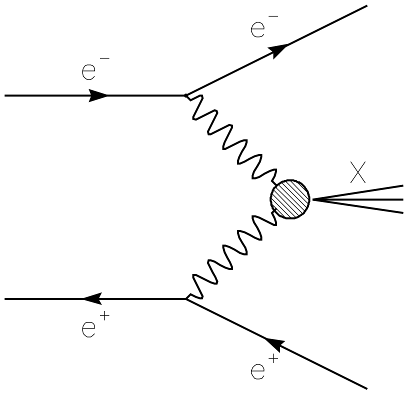
Introduction

Four $\gamma\gamma$ results from LEP.

All untagged, mostly LEP II

L3	$\gamma\gamma \to f_1(1285)$	Exclusive	LEP II	Resonance
ALEPH	$\gamma\gamma \to \eta_b$	Exclusive	LEP II	Resonance
L3	$\gamma\gamma \to \Lambda/\Sigma$	Exclusive	LEPI/II	Non Resonance
L3	$\gamma\gamma \to \pi^0$ K^0	Inclusive	LEP II	Resonance



LEP	L	$\sigma^{tot}(W > 4)$	Events
I	$200pb^{-1}$	9nb	1.8M
II	$725pb^{-1}$	16nb	12M

L3 $\gamma\gamma \rightarrow f_1(1285)$

$$J^{\mathrm{PC}} = 1^{++}$$

Previously observed in single tag events by TPC/Two-gamma and Mark II

First time in untagged events.
First time at LEP

$$\begin{array}{rcl} \gamma\gamma & \rightarrow & \mathrm{f}_1(1280) \\ & & \eta\,\pi^+\pi^- \\ & & \quad\hookrightarrow \gamma\gamma \end{array}$$

L3 $\gamma\gamma \rightarrow f_1(1285)$

Decay is predominantly via $a_0(980)$

$$
\begin{aligned}
\gamma\gamma \;\rightarrow\;& \mathrm{f}_1(1280) \\
& \mathrm{a}_0(980)\ \pi^- \\
& \quad \hookrightarrow \eta\ \ \pi^+ \\
& \qquad\quad \hookrightarrow \gamma\gamma
\end{aligned}
$$

Divide into 4 P_T^2 bins.

$P_T^2 \approx \mathrm{max} Q^2$

Plot $d\sigma/dQ^2$ and compare to theory.

L3 $\gamma\gamma \to f_1(1285)$

Theory

Transverse-transverse and transverse-scalar photons contribute to the production of an axial vector resonance.
In principle two $\Gamma_{\gamma\gamma}$
Parameterized as an effective radiative width. $\tilde{\Gamma}_{\gamma\gamma}$.

$$\sigma_{\gamma\gamma\to R} = \delta(W^2 - M^2) 24\pi^2 \frac{\tilde{\Gamma}_{\gamma\gamma}}{M} \left(1 + \frac{Q^2}{M^2}\right) \tilde{F}^2(Q^2)$$

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

Λ conventionally set to resonance mass.

L3 $\gamma\gamma \to f_1(1285)$

Fit to the data to find Λ and $\tilde{\Gamma}_{\gamma\gamma}$.

$$\boldsymbol{\Lambda} = 1.06 \pm 0.12(stat) \pm 0.09(sys)\text{GeV}$$

Compare to $\boldsymbol{\Lambda} = M = 1.285$

$$\tilde{\Gamma}_{\gamma\gamma} = 3.3 \pm 0.6(stat.) \pm 1.1(sys.)\text{keV}$$

(correlation coefficient = 0.883)

ALEPH $\gamma\gamma \to \eta_b$

η_b has never been observed.

Predict properties...

- Mass $\sim$ 9.40 GeV
- $\Gamma_{\gamma\gamma} \sim$ 400 eV

  $\Rightarrow$ 160 η_b in ALEPH LEP II data
- Decay modes?

