Jack Collins, Cornell University

Oddest Little Higgs:
Top Partners Decaying into Jets

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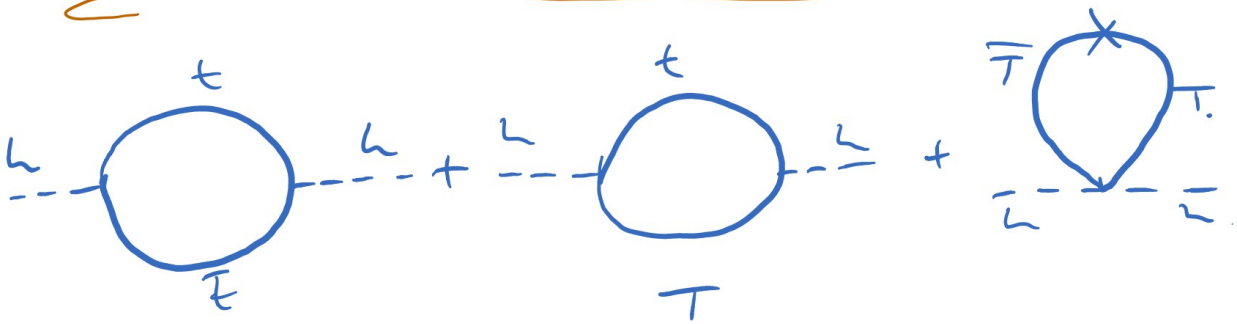
Motivation

Pseudo-Goldstone Higgs



$$a\Lambda^2 + b\Lambda^2 - c\Lambda^2 = 0.$$

$$\frac{\delta m_h^2}{m_h^2} \sim \frac{\frac{3}{8\pi^2} m_T^2}{(88\ \mathrm{GeV})^2}$$

$$10\% \Longrightarrow m_T \lesssim 1.5\ \mathrm{TeV}$$

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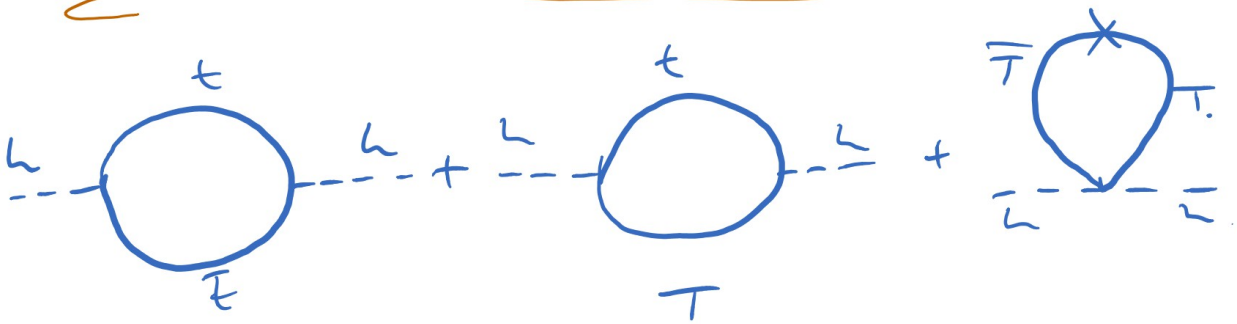

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$10\% \Rightarrow m_T \lesssim 1.5\ \mathrm{TeV}$

Charge 2/3 T decays:

	BR
$T \to th$	0.25
$T \to tZ$	0.25
$T \to Wb$	0.5

$\Rightarrow m_T \gtrsim 800\ \mathrm{GeV}$

ATLAS-CONF-2015-012
CMS-B2G-12-015

Mixing things up:
A recipe for odd top partners

1) Introduce a parity under which all SM particles are even and the top partner T which cancels top quadratic divergences is odd. (familiar from Little Higgs with T-Parity (LHT), but that has lots of moving parts)

[Cheng, Low, Wang, hep-ph/0510225]

2) This forbids the couplings Tth, TtZ, TbW responsible for the typical decays. Now include new odd scalars in your non-linear sigma model into which the T can decay instead.

3) Finally, we can add a small parity breaking to make the lightest odd particle decay.

Naturalness does not require light (sub-TeV) gauge partners and so we won't include them.

