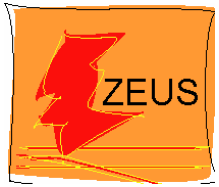

Measurement of D^+ production in Deep Inelastic ep Scattering with the ZEUS detector at HERA

DESY-13-028, arXiv:1302:5058

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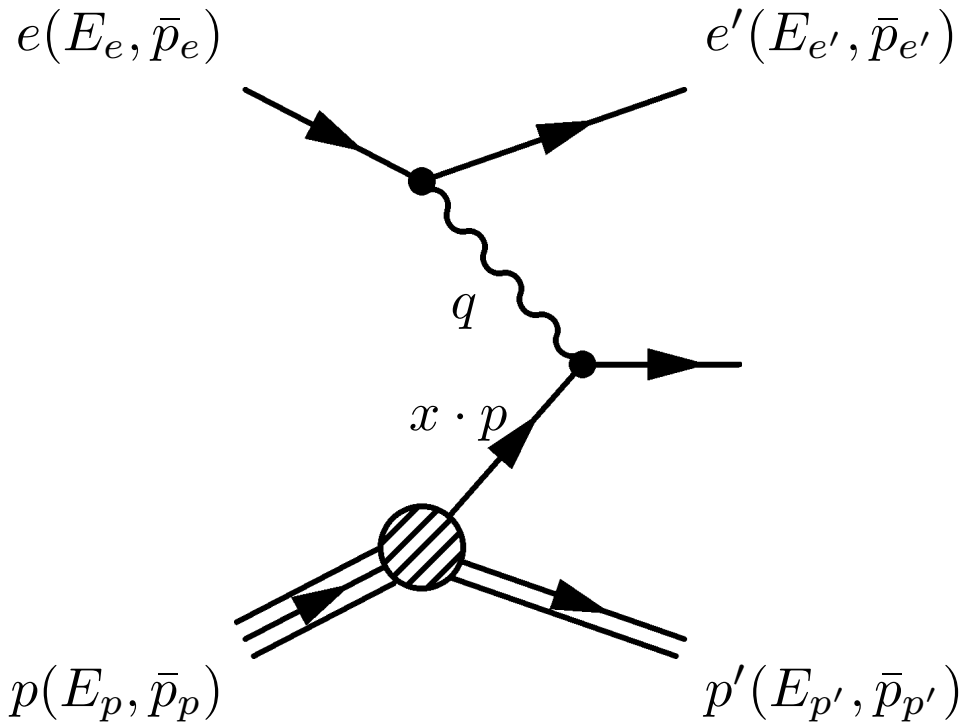
(DESY)
on behalf of the ZEUS Collaboration

Marseille, 25.04.2013

Kinematics

$$Q^2 = -q^2 = -(e - e')^2$$
$$x = \frac{Q^2}{2q \cdot p}$$
$$y = \frac{q \cdot p}{q \cdot e}$$
$$s = (e + p)^2$$



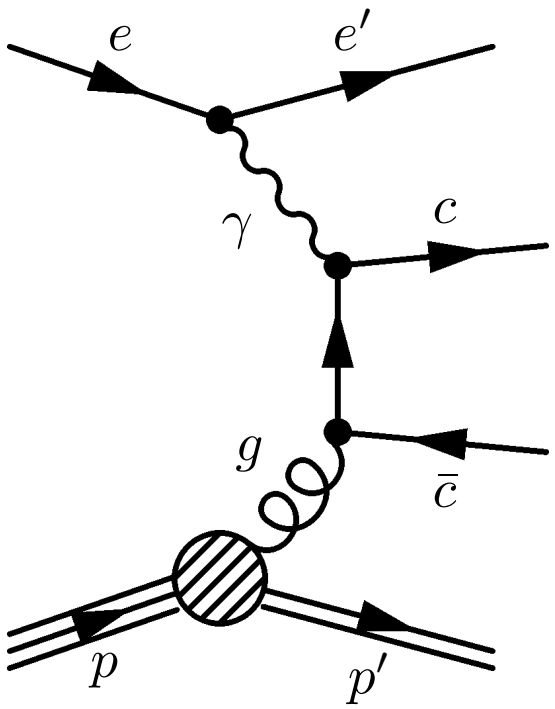
For high energies $Q^2 \approx sxy$.
Since s is fixed ($\sqrt{s} = 318$ GeV for HERA II), any other two variables can be used for kinematic space determination.

$Q^2 < 1\ GeV^2$ — photoproduction processes (PHP)
$Q^2 > 1\ GeV^2$ — deep inelastic scattering (DIS)

Motivation

Test of pQCD (multiple hard scales: Q^2, $p_T(c)$, m_c)

