

Diffractive cross sections and PDFs

Laurent Schoeffel
CEA Saclay

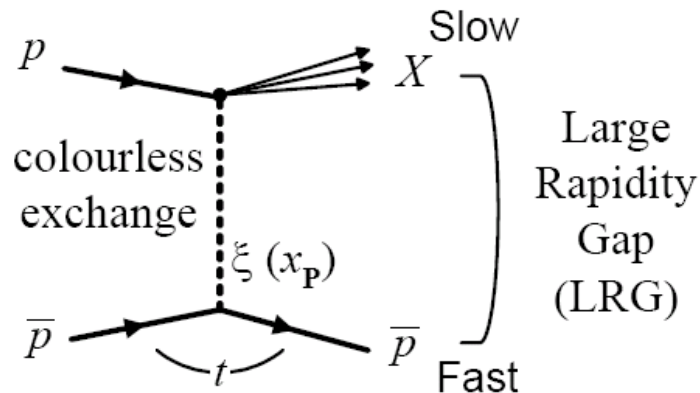


On behalf of H1 & ZEUS collaborations

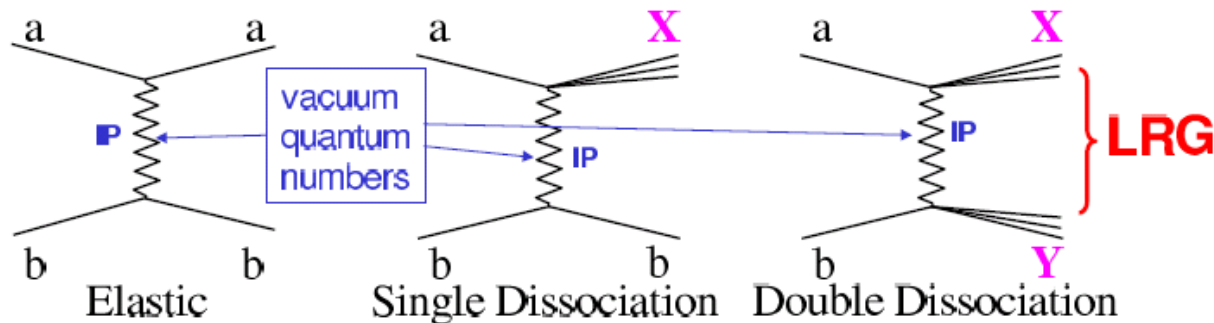
New Trends in HERA Physics 2008
October 5 - 10, 2008
Ringberg Castle, Tegernsee

Definition of hadronic diffraction

Diffraction in particle physics @ large Energy ($s \gg t$)



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

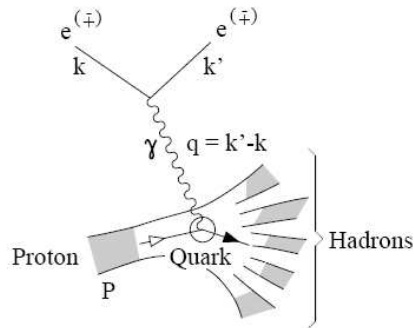


Diffraction :
generalisation of elastic scattering

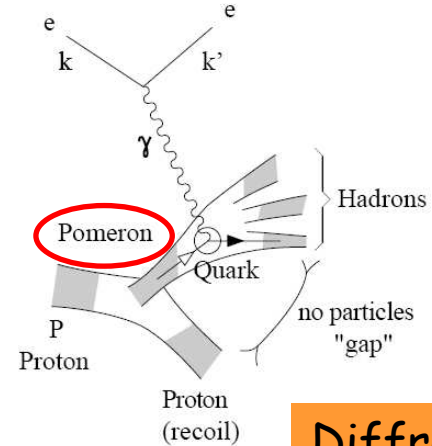
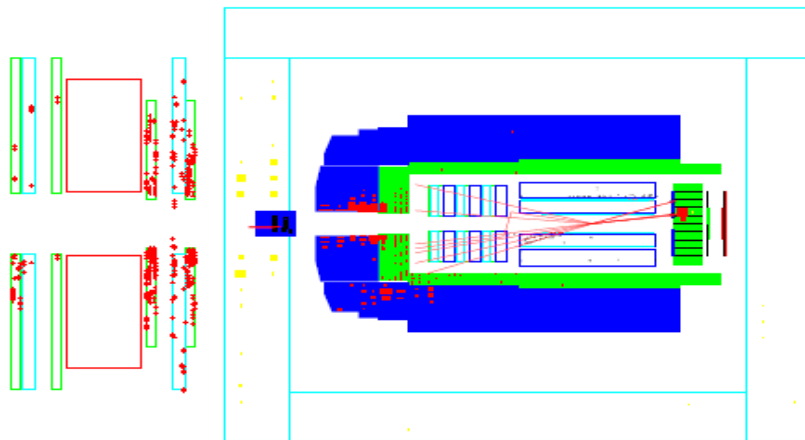
What does it give for real events @ HERA?

"Ordinary" Deep-Inelastic

PDFs

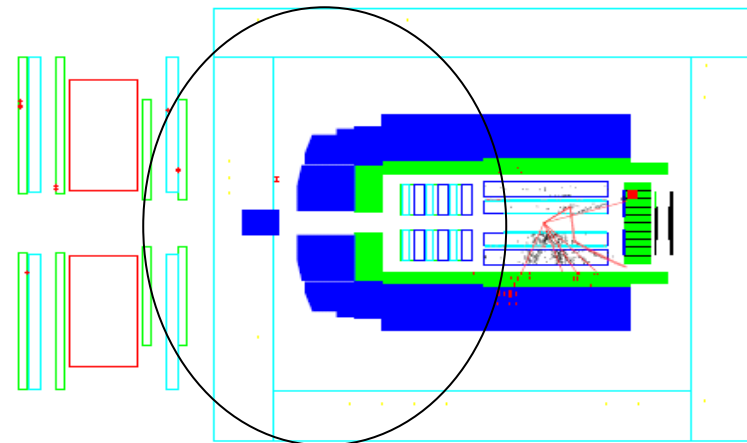


- = quark momentum XP
- = interaction volume : $Q^{-1} = (-q^2)^{-1/2}$
- = final quark momentum $(xP + q)$



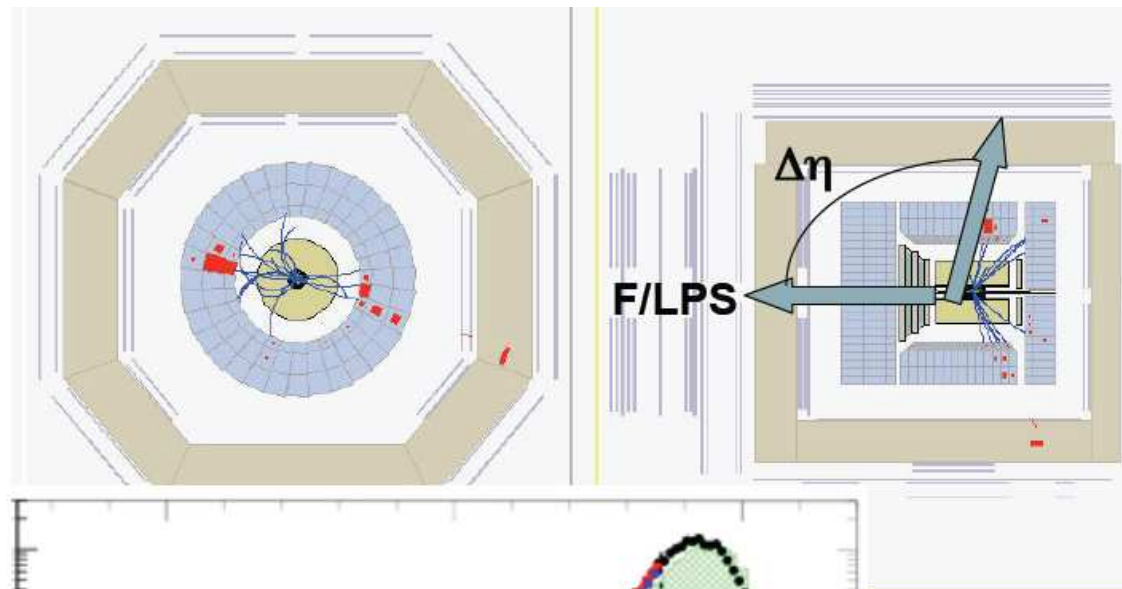
Diffractive PDFs

"Diffractive" Deep-Inelastic The Pomeron as a composite object



~ 10% of the total DIS events

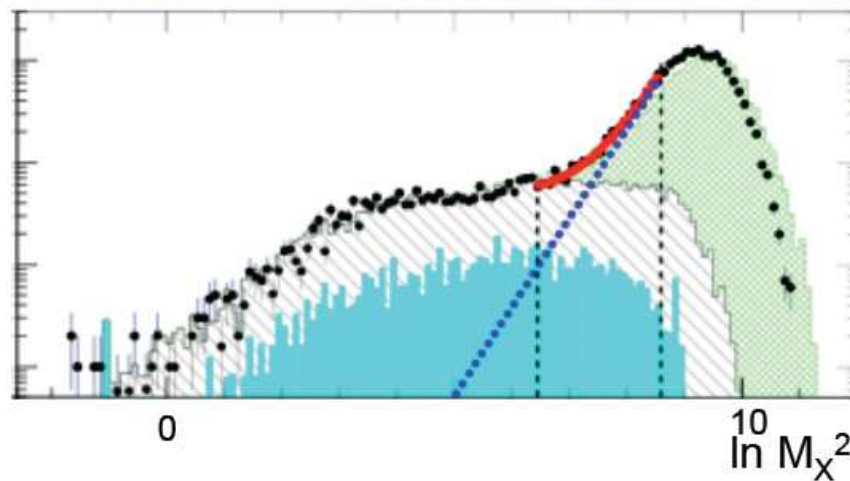
Experimental signatures of diffraction



Forward Leading protons
The cleanest but restricted kinematics...

Large Rapidity Gap events

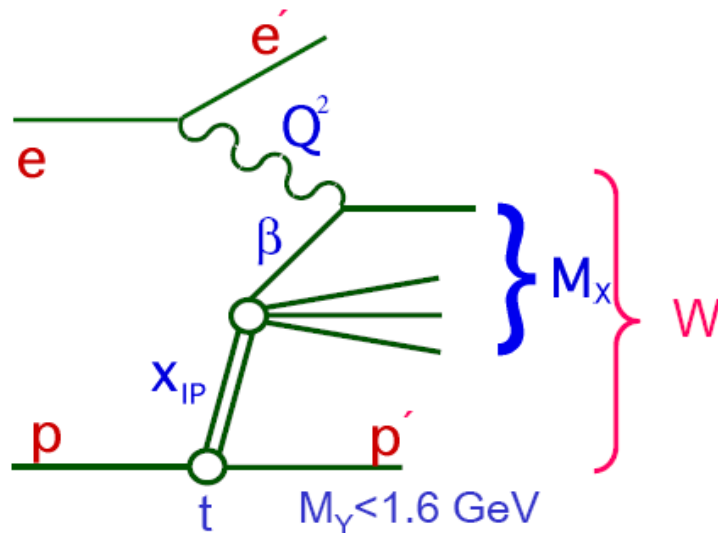
Mx method



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...

