XII International Workshop on Deep Inelastic Scattering
DIS 2004

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Beauty Photoproduction at ZEUS

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Outline:

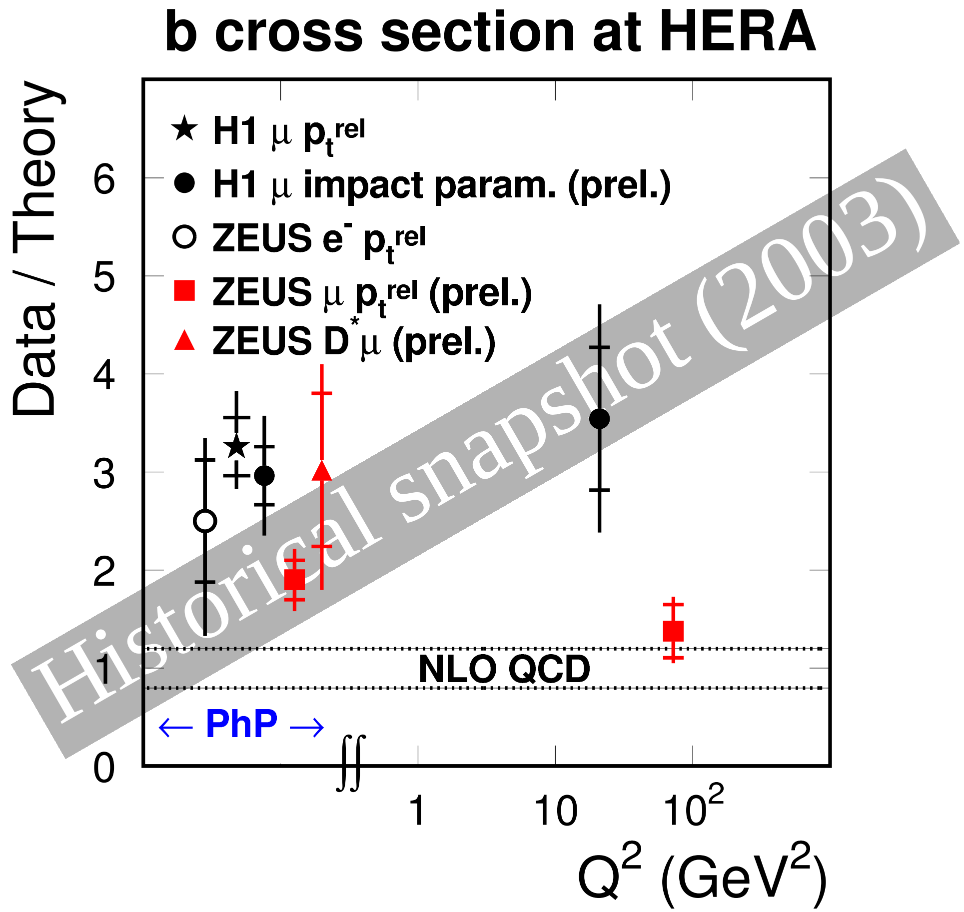
- Motivations
- Experimental situation
- $\mu +$ dijet channel
- $D^* + \mu$ channel
- Conclusions

Motivations

The study of b production is important because:

- it helps in understanding the structure of the proton and of the photon;
- the heavy b quark mass provides a hard scale that makes pQ CD calculations more reliable.

But what happens in *experiments*?



The previous ZEUS measurement...

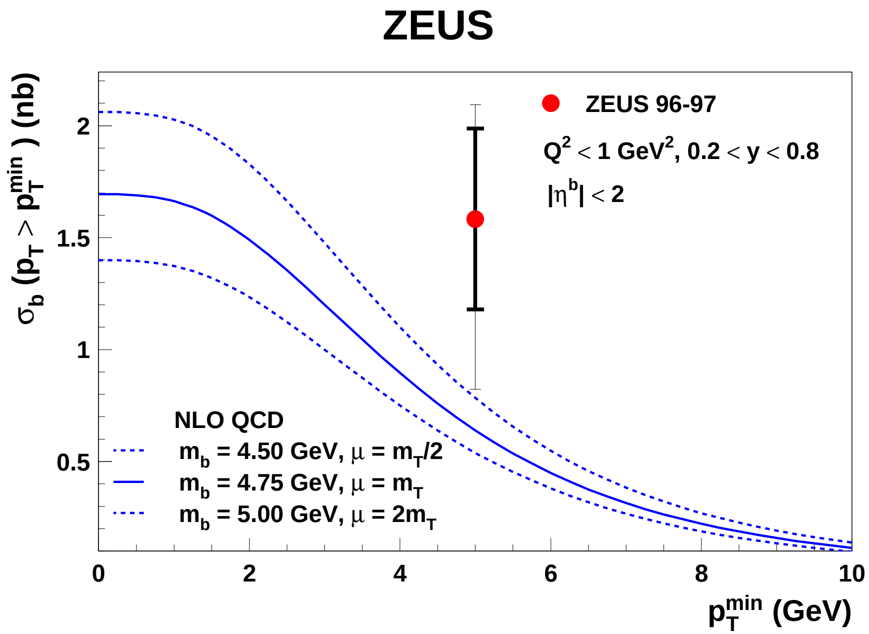
$e^+ p \rightarrow e^+ b \bar{b} X \rightarrow e^+ dijet\ e^- X$

Data sample: 38.5 pb^{-1}

Visible cross section extrapolated to the kinematic range:

- $p_T^b > 5$ GeV, $|\eta^b| < 2$
- $Q^2 < 1$ GeV, $0.2 < y < 0.8$

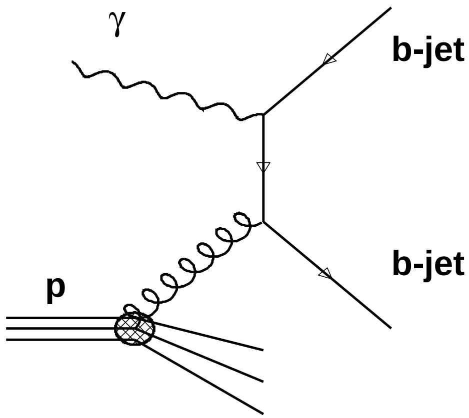
and compared to NLO QCD predictions.



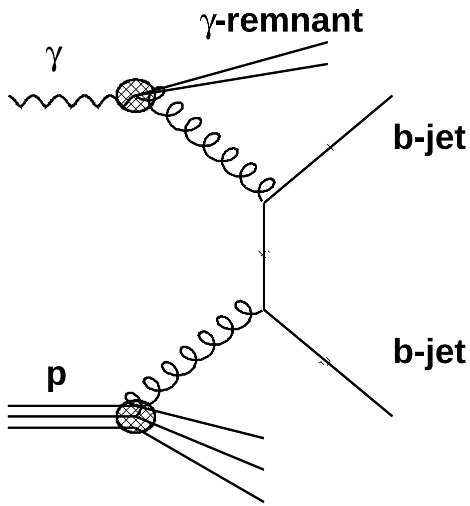
Measurement somewhat above the NLO QCD prediction...

