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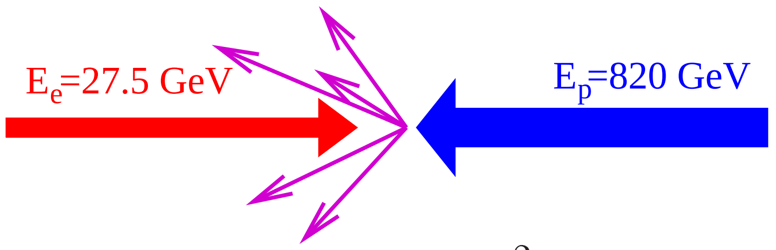
on behalf of the
ZEUS collaboration

Beauty photoproduction

Outline

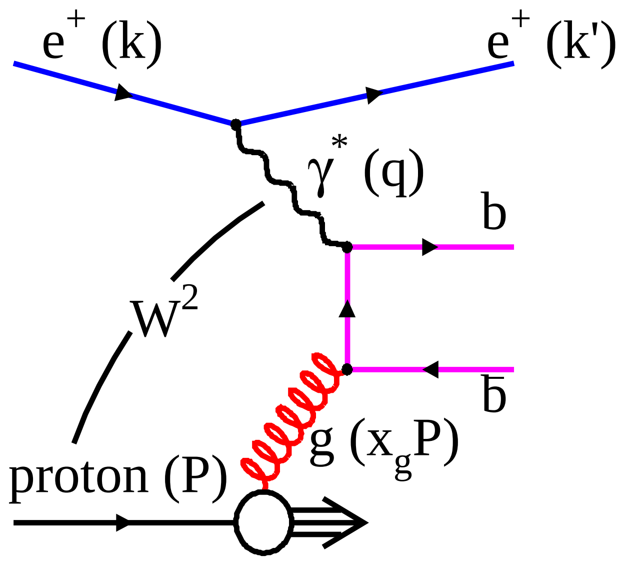
- b production at HERA
- b experimental signature
- ZEUS e and μ PHP analyses
- Conclusion

b production at HERA



$1992 - 1997 \;:\; \sqrt{s} \simeq 300\ GeV$

$$
\begin{aligned}
s &= (P+k)^2 \\
W^2 &= (P+q)^2 \\
y &= \frac{q \cdot P}{k \cdot P} \\
Q^2 &= -q^2 = -(k-k')^2
\end{aligned}
$$



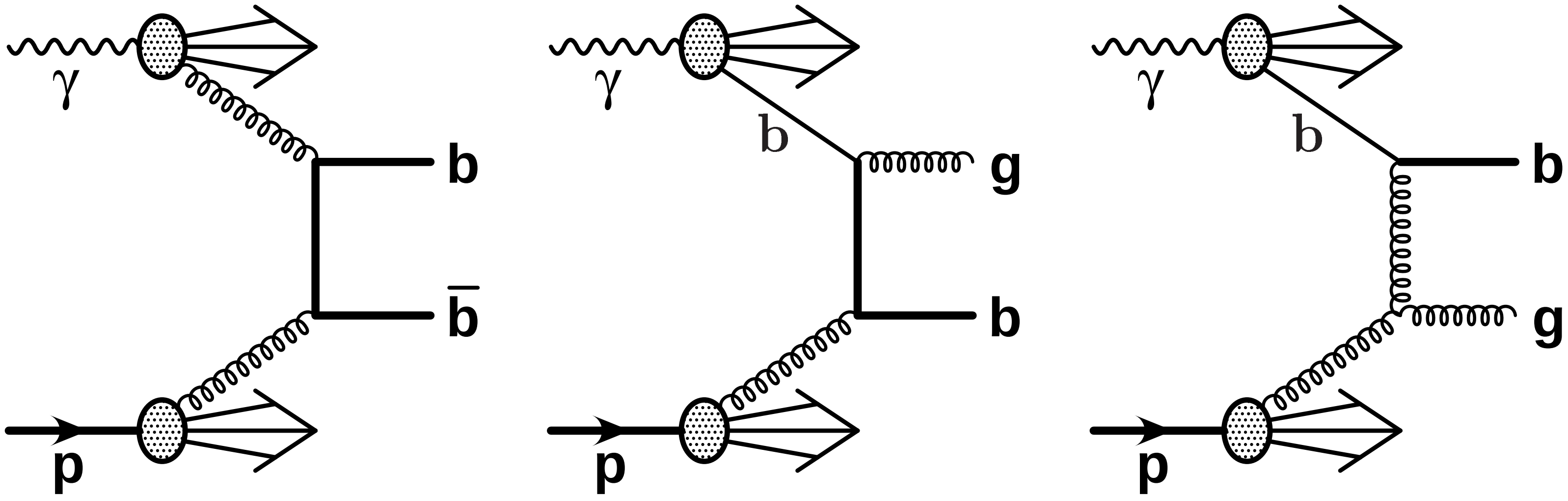
in photoproduction processes $Q^2 \simeq 0\ GeV^2$.

