

# MC comparison and tuning for b production with JetWeb

HERA-LHC Workshop - WG3 - II workshop

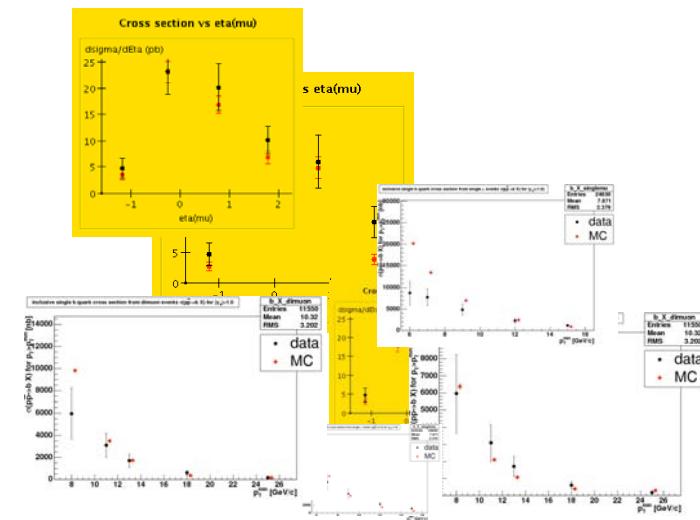
02.06.2004

Jon Butterworth, Achim Geiser, Oliver Gutsche, Ben Waugh  
DESY / ZEUS & University of Hamburg & University College London



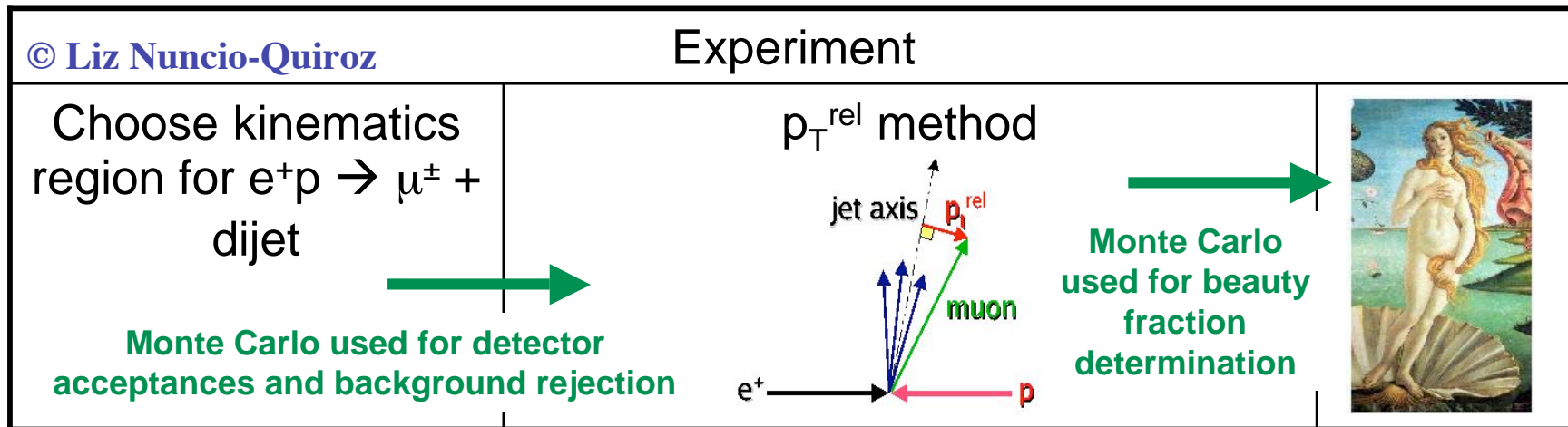
# Outline

- JetWeb: Introduction and description
  - Functionality
  - Structure
  - HZTOOL
  - JetWeb
- Comparison Structure
- Paper implementation for
  - ZEUS
  - UA1
  - D0
- Direct Comparison of beauty quark cross sections
- Summary & Outlook



# Introduction

- Cross section measurements depend often on a single or several specially tuned Monte Carlo simulations (used for determination of detector acceptances, extrapolations, etc.)



- Questions about the universality of the measured cross sections and their comparison to theoretical predictions arise:
  - How does a change in the used Monte Carlo model and tuning affect the description of the results by the Monte Carlo?
  - Do the measurements depend on the Monte Carlo tuning or can they be described at the same time by a unique Monte Carlo simulation and prove their universality?

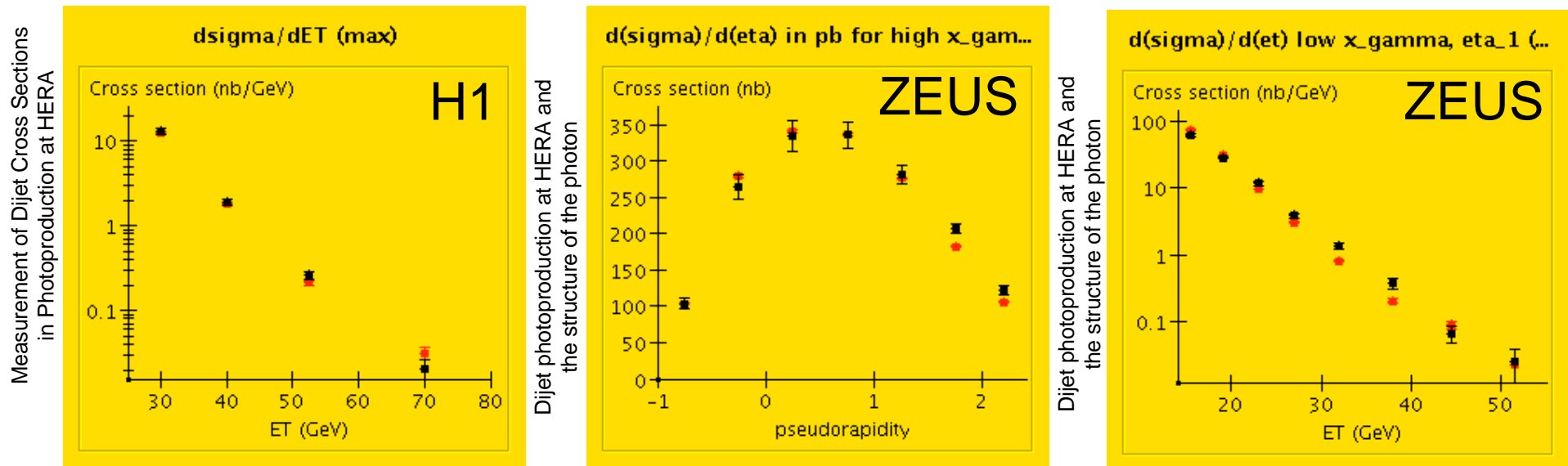
# JetWeb

JetWeb is an „easy-to-use“ facility to compare cross sections from high energy physics experiments to Monte Carlo predictions

It is accessed and used by a WWW interface at <http://jetweb.hep.ucl.ac.uk/> and therefore publicly available.

# JetWeb-Scale - global normalization

- Input: cross section measurements from different experiments
- A common normalization factor is obtained by a fit of the MC prediction to a selection of high  $E_T$ -jet cross sections from the HERA experiments (the following plots are examples of the used selection of cross sections):

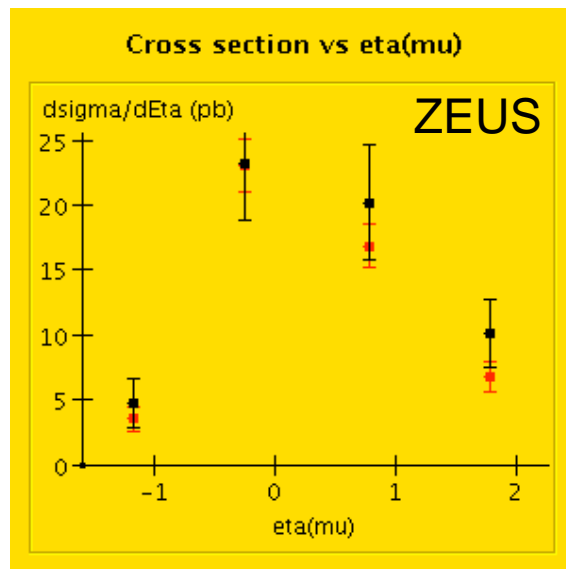


- the fit is done for every Monte Carlo generator and parameter configuration
- the cross sections used in this fit are from the following papers:
  - **Measurement of Dijet Cross Sections in Photoproduction at HERA**  
(Eur.Phys.J.C25:13-23,2002)
  - **Dijet photoproduction at HERA and the structure of the photon**  
(Eur.Phys.J.C23:615-631,2002)

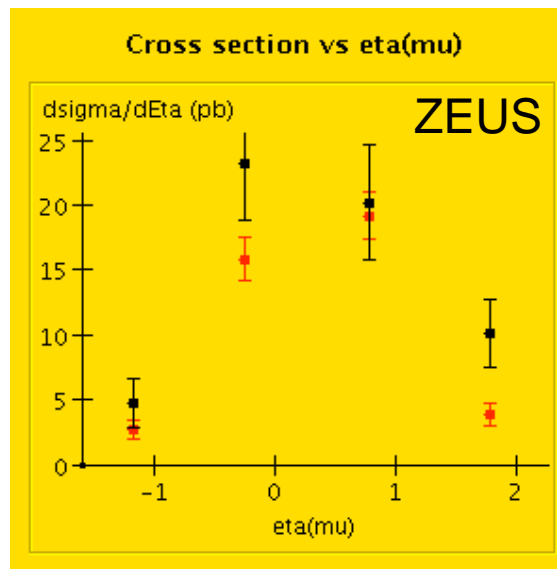
# JetWeb - Functionality I

- JetWeb offers an general interface to:
  - compare cross sections individually to **different settings** of one Monte Carlo generator
  - Example: variation of type of multiple interactions for **PYTHIA** (MSPT(82))

