diffractive results at HERA and TEVATRON

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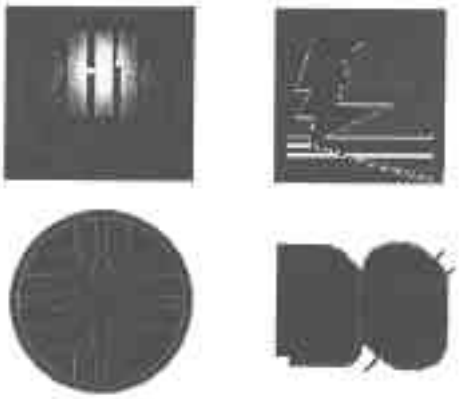
CERN

For the H1, ZEUS, CDF and D0 Collaborations



XIVth Rencontres de Physique de la Vallee d'Aoste
Feb 27 - Mar 04, 2000
La Thuile, Aosta Valley (Italy)

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Plan

I. Introduction

II. Diffractive structure functions at HERA

III. Hadronic final state in diffractive DIS

IV. Hard diffraction at TEVATRON

V. Exclusive diffraction at HERA

VI. Conclusions

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I. INTRODUCTION

DIFFRACTION : FUNDAMENTAL !
CONTRAST ENERGY BEHAVIOUR OF σ_{tot} vs σ_{tot}

First studied in had.-had. collisions in '60
→ Regge model, based on local concepts
→

TODAY :
- What is the "microscopic" QCD picture of IP ?
- How does QCD account for properties of IP ?

→ challenge for QCD!

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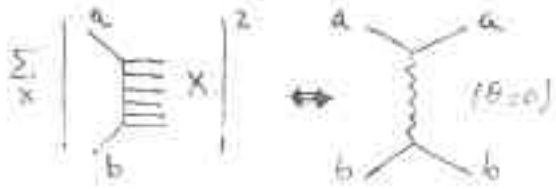
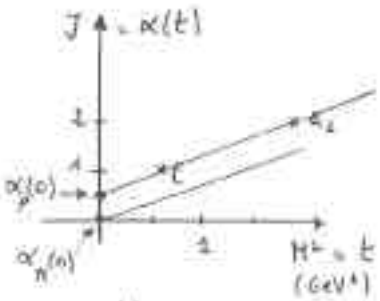
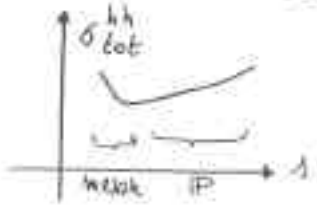
Regge model : based on :



$$\sigma_{tot}^{hh}(s) \sim s^{\alpha(0)-1}$$

$\alpha(t) = \alpha(0) + \alpha' t$



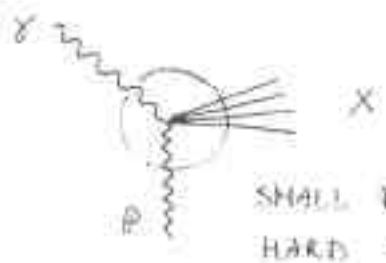


DIFFRACTION = $\mathbb{P}$ EXCHANGE

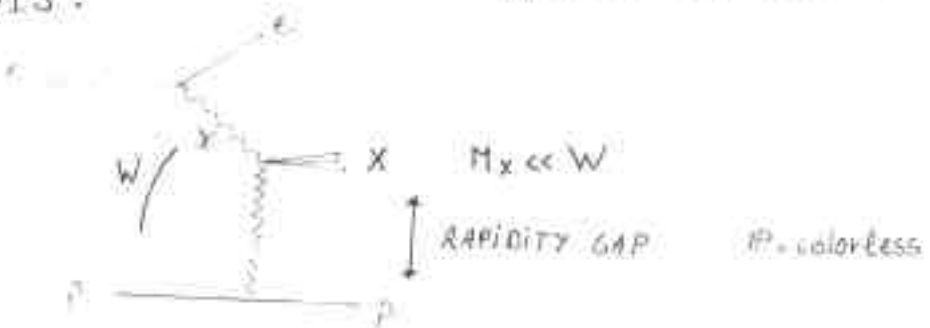
$\mathbb{P}$ = Q.N. OF VACUUM

$\mathbb{P}$ = GLUEBALLS ?

→ How can we study P in QCD ?



DIS :



