Collaboration ATLAS_CPPM/IFAC_UM2

Probing the nature of Electroweak Symmetry Breaking at the LHC

with the ATLAS Detector

PESBLADe

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1/ quick reminder of IFAC expertise and possible involvement

2/ ATLAS/CPPM expertise and possible involvement

3/ CPPM/IFAC (OCEVU) Postdoc + (OCEVU) PhD project

4/ quick overview of EW effective operators zoology

5/ Heavy colored states + Higgs(->bb) "final states"
back to some pending questions since the 16-17-may meeting
5.1/composite Higgs
5.2/susy
5.3/ model-independent effective approach

6/ generators and a roadmap involving the Postdoc

7/ the Postdoc and PhD projects

1/ quick reminder of IFAC expertise and possible involvement

[Michele Frigerio, Cyril Hugonie, Jean-Loïc Kneur,

Julien Lavalle, G. M.] + Felix Brümmer

susy: MSSM, NMSSM (specific models, mSUGRA, GMSB, AMSB,etc. spectrum calc. authors, SuSpect2,3 (C++), NMSTools)

composite Higgs: "SILH-like", GUT scenarios, heavy top-like states,...

dark matter: candidates, relic density, DD & ID constraints,...)

2/ ATLAS/CPPM expertise and possible involvement

[Yann Coadou] $H \to bb$, τ

[Cristinel Diaconu] PDF + multi Ws

[Lorenzo Feligioni] top, trigger, b-tagging!

[Yanwen Liu (ext.) + Monnier] Generators + TGCs

[Steve Muanza] RPV susy + Generators

[Mossadek Talby] top, b-tagging

[Laurent Vacavant] top, $H \to bb$, b-tagging

3/ CPPM/IFAC Postdocs: Sara Diglio, Lorenzo Basso

CPPM/IFAC PhDs: Venugopal Ellajosyula, Rima El Kosseifi.

stop decays in RPV SUSY scenarios

R-Parity Violation in $t\bar{t}H$ Final States

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Abstract

We study signatures of R-parity violation originating from hadronically decaying light top squarks at the LHC. It is shown that higher jet multiplicities scan typically smaller R-parity violating couplings, down to tiny values where the R-parity conserving experimental bounds set in due to long-lived lightest supersymmetric particles. This suggests a general search strategy involving different final states with heavy- and light-jets or leptons that would allow a more complete interpretation of the signal or of mass versus coupling exclusion limits. We illustrate the case with some benchmark points in the model independent setting of the low-energy phenomenological MSSM and discuss signal versus background issues stressing the similarity with the $t\bar{t}H(\to b\bar{b})$ final states.

PACS numbers:

stop decays in RPV SUSY scenarios

- R-parity concerving SUSY seems decreasingly natural
- if SUSY is around $\rightarrow$ a light stop (cf. 125GeV Higgs mass)
- if R-parity violated present experimental limits much weaker.

stop decays in RPV SUSY scenarios

lepton number violation,

$$W_{\not{L}} = \frac{1}{2}\lambda_{ijk}\hat{L}_i.\hat{L}_j\hat{E}^c_k + \lambda'_{ijk}\hat{L}_i.\hat{Q}_j\hat{D}^c_k + \mu_i\hat{L}_i.\hat{H}_2$$

baryon number violation,

$$W_{\not{B}} = \frac{1}{2}\lambda''_{ijk}\hat{U}^{\alpha c}_i\hat{D}^{\beta c}_j\hat{D}^{\gamma c}_k\epsilon_{\alpha\beta\gamma}$$

$$\lambda_{ijk} = -\lambda_{jik} \text{ and } \lambda''_{ijk} = -\lambda''_{ikj}$$

...+ corresonding soft breaking parameters.

$\rightarrow$ unstable MSSM LSP!

Assumptions

(i) λ''_{33i}, $i = 1, 2$ are the only non-vanishing RPV couplings.

