Exclusive Channels in Photon-Photon Collisions at LEP

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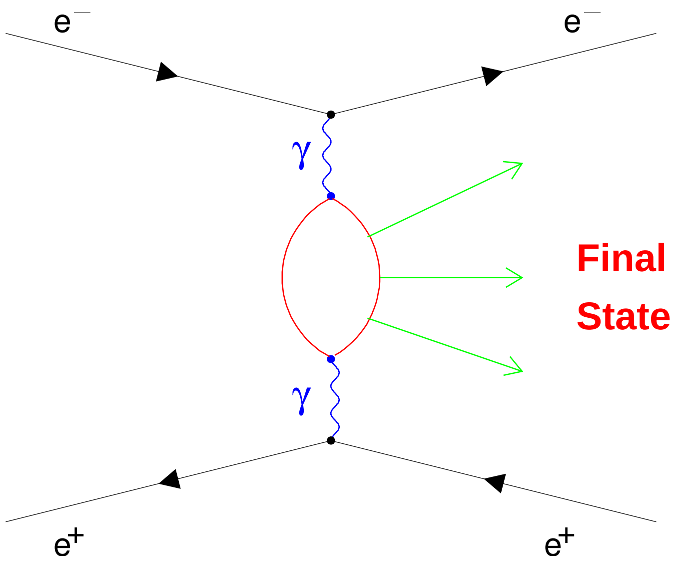
Outline

- Introduction
- Baryon-antibaryon production
- Formation of light resonances
- Search for the η_b
- Conclusions & Outlook

Exclusive channels



- Outgoing e^+e^- are undetected ("No Tag")
  $\longrightarrow$ Quasi-real photons
- Exclusive channel
  $\longrightarrow$ the final state is fully reconstructed
- Final state
  $\longrightarrow$ Baryon-antibaryon pair
  $\longrightarrow$ R neutral unflavoured meson with C=+1

The cross section for the process

$$e^+e^- \rightarrow e^+e^-\gamma\gamma \rightarrow e^+e^-X$$

can be written as

$$\sigma(e^+e^- \rightarrow e^+e^- R) = \int d^5\mathcal{L}(\alpha_i)\cdot\sigma(\gamma\gamma \rightarrow X)$$

The Luminosity Function $\mathcal{L}(\alpha_i)$ is QED calculable.

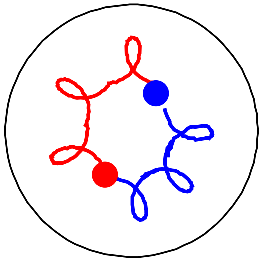
- Resonant state

$$\boxed{\boldsymbol{\sigma}(e^+e^- \rightarrow e^+e^- \boldsymbol{R}) = \boldsymbol{\mathcal{K}}\cdot\boldsymbol{\Gamma}_{\gamma\gamma}}$$

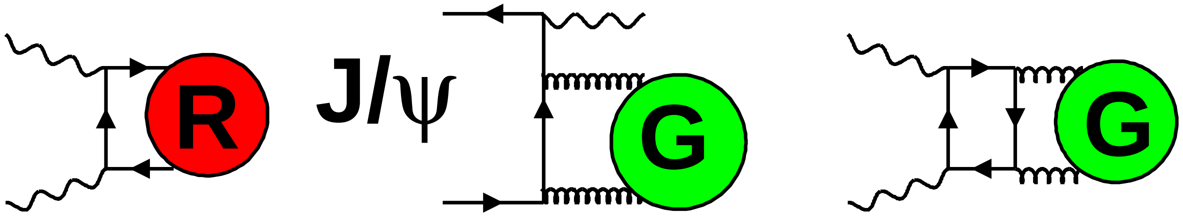
Glueballs?

- QCD is non abelian
- Glueballs:

  bound states of two or more gluons



Glueball



$\Gamma_{\gamma\gamma}$(R) $\Gamma_{\gamma G}$(J/ψ) $\Gamma_{\gamma\gamma}$(G)

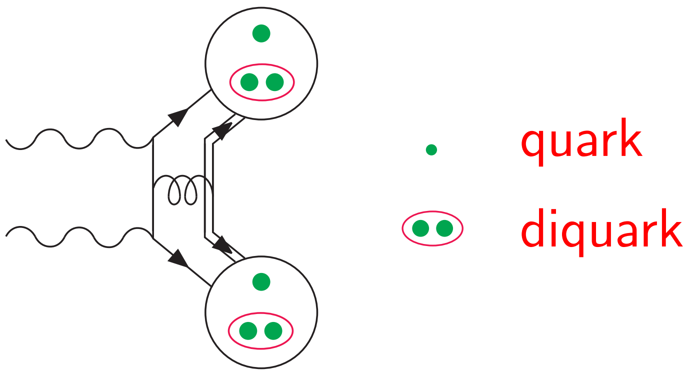
$\boxed{\Gamma_{\gamma\gamma}(\mathrm{G}) \text{ is very small !}}$

