How to Probe a Dark Matter Model with Monotop and Same Sign Top final state?

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Introduction

Context: Search for monotop final state allows to constrain a pretty generic dark matter model (DM candidate χ + interaction with SM fields via V_μ)

$$\begin{aligned}\mathcal{L}_{\text{NP}} &= \mathcal{L}_{\text{kin}}\left[\chi, V_\mu\right] \\ &+ a_R\, V_\mu\, \bar{t}_R \gamma^\mu u_R \;+\; a_L\, V_\mu \left(\bar{t}_L \gamma^\mu u_L + \bar{b}_L \gamma^\mu d_L\right) \\ &+ V_\mu \left(g_{R\chi}\, \bar{\chi}_R \gamma_\mu \chi_R \;+\; g_{L\chi}\, \bar{\chi}_L \gamma_\mu \chi_L\right) \end{aligned} \tag{1}$$

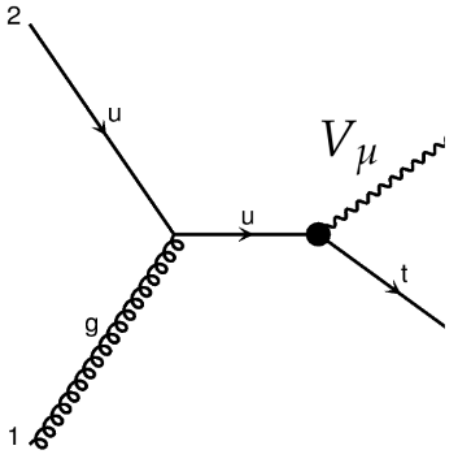
Underlying ingredients of the model:

- relies on an effective theory on which $SU(2)_L \times U(1)$ was imposed
- couplings are such the production can occur at hadron colliders
- should induce monotop final state (justifying Vtu vertex)

References:

- ATLAS Monotop search: http://arxiv.org/abs/1410.5404
- Theory pre-print: http://arxiv.org/abs/1407.7529

Why Same Sign Top Production ?



Monotop assumes that BR [V→χχ] = 100%
But V→tū + t̄u is also possible: visible in SS dilepton analysis

$$\Gamma(V\to\chi\chi)=\frac{m_V}{24\pi}\sqrt{1-4\frac{m_\chi^2}{m_V^2}}\left[\left(|g_{L\chi}|^2+|g_{R\chi}|^2\right)\left(1-\frac{m_\chi^2}{m_V^2}\right)+\frac{6m_\chi^2}{m_V^2}\Re\{g_{L\chi}g_{R\chi}^*\}\right]$$

$$\Gamma(V\to t\bar{u}+\bar{t}u)=\frac{m_V}{4\pi}\left(|a_R|^2+|a_L|^2\right)\left(1-\frac{m_t^2}{m_V^2}\right)\left(1-\frac{m_t^2}{2m_V^2}-\frac{m_t^4}{2m_V^4}\right)$$

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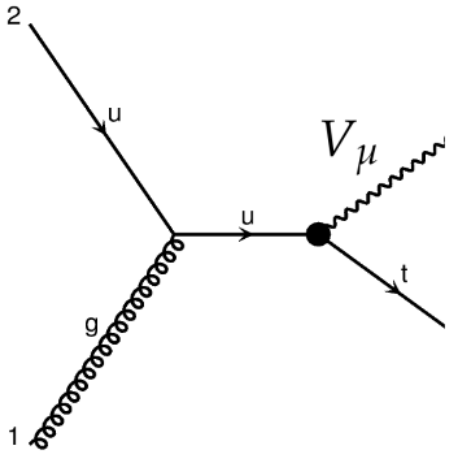

