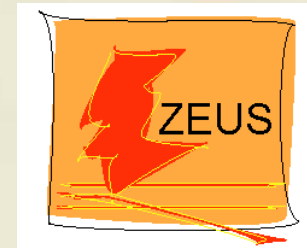


Leading Protons at HERA



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on behalf of H1 and ZEUS Collaborations

- *Diffraction 08* -

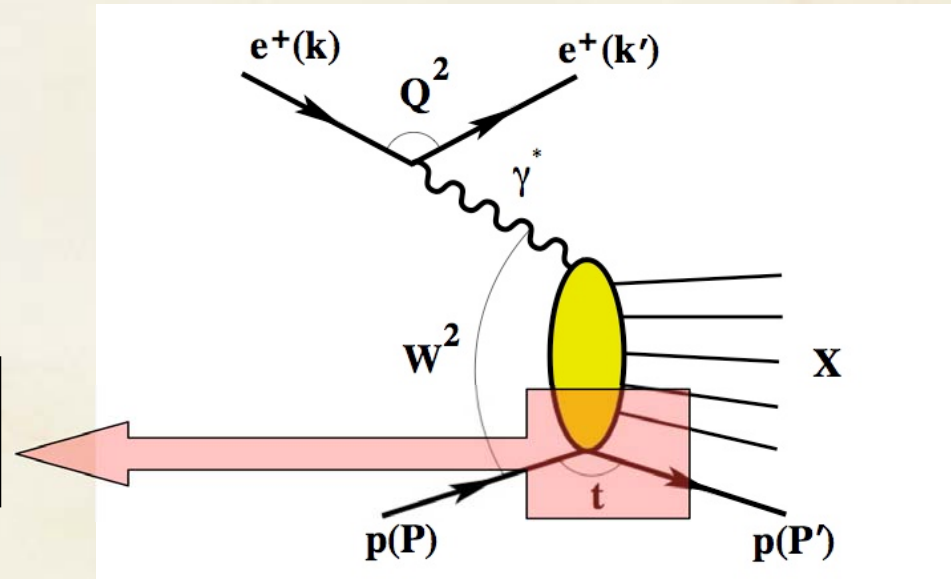
*La Londe-les-Maures, France,
September 9-14, 2008*

Physics of the Leading Protons:

- . A semi-inclusive reaction : $ep \rightarrow epX$

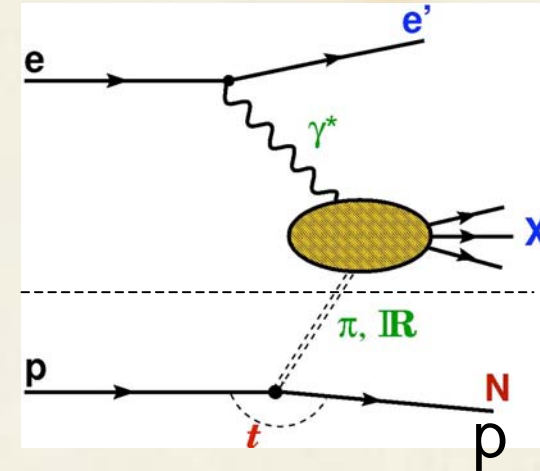
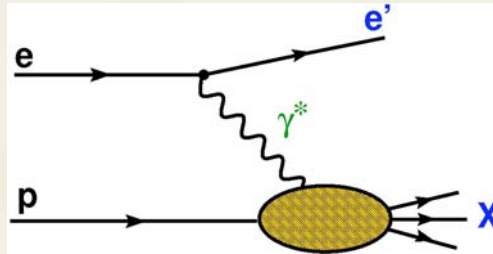
$$x_L : E_{p'}/E_p$$
$$t : p(P) - p(P')$$

BIG
small



- . DIS regime: scale for secondary particle production Q^2 (hard) and low- p_T (soft)
- . Photoproduction regime: $Q^2 \approx 0$

Typical models:



- Protons produced at high- x_L but low- p_T :
non-perturbative approach

- Perturbative:
standard fragmentation
 - usually implemented in MC : DJANGO, RAPGAP

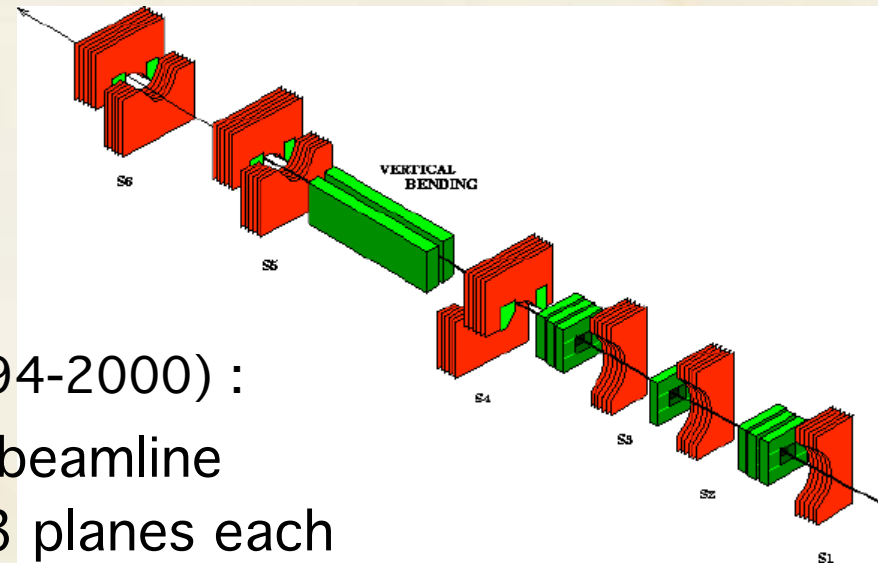
- Non-perturbative:
Regge-based models
 - dynamical particle-exchange of virtual particles (ρ, IP, π , etc)
 - \sim vertex factorization

