Jet cross sections in D^* photoproduction at ZEUS

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on behalf of the ZEUS Collaboration

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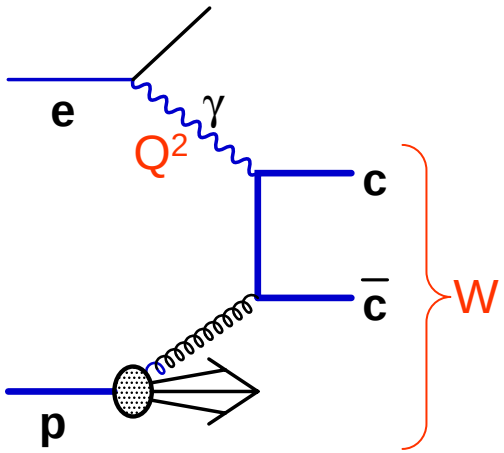
Contents

Introduction

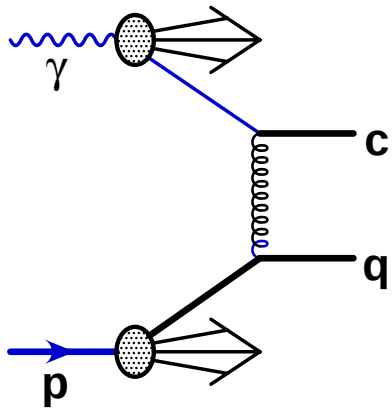
- Heavy quark production in *ep* collisions
  - Hard scale provided by heavy quark mass (m_c, m_b). Calculable in pQCD.
  - Parton dynamics of the hard scattering.
  - Sensitive to gluon and/or heavy quark PDFs.
  - Study non-perturbative effects : fragmentation etc.
  - Still an unresolved part of the pQCD.

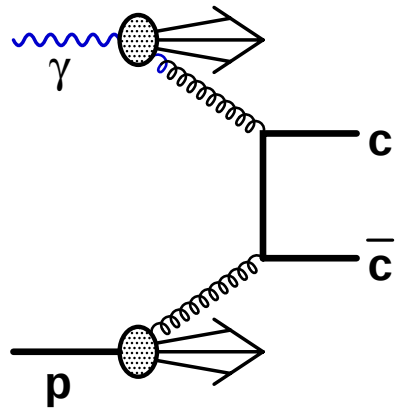
- Inclusive jet cross sections in D^* photoproduction.
  - Jets are as close as you can get to reconstruct parton dynamics.
  - Reduce uncertainty from hadronization effects.
  - Wider kinematic range of measurement.

