DIS2006

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Beauty production using D*+μ and $\mu^+\mu^-$ correlations at ZEUS

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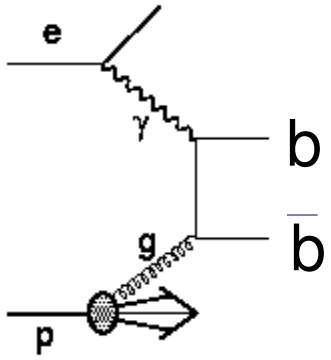
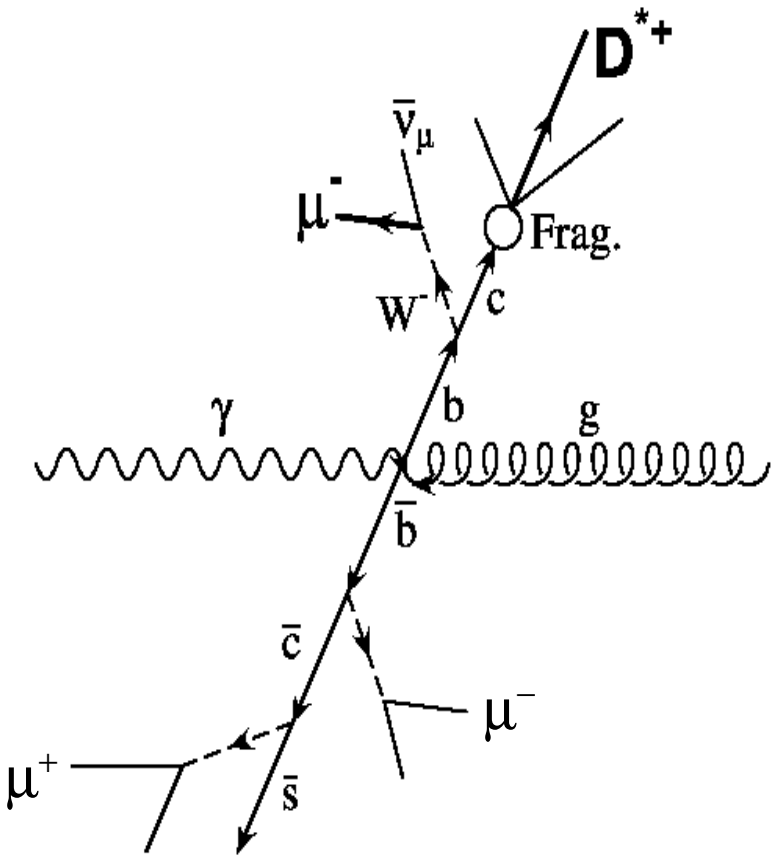
on behalf of the ZEUS Collaboration

Outline

- Motivation
- Reminder: D*+μ and $\mu^+\mu^-$ analysis
- Interface FMNR + PYTHIA
- Results
- Conclusions



Motivation



Double b tagging using D*+μ and $\mu^+\mu^-$

- Low background → soft kinematic cuts → almost full rapidity coverage → access low p_{Tb} region →

