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)

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

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

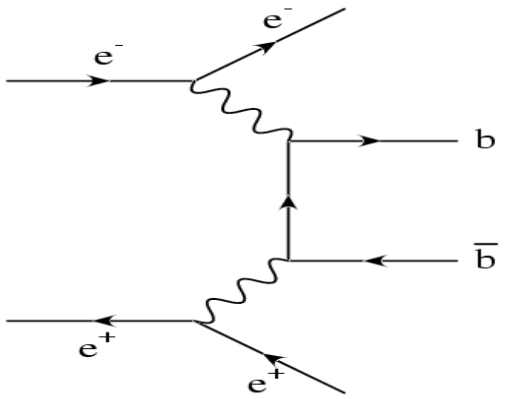
✔ The double resolved and non perturbative contributions are both expected to be small

The Monte Carlo for the analysis

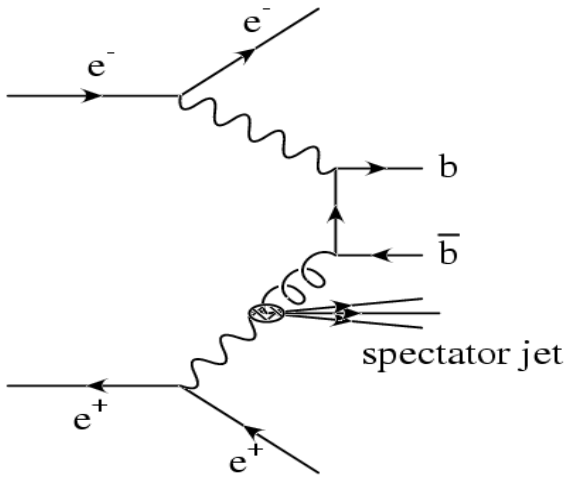
Pythia 6.143

- 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

❶Select anti-tagged $\gamma\gamma$ events

❷Select a reconstructed μ as a signature for semi-leptonic beauty decays

❸Jets are reconstructed within the selected events and the sensitive variable (the μ 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

