Bottom and Charm Quark Production in Two-Photon Collisions at LEP

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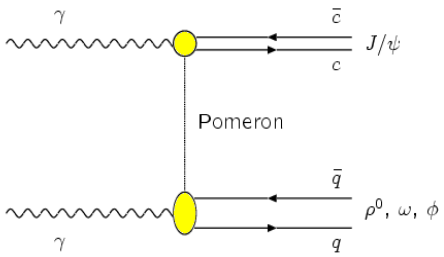
J/ψ production in γγ collisions (DELPHI)
Cross section $\sigma(e^+e^- \rightarrow c\bar{c}, b\bar{b}\ X)$
$\Rightarrow$ charm tagged by $D^{*\pm}$ (L3)
$\Rightarrow$ beauty, charm tagged by leptons (DELPHI, L3)
Summary

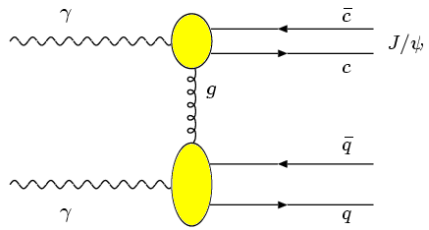
J/ψ production at LEP2 (DELPHI) $e^+e^- \rightarrow e^+e^-$ J/ψ X

- Two independent leading processes

  ⇒ VDM (pomeron exchange or diffractive dissociation of the photon)

  ⇒ Resolved processes + color octet model : most probable hypothesis.

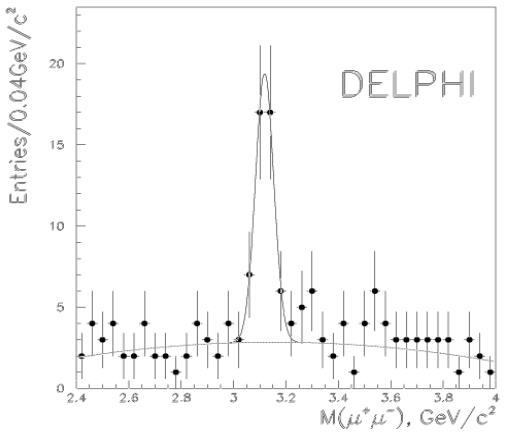




- Data LEP2 $\sqrt{s}$ = 161-207 GeV, $\boldsymbol{L}$ = 617 pb^{-1}
- MC : PYTHIA 6.156

  ⇒Select γγ events

  ⇒Tag J/ψ with muon pairs N=36 ±7 evts

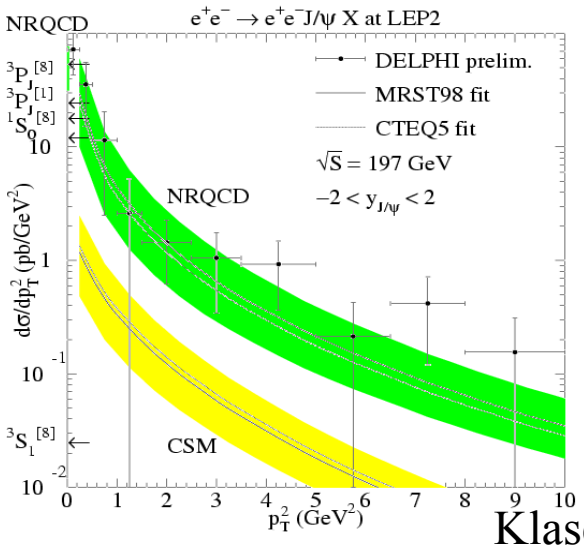


  ⇒Background :

J/ψ coming from bb̄ estimated 2.1 ± 0.6 evts

N(e+e– → Zγ → J/ψ X) < 0.2 evts

N(γγ → χ_{c2} → J/ψ $\pi^+\pi^-\pi^0$) < 0.3 evts



Results

Estimated fraction of resolved processes: 74% ± 22%

Rate = $N_{J/\psi}$ / $N_{vis\ \gamma\gamma}$ = (6.7 ± 1.3 (stat) ± 0.2 (syst)) 10^{-3}

