Studies of Beauty at H1 and ZEUS

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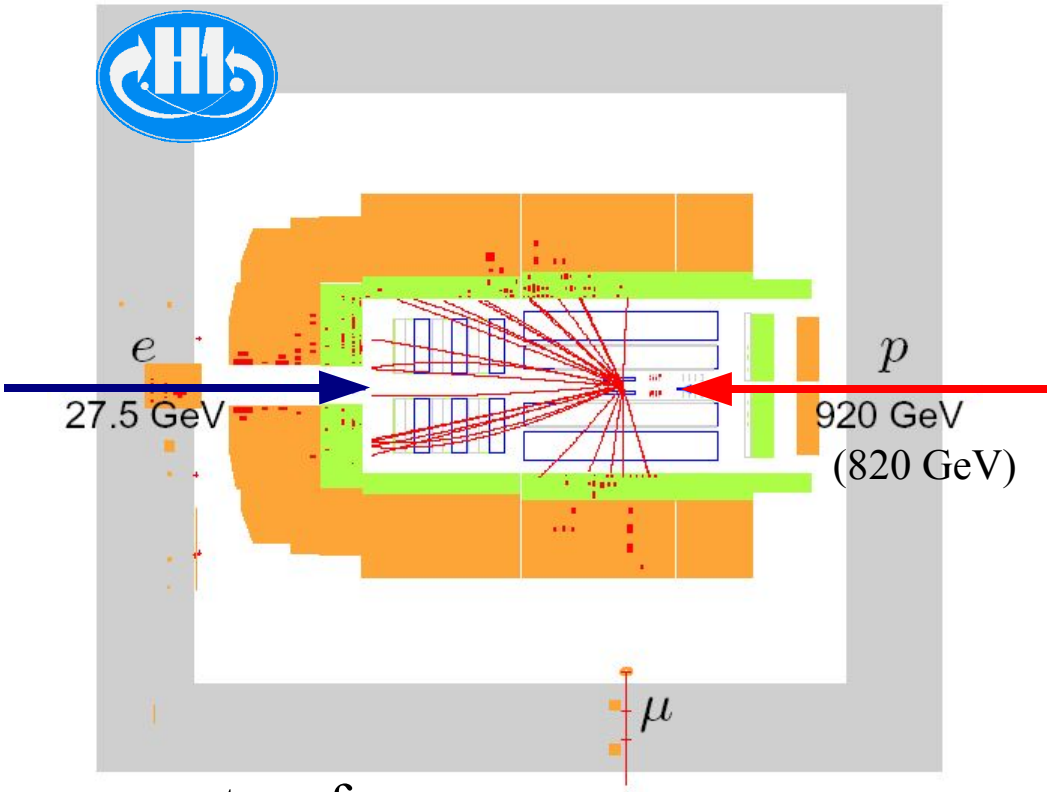
XXXXth Rencontres de Moriond

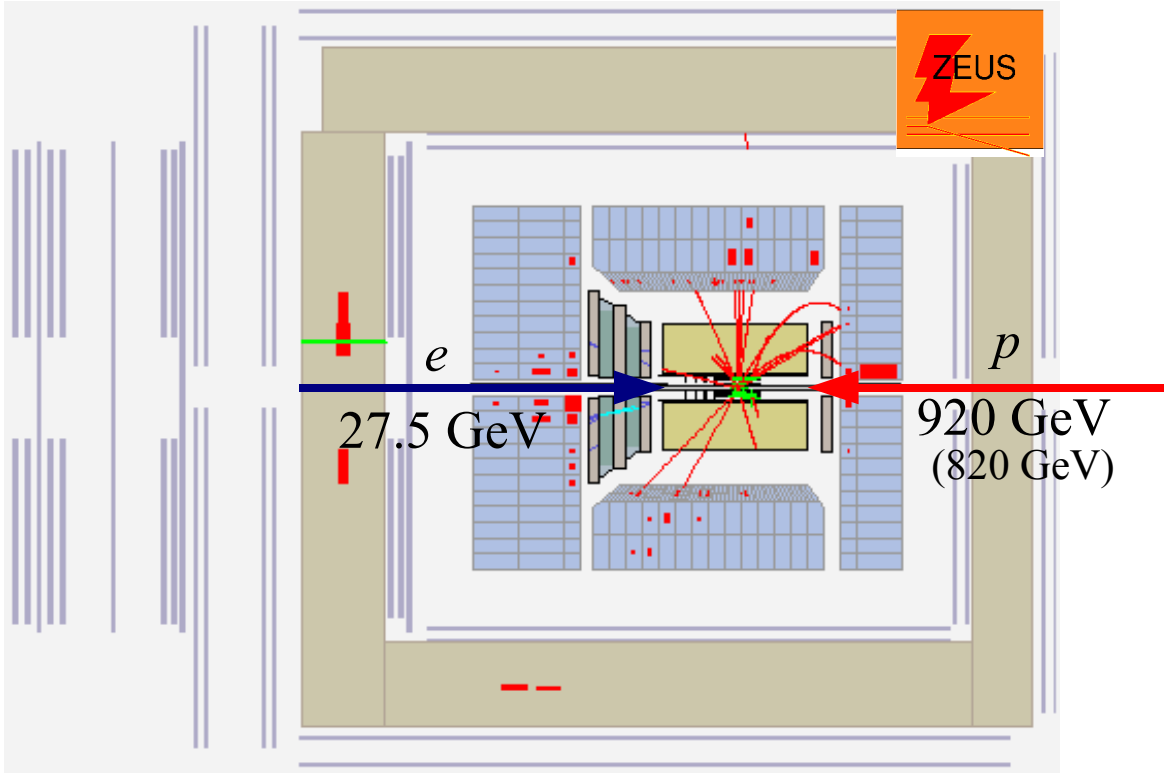
March 12th - 19th 2005

QCD and High Energy Hadronic Interactions

- Introduction & Theory
- Measurement methods & Results:
  - → γp μ+jets
  - → DIS μ+jet
  - → DIS inclusive $F_2^{b\bar{b}}$
- Summary & Outlook

HERA: ep collisions within H1 & ZEUS





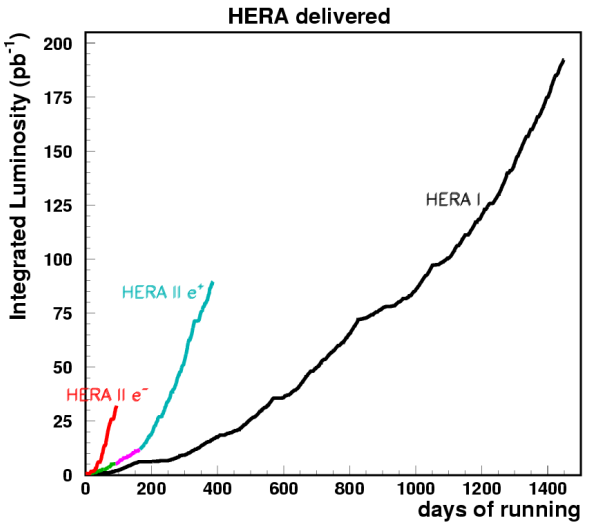
ep centre of mass energy:

1992 - 1997:	300 GeV
1998 - 2005:	318 GeV

H1&ZEUS integrated Luminosity: 96-00 / 03-05

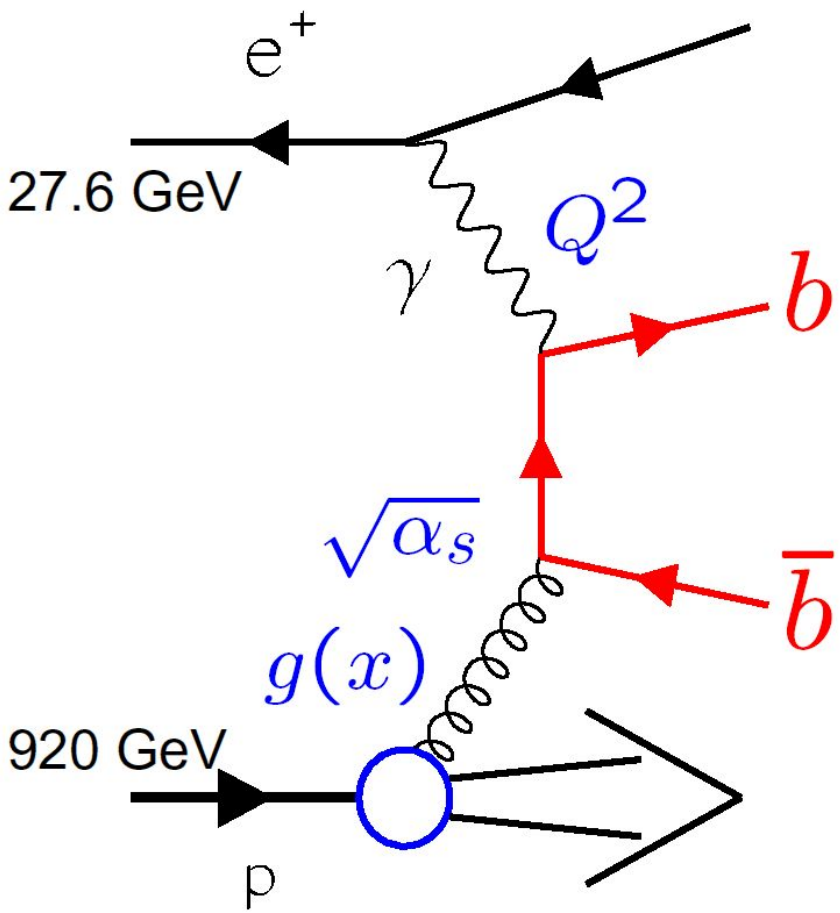
e^+p scattering: $L \approx$ 100 / 40 pb^{-1}

e^-p scattering: $L \approx$ 15 / 20 pb^{-1}



Beauty Production in ep collisions

Dominant process in ep collisions:
Boson-Gluon-Fusion



Multiple scales:

$\mathbf{m_b}$ ~ 5GeV

$\mathbf{p_T^b}$ ~ typically few GeV

$\mathbf{Q^2}$ $\lesssim$ 1 GeV^2 Photoproduction (γp)

$\gtrsim$ 1 GeV^2 Deep inelastic scattering (DIS)

NLO calculations with different schemes **depend on dominant scale**:

- „massive scheme“ **FFNS**:

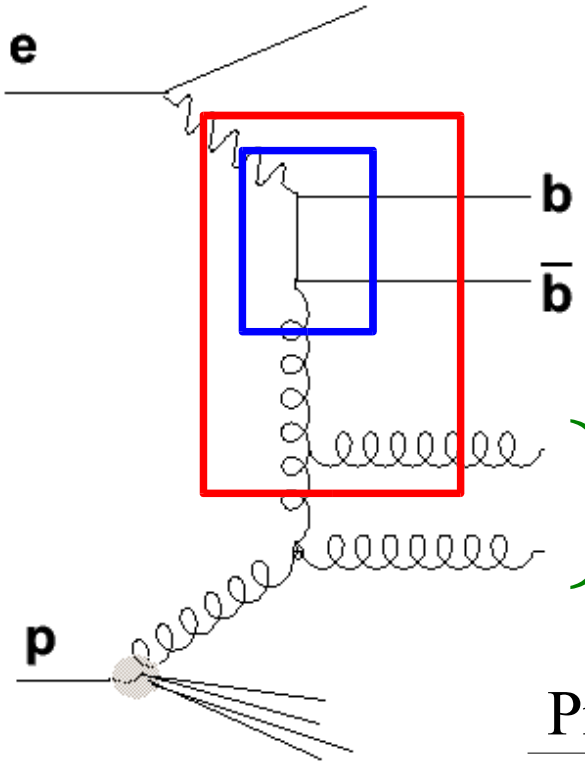
$$Q^2, p_{Tb}^{\ 2} \approx m_b^{\ 2}$$

- „massless scheme“ **ZM-VFNS**:

$$Q^2, p_{Tb}^{\ 2} \gg m_b^{\ 2}$$

- combined massive⊗massless: **VFNS**

Beauty Production in ep collisions

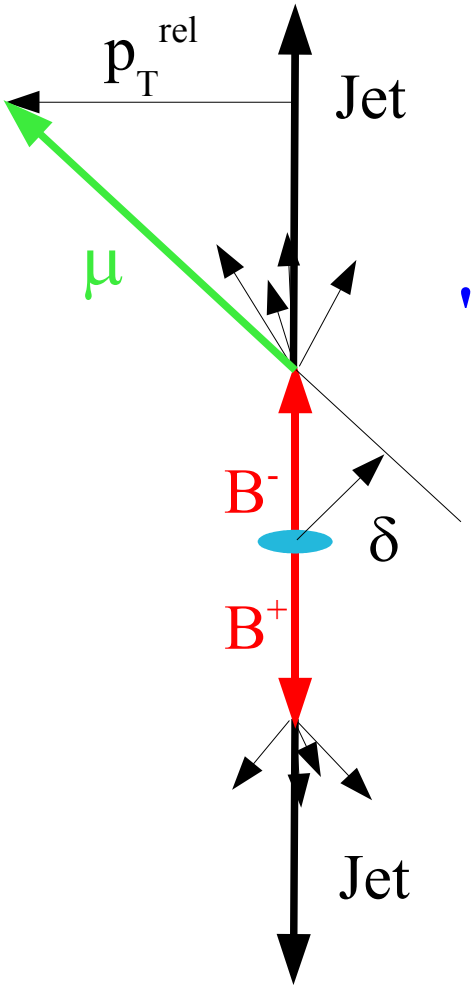


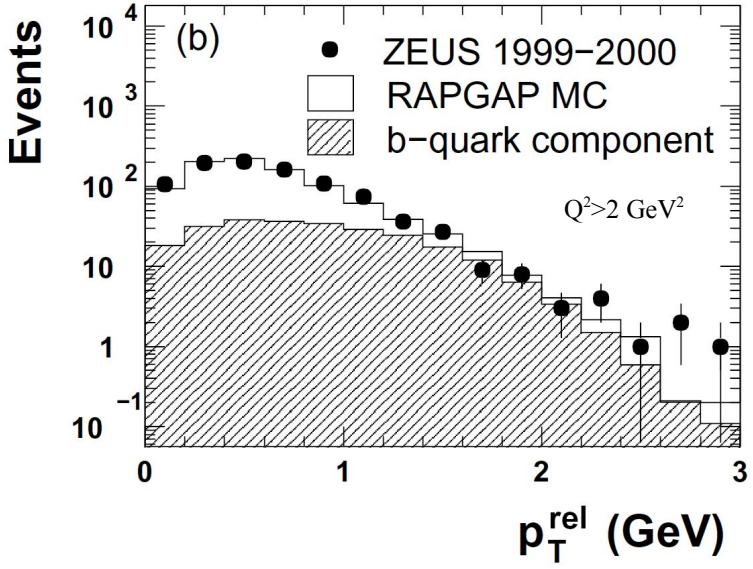
Prediction:		Describes:
LO+**PS**: PYTHIA, HERWIG	(DGLAP)	γp
RAPGAP	(DGLAP)	DIS
CASCADE	(CCFM)	γp&DIS
NLO: FMNR		γp
HVQDIS		DIS

Measurement techniques - μ+jets

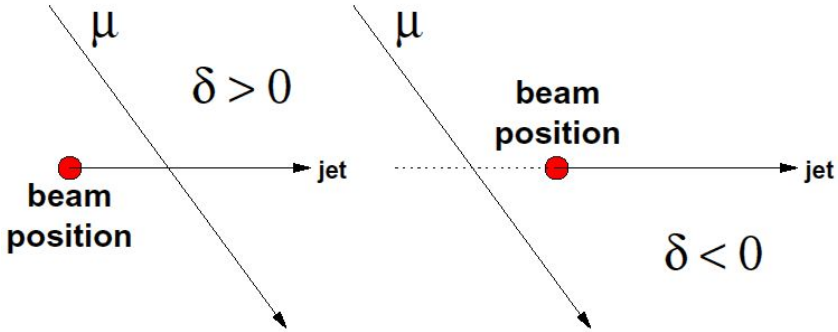
Tag μ+jets beauty events by exploiting:

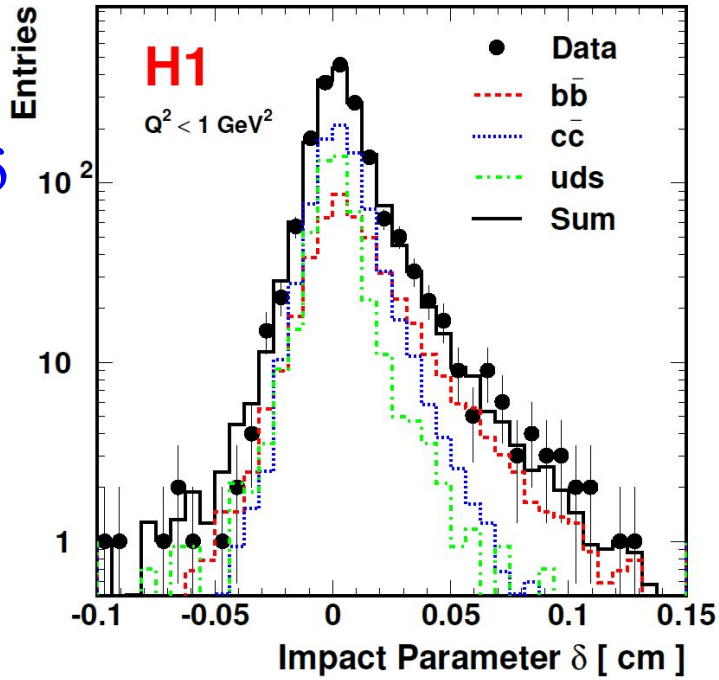
large B mass - μ-momentum relative to associated jet, p_T^{rel}





"long" lifetime - signed impact parameter relative to vertex/beamspot, δ





Beauty in γp, μ+jets and δ (1)

hep-ex/0502010

H1 - Beauty in μ+**dijet**:

Simultaneous two-dimensional p_T^{rel} and δ fit.

Method yields **enhanced statistics** and **reduced systematic uncertainties**.

