Leading Baryon Production at ZEUS

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Leading Baryons production

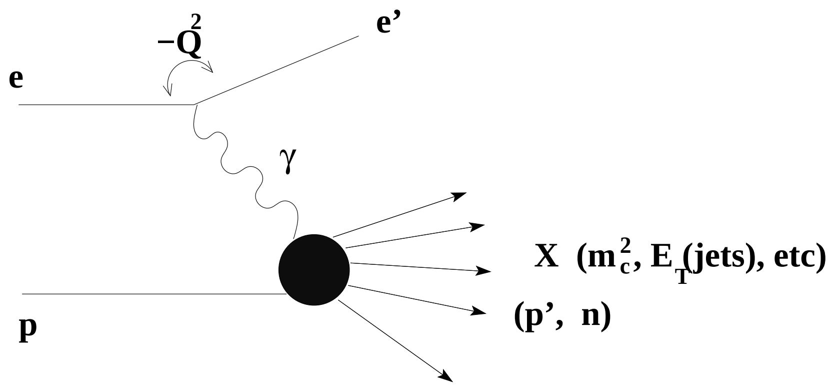
. *In a large fraction of events p,n carry a large fraction of the proton beam energy*

- typically $0.2 < x_L = \frac{E_{LB}}{E_p} < 1$

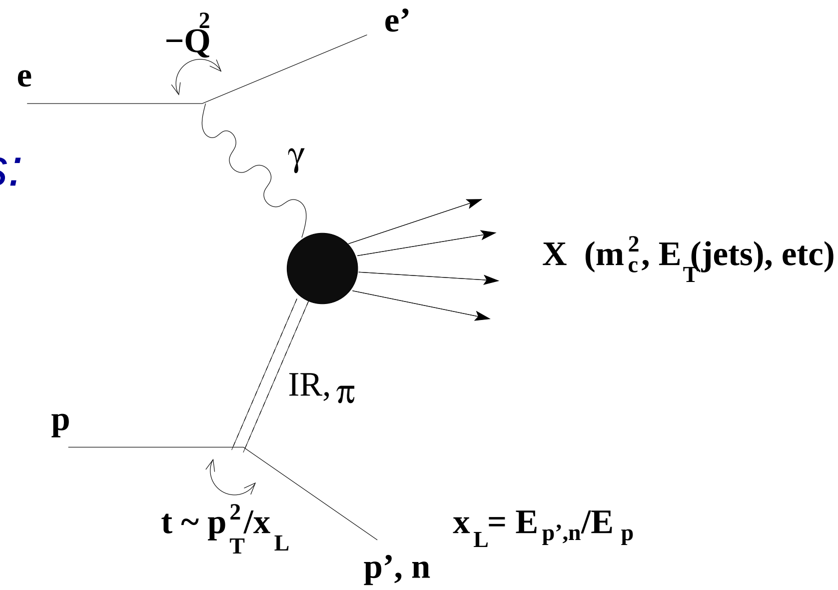
. *Good ground to study soft vs hard physics:*

- hard scale: e.g. $Q^2,\ m^2_{HQ},\ E_T^{jet}$
- soft scale: p_T of the baryon

. *Tests of Leading Baryon production models:*



standard fragmentation

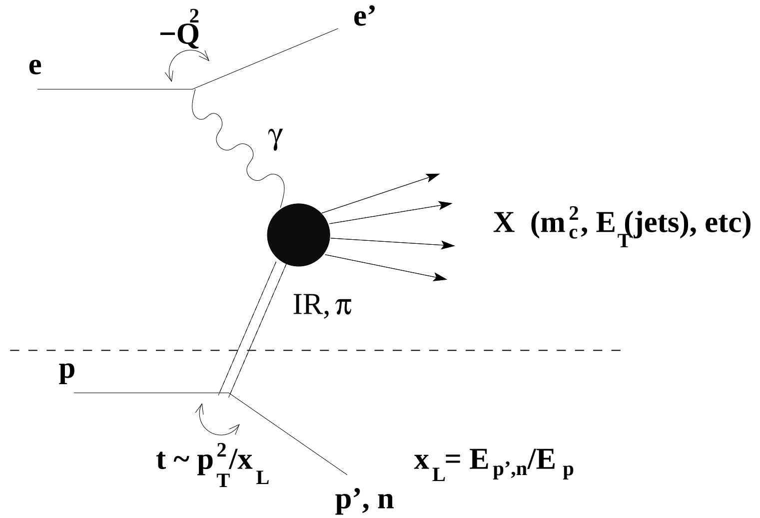


particle exchange (dominant process)

Leading Baryon production

. Probe structure function of the exchanged particle:

- e.g. leading neutrons: $\sigma_{LN} = f(x_L, t) \times \hat{\sigma}^{\gamma\pi}_{hard}$
- especially important to region inaccessible to Drell-Yan *(gluons and sea)*



. Vertex factorization:

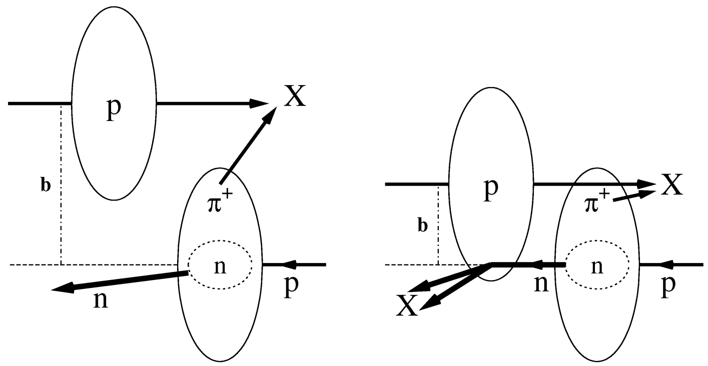
- In the dominant process: leading baryon production is independent of the photon vertex variables
- Many models predict factorization violation (absorption)

Listing only a few...

