Testing the Anomaly-Mediation SUSY Model at the LHC

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Refs:

Ibe, Moroi and Yanagida, PL B644 (2007) 355

Asai, Moroi, Nishihara and Yanagida, arXiv:0705.3086 [hep-ph]

1. Introduction

What can we do with the LHC, if SUSY really exists?

$\Rightarrow$ Answer is model-dependent

$\Rightarrow$ We should consider various possibilities

I consider the following case:

$\Rightarrow$ Gaugino masses $\sim O(100\ \text{GeV})$

$\Rightarrow$ Scalar and Higgsino masses $\sim O(10\ \text{TeV})$

- Various problems in SUSY models can be solved
- Fine-tuning is necessary for viable EWSB

  $\Rightarrow$ Landscape, degenerate vacua, $\cdots$?

- LHC phenomenology is very non-trivial

Outline

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2. Model
3. LHC Phenomenology
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2. Model

Underlying model:

[Wells; Ibe, Moroi & Yanagida]

- There is no singlet field in the SUSY breaking sector

  $\Rightarrow$ Tree-level gaugino masses are suppressed
- No special Kähler potential is assumed

In this class of models:

- Scalar masses are from (tree-level) Kähler interaction
- Gaugino masses are mainly from Anomaly-mediation

  [Randall & Sundrum; Giudice, Luty, Murayama & Rattazzi]

Mass spectrum is like (mild) split-SUSY

[Arkani-Hamed & Dimopoulos]

$\Rightarrow$ Gaugino masses $\sim O(100$ GeV$)$

$\Rightarrow$ Gravitino mass $\sim O(10$ TeV$)$

$\Rightarrow$ Scalar and Higgsino masses $\sim O(10$ TeV$)$

Phenomenological implications:

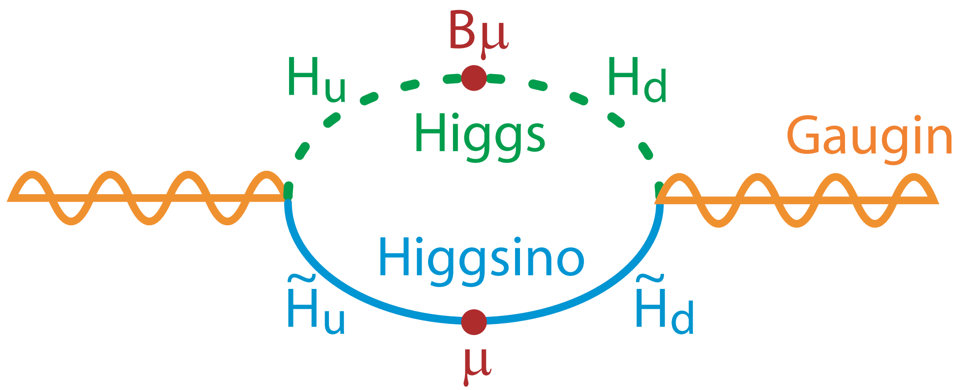
- Model is simple
- FCNC, CP, and proton-decay constraints are relaxed
- The LEP bound on the Higgs mass can be easily avoided
- Cosmological gravitino problem is relaxed
- Only the gauginos are accessible at the LHC

Gaugino masses have two sources

- Anomaly-mediation contribution

  [Randall & Sundrum; Giudice, Luty, Murayama & Rattazzi]

- Higgs-Higgsino loop contribution



μ and B are $O(m_{3/2})$ via Giudice-Masiero mechanism

$\Rightarrow$ Higgs-Higgsino loop contribution is of the same order of the AMSB contribution

Gaugino masses (at the sfermion mass scale):

[Giudice, Luty, Murayama & Rattazzi; Gherghetta, Giudice & Wells]

$$m_{\tilde{B}} \simeq \frac{g_1^2}{16\pi^2}\left|11 m_{3/2} + L\right| \qquad L \equiv \mu \sin 2\beta \frac{m_A^2}{|\mu|^2 - m_A^2} \ln \frac{|\mu|^2}{m_A^2}$$

$$m_{\tilde{W}} \simeq \frac{g_2^2}{16\pi^2}\left|m_{3/2} + L\right|$$

$$m_{\tilde{g}} \simeq \frac{g_3^2}{16\pi^2}\left|-3 m_{3/2}\right|$$

Gaugino masses depend on $|m_{3/2}|$, $|L|$ and Arg$(L/m_{3/2})$

$$\left|\frac{10 g_1^2}{3 g_3^2} m_{\tilde{g}} - \frac{g_1^2}{g_2^2} m_{\tilde{W}}\right| \lesssim m_{\tilde{B}} \lesssim \frac{10 g_1^2}{3 g_3^2} m_{\tilde{g}} + \frac{g_1^2}{g_2^2} m_{\tilde{W}}$$