Charm production at HERA



Direct photon process





Resolved photon process

Kinematic variables

Q^2 : virtuality of the exchanged photon

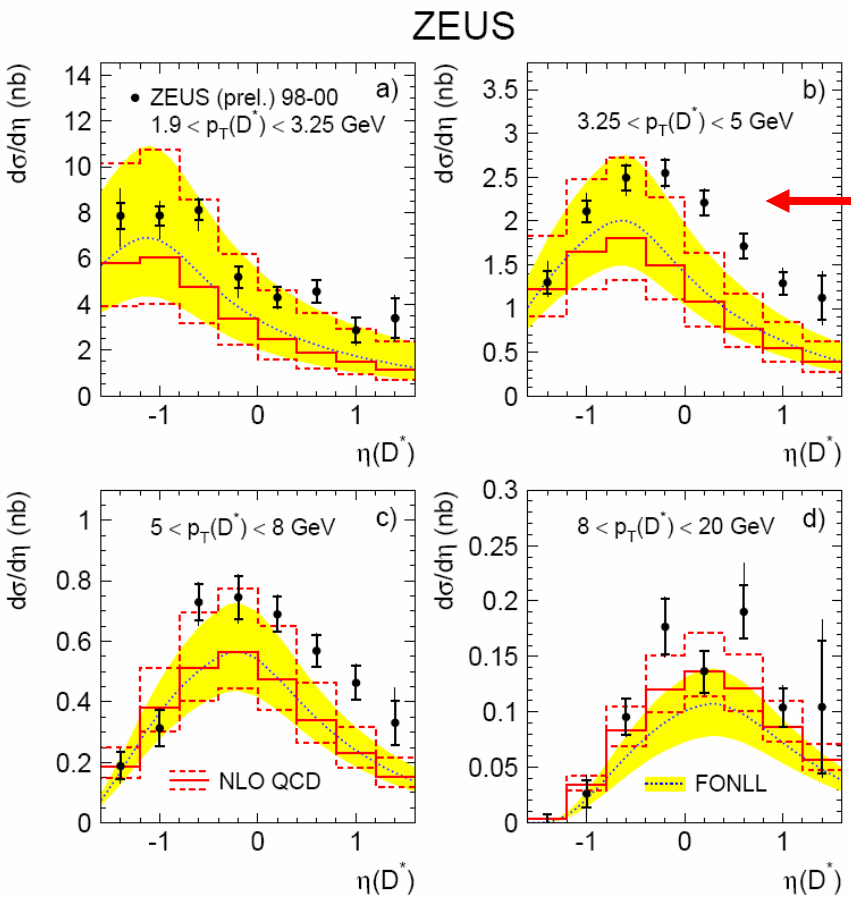
W : photon-proton center of mass energy

η : pseudo-rapidity ($\eta = -\ln(\tan\theta)$)

$Q^2 < 1\ GeV^2$: photoproduction

Charm tagging is efficiently done by reconstructing D*.

Measurement of D* photoproduction at ZEUS



- $Q^2 < 1$ GeV^2, $130 < W < 300$ GeV
- $1.9 < p_T(D^*) < 20$ GeV, $|\eta(D^*)| < 1.6$

Data > NLO QCD at medium p_T and forward region (η >0).

<u>Jet cross sections</u>

(E_T^{jet}>6 GeV, p_T(D*)>3 GeV)

→ less sensitive to hadronization effects.

→ what is happening in the rest of the hadronic final state.

→ extend measurement into the forward region (η^{jet}<2.4). (other jet distributions)

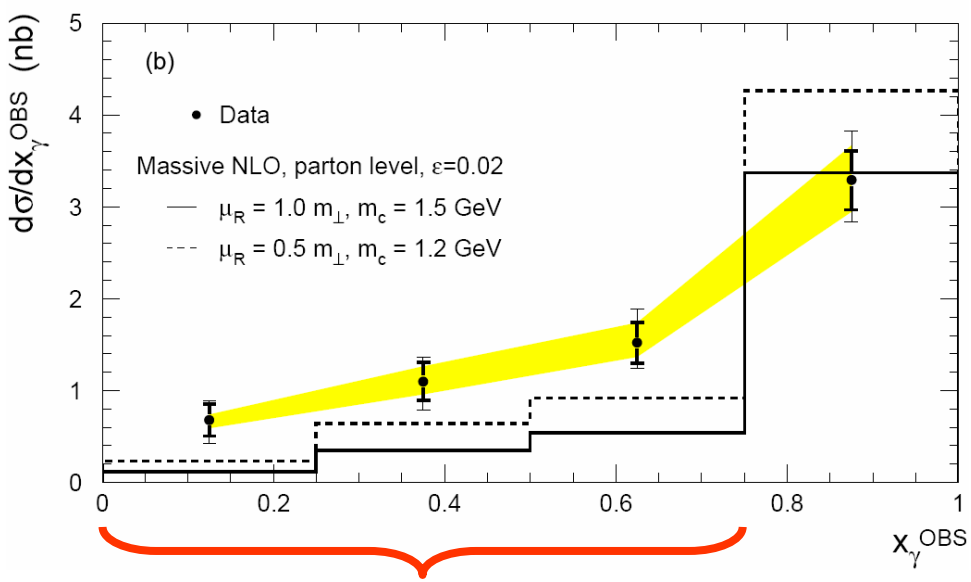
Dijet in D* photoproduction

$$x_\gamma^{obs} = \sum_i \frac{E_{T,i} e^{-\eta_i}}{2 y E_e}$$

Fractional momentum of the photon contributing to the dijet production.

