

Charm production at low Q^2 with ZEUS

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on behalf of



Collaboration



bmb+f - Förderschwerpunkt

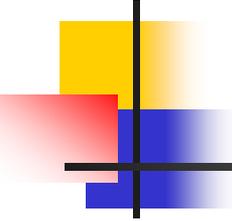
ZEUS

Großgeräte der physikalischen
Grundlagenforschung



Rheinische Friedrich-Wilhelms-Universität

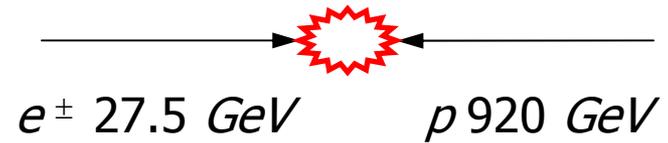
**XIII International Workshop on Deep Inelastic Scattering
Madison, Wisconsin USA, April 27th – May 1st, 2005**



Outline

- Introduction
- BPC – detector for low Q^2
- Cross sections
- Theoretical predictions
- Summary

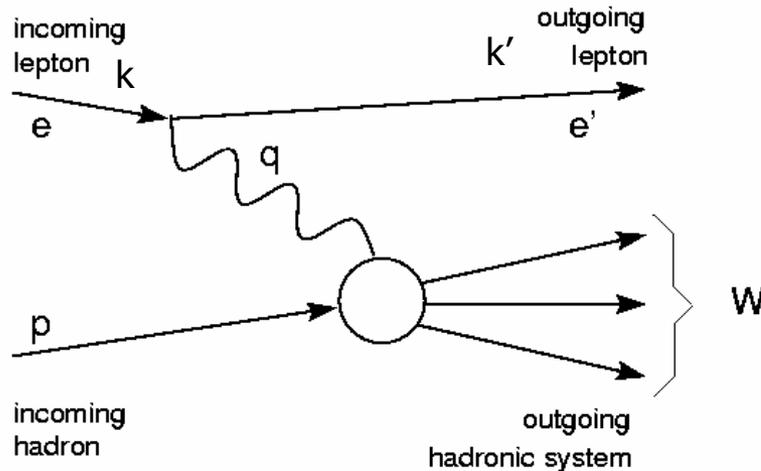
Introduction



$e^\pm 27.5 \text{ GeV}$ $p 920 \text{ GeV}$

$$\sqrt{s} \approx 318 \text{ GeV}$$

Kinematic Variables



4-mom. transfer: $Q^2 = -q^2 = -(k - k')^2$

Fraction of energy transfer: $y = \frac{\mathbf{P} \cdot \mathbf{q}}{\mathbf{P} \cdot \mathbf{k}}$

γp CMS energy: $W = (\mathbf{P} + \mathbf{q}) \cong \sqrt{(4 E_e E_p y)}$

Photoproduction (PHP)

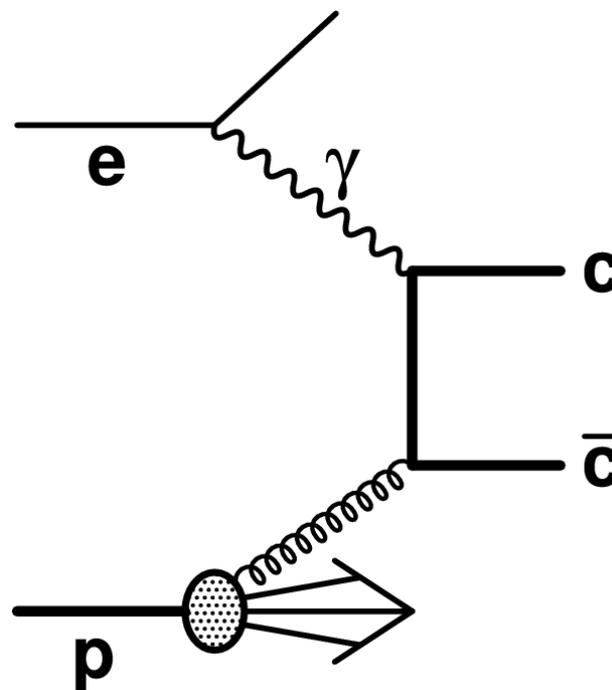
$$Q^2 < 1 \text{ GeV}^2$$

Deep Inelastic Scattering (DIS)