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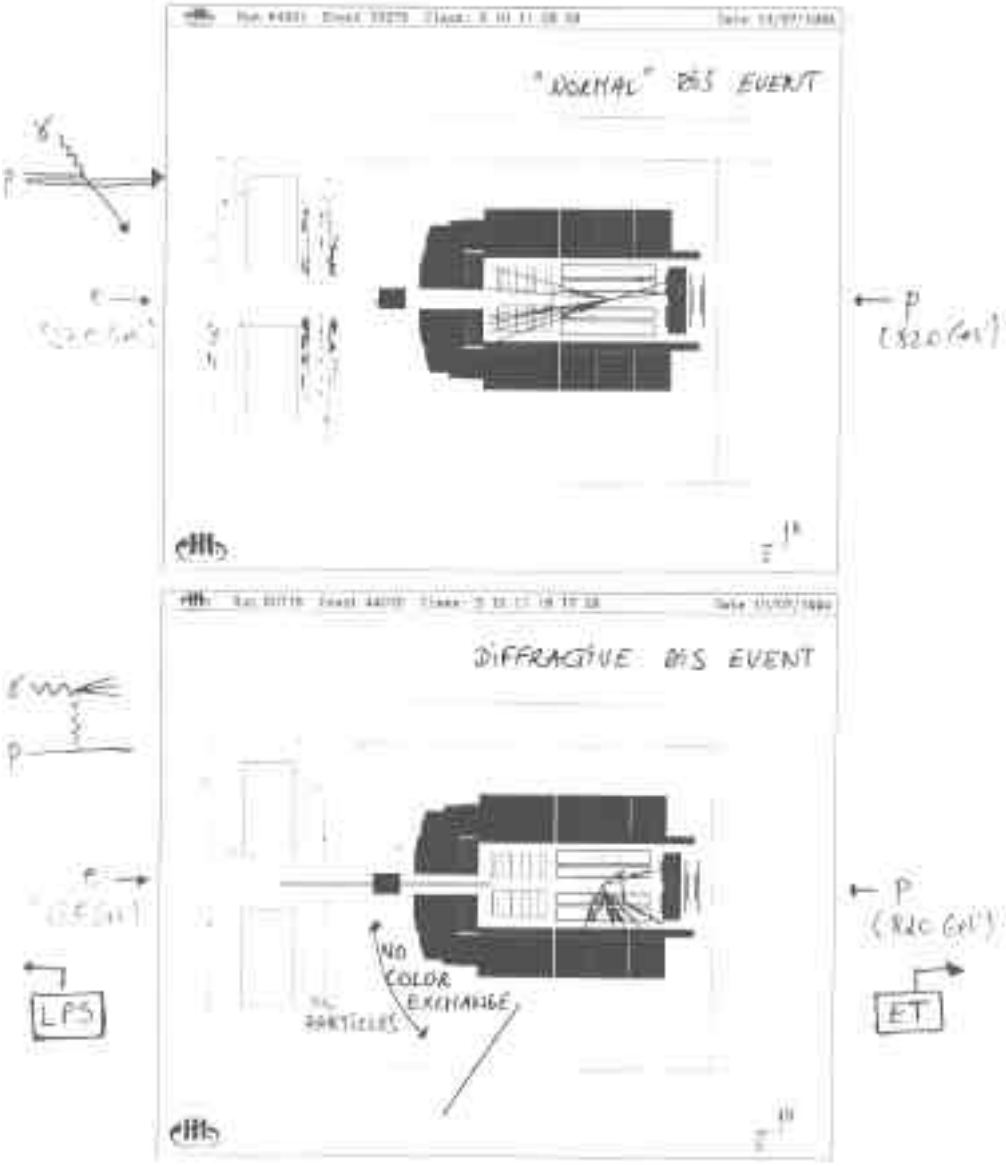
III - XXX's DIFFRACTIVE DIS - ASYMMETRIE

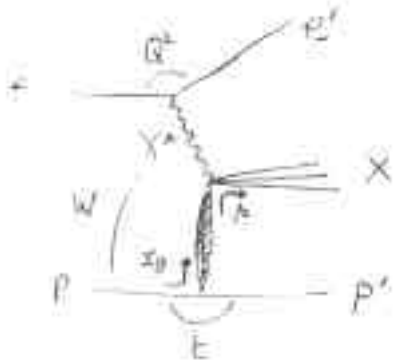


~ 5% of σ_{tot} !

constant Q^2, W

II. DIFFRACTIVE STRUCTURE FUNCTIONS AT HERA

- select diffractive events:



kinem.:
Q^2, W, t
$x_{IP} = \frac{M_X^2 + Q^2}{W^2 + Q^2}$
$\beta = \frac{Q^2}{M_X^2 + Q^2}$

↕ no color flow → RAPIDITY GAP

p' : 1. → p is tagged in LPS
2. → asked for LRG (p escapes in beam pipe)

X : → central detector

e' : 1. → central detector $Q^2 >$ few GeV^2
2. → tagged in ET, escapes in BP $\Big\}$ $Q^2 \simeq 0$ (photoproduction)

→ $\frac{d\sigma^{ep \to eXp}}{d\beta\, dQ^2 dx_{IP}} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right) F_2^{D(3)}(\beta, Q^2, x_{IP})$

diffractive structure function

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Collins factorization theorem:
(large Q^2, long. pol. γ)

As in the proton, one can factorize the long distance physics at p vertex from the rest [illegible]

$$F_2^{D(3)}(x_{I\!P}, \beta, Q^2) = f_{I\!P/p}(x_{I\!P}) \times F_2^{I\!P}(\beta, Q^2)$$

$F_2^{I\!P}$ → $I\!P$ structure function → QCD fit

$f_{I\!P/p}$ → test Regge factor. for energy dep.

$$f_{I\!P/p}(x_{I\!P}) \sim \int dt \left(\frac{1}{x_{I\!P}}\right)^{2\alpha_{I\!P}(t)-1}$$