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

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

Why studying diffraction?

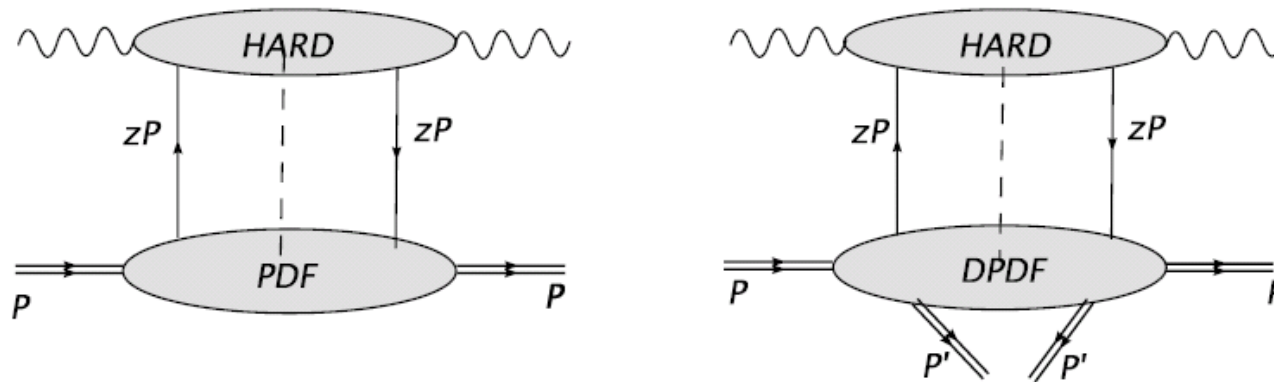
A few points for inclusive diffraction:

- Significant fraction of the inclusive DIS cross section
It deserves a specific analysis...
- long standing pb of the IP structure (specific PDFs?,
no PDFs at 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?!



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

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

More on diffractive events in pQCD...

Proof of factorization for diffractive hard scattering

John C. Collins*

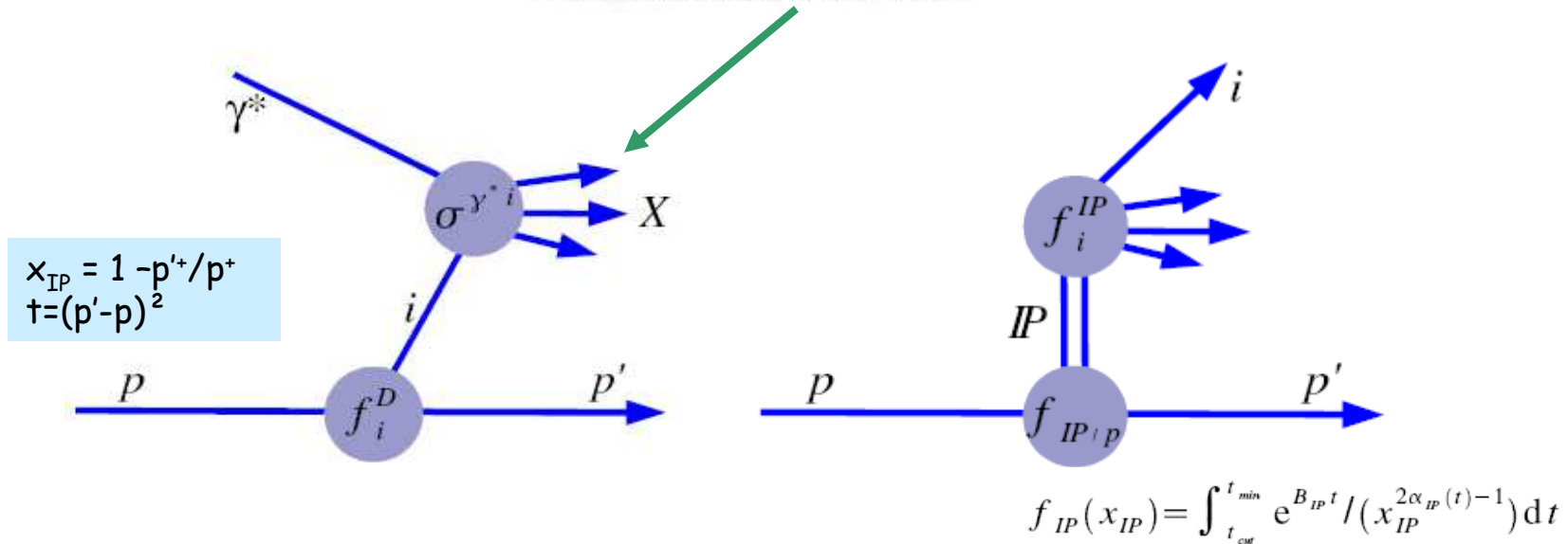
Penn State University, 104 Davey Lab, University Park, Pennsylvania 16802

(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



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

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

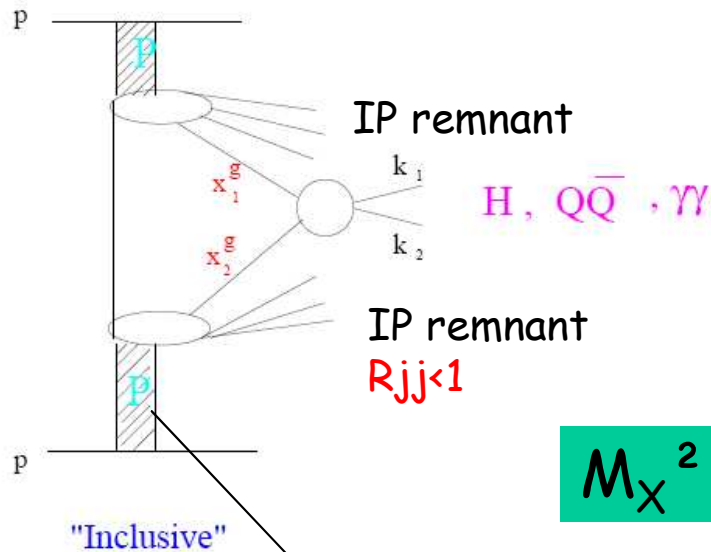
Proton vertex factorisation of the x_{IP} dependence (hypothesis not rooted in QCD)

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

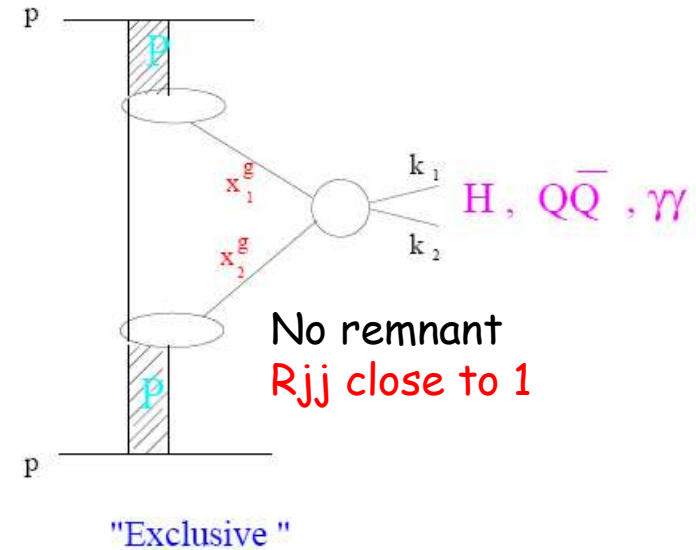
dPDFs

Higgs and diffraction @ LHC

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



$$M_X^2 = s \xi_1 \xi_2$$



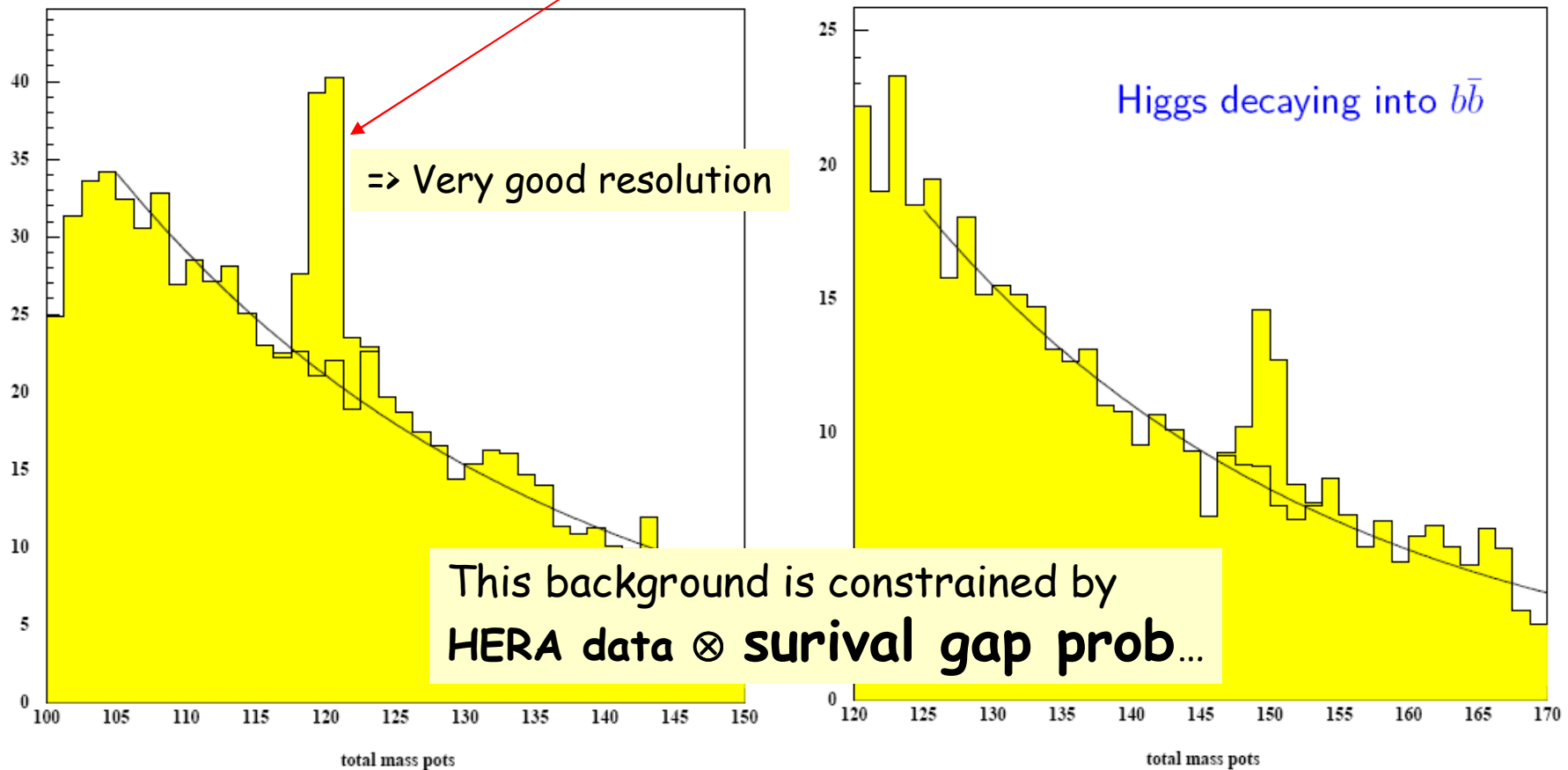
$$R_{jj} = \frac{M_{jj}}{M_X}$$

Diffractive PDFs enter here \otimes **survival 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...