$$Q^2 > 1 \text{ GeV}^2$$

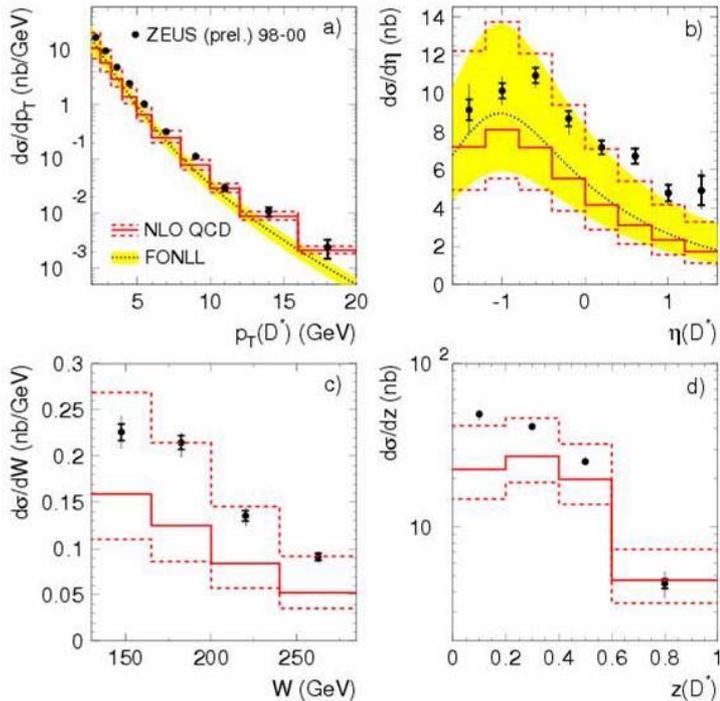
Motivation

- Measurement of charm production in Q^2 region just below 1 GeV^2
- Theoretical interest in the transition region between DIS and PHP
- D^* production dominated by Boson Gluon Fusion (BGF)
- Do $pQCD$ models still describe the data here?



PHP and DIS results

ZEUS



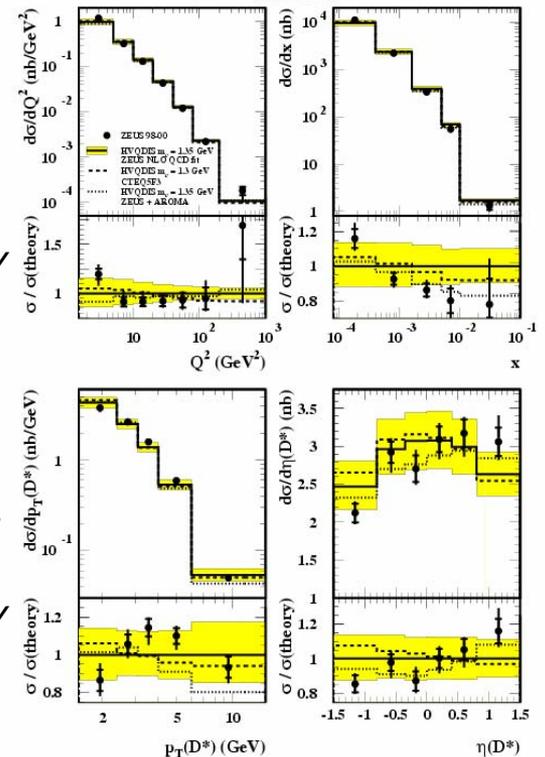
← PHP

$Q^2 < 1 \text{ GeV}$
 $130 \text{ GeV} < W < 285 \text{ GeV}$
 $1.9 \text{ GeV} < p_t(D^*) < 20 \text{ GeV}$
 $-1.6 < \eta(D^*) < 1.6$

DIS →

$1 \text{ GeV}^2 < Q^2 < 1500 \text{ GeV}^2$
 $0.02 < y < 0.8$
 $1.5 \text{ GeV} < p_t(D^*) < 15 \text{ GeV}$
 $-1.5 < \eta(D^*) < 1.5$

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Charm results reasonably described by $pQCD$ calculation

