

LEADING PROTON PRODUCTION in DIS at HERA

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Introduction

- Leading protons (LP) carry large fraction of proton beam-energy (x_L) and have small transverse momentum (p_T)
- LP production mainly soft process, non perturbative-QCD
- Alternative approach needed (example: Reggeon-exchange)
- Possible implication on LHC (simulation of forward protons) and extended cosmic ray showers

Results discussed in this talk:

Measurement of LP production in DIS ($Q^2 > 3 \text{ GeV}^2$, $45 < W < 225 \text{ GeV}$), for leading proton with $0.5 < x_L < 1$ (diffractive and not-diffractive regimes) and $p_T^2 < 0.5 \text{ GeV}^2$:

- LP longitudinal momentum spectrum
- LP transverse momentum spectrum and slopes
- LP rate vs DIS variables x, Q^2
- LP-tagged structure function
- Comparison to models and other data

Leading proton production in ep collisions

LP cross sections vs structure functions:

(QCD-based approach)

$$\frac{d^4\sigma(x, Q^2, x_L, p_T^2)}{dx dQ^2 dx_L dp_T^2} = \frac{4\pi\alpha^2}{xQ^4} \left(1 - y + \frac{y^2}{2}\right) F_2^{LP(4)}(x, Q^2, x_L, p_T^2)$$

Standard fragmentation

- LP from hadronization of p remnant
- Implemented in MC models (Cluster, Lund strings...)

Virtual particle exchange

π , IR, IP

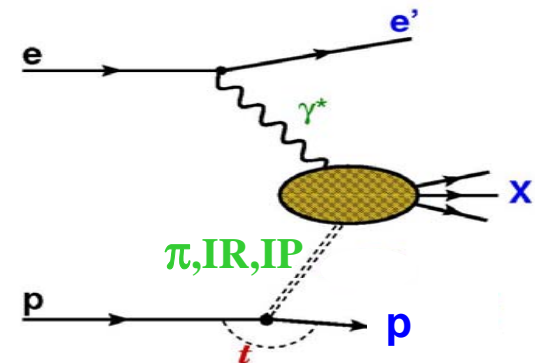
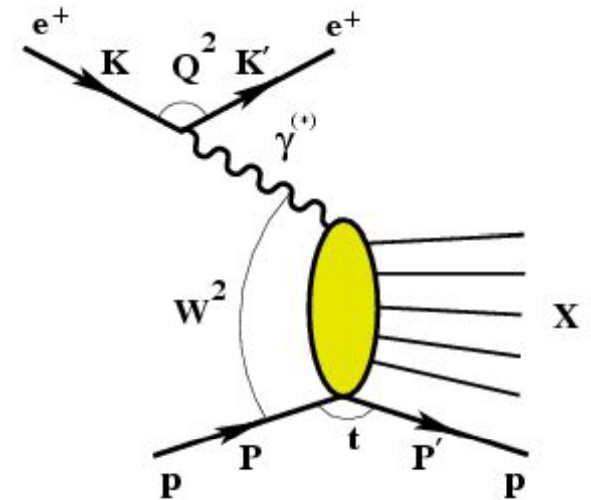
LP also from p fragmentation in double dissociative diffraction

Kinematics

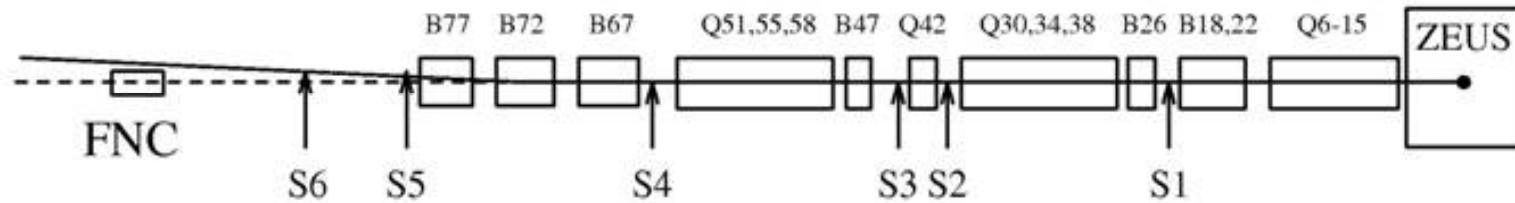
Lepton vertex variables: x , Q^2 , (W, y)

