

η_c and η_b in two-photon collisions

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IHEP Protvino

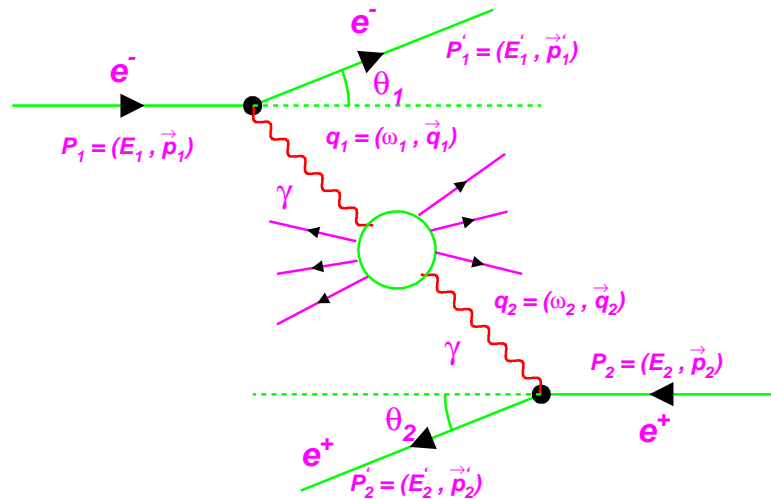
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(DELPHI Collaboration)

OUTLINE

η_c formation

Search for η_b

Heavy quarkonium formation

Outgoing e^+e^- are undetected ('No TAG') \rightarrow photons are quasi-real

Final state is neutral unflavored meson with $C=+1$

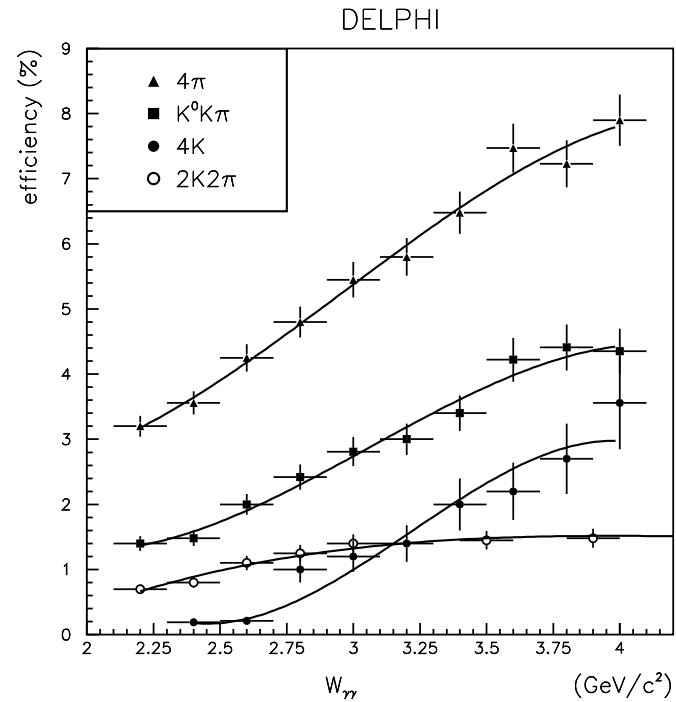
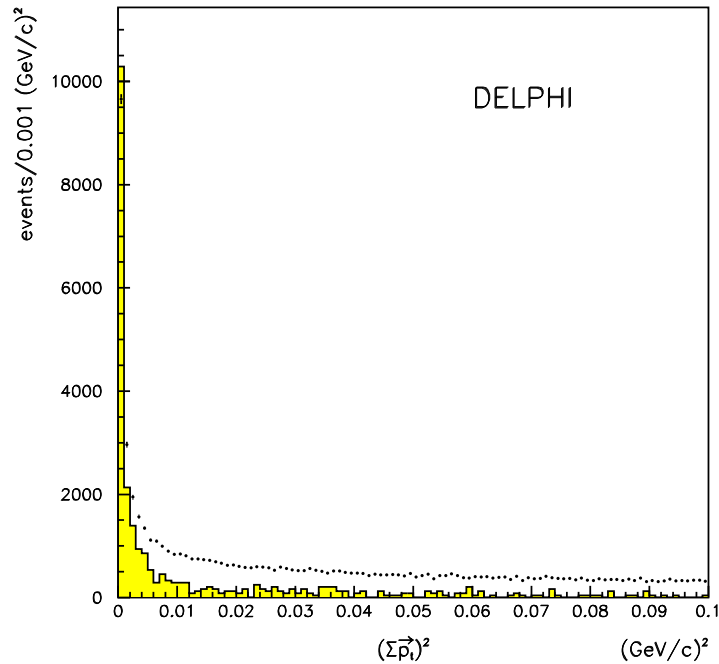
$$\sigma(\gamma\gamma \rightarrow \eta_{c,b}) = 8\pi \cdot F^2(q_1^2, q_2^2) \cdot \frac{\Gamma_{\gamma\gamma}(\eta_{c,b}) \cdot \Gamma_{tot}(\eta_{c,b})}{(W^2 - M_{\eta_{c,b}}^2)^2 + M_{\eta_{c,b}}^2 \Gamma_{tot}^2(\eta_{c,b})}$$