In the case of direct photon processes, $\gamma g \to Q\bar{Q}$, the whole γ momentum takes part to the hard interaction:

$$x_\gamma^{OBS} = \frac{E_T^{\text{jet1}} e^{-\eta^{\text{jet1}}} + E_T^{\text{jet2}} e^{-\eta^{\text{jet2}}}}{2yE_e} \simeq 1$$

b production at HERA – II

Resolved photon and b excitation processes (mainly from the photon) give their contribution to beauty PHP cross–section:



In this case $x_\gamma^{OBS} < 1$, only a fraction of the γ momentum takes part to the hard interaction. Resolved γ processes are expected to give a more sizeable contribution in the forward region (w.r.t. the proton direction). This is a Leading Order picture.

The study of b–quarks production is important because:

- it helps in understanding the structure of the proton and the photon.
- the heavier b–quark mass is expected to make pQCD calculations reliable (NLO available).

Theoretical models

Leading order parton shower Monte Carlo:

- PYTHIA: direct and resolved γ;
- HERWIG: direct and resolved γ;
- CASCADE: only direct γ but CCFM gluon in p.

NLO QCD calculations:

Massive approach valid for $p_T \sim m_b$ (large logarithms $\frac{p_T}{m_Q}$):

- light quarks are active flavours in p and γ;
- b produced dynamically in hard subprocess;
- calculations done by Frixione et al. (FMNR).

Theoretical uncertainties

The values for the cross–sections predicted by NLO calculations depend on:

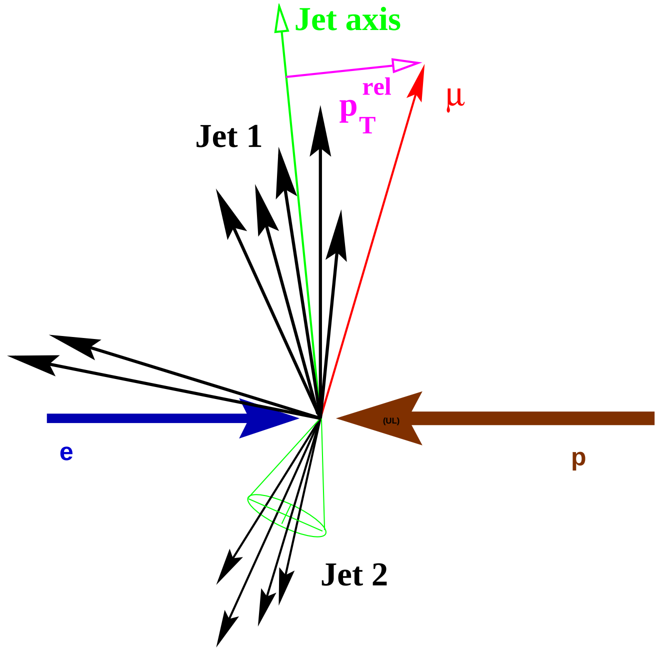
- the structure functions chosen for the proton and the photon;
- the factorisation and renormalisation scales μ_F and μ_R;
- the mass of the bottom quark;
- the fragmentation functions used.

In the extrapolation of the calculated cross sections the main uncertainties are due to:

- different hadronisation models;
- the mass of the bottom quark;
- indetermination on the $\mathcal{BR}(b \rightarrow lepton)$.

