

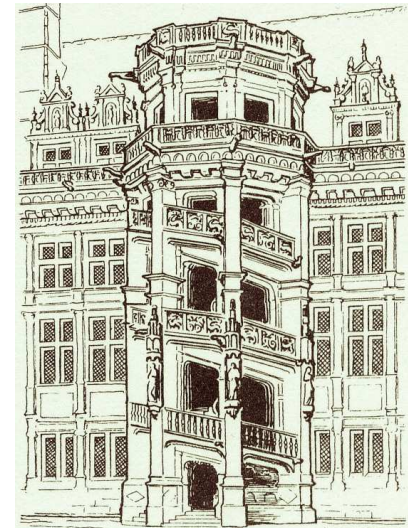
Leading Baryon Production at HERA

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On behalf of H1 and ZEUS Collaborations

Château Royal de Blois

France

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What can we learn from Leading Baryons?

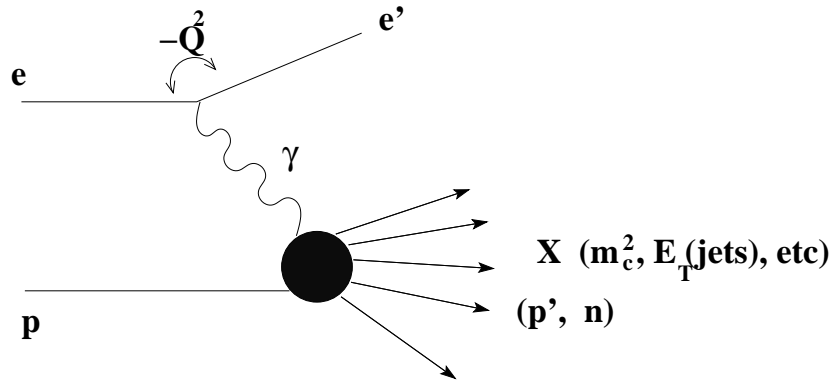
. In a large fraction of events p, n carry a large fraction of the proton beam energy

- neutrons: $0.2 < x_L = \frac{E_n}{E_p} < 1$ protons: $0.2 < x_L = \frac{E'_p}{E_p} < 0.97$

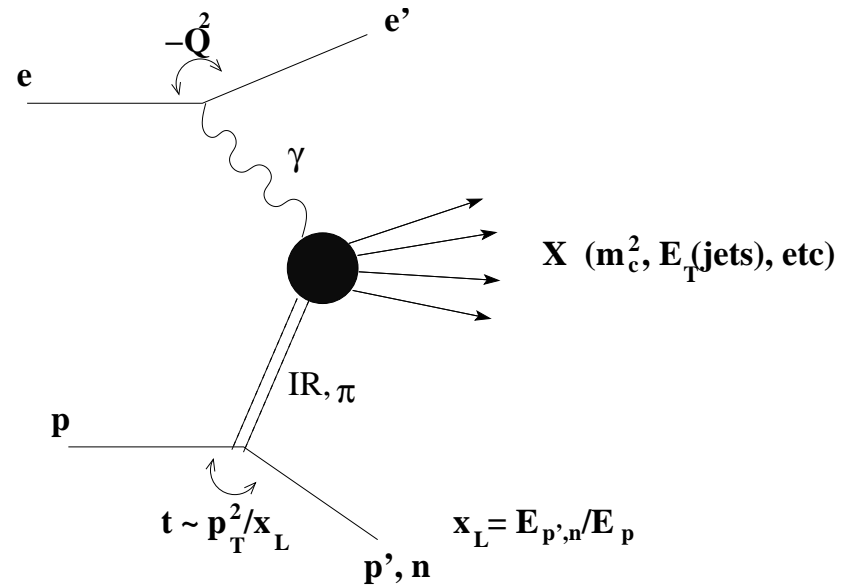
. Rel. between soft and hard interaction: (two scale physics)

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

. Tests of Particle Exchange Models:



standard fragmentation

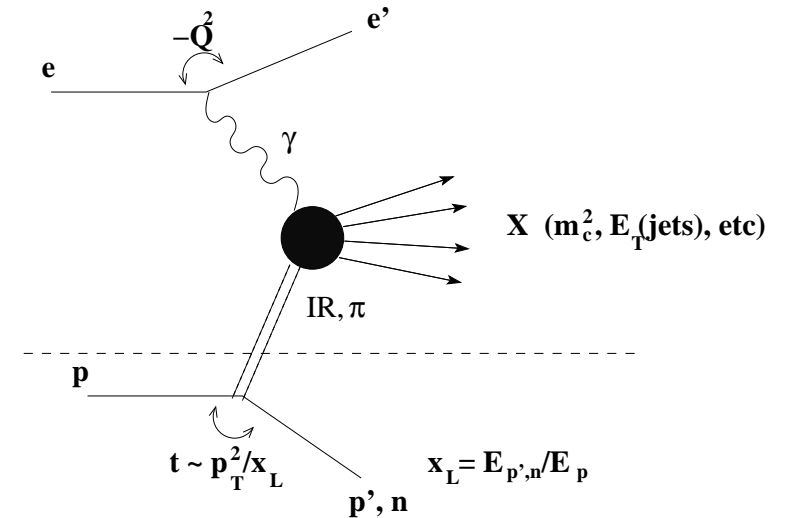


particle exchange (dominant process)

What can we learn from Leading Baryons?

