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Leading Baryon Production at HERA

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D E S Y

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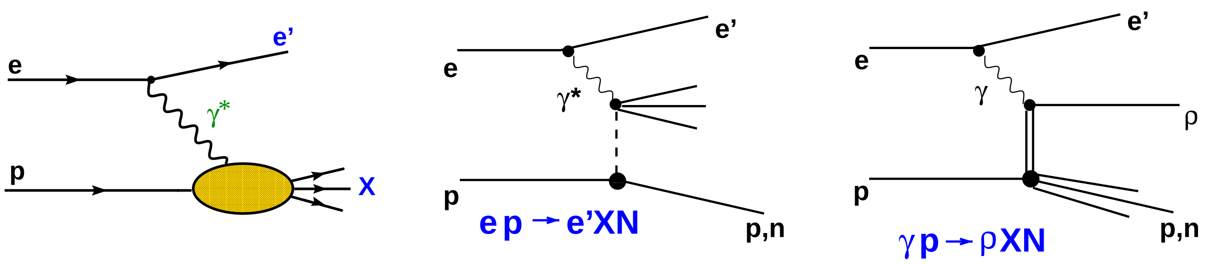
Contents:

- Introduction
- Kinematics
- Cross sections, Structure Functions, Factorization
- Dijets with leading neutrons
- ρ production with leading baryons
- Summary

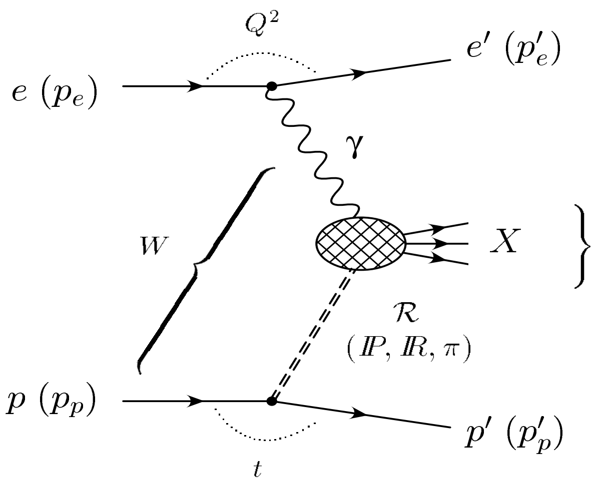
Motivation

Why study leading baryon production at HERA ?

- **What are the production mechanism:**
  - exchange processes (π, $I\!R$, ...)
  - fragmentation of proton remnant



- **Factorization tests:**
  Hypothesis: cross section dependence on baryon variables is independent of the particle production at the photon vertex.
  $\Rightarrow$ Look at production rates for different processes as function of kinematic variables:



Photon vertex
lepton variables:
$Q^2,\ x,\ W,\ y$

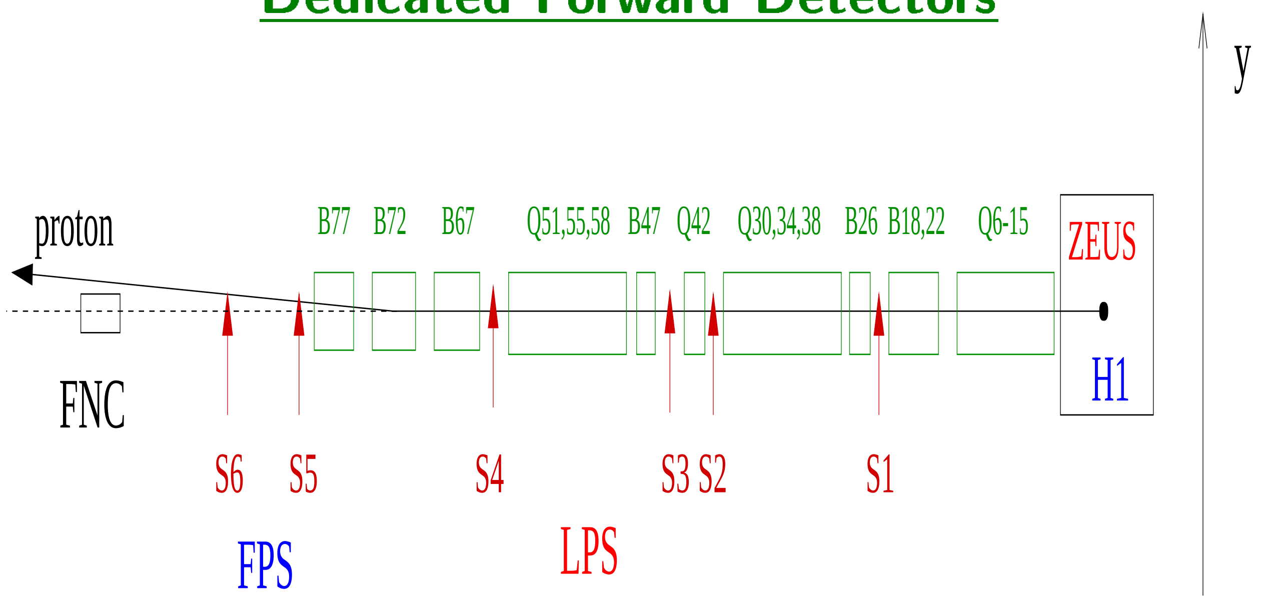
$\Uparrow$

$\Downarrow$

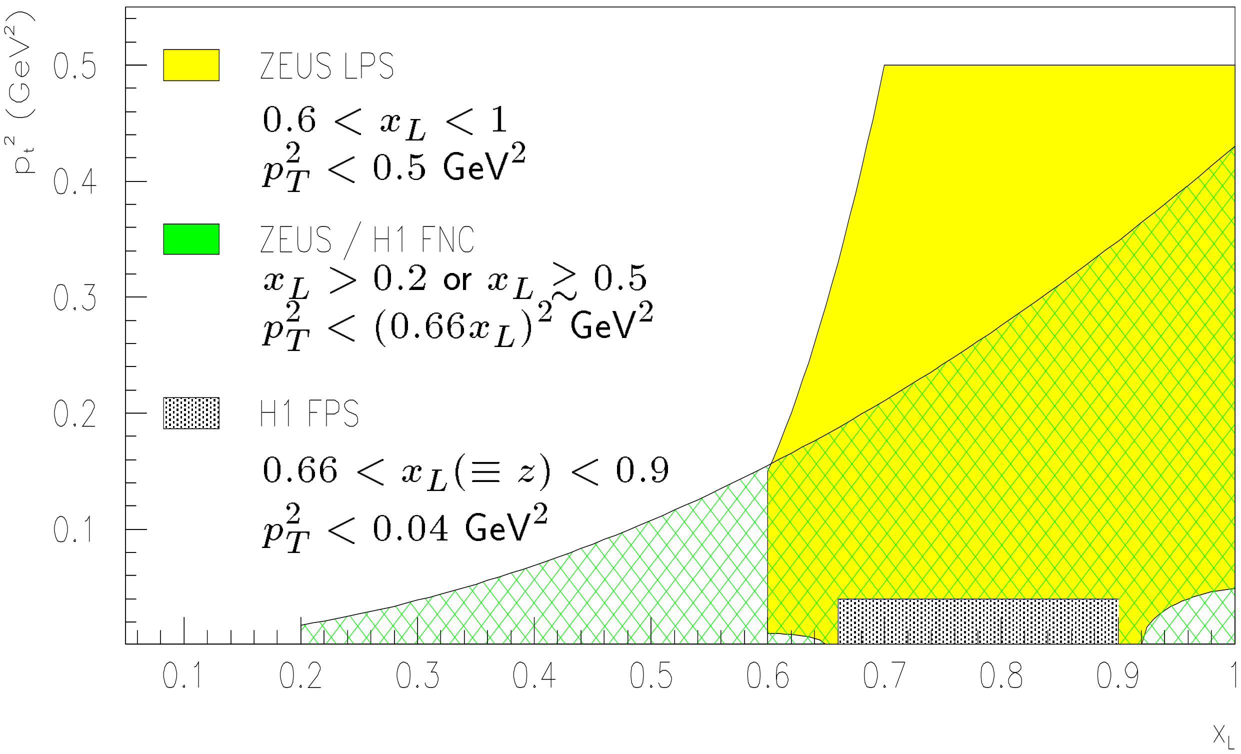
Proton vertex
leading baryon variables:

$$x_L \equiv z \ = \ E_{p'}/E_p$$
$$t = (p' - p)^2$$
$$= -\frac{p_T^2}{x_L} - \frac{m_B^2(1-x_L)^2}{x_L}$$