- “In between”: **SCI**
 - quarks, gluons + non-perturbative elements

Detectors - H1 and ZEUS

ZEUS Leading Proton Spectrometer (1994-2000) :

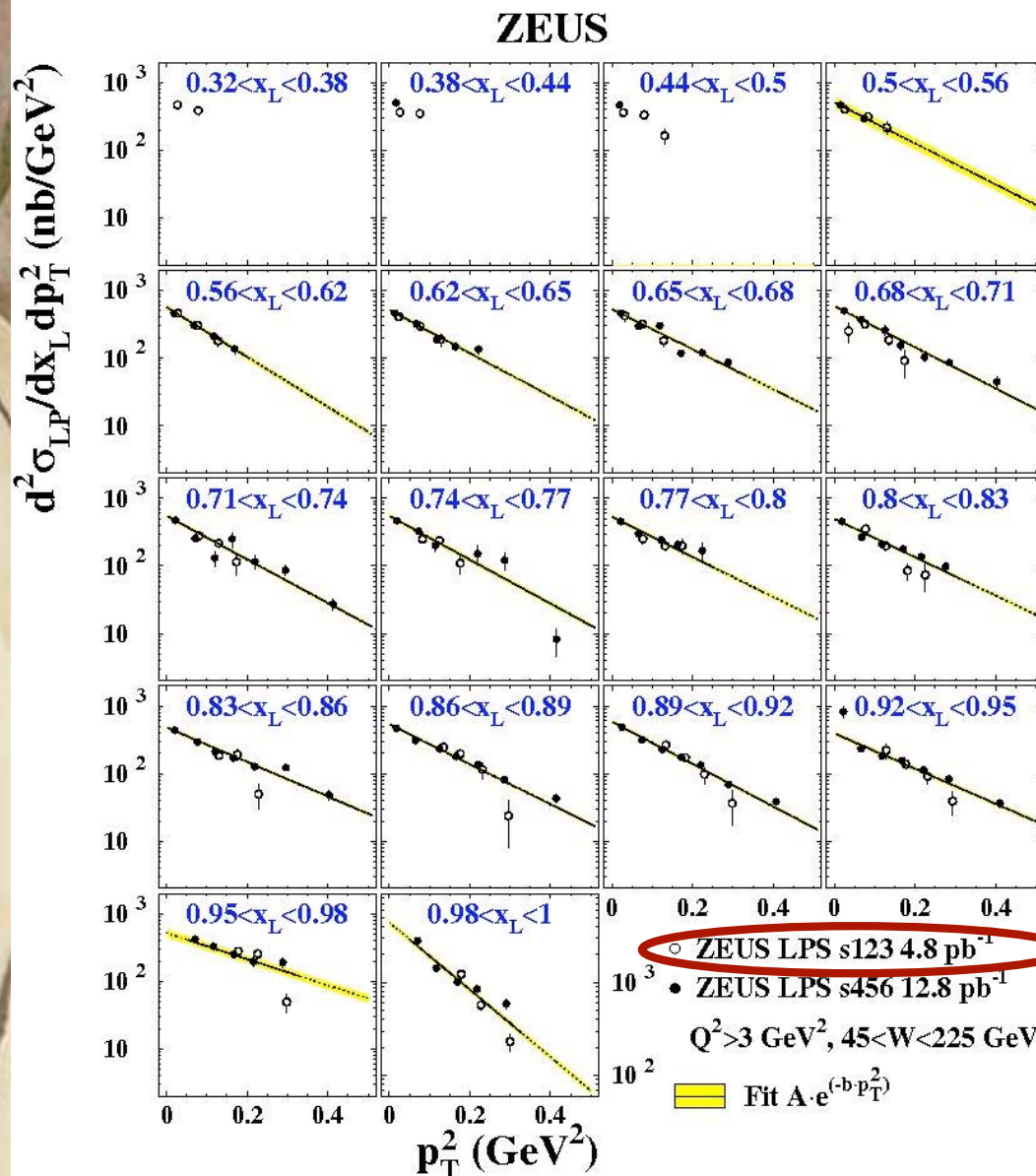
- . Six stations along proton beamline
- . 6 Silicon-strip detectors, 3 planes each
- . S123 and S456
- . $\sigma_{xL} < 1\%$, $\sigma_{pT}^2 \sim$ a few MeV^2
(better than p-beam spread $\sim 50 - 100 \text{ MeV}^2$)



H1 Forward Proton Spectrometer (until 2007):

- . new detector at 200 m from IP, VFPS (will gain acceptance)
- . two stations along proton beamline
- . 4 planes scintillator fiber hodoscope + trigger scintillator
- . $\sigma_{px} = \sigma_{py} \sim$ a few MeV (No H1 data today)