Gaugino masses may deviate from pure-AMSB relation

$\Rightarrow$ Wino is the lightest gaugino as far as $|L| \lesssim 3|m_{3/2}|$

It is likely that the neutral Wino $\tilde{W}^0$ is the LSP

- $m_{\tilde{W}^\pm} - m_{\tilde{W}^0} \simeq 155 - 170$ MeV (by radiative correction)
- $\tilde{W}^\pm$ decays into $\tilde{W}^0$ and soft $\pi^\pm$
- Lifetime of $\tilde{W}^\pm$: $c\tau_{\tilde{W}^\pm \to \tilde{W}^0 \pi^\pm} \sim O(10 \text{ cm})$

What happens at the LHC?

- Can we find SUSY signals?
- What can we measure?

3. LHC Phenomenology

We choose: $|m_{3/2}| = 39$ TeV, $|L| = 28$ TeV, Arg$(L/m_{3/2}) = 0$

$\Rightarrow m_{\tilde{B}} = 400$ GeV, $m_{\tilde{W}} = 200$ GeV, $m_{\tilde{g}} = 1$ TeV

Dominant production process of gauginos: $pp \to \tilde{g}\tilde{g}$

For $m_{\tilde{g}} = 1$ TeV, $\sigma_{pp\to\tilde{g}\tilde{g}} \simeq 700$ fb

Once produced, gluino decays into lighter particles

- $\tilde{g} \to \tilde{W} q\bar{q}$
- $\tilde{g} \to \tilde{B} q\bar{q}$ (followed by the decay of $\tilde{B}$)

We have generated SUSY events (and backgrounds)

- Parton-Shower generator: JIMMY4.0/Herwig6.5
- MC simulation of the ATLAS detector: ATLFAST
- Background: ALPGEN2.05

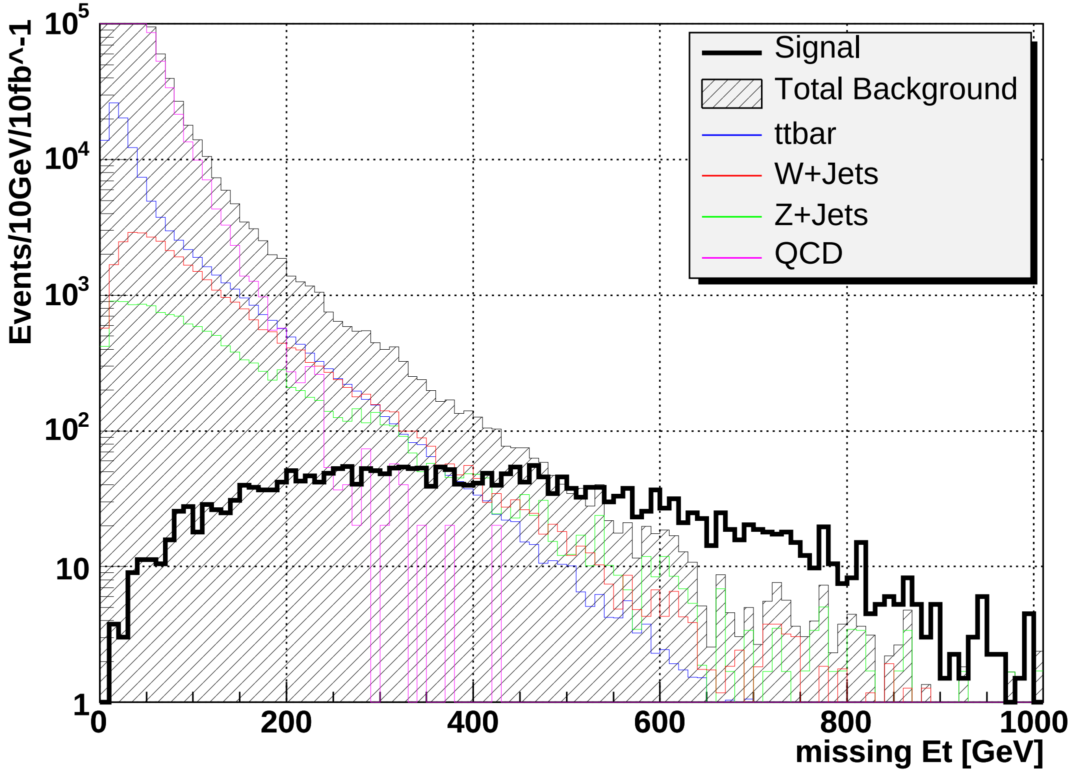
Event selections:

- (Number of jets with $E_T > 50\ \mathrm{GeV}) \geq 4$
- (Missing $E_T) \geq 300$ GeV
- $\cdots$

Then, various distributions are obtained (see the following)

Discovery of SUSY signal is easy with missing E_T events

Notice: $\tilde{W}^{\pm}$ also contributes to missing E_T

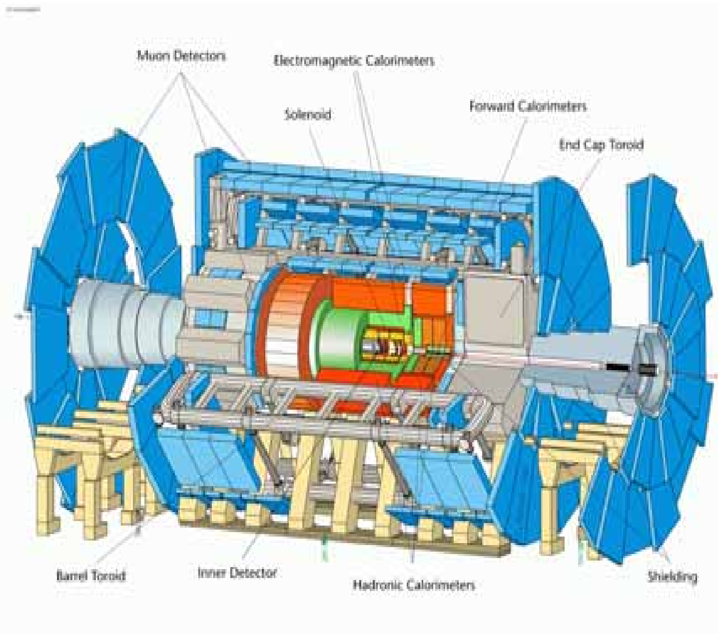


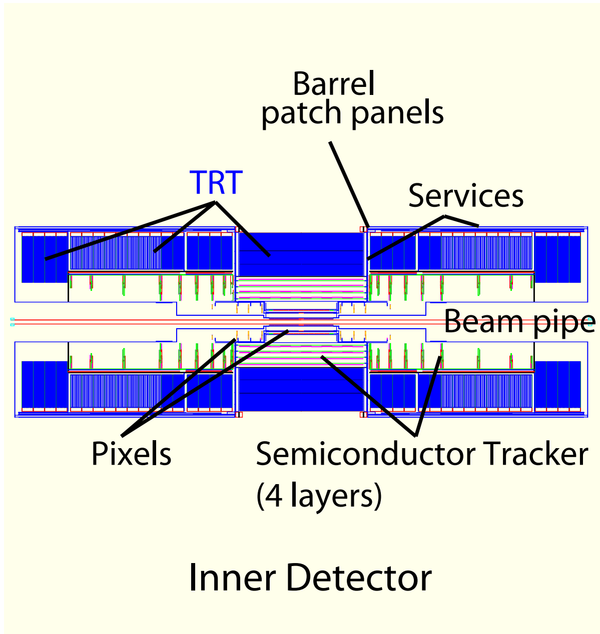
Discovery potential: $m_{\tilde{g}} \lesssim 1.2$ TeV (with $\mathcal{L} = 10$ fb^{-1})

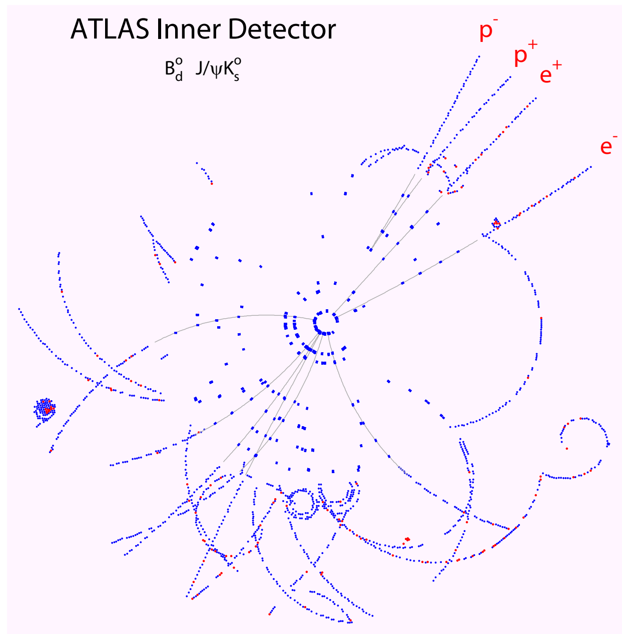
Can we find charged Wino even if $c\tau_{\tilde{W}^\pm} \sim O(10\ \mathrm{cm})$?

