

Jet cross sections in D^* photoproduction at ZEUS



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on behalf of the ZEUS Collaboration



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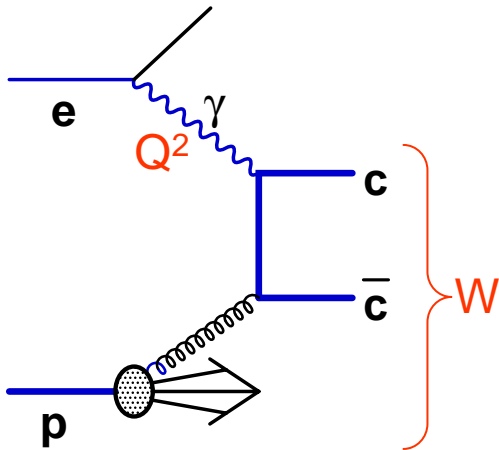
Contents

1. Motivation
2. Event selection
3. Results
4. Conclusion

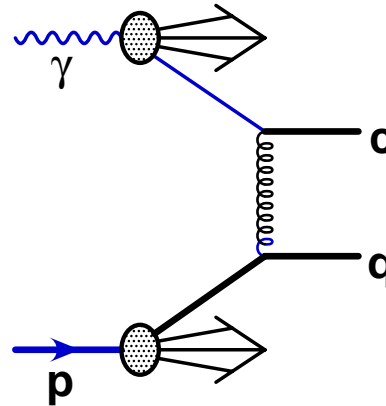
Introduction

- 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

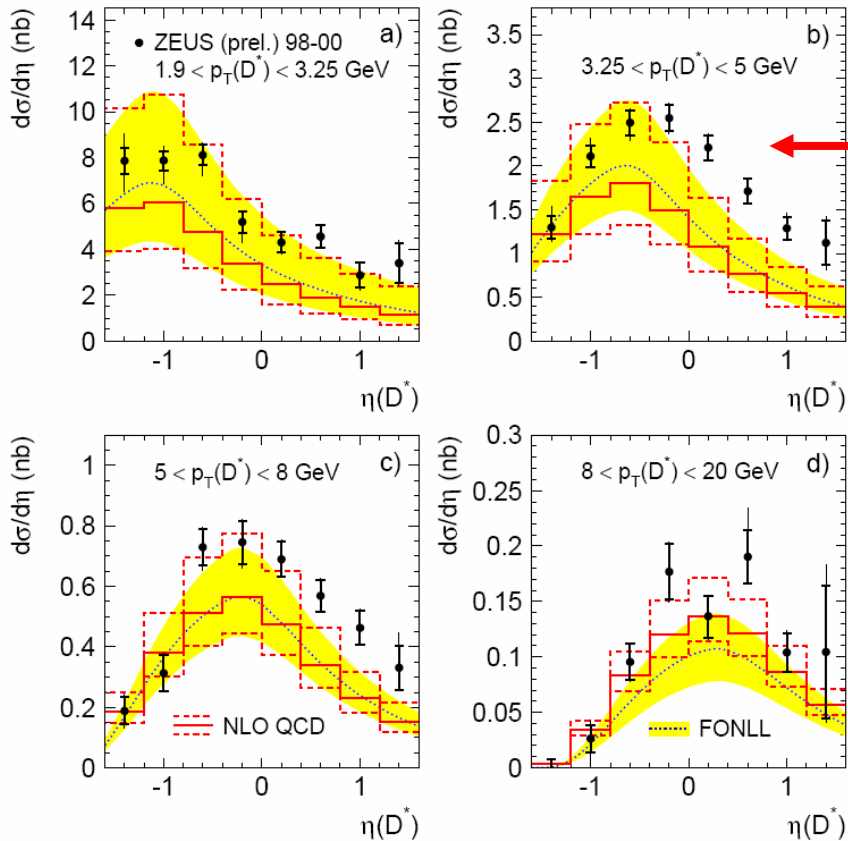
η : pseudo-rapidity ($\eta = -\ln(\tan \theta)$)

$Q^2 < 1 \text{ GeV}^2$: photoproduction

Charm tagging is efficiently done by reconstructing D^* .

