Search for gluinos in their decays through third generation quarks at LHC

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Introduction

• $m_{sparticle} > \mathcal{O}(1\ TeV)$ disfavored from Naturalness and Fine-tuning. However, $m_{sparticle} \gtrsim \mathcal{O}(1\ TeV)$ (1st and 2nd gen.) cures: SUSY FCNC, SUSY CP, suppress proton decay rates and etc.

• Therefore, models with $m_{sparticle} \sim \mathcal{O}(1\ TeV)$ without sacrificing naturalness, *if viable*, are indeed pretty good.

• These attractive features are realized in Focus point or Hyperbolic Branch of mSUGRA model. **Ref: Feng and Wilczek, hep-ph/0507032; Feng etal. hep-ph/9909334; Chan etal. hep-ph/9710473.**

• REWSB criterion:

$$\frac{1}{2} M_Z^2 = \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2\beta}{\tan^2\beta - 1} - \mu^2 , \tag{1}$$

• For all $\tan\beta$, $m_{H_u}^2 >> M_Z^2$ is disfavored by the naturalness criterion, as in that case, a large cancellation between $m_{H_u}^2$ and μ^2 is needed to arrive at the physical value of the weak scale. For moderate and large values of $\tan\beta$, however, $m_{H_d}^2 >> M_Z^2$ does not necessarily lead to fine-tuning.

• At moderate to large $\tan\beta$, $\mu^2 \sim m_{H_u}^2$; $m_{H_u}^2 \sim \mathcal{O}(M_Z^2)$ ($m_{1/2}$ or A_0 is not too large ($\sim 1\ TeV$));$\mu \sim \mathcal{O}(M_Z)$

Focus Point

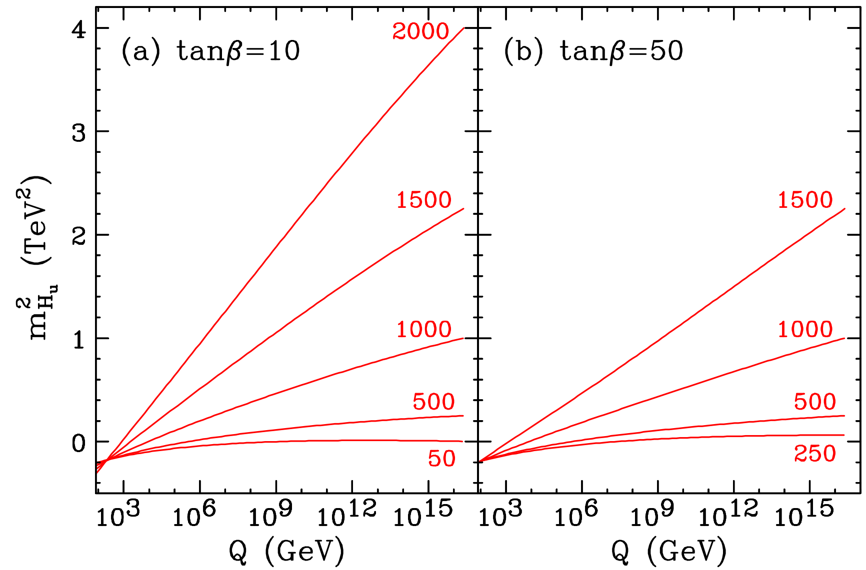

Figure 1: *For* $m_{1/2} = 300$ *GeV,* $A_0 = 0$, *and* $= 174$ *GeV.* **Ref: Feng etal. hep-ph/9909334**

• low μ important phenomenological implication:
$\widetilde{\chi}_1^0, \widetilde{\chi}_2^0, \widetilde{\chi}_1^{\pm}$ Higgsino dominated and are also mass degenerate ($\sim \mu$).
A higgsino dominated gaugion couples to a light fermion and its super-partner with suppressed couplings $\rightarrow$ important for collider and dark matter phenomenology. **Ref: H. Baer etal. hep-ph/0507282**

