Open Charm and Beauty Production at HERA

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New Results from H1 and ZEUS

Selected Topics:

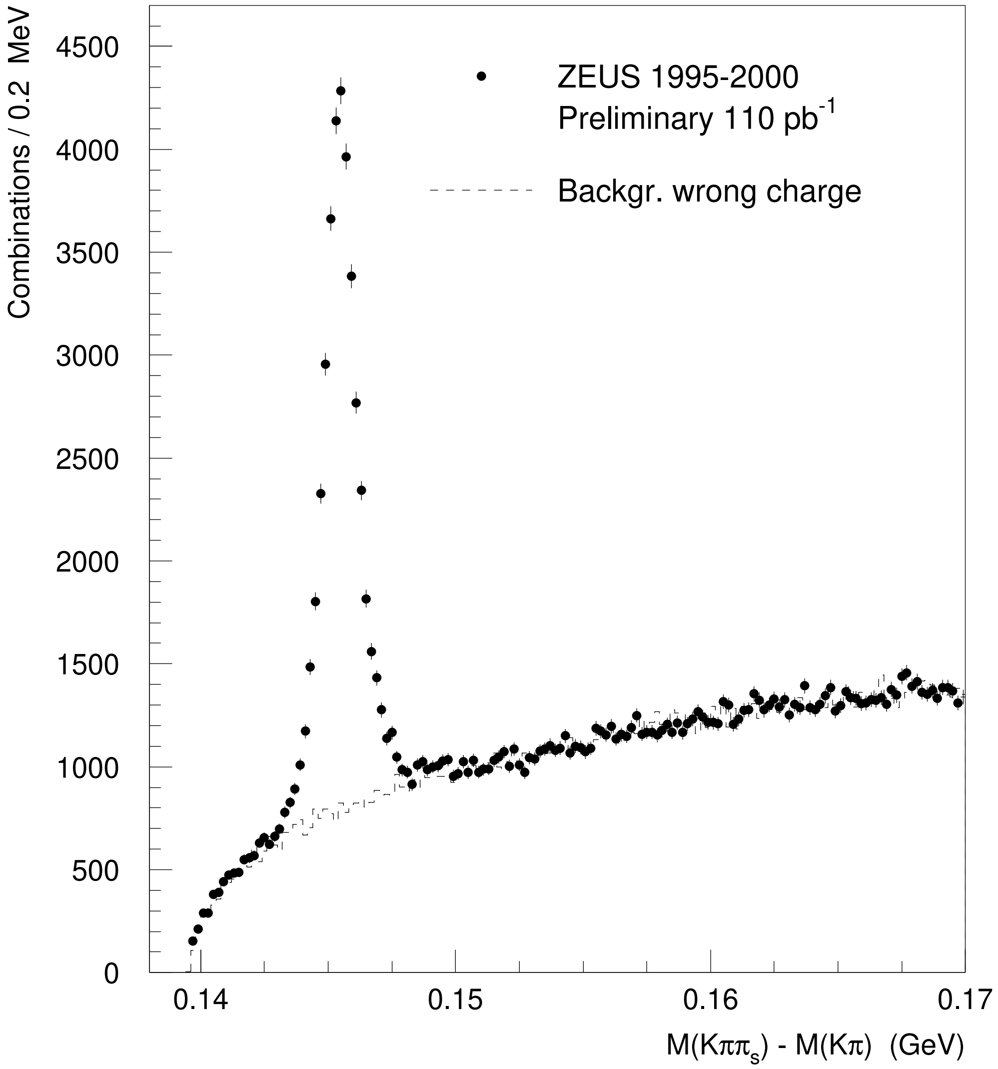
New tests of perturbartive QCD
in ep interactions at $\sqrt{s} = 300...318$ GeV

- Charm production – using $\int \mathcal{L} = 100$ pb^{-1}
- Beauty production – using a vertex detector

Charm as a probe of proton structure:
see E. Tzamariudaki's talk in Session PA 03b

Millions of Charm Quarks

- 27,000 $D^* \to D^0\pi^+ \to K^-\pi^+\pi^+$ decays



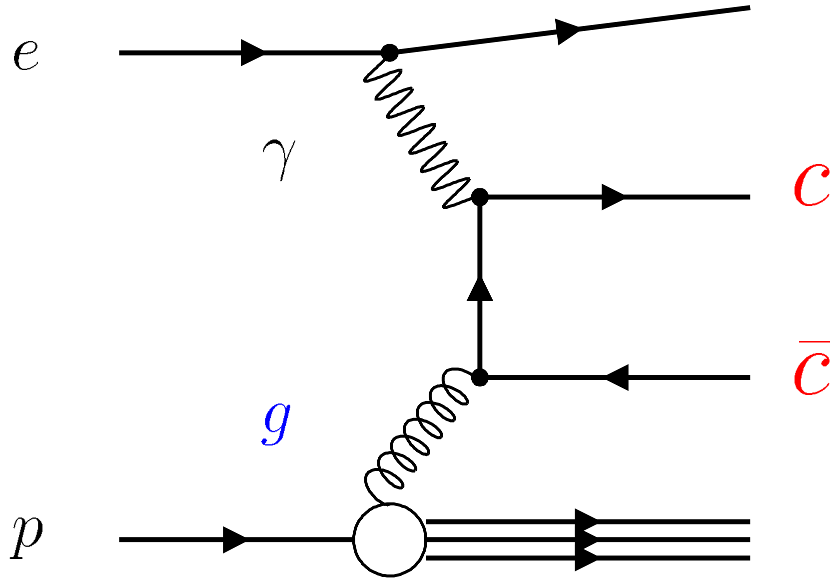
$\rightarrow$ Production at high x_{Bj} and Q^2

(x, Q^2: Deep Inelastic Scattering scaling variables)

