Diffraction with a Very Forward Proton Spectrometer at HERA

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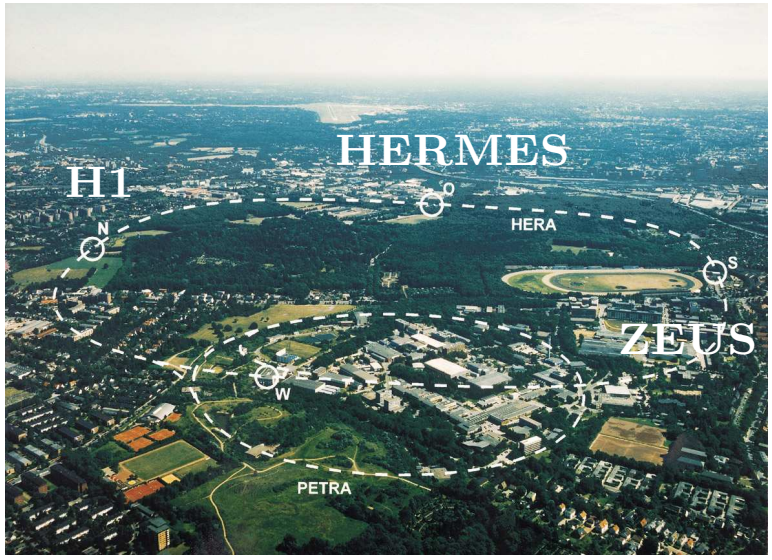
I.I.H.E., ULB.

HERA collider



$e(27.5GeV) \longrightarrow\!\!\!\!\leftarrow p(920GeV)$

$\sqrt{s} \sim 320$ GeV

10^{10} à 10^{11} particles

Rate: 10.4 MHz

$\mathcal{L} \simeq 10^{31}$ cm^{-2} s^{-1}

Integrated luminosity $\approx 600\ pb^{-1}$

HERA-I :⟶ 00

HERA-II: 03⟶ 07 (Lumi ↑)

Data Taking : started: 1992
ended: july 2007

Main goals:

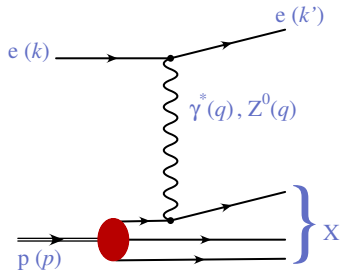
- Study the structure of the proton in terms of quarks and gluons = PARTONS
- Study the interaction between partons

- 2 general detectors : H1 et ZEUS
- 1 experiment on fixed target to study the spin of the proton : HERMES (e-polarised gaz)

Diffraction $ep \to epX$

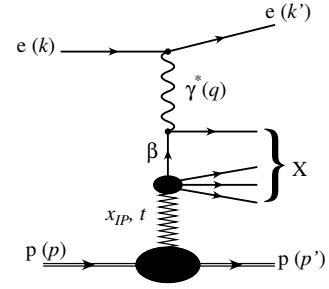
Deep Inelastic Scattering DIS:

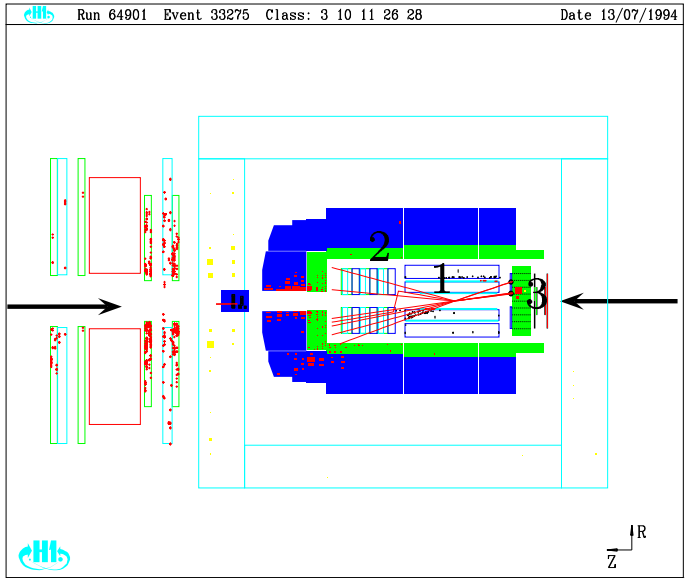
$ep \to eX$



Diffraction:

$ep \to epX$





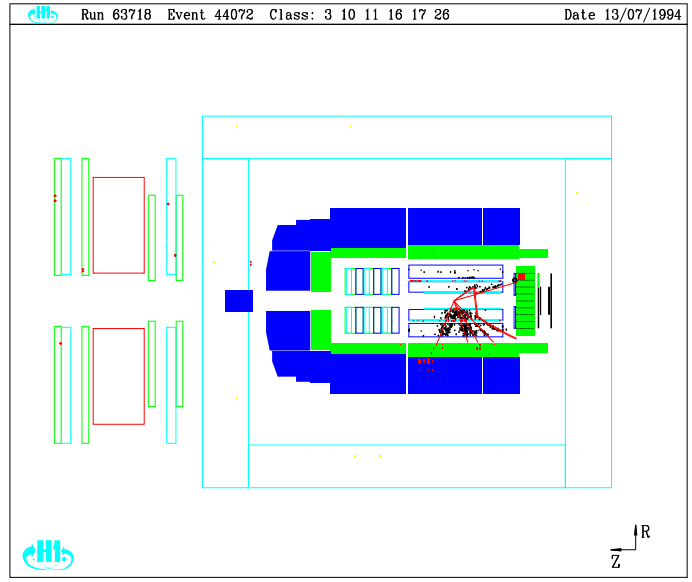
e

1: Trackers

2: LAr Calo.

3: SpaCal Calo.

