Monotop searches at the LHC

Giacomo Cacciapaglia

IPNL

(and thanks to Benjamin Fuks)

LHC Dark Matter WG public meeting

22 June 2016

Monotops at hadron colliders: the general case

✦ The bottom-up strategy: we start from the final state signature and build a model

✦ Allows us to simultaneously analyse several new physics models, e.g.,

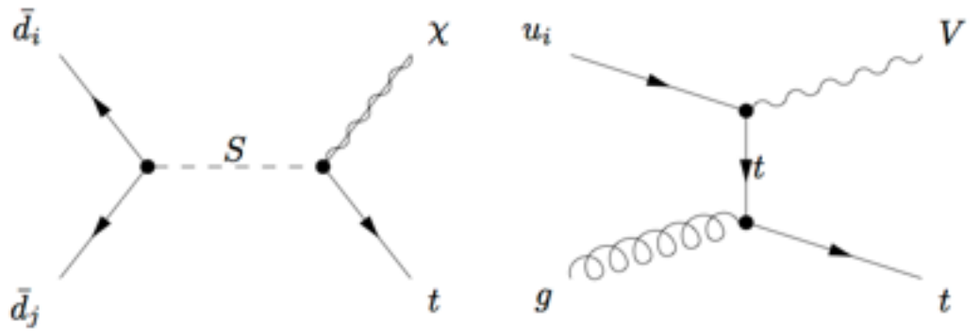
- ✤ Supersymmetric compressed spectrum: undetected soft objects
- ✤ Dark matter models with a mediator coupling to quarks in a flavour-violating way
- ✤ *etc.*

[Andrea, Fuks, Maltoni (PRD '11)]

✦ Generic monotop production

- ✤ Missing energy (long-lived state or mediator decaying to dark matter particles)
  - ★ Bosonic or fermionic state
  - ★ More complicated cases: n-particle state, cascade decays…
- ✤ Initial state: two possibilities
  - ★ A down-type (anti)quark pair → baryon-number-violating process
  - ★ An up-type quark / gluon associated pair → flavour-changing neutral interactions

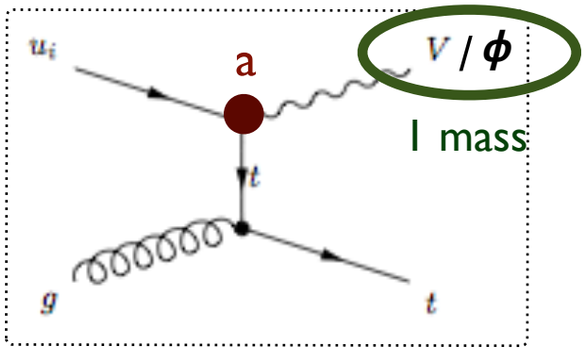
Two classes of models



V and chi are mediators, NOT dark matter!

Flavour-changing monotop production (1)

✦ Simplified model Lagrangian: $\mathcal{L} = \phi \bar{u} a^0_{FC} u + V_\mu \bar{u} a^1_{FC} \gamma^\mu u$



[Andrea, Fuks, Maltoni (PRD '11)]

✤ Two `*flavour-changing*' models

✤ V (ϕ) is the mediator and is connected to the dark sector (invisible decay)

✤ Three parameters for each model

★ The mediator mass and the couplings (left and right-handed)

✦ What about the electroweak symmetry?

[Boucheneb, Cacciapaglia, Deandrea, Fuks (JHEP '15)]

✤ We impose the monotop signal to be the most important way to probe the model

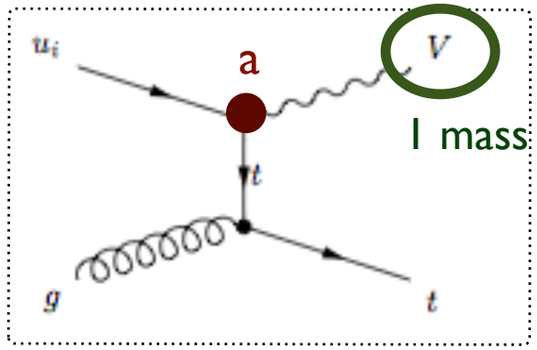
★ The mediator and is a vector state

★ It couples to the right-handed quarks only

$$\mathcal{L} = a^{ij}_R \, V_\mu \bar{u}_{R,i} \gamma^\mu u_{R,j}$$

✤ One single model and two parameters

✤ Other cases (scalar mediator, different couplings): New physics should appear in other channels first



Other cases predict different (more constraining) signatures!

