9th International Workshop on Deep Inelastic Scattering

Bologna, April 27th – May 1st 2001

Open Beauty Production at HERA

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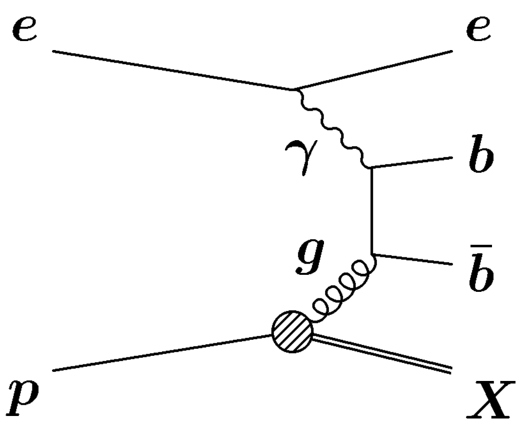
on behalf of the
H1 and ZEUS collaborations

Cross section measurements
in photoproduction and DIS

Production of Open Beauty at HERA



- necessary ingredient to **understand proton structure**

- b mass provides hard scale, i.e. good **testing ground for pQCD**

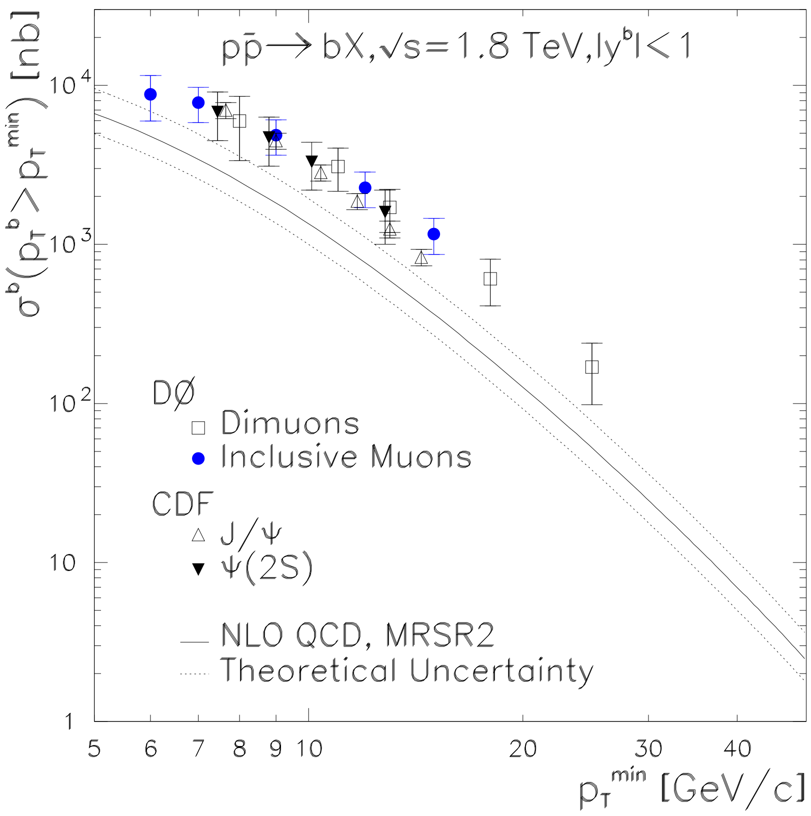
QCD calculations available in NLO
$p_t \approx m_b \rightarrow$ **'massive' approach**
(b produced dynamically in hard subprocess)

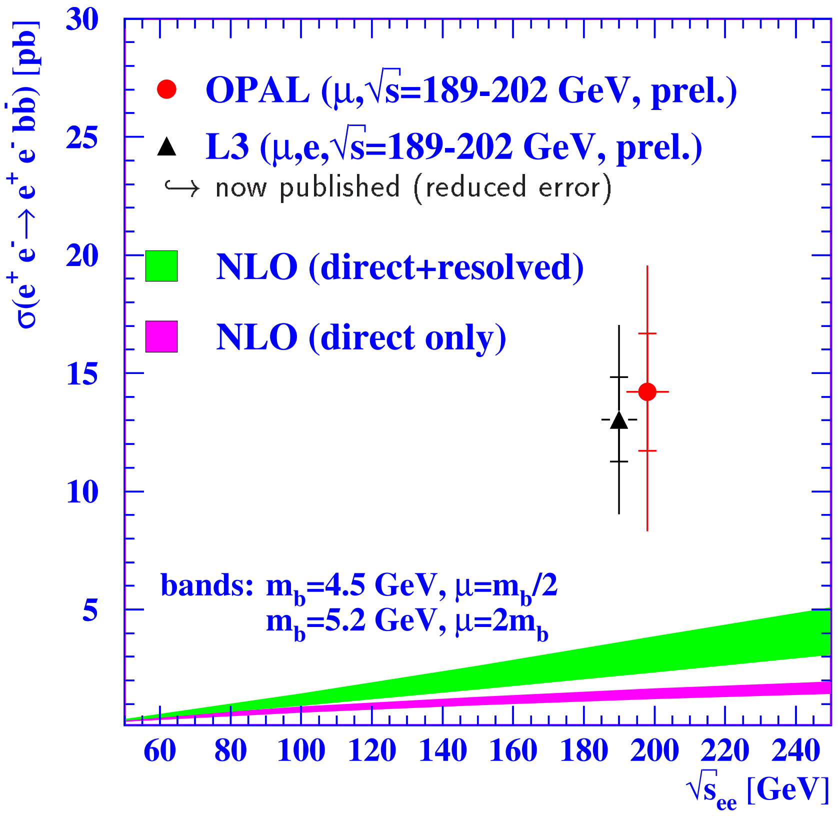
- γp: **'FMNR'** (Frixione et al.)