Beauty experimental signature

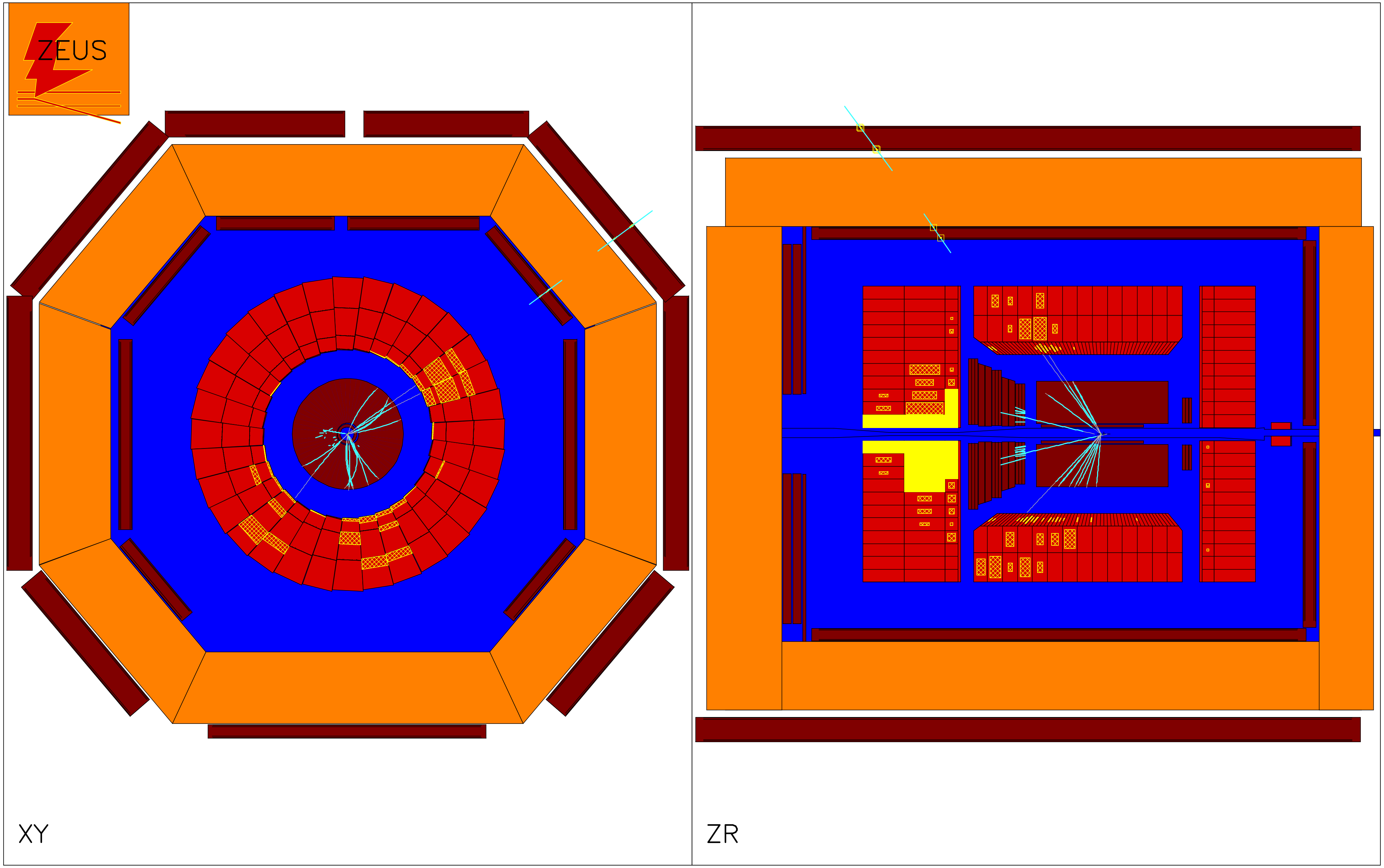
Search for beauty production through its semi–leptonic decay ($\mathcal{BR} \sim 10\%$).



Experimental signature:

- two high transverse energy jets
- at least one high–p lepton

Signal–background discrimination based on p_T^{rel} distribution (expected to be harder for beauty events).


ZEUS
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ZEUS electron analysis

Look for events $e^+p \to e^+ + dijet + e^- + X$ in 1996-97 data

Kinematic region defined by:

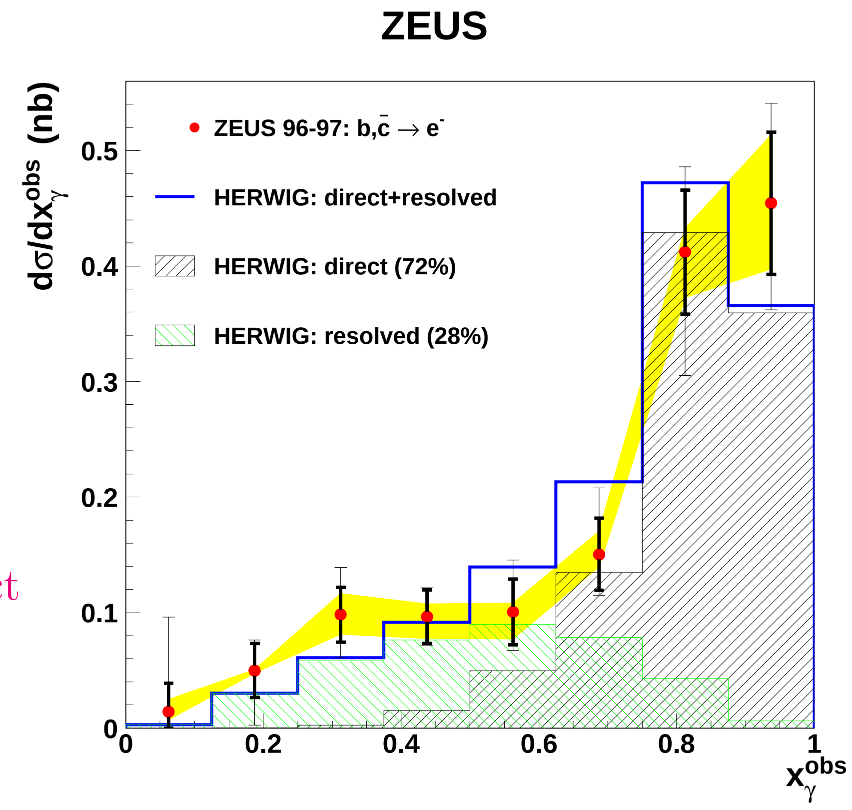
- $Q^2 < 1\ GeV^2,\ 0.2 < y < 0.8$
- $E_T^{\mathrm{jet1(2)}} > 7(6)\ GeV,\ \mid \eta^{\mathrm{jet1(2)}} \mid < 2.4$
- $p_T^{e^-} > 1.6\ GeV,\ \mid \eta^{e^-} \mid < 1.1$

No *forward region*

x_γ distribution fitted in order to separate direct and resolved contribution.

Result from the fit: $f_{RES} = (28 \pm 5)\%$.

HERWIG MC prediction: $f_{RES} = 35\%$.



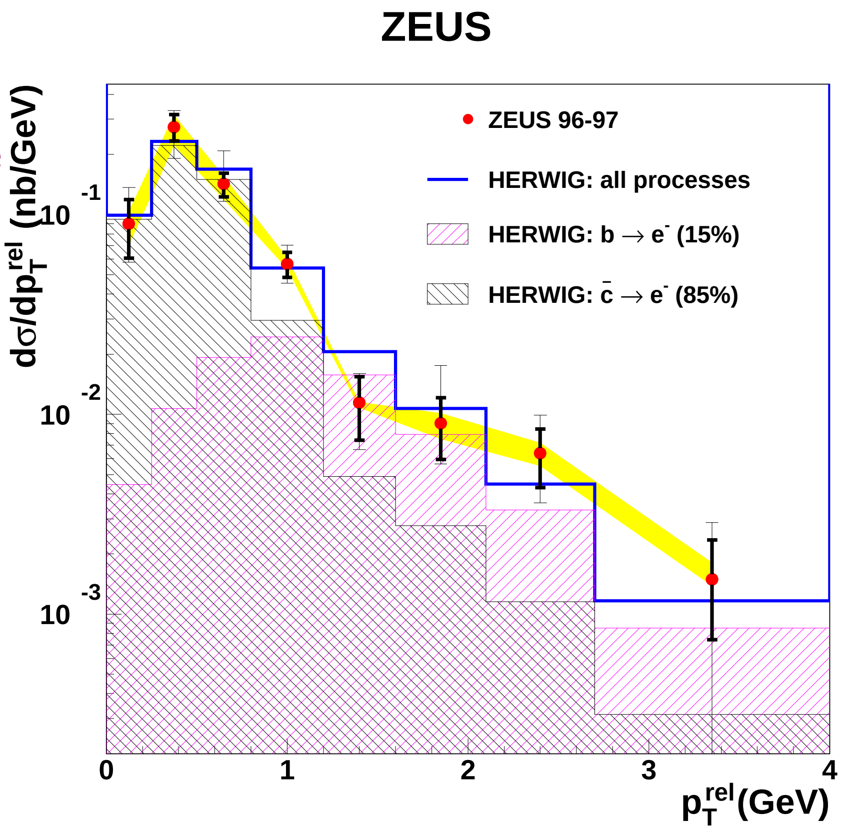
LO MC models require resolved processes in order to explain data shapes.

