

## News on ZEUS Leading Baryon analyses

- Introduction
- Study of the pion trajectory in  $gp$  interactions with LN
- Study of DIS events containing a LP
- Conclusions

Legenda: LP = Leading Proton

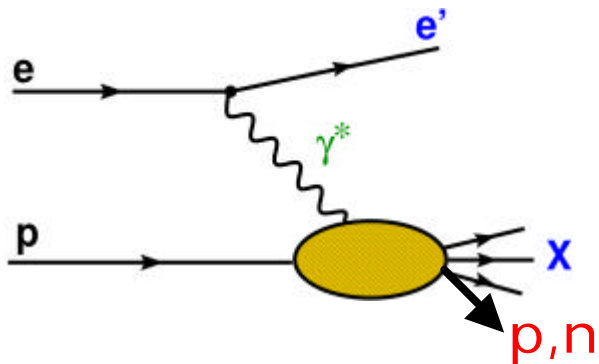
LN = Leading Neutron

LB = Leading Baryon

OPE = One Pion Exchange

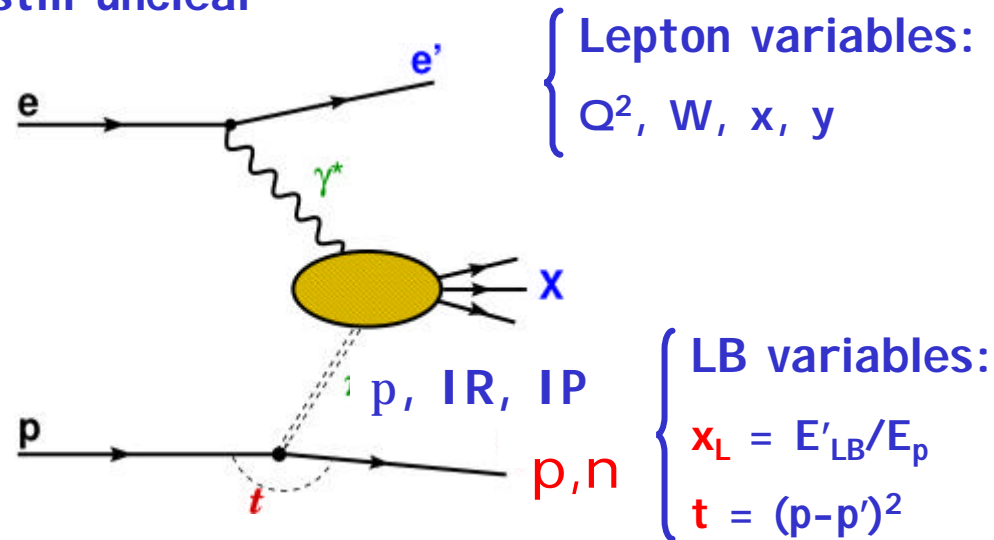
# Introduction

- Events with LB are a large fraction of the HERA cross-section
- Production mechanism is still unclear
- Models:



## Standard fragmentation

- LB from hadronization of p remenant
- MC models



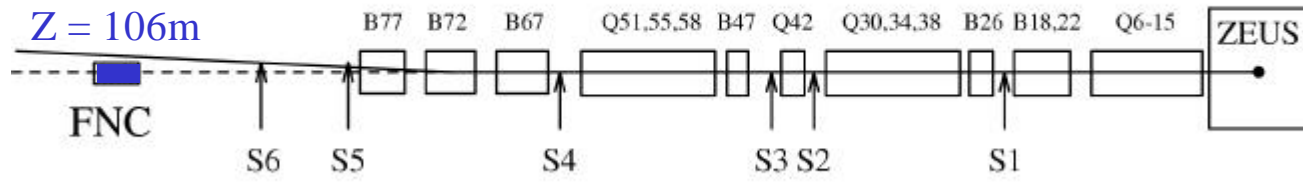
Lepton variables:  
 $\left\{ \begin{array}{l} Q^2, W, x, y \end{array} \right.$

LB variables:  
 $\left\{ \begin{array}{l} x_L = E'_{LB}/E_p \\ t = (p-p')^2 \end{array} \right.$

## Virtual particle exchange

- LP: neutral iso-scalar iso-vector (p, IR, IP)
- LN: charged iso-vector ( $p^+, r^+, \dots$ )
- Vertex factorization
- LP, LN: also from p fragmentation in diffractive processes

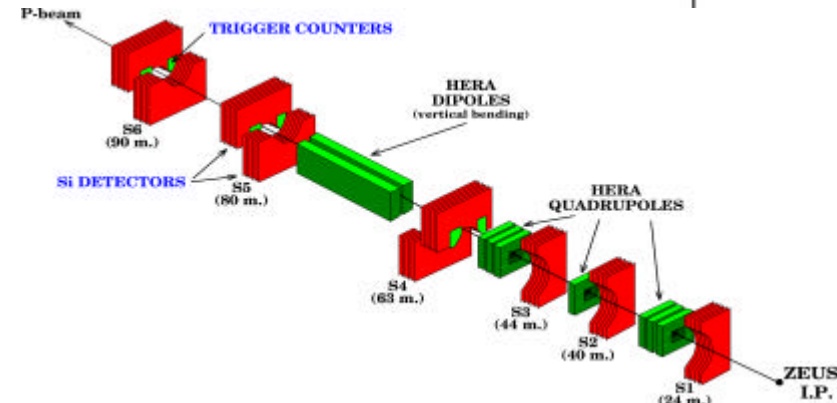
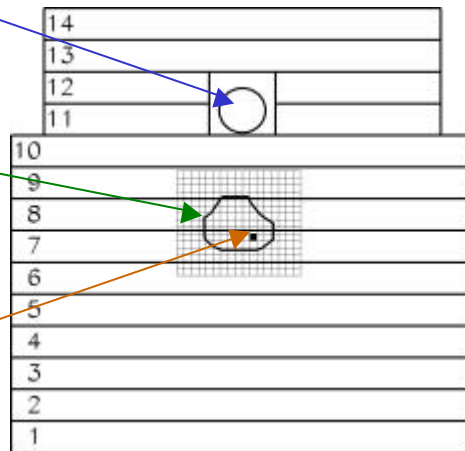
# ZEUS forward detectors



