Open Charm Contribution to $F_2^{D(3)}$ in DIS and Leading Baryon Production at HERA

Thorsten Koop
University of Toronto

On behalf of the ZEUS Collaboration

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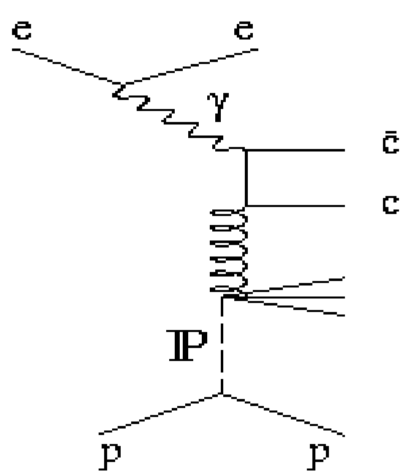
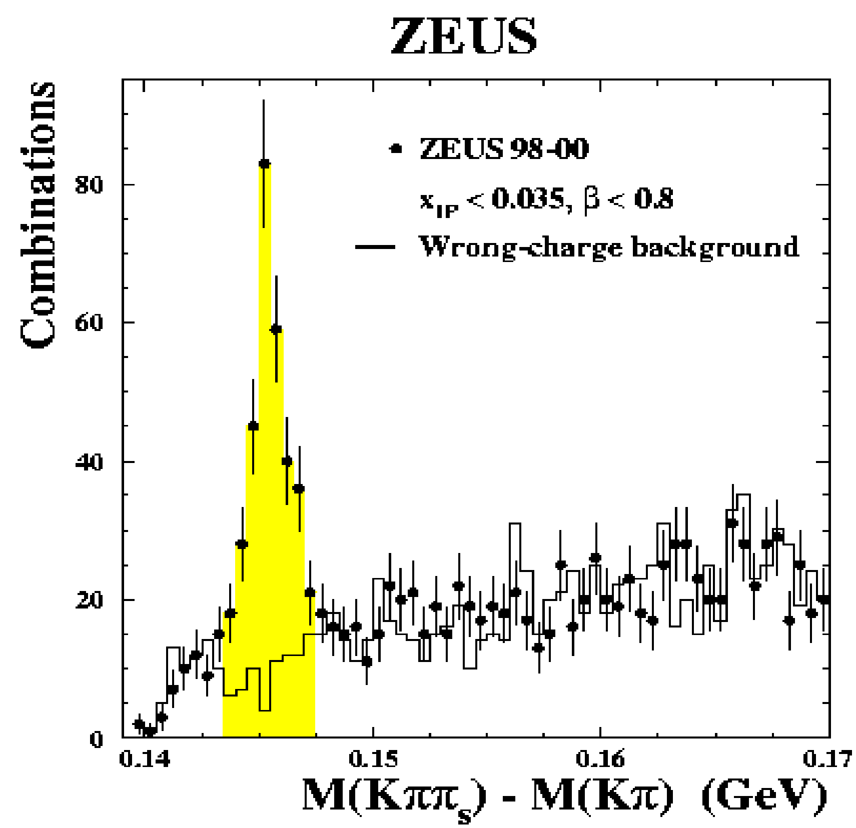
- Diffractive open charm contribution to F2D(3) in DIS
- Leading baryons and forward detectors at ZEUS
- D* photoproduction with a leading neutron
- Search for pion trajectory in photoproduction of leading neutrons
- Leading protons in DIS

Diffractive Open−Charm Contribution to $F_2^{D(3)}$ in DIS

Charm sensitive to gluon density and to Charm in the Pomeron



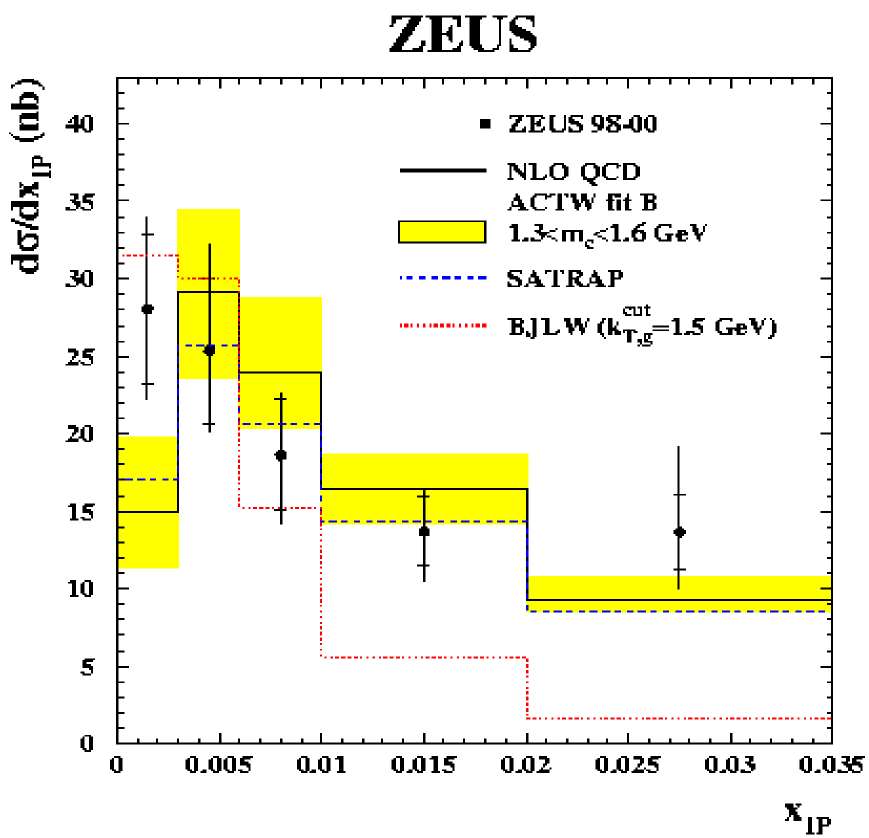


Open Charm Decay Channel:

$D^{*\pm}(2010) \rightarrow D^0\pi_s^{\pm} \rightarrow (K^{\mp}\pi^{\pm})\pi_s^{\pm}$

Luminosity = 82 pb^{-1}

Total Cross Section in Open Charm

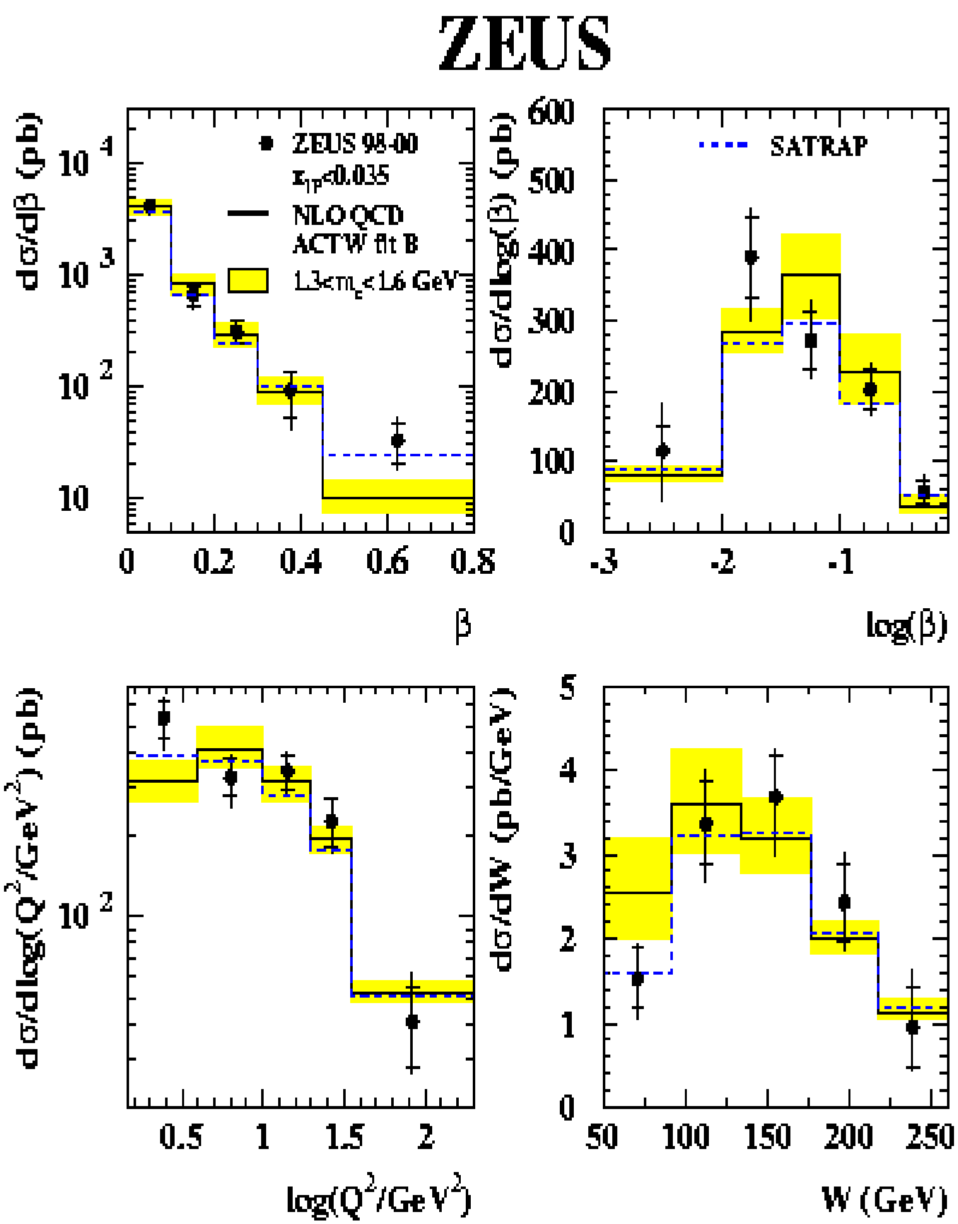


- Precision of data much improved over previous results
- Larger kinematic region in x_{IP}

