DØnote 4740-CONF

Search for the Associated Production of Chargino and Neutralino in Final States with Three Leptons involving τ Leptons

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Existing DØ trilepton analyses with electrons and muons have been extended with searches for trilepton final states containing one or more tau leptons decaying hadronically. The searches use data taken with the DØ detector at the Fermilab Tevatron $p\bar{p}$ collider at a center-of-mass energy of 1.96 TeV corresponding to an integrated luminosity of about 325 pb^{-1}. The results constrain the associated production of charginos and neutralinos beyond the existing limits.

Preliminary Results for Spring 2005 Conferences

I. INTRODUCTION

Supersymmetry (SUSY [1, 2]) postulates a symmetry between bosonic and fermionic degrees of freedom and predicts the existence of a supersymmetric partner for each Standard Model particle. In R-parity-conserving minimal supersymmetric extensions of the Standard Model, the charged and the neutral partners of the gauge and Higgs bosons (charginos and neutralinos) are produced in pairs at $p\bar{p}$ colliders and decay into fermions and the Lightest Supersymmetric Particle (LSP).

This note describes the combination of six analyses which search for the associated production of the lightest chargino and the second-lightest neutralino in final states with three leptons and large missing transverse energy:

– final states with an electron, a tau decaying hadronically and a third lepton ("e+τ_{had}+ℓ");

– final states with a muon, a tau decaying hadronically and a third lepton ("μ+τ_{had}+ℓ");

– final states with two electrons and a third lepton ("e+e+ℓ");

– final states with an electron a muon and a third lepton ("e+μ+ℓ");

– final states with two muons and a third lepton ("μ+μ+ℓ");

– final states with two like sign muons ("LS μ+μ").

The analyses, which are described in [3], [4] and [5], use data taken with the DØ detector [6].

As a guideline, the results are interpreted in the minimal supergravity model (mSUGRA) with chargino and neutralino masses mainly following the relation $m_{\chi_1^\pm} \approx m_{\chi_2^0} \approx 2m_{\chi_1^0}$. The points in mSUGRA parameter space considered are characterized by low slepton masses (Table I), which leads to an enhanced leptonic branching fraction because decays via virtual/real slepton cascades are contributing in addition to the decay via virtual gauge bosons . The experimentally and theoretically favored mSUGRA parameter space is typically within the *Gaugino region*, with a mostly wino-like chargino, a wino-like 2nd neutralino and a bino-like LSP. The additional left-handed component of the lightest stau increases the BF of the dominant wino components of chargino and neutralino into final states with taus. The latter is further enhanced by the stronger coupling of the remaining higgsino component to the heavier taus.

Depending on the mass difference of the slepton and the 2nd neutralino, several regions of interest can be distinguished:

- If the slepton mass is lower than the neutralino mass, chargino and neutralino decay via on-shell sleptons. In this case, the gaugino-slepton mass differences are crucial for the efficiency of the selection.

  a) For sufficiently large mass difference of the neutralino and the slepton, both leptons originating from the neutralino cascade decay have large enough momentum to be detected at DØ .

  b) For low mass differences, the slepton is produced together with a very soft lepton and the selection efficiency decreases significantly.

- If the slepton mass is larger than the neutralino mass, leptons can be produced either via virtual gauge bosons or virtual slepton cascades, with a sufficiently large phase space for all leptons.

  a) For slepton masses comparable to the neutralino mass, the contribution of the virtual slepton cascades is large, which increases the branching fraction into leptons.

  b) For slepton masses significantly larger than the neutralino mass, the slepton cascades are in general suppressed and the leptonic branching fraction corresponds approximately to the leptonic decay fractions of the W and Z bosons.

A set of reference parameter combinations (Table I) has been simulated for chargino masses in the region near and beyond the LEP II chargino mass limit at 103 GeV [7]. The MC has been generated using the CTEQ5L PDF [8]. The values of $\sigma\times$ BF are calculated with CTEQ6L1 at LO and multiplied with the NLO QCD k-factors taken from [2]. The PDF uncertainty of -3.7% to -4.2% is taken into account in deriving limits on the chargino mass.

II. RESULTS

Table II shows the number of events observed in data and the number of background events expected from Monte Carlo for the six analyses.

The number of signal events expected for the six analysis channels for each reference point is summarized in Table III.

To avoid double-counting, a signal selected by more than one analysis channel is assigned to one channel and removed from the other channels in a way which maximizes the combined sensitivity.

No evidence for SUSY has been found. The results are combined to extract limits on the total cross section using the likelihood ratio method (LEP CLs method [9]). Systematic and statistical errors, which are discussed in the individual analysis descriptions and are summarized in Tables II and III, are taken into account in the combination including their correlations.