p beam

window of acceptance  
 $q_n < 0.8$  mrad

$q = 0^\circ$



**FNC:** 10 l<sub>1</sub> Pb-sci. sandwich

- $s/E = 65\%/\sqrt{E}$
- e-scale accuracy  $\pm 2\%$

**FNT:** scintillator hodoscope at 1 l<sub>1</sub>

- installed in 1998
- $s_{X,Y} = 0.23$  cm  $\text{P}$   $s_q = 22$  mrad

**LPS:** 6 stations with mstrip detectors

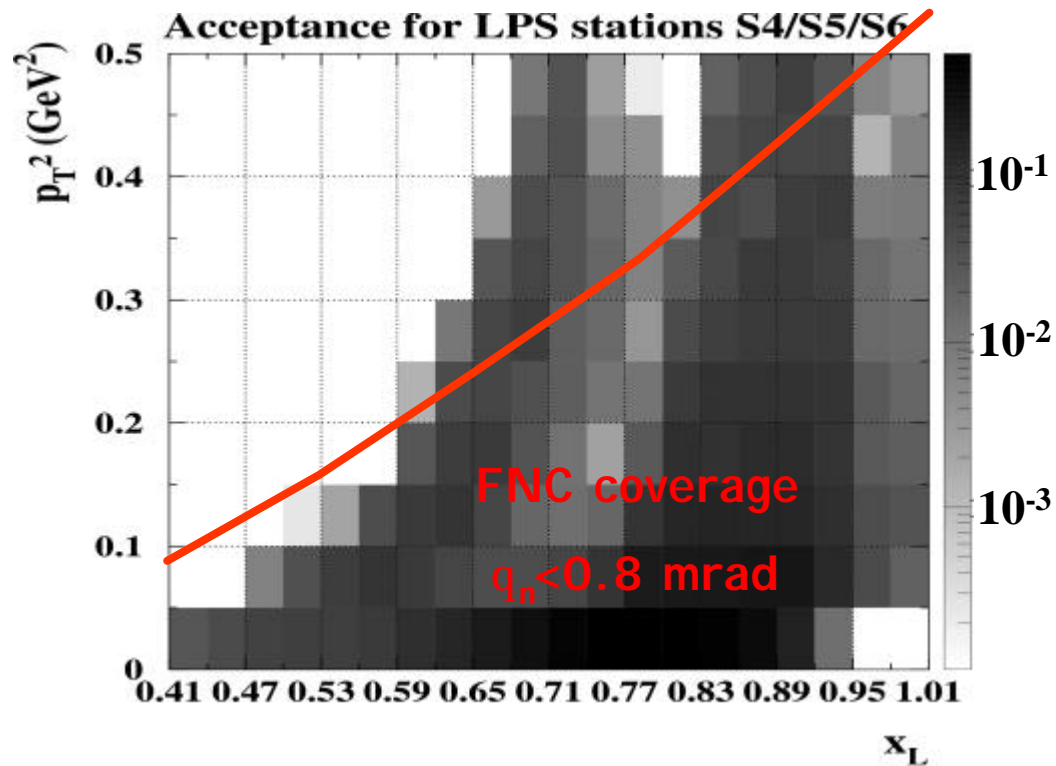
- only stations S4-S6 analyzed sofar
- hit position resolution  $\gg 30$  mm
- $S_{XL} < 1\%$
- $S_{PT} \sim \text{few MeV}$
- momentum accuracy  $< 1\%$

For both,  $p_T$  resolution is dominated by  $p_T$  spread of p-beam (50-100 MeV)

# ZEUS forward detectors: acceptance

Limited by apertures and detector size (LPS)

Integrating over the azimuth:



LPS (s4-s6):

- $p_T$  range varies with  $x_L$ ;
- for  $x_L > 0.6$ ,  $p_T^2 < 0.5$  GeV<sup>2</sup>  
acceptance  $\gg$  15 %

FNC:

- restricted to  $q_n < 0.8$  mrad
- $p_T$  range increases with  $x_L$ ;
- for  $x_L > 0.6$ ,  $q_n < 0.8$  mrad  
acceptance  $\gg$  25 %

## Main Issues in LB analyses

- Measure  $x_L$ , Pt spectra of LB;
- Compare to hadronization and particle exchange models
- Test validity of vertex factorization hypothesis with different reactions
- In LN production, test the validity of OPE  $\longrightarrow S_{gp}, F_p^2$

### In the following:

- **Study of the pion trajectory in gp interactions with LN**  
(DESY-04-037, submitted to Phys. Lett. B, hep-ex/0404002)
- **Study of DIS events containing a LP in 1997 data**  
(EPS03 #544)