  $x_{IP} < 0.0016 \Rightarrow x_{IP} < 0.0035$

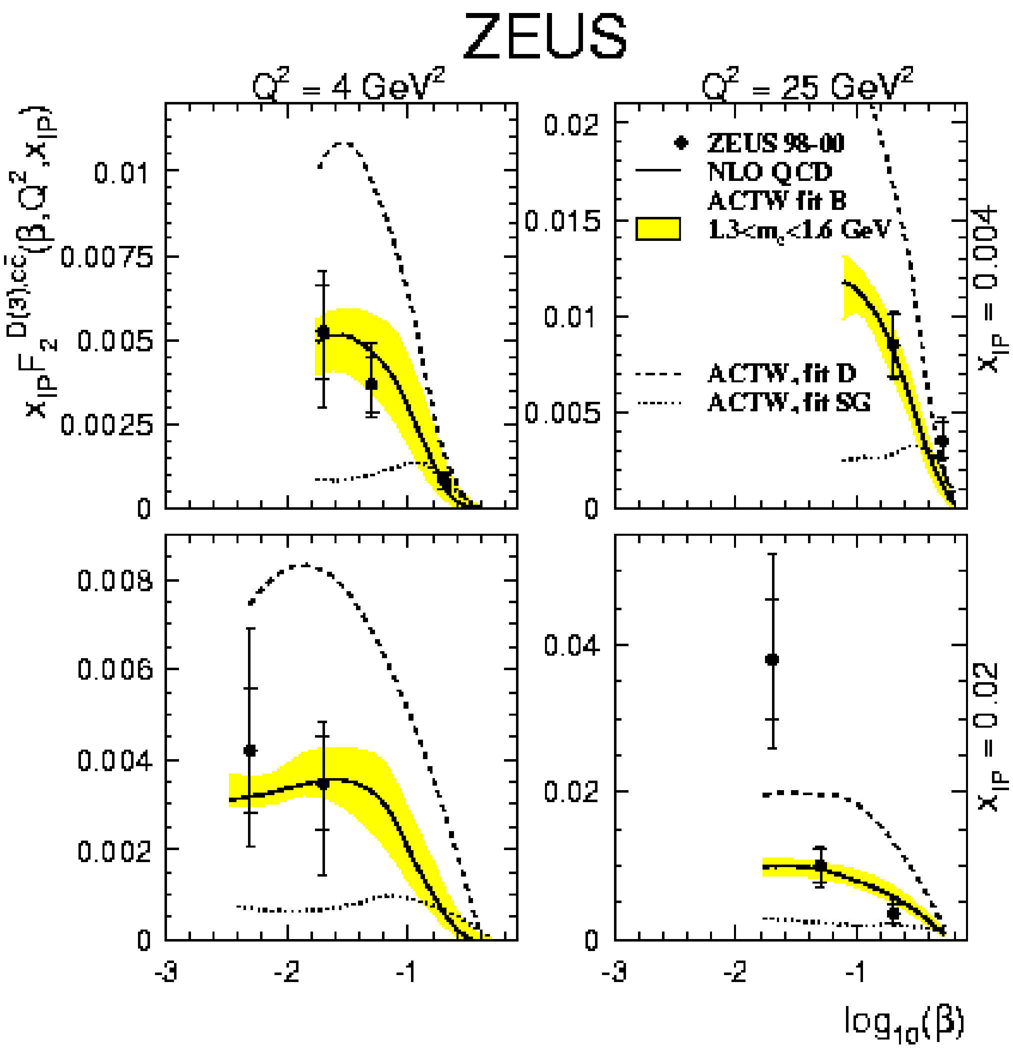
$$R_D = \frac{\sigma_{ep \to e D^{*\pm} X' p}(x_{IP} < 0.035, \beta < 0.8)}{\sigma_{ep \to e D^{*\pm} Y}(x < 0.028)} = 6.4 \pm 0.5(stat.)^{+0.3}_{-0.7}(syst.)^{+0.3}_{-0.3}(p\,diss.)\%$$

Differential Cross Section



- Compare Shape and Normalization of Data:
  - Good Agreement with Gluon dominated fit in NLO QCD
  - SATRAP (2 gluon exchange model) can describe data

Measured Charm Contribution to the diffractive Structure Function $F_2^{D(3)}$



- First determination of $F_2^{D,cc}$
- In all regions of $x_{|P}$, $F_2^{D,cc}$ rises as $\beta \rightarrow 0$
- For $x_{|P}$~0.004, $F_2^{D,cc}$ contributes ~ 30 % to inclusive $F_2^{D(3)}$

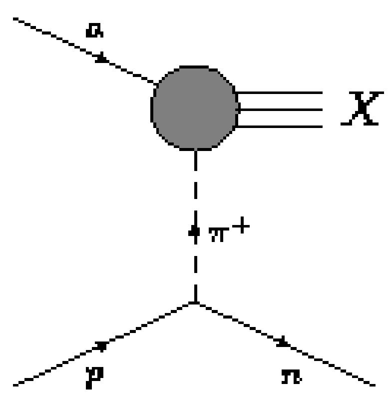
- Sensitivity to choice of diffractive parton density
- Data may be able to help constrain gluon in Pomeron

Leading Baryons

- Significant part of *ep* scattering events at HERA contain a baryon in the final state
- Production mechanism is not yet completely understood
- Exchange models are used to describe data

Exchange models (e.g. π^+ exchange)

$\Rightarrow$ Factorization: $\sigma(ep \rightarrow e'n\,X) = f_{\pi/p}(x_L, p_T)\,\sigma(e\pi \rightarrow e'\,X)$

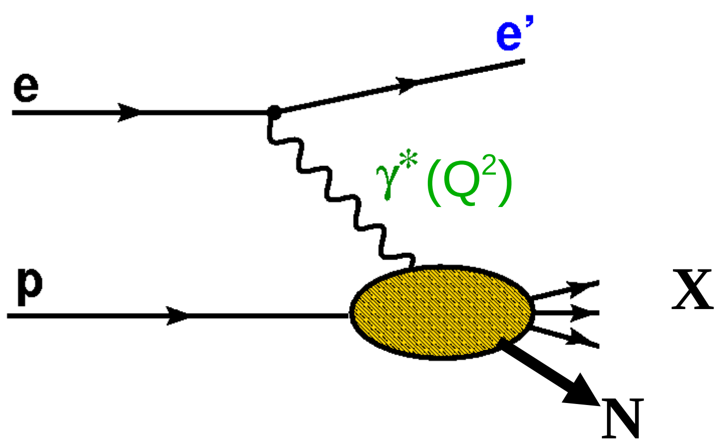


Vertex Factorization:

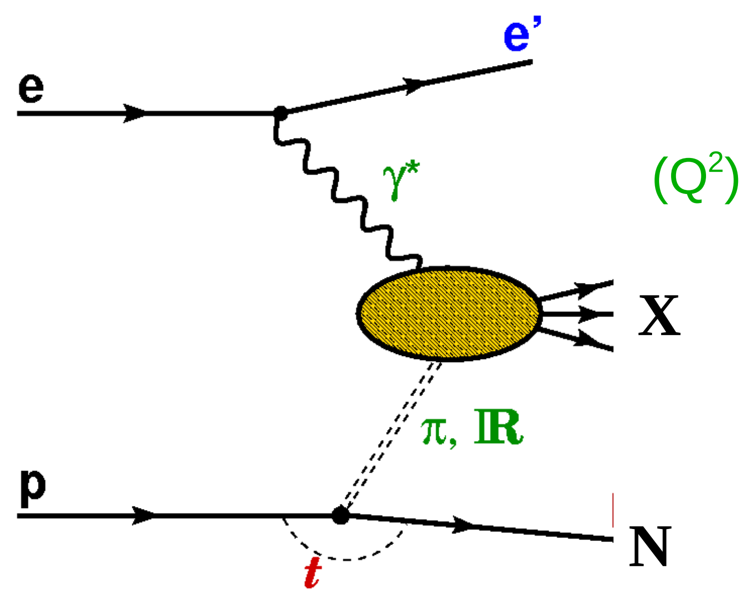
Upper vertex (event kinematics) independent of lower vertex (baryon kinematics)

