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Measurement of Dijet Cross Sections with Leading Neutrons in Photoproduction at HERA

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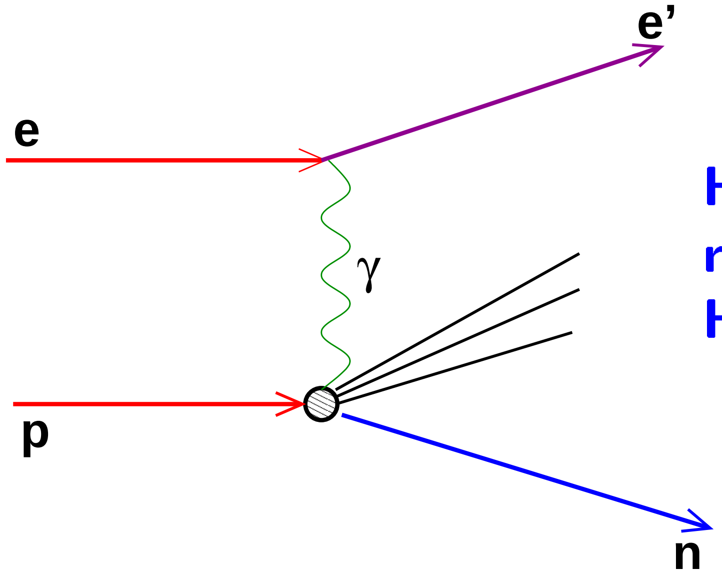
Representing the H1 and ZEUS Collaborations

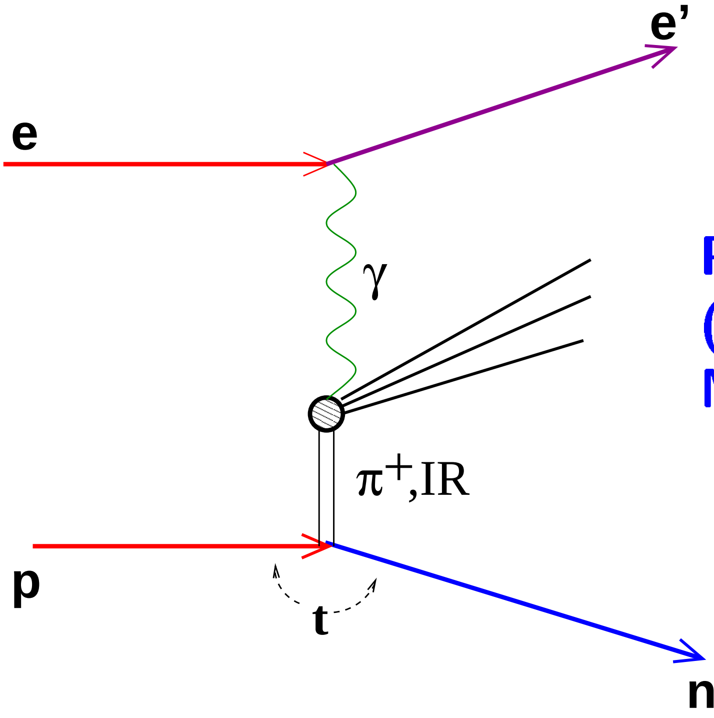
- Introduction
- Data selection
- Monte Carlo models
- Results
  - Test of factorization
  - Dijet cross-sections
- Conclusions

Introduction

Possible mechanisms for production of high-energy neutrons in ep interactions:



Hadronization of proton remnant (e.g.PYTHIA, HERWIG Monte-Carlo)