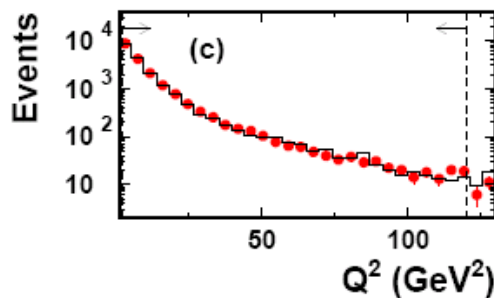
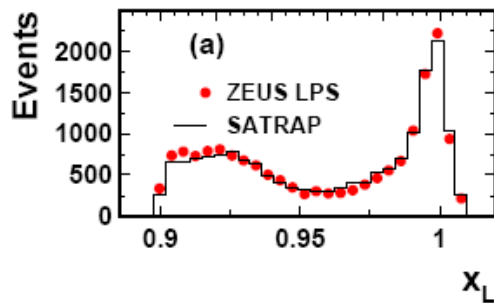
Step 1:
Measurements at HERA

Diffractive cross sections (latest analysis)

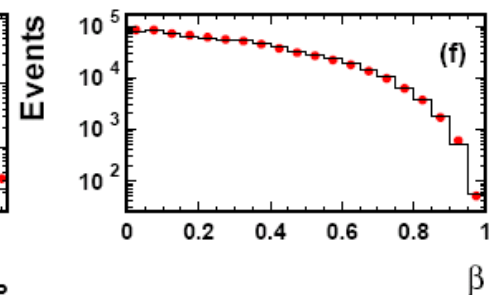
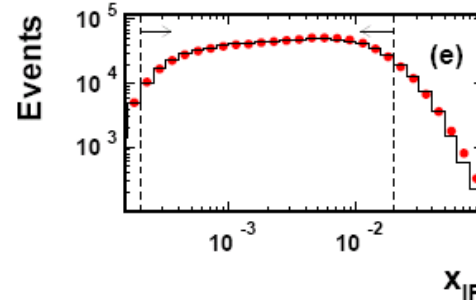
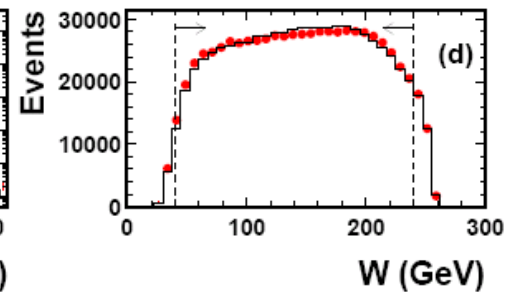
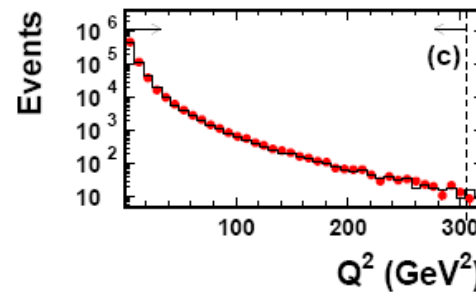
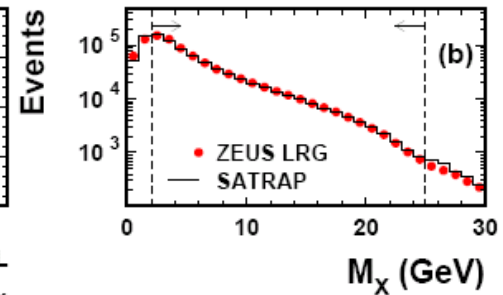
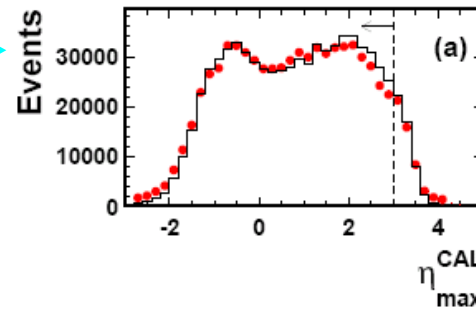
Latest ZEUS data on **LRG sample**:
 from 2.5 GeV^2 till 300 GeV^2
 (last bin @ 225 GeV^2)



& on the **LPS sample**:
 $2.5 \text{ GeV}^2 - 120 \text{ GeV}^2$
 (last bin @ 40 GeV^2)

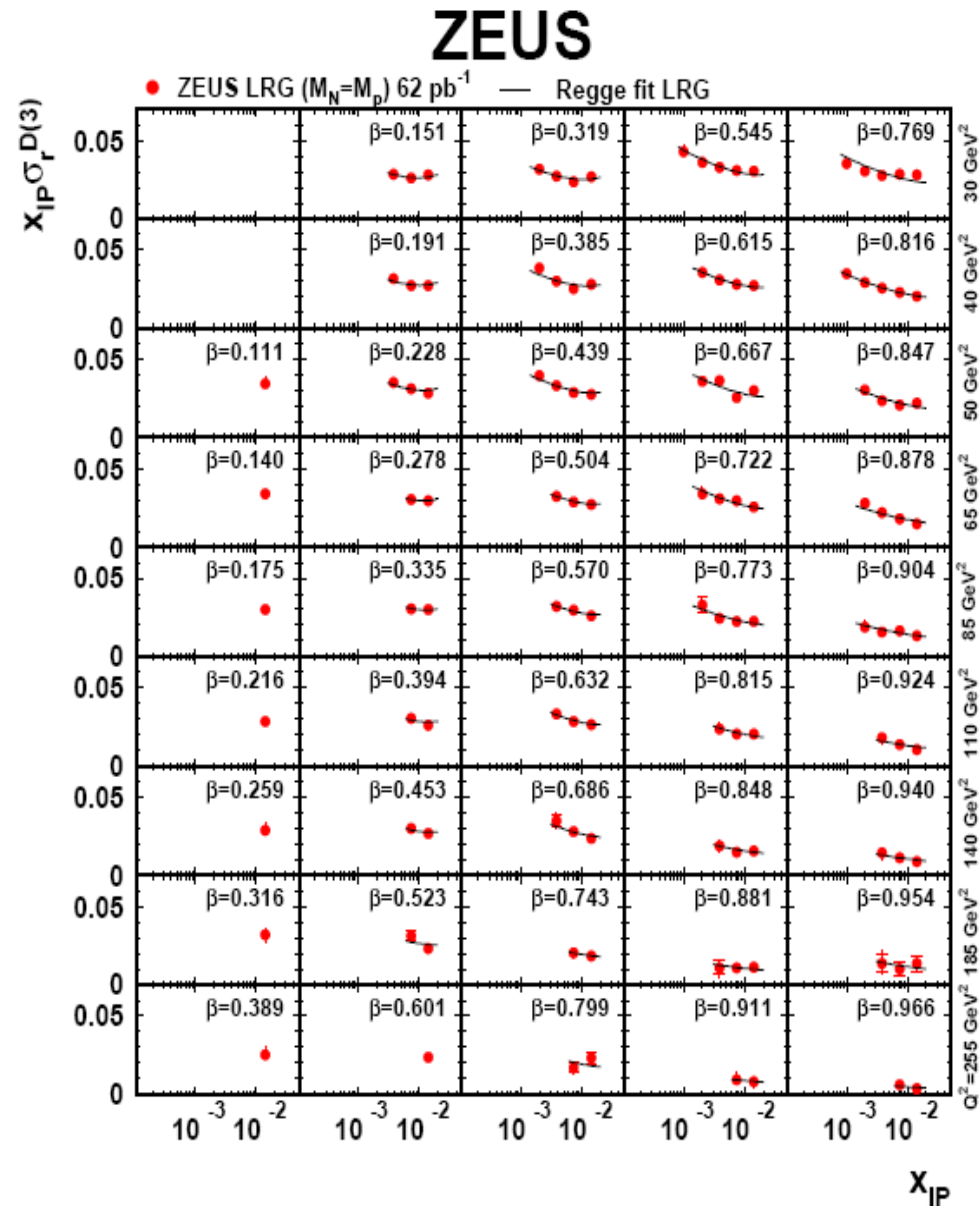
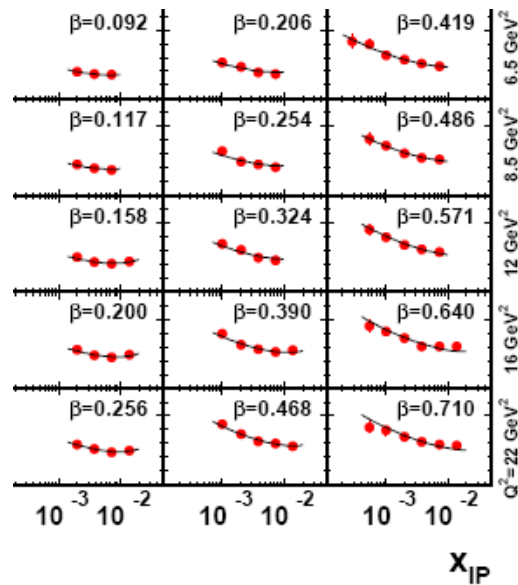


ZEUS



Diffractive cross sections (latest analysis LRG ZEUS)