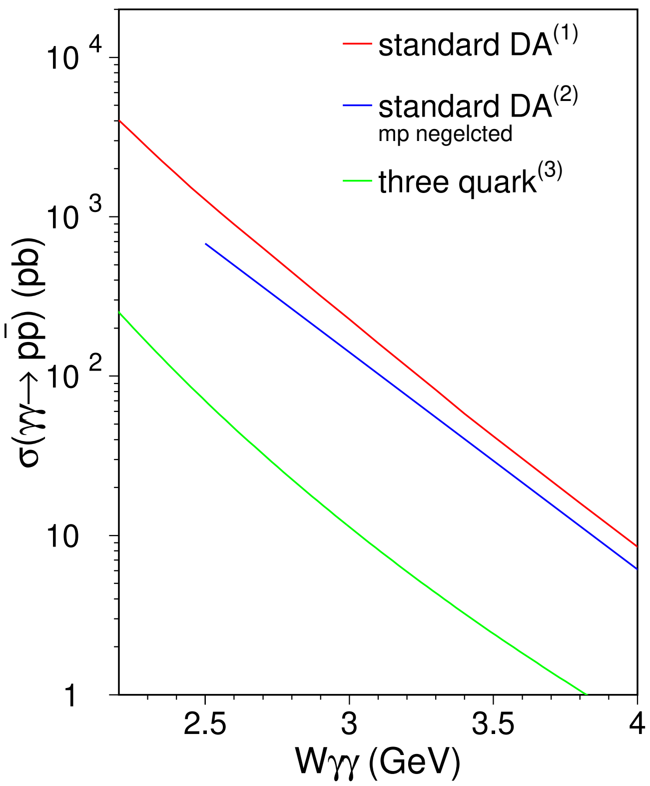
☞ $q\bar{q}$/glueball mixing is possible!

The cross section is sensitive to the quark structure

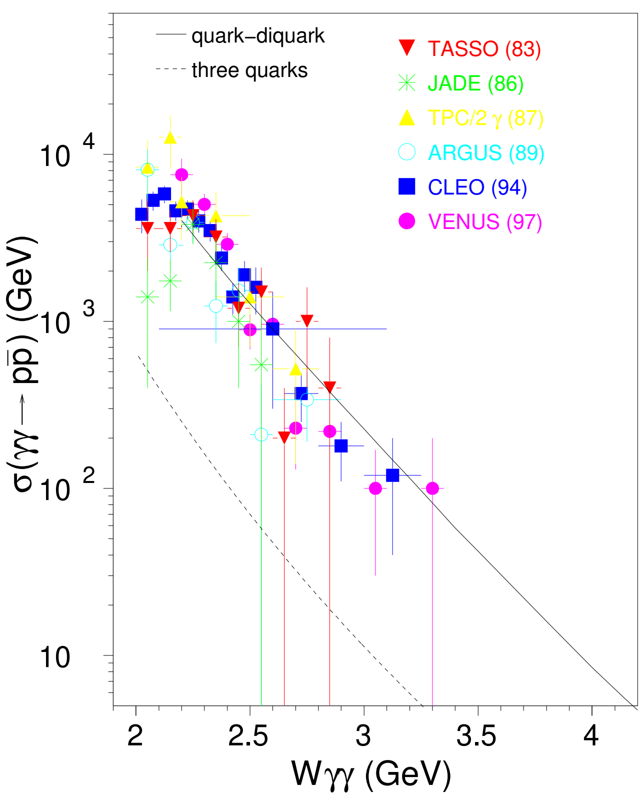
Baryon $\longrightarrow$ three quark bound state

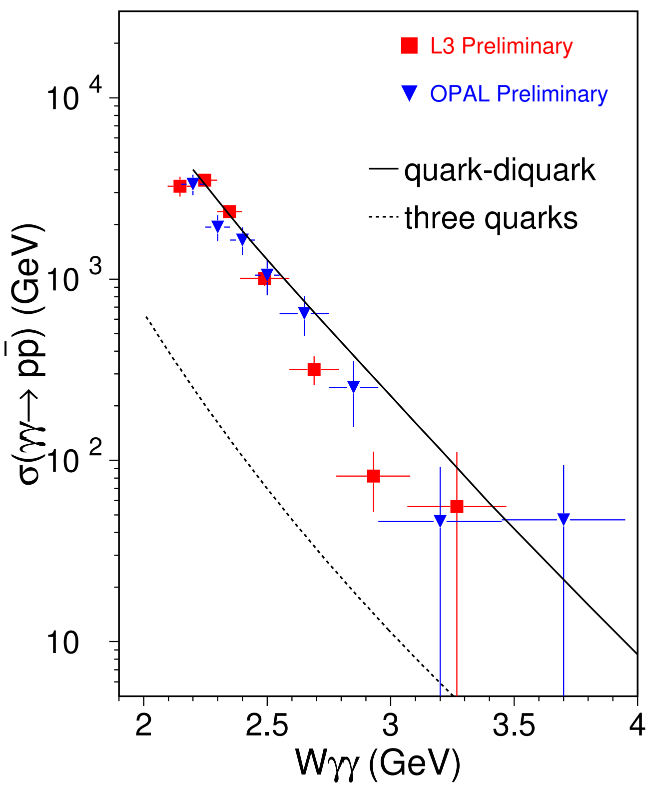
$\longrightarrow$ quark-diquark bound state





(1) C. Berger, B. Lechner and W. Schweiger, Fizika **B 8** (1999) 371.
(2) M. Anselmino *et al.*, Int. J. Mod. Phys. **A 4** (1989) 5213.
(3) G. Farrar *et al.*, Nucl. Phys. **B 259** (1985) 702.