. Probe structure function of the exchanged particle:

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



. Vertex factorization:

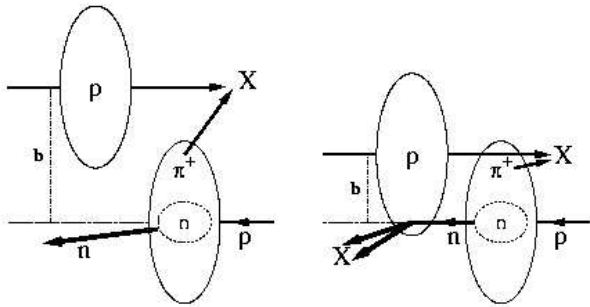
- In the dominant process: leading baryon production is

independent of the photon vertex variables
- Many models predict factorization violation (absorption)

Listing only a few...

Factorization violation models

Model 1: (for leading neutrons)

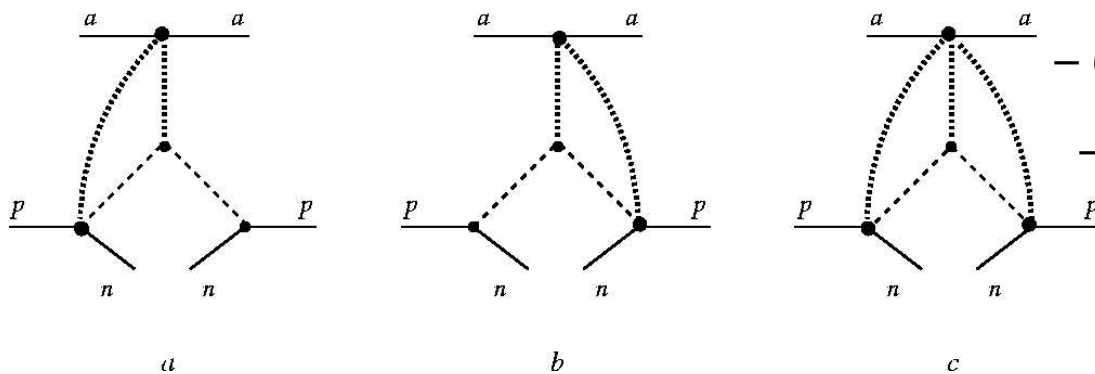


d'Alesio and Pirner, EPJ A7 (2000) 109

- 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: (for leading neutrons)

Nikolaev, Speth and Zakharov, hep-ph/9708290



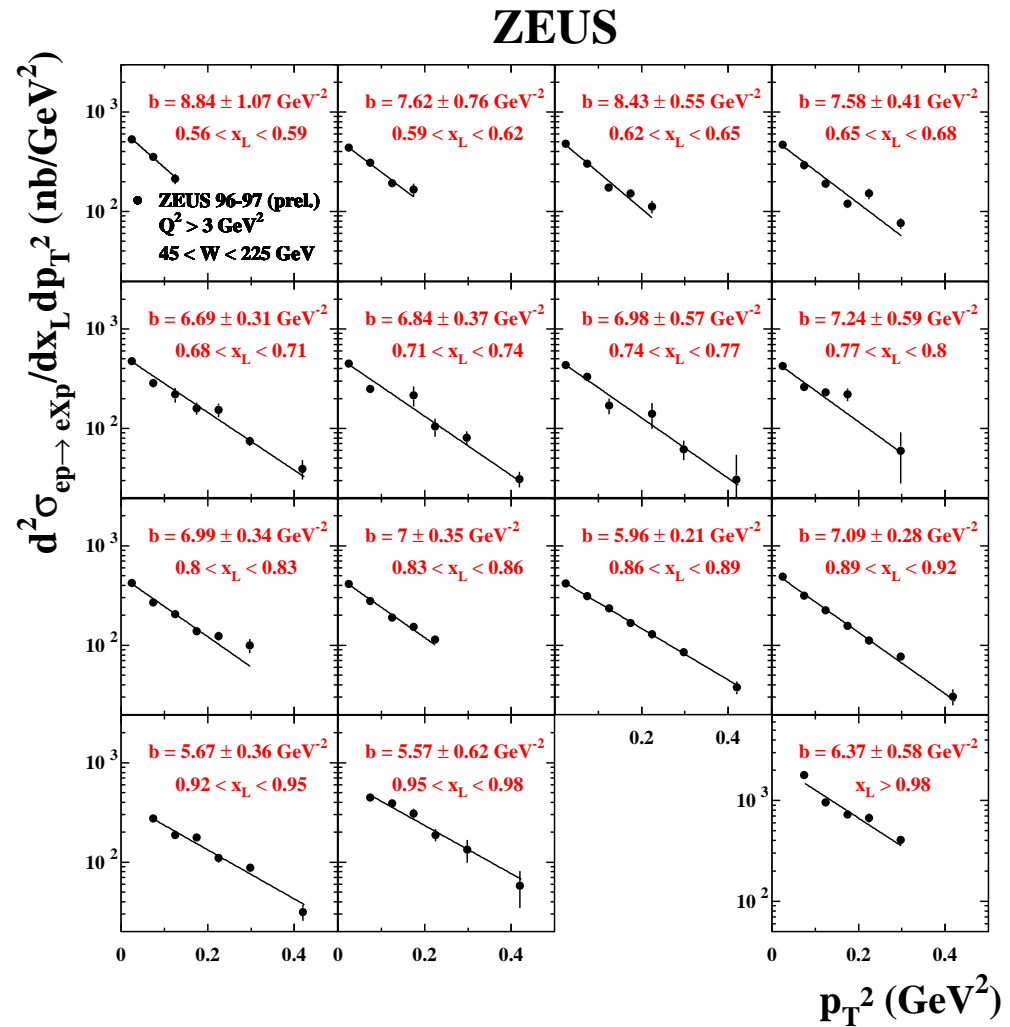
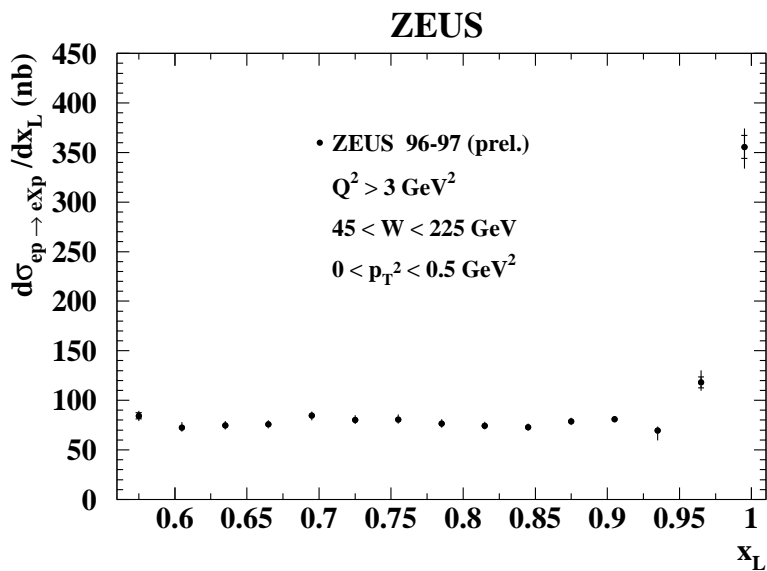
- absorption from additional pomeron exchange
- (a)-(c) contribute to the dominant process
- absorption effects different for ep and pp
- implies large uncertainties to pion pdf parametrizations

