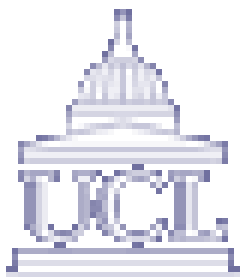
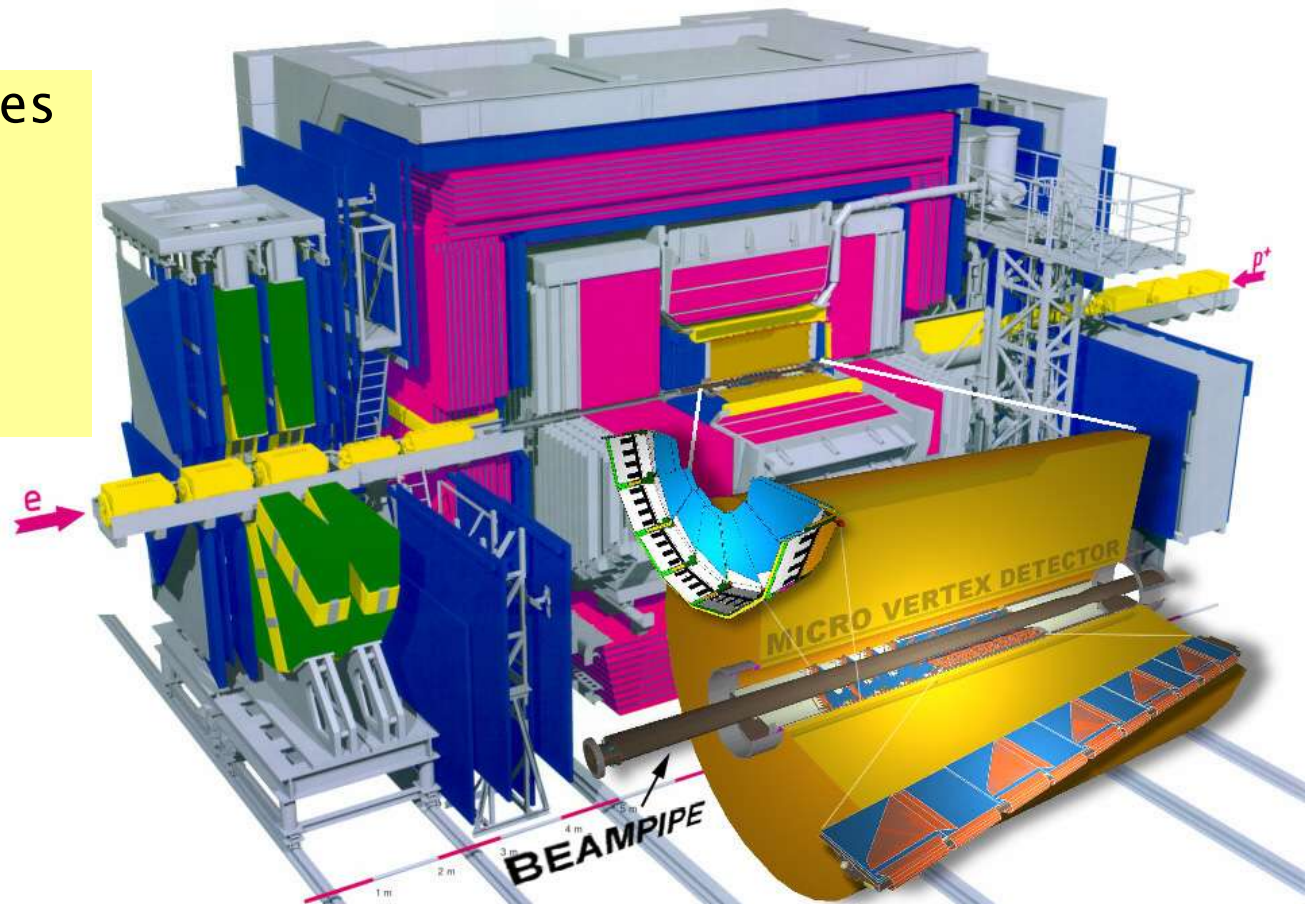


# First results on beauty production using HERA II data at ZEUS

Silvia Miglioranzi  
UCL/ANL

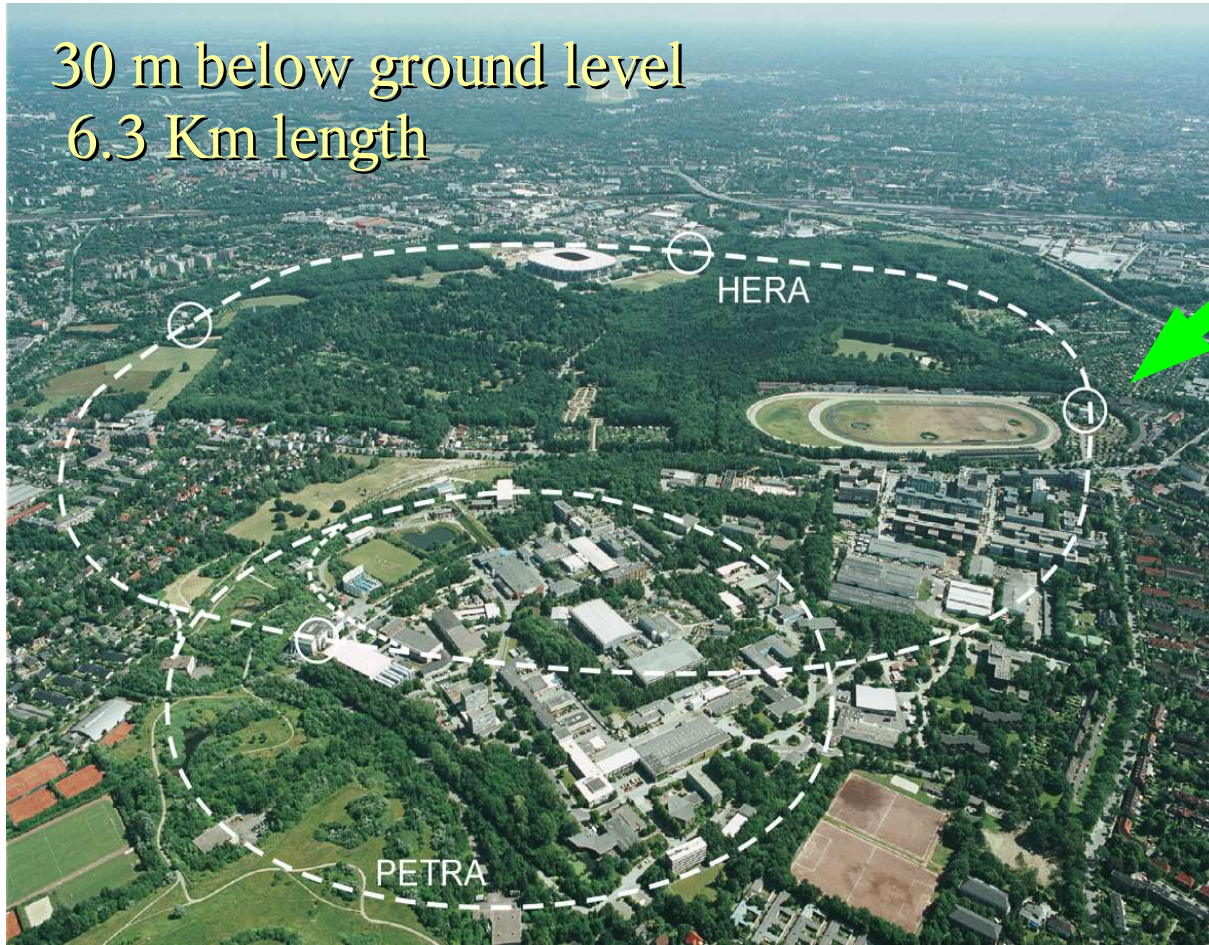
Iop Hepp 2005, Dublin, 22 March

- Beauty production processes
- b tagging methods
- Results from HERA I
- Analysis of HERA II data

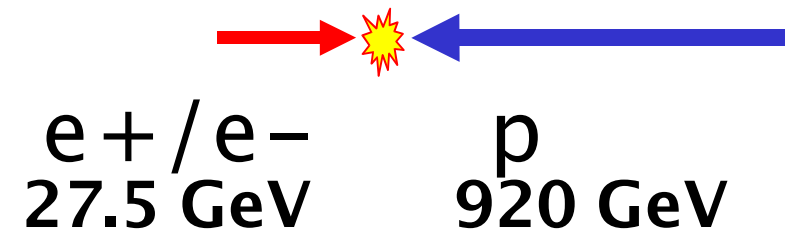


# HERA and ZEUS

30 m below ground level  
6.3 Km length



ZEUS

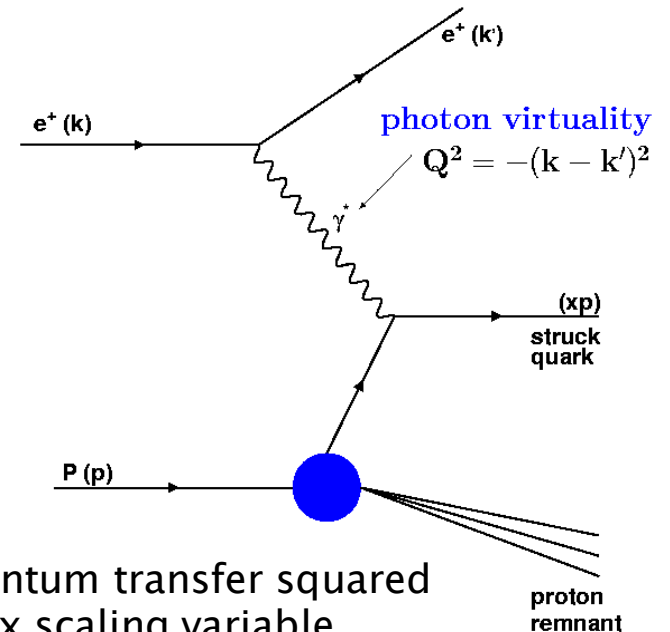


Maximum center of mass energy:  
 $\sqrt{s} = 318 \text{ GeV}$

## Two kinematic regimes:

Deep Inelastic Scattering (DIS):  $Q^2 > 1 \text{ GeV}^2$

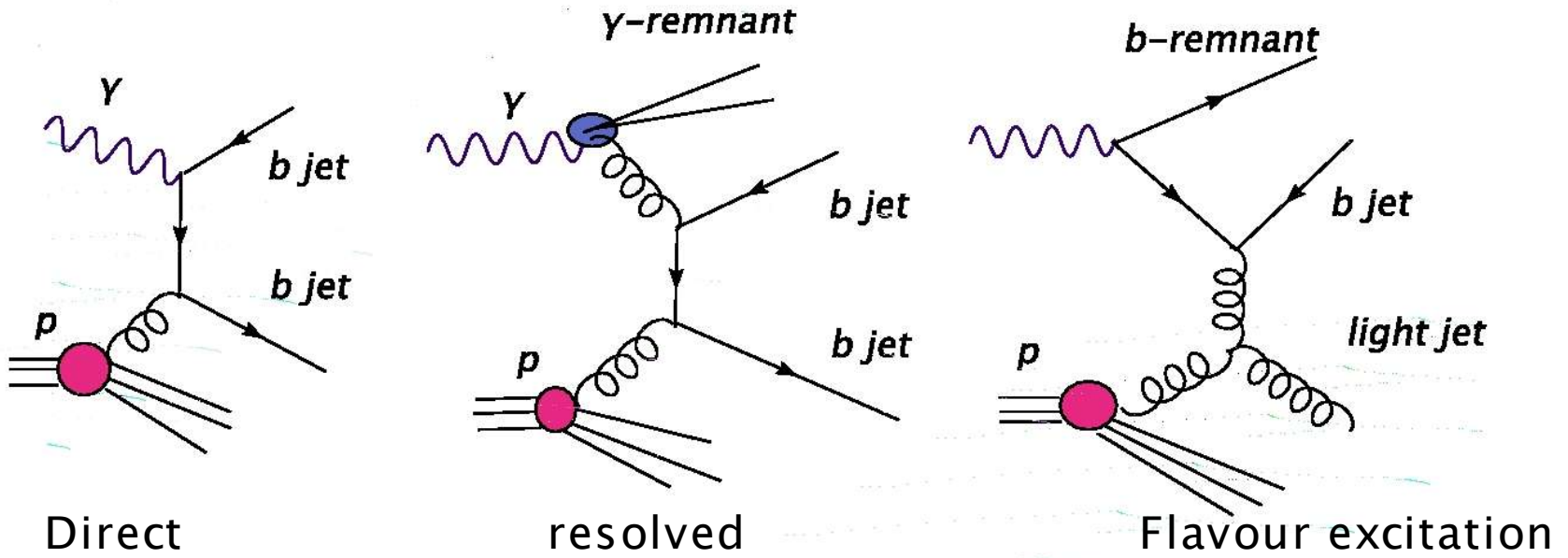
Photoproduction ( $\gamma p$ ):  $Q^2 \sim 0 \text{ GeV}^2$



