ZEUS

The Charm Structure Function of the Proton

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For the ZEUS and H1 Collaborations

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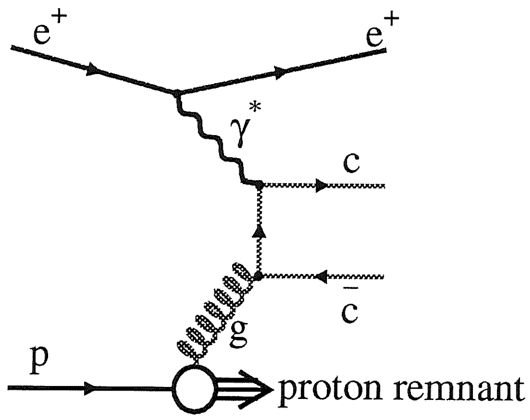
Outline

- Motivation
- Methodology
- Cross Sections
- Differential distributions
- Confrontation with calculations
- Extraction of F_2^{charm}
- Conclusions

Motivation



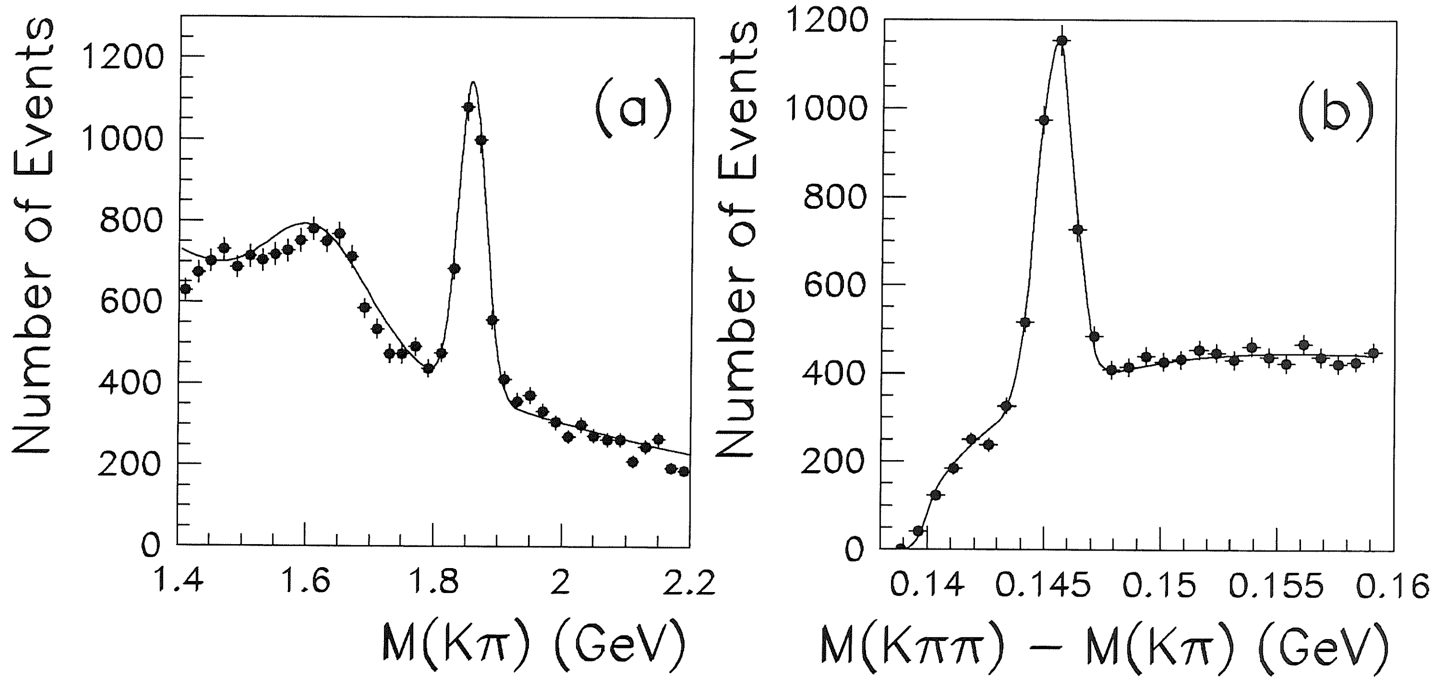
- Charm production dominated by BGF mechanism
- Sensitive to gluon distribution
- Process should be amenable to pQCD calculations
  - Various calculation schemes on the market (FFNS, VFNS, interpolating)
  - Test of universality of parton distributions

Methodology

- Charm tagged in DIS events using $D^{*\pm}$ mesons
  - Decay used:
    - $D^{*} \rightarrow D^{0}\pi_{s}$
    - with subsequent decays $D^{0} \rightarrow K\pi$ and $D^{0} \rightarrow K\pi\pi\pi$
- Zeus results based on $37pb^{-1}$ $e^{+}p$ data taken in 1996 and 1997
- H1 results based on $7pb^{-1}$ data from 1996

