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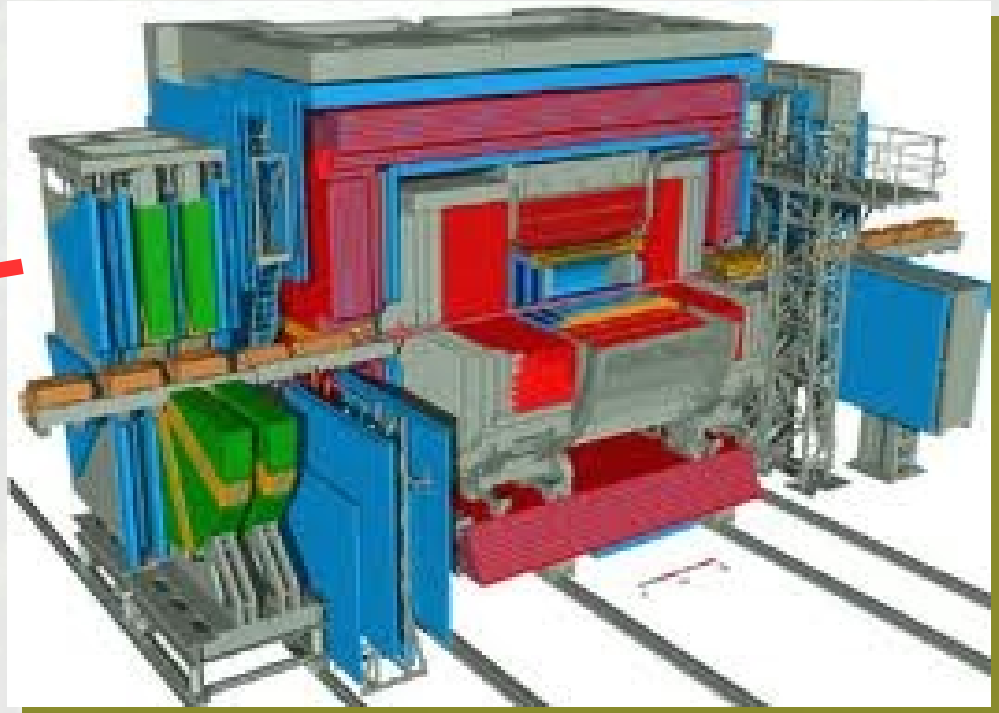
On behalf of the ZEUS collaboration

Charm Quark Production in DIS at ZEUS

EPS2011
Grenoble, France

The HERA collider and the ZEUS detector

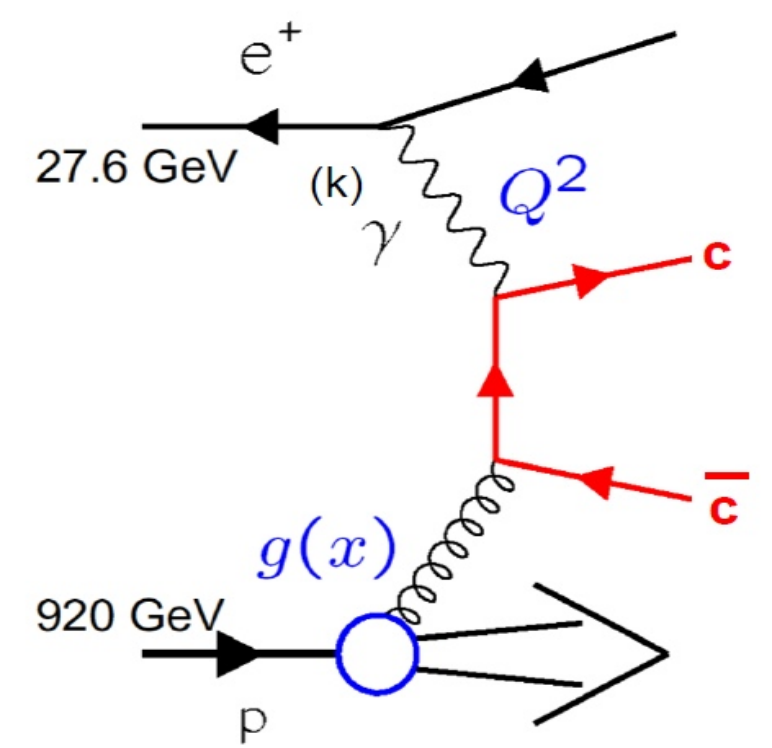


- Protons 920 GeV
- Electrons 27.6 GeV
- 500 pb^{-1} accumulated
- In operation 1992-2007

- ZEUS is a general purpose detector
- The two heavy quarks c and b are both accessible at HERA, the latter one is strongly suppressed due to its smaller electric charge and larger mass.

Motivations

- Boson-gluon fusion is a dominant process for the charm creation in DIS, charm contribution to the inclusive DIS cross section is up to 30% (sizable part of cross section)
- Multiple hard scale give us a possibility to test pQCD p_T, Q^2, m_c
- Charm production is sensitive to the gluon density of the proton
- Measurements of the charm structure function are the subject of interest because:

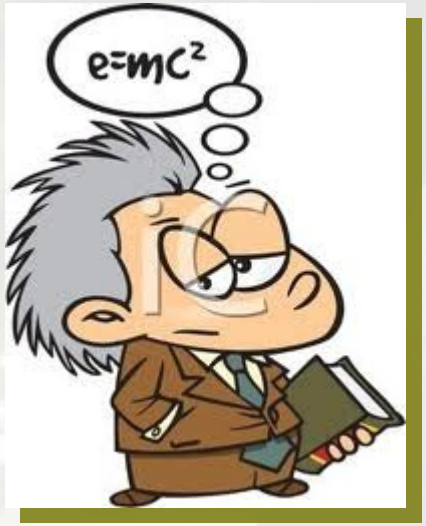


  - Better understanding of the charm is one of the key issues for higher energies experiments (e. g. pp collisions)
  - Wrong PDF will give wrong simulations
  - Test of the different theoretical models (charm mass constrains)