Results: transverse momentum



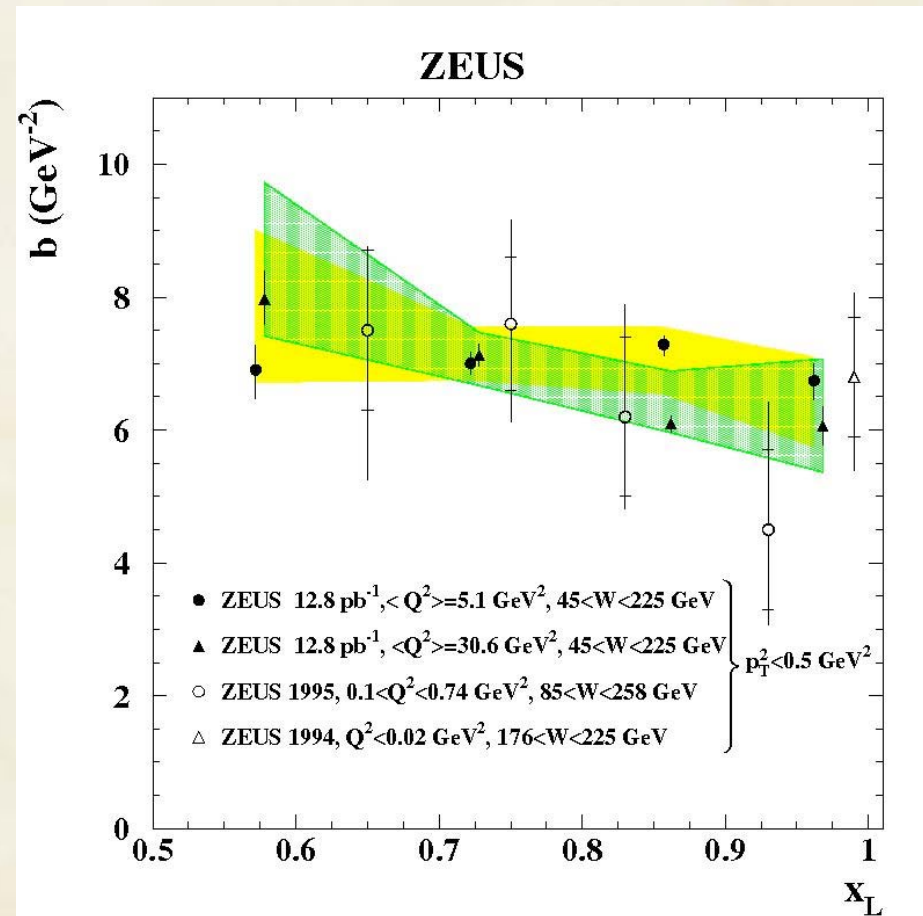
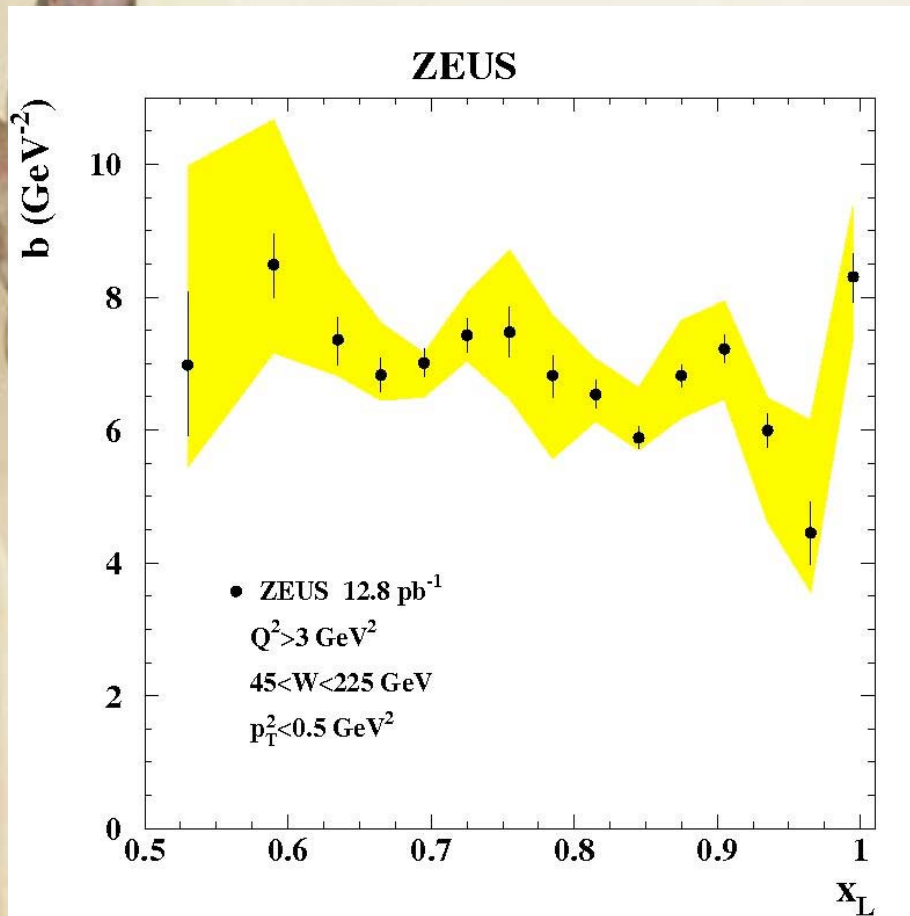
- Fits to exponential:
 $A \cdot e^{(-b p_T^2)}$

- b-slopes
(next)