Cross Sections: $D^* \rightarrow K\pi\pi_s$

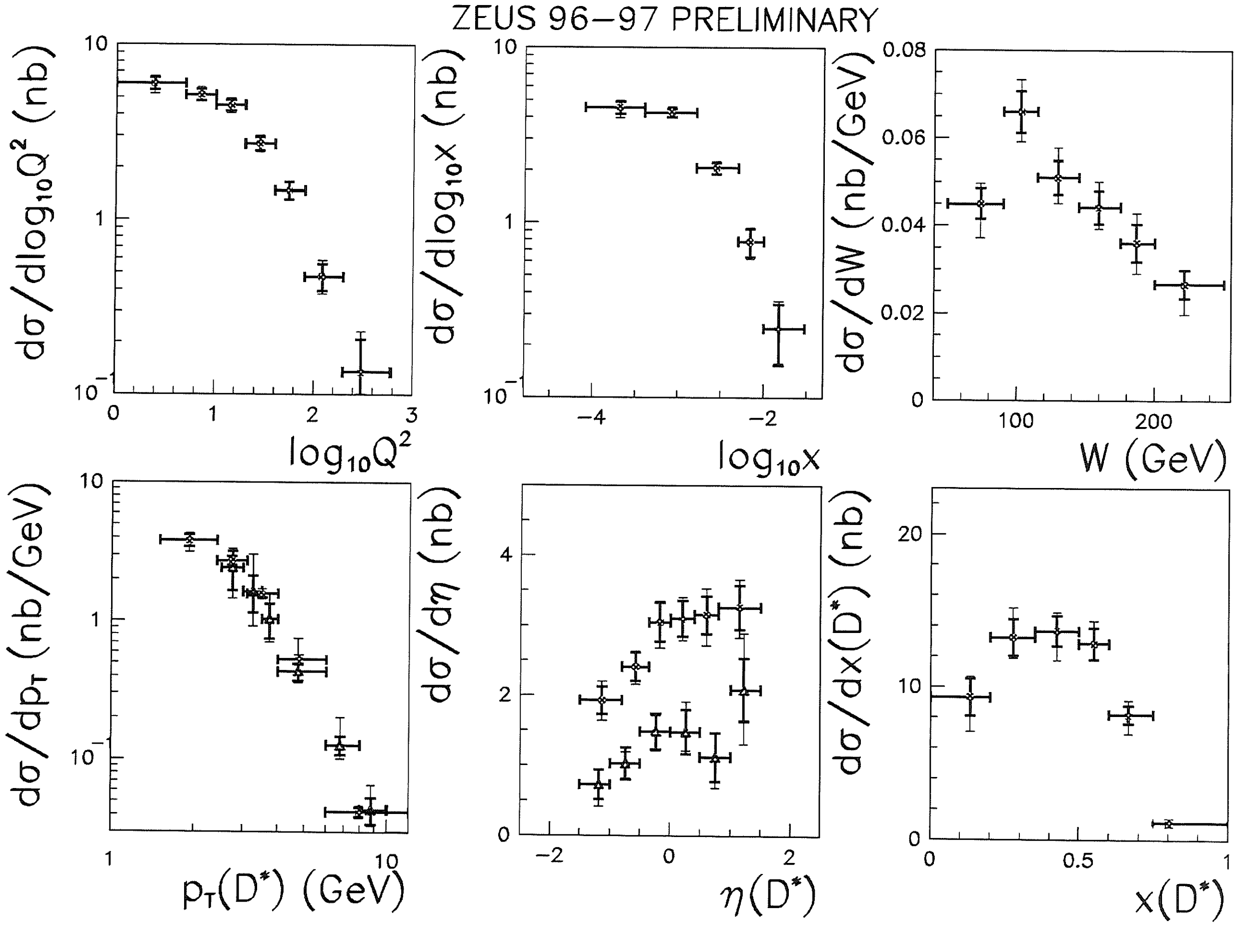
Zeus 1996-97



Cross Section $\sigma\left(e^+ p \rightarrow e^+ D^{*\pm} X\right) = 8.31 \pm 0.31(stat)^{+0.3}_{-0.5}(syst)\,\mathrm{nb}$

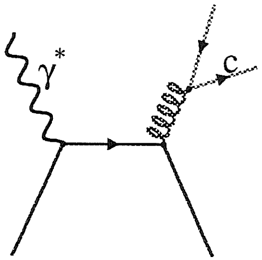
Kinematic Region $0.02 < y < 0.7; 1\,\mathrm{GeV}^2 < Q^2 < 600\,\mathrm{GeV}^2$
$1.5\,\mathrm{GeV/c} < P_t\left(D^*\right) < 15\,\mathrm{GeV/c}; \left|\eta\left(D^*\right)\right| < 1.5$