Factorization violation models (for Leading Neutrons)

Model 1:

d'Alesio and Pirner, EPJ A7 (2000) 109



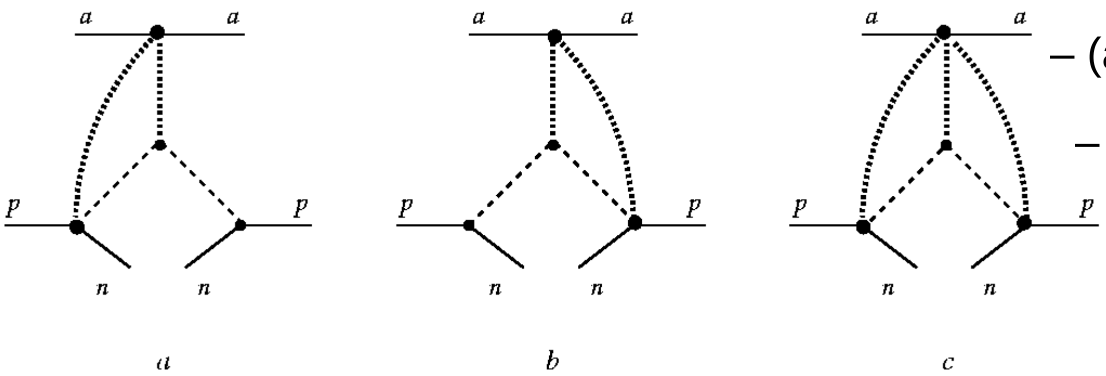
– substitute the proton by a photon for ep collisions

– the larger the photon, fewer neutrons detected (more absorption in PHP than DIS)

– the smaller the πn system, fewer neutrons detected (more absorption in low x_L)

Model 2:

Nikolaev, Speth and Zakharov, hep-ph/9708290



– absorption from additional pomeron exchange

– (a)-(c) contribute to the dominant process

– absorption effects different for ep and pp

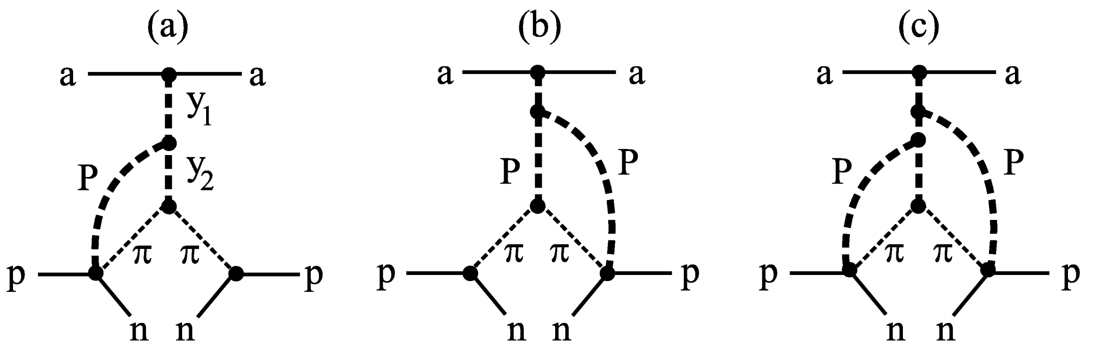
– implies large uncertainties to pion *pdf* extraction

Factorization violation models (for Leading Neutrons)

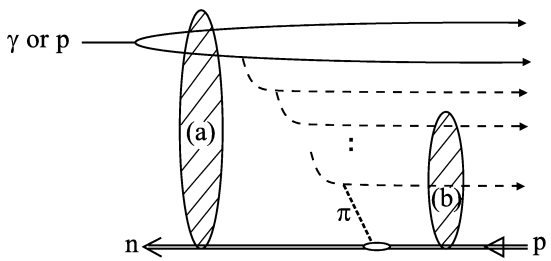
Model 3: *Kaidalov, Khoze, Martin, Ryskin, hep-ph/062215*

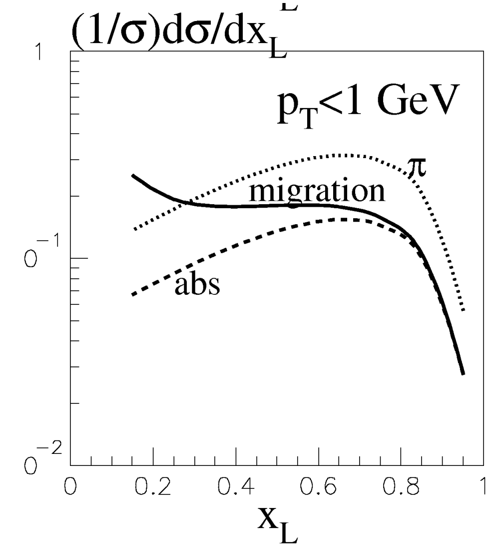
– refine the corrections in Model 2

– calculate *enhanced absorptive corrections* (gap survival probability)

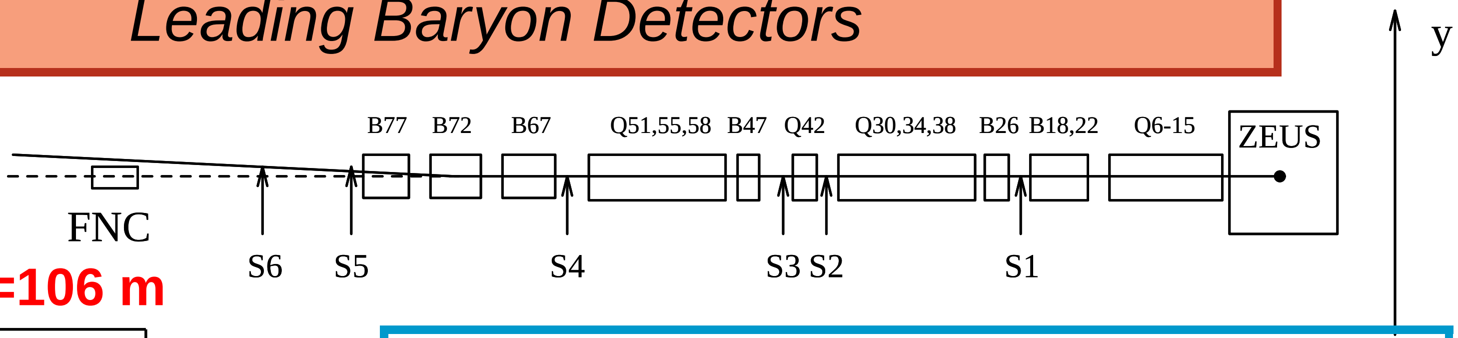


– calculate *migrations* (distortions to energy spectra after absorption)