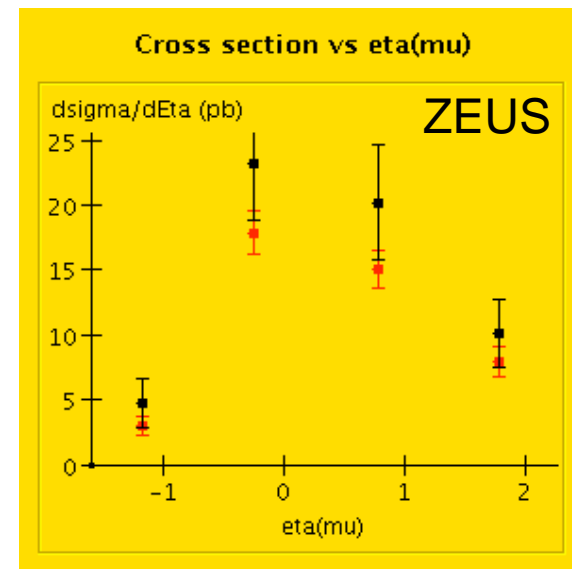
mion 1 , Fit 761, Scale 1.45



mion 2 , Fit 823, Scale 1.5

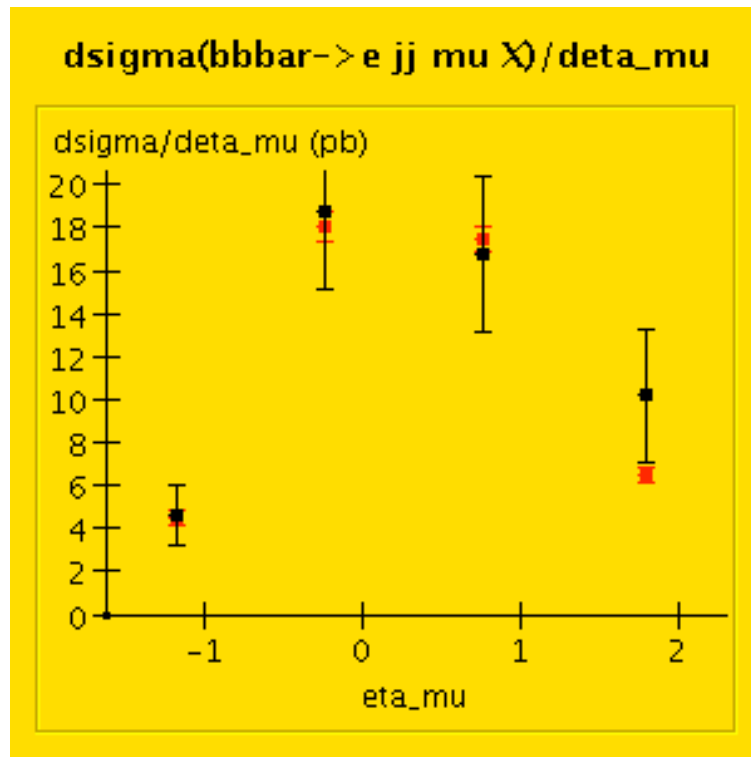


mion 3 , Fit 796, Scale 1.25

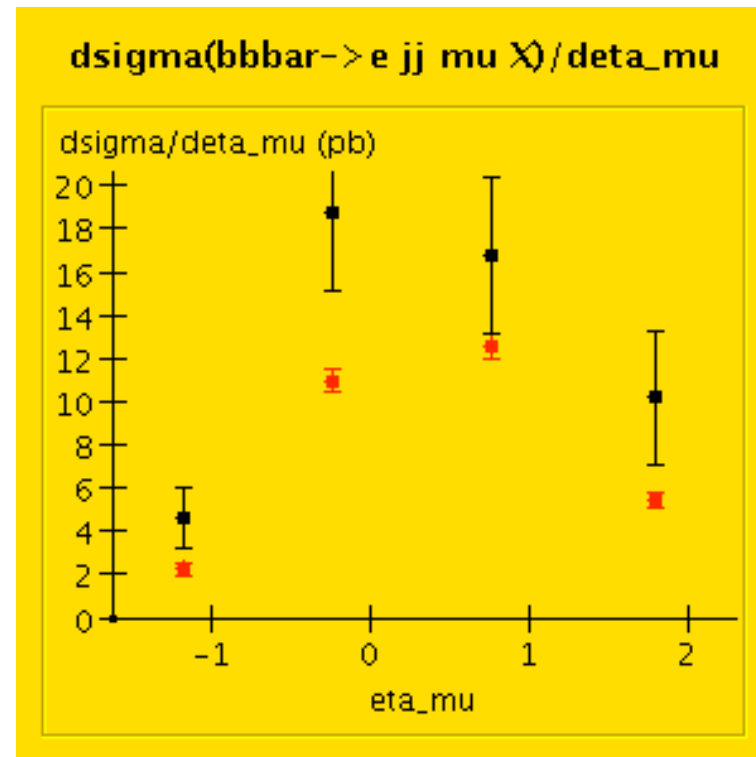


# JetWeb - Functionality II

- JetWeb offers an general interface to:
  - compare cross sections individually to predictions from **different Monte Carlo generators**



**PYTHIA** standard, FIT 761, JetWeb-Scale=1.45

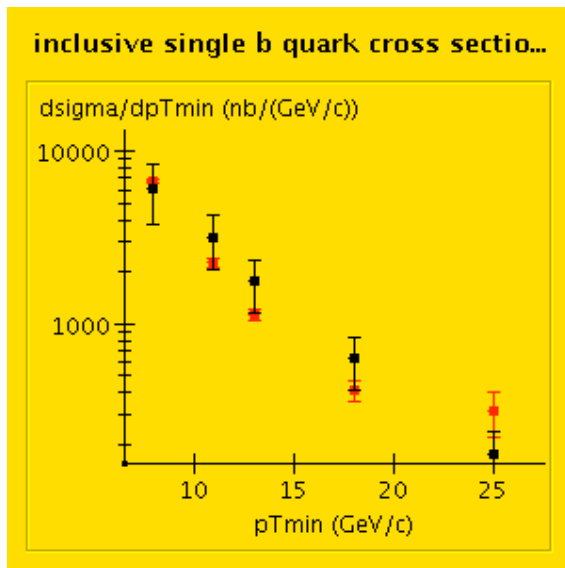


**HERWIG** standard, FIT 42, JetWeb-Scale=1.7

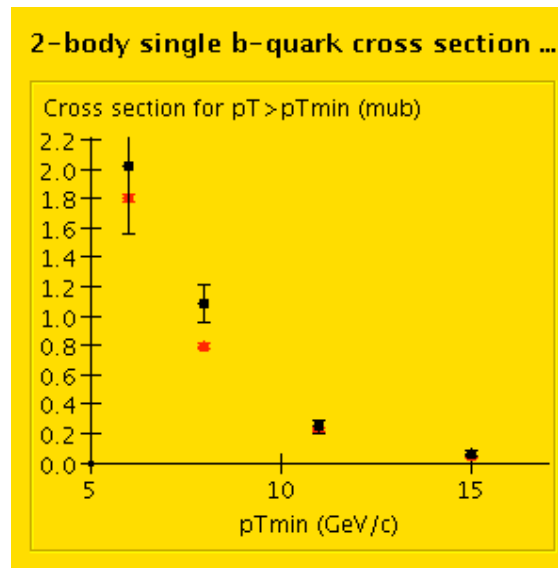
# JetWeb - Functionality II

- JetWeb offers an general interface to:
  - compare cross sections in **different variables** from **different experiments** to predictions of a single Monte Carlo generator configuration (generator type and settings)

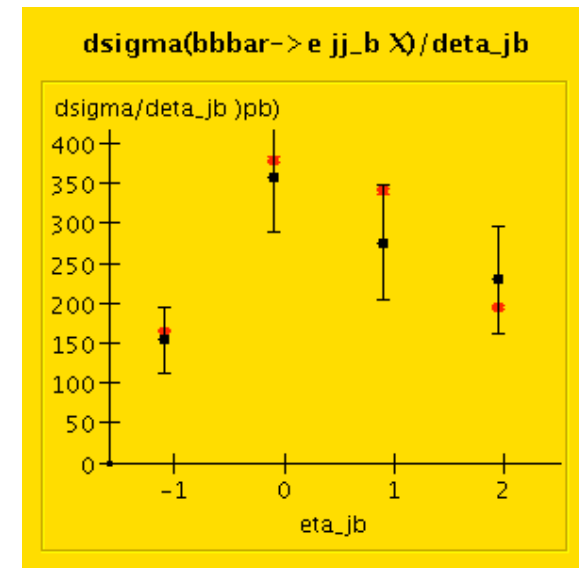
**PYTHIA** standard, FIT 761, JetWeb-Scale=1.45



D0



UA1



ZEUS



# JetWeb - Components

## JetWeb User Interface



## HZTOOL

( N. Brook et. al., see <http://www.desy.de/~carli/hztool.html> )

- general interface to Monte Carlo generators

## JetWeb components

( J.M. Butterworth, S. Butterworth

(Comp. Phys. Comm. vol 153/2 164-178 (2003) ) )

- database
- job submission

# HZTOOL

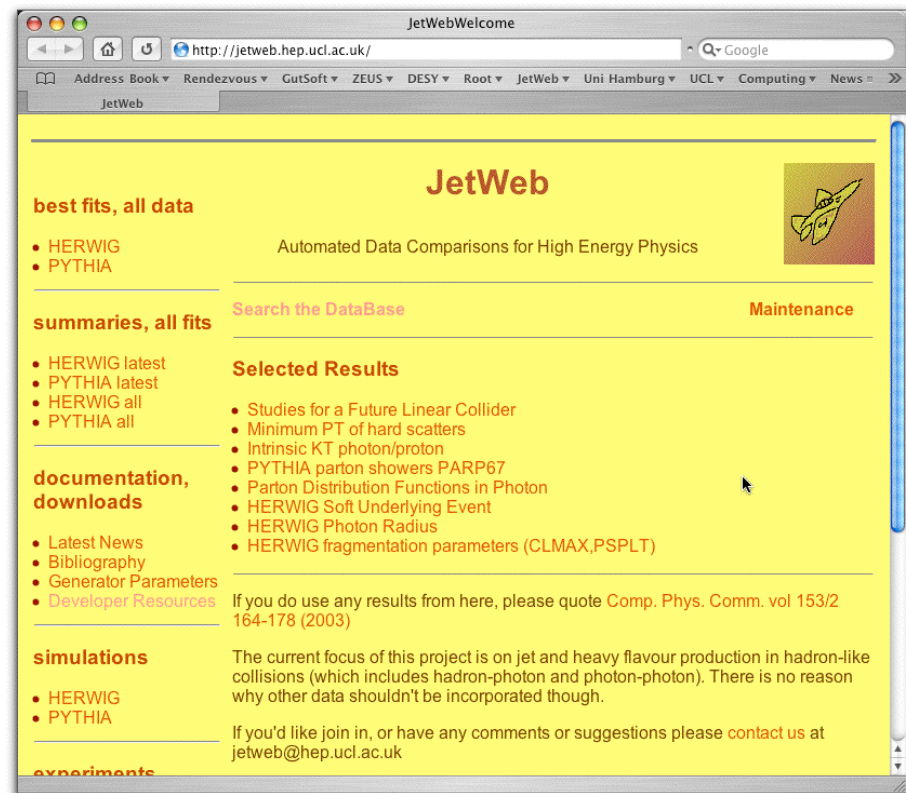
## General interface to Monte Carlo generators

- currently available generators:
  - PYTHIA 6.206
  - HERWIG 6.100
  - HERWIG 6.400
- produces MC predictions for implemented cross sections
- cross sections grouped by paper in individual routines:

| Routine | Initialization   | Execution  | Finalization  |
|---------|--|--|---|
|         | <ul style="list-style-type: none"><li>• booking of histograms for cross sections</li><li>• filling data histograms with hard coded data points</li></ul> | <ul style="list-style-type: none"><li>• applying specific cuts per cross section to generated MC event (kin. region, etc.)</li><li>• fill entry to histogram</li></ul> | <ul style="list-style-type: none"><li>• transformation of filled histograms to cross sections using the actual generated luminosity</li></ul> |

# JetWeb

- JetWeb components:
  - User interface
  - batch submission of HZTOOL jobs
  - Database for completed HZTOOL jobs
- Database:
  - stores all generated cross sections from all available HZTOOL routines depending on their Monte Carlo configuration
  - adds up generated luminosities for cross sections with the same Monte Carlo configuration





# Introduction to comparison

- Comparison between beauty quark cross sections from three different experiments:



- compare differential and inclusive beauty cross sections to MC predictions from PYTHIA and HERWIG and to jet cross sections from HERA (normalization)