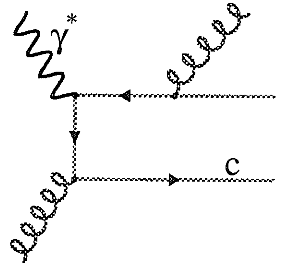
ZEUS Differential Cross Sections



Results from both decay channels in agreement

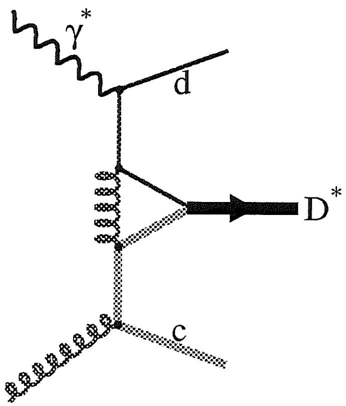
NLO Calculations





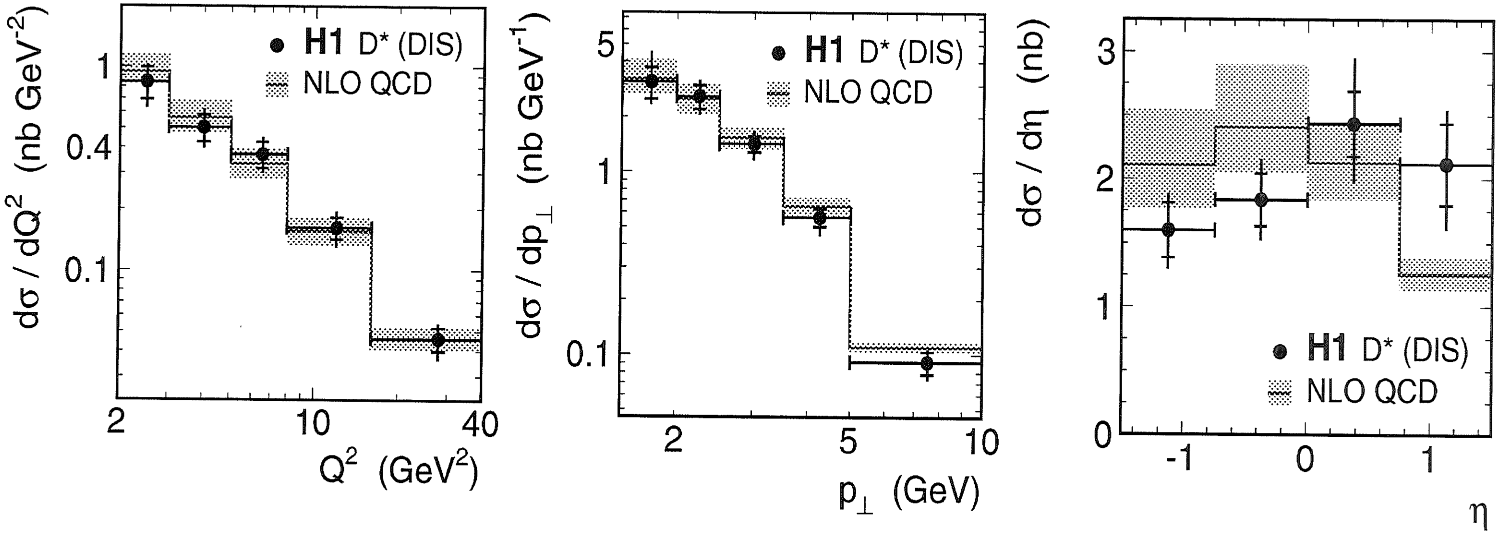
- HVQDIS
  - FFNS calculation
    - All charm is generated dynamically from light quarks and gluon PDFs
  - Peterson fragmentation

- ACOT
  - Interpolates between FFNS at low Q^2 and massless evolution at high scales



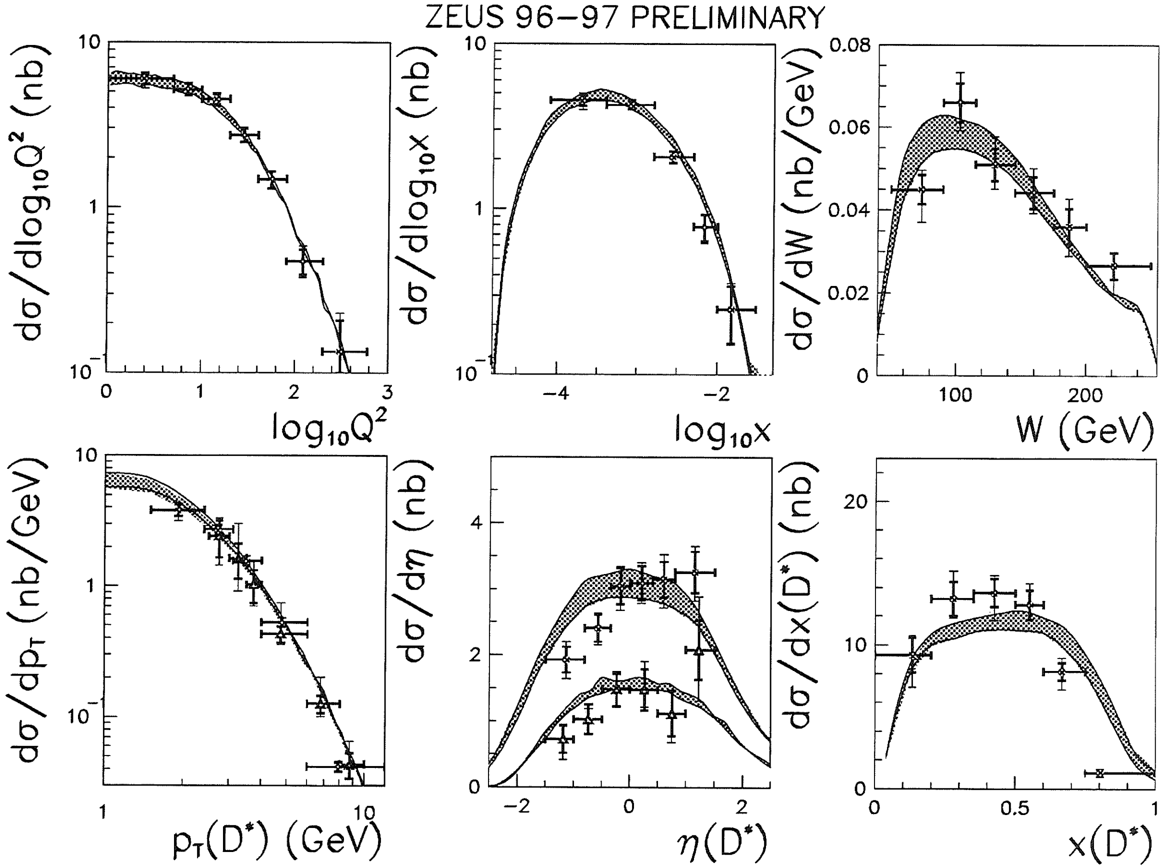
- BKL
  - Includes combination of charm quark with a light quark to form D^* meson

