



Universität Heidelberg

Carl Zeiss Stiftung



# Dark matter from electroweak single-top production

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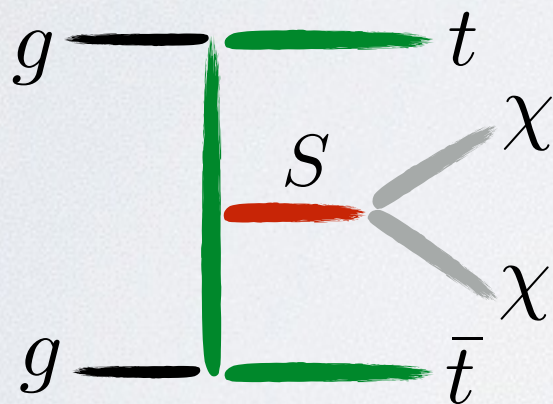


# TOP PORTAL TO INVISIBLES

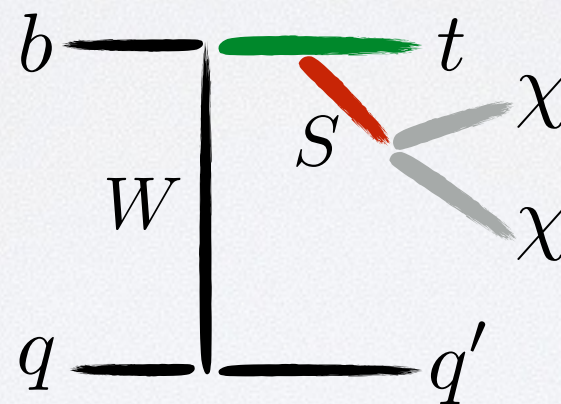
Dark fermions with dominant top-quark interactions:

$$\mathcal{L}_S \supset g_S^\chi (\bar{\chi}\chi)S + g_S^t \frac{m_t}{v} (\bar{t}t)S$$

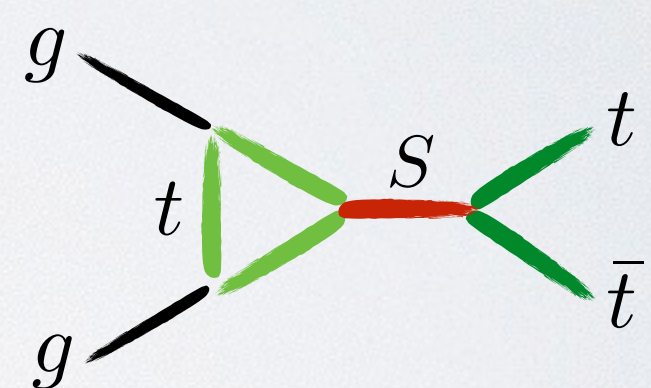
LHC searches for missing energy .... and mediators