Leading Protons

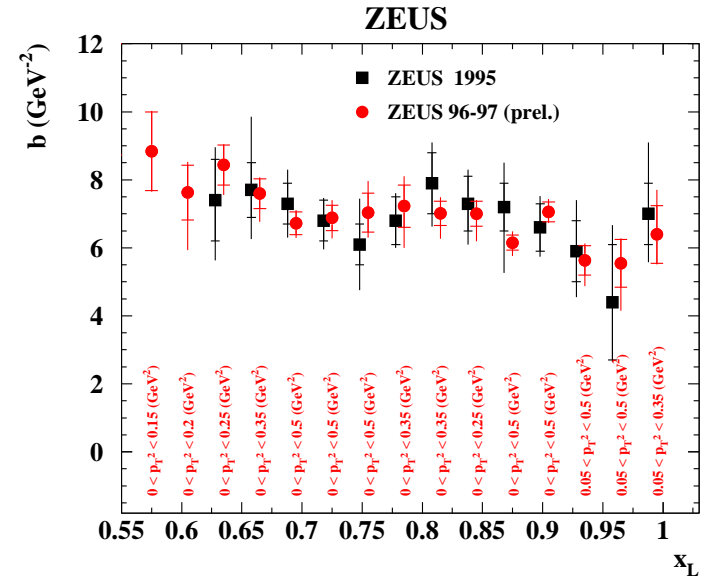
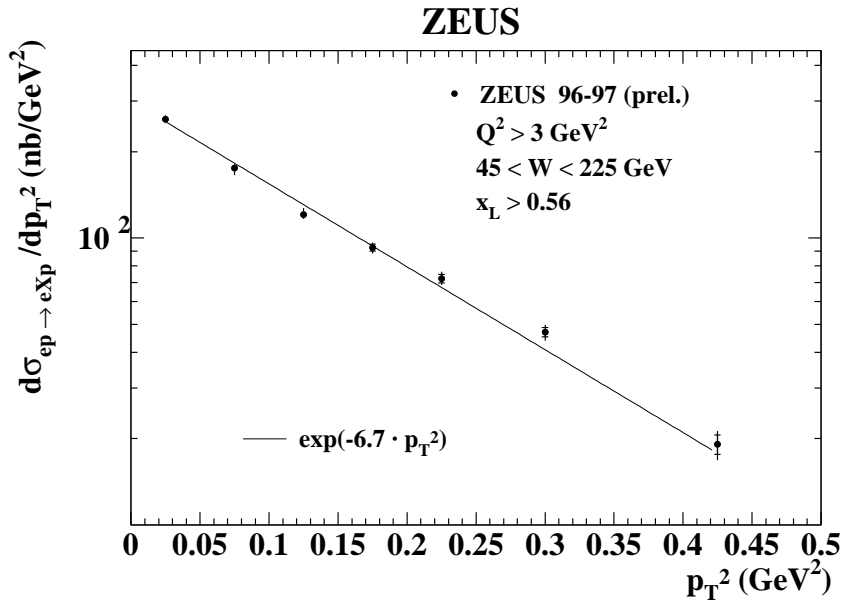
angular distribution →

