

# Charm and beauty in deep inelastic scattering

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DESY

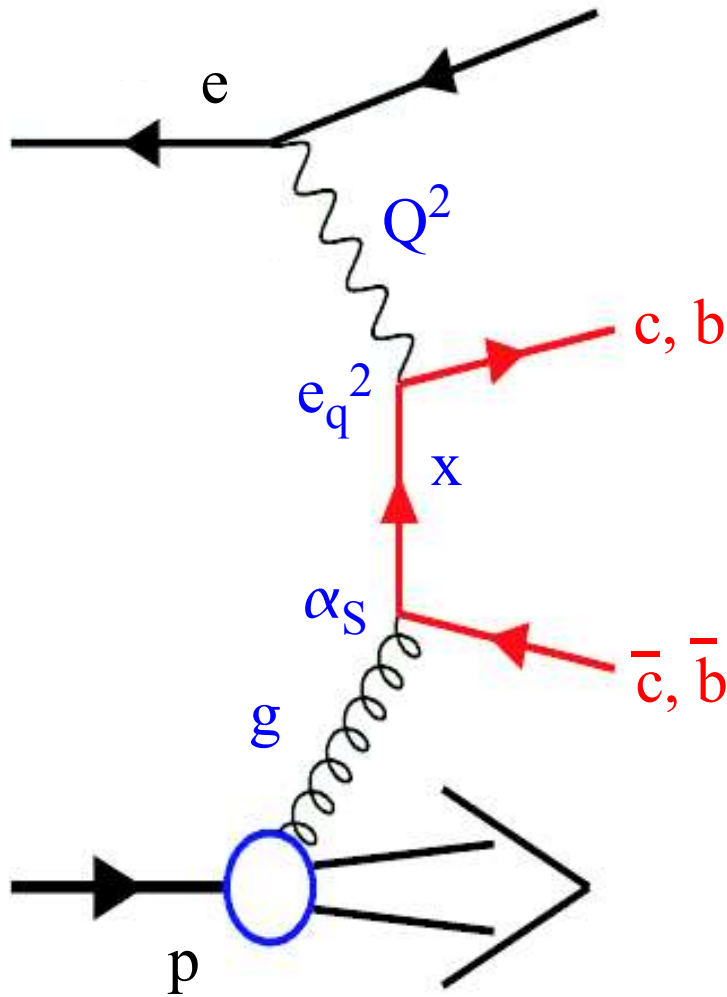
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- Boson-gluon fusion.
- Experimental methods:
  - $D^*$
  - muons
  - impact parameter.
- Cross sections.
- $F_2^c, F_2^b$ .
- Outlook.

# Heavy flavour production in ep collisions

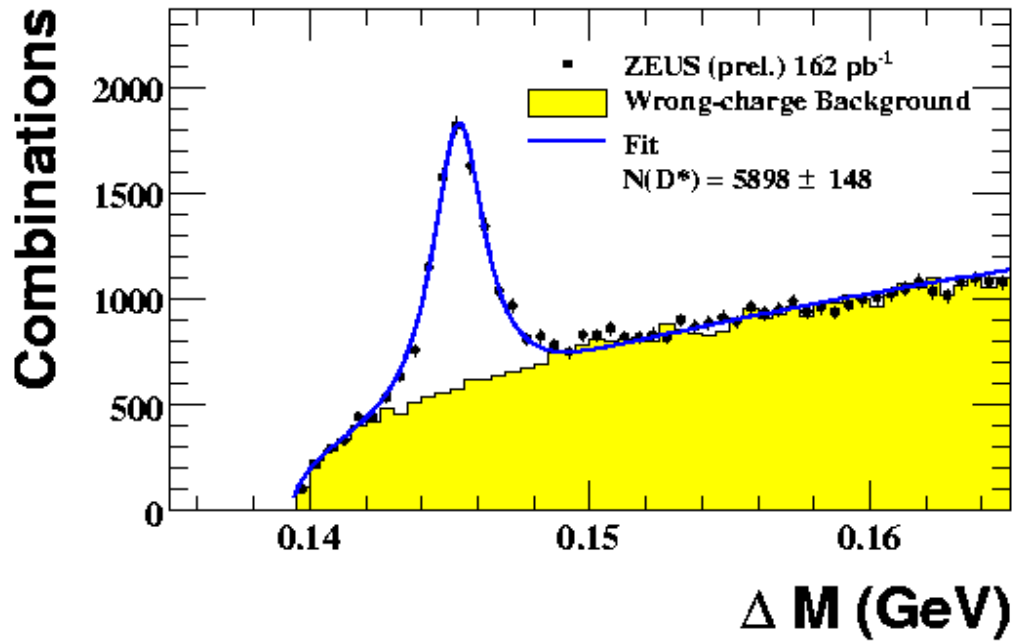
Dominant process:  
Boson-Gluon fusion



- Driven by the gluon density.
- Test of perturbative QCD in next-to-leading order of  $\alpha_S$ .
- Multiple hard scales:  $M_q, p_t, Q^2$ .
- Mass treatment:
  - massive:  $Q^2 \sim M^2$
  - massless:  $Q^2 \gg 4 M^2$ .
  - variable: interpolate.

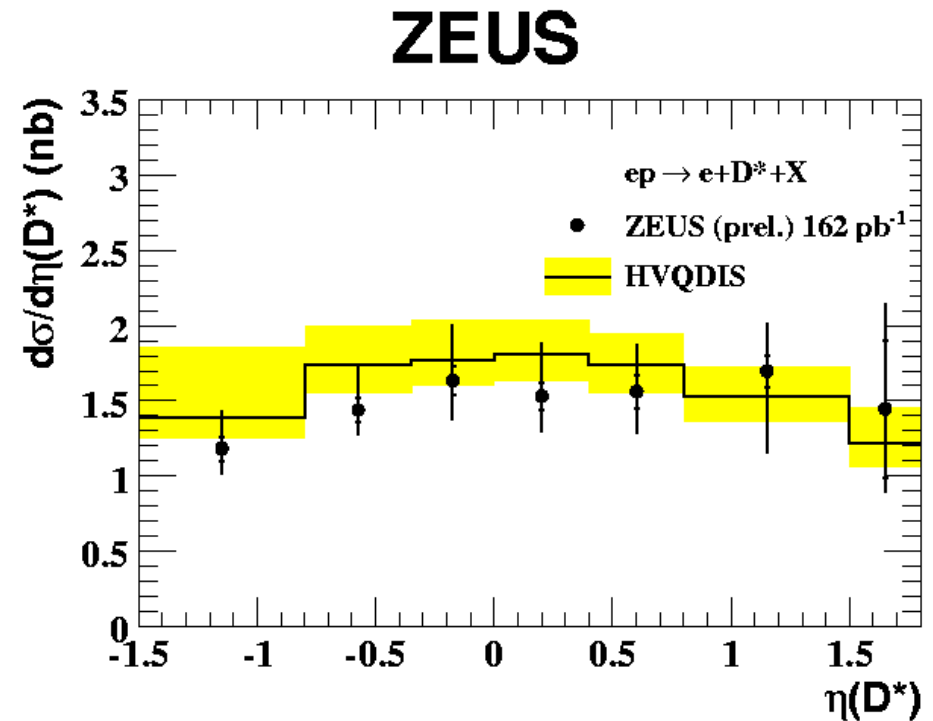
$$\frac{d^2 \sigma^q}{dx dQ^2} = \frac{2 \pi \alpha^2 (1 + (1 - y)^2)}{x Q^4} F_2^q - y^2 F_L^q$$

# D\* production in DIS



- $D^* \rightarrow D^0 \pi_S$
- $D^0 \rightarrow K\pi$
- $5 < Q^2 < 1000 \text{ GeV}^2$ .