  Measurement of total $b\bar{b}$ cross section

- Tagging both b quarks ($\mu^+\mu^-$) →

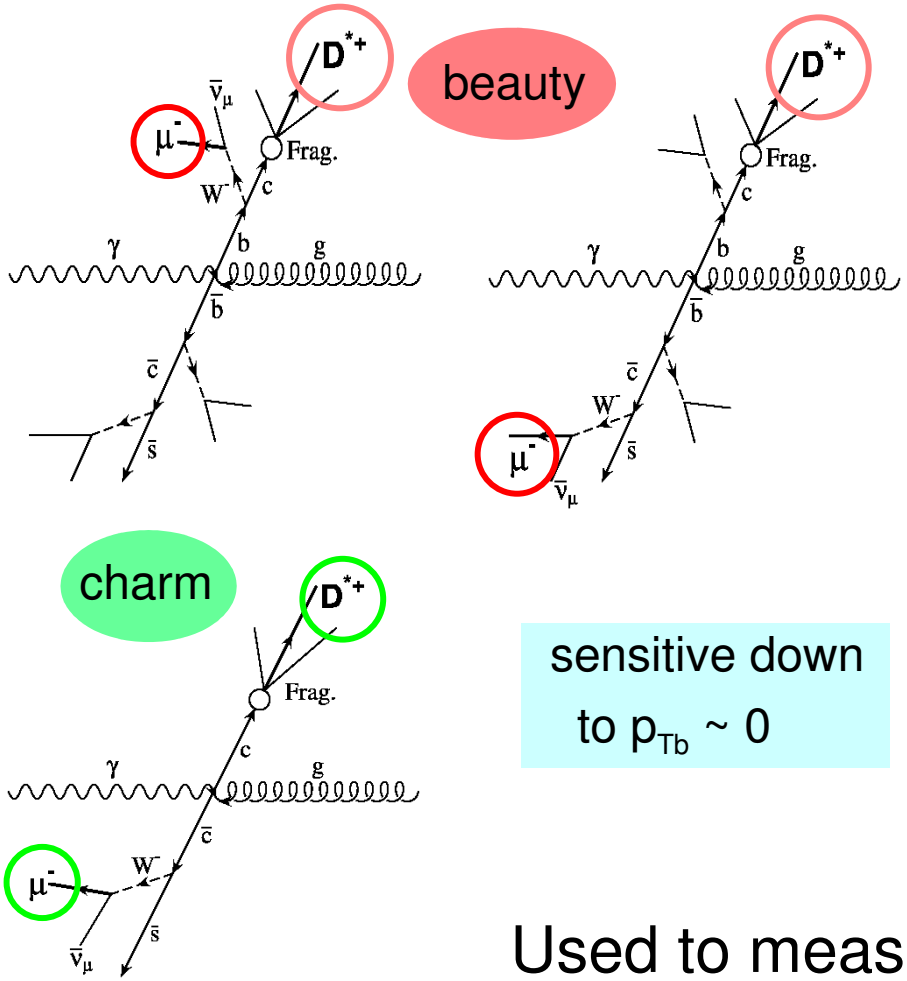
  Measure $b\bar{b}$ correlations

Motivation

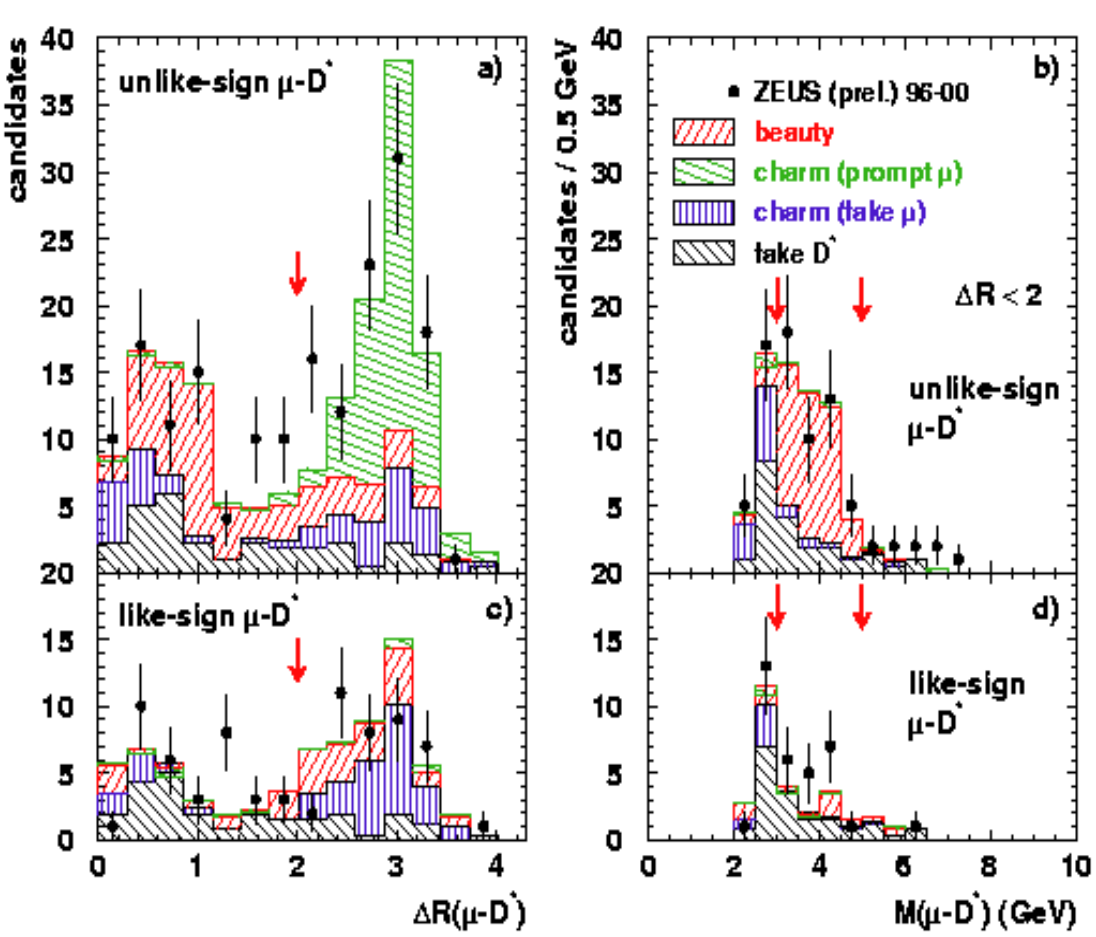
preliminary 2002/3

Beauty cross section from D*+ μ

ZEUS data 1996/00, 114 pb^{-1}, similar study by H1



sensitive down to $p_{Tb} \sim 0$



Used to measure total and differential cross sections

Motivation

Visible Beauty cross sections from D*+ μ

$p_T(D^*) > 1.9$ GeV, $-1.5 < \eta(D^*) < 1.5$,

$p_T(\mu) > 1.4$ GeV, $-1.75 < \eta(\mu) < 1.3$

ZEUS $\sigma_{vis} = 214 \pm 52(\text{stat})\ ^{+96}_{-84}$ (syst.) pb (preliminary)

Photoproduction only: $Q^2<1$ GeV^2, $0.05<y<0.85$

ZEUS $\sigma_{vis} = 159 \pm 41(\text{stat})\ ^{+68}_{-62}$ (syst.) pb (preliminary)

There were no NLO predictions!

Extrapolated to b level using PYTHIA

$y_{rap}(b) < 1$, $Q^2 < 1$ GeV^2, $0.05<y<0.85$,

σ (ep –> b or b X) = 15.1 +– 3.9 (stat) $^{+3.8}_{-4.7}$ (sys) nb (preliminary)

NLO QCD (FMNR) = 5.0 +1.7 -1.1 nb (preliminary)

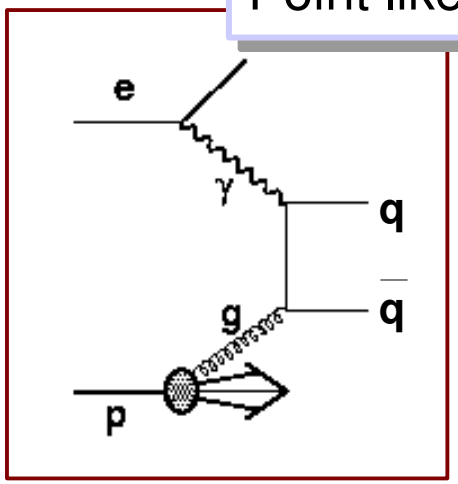
Is the Extrapolation reliable?

