String motivated SUSY at 100 TeV collider

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January 8, 2015

Epiphany 2015

KING'S College LONDON

Theory of everything?

- String/M theory is the only theory, known so far, capable of solving the biggest theoretical issues:
  - combining GR with QFT,
  - having UV completed theory,
  - providing dark matter candidates,
  - theory without free parameters.
- It does not have to, but might be true (like all theories...).
- We assume that M-theory compactified on G_2-holonomy manifold is true.

- What are generic predictions of that (knowing SM is the low energy limit)?

M-theory on G_2

Acharya et al. (2006, 2007)

Considering "low-energy", SUGRA limit of M-theory:

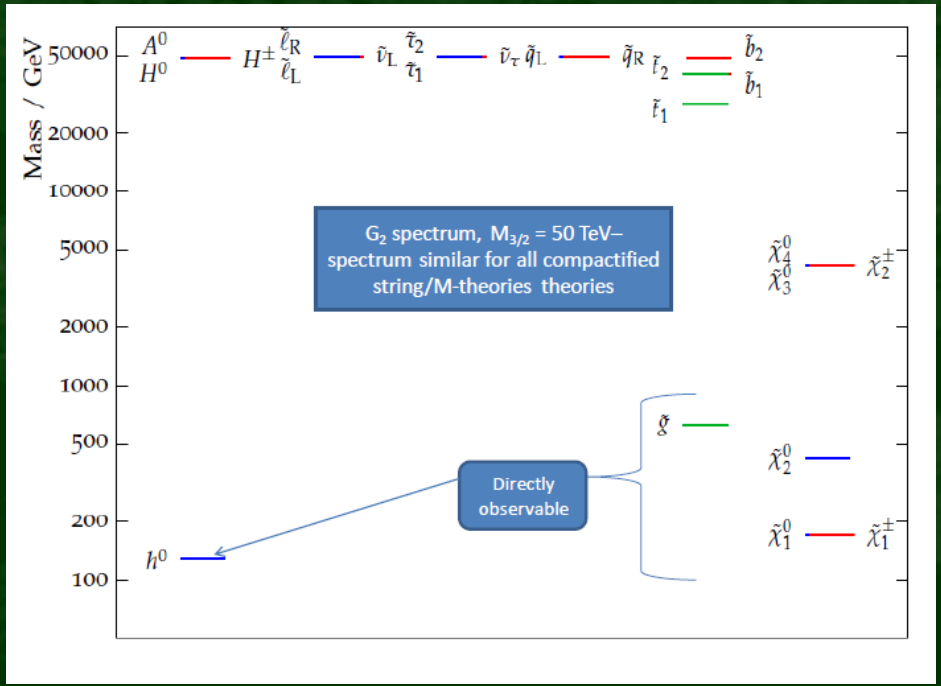
- Masses and couplings of an effective 4 dim. theory given by moduli,
- ~~SUSY~~ of two strongly coupled hidden sectors stabilises all moduli and solves hierarchy problem ($M_P/M_{SUSY} \gg 1$).
- mass of all scalars (except axions, protected by a shift symmetry) set by gravitino mass $m_{3/2}$,
- Gaugino masses are suppressed relative to $m_{3/2}$, by factor about 10.
- Given above, cosmological constrains predicts $30\ \mathrm{TeV} \lessapprox m_{3/2} \lessapprox 100\ \mathrm{TeV}$

M-theory on G_2

Acharya et al. (2006, 2007)

General predictions:

- Scalars are heavy (beyond the reach of the LHC, maybe even future colliders),
- Gauginos and higgsinos are the only light SUSY particles,
- Lightest neutralino, and/or axions can account for the correct DM relic abundance of the Universe.



Possible M-theory motivated SUSY spectrum. From G. Kane's talk, Madison 2011.