  Various estimates give $2 \sim 4$ % each

  for 4 and 6 charged tracks

ALEPH $\gamma\gamma \rightarrow \eta_b$

Monte Carlo gives selection efficiencies:

16% (4 prong)

10% (6 prong)

$\Rightarrow$ 0.7 $\eta_b \rightarrow 4$ prong in ALEPH LEP II data

$\Rightarrow$ 0.5 $\eta_b \rightarrow 6$ prong in ALEPH LEP II data

Background estimate, using data:

0.3 events in 4 prong

0.8 events in 6 prong

Observe:

0 events in 4 prong

1 event in 6 prong

ALEPH $\gamma\gamma \rightarrow \eta_b$

Calculate Limit:

$$\Gamma_{\gamma\gamma} \times B.R. < 57(eV)(4prong)$$

$$\mathbf{\Gamma}_{\gamma\gamma} \times B.R. < 128(eV)(6prong)$$

6 prong event has:

$\mathbf{m} = 9.30 \pm 0.04\,\mathrm{GeV}$

L3 $\gamma\gamma \to \Lambda/\Sigma$

History:

Brodsky and Lepage predicted rates for $\gamma\gamma \to mm$

Good results for meson pairs.

Farrar et al calculated for baryon pairs

Order of magnitude low for $\mathrm{p\bar{p}}$

quark-diquark model

replace 2 quarks by a diquark.

(Anselmino $\mathrm{et}\,al$ and Kroll $\mathrm{et}\,al$)

Matches data for $\mathrm{p\bar{p}}$ – but a postdiction.

Measurement of other baryons act as a test.

L3 $\gamma\gamma \to \Lambda/\Sigma^0$

Measurement

Look for pairs of Baryons - Λ or Σ^0

Λ identified via decay to $\mathrm{p}\pi$

Σ^0 includes additional (low energy) photon.

Require $\mathrm{P}_T^2 < 0.26\,\mathrm{GeV}^2$

leaves 32 events from all LEP data

Extract $\mathrm{d}\sigma/dW$.

For combined sample - fit a power law $\sim W-^n$

RESULT:	$\mathrm{n} = 7.5 \pm 3.1$	
THEORY:	n=8	quark-diquark
	n=12	three quark

L3 $\gamma\gamma \to \Lambda/\Sigma^0$

Separate measurements of:

$$\gamma\gamma \to \Lambda\overline{\Lambda}$$
$$\gamma\gamma \to \Lambda\overline{\Sigma}^0$$
$$\gamma\gamma \to \Sigma^0\overline{\Sigma}^0$$

Compare to recent quark-diquark calculation

3 different Baryon distribution amplitudes

- **'Standard'**
- **'Dziembowski'**
- **'Asymptotic'**

Data favour the 'standard' amplitude.

L3 $\gamma\gamma \rightarrow \pi^0 X$

$\gamma\gamma \rightarrow K^0 X$

- **Hadronic $\gamma\gamma$ events with $\mathrm{W} > 5\,\mathrm{GeV}$**
  (414 pb^{-1} of LEP II data.)

- **Identify π^0 and K^0_S**

π^0	$0.2 < p_t < 20$	$\lvert\eta\rvert < 4.3$
K^0_S	$0.4 < p_t < 4$	$\lvert\eta\rvert < 1.5$

- **Calculate Efficiencies**
  (PHOJET and PYTHIA)

- **Plot $\mathrm{d}\sigma/dp_t$ and $\mathrm{d}\sigma/d\lvert\eta\rvert$**

L3 $\gamma\gamma \rightarrow \pi^0 X$

$\gamma\gamma \rightarrow K^0 X$

Fit curves to the data:

- **(1) Low p_t region:**

  Fit with exponential

  $\mathrm{d}\sigma/dp_t = Ae^{-p_t/<p_t>}$ $<p_t>$ = 230 $\pm$9 MeV for π^0

  $<p_t>$ = 286 $\pm$11 MeV for K_s^0

- **(2) High p_t ($\mathrm{p}_t > 1.0$)region:**

  Fit with power law

  $\mathrm{A}p_t^{-B}$ $\mathrm{B} = 4.1 \pm 0.1$ - same value for π^0 and K^0

  Compatible with Brodsky and Ferrar prediction.

- **Compare to NLO QCD.**

  At high p_t (π^0) not compatible with a NLO QCD prediction by Kniehl et al.

?

Summary

Four $\gamma\gamma$ results from LEP.

All untagged, mostly LEP II

L3	$\gamma\gamma \to f_1(1285)$	**First measurement in LEP**
ALEPH	$\gamma\gamma \to \eta_b$	**First limit in $\gamma\gamma$**
L3	$\gamma\gamma \to \Lambda/\Sigma$	**Confirms diquark model**
L3	$\gamma\gamma \to \pi^0$	**Problems with NLO QCD ?**
	K^0	