σ(J/ψ + X) = 45 ± 9 (stat) ± 17 (syst) pb

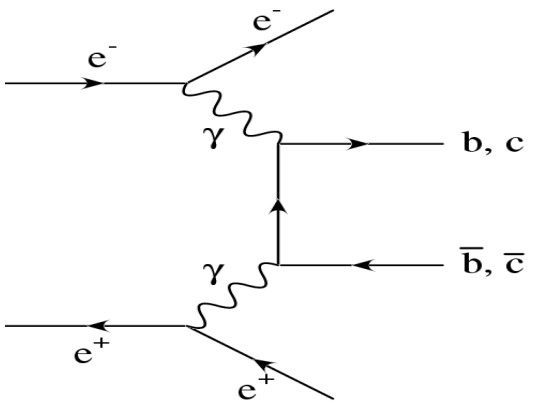
Klasen

Measurement of $\sigma(e^+e^- \to e^+e^- c\bar{c}X)$ and $\sigma(e^+e^- \to e^+e^- b\bar{b}X)$

Open charm and beauty production measurement $\Rightarrow$ provide a good test of PQCD

- Two LO main contributions
  direct and single resolved terms

Large m_b and $m_c \Rightarrow$ more reliable calculations.



Direct term

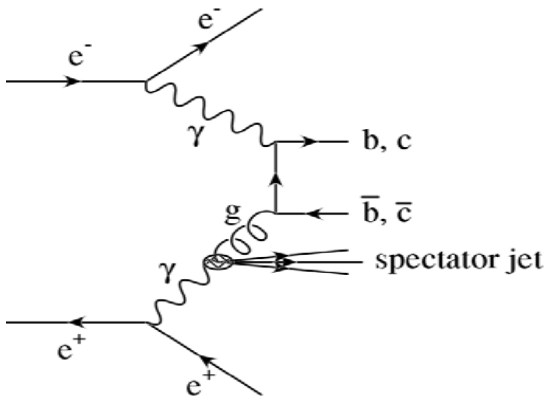
☞ NLO total cross sections computations available
Use the 10 years old Drees, Kraemer, Zunft, Zerwas

$$\kappa = \frac{\sigma^{\text{direct}\ b\bar{b}}_{\text{NLO}}}{\sigma^{\text{direct}\ b\bar{b}}_{\text{LO}}} \simeq 1.236 \qquad \kappa = \frac{\sigma^{\text{1 res}\ b\bar{b}}_{\text{DG,GRV}}}{\sigma^{\text{direct}\ b\bar{b}}_{\text{NLO}}} = 0.997\,,1.039 \qquad \text{at } \sqrt{s} = 180 \text{ GeV}$$

☞ At LEP2 energies direct and single resolved contributions are of the same order

☞ VDM and double resolved contribution are expected to be small

- Default MC used in all analyses : PYTHIA / γ pdf SaS1D



Single resolved term

Measurement of $\sigma(e^+e^- \to e^+e^- c\bar{c}X)$ using $D^{*\pm}$

LEP II data $\sqrt{s}$ = 183 - 209 GeV L = 683 pb^{-1}

$\gamma\gamma$ selection and antitagged events

Charm tagged by $D^{*\pm}$:

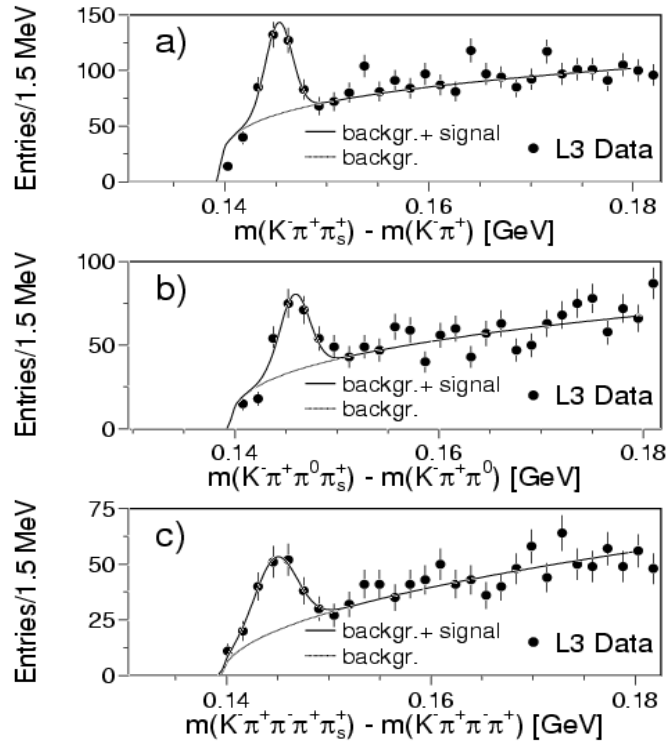
$$D^{*+} \to D^0 \; \pi_S^+$$

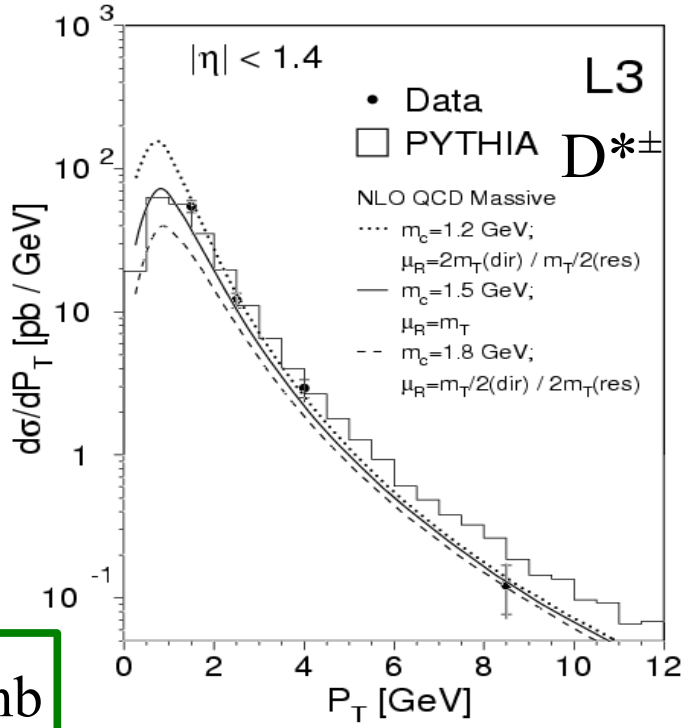
$$\hookrightarrow \; K^- \pi^+, \; K^- \pi^+ \pi^0, \; K^- \pi^+ \pi^- \pi^+$$

Results :

$d\sigma/dp_T(D^{*\pm})$ with $|\eta| < 1.4$ and $1.\ \text{GeV} < p_T < 12.\ \text{GeV}$

Visible region





Comparison with PYTHIA LO
Frixione NLO MC

$$\sigma(e^+e^- \to e^+e^- D^{*\pm} X)_{vis} = 71.2 \pm 5.3\ (\text{stat}) \pm 9.8\ (\text{syst})\ \text{pb}$$

Extraction of the charm cross section

$$\sigma(e^+e^- \to e^+e^- c\bar{c}X) = (\ 1.12 \pm 0.09\ (\text{stat}) \pm 0.16\ (\text{syst})\ ^{+0.54}_{-0.25}\ )\ \text{nb}$$

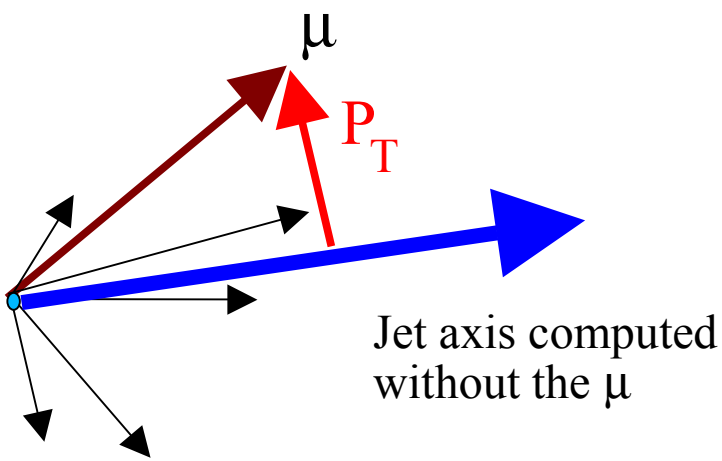
Measurement of $\sigma(e^+e^- \to e^+e^- c\bar{c}X)$ and $\sigma(e^+e^- \to e^+e^- b\bar{b}X)$