Models for Production Mechanisms

ep scattering: baryon # should be conserved:



Standard fragmentation:
Final−state N in *p* remnant
MC models



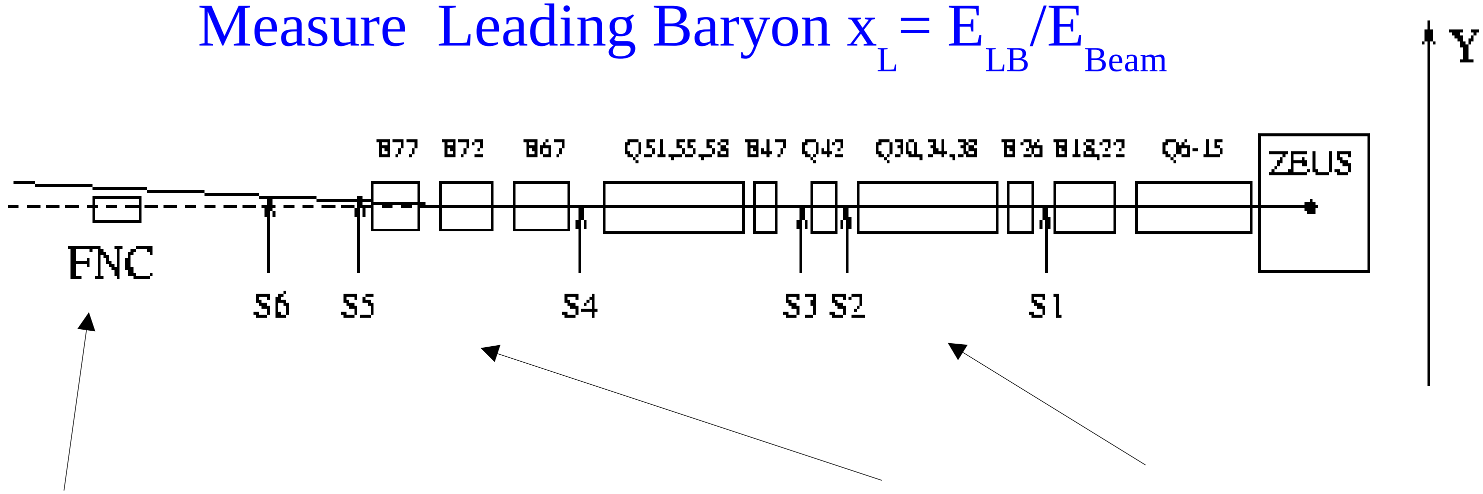
Particle exchange:
ep scattering
→ eπ scattering (e.g.)
fast final state N

Protons: isoscalar, isovector exch.
neutrons: isovector (e.g. π^+) exch.

ZEUS Forward Detectors

HERA beamline in *p* direction downstream from ZEUS:

Measure Leading Baryon $x_L = E_{LB}/E_{Beam}$



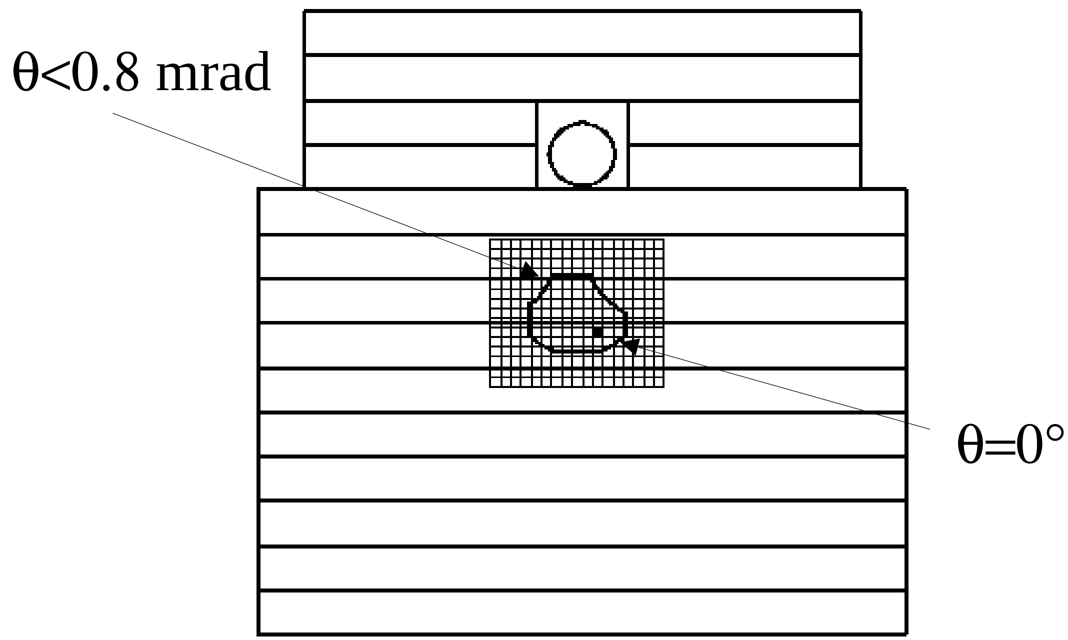
Forward Neutron Calorimeter (FNC)
on neutral zero−degree line

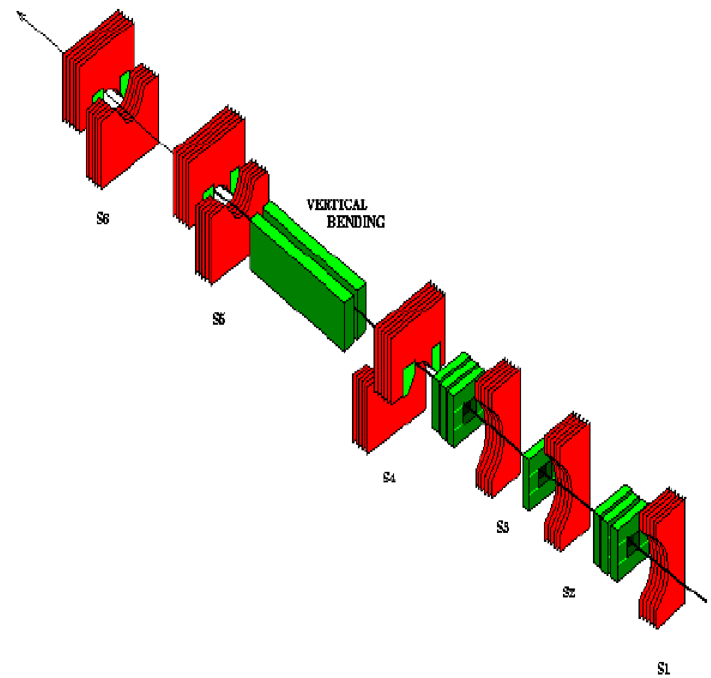
Leading Proton Spectrometer (LPS)
roman pot stations

Vertical bend at 70m serves as:

- Analyzing magnet for proton spectrometer
- Sweeping magnet for neutron calorimeter

ZEUS Forward Detectors





FNC:

- $10\ \lambda_I$ Pb−scintillator sandwich, 17x15 scintillator hodoscope
- $\sigma_E / E = 70\% / \sqrt{E}$
- $\sigma_\theta = 25\ \mu$rad

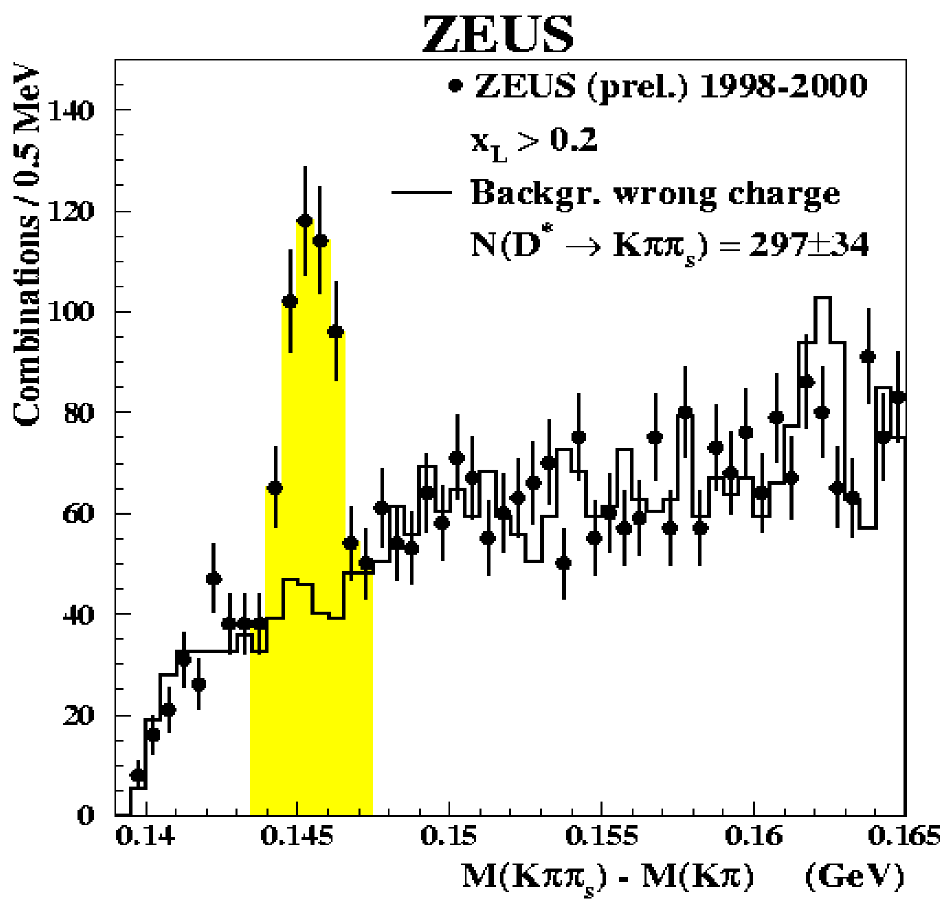
LPS:

- 6 stations of Si strips
- σ_{xL} below 1 %
- $\sigma_{PT} \simeq 5$ MeV

For both detectors resolution of p_T dominated by p beam spread (50−100 Mev)

D* Meson in Photoproduction with a Leading Neutron

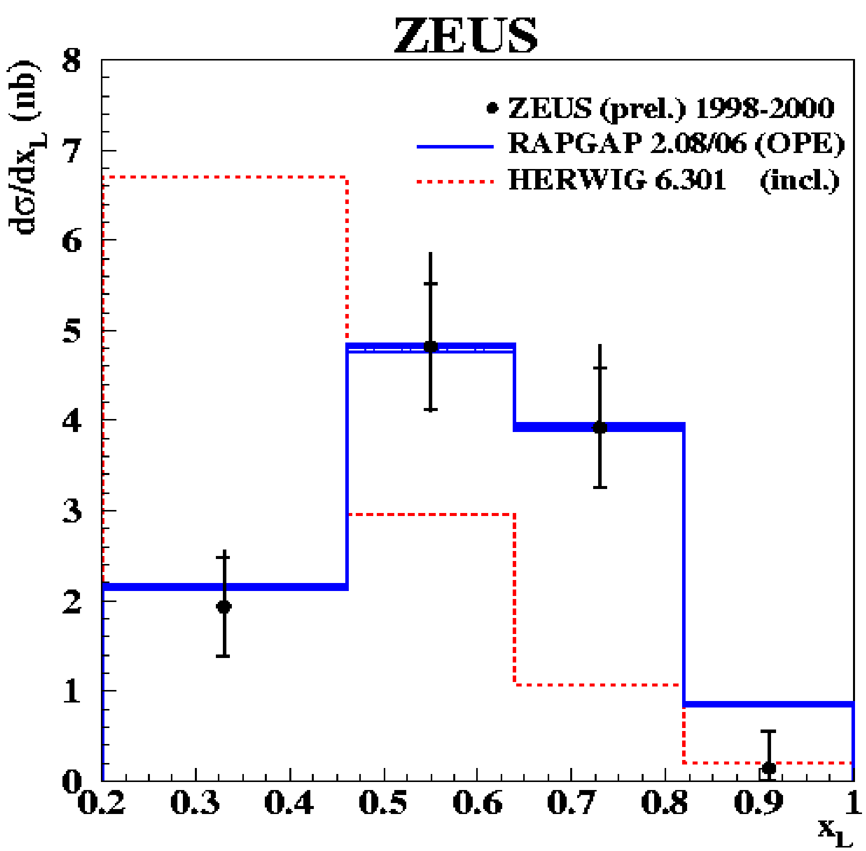
- Study relationship between soft and hard interactions
  hard scale for D* production (m_c^2) <=> soft scale for neutron production (p_T)
- Study vertex factorization hypothesis

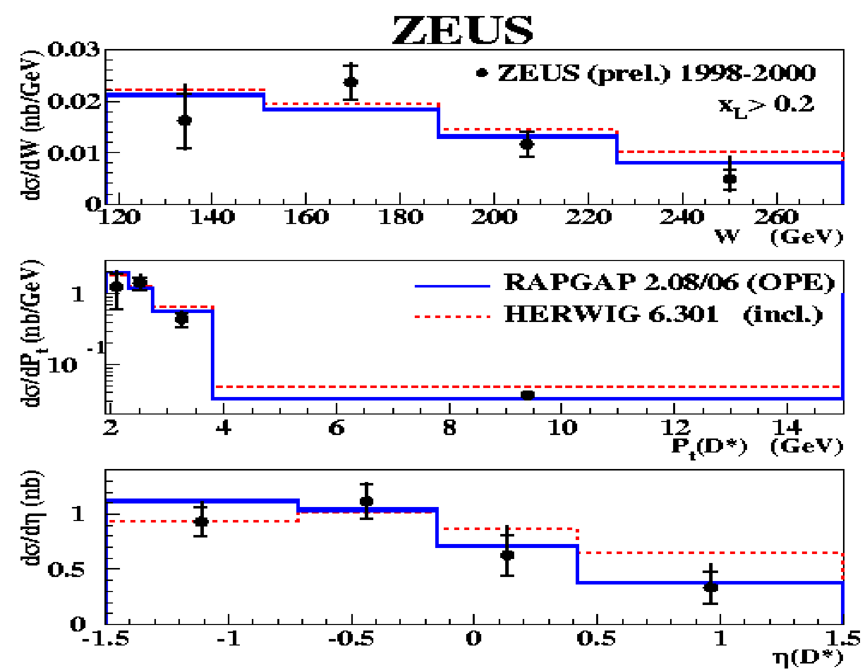


Tag with Δm method

$$D^{*\pm} \to D^0\pi_s^{\pm} \to (K^{\mp}\pi^{\pm})\pi_s^{\pm}$$

Differential Cross Section





Rapgap with One−Pion−Exchange describes the x_L distribution best

➨ One−Pion−Exchange model

For W, η, P_t, both

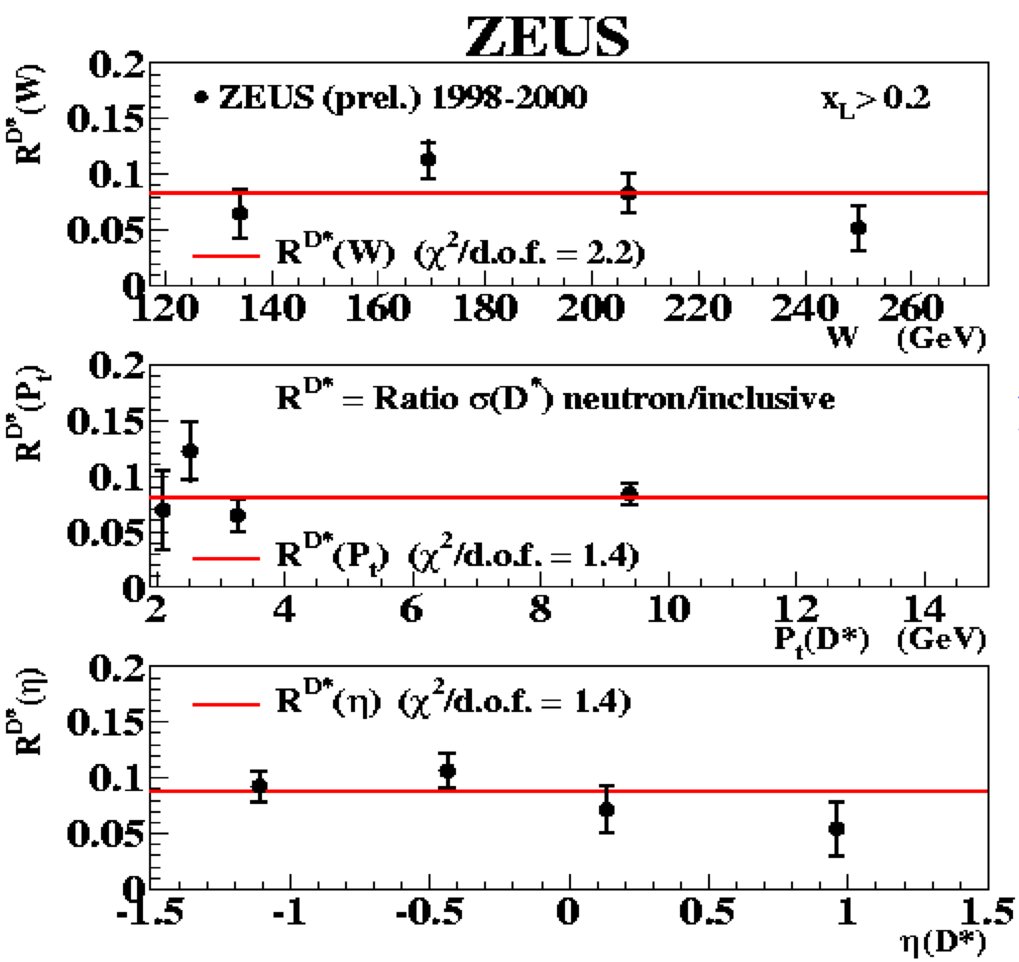
One Pion Exchange **(RAPGAP)**

standard fragmentation

(HERWIG)