top-pair  
production



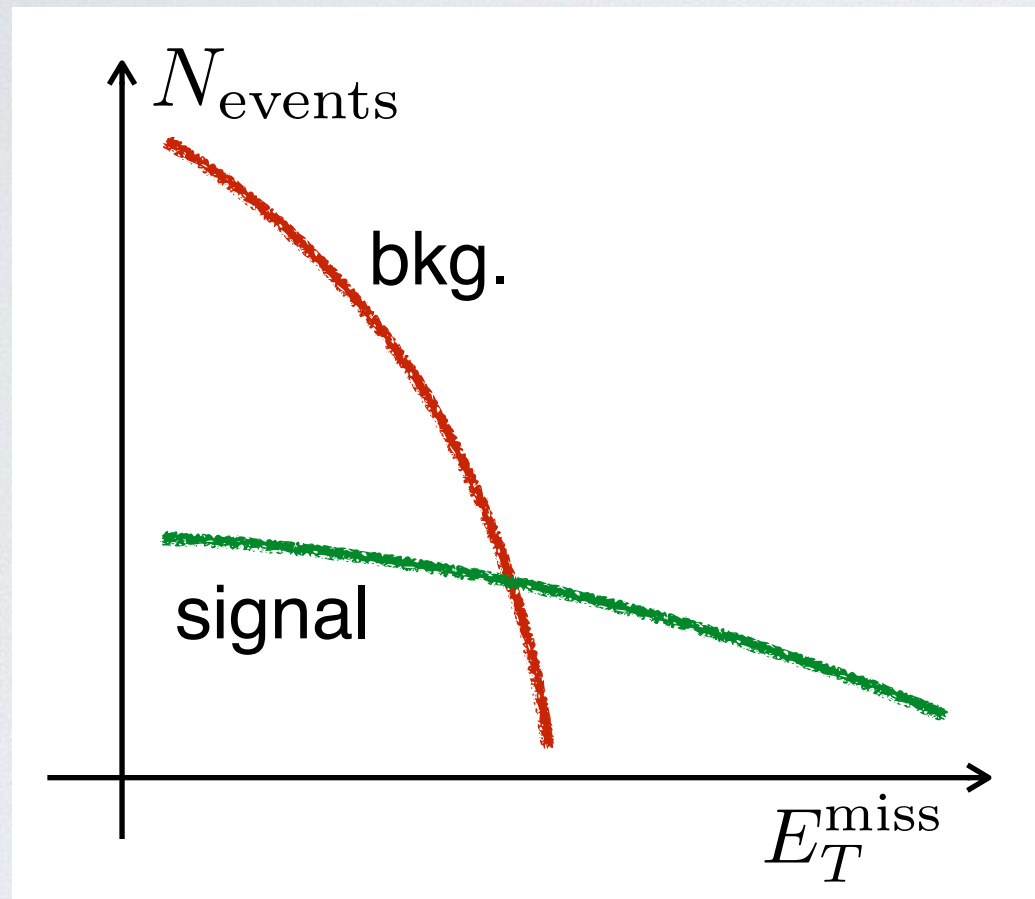
single-top  
production



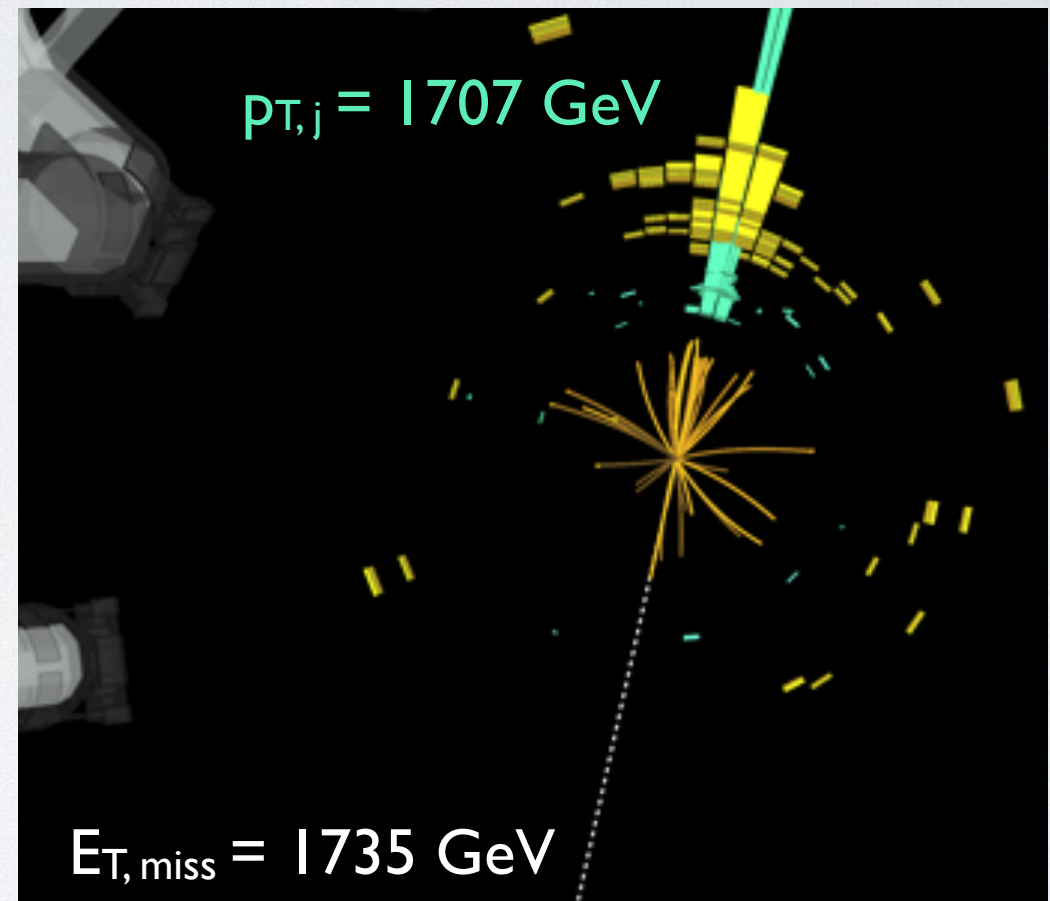


# MISSING ENERGY

- Signal-background discrimination:



[mono-jet candidate, ATLAS collaboration]



$$\vec{p}_T^{\text{miss}} = - \sum \vec{p}_T^{\text{vis}}$$

- Efficient triggering on missing energy for

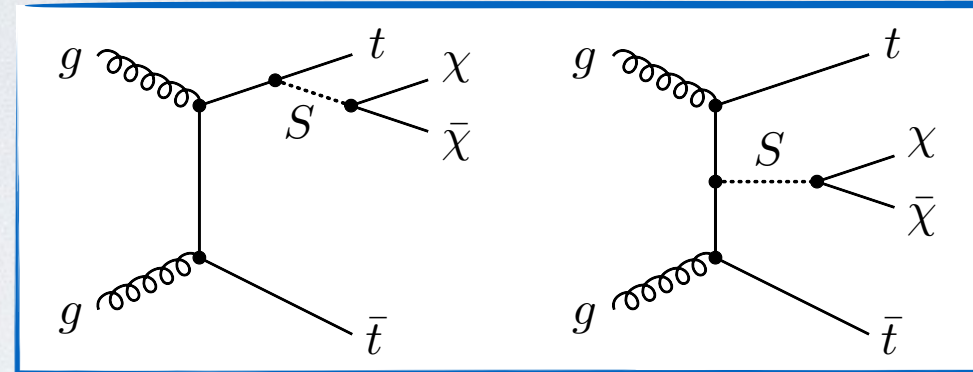
$$E_T^{\text{miss}} \gtrsim 100 \text{ GeV}$$



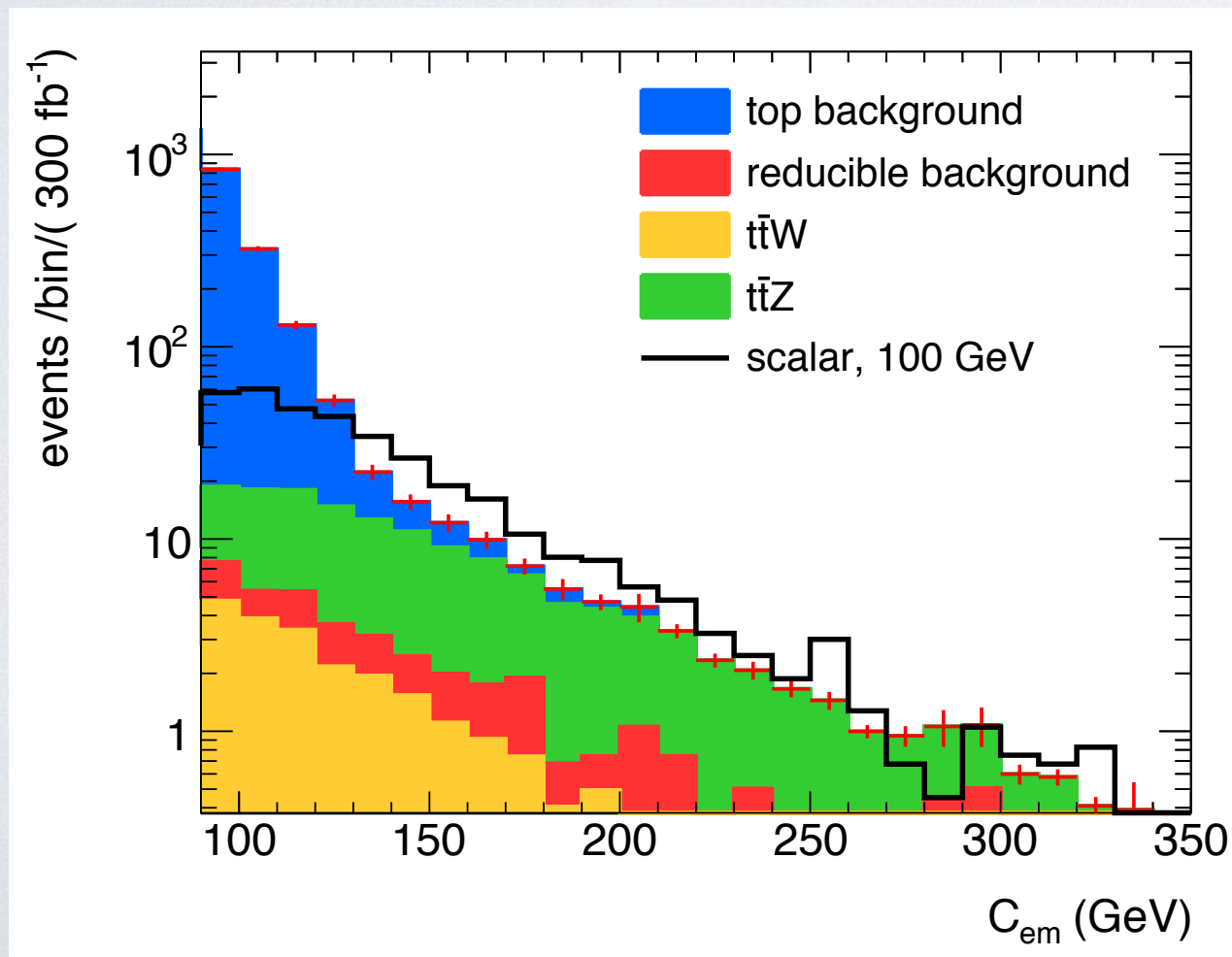
# TOP PAIRS PLUS MISSING ENERGY

Signal in di-lepton channel:

$$pp \rightarrow t\bar{t}S \rightarrow \ell^+\ell^- + 2b + E_T^{\text{miss}}$$



Use lepton kinematics to suppress background with W's:



$$m_{T2}^2(\vec{p}_T^{\ell_i}, \vec{p}_T^{\ell_j}, \vec{p}_T^{\text{miss}}) \equiv$$

$$\min_{\vec{q}_T^1 + \vec{q}_T^2 = \vec{p}_T^{\text{miss}}} \left\{ \max \left[ m_T^2(\vec{p}_T^{\ell_i}, \vec{q}_T^1), m_T^2(\vec{p}_T^{\ell_j}, \vec{q}_T^2) \right] \right\}$$

Discriminating function:

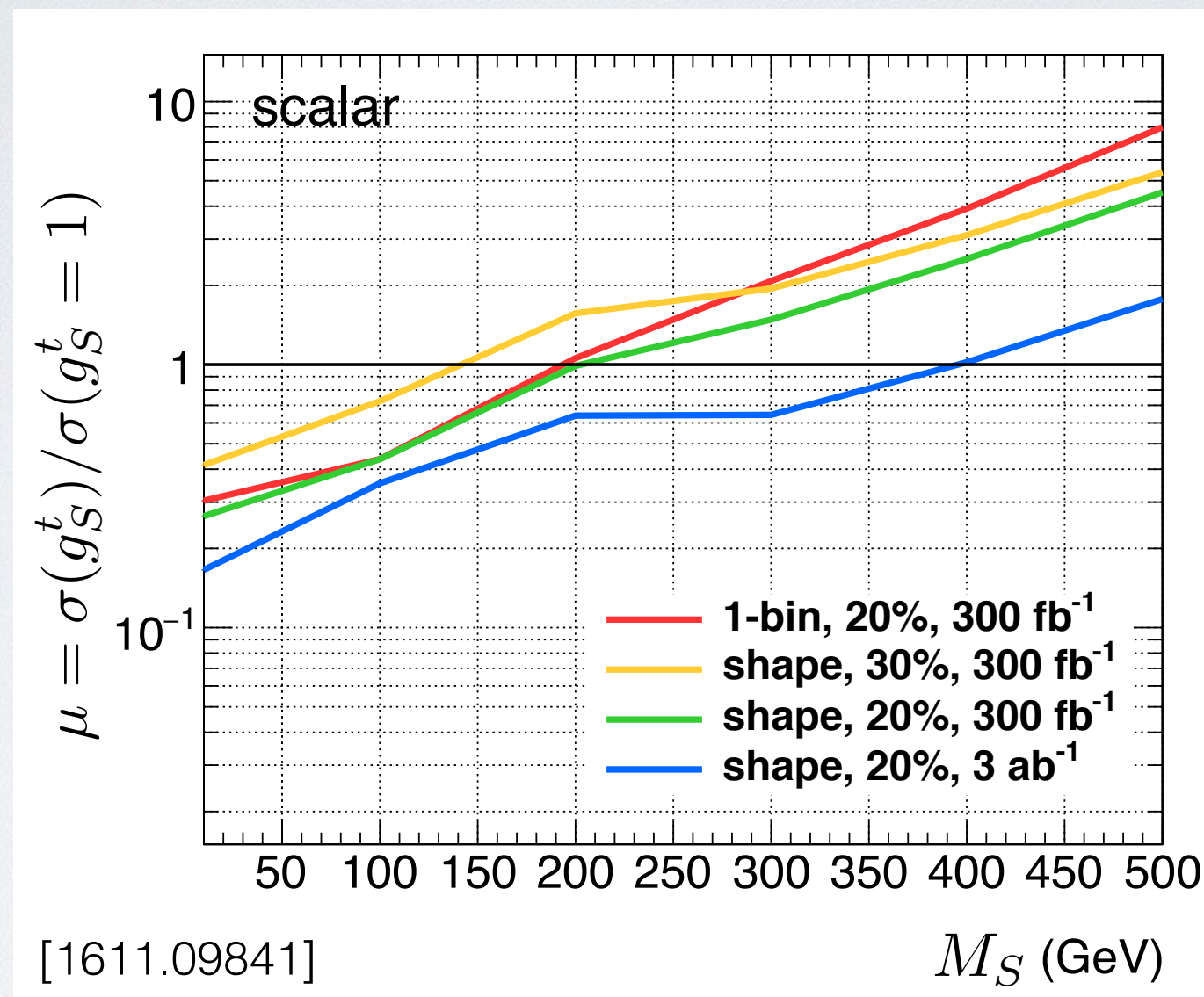
$$C_{\text{em}} \equiv m_{T2} + 0.2 \cdot (200 \text{ GeV} - E_T^{\text{miss}})$$

[Haisch et al., 1611.09841]



# EXPECTED LHC SENSITIVITY

Signal strength that can be excluded at 95% CL at 14 TeV:



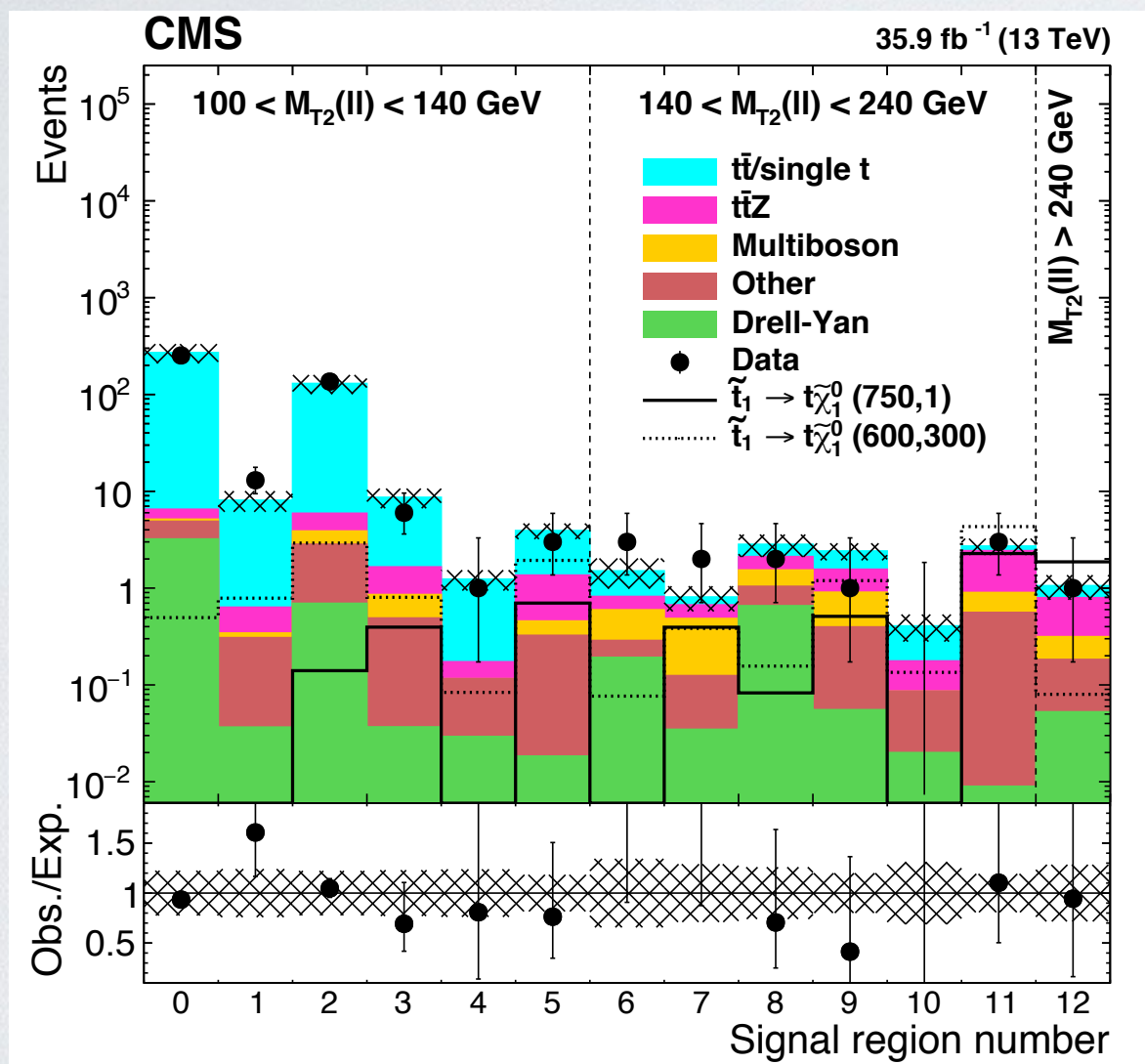
Lepton angular correlations enhance sensitivity („shape“).



