Beauty Production at H1

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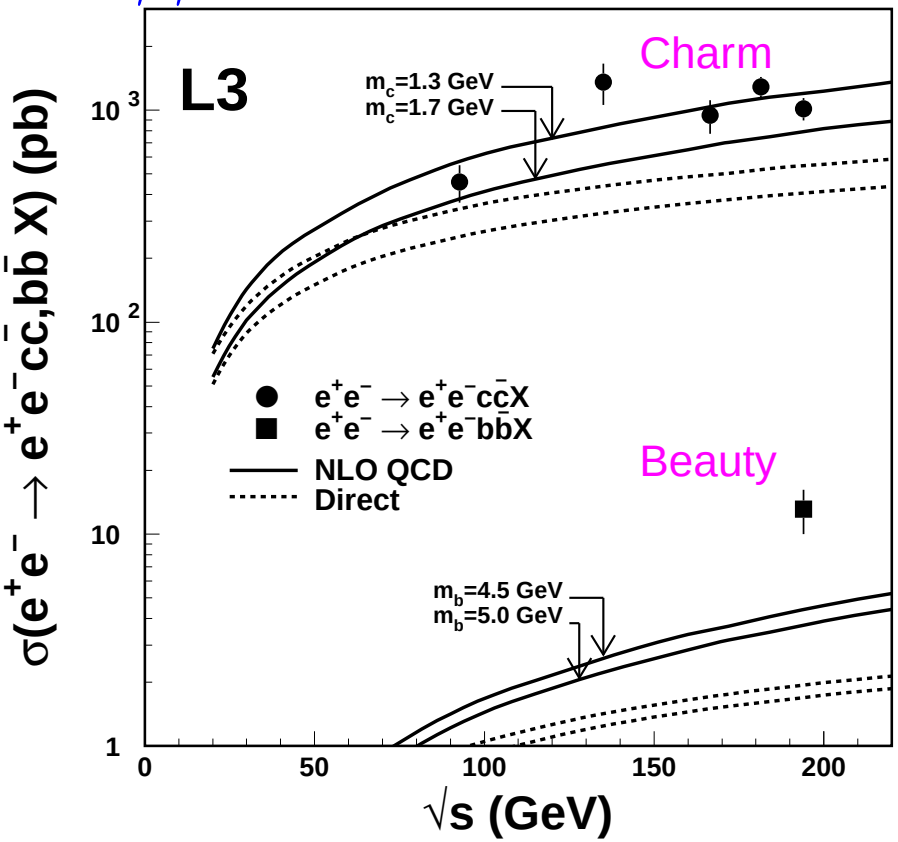
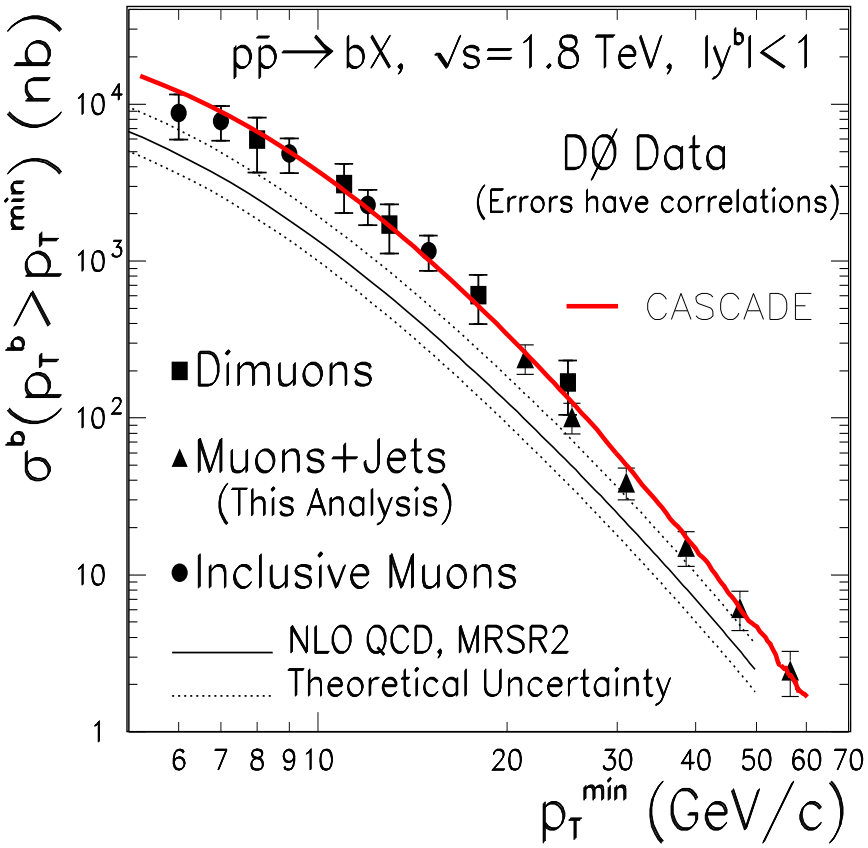
Introduction

$\gamma\gamma$ LEP



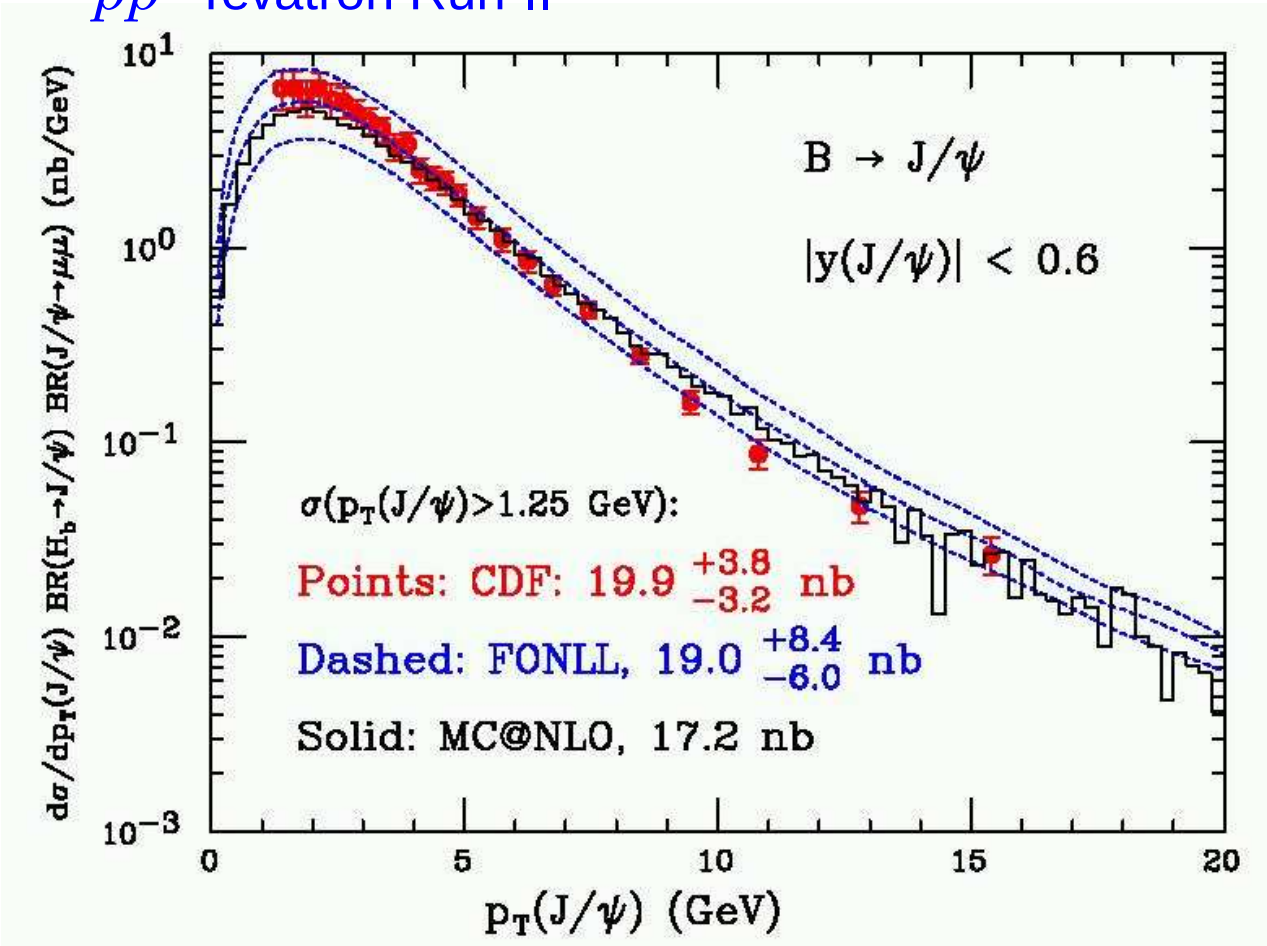
$p\bar{p}$ Tevatron Run-I



- Tevatron, LEP: Originally, NLO-expectations low compared to data
- $p\bar{p}$: Improved calculations come closer e.g. Cascade-MC (CCFM)

Introduction

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

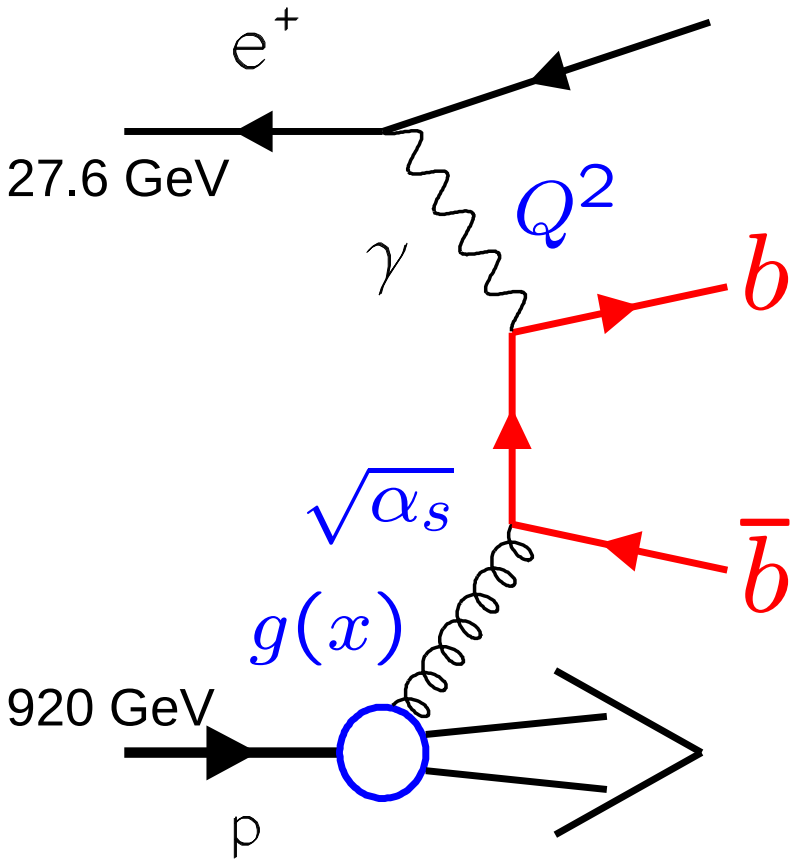


- New CDF Run-II data in good agreement with improved theory

What about the b-data at HERA?