Solution: Interface FMNR → PYTHIA

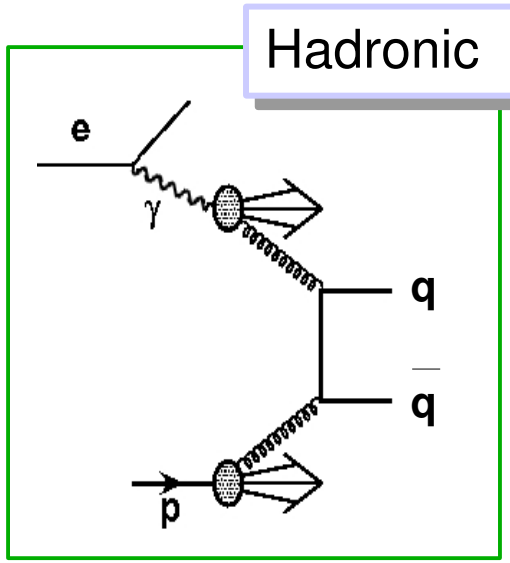
FrixioneManganoNasonRidolfi

Phys. Lett. 348, 633 (1995)

Point like



Hadronic

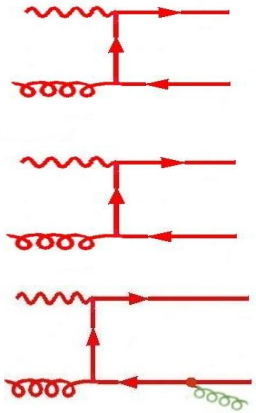


- Calculations @ NLO in QCD for heavy quarks in ep collisions
- Point like and Hadronic contributions to the cross section
- Photoproduction (γp)
- Fixed order massive scheme

  scale $\mu^2 = p_T^{\,2} + m_q^{\,2}$

FMNR

Example: some terms that contribute to the cross section



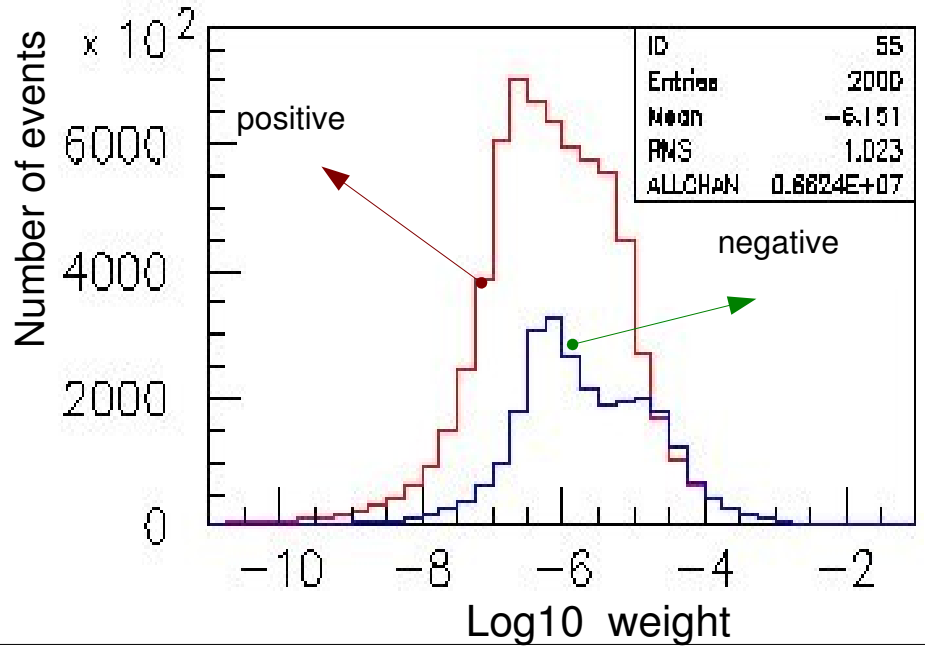
→ Real, positive

⊕ → Negative, divergent!

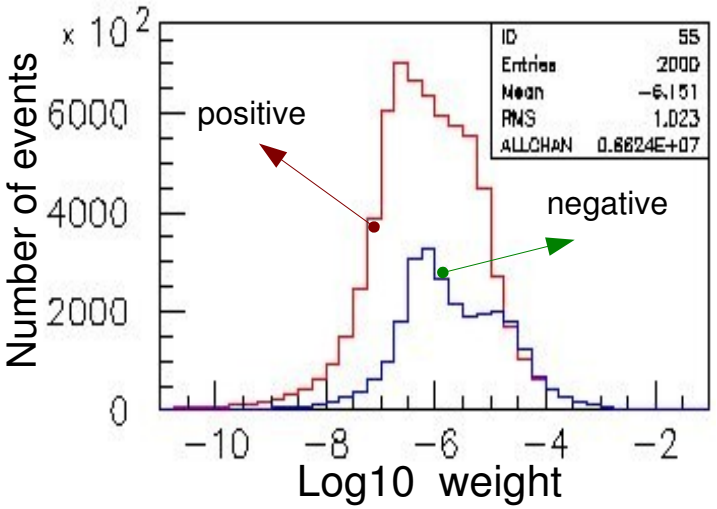
→ Positive, divergent!

} Combining: finite (+ or −)

- Events have weights →
  It can not be realistically linked to fragmentation or simulation chain.
- Weights range over several orders of magnitude →
  High statistics is needed to keep fluctuations low.



REDucedSTATistics



REDSTAT is an extension to FMNR:

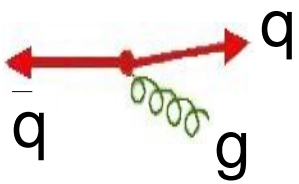
- Reduce the range of weights for the generated events.
- Reduce the necessary statistics without loosing NLO accuracy.