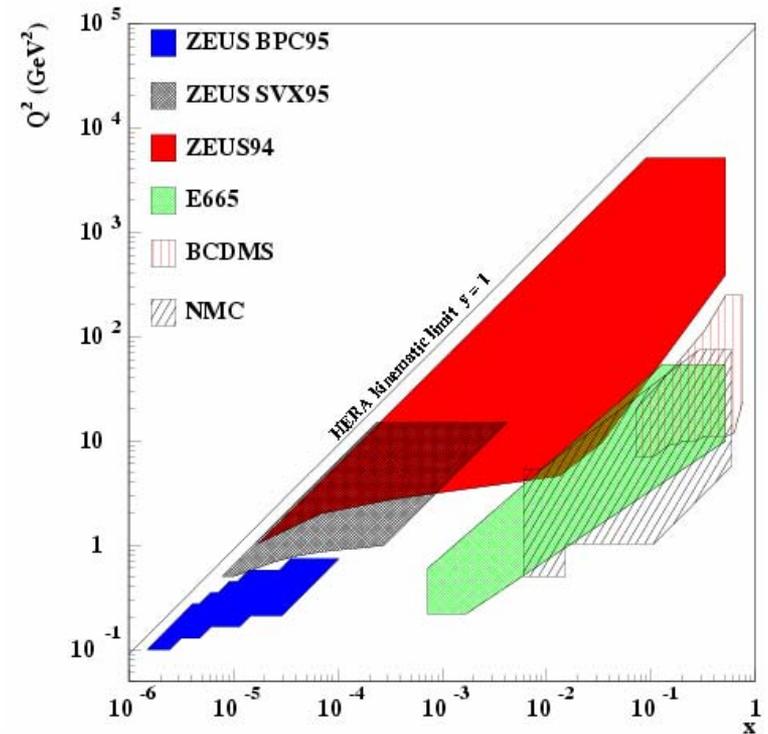
Low Q^2 in ZEUS

- F_2 at low Q^2

$$0.1 \text{ GeV}^2 < Q^2 < 5000 \text{ GeV}^2$$

$$2 \times 10^{-6} < x < 0.5$$

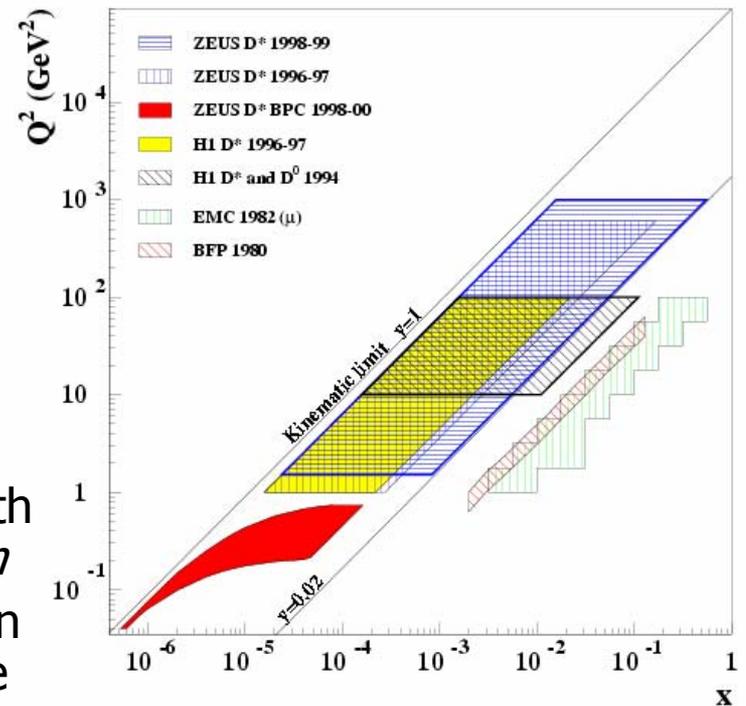
coverage of kinematic plane by ZEUS \Rightarrow



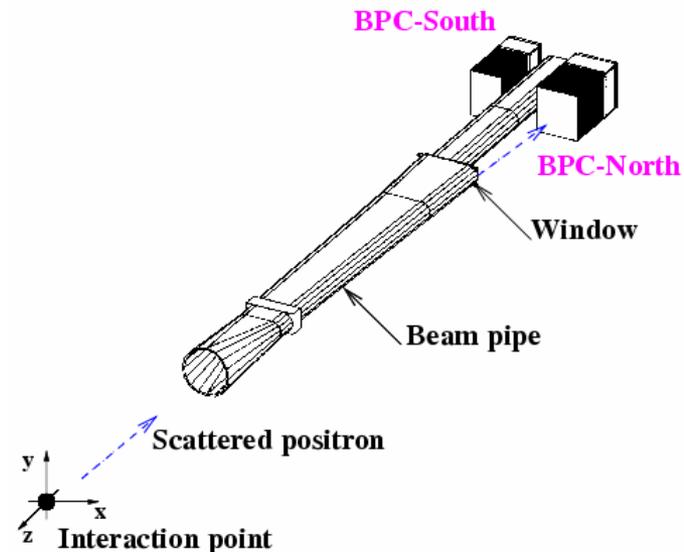
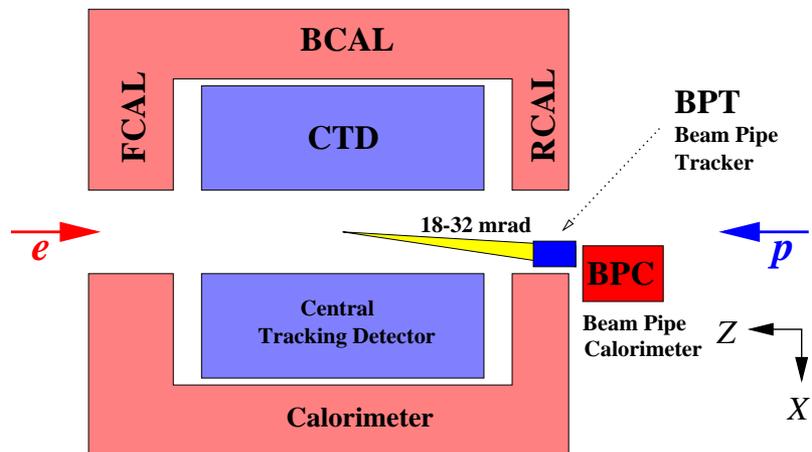
Low Q^2 in ZEUS (charm production)