Measurement of D^* photoproduction at ZEUS

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Data > NLO QCD at medium p_T and forward region ($\eta > 0$).

Jet cross sections

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

- less sensitive to hadronization effects.
- what is happening in the rest of the hadronic final state.
- extend measurement into the forward region ($\eta^{\text{jet}} < 2.4$). (other jet distributions)

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

Dijet in D^* photoproduction

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

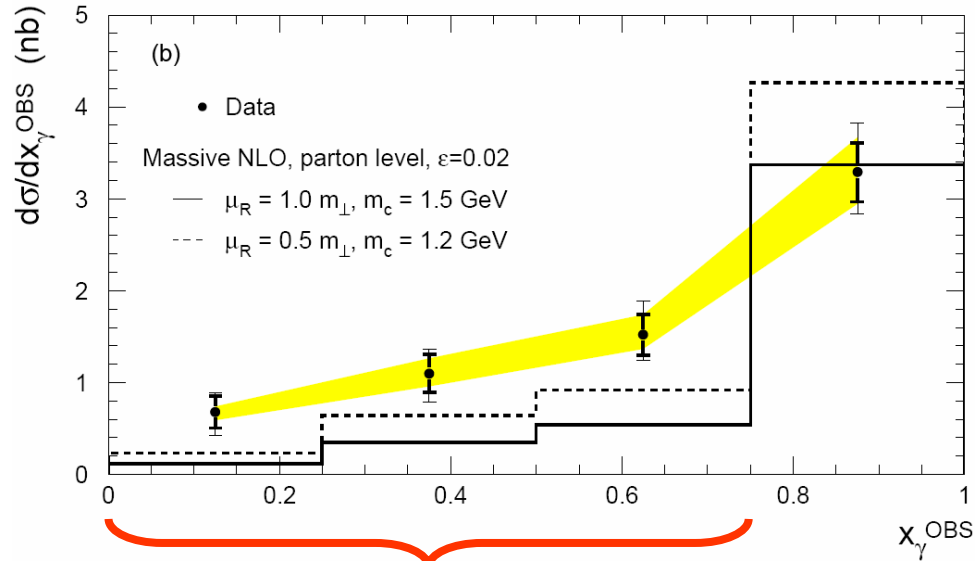
Fractional momentum of the photon contributing to the dijet production.

- $x_\gamma^{OBS} > 0.75$: “direct” process
- $x_\gamma^{OBS} < 0.75$: “resolved” process

- 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.

ZEUS 96+97 data

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



Measurement underestimated by NLO calculation in resolved enriched region.