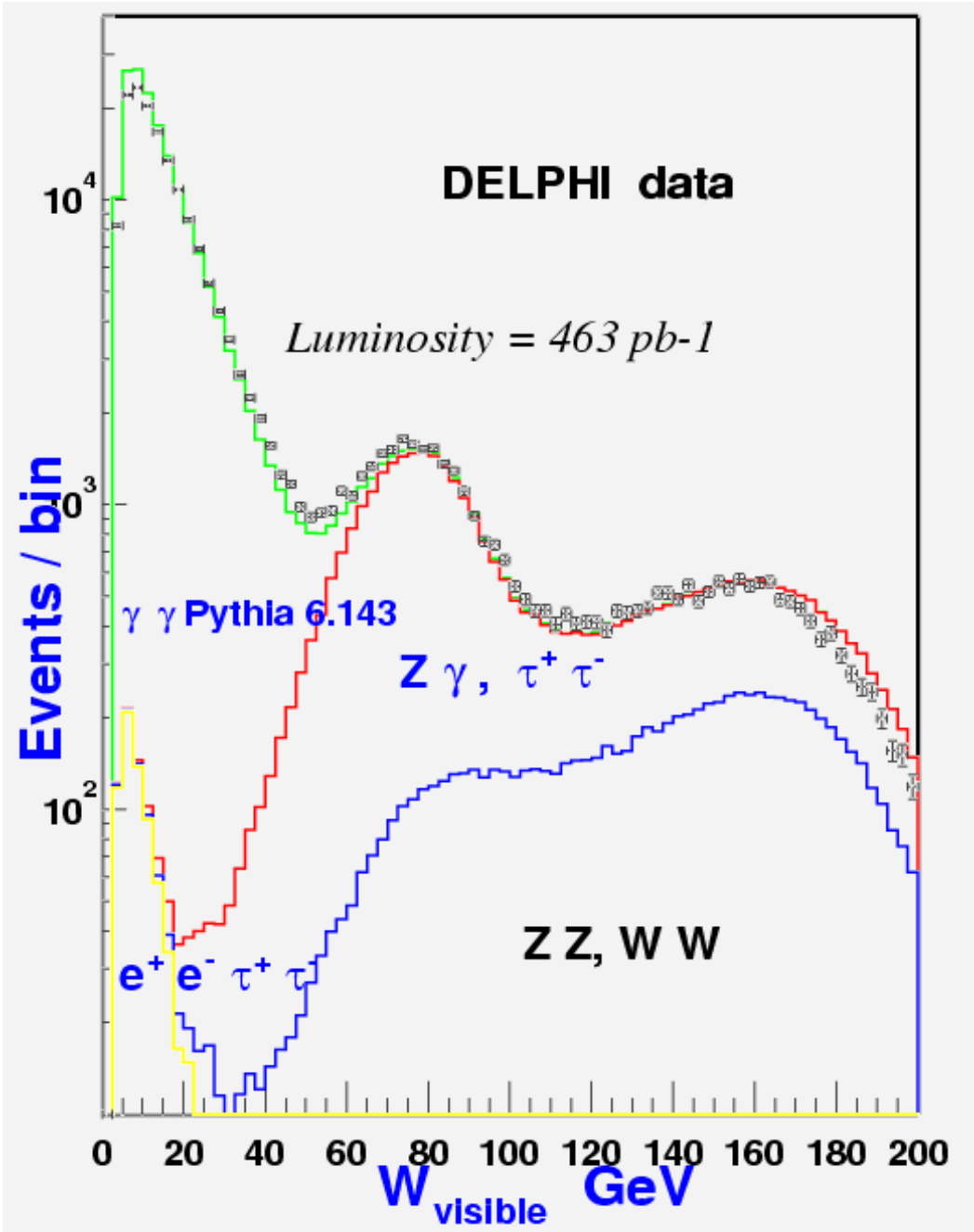
Track :
p > 200 MeV/c 10°< θ <170°

Neutral :
E > 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 < pμ < 20 GeV/c

| cos θμ | < 0.94 with θμ ∉ cracks

μ Identification using muon chambers

Jet reconstruction

✔ μ included in the jet search

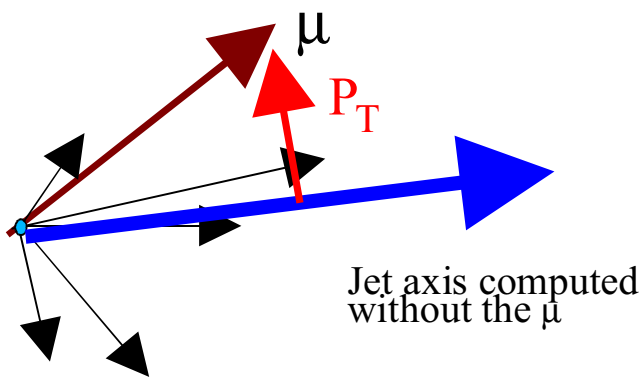
✔ LUCLUS algorithm (djoin = 2,5 GeV)

✔ cut on Polar angle

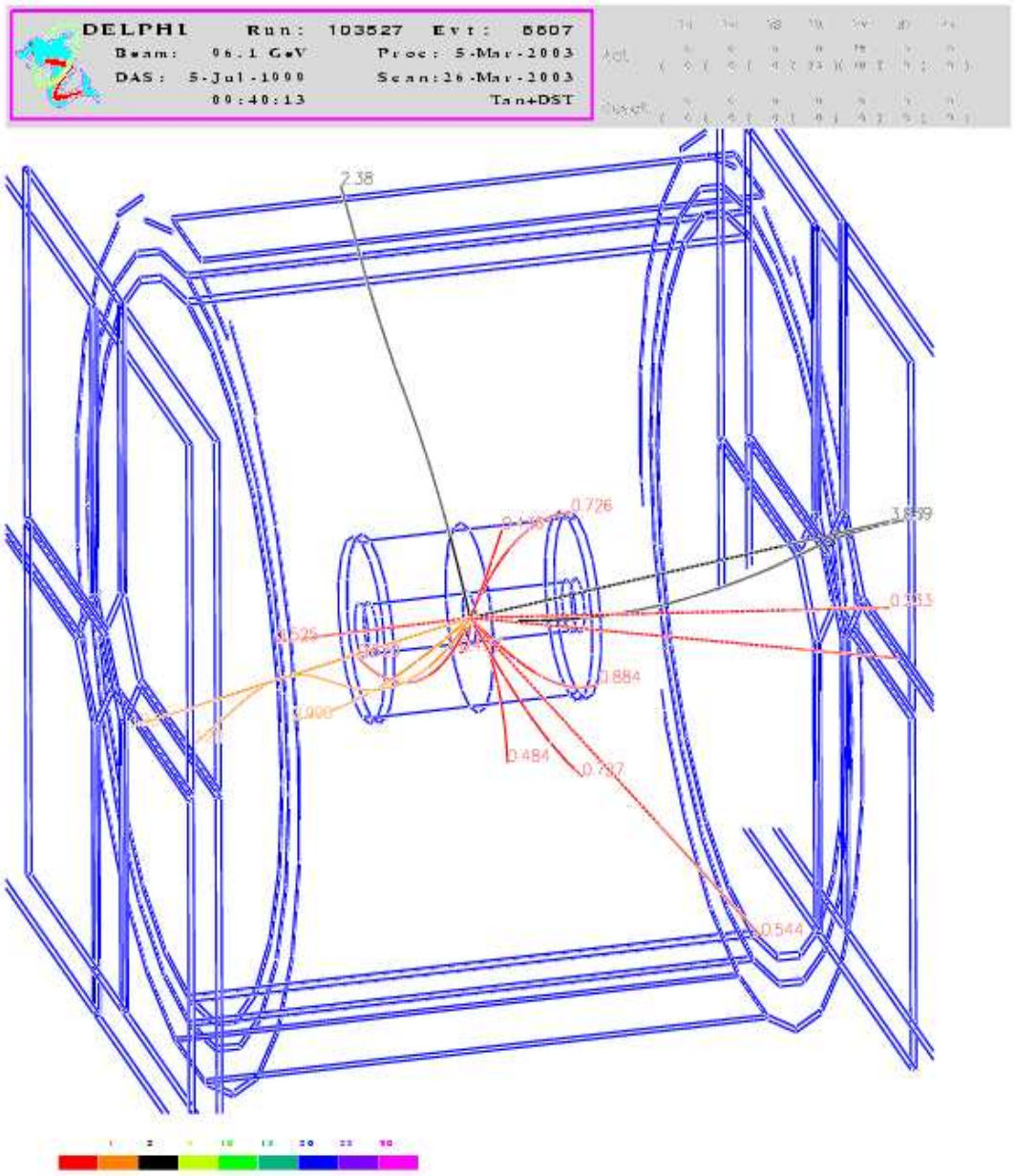
$$E_T^{\text{jet}} = \sum_{i \in \text{jet}} E_i \sin(\theta_i)$$

