

Intern. Conference on the Structure and Interactions of the Photon



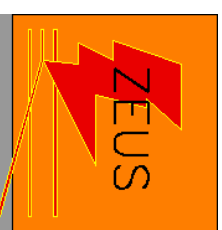
Frascati, 7-11 April 2003

Beauty in ep Collisions

Jürgen Kroseberg (Universität Zürich)



on behalf of the
H1 and ZEUS
collaborations

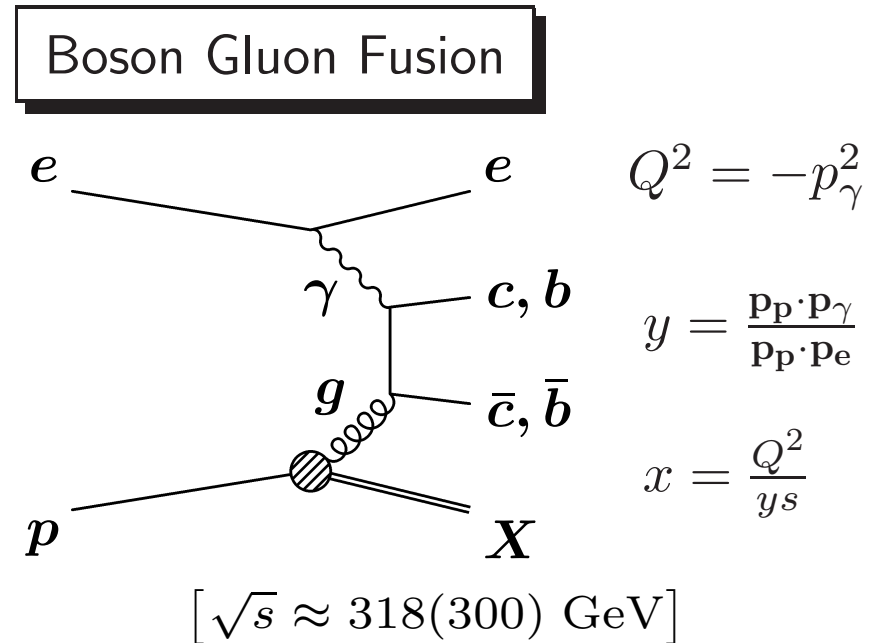


Open beauty measurements in photoproduction
and deep inelastic scattering at HERA



Open Heavy Flavour Production at HERA

- quark mass provides hard scale:
good **testing ground for pQCD**
- gives insight into **proton and photon structure**
- dominantly **gluon induced**
- **photoproduction dominates**
($Q^2 \approx 0$) over DIS ($Q^2 \gg 0$).
- **b production** is heavily **suppressed**:



$$\sigma_b : \sigma_c : \sigma_{uds} \approx 1 : 200 : 2000$$

Modelling Beauty Production

$$\sigma_{\gamma p} \sim f^\gamma \otimes \hat{\sigma} \otimes f^p \otimes \mathcal{D}(z)$$

pQCD calculations in NLO

fixed order, **massive scheme**:

HQ produced dynamically;

reliable for $p_t \lesssim m_q$

→ appropriate for beauty at HERA

- **γp** : FMNR (Frixione et al.)

$$(m_b = 4.75 \text{ GeV}, \mu_{R,F}^2 = p_{t,b}^2 + m_b^2, \epsilon = 0.0033-35)$$

- **DIS**: HVQDIS (Harris & Smith)

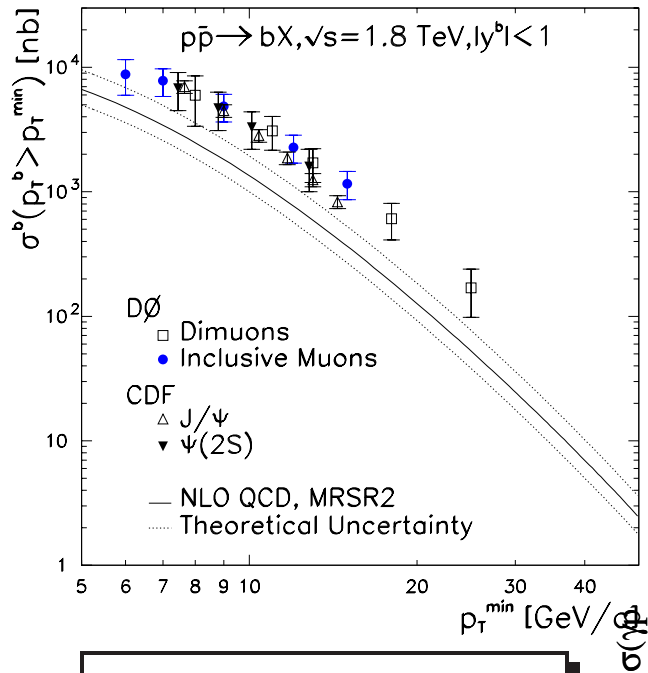
$$(m_b = 4.75 \text{ GeV}, \mu_{R,F}^2 = Q^2 + 4m_b^2, \epsilon = 0.0020-33)$$

→ **k factors ~ 1.4**

MC generators (LO ME + PS)

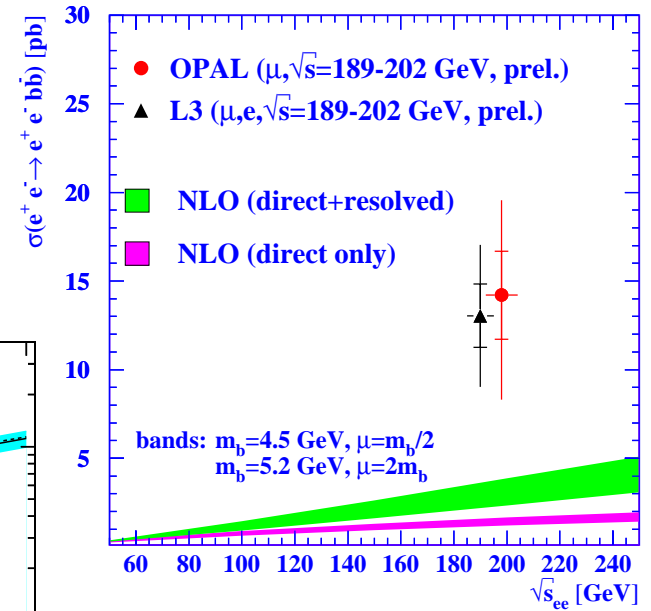
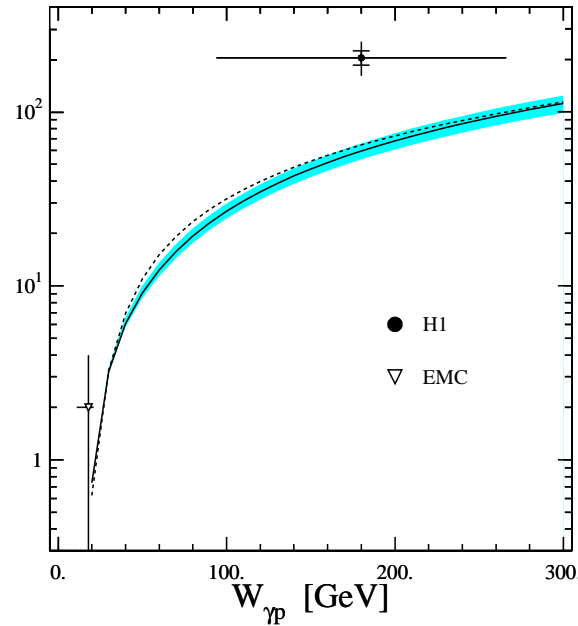
- **AROMA**:
direct only, **DGLAP** evolution
- **PYTHIA, RAPGAP, HERWIG**:
direct + **resolved**, DGLAP
- **CASCADE**:
direct only, **CCFM**-like evolution,
 k_t dependent gluon density

