The most recent results of inclusive hadron, baryon pair and $\rho^0\rho^0$ productions in two-photon collisions measured at LEP are presented.

1 Introduction

Electron-positron colliders are a suitable place for the study of two-photon interactions via the process $e^+e^- \rightarrow e^+e^-\gamma\gamma \rightarrow e^+e^-X$. The outgoing electron and positron carry almost the full beam energy and are usually undetected, due to their small transverse momenta. When the scattered electron is detected ("tagged") by the forward detector, an off-shell photon $\gamma^*$ with a large squared four-momentum, $Q^2$, is emitted. The final state $X$ can be leptonic or hadronic. The cross-sections of two-photon interactions with different final states are calculable by QCD or QED. In this report, we present some results of measurements of pair production and inclusive hadron production in two-photon collisions at LEP.

2 Baryon pair production

The process of $\gamma\gamma \rightarrow \text{baryon antibaryon}$ is sensitive to the quark structure of the baryon, the cross-section of this process being calculable in the framework of the hard scattering approach. At LEP three different processes of the baryon pair production were studied at $\sqrt{s} = 183$ –

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In the study, protons and antiprotons were mainly identified by the energy loss and the ratio of energy and momentum measured by the central tracker and the electromagnetic calorimeter. The measured cross-sections of the three processes as a function of two-photon mass, $W_{\gamma\gamma}$, are shown in Figure 1. Good agreement is found between the L3 and OPAL experiments. The predictions of the quark-diquark model are consistent with the data. The predictions of three-quark model are too low. For the high statistics $\gamma\gamma \to p\bar{p}$ process, its cross-section is also measured as a function of $\cos \theta^*$ in three $W_{\gamma\gamma}$ bins shown in Figure 2. In the low mass region the angular distribution is strongly peaked at large angles and the quark-diquark models fail to describe the data. The agreement improves in the high mass region, where the angular distribution is instead peaked at small angles.

$$\gamma\gamma \to p\bar{p}$$
$$\gamma\gamma \to \Lambda\bar{\Lambda} \to p\pi^- \bar{p}\pi^+$$
$$\gamma\gamma \to \Sigma^0\bar{\Sigma}^0 \to \Lambda\gamma\bar{\Lambda}\gamma \to p\pi^- \gamma \bar{p}\pi^+ \gamma$$
3 Exclusive $\rho^0\rho^0$ production at high $Q^2$

Exclusive $\rho^0\rho^0$ production with a highly virtual photon in two-photon collisions can be used to verify the mechanism of $qq, gg \rightarrow$ meson pair. Recently, perturbative QCD predictions of the cross-section of such process has been made.

The data used in this study were collected by the L3 detector at $\sqrt{s} = 89 - 209$ GeV. The events were selected by identifying a scattered electron and four charged pions in the detector. The background processes $\gamma\gamma^* \rightarrow \rho^0\pi^+\pi^-$, $4\pi(non - resonant)$ are separated by a box method. Figure 3a shows the cross-section of the process $\gamma\gamma^* \rightarrow \rho^0\rho^0$ as a function of $W_{\gamma\gamma}$. A board enhancement at threshold is observed. The differential cross-section of the process $e^+e^- \rightarrow e^+e^-\rho^0\rho^0$ as a function of $Q^2$, which is consistent with the pQCD expectation, is shown in Figure 3b.

4 Inclusive hadron production

Inclusive hadron production production in two-photon collisions can be used to study the structure of photon interactions. The measurements were performed at LEP at $\sqrt{s} = 161 - 202$ GeV.
Several types of hadron, $\pi^\pm$, $\pi^0$, $K^\pm$ and $K^0_S$, were measured or deduced from Monte Carlo fragmentation functions. Figure 4 shows the differential cross-section $d\sigma/dp_t$ for inclusive charged particle ($\pi^\pm$ and $K^\pm$), $\pi^0$ and $K^0_S$ production. The results from different experiments, L3 and OPAL, agree well. The measurement of charged particles is also consistent with that of neutral particles after phase space renormalization. This agreement tests Monte Carlo fragmentation functions. In Figure 5 the data are compared to analytical NLO QCD predictions, which take into account both transverse and longitudinal virtual photons. The scale uncertainty in the NLO calculation is also shown. The prediction is compatible with the data for $p_t < 5$ GeV. However, the distribution of the data is much flatter than the NLO predictions at high $p_t$.

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