We can reach low Q^2 :

- Beam Pipe Calorimeter (BPC)
 - covers small area near beam pipe
- Shifted vertex runs –
 - in 2000 few runs were taken with the ep vertex shifted by +70 cm
 - covers region in x & Q^2 between BPC and Calorimeter acceptance
- Initial State Radiation (ISR)



The BPC



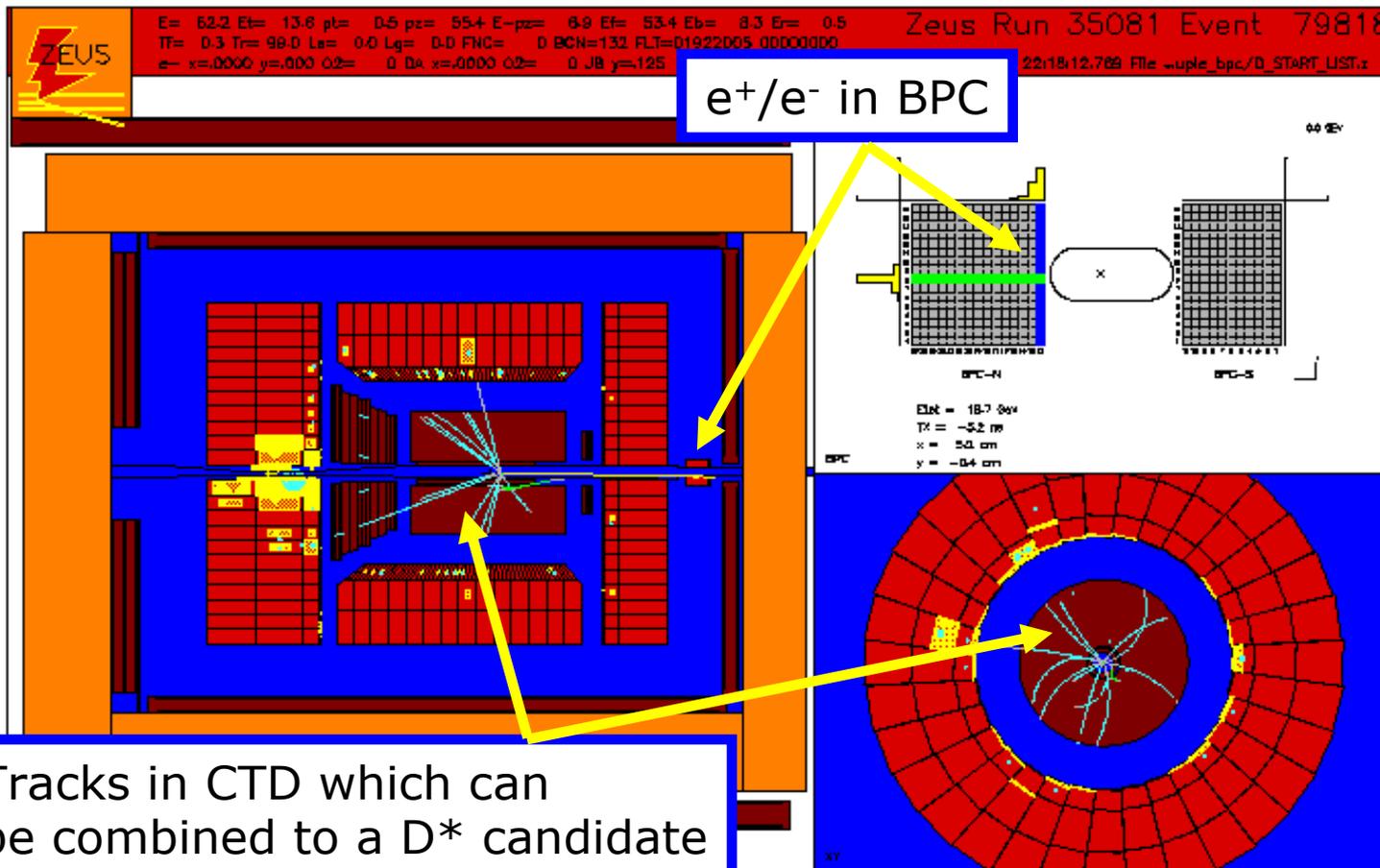
BPC – detector for low- Q^2 physics

located at $z = -295 \text{ cm}$ from interaction point

$18 \text{ mrad} < \Theta < 32 \text{ mrad}$

$0.05 \text{ GeV}^2 < Q^2 < 0.7 \text{ GeV}^2$

Event topology



BPC Contribute to Event Reconstr.