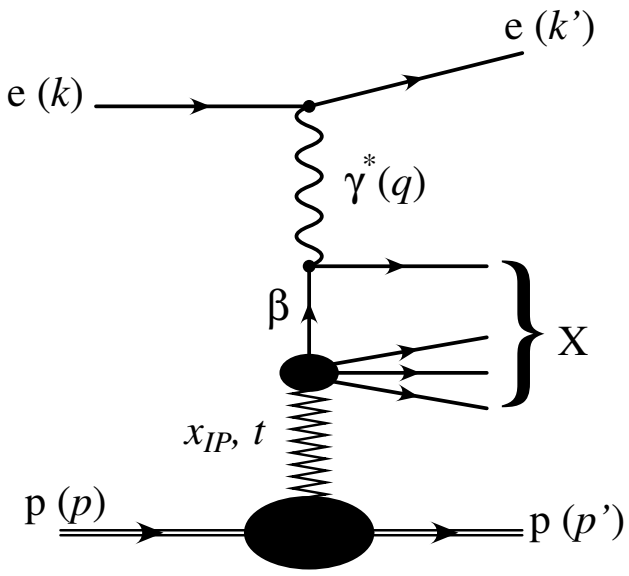
p



rapidity gap $\Rightarrow$ no colour string between the proton and the X system $\Rightarrow$

colourless object exchanged: **Pomeron**

Kinematics



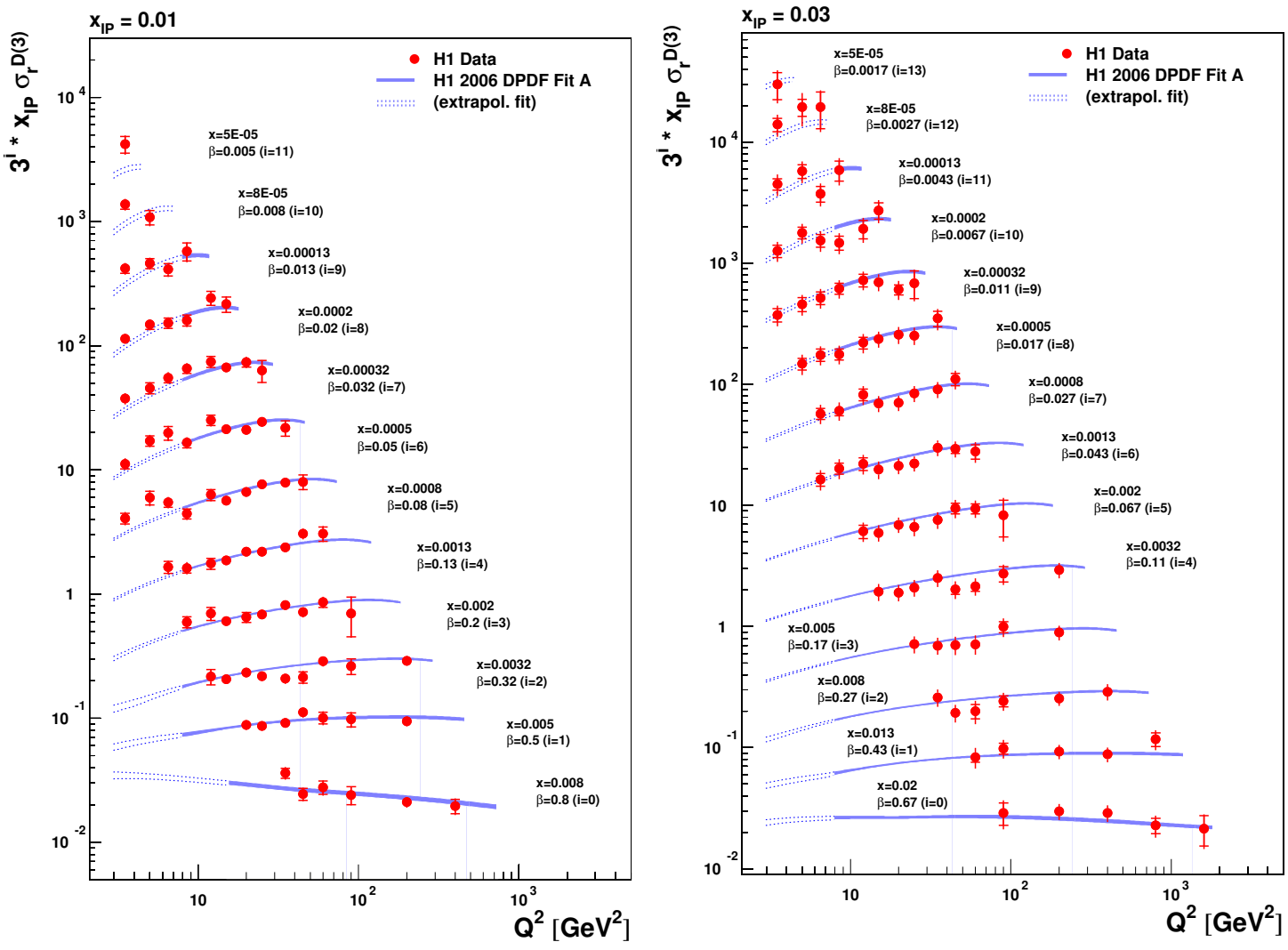
Q^2 = virtuality of the photon
$x_{I\!P}$ = momentum fraction of the proton carried by the pomeron ($\mathbb{P}$)
β = momentum fraction of the pomeron interacting with the photon
t = momenta squarred of the pomeron
y = inelasticity

Diffractive cross section

$$\frac{d^4\sigma(x_{I\!P},Q^2,\beta,t)}{dx_{I\!P}dQ^2d\beta dt} = \frac{4\pi\alpha^2}{\beta Q^4}(1-y+\frac{y^2}{2})\ F_2^{D(4)}(x_{I\!P},Q^2,\beta,t)$$

F_2^D related to quark and gluon densities in $\mathbb{P}$ $\Rightarrow$ Probe the QCD structure of the $\mathbb{P}$