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

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



Jet axis computed
without the μ



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

① α_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_{MC} = use for normalization (stat + syst)

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

④ α_{uds} = fix variable estimated from data

Results

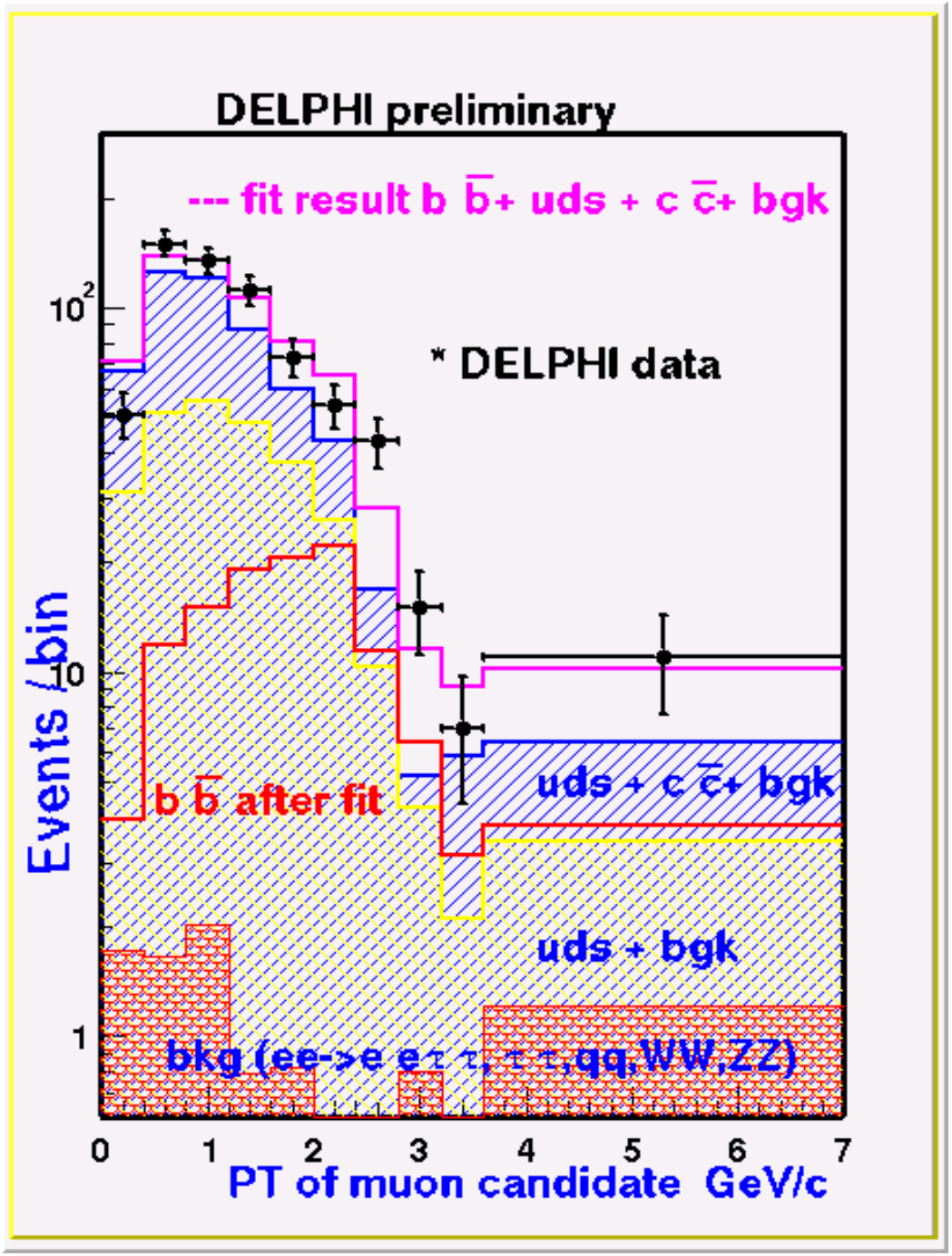
$$N^b_{\text{data}} = 118 \pm 26 \text{ evts} \quad (N^{\text{all}}_{\text{data}} = 651)$$

