Tracking down the elusive charginos / neutralinos through τ leptons at the Large Hadron Collider.

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Introduction

Current lower limits on sparticle masses:

Sleptons ($\widetilde{l}$), lighter chargino ($\widetilde{\chi}_1^{\pm}$)$\sim 100 GeV$ (LEP)

Squarks($\widetilde{q}$)-Gluino ($\widetilde{g}$) $\sim 300 - 350 GeV$ (TEVATRON)

A Model Independent search strategy at LHC designed for sparticle masses just above these limits is called for.

These has not been done systematically.

Discovery dificult if squarks and gluinos beyond LHC reach; sleptons and electroweak gauginos are little above the LEP limit.

Can we see the SUSY signal ?

Introduction

This scenario is consistent with all experimental data including DM (to be discussed later) but it violates naturalness condition.

This scenario is somewhat similar to the Split SUSY model.

Introduction

Cannot exclude out this scenario since SUSY breaking mechanism unknown

Essential reason: chargino and second lightest neutralino decays to final states with lighter stau killing the clean trilepton signal,second lightest neutralino also decays invisiblly making matters more complicated

A possible scenario non-universal gaugino masses:
$M_3 >> M_2, M_1$, m_0 **(common slepton mass) small**
(to be discussed later)

Proposed Signal

2$l+$ **1** τ **or 1**$l+$**2** τ

Introduction

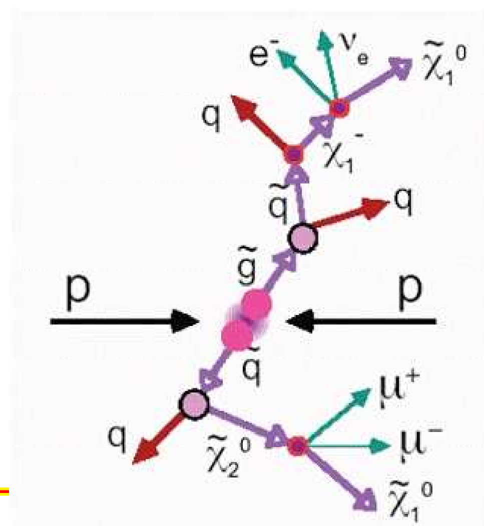
Main Discovery Channels at the LHC:

Squark -Gluino production followed by cascade decays

Generic SUSY Signals:

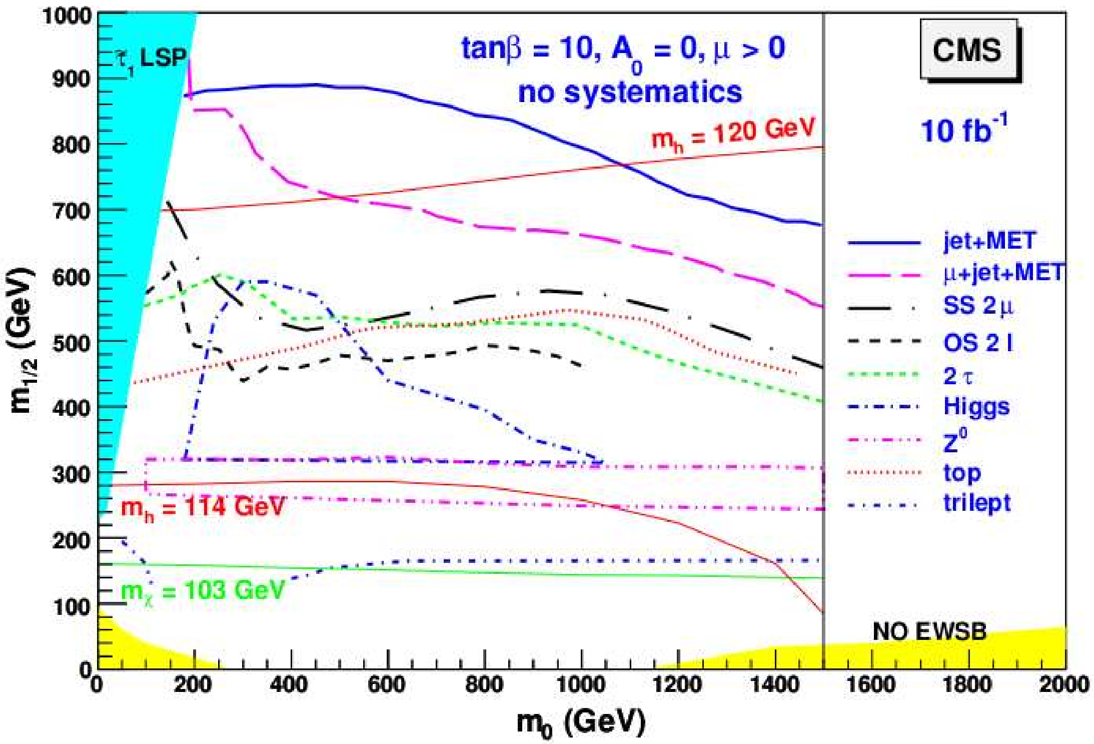
m -Jets + n -leptons + $\not{E}$; lepton = e, μ