[For Tevatron, see Feng, Moroi, Randall, Strasslar & Su]

$\Rightarrow$ ATLAS has Transition Radiation Tracker (TRT)

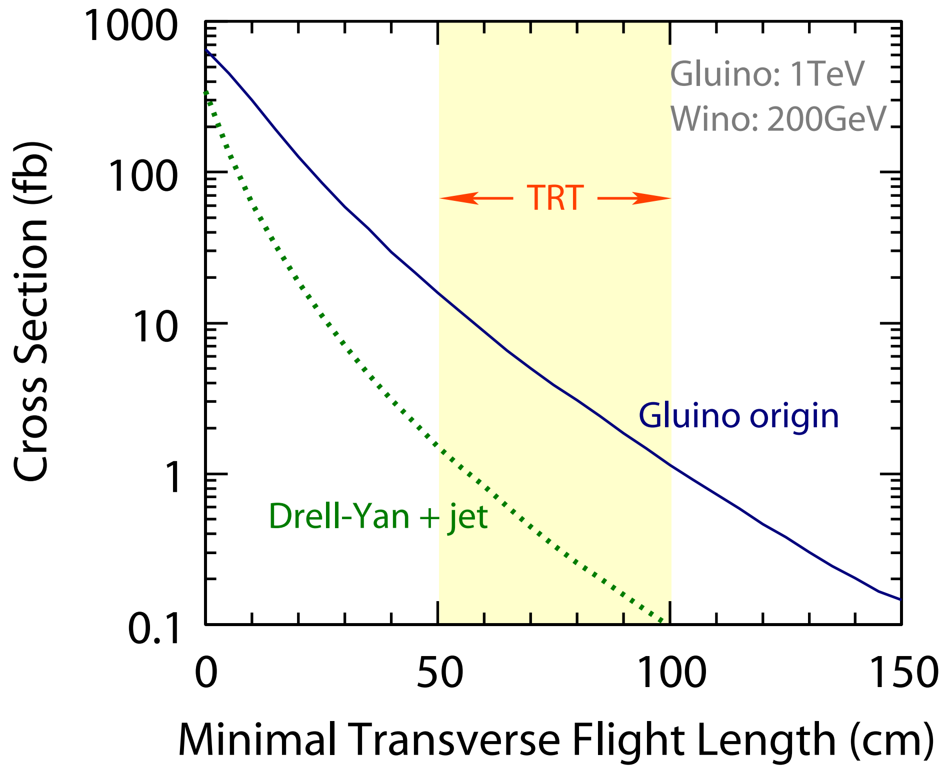






- TRT: 50 – 100 cm from the beam pipe
- TRT continuously follows charged tracks

Cross section to produce $\tilde{W}^{\pm}$-tracks with some length



$\Rightarrow$ Exotic short high p_T tracks may be seen in the data

TRT has timing information: $\delta\beta \sim 0.1$ for $\beta < 0.85$

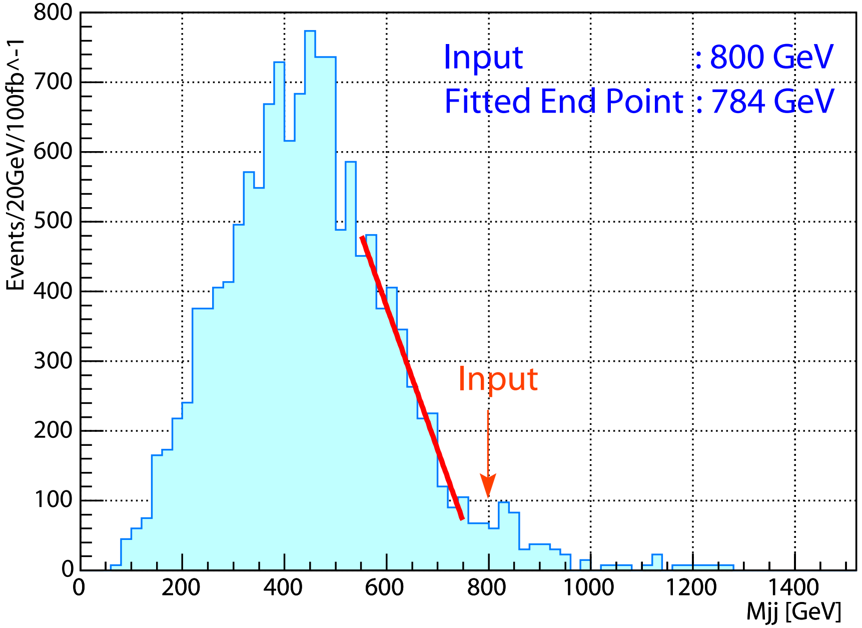
$\Rightarrow$ Wino mass may be determined: $\delta m_{\tilde{W}} \sim 10$ %