The idea:

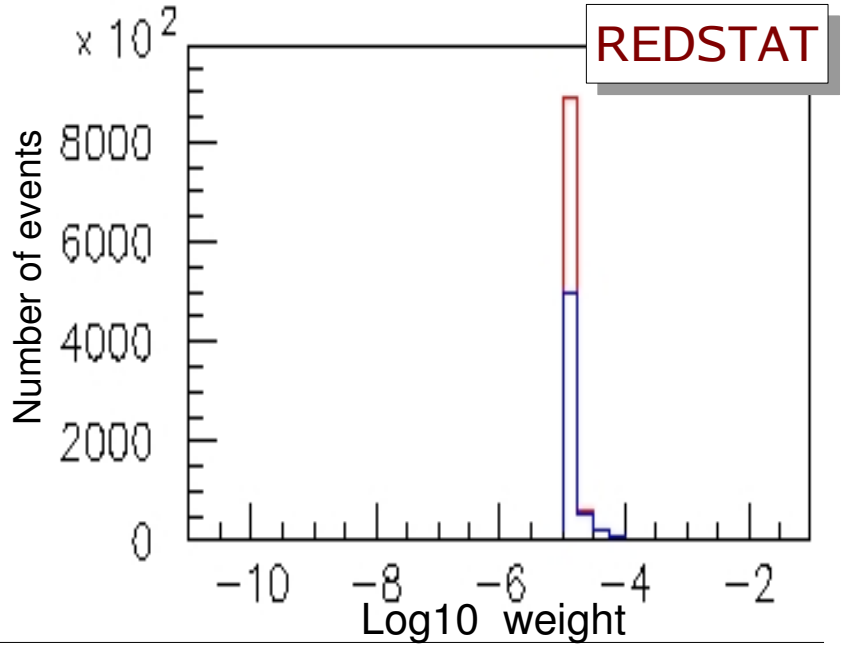
Combine events to get new ones with proper weight

How to combine:

- High weight events:
  Search for events with similar kinematics
- Low weight events:
  Random decision to keep the event



Similar events:
Difference in p_T, y_{rap}, ϕ < user cuts



Some REDSTAT results:

NLO accuracy preserved:

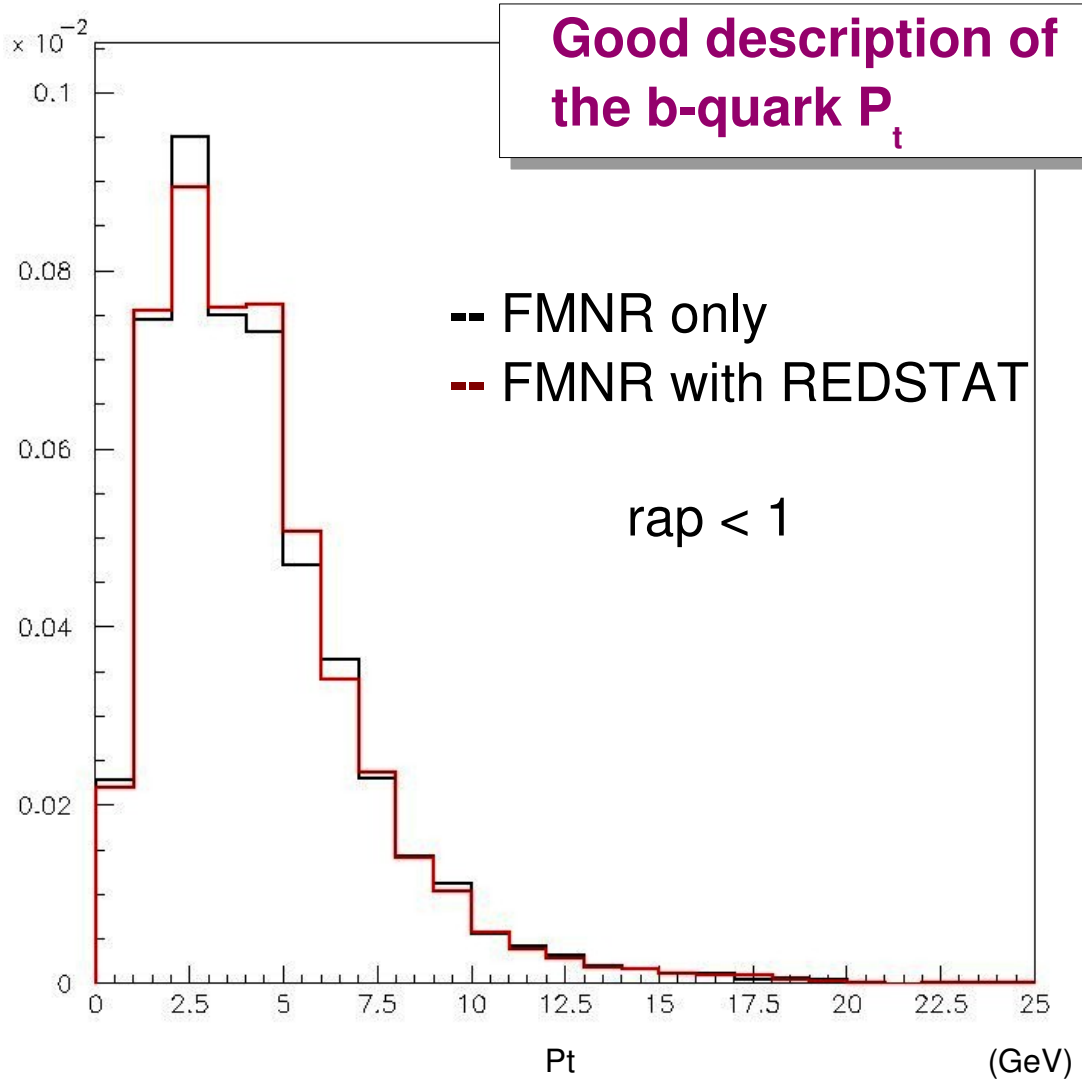
- without REDSTAT

  $\sigma_{\gamma p \to b (\bar{b}) X} = 4.95$ nb

- with REDSTAT

  $\sigma_{\gamma p \to b (\bar{b}) X} = 4.94$ nb

Good description of the b-quark P_t



FMNR Parameters

- Mass of the b quark

  $m_b = 4.75$ GeV, (4.5 - 5.0)

