Photo-Production with Leading Protons

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for the H1-collaboration

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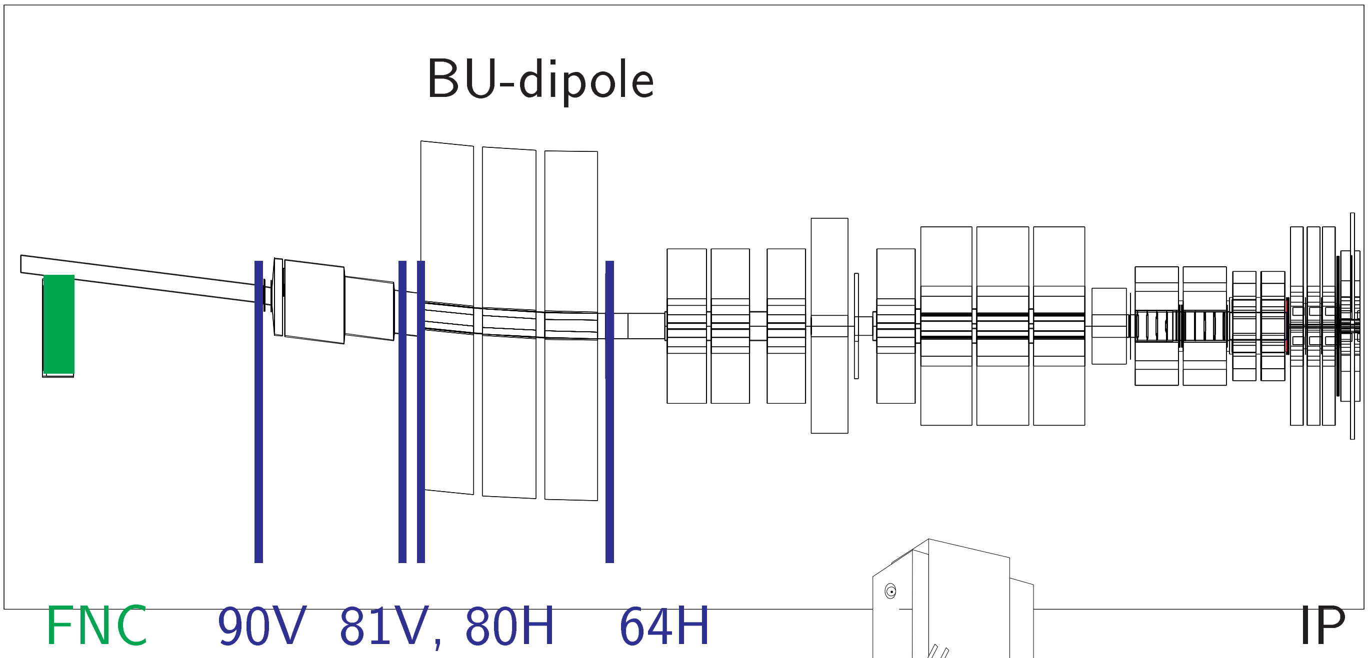
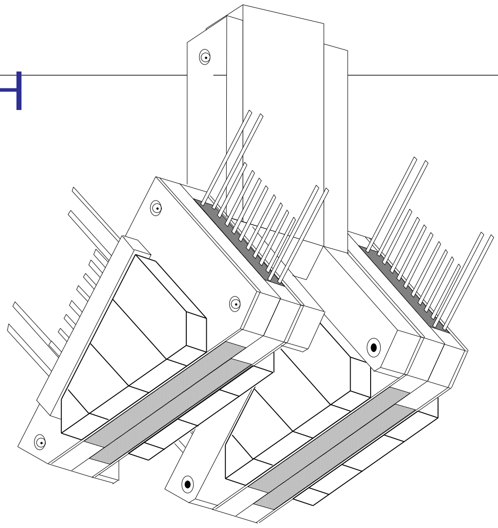
- Introduction
  FPS, forward proton range, kinematics
- Semi-Inclusive Cross Section
  data selection, $d\sigma/dW$, $d\sigma/dz$
- Comparison with DIS
  $d\sigma/dQ^2$, forward proton fraction
- A Triple Regge analysis