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

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

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

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



Test of u, d, s background Normalisation

✔ p_{Hadron} > 2 GeV/c

✔ π , K, p identification using dE/dx

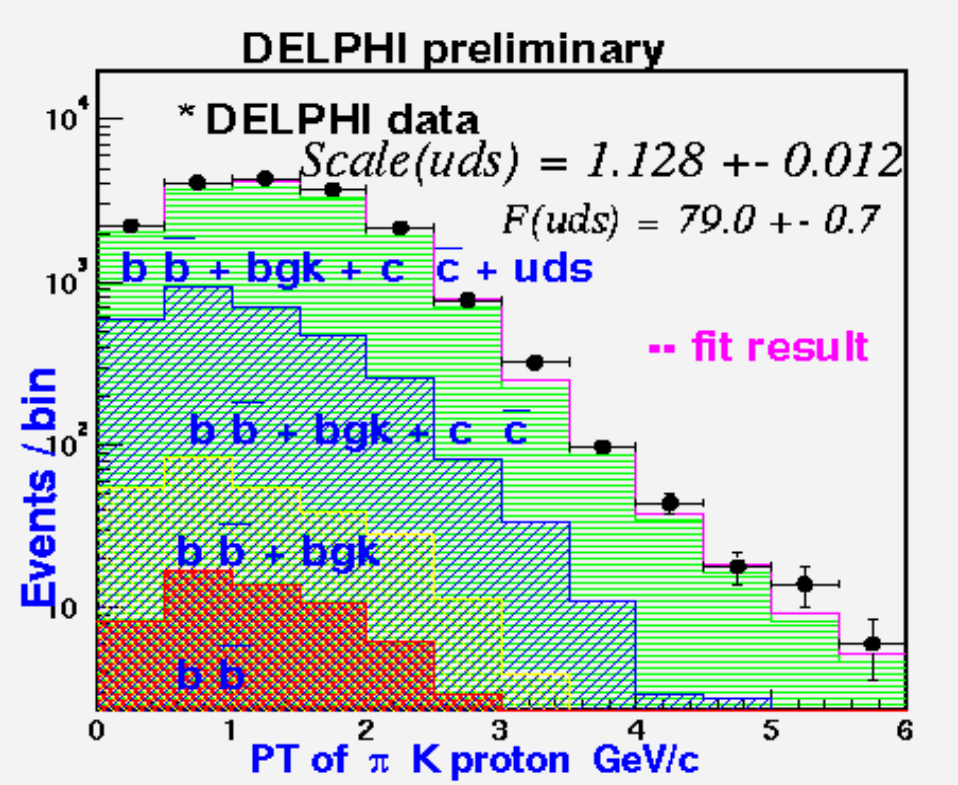
✔ Fit α_{uds}

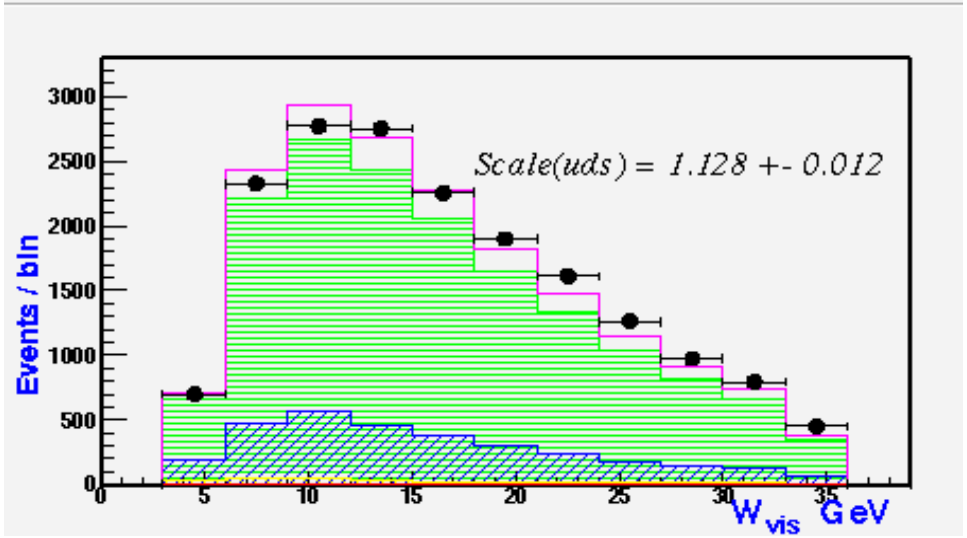
$$\chi^2 = \sum_{bin} \frac{\left(N^{data} - \alpha_{uds} N^{uds}_{MC} - N^{b}_{MC} - N^{c}_{MC} - N^{bckgd}_{MC}\right)^2}{\sigma^2}$$