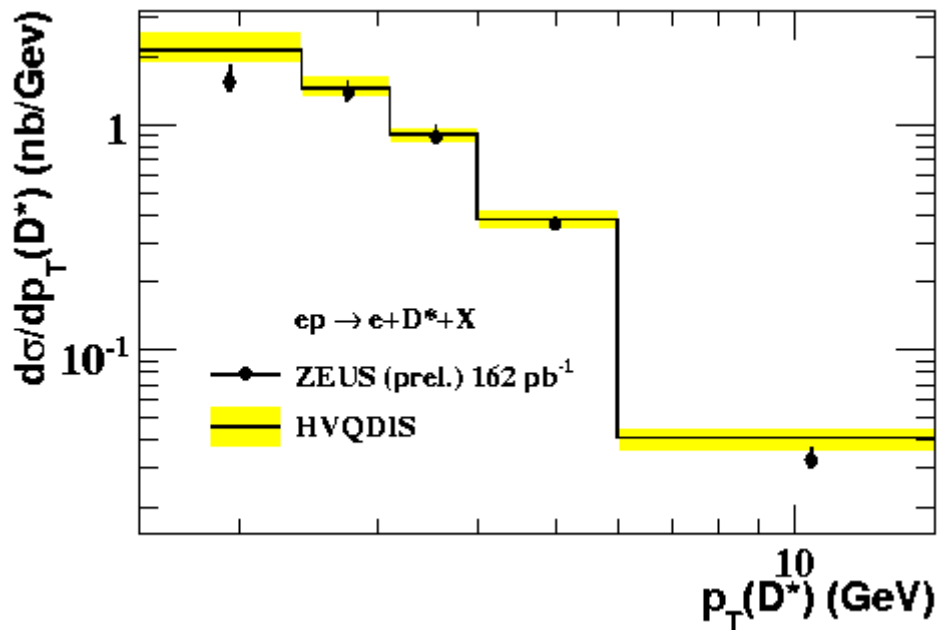
Measured in the central rapidity region:



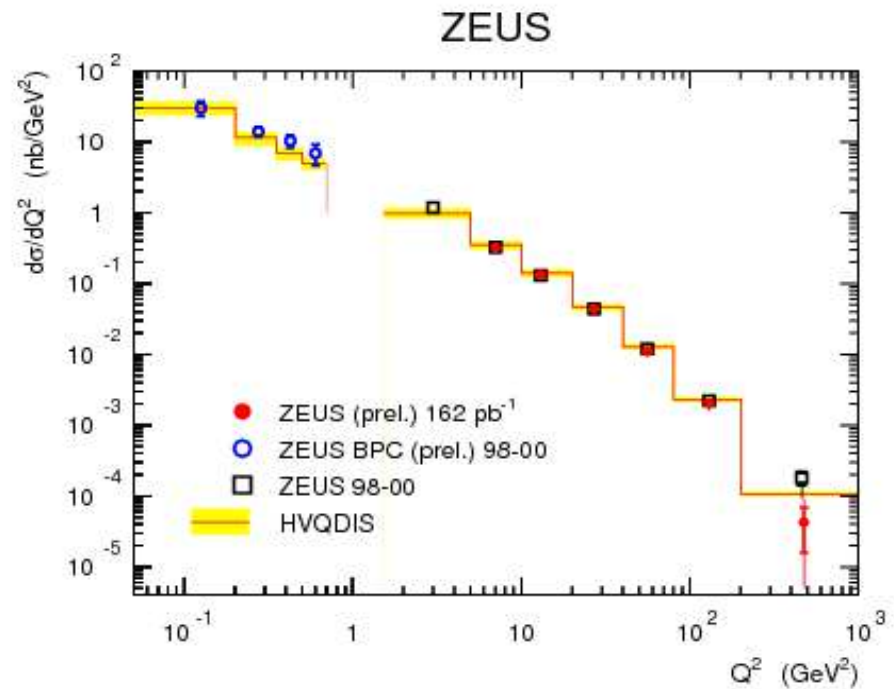
$\pm 15\%$  uncertainty in NLO calculation.

# D\* production in DIS

$p_T$  spectrum above 1.5 GeV:



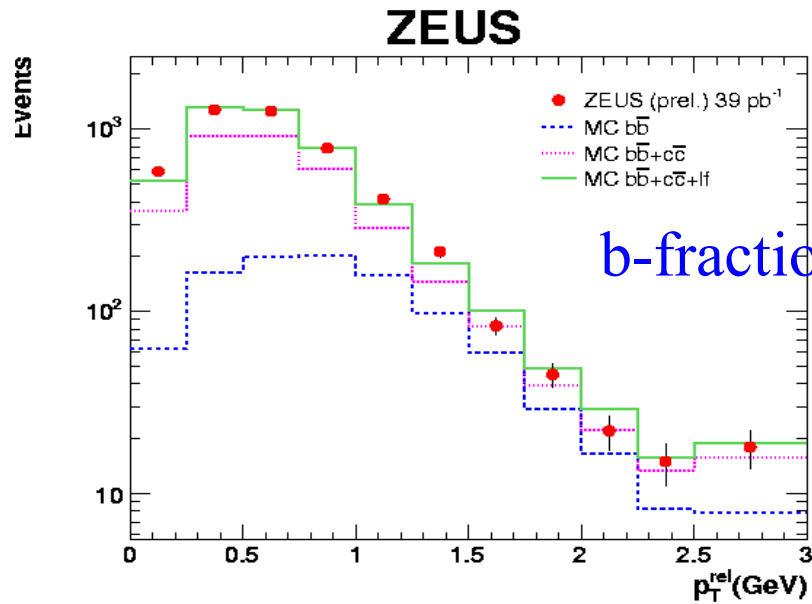
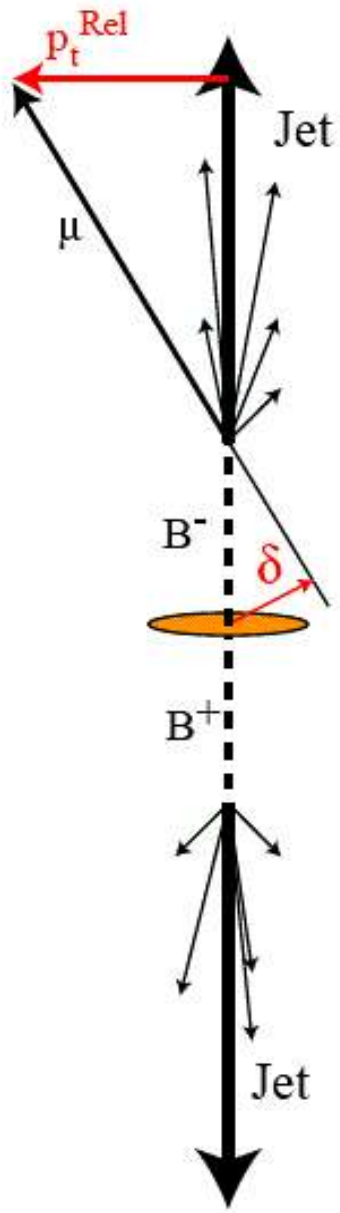
$Q^2$  spectrum:



Extrapolation to full phase space introduces model dependence.

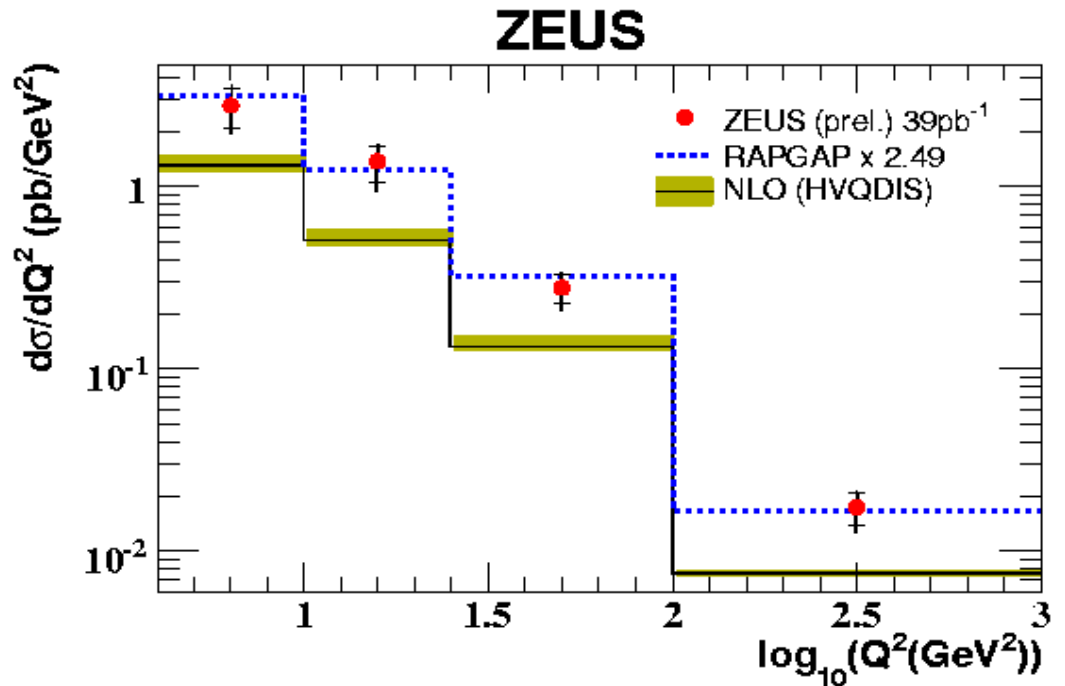
- Cross section well described by NLO pQCD over 5-6 orders of magnitude.

# B-tagging with muons in DIS



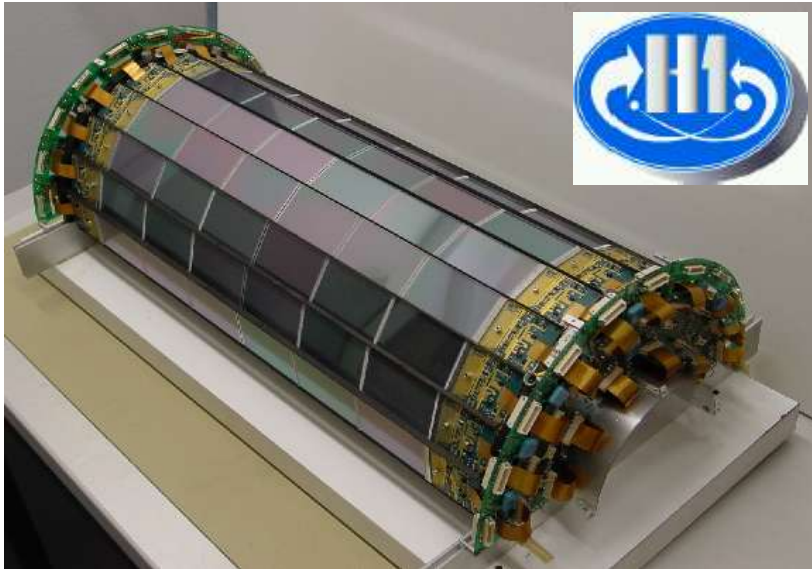
Visible cross section:

LO and NLO describe shape.  
NLO is a factor  $2.4^{+0.4}_{-0.6}$  below the data.

