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DIFFRACTION

Giuseppe Barbagli
INFN Firenze

representing the

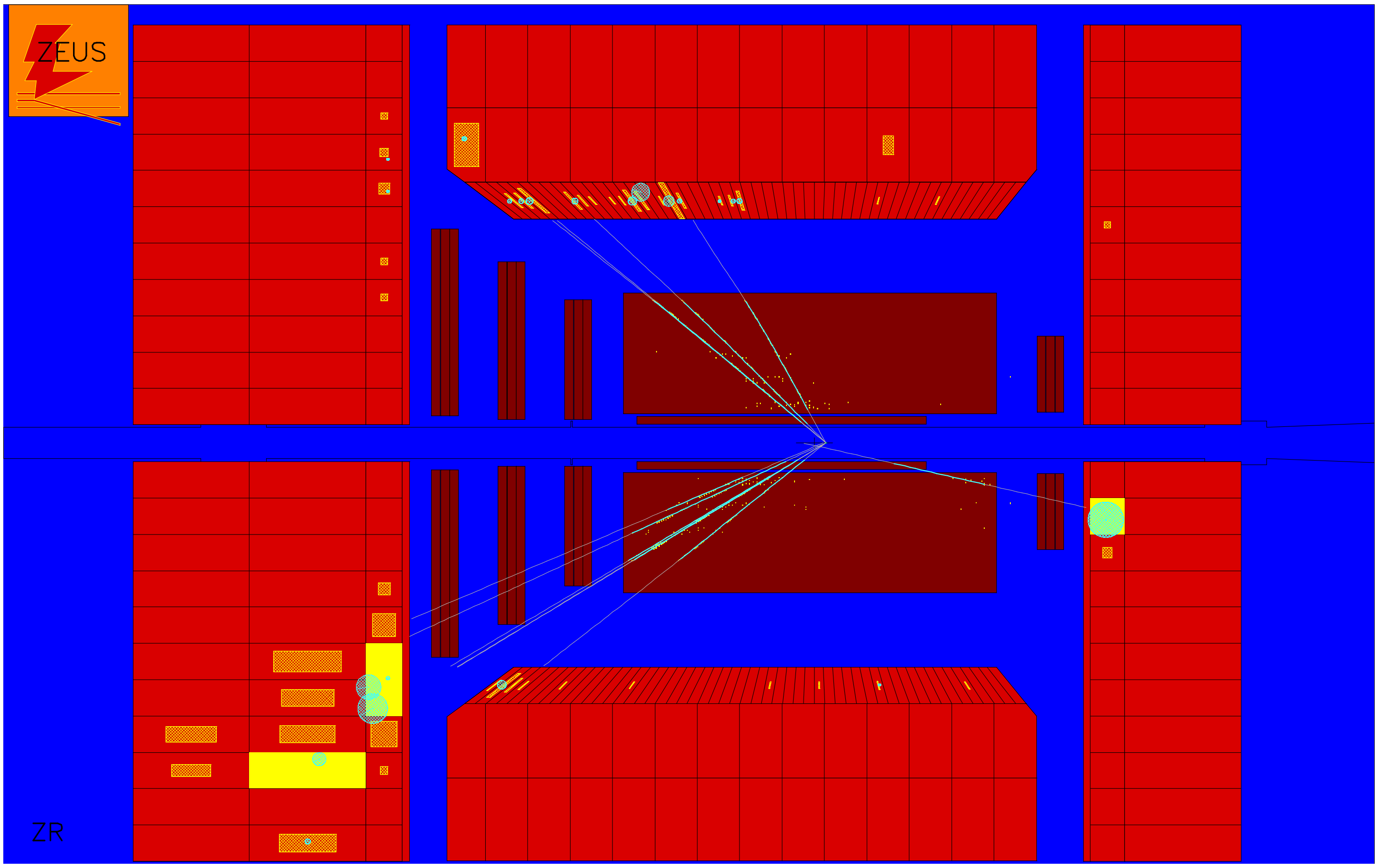
ZEUS H1

collaborations

1. Introduction
2. Exclusive vector meson production
3. Diffractive photon dissociation
4. Hadronic final states
5. Conclusions

HERA beams: **$e^{\pm}$ 27.5 GeV** $\longrightarrow\longleftarrow$ **p 820-920 GeV** **($\sqrt{s_{ep}}$ = 300-320 GeV)**

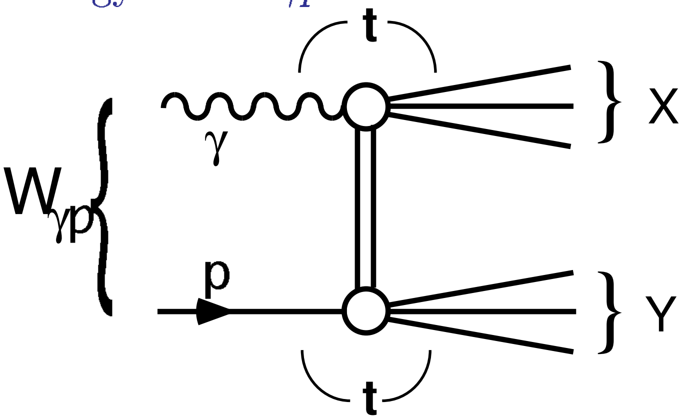
ZEUS event $\qquad\qquad$ $\eta = -ln\ tan(\frac{\theta}{2})$



η_{max}

COLOUR SINGLET EXCHANGE PROCESSES IN $\gamma^{(*)}p$

Phenomenology of soft γp collisions:



- Elastic ($M_X = m_\rho, m_\omega, m_\phi$, $M_Y = M_N$)
- Single photon dissociation ($M_X =$, continuum $M_Y = M_N$)
- Single proton dissociation ($M_X = m_\rho, m_\omega, m_\phi$, $M_Y =$ continuum)
- double dissociation ($M_X =$ continuum, $M_Y =$ continuum)

REGGE TRAJECTORIES AND THE POMERON

Hadronic scattering can be described in terms of exchange of Regge trajectories (with angular momentum as a function of t

$\alpha(t) = \alpha(0) + \alpha' \cdot t \qquad \alpha_{I\!P}(0) \simeq 1$

$\sigma^{tot} \propto s^{\alpha_k(t)-1} \qquad \frac{d\sigma_{el}}{dt} \propto s^{2(\alpha_k(t)-1)}$

At high s hadronic cross sections are dominated by a Regge trajectory with the same quantum number as the vacuum, called Pomeron ($I\!P$) which describes elastic scattering and the asymptotic behaviour of the high energy total cross section

The Pomeron was again an intensively studied subject after the observation of jets in $\bar{p}p$ diffractive final states

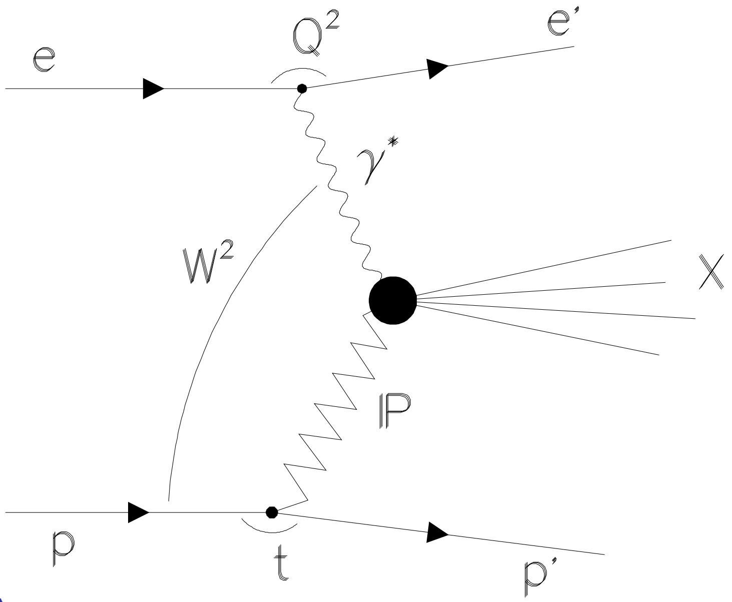
$\longrightarrow$ Ingelman-Schlein approach, pomeron "structure"
HERA data on the behaviour of F_2 at low x
and the observation of rapidity gap events in ep DIS
$\longrightarrow$ New interpretation of non-perturbative effects linking soft processes and hard, perturbative regime
Donnachie-Landshoff global fit : $\longrightarrow$ soft pomeron
Hard contributions : $\longrightarrow$ steeper W dependence of cross sections
Search for effects of QCD inspired pomeron