- x_γ^{OBS} >0.75 : "direct" process
- x_γ^{OBS} <0.75 : "resolved" process

ZEUS 96+97 data
- Q^2<1 GeV^2, 130<W<280 GeV
- $p_T(D^*)$>3 GeV, $|\eta(D^*)|$<1.5
- $E_{T,jet1}$ > 7 GeV, $E_{T,jet2}$ > 6 GeV
- $|\eta^{jet}| < 2.4$



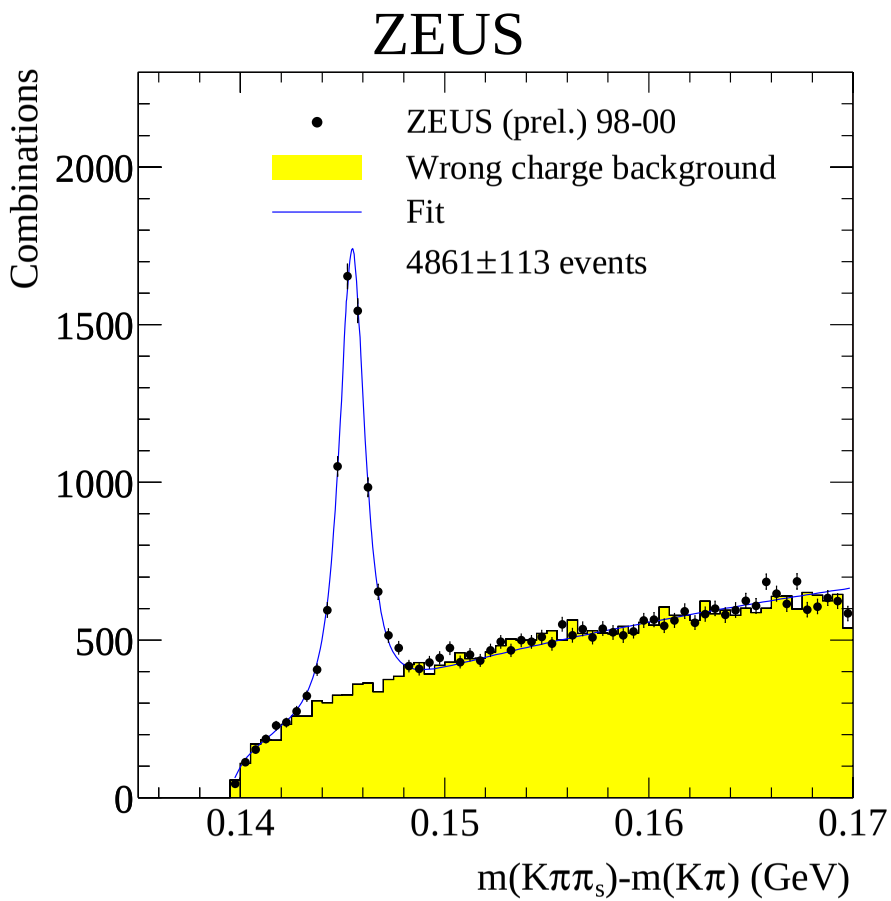
- Measure differential jet cross section as functions of E_T^{jet} and η^{jet}. ($d\sigma/dE_T^{jet}$, $d\sigma/d\eta^{jet}$)
- In LO MC, resolved contribution increases in the forward region.

Measurement underestimated by NLO calculation in resolved enriched region.

Event selection

98-00 e^-p and e^+p data ($L=78.6\ pb^{-1}$)

- Kinematic range
  - $Q^2 < 1\ GeV^2$ (No scattered electron)
  - $130 < W < 280\ GeV$
- D^* selection
  - $D^{*+} \to D^0 \pi_s^+ \to (K^- \pi^+)\pi_s^+ + c.c.$
  - $p_T(\pi, K) > 0.4\ GeV$, $p_T(\pi_s) > 0.12\ GeV$
  - $|\eta(track)| < 1.75$
  - $1.80 < m(D^0) < 1.92\ GeV$,
  - $0.143 < \Delta m < 0.148\ GeV$
  - $p_T(D^*) > 3\ GeV$, $|\eta(D^*)| < 1.5$
- Jet reconstruction
  - Inclusive k_T algorithm on energy flow objects
  - $E_T^{jet} > 6\ GeV$, $-1.5 < \eta^{jet} < 2.4$



4861±113 events after all selections.
Signal extracted by subtracting wrong charge background.