- NEW:** first
(and only)
measurement
with LPS S123

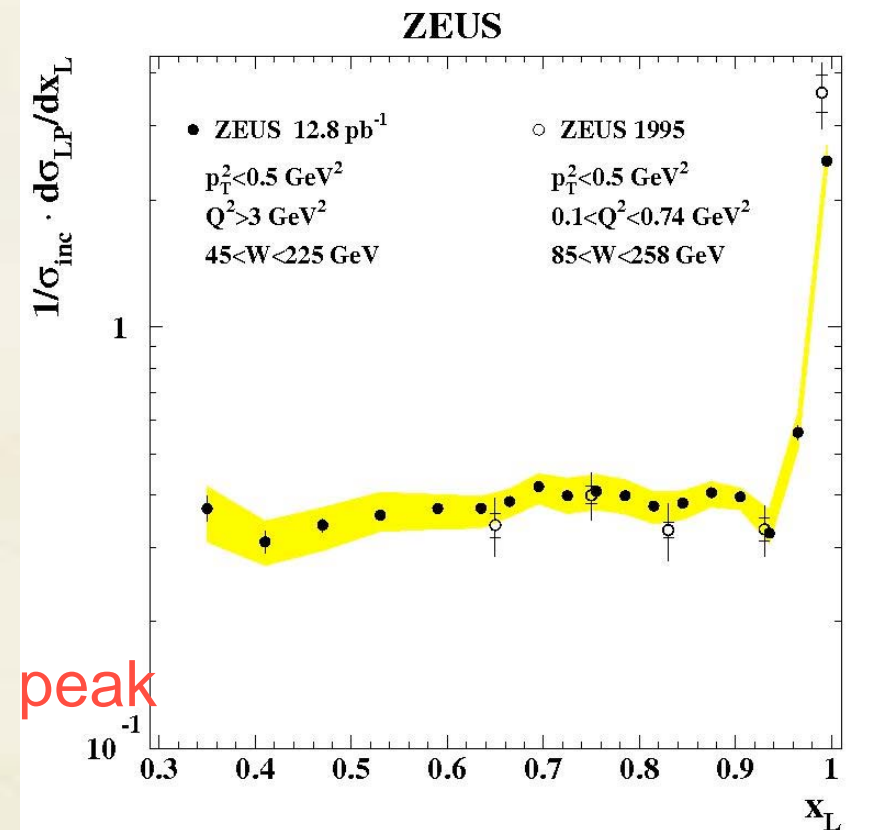
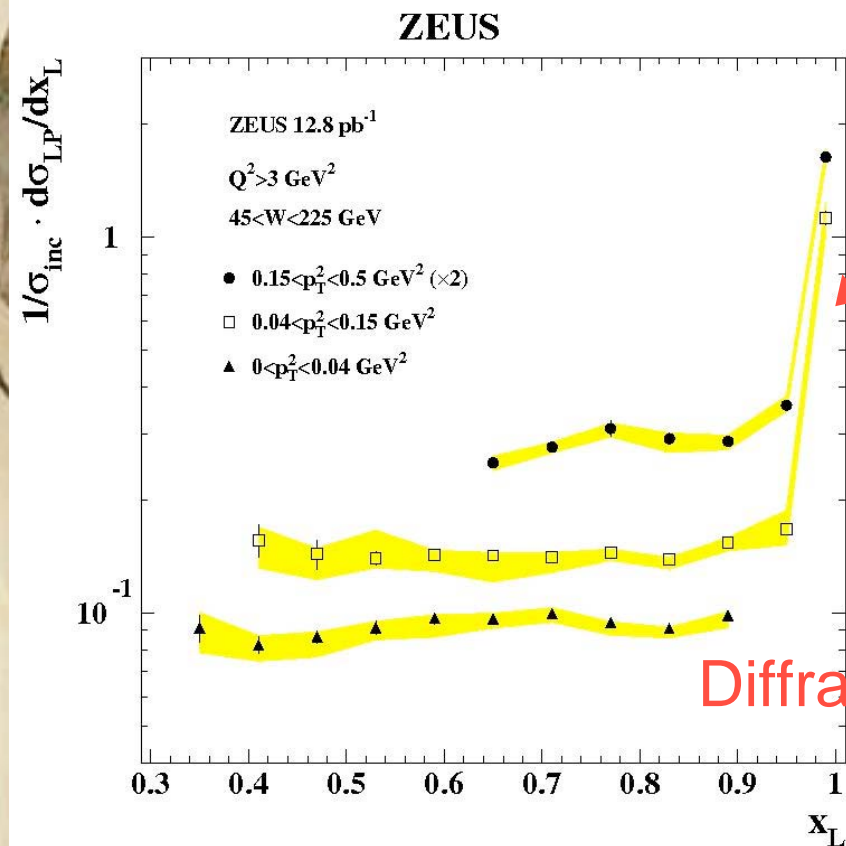
- S123 and S456
data in good
agreement