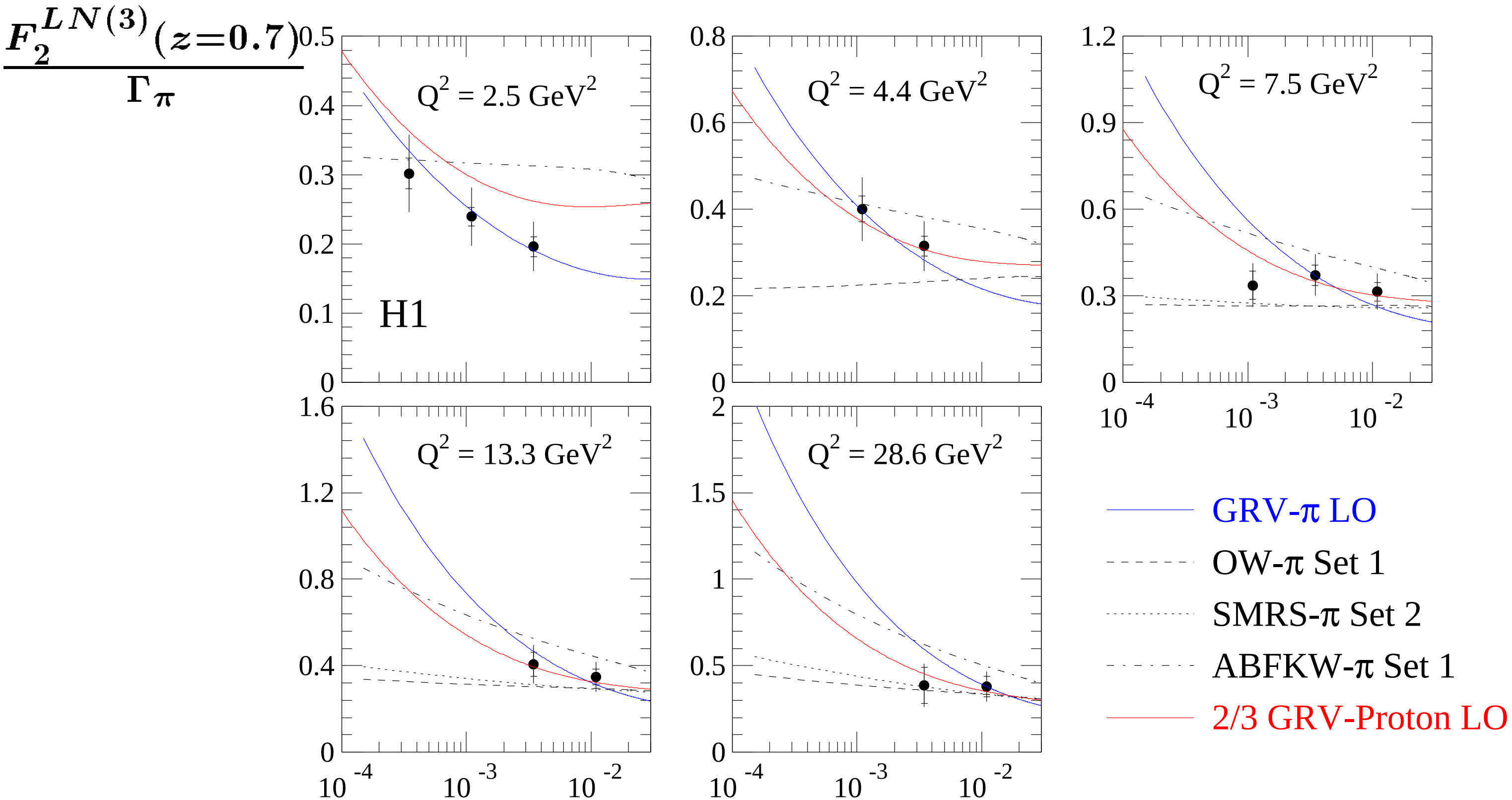
Particle (pion) exchange (e.g. POMPYT, RAPGAP Monte-Carlo)

$$\boxed{\sigma(ep \to e'nX) = f_{\pi/p}(z,t) \times \sigma(e\pi \to e'X)}$$

where $z = E_n/E_p^0$–fraction of incoming proton energy,
$t = (p_n - p_p)^2$– 4–momentum transfer squared

- The pion pole contribution dominates in the kinematical region $z \approx 0.7-0.9$, $|t| < 0.2-0.3\ GeV^2$.

- The first estimate for F_2^{π} in low x region in the DIS at HERA ($2 < Q^2 < 50\ GeV^2$):
(H1 Coll., *Eur.Phys.J. C6(1999)587*.

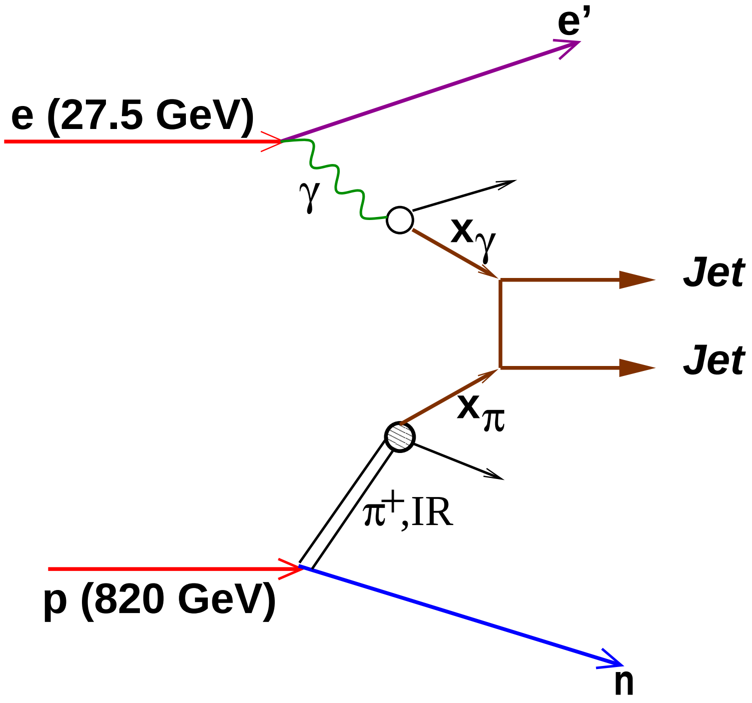


$$\beta = \frac{x}{1-z}$$

- Data show sensitivity to the parametrizations of the pion structure function (constrained for $x \gtrsim 0.1$ from the fixed target experiments).

- What about real photoproduction ?