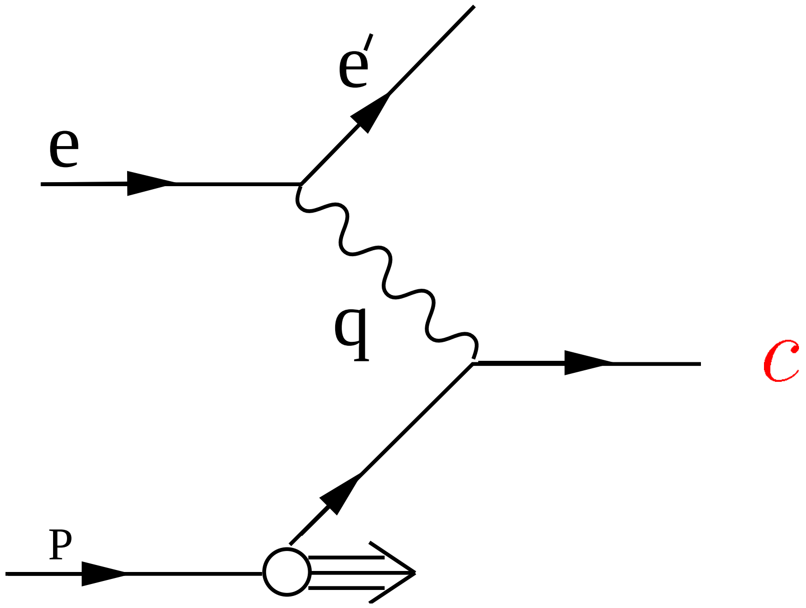
$\rightarrow$ Charm spectroscopy

Charm Production

- At low Q^2: Boson Gluon Fusion



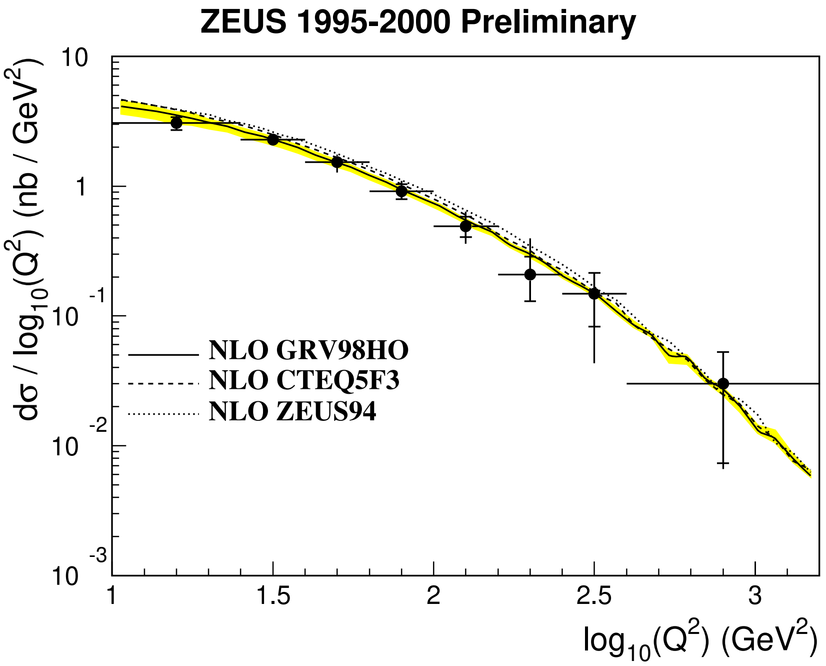
- At higher $Q^2 >> m_c^2$ charm can be treated as active parton in the proton

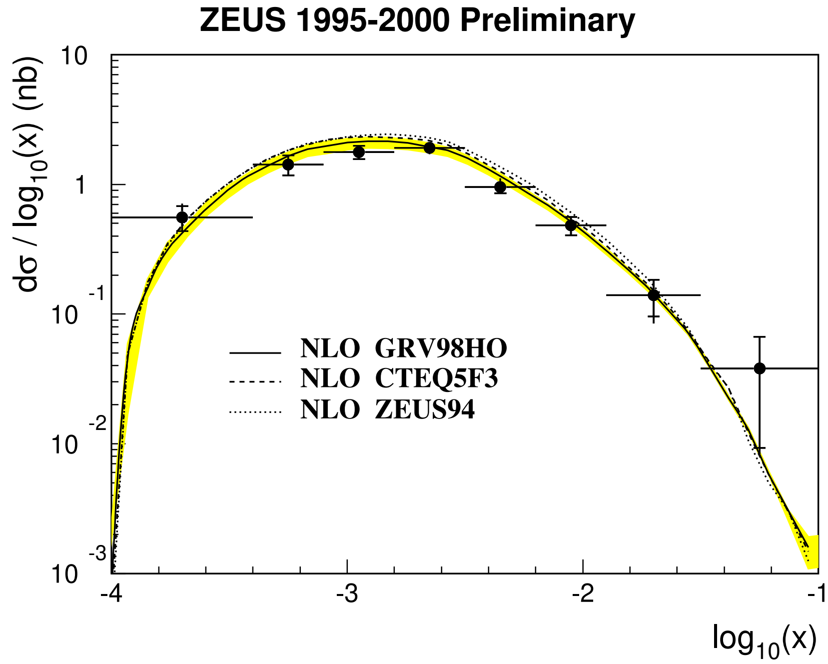


In Variable Flavour Number schemes expect deviations from the Boson Gluon Fuson picture

D^* cross sections in DIS

- Compare with NLO QCD (3 Flavour $\overline{\text{MS}}$ scheme)
  HVQDIS program (Harris & Smith), Peterson fragmentation
- Use gluon density from scaling violations of proton structure function F_2 (shaded: $m_c =$ 1.3 - 1.6 GeV)