→ extract $\alpha_{I\!P}(t)$ and compare to soft-had: $\alpha_{I\!P}(0) = 1.08$

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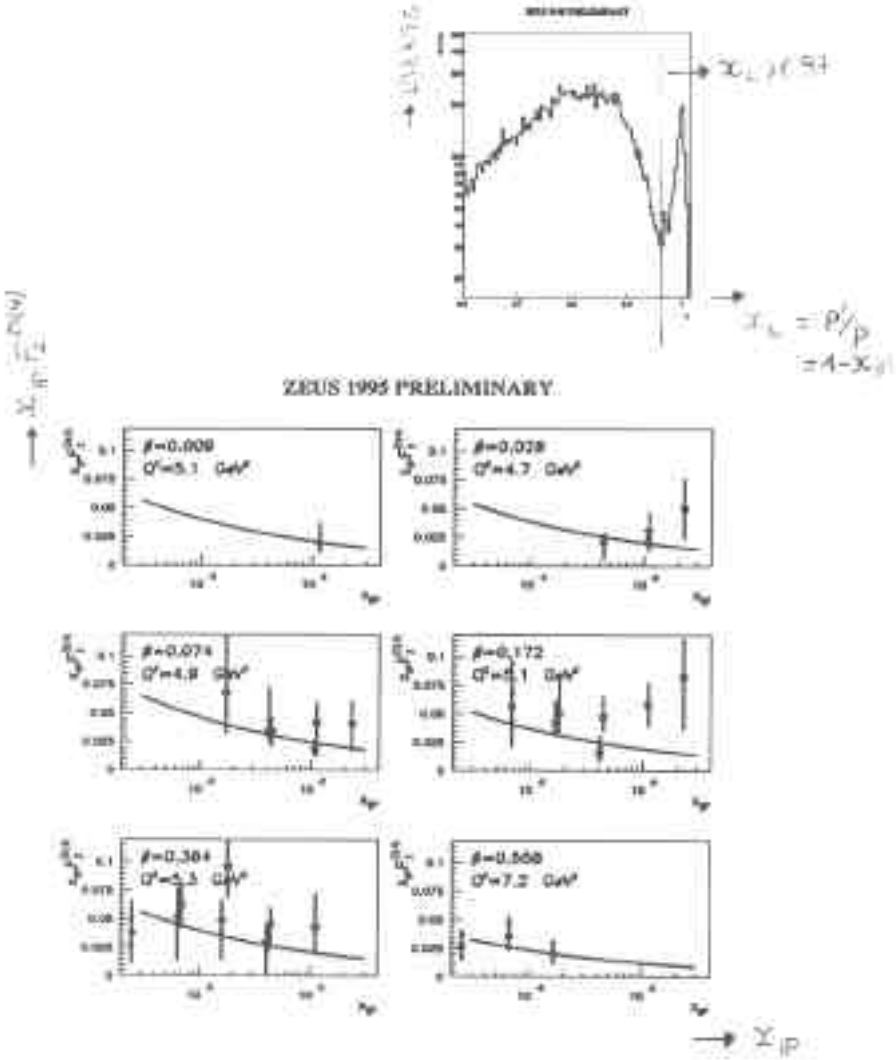
Tagged proton measurement



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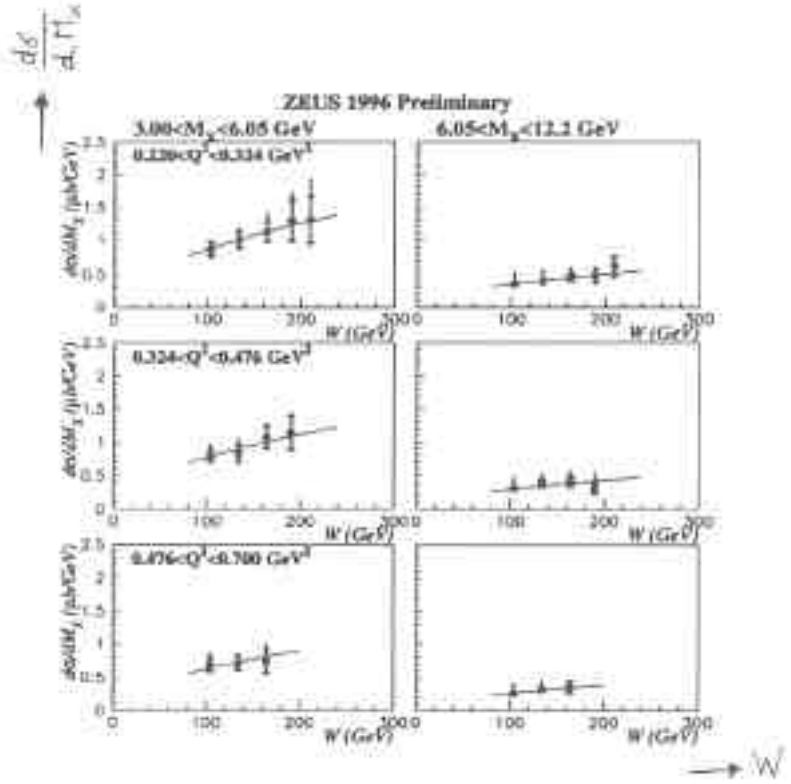
Low Q^2 measurement



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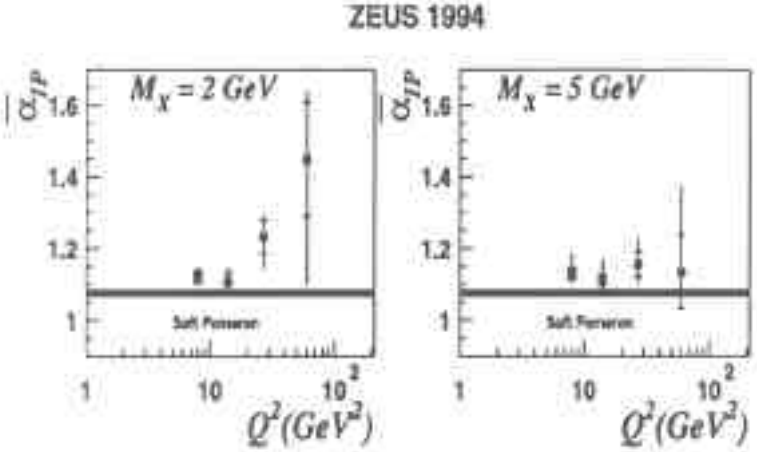
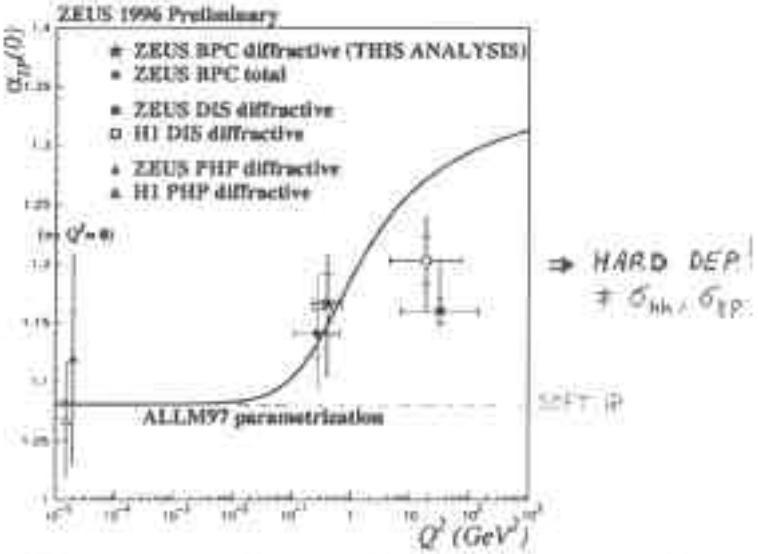
Pomeron intercept





