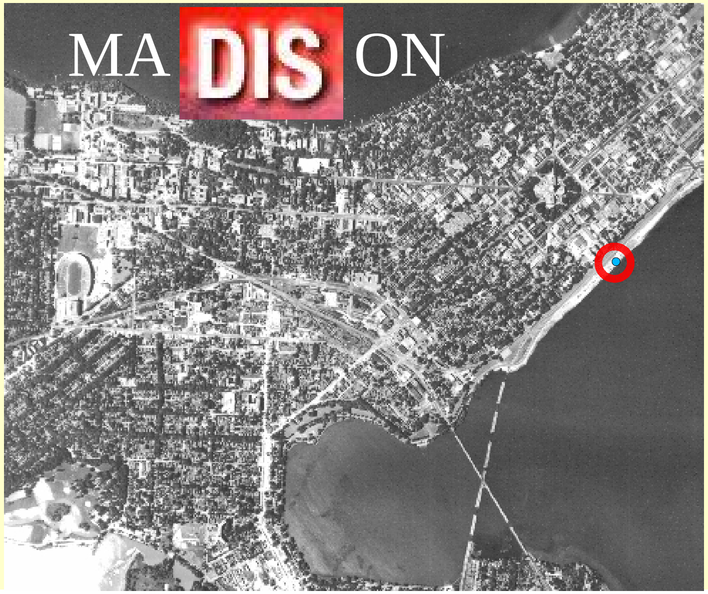
DIS05

XIII International Workshop on Deep Inelastic Scattering

Madison, Wisconsin U.S.A.

29 April 2005



Measurement of beauty production from μμ correlations

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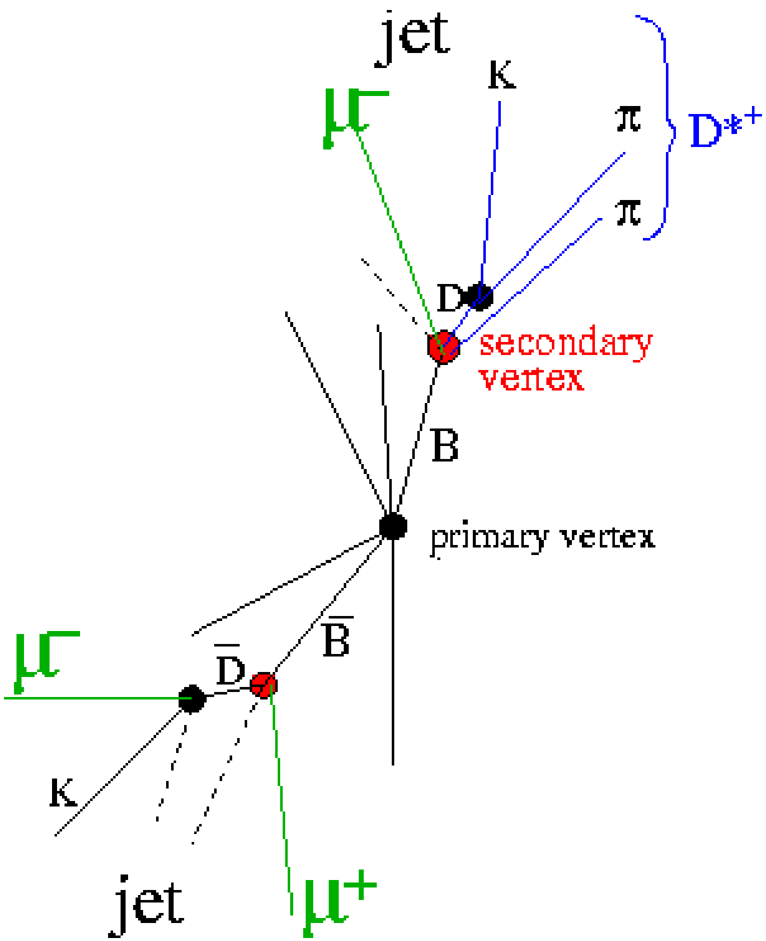
Outline

- Double-tag *b* analyses: motivation and goals
- previous results reminder : μD^{*} analysis
- $\mu\mu$ analysis
  - ✗ Signal topologies
  - ✗ Selection cuts
  - ✗ Normalisations and background-method
  - ✗ Visible & total $b\bar{b}$ cross-section
- Conclusions and Outlook

Motivation and goals

multi-tagged $b\bar{b}$ event



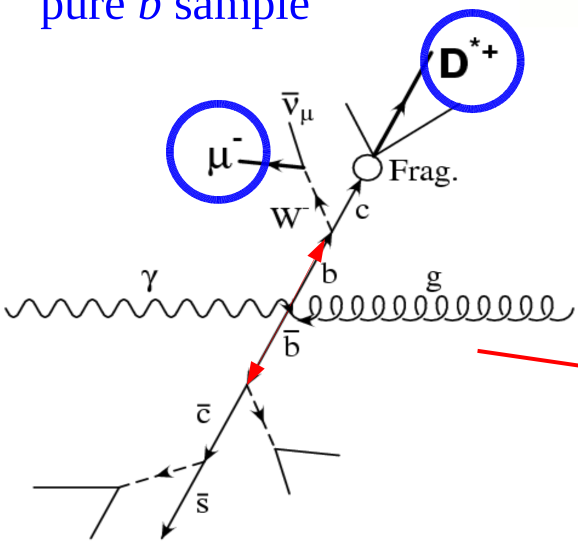
- Double tag *b*-analyses (μμ, μD*): low bckg
  - → low muon p_T cuts
  - → sensitive even to B mesons ~ "at rest"
- Rear and Forward μ–detectors
  - → almost full rapidity coverage

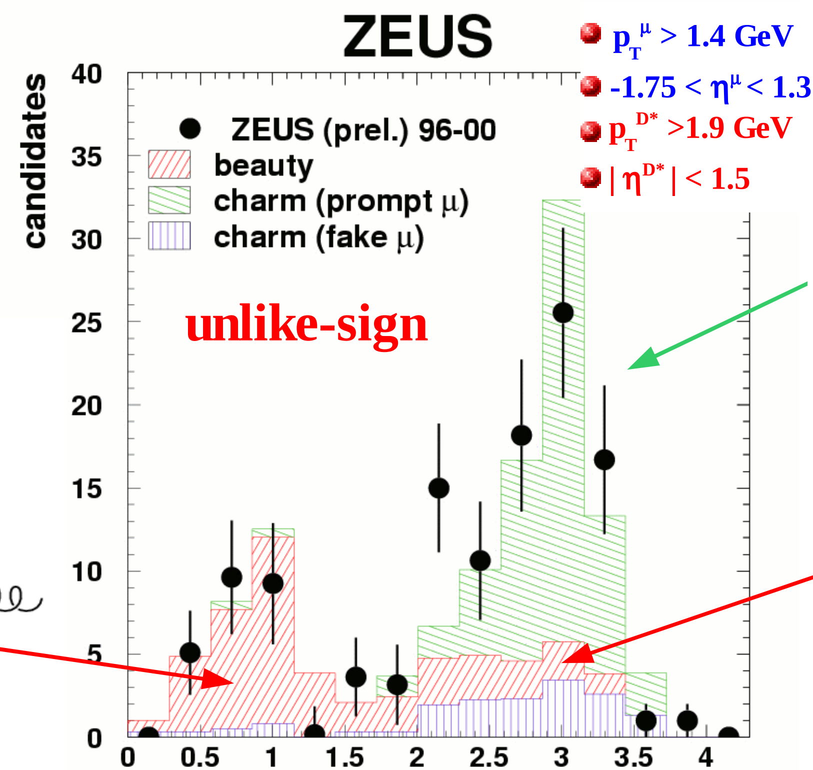
direct measurement of <u>total</u> $b\bar{b}$ cross section without cuts ✓

