

# Heavy Quark Production at the H1 Experiment at HERA



<http://h1.desy.de/>

Andreas B. Meyer

EPS, 21/7/11



# The HERA Electron Proton Storage Ring

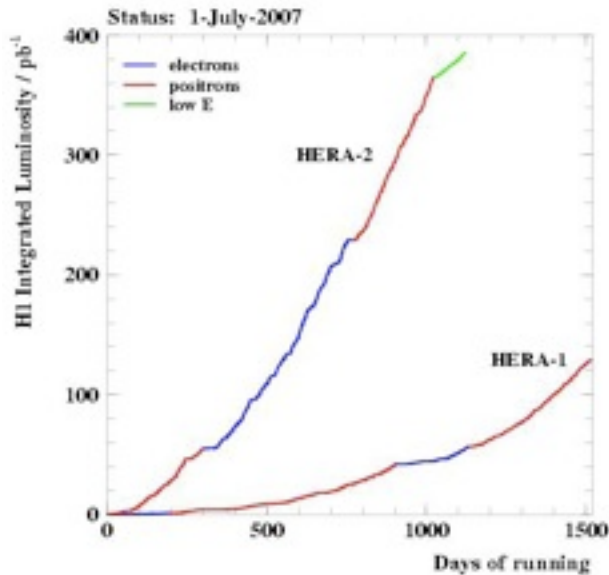


# HERA

$$\sqrt{s_{ep}} \sim 320 \text{ GeV}$$

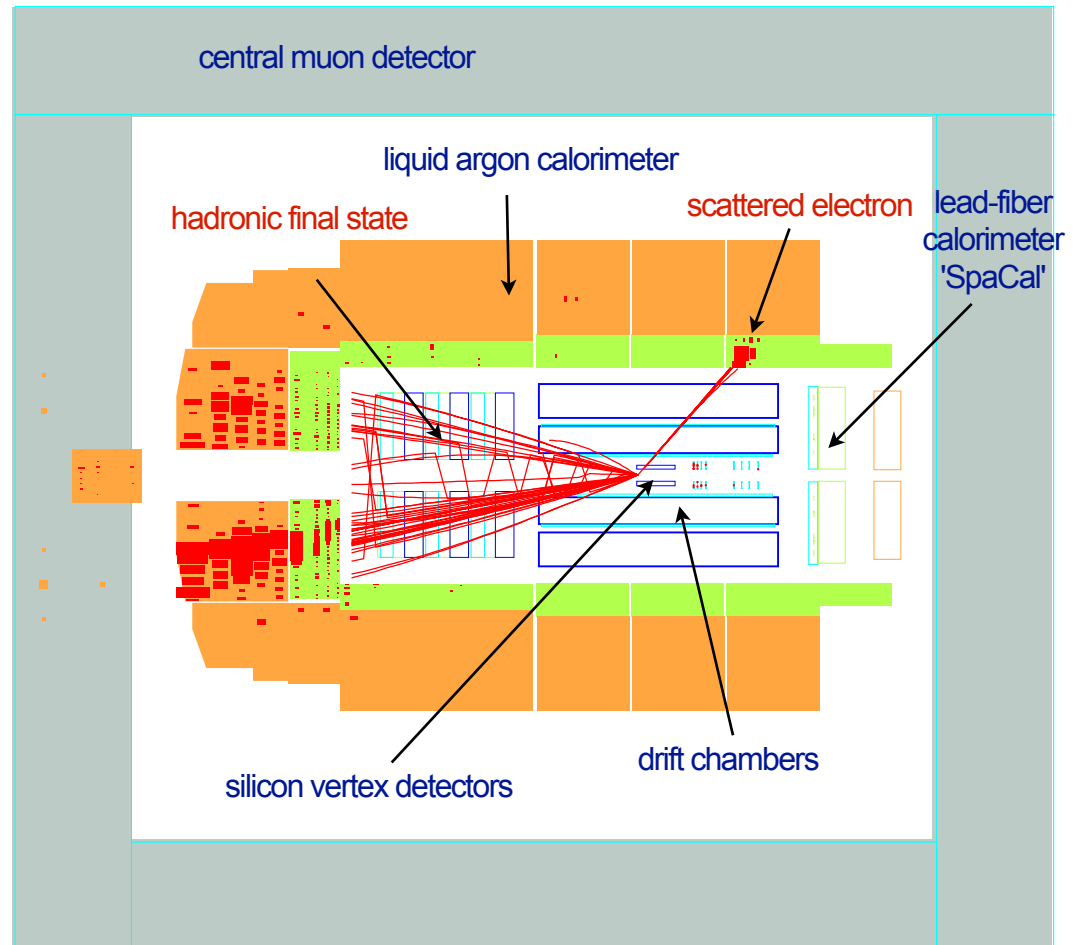
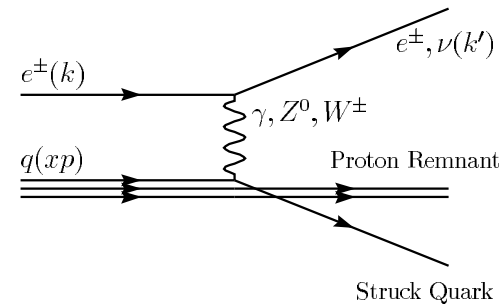


Integrated Luminosity (1992-2007):  
~500 pb<sup>-1</sup> per experiment



## H1 Detector:

- 12x10x15 m<sup>3</sup>, 2800 tons
- 600k r/o channels
- BX rate: 10.4 MHz (96 ns)
- 4 trigger levels, ~20 Hz to tape

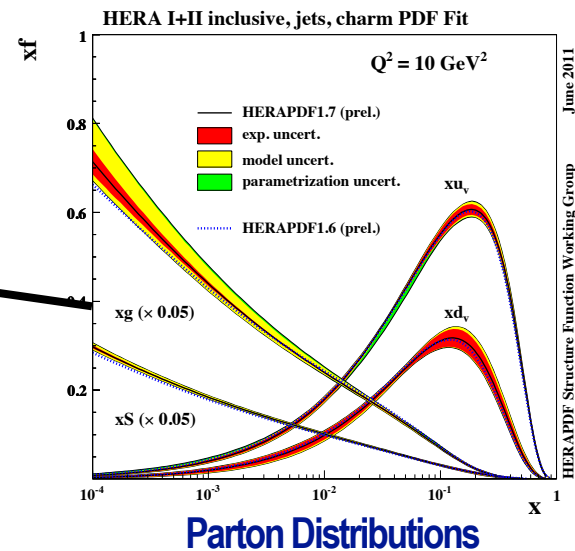
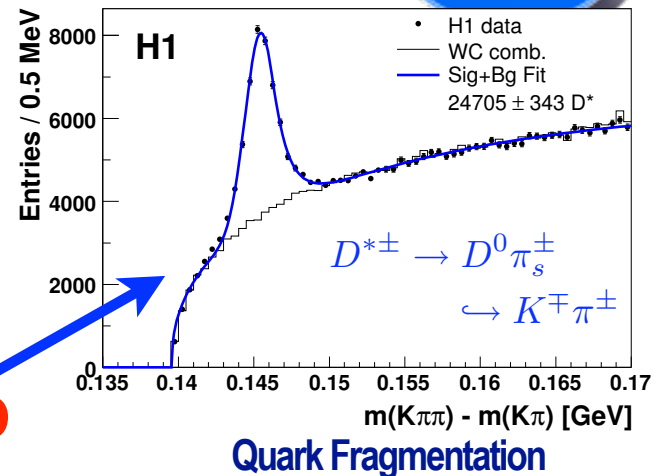
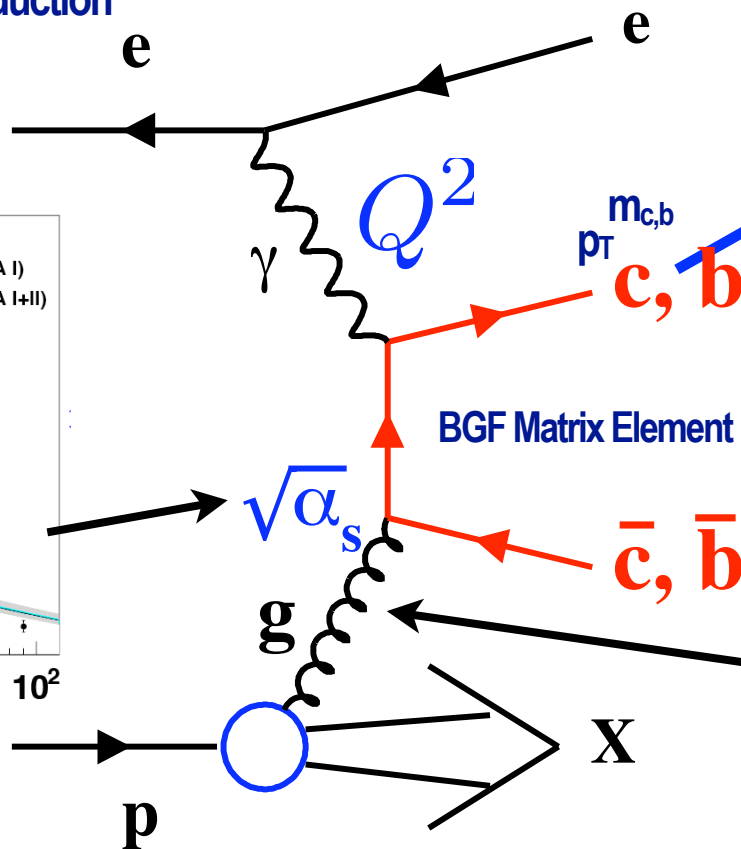
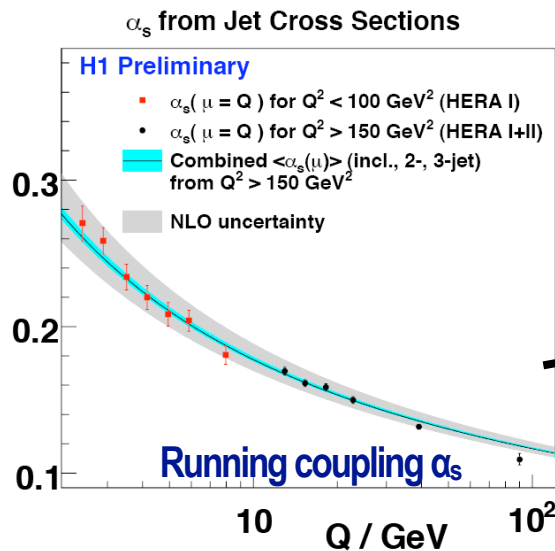