Results: transverse momentum



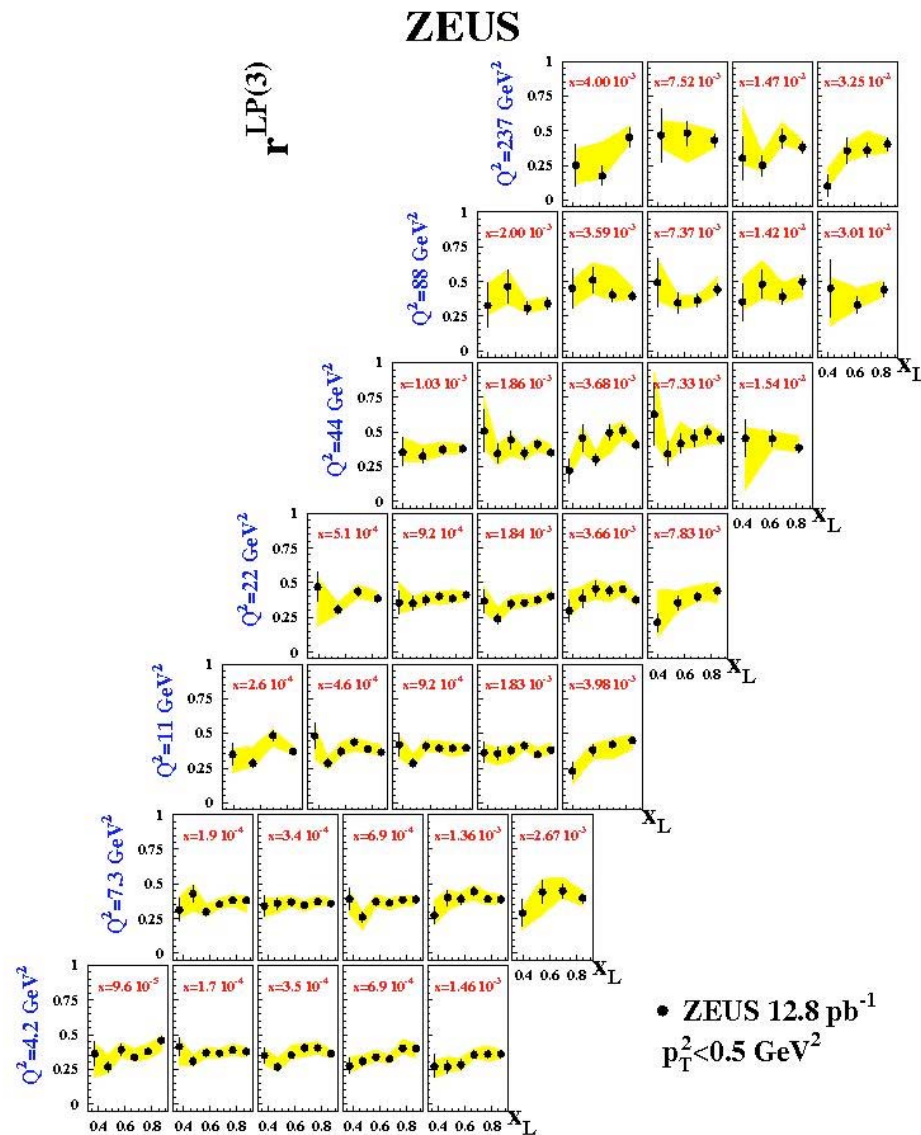
- b -slopes: no x_L dependence
- no Q^2 dependence

Results: longitudinal momentum



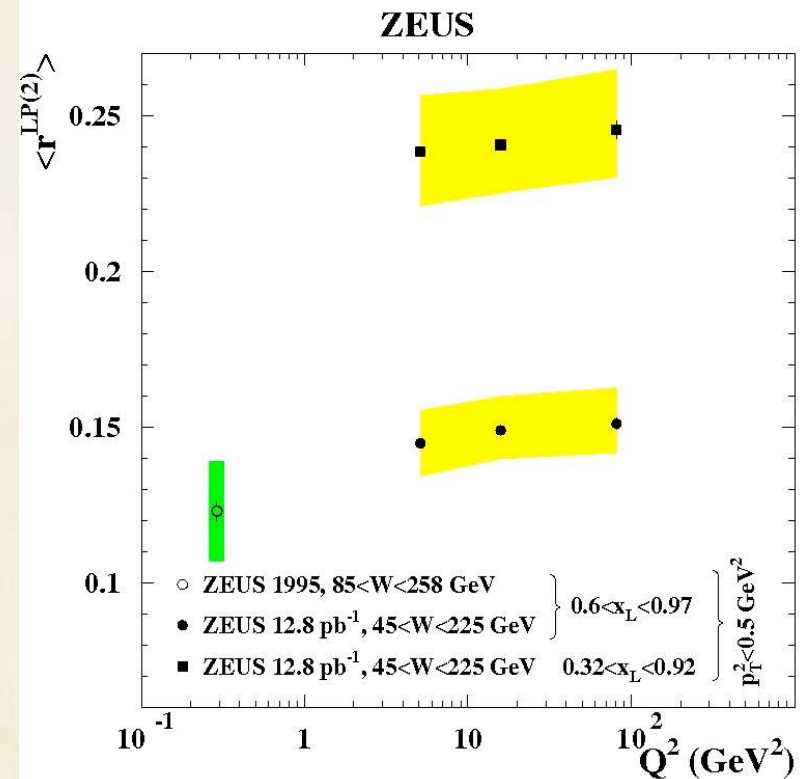
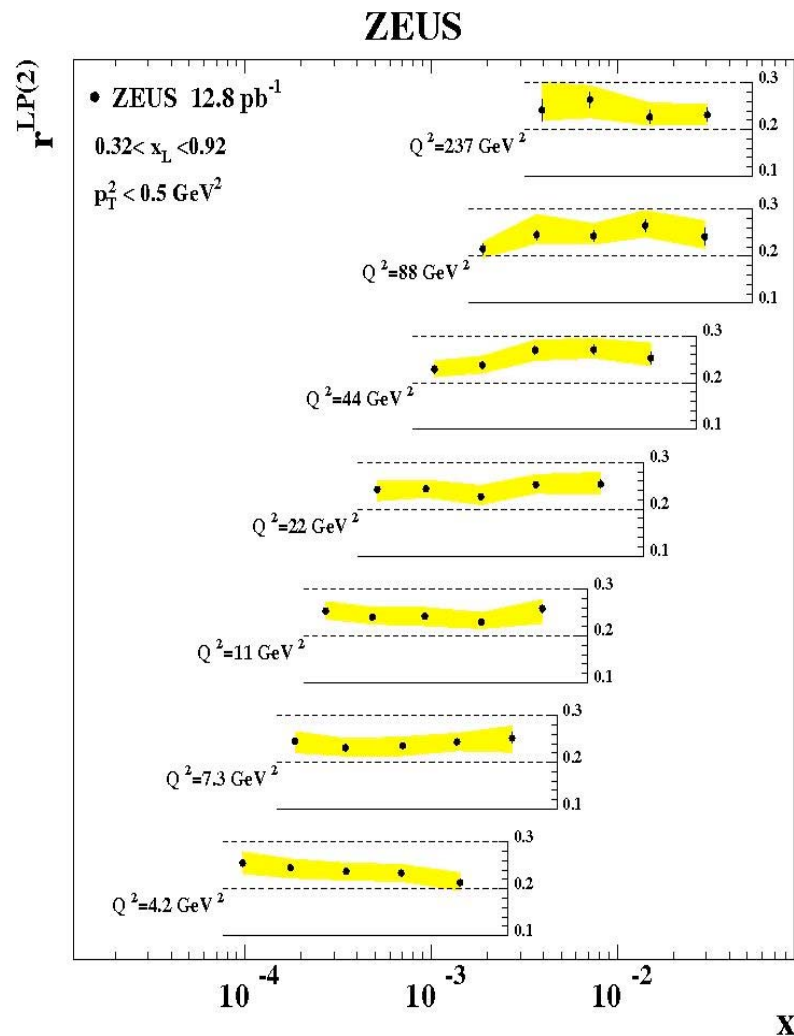
- Data normalized by total (no p -tag) DIS cross section
- Below diffractive peak: no x_L dependence
- Comparison to very low- Q^2 data : no Q^2 dependence