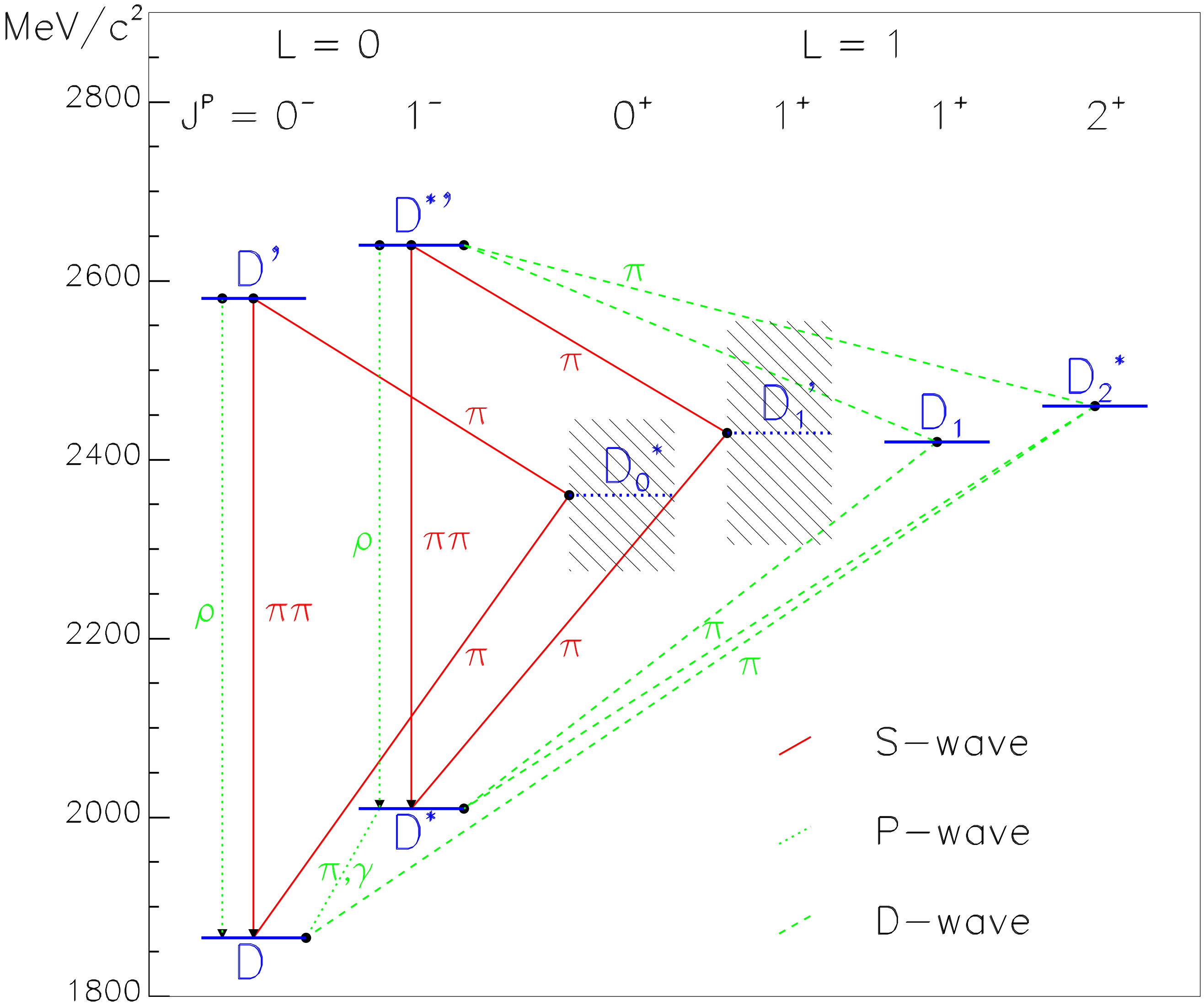




- Good description up to $Q^2 \simeq$ 1000 GeV^2 and $x_{Bj} \simeq$ 0.1
- Need much more luminosity to detect 1% intrinsic charm contribution at high x_{Bj}

