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Measurement of the Dijets with a Leading Neutron in ep Interactions at HERA

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Representing the H1 Collaboration

Outline:

- Introduction
- Cross section measurements
- Comparison of photoproduction cross sections with NLO
- Ratios of leading neutron to inclusive dijet cross sections
- Summary

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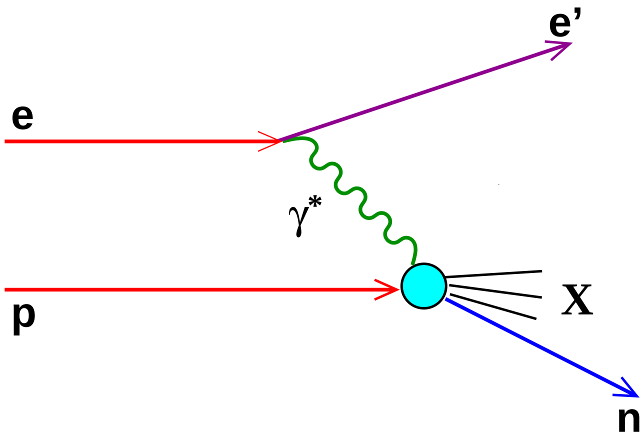
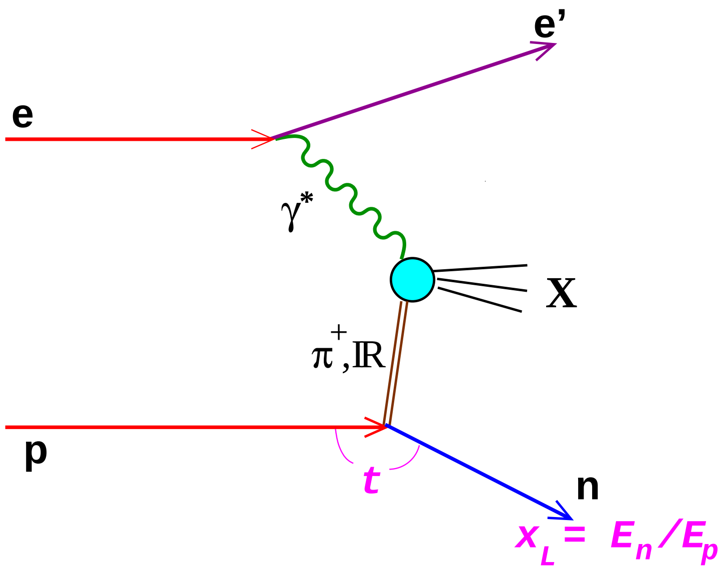
Introduction

Possible mechanisms for production of highly energetic forward neutron:

– Fragmentation of proton remnant



– Exchange processes



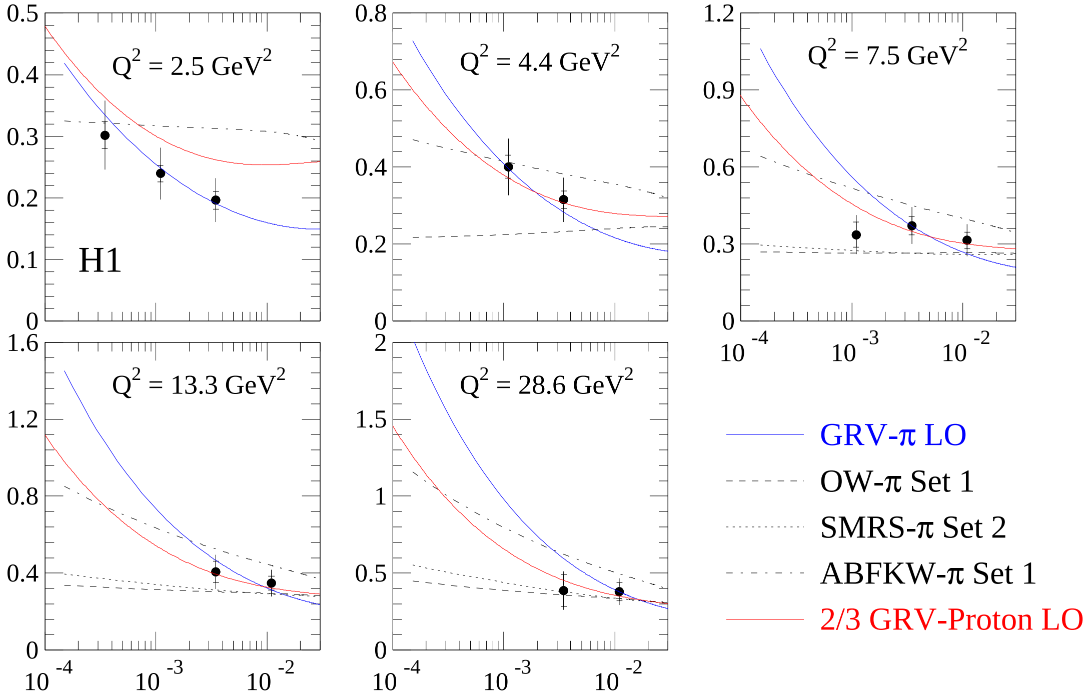
$$\sigma(ep \longrightarrow e'nX) = f_{\pi/p}(x_L, t) \times \sigma(e\pi \longrightarrow e'X)$$

the pion pole contribution dominates for $x_L \gtrsim 0.7$

- The leading neutron (LN) production in semi-inclusive DIS is described well by pion exchange model and by soft colour interaction (LEPTO-SCI) model.