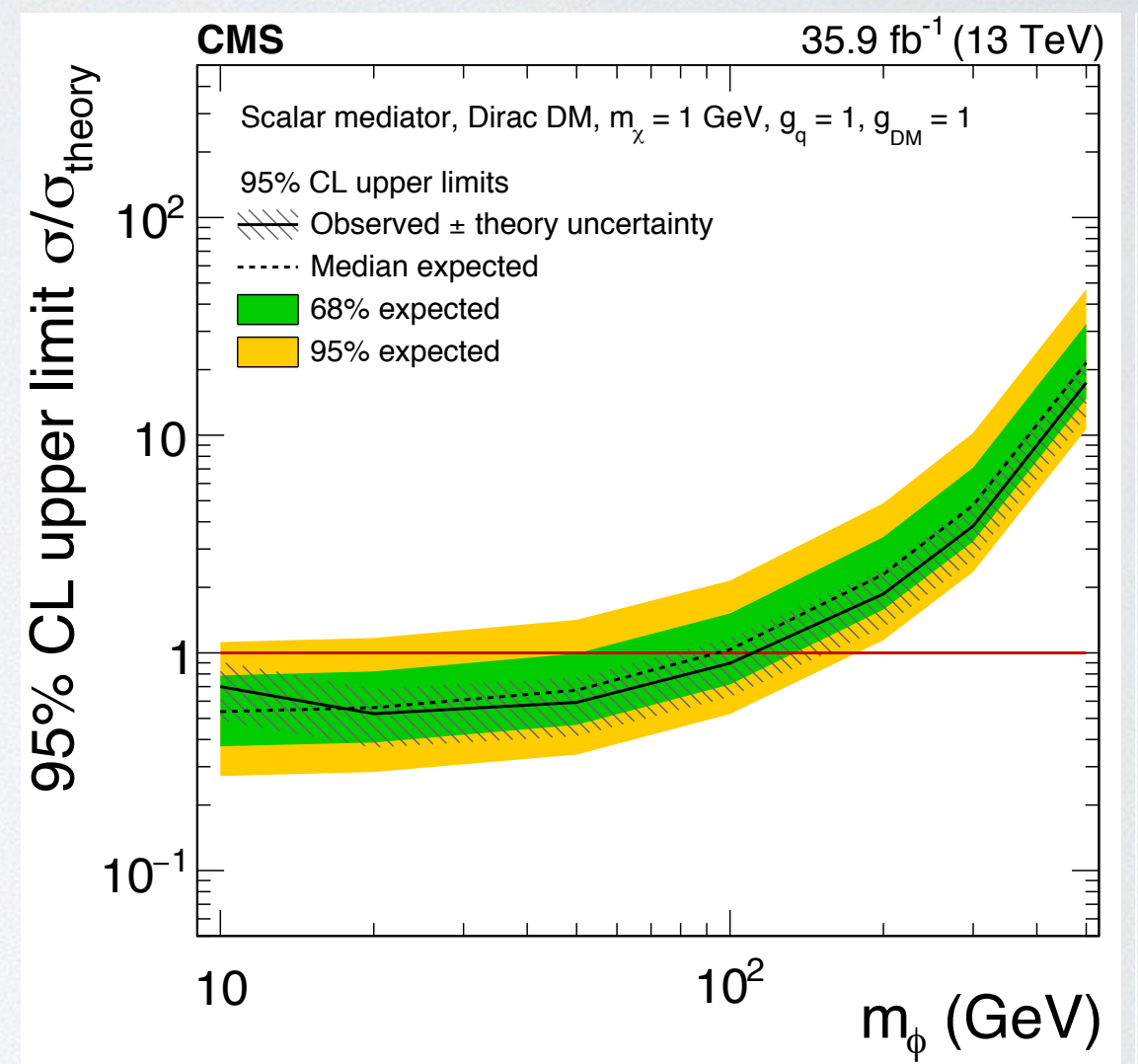
# OBSERVED SENSITIVITY

With 13-TeV LHC data: [CMS, 1711.00752]

background in signal regions



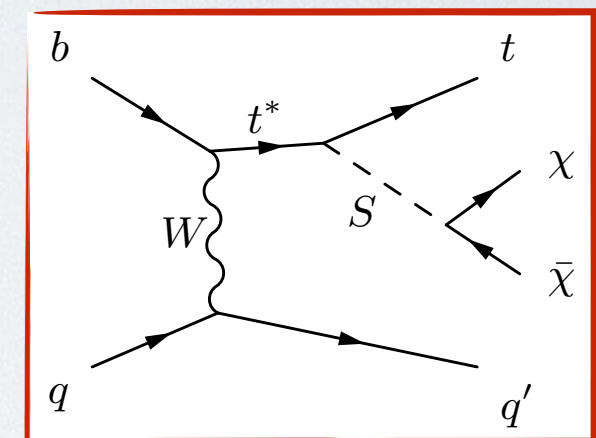
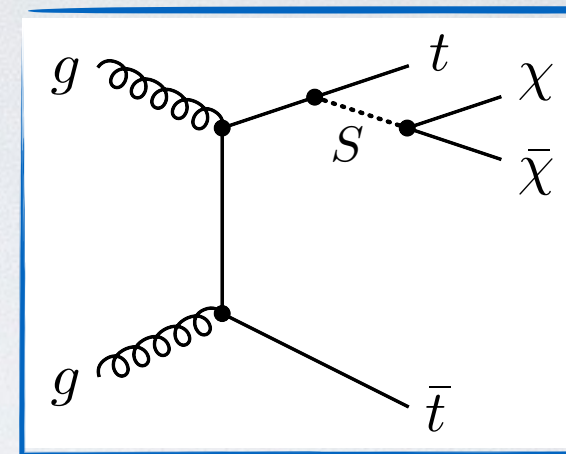
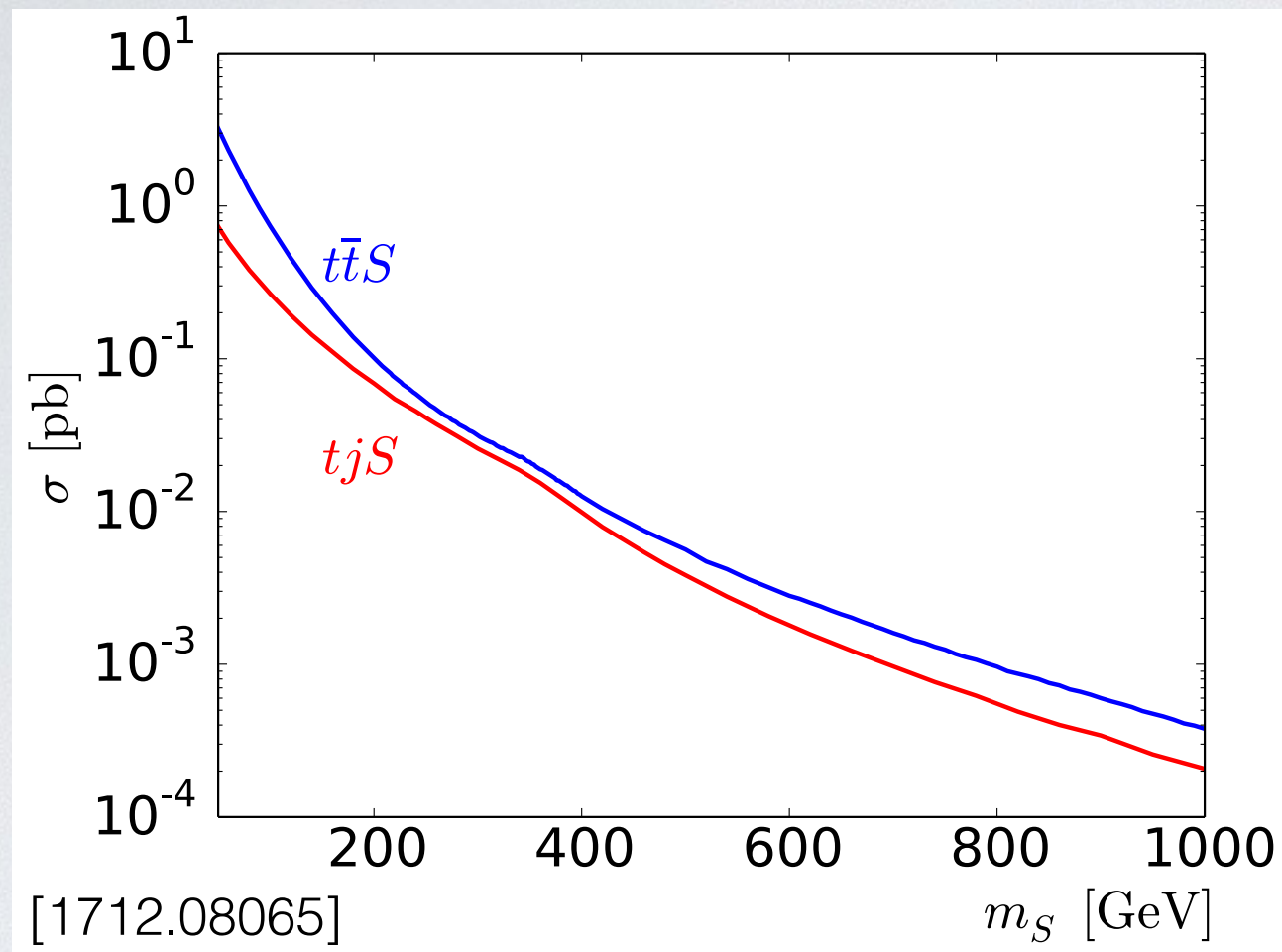
bound on resonant mediators