D Meson Spectrum

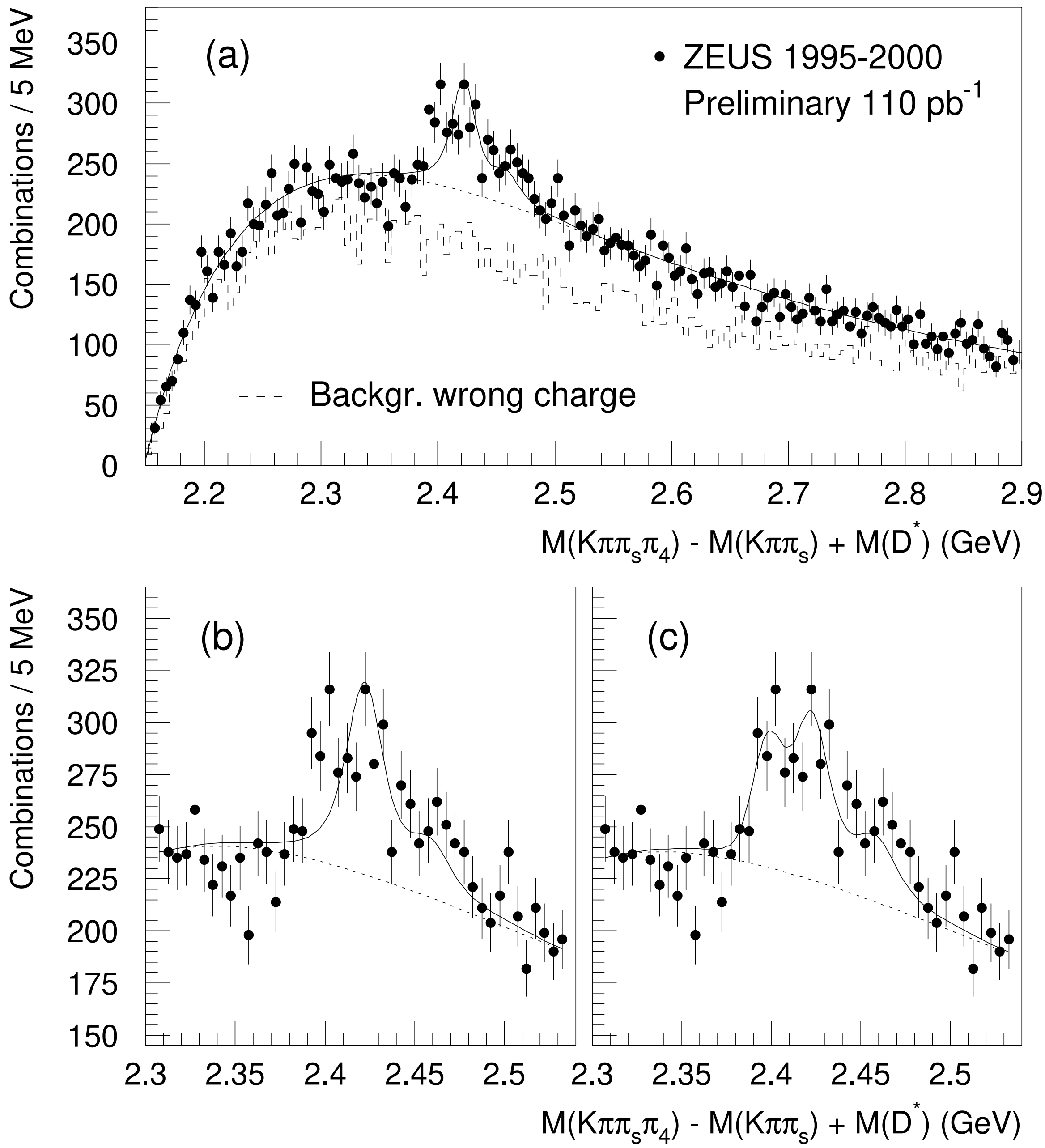
non-strange mesons



- orbital excitations D_1 and D_2^* established
- radial excitation $D^{*\prime}$ seen

Neutral P-wave Mesons D_1^0 and D_2^{*0}

- Reconstruction via $D_J^{(*)0} \rightarrow D^{*+}\pi^- + \text{c.c.}$



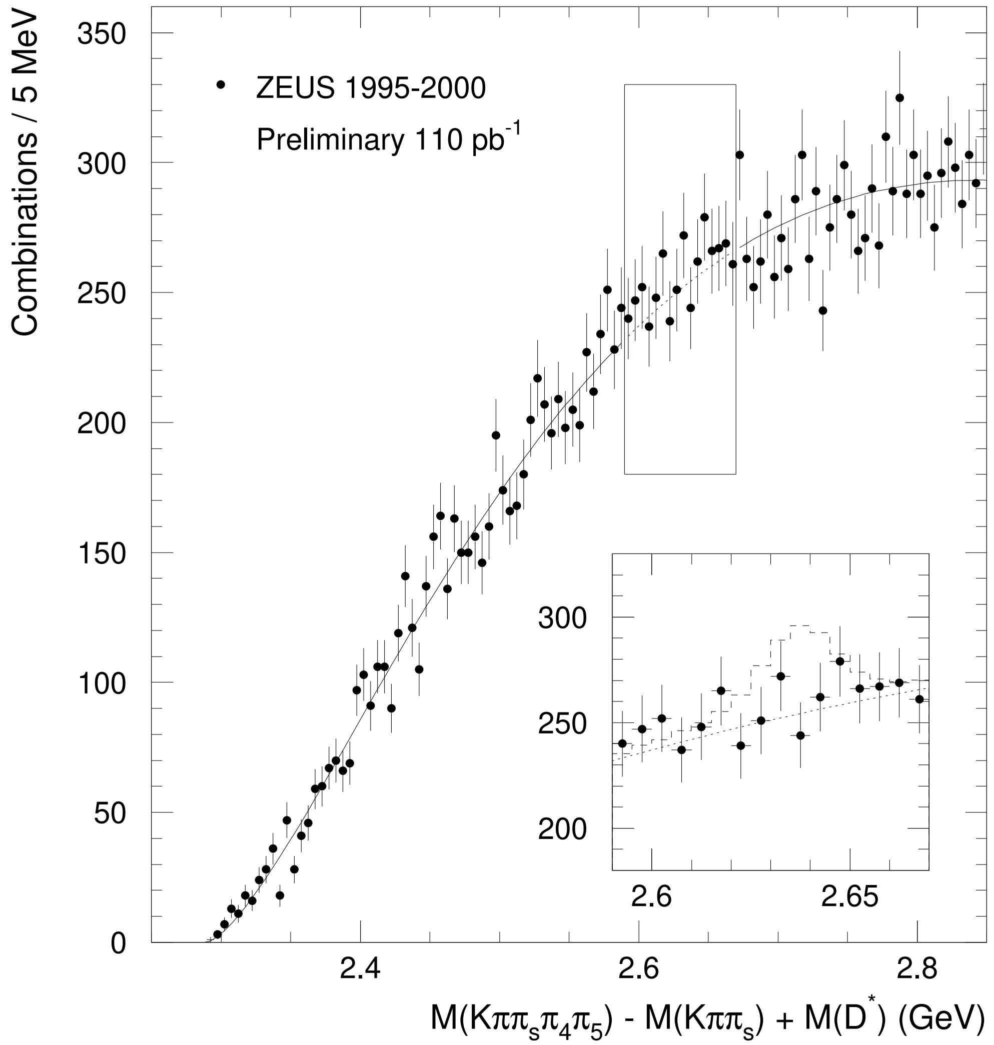
- Fit invariant mass and π helicity angle

  include narrow enhancement at $m(D^*\pi) = 2398$ MeV

- $\frac{D_1^0 \rightarrow D^{*+}\pi^-}{D^{*+}} = 3.40 \pm 0.42\,^{+0.78}_{-0.63}\,\%$
- $\frac{D_2^{*0} \rightarrow D^{*+}\pi^-}{D^{*+}} = 1.37 \pm 0.40\,^{+0.96}_{-0.33}\,\%$

Search for radially excited $D^{*\prime}$

- Reconstruction via $D^{*\prime +} \to D^{*+}\pi^+\pi^-$ + c.c.



