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Beauty Production at HERA

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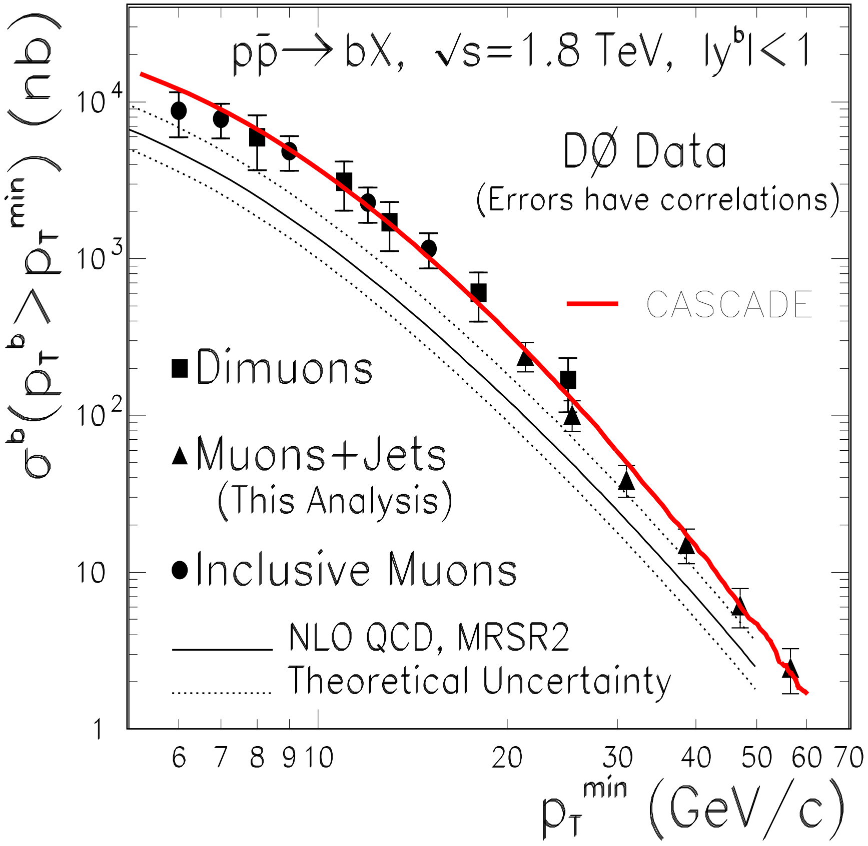
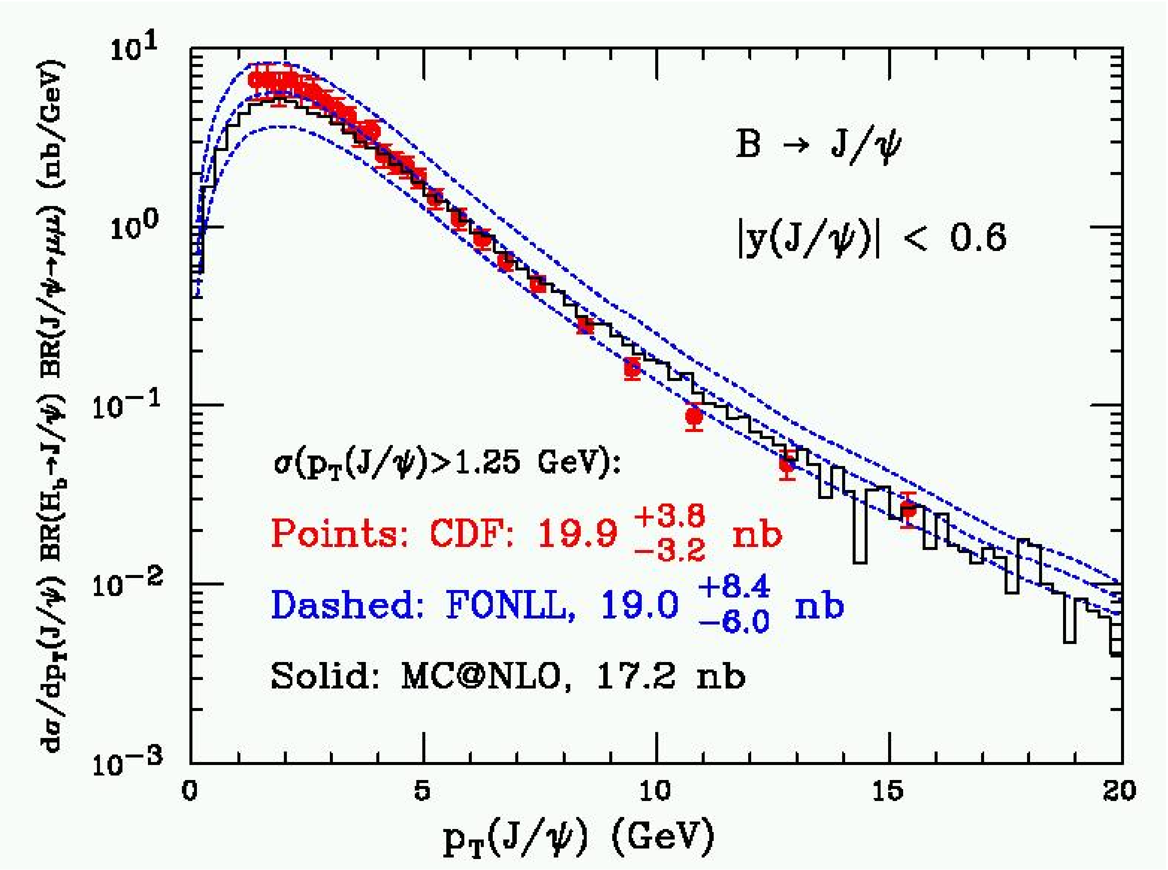
Introduction

$p\bar{p}$ Tevatron Run-I



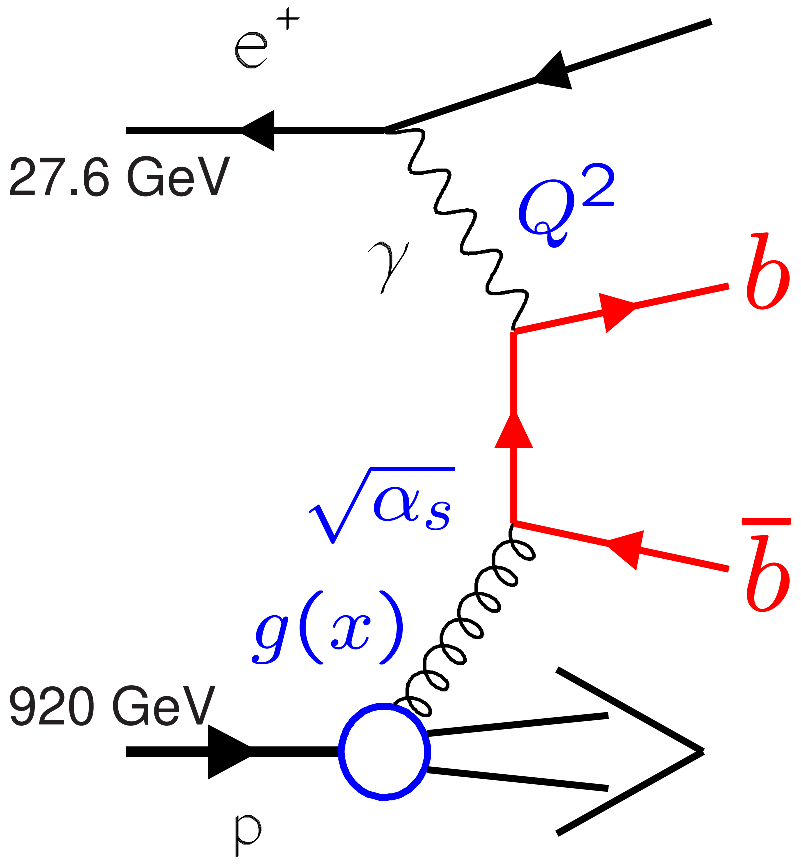
Run-II



- New CDF Run-II data in good agreement with improved theory

What about the b-data at HERA?