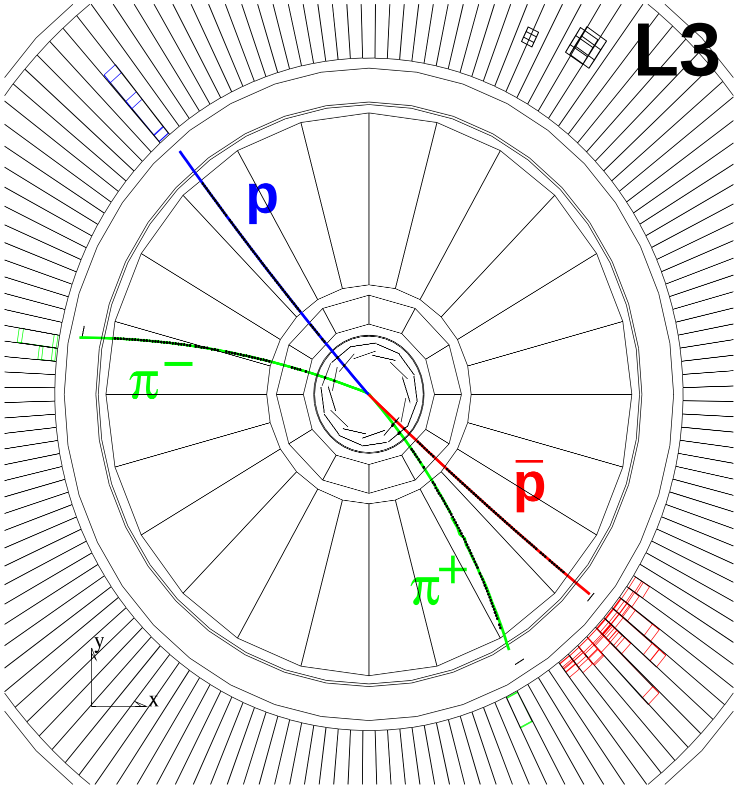




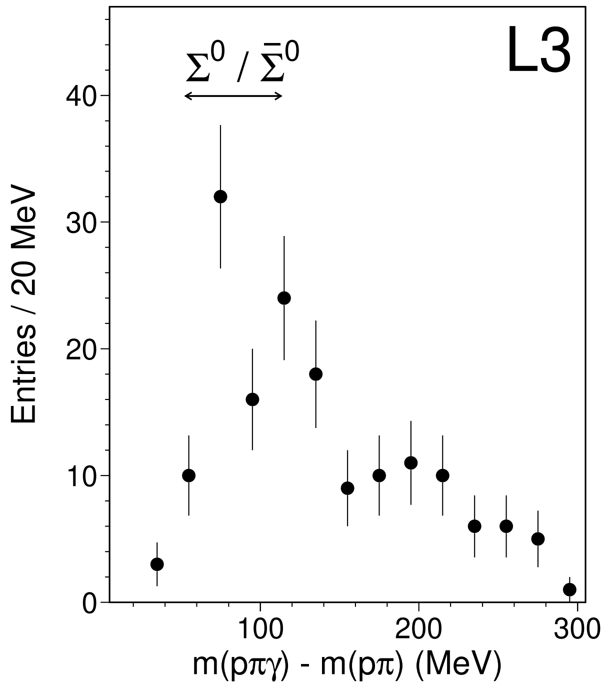
	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	Events	Reference
OPAL	183 - 189	249	189	OPAL PN487 (2001)
L3	183 - 209	610	757	

- Three quark models are excluded!