Measured Beauty Cross Sections vs. QCD (Spring 2000 Status)



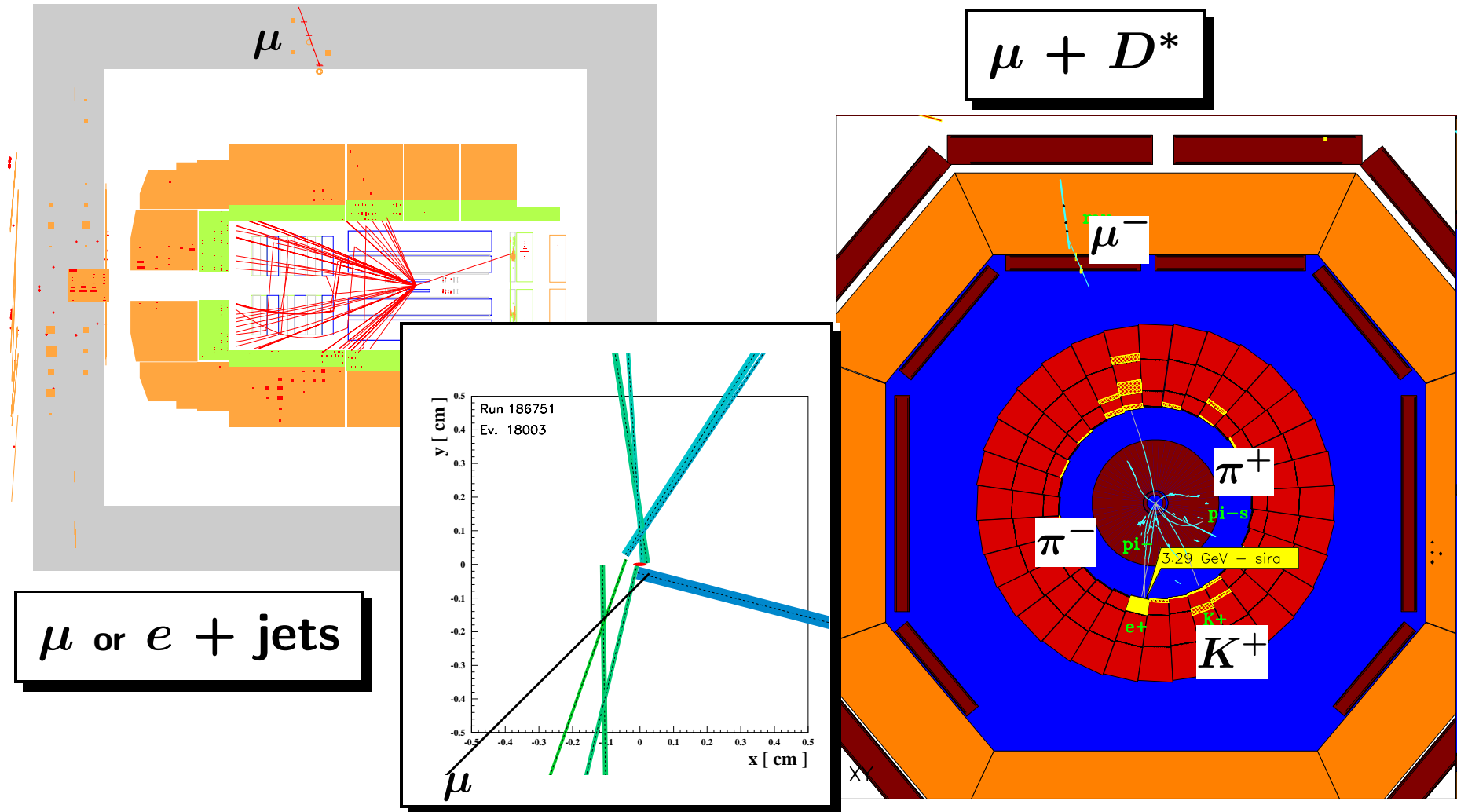
TEVATRON ($p\bar{p}$)

HERA (ep)



LEP ($\gamma\gamma$)

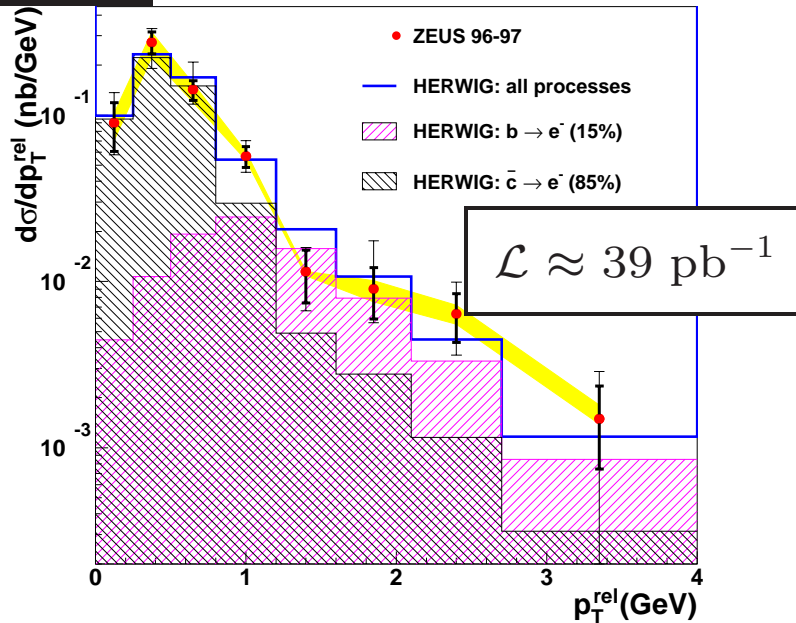
Experimental Beauty



B in γp (I): 1996/97 Results (\rightarrow Photon 2001)

