Dark matter production in association with a single top quark in 2HDM+a

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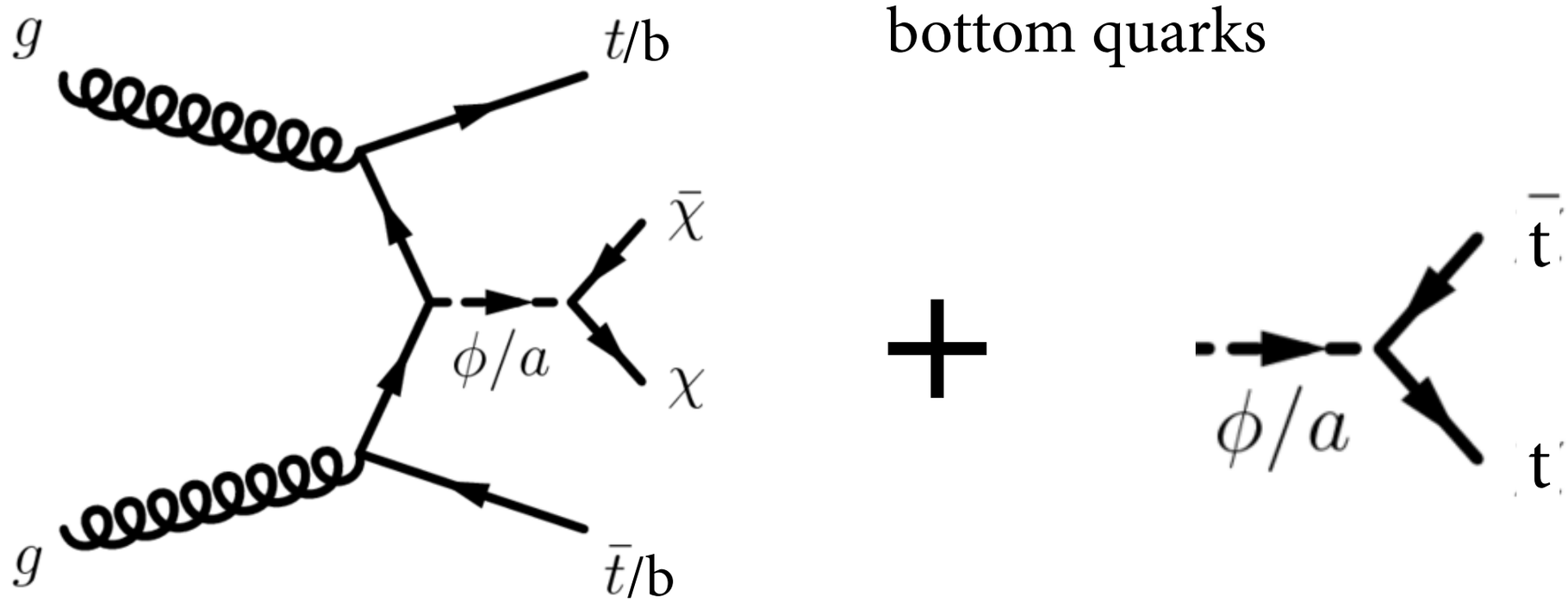
arXiv:1712.03874

Dark Matter with heavy quarks

$$\mathcal{L} \sim \sum_f i g_v \frac{y_f}{\sqrt{2}} A \bar{f} \gamma^5 f$$

Needed to easily fulfil Flavour Constraints (MFV)

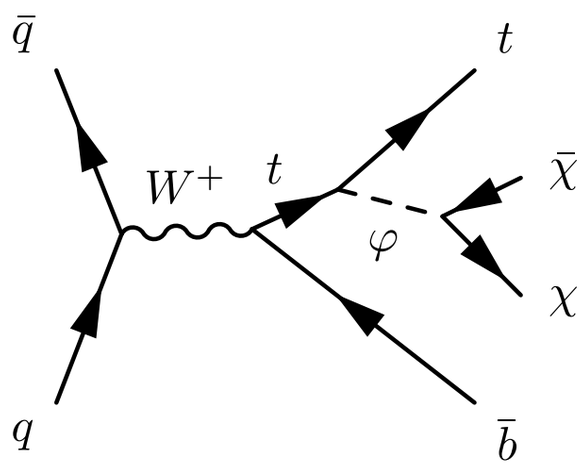
- ★ Typical Yukawa structure for spin-0 mediators
- ★ tanβ regulates *b*-quark enhancement
- ★ Enhanced cross sections for top and bottom quarks