- Renormalization and factorization scales

  $\mu^2 = m_b^2 + p_{Tb}^2$ ($\mu/2 - 2\mu$)

- Proton: CTEQ5M Photon: GRV-G-HO

  PDF error << scale/mass error $\rightarrow$ neglected

Interface FMNR to PYTHIA

- Use weight range reduction (**REDSTAT**) preserving NLO accuracy

- Feed FMNR partons into PYTHIA 6.2 using "Les Houches accord" interface

Interface FMNR to PYTHIA

PYTHIA parameters

- **Intrinsic k_T kick : yes**
- **Parton showering: NO**

  avoid double counting of higher order contributions

  main difference w.r.t. MC@NLO in preparation

- **Fragmentation**, all based on the Peterson formula:

  a) Independent (FMNR does not provide colour flow)

  b) Lund string (invent "reasonable" color flow)

  c) Comparison with default FMNR fragmentation, where possible.

  use b) as central value, a) as lower error (-5%), c) as upper error (+15%)

  Peterson, $\varepsilon = 0.0035$

  (variation 0.0023 – 0.0045 -> error negligible compared to a or c)

- **Standard PYTHIA decay tables**

  all branching ratios included

  corrected to match PDG

➜ Obtain full hadron level event

Results

Visible Beauty cross sections from D*+ μ

$p_T(D^*) > 1.9$ GeV, $-1.5 < \eta(D^*) < 1.5$,

$p_T(\mu) > 1.4$ GeV, $-1.75 < \eta(\mu) < 1.3$

ZEUS $\sigma_{vis} = 214 \pm 52(\text{stat})\ ^{+96}_{-84}$ (syst.) pb (prel.)

FMNR§PYTHIA $\sigma_{vis} = 72\ ^{+20}_{-13}$ (NLO) $^{+14}_{-10}$ pb new

data/NLO = 3.1 $^{+1.6}_{-1.7}$

Photoproduction only: $Q^2<1$ GeV^2, $0.05<y<0.85$

ZEUS $\sigma_{vis} = 159 \pm 41(\text{stat})\ ^{+68}_{-62}$ (syst.) pb (prel.)

FMNR§PYTHIA $\sigma_{vis} = 57\ ^{+16}_{-10}$ (NLO) $^{+11}_{-9}$ pb new

data/NLO = 2.8 $^{+1.5}_{-1.6}$

Extrapolated to b level using PYTHIA

$y_{rap}(b) < 1$, $Q^2 < 1$ GeV^2, $0.05<y<0.85$,

σ (ep –> b or b X) = 15.1 +– 3.9 (stat) $^{+3.8}_{-4.7}$ (sys) nb (prel.)

NLO QCD (FMNR) = 5.0 +1.7 -1.1nb (prel.)

data/NLO = 3.0 $^{+1.3}_{-1.6}$

Comparisons at b quark and visible level yield the same result

Results

Comparison with H1

H1 visible range:

$p_T(D^*) > 1.5$ GeV, $-1.5 < \eta(D^*) < 1.5$,

$p(\mu) > 2.0$ GeV, $-1.735 < \eta(\mu) < 1.735$

Photoproduction only: $Q^2<1$ GeV^2, $0.05<y<0.85$

H1 σ_{vis} = 206 +- 53(stat) +- 35 (syst.) pb (published)

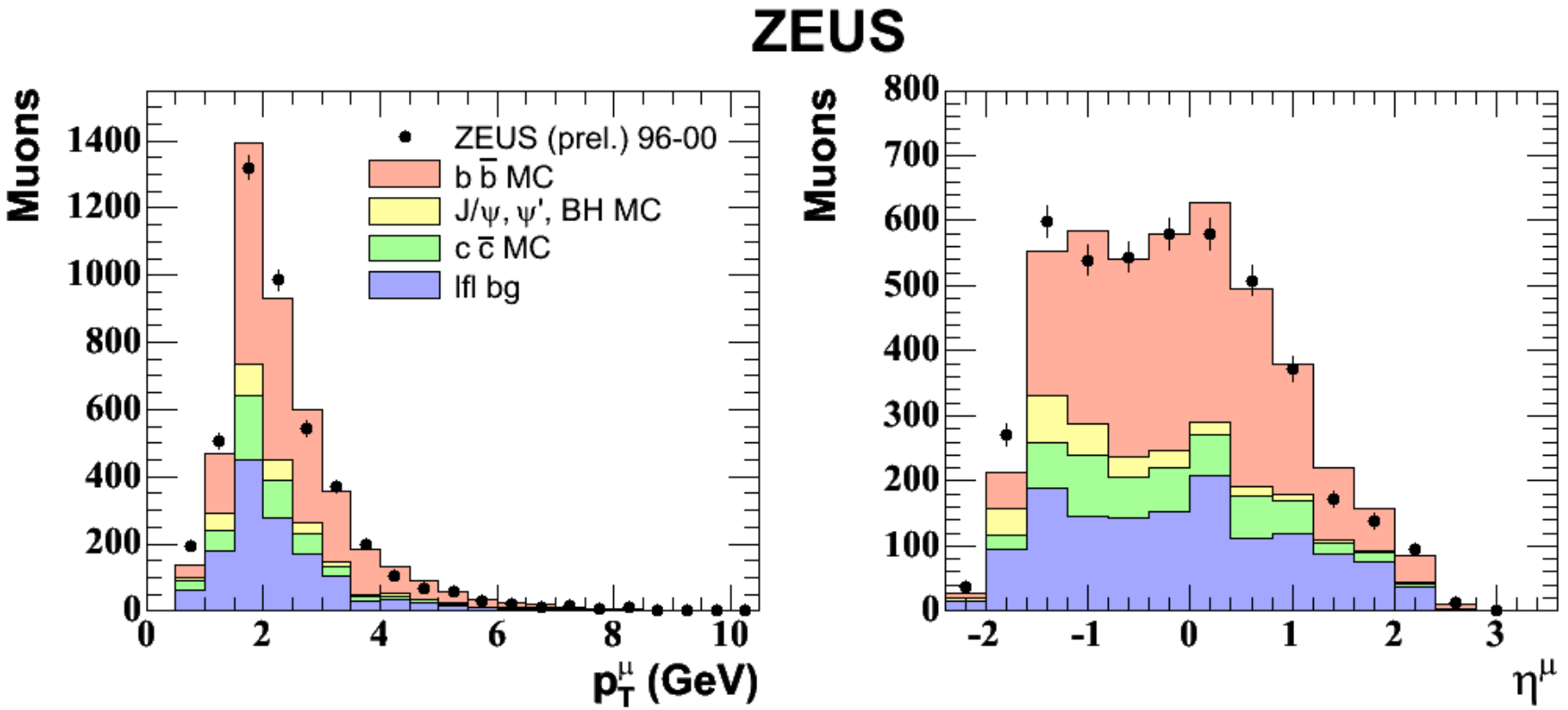
ZEUS -> H1 $\sigma_{vis} = 189 +- 48(stat)\ ^{+80}_{-73}$ (syst.) pb new