Beauty Production in ep-Scattering

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



- Driven by gluons in the proton
- Relevant scales:

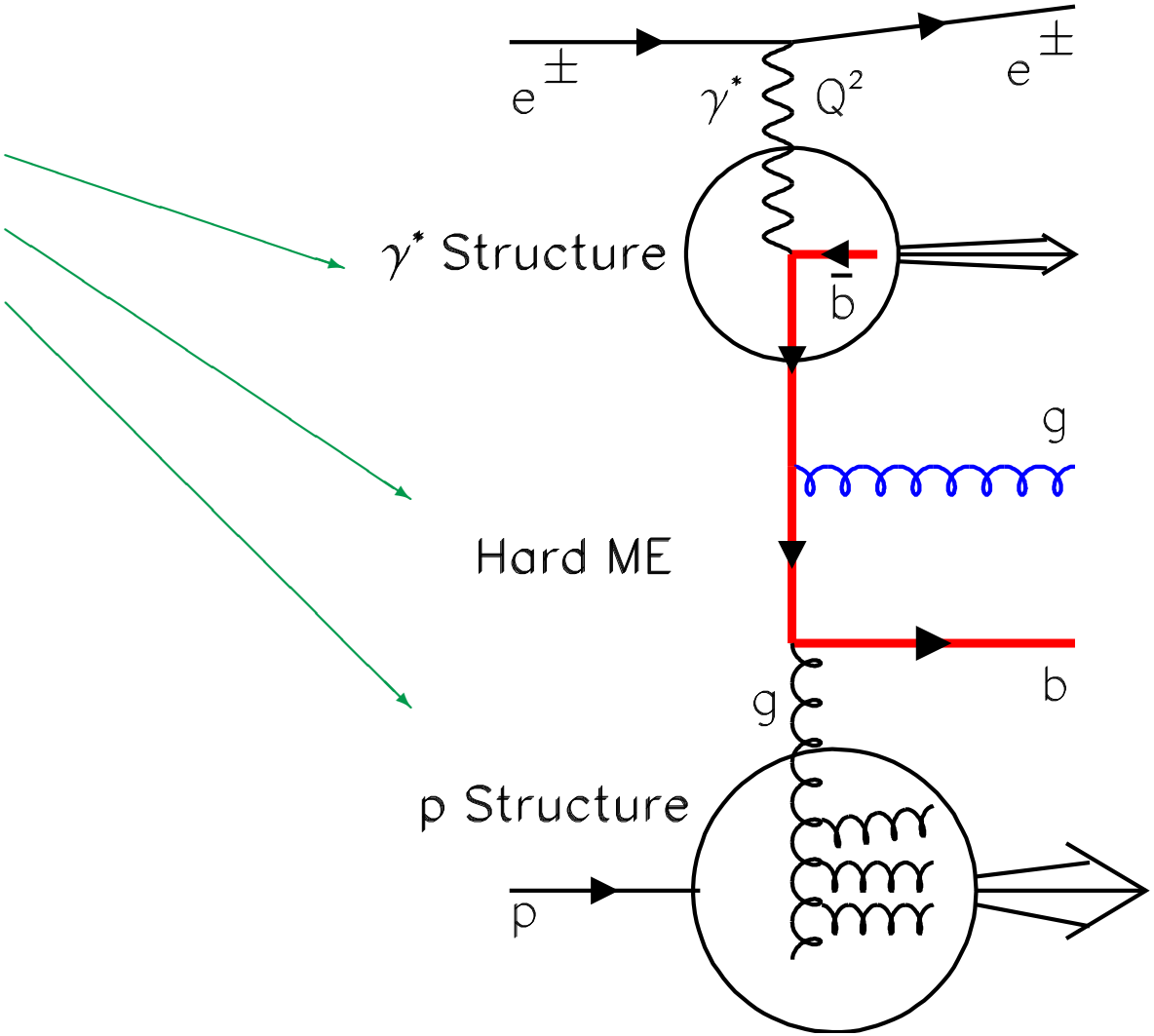
m_b	$\sim$ 5 GeV
Q^2	$\lesssim$ 1 GeV^2 $\rightarrow \gamma p$
	$>$ 2 GeV^2 $\rightarrow$ DIS: new results
p_T^b	Event selection: $p_t^{jet} >$ 6 or 7 GeV

- Various scales available: pQCD should work

Heavy Quarks: Multiscale Problem in pQCD

Beauty Production in pQCD

- Factorisation:
  - ⊗ Photon Structure
  - ⊗ Matrix Element
  - ⊗ Proton Structure
  - ⊗ Fragmentation

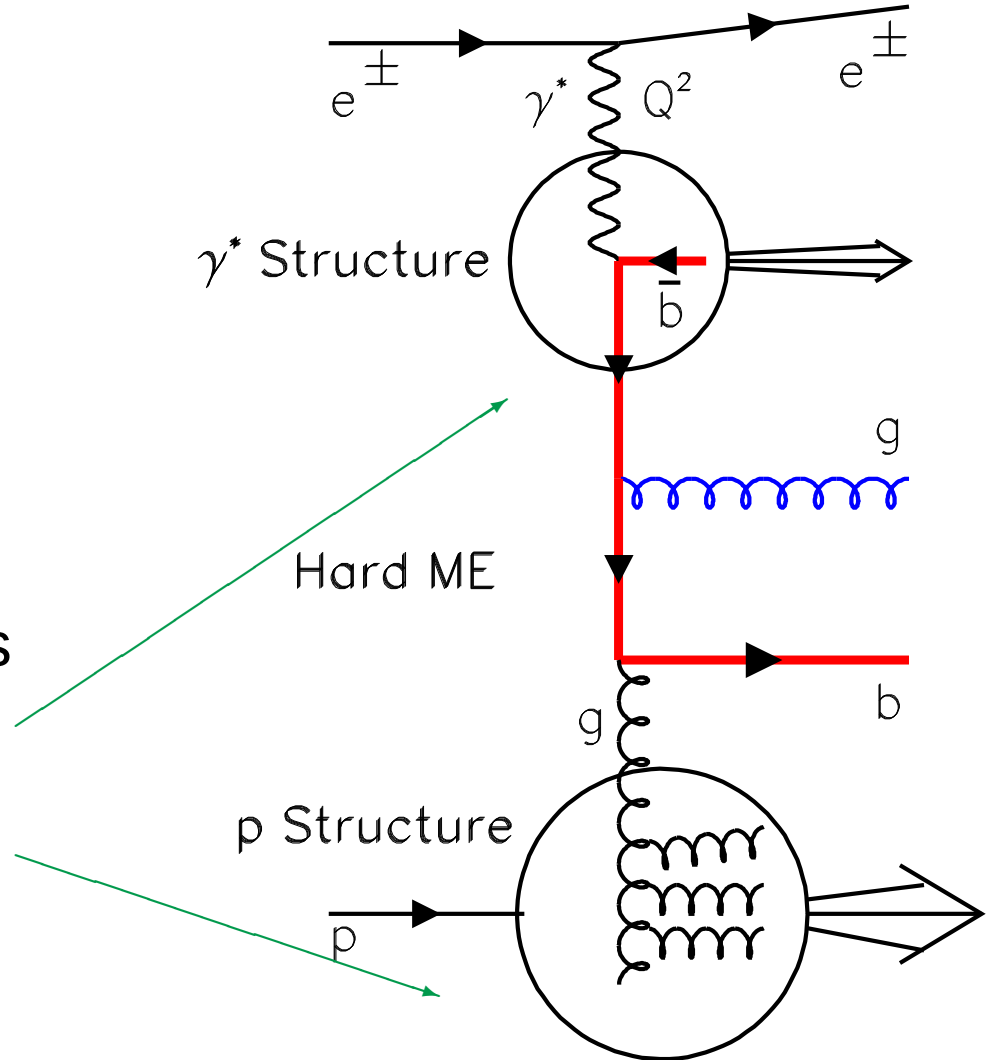


Beauty Production in pQCD

- Factorisation:
  - ⊗ Photon Structure
  - ⊗ Matrix Element
  - ⊗ Proton Structure
  - ⊗ Fragmentation

- Key Questions:
  - Role of resolved photons for beauty production?
  - pQCD approximation of gluon radiation (DGLAP, CCFM, BFKL)

→ can be addressed at HERA



Beauty Production in pQCD

QCD models:

- NLO $\mathcal{O}(\alpha_s^2)$ calculations

  γp: FMNR

  Frixione, Mangano, Nason, Ridolfi

  DIS: HVQDIS

  Harris, Smith

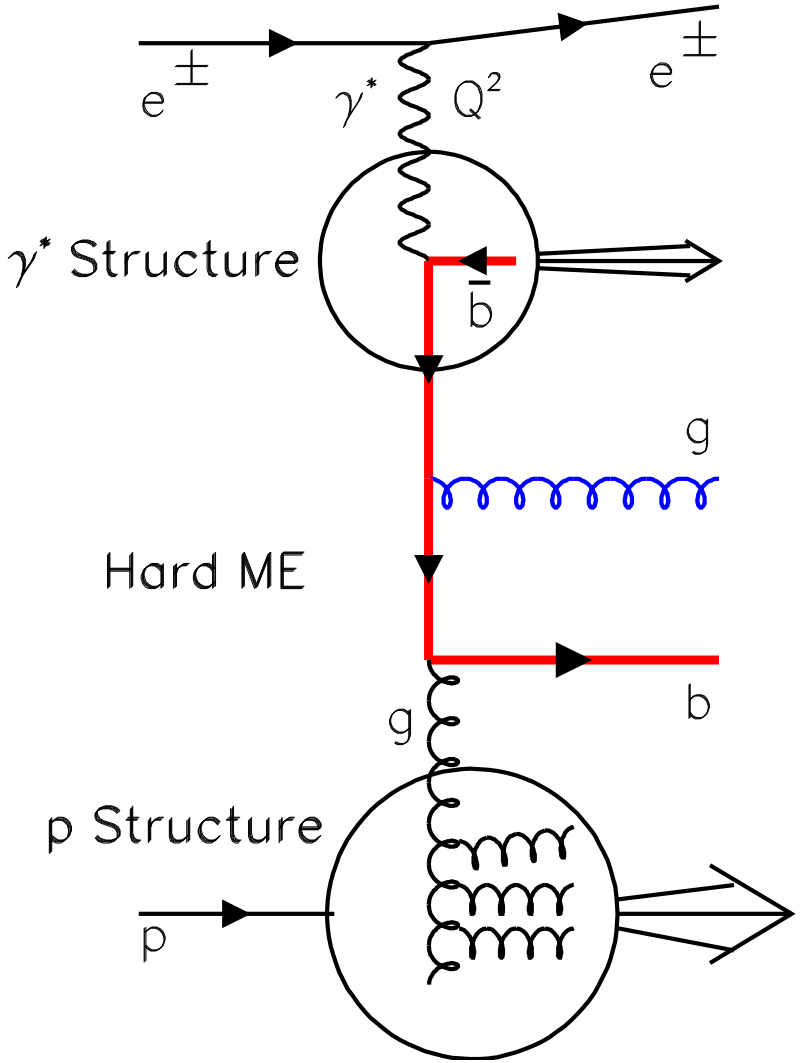
- LO $\mathcal{O}(\alpha_s)$ + Parton shower:

  Pythia / Rapgap MC (DGLAP)

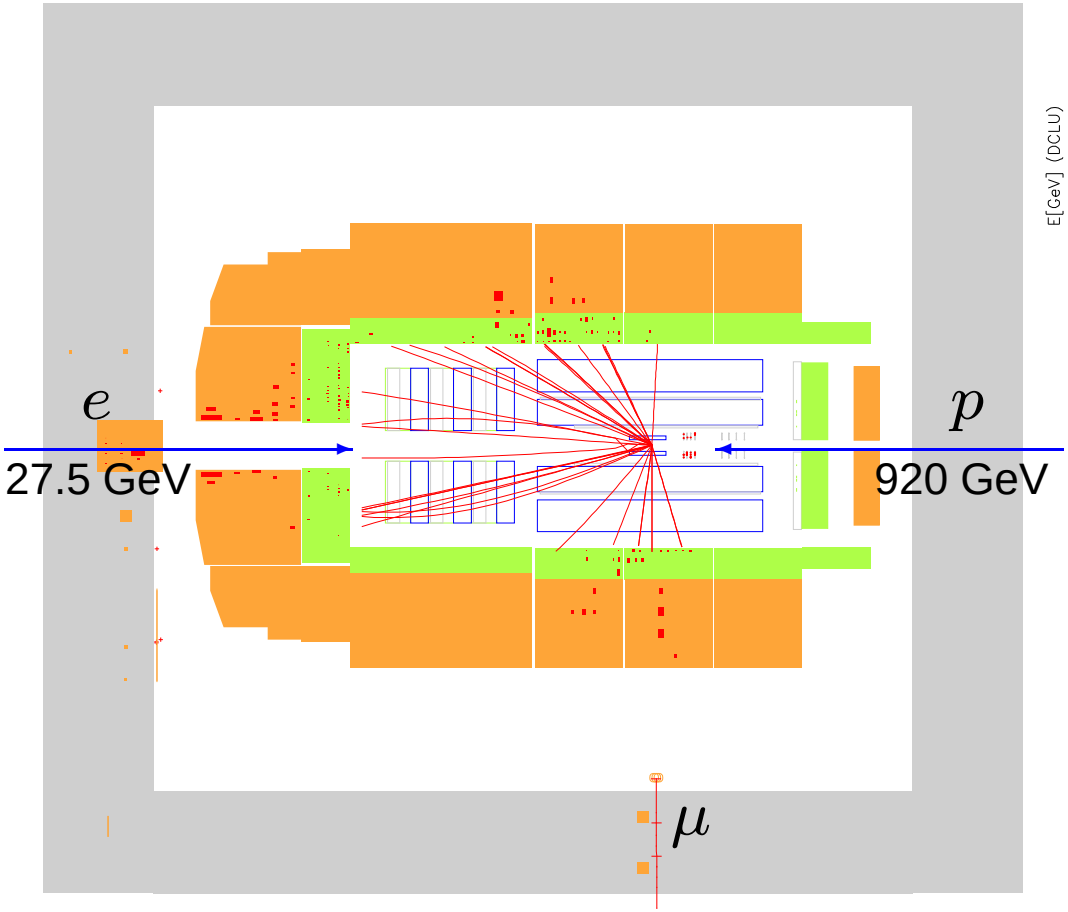
  T.Sjöstrand / H.Jung

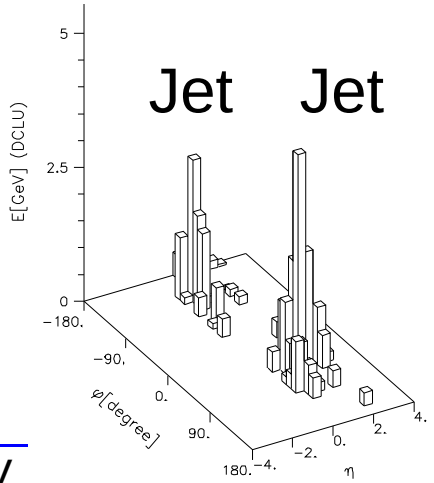
  Cascade MC (CCFM)

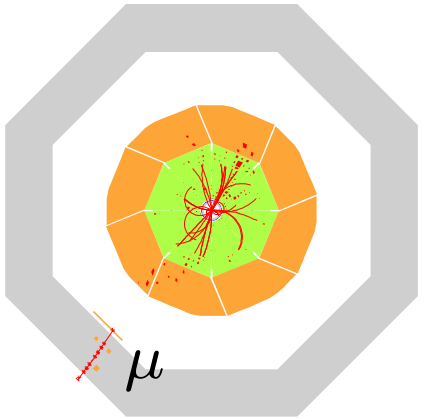
  H.Jung

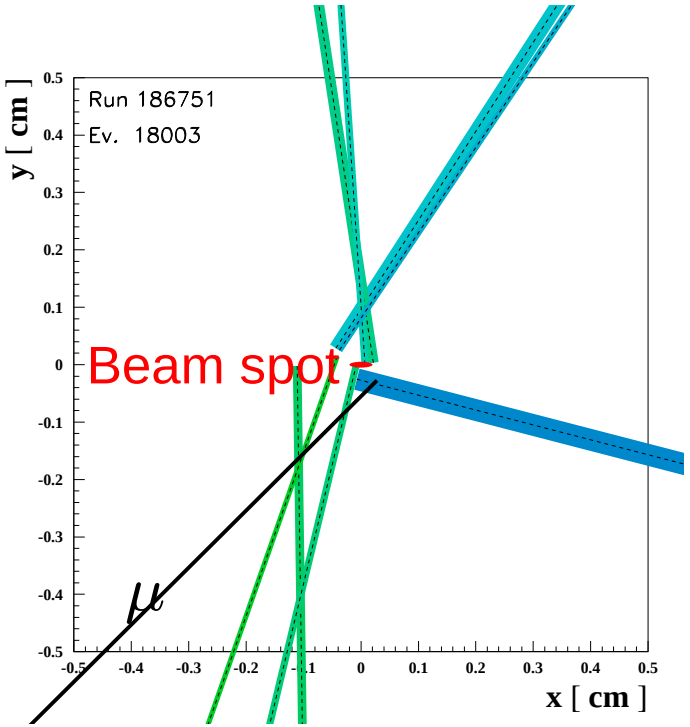


H1 Beauty Event Selection







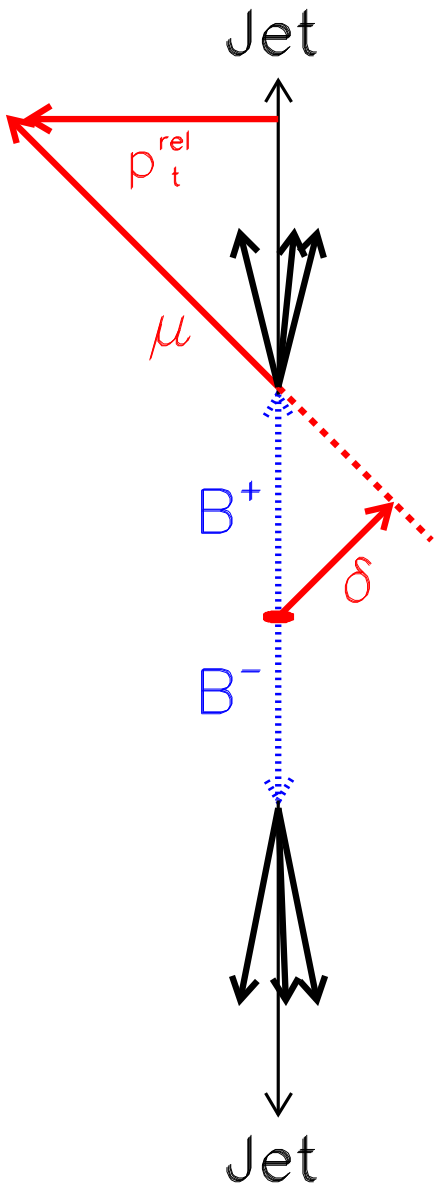


H1: $\sim 50\ \mathrm{pb}^{-1}$ with Silicon Vertex Detector

- Selection of semileptonic B-decays
- Require jet-topology and identified μ

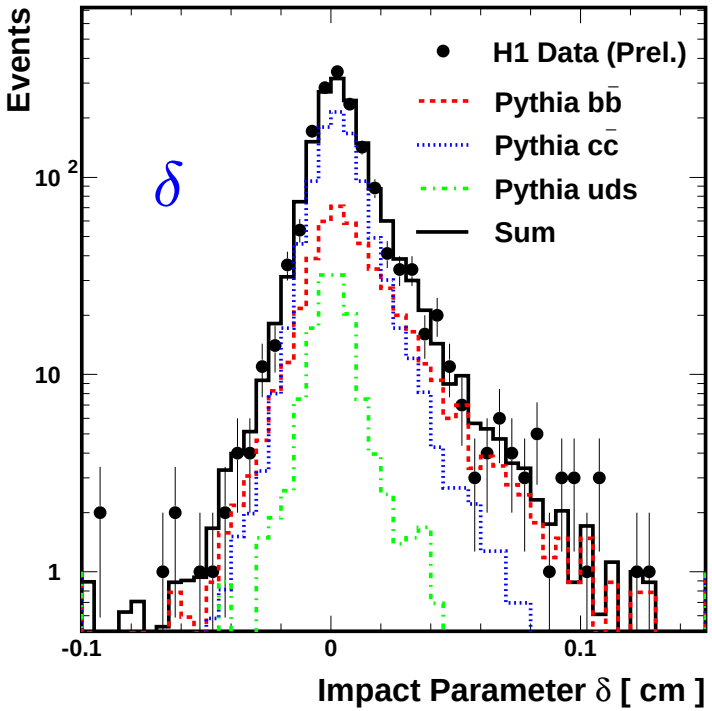
New differential measurements of visible cross section in DIS and γp