(ii) the light part of the SUSY spectrum is composed of one stop, one chargino, one neutralino and the lightest CP-even Higgs.

(iii) the RPV-MSSM-LSP is the lightest neutralino.

(iv) all other SUSY and Higgs particles, except possibly for the gluino, are assumed to be too heavy to be produced at the LHC.

$$m_{\tilde{t}} \geq m_{\chi^+} \geq m_{\chi^0} > m_t$$

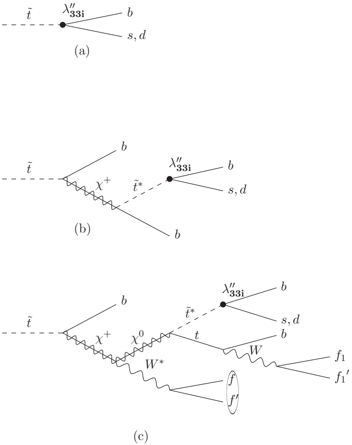
and for the present study

$$\begin{aligned} m_{\chi^+} &\approx m_{\chi^0} \\ m_{\tilde{t}} - m_{\chi^0} &< m_t \\ m_{\tilde{t}} - m_{\chi^+} &> m_b \end{aligned}$$

- stop production at the LHC:

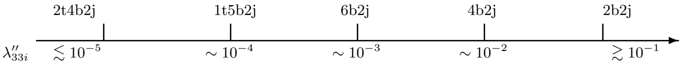
$$pp \to \tilde{t}\bar{\tilde{t}}$$

  mainly through gluon fusion processes.
- each stop can decay into one of the three channels:



$\bar{\tilde{t}}$ \ $\tilde{t}$	$\tilde{t}$-$\not{R}_p$	χ^+-$\not{R}_p$	R_p-like
$\tilde{t}$-$\not{R}_p$	2b2j	4b2j	1t3b2j
χ^+-$\not{R}_p$		6b2j	1t5b2j
R_p-like			2t4b2j

- all present LHC experimental limits consider only the (a) channel decays. (e.g. $m_{\tilde{t}} \gtrsim 300 GeV$, indep. of λ''_{33i}).
- the main message of our study: higher b+jet multiplicity final states scan lower values of λ''_{33j}!



Narrow Width Approximation ?

- $2b2j$

$$\sigma(pp \to \bar{b}\bar{s}\ bs) \simeq \sigma(pp \to \tilde{t}\bar{\tilde{t}}) \times Br(\tilde{t} \to \bar{b}\bar{s}) \times Br(\bar{\tilde{t}} \to bs)$$

- $6b2j$

$$\sigma(pp \to \bar{b}\bar{s}\bar{b}b\ bsb\bar{b}) \simeq \sigma(pp \to \tilde{t}\bar{\tilde{t}}) \times Br(\tilde{t} \to \bar{b}\bar{s}\bar{b}b) \times Br(\bar{\tilde{t}} \to bsb\bar{b})$$

- $2t4b2j\ldots$

$$\sigma(pp \to t\bar{b}\bar{s}b\ \bar{t}sb\bar{b}\ldots) \simeq \sigma(pp \to \tilde{t}\bar{\tilde{t}}) \times Br(\tilde{t} \to \bar{b}\bar{s}b\ldots) \times Br(\bar{\tilde{t}} \to bs\bar{b}\ldots)$$

- + all the other mixed final states

Narrow Width Approximation ?