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

Theoretical model

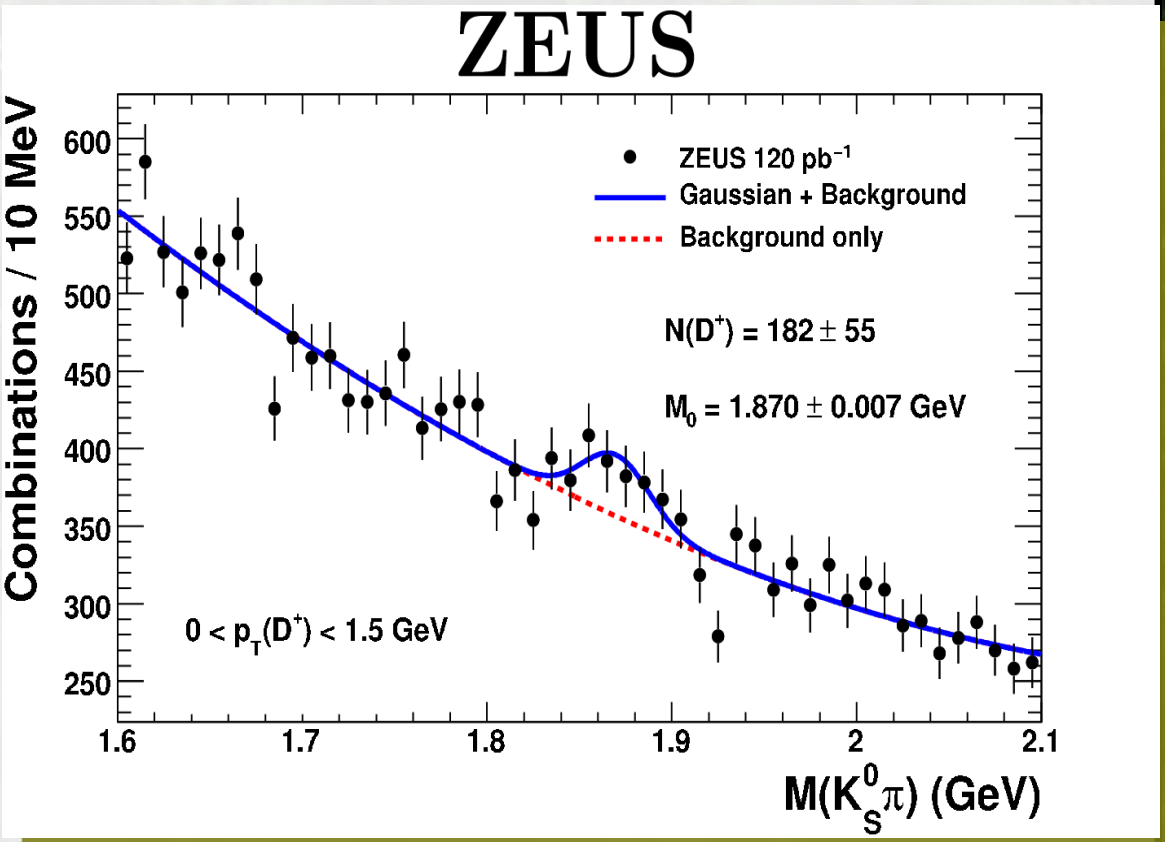
- NLO HVQDIS by Harris & Smith:
  - Fixed-flavor-number scheme:
    - c, b are massive. m_c=1.50 GeV
    - only 3 flavors (u,d,s) in the proton structure, c is produced directly in BGF
  - Peterson fragmentation with ε=0.079 (taken from ZEUS PHP measurement)
  - PDF: ZEUS-S NLO QCD fit
  - $\mu_R = \mu_F = \sqrt{(Q^2 + 4m_c^2)}$
  - Uncertainty:
    - experimental error on PDF
    - varying charm mass (+/-0.15 GeV)
    - varying renormalization and factorization scales (by factor 2)
    - varying ε parameter (0.1/0.01)



D^+ production at a low p_T threshold

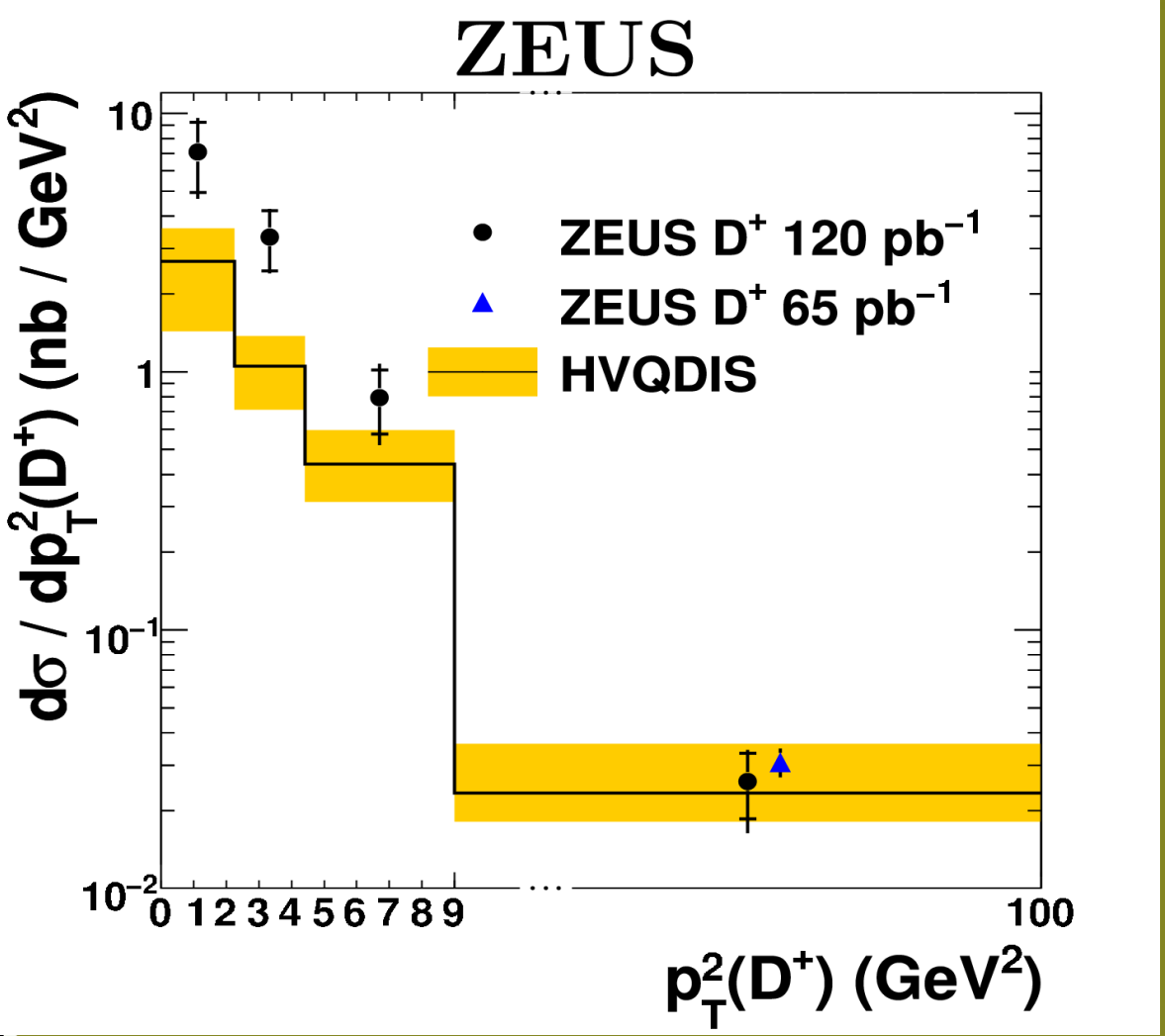
$D^+ \rightarrow K^0_s \pi^+ \rightarrow \pi^- \pi^+ \pi^+$

