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Search for Anomalous photon events at LEP

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1302:Search for Anomalous photon events at LEP

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Abstract. At e^+e^- high energy colliders, events with photons and missing energy can offer the first hint of the emergence of new physics. We report on the results obtained by the four LEP experiments concerning such anomalous events, in the 1996 data at $\sqrt{s} = 161 \div 172$ GeV.

1 Introduction

Events with photons, missing energy and nothing else in the detector can offer the first hint of the emergence of new physics. Near the Z^0 energy, the measurement of the cross section for the single photon process has long been recognised as the direct method for the determination of the number of light neutrino generations and all experimental groups at LEP1 reported studies of the single photon production [1]. But new physic processes, implying weakly interacting particles, could also arise through the same channel and this can be particularly true at LEP2 for supersymmetric particles.

Two photons + missing energy search is more recent and is mainly accountable to the 1995 CDF event $ee\gamma\gamma + \cancel{E}$, where two high energy electrons and two high energy photons with large missing transverse energy have been observed [2]. In the hypothesis where supersymmetry would be relevant for the explanation of the topology of the event, photonic states with 1 or 2 photons and missing energy, would be likely to appear at LEP energies.

In this paper, we present the results obtained in 1996 by the 4 LEP experiments. During this period, the machine delivered about $11pb^{-1}$ at centre-of-mass energies of both 161 and 172 GeV. All the results given use both $\sqrt{s}$ and most are preliminary. Limits are at 95 % confidence level.

2 Results, interpretations and limits.

No deviation from the Standard Model(SM) expectations have been observed in the single photon data. For illustration, one can see in Fig.1 and Fig.2 the results from L3. The recoil mass spectrum has photons with energy $E_\gamma > 10$ GeV and the energy spectrum is due to a second analysis for the selection of low energy photons. The main contribution to the samples comes from the $\nu\bar{\nu}\gamma$ reaction, mainly due to a radiative return to the Z^0 energy,

followed by its decay to 2 neutrinos. Generators agree at the few % level. Others contributions are negligible, except for radiative low angle Bhabhas in the case of the low energy sample.

Fig.3 collects all the 2γ events from the 4 experiments together with the cumulative expected contribution of the $\nu\bar{\nu}\gamma\gamma$ process. It has been produced by the LEP Susy Working Group (LSWG), a group setup to combine and optimise the results of LEP experiments. A few events are seen with a recoil mass $M_R > 100 \text{ GeV}/c^2$. A correct background estimation is essential if one would like to address the significance of such events with large missing energy. There were some concerns about the Monte Carlo predictions. New results [3] in the LSWG and the collaborations show better agreement. The low statistics taken into account, nothing really puzzling is seen in these data.

Figure 1: L3 recoil mass spectrum for high energy 1γ data.

Figure 2: L3 energy spectrum for low energy 1γ data.

Absence of any obvious anomaly in $\gamma\cancel{E}$ or $\gamma\gamma\cancel{E}$ spectra is interpreted by LEP collaborations in the framework of supersymmetric models with R-parity conservation and thus with the existence of a stable lightest supersymmetric particle (LSP).

In a first class of studies, the neutralino $\tilde{\chi}_1^0$ is the LSP and the CDF event is interpreted in the framework of the Minimal Supersymmetric extension of the Standard Model (MSSM), in a particular mass scenario, proposed in [4] which is consistent with all existing data. At LEP, the best possibility to verify this scheme, is the production of $\tilde{\chi}_2^0\tilde{\chi}_2^0$ which leads to $\gamma\gamma + \cancel{E}$. The channel has been studied by ALEPH which has produced cross section limits and an exclusion plot of the CDF allowed region (Fig.4).