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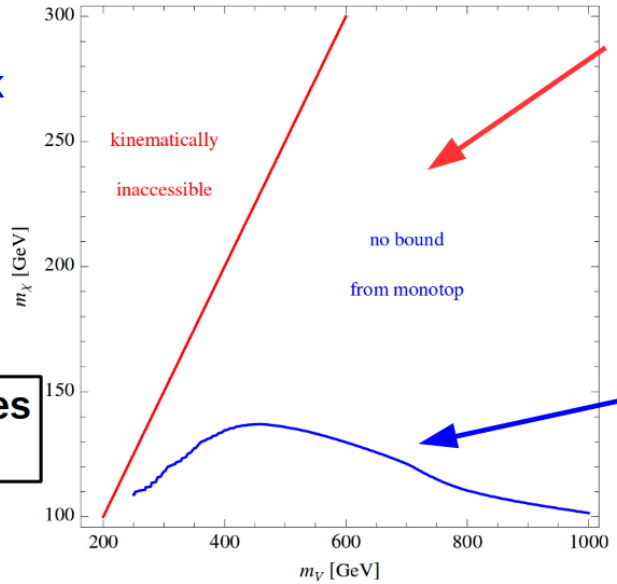
The product BR[V → χχ] x BR[V → tū + t̄u] is constrained by the relic density of dark matter in the universe, through the DM annihilation process :

$$\chi\chi \to V \to t\bar{u} \text{ and } \bar{t}u$$

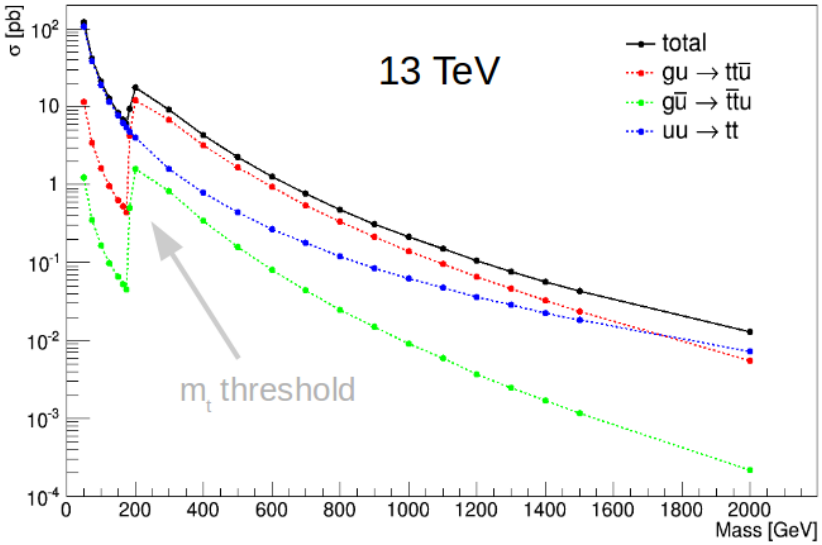
Nice interplay between 2 exotic analyses and cosmological constraints