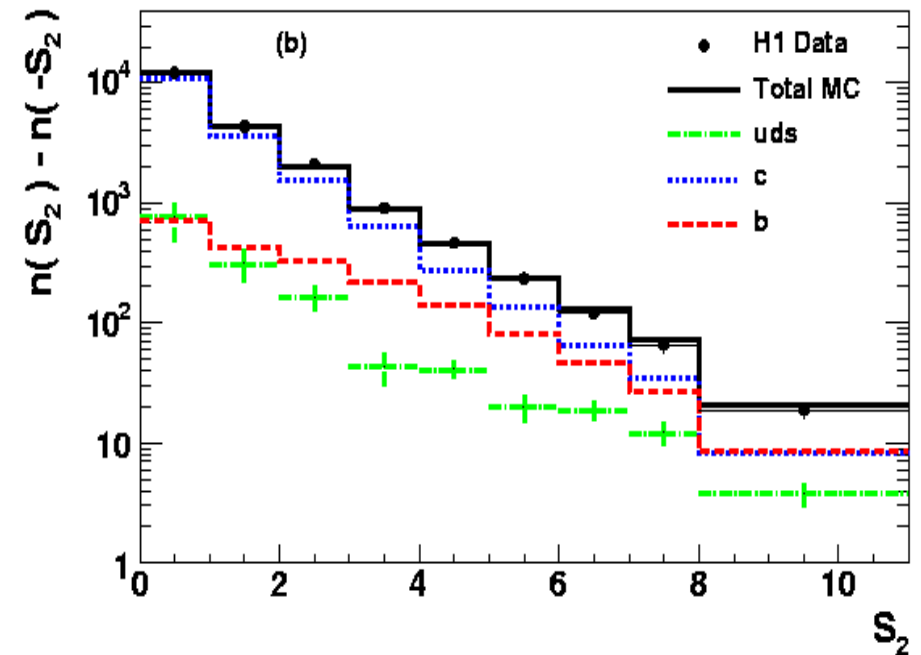
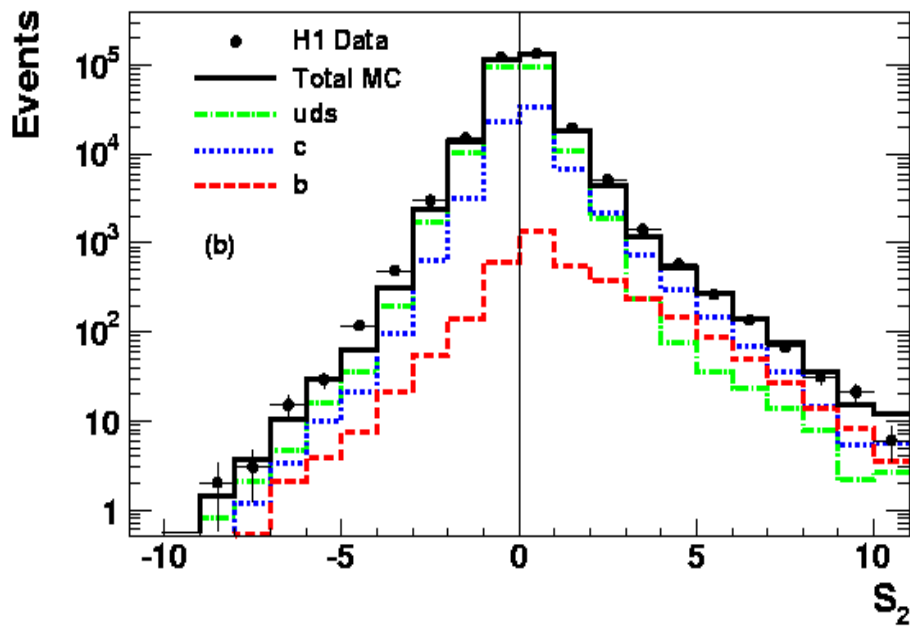