Neutralino relic density

- The properties of the Universe: density of baryons, matter, vacuum energy and the Hubble expansion rate.
- From WMAP $\Omega_{CDM}h^2 = 0.1126^{+0.0161}_{-0.0181}$ at 95% CL
- $\widetilde{\chi}_1^0$ can be CDM candidate and only certain regions give rise to relatively low $\Omega_{\widetilde{\chi}_1^0}h^2$ consistent with WMAP where $\widetilde{\chi}_1^0\widetilde{\chi}_1^0 \rightarrow$ SM particles is large.
- $0.094 < \Omega_{\widetilde{\chi}_1^0}h^2 < 0.129$

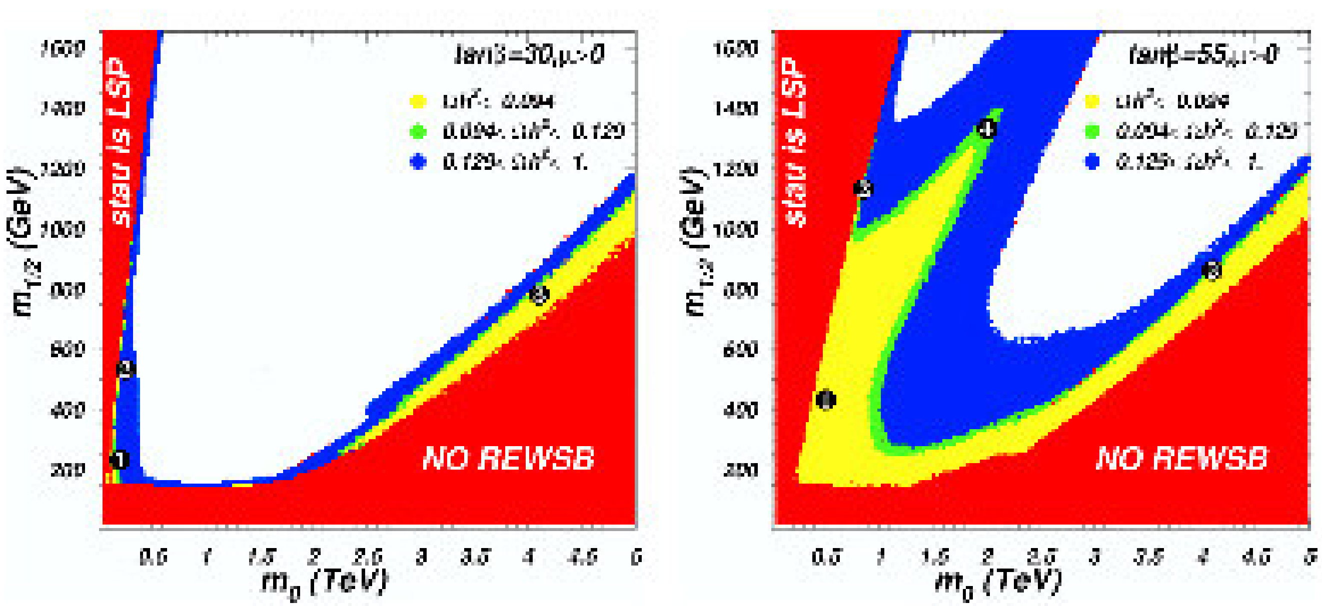

Figure 2: *Regions of Neutralino relic density for* A_0*= 0 and* $\tan\beta$*= 30 (55).*
Ref: A. Belyaev, IJMPA 21(2006)205-235.