Leading Neutrons (LN) in Dijet Photoproduction



- E_T^{jet}, η^{jet} – Transverse energy and pseudorapidity
- $x_\gamma = \Sigma E_T^{jet} e^{-\eta^{jet}} / 2E_\gamma$ – fraction of photon momentum carried by initial state parton participating in hard scattering

  - $x_\gamma = 1 \Longrightarrow$ direct photoproduction
  - $x_\gamma < 1 \Longrightarrow$ resolved photoproduction
- $x_\pi = \Sigma E_T^{jet} e^{\eta^{jet}} / 2(E_p^0 - E_n)$ – fraction of "pion" momentum carried by initial state parton participating in hard scattering

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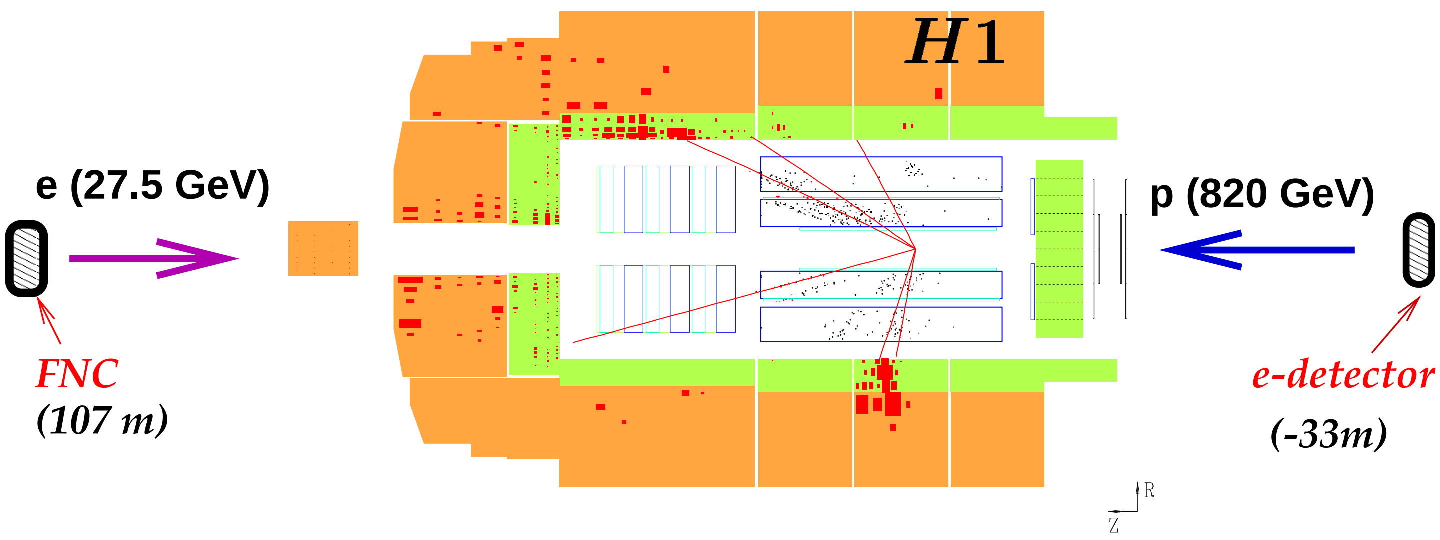
What can we study with this data ?

- Neutron production mechanism → compare hadronization and particle exchange models
- Test of factorization
- Are these measurements sensitive to F_2^π ?

