEUS LPS data... → Global parameters are extracted



$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP}\cdot t$

χ^2 /ndf = 162/153

$\alpha_{IP}(0)$ = 1.11 ± 0.02(stat) +0.01 -0.02(syst) +0.02(model)

α'_{IP} = -0.01 ± 0.06(stat) +0.04 -0.08(syst) GeV^{-2}

Results in very good agreement with H1…
'soft' value for $\alpha_{IP}(0)$
'hard' value for $\alpha'_{IP}(0)$

=> provide the x_{IP} dependence inputs in the QCD fit process…

Comments on the procedure

$$f_i^D(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{IP}$$

What does it mean?

IP flux is factorised here
(pure Regge pole or not)
Input to the QCD fit (not fitted)
=> It gives the x_{IP} dependence…

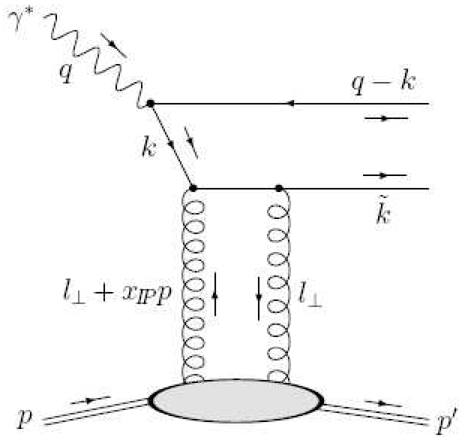
For the diffractive PDFs:
Q^2 given by DGLAP equations
β dependence fitted
Only leading twist approach

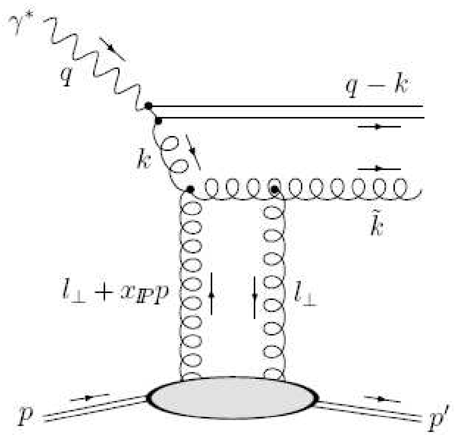
& apply only on diffractive DIS
(not valid for exclusive diffraction)

Can mix a **non-perturbative** IP trajectory with **pQCD** (partons driven prediction)…

To compare with another approach

2g exchange model





The 2g exchange models the IP as a perturbative 2g ladder
=> x_{IP} dependence as the square of the gluon density or dipole cross section (the same used for F2)