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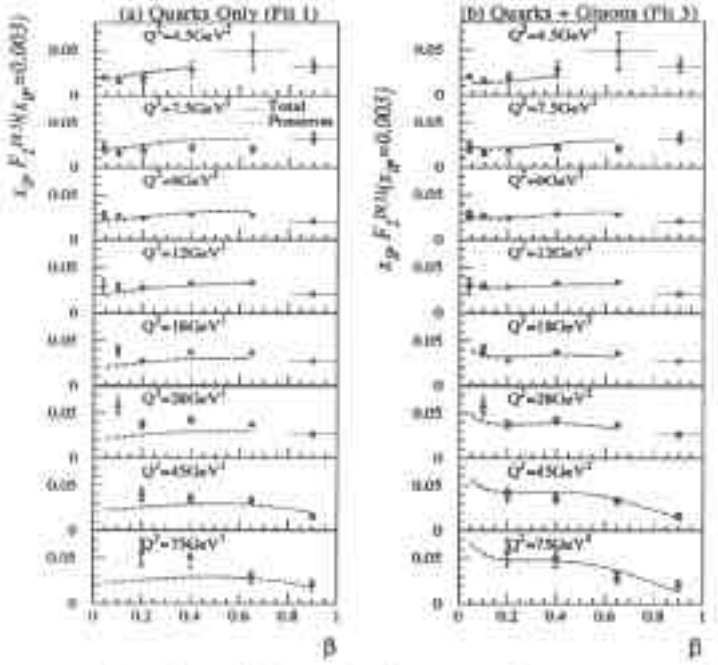
fit QCD

Factorization theorem:
Pomeron flux in the p ⊗ hard interaction
→ PDF's of pomeron obey DGLAP evolution

QUARKS ONLY at $Q_0^2 = 3.0\ GeV^2$ QUARKS + GLUONS

H1 1994



β = fraction of P momentum carried by struck quark ($\sum x_{i\mathbb{P}}$ in $\mathbb{P}$)

→ $\mathbb{P}$ SF ~ FLAT in β (≠ had. SF)
→ gluon in pomeron

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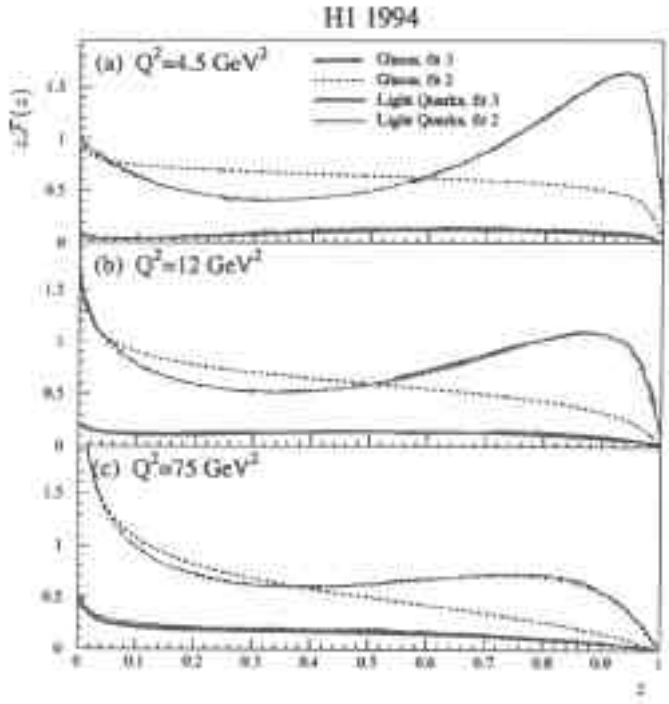
extract quark and gluon densities in the pomeron



→ gluons dominate
→ input to compute final state in diffraction

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III. Hadronic final state in diffractive DIS

Introduction

Go to $\gamma - I\!P$ centre of mass system
and measure particle production
Select diffractive events by LRG or LPS

on the track on understanding pomeron in DIS:

- jets
- charm
- particle spectra

→ compare the results with:

1. Pomeron structure function approach
2. pQCD approach (models)

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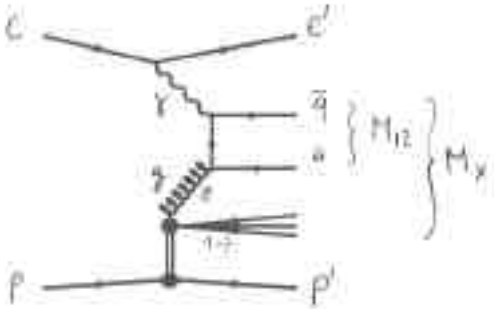
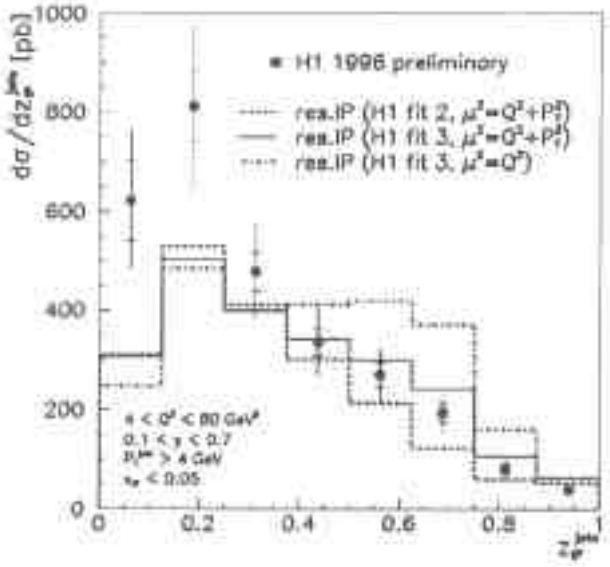
Di-jets production



$$z_P^{jets} = \frac{M_{12}^2+Q^2}{M_X^2+Q^2}$$

Direct probe of the gluon in the (resolved) pomeron



$M_{12} \neq M_X$: large signal at low z_P

Good agreement with pred. based on F_2^D measurements

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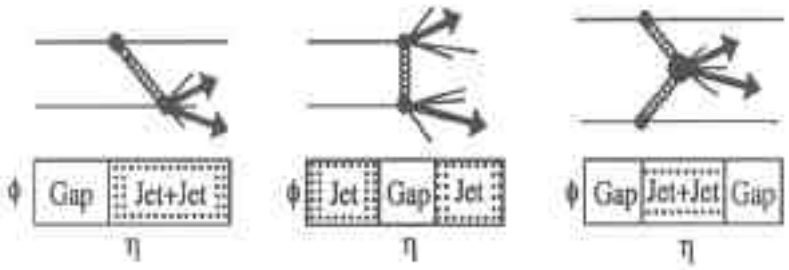
IV. Hard diffraction at TEVATRON

Introduction



Single Diffraction Double Diffraction Double Pomeron Exchange

Hard scales:

- High p_t jets
- W
- b
- J/ψ

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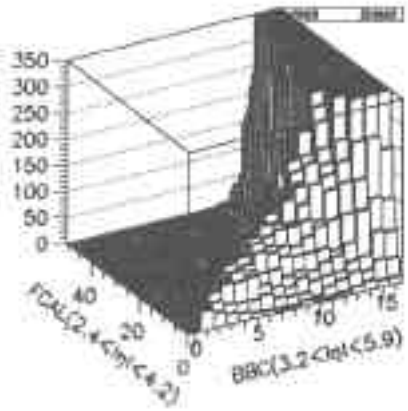
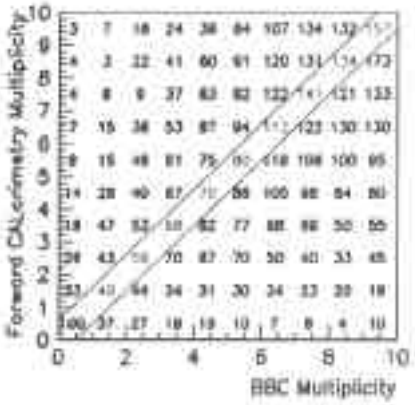
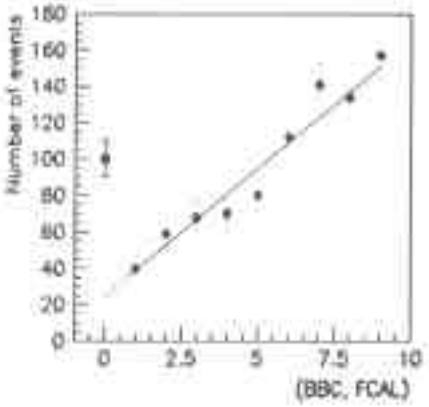
single diffraction

Diffractive Heavy Quark Production

CDF Preliminary







Diffractive/Non-Diffractive Ratio

$R_{ss} \times A = (0.26 \pm 0.06(stat.))\%$

where A is the GAP Acceptance

GAP definition:

- $-5.9 \leq \eta \leq -3.2$ or $3.2 \leq \eta \leq 5.9$
  No charged particles
- $-4.2 \leq \eta \leq -2.4$ or $2.4 \leq \eta \leq 4.2$
  No charged or neutral particles
  of $E \geq 1.5$GeV