...but large statistical and systematic uncertainties

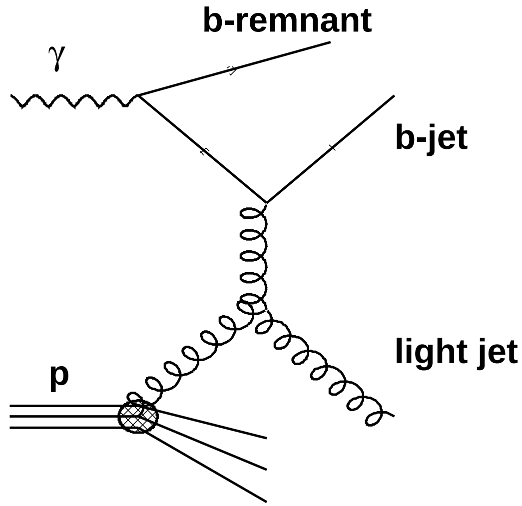
Production mechanism and theoretical models



Direct



Resolved



Flavour Excitation

Monte Carlo:

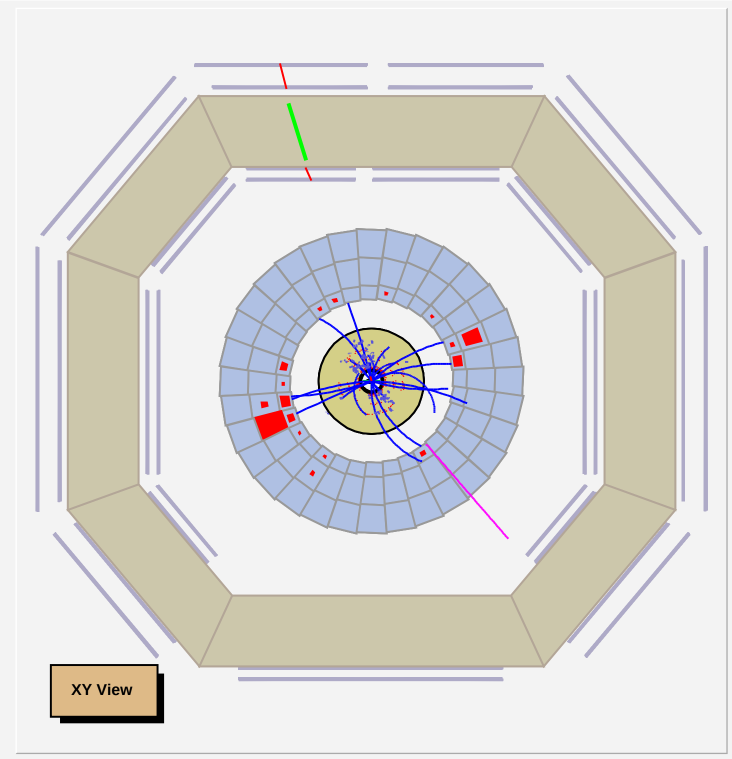
- ❖ Leading Order + Parton Shower models available, including flavour excitation (PYTHIA and HERWIG)
- ❖ CCFM evolution with k_T factorisation (CASCADE)

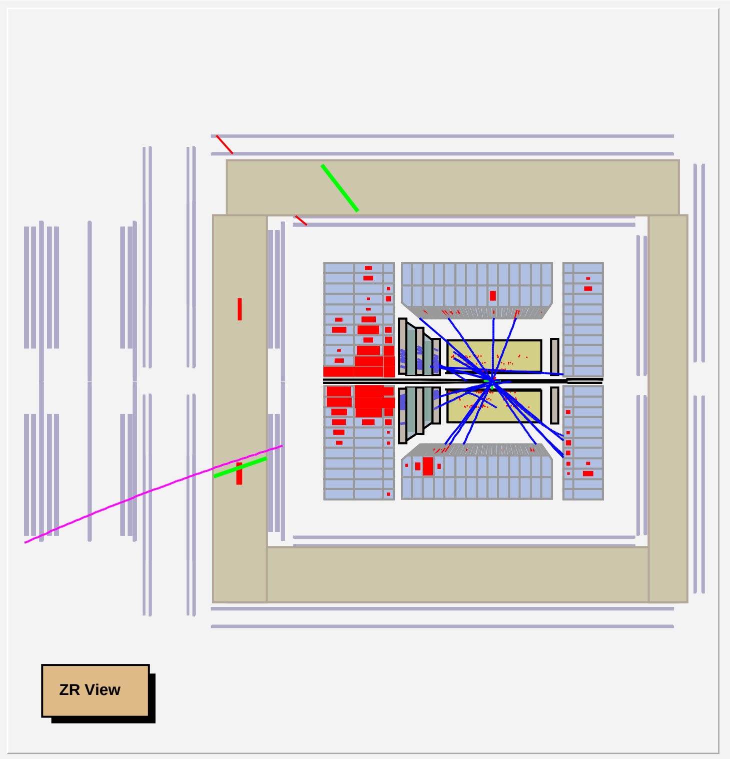
Theoretical calculations: Full NLO calculation (FMNR) available

Dijet+μ analysis — *Data sample:* 110 pb^{-1}

DIS rejection: $Q^2 < 1$ GeV^2,
$0.2 < y < 0.8$
At least 2 jets:
$p_T^{\text{jet}1,2} > 7, 6$ GeV, $|\eta^{\text{jet}1,2}| < 2.5$
K_T algorithm, long. invariant, E recomb. scheme

Muon selection: at least 1 muon with
$p^{\mu} > 4$ GeV, $p_T^{\mu} > 1.5$ GeV, $1.5 < \eta^{\mu} < 2.3$
$p_T^{\mu} > 2.5$ GeV, $-0.9 < \eta^{\mu} < 1.3$
$p^{\mu} > 2.5$ GeV, $-1.6 < \eta^{\mu} < -0.9$



