# Measurement of the open charm and beauty production cross sections in $\gamma\gamma$ collisions at DELPHI using semileptonic decays

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- Introduction
- Data and MC samples
- Event selection
- Cross section determination
- Conclusions

# Beauty production

## Theoretical predictions

At Ecm=180 GeV

Drees, Kramer, Zunft, Zerwas. PL B306 (1993)

☞ $$\kappa = \frac{\sigma_{NLO}^{direct\ b\bar{b}}}{\sigma_{LO}^{direct\ b\bar{b}}} \simeq 1.236$$

☞ $$\kappa = \frac{\sigma_{DG,GRV}^{1\ res\ b\bar{b}}}{\sigma_{NLO}^{direct\ b\bar{b}}} = 0.997\ ,\ 1.039$$

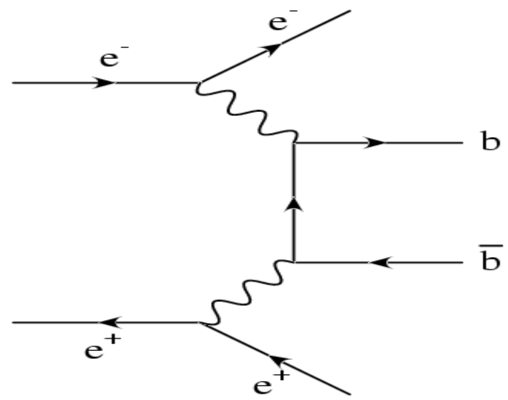
✔ The double resolved and non perturbative contributions are both expected to be small

## The Monte Carlo for the analysis

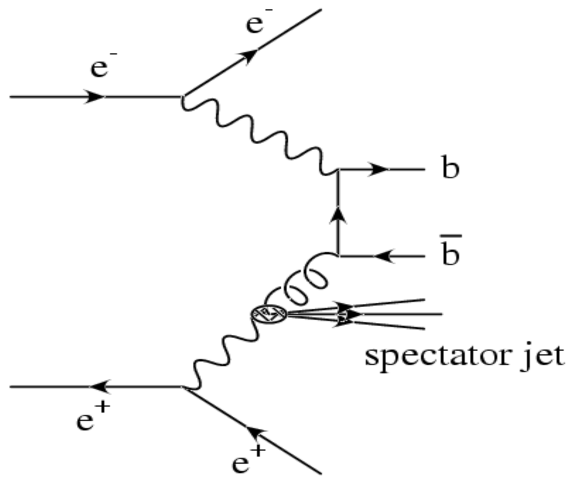
Pythia 6.143

- Direct term Massive matrix elements
  Mb = 4.8 GeV
- 1 resolved term     γ pdf SaS1D

Sig 1 res forced to be equal to sig direct = 1.62 pb




Direct term




Single resolved term

## Strategy for the Event selection

The open beauty event selection is performed in 3 steps

1. Select anti-tagged $\gamma\gamma$ events

2. Select a reconstructed $\mu$ as a signature for semi-leptonic beauty decays

3. Jets are reconstructed within the selected events and the sensitive variable ( the $\mu$ transverse momentum with respect to the jet axis) is computed

## Data and MC samples used

- **Data**

| Year | Luminosity ($pb^{-1}$) | $E_{CM}$(GeV) |
|---|---|---|
| 1998 | 129 | 189 |
| 1999 | 195 | 198 |
| 2000 | 139 | 206 |
| Total | 463 | Average 198 |

- **MC** $\gamma\gamma$ PYTHIA 6.143
  - Open Beauty and open charm : dedicated sample direct and 1 resolved were produced for each year
  - Light quarks uds default version $\gamma^*\gamma^*$ machinery
- Background to antitagged $\gamma\gamma$ physics :
  $e^+e^- \rightarrow \tau^+\tau^-$, $e^+e^- \tau^+\tau^-$
  $Z\gamma$, WW (CC), ZZ (NC)
  DIS $e\gamma$

