Measurement of beauty production from dimuon events in ep interactions at HERA

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Motivation of study

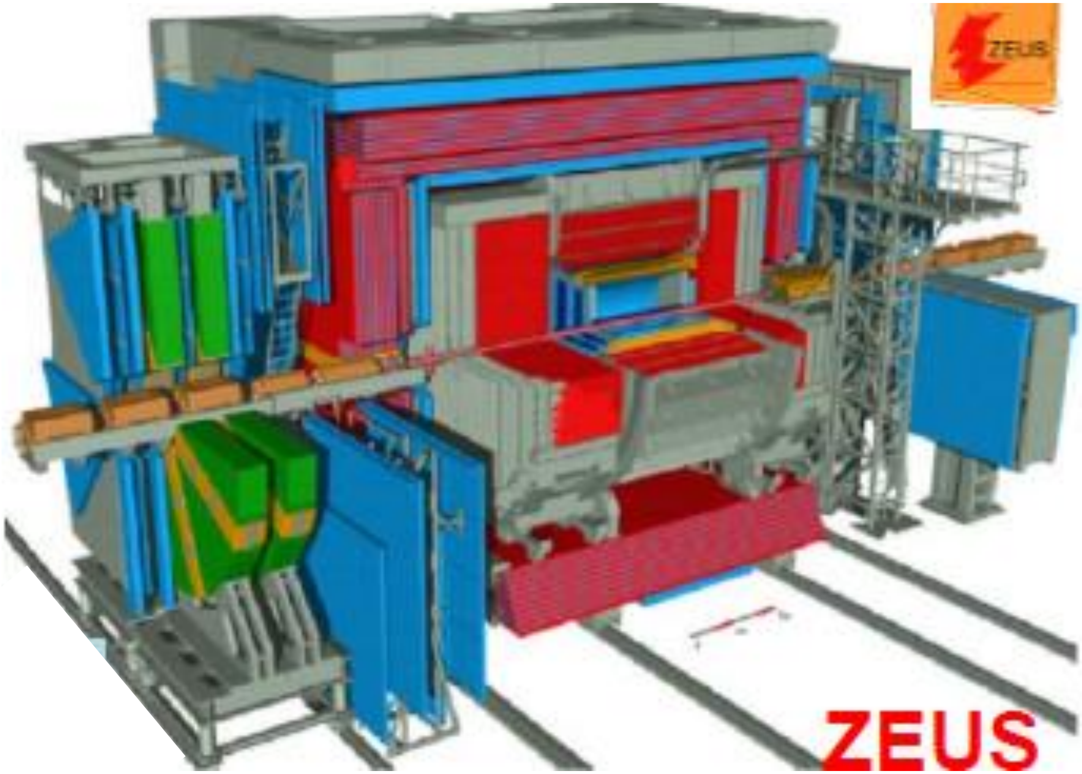
Production of $b\bar{b}$ pairs is governed by perturbative QCD at all transverse momentum values, owing to mass of b quark.
Good area to test models.

HERA recorded ep collisions from 1992-2000 (HERA I)
and 2003-2007 with higher luminosity (HERA II)
27.5 GeV electrons/[positrons + 920 GeV protons.

This study is of $ep \rightarrow ep b\bar{b} X$ using HERA II data.
Factor of 3 times luminosity of previous HERA I study
ZEUS Coll., S. Chekanov et al., JHEP 02 (2009) 032