This slide is mainly for Little Higgs aficionados

Example:
The Oddest Littlest Higgs (SU(5)/SO(5))

$$\Sigma = e^{2i\Pi/f}\Sigma_0 , \quad \Sigma_0 = \begin{pmatrix} & & \mathbb{1} \\ & 1 & \\ \mathbb{1} & & \end{pmatrix} \begin{matrix} \updownarrow 5 \\ \\ \\ \end{matrix}$$

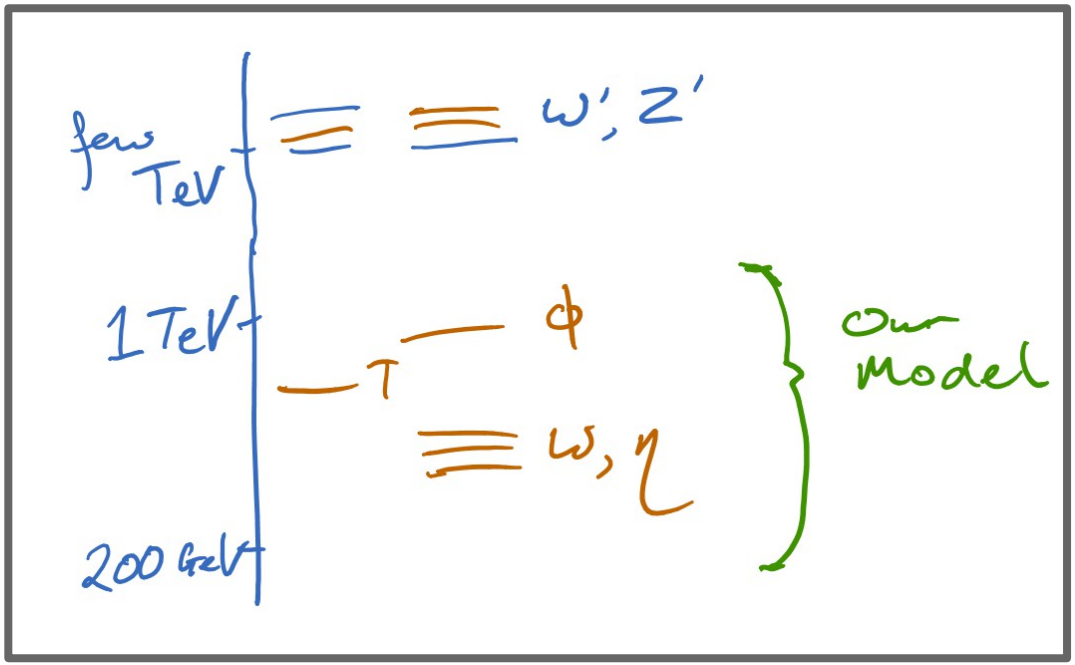
$$\underbrace{\qquad\qquad}_{5}$$

$$\Pi = \begin{pmatrix} \omega+\eta & H & \phi \\ H^\dagger & -\eta & H^T \\ \phi^\dagger & H & \omega^T+\eta \end{pmatrix}$$

odd

even

Gauge only SM $SU(2)_L \times U(1)_Y$



Key Point: Only one fermionic top partner, and it does not have Tth, TtZ, TbW couplings.