- Kinematic variables reconstructed by e -method:

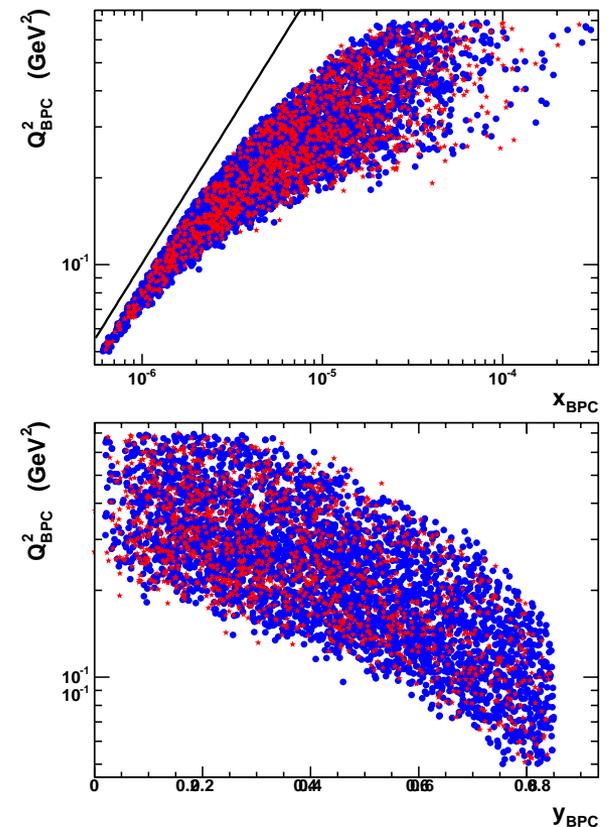
$$E_{BPC} \text{ and } \Theta_{BPC} \Leftrightarrow Q^2, \gamma \text{ and } x$$

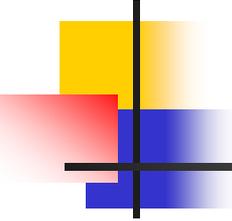
$$Q^2 = 2E_e E_{BPC} (1 - \cos(\Theta_{BPC}))$$

$$\gamma = 1 - \frac{E_{BPC} \cos^2(\Theta_{BPC} / 2)}{E_p (1 - E_{BPC} \sin^2(\Theta / 2))}$$