LHC reach from jets+$\not\!\!E_T$ channel

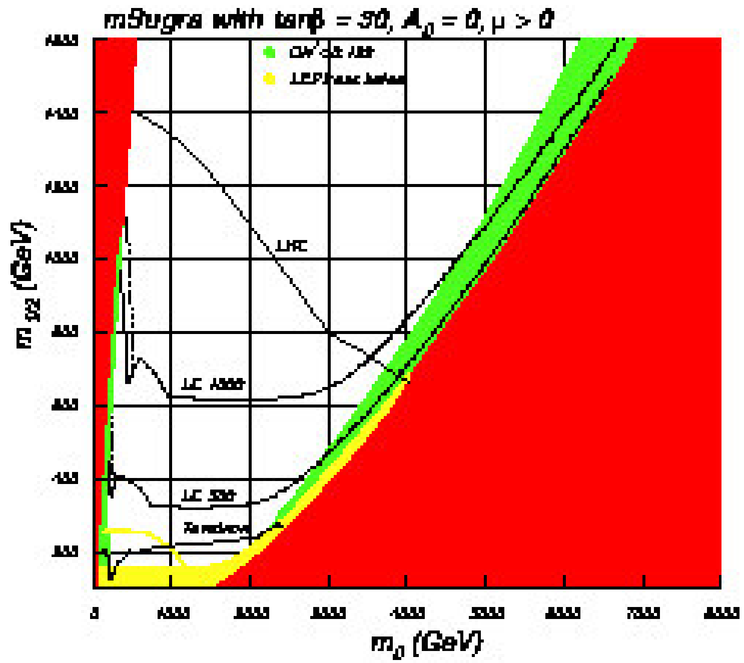

Figure 3: *Parameter space of mSUGRA model for* $\tan\beta$*= 30 showing the reach of different colliders for supersymmetry discovery in the* **jets+** $\not\!\!E_T$ *channel from* $\widetilde{q}$ *and* $\widetilde{g}$ *pair production.*

Ref: **A. Belyaev, IJMPA 21(2006)205-235**.

Signal and Backgrounds

In addition the $\widetilde{g}$ is light and $\widetilde{t}_1, \widetilde{b}_1$ are also light compared to the 1st and 2nd generation squarks

Gluino can decay: $\tilde{\mathbf{g}} \rightarrow \mathbf{tb}\widetilde{\chi}_{\mathbf{i}}^{\pm}; \mathbf{t\bar{t}}\widetilde{\chi}_{\mathbf{j}}^{\mathbf{0}}; \mathbf{b\bar{b}}\widetilde{\chi}_{\mathbf{i}}^{\mathbf{0}}$

$\Rightarrow$

(I)2 W + 4 b + jets + $\not{E}_T$

(II)4 W + 4 b + jets + $\not{E}_T$

Backgrounds: $t\bar{t}t\bar{t}, t\bar{t}b\bar{b}, b\bar{b}b\bar{b}, t\bar{t}qq, b\bar{b}qq, Wtb, QCD....$

Events generated with ALPGEN and then interfaced with PYTHIA (We also checked using CalcHEP and Madgraph)

Earlier works: parton level by U. Chattopadhyay etal., hep-ph/0008228; generator level by P.G. Mercadante etal., hep-ph/0506142; b-tagging improves the Gluino discovery reach.

Present work (in preparation): with backgrounds. eg. $tt\bar{t}t$, $tt\bar{b}b$ and $bb\bar{b}b$, W and top quark reconstruction.

Selection of events

1) Lepton selection: Leptons are identified by using its particle identity at the generator level p_T^ℓ >20 GeV and $|\eta|_\ell$ <2.5.
2) Jet reconstruction: jets are constructed using the default subroutine `PYCELL` in `PYTHIA`: $|\eta|_j$ <4.5; $\Delta R(j,j)$ >0.5; $p_T^j > 30GeV$
Cuts used: $p_T^{j^{1-4}}$ > 350., 250., 150., 100. GeV
3) b-tagging: If a jet (j^b) matches with a decayed B-hadron within a cone with ΔR <0.3 of the jet axis and if $|\eta|_{j^b} <$ 2.5 and *the decay length of the B-hadron* > 3.0 mm.
4) $\not{E}_T$: 300 GeV
5) Effective mass: $M_{eff} = \sum p_T^j + \sum p_T^\ell + \not{E}_T$
Benchmark Point: $m_0, m_{1/2}, A_0, \tan\beta, sgn(\mu)$ =3712 GeV, 700 GeV,0.0,30.,+1 and m_t=175 GeV and Ωh^2=0.124 (using `micrOMEGA v2.0`)
`ALPGEN` except $t\bar{t}$) with $\hat{p_T}(j,b)$ >10 GeV and $\Delta R(j,b)$ >0.3, $\eta(j,b)$ <5.0.