Large kin coverage
in Q^2 , x_{IP} & β
+
precision data

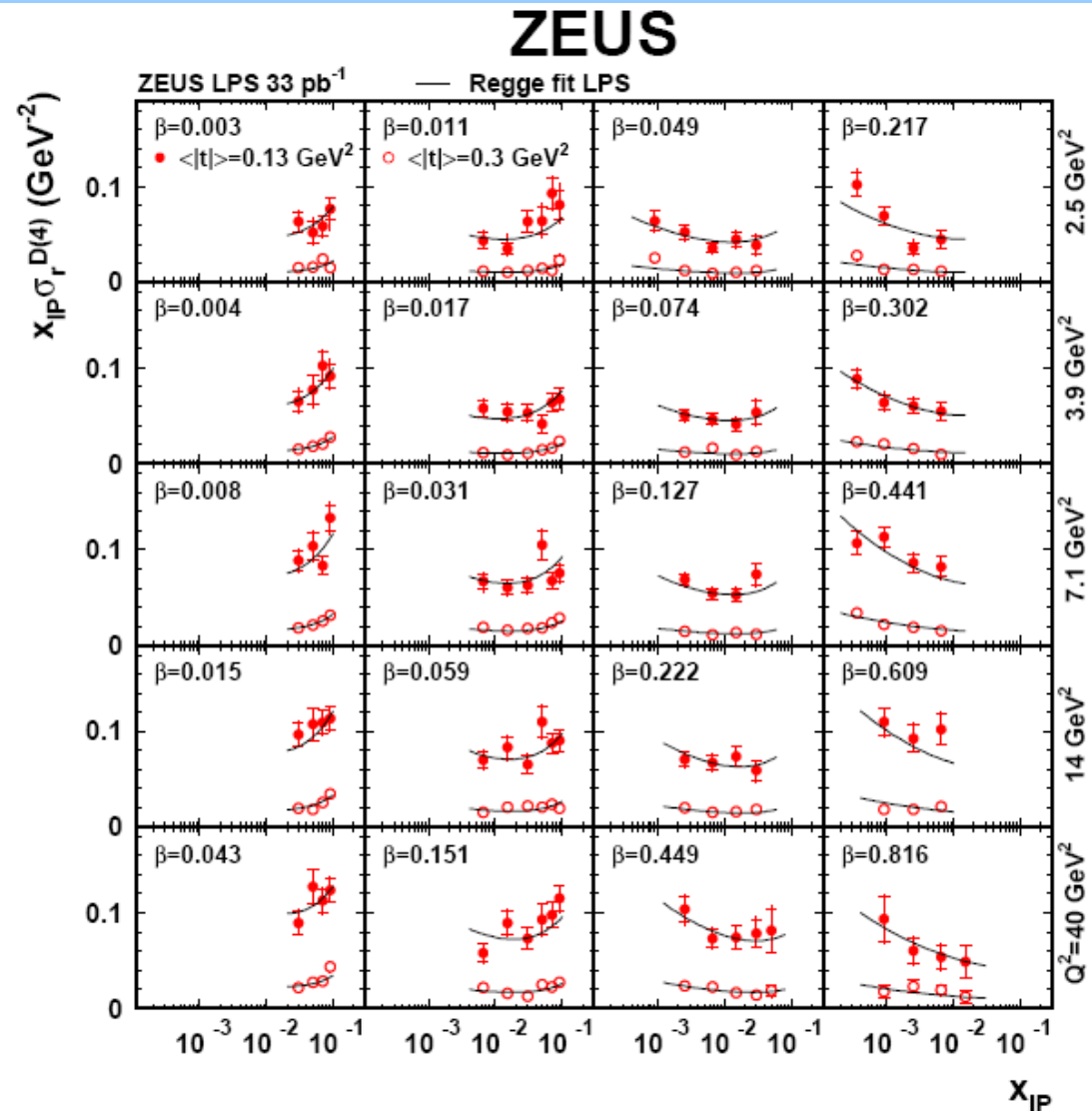


Diffractive cross sections (latest analysis LPS ZEUS)

Note that 2 bins of $\langle t \rangle$ 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)

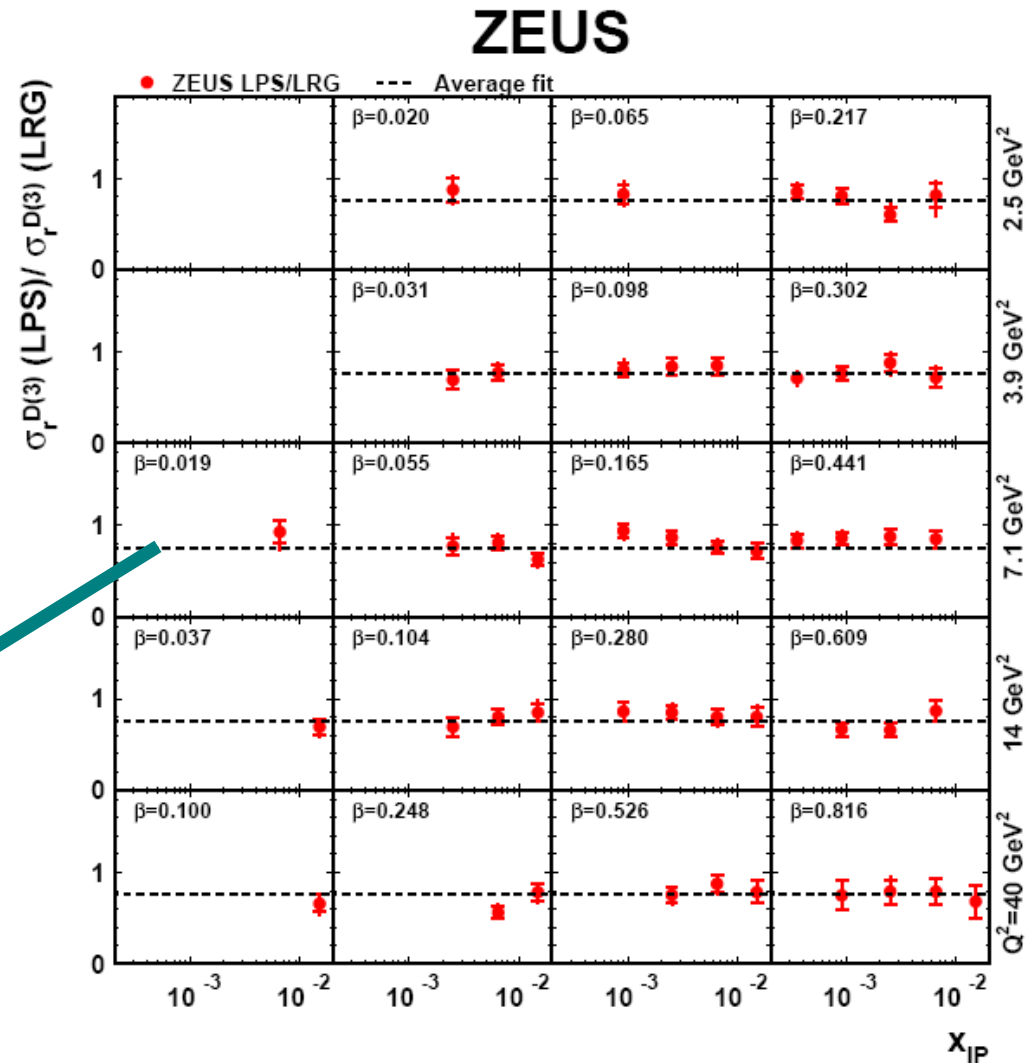
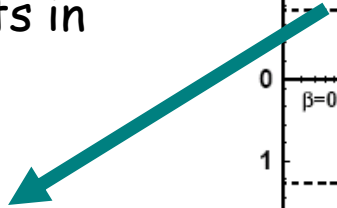
In LPS we expect a clean sample with no proton-diss background as the scattered proton is detected...

=>

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

Result:

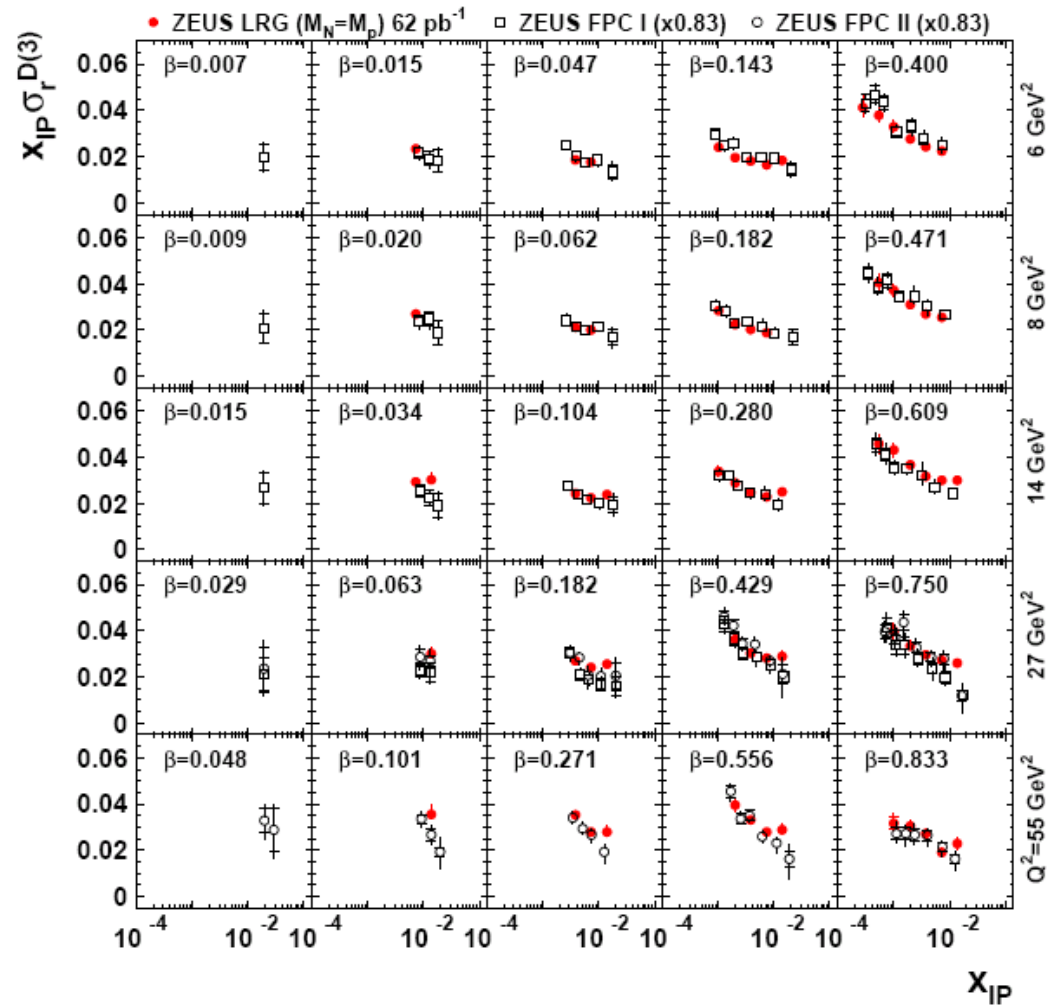
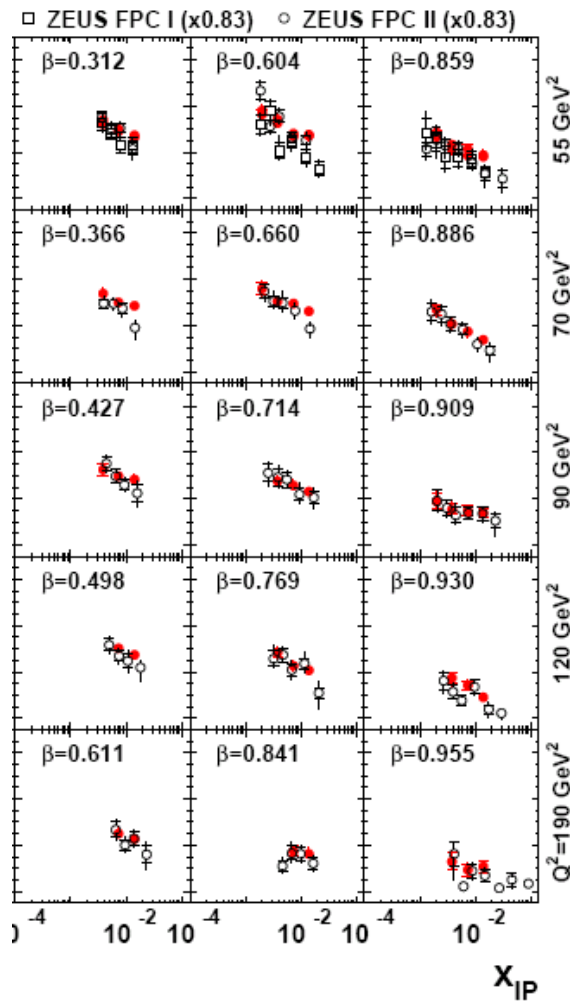
The LRG sample contains a significant fraction of pdiss ~24%... almost independent of the kinematics // H1 result...