Most likely pomeron is a unique object, where hard contributions can develop on top of something soft and show up, depending on kinematics and experimental conditions, and on the role played by "hard" scales

KINEMATICS

$Q^2 = -q^2 = -(k - k')^2$ $\qquad$ $x = \frac{Q^2}{2P\cdot q}$

$y = \frac{P\cdot q}{P\cdot k}$ $\qquad$ $W^2 = \frac{Q^2(1-x)}{x} + M_p^2 \approx \frac{Q^2}{x}$



$M_X^2 = (q + IP)^2$ invariant mass squared in the γIP frame;
$t = (P - P')^2$ 4-momentum transfer squared at the proton vertex

Long distance physics at p-vertex

$x_{IP} = \frac{(P-P')\cdot q}{P\cdot q} = \frac{M_X^2+Q^2-t}{W^2+Q^2-m_p^2}$ fraction of proton momentum carried by the pomeron

Short distance physics at γ^*-vertex

$\beta = \frac{Q^2}{2(P-P')\cdot q} = \frac{x}{x_{IP}} = \frac{Q^2}{Q^2+M_X^2-t}$ fraction of pomeron momentum carried by a parton

$\frac{M_X^2}{Q^2} << 1 \;\; \beta \sim 1.$ $\frac{M_X^2}{Q^2} >> 1 \;\; \beta \sim 0.$

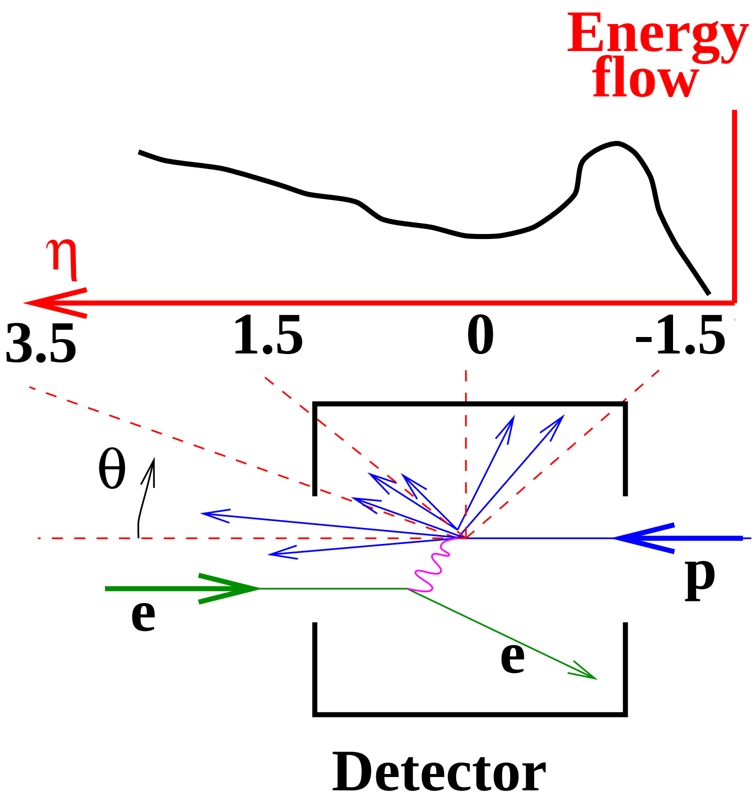
TYPICAL FEATURES OF DIFFRACTIVE INTERACTIONS

- exponential suppression of the squared momentum transfer t
- non-decreasing and weak energy dependence of cross sections
- presence of a rapidity gap between diffractively produced hadronic final states
- almost imaginary forward elastic scattering amplitude
- dominance of low mass states $M^2 << s$

RAPIDITY GAPS

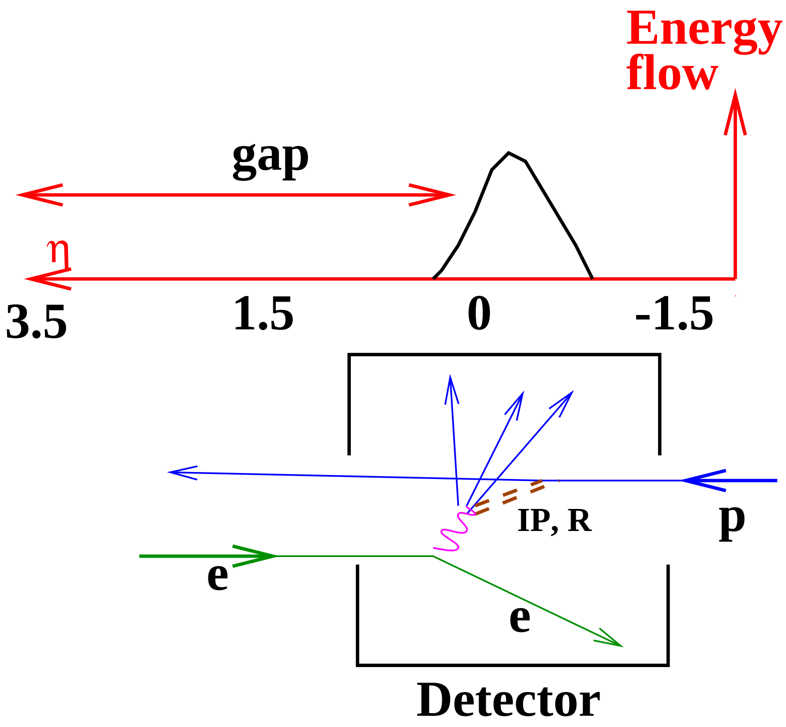
For a standard DIS event: Total pseudorapidity $\Delta\eta_{tot} \sim ln(\frac{W^2}{m_p^2})$

Pseudorapidity interval between proton remnant and struck quark: $\Delta\eta \sim ln(\frac{1}{x})$



Hadrons fill the gap in colour flow and the probability to have a gap is: $p(\Delta\eta) \sim e^{-\Delta\eta}$

For reggeon or pomeron exchange:



The rapidity gap generated by the exchange has a probability:

$p(\Delta\eta) \sim e^{-2(\alpha(0)-1)\Delta\eta}$

pomeron	exchange	$\alpha(0) \sim 1$	$\Rightarrow$	$p(\Delta\eta) \sim e^{0}$
ρ, a_2, f_2, ω	exchange	$\alpha(0) \sim 0.5$	$\Rightarrow$	$p(\Delta\eta) \sim e^{-\Delta\eta}$
π	exchange	$\alpha(0) \sim 0$	$\Rightarrow$	$p(\Delta\eta) \sim e^{-2\Delta\eta}$

$\Rightarrow$ Diffractive events typically exhibit a large rapidity gap in final state phase space, not exponentially suppressed as a function of gap width.

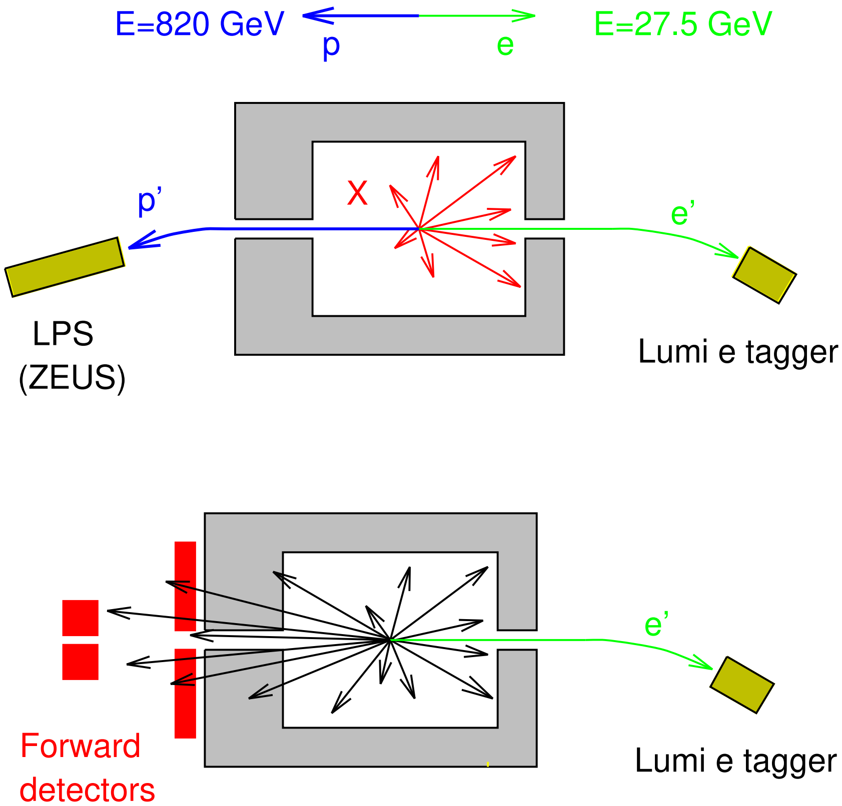
EXPERIMENTAL DEFINITIONS OF DIFFRACTION

Large rapidity gap

Diffractive events were originally selected by limiting the pseudorapidity of the most forward energy deposit (ZEUS,H1). BUT:
this cut limits the η interval available for fragmentation
and restricts the masses M_X which can be studied up to lower values.
$\Delta\eta$ large when $M_X << W$

Veto to forward activity

Diffractive events can also be identified by defining a rapidity gap vetoing forward activity detected by some tagger.
Especially searching for esclusive vector meson production any activity besides the one associated with the decay is excluded.