$Q^2$ : 4-momentum transfer squared

$x$ : Bjorken- $x$  scaling variable

# Beauty production mechanism



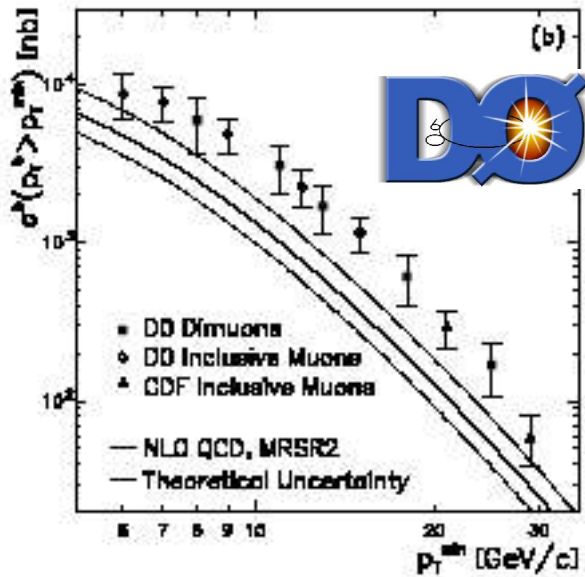
- **Boson-Gluon-Fusion** dominant contribution
  - Sensitive to gluon content of proton
- $M_b$  gives a hard scale to process
  - Good testing ground for QCD
- $Q^2$  and  $E_t^{\text{jet}}$  can also provide a hard scale
  - Multi-scale problem

$$\sigma_b : \sigma_c : \sigma_{uds} \approx 1 : 200 : 2000$$

Need clear experimental starting point :

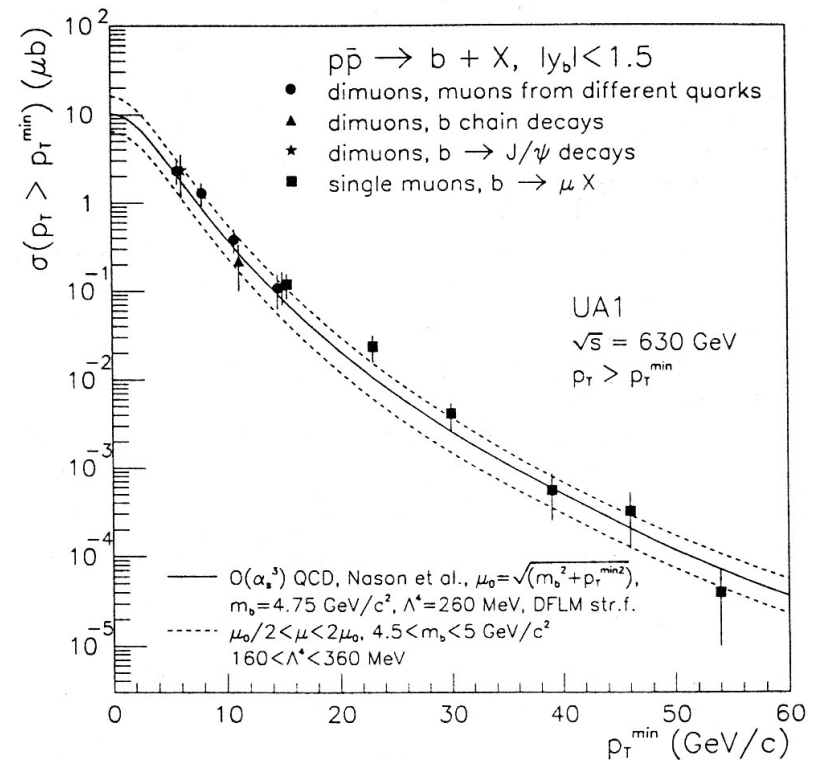
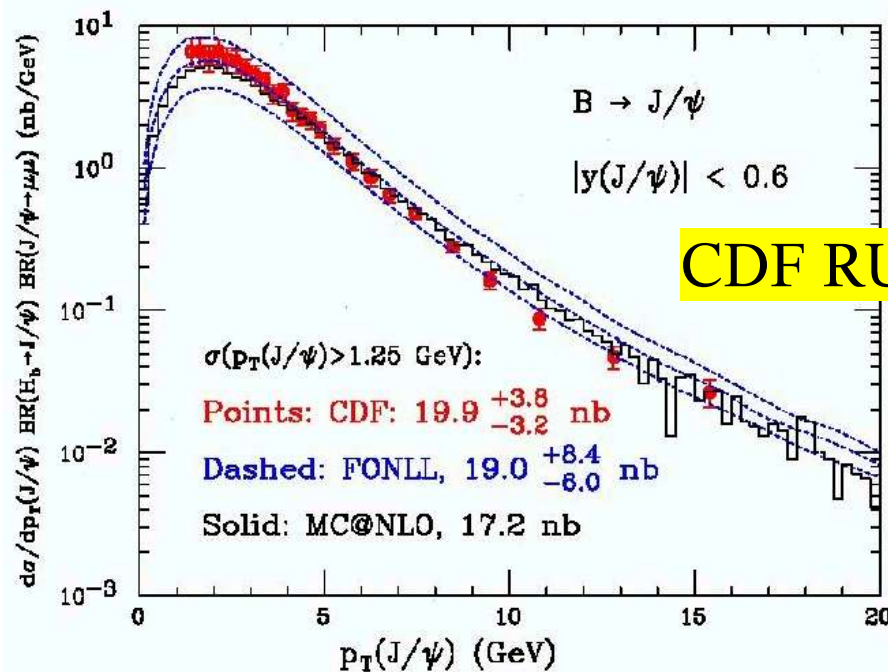
- use **semileptonic decay** (BR~10%)
- select dijet events with high  $P_t$  lepton

# b production overview



Description by NLO calculation not completely settled:

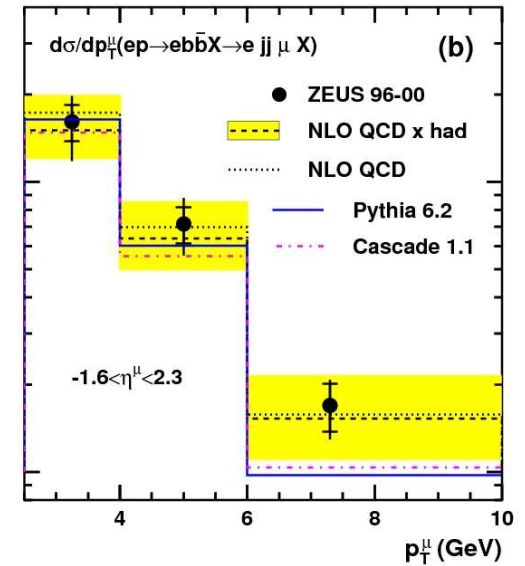
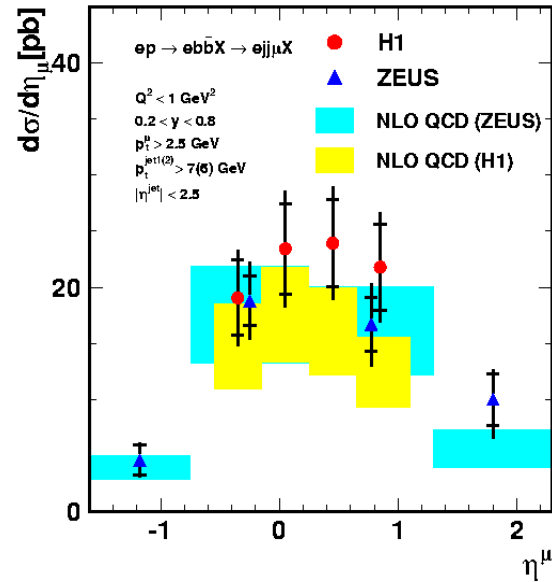
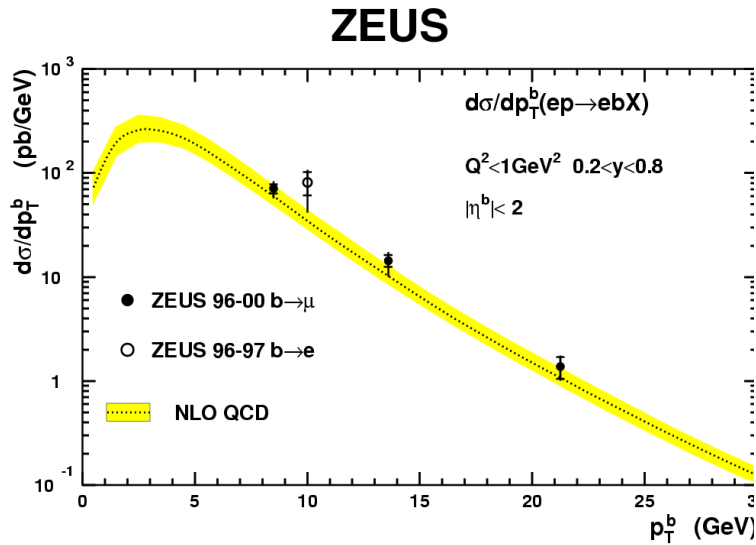
- problems in Tevatron (not anymore in recent results)
- good description of UA1



# b production overview

**ZEUS** latest published results:

**Beauty photoproduction measured using decays into muons in dijet events in ep collisions at  $\sqrt{s}=318$  GeV (DESY-03-212)**



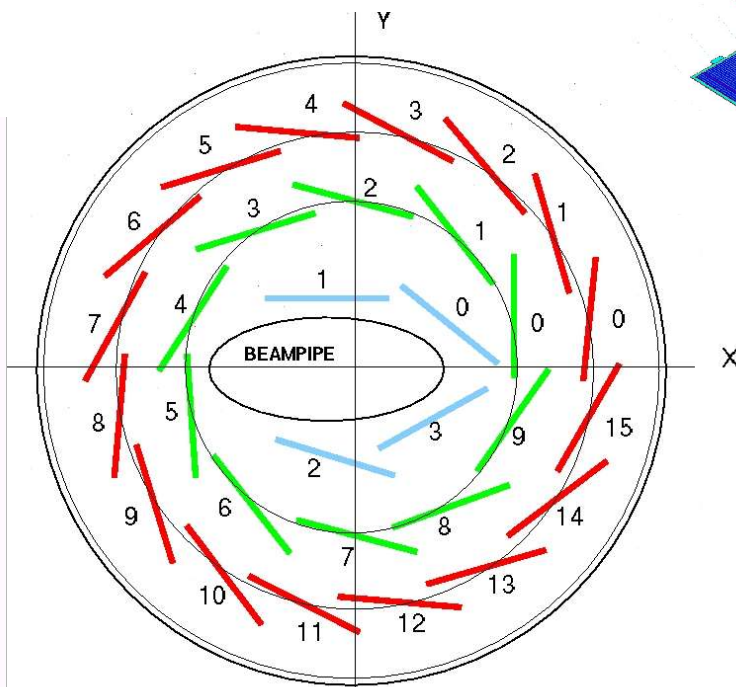
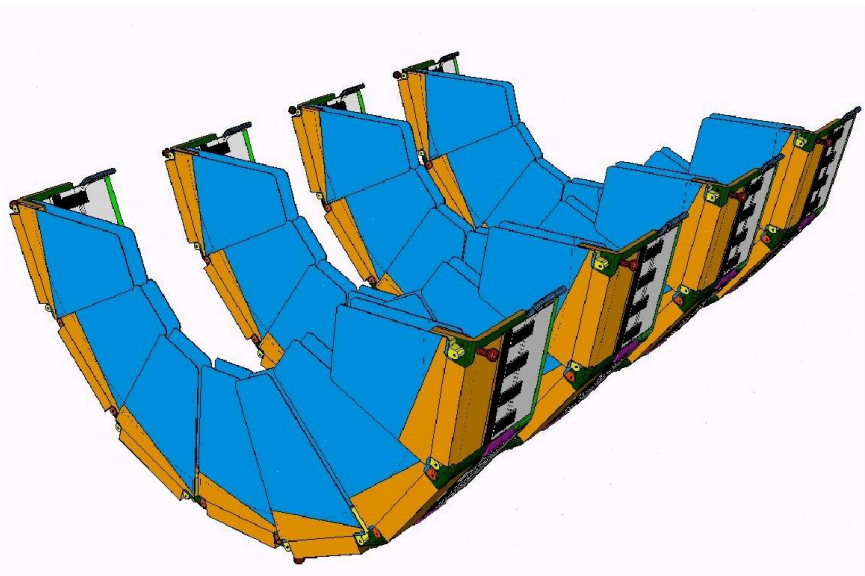
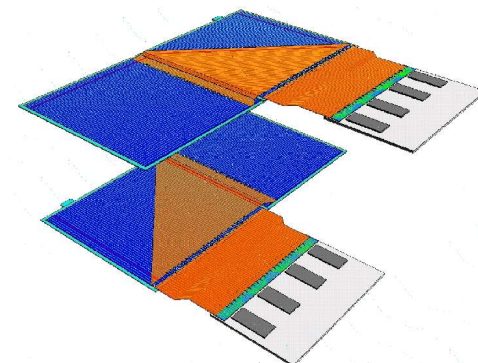
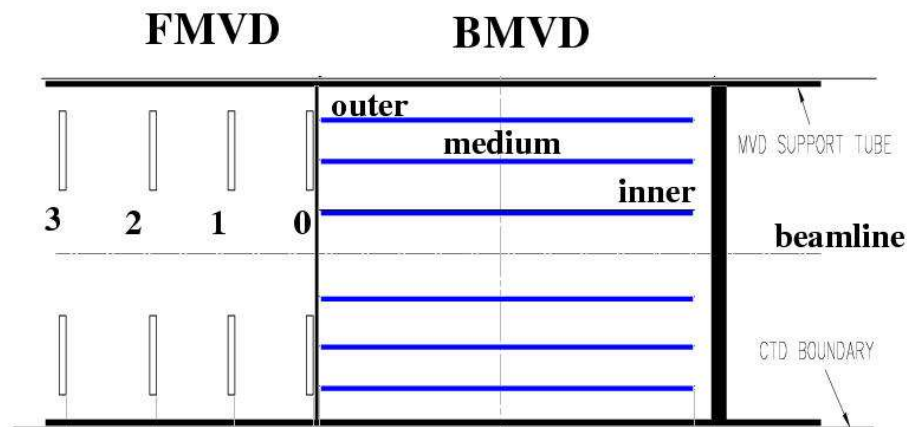
Good agreement between data and NLO!