$m_{\tilde{g}} - m_{\tilde{W}}$ can be measured from dijet invariant mass

For $\tilde{g} \to \tilde{W} q\bar{q}$: $M_{q\bar{q}} \leq m_{\tilde{g}} - m_{\tilde{W}} \Leftarrow$ parton-level relation

Dijet invariant mass: $Br(\tilde{g} \to \tilde{W} q\bar{q}) = 0.75$

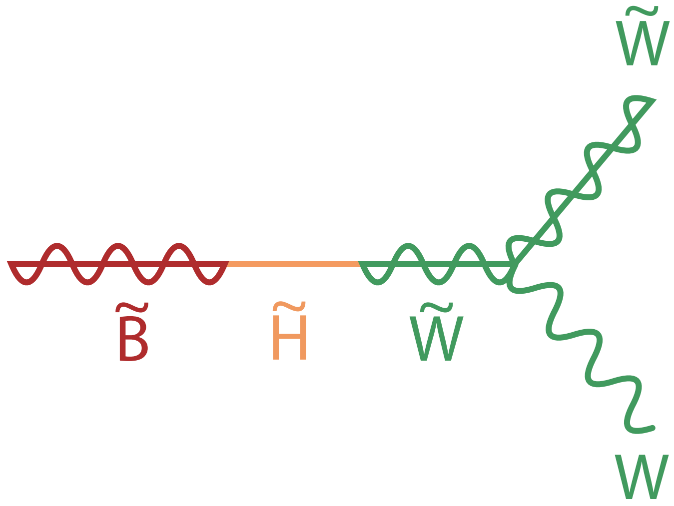
- Four leading jets (j_1, j_2, j_3, j_4) are used
- (M_{13}, M_{24}) or (M_{14}, M_{23}), whichever $|M_{ij} - M_{kl}|$ is smaller

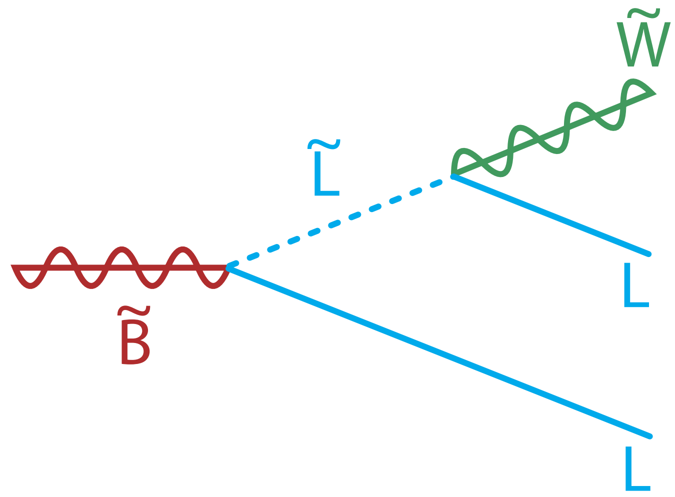


$\Rightarrow \delta(m_{\tilde{g}} - m_{\tilde{W}}) \simeq 5\ \%$

Information about Bino is hardly obtained

The dominant decay mode of $\tilde{B}$ is likely to be $\tilde{B} \to \tilde{W}^{\pm} W^{\mp}$