Tagging of final state baryons

By requiring a scattered proton with high fraction of beam longitudinal momentum (ZEUS,H1)
$x_L = p_z^{'}/820$ GeV
$0.97 < x_L < 1.02$ for diffraction

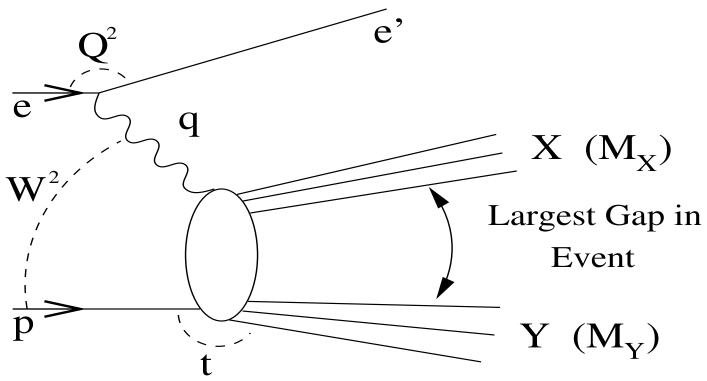
From the momemtum of the proton other variables can be determined:

$t \simeq -\frac{p_T^2}{x_L}$
$M_X^2 = W^2 \cdot (1 - x_L)$

Limits in the acceptance
$\Rightarrow$ limited statistics

Largest rapidity gap

Defining the photon and proton system looking for the largest rapidity gap H1
The largest rapidity gap within an event defines the system X and Y

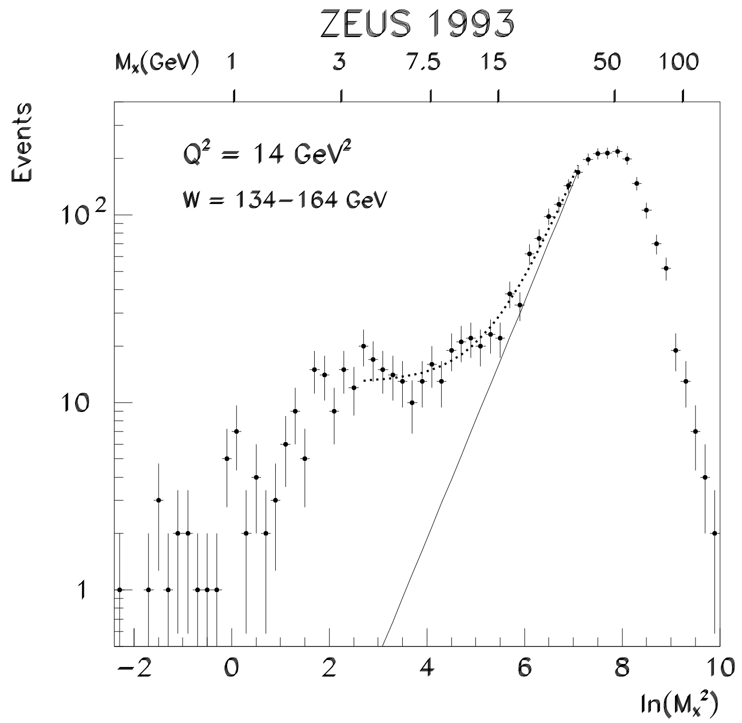


$\boxed{M_X \textbf{ method}}$

In a statistical and complementary way assuming a certain behaviour for non-diffractive events

(ZEUS)

Diffractive sample of events defined as
excess contribution in the ln M_X^2 distribution above the exponential fall-off of the non-diffractive peak



$$\frac{dN}{d \ln M_X^2} = D + c \exp(b_{ND} \ln M_X^2)$$

consistent with the assumption of uncorrelated particle emission

VECTOR MESON PRODUCTION

IN PHOTOPRODUCTION AND DEEP INELASTIC SCATTERING

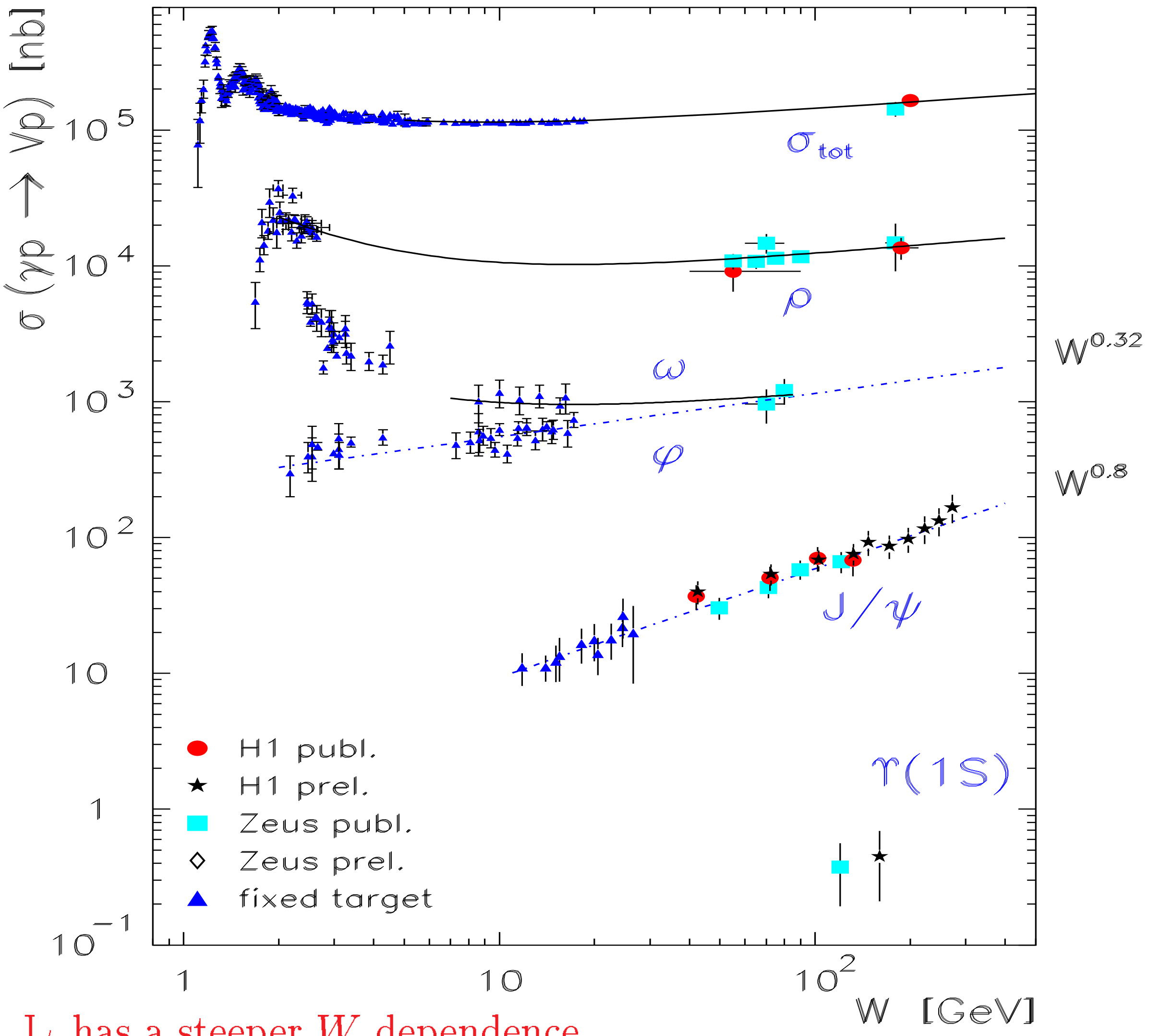
Good field to test the role of hard physical scales: Q^2, M_V^2, t