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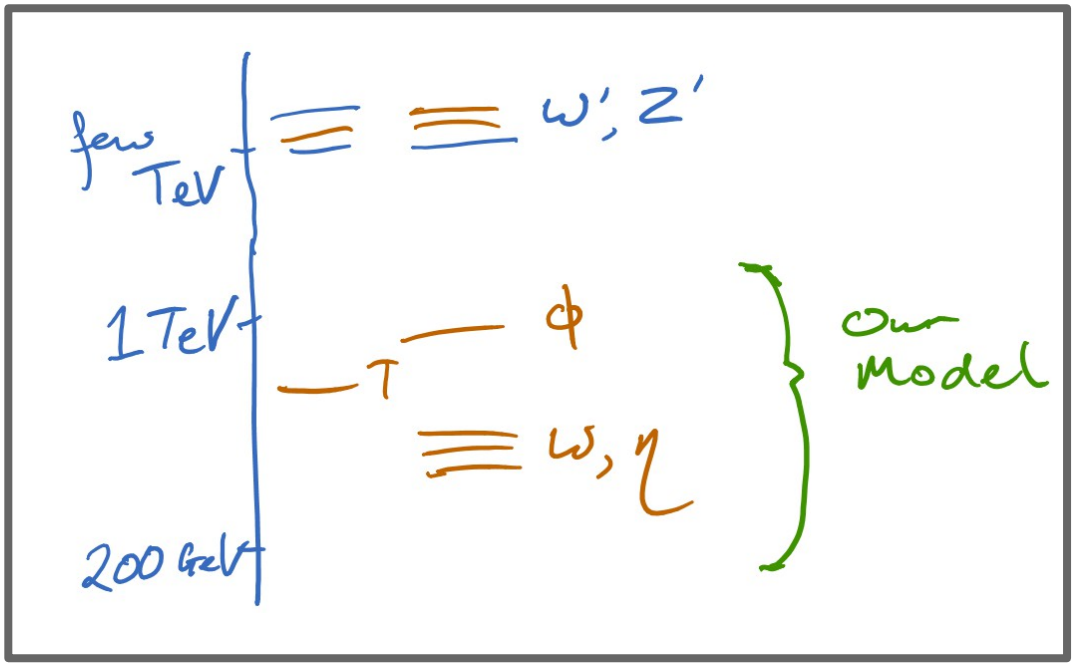

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Fermions:

$$\chi_i = \begin{pmatrix} Q \\ T \end{pmatrix} \qquad u_1^c \qquad u_2^c$$

$$T^c \propto u_1^c - u_2^c$$

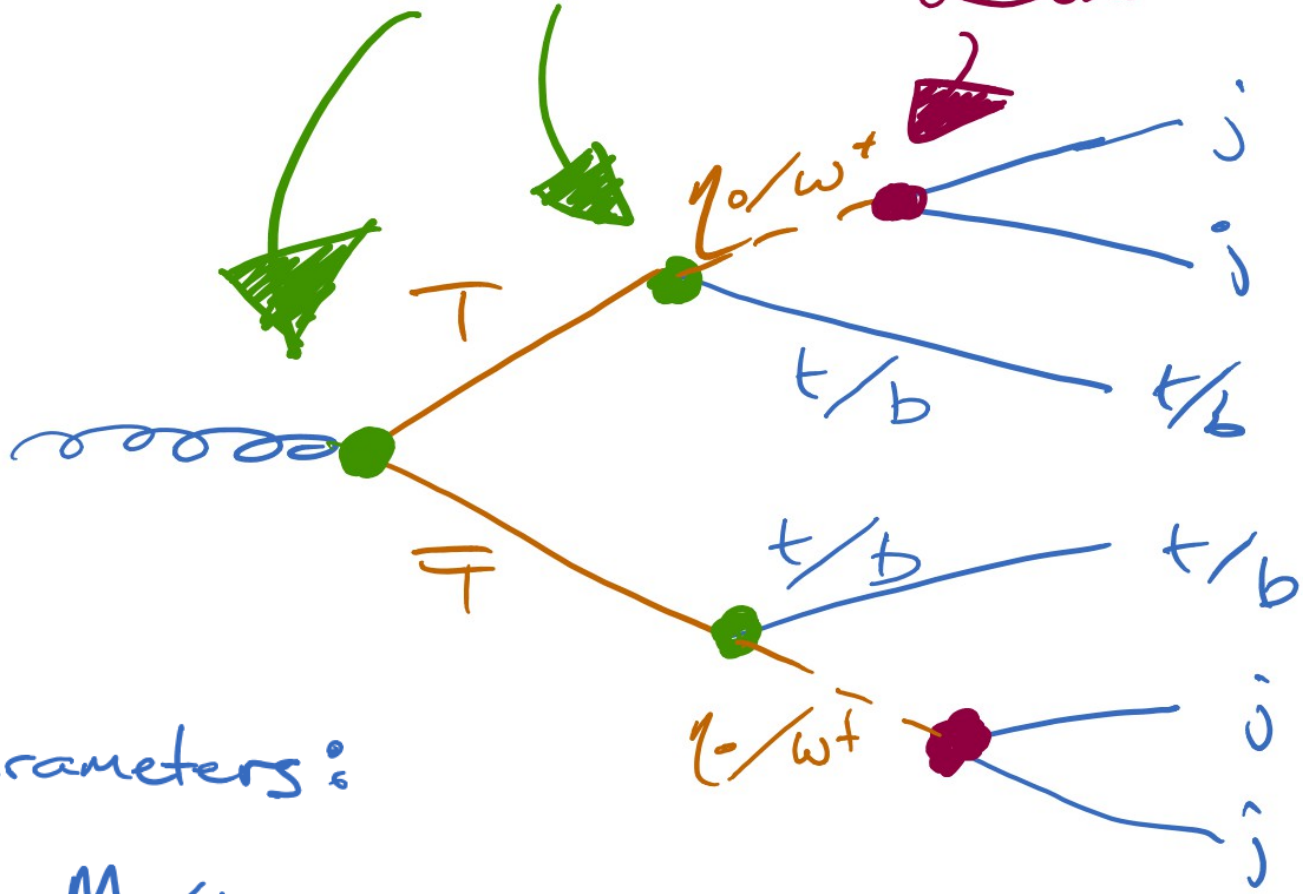
$$\chi_i^t = \begin{pmatrix} Q \\ -T \end{pmatrix} \qquad t^c \propto u_1^c + u_2^c$$