ZEUS

electron p_t^{rel} analysis



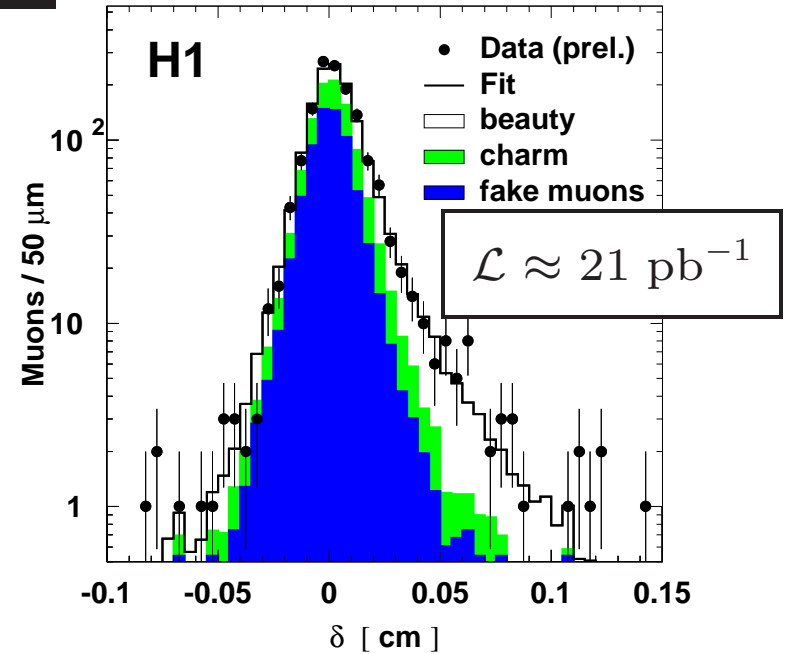
parton level cross section:

$$\sigma_{ep \rightarrow e + bX} = (1.6 \pm 0.4 \begin{smallmatrix} +0.3 & +0.2 \\ -0.5 & -0.4 \end{smallmatrix}) \text{ nb}$$

$$[\text{NLO QCD: } \sigma = (0.64 \pm \begin{smallmatrix} +0.14 \\ -0.10 \end{smallmatrix}) \text{ nb}]$$

H1

muon IP + p_t^{rel} analysis



visible μ cross section:

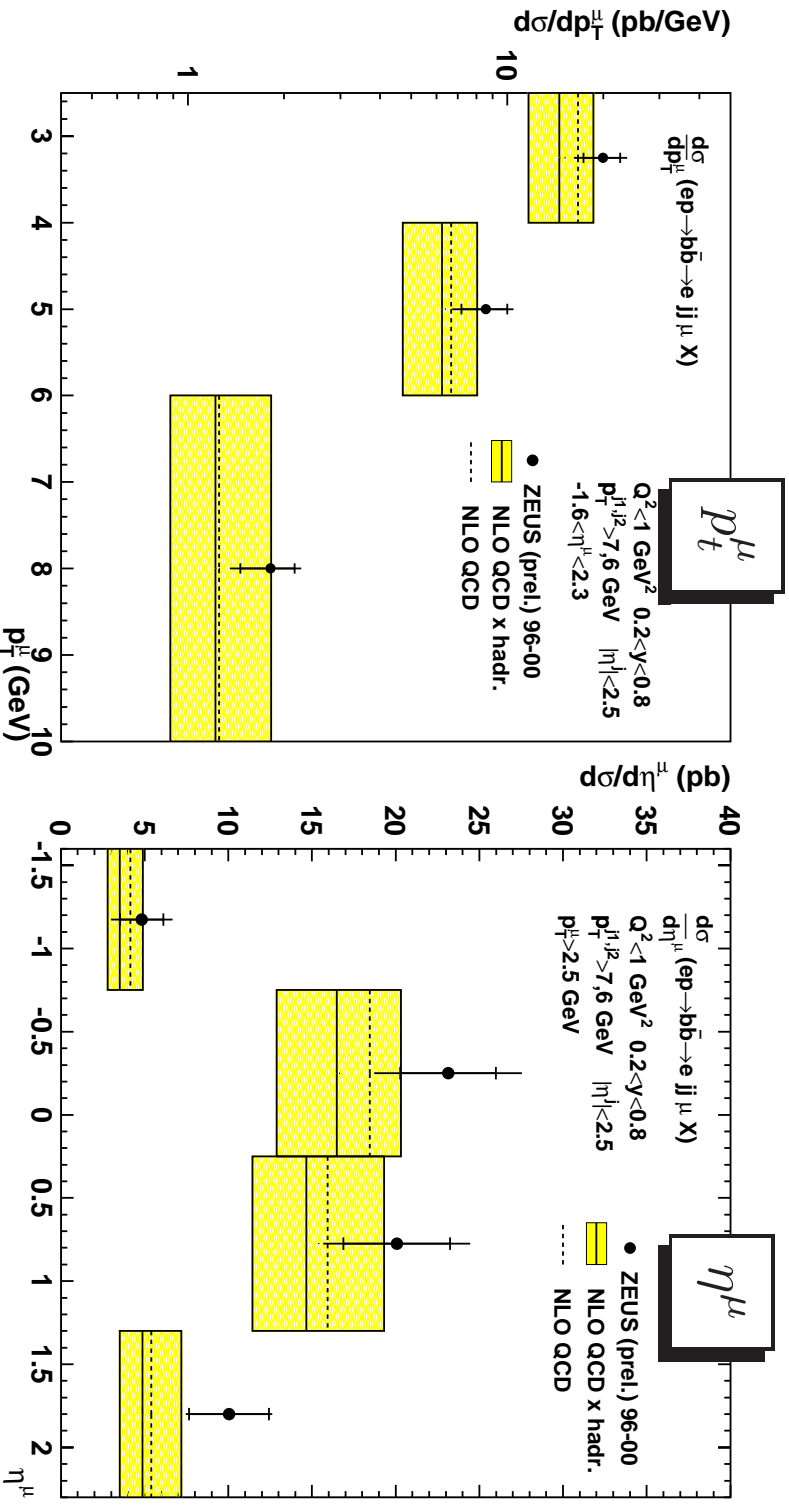
$$\sigma_{vis}^{ep \rightarrow b\bar{b}X \rightarrow \mu X'} = (170 \pm 25) \text{ pb}$$

$$[\text{NLO QCD: } \sigma = (54 \pm 9) \text{ pb}]$$

B in γp (II): 1996–2000 Results (new!)