Dedicated Forward Detectors



Analysis Cuts:

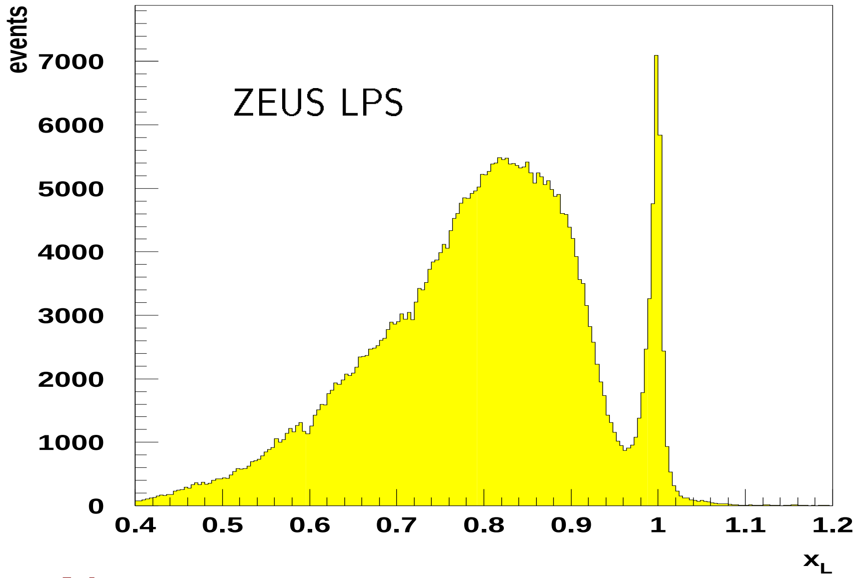


Three samples in Q^2:

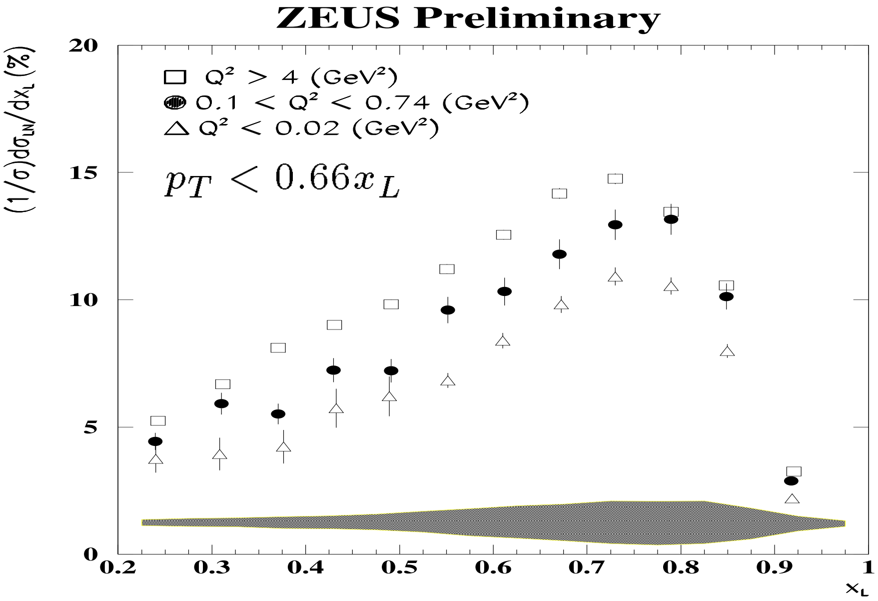
	Q^2 [GeV^2]	W [GeV]	x
DIS	$3 - 254$	$45 - 225$	1.2E-4 – 2.E-2
low Q^2	$0.1 - 0.74$	$85 - 258$	
γp	< 0.01	$60 - 250$	

Typical x_L Spectra

Leading Protons:



Leading Neutrons:



Not covered here: diffractive events with a leading proton complementary to the selection with a rapidity gap or the M_X method, access different kinematic regions, measure the transition region from diffractive peak to low x_L. See for example:

- talk of P.Thompson,
- ZEUS 97 LPS data: inclusive diffraction (EPS01-566, DIS2001),
- ZEUS 95 LPS data: inclusive diffraction at low Q^2 (DIS2001),
- H1 99-00 FPS data: inclusive diffraction (H1-Prelim-01-112),
- H1 99 FPS data: ρ production in γp (H1-Prelim-01-113).

Guide Through This Talk

Cross Sections, Structure Functions, Factorization:

- Photoproduction cross section with a leading proton,
- Ratios σ^{LP}/σ as function of Q^2,
- Structure function $F_2^{LP(3)}$,
- Ratios σ^{LN}/σ as function of Q^2,
- Structure function $F_2^{LN(3)}$,
- Dijets with a leading neutron,
- Proton-dissociative ρ production in γp at large t.

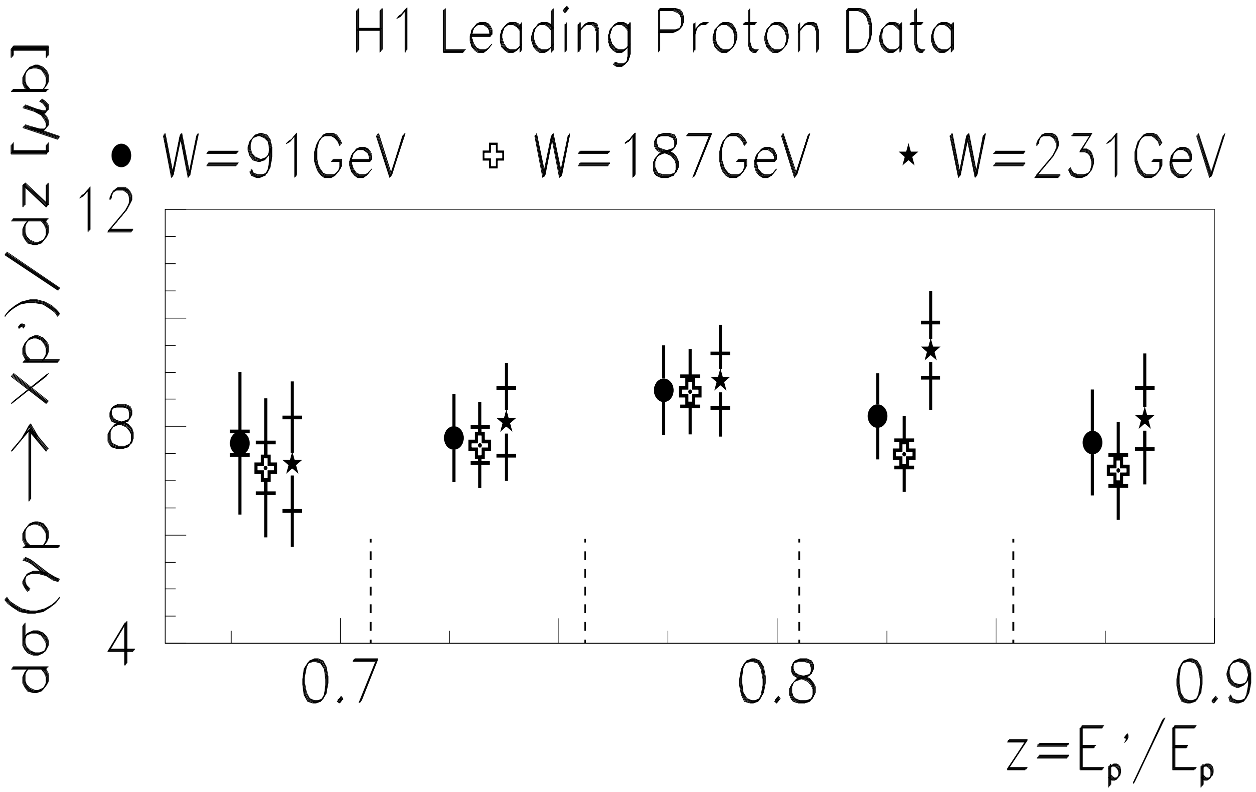
Semi-Inclusive Cross-section in γp

Fraction:

$$1.17 \pm 0.02(\text{stat}) \pm 0.15(\text{syst})\ \%$$

of all inclusive γp events have a leading proton in the region of $Q^2 < 0.01$ GeV^2, $W = 60 - 260$ GeV, $0.66 < x_L (\equiv z) < 0.9$, $p_T^2 < 0.04$ GeV^2 .

No z–,W–,M_X– Dependence:



$$\langle d\sigma/dz \rangle = 8.05 \pm 0.06(\text{stat}) \pm 0.89(\text{syst})\mu b$$

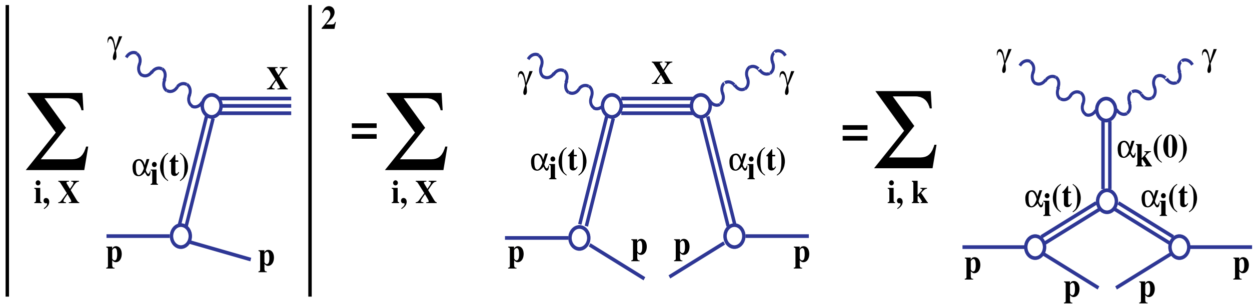
Note: no $1/M_X^2$ dependence as in diffraction.
$(M_X^2 = (1-z)W^2)$

Semi-Inclusive Cross-section in γp II

Interpretation in the Exchange Picture:

Regge parameterization for $W-$, $z-$ and M_X- dependence:

- α_i effective trajectory for γp, with $\alpha_i(t) = \alpha_i(0) + \alpha_i' \cdot t$ and $\alpha_i' = (1.0 \pm 0.2)$ GeV^{-2}
- α_k effective trajectory for total $\gamma I\!\!R$ cross section,
- unique $t-$dependence with e^{bt} with $b = b_0 - 2\alpha_i' ln(1-z)$



$$\frac{d\sigma}{dz} = \frac{A}{b}(e^{bt_{min}} - e^{bt_{max}}) \cdot (W^2)^{2\alpha_i(0)-1} \cdot (M_X^2)^{2\alpha_k(0)-2\alpha_i(0)}$$

Fit Results (H1):

$\alpha_k(0) = 0.99 \pm 0.01$(stat) ± 0.05(syst)
$\Rightarrow$ total $\gamma(\pi, I\!\!R) \rightarrow X$ cross section mainly due to Pomeron exchange.

$\alpha_i(0) = 0.33 \pm 0.04$(stat) ± 0.04(syst)
$\Rightarrow$ γp processes dominated by π and $I\!\!R$ exchanges ($\alpha_\pi(0) \approx 0$, $\alpha_{I\!\!R}(0) \approx 0.5$).

$b = 0.62 \pm 0.7$(stat) ± 1.5(syst) GeV^{-2} for $z = 0.78$
ZEUS direct measurement: $b = 0.68 \pm 0.9$(stat)$^{+1.2}_{-1.1}$(syst) GeV^{-2}

Semi-Inclusive Cross-section in DIS: F_2^{LP}

Measure ratios:

$$
\begin{aligned}
r^{LP(3)}(x_L, x, Q^2) &= \frac{N^{LP}(x_L, \Delta p_T^2, x, Q^2)}{N(x, Q^2)} \cdot \frac{1}{\epsilon^{LP}(x_L, p_T^2)} \\
&= \frac{F_2^{LP(3)}(x_L, x, Q^2)}{F_2(x, Q^2)}
\end{aligned}
$$

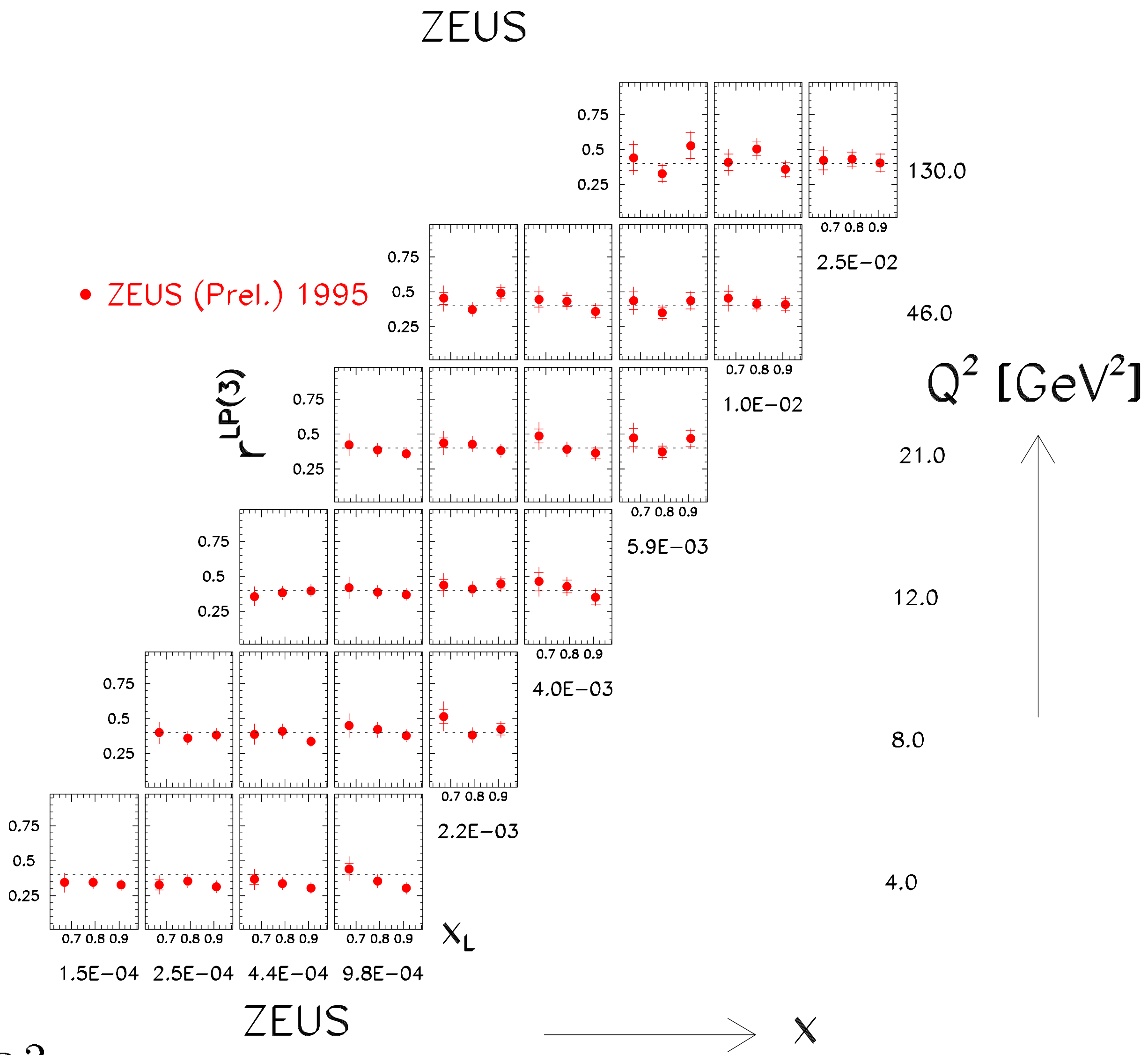
and unfold :