$$\mathcal{L}_{yuk} = y\left(\chi_i\, O_i\, u_1^c + \chi_i^t\, O_i^t\, u_2^c\right) \qquad O_i = \epsilon_{ijk}\,\epsilon_{xy}\,\Sigma_{jx}\,\Sigma_{ky}$$

Key Point: Only one fermionic top partner, and it does not have Tth, TtZ, TbW couplings.

Phenomenology
General Setup

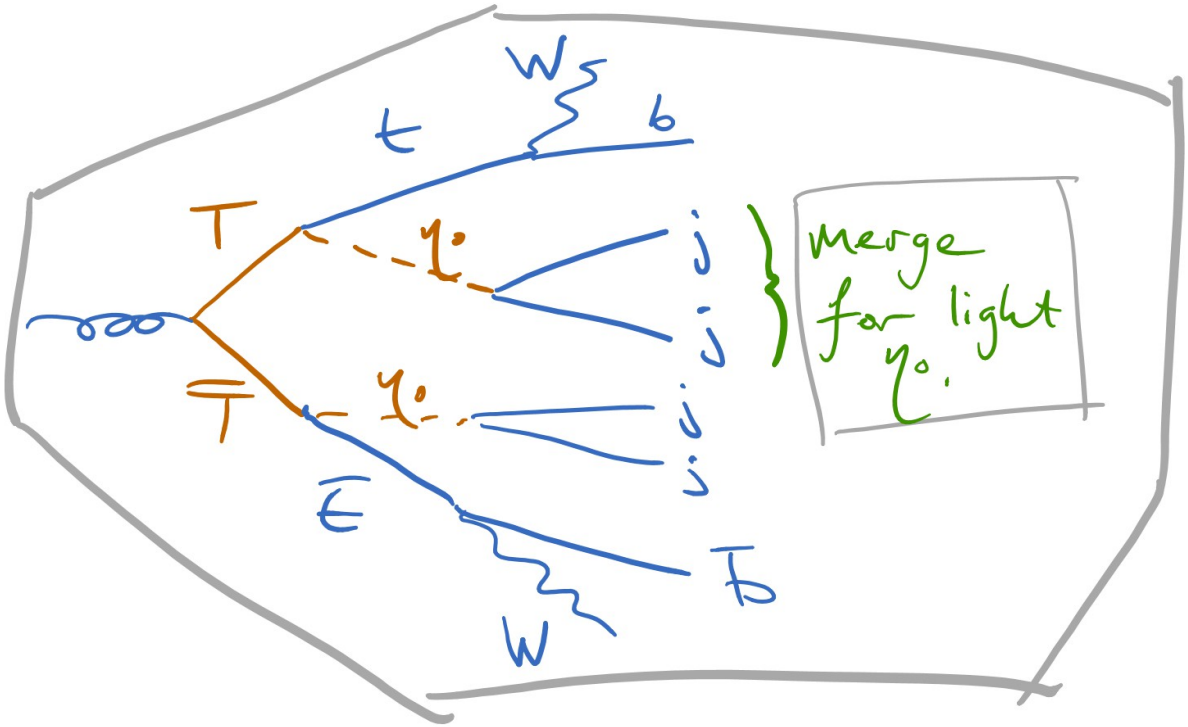
$$\mathcal{L} = \mathcal{L}_{even} + \varepsilon \mathcal{L}_{odd}$$