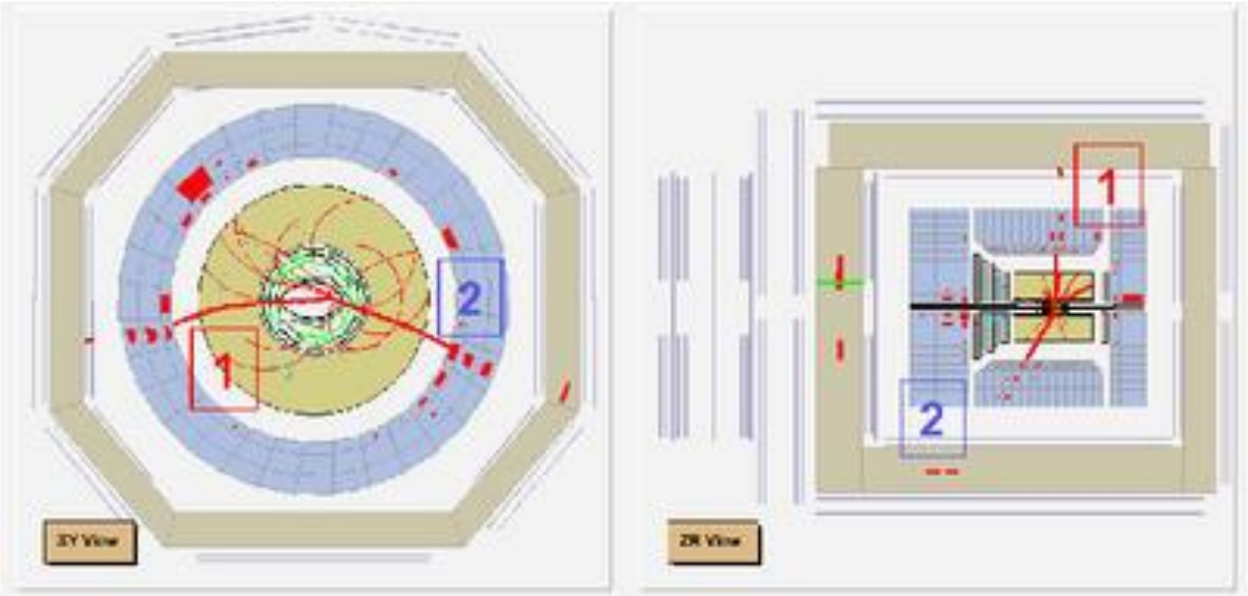
Events with two identified muons are used. No jet requirement.

Photoproduction ($Q^2 < 1.0$ GeV^2) and DIS ($Q^2 > 1.0$ GeV^2)
are included together in this analysis.



The ZEUS detector

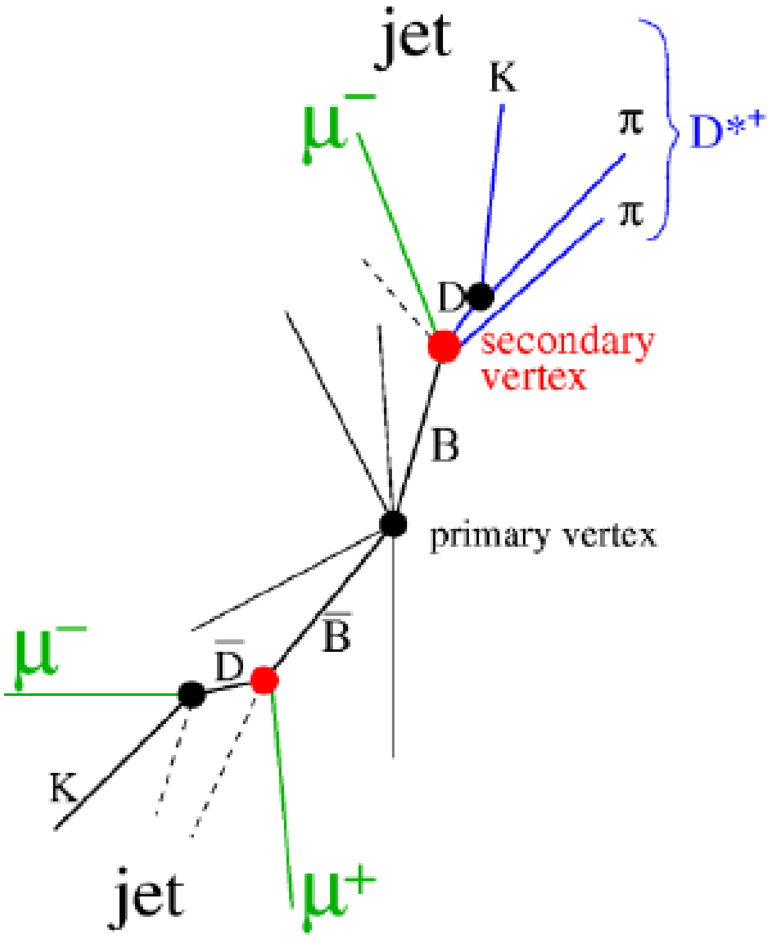
Close to 100 % coverage for muon detection over forward, central and rear regions.