- **DIS:** **'HVQDIS'** (Harris, Smith)

NLO corrections large in both cases

Beauty Production at TEVATRON and LEP

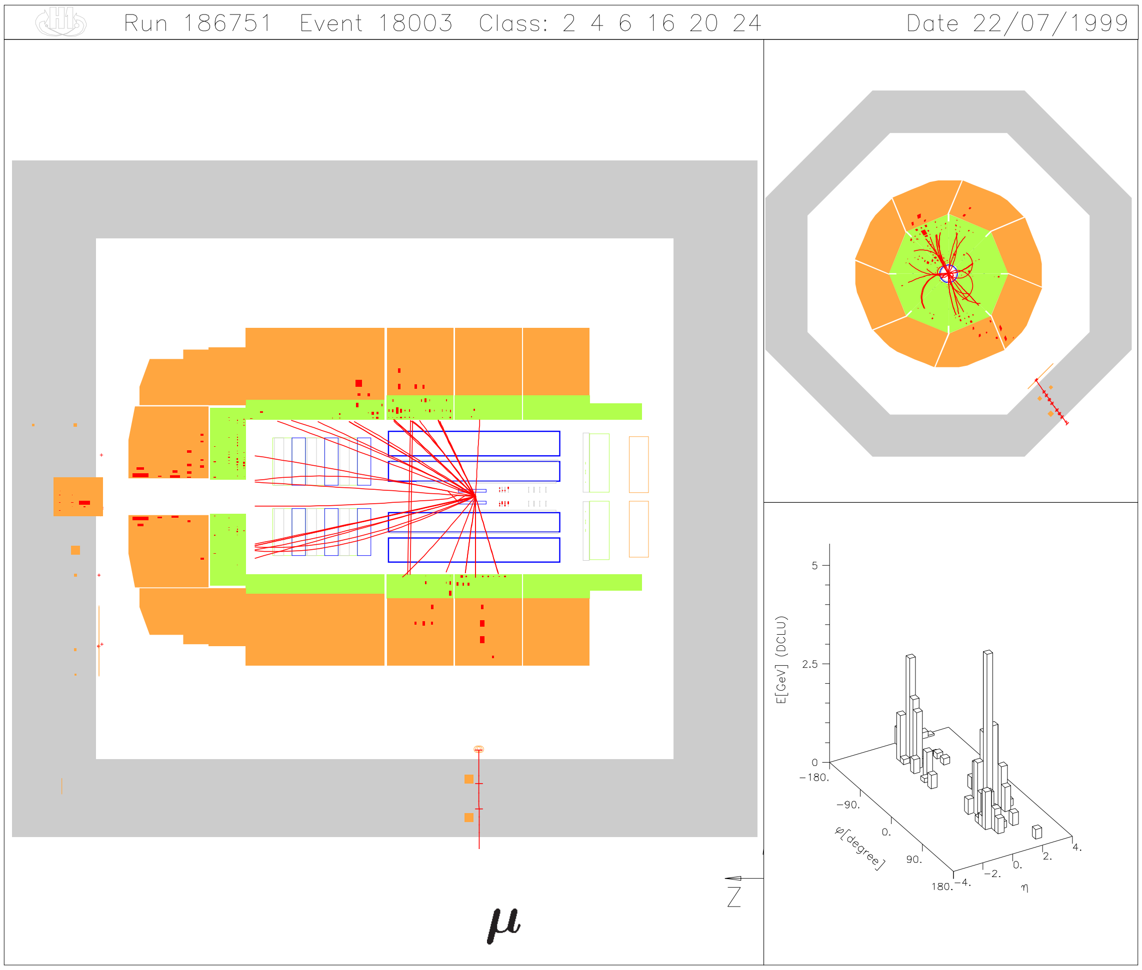




Semi-leptonic Decay

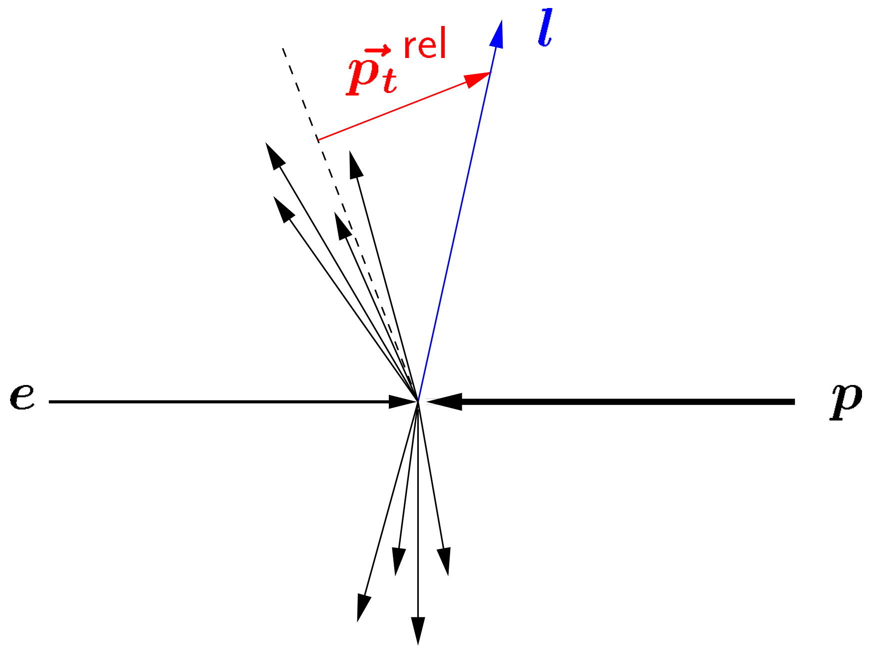
- **branching ratio** $\approx 10\%$
- clear **experimental starting point**:

  $\rightarrow$ dijet events with high p_t lepton



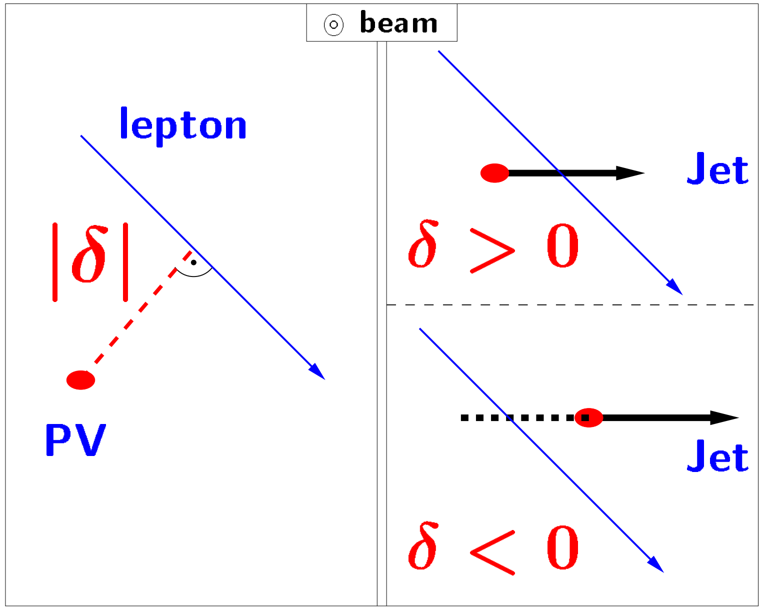
Beauty Signatures and Observables

mass lepton p_t w.r.t. jet



→ **ZEUS, H1**

lifetime impact parameter



→ **H1 (vertex detector)**

ZEUS Electron Analysis (γp)

$$\boxed{e^+p \rightarrow e^+ + \textbf{dijet} + e^- + X}$$

$Q^2 < 1\ \mathrm{GeV}^2$, $0.2 < y < 0.8$

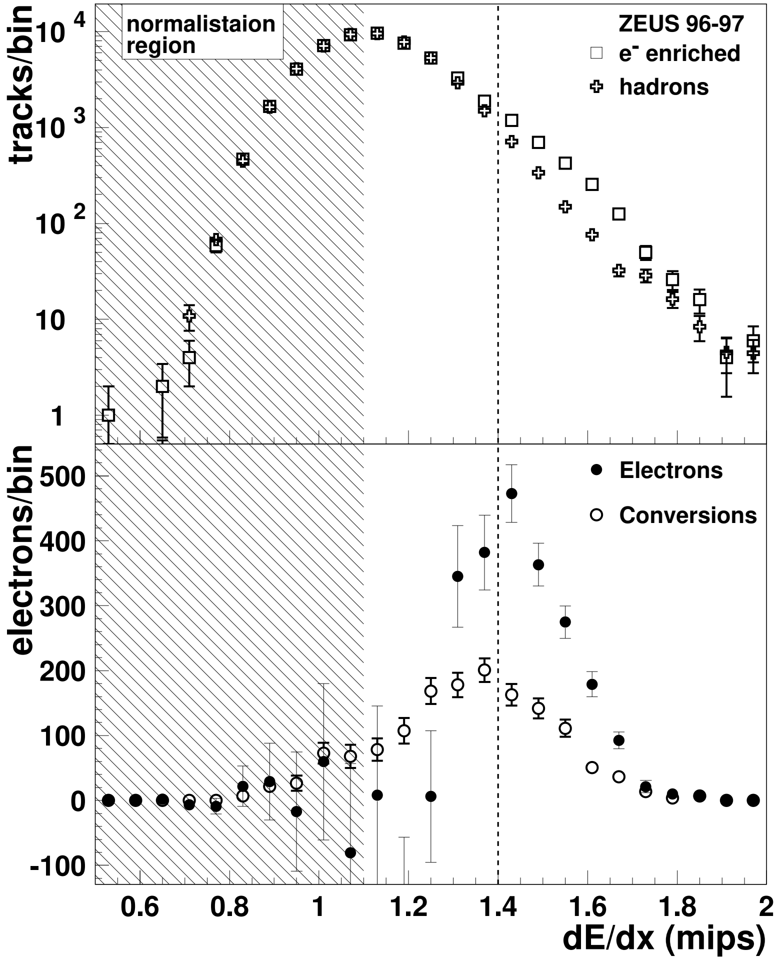
$E_t^{\mathrm{jet}1(2)} > 7(6)\mathrm{GeV}$, $|\eta^{\mathrm{jet}}| < 2.4$