- Assuming pion exchange, F_2^{π} is measured in low x region in the DIS at HERA ($2 < Q^2 < 50\ GeV^2$): (H1 Coll., *Eur.Phys.J. C6(1999)587*).

$$\frac{F_2^{LN(3)}(x_L{=}0.7)}{\Gamma_\pi}$$



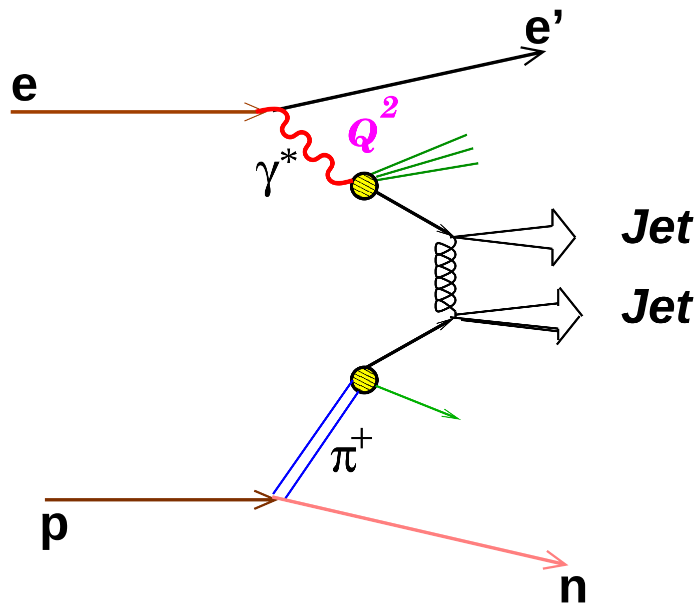
$$\beta = \frac{x}{1-x_L}$$

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

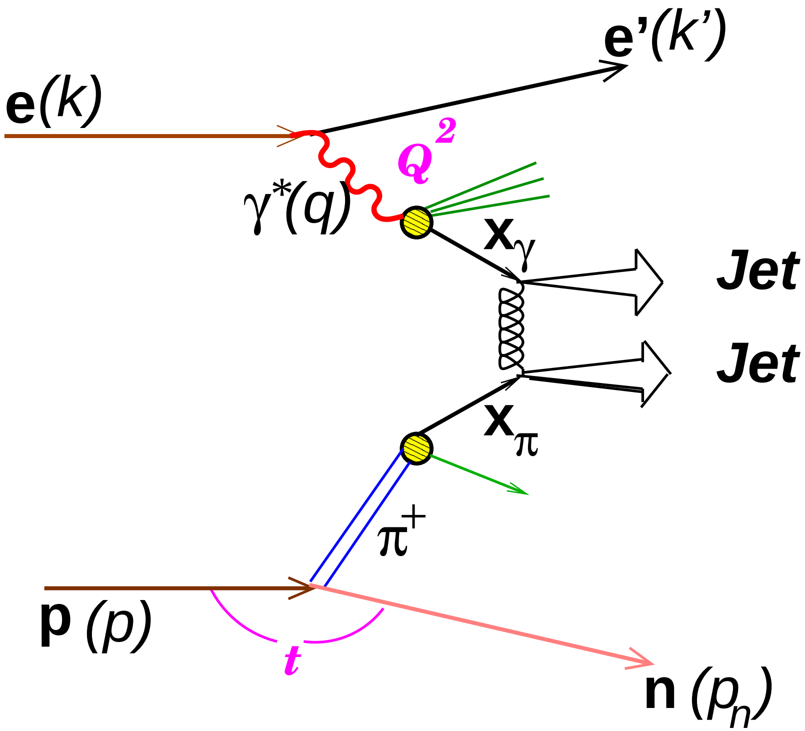
Present Analysis

- hadronic final state contains two hard jets
- Photoproduction ($Q^2 < 10^{-2} GeV^2$) and DIS regimes ($2 < Q^2 < 80\ GeV^2$)
- pQCD is applicable (Monte Carlo models, theory calculations)
- complementary to semi-inclusive DIS with leading neutrons
- assuming factorization the structure of exchanged object can be investigated
- analyse ratio of cross sections with and without neutron tag $\longrightarrow$ test of factorization (leading neutron production rate is independent from the jet kinematical variables)

$$e + p \longrightarrow e' + n + jet + jet + X$$



Definition of kinematic variables



$Q^2 = -q^2 = -(k - k')^2$	photon virtuality
$x = \frac{Q^2}{2q \cdot p}$	Bjorken scaling variable
$y = \frac{(q \cdot p)}{(k \cdot p)}$	inelasticity

$t = (p - p_n)^2$	4-momentum transfer squared
$x_L = \frac{(q \cdot p_n)}{(q \cdot p)} \simeq \frac{E_n}{E_p}$	fraction of p momentum transferred to neutron

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x_γ, x_π, x_p — fractional momenta of the partons from the photon, pion, and proton, which enter the hard interaction

$$x_\gamma^{jets} = \frac{\sum E_{T,i}^{jet} exp(-\eta_i^{jet})}{2yE_e}, \quad x_\pi^{jets} = \frac{\sum E_{T,i}^{jet} exp(\eta_i^{jet})}{2(E_p - E_n)}$$

$$x_p^{jets} = \frac{\sum E_{T,i}^{jet} exp(\eta_i^{jet})}{2E_p}$$

Monte-Carlo programs and NLO calculations

	Photoproduction	DIS
π-exchange	RAPGAP-π, POMPYT	RAPGAP-π
Inclusive (no π-exchange)	PYTHIA-MI, PYTHIA	RAPGAP, LEPTO, LEPTO-SCI
NLO calculations (π-exch.)	M.Klasen & G.Kramer	

π-exchange:

– assume factorization : $\sigma(ep \rightarrow e'nX) = f_{\pi/p}(x_L, t) \times \sigma(e\pi \rightarrow e'X)$