$\rightarrow$ assuming the NWA at all the stages of the (on-shell) cascade decays one obtains:

- 2b2j

$$\sigma(pp \to 2b2j) \simeq \sigma(pp \to \tilde{t}\bar{\tilde{t}}) \times \frac{r_1^2 \times (\lambda''_{332})^4}{(1 + r_1 \times (\lambda''_{332})^2)^2}$$

- 6b2j

$$\sigma(pp \to 6b2j) \simeq \sigma(pp \to \tilde{t}\bar{\tilde{t}}) \times \frac{r_2^2 \times (\lambda''_{332})^4}{(1 + r_1 \times (\lambda''_{332})^2)^2 (1 + r_2 \times (\lambda''_{332})^2)^2}$$

- 2t4b2j...

$$\sigma(pp \to 2t4b2j\ldots) \simeq \sigma(pp \to \tilde{t}\bar{\tilde{t}}) \times \frac{1}{(1 + r_1 \times (\lambda''_{332})^2)^2 (1 + r_2 \times (\lambda''_{332})^2)^2}$$

- ...+ all the other mixed final states

$$r_1 \equiv \frac{\Gamma(\tilde{t} \to \bar{b}\bar{s})}{\Gamma(\tilde{t} \to \chi^+ b)} \quad [\text{taken at } \lambda''_{332} = 1] \tag{0.1}$$

$$r_2 \equiv \frac{\Gamma(\chi^+ \to \bar{b}\bar{s}\bar{b})}{\Gamma(\chi^+ \to \bar{b}\bar{s}\bar{b} f_1 \bar{f}'_1 f'_2 \bar{f}_2)} = \frac{\Gamma(\chi^+ \to \bar{b}\bar{s}\bar{b})}{\Gamma(\chi^+ \to \chi^0 f'_2 \bar{f}_2)} \quad [\text{taken at } \lambda''_{332} = 1] \tag{0.2}$$

N.B. when $\lambda''_{332} \ll 1$ the RPC-like final states dominate!

setting the tools from scratch

the R-parity violating MSSM has been generated by Sara through SARAH $\rightarrow$ SPheno $\rightarrow$ MD5

benchmark points	1	2
$\tan\beta$	10	
M_1	2.5 TeV	
M_2	1.5 TeV	
M_3	1.7 TeV	
$m_{\tilde{Q}}$	2 TeV	
$m_{\tilde{t}_R}$	570 GeV	964 GeV
$m_{\tilde{b}_R} = m_{\tilde{u}_R} = m_{\tilde{d}_R} = m_{\tilde{e}_R} = m_{\tilde{q}} = m_{\tilde{l}}$	3 TeV	
T_t	-2100 GeV	-2150 GeV
$(m_A)_{in}$	2.5 TeV	
μ	400-650 GeV	750-1000 GeV
λ''_{33i}	$10^{-7} - 10^{-1}$	$10^{-7} - 10^{-1}$

benchmark points	1	2
$m_{\tilde{t}}$	$\sim$ 600 GeV	$\sim$ 1 TeV
m_{χ^+}	$\sim$ 400-650 GeV	$\sim$ 750-1000 GeV
m_{χ^0}	$\sim$ 400-650 GeV	$\sim$ 750-1000 GeV
$m_{\tilde{t}} - m_{\chi^0}$	$\sim$ 5 - 194 GeV	$\sim$ 1 - 239 GeV
m_{h^0}	$\sim$ 125 GeV	
$m_A \approx m_{H^0} \approx m_{H^\pm}$	$\sim$ 2.5 TeV	
$M_{\tilde{g}}$	$\sim$ 1.87 TeV	
$M_{\tilde{t}2} \approx M_{\tilde{b}1}$	$\sim$ 2 TeV	
$M_{\tilde{b}2} \approx M_{\tilde{u}1,2} \approx M_{\tilde{d}1,2}$	$\sim$ 3 TeV	
$M_{\tilde{l}1,2}, M_{\tilde{\nu}1,2}$	$\sim$ 3 TeV	
$(g-2)_\mu$	$3 - 3.3 \times 10^{-11}$	$3.2 - 3.3 \times 10^{-11}$
$\delta\rho$	$5.7 - 5.9 \times 10^{-5}$	$\sim 5.5 \times 10^{-5}$
$BR(B \to X_s\gamma)/BR(B \to X_s\gamma)^{SM}$	$0.89 - 0.92$	$0.95 - 0.96$
$BR(B_s^0 \to \mu\mu)$	$3.36 - 3.39 \times 10^{-9}$	$3.38 - 3.40 \times 10^{-9}$
$BR(B_d^0 \to \mu\mu)$	$1.08 - 1.09 \times 10^{-10}$	$\sim 1.09 \times 10^{-10}$