Forward Beam Line with FPS

4 Roman Pots with fiber detectors at 64, 80, 81, 90 m



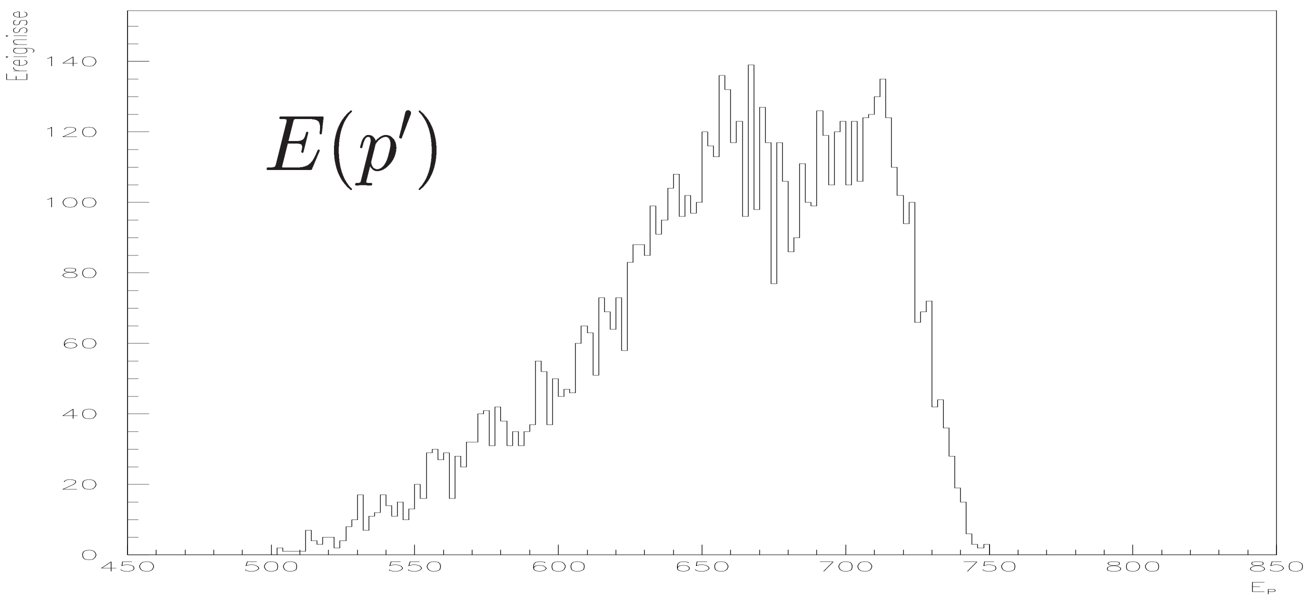


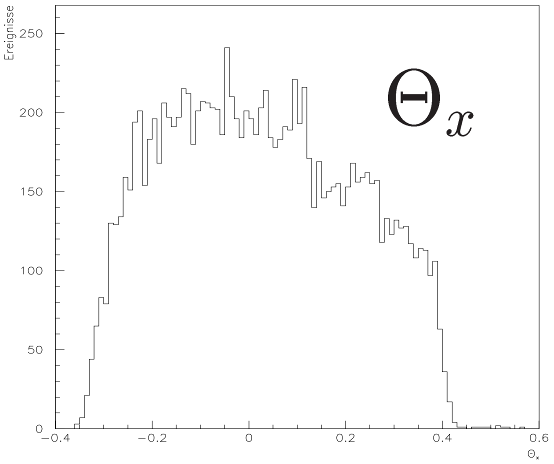
FIBER DETECTORS:

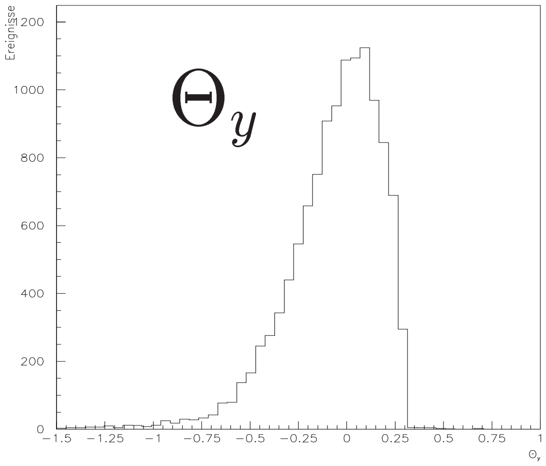
- 4×5 layers of 1 mm scintillating fibers per pot
- $\sigma_{x/y} = 150\mu m$
- $\sigma_E =$ 2 ... 6 GeV , add.calibration uncertainty of 8 GeV
- $\Theta <\sim 0.5 mrad$
- acceptance 81V $\oplus$ 90V $> 50\%$ for $580 < E_p < 740 GeV$