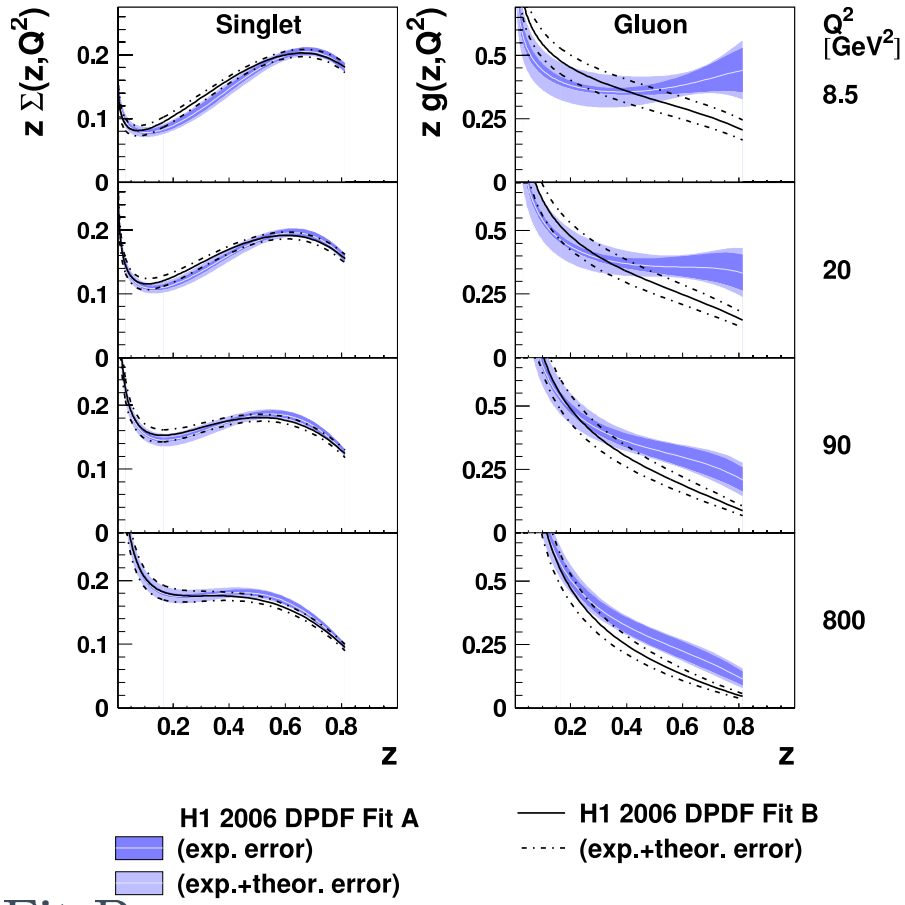
Measure $\sigma \Rightarrow$ Measure F_2^D



H1 Collab.,Eur.Phys.J.C48:715-748,2006.

PDFs

$F_2^D \Rightarrow$ determine parton densities via the equations of evolution of QCD (DGLAP)



$z = \beta$ at LO

2 DPDF : Fit A and Fit B

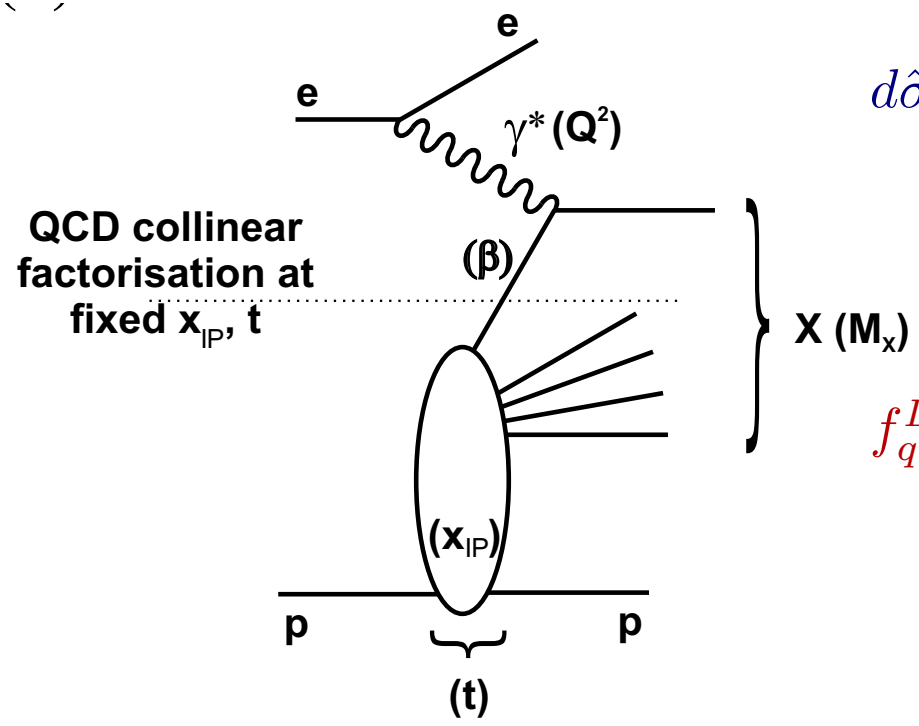
H1 Collab., A. Aktas et al., Eur. Phys. J. C48 (2006) 715-748

Factorization theorem

Factorization theorem

Proved for diffraction in electro-production (DIS) ($Q^2 > 1\,GeV^2$)

$$d\sigma^{ep\to epX}(\beta, Q^2, x_{I\!P}, t) = \sum_q f_q^D(\beta, Q^2, x_{I\!P}, t) \bigotimes d\hat{\sigma}^{eq}(\beta, Q^2)$$



$d\hat{\sigma}^{eq}(x, Q^2) \approx$ Hard scattering matrix elements $\gamma - q$
$\Rightarrow$ PERTURBATIVE

.....

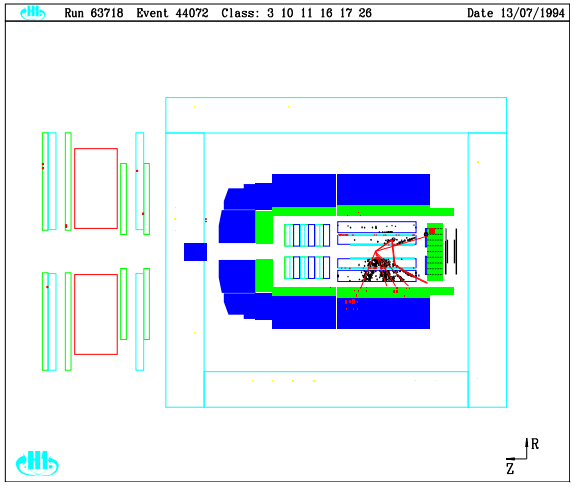
$f_q^D(x, Q^2, x_{I\!P}, t)=$ Partons Density Function **universal** (PDF) $\Rightarrow$ NON PERTURBATIVE