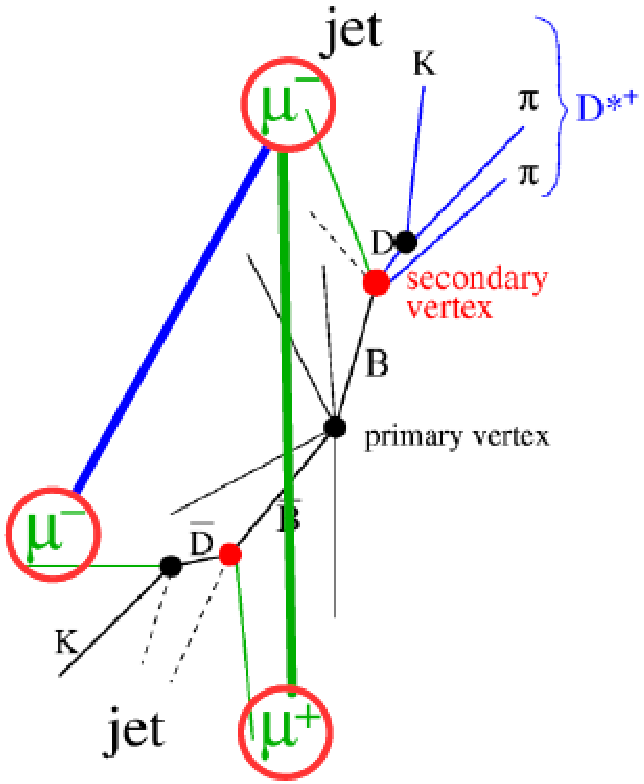
A $b\bar{b}$ event can contain several muons.

Either from the B decay itself or from later D decay.

They are associated with jets and/or hadronic activity (but we do not measure jets here).

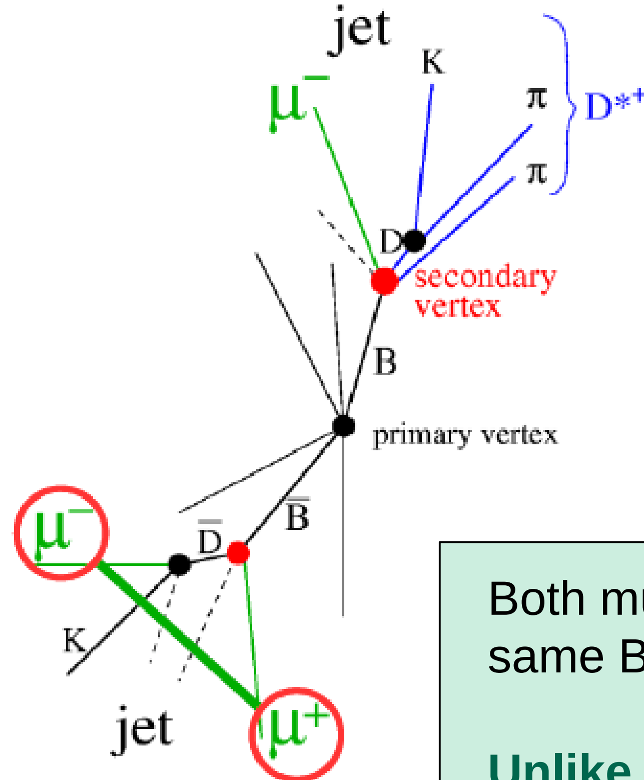


Here we select events with **2 identified muons**. They may be like or unlike sign.



Muons from
different B’s..

Like or **unlike** sign



Both muons from
same B.

Unlike sign.

So the two-muon events can be classified:

	low mass (< 4 GeV)	high mass (> 4 GeV)
unlike sign $\pm / \mp$	muons from same b J/ψ, ψ' + light-flavour bg	muons from diff. b or c Υ, Bethe Heitler + light-flavour bg
like sign $+ + / - -$	light flavour bg + few muons from diff. b	muons from diff. b + light-flavour bg

Event selections

-Total measured transverse energy (excluding scattered e) > 8 GeV.
(removes much DD and light flavour background.)