**ZEUS** goal:  
 include **MYD** → improve HERA I results!

# The ZEUS Micro Vertex Detector

Silicon detector installed in 2001

- Polar angle coverage  $10^\circ < \theta < 160^\circ$   
3 layers in the barrel region (64 cm)  
4 wheels in the forward region
- Microstrips pitch  $20\ \mu\text{m}$   
Hit resolution  $\sim 20\ \mu\text{m}$   
2 track separation  $\sim 200\ \mu\text{m}$



# Technical strategy (I)

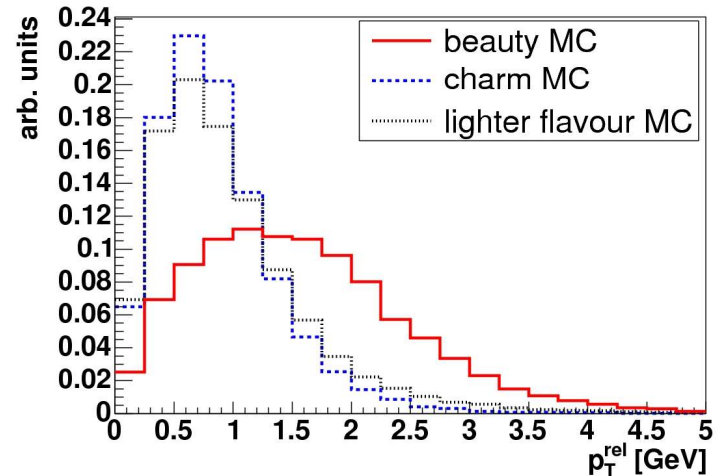
Goal: identify beauty by its **semi-leptonic decay** into **muons**

$$ep \rightarrow ebbX \rightarrow e \mu^\pm \text{ dijet } X$$

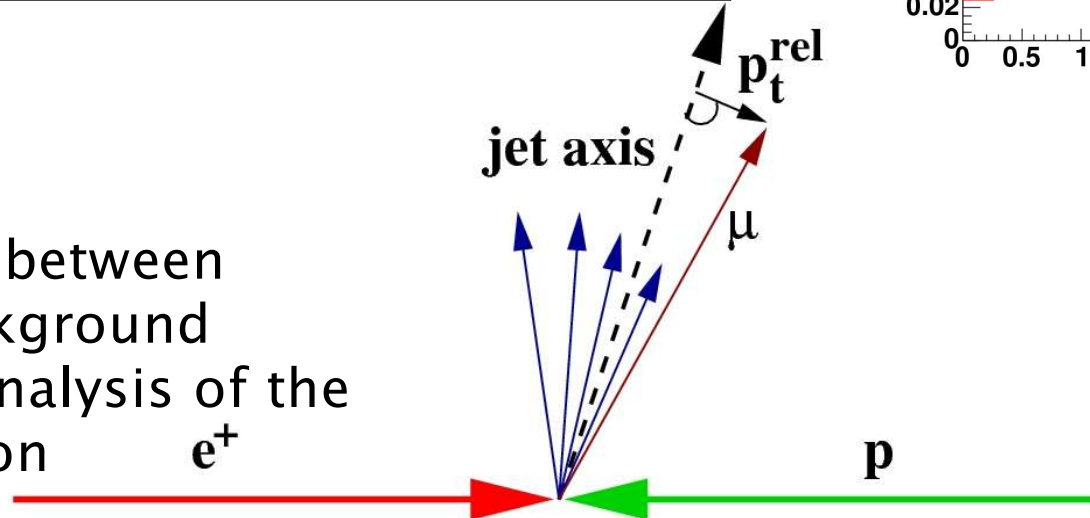
- 1<sup>st</sup> statistical method :  $p_T^{\text{rel}}$  (exploiting b quark high mass)

Momentum of the muon relative to its jet ( $p_T^{\text{rel}}$ ) is harder for beauty jets compared to jets from lighter flavours

$$p_T^{\text{rel}, \text{jet}-\mu} = |\vec{p}_T^\mu| \cdot \sin \left( \arccos \left( \frac{\vec{p}_T^\mu \cdot (\vec{p}_T^{\text{jet}} - \vec{p}_T^\mu)}{|\vec{p}_T^\mu| \cdot |\vec{p}_T^{\text{jet}} - \vec{p}_T^\mu|} \right) \right)$$



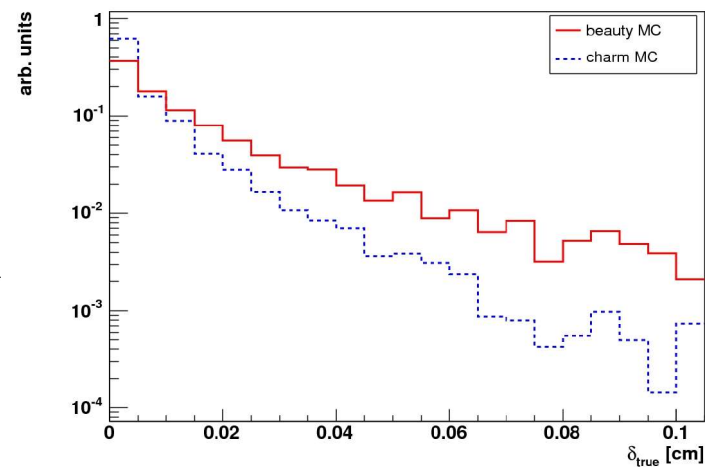
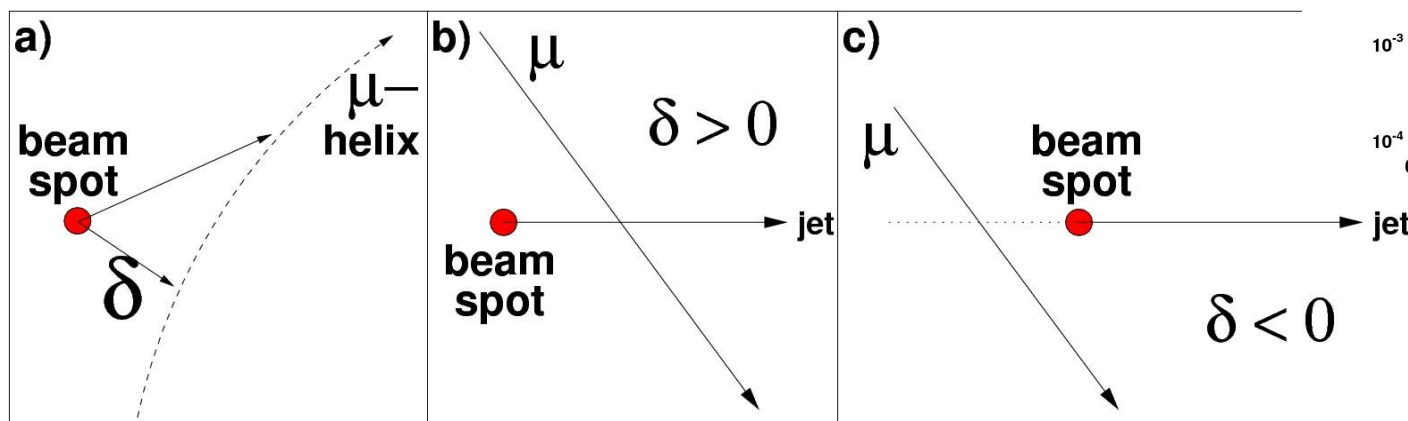
Discrimination between signal and background based on the analysis of the  $p_T^{\text{rel}}$  distribution



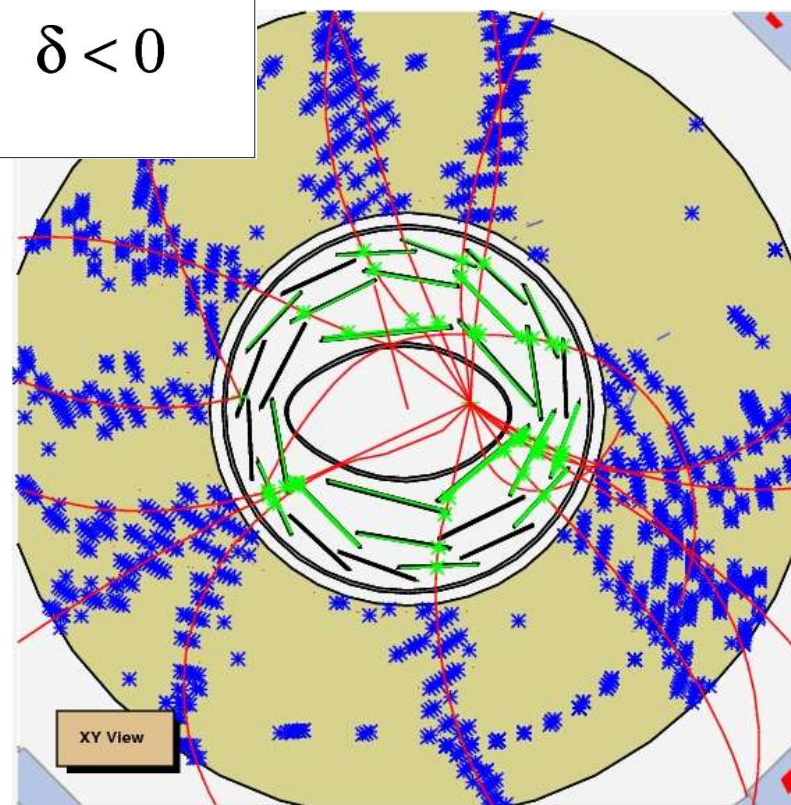
# Technical strategy(II)

Goal: identify beauty by its **semi-leptonic decay** into **muons**

- Impact parameter method  
(exploiting b quark long lifetime)



- Decay distance for B-hadrons:  $c\tau \sim 500 \mu\text{m}$  measurable using MVD
- statistical extraction of b fraction from data (analog to  $p_{\text{T}}^{\text{rel}}$ -Method)





# Dijet + $\mu$ sample

Photoproduction events:

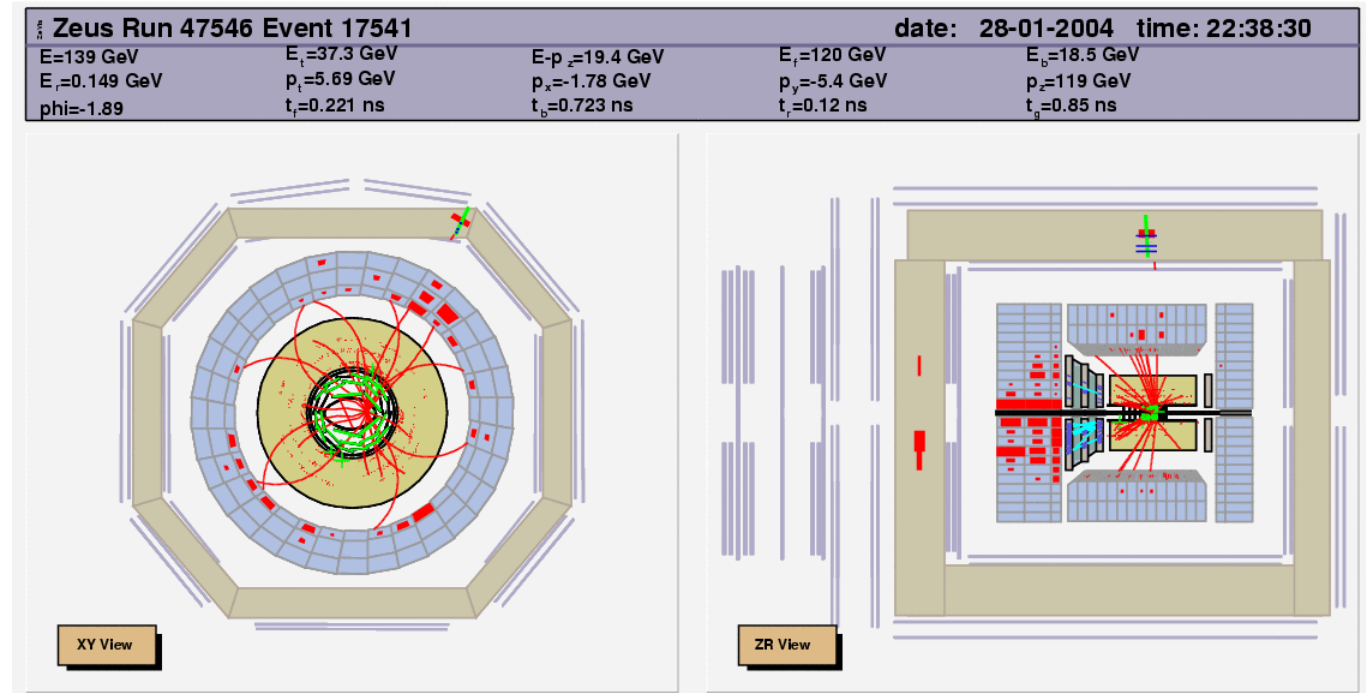
- $Q^2 < 1 \text{ GeV}^2$
- $0.2 < y < 0.8$

with at least **two jets**

- Kt algorithm,  
long. Invariant,  
massive scheme
- $|\eta| < 2.5$
- $p_T^{1(2)} > 7(6) \text{ GeV}$

and a **muon** with

- $p_t > 1.5 \text{ GeV}$



**Total luminosity: 31.03 pb<sup>-1</sup>**

**General muon reconstruction:**

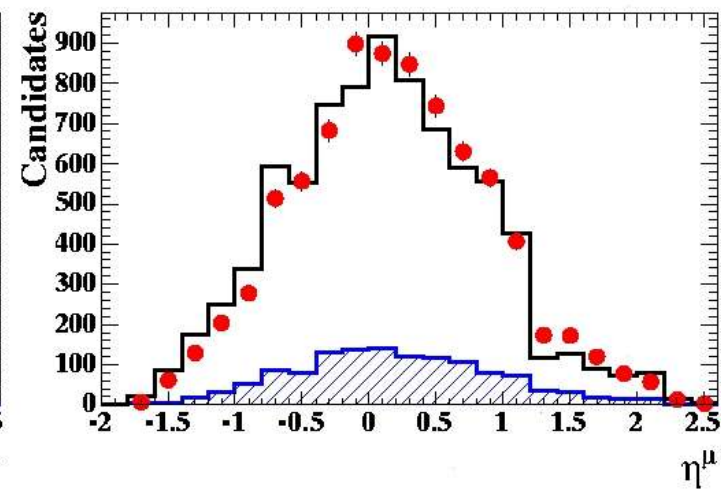
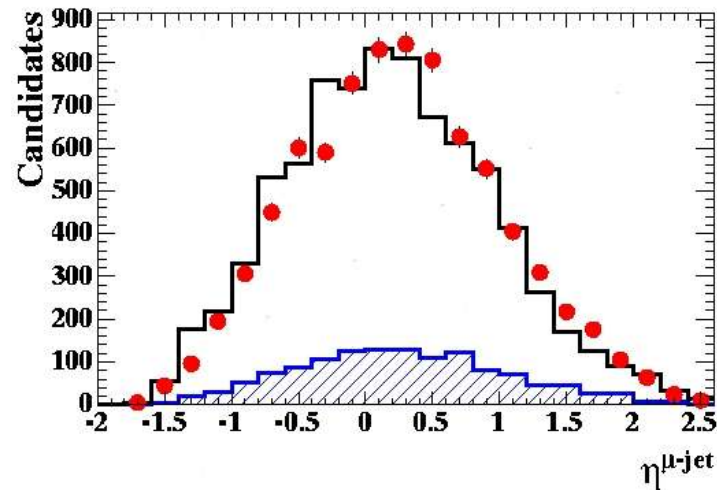
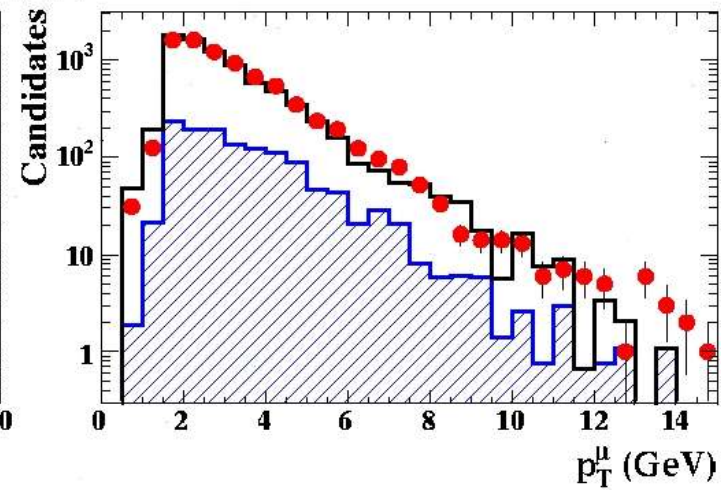
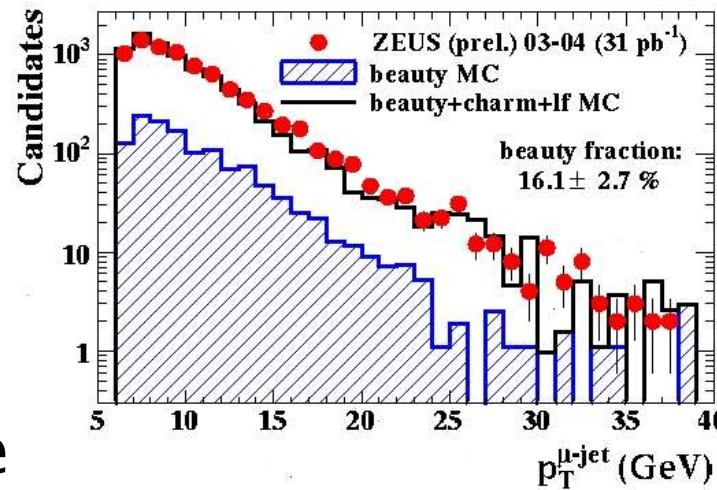
- Combination of different muon-reconstruction algorithms
- Use of several detector components

(Tracking chambers, calorimeter, muon chambers, instrumented Iron-Yoke)

# $p_t^{\text{rel}}$ method: control plots

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

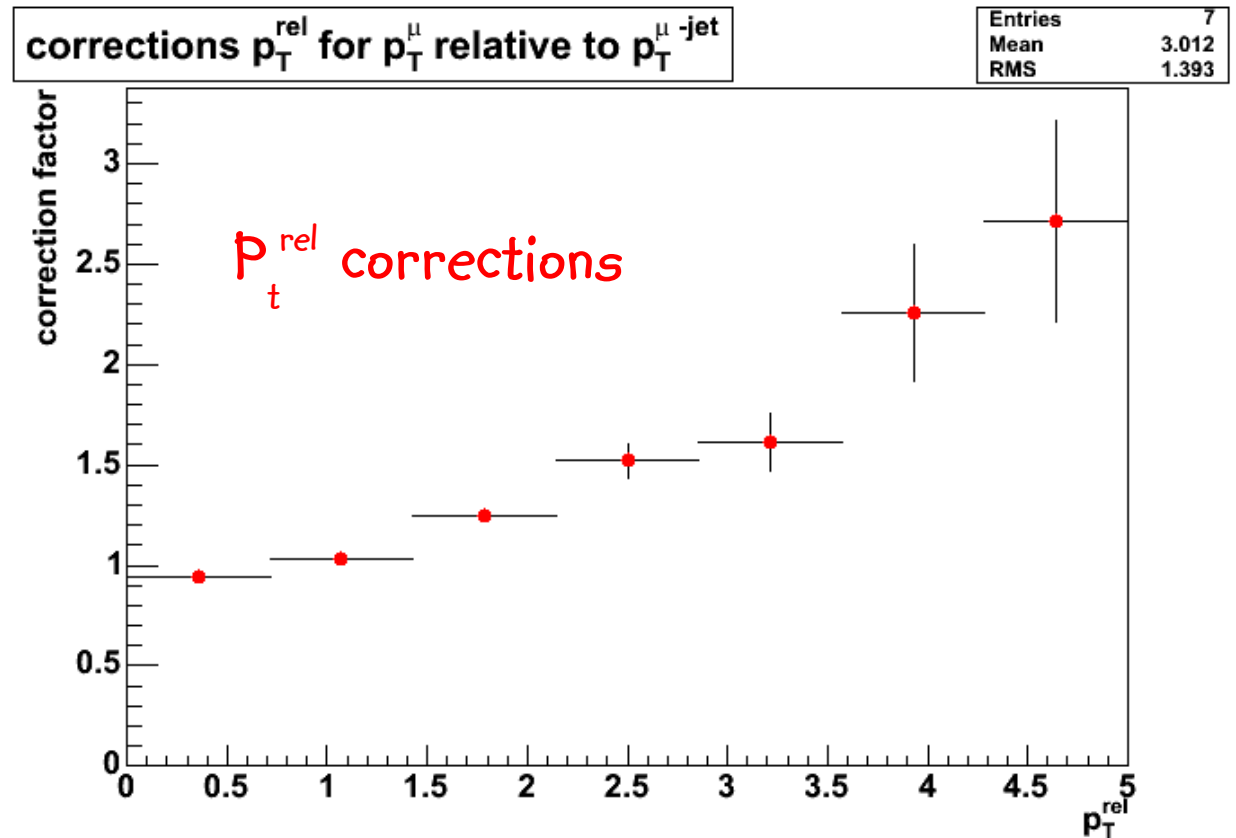
## ZEUS



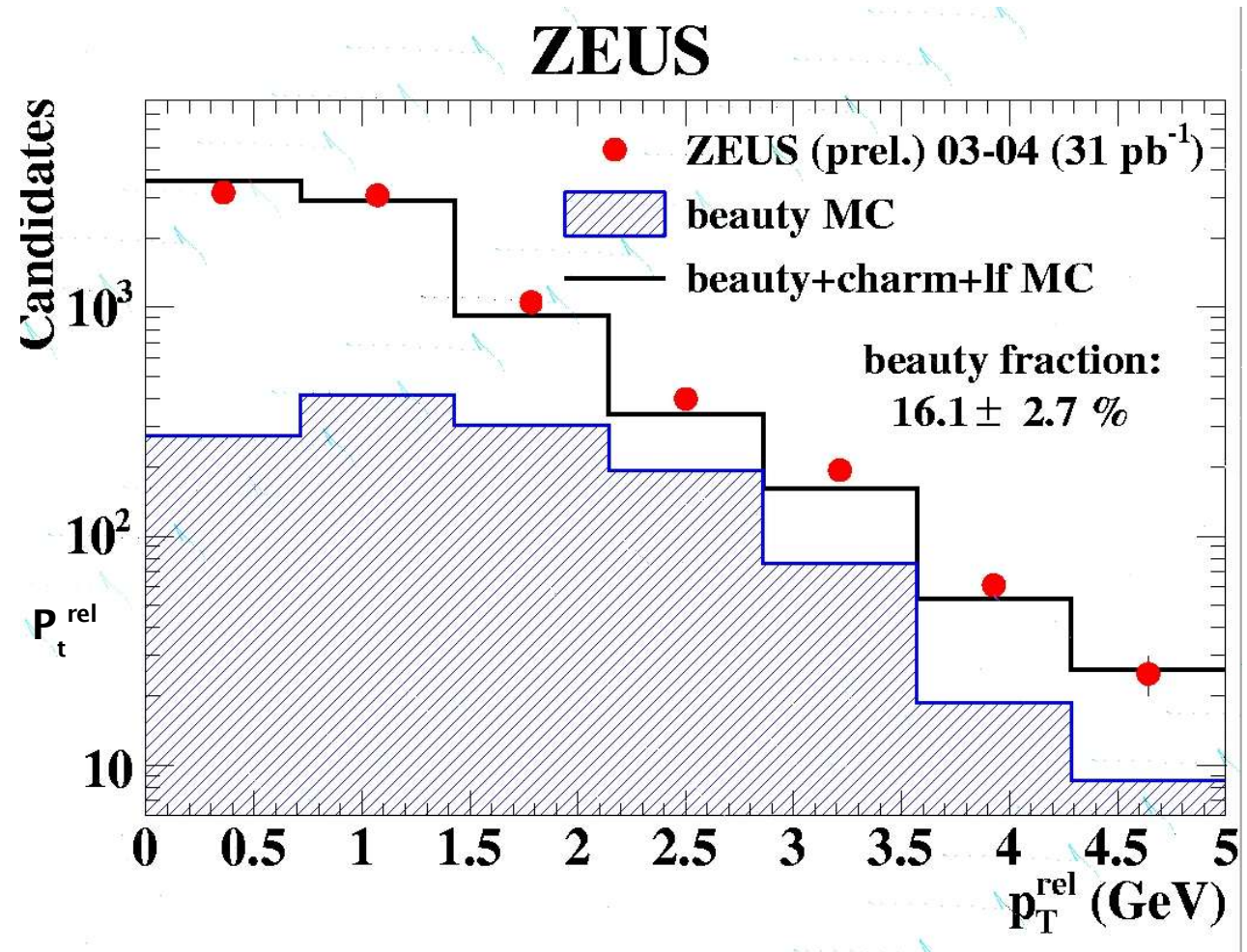
Good agreement between data and Monte Carlo.