Proton Momentum and Angles

1996 data with vertical pots, 820 GeV p on 27.5 GeV e^+

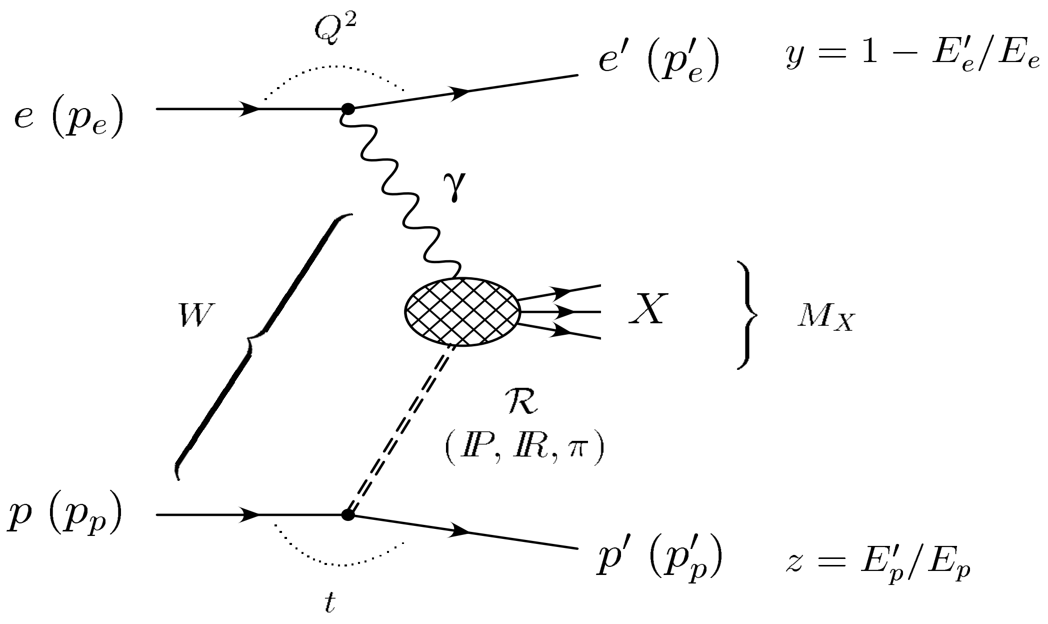






- kinematic range : $500 GeV < E(p') < 750 GeV$, $p_T <\sim 300 MeV$
- ~ 2 % of all events have an observed proton with $E_p > 500 GeV$

Kinematics of Semi-Inclusive Process



Apart from the "standard variables" x, Q^2, y of the inclusive process, two more variables, e.g. z and t, are needed to describe the scattered proton.

where:

$z = E(p')/E(p)$
... fractional proton momentum
... alternatively: $x_{\mathbb{P}} = 1 - z$, or $\beta = x/x_{\mathbb{P}}$

$t = t_{min} - p_T^2/z$
... momentum transfer squared off the proton

Event Selection

1996 data with luminosity 3.3 pb^{-1}
23000 events with stable pot positions

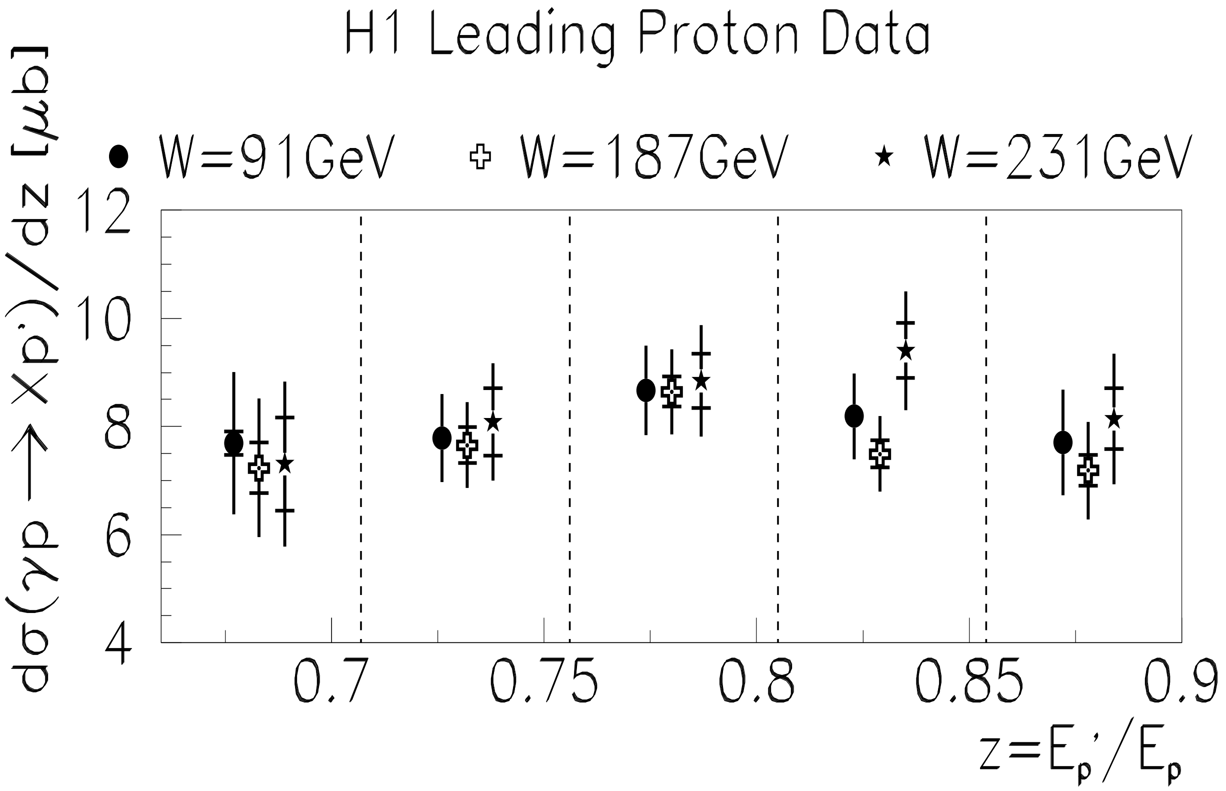
- Identify quasi-real photon by electron at small angle, $y \sim 0.03...0.7$