H1 Differential Cross Sections



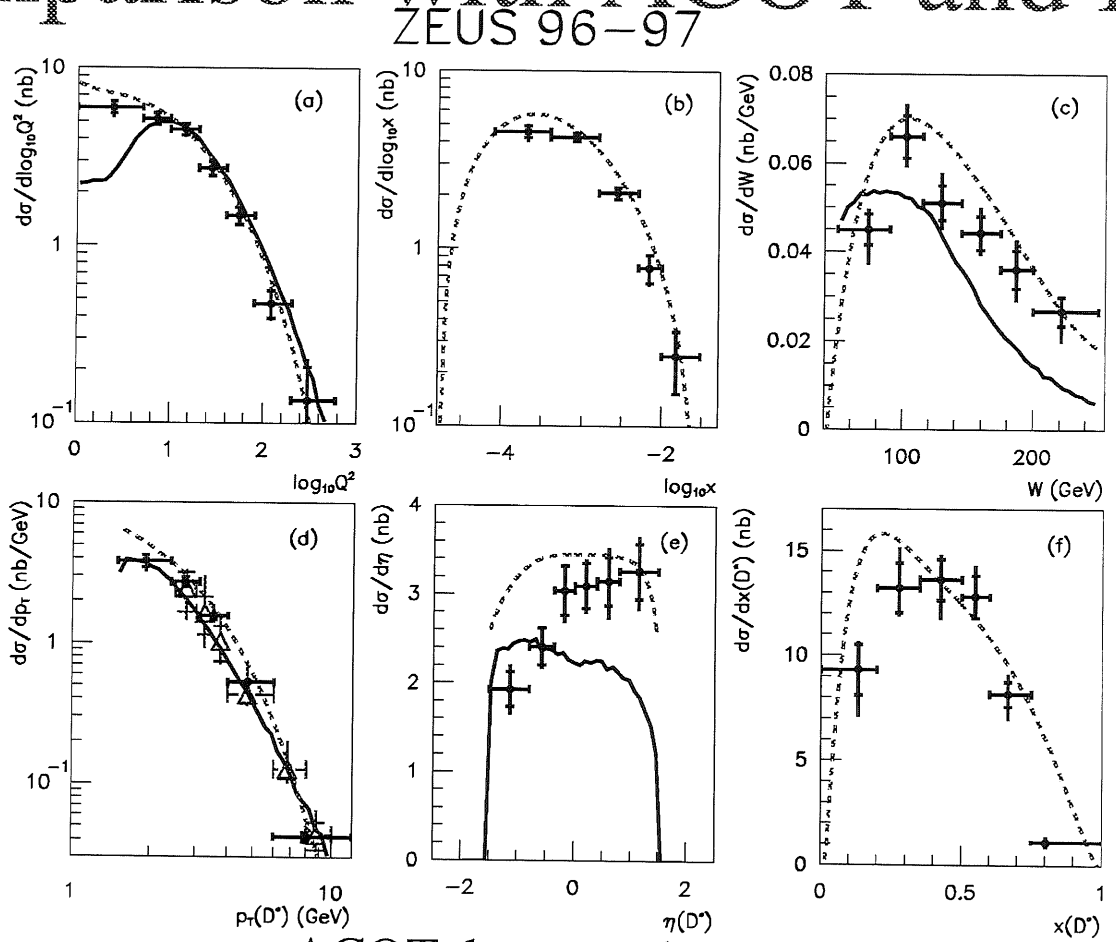
HVQDIS with CTEQ4F3 and 1.3 GeV< m_c<1.7 Gev
Peterson ε=0.035

Zeus Data and HVQDIS



- Band shows HVQDIS predictions for 1.3 GeV< m_c<1.5 GeV
- Zeus 1994 PDF
- Peterson Fragmentation parameter ε=0.035