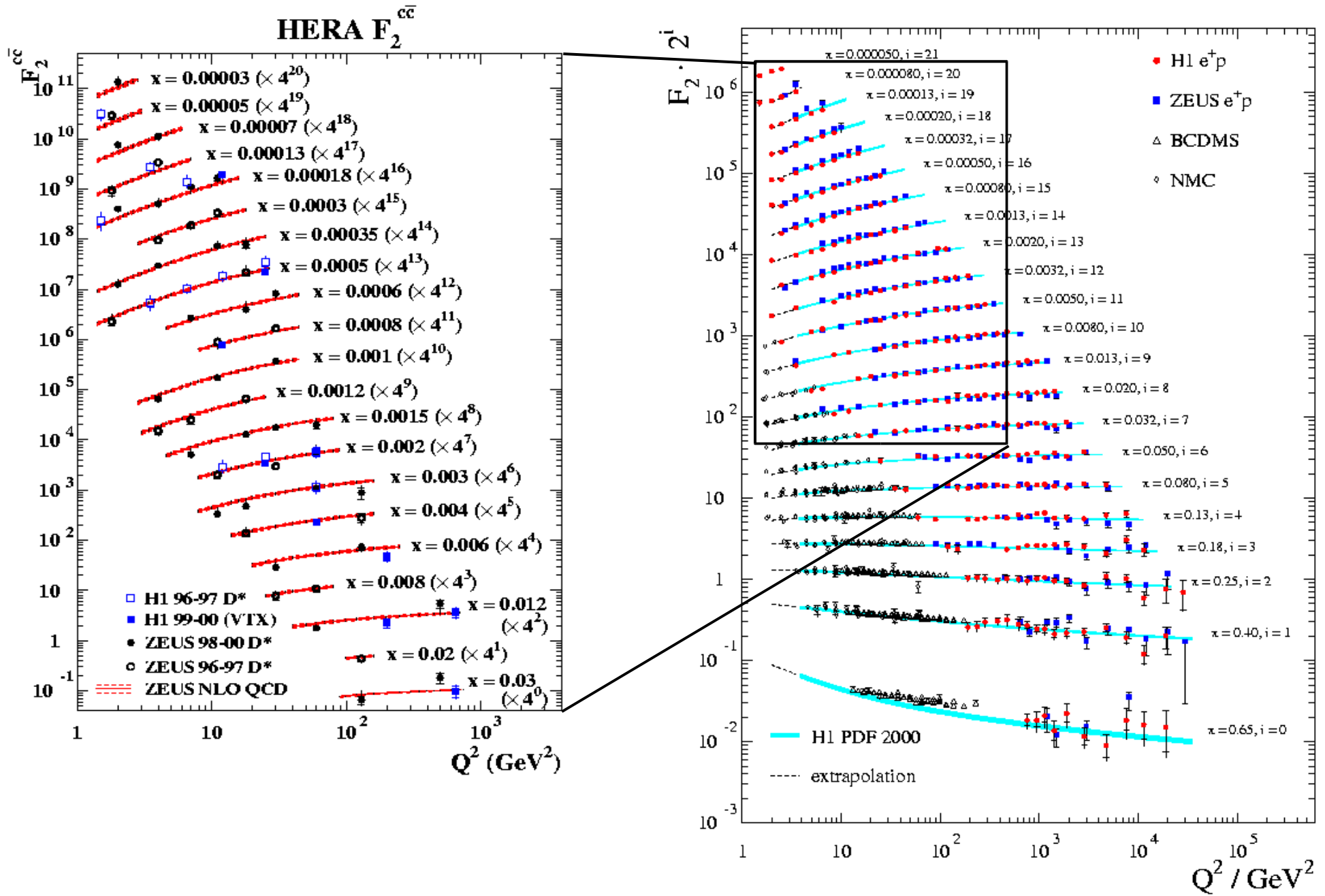
# Inclusive impact parameter tagging



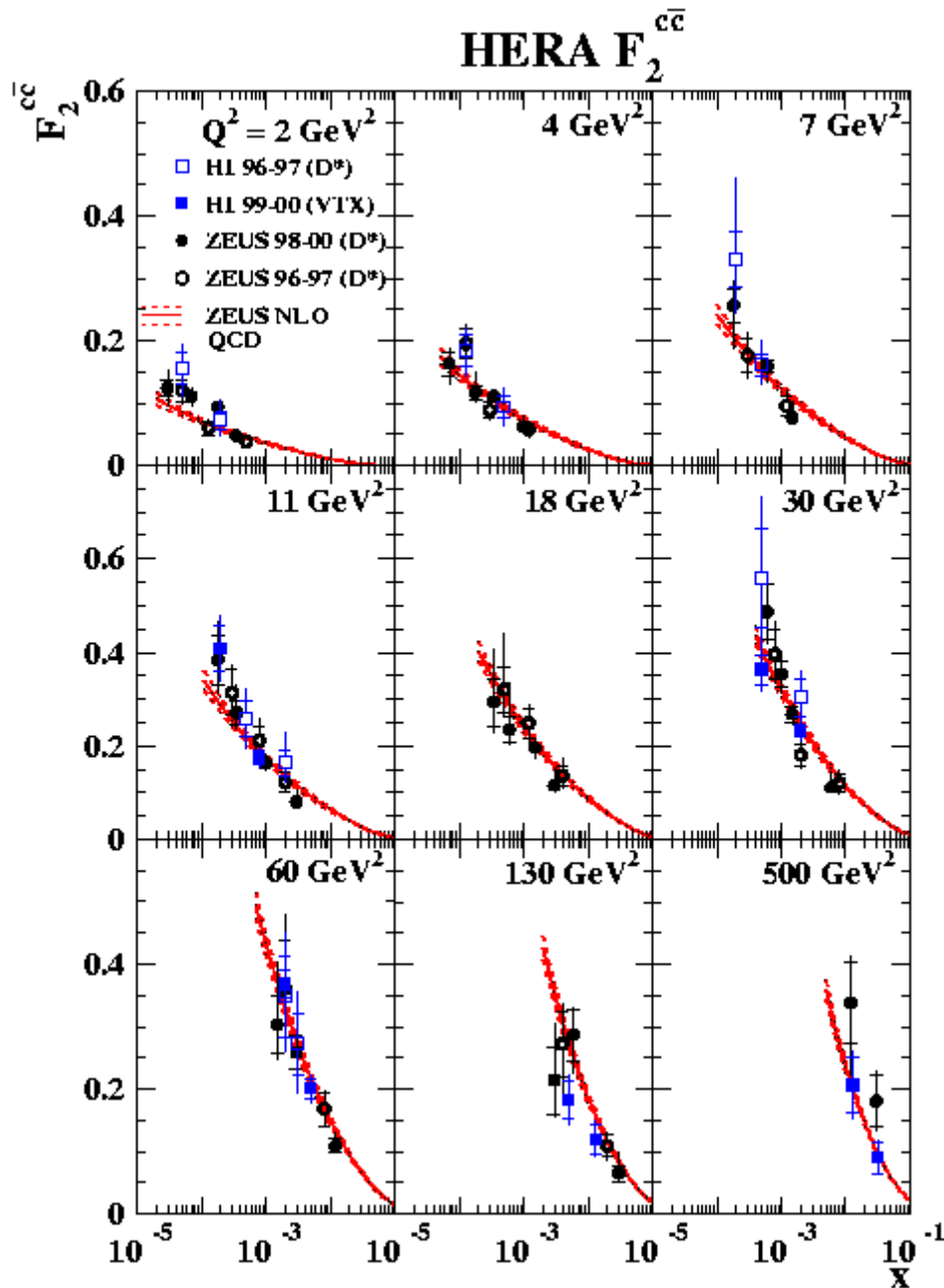
- Silicon vertex detector.
- Signed impact parameter.
- Rank tracks by significance.
- Subtract negative part.
- Extract **c** and **b** fractions.
- Small phase space extrapolation.



# F<sub>2</sub><sup>c</sup> and F<sub>2</sub>



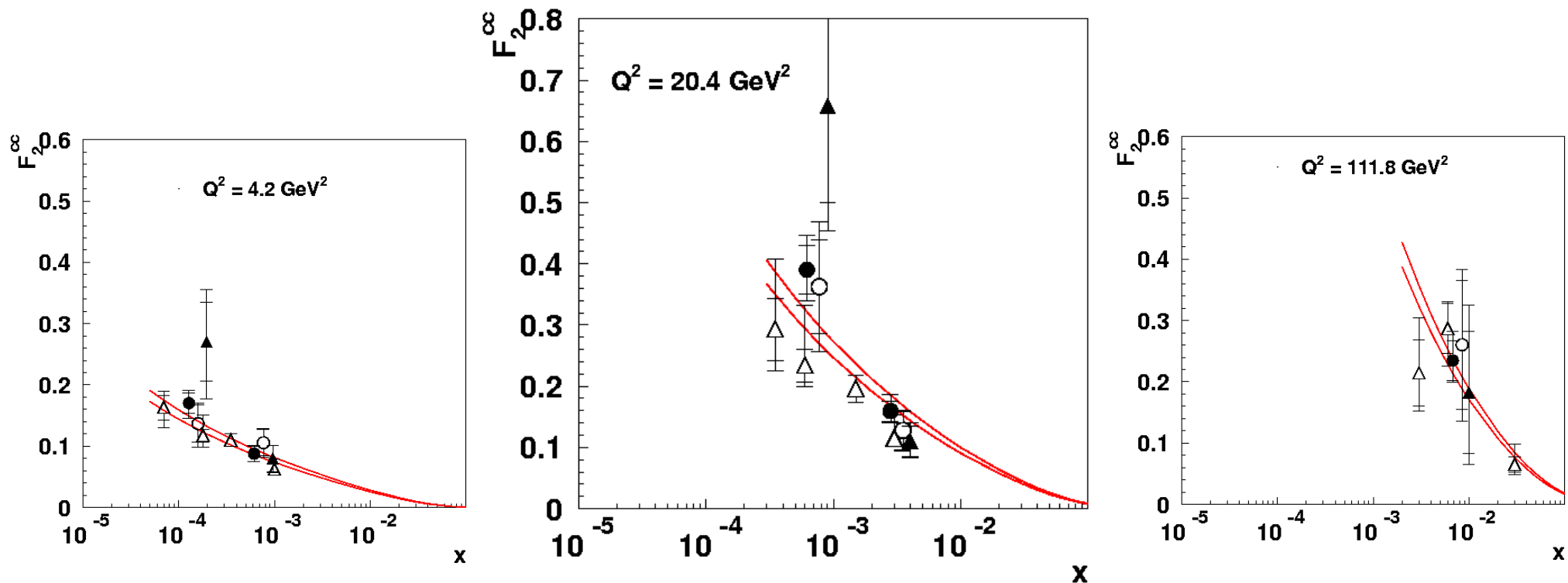
# $F_2^c$ vs $x$



- Data precision reaches 7%.
- Good agreement between  $D^*$  and impact parameter methods.
- Strong rise towards low  $x$  driven by gluon density in the proton.
- Well described by NLO QCD fit.