Charm in DIS is predominantly produced via Boson-Gluon Fusion (BGF) process

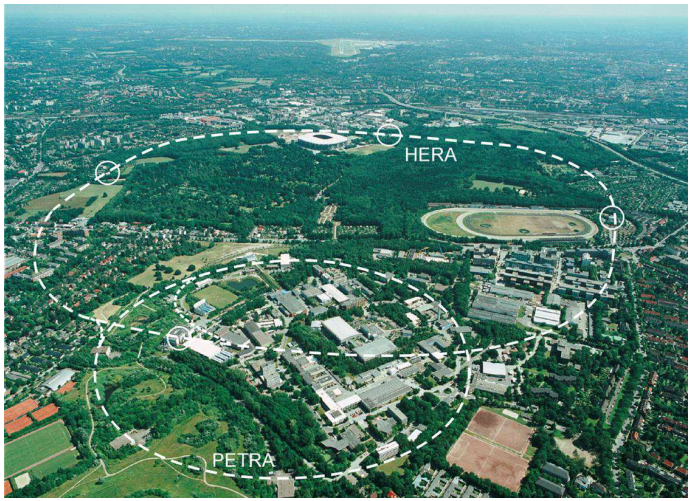


Production is directly sensitive to gluon density in the proton and to the charm quark mass

Experimental set-up

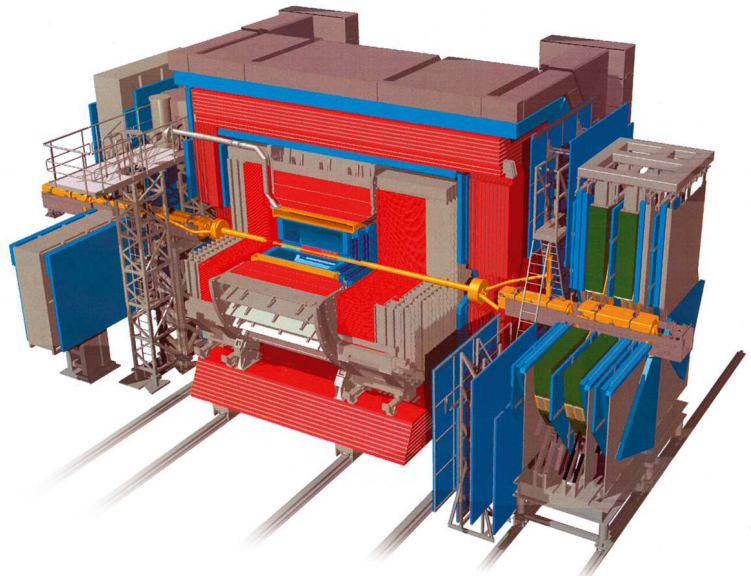
HERA Collider

- ep interactions
- $\mathcal{L} \sim 500\ \mathrm{pb}^{-1}$
- $\sqrt{s} = 300...318\ \mathrm{GeV}$



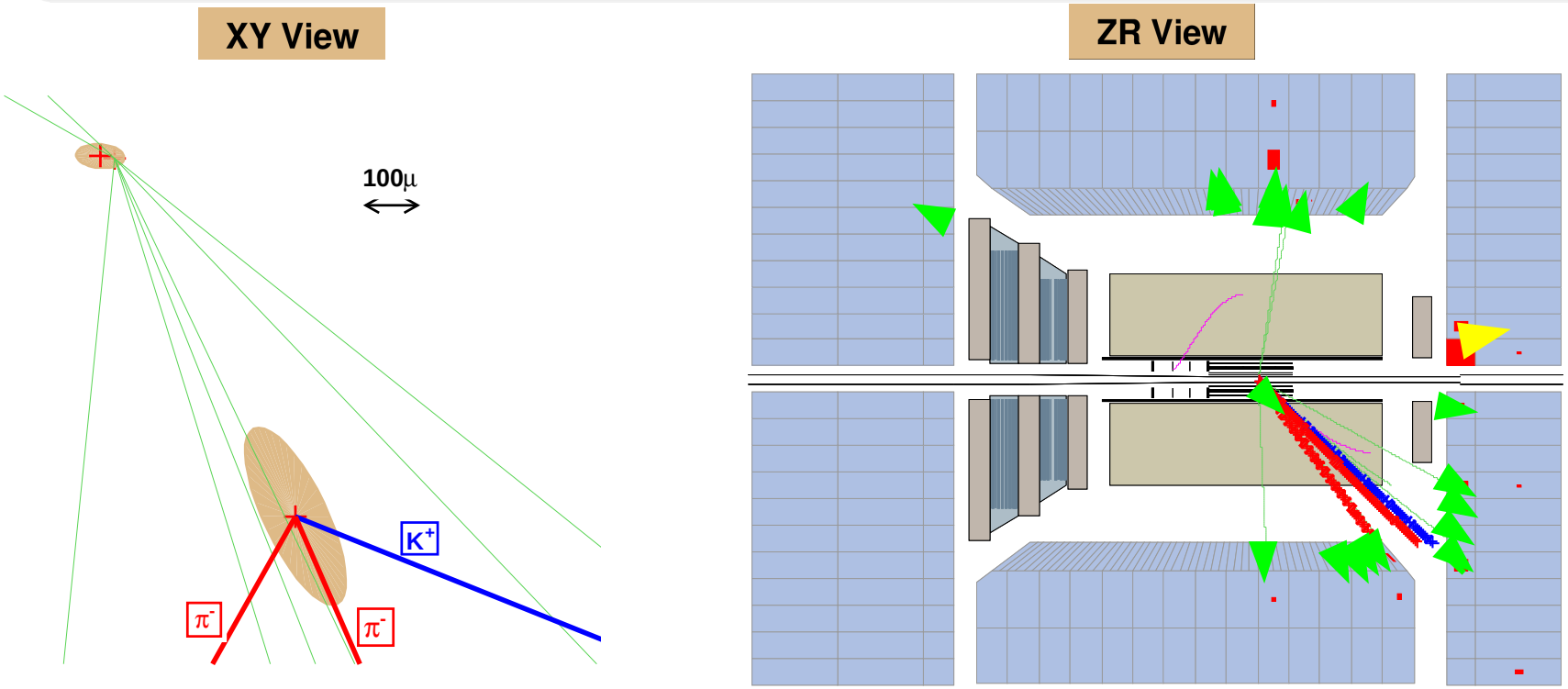
ZEUS Detector

- Microvertex Detector
- Central Tracking Detector
- Electron and Hadron Calorimeters