do a similar job

Ratio D* to Leading Neutrons



- Ratios are flat
- Factorization Model holds

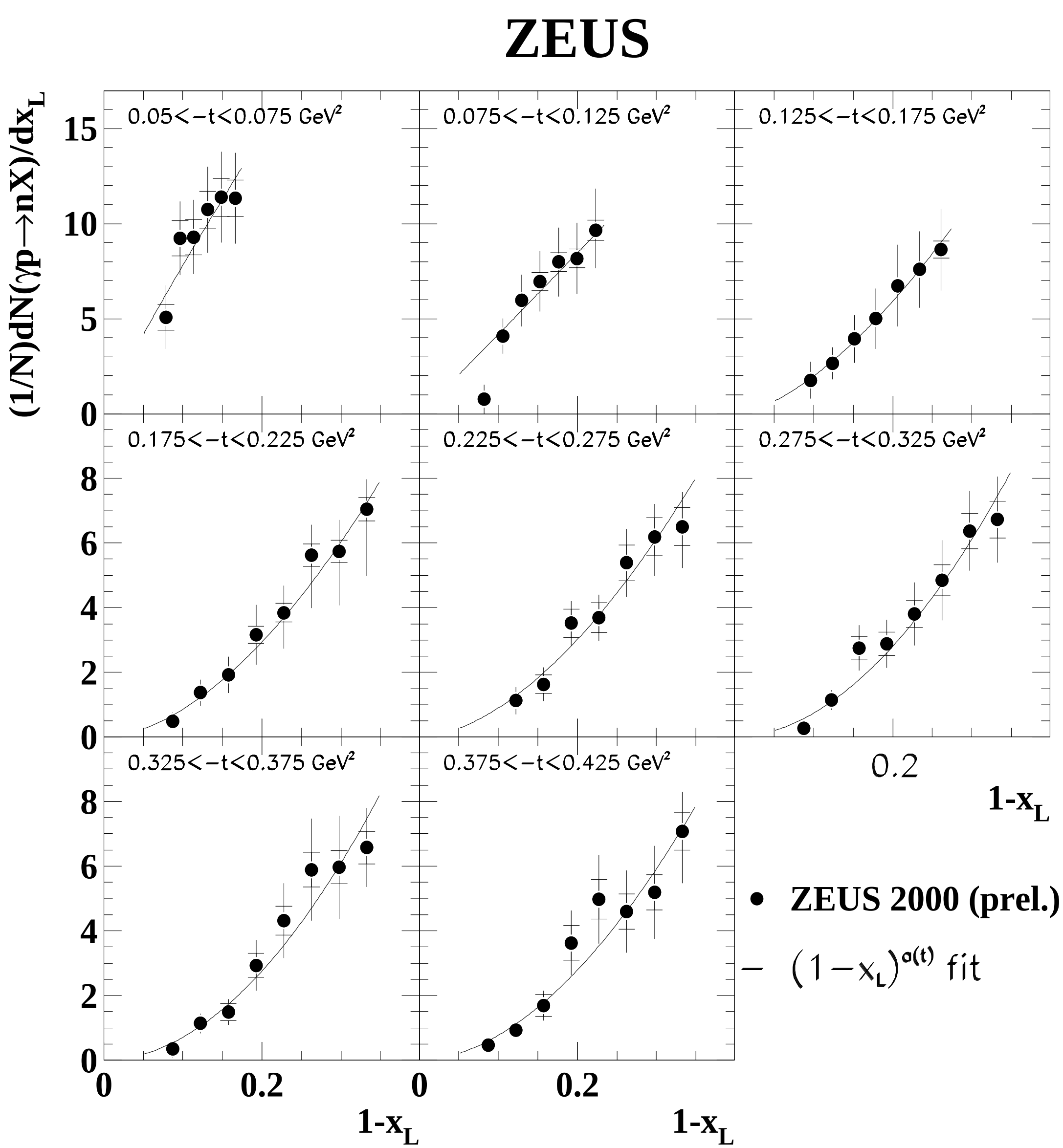
Ratio inclusive PHP to Leading Neutrons
is smaller than
Ratio D* to Leading Neutrons

- Factorization violation
- Possible explanation: Rescattering

$$R^{D^*} = (\sigma^{D^*}{}_{LN}/\sigma^{D^*}{}_{inc}) = 8.1 \pm 0.9\ (stat.) \pm 0.3\ (sys.)\ \%$$

$$R^{incl} = (\sigma^{PhP}{}_{LN}/\sigma^{PhP}{}_{tot}) = 5.7 \pm 0.4\ \%$$

Measurement of the effective Pion Trajectory in Photoproduction with Leading Neutrons



- Kinematic range:

  $Q^2 < 0.0\ 3\ GeV^2$

  $0.2 < x_L < 0.925$

  $|t| < 0.425\ GeV^2$

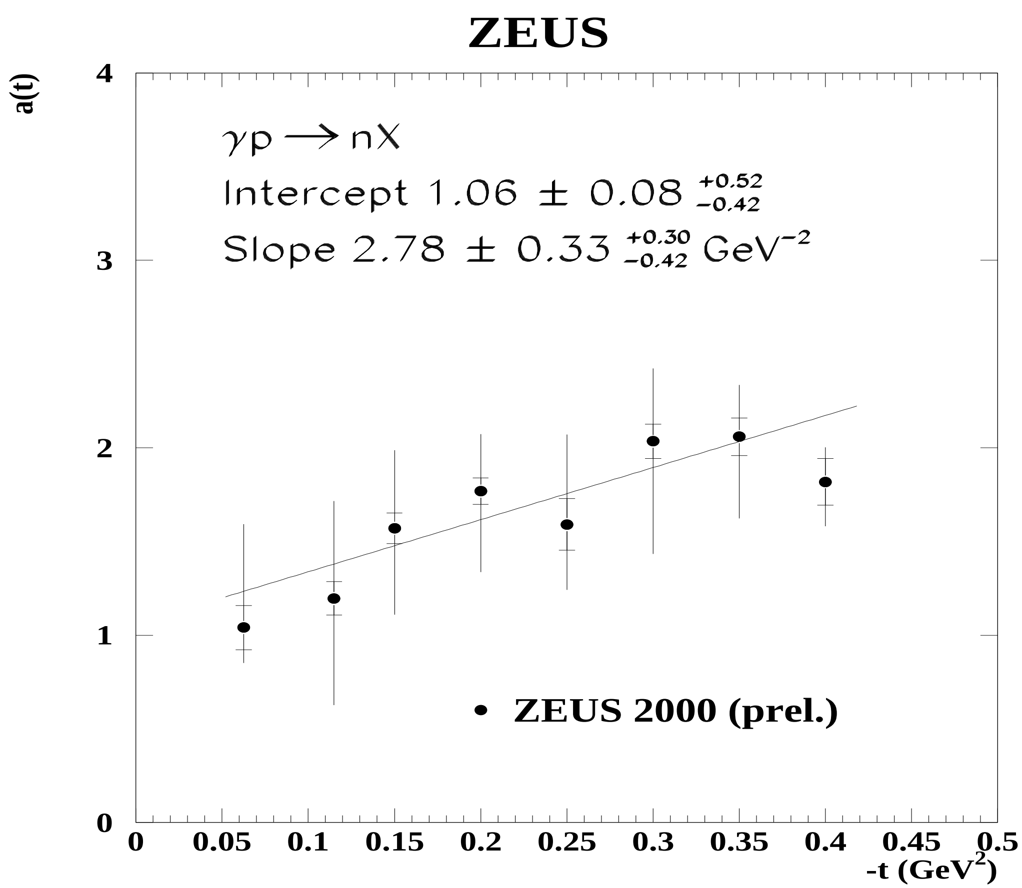
- 2000 data taking,

  $9\ pb^{-1}$

- $(1-x_L)$ distribution as a function of t satisfies power law

  $dN/dx_L \propto (1-x_L)^{a(t)}$

Powers of photoproduced Leading Neutrons as a Function of t



Powers a(t) lie on linear trajectory in t

$$a(t)=1.06\pm0.08^{+0.52}_{-0.42}-(2.78\pm0.33^{+0.30}_{-0.42}\ GeV^{-2})\,t$$

Interpretation in OPE Model

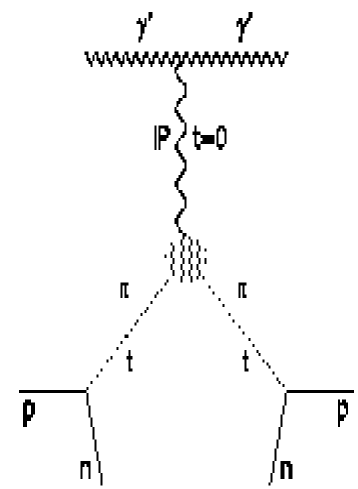
Pion flux

$$f_{\pi/p}(x_L,t)=\frac{1}{4\pi}\frac{g^2_{n\pi p}}{4\pi}\frac{-t}{(m^2_\pi-t)^2}(1-x_L)^{1-2\alpha_\pi(t)}(F(t))^2$$