γp

99-00: 50 pb^{-1}

$Q^2 < 1\ GeV^2$

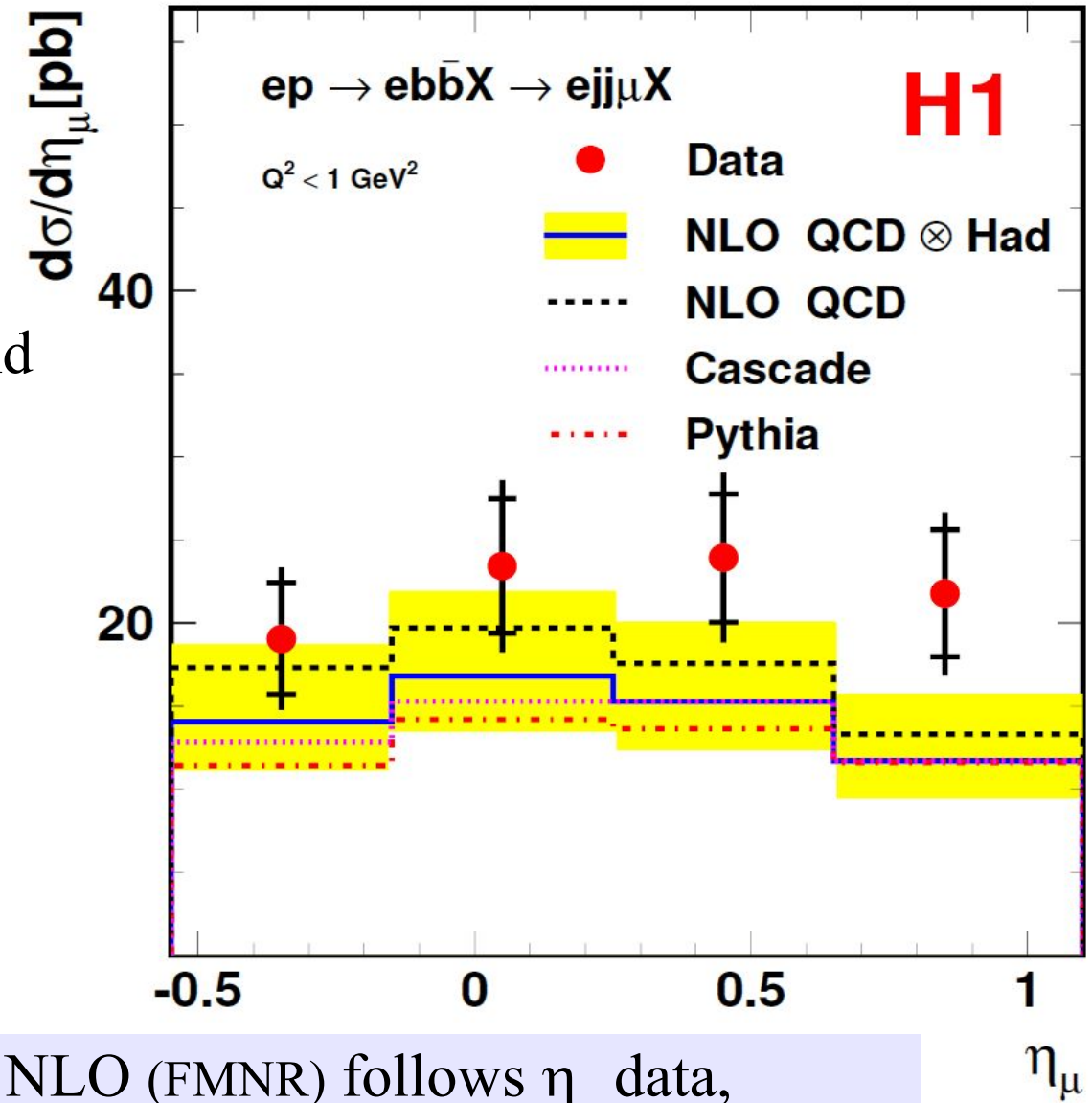
$y \in [0.2, 0.8]$

$p_T^{\mu} > 2.5\ GeV$

$\eta^{\mu} \in [-0.55, 1.1]$

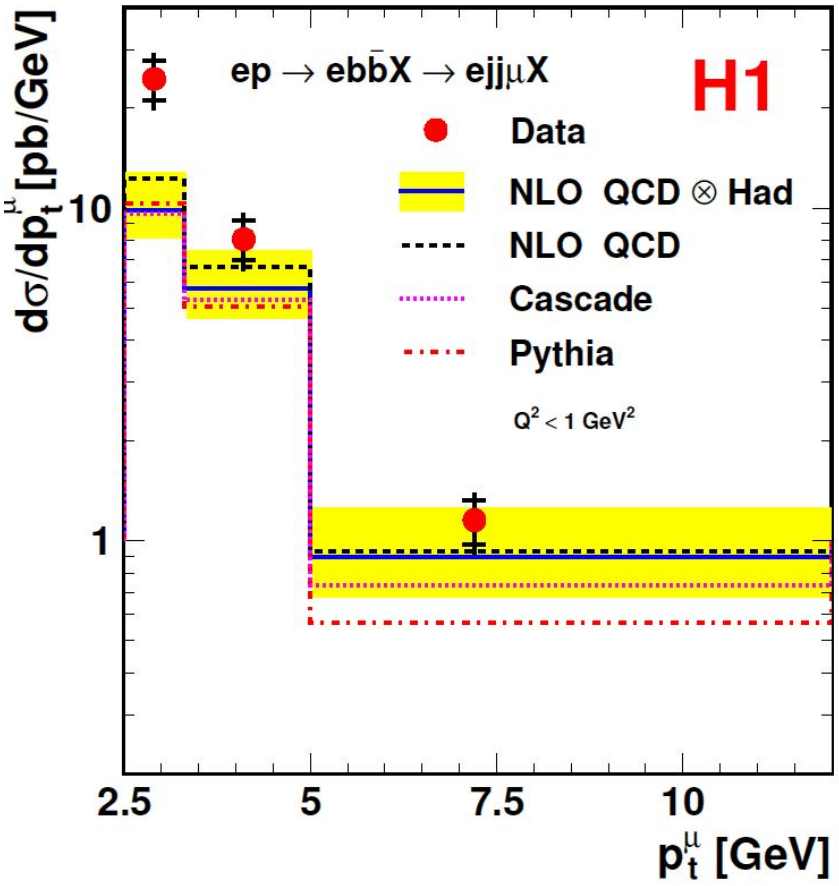
$p_T^{jet} > 7\ (6)\ GeV$

$|\eta_{lab}^{jet}| < 2.5$



Shape of NLO (FMNR) follows η_μ data, though data tend to slightly higher values.

Beauty in γp, μ+jets and δ (2)



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$p_T^{\mu} > 2.5$ GeV

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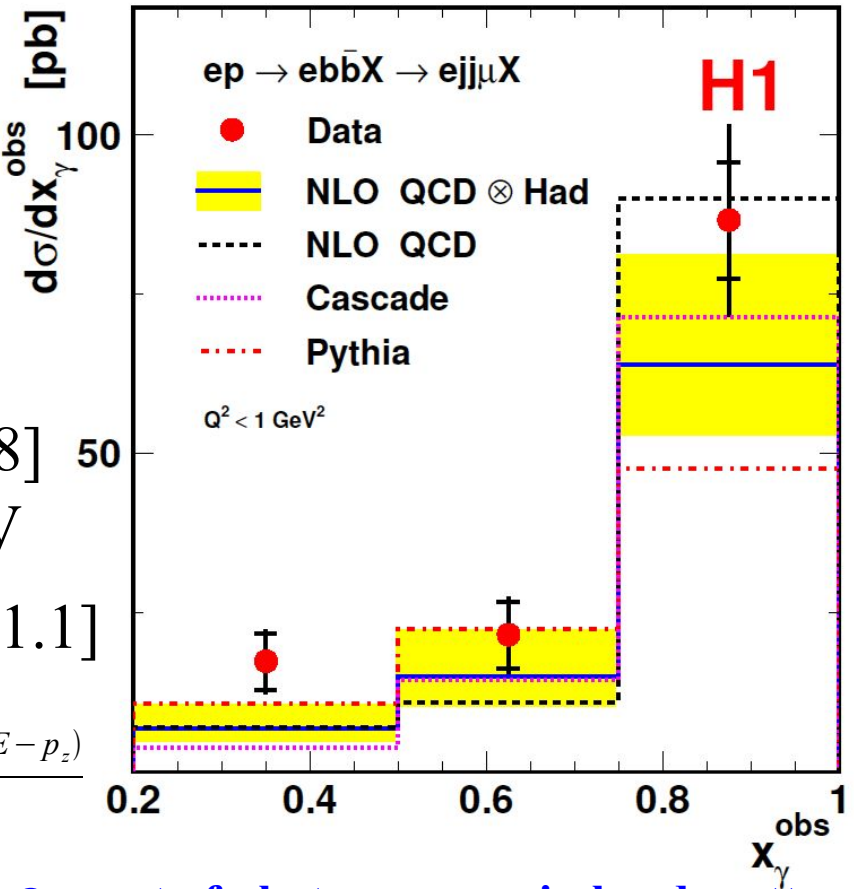
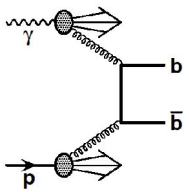
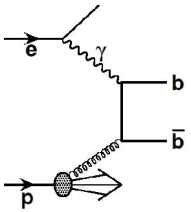
$$x_\gamma^{obs} = \frac{\sum_{Jet_1}(E-p_z)+\sum_{Jet_2}(E-p_z)}{\sum_h (E-p_z)}$$