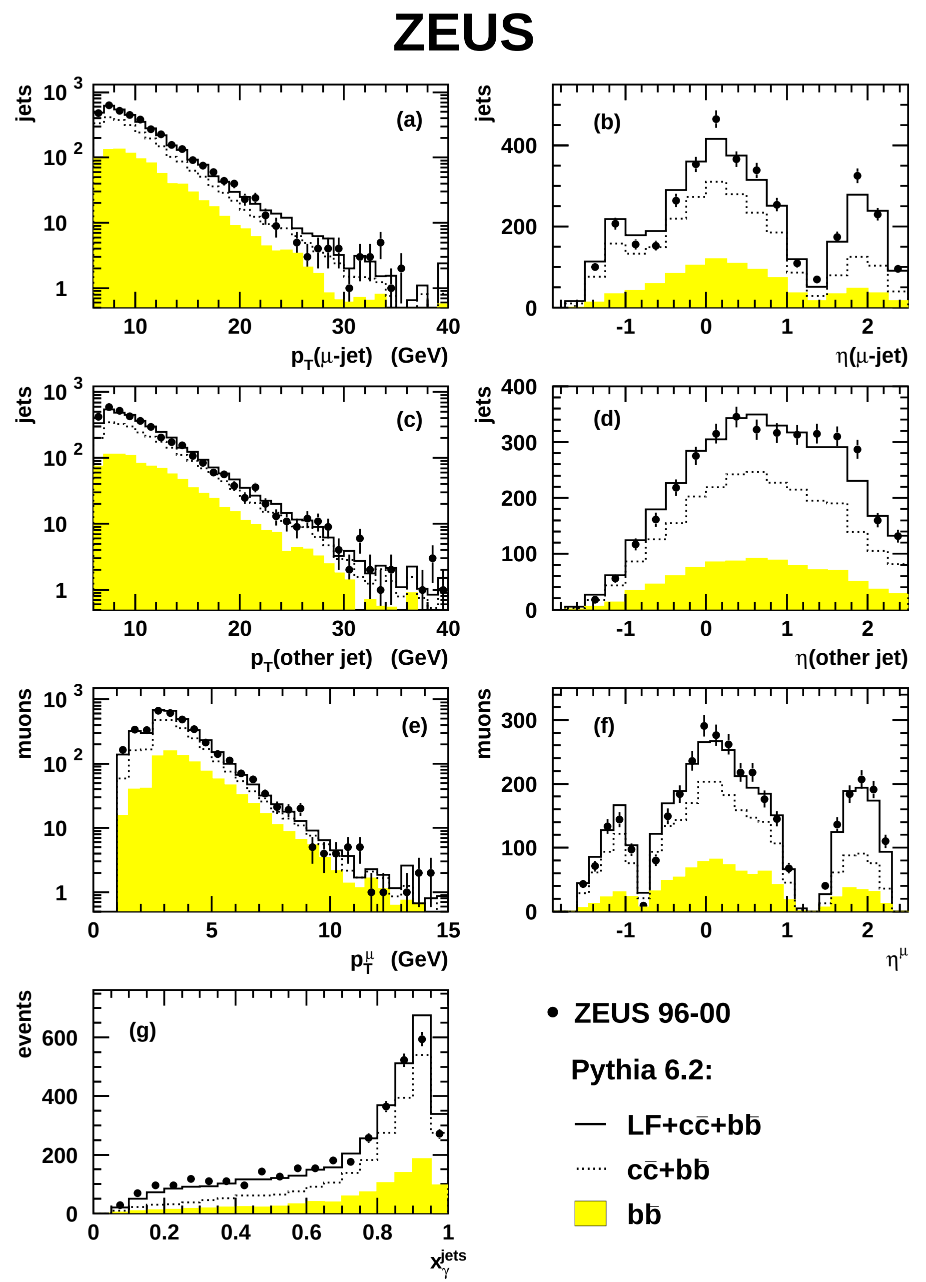


Control plots

Data compared to the PYTHIA MC, contributions from b, c and LF mixed accordingly to the PYTHIA cross section, and normalized to the data.

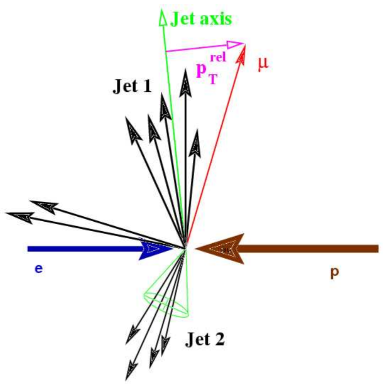
Good agreement between data and Monte Carlo.

$$x_\gamma^{\rm jets} = \frac{\sum_{i=1}^{2}(E-p_Z)^{\rm jet_i}}{E-p_Z}$$

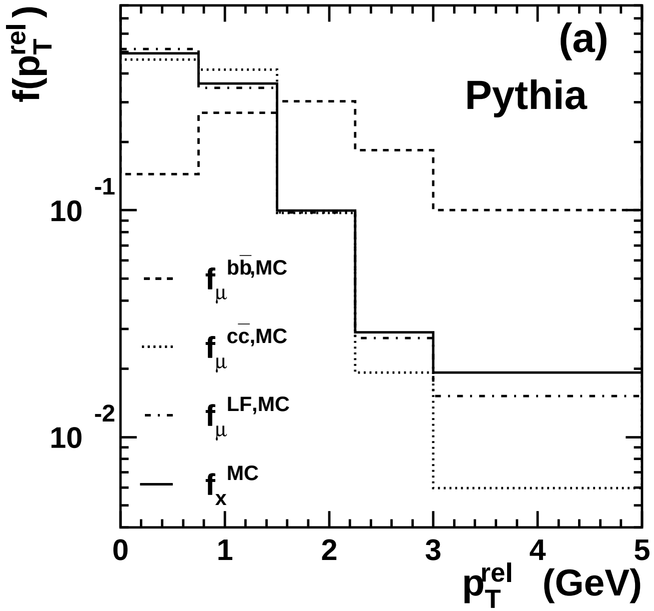


Signal extraction

Discrimination between
signal and background based on
the analysis of the p_T^{rel} distribution:



$$\mathbf{p}_\mathbf{T}^{\mathrm{rel}} = \frac{\mathbf{p}^\mu \times (\mathbf{p}^{\mathrm{jet}} - \mathbf{p}^\mu)}{|\mathbf{p}^{\mathrm{jet}} - \mathbf{p}^\mu|}$$



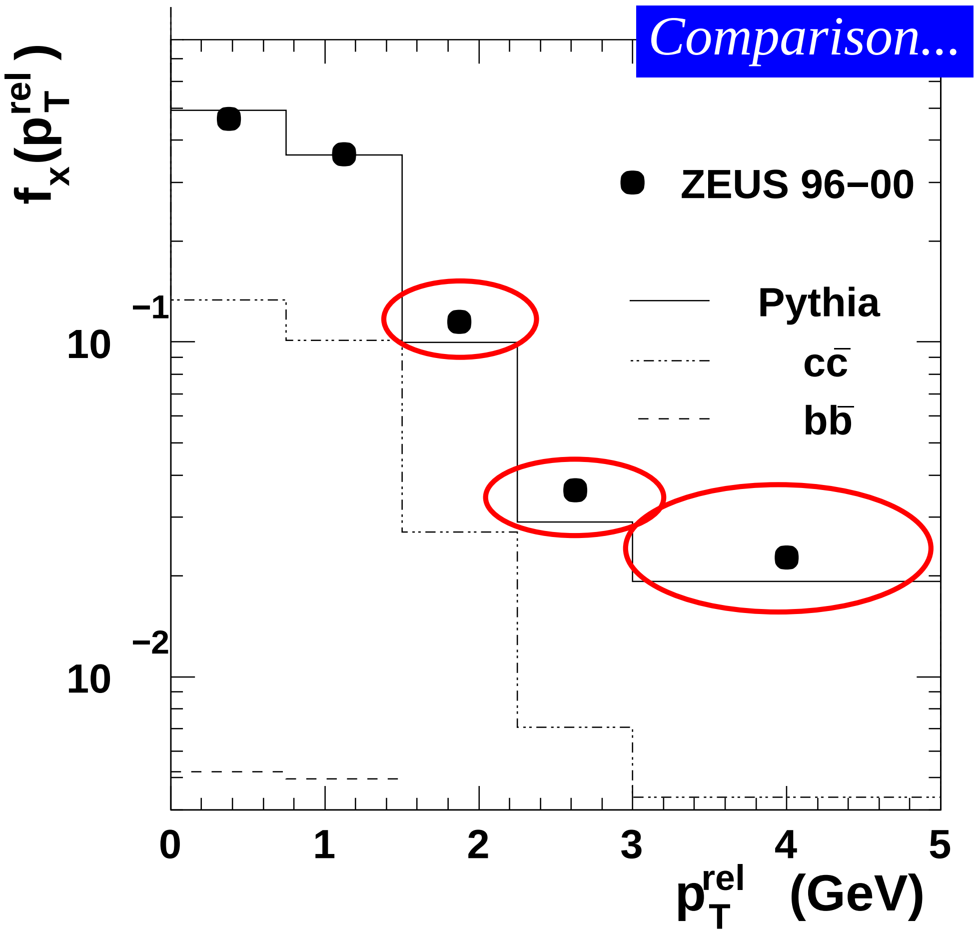
p_T^{rel} distribution of beauty taken from the PYTHIA *Monte Carlo*