$p_t^{e-} > 1.6\mathrm{GeV}$, $|\eta^{e-}| < 1.1$

electron selection (calorimeter + CTD):

- statistical substraction of hadronic background via dE/dx
- explicit rejection of background from photon conversion and Dalitz decays

$\boxed{(943 \pm 69)\ e^-\ \text{in}\ 38.5\ \mathrm{pb}^{-1}}$ (1996/97)

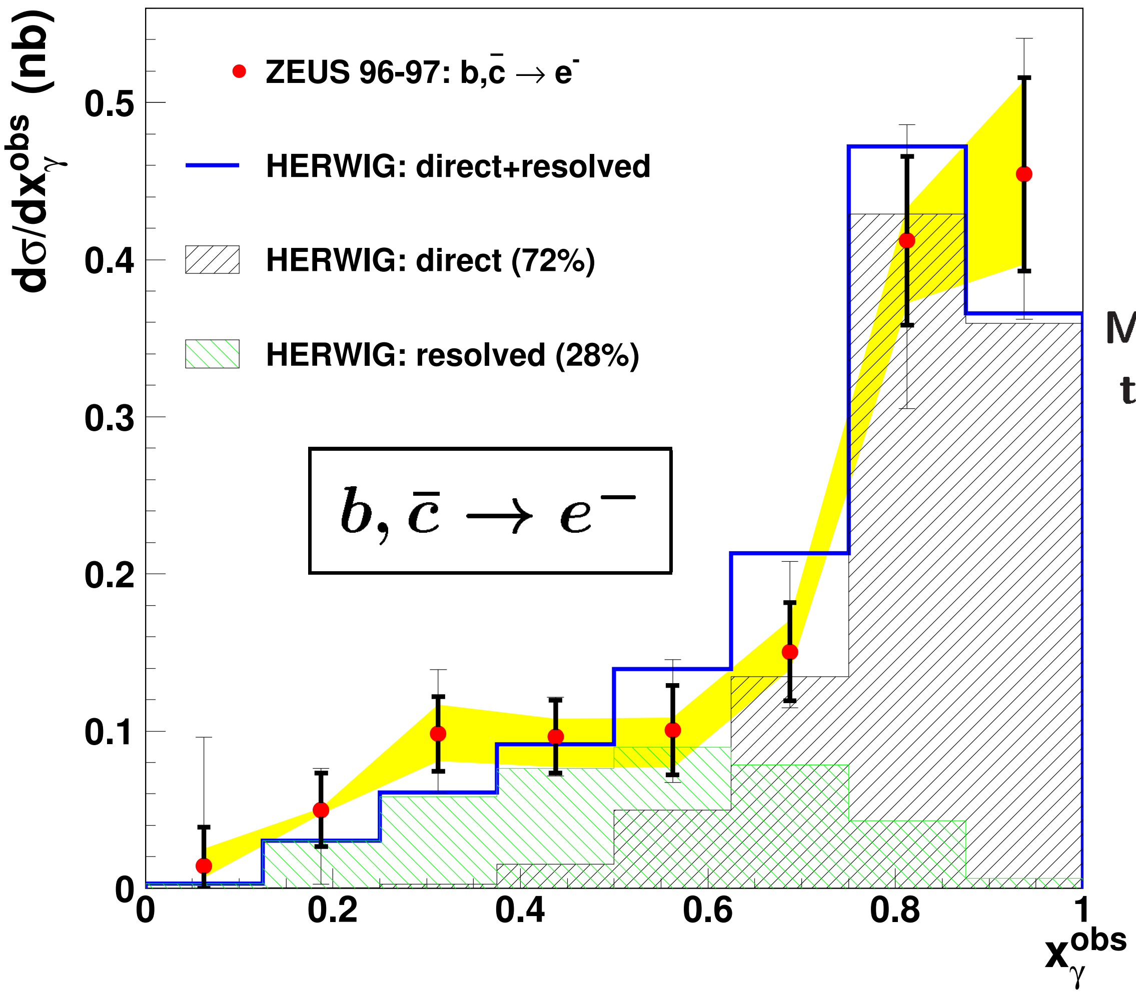


Resolved γ in Heavy Quark Production

$$x_\gamma = \frac{\sum_{\text{jet }1,2} E_\perp^j e^{-\eta^j}}{2yE_e}$$

$\ll 1 \leftarrow$ $\rightarrow \approx 1$

resolved γ direct processes



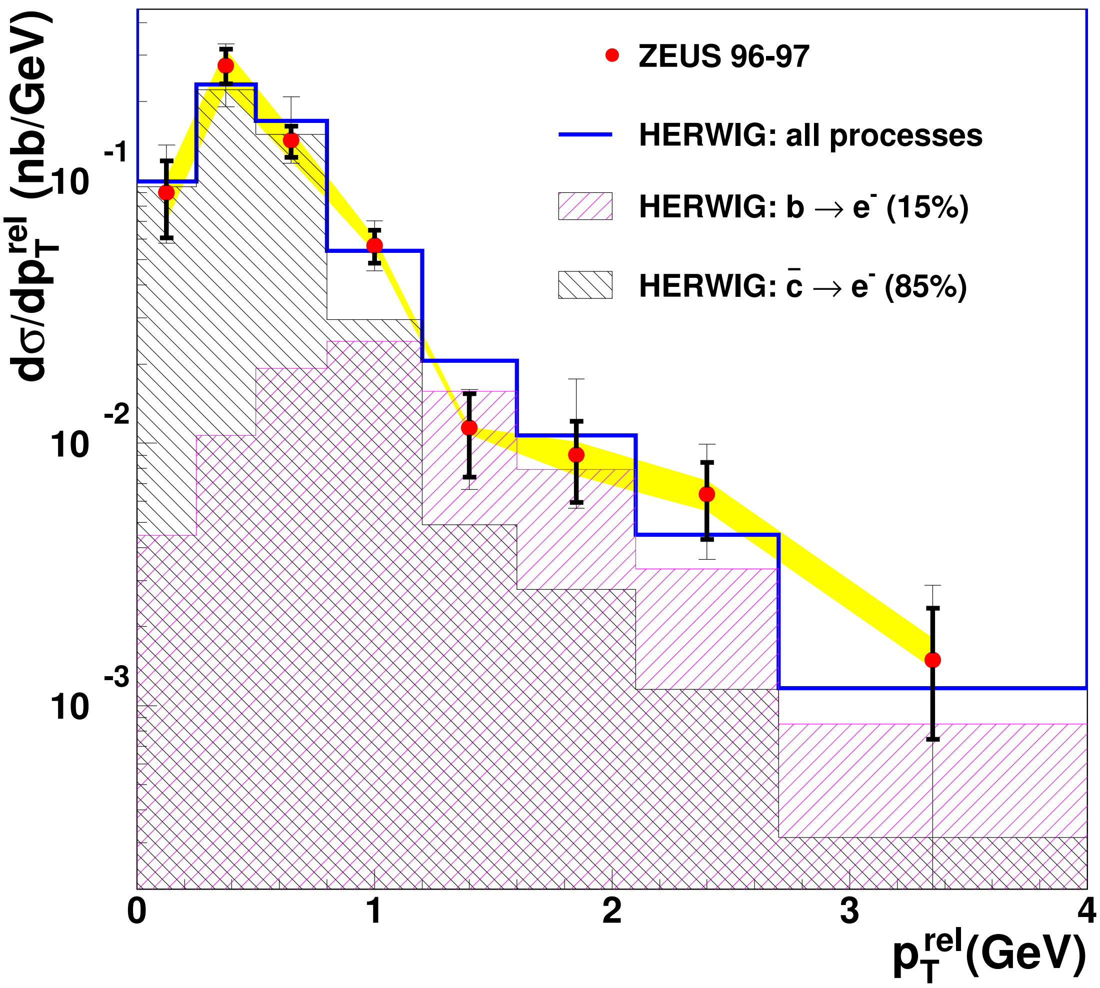
MC norm. to data

x_γ **fit** $\rightarrow$ resolved contribution : $\boxed{(28 \pm 5(stat.))\ \%}$

