Searching for Dark Matter in top quark production with the CMS experiment

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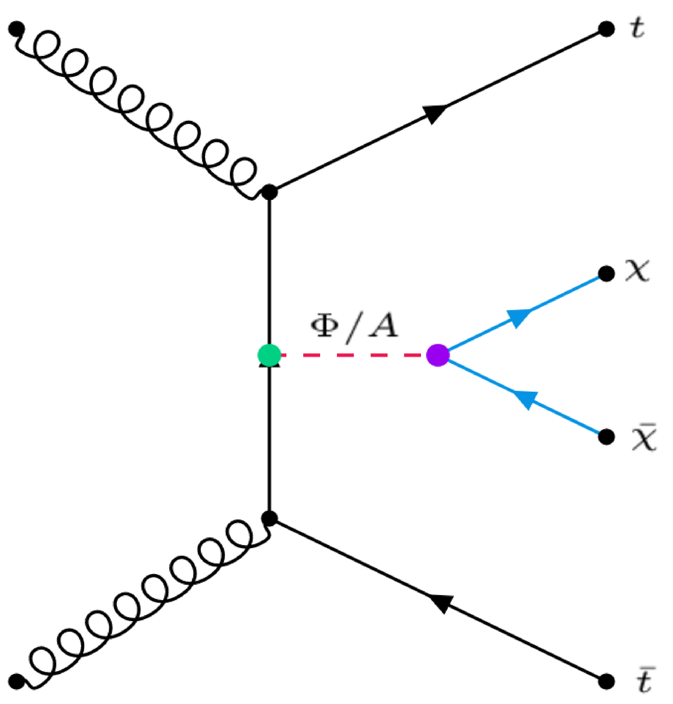
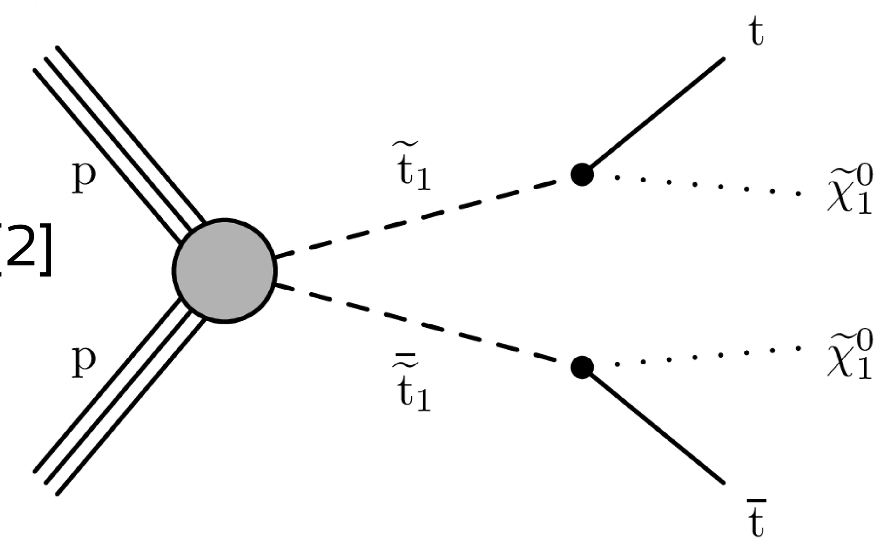
Motivation