Model Building

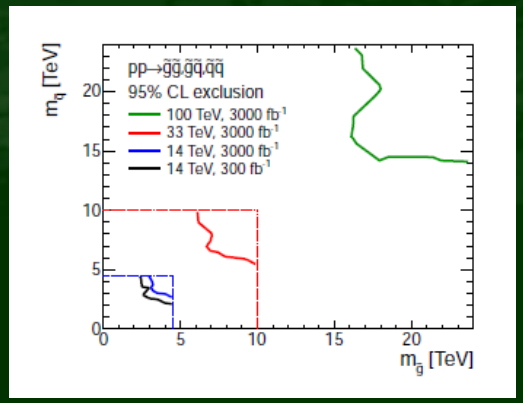
More specific predictions depend on model details (e.g. visible gauge gruop):

1. G_2-MSSM (Acharya et al. (2008)):
   - $SU(5)$ GUT group broken to SM using Witten's idea (Witten (2002)),
   - Witten's discrete symmetry provides the solution of the doublet–triplet problem,
   - low-energy spectrum (below compactification scale) is MSSM
   - LSP is mostly Wino, NLSP Bino
     $m_{\tilde{g}} > m_{\tilde{\chi}_2^0} > m_{\tilde{\chi}_1^\pm} > m_{\tilde{\chi}_1^0}$
   - R-parity conservation (Acharya, Kane, Kumar, Lu, Zheng (2014))

$SU(5)$		SM
5_H	$\rightarrow$	$H_u{}_{(H_u^+, H_u^0)} + D$
$\bar{5}_H$	$\rightarrow$	$H_d{}_{(H_d^0, H_d^-)} + \overline{D}$
10_M	$\rightarrow$	$e^C + u^C + Q_{(u,d)}$
5_M	$\rightarrow$	$L_{(\nu,e)} + d^C$

Collider phenomenology

- squarks beyond direct reach of LHC (and possibly future colliders) (Cohen et al. (2013))



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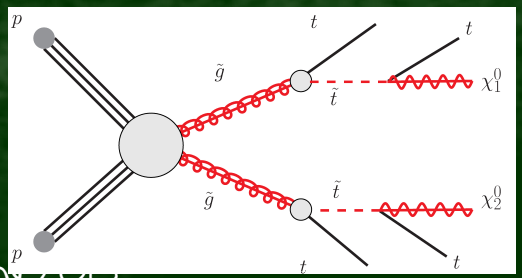
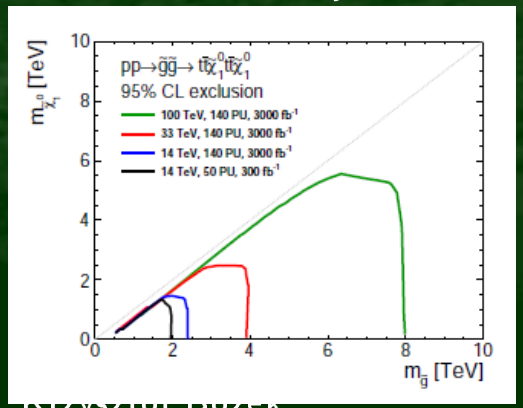
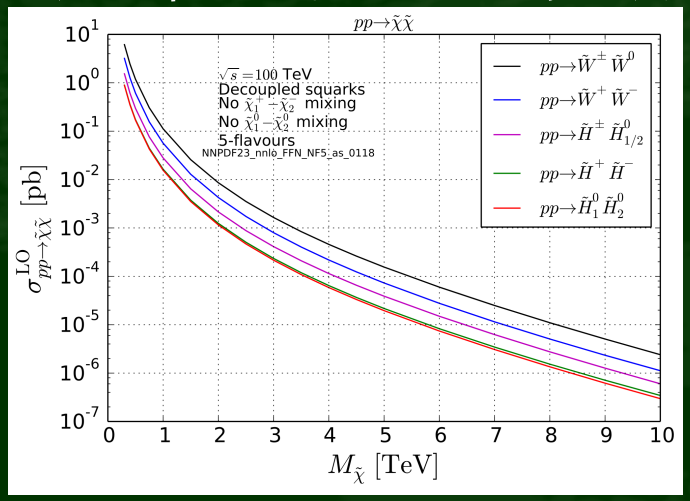
- digluino events can produce 4 tops events!