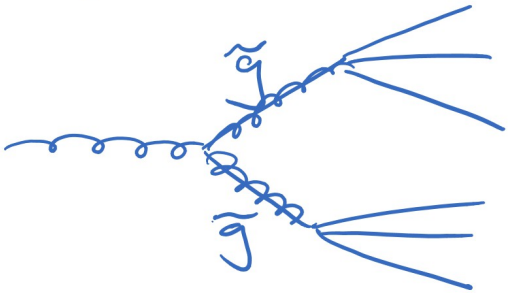
Free parameters:

m_T, $M_{\eta/\omega}$

Phenomenology
Scenario 1: ttjjjj



Looks like RPV gluino



ATLAS Search:

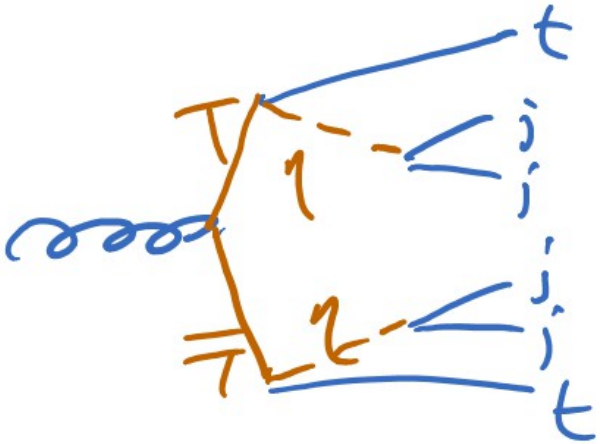
7 jets with $p_T \gtrsim 80$ GeV

$\Rightarrow m_{\tilde{g}} \gtrsim 800$ GeV

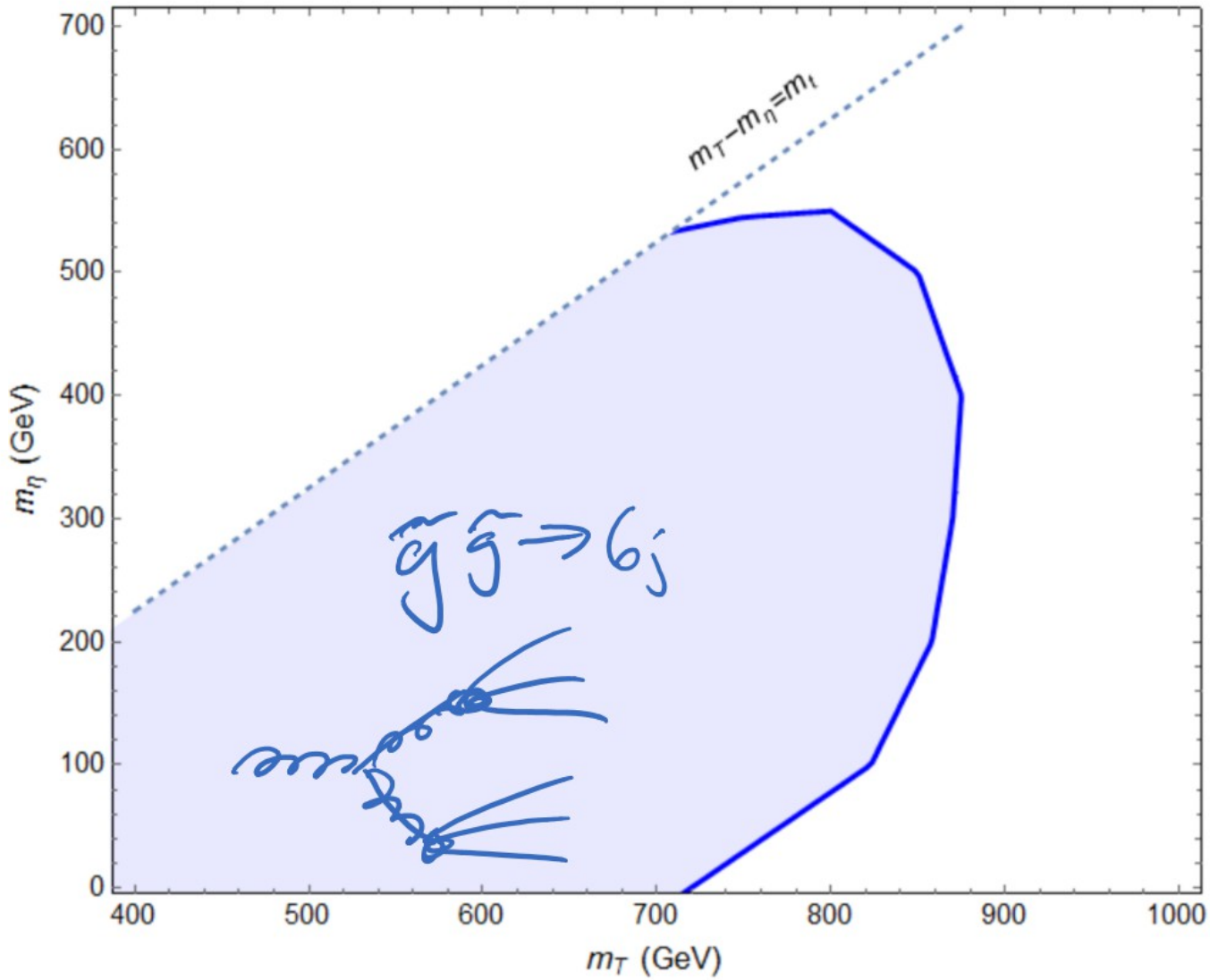
(when final state has t's)