energy distribution ↓

- Very precise data
- Flat for $x_L < 0.95$



b-slopes

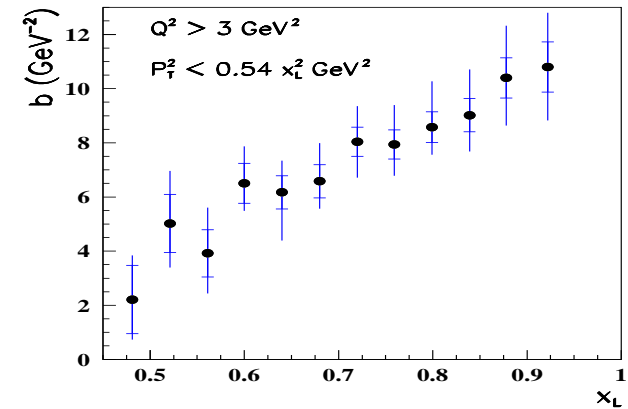


• Protons: slopes flat as a function of x_L

compare to Leading Neutrons →

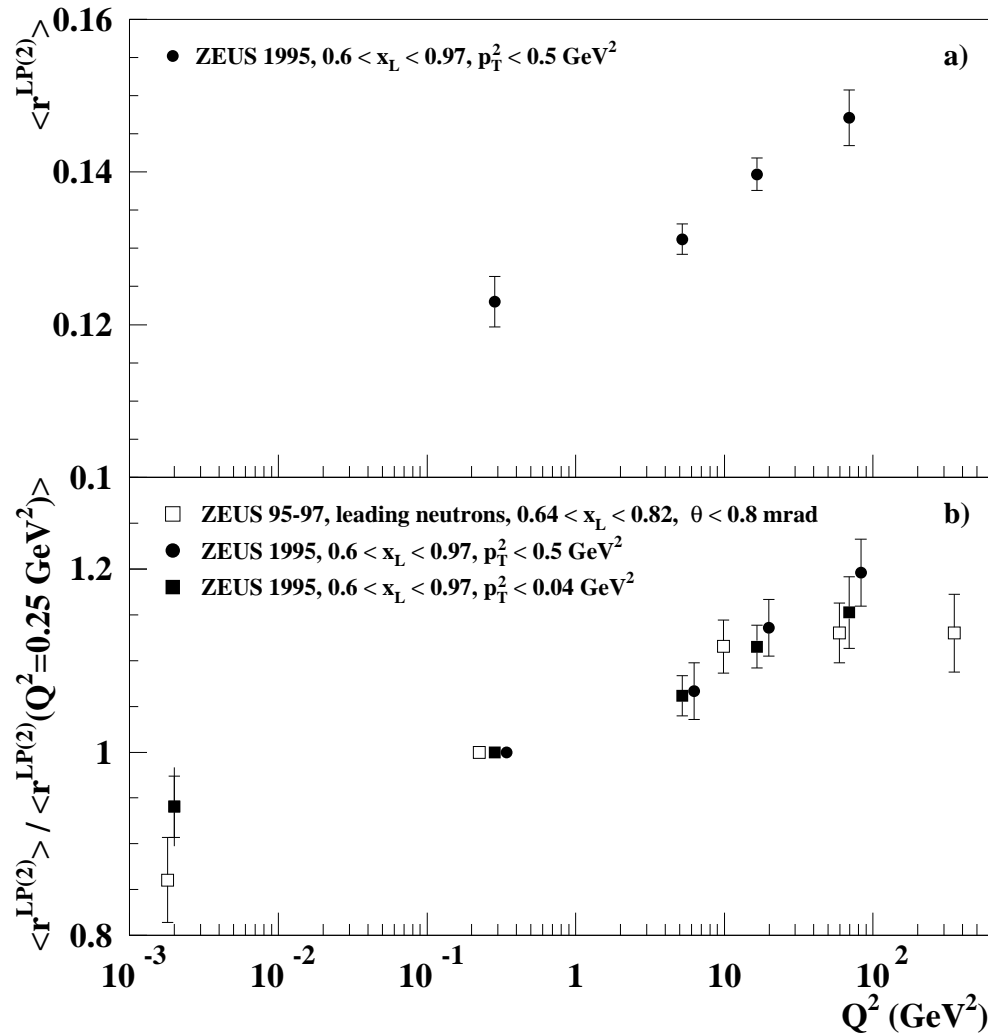
• Steep rise for leading neutrons

ZEUS PRELIMINARY 1999



Q^2 dependence

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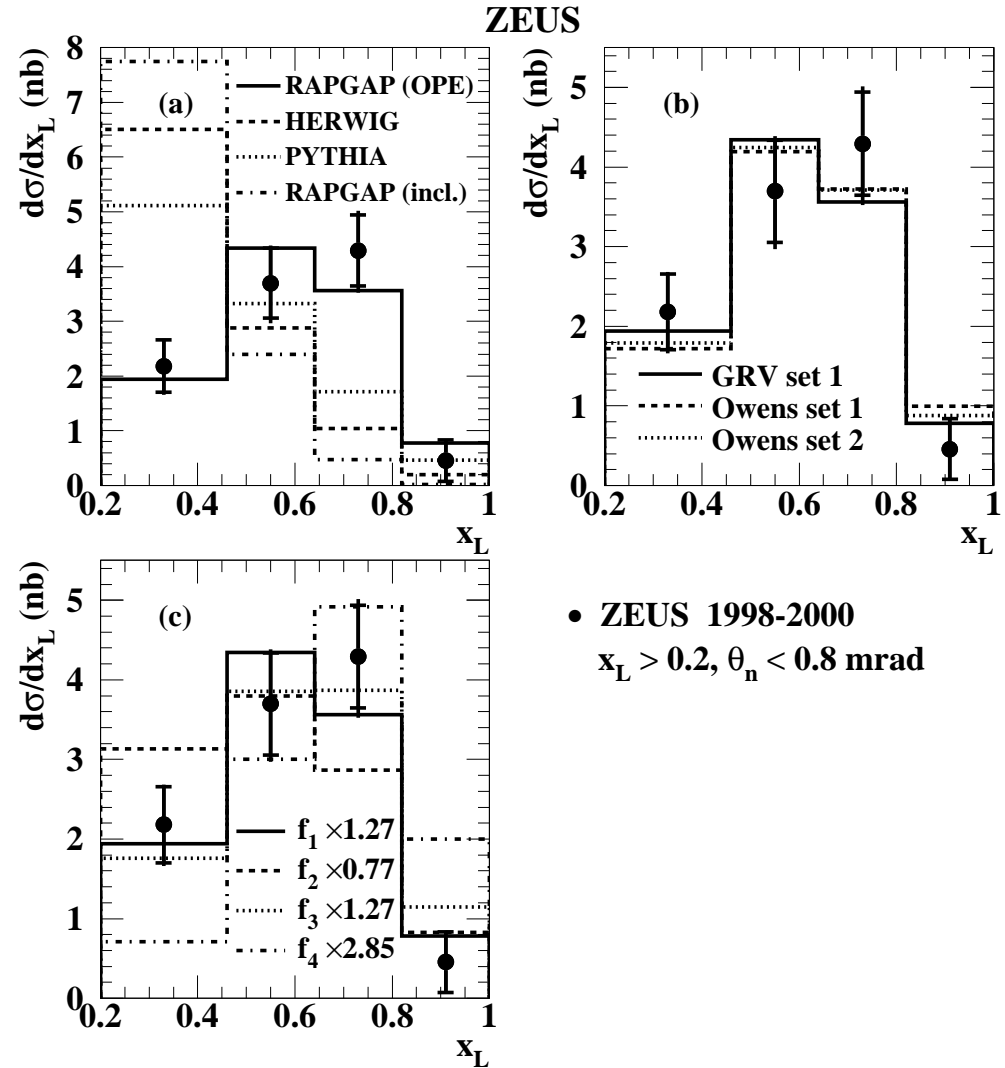
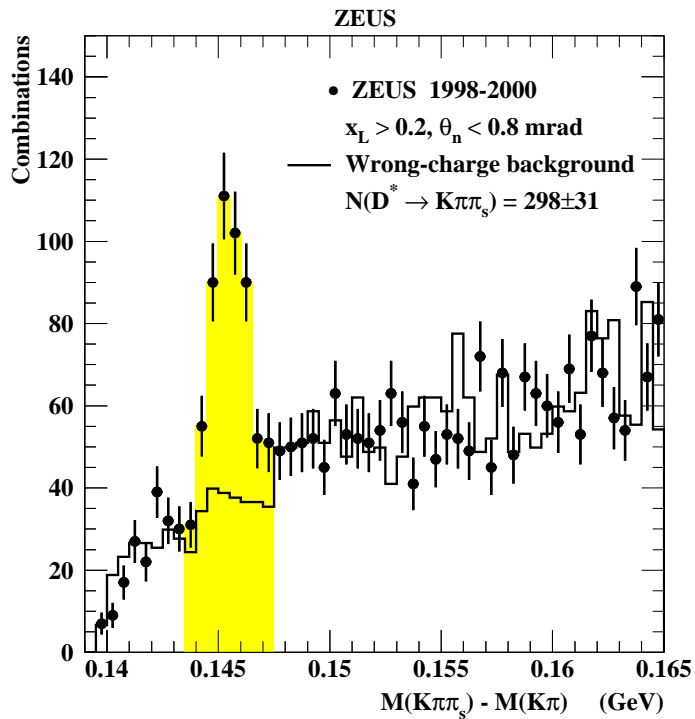


