HEP'97 #855
Submitted to Pa 11, 13
Pl 9, 17

DELPHI 97-138 CONF 112
13 August, 1997

Search for $\tilde{\chi}_1^0 \rightarrow \tilde{\tau}\tau$ in Light Gravitino Models

Preliminary

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Abstract

Lightest neutralino pair production is searched for within the Gauge Mediated Symmetry Breaking model context. It is assumed that the lightest neutralino is the NNLSP and that the $\tilde{\tau}$ is the NLSP. Data at 161 and 172 GeV center of mass energy are analysed and no candidate is found. Limits on the lightest neutralino pair production cross section are set at 95% CL, as a function of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\tau}}$.

Paper submitted to the HEP'97 Conference
Jerusalem, August 19-26

1 Introduction

If supersymmetry at the electro-weak scale is established, one of the most important questions to address experimentally is the scale and mechanism of supersymmetry breaking. It is often assumed that the messengers of supersymmetry breaking interact with gravitational strength and that the breaking scale in a hidden sector is of the order of 10^{11} GeV/c^2. An alternative possibility is that supersymmetry is broken at some low scale (between the Plank and the electro-weak scale), and that the ordinary gauge interaction acts as the messenger of supersymmetry breaking [1, 2]. In local supersymmetry, the Goldstino ($\tilde{G}$) becomes the longitudinal component of the gravitino. In this case, the gravitino is naturally the lightest supersymmetric particle (LSP) and the lightest standard model superpartner is the next to lightest supersymmetry particle (NLSP). Then, the NLSP is unstable and decays to its SM partner plus a Goldstino.

Since the Goldstino couplings are suppressed compared to electro-weak and strong interactions, decays to the Goldstino are only relevant for the NLSP and therefore the production of pairs of supersymmetric particles at high energy colliders would generally take place through standard model couplings [2]. The supersymmetric particles cascade to NLSP's, that eventually decay to their SM partners and a Goldstino. The specific signatures of such decays depend crucially of the quantum numbers and composition of the NLSP, which are model dependent.

Although most of the attention has been focused on the case where the neutralino is the NLSP, it is equally possible that the NLSP is any other sparticle, and in particular a charged lepton. The number of $5+\bar{5}$ generations of the gauge mediate messenger, over most of the parameter space, determines what particle is the NLSP [4, 5, 6]. For example, for one generation of $5+\bar{5}$ the lightest neutralino tends to be the NLSP, while for two or more generations the balance tips towards right handed sleptons.

Throughout this work, it will be assumed that the $\tilde{\tau}_1$ is the NLSP, and that the lightest neutralino ($\tilde{\chi}^0_1$) is the *next-to*-NLSP.

This paper describes the search for $\tilde{\chi}^0_1$-pair production, followed by the decay $\tilde{\chi}^0_1 \to \tilde{\tau}\tau$. The $\tilde{\tau}$ decays promptly into $\tilde{\tau} \to \tau\tilde{G}$. Long lived decays of the $\tilde{\tau}$ will be studied in a future work. The search for direct pair production of $\tilde{\tau}$'s is described elsewhere [7]. The former search is complementary to the later in regions where $\tilde{\tau}$- pair production has small cross section.

Thus, the signature of the signal is four τ's plus missing energy and momentum from the two gravitinos (plus the energy and momentum carried away by the neutrinos of the decay of the τ's).

The experimental procedure and event selection are described in section 2 and the results are presented in section 3.

2 Experimental procedure and event sample

The analysis is based on data collected by DELPHI in 1996 at center of mass energies from 161 GeV/c^{2}to 172 GeV/c^2. The total integrated luminosities for the two periods are

[2] One exception to this rule being the process $e^+e^- \to Z^0/\gamma^* \to \tilde{G}\tilde{\chi}^0_1$, which will be studied in a future work.

9.8 pb^{-1} and 9.9 pb^{-1} respectively. A detailed description of the DELPHI detector can be found in [8] and its performance in [9].