# Heavy Quark Production

Multiple Hard Scales:  $m_{c,b}$ ,  $Q^2$ ,  $p_T$

$Q^2 \sim 0$ : yp: 'photoproduction'

$Q^2 > 5 \text{ GeV}^2$ : 'DIS'



Probe of perturbative QCD:

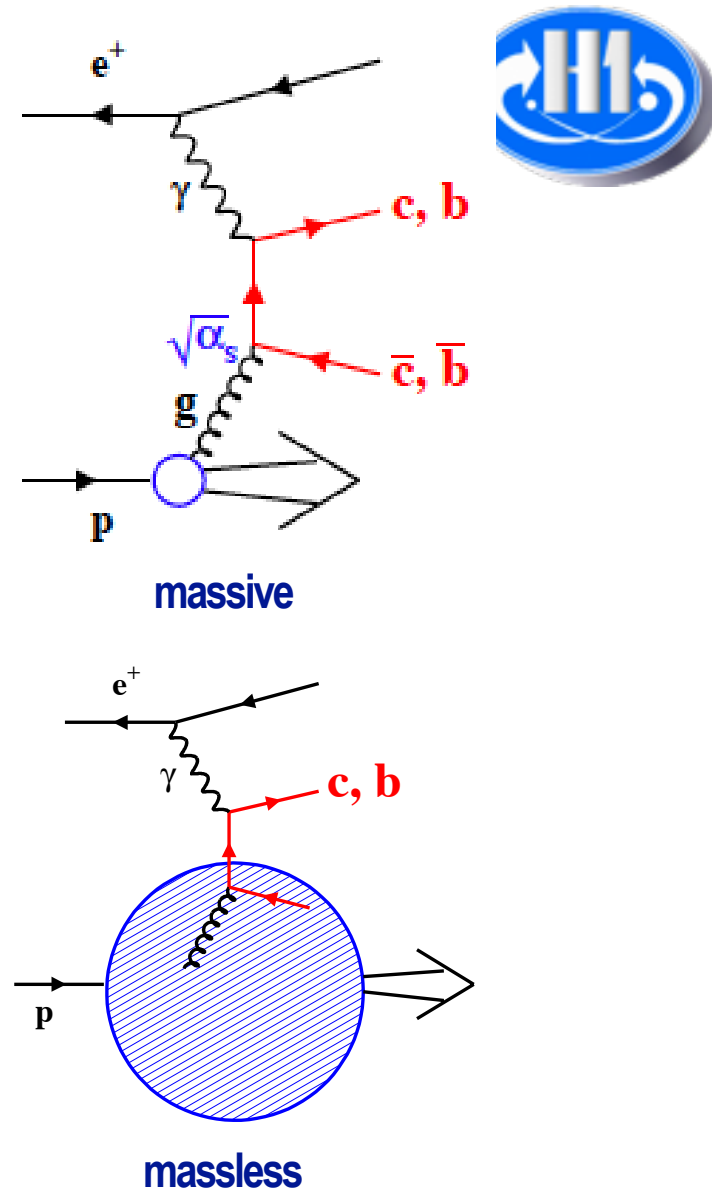
Test factorization / universality of calculable and non-calculable components

Input to Parton Density Functions



# Calculations

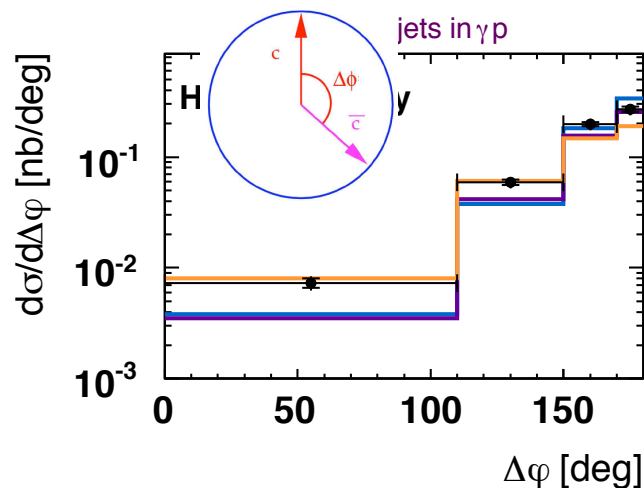
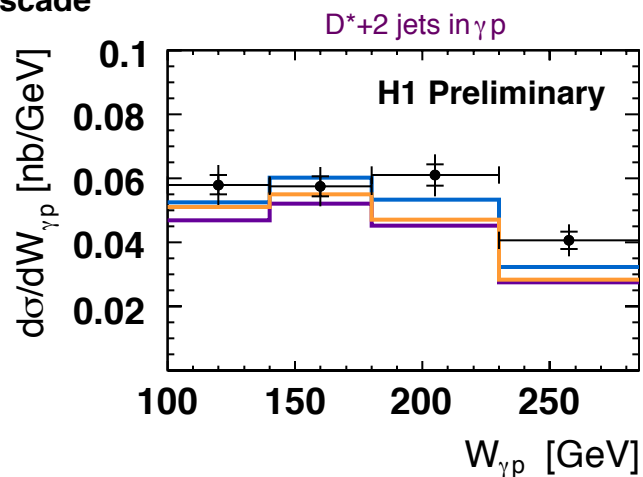
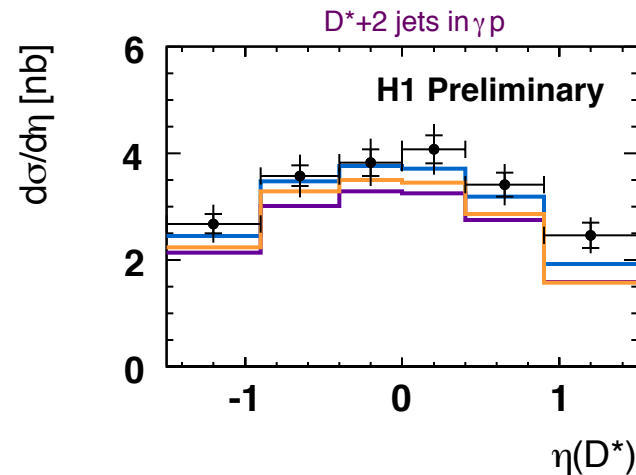
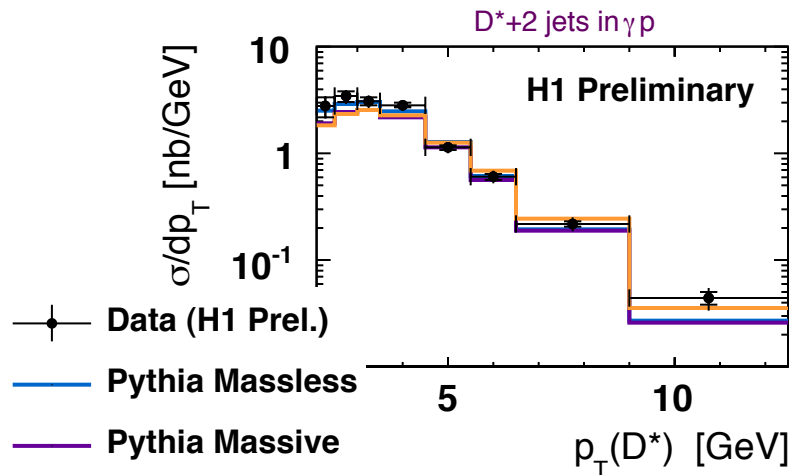
- PYTHIA MC: LO+PS ( $\gamma p$ )
- FMNR: fixed order NLO ( $\gamma p$ )
- MC@NLO: FMNR + Herwig (matched)
  