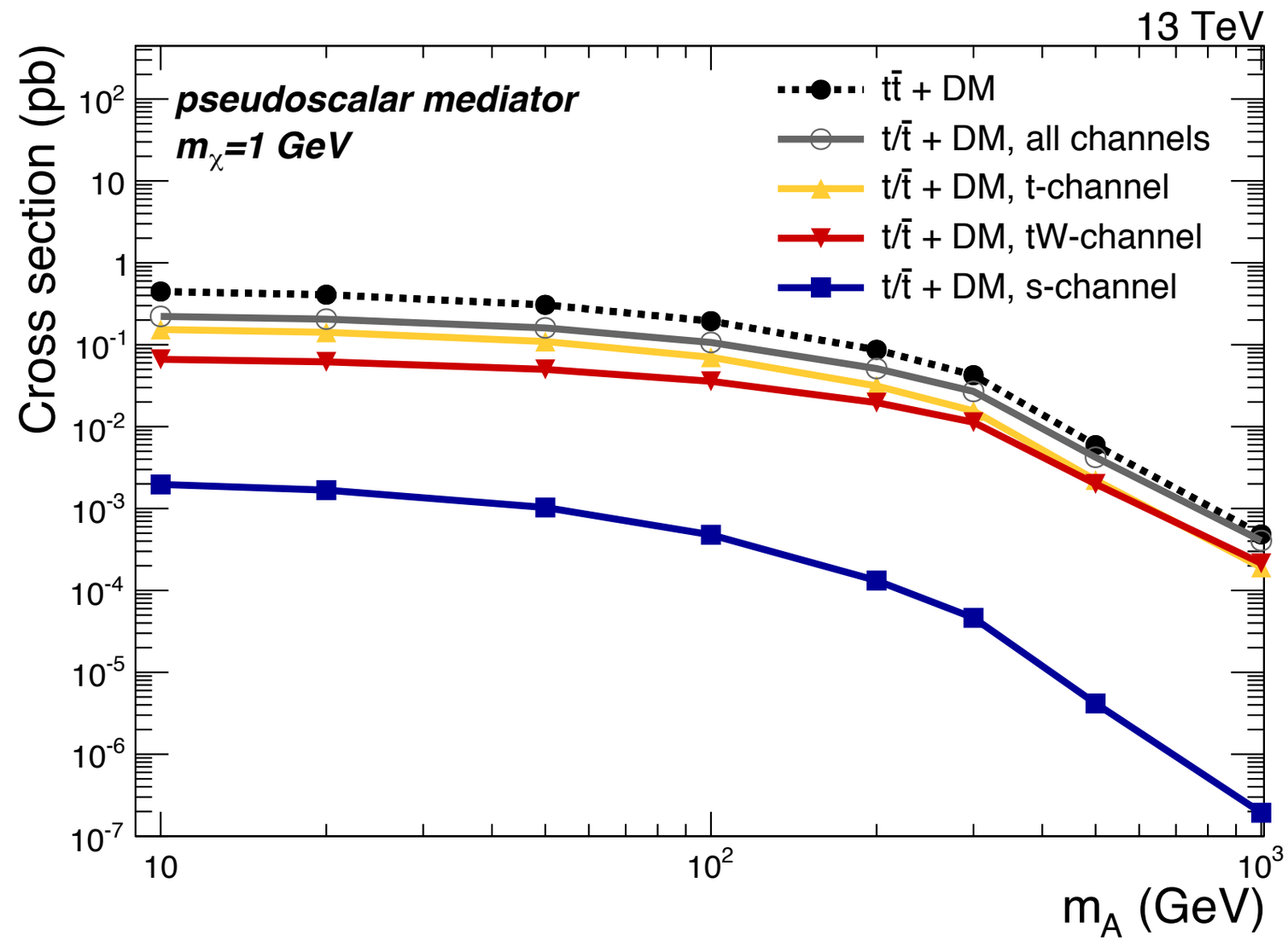
- ★ Interesting signature with increasing sensitivity
- ★ So far considered: top and bottom pairs.

Additional HF signatures?

