Monotop searches at the LHC

Fuks Benjamin

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Monotops at hadron colliders: the general case

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

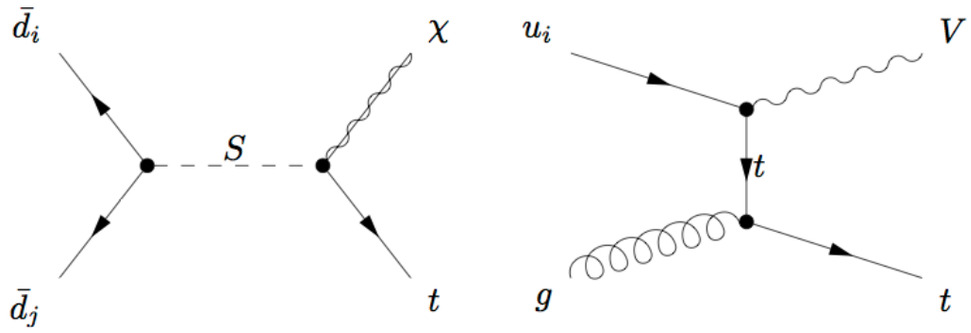
✦ Allows us to simultaneously analyze several new physics models, e.g.,

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

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

✦ Generic monotop production

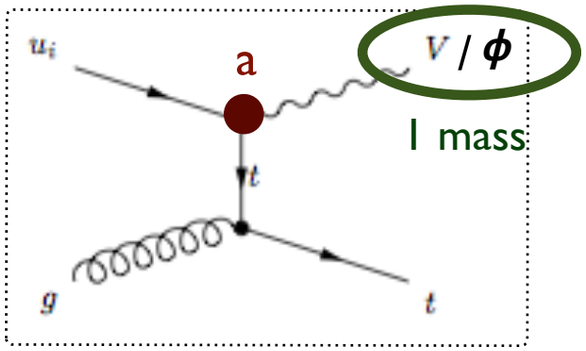
- ✤ Missing energy (dark matter candidate or mediator decaying to dark matter particles)
  - ★ Bosonic or fermonic state
  - ★ One-particle or n-particle state
  - ★ Neutral, weakly-interacting, long-lived/stable/invisible
- ✤ Initial state: two possibilities
  - ★ A down-type (anti)quark pair → baryon-number-violating process
  - ★ An up-type quark / gluon associated pair → flavor-changing neutral interactions



Two classes of models

Flavor-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, BF, Maltoni (PRD '11)]

✤ Two `*flavor-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)

✦ This class of scenarios has been investigated by CDF and CMS

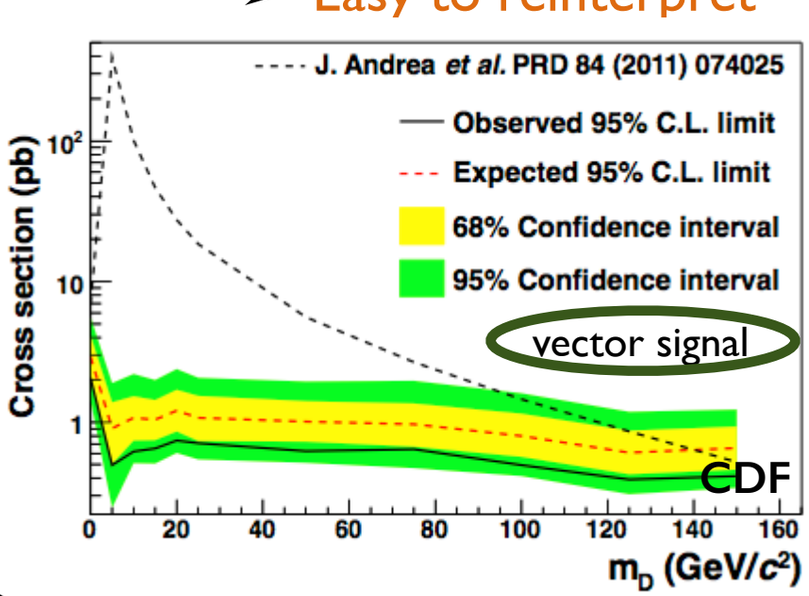
[CDF (PRL '12)]
[CMS (PRL '15)]