- $0.05 \text{ GeV}^2 < Q^2 < 0.7 \text{ GeV}^2$
 $0.02 < \gamma < 0.85$

DATA / MC



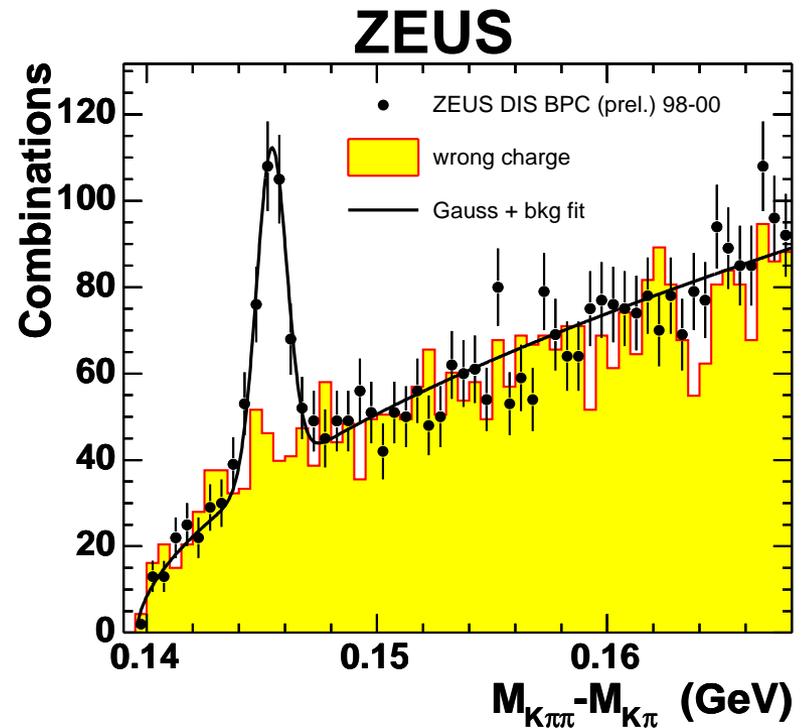


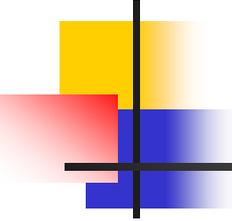
Event Selection / MC

- $|z_{\text{vertex}}| < 50 \text{ cm}$
- BPC cuts
 - $E_{BPC} > 4 \text{ GeV}$
 - fiducial area cut
- Kinematic cuts
 - $0.02 < y < 0.85$
 - $0.05 \text{ GeV}^2 < Q^2 < 0.7 \text{ GeV}^2$
 - $35 \text{ GeV} < E - p_z < 65 \text{ GeV}$
- D* cuts
 - $p_t(D^*) > 1.5 \text{ GeV}$
 - $|\eta(D^*)| < 1.5$
 - $p_t(\pi_s) > 0.12 \text{ GeV}$
 - $p_t(K, \pi) > 0.45 \text{ GeV}$
 - Variable window for $M(D^0)$
 $1.79 \dots 1.82 \text{ GeV} < M(D^0) < 1.91 \dots 1.94 \text{ GeV}$
 - $0.1435 \text{ GeV} < \Delta M < 0.1475 \text{ GeV}$
- HERWIG
Charm and Beauty MC
 - Includes Resolved + Direct Processes
- PYTHIA, RAPGAP
Charm and Beauty MC is used for systematics

D* tagging

- Data from 98-00
- $L = 81.9 \text{ pb}^{-1}$
- Clear D* signal observed
- Unbinned maximum likelihood fit used for number of events throughout
- Fit to ΔM signal gives 250 ± 22 events





Total cross sections

$$\sigma_{ep \rightarrow e'D^*X} = \frac{N_{D^*}}{A \cdot BR(D^{*\pm} \rightarrow K\pi\pi_s) \cdot L}$$

Kinematic range: $0.05 \text{ GeV}^2 < Q^2 < 0.7 \text{ GeV}^2$;

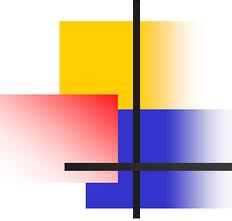
$0.02 < y < 0.85$;

$1.5 < p_t(D^*) < 9 \text{ GeV}$;

$|\eta(D^*)| < 1.5$

Measured cross section $\sigma = 10.1 \pm 1.0 \text{ (stat)}^{+1.1}_{-0.8} \text{ (syst)} \pm 0.23 \text{ (BR)} \text{ nb}$

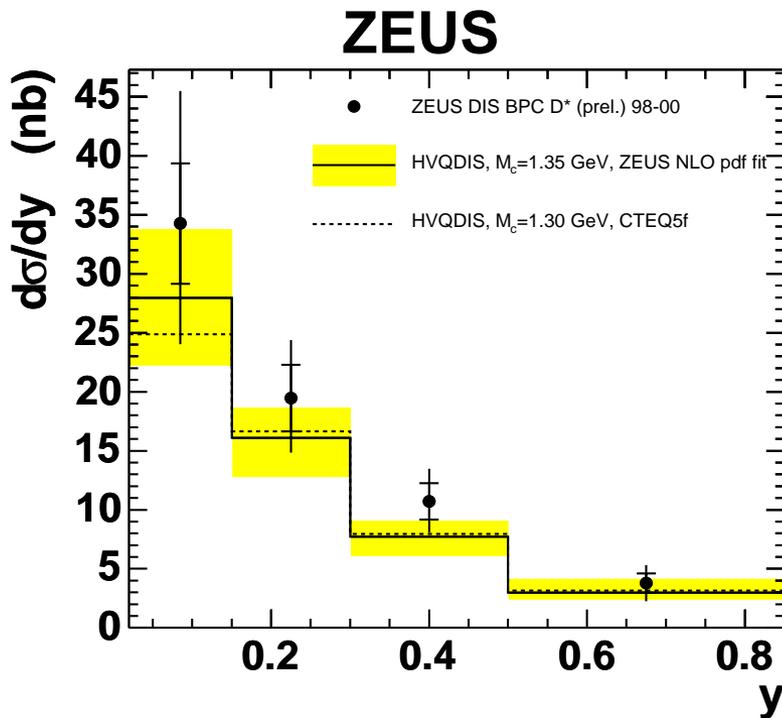
Calculated cross section $\sigma_{HVQDIS} = 8.6^{+1.9}_{-1.8} \text{ (syst)} \text{ nb}$