$$
F_2^{LP(3)}(x_L, x, Q^2) = \int dp_T^2 \; F_2^{LP(4)}(x_L, p_T^2, x, Q^2)
$$

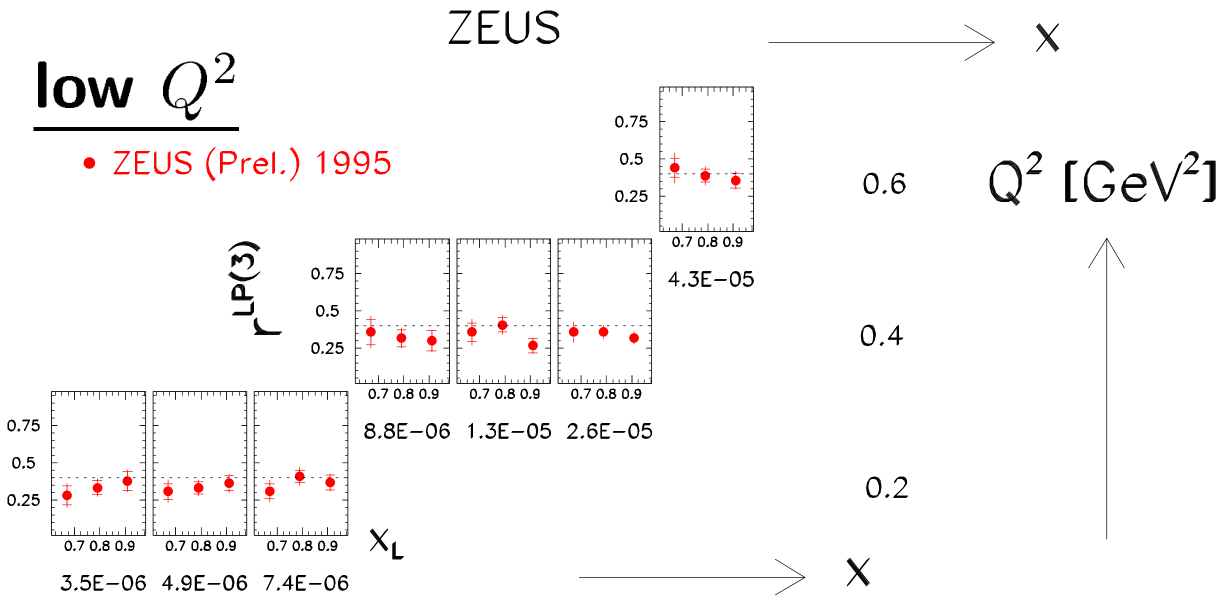
by multiplying the ratio by a parameterization of the measured F_2.