Fit performed with modified Gaussian form.

$$f(\Delta m) = \frac{p_0}{\sqrt{2\pi}\,p_2} \cdot \exp\left(-0.5 \cdot x^{1+1/(1+0.5\cdot x)}\right),\ x = \left|\frac{\Delta m - p_1}{p_2}\right|$$

NLO QCD prediction (FMNR)

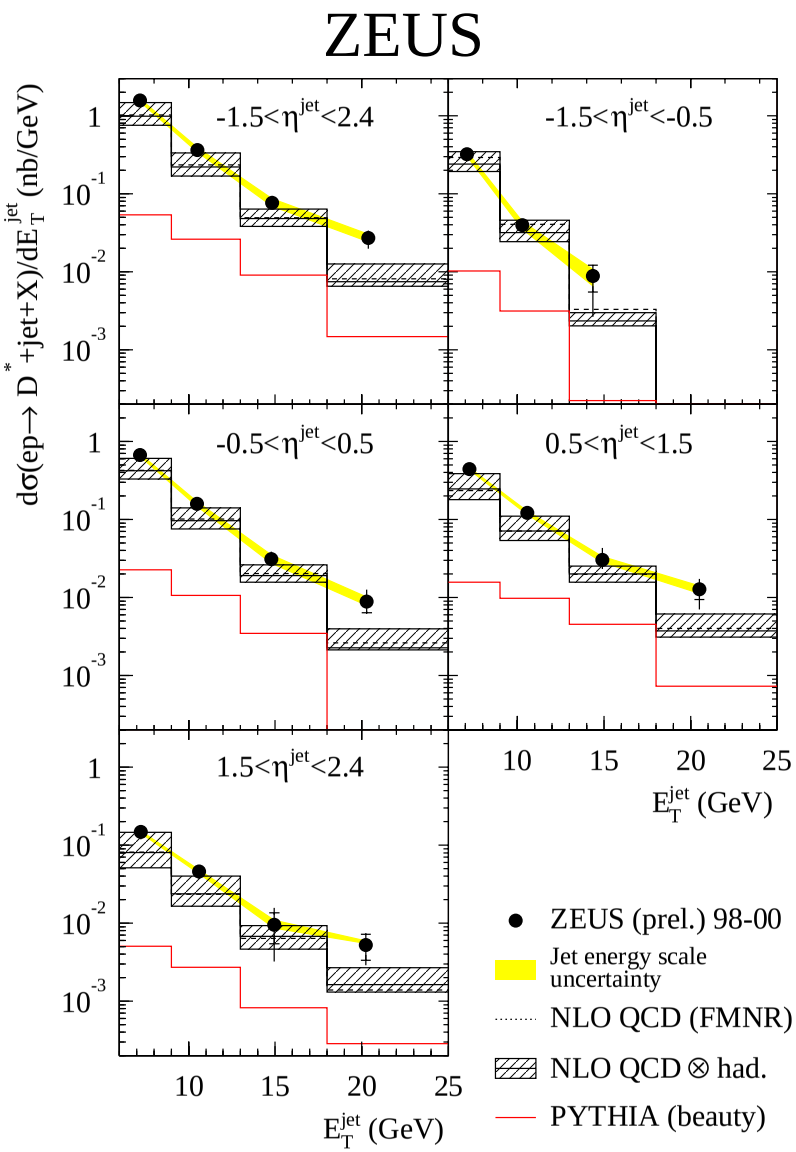
Next-to-leading order (NLO) QCD calculation with 3 active flavors in hadrons with massive charm (FMNR).

Calculation of the cross sections

- proton PDF : CTEQ5M1
- photon PDF : AFGHO
- m_c = 1.5 GeV, $\mu_F = \mu_R = m_T$ ($m_T^2 = m_c^2 + \langle p_T^2 \rangle$)
- D* momentum calculated using Peterson function (ε =0.035).
- Jet algorithm run over final state partons.
- Correction from parton level to hadron level done using MCs (average of HERWIG and PYTHIA).

- Estimation of theoretical uncertainty
  - m_c=1.3 GeV, $\mu_R = m_T/2$ (upper bound)
  - m_c=1.7 GeV, $\mu_R = 2m_T$ (lower bound)

Cross sections ($d\sigma/E_T^{jet}$)