Beauty Observables

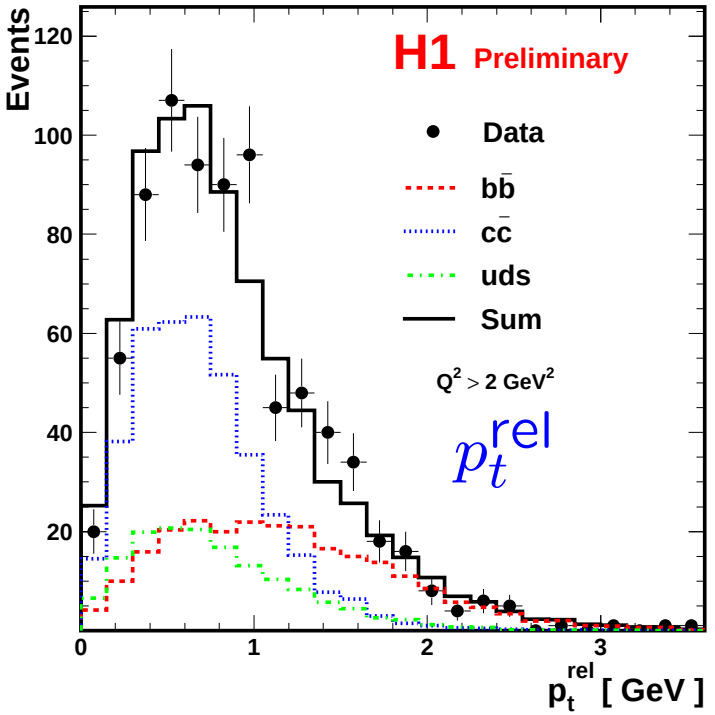


- Large B-Mass:
  p_t^{rel}: p_t of μ relative to jet axis
- Large B-Lifetime:
  μ Impact-Parameter δ

γp sample: $\sim$ 1600 events



DIS sample: $\sim$ 800 events



MC for simulation of b, c, uds

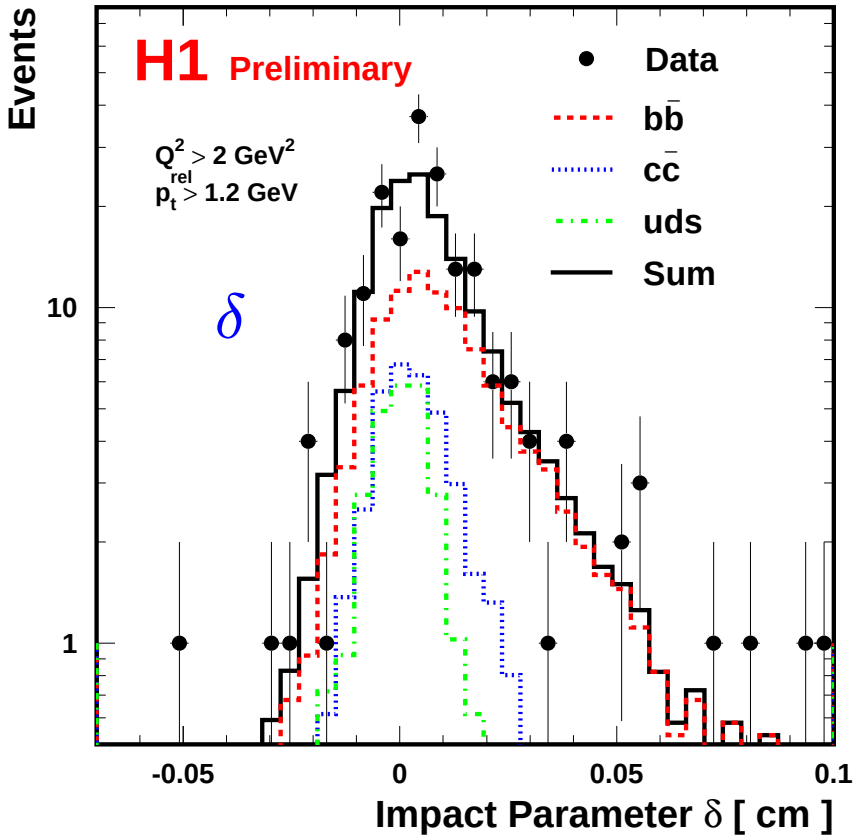
3-parameter fit of b, c and uds simultaneously to p_t^{rel} and δ

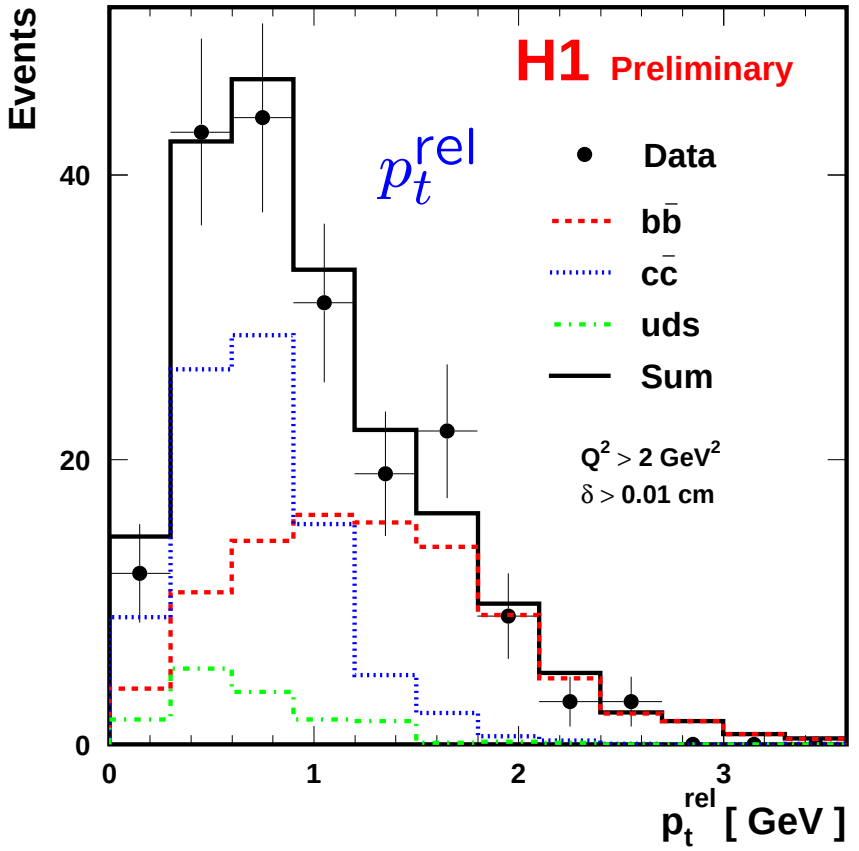
$\rightarrow$ b-fraction (typically 30%)

Enhanced Purity Beauty Samples

Two independent observables: δ and p_t^{rel}

- Facilitate experimental cross checks
- Access to regions of enhanced b-fraction





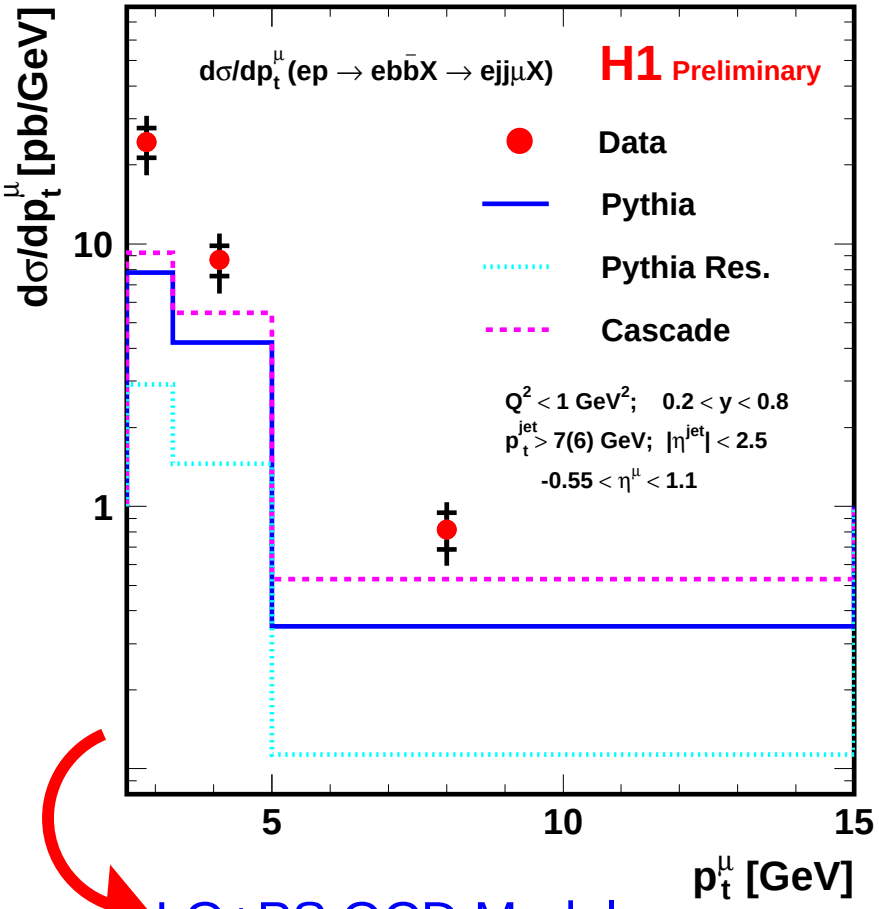
→ Well described by MC with fractions fixed from 2d-fit of complete sample

