Leading Neutron Energy & p_T Distributions from ZEUS

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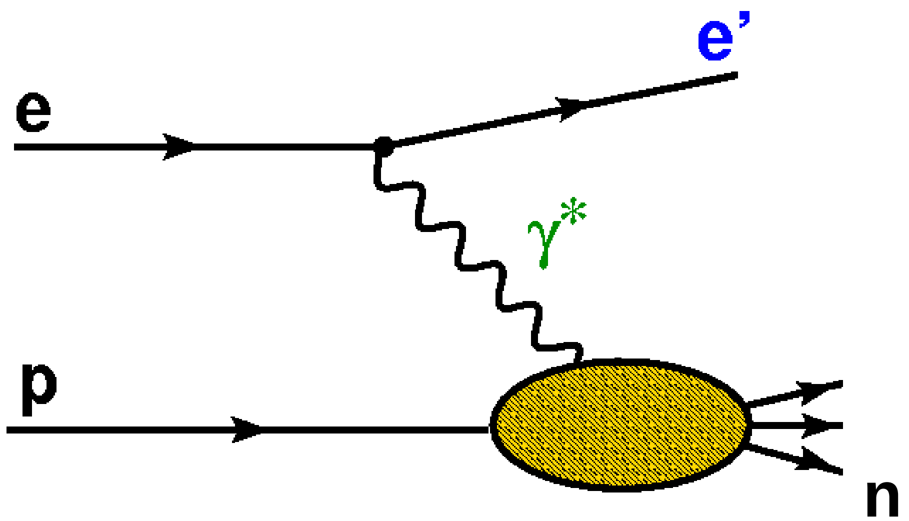
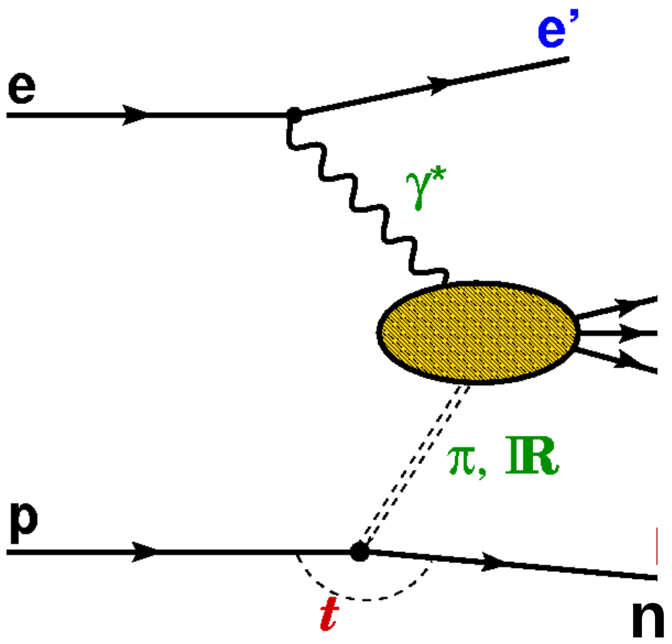
Outline:

- Motivations: LN production, One Pion Exchange (OPE), absorption
- Data sets: DIS, photoproduction (γp), LN measurement
- LN in DIS: energy, p_T distributions
- Comparison: LN in photoproduction & DIS
- Comparison: LN & leading protons
- Comparison: OPE models, absorption (rescattering) models
- Comparison: LN in non-OPE MC models

Motivations: LN production, OPE



$x_L = E_n / E_p$

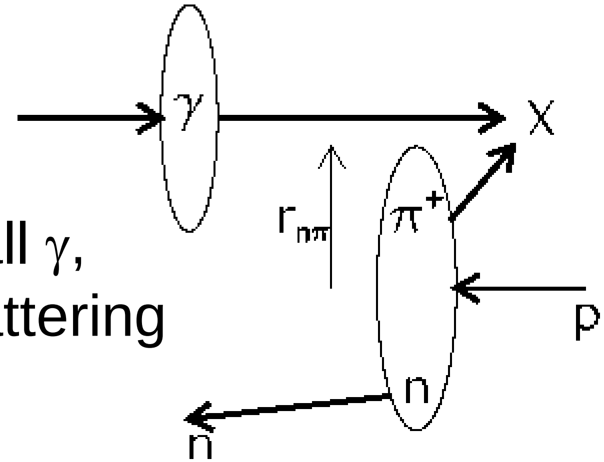


- LN can come from 'standard' fragmentation (baryon # has to go somewhere)
- Can compare to 'standard' MC gens.: x_L, p_T^2 distributions
- LN can be produced via isovector exchange: One Pion Exchange (OPE)
- Parameterizations from low energy hadronic scattering data. Can compare: x_L, p_T^2 distributions

Motivations: Absorption

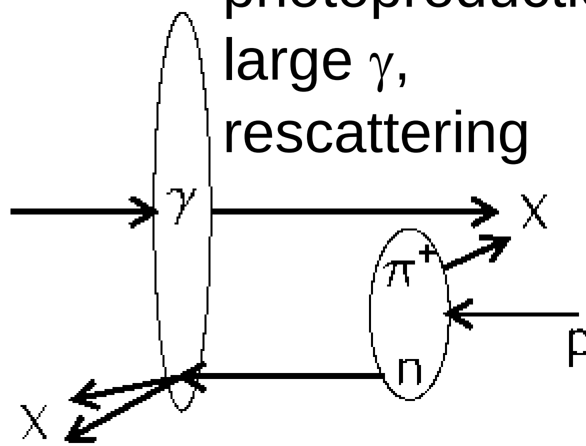
In DIS γ^* is small; in photoproduction γ large, rescattering (absorption) of *n* may occur:

- Compare photoproduction & DIS:
  - x_L , $p_T^{\,2}$ distributions
  - effects of absorption?
- Compare to absorption (loss) calculations of D' Alesio & Pirner: Eur. Phys. J. **A7** (2000) 109
- Recently: Kaidalov, Khoze, Martin, Ryskin 'Leading neutron spectra' hep-ph/0602215
- They calculate the effects of *absorption* (rescattering), and subsequent *migration* of LN in (x_L, $p_T^{\,2}$) space
- Next speaker for details



DIS small γ, no rescattering

photoproduction large γ, rescattering



n kicked to lower x_L, higher p_T; may escape detection (migration)

Data Sets

<u>Inclusive data (i.e. no LN tag):</u>

- DIS: $Q^2 > 2$ GeV^2, $\langle Q^2 \rangle \approx 14$ GeV^2
- γp: $Q^2 < 0.02$ GeV^2, e^+ tagged $\Rightarrow$ $180 < W_{\gamma p} < 255$ GeV

<u>LN measurement:</u> Forward Neutron Calorimeter (FNC) & Tracker (FNT)

- 10.2 λ_I Pb-scint. calorimeter 105m from I.P.
- Scintillator hodoscope 1 λ_I into calorimeter for position detection
- Energy resolution $\sigma_E/E \approx 0.7/\sqrt{E}$
- p_T resolution dominated by proton beam p_T spread ~50-100 MeV
- Magnet apertures limit $\Theta_n < 0.75$ mrad $\Rightarrow$ $p_T^2 < 0.476\, x_L^2$ GeV^2