$\gamma\gamma \to \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$



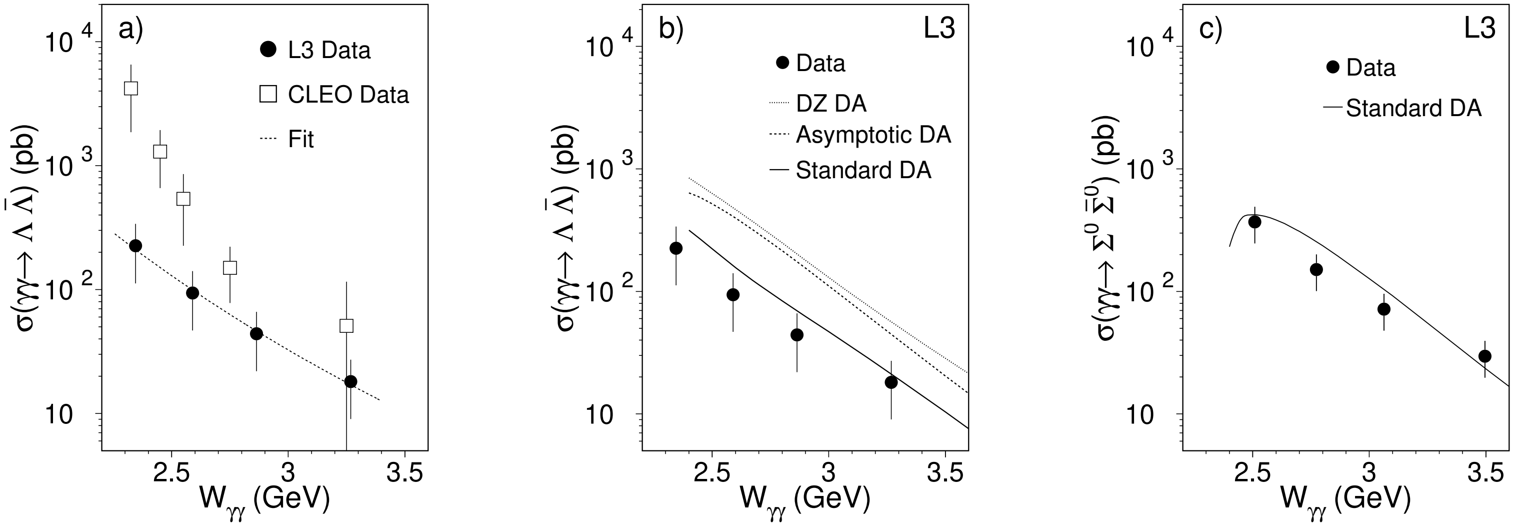
$\Sigma^0 \to \Lambda\gamma \to p\pi^-\gamma$
$\bar{\Sigma}^0 \to \bar{\Lambda}\gamma \to \bar{p}\pi^+\gamma$



$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	$\Lambda\bar{\Lambda}$ Events	$\Sigma^0\bar{\Sigma}^0$ Events
91 - 208	844	19	14

L3 Collab., CERN-EP/2002-013, Submitted to Phys.Lett.B.

$\gamma\gamma \rightarrow \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$



- Good agreement with the quark-diquark model

- Dimensional counting rule: $\sigma \propto \mathrm{W}^{-n}$

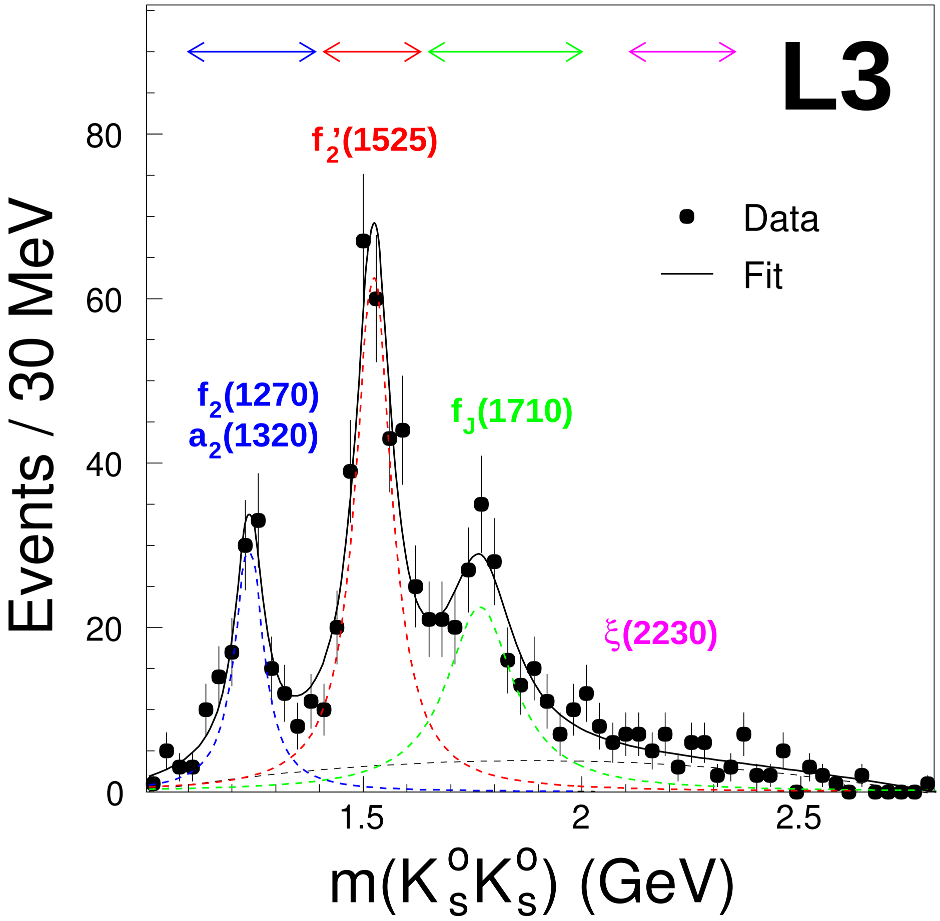
(S.J.Brodsky and J.P.Ferrar,Phys.Rev.Lett.31(1973)1153)

n=6 quark-diquark

n=10 three quarks

$$\boxed{\text{Fit} : \boldsymbol{n} = 7.6 \pm 3.9}$$

$\gamma\gamma \rightarrow R \rightarrow K^0_S K^0_S$



L3 Collab., Phys.Lett.B.501 (2001) 173.