$D^+ \to K^-\pi^+\pi^+$ lifetime tagging

MVD allows for reconstruction of displaced secondary vertices from charm hadron decays with spatial resolution $\sim 200\mu$:



Lifetime tag based on decay length significance $S_l = \frac{L_{xy}^{proj}}{\sigma(L_{xy}^{proj})}$

L_{xy}^{proj} is a vector in XY plane from the interaction point to the decay vertex projected on the D^+ meson momentum

$D^+ \to K^-\pi^+\pi^+$ lifetime tagging

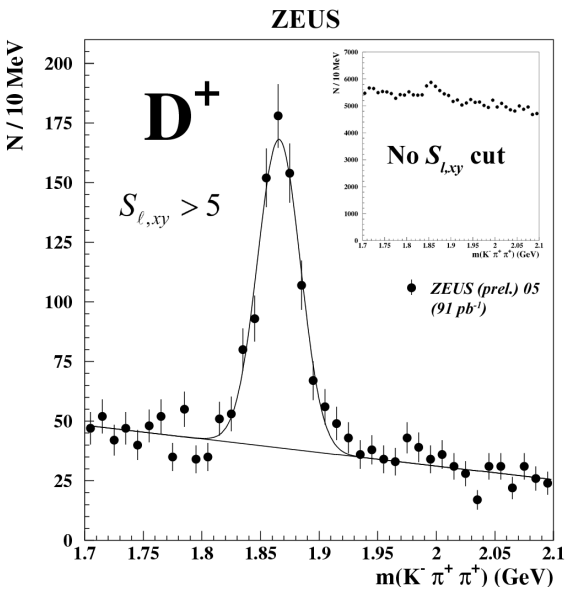
D^+

- longest lifetime
  $c\tau(D^+) = 312\mu$
- $f(c \to D^+) = 0.23$

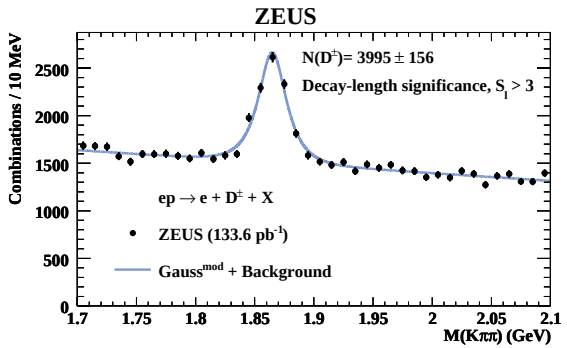
$D^+ \to K^-\pi^+\pi^+$

- 3 charged daughter particles
- $BR = 9.13\%$

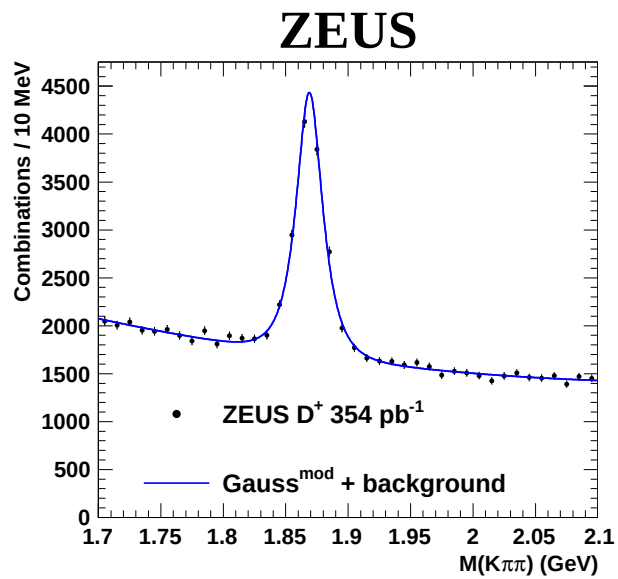
...But benefiting from lifetime tagging requires good understanding of the detector