F(t) independent of x_L: $$f_{\pi/p}=A(t)(1-x_L)^{a(t)}$$

Cross section for neutron production:

$$\frac{d^2\sigma}{dx_L\,dt}=A(t)(1-x_L)^{a(t)}\sigma_{\gamma\pi}(s'=(1-x_L)W^2)$$



In PHP: $$\sigma_{\gamma\pi}(s')=A(s')^{\epsilon}+B(s')^{-\eta}$$

$\varepsilon\approx0.1$, $\eta\approx0.5$ --> $a_{eff}(t)=1+\epsilon-2\alpha'_\pi t$

Interpretation in OPE Model

$$a_{eff}(t) = 1 + \epsilon - 2\alpha'_{\pi} t$$

$$a(t) = 1.06 \pm 0.08^{+0.52}_{-0.42} - (2.78 \pm 0.33^{+0.30}_{-0.42}\ GeV^{-2})\, t$$

--> slope/2 = α'_{π} is the slope of the pion trajectory

--> the intercept is the intercept of the Pomeron trajectory $\alpha_{IP}(0)$

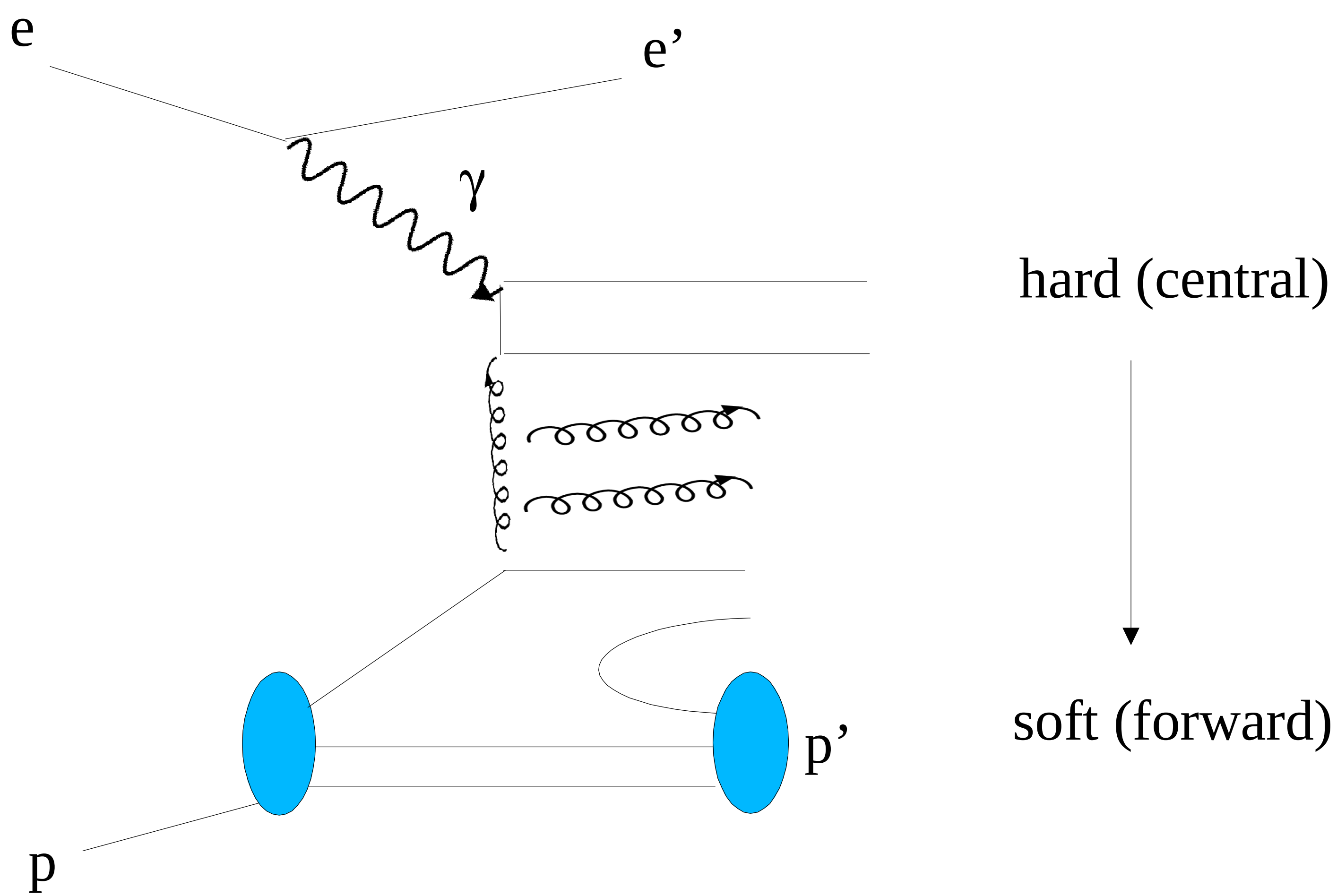
$\alpha_{\pi}' = (1.38 \pm 0.17^{+0.21}_{-0.15}\ GeV^{-2})$ $\alpha_{IP}(0) = 1.06 \pm 0.08^{+0.52}_{-0.42}$

In the OPE picture expect $\alpha_{\pi}(t) = t - m_{\pi}^2$

Measurement of Leading Protons in DIS

- Leading Protons in final state

=> non−perturbative side of strong interactions
Hard Scale (central) <−> Soft Scale (forward)



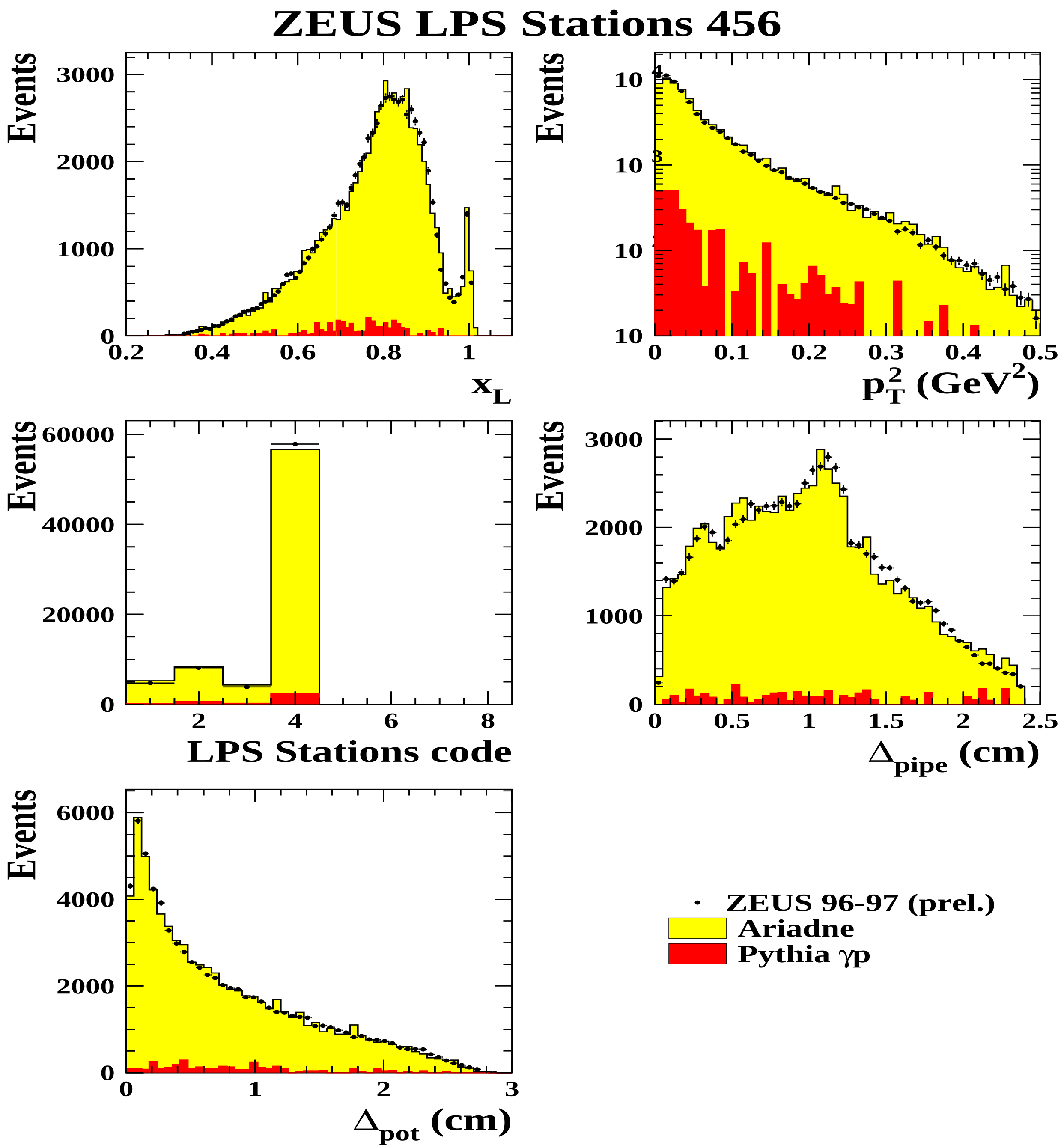
Measurement of Leading Protons in DIS

- Leading protons in ep collisions in the kinematic range:

$$Q^2 > 3\ \mathrm{GeV}^2$$
$$45 < W < 225\ \mathrm{GeV}$$
$$0 < p_T^{\,2} < 0.5\ \mathrm{GeV}^2$$
$$x_L > 0.56$$