(shown for DIS sample, $Q^2 > 2$ GeV^2)

Beauty in Photoproduction

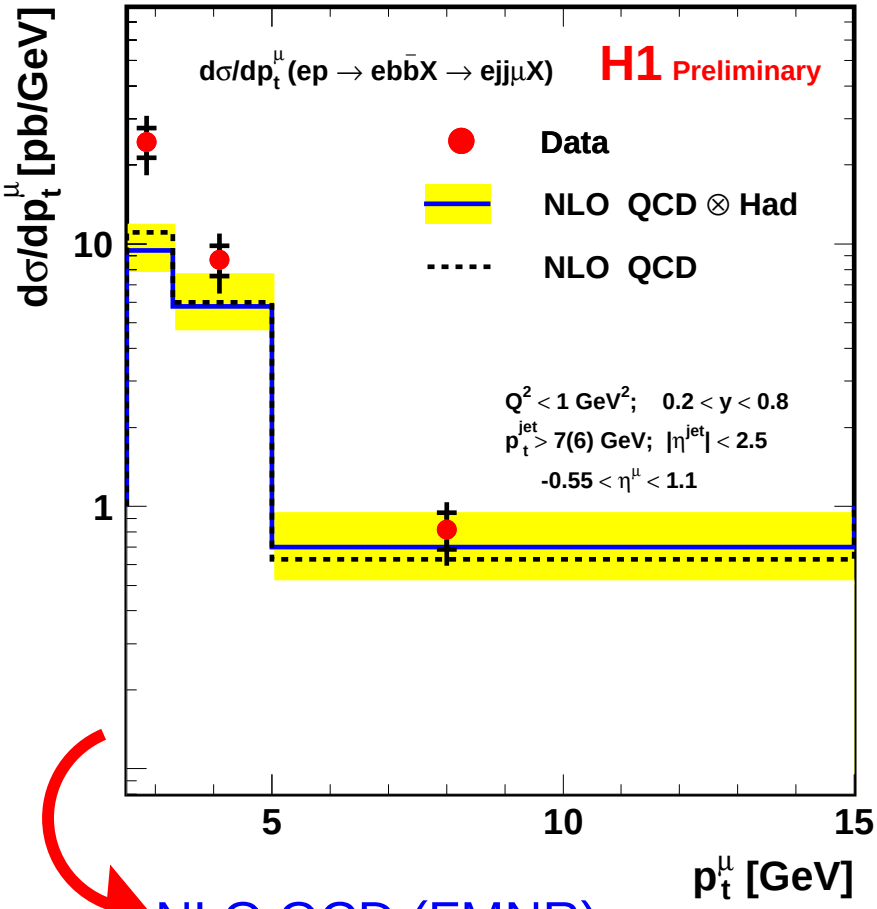
$Q^2 \sim 0$ $\quad b\bar{b} \rightarrow jj\mu X$

$p_t^{jet} > 7(6)$ GeV, $|\eta^{jet}| < 2.5$, $0.2 < y < 0.8$
$p_t^{\mu} > 2.5$ GeV, $-0.55 < \eta^{\mu} < 1.1$



LO+PS QCD Models

Too low in normalization



NLO QCD (FMNR):

Too low at low p_T^{μ}

NLO Calculations

Recipe for data/MC comparison of visible cross sections:

Event Generation at NLO FMNR, HVQDIS

- Jet-algorithm (incl.k_t massless) at parton level
- b-quark fragmentation into B-hadrons Peterson $\epsilon = 0.0033$
- B-hadron decay into $\mu + X$ μ-spectrum from MC

Event Selection:

- Jet selection at parton level $|\eta^{jet}| < 2.5$; DIS: Breit-frame $p_t^* > 6$ GeV, γp: $p_t > 7(6)$ GeV
- μ-selection $p_t^\mu > 2.5$ GeV , Jet-μ association $\Delta R < 1$
- Parton-to-hadron-level correction $\sim -20\%$ from LO+PS PYTHIA (γp) or RAPGAP (DIS)

Systematic Error Estimate:

- Structure Functions CTEQ5F3 / CTEQ4F3 / GRV98
- Fragmentation Parameter $\epsilon \pm 0.0008$
- Scales: $m_b = 4.75$ GeV: vary by ± 0.25 GeV
  μ_r, μ_f DIS: $\sqrt{Q^2 + 4m_b^2}$, γp: $\sqrt{m_b^2 + (p_t^b)^2}$: vary up and down by factor 2

$\Rightarrow$ Total uncertainty: DIS: $\sim 15 - 20\%$, γp: $\sim 25\%$

NLO calculation including fragmentation needed, e.g. MC@NLO for HERA ?

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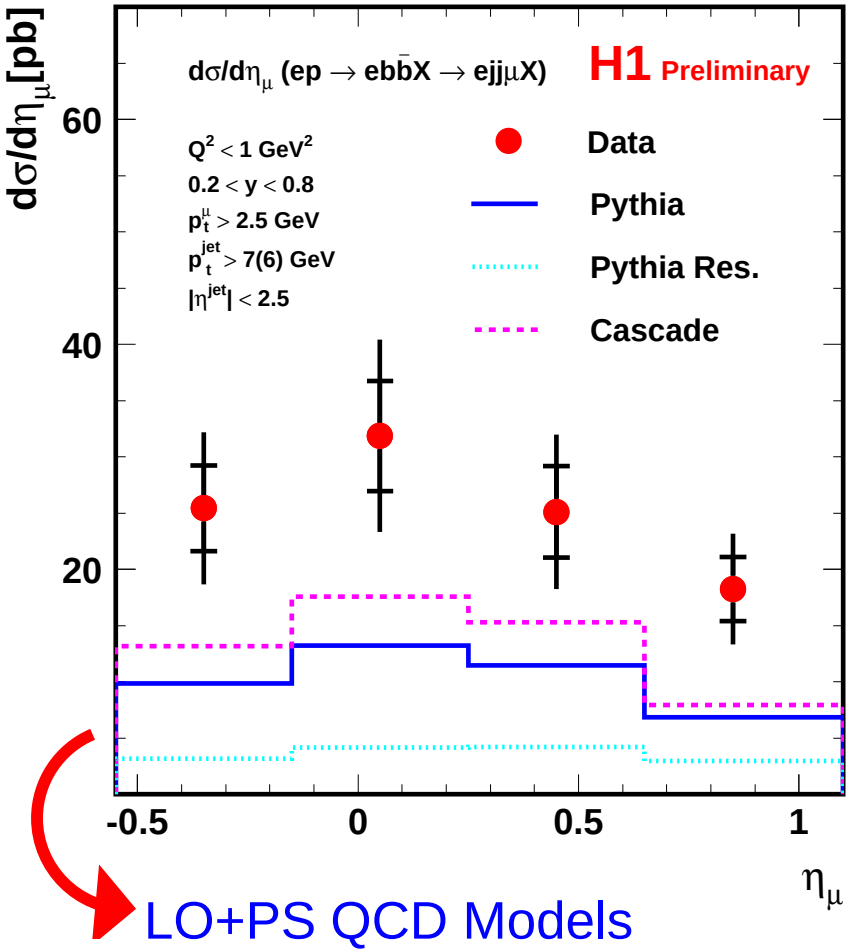