2006

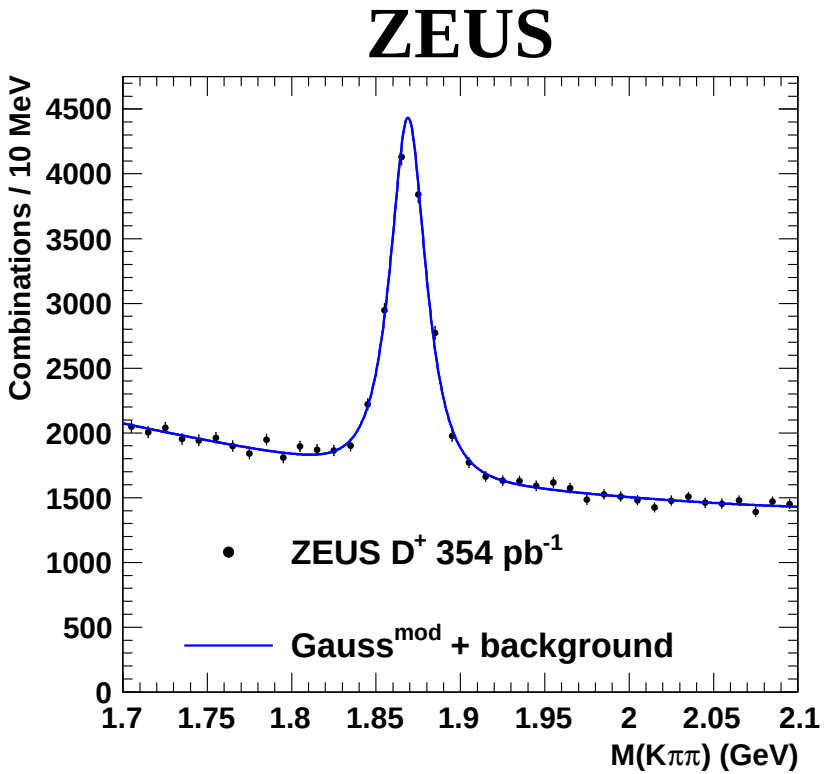


2008



2013

D^+ mesons reconstruction



Decay channel

$D^+ \to K^-\pi^+\pi^+$

Data sample

$\mathcal{L} = 354\ pb^{-1}$ (2004-2007 data)