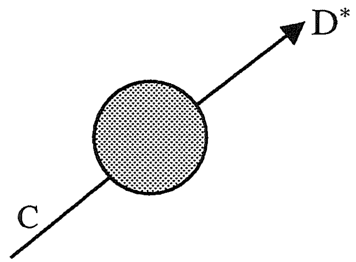
Comparison with ACOT and BKL

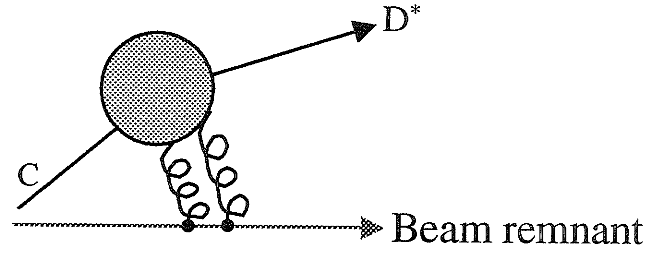


ACOT does not describe data

BKL overestimates cross section at high W and low η, x_{D*}

Fragmentation Effects

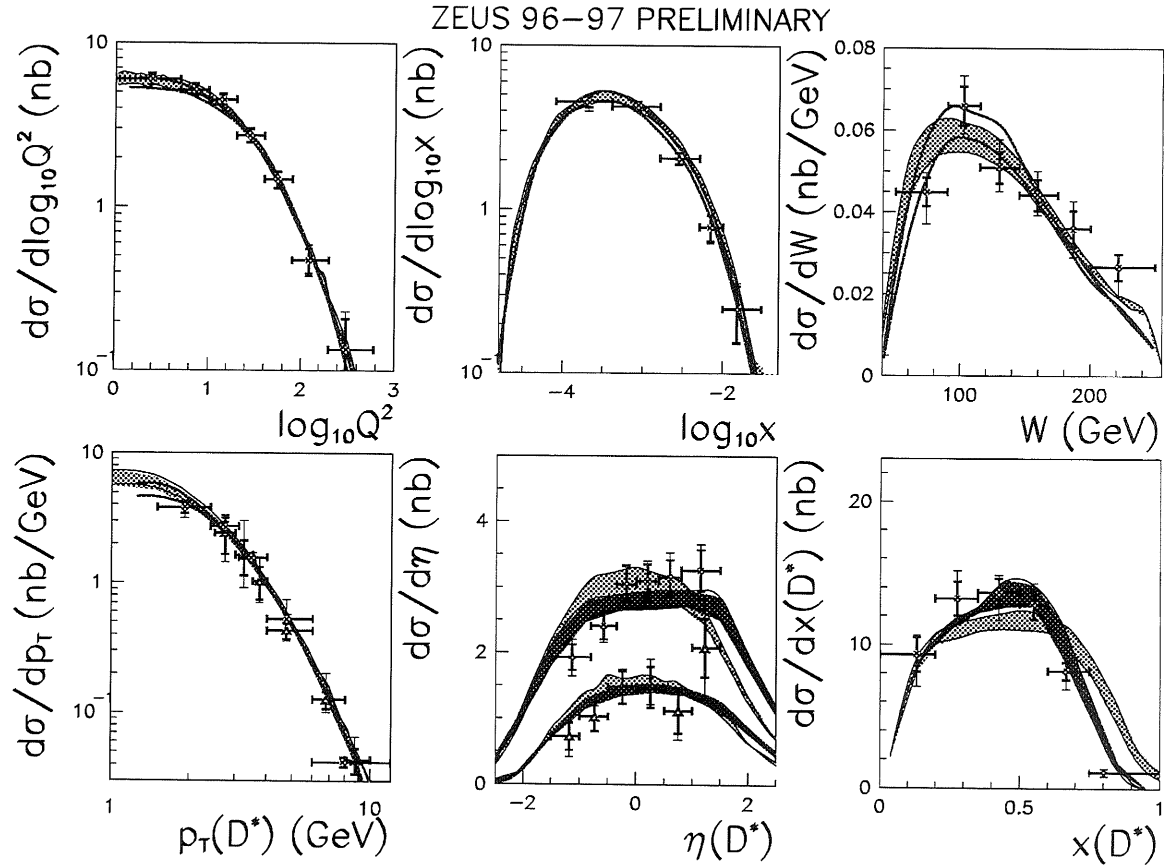




- Peterson style fragmentation
- Final state meson has same direction as parent quark

- More realistic models (e.g. Lund String) allow for interaction between quark and remnant before final meson formed

Zeus Data and HVQDIS with Fragmentation Effects



RAPGAP (JETSET) reweighted to HVQDIS charm P_t and η distributions

Definition and Extraction of F_2^{charm}

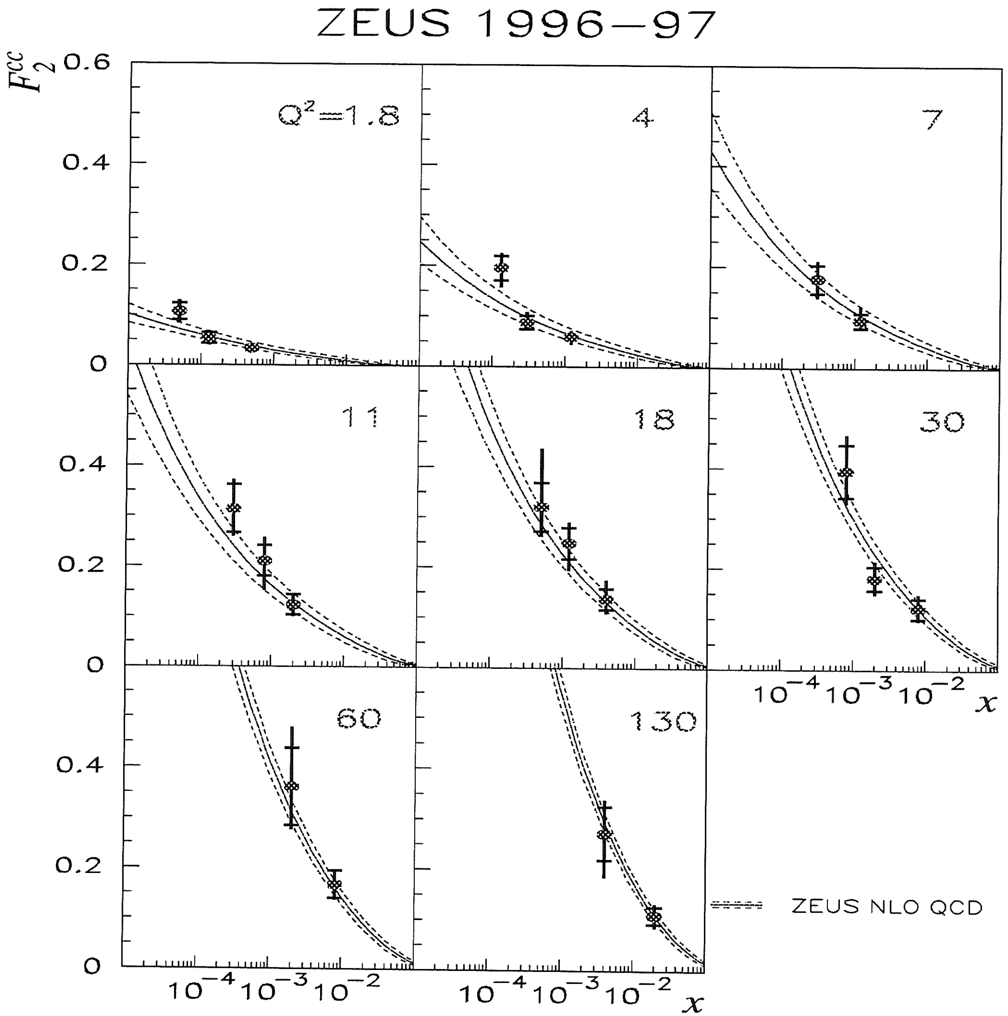
$$\frac{d^2\sigma^{c\bar{c}}(x,Q^2)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left\{\left[1+(1-y)^2\right]F_2^c(x,Q^2) - y^2F_L^c\right\}$$

- Assumptions:
  - FFNS
  - Neglect F_L^c
  - Neglect bound charm (3-4%)
  - $BR(c \rightarrow D^*)$ from e^+e^- is valid
- Extrapolate outside kinematic region

$$F_2^{cMeas} = \sigma_{Kin}^{Meas}(y,Q^2) \times \frac{F_2^{cNLO}(y,Q^2)}{\sigma_{Kin}^{NLO}(y,Q^2)}$$

