Testing the Supersymmetric Coupling Relations with Monojets at the LHC

Sebastian Grab

Santa Cruz Institute for Particle Physics
University of California, Santa Cruz

2010 Phenomenology Symposium
Madison, May 10-12, 2010

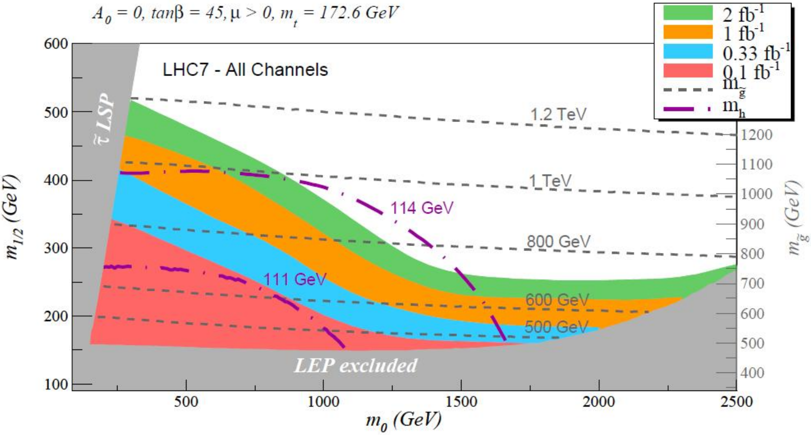
Alexander von Humboldt
Stiftung/Foundation

in collaboration with
B. Allanach and *H. Haber*

Outline

SUSY Discovery Potential with $\sqrt{S} = 7$ TeV.

[Baer, Barger, Lessa and Tata, arXiv:1004.3594 [hep-ph]]



⇒ Discovery of new physics might be around the corner!

How do we know that new physics is SUSY?

Test of Supersymmetric Coupling Relations

Supersymmetry predicts:

$$g_i(V_i f f') = \hat{g}_i(\tilde{V}_i f \tilde{f}')$$

Proposed analysis:

Linear Collider

- $\hat{g}(\tilde{W}\tilde{\nu}_e e)$ via $e^+e^- \longrightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-$ or $\tilde{\nu}_e\tilde{\nu}_e$.
  [Feng, Peskin, Murayama, Phys. Rev.D52, 1418, 1995],
  [Cheng, Feng, Polonsky, Phys. Rev.D57, 152, 1998],
  [Choi et al., Eur. Phys. J. C14, 535, 2000],
  [Nojiri, Pierce, Yamada, Phys. Rev.D57, 1539, 1998],
  [Freitas, Manteuffel, Zerwas, Eur. Phys. J. C40, 435, 2005]
- $\hat{g}(\tilde{B}\tilde{e}_R e)$ and $\hat{g}(\tilde{W}\tilde{e}_L e)$ via $e^+e^- \longrightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0$ or $\tilde{e}\tilde{e}$.
  [Choi et al., Eur. Phys. J. C22, 563, 2001],
  [Nojiri, Fujii, Tsukamoto, Phys. Rev.D54, 6756, 1996],
  [Freitas, Manteuffel, Zerwas, Eur. Phys. J. C34, 487, 2004],
  [Cheng et al., Phys. Rev.D57, 152, 1998], [Nojiri et al., Phys. Rev.D57, 1539, 1998]
- $\hat{g}(\tilde{g}\tilde{q}q)$ via $e^+e^- \longrightarrow \tilde{g}\tilde{q}q$.
  [Brandenburg et. al., Eur. Phys. J. C58, 291, 2008]

Test of Supersymmetric Coupling Relations

LHC

- $\hat{g}(\tilde{g}\tilde{q}_L q)$ via $PP \longrightarrow \tilde{q}_L\tilde{q}_L$.
  [Freitas, Skands, JHEP **0609**, 043, 2006],
  [Freitas, Skands, Spira, Zerwas, JHEP **0707**, 025, 2007]
- $\hat{g}(\tilde{W}\tilde{q}_L q)$ via $PP \longrightarrow \tilde{q}_L\tilde{q}_L^*$ with $\tilde{W}$ exchange in t- and u-channel.
  [Bornhauser, Drees, Dreiner, Kim, Phys. Rev.D80, 095007, 2009]

  $\longrightarrow$ see talk by *Sascha Bornhauser*.

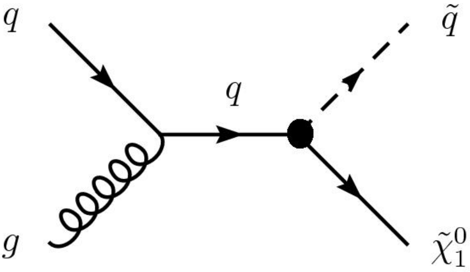
Another possibility for LHC:

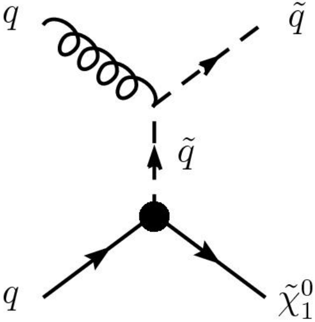
Monojets,
i.e. one hard jet + $\not{E}_T$.