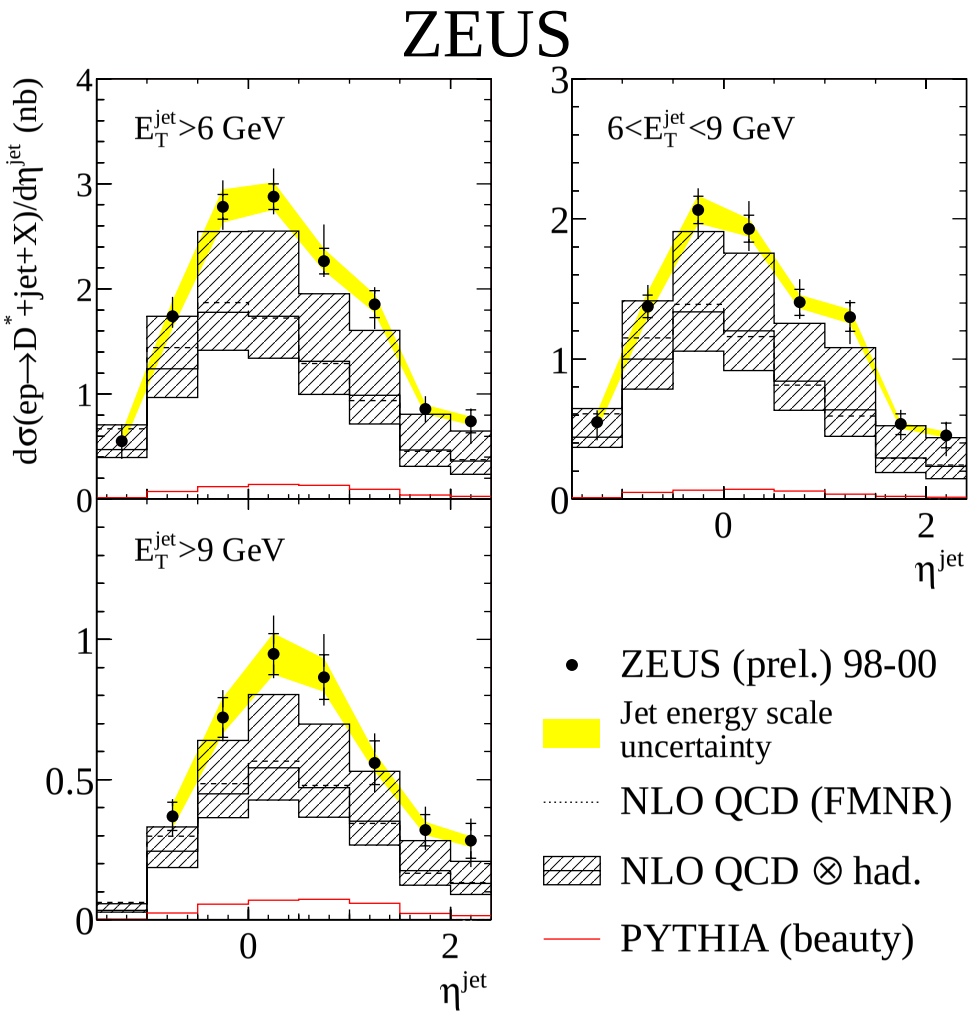


$d\sigma/dE_T^{jet}(ep\to D^*+jet+X)$ in bins of η^{jet}.

- $Q^2 < 1$ GeV^2
- $130 < W < 280$ GeV
- $p_T(D^*) > 3$ GeV, $|\eta(D^*)| < 1.5$
- $E_T^{jet} > 6$ GeV, $-1.5 < \eta^{jet} < 2.4$

- Measured cross sections are higher than NLO QCD predictions but compatible within the theoretical uncertainties.
- General trends of $d\sigma/dE_T^{jet}$ are described by NLO QCD predictions in all regions of η^{jet}.

Cross sections (d σ /d η^{jet})



d σ /d η^{jet}(ep→D*+jet+X) in bins of E_T^{jet}.

- $Q^2 < 1$ GeV^2
- 130 < W < 280 GeV
- $p_T(D^*) > 3$ GeV, $|\eta(D^*)| < 1.5$
- $E_T^{jet} > 6$ GeV, $-1.5 < \eta^{jet} < 2.4$

- Shapes of d σ /d η^{jet} agree with the NLO QCD predictions with hadronization corrections for high and low E_T^{jet} regions.
- No significant excess in the forward region seen in jet cross sections.

D* jet matching

Identify jet associated to D^* (D^* jet) and other jet.