- Identify forward proton by FPS track $E'_P \sim 500...750 GeV$

- Identify hadronic final state: ≥ 1 track with $p_t > 500 MeV$ in central detector

- Kinematic range:
  - $W = \sqrt{y \cdot s} = 60...250 GeV$
  - $Q^2 < 0.01 GeV^2$
  - $z = 0.66...0.90$
  - $p_t < 200 MeV$ (acceptance cut)

Semi-Inclusive Cross Section



- $1.17 \pm 0.02(stat) \pm 0.15(syst)\%$ of inclusive events have leading proton with $0.66 < z < 0.90$ and $p_T < 0.2GeV$
- $d\sigma/dz = 8.05 \pm 0.06(stat) \pm 0.89(syst)\mu b$ on average
- no z-dependence
- no W-dependence
- since $M_X^2 = (1-z) \cdot W^2$ no M_X-dependence of $d\sigma/dM_X^2$, different from diffractive $1/M_X^2$ behaviour

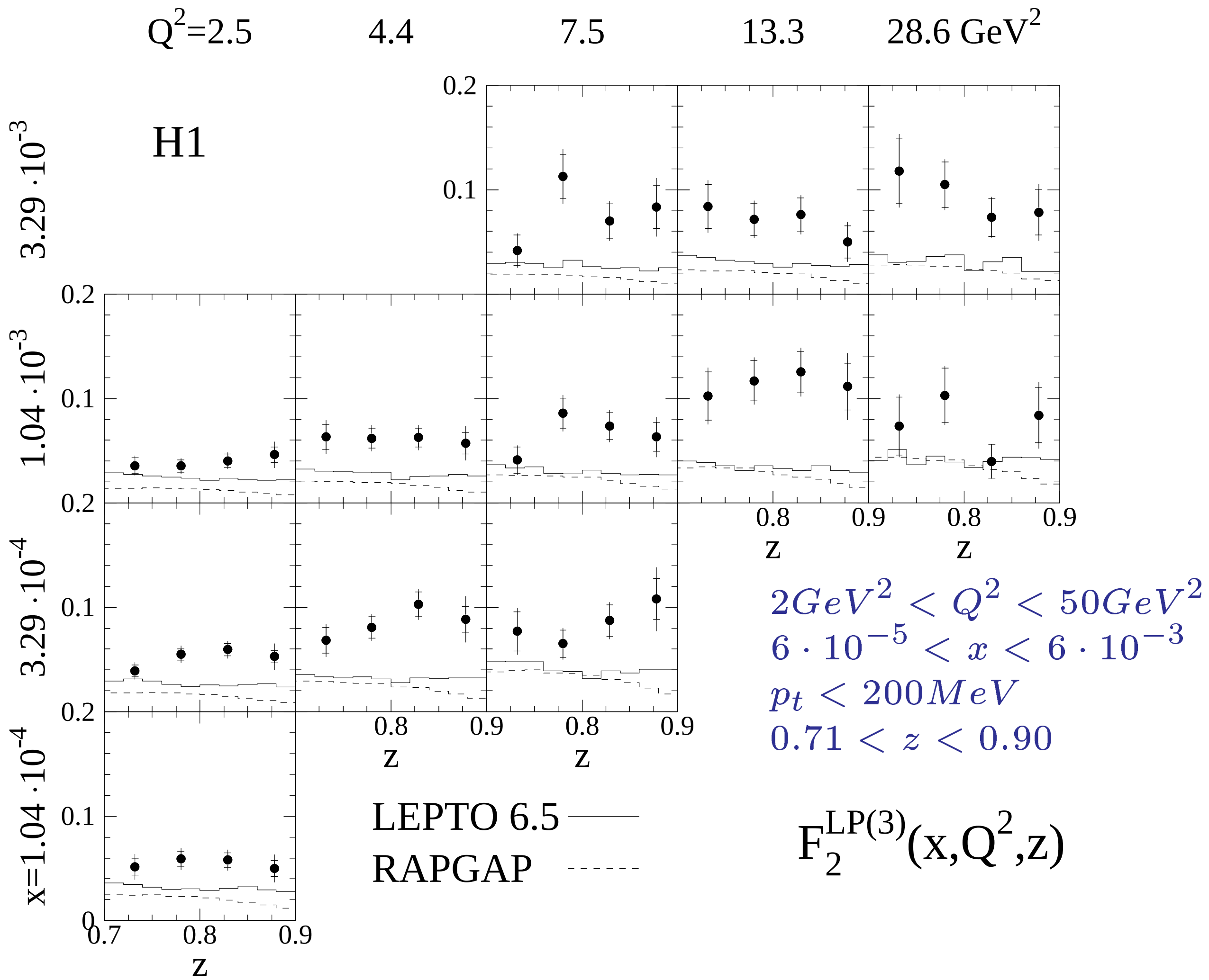
Comparison with DIS (1)