✔ Dominant uds fraction

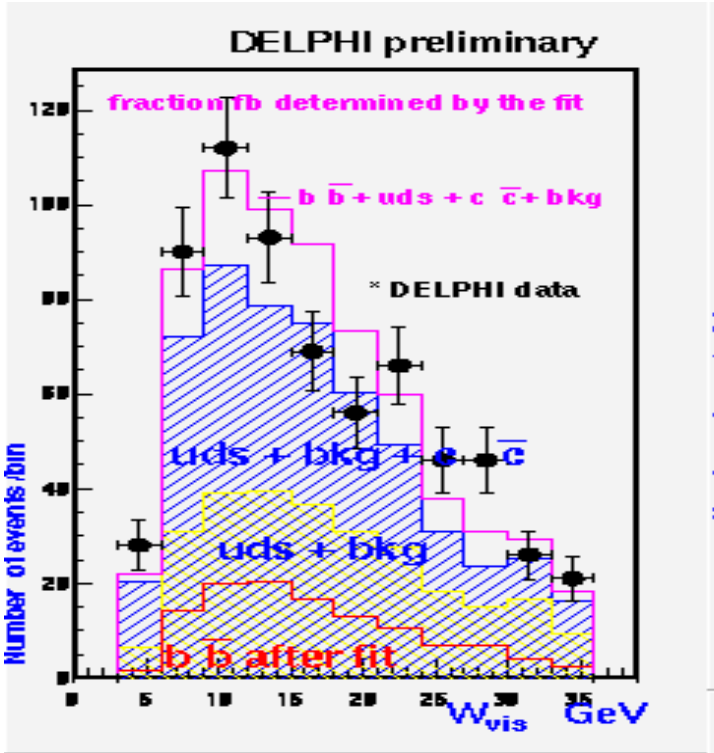
✔ Test uds normalization on two variables : inclusive transverse momentum and visible invariant mass

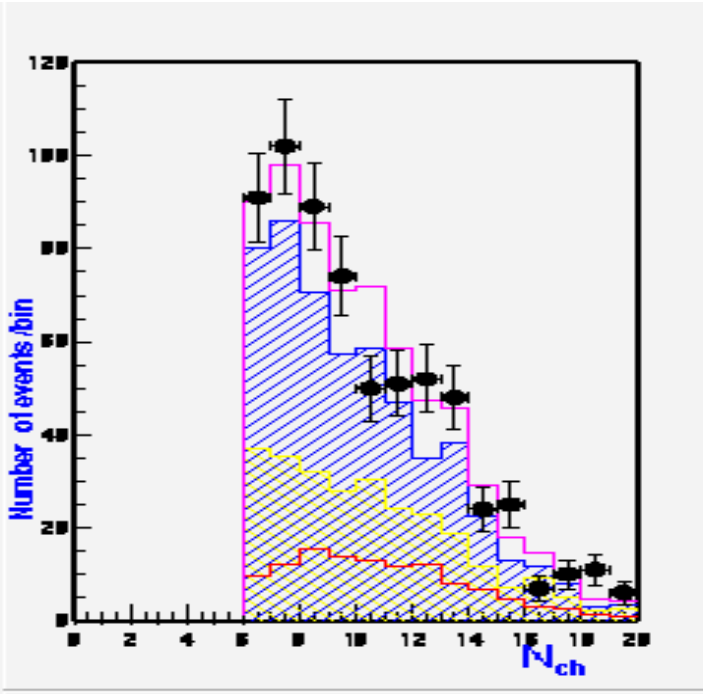
➪ Internal consistency check : a good agreement is found

