Status of the Write-up for Top-related Dark Matter Models

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Dark matter models coupled to the top quark and discovery potential at LHC

Abstract

This document presents different dark matter models that couple to the top quark, leading to monotop and same sign top pair production. The main ingredients of each models will be described, as well as the different assumptions and simplifications needed to derive a well defined collider phenomenology. The search strategy and the discovery potential at the LHC will be also discussed for each of these models.

N.B.: the models leading to ttbar + mET will be in a different part

Contents

Overview of the **models**
+
Model **simplifications** needed to define the collider signatures (with, when possible, some justifications)

To be removed or moved to appendix

Search strategy at the LHC

References

Theory / phenomenology

[1] J. Andrea, B. Fuks and F. Maltoni, *Monotops at the LHC*, Phys.Rev. **D84** (2011) 074025, arXiv: 1106.6199 [hep-ph].

[2] J.-L. Agram et al., *Monotop phenomenology at the Large Hadron Collider*, Phys.Rev. **D89**.1 (2014) 014028, arXiv: 1311.6478 [hep-ph].

[3] I. Boucheneb et al., *Revisiting monotop production at the LHC* (2014), arXiv: 1407.7529 [hep-ph].

[4] B. Fuks, *Monotop Effective Theory: MadGraph model*, http://feynrules.irmp.ucl.ac.be/wiki/Monotops.

Experimental searches

[5] *Search for a single-top quark produced in association with missing energy in proton-proton collisions at* $\sqrt{s}$ = 8 TeV *with the ATLAS detector*, Eur. Phys. J. C **75:79** (2015), arXiv: 1410.5404 [hep-ex].

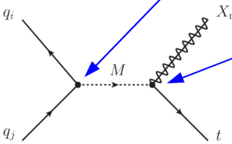
[6] *Search for new physics with monotop final states in pp collisions at* $\sqrt{s}$ = *8 TeV* (2014), URL: http://cds.cern.ch/record/1668115/.

[7] T. Aaltonen et al., *Search for a dark matter candidate produced in association with a single top quark in* $p\bar{p}$ *collisions at* $\sqrt{s}$ = *1.96 TeV*, Phys.Rev.Lett. **108** (2012) 201802, arXiv: 1202.5653 [hep-ex].

[8] *Analysis of events with b-jets and two leptons of the same charge or three leptons in pp collisions at* $\sqrt{s}$ = *8 TeV with the ATLAS detector*, Submitted to Eur. Phys. J. C (2015), arXiv: 1504.04605 [hep-ex].

Resonant model (Mediator=saclar field)

$$\mathcal{L}_{\text{int}} = d_i^C \left[\left(g^v_{\phi d}\right)^{ij} + \left(g^a_{\phi d}\right)^{ij} \gamma^5 \right] d_j \, \phi^{\pm} + u_k^C \left[\left(g^v_{u\chi}\right)^{k} + \left(g^a_{u\chi}\right)^{k} \gamma^5 \right] \chi \, \phi^{\pm}$$

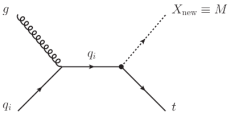


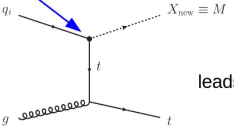
Here, the "mediator" has vertex involving SM particle and DM at the same time … This probably doesn't match the definition of a mediator, strictly speaking.

Montop model probably less relevant for the DM interpretation

Non-resonant model (Mediator=vectorial field)

$$\mathcal{L}_{\text{int}} = \bar{u}_i \left[\left(g^v_{Vu}\right)^{ij} \gamma^\mu + \left(g^a_{Vu}\right)^{ij} \gamma^5 \right] u_j \, V_\mu + \bar{\chi} \left[g^v_{Vu} \gamma^\mu + g^a_{V\chi} \gamma^5 \right] \chi \, V_\mu$$





Production of Top + Mediator
leads to montop when V decays into DM

Madgraph Model and parameters

Resonant model

1. Resonant scalar model described by the Lagrangian (1)
   - AQS and BQS: 3×3 matrices (flavour space) fixing the coupling of the scalar $\phi^{\pm}$ (S stands for scalar) and *down*-type quarks (Q stands for quarks), written in this note $g_{\phi u}$ or a^{q}_{res}.
   - A12S and B12S: 3×1 matrices (flavour space) fixing the coupling of the fermion χ (12 stands for spin-1/2 fermion) and *up*-type quarks, written in this note $g_{u\chi}$ or $a^{1/2}_{\text{res}}$.
   - particle name: the scalar $\phi^{\pm}$ is labelled S and the fermion χ is f_{met}