# $x_L$ distribution vs $t$ in $gp^{\oplus}nX$ reaction

Aim: test the consistency of the OPE model

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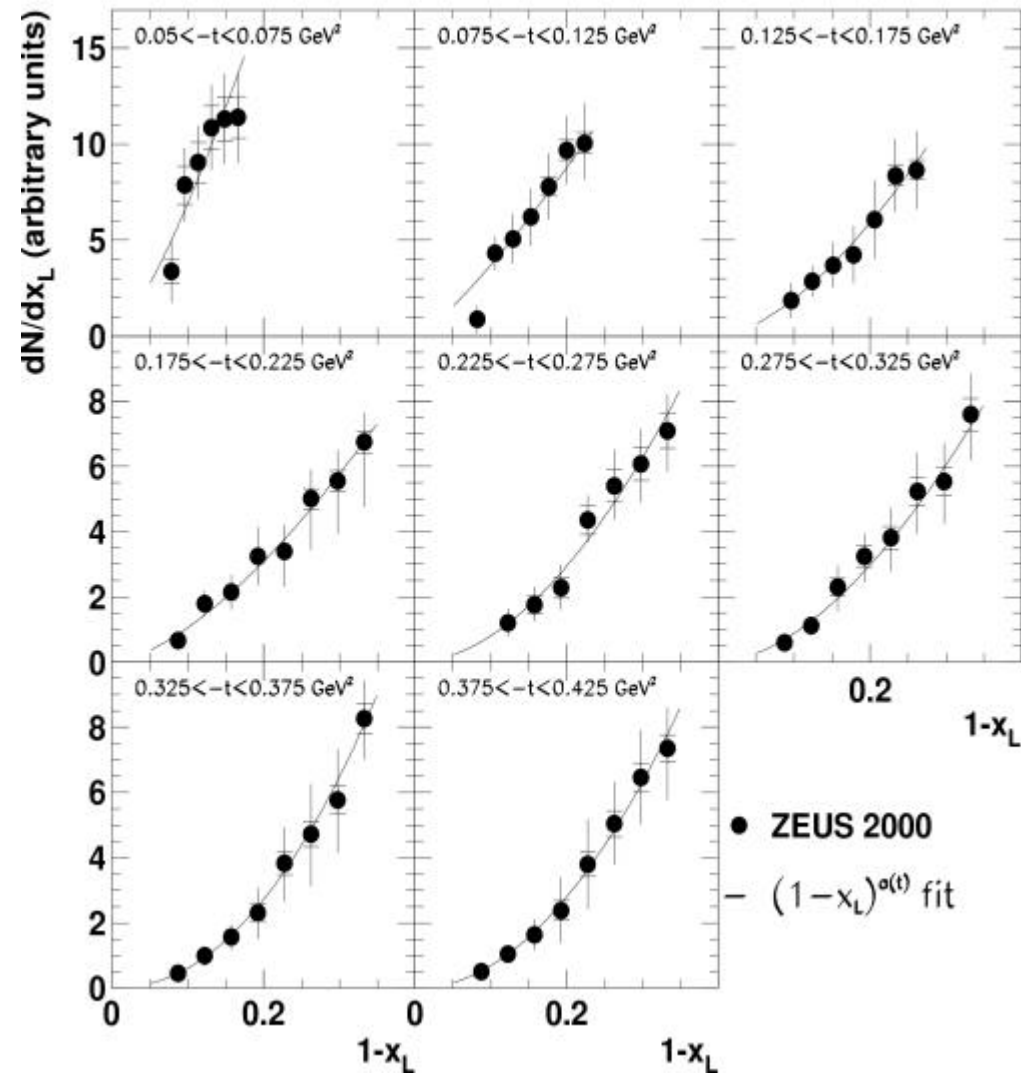
- 2000 data,  $L = 9 \text{ pb}^{-1}$
- special LUMI + FNC trigger
- Kinematic range:

$$\text{Lumi} \begin{cases} Q^2 < 0.02 \text{ GeV}^2 \\ \langle W \rangle = 220 \text{ GeV} \end{cases}$$

$$\text{FNC} \begin{cases} 0.6 < x_L < 0.925 \\ 0.05 < |t| < 0.425 \text{ GeV}^2 \end{cases}$$

- $(1-x_L)$  distributions are consistent with a power-law dependence

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



# Interpretation: the reggeized OPE model

$$\frac{d^2 \mathbf{S}_{gp \rightarrow nX}}{dx_L dt} = f_{p/p}(x_L, t) \cdot \mathbf{S}_{gp}(s' = (1-x_L)W^2)$$

**Pion flux:**  $f_{p/p}(x_L, t) =$

$$= \frac{g_{npp}^2}{8\mathbf{p}^2} \frac{-t}{(m_p^2 - t)^2} (1-x_L)^{1-2a_p(t)} [F(t)]^2$$

where  $a_p(t) = a'_p(t - m_p^2)$

**Total gp cross section:**

$$\mathbf{S}_{gp}(s') = A(s')^e + B(s')^{-h}$$

$e \gg 0.1$  (IP) and  $h \gg 0.5$  (IR)

dominant term even at largest  $x_L$

$\longrightarrow$  ( $s'_{\min} \approx 60$  GeV)

Neglecting the  $(s')^{-h}$  term, the OPE model predicts the power law dependence  $dN/dx_L \propto (1-x_L)^{a(t)}$  where:

$$a(t) = 1 + \mathbf{e} + \cancel{2\mathbf{a}'_p m_p^2} - 2\mathbf{a}'_p \cdot t = \mathbf{a}_{IP}(0) - 2\mathbf{a}'_p \cdot t$$

ignored
Pomeron intercept  $\nearrow$ 
Pion slope  $\nwarrow$

# Powers $a(t)$ as a function of $t$

Powers  $a(t)$  nicely fit to a line.