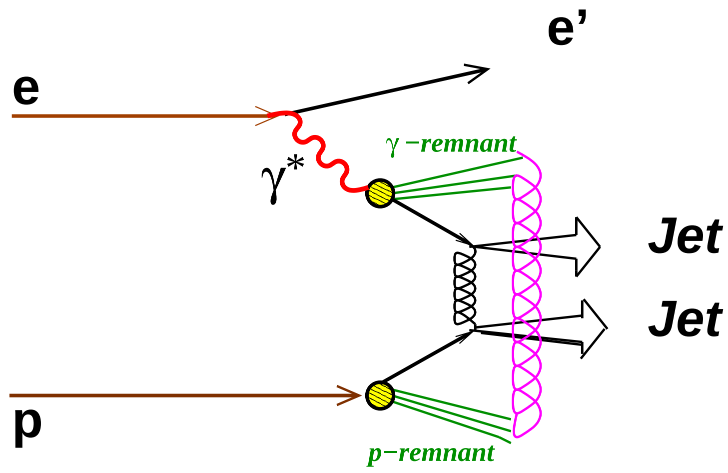
– pion flux (light cone - Holtmann et al. *Phys.Lett. B338, 363 (1994)*):

$$f_{\pi^+/p}(x_L, t) = \frac{1}{2\pi}\frac{g^2_{p\pi N}}{4\pi}(1 - x_L)\frac{-t}{(m^2_\pi - t)^2} exp(-R^2_{\pi n}\frac{m^2_\pi - t}{1 - x_L})$$

– the phenomenological parameters describing the π-exchange are taken from analyses of hadronic interactions.

'Multiple interactions' (MI)

– interactions between partons from the remnants– necessary to describe the inclusive jet production

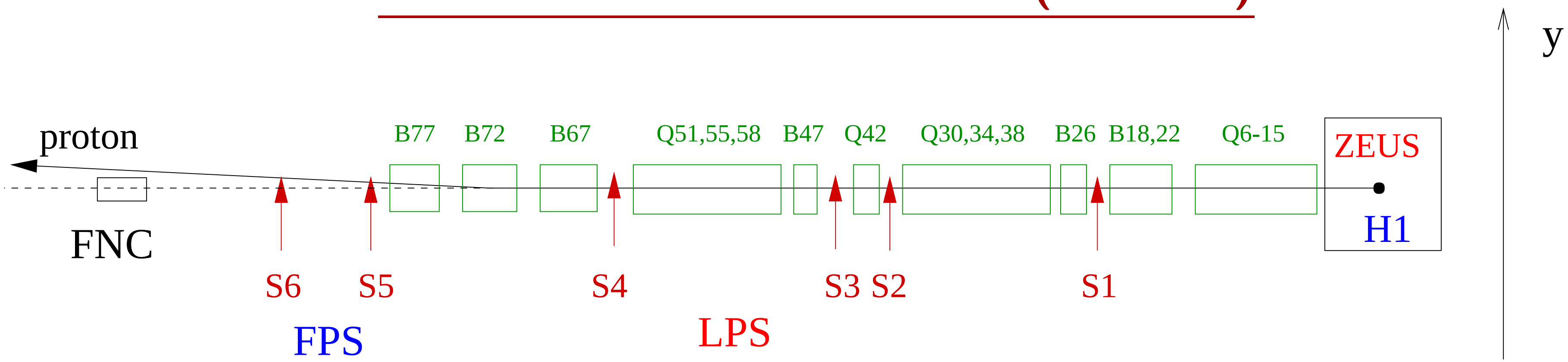


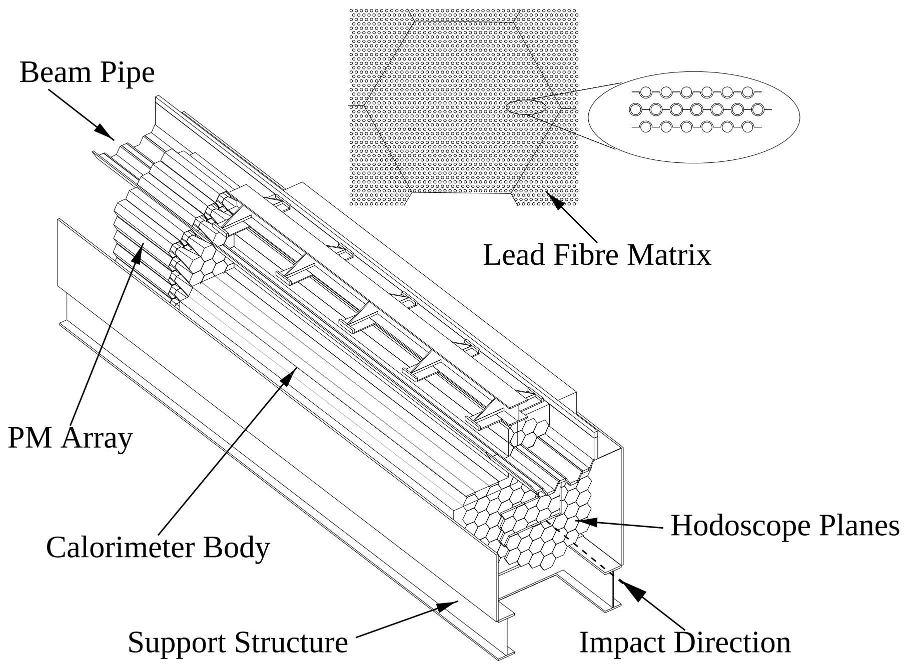
Event Sample

- Data sample from 1996-97, total luminosity $\simeq$ 20 pb^{-1}

	Kinematic regions
Photoproduction DIS	$Q^2 < 10^{-2}\ GeV^2, \quad 0.3 < y < 0.65$ $2 < Q^2 < 80\ GeV^2, \quad 0.1 < y < 0.7$
Dijets Neutrons	$E_T^{jet1} > 7\ GeV, \quad E_T^{jet2} > 6\ GeV, \quad -1 < \eta_{lab}^{jet1,2} < 2$ $E_n > 500\ GeV, \ \theta_n < 0.8$ mrad