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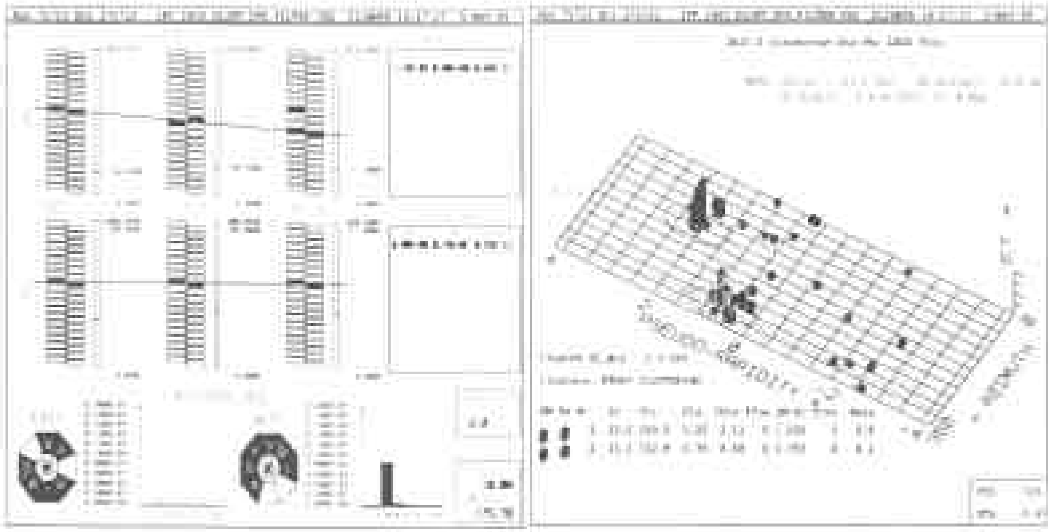
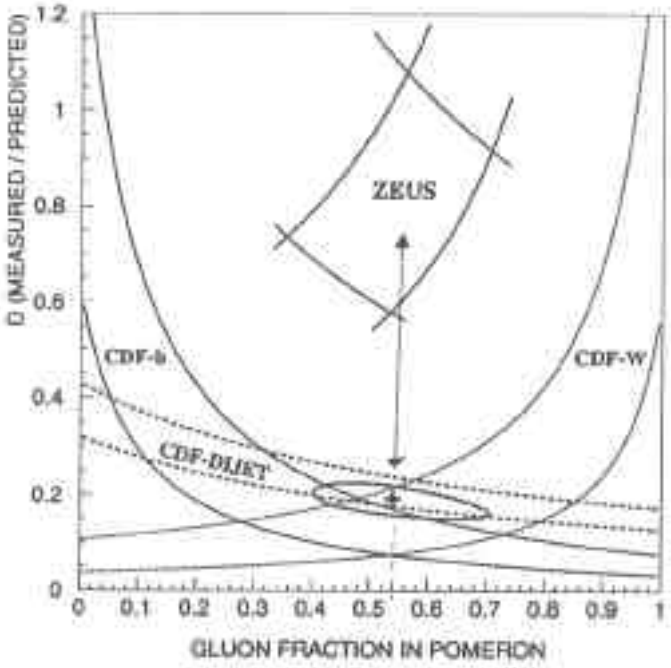
Candidate of Double Pomeron Exchange Dijet



Jet 1	$E_T = 19.0$ GeV, $\eta = 2.2$	Proton Side	$N_{BBC}(2.4 < \eta < 4.2) = 0$
Jet 2	$E_T = 18.1$ GeV, $\eta = 0.79$		$N_{FCAL}(2.4 < \eta < 4.2) = 0$
Pot	$\xi = 0.070$, $\lvert t\rvert = 0.0097$ GeV^2		

Hard diffraction at TEVATRON

Gluon fraction in pomeron



$D \neq 1$

DIS → TEVATRON: factorization breaking $\simeq 4$

Hard diffraction at TEVATRON

- Single diffraction rates:

jets, W, b, J/ψ

$\sim 10^{-2}$

- Double pomeron exchange rates:

$\sim 10^{-4}$

- Rapidity gap between jets:

R (600/1800) > 1 !

R (600/1800) $= 2.7 \pm 0.4$ D0

R (600/1800) $= 2.4 \pm 0.9$ CDF

$\rightarrow$ Survival probability:

- underlying int. destroying gap
- multiple pomeron exchange

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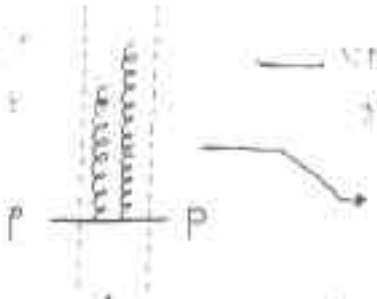
V. Exclusive diffraction at HERA

Introduction



$\mathbb{P}$ = 2 gluons simpliest case

$\leftarrow l_1 \rightarrow \gg l_2 \ll \rightarrow \zeta_3$ → FACTORIZATION (COLLINS)

$$\mathcal{M} = \Psi_{\gamma \to q\bar{q}} \cdot H_{(q\bar{q})\text{-}p} \cdot \Psi_{VM}$$

most models $\quad \sigma \sim \frac{\alpha_s^2(Q^2)}{Q^4} \left| x g(x, Q^2) \right|^2$