The Ratio $r^{LP(3)}(x_L, x, Q^2)$

DIS



low Q^2

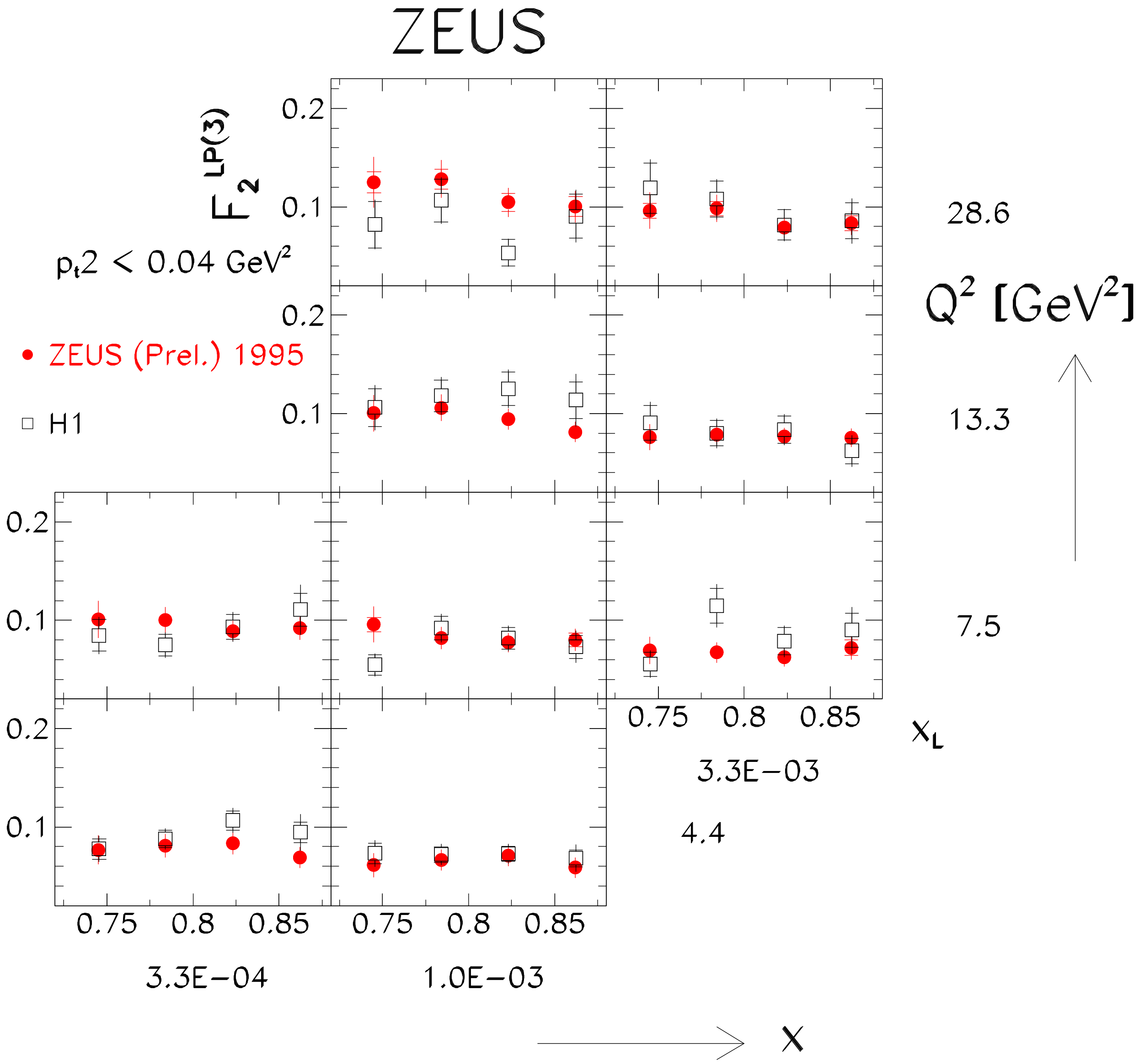


No strong dependence on x_L, x and Q^2

$\Rightarrow F_2^{LP(3)}$ has similar x and Q^2 dependence as F_2

The Structure Function $F_2^{LP(3)}(x_L, x, Q^2)$

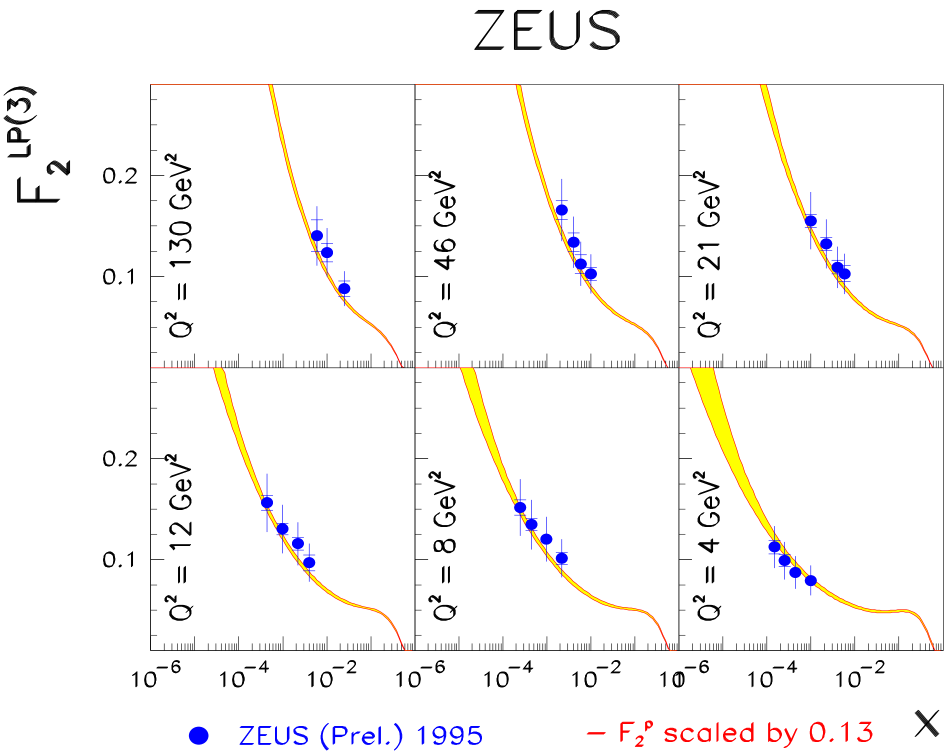
ZEUS - H1 comparison:
data restricted to $p_T < 200$ MeV, $0.7 < x_L < 0.9$



Reasonable agreement between measurements.

The Structure Function $F_2^{LP(3)}(x_L, x, Q^2)$

Full ZEUS data set $p_T^2 < 0.5$ GeV, $0.6 < x_L < 0.97$



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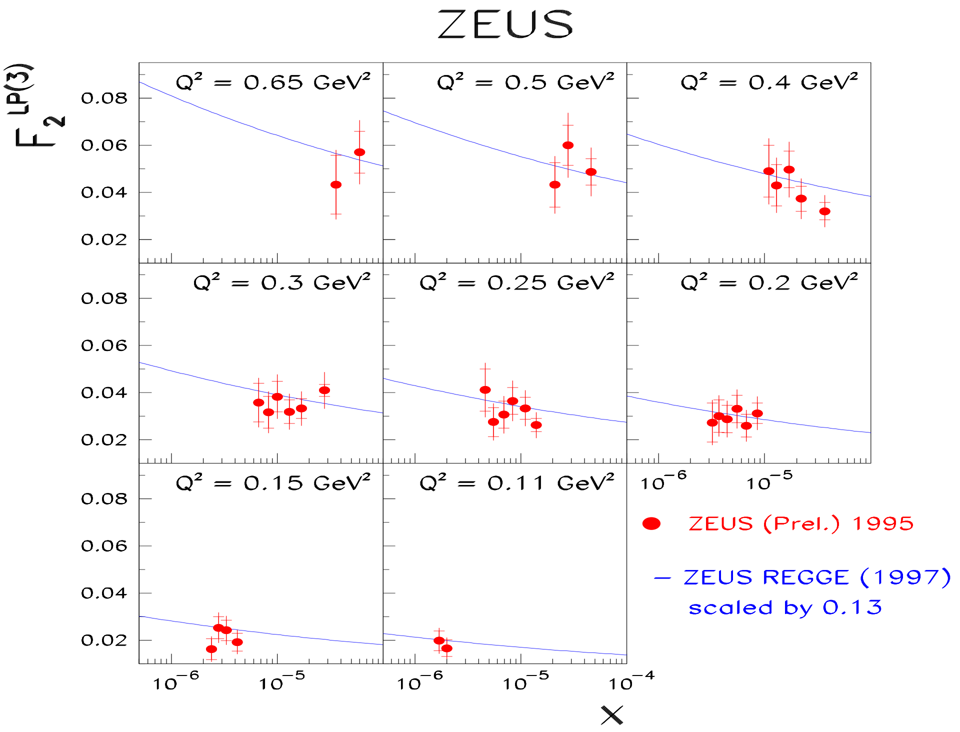


low Q^2

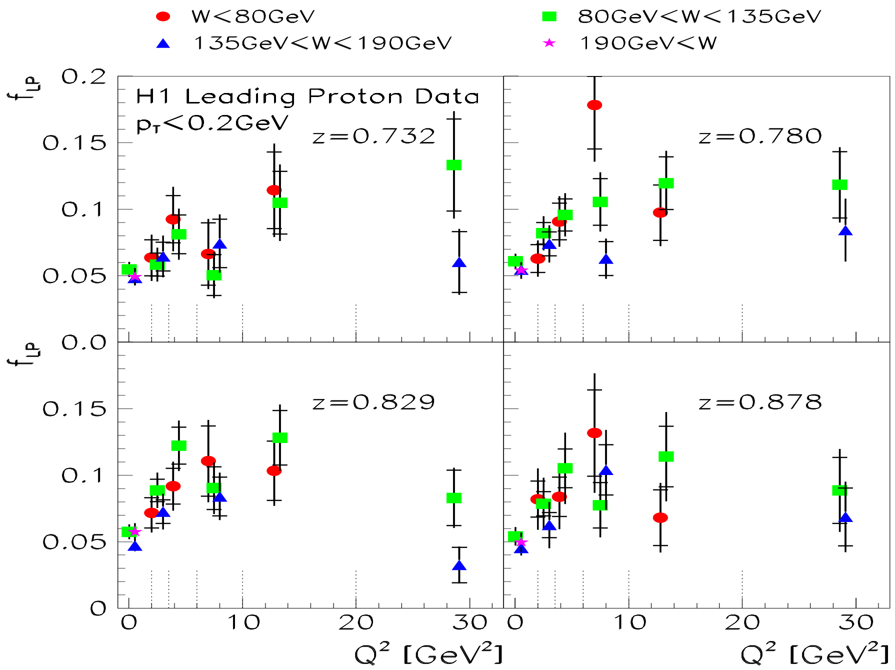
F_2 scaled down by 0.13 describes F_2^{LP}, only at higher values of Q^2 a bit low.