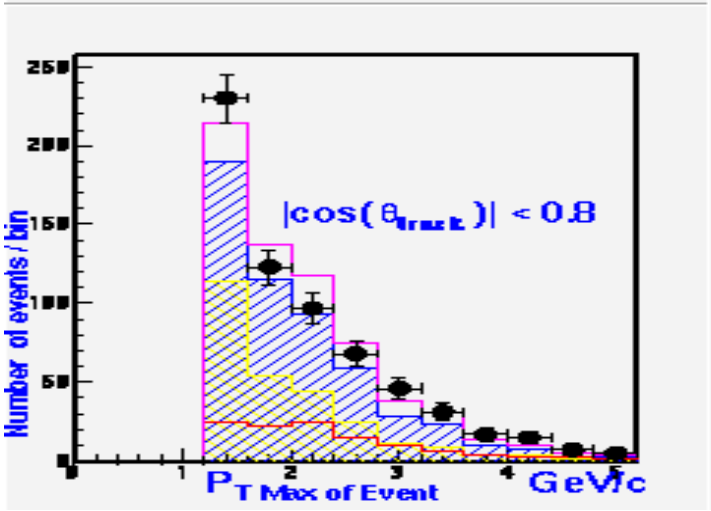


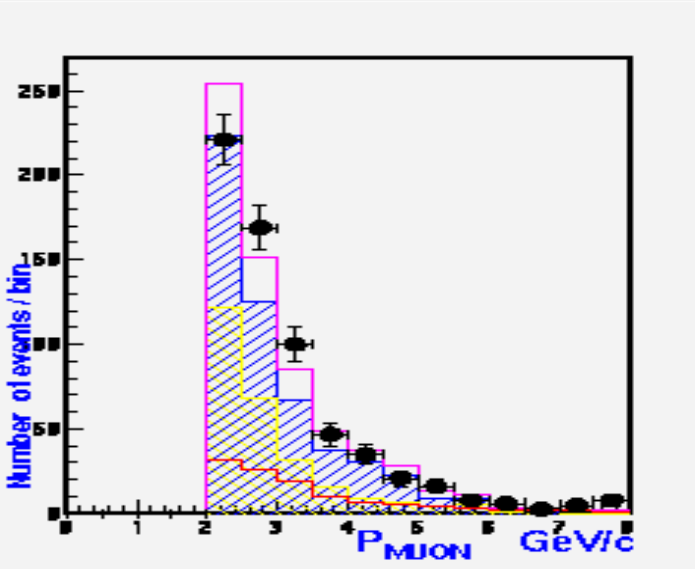


Various plots after fit







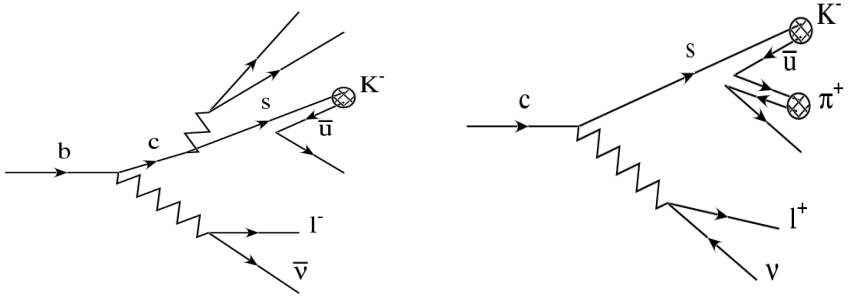


$\sigma^{e^+e^- \to e^+e^- b\bar{b}X}$ Systematics

N_{ch}, p_T, W_{vis}, p_μ, $\cos\vartheta_\mu$ varying cuts $\oplus$ Data/MC discrepancy	16.5 %
μ efficiency + misidentification	9.8 %
Choice of $\sigma_{<LEP>} = 984 \pm 128$pb	8.3 %
Jet reconstruction : leading particle	7.8 %
α_{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 %