# Comparison of beauty quark cross sections

| cross section                              | plotted variable         | UA1 |  |  |
|--|--------------------------|-----|---|---|
| $\sigma(b \bar{b} \rightarrow \mu \mu X)$  | $p_T^\mu$                | X   | X   |   |
| $\sigma(b X)$                              | $p_T^b$                  | X   | X   | X   |
| $\sigma(b \bar{b})$                        | $\Delta\phi$             | X   |   |   |
| $\sigma(b \bar{b} \rightarrow \mu \mu)$    | $\Delta\phi$             |     | X   |   |
| $\sigma(B X)$ for $p_T > p_T^{\min}$       | $p_T^{\min}$             | X   |   |   |
| $\sigma(b \bar{b})$                        | $\Delta R$               | X   |   |   |
| $\sigma(b \bar{b} \rightarrow e jj \mu X)$ | muon region              |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj \mu X)$ | $x_\gamma^{\text{jets}}$ |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj \mu X)$ | $\eta^\mu$               |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj \mu X)$ | $p_T^\mu$                |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj \mu X)$ | $\eta^{\mu\text{-jet}}$  |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj \mu X)$ | $p_T^{\mu\text{-jet}}$   |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj X)$     | $\eta^{\text{b-jet}}$    |     |   | X   |
| $\sigma(b \bar{b} \rightarrow e jj X)$     | $p_T^{\text{b-jet}}$     |     |   | X   |

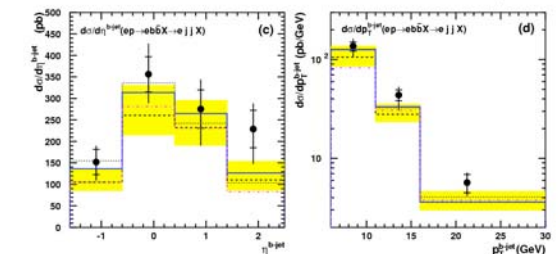
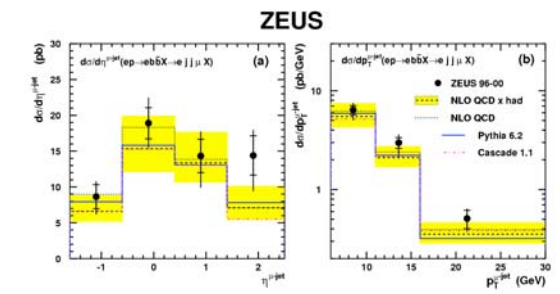
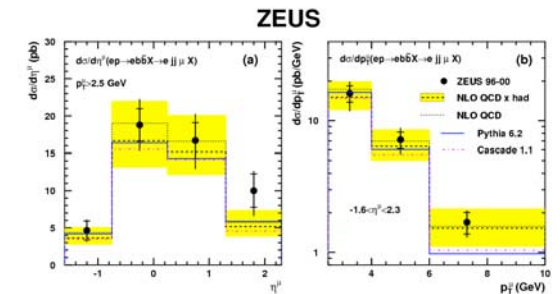
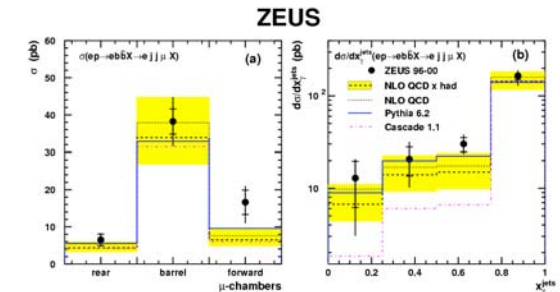
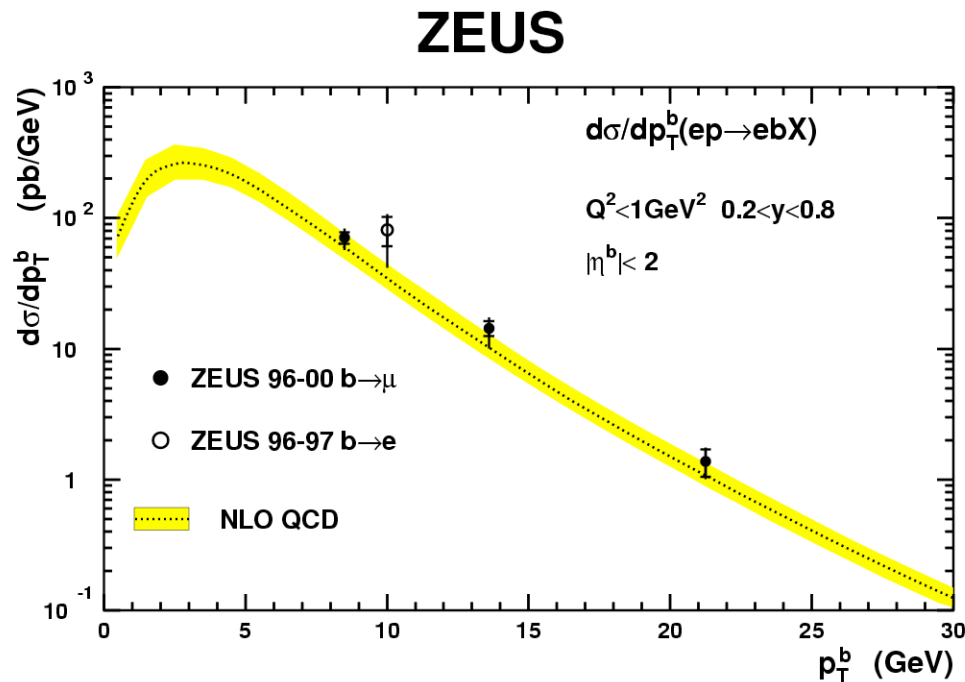
# ZEUS paper

- Beauty photoproduction measured using decays into muons in dijet events in ep collisions at  $\sqrt{s}=318$  GeV

(DESY-03-212 (December 2003))

- main statement:

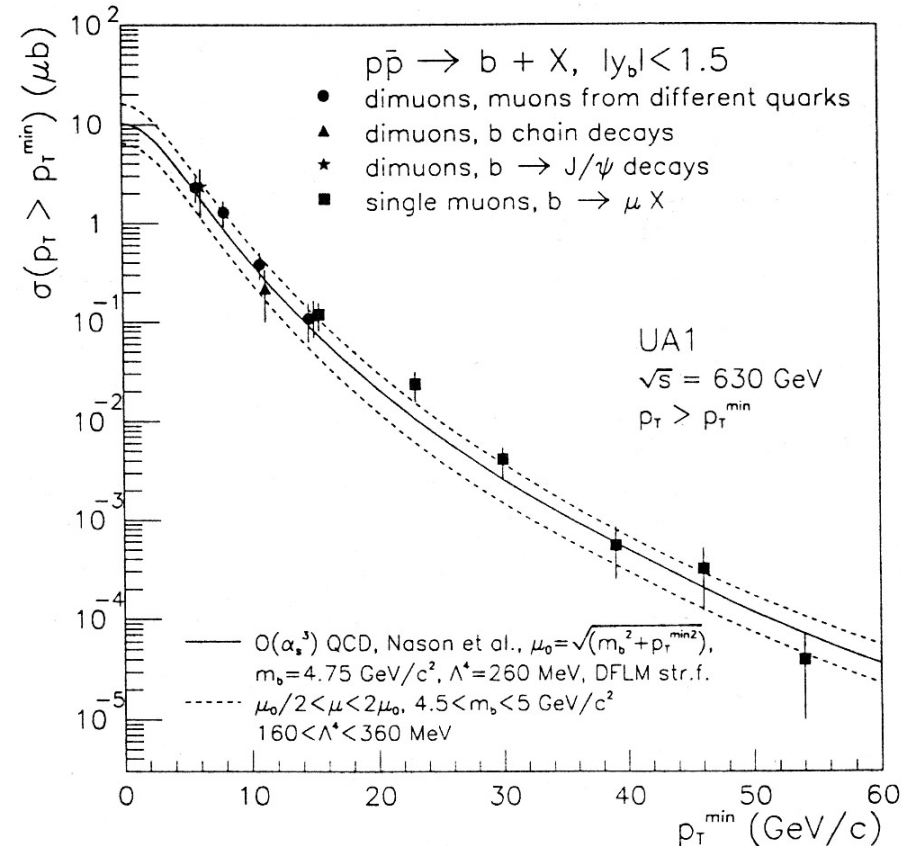
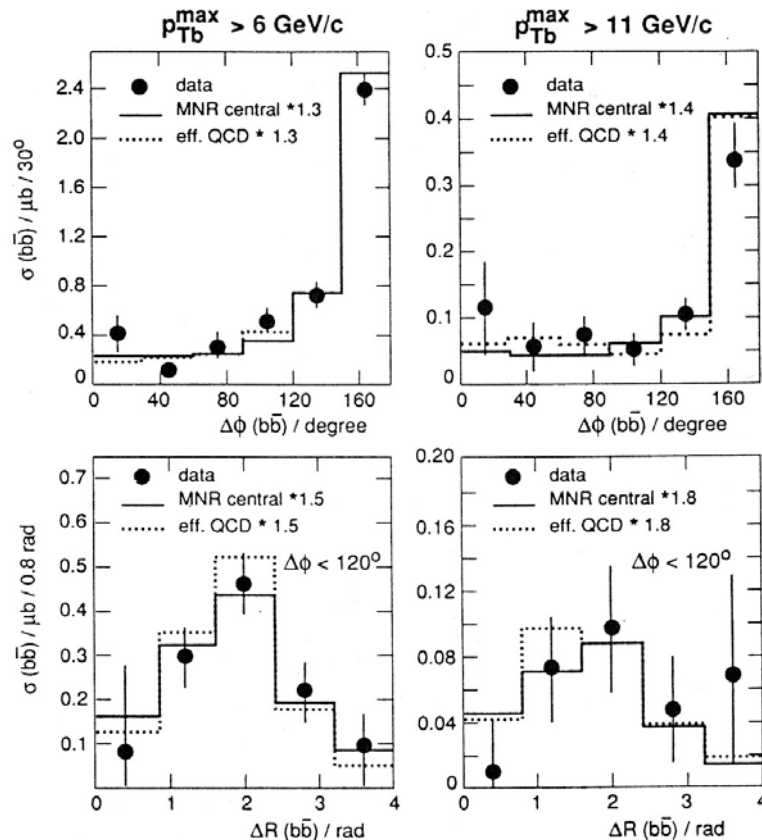
- **cross sections are reasonably well described** both by NLO QCD and by PYTHIA