p_T^{rel} distribution of the background obtained from

a comparison with the data... $\longrightarrow$

Background p_T^{rel} distribution

A sample of data with two jets and no muon requirements was selected.



The p_T^{rel} distribution was obtained using all the tracks satisfying the same momentum and angle requirements of the muon.

Monte Carlo underestimates the data at high p_T^{rel}!

→ correction applied to the LF Monte Carlo to reproduce the data p_T^{rel} distribution

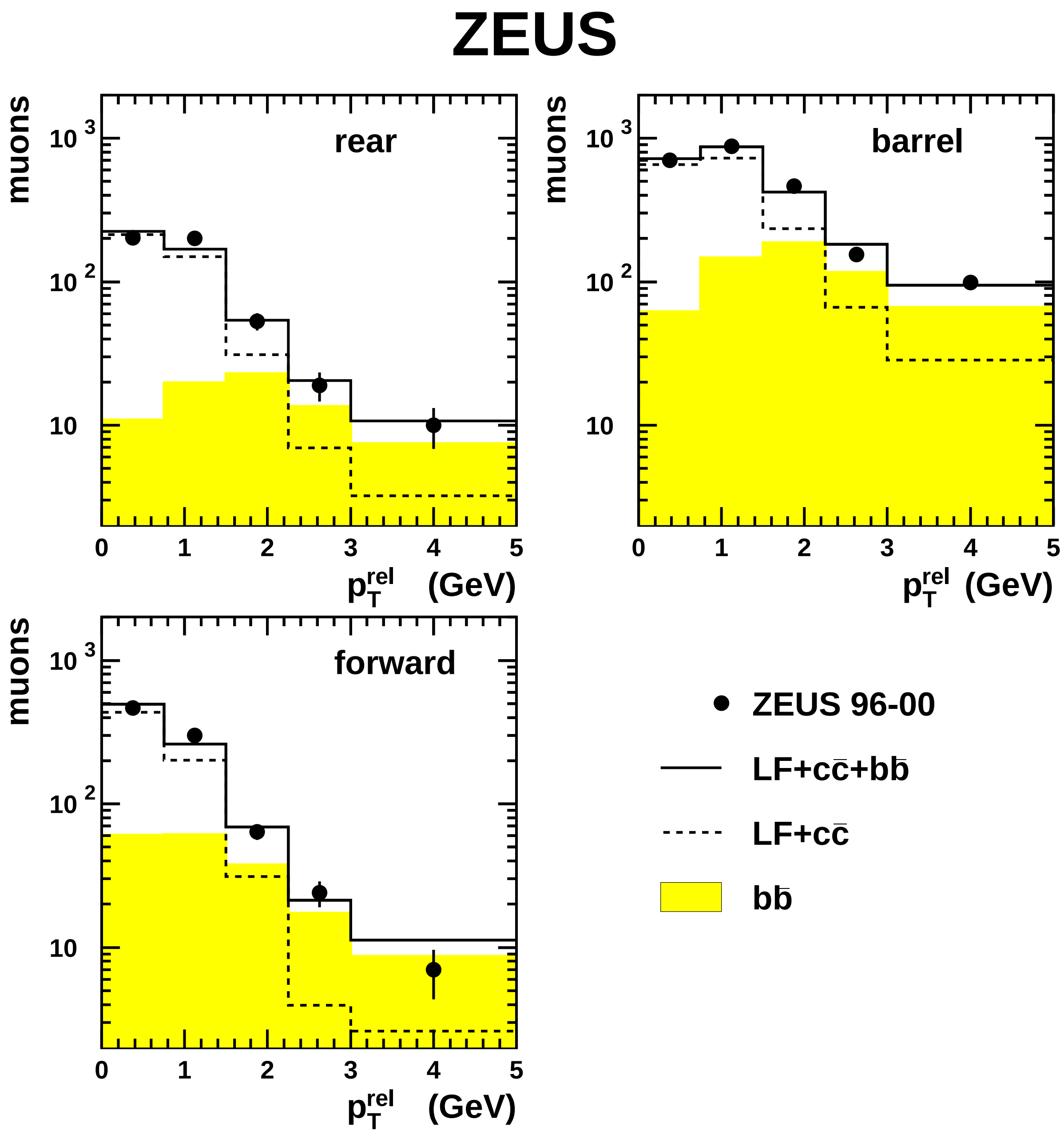
b fraction in the data

b fraction determined in the three regions of good acceptance for the muon:

REAR: $f_b = 15\%$
$p^\mu > 2.5$ GeV, $-1.6 < \eta^\mu < -0.9$

BARREL: $f_b = 25\%$
$p_T^\mu > 2.5$ GeV, $-0.9 < \eta^\mu < 1.3$

FORWARD: $f_b = 21\%$
$p^\mu > 4$ GeV, $p_T^\mu > 1.5$ GeV,
$1.5 < \eta^\mu < 2.3$



Cross sections determination

All the cross sections were determined in the kinematic region defined by:

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

$$p_T^{\text{jet}1,2} > 7,6\ \text{GeV},\ \ |\eta^{\text{jet}1,2}| < 2.5$$

for hadron level jets reconstructed before the B hadron decay.

All the acceptance corrections have been determined using the PYTHIA Monte Carlo, reweighted so that the p_T^b distribution was in agreement with that of the NLO QCD predictions.

The main systematic uncertainties arise from:
the uncertainty on the muon chambers efficiencies
the uncertainty on the shape of the background p_T^{rel} distribution.

MC models and NLO QCD calculations

PYTHIA 6.2:

- includes direct, resolved and flavour excitation (27%) processes;
- b–quark string fragmentation with Peterson, $\varepsilon = 0.0041$;
- branching–ratios for b decay, $b \to \mu X$ and via cascade, taken from the PDG;
- $B \to \mu$ momentum spectrum checked with measurements from Belle and BaBar;

CASCADE 1.1:

- k_T factorisation;
- CCFM evolution for the proton parton densities;
- Peterson fragmentation, $\varepsilon = 0.0041$.