# Select antitagged two-photon events

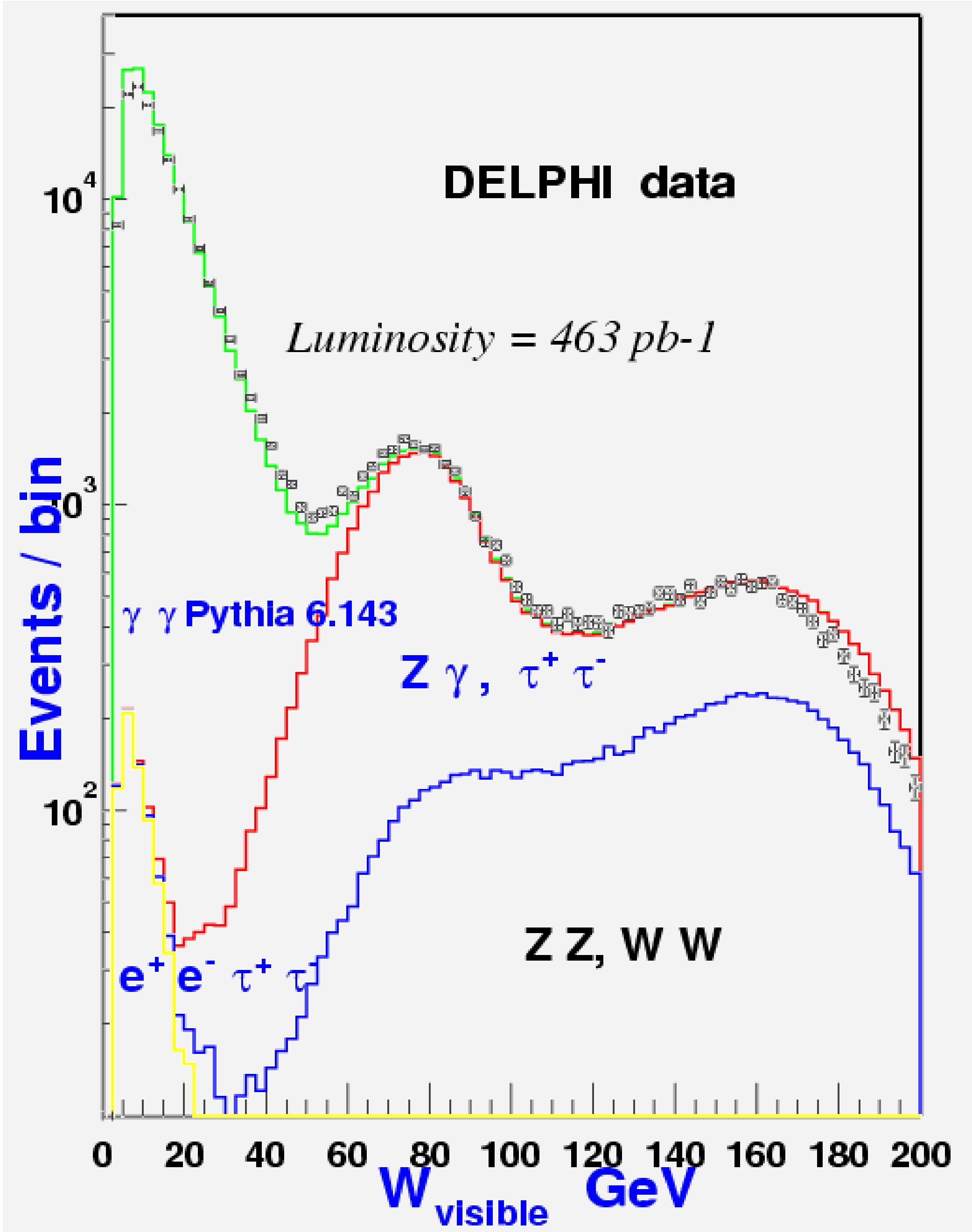
Track :
p > 200 MeV/c  10°< θ <170°

Neutral :
$E_T$ > 250 MeV
p(Hadronic Calorimeter)>1 GeV

Trigger :
At least a track
with $p_T$ >1,2 GeV/c
and | cos θ | < 0,8

Antitagging conditions :
no neutral with E > 40 GeV
use of the calorimeters
at low angle (STIC)
33 mrad ≤θ ≤ 180 mrad

Events :
Nch ≥ 6 ,
3 GeV≤ Wvis≤ 35 GeV,
Echa +Eneut < 70 GeV



## μ selection

2 GeV/c < $p_\mu$ < 20 GeV/c

| cos $\theta_\mu$ | < 0.94 with $\theta_\mu \notin$ cracks

μ Identification using muon chambers

## Jet reconstruction

✔ μ included in the jet search

✔ LUCLUS algorithm ( djoin = 2,5 GeV)