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

K-lepton correlations



Identify a K in lepton jet with RICH and TPC

$c\bar{c}$

Fix α_b = value given by the previous measurement

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

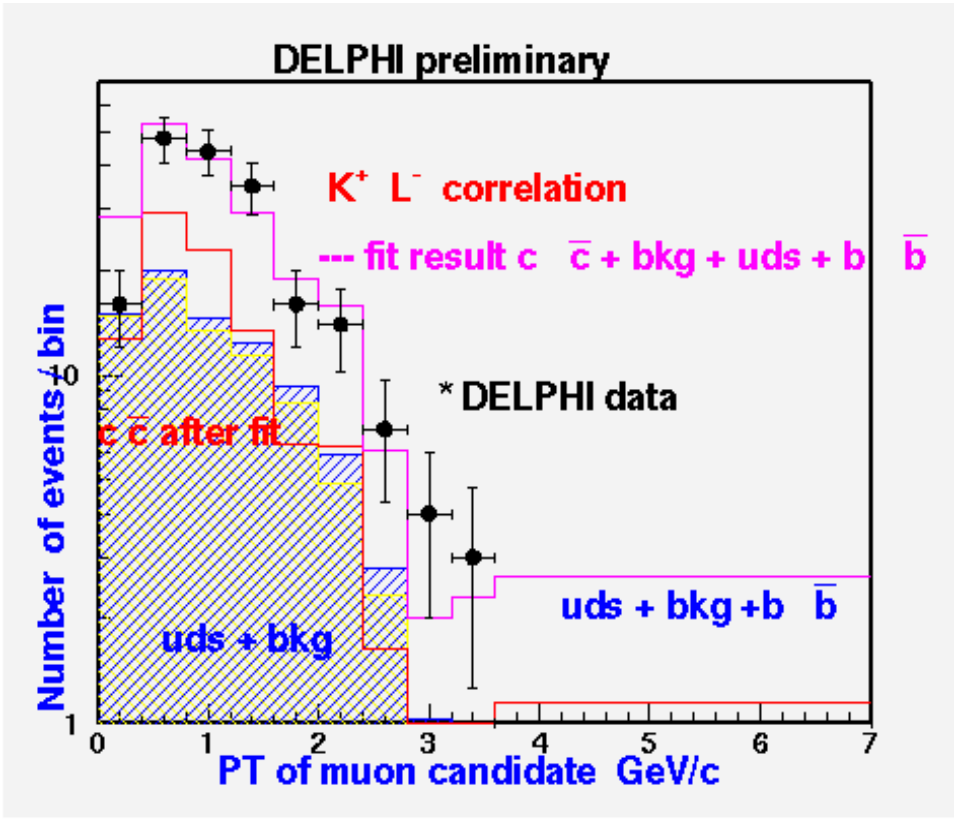
Results : $N_{data} = 171$

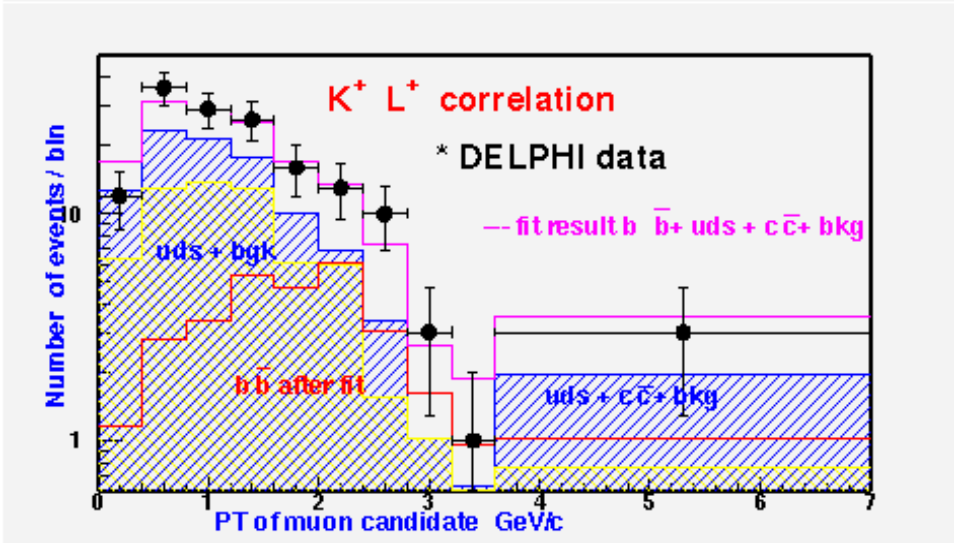
$f_{uds} \simeq 35\,\%$, $f_c \simeq 48\,\%$, $f_b \simeq 16\,\%$, $f_{bckgd} \simeq 1\,\%$

Eventselection	12.5 %
Kaon (efficiency + fragmentation)	11.0 %
Jet reconstruction	10.9 %
Ratio direct/resolved	5.6 %
α_{uds} normalization	4.2%
$\sigma_{b\bar{b}}$	3.5 %
Br(c$\to\mu$)	3.2 %
Total	22.0 %