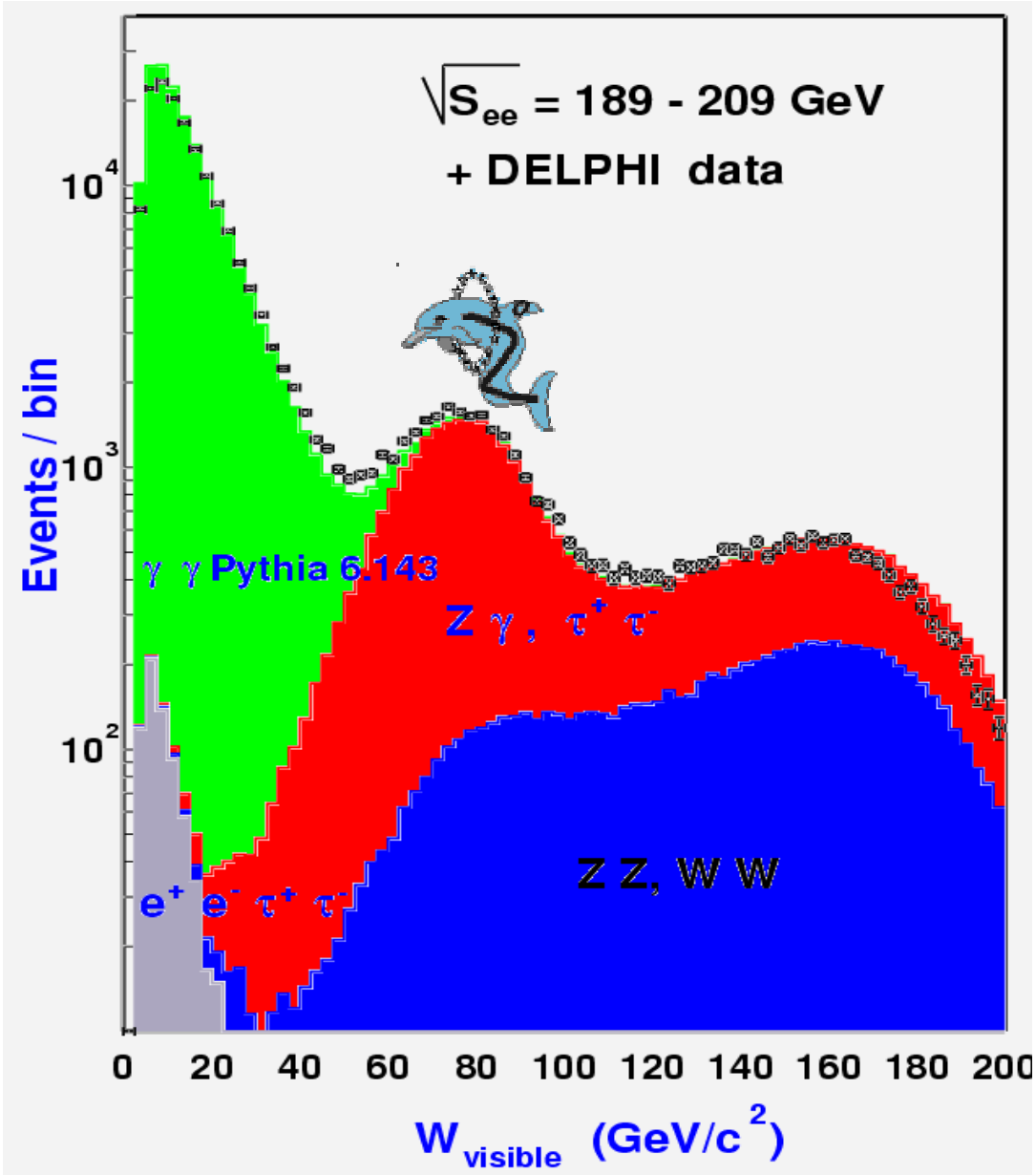
Event selection strategy
(for L3 and DELPHI)