Assuming  $a(t) = a_{\text{IP}}(0) - 2a'_p \cdot t$  yields

$$a_{\text{IP}}(0) = 1.08 \pm 0.08^{+0.15}_{-0.28}$$

$$a'_p = 1.39 \pm 0.16^{+0.26}_{-0.24} \text{ GeV}^{-2}$$

Consistent with:

✓ soft pomeron intercept  $a_{\text{IP}}(0) \gg 1.1$

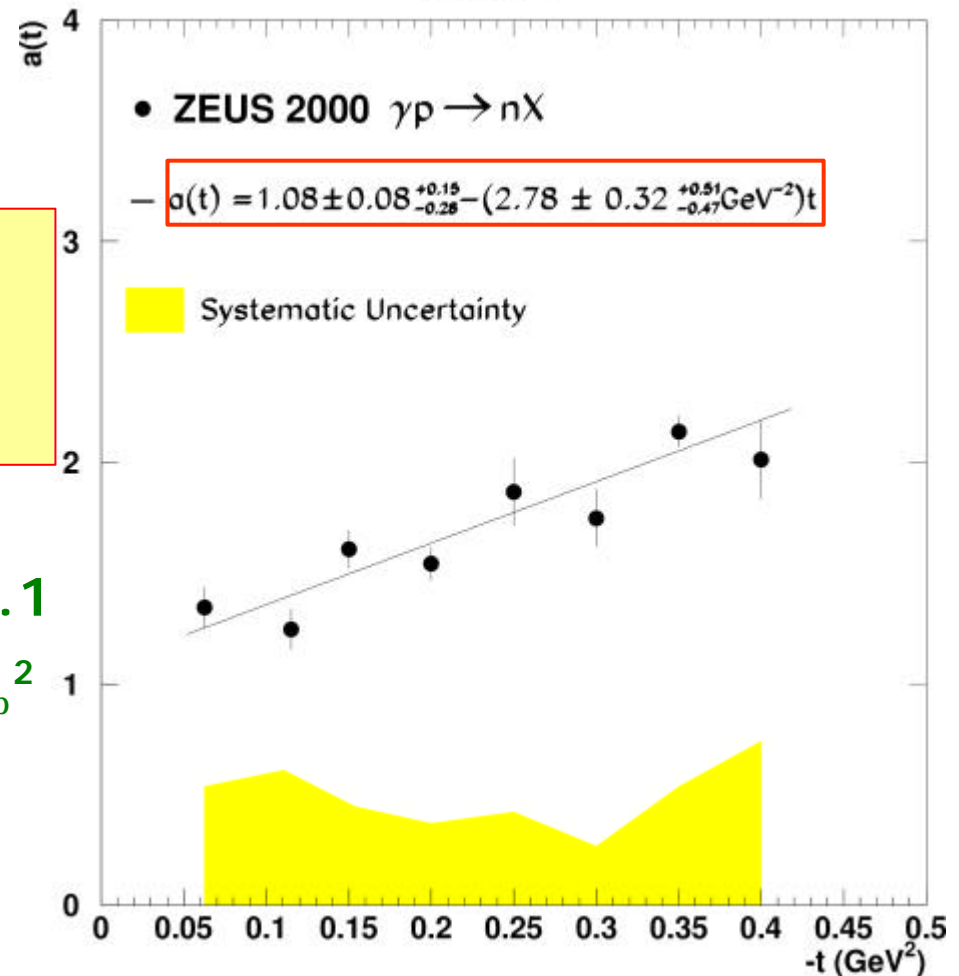
✓ pion trajectory  $a_p(t) = t - m_p^2$

Note: contribution of a r trajectory

$$a_r(t) = 0.5 + t$$

would lead to  $a(t) = \underline{2.08} - 2 \cdot t$

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Data further support OPE as the dominant process in  $gp \rightarrow nX$  reaction