ZEUS electron analysis – II

b–c discrimination based on a fit to the $p_T^{\rm rel}$ variable.

- Fit: $f_b = (14.7 \pm 3.8)\%$
- HERWIG: 16%, PYTHIA: 19%

Difference between the two Monte Carlo: different scales and hadronisation, different flavour excitation processes calculation.



Measured cross section:

$$\sigma_{vis} = (24.9 \pm 6.4({\rm stat.})^{+4.2}_{-7.3}({\rm syst.}))\ {\rm pb}$$

HERWIG: $\sigma_{vis} = 8$ pb

PYTHIA: $\sigma_{vis} = 18$ pb

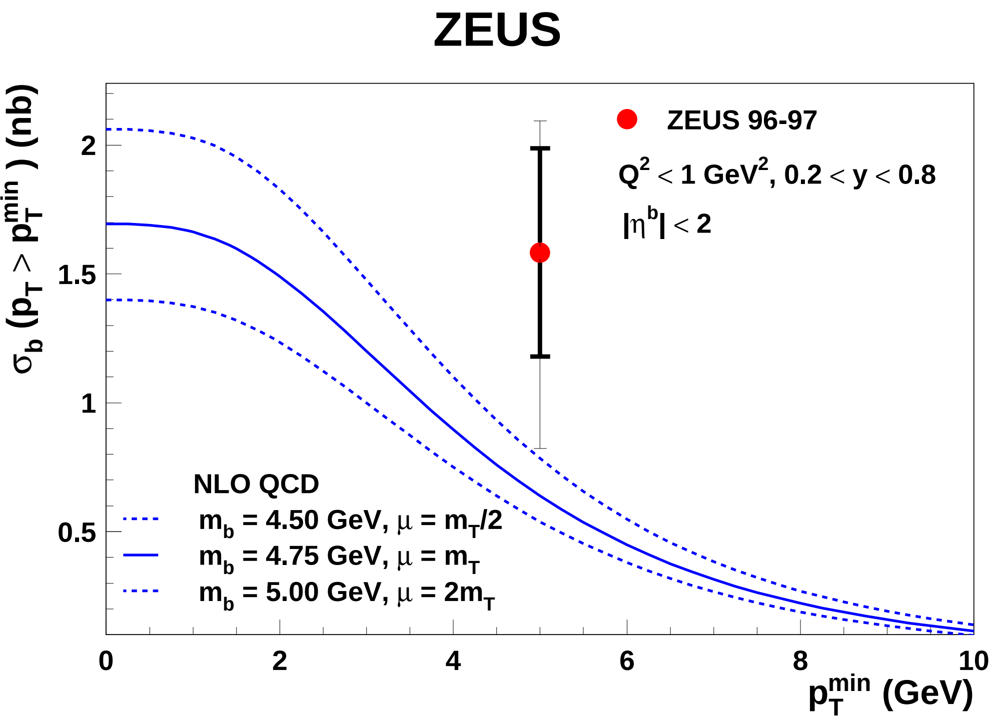
CASCADE: $\sigma_{vis} = 18$ pb

ZEUS electron analysis–III

The visible cross section has been extrapolated to the parton level in the kinematic region defined by:

- $p_T^b > p_T^{\min} = 5\ GeV, \quad |\eta^b| < 2$
- $Q^2 < 1\ GeV^2,\ 0.2 < y < 0.8$

Uncertainties in the extrapolation: different hadronization models, variation of the mass of the b quark, indetermination on the $\mathcal{BR}(b \to e^-)$.



$$\sigma^{ext}_{ep\to e+bX} = (1.6 \pm 0.4(\text{stat.})^{+0.3}_{-0.5}(\text{syst.})^{+0.2}_{-0.4}(\text{ext.}))\ \text{nb}$$

Central value: HERWIG, systematic PYTHIA.