# UA1 paper

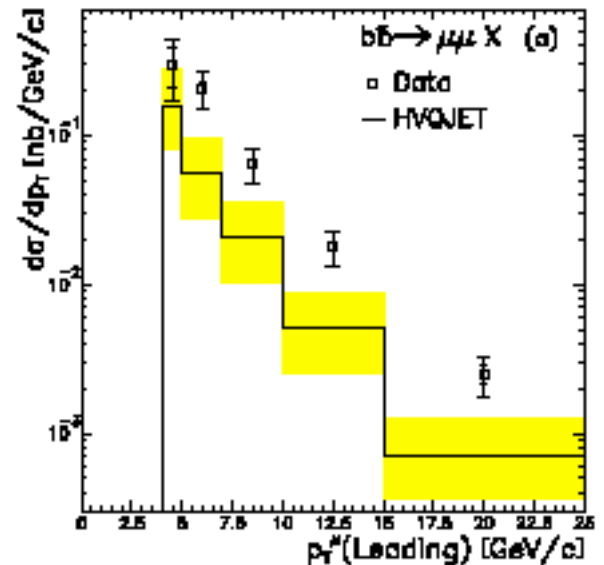
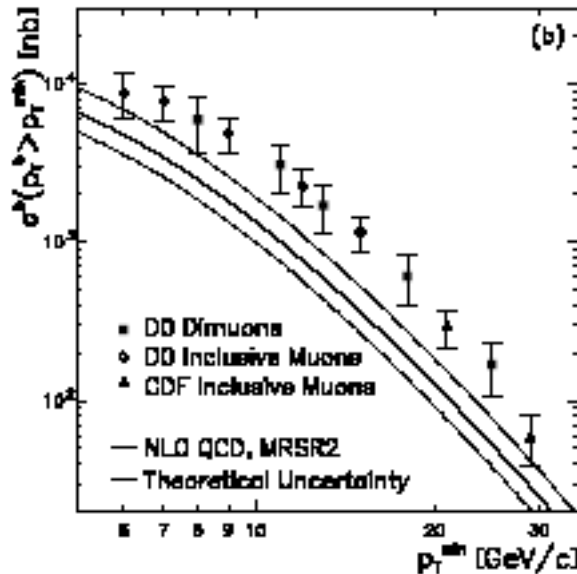
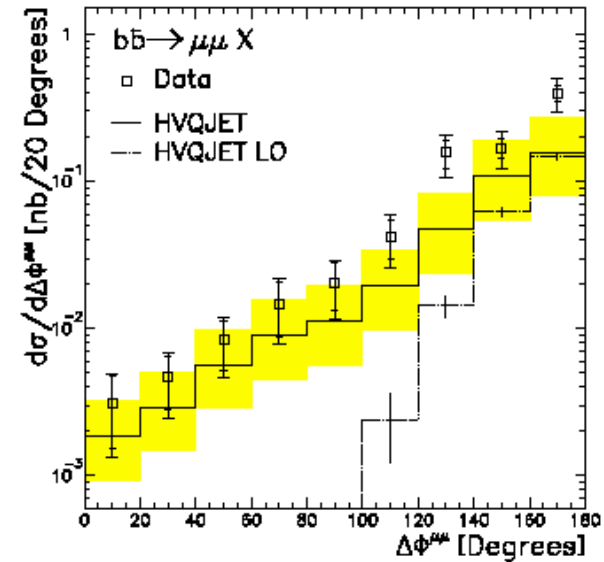
- Measurement of  $b\bar{b}$  correlations at the CERN  $p\bar{p}$  collider (Z. Phys. C 61, 41-52 (1994))
- main statement:
  - **good agreement of the measured  $b\bar{b}$  correlations with QCD predictions**

## UA1



# D0 paper

- The  $b\bar{b}$  Production Cross Section and Angular Correlations in  $p\bar{p}$  Collisions at  $\sqrt{s}=1.8$  TeV (Phys.Lett.B487:264-272,2000)
- main statement:
  - the measurements **agree in shape** with the NLO QCD calculations of heavy flavour production **but lie above the central values of these predictions**

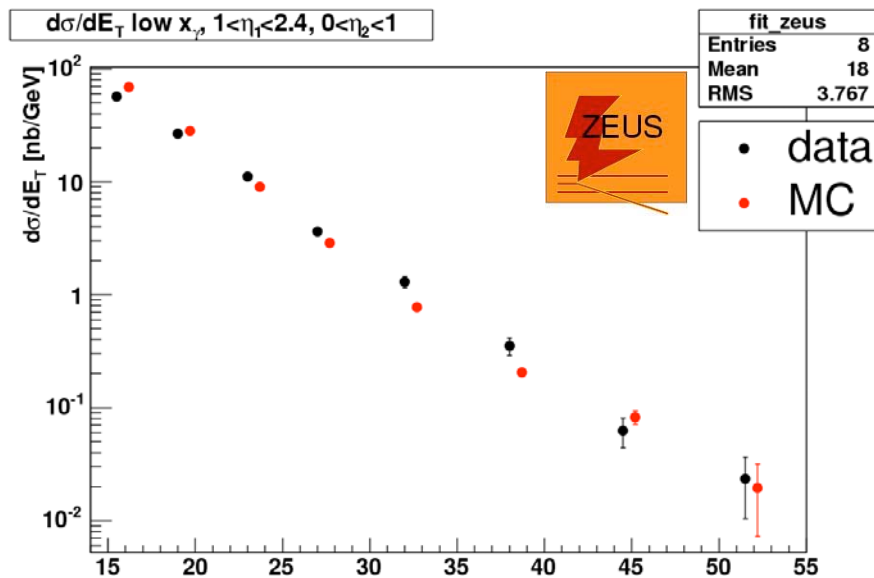




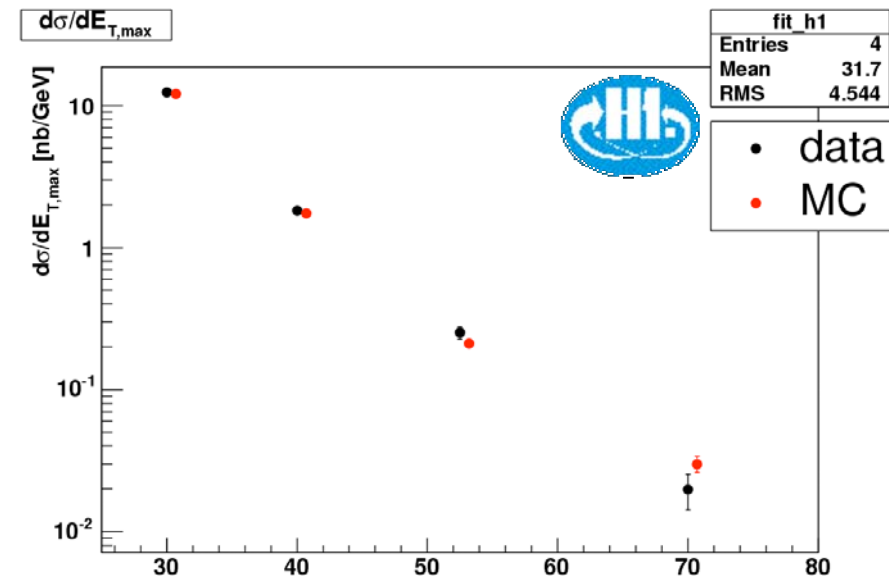
# Chosen Monte Carlo configurations

- Generator: **PYTHIA**
  - inclusive mode
  - Proton PDF: CTEQ5L
  - Photon PDF: GRV LO
  - min. trans. momentum: 3 GeV/c
  - JetWeb scale = **1.45**
- Generator: **HERWIG**
  - inclusive mode
  - Proton PDF: CTEQ5L
  - Photon PDF: GRV LO
  - min. trans. momentum: 3 GeV/c
  - JetWeb scale = **1.7**

Comparison of the chosen **PYTHIA** configuration with HERA jet cross sections

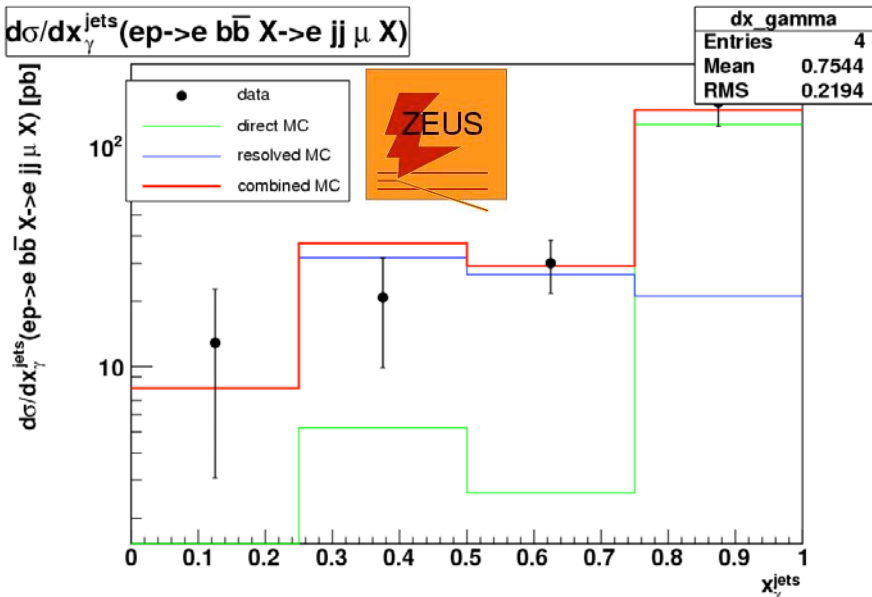
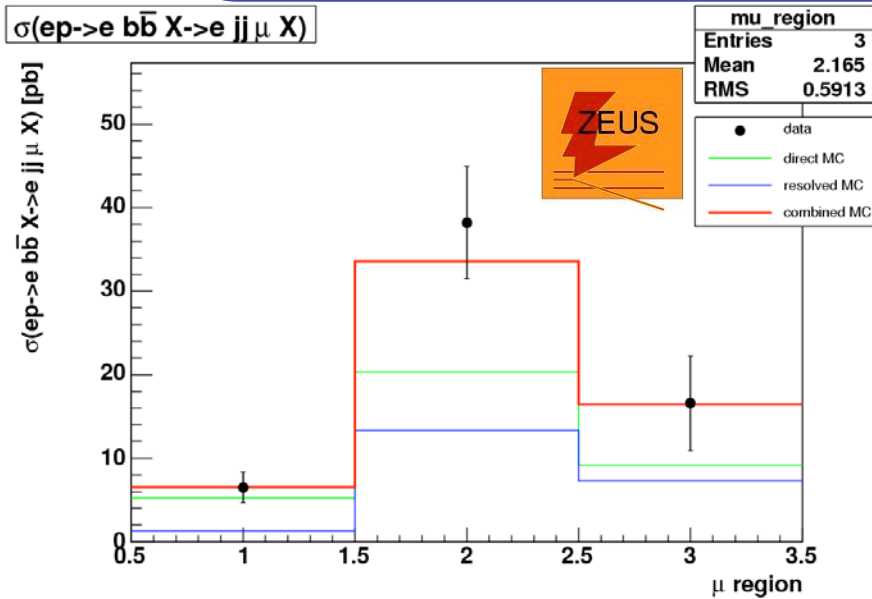


Dijet photoproduction at HERA and the structure of the photon (Eur.Phys.J.C23:615-631,2002)



Measurement of Dijet Cross Sections in Photoproduction at HERA (Eur.Phys.J.C25:13-23,2002)

# ZEUS: beauty cross section in 3 muon regions and $d\sigma/dx_\gamma^{\text{jets}}$



PYTHIA

## Requirements:

- b or anti b quark in event
- $Q^2 < 1 \text{ GeV}^2$
- $0.2 < y < 0.8$
- $\geq 2$  jets with:
  - $p_T^{j1,j2} > 7,6 \text{ GeV}$
  - $|\eta^j| < 2.5$
- $\geq 1 \mu$  in one  $\mu$  region coming from b or anti b quark
  - 1:  $p^\mu > 2.5 \text{ GeV}, -1.6 < \eta^\mu < -0.9$
  - 2:  $p_T^\mu > 2.5 \text{ GeV}, -0.9 < \eta^\mu < 1.3$
  - 3:  $p^\mu > 4 \text{ GeV}, p_T^\mu > 1 \text{ GeV}, 1.48 < \eta^\mu < 2.3$

