Strongly Interacting Gauge Mediation (SIGM) at the LHC

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based on

K.Hamaguchi, E.N., S.Shirai and T.T.Yanagida JHEP **0807**, 107 (2008)

and E.N., R.Sato and S.Shirai *work in progress*

1. **Strongly interacting gauge mediation (SIGM)**
2. **Sparticle spectrum in SIGM models**
3. **LHC signature**

1. Strongly interacting gauge mediation (SIGM)

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Among various supersymmetric extension of standard model, we consider gauge mediation:

$$\boxed{\text{MSSM (visible) sector}} \xleftarrow{\text{messengers}} \boxed{\not{\text{SUSY}}\text{ (hidden) sector}}.$$

Motivations:

- Uses only well-established gauge interactions.
- Solution for the flavor (FCNC) problem.
- If $m_{\text{gravitino}} < \mathcal{O}(10)$ eV, no gravitino problem.

1. Strongly interacting gauge mediation (SIGM)

— minimal gauge mediation model.

[MSSM (visible) sector] $\xleftarrow{\text{messengers}}$ [~~SUSY~~ (hidden) sector].

	$\Phi_{\rm SM}$	$\Phi_{\rm mes}$	Φ_S
SM gauge interaction ($g_{\rm SM}$)	couple	couple	$\times$
Yukawa interaction (y)	$\times$	couple	couple

$$W = W_{\rm MSSM}(\Phi_{\rm SM}) + y\Phi_S\overline{\Phi}_{\rm mes}\Phi_{\rm mes} + W_{\cancel{\rm SUSY}}(\Phi_S, \cdots).$$

$\Phi_{\rm SM}$: the standard model superfield.

$\Phi_{\rm mes}, \overline{\Phi}_{\rm mes}$: messenger superfields.

Φ_S: a SUSY-breaking superfield: $\langle\Phi_S\rangle = \langle\varphi_S\rangle + \theta^2\langle F_S\rangle$.

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MSSM (visible) sector $\xleftarrow{\text{messengers}}$ ~~SUSY~~ (hidden) sector.

	$\Phi_{\rm SM}$	$\Phi_{\rm mes}$	Φ_S
SM gauge interaction ($g_{\rm SM}$)	couple		$\times$
Yukawa interaction (y)	$\times$	couple	

Minimal gauge mediation models suffers from the problem of unstable vacuum. E.g. with the condition $m_{\rm gravitino} < \mathcal{O}(10)$ eV, m(squark),m(gluino)$\lesssim 1$ TeV.

[Hisano et al. '07, '08]

1. Strongly interacting gauge mediation (SIGM)

— Strongly interacting gauge mediation (SIGM).

MSSM (visible) sector $\xleftarrow{\text{messengers}}$ ~~SUSY~~ (hidden) sector.

	$\Phi_{\rm SM}$	$\Phi_{\rm mes}$	Φ_Q
SM gauge interaction ($g_{\rm SM}$)	couple	couple	$\times$
"Hidden" strong interaction ($g_{\rm hid}$)	$\times$	couple	couple

$$W = W_{\rm MSSM}(\Phi_{\rm SM}) + m_{\rm mes}\overline{\Phi}_{\rm mes}\Phi_{\rm mes} + W_{\cancel{\rm SUSY}}(\Phi_Q).$$

$\Phi_{\rm SM}$: the standard model superfield.

$\Phi_{\rm mes}, \overline{\Phi}_{\rm mes}$: messenger superfields.

Φ_Q: hidden quarks.

1. Strongly interacting gauge mediation (SIGM)

Advantages of SIGM:

Natural realization of gravitino with mass $m_{\text{gravitino}} < \mathcal{O}(10)$ eV.

Avoiding the problem of metastable vacuum.

An example of SIGM model:

$G_{\text{SM}} \subset \text{SU}(5)_{\text{GUT}} \quad G_{\text{hid}} = \text{SU}(5)_{\text{hid}}$.