- Literature shows that t-channel single top is also relevant for DM+p simplified models



[Pinna,Zucchetta, Buckley,Canelli] arXiv:1701.05195



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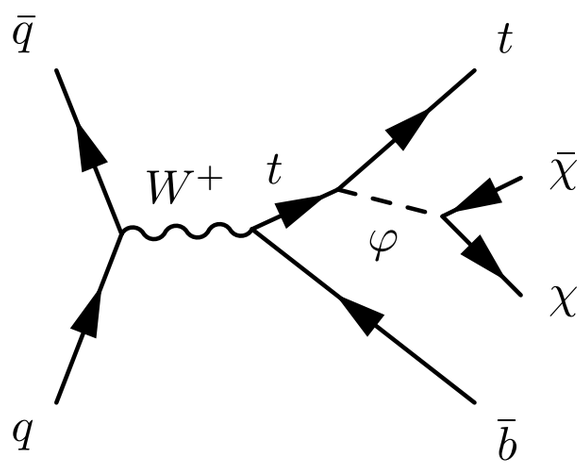

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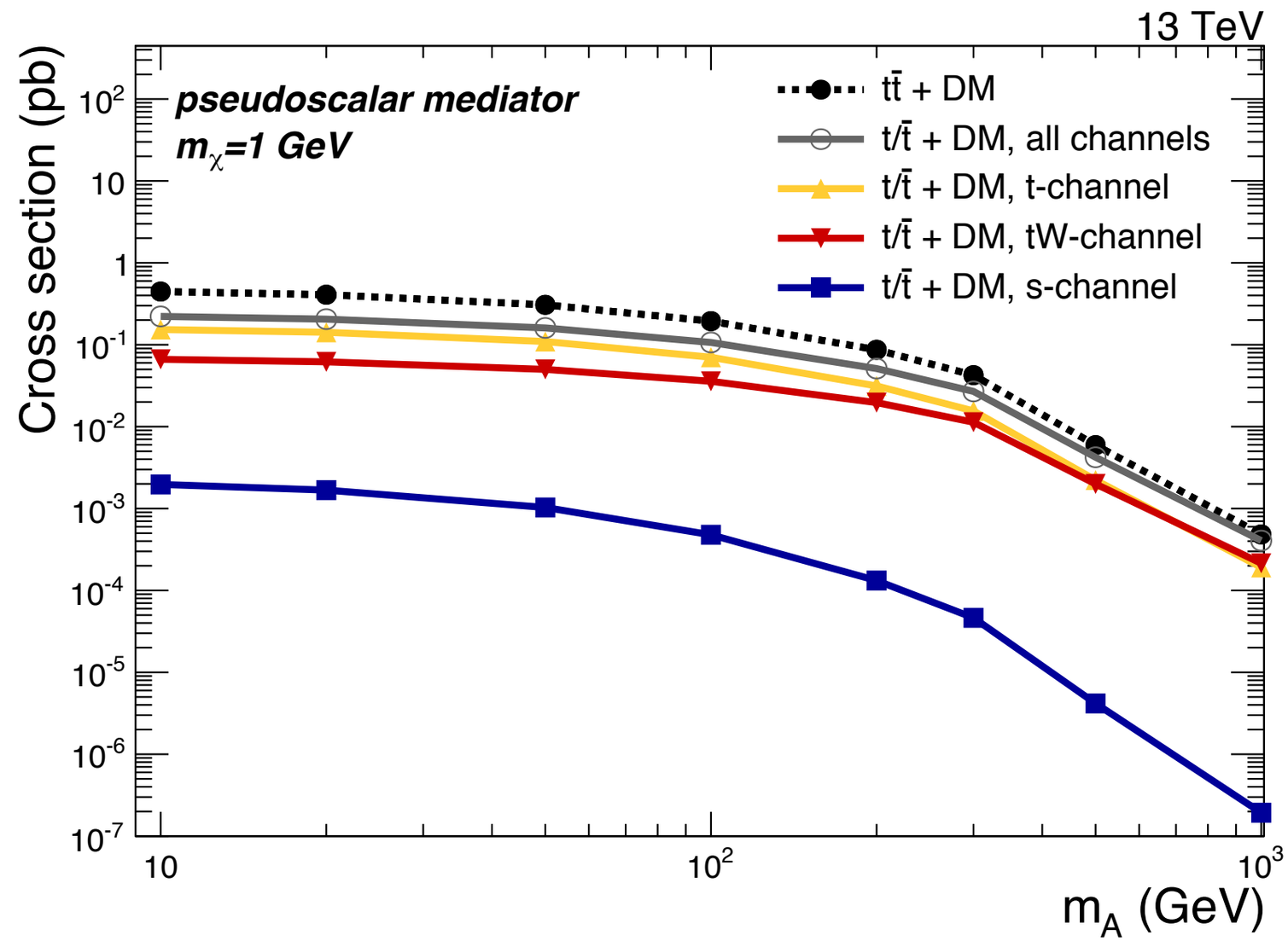


PROBLEM: unitarity violation at high energies

Additional HF signatures?

★ What about UV-complete models, e.g. 2HDM+a?