(incl. flavour excitation)

(HERWIG prediction : 35%)

Visible Beauty Cross Section



- min. χ^2 **fit to e^- p_t^{rel} spectrum**

  $\rightarrow$ b **contribution** $f_b = [14.7 \pm 3.8(stat.)]$ %

- b **cross section in visible range** (Q^2, y, e^-, jets)

$$\boxed{\sigma^{b\rightarrow e^-}_{e^+p\rightarrow e^+ + \mathrm{dijet} + e^- + X} = 24.9 \pm 6.4^{+4.2}_{-7.3}\ \mathrm{pb}}$$

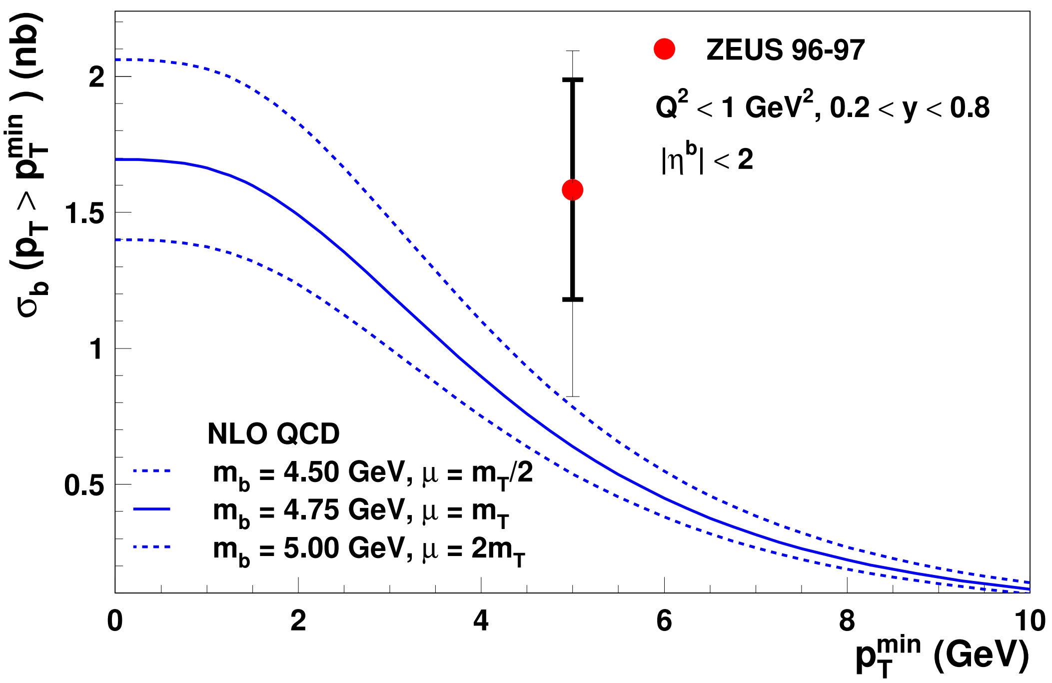
Parton Level Cross Section

- **extrapolation to the parton level** for the region

$p_T^b > p_T^{\min} = 5$ GeV, $|\eta^b| < 2$, $Q^2 < 1\mathrm{GeV}^2$, $0.2 < y < 0.8$:

$$\boxed{\sigma^{\mathrm{ext}}_{ep\to e^+bX} = 1.6 \pm 0.4(stat.)^{+0.3}_{-0.5}(syst.)^{+0.2}_{-0.4}(ext.)\ \text{nb}}$$

[somewhat **above NLO QCD (FMNR)**]



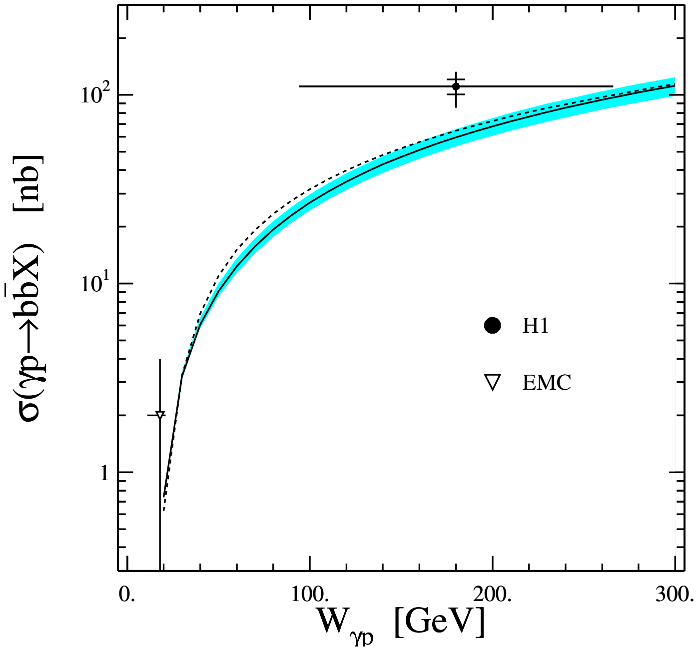
NB: Also earlier preliminary ZEUS results in the

μ **channel** ; consistent with e analysis.

H1 Photoproduction Analyses

H1 publication:

muon p_t^{rel} analysis in γp; 1996 data



(first observation of open beauty at HERA)

Now:

new data, new tools

(vertex detector CST operational since 1997)

similar selection

≥ 1 μ: $p_t > 2$ GeV , $35° < \theta < 130°$

≥ 2 jets: $E_t > 5$ GeV , $10° < \theta < 170°$

on **same kinematic region**

γp: $Q^2 < 1\ \mathrm{GeV}^2$, $0.1 < y < 0.8$

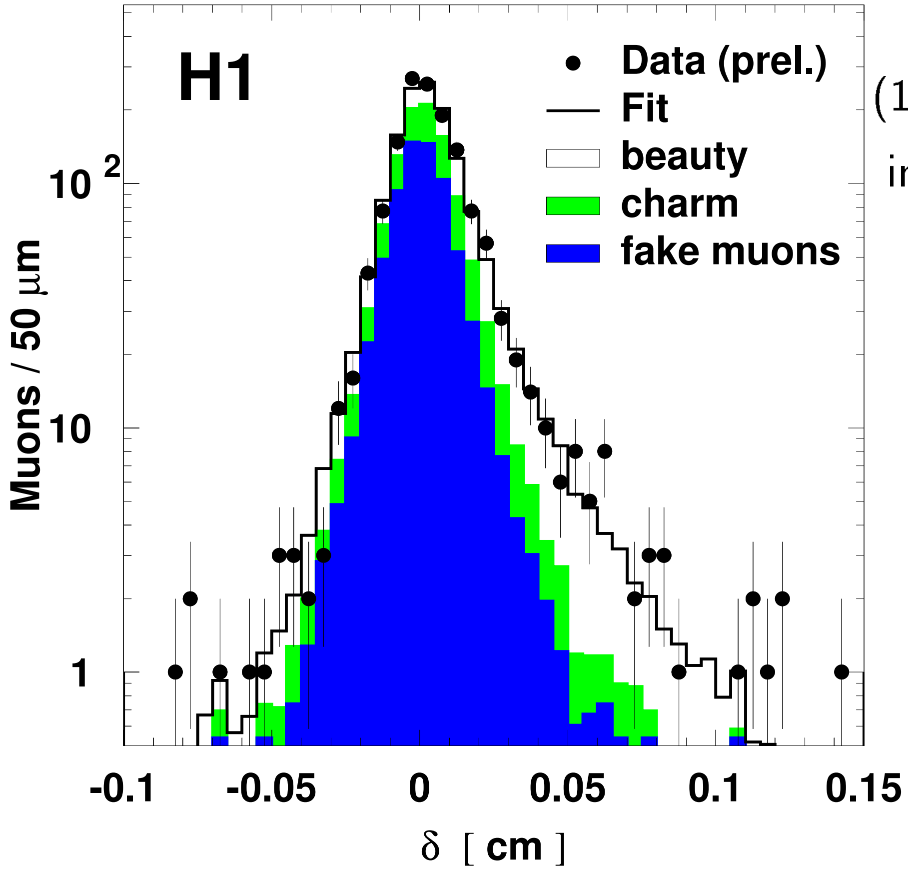
using **independent data set** (1997 data)