Dominant production process in ep-collisions: Boson-Gluon -Fusion



- Driven by gluons in the proton
- Relevant scales:

$$
\begin{array}{ll}
m_b & \sim 5\ \text{GeV} \\
Q^2 & \lesssim 1\ \text{GeV}^2 \rightarrow \gamma p \\
 & > 2\ \text{GeV}^2 \rightarrow \text{DIS} \\
p_T^b & \text{Event selection: } p_t^{jet} > 6 \text{ or } 7\ \text{GeV}
\end{array}
$$

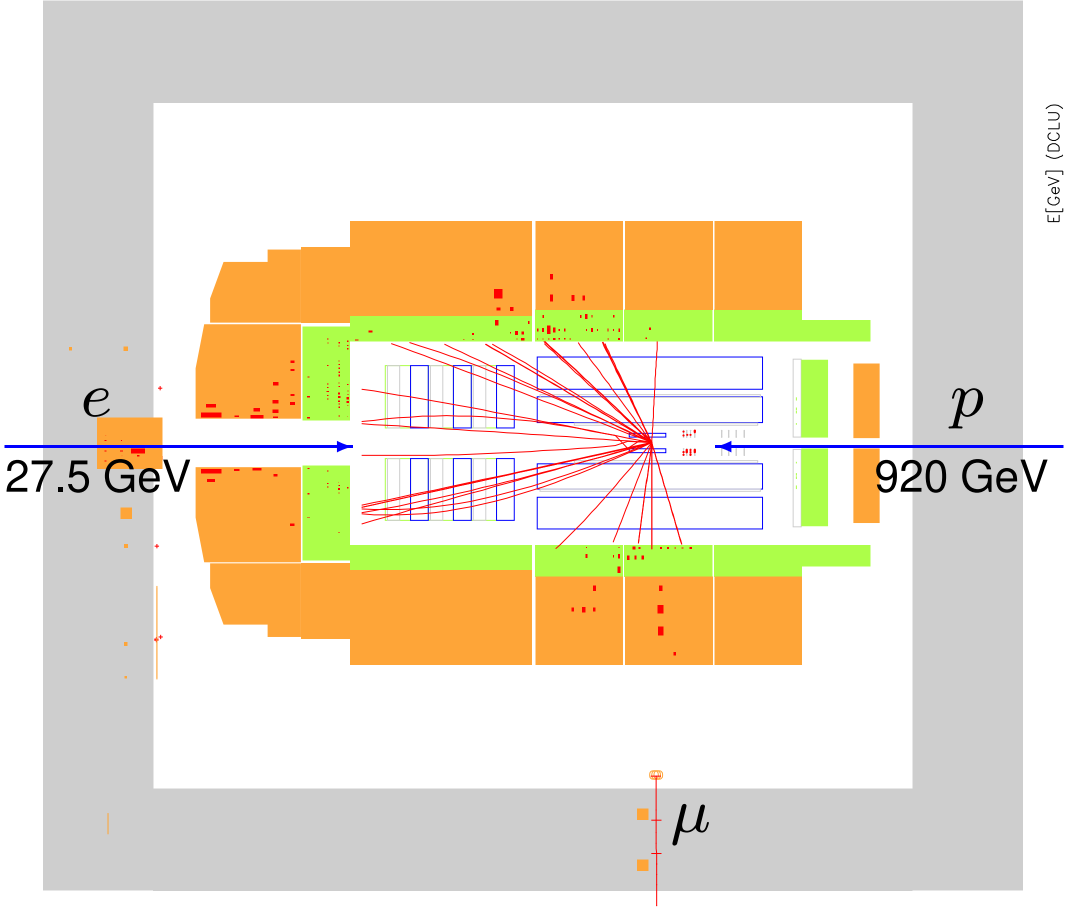
- QCD calculations at NLO available:

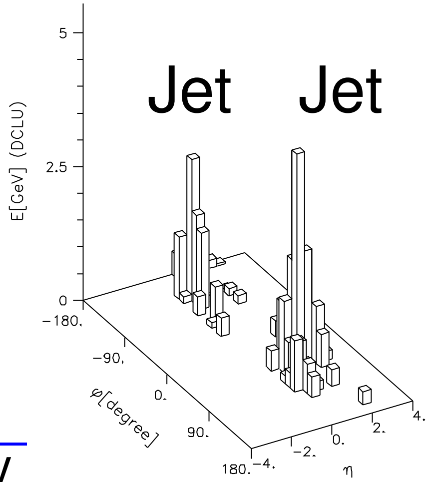
  γp: FMNR Frixione, Mangano, Nason, Ridolfi

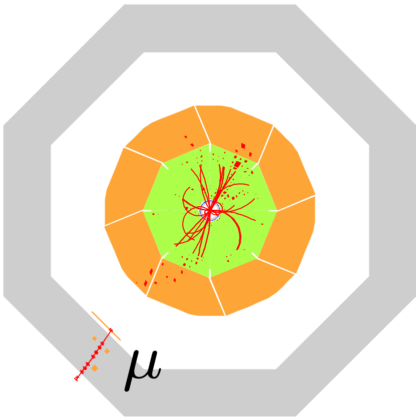
  DIS: HVQDIS Harris, Smith

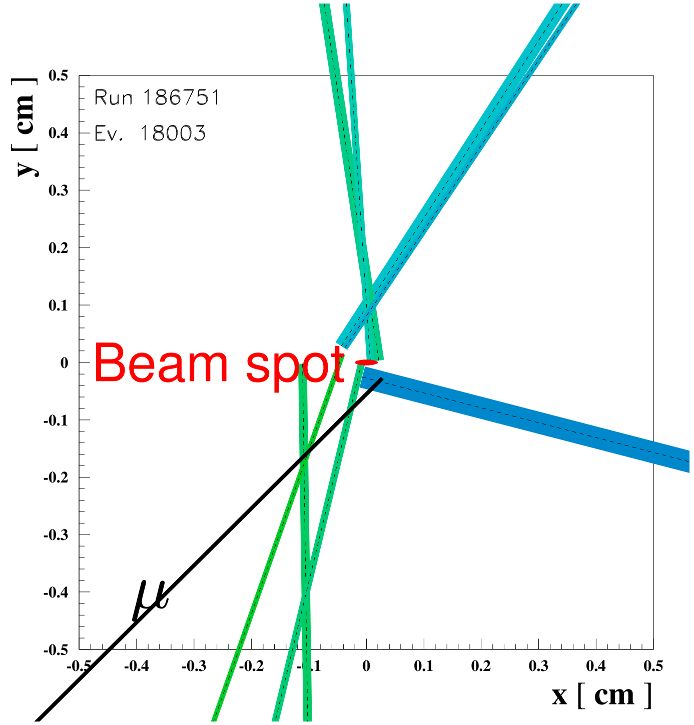
Heavy Quarks: Multiscale Problem in pQCD

Beauty Event Selection







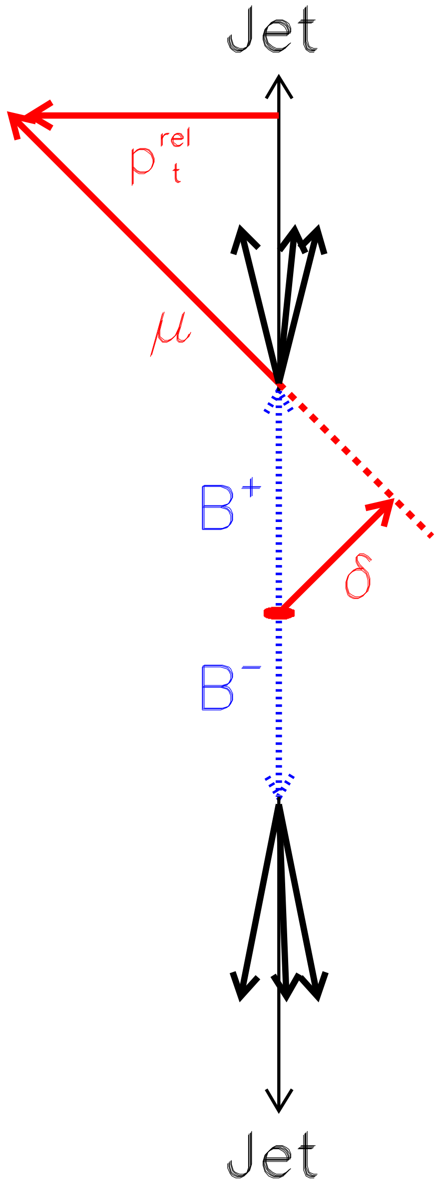


HERA-I data fully analysed

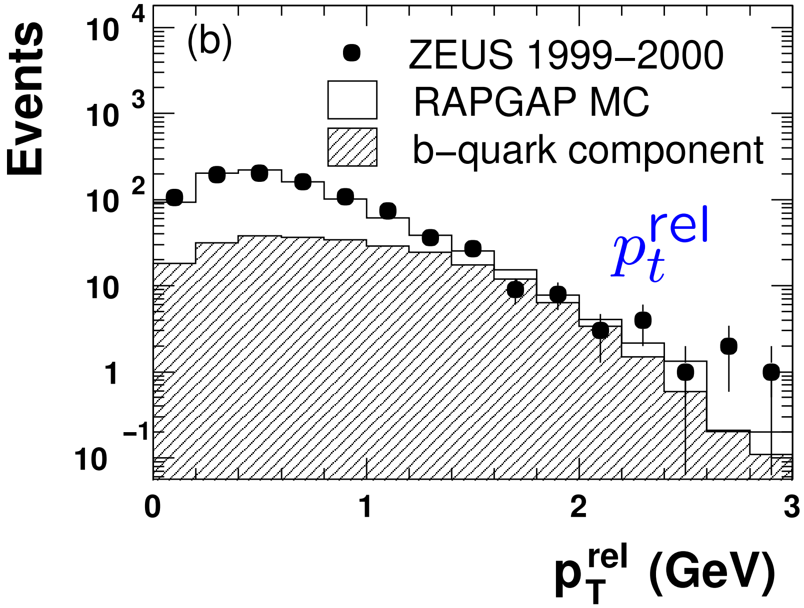
$\int \mathcal{L}dt \sim 100$ pb^{-1} (ZEUS)