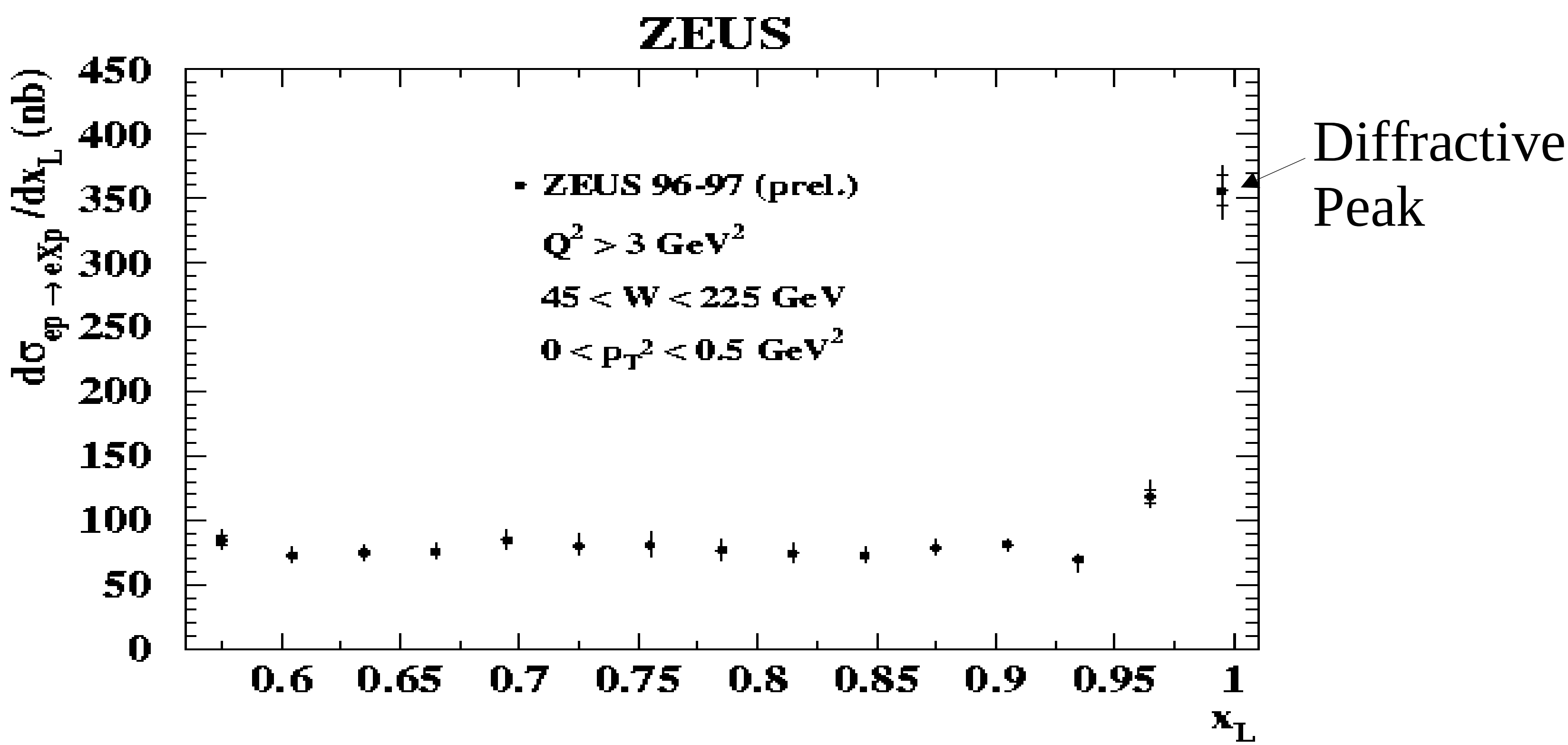
- Cross sections for the reaction $e^+p \rightarrow e^+Xp$ vs. x_L, $p_T^{\,2}$, $d^2\sigma/dx_L dp_T^{\,2}$
- $P_T^{\,2}$ slopes
- 1996−1997 data taking, 12.8 pb^{-1}
- Protons detected in LPS