- RAPGAP MC: LO+PS (DIS, includes QED corrections)
- HVQDIS: fixed order NLO (DIS)
  
- NNLO: inclusive c and b contributions  $F_2^{cc}$ 
  - ABKM
  - MSTW08
  
- Cascade:  $k_T$ -factorization ( $\gamma p$  and DIS)



(VFNS interpolate between the two)

# Photoproduction: $D^* + \text{dijets}$

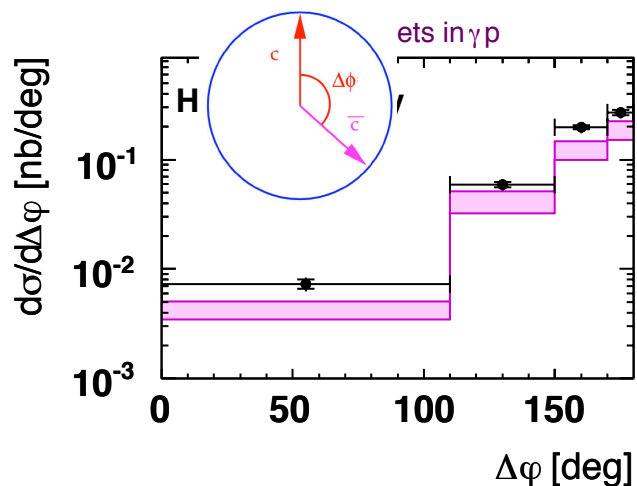
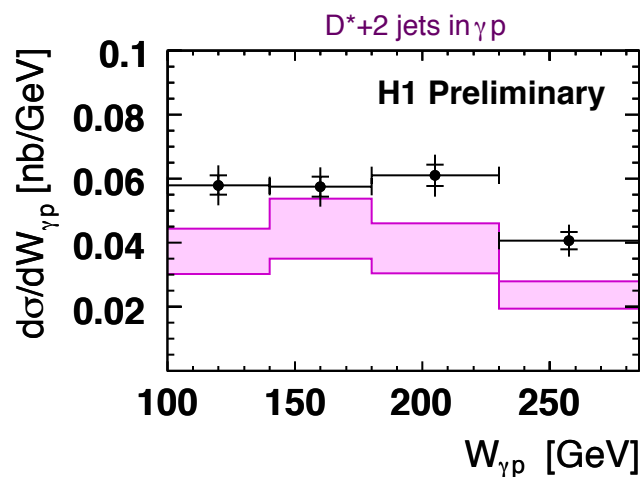
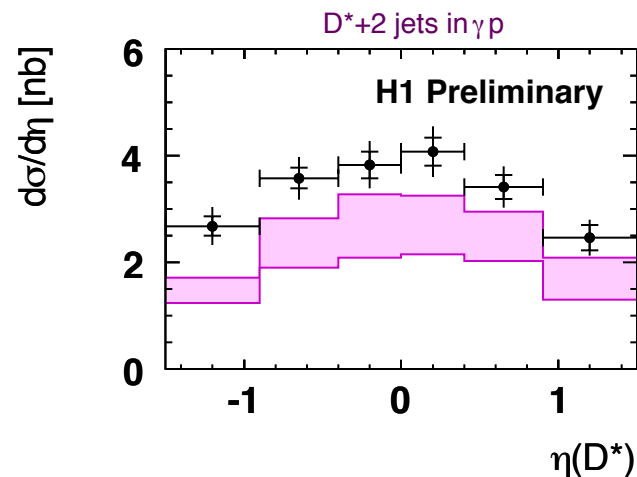
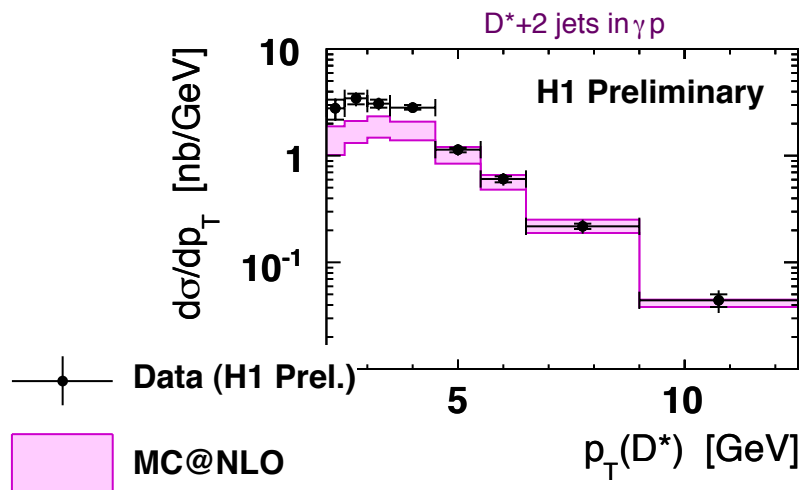
H1prelim-10-072



Generally good description, CASCADE somewhat superior in describing higher order effects

# Photoproduction: $D^* + \text{dijets}$

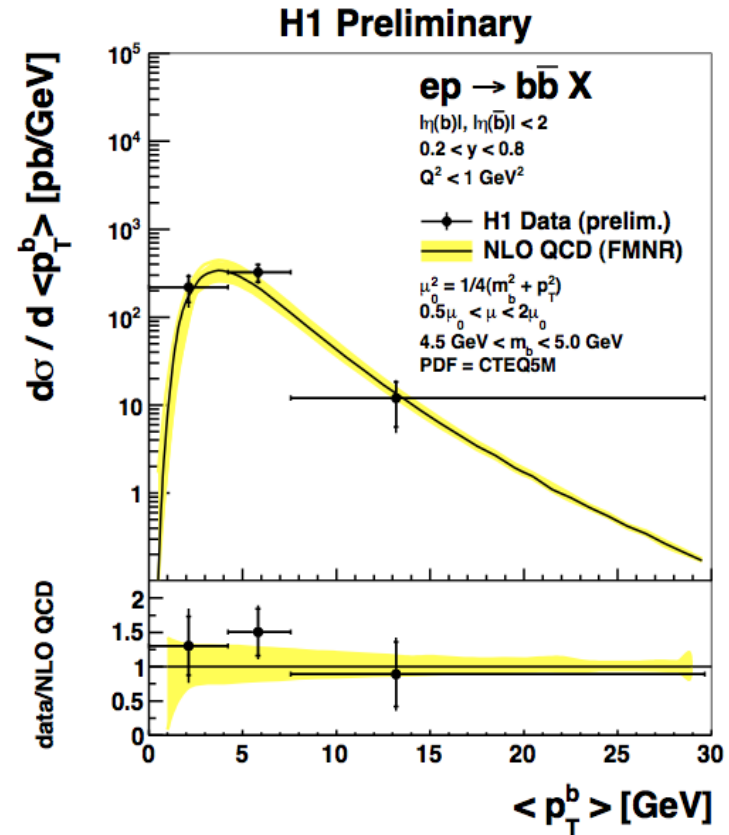
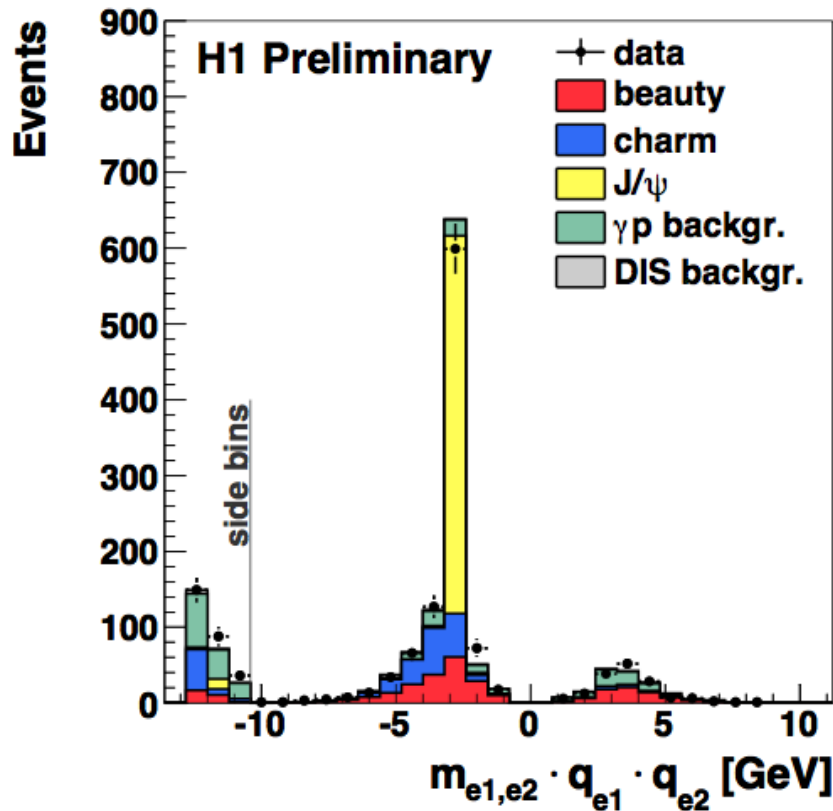
H1prelim-10-072