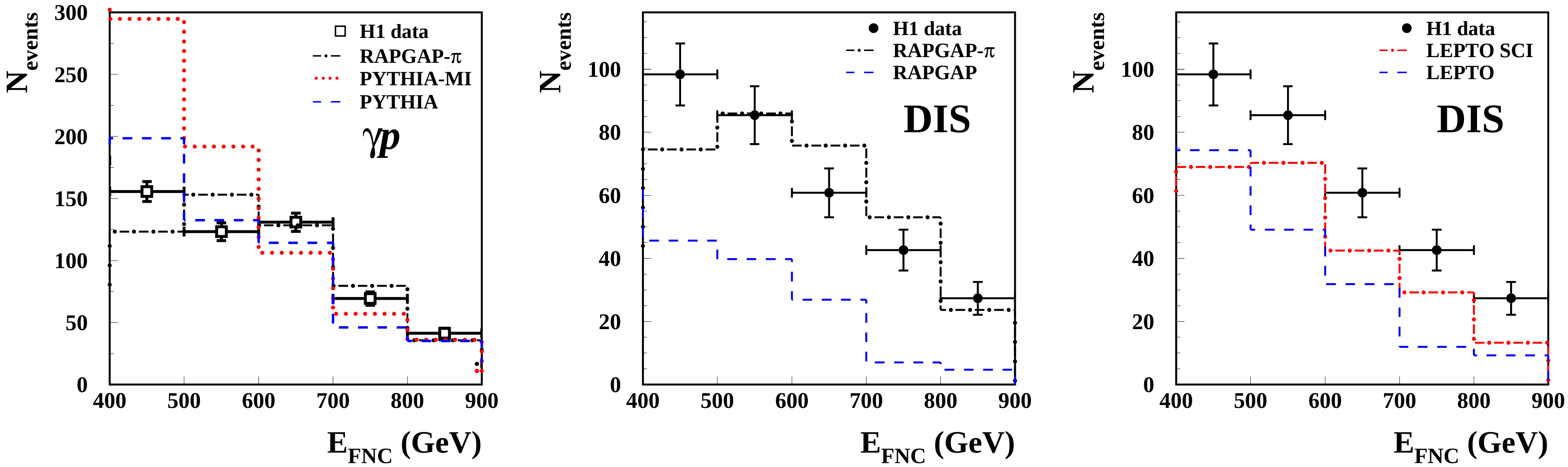
Forward Neutron Calorimeter (H1-FNC)





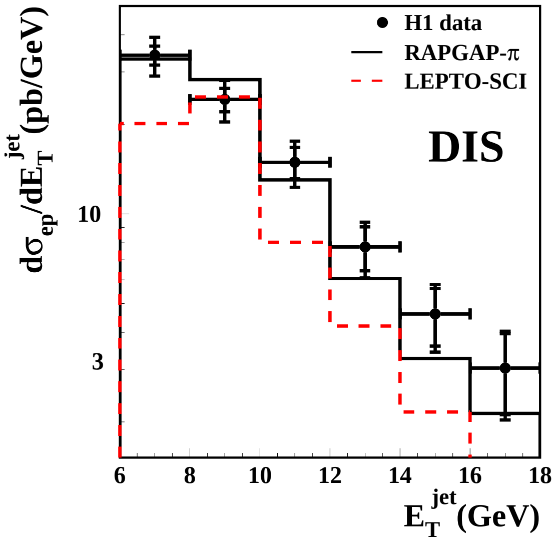
- **Dedicated detector at 107 m downstream in proton direction from interaction point**
- **Acceptance limited by magnet apertures:** $\theta_n \lesssim 0.8\ mrad,\ p_t < 0.66\ x_L$
- **Spaghetti calorimeter**
- **75 modules (1141 fibers in each)**
- $\sigma_E/E \sim 20\%$ **at high** E,
- $\sigma_{XY} = 5.13/\sqrt{E[GeV]} \oplus 0.22\ cm$
- **H1 Collab.,** *Eur.Phys.J.* **C6 (1999) 587.**

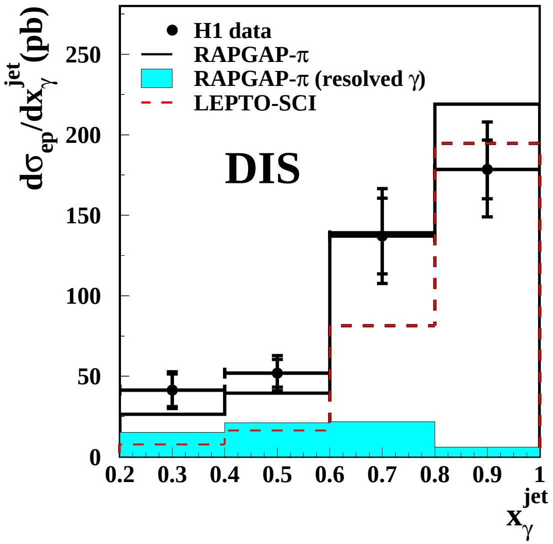
Neutron Energy Distribution



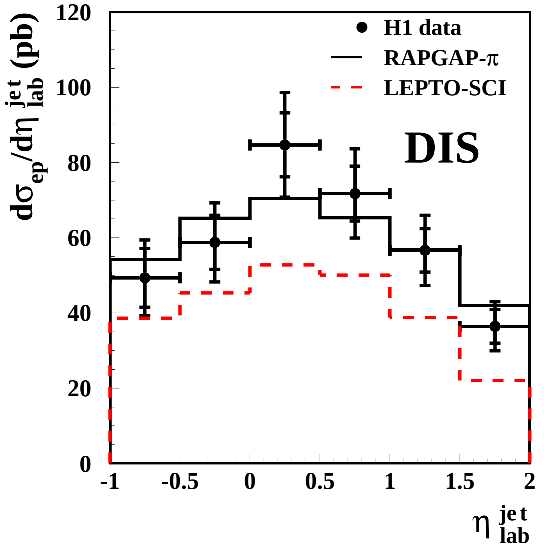
- Well described by π–exchange Monte Carlo models (RAPGAP-π, POMPYT)
- The 'standard' DIS models - RAPGAP, LEPTO predict too low neutron rates (even with SCI included)
- The 'standard' γp model PYTHIA (with multiple interactions) predicts too high rates at low E_{FNC}.
  Without multiple interactions included, PYTHIA provides reasonable description of E_{FNC}