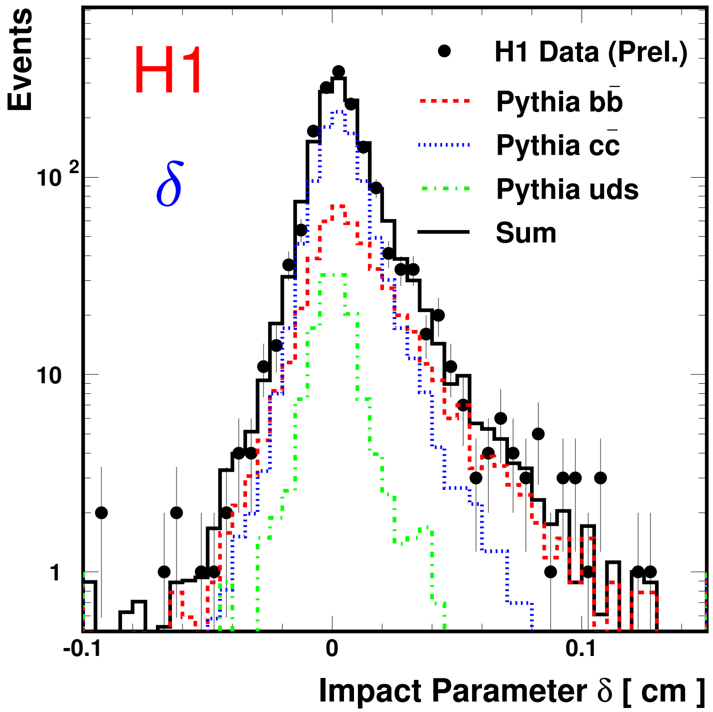
$\sim$ 50 pb^{-1} with Silicon Vertex Det. (H1)

Beauty Observables



- Large B-Mass:
  p_t^{rel}: p_t of μ relative to jet axis
- Large B-Lifetime:
  μ Impact-Parameter δ



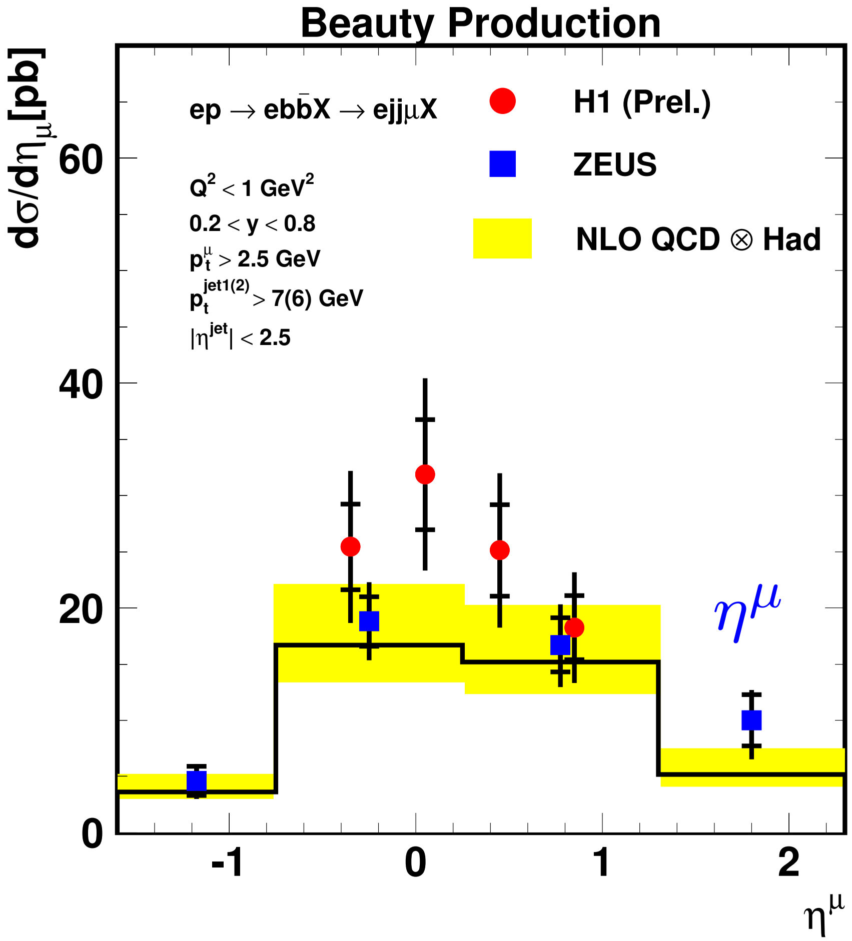


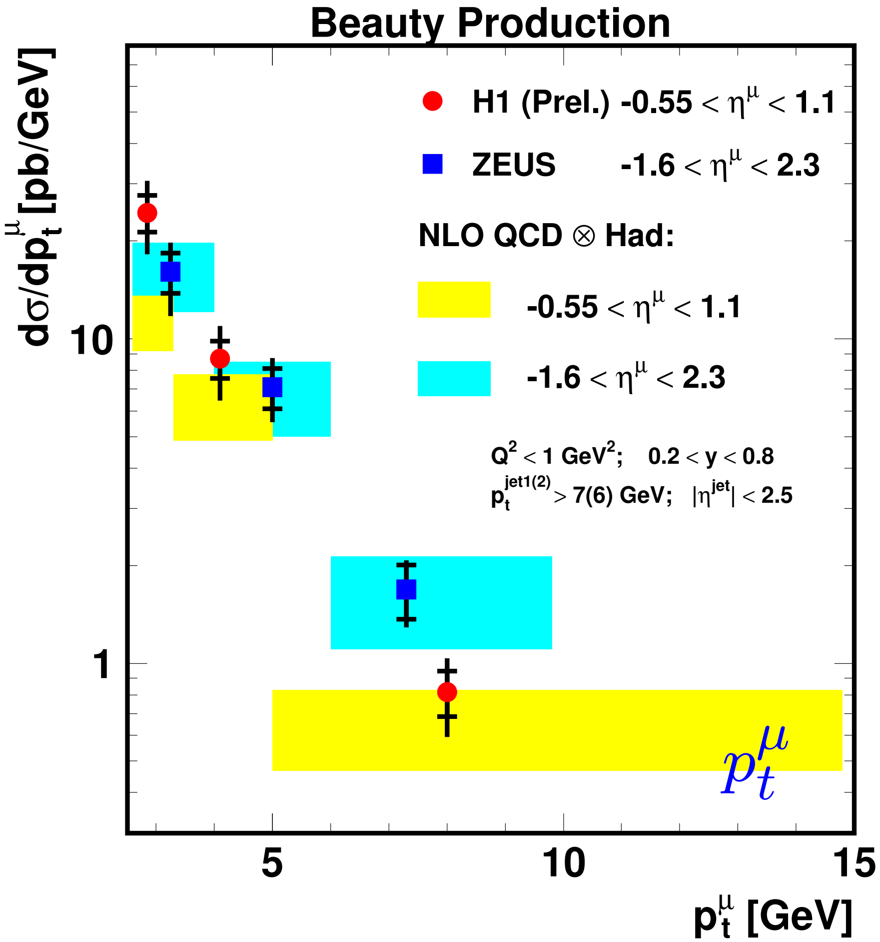
Shapes of b, c, uds from MC

Beauty fraction from fit to p_t^{rel} (ZEUS), p_t^{rel} and δ (H1)