Kinematic region

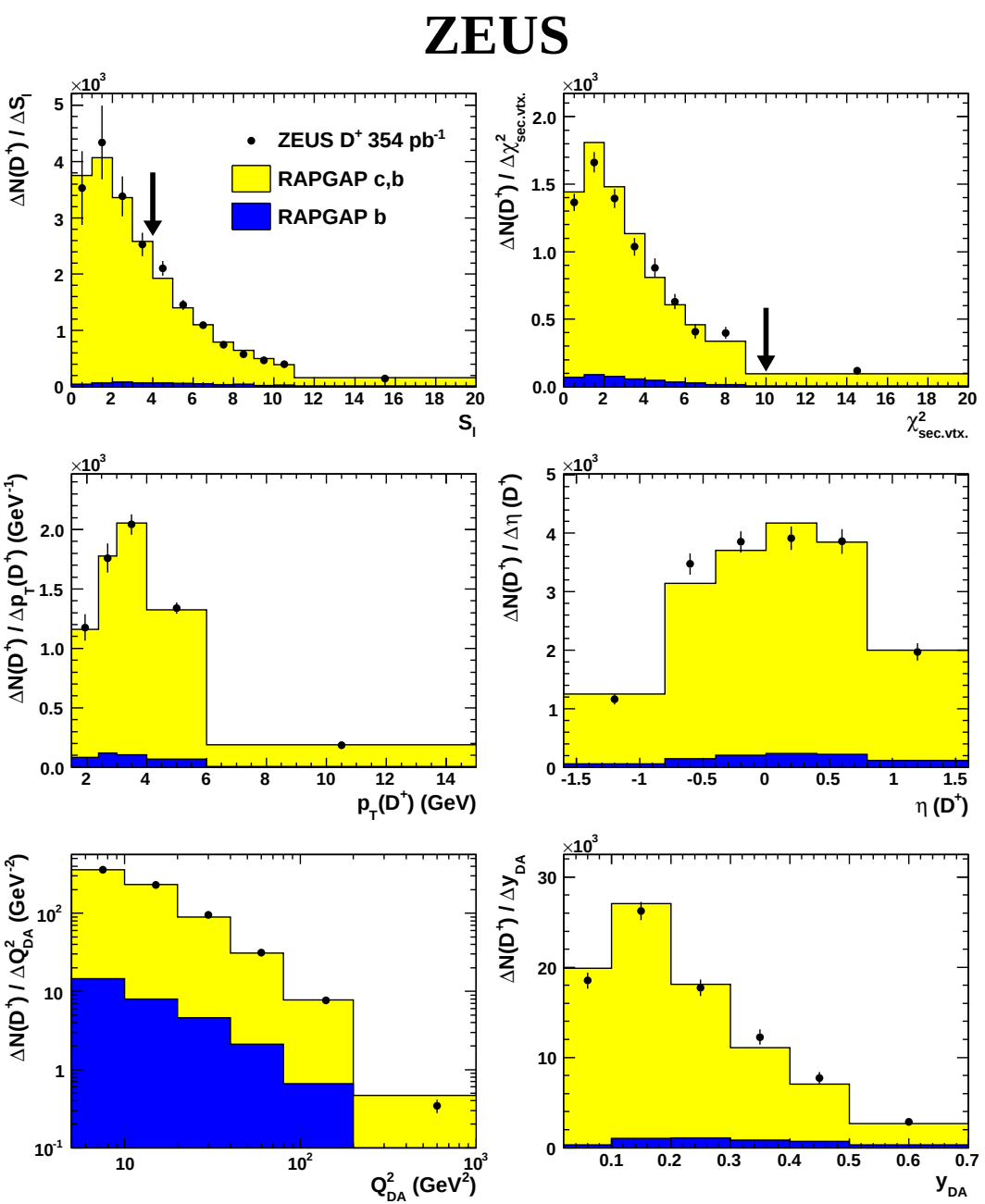
$5 < Q^2 < 1000\ GeV^2$

$0.02 < y < 0.7$

$1.5 < p_T(D^+) < 15\ GeV$

$|\eta(D^+)| < 1.6$

Important variables distributions



Monte Carlo simulations provide a reasonable description of the data

Small systematic uncertainties

Systematic uncertainties

- Monte Carlo shape ($\pm 5\%$)
- S_l and $\chi^2_{sec.\ vtx.}$ smearing ($\pm 1\%$, $+2\%$)
- $D^+ \to K^-\pi^+\pi^+$ branching ratio ($\pm 2.1\%$)
- Beauty contribution ($\pm 2\%$)
- Luminosity measurement ($\pm 1.9\%$)
- Tracking efficiency ($\pm 1.5\%$)
- Signal extraction procedure ($^{+0.7\%}_{-1.5\%}$)

NLO QCD calculations

NLO QCD calculations in FFNS (HVQDIS program)

- ZEUS-S NLO QCD PDF within the total uncertainties
- $m_c = 1.5 \pm 0.15\ GeV$
- $\mu_r = \mu_f = \sqrt{Q^2 + 4m_c^2}$, varied independently up and down by factor 2
- $\alpha_s^{nf=3}(M_Z) = 0.105$
- Fragmentation:
  - Kartvelishvili fragmentation function $f(z) = z^{\alpha_k}(1-z)$ α_k parametrized as a smooth function of $m(c\bar{c})$ and varied within uncertainties
  - Hadronization fraction $f(c \to D^+) = 0.2297 \pm 0.0078$

Charm quark contribution to the the proton structure function

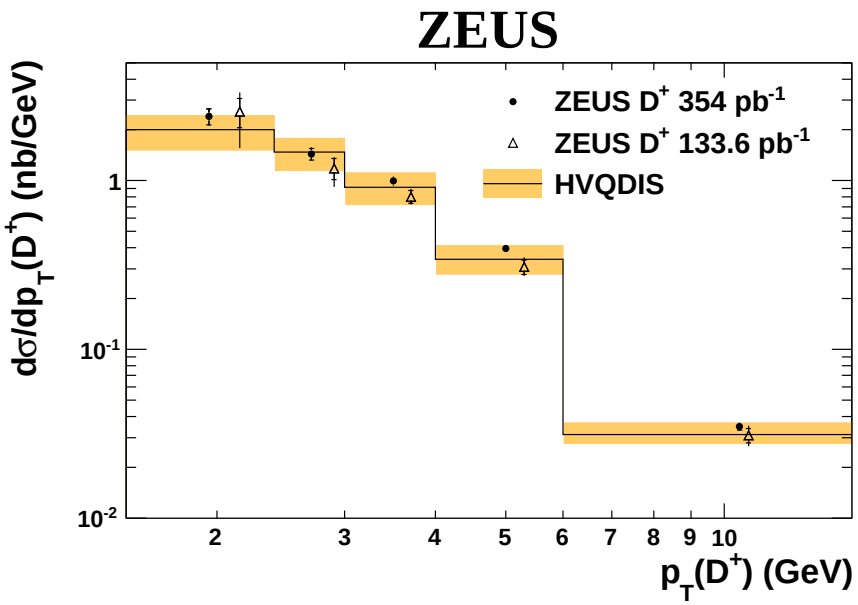
$$\frac{d\sigma^{c\bar{c}}(e^{\pm}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2^{c\bar{c}}(x,Q^2) - y^2 F_L^{c\bar{c}}(x,Q^2) \mp Y_- x F_3^{c\bar{c}}(x,Q^2)\right]$$

