Measurement of the $D^{*\pm}$ Meson Production and F_2^{cc} at High Q^2 with the H1 Detector

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- Charm production
- D^* at high Q^2
- Results
- Summary

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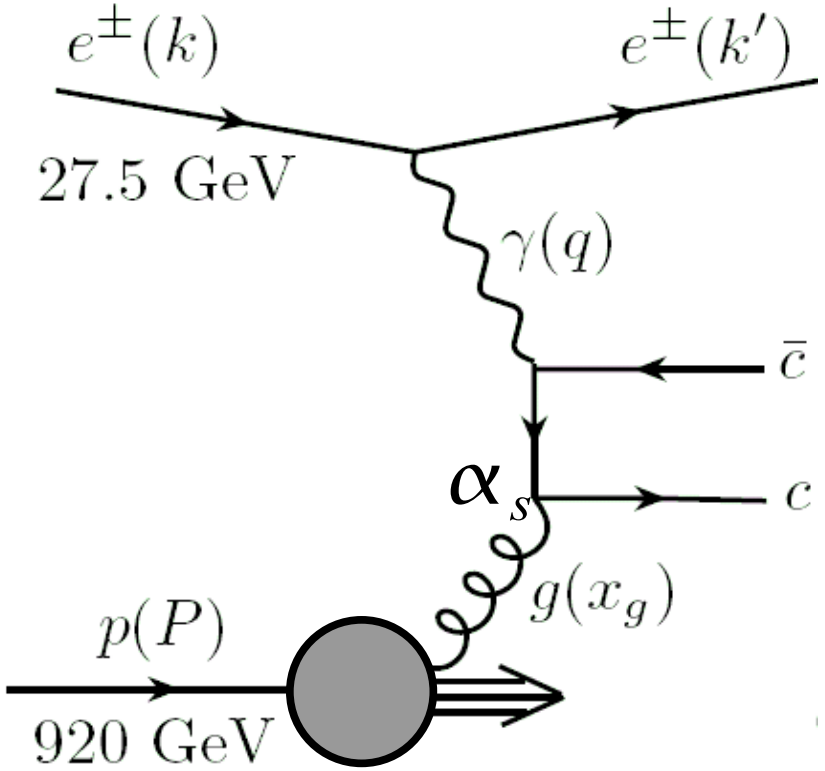
Charm Production at HERA

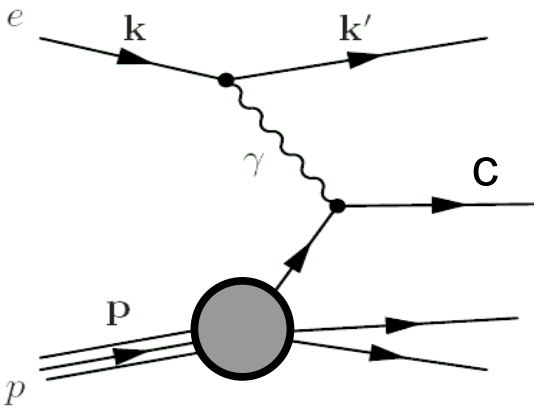
Dominant mechanism in the massive scheme:
Boson Gluon Fusion (BGF)



fragmentation

D*,D⁺,D⁰,... -mesons

Massless scheme – charm directly from the sea:



Charmed meson production cross section in QCD factorisation:

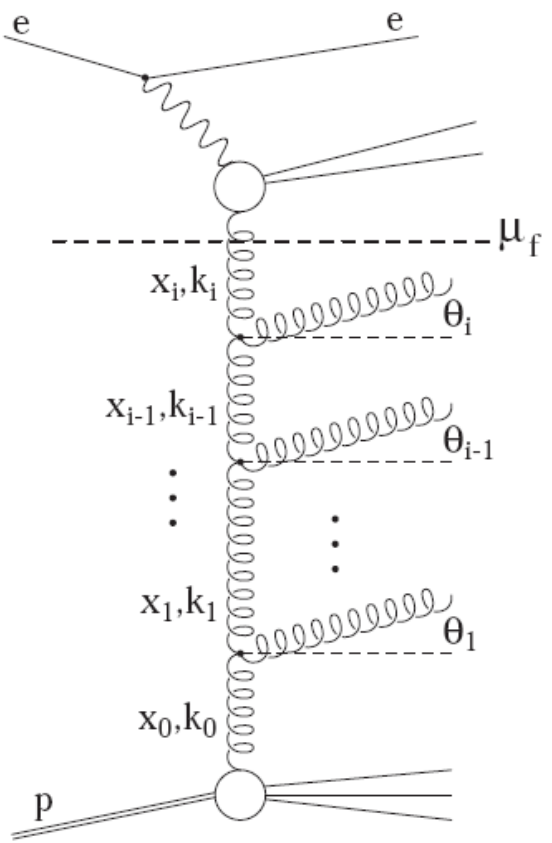
σ^{D^*} = protonstructure (gluons) $\otimes$ ME $\otimes$ fragmentation

Test different evaluation schemes for the hard ME at $Q^2 >> m_c^2$

Models for QCD Calculations

NLO and NNLO calculations

- **HVQDIS (NLO)**:
  - Massive (BGF) in 3-FFNS
  - DGLAP Evolution; set MRST2004FFF3 (CTEQ5F3)
  - Independent fragmentation (Kartvelishvili)
- **ZMVFNS calculation (NLO)**
  - PDF set: CTEQ6.6M
  - Fragmentation KKKS
- **GMVFNS calculation (NLO and NNLO)**
  - PDF set: MSTW08, ABKM

