Post-LHC RPV SUSY

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(University of Maryland)

- ArXiv:1301.3637 with R. Mohapatra
- ArXiv:1212.3622 with R. Torre
125 GeV Boson Discovery and SUSY

\[ m_h = 125 \text{ GeV} \gg m_Z \]

Possible in the MSSM
But requires large soft masses

\[ \text{Lightest Stop Mass} \]

\[ m_{\tilde{t}} \quad [\text{GeV}] \]

\[ m_{\tilde{t}} \]

\[ X_t/m_{\tilde{t}} \]

From 1112.2703

\[ \rightarrow \text{Non-Minimal Models} \]
Can't decide? Order a Particle Pack!

He's the one everyone wants to meet, and with recent events, it looks like we finally get to meet him. Higgs Boson is also part of the Boson 5-Pack.

Approximately 14 oz/388 grams; 5.5 inches/15 cm across. For ages 5 and up as it contains small parts.

Higgs Boson

The Higgs Boson is the theoretical particle of the Higgs mechanism, which physicists believe will reveal how all matter in the universe gets its mass. Many scientists hope that the Large Hadron Collider in Geneva, Switzerland, which collides particles at 99.99% the speed of light, will detect the elusive Higgs Boson.

$10.49 Lux

Wool felt, fleece with gravel fill for maximum mass.
The PARTICLE ZOO
Subatomic Particle Plush Toys FROM THE STANDARD MODEL OF PHYSICS & beyond!

Can't decide? Order a Particle Pack!

Add to Cart

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$14.99

X 20,000 $ EACH
IF YOU WANT SUPERSYMMETRIC PARTNER (SUSY) PARTICLES...

I was going to offer particle plushies which were larger and heavier than the regular squishies to include the as-yet-unobserved supersymmetric partners: the wino, zino, photino, Higgsino, selectron, stop quark and so on. However, these would be prohibitively expensive to ship overseas and given the small amount of requests, I decided to do the following:

If you would like any or all of the SUSY particles, I will make them the same size as the regular particles, but fill them with gravel to represent their enormous mass. This means the heavier particles like the Higgs, top quark, etc., would be identical except for the tag. If you wanted to use the plushies to demonstrate the difference in mass between SUSY particles and the standard model particles, I would suggest ordering the "Universe-in-a-Box" to represent standard particles. They are 1/3 size and so the "regular" particles will be large next to them. Please email me at particle @ particlezoo.net if you would like to order any SUSY particles.
NO SIGNAL FROM SUPERPARTNERS

SEARCHES IN FINAL STATES jets + leptons + photons + m_{E_T}

MISSING TRANSVERSE ENERGY IS ASSUMED FROM THE

PRODUCTION OF INVISIBLE \( \chi^0 \)

\[ q \rightarrow q' + \chi^0 \]
\[ \tilde{g} \rightarrow \chi^0 + q \]
\[ \tilde{g} \rightarrow \chi^0 + q \]

\( \chi^0 \) IS THE DM CANDIDATE

\[ m_{\chi^0} > \text{TeV} \]
Susy Alternatives: Dirac Gluino

Give mass to the gauginos introducing $A_i$: Dirac Partner

$$\int \frac{1}{M} A_i W_i^a W^a \rightarrow m_D A_i \tilde{l}_i \quad m_D \sim \frac{D}{M}$$

- **Dirac Gluino**

$$pp \rightarrow \tilde{q}_L \tilde{q}_L, \tilde{q}_R \tilde{q}_R, \tilde{q}_L \tilde{q}_R$$

At high $m_{\tilde{q}}$, $qq \rightarrow \tilde{q} \tilde{q}$

**Gaugino Partners** Phenomenology $A_3 \rightarrow j j$
"NATURAL" SUSY

ONLY FEW SUPER PARTNERS

\( \tilde{t}, \tilde{b}, \tilde{g}, \tilde{h} \) ARE CRUCIAL

TO STABILIZE THE WEAK SCALE

\[ \tilde{t} \rightarrow Z \rightarrow H_u, \quad \delta m_{H_u}^2 \approx \frac{1}{16\pi^2} Y_t^2 m_t^2 \]