arXiv:1502.05686

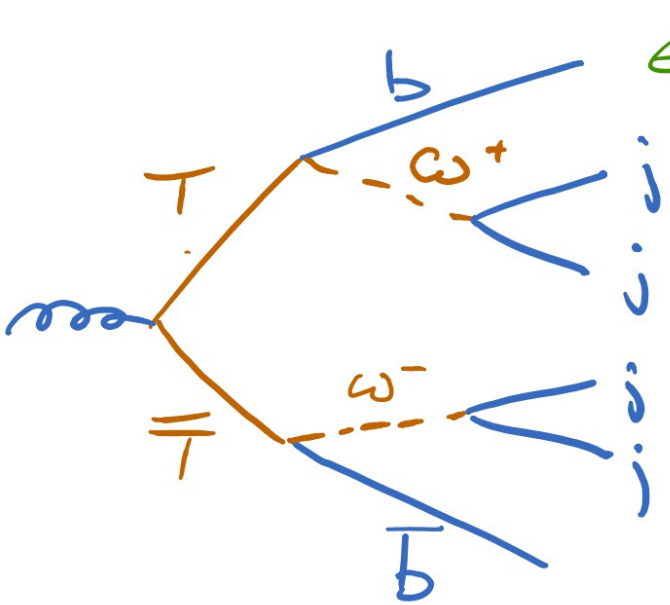
Phenomenology
Scenario 1: ttjjjj Bounds



Cuts:
– 7 jets > 80 GeV
– 2 b tags



Phenomenology: Scenario 2: bbjjjj



← soft b if $m_\omega \simeq m_T$.