$\Rightarrow$ allows test of $\hat{g}_1(\tilde{B}\tilde{q}_R q)$ and $\hat{g}_2(\tilde{W}\tilde{q}_L q)$.

Monojets in the MSSM

relevant Feynman diagrams:





with $\tilde{q} \rightarrow \tilde{\chi}_1^0 + q$.

main SM backgrounds

- $PP \rightarrow Z(\rightarrow \nu\nu)$+jet. Can be measured from $Z(\rightarrow \ell^+\ell^-)$+jet.
- $PP \rightarrow W(\rightarrow \ell\nu)$+jet.

Discovery Potential for Bino LSP Scenarios

Assume bino LSP scenario with
$m_{\tilde{\chi}_1^0} = 100$ GeV and $m_{\tilde{u}_R} = m_{\tilde{d}_R} = 500$ GeV (other sparticles decoupled).

cuts

- 2nd jet veto if $p_T|_{2nd\ jet} > 50$ GeV.
- Isolated lepton veto.
- $p_T|_{1st\ jet} > 200$ GeV and $\not{p}_T > 200$ GeV.

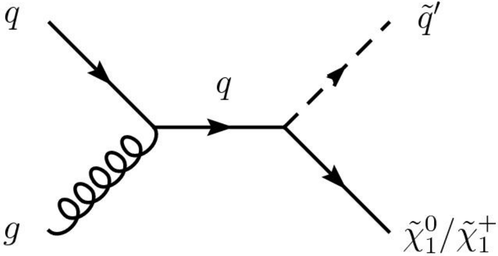
$$\Rightarrow \mathrm{S}/\sqrt{\mathrm{B}} = 5.2 \text{ for } 100\mathrm{fb}^{-1} \text{ at } \sqrt{S} = 14 \text{ TeV}.$$

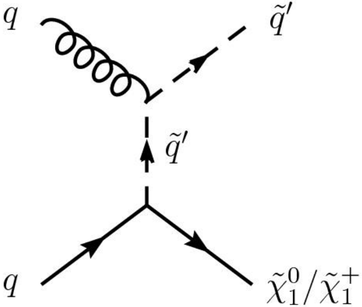
$\Rightarrow$ Monojets only visible in light bino LSP scenarios!
Reason: Small cross section.

Can we do better?

Monojets in Wino LSP Scenarios

relevant Feynman diagrams:





with $\tilde{q}' \rightarrow \tilde{\chi}_1^0/\tilde{\chi}_1^+ + q$ and $\tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0 + \pi^+$.

enhancement (compared to bino LSP) due to

- Larger gauge coupling: $\hat{g}_2(\tilde{W}\tilde{q}'_L q) \approx 2\hat{g}_1(\tilde{B}\tilde{q}_R q)$.
- More Processes: $ug \rightarrow \tilde{u}_L\tilde{\chi}_1^0$ and $ug \rightarrow \tilde{d}_L\tilde{\chi}_1^+$.

Discovery Potential for Wino LSP Scenarios

Assume light wino and light $\tilde{u}_L$ and $\tilde{d}_L$ and $100\mathrm{fb}^{-1}$ at $\sqrt{S} = 14$ TeV.

$m_{\tilde{u}_L/\tilde{d}_L}$	$m_{\tilde{\chi}_1^{0/+}}$	$p_T\|_{1st\ jet}$, $\not{p}_T$	$\sqrt{\mathrm{S}}/\mathrm{B}$
500 GeV	100 GeV	$>$ 210 GeV	39
500 GeV	300 GeV	$>$ 160 GeV	9.2
700 GeV	100 GeV	$>$ 330 GeV	16
700 GeV	300 GeV	$>$ 270 GeV	6.9
700 GeV	500 GeV	$>$ 160 GeV	1.4
900 GeV	100 GeV	$>$ 430 GeV	9.5
900 GeV	300 GeV	$>$ 380 GeV	4.8

$\Rightarrow$ Monojet signal visible for $m_{\tilde{q}_L}$ up to 1.2 TeV!

Reconstruction of the Coupling $\hat{g}_2(\tilde{W}\tilde{q}'_L q)$

Choose mAMSB scenario with
$M_0 = 200$ GeV, $M_{3/2} = 33$ TeV, $\tan\beta = 10$, and sgn(μ)=+1.

$$\Rightarrow m_{\tilde{q}_L} \approx 720 \text{ GeV and } m_{\tilde{\chi}_1^0} \approx m_{\tilde{\chi}_1^+} \approx 107 \text{ GeV}.$$

error	$\Delta\sigma/\sigma$	$\Delta\hat{g}/\hat{g}$
luminosity	3%	1.5%
PDF uncertainty	17%	8.5%
NNLO corrections	18%	9%
statistics	9%	4.5%
$\Delta\tilde{m} = 10$ GeV	8%	4%
SUSY background	10%	5%
	29.4%	14.7%

Remark: $\mathrm{S/B}|_{\mathrm{SUSY}} \approx 1$.
Main SUSY background: $PP \rightarrow \tilde{\chi}_1\tilde{\chi}_1 + jet$ (without $\tilde{q}$).
[Giudice, Han, Wang, Wang, arXiv:1004.4902[hep-ph]]

Summary and Outlook

Summary

- New physics consistent with SUSY might be discovered soon!
- How do we know, that it is SUSY?
  $\rightarrow$ Test of SUSY coupling relations.