MC@NLO too low in normalization

# Photoproduction: b at threshold

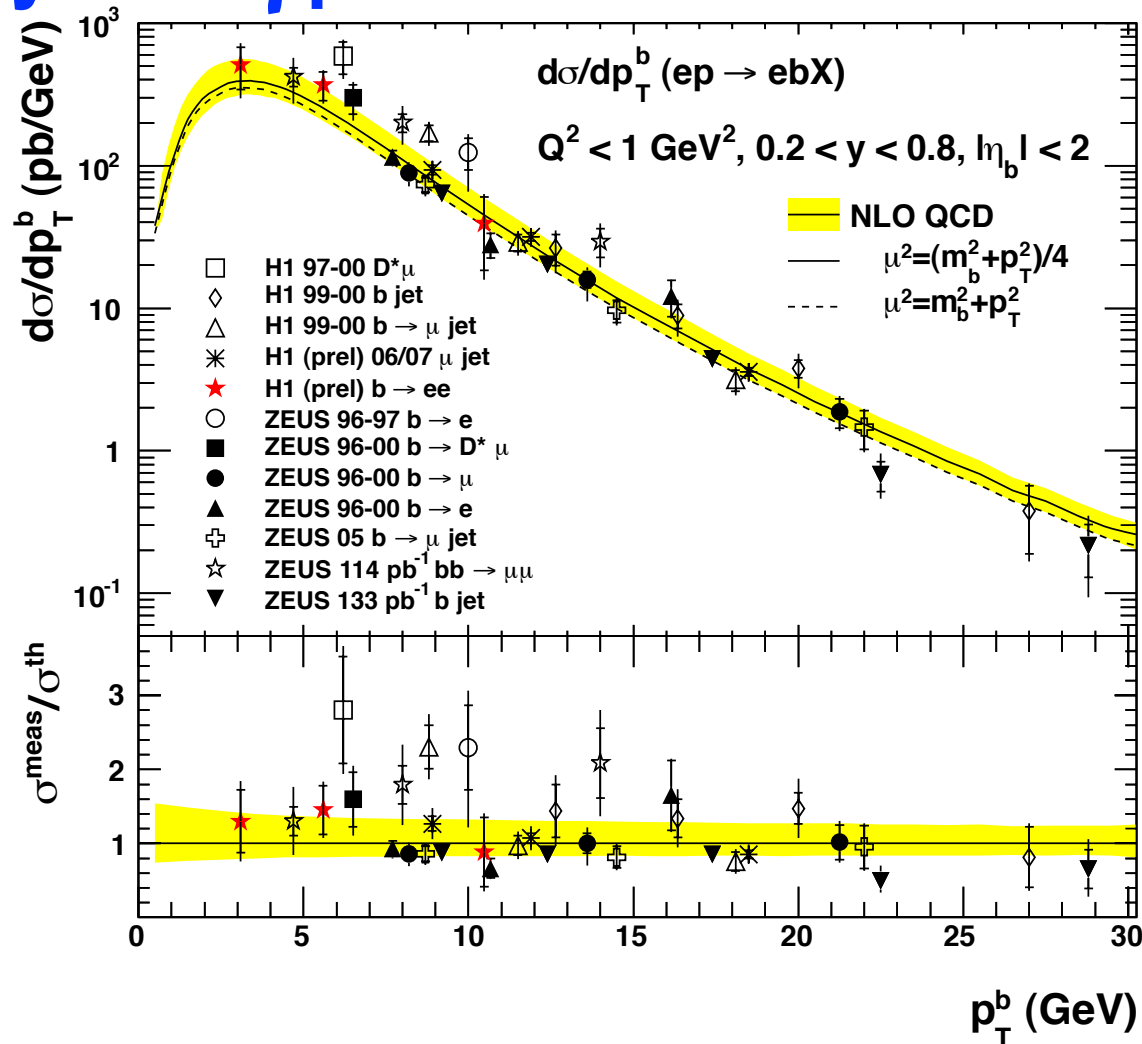
H1prelim-11-071



$bb \rightarrow eeX$  with  $p_T(e) > 1 \text{ GeV}$  - no jet selection  
 event sample collected using H1 Fast Track Trigger (FTT)  
 b-tag from charge and angular correlations

# Summary: b in $\gamma p$

## HERA



$\langle p_t^b \rangle$

A large number of b-production results from HERA is available  
 various channels, techniques (in a wide kinematic range)

general consistency between data (with a minimal trend of NLO being only slightly too low)

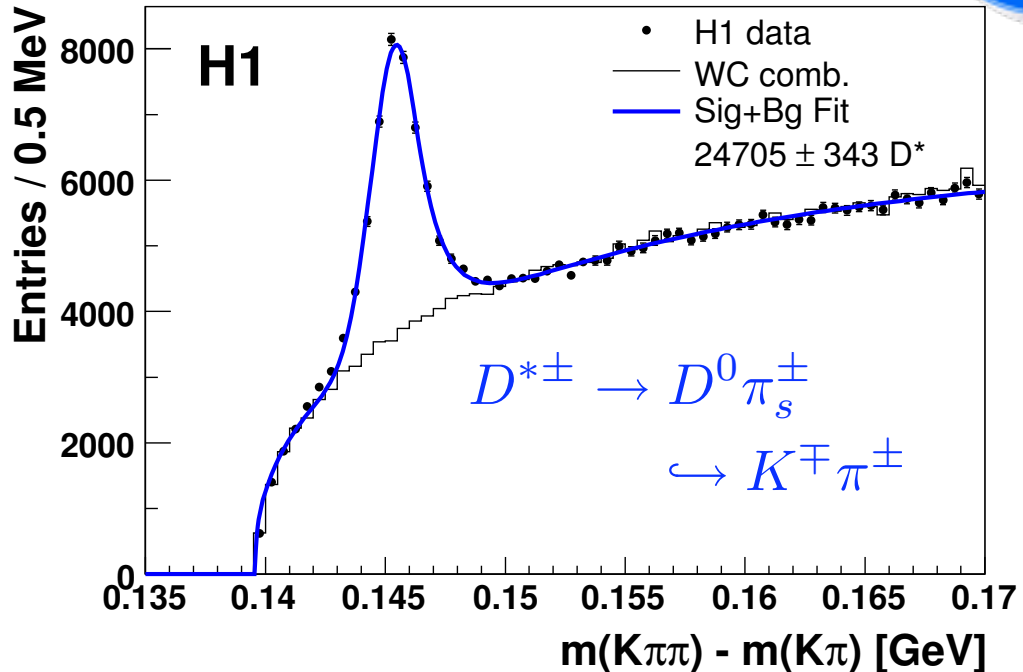


# DIS: D\* Inclusive Cross Section

arXiv:1106.1028



- H1 data set:
  - $\int L dt \sim 348 \text{ pb}^{-1}$
  - $\sim 25000 \text{ D}^*$
- Cross section measured in experimentally visible range
  - $5 < Q^2 < 100 \text{ GeV}^2$
  - $0.02 < y < 0.7$
  - $p_t(\text{D}^*) > 1.25 \text{ GeV}$
  - $|\eta(\text{D}^*)| < 1.8$
- Extended phase space w.r.t previous D\* measurements  $\rightarrow$  extrapolation factor typically 1.5 (up to  $\sim 3$  at highest x)



- Total systematic error: 7.6%
  - Track Reconstruction (3 tracks + vertex): 4.1 %
  - Luminosity 3.2 %
  - Fragmentation 2.6%