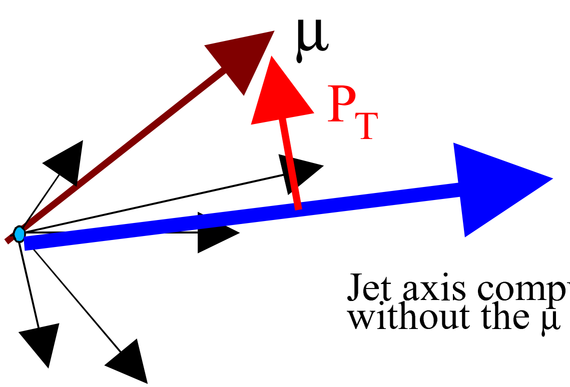
✔ cut on

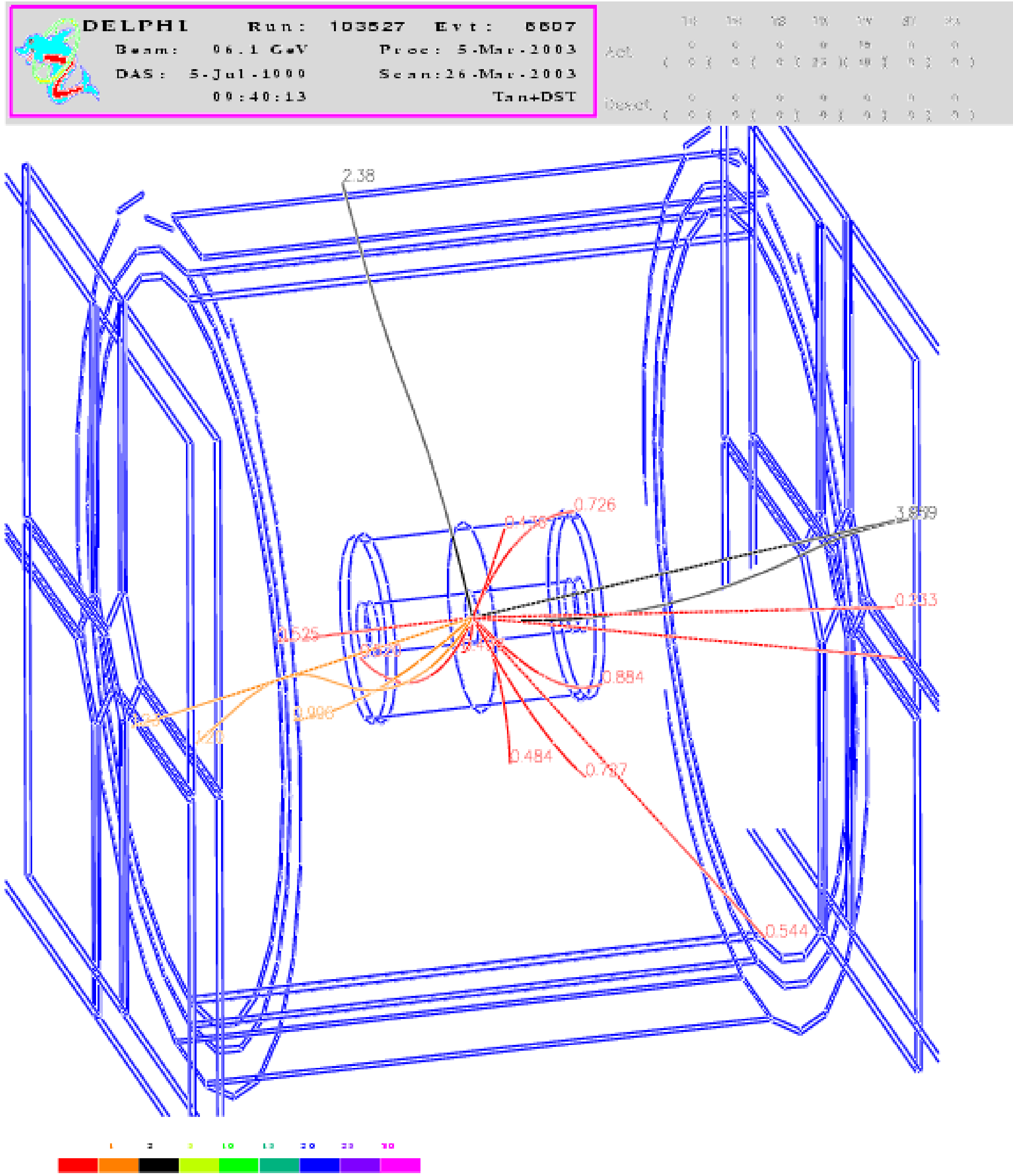
Polar angle

$$E_T^{jet} = \sum_{i \in jet} E_i \sin(\theta_i)$$

$$0{,}5\ \text{GeV} \le E_T^{Jet} < 8\ \text{GeV}$$

Sensitive variable for beauty events :
the μ transverse momentum
with respect to the jet axis



## Extraction of $\sigma^{e^+e^-\to e^+e^-b\bar{b}X}$

① $\alpha_b$ Fit variable rescaling the bb MC

$$\chi^2 = \sum_{\text{bin}} \frac{\left(N^{\text{data}} - \alpha_b N^b_{\text{MC}} - N^c_{\text{MC}} - \alpha_{\text{uds}} N^{\text{uds}}_{\text{MC}} - N^{\text{bckgd}}_{\text{MC}}\right)^2}{\sigma^2}$$

② $N^{\text{bckgd}}_{\text{MC}}$ = estimated background from MC

③ $N^c_{\text{MC}}$ = use for normalization (stat + syst)