- Peterson↔MC fragmentation effect is typically 1/2 statistical error
- For Zeus, combine both decay channels

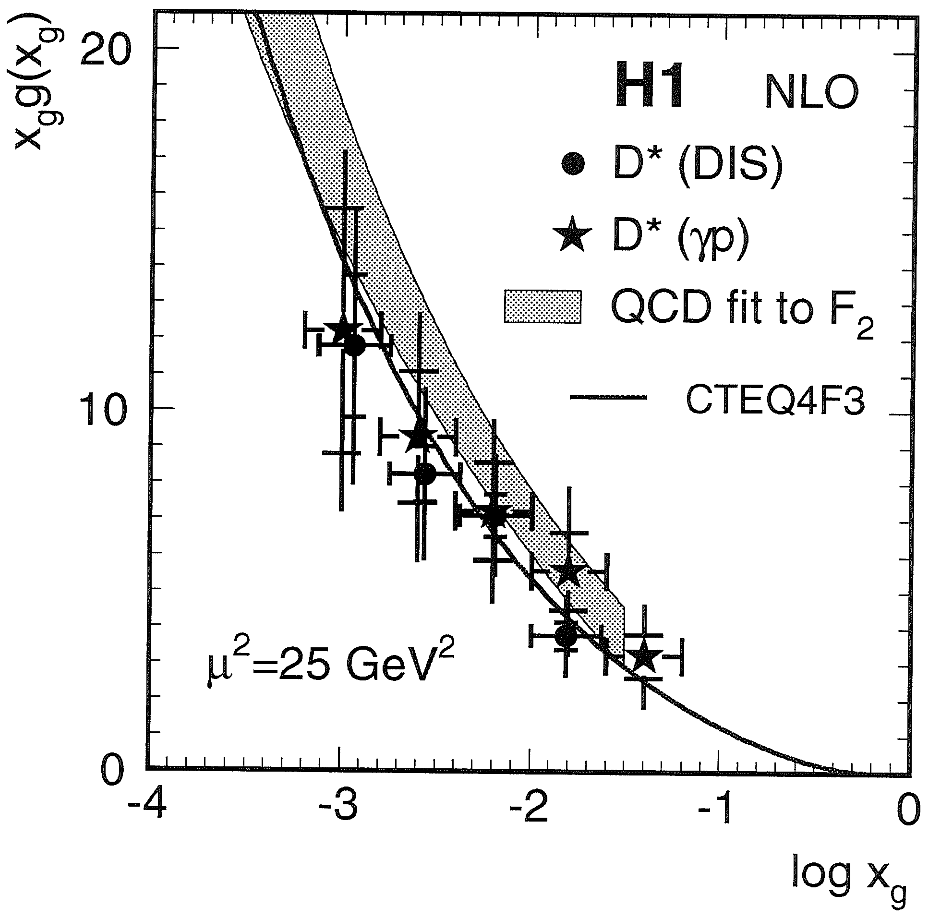
Zeus F_2^{charm} Results



- Structure function rises strongly as we go to lower x
- F_2^{charm} well described by NLO QCD fits