Results: $F_2^{\text{LP}(4)} / F_2$



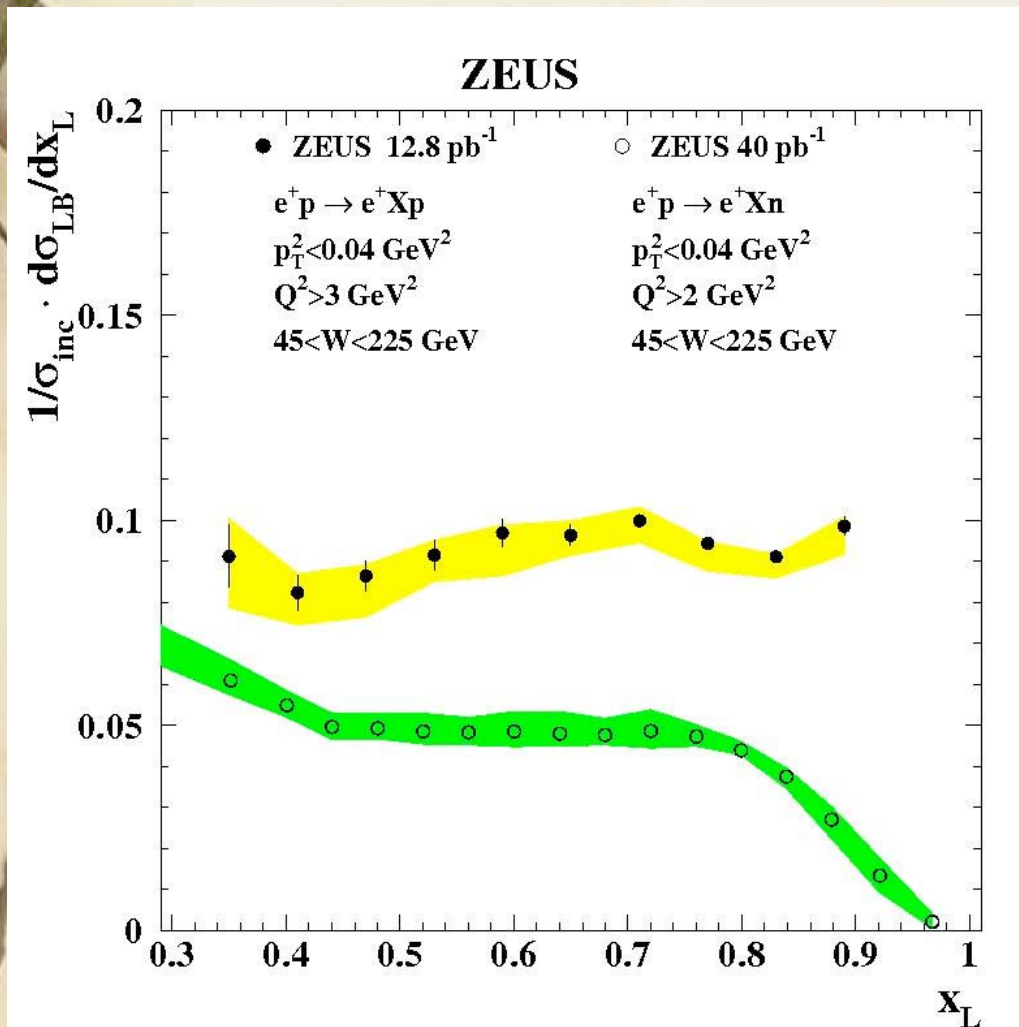
- $F_2^{\text{LP}(4)}$ analogous to proton F_2 for events containing a leading proton
- Known as *Fracture functions* in some models
- LP: apart from (x, Q^2) is also function of (x_L, p_T)
- no x_L, p_T dependence

Results: $F_2^{LP(4)} / F_2$



- Rates ~ flat
- Mild Q^2 dependence not excluded
- Compatible with particle-exchange prediction