Theory prediction for $\Gamma_{\gamma\gamma}(\eta_c)$ from 3 to 14 keV

L.J.Reinders, H.Rubinstein, S.Yazaki Phys.Rep. 127-1 (1985) 1.

Experiments give $\Gamma_{\gamma\gamma}(\eta_c)$ from 3.7 to 27 keV

η_c and η_b production in two-photon collisions

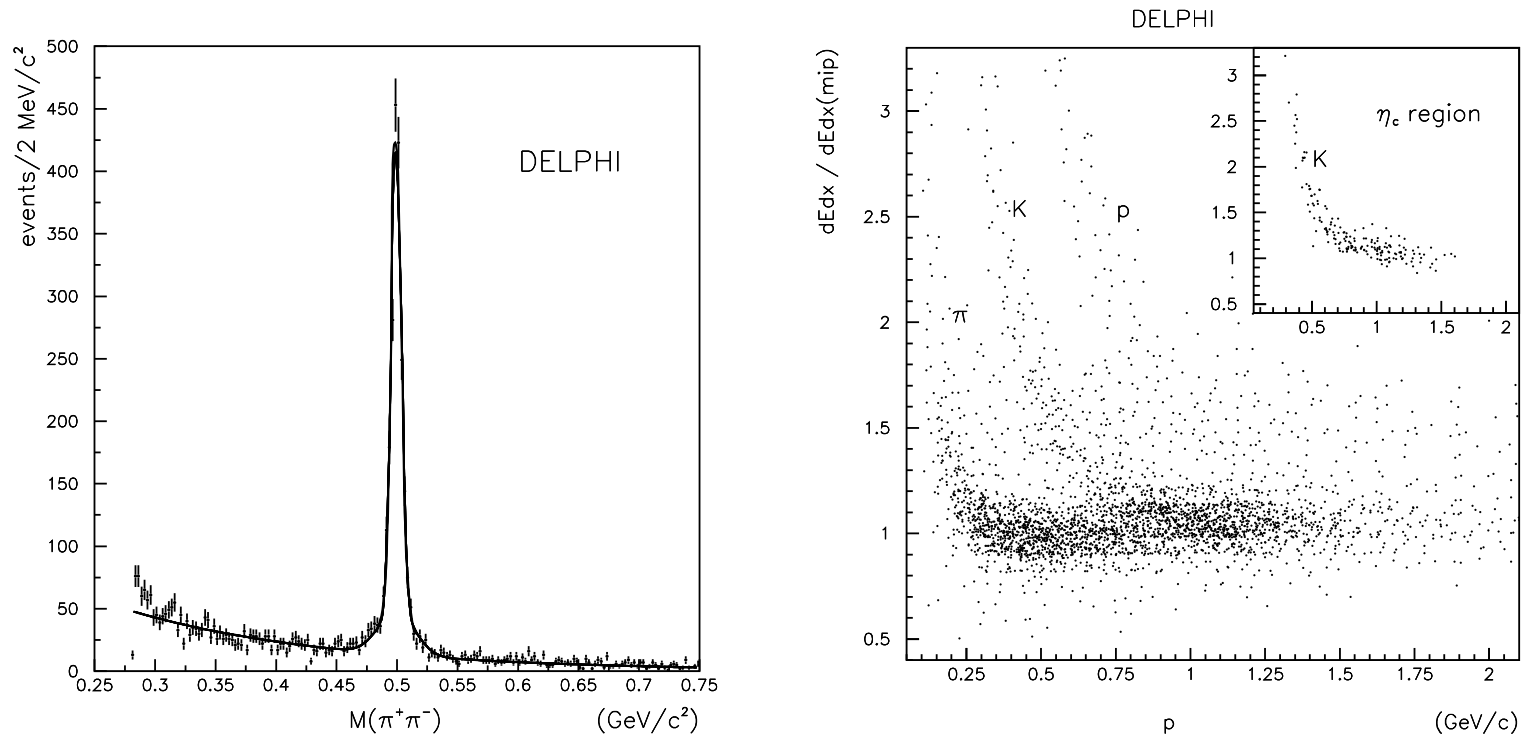