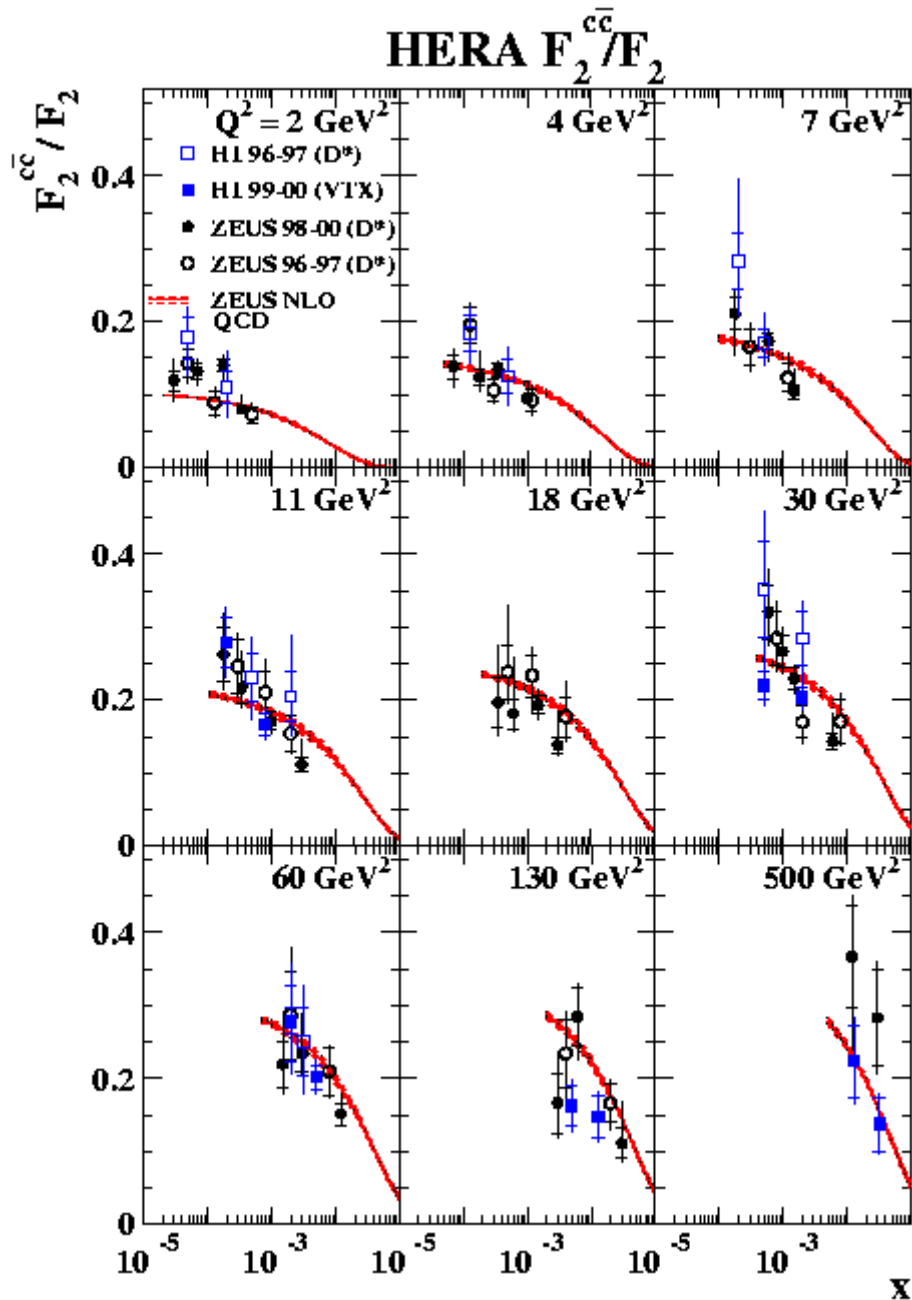
# $F_2^c$ from $D^0$ , $D_s$ , $D^+$



- ZEUS (prel.) 98-00  $D^0$
- ▲ ZEUS (prel.) 98-00  $D_s$
- ZEUS (prel.) 99-00  $D^+$
- △ ZEUS 98-00  $D^*$
- NLO QCD

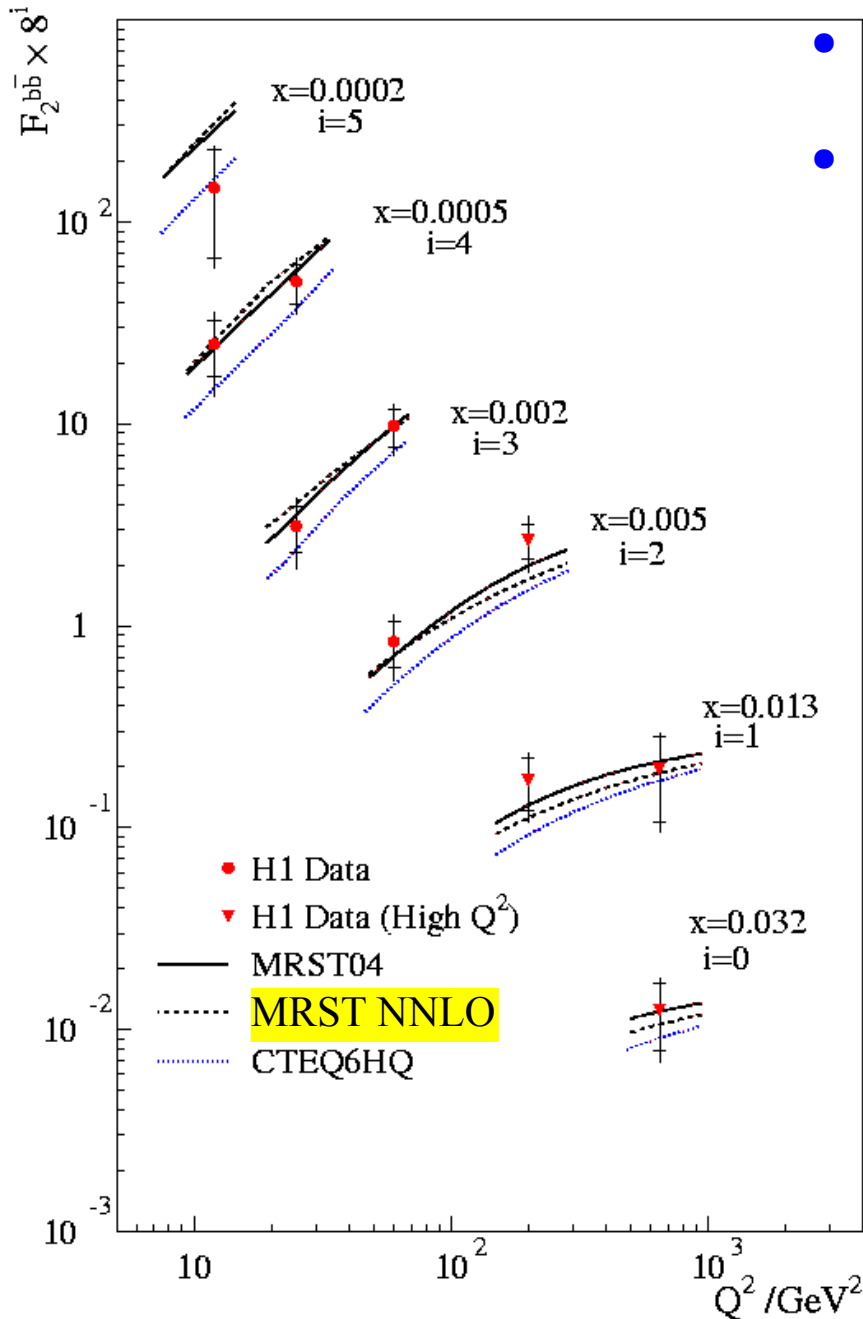
- Good agreement with  $F_2^c$  from  $D^*$ .
- High statistics in direct  $D^0$  channel.