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

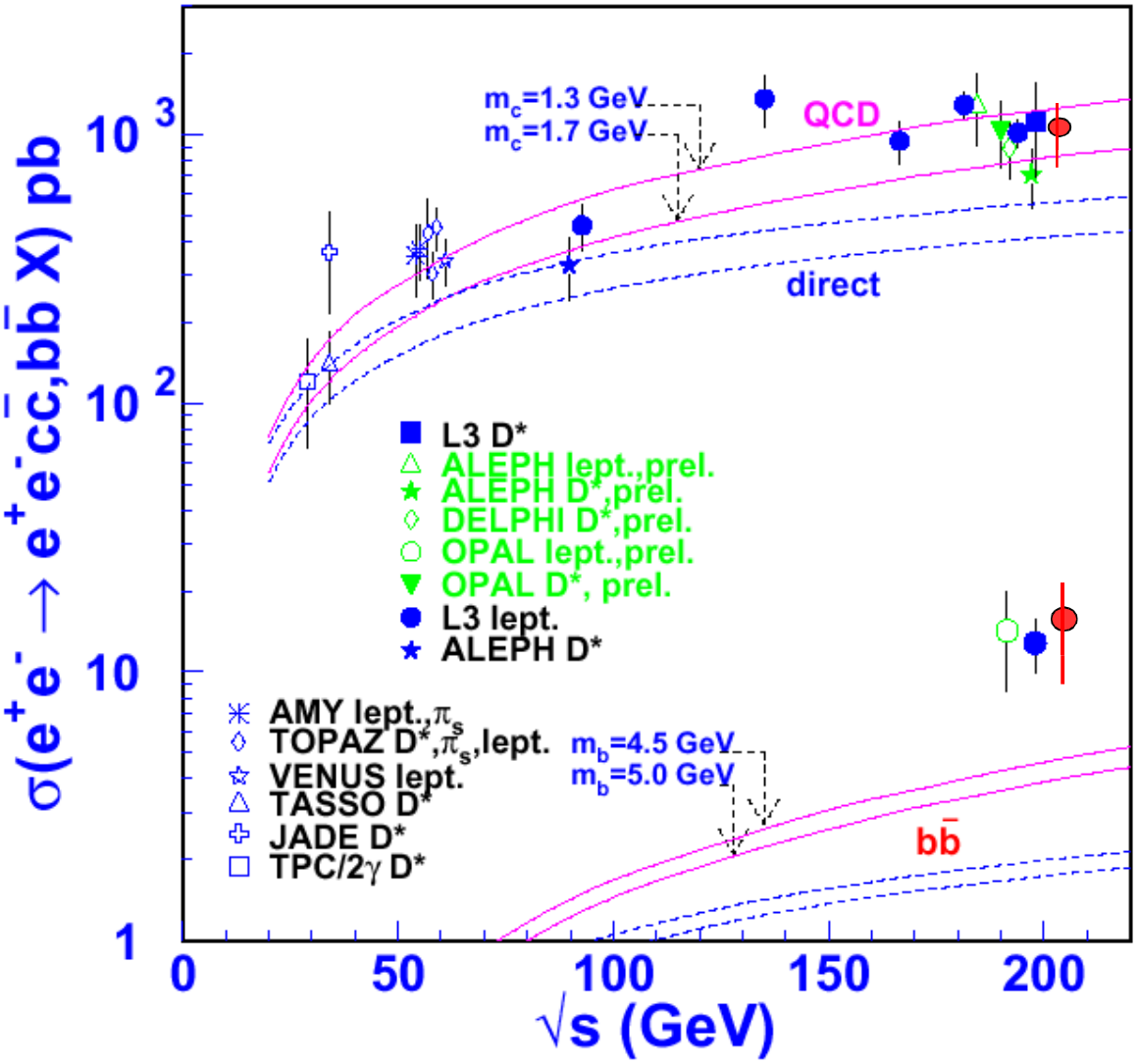
$\sigma^{b\bar{b}} = 11.4 \pm 4.5$ pb





Comparison with L3 and OPAL

● DELPHI



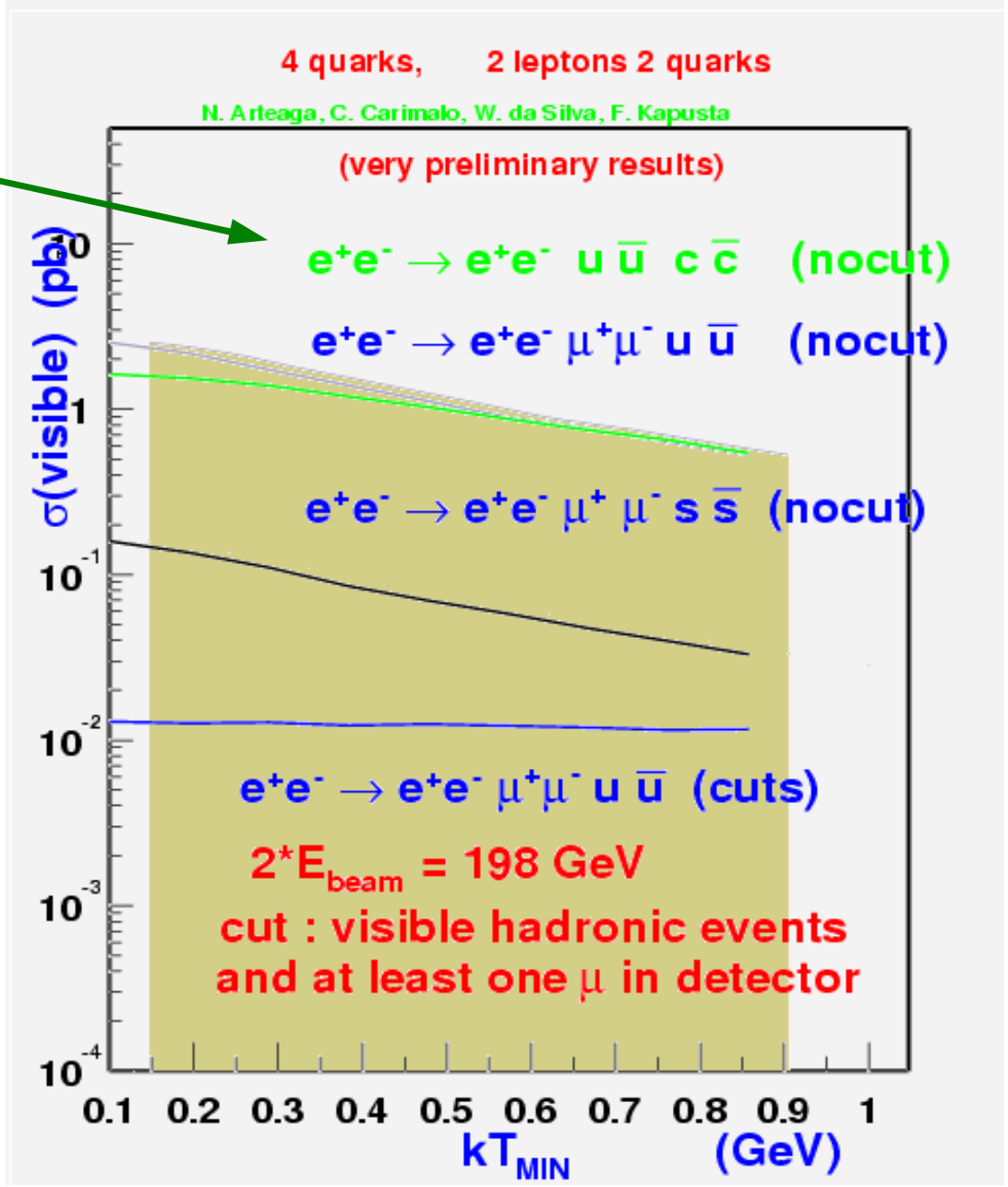
Computation of $\gamma\gamma \rightarrow$ 4 quarks and $\gamma\gamma \rightarrow$ 2 quarks 2 leptons at LEPII

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.

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

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

Statistics could be slightly improved.

A few systematics to improve especially in the uds region.

Use an additional variable as the muon impact parameter.