# $p_t^{\text{rel}}$ corrections

- $P_t^{\text{rel}}$  method relies on the MC description
- background studies performed in order to improve the knowledge of  $p_t^{\text{rel}}$  distribution
- reduce dependance from MC by taking the data



$P_t^{\text{rel}}$  method: b fraction



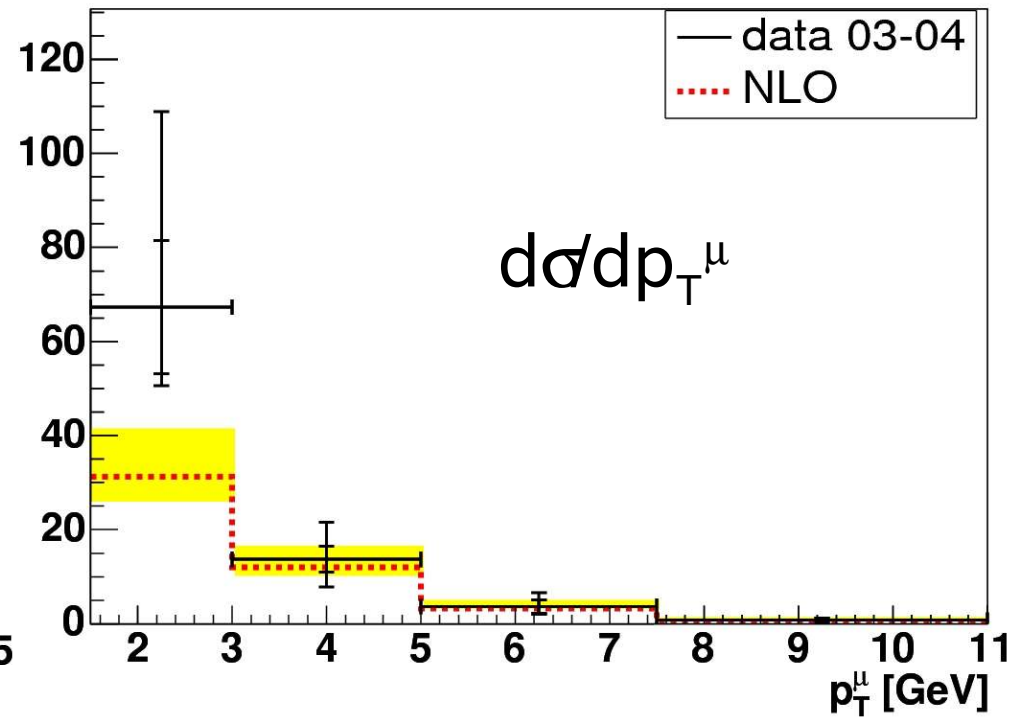
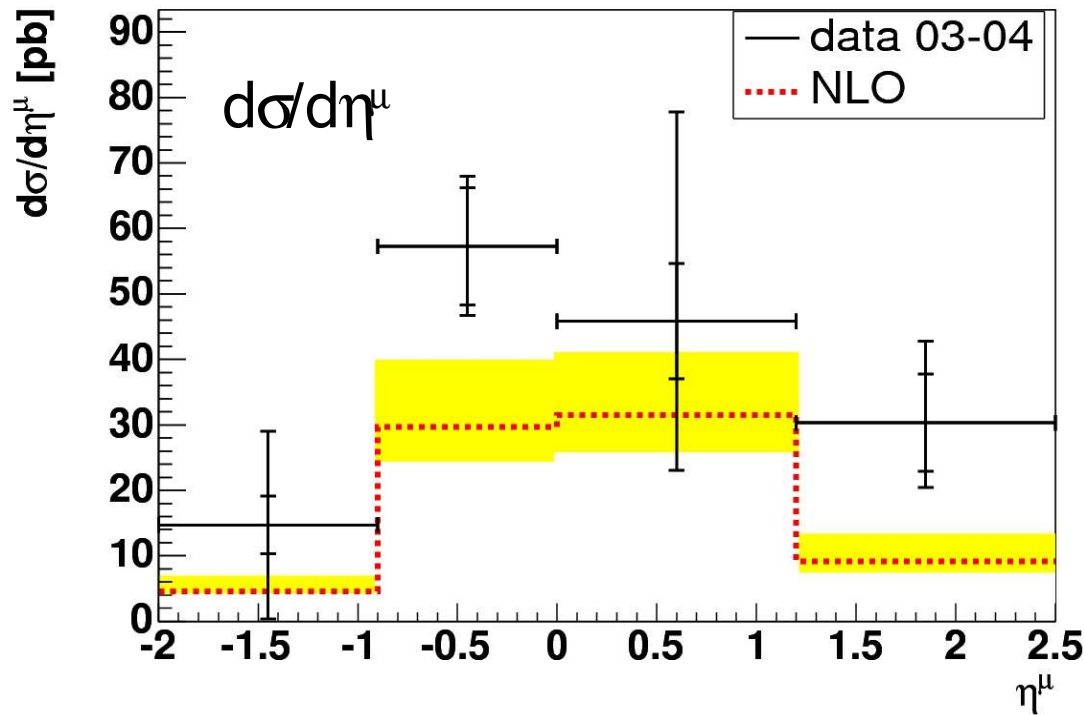
Preliminary  
ICHEP04

**b fraction (16.1 ± 2.7%)**

# $p_t^{\text{rel}}$ cross sections

$$\text{acc} = \frac{N_{\text{reconstructed}}^{\mu}}{N_{\text{true}}^{\mu}}$$

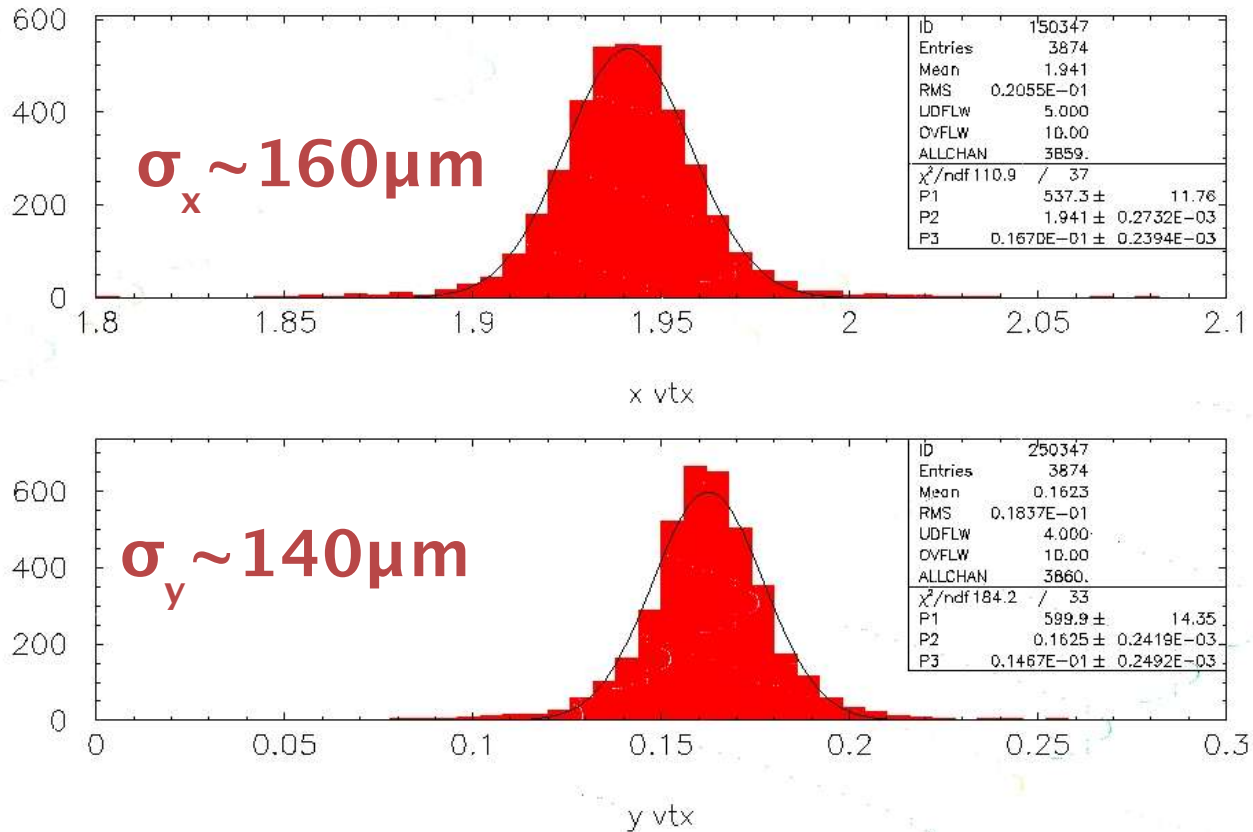
$$\sigma = \frac{N_{\text{data}} \cdot f_{\text{beauty}}}{\mathcal{L} \cdot \text{acc}}$$



measurement compatible to NLO predictions

# Impact parameter method: beam spot

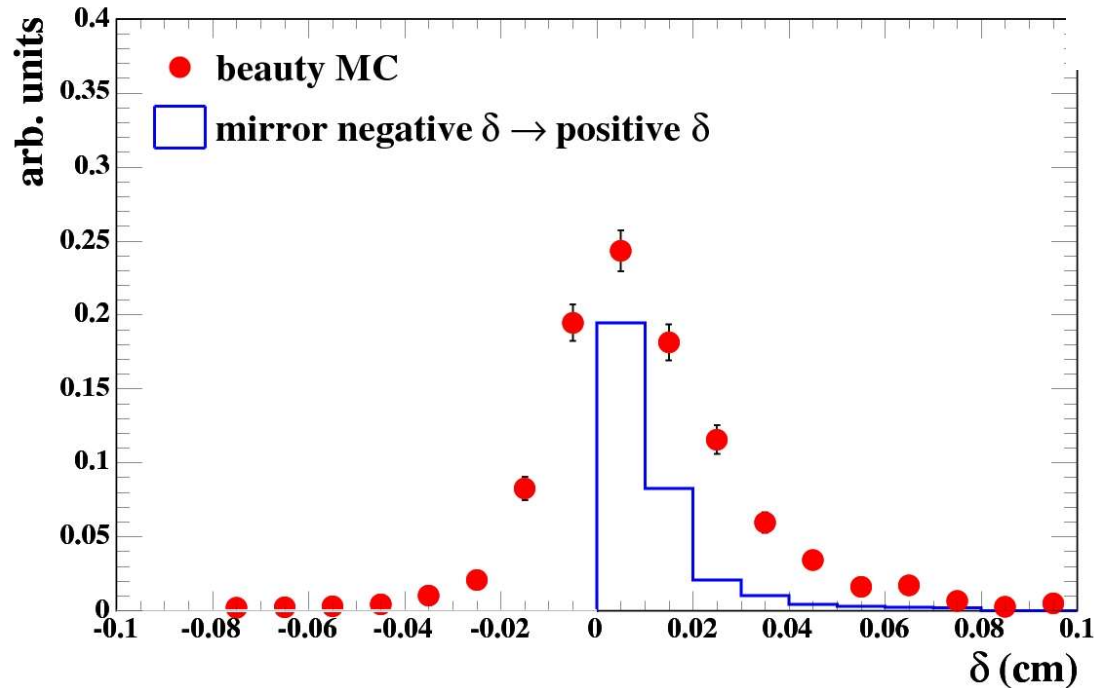
Impact parameter measurement depends on track and primary vertex resolution  $\longrightarrow$  improvement using **average vertex position** over many events