Event Selection



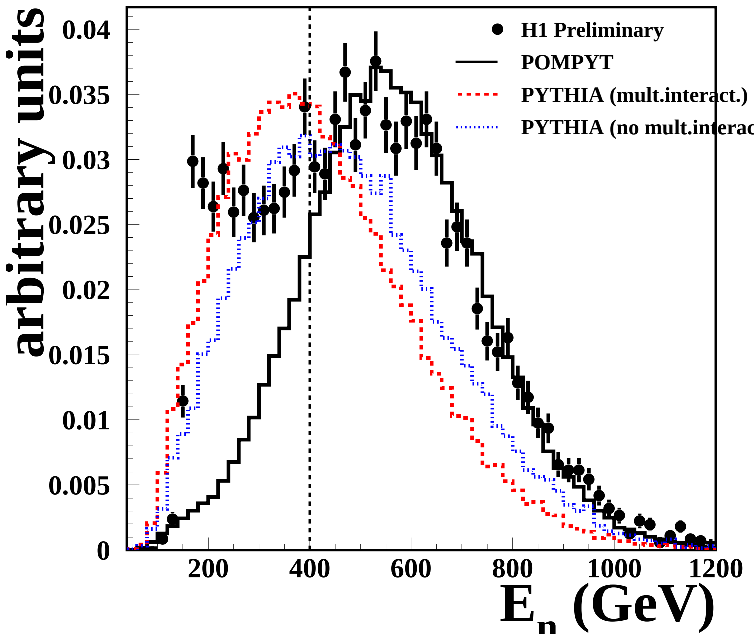
H1

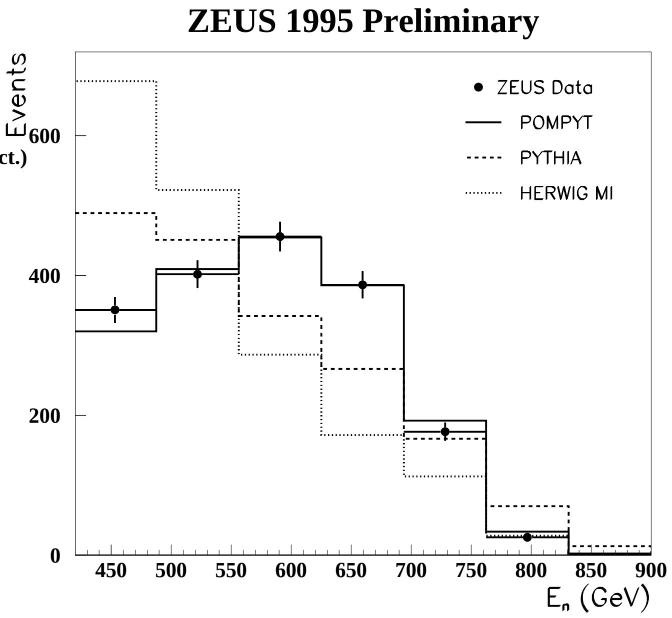
- 1996-97 data, Lumi$\sim 19.2 pb^{-1}$
- $Q^2 < 0.01\ GeV^2$, $0.3 < y \equiv E_\gamma / E_e^0 < 0.65$
  $156 < W_{\gamma p} < 242\ GeV$
- 2-jet events selected with cone-type algorithm,
  $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 1$
  $E_T^{jet} > 7\ GeV\ (4\ GeV)$, $-1 < \eta^{jet} < 2$
- Neutron detected in the Forward Neutron Calorimeter (FNC)
  $E_n > 400\ GeV$, $\theta_n < 0.8\ mrad$ (acceptance $\sim$ 35%).

ZEUS

- 1995 data, Lumi$\sim 6.4 pb^{-1}$
- $Q^2 < 1\ GeV^2$, $0.2 < y < 0.8$
  $134 < W_{\gamma p} < 269\ GeV$
- At least two jets with k_T-algorithm, $E_T^{jet} > 6\ GeV$, $|\eta^{jet}| < 2$
- $E_n > 400\ GeV$, $\theta_n < 0.8\ mrad$

Neutron Energy Spectrum





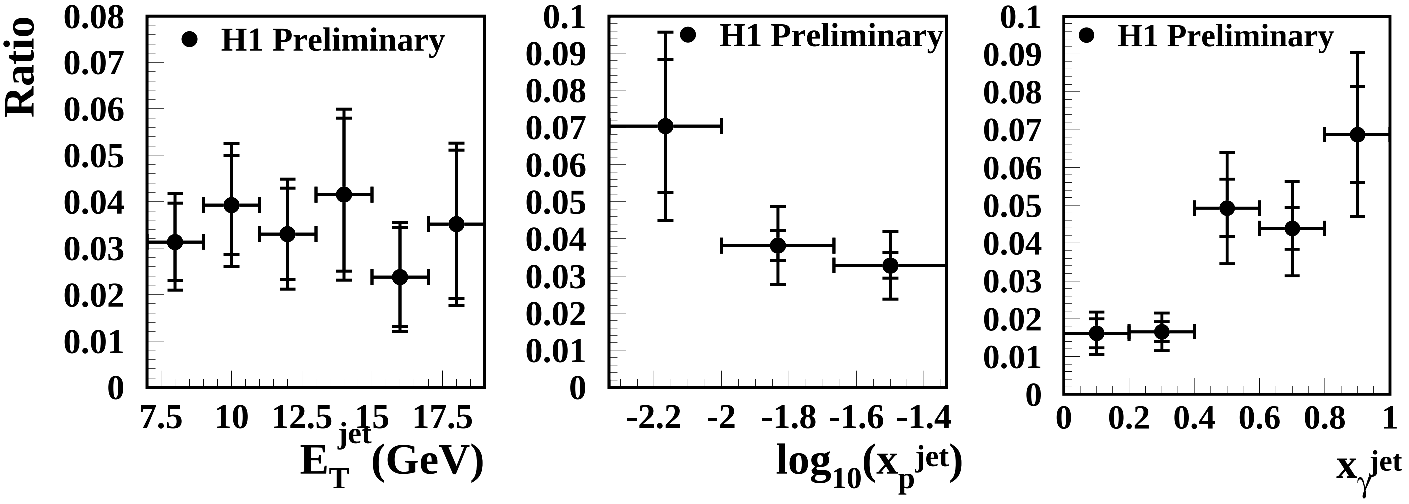
- **PYTHIA 5.7, HERWIG 5.9**
  - Leading neutron production through the Lund string (PYTHIA) or cluster (HERWIG) hadronization models
  - possibility for multiple interactions between the remnant partons
- **POMPYT 2.6**
  - Leading neutron production through the pion exchange
  - Pion flux factor from Holtmann, Levman, Nikolaev, Szczurek, Speth (*Phys.Lett.B338(94)363*)