$\rightarrow$ samples used for fit:
b-fraction typically 30%

$Q^2 \sim 0$ $\quad ep \rightarrow eb\bar{b}X \rightarrow ejj\mu X'$ $\quad 0.2 < y < 0.8$ $\quad p_t^{jet} > 7(6)$ GeV

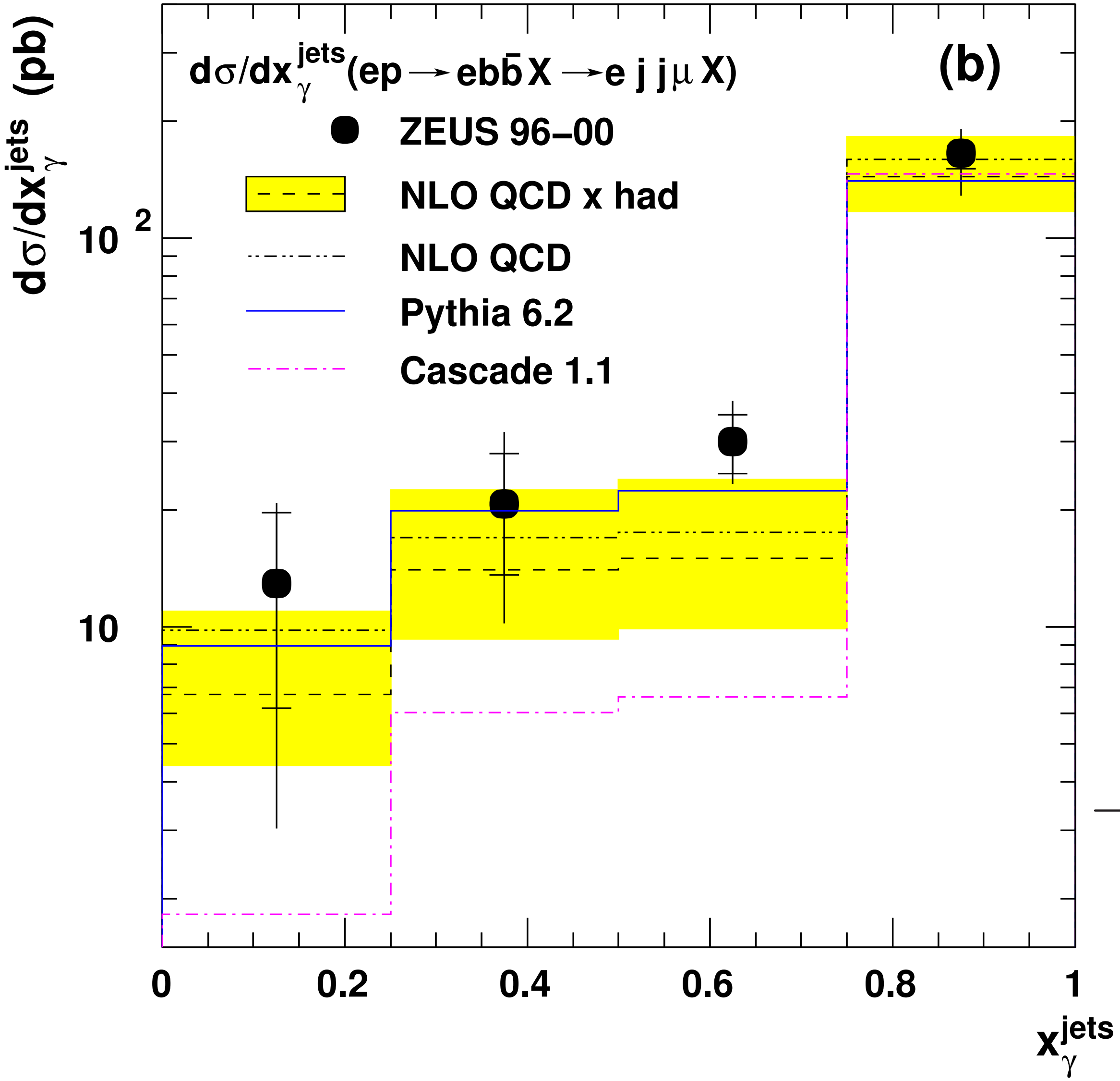


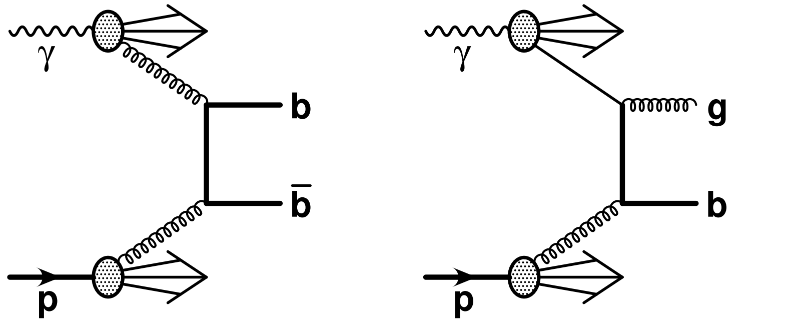


- General agreement between H1 and ZEUS
- H1 higher at low p_t^μ
- Still agreement within errors with massive NLO QCD (FMNR)

Contributions from Resolved Photons

$Q^2 \sim 0$ $\quad ep \to eb\bar{b}X \to ejj\mu X'$





hadron-like: $gg \to b\bar{b}$ $\quad$ b-excitation: $bg \to gb$

$$x_\gamma^{\text{jets}} = \frac{\sum_{j_1,j_2}(E_T^j e^{-\eta^j})}{2yE_e}$$

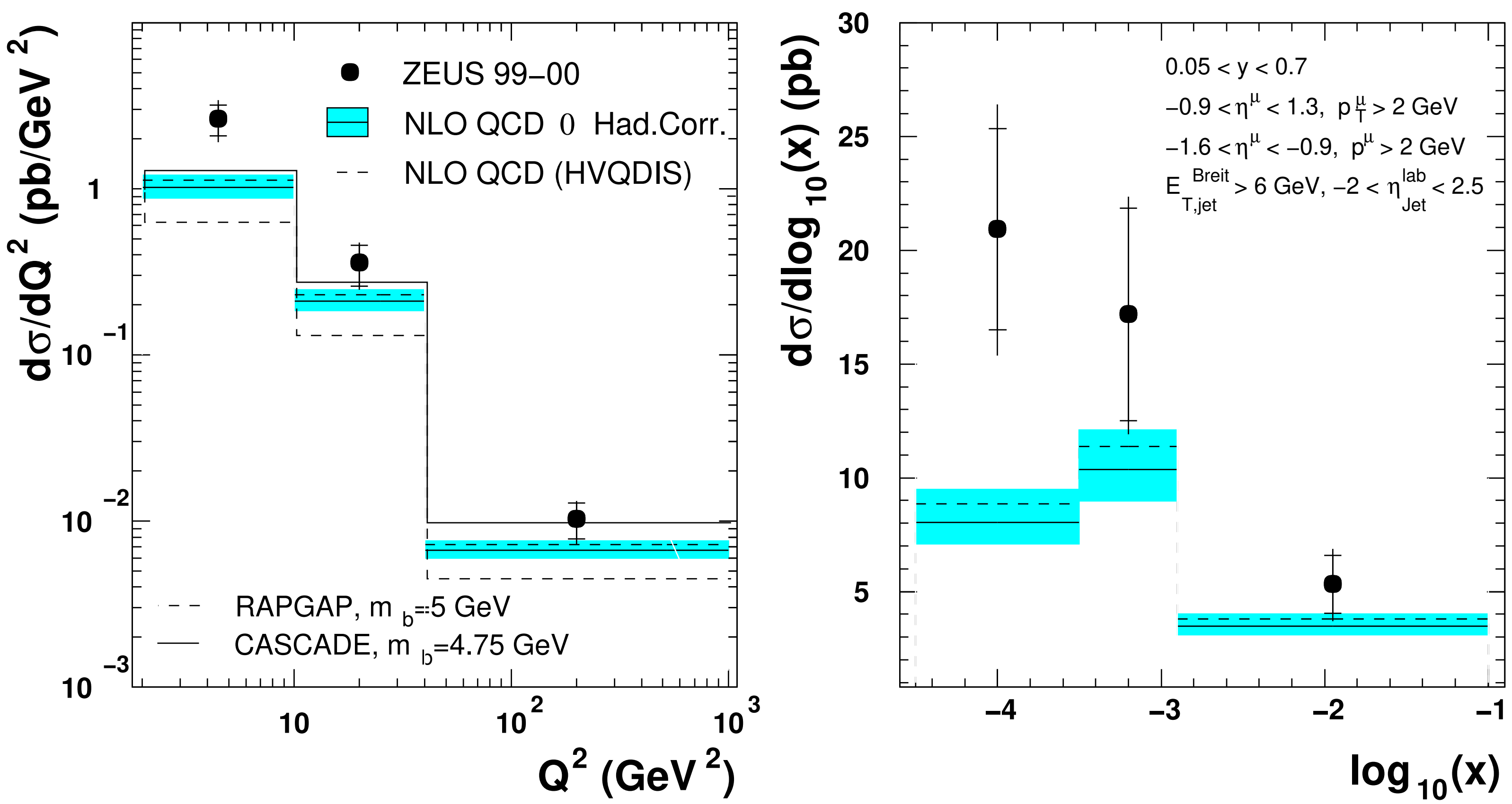
- Resolved Photon: ($x_\gamma \lesssim 0.75$)