EXPERIMENTAL CHALLENGE

SEARCHES ARE MORE DIFFICULT

HEAVY FLAVOR FINAL STATES

LARGER MULTIPULITIES, SOFTER OBJECTS
CHALLENGE ACCEPTED!
SUSY ALTERNATIVES: COMPRESSED/STEALTH

REDUCE THE AMOUNT OF $m_{\text{ET}}$

- LARGER MULTIPLICITY
- MORE DEGENERATE INVISIBLE PARTICLES $m_{\tilde{\psi}} = m_\psi + m_\chi$

or $m_{\tilde{\psi}} = m_\psi$ if $m_\chi = 0$

ZER0 MOMENTUM IN THE $\chi^0$
SUSY ALTERNATIVES: R-PARITY VIOLATION

GAUGE INVARiance ALLOWS NEW YUKAWA INTERACTIONS

\[ W_{\text{new}} = \lambda'' \bar{u}d\bar{d}c + \lambda' QLd\bar{c} + \lambda LLe\bar{\nu} + \mu' LH_u \]

- ALL THE MASSIVE SUSY PARTICLES DECAY INTO SM STATES
- NO BSM SOURCE OF mET

MUCH WEAKER LIMITS:

\[
\begin{align*}
\tilde{g} &\rightarrow jjj \\
\tilde{g} &\rightarrow Q\bar{Q} \rightarrow b^+l^+x, \bar{b}^{-}l^+x, l^+jdt, l^+b^+pt_3
\end{align*}
\]
At this stage all these options are worth being considered
WHY NOT RPV?

\[ W_{\text{RPV}} = \lambda'' u^c d^c d^c + \lambda' Q L d^c + \lambda L L e^c + \mu' L H_u \]

- **LEPTONIC & BARYONIC NUMBER VIOLATION**

- **PROTON DECAY** \[ \lambda'' \cdot \lambda' < 10^{-25} \]

  ![Proton Decay Diagram]

- **WIMP DARK MATTER IS NO LONGER STABLE**

- **UNIFICATION IS HARDER TO ACHIEVE** \[ W_{\text{RPV}} = 10^{55} \]

- **VERY SMALL COUPLING**
R-parity is not baryon number

- Proton decays via higher dim operators

\[ W^3 = \frac{1}{M} \ u \bar{u} \bar{d} \bar{e} = M \] mediates proton decay too fast even for \( M \sim M_{\text{GUT}} \)

In low-scale models, R-parity is not enough

"Effective" SUSY

Typically involves low-scales of SUSY mediation

\[ \downarrow \]

Proton decay becomes a UV issue
WHY RPV?

PHENOMENOLOGY IS DISTINCT:
- REDUCED MISSING ENERGY
- RESONANCES $g \rightarrow jjj$, $q \rightarrow jj$
- META-STABLE, MESINO-Oscillation

NATURAL SUSY:
- RPV LESS CONSTRAINED THAN RPC

LIMITS ON PAIR PRODUCTION
... still the flavor, structure and the size of the couplings looks special
GAUGED FLAVOR SYMMETRIES

- The Yukawa couplings of the SM break a large symmetry $SU(3)_{q,L,u,d,e,\nu}$
- The pattern of Yukawas/masses/mixing is explained by a gauged flavor symmetry
- Flavor gauge bosons have mass $m_f \sim \langle \phi \rangle \sim Y_{sm}$

$$\frac{1}{m_f^2} \bar{\Psi}_a \Psi_b \bar{T}_c \Psi_d$$  
FCNC $\sim \frac{1}{m_f^2} \sim \frac{1}{m_{	ext{light}}}$

$m_f > 10^5 \text{ TeV}$
FLAVOR DYNAMICS CAN BE AT A MUCH LOWER SCALE IF

\[ m_{\text{light}} \sim \frac{1}{M_{\text{heavy}}} \sim \frac{1}{m_s} \]  