LP variables: $p_T^2, x_L = E_{LP}/E_p$

LP and DIS variables assumed to be independent (vertex factorization) ³

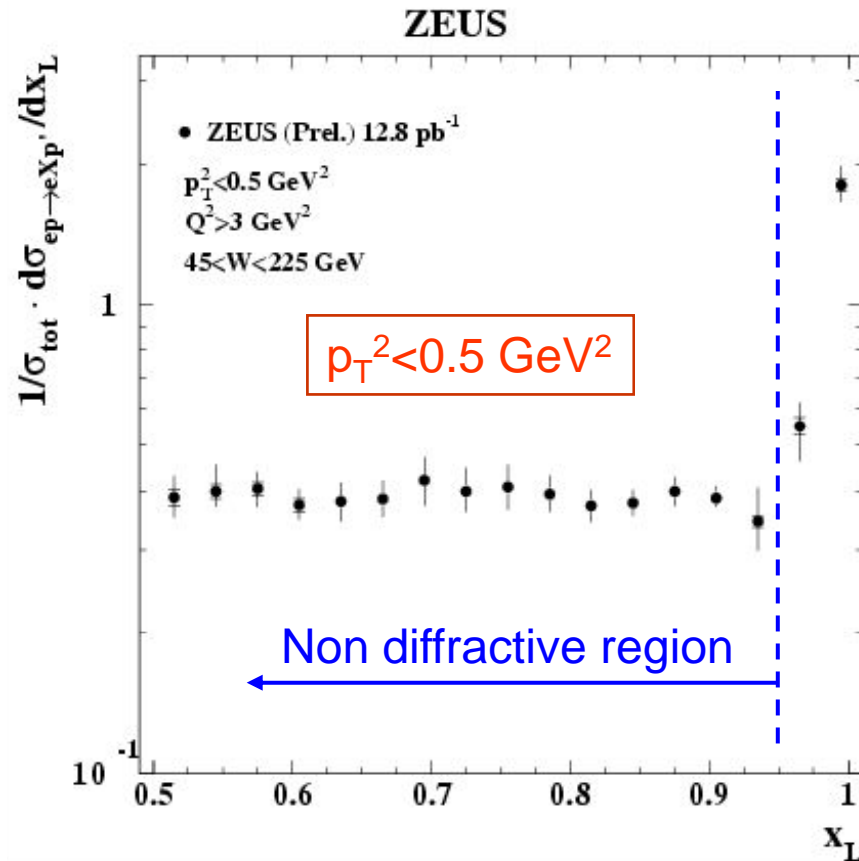


The ZEUS Leading Proton Spectrometer (LPS)



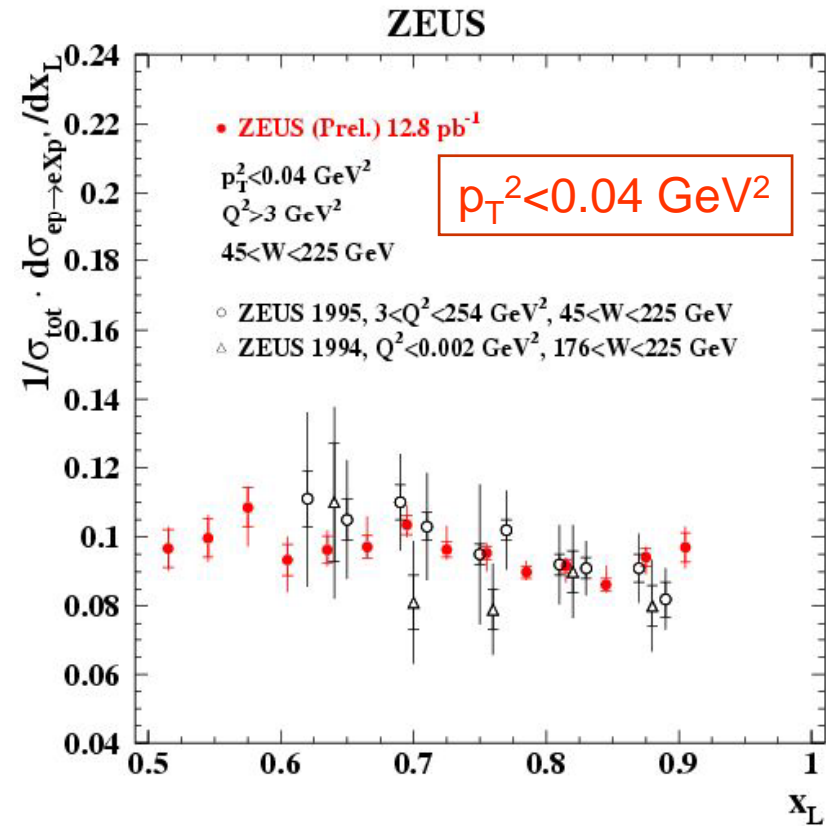
- 6 stations (s1→s6) each made by 6 Silicon-detector planes
- Stations positioned at 20 → 90m from I.P.
- Stations inserted at $10\sigma_{\text{beam}}$ from the proton beam during data taking
- $\sigma_{x_L} < 1\%$ $\sigma_{p_T^2} \sim \text{few MeV}^2$ (better than p-beam spread $\sim 50\text{-}100 \text{ MeV}$)
- Full LPS set used in this analysis ($x_L > 0.5$, possibility to extend $x_L > 0.32$)