Transition from Photoproduction to DIS

Ratios σ^{LP}/σ as function of Q^2:

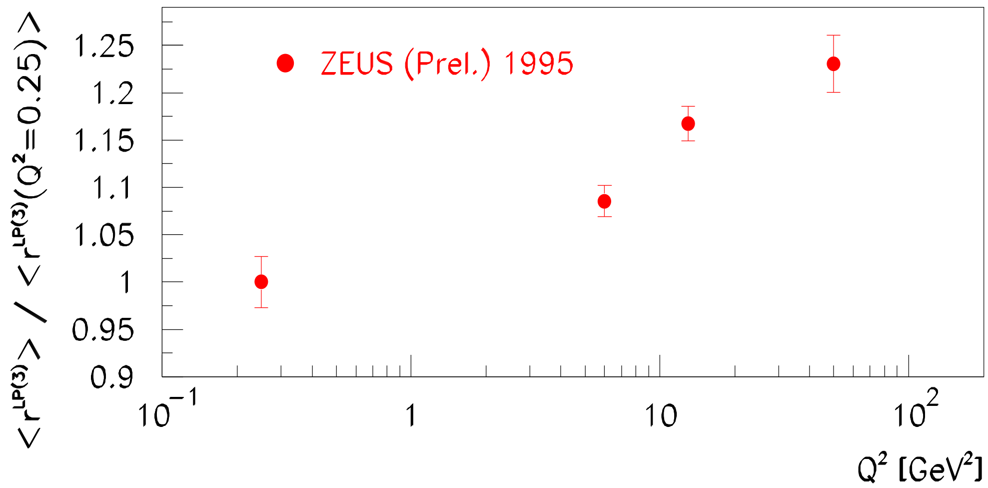
H1 – measure σ^{LP}, take $\sigma(W)$ from parameterizations (Donnachie-Landshoff, F_2^{H1QCD}),

ZEUS – measure ratios.



H 1

ZEUS

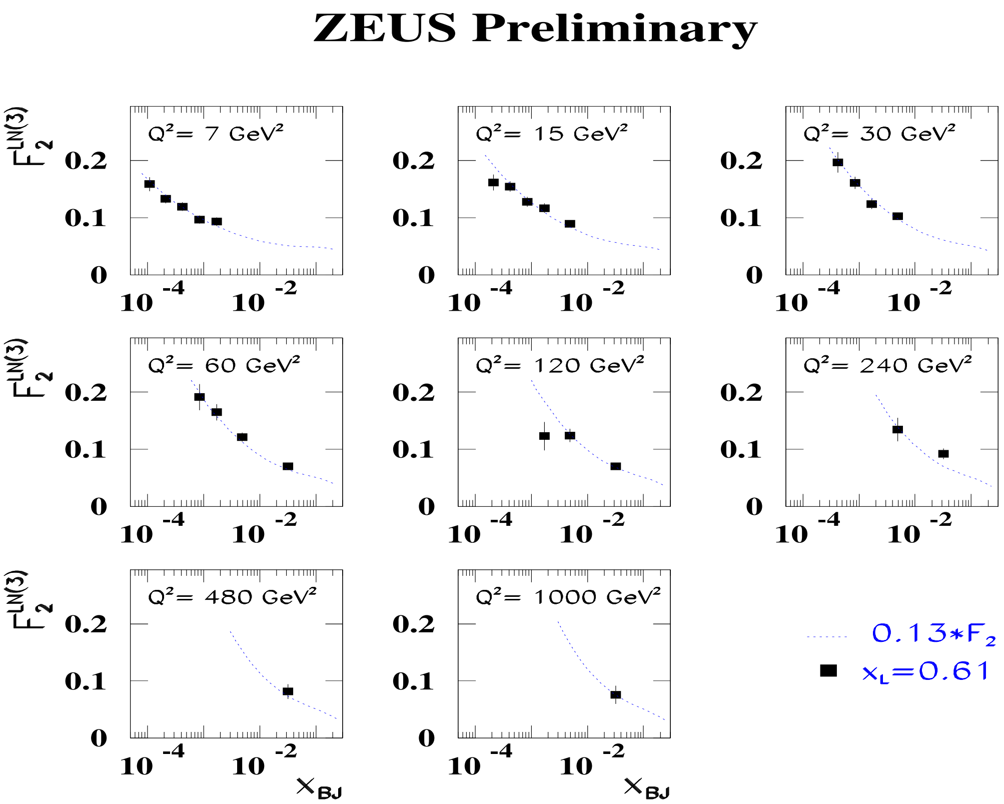


Small rise of the ratio with Q^2:

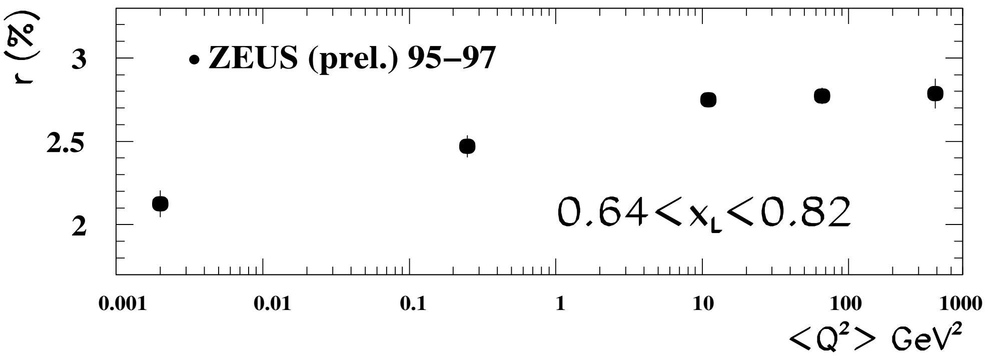
- Absorption ($Q^2 \sim 0$: γ hadron like, DIS: γ smaller size) ?
- Reggeon flux depending on Q^2 ?
- Violation of factorization ?

The Structure Function $F_2^{LN(3)}(x_L, x, Q^2)$

Ratios σ^{LN}/σ for leading neutrons as function of x, Q^2 and x_L are similar flat as for leading protons, unfolding done in the same way:



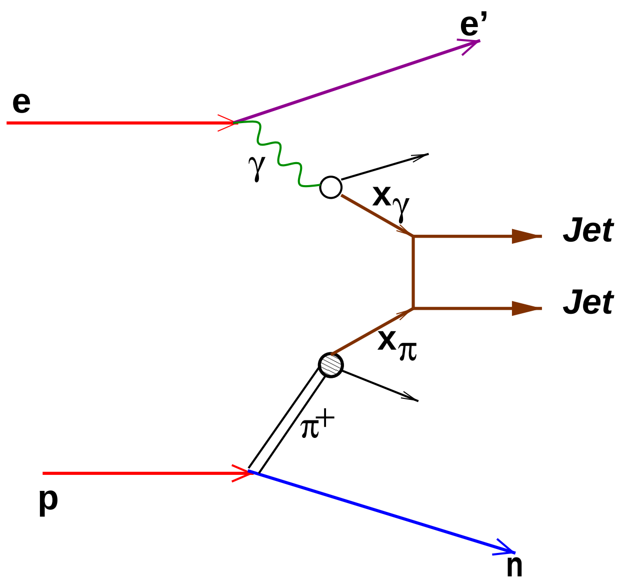
F_2 scaled down by 0.13 describes F_2^{LN}
(different kinematic ranges and production rates
$\Rightarrow$ same scaling factor by accident)



Again small rise of the ratio with Q^2.