- Production rate decreasing with Q^2

- indication of absorption

Leading Neutrons: D^* photoproduction

- O.P.E. needed to describe data
- large uncertainty on flux factors (f_1 to f_4)
- little sensitivity to pion $pdfs$

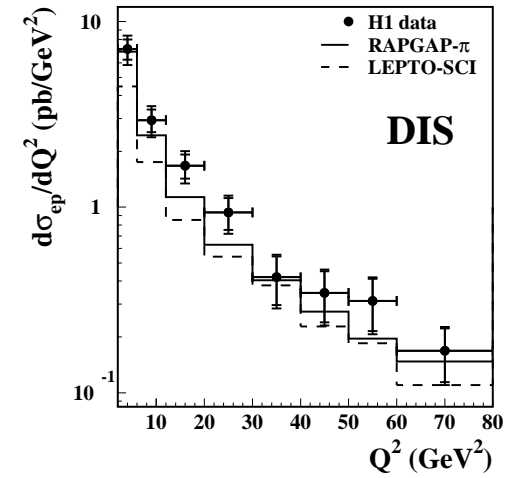
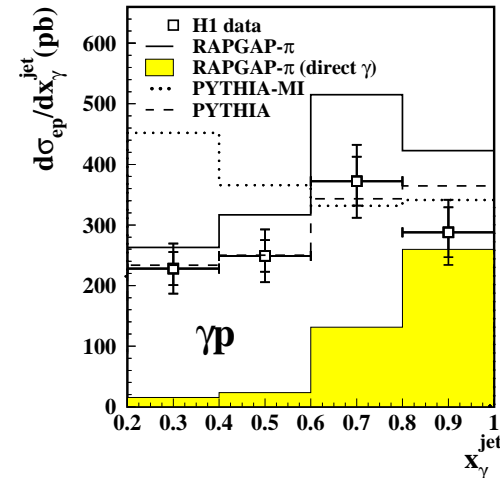
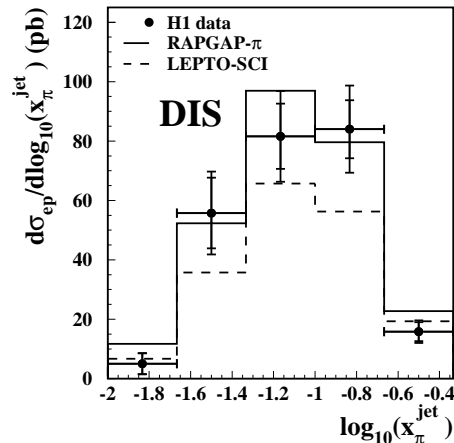
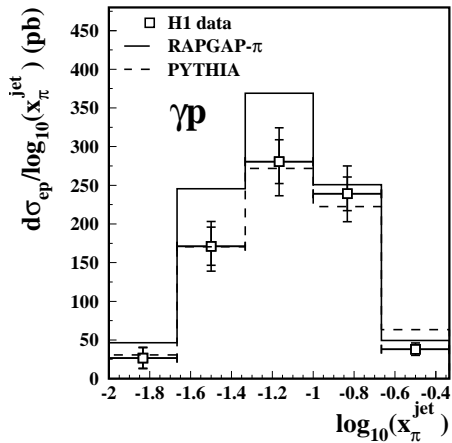
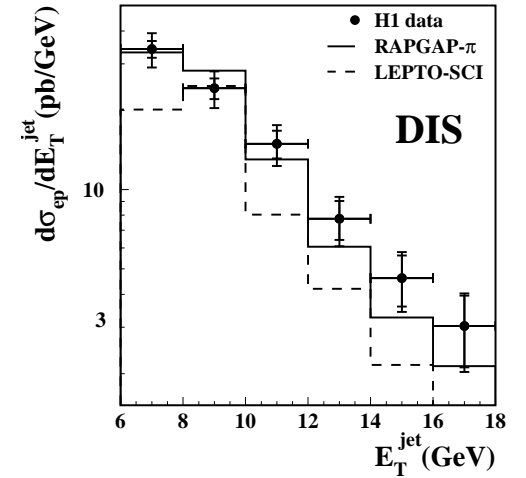
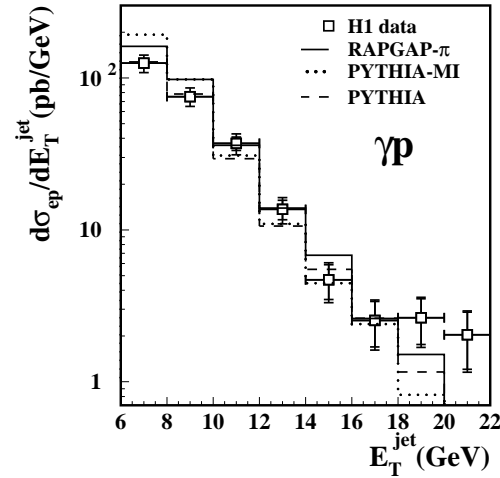