[Bauer,Haisch,Kahlhoefer] arXiv:1701.07427

parameters

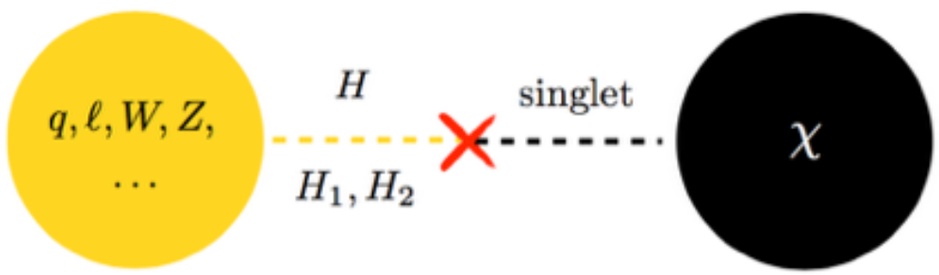
v, M_h, $\cos(\beta - \alpha)$

M_a, M_A, M_H, $M_{H^\pm}$

$\tan(\beta)$, $\cos(\theta)$

λ_3, λ_{P1}, λ_{P2}, λ_P

M_χ, y_χ



$$\mathcal{L} \supset -\bar{Q} Y_u \tilde{H}_2 d_R + \bar{Q} Y_d H_1 u_R - i b_P P H_1^\dagger H_2 - i y_\chi P \bar{\chi} \gamma_5 \chi + \text{h.c.}$$