new ZEUS (muon p_t^{rel}) **results**, $\mathcal{L} \approx 98 \text{ pb}^{-1}$

$$\sigma(ep \rightarrow b\bar{b}X \rightarrow jj\mu X)$$



extrapolation (PYTHIA) \rightarrow **di-jet cross section:**

$$\sigma(ep \rightarrow b\bar{b}X \rightarrow jjX) = [733 \pm 61(\text{stat.}) \pm 104(\text{syst.})] \text{ pb}$$

$$\text{NLO QCD: } [381_{-78}^{+117}] \text{ pb}$$

B in γp (III): x_γ Analysis

- **LO QCD picture**

direct γ processes : $x_\gamma = 1$

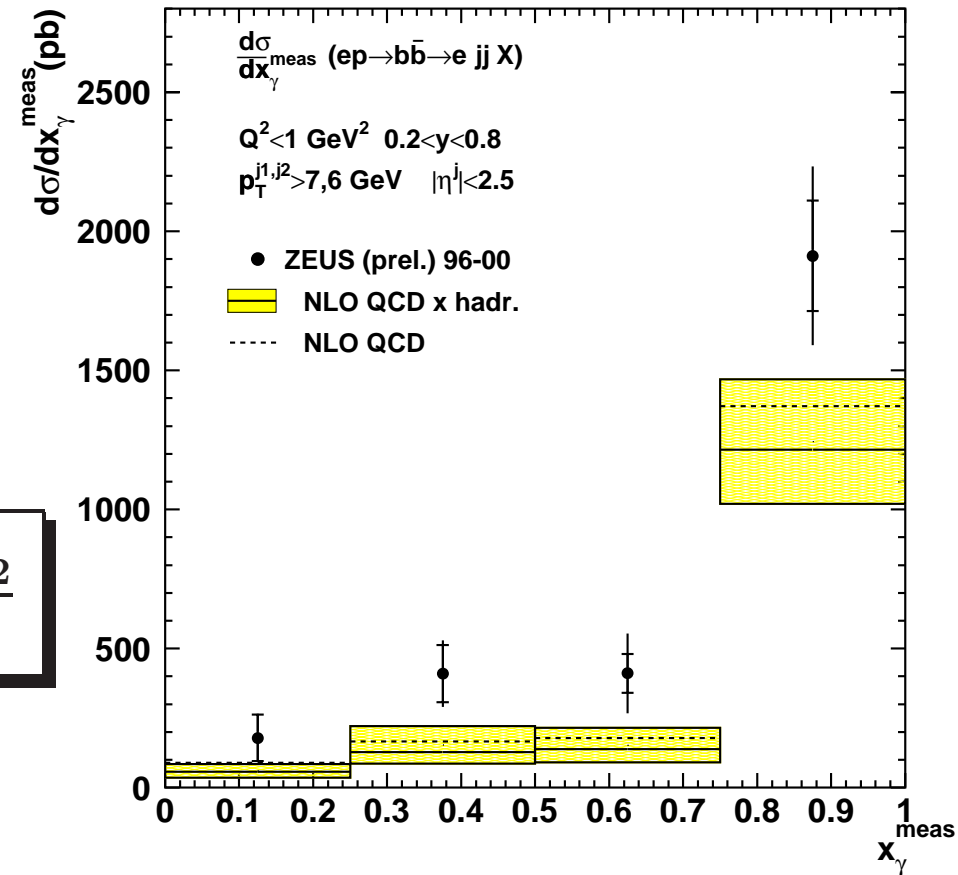
resolved γ processes : $x_\gamma < 1$

- **for all orders**

can **define observable**

$$x_\gamma^{\text{meas}} = \frac{(E - p_z)_{\text{jet1}} + (E - p_z)_{\text{jet2}}}{(E - p_z)_{\text{hfs}}}$$

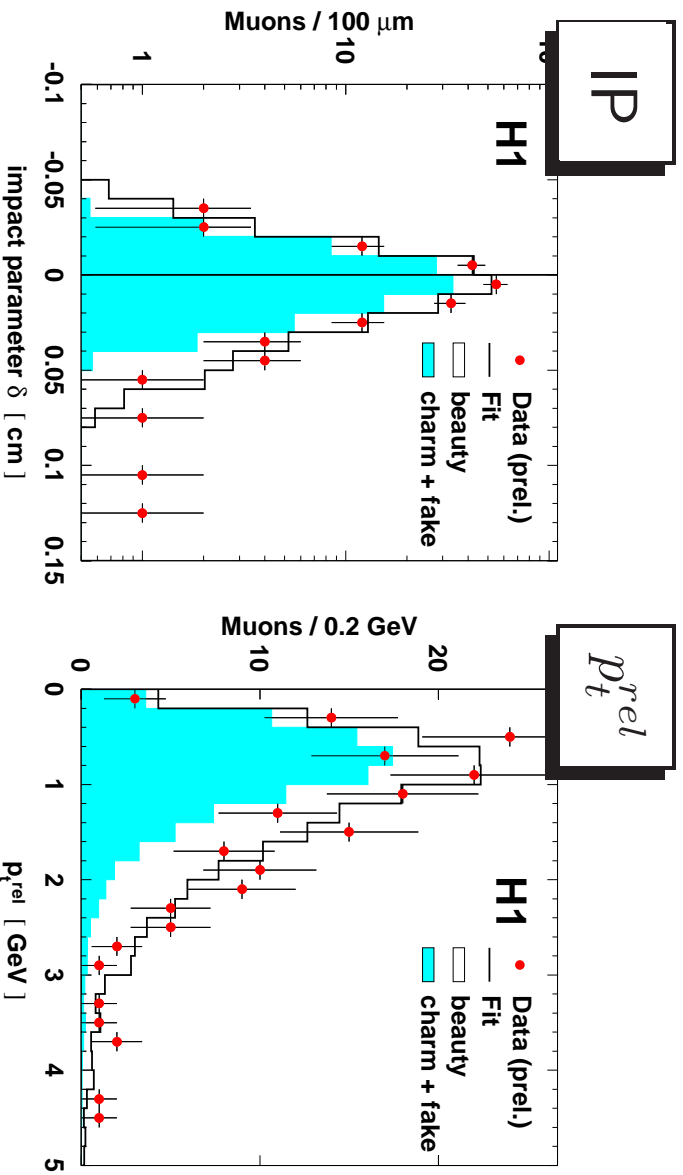
based on the two leading jets



B in DIS (I): 1997 Results (\rightarrow Photon 2001)

first DIS measurement, based on $\mathcal{L} \approx 11 \text{ pb}^{-1}$

- selection: $\mu^+ \geq 2$ jets; combined (IP, p_t^{rel}) analysis:



muon cross section:

$$2 \text{ GeV}^2 < Q^2 < 100 \text{ GeV}^2, 0.05 < y < 0.7, p_t(\mu) > 2 \text{ GeV}, 35^\circ < \theta(\mu) < 130^\circ$$

$$\sigma(ep \rightarrow bX \rightarrow \mu X) = [39 \pm 8(\text{stat.}) \pm 10(\text{syst.})] \text{ pb}$$