Decay modes are 4π , $K^0K\pi$, $4K$, $2K2\pi$

p_t^2 cut is 0.04 (GeV/c)²

Luminosity-weighted efficiencies for the given final states have different behaviour as a function of corresponding invariant mass

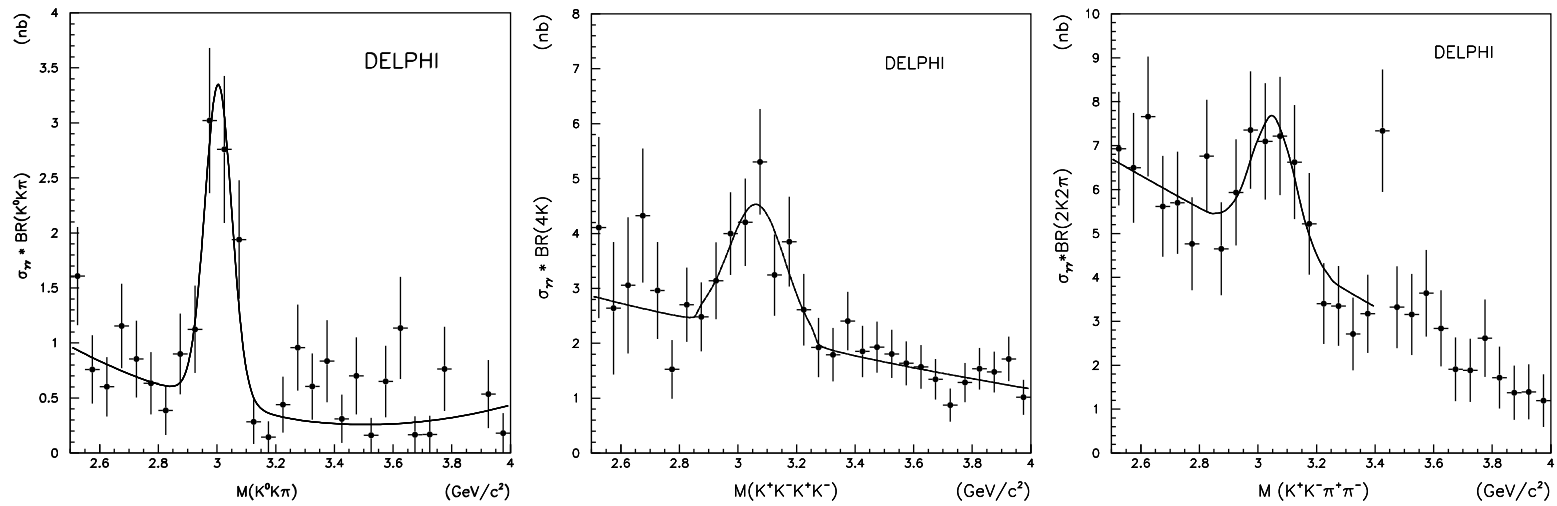
η_c and η_b production in two-photon collisions