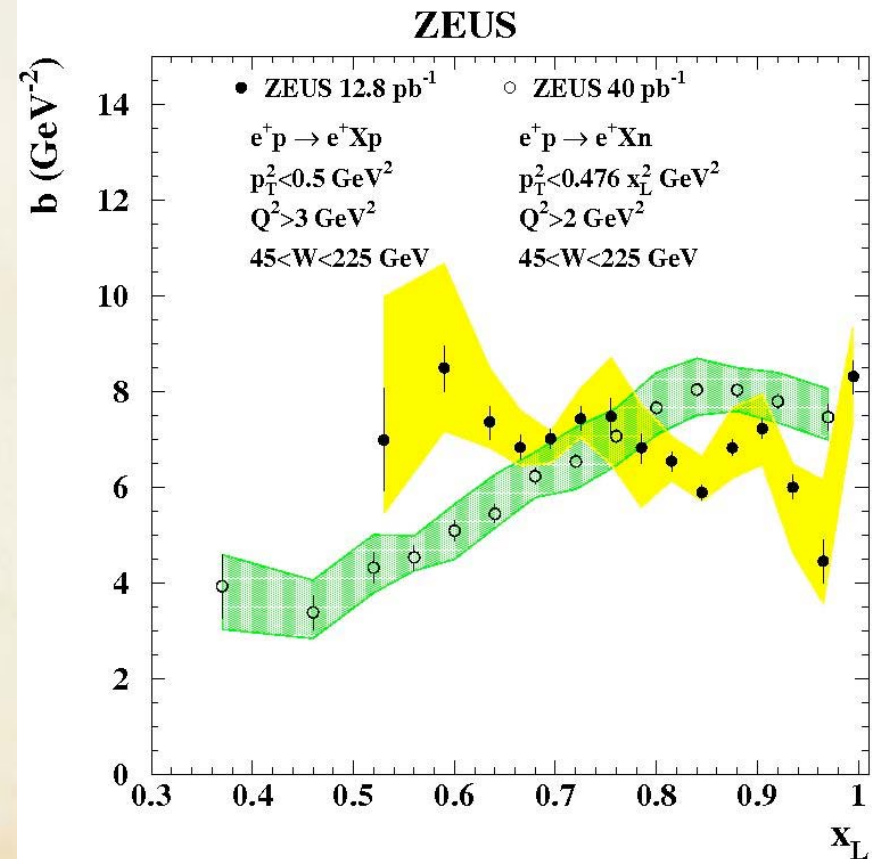
Comparison with leading neutrons: yield (see talk by V.Dodonov)



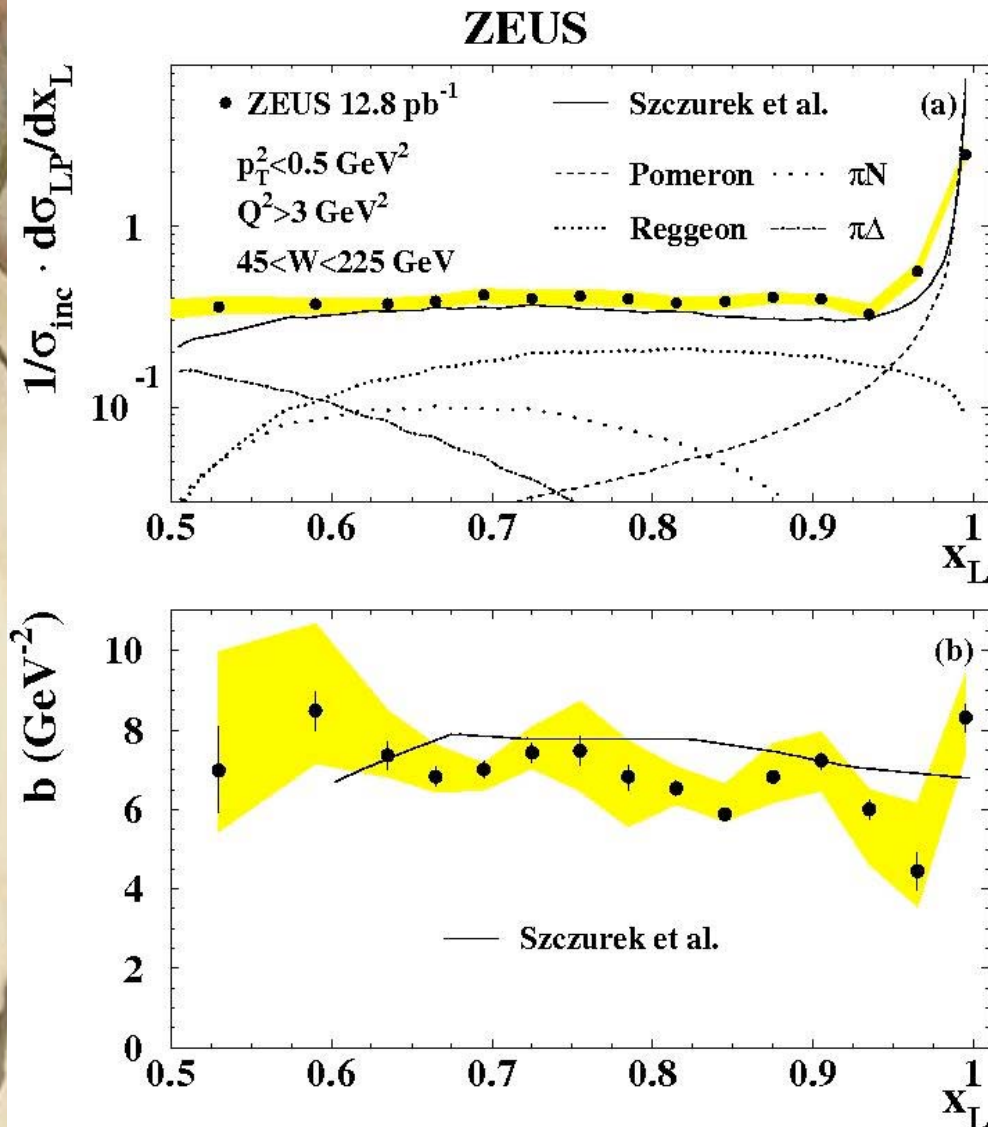
- Expected in case of pure isovector exchange: LP = 1/2 LN (Clebsh-Gordan)
- Data: LP = 2 LN
(compared at same p_T range, $p_T^2 < 0.04 \text{ GeV}^2$)
- Conclusion: leading proton production involves other IR contributions (isoscalar)