$\to$ NLO QCD somewhat lower than data

Beauty in DIS

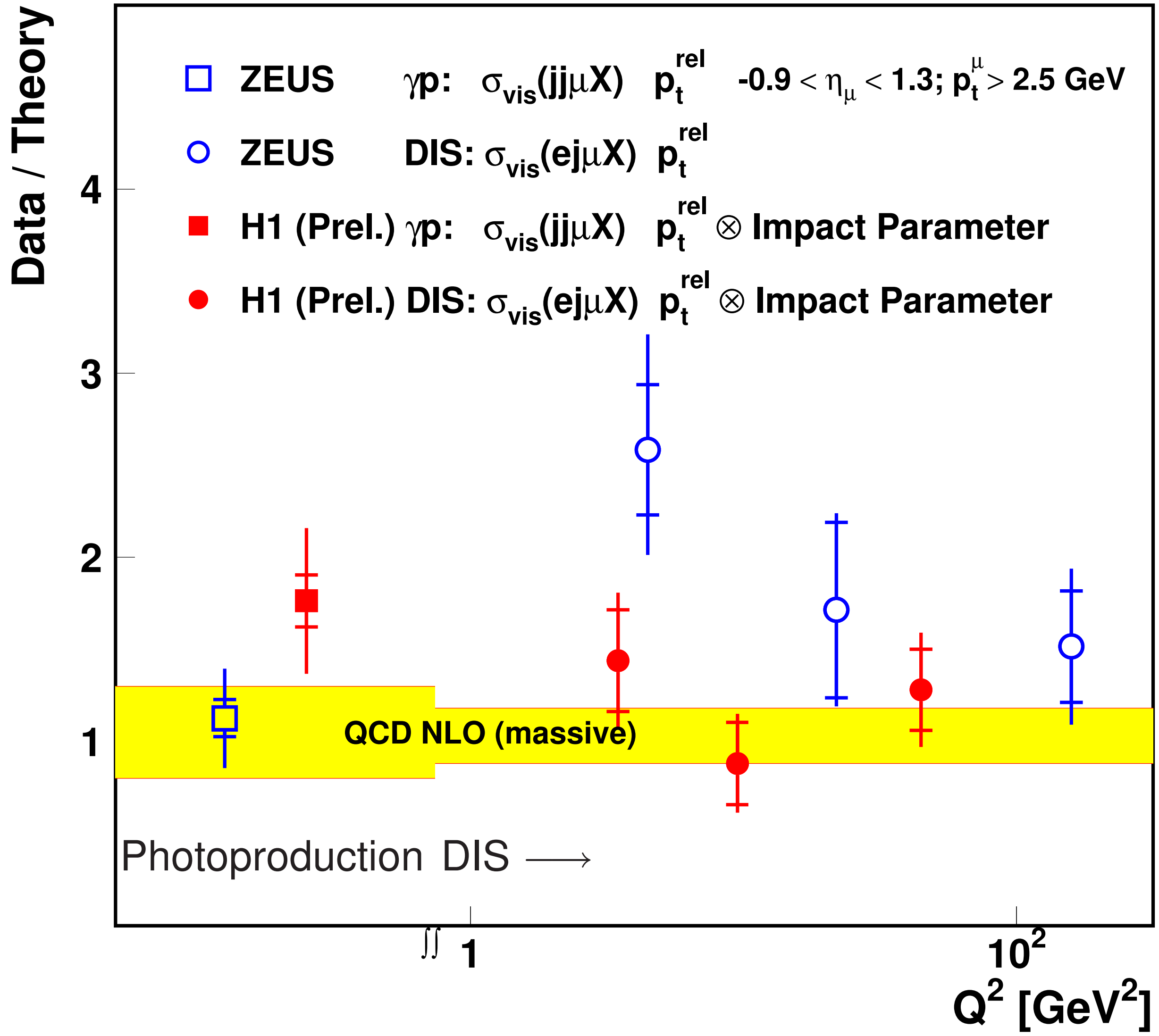
$Q^2 > 2$ GeV^2 $\qquad ep \to eb\bar{b}X \to ej\mu X'$ $\qquad 0.05 < y < 0.7$

$E_{t,jet}^{Breit} > 6$ GeV $\quad -2 < \eta_{jet}^{lab} < 2.5$



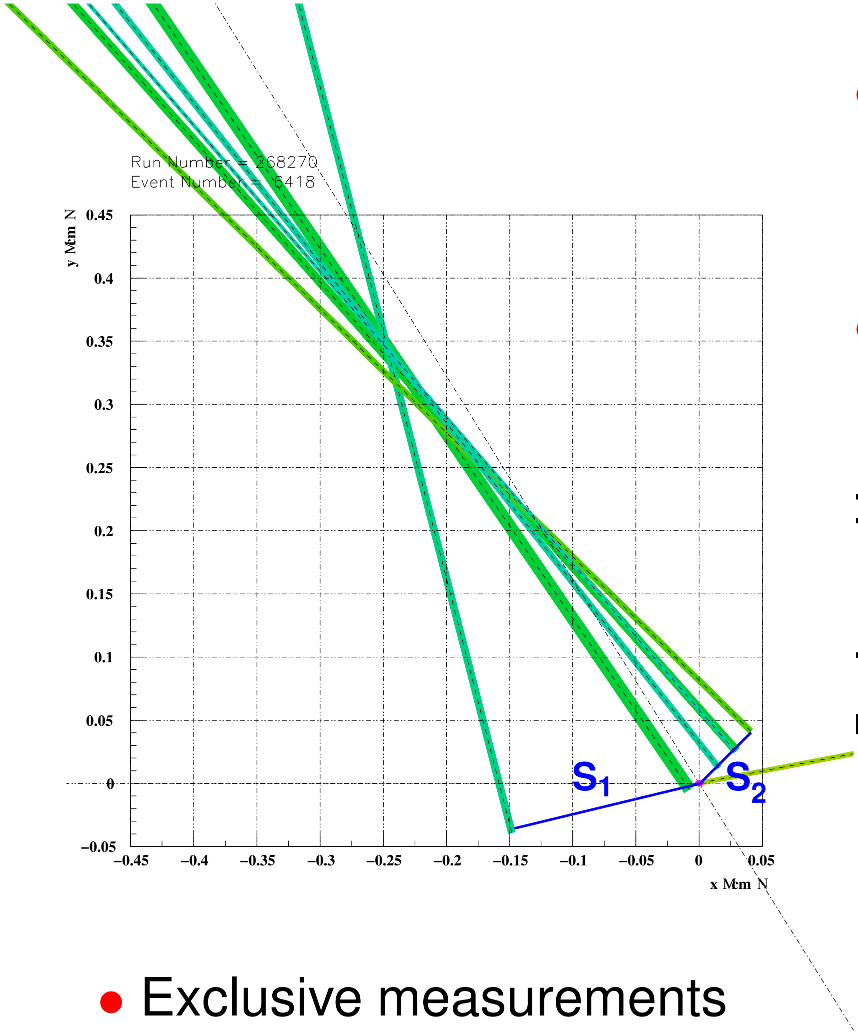
- Similar results available from H1
- Data higher than NLO esp. at small Q^2, x