Cross section vs x_L



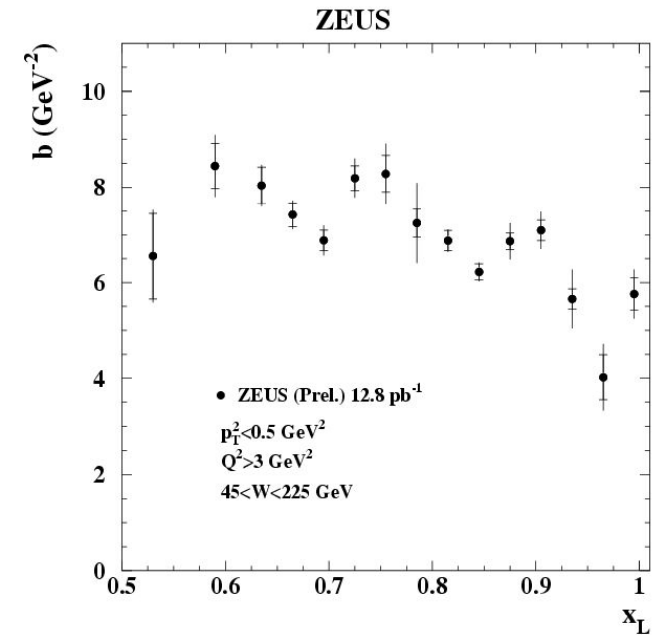
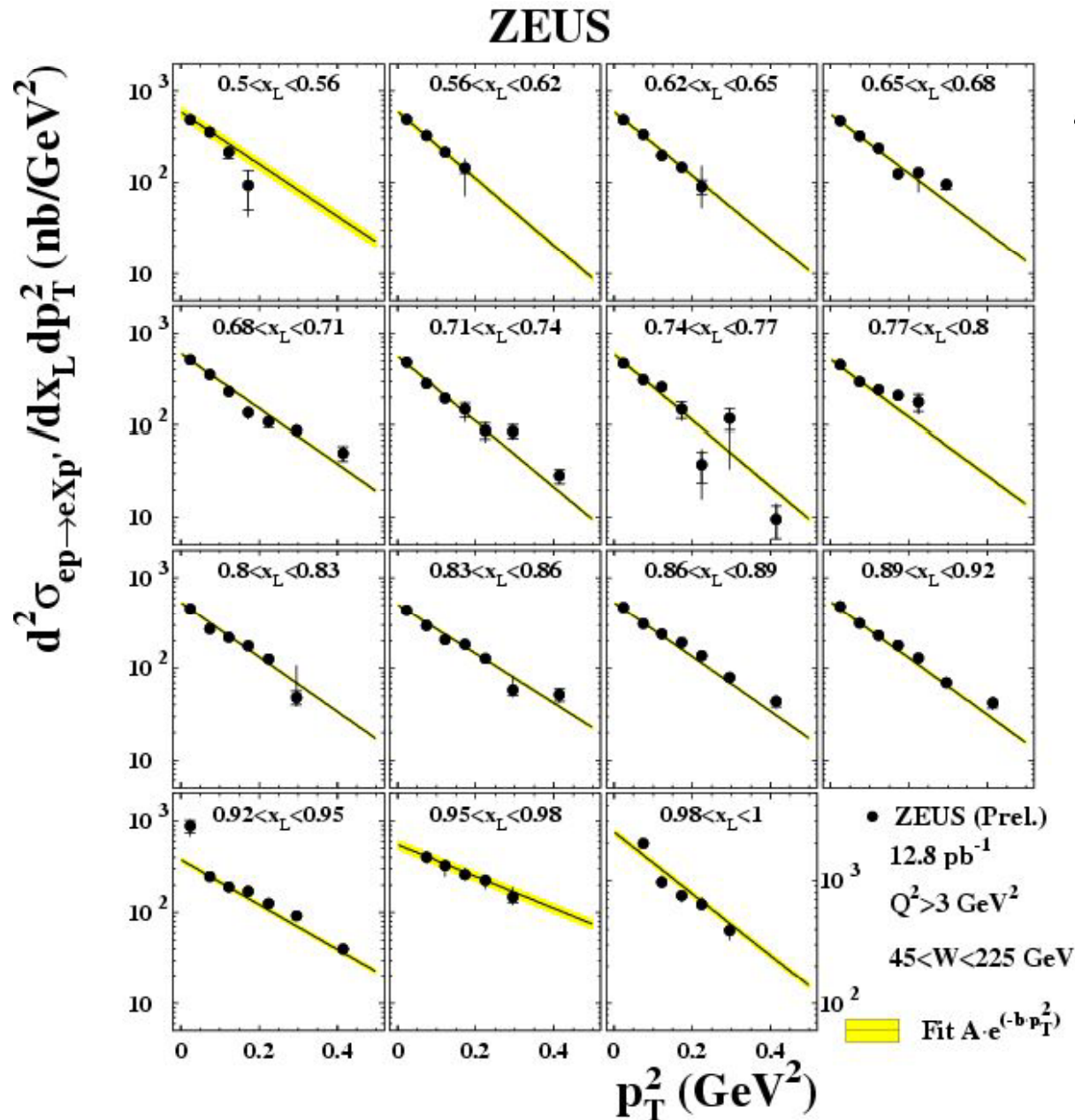
Cross section normalised to
inclusive DIS cross section