Hidden quarks $Q : \mathbf{5}^* \oplus \mathbf{10}\big|_{\text{SU}(5)_{\text{hid}}} \Rightarrow \cancel{\text{SUSY}}$

[Affleck–Dine–Seiberg, Murayama]

Messengers P_d, P_ℓ, $\overline{P}_d$, $\overline{P}_\ell$.

$$P_d + P_\ell : (\mathbf{5}, \mathbf{5}^*)\big|_{\text{SU}(5)_{\text{GUT}} \times \text{SU}(5)_{\text{hid}}}.$$

2. Sparticle spectrum in SIGM models

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Properties of sparticle spectrum in SIGM models:

1. $\boldsymbol{m_{\mathrm{gaugino}} \ll m_{\mathrm{scalar}}}$

$$\text{In SIGM,} \quad m_{\mathrm{gaugino}} \simeq \frac{\alpha_{\mathrm{SM}}}{4\pi} \frac{\Lambda^2}{M_{\mathrm{mes}}} \left(\frac{\Lambda}{M_{\mathrm{mes}}} \right)^5, \quad \frac{\Lambda}{M_{\mathrm{mes}}} < 1.$$

Λ: dynamical scale of the hidden gauge interaction.

Cf. In minimal gauge mediation, $m_{\mathrm{gaugino}} \simeq \dfrac{\alpha_{\mathrm{SM}}}{4\pi} \dfrac{\Lambda^2}{M_{\mathrm{mes}}}$.

2. Dependence on $M_d/M_\ell > 1$ (ratio of messenger masses).

$$(M_{\mathrm{mes}} \overline{\Phi}_{\mathrm{mes}} \Phi_{\mathrm{mes}} \text{ (at } m_{\mathrm{GUT}}) \xrightarrow{\text{RG-evolve}} M_d \overline{\Phi}_d \Phi_d + M_\ell \overline{\Phi}_\ell \Phi_\ell .)$$

Especially, **gluino becomes light**. $\swarrow$ $m_{\tilde{\lambda}_1} : m_{\tilde{\lambda}_2} : m_{\tilde{\lambda}_3} \simeq 1 : 2 : 6$

Breaking of GUT relation among gaugino masses.

2. Sparticle spectrum in SIGM models

Mass spectrum example : $\kappa_1 = \dfrac{M_d}{M_\ell}, \quad \kappa_2 = \dfrac{M_d}{\Lambda}.$