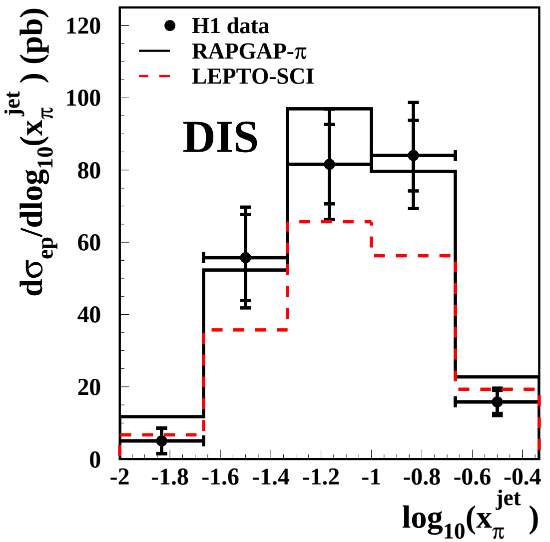
Cross Section measurements in DIS

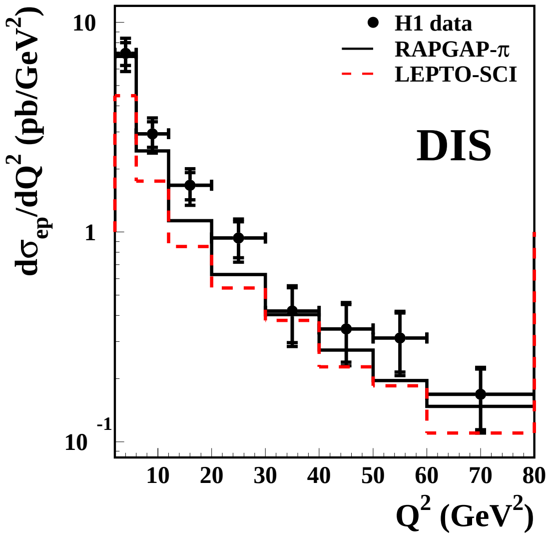




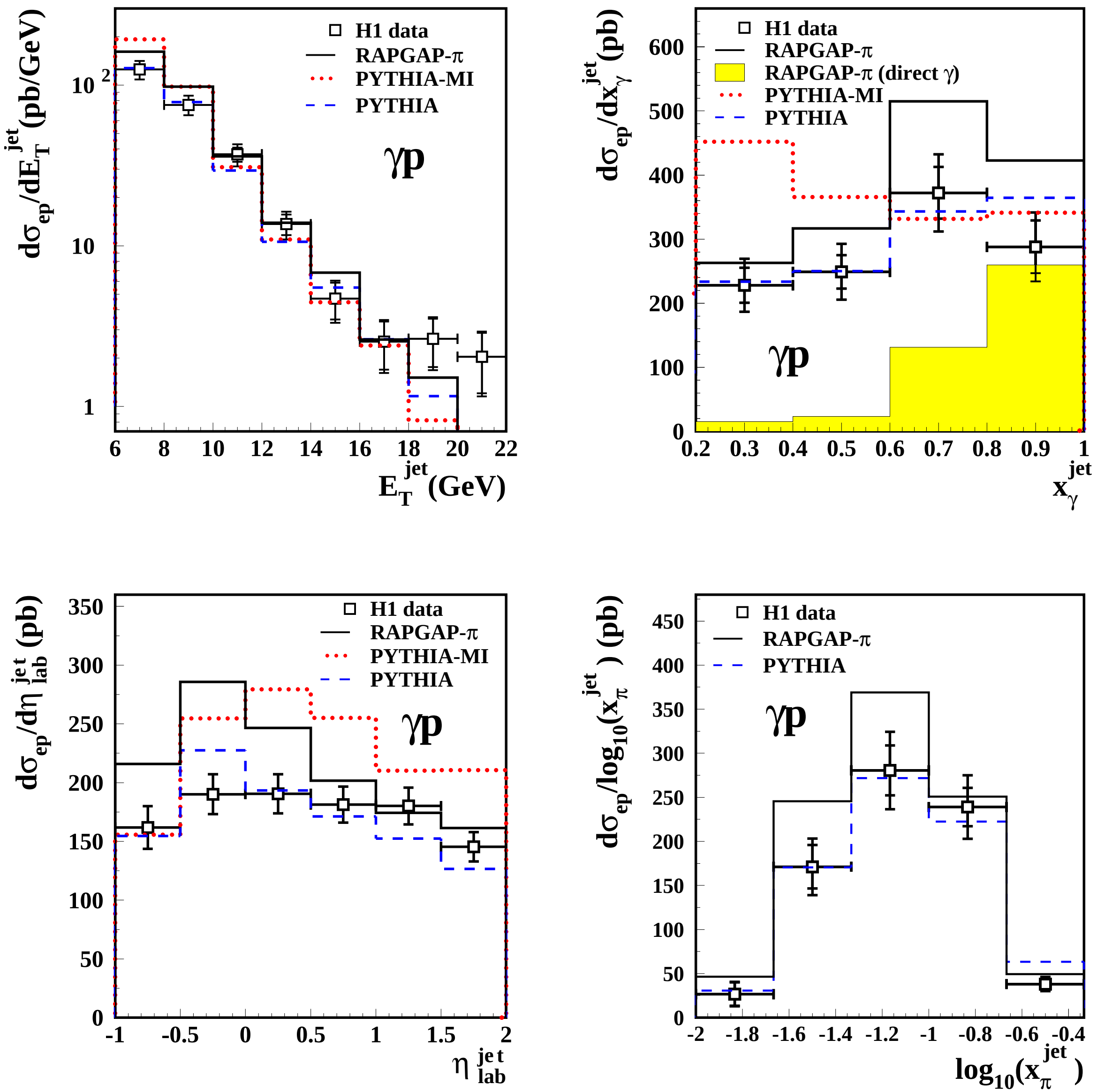
- Good description by π–exchange model RAPGAP-π
- The model for inclusive jet production- LEPTO - is too low
- A small contribution of resolved photon processes is necessary
- normalization uncertainty ~20% is not shown