Flat below diffractive peak



DIS and photoproduction
data are compatible

Cross section vs p_T^2 in bins of x_L and slopes



Exponential behaviour

Fit to $A \cdot \exp(-b \cdot p_T^2)$ shown with stat. error

No strong dependence of b on x_L

$$\langle b \rangle \approx 6.7 \text{ GeV}^{-2}$$

Rates to inclusive DIS

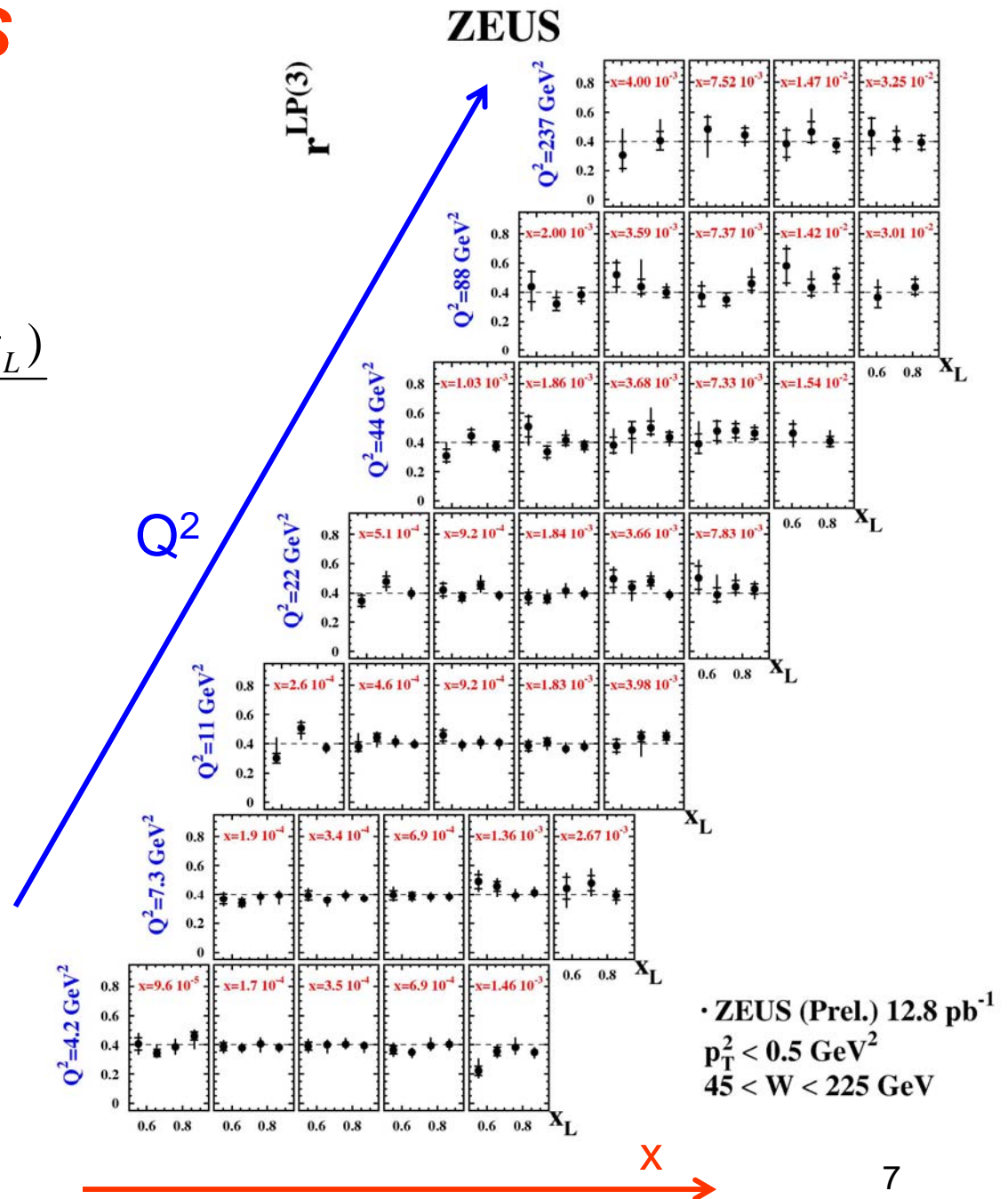
Structure function ratio

$$r^{LP(3)}(x, Q^2, x_L) = \frac{F_2^{LP(3)}(x, Q^2, x_L)}{F_2(x, Q^2)}$$

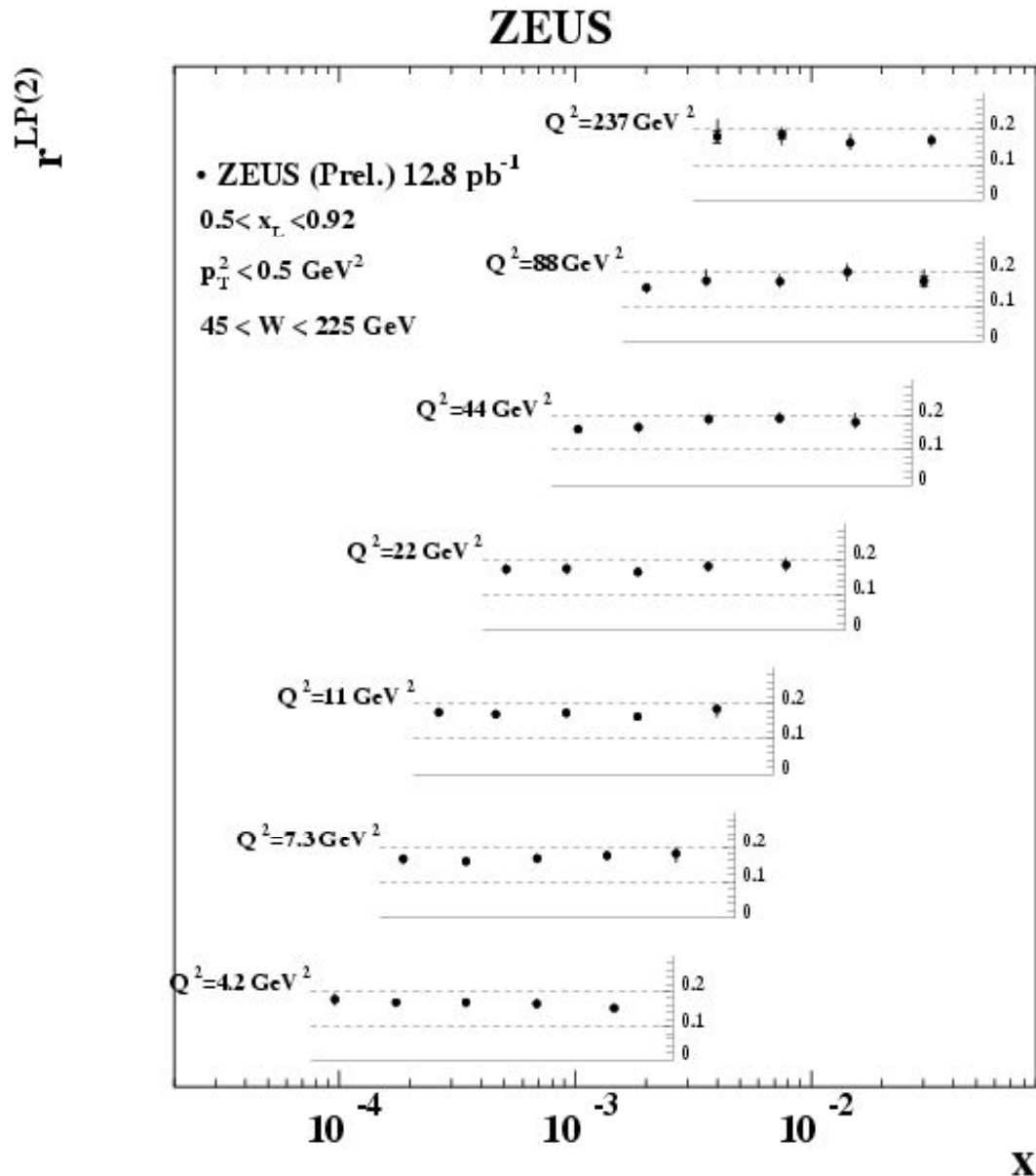
Information on LP production
as a function of DIS variables

Measurement for $0.5 < x_L < 0.92$
(NO diffraction)