Competition of Regge theory and Vector Dominance and pQCD inspired models

$\sigma_{tot}^{\gamma p} \propto (W^2)^{(2\alpha_{I\!P}(0)-2)}$

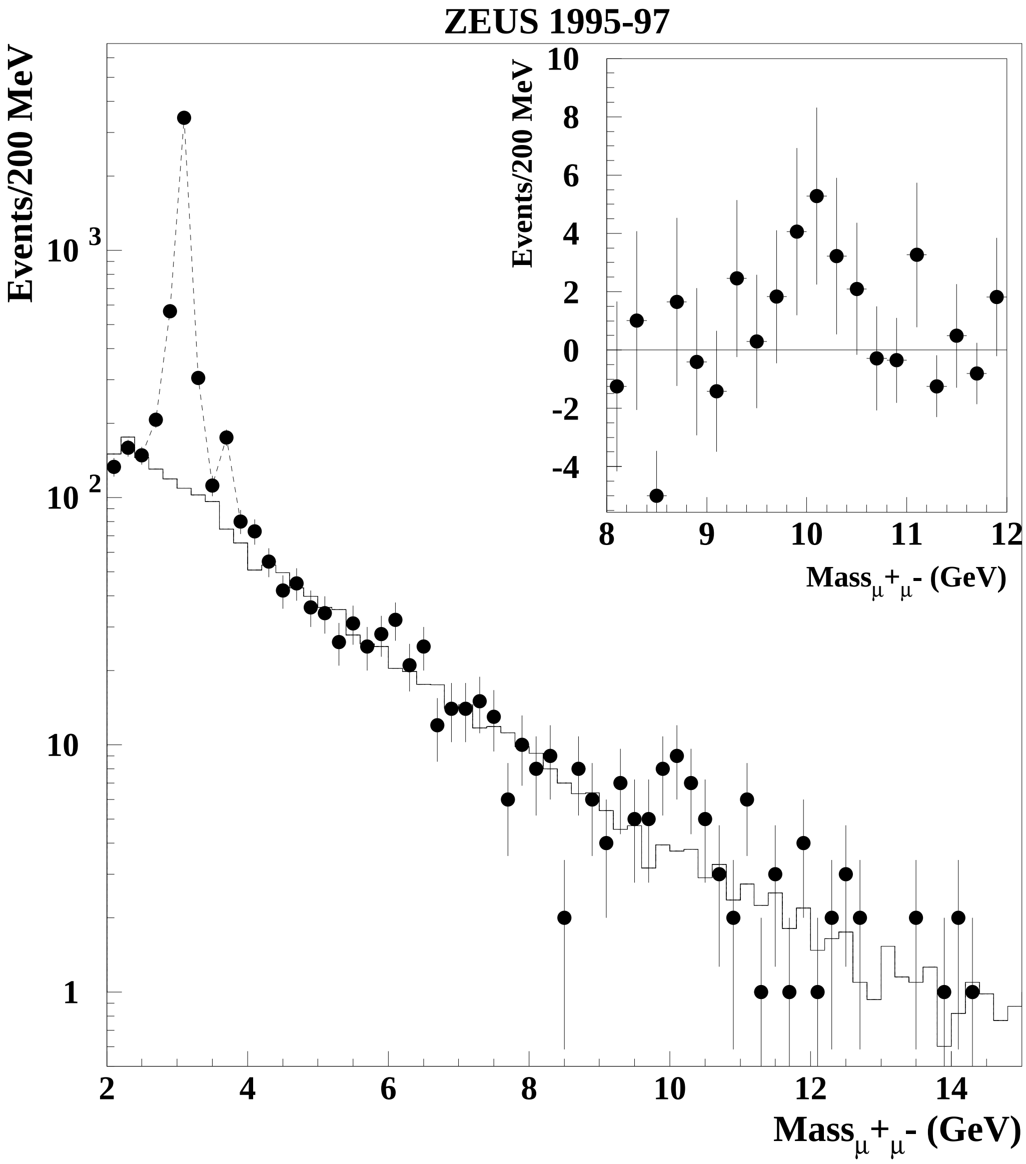
$\sigma^{\gamma p \to Vp} \propto (W^2)^{(4\alpha_{I\!P}(t)-4)}$

ρ, ω, ϕ have a Regge compatible behaviour



J_ψ has a steeper W dependence

OBSERVATION OF Υ

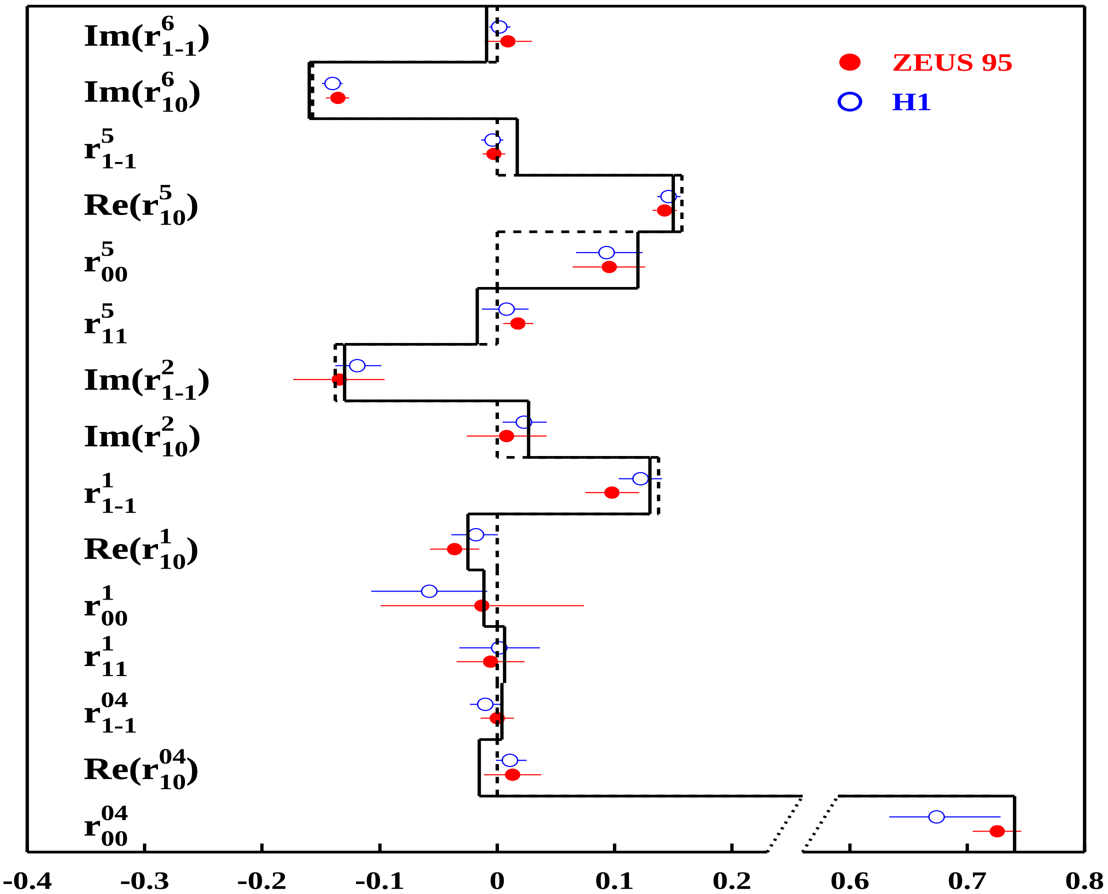


HELICITY STUDIES

Angular distribution of ρ productyion involves 15 terms of spin density matrix

ZEUS $3 < Q^2 < 30$ GeV^2 $40 < W < 120$ GeV^2 $|t| < 0.6$ GeV^2

H1 $1 < Q^2 < 60$ GeV^2



$r^5_{00} \neq 0$ violation of SCHC

Helicity flip amplitude $\rightarrow \rho$ with 0 helicity:
longitudinally polarized ρ^0 can be produced from transverse photons

$\boxed{\textbf{DIFFRACTIVE PHOTON DISSOCIATION}}$
$\boxed{\textbf{IN DEEP INELASTIC SCATTERING}}$

$\boxed{\textbf{DIFFRACTIVE STRUCTURE FUNCTIONS}}$

Parametrization of diffractive cross sections in DIS:

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

Integrating over t:
$F_2^{D(4)} \longrightarrow F_2^{D(3)}(\beta, Q^2, x_{I\!P})$

Integrating over $x_{I\!P}$:
$F_2^{D(3)} \longrightarrow F_2^{I\!P}(\beta, Q^2)$

Result of semi-inclusive cross section measurements

$\boxed{\textbf{FACTORIZATION}}$

Independence of proton and photon vertices $\Rightarrow$

$F_2^{D(3)}(Q^2, \beta, x_{I\!P}) \sim (\frac{1}{x_{I\!P}})^a \cdot F_2^{I\!P}(Q^2, \beta)$ with a independent of Q^2, β