To be compared with

NLO (FMNR) $= (0.64^{+0.14}_{-0.10})$ nb

CASCADE $= 0.88$ nb

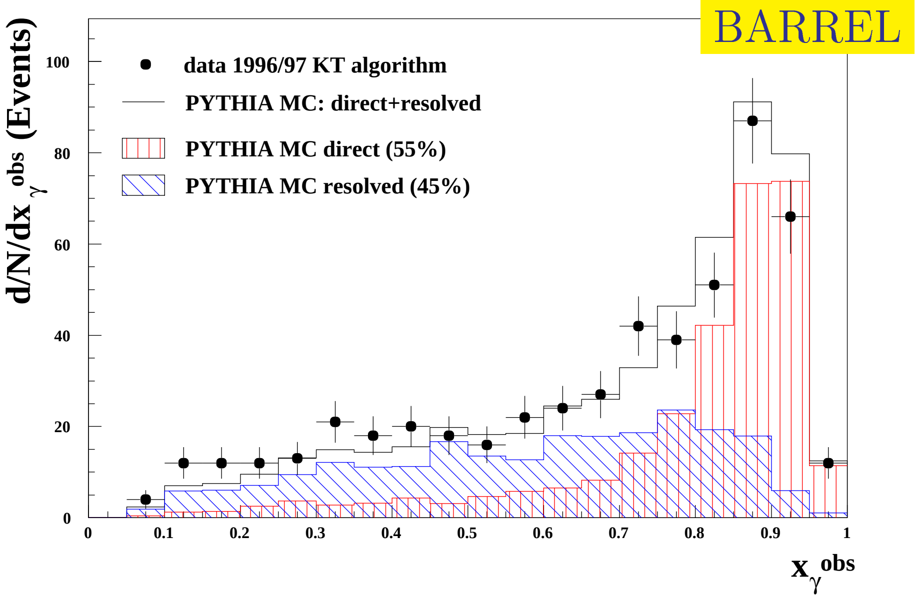
ZEUS muon analysis–I

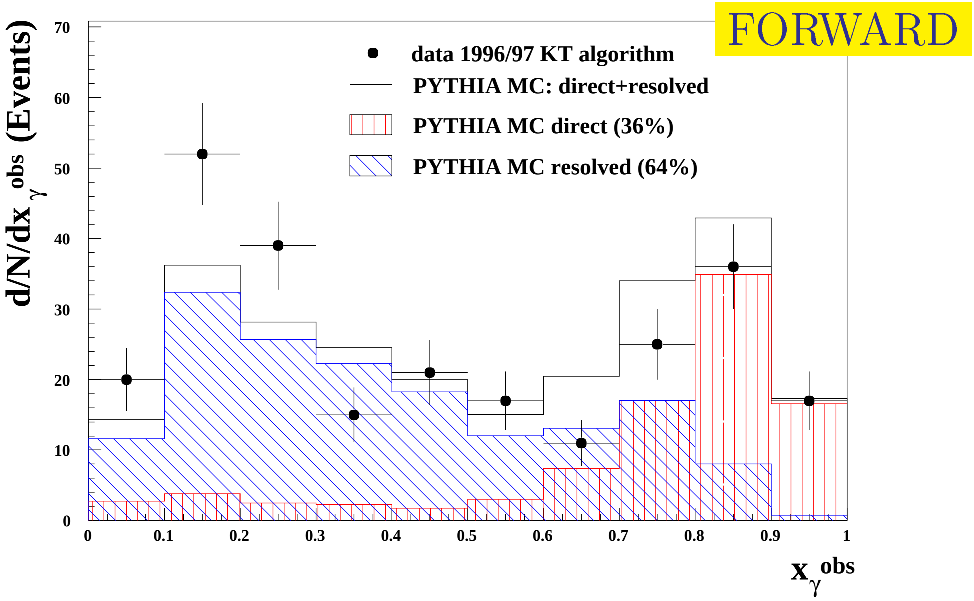
Look for events $e\ p \to \mu\ dijet\ X$ in 1996–97 data.

Kinematic region defined by:

- $Q^2 < 1\ GeV^2,\ 0.2 < y < 0.8$
- $E_T^{\mathrm{jet}1(2)} > 7(6)\ GeV, |\ \eta^{jet1(2)}\ | < 2.5$
- $p^\mu > 3\ GeV,\ \ -1.75 < \eta^\mu < 2.3$