<u>LN yields:</u>

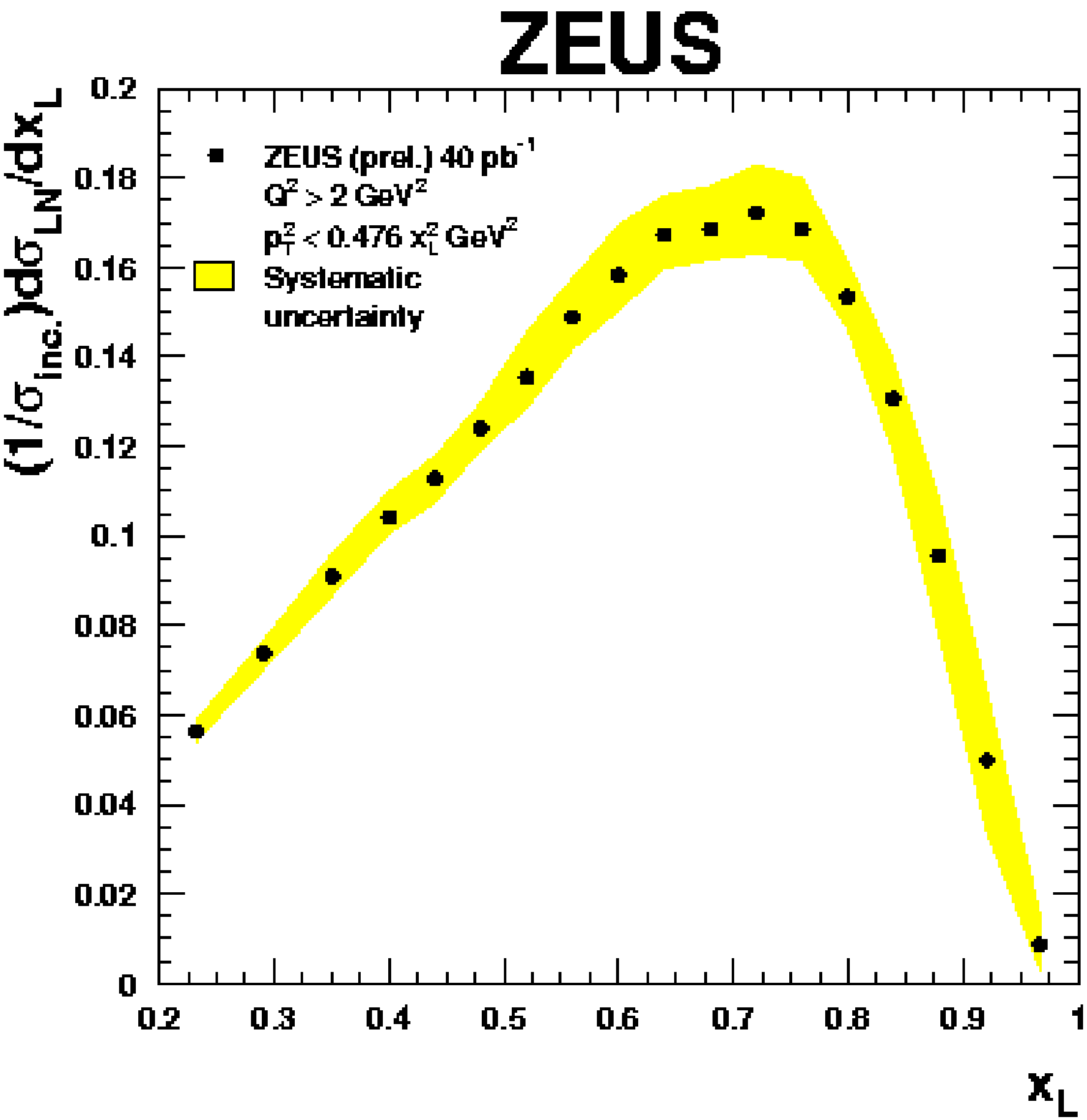
- DIS, γp have very different inclusive cross sections $\sigma_{inc.}$
- For sensible comparisons look at LN yields: $\sigma_{LN} / \sigma_{inc}$
- Additional benefit: systematic uncertainties of central ZEUS cancel; only have LN systematic uncertainties

LN in DIS: x_L distribution

- LN yield → 0 at kinematic limit $x_L^2 \to 1$
- Below $x_L^2 \approx 0.7$ yield drops due to decreasing p_T^2 range

Systematic uncertainties from:

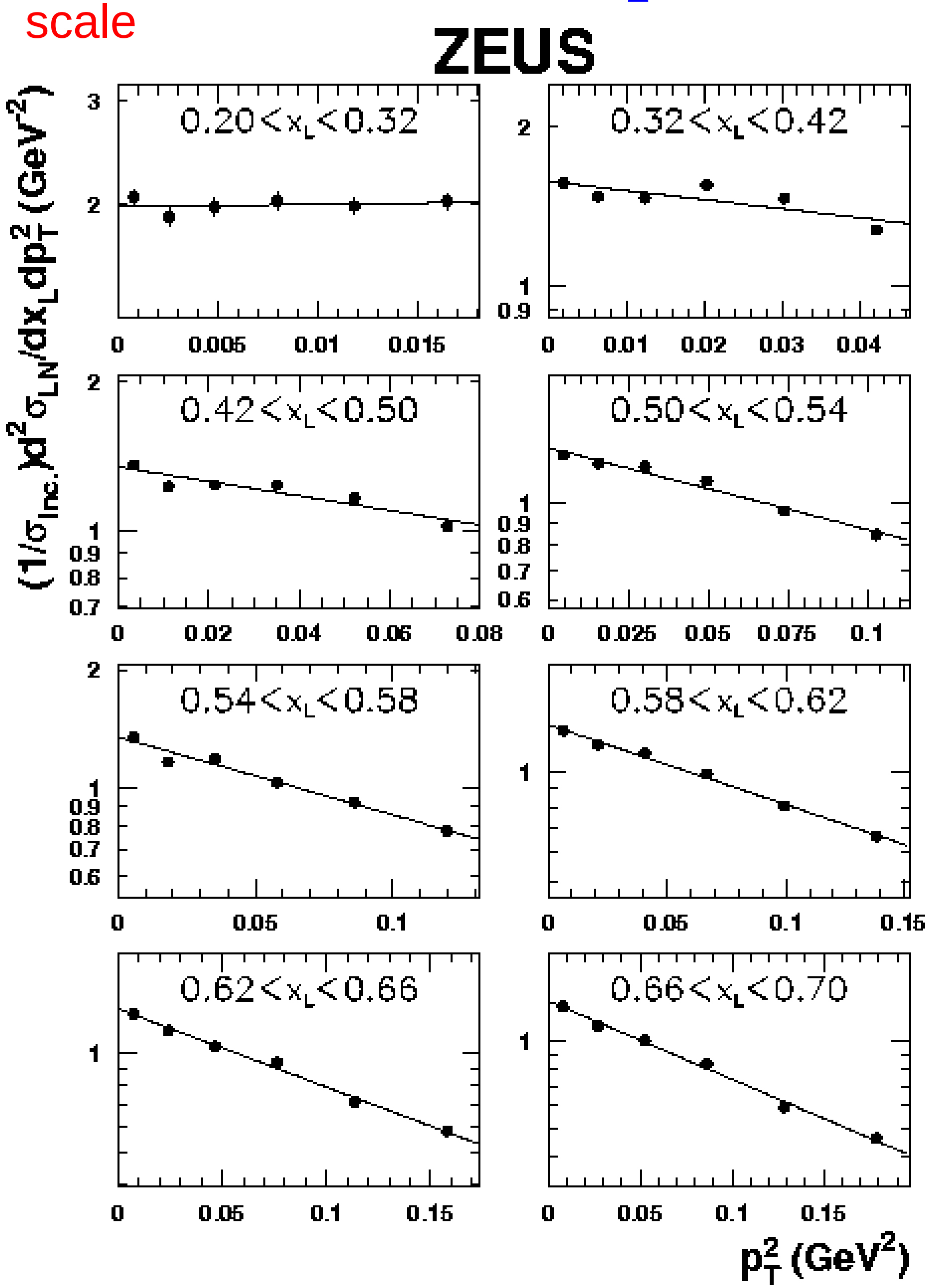
- Proton beam 0° point
- FNC energy scale
- Dead material before FNC