Method of selection of diffraction

Diffractive events are selected by:

large rapidity gap LRG

In most of the analysis of the H1 Collaboration



√ **High statistic**

× **Background important**

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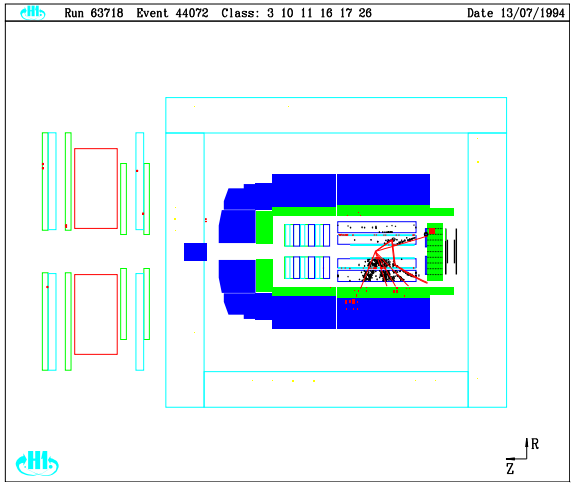
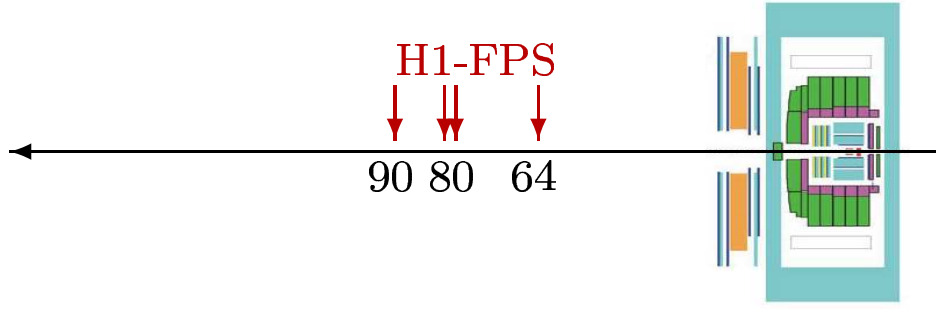


√ **High statistic**
× **Background important**

proton spectrometer

Direct measurement of the scattered proton

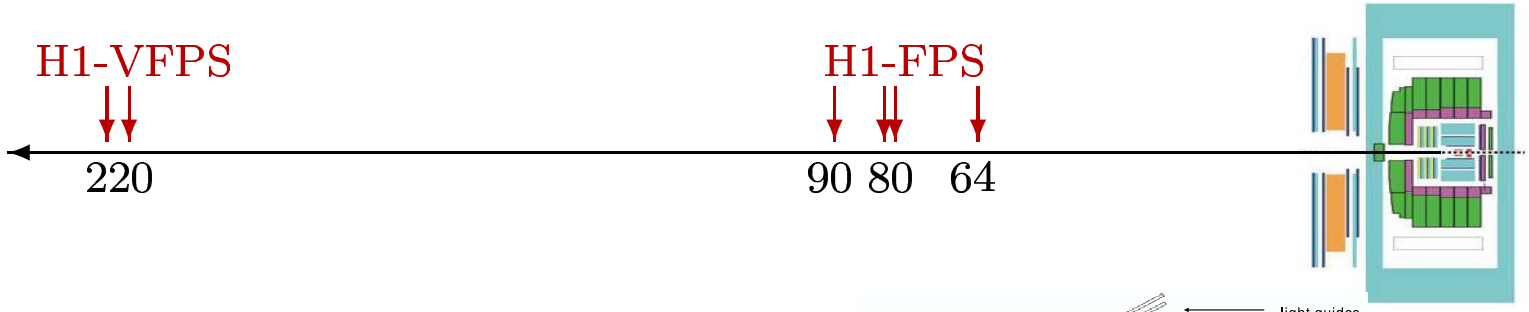


√ **Highly reduced background**
× **low acceptance ⇒ low statistic**

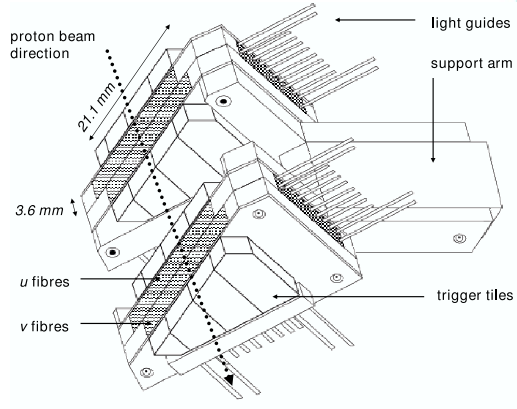
The Very Forward Proton Spectrometer

Purpose : direct measurement of the scattered proton momentum with high acceptance and low background

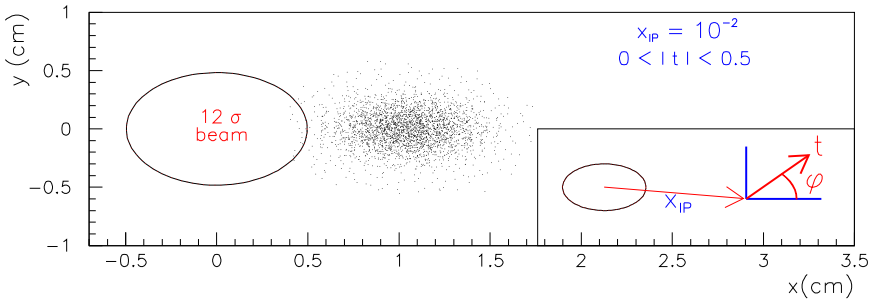
Belgian Project : I.I.H.E. (ULB-VUB) and UA
Since 2004, located at 220 meters from the interaction point
Stable data since 2006



- 2 stations each with 2 scintillating fibers detector
- 4 planes of 4 trigger tiles