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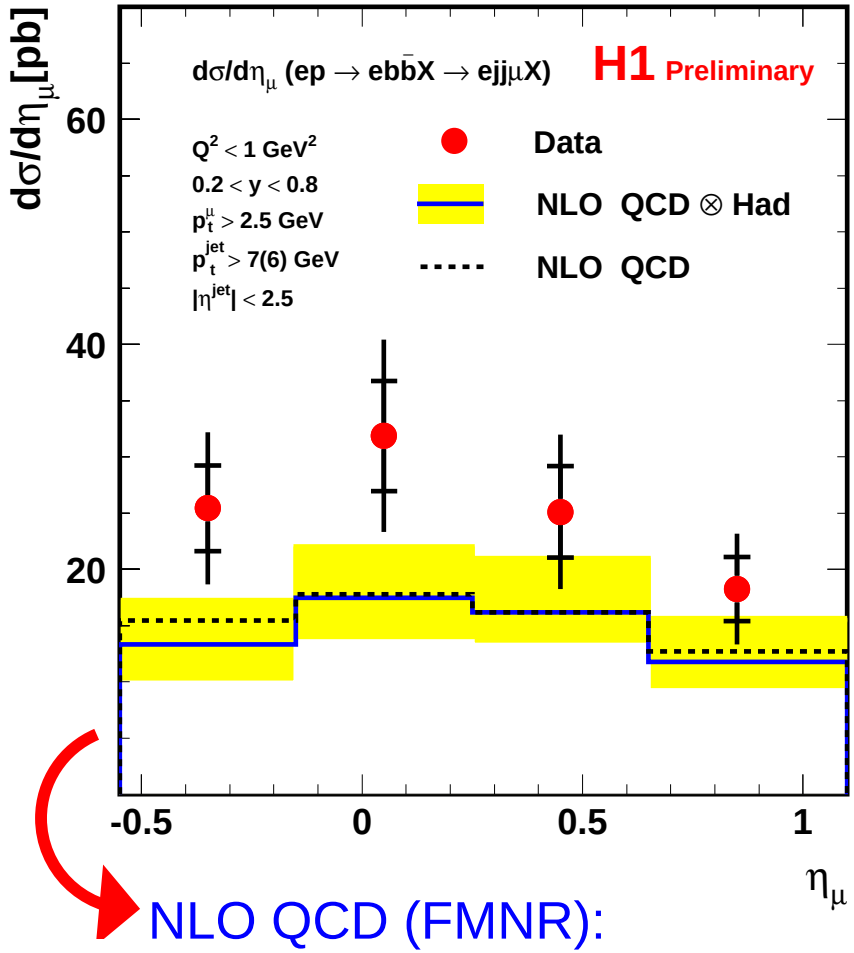
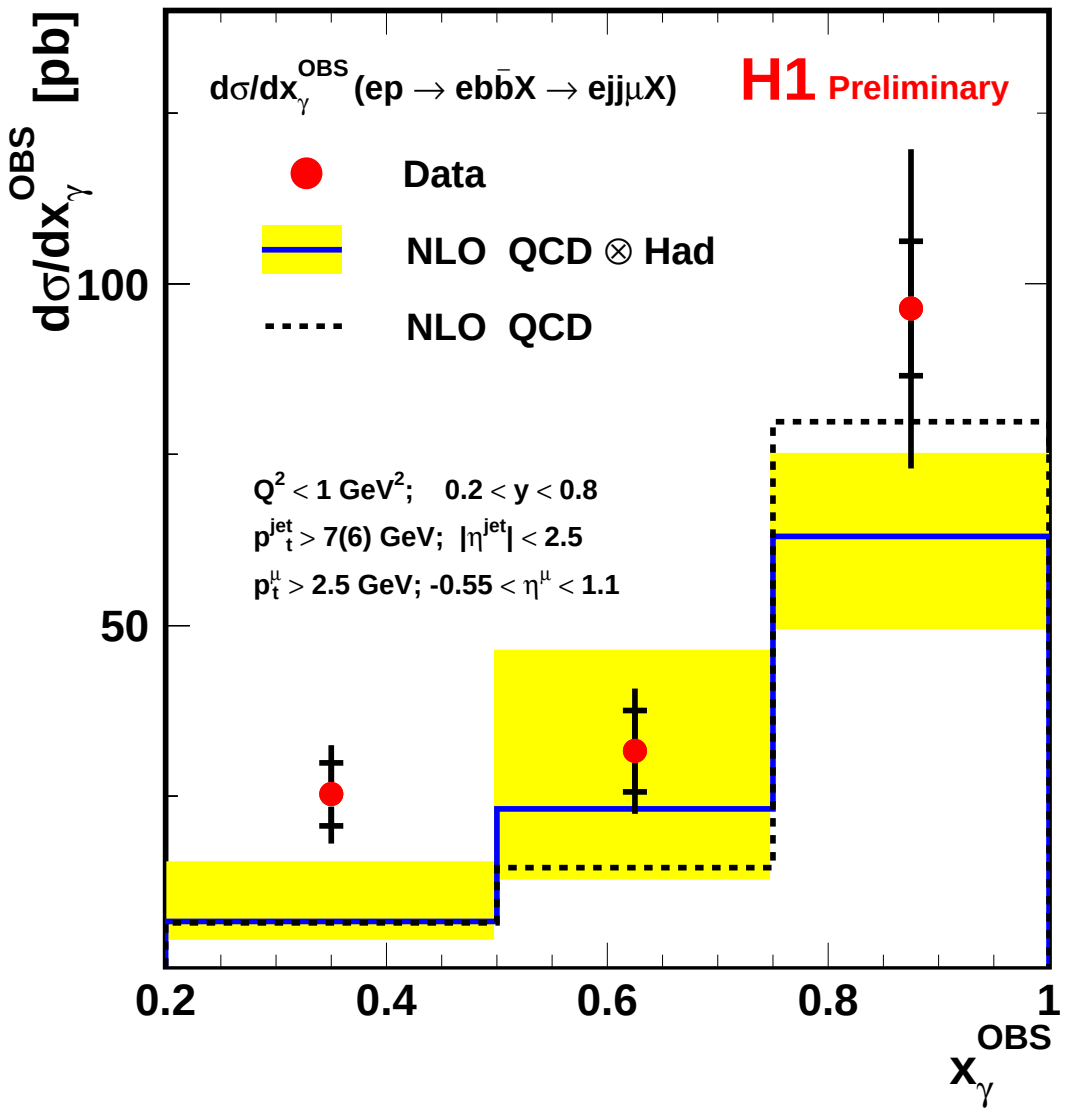


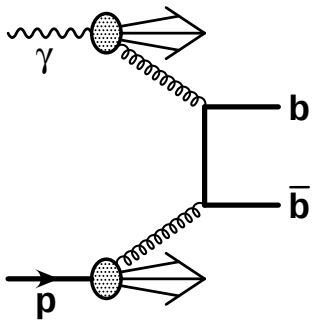
NLO QCD (FMNR):

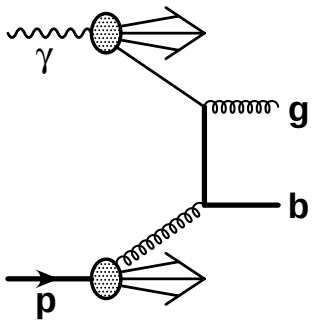
Almost OK within large errors
(syst. errors mostly correlated)

Contributions from Resolved Photons

$Q^2 \sim 0$ $\quad b\bar{b} \to jj\mu X$







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

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

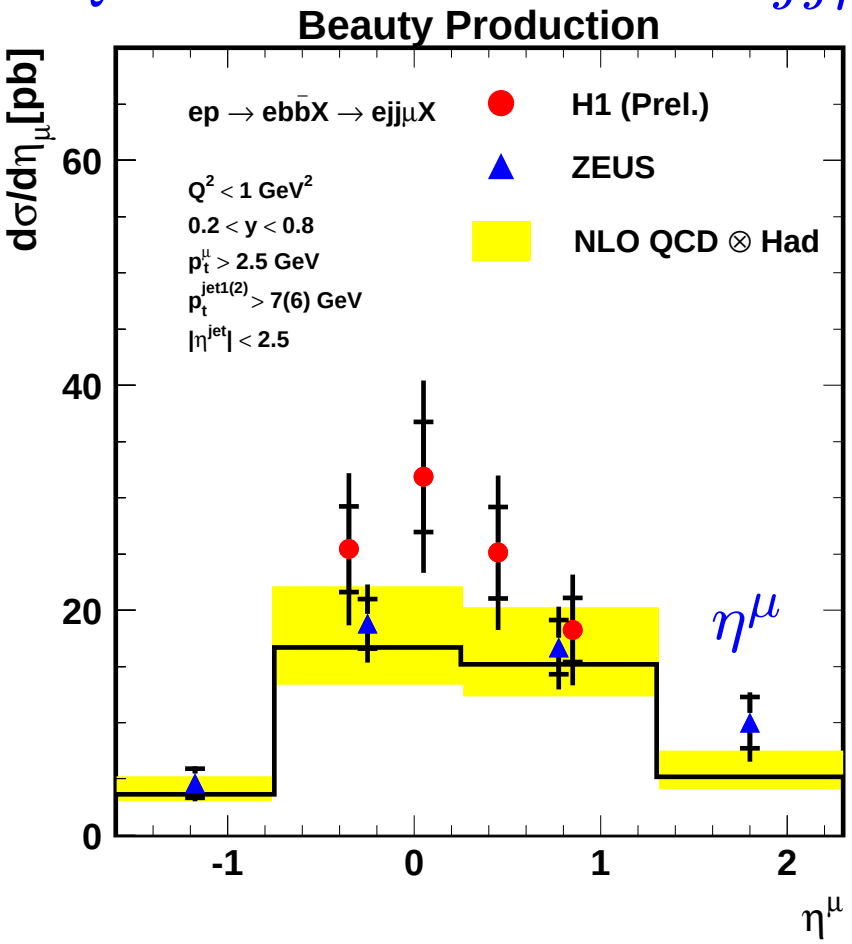
- Resolved Photon: ($x_\gamma \lesssim 0.75$)
  $\to$ significant contribution

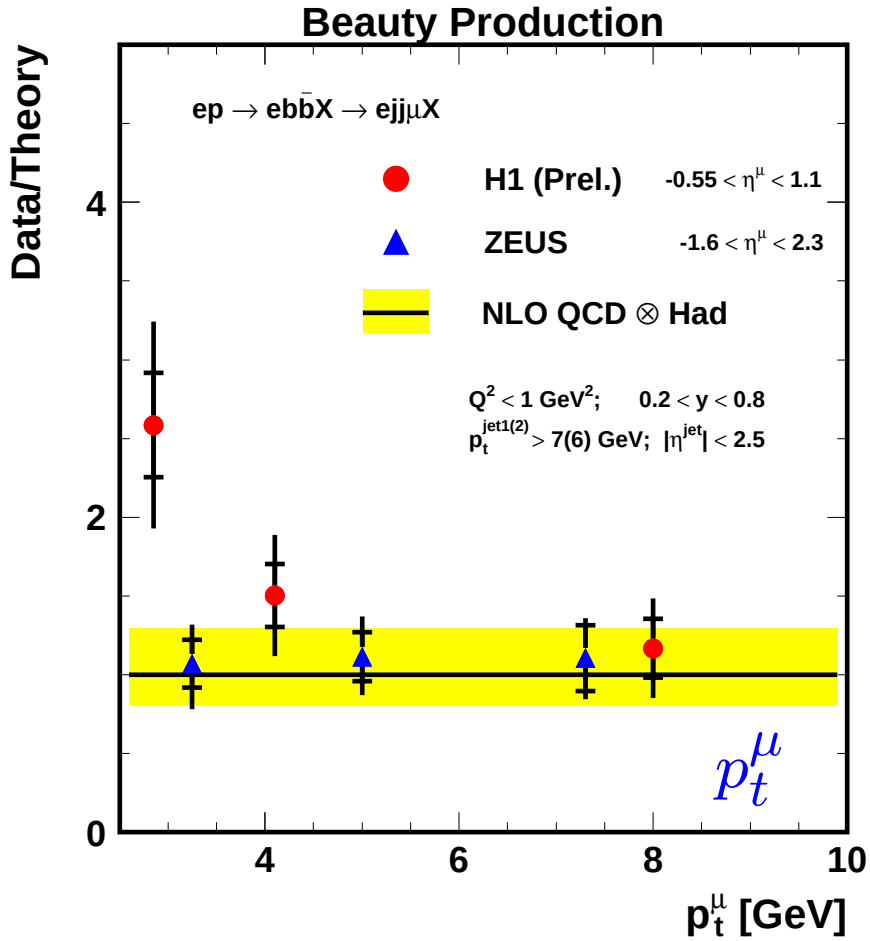
- NLO QCD:
  $\to$ lower than data at low x_γ
  $\to$ large uncertainties

H1: $\sigma^{\text{vis}} = 42.5 \pm 3.4 \pm 8.9$ pb
NLO (FMNR) : $(24.1^{+7.2}_{-5.1})$pb