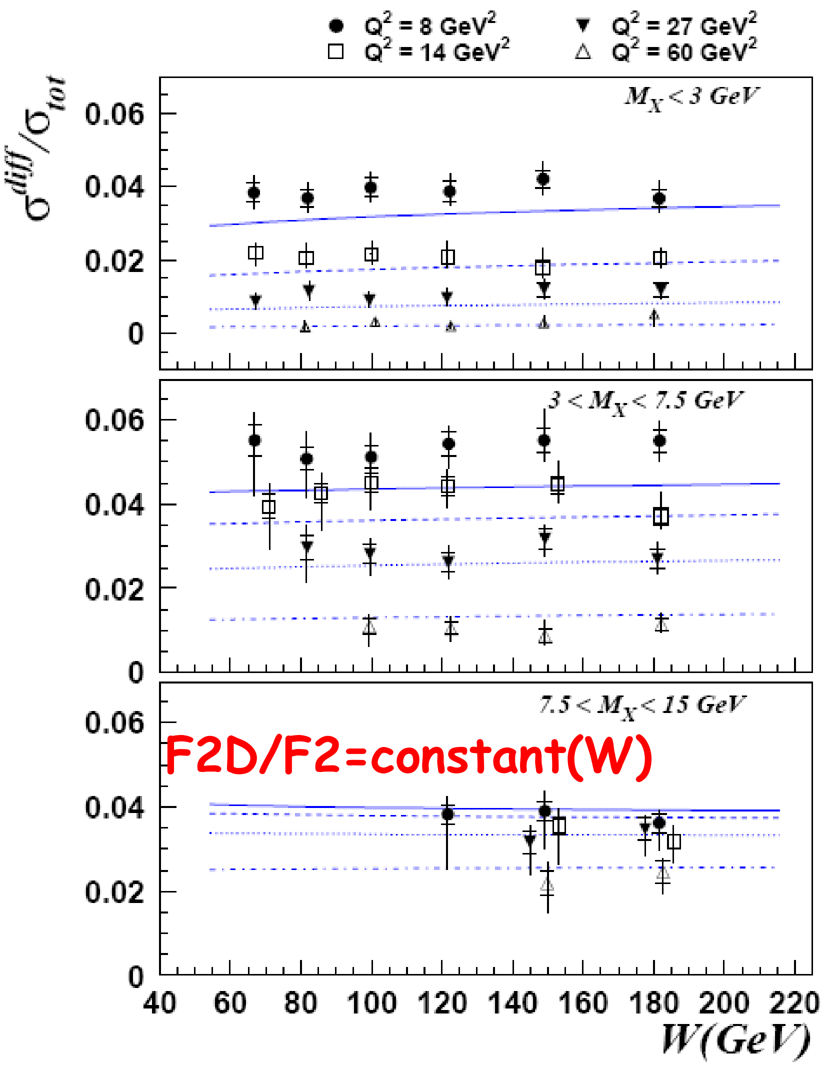
Q^2 dependence is predicted
β dependence also predicted
beyond LT
Only qqbar & qqbarg