VFPS

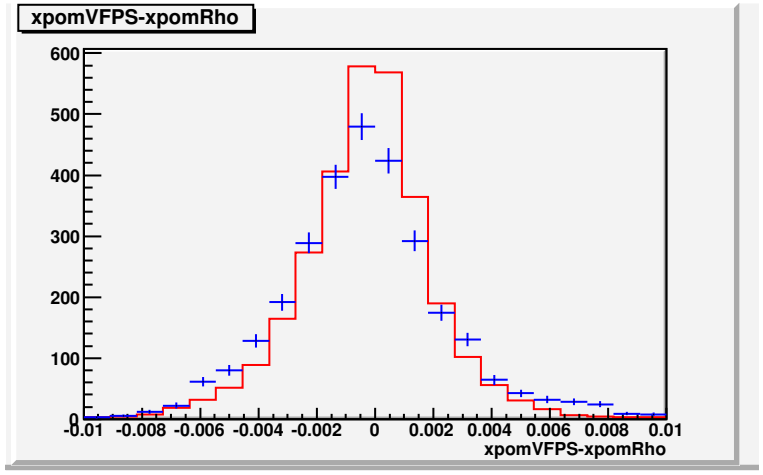


In a simple approximation ($t \approx 0\ GeV^2$) position in x (X_{tracks}) is related to $x_{\mathbb{P}}$
$\Rightarrow$ $x_{\mathbb{P}}$ is reconstructed directly from the VFPS

$$x_{\mathbb{P}} = A.X_{tracks} + B$$

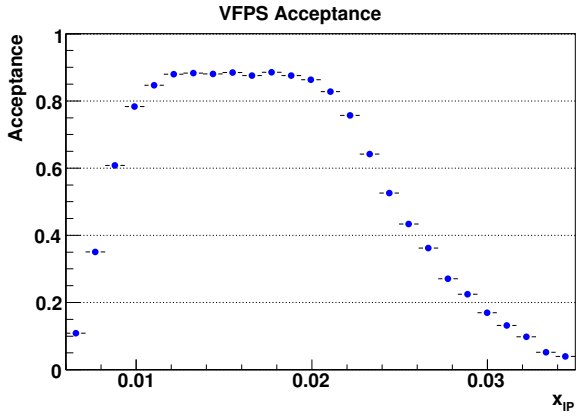
A = 0.001077 $[mm^{-1}]$
B = -0.00541

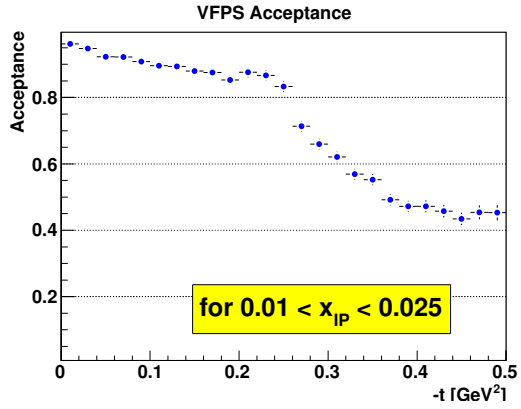
Check with exlusive events (ρ)



The VFPS

- High Acceptance ≈ 90 % for $0.01 < x_{\mathbb{P}} < 0.025$

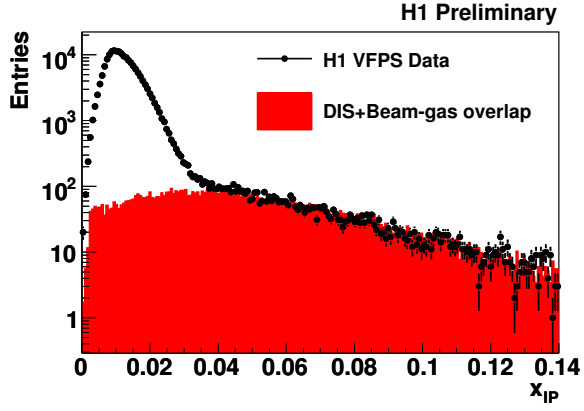




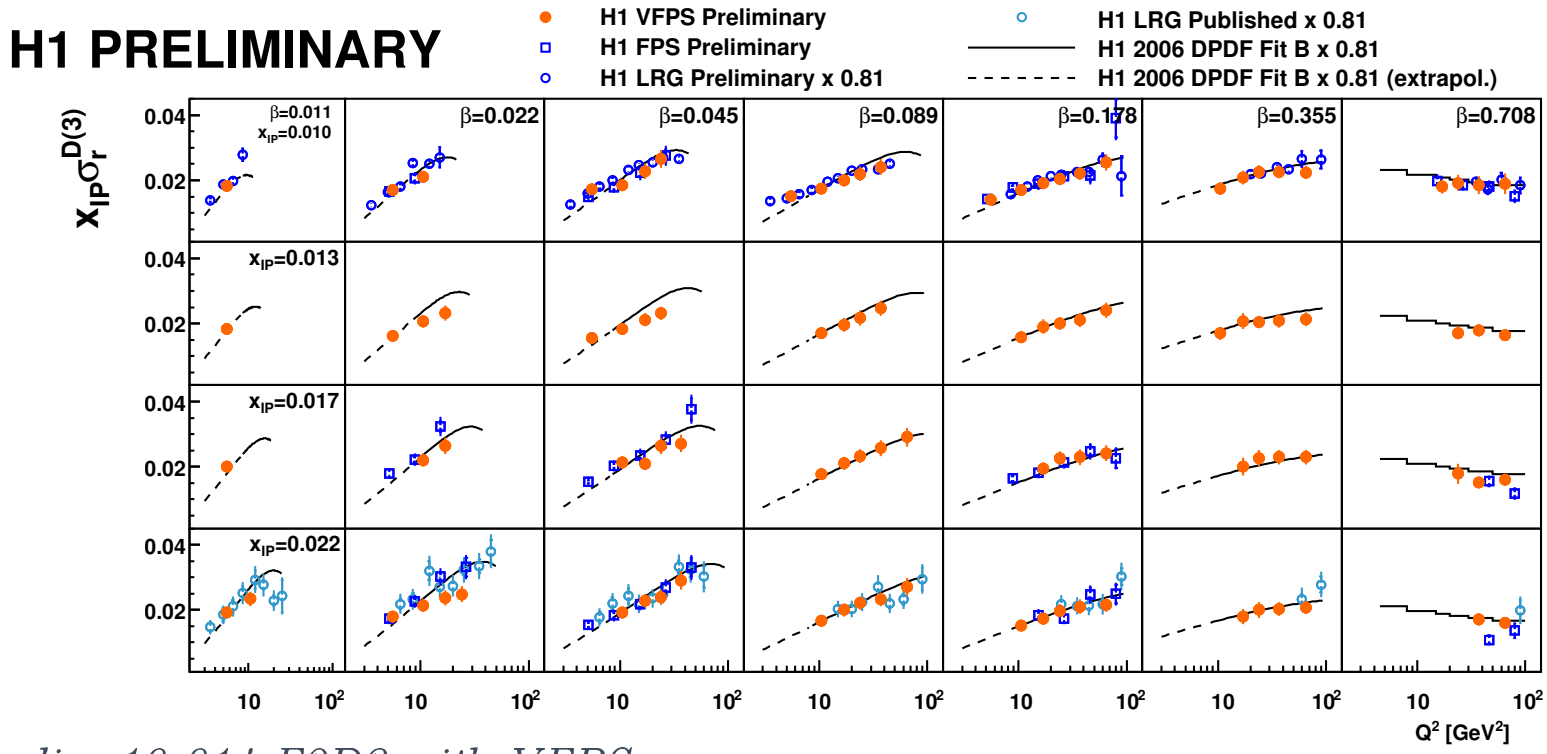
- High track reconstruction efficiency $\approx 96\%$