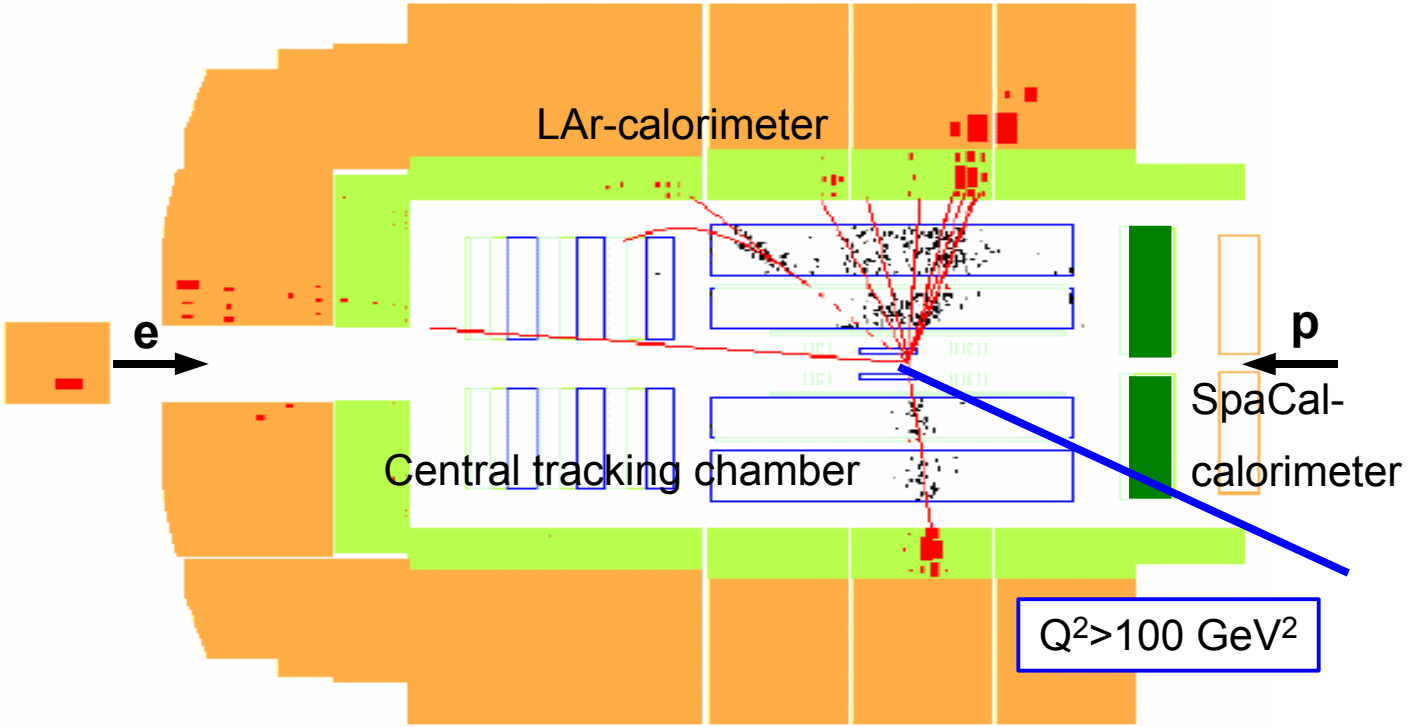


Monte Carlo: LO + Partonshower

- Massive (BGF), 3-FFNS
- **RAPGAP:** DGLAP Evolution; set CTEQ6.5M (CTEQ6L)
- **CASCADE**: CCFM Evolution; set A0 (A2)
- Fragmentation (both MCs):
  - uds : Lund String Model; c,b : Kartvelishvili

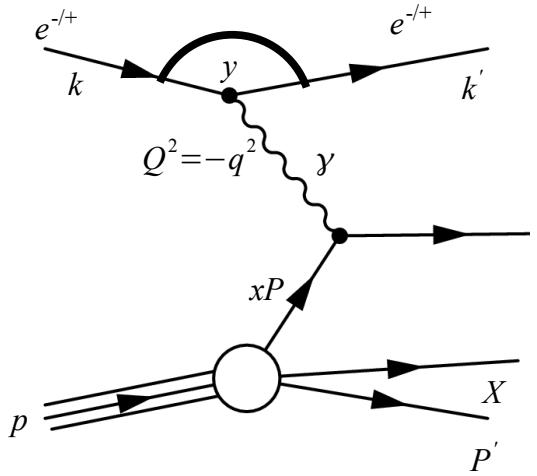
Selection of the Analysis Sample

Data: HERAII, $\mathcal{L}$=351 pb^{-1}



- Scattered Electron: Cluster in LAr or SpaCal calorimeter
- Reconstruction of the D* from the tracks in the central jet chamber

Kinematics:



- Photon virtuality:

$$Q^2 = -q^2 = (k - k')^2$$

- Inelasticity:

$$y = \frac{Pq}{Pk}$$

- Bjorken scale variable:

$$x = \frac{Q^2}{2\,Pq}$$

D* Reconstruction

- Select D* in decay channel:

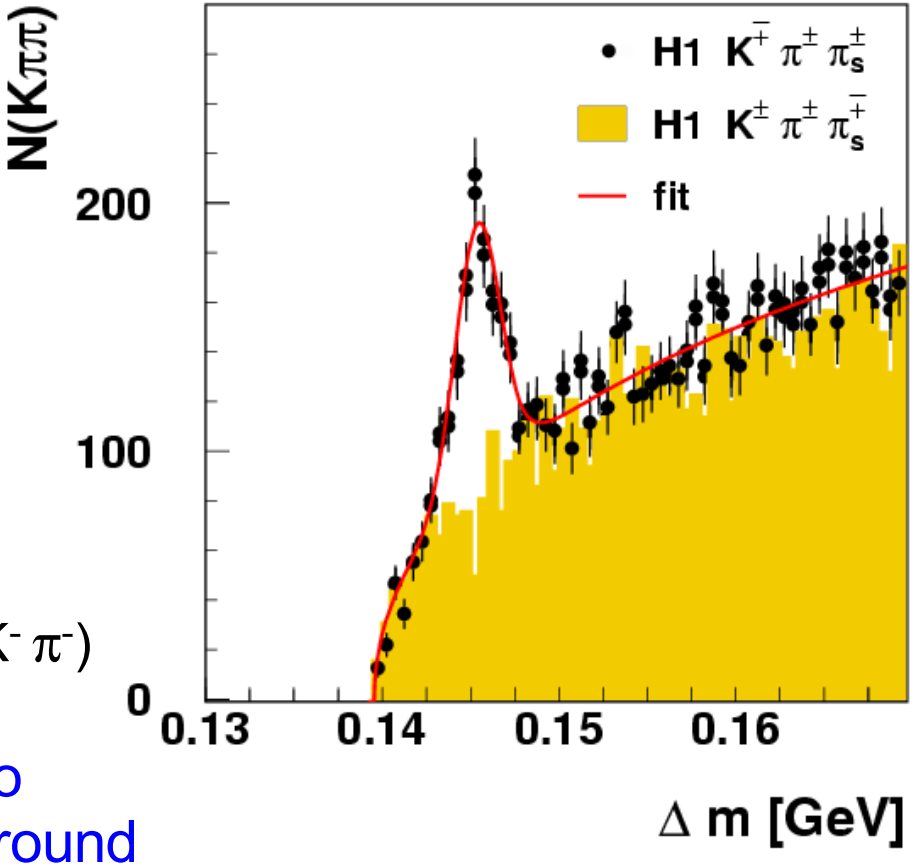
$D^{*\pm}(2{,}010) \longrightarrow D^0(1{,}864)\,\pi_s^{\pm}$

$D^0 \longrightarrow K^{\mp}\,\pi^{\pm}$

- Branching ratio BR=2.6%
- Use mass difference method:

$\Delta m(D^*) = M_{inv}(K\pi\pi_s) - M_{inv}(K\pi)$

- Combinatorial background via doubly charged combinations ($K^+\,\pi^+/K^-\,\pi^-$)
- Signal extraction: simultaneous fit to signal and background



Cross Section Measurement

Total cross section in the visible range: $100<Q^2<1000\ \text{GeV}^2$, $0.02<y<0.7$

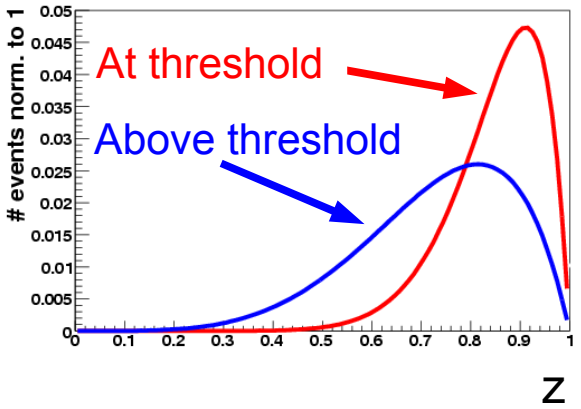
$p_T(D^*)>1.5$ GeV, $-1.5<\eta(D^*)<1.5$

$$\sigma_{tot}\,(ep\rightarrow D^* X) = 225 \pm 14_{stat} \pm 27_{syst}\ \text{pb}$$

Data Compared to HVQDIS prediction: $\sigma_{tot}^{theo} = 241 \pm 15$ (model) pb

Model Input parameters:

- PDF MRST2004FF3 (CTEQ5F3); $1.3 < m_c < 1.7$ GeV; $0.5\mu < \mu_r = \mu_f < 2\mu$, $\mu=\sqrt{Q^2+4m_c^2}$
- Use threshold dependent fragmentation (Kartvelishvili) as measured by H1:



$$D_Q^{D^*}(z) = N\ z^{\alpha}\,(1-z)$$

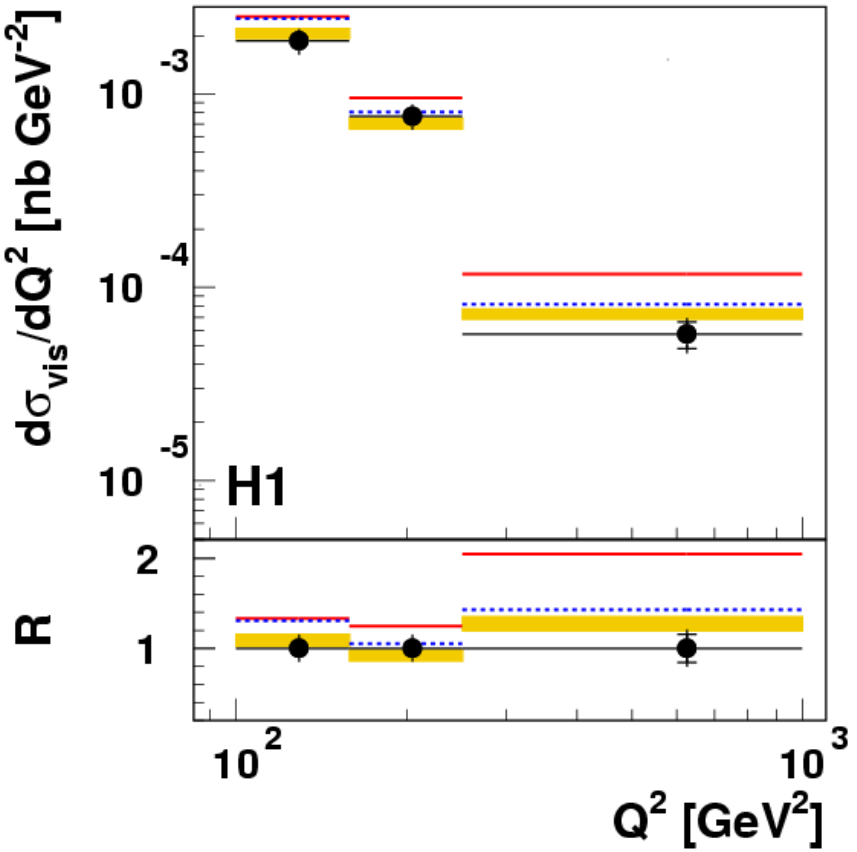
with

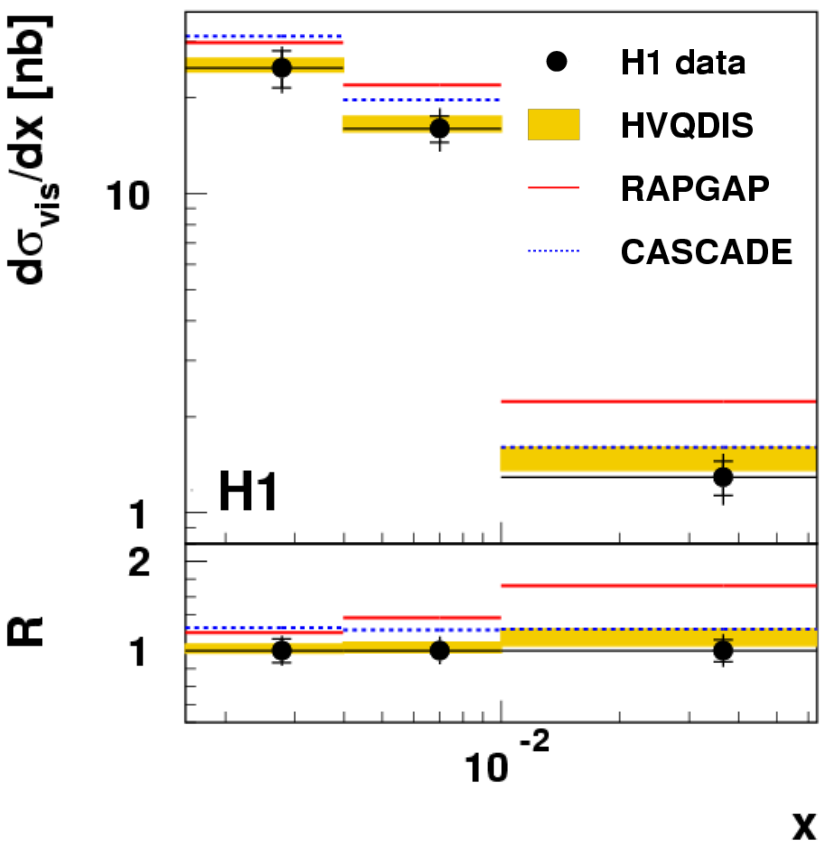
$$\alpha = 6.0^{+1.1}_{-1.3} \quad \text{for } \hat{s} < 70\ \text{GeV}^2$$

$$\alpha = 3.3^{+0.4}_{-0.4} \quad \text{for } \hat{s} > 70\ \text{GeV}^2$$

$\hat{s}$ - center of mass energy of the hard process

Cross Sections – Event Kinematics

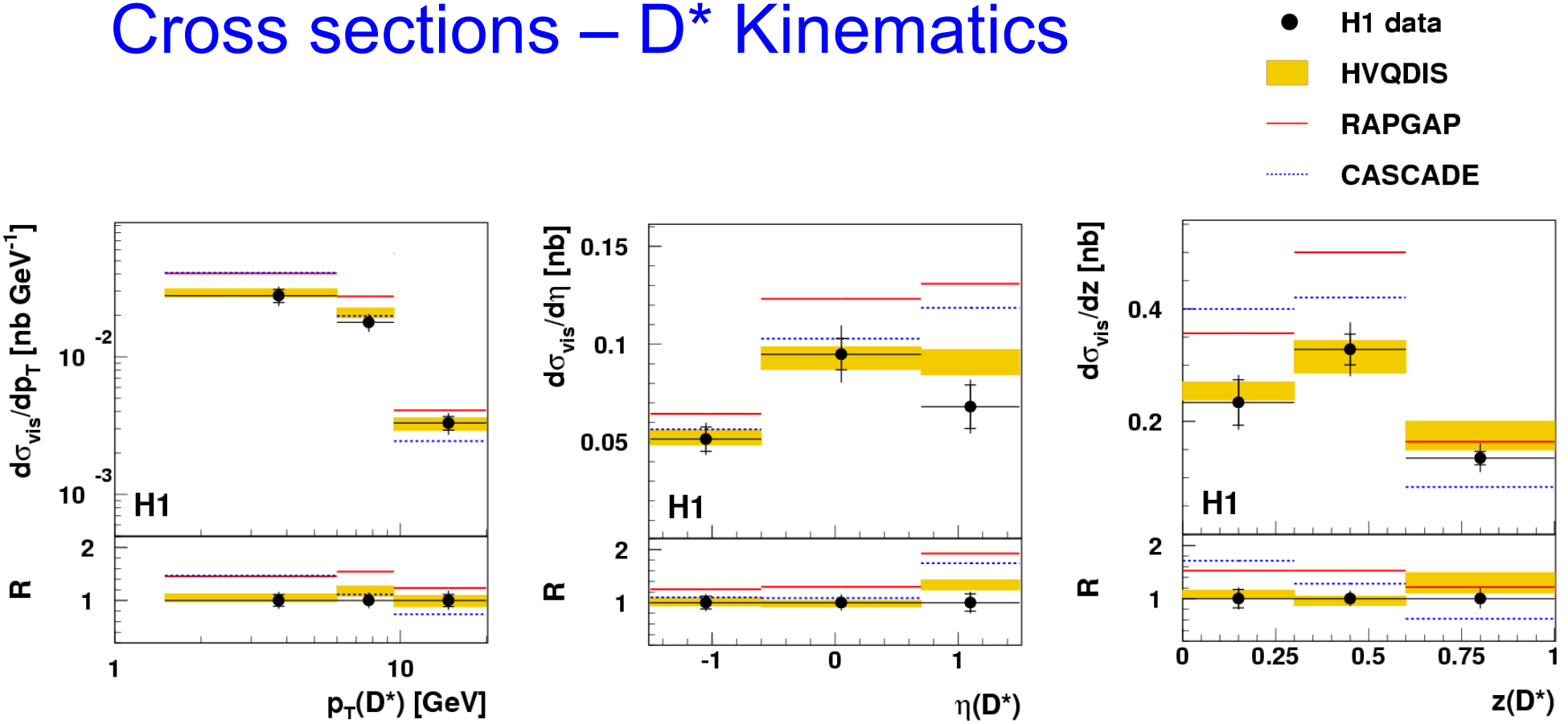




➔ **Massive NLO calculation describe data well despite $Q^2 >> m_c^2$**

➔ **Monte Carlo predictions in leading order do not describe the data**

Cross sections – D* Kinematics



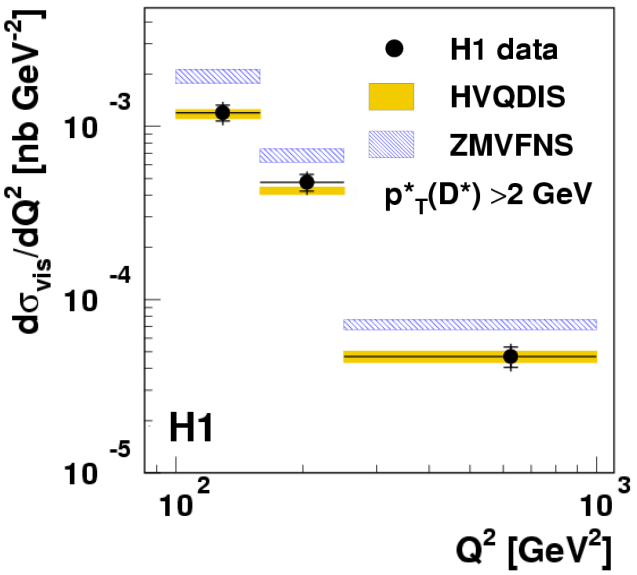
D* inelasticity:

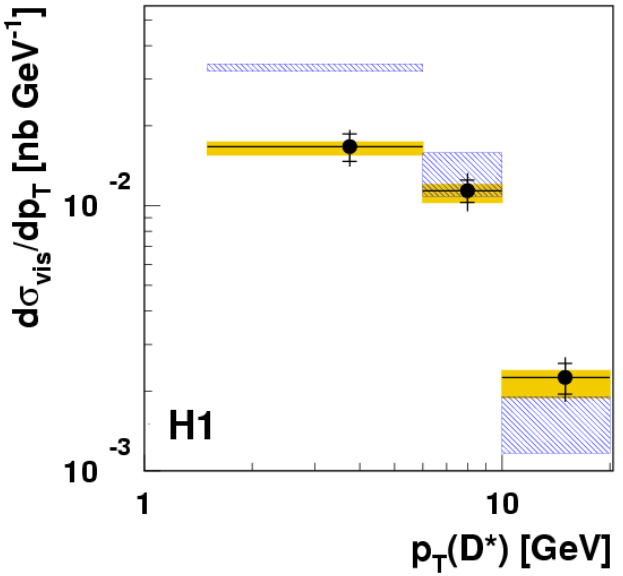
$$z_{D^*} = \frac{(E - p_z)_{D^*}}{2\ y\ E_e}$$

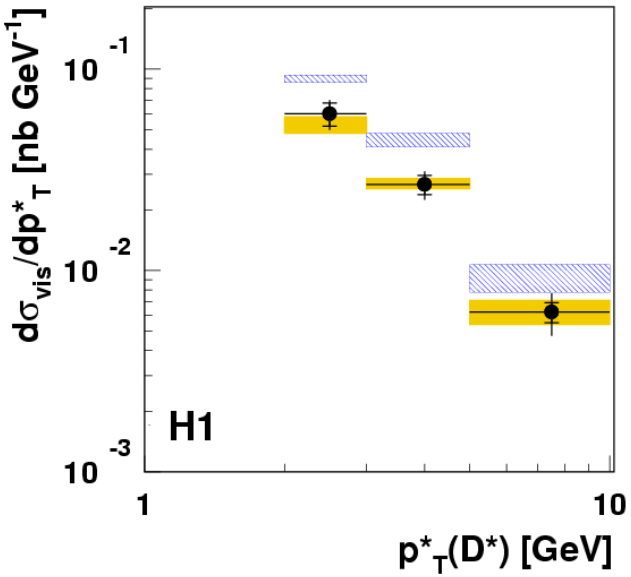
- **Good agreement with HVQDIS**
- **Monte Carlo predictions fail to describe the data**

Test of the NLO Predictions

- For validity of ZMVFNS calculations $p_t^*(D^*)>2$ GeV is required ($p_t^*(D^*)$: transverse momentum of the D* in the γp – system)
- Comparison with data in this limited phase space



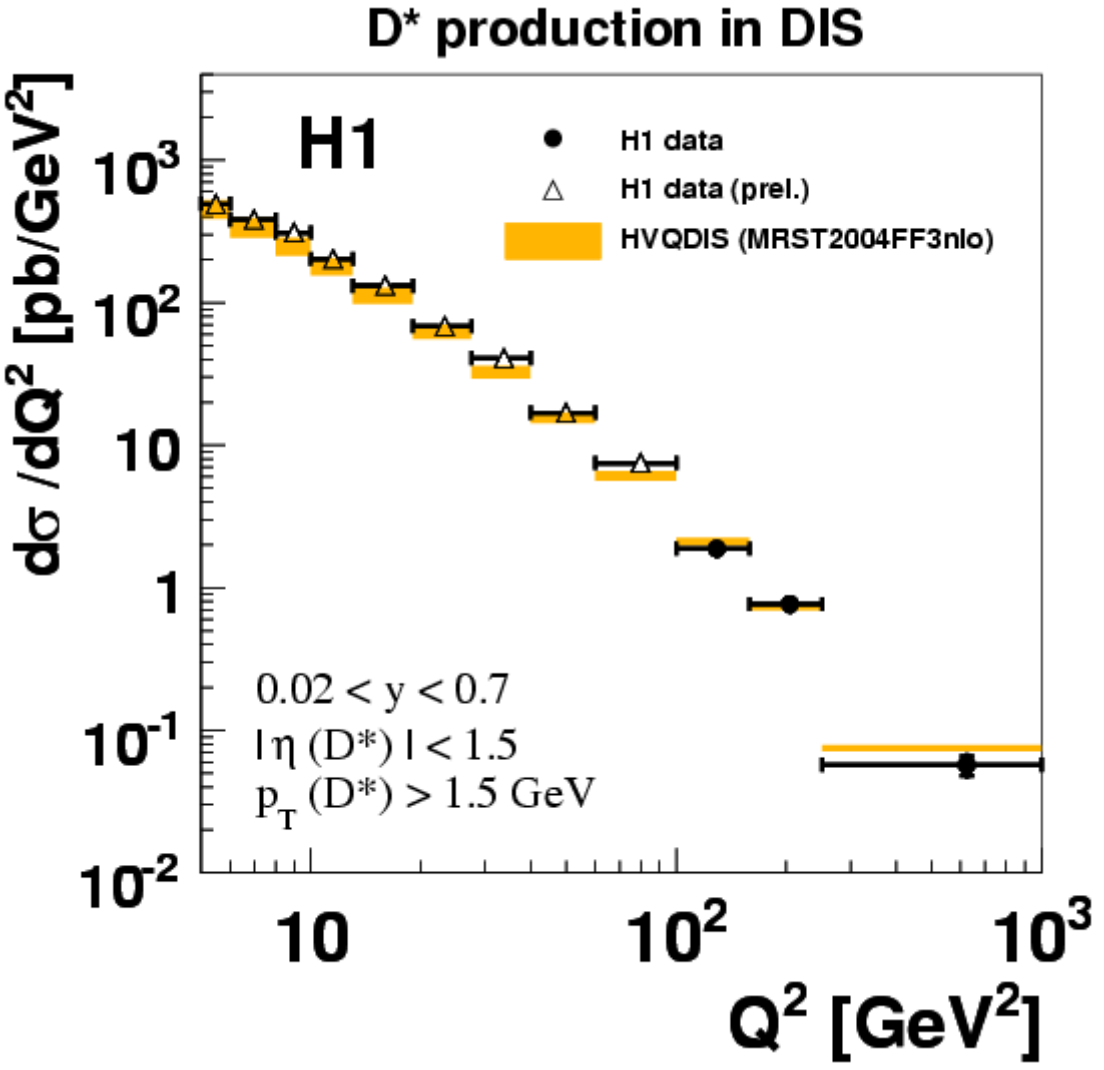




➔ Massive predictions fit well

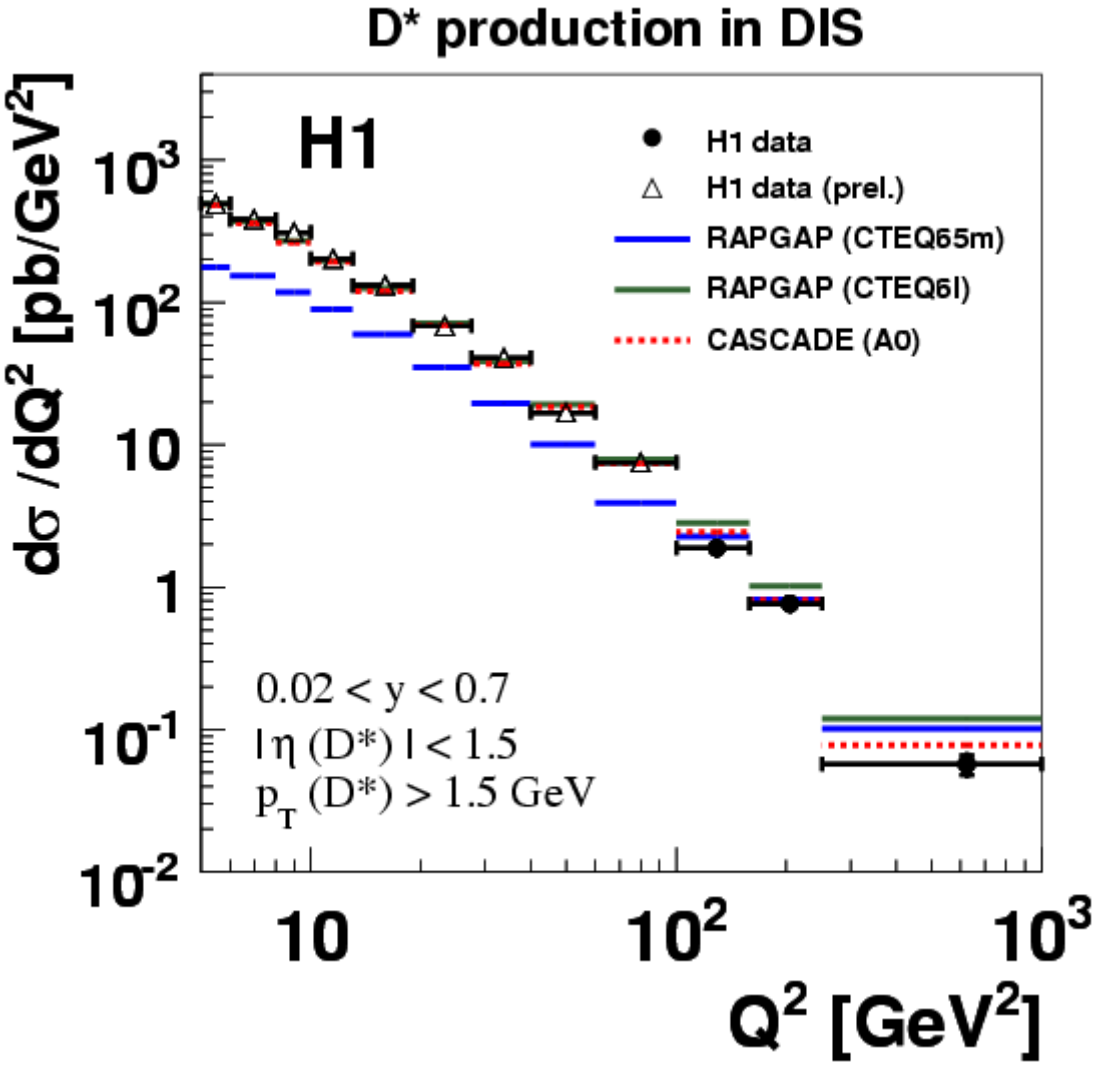
➔ ZMVFNS predictions do not describe the data in form and normalisation.

Cross Sections in full Q^2 Range



➔ **Reasonable description of Q^2 slope by the massive calculation HVQDIS for $5<Q^2<1000$ GeV^2**

Cross Sections in full Q^2 Range

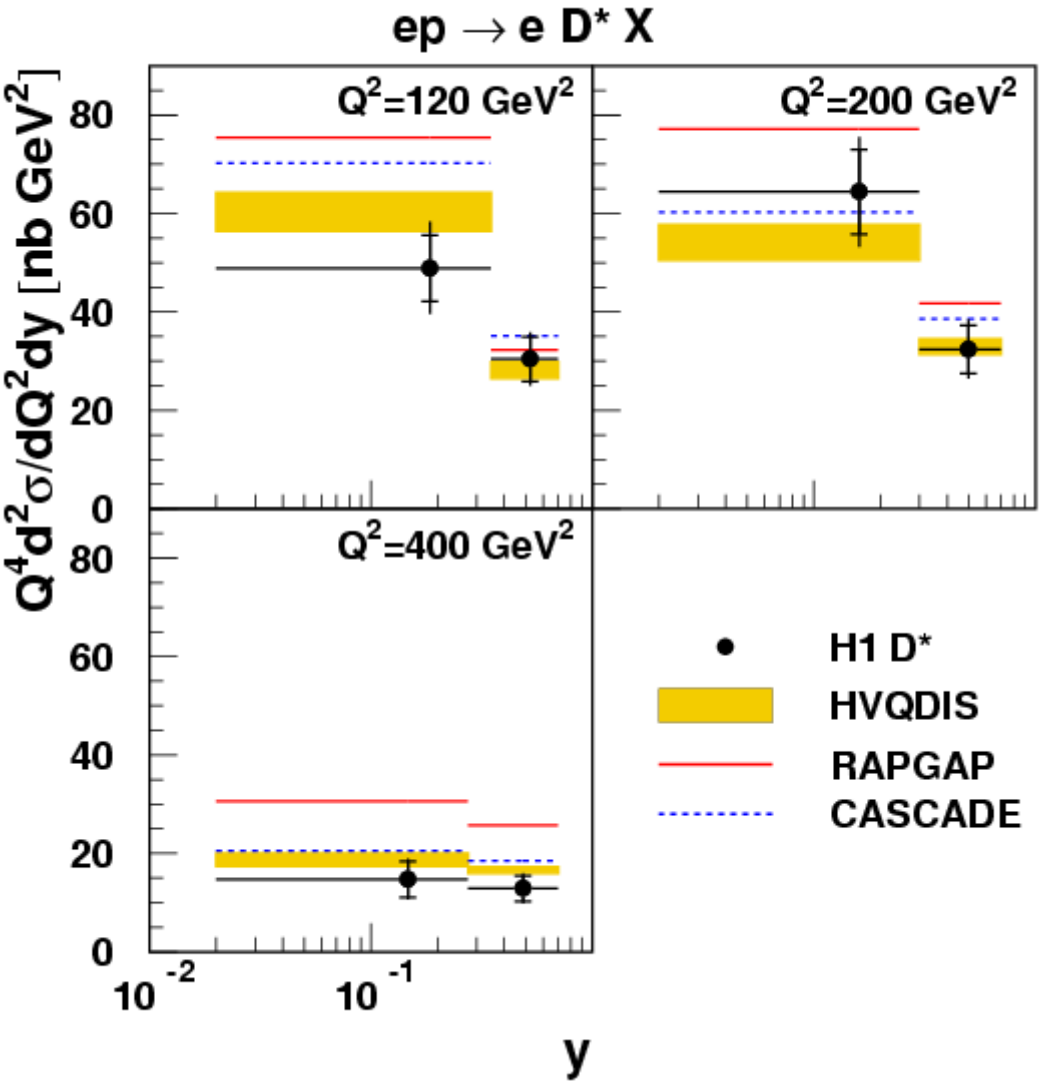


➔ **CASCADE (LO+PS CCFM): reasonable description of the data**

➔ **RAPGAP (LO+PS DGLAP): both PDFs don't describe data well**

Cross Sections – Double differential in (Q^2,y)

- **HVQDIS describes data well**
- **CASCADE prediction differs from data in 1. Q^2y bin**
- **RAPGAP prediction too high**



- Use double differential cross sections for extraction of F_2^{cc}

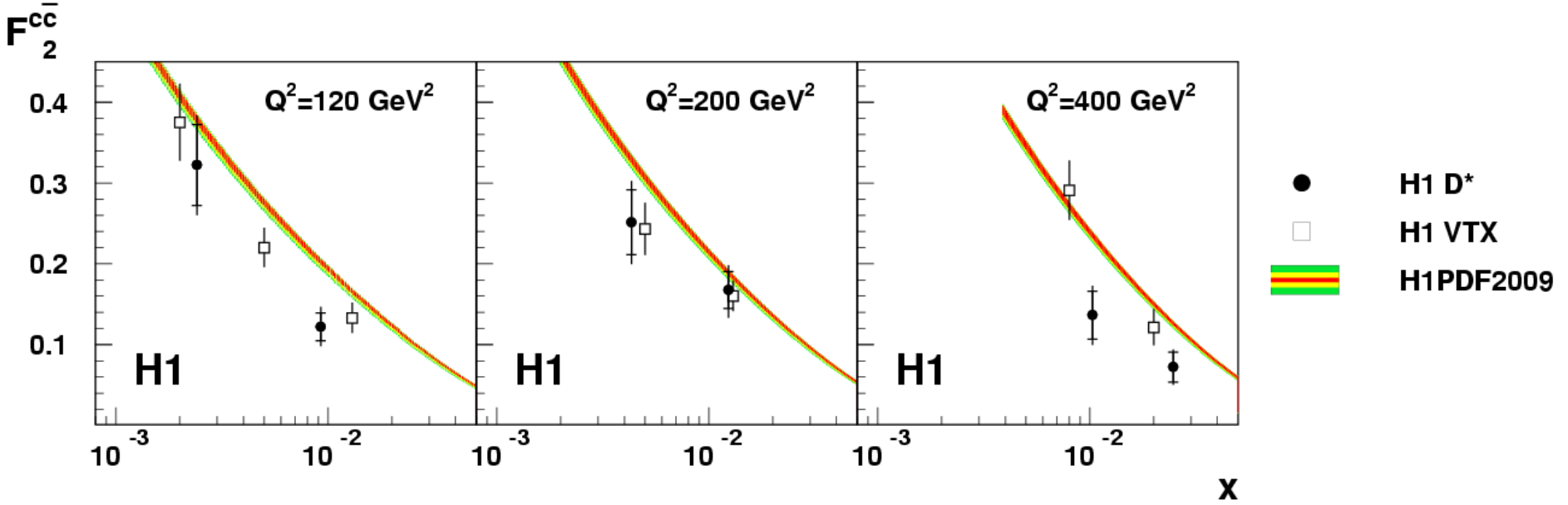
Charm Contribution F_2^{cc} to F_2

- Definition of F_2^{cc} :

Contribution of F_L^{cc} (~3%) neglected !

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

- Extrapolation in $p_t(D^*)$ and $\eta(D^*)$ with NLO QCD (HVQDIS) – $(\sigma_{tot}/\sigma_{vis})$: 1.4 – 2.3

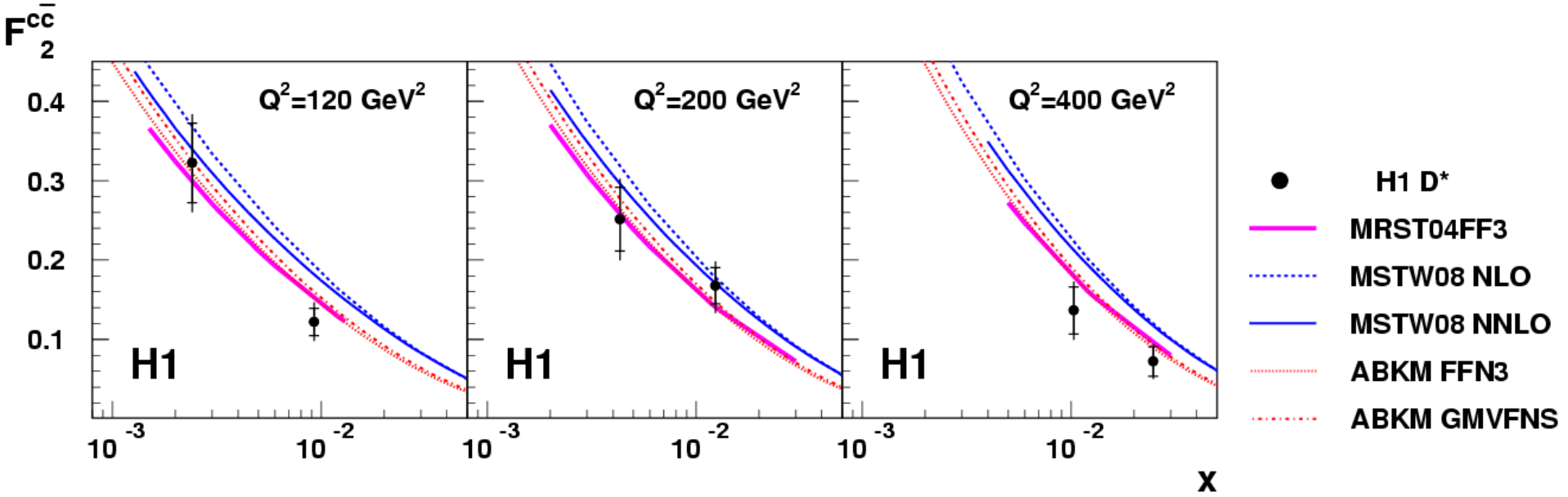


➔ **Overall agreement with results from charm identification via lifetime tag (with H1 vertex detector)**

➔ **H1 PDF fit H1PDF2009 (inclusive DIS data) above D* measurement**

Results of F_2^{cc} in Comparison to QCD Predictions

- Charm contribution on total DIS cross section up to 30% @ high Q^2
- Test different schemes for treatment of heavy quarks in PDF fits



➔ **Measured F_2^{cc} consistent with predictions within errors**

- Measurement used in H1 ZEUS combination of F_2^{cc} !

Summary

- Charm production for $Q^2>100$ GeV^2 investigated via measurement of D* meson production cross sections
- Allows test of perturbative QCD in this region of phase space
  - ➔**Good agreement with massive calculation based on BGF in NLO also at $Q^2>>m_c^2$**
  - ➔**Data are not described by massless calculations (ZMVFNS)**
  - ➔**LO+PS Monte Carlo predictions differ from data**
- F_2^{cc} extracted at high Q^2.
- Measurement contributes to H1ZEUS Combination of F_2^{cc} at high Q^2