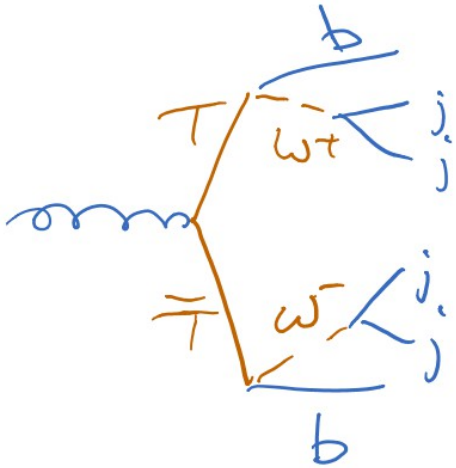
$$m_T - m_t < m_\omega < m_T$$

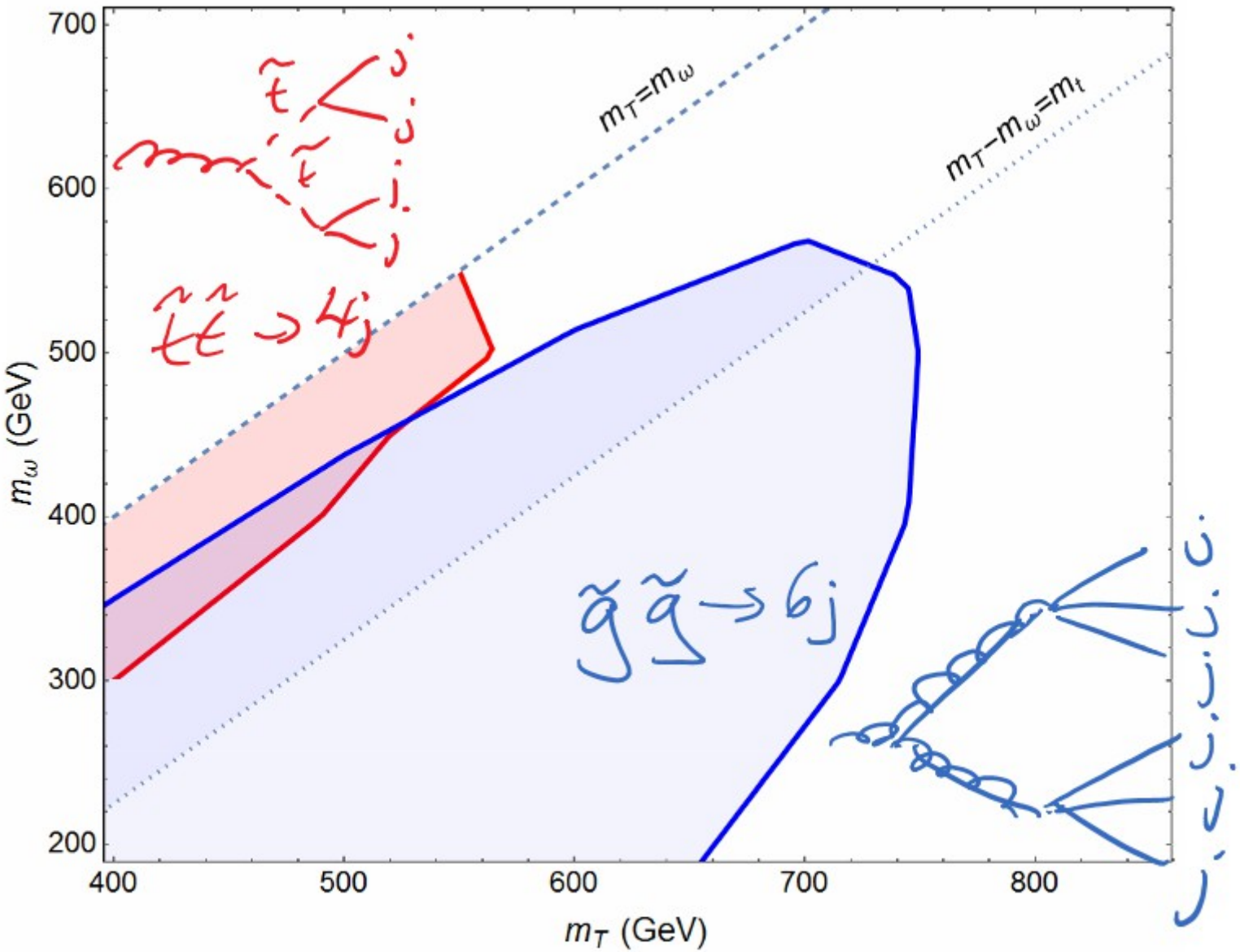
Looks like:

- RPV gluino for hard b's.
- $\tilde{t}\tilde{t} \to 4j$ for soft b's.

arXiv:1412.7706

Phenomenology: Scenario 2: bbjjjj bounds





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Conclusions

- The bare minimum requirement on the sub-TeV(ish) spectrum coming from naturalness is a top partner (any spin).
- Standard and minimal scenarios with coloured top partners are becoming increasingly constrained.
- It is about time that we started playing games with coloured fermionic top partners, as we have we have with scalar top partners.
- Here we have killed the standard decays by implementing a parity symmetry, under which the top partner is odd. Instead it decays into a scalar and a t or b quark.
- We then introduce a very small breaking to allow decays of the lightest odd particle into jets (like RPV SUSY).
- This is usually well constrained by RPV gluino searches (~ 800 GeV), but there is a compressed region with soft bottoms which allows a top partner mass ~ 550 GeV.
- I'm sure that we can be more clever and do better if we really want to!