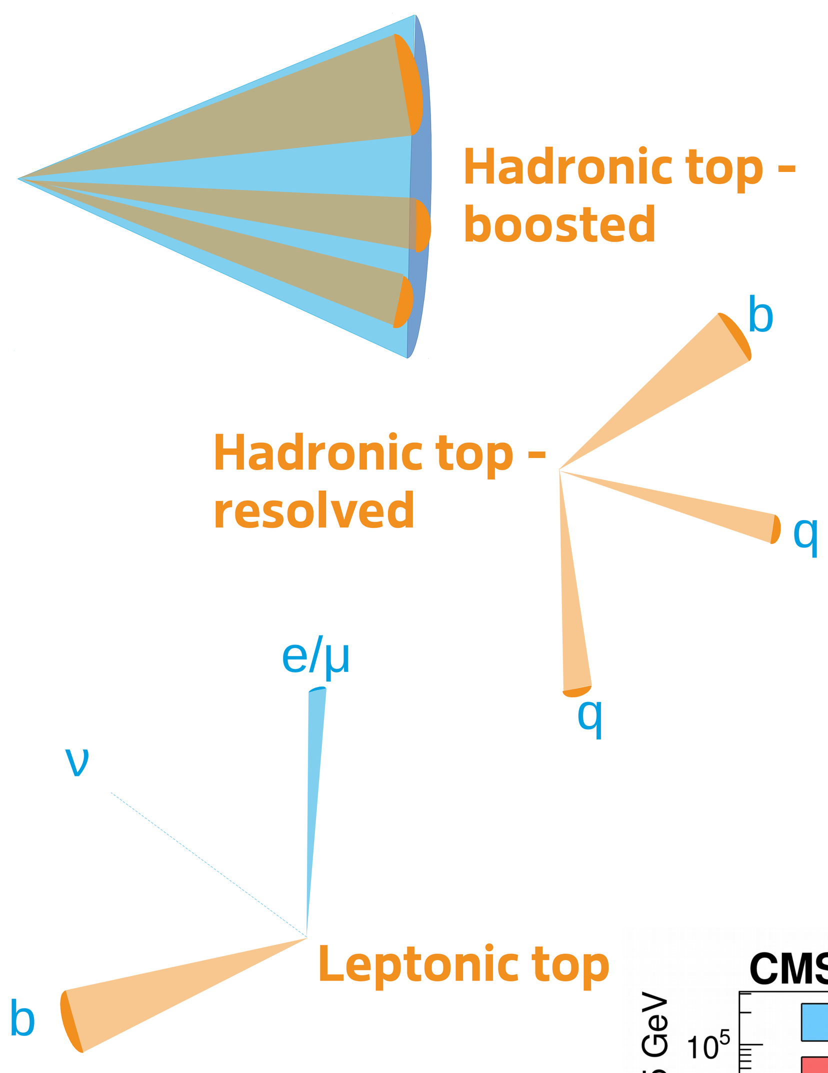
- Cosmology suggests Dark Matter (DM) may couple to the Standard Model (SM) around the weak scale
- Search for spin-0 mediator with Yukawa coupling => large coupling to top quarks
- Interactions described by simplified Lagrangians [1] (e.g. for scalar mediator):



$$\mathcal{L}_\phi \supset -g_\chi \phi \bar{\chi}\chi - \frac{\phi}{2} \sum_{q=u,d,s,c,b,t} g_q y_q \bar{q} q - \frac{1}{2} m_\phi^2 |\phi|^2 - m_\chi |\chi|^2$$

- Very similar final state to stop production in MSSM [2]
- Can also probe SM Higgs invisible decays