K^0 identification was done using standard V^0 reconstruction

Charged tracks are identified in TPC using DE/DX measurement

η_c and η_b production in two-photon collisions

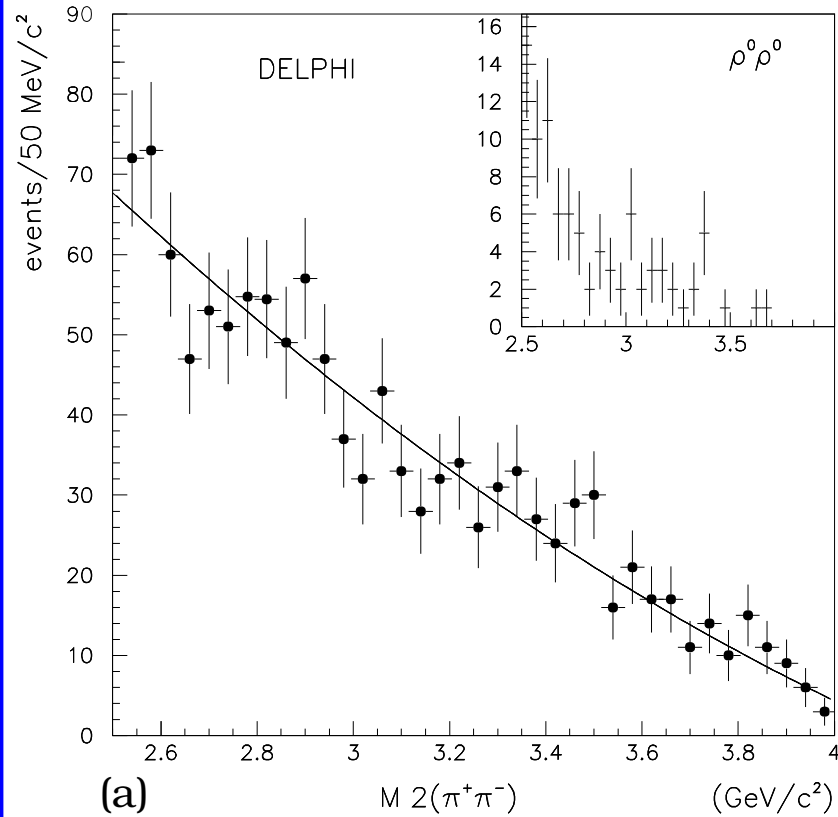


$$\Gamma_{\gamma\gamma} = 13.3 \pm 2.6(stat.) \pm 2.0(syst) \pm 3.5(BR) \text{ keV for } K^0 K \pi$$

$$\Gamma_{\gamma\gamma} = 16.5 \pm 4.3(stat.) \pm 2.7(syst) \pm 9.4(BR) \text{ keV for } K^+ K^- K^+ K^-$$

$$\Gamma_{\gamma\gamma} = 14.2 \pm 4.9(stat.) \pm 2.9(syst) \pm 4.9(BR) \text{ keV for } K^+ K^- \pi^+ \pi^-$$