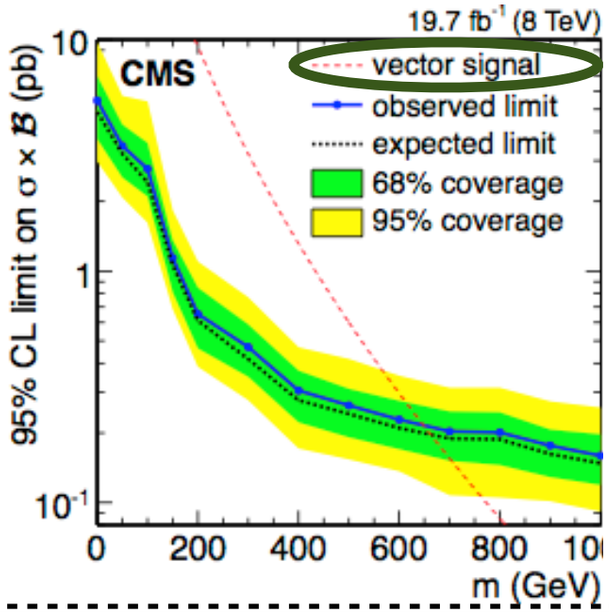
✤ The coupling is taken as a vector / scalar coupling and factorizes

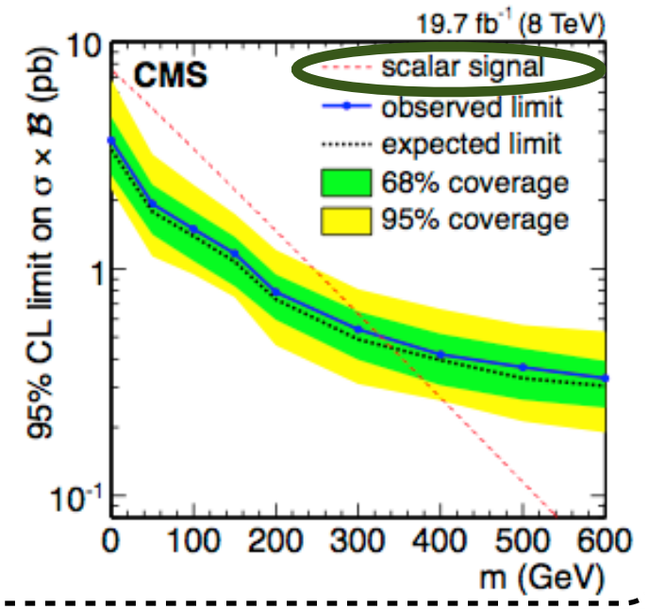
➢ one free parameter (the mediator mass)

✤ Limits given on the signal cross section for a given coupling strength

➢ Easy to reinterpret







Flavor-changing monotop production (2)

✦ What about the electroweak symmetry?

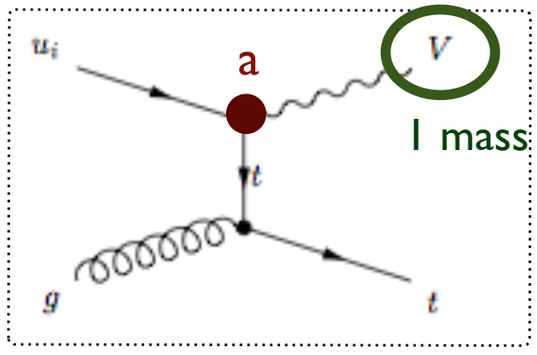
[Boucheneb, Cacciapaglia, Deandrea, BF (JHEP '15)]

✤ 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

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



✤ One single model and two parameters

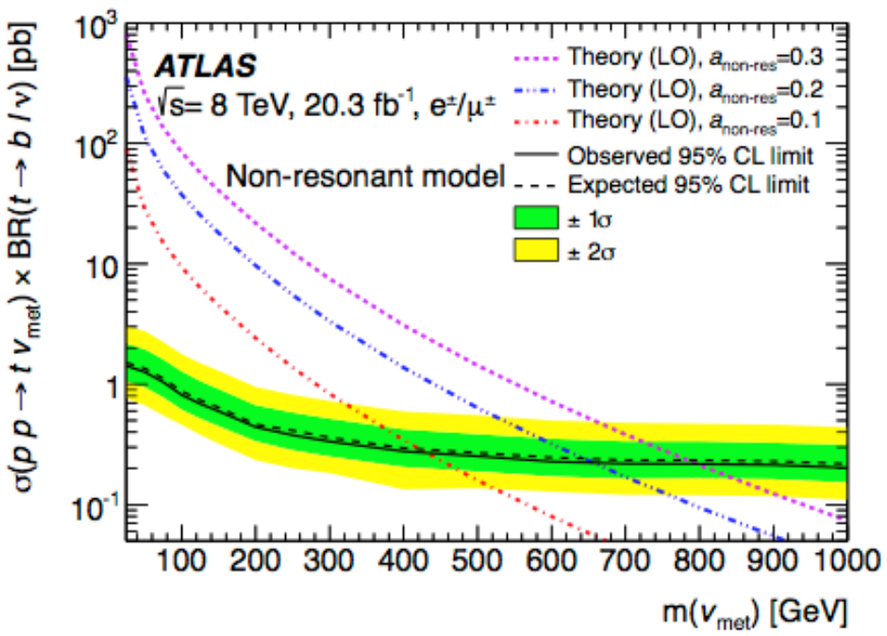
✤ Other cases (scalar mediator, different couplings): New physics should appear in other channels first