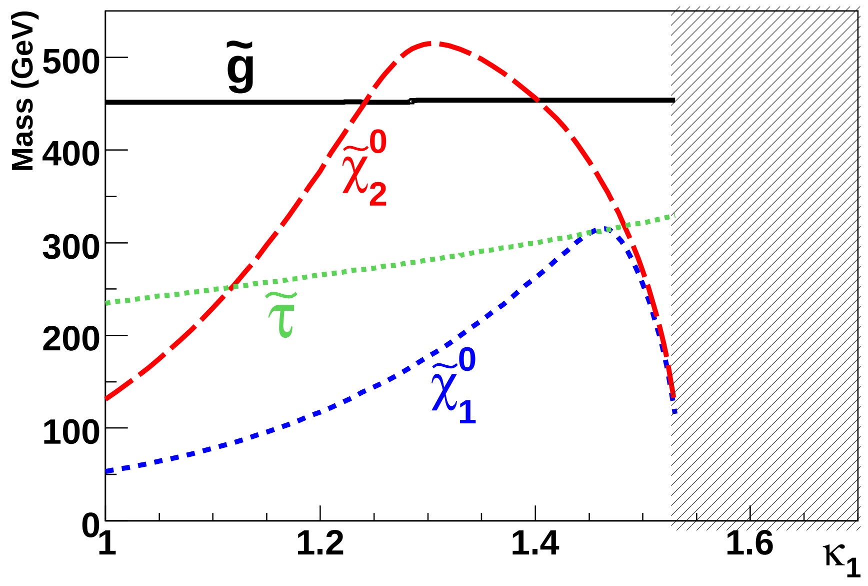

Fig. 1

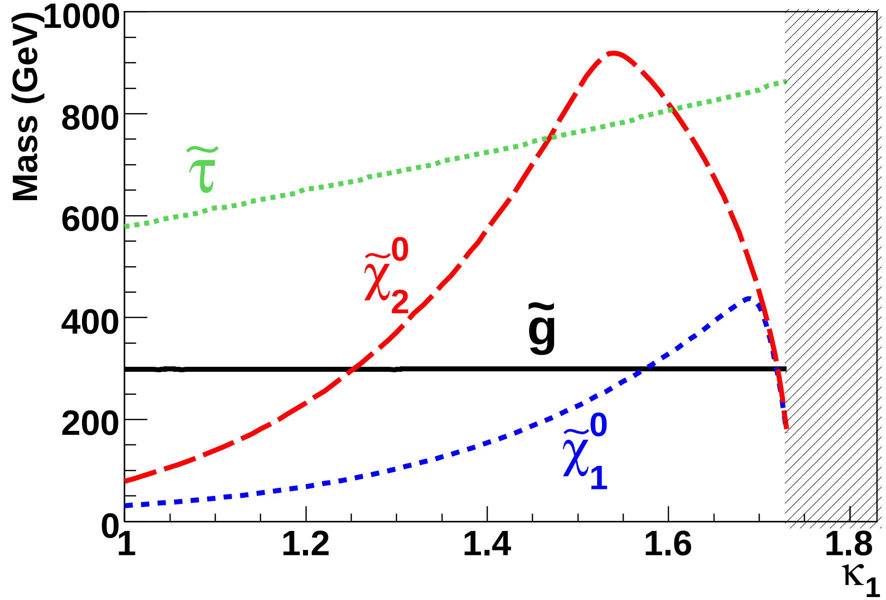

Fig. 2

Fig. 1: $\Lambda = 280$ TeV ($m_{\rm gravitino}$=1.5 eV), $\kappa_2 = 1.35$. $m_{\rm squark} \sim 1.5$ TeV.

Fig. 2: $\Lambda = 900$ TeV ($m_{\rm gravitino}$=16 eV), $\kappa_2 = 1.8$. $m_{\rm squark} \sim 3.5$ TeV.

3. LHC signature

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In SIGM models, the lightest SUSY particle (LSP) is the gravitino (nearly massless).

We consider,

1. Gluino NLSP case
2. Bino NLSP case

3. LHC signature

1. Gluino NLSP case

SUSY production at the LHC is mainly via $pp \to \tilde{g}\tilde{g}$.

Gluino decays into a gluon and a gravitino.

$\Rightarrow$ Signal: 2 jets + missing.

(Background events comes from QCD, $t\bar{t}$, W/Z, diboson etc.)

Discovery potential of the LHC:

$m(\text{gluino}) \lesssim 600$ GeV ($\sqrt{s} = 7$ TeV, 1 fb^{-1})

$m(\text{gluino}) \lesssim 1.2$ TeV ($\sqrt{s} = 14$ TeV, 1 fb^{-1}).

(Cuts for Etmiss, Meff, and jet Pt are optimaized)

3. LHC signature

2. Bino NLSP case

$pp \to \tilde{g}\tilde{g}$. (wino production is also possible)

Bino $\to \gamma/Z +$ gravitino.

Signal: (multiple jets) $+2\gamma+$ missing.

(After the cuts (next slide), SM bkg are negligible.)

Discovery potential of the LHC:

$m(\text{gluino}) \lesssim 900$ GeV ($\sqrt{s} = 7$ TeV, 1 fb^{-1})

$m(\text{gluino}) \lesssim 1.5$ TeV ($\sqrt{s} = 14$ TeV, 1 fb^{-1}).