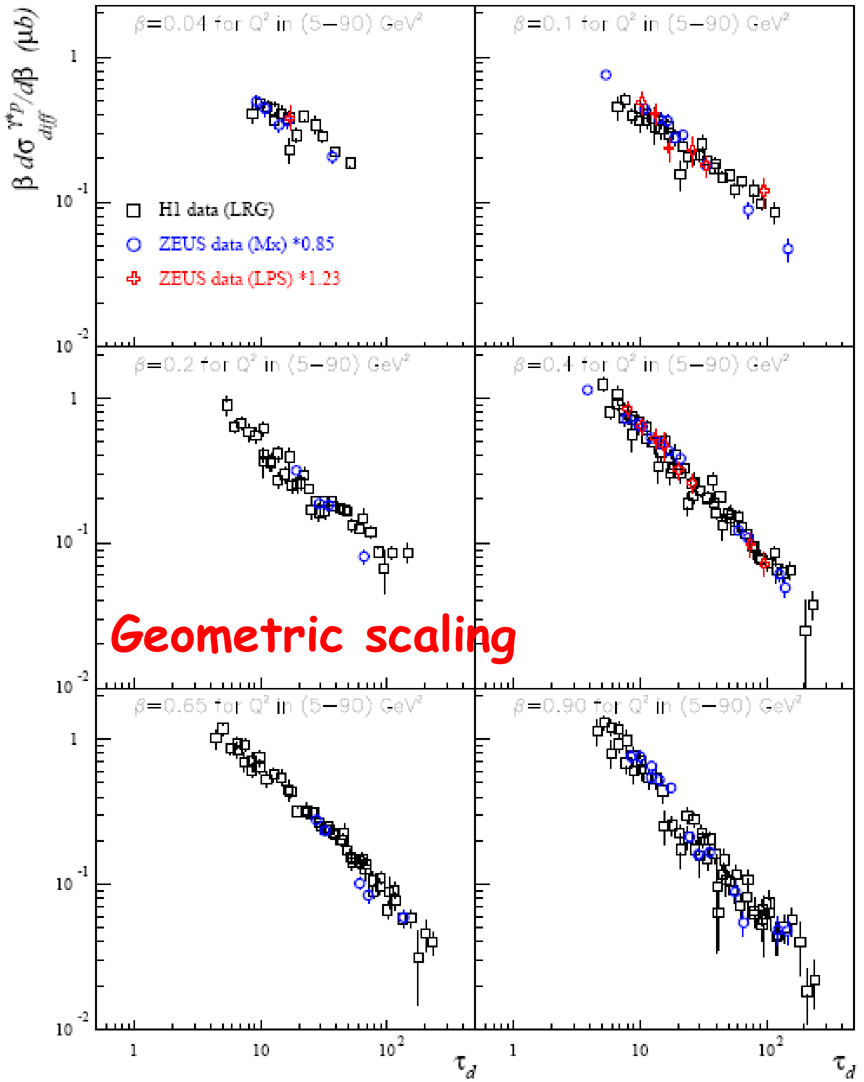
Valid for all diffractive processes…

Well suited for pure **pQCD driven** processes…

A comment on the 2g approach

It gives natural predictions for these 2 properties of diffractive scattering



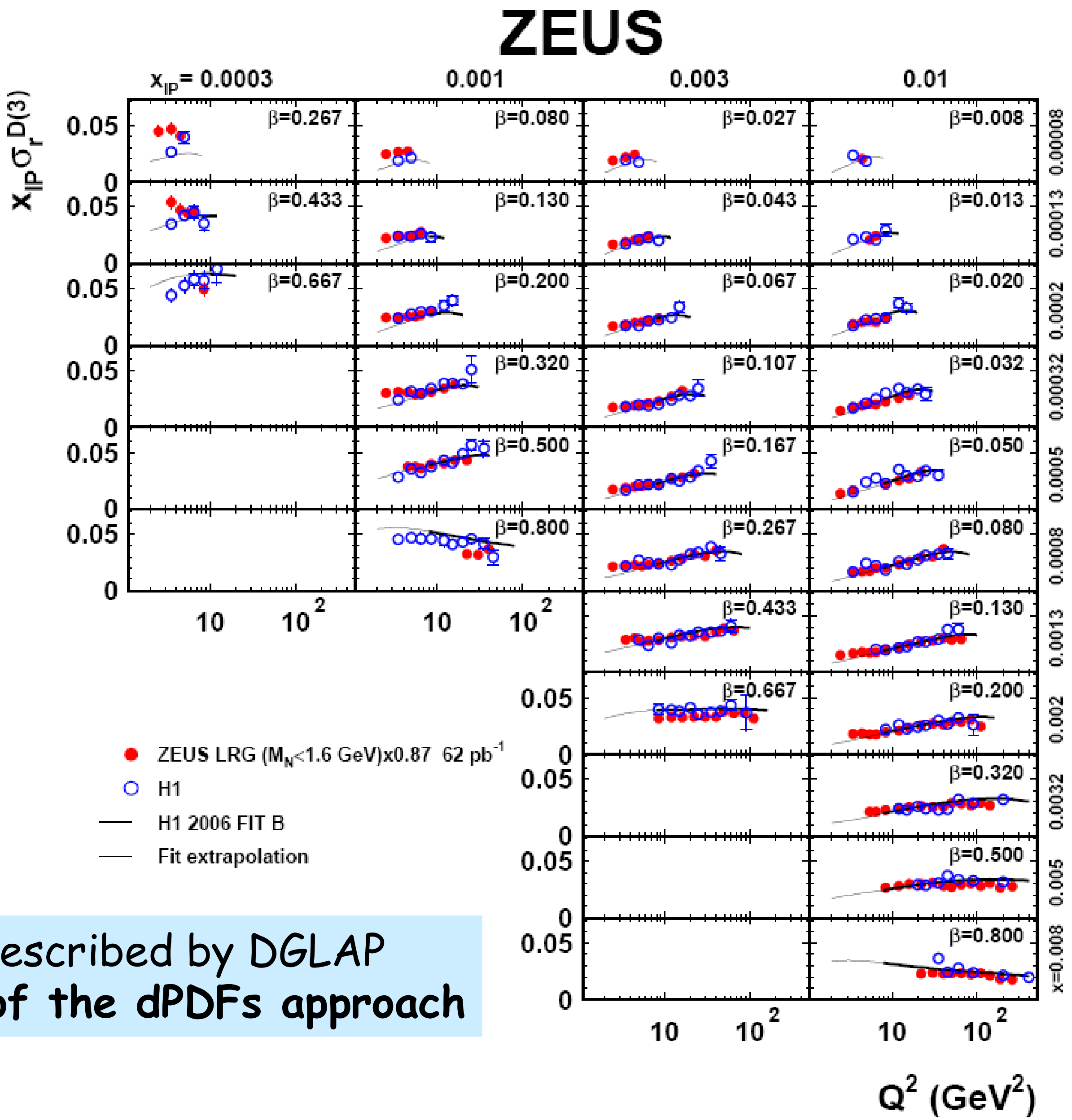