NLO QCD: FMNR:

- GRVG-HO for γ, CTEQ5M for p;
- $m_b = 4.75$ GeV, $\mu = m_T = \sqrt{< p_T^b >^2 + m_b^2}$;
- jets done running k_T on partons;
- parton level jets corrected to hadron level using PYTHIA and HERWIG: from 20% (rear region) to 3% (large p_T^μ)
- $b \to B$ fragmentation with Peterson, $\varepsilon = 0.0035$;
- $B \to \mu$ according to PYTHIA.

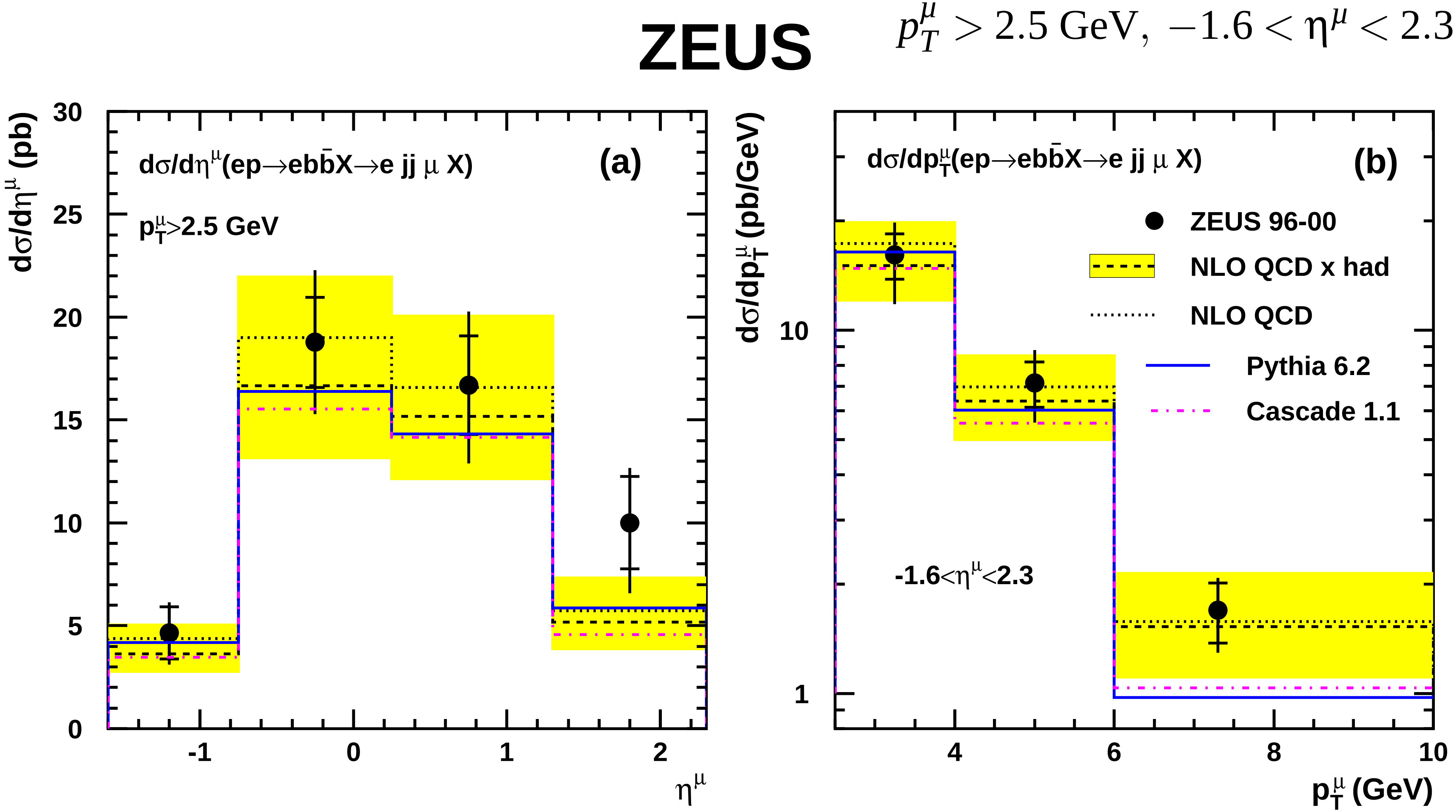
Uncertainty on NLO calculations:

- $m_b = 4.5$ GeV, $\mu = m_T/2 \;\to m_b = 5.0$ GeV, $\mu = 2m_T$: variations from +34% to -22%;
- $\varepsilon = 0.0020 \to \varepsilon = 0.0055$, Peterson to Kartvelishvili: $\pm 3\%$;
- different parton densities and $\Lambda_{QCD}^{(5)}$: $\pm 4\%$.

Muon cross sections

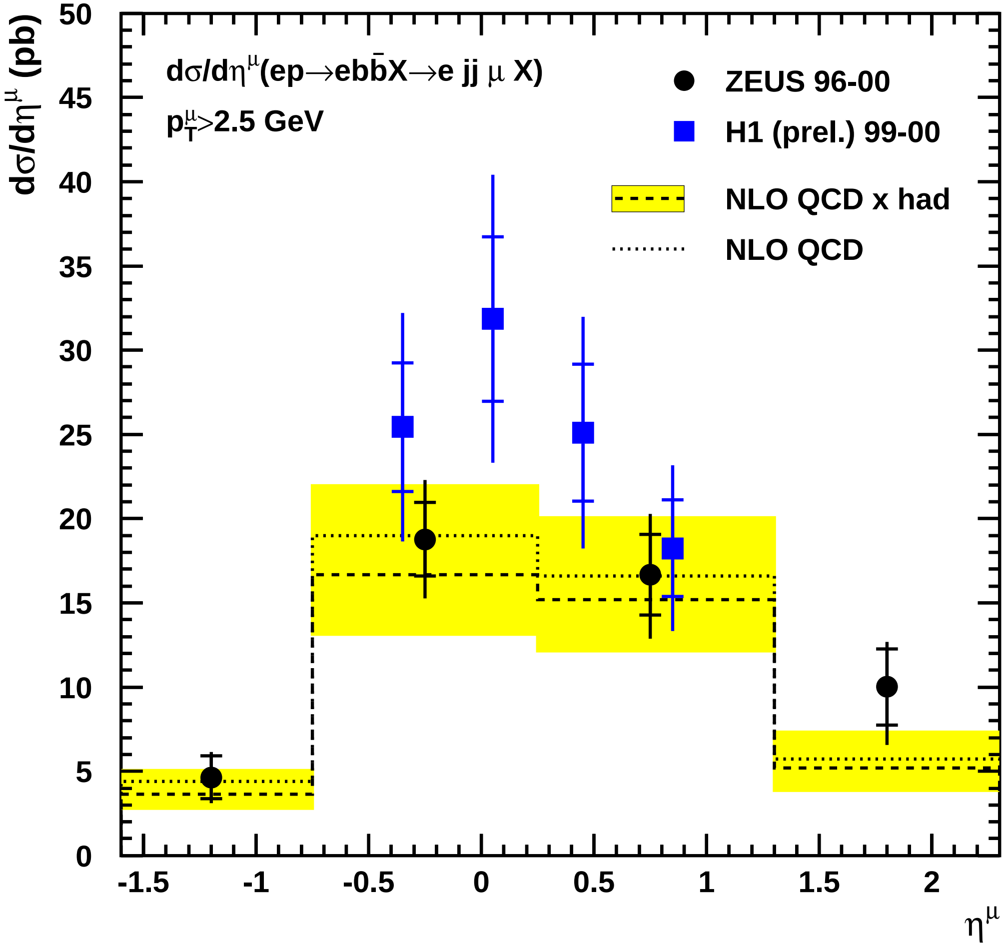
μ kinematic region:

$$p_T^\mu > 2.5 \text{ GeV}, \; -1.6 < \eta^\mu < 2.3$$



Good agreement between data, NLO QCD and MC predictions...

...and nice agreement also with H1



Visible cross sections

μ kinematic region:

REAR:

$p^{\mu} > 2.5$ GeV,

$-1.6 < \eta^{\mu} < -0.9$

BARREL:

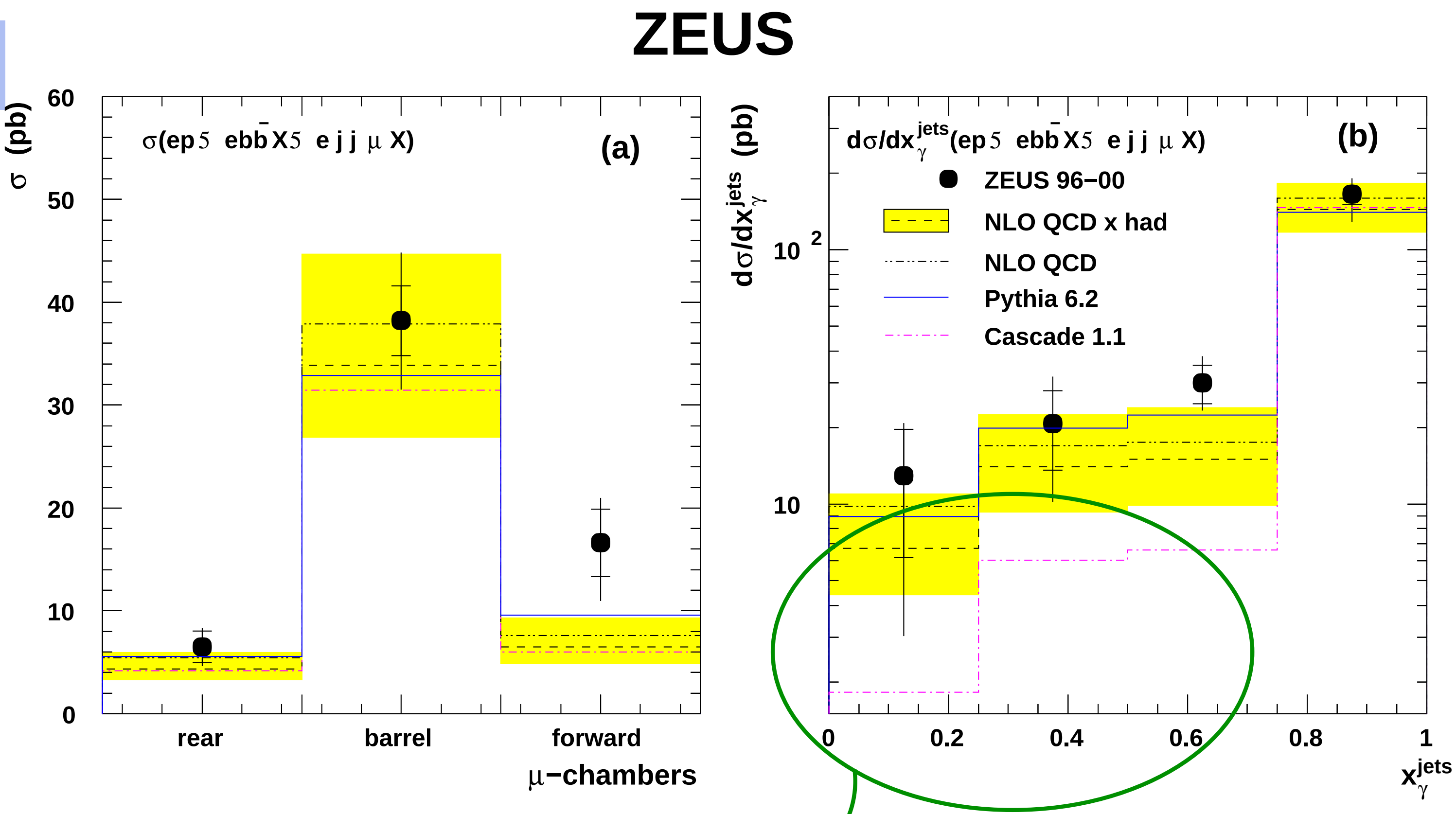
$p_T^{\mu} > 2.5$ GeV,

$-0.9 < \eta^{\mu} < 1.3$

FORWARD:

$p^{\mu} > 4$ GeV, $p_T^{\mu} > 1.5$ GeV

$1.5 < \eta^{\mu} < 2.3$



low x_{γ}

resolved processes dominant

Cascade fails in describing

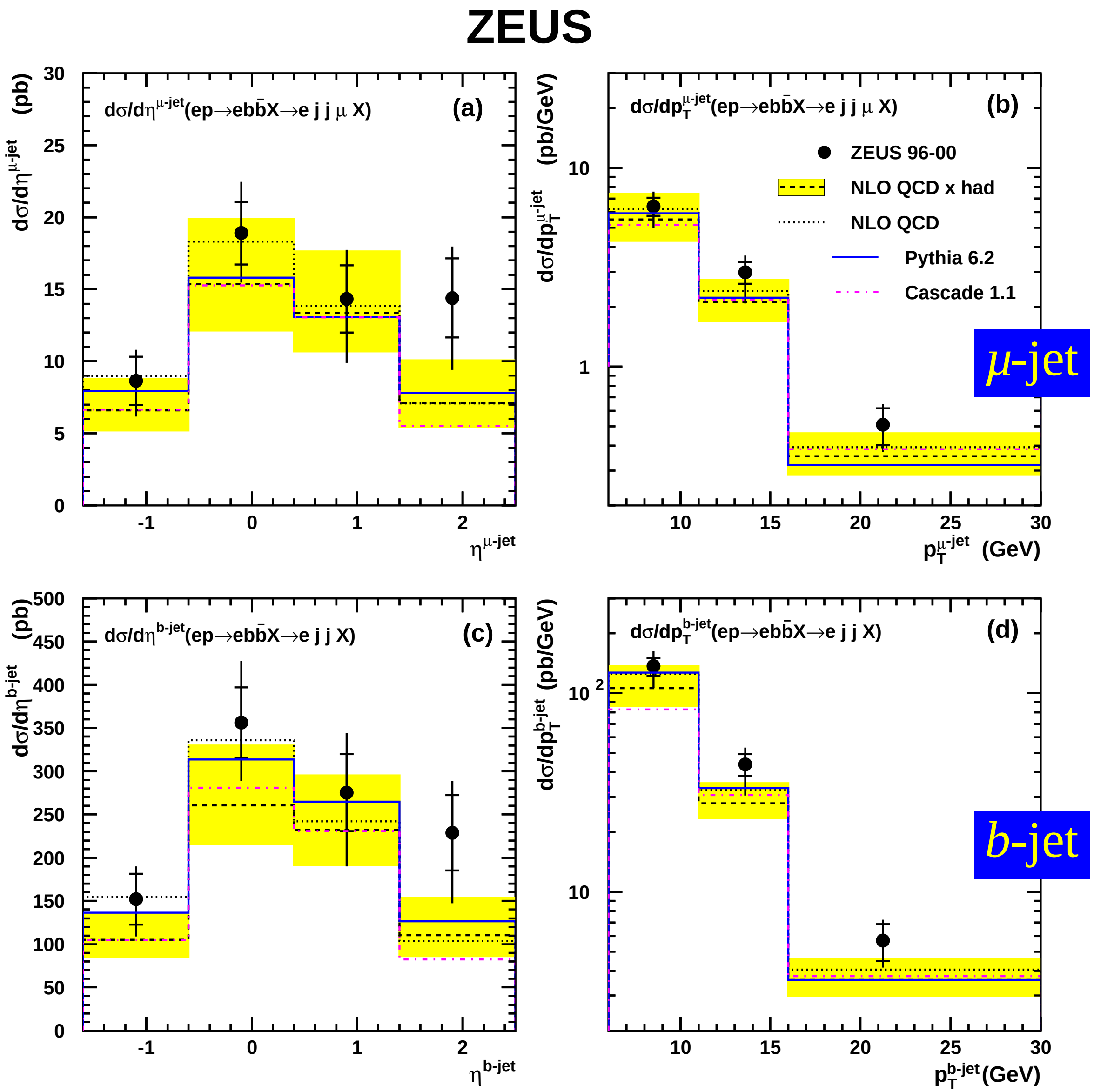
Good agreement between data and NLO QCD and PYTHIA predictions

μ-jet cross sections

μ kinematic region:
as for the visible cross sections

b-jet cross sections

μ-jet cross sections extrapolated for μ decay and BR using PYTHIA



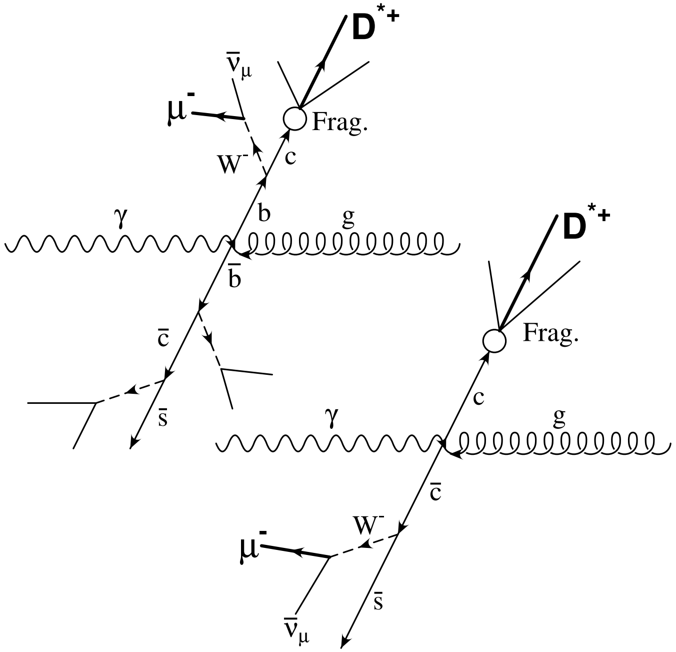
Good agreement between data, NLO and MC for both μ-jet and b-jet cross sections.