Hardly identifies the underlying model. At least some of the sparticle masses should be reconstructed –> underlying SUSY breaking mechanism (with some luck).



Introduction

CMS Discovery Channels(mSUGRA)



Chargino mass reach : $m_{\tilde{\chi}_1^\pm} \lesssim 140$ GeV for $m_{\tilde{l}_R} \approx 100$GeV

$m_{\tilde{\chi}_1^\pm} \lesssim 110$ GeV for $m_{\tilde{l}_R} > 500$ GeV

Introduction

Points to be noted :

- The chargino mass reach is not much larger than the current LEP lower bounds.
- Almost the entire parameter space accessible to the clean trilepton signal is forbidden by the lower limit on $m_h > 114.7$ GeV.
- In addition recent studies (Zack Sullivan, Edmond L. Berger, PRD 78,034030,(2008)) indicates there are backgrounds neglected in previous analyses. For e.g. $Zb\bar{b}$, $W\gamma^*/Z^*$.

PLAN OF THE TALK

- Can $2l$+1τ and $1l$+$2\ \tau$ produce visible signals

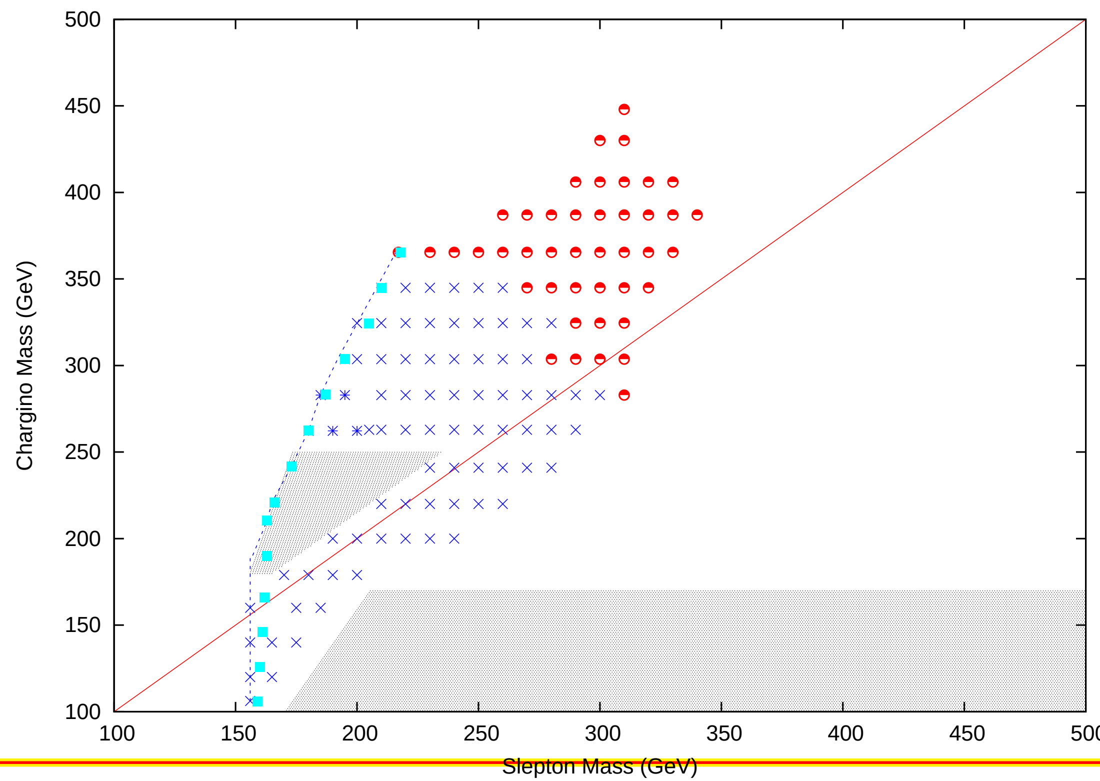
  if the $3l$ signal is too weak
- Can $3l+$ ($2l$+$1\ \tau$) + ($1l$+$2\ \tau$) signal can improve the discovery reach
- The status of the τ rich final states in the mSUGRA model with low m_0 - $m_{1/2}$