Excludes mediators with  $m_S \lesssim 100$  GeV and  $g_S^t = g_S^\chi \approx 1$ .



# TOP PAIRS VERSUS SINGLE TOP



Single-top processes contribute significantly to signal region in top-pair + missing energy searches.

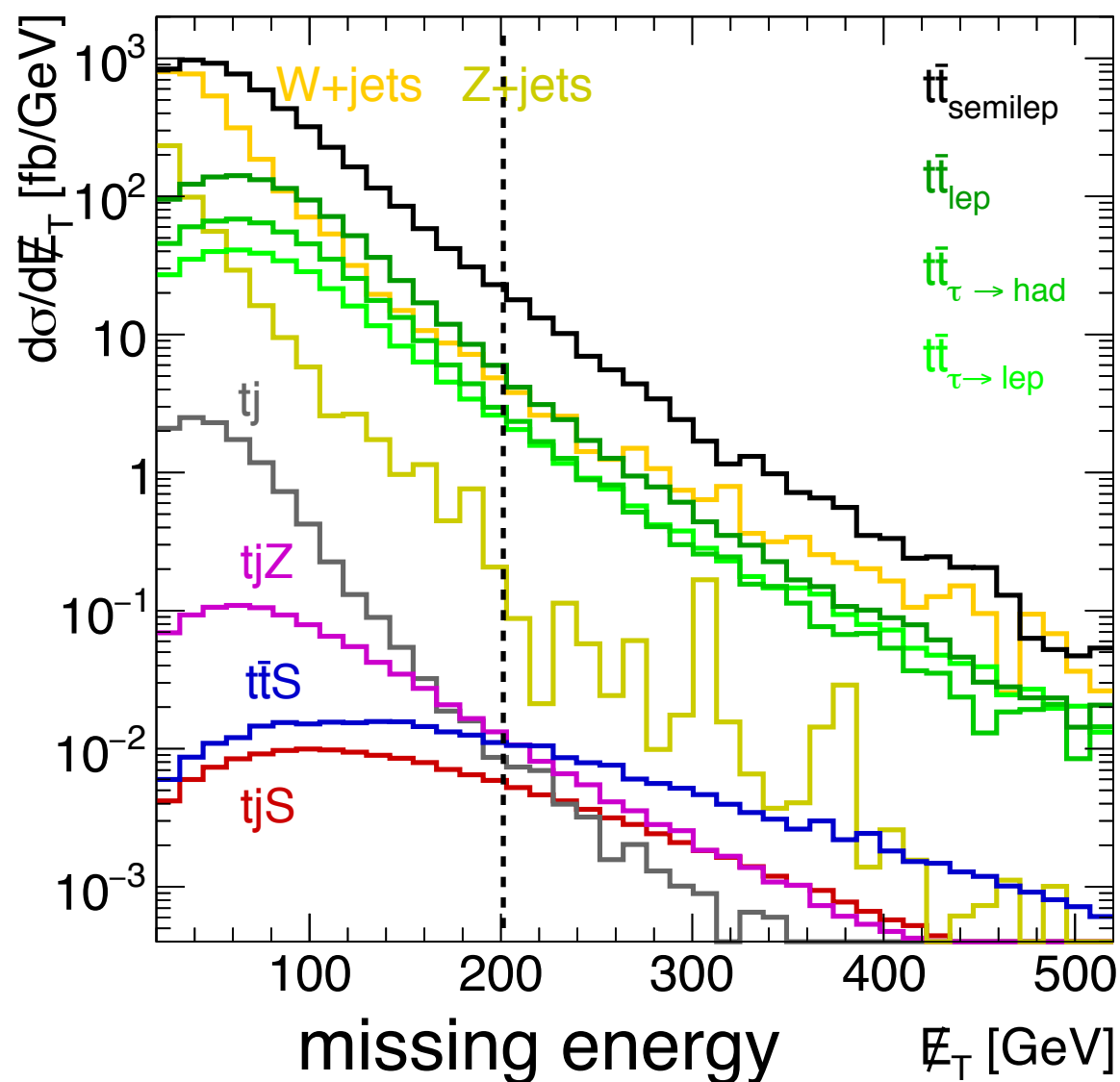
[Pinna et al., 1701.05195]



# SINGLE TOP AS A SIGNAL

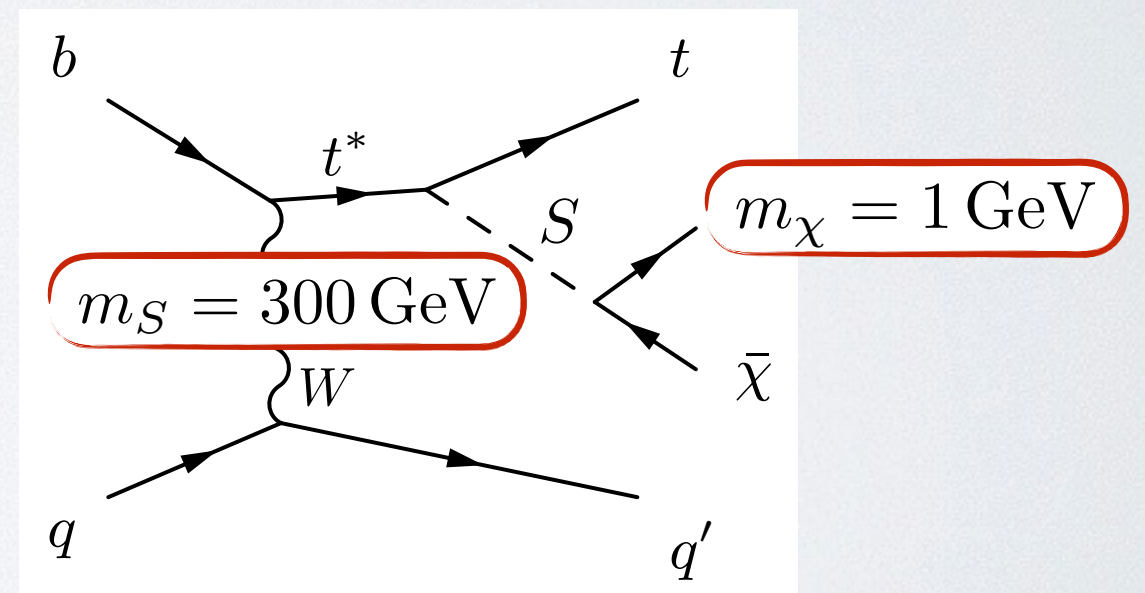
Forward jet is characteristic of electroweak top production:

$$pp \rightarrow tjS \rightarrow \ell^+ b + j + E_T^{\text{miss}}$$



Benchmark scenario:

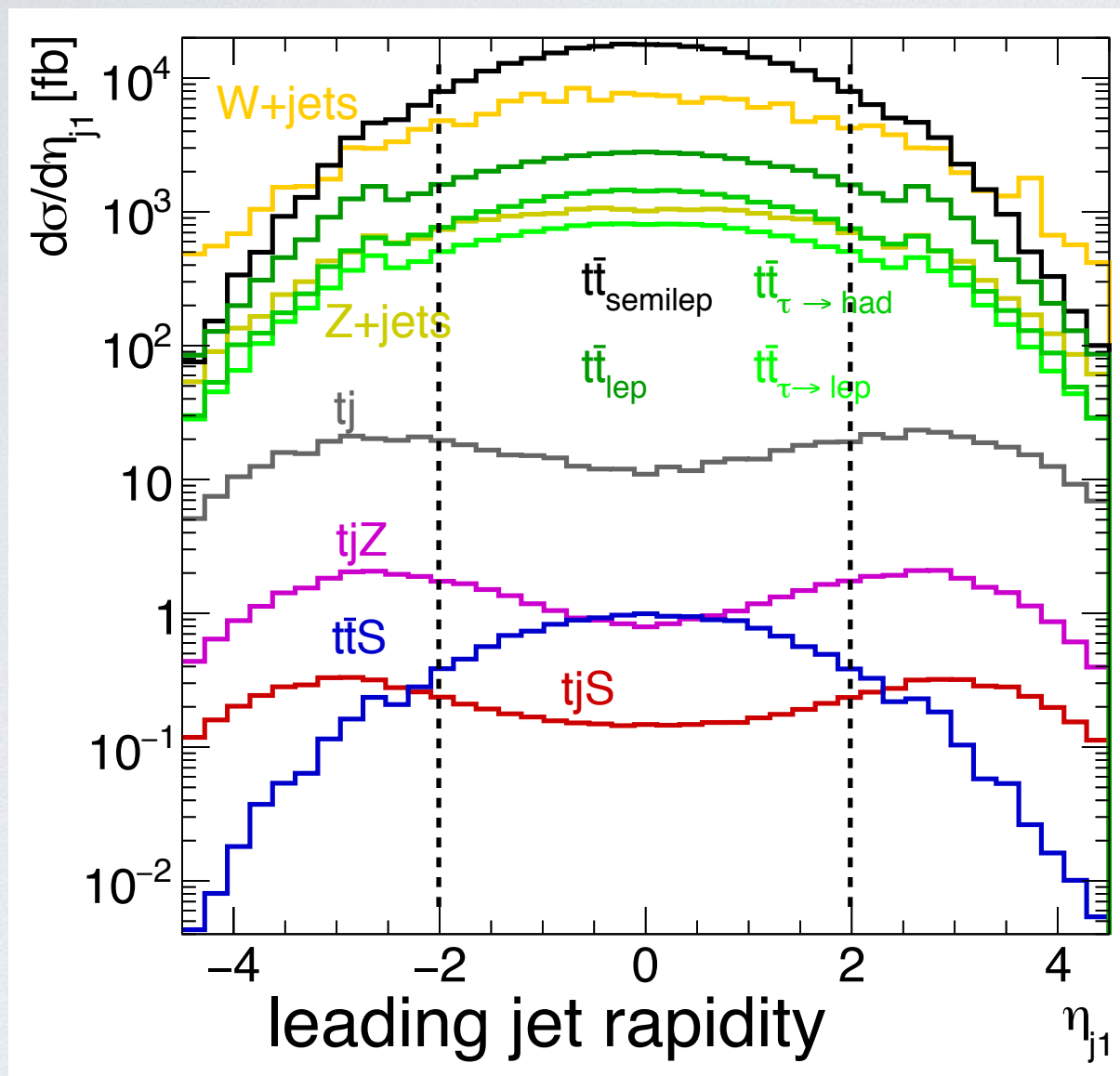
$$g_S^t = g_S^\chi = 1$$



[Plehn, Thompson, SW, 1712.08065]



# EXPLOITING SINGLE-TOP KINEMATICS



Signal pre-selection:

$$E_T^{\text{miss}} > 200 \text{ GeV}$$

$$|\eta_j| > 2$$

$$m_T > 85 \text{ GeV}$$

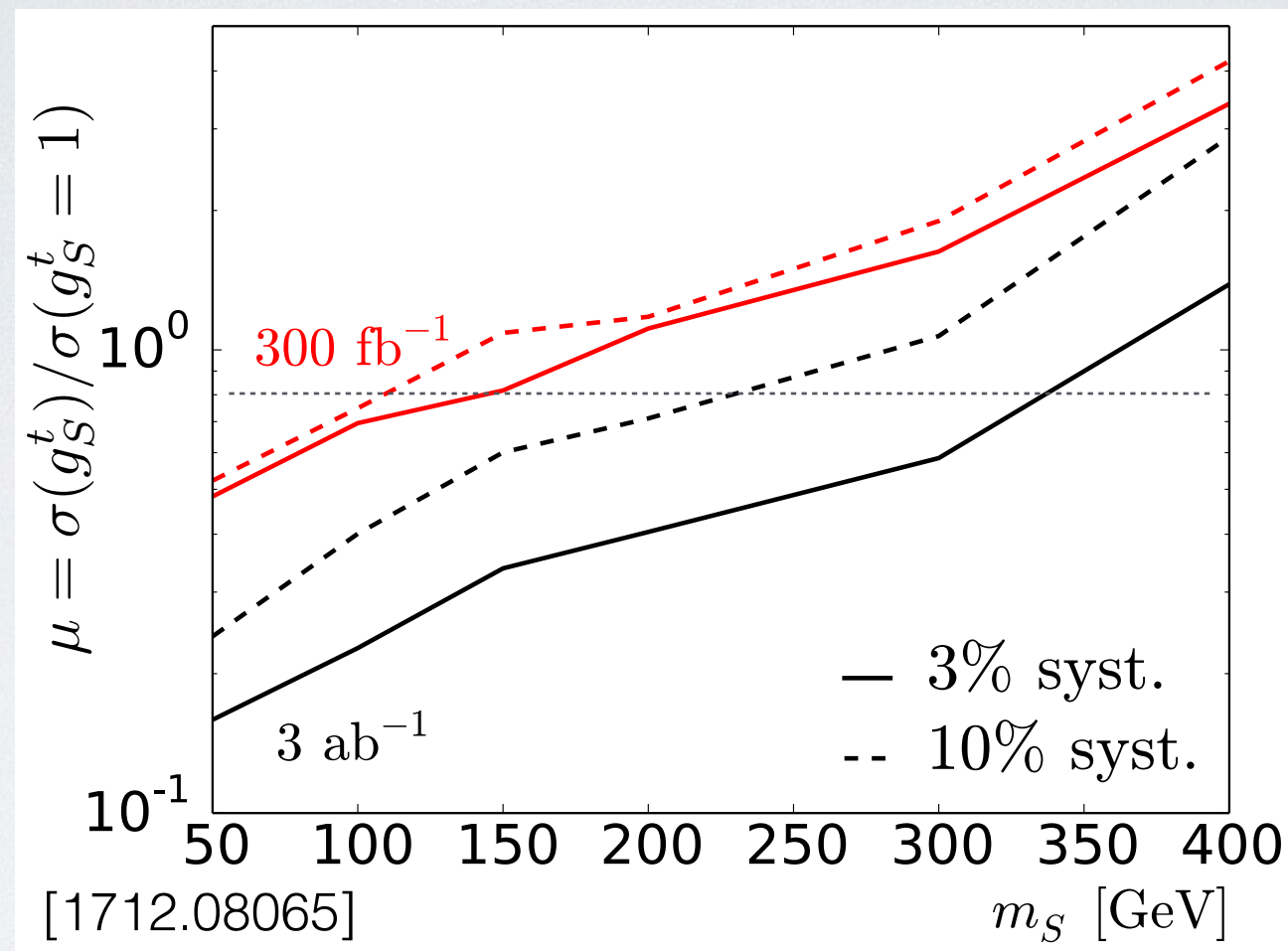
Reduce background with  $W$ 's:  $m_T^2 = 2p_T^\ell E_T^{\text{miss}} (1 - \cos \phi_{\ell, E_T^{\text{miss}}})$