- **statistic significance is already good**
- **tagging both b quarks (μμ)**
  - → **explicitly measure $b\bar{b}$ correlations** ○

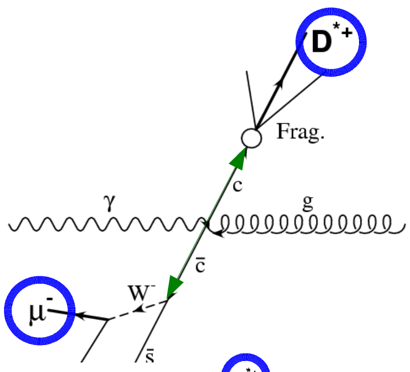
Previous "double-tag" *b* results : μD*

• unlike-sign μD* pairs produced in the same hemisphere: pure *b* sample

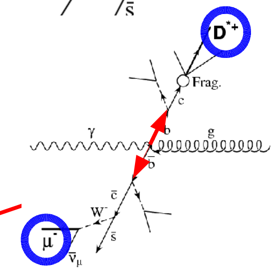


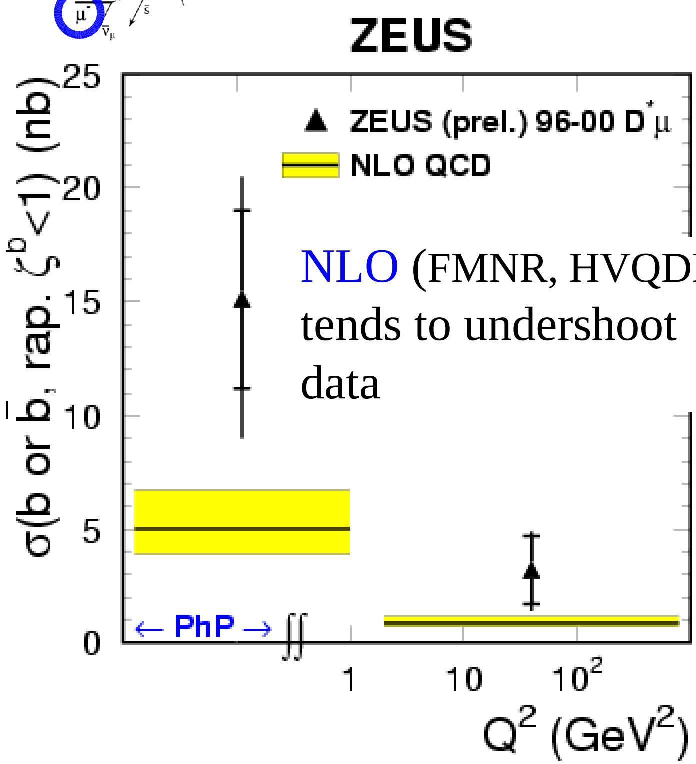


$\Delta R \stackrel{def}{=} \mu D^*$ distance in η–ϕ plane



b cleanly separated from high ΔR charm background





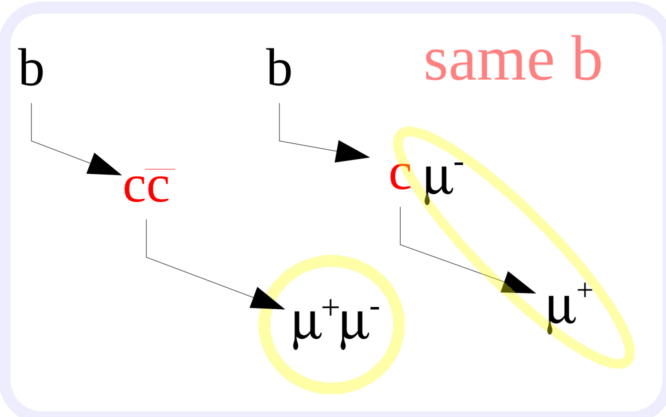
NLO (FMNR, HVQDIS) tends to undershoot data

• Measured *b*-level cross sections separately in DIS ($Q^2>2$ GeV², $0.05<y<0.7$) and PHP ($Q^2<1$ GeV², $0.05<y<0.85$) for *b*-rapidity $\zeta_b < 1$ (& whole p_T range)

σ_{PHP} = **15.1** ± 3.9 (stat.)$^{+3.8}_{-4.7}$(sys.) nb
σ_{DIS} = **3.2** ± 1.5 (stat.) $^{+0.9}_{-1.0}$(sys.) nb

σ_{PHP} = **5.0** $^{+1.7}_{-1.1}$ nb
σ_{DIS} = **0.87** $^{+0.28}_{-0.16}$ nb

Signal topologies and data sub-samples



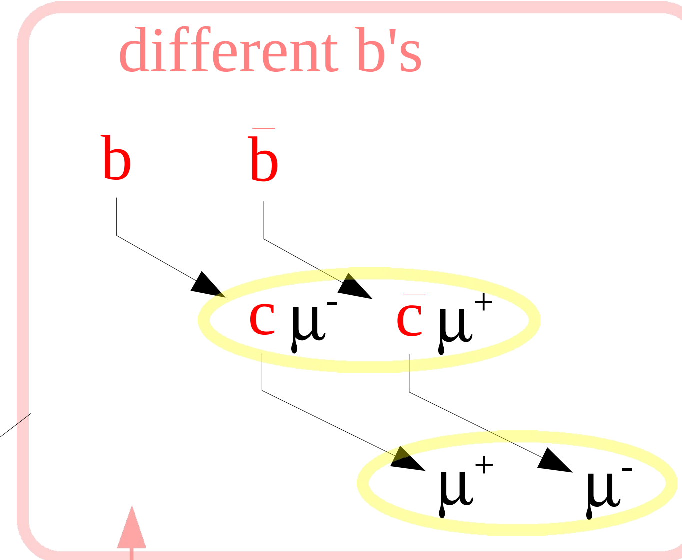
Mass + charge:

→ **4 regions**

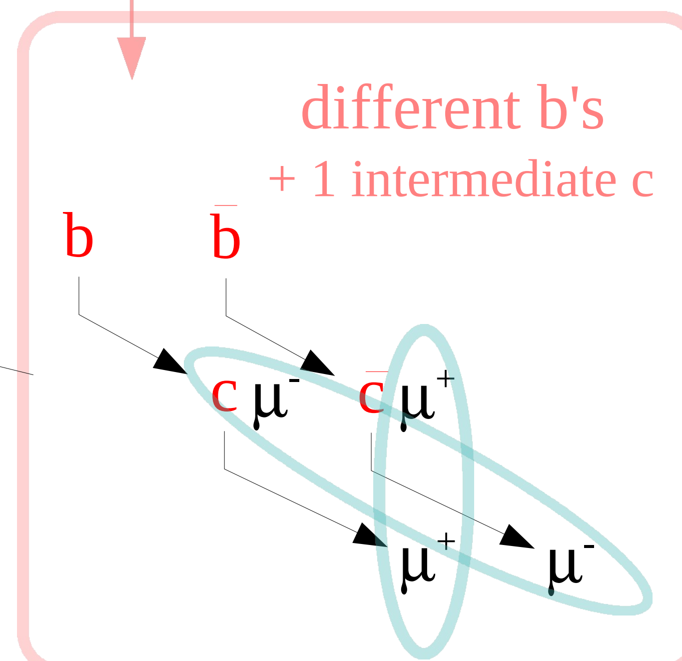
	low mass	high mass
unlike-sign	$m_{\mu\mu}$ < 4 GeV $\pm\ \mp$	$m_{\mu\mu}$ > 4 GeV $\pm\ \mp$
like-sign	$m_{\mu\mu}$ < 4 GeV $\pm\ \pm$	$m_{\mu\mu}$ > 4 GeV $\pm\ \pm$