# DIS events containing a leading proton

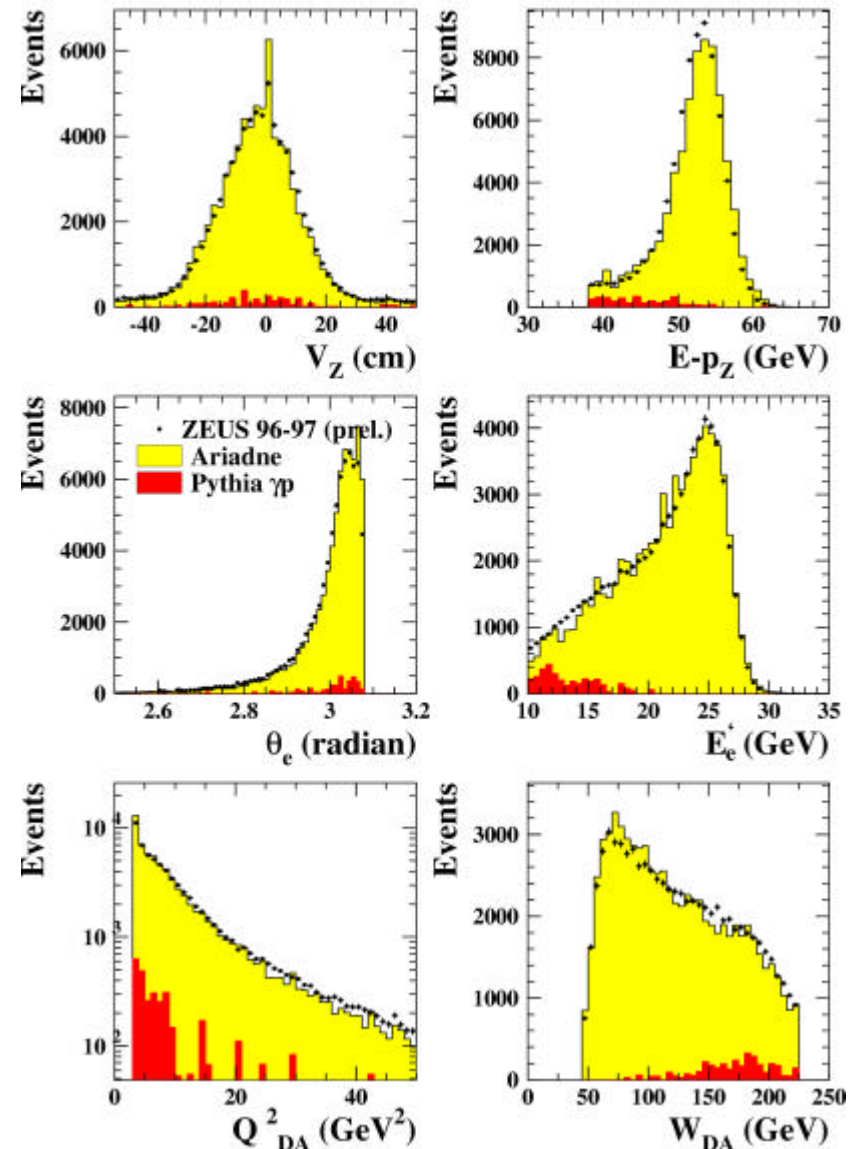
- 1997 data,  $L = 12.8 \text{ pb}^{-1}$ 
  - **4 X larger statistics !**
- Standard DIS selection + LPS track
  - $D_{\text{pipe}} > 0.4 \text{ mm}$
  - $D_{\text{pot}} > 0.2 \text{ mm}$
  - $E + P_z > 1655 \text{ GeV}$  (rejects beam halo)
- DA reconstruction used
- Kinematic range:

$$\text{CAL} \begin{cases} Q^2 > 3 \text{ GeV}^2 \\ 45 < W < 225 \text{ GeV} \end{cases}$$

$$\text{LPS} \begin{cases} x_L > 0.56 \\ p_T^2 < 0.5 \text{ GeV}^2 \end{cases}$$

track  
containment

ZEUS LPS Stations 456



# DIS events containing a leading proton

- MC used:

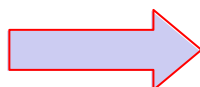
- **Ariadne+SCI** (diff. and nondiff. DIS)  
( $K^+$  and  $p^+$  contamination)

- **Pythia** (PHP)

- Reweight Ariadne to reproduce LP data distributions

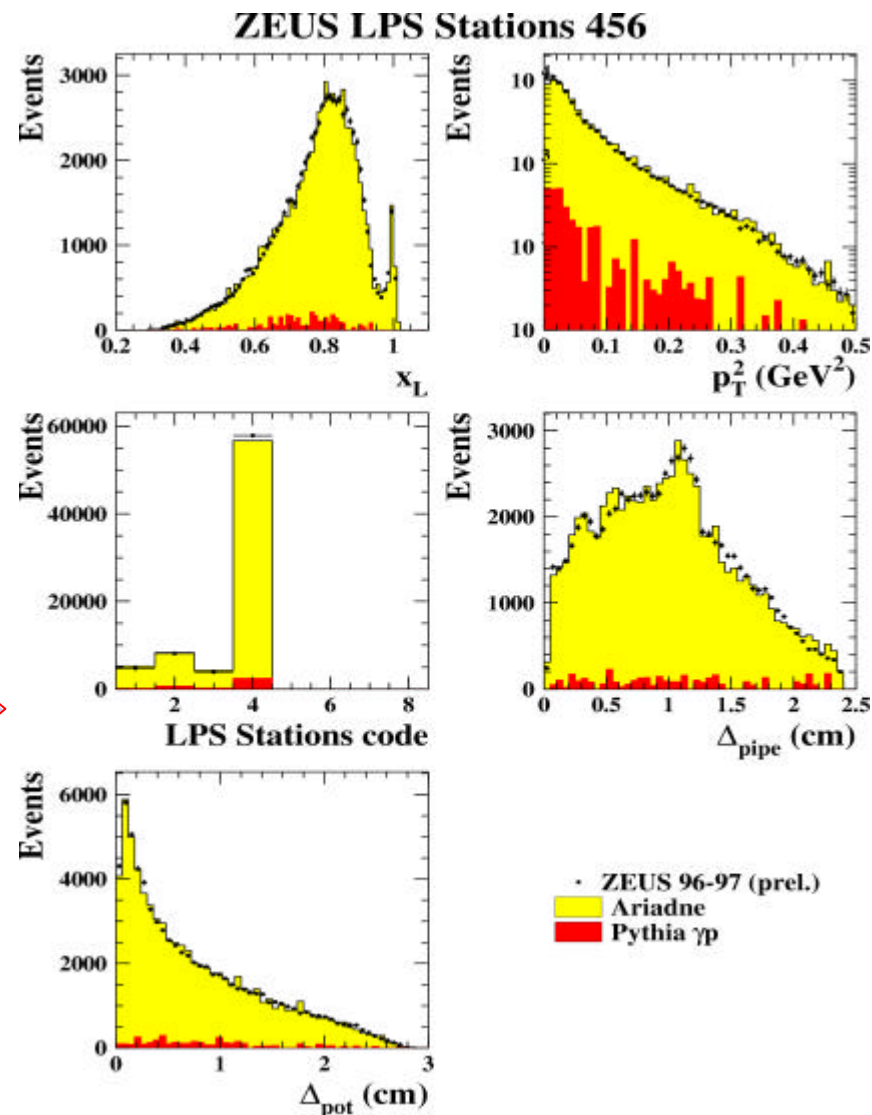
- flat  $x_L$  (nondiff. part)
  - exponential  $p_T^2$  with  $b=7.0 \text{ GeV}^{-2}$
  - diff/total in bins of  $x_L$