- Low background (Beam Gas + DIS) $< 2\%$

$$\begin{cases} pA \to p(A') \\ ep \to eX \end{cases}$$



Inclusive Diffraction with VFPS

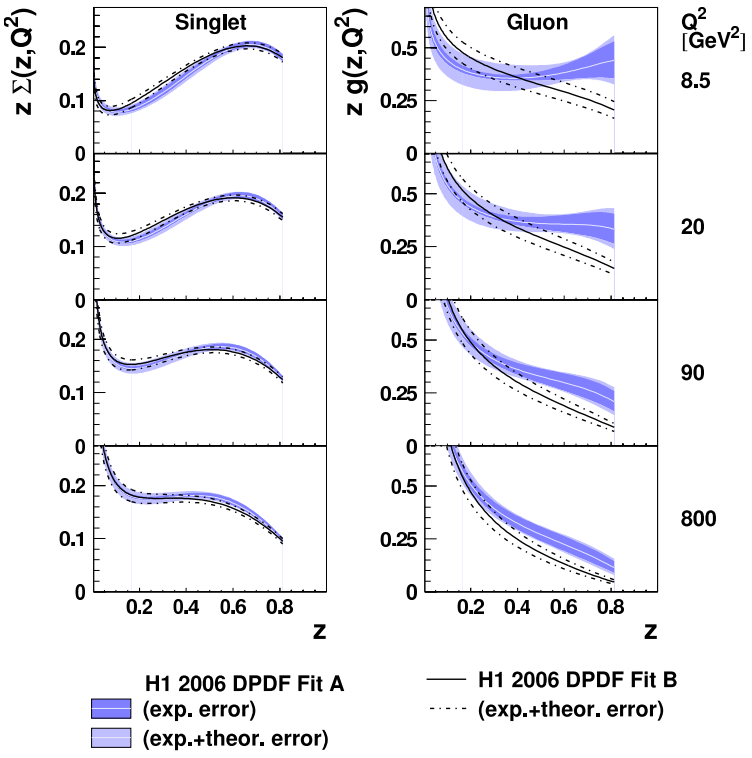


H1prelim-10-014 F2D3 with VFPS

- Highest precision measurement :
  - → lower normalisation uncertainty (5%)
  - → higher precision (factor 2) in $x_{\mathbb{P}}$ (thinner binning)