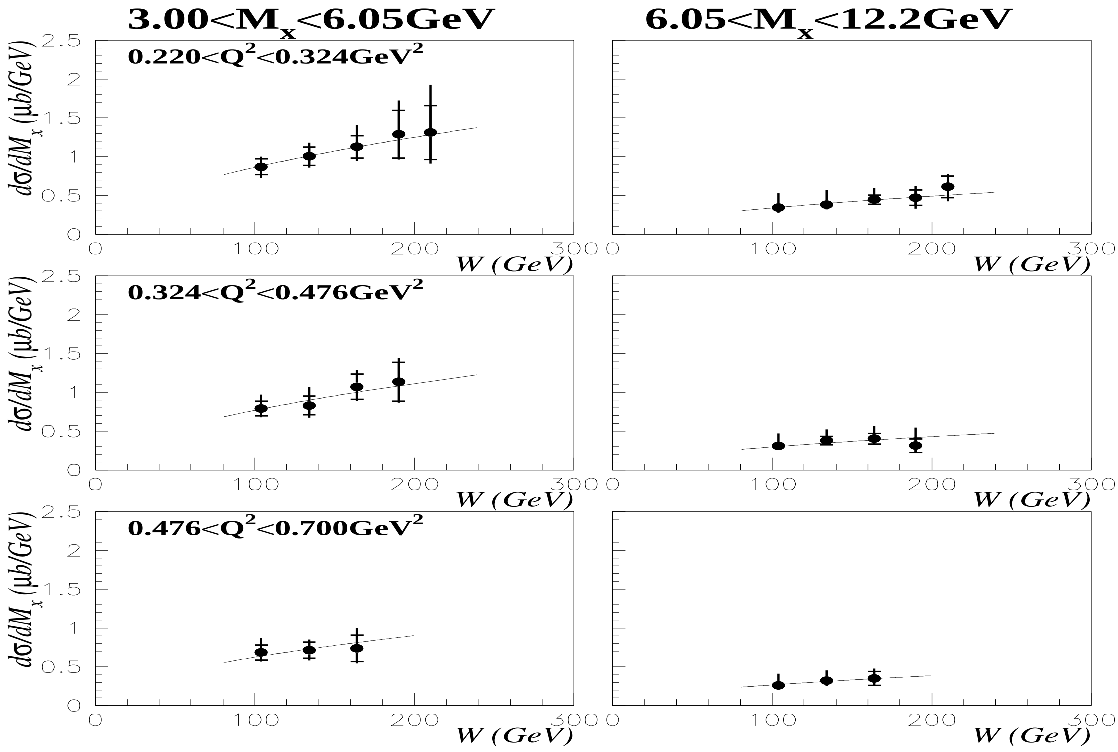
and similar features of $I\!P$ exchange in DIS and photoproduction

ZEUS. DIFFRACTIVE CROSS SECTIONS

Cross sections VS W AND $\alpha_{I\!P}$

$\frac{d\sigma}{dM_X}$ vs W

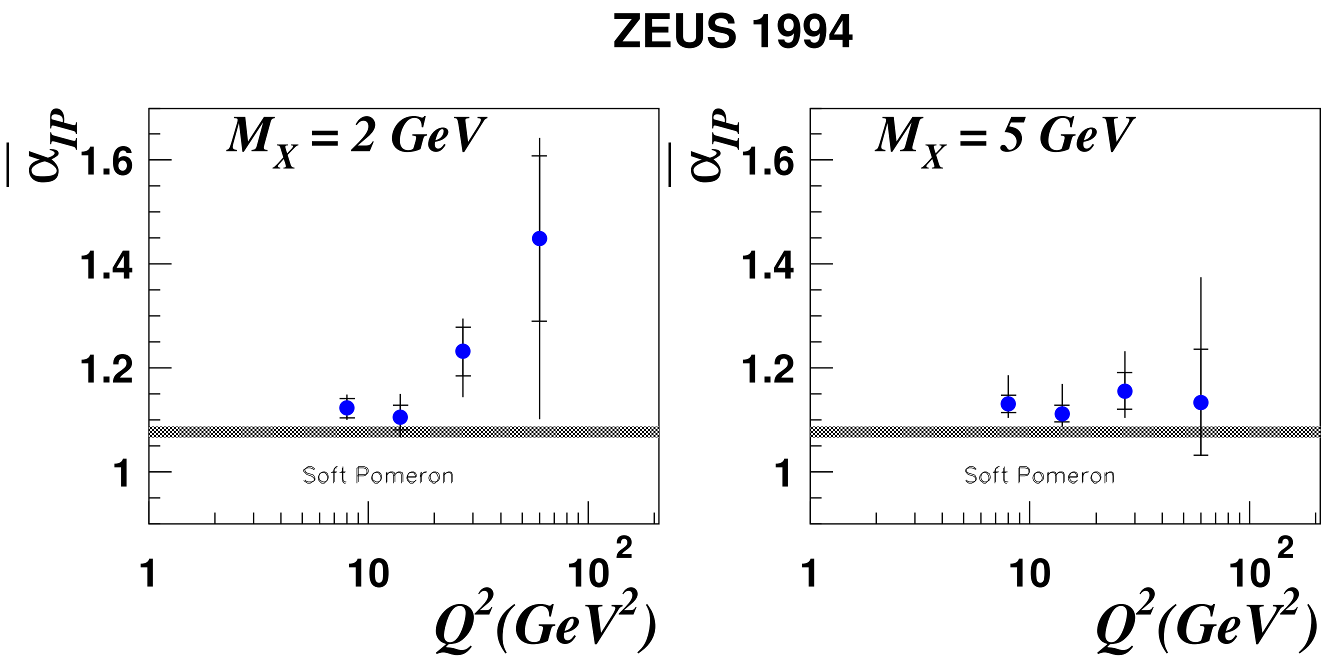
ZEUS 1996 Preliminary

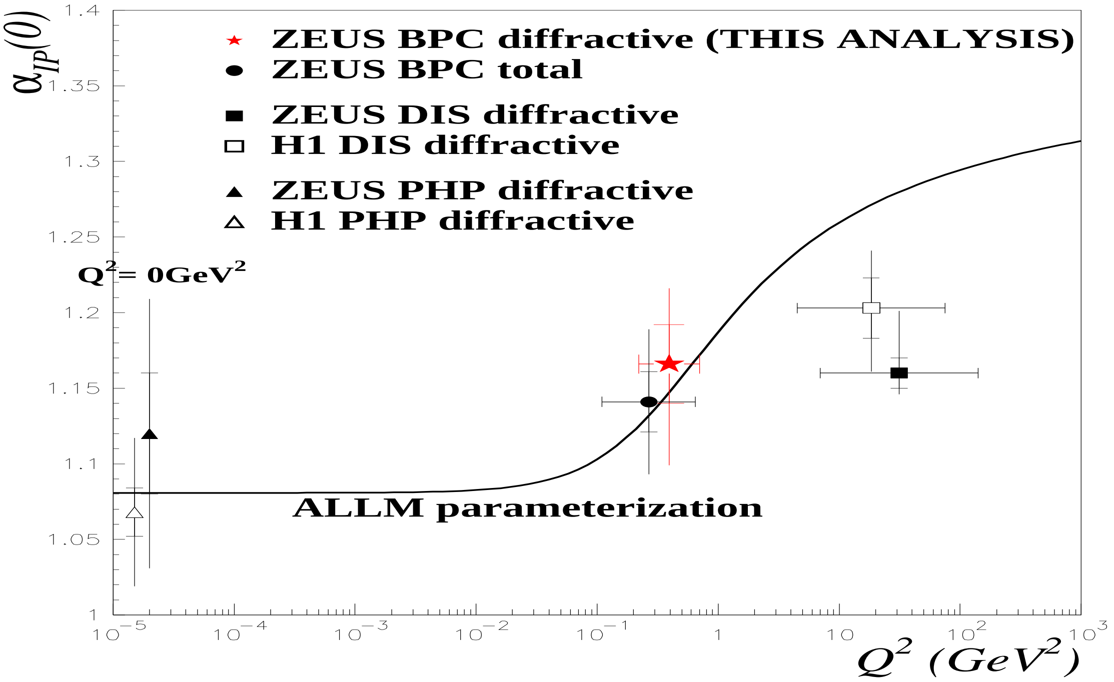


Fit: $\frac{d\sigma^{diff}_{\gamma^* p \to XN}(M_X,W,Q^2)}{dM_X} \propto (W^2)^{(2\overline{\alpha_{I\!P}}-2)}$