Large mixing case

Scenario MSSM: Heavy Squark, gluino

$M_1 \approx 0.5 M_2$, $M_{\tilde{g},\tilde{q}} = 3000 GeV$, $m_{\tilde{l}_L} = m_{\tilde{l}_R} = m_{\tilde{\ell}}$, $A_0 = 0$, $tan\beta = 10$, $m_A = 1000 GeV$ **and** $\mu = 1000$. **All values given at EWSB scale.**

hep-ph/0906.1460



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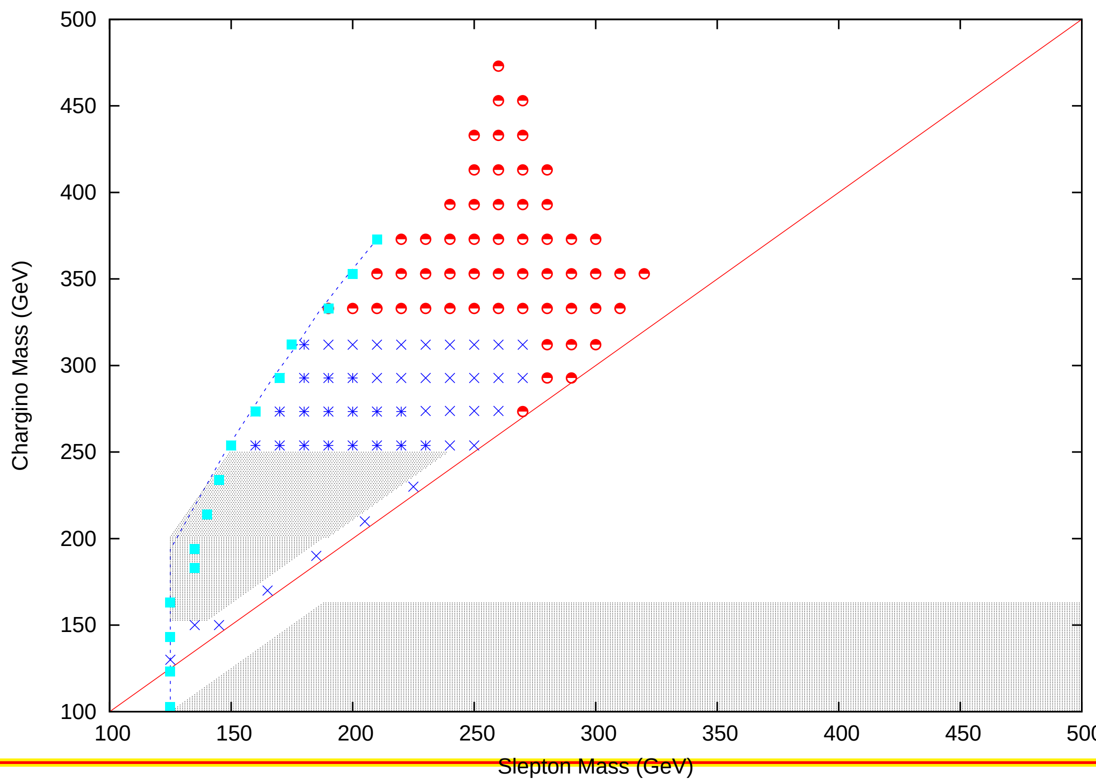

A representative point

Ex. $M_1 = 125 GeV$, $M_2 = 250 GeV$, $M_{\tilde{g}} = 3000 GeV$, $m_{\tilde{\ell}} = 250 GeV$, $m_{\tilde{q}} = 3000 GeV$, $A_0 = 0$, $tan\beta = 10$, $\mu = 500 GeV$, $m_A = 1000 GeV$. **All values given at EWSB scale.**