forward region included



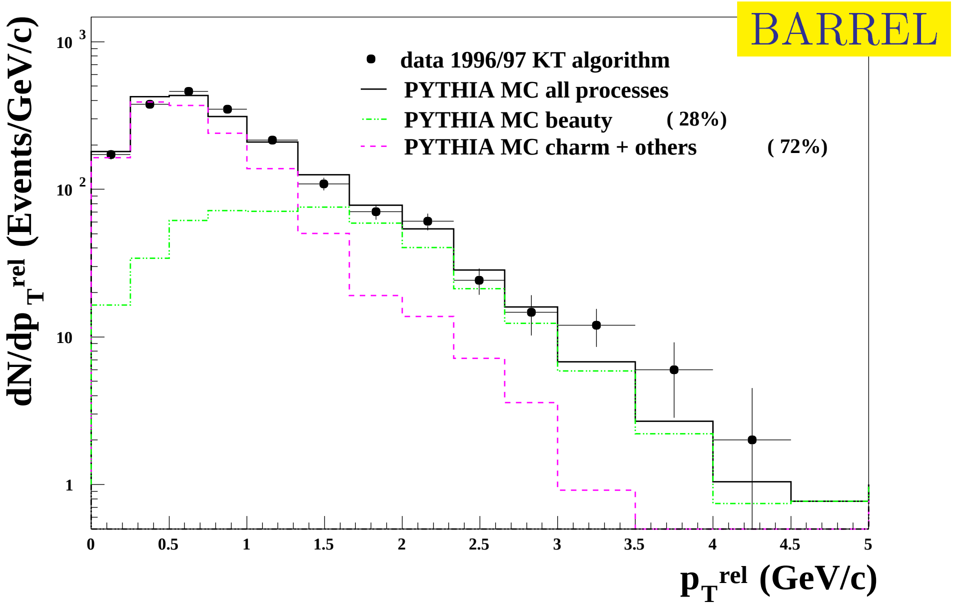


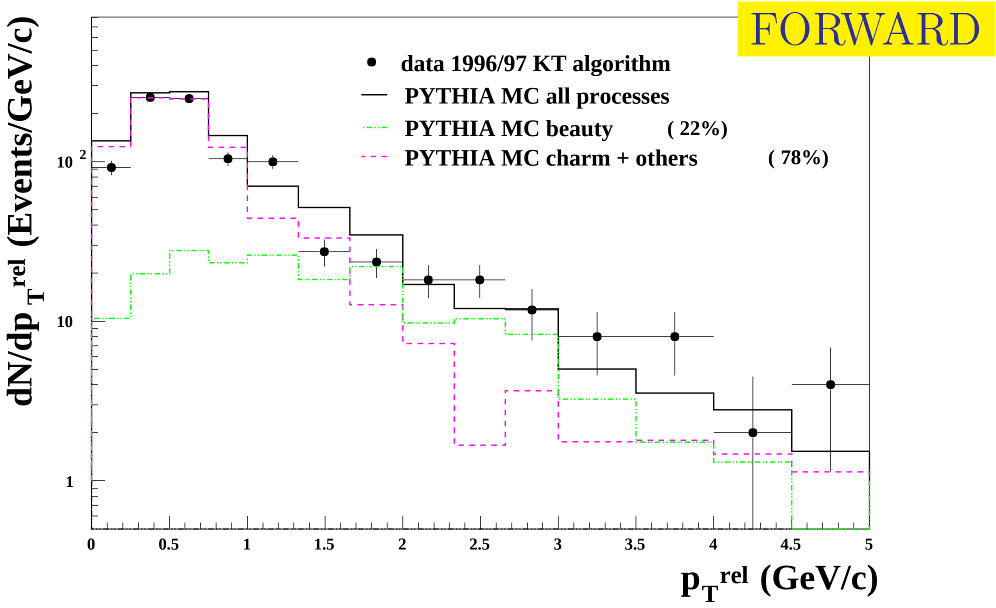
Different x_γ distribution in the forward region: resolved processes are found to be dominant.

The main contribution to resolved processes is given by b excitation in γ.

ZEUS muon analysis–II

b fraction extracted by a fit on the p_T^{rel} variable in the two different regions.