4 GeV ~ *B* mass – hadrons / νs

Mainly light flavour background

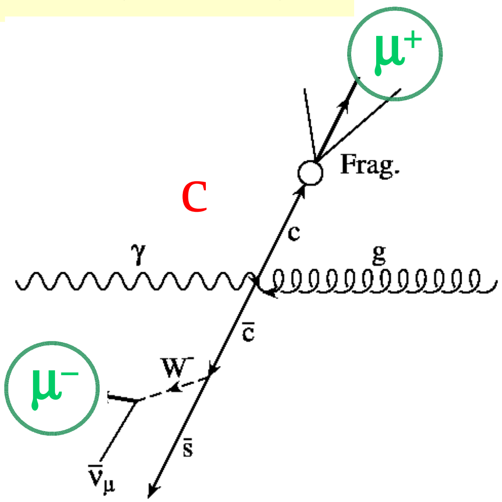


$B^0\bar{B}^0$ mixing

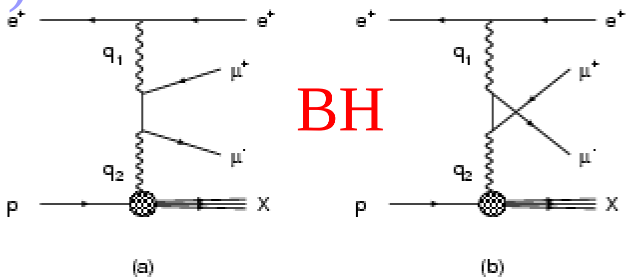


Backgrounds (bg) and Monte Carlo (MC)

di-μ backgrounds



- open *c* production (from μD* sample, see later)
  - *high mass, unlike-sign*
- hidden *c* (J/ψ, ψ´) (isolation cut, see later)
  - *low mass, unlike-sign*
- Bethe-Heitler processes (BH) (isolation cut, see later)
  - *high mass, unlike-sign*
- fake μ (~ light flavour bg) (from data), cosmics



Monte Carlo samples

- **beauty and charm: RAPGAP** ($Q^2 > 1$ GeV) & **PYTHIA** ($Q^2 < 1$ GeV)
- J/ψ, ψ´, Y, BH each DIS/PHP from various generators

  - μ and trigger efficiency corrections from data applied

Main selection cuts

Data sample L = 121 pb $^{-1}$ ***HERA I data, 96-00***

Event selection

- **Online:** ***combination of μ, hadr-charm, di-jet and DIS triggers***
- **Calorimeter :** $E_T^{-10^o\,beam} - E_T^{elec.} > 8$ GeV (~ $2\,m_b$ - missing νs)

↘ charm
↗ beauty

- **di-μ background cleaning cuts**

p_T asymmetry < 0.7 $\Delta\eta < 3$

$0.1 < p_T(\mu_1+\mu_2) / E_T < 0.7_{high-} / 0.5_{low-mass}$

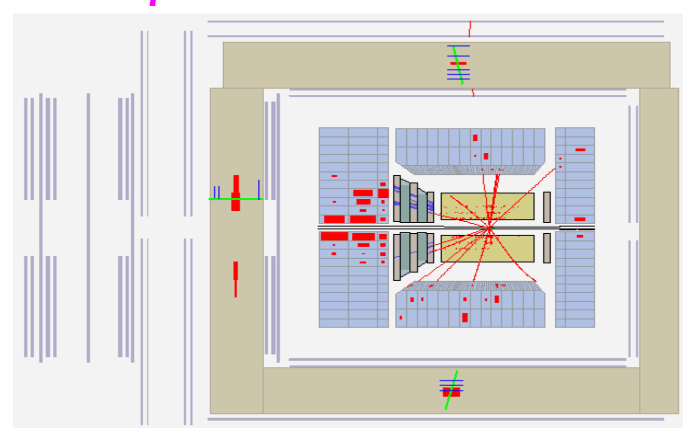
$|Z_{vtx}| < 50$ cm

μ selection

$-2.2 < \eta \overset{def}{=} -\ln \tan \frac{1}{2}\theta < 2.5$

- **2 μ with a μ-finder integrating various detectors**

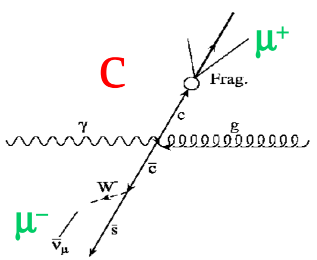
Barrel-Rear Muon chambers (inner or outer), Forward muon chambers,
Instrumented Iron Yoke, supplemented by Calorimeter (m.i.p.s)