- $f_2(1270) - a_2(1320)$ destructive interference
- $f_2'(1525)$ J=2,λ=2 dominant:
  $\Gamma_{\gamma\gamma}(f_2'(1525)) \times \mathrm{BR}(K\bar{K}) = 76 \pm 6 \pm 11$ eV
- Resonance at 1750 MeV J=2 dominant and J=0
  $\Gamma_{\gamma\gamma}(f_2(1750)) \times \mathrm{Br}(K\bar{K}) = 49 \pm 11 \pm 13$ eV
- No signal for the glueball candidate :
  $\Gamma_{\gamma\gamma}(\xi) \times \mathrm{BR}(\xi \rightarrow K^0_S K^0_S) < 1.4$ eV (95% C.L.)

- Landau-Yang theorem:
  $\Gamma_{\gamma\gamma}$=0 for a J=1 state
- One of the photons must be virtual to have J=1
- Study the formation as a function of $Q^2 \simeq P_t^2 > 0$

$$\sigma \propto \tilde{\Gamma}_{\gamma\gamma} \times \tilde{F}^2(Q^2)$$

where

$$\tilde{F}^2(Q^2) = \frac{Q^2}{M^2}\left(1 + \frac{Q^2}{2M^2}\right)\frac{2}{(1+Q^2/\Lambda^2)^4} \qquad (1)$$

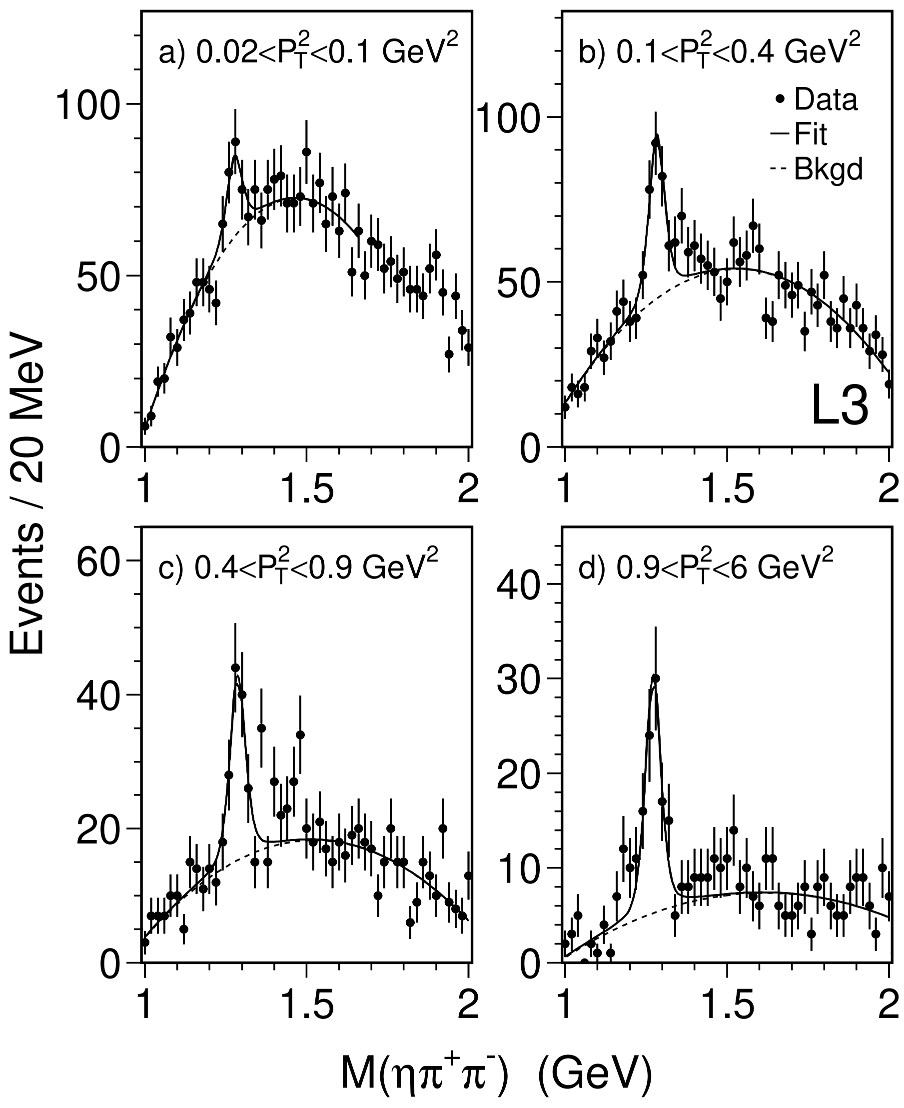
or

$$\tilde{F}^2(Q^2) = \frac{Q^2}{M^2}\left(1 + \frac{Q^2}{2M^2}\right)\frac{2}{(1+Q^2/M_\rho^2)^2} \qquad (2)$$