“seesaw-like”

MSSM FIELDS: \( Q, L, u^c, d^c, e^c, \nu^c \)

FLAVOR GROUP: \( SU(3)_Q \times SU(2)_L \times U(1)_Y \)

EXOTIC FIELDS: \( U, U^c, D, D^c \) (to cancel flavor anomalies)

- EACH MSSM FIELD IS A FUNDAMENTAL OF HIS OWN \( SU(3) \)
- \( U^c, D^c \sim 3^* \) \( SU(3)_Q \)  \( U, D \sim 3 \) \( SU(3)_{u^c, d^c} \)

\[ W^{\text{RPV}}_{\text{MSSM}} \text{ is FORBIDDEN BY THE FLAVOR SYMMETRY} \]

\[ W^{\text{RPV}}_{\text{MSSM}} = \sum U^c D^c D^c \]
\[ W = \chi' W W^c Y_u + \mu_u U u^c + \lambda_u Q H u u^c \]

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**ANOMALY FREE**
\[ W = \lambda'_u U^c Y_u + \mu_u U w^c + \lambda_u Q H_u U^c \]

\[ U_{u,u} = \begin{pmatrix} 0 & \mu_u \\ \lambda_u u & \lambda_u \langle Y_u \rangle \end{pmatrix} \]

\[ Y_R = \frac{\mu_u}{\lambda_u \langle Y_u \rangle} - \frac{i}{\lambda_u} \frac{m_{sm}}{v} \]

**Flavor Blind** \( \mu_u, \lambda_u, \lambda'_u \)

**Hierarchy of SM Yukawas**

\[ Y_{sm} \sim \frac{\lambda_u \mu_u}{\lambda'_u \langle Y_u \rangle} \]

**Hierarchy of RPV Couplings**

\[ \lambda''_{ij} \sim \sqrt{\frac{m_{ui} m_{dj} m_{lk}}{\alpha}} \frac{1}{m^3_{ij}} \]

**Hierarchy of SM fermion masses**

\[ W_{mV} = \lambda''_u U^c D^c D^c \rightarrow \lambda''_u w^c d^c d^c \]
\[ \chi''_{ij} \sim \sqrt{\frac{g_{\alpha\beta}}{m_t^3}} \tilde{m}_{i} \tilde{m}_{j} \epsilon_{ij} \]

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KRNJAIC, STOLARSKI
Csáki et al.
1212.4860

- **RPV couplings are predicted**
  up to an overall factor
  (ratio of couplings and \(SU(2)_W\) VEVs)
  
  Very small couplings from the small mixings
  between MSSM and the RPV sector

- **Flavor dynamics can be low-scale**
  flavor partners of the top are the lightest

- \(X'\) QLQD RPV cannot be generated
  
  \(Q\) and \(L\) are charged under different groups
\[ \lambda_i \Psi_i^\nu \rightarrow \psi_{\nu} \rightarrow O_i \]

0: OF DIMENSION \( \Delta_i = \frac{5}{2} + \delta_i \)

\[ \lambda_i = \mathcal{g}_i \leq \lambda_i (\Lambda_W) \left( \frac{m_p}{\Lambda_W} \right)^{\delta_i} \]

\[ \chi_{ij} \sim \mathcal{E}_{\alpha_i} \mathcal{E}_{\nu_j} \]

NEARLY MARGINAL INTERACTIONS

GENERATE THE LARGE MASSES (\( m_{\text{top}} \))

TO REPRODUCE CKM

\[ \frac{\mathcal{E}_{\alpha_i}}{\mathcal{E}_{\alpha_0}} \sim \chi \quad \frac{\mathcal{E}_{\Delta_i}}{\mathcal{E}_{\Delta_0}} \sim \chi \]

\[ O_{uc} O_{uc} O_{cd} \rightarrow \lambda'' u_c d_c d_c \]

\[ \lambda'' \sim E_{\nu_i} E_{d_j} E_{d_k} \sim \frac{\mathcal{E}_{\eta_i}}{E_{\eta_i}} \frac{\mathcal{E}_{\eta_j}}{E_{\eta_j}} \frac{\mathcal{E}_{\eta_k}}{E_{\eta_k}} (E_{\nu_3})^3 \frac{m_{\nu_i} m_{d_j} m_{d_k}}{m_t^3} \]
SO FAR

\[ \lambda \sim \frac{m_{u_1} m_{d_1} m_{d_2}}{m_{s_2}^3} \]

ALTHOUGH DIFFERENT CKM STRUCTURES

IS THIS ALL THAT ONE CAN DO?