NLO QCD: $[11 \pm 2] \text{ pb}$

AROMA: 9 pb, **CASCADE:** 15 pb

B in DIS (II): 1999/2000 Results (new!)

new ZEUS results, $\mathcal{L} \approx 60 \text{ pb}^{-1}$

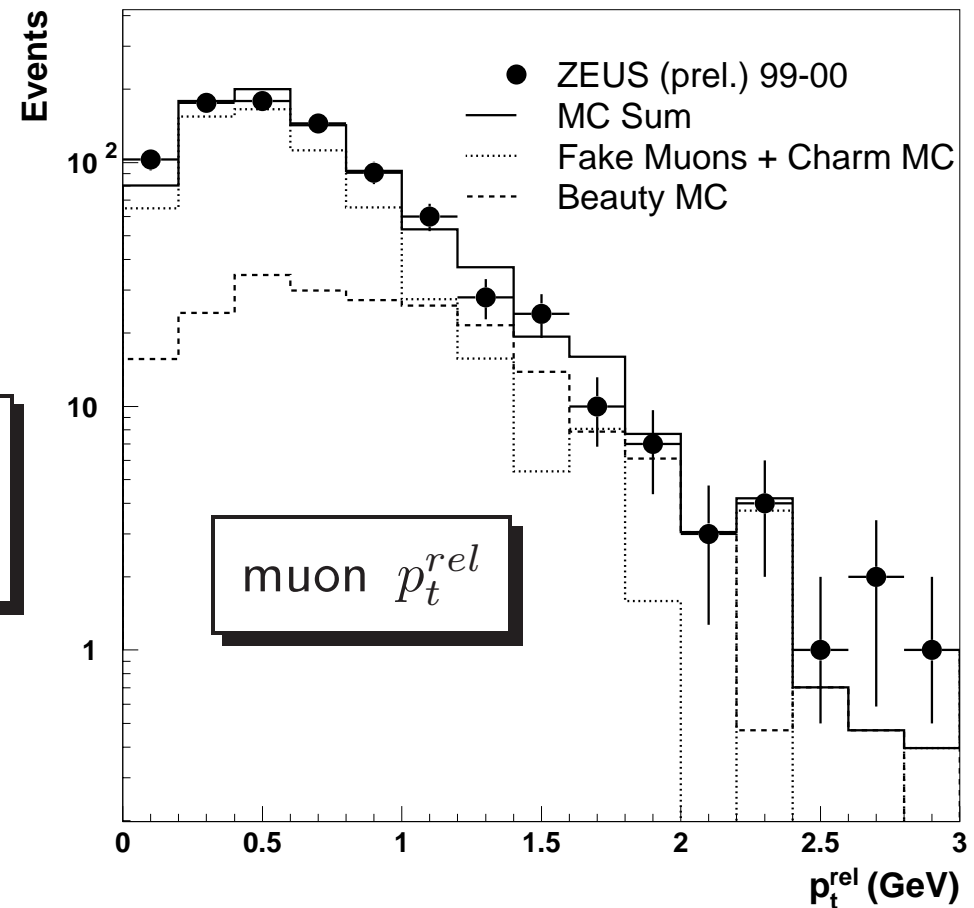
- selection: $\mu^+ \geq 1 \text{ jet}$ (Breit system);
 p_t^{rel} analysis

muon/jet cross section:

$$\sigma (ep \rightarrow b\bar{b}X \rightarrow ej\mu X) = [38.7 \pm 7.7(\text{stat.})_{-5.0}^{+6.1}(\text{syst.})] \text{ pb}$$

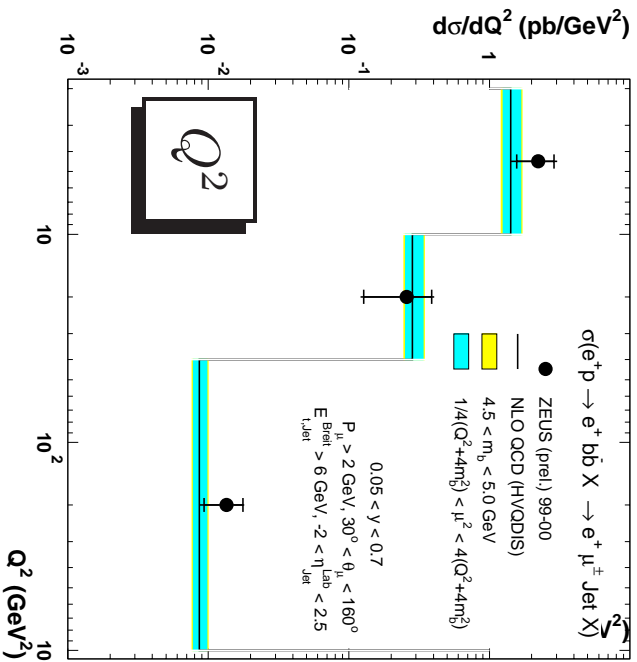
NLO QCD: $[28.1_{-3.5}^{+5.3}] \text{ pb}$