LO: **part of photon energy in hard scatter**

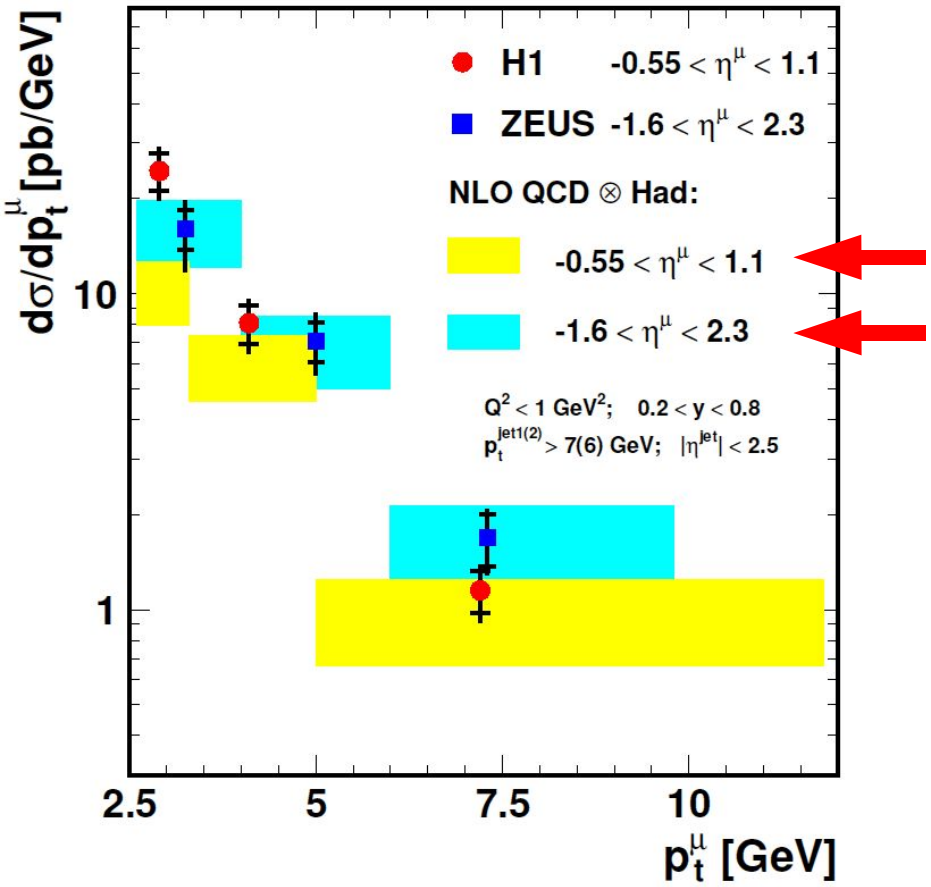
low ⟷ **high**

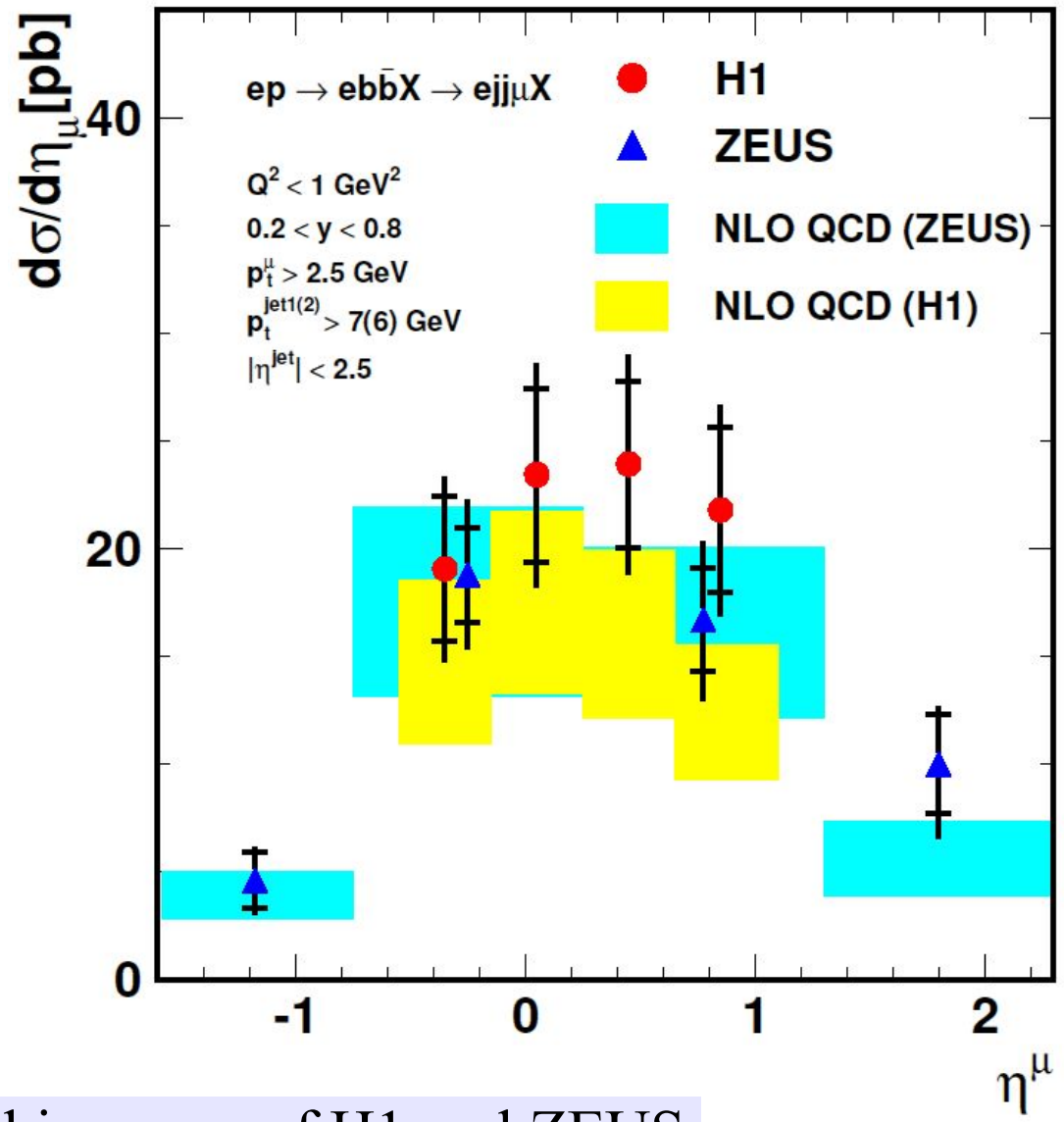




Data steeper in $p_t^{\mu,jet}$ and slightly higher at low x_γ^{obs}.

Beauty in γp, μ+jets and δ (3) - comparison with ZEUS





H1: $p_T^{rel} + \delta$, 99-00

hep-ex/0502010

ZEUS: p_T^{rel}, 96-00

hep-ex/0312057

Agreement within errors of H1 and ZEUS.

Beauty in DIS, μ+jet and δ (1)

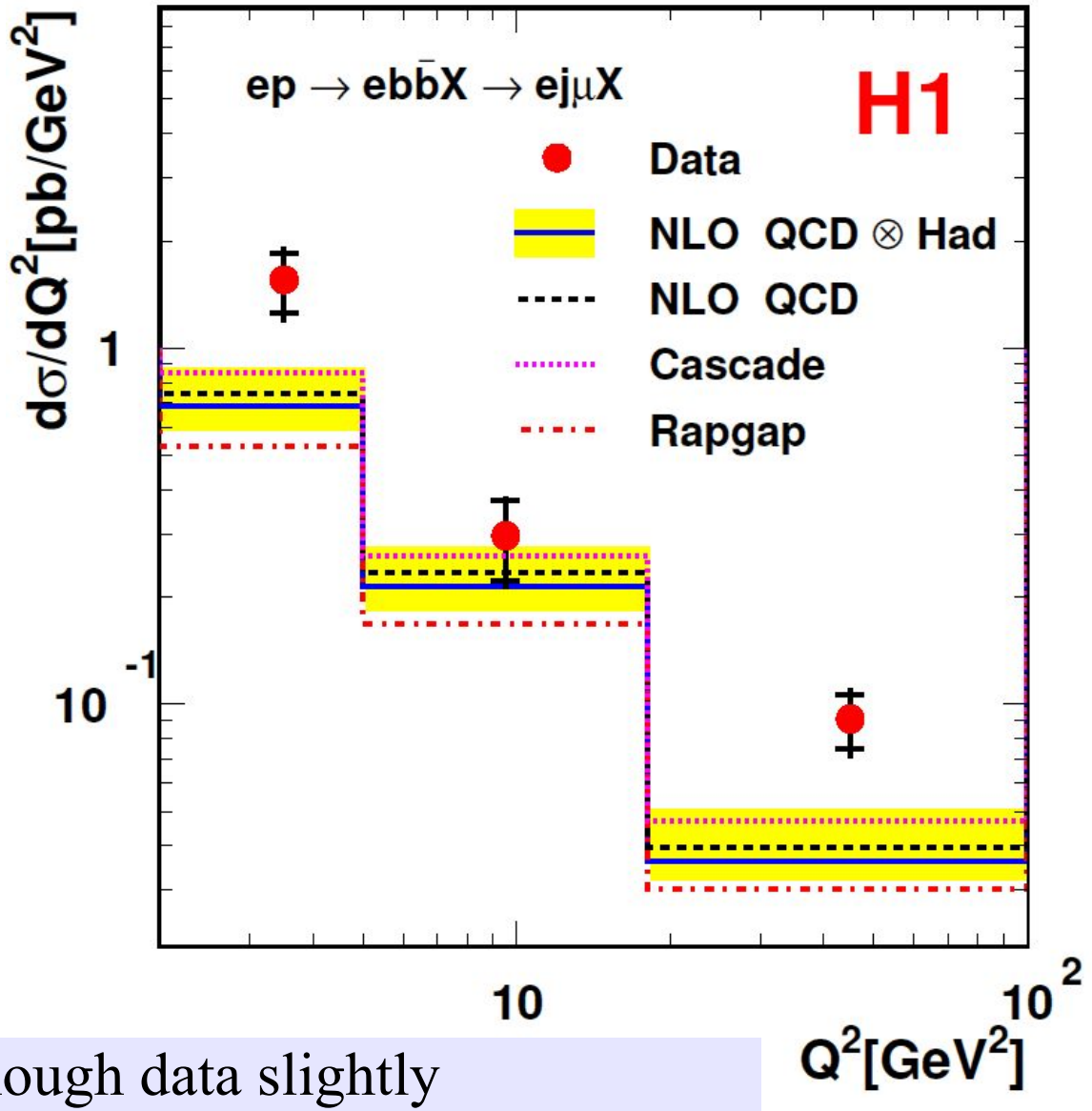
hep-ex/0502010

Simultaneous **fit to p_T^{rel} and δ**
as shown before ($Q^2 < 1$ GeV^2), now
for 2 GeV^2 < Q2 < 100 GeV^2 (DIS)
using the breit frame for the jet:

DIS

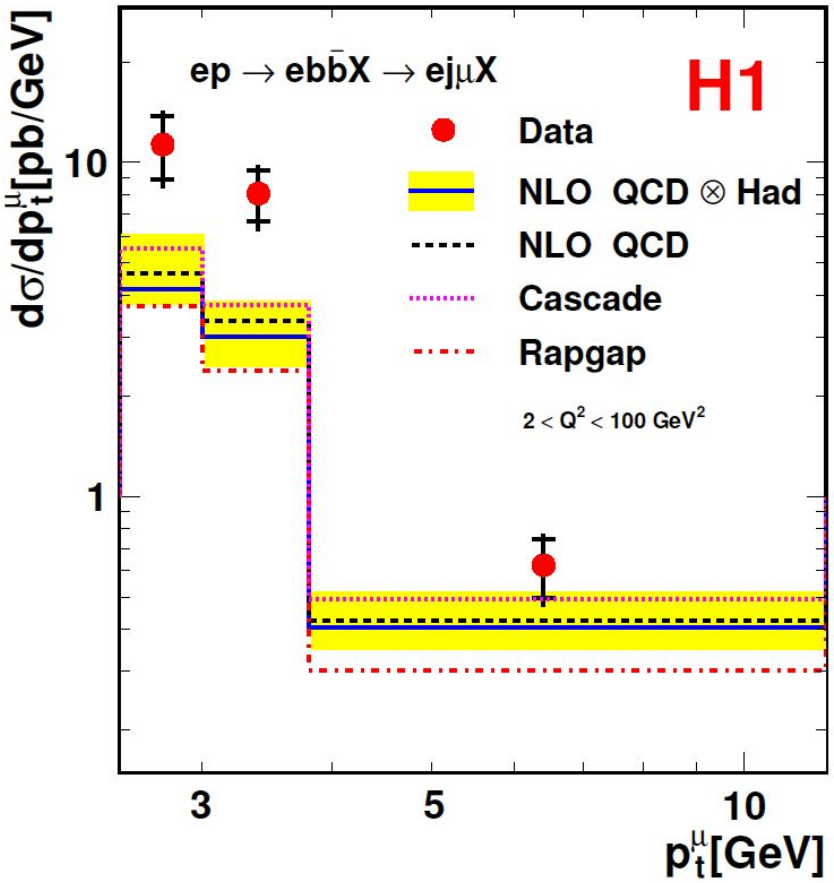
99-00: 57 pb^{-1}

$Q^2 \in [1, 100]$ GeV^2
$y \in [0.1, 0.7]$
$p_T^{\mu} > 2.5$ GeV
$\eta^{\mu} \in [-0.75, 1.15]$
$p_T^{jet} > 6$ GeV
$|\eta_{lab}^{jet}| < 2.5$



Q^2 shape is described, though data slightly above the NLO (HVQDIS) prediction in DIS as in γp.

Beauty in DIS, μ+jet and δ (3)



DIS

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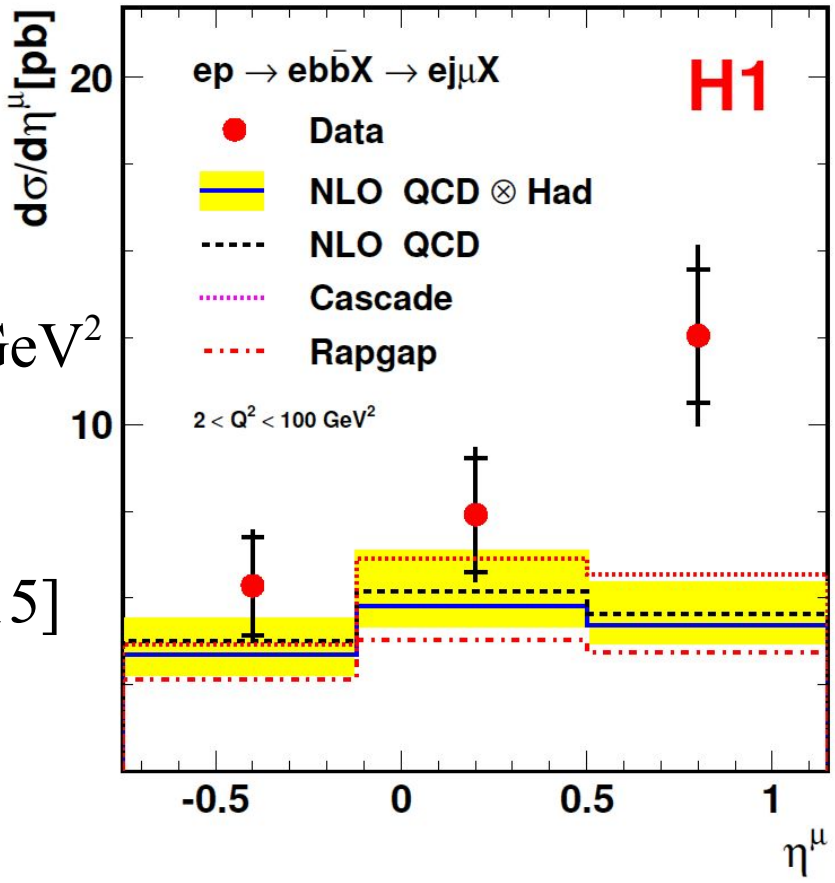
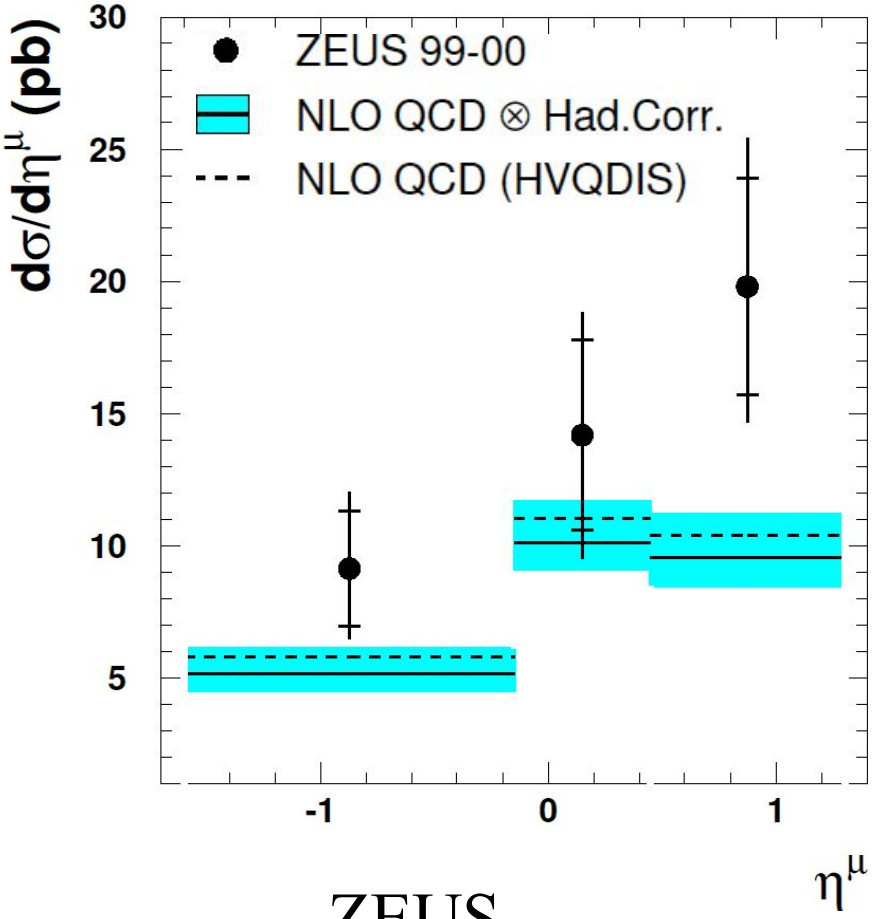
$\eta^{\mu} \in [-0.75, 1.15]$



Data higher at low p_T^{μ} as for the γp measurement.

Higher data **also in forward η**.

Beauty in DIS, μ+jet and δ (3) – comparison with ZEUS



ZEUS

$Q^2 \in [1, 1000]\ \mathrm{GeV}^2$

$y \in [0.05, 0.7]$

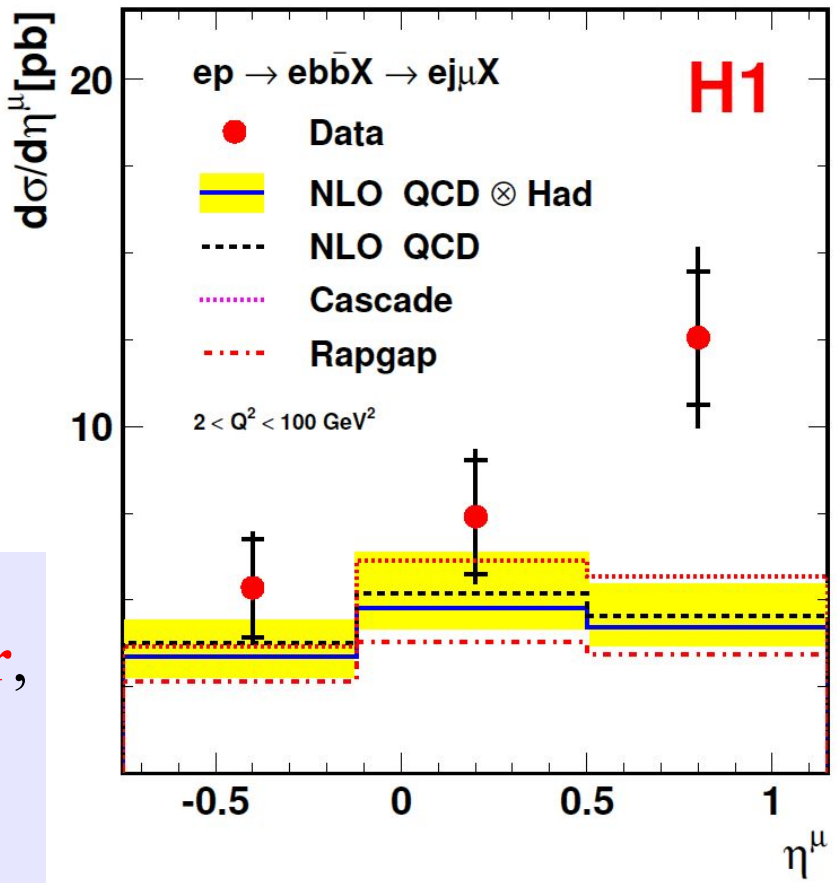
$p_T^\mu > 2.0\ \mathrm{GeV}$

$\eta^\mu \in [-1.6, 1.3]$

hep-ex/0405069

Kinematic ranges differ, but **similar trend in η** is seen.