THE TWO MODELS HAVE VERY SIMILAR LSP PHENO

\[
\text{BR}(\tilde{t} \rightarrow b j) \approx 99\%.
\]

CRUCIAL FOR THE DETECTION OF A LIGHT \( \tilde{t} \)
**SUSY LEFT-RIGHT GAGED FLAVOR**

- **Embed** $SU(2) \times U(1)$ **in a** $SU(3)_L \times SU(3)_R \times U(1)_{B-L}$ **broken by** $\langle \chi \rangle$
- **Right-handed SM fields in doublets**
- **Gauge the flavor group** $SU(3)_Q \times SU(3)_q \times SU(3)_d \times SU(3)_u$

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<tr>
<td>$\bar{Y}_e$</td>
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</table>

**ANOMALY FREE**
$W = \lambda_u (QXU^c + Q^cX^cU)$

$+ \lambda_d (QX D^c + Q^c X^c D)$

$+ \lambda' Y_u UU^c + \lambda' Y_d DD^c$

**NO "μ-TERMS"**

$L-R$

$W_{\text{mix}} = X^u(UDD + U^c D^c D^c)$

$W_{\text{mix}} = X^u u^c d^c d^c$

$W_{\text{mix}} = X^u u^c d^c d^c$

$M_d = \frac{\Delta^2}{Y_d} \frac{v_L v_R}{\sqrt{\sum_{m} v_L v_R}}$

$M_u = \frac{\Delta^2}{Y_u} \frac{v_L v_R}{\sqrt{\sum_{m} v_L v_R}}$

$\theta_{L,R} = \frac{\lambda' U_{L,R}}{\lambda' Y_{u,d}}$

$v_L \ll v_R \ll \langle Y_{u,d} \rangle$

$\phi_{W,\mu} \sim \frac{m_{W,\mu}}{m_t}$

$\chi_{ijk} \sim \sqrt{\frac{m_{m_{ij}} m_{m_{jk}}}{m_t}}$

$\chi_{ijk} \sim \sqrt{\frac{m_{m_{ij}} m_{m_{jk}}}{m_t}} \in \ell_{ijk}$
\[
\text{SU}(3)_{\nu,q} \times \text{SU}(3)_{\nu,\ell}
\]

<table>
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<tr>
<th>(Q)</th>
<th>(Q^c)</th>
<th>(U)</th>
<th>(U^c)</th>
<th>(D)</th>
<th>(D^c)</th>
<th>(L)</th>
<th>(L^c)</th>
<th>(E)</th>
<th>(E^c)</th>
<th>(N)</th>
<th>(N^c)</th>
<th>(\chi, \bar{\chi})</th>
<th>(\chi^c, \bar{\chi}^c)</th>
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<td>(6)</td>
<td>(6)</td>
<td>(6^*)</td>
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</table>

- **ANOMALY FREE**
- \(\Delta \sim 6\) OF FLAVOR GROUP
\[ W = \frac{\lambda_4}{\Lambda^2} (Q \times D^c A_\Delta + Q^c \times D \bar{A}_\Delta) + M_0 \text{DD}^c \]