$$\sigma^{e^+e^-\to e^+e^-c\bar{c}X}_{<\text{LEP}>} = 984 \pm 128\,\text{pb}$$

④ $\alpha_{\text{uds}}$ = fix variable estimated from data

### Results

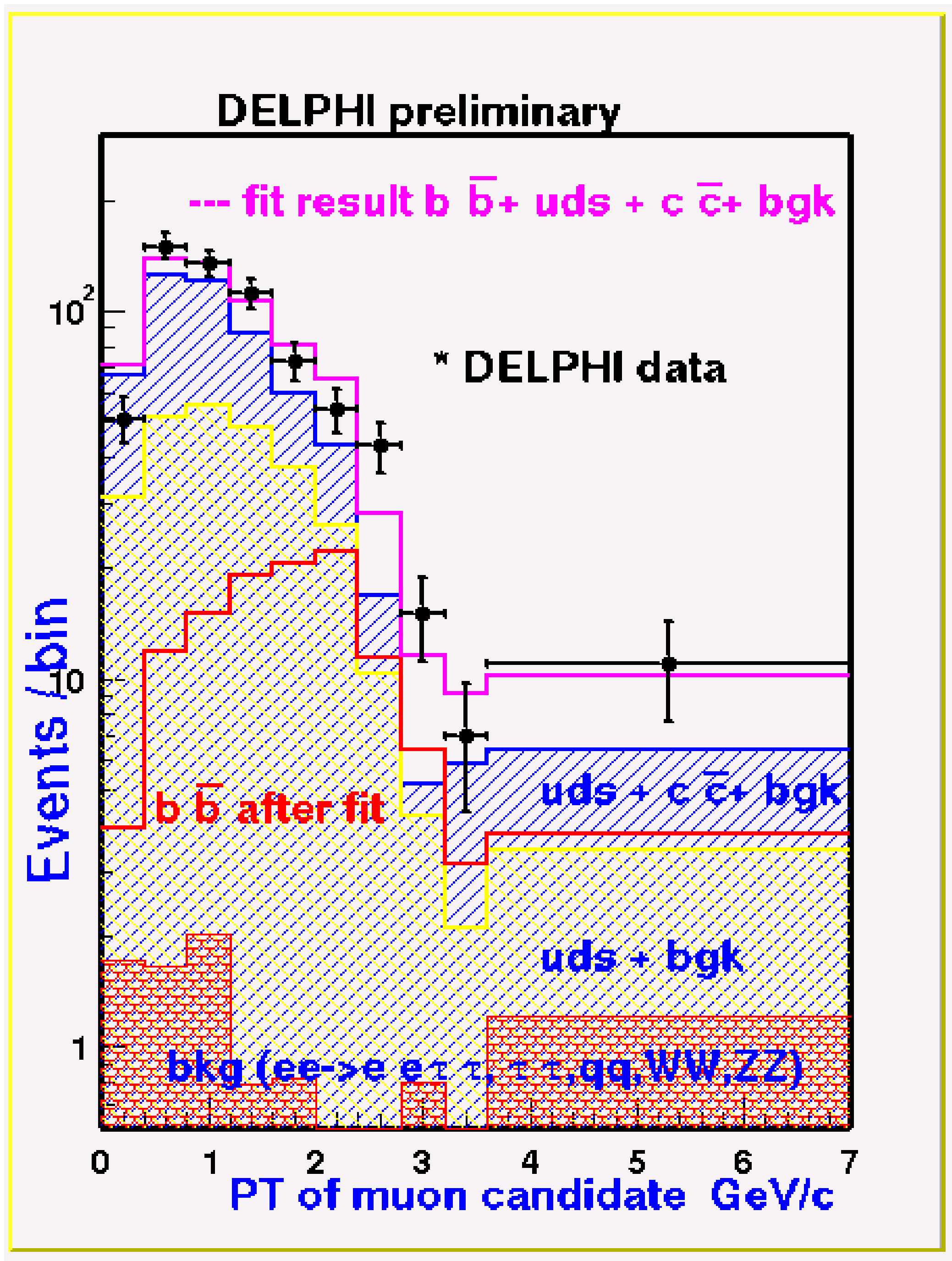
$N^b_{\text{data}} = 118 \pm 26$ evts $\quad (N^{\text{all}}_{\text{data}} = 651)$

$f_b = (18 \pm 1_{(\text{stat})})\ \% \quad f_c \simeq 41\ \%$

$f_{\text{uds}} \simeq 39\% \quad f_{\text{bckgd}} \simeq 2\ \%$

$\epsilon^{b\bar{b}}_{\text{MC}} \simeq 1.7\ \%\quad (b\bar{b}$ event efficiency$)$

$\sigma^{e^+e^-\to e^+e^-b\bar{b}X} = 14.9 \pm 3.3_{\text{(stat)}}$ pb



# Test of u, d, s background Normalisation

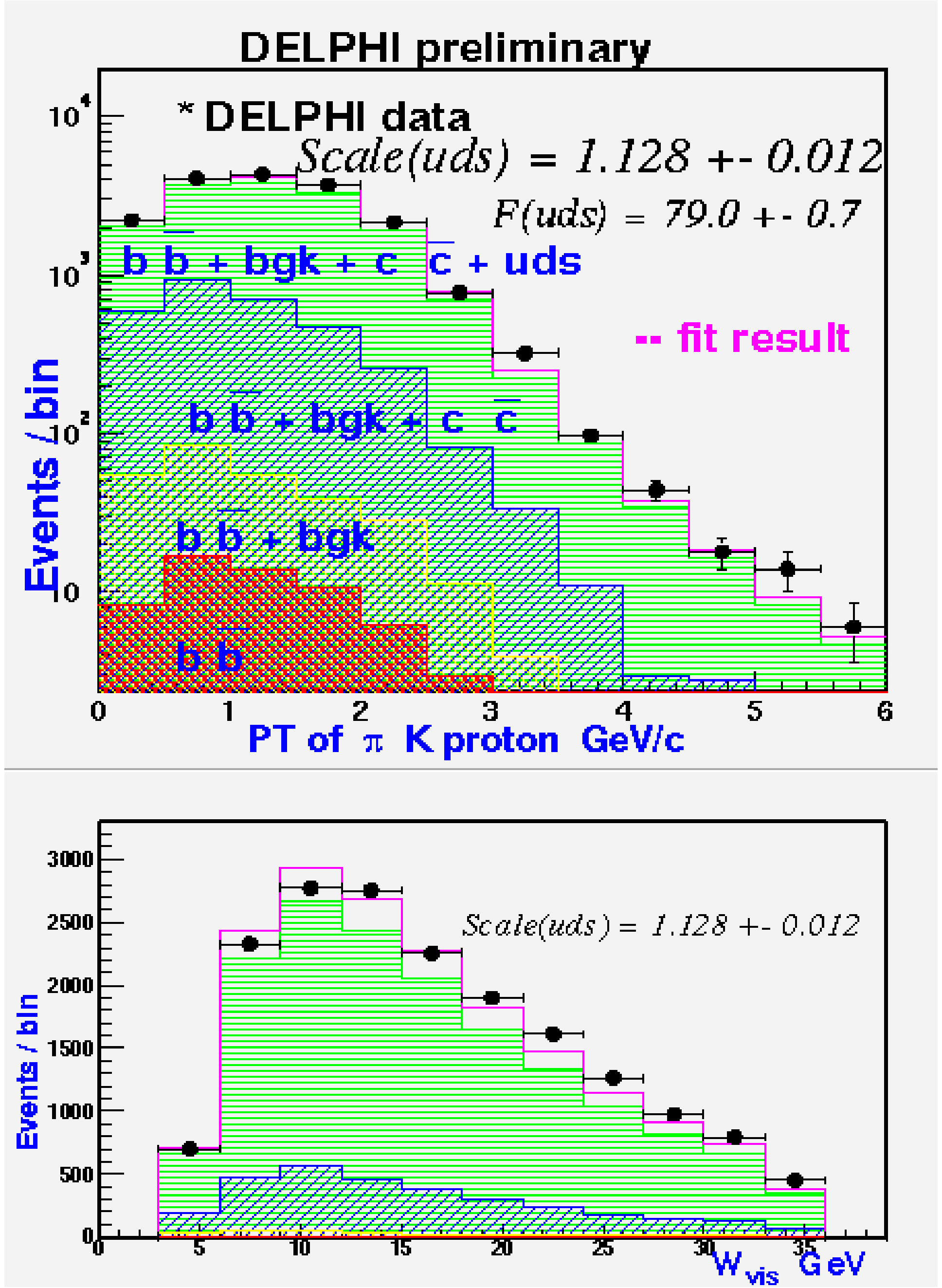
- ✔ $p_{Hadron}$ > 2 GeV/c
- ✔ $\pi$ , K, p identification using dE/dx
- ✔ Fit $\alpha_{uds}$