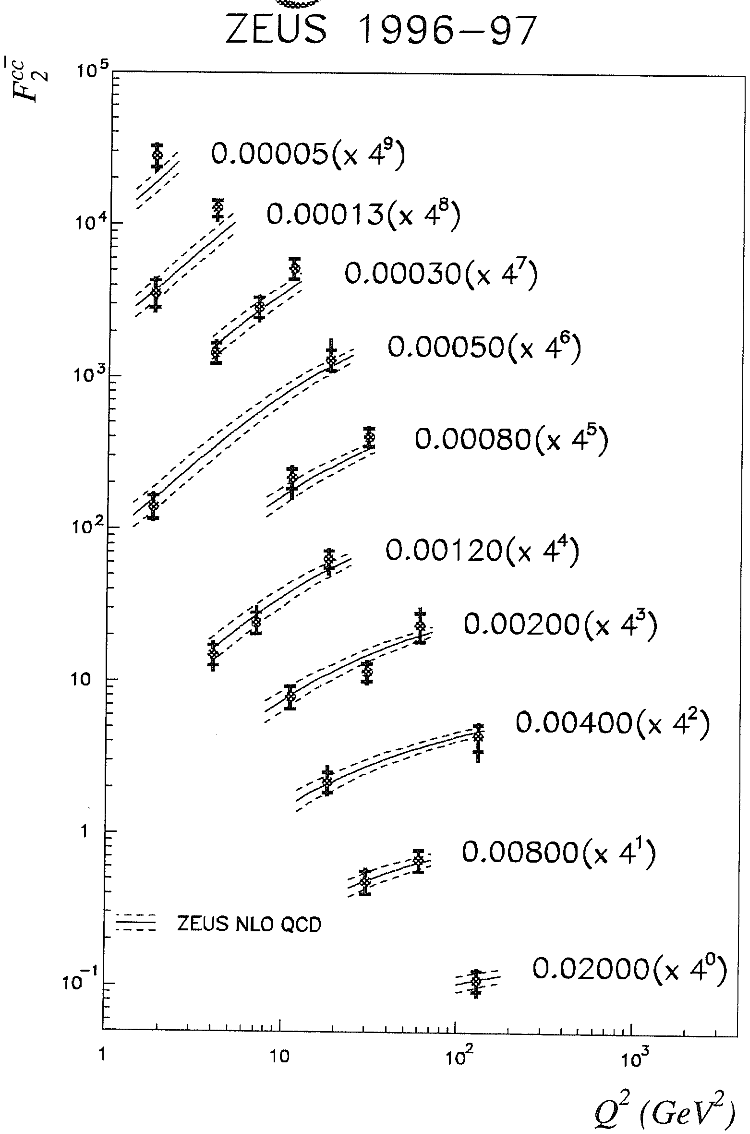
$\rightarrow$ Gluon distribution

H1 NLO Gluon



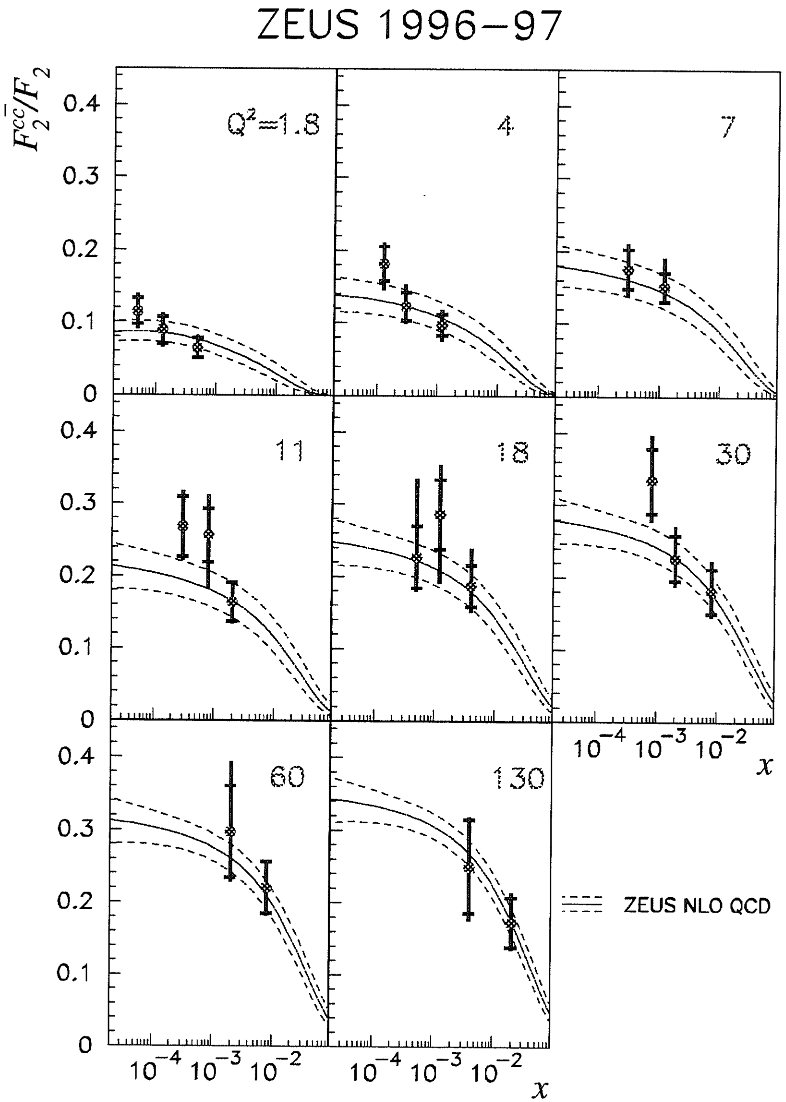
- Gluon distribution consistent between determinations from inclusive F_2 and D* measurements

Scaling Violations



- F_2^{charm} shows large scaling violations with Q^2 for various x bins

Charm Contribution to Total F_2



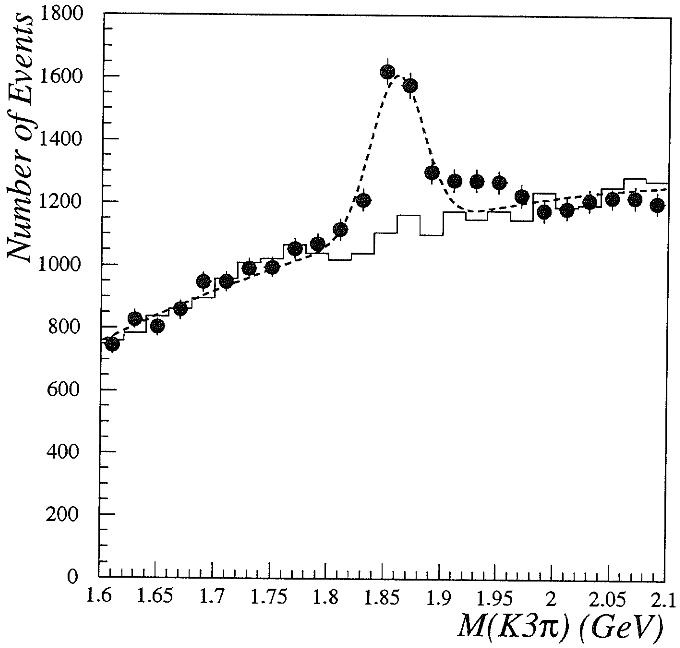
- F_2^{charm} rises more rapidly than F_2
- F_2^{charm} is around 30% of F_2 at low x and high Q^2

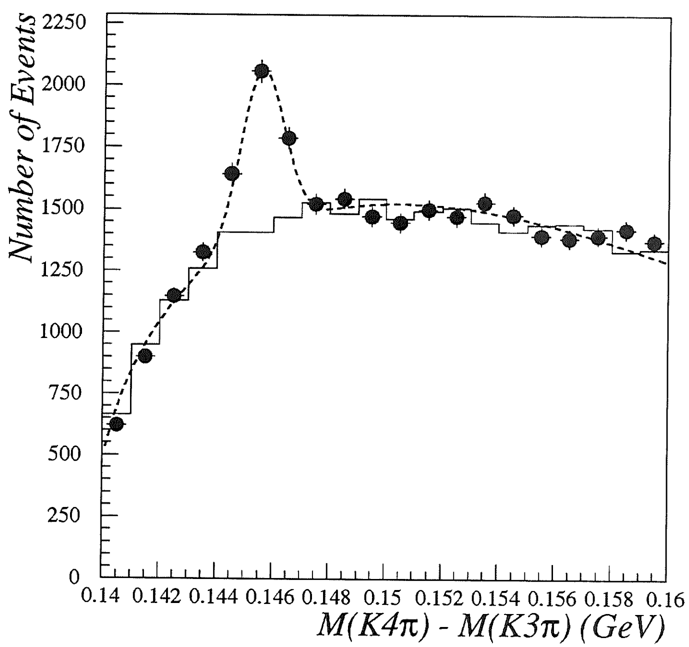
Conclusions

- D^* production cross sections have been measured with much improved precision
- Good agreement with FFNS NLO calculations
  - Need to account for fragmentation effects
  - Peterson fragmentation not appropriate
- F_2^{charm} has been extracted
  - Rises strongly
  - Demonstrates large scaling violations
  - Faster rise than F_2, reaching ~30% of F_2 at low x and high Q^2