**Mass Term (Without Flavour NFLV)**

\[ W_{\text{RPV}}^{\text{Exp}} = \lambda'' (UDD + U^c D^c D^c) + \lambda' (LLE^c + LLE^c) \]

\[ \mathcal{G} \sim \frac{\lambda_4 V_{L_R}}{\Lambda M_D} \sqrt{\frac{m_{d_{1\text{sm}}} V_{L_{L_R}}}{V_{R_{L}}} \left( \frac{m_{d_{1\text{sm}}}}{V_{L_R}} \frac{V_{L_{L_R}}}{M_D} \right)} \sim \sqrt{\text{REACH}} \]

\[ W_{\text{RPV}}^{\text{max}} = \lambda'' \ U^c d^c d^c d^c + \lambda' \ L L e^c \]

*Separate BNV, LNV*
$W_{RNV}^{\text{new}} = \lambda'' \ u_{cd}^c d^c + \lambda \ L L e^c$

- SEPARATE BNV, LNV
- DIFFERENT DEPENDENCE ON THE SM MASSES

\[ \Delta \sim \sqrt{\frac{m_{d_{i\text{SM}}}}{m_{d_{i\text{LR}}}}} \frac{U_{LR}}{U_{RLL}} m_0 \]

MORE PROMPT DECAYS

- SIMILARLY LNV $\lambda \sim \left( \frac{m_{e}}{m_{\tau}} \right)^2$

- $m_{\text{SM}}^2 \sim \langle \text{FLAVON} \rangle$

"NORMAL" HIERARCHY OF FLAVOR GAUGE BOSONS

<table>
<thead>
<tr>
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<th>bs</th>
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<tbody>
<tr>
<td>t</td>
<td>$3.94 \times 10^{-5}$</td>
<td>$4.38 \times 10^{-5}$</td>
<td>$1.43 \times 10^{-4}$</td>
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<tr>
<td>c</td>
<td>$6.22 \times 10^{-5}$</td>
<td>$6.93 \times 10^{-5}$</td>
<td>$5.3 \times 10^{-7}$</td>
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<tr>
<td>u</td>
<td>$1.55 \times 10^{-5}$</td>
<td>$8.35 \times 10^{-7}$</td>
<td>$6.39 \times 10^{-9}$</td>
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</table>
LIMITS: $pp \rightarrow k^+k^+$ \quad \tau > 1.7 \times 10^{32}$ years

\[ p \underbrace{\left\{ \begin{array}{c} u \\ \bar{u} \\ u \\ \bar{u} \end{array} \right\} }_{\text{FV}} + \bar{t} \rightarrow \bar{u} + \]

\[ p \underbrace{\left\{ \begin{array}{c} u \\ \bar{u} \\ d \\ \bar{d} \end{array} \right\} }_{\text{FV}} \]

\[ \overline{\text{SQUARE FV}} \]

\[ \text{FLAVOR CONSERVING} \]

\[ A_{\overline{\text{FC}}} \sim \frac{1}{m_\nu} \left( \frac{1}{m_\nu^2} \right)^4 \left( \frac{m_u m_d m_s}{m_\nu^2} \right)^\mu V_{td}^2 \]

\[ \mu = 1 \text{ or } 2 \]

\[ \tau_{\overline{\text{FC}}}(\mu=1) \sim 10^{24} \text{ y} \]

\[ n \rightarrow \bar{n} \]
Proton decay $p \rightarrow k^+ \nu \hspace{1cm} \tau > 10^{33}$ y

$p \rightarrow k^+ \bar{G}$

$$A \sim \frac{1}{m_{\tau}^2} \frac{1}{m_{3\tau}^2} \mathcal{V}_{tb \bar{d}} \left( \frac{m_{d} m_{s}}{m_{t}} \right)^\mu \delta_{13}$$

$$\tau \sim 10^{33} y \left( \frac{m_{3\tau}}{\text{keV}} \frac{0.01}{\delta_{13}} \right)^2 \mu = \frac{3}{2}$$

$$\tau \sim 10^{33} y \left( \frac{m_{3\tau}}{\text{MeV}} \frac{0.01}{\delta_{13}} \right)^2 \mu = \frac{1}{2}$$
Proton decay \( p \rightarrow k^+ \nu \quad \tau > 10^{33} \text{ y} \)