$\to$ **establish lifetime method**

$\to$ **get improved measurement**

γp Lifetime Analysis

likelihood fit to μ impact parameter spectrum:



(1415 μ cand. in 15 pb^{-1})

$\rightarrow$ **beauty contribution** $f_b = (26 \pm 5)\%$

$ep \rightarrow b\bar{b}X \rightarrow \mu X'$ **cross section in visible range**

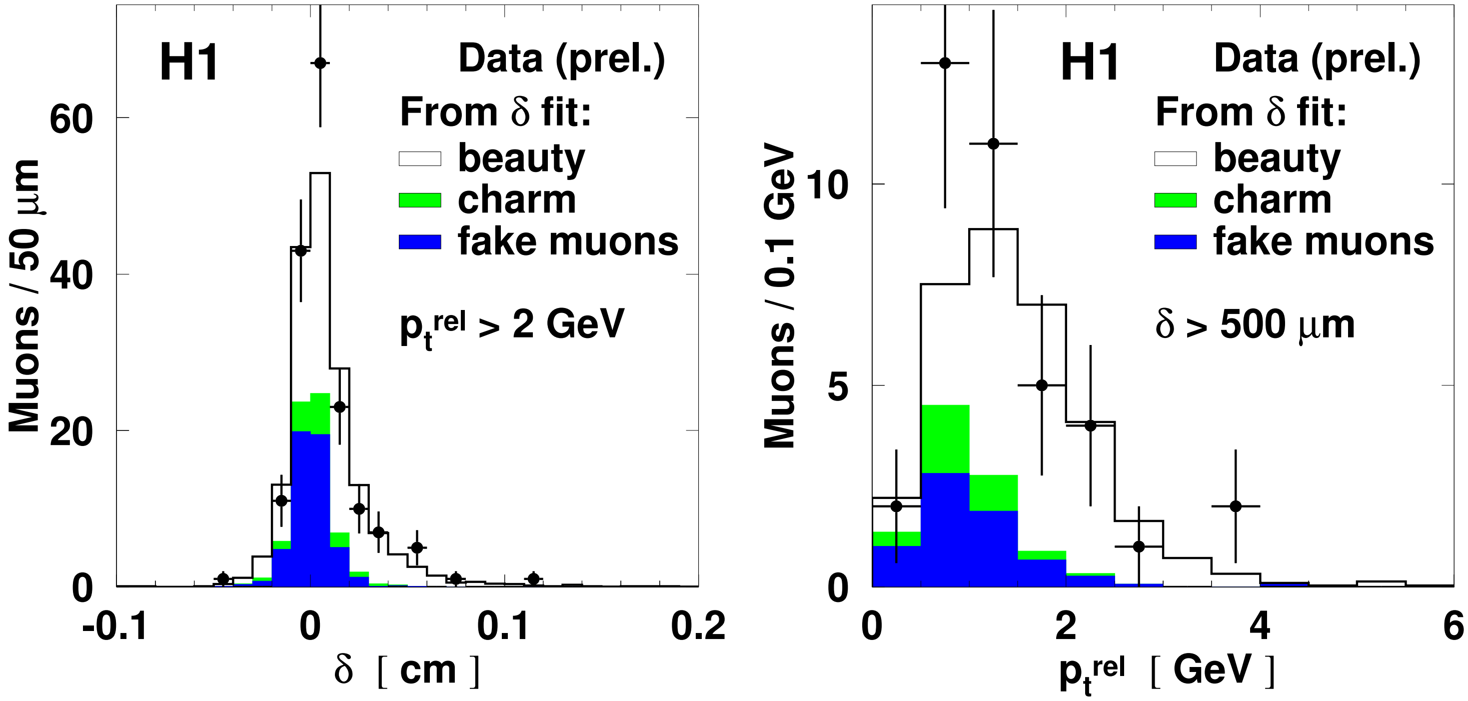
$Q^2 < 1$ GeV^2, $0.1 < y < 0.8$; $p_t(\mu) > 2$ GeV, $35° < \theta(\mu) < 130°$:

$$\boxed{\sigma_{vis} = [159\ \pm\ 30\ (stat.)\ \pm 29\ (syst.)\ ]\ \mathrm{pb}}$$

[confirms publ. H1 result $(176\ \pm\ 16\ ^{+27}_{-17}\ )$ pb]

γp Combined (δ, p_t^{rel}) Analysis

- **establish consistency**, e.g. in high purity regions:



- **combined** (δ, p_t^{rel}) **fit** $\rightarrow$ $f_b = (27 \pm 3)\%$

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

combine with publ. result $\rightarrow$ $\boxed{\sigma_{vis}^{\text{comb.}} = (170 \pm 25)\ \text{pb}}$