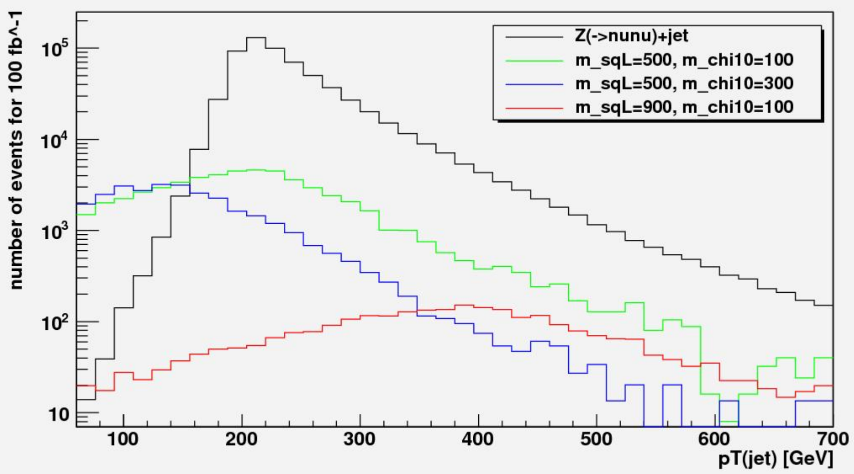
- Monojets can test $\tilde{\chi}_1^0$-$\tilde{q}$-q coupling.
- Only possible for very light bino LSP scenarios.
- Coupling can be tested at 10% level for wino LSP.

Outlook

- Investigate Wino LSP parameter space.
- Test of $\tilde{H}^+$-$\tilde{t}$-b coupling.
  [Bornhauser, Drees, SG, Kim, work in progress]

backup slides

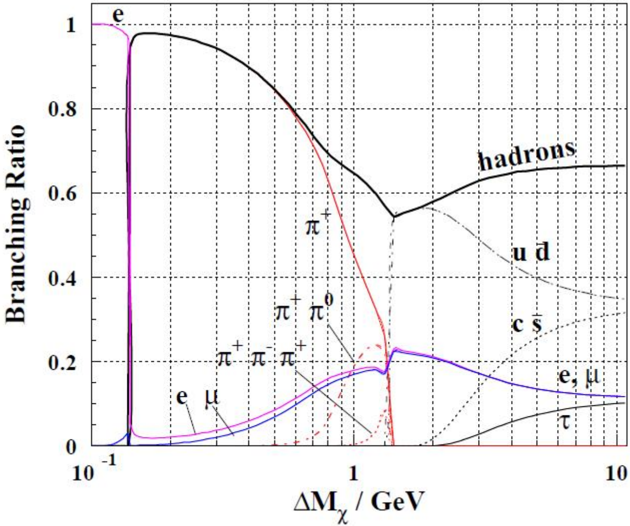
Monojet pT-Distributions for Wino LSP



Note: Parton level cut applied on $Z(\to \nu\nu)$+jet sample, *i.e.* $p_T|_{\text{parton}} > 100$ GeV.

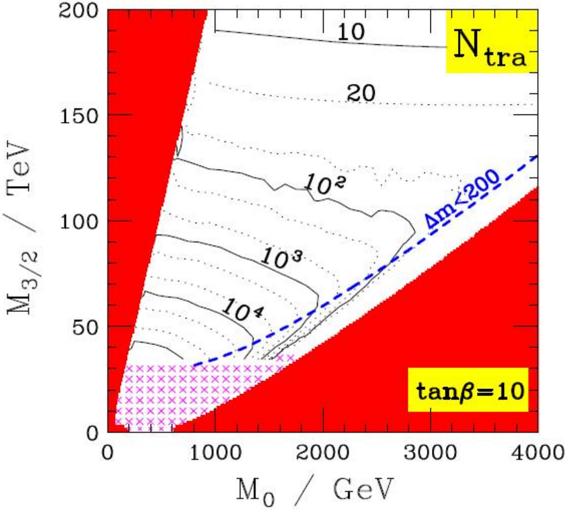
Wino Branching Ratios

[Barr et al., hep-ph/0208214]



Number of detached Vertices for $\tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0 + X$ for $100\,\mathrm{fb}^{-1}$

[Barr et al., hep-ph/0208214]



Discovery Reach for mAMSB for 100 fb^{-1}

[Barr et al., hep-ph/0208214]