- 120 pb^{-1} (1996-2000)
- $1.5<Q^2<1000$ GeV^2
- $0.02<y<0.07$
- $|\eta(D^+)|<1.6$
- **$0 < p_T < 10$ GeV**
- Presence of the strange quark in the decay products reduces significantly a combinatorial background (V^0-like long leaved particles)



Thus measurement can be made at **low p_T** threshold

D^+ production at a low p_T threshold



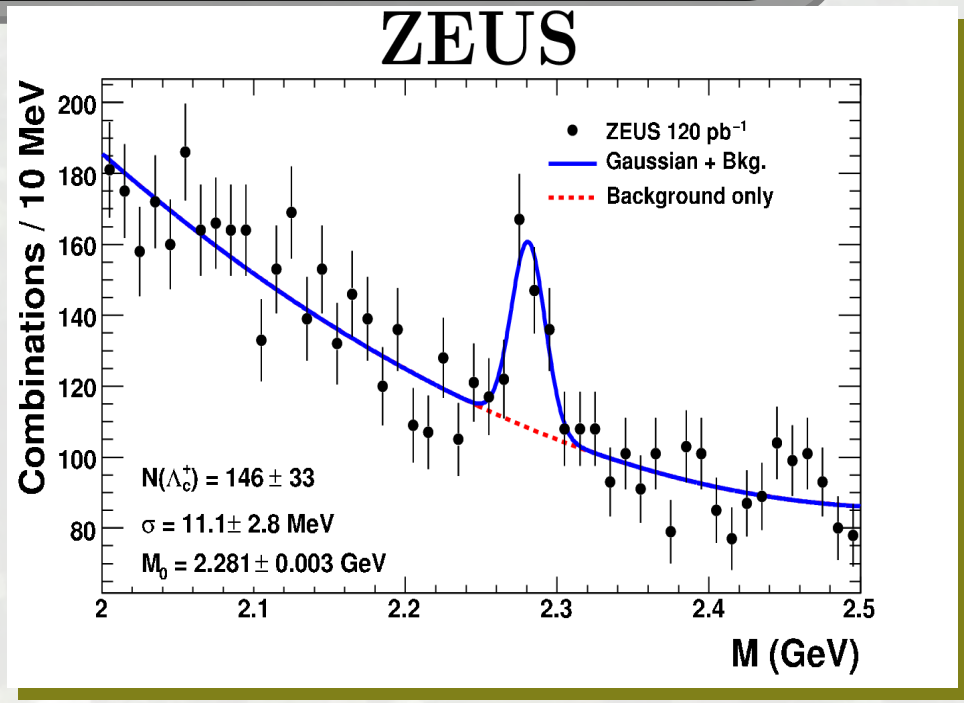
- Measurements are in agreement with previous **high p_T D^+** measurements
- Measurements are in agreement with NLO QCD predictions in a range of 2 sigma
- It is the first measurement at HERA in a **low p_T** kinematic region

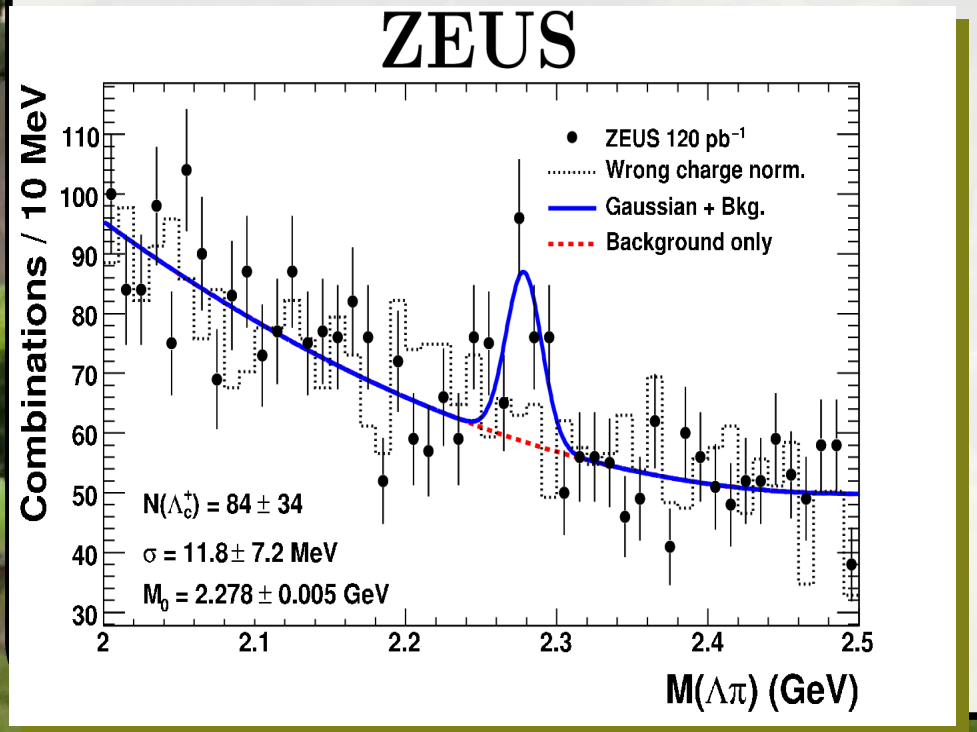
$D^+ \rightarrow K^0_s \pi^+ \rightarrow \pi^- \pi^+ \pi^+$

Λ_c production at a low p_T threshold

- 120 pb^{-1} (1996-2000)
- 1.5<Q2<1000 GeV2
- 0.02<y<0.07
- $|\eta(\Lambda_c)|<1.6$ $0<p_T(\Lambda_c)<10$ GeV