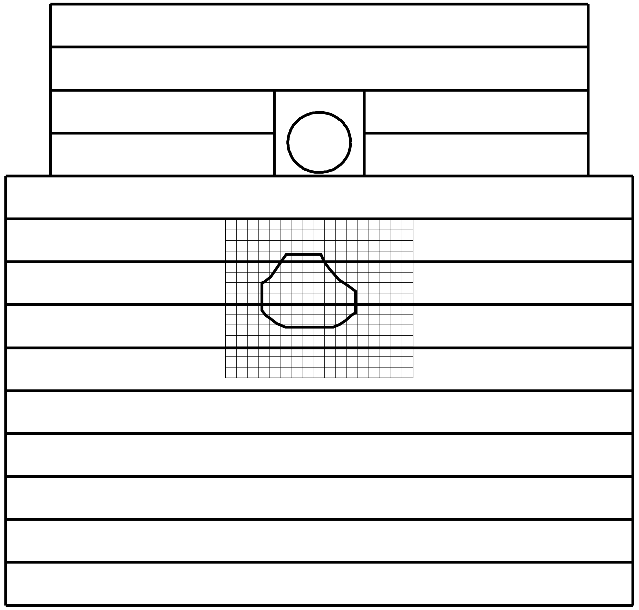




Leading Baryon Detectors



Z=106 m



$$p_T^2 = E_n^2 \frac{(X_{FNT}-x_0)^2+(Y_{FNT}-y_0)^2}{Z^2}$$

Leading Proton Spectrometer

. silicon μstrips (6 stations)

. $\sigma_{x_L} < 1\%$, $\sigma_{p_T} \sim 5$ MeV

Forward Neutron Calorimeter (FNC)

. 10 λ_l Pb-sci. sandwich

. $\sigma/E = 0.65/\sqrt{E}$, energy scale accuracy $\pm$ 2%

Forward Neutron Tracker (FNT)

. sci. hodoscope at 1 λ_l (position detector)

. $\sigma_{X,Y}$ = 0.23 cm $\rightarrow$ $\sigma_\theta = 22$ μrad

p_T resol. dominated by p_T spread of p beam (50-100 MeV)

Data samples: ep and γp

Deep Inelastic Scattering ($ep \to Xn$)

40 pb^{-1}

$Q^2 > 2$ GeV^2

neutron: $0.2 < x_L < 1$

$\theta_n < 0.75$ mrad

Photoproduction ($\gamma p \to Xn$)

6 pb^{-1}

$Q^2 < 0.02$ GeV^2

neutron: $0.2 < x_L < 1$

$\theta_n < 0.75$ mrad

Dijets in Photoproduction ($\gamma p \to jjXn$)