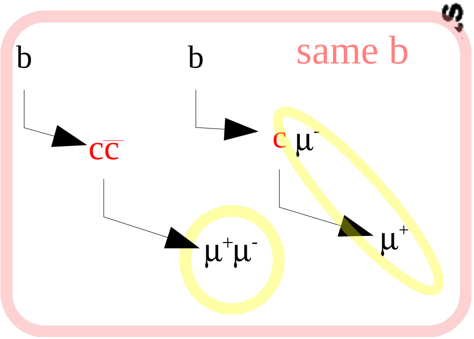


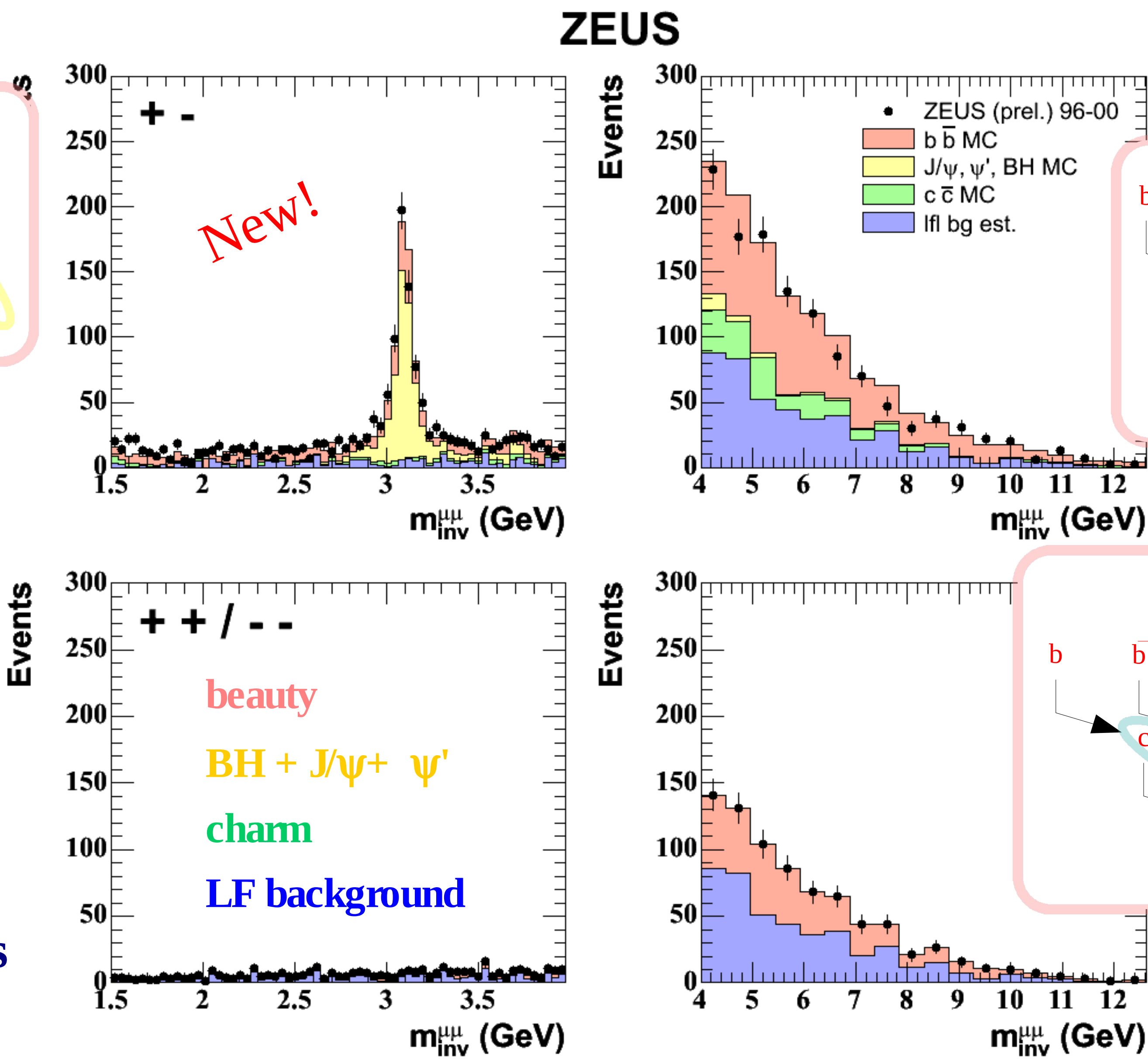
$p_T(\mu) > 0.75$ GeV for "high quality" μ (several det.s)

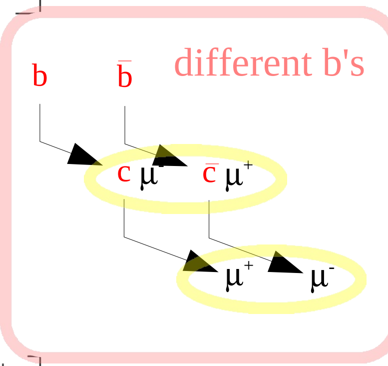
$p_T(\mu) > 1.5$ GeV for "lower quality" μ (one det. only)

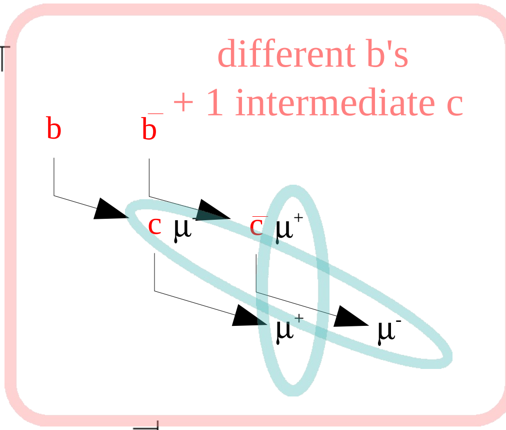
di-μ mass distributions







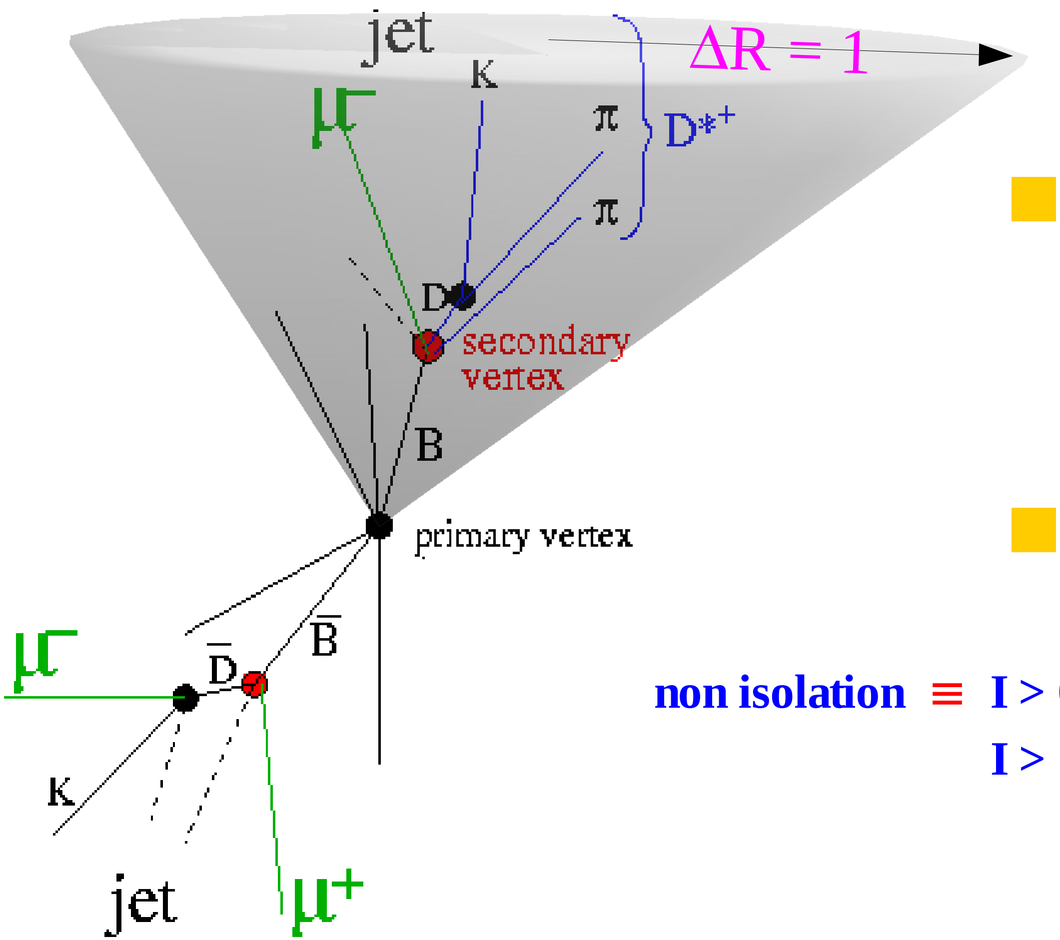




- good MC description
- ***b* contribution:**
  - ✓ **~ 2000 events**

- signal and background normalisation: see next slides ↪

Isolation cuts



- **μ from *b* accompanied by hadrons**
  → non-isolated

- for each μ:
  ∑ E = sum of energies (CAL + tracking info)
  in cone of $\Delta R\ (= \sqrt{\Delta\phi^2+\Delta\eta^2}\ ) < 1$ around μ
  (excluding μs)