$\Lambda_c^+ \rightarrow \Lambda^0\pi^+ \rightarrow \pi^+\pi^-p$





$\Lambda_c^+ \rightarrow K^0_s p \rightarrow \pi^+\pi^-p$

$$f(c \rightarrow \Lambda_c)$$

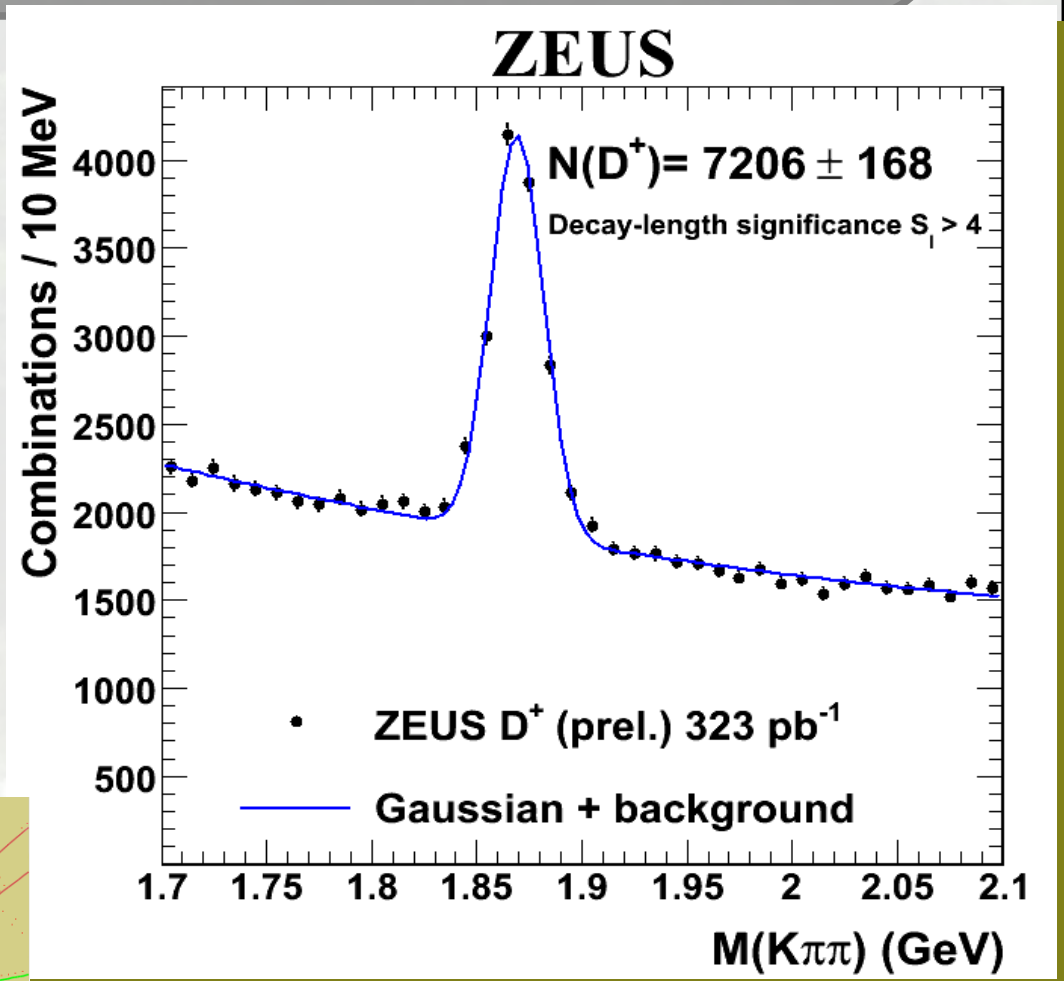
$$0.117 \pm 0.033(stat.)^{+0.026}_{-0.022}(syst.) \pm 0.027(BR)$$ **DIS**

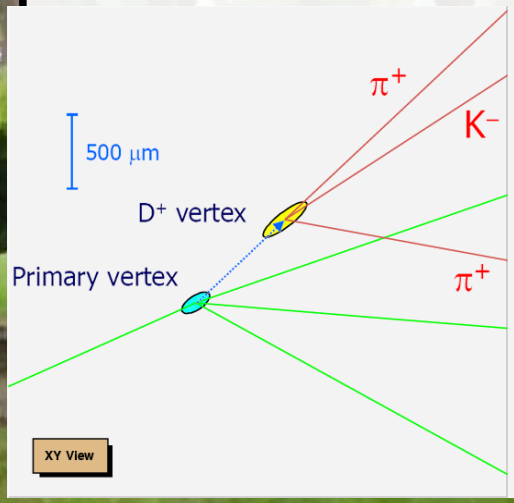
$$0.144 \pm 0.022(stat.)^{+0.013}_{-0.022}(syst.)^{+0.037}_{-0.025}(BR)$$ **PHP**

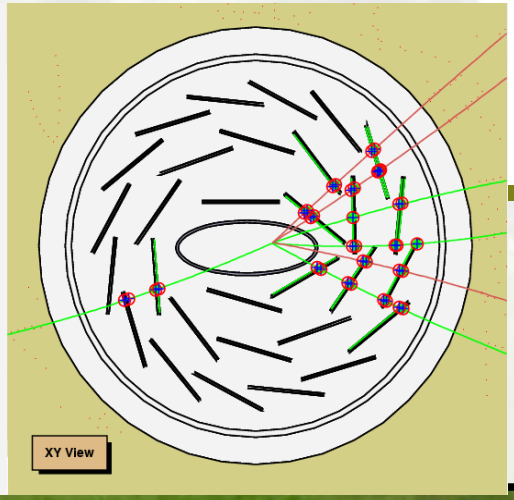
$$0.076 \pm 0.007(stat. \otimes syst.)^{+0.027}_{-0.016}(BR)$$ **e+e-**

$D^+ \rightarrow K^- \pi^+ \pi^-$ measurement

- Life time information were used to extract signal with a help of MVD detector HERAII. $S_l = L_{xy} / \sigma_{xy}$
- Significant improvement in signal to background ratio
- Smaller stat. Errors due to the HERAII statics