$\overline{\alpha_{I\!P}} = 1.133 \pm\ 0.026$ (stat.) $^{+0.043}_{-0.062}(syst.)$
$\to \alpha_{I\!P}(0)$

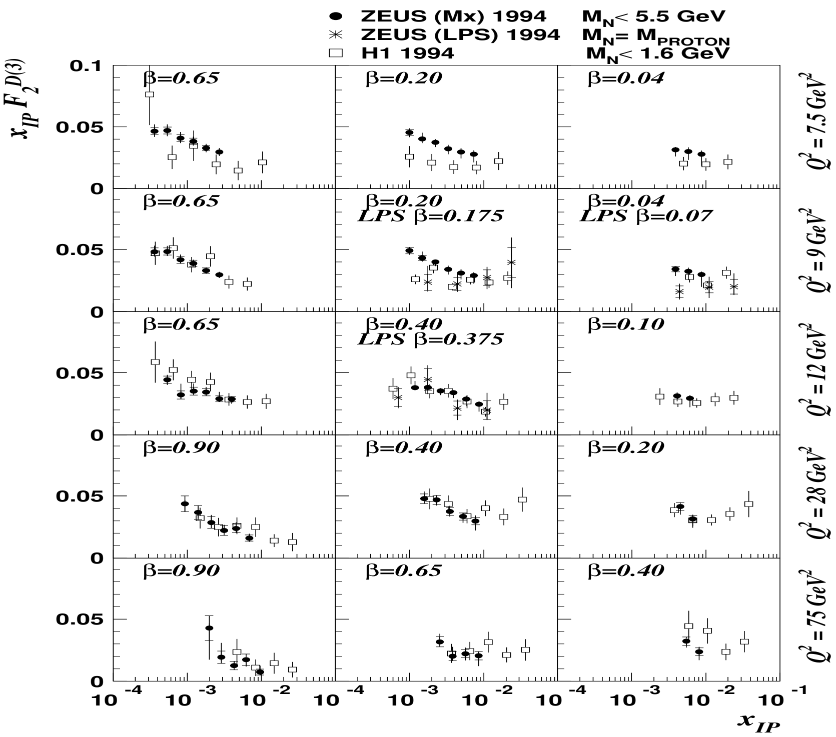
Extracted $\alpha_{I\!P}$ VS Q^2





ZEUS. DIFFRACTIVE STRUCTURE FUNCTION

. The M_X method has $x_{I\!P} < 0.01$



Comparison of LPS and M_X analysis requires taking into account double dissociation and non $I\!P$ exchange

ZEUS points are higher than H1 points for $Q^2 < 9$ GeV ^{2}

Both ZEUS and H1 results leads to values of $\alpha_{I\!P}$ higher compared to the classical Donnachie-Landshoff pomeron

H1 results obtained in the range 0.4< $Q^2 < 800$ GeV ^{2} lead to factorization breaking, needing both

Pomeron and (subleading) reggeon contribution

$\overline{\alpha_{I\!P}} = 1.127 \pm 0.009$ (stat.) $^{+0.030}_{-0.035}$ (syst)

H1 gives:

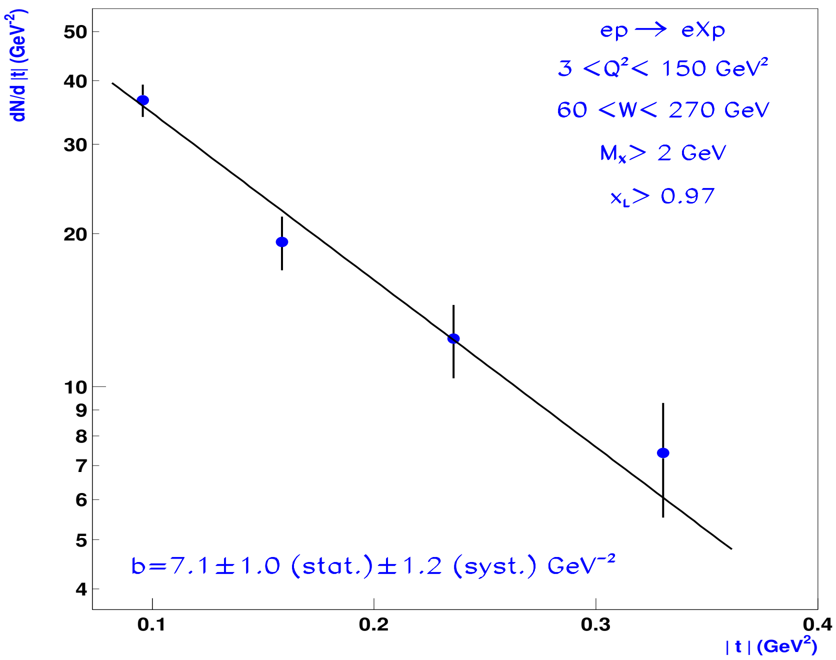
$\alpha_{I\!P}(0) = 1.203 \pm 0.020$ (stat.) $^{+0.030}_{-0.035}$(syst.)

ZEUS. t SLOPE IN DEEP INELASTIC SCATTERING

t distribution of diffractive DIS measured directly, at HERA. It falls down exponentially:

$\frac{d\sigma}{dt} \propto e^{-b|t|}$

ZEUS 1994



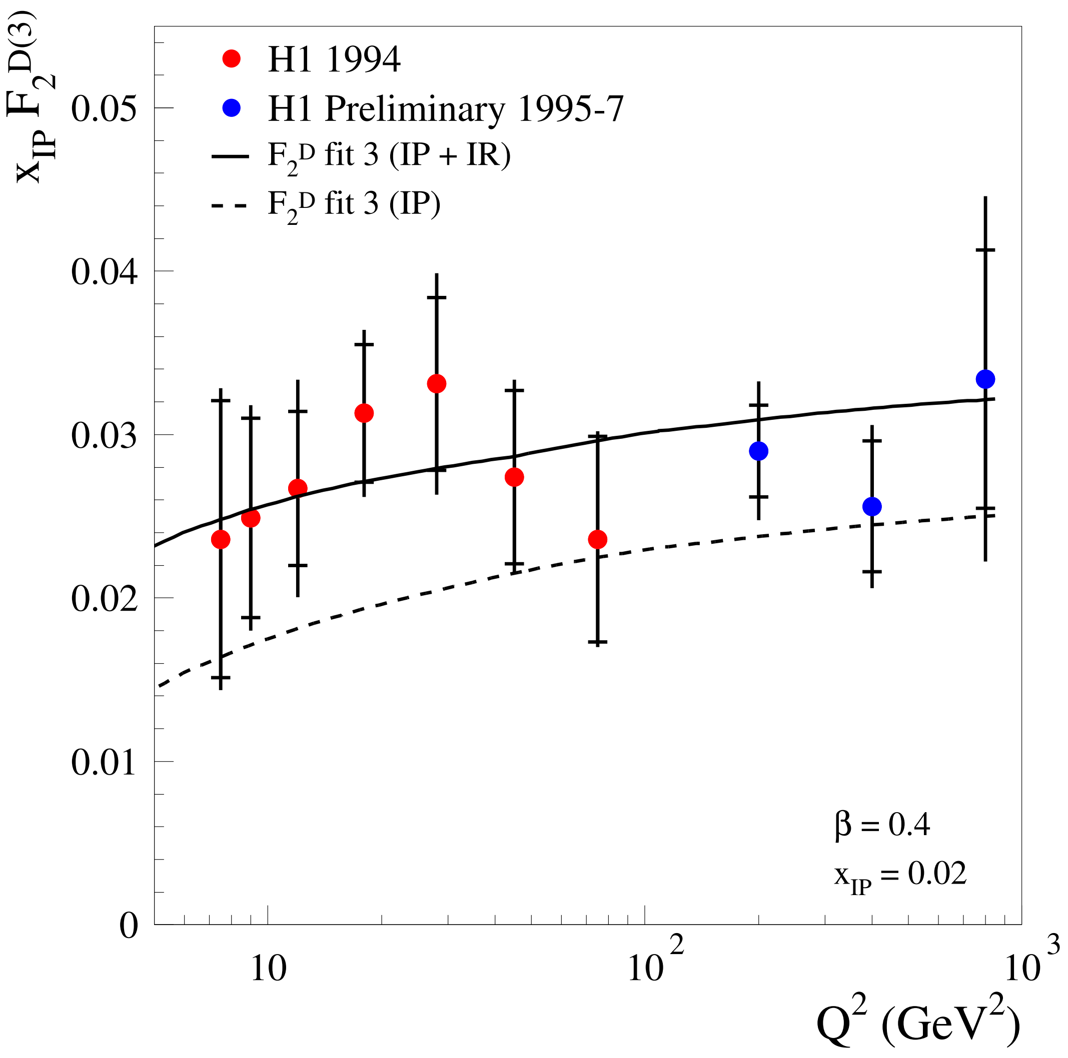
$b = 7.1 \pm\ 1.0$ (stat.) $\pm\ 1.2$ (syst.)