Top-pair background with 2 neutrinos:  $m_{T2}^W$



# A MULTI-VARIATE ANALYSIS LATER...

Signal strength that can be excluded at 95% CL at 13 TeV:



Main remaining background:  $pp \rightarrow t\bar{t} \rightarrow \ell^+ \ell^- + \text{jets} + E_T^{\text{miss}}$   
(one lepton missed)

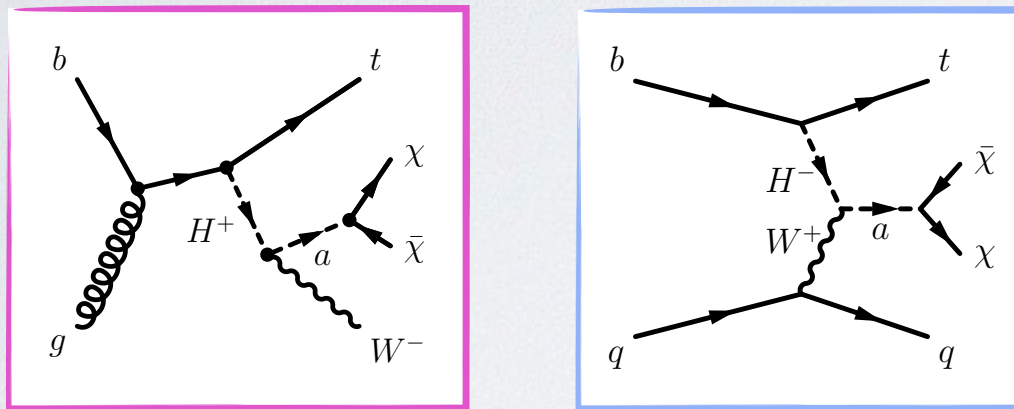
**Goal:** combine with top-pair search for optimal sensitivity.



# MORE ON SINGLE-TOP SEARCHES

In complete models, additional states can contribute.

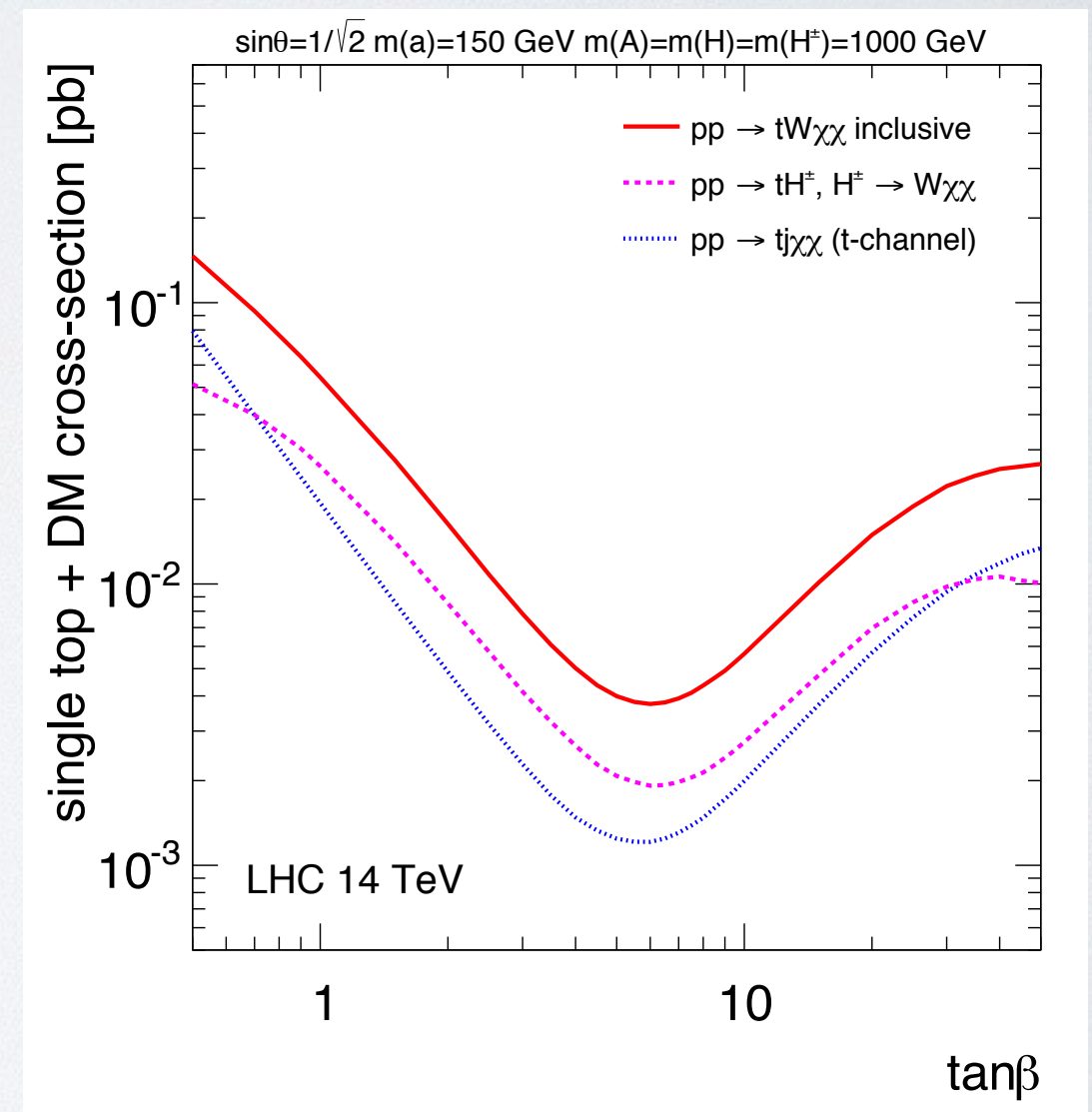
Here: two Higgs doublets + pseudo-scalar  $h^0, H^0, A^0, H^\pm, a$



tW associated production from resonant charged Higgs:

$$pp \rightarrow tH^- \rightarrow tW^- + E_T^{\text{miss}}$$

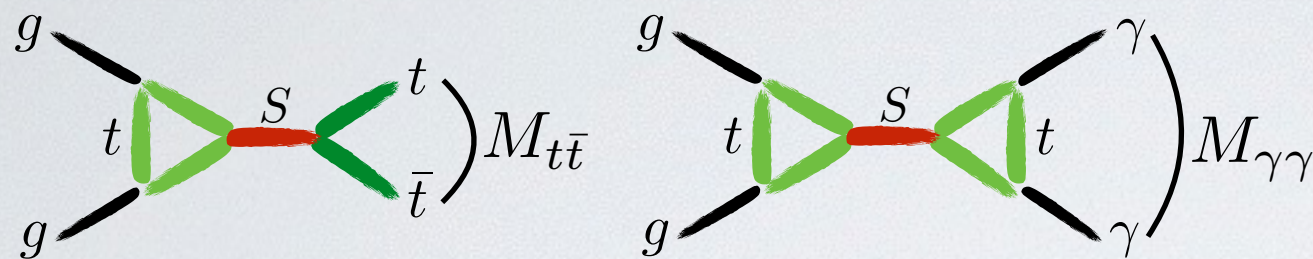
[Pani, Polesello, 1712.03874]





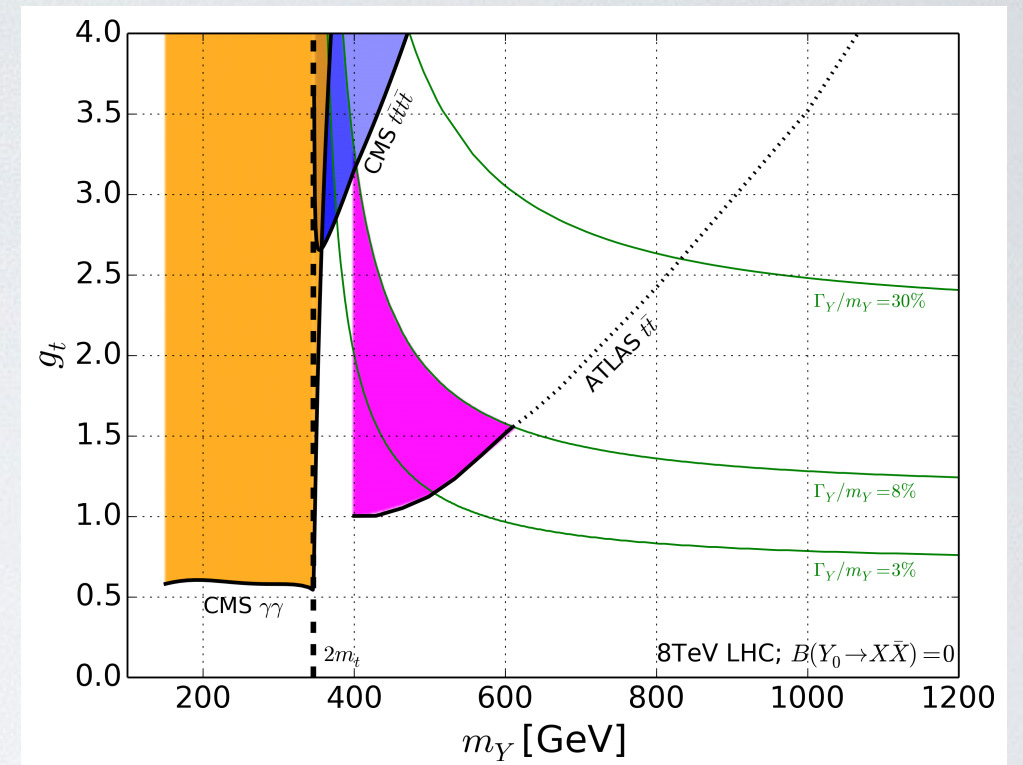
# MEDIATOR SEARCHES

Resonance searches:

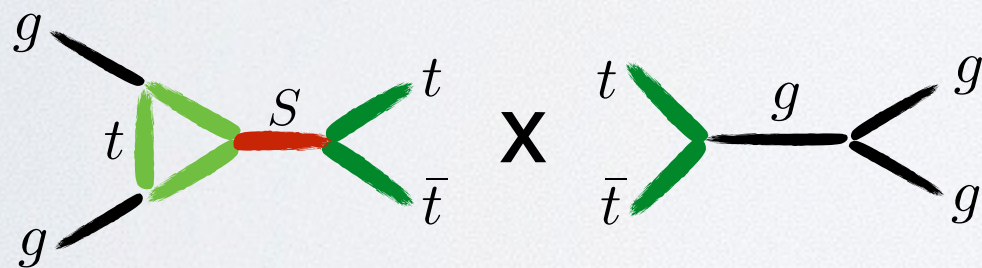


Probe scenarios with  $m_S < 2m_\chi$ .

[Arina et al., 1605.09242]

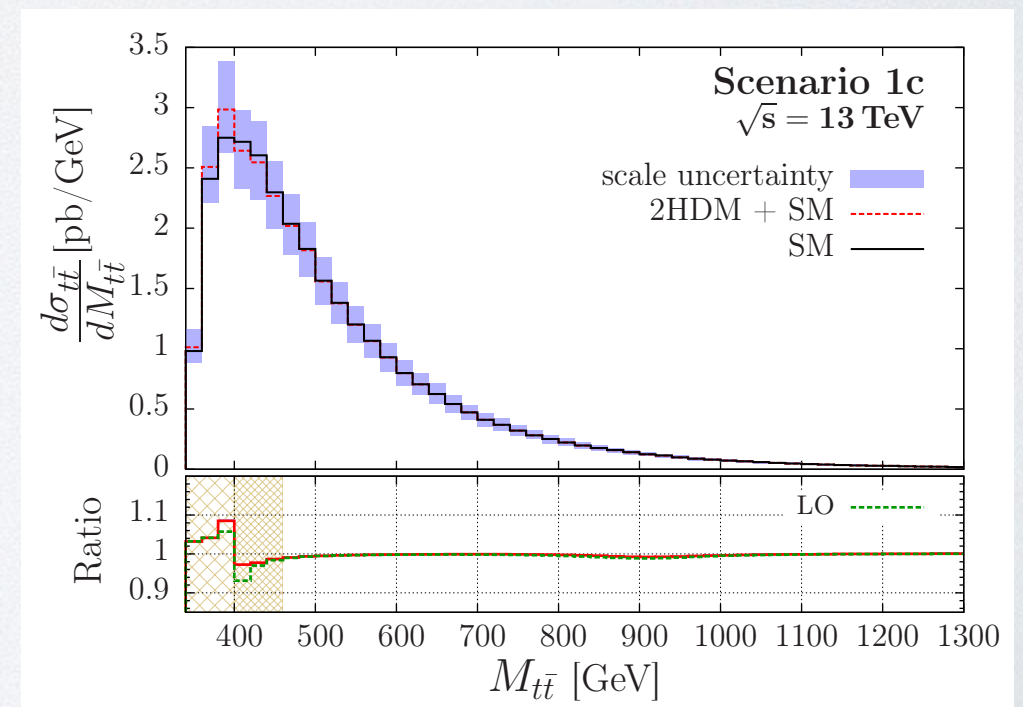


Interference can hide resonance:



Resolve with lepton correlations?

[Bernreuther et al., 1702.06063]





# TAKE HOME

- Explore single-top production as a new search channel for invisible particles.
- Sensitivity of t-channel or tW-associated single-top production model-dependent.
- Combine missing-energy searches in top-pair and single-top production with mediator searches.