good description



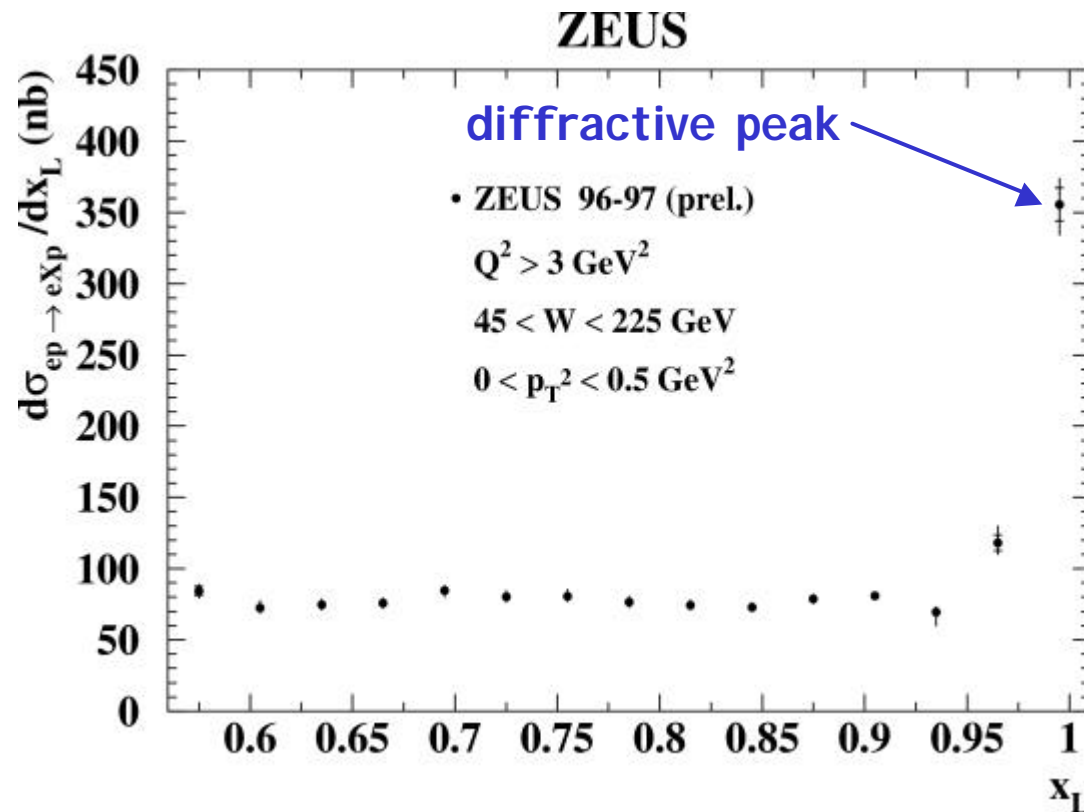
- Remaining background:

- **PHP** and low  $Q^2$  (11%)
  - residual **beam halo** (7% at  $x_L > 0.98$ )
  - $K^+$  and  $p^+$  (max 8% at  $x_L = 0.56$ )



Note:  $K^+$  and  $p^+$  contamination cross-checked with LPS+FNC coincidences

## Cross section vs $x_L$



- Constant bin widths chosen according to resolution ( $\Delta x_L = 0.03$ )

- Syst. uncertainties added.

- vary  $V_z$ ,  $Ee'$ ,  $E-p_z$  cuts
- vary  $D_{\text{pipe}}$  and  $D_{\text{pot}}$  cuts
- vary MC  $p_T^2$  slope
- vary  $K^+$  and  $p^+$  fraction