Combine measurements + extract new QCD Fits

Jets in diffraction

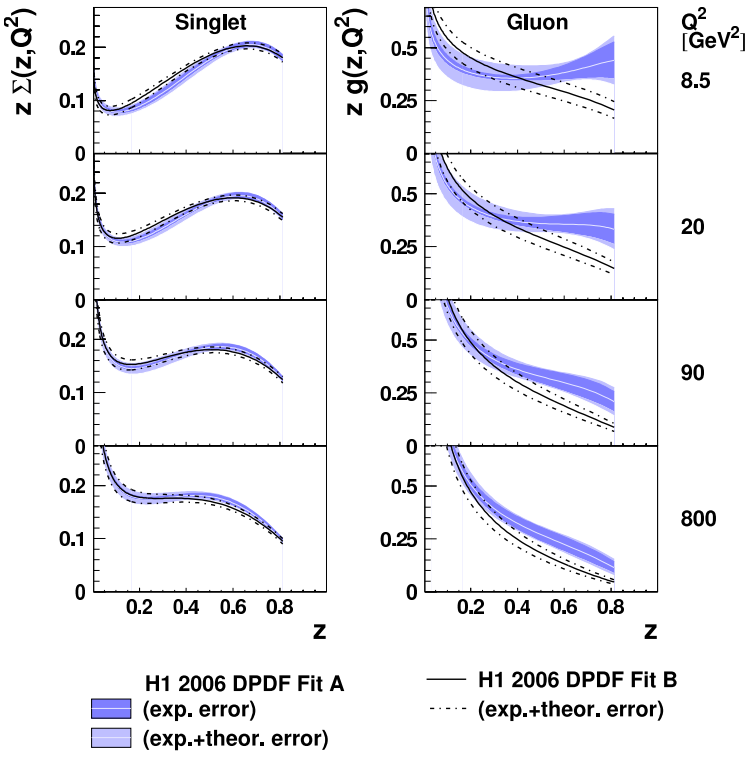


No direct access to gluon component

$\Downarrow$

Large uncertainty on gluon distribution

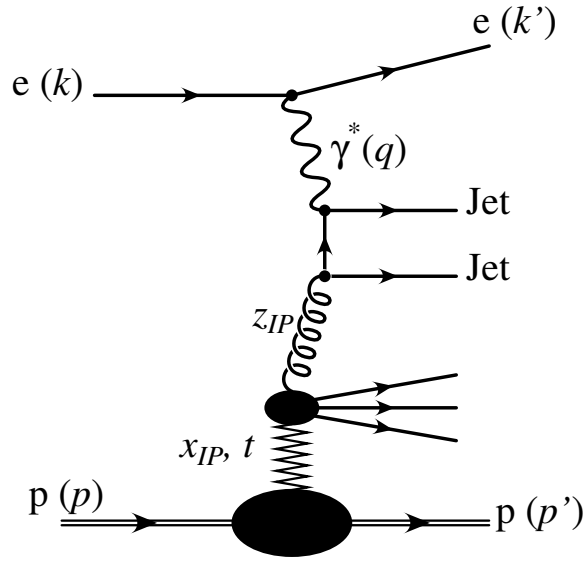
Jets in diffraction



No direct access to gluon component

⇓

Large uncertainty on gluon distribution

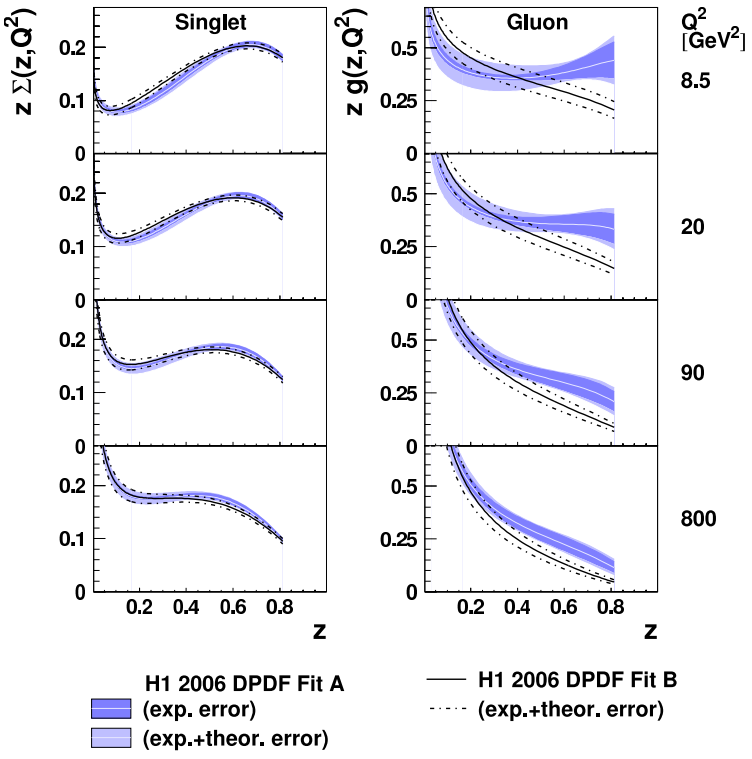


Jets via GLUON-BOSON FUSION

⇓

Directly sensitive to gluon densities in $\mathbb{P}$

Jets in diffraction



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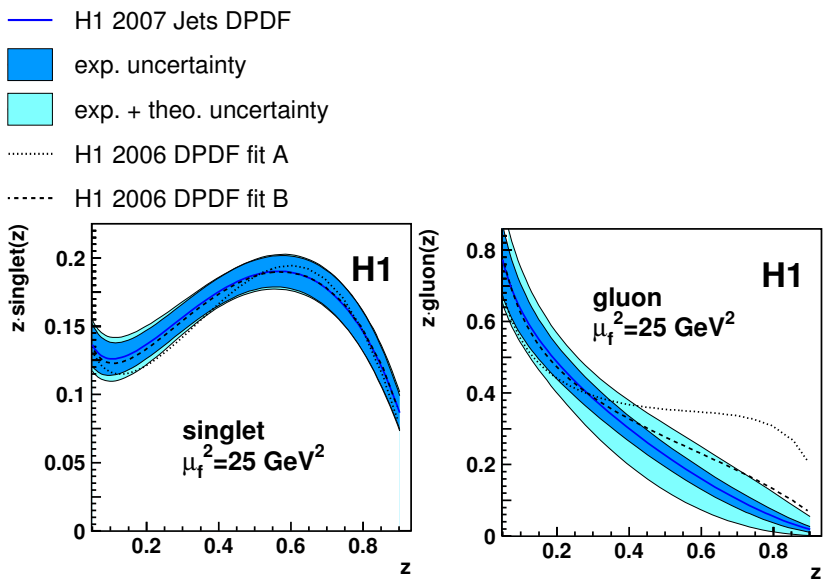
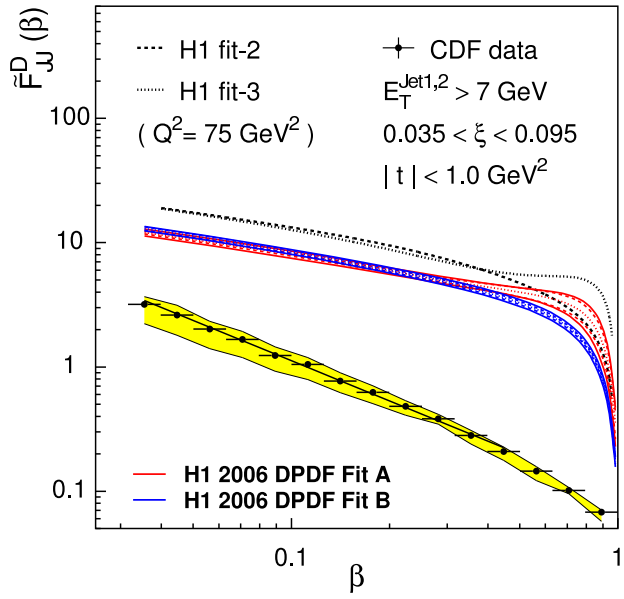


New DPDF Fit Jet 2007

Jets in diffraction

TeVatron : $p\bar{p}$ with E.C.M $\approx 1800\ GeV$
Used the DPDF of H1 to describe their data :



$\Downarrow$

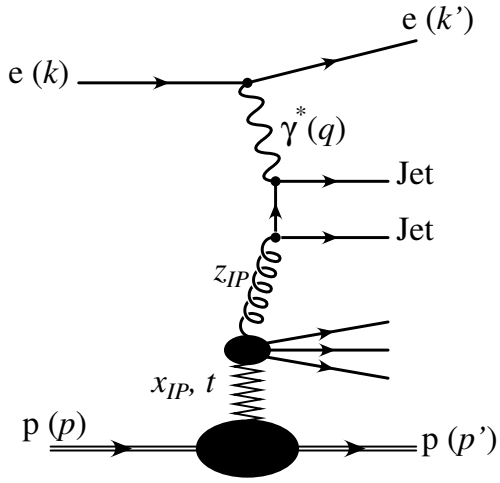
Factorization breaking from factor 5-10 !