\( p \rightarrow k^+ \nu \)

\[
W_{\text{mass}} = \lambda_{iju} L_i L_j e^c_k
\]

\[
\lambda \sim \frac{m_{e^c}}{m_\nu}
\]

In the model \( SU(3) \_w \times SU(3) \_v \_e \)

LNV gives \( \nu - x^0 \) mixing

\[
A \sim \frac{\lambda}{16\pi^2} V_{tb} (\frac{m_d m_{x^0}}{m_t^2})^{1/2} \frac{1}{m_{\nu}^2 m_{x^0}}
\]

\[
\begin{array}{c}
\text{P} \\
\text{d} \quad \tilde{u} \\
\text{u} \quad \nu \\
\text{u} \\
\end{array}
\]

\[
\begin{array}{c}
k^+ \\
\text{u} \\
\nu \\
\text{L}_i \\
\end{array}
\]

\[
\begin{array}{c}
p \\
v \\
\lambda \\
\chi \\
\tilde{e} \\
\end{array}
\]
THE RPV FLAVOR STRUCTURE IS PREDICTED IN TERMS OF SM MASS RATIOS AND CKM

\[ \chi_{\nu} \sim V_{\text{CKM}} \left( \frac{m_{u_i} m_{d_j} m_{d_k}}{m_t^3} \right)^\mu \in \nu_{ijk} \]

AN OVERALL FACTOR IS TYPICALLY NOT FIXED

\[ \mu = 1 \quad B_2 (\tilde{\tau} \rightarrow b d + b \bar{s}) \approx 99 \% \]

\[ \mu = \frac{1}{2} \quad B_2 (\tilde{\tau} \rightarrow b d + b \bar{s}) \approx 14 \% \]

DECAY RATES IN HEAVY FLAVOR OF THE STOP/SBOTTOM LSP
$pp \rightarrow Ef \rightarrow \mu t\bar{t}$

TeVatron+LEP $m_{\tilde{t}} \geq 100 \text{ GeV}$

CHALLENGING ESPECIALLY FOR LIGHT $\tilde{t}$

- In general, fully hadronic signals have large backgrounds from QCD MULTI-JET BACKGROUND

- Even triggering is an issue
  - 4 jet $p_T > 85 \text{ GeV}$ @ LHC
  - 4 jet $p_T > 45 \text{ GeV}$ "mixed"
  - b-trigger

- $t \rightarrow b \bar{q} \quad q=d,s$
  - Provides extra handles B-TAG (TRIGGER & ANALYSIS)
• $pp \rightarrow \bar{\tau} \tau \rightarrow bbqq$

  $b$-tag $\varepsilon \sim 66\%$  $\phi < 10^2$

• $pp \rightarrow \mu^\pm q\bar{q}$  $\varepsilon \ll 1$  **BECAUSE ONE FLAVOR**

• $pp \rightarrow t\bar{t} \rightarrow bbqqqq$

• **DOUBLE RESONANCE STRUCTURE**

  $\hat{E} = \text{jett}_1 \cdot \text{jett}_i$

  $\hat{E} = \text{jett}_p \cdot \text{jett}_q$

• **IDENTIFICATION OF THE CANDIDATE RESONANCE $\tau$**
- Pairing by minimizing $|1 - \Delta R_{ij}| + |1 + \Delta R_{uv}|$
- Resonance candidates with similar mass $\delta m$
- Hard vs. forward process
- Mass of the signal has little sensitivity to $\Delta R$
- Look inside the candidate resonances $(\Delta R_{12} + \Delta R_{34})/2$
$p_T,j > \frac{m_T}{2}$, \quad $|\eta_j| < 2.8$, \quad $\Delta R_{jj} > 0.7$, \quad $\delta_m < 0.075$, \quad $|\cos \theta^*| < 0.4$, \quad $\Delta R_{\text{best}} < 1.5$, \quad $\Delta \eta_{\text{best}} < 0.8$.