(large value, typical of peripheral processes)

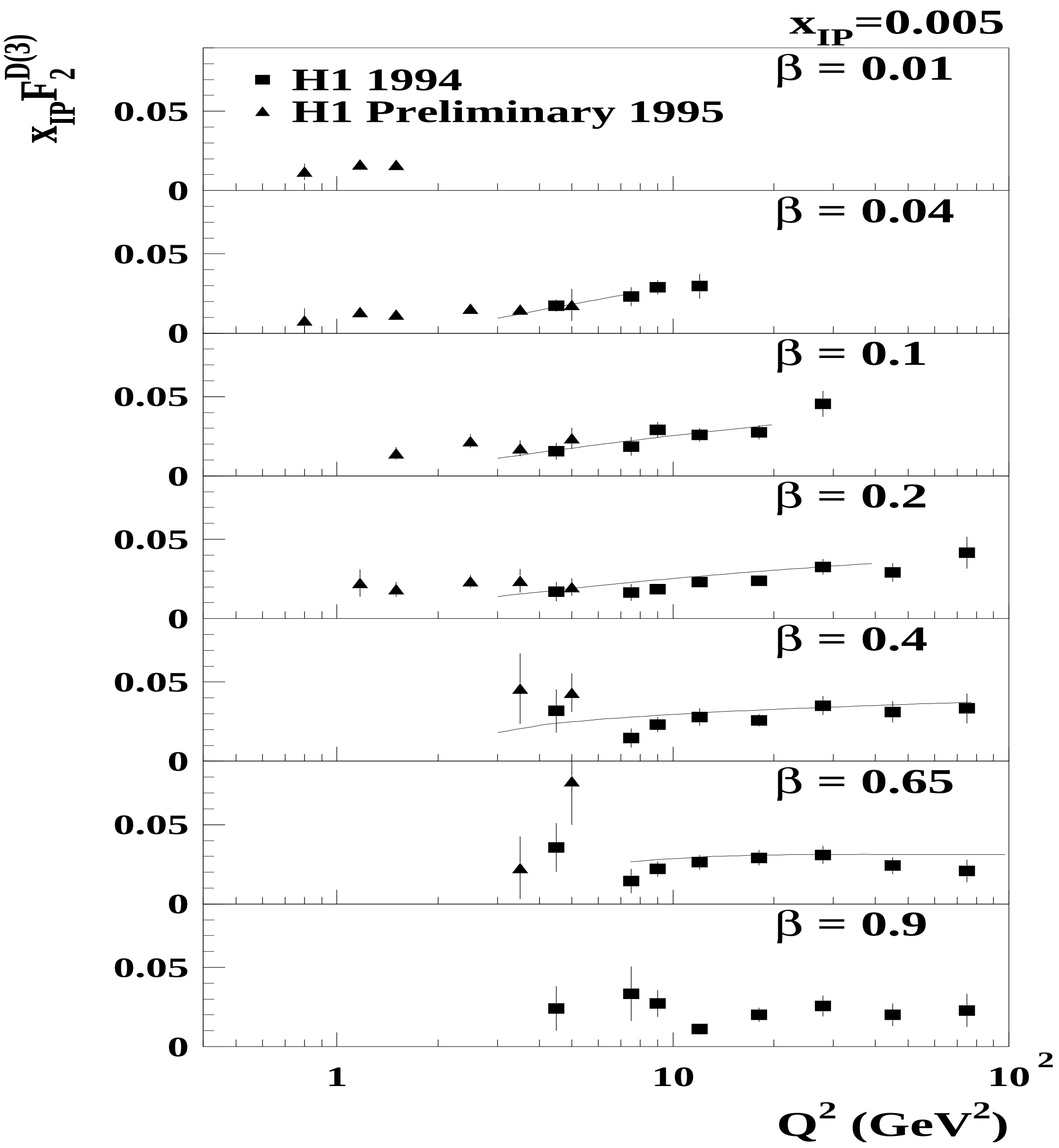
H1. FITS TO DIFFRACTIVE STRUCTURE FUNCTIONS

Q^2 dependence of $F_2^{D(3)}$ at $\beta = 0.4$ $x_{I\!P} = 0.002$

DGLAP fit with both pomeron and reggeon (quarks and gluons)



Scaling violations of $F_2^{D(3)}$ over large Q^2 range ($0.8 < Q^2 < 800$ GeV ^{2}) rising up to large β indicate gluon dominance



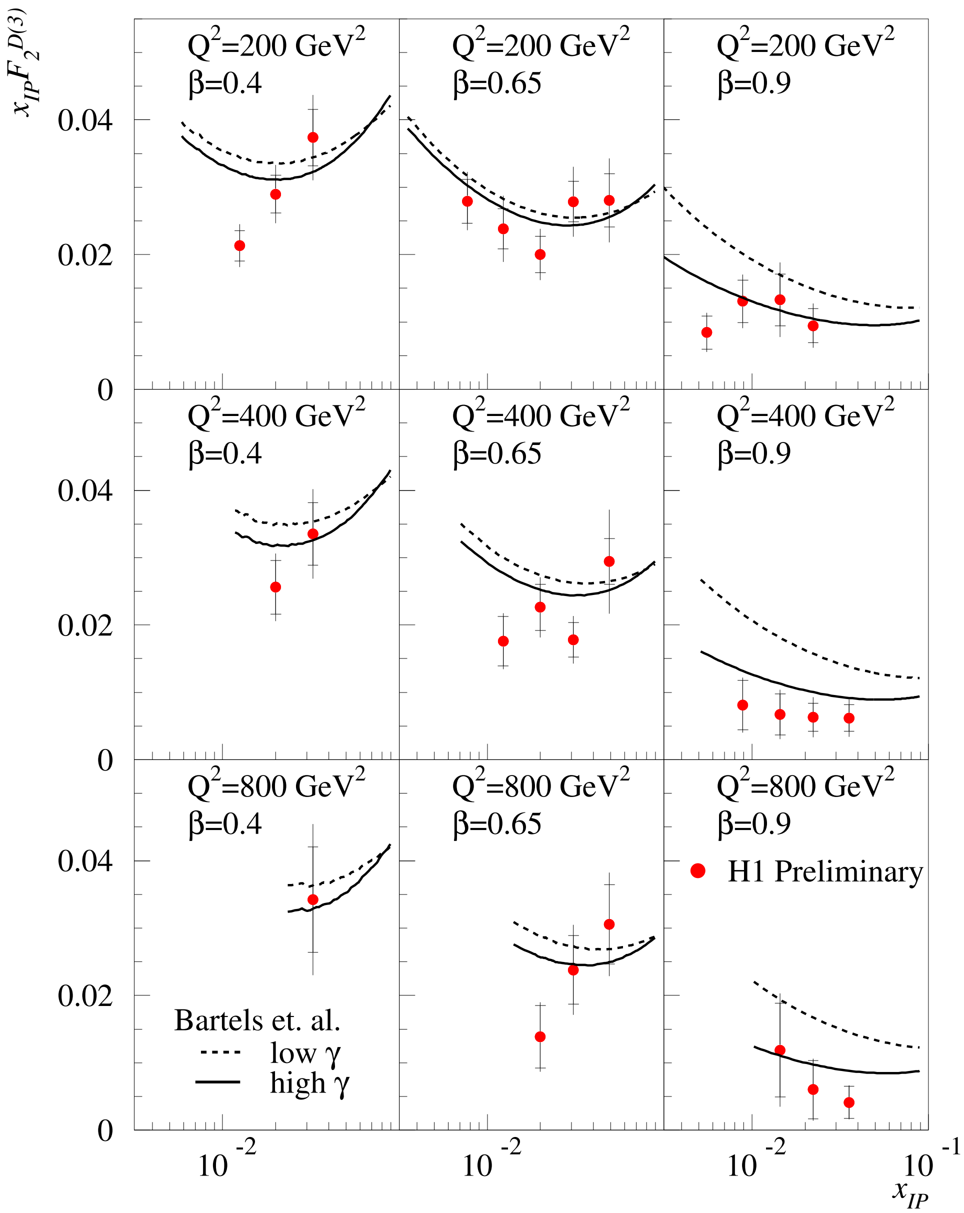
Fits suggest: 90 % gluon at $Q^2 = 4.5$ GeV ^{2}