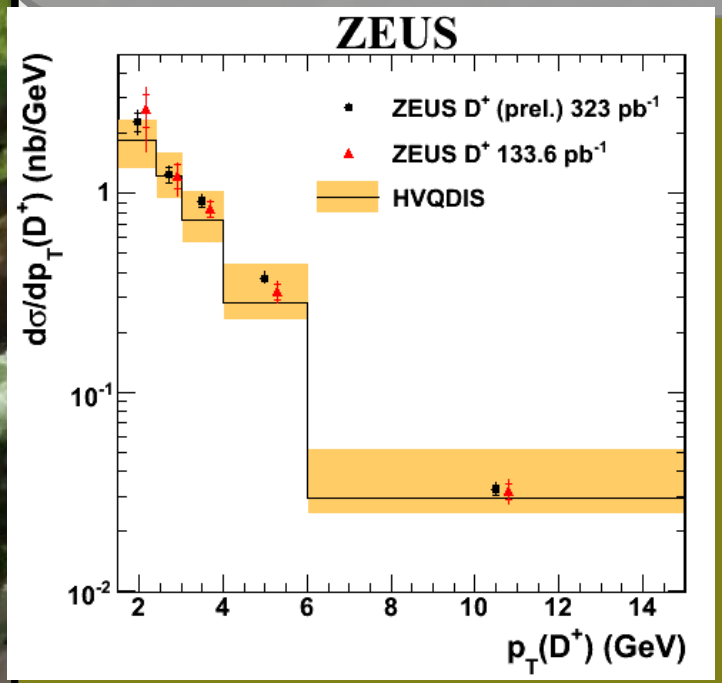


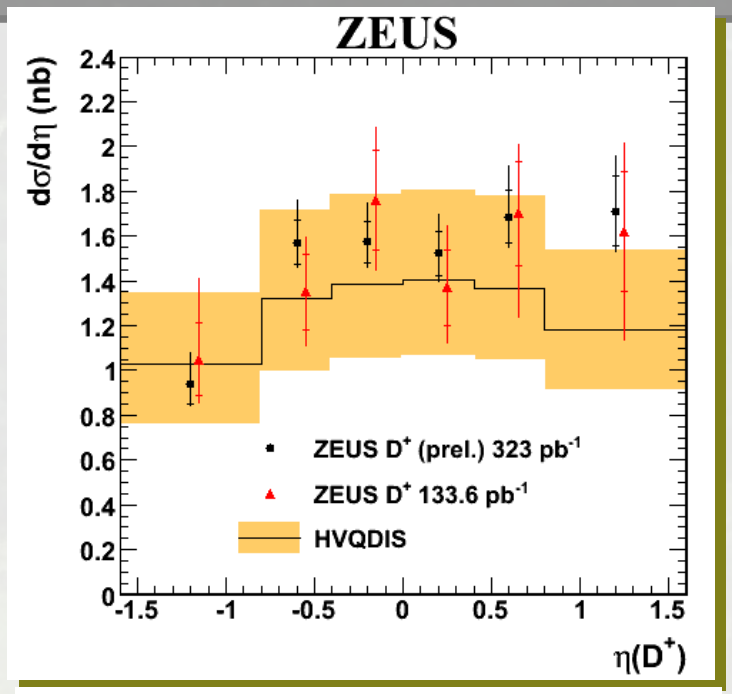


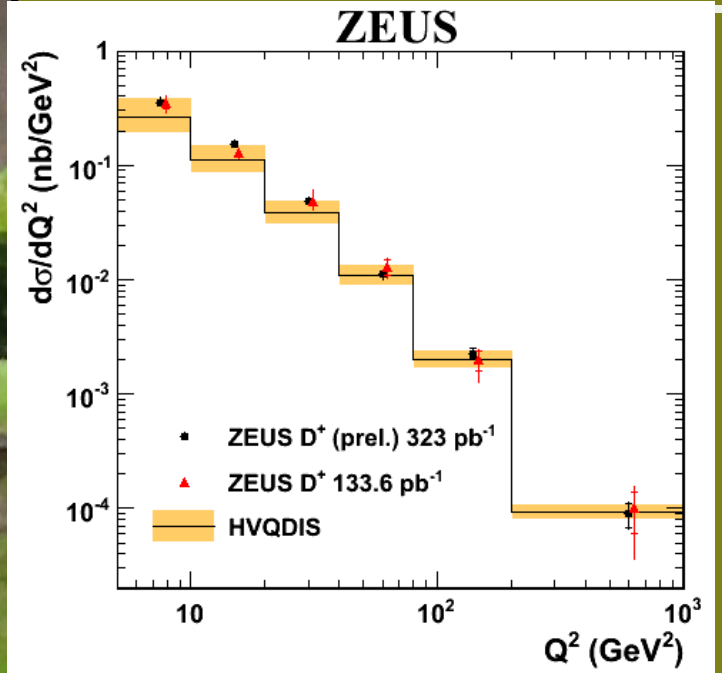


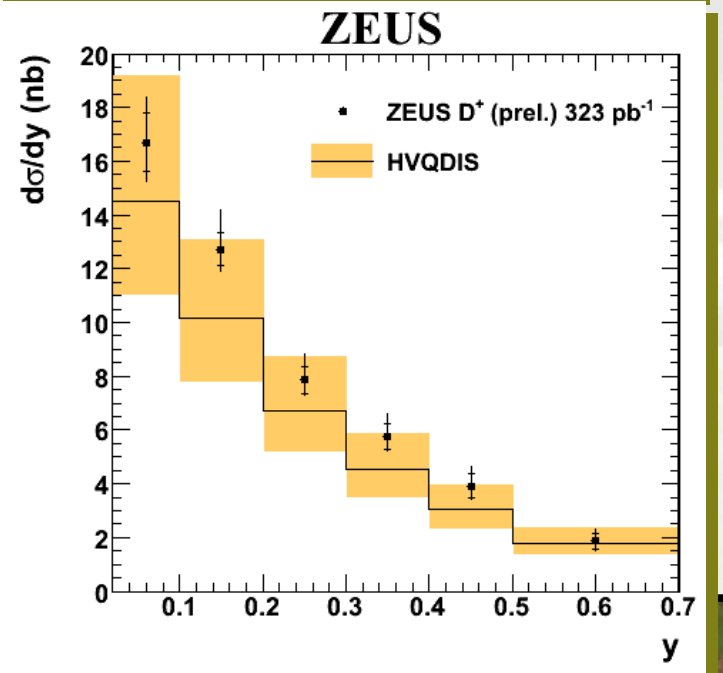
- $5<Q^2<1000$ GeV^2
- $0.02<y<0.07$
- $|\eta(D+)|<1.6$, $1.5<p_T(D+)<15$ GeV

Cross sections $D^+ \rightarrow K^- \pi^+ \pi^-$









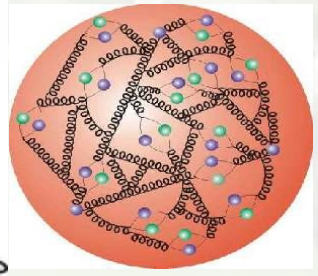
- Improved statistical precision w.r.t. published results
- NLO QCD predictions describe the measured cross sections