sketch from U. Haisch

Particle Content

CP-even bosons: h, H

CP-odd bosons: A, a

Charged bosons: $H^\pm$

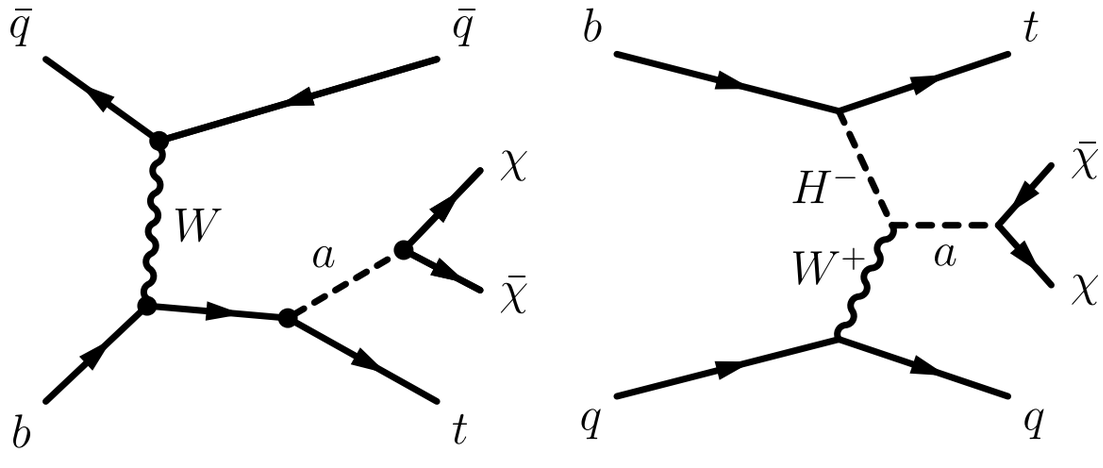
Dirac DM χ

★ Investigate single top signatures in this context

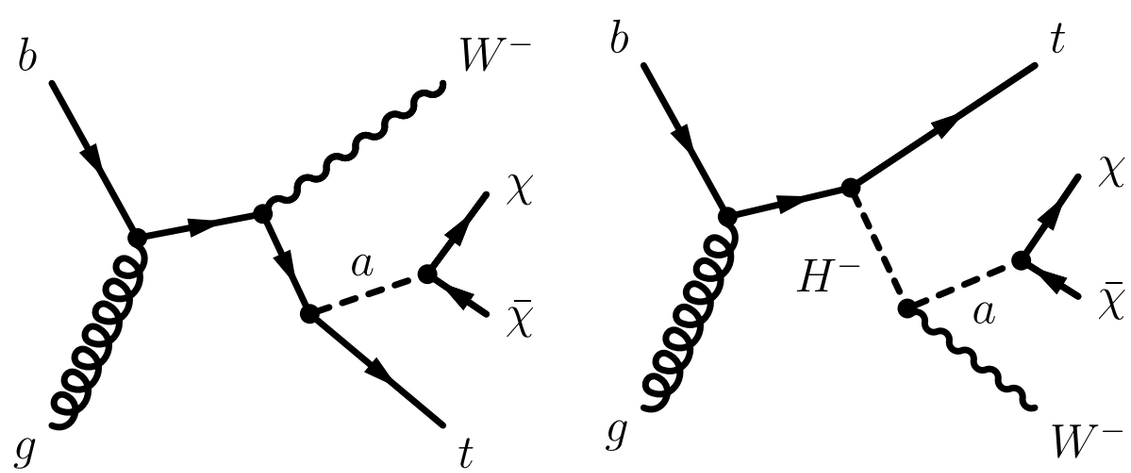
[Pani,Polesello] arXiv:1712.03874

Single top+a production

t-channel



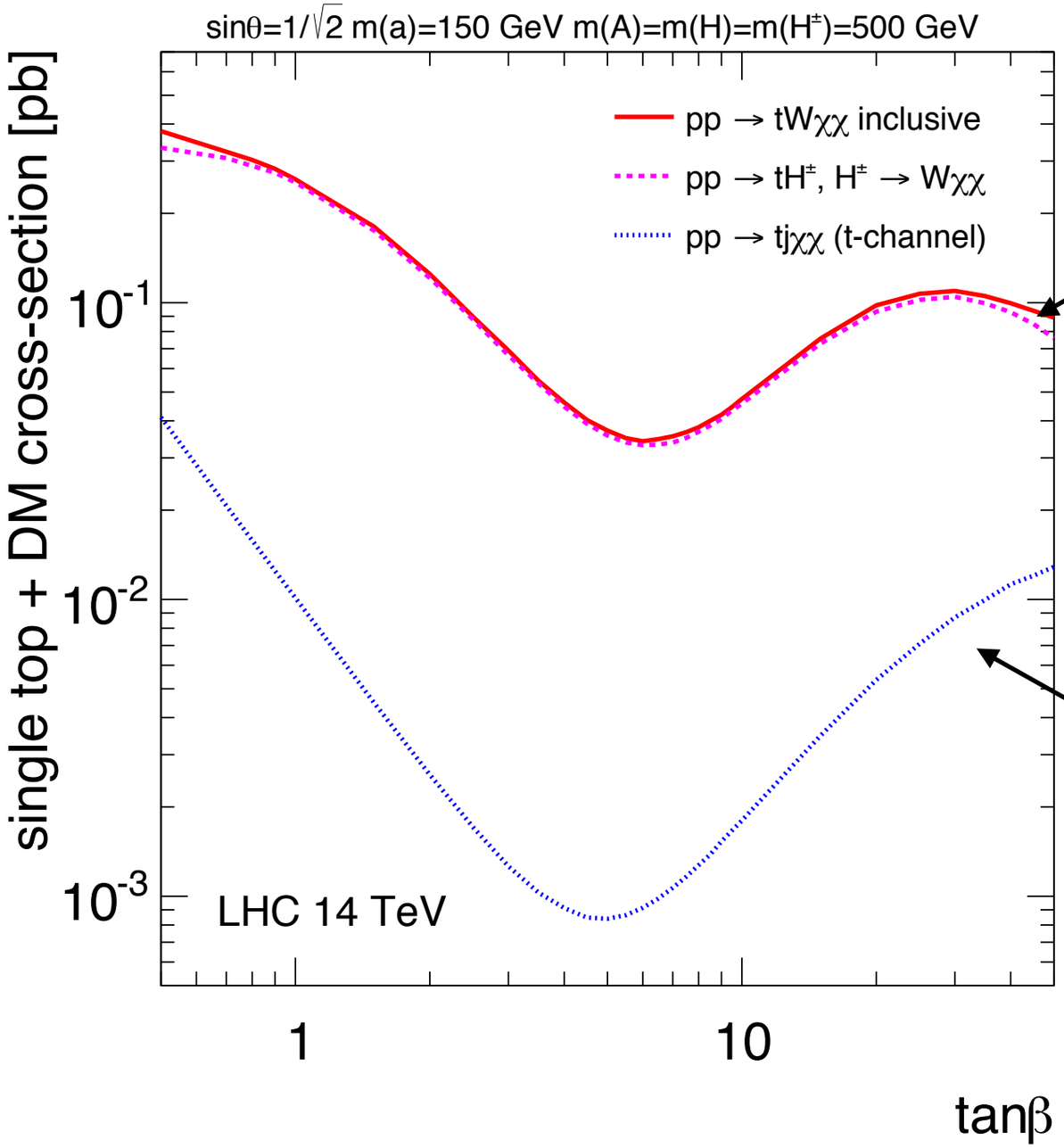
(a) (b)