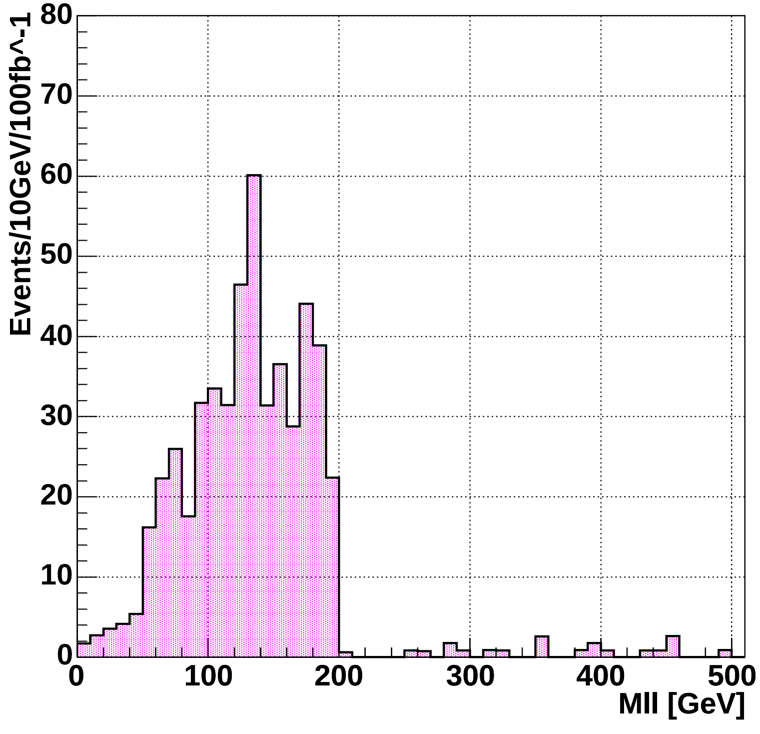


$Br(\tilde{B} \to \tilde{W} l \bar{l})$ may become sizable if $m_{\tilde{l}} \ll \mu$

$\Rightarrow m_{\tilde{B}} - m_{\tilde{W}}$ can be determined by using $M_{l^+ l^-}$

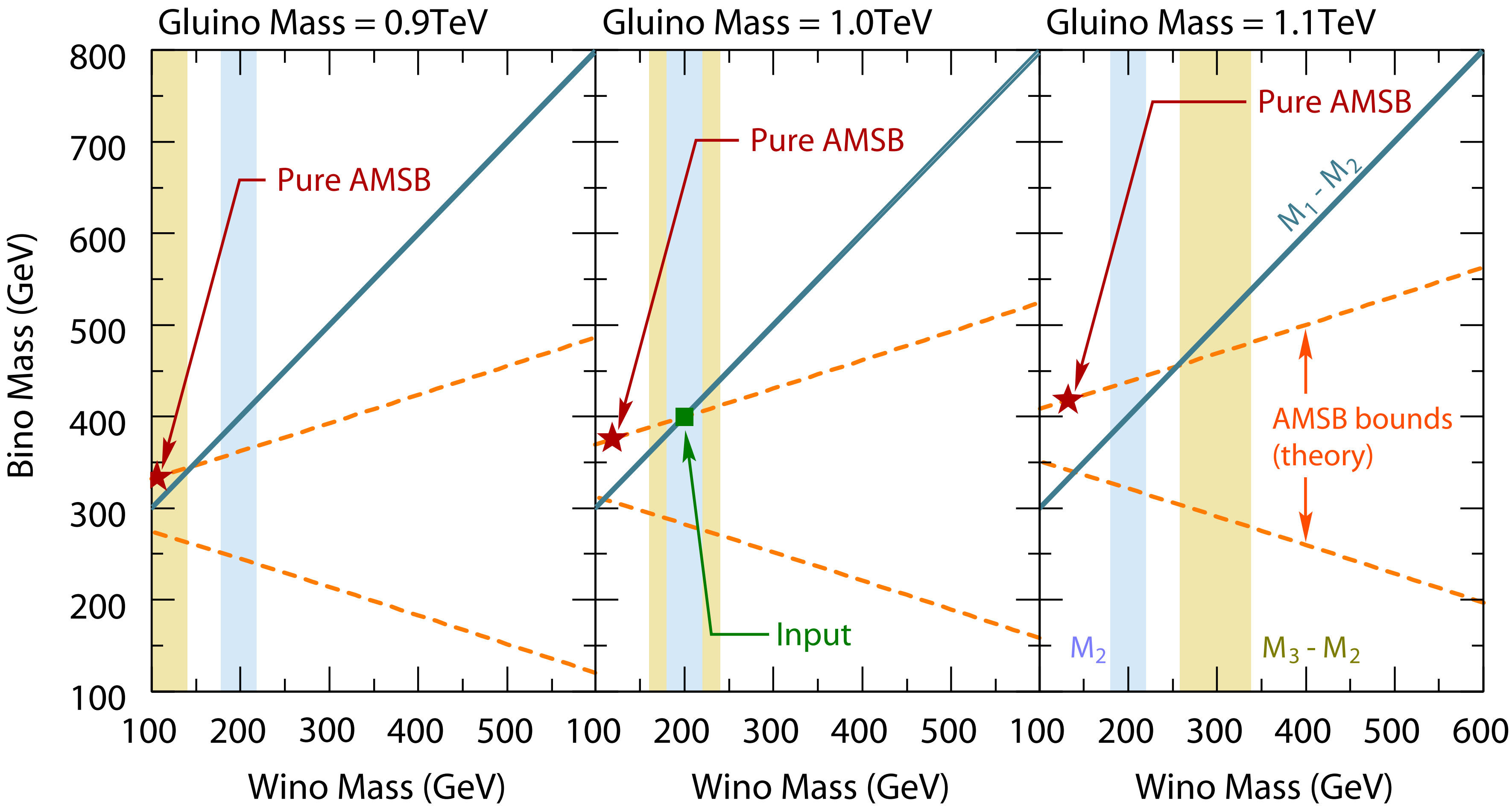
Same-flavor dilepton invariant mass: $Br(\tilde{B} \to \tilde{W} l \bar{l}) = 0.3$