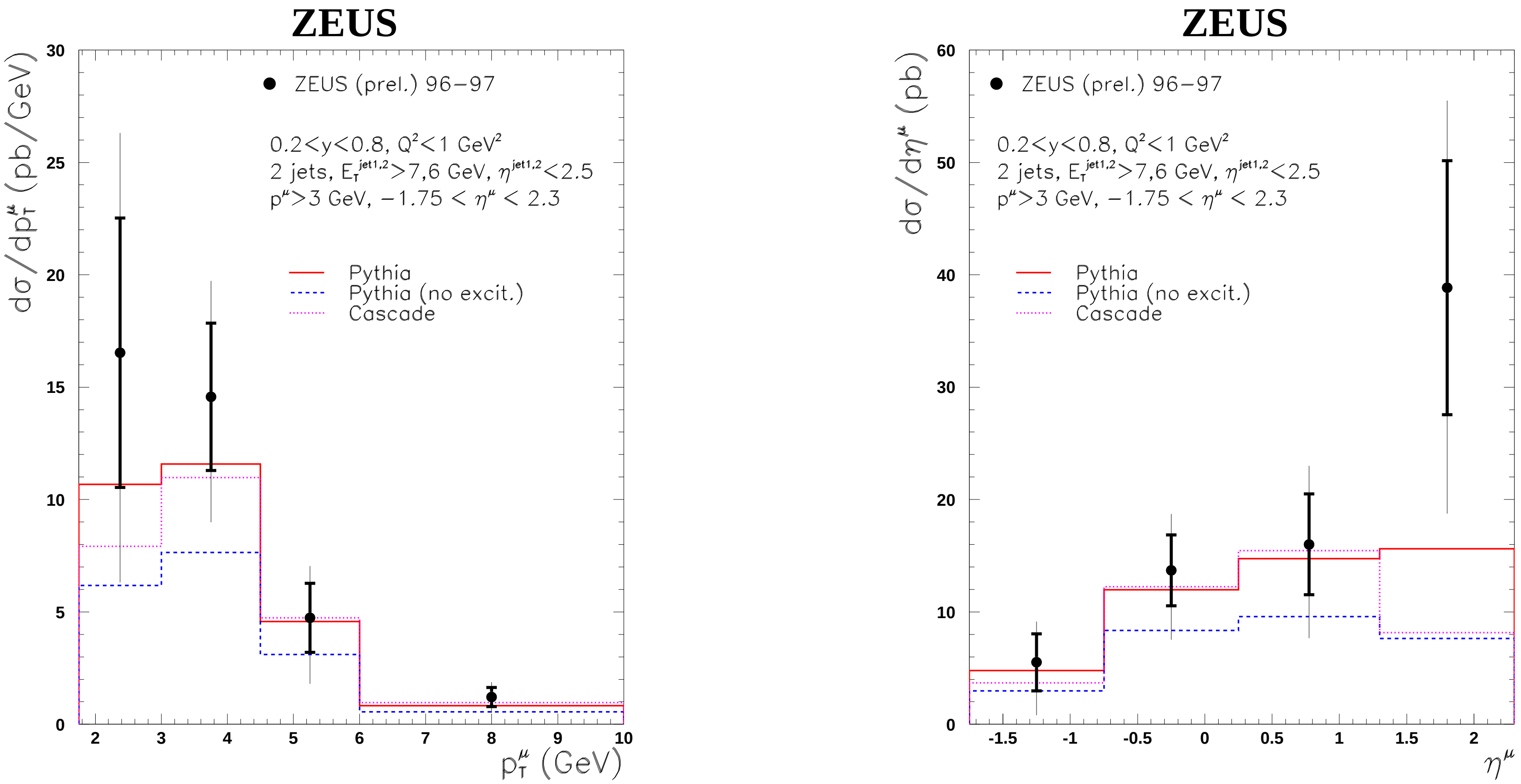
$-1.75 < \eta^\mu < 1.3$

- $f_b = (28 \pm 5)\%$
- $\sigma^{vis}_{\mathrm{B/R}} = (36.4 \pm 5.2(\mathrm{stat.})^{+10.4}_{-9.1}(\mathrm{syst.}))$ pb
- PYTHIA: 30 pb
  HERWIG: 12 pb
  CASCADE: 24.5 pb

$1.4 < \eta^\mu < 2.4$

- $f_b = (22 \pm 7)\%$
- $\sigma^{vis}_{\mathrm{F}} = (20.5 \pm 6.5(\mathrm{stat.})^{+6.3}_{-5.7}(\mathrm{syst.}))$ pb
- PYTHIA: 9.6 pb
  HERWIG: 4.1 pb
  CASCADE: 5.9 pb

Differential cross–sections



PYTHIA with b excitation processes describes the data reasonably well.

In the forward region PYTHIA predictions show a tendency to be below the data.

Also CASCADE succeeds in explaining data shapes reasonably well, except for the forward region.

Conclusion

- Open beauty production has been observed at HERA, with the ZEUS detector.
- The measured cross–section in the e channel is somewhat above the NLO and CASCADE predictions.
- The μ analysis has been extended to a more forward region.
- Differential cross–sections have been calculated and compared to various Monte Carlo predictions.

Outlook

- Extending the analysis to 1999-2000 data, the statistics will increase by a factor 2.5.
- Hope to have NLO soon for the μ channel.
- HERA II will provide much larger statistics, ZEUS has a new vertex detector: stay tuned!