Four Results in Untagged $\gamma\gamma$ Physics

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Abstract: Four recent result in untagged two photon physics events are described, they are: a measurement of $f_1(1285)$ resonance production; exclusive Λ and Σ^0 production; inclusive π^0 and K_s^0 production; and a search for the η_b resonance.

1. Introduction

In this article I describe four measurements made in $\gamma\gamma$ collisions observed at the LEP accelerator via the process shown in figure 1. All four measurements were made in untagged events, so the scattered electrons are not observed, and the virtual photons are described as 'nearly real', in other words they have Q^2 close to zero. The measurements take advantage of the large quantity of data collected at LEP particularly LEP II, as shown in table 1.

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

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

Table 1: Integrated luminosity, total cross section and number of events for hadron production in untagged two photon physics at LEP.

This resonance has previously been observed in single tag events by TPC/Two-gamma[1] and Mark II[2]. The new measurement by L3[3] is the first time it has been observed in untagged events and the first time it has been measured at LEP. The resonance is observed via its decay into $\eta\pi^+\pi^-$ with the η subsequently decaying into two photons. L3 show that the decay is predominantly via $a_0(980)$ ($f_1(1285) \to a_0(980)\pi \to \eta\pi\pi$)

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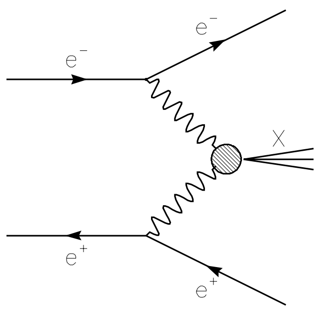

Figure 1: The two photon physics process as observed in an e^+e^- collider.

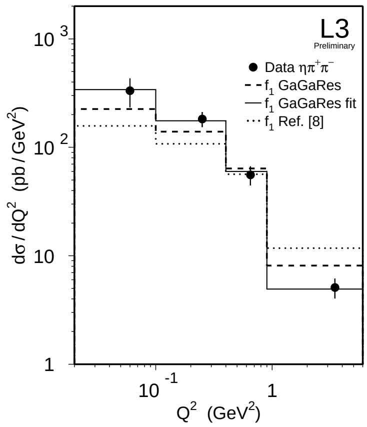

Figure 2: $d\sigma/dQ^2$ for $f_1(1285)$ production.

They divide the measurement into four bins of the transverse momentum of the resonance (P_T^2). To a good approximation $P_T^2 = Q^2$ where Q^2 is the maximum virtuality of the two photons. They then extract a measurement of $d\sigma/dQ^2$ to compare to theory as shown in figure 2.

Interactions of both two transverse polarised photons, and one transverse polarised photon with one scalar photon can contribute to the production of an axial vector resonance. In principle there are therefore two radiative widths ($\Gamma_{\gamma\gamma}$). This is conventionally parameterized as an effective radiative width, $\tilde{\Gamma}_{\gamma\gamma}$, which is defined by:

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

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

Λ is normally set equal to the resonance mass, however L3 choose to perform a fit to the data to find values for Λ and $\tilde{\Gamma}_{\gamma\gamma}$. They find:

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

which should be compared to $\Lambda = M = 1.285$ GeV, and

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

There is a 0.88 correlation between these two measurements.

3. ALEPH $\gamma\gamma \to \eta_b$

ALEPH [4] have searched for the exclusive production of the η_b in their two photon data. As this particle has never been observed it is necessary to estimate its properties to discover whether this is a reasonable thing to attempt. ALEPH estimates the mass to be ~ 9.40 GeV and the radiative width ($\Gamma_{\gamma\gamma}$) to be approximately 400 eV. This leads to an estimate that there are approximately 160 η_b in LEP II data. In order see these particles one must pick out one or two clear decay modes. They find various estimates give branching ratios of about 2 to 4 percent each for events with just four charged tracks and similarly for events with just six charged tracks. They then use a Monte Carlo to estimate the selection efficiencies which come out at 16% for 4 prong decays and 10% for 6 prong. They thus expect to see 0.7 events of the type $\eta_b \to 4$ prong and 0.5 $\eta_b \to 6$ prong events in LEP II data. The data outside the η_b mass window was used to estimate the background and was found to be 0.3 events in 4 prong and 0.8 events in 6 prong. They observe no events in the 4 prong sample and one event in the 6 prong sample from which they calculate a limit on the product of the radiative width and the branching fraction to each mode of:

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

$$\Gamma_{\gamma\gamma} \times B.R. < 128(eV)\,(6\,\mathrm{prong})$$

The 6 prong event has: $m = 9.30 \pm 0.04\,\mathrm{GeV}$.