Test of Factorization at HERA

In Electro-production

$Q^2 > 1\ GeV^2$

Factorization proved in DIS



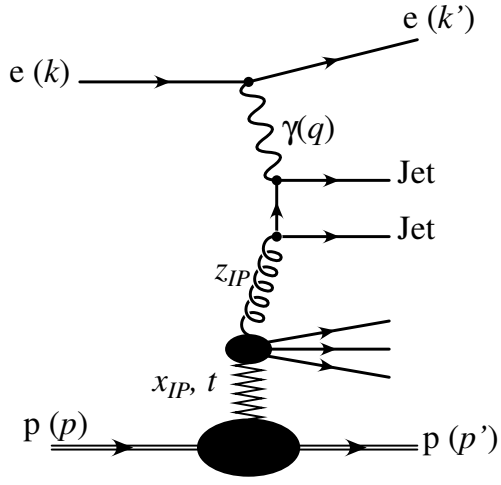
Exp. : Factorization observed

In Photo-production

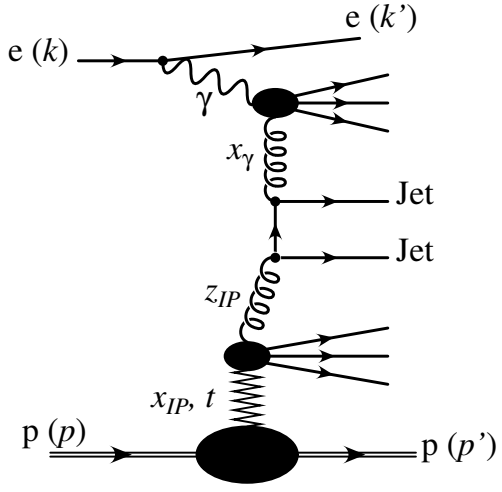
$Q^2 \sim 0 GeV^2 \Rightarrow$ Hard Scale : P_t^{jets}

Factorization NOT proved

Direct Photon



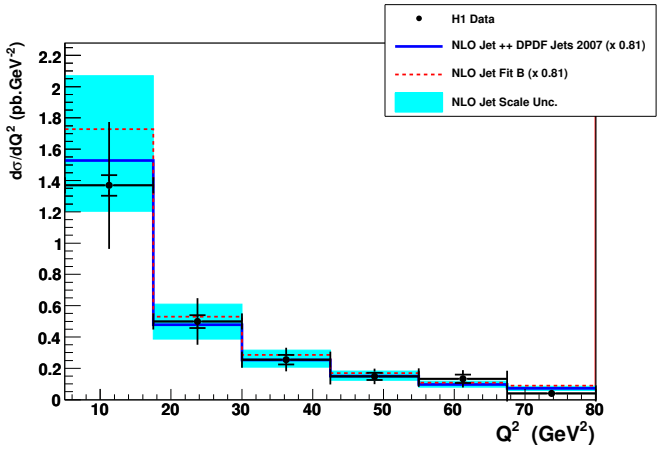
Resolved Photon

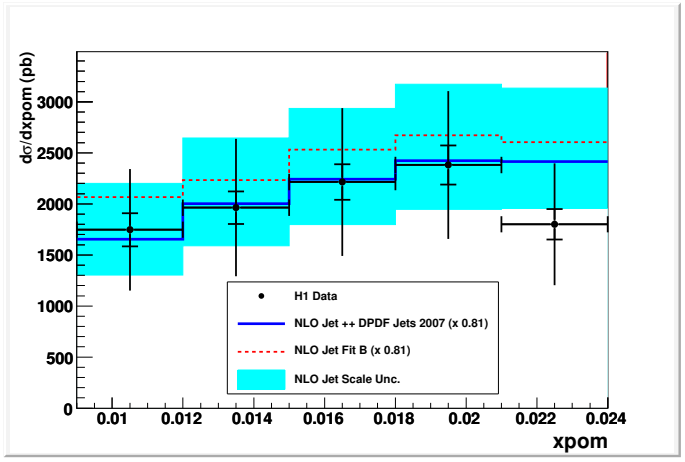


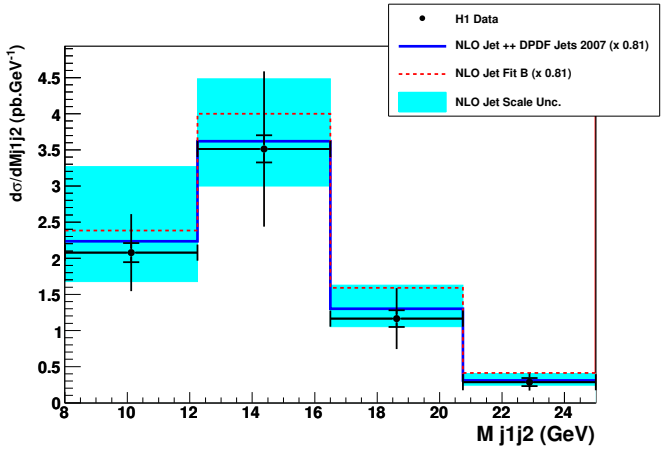
Exp. : possible factorization breaking

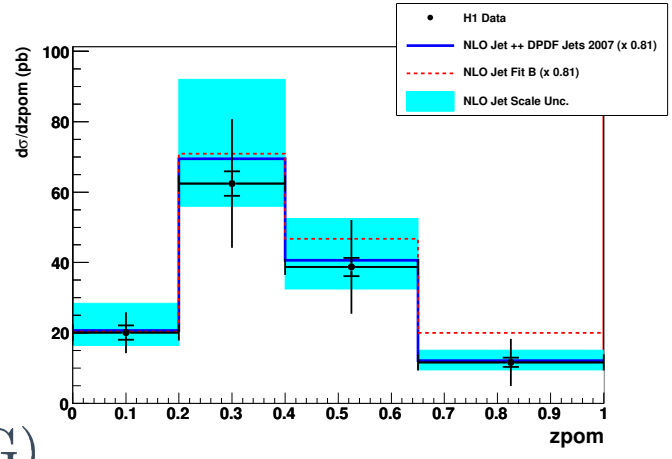
$z_{\mathbb{P}}$ = fraction of momentum of $\mathbb{P}$ entering in the hard interaction.

Jet Cross Section in DIS : THESIS RESULTS









- Independent measurement (no LRG)
- Agreement with predictions → confirmation of validity of the factorization theorem

Combine measurements + extract new QCD Fits

Conclusions

The VFPS

- Good quality data for 130 pb^{-1}
- High acceptance and efficiency, Low background
- improved resolution on $x_{\mathbb{P}}$

First results in diffraction using the VFPS :

- Inclusive diffraction
  - → high precision measurement
  - → agreement with previous analysis and with predictions
- Jets in diffraction in DIS
  - → independent measurement
  - → agreement with previous analysis and with predictions
  - → confirmation of the validity of factorization theorem in DIS

Conclusions

In the future :

- Combine measurement and extract new QCD fit with highest precision
- Test factorization of jets in photo-production
- Reconstruct t from VFPS
  - → $F_2^{D(4)}$
  - → t-slope of jet cross section