91 ± 75 cand.

- $\frac{D^{*\prime +} \to D^{*+}\pi^+\pi^-}{D^{*+}} < 2.3\% \quad (95\%\ C.L.)$

- Compare: $\frac{\langle N_{D^{*\prime +}}\rangle\ \mathrm{BR}(D^{*\prime +} \to D^{*+}\pi^+\pi^-)}{\sum_{J=1,2}\langle N_{D_J^{(*)0}}\rangle\ \mathrm{BR}(D_J^{(*)0} \to D^{*+}\pi^-)}$

  $= 0.49 \pm 0.18 \pm 0.10$ (DELPHI)
  $< 0.21 \quad (95\ \% C.L.)$ (OPAL)
  $< 0.16 \quad (95\ \% C.L.)$ (CLEO)

- $f(c \to D^{*\prime +}) \cdot \mathrm{BR}(D^{*\prime +} \to D^{*+}\pi^+\pi^-)$
  $< 0.7\% \quad (95\%\ C.L.)$
  $< 1.2\% \quad (95\%\ C.L.)$ (OPAL)

Open Charm Production:

- Thanks to the excellent HERA performance : strong increase in statistics
- NLO QCD in the 3 flavour scheme describes DIS charm cross sections up to high x_{Bj} and Q^2
- First charm spectroscopy results: orbitally excited D mesons seen; radial excitations not