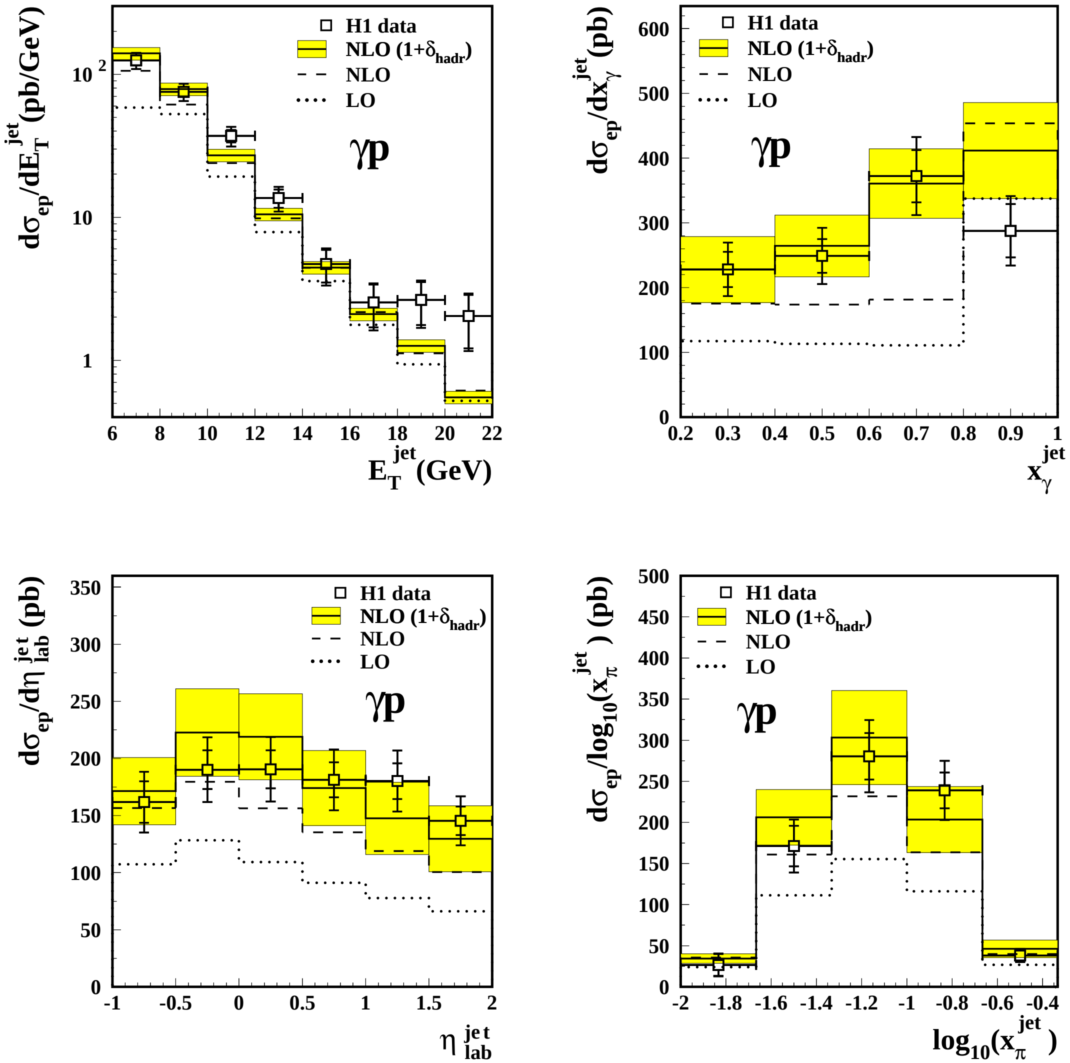
Cross Section measurements in photoproduction



- Within uncertainties described by π−exchange Monte Carlo model
- PYTHIA also describes LN data, but not the inclusive γp
- The models for inclusive jet production- PYTHIA-MI - is too high at $\eta^{jet} > -0.5$ and low x_γ^{jet} $\Longrightarrow$ resolved photon processes dominate, but the relative contribution of resolved photons is less in dijet events with LN than in inclusive case.