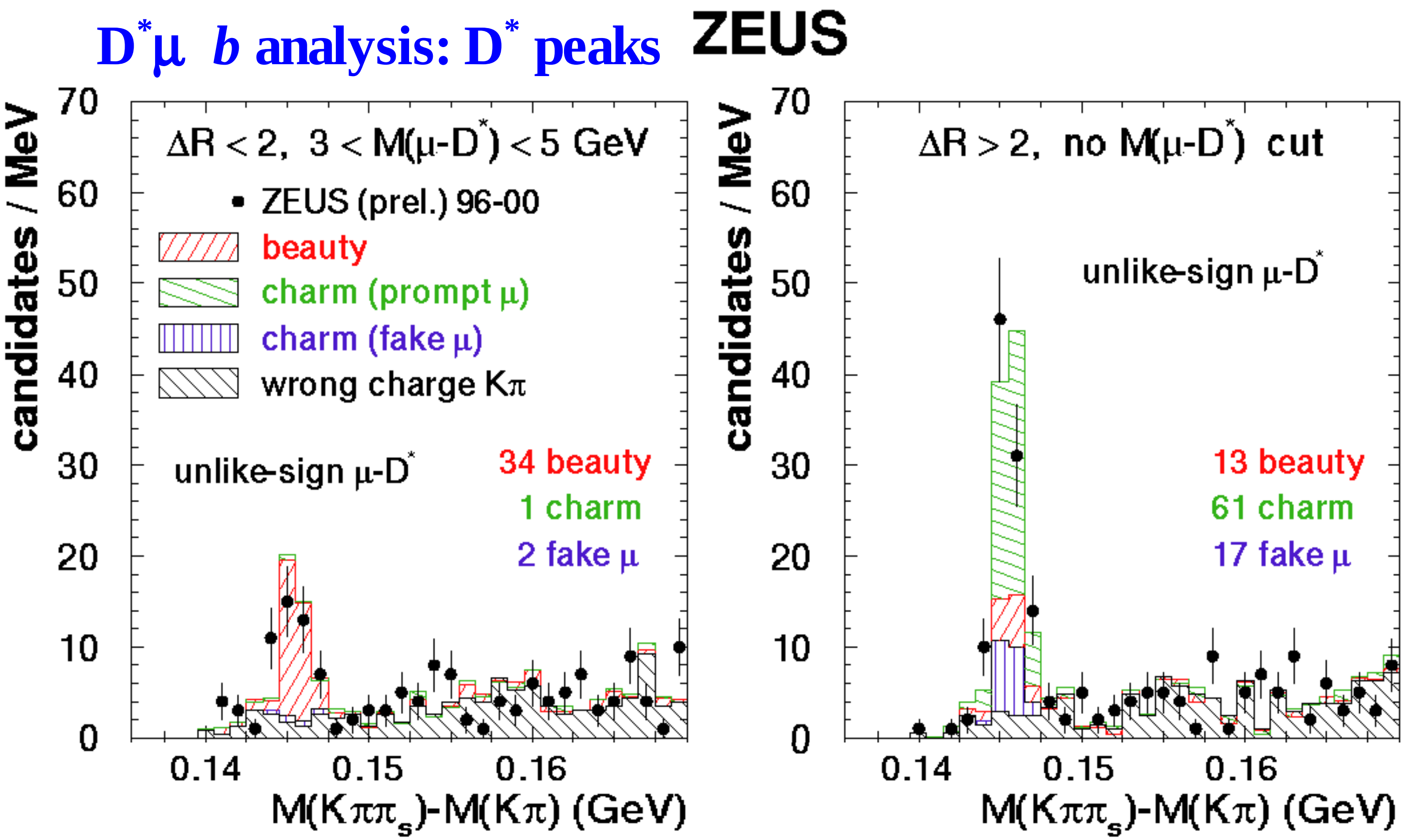
- **di-μ isolation $I \equiv \sqrt{\sum E_1^2 + \sum E_2^2}$**

non isolation ≡ I > 0.25 GeV
I > 2.0 GeV in J/ψ-ψ´ mass region
(2.9-3.25, 3.6-3.75)

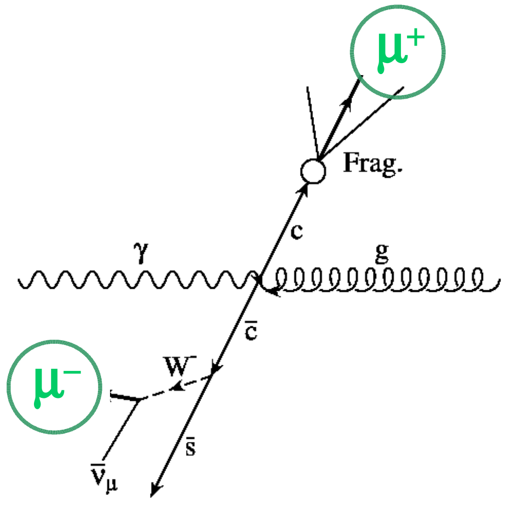
- **BH, elastic J/ψ,ψ' background easily constrained by using the isolated di-μ samples**

Charm background normalisation

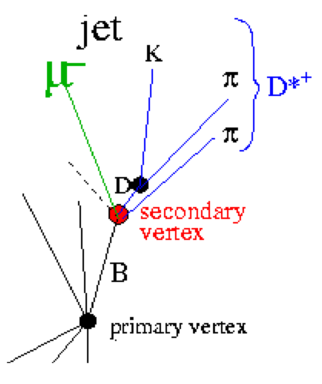
D*μ *b* analysis: D* peaks

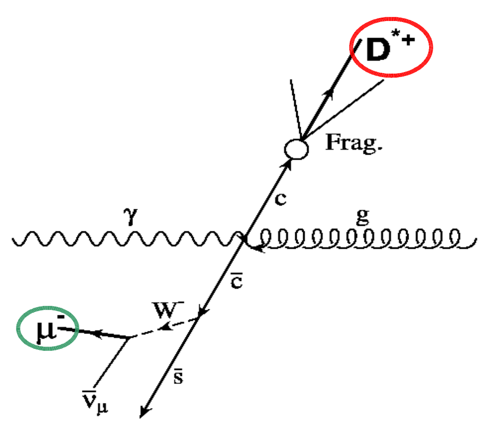


di-μ : charm bg



non-isolated unlike-sign





- **D*μ** analysis: *c* is well separated
- clean correlated *cc* data sample
- **D*μ topology very similar to μμ**

→ μμ charm MC normalised to D*μcharm data sample

Light flavour bg method and signal normalisation

Light flavour (LF) background for the non-isolated high mass sample:

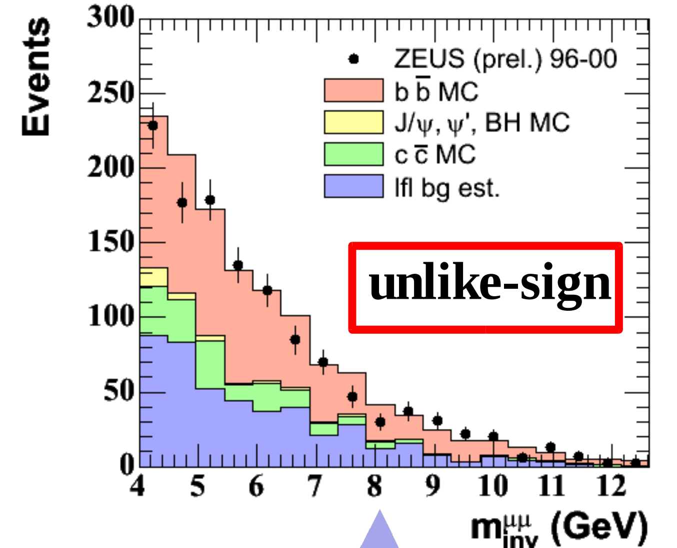
obtained from the like-sign data (would require fully inclusive PHP MC sample!)