CASCADE: 35 pb

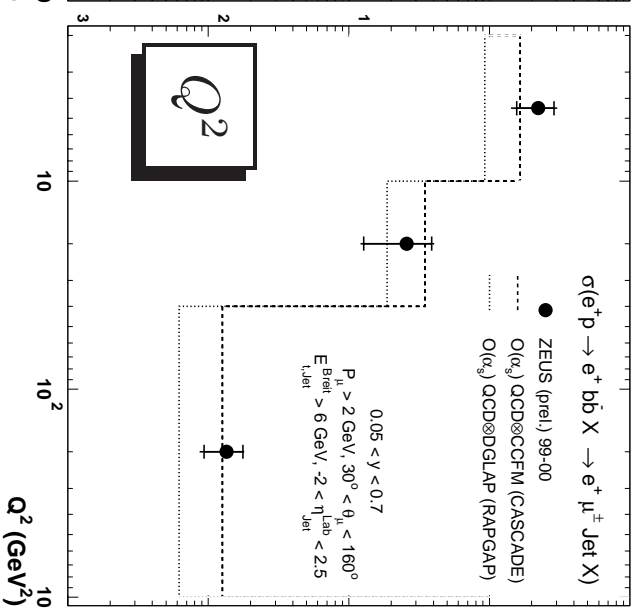


B in DIS (II): Differential Xsections

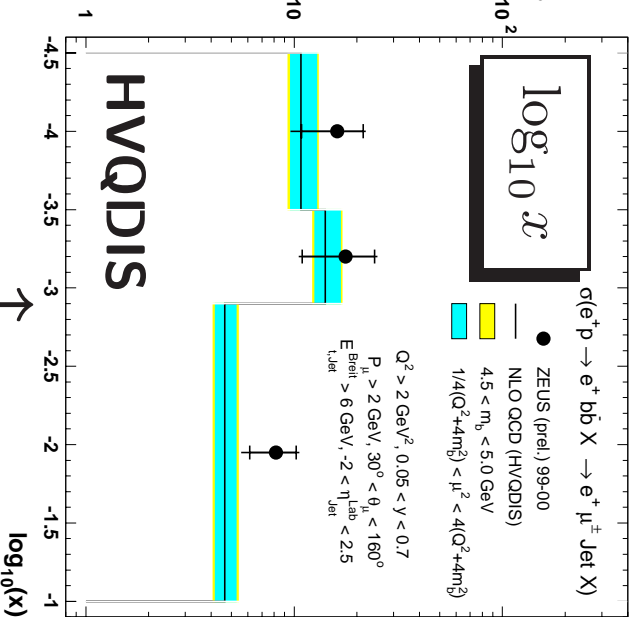
ZEUS



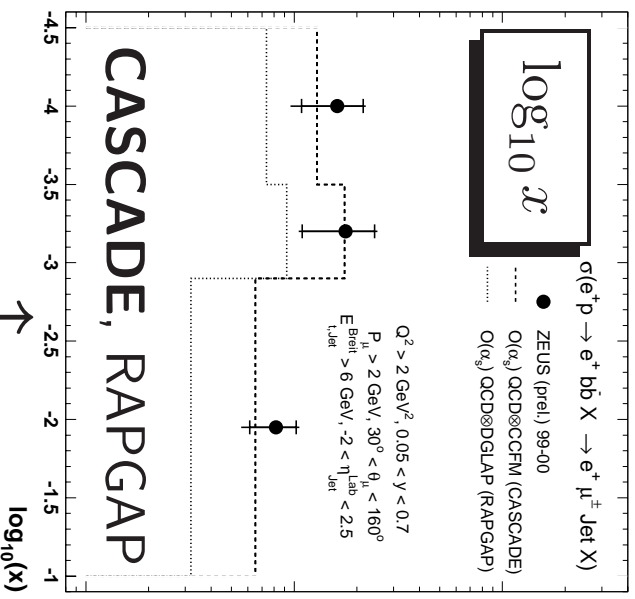
ZEUS



$d\sigma/d\log_{10}(x)$ (pb)



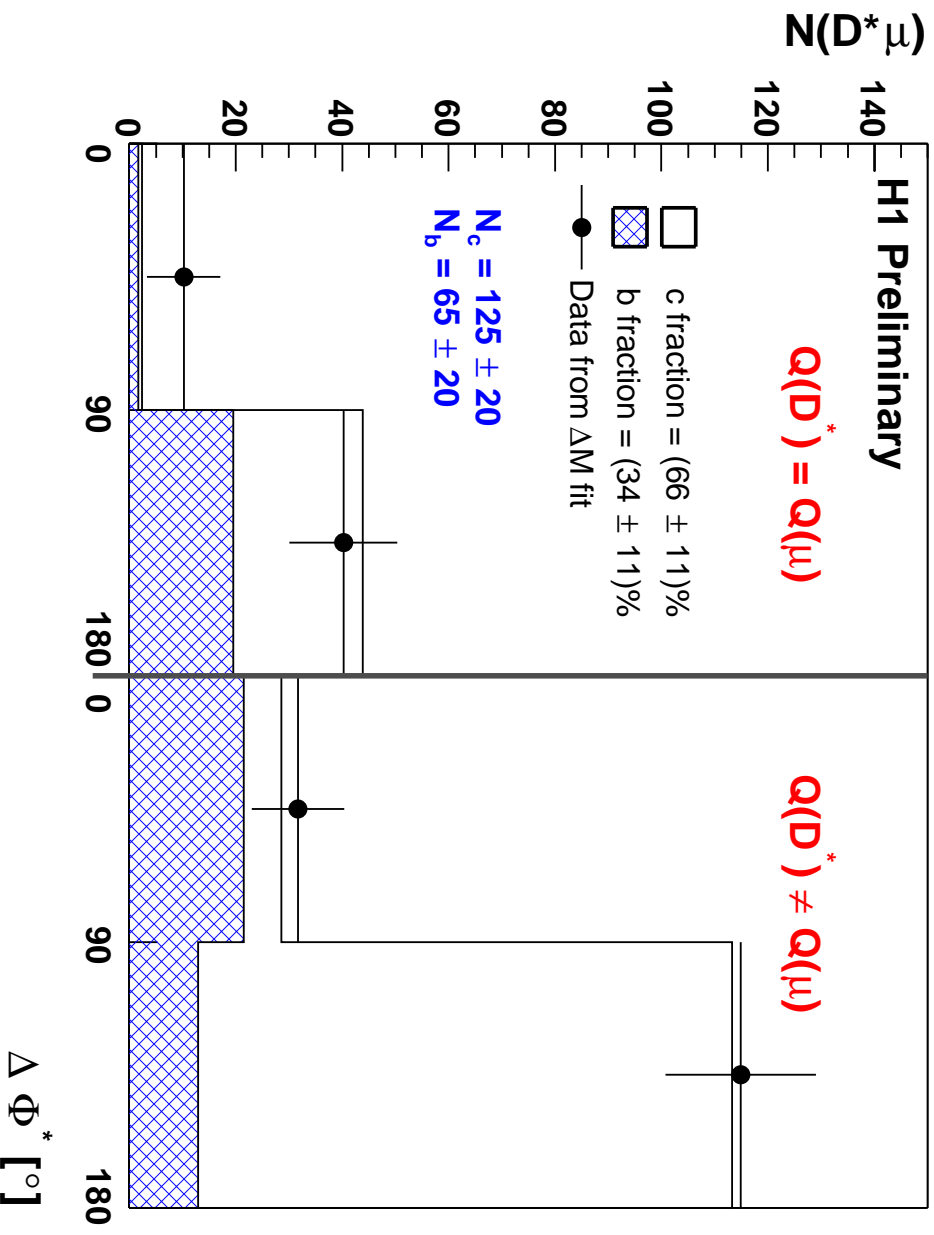
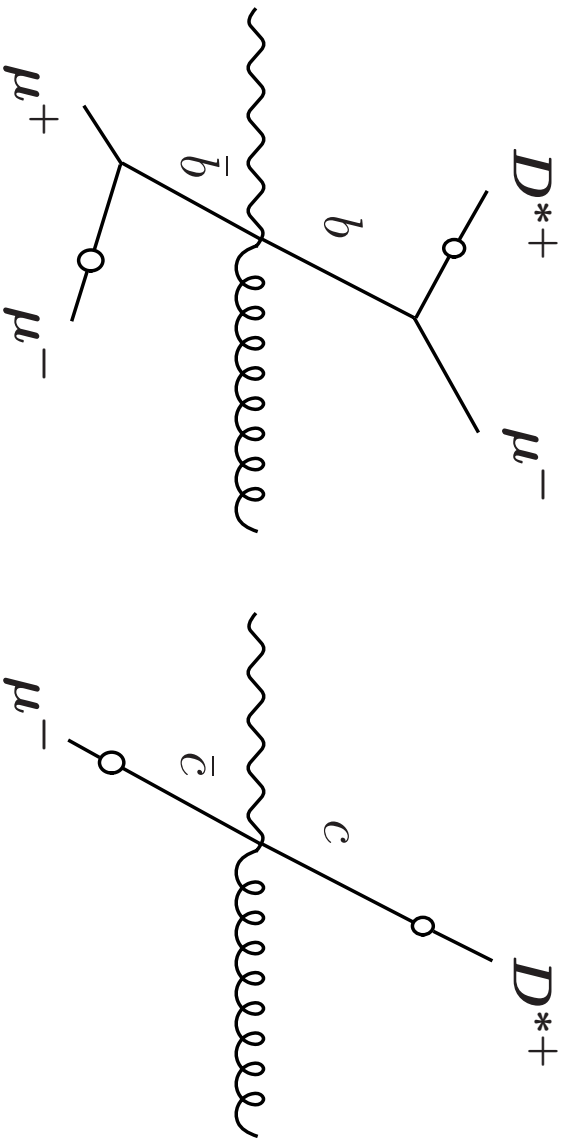
Log₁₀ x