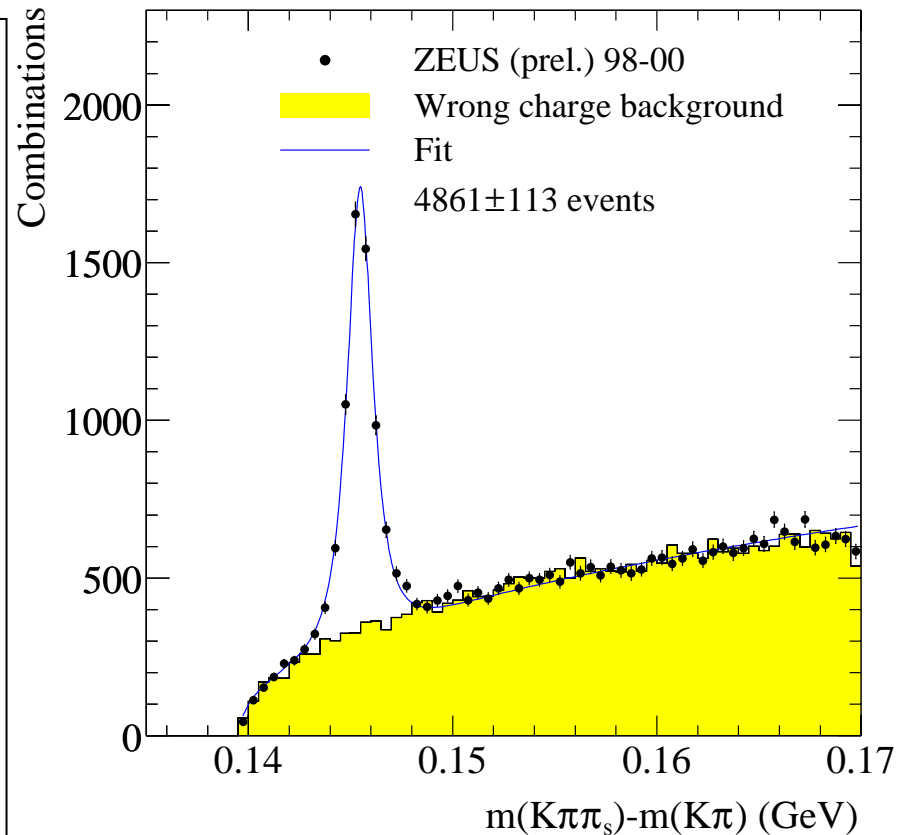
Event selection

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

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

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

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Fit performed with modified Gaussian form.

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

NLO QCD prediction (FMNR)

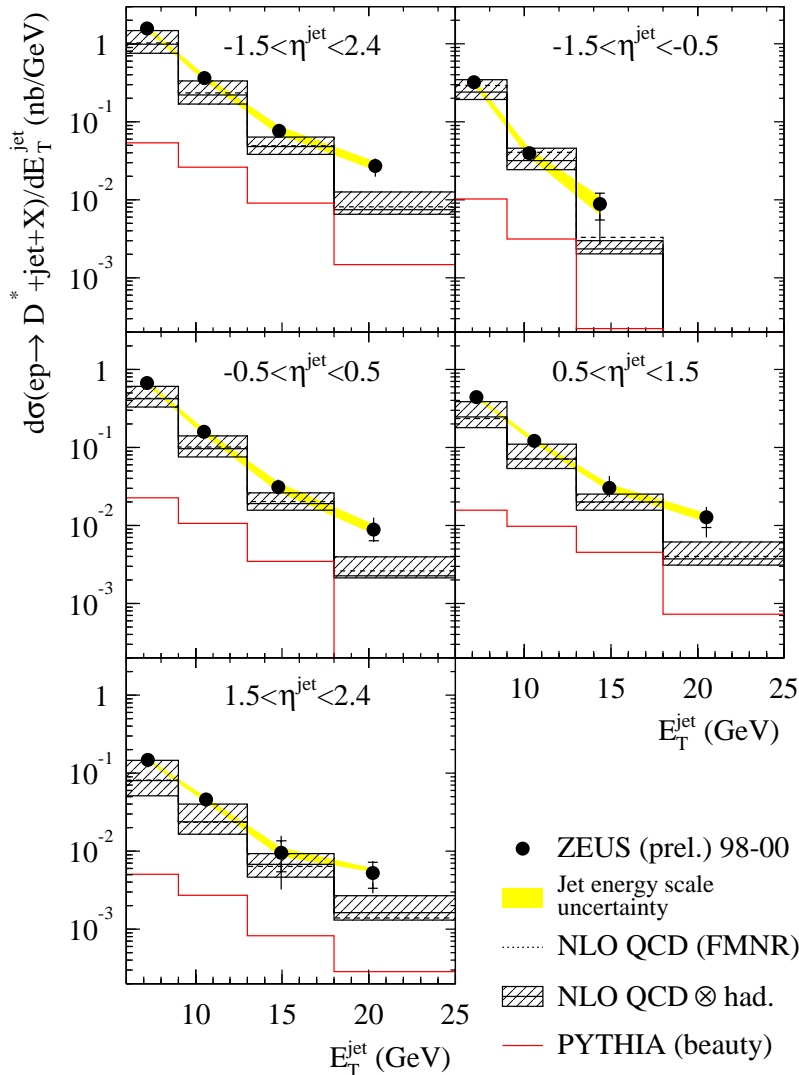
Next-to-leading order (NLO) QCD calculation with 3 active flavors in hadrons with massive charm (FMNR).