- Standard ZEUS muon identification using muon chambers and tracking detectors. Efficiency > 80% for high-momentum muons.

- Some cuts on low-mass muon pairs and low muon p_T values.
Cosmic ray events were removed.

- To remove Bethe-Heitler and primary J/ψ events, the muon pairs must not be isolated. Require extra energy near muons.

Cross section determination

Use M.C. to evaluate remaining backgrounds from charm, J/ψ and Bethe-Heitler bgs. Charm contribution is normalised to ZEUS charm measurements.

False-muon backgrounds cancel out by taking the difference

N(unlike sign) – N(like sign)

as a measure of the B cross section.

This must be corrected for the remaining backgrounds,
An acceptance factor then converts to the full B cross section in a defined kinematic region..

Monte Carlo models

- Photoproduction simulation uses **PYTHIA**.
- DIS simulation of beauty and charm events uses **RAPGAP** :

  Leading order parton-level QCD matrix elements.
  Some higher orders are modelled by initial/final state leading-log parton showers. Fragmentation uses the Lund string model as in PYTHIA.

- Photoproduction simulation uses **PYTHIA**.
- Exclusive Bethe-Heitler and quarkonium uses **GRAPE.**
- Inelastic quarkonium uses **HERWIG.**

Theoretical models

- The data shapes are compared with RAPGAP and PYTHIA rescaled to the total observed cross section.
- NLO QCD predictions from:

  Photoproduction**:** **FONLL** linked to PYTHIA

  DIS: **HVQDIS** taken at parton level only

NLO theory uncertainty: b quark mass and factorisation/renormalisation scales.

Cross section calculation

The corrected (unlike – like) sign data are converted, using PYTHIA/RAPGAP, to a full cross section in a “visible” kinematic region defined by:

- 2 muons satisfying $-2.2 < \eta < 2.5$

- $p_T > 1.5$ GeV for one muon
- $p_T > 0.75$ GeV for the other muon with $p > 1.8$ GeV for $\eta < 0.6$
  ($p > 2.5$ or $p_T > 1.5$) GeV for $\eta > 0.6$

If >2 such muons in an MC event, the muons directly from B decay have priority.

Muons from kaon and pion decay are not included.

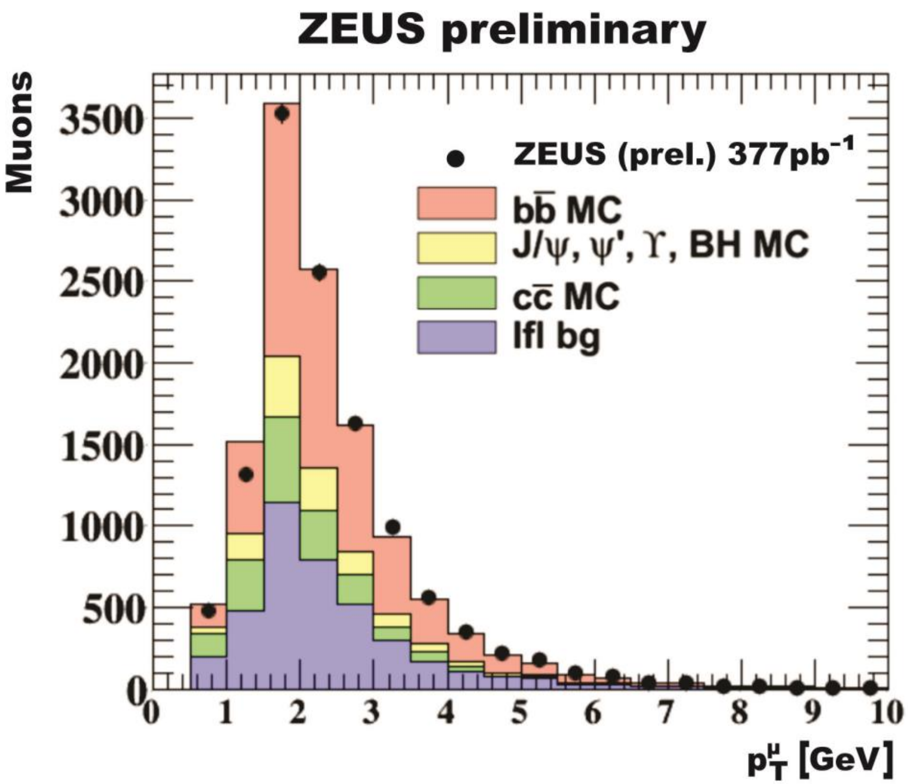
This region was used (see later) for the **total cross section** calculation.