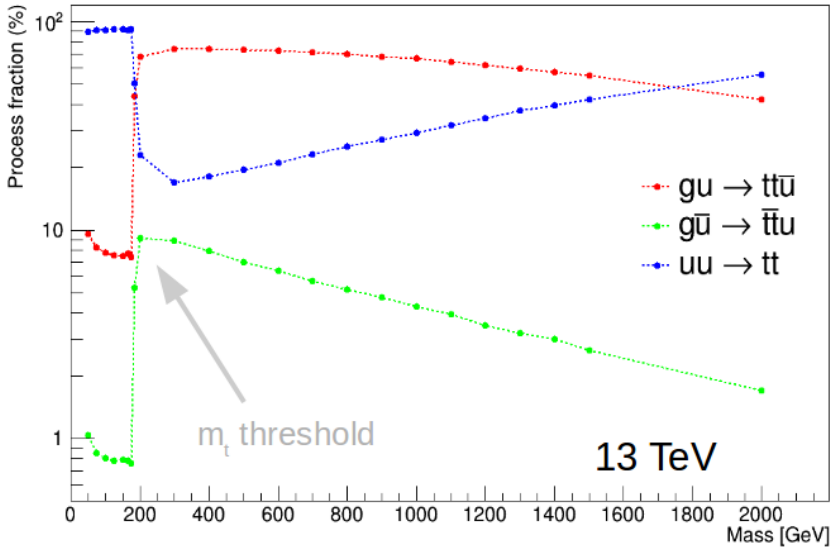


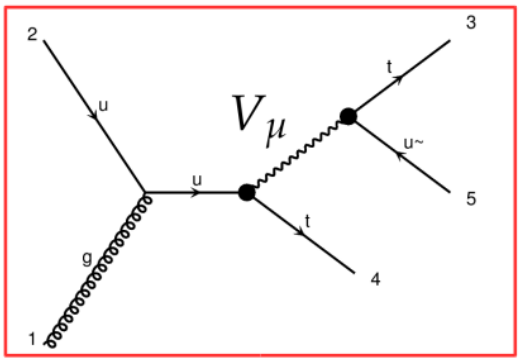
Possible to cover with SS analysis

Monotop CMS results, interpreted to constraint DM

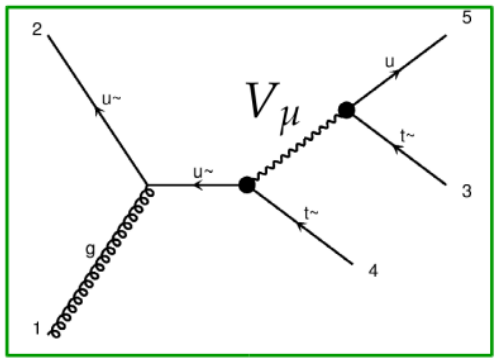
Relevant processes and cross-sections



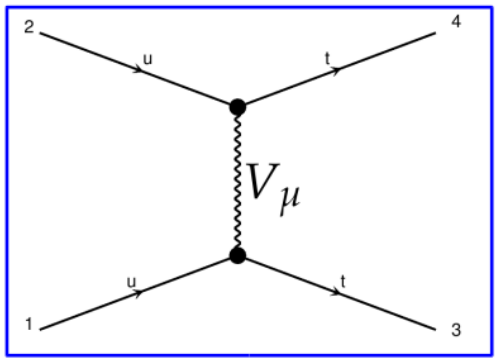




Valence quark
needs $m_V > m_t$



see quark
needs $m_V > m_t$



t-channel,
virtual V

Signal / background (naive) comparison

Generation at LO with MG5_MC@NLO → PS and hardonization with Pyhia8 → Production of the *truth* ATLAS tree

- sqrt(s) = 13 TeV
- N[evts] = 5000
- PDF set: NNPDF23 LO
- μ_R & μ_F computed in MG