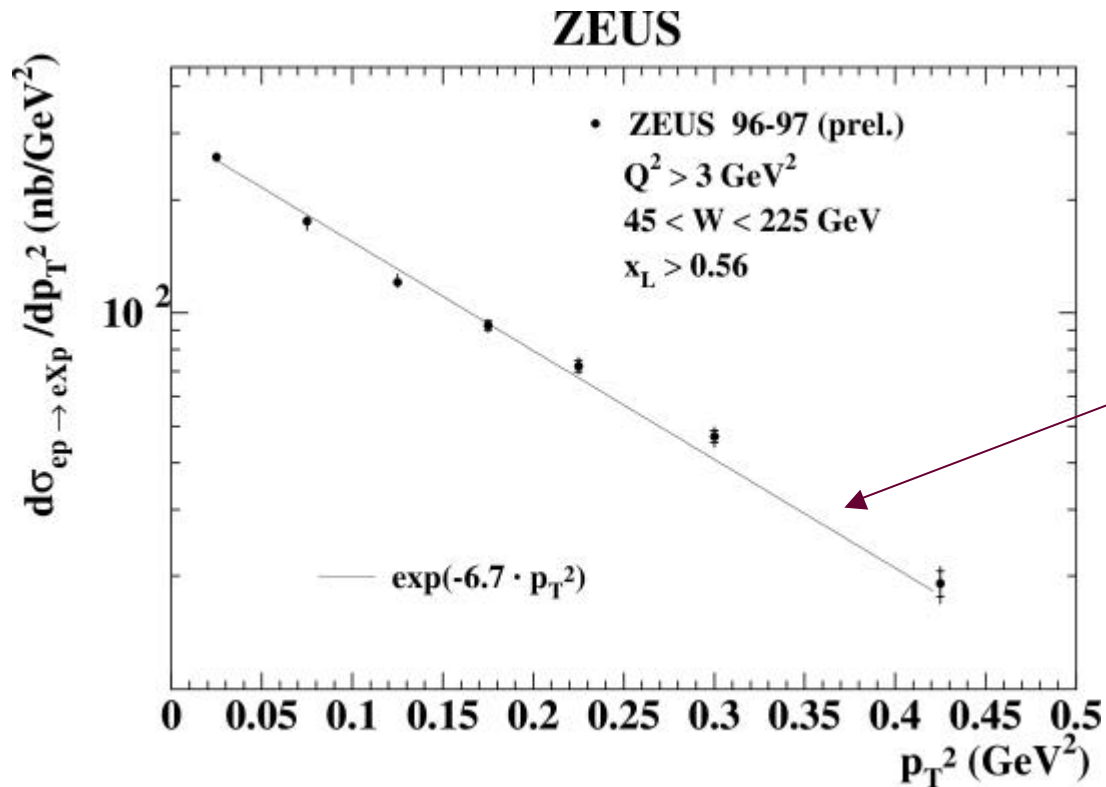
Effect normally within statistical error

➡ data precise !

Flat distribution up to the diffractive peak (expected from pp interactions)

Note: p-dissociative diffraction included in low  $x_L$  spectrum

## Cross section vs $p_T^2$



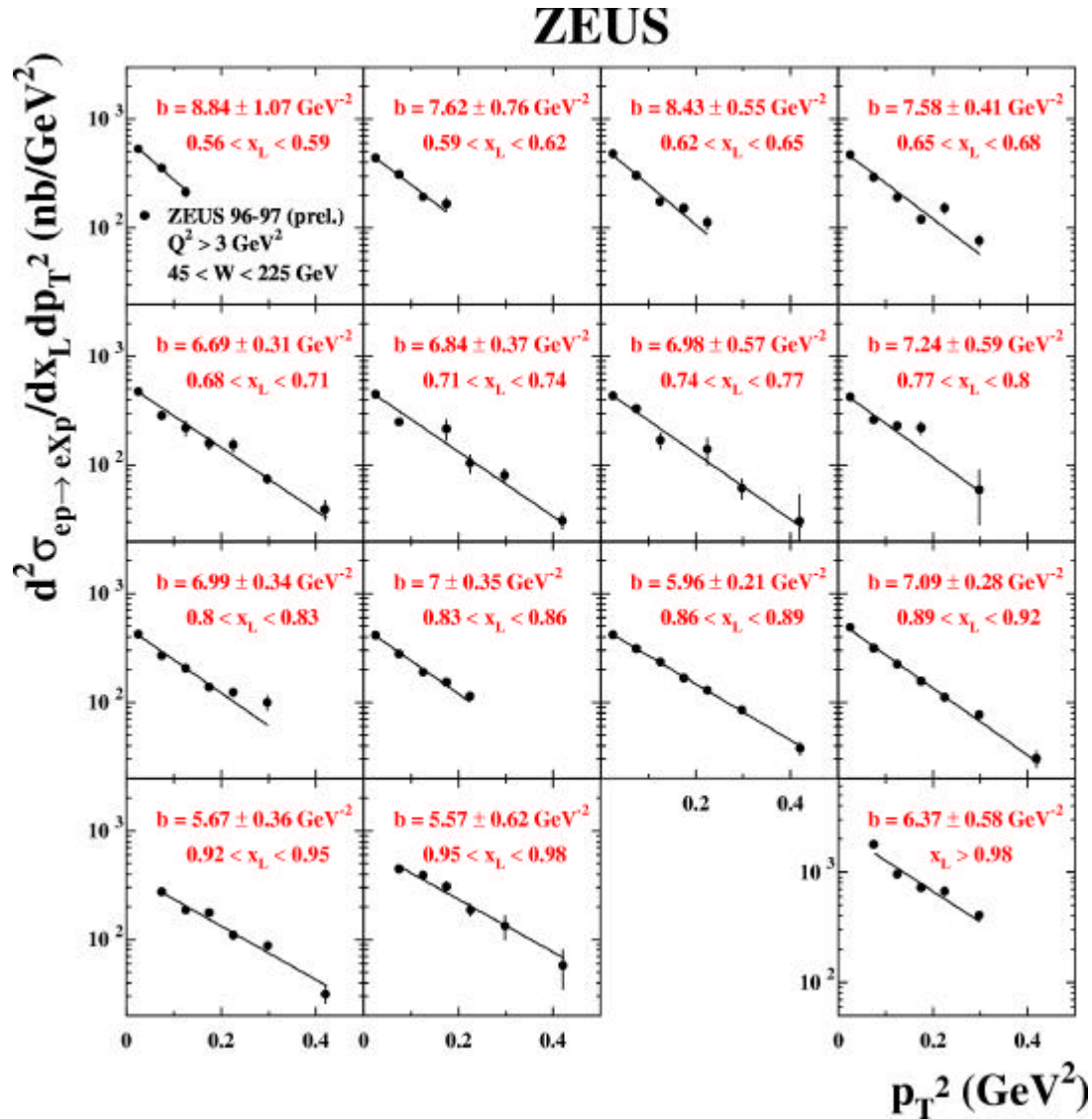
- Variable bin widths chosen according to  $p_T^2$  resolution
- Line shown is just to guide the eye