η_c and η_b production in two-photon collisions

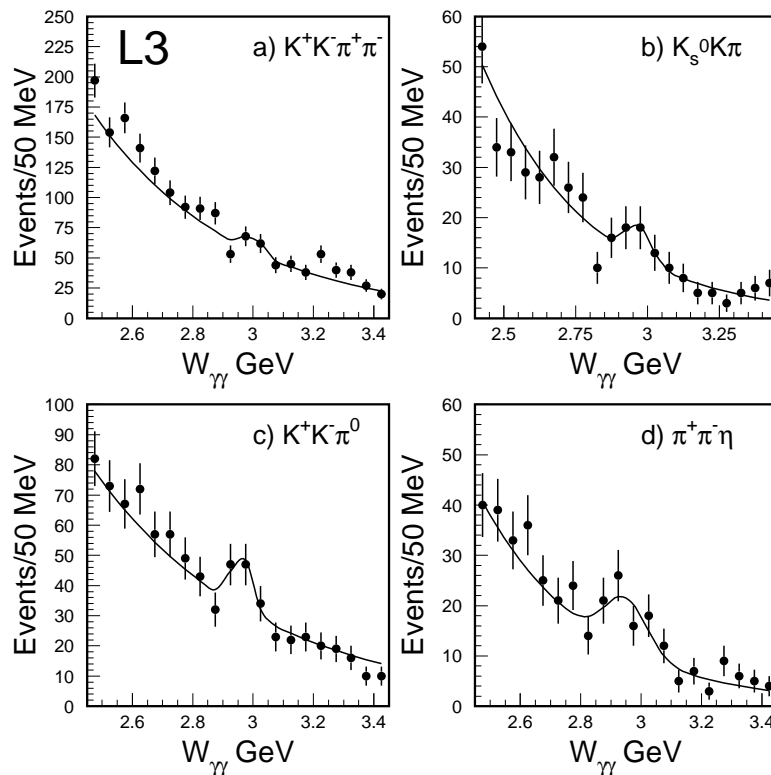


No signal is seen in the $\pi^+\pi^-\pi^+\pi^-$ mode

Upper limit of $\Gamma_{\gamma\gamma}$ assuming PDG branching ratio $1.2 \pm 0.4\%$

$\Gamma_{\gamma\gamma} < 3.8\text{keV}$ at 95% CL

η_c and η_b production in two-photon collisions



Published L3 result at $\sqrt{s} = 91\text{GeV}$ and $\sqrt{s} = 183\text{GeV}$:

$$\Gamma_{\gamma\gamma} = 6.9 \pm 1.7(\text{stat.}) \pm 0.8(\text{syst}) \pm 2.0(\text{BR}) \text{ keV}$$

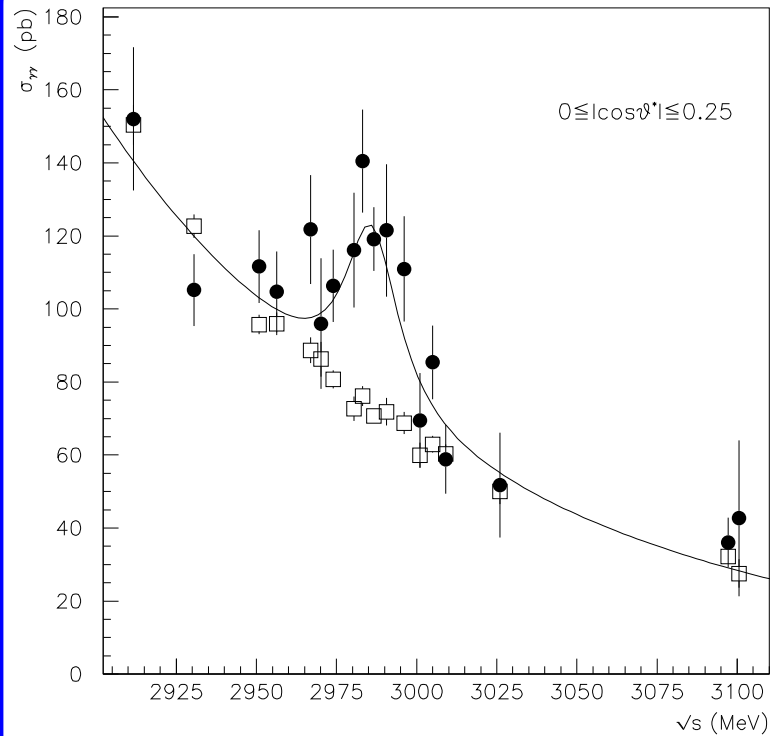
Phys. Lett. B 461 (1999) 155-166

Result reported at this Conference for all LEP2 statistics:

$$\Gamma_{\gamma\gamma} = 3.68 \pm 0.87(\text{stat.}) \pm 0.8(\text{syst}) \pm 2.0(\text{BR}) \text{ keV}$$

No signal is seen by L3 in 4π mode

η_c and η_b production in two-photon collisions



Recent result from FNAL E835 on η_c in proton-antiproton annihilation

$$M = 2984.1 \pm 2.1 \pm 1.0 \text{ MeV}$$

$$\Gamma = 20.4_{-6.7}^{+7.7} \pm 2.0 \text{ MeV}$$

$$\Gamma_{\gamma\gamma} = 3.8_{-1.0}^{+1.1+1.9} \text{ keV}$$

η_c results

DELPHI weighted mean result

$$\Gamma_{\gamma\gamma} = 13.9 \pm 2.0(\text{stat.}) \pm 1.4(\text{syst}) \pm 2.7(\text{BR})\text{keV}$$