Comparison with leading neutrons: slopes (see talk by V.Dodonov)

- Similar kinematic region
- Clear rise with x_L for LN
- Flat distribution for LP
- Similar slopes for $x_L > 0.7$ where pion exchange dominates



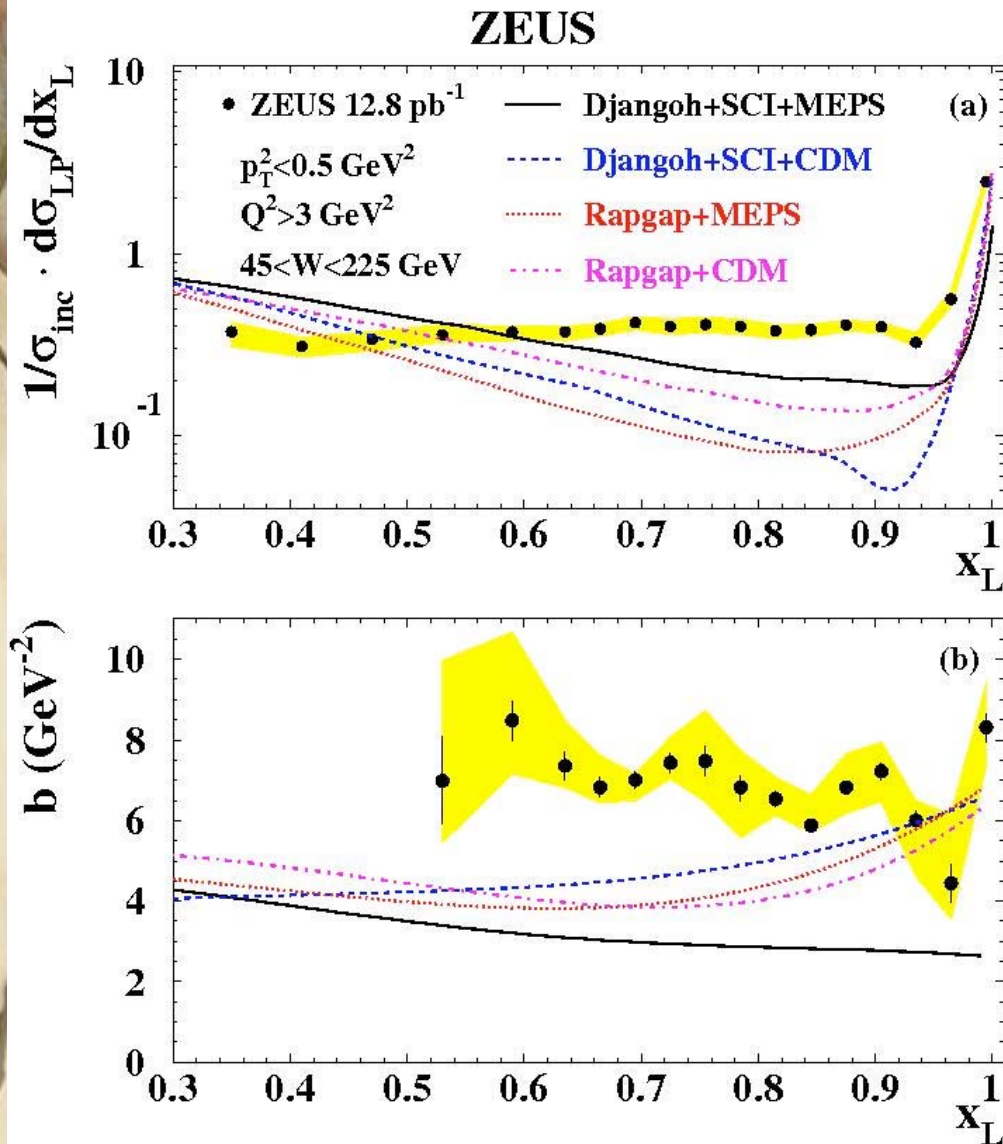
Comparison to models



- Particle exchange is able to describe the data
- Different exchanges populate different regions of leading-proton energy spectra
- b-slopes (angular distribution) also well described

**A.Szczurek, N.N.Nikolaev, J.Speth,
Phys.Lett. B428 (1998) 383**

Comparison to models



- DJANGO with Soft Color Interaction + MEPS describes reasonably well x_L spectra
- Same MC describes reasonably well b-slopes in shape but not normalization
- Other MC models fail to describe the data



Conclusions and final remarks:

- HERA data on leading protons are in agreement with the hypothesis of particle-exchange
- Comparison with leading neutrons suggests isoscalar-IR contributions are present
- Model incorporating this hypothesis is in agreement with the data
- First measurements with ZEUS LPS s123 are presented
- H1 HERA-II data still being analysed
- Leading protons analyses at HERA are not yet finished