→ STRONG ENERGY DEPENDENCE
→ HARD BEHAVIOUR
≠ had.-had. SOFT ENERGY DEPENDENCE

→ VM PRODUCTION
- CLEAN WAY STUDY $\mathbb{P}$
- TEST MODELS (pQCD)
- NOVEL WAY TO PROBE PARTON DENSITIES

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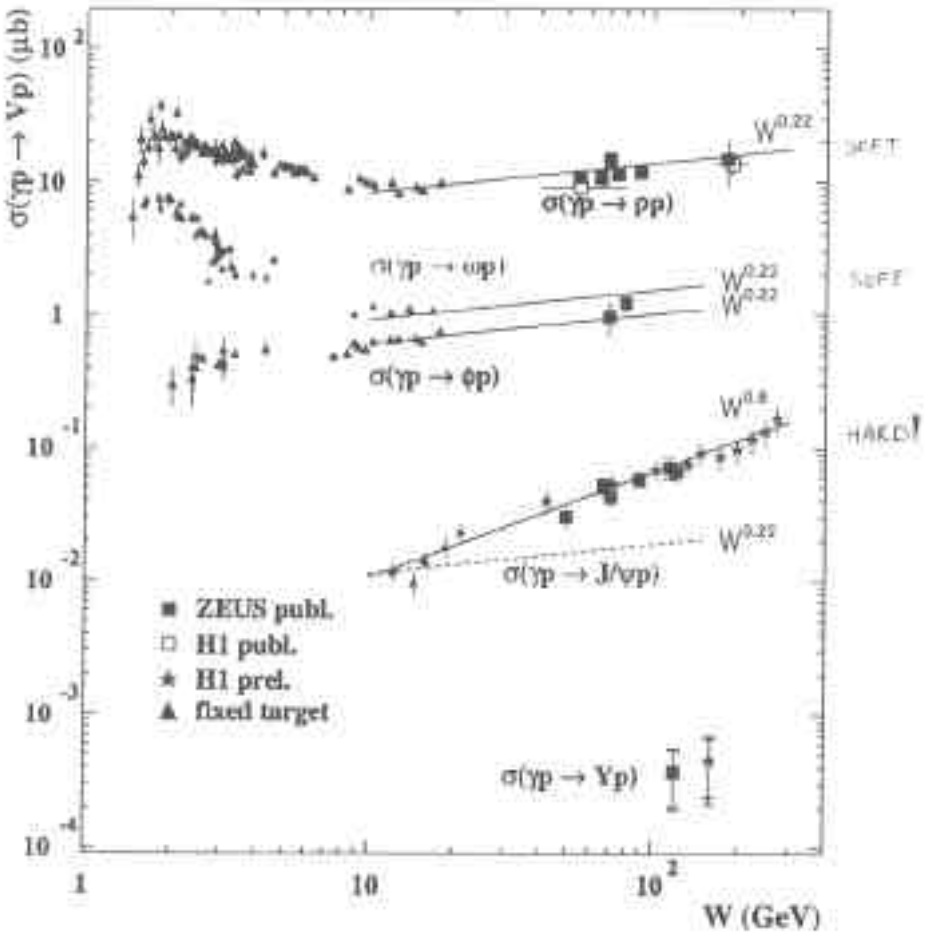
Energy dependence



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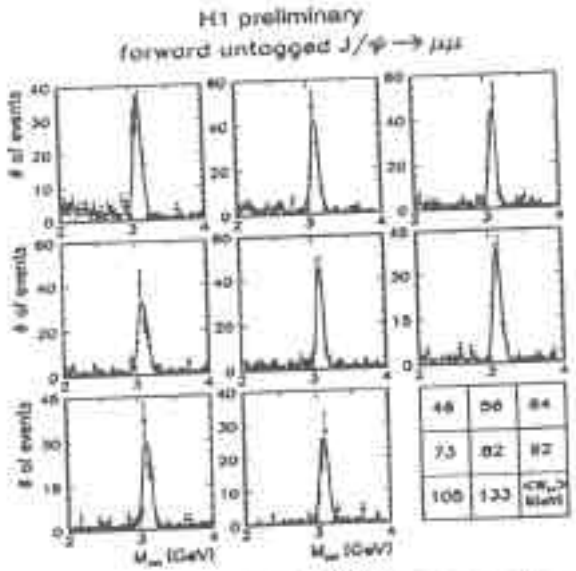
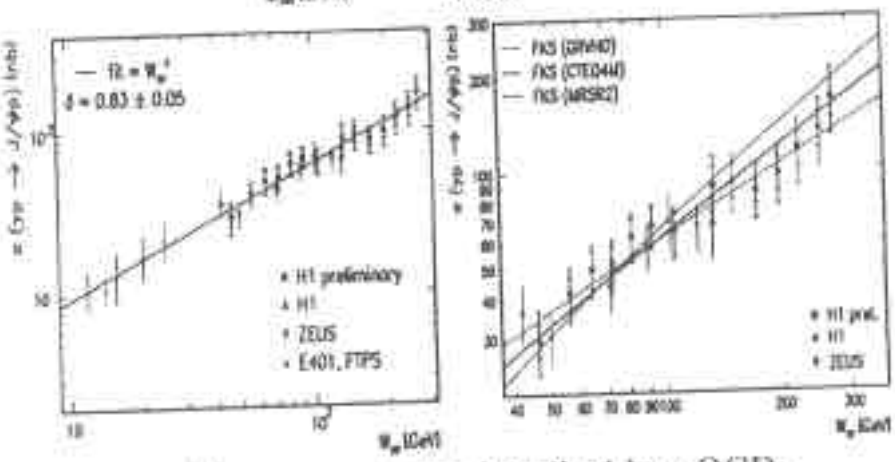
- J/ψ photoproduction





→ rise of σ with energy can be described by pQCD:

$$\sigma(W) \propto |xg(x, Q^2)|^2$$

→ sensitivity to param. of $xg(x, Q^2)$

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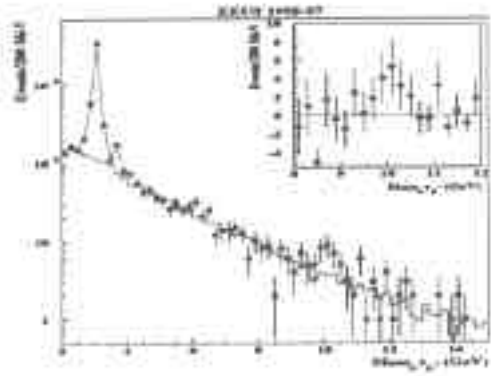
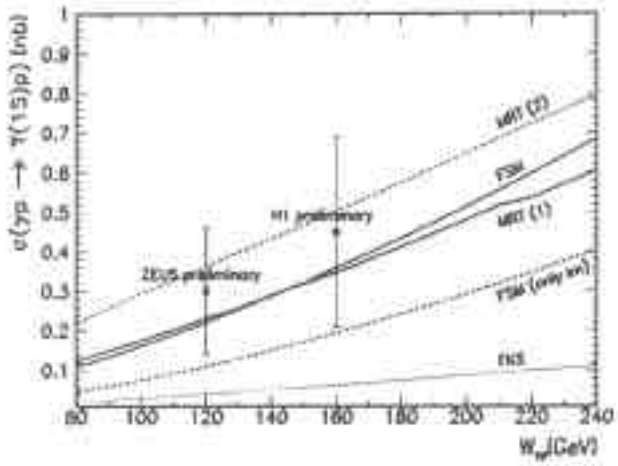
Υ photoproduction