## jetfinder:

kt-algorithm

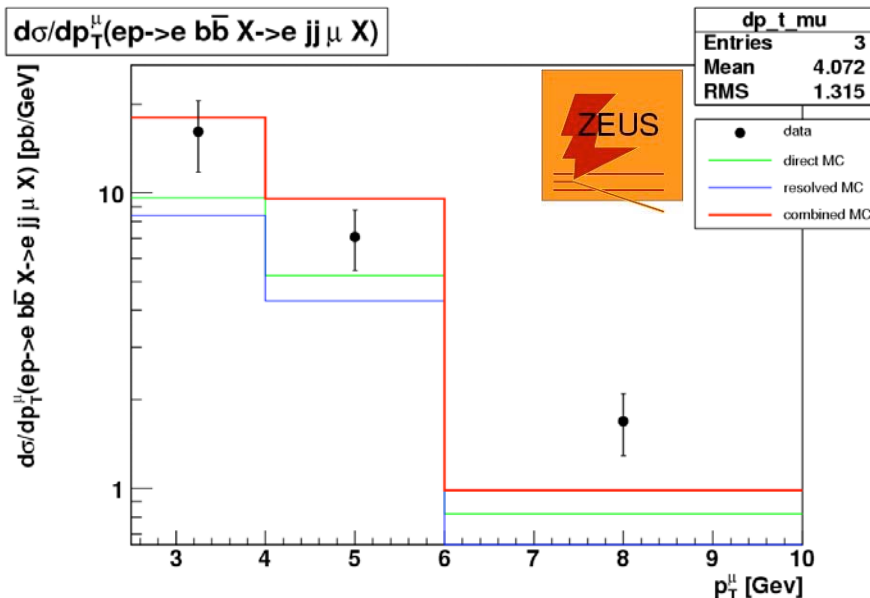
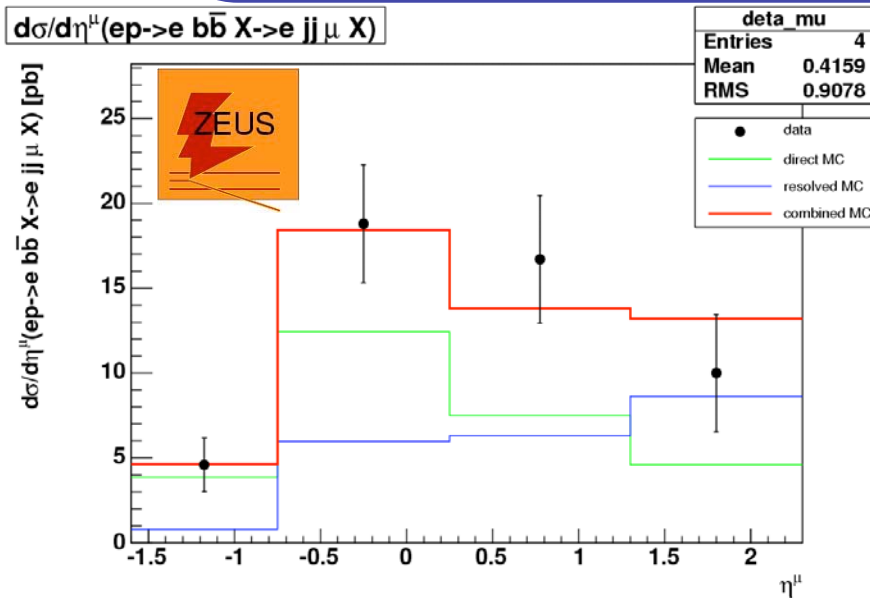
E recombination scheme (massive mode)

consider b- and c-hadrons as stable for clustering:

- look for appearance of list of b- and c-hadrons in event record
- take found hadron in jetfinder-particle-list and discard all daughters of hadron

histogram filling per valid object (jet, muon, quark, etc.)

# ZEUS: $d\sigma/d\eta^\mu$ and $d\sigma/dp_T^\mu$



PYTHIA

## Requirements:

- b or anti b quark in event
- $Q^2 < 1 \text{ GeV}^2$
- $0.2 < y < 0.8$
- $\geq 2$  jets with:
  - $p_T^{j1,j2} > 7,6 \text{ GeV}$
  - $|\eta^j| < 2.5$
- $\geq 1 \mu$  coming from b or anti b quark with:
  - $p_T^\mu > 2.5 \text{ GeV}$
  - $-1.3 < \eta^\mu < 2.3$

## jetfinder:

kt-algorithm

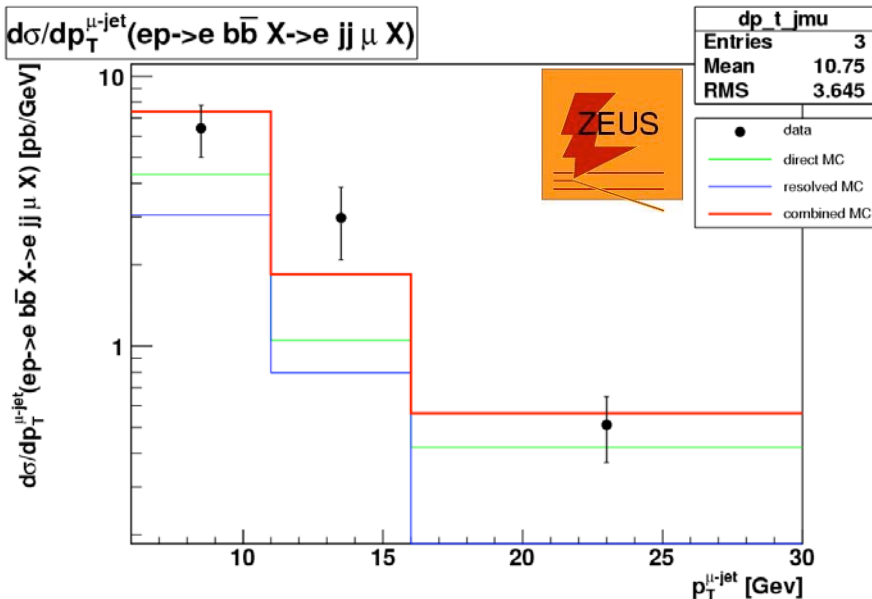
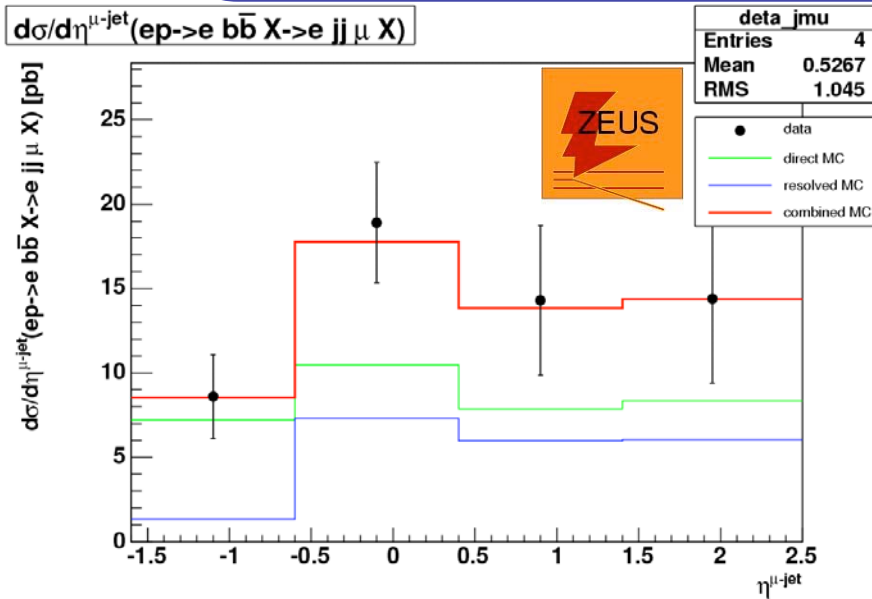
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histogram filling per valid object (jet, muon, quark, etc.)

# ZEUS: $d\sigma/d\eta^{\mu\text{-jet}}$ and $d\sigma/dp_T^{\mu\text{-jet}}$



PYTHIA

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- b or anti b quark in event
- $Q^2 < 1 \text{ GeV}^2$
- $0.2 < y < 0.8$
- $\geq 2$  jets with:
  - $p_T^{j1,j2} > 7,6 \text{ GeV}$
  - $|\eta^j| < 2.5$
- $\eta$  taken from jet which includes highest- $p_T \mu$  in one  $\mu$  region coming from b or anti b quark
  - 1:  $p^\mu > 2.5 \text{ GeV}$ ,  $-1.6 < \eta^\mu < -0.9$
  - 2:  $p_T^\mu > 2.5 \text{ GeV}$ ,  $-0.9 < \eta^\mu < 1.3$
  - 3:  $p^\mu > 4 \text{ GeV}$ ,  $p_T^\mu > 1 \text{ GeV}$ ,  $1.48 < \eta^\mu < 2.3$
- and fulfilling
  - $p_T^{\mu\text{-jet}} > 6 \text{ GeV}$
  - $|\eta^{\mu\text{-jet}}| < 2.5$

## jetfinder:

kt-algorithm

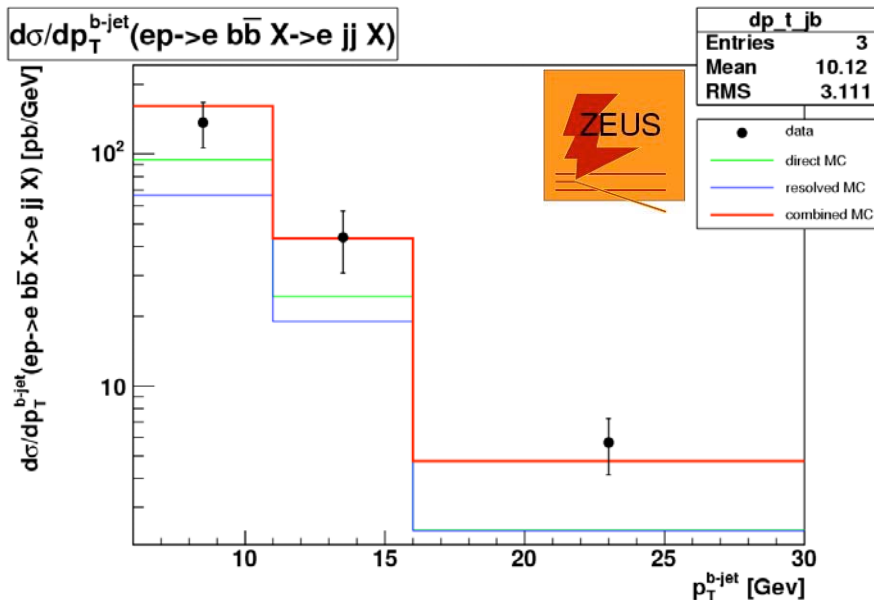
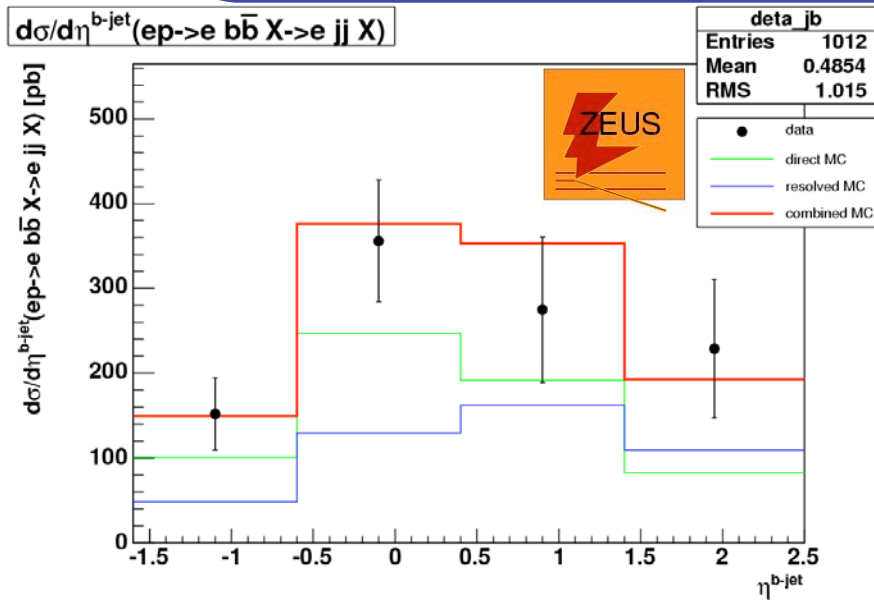
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# ZEUS: $d\sigma/d\eta^{b\text{-jet}}$ and $d\sigma/dp_T^{b\text{-jet}}$