(extrapolated to H1 with FMNR)

Measured H1 and ZEUS visible cross sections consistent

Beauty cross section from $\mu^+ \mu^-$

preliminary 2005



Measured total cross section:

$\sigma_{ep \to b\bar{b} X}$ (318 GeV) $= 16.1 \pm 1.8$ (stat.) $^{+5.3}_{-4.8}$ (syst.) nb

NLO(FMNR+HVQDIS) = $6.8\ ^{+3.0}_{-1.7}$ nb

Results

Visible Beauty cross sections from μμ

Complicated set of muon p_T and η cuts, from beauty (for maximal acceptance)

Visible range:

1st μ : p_T > 1.5 GeV

2nd μ : (p > 1.8 GeV for η < 0.6 ,

p > 2.5 GeV or p_T > 1.5 GeV for η > 0.6) and

p_T > 0.75 GeV

both μ : -2.2 < η < 2.5

ZEUS σ_{vis} = 63 +- 7(stat) $^{+20}_{-18}$ (syst.) pb (prel.)

FMNR§PYTHIA σ_{vis} = 30 $^{+9}_{-6}$ (NLO) $^{+5}_{-3}$ (frag+br) pb

data/NLO = 2.1 $^{+0.8}_{-1.0}$

Extrapolated to quark level using PYTHIA

ZEUS σ(ep –> b or b $\bar{X}$) = 16.1 +– 1.8 (stat) $^{+5.3}_{-4.8}$ (sys) nb (preliminary)

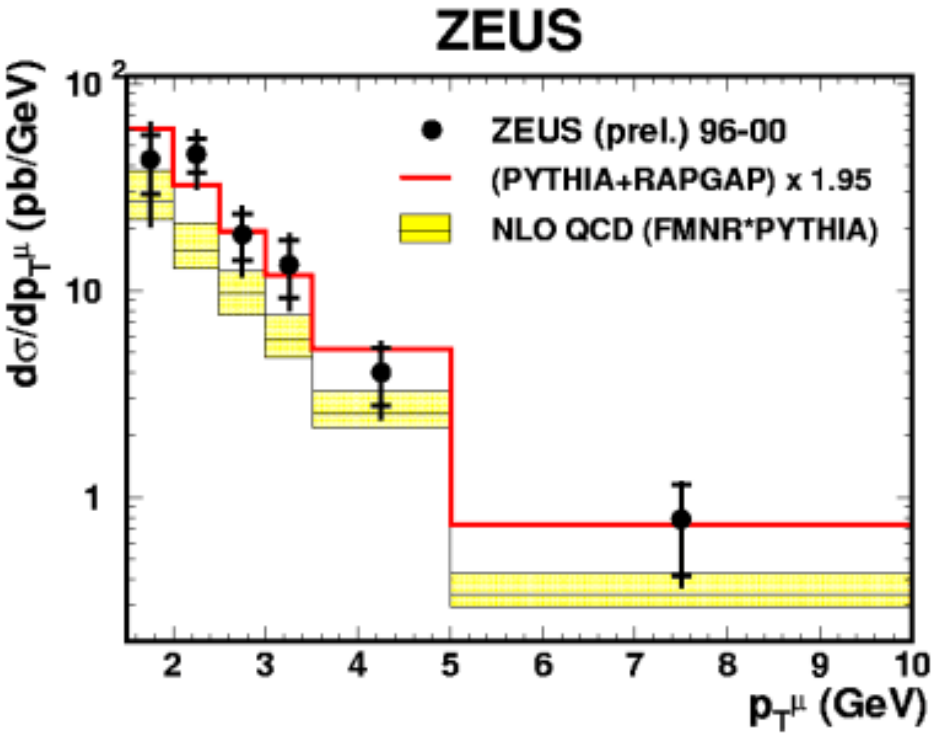
NLO(FMNR+HVQDIS) : 6.8 $^{+3.0}_{-1.7}$ nb (preliminary) **data/NLO = 2.3 $^{+1.0}_{-1.2}$**