Leading Neutrons: dijets

- O.P.E. needed to describe data

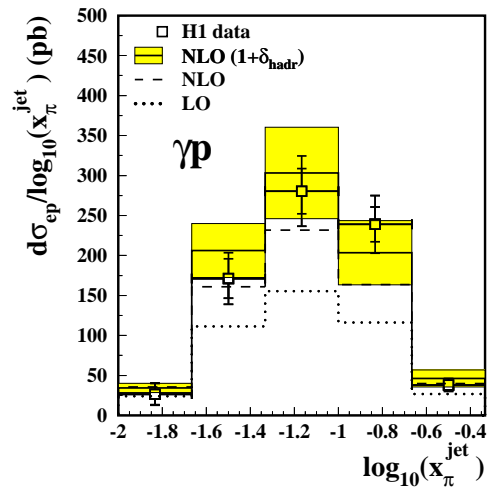
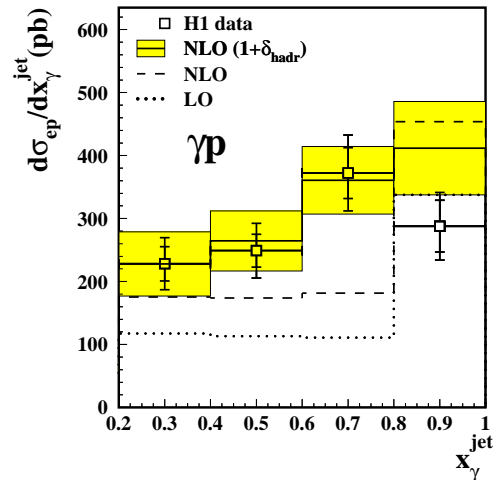
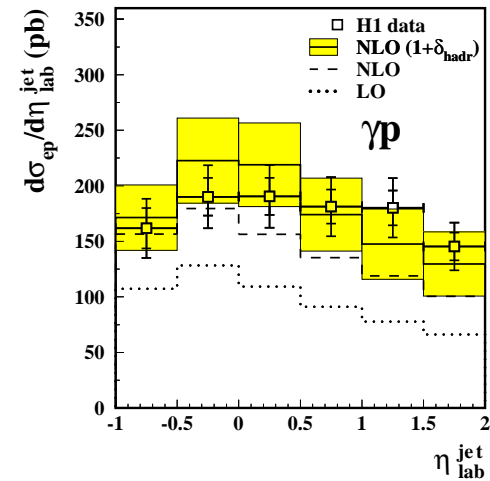
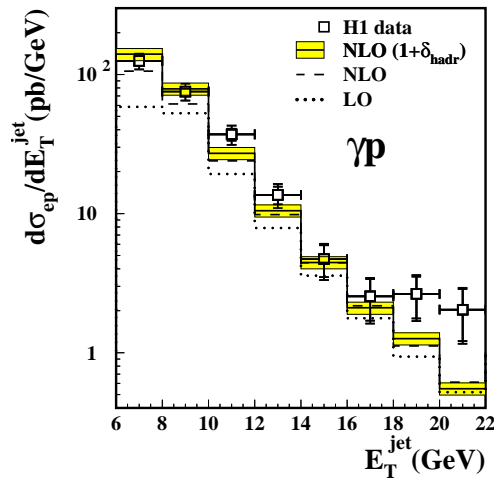
$$x_{\pi}^{jet} = \frac{\sum_{jets} E_T^{jet} e^{\eta^{jet}}}{2E_p(1-x_L)}$$