L3 published result

$$\Gamma_{\gamma\gamma} = 6.9 \pm 1.7(\text{stat.}) \pm 0.8(\text{syst}) \pm 2.0(\text{BR})\text{keV}$$

L3 latest result

$$\Gamma_{\gamma\gamma} = 3.68 \pm 0.87(\text{stat.}) \pm 0.8(\text{syst}) \pm 2.0(\text{BR})\text{keV}$$

E835 result

$$\Gamma_{\gamma\gamma} = 3.8_{-1.0-1.0}^{+1.1+1.9}\text{keV}$$

No signal in 4π decay mode is seen at LEP experiments

Search for η_b

Theory prediction:

$$m_{\eta_b} < m_{\Upsilon}(9.46 \text{ GeV}/c^2)$$

$$\Delta m(\Upsilon, \eta_b) \simeq 10 \div 130 \text{ MeV}$$

$$m_{\eta_b} \simeq 9.33 \div 9.45 \text{ GeV}/c^2$$

$$\Gamma_{tot}(\eta_b) \simeq \Gamma_{tot}(\eta_c) \simeq 16.0 \text{ MeV},$$

$$\Gamma_{\gamma\gamma}(\eta_b) \simeq .4 \div .5 \text{ keV}$$

$$\sigma(\eta_b) |_{\sqrt{s_{ee}}=200\text{GeV}} \simeq (.21 \div .27) \text{ pb}$$

$$BR(\eta_b \rightarrow 4\pi^\pm(\text{K}^\pm)) \simeq 2\%,$$

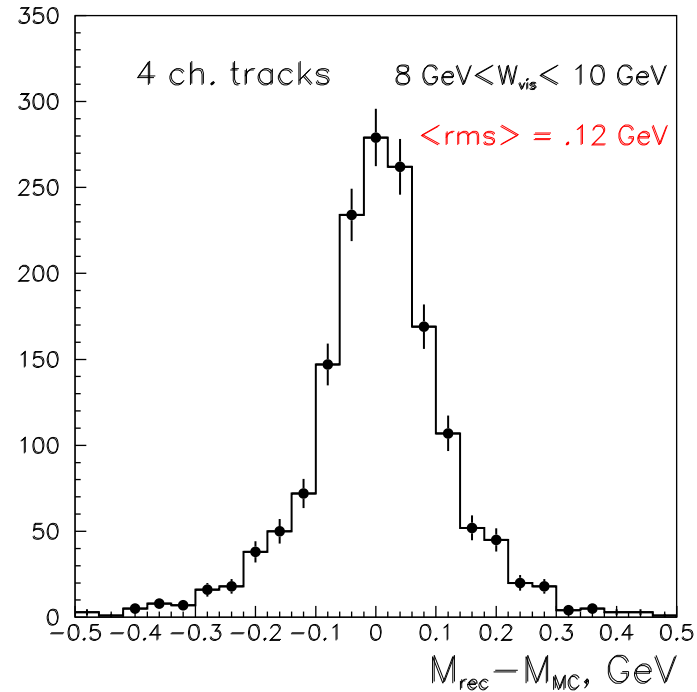
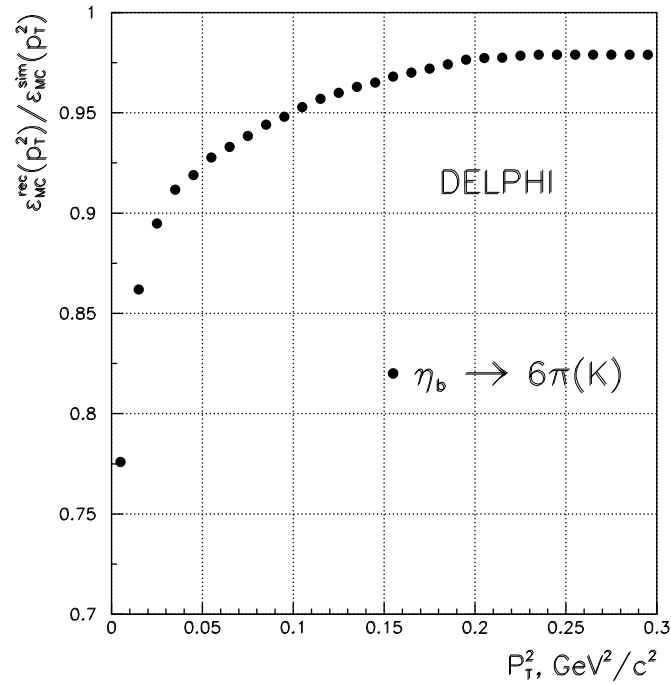
$$BR(\eta_b \rightarrow 6\pi^\pm(\text{K}^\pm)) \simeq 2\%,$$