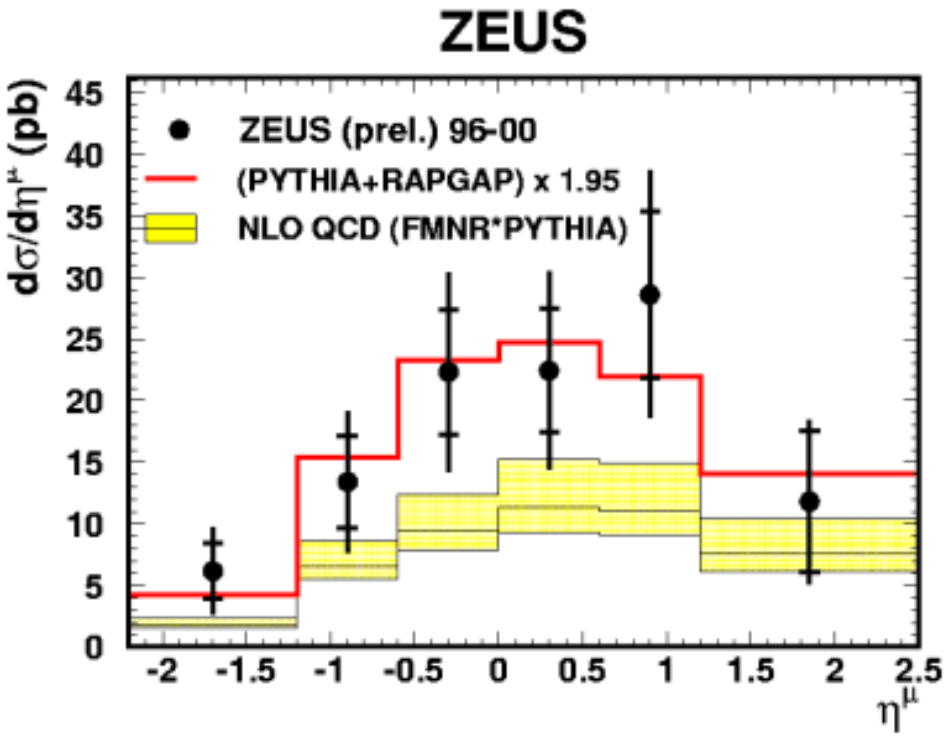
Comparisons at b quark and visible level consistent