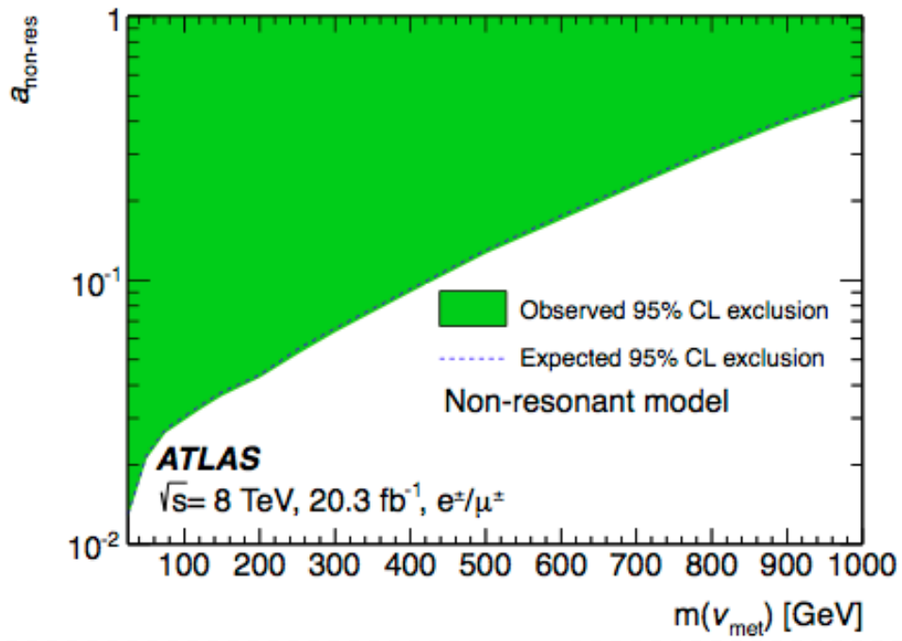
✦ This class of scenarios has been investigated by ATLAS

[ATLAS (EPJC '15)]

✤ Parameter space 2D-scans have been performed

✤ Easy to reinterpret

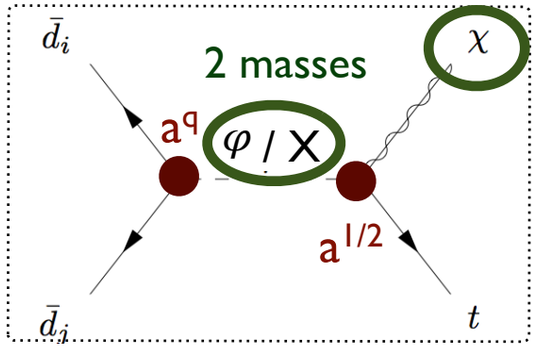




Resonant monotop production (1)

✦ Simplified model Lagrangian:

$$\mathcal{L} = \epsilon^{ijk}\varphi_i \bar{d}_j^c a_{SR}^q d_k + \varphi_i \bar{u}^i a_{SR}^{1/2}\chi \;\; + \epsilon^{ijk} X_{\mu,i}\; \bar{d}_j^c a_{VR}^q \gamma^\mu d_k + X_{\mu,i}\; \bar{u}^i a_{VR}^{1/2}\gamma^\mu \chi$$



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

- ✤ Two `*resonant*' models
- ✤ Not really connected to dark matter
  - ★ Less minimal models however exist (e.g., hylogenesis) [Davoudiasl *et al.* (IJMPA'12)]
- ✤ 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

✦ This class of scenarios is being investigated by CMS (analysis not public)

- ✤ The model must be simplified
  - ★ The width of the resonance is tuned so that the monotop branching is 1 (the $a^{1/2}$ parameters are not relevant anymore)
  - ★ The a^q coupling is fixed to be of a scalar (vector) type (and factorizes)
- ✤ 2D mass plane to probe
- ✤ Mostly easy to reinterpret (if the NWA holds)

Resonant monotop production (2)

✦ What about the electroweak symmetry?