# $F_2^c / F_2$ vs x



- Charm contribution to  $F_2$  rising towards 30% at low x and medium  $Q^2$ .
- Flavour-democratic limit would be  $4/11 = 36\%$ .

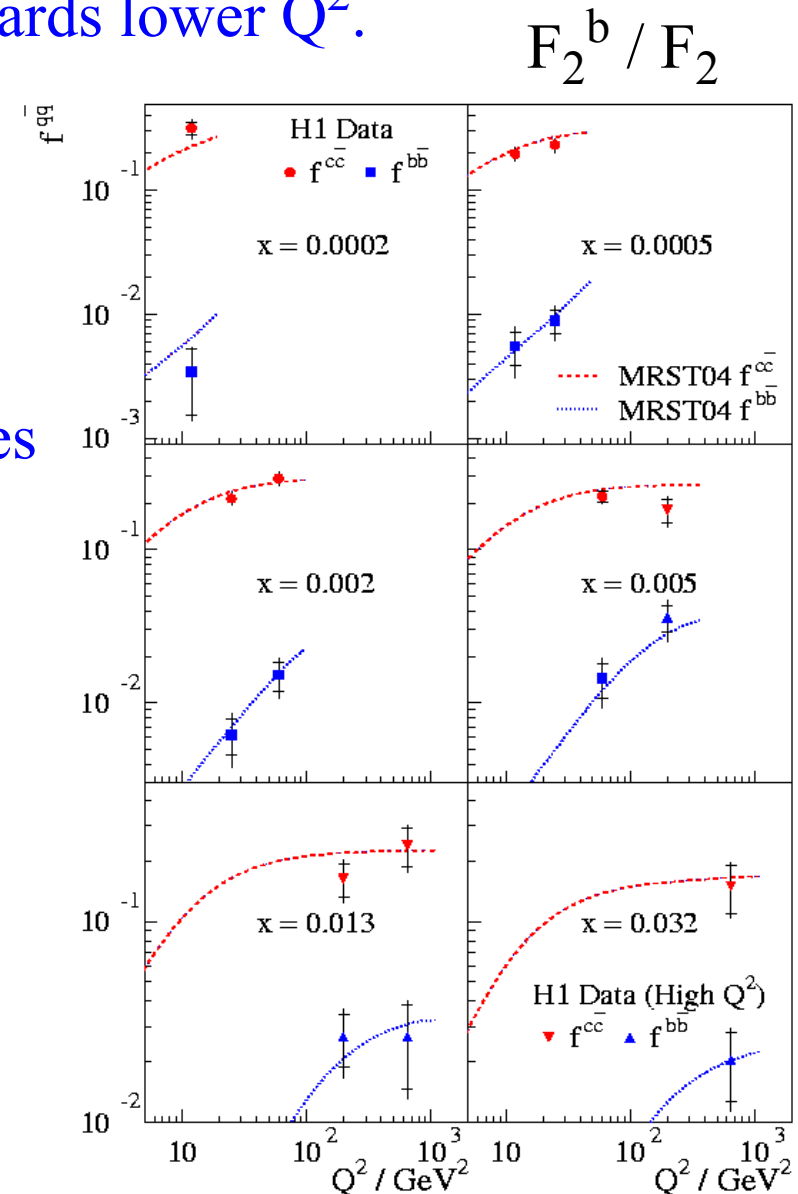
# First measurements of $F_2^b$



- Impact parameter method.
- Extended towards lower  $Q^2$ .

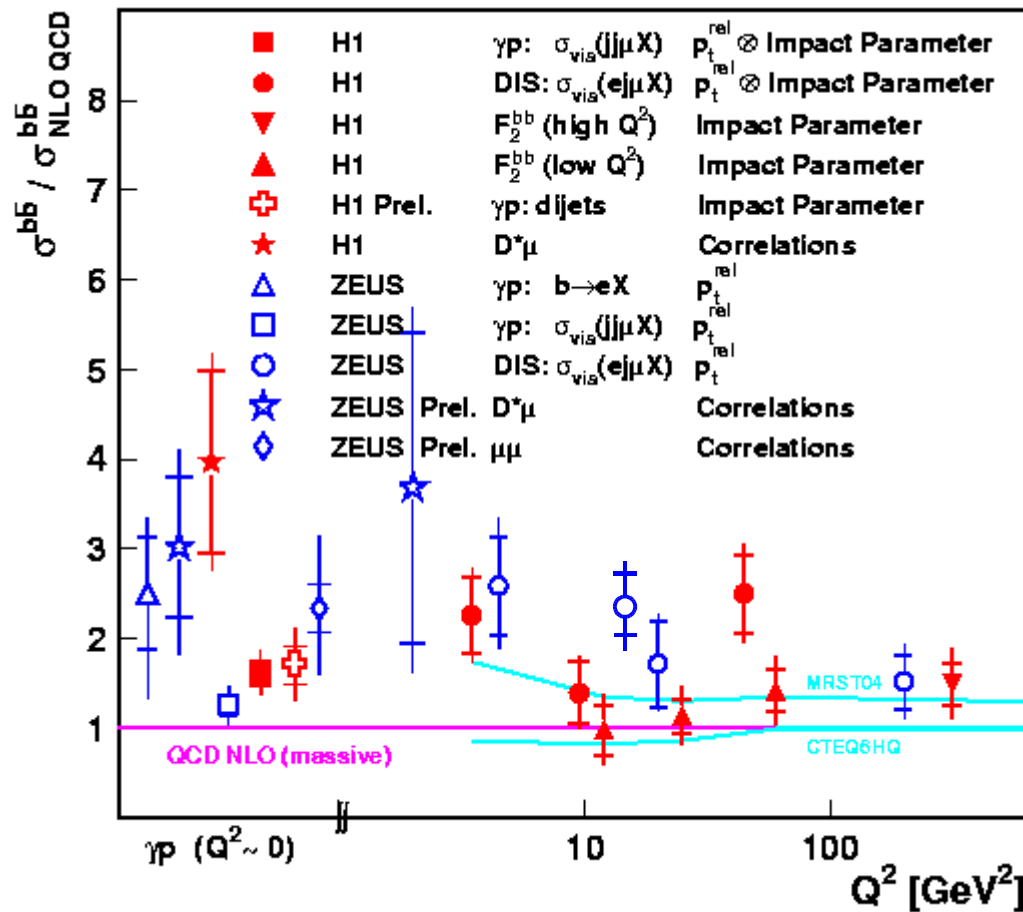
Beauty contributes up to 3%.