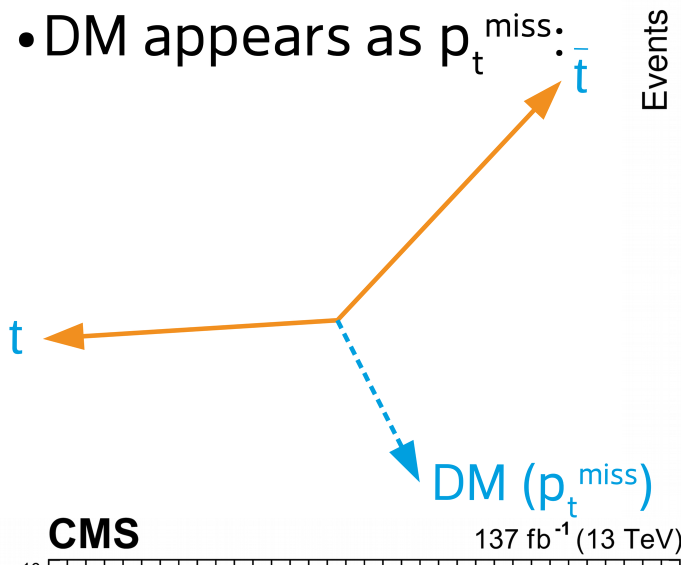


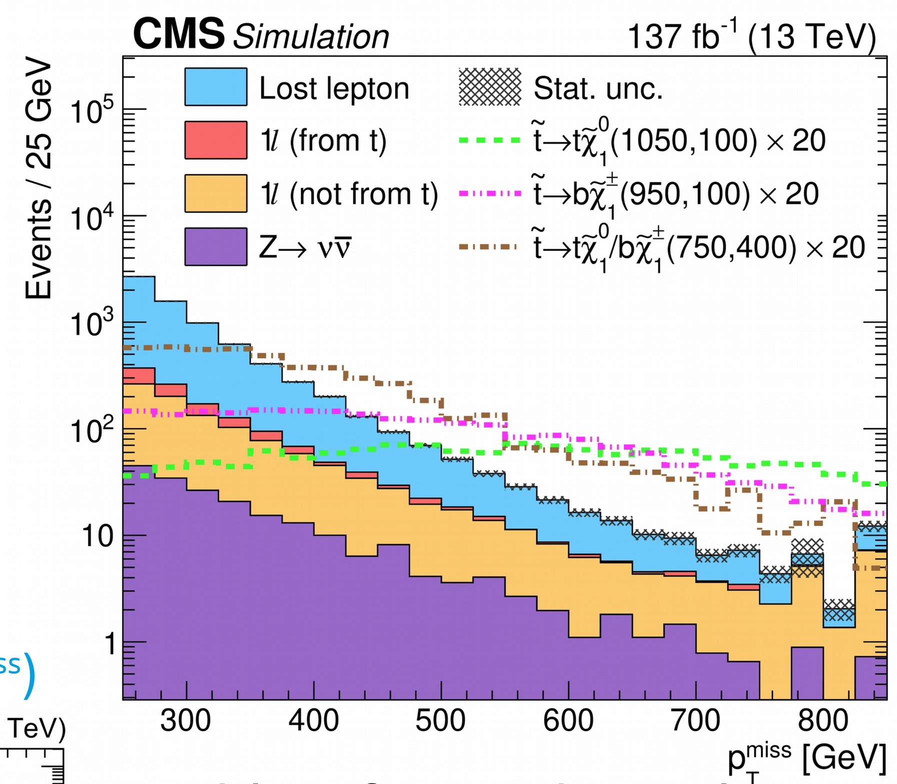


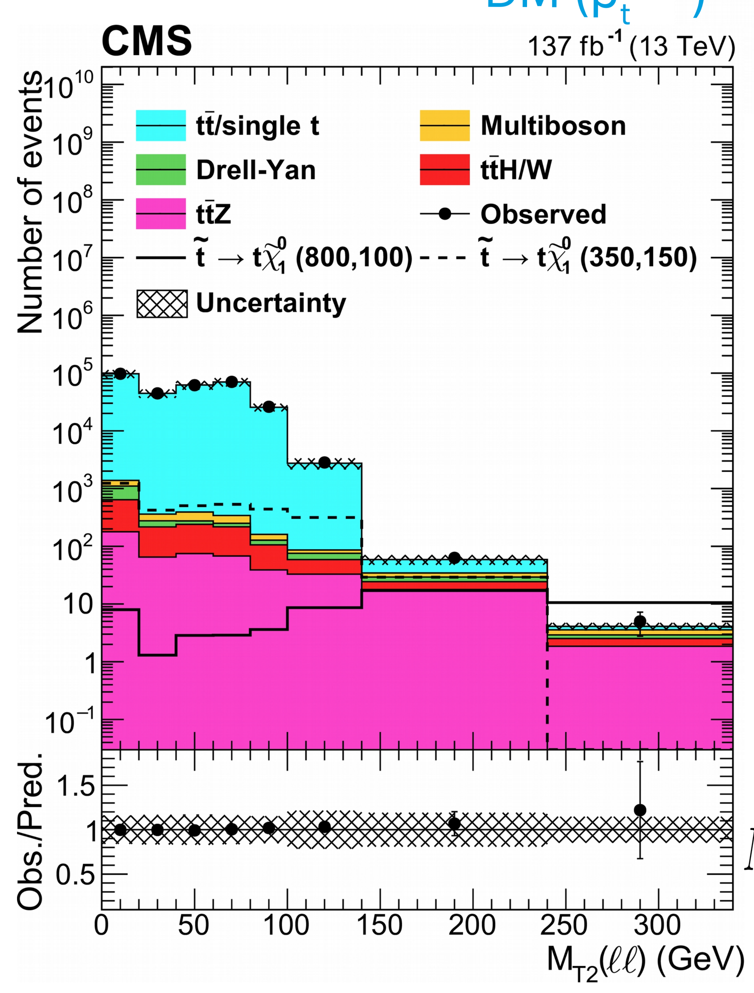
Analysis strategy

- Split into channels based on decay of top quarks: dileptonic (DL) [3], semileptonic (SL) [4] and all hadronic (AH) [5]
- Basic selection requires large p_t^{miss} + decay products from tops
- Background rates measured in dedicated control regions