40 pb^{-1}

$E_T^{jet_1} > 7.5$ GeV, $E_T^{jet_2} > 6.5$ GeV

$-1.5 < \eta^{jet_{1,2}} < 2.5$

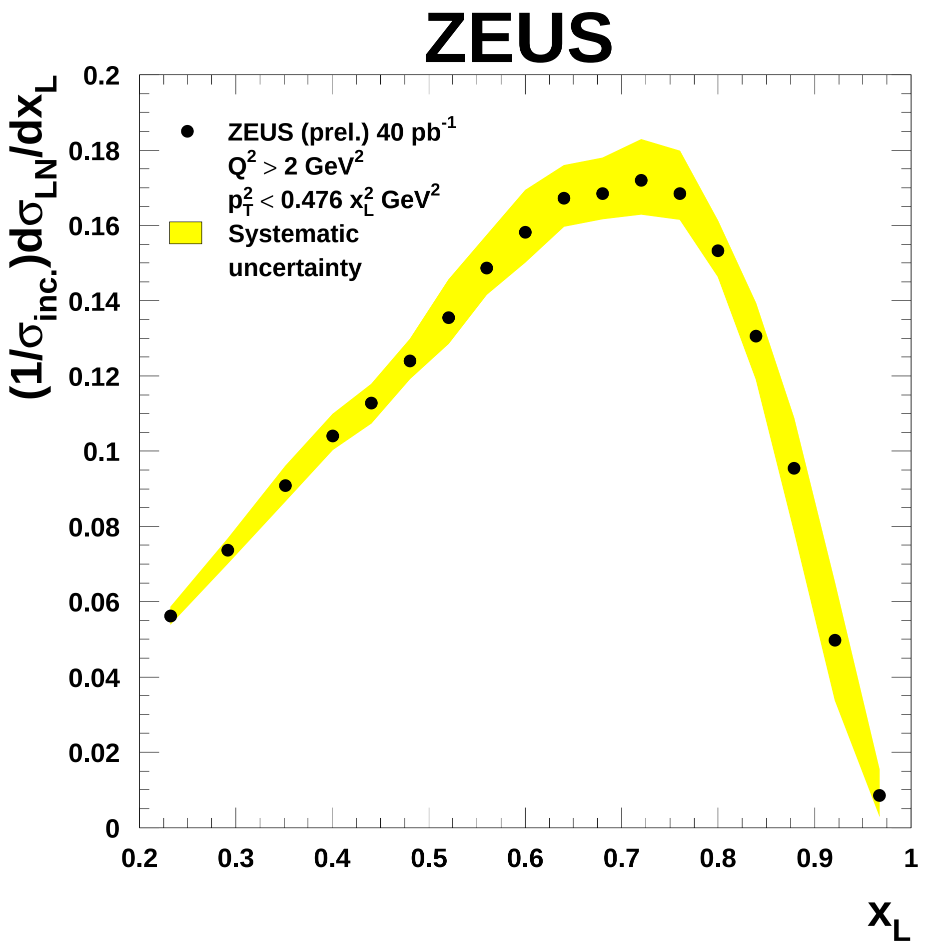
$Q^2 < 1$ GeV^2

$130 < W < 280$ GeV

neutron: $0.2 < x_L < 1$

$\theta_n < 0.75$ mrad

Leading Neutron in DIS



$x_L = \frac{E_n}{E_p}$

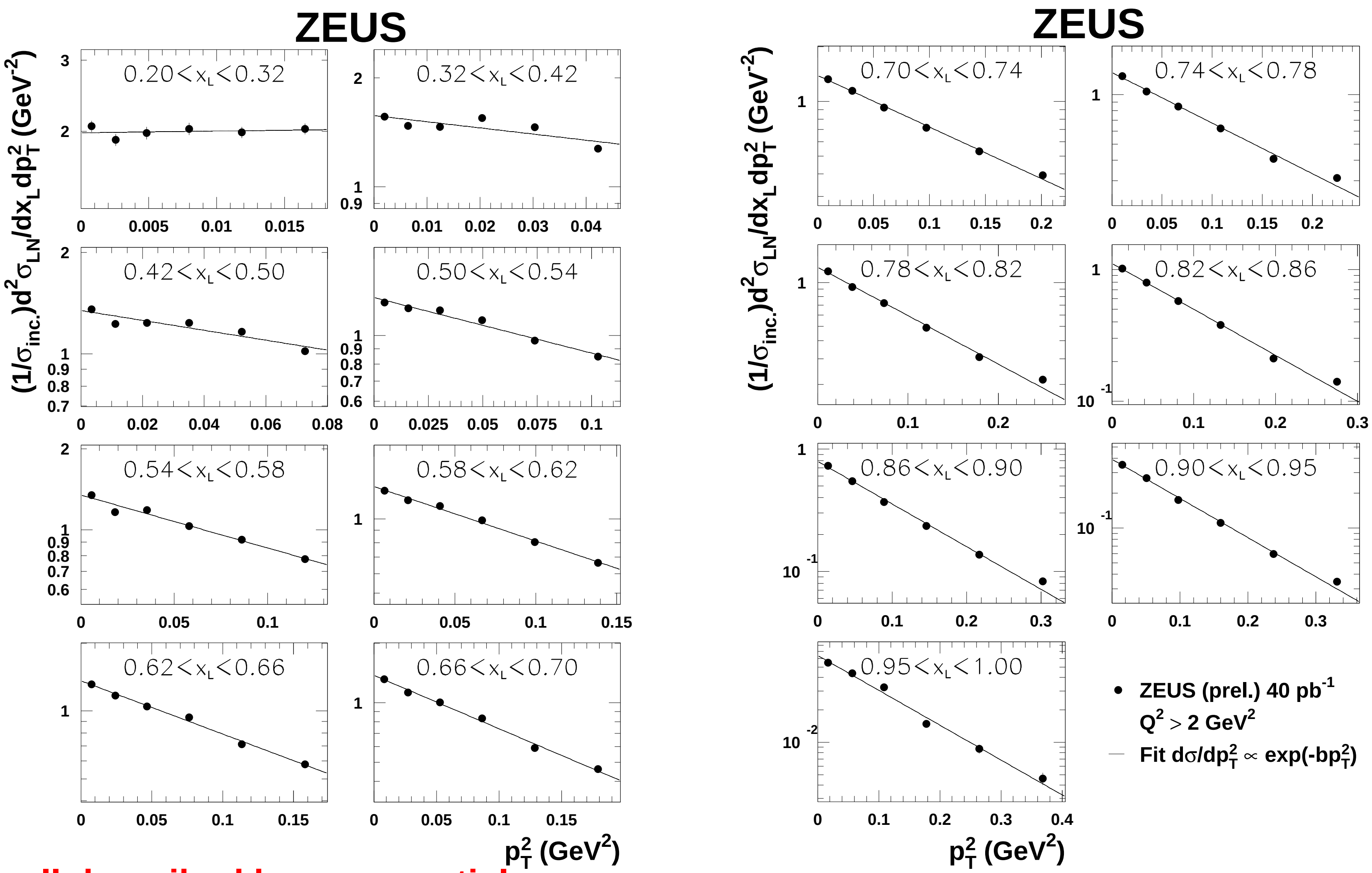
$\theta_n < 0.75$ mrad

$\longrightarrow$ limit of geometric acceptance

(integrated over p_T^2)