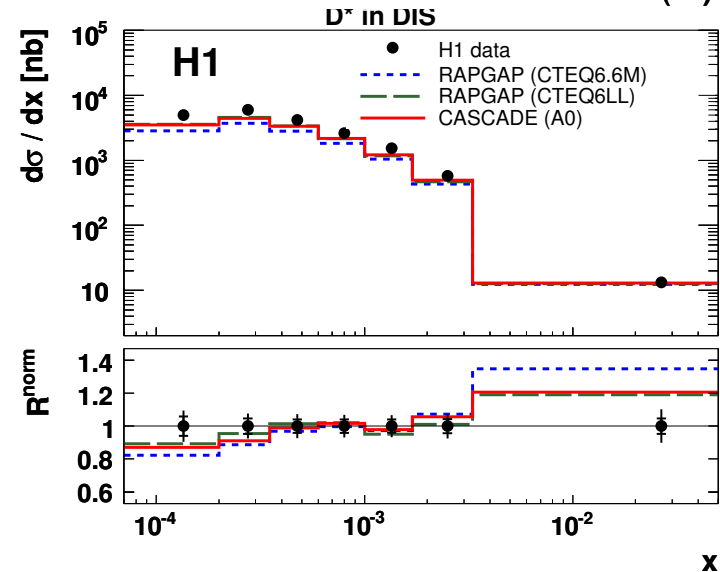
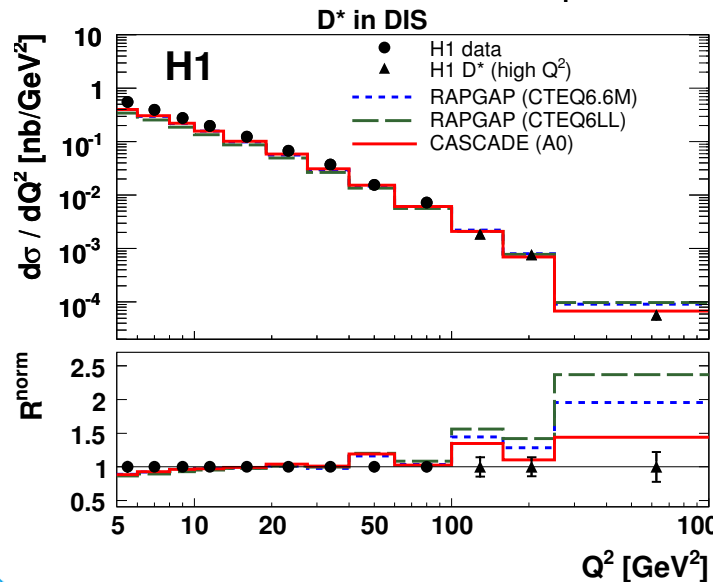
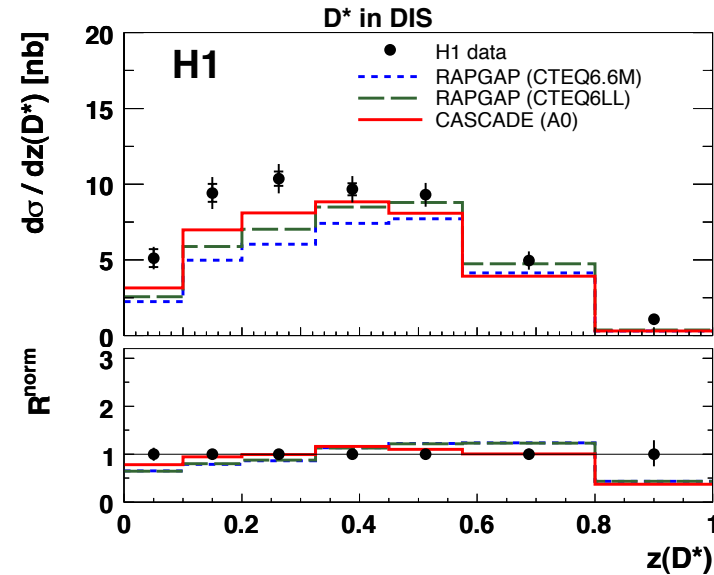
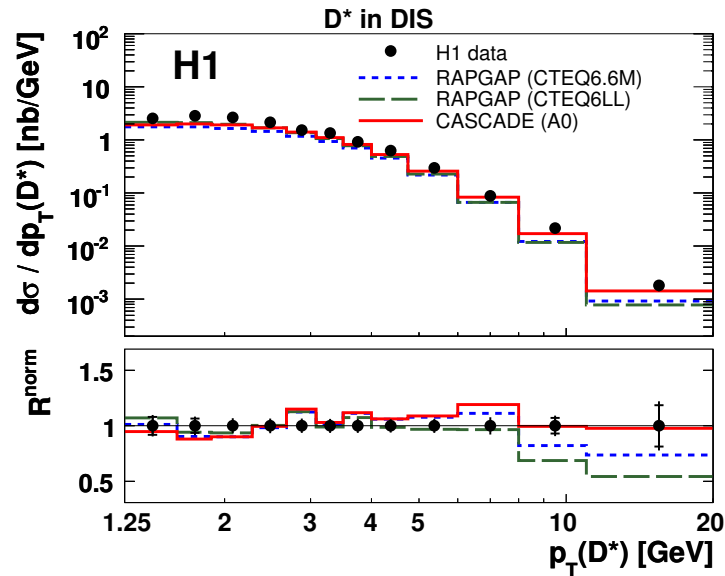
$$\sigma_{\text{vis}}(ep \rightarrow eD^{*\pm}X) = 6.44 \pm 0.09 \text{ (stat.)} \pm 0.49 \text{ (syst.) nb} .$$

$$\text{NLO (HVQDIS using CT10f3): } 5.98^{+1.10}_{-0.88} \text{ nb}$$



# DIS: D\* Inclusive Cross Section

arXiv:1106.1028

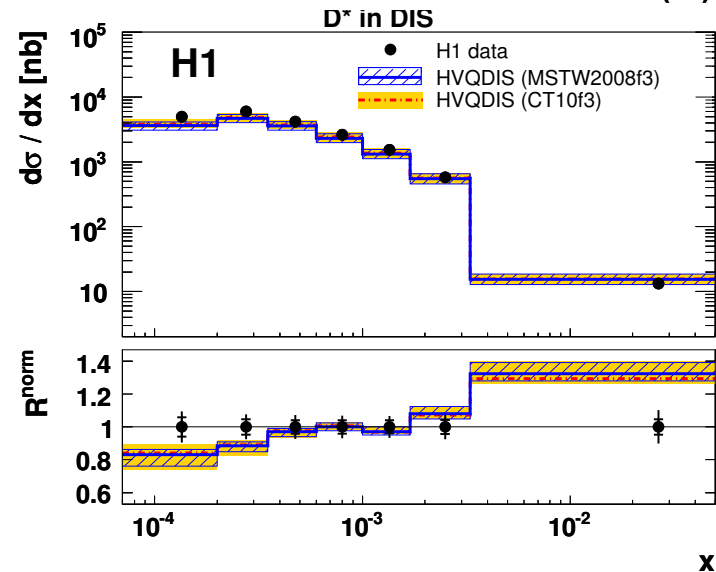
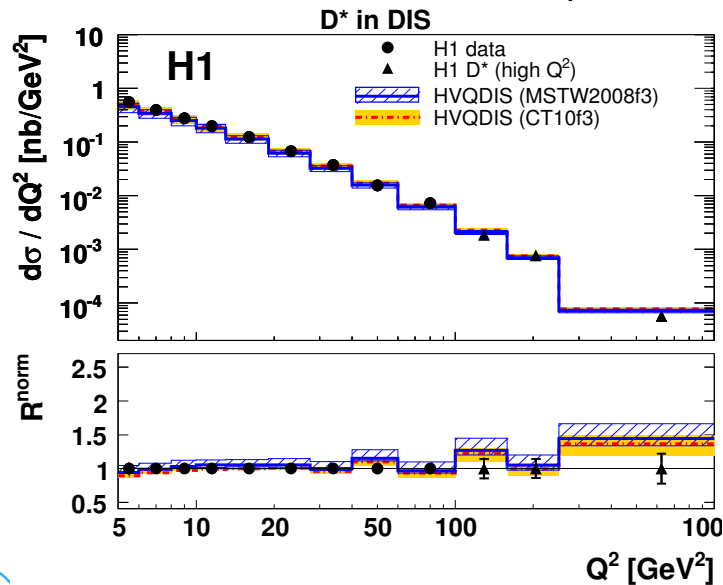
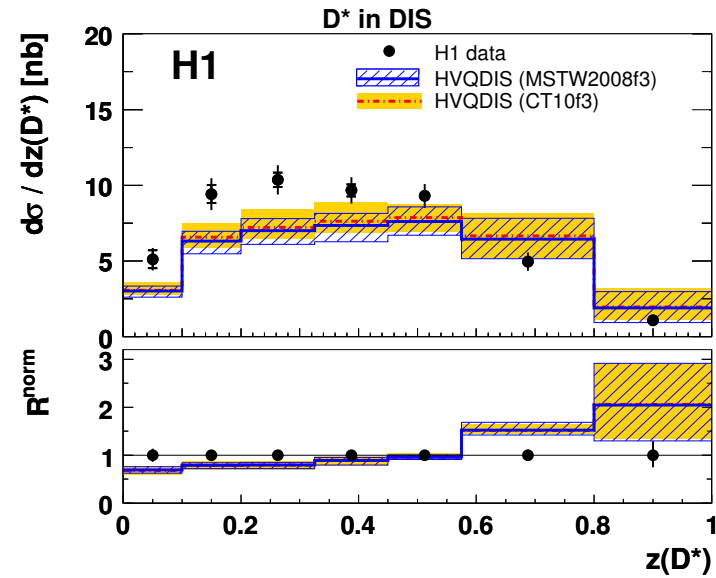
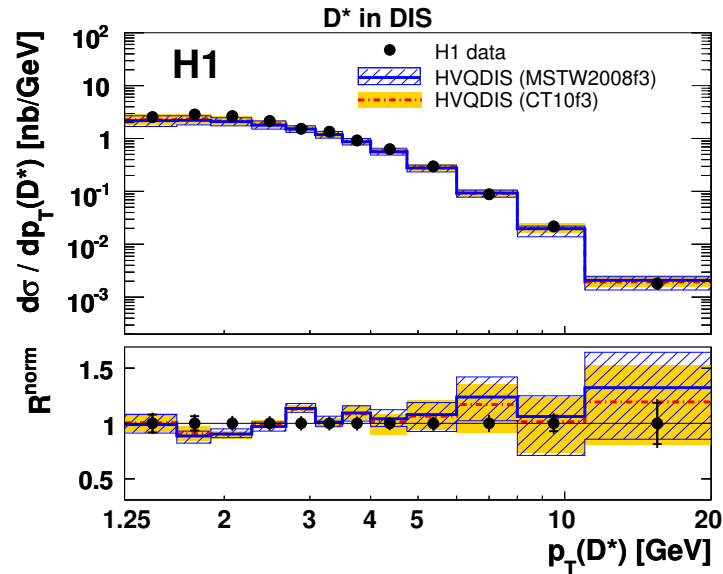