Comparison with ZEUS Results

$Q^2 \sim 0$ $\quad b\bar{b} \rightarrow jj\mu X$

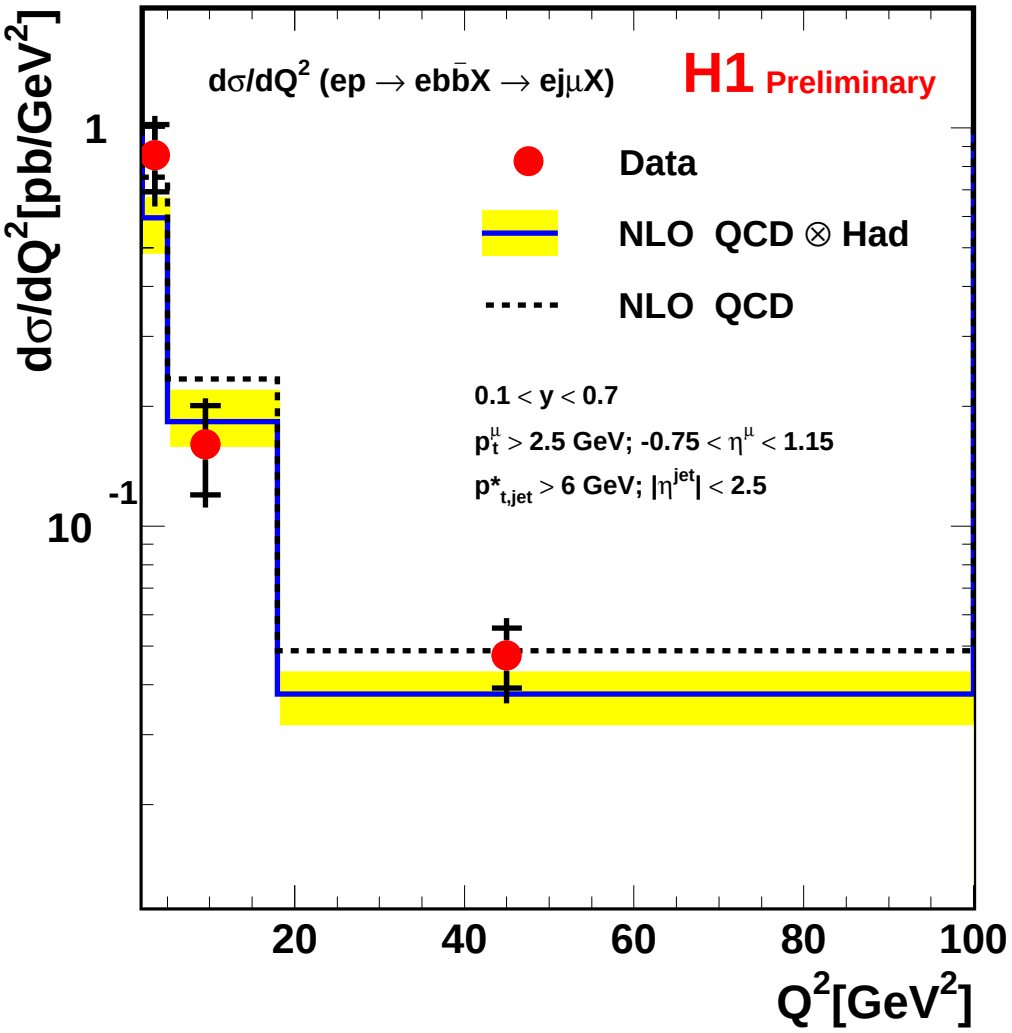




- General agreement between H1 and ZEUS
- H1 high at low p_t^μ
- Exp. and theory errors fairly large: Agreement within errors

Beauty in DIS

$2 < Q^2 < 100$ GeV^2 $\quad ep \to eb\bar{b}X \to ej\mu X$



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$p_t^{\mu} > 2.5$ GeV, $-0.75 < \eta^{\mu} < 1.15$

$$\sigma^{\text{vis}} = (8.8 \pm 1.0 \pm 1.5)\ \text{pb}$$

- DGLAP (NLO):
  - ok within errors

  NLO (HVQDIS) : $\sigma^{\text{vis}} = (7.3^{+1.0}_{-1.5})$pb

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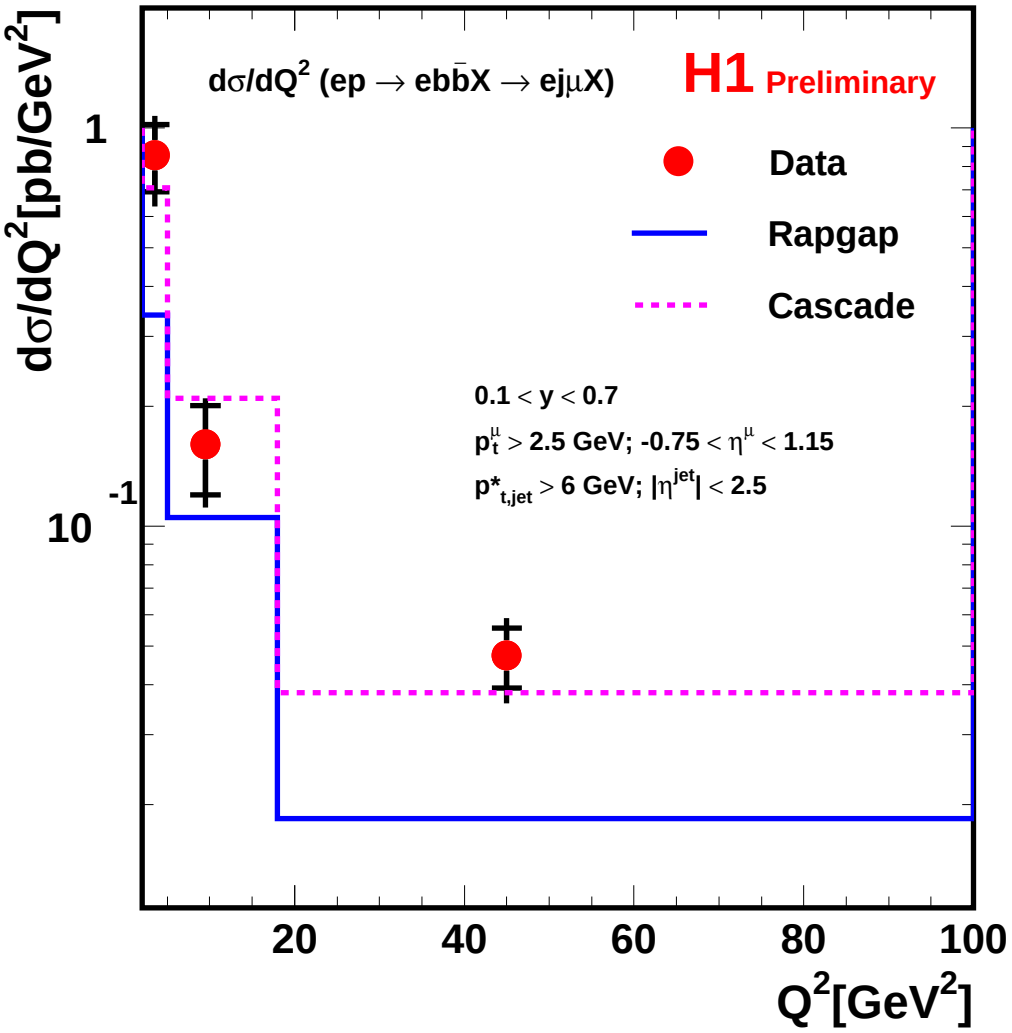

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- DGLAP (NLO):
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  NLO (HVQDIS) : $\sigma^{\text{vis}} = (7.3^{+1.0}_{-1.5})$pb
- CCFM:
  - Good description