Not reproduced by the predictions.



H1

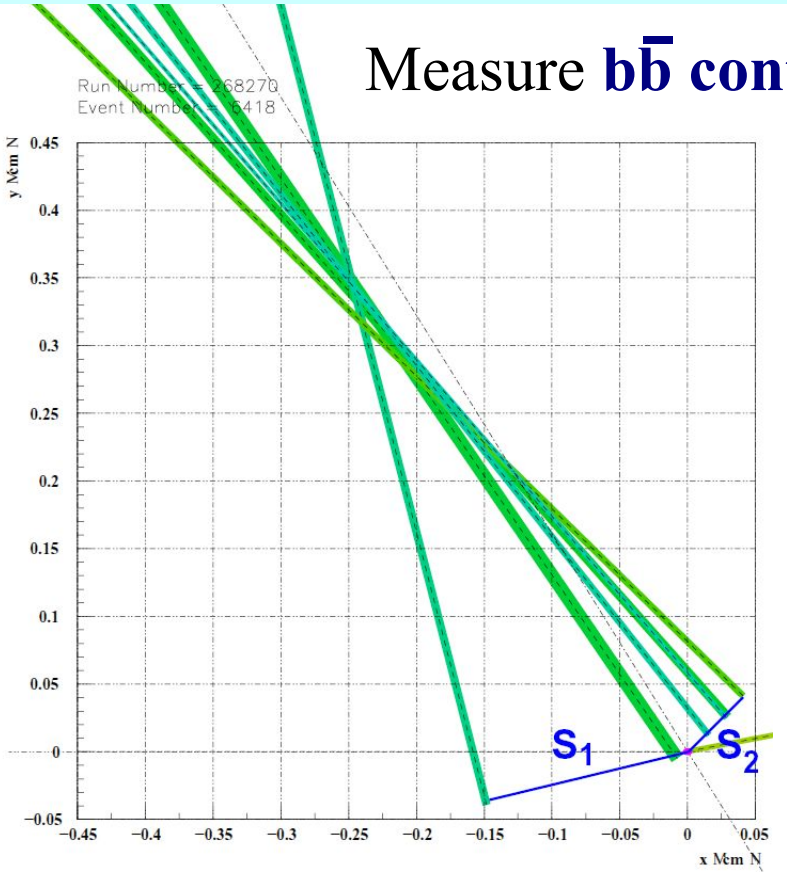
$Q^2 \in [1, 100]\ \mathrm{GeV}^2$

$y \in [0.1, 0.7]$

$p_T^\mu > 2.5\ \mathrm{GeV}$

$\eta^\mu \in [-0.75, 1.15]$

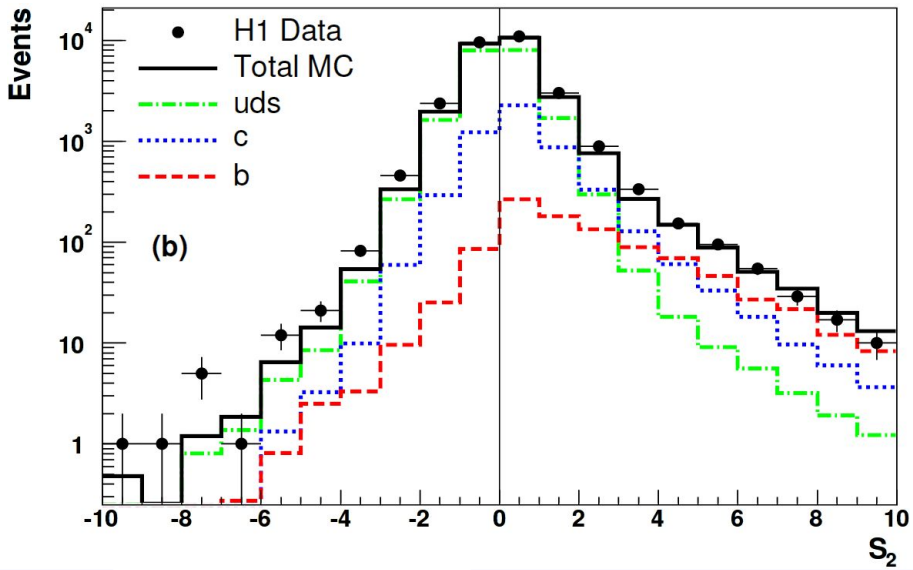
Beauty contribution to F_2 in DIS - method



Measure **$b\bar{b}$ contribution to proton structure** F_2 at **$Q^2>150\ GeV^2$**.

Method: **inclusive lifetime tagging**

- use all tracks ($p_t > 0.5$ GeV) with at least one silicon track.
- $S_{1(2)}$ = significance $S_{1(2)} = \delta/\sigma_\delta$ of (second) largest imp. parameter δ. ($|\delta| < 0.1$cm)
- $S_{1(2)}$ sign from jets (97%) or hadronic final state, select only: sign(S_1) = sign(S_2)



High statistics and **high separation of beauty** at high S_2.

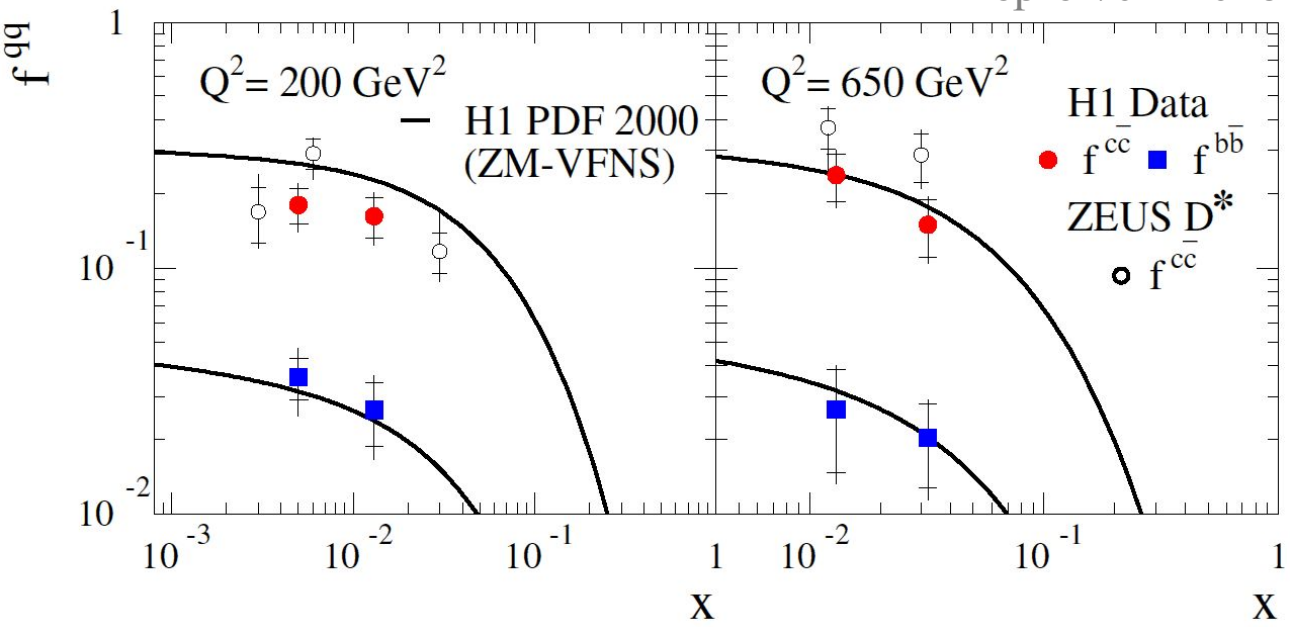
Fitted to determine beauty fraction:

$F_2^{b\bar{b}}$ in DIS at high Q^2

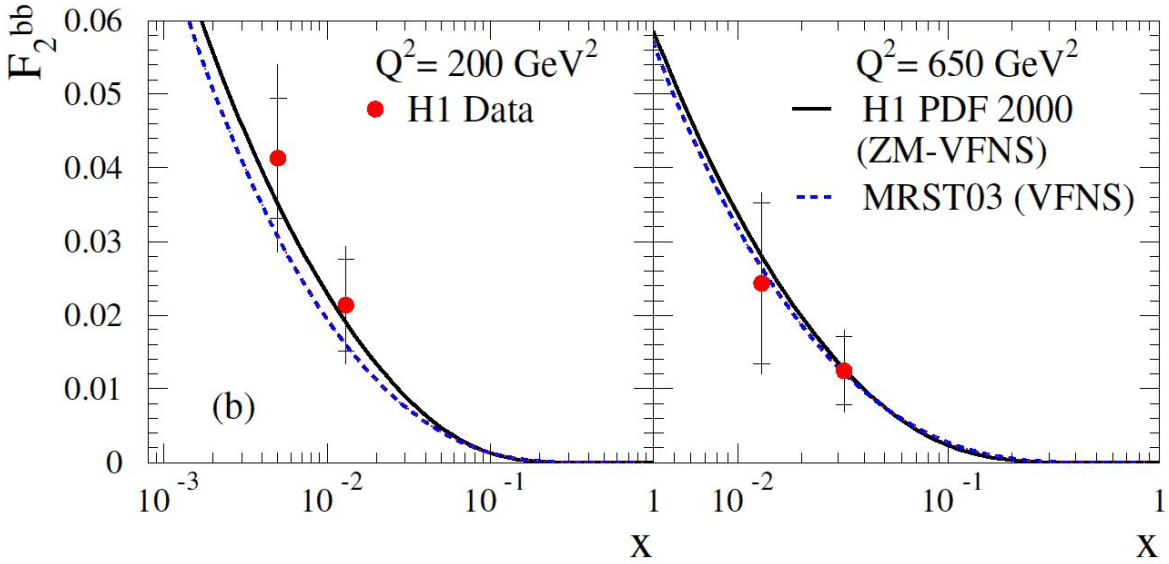
hep-ex/0411046

Differential fraction of cross sections:

$$f^{q\bar{q}} = \frac{d^2\sigma^{q\bar{q}}}{dQ^2\,dx} \Big/ \frac{d^2\sigma}{dQ^2\,dx}$$