In DIS the γ couples dominatly direct, while in photo-production the hadronic coupling is dominant

How does the X-section behave in the transition region ?

DIS data with leading proton:
H1 Collab., Adloff et al., Eur.Phys. C6 (1999) 587.

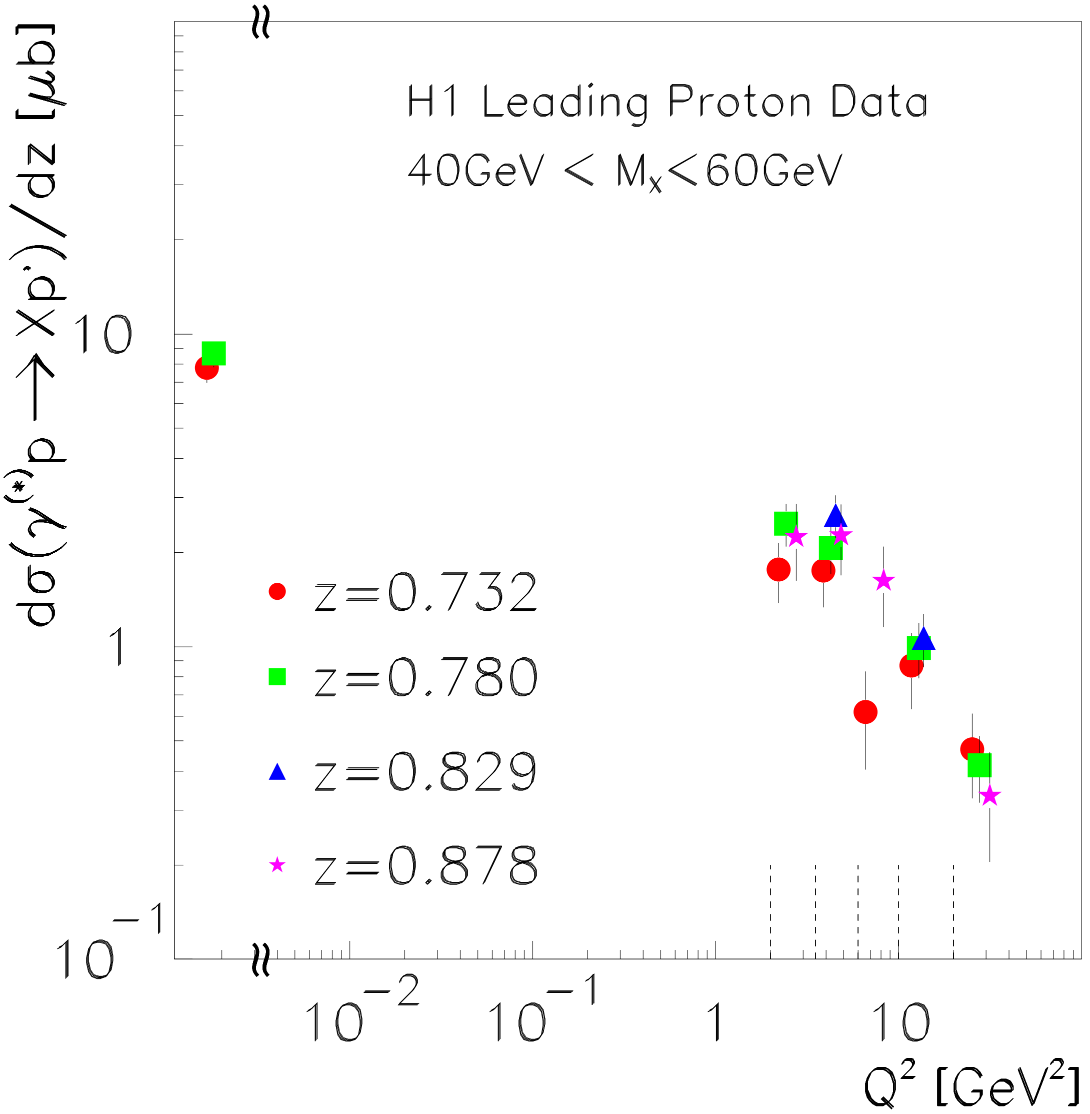
$$\frac{d^3\sigma^{LP}}{dQ^2dxdz} = \frac{4\pi\alpha^2}{xQ^4}\left(1 - y + \frac{y^2}{2(1+R)}\right)F_2^{LP}(x, Q^2, z)$$