$\widetilde{\chi}_1^0$	**123.6**	$\widetilde{\tau}_1$	**236.1**	$\widetilde{\nu}_{l_L}$	**241.8**
$\widetilde{\nu}_{\tau_L}$	**241.8**	$\widetilde{l}_R$	**253.8**	$\widetilde{l}_l$	**254.1**
$\widetilde{\chi}_1^{\pm}$	**254.8**	$\widetilde{\chi}_2^0$	**254.9**	$\widetilde{\tau}_2$	**270.6**
$\widetilde{\chi}_3^0$	**518.9**	$\widetilde{\chi}_4^0$	**531.7**	$\widetilde{\chi}_2^{\pm}$	**531.9**
$\widetilde{b}_1$	**2888.7**	$\widetilde{q}_L$	**2890.0**	$\widetilde{q}_R$	**2890.0**
$\widetilde{b}_2$	**2893.0**	$\widetilde{t}_1$	**2923.3**	$\widetilde{g}$	**2942.9**
$\widetilde{t}_2$	**2956.5**				

3l Signal Non-Universal Gaugino Masses (S.Bhattacharya,Asesh K Datta and B. Mukhapadhayay; arXiv:0809.02012[hep-ph])

BRs of the representative point

Decay modes	BR
$\widetilde{\chi}_1^+ \longrightarrow \tilde{\nu}_l l^+$	42.0
$\widetilde{\chi}_1^+ \longrightarrow \tilde{\nu}_\tau \tau^+$	21.4
$\widetilde{\chi}_1^+ \longrightarrow \widetilde{l}_l \nu_l$	–
$\widetilde{\chi}_1^+ \longrightarrow \widetilde{\tau}_1^+ \nu_\tau$	22
$\widetilde{\chi}_2^0 \longrightarrow \widetilde{l}_l l$	–
$\widetilde{\chi}_2^0 \longrightarrow \widetilde{\tau}_1 \tau$	25
$\widetilde{\chi}_2^0 \longrightarrow \tilde{\nu} \nu$	62

Is this scenario dark matter allowed

$\Omega_{CDM} h^2 = .0903$

Channels	Relative Contribution
$\widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \rightarrow \tau\tau$	16
$\widetilde{\chi}_1^0 \widetilde{\chi}_1^0 \rightarrow ll$	18
Bulk	34
$\widetilde{\chi}_1^0 \widetilde{\tau}_1 \rightarrow \tau h$	2
$\widetilde{\chi}_1^0 \widetilde{\tau}_1 \rightarrow Z\tau$	8
$\widetilde{\chi}_1^0 \widetilde{\tau}_1 \rightarrow A\tau$	22
$\widetilde{\chi}_1^0 \widetilde{\tau}_1 \rightarrow W\nu_\tau$	8
Co-annilation	40

Details of analysis

- $\tau - jets$: $E_{visible} = E_T^{\tau} - E_T^{\nu_\tau}$; $|\eta_\tau| < 2.4$. Tagging efficiency (ϵ_τ) from $E_{visible} = 30$GeV given in CMS TDR -II.
- Leptons ($l = e, \mu$): $P^e{}_{\mathrm{T}} \geq 17$ GeV, $P^\mu{}_{\mathrm{T}} \geq 10$ GeV and $|\eta^l| < 2.4$. Lepton-jet isolation: $\Delta R(l, j) > 0.5$.
- 2τ + 1l : $\not{E}_T > 100$ GeV
- 1τ + 2l : $\not{E}_T > 100$ GeV and 80$< M_{inv}^{ll} <$ 100 GeV.

Background (hep-ph/0906.1460)

σ (pb)	Signal 0.896	QCD 1.48 x E^8	WZ 31.47	ZZ 13.11	$t\bar{t}$ 400	Z + j 1.7 x E^5
$2\ \tau + 1\ l$	0.00134	105.7	0.0066	0.0017	0.004	4.7
$\not{E}_T > 100$ GeV	0.00108	–	–	–	–	–
$1\ \tau + 2\ l$	0.00206	63.4	0.015	0.0111	0.24	19.6
$\not{E}_T > 100$ GeV	0.00072	–	0.0094	0.0026	.068	–
$80 < M_{inv}^{ll} < 100$ GeV	0.00045	–	–	–	.064	–

$\sigma \times \epsilon$ is given above.
The $W\gamma^*/Z*$ is numerically significant (0.0005 for $2\tau + 1l$ and 0.0003 for $1\tau + 2l$)but not negligible.