Normalization: $\sigma_{\text{inc}} = \sigma(ep \to eX)$

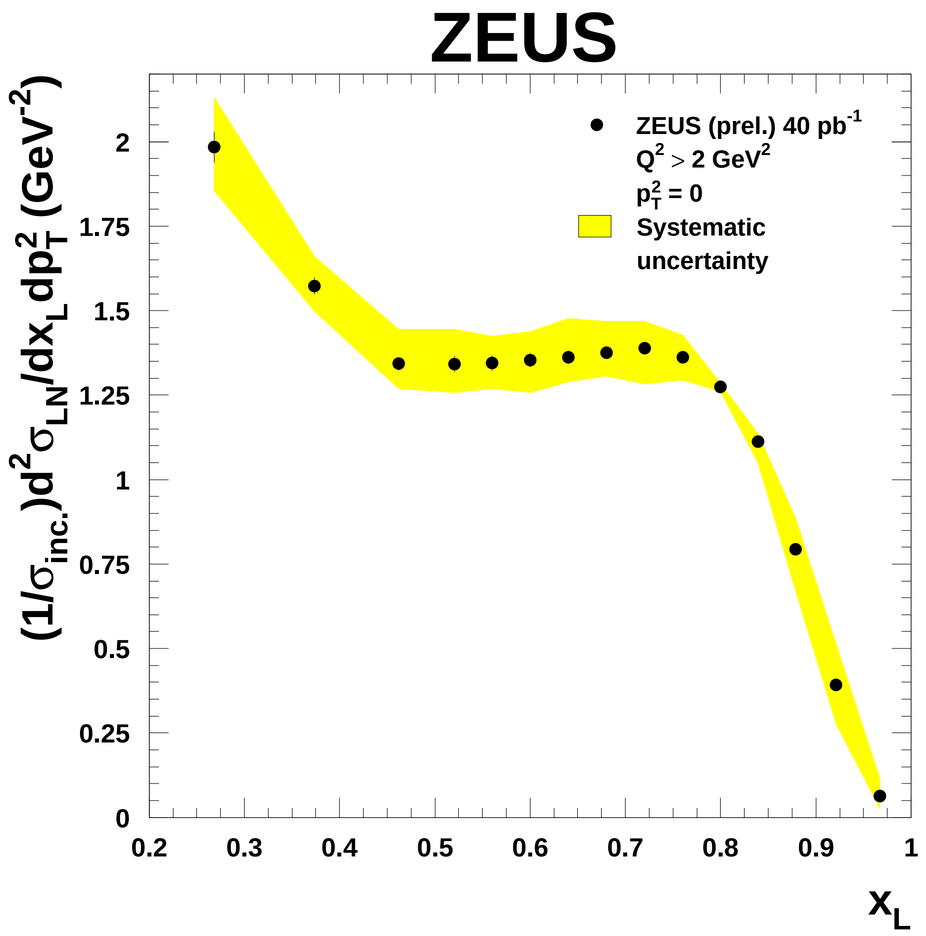
Leading Neutron in DIS - $d\sigma_{LN}/dx_L dp_T^2$



Data well described by exponential

intercept (= $d\sigma_{LN}/dx_L dp_T^2|_{p_T^2=0}$**) and b-slope (from** $e^{-bp_T^2}$**) fully characterize the data**

Leading Neutron in DIS (intercept)

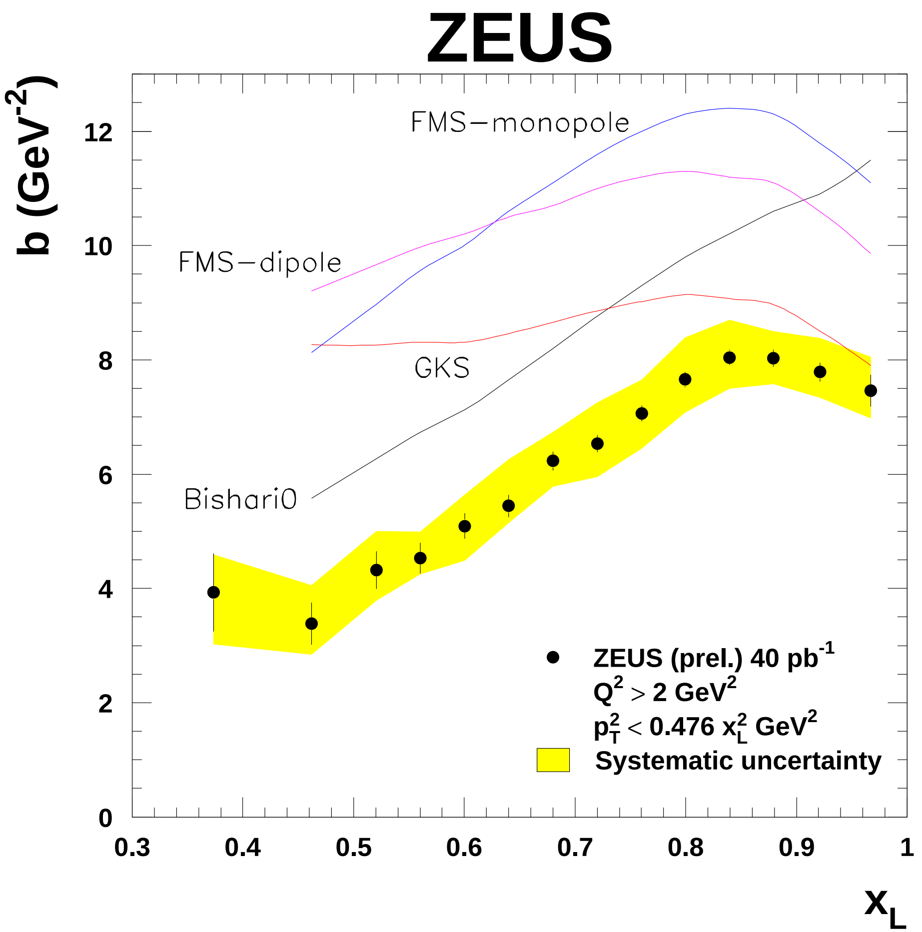


$$\frac{d\sigma_{LN}}{dx_L dp_T^2}\Big|_{p_T^2=0}$$

(intercept)

Normalization: $\sigma_{\text{inc}} = \sigma(ep \to eX)$

Leading Neutron in DIS (slope)



One-Pion-Exchange Model:

$$\frac{d\sigma_{ep\to e'nX}}{dx_L t} = f_{\pi/p}(x_L,t)\sigma^{e\pi}(s')$$

. s' = squared cm energy of the $e\pi$ system

. Pion flux factor:

$$f_{\pi/p}(x_L,t) \propto \frac{-t}{(t-m_\pi^2)^2}(1-x_L)^{1-2\alpha(t)}\,[F(x_L,t)]^2$$