Select anti-tagged $\gamma\gamma$ events

Identify a lepton as
a signature for semi-leptonic
charm and beauty decays

Reconstruct jets and compute the sensitive variable (the lepton transverse momentum with respect to the lepton jet axis)





Measurement of $\sigma(e^+e^- \to e^+e^- b\bar{b}X)$

Fitting strategy

. Data LEP2 $\sqrt{s}$ = 189-209 GeV, L =413 pb^{-1}

Use muons

☞ Charm and beauty contributions well separated in p_T distribution

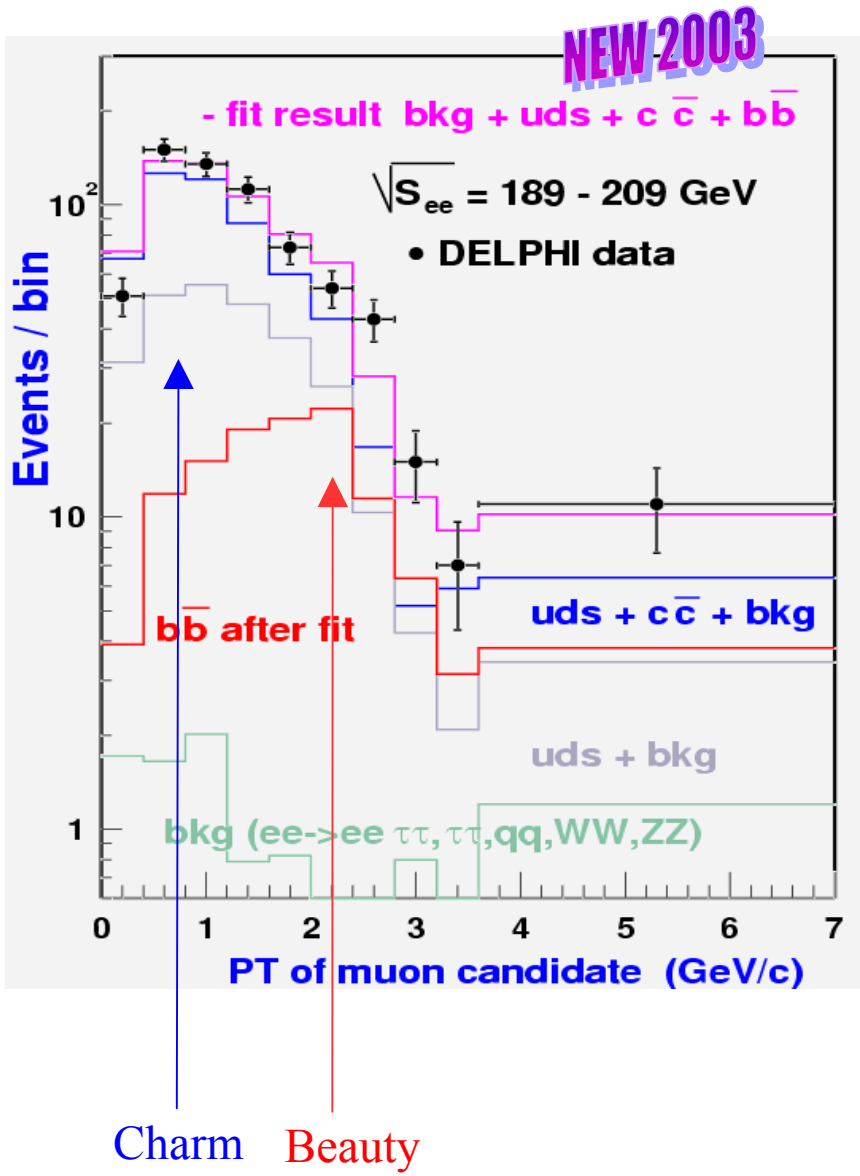
☞ χ^2 one variable fit

① N_{bb} fit parameter variable

② $N_{\mathrm{MC}}^{\mathrm{bckgd}}$ estimated background from MC

③ N_{MC}^{c} fixed by LEP average charm cross section