The long standing problem of LRG versus Mx samples

Good agreement // preliminary result of H1 in 2006...

ZEUS

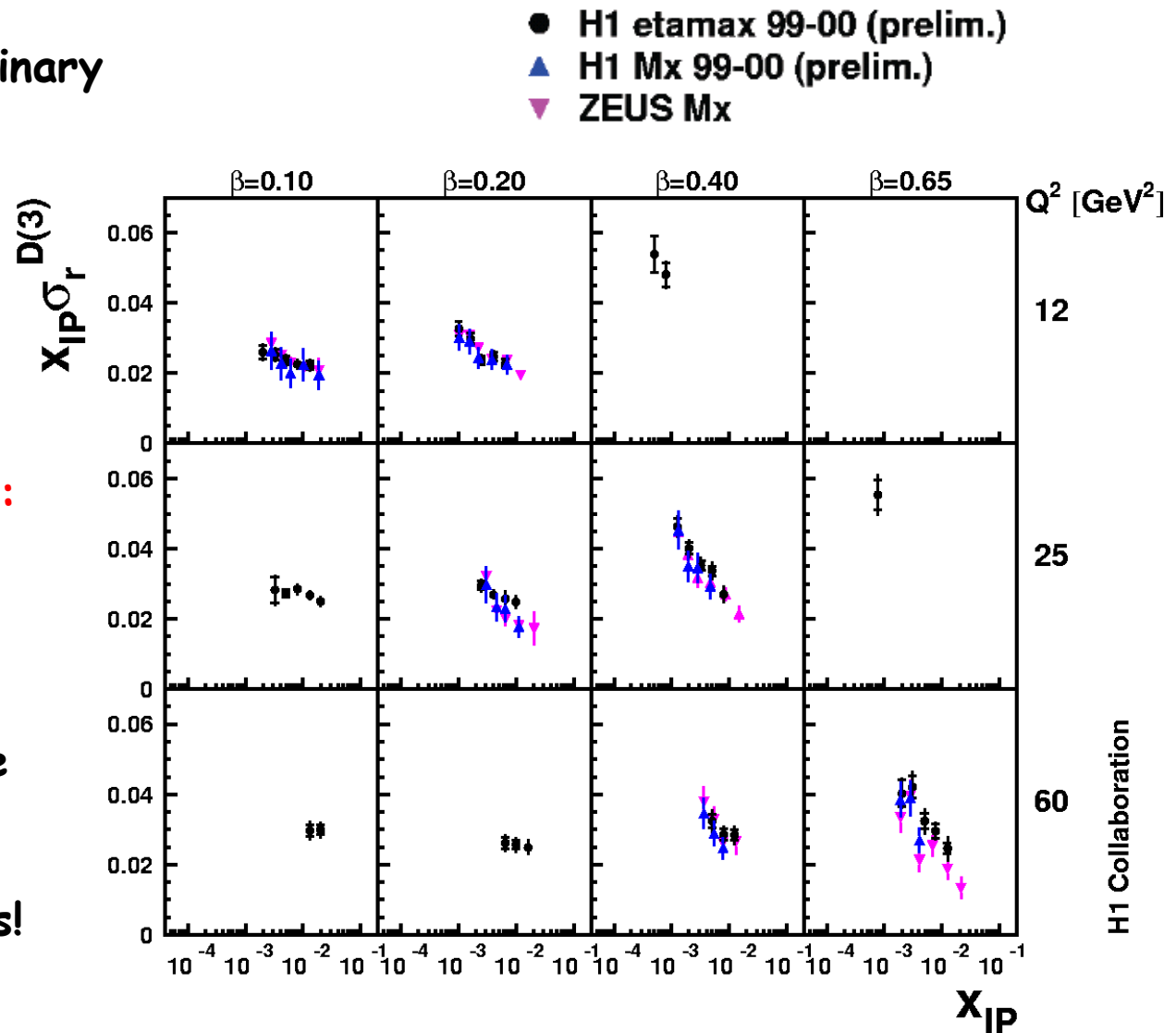


The long standing problem of LRG versus Mx samples

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...

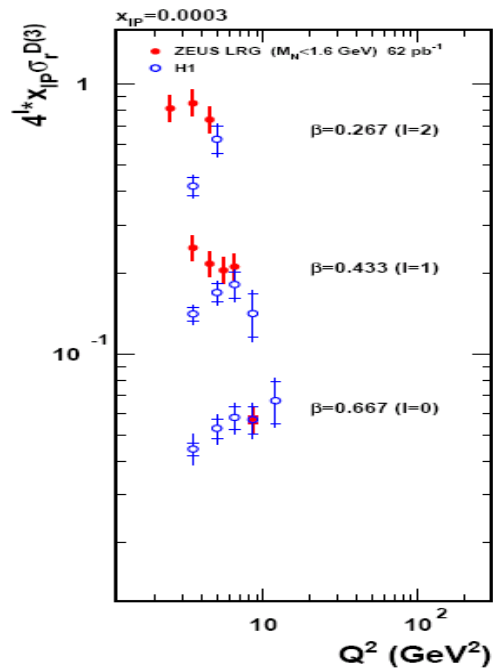
It shows the coherence of the analysis of diffraction using many experimental techniques!



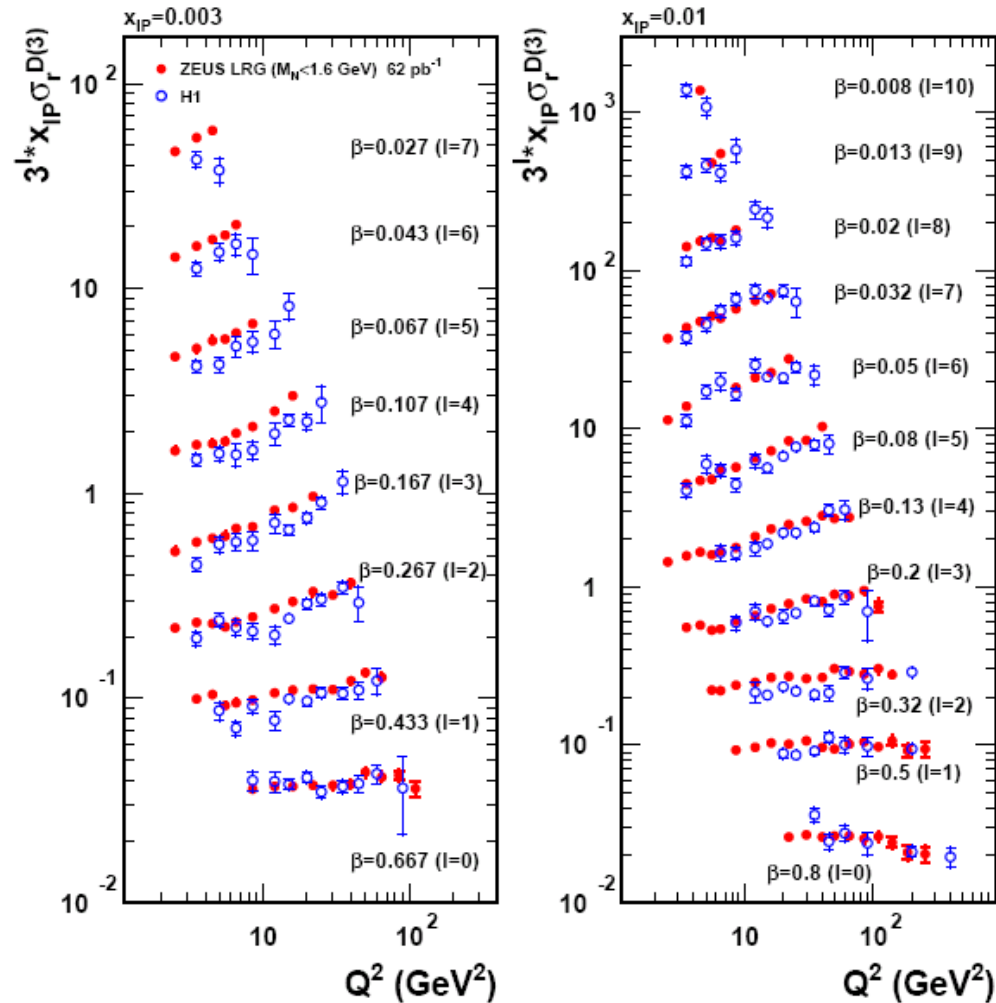
H1 LRG versus ZEUS LRG

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

Differences in shape @ low Q^2



ZEUS



Data samples: some key points

Large wealth of data with the LRG method in reasonable 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:

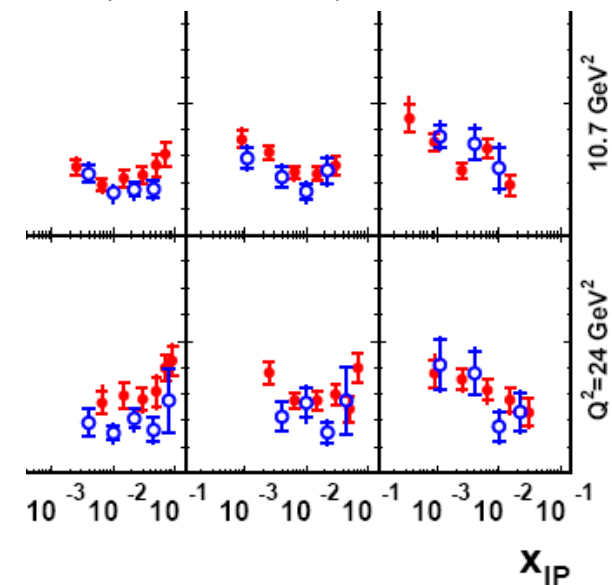
2 bins in t from ZEUS (33 pb⁻¹)

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)



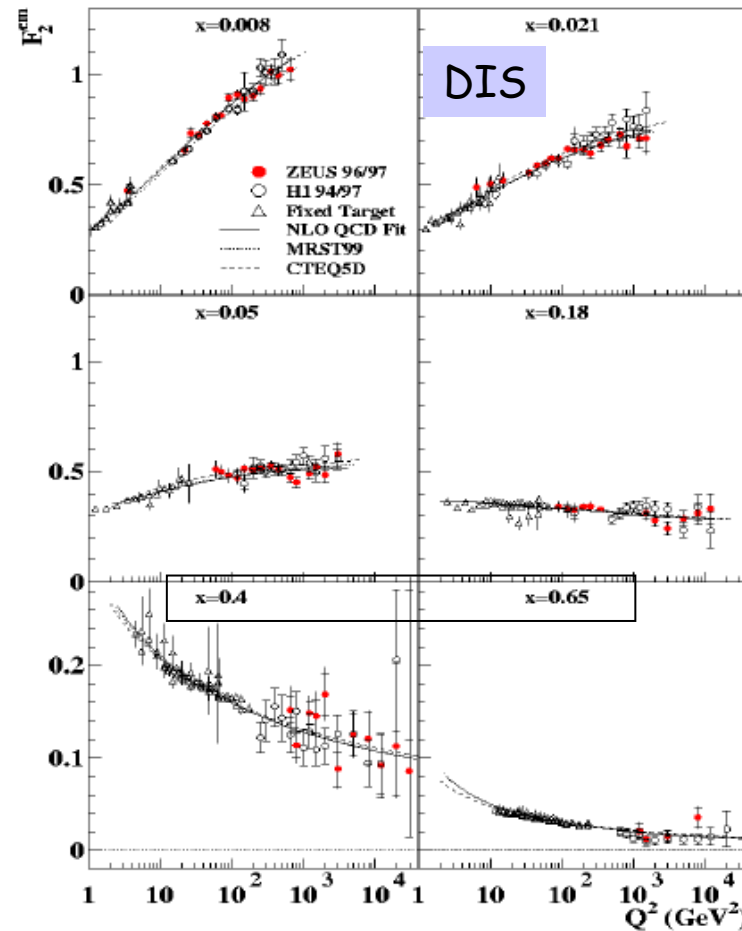
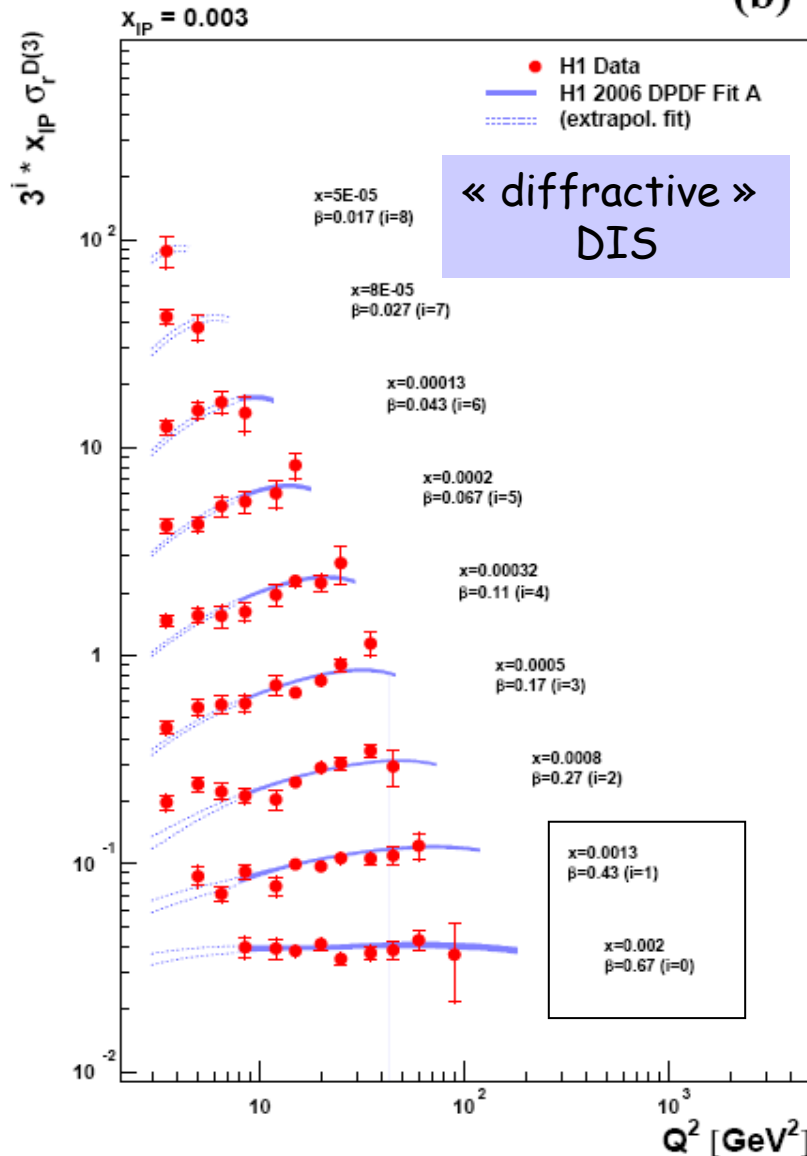
First of all, we need to have good measurements
& then to check if these measurements are
described by **calculations based on diffractive PDFs...**



Step2:
Compatibility with diffractive PDFs

First look

(b)



At large β values : scaling violations still >0
for diffraction, <0 for standard DIS
 \Rightarrow Large gluon content expected for DIFF

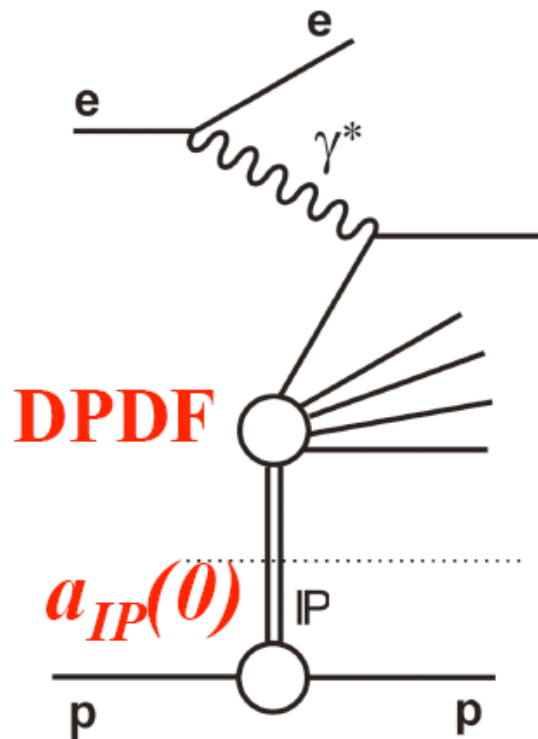
Diffractive QCD fits process

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...

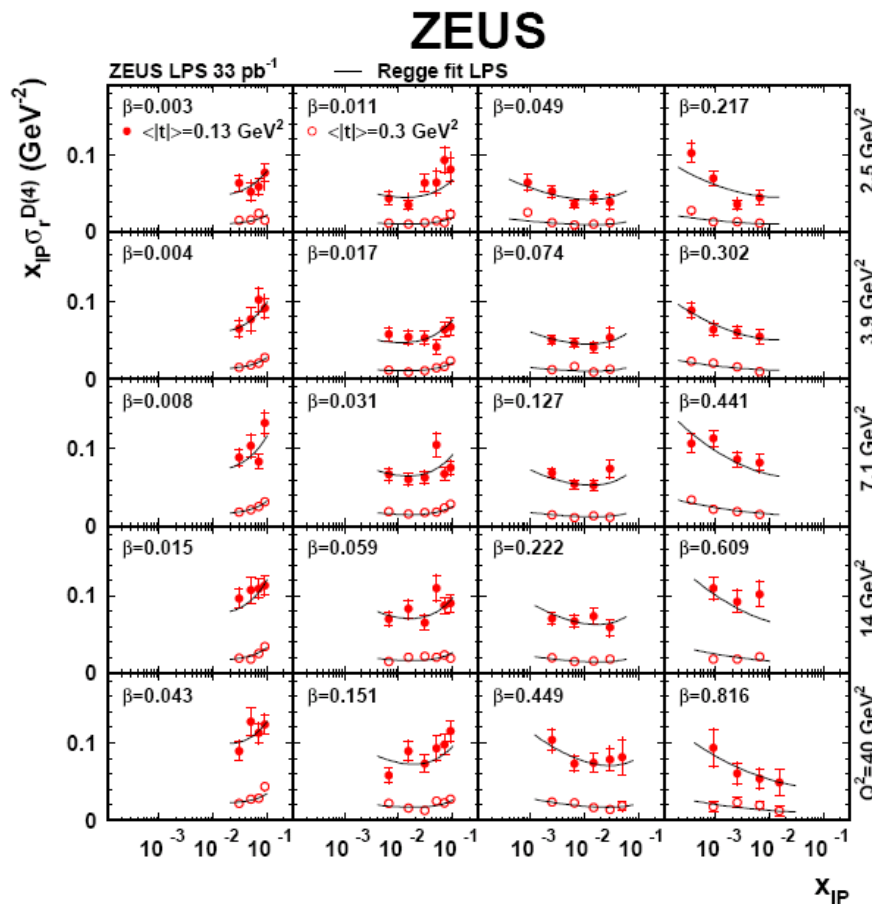
@ large x_{IP} a subleading trajectory is needed for the LRG sample (not for the Mx sample)

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



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

$$\chi^2 / \text{ndf} = 162/153$$

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

$$\alpha'_{IP} = -0.01 \pm 0.06(\text{stat}) \\ +0.04 -0.08(\text{syst}) \text{ GeV}^{-2}$$

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...