Leading Protons in DIS



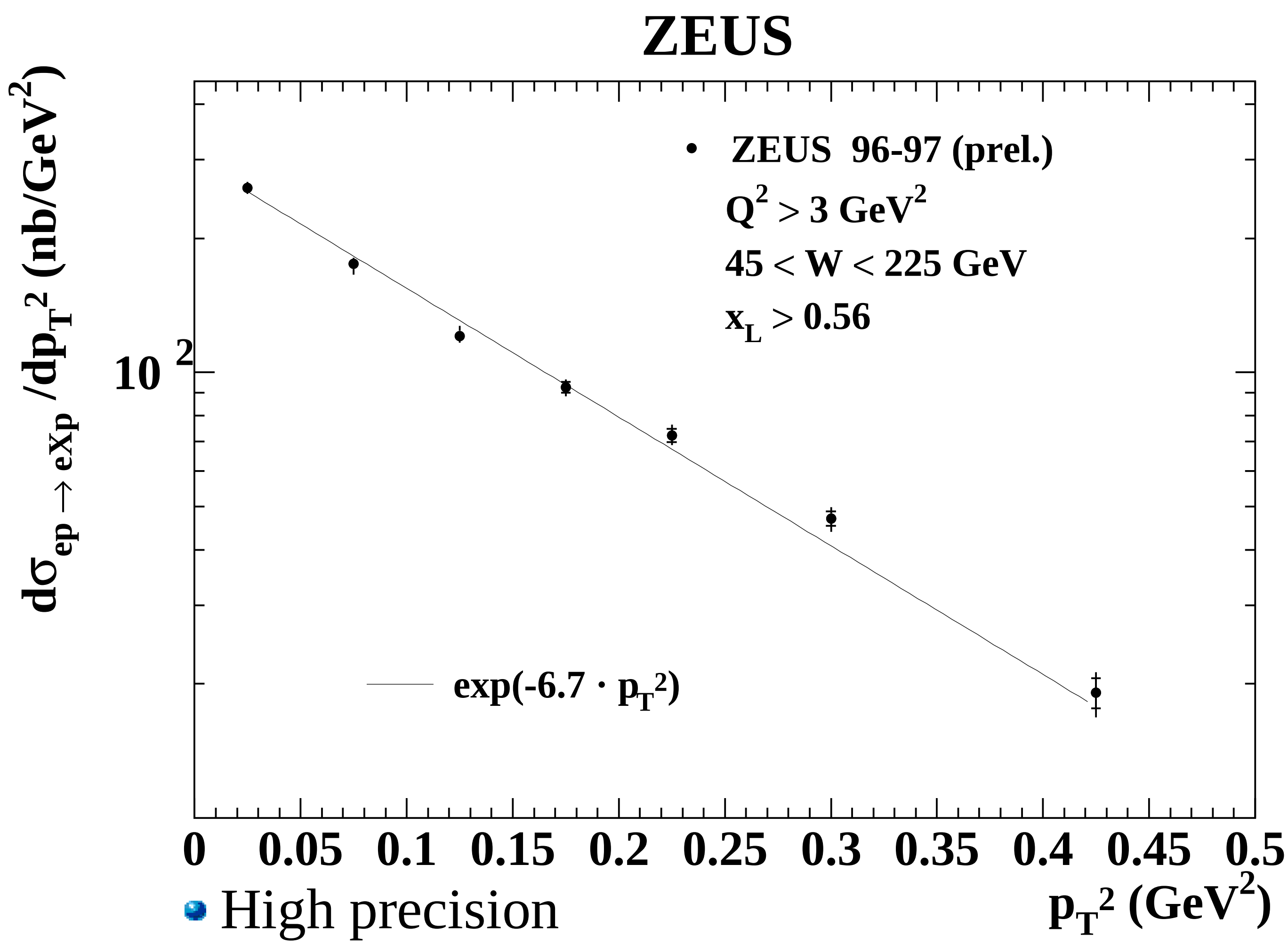
MC describes data well

Differential Cross Section as function of x_L



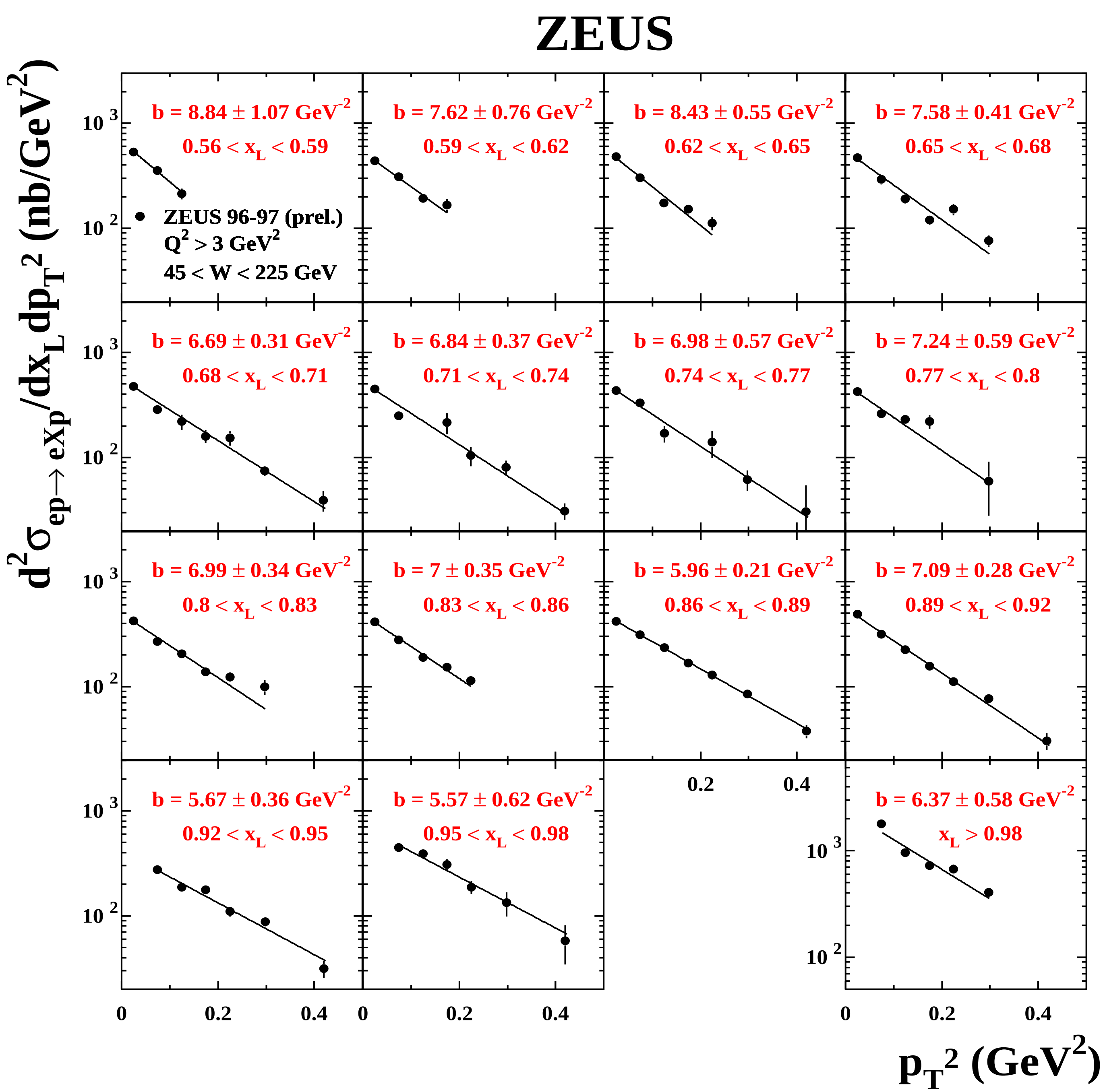
- Data precise
- Flat for $X_L < 0.95$
- Proton−dissociative diffraction (ep−>eXN) included in $X_L < 0.97$

Differential Cross Section as function of p_T^2



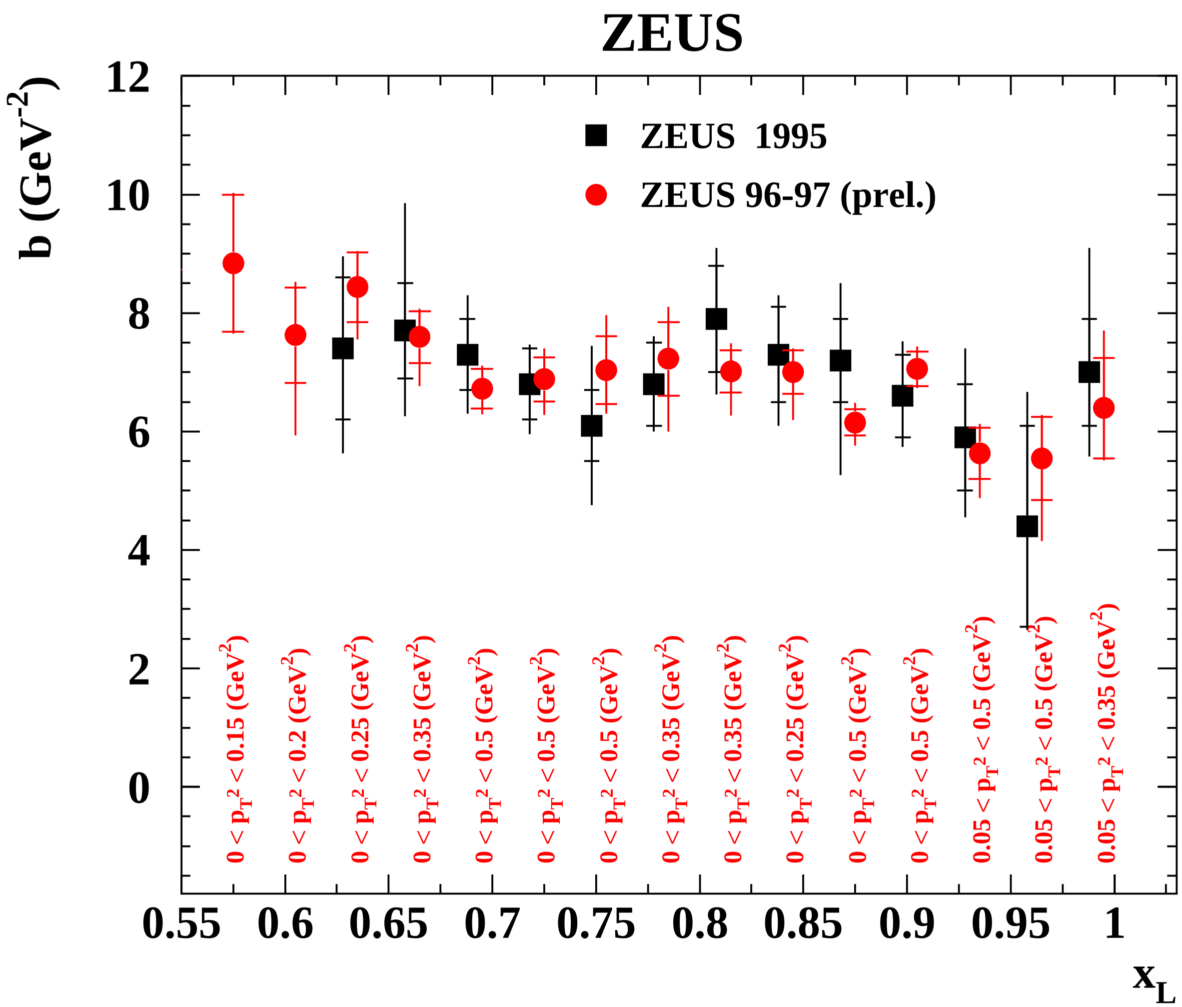
- High precision
- Line is guide−to−the−eye
- Avoid exponential fit in the full x_L range since single exponential is not a good model

b−slopes in bins of x_L



- $P_T^{\ 2}$ range in each x_L bin dictated by the acceptance of the LPS stations
- Fit: $A \exp(-bp_T^{\ 2})$

Leading Proton b−slopes as a Function of x_L



- 96−97 data consistent with 95 data
- The variation of the b−slopes vs. x_L are due to the different p_T^2 ranges

Leading Proton b−slopes: no dependence on x_L range seen

Summary

- Open Diffractive Charm Differential Cross Sections: best Agreement with Gluon dominated fit
- $F_2^{D,cc}$ was measured
- in all regions of $x_{|P}$, $F_2^{D,cc}$ rises as $\beta \rightarrow 0$, for $x_{|P} \sim 0.004$, ^{,cc} contributes ~ 30 % to inclusive $F_2^{D(3)}$
- D* in Photoproduction with a Leading Neutron $_{xL}$ is described by One−Pion−Exchange production mechanism
- Ratio D* to Leading Neutrons is flat, Factorization Model holds, ratio higher than in PHP ratio −> rescattering

Summary

- $(1-x_L)$ distribution at a given t satisfies power law $dN/dx_L \propto (1-x_L)^{a(t)}$, Powers a(t) lie on linear trajectory in t

- Interpretation in OPE picture the trajectory found by this fit is broadly consistent with Pion Trajectory

- Leading Proton Differential Cross Section is flat in $x_L < 0.95$

- Leading Proton b−slopes have no visible dependence on x_L