Comparison of dPDFs approach with diffractive data

ZEUS & H1 diffractive cross Sections (ZEUS normalised to H1 by a global factor on this plot)

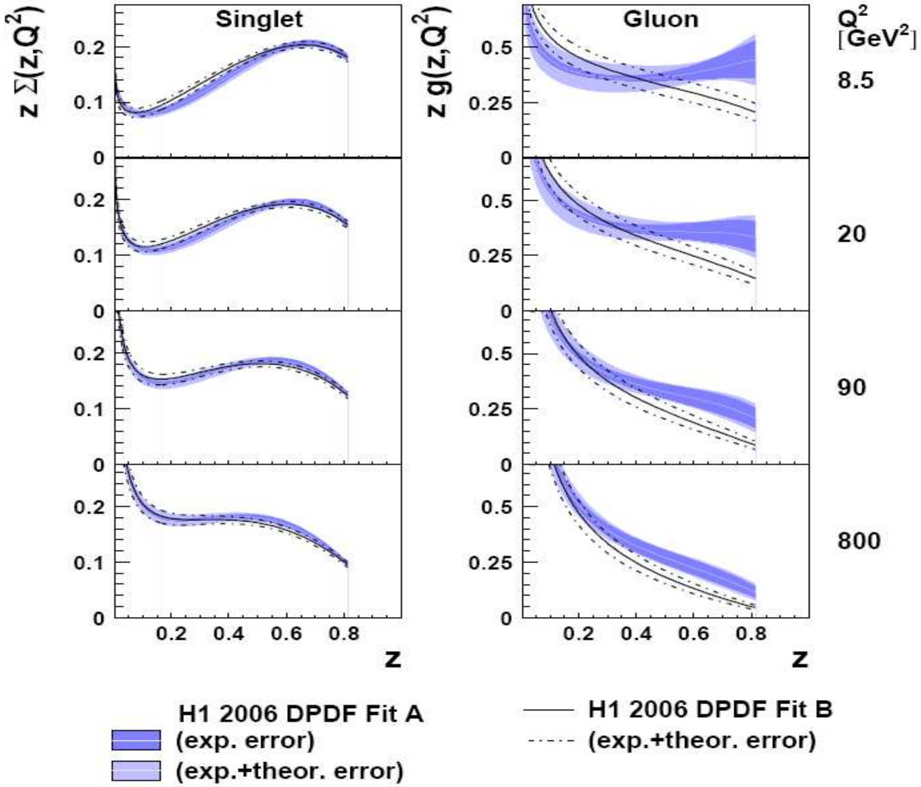
+ QCD fit result (dPDFs approach)…

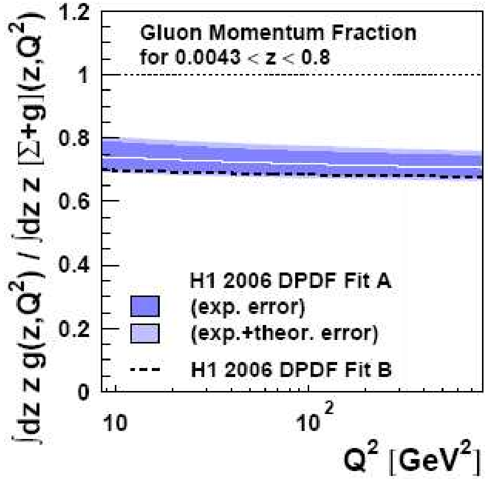
Good agreement
=>
Scaling violation are well reproduced…