Top decays are done in Pythia

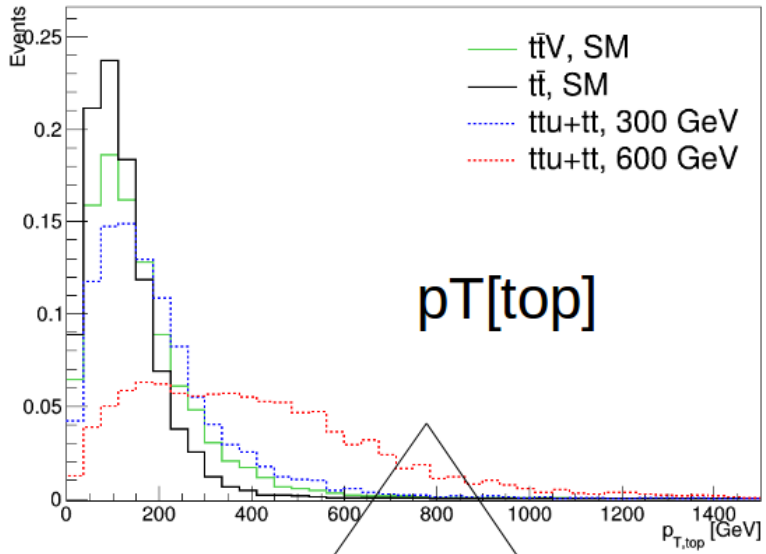
Event selection : no selection

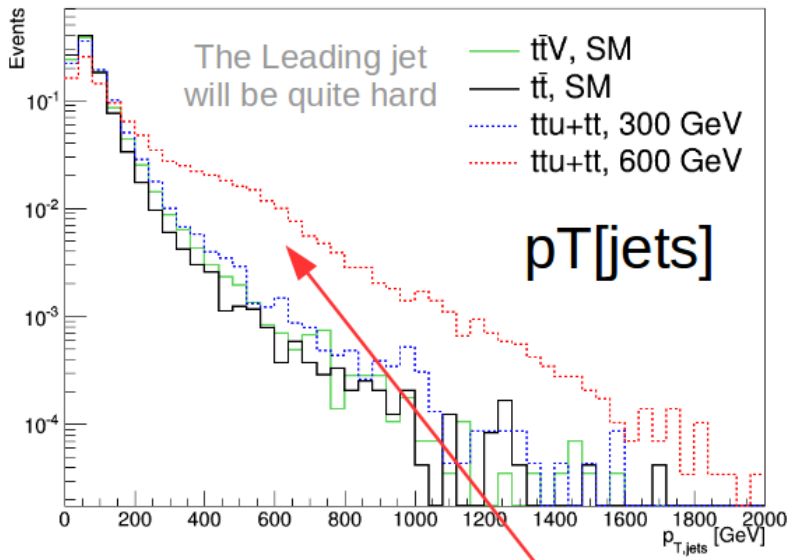
Object selection :
– *Kinematic*: p_T[lep/jets] > 25 GeV, | η [lep/jets] | < 2.5
– *Overlap removal*: only jets which are not electrons are kept
- if dR(e,jet)<0.2 →the jet is disregarded (except if this is a b-jet, due to HF decay)
– *Isolation*:
- if dR(μ,j) < 0.04 + 10/pT[μ] → the muon is not isolated, disregarded
- if dR(e,j) < 0.4 → the electron is not isolated, disregarded

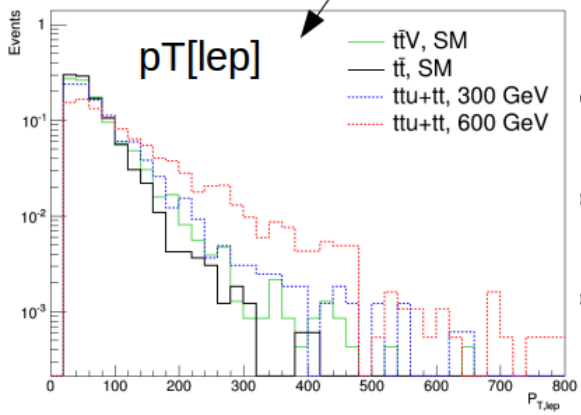
Comments:

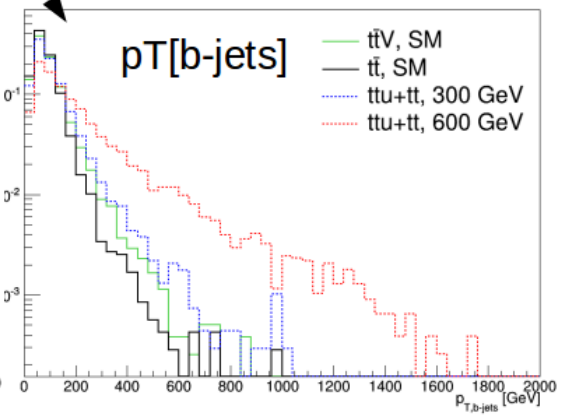
- this comparison is very naive: LO calculations, no detector effects
- Main backgrounds: $t\bar{t}$ (with charge mis-reconstruction), $t\bar{t} + V$
- the V_μ width is not computed properly (affect distributions, not the previous xsections)