Cross Sections: $D^* \rightarrow K\pi\pi\pi\pi_s$

Zeus 1996-97





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Kinematic Region

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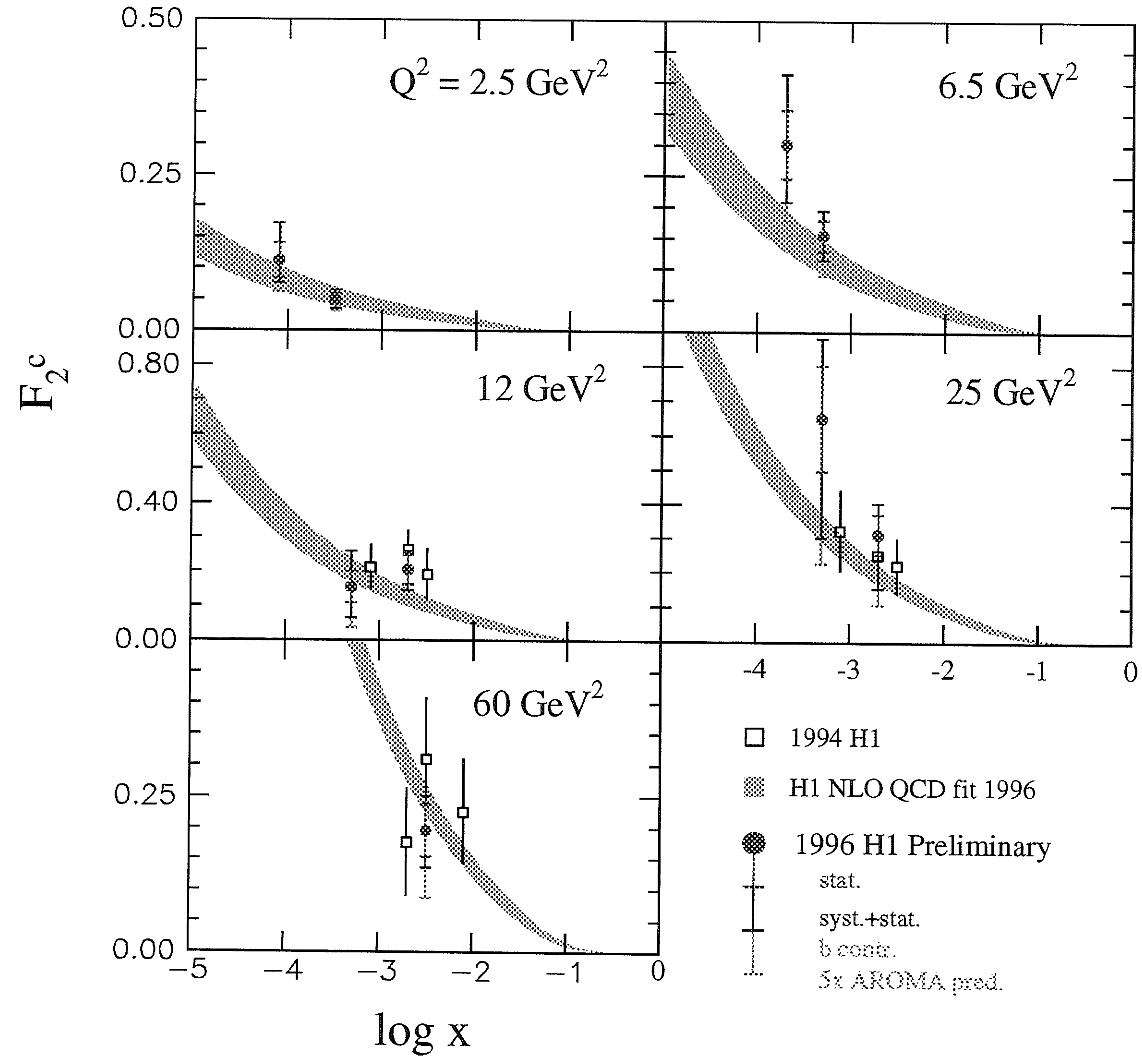
H1 F_2^{charm} Results



H1 Gluon Extraction

Define

$$x_g^{OBS} = \frac{M^2 + Q^2}{ys}$$

$$\text{where } M^2 = \frac{1.2 p^*_{\perp D^*} + m_c^2}{z(1-z)} \text{ and } z \equiv \frac{(E - p_z)_{D^*}}{2yE_e}$$

then

$$\sigma\left(x_g^{OBS}\right) = \int dx_g \left[g\left(x_g, \mu^2\right) \cdot \hat{\sigma}\left(x_g, \mu^2\right) A\left(x_g^{OBS}, x_g, \mu^2\right) \right] + \sigma_{quark}\left(x_g^{OBS}\right)$$

is the differential D^* cross section in x_g^{OBS} bins.
Unfold this distribution, correcting for the quark initiated processes, and use the factorisation in a bin

$$\sigma\left(x_g\right) \sim g\left(x_g, \mu^2\right) \cdot \hat{\sigma}\left(x_g, \mu^2\right)$$