$r^{LP(3)}$ almost independent
of x and Q^2 with average
value ~ 0.4



Rates to inclusive DIS - 2

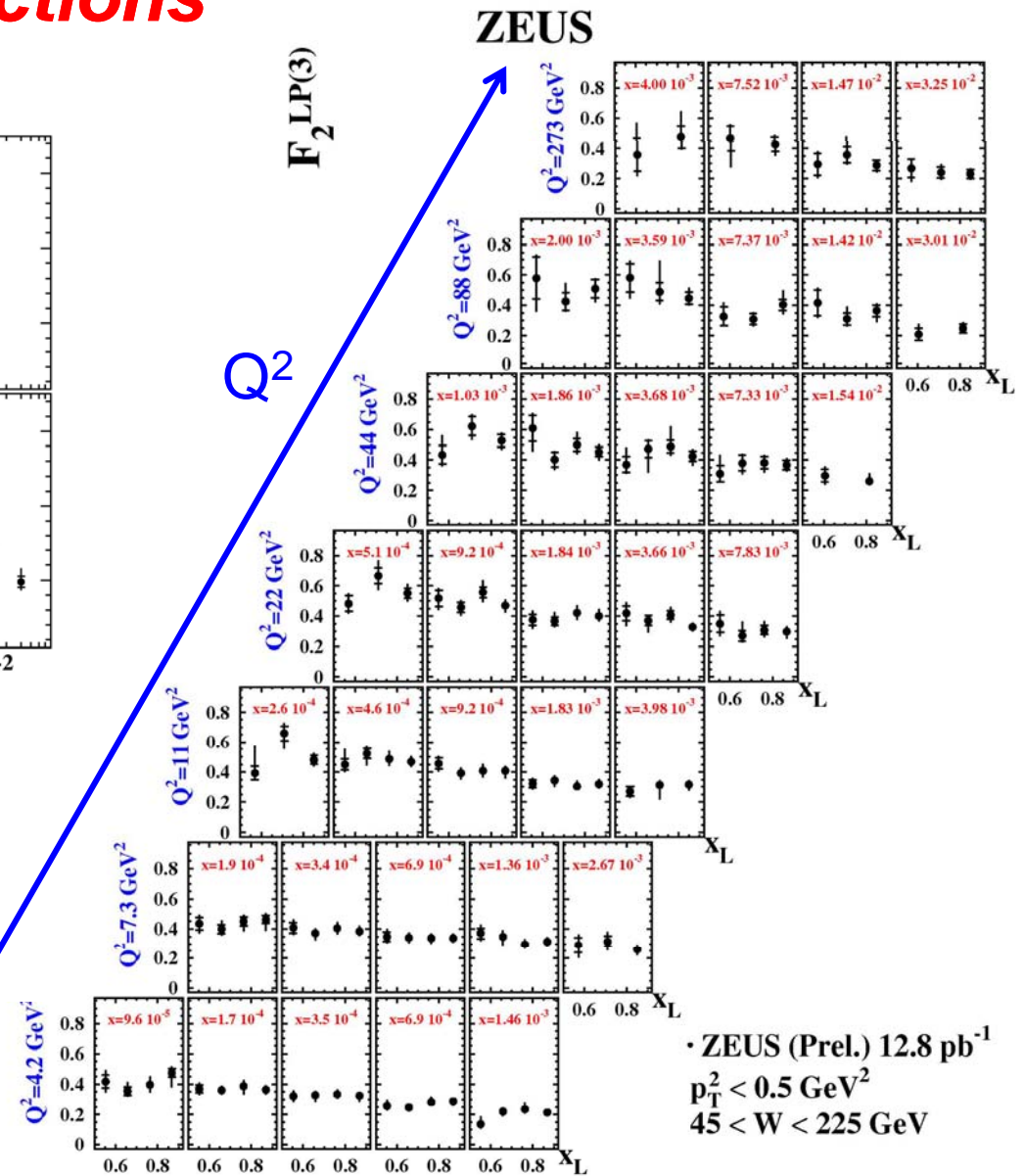
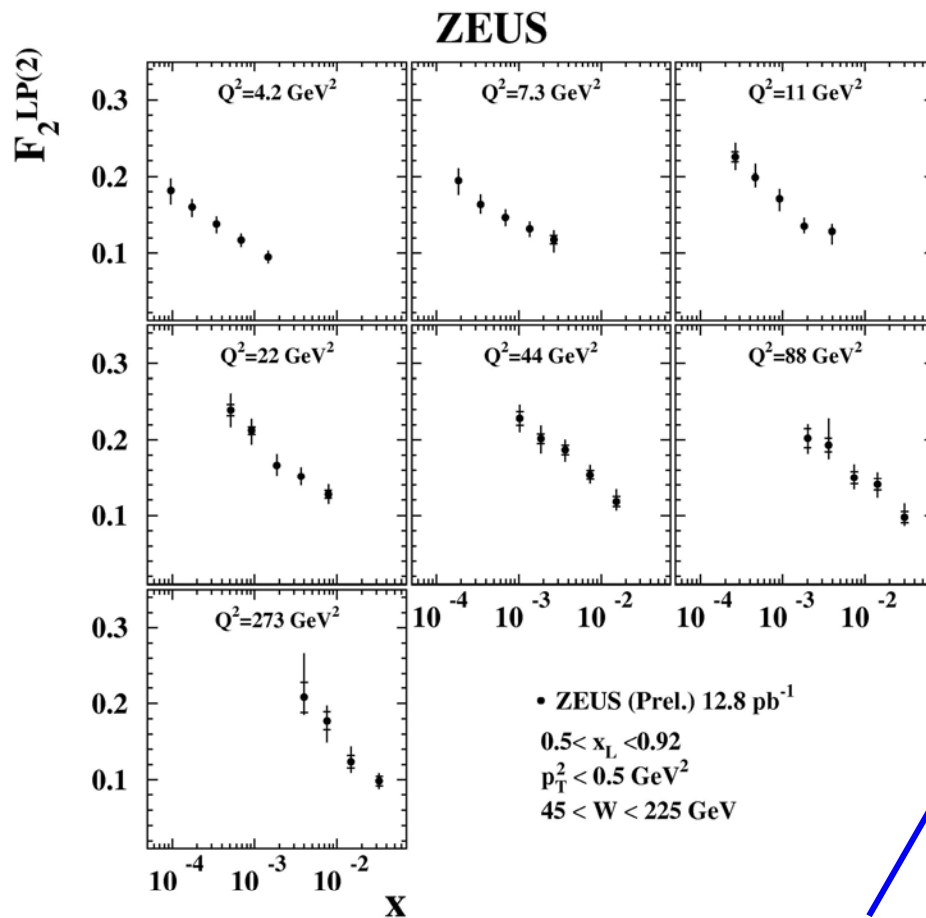


$$r^{LP(2)} = \frac{F_2^{LP(2)}(x, Q^2)}{F_2(x, Q^2)}$$

~17% of DIS events have a LP
 with $0.5 < x_L < 0.92$, almost
 independently of x and Q^2