Q^2 dependence is well described by DGLAP
This is the **main check of the dPDFs approach**

Diffractive PDFs





Large gluon content (in the IP)
carrying the main part of the momentum

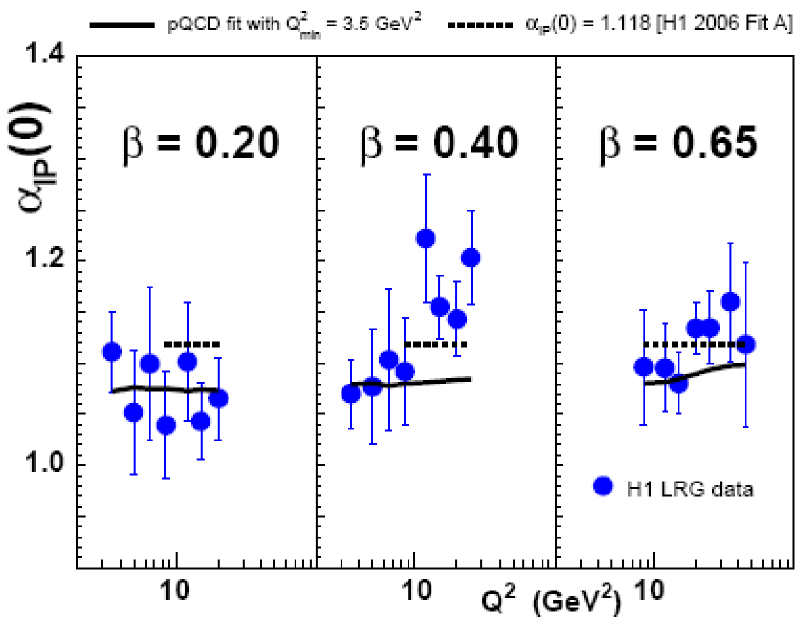
As anticipated with the >0 scaling violations till large β

Large uncertainty @ large β

Diffractive PDFs: comments

$$f_i^D(x,Q^2,x_{IP},t) = f_{IP/p}(x_{IP},t)\cdot f_i^{IP}$$

Remember that if the x_{IP} dependence also depend on Q^2 & β
It is not that simple => still factorisation but no dPDFs(z,Q²)



The most complete tests have been done by G.Watt et al.

Compatible with a constant within the errors but we need further studies…

Note that it is possible to extract dPDFs with a IP flux taken from Pure Regge (soft IP trajectory)… Results are very close to the H1 dPDFs…

The use of ZEUS data and new high stat analysis in H1 will clarify these issues in the near future…