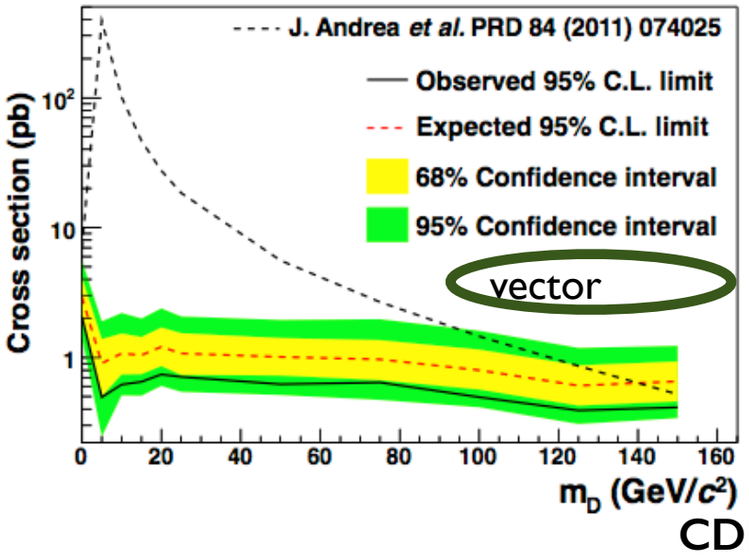
Flavour-changing monotop production (II)

[CDF (PRL '12)]
[CMS (PRL '15)]

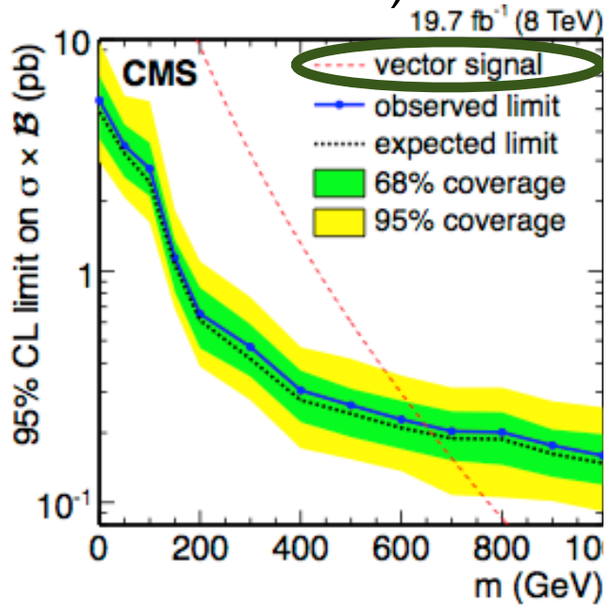
✦ Scenarios investigated by CDF and CMS:

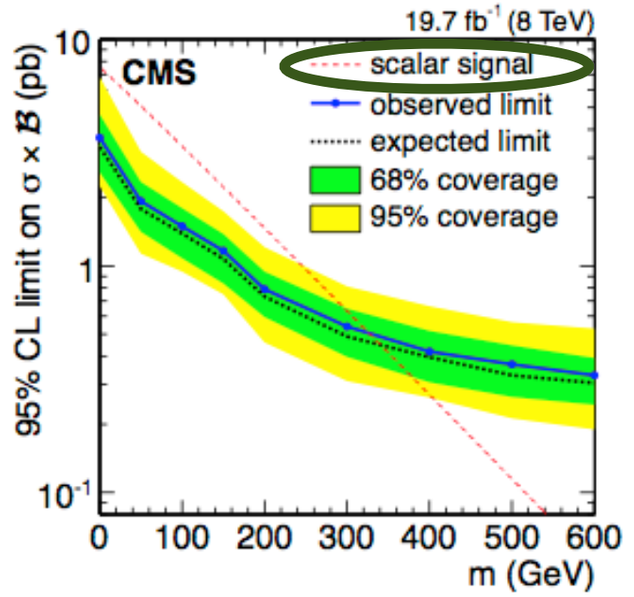
✤ The coupling is taken as a vector / scalar coupling and factorises

➢ one free parameter (the mediator mass)



