Singly Produced Top Partners at (Next) Future Colliders

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LTS1, La Biodola

References

Based on:

- G.F. Giudice, C. Grojean, A. Pomarol, R. Rattazzi. JHEP 0706 (2007) 045
- A. De Simone,O. Matsedonskyi, R. Rattazzi, A. Wulzer. JHEP 1304 (2013) 004
- N. Gutierrez Ortiz, J. Ferrando, D. Kar, M. Spannowsky. arXiv:1403.7490 [hep-ph]

Outline

Partial Compositeness

- Higgs as a **composite state** (strong dynamics) is a possible solution to the **Hierarchy Problem** (pNGB)

- Here sp. broken global symmetry minimal $SO(5) \to SO(4)$

Postulate a new strong sector,
scale $\simeq f \gg v$ (EWPT)

- SM fields obey partial compositeness

$$\mathcal{L}_{mix} = y_L\, \bar{q}_L\, \mathcal{O}_L + y_R\, \bar{t}_R\, \mathcal{O}_R + h.c.$$

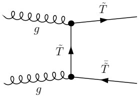
- Light Higgs requires **light Partners**

$$y_t \simeq y_L y_R \frac{f}{m_{light}}, \quad m_h \simeq 100\text{GeV} \left(y_t \frac{m_{light}}{f} \right)$$

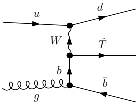
Remarks

No particular assumption, here, on the model details (embedding of top/top partner in broken global group). Let's only call a generic $Q_{EM} = +2/3$ top-partner "$\tilde{\mathbf{T}}$", $M_{\tilde{T}} \simeq 1$ TeV.

Main production mechanisms

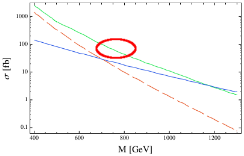


Pair production



Single production with light quark

- σ_{single} can dominate over QCD σ_{pair} already at moderate $m_{\tilde{T}}$

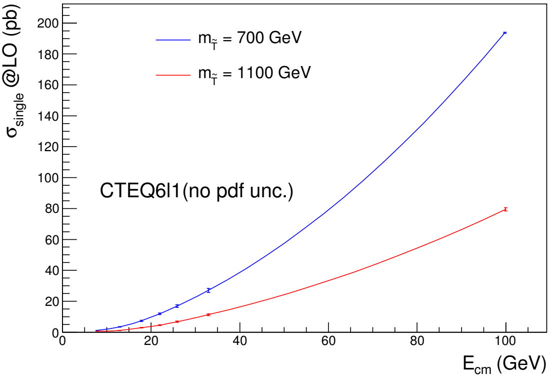


from De Simone, Matsedonskyi, Rattazzi, Wulzer, JHEP 1304 (2013) 004

- LHC searched pair production (excl. $M_{\tilde{T}} \simeq 700$), here I (start to) investigate **single production** @**13** TeV, **33** TeV, **100** TeV (see Ortiz, Ferrando, Kar, Spannowsky, arXiv:1403.7490 [hep-ph])

Typical Cross sections

Typical allowed cross sections (model dependence!):



Building Event Selection: Light quark Jets

- Light jets η distributions suggest a search strategy:

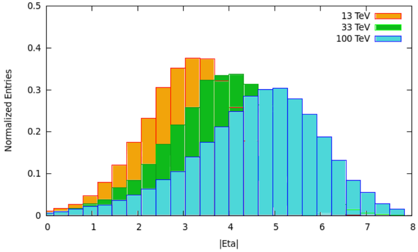


Figure: Final state light quarks (CalcHEP).

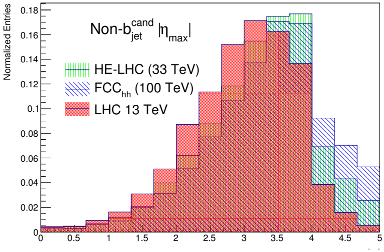
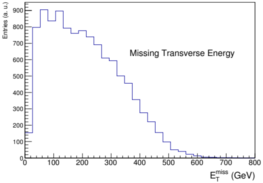


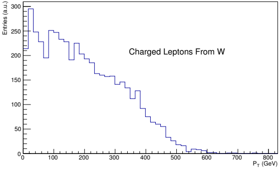
Figure: Light jet with highest η (MG5+Pythia6).

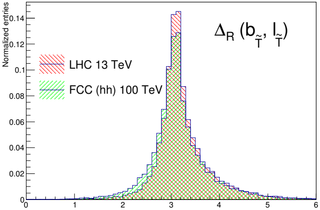
- For SM top-like background need other strategies ($\simeq$same features)

Building Event Selection: Leptons

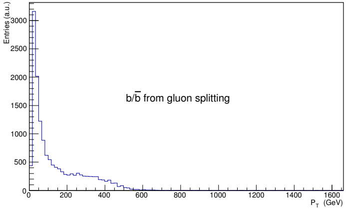
Look for dominant decay $\tilde{T} \rightarrow W^{+}\, b$, W decaying leptonically (cleaner, good point to start with!)

