Brief Update on Ttbar without MET

\[ L = 100 \text{ pb}^{-1} \]

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With MET cut

No MET Cut

The MET cut of 20 GeV doesn’t seem to make all that much difference.
We should be able to obtain a top rich sample without which we can then look at to commission The MET observable.

Preliminary!
The G2-MSSM at the LHC

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Abdus Salam ICTP and INFN Trieste

Based Upon

• Work done with the MCTP, Ann Arbor
  • K. Bobkov, P. Grajek, G. Kane, P. Kumar, J. Shao

• Two earlier foundational papers:
  • “M Theory Solution to the Hierarchy Problem”, PRL 97, 191601, 2006
  • “Explaining the Electroweak Scale and Stabilising Moduli in M theory” hep-th/0701034

• Mostly taken from
  • “The G2-MSSM”, arXiv 0801.0478
  • “The G2-MSSM at the LHC”, to appear
Outline of Talk

• Introducing the “G2-MSSM” – a supersymmetric particle physics model essentially derived from M theory.

• Mass Spectrum of the G2-MSSM

• The G2-MSSM at the LHC – unique and reasonably identifiable set of signatures

• Compare ATLAS and CMS detection of the G2-MSSM
Introducing the G2-MSSM

- In the two earlier papers we explained how to stabilise all moduli whilst generating the hierarchy between $M_W$ and $M_{pl}$, preserving Grand Unification
- M theory vacua without FLUX.
- G2-manifold - xtra dimensions + SUSY
- Strong Dynamics both generates a small scale and a potential for all moduli
- Unique de Sitter vacuum

- Can calculate most of the spectrum BSM
\[ W^{np} = A_1 e^{ib_1 f_1} + A_2 e^{ib_2 f_2} . \quad f_k = \sum_{i=1}^{N} N^k i z_i = \frac{\theta_k}{2\pi} + i \frac{4\pi}{g_k^2} \]

\[ K = -3 \ln(4\pi^{1/3} V_X) , \quad (1) \]

where the volume of the $G_2$ holonomy manifold as a function of the $N$ scalar moduli $s_i$ is (in 11d units)

\[ V_X = \prod_{i=1}^{N} s_i^a , \quad \text{with} \quad \sum_{i=1}^{N} a_i = 7/3 . \quad (2) \]

\[ V = \frac{1}{48\pi V_X^2} \left[ \sum_{k=1}^{2} \sum_{i=1}^{N} a_i v_i^k (v_i^k b_k + 3) b_k A_k^2 e^{-2b_k v^k \cdot \vec{a}} + 3 \sum_{k=1}^{2} A_k^2 e^{-2b_k v^k \cdot \vec{a}} \right. \]

\[ \left. -2 \sum_{i=1}^{N} a_i \prod_{k=1}^{2} v_i^k b_k A_k e^{-b_k v^k \cdot \vec{a}} - 3 \left( 2 + \sum_{k=1}^{2} b_k v^k \cdot \vec{a} \right) \prod_{j=1}^{2} A_j e^{-b_j v^j \cdot \vec{a}} \right] \]
\[
(m_{3/2})^{(1,2)}_0 = m_p 2^{1/2} \pi^3 \left(7 + \sqrt{17}\right)^{7/4} (N_1 N_2)^{7/4} A_2 P \left| \frac{P - Q}{P Q} \right| \left( \frac{A_2 P}{A_1 Q} \right)^{-\frac{p}{P - Q}} \left( \frac{P Q}{P \ln A_2 \frac{P}{A_1 \frac{Q}{P}} \right)^{-\frac{7}{2}}
\]

\[
\sim m_p 2.97 \times 10^3 (N_1 N_2)^{7/4} A_2 P \left| \frac{P - Q}{P Q} \right| \left( \frac{A_2 P}{A_1 Q} \right)^{-\frac{p}{P - Q}} \left( \frac{P Q}{P \ln A_2 \frac{P}{A_1 \frac{Q}{P}} \right)^{-\frac{7}{2}}
\]

(162)

\[
M_{1/2} \approx -\frac{e^{-i\gamma w}}{P \ln \left( \frac{A_1 Q}{A_2 P} \right)} \left( 1 + \frac{2}{\phi_0^2 (Q - P)} + \frac{7}{\phi_0^2 \ln \left( \frac{A_1 Q}{A_2 P} \right)} \right) \times m_{3/2},
\]

\[
M_{1/2} \approx -\frac{e^{-i\gamma w}}{84} \left( 1 + \frac{2}{3\phi_0^2} + \frac{7}{84\phi_0^2} \right) \times m_{3/2}
\]

\[
\approx -e^{-i\gamma w} 0.024 \times m_{3/2}.
\]
Introducing the G2-MSSM

• The Spectrum is determined by the particular G2 manifold, X.
  • Many qualitative features don’t depend on detailed properties of X:
• Heavy Squarks/Sleptons, Light Gauginos.
• Particular X’s give values for “microscopic” constants
  • (eg rank of gauge groups, and other integers) which determine the detailed spectrum.
• These constants can be varied within reason:
  • Unification + the SUGRA approximation. Typical.
• This defines the G2-MSSM
G2-MSSM Spectrum