CDF



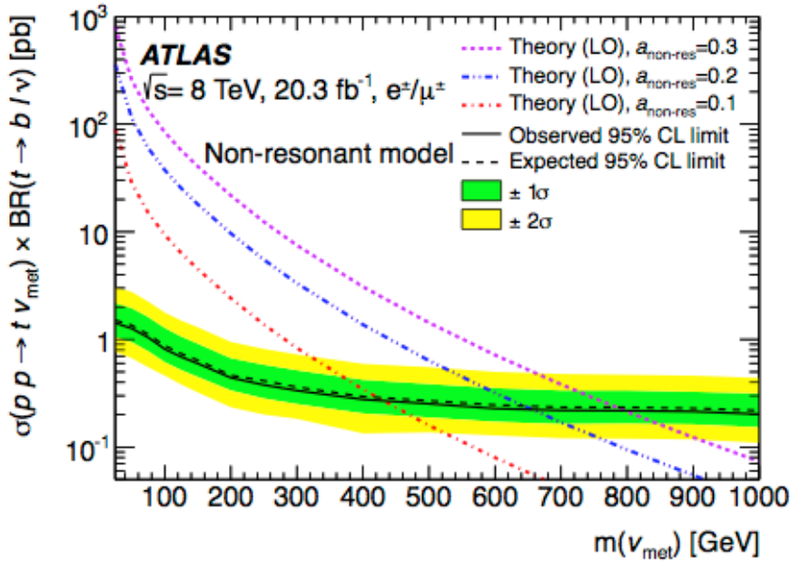


✦ Vector with RH couplings investigated by ATLAS

✤ Parameter space 2D-scans have been performed

Need for a unified scenario?
Easy to reinterpret!!!

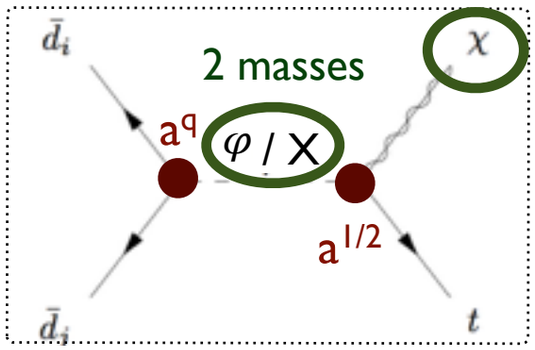
[ATLAS (EPJC '15)]



Resonant monotop production (1)

✦ Simplified model Lagrangian:

$$\mathcal{L} = \epsilon^{ijk}\varphi_i \bar{d}^c_j a^q_{SR} d_k + \varphi_i \bar{u}^i a^{1/2}_{SR}\chi \;\; + \epsilon^{ijk} X_{\mu,i}\; \bar{d}^c_j a^q_{VR}\gamma^\mu d_k + X_{\mu,i}\; \bar{u}^i a^{1/2}_{VR}\gamma^\mu \chi$$



[Andrea, Fuks, Maltoni (PRD '11)]

- ✤ Two `*resonant*' models
- ✤ The fermion χ is long-lived (but not stable) or connected to some dark sector
- ✤ 6 parameters for each model
  - ★ Two masses (resonance + invisible fermion)
  - ★ Four couplings (left and right-handed) if only one production channel is considered

✦ What about the electroweak symmetry? [Boucheneb, Cacciapaglia, Deandrea, Fuks (JHEP '15)]

- ✤ We impose the monotop probe to be the dominant way to test the model
  - ★ The resonance and is a scalar that couples to a pair of right-handed quarks
  - ★ The invisible fermion is a SM singlet and couples to right-handed tops
- ✤ 4 parameters (2 masses + 2 couplings)

$$\mathcal{L} = \lambda^{ij}_s\; \varphi_s\, \bar{d}^C_{R,i} d_{R,j} + y_s\; \varphi^\dagger_s\, \bar{\chi} t_R + \text{h.c.}$$

More simplifying assumptions needed!

Resonant monotop production (II)