F_2^{cc} measurement from $D^+ \rightarrow K^- \pi^+ \pi^-$

Measured cross section in a bin (Q^2_i, y_i)

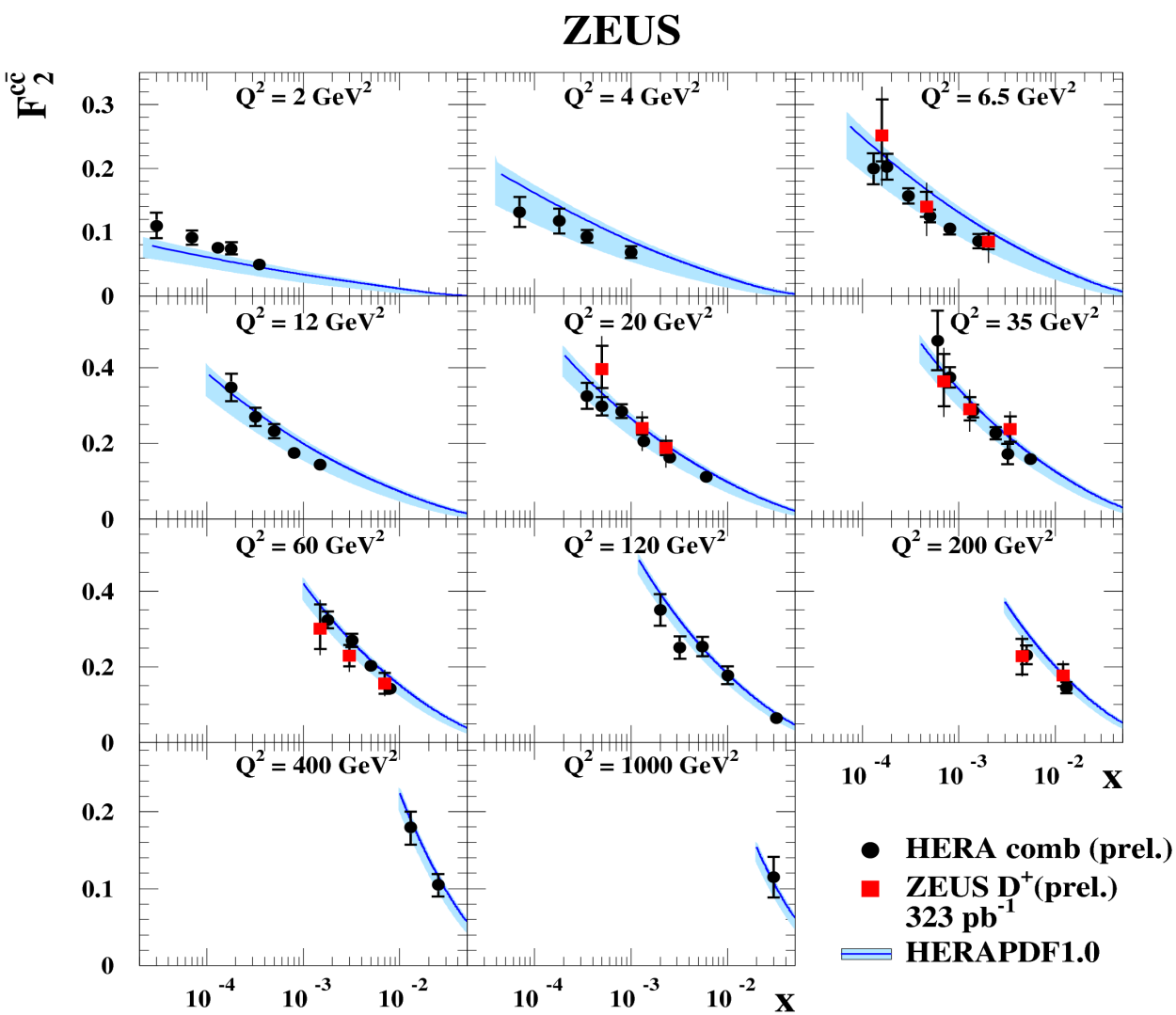
$$F^{c\bar{c}}_{2,meas}(x_i, Q_i^2) = \frac{\sigma_{i,meas}(ep \rightarrow e' D^+ X)}{\sigma_{i,theo}(ep \rightarrow e' D^+ X)} F^{c\bar{c}}_{2,theo}(x_i, Q_i^2)$$

NLO QCD in FFNS by HVQDIS



- Extrapolation is being done with NLO
- Measurements are done in a restricted kinematic region
- F^{2cc} is a part of F^2 structure function where charm quark is in the ground state