Data/Theory as a Function of Q^2



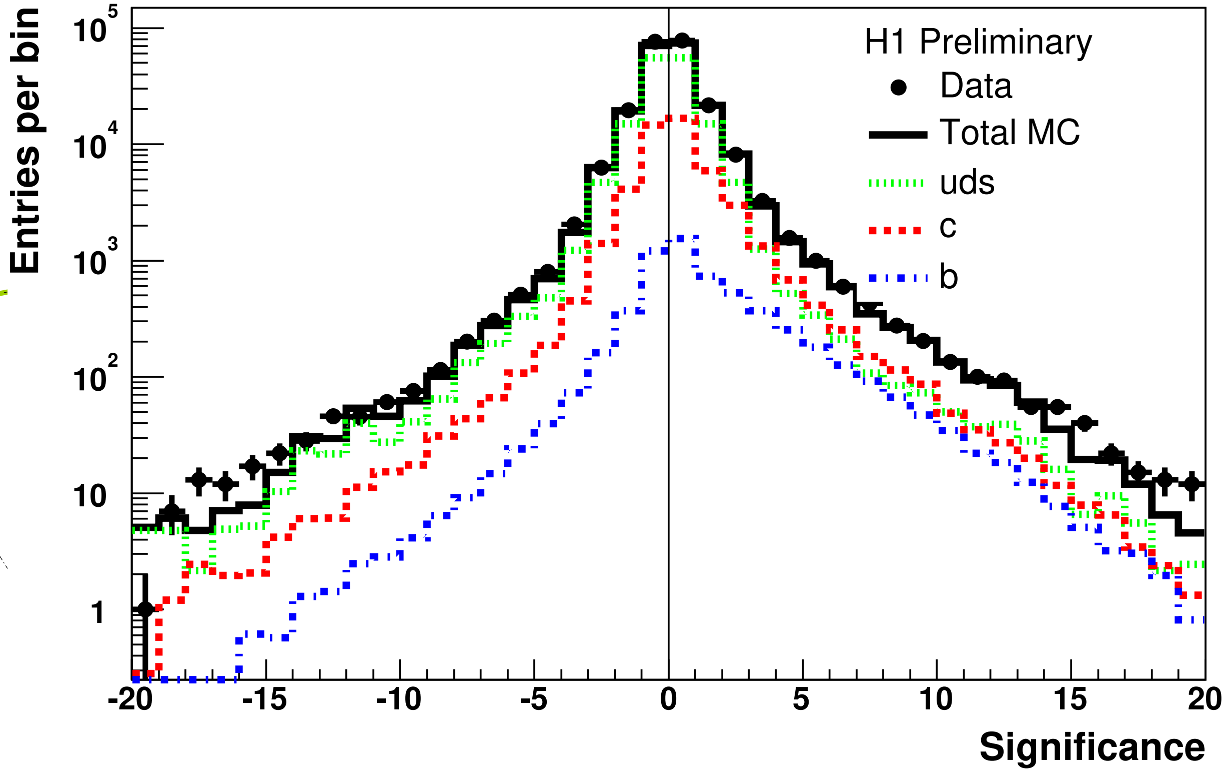
- Data somewhat higher than (massive) NLO predictions

Inclusive Lifetime Tagging (H1)



- Use all tracks ($p_t > 500$ MeV) with full Silicon Det. info for multi-impact parameter δ (in r-ϕ plane)

- Significance $S = \delta/\sigma_\delta$ (require $|\delta| < 0.1$cm)

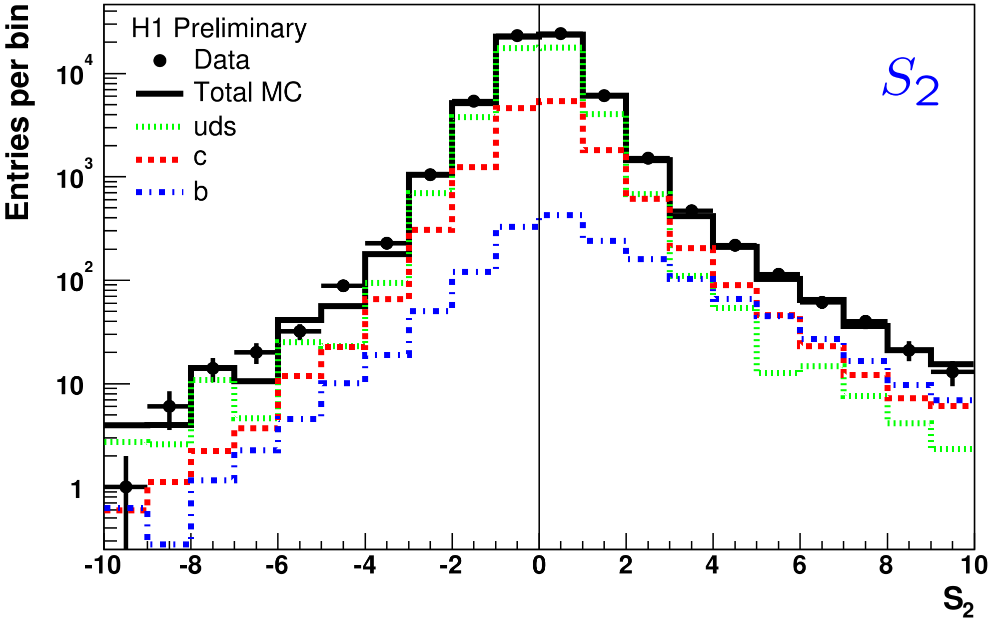


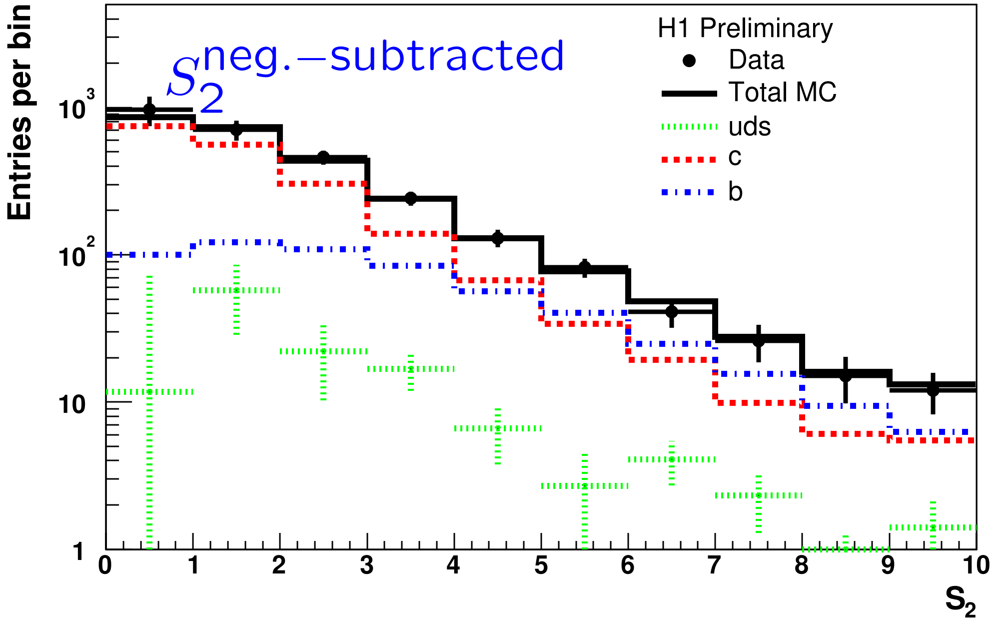
- Exclusive measurements (with D^* or leptons) suffer from statistical limitations

- Two Independent Significance Distributions S_1, S_2

  S_1: Highest significance track for 1-track events

  S_2: 2^{nd} highest significance track for $>$ 1-track events: enhanced sensitivity to b