Systematic uncertainties

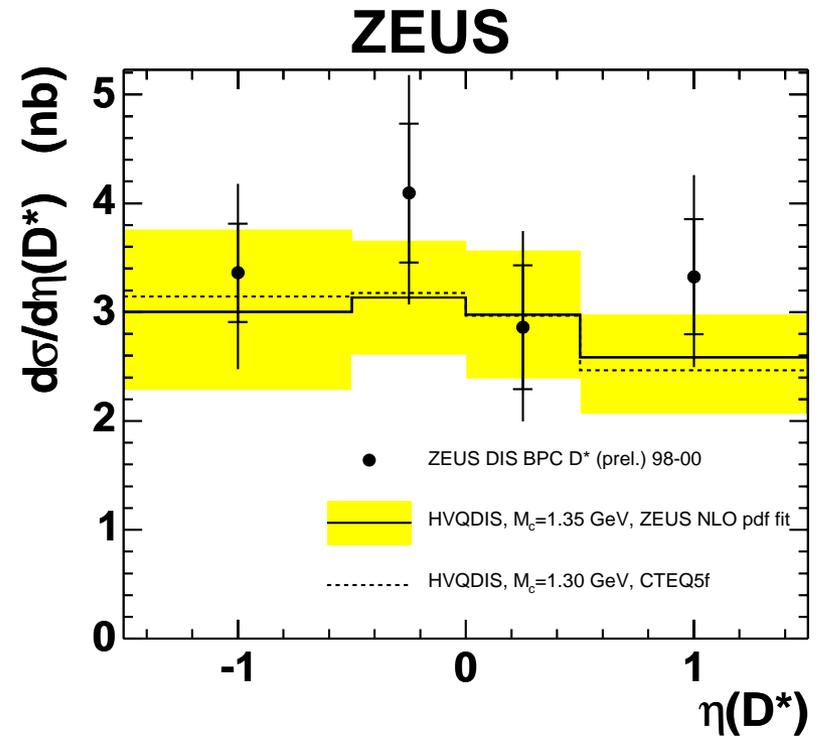
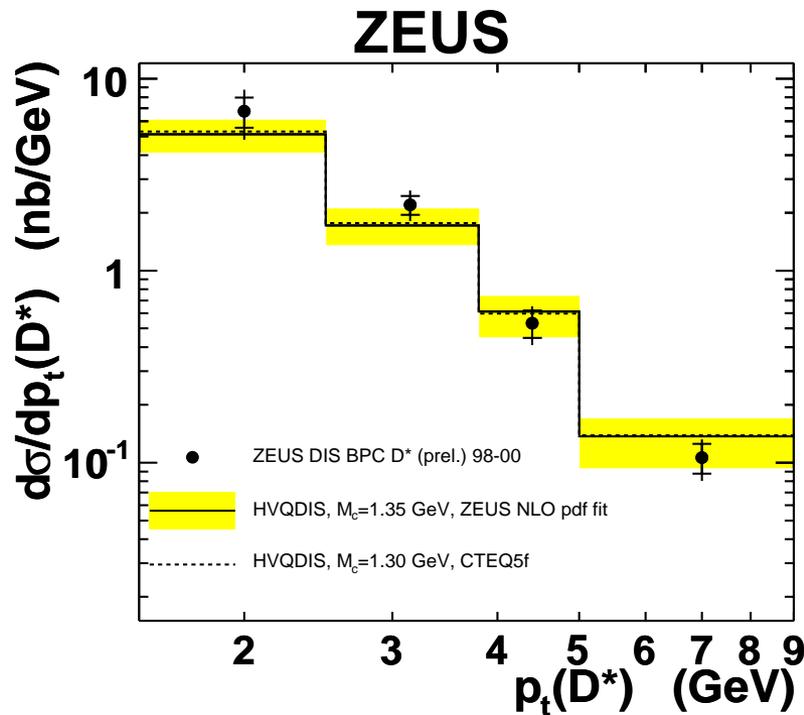
- 1 **RAPGAP:** instead of HERWIG MC
- 2, 3 **HW \pm RS \pm DR:** direct and resolved varied by $\pm 30\%$
- 4, 5 **$X_{\text{BPC}} \pm 1$:** shift of BPC X position in MC by $\pm 1 \text{ mm}$
- 6, 7 **$Y_{\text{BPC}} \pm 1$:** shift of BPC Y position in MC by $\pm 1 \text{ mm}$
- 8, 9 **\pm CTD Scale:** CTD momentum scale variation $\pm 0.3\%$ in MC
- 10, 11 **BPC fiducial area:** fiducial area extended or reduced by $\pm 1 \text{ mm}$
- 12, 13 **$\Delta M(D^0)$:** $\Delta M(D^0)$ window decreased or increased by 10 MeV
- 14, 15 **$\pm E_{\text{BPC}}$ - Scale:** variation of BPC energy by $\pm 1\%$ in MC
- 16, 17 **$\pm \sigma$ fixed fit:** σ_i varied by $\pm \Delta\sigma$
- 18, 19 **\pm CAL E:** CAL energy scale variation by $\pm 3\%$ in MC
- 20, 21 **$p_t(D^*)/E_t \pm 0.02$**
- 22, 23 **\pm CTD res:** variation of CTD track resolution by $+ 20\%$ or $- 10\%$ in MC
- 24, 25 **LUMI ± 2.25**