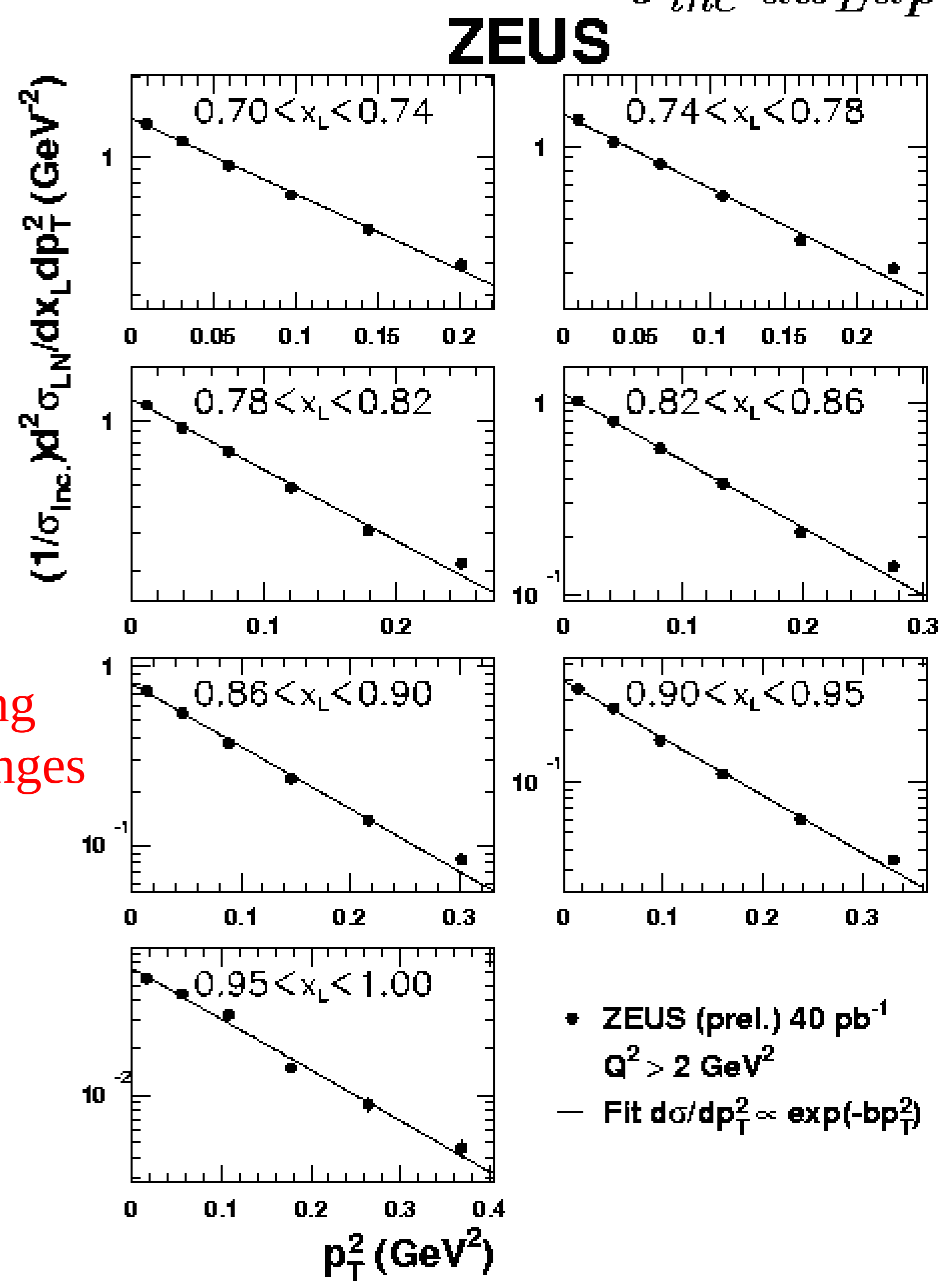
$p_T^{\,2}$ distributions DIS

log scale

$$\frac{1}{\sigma_{inc}}\frac{d^2\sigma_{LN}}{dx_L dp_T^2}$$



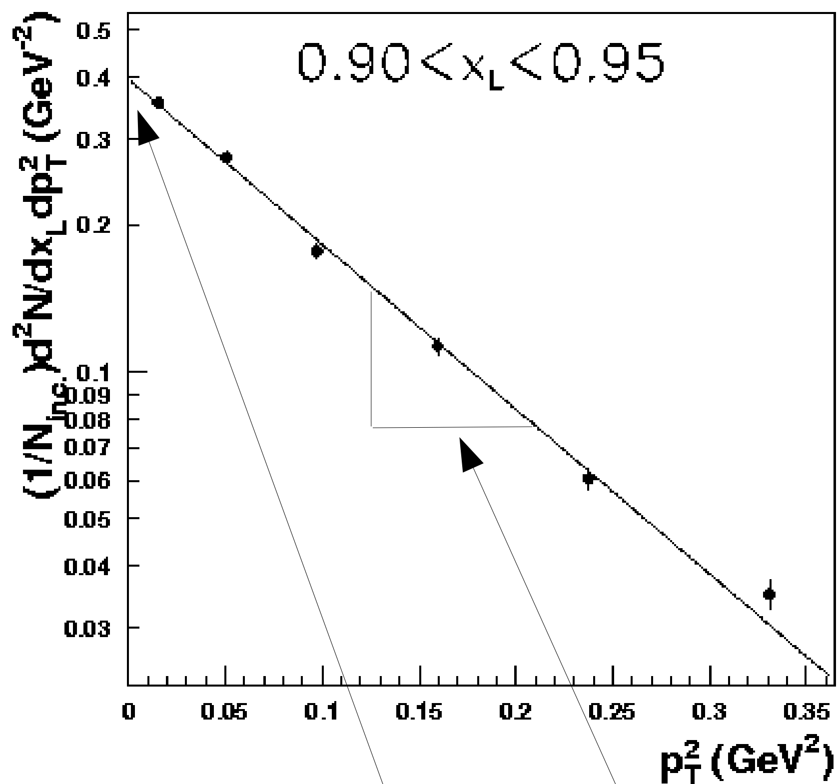
note varying $p_T^{\,2}$ ranges $\propto x_L^{\,2}$



- Well described by exponential in $p_T^{\,2}$

$p_T^{\,2}$ distributions: slopes & intercepts

- $p_T^{\,2}$ distributions well described by exponential:

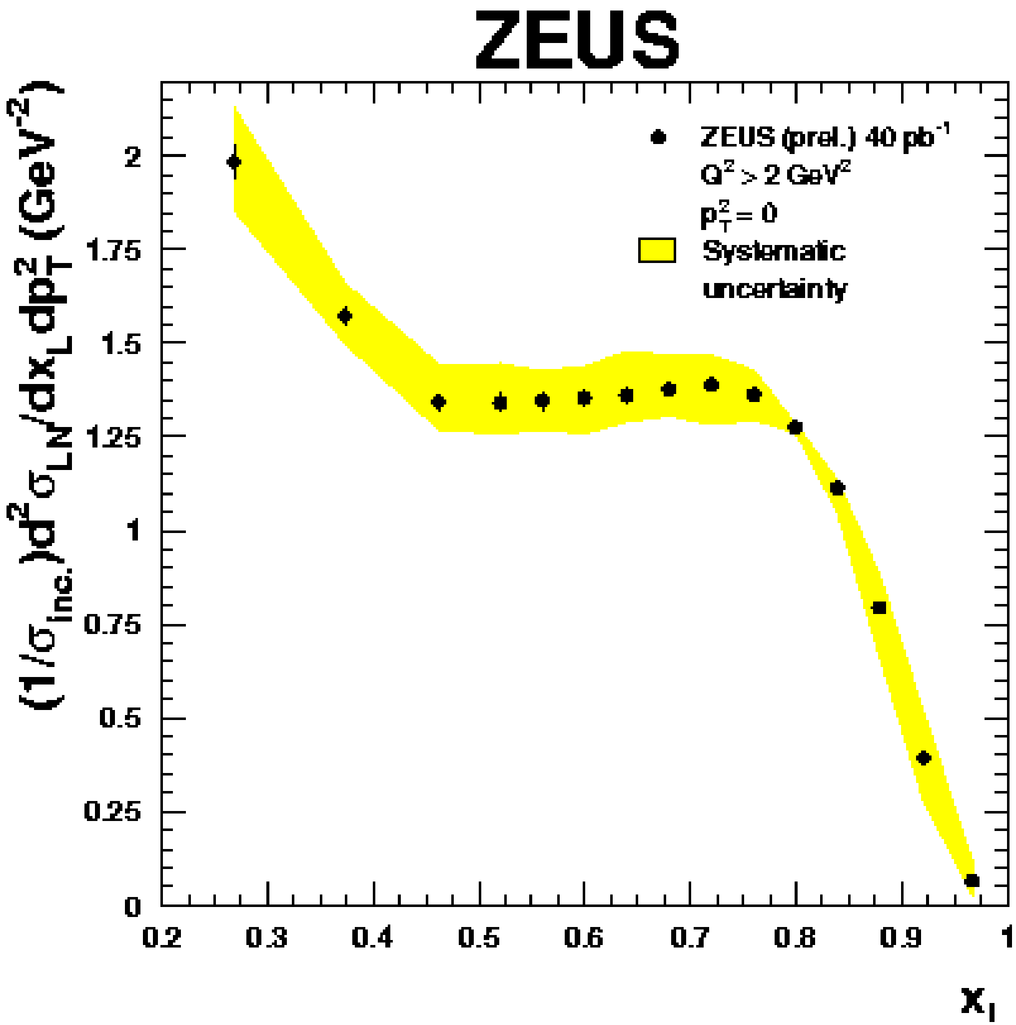


$$\frac{1}{\sigma_{inc}}\frac{d^2\sigma_{LN}}{dx_L\,dp_T^2} = a(x_L)e^{-b(x_L)p_T^2}$$