$$BR(\eta_b \rightarrow 8\pi^\pm(\text{K}^\pm)) \simeq 2.2\%.$$

Event selection in DELPHI:

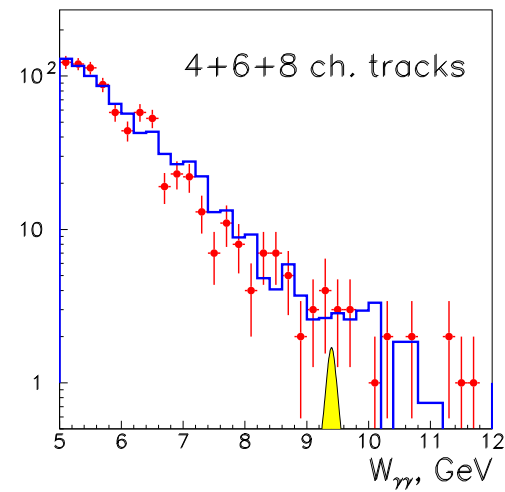
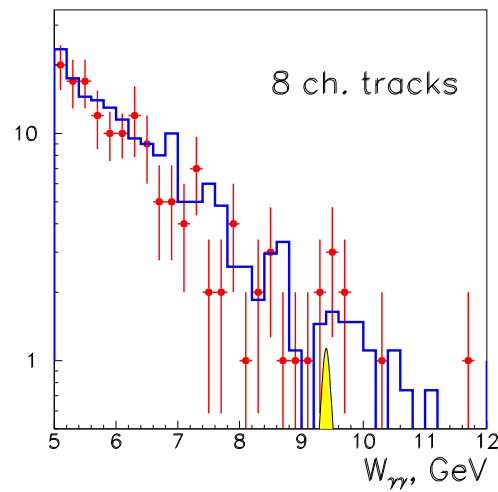
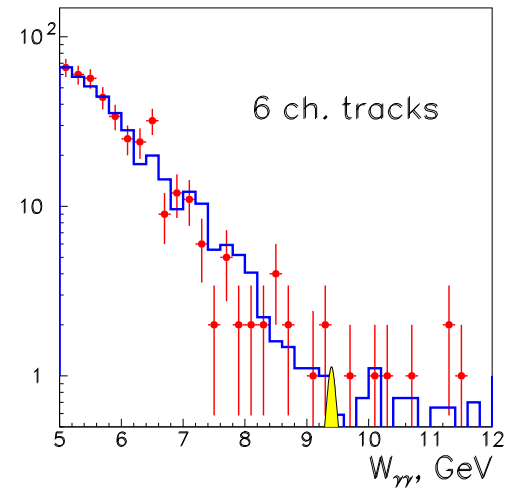
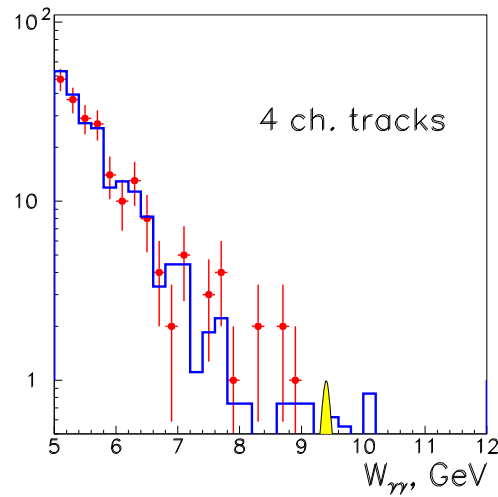
- Number of charged tracks
4, 6 or 8 $\pi^\pm(\text{K}^\pm)$
- $\sum Q_i = 0$
- no muons
- no electrons
- no protons
- no gammas
- for 4 charged track events
 $M(3\pi)^\pm > 1.9\text{GeV}/c^2$
- $(\sum \vec{p}_t)^2 < 0.08(\text{GeV}/c)^2$