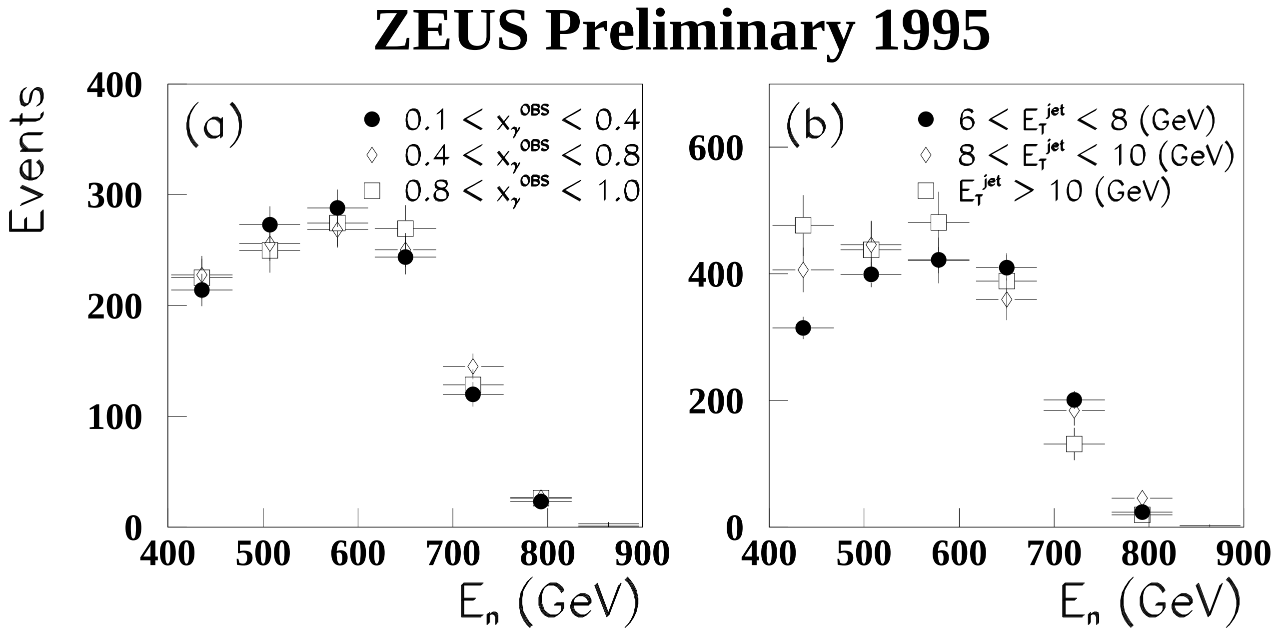
- Models without pion exchange (PYTHIA, HERWIG) do not reproduce neutron energy distribution.

- Model with pion exchange (POMPYT) reproduce the neutron energy distribution for $E_n > 400\ GeV$.

Test of factorization:

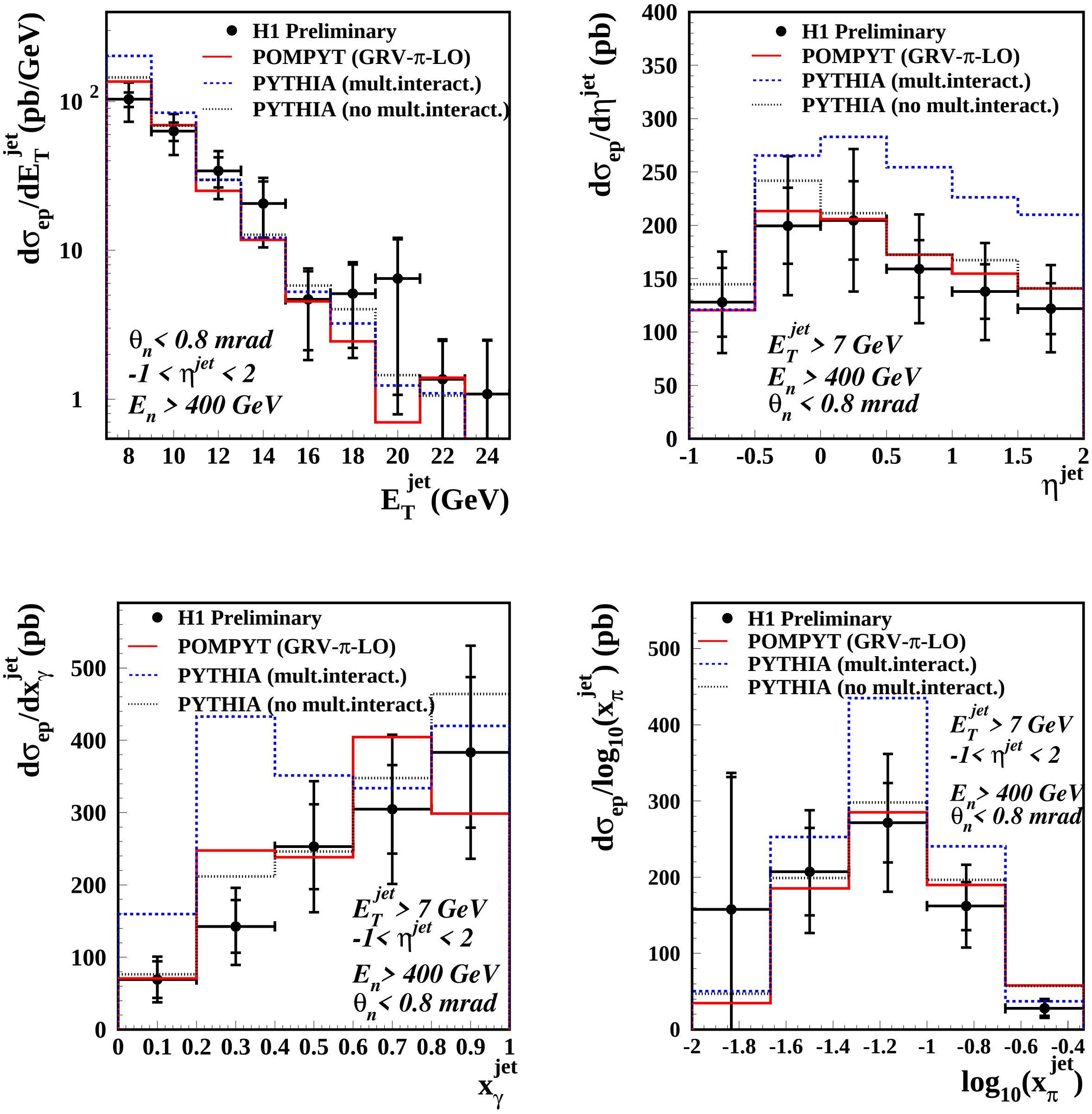
- Rate of neutron production as a function of jet variables
- Compare E_n spectra at different x_γ, E_T^{jet}.