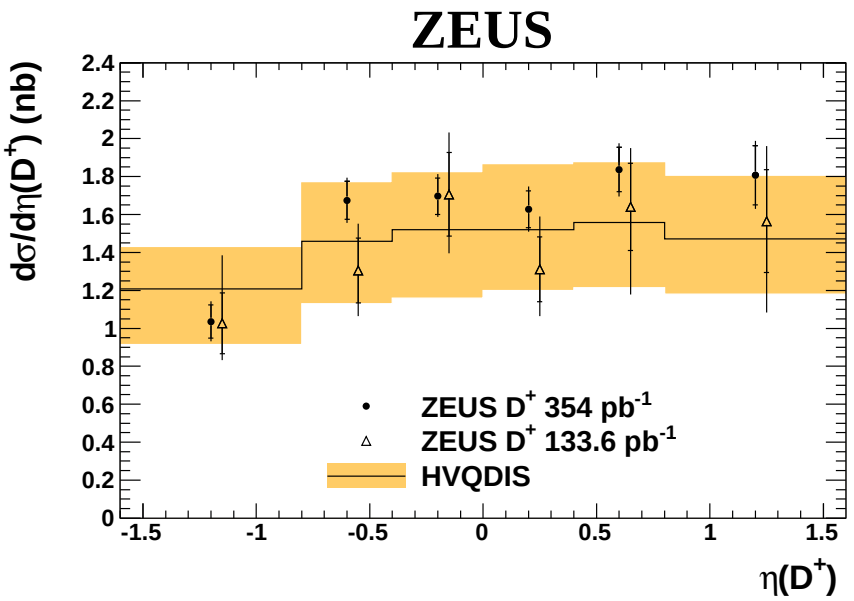
$$Y_\pm = 1 \pm (1-y)^2$$

Single differential cross sections

$5 < Q^2 < 1000\ GeV^2$ $\quad$ $1.5 < p_T(D^+) < 15\ GeV$

$0.02 < y < 0.7$ $\quad$ $|\eta(D^+)| < 1.6$





- Good agreement between data and NLO QCD predictions
- Improved precision in comparison with previously published D^+ measurement

Single differential cross sections

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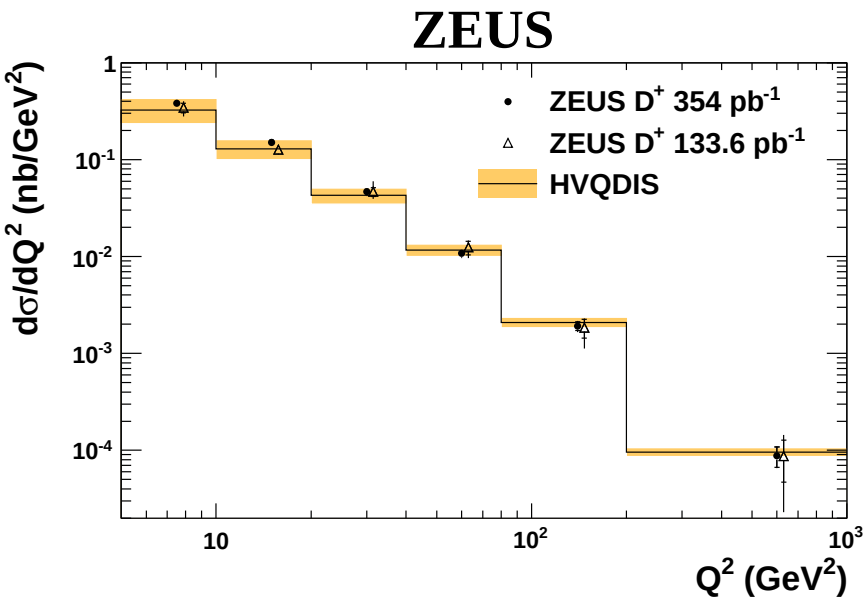
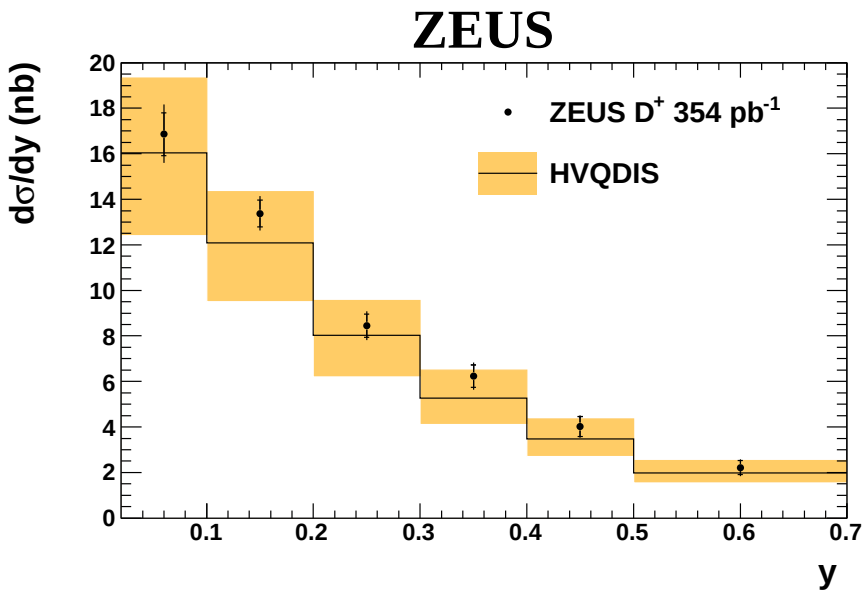
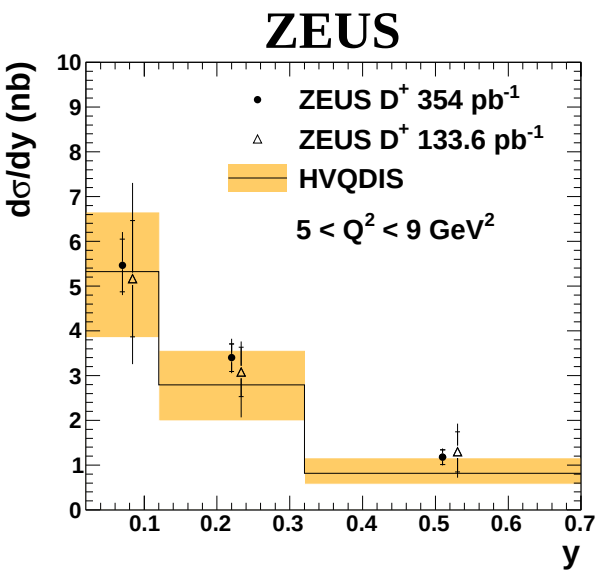
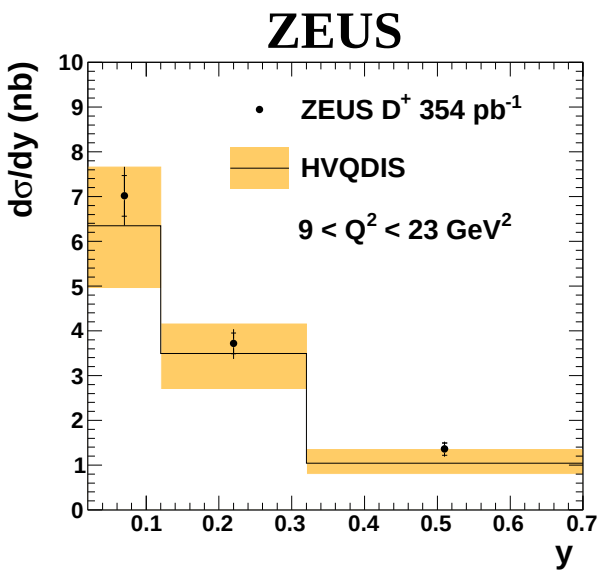