No clear evidence of vertex
 factorization violation

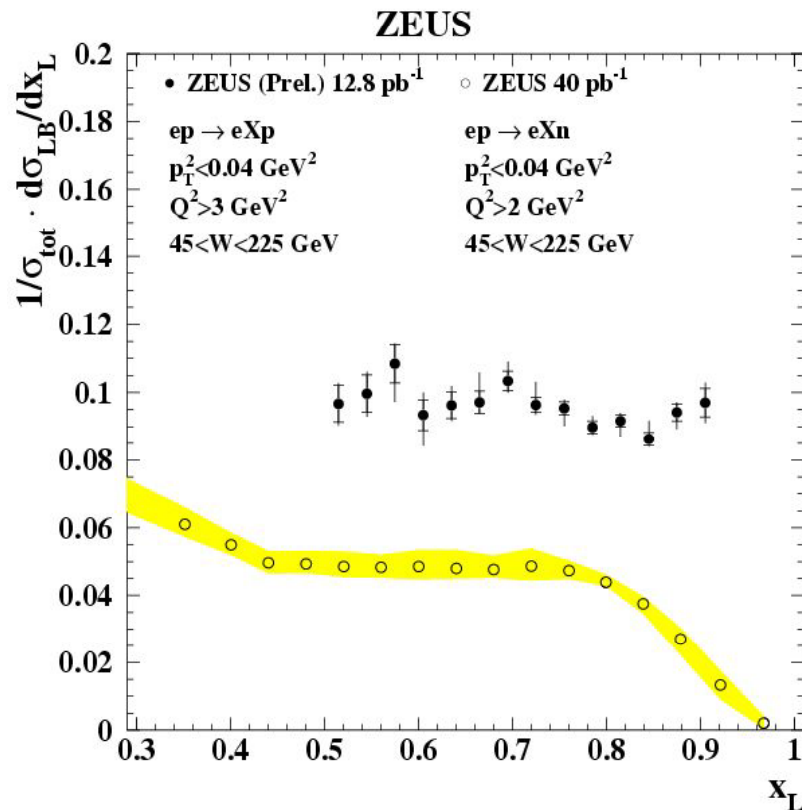
LP-tagged structure functions



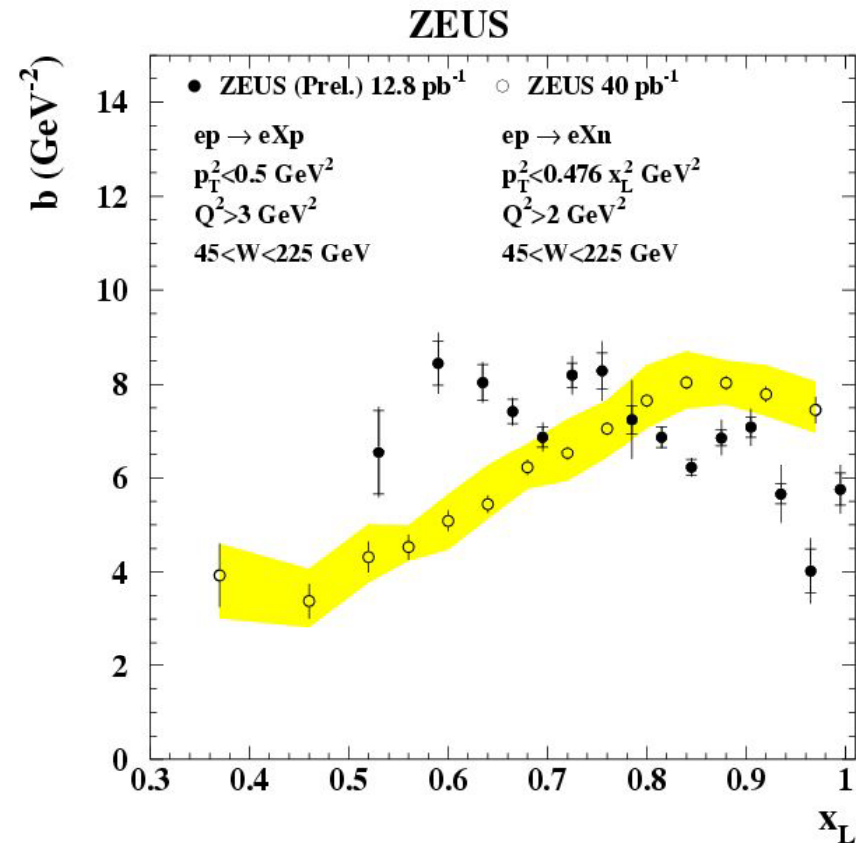
$F_2^{LP} = r^{LP} \cdot F_2$
 (ZEUS-S parametrization used)
 F_2^{LP} : same dependence on x and Q^2 as F_2