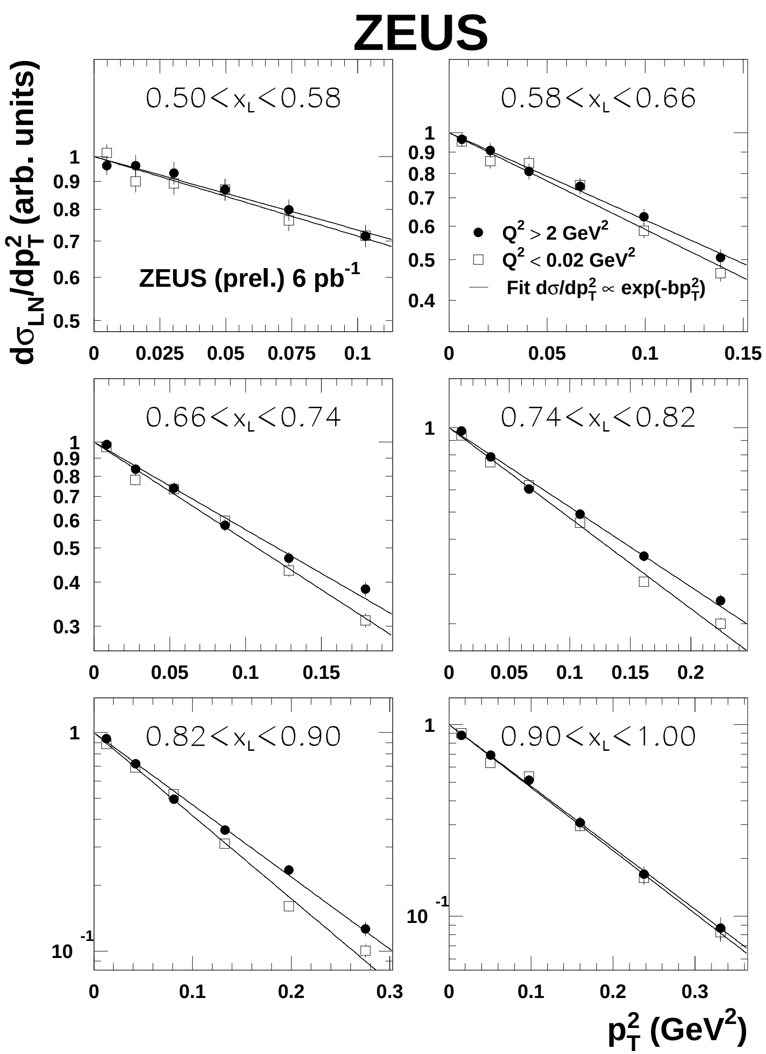
. t = sq. 4-momentum transfer @ p vertex

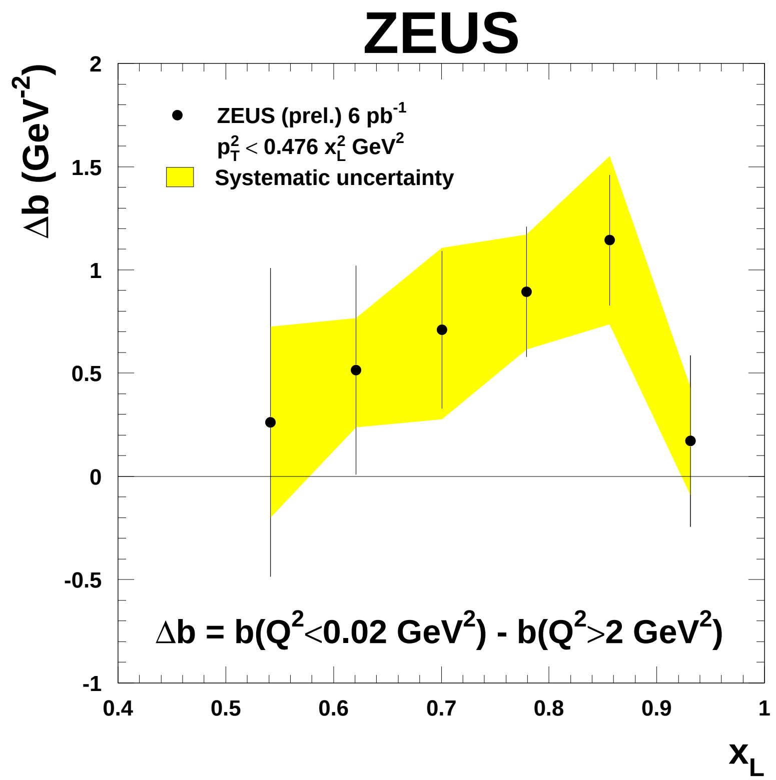
$$\approx -\frac{p_T^2}{x_L} - \frac{(1-x_L)}{x_L}(m_n^2 - x_L m_p^2)$$