80 % gluon at $Q^2 = 75$ GeV ^{2}

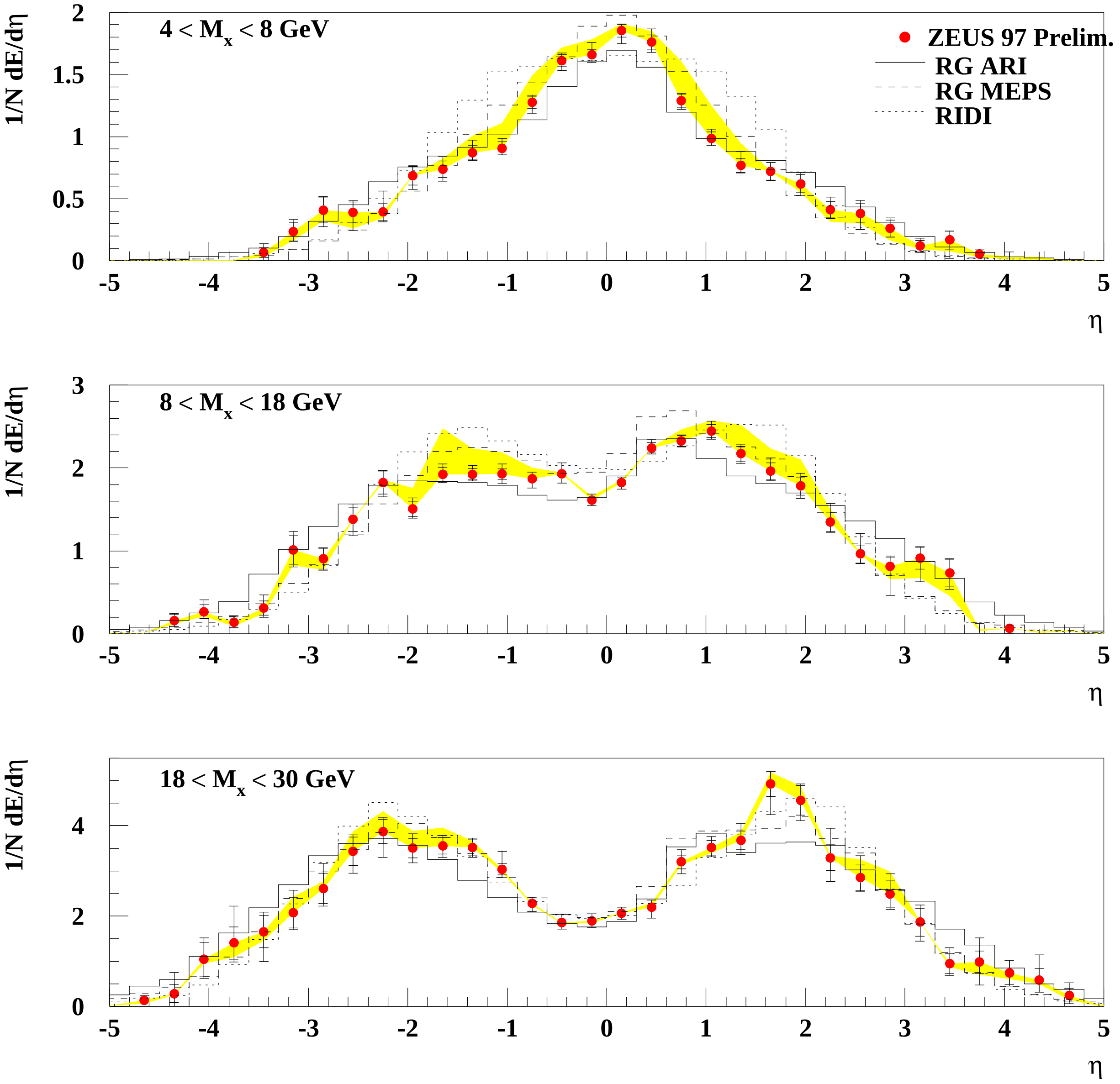
$F_2^{D(3)}$ at large Q^2

Extrapolating DGLAP fits good description of data up to $Q^2 = 800$ GeV ^{2}

Also in agreement with 2g exchange model

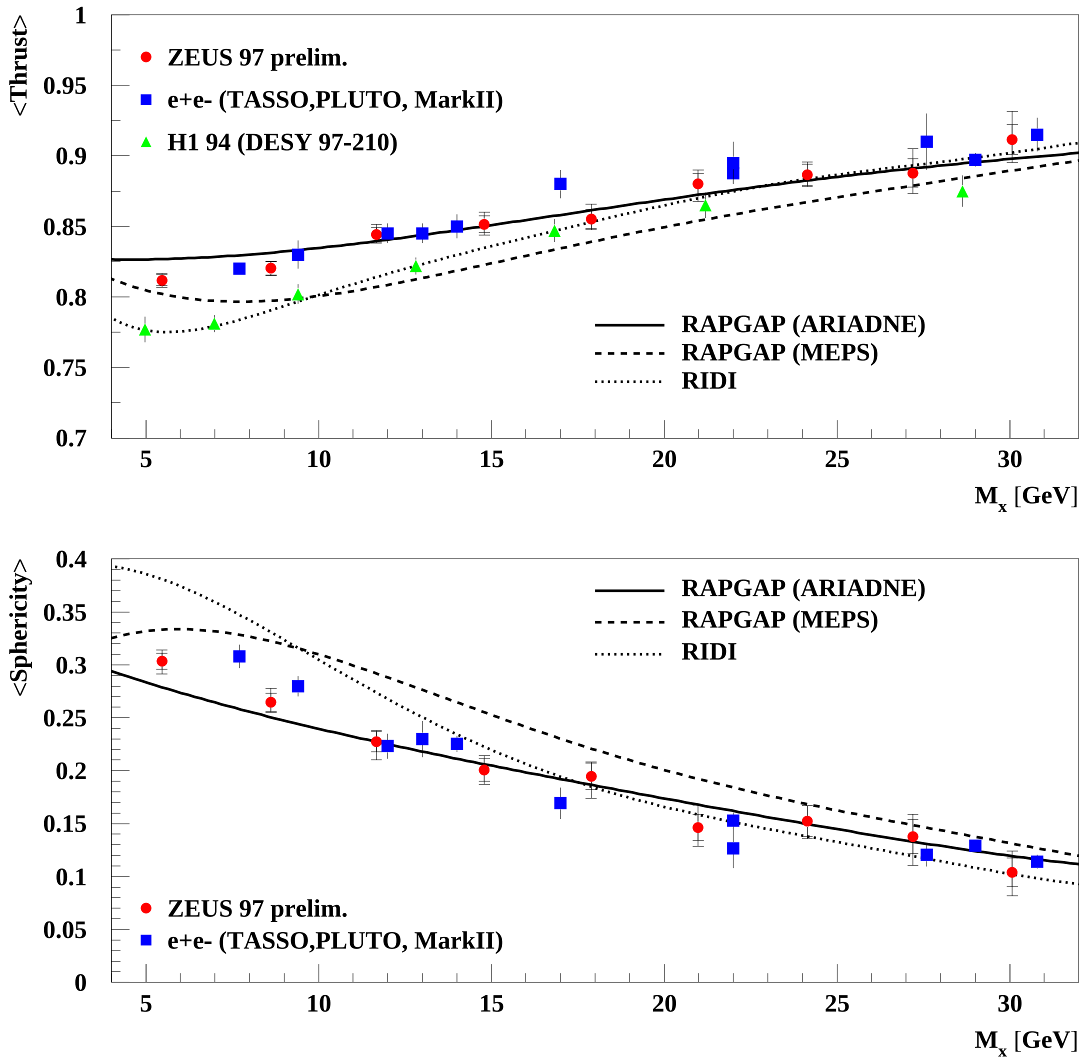


ZEUS. HADRONIC FINAL STATES IN DIFFRACTION



As M_X grows jet structures begin to show up

Diffractive events tagged with LPS $4 < Q^2 < 90$ GeV^2 $4 < M_X < 35$ GeV^2
Boost into the $\gamma - IP$ center of mass frame



Comparison with a MC based on 2 gluon exchange

CONCLUSIONS

ZEUS and H1 have studied diffractive processes using different experimental definitions of diffraction, in photoproduction and Deep Inelastic Scattering, in a wide and increasing kinematic range

Exclusive vector meson production and inclusive virtual photon dissociation have been investigated in great detail

The partonic structure of the pomeron has been studied and results favour a strong gluon component