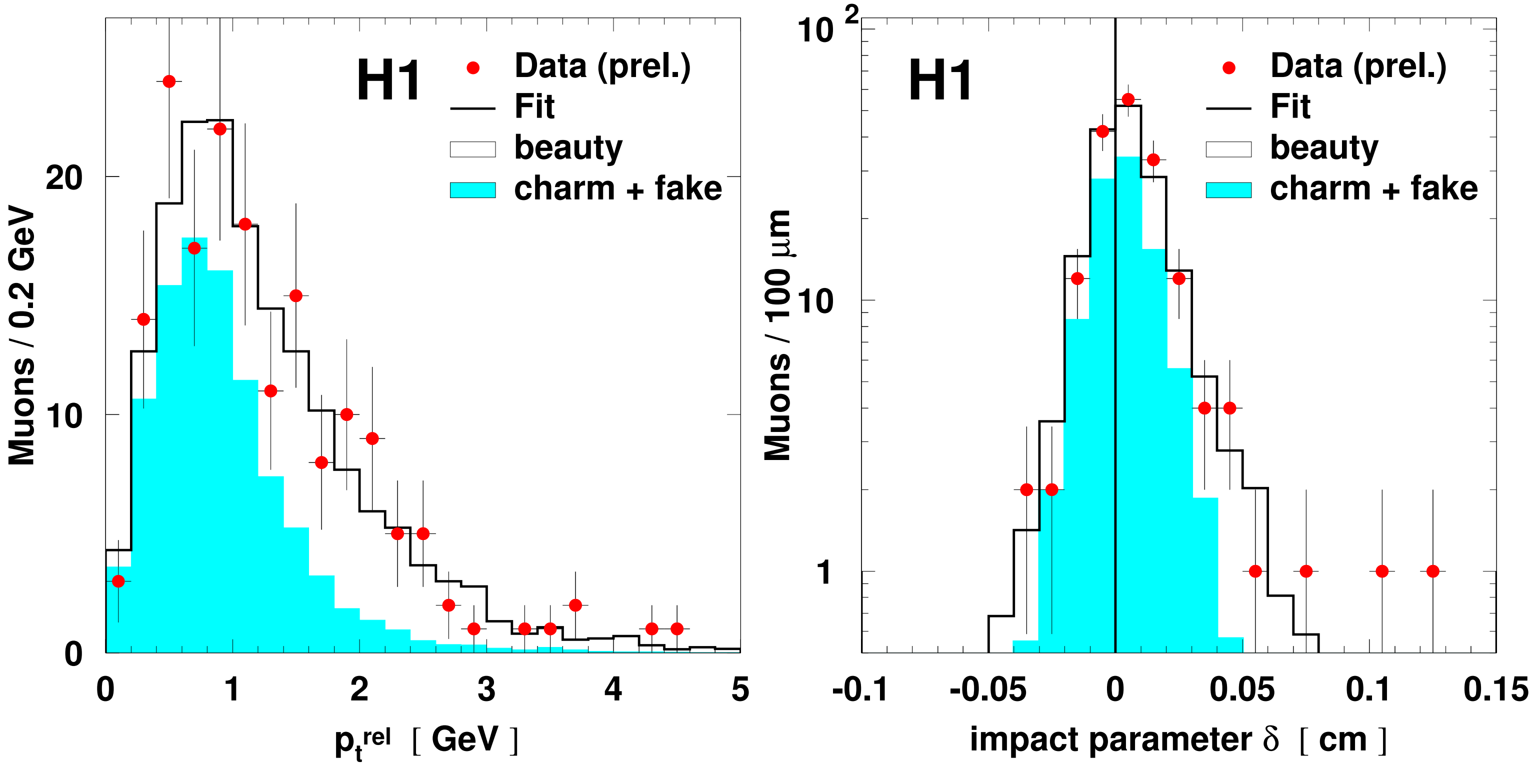
NLO QCD prediction: $\boxed{\sigma_{vis}^{NLO} = (104 \pm 17)\ \text{pb}}$

First Measurement of Open Beauty in DIS

$2\ \mathrm{GeV}^2 < \mathrm{Q}^2 < 100\ \mathrm{GeV}^2$, $0.05 < y < 0.7$ (+ jets, μ as in γp analysis)

171 μ cand.

in 11 pb^{-1}



combined (δ, p_t^{rel}) fit $\rightarrow$ $\boxed{f_b = (43 \pm 8)\%}$

Visible DIS Cross Section

$ep \to b\bar{b}eX \to \mu X'$ **cross section in visible range:**

$$2\ \mathrm{GeV}^2 < \mathrm{Q}^2 < 100\ \mathrm{GeV}^2,\ 0.05 < y < 0.7$$

$$p_t^\mu > 2\ \mathrm{GeV}\ ,\ 35^\circ < \theta^\mu < 130^\circ$$

$$\boxed{\boldsymbol{\sigma_{vis} = [39\ \pm\ 8\ (stat.)\ \pm 10\ (syst.)\ ]\ \mathrm{pb}}}$$

NLO QCD prediction (HVQDIS):

$$\boxed{\boldsymbol{\sigma_{vis}^{NLO} = (11 \pm 2)}\ \mathrm{pb}}$$

LO MC predictions:

AROMA (DGLAP evolution) : $\sigma_{vis} = 9$ pb

CASCADE (CCFM evolution): $\sigma_{vis} = 15$ pb

Summary

Open beauty measurements at HERA using new data and new methods

- γp results confirmed and improved
- DIS cross section measured for the first time

NLO QCD predictions undershoot measured cross sections

- discrepancy theory $\leftrightarrow$ data further established
- now seen in ep, γp, $\gamma\gamma$ and $p\bar{p}$ interactions