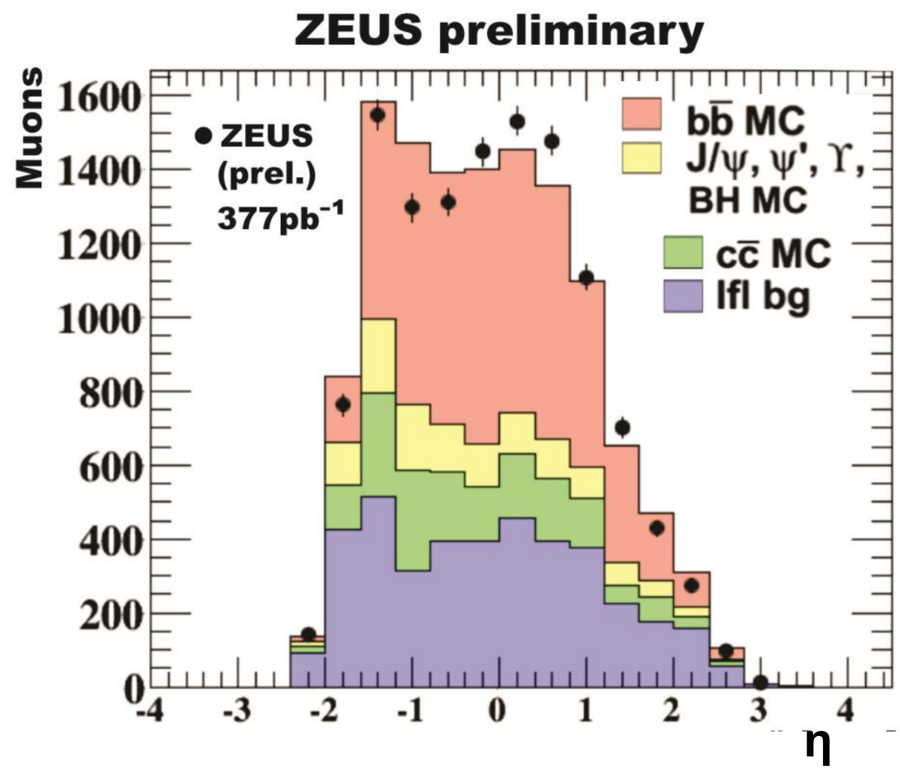
For **differential cross sections,** the kinematic region was