MC describe data rather well



# DIS: D\* Inclusive Cross Section

arXiv:1106.1028



Experimental uncertainties generally smaller than scale uncertainties (NLO)

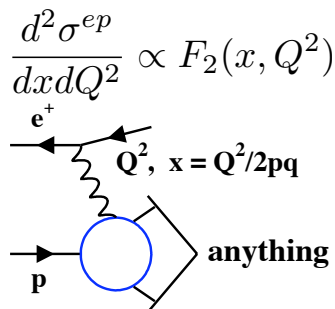


# Charm Structure Function $F_2^{c\bar{c}}$

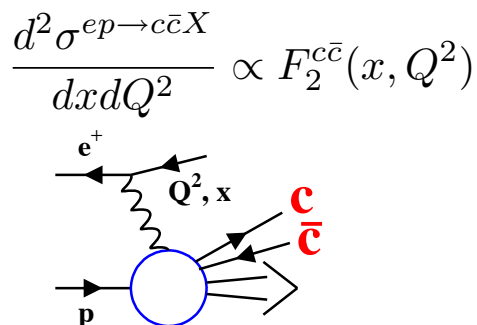
arXiv:1106.1028



- In analogy to inclusive structure function



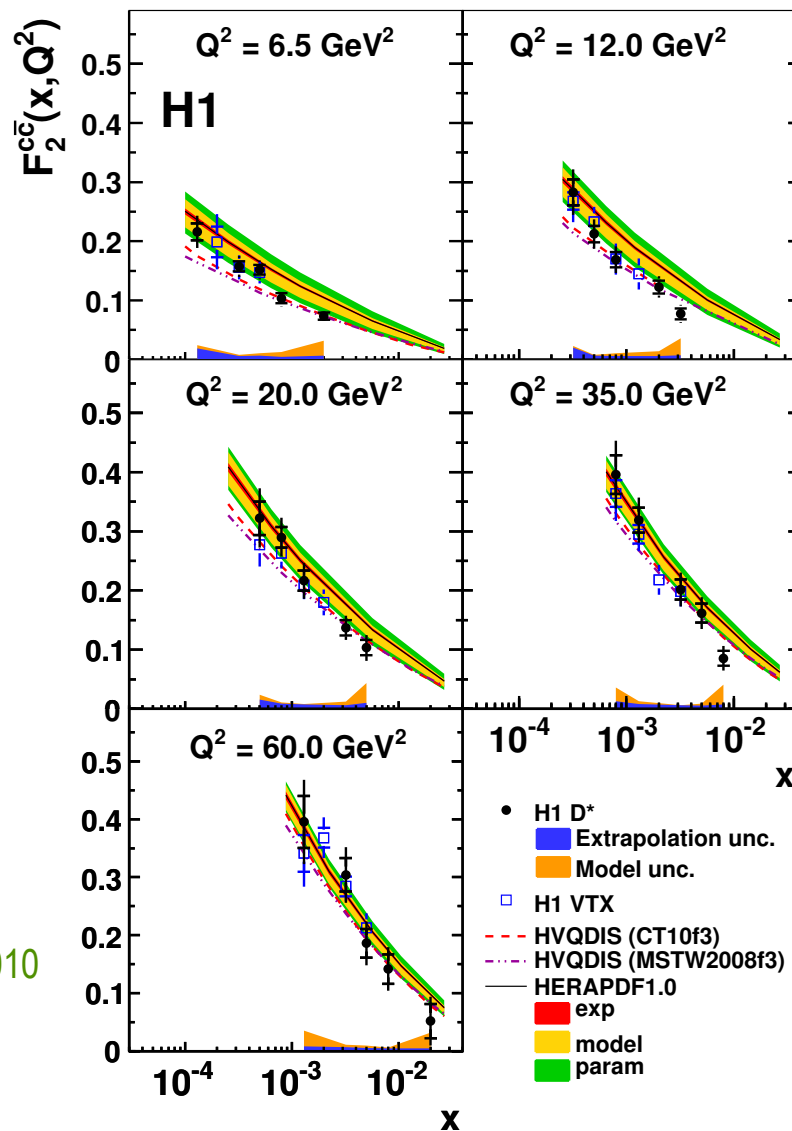
- define charm structure function



- H1 results:

- inclusive lifetime tag [Phys.Lett.B686:91-100,2010](#)

- D\* reconstruction [arXiv:1106.1028](#)