To evaluate the signal efficiencies and background contaminations, events were generated using several different programs. All relied on `JETSET` 7.4 [10], tuned to LEP 1 data [11], for quark fragmentation. The program `SUSYGEN` [12] was used to generate the neutralino-pair events, and their subsequent decay products. In order to compute detection efficiencies, a total of 7,000 events with center of mass energy 172 GeV/c^{2}and masses 45GeV/c$^2\leq m_{\tilde{\tau}} \leq$ 83GeV/c^2, $m_{\tilde{\tau}}$ + 2GeV/c$^2\leq m_{\tilde{\chi}^0_1} \leq$ 85GeV/c^2. Other 1,000 events at center of mass energy 161 GeV/c^{2}to obtain a scaling factor for efficiencies were also generated. All signal events were processed through the full DELPHI detector simulation [13].

The background process $e^+e^- \rightarrow q\bar{q}(n\gamma)$ was generated with `PYTHIA 5.7` [10], while `DYMU3`[14] and `KORALZ`[15] were used for $\mu^+\mu^-(\gamma)$ and $\tau^+\tau^-(\gamma)$, respectively. The generator of Ref. [16] was used for $e^+e^- \rightarrow e^+e^-$ events.

Processes leading to four-fermion final states, $(Z/\gamma)^*(Z/\gamma)^*$, W^+W^-, $We\nu_e$ and Ze^+e^-, were also generated using `PYTHIA`. The calculation of the four-fermion background was verified using the program `EXCALIBUR` [17], which consistently takes into account all amplitudes leading to a given four-fermion final state. `EXCALIBUR` does not, however, include the transverse momentum of initial state radiation.

Two-photon interactions leading to hadronic final states were generated using `TWOGAM` [18], separating the VDM, QPM, and QCD components. The generators of Berends, Daverveldt and Kleiss [19] were used for the leptonic final states.

The generated signal and background events were passed through the detailed simulation of the DELPHI detector [8] and then processed with the same reconstruction and analysis programs as the real data. The simulated number of events from different background processes was several times the number in the real data.

2.1 Data selection

The following cuts were applied in order to reduce the SM background preserving the signal efficiency:

As a Preselection: To assure good quality of the data, the ratio of good charged tracks [20] to total number of tracks was required to be above 0.8. Very forward-going events and part of the $\gamma - \gamma$ background were eliminated by requiring that the energy in a cone of 30^o around the beam-pipe be less than 30% of the total visible energy.

1. Events with 4 τ's contain less than 7 charged tracks in about 90% of the cases. Thus, the number of charged tracks was required to be smaller than 7. This cut eliminates most of multihadronic background. To eliminate dilepton events, it was also required that the charged multiplicity be bigger than 2. 3-tracks events were allowed to remain to allow for the possibility of a track being lost in the beam-pipe or the detector.

2. Most of the two-photon background was eliminated by asking the missing transverse momentum to be greater than 5 GeV, the transverse energy to be bigger than 10 GeV and that the event contains at least one track with momentum bigger than 6.5 GeV.

3. Events with no missing energy, like $WW \to 4$ -jets, were eliminated by asking the missing mass of the event to be greater than 60 GeV and its thrust smaller than 0.97 .

4. To eliminate ISR events with a photon lost in the beam-pipe, the absolute value of the cosine of the angle of the missing momentum vector ($|\cos(\theta_{miss})|$) was required to be less than 0.9. Also the acoplanarity of the events should be bigger than 5^o.

5. Background events containing hard electrons or photons were eliminated by asking the total energy deposition on the electromagnetic calorimeters to be smaller than 60 GeV.

6. Signal events present naturally a four-jet topology. Thus, when the event is forced to be reconstructed as two-jet by the Durham algorithm [21], the jets should be broad. Events were asked to have at least one jet broader than 20^o in the two-jet configuration.

7. The event are then required to be reconstructed in a 4-jet topology by the Durham algorithm, and the axes of all jets were asked to be at least at 9^o from the beam-pipe. Each jet should also be separated at least by 4^o from any other jet.

8. Finally, jet-clustering algorithms, when forced to split the events into a 4-jet configuration, would take one jet out of a natural 2- or 3-jet background event and divide it (if its multiplicity allows for it). Thus, this events will have hard and soft jets near each other in space. We required that the most energetic jet and the least energetic jet of the event be separated at least by 20^o.

After these cuts, an efficiency between 30 and 40% was obtained for the signal events, and an estimated background of $.24 \pm 0.1$ and 0.27 ± 0.1 was expected at center of mass energies of 161 and 172 GeV respectively. As an illustration, Table 1 shows the evolution of the data, expected background and one of the signal samples throughout these cuts for $\sqrt{s} = 172$ GeV. The signal sample at 161 GeV gave about 6% better efficiency than its counterpart at 172 GeV. Conservatively, we assume equal efficiencies for both center of mass energies.