Comparison with DIS (2)

The structure function is related to the γp cross section:

$$\frac{\sigma_{\gamma p \to X p'}}{dz} = \frac{4\pi^2\alpha}{Q^2} F_2^{LP(3)}(x, Q^2, z)$$



- $d\sigma/dz$ approach $Q^2 \to 0$ in all z ranges very similar
- other M_X ranges show similar behaviour
- transition $Q^2 \to 0$ same shape in inclusive reactions

Fraction of Leading Protons(1)

Compare the semi-inclusive cross section with the total inclusive cross section:

Photo-Production:

$$f_{LP}(Q^2 \sim 0, W, z) = \frac{d\sigma_{\gamma p \to X p'}(Q^2 \sim 0, W, z)/dz}{\sigma^{tot}_{\gamma p}(W)}$$

with: $\sigma^{tot(DL)}_{\gamma p \to X} = 0.677 W^{2 \cdot 0.0808} + 0.129 W^{2 \cdot (-0.4525)}$

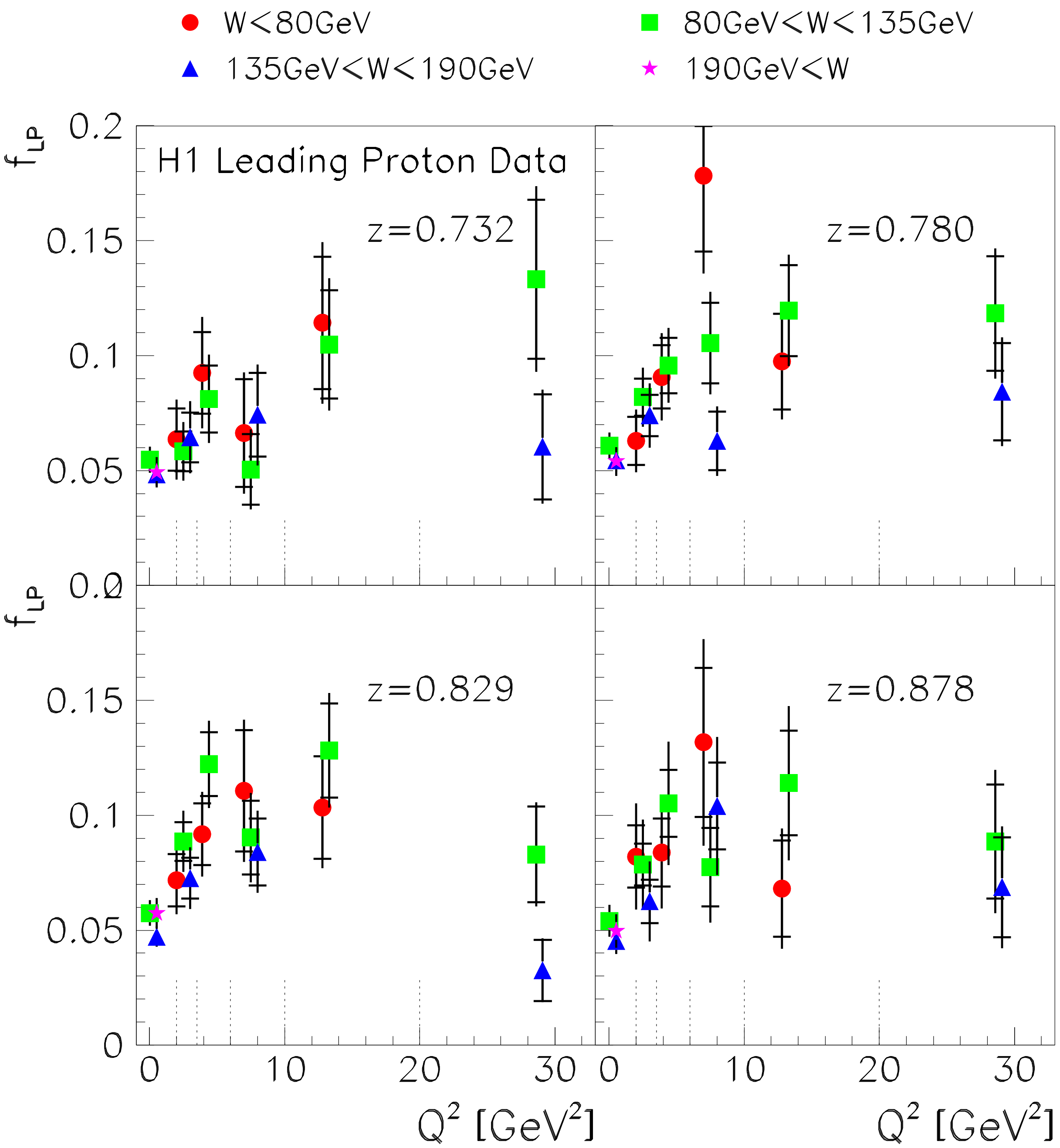
Deep Inelastic Scattering:

$$f_{LP}(Q^2, W, z) = \frac{F_2^{LP(3)}(x, Q^2, z)}{F_2^{H1QCD}(x, Q^2)}$$

F_2^{H1QCD} from H1 Collab., Adloff et al., Eur.Phys.J.C13(2000)609

RESULT:
Leading proton fraction is about 5 % in γp and increase to about 10 % in the DIS region

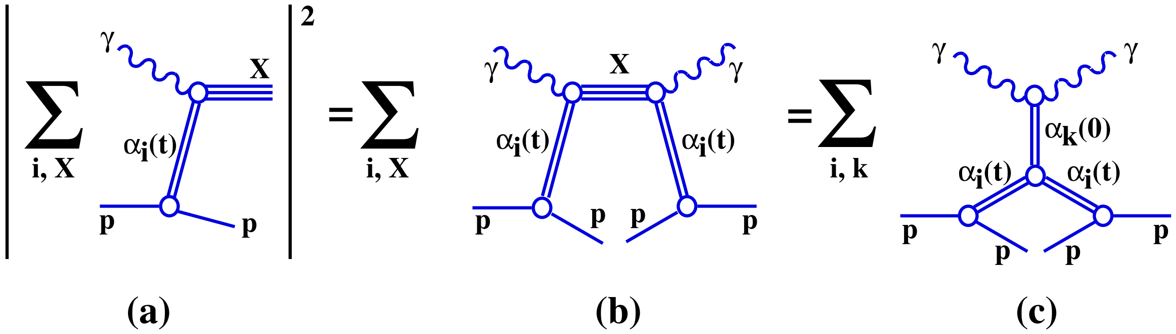
Fraction of Leading Protons(2)



INTERPRETATION:
- contribution from longitudinal photons in DIS
- Reggeons flux depends on Q^2, factorization breaking ?

Regge Parametrisation (1)

The W and z dependences gives information about the exchange mechanisms. Use Triple Regge ansatz:



Data do not allow full decomposition - use approaches:

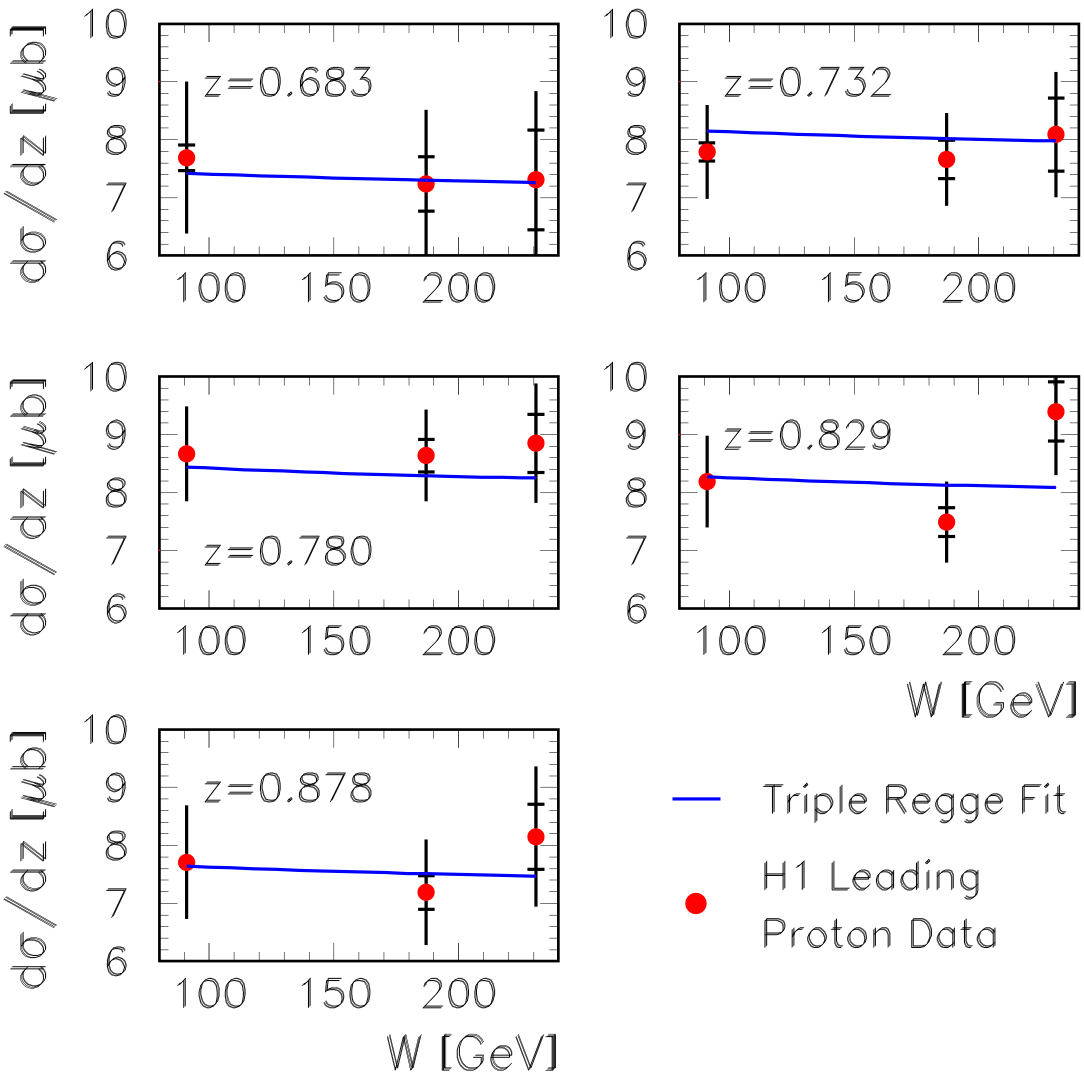
- effective trajectories α_i for γ p exchange, and α_k for the total cross section of $\gamma\mathbb{R}(\rho, \omega, a_2, f_2)$ exchange
- no interference terms, identical trajectories on proton
- unique t-dependence e^{bt} with $b = b_0 - 2\alpha_i^{'} ln(1-z)$
- $\alpha_i(t) = \alpha_i(0) + \alpha_i^{'} t$ with $\alpha_i^{'} = 1.0 \pm 0.2 GeV^{-2}$

Integration over t results:

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

CONCLUSION: from constant W and M_X^2 behaviour results $\alpha_i(0) \sim 0.5$ as for $\mathbb{R}$ trajectory and $\alpha_k(0) \sim 1$ as for $\mathbb{P}$ trajectory.

Regge Parametrisation (2)



FIT RESULTS:

$\alpha_i(0) = 0.33 \pm 0.04(stat) \pm 0.04(syst)$

$\alpha_k(0) = 0.99 \pm 0.01(stat) \pm 0.05(syst)$

$b = 6.2 \pm 0.7(stat) \pm 1.5(syst) GeV^{-2}$ for z $= 0.78$

(ZEUS direct measurement: $b = 6.8 \pm 0.8 GeV^{-2}$)

CONCLUSION:

- mixture of π and $\mathbb{R}$ exchanges dominate γp process
- total cross section $\gamma(\mathbb{R}, \pi) \rightarrow X$ mainly by $\mathbb{P}$ exchange

Summary

Photo-production with leading protons in the kinematic range $0.66 < z < 0.90, p_t < 0.2 GeV$ was measured with the H1 FPS.

For different center-of-mass energies the $d\sigma/dz$ is about $8 \mu b$ independent on W and z.

The comparison with DIS data indicates a for $Q^2 \to 0$ similar dependence in all z and M_X ranges.

The fraction of leading protons is about 5 % , with the tendency to increase with Q^2

A Triple Regge model describes the data:

The exchange between the photon and the proton in the range $0.66 < z < 0.90$ can be well described by a mixture of π and $\mathbb{R}$ trajectories.