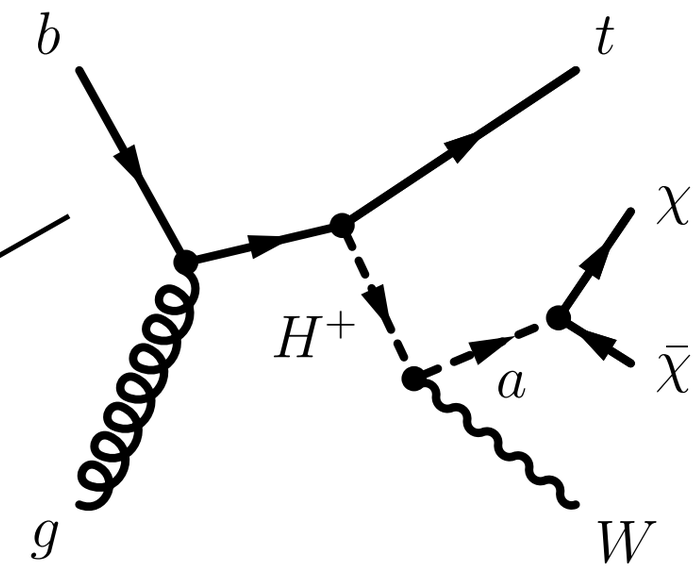


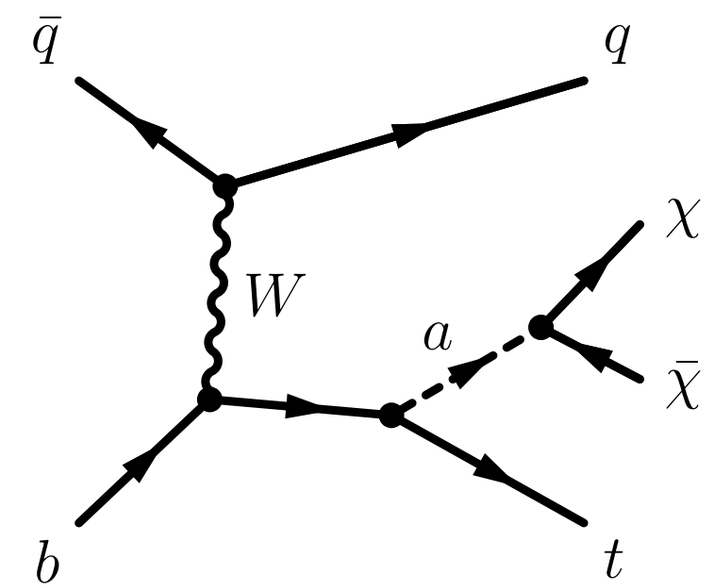
Wt-channel

★ (a) diagram divergence is cured by negative interference with (b) diagram

Single top+a production - m(H±) = 500 GeV

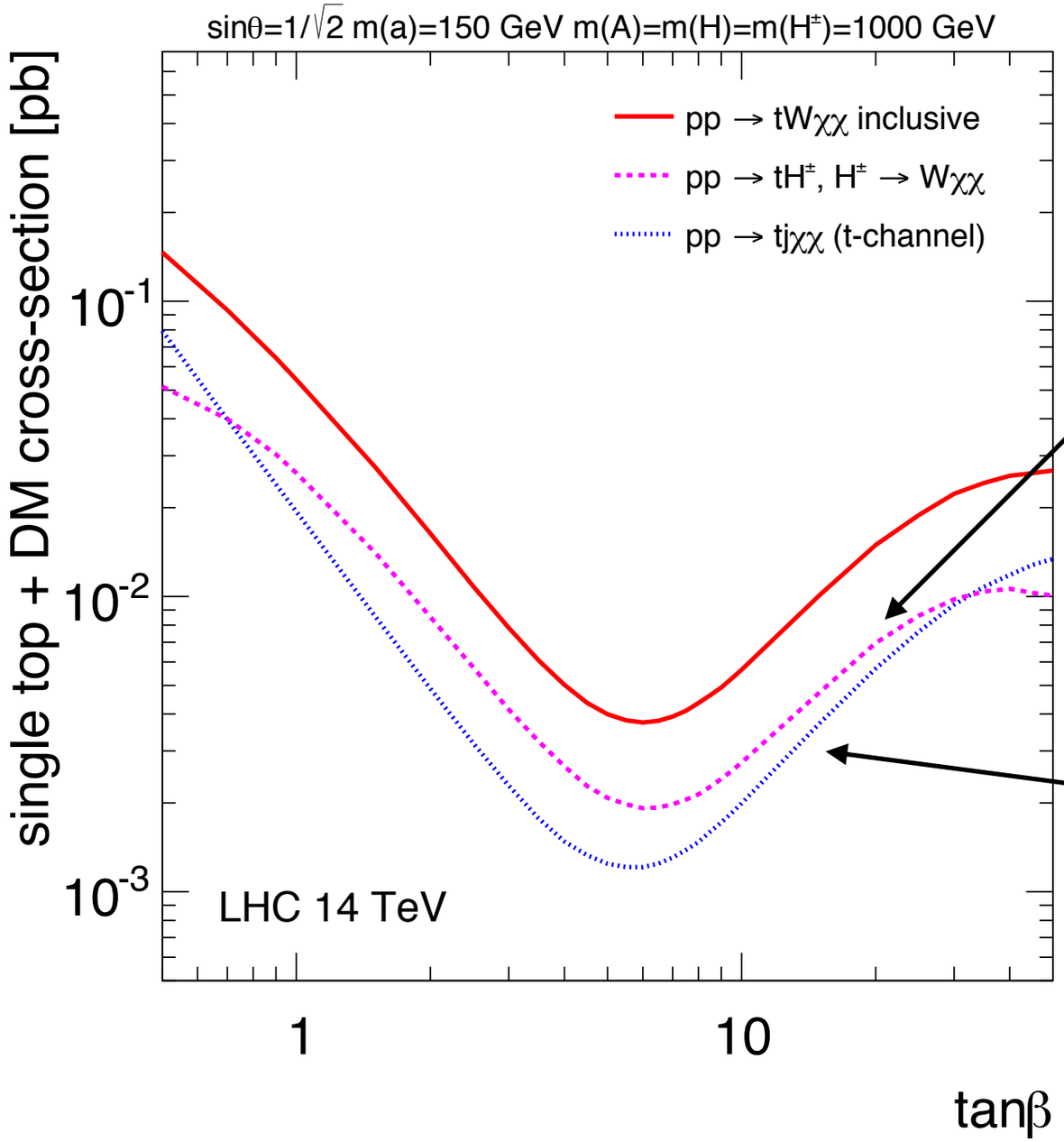


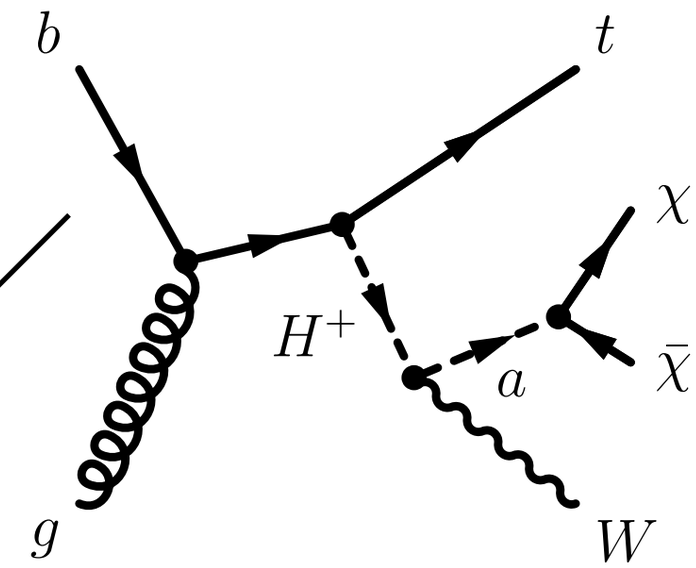


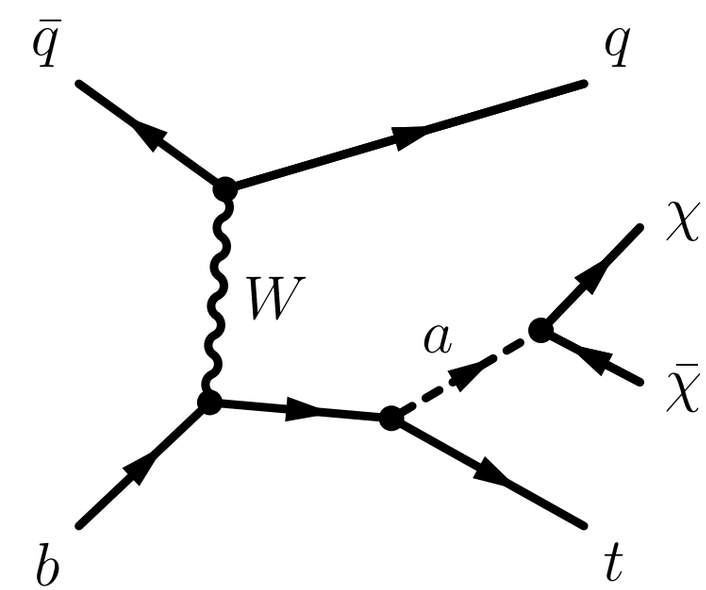


