Non-SUSY simplified models

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Introduction

Non-SUSY searches include a huge number of different BSM scenarios: impossible to review all of them

Several searches are related to new strongly interacting dynamics:

- Extra dimensions
- Composite Higgs
- Little Higgs
- ...

Common feature: **resonances** with the same statistics and quantum numbers of the SM fields (generically "KK modes")

- fermionic states (eg. top partners motivated by naturalness)
- gauge resonances

Introduction

Few simplified models available for non-SUSY scenarios, in most cases just simple explicit models.

In this talk proceed by examples:

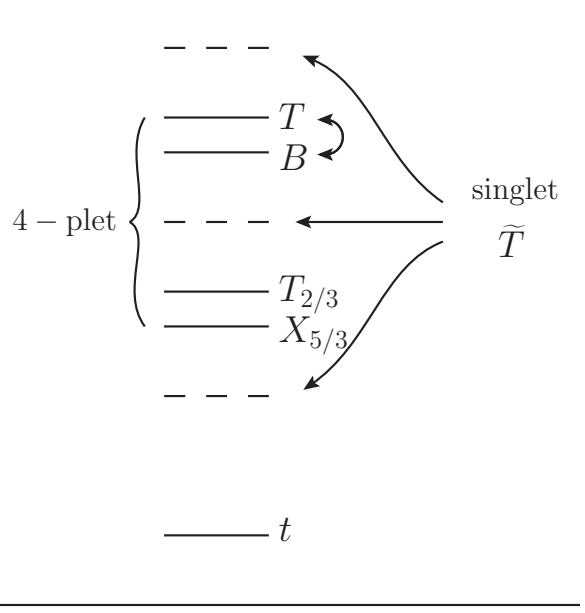
- present a few search strategies (related to the composite Higgs scenario)
- highlight good and weak points
- show a few ways to improve them

Top partners

Extended (global) symmetries (eg. custodial) determine the representations of the top partners

In minimal models $SO(5) \to SO(4)$

- 4-plets (with exotic states $X_{5/3}$)
- singlets



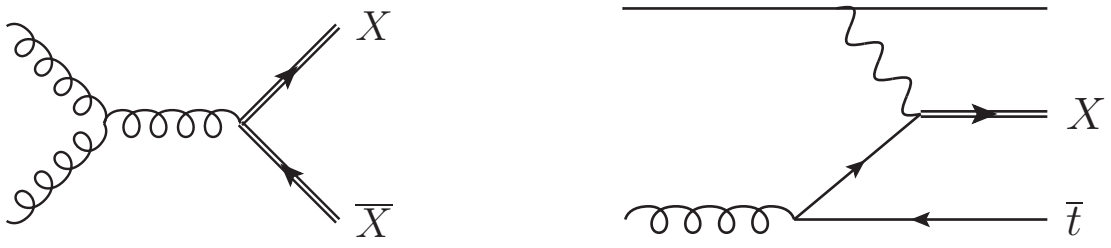
Useful search strategy:

- select the **lightest multiplet**
- focus on **one resonance at a time**

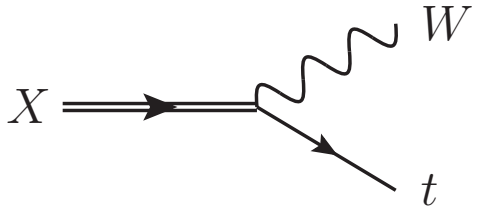
The exotic $X_{5/3}$: Cut and count

The $X_{5/3}$ is the lightest state in the 4-plet

- QCD pair production or single production with top



- Always decays into W and top



The exotic $X_{5/3}$: Cut and count

Best search channel: **same sign dileptons**

Existing analyses from ATLAS and CMS use **cut and count** strategy with generic (mass-independent) cuts

[ATLAS-CONF-2013-051, CMS PAS B2G-12-012]

Advantages:

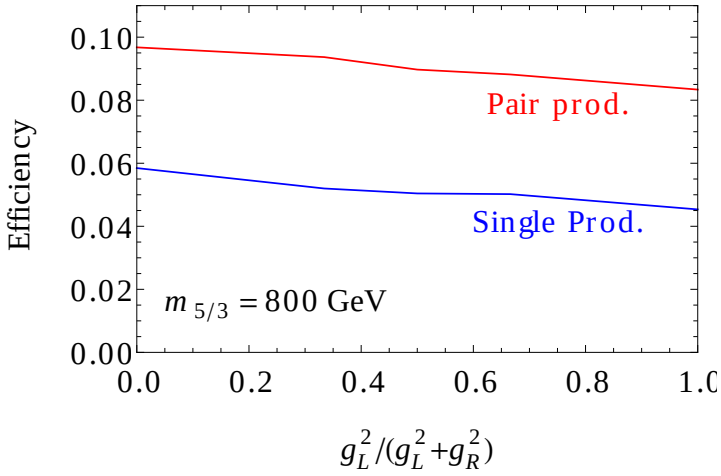
- minimizes the dependence on the model
- easy to recast
- can be adapted to the case in which other resonances contribute to the same final state (eg. pair produced $B' \to W\,t$)