A step further towards LHC

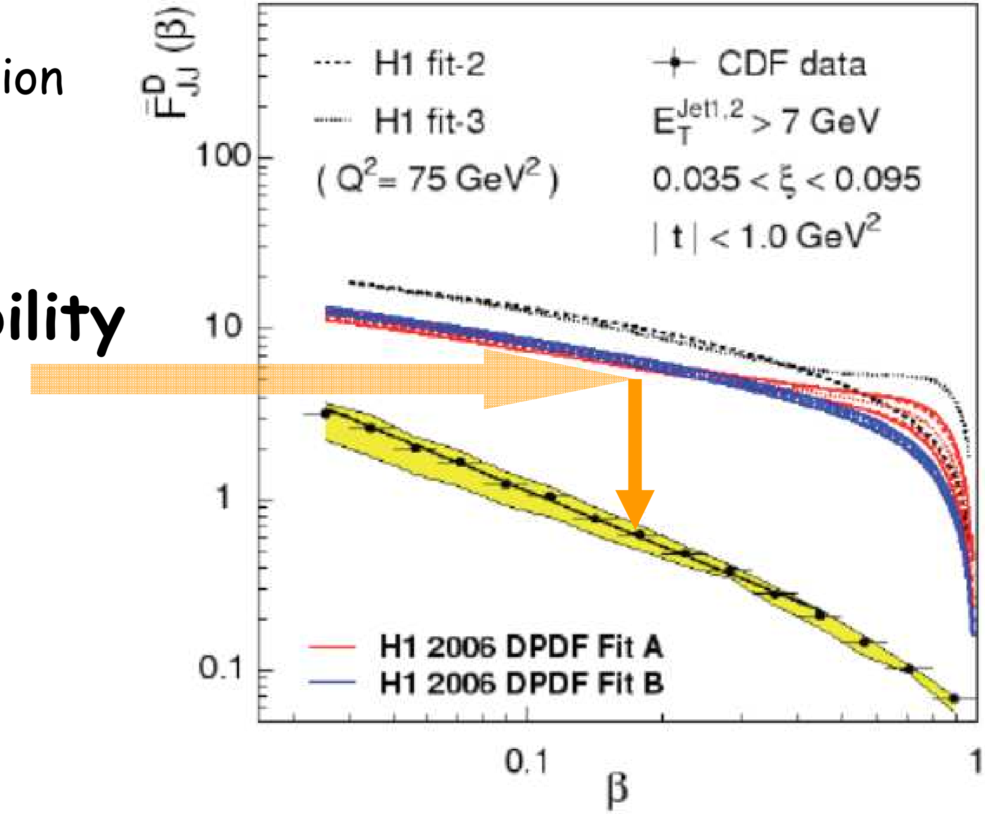
Breaking of factorisation in hh

In hadron-hadron collision,
NO factorisation!

We can not write the cross section with dPDFs only…

=> Main ingredient:
the survival gap probability
[⊗ diffractive PDFs]

With survival gap prob
@ Tevatron energies ~ **0.1**
Can we understand this effect with HERA data only?
Not really… **see talk of Armen** on « factorisation issues… »



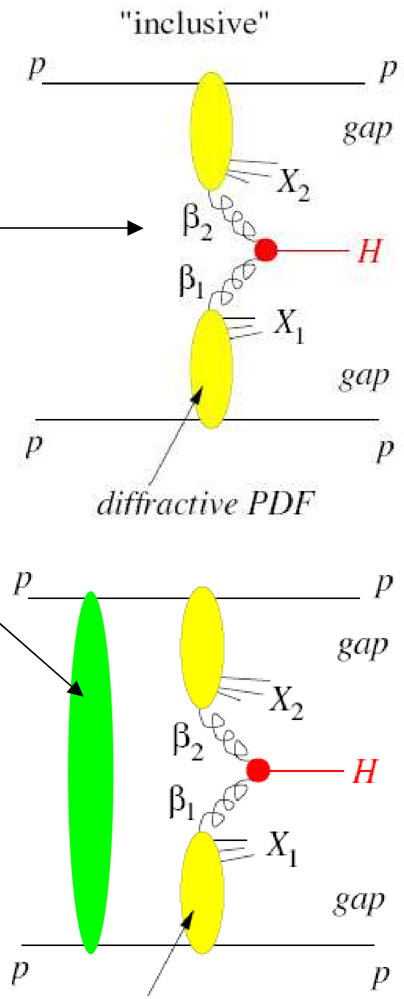
Breaking of factorisation in hh

A short comment:

In the introduction, we have motivated the study of dPDFs with the idea that it comes as an input in this reaction.
This is important to show the context of those analysis…

BUT =>
As the survival gap probability is so huge (and not really predicted with a good accuracy), we need to moderate the above argument for quantitative statements!

When we do not really understand an effect that makes a factor 10 in the prediction, effects of about 10% (from dPDFs) are marginal… till we get an understanding of this factor 10 to a few % accuracy…



Conclusions

Long history of diffractive measurements @ HERA:
difficult experimental analysis…

Completion of data sets with high stat samples only recently
reasonnable agreement between H1 & ZEUS to be studied with larger stat analysis from H1…
Then, get a definite answer from HERA on diffractive cross sections within the next year…

Diffractive PDFs give a good description of inclusive diffractive data
=> relevant functions once the IP vertex factorisation is assumed…
Already nice results obtained with new analysis on going to clarify important issues… The new data sets will help…

Of course, other models are also essential to understand the data…