models: $\neq$ parametrizations for $\alpha(t)$ and $F(x_L,t)$

no agreement in scale, reasonable agreement in shape

Photoproduction vs. DIS - $d\sigma/dp_T^2$

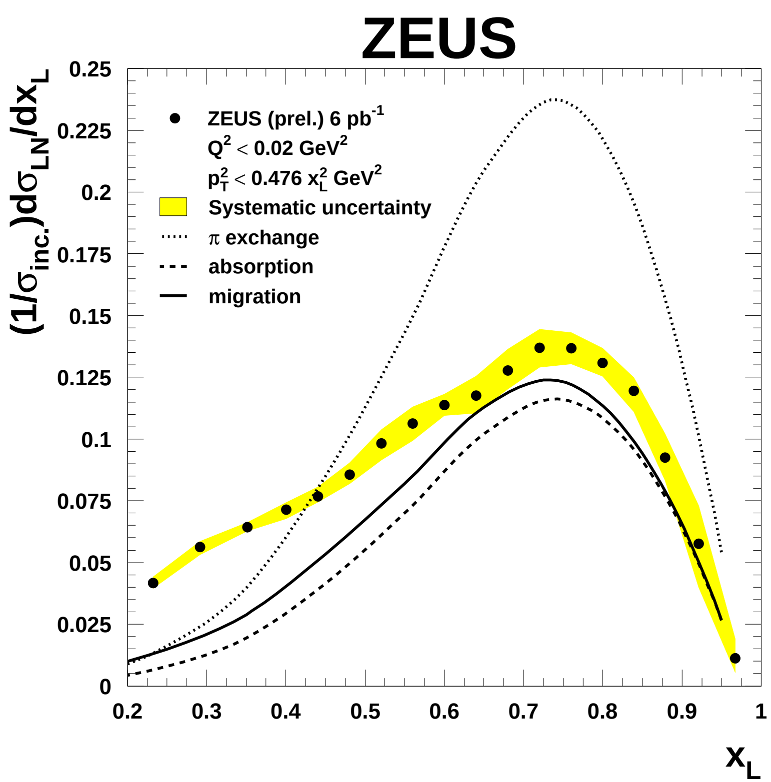


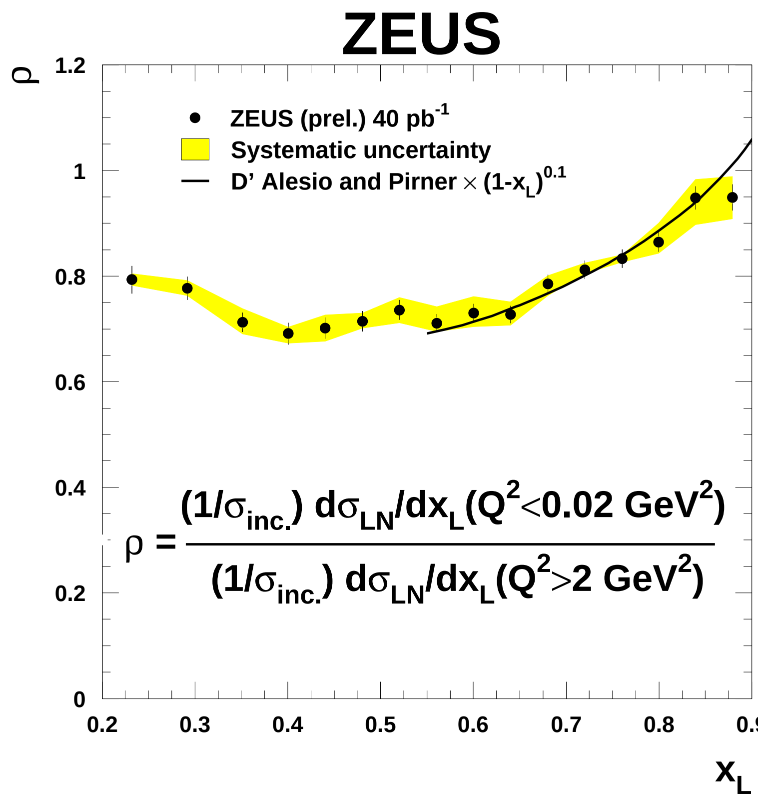


Clear difference between DIS/photoproduction

Normalization: unity @ $p_T^2 = 0$

Photoproduction - $d\sigma/dx_L$



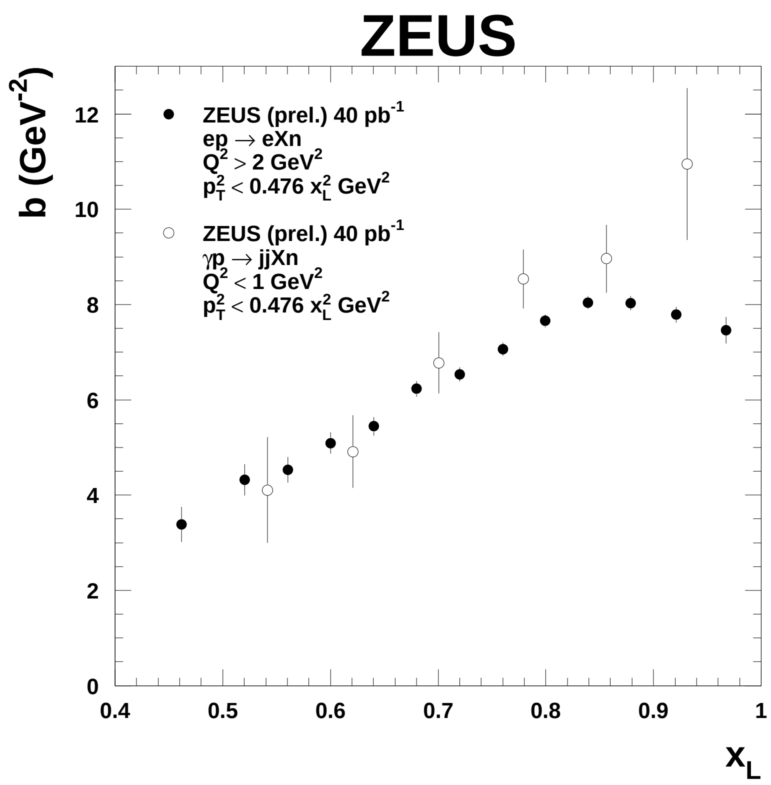


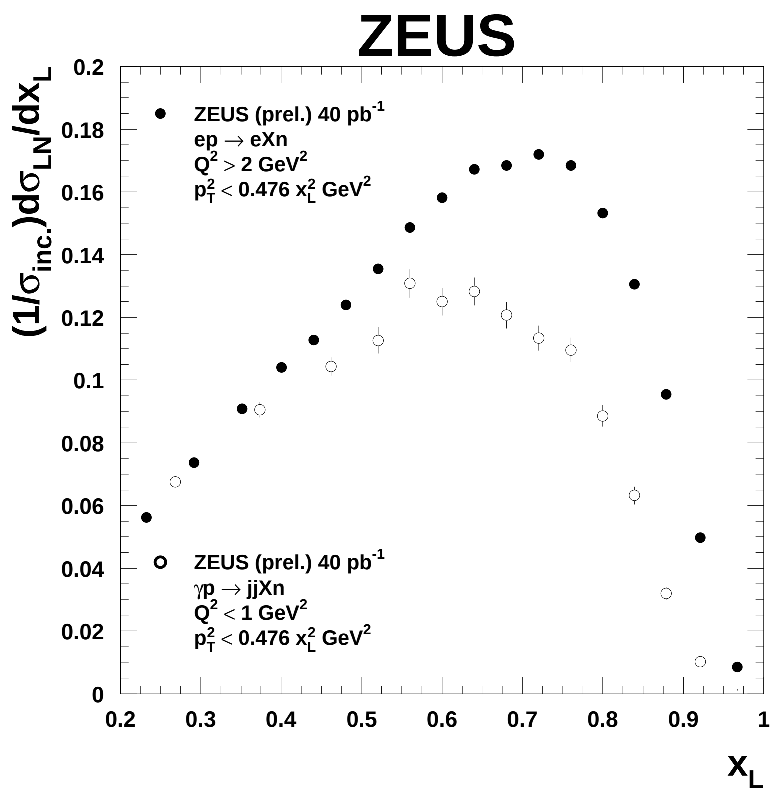
Curves from "Model 3" (Kaidalov, Khoze, Martin, Ryskin) for $p_T^2 < 0.43 x_L^2$ GeV^2

Curve from "Model 1" (d'Alesio and Pirner)

data in agreement with absorption hypothesis

Dijets in Photoproduction vs. DIS





- b-slopes similar magnitude in DIS and dijets samples
- Normalization, shape of the neutron energy spectrum visibly different between DIS and dijet

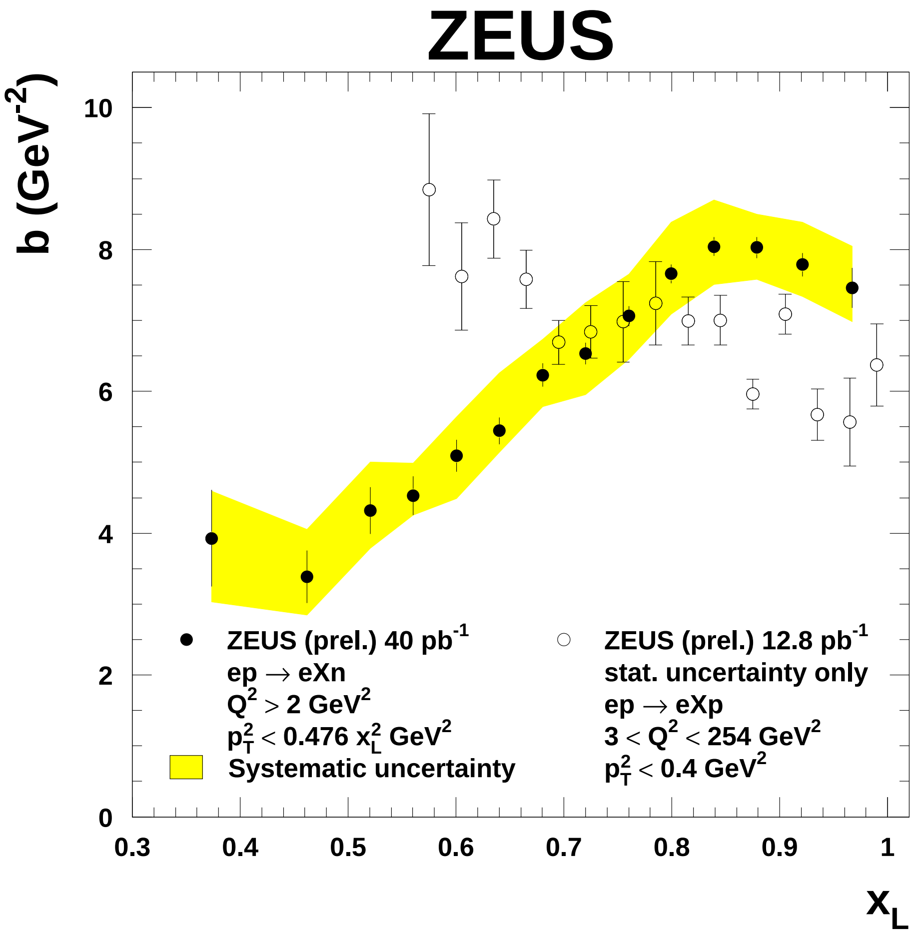
suggestive of phase space limitation

- with very energetic dijets in the final state, little room is left for neutron production -

- *harder to draw any conclusion on absorption*

Comparison: Leading Neutrons vs. Leading Protons

- Protons: $Q^2 > 3$ GeV^2
- Neutrons: $Q^2 > 2$ GeV^2
- Different trends
- LN: main contribution: π exchange
- LP: contribution of other trajectories
- Similar magnitude x_L $\sim$0.6-0.8
  $\rightarrow \pi$ exchange LP $\sim$ LN



Summary

- Most precise measurement of neutron $x_L,\ p_T$ distributions in ep collisions was presented

- The measured p_T distributions are not in good agreement with any ‘version’ of the OPE model available in the literature

- Photoproduction vs. DIS :
  LN production suppressed for photoproduction, high-p_T, low x_L
  Agrees with absorption within OPE

- Neutron energy spectra in photoproduction is compatible with effects of *absorption* and *migration* as predicted by Kaidalov, Khoze, Martin, Ryskin

Summary

- Leading neutrons in dijet photoproduction have similar slopes but different energy spectra than in DIS *(phase space constraints)*

- **Comparison Leading Protons:**
  steep rise as of $b(x_L)$ in LN vs. flat behavior in LP *(other exchanges)*
- The $b-$slopes of protons and neutrons agree at $x_L \sim$ 0.6-0.8 where pion-exchange is dominant in both cases

- Potential interests on LN data:
  - Information on the pion structure function
  - Understanding *gap survival probability* (important at LHC) ...
- ... but for that several issues need to be addressed:
  - Pion flux factor models must be constrained
  - The role of absorption (e.g. in dijet photoproduction events) must be understood

Input from theorists / phenomenologists is very welcome