Table 1: Mass spectrum for given mSUGRA parameter

$\tilde{g}$	$\tilde{q}_L$	$\tilde{q}_R$	$\tilde{t}_1$	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^\pm$	$\tilde{\chi}_1^0$	$\tilde{\chi}_2^0$	$\tilde{\chi}_3^0$	$\tilde{\chi}_4^0$	h
1751	3912	3907	2469	397	599	287	393	404	612	121

Response (preliminary)

Table 2: Cumulative effects of cuts

Cuts	$t\bar{t}t\bar{t}$	$t\bar{t}b\bar{b}$	$t\bar{t}$ $\hat{p}_T < 500$	$t\bar{t}$ $\hat{p}_T > 500$	$b\bar{b}b\bar{b}$	Signal $(\widetilde{g}\widetilde{g})$	Signal $(\widetilde{g}\widetilde{q})$
No cuts	287616	118680	1000000	1000000	87621	100000	100000
$N_j \geq 6$	273977	62138	185574	255840	1122	97557	97764
$N_{j+l} \geq 9$	208565	12725	12599	43947	33	86013	88712
$N_b \geq 2$	123472	6909	3351	13004	13	52595	50228
$P_T^{b_1} \geq .3$	18963	486	270	8086	1	37614	38742
$\not{E}_T \geq .3$	1591	17	9	814	0	27870	32340
$M_{eff} \geq 2.2$	719	11	5	292	0	25269	32298
$\sigma(fb)$	2.9	190	4.3×10^5	1.4×10^3	8.0×10^6	1.64	0.11
$\sigma\times\epsilon_{ac}$(fb)	0.0073	0.0176	2.1	0.4	<1	0.41	0.036