- Leading Neutrons are observed in $\sim 4\%$ of the inclusive dijets.
- Strong dependence from x_γ^{jet} $\longrightarrow$ expected from kinematics
- The leading neutron production is independent of E_T^{jet}, x_p^{jet} $\longrightarrow$ consistent with factorization of the lepton and hadron vertices.

Dijet cross-sections (H1)



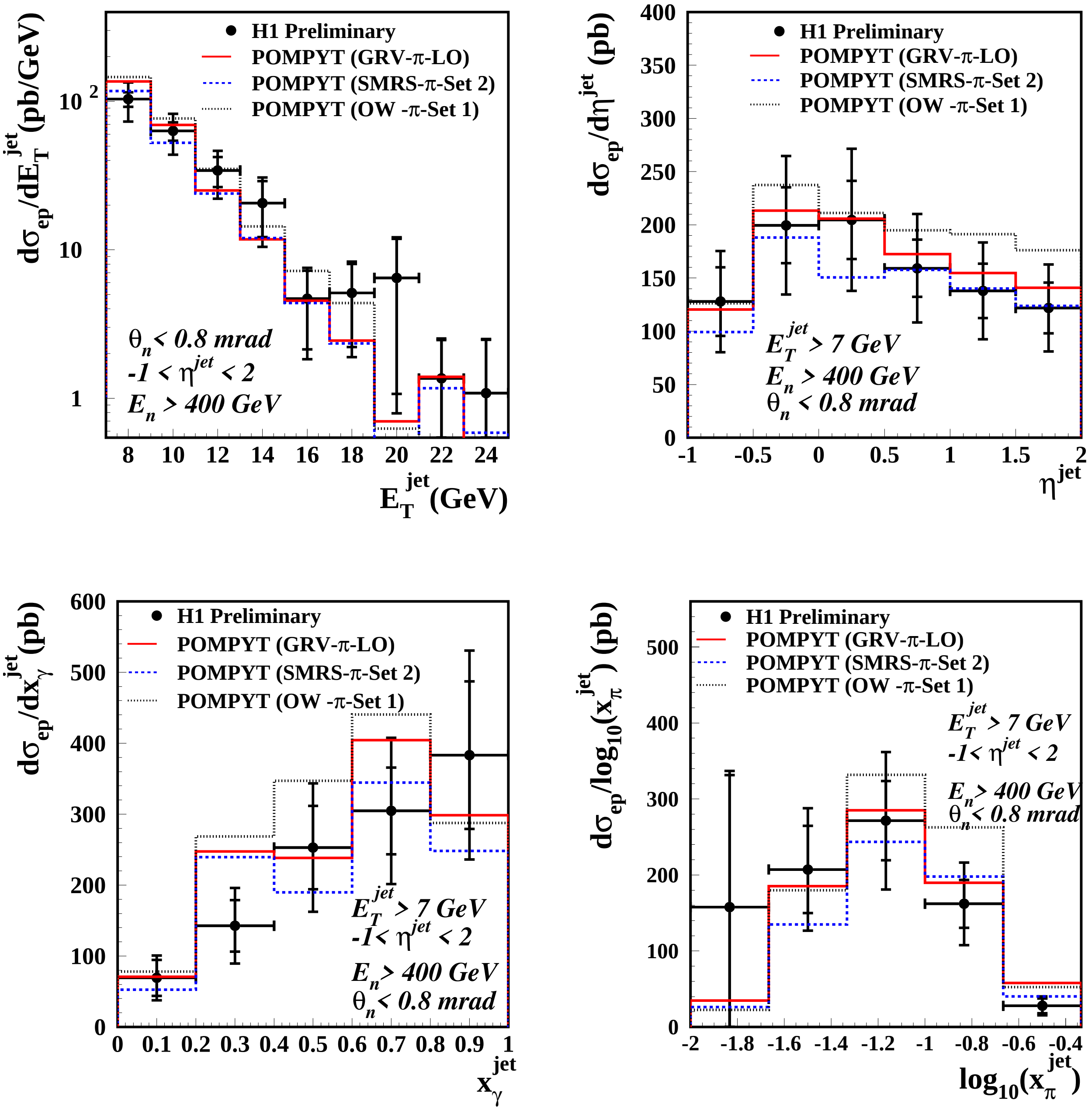
- OPE model (POMPYT) describes jet cross-sections