- not possible to discriminate *pdfs*



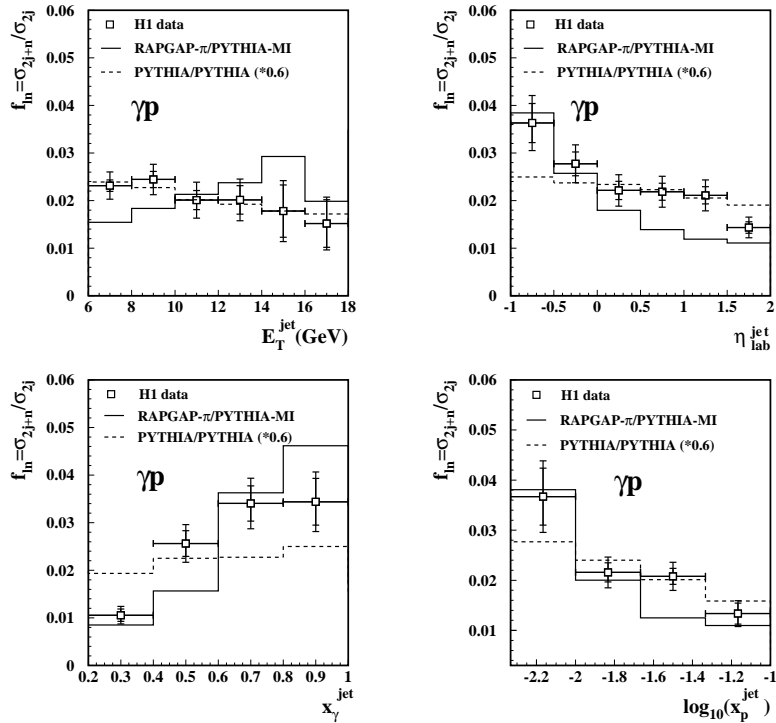
Leading Neutrons: *dijets*

- NLO pQCD with O.P.E. (*Klasen, Kramer*) describe data well

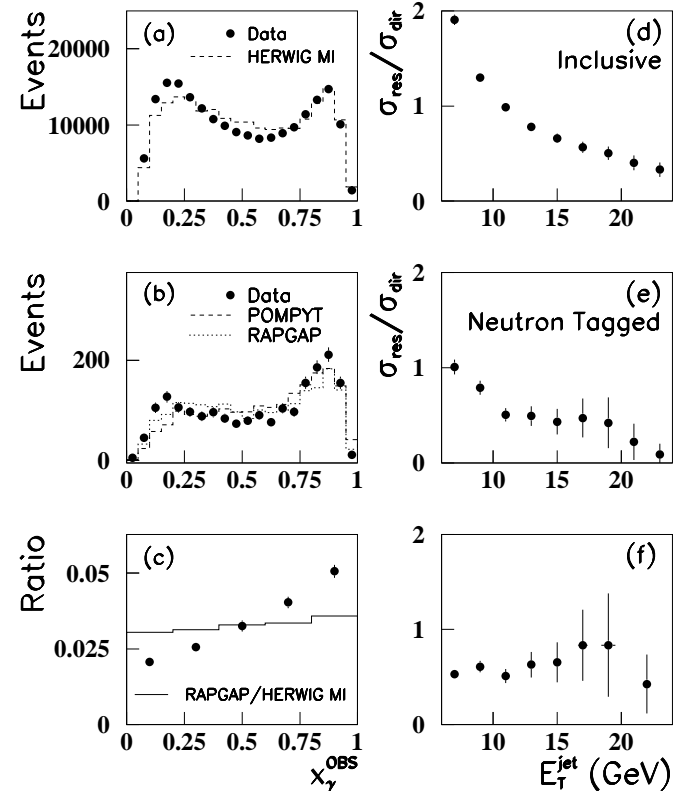


Leading Neutrons - ratios dijets+n/inclusive dijets

H1 dijets



ZEUS 1995



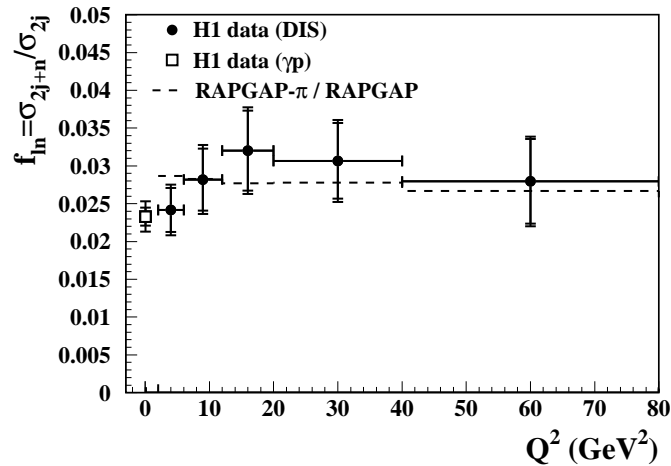
- Neutron production suppressed in resolved-photon enriched region
- Multiple interactions between γ and p remnants play a very important role in the inclusive dijets production

absorption ?? \rightarrow must be disentangled in experiment

prediction from theory ??