Beauty contribution to F_2:



Integrated cross sections,

$Q^2 > 150$ GeV^2, $0.1 < y < 0.7$:

$$\sigma_{b\bar{b}} = 55.4 \pm 8.7 \pm 12.0 \text{ pb}$$

H1 PDF 2000$_{\text{massless[ZM-VFNS]}}$ $\sigma_{b\bar{b}} = 52$ pb

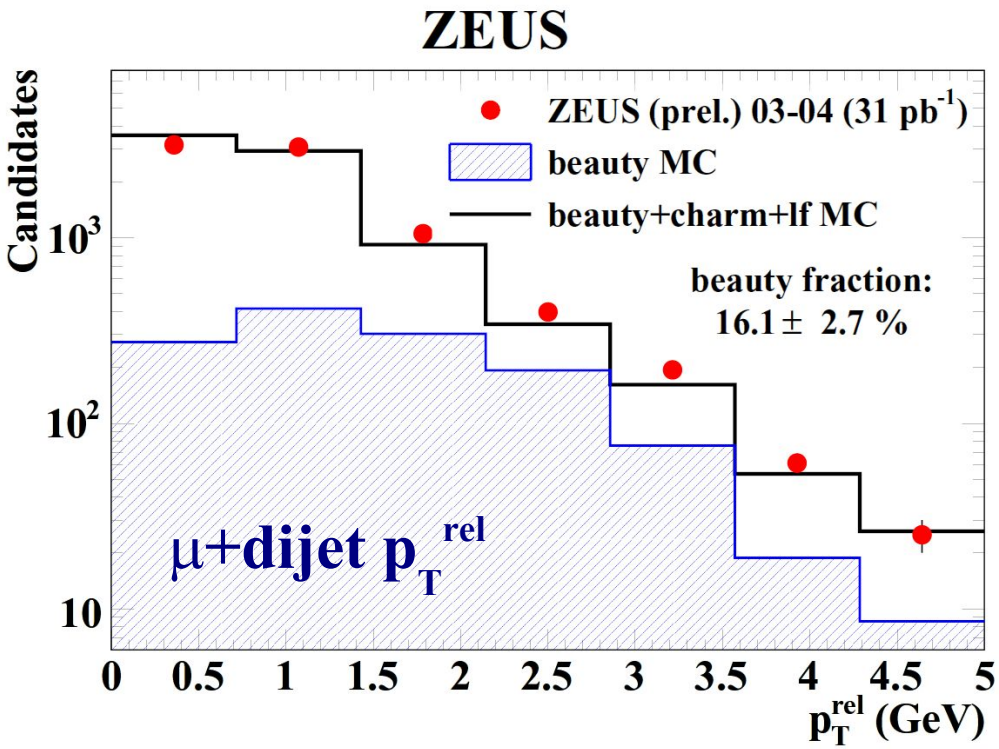
NLO$_{\text{massive}\otimes\text{massless[VFNS]}}$ $\sigma_{b\bar{b}} = 47$ pb

NLO$_{\text{massive[FFNS]}}$ $\sigma_{b\bar{b}} = 37$ pb

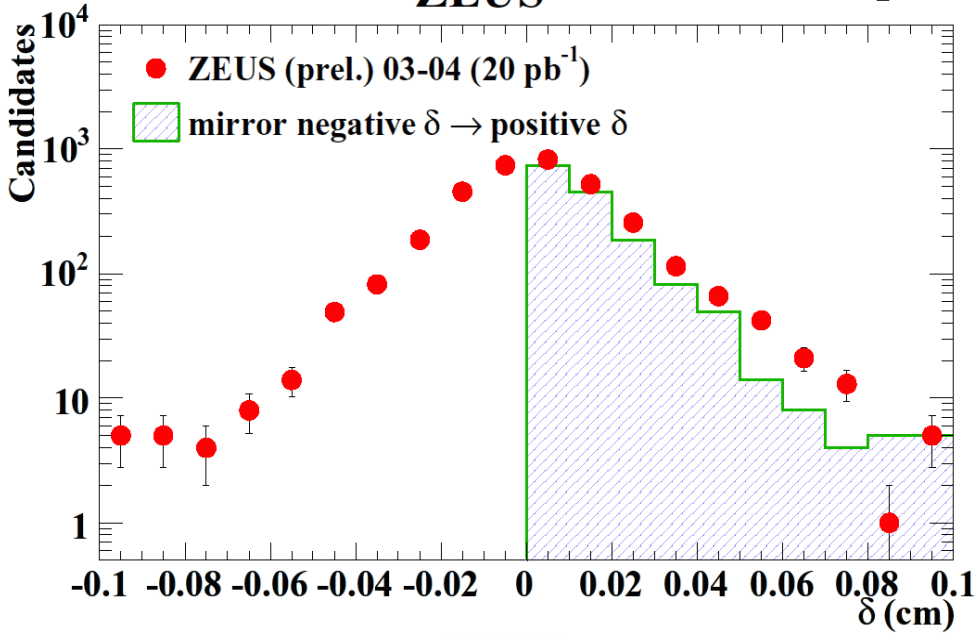
Beauty in γp, μ+jets or δ, HERA II

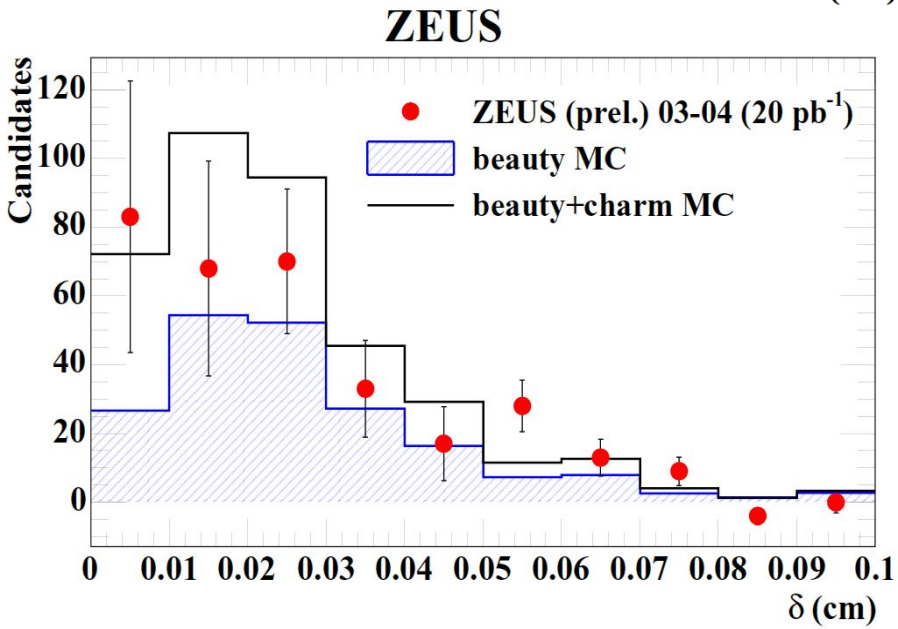
ZEUS: First look at **impact parameter method:**

(Vertex detector in ZEUS since upgrade 2001)



based on 20 pb^{-1}



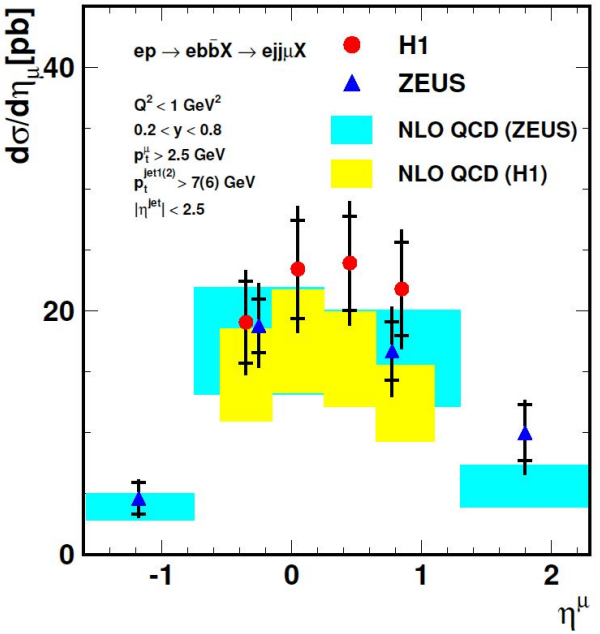


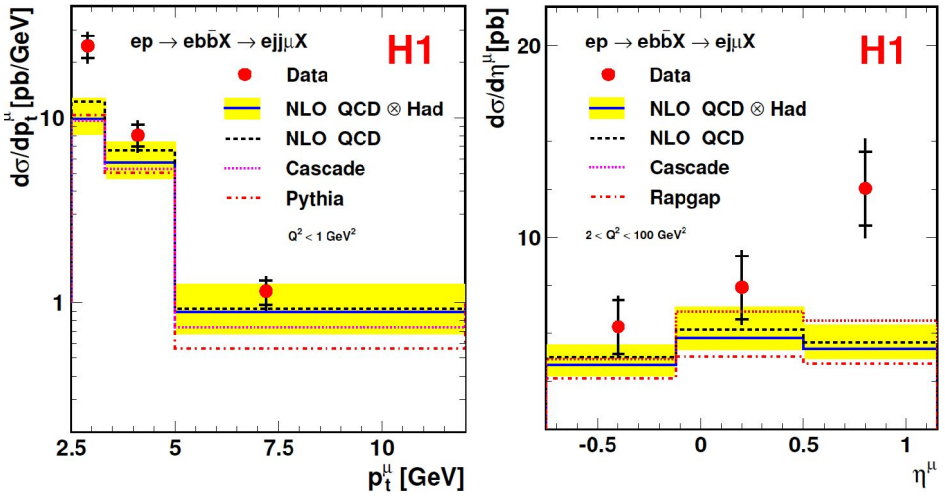
Methods and new detectors work

→ **heading for improved HERA II measurements**.