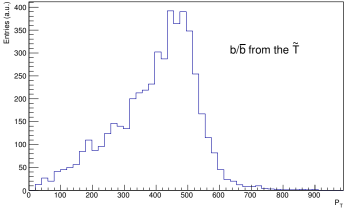






- Two $b-$ jets in the event, different features:



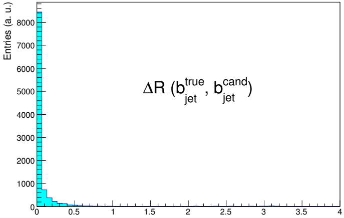


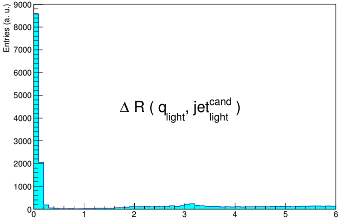
- $b-$ jet from $\tilde{T}$ highest P_T jet !

Event Selection: summary

- Leptons:
  - $E_T^{miss} > 20$ GeV
  - One isolated $\Delta R = 0.5$ lepton (e, μ)
- Jets:
  1. Highest P_T jet has to be $b-$tagged (future analysis also some expl. P_T cut)
  2. Highest $|\eta|$ jet not coinciding with $(1) \equiv \eta_{max} > 2$ (when bckg., optimize it)
- Call (1) "$b-$jet candidate", (2) "light$-$jet candidate"

With defined event selection candidates matches well partonic objects:



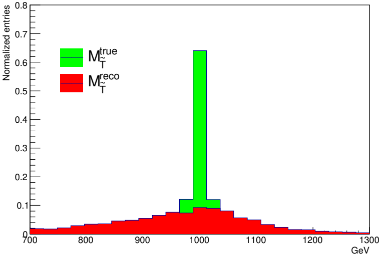


Invariant mass reconstruction

Ready for first $\tilde{T}$ invariant mass reconstruction:

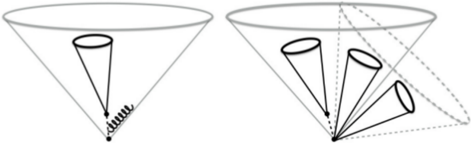
- Infer a candidate $p_{\nu/\bar{\nu}}$ from $W^{\pm}$ imposing $M_W^{reco} = M_W^{true}$
- Define

$$p_{\tilde{T},\text{cand}} \equiv p_\nu + p_{lep} + p_{b,\text{cand}}, \qquad \left(M_{\tilde{T}}^{\text{reco}}\right)^2 \equiv p^2_{\tilde{T},\text{cand}}$$



Peak not artificial, did not introduced any P_T explicit cut (besides E_T^{miss})

Outlook: top background suppression



- In $\tilde{T} \to bW$ b recoils, isolated.
- In semileptonic $t\bar{t}$, hadronically decaying top products increase fat jet mass.

...Thanks!

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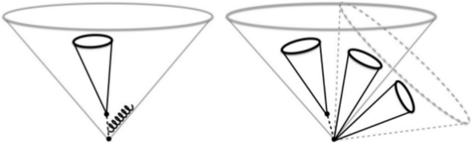

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...Thanks!

Writing the relevant term in the low en. Lagrangian for single production ($+q_{\text{light}}$) as

$$\mathcal{L} \supset g^i_{L,X}\bar{q}_L \not{V}^i X + g_{R,X}\bar{t}^i_R \not{V}^i X$$

(for our purposes here $V = W$, $X = \tilde{T}$) the single production cross section can be decomposed as

$$\sigma_{\text{single},\tilde{T}} = g_{L,\tilde{T}}{}^2 \sigma(m_{\tilde{T}})$$

Computing LO cross sections

#	$\sigma^b_{sp,1}$ @ NLO (fb)	$\sigma^b_{sp,2}$ @ NLO (fb)	$\sigma^b_{sp,2}$ @ LO (fb)	$\sigma^{b,4\mathrm{FNS}}_{sp,\mathrm{MG5}}$ (fb)	$\sigma^{b,5\mathrm{FNS}}_{sp,\mathrm{MG5}}$ (fb)
1	3528	3515	2737	4547	3809
2	1047	1044	760	1418	1145
3	386	384	277	539	428
4	165	164	115	238	182
5	78	78	50	112	84
6	-	19	12	31	22

Table 2: $\sigma^b_{sp,1}$ is the single production cross section given by Ferrando; $\sigma^b_{sp,2}$ is computed starting from the generic ones in the article by Wulzer and inserting the couplings computed in the previous table. This is the best check that we understood well the model. $\sigma^{b,4(5)\mathrm{FNS}}_{sp,\mathrm{MG5}}$ is the cross section obtained with MadGraph 5 using fixed renormalization scale set to the $\tilde{T}$ mass in the two different flavour number schemes. Notice that the cross section in the first two columns are NLO, while in the last two they are LO, so a certain discrepancy still remains. Anyway, the best way to compute the cross sections is the last one (that should resum logarithms of the type $ln(m_b/m_{\tilde{T}})$).