the cross section is dominated by H± on-shell production

Single top+a production - m(H±) = 1 TeV







For m(H±) → ∞ t-channel dominates again

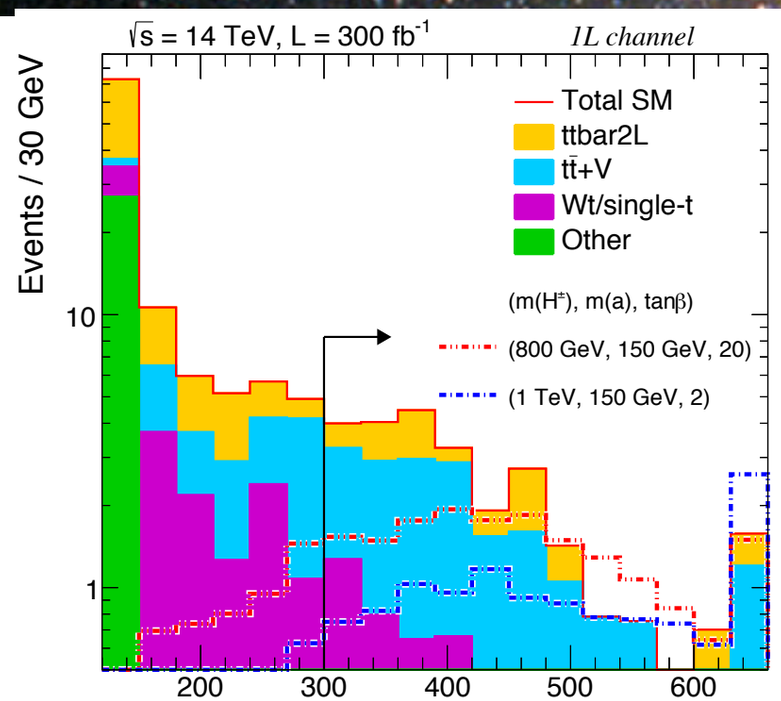
Sensitivity forecast

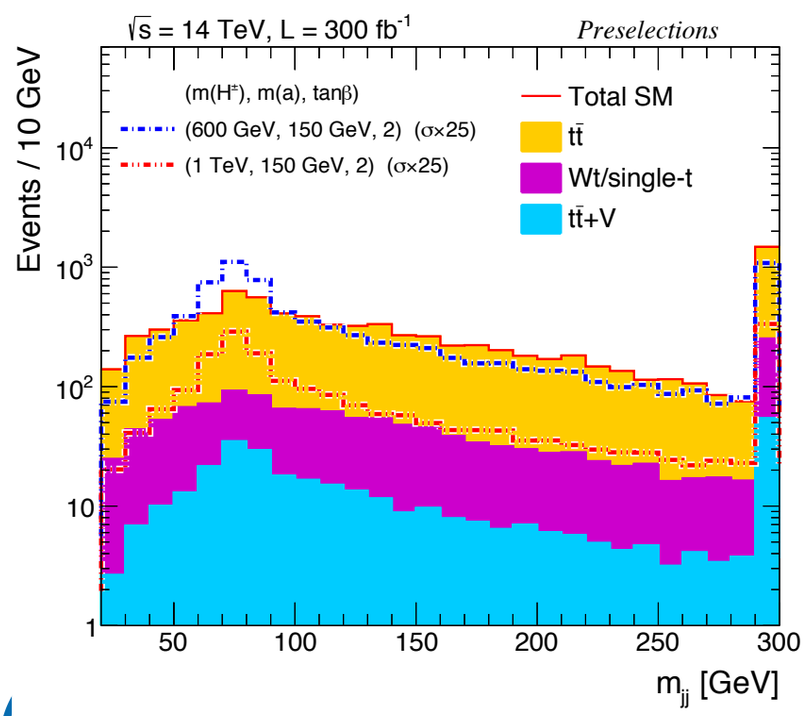
- ★ Study experimental sensitivity with simulated samples and parametrized detector smearing.
- ★ Considered both *1-lep* and *2-lep* final states.

- ★ Backgrounds: tt, tV, single-t, ttV, VV, V+jets.
- ★ Signal (Madgraph+Pythia8, 2HDM+a UFO)
- ★ Systematic uncertainties: 20% background, 5% signal.

- ★ Dataset: 300 fb-1 @ 14 TeV

1-lep: discriminant masses





SIGNATURE: 1 *lep* + 1 *b*-jet + 2 jets + E_T^{miss}

1) transverse mass lep-E_T^{miss} **≳ *120 GeV***