x

Leading proton vs leading neutron data



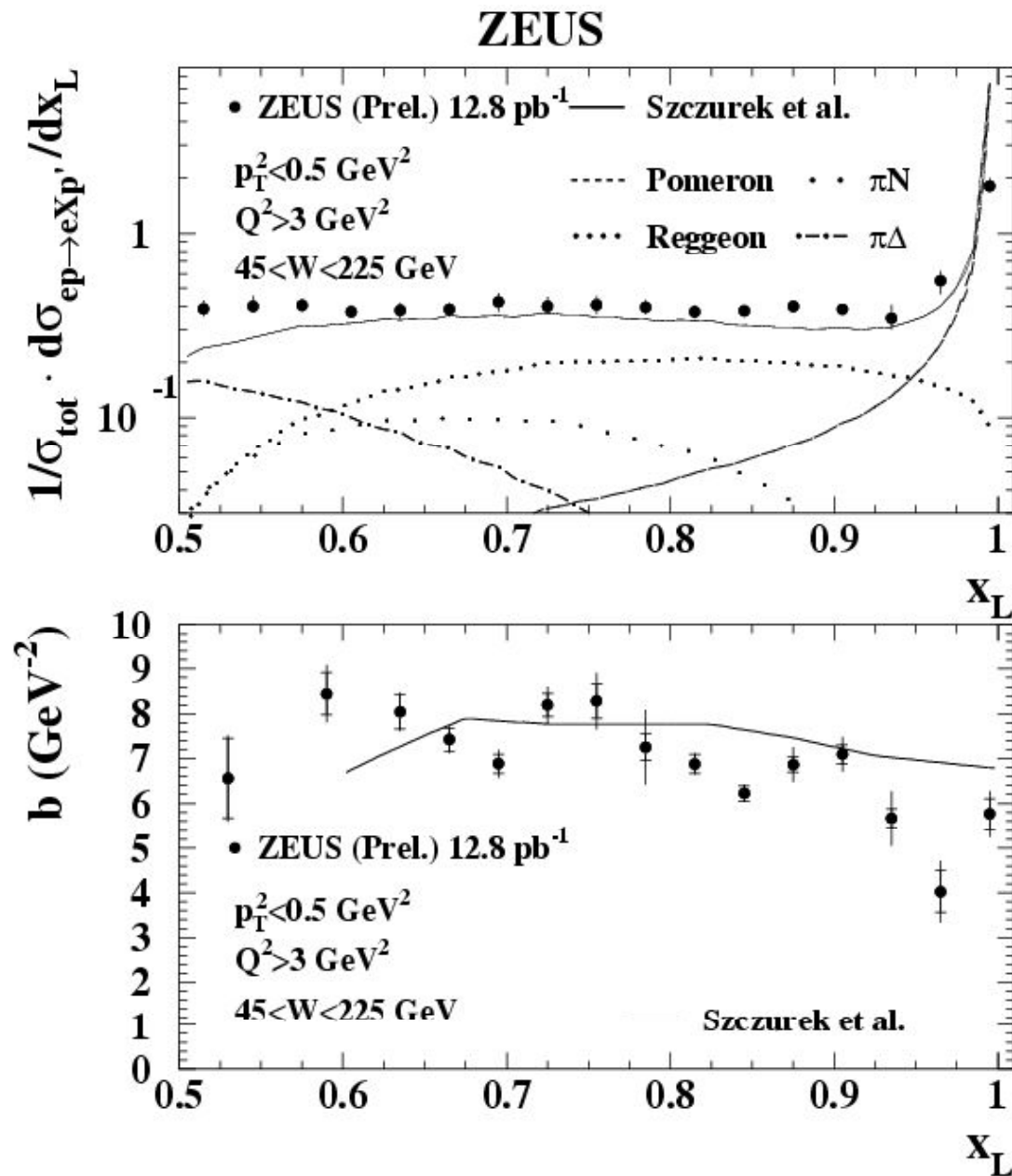
Very similar behaviour $x_L < 0.85$
 LP cross section almost twice LN



Slopes comparable $0.7 < x_L < 0.8$
 where π exchange dominates

In particle exchange model:
 expected from isovector: $LP = 1/2 LN$
 Other exchanges needed (isoscalars)

Comparisons to Reggeon exchange model



Very good description in shape

x_L slightly underestimated

b-slope slightly overestimated

Summary and conclusions

LP production measured in DIS:

- Cross section vs x_L flat below the diffractive peak
- LP cross section vs p_T^2 falls exponentially with a mean slope $\sim 6.7 \text{ GeV}^{-2}$, approximately independent on x_L
- the rates $r^{\text{LP}(2)}$ and $r^{\text{LP}(3)}$ show no dependence on x and Q^2 and LP structure functions proportional to F_2
- No evidence of vertex factorization violation
- LP and LN: agreement with expectations from particle-exchange models
- A Regge-inspired model reproduces quite well the LP features