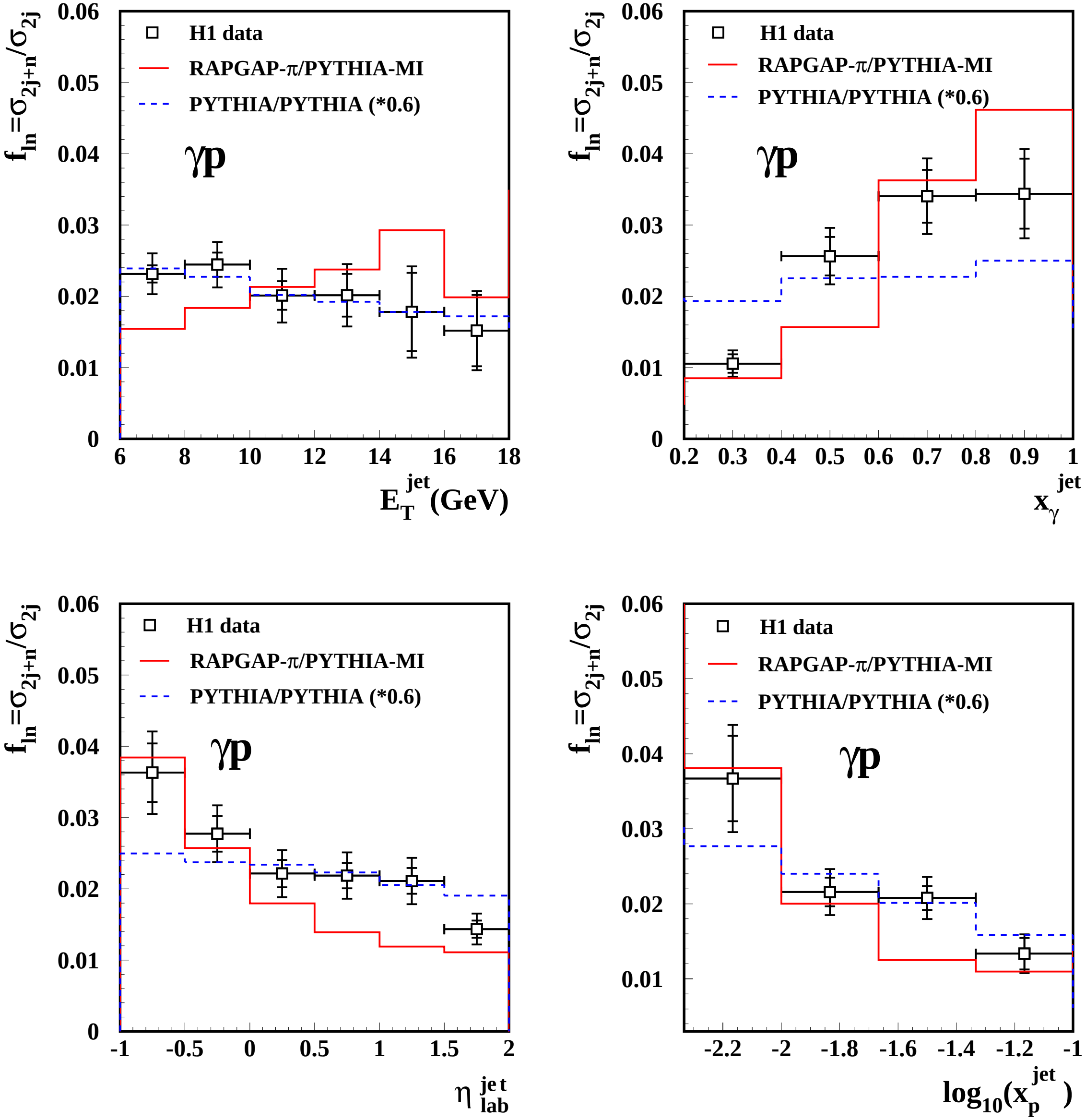
Cross Section – comparison with NLO (M.Klasen, G.Kramer)

(*Phys.Lett. B508, 259 (2001)*)



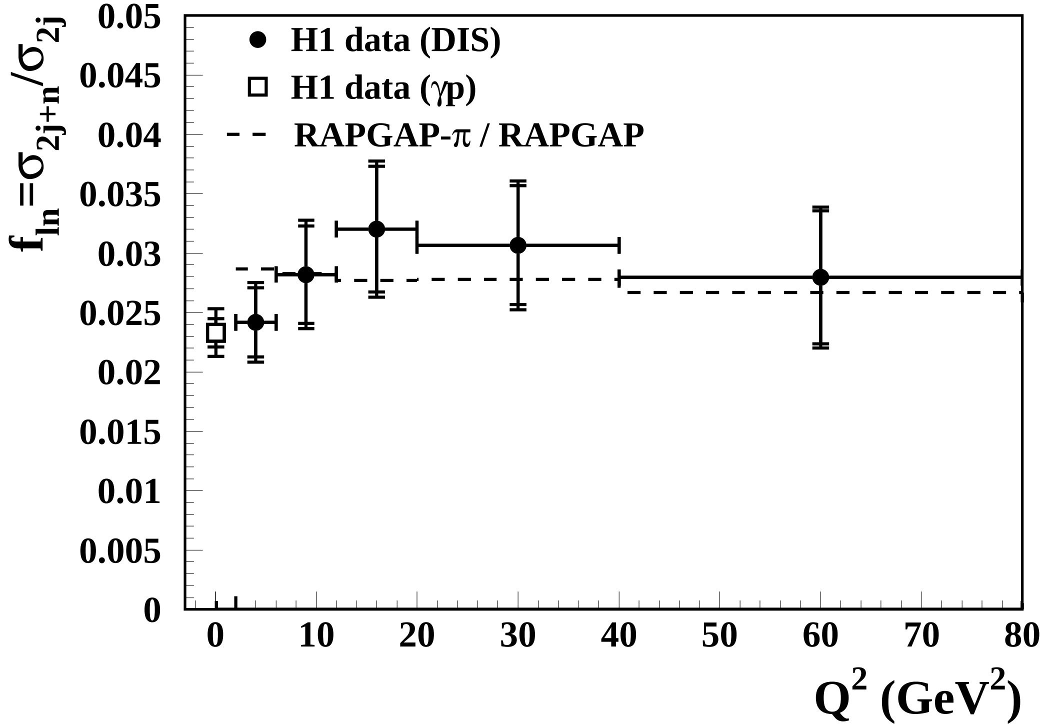
- **NLO QCD calculation, based on pion exchange, corrected for hadronization effects describes the measurement well**

