The MSSM with Decoupled Scalars at the LHC

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Decoupled Scalar Supersymmetry

[Arkani-Hamed & Dimopoulos, 2004] and [Giudice & Romanino, 2004]

SUSY is broken at $M_S = \mathcal{O}(10^{4 \text{ to } 16}$ GeV).

Spectrum

- **Scalars** ($\tilde{q}$, $\tilde{l}$, H and A) @ M_S.
- **Fermions** ($\tilde{\chi}$ and $\tilde{g}$) protected by sym. @ $M_{EW} \sim \mathcal{O}(1$ TeV).
- **SM Higgs** h fine-tuned @ M_{EW}.

- Scalars (but h) are decoupled from the low energy spectrum.
- Effective theory below M_S (eff. RGE).
- At M_S, matching with the complete theory and MSSM RGE beyond.

Parameters and Phenomenology

Parameters are

- M_S : breaking scale, scalars mass.
- M_1, M_2, $M_3(M_{\text{GUT}})$: gauginos mass parameters at the GUT scale.
- $\mu(M_Z)$: Higgs mass parameter at the EW scale.
- $A_t(M_S)$: trilinear $H - \tilde{t} - \tilde{t}$ coupling at the breaking scale.
- $\tan\beta(M_S)$: vevs ratio at M_S.

Phenomenology

- No scalars at the LHC (except h)
- Light Higgs between 110 and 160 GeV
- Relic density in agreement with WMAP
- Possibility of gluino stability (not in this study)

Observables @ LHC

Parameter point

M_S	10 TeV
$M_{2,EW}$	129 GeV
μ	290 GeV
$\tan\beta$	30
A_t	0.

- low fine-tuning
- $\Omega_{DM} h^2$ in agreement with WMAP

Masses in GeV (SuSpect)

h	129	$\tilde{g}$	438	$\tilde{\chi}_1^\pm$	117	$\tilde{\chi}_2^\pm$	313
$\tilde{\chi}_1^0$	60	$\tilde{\chi}_2^0$	117	$\tilde{\chi}_3^0$	296	$\tilde{\chi}_4^0$	310

SplitSusy in SuSpect → [Bernal *et al.*, 07]

NLO production (Prospino)

$\tilde{g}\tilde{g}$	63 pb	$\tilde{\chi}^\pm\tilde{g}$	311 fb
$\tilde{\chi}^\pm\tilde{\chi}^0$	12 pb	$\tilde{\chi}^0\tilde{g}$	223 fb
$\tilde{\chi}^\pm\tilde{\chi}^\pm$	6 pb	$\tilde{\chi}^0\tilde{\chi}^0$	98 fb
Total		82 pb	
$\sigma_{\mathrm{SPS1a}} \sim 60$ pb		$\sigma_{\mathrm{SPS1a}}(\tilde{g}\tilde{g}) \sim 8$ pb	

- High tri-lepton signal (no hard jet) : $\sigma_{3\ell} = 145$ fb $= 110 \times \sigma_{3\ell}(\mathrm{SPS1a})$
  $\sigma(\tilde{\chi}_1^\pm \tilde{\chi}_2^0) \simeq 12$ pb, no t-channel destructive interference
- End-point : $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$ in $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \ell^+ \ell^-$
- $\sigma(\tilde{g}\tilde{g})$ and $R(\tilde{g} \to b/!b) = BR(\tilde{g} \to bX)/BR(\tilde{g} \to !bX)$
- $m_h \pm 0.1\%$ in $h \to \gamma\gamma$

Parameter determination : SFITTER

- SFITTER : model fitting from collider observables (+errors). Uses SuSpect, SDecay, Minuit, MicroMegas, etc...
- New : Implementation of Heavy Scalar Susy.
- Observable are verified using Monte Carlo fast-simulated data.
- Statistical errors based on 1 year of LHC operation at full luminosity.

Observables		Exp. systematic errors		Statistical errors	Theoretical
	Value	Error	Source	100 fb^{-1}	
m_h	128.8 GeV	0.1%	energy scale	0.1%	4%
$m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$	57 GeV	0.1%	energy scale	0.3%	1%
$\sigma(3\ell)$	145.2 fb	5%	luminosity	3%	20%
$R(\tilde{g} \to b/!b)$	0.11	5%	b-tagging	0.3%	20%
$\sigma(\tilde{g}\tilde{g})$	63 pb	5%	luminosity	0.1%	20%

Parameter determination

Three fit strategies :

- Low statistic (100 fb^1) : systematic and statistical errors included.
- Infinite statistic : only systematic errors included.
- Infinite stat. and theoretical : systematic and theoretical errors included.

Parameter	Nom. values	Fit values	Low stat.		∞ stat.		∞ stat.+th	
M_2	132.4 GeV	132.8 GeV	6	5%	0.24	0.2%	21.2	16%
M_3	132.4 GeV	132.7 GeV	0.8	0.6%	0.16	0.1%	5.1	4%
μ	290 GeV	288 GeV	3.8	1.3%	1.1	0.4%	48	17%
$\tan\beta$	30	28.3	60	undet.	1.24	4%	177	undet.
M_1	132.4 GeV	132.8 GeV	$= M_2$					
A_t	0		fixed					
M_S	10 TeV		fixed					

- No info on scalar sector (except non obs.) : A_t and M_S fixed.
- Not enough observables : we fix $M_1 = M_2$.
- Invisible Higgs sector (except h) : no sensitivity on $\tan\beta$.
- Fit converges to nominal values.
- Theoretical errors dominant. Still M_2, M_3 and μ determined to 15%.

Conclusions

- A model with decoupled scalars (except h), SUSY breaking at $M_S = \mathcal{O}(10^{4 \text{ a } 16}$ GeV).
- Grande unification and DM respected but fine tuning of m_h required.
- No scalars at the LHC but high σ_{SUSY}.
- $\tilde{g}\tilde{g}$ and trilepton visible at the LHC.
- Few observables but model can be partially determined.
- Errors of the order of 15%.

Outlook :

- Include indirect constraints ($\Omega_{\text{DM}} h^2$, $b \to s\gamma$ etc...).
- Look at other less favorable parameter points.
- Use Markov Chain fitting techniques.
- Better treatment of errors.

Note : This work is reported in the 2007 Les Houches Beyond-SM group report.

BACKUP

The MSSM : yes but...

Traditional MSSM $\Rightarrow m_{\text{SUSY}} \simeq \mathcal{O}(1\ \text{TeV})$
SPS1a : $m_{\tilde{q}} \simeq 540$ GeV ; $m_{\tilde{l}} \simeq 170$ GeV ; $m_{\chi} \simeq 260$ GeV ; $m_{\tilde{g}} \simeq 600$ GeV

Advantages

- Control over $m_h \simeq \mathcal{O}(100\ \text{GeV})$ $\Rightarrow$ no fine tuning
- Dark Matter candidate
- Grand Unification

Inconvenients

- No Higgs/SUSY @ LEP $\Rightarrow$ fine tuning
- expected FCNC
- Proton decay
- CP violation
- Fine tuning of Λ

If SUSY is broken at high scale ($\gtrsim 10$ TeV):

- Dark Matter candidate
- Grand Unification
- Heavier Higgs

- m_h not protected by SUSY anymore $\Rightarrow$ fine tuning
- Fine tuning of Λ