- **At GUT scale:**
  - universal scalar masses - large eg 50 TeV
  - unified tree level gaugino masses - small eg 300 GeV
  - Large Higgsino mass eg 50 TeV
  - one loop gaugino masses partly cancel against suppressed tree contribution (unlike AMSB)

- **At the TeV scale:**
  - Right Handed Top Squark is the lightest Squark (several TeV)
  - Significant threshold corrections to Wino and Bino masses from the large Higgsino mass

- **LSP and Dark Matter:**
  - LSP usually Wino, but can also be Bino
  - For the Wino, non-thermal production dominates.
Comments on EWSB

• Although a hierarchy is both generated and stabilised, the usual “Little Hierarchy Problem remains”
  – We don’t solve this problem
  – Just assume that the microscopic constants (ie the G2 Manifold) are such that both
    • Radiative EWSB occurs and
    • $M_Z$ is 91.1876 GeV ± 0.0021 GeV
  
  – Just applying Giudice-Masiero without this additional fine tuning would give $M_Z = O$(few TeV).

• TanBeta turns out to be order ONE.
Spectrum at the LHC

Microscopic Constants

Light Gluino, Neutralinos
Charginos, Higgs

Stop Right Lightest Squark

Heavy Squarks/Sleptons

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G2-MSSM at the LHC

• X-sections

• Event topologies

• Discovery strategy
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**TABLE II:** Production Cross Section for $\tilde{C}_1\tilde{N}_1$, $\tilde{C}_1\tilde{C}_1$, and $\tilde{g}\tilde{g}$ pair production (units are in pb)
• Gluino Pair Production:
• 6 W’s + 4 b-jets!!
• Should be many ways to find these events!!
The Meta-Stable Chargino

- The Lightest Chargino and $N_1$ (lightest neutralino) have the same mass at tree level (they are both W-ino’s and there’s little mixing).

- Their masses get small 1-loop corrections and the mass difference is between one and two PION masses. (Similar to some AMSB models, but the combined set of signatures different).

- The Chargino decays into $N_1$ and a “W”
- The “W” decays either into a soft PION or lepton

- The Chargino decays inside the detector (few cm’s)
IN C.M.S.

Select:
- Muon
- Electron
- Neutral Hadron
- Charged Hadron
- Photon

Short track stubs.
With only these partons the C-N and C-C events will not Trigger.

The Big Question is: Are some events with short track Stubs Triggered on???
CMS has pixels at 4, 7, 10 cm. Next layer at 20 cm.
Discovery and Triggers

- **Gluino pair production:**
  - Many hard jets and missing Energy. Trigger often.
  - Order $10^4$ events at $L = 10$ fb$^{-1}$. (few per hour if this is one LHC year)
  - Many b-jets and W-bosons originating from tops.

- **Chargino Production channels:**
  - More events ($10^5$ at 10fb$^{-1}$), but do they trigger?
  - Naively difficult since there are no quarks/leptons/photons in the main process
  - Since the main signature is the short Track Stub, the events have to be triggered and searched for later, "offline".
  - **We find that often there is initial state radiation which produces a jet with a PT > 35 GeV. This really helps for Triggering.**
Comparing CMS/ATLAS

- **CMS Triggering Charginos:**
  - With current low L ($10^{32}$) triggers, CMS has a pure Missing ET trigger of 65 GeV, which triggers these events more than 10% of the time :))
  - However, this is only for the first 100 pb-1 or so and there will be a few hundred events.
  - Latest Trigger menus (after September 07) ?
  - At Higher L ($10^{33}$) this moves to 91 GeV and very few events will pass this :((
  - The ID has layers at 4cm, 7cm, 10cm and 20cm
  - The “C” in CMS is a very good thing for these phenomena!
Comparing CMS/ATLAS

- **ATLAS Triggering Charginos:**
  - Low L \((10^{32})\) trigger menu has a jet45GeV+MET50GeV trigger which keeps > 10% of evts :))
  - ATLAS ID has pixel layers at 5cm, 9cm and 12cm with the first SCT layer at 30cm
  - In ATLAS the **only** information about the direct Chargino production will be from the pixel detector, unlike CMS, which will sometimes have more than three hits.

- **Overall, both CMS and ATLAS have plus and minus points.**
  - Clearly needs more serious Detector sim. Study.
  - Underway (in both CMS and ATLAS).
Conclusions

• The G2-MSSM is a well motivated phenomenological model
• It has a very distinctive set of signatures
• If we discover evidence for events with many tops, W’s, b-jets we should also start looking for short track stubs in monojet + EtMiss events
• Though non-trivial, it seems possible and challenging to find these in the CMS and ATLAS detectors