✦ Strategy by ATLAS

✤ Scalar with RH couplings

✤ Simplification: λ = y; m^{φ} = 500 GeV

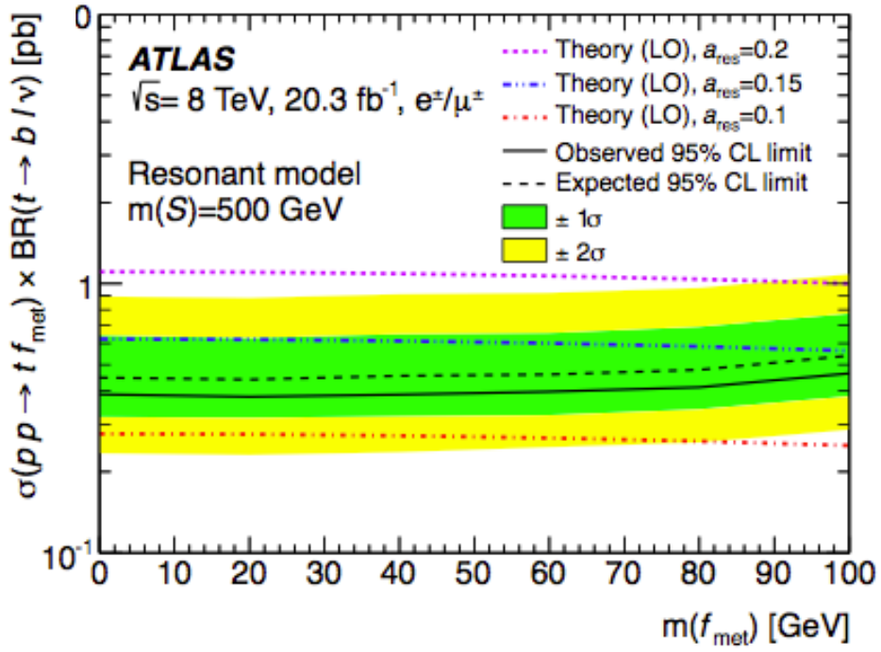
➢ 2 parameters: y and m^{χ}

✤ Not easy to reinterpret

★ Different resonance and invisible masses?

★ The resonance width must be calculated for each benchmark before comparing

[ATLAS (EPJC '15)]



✦Strategy by CMS

✤ Scalar (Vector)

★ The width tuned to 100% monotop

★ The a^q coupling is fixed to be of a scalar (vector)

✤ 2D mass plane to probe

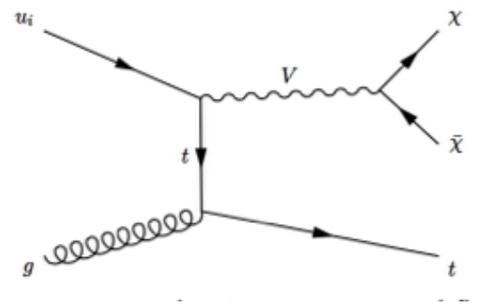
✤ Mostly easy to reinterpret (if the NWA holds)

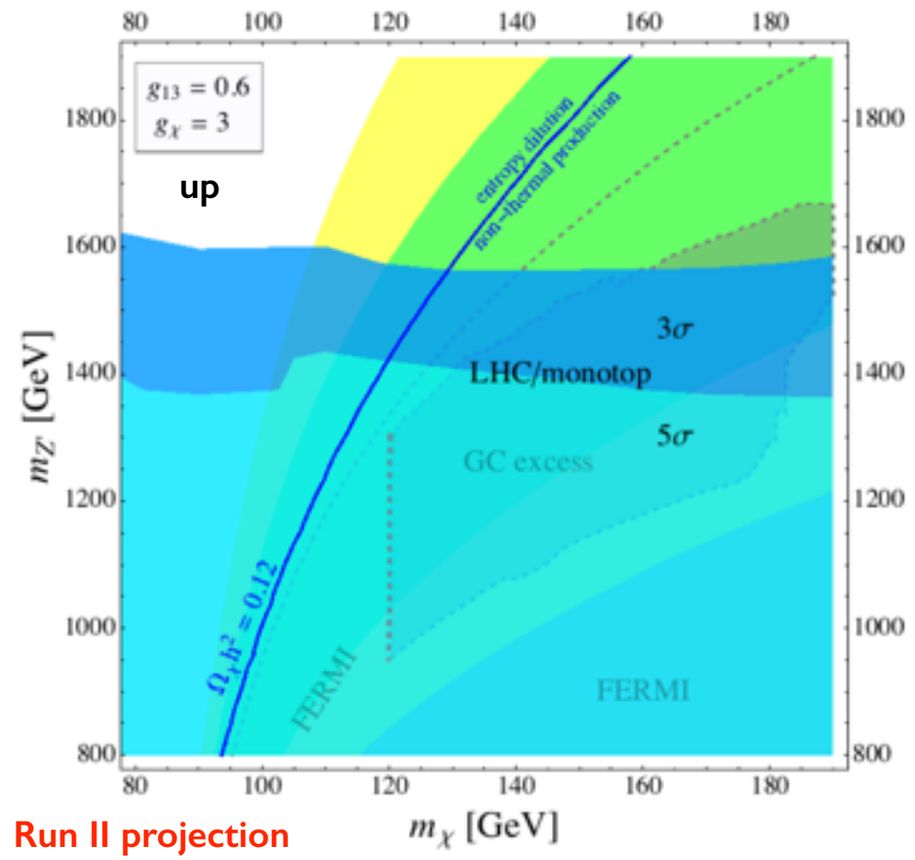
Is it still worthy pursuing?

Flavour-changing production can be directly connected to Dark Matter!