Calculation of the cross sections

- proton PDF : CTEQ5M1
- photon PDF : AFGHO
- $m_c = 1.5 \text{ GeV}$, $\mu_F = \mu_R = m_T$ ($m_T^2 = m_c^2 + \langle p_T^2 \rangle$)
- D^* momentum calculated using Peterson function ($\varepsilon = 0.035$).
- 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
 - $m_c = 1.3 \text{ GeV}$, $\mu_R = m_T/2$ (upper bound)
 - $m_c = 1.7 \text{ GeV}$, $\mu_R = 2m_T$ (lower bound)

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

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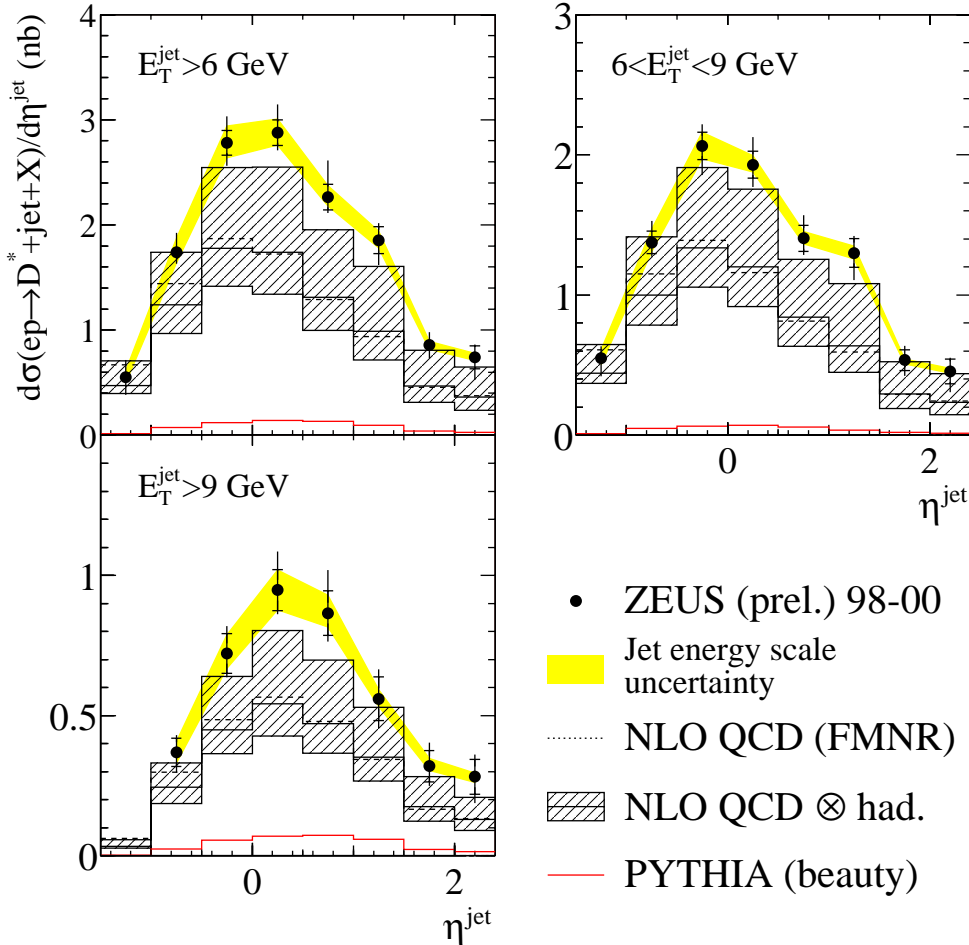
$d\sigma/dE_T^{\text{jet}}(ep \rightarrow D^* + \text{jet} + X)$ in bins of η^{jet} .