3. LHC signature

2. Bino NLSP case

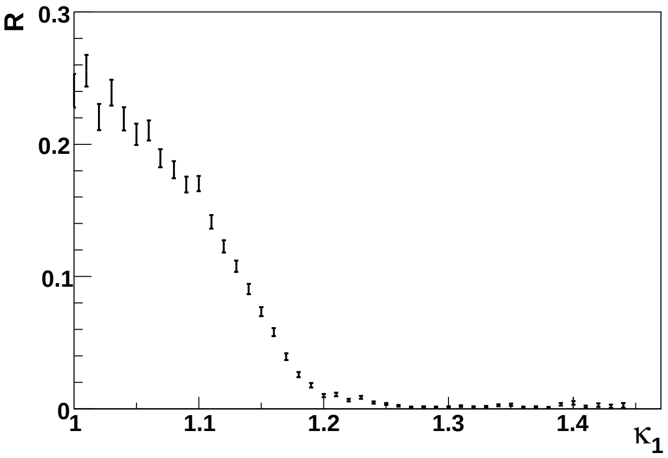
If $m(\text{wino}) > m(\text{gluino})$, no lepton comes from the decay chain

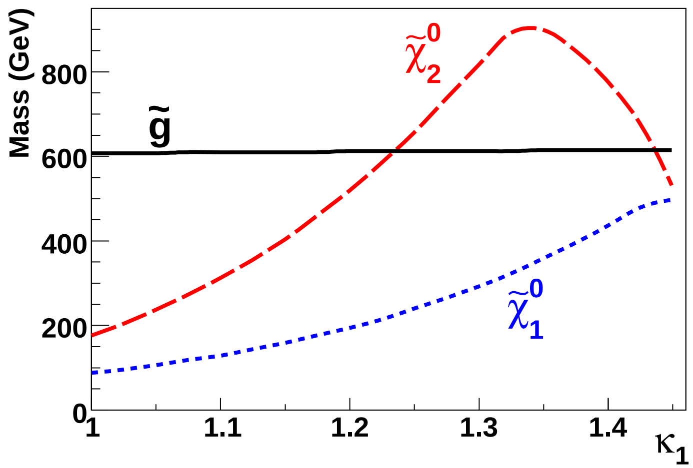
$$\tilde{g} \xrightarrow{q,\bar{q}} \widetilde{W} \xrightarrow{\ell} \tilde{\ell} \xrightarrow{\ell} \widetilde{B}.$$

$$R \equiv \frac{\#\text{ of events after the cuts with at least one lepton } (p_\mathrm{T} > 20 \text{ GeV})}{\#\text{ of all events after the cuts}}$$

Event cuts:

- ≥ 4 jets$(p_\mathrm{T} > 50 \text{ GeV})$ & $p_{\mathrm{T},1,2} > 100$ GeV,
- $\geq 2\gamma(p_\mathrm{T} > 10\text{GeV})$ & $p_{\mathrm{T},1} > 20\text{GeV}$,
- $M_\mathrm{eff} = \sum p_{\mathrm{T},j} + p_\mathrm{T}^\mathrm{miss} > 500$ GeV,
- $E_\mathrm{T}^\mathrm{miss} > 0.2 M_\mathrm{eff}$.





SIGM: Λ=720 TeV ($m_{\widetilde{G}}$=10 eV), $\kappa_2 = 1.5$, $\tan\beta = 10$.

minimal gauge mediation ($M = 160$ TeV, $F_S/M = 80$ TeV, $N_5 = 1$, $\tan\beta = 10$): R=0.4.

The discrimination between the SIGM ($m_{\widetilde{B}} < m_{\tilde{g}} < m_{\widetilde{W}}$) and the minimal gauge mediation may be possible.

Summary

- Sparticle mass spectrum of SIGM:

– $m_{\rm gaugino} \ll m_{\rm scalar}$

– Lighter gluino, breaking of the GUT relation among gaugino masses.

- SIGM at the LHC:

– Gluino-NLSP signal: 2 jets + missing

– Bino-NLSP signal: (multiple jets) $+2\gamma+$ missing

Discrimination between SIGM($m_{\widetilde{B}}<m_{\tilde{g}}<m_{\widetilde{W}}$) and minimal GMSB may be possible.