Numerous studies have been done using a second class of models where a very light gravitino $\tilde{G}$, is the LSP. This happens in Gauge Mediated Supersymmetry Breaking models (GMSB) where supersymmetry breaking is realized at low energy scale [5] and in "no-scale" supergravity models, such as the LNZ model [6] where gravity is still responsible of supersymmetry breaking. They imply, always for LNZ, most of the time for GMSB models,

the neutralino as the Next Lightest Supersymmetric particle (NLSP), opening channels with very attractive signatures such as $1\gamma + \cancel{E}$ or acoplanar $2\gamma + \cancel{E}$. All LEP experiments have presented interpretations in this frame.

Figure 3: 2γ data. Recoil mass spectrum using the combined data of the 4 LEP experiments, compared with the KORALZ generator results [7].

Figure 4: Exclusion plot from 2γ data in the $\tilde{\chi}_1^0$ LSP hypothesis. The shaded area is for $m_{\tilde{e}_L} = m_{\tilde{e}_R}$ and the darker area for $m_{\tilde{e}_L} \gg m_{\tilde{e}_R}$. Curves are labelled with $\tilde{\chi}_1^0$ masses.

The first example, with the gravitino as LSP, is in the "single photon" channel. Excess above the SM contribution can be interpreted as signal for the direct production of a gravitino with an accompanying neutralino which decays radiatively to gravitino. The 4 experiments present results and cross section limits. Using the LNZ model, it is possible to constrain the $\tilde{\chi}_1^0$ mass versus the gravitino mass. For $m_{\tilde{G}} \sim 10^{-5} \text{ eV}/c^2$, a neutralino mass of $100 \text{ GeV}/c^2$ is excluded.

In the gravitino LSP scenario, acoplanar photon pairs come from $\tilde{\chi}_1^0$ pair production followed by the decay to photons and invisible gravitinos. The 4 experiments have set limits on the production cross section and have given lower limit on the neutralino mass in the frame of the LNZ or GMSB models. The LSWG has combined their results and put limit on the neutralino mass, $m_{\tilde{\chi}_1^0} > 76 \text{ GeV}/c^2$. The interpretation of the CDF event in the light gravitino scenario leads to a specific area in the $m_{\tilde{\chi}_1^0}, m_{\tilde{e}_R}$ plane seen in Fig.5. A significant fraction of the allowed region is already excluded.

There exists another possibility, always with the gravitino as LSP. For part of the parameter space, an $\tilde{l}$ and in particular a $\tilde{\tau}$ can be the NLSP. The decay length is function of $m_{\tilde{\tau}}$ and $m_{\tilde{G}}$ and, depending of its value, experiments must develop different strategies : search for leptons + $\cancel{E}$, large impact parameter tracks, secondary vertices or stable heavy ionising particles (HIP). ALEPH, DELPHI and OPAL have searched for such HIPs and combined their results inside the LSWG, to give an experimental limit on the mass of the $\tilde{\tau}$ in this scenario, $m_{\tilde{\tau}_R} > 75.6 \text{ GeV}/c^2$ or $m_{\tilde{\tau}_L} > 76.5 \text{ GeV}/c^2$. DELPHI has specific analyses for all the different signatures of $\tilde{\tau}$ decay and has combined all of them to give cross section limits and an exclusion area in

the plane $m_{\tilde{\tau}}, m_{\tilde{G}}$ (Fig.6). The $\tilde{\tau}$ must have a mass higher than 55 GeV/ c^2 for $m_{\tilde{G}} > 1$ eV/ c^2 or higher than 65 GeV/ c^2 for $m_{\tilde{G}} > 40$ eV/ c^2 [8].

Figure 5: Exclusion plot from 2 γ data in the $\tilde{G}$ LSP hypothesis (from LSWG).

Figure 6: Exclusion plot in the $\tilde{\tau}$ NLSP hypothesis (from DELPHI).

3 Conclusions

No anomaly with respect to standard model predictions has been reported by any experiment. In both the neutralino NLSP and the $\tilde{\tau}$ NLSP option, constraints on the mass of the intervening particles have been set and a significant part of the region deduced from the CDF event in the gravitino scenario has been excluded. Final results can be seen in [9].

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