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

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

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

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$d\sigma/d\eta^{\text{jet}}(ep \rightarrow D^* + \text{jet} + X)$ in bins of E_T^{jet} .

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

- Shapes of $d\sigma/d\eta^{\text{jet}}$ 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 $\eta - \Phi$ space.

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

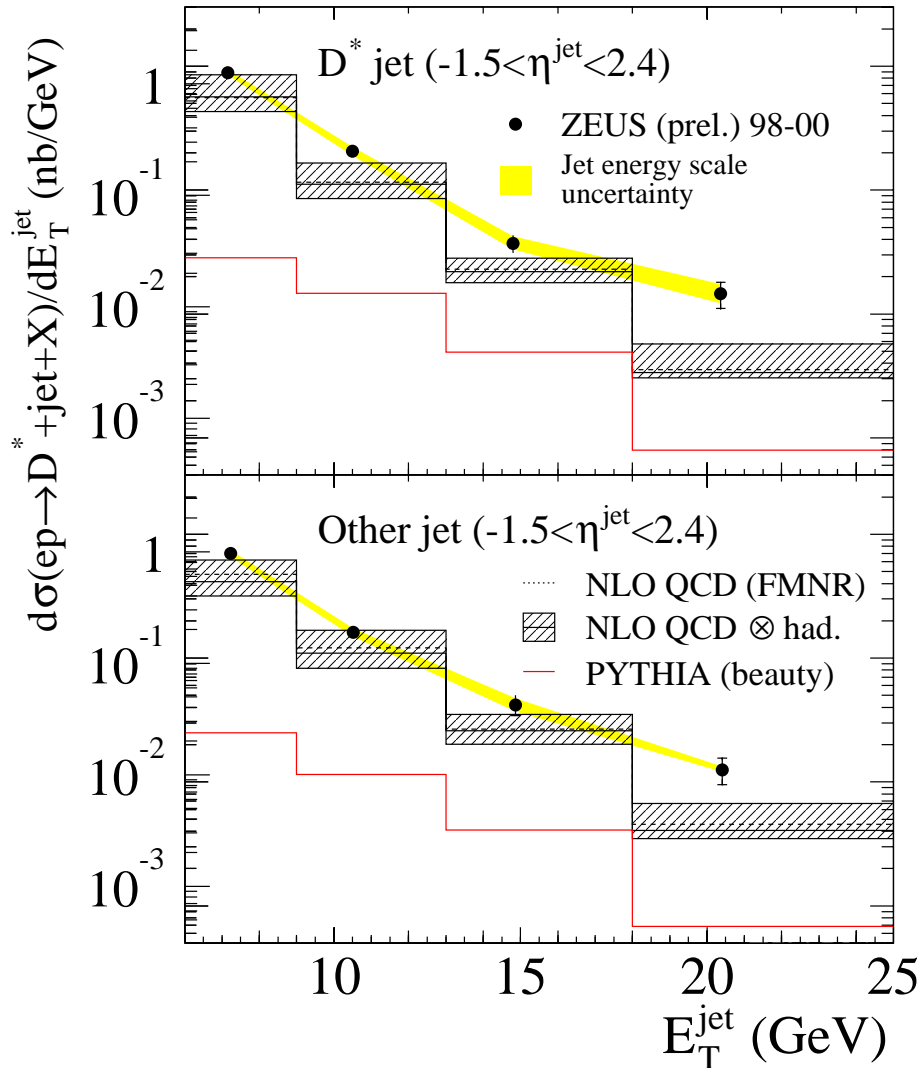
Hadron level

Jet algorithm is run over D* instead of decay products.