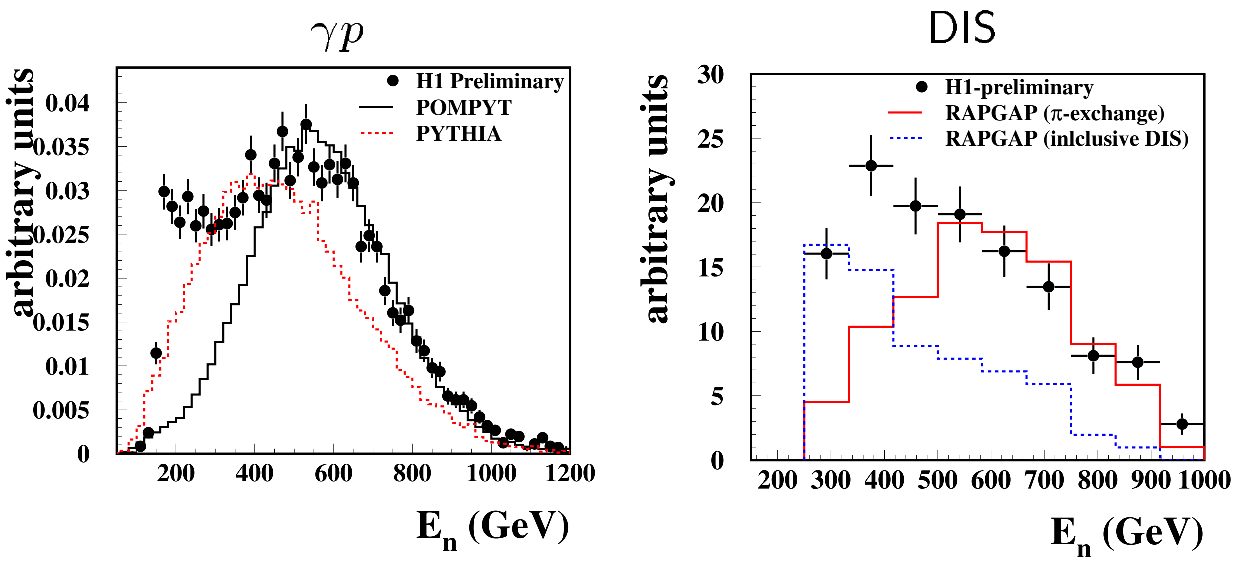
Dijets with a Leading Neutron

Test π exchange picture:



Look at neutron energy spectra, and differential cross sections as function of Q^2, x_π, . . .

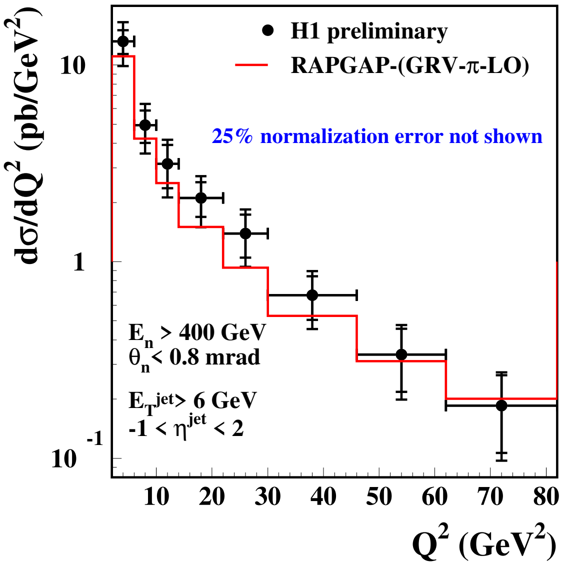
Neutron Energy spectra:

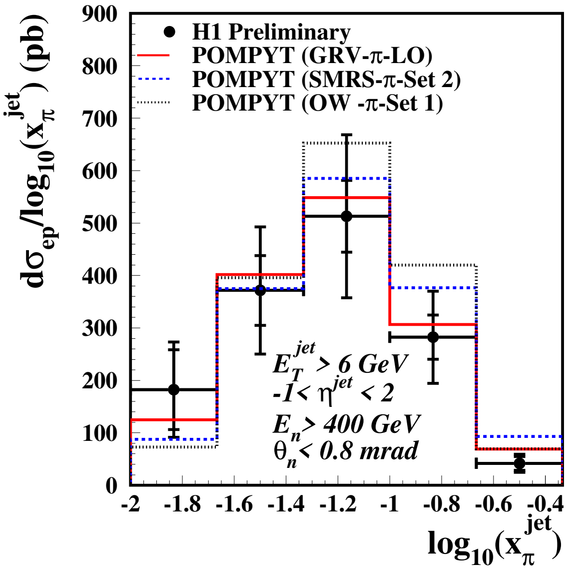


$x_L \gtrsim 0.5$: agreement in shape and rate with One-Pion-Exchange MC models(POMPYT,RAPGAP)

Differential Dijets Cross Section and Ratio

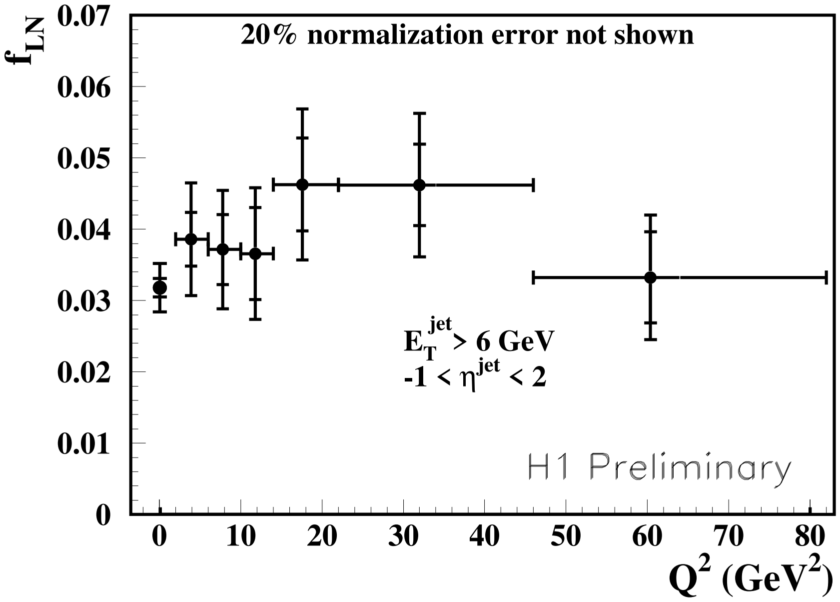
Differential Cross Sections:





Agreement in shape and rate with One-Pion-Exchange MC models (POMPYT,RAPGAP).
No preference for one of the π structures within the experimental uncertainties yet.

Ratio and Factorization:

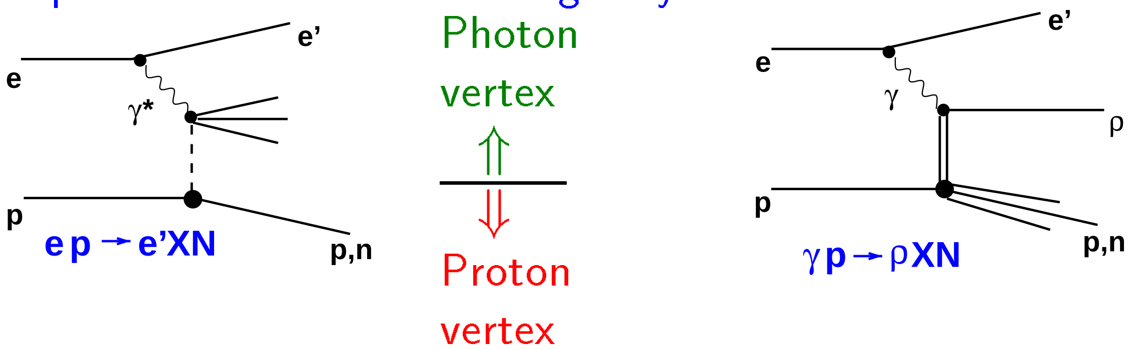


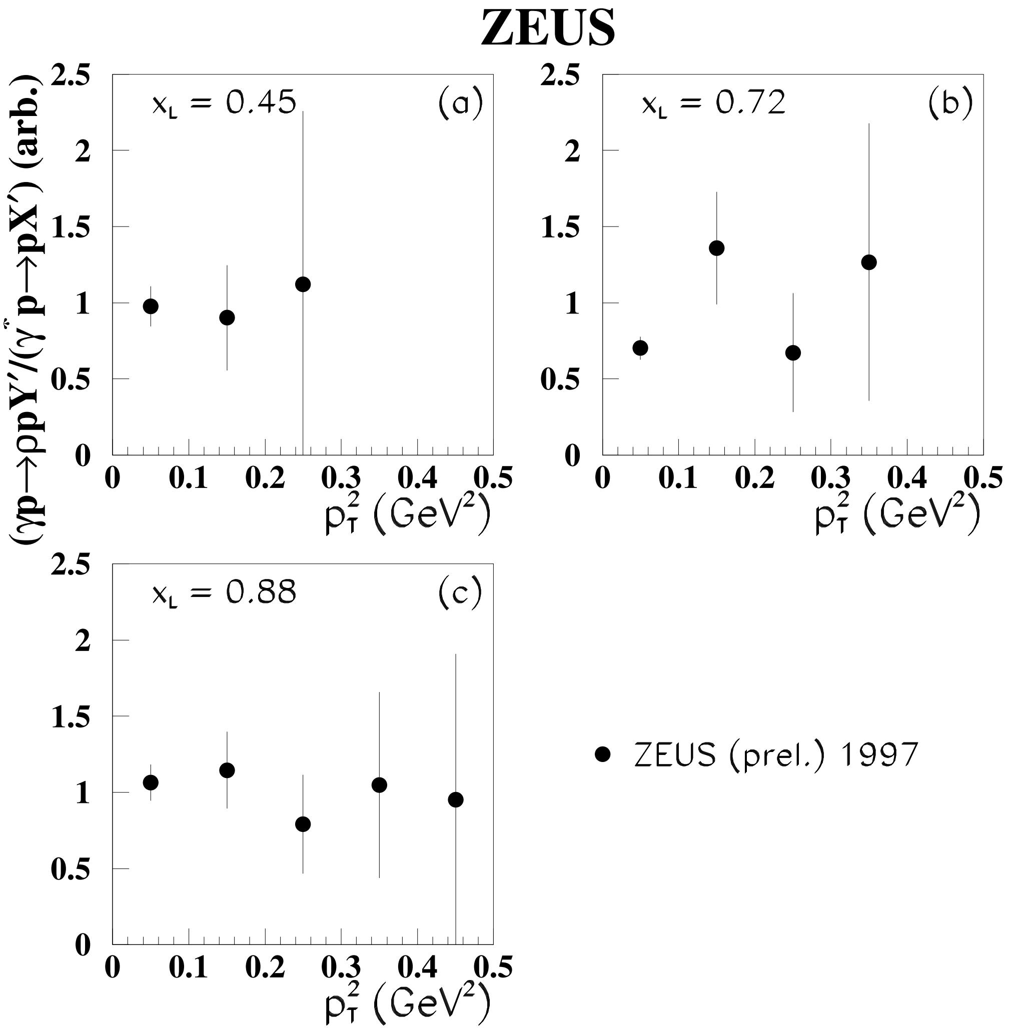
No conclusion about factorization within the experimental uncertainties.

Factorization Tests with ρ Production

Hypothesis of vertex factorization:
cross section dependence on nucleon variables is independent of the particle production at the photon vertex.

Proton-dissociative photoproduction of ρ mesons at large t compared to DIS with a leading baryon.

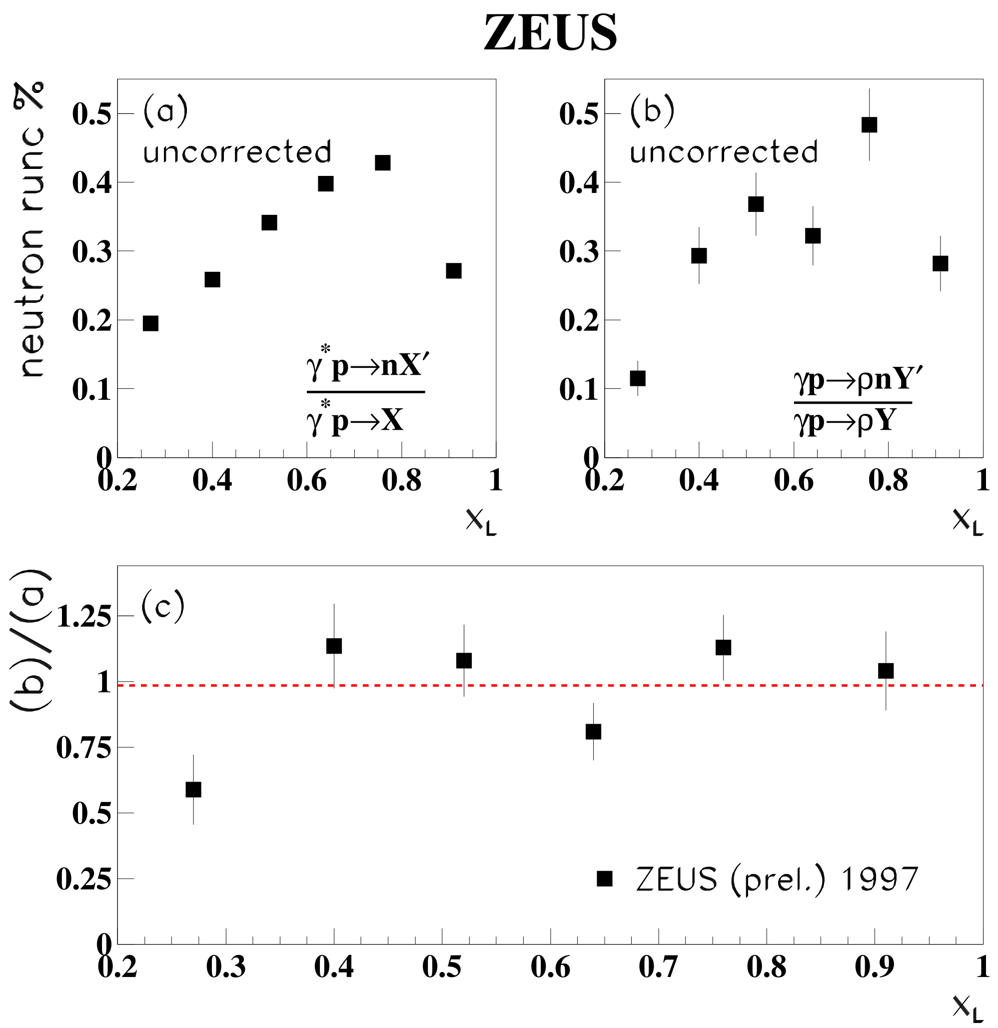




No significant deviation in the angular distributions.

Factorization Tests with ρ Production

Rate of neutron production in DIS compared to proton-dissociative photoproduction of ρ mesons at large t.



Similar distributions and rates.
Same conclusion for leading proton production.
No $t-$ dependence found in the rates of leading proton and neutron production in ρ events.

⇒ **Within the experimental uncertainties support of the hypothesis of vertex factorization.**

Summary

A lot of new results from the study of leading baryon production at HERA:

- $\sigma_{\gamma p}^{LP}$ shows dominance of $\pi/I\!R$ exchanges for γp processes and $I\!P$ exchange for the total cross section $\gamma(\pi, I\!R) \to X$.

- Ratios σ^{LP}/σ and σ^{LN}/σ almost flat in x, Q^2 and $x_L \Rightarrow F_2^{LP}, F_2^{LP}$ similar to F_2.

- Ratios σ^{LP}/σ and σ^{LN}/σ show a small rise with $Q^2 \Rightarrow$ absorption, factorization violation ... ?

- Dijet production with leading neutrons consistent with π exchange models, factorization holds within the experimental uncertainties.

- Proton-dissociative ρ photoproduction compared to different processes supports factorization within the experimental uncertainties.

Much more to come from the higher statistics of the data samples '97 and '99 –'00.