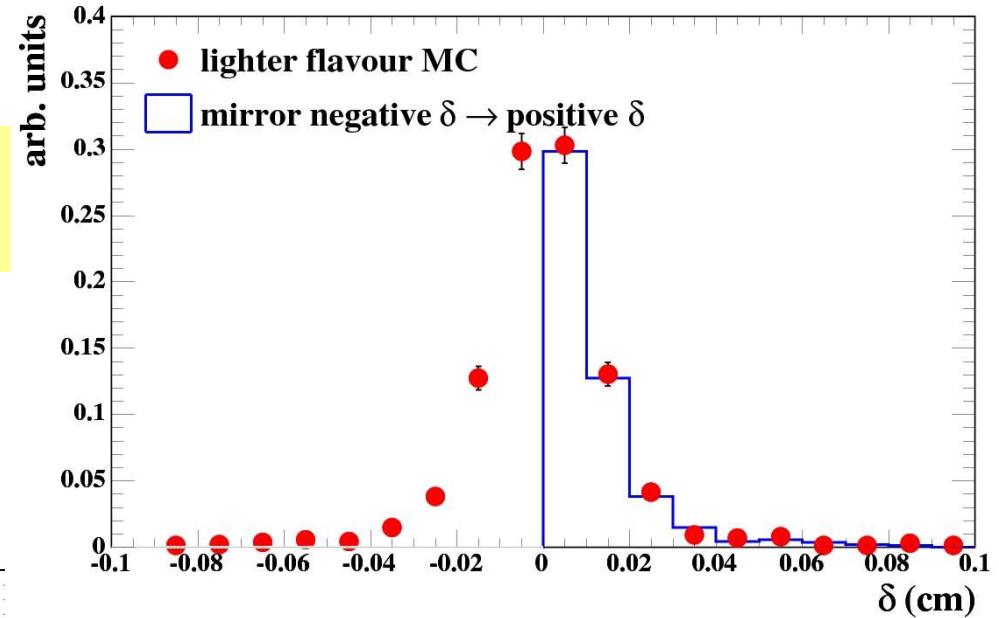
tracks re-referenced to the beam spot instead of the primary vertex

# Impact parameter method

mirrored-subtracted impact parameter distribution



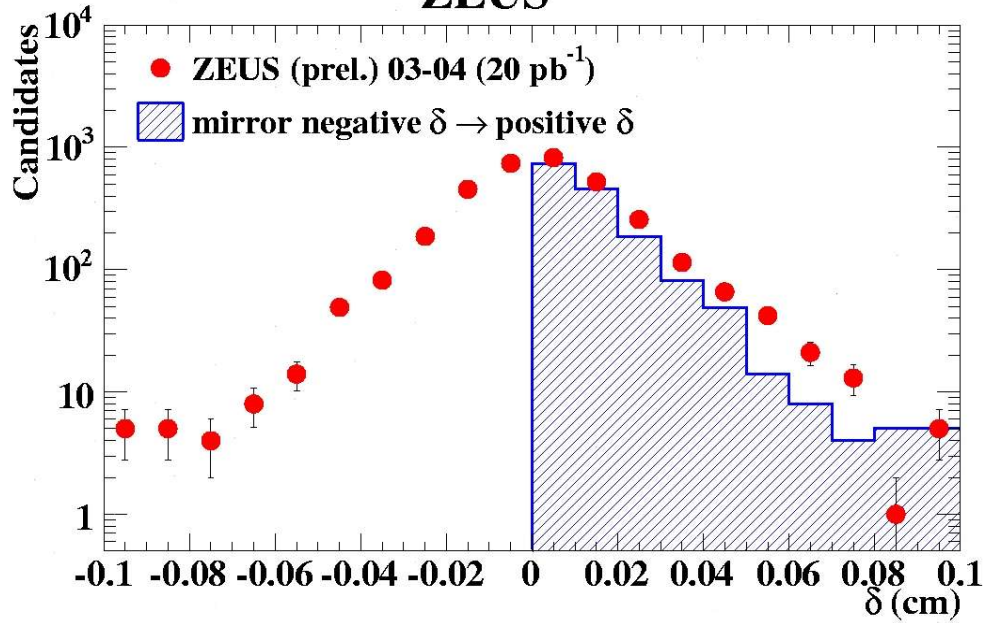
light flavour contribution vanishes



Beauty IP : asymmetric towards higher values

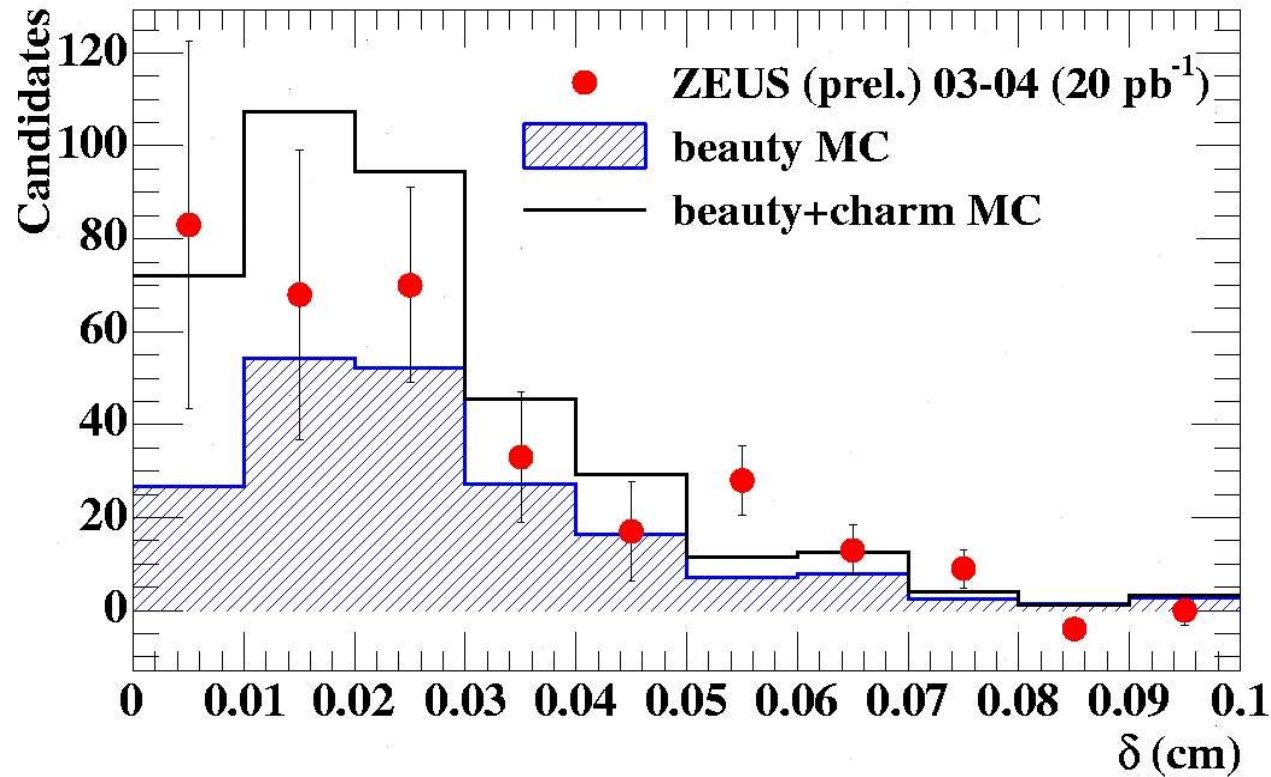
# Impact parameter method

ZEUS



Preliminary  
ICHEP04

ZEUS

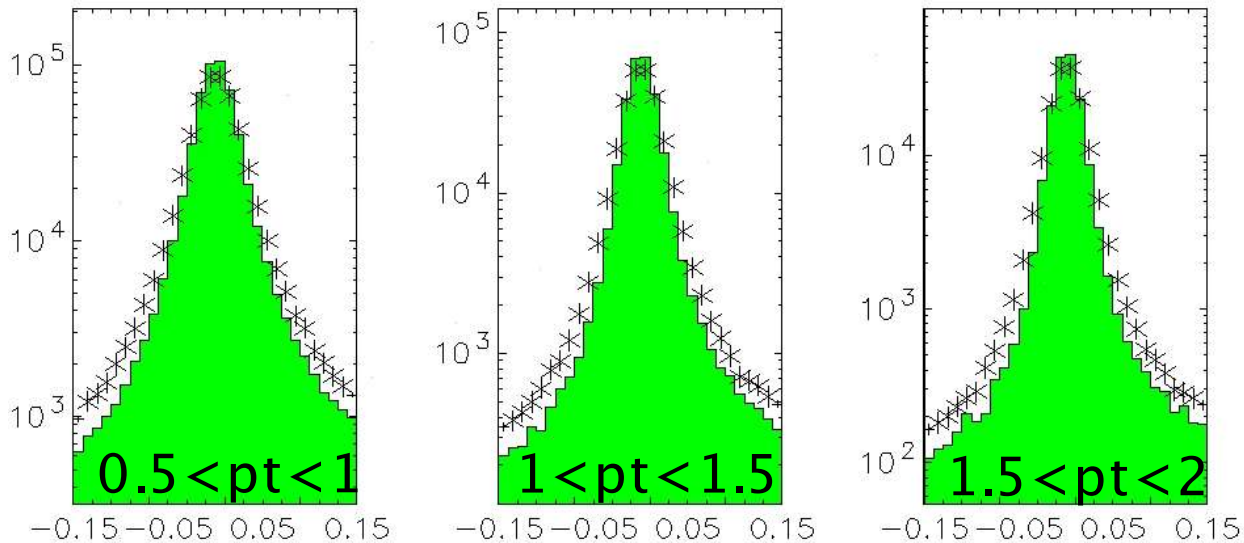


consistent within  
statistical errors



# Impact parameter method

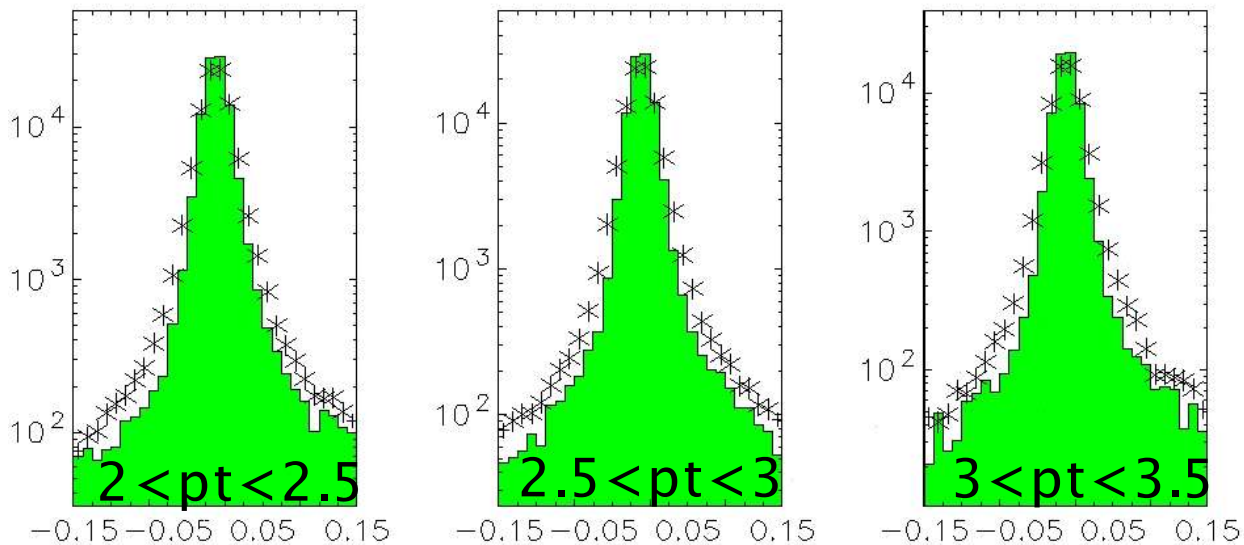
As for  $P_t^{\text{rel}}$  also the impact parameter method relies on the MC description  $\longrightarrow$  background studies