- 2 muons satisfying $-2.2 < \eta < 2.5$

- $p_T > 1.5$ GeV for both muons

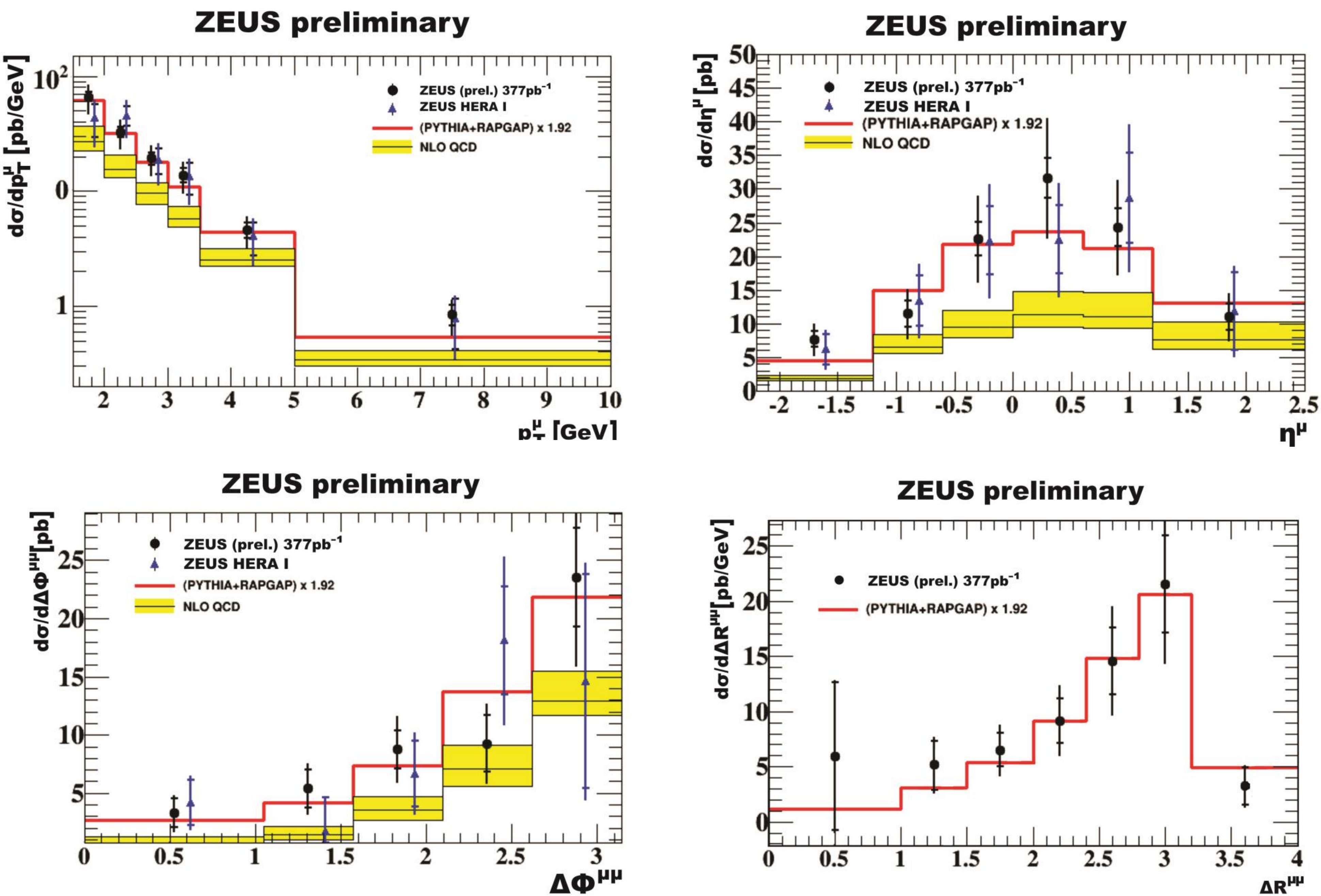
Muon distributions at detector level in unlike-sign events





The plotted light-flavour (“false muon”) background is not simulated but obtained from the like-sign events, with other contributions subtracted out.

Cross sections for single muons, and for intervals in Φ and R between muon pairs



Conclusions from differential cross sections:

- PYTHIA/RAPGAP describe the shapes well and can be used for acceptance calculations.

- Agreement with earlier ZEUS analysis from HERA I.

- FONLL/HVQDIS describes the shapes well, but seems somewhat low.

Total beauty cross section

The effective branching ratio for a $b\bar{b}$ pair into ≥2 muons is 6.3%.
The probability for such a muon pair to be in our defined kinematic range is ≈6%
Correcting for these factors gives

$$\sigma_{TOT}(ep \rightarrow b\bar{b}X) = 11.4 \pm 0.8 \; +3.5/-2.9 \text{ nb}$$

Systematic uncertainties are from muon reconstruction efficiency, normalisation of charm and other backgrounds, various modelling uncertainties.

The NLO theory calculation gives (s = 318 GeV)

$$\sigma_{TOT}^{NLO}(ep \rightarrow b\bar{b}X) = 7.5 \; +4.5/-2.1 \text{ nb}$$

Summary

ZEUS at have measured events with two muons in the full HERA II data set.

These are used to extract differential cross sections for $b\bar{b}$ production decaying into two muons, over the full photoproduction/DIS range.

Also the total cross section for $ep \rightarrow b\bar{b}X$ is evaluated.

The shapes of the differential cross sections agree well with those of a RAPGAP/PYTHIA model and a FONLL/HGVDIS NLO model. However the NLO cross sections are somewhat low.

The total cross section is agreement with the NLO theory, to within the large overall theory uncertainties.

backups

ZEUS preliminary