④ N_{uds} contribution estimated from the data



Result

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

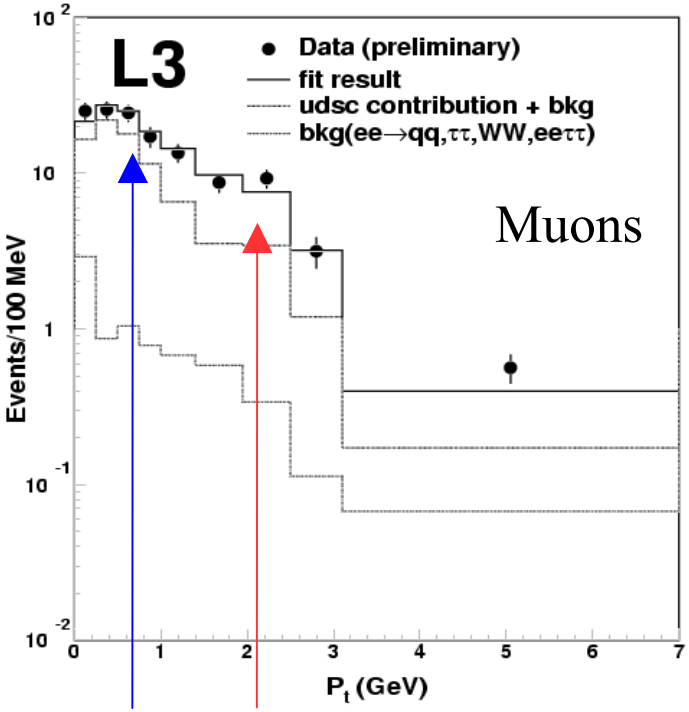
Measurement of $\sigma(e^+e^- \to e^+e^- c\bar{c}X)$ and $\sigma(e^+e^- \to e^+e^- b\bar{b}X)$

$\Rightarrow$ Upgrade of their previous measurement

. Data $\sqrt{s}$ = 189 – 209 GeV L = 627 pb^{-1}

. Use muons and electrons

. χ^2 : 3 variable fit N_{bb}, N_{cc}, N_{uds}



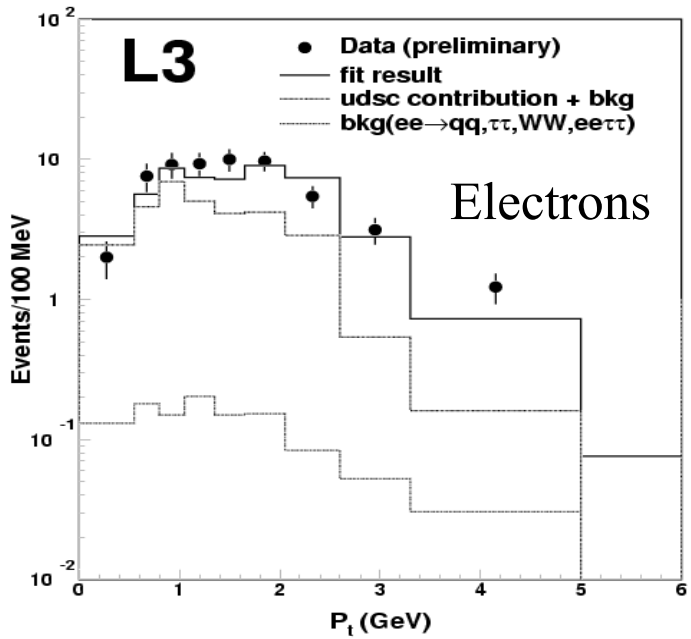
Results

$\sigma(e^+e^- \to e^+e^- b\bar{b}X)_{muons}$ = 13.0 $\pm$ 2.3 (stat) $\pm$ 2.3 (syst) pb

$\sigma(e^+e^- \to e^+e^- b\bar{b}X)_{electrons}$ = 12.6 $\pm$ 2.4 (stat) $\pm$ 2.3 (syst) pb