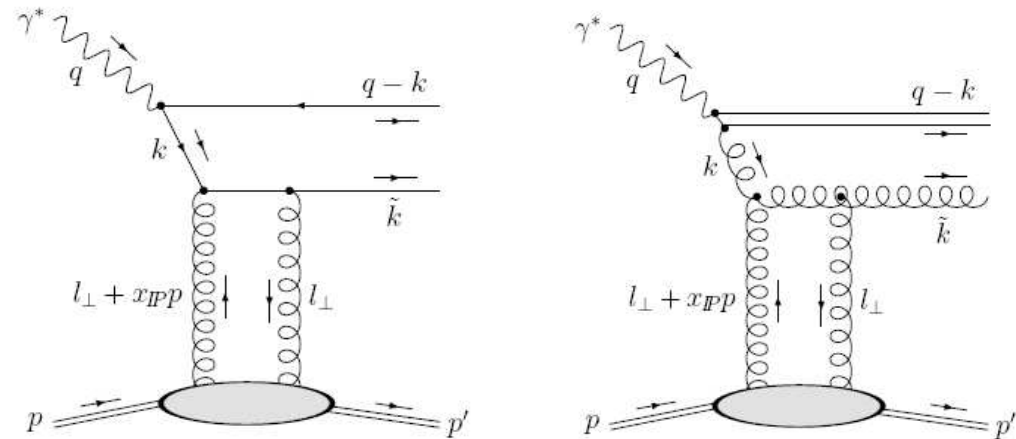
For the diffractive PDFs:
 Q^2 given by DGLAP equations
 β dependence fitted
Only leading twist approach

& 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

$\Rightarrow x_{IP}$ 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

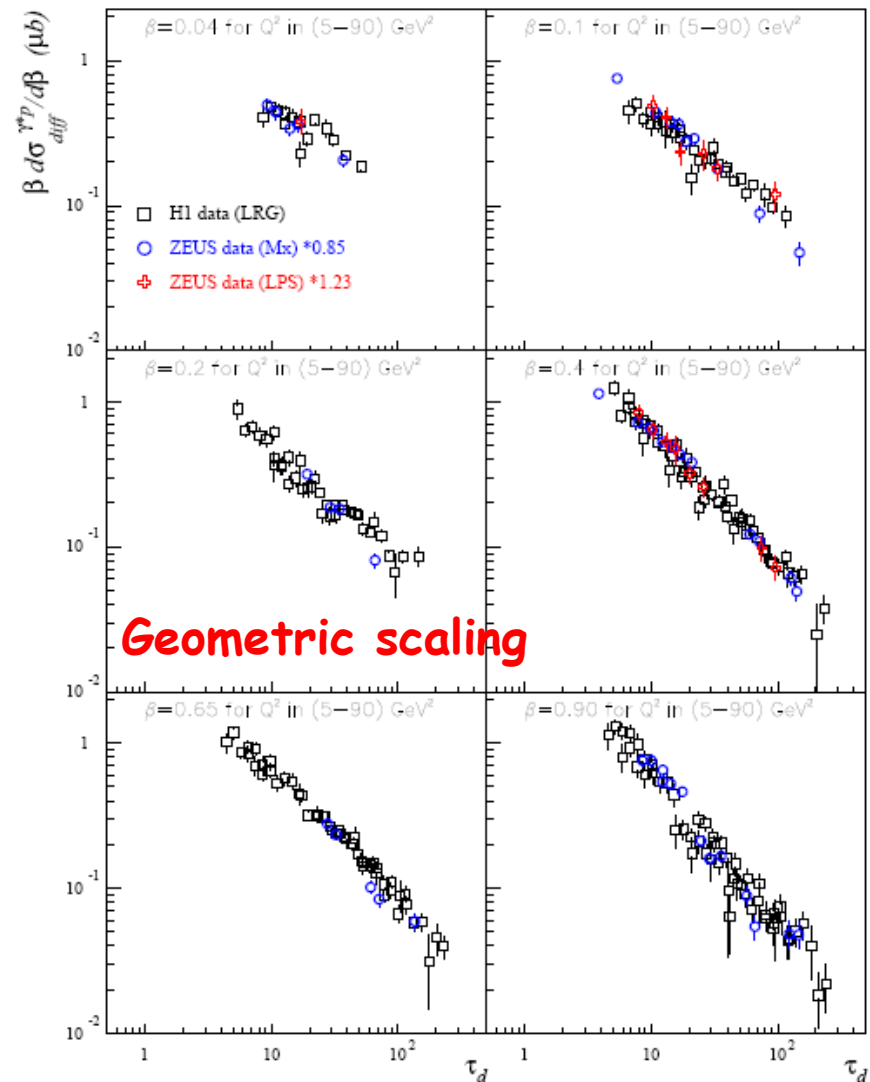
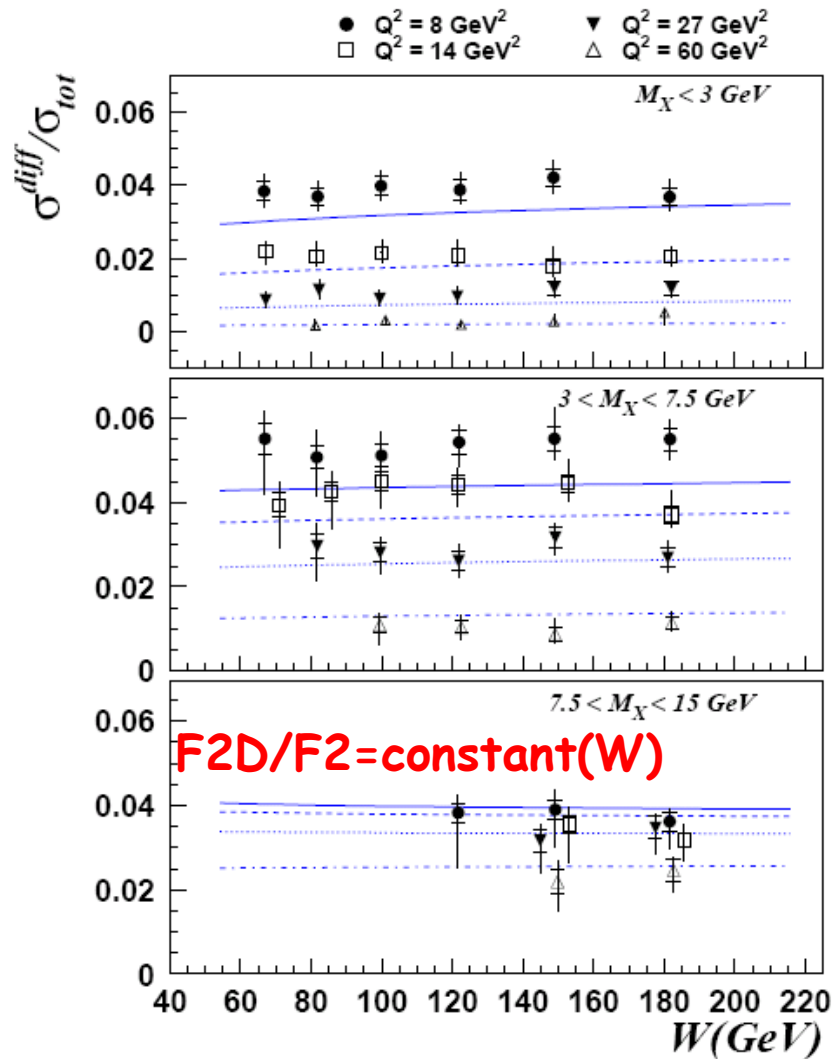
Only qqbar & qqbarg

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

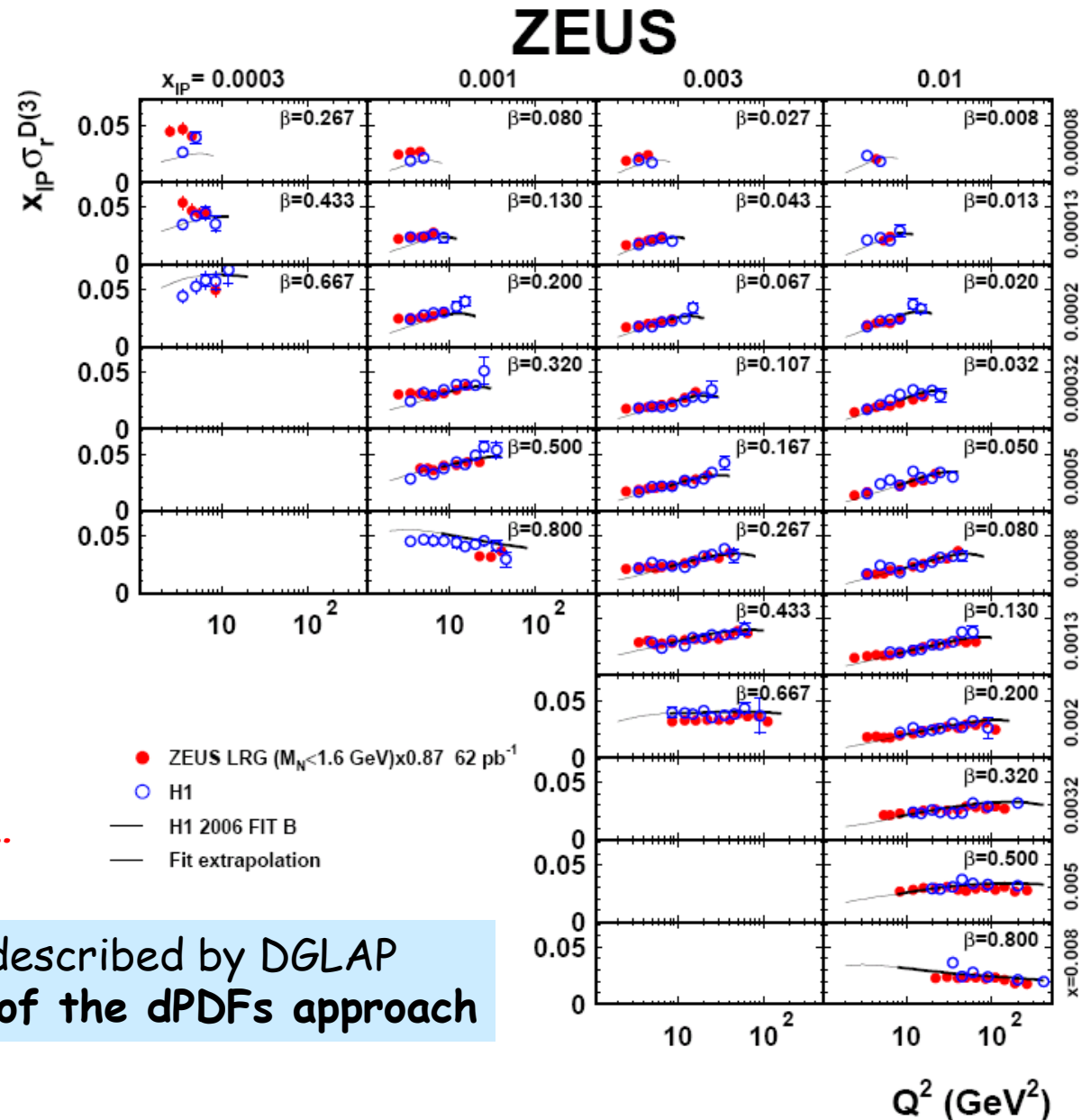
ZEUS & H1
diffractive cross
Sections (ZEUS
normalised to H1
by a global factor
on this plot)

+ QCD fit result
(dPDFs approach)...