The exotic $X_{5/3}$: Cut and count

Possible issues:

- analysis assumes a purely L-handed coupling: $g_L \overline{X}_{5/3L} W\!\!\!/ t_L$

- in generic models (eg. composite Higgs) L and R couplings are typically present
- distributions, efficiency and cross section depend on the couplings



Suggestions:

- specify the couplings used in the analysis
- can be improved by adding L and R couplings

Top-like resonances, T, $X_{2/3}$ and $\widetilde{T}$

Different decay channels are possible:

$$T' \to Wb \qquad T' \to Zt \qquad T' \to ht$$

The last analyses look at single channels or combine them

Many searches **rely on the distributions**

- H_T distribution for $T' \to ht$ [ATLAS-CONF-2013-018]
- $M(Zb)$ distribution for $T' \to Zt$ [ATLAS-CONF-2013-056]
- BDT for single and multilepton channels [CMS PAS B2G-12-015]

Comments:

- shape analyses can (in principle) be more model-dependent (eg. can depend pair/single prod. and on chirality of the couplings)
- more complicated (sometimes impossible) to recast
- useful only if simplified model is general enough

What to do with multiple resonances?

Realistic models often predict **several relatively light resonances** (eg. 4-plet and singlet with comparable masses)

How can we treat them and combine the bounds?

- Use more **complete simplified models** which includes the relevant states and couplings

  [De Simone, Matsedonskyi, Rattazzi, Wulzer;
  Buchkremer, Cacciapaglia, Deandrea, Panizzi;
  Grojean, Matsedonskyi, G. P.; ...]

- Find a **statistical procedure** to combine the results.

Light generations partners: The singlet $\widetilde{U}$

Partners of the light quark families are sometimes required by the flavor structure (eg. MFV in composite models)

With only renormalizable interactions: $\widetilde{U} \longrightarrow jj$ or $\widetilde{U} \longrightarrow jjj$

[Redi, Sanz, de Vries, Weiler]

For a Goldstone Higgs higher-order interactions are present and the dominant channel is $\widetilde{U} \longrightarrow hj$

[Delaunay, Flacke, Gonzales-Fraile, Lee, G. P., Perez in preparation]

- **Important** to adopt a general parametrization (inspired by a complete model)
- Signals with $h + jets$ could be a good way to probe singlets

Lessons from gauge resonances

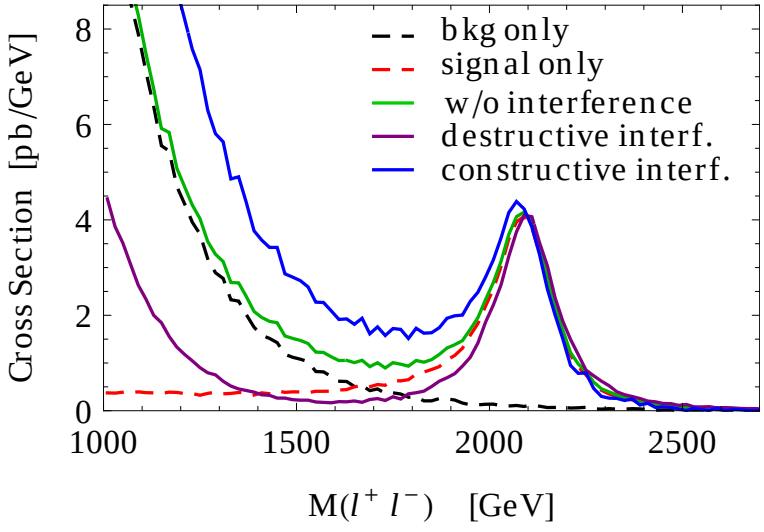
Search for an **heavy vector** decaying into leptons: $\rho \longrightarrow l^+ l^-$

ATLAS analysis based on a sequential Z' model [ATLAS-CONF-2013-017]

- Interference can drastically modify the shape of the signal away from the pick

  [Accomando, Becciolini et al.]

[Thamm, Torre, Wulzer in progress]



Analysis based on fit of the **whole shape**:

- Highly dependent on the model used
- Dramatic dependence on the sign of the interference

Lessons from gauge resonances

CMS analysis based on a shape fit with **cuts around the pick**

[CMS PAS EXO-12-061]

Signal parametrized with a narrow resonance with gaussian experimental smearing

- Model-independent parametrization

Possible **issues/improvements**:

- Not accurate if ρ width is larger than the experimental resolution
- Could be improved by considering non-zero width

Conclusions

Searches based on observables with **minimal model-dependence** have many appealing features

- can be directly applied to several scenarios
- can be simply recast

Searches based on **shape analysis** should be carefully handled

- can strongly depend on the model
- are mode complicated to recast
- useful if model is general enough