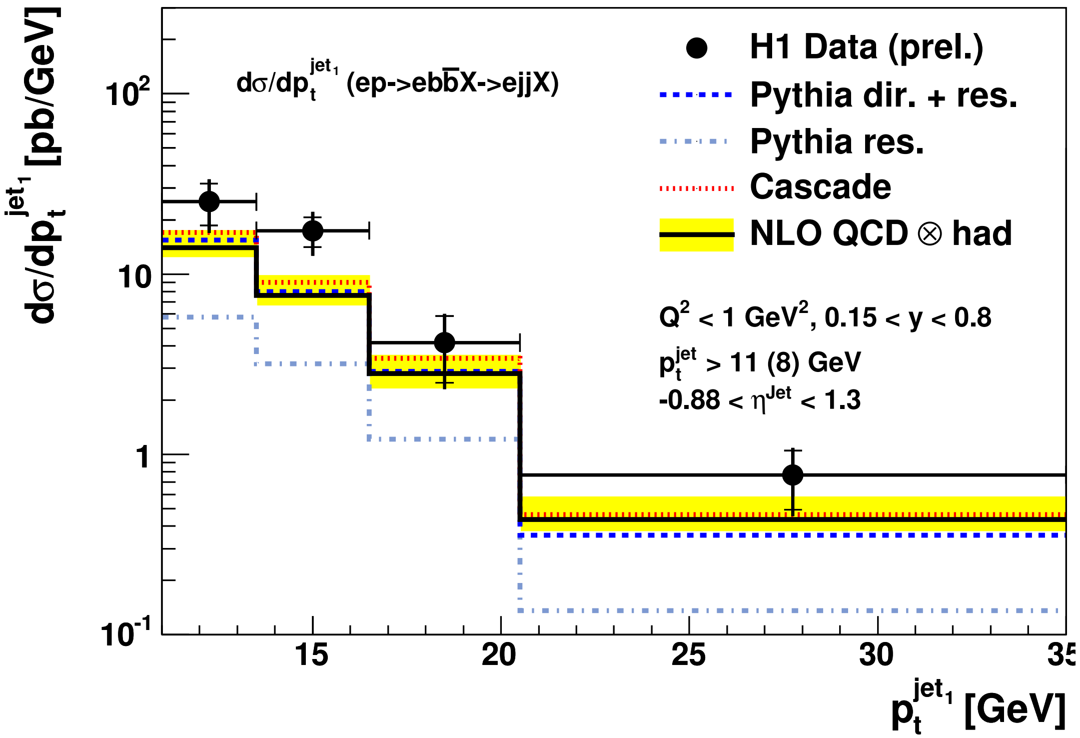


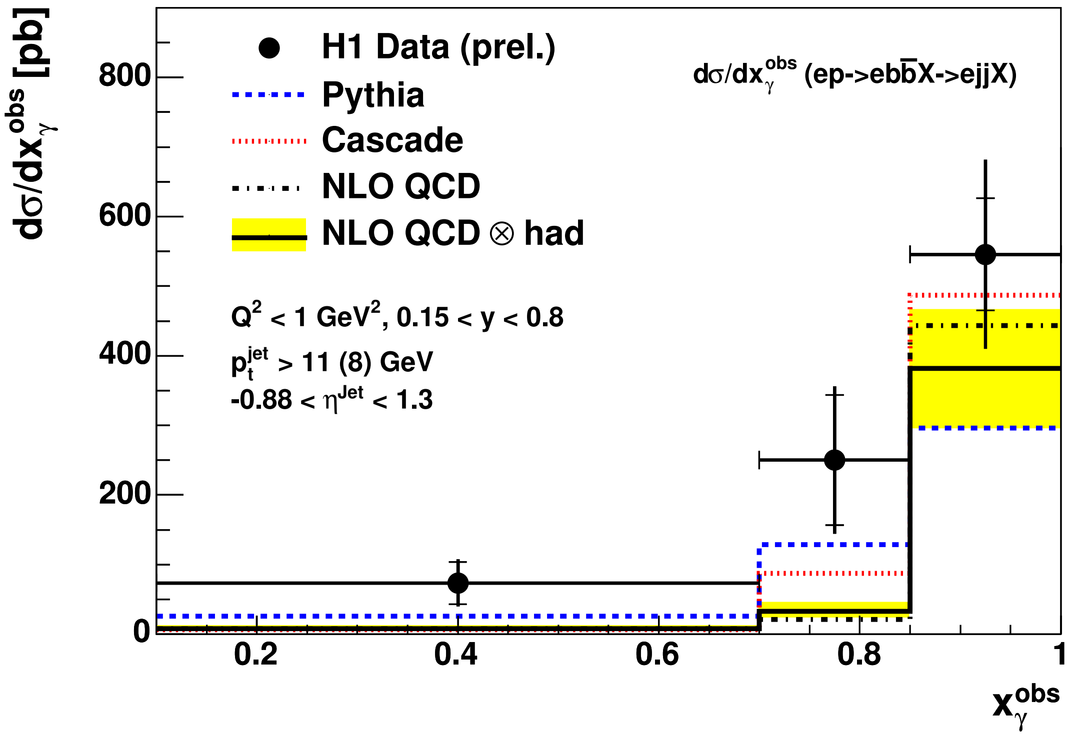
- Subtract negative side from positive side (remove symmetric part of distributions)
- Extract b and c fraction from fit to subtracted significance distributions

Beauty Photoproduction

$Q^2 \sim 0$ $\quad ep \to eb\bar{b}X \to ejjX'$ $\quad 0.15 < y < 0.8$

$p_t^{jet} > 11(8)$ GeV $\quad -0.88 < \eta^{jet} < 1.3$





- Data higher than NLO QCD by factor ~ 1.8

  difference mostly at small x_γ^{obs}

- LO+PS Monte Carlo simulations PYTHIA, CASCADE:

  shape ok, low in normalization

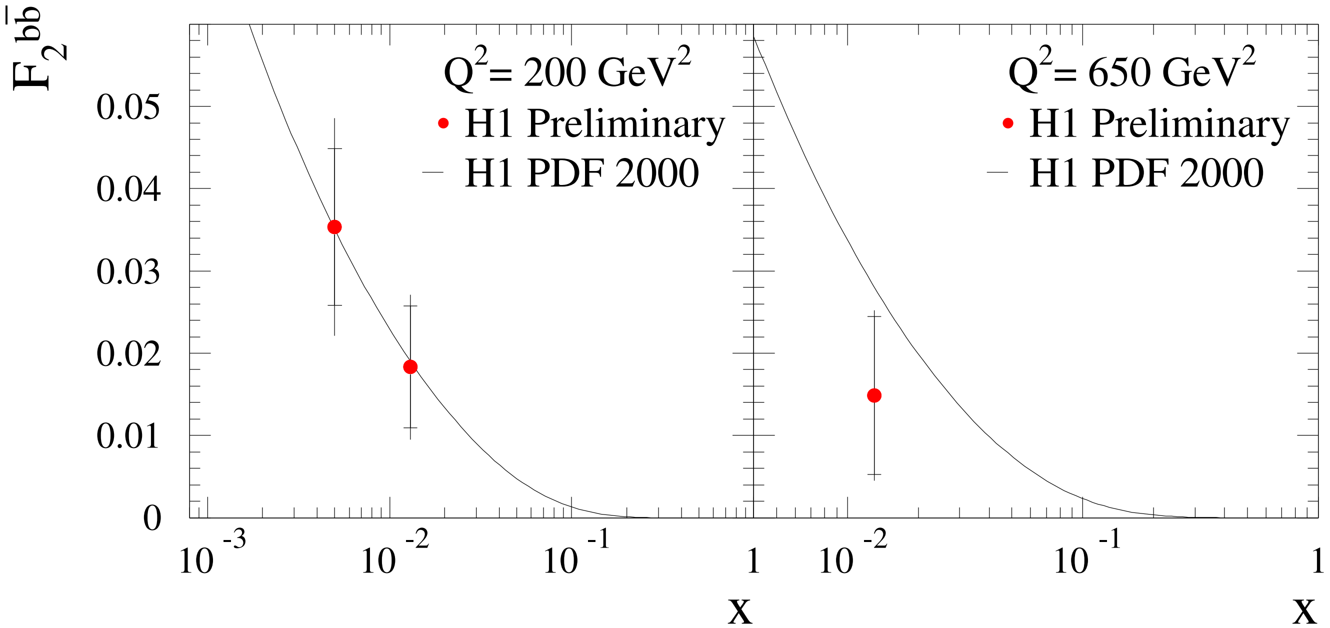
$F_2^{b\bar{b}}$ and $F_2^{c\bar{c}}$ at $Q^2 > 110$ GeV^2

- Choose x, Q^2 range such that events have jet with track inside det. acceptance
- Model extrapolations small! (10%)

$\Rightarrow$ Extract fully inclusive cross sections (structure functions) in x and Q^2