data + NLO QCD

data + LO/PS MC

$D^* \mu$ Correlations (I): Method



$D^* \mu$ Correlations (II): H1 Analysis

combined $D^* (\Delta M)$ + $D^* \mu$ correlation analysis

$(p_t^{D^*(\mu)} > 1.5(1.0) \text{ GeV}, |\eta^{D^*(\mu)}| < 1.5(1.74), 0.05 < y < 0.75)$



$$\sigma(ep \rightarrow D^* \mu)$$

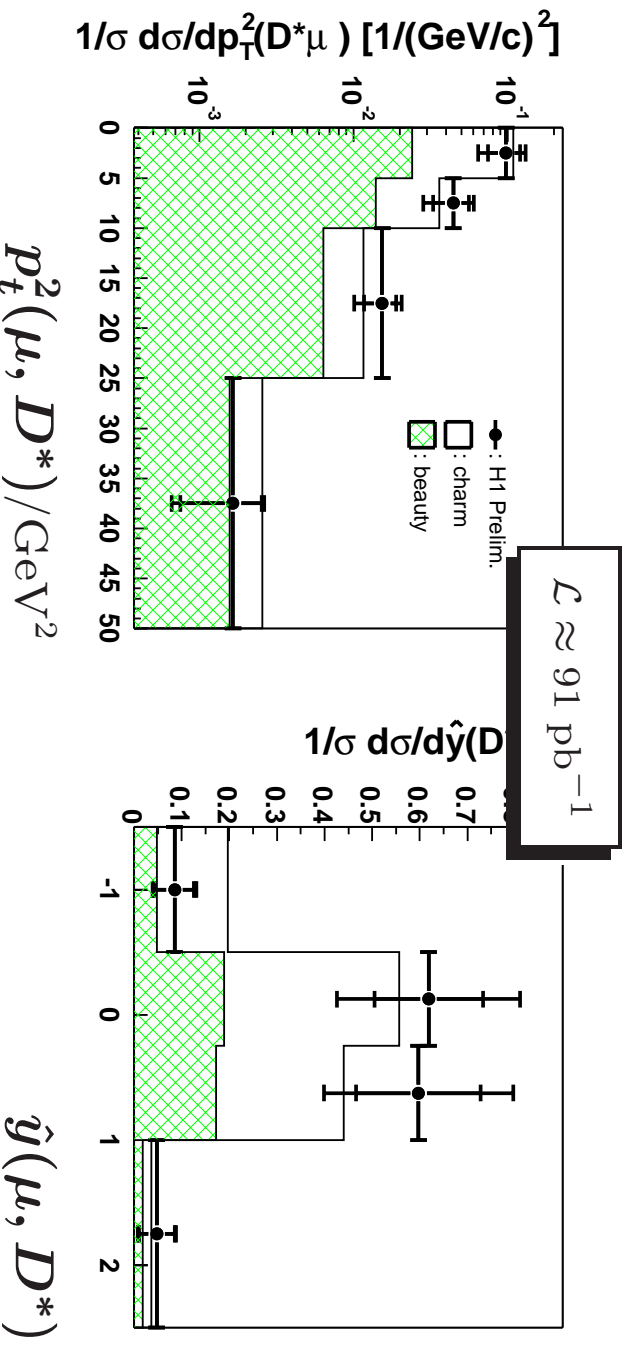
charm : $[720 \pm 115(stat.) \pm 245(syst.)] \text{ pb}$

→ **factor 1.8** above AROMA

beauty: $[380 \pm 120(stat.) \pm 130(syst.)] \text{ pb}$

→ **factor 3.6** above AROMA

- use results to compare to LO/PS MC (AROMA):