Total cross sections, Background: 2.52 fb, signal:0.446fb

So, for 100 fb^{-1} Significance $\simeq$ 2.8

Other backgrounds, Optimization

$\not{E}_T$-distribution

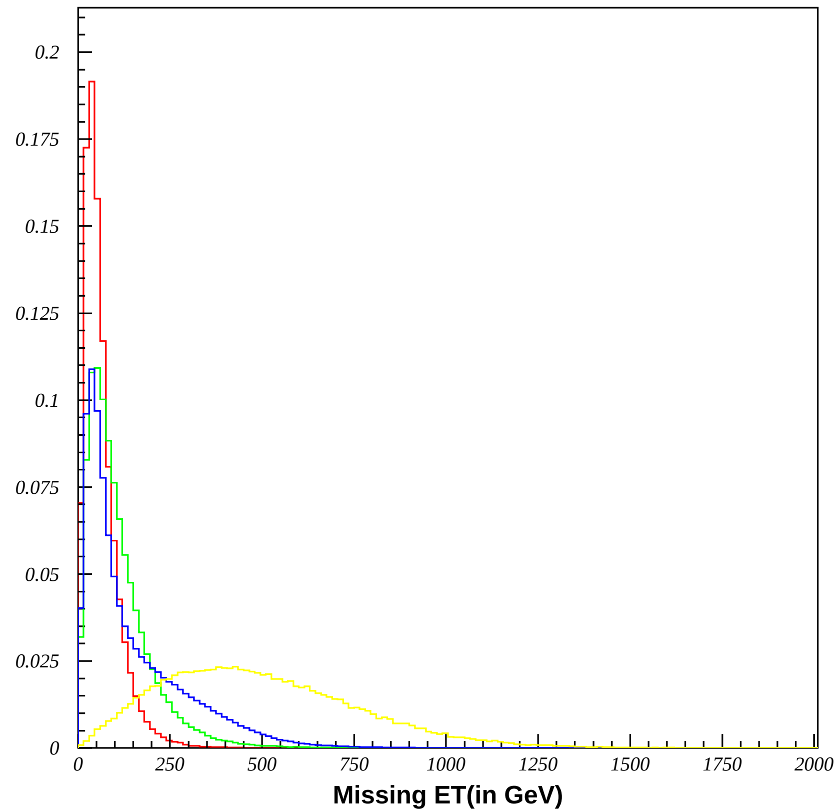

Figure 4: $\not{E}_T$ *distribution : Normalized to Unity ; Signal:yellow ;* $t\bar{t}$ *(*$\hat{p_T} > 500$ *): blue ;* $t\bar{t}t\bar{t}$ *: green ;* $t\bar{t}b\bar{b}$ *: red .*

M_{eff} distribution

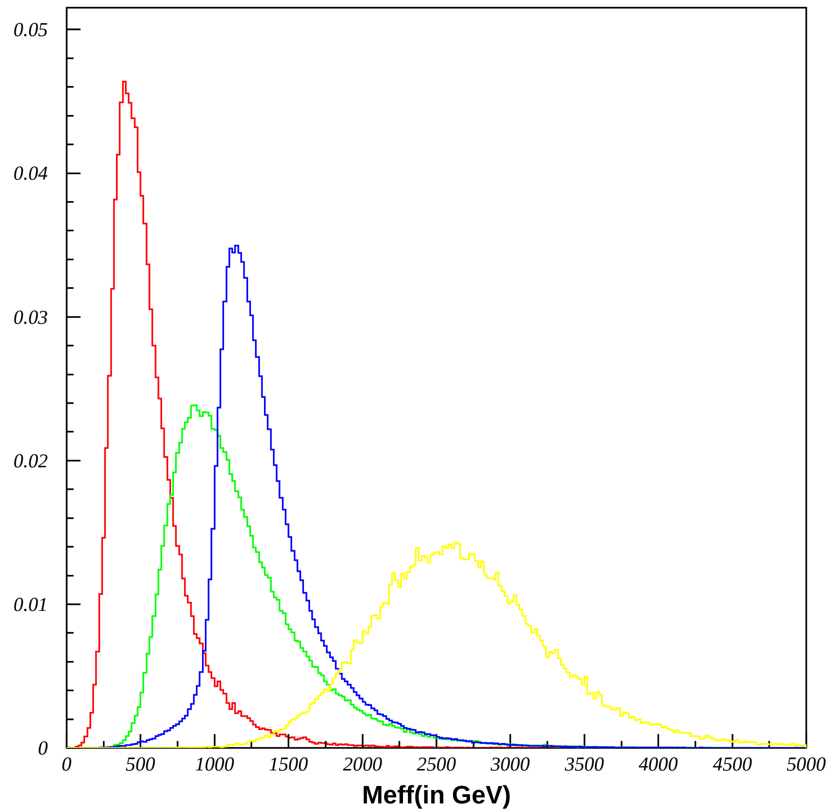

Figure 5: M_{eff} *distribution : Normalized to Unity ; Signal:yellow ;* $t\bar{t}$ *(*$\hat{p_T} >$ *500): blue ;* $t\bar{t}t\bar{t}$ *: green ;* $t\bar{t}b\bar{b}$ *: red .*

Conclusion

• In the Focus point regions, lighter neutralino and chargino are higgsino dominated.
• Neutralino may be the CDM candidates from WMAP.
• Gluino is light (since $m_{1/2}$ is not so large); 3rd generation squarks are also light compare to first two generations.
• Gluino pair production and Squark-Gluino production and their subsequent decay contains more number of b-jets; b-tagging helps.
• Considered the heavy flavour background, $e.g.$, tttt, ttbb, bbbb, ttqq,..
• $\not{E}_T$ and M_{eff} reject large fraction of backgrounds.
• Optimization.