3 Results

No data event was observed to pass the cuts at either center of mass energy. Thus, results can be expressed as a limit on the production cross section for neutralino pairs. Efficiencies being taken the same for both energies, plus the fact that no candidate is present, allows for only one plot to be introduced. Fig. 1 shows the limit at the 95% CL on $\tilde{\chi}^0_1$-pair production cross section, as a function of $m_{\tilde{\chi}^0_1}$ and $m_{\tilde{\tau}}$ at $\sqrt{s} = 172$ GeV. The same plot holds for $\sqrt{s} = 161$ GeV, up to $m_{\tilde{\chi}^0_1} = 80.5$.

Acknowledgements

I would like to thank François Richard and Pierpaolo Rebecchi for many discussions and technical support.

Cut	data	$\tau\bar{\tau}$	$\gamma\gamma$	4-fermion	$ff\gamma$	signal
1	15964	15.0	14448	81.8	389.	481
2	356	12.8	37.5	6. 9	276.9	438
3	57	4.6	19.8	2.4	12.0	431
4	8	0.95	2.0	1.32	0.9	380
5	7	0.51	1.4	1.10	0.	376
6	6	0.25	1.1	0.34	0.	370
7	0	0.11	0.2	0.19	0.	347
8	0	0.04	0.09	0.15	0.	341

Table 1: Evolution of data and MC through the different cut described in the text. Signal corresponds to $m_{\tilde{\chi}_1^0} = 75\mathrm{GeV/c^2}$ and $m_{\tilde{\tau}} = 55\mathrm{GeV/c^2}$.

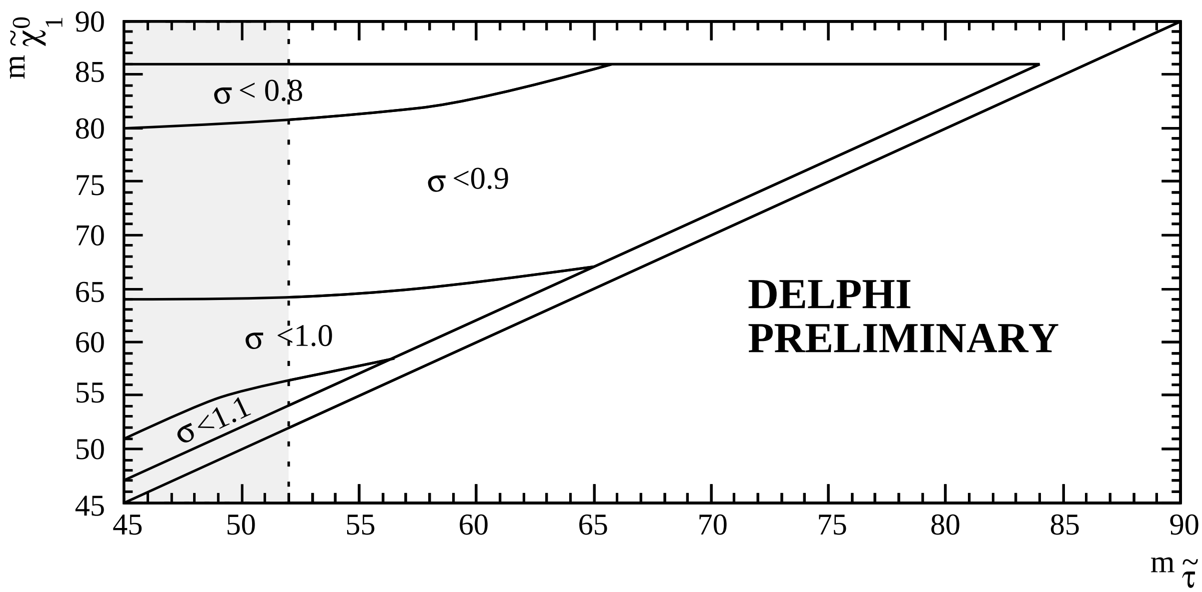

Figure 1: Limit at the 95% CL on $\tilde{\chi}_1^0$-pair production cross section at $\sqrt{s} = 172$ GeV, as a function of $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\tau}}$. The grey-shaded area is eliminated by [7].

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