  CASCADE-MC: $\sigma^{\text{vis}} \approx 9$pb
- DGLAP (LO+PS):
  - too low

  RAPGAP-MC: $\sigma^{\text{vis}} \approx 5.5$pb

Beauty in DIS

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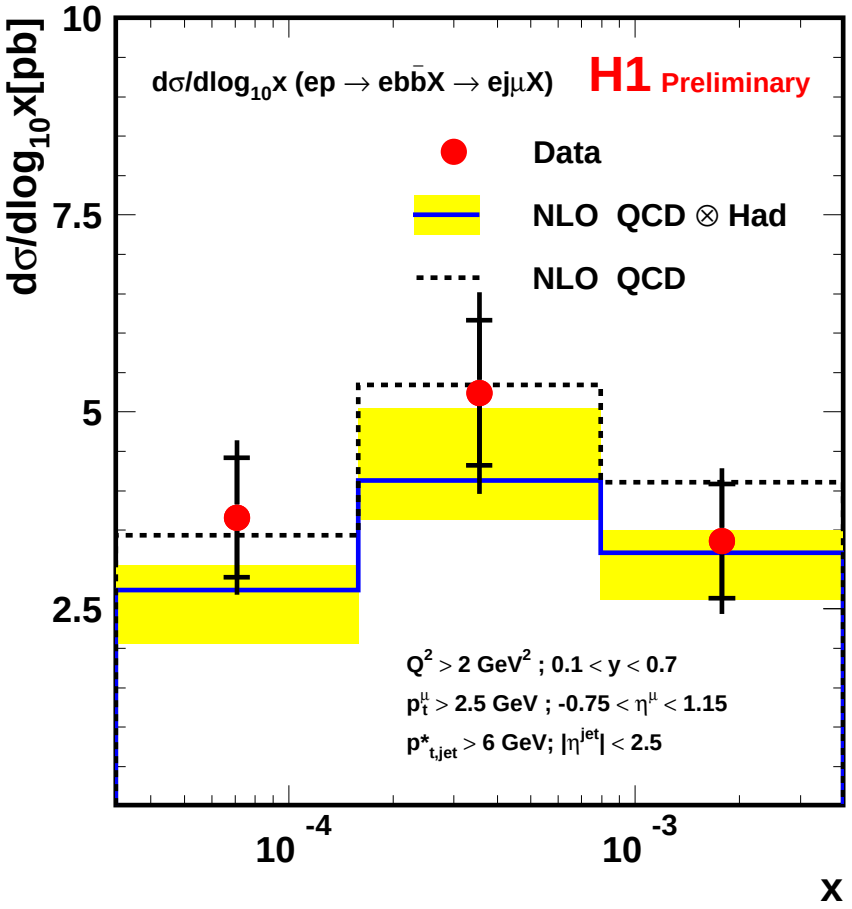
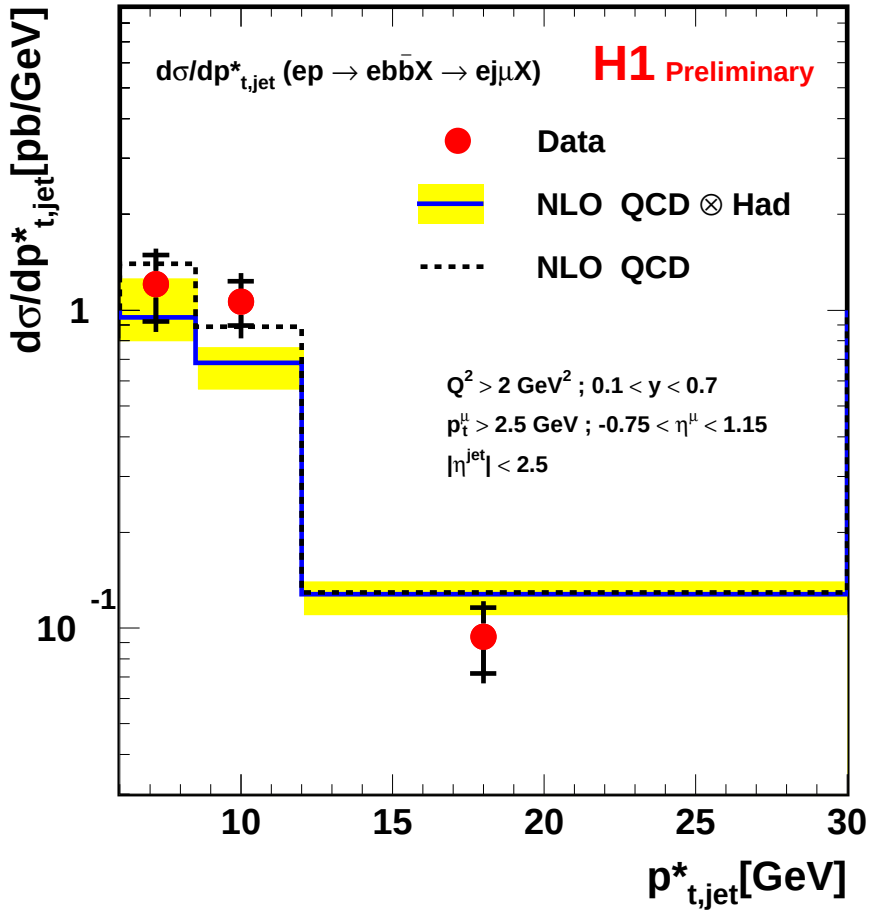
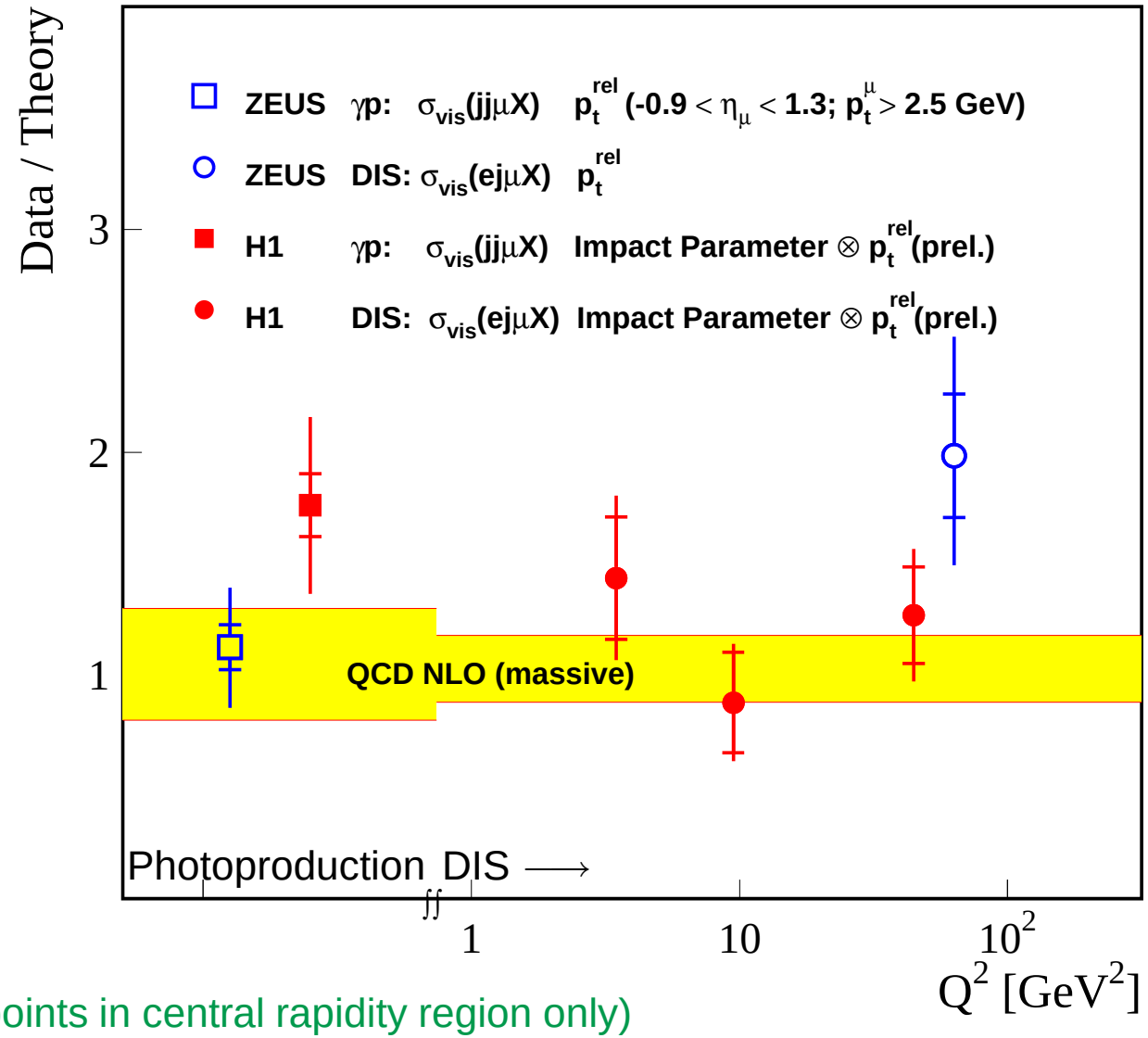




- Good description also in $x_{Bjorken}$ and $p^*_{t,jet}$

Comparison with ZEUS



(Data points in central rapidity region only)

ZEUS DIS results: cf. talk by K.Klimek

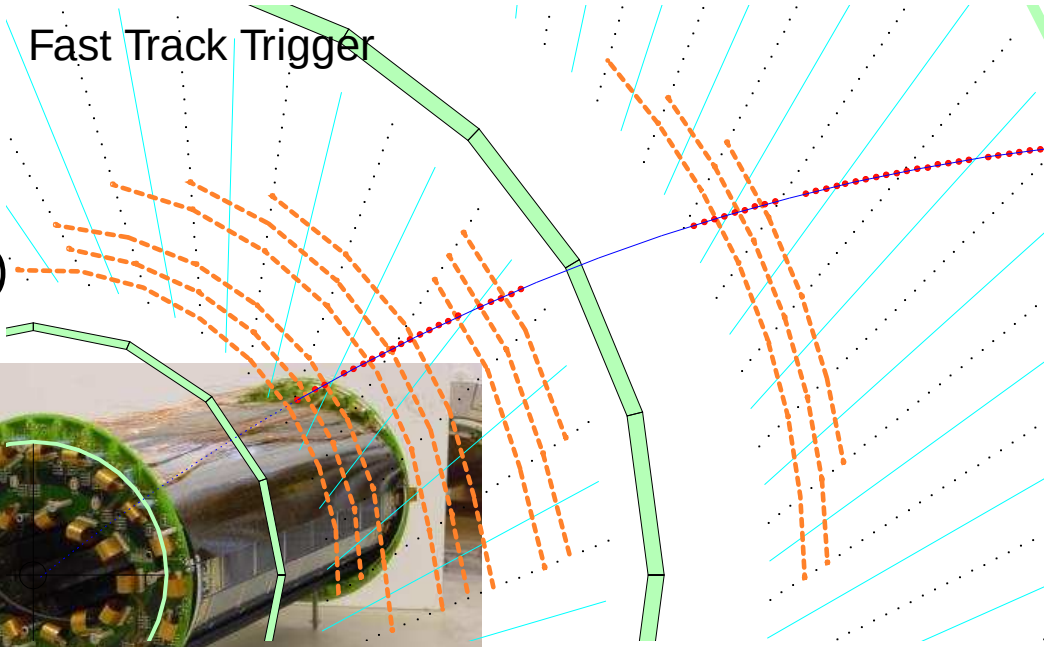
Conclusions

Summary: Beauty at HERA I

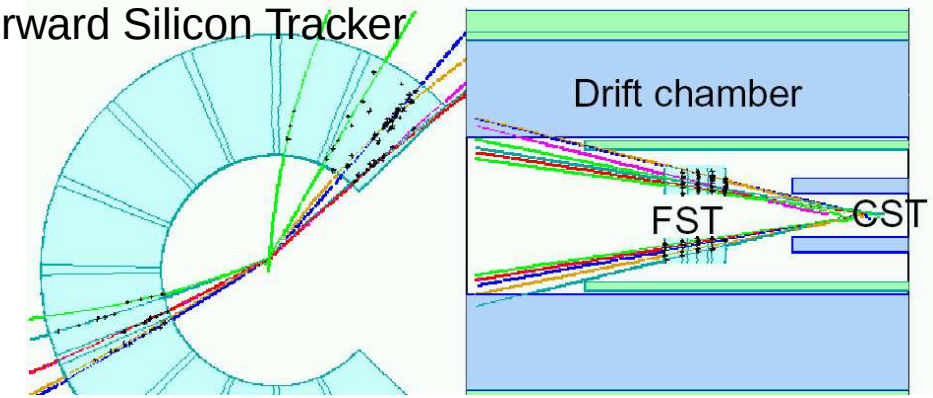
- New precise differential b-cross-section measurements in Photoproduction and DIS
- H1: Two independent variables p_t^{rel} and δ
- Measurements agree with NLO QCD predictions for visible cross sections within errors
- H1 Photoproduction data: Higher than models esp. at low p_T^{μ}

Outlook: Beauty at HERA II

- Go for precision
  - Factor of 10 in luminosity
  - Improved detectors
    (e.g. trigger, vertexing angular coverage)



Forward Silicon Tracker



Central Silicon Tracker