Leading Neutrons: Q^2 dependence

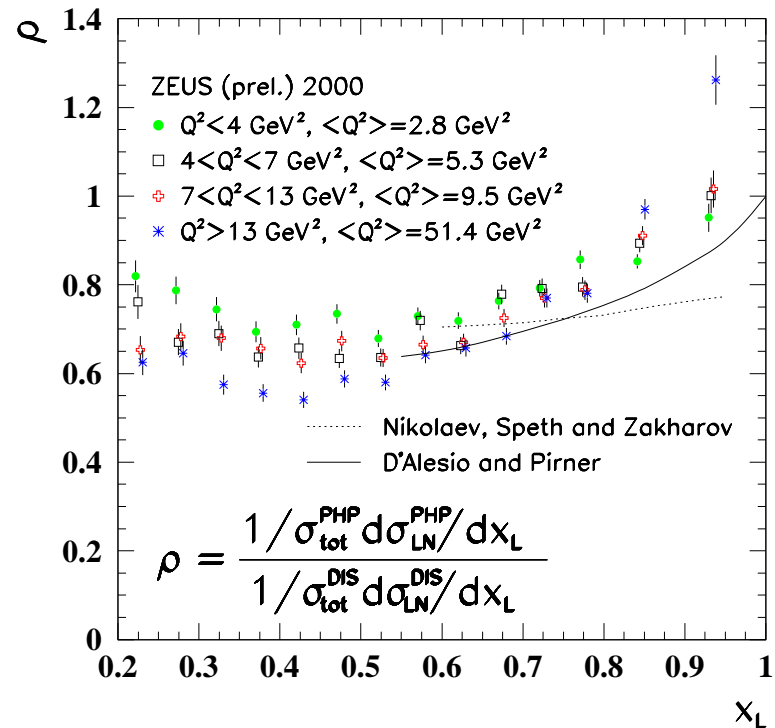
H1 dijets



Ratio dijets+n/inclusive dijets

No strong Q^2 dependence

ZEUS



Vertex factorization: $\rho = 1$

Indication of absorption for lower x_L , lower Q^2

Qualitative agreement with absorption models

Leading Neutrons

ZEUS

charm PhP: $R_{LN}^{D*}(x_L > 0.49) = 6.55 \pm 0.76_{-0.45}^{+0.35} \%$

Inclusive DIS: $R_{LN}^{DIS}(x_L > 0.49) = 5.8 \pm 0.3 \%$

Dijet PhP: $R_{LN}^{jj}(x_L > 0.49) = 4.8 \pm 0.4 \%$

Inclusive PhP: $R_{LN}^{PhP}(x_L > 0.49) = 4.3 \pm 0.3 \%$

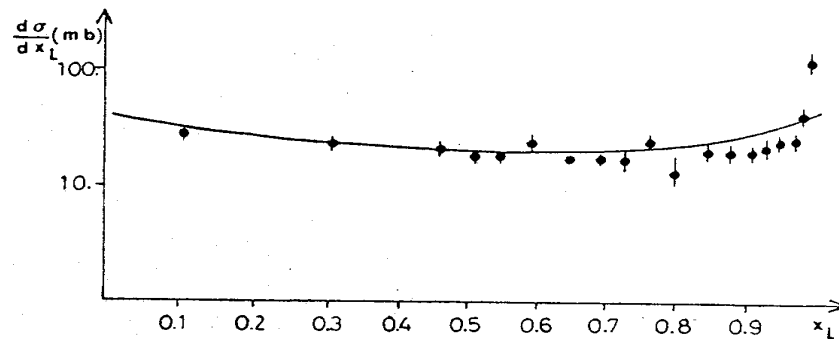
$$R_{LN}^{PhP} < R_{LN}^{jj} < R_{LN}^{D*} \approx R_{LN}^{DIS}$$

Neutrons production suppressed for resolved-photon enriched processes

20 years ago...

- 5 -

particle effect. From low energies up to ISR the leading proton spectrum has shown no detectable energy dependence. It is essentially flat in $x_L \equiv E_{\text{proton}}/E_{\text{incident}}$, apart from the increase in the $x_L \rightarrow 1$ limit (diffraction dissociation), and corresponds to a mean value $\langle x_L \rangle \approx 1/2$, i.e., on the average the leading proton retains half of the incoming energy (see Fig.3)



(Leading proton spectrum at ISR, $|\eta|$)

Fig. 3

So far, at the Collider, there are no data on the leading proton (leading anti-proton) spectrum. From cosmic rays there seems to exist an indication of a softening of the spectrum¹⁰⁾. From our previous discussion on contamination of soft physics by QCD hard physics, with multiple parton interactions and large P_T jets, it is indeed rather natural to expect a softening of the spectrum.

I describe next a very simple geometrical model to evaluate the leading particle spectrum¹¹⁾. In a recent paper by Chou, Yang and Yen¹²⁾ it was shown, from an analysis of pseudo-rapidity distributions at the SPS pp Collider, that the available energy E_A for particle production in central region is a monotonous decreasing function of the impact parameter b . This result is very suggestive. From our Fig.1 one easily accepts that at $b \rightarrow 0$, central collision, the hadrons are mutually stopped and most of their incoming kinetic energy is converted into available energy E_A .

from *J. Dias de Deus*

“Workshop on Elastic and Diffractive Scattering”

Blois, June 3-6, 1985

“So far, at the Collider, there are no data on the leading proton (leading anti-proton) spectrum...”

Summary and outlook

- 20 years have passed and Leading Baryon production remains a topic of great interest in High-Energy Physics
- HERA has contributed a lot to the understanding of Leading Baryon production, providing a large amount of precise data
- Results from Leading Protons:
 - no x_L dependence in cross sections and b -slopes
 - rates rising with Q^2
- Results from Leading Neutrons:
 - b -slopes show steep rise as a function of x_L
 - all results compatible with one-pion-exchange Model
 - data still not precise enough to offer improvement to pion *pdfs*
 - absorption effects observed as a function of x_L , Q^2
- Leading Baryon production suppressed in less 'point-like' processes
→ **is it another indication of rescattering?**

Summary and outlook

- Several issues are still to be understood:
 - Leading Neutrons: pion flux factor models must be constrained
 - The role of multiple-interactions / absorption must be understood
- More precise HERA data with leading baryons coming soon
- Input from theorists / phenomenologists is crucial

END