Assuming the mSUGRA-inspired mass relation $m_{\chi^\pm} \approx m_{m_{\chi^0_2}} \approx 2 m_{m_{\chi^0_1}}$ as well as degenerate slepton masses $m_{\tilde{\ell}}$ (no slepton mixing), the limit on $\sigma \times BR(3\ell)$ is a function of $m_{\chi^\pm}$ and $m_{\tilde{\ell}}$, with a relatively small dependence on the other SUSY parameters. Therefore this result can be interpreted in more general SUSY scenarios, as long as the above mass relations are satisfied and R-parity is conserved. The leptonic branching fraction of chargino and neutralino depends on the relative contribution from the slepton- and W/Z-exchange graphs. W/Z exchange is dominant in the limit of large slepton masses, resulting in relatively small leptonic branching fractions (*large-m_0 scenario*). The leptonic branching fraction is maximally enhanced for $m_{\tilde{\ell}} \gtrsim m_{m_{\chi^0_2}}$ (*3l-max scenario*) and will even dominate, if sleptons are light enough that two-body decays are possible. In addition, the $\chi^\pm_1 \chi^0_2$ production cross section depends on the squark masses due to the negative interference with t-channel squark exchange. Relaxing scalar mass unification, the cross section is maximal in the limit of large squark masses (*heavy-squarks scenario*). The NLO prediction [2] for $\sigma \times BR(3\ell)$ for these reference scenarios is shown in Fig. 1. The cross section limit, which is set in this analysis, corresponds to a chargino mass limit of 116 GeV (128 GeV) in the 3l-max (heavy-squarks) scenario, which improves on the mass limit set by chargino searches at LEP.

With increasing size of the data set, the sensitivity of the analysis will be extended towards larger slepton masses.

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[5] DØ Collaboration, "Search for the Associated Production of Chargino and Neutralino in the μ + τ_{had} + ℓ Final State", DØnote 4742-CONF,

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TABLE I: Properties of SUSY reference points (masses in GeV). All points have tan β=3 and $A_0 = 0$. The combination of the results of the six analyes excludes the points 1 to 5.

Pt	$m_{\chi^0_2}$ [GeV]	$m_{\chi^\pm}$ [GeV]	$m_{\tilde{\ell}_R}$ [GeV]	$m_{\chi^0_1}$ [GeV]	BF(lep)	$\sigma \times$ BF [pb]
1	102	98	99	103	0.35	0.536
2	102	103	104	103	0.35	0.400
3	106	107	107	107	0.34	0.331
4	110	111	111	111	0.33	0.264
5	114	114	115	115	0.32	0.231
6	118	119	119	119	0.30	0.179
7	131	132	136	132	0.23	0.102

TABLE II: Number of candidate events observed and background events expected in the six analysis channels.

Analysis	Data	Total Background
e+e+ℓ	0	0.21 ± 0.11 ± 0.05
e+μ+ℓ	0	0.31 ± 0.13 ± 0.03
$\mu + \mu$+ℓ	2	1.75 ± 0.37 ± 0.44
LS $\mu + \mu$	1	0.64 ± 0.36 ± 0.13
e+τ+ℓ	0	0.58 ± 0.11 ± 0.09
$\mu + \tau$+ℓ	1	0.36 ± 0.12 ± 0.06
SUM	4	3.85 ± 0.57 ± 0.49

TABLE III: Number of signal events expected for the six analysis channels after subtracting overlaps.

Point	e+e+ℓ	e+μ+ℓ	μ+μ+ℓ	LS μ+μ	μ+τ+ℓ	e+τ+ℓ
1	3.19±0.14±0.26	2.17±0.07±0.17	1.41±0.04±0.18	1.03±0.19±0.16	1.02±0.04±0.08	0.65±0.02±0.05
2	2.94±0.11±0.24	2.11±0.04±0.17	1.16±0.03±0.15	0.82±0.19±0.13	1.08±0.03±0.09	0.65±0.01±0.05
3	2.62±0.09±0.21	1.92±0.04±0.15	0.91±0.02±0.12	0.73±0.12±0.11	0.93±0.02±0.08	0.51±0.01±0.04
4	2.15±0.08±0.17	1.48±0.04±0.12	0.75±0.02±0.10	0.63±0.12±0.10	0.82±0.02±0.07	0.51±0.01±0.04
5	2.15±0.07±0.17	1.47±0.04±0.12	0.65±0.03±0.08	0.62±0.12±0.10	0.72±0.02±0.06	0.41±0.01±0.03
6	1.63±0.06±0.13	1.11±0.04±0.09	0.49±0.01±0.06	0.51±0.11±0.08	0.56±0.02±0.04	0.30±0.01±0.02
7	0.97±0.03±0.08	0.68±0.04±0.05	0.23±0.01±0.03	0.28±0.05±0.04	0.41±0.02±0.03	0.20±0.00±0.01