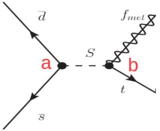
Non-resonant model

2. Non-resonant vectorial model described by the Lagrangian (3)
   - A1FC and B1FC: 3×3 matrices (flavour space) fixing the coupling of the vector V (1 stands for vector) and *up*-type quarks, written in this note g_{Vu} or $a_{\text{non-res}}$.
   - particle name: the vector V is labelled v_{met} and the fermion χ doesn't exist
   - the dark matter candidate χ is not implemented (this model assumes BR($V \to \chi\chi$) = 100%)

ATLAS / CMS comparison:

→ non-resonant model: they are on the same page (except a factor 2 in the constant definition, not hard to agree on this)

→ resonant model only: differences in the benchmarks interpretation:



Let's call a and b the 2 coupling constant:
- ATLAS: g=a=b, width and BR computed consistently
- CMS: g=a, BR[S->top+inv] is set at 100%

Need to clarify:

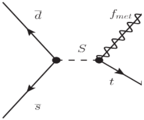
1. what is the total width CMS takes?

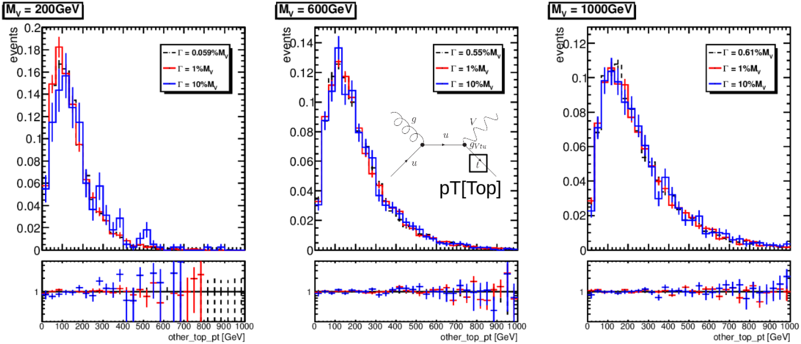
2. is the S width change the signature?

Is the mediator width impact the event kinematic?

→ No for the non-resonant model (plot below)

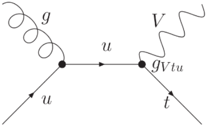
→ Was it checked for the resonant model? Because it could change!
And CMS and ATLAS treatment differs on this aspect.





A bit more on the following points (even if it's planned to remove them)

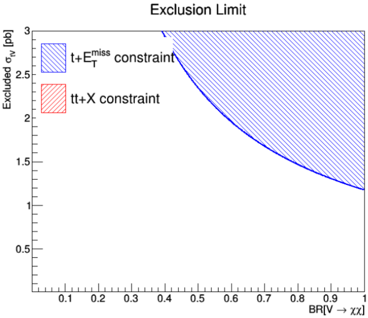
Production of tV (σ_{tV})



BR[V → χχ] = 100%

Monotop final state. Experimental search tells us: σ_{tV} > 1.2 pb

BR[V → χχ] < 100%
And **it MUST be** since V is produced via a Vtu vertex
(if not, no production of V ...)

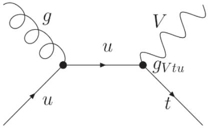


A bit more on the following points (even if it's planned to remove them)

2.1.2 $tt + X$ final state

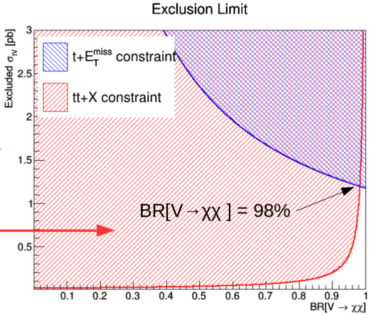
2.1.3 Combination of $tt + X$ and $t + E_T^{miss}$ analysis for the non-resonant production

Production of tV (σ_{tV})



BR[V→χχ] = 100%

Monotop final state. Experimental search tells us: σ_{tV} > 1.2 pb



BR[V→χχ] < 100%
And **it MUST be** since V is produced via a Vtu vertex
(if not, no production of V ...)

Consider the other main decay :
V → tu
Signature: same-sign top pair.
Experimental search tells us:
σ_{tV} > 0.010 pb
(SS dilepton very pure ...)

Summary and outlook

What was done: a certain amount of work about

- width effect on the signature
- the potential a visible decay of the mediator (actually quite powerful, but seems to be outside of the DMF scope)
- much more details and plots in the draft (loaded on this agenda)

Document in a good shape. To do:

- Move it in the DMF svn
- Still iterate to get an agreement between ATLAS and CMS on models

Signal sample generation To do:

- Put the proc and param card (common to ATLAS and CMS) in the DMF svn

BACKUP SLIDES