- Flavor subtraction is applied to subtract $t\bar{t}$ background



$\Rightarrow \delta(m_{\tilde{B}} - m_{\tilde{W}}) \simeq 1\ \%$

Testing the model:



4. Summary

LHC is useful even if sfermions are extremely heavy

$\Rightarrow$ An excess of missing E_T events will be seen (but no signal of sfermions)

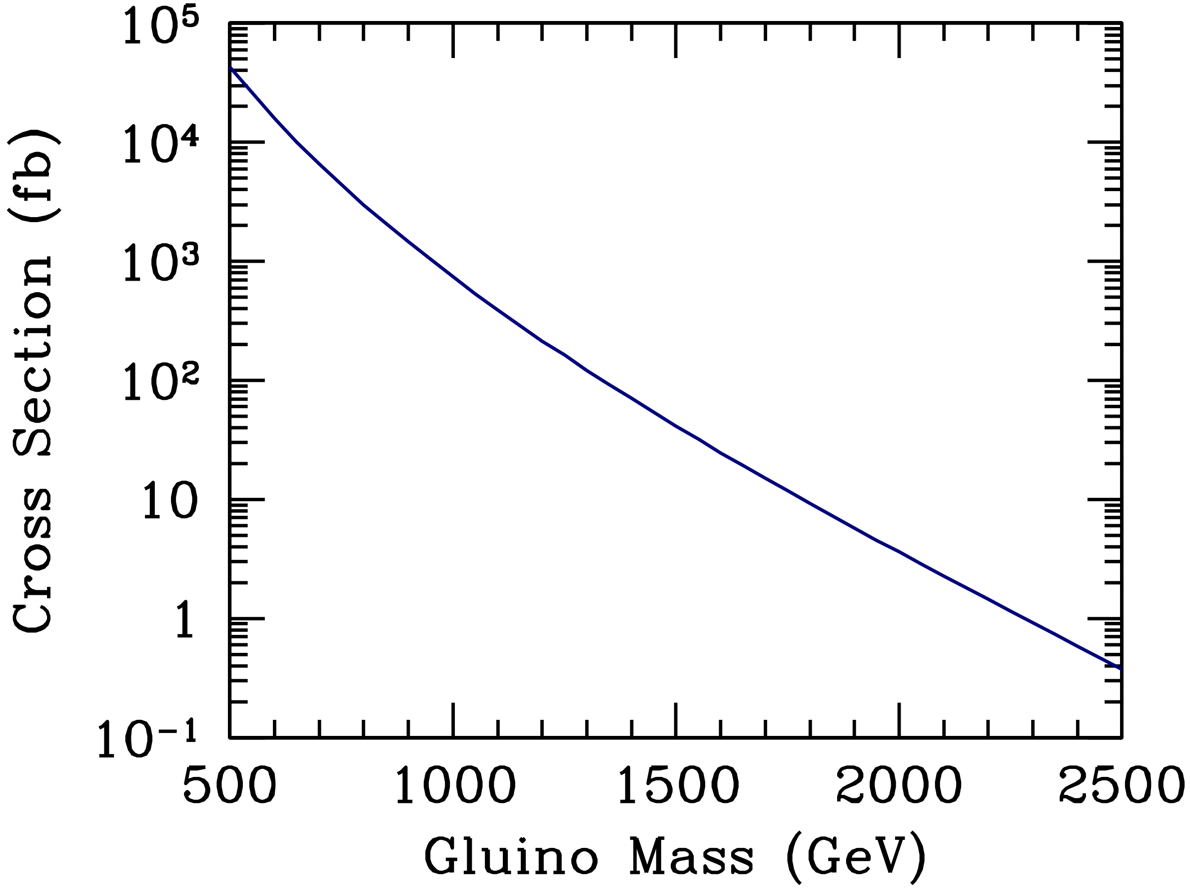
$\Rightarrow$ The search for the charged-Wino track is suggested