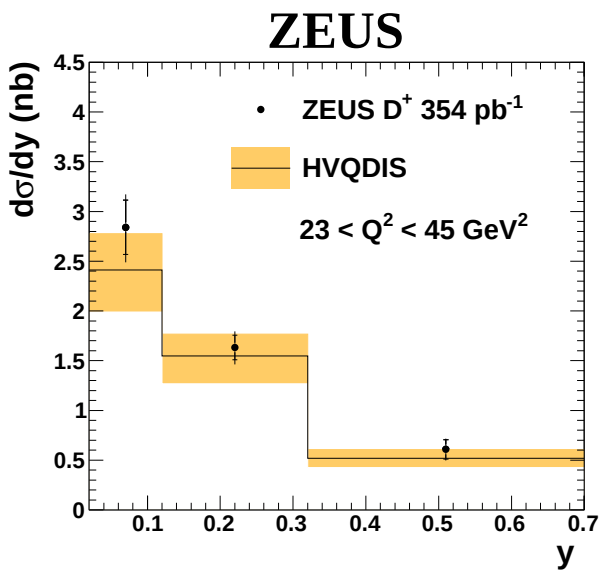


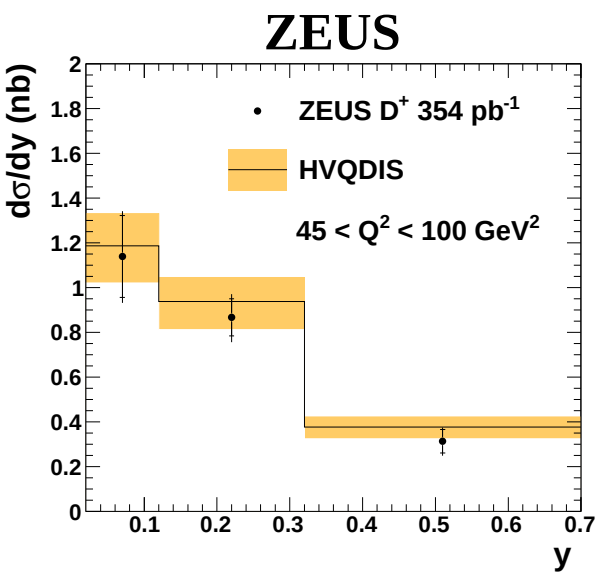
- Good agreement between data and NLO QCD predictions
- Improved precision in comparison with previously published D^+ measurement