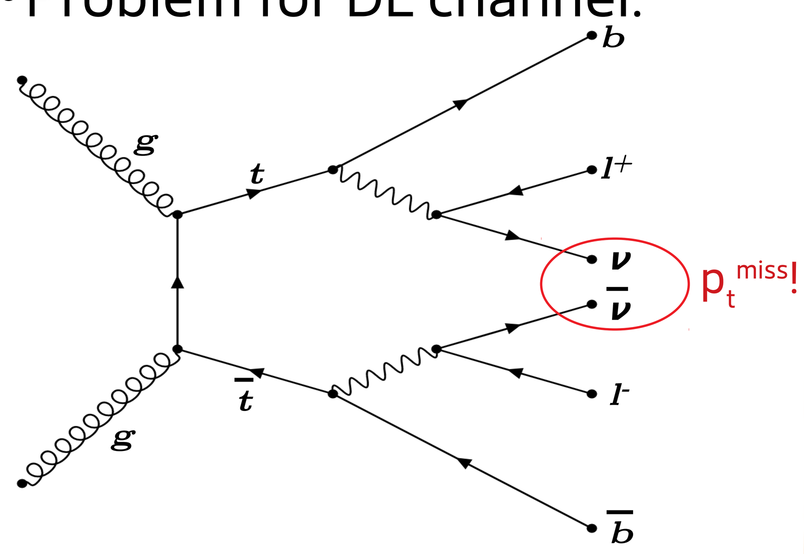
- DM appears as p_t^{miss}:







- Problem for DL channel:



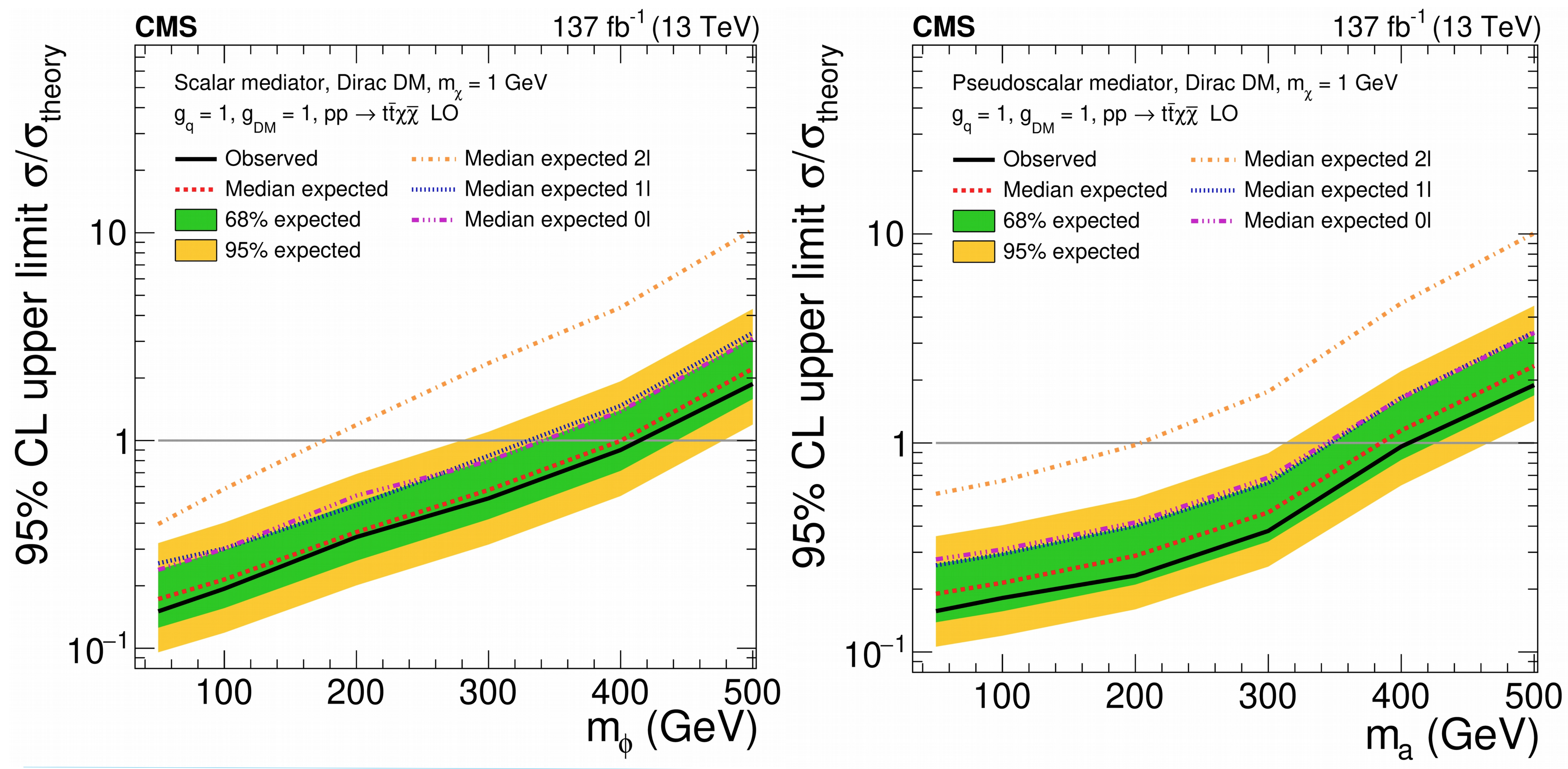
- Solution:

$$M_{T2}(ll) = \min_{q_1+q_2=p_T} \left[\max(m_T(p_{l1}, q_1), m_T(p_{l2}, q_2))\right]$$

- Has W boson mass as an upper bound for SM $t\bar{t}$

Results

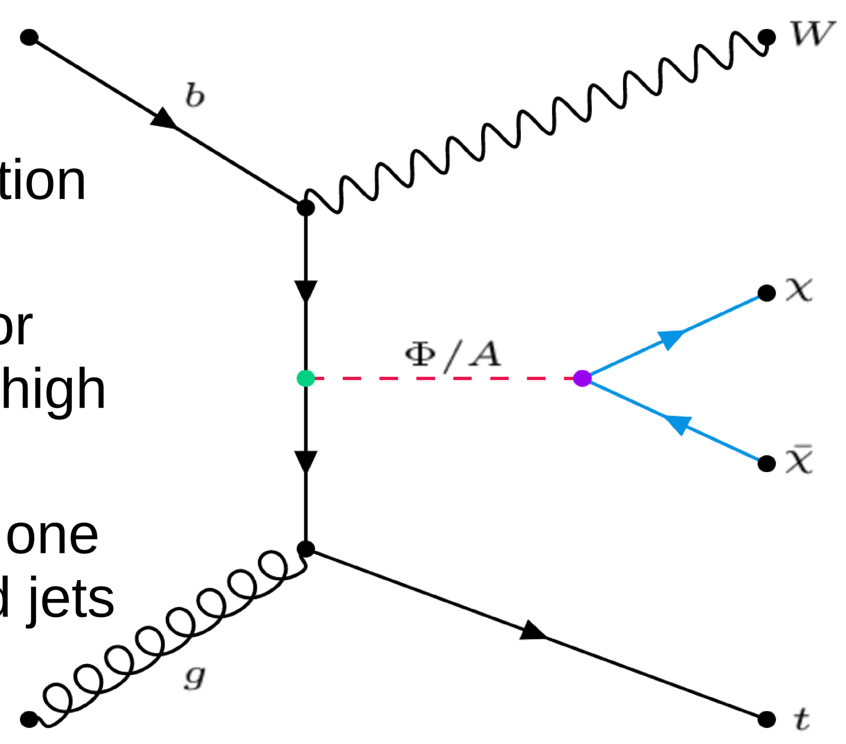
- Limits set on scalar (left) and pseudoscalar (right) mediator hypotheses for $g_q = q_\chi = 1$
- Limits independent of m_χ for $m_\chi < m_{\phi/a}/2$