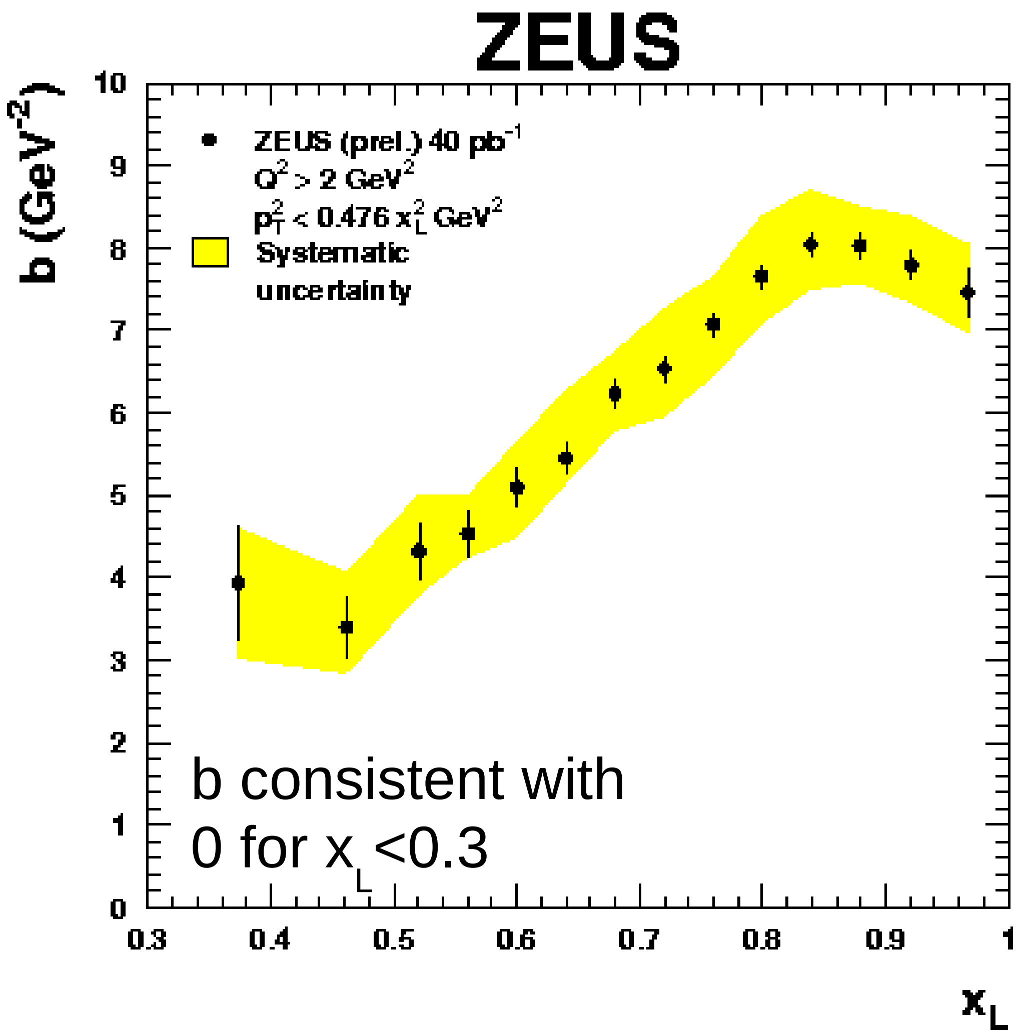
- Together intercepts $a(x_L)$ and slopes $b(x_L)$ fully characterize $(x_L,p_T^{\,2})$ distribution

p_T^2 distributions: slopes & intercepts

- DIS intercepts $a(x_L)$:



- DIS slopes $b(x_L)$:



$$\frac{1}{\sigma_{inc}}\frac{d^2\sigma_{LN}}{dx_L dp_T^2} = a(x_L)e^{-b(x_L)p_T^2}$$

Comparing γp & DIS

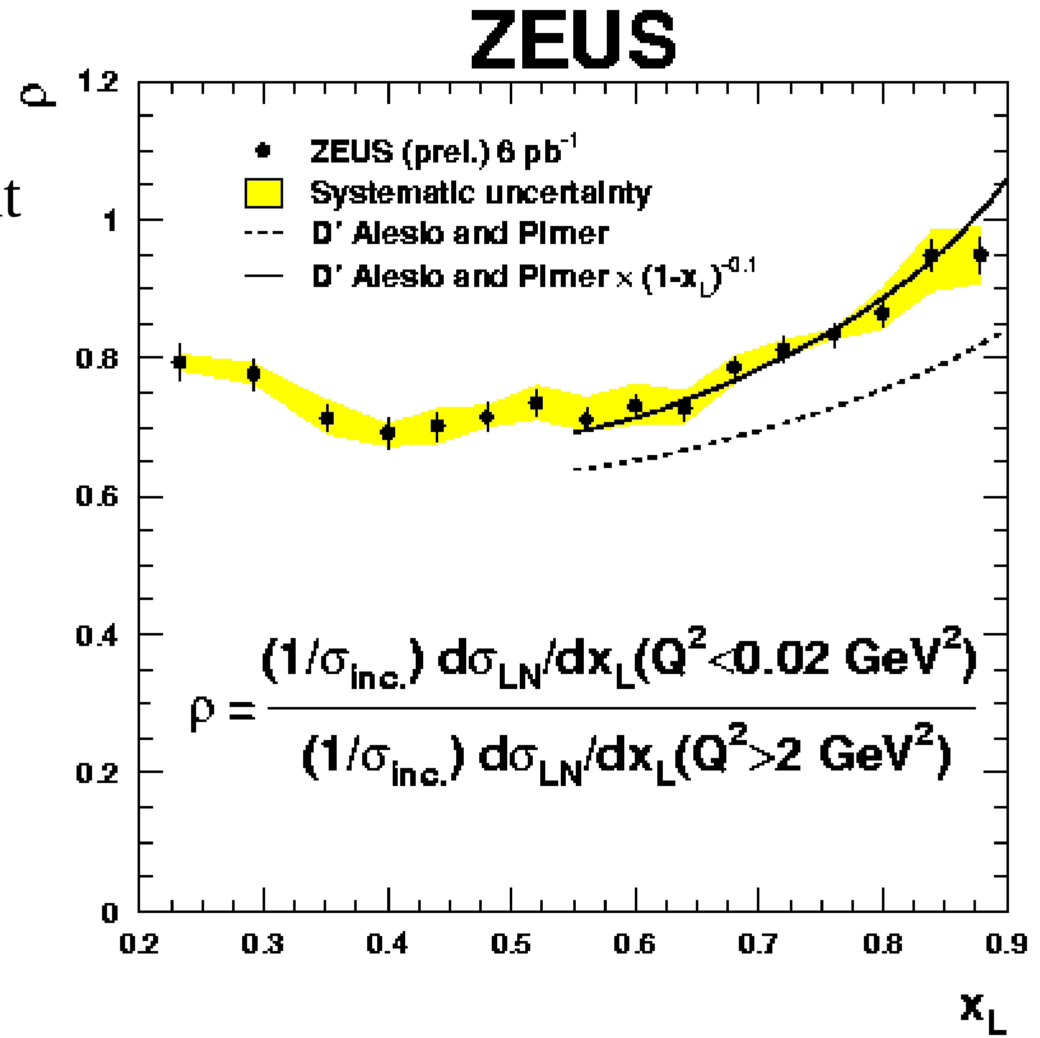
To minimize systematic uncertainties in comparison:

- Use only DIS from period when γp+LN trigger active (~20% of DIS sample)
- Many LN systematic uncertainties cancel taking ratios:
- Ratio of x_L distributions: γp/DIS
- Ratio of p_T^2 distributions: γp/DIS

$\Rightarrow$ $\Delta b = b(\gamma p) - b(\text{DIS})$

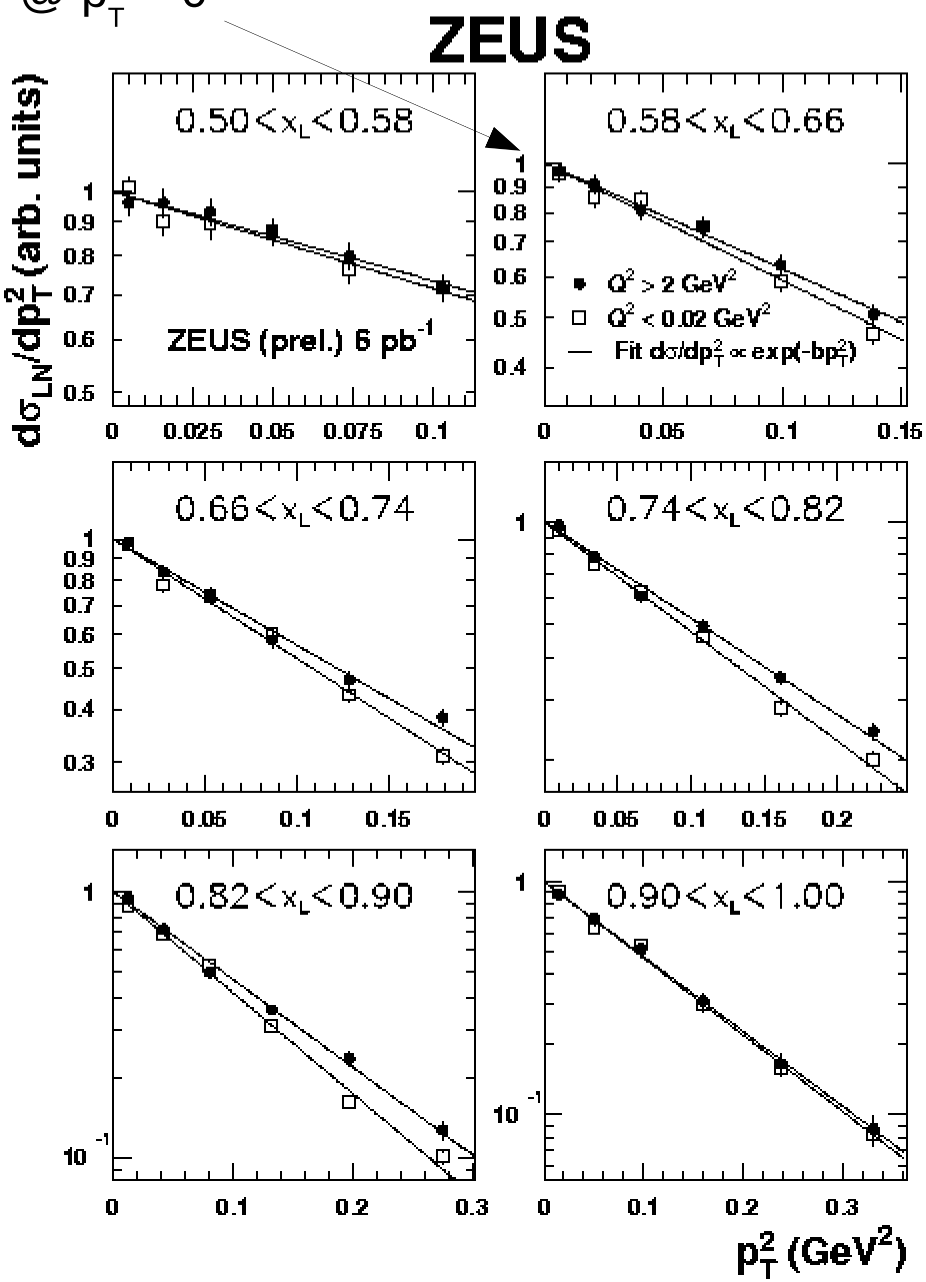
Comparison γp/DIS: x_L distributions

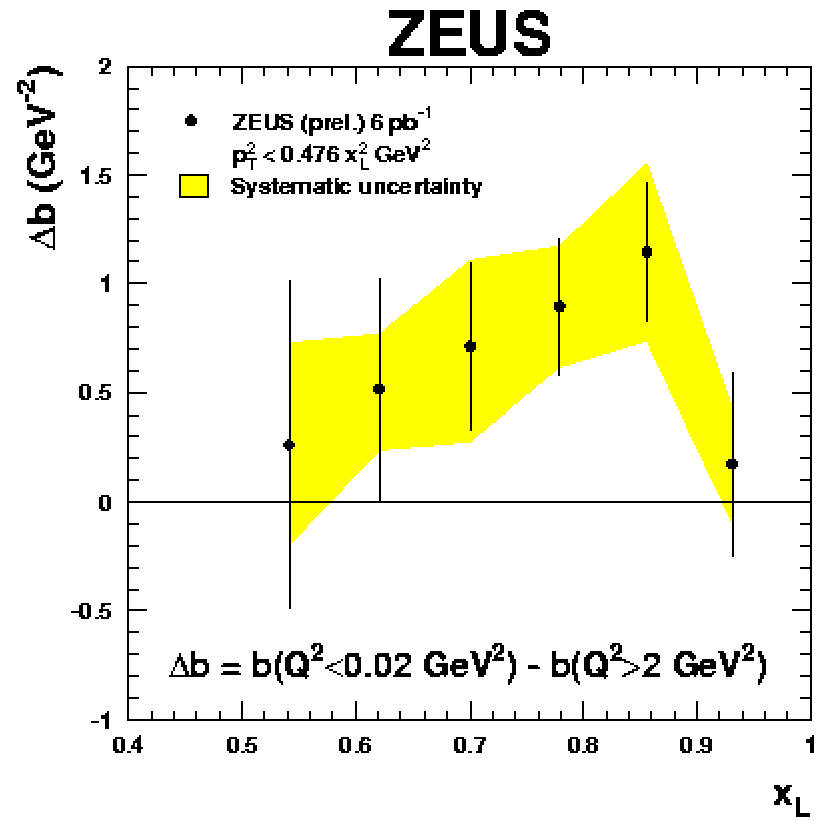
- Ratio ~70% mid-x_L, rising to 1 as $x_L \rightarrow 0.9$
- Qualitatively similar to D' Alesio & Pirner (loss through absorption)
- Know for $\gamma^{(*)}p$: $\sigma_{\gamma p}$, $\sigma_{DIS\text{-}p}$ have different α's: $\sigma \propto W^{\alpha}$ (W = $\gamma^{(*)}p$ c.m. energy)
- Assume same α's for $\sigma_{\gamma\pi}$, $\sigma_{DIS\text{-}\pi}$
- Also: $W^2_{\pi} = (1-x_L)W^2_p$
- $\Rightarrow$ scale absorption ratio by $(1-x_L)^{-0.1}$
- Nice agreement with data