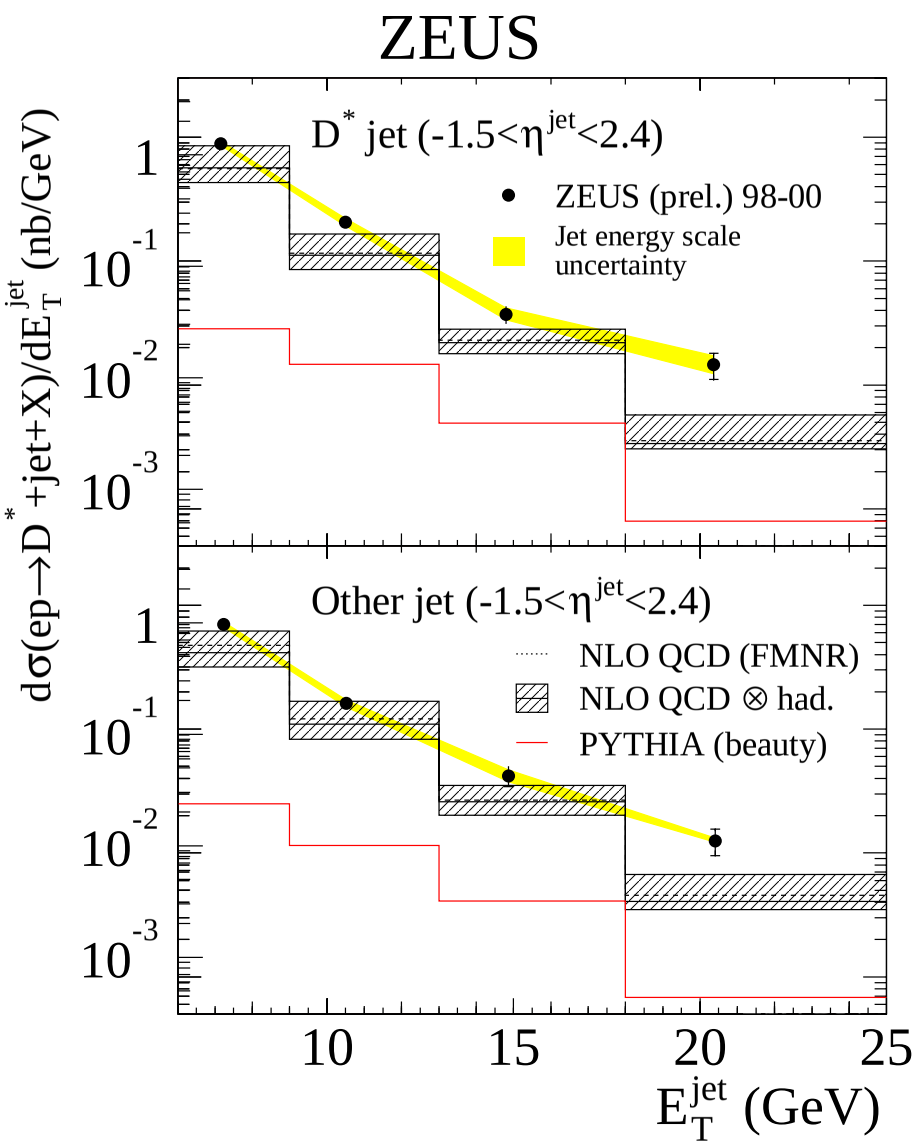
D^* jet : similar phase space to D* measurement.
Other jet : Other parton in the final state which does not form D*.
→ distribution depends on the production mechanism.

Detector level
Use closeness in η - Φ space.

$$\sqrt{\left(\eta_{jet}-\eta_{D^*}\right)^2+\left(\phi_{jet}-\phi_{D^*}\right)^2}<0.6$$

Hadron level
Jet algorithm is run over D* instead of decay products.
→ matching is trivial.

Cross sections for D^*/other jets ($d\sigma/E_T^{jet}$)