$\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ states: not separated
background: Bethe-Heitler μ pair production ($\gamma\gamma \to \mu^+\mu^-$)



FKS: same hypothesis as for the J/ψ
MRT,FSM: modification → real part of the amplitude
→ skewed parton distribution

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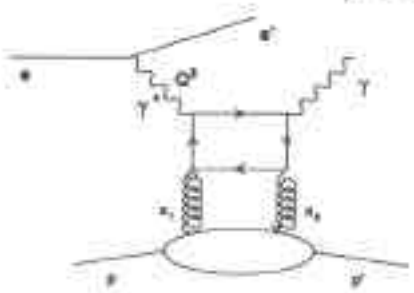
Deep Virtual Compton Scattering

- Signal:

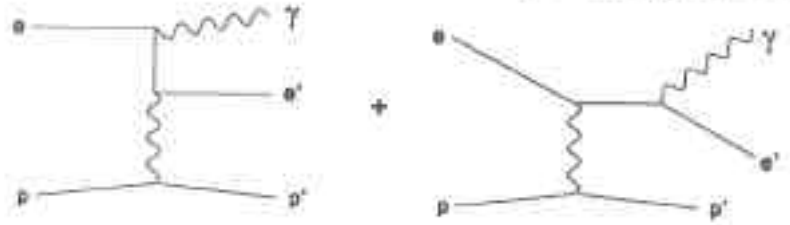
$\gamma \sim$ along the p beam



Completely calculable → Gold-plated process
$x_1 \neq x_2 \rightarrow$ "skewed" PDF's

- Bethe-Heitler background:

$\gamma \sim$ along the e beam



signal and background: different θ distribution

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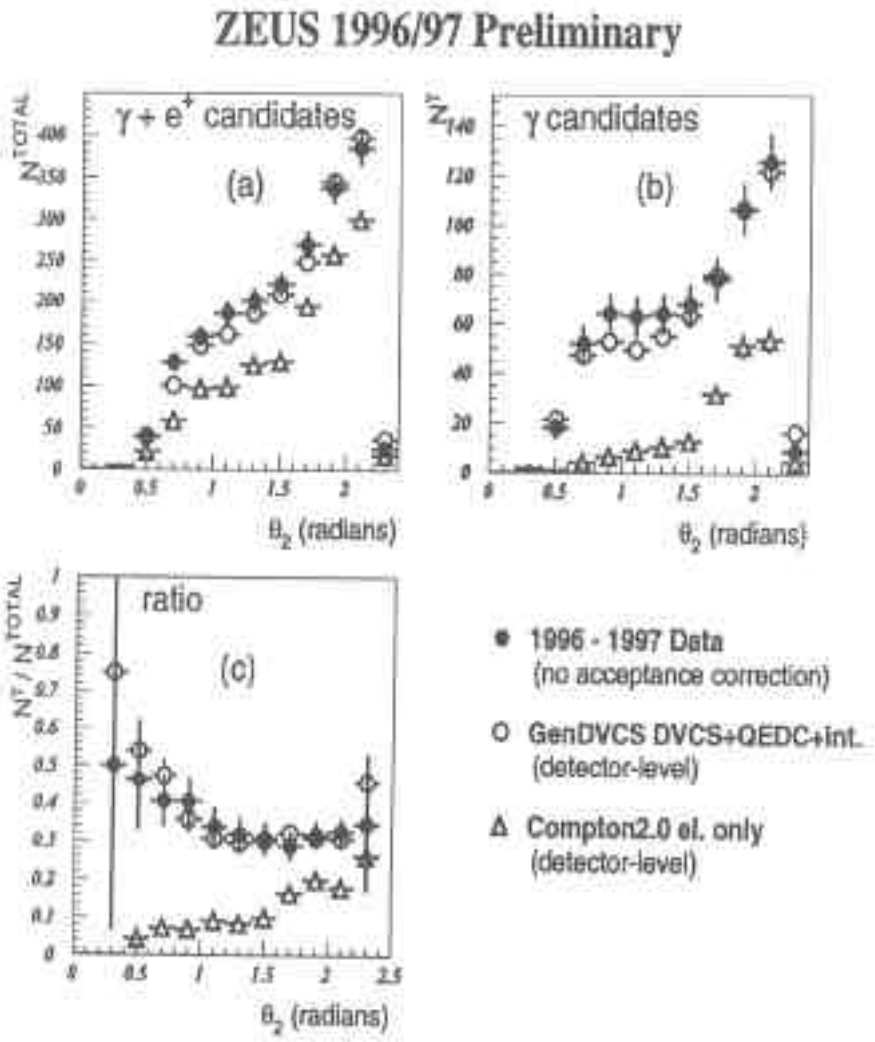

→ Clear signal for DVCS

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VI. Conclusions

– DIFFRACTION ∃ at HERA !

TEVATRON !

... LHC

- [illegible] diffractive structure functions
- [illegible] partonic structure of P → mostly gluonic
- [illegible] diffractive final states
- [illegible] : gap survival probability
- [illegible] – [illegible] calculations

– Very active interplay between:

experim.	–	theorists
soft	–	hard
bulk of data	–	rare process

AT HERA:

- Results based 94, 95, 96 data
- New data to be analysed: 97, 98, 99, 00 ...

TEVATRON

- RUN II