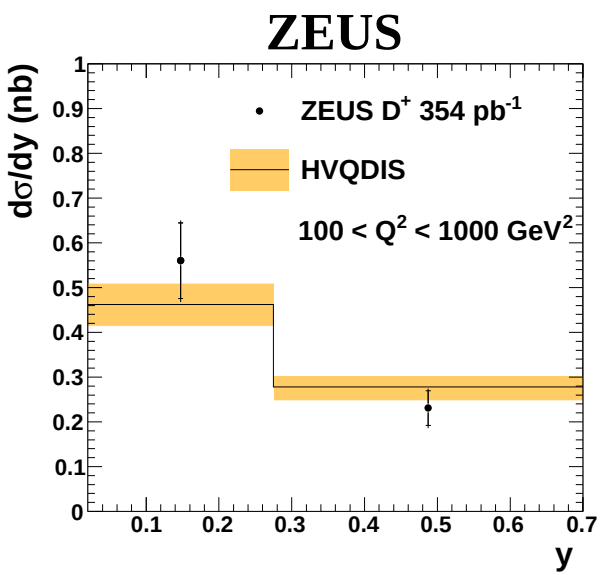
Double differential cross sections





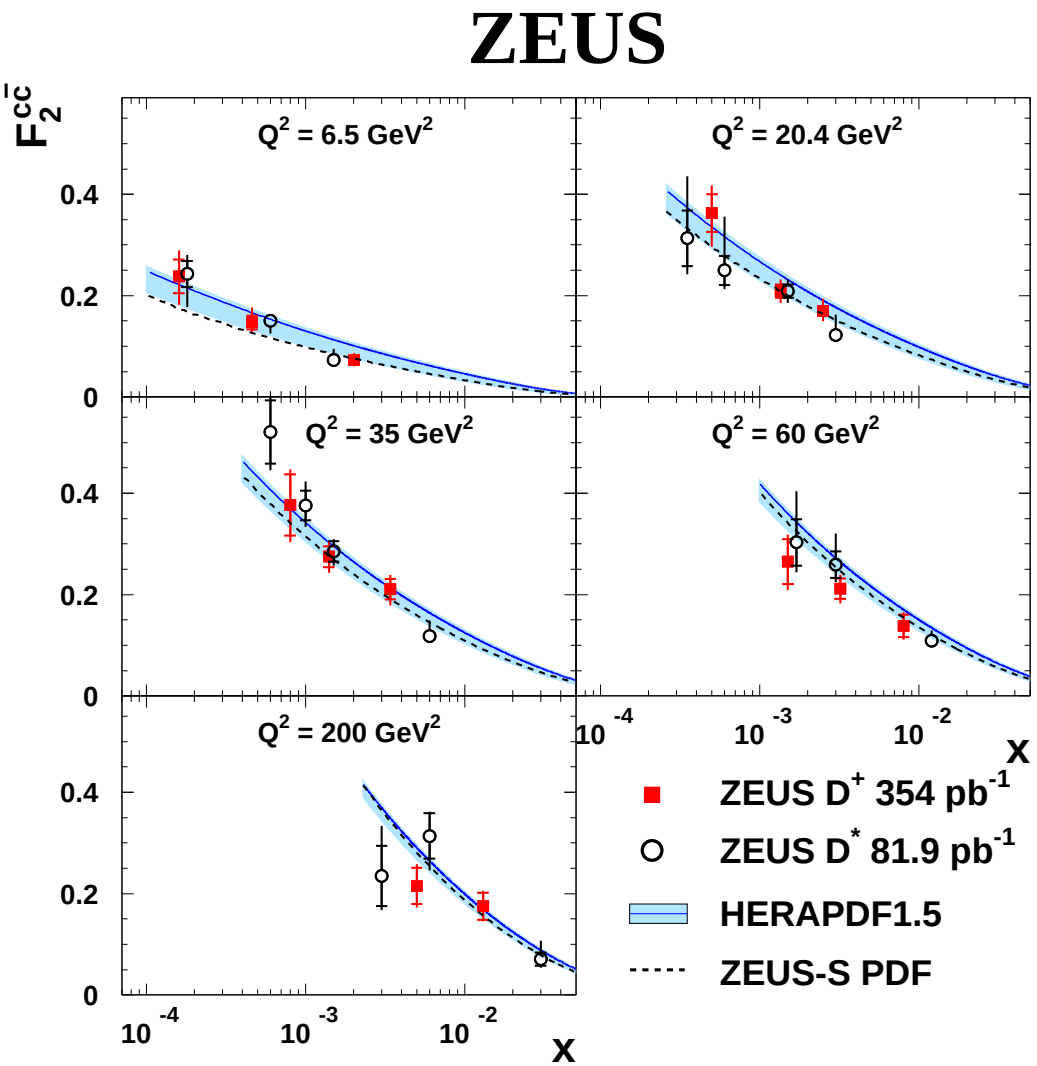






Input to $F_2^{c\bar{c}}$ extraction:

$$F_{2,\ meas}^{c\bar{c}}(x_i, Q_i^2) = \frac{\sigma_{i,\ meas}}{\sigma_{i,\ NLO}} F_{2,\ NLO}^{c\bar{c}}(x_i, Q_i^2)$$



- The results are in good agreement with a previous ZEUS measurement of $F_2^{c\bar{c}}$ using D^* mesons (PRD 69, 012004 (2004))
- Both measurements have similar precision
- The results are well described by NLO QCD predictions

Summary

- Charm production was measured using the decay channel $D^+ \to K^-\pi^+\pi^+$ with $354\ \mathrm{pb}^{-1}$ of ZEUS HERAII data
- Measurement is in agreement with NLO QCD predictions providing an improved check of pQCD
- $F_2^{c\bar{c}}$ was extracted and results are in agreement with other ZEUS measurements and well described by the PDF based on HERA combined data

The present results improve and supersede previous ZEUS D^+ measurement and have the potential to constrain further the parton densities in the proton

BACKUP: pQCD approximation of charm production

Fixed Flavour Number Scheme (FFNS)

- c-quark is massive $\Rightarrow$ not a part of the proton, produced perturbatively in hard scattering
- valid for $Q^2 \sim m_c^2$

Zero Mass Variable Flavour Number Scheme (ZM-VFNS)

- c-quark is massless $\Rightarrow$ a part of the proton
- valid for $Q^2 >> m_c^2$

General Mass Variable Flavour Number Scheme (GM-VFNS)

- equivalent to FFNS at low Q^2
- equivalent to ZM-VFNS at high Q^2