$$\chi^2 = \sum_{bin} \frac{\left(N^{data} - \alpha_{uds} N^{uds}_{MC} - N^{b}_{MC} - N^{c}_{MC} - N^{bckgd}_{MC}\right)^2}{\sigma^2}$$

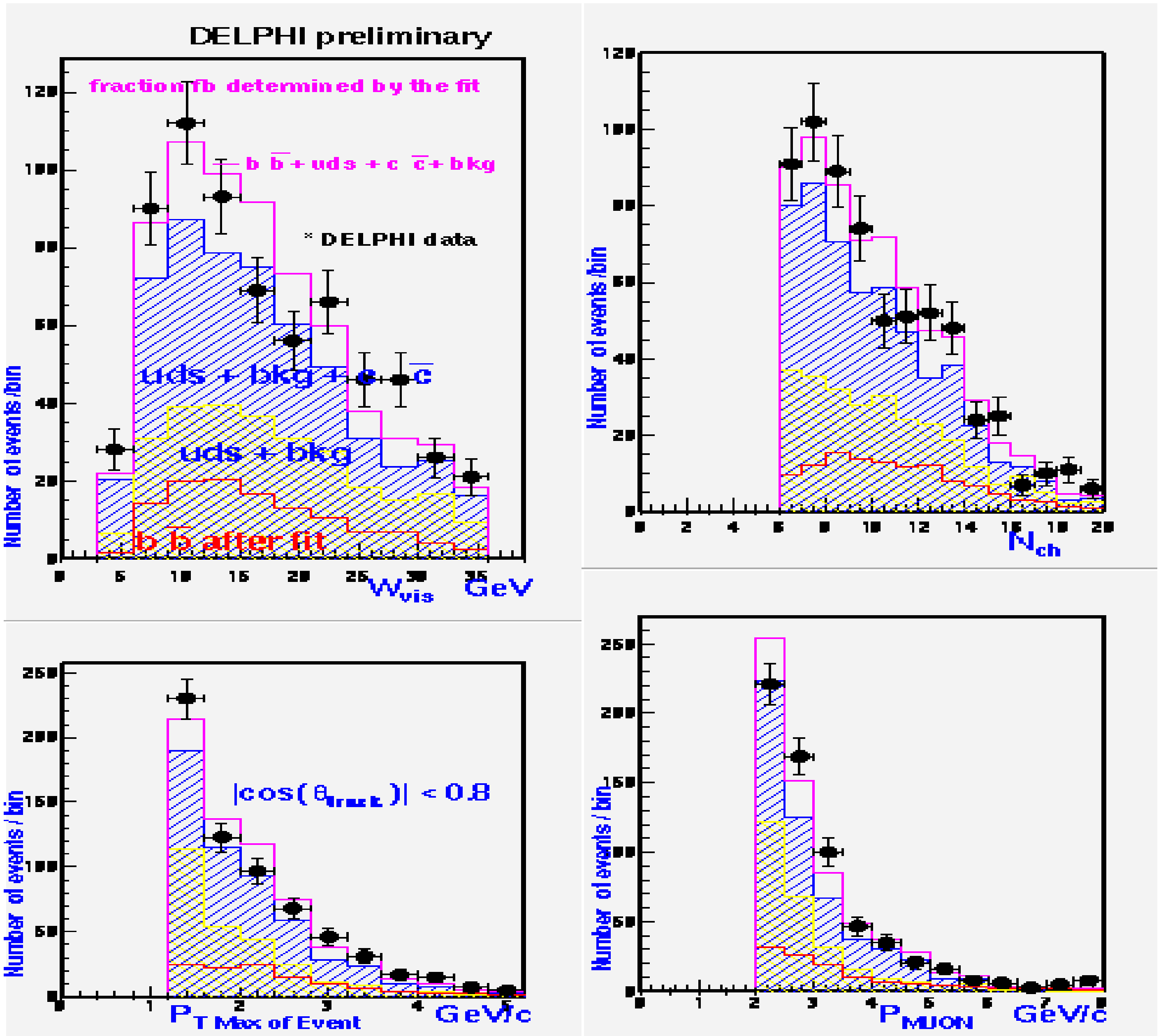
- ✔ Dominant uds fraction

- ✔ Test uds normalization on two variables : inclusive transverse momentum and visible invariant mass