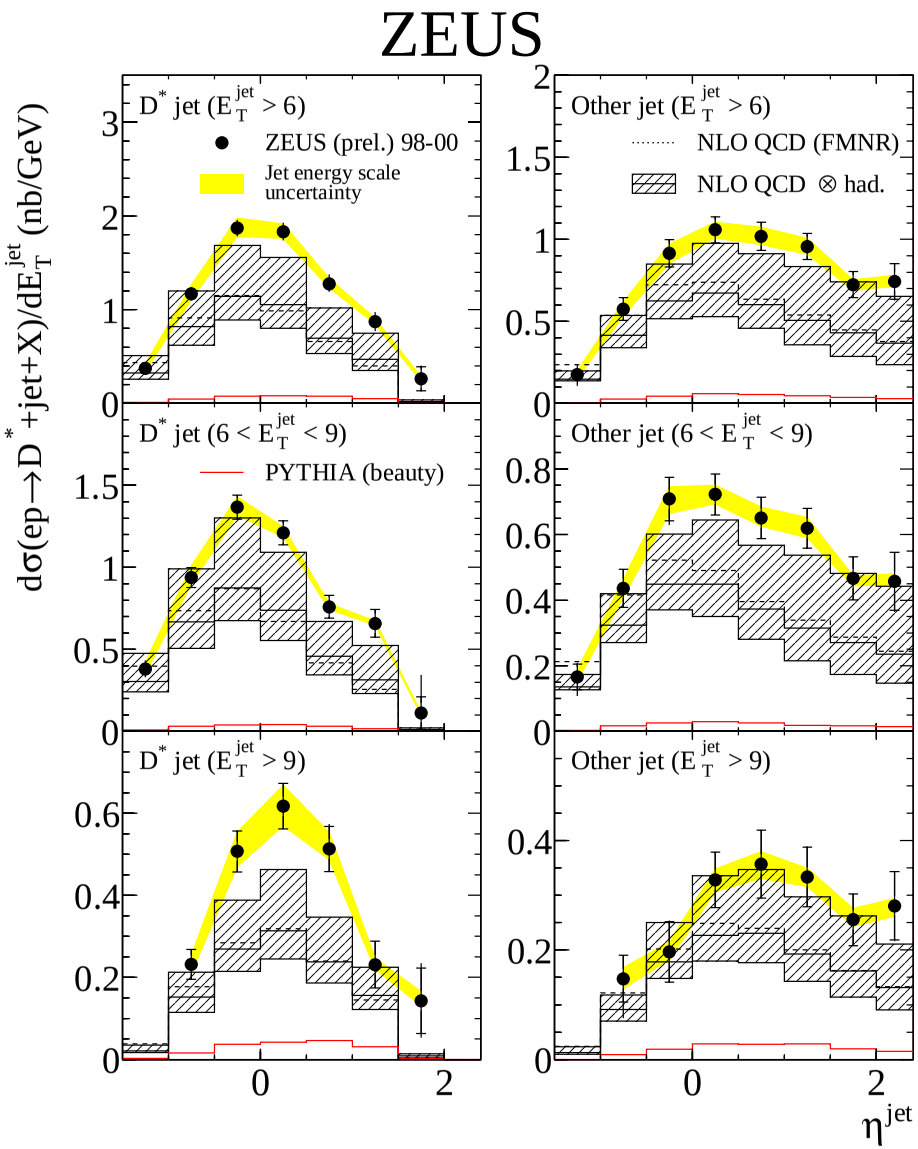


$d\sigma/dE_T^{jet}(ep \rightarrow D^* + jet + X)$ for D* jet and other jet.

- $Q^2 < 1$ GeV^2
- $130 < W < 280$ GeV
- $p_T(D^*) > 3$ GeV, $|\eta(D^*)| < 1.5$
- $E_T^{jet} > 6$ GeV, $-1.5 < \eta^{jet} < 2.4$

Normalization and shapes of both D* jet and other jet distributions are fairly described.

Cross sections for D^*/other jets ($d\sigma/d\eta^{jet}$)



$d\sigma/d\eta^{jet}(ep\to D^*+jet+X)$ for D* jet and other jet in bins of E_T^{jet}.

- $Q^2 < 1$ GeV^2
- $130 < W < 280$ GeV
- $p_T(D^*) > 3$ GeV, $|\eta(D^*)| < 1.5$
- $E_T^{jet} > 6$ GeV, $-1.5 < \eta^{jet} < 2.4$

- Shapes of the cross sections are described by the upper bound (m_c=1.3 GeV, $\mu_R = m_T/2$) of the NLO QCD predictions with hadronization corrections.

Conclusion

- Inclusive jet cross sections were measured for events containing D^* in photoproduction ($L=78.6\ pb^{-1}$).
- Normalization
  - Larger than central value of NLO QCD prediction but compatible within theoretical uncertainty.
  - Due to the lack of resolved contribution in NLO calculation as indicated by dijet analysis or favors low charm mass?
- Shape of the cross section
  - Generally described well by the NLO QCD calculation with hadronization correction.
  - Described in the whole measured region including the forward region.
  - Other jet distributions are also described.