Summary

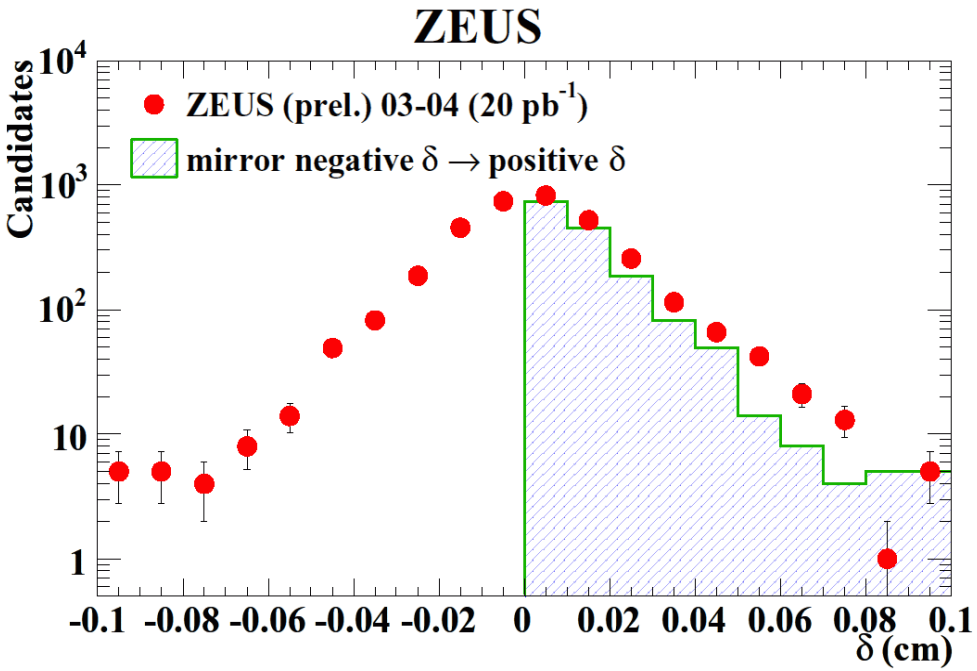
- Jet-μ p_T^{rel} and impact parameter measurements have been performed in DIS and γp
- H1 and ZEUS measurements agree
- Beauty data in general agreement with NLO
- data generally slightly higher, localised
  - at low p_T^{μ} (γp+DIS) and
  - forward η (DIS)
- inclusive DIS impact parameter measurement used for $F_2^{b\bar{b}}$ is in good agreement with NLO

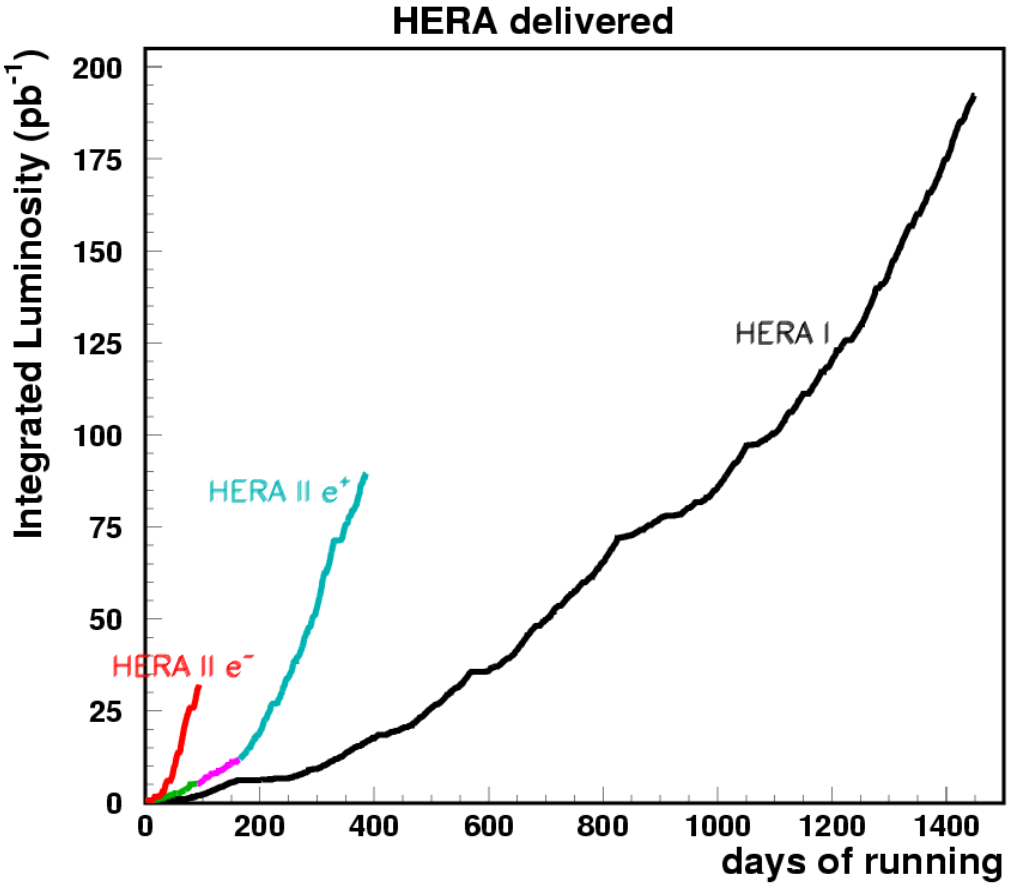




Outlook

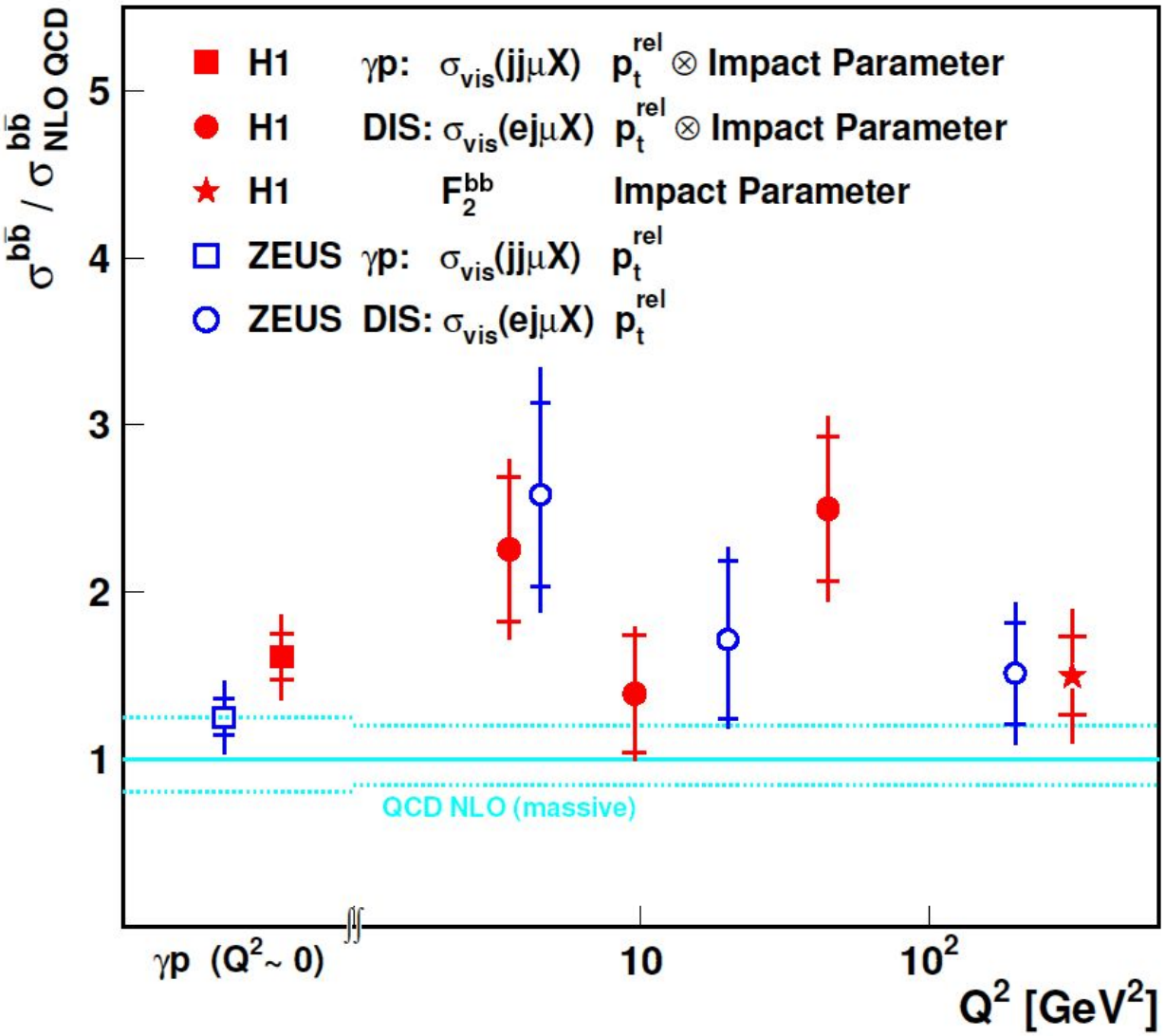
- HERA II is running smoothly in electron mode
  - already accumulated more e- data than ever before
- new detectors performing well, quantitative results soon
- expect higher precision results.





backup slides follow

Backup: Data - NLO ratio



This is just a rough comparison. Q^2 is not the driving scale in the whole range!

Main caveats:

- NLO has been extrapolated to hadron level using different approaches
- NLO has been calculated for different sets of scales and parameters, same for the uncertainty
- Cross section definitions and kinematic ranges somewhat different