⇨ Internal consistency check : a good agreement is found



# Various plots after fit

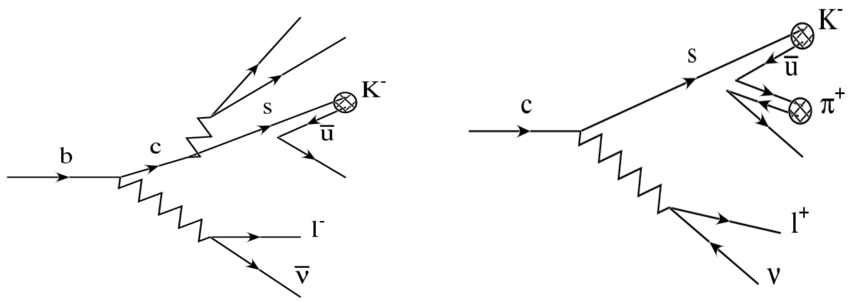


# $\sigma^{e^+e^- \to e^+e^- b\bar{b}X}$ Systematics

| | |
|---|---|
| $N_{ch}$, $p_T$, $W_{vis}$, $p_\mu$, $\cos\vartheta_\mu$ varying cuts $\oplus$ Data/MC discrepancy | 16.5 % |
| $\mu$ efficiency + misidentification | 9.8 % |
| Choice of $\sigma_{<LEP>} = 984 \pm 128$ pb | 8.3 % |
| Jet reconstruction : leading particle | 7.8 % |
| $\alpha_{uds}$ rescaling + discrepancy data/MC on $N_{ch}$, $p_T$, $W_{vis}$ | 3.5 % |
| Br(b $\to \mu$) model | 3.4 % |
| Ratio direct/resolved 1:2 to 2:2 | 3.1 % |
| Total | 23.0 % |