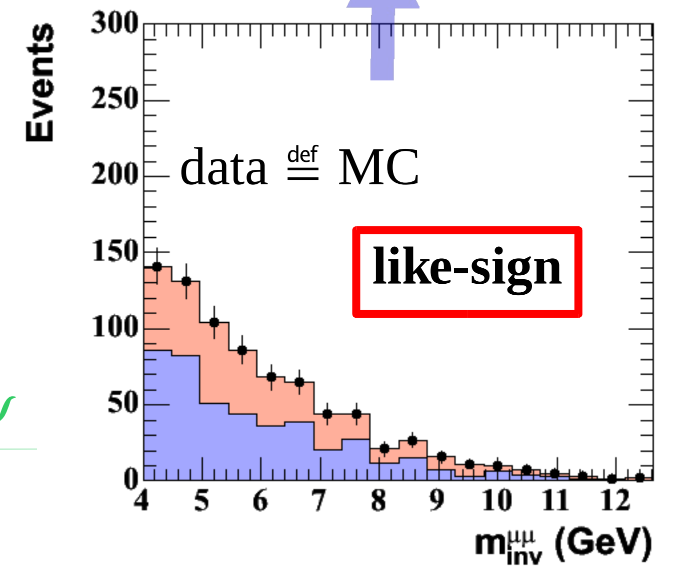
- **Like-sign : just beauty** & **LF bg**

→ LF **bg** $\stackrel{def}{=}$ **data - beauty MC**

- Assumption:
  LF **bg unlike-sign = LF bg like-sign**

  tested to hold to high degree on a on dedicated bg sample (loose μ quality cuts). O**nly small mass dependent correction needs to be applied.**





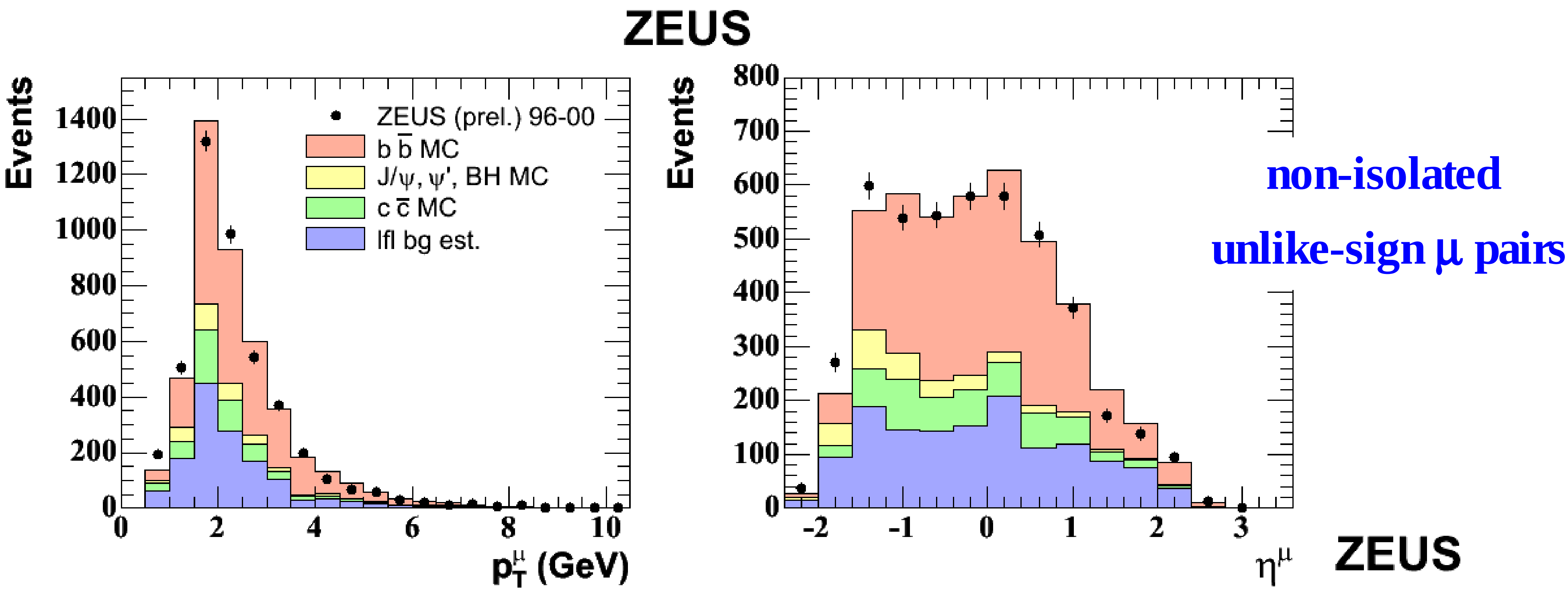
- charm + BH + J/ψ+ ψ' fixed

→ vary **beauty MC** normalisation to fit unlike-sign data

→ **obtain *b* contribution**

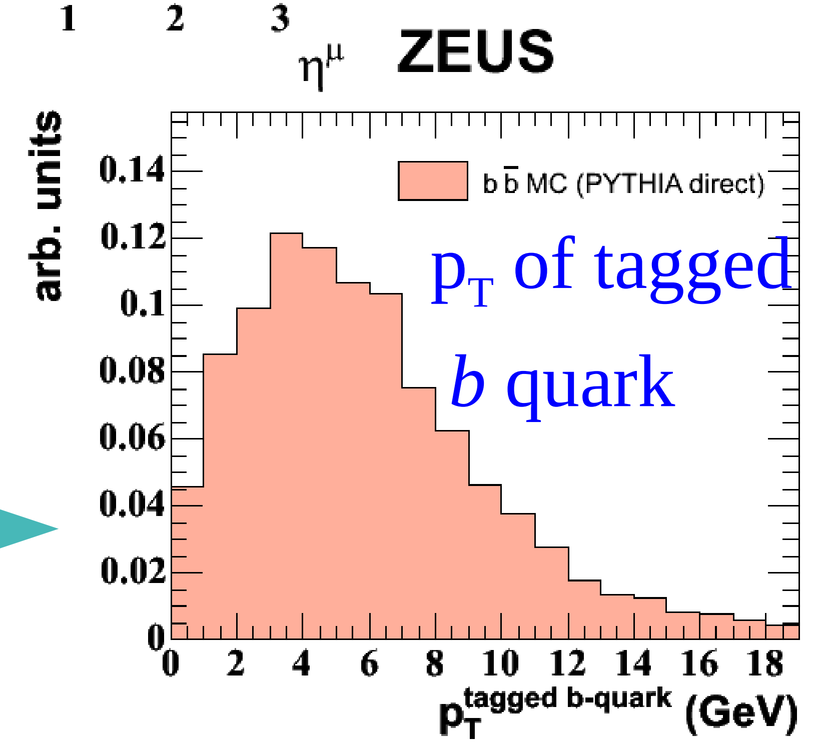
$$bb\ MC\ scale\ factor = \frac{data_{unlike} - data_{like} - cc - BH - J/\psi}{bb_{unlike} - bb_{like}}$$

Muon p_T and η distributions



- Purity ~ 40-50 %
- Acceptance down to very low p_T
- Very large η range (-2.2 → 2.5)
- MC (scaled ~ 2 ×) agrees with data

Measurement is directly sensitive to total *b* cross section.