→ matching is trivial.

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

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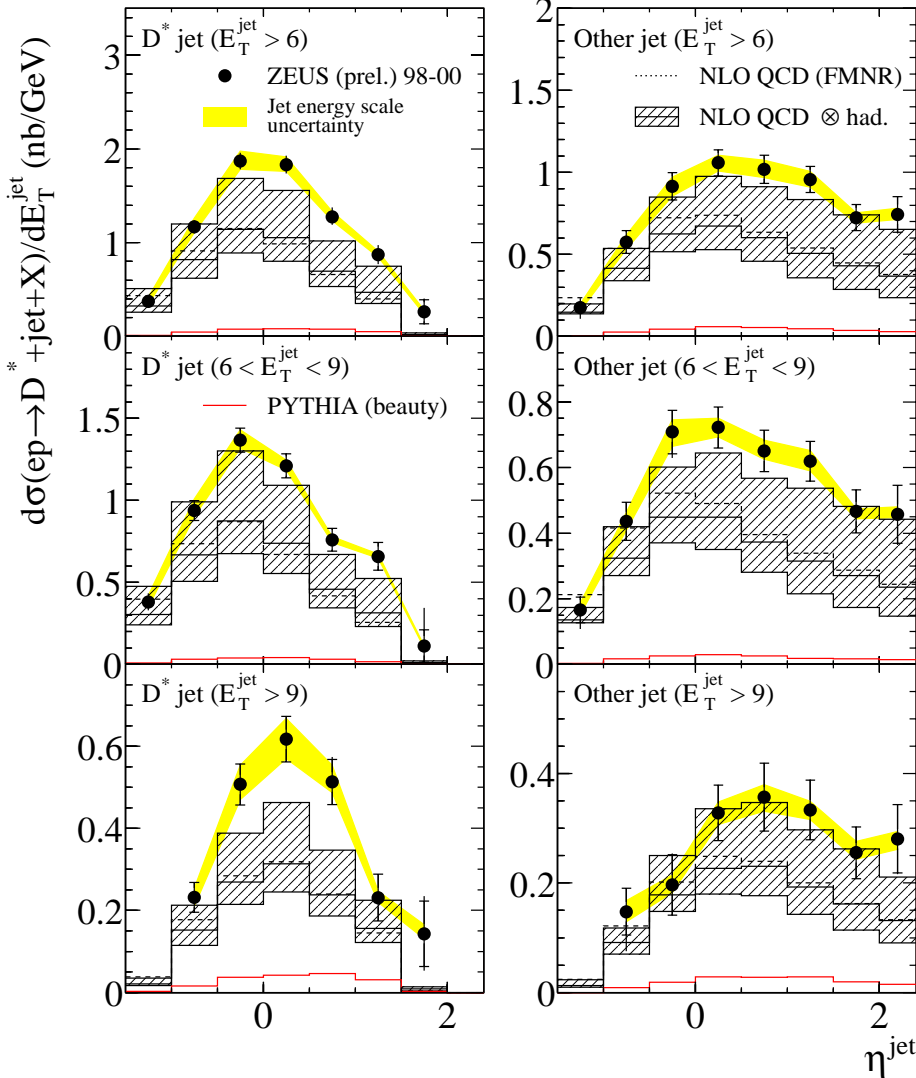
$d\sigma/dE_T^{\text{jet}}(ep \rightarrow D^* + \text{jet} + X)$ for D^* jet and other jet.

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

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

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

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

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

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

Conclusion

- Inclusive jet cross sections were measured for events containing D^* in photoproduction ($L=78.6 \text{ pb}^{-1}$).
- 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.