$\Rightarrow$ μ and e tag results are consistent

$\sigma(e^+e^- \to e^+e^- b\bar{b}X)_{combined}$ = 12.8 $\pm$ 1.7 (stat) $\pm$ 2.3 (syst) pb



$\Rightarrow$ result in agreement with L3 previous measurement

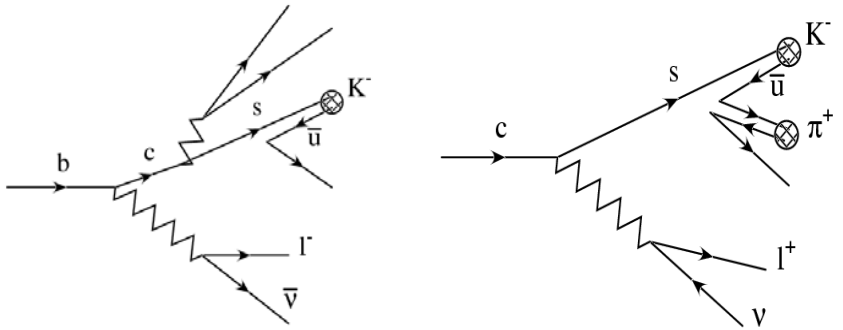
$\Rightarrow$ as a subproduct of the control test of the charm sample

$\sigma(e^+e^- \to e^+e^- c\bar{c}X)_{combined}$ = 998 $\pm$ 117 (stat) pb

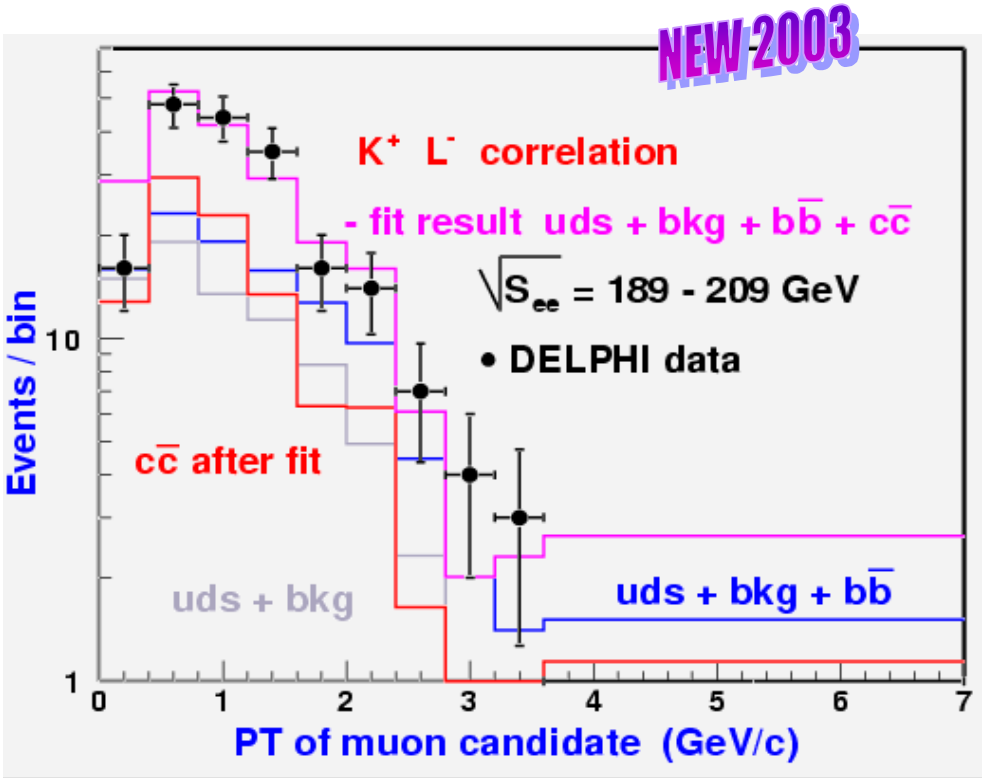
(in agreement with L3 previous measurement)