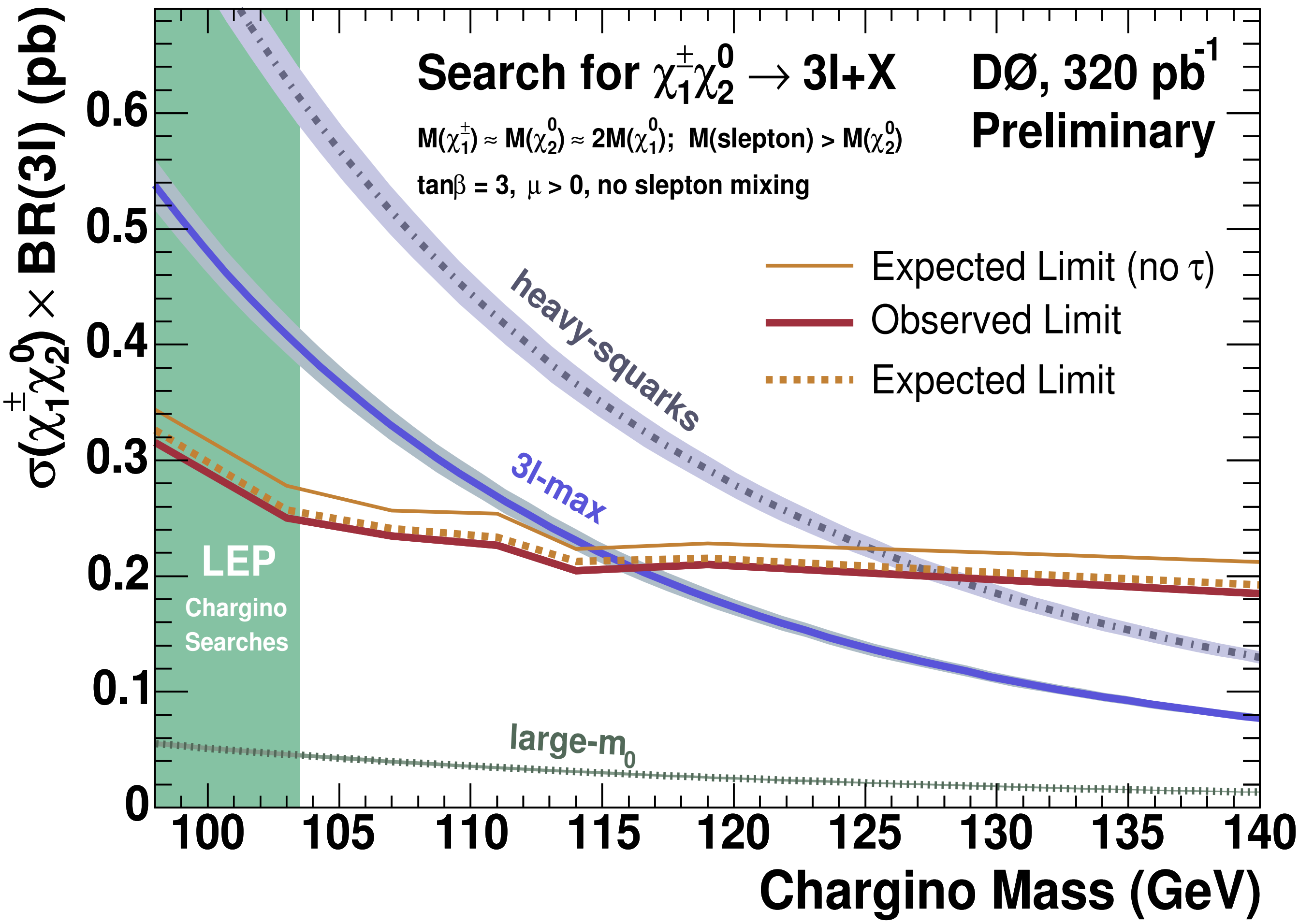

FIG. 1: Limits on the total cross section for associated chargino and neutralino production with leptonic final states. Three model lines are plotted as a reference: The top line corresponds to the signal cross section × leptonic branching fraction predicted for models with heavy squark masses and low slepton masses. The middle line corresponds to the signal expectation for low slepton masses in mSUGRA. The bottom line describes the signal expectation for large m_0 with the chargino and the neutralino decaying via virtual gauge bosons. The PDF and scale uncertainties are shown as shaded bands. Chargino masses below 103 GeV are excluded by direct searches at LEP.