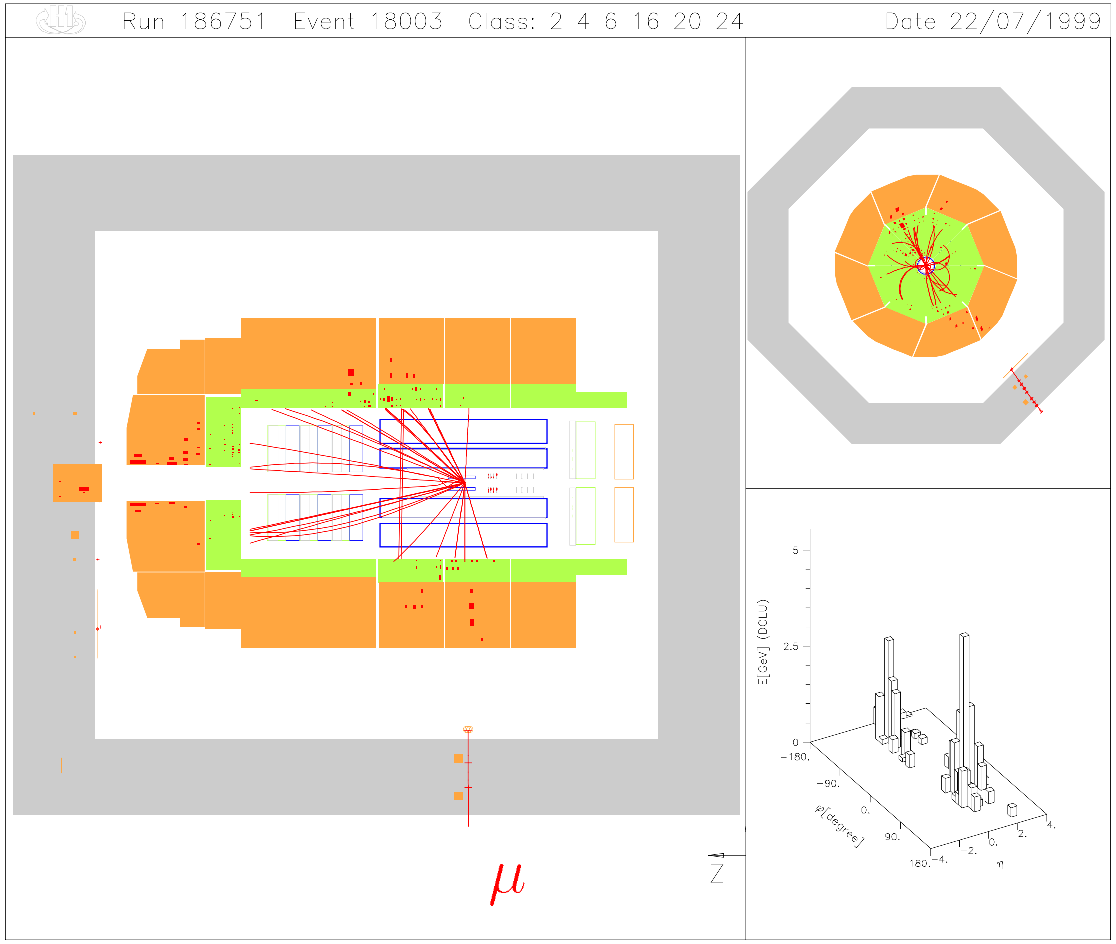
Signatures of Beauty

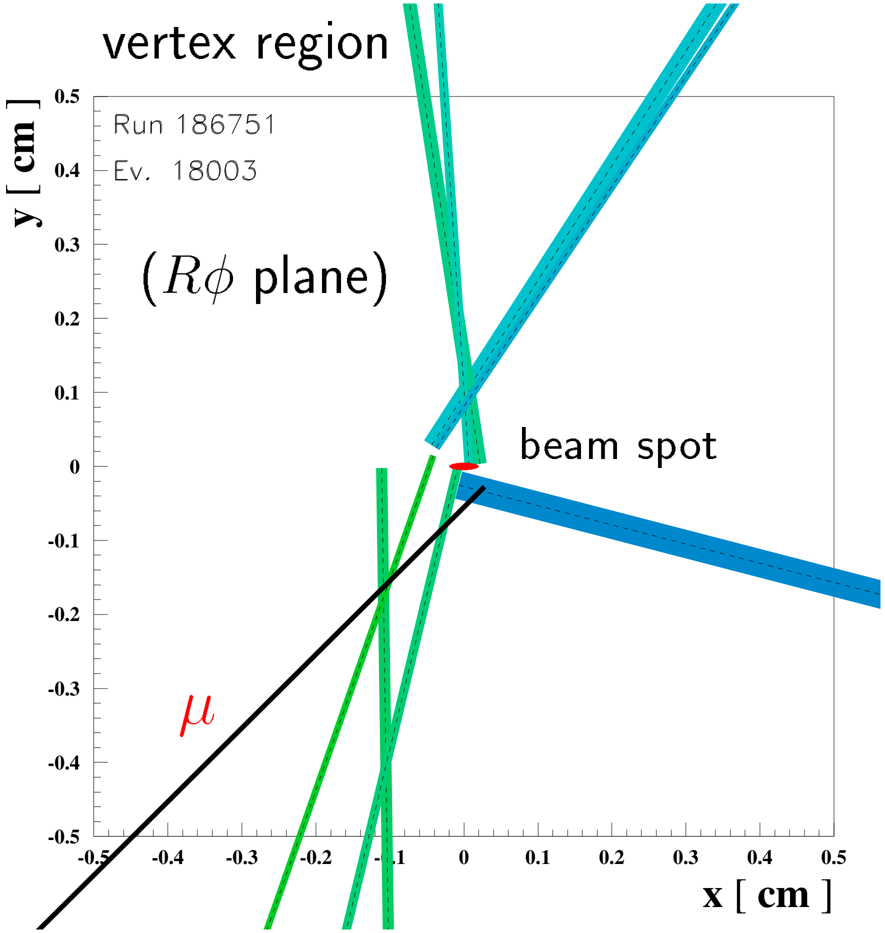
1. Mass

$\rightarrow$ rel. transverse momentum p_T^{rel}

2. Lifetime

$\rightarrow$ impact parameter δ

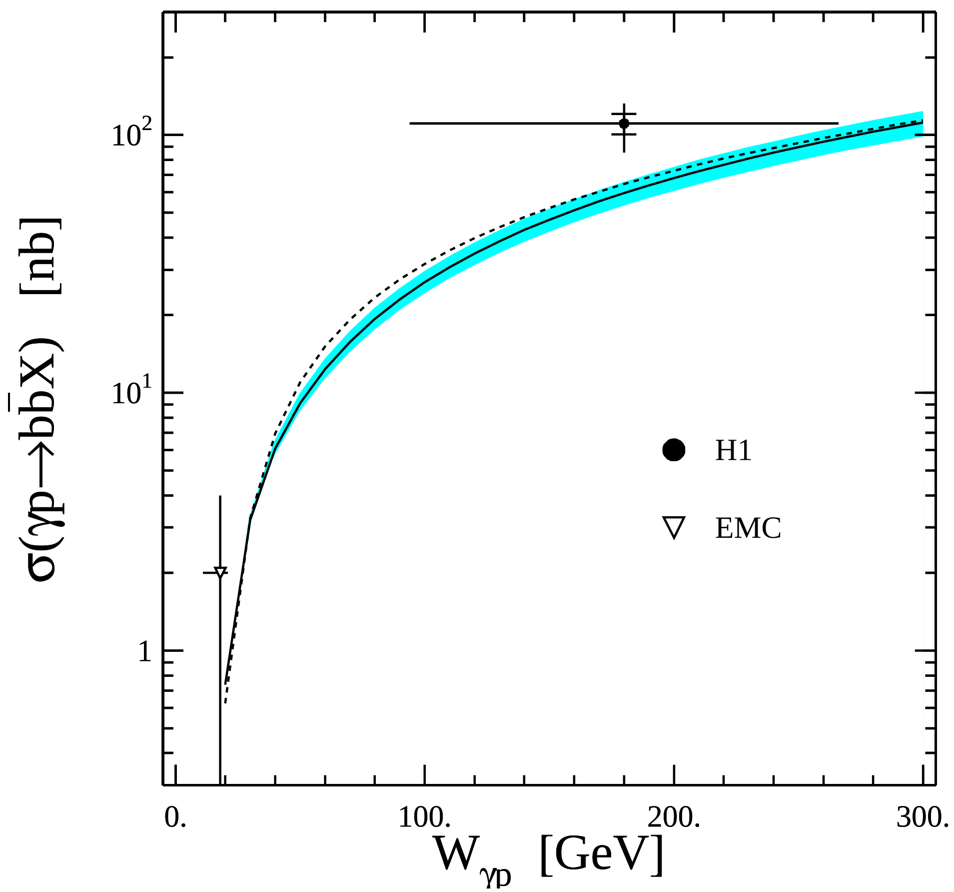




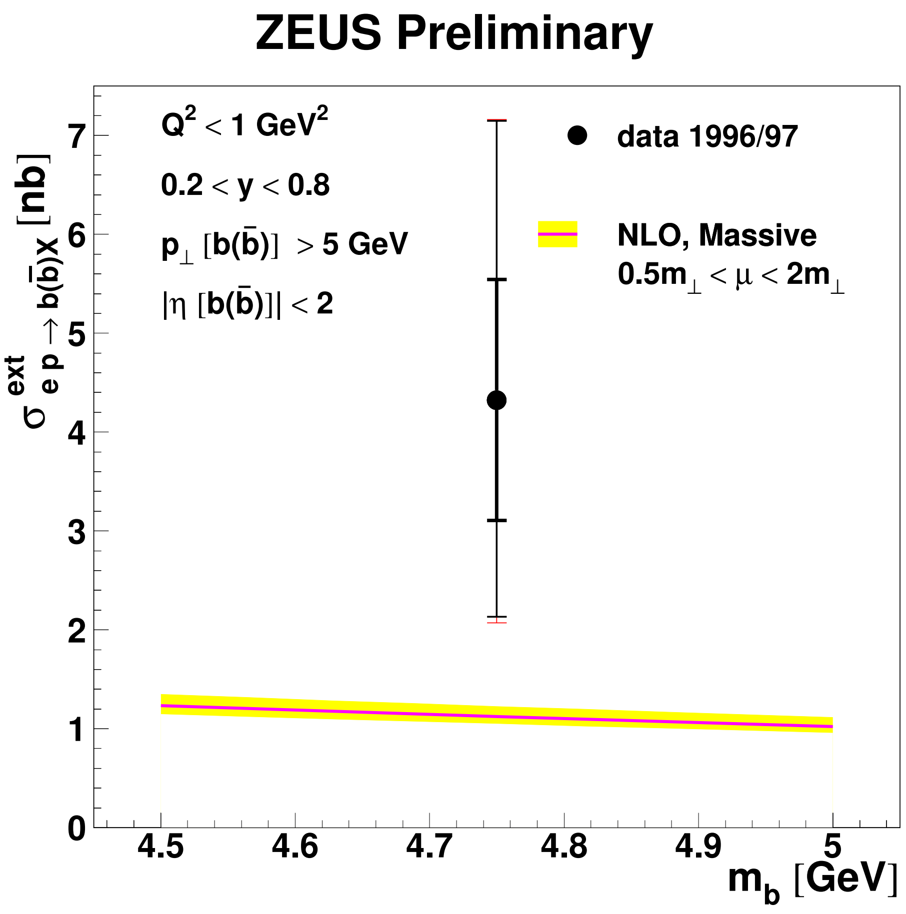