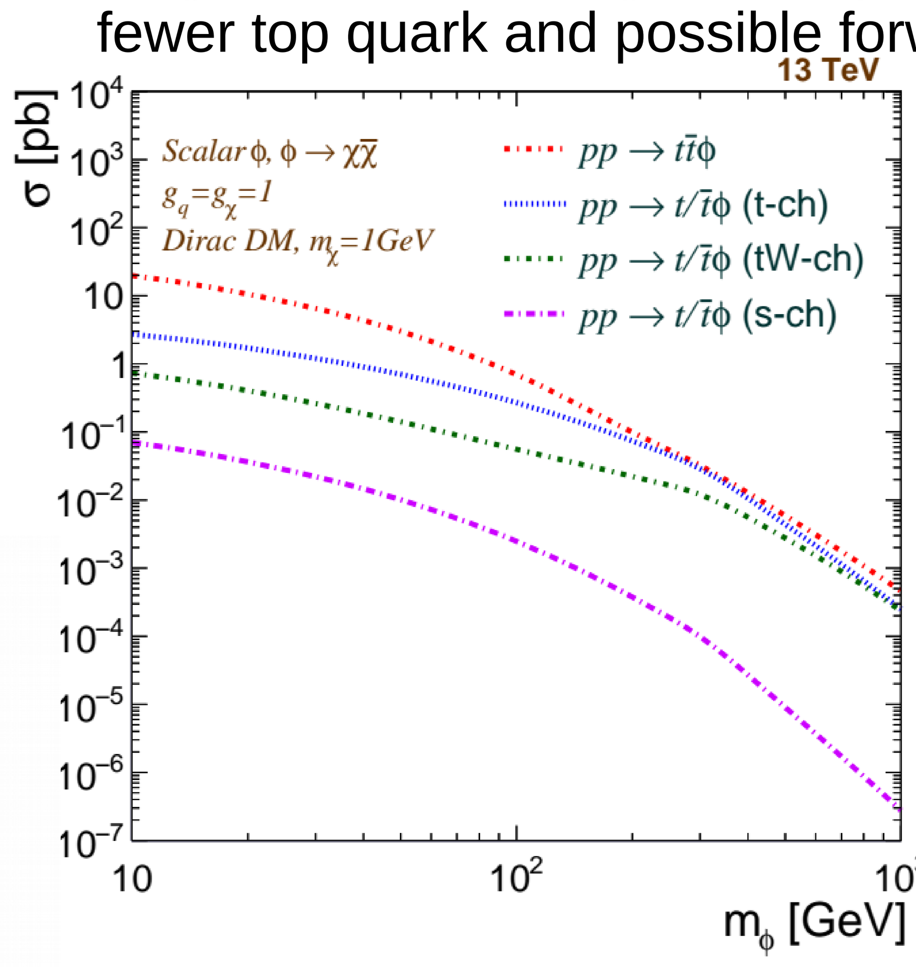


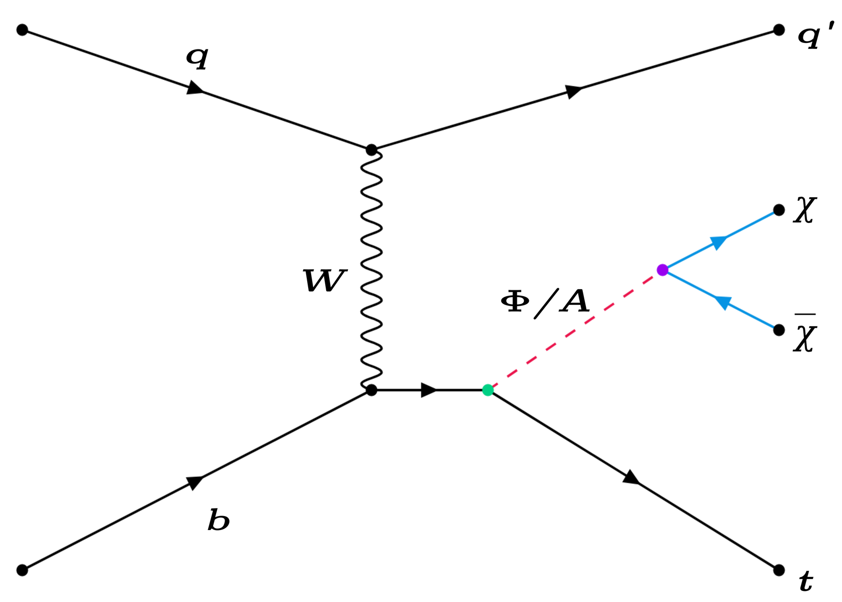
Future Plans

Single top + DM

- DM can also be produced in association with a single top quark
- Cross-section generally lower than for $t\bar{t}$+DM, but becomes comparable for high mediator masses [6]
- Target with new categories requiring one fewer top quark and possible forward jets







Neural Networks

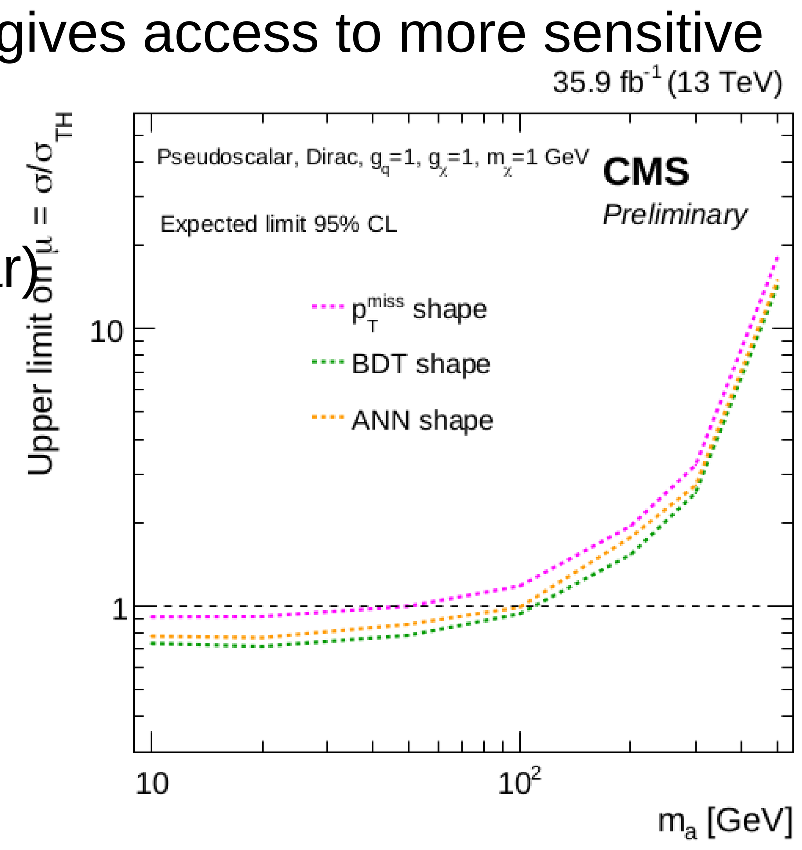
- DL channel usually gives weakest limits due to low branching ratio and high SM $t\bar{t}$ background
- However "clean" 2 lepton final state gives access to more sensitive variables:

  -Spin correlation observables (especially sensitive for pseudoscalar)

  -Single top observables help distinguish t+DM from SM $t\bar{t}$

  -p_t^{miss} assigned to DM in top reconstruction

- Train a neural network on these variables + M_{T2}(ll) and p_t^{miss}



[1] J. Abdallah et al., doi:10.1016/j.dark.2015.08.001, arXiv:1506.03116
[2] CMS Collaboration, doi:10.1140/epjc/s10052-021-09721-5, arXiv:2107.10892
[3] CMS Collaboration, doi:10.1140/epjc/s10052-020-08701-5, arXiv:2008.05936
[4] CMS Collaboration, doi:10.1007/JHEP05(2020)032, arXiv:1912.08887
[5] CMS Collaboration, doi:10.1103/PhysRevD.104.052001, arXiv:2103.01290
[6] D. Pinna et al., doi:10.1103/PhysRevD.96.035031,573 arXiv:1701.05195