(1) with $\Lambda = $ M, G.A.Schuler, F.A.Berends, R.van Gulik, Nucl.Phys.B523 (1998) 423

(2) R. N. Cahn, Phys.Rev.D35 (1987) 3342

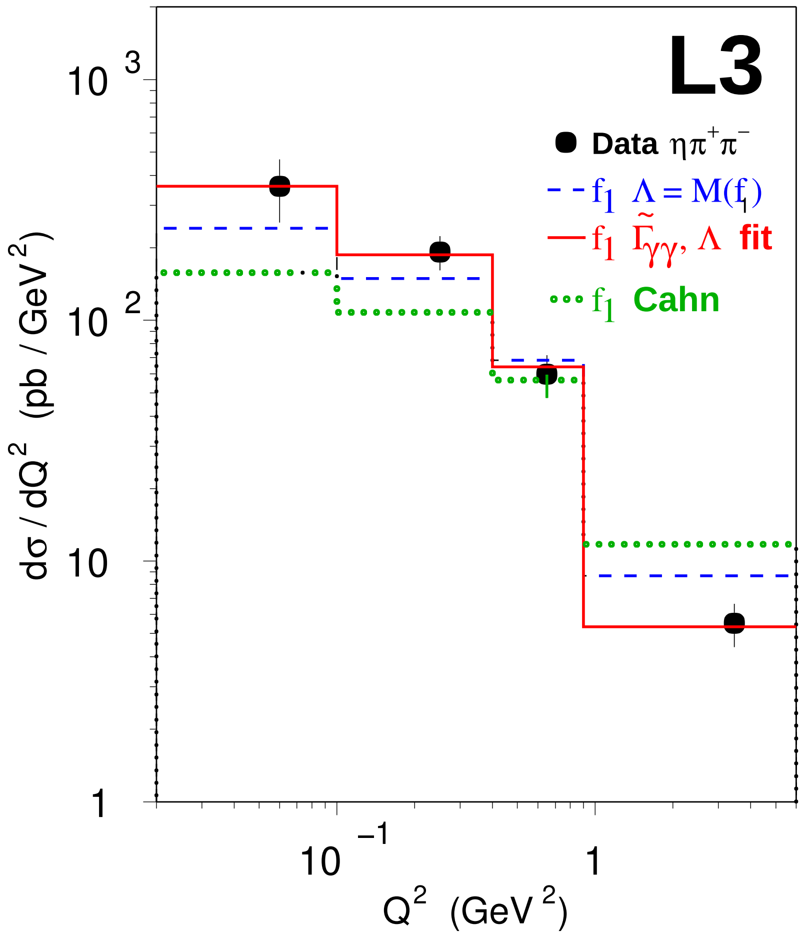
$\gamma\gamma \rightarrow \mathrm{f}_1(1285) \rightarrow \pi^+\pi^-\eta$



L3 Collab., Phys.Lett.B.526 (2002) 269.

- Clear signal as a function of $Q^2 \simeq P_t^2$
- Decay trough the intermediate state $\mathrm{a}_0(980)\pi$ compatible with 100%

$\gamma\gamma \to \mathrm{f}_1(1285) \to \pi^+\pi^-\eta$



- Calculation by R.N.Cahn C.L. ~ 0
- $\Lambda = M_{\mathrm{f}_1(1285)}$ C.L. 2%
- Fit

$$\Lambda = 1.04 \pm 0.06 \pm 0.05 \text{ GeV}$$
$$\tilde{\Gamma}_{\gamma\gamma} = 3.5 \pm 0.6 \pm 0.5 \text{ keV}$$

C.L. 91%

Search for the η_b

- $b\bar{b}$ J^{PC}=0^{-+} ground state
- Theoretical predictions (pQCD, lattice QCD)

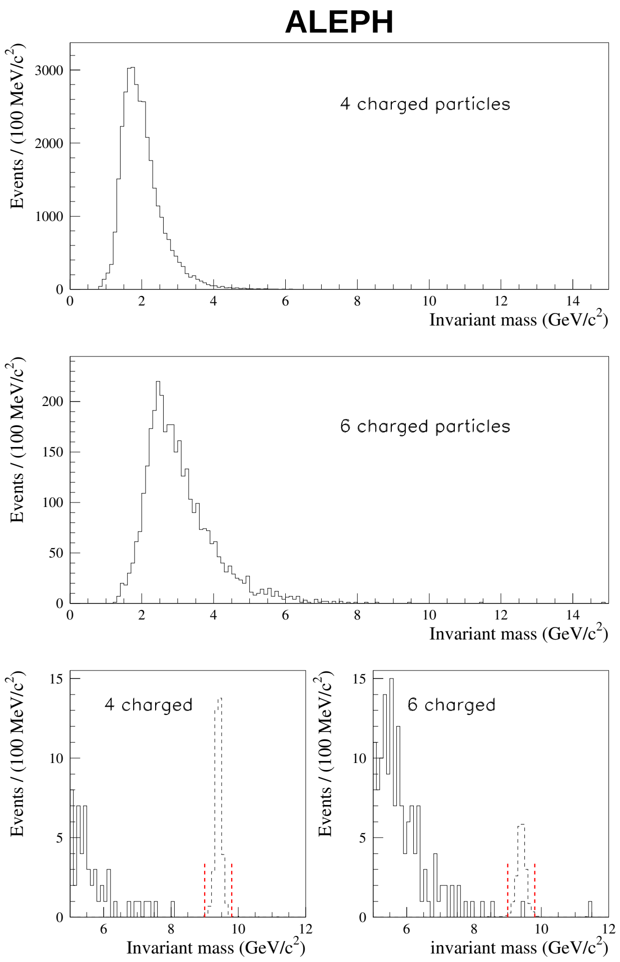
$m(\Upsilon) - m(\eta_b) = 34 - 141$ MeV [$m(\Upsilon) = 9.46$ GeV]