$\sigma_{b\bar{b}} = 14.9 \pm 3.3\,(\mathrm{stat}) \pm 3.4\,(\mathrm{syst})$ pb

# K-lepton correlations




Identify a K in lepton jet with RICH and TPC

$c\bar{c}$

Fix $\alpha_b =$ value given by the previous measurement

Fit $\alpha_c = c\bar{c}$ MC rescaling variable

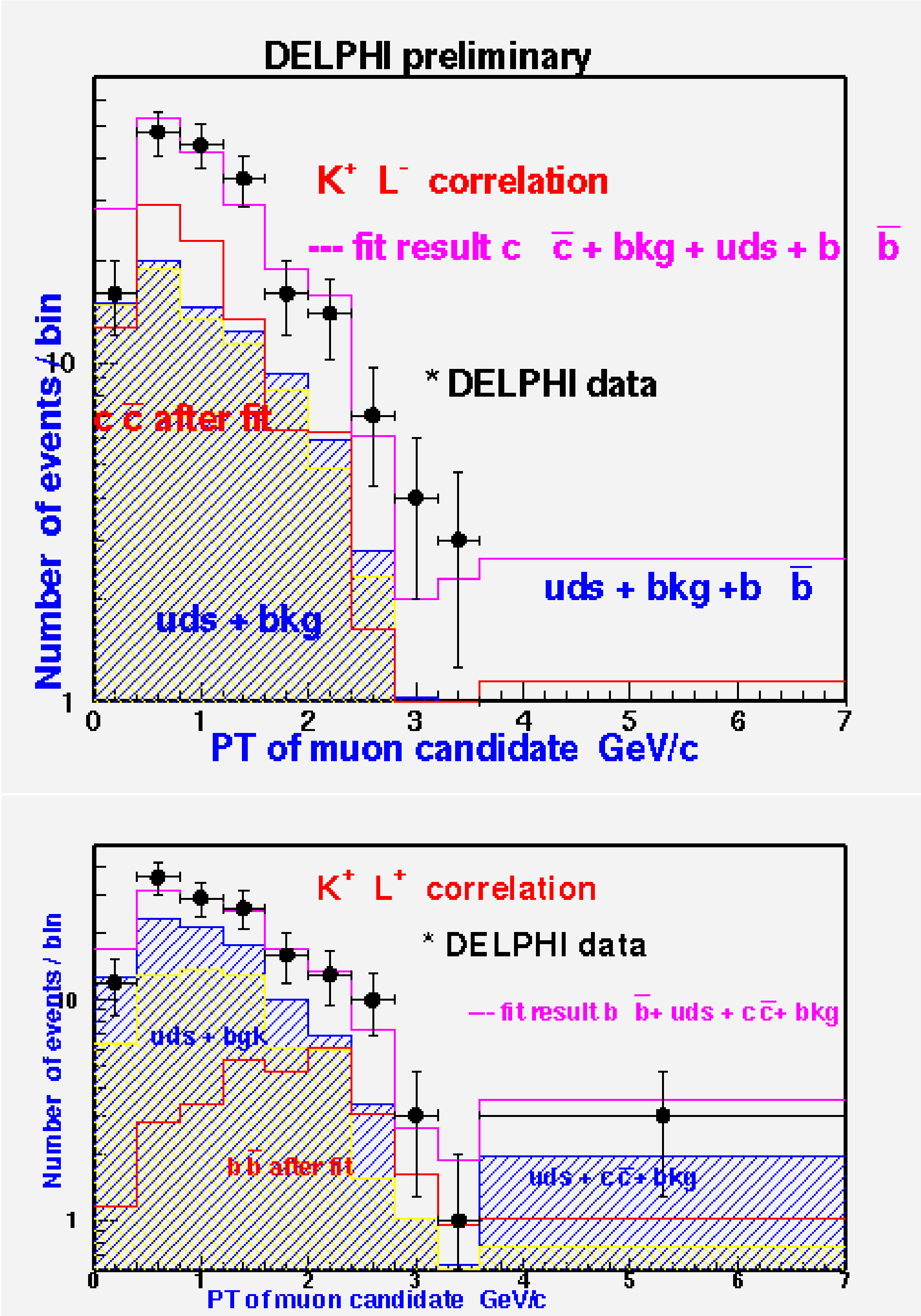
Results : $N_{\rm data} = 171$

$f_{\rm uds} \simeq 35\,\%$, $f_c \simeq 48\,\%$, $f_b \simeq 16\,\%$, $f_{\rm bckgd} \simeq 1\,\%$

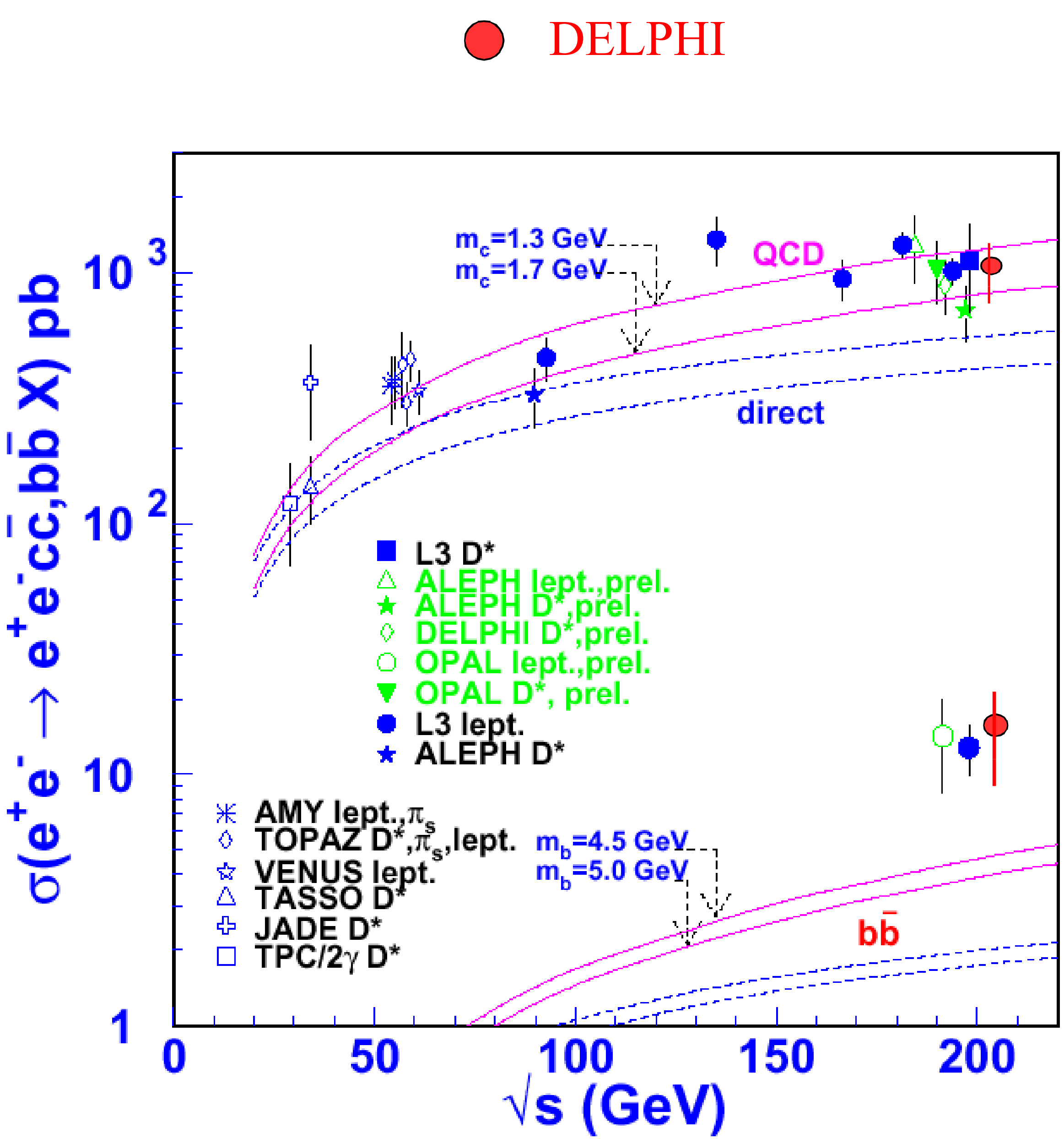
| | |
|---|---|
| Eventselection | 12.5 % |
| Kaon (efficiency + fragmentation) | 11.0 % |
| Jet reconstruction | 10.9 % |
| Ratio direct/resolved | 5.6 % |
| $\alpha_{\rm uds}$ normalization | 4.2% |
| $\sigma_{b\bar{b}}$ | 3.5 % |
| Br(c→μ) | 3.2 % |
| Total | 22.0 % |