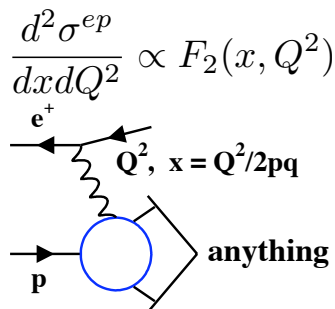


# Charm Structure Function $F_2^{c\bar{c}}$

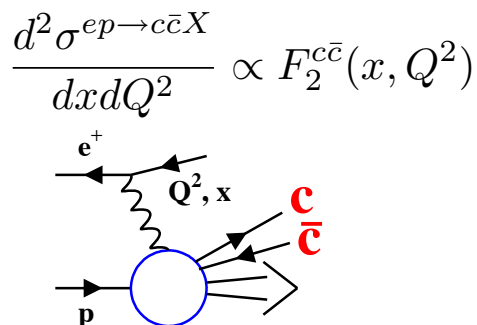
arXiv:1106.1028



- In analogy to inclusive structure function

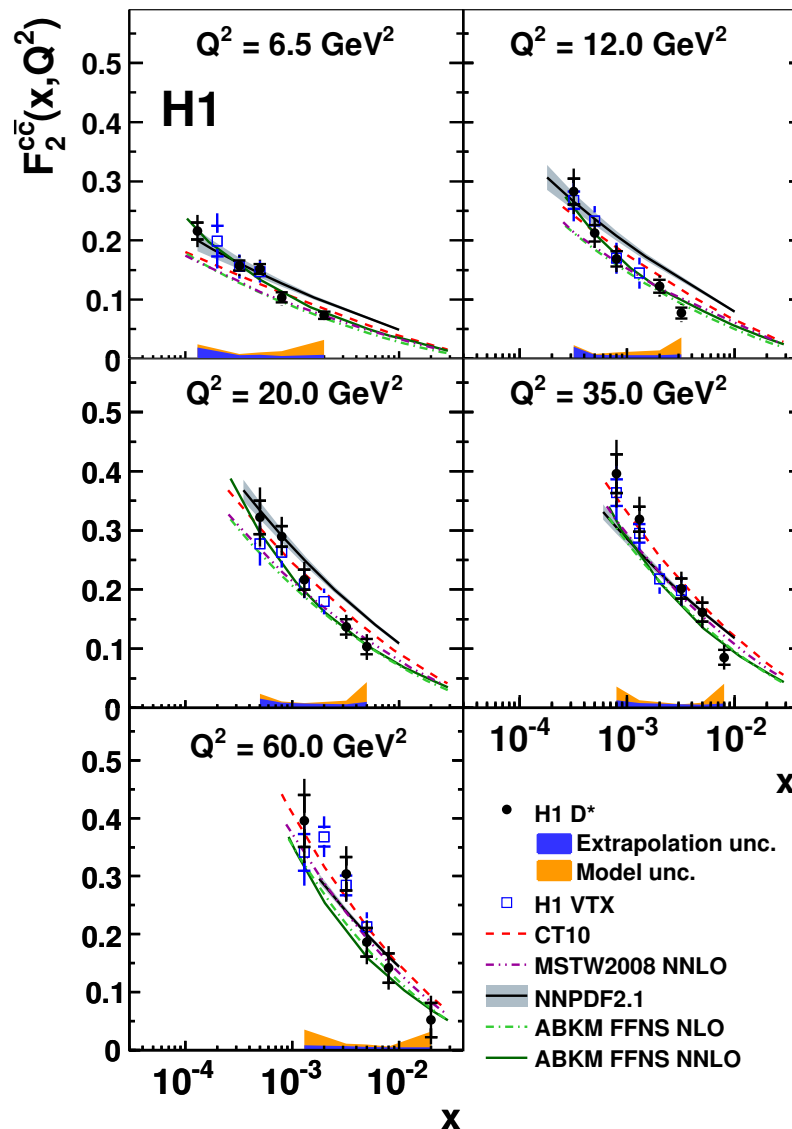


- define charm structure function

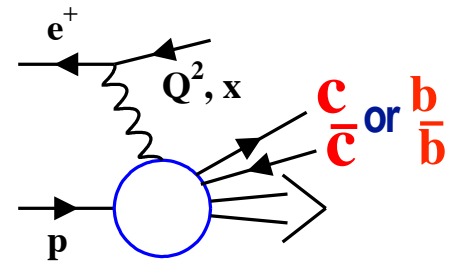


- H1 results:

- inclusive lifetime tag: somewhat smaller extrapolation than  $D^*$
- $D^*$  reconstruction: larger reach in  $x$ , more precise than incl. lifetime tag

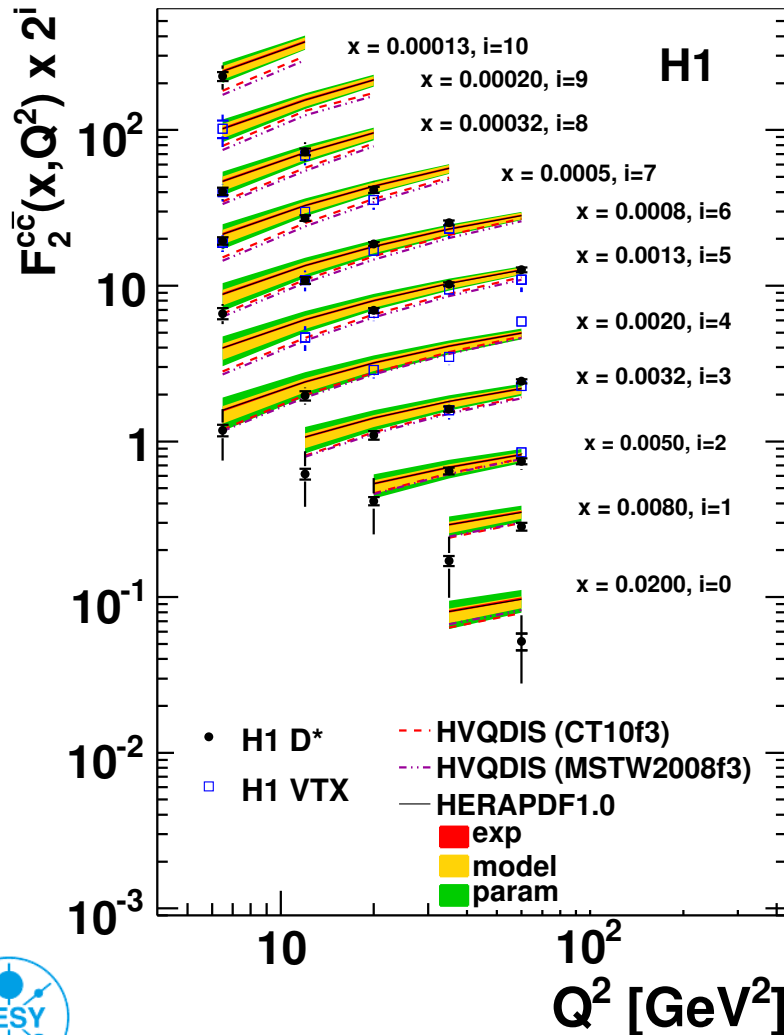


# Charm & Beauty Structure Functions



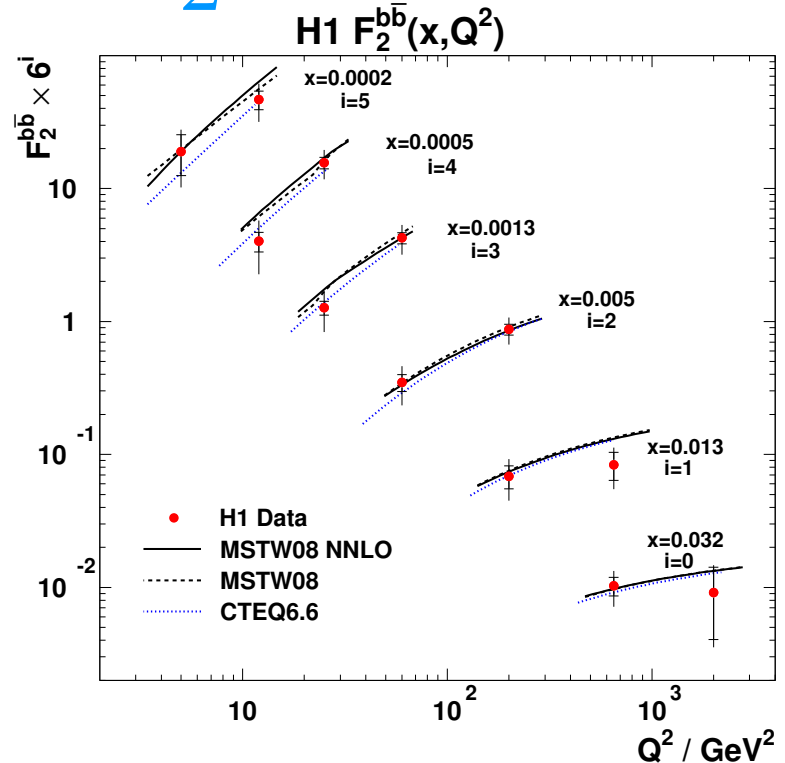
$F_2^{c\bar{c}}$

arXiv:1106.1028



$F_2^{b\bar{b}}$

Phys.Lett.B686:91-100,2010



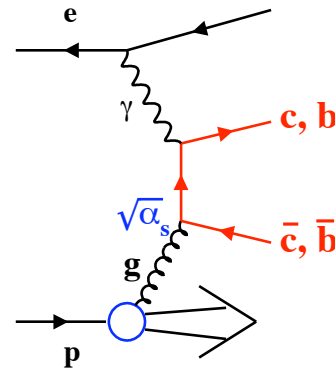
- Good agreement with predictions using gluon distribution from scaling violations
- Charm data are in precision regime constraining gluon density  $g(x)$



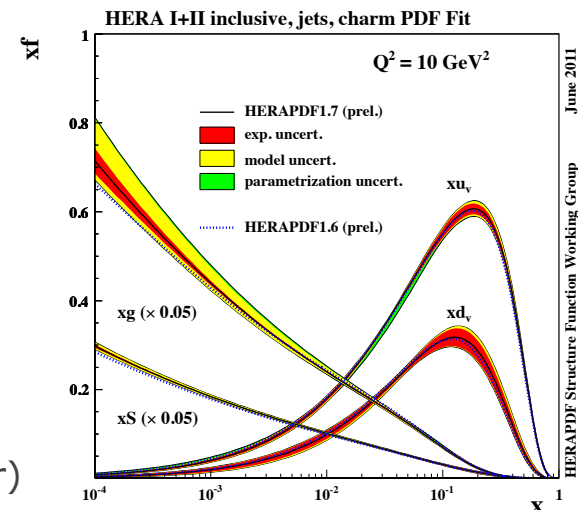
# Conclusions



- New results from H1
  - $D^* + \text{jets}$  in photoproduction
  - $b \rightarrow eX$  at threshold
  - Inclusive  $D^*$  in DIS and  $F_2^{\text{cc}}$
- complementing a large number of already existing results on Heavy Quark Production at HERA
- HQ measurements at HERA provide valuable precision input to
  - understanding of perturbative QCD calculations (esp. in the regime where  $m_b, m_c \sim p_T \sim Q$ )
  - improving PDF



e.g. HERAPDF 1.7  
cf. talk 994 (A.Cooper Sarkar)