$\mathbf{m}_T = 100 \text{ GeV}$

$\mathbf{m}_T = 200 \text{ GeV}$

**Enforcing loosely collinear jets in the resonance candidate**

**Enforcing more collinear jets in the resonance candidate**

$\mathcal{L} = 20 \text{ fb}^{-1}$, $\sqrt{s} = 8 \text{ TeV}$ $\Rightarrow$ $m_T$ up to 200 GeV
CONCLUSIONS AND OUTLOOK

1) RPV STILL CAN HAVE SUB-TeV SUPER PARTNERS

2) PROTON DECAY IS NOT AUTOMATICALLY SAVED BY R-PARITY IN LOW SCALE MODELS

3) BREAKING OF GAUGED FLAVOR SYMMETRIES CONNECTED TO THE SIZE OF RPV COUPLINGS

\[ W_{\text{RPV}} = \lambda_{ijk} u_i^c d_j^c d_k \]

\[ \lambda''_{ijk} \sim V_{il} \left( \frac{m_{u_i} m_{d_j} m_{d_k}}{m^2_{e_i}} \right)^\mu e_{jk} \]

[\mu = 1, \frac{3}{2}]
- Challenging Light Squark Scenario

- \( \tilde{g}, \tilde{h}, \tilde{q}_3 \): Pair Stop Production \( \tilde{t} \rightarrow qq \)

- \( \mathcal{B}_\tau (\tilde{t} \rightarrow b\bar{d} + b\bar{s}) \approx 99.7 \) \( \text{SU}(3)_{u, d, l, \nu, e} \) \( \mu = 1 \)

- \( \mathcal{B}_\tau (\tilde{t} \rightarrow b\bar{d} + b\bar{s}) \approx 114 \) \( \text{SU}(3)_{u, d, l, \nu, e} \) \( \mu = 1/2 \)

- LHC Can Tell

- \( pp \rightarrow \tilde{t}\tilde{t} \rightarrow b\bar{b}q\bar{q} \)

![Graph showing Events/(20 GeV) vs. \( m_{\text{best}} \) with different QCD and \( t\bar{t} \) backgrounds.](image)
DIRAC GLUINO

![Graph showing the mass spectrum of Dirac gluino](graph.png)
PAIRED DIJET $q \rightarrow jj$
Figure 6: The expected and observed 95% confidence limit channel. The published CMS results using 35 pb$^{-1}$ of 2010 data are shown for comparison.

Figure 4: Observed and expected 95% CL upper limits on the cross section times branching fraction for gluino pair production followed by RPV decay of each gluino to three light-flavored quark jets. Also shown are the ±1σ and ±2σ bands on the expected limit, as well as the theoretical LO and NLO cross sections for gluino production.
HIGH MULTIPICITY FINAL STATES

\( \tilde{g} \rightarrow \text{many jets} \)

- SUBSTRUCTURE BY ACCIDENT, JET MASS OBSERVABLES
\[ W_{\alpha\beta} = \lambda_{ijk}^\alpha u_i^c d_j^c d_k^c \]

\[ \lambda_{\alpha ij} \sim V_{ilc} \left( \frac{m_{u_i} m_{d_j} m_{d_k}}{m_t^3} \right) \epsilon_{ljk} \]

\[ \mu = 1, \frac{1}{2} \]

- \( m_p \sim m_{f,s,n} \)
- \( pp \rightarrow k^+ k^+ \rightarrow k^+ v \) \( h \rightarrow \bar{h} \) \text{ok for the expected } \lambda_{ij}^\alpha

\[ \mathcal{B}_Z (\tilde{\tau} \rightarrow bd + b\bar{g}) = 99 \% \]

\[ \mathcal{B}_Z (\tilde{\tau} \rightarrow bd + b\bar{g}) = 14 \% \]

- \( LHC \text{ can tell } pp \rightarrow \tilde{\tau} \tilde{\tau} \rightarrow b\bar{b} q\bar{q} \)

- \text{Susy Breaking for a complete analysis of } FV

- Sparticle Spectrum \( q \rightarrow y^2 \sim \delta_{\text{finn}} \)

- Flavor-Aware Susy Breaking Mediation