$\sigma^{c\bar{c}} = 937 \pm 191({\rm stat}) \pm 206({\rm syst})$ pb

$\sigma^{b\bar{b}} = 11.4 \pm 4.5$ pb

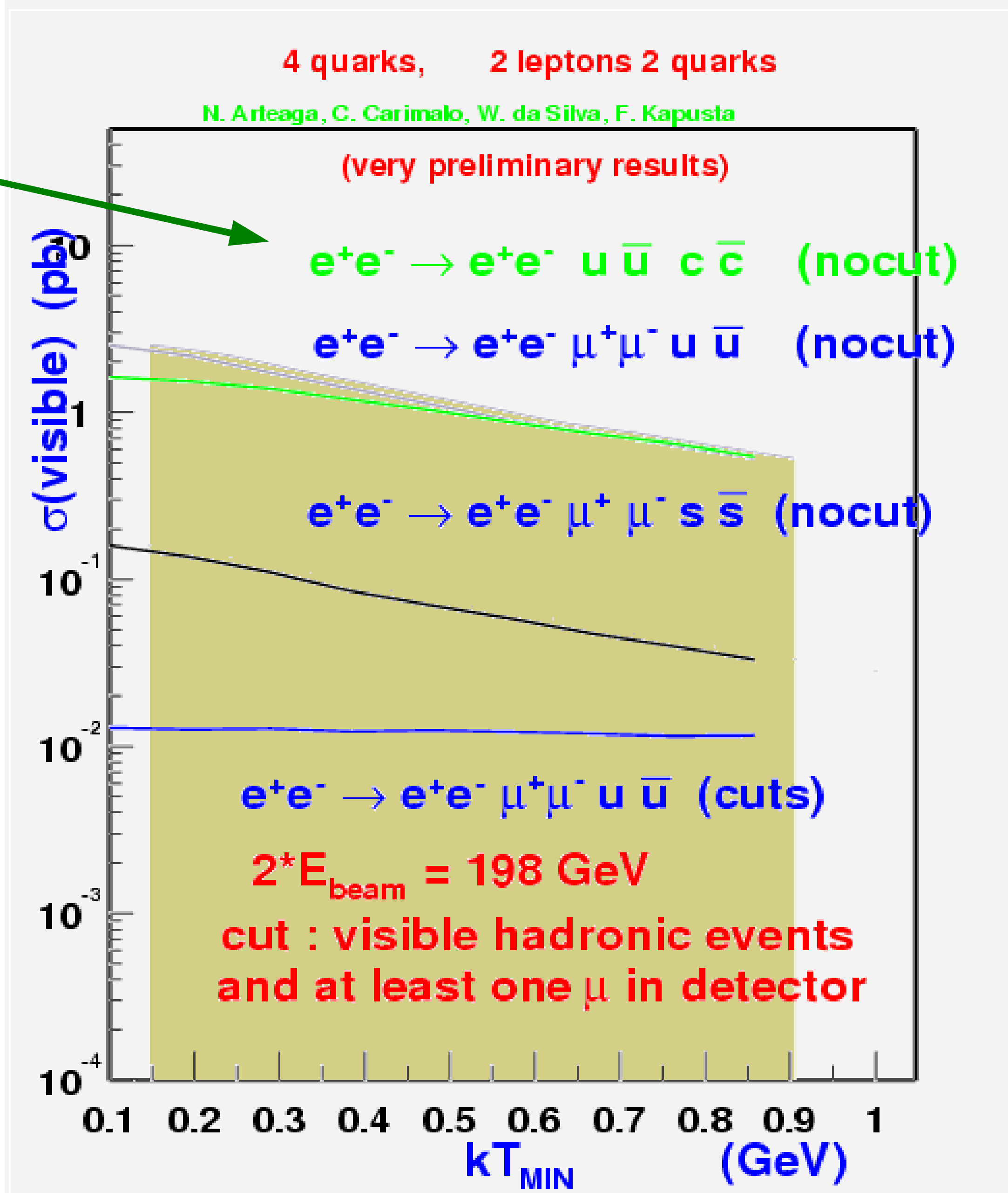


# Comparison with L3 and OPAL



# Computation of $\gamma\gamma \rightarrow$ 4 quarks and $\gamma\gamma \rightarrow$ 2 quarks 2 leptons at LEPII

Computation of the 4 quarks contribution not taken into account by the resolved term




$K_{T\,MIN}$

Mimimun value of the central transverse momentum (the lowest one by construction) in the case of 4 quarks production

Mimimun value of the 2 quarks production subprocess transverse momentum in the case of 2 quarks 2 leptons production

# Conclusions

**Charm and Beauty cross sections have been measured and checked through muon semileptonic decays.**

**The L3 and OPAL $b\bar{b}$ excess is confirmed at the same level.**

$$\sigma^{b\bar{b}} = 14.9 \pm 3.3\,(\mathrm{stat}) \pm 3.4\,(\mathrm{syst})\ \mathrm{pb}$$

$$\sigma^{c\bar{c}} = 937 \pm 191\,(\mathrm{stat}) \pm 206\,(\mathrm{syst})\ \mathrm{pb}$$

**Statistics could be slightly improved.**

**A few systematics to improve especially in the uds region.**

**Use an additional variable as the muon impact parameter.**