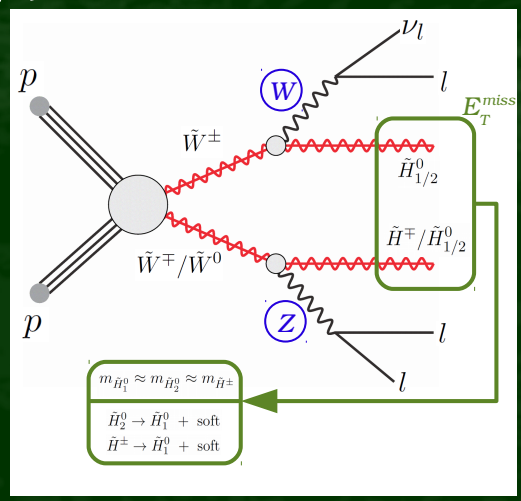




Collider phenono, part 2

- Electrowikinos should be light!





- Prospect of electrowikinos searches at 100 TeV,

  (Acharya, K.B, Pongkitivanichkul, Sakurai (2014))

  For simplicity:

  - Higgsino LSP, W-ino NLSP ($\mu < M_2 < M_1$),
  - All other SUSY particles decoupled,
  - $WZ \to 3l$ final state ($3l + E_T^{miss}$ signature),
  - Main SM background: WZ, ttZ, WWW.

Simulation Setup

Signal

SUSY-HIT – spectrum
↓
MadGraph 5 – generator level
↓
BRIDGE – decay
↓
Pythia 6 – hadronisation
↓
Delphes 3 – detector simulation

Background

- SNOWMASS background samples [1308.1636],
- Prepared and validated by SNOWMASS community,
- Should be rubust up to $\mathcal{L} = 3ab^{-1}$,
- Detector level sample.

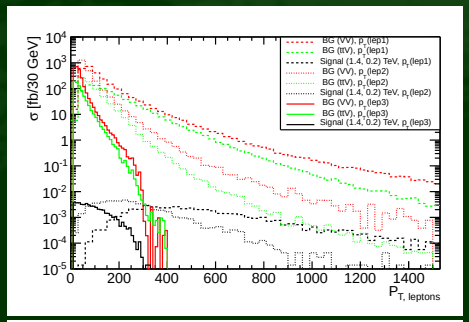
same detector card

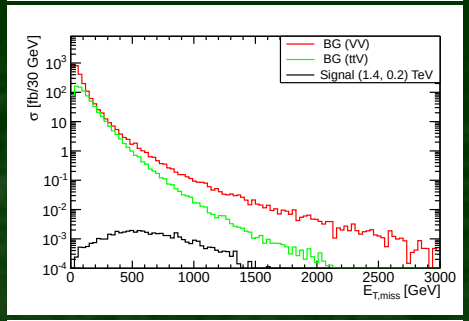
Preselection Cuts

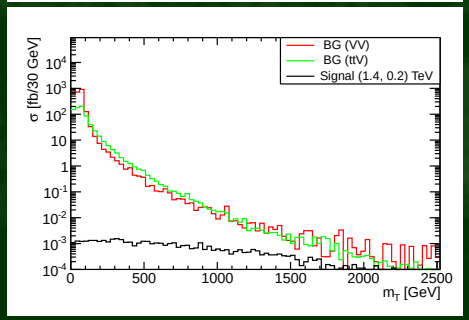
- $= 3l$ with $p_T > 10$ GeV & $|\eta| < 2.5$
- same-flavour opposite-sign (SFOS) lepton pair with: $|m_{ll}^{\mathrm{SFOS}} - m_Z| < 10$ GeV
- no b-tagged jet,

Signal Regions

Signal Region	3 lepton p_T [GeV]	E_T^{miss} [GeV]	m_T [GeV]
Loose	$> 100, 50, 10$	> 150	> 150
Medium	$> 250, 150, 50$	> 350	> 300
Tight	$> 400, 200, 75$	> 800	> 1100