impact parameter

impact parameter

impact parameter



impact parameter

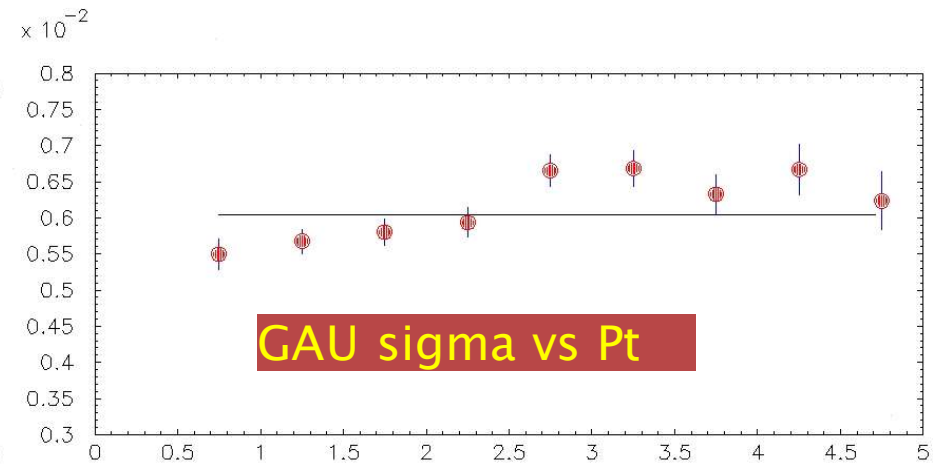
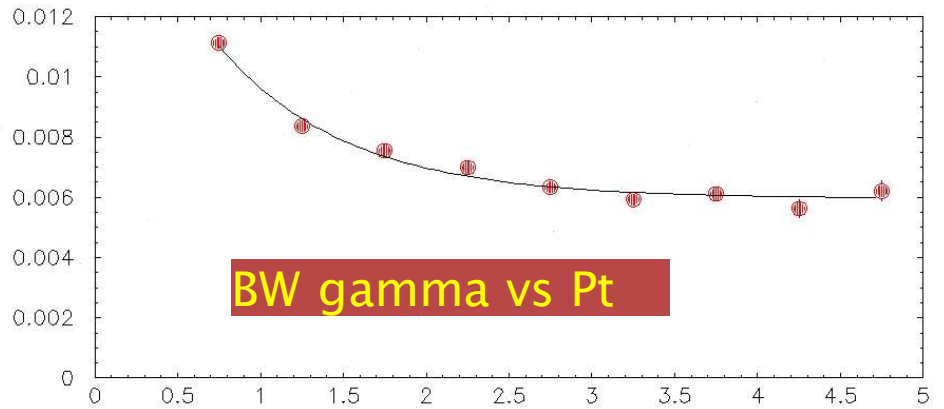
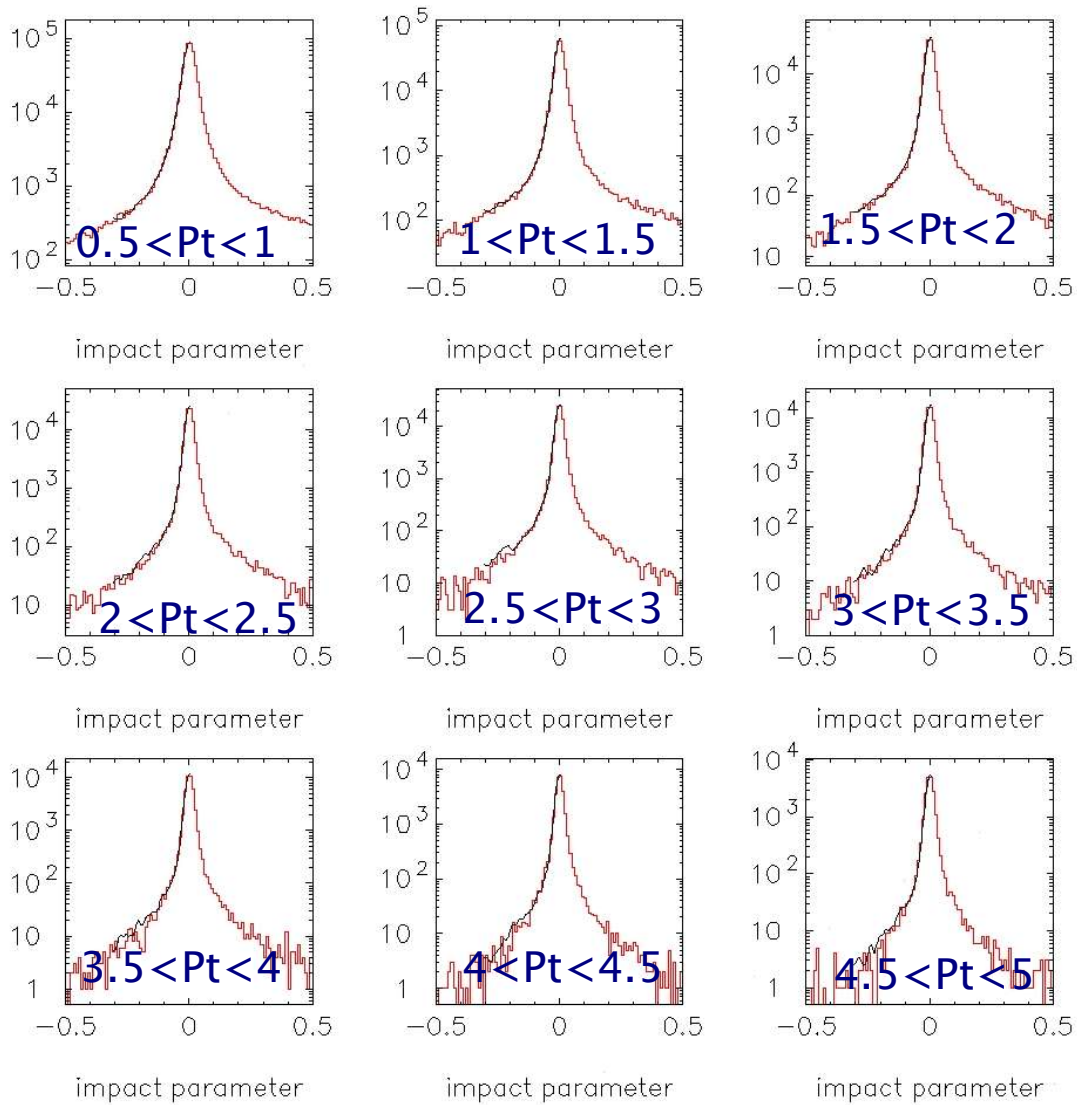
impact parameter

impact parameter

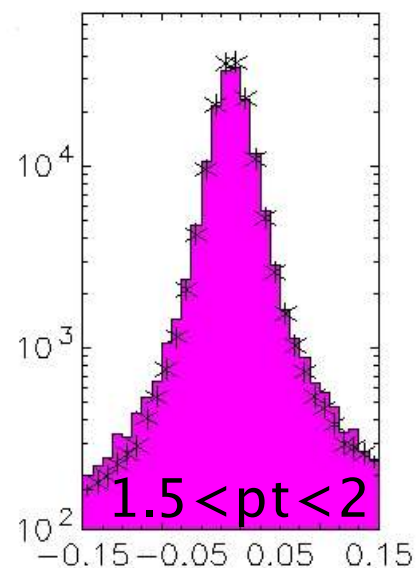
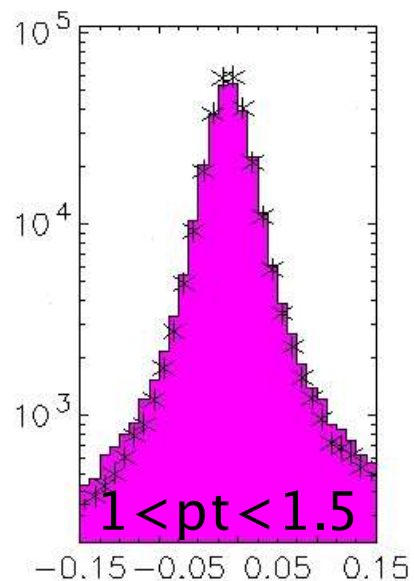
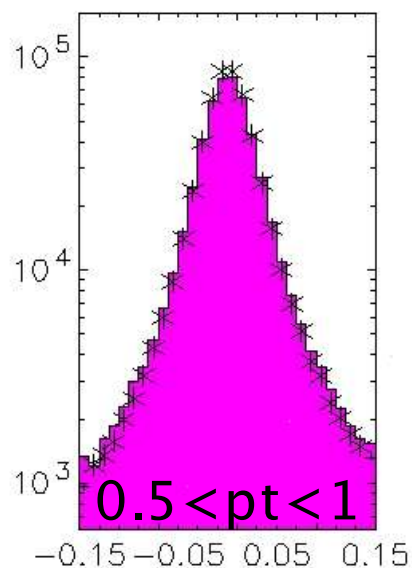
Data have a larger impact parameter distribution w.r.t. MC (dead material, resolution, alignment...)

# Impact parameter: smearing

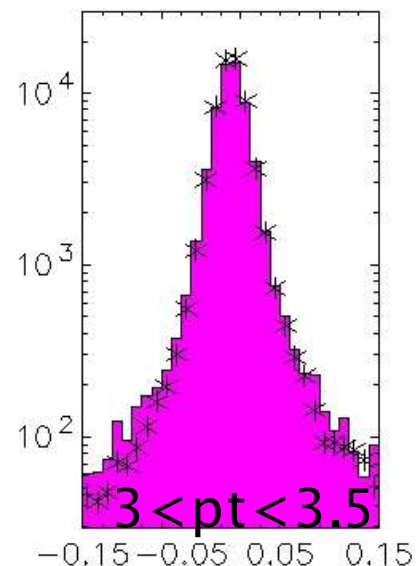
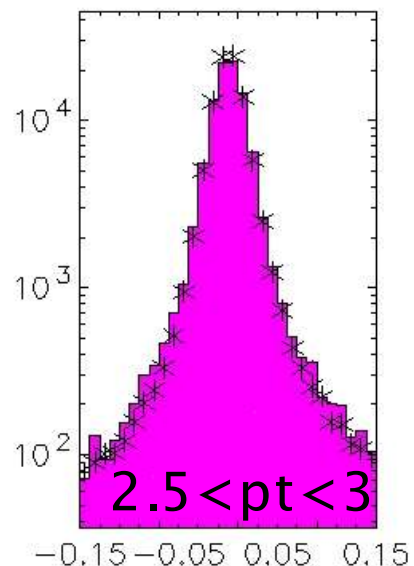
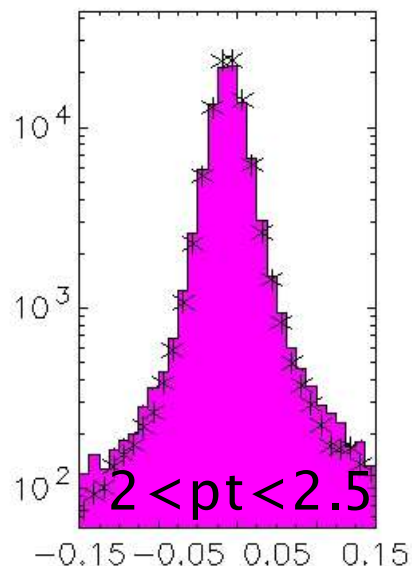
Data fitted with a double convolution:  
**MC $\otimes$ BW $\otimes$ GAUSSIAN**