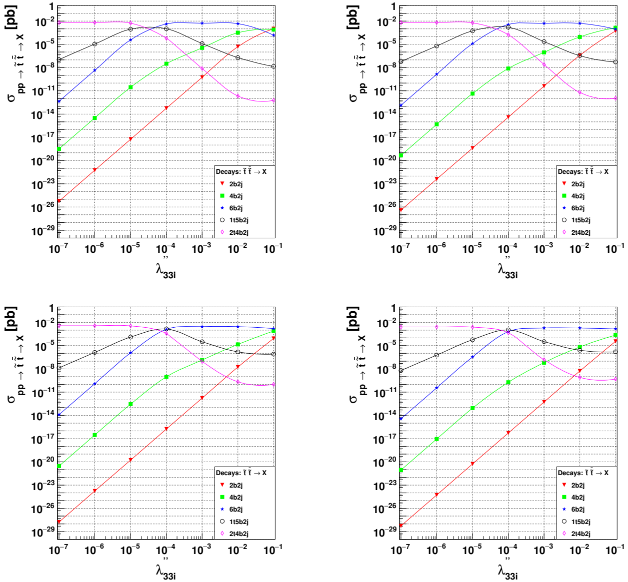


Figure : stop-anti-stop production and decay cross-sections at $\sqrt{s} = 13$TeV, for 4, 6, 8, 10, 12jets or jets+leptons final states, versus λ''_{33i}; $m_{\tilde{t}} = 1$TeV and $m_{\tilde{t}} - m_{\chi^+} = 50, 100, 200, 250$GeV.

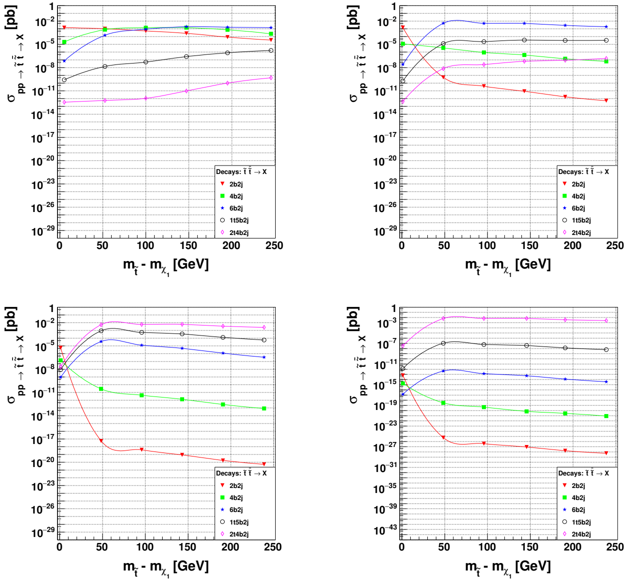


Figure : stop-anti-stop production and decay cross-sections at $\sqrt{s} = 13$TeV, for 4, 6, 8, 10, 12jets or jets+leptons final states, versus $m_{\tilde{t}} - m_{\chi^+}$; $m_{\tilde{t}} = 1$TeV and $\lambda''_{33i} = 10^{-1}, 10^{-3}, 10^{-5}, 10^{-7}$.

Conclusion

- if light decaying stops are excluded in the most simple decay patterns this means either heavier stops or smaller RPV couplings or both $\longrightarrow$ model-dependence
- smaller RPVs have increased sensitivity to higher b+jet multiplicities
- aer these feasible in ATLAS (CPPM experts)
- the pheno message is more general $\rightarrow$ study other RPV couplings, other final states, top-down models, etc.

SU(2) triplet Higgs extensions