$\Gamma_{\gamma\gamma}(\eta_b)$= 500 - 570 eV

Decay mode	Estimated BR
4 charged particles	2.7%
6 charged particles	3.3%

- About 10 η_b per channel are expected at LEP2 per experiment

Search for the η_b



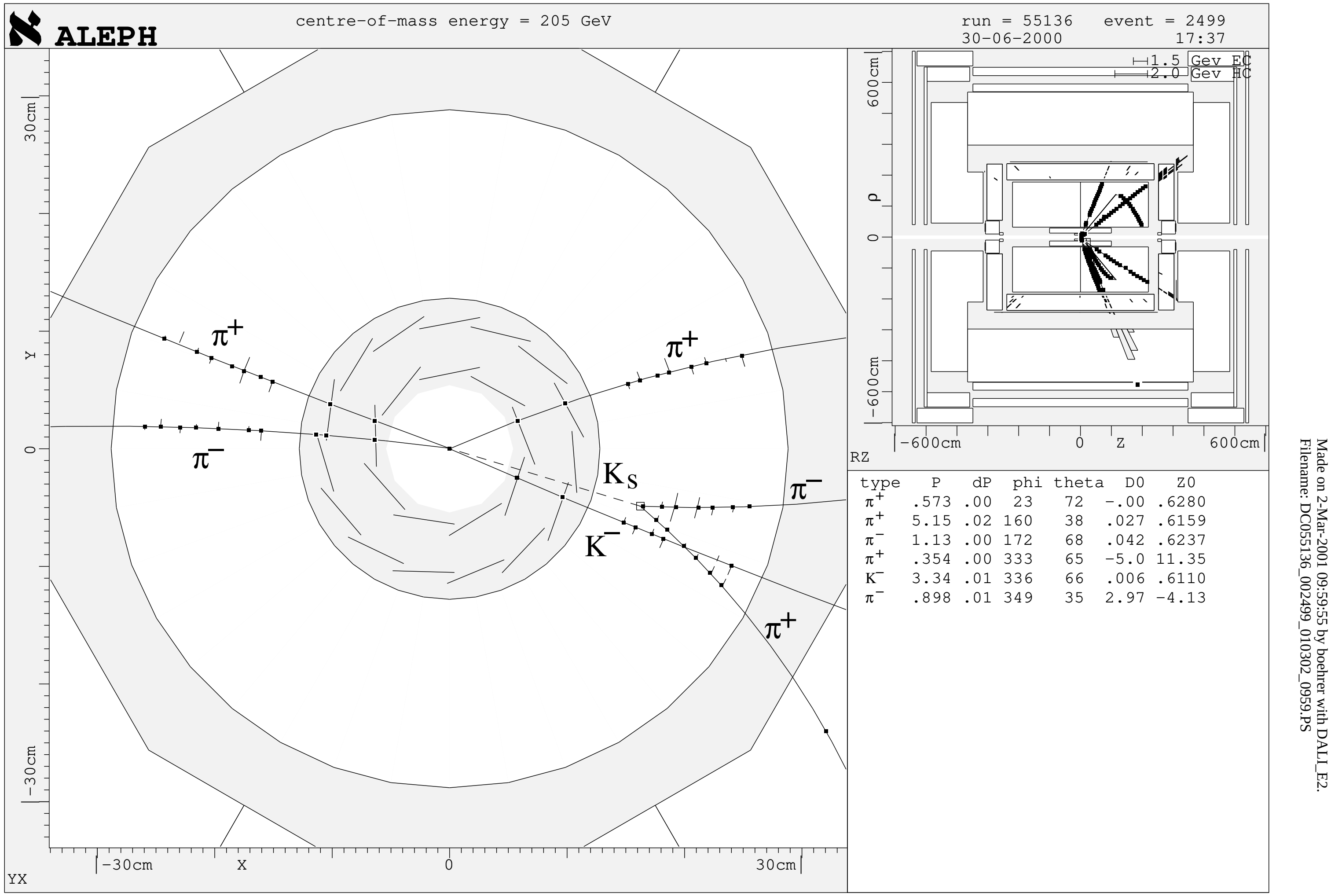
$\sqrt{s} = 181$ - 209 GeV, $\mathcal{L} = 699$ pb^{-1}

- **4 charged particles**
  $\varepsilon = 16.7$ %
  Bgd 0.30 ± 0.25 events
  $\Gamma_{\gamma\gamma}(\eta_b) \times \mathrm{BR(4charged)} < 48$ eV at 95% C.L.
  No candidates

- **6 charged particles**
  $\varepsilon = 9.3$ %
  Bgd 0.70 ± 0.34 events
  $\Gamma_{\gamma\gamma}(\eta_b) \times \mathrm{BR(6charged)} < 132$ eV at 95% C.L.
  One candidate

ALEPH Collab., CERN-EP/2002-009, Submitted to Phys.Lett.B.