# Impact parameter: smearing



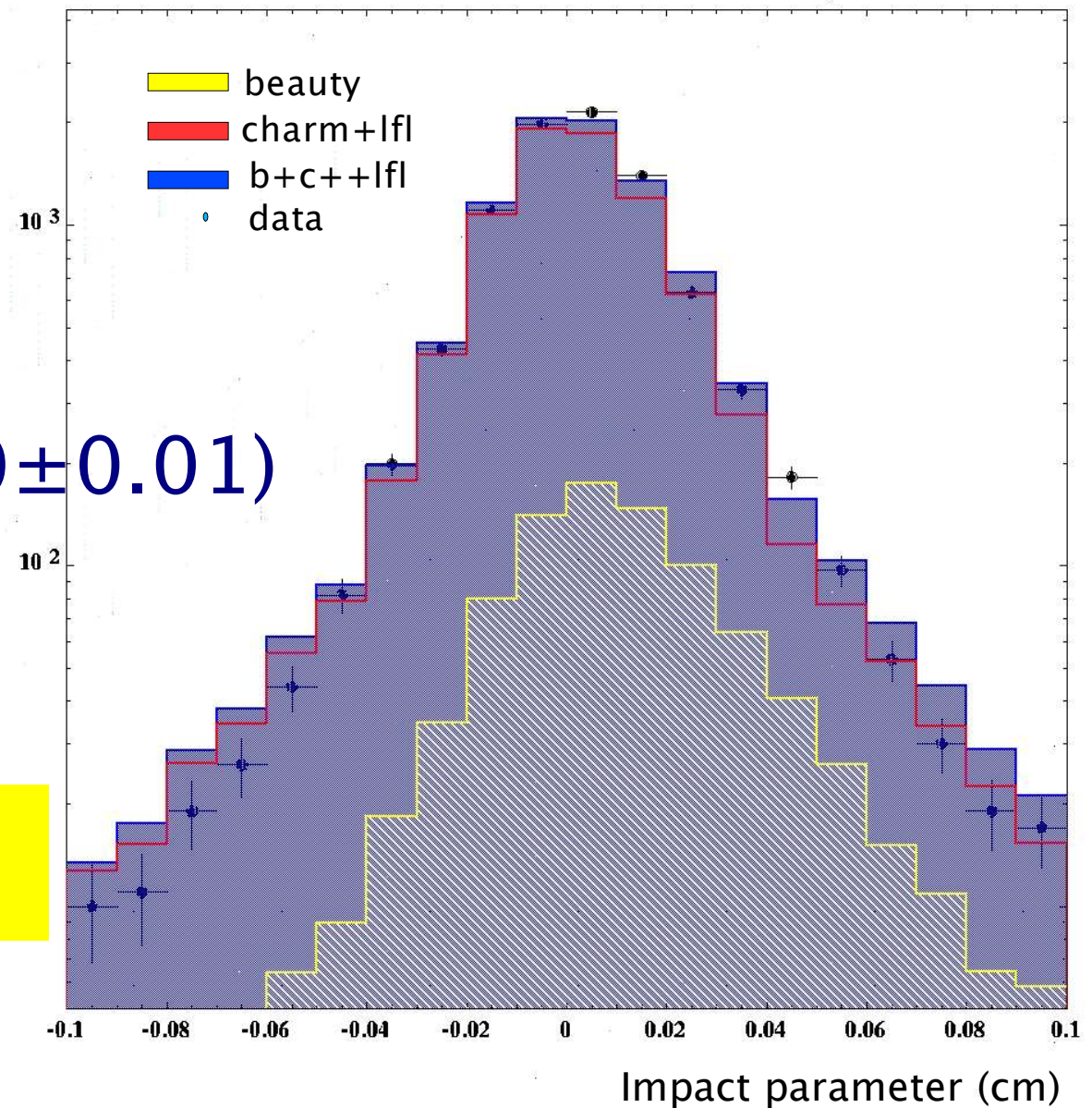
MC description of data largely improved



# Impact parameter: $b$ fraction

Poissonian likelihood fit

$b$  fraction ( $0.10 \pm 0.01$ )



Light flavour contribution over-estimated, MC description to be improved

# Conclusions

## HERA I

- results in reasonable agreement with theory. Only large  $b$  mass value ( $P_t^{\text{rel}}$ ) exploited

## HERA II

- Improved detector performances (MVD)
- Both long lifetime (impact parameter) and large mass ( $P_t^{\text{rel}}$ ) are used for  $b$  tagging
- First measurement of **cross sections** using  **$p_t^{\text{rel}}$  method** in agreement with NLO QCD. Statistics to be increased.
- First measured **impact parameter** distribution exhibits an **enhancement at positive values**. This is found to be compatible with coming from beauty and charm quarks and the beauty fraction determined by the  $P_t^{\text{rel}}$ -fit
- Cross sections measured combining both methods are coming soon...

# Cross section NLO comparison

- NLO calculation: FMNR

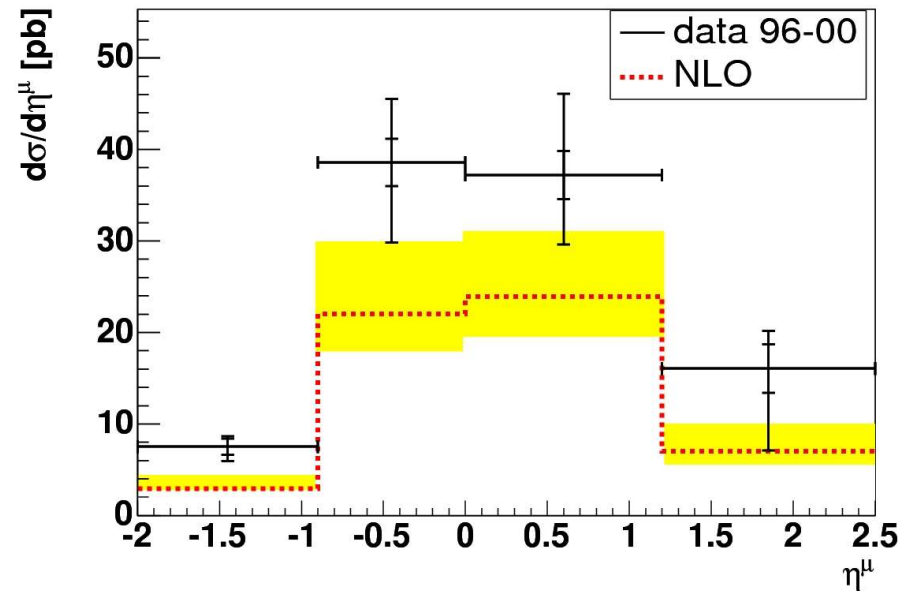
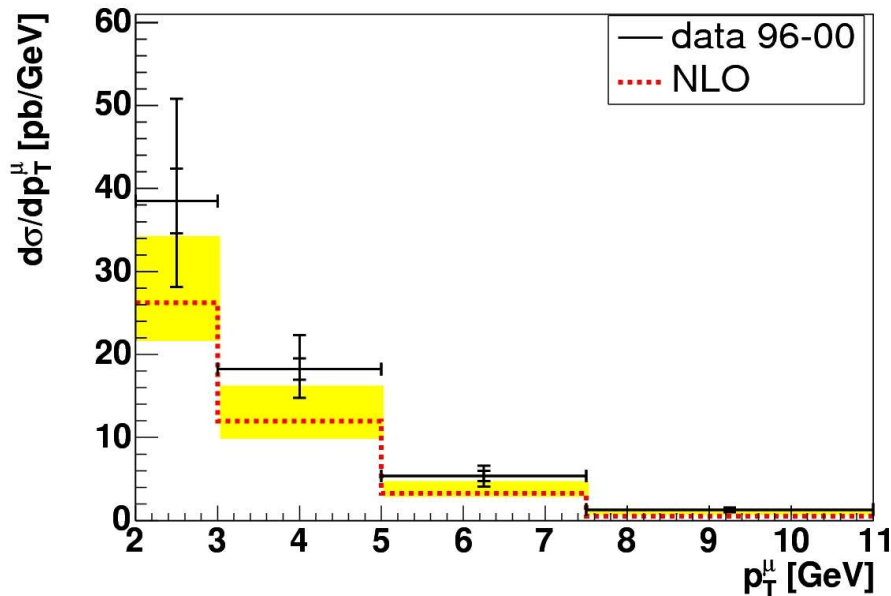
- beauty mass: 4.75 GeV
- proton pdf: CTEQ5m, photon pdf: GRV-HO

- dominating theoretical systematic error

- change in scales by factor 0.5 and 2 and change in beauty mass between 4.5 and 5.0 GeV

- scales

$$\mu_R = \mu_F = \langle m_T \rangle = \sqrt{\frac{1}{2} \left( (p_T^b)^2 + (p_T^{\bar{b}})^2 \right) + m_b^2}$$



- dominating systematic error of measurement (not final yet):

- normalization of charm contribution

- comparison to NLO:

- compatible within errors but slightly higher

# Event and trigger selection

## vertex:

- $-40\text{cm} < z_{\text{vertex}} < 40\text{cm}$

## photoproduction selection :

reject event if electron candidate with:

- $\text{Prob}_e > 0.9$
- $E_e > 5 \text{ GeV}$
- $y_{\text{el}} < 0.9$

## zufos:

- $0.2 < y_{\text{JB}} < 0.8$

## calorimetry:

- $E_T$  minus 2 inner rings  $\geq 10 \text{ GeV}$
- $p_T/E_T < 0.5$

## tracking:

- number of vertex tracks  $> 2$
- number of total tracks / number of vertex tracks  $\leq 10$

## jet selection:

at least two jets found with kt algorithm in E recombination scheme (massive mode) (3211) with:

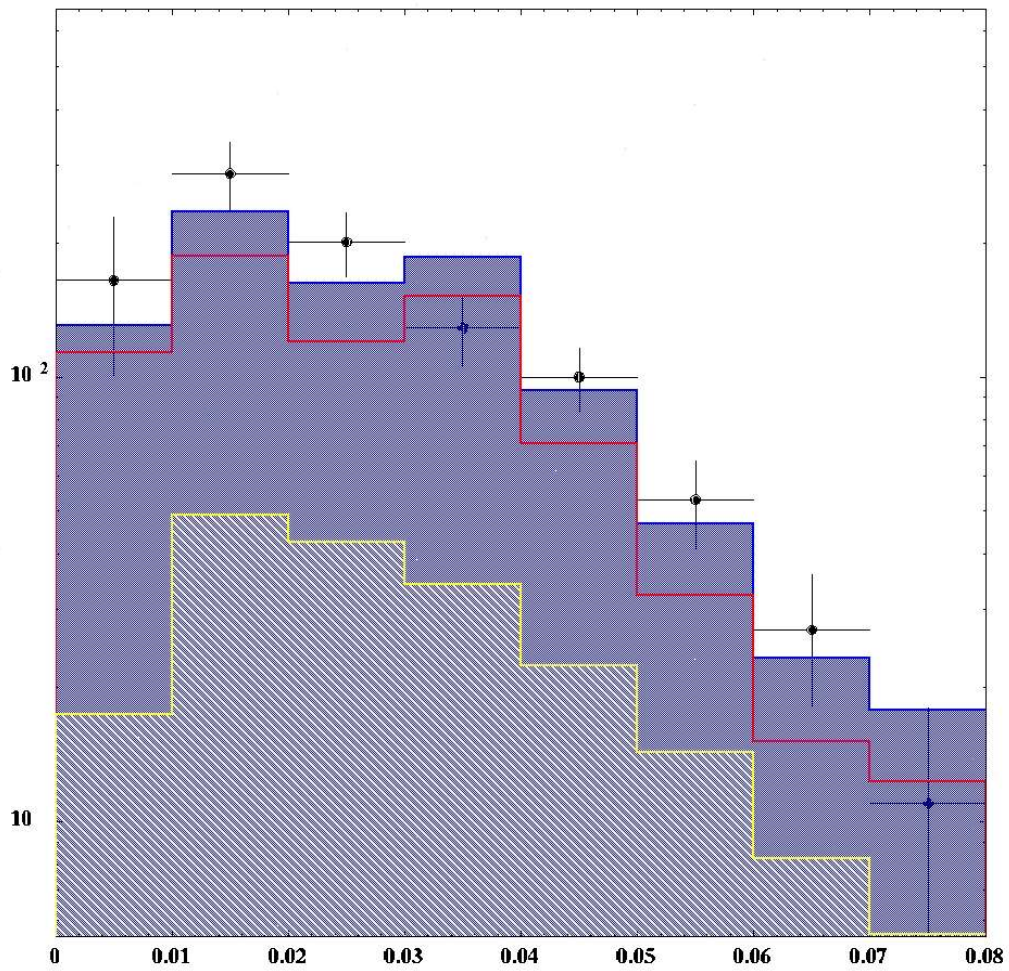
- $|\eta| < 2.5$
- $p_T^{1(2)} > 7(6) \text{ GeV}$

## $p_T^{\text{rel}}$ calculation

- using all jets with:
  - $p_T^{\text{jet}} > 6 \text{ GeV}$
- using events with
  - $p_T^{(\text{jet-})} > 2 \text{ GeV}$

## trigger

- TLT HFL5, HFL13, HFL25



chi2 fit

chi2=5.6

$f_b = 0.19 \pm 0.37$

$f_{\text{bkg}} = 0.73 \pm 0.41$



- **Total luminosity: 31.03 pb<sup>-1</sup>**
- used MC
  - beauty:
    - direct (39.37 pb<sup>-1</sup>)
    - resolved (70.71 pb<sup>-1</sup>)
    - excitation in photon (55.86 pb<sup>-1</sup>)
    - excitation in proton (65.40 pb<sup>-1</sup>)
  - charm:
    - direct (29.92 pb<sup>-1</sup>)
    - resolved (96.48 pb<sup>-1</sup>)
    - excitation in photon (26.44 pb<sup>-1</sup>)
    - excitation in proton (27.07 pb<sup>-1</sup>)
  - charm (one muon preselection):
    - direct (20.60 pb<sup>-1</sup>)
    - resolved (88.29 pb<sup>-1</sup>)
    - excitation in photon (23.05 pb<sup>-1</sup>)
    - excitation in proton (27.07 pb<sup>-1</sup>)
  - light flavours (heavy flavours rejected):
    - direct (9.92 pb<sup>-1</sup>)
    - resolved (10.06 pb<sup>-1</sup>)