- PYTHIA (without MI) is also able to describe the jet cross-sections (but not the E_n spectrum !)

- PYTHIA with mult.interactions does not describe LN cross-sections

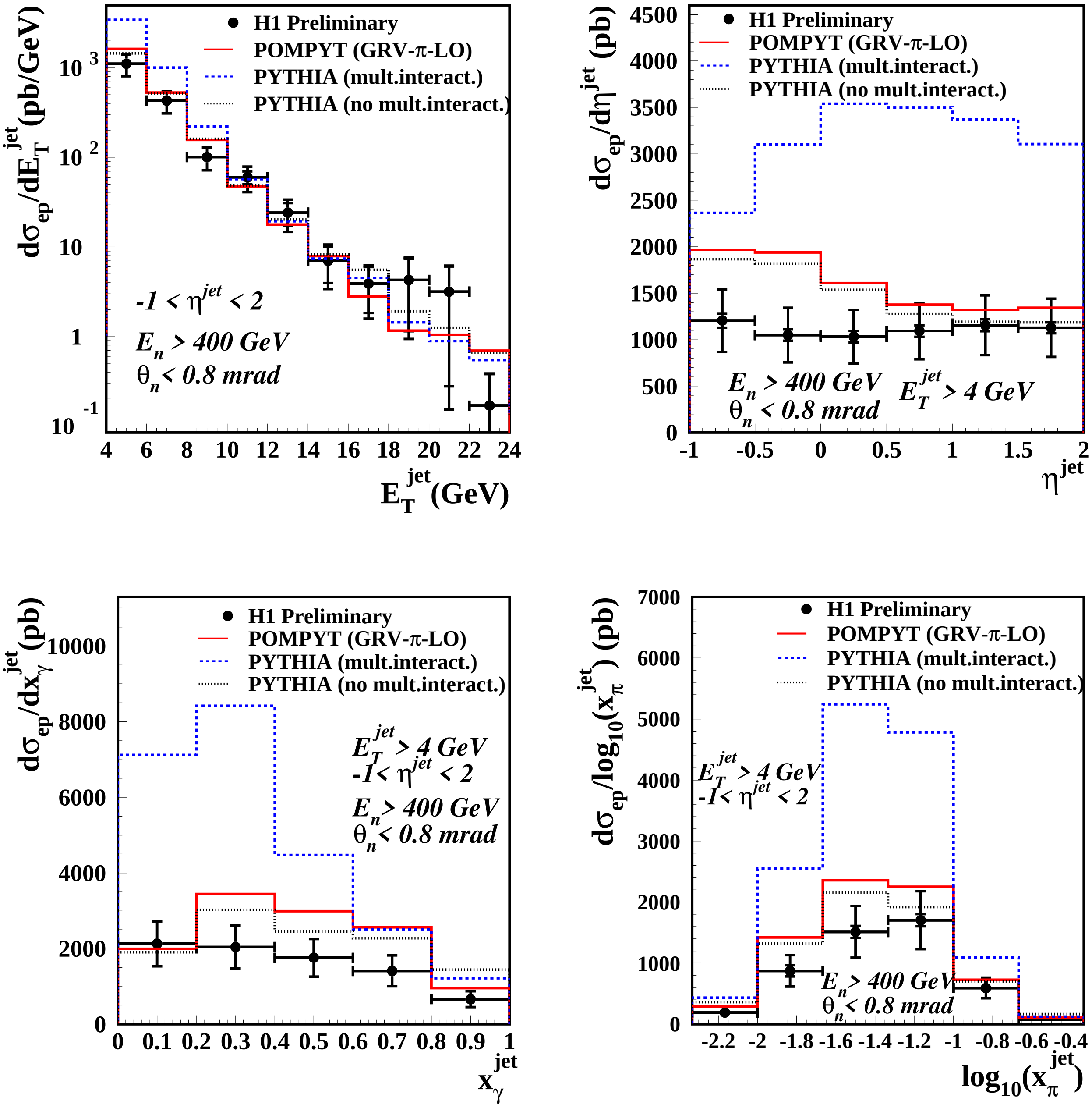
- Direct photon processes dominate

Comparison of different parameterizations of pion structure function



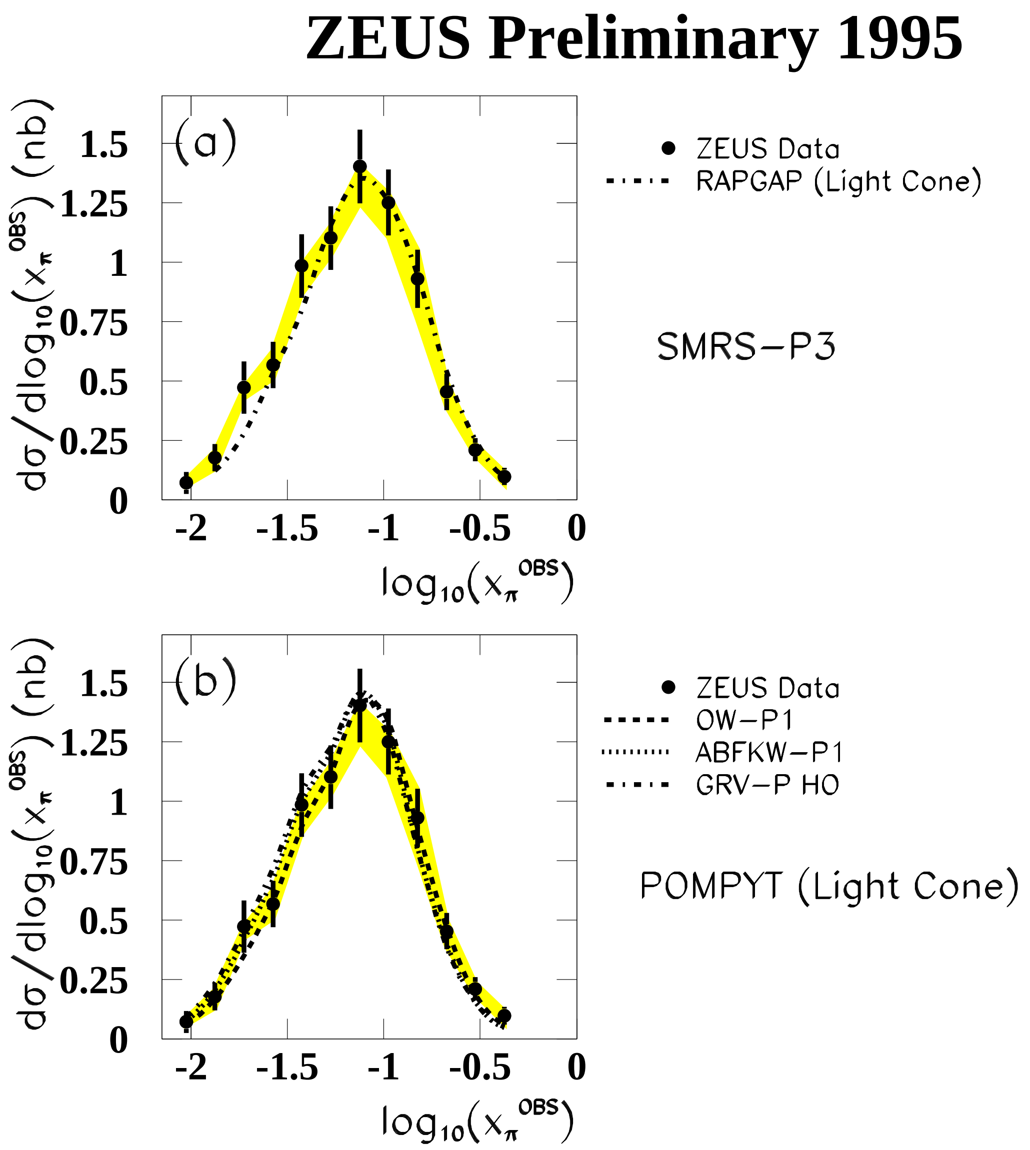
- At the present level of experimental uncertainties in the measurement no preference for any of the π-structure function parameterizations can be given yet.

Dijet cross-sections ($E_T^{jet} > 4\ GeV$) (H1)



- At lower jet energies none of models can describe jet cross-sections.

Dijet cross-section in photoproduction (ZEUS results)



One-pion-exchange models describe shape and normalisation of both the neutron and jet distributions.

Summary

The photoproduction of dijets with the highly energetic forward neutrons in the final state has been studied.

- Leading Neutrons are observed in $\sim 4\%$ of the inclusive processes, independent of the E_T jet.
  The neutron energy distribution is independent of the jet E_T and x_γ $\longrightarrow$ The present data support the idea of factorization of the lepton and hadron vertices.

- Models with one pion exchange describe the neutron energy spectrum and the jet production differential cross-sections (but fail at lower jet energies).
  A colour singlet component of proton structure is needed to describe the data.

- Within the present experimental uncertainties of this measurement, it is not yet possible to discriminate between different parameterizations of the pion structure function.