Measurement of $\sigma(e^+e^- \to e^+e^- c\bar{c}X)$ and $\sigma(e^+e^- \to e^+e^- b\bar{b}X)$

K-lepton charge correlations for beauty or charm enrichment



Identify a K in lepton jet with RICH and TPC

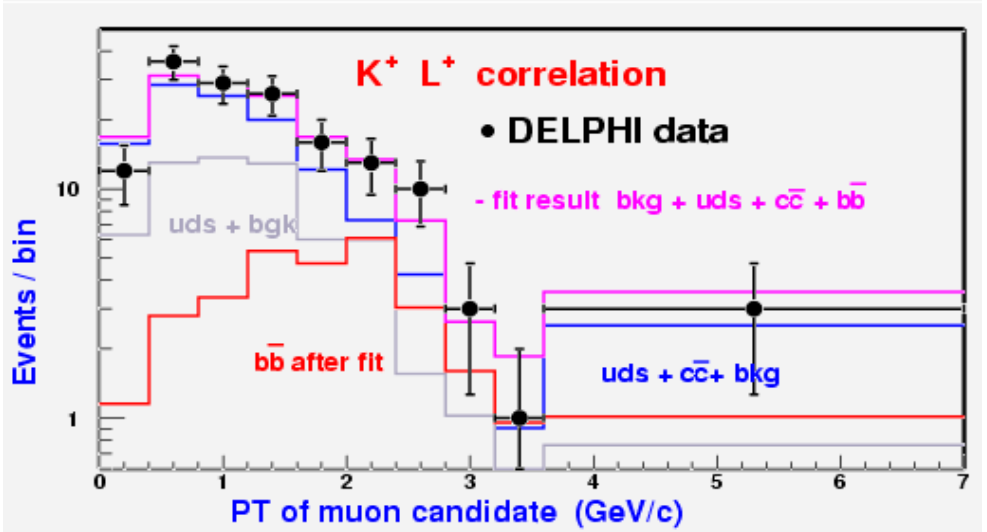


$c\bar{c}$: K^+l^- charge correlation

fix N_{bb}: value given by the previous measurement

fit N_{cc}

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



$b\bar{b}$: K^+l^+ charge correlation

fix N_{cc} : value given by LEP average

fit N_{bb}

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

⇨ in agreement with previous DELPHI measurement

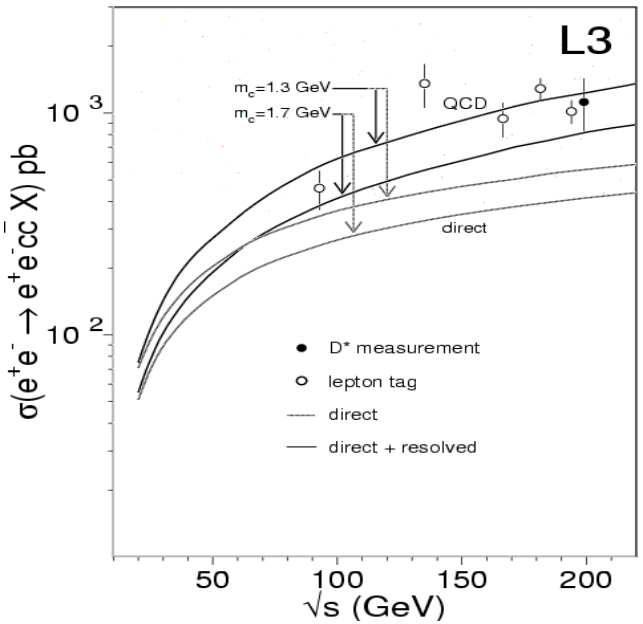
Measurement of $\sigma(e^+e^- \to e^+e^- c\bar{c}X)$ and $\sigma(e^+e^- \to e^+e^- b\bar{b}X)$

Summary

Single resolved processes are needed
to describe the data

Consistent LEP results

Good agreement with QCD
Drees, Kraemer, Zunft, Zerwas



New results from DELPHI
with K-lepton charge correlations
for the first time in $\gamma\gamma$ physics

DELPHI NEW
2003

DELPHI confirms the L3 and OPAL
beauty excess