b coss section at HERA vs. NLO QCD

- Measurements using p_T^{rel}

- H1 (μ channel)

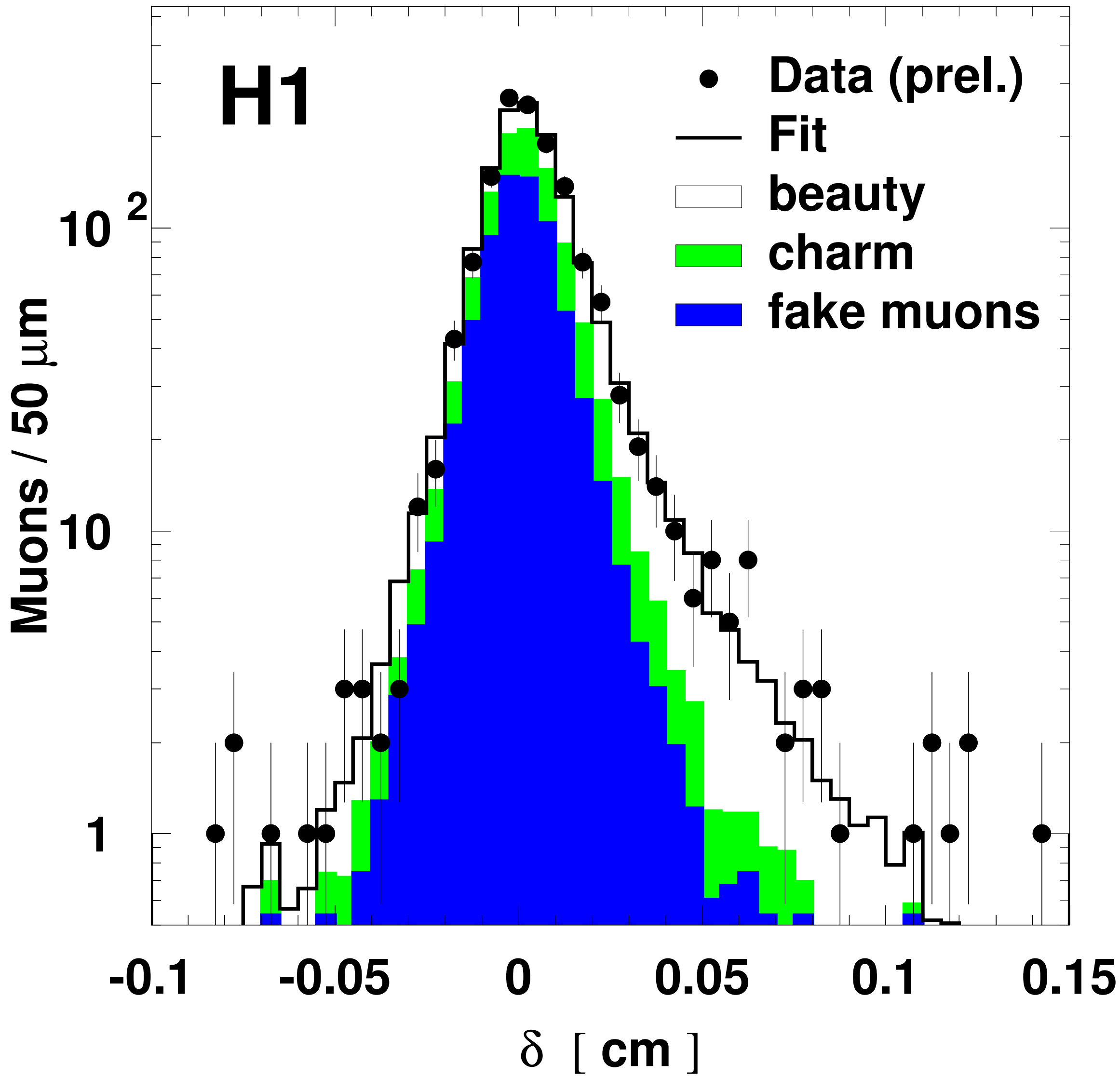


- ZEUS (e channel)



b production: impact parameter

- Photoproduction, ≥ 2 jets $E_T > 5$ GeV, $\geq 1\ \mu$ in 2 layer silicon vertex detector