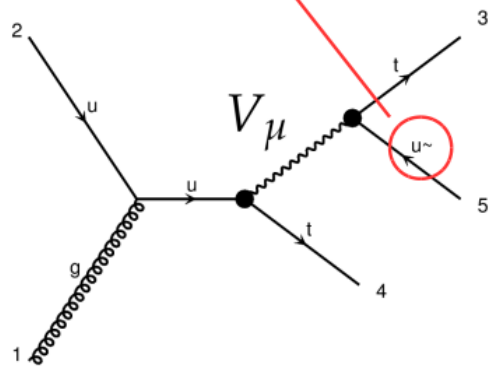
Typical signature



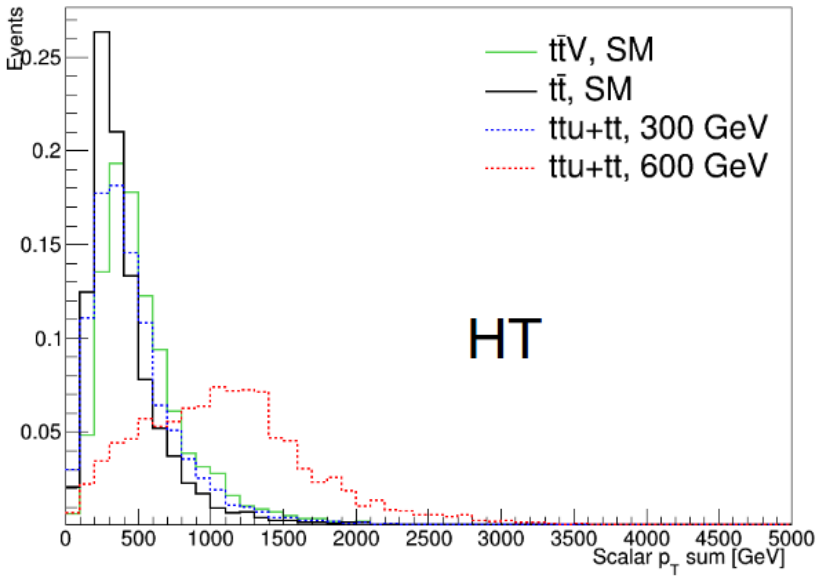


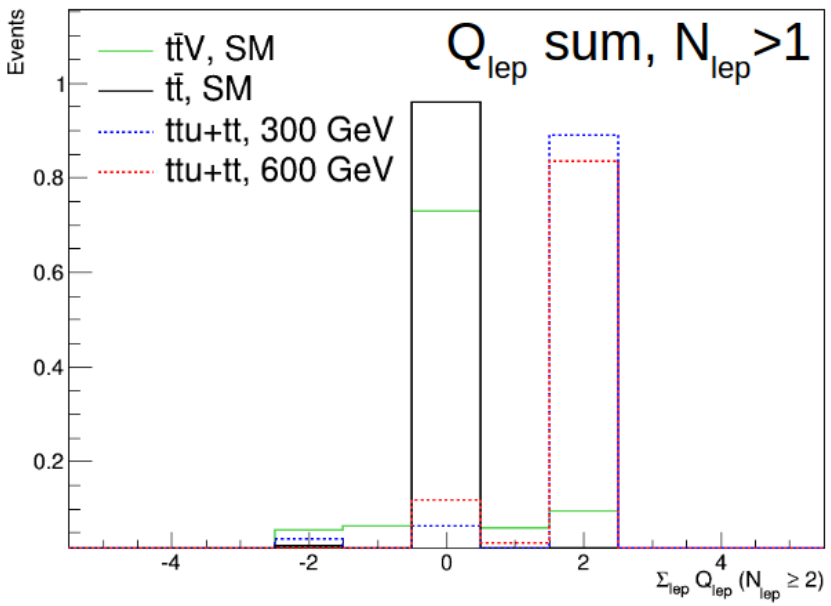






Typical signature





Questions:

- Why there are some signal events with $\Sigma Q_\ell = 0$? Investigating ...

Comments:

- Main signatures are charge of leptons, object momentum
- Since t and $\bar{u}$ are boosted, $\Delta\phi(\ell, j)$ should be interesting
- Interesting signature tt + high p_T jet (new(?) phase-space region).

Summary and Proposal

General comment:
It is important to probe new models, but as experimentalist, this is even more important to look at data in new phase-space regions

Search for same sign top pair production:

- (Only) positive same sign leptons (less activity than in $t\bar{t}t\bar{t}$ events)
- Interesting because sensitive to FCNC (in particular $t - u$ coupling)
- Models: 2HDM (type III), contact int., RPV-SUSY, colored scalar ...

Interplay between SS top, monotop, cosmology:

- Combine monotop and SS top: probes scenario where $\mathcal{BR}_{V\to\chi\chi} < 1.0$
- Potential to add cosmological constaints on $\mathcal{BR}_{V\to\chi\chi} \times \mathcal{BR}_{V\to tu}$
- $V \to tu$ signature leads to tt + high momentum jet: interesting (new?) phase-space corner