PYTHIA

## Requirements:

- b or anti b quark in event
- $Q^2 < 1 \text{ GeV}^2$
- $0.2 < y < 0.8$
- $\geq 2$  jets with:
  - $p_T^{j1,j2} > 7,6 \text{ GeV}$
  - $|\eta| < 2.5$
- $p_T / \eta$  taken from jet which includes highest- $p_T$  B-hadron

## jetfinder:

kt-algorithm

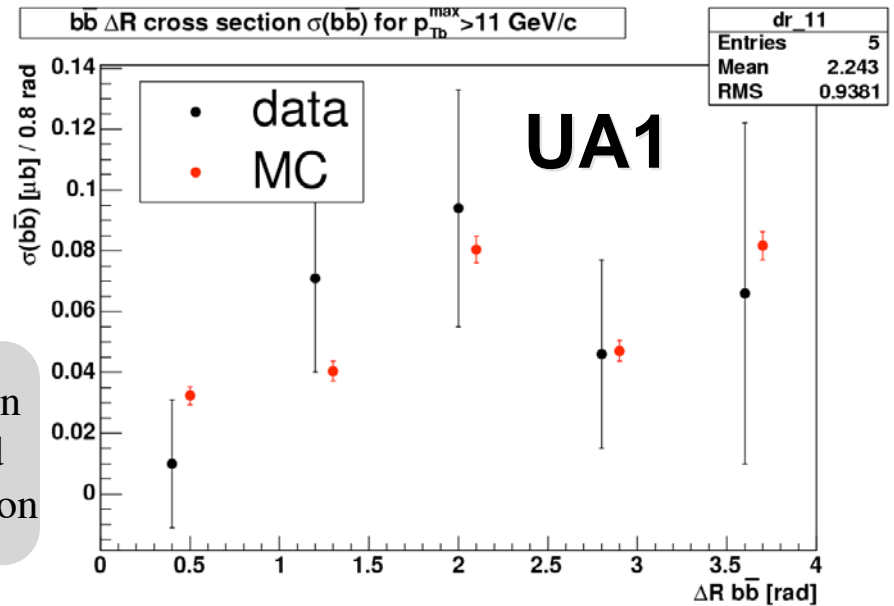
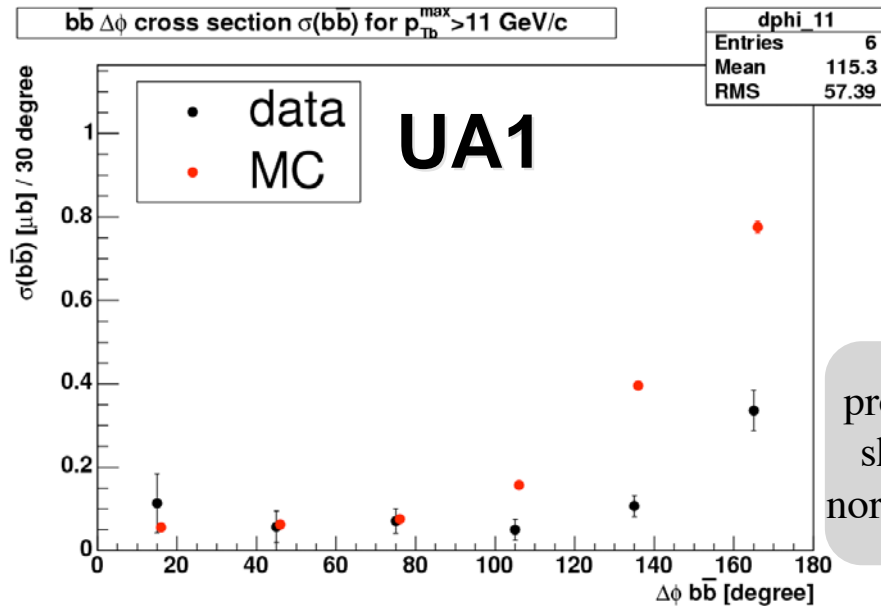
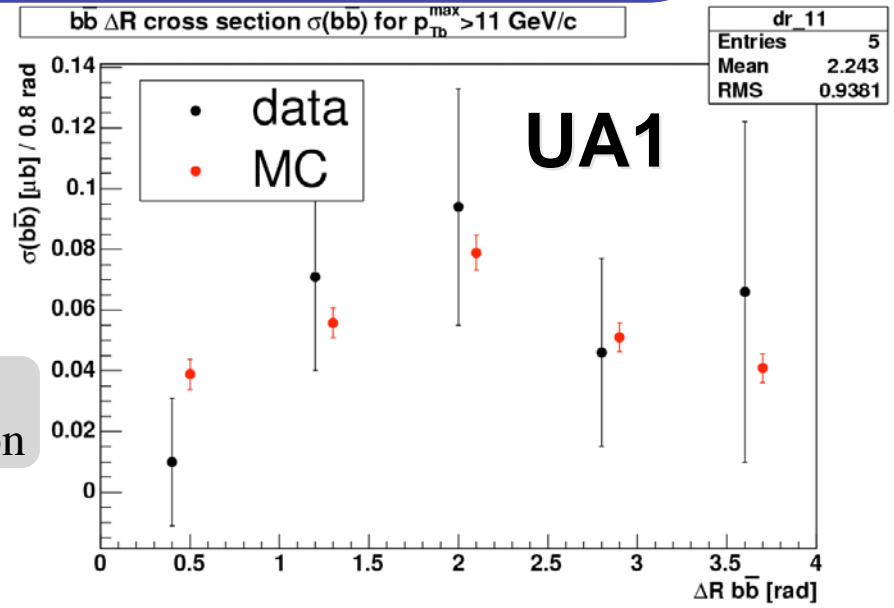
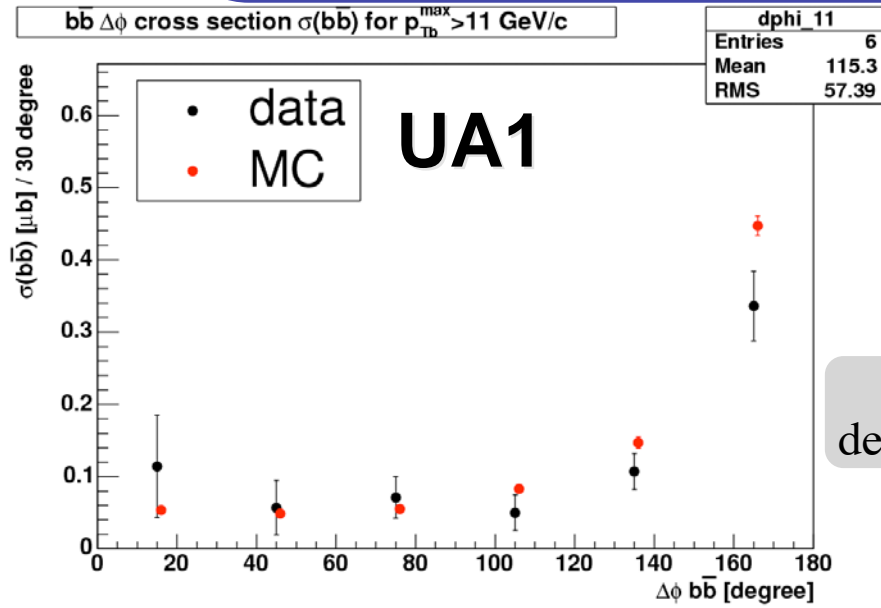
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consider b- and c-hadrons as stable for clustering:

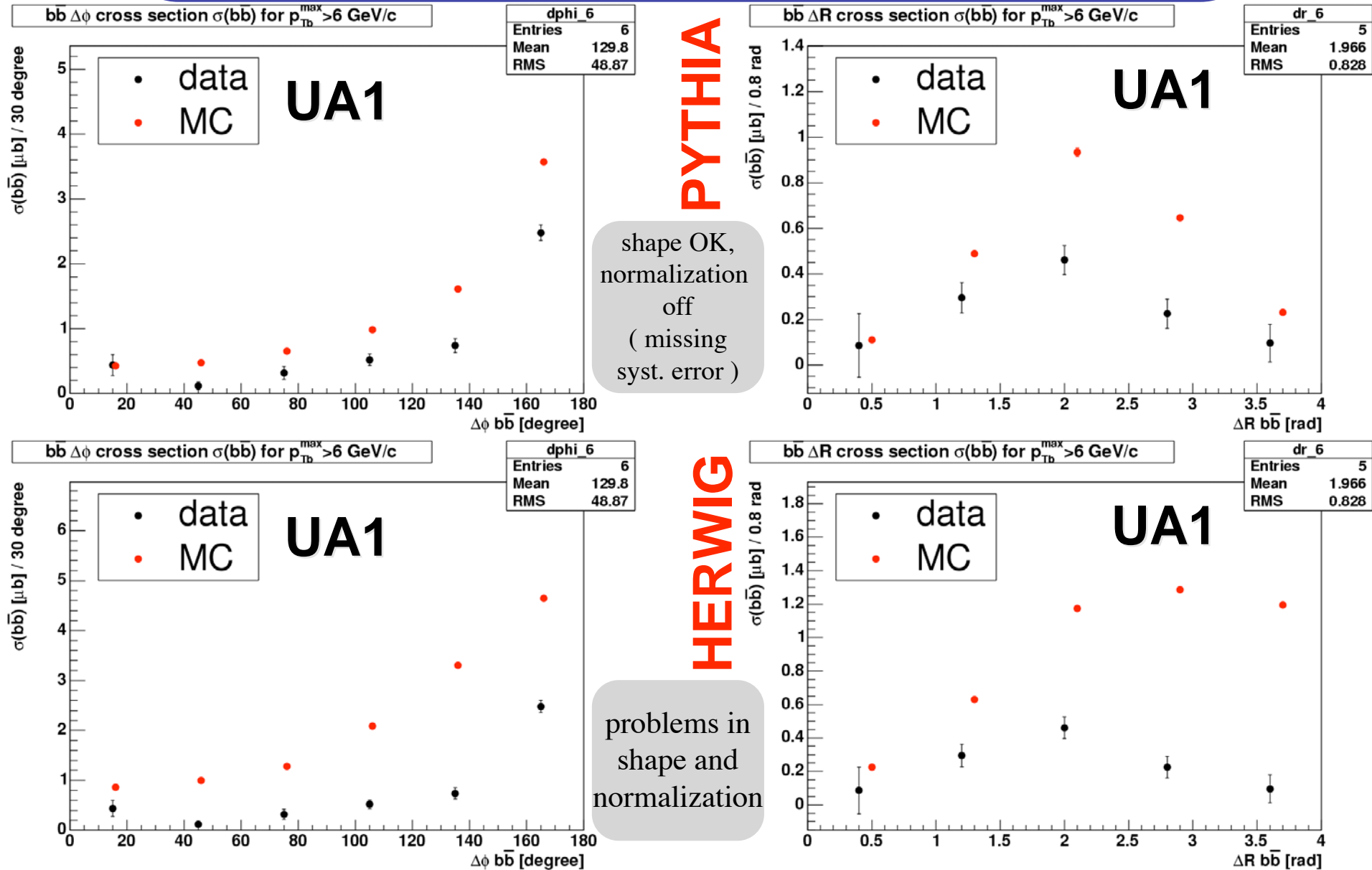
- look for appearance of list of b- and c-hadrons in event record
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histogram filling per valid object (jet, muon, quark, etc.)