F_2^{cc} measurements from $D^+ \rightarrow K^- \pi^+ \pi^-$

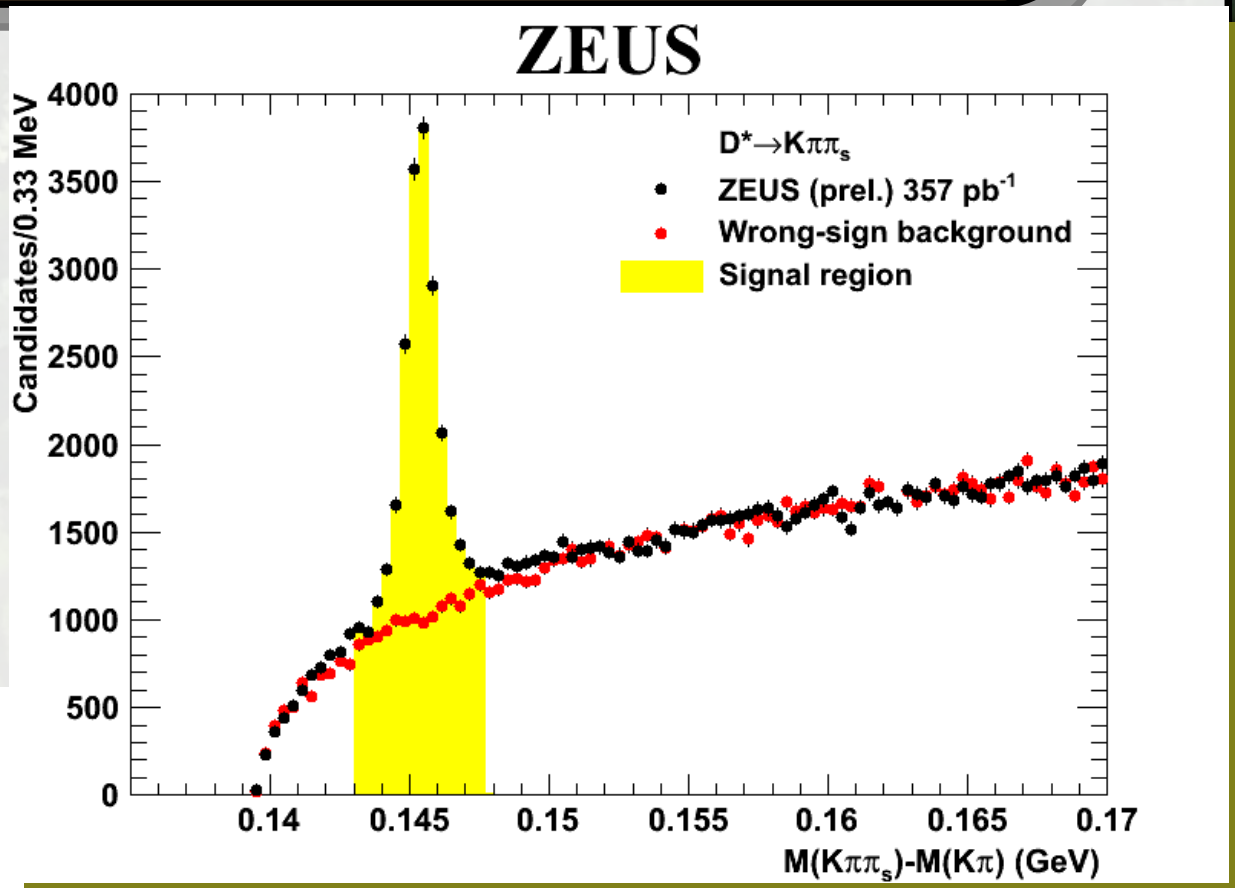


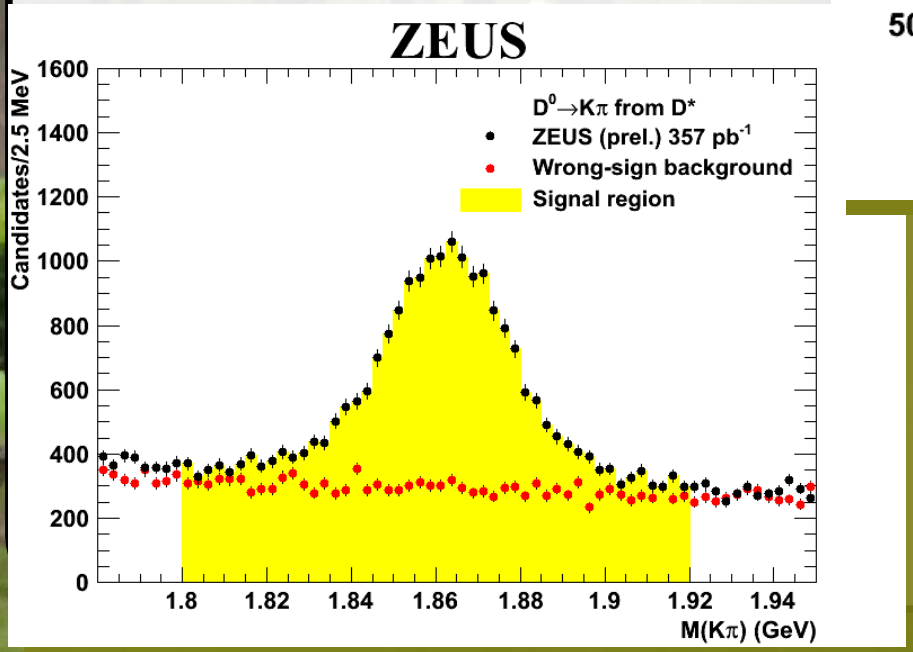
- Measurements are described by the HERAPDF1.0

  (note, that HERAPDF doesn't include charm data)
- Measurements agree with the combined HERA results

$D^* \rightarrow D^0\pi_s$ measurement

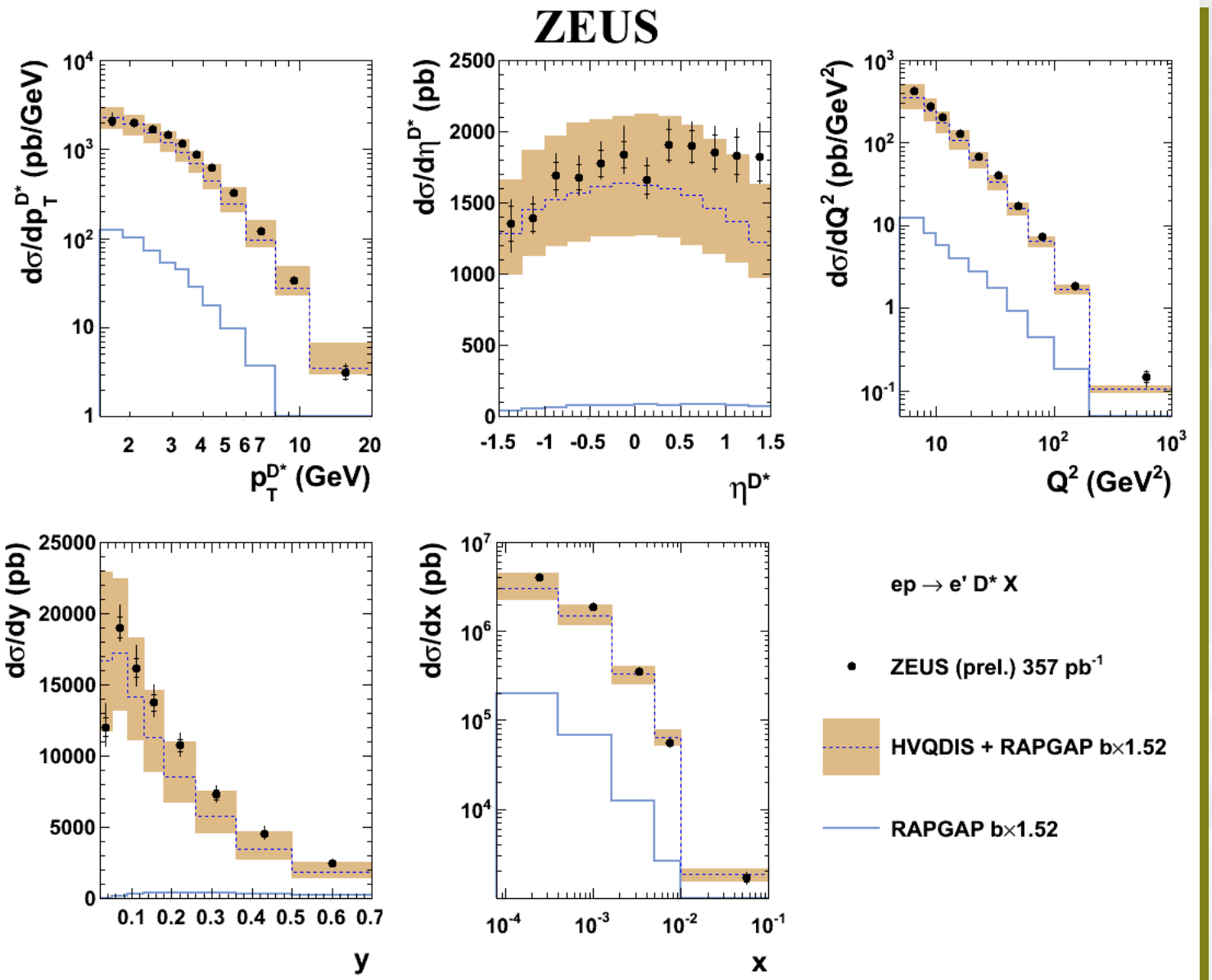
- HERAII 357 pb^{-1}
- p_T>1.5 GeV, |η|<1.5
- $5<Q^2<1000$ GeV^2
  $0.02<y<0.7$
- D* from B meson origin are included in the cross sections