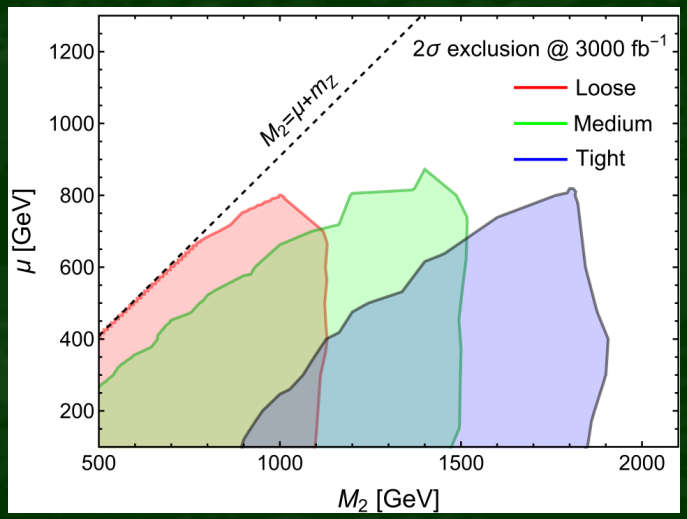


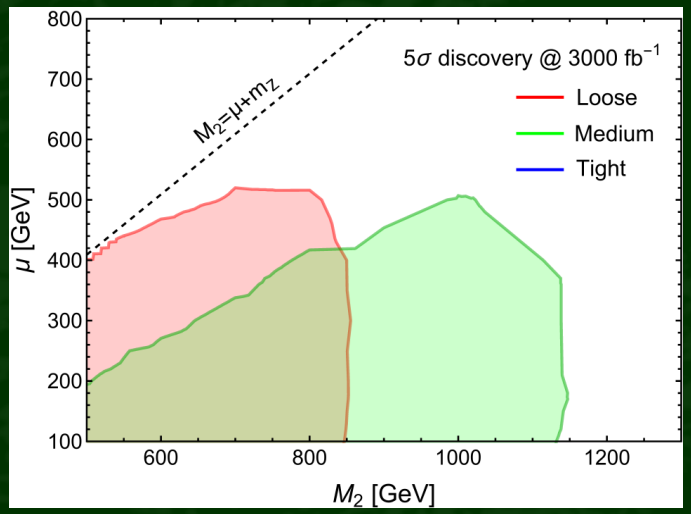


where transverse mass m_T is define as:

$$m_T = \sqrt{2\ |p_T(l')||E_T^{miss}|(1 - \cos\Delta\phi)}$$

- Results:

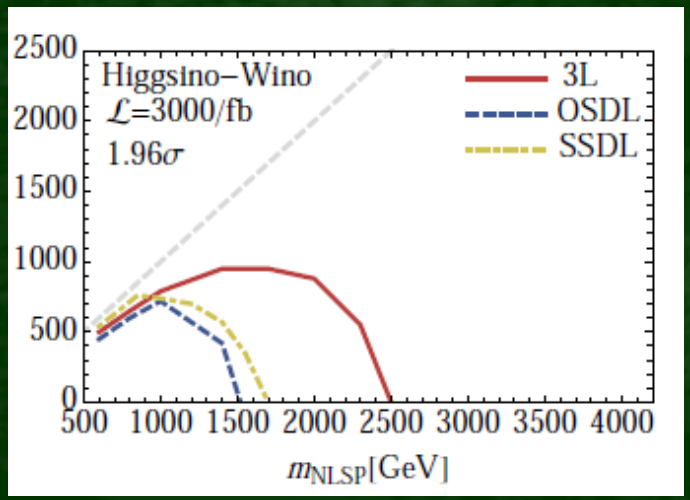


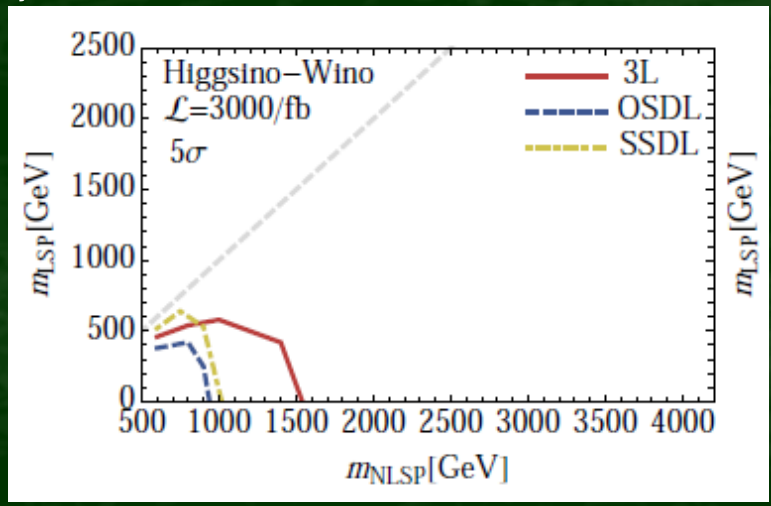


The exclusion limits (**left**) and the discovery reaches (**right**) obtained from three signal regions.

The integrated luminosity of 3000 fb^{-1} is assumed.

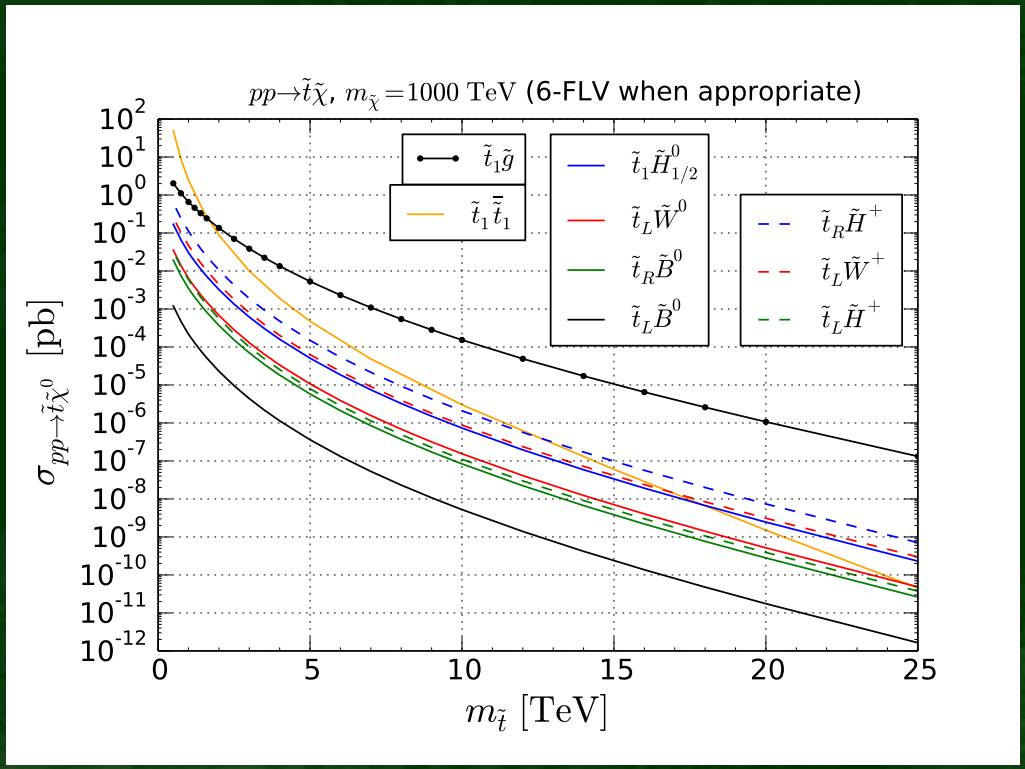
- Limits from other group: (Gori, Jung, Wang, Wells (2014))





Outlook

- Production channel $pp \to \tilde{t}\tilde{\chi}$ looks promising:



- At high enough mass, xsec comparable with the $pp \to \tilde{t}\tilde{t}$ xsec.
- Clear signal (monotop + $E_{T,miss}$)

Outlook, Model Building

- SO(10) GUT model from M-theory

  Acharya, KB, King, Pongkitivanichkul, Romao (to appear soon)
- G_2-MSSM has tiny parameter space left,
- Avoiding proton decay, we need to introduce new irreps,
- new DM candidates, and new discovery channels!