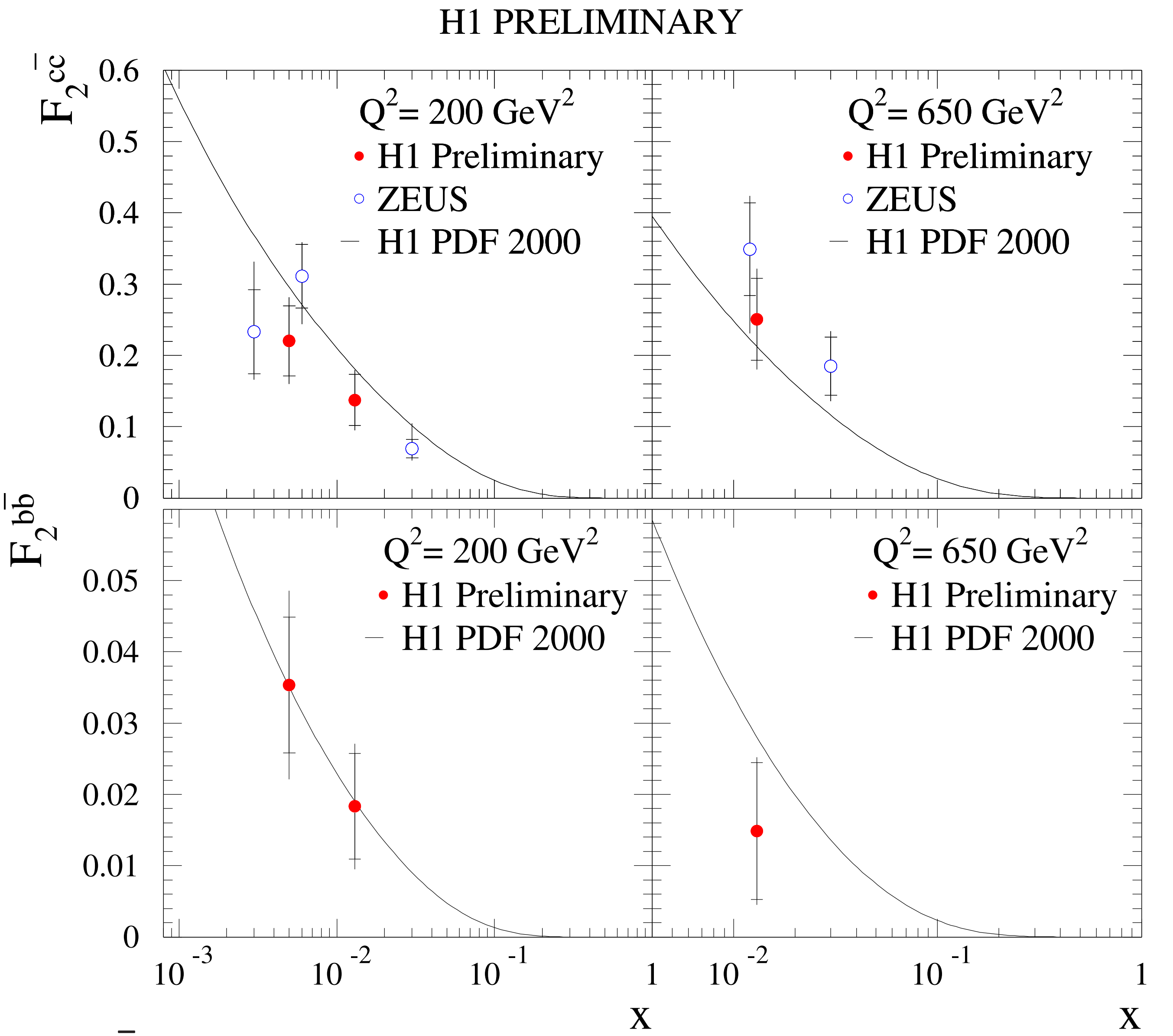
Measurement: $Q^2 > 150$ GeV^2, $0.1 < y < 0.7$: $\sigma_{b\bar{b}} = 45 \pm 11 \pm 11$ pb

Prediction using H1 NLO Fit to inclusive data: $\sigma_{b\bar{b}}^{NLO,massless} = 51.8$ pb



- Data consistent with NLO massless QCD within errors

$F_2^{b\bar{b}}$ and $F_2^{c\bar{c}}$ at $Q^2 > 110$ GeV^2



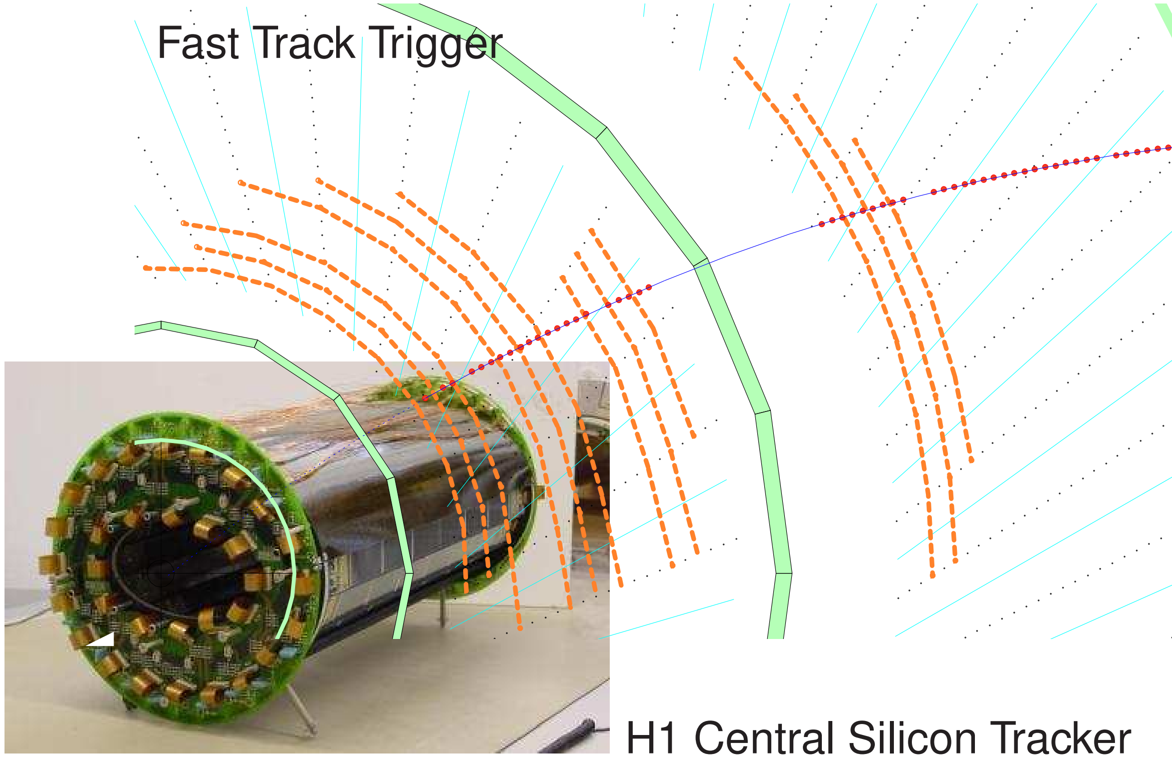
- $F_2^{c\bar{c}}$ consistent with NLO massless QCD and with ZEUS (from D^*)

Summary: Beauty at HERA I

- New precise differential b-cross-section measurements in Photoproduction and DIS
- Independent variables: p_t^{rel} and δ , multi-impact parameter methods
- Measurements are generally somewhat above massive NLO QCD predictions
- First determination of $F_2^{b\bar{b}}$ at $Q^2 > 110$ GeV^2
- Agreement with massless NLO QCD at large Q^2 within errors

Outlook: Beauty at HERA II cf. J.Loizides

- Go for precision !
  - Increased luminosity
  - Improved detectors
    (e.g. trigger, vertexing)



ZEUS Microvertex Detector

H1 Central Silicon Tracker

Backup: Extraction of b and c components

3-parameter fit to S_1, S_2 and number of all events in selection

- P_{li} - MC scale factor for uds
- P_c - MC scale factor for c
- P_b - MC scale factor for b

$$\chi^2 = \sum_i \frac{(N_i^{\text{data}} - P_b N_{bi}^{\text{MC}} - P_c N_{ci}^{\text{MC}} - P_l N_{li}^{\text{MC}})^2}{\sigma^2(N_i^{\text{data}}) + (P_b \sigma(N_{bi}^{\text{MC}}))^2 + (P_c \sigma(N_{ci}^{\text{MC}}))^2 + (P_l \sigma(N_{li}^{\text{MC}}))^2}$$
$$+ \frac{(N_{\text{tot}}^{\text{data}} - P_b N_{\text{tot}b}^{\text{MC}} - P_c N_{\text{tot}c}^{\text{MC}} - P_l N_{\text{tot}l}^{\text{MC}})^2}{\sigma^2(N_{\text{tot}}^{\text{data}}) + (P_b \sigma(N_{\text{tot}b}^{\text{MC}}))^2 + (P_c \sigma(N_{\text{tot}c}^{\text{MC}}))^2 + (P_l \sigma(N_{\text{tot}l}^{\text{MC}}))^2}$$

Fraction of events with beauty: $f^{b\bar{b}} = \frac{P_b N_b^{gen}}{P_{li} N_{li}^{gen} + P_c N_c^{gen} + P_b N_b^{gen}}$

Obtain b cross section from total: $F_2^{b\bar{b}} = F_2^{meas.} \cdot f^{b\bar{b}}$

Backup: Distributions of high Q^2 inclusive sample