Ratios of leading neutron to inclusive cross sections



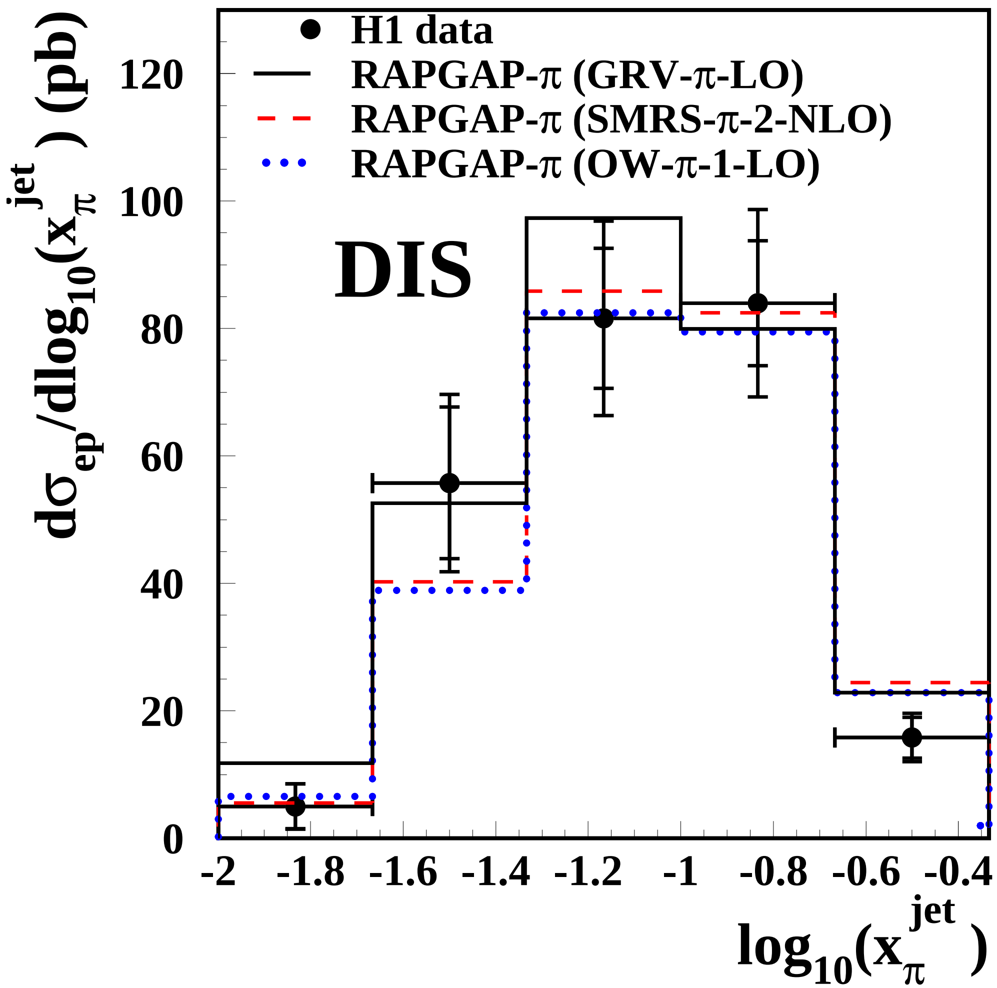
- factorization – hard interaction independent of leading neutron production
- f_{ln} is almost independent of E_T^{jet}, $\sim 2.3\%$ in average
- f_{ln} shows a strong dependence on η^{jet}, x_γ^{jet} and x_p^{jet}
  - this dependence is not due to 'phase space' effects
  - relative contribution of resolved photons is less in dijet events with leading neutrons than in inclusive case $\Longrightarrow$ no 'multiple interactions' in leading neutron jet events

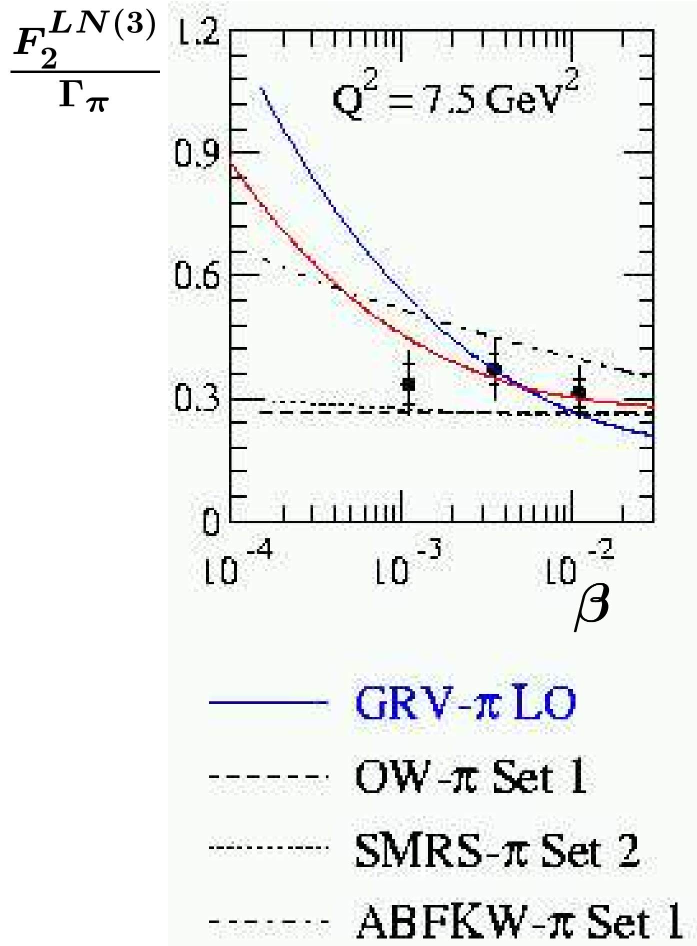
Ratios of leading neutron to inclusive cross sections



The fraction of dijet events with leading neutron does not show significant Q^2 dependence (tendency for rise for $Q^2 \lesssim 20\ GeV^2$ - absorptive effects ?)

Cross Section vs x_π^{jet} – comparison of different pion PDFs





Within uncertainties, the dijet data can not give preference to any pion PDF.

Conclusions

- The cross sections for dijet production in events with leading neutrons is measured in DIS ($2 < Q^2 < 80\ \mathrm{GeV}^2$) and photoproduction ($Q^2 < 10^{-2}\ \mathrm{GeV}^2$)

- The ratios of cross sections with and without the leading neutron requirement don't show strong dependence on E_T^{jet} (in photoproduction) or on Q^2.

- In photoproduction, the ratio shows strong increase with x_γ^{jet}. The leading neutron dijet data have a lower fraction of resolved photon processes than do the inclusive dijet data- the multiple interactions which contribution to inclusive jet production increases with decreasing x_γ, have no effect in leading neutron events.

- The differences between the dijet production data with and without leading neutrons point to differences in the production mechanism of events with and without leading neutrons. In general, the LO QCD MC models and NLO QCD calculation, in which the neutrons are produced via a pion exchange, are able to describe the different properties of leading neutron events.