# UA1: angular correlations I

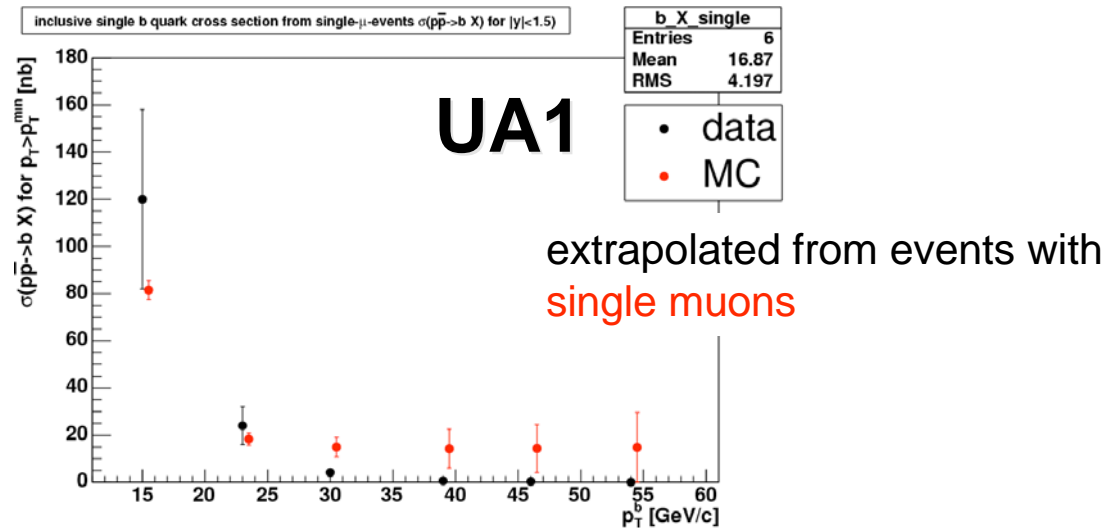
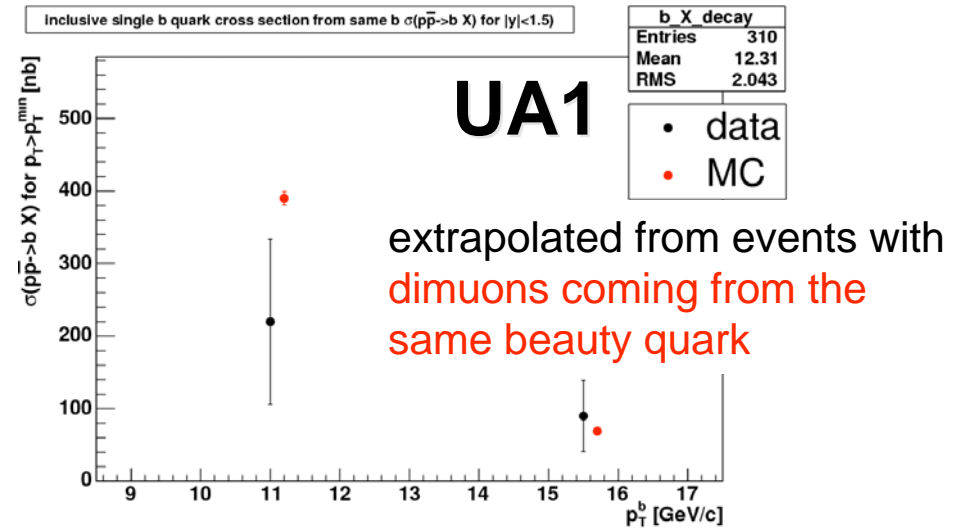
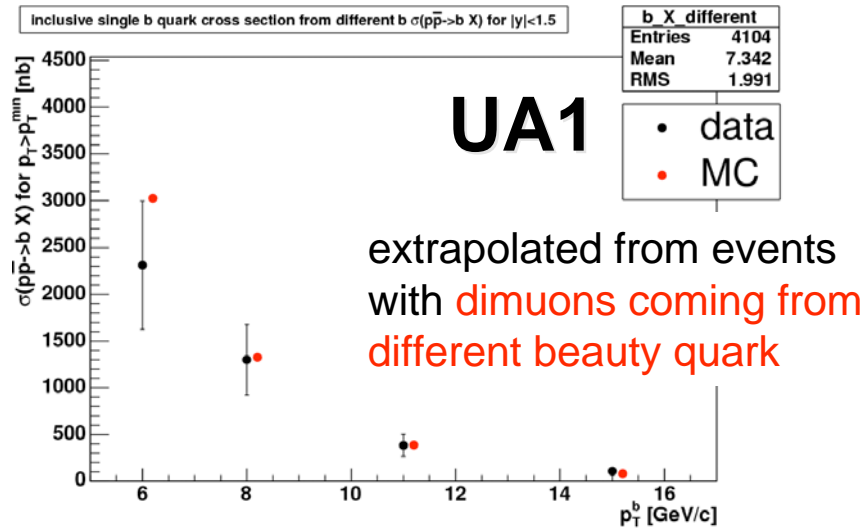


# UA1: angular correlations II



# UA1: inclusive single b quark cross section: PYTHIA

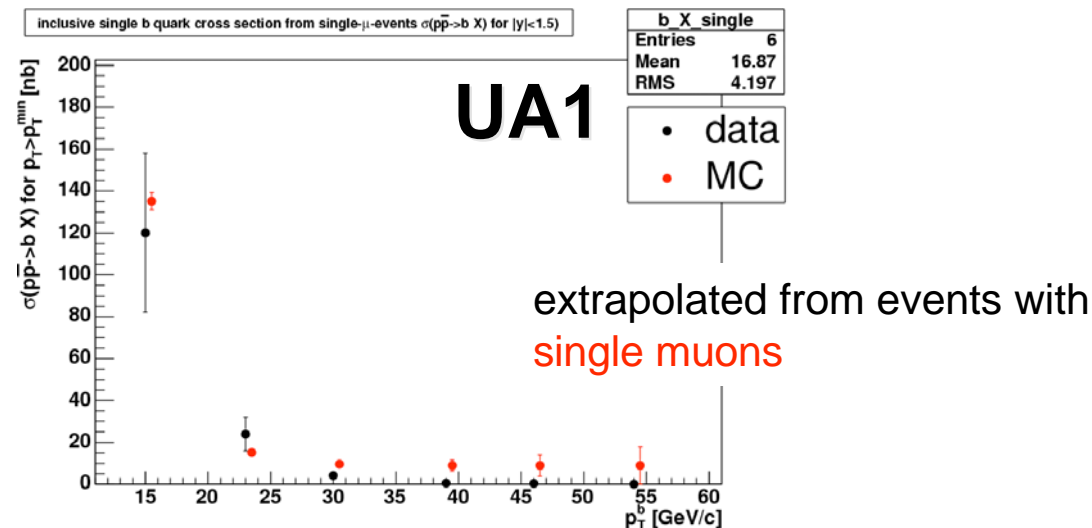
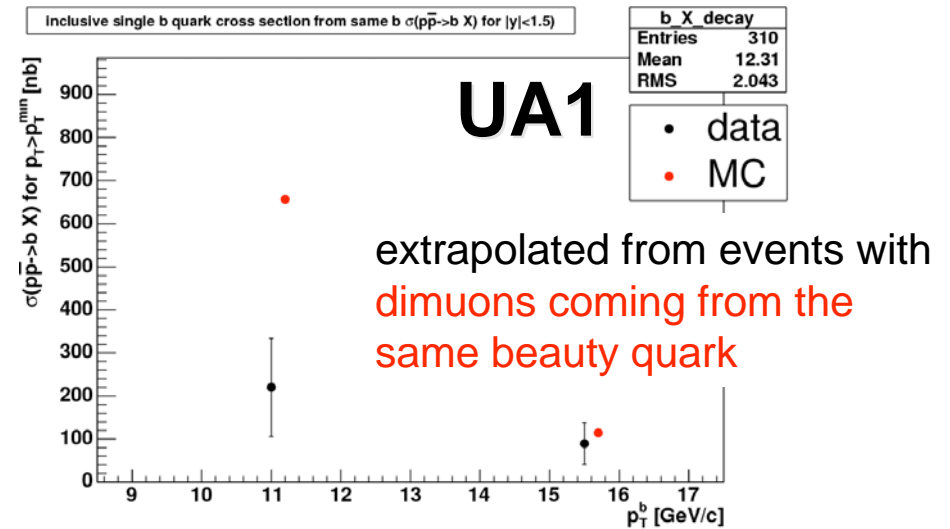
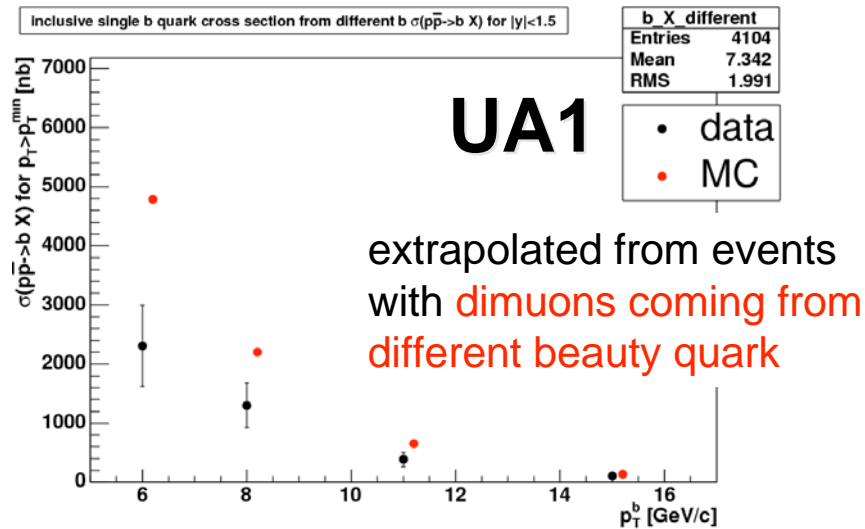
- PYTHIA** shows good description of inclusive single beauty quark cross sections