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

The study of exclusive meson and baryon pair production has long been recognised as a potentially important testing ground of QCD [5, 6, 7]. The calculation factorizes into a hard scattering amplitude which at sufficiently large momentum transfers is calculable in QCD, and hadron wavefunctions $\phi_M(x, Q)$. As these wavefunctions are supposed to be process independent, measurements from many different fields should be complementary. Measurements in $\gamma\gamma$ collisions are important as they are the simplest calculable large-angle exclusive hadronic scattering reactions. The calculations for meson pairs are in fairly good agreement with data[5], however when Farrar *et al*[8] extended the theory to baryon pairs the result was an order of magnitude low for $\gamma\gamma \to \mathrm{p\bar{p}}$. Other authors[10] using a quark-diquark model where two of the quarks in a baryon are replaced by a diquark were able to reproduce the data for $\mathrm{p\bar{p}}$. As this was a postdiction, measurement of other baryons acts as a more stringent test of the model.

L3 [9] have looked for pairs of baryons which can each be either a Λ or Σ^0. The Λ is identified via its decay to $\mathrm{p}\pi$, Σ^0 are identified by the presence of an additional (low energy) photon. To ensure exclusive production is being measured they require $P_T^2 < 0.26\,\mathrm{GeV}^2$ which leaves 32 events from all LEP data. They use this data to extract $d\sigma/dW$, shown in figure 3. For the combined sample they fit the data with a power law W^{-n} and find $n = 7.5 \pm 3.1$. Theoretical predictions for n are 8 from the quark-diquark model and 12 from a three quark model so this fit clearly favours the quark-diquark model.

They then separate the data into measurements of $\gamma\gamma \to \Lambda\overline{\Lambda}$, $\gamma\gamma \to \Lambda\overline{\Sigma}^0$, and $\gamma\gamma \to \Sigma^0\overline{\Sigma}^0$ and compare them to recent quark-diquark calculation[10]. Three different baryon distribution amplitudes are considered, which they label 'Standard', 'Dziembowski', and 'Asymptotic'. The data favour the 'Standard' amplitude.

5. L3 $\gamma\gamma \to \pi^0 X$ and $\gamma\gamma \to K^0 X$

The three measurements reported above were all exclusive measurements. The final measurement is an inclusive measurement, using hadronic $\gamma\gamma$ events with $W > 5\,\text{GeV}$ based on 414 pb^{-1} of LEP II data [11] . L3 identify π^0 and K_S^0 particles in this data in the ranges

$$\begin{array}{lll} \pi^0: & 0.2 < p_t < 20, & |\eta| < 4.3 \\ \mathbf{K}_S^0: & 0.4 < p_t < 4, & |\eta| < 1.5 \end{array}$$

where η is the pseudorapidity of the particle.

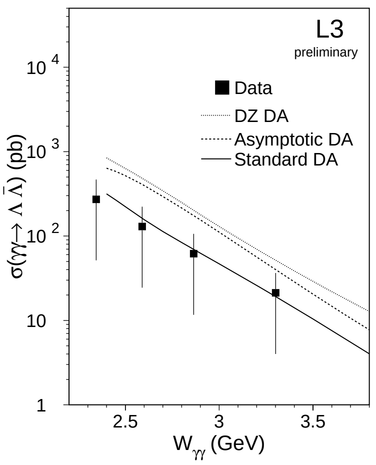

Figure 3: The $\gamma\gamma \to \Lambda\bar{\Lambda}$ cross section as a funtion of $W_{\gamma\gamma}$

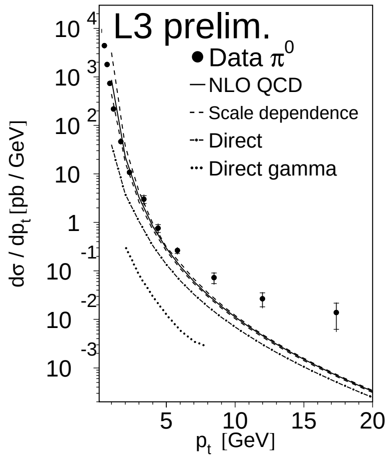

Figure 4: $d\sigma/dp_t$ for π^0 with $|\eta| < 0.5$ compared to a NLO QCD prediction.

They calculate selection efficiencies using the PHOJET and PYTHIA programs, and then plot $d\sigma/dp_t$ and $d\sigma/d|\eta|$. In the low p_t region they fit the data with an exponential function

$$d\sigma/dp_t = Ae^{-p_t/<p_t>} \begin{array}{l} <p_t> = 230 \pm 9 \text{ MeV for } \pi^0 \\ <p_t> = 286 \pm 11 \text{ MeV for } K_s^0 \end{array}$$

which is similar to that found in hadronic processes, reflecting the hadron like nature of the photon at low transverse momenta. At transverse momenta greater than 1.0 GeV the photon already starts to show its pointlike nature. L3 use a power law Ap_t^{-B} to fit to this region and find $B = 4.1 \pm 0.1$ with the same value for both π^0 and K^0. This is compatible with the prediction of Brodsky and Farrar[12]. The result is also compared to an NLO QCD, see figure 4. At high p_t where only π^0 data are available, the data are not compatible with the prediction.

6. Summary

Four $\gamma\gamma$ results from LEP have been described. They all use untagged data, mostly from LEP II. None of the measurements would be possible without the huge sample of untagged two photon physics events available from LEP. This will be a unique resource for many years to come and it is important in the rush toward new accelerators and detectors that there is still time and man power available to analyse it.

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