$D^* \mu$ Correlations (III): ZEUS Analysis

similar analysis ($\mathcal{L} \approx 114 \text{ pb}^{-1}$)

$$p_t^{D^*(\mu)} > 1.9(1.4) \text{ GeV},$$

$$-1.5(-1.3) < \eta^{D^*(\mu)} < 1.5(1.75)$$

↓ PYTHIA MC ↓

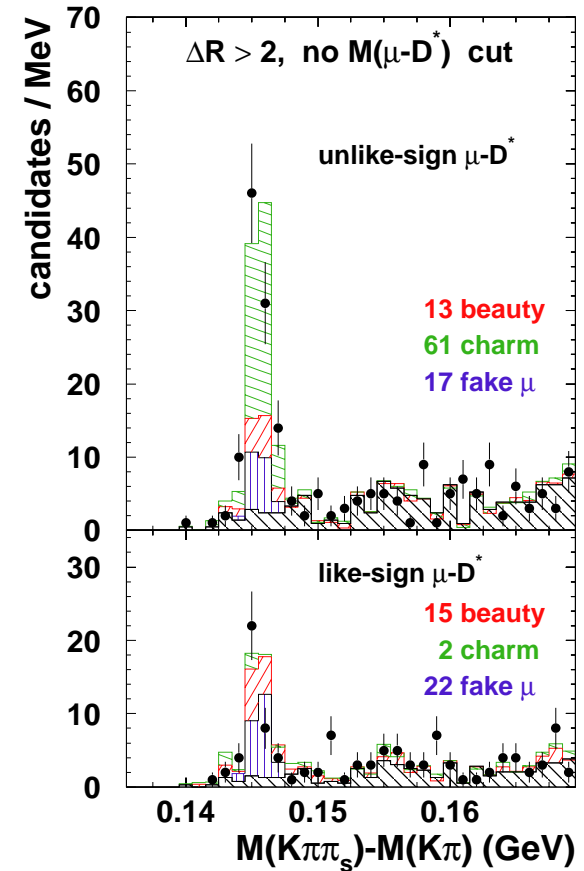
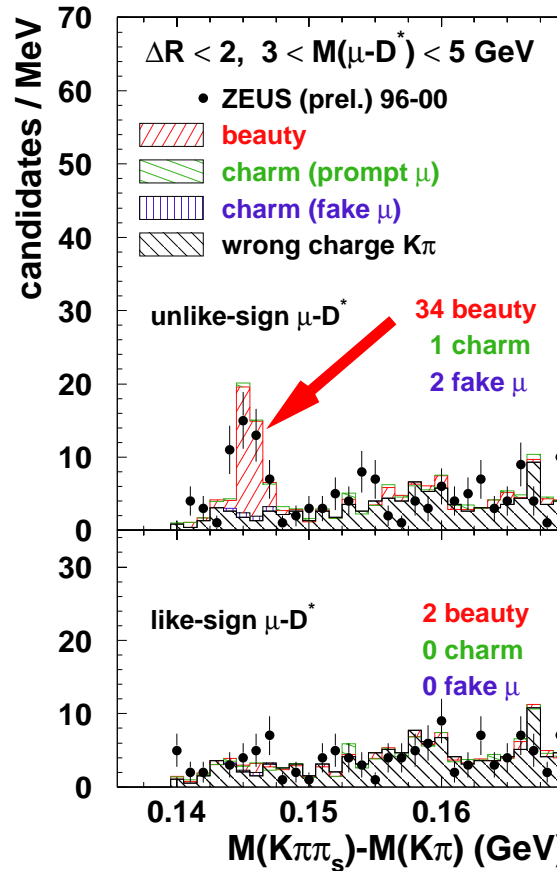
γp cross section (for $\hat{y}^b < 1$,
 $Q^2 < 1 \text{ GeV}^2, 0.05 < y < 0.85$)

$$\sigma(ep \rightarrow b(\bar{b})X) = [15.1 \pm 3.9^{+3.8}_{-4.7}] \text{ nb}$$

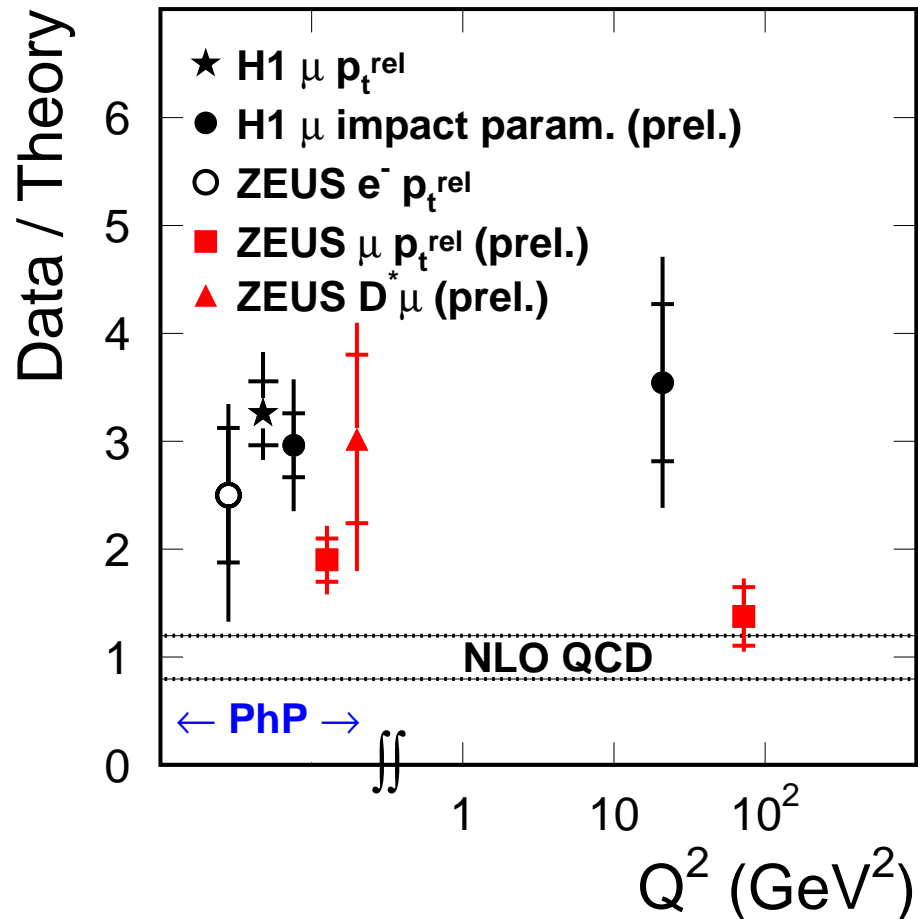
NLO QCD: $[5.0^{+1.7}_{-1.1}] \text{ nb}$

$\Delta R < 2$

$\Delta R > 2$



Summary and Outlook



- **new** (prelim.) **beauty results from HERA**
- significantly **increased statistics**
 - **improved** precision in γp
 - **differential DIS** cross sections
 - **double tag** analyses ($D^* \mu$)
- γp data above NLO **QCD**, **DIS** situation **not clear** (yet)

NB:

various different kinematic ranges and cross section definitions

- expect **future results** based on **new data**, **upgraded detectors**, and **additional methods**