Visible cross section

guided by detector efficiency, to yield minimum extrapolation factor (*acceptance ~ 30 %*, *purity ~ 40-50 %*)

Definition of the visible cross section

1[st] μ : $p_T > 1.5$ GeV

2[nd] μ : $p > 1.8$ GeV for $\eta < 0.6$

$p > 2.5$ *or* $p_T > 1.5$ GeV for $\eta > 0.6$

$p_T > 0.75$ GeV

both μ: $-2.2 < \eta < 2.5$

$$N_{bb \to \mu\mu} = (data_{unl} - data_{like} - charm - BH - J/\psi) \times \frac{bb_{unl} + bb_{like}}{bb_{unl} - bb_{like}}$$

MC

Result:

$$\sigma_{vis}(ep \to b\bar{b}X) = 44 \pm 5\,(stat.)\,^{+14.1}_{-12.3}\,(sys.)\ pb$$ (prel.)

Total *b* cross section

Monte Carlo cross sections

PHP (Q^2<1 GeV^2): Pythia 6.203 σ_b(318 GeV) = 6.89 nb

DIS (Q^2>1 GeV^2): Rapgap 2.0806 0.92 nb

DIS+PHP = 7.81 nb

Measured MC scale factor:
2.06 ± 0.23 (stat.)

$$\sigma_{b\,tot}\,(ep \to b\bar{b}X)\,(\sqrt{s} = 318\text{ GeV}) = 16.1 \pm 1.8\text{ (stat.)}\,^{+5.3}_{-4.8}\text{ (sys.) nb}$$ (prel.)

NLO QCD predictions:

- **FMNR (PHP) (CTEQ5M) 5.8**
- **HVQDIS (DIS) (CTEQ5F4) 1.0**

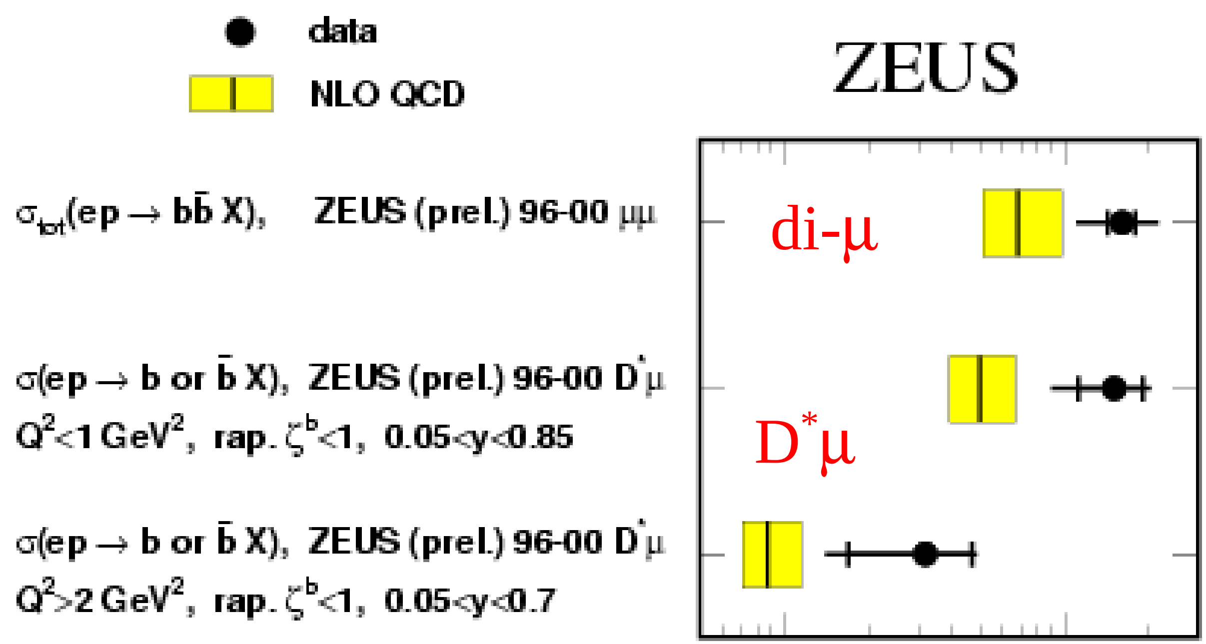
→ **6.8 $^{+3.0}_{-1.7}$ nb**

4.5 < m_b < 5.0 GeV

0.5 < μ/μ_0 < 2

$\mu_0 = \sqrt{m_b^2 + p_T^2}$ (FMNR)

$\mu_0 = \sqrt{m_b^2 + Q^2}$ (HVQDIS)



Main contributions to systematic error (+33 -30 %):

μ-efficiency, bg subtraction, $p_T(b)$ shape (varying dir-res, exc. components)

Conclusions

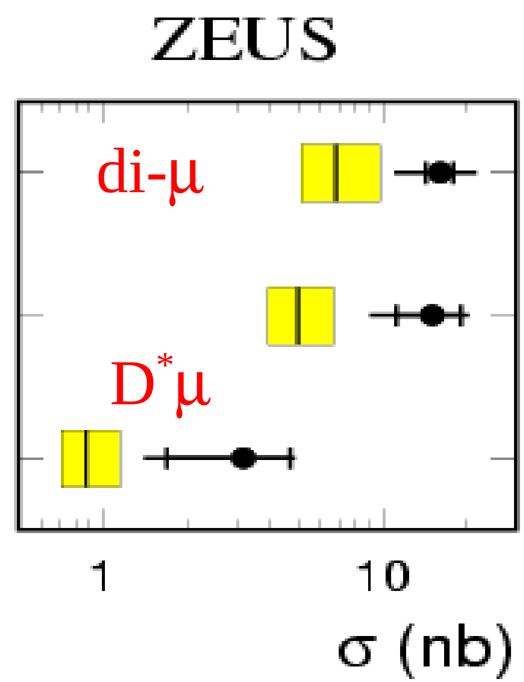
- Di-μ method established, proved reliable for measurement of b production, good statistics

$\sigma_{b\ vis}$ (ep→$b\bar{b}$X) = 44 ± 5 (stat.) $^{+14.1}_{-12.3}$ (syst.) pb

$\sigma_{b\ tot}$ (ep→$b\bar{b}$X) = 16.1±1.8 (stat.) $^{+5.3}_{-4.8}$ (syst.) nb