GUT representative point

$M_1 = M_2 = 300$, $M_3 = 1200$, $m_{\tilde{\ell}} = 150$, $m_0 = 160$, $A_0 = 0$, **tan**$\beta = 10$ **and Omega(**Ω**)** $= 0.10$.

$\widetilde{\chi}_1^0$	**117.2**	$\widetilde{\tau}_1$	**132.1**	$\widetilde{l}_R$	**193.6**
$\widetilde{\nu}_{\tau_L}$	**221.6**	$\widetilde{\nu}_{l_L}$	**222.5**	$\widetilde{\chi}_1^{\pm}$	**225.3**
$\widetilde{\chi}_2^0$	**225.3**	$\widetilde{l}_l$	**235.7**	$\widetilde{\tau}_2$	**272.7**
$\widetilde{\chi}_3^0$	**1433.5**	$\widetilde{\chi}_4^0$	**1435.4**	$\widetilde{\chi}_2^{\pm}$	**1436.1**
$\widetilde{t}_1$	**1913.1**	$\widetilde{b}_1$	**2101.9**	$\widetilde{t}_2$	**2125.9**
$\widetilde{b}_2$	**2240.9**	$\widetilde{q}_L$	**2245.1**	$\widetilde{q}_R$	**2248.6**
$\widetilde{g}$	**2594.7**				

- Intuitively this scenario can also arise in GMSB model.
- In GMSB model mass arises via gauge interaction; hence strongly interacting sparticles could be expected to be much heavier than the sparticles in EW sector.

Signals in mSUGRA

- Low $m_0 - m_{1/2}$ is disfavoured in mSUGRA if $A_0 = 0$ by Higgs mass bound.
- For $A_0 \neq 0$, there are regions of parameter space satisfying the Higgs mass bound as well as DM data.
- The three **benchmark scenarios** in mSUGRA are as follows :
  - **A**:$m_0 = 120$,$m_{1/2} = 300$,$A_0 = -930$,$tan\beta = 10$,$\mu > 0$
  - **B**:$m_0 = 120$,$m_{1/2} = 350$,$A_0 = -930$,$tan\beta = 10$,$\mu > 0$
  - **C**:$m_0 = 120$,$m_{1/2} = 500$,$A_0 = 0$,$tan\beta = 10$,$\mu > 0$

Signals in mSUGRA

The dominant DM relic density producing mechanisms in the above scenarios are as follows:

- Scenario A is charecterized by both LSP pair annihilation and LSP-$\widetilde{\tau}_1$ coannihilation.
- In scenario B LSP-$\widetilde{\tau}_1$ coannihilation dominates.
- In scenario C LSP-$\widetilde{\tau}_1$ coannihilation is the only DM producing mechanism.

Signals in mSUGRA

	A	B	C
σ (pb)	0.747	0.403	0.106
2 τ + 1 l	0.000276	0.000189	0.000210
$\not{E}_T > 100$ GeV	0.000149	0.00010	0.00012
1 τ + 2 l	0.000366	0.000387	0.001257
$\not{E}_T > 100$ GeV	0.000187	0.000185	0.000831
$80 < M_{inv}^{ll} < 100$ GeV	0.000172	0.000165	0.000670

None of them leads to observable signal at 10fb^{-1}

Signals in mSUGRA

Reasons for small (non observable) signals in mSUGRA :

- **General model yeild a larger $\widetilde{\chi}_1^{\pm} - \widetilde{\chi}_2^0$ production cross-section compared to mSUGRA for the same $m_{\widetilde{\chi}_1^{\pm}}$.**
- **In mSUGRA with a common scalar mass m_0 at M_G, $\widetilde{\tau}_R$ becomes lightest charged slepton at weak scale.**
- **Decay products of $\widetilde{\tau}_1$ are soft.**

CONCLUSION

Final states with tagged $\tau - jets$ have excellent potential in the context of SUSY searches at the LHC.