η_c and η_b production in two-photon collisions

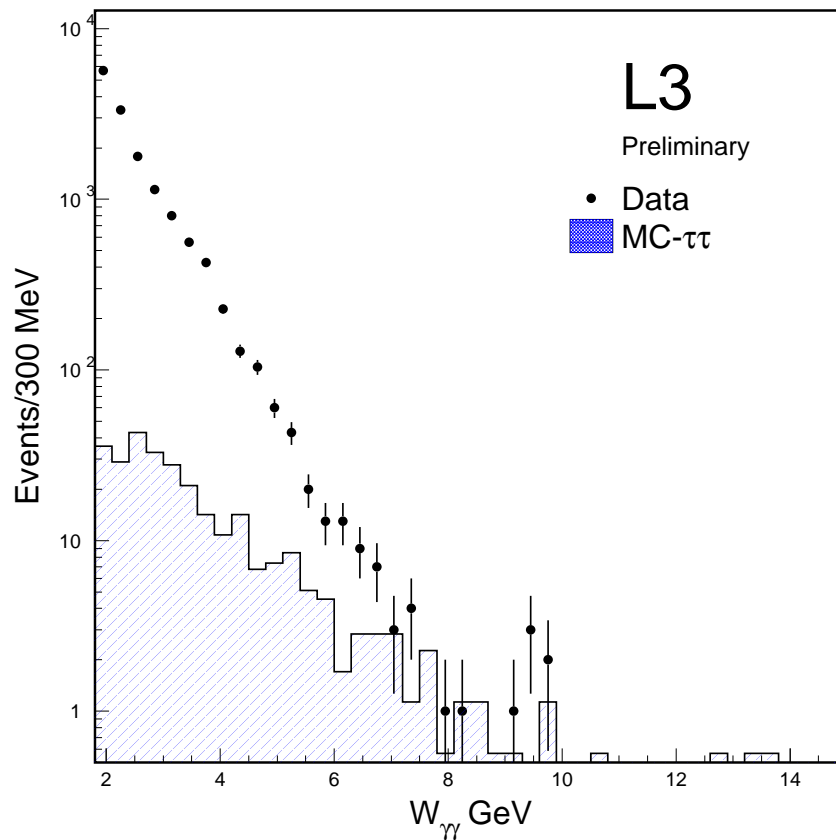


Characteristics of DELPHI resolution in P_T^2 and invariant mass

η_c and η_b production in two-photon collisions



η_c and η_b production in two-photon collisions



L3 observes 6 candidates
while 2.5 of background
are expected

Average mass of η_b candi-
dates is 9.51 ± 0.30 GeV

η_c and η_b production in two-photon collisions η_b results

Mass, GeV	4 ch.tr (bkg)	6 ch.tr (bkg)	8 ch.tr (bkg)
9.2 ÷ 9.4	0 (.2)	2 (1.)	2 (1.4)
9.4 ÷ 9.6	0 (.6)	0 (.6)	3 (1.7)
N_{ev} (95% upp. lim)	3.0	5.0	7.5
efficiency, ε	9.5%	5.5%	2.7%
$\Gamma_{\gamma\gamma}(\eta_b) \cdot Br$, keV (95% upp. lim)	.093	.27	.78
ALEPH	.057	.128	
L3	.3	.4	

Conclusions

$\eta_c(2980)$ is studied by DELPHI and L3 in many decay modes. Their results on $\Gamma_{\gamma\gamma}(\eta_c)$ are not well compatible.

The latest result from L3 and result from FNAL E835 are compatible and twice lower than the PDG value.

No signal seen in the four charged pion decay mode.

η_b has been searched in the 4,6,8-prong decay modes by ALEPH, DELPHI and L3. Few candidates are seen in the signal region and their numbers are compatible with the expectation from the background processes. Upper limits for $\Gamma_{\gamma\gamma}(\eta_b) \times BR(\eta_b)$ are obtained.