Cross sections vs. y

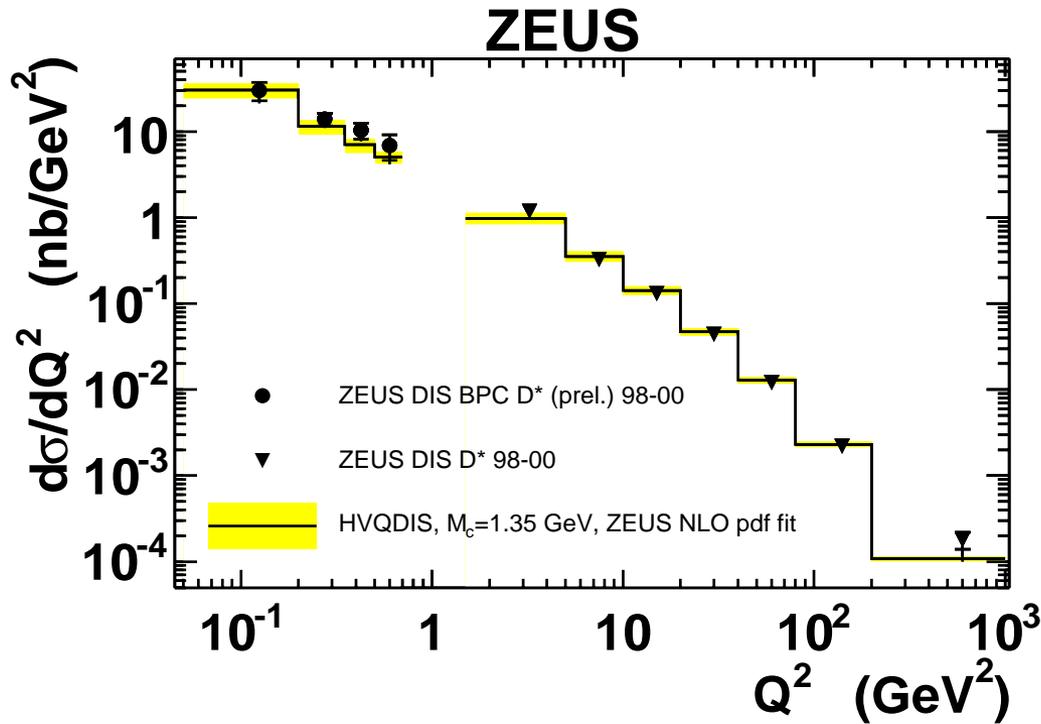


- NLO \Leftrightarrow HVQDIS \Leftrightarrow fixed-flavor-number scheme (FFNS)
 - fragmentation \Leftrightarrow Peterson model
 - $\varepsilon = 0.035$
 - nominal mass $m_c = 1.35$ GeV
 - normalisation & factorisation
$$\mu = \sqrt{Q^2 + 4m_c^2}$$
 - proton PDFs parametrisation \Leftrightarrow ZEUS NLO QCD fit & CTEQ5F3
 - $(Q^2/4 + m_c^2) < \mu^2 < 4(Q^2 + 4m_c^2)$
 $1.2 < m_c < 1.5$ GeV
 $0.02 < \varepsilon < 0.05$

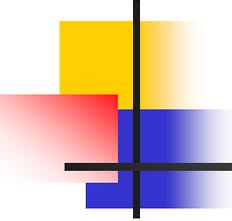
Cross sections vs. $p_t(D^*)$ & $\eta(D^*)$



Cross sections vs. Q^2



$0.02 < y < 0.7$ (0.85)
 $N(D^*) = 239 \pm 23$



Summary

- D^* production has been measured at low Q^2 with BPC at ZEUS
- Cross sections as a function of Q^2 , p_t , η and y were measured in transition region between PHP and DIS
- Results match HVQDIS predictions
 - Results extend previous ZEUS measurements below Q^2 of 1.5 GeV^2
 - NLOQCD $pQCD$ describes charm production in DIS over 4 orders of magnitude in Q^2