Comparison γp/DIS: p_T^2 distributions

normalized
@ p_T^2 =0

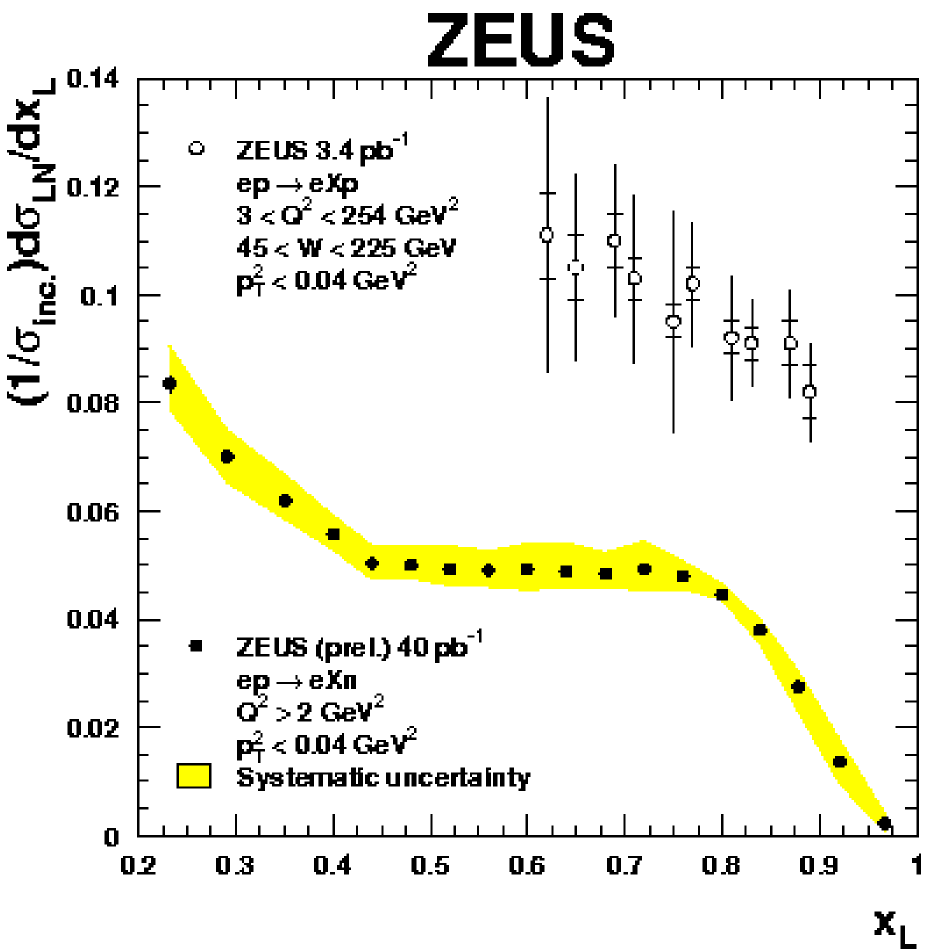




- Small but clear difference:
  b(γp) > b(DIS) for $0.6<x_L<0.9$
- Qualitatively consistent w/ absorption:
  more abs. @ small $r_{n\pi}$ ~ large p_T
- Quantitative comparison: next speaker

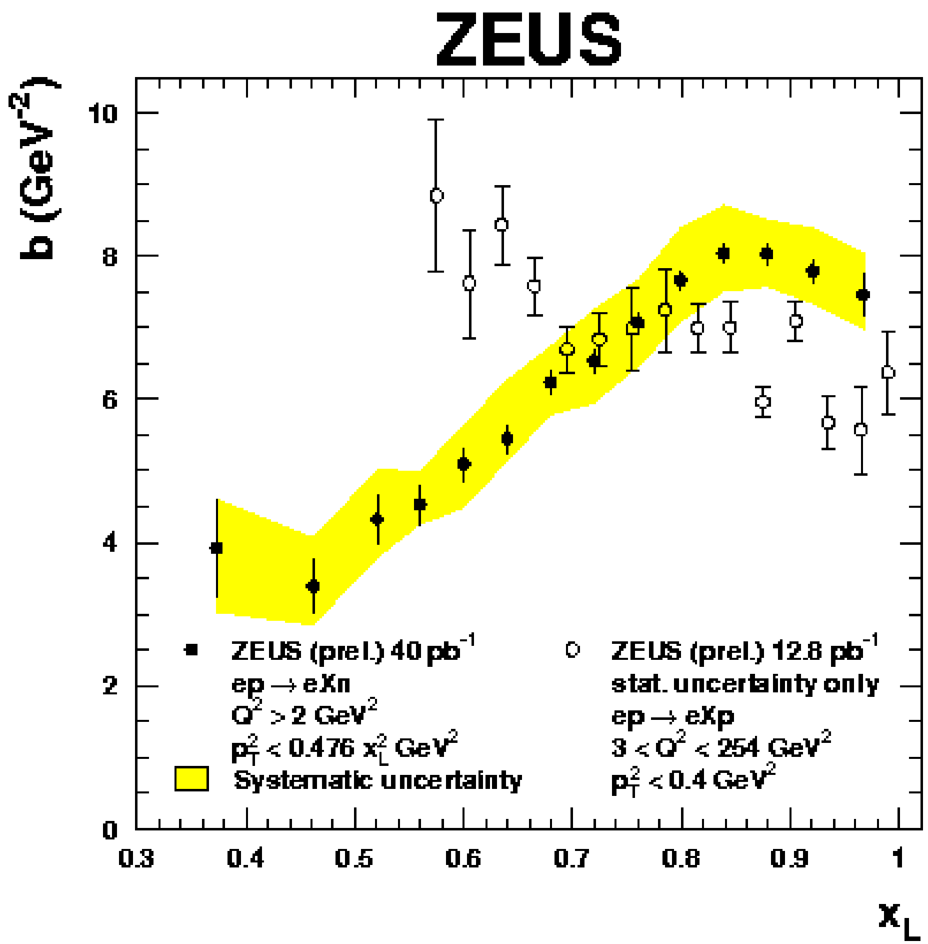
Comparison: LN & leading protons

- DIS x_L distribution p_T^2<0.04 GeV^2:



- For pure isovector exchange isospin Clebsch-Gordan ⇒ $r_{LP} = ½\, r_{LN}$
- $r_{LP} > r_{LN}$ ⇒ other exchanges needed

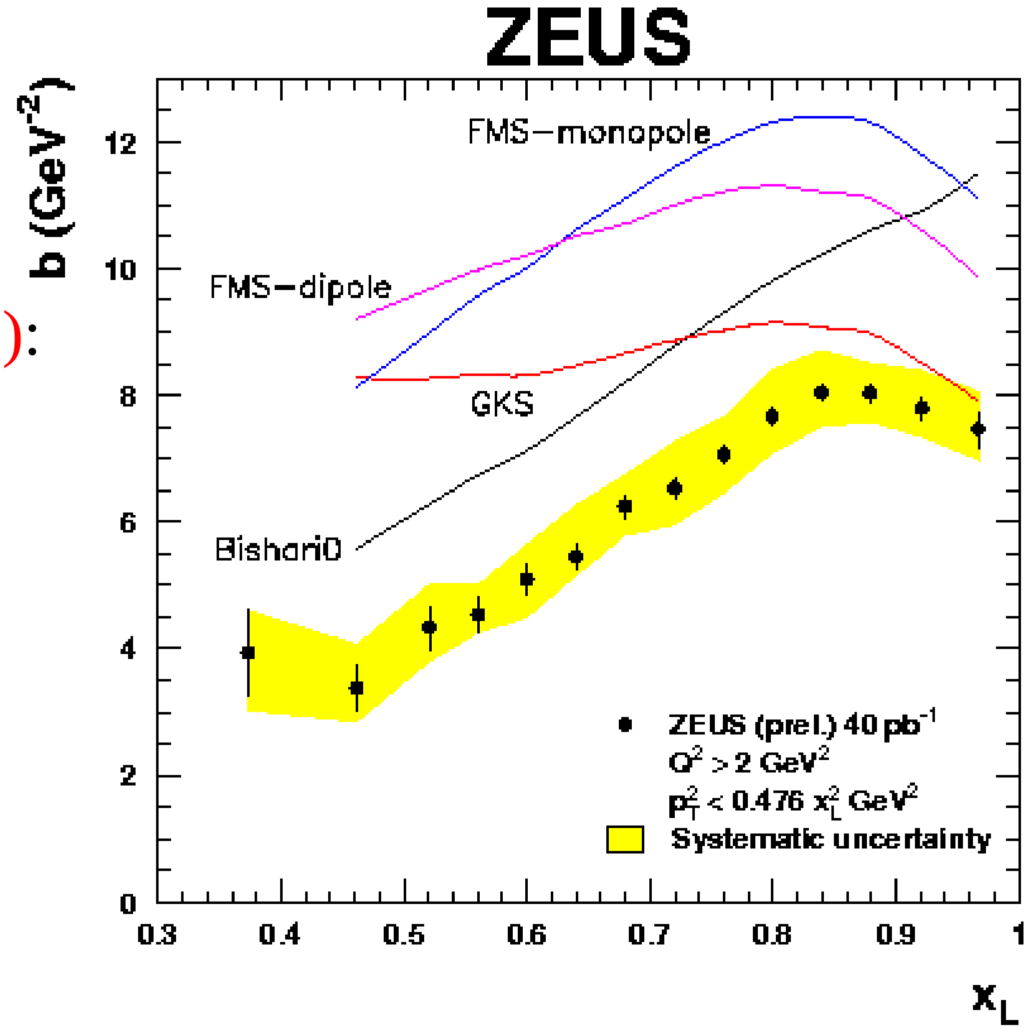
- DIS b-slopes:



- Different exchanges conspire to give ~flat $b(x_L)$ for LP

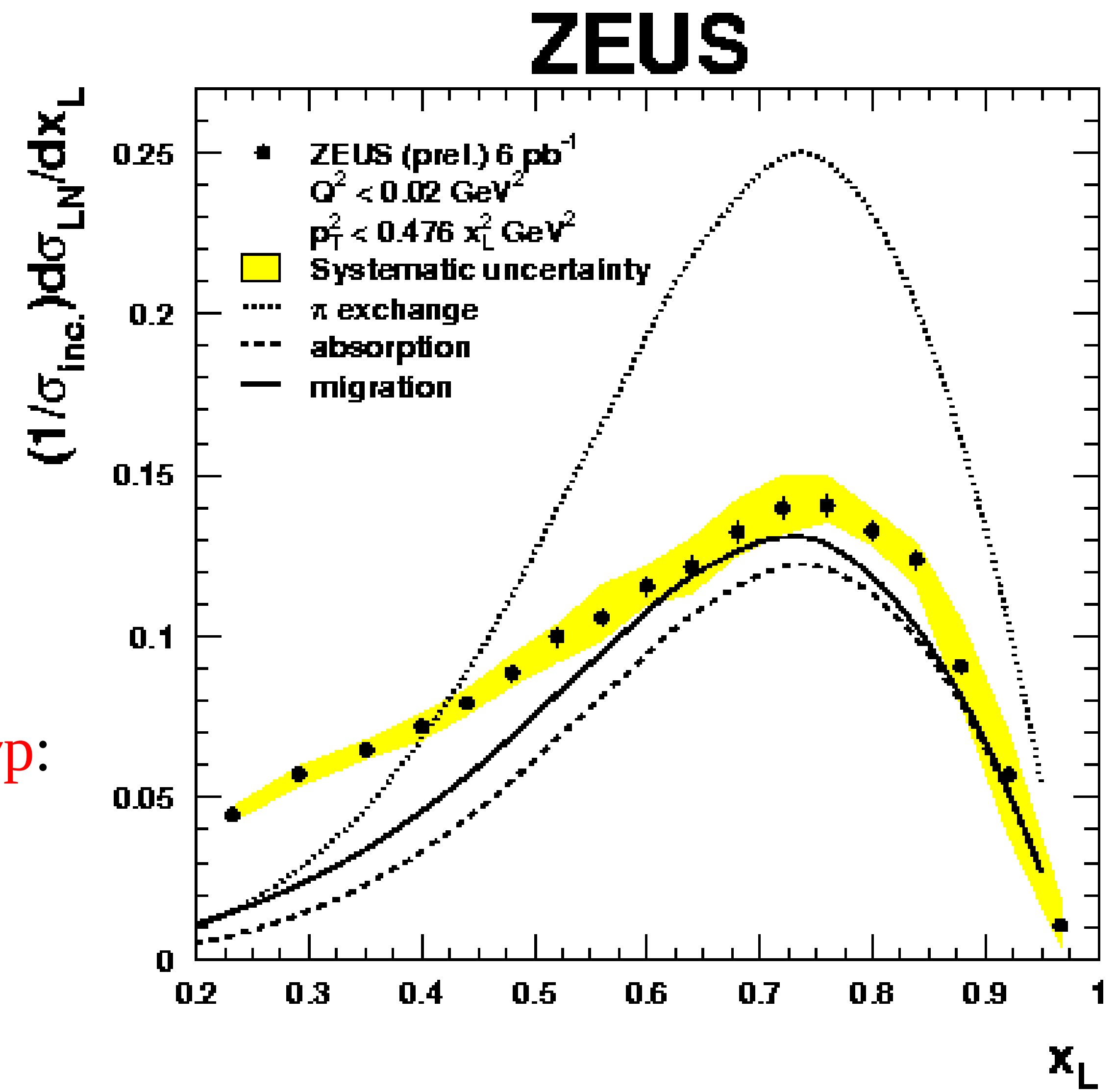
Comparison: OPE models

- Numerous parameterizations of pion flux $f_{\pi/p}(x_L,p_T)$ in literature
- Here compare to measured DIS $b(x_L)$:
- Best agreeing models shown here; others wildly off
- All give too large $b(x_L)$
- More refinement needed: absorption, migration



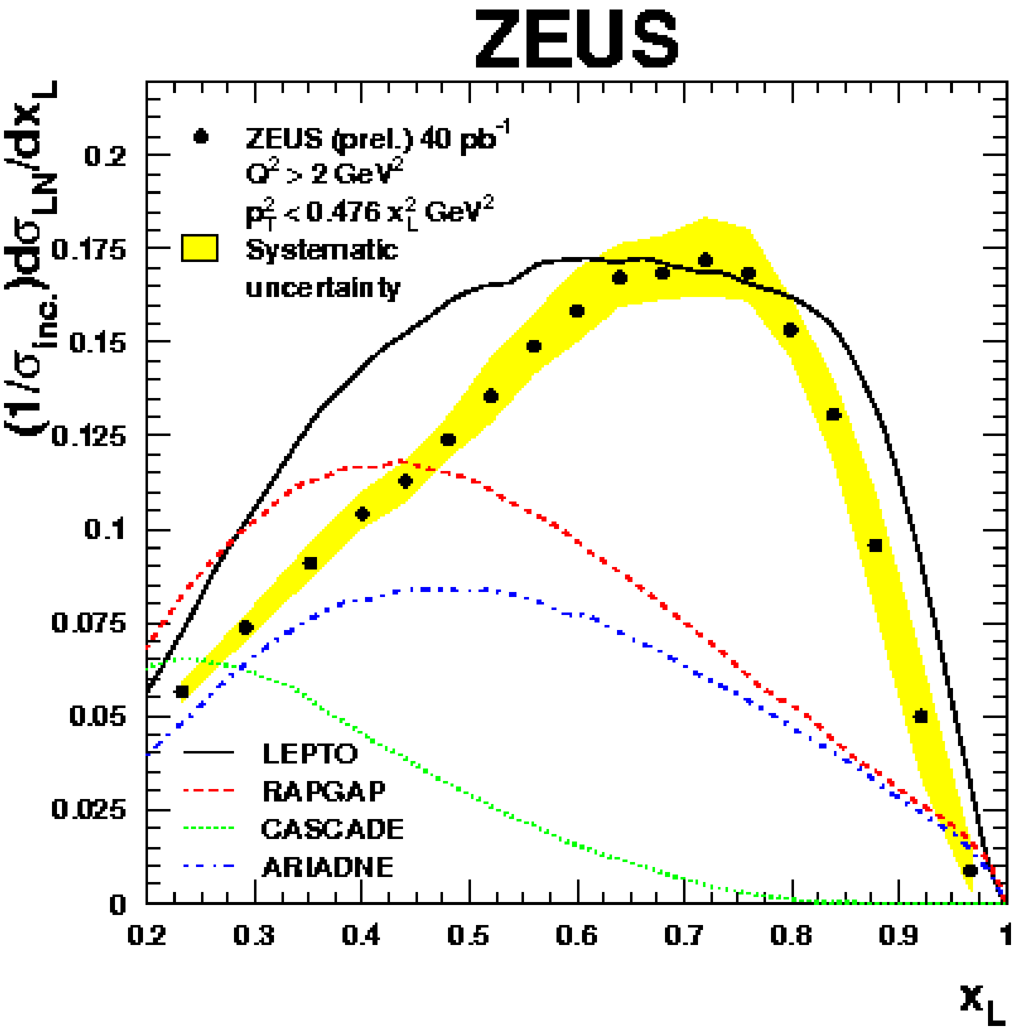
Comparison: OPE w/ absorption

- Recent work of Kaidalov, Khoze, Martin & Ryskin:
  - start with pure OPE
  - some *n* rescatter on γ
  - rescattered *n* migrate in (x_L, p_T)
- Very nice agreement with LN in γp:
- Much more next speaker ➘