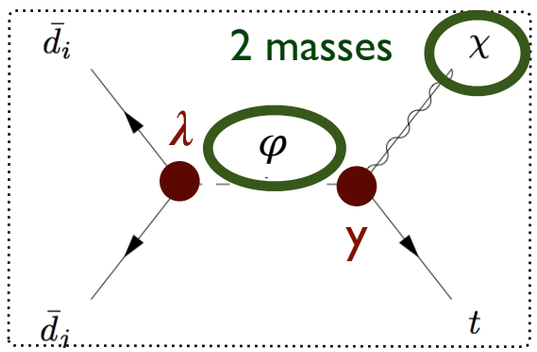
[Boucheneb, Cacciapaglia, Deandrea, BF (JHEP '15)]

✤ 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 quarks

$$\mathcal{L} = \lambda_s^{ij}\ \varphi_s\, \bar{d}^C_{R,i} d_{R,j} + y_s\ \varphi_s^\dagger\, \bar{\chi} t_R + \text{h.c.}$$



✤ One single model and four parameters

★ Two masses (resonance + invisible fermion)

★ Two coupling strengths

✦ This class of scenarios has been investigated by ATLAS

[ATLAS (EPJC '15)]

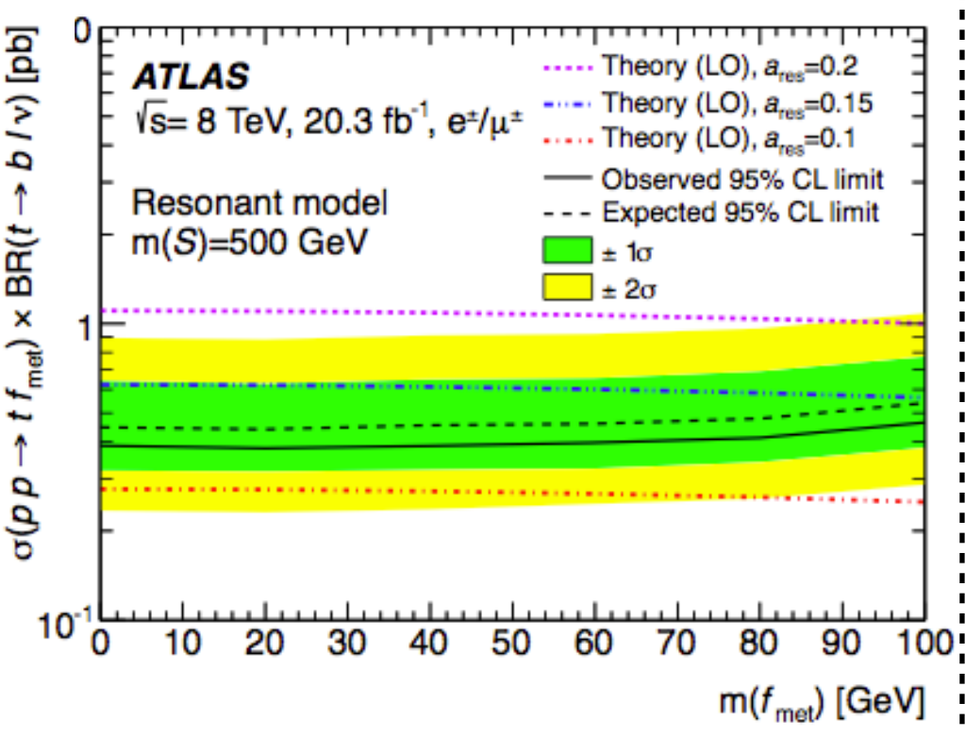
✤ Simplification: λ = y; m_φ = 500 GeV

➢ 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



Summary

✦ Flavor-changing monotop production

Fits in the DM context

- ✤ CMS: SU(3) x U(1) based model
  - ★ Vector (or scalar) mediator with vector (or scalar) couplings to the quarks
  - ★ Several models, simplified ➢ one relevant parameter for each model
- ✤ ATLAS: SU(3) x SU(2)xU(1) based model
  - ★ Vector mediator couplings to the right-handed quarks
  - ★ One relevant parameter
- ✤ Both approaches easy to reinterpret by theorists

✅ **Nothing to be changed (?)**

✦ Resonant monotop production

Fits more hardly in the DM context

- ✤ CMS: SU(3) x U(1) based model
  - ★ Vector (or scalar) resonance with vector (or scalar) couplings
  - ★ The BR of the resonance into a monotop system is 1
  - ★ Several models, simplified ➢ two relevant mass parameters for each model
- ✤ ATLAS: SU(3) x SU(2)xU(1) based model
  - ★ Scalar resonance (with a fixed mass) with right-handed couplings taken equal
  - ★ The resonance width must be calculated for each scenario
  - ★ Two parameters
- ✤ ATLAS configuration not easy to reinterpret (resonance mass and width issues)

⚠ **Discussions needed!**