Results

Visible Beauty cross sections from μμ

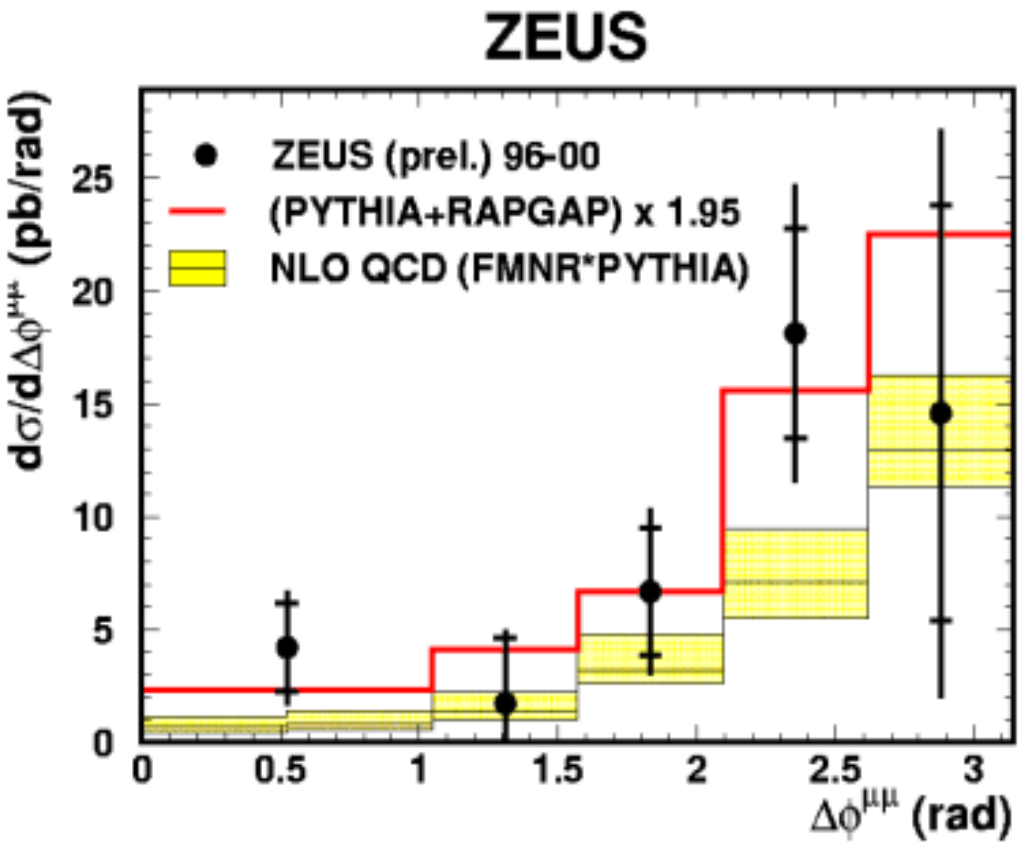
New NLO predictions added





Results

Visible Beauty cross sections from μμ



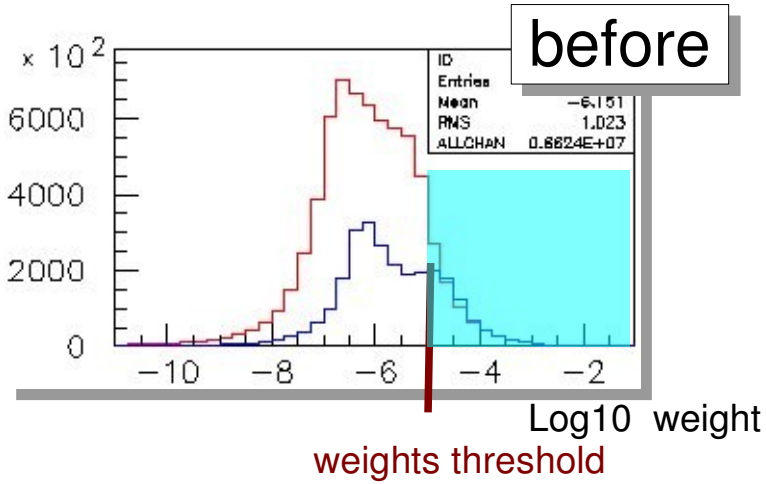
Conclusions

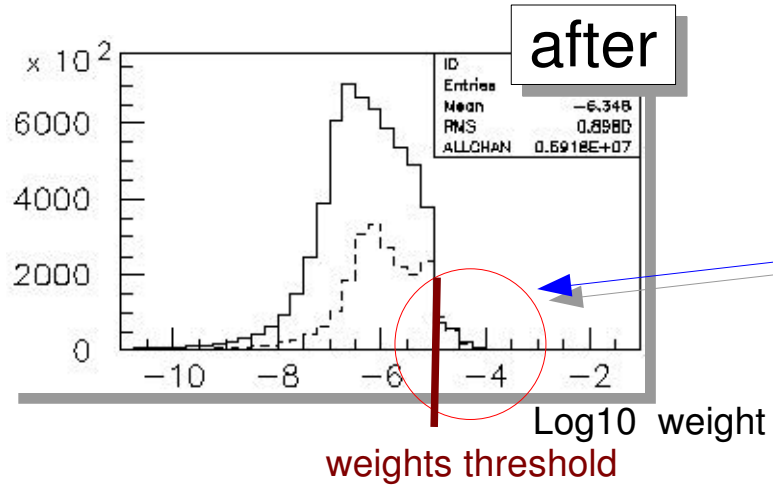
- D* μ and μμ beauty tagging methods reliable for measurement of total cross section for b production and $b\bar{b}$ correlations.
- The new FMNR§PYTHIA interface allows calculation of complicated visible NLO cross sections not available previously.
- data/NLO cross section comparisons for $b\bar{b} \rightarrow$ D* μ and $b\bar{b} \rightarrow \mu\,\mu$ at **visible** and **b quark level** are **consistent and equivalent.**
- We can use this method now, and compare with MC@NLO whenever available.

Backup slides !

How REDSTAT works:

Part 1: Weights > threshold





- Sets a threshold for the weights.
- Search for events with similar kinematics and combines them to produce a new event with proper weight.

Similar events:

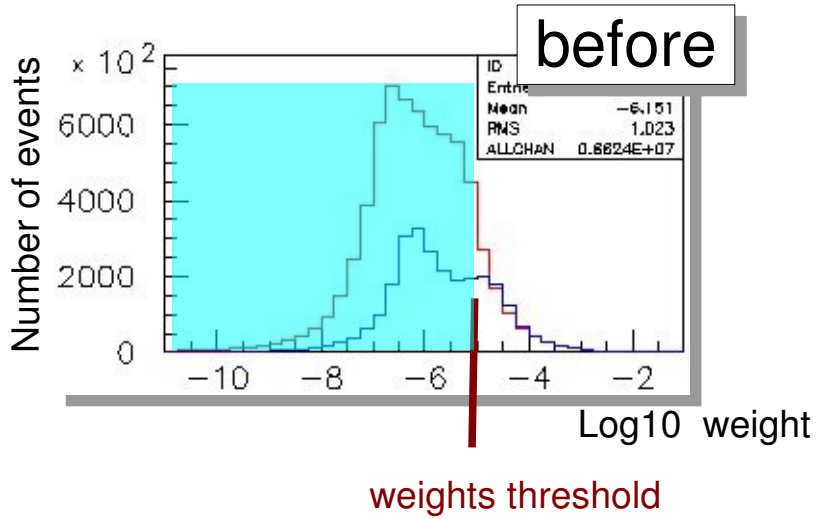
Δp_t , Δy , $\Delta\phi$ < user cuts

- Weights range reduced in 2 orders of magnitude
- Fewer high weight events !

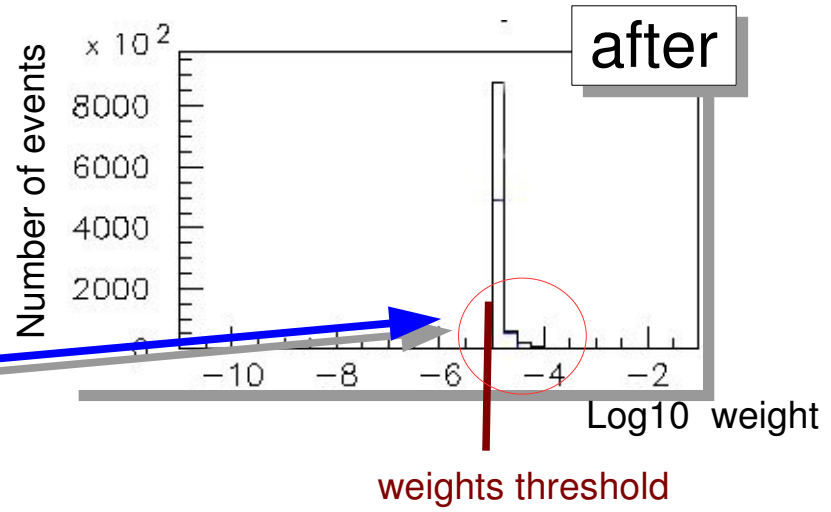
How REDSTAT works:

Part 2: Weights < threshold

- Makes a Random decision to keep the event.
- Sets the weight of the event to the threshold weight.



- Weights are now in very small range.
- Interface to PYTHIA possible !



http://www.hep.phy.cam.ac.uk/theory/webber/MCatNLO/

The MC@NLO Package

by

Stefano Frixione

and

Bryan Webber

MC@NLO is a Fortran package to implement the scheme we have proposed for combining a Monte Carlo event generator with Next-to-Leading-Order calculations of rates for QCD processes.

MC@NLO makes use of the HERWIG event generator.

The current version is MC@NLO 3.2, released on 20 January 2006. It differs from the previous version (3.1) in the following ways: single top quark production has been added, and use of the parton density library LHAPDF is supported. Users are reminded that in versions 3.1 onwards the format of the event file, produced by the `NLO' part of the package and read by the `MC' part, has been changed relative to earlier versions, and therefore event files created by versions 2.3 or earlier cannot be used with this version.

The processes available in this version are those of Higgs boson, single vector boson, vector boson pair, heavy quark pair, single top, lepton pair and associated Higgs+W/Z production in hadron collisions.

This version is compatible with HERWIG 6.5 or higher, which can be obtained from the HERWIG home page.