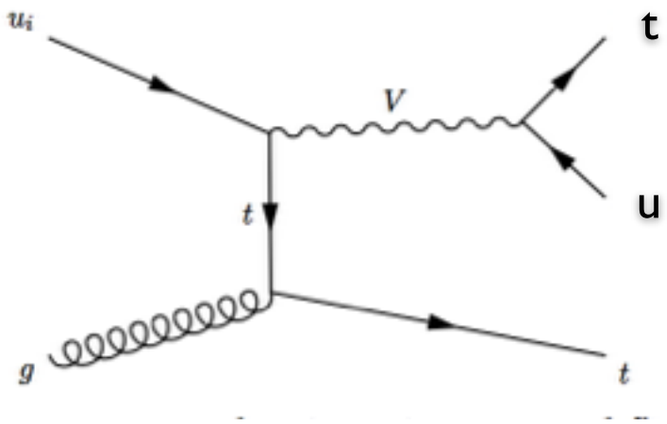
✤ Dark Matter search can provide complementary information

✤ Also, correlation to other signatures at the LHC should be explored!





Run II projection by the authors [d'Hondt, Mariotti, Mawatari, et al (JHEP '16)]



Strong bounds from same-sign tops if BR(V -> DM) < 99%!!

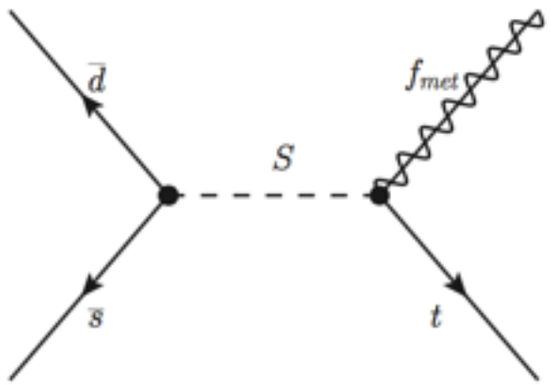
Talk by Romain Madar, previous DM working group meeting

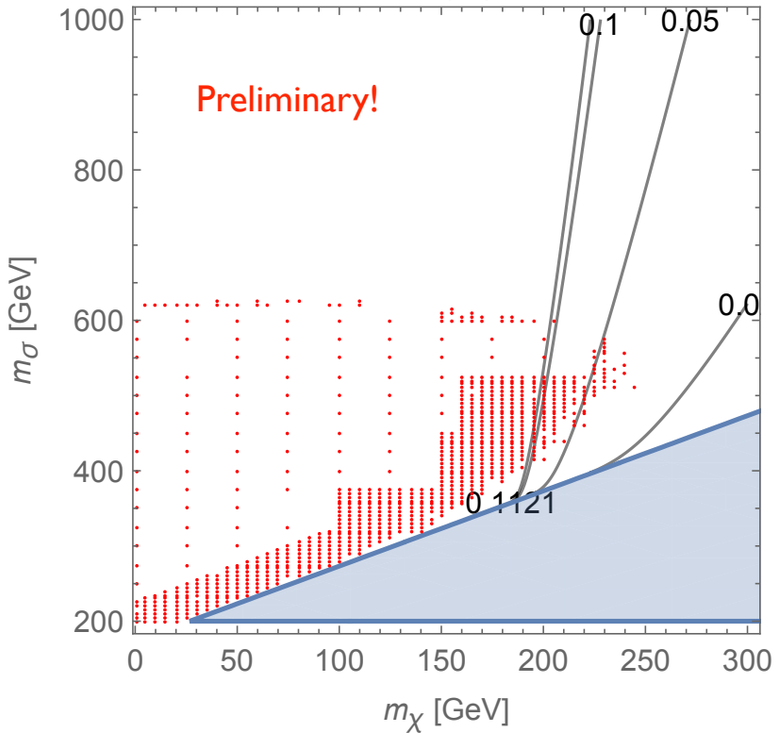
Is it still worthy pursuing?

Resonant production more similar to RPV SUSY!

✤ Other signatures at the LHC provide crucial information on the viability of the model.

✤ NLO@QCD implementation under preparation!





[Cacciapaglia, Fuks et al, in preparation]

Red points excluded by stop pair searches

Upper bound on lambda from f_{met} -> tds decays

Need to rethink experimental strategy!

Discussion

- Flavour-changing monotop production
  - Easy to recast (dependence on chirality?)
  - Still relevant for DM phenomenology (Is it?)

- Resonant monotop production
  - Define an optimal strategy for searches (too many parameters)
  - Is the param. space still open (vis a vis other signatures)?

⚠ **Discussion needed!**