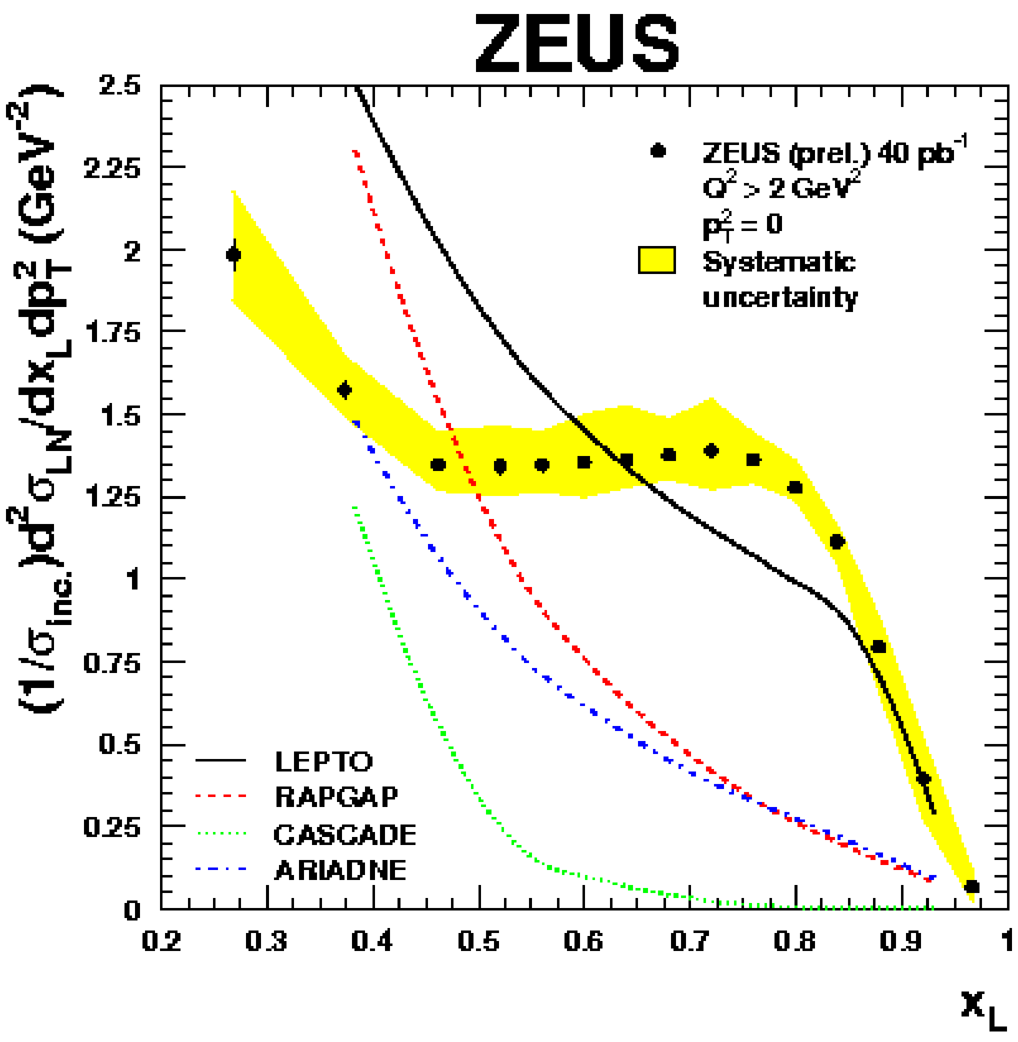
Comparison: non-OPE MC models

- Compare to several popular MC models w/o OPE (i.e. RAPGAP in *standard* mode)
- ~default settings for all models
- Here compare to DIS x_L distribution:
- LEPTO ~OK in shape, magnitude
- Others too few *n*, too low x_L

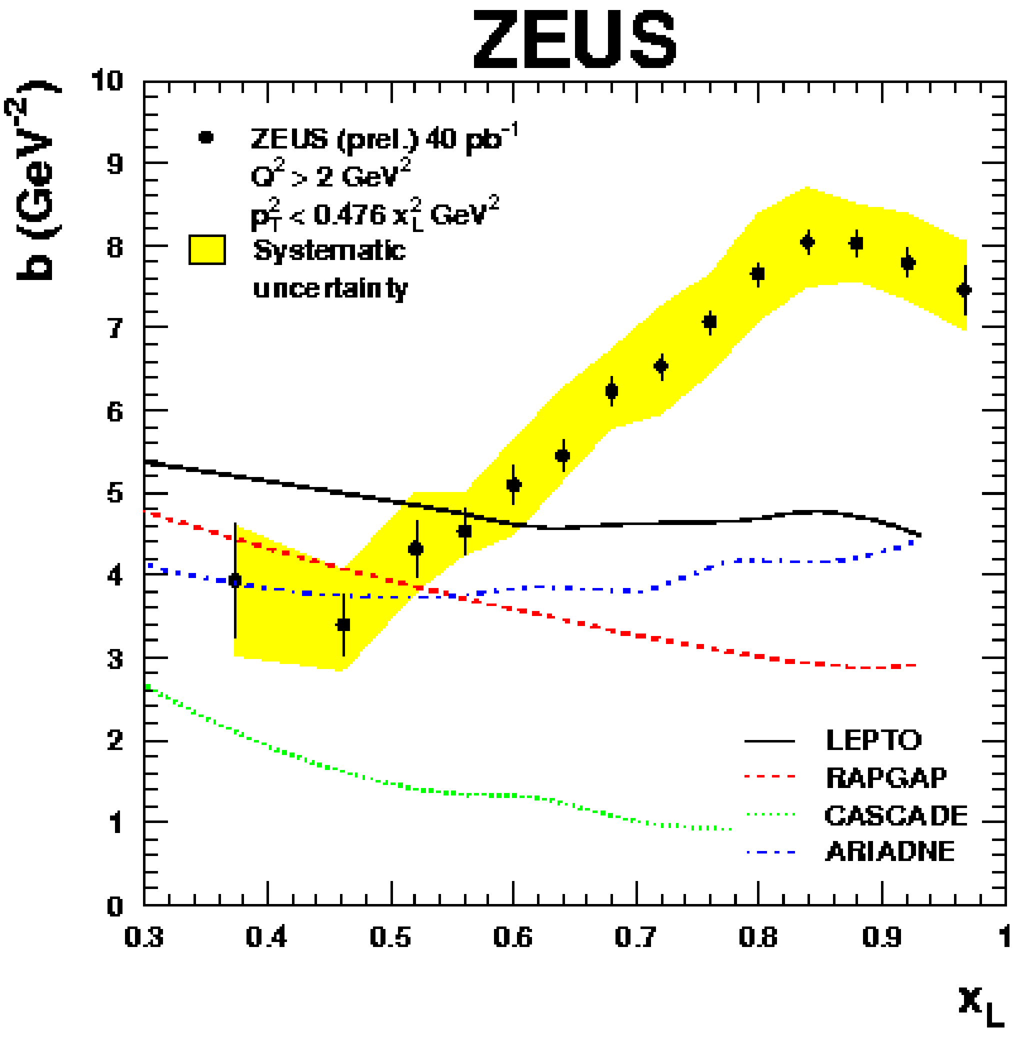


Comparison: non-OPE MC models

- Intercepts in DIS:



- Slopes in DIS:



- LEPTO ~hint of shoulder high x_L
- Others wrong dependence, too low for x_L>0.5

- No models have the steep $b(x_L)$ in the data

Summary

- Best measured LN x_L, p_T distributions in DIS, γp
- Comparison DIS↔γp: evidence for absorption of *n* in large γ
- Pure OPE does not fully describe data
- More refined calculations: OPE+absorption+migration

  ⇒ very promising agreement with data (next speaker ↘)
- MC models with 'standard' fragmentation do not

  describe the data (LEPTO has some promise)