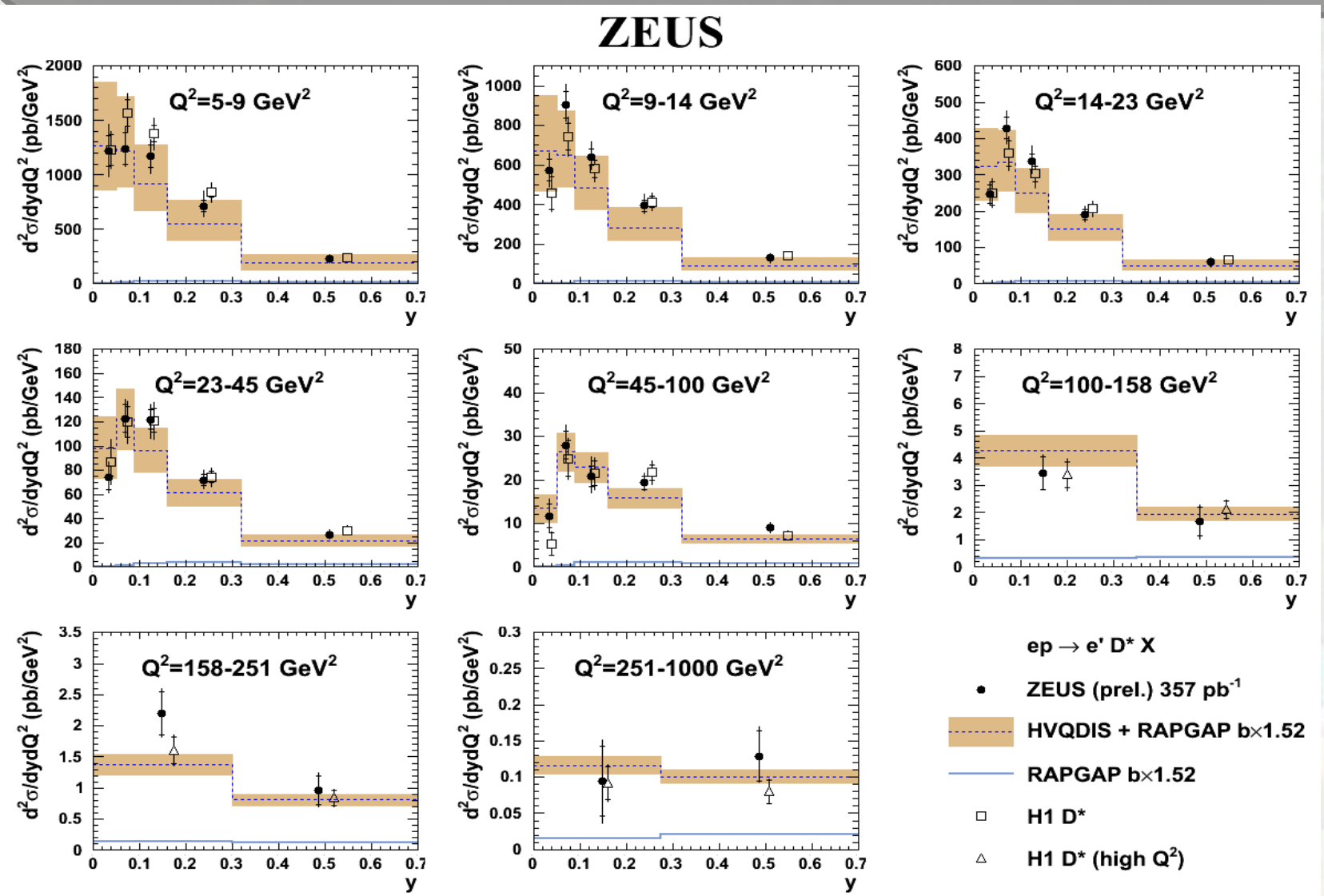
N(D*) were obtained by subtraction of the wrong-sign background

D* measurement



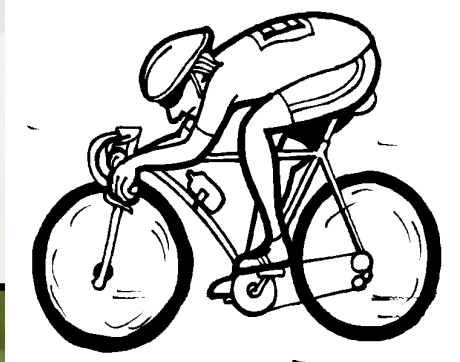
- NLO QCD predictions described our measurements predictions
- All differential cross sections are corrected for QED processes

D* double differential cross sections



On a way to extract F_2^{CC} with D*s

- Measurements are described by NLO QCD predictions
- Measurements are in agreement with H1 results

Summary

- Measurements of the charm quark in DIS at the HERA collider with the ZEUS detector were reported:
  - Low transverse momentum **threshold D^+** and **Λ_c**
  - fragmentation fraction was extracted from **Λ_c**
  - Measurement of **D^*** and **D^+** mesons in a wide Q^2 region were done.
  - QCD predictions in all cases describe measured cross sections thus giving a positive test of the theory
  - **Charm structure function** was extracted from D^+ cross sections. It will improve the combined HERA result