Gaugino masses may be constrained:

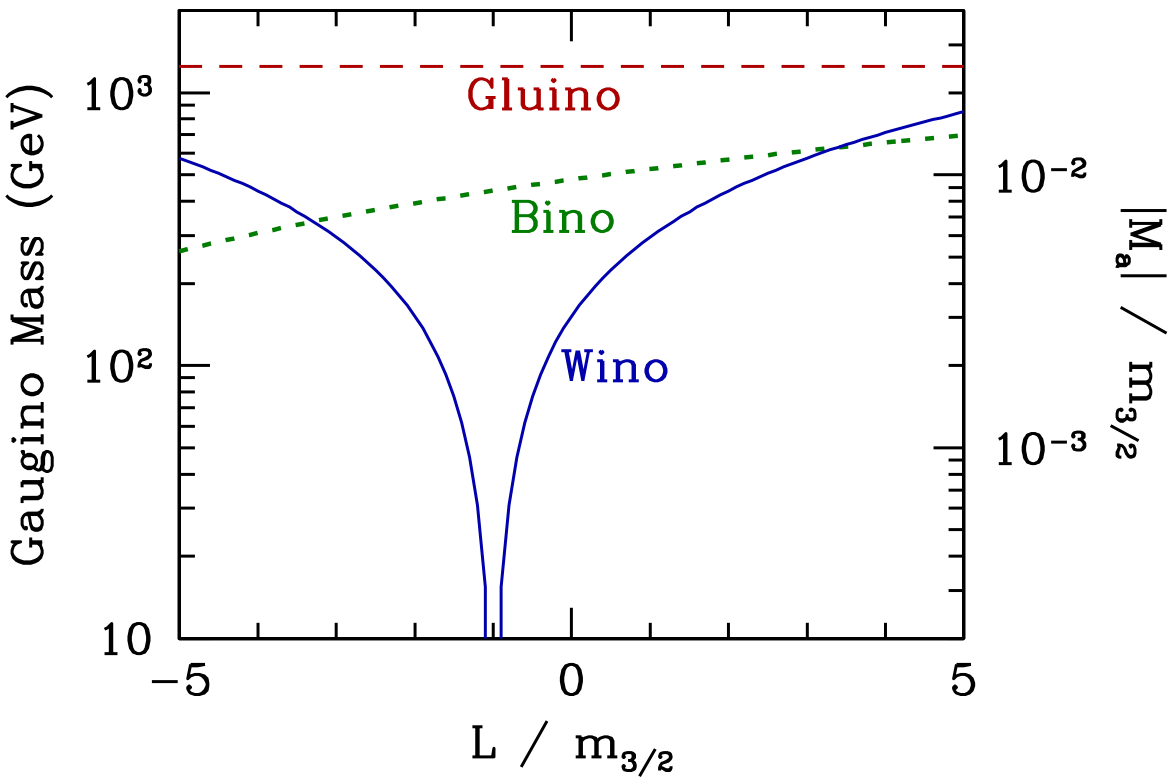
- $\delta(m_{\tilde{W}}) \simeq 10\ \% \Leftarrow$ from $\tilde{W}^{\pm}$-track
- $\delta(m_{\tilde{g}} - m_{\tilde{W}}) \simeq 5\ \% \Leftarrow$ from M_{jj}
- $\delta(m_{\tilde{B}} - m_{\tilde{W}}) \simeq 1\ \% \Leftarrow$ from $M_{l^+l^-}$, if we are lucky

Quantitative test of the anomaly-mediation mass relation may be possible

Gluino pair production cross section: $pp \to \tilde{g}\tilde{g}$



Gaugino masses for Arg$(L/m_{3/2}) = 0$



[Ibe, Moroi & Yanagida]