- Likelihood fit: $f_b = 26 \pm 5\ \%$
- Cross section in kinematic range

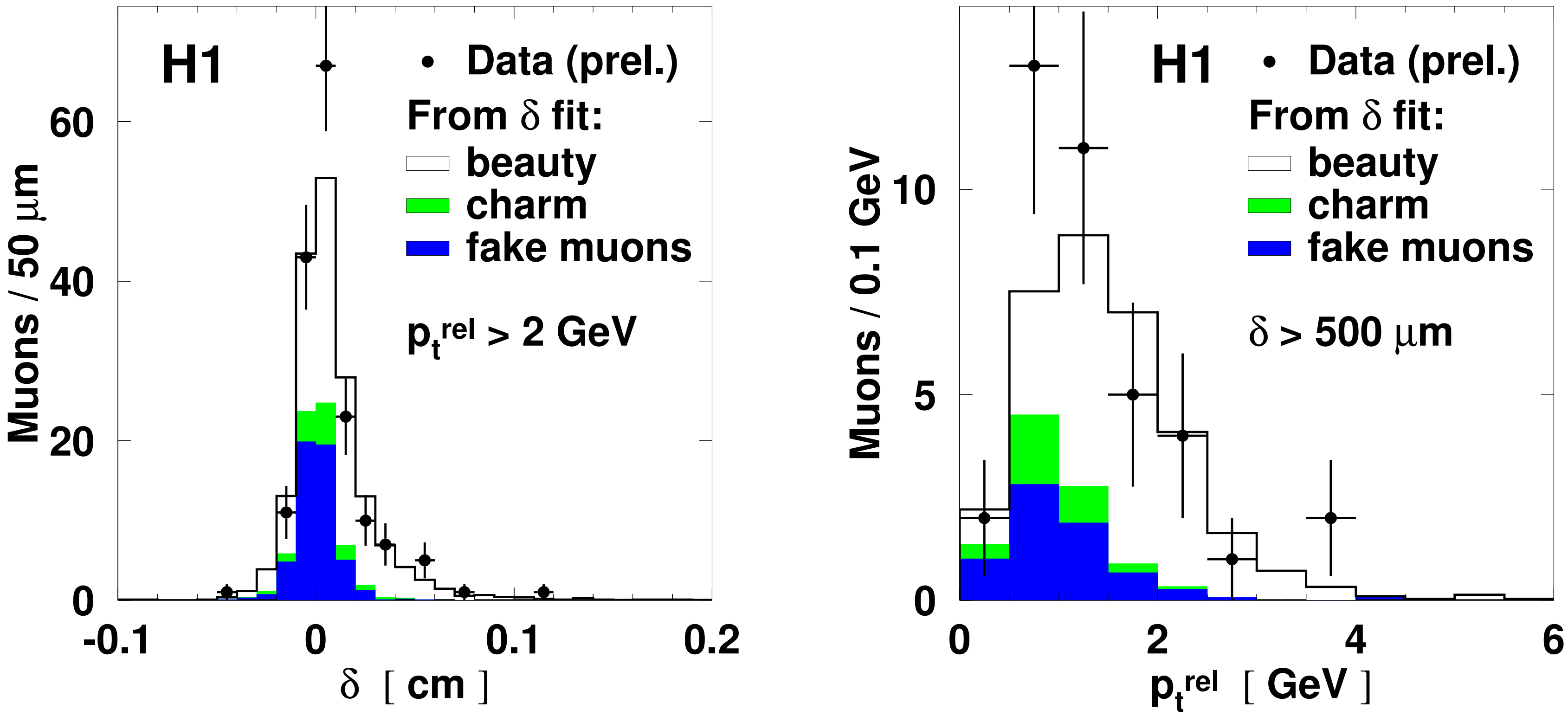
  $Q^2 < 1$ GeV^2, $0.1 < y < 0.8$, $p_T(\mu) > 2$ GeV, $35^\circ < \theta(\mu) < 130^\circ$

  $\sigma_{vis}(ep \to b\bar{b}X \to \mu X) =$

  $[159\ \pm\ 30\ (stat.)\ \ \pm 29\ (syst.)\ ]$ pb
- Confirms published H1 result $(176 \pm 16\ ^{+27}_{-17})$ **pb**

b production: combine impact parameter δ and p_T^{rel}

- High b purity regions



- Combined likelihood fit in (δ, p_T^{rel}) plane:

  $\sigma_{vis}(ep \to b\bar{b}X \to \mu X) = [160 \ \pm \ 16\,(stat.) \ \pm 29\,(syst.)\,]$ pb

- Average with publ. H1 result: $\sigma_{vis} = (170 \pm 25)$ pb
- NLO QCD (3 Flavour): $\sigma_{vis} = (104 \pm 17)$ pb

Open Beauty Production:

- First b cross section measurement confirmed with lifetime based method
- Exceess over NLO QCD established

Conclusion:

With plenty of Charm
and long-lived Beauty:

HERA

takes another step forward in precision
to probe the strong interactions