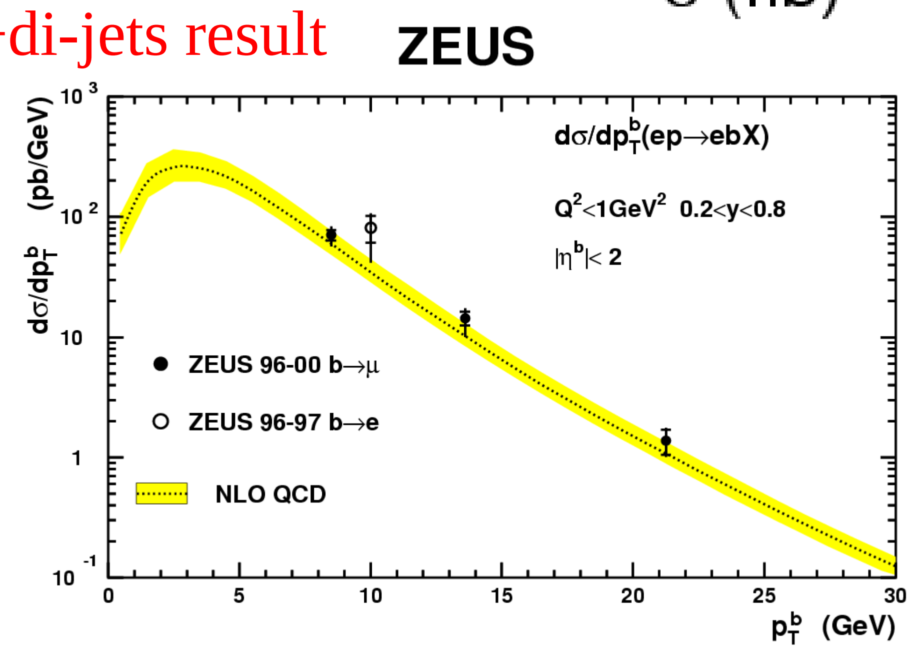
NLO QCD 6.9 $^{+3.0}_{-1.8}$ nb

(prel.)



- Does not NLO prediction (FNMR+HVQDIS) look too small ... ?!

μ+di-jets result



Outlook

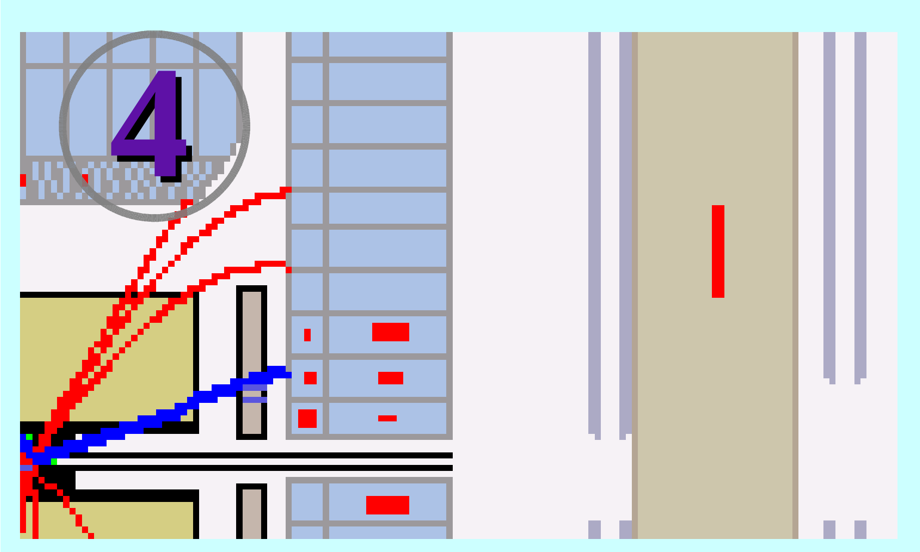
- measure differential cross sections (p_T)
- extend to HERA II data

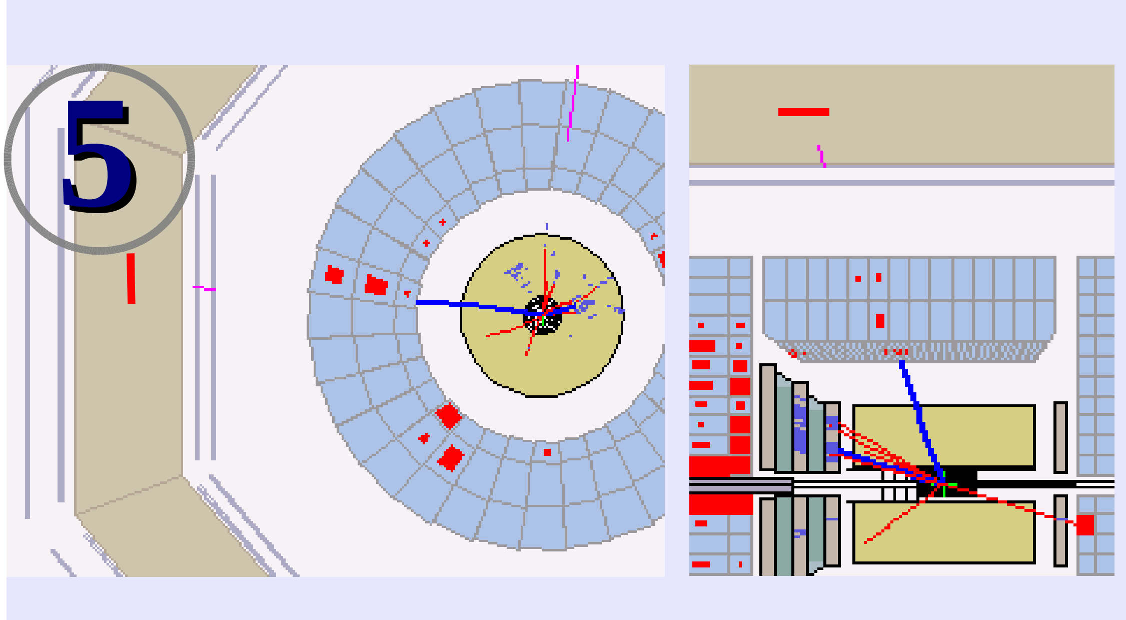
Back-up slides

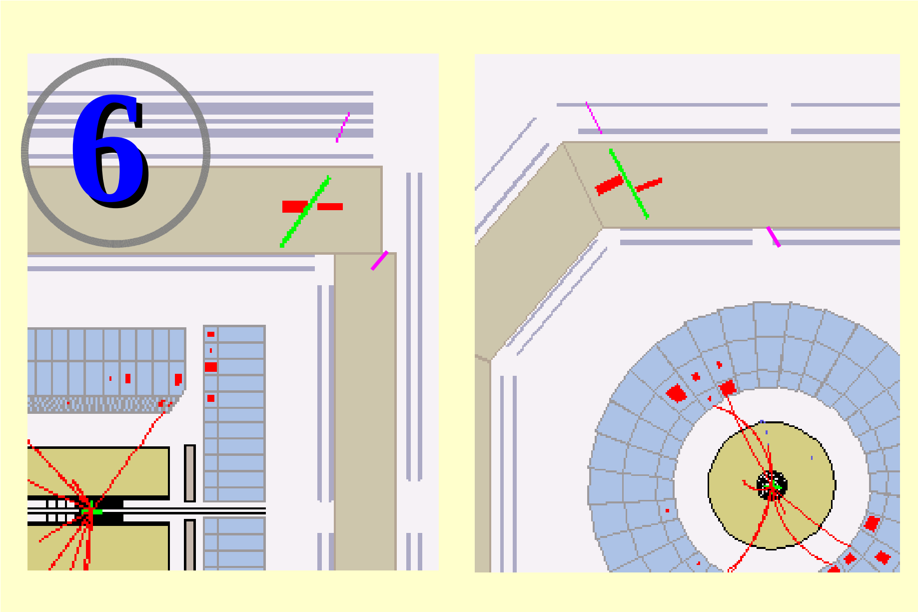
Muon classification quality

By the **“clarity”** of the muon signature the reconstructed tracks are classified - exploiting detector redundancy.

Examples of muons with different quality:







Muon chambers η coverage