- Decrease by an order of magnitude in the  $p_T^2$  range considered;
- data are not well described by exponential function with single slope



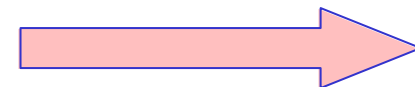
steepness decreases at high  $p_T^2$

# Cross section vs $p_T^2$ and $x_L$

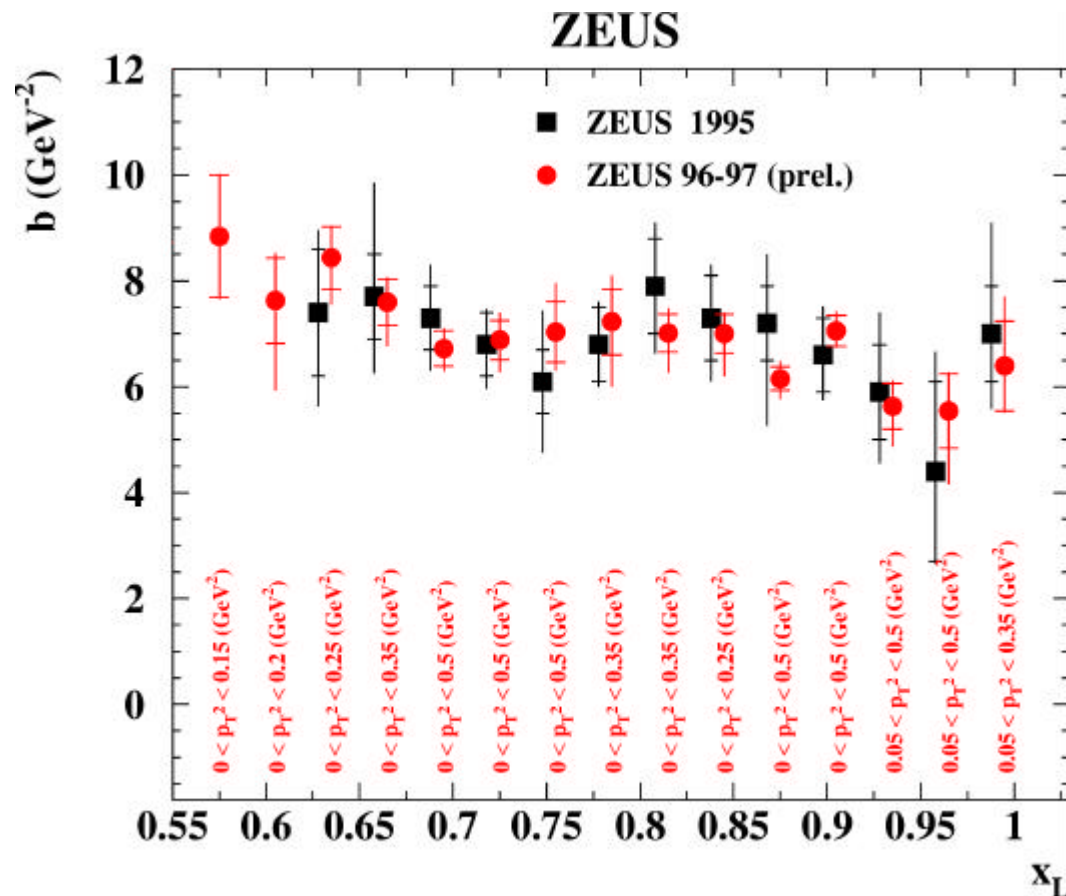


- $p_T^2$  range in each  $x_L$  bin determined by LPS acceptance range;
- few bins with low or unstable acceptance excluded;
- fit to exponential function with single slope performed in each bin;

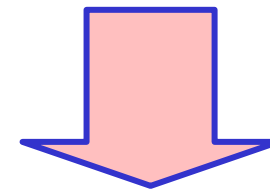
$$\frac{d^2 S}{dx_L dp_T^2} \sim e^{-b(x_L) \cdot p_T^2}$$



## b-slopes vs $x_L$



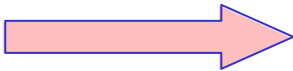
- Result consistent with 95 measurement;
- smaller slopes observed around  $x_L=0.75$  and  $x_L=0.95$ ;



partially explained as the effect of the **different  $p_T^2$  range** in different  $x_L$  bins.

No clear evidence of  $x_L$  dependence of the exponential fall-off with  $p_T^2$

## Summary

- Lot of leading baryon pre-upgrade data are available; analyses still alive and making progresses
  - LN  $(1-x_L)$  distributions in gp interactions measured at fixed t
    - satisfy power law  $dN/dx_L \mu (1-x_L)^{a(t)}$
    - $a(t)$  consistent with pion trajectory being exchanged
-  supports OPE model
- LP DIS cross section measured with high statistics vs  $x_L$  and  $p_T^2$ 
    - flat  $x_L$  distribution below diffractive peak
    - exponential fit with single slope inadequate
    - falling  $p_T^2$  distribution almost independent of  $x_L$

## Outlook

- Increase knowledge on  $x_L$ ,  $p_T$  spectra, vertex factorisation by completing the analyses of the available data
- Extend the  $x_L$  range (LPS) by adding the S1-S3 stations
- Theoretical input needed....