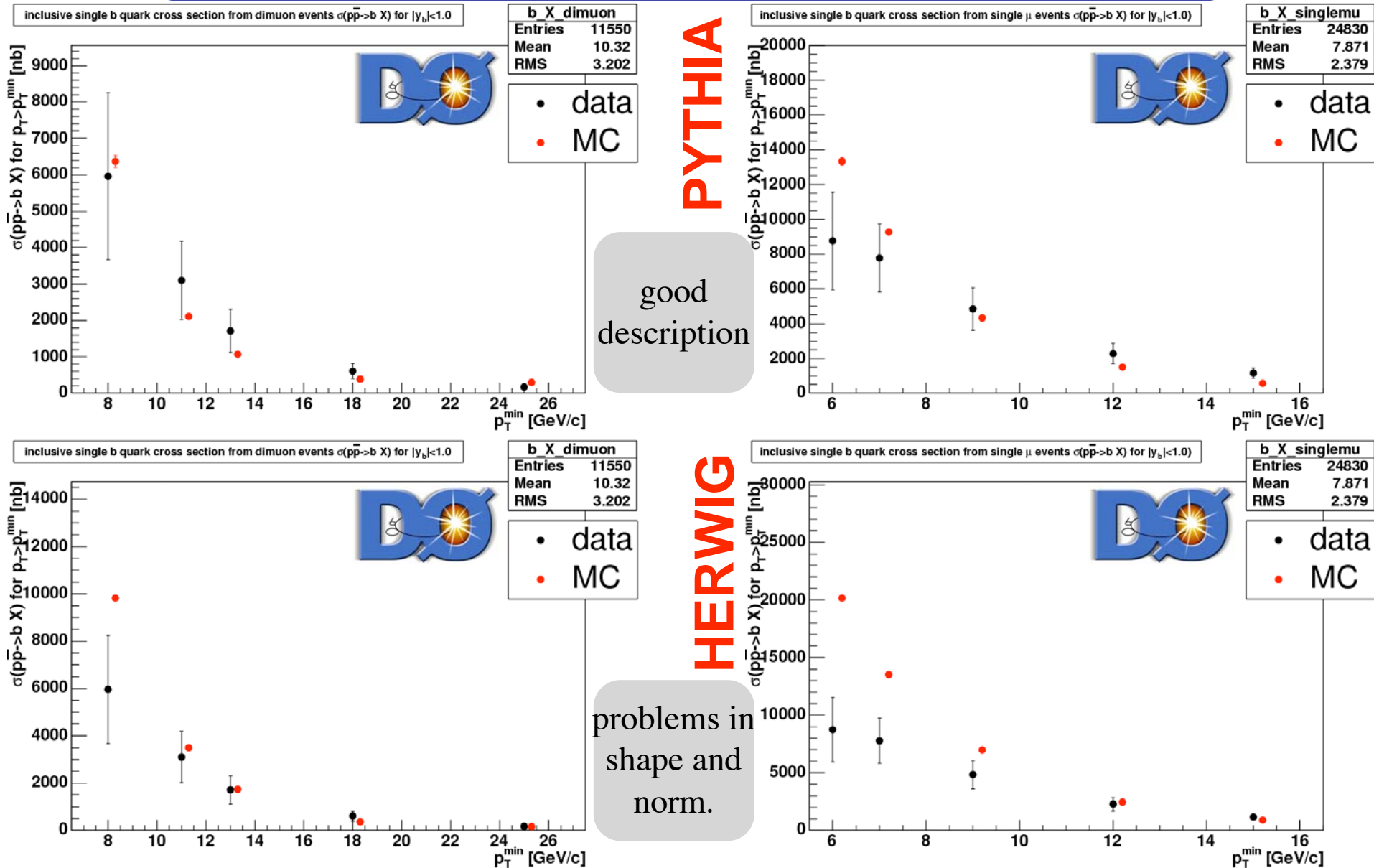


# UA1: inclusive single b quark cross section: HERWIG

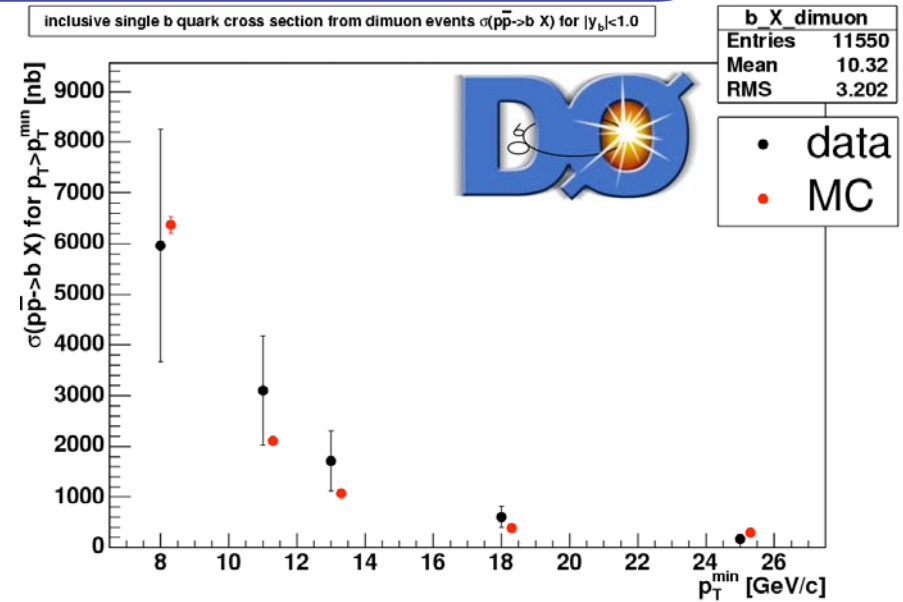
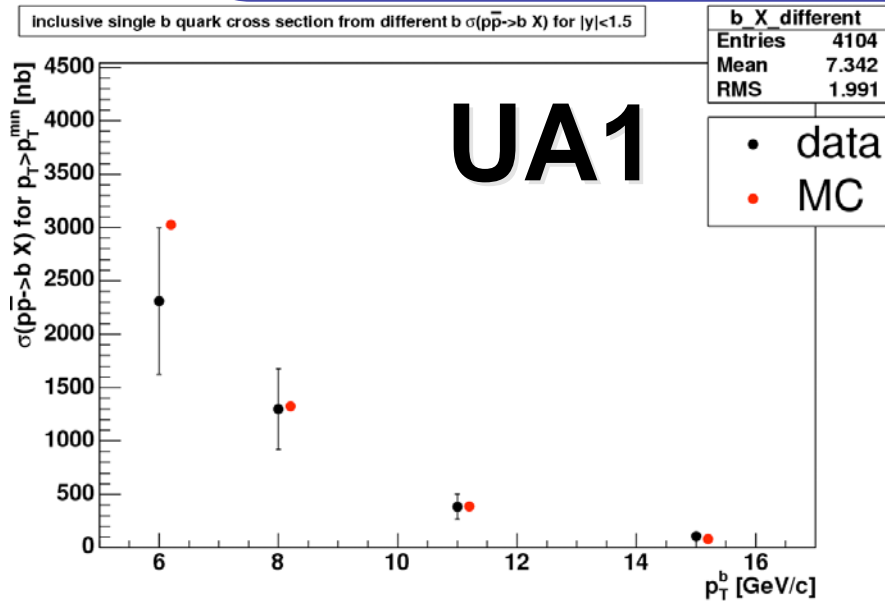
- HERWIG** shows problems in the description of inclusive single beauty quark cross sections



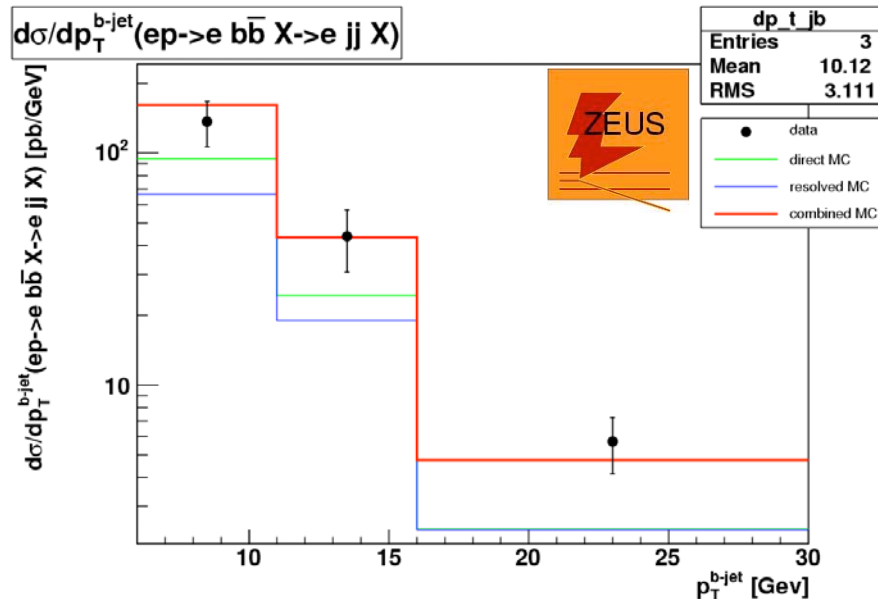
# D0: inclusive single b quark cross section



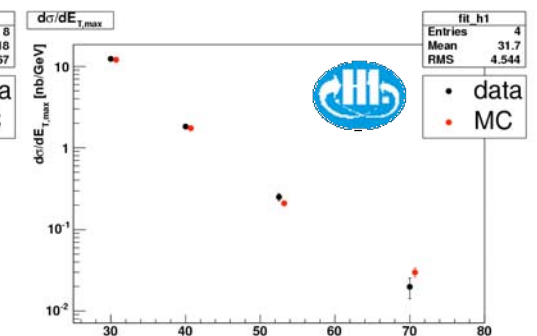
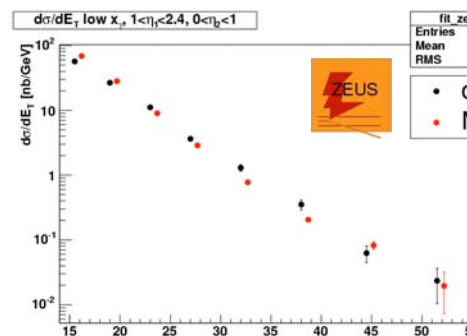
# inclusive single b quark and differential n quark cross sections: PYTHIA



PYTHIA



- good simultaneous description of UA1 and D0 results and HERA-jet cross sections



# Conclusion

- **JetWeb**, a Monte Carlo tuning and validation database, was used to compare beauty cross sections from **three different experiments**:

UA1



Such simultaneous comparison is not easily done with other tools and is possibly the first in this area.

- Individual **visible and inclusive beauty quark cross sections** from three experiments and HERA-jet cross sections are **simultaneously well described by PYTHIA**.
- In comparison, the description of the cross sections by HERWIG is not as good as in the previous case and has problems at lower momenta.
- The **QCD** in **PYTHIA** can therefore be regarded as **universal valid and applicable**.

**HOPE**: this will also be true for **LHC**