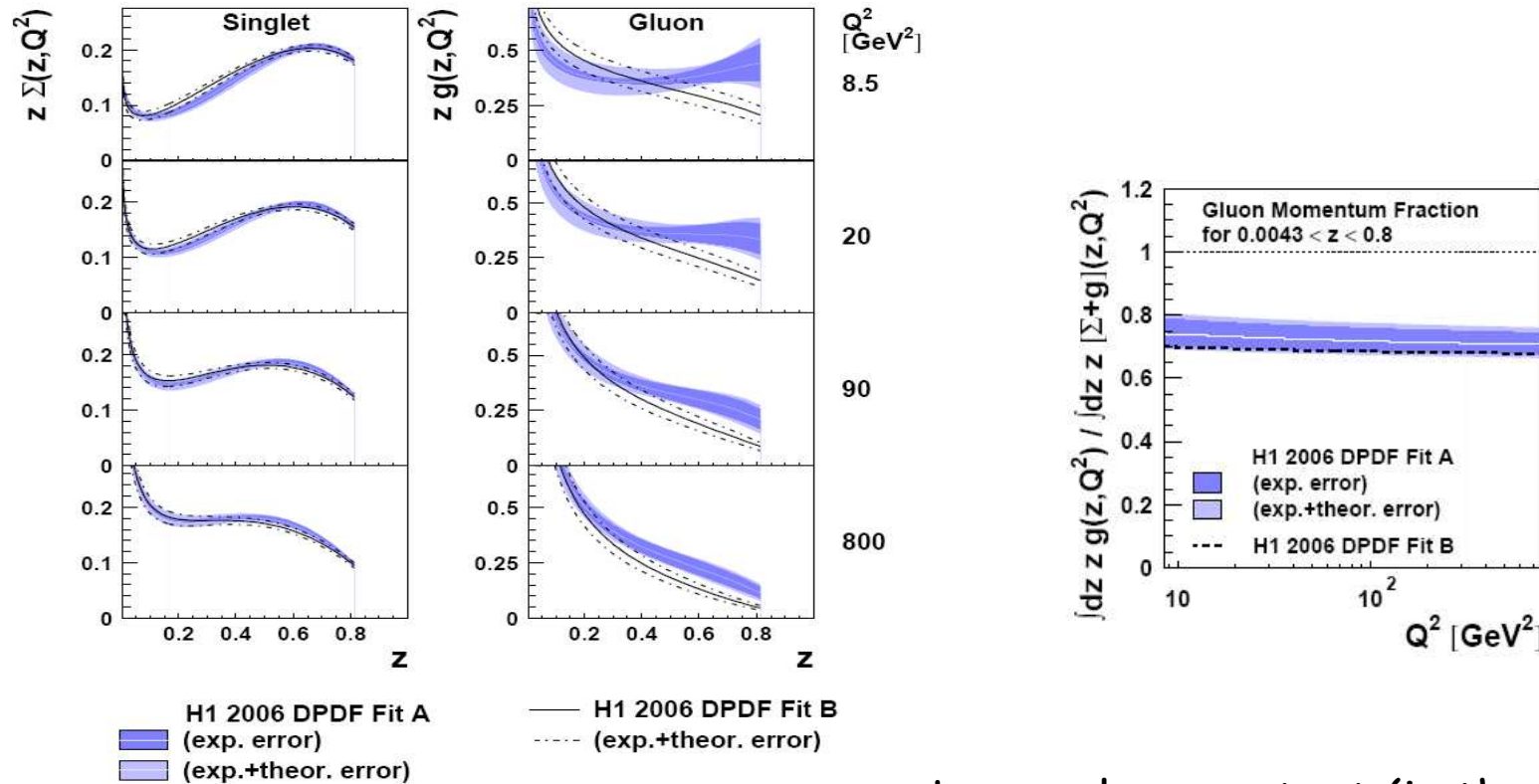
Good agreement
=>

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

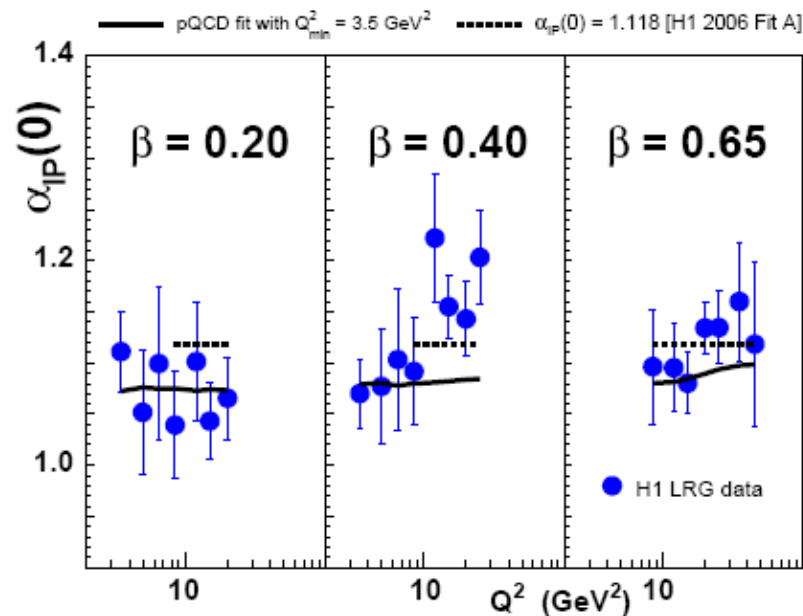
Large uncertainty @ large β

As anticipated with the
 $\beta > 0$ scaling violations till
large β

Diffraction 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, Q^2)



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:

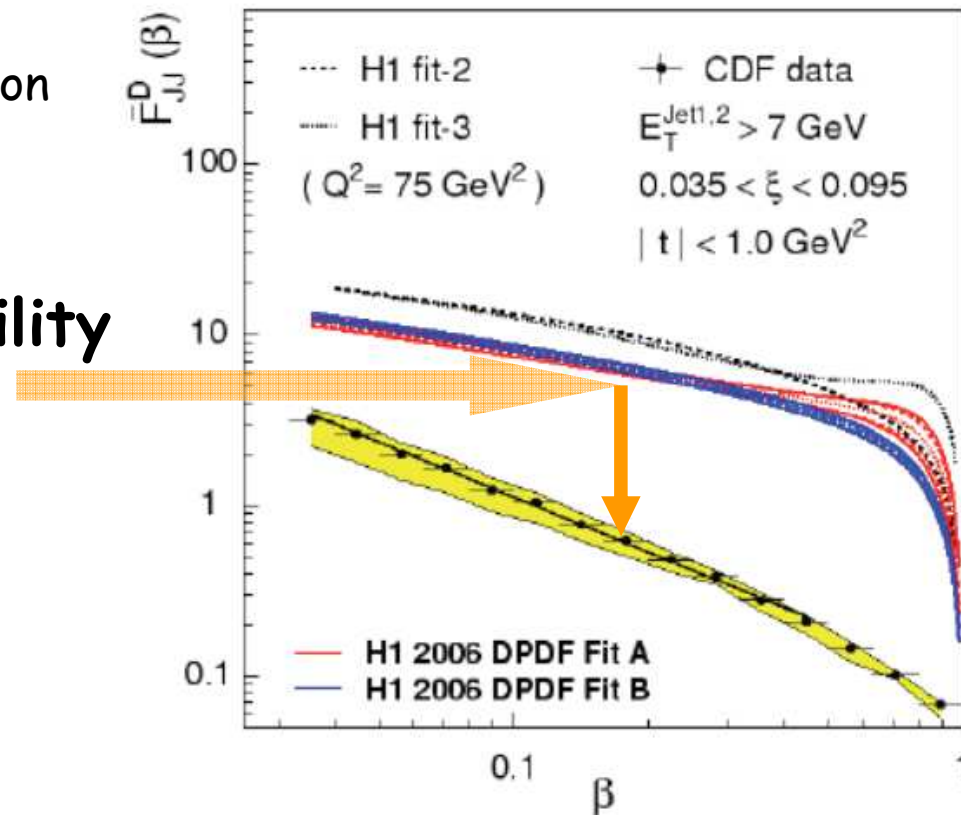
the survival gap probability
[⊗ diffractive PDFs]

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

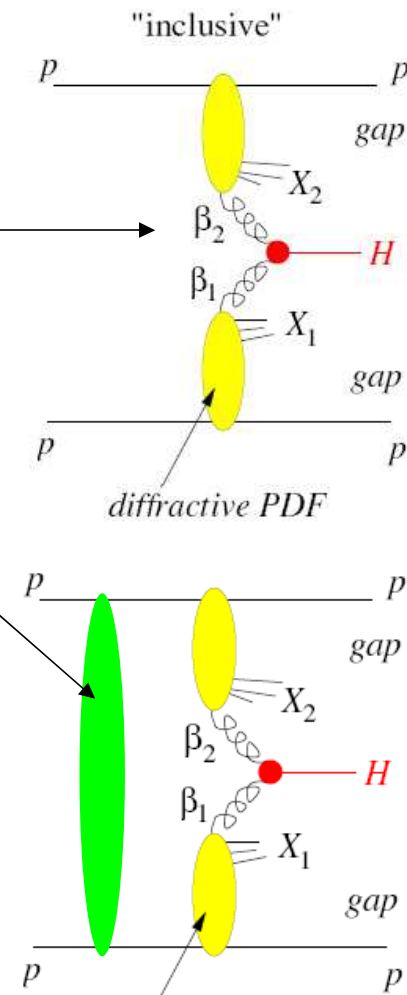
A short comment:

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
reasonable 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...