$D^* + \mu$ analysis

Data sample: 114 pb^{-1}

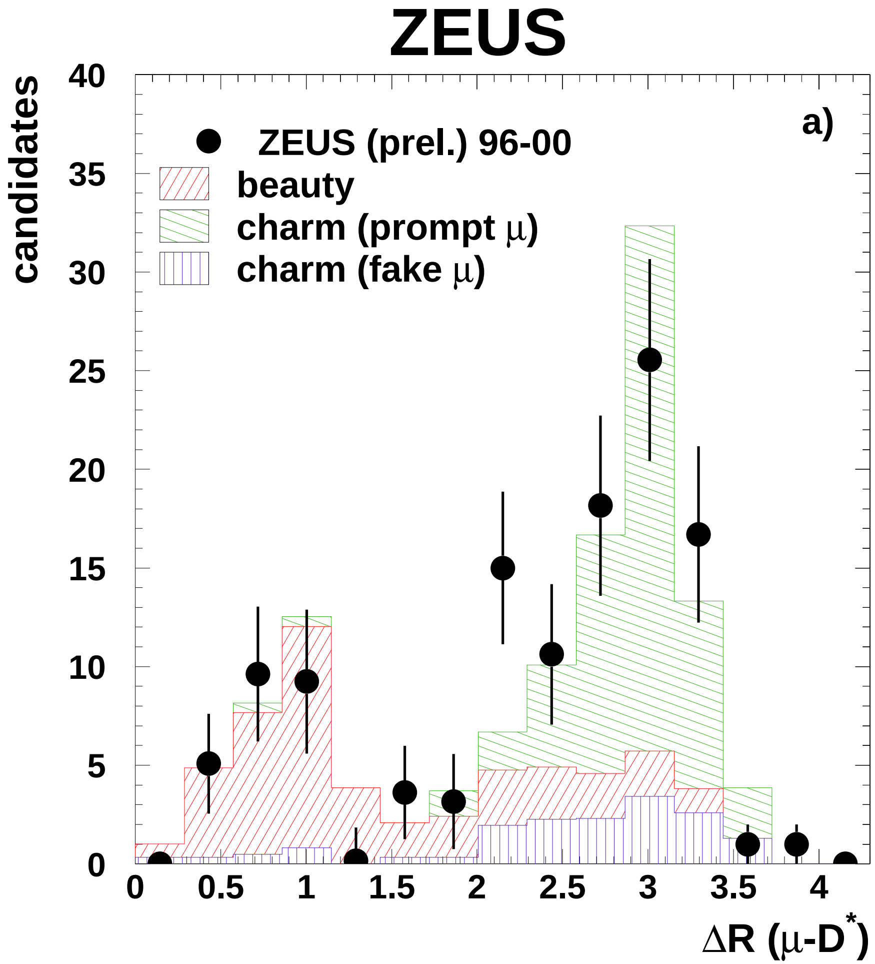
Search for b in the reaction

$$ep \to eb\bar{b}X \to eD^*\mu X$$



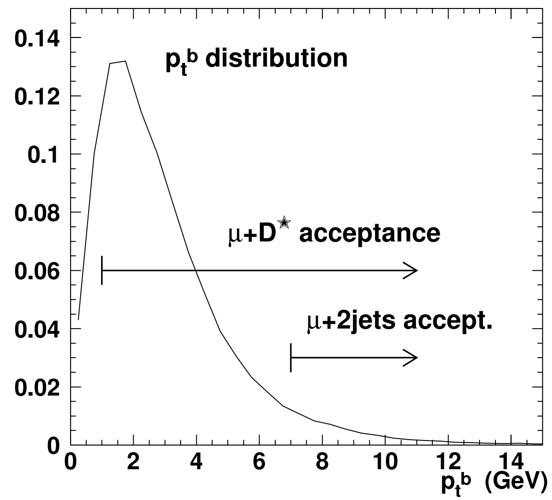
Unlike–sign D^* and μ coming from the same b parent are mainly produced in the same emisphere.

Beauty fraction extracted by fitting the ΔR and $\Delta\phi$ distributions.



Results

Beauty and charm very well separated $\longrightarrow$ very low background contamination.
Analysis sensitive to very low b quark transverse momenta.



Cross section evaluated for the process $\gamma p \longrightarrow b(\bar{b})X$, for b or $\bar{b}$ production (avoid problems due to correlation) and extrapolated to the kinematic region defined by:

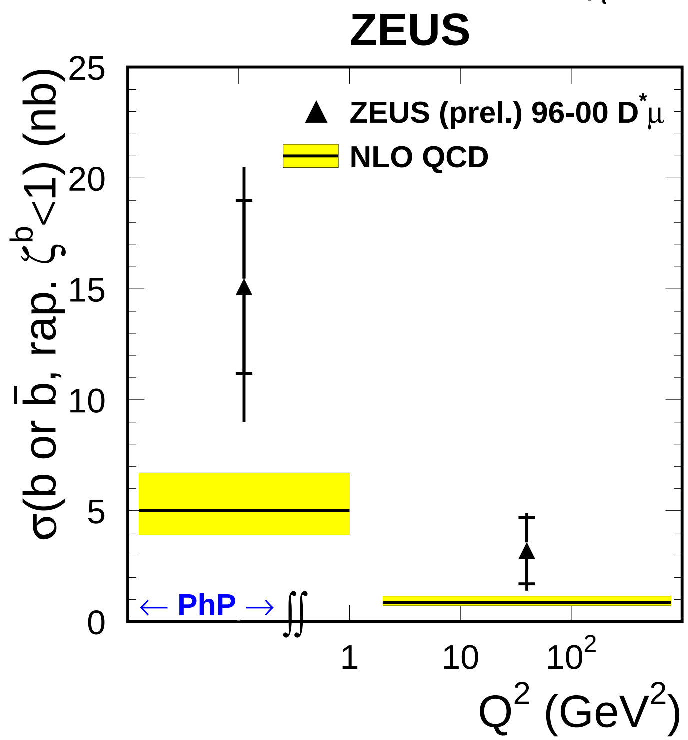
$\zeta^b < 1, \quad Q^2 < 1\ \mathrm{GeV}^2 \quad 0.05 < y < 0.85$

no cuts on p_T^b:

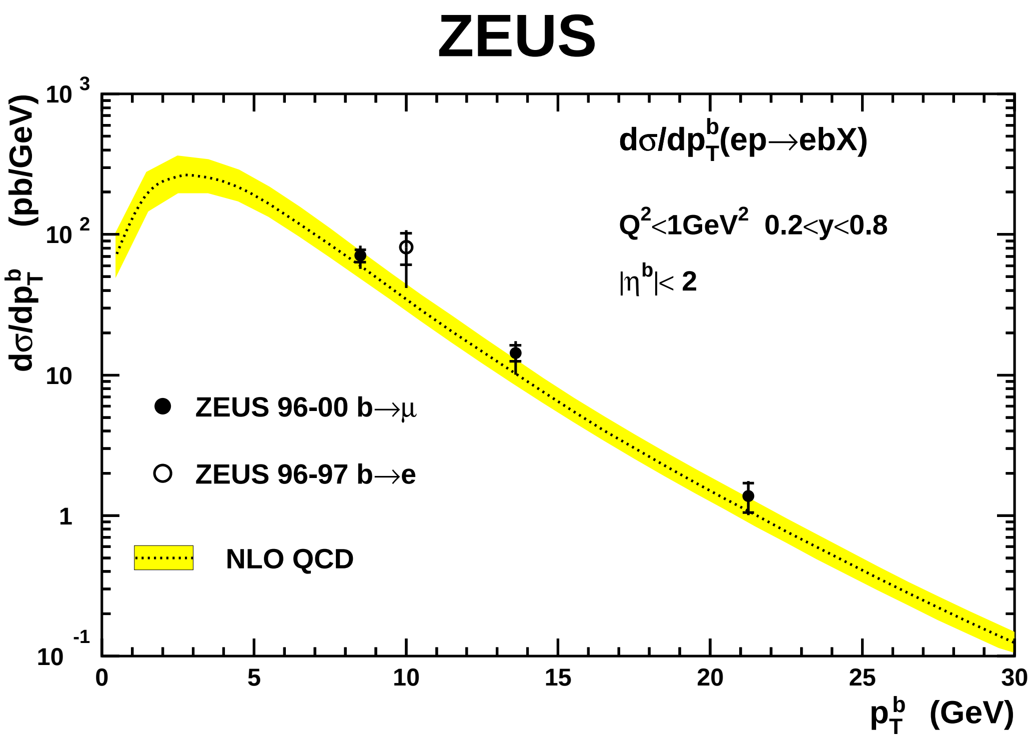
$$\sigma(\gamma p \longrightarrow b(\bar{b})X) = 15.1 \pm 3.9\ (\mathrm{stat.})^{+3.8}_{-4.7}\ (\mathrm{syst.})\ \mathrm{nb}$$

to be compared to a NLO prediction (FMNR) of

$$\sigma_{\mathrm{NLO}}(\gamma p \longrightarrow b(\bar{b})X) = 5.0^{+1.7}_{-1.1}\ \mathrm{nb}$$



Summary of the ZEUS measurements...



Cross section for b–quark extrapolated using NLO calculations.

...with the low p_T^b region to be covered by the $\mu + D^*$ analysis.

Very good agreement with the NLO QCD predictions

Good agreement with the previous ZEUS publication

Conclusions

The beauty photoproduction cross section has been measured at ZEUS using both muon plus dijet and muon plus D^* events.

In the muon plus dijet channel, differential cross sections for muons , μ-jet and b-jet have been evaluated and compared to Monte Carlo models and NLO QCD predictions.

In all the cases very good agreement has been found between data and NLO QCD.

A b–quark cross section has been obtained,
extrapolating the visible measurements using NLO.

In the muon plus D^* channel, ZEUS is investigating a different kinematic region, complementary in p_T^b.