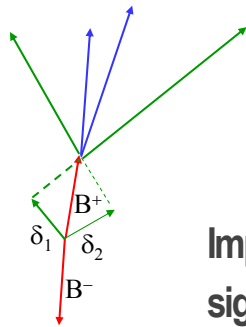
# Backup

# DIS: c or b + jets

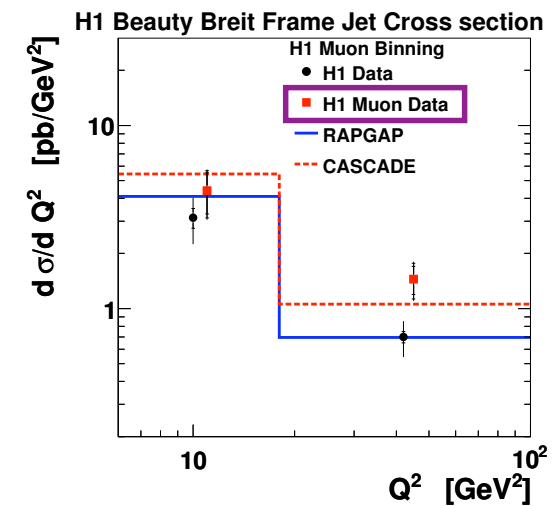
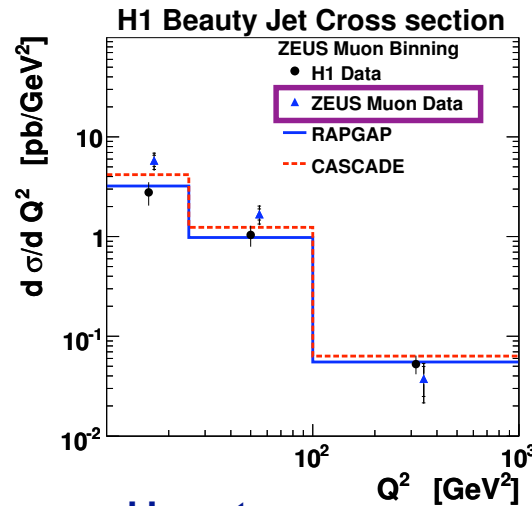
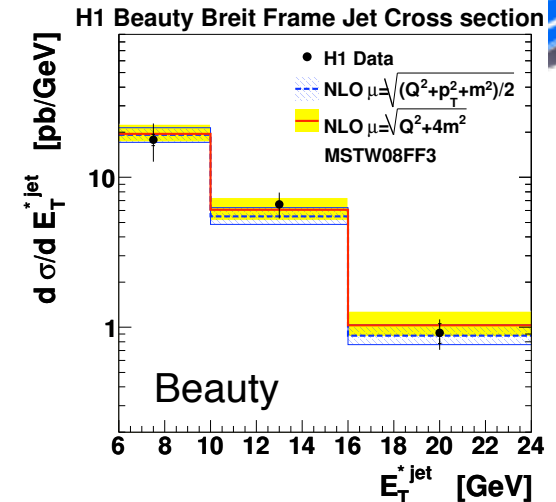
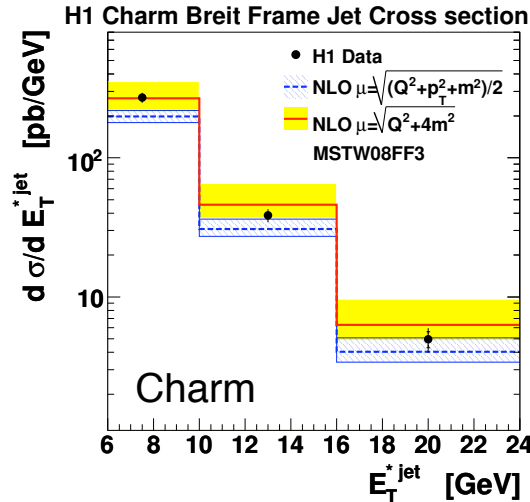
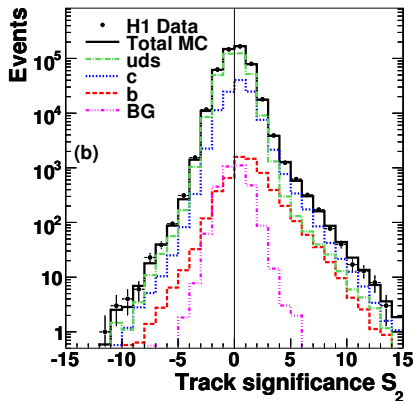
Eur.Phys.J.C71:1509,2011



## Inclusive Lifetime tag



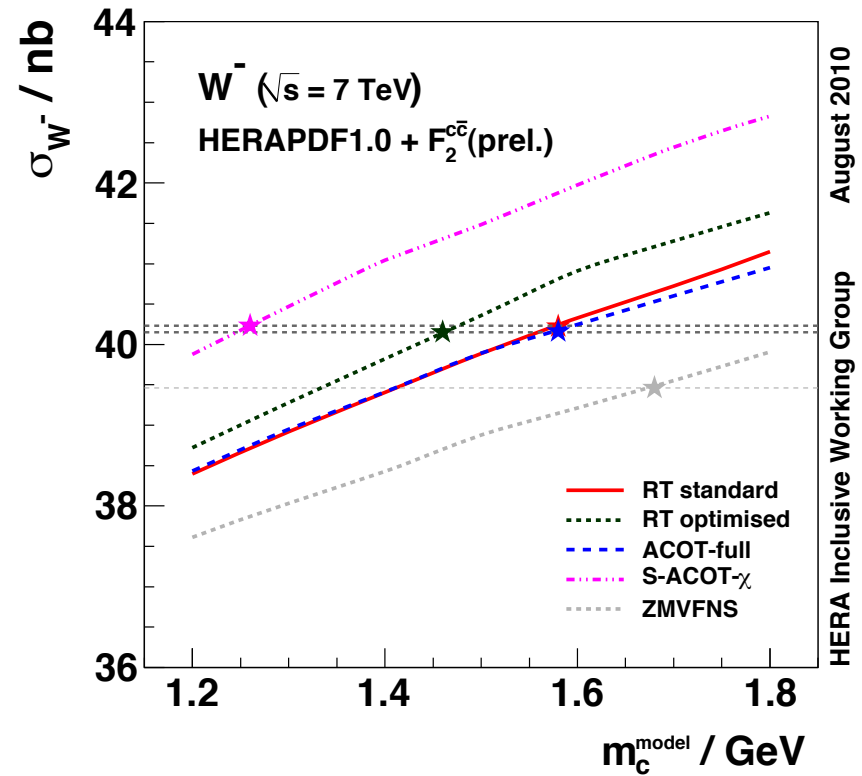
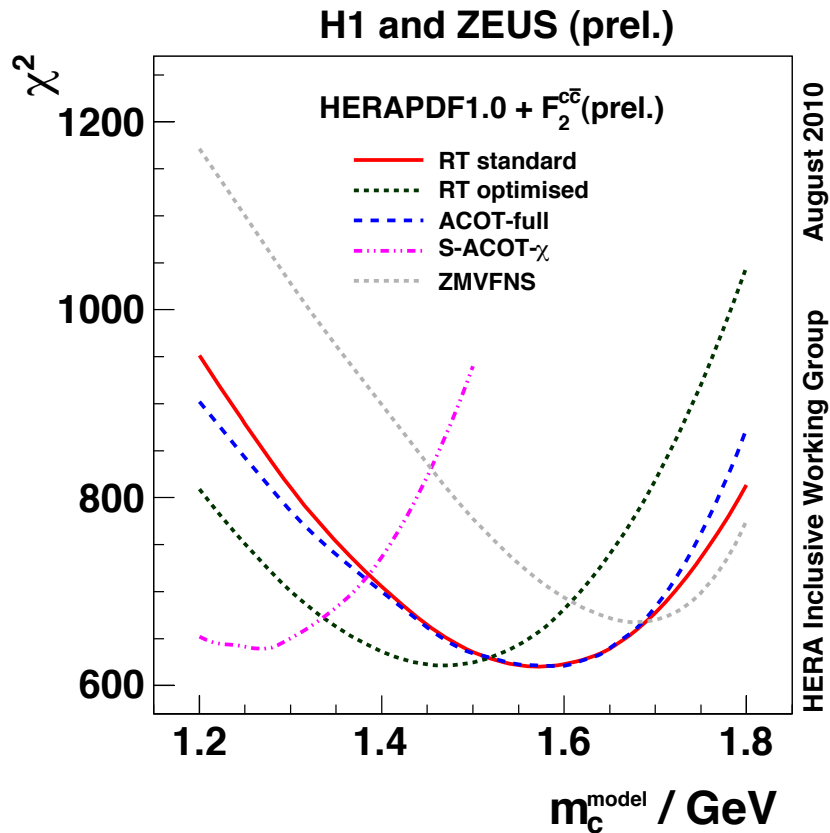
Impact parameter  
significance



- Simultaneous measurement of charm and beauty
- No hadron reconstruction or lepton tag → larger statistics → reach to higher  $p_t$



# Charm Mass Scan



[https://www.desy.de/h1zeus/combined\\_results/index.php?do=heavy\\_flavours](https://www.desy.de/h1zeus/combined_results/index.php?do=heavy_flavours)