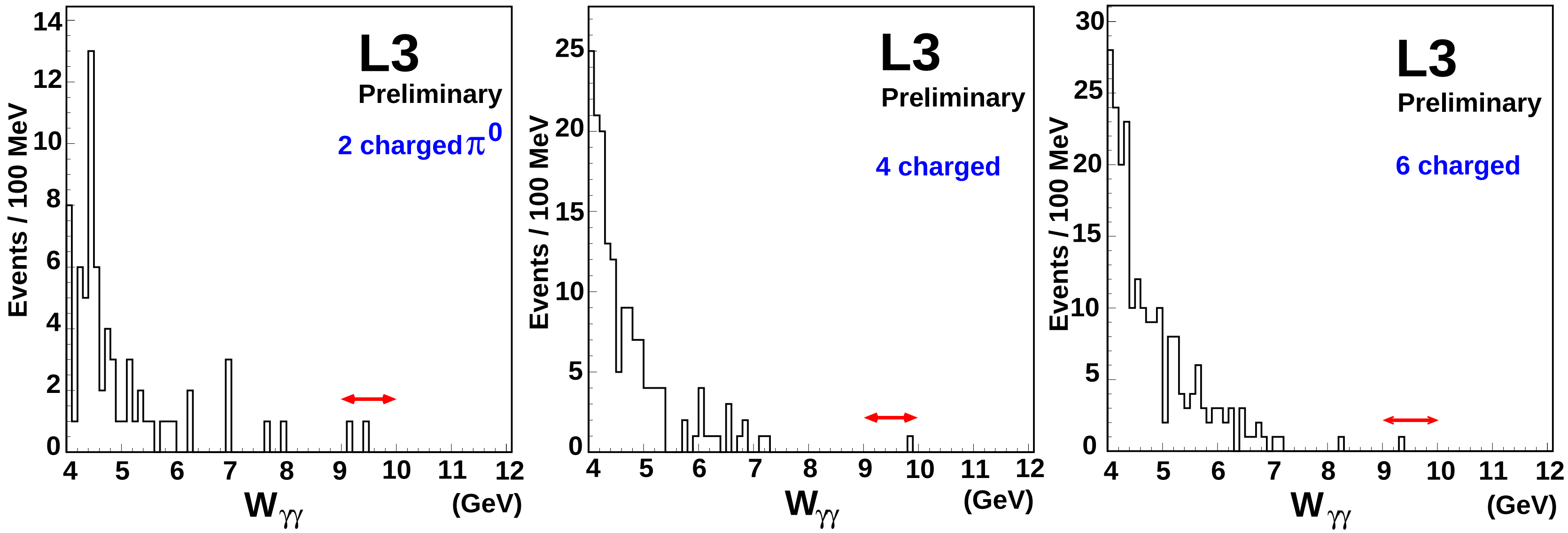
Search for the η_b



type	P	dP	phi	theta	D0	Z0
π^+	.573	.00	23	72	-.00	.6280
π^+	5.15	.02	160	38	.027	.6159
π^-	1.13	.00	172	68	.042	.6237
π^+	.354	.00	333	65	-5.0	11.35
K^-	3.34	.01	336	66	.006	.6110
π^-	.898	.01	349	35	2.97	-4.13

$$M = 9.30 \pm 0.02 \pm 0.02 \text{ GeV}$$

Search for the η_b



L3 Collab., L3 Note 2736 - March 2002

- $\sqrt{s}$ = 183 - 209 GeV
- $\mathcal{L}$ = 610 pb^{-1}
- Mass regions:

Decay mode	7-8 GeV	8-9 GeV	9-10 GeV	10-15 GeV
2 ch. $+ 2\gamma$	2	0	2	0
4 ch.	2	0	1	0
6 ch.	2	1	1	0

Conclusions and Outlook

- Baryon-antibaryon production:
  $\mathrm{p\bar{p}}, \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$ final states
  Quark-diquark models are favoured
- Formation of light resonances:
  $\mathrm{f}_2'(1525)$
  First observation of the $\mathrm{f}_2(1750)$
  No signal for the $\xi(2230)$ in $\gamma\gamma$ collisions
  $\mathrm{f}_1(1285)$ as a function of Q^2
- Search for the η_b:
  Some candidates seen by ALEPH and L3
- Significant contribution of LEP to QCD
  ... and more results to be expected!