First NNLO calculation.



# b cross section vs Q<sup>2</sup>

Comparison to NLO QCD: FMNR ( $\gamma p$ ), HVQDIS (DIS):



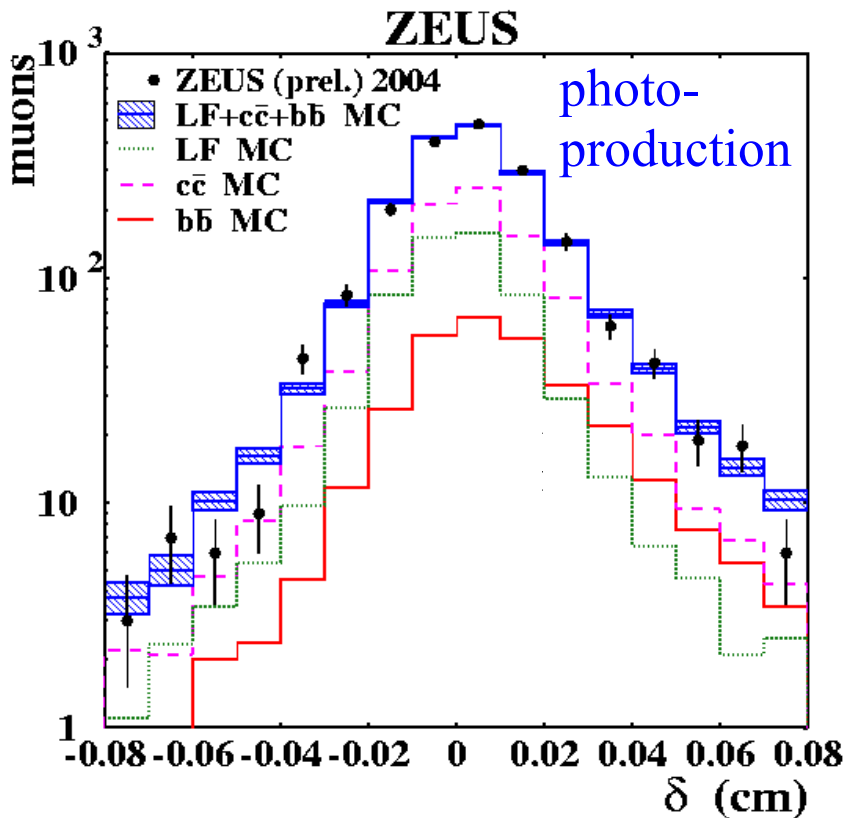
- NLO QCD tends to be below the data.
- Up to factor 1.8 between different NLO calculations.
- More precise measurements will come.
- NNLO QCD calculations are underway.

# Outlook

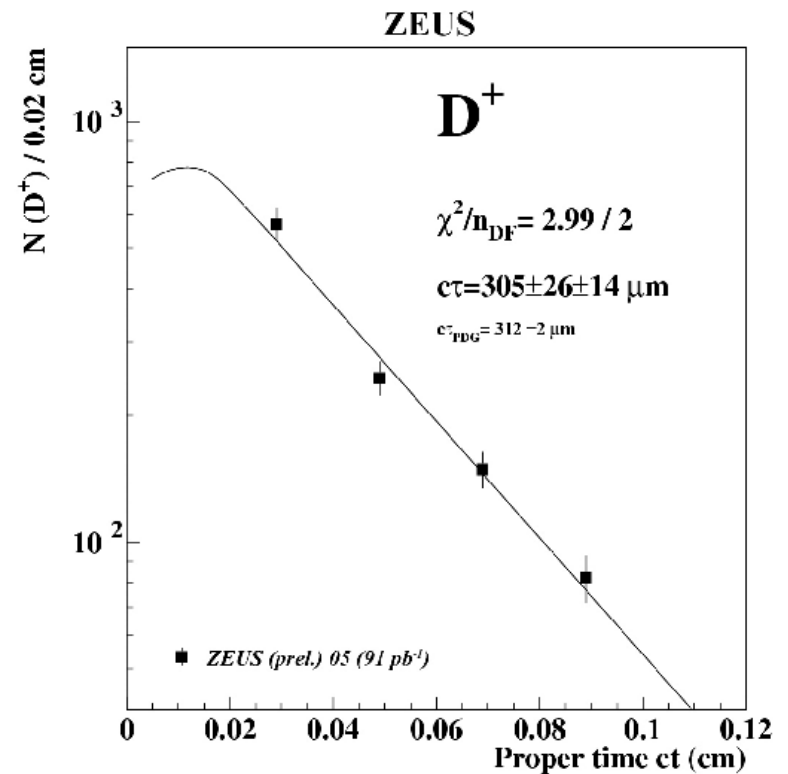
Luminosity: HERA I: 130 pb<sup>-1</sup>  
 2003-06: 310 pb<sup>-1</sup>  
 expect 06/07: 120 pb<sup>-1</sup>

## Detectors:

Muon impact parameter distribution  
 with the ZEUS silicon vertex detector:



D<sup>+</sup> lifetime measurement:



# Conclusions

- Charm production gives a large contribution to the inclusive DIS cross section.
  - Measured with good precision at HERA in a large part of phase space.
  - NLO QCD calculations describe the data within accuracy.
- Beauty production: first  $F_2^b$  measurements.  
NLO calculations tend to lie below the data.
- Double tagging in DIS ( $\mu\mu, D^*\mu$ ) will allow access to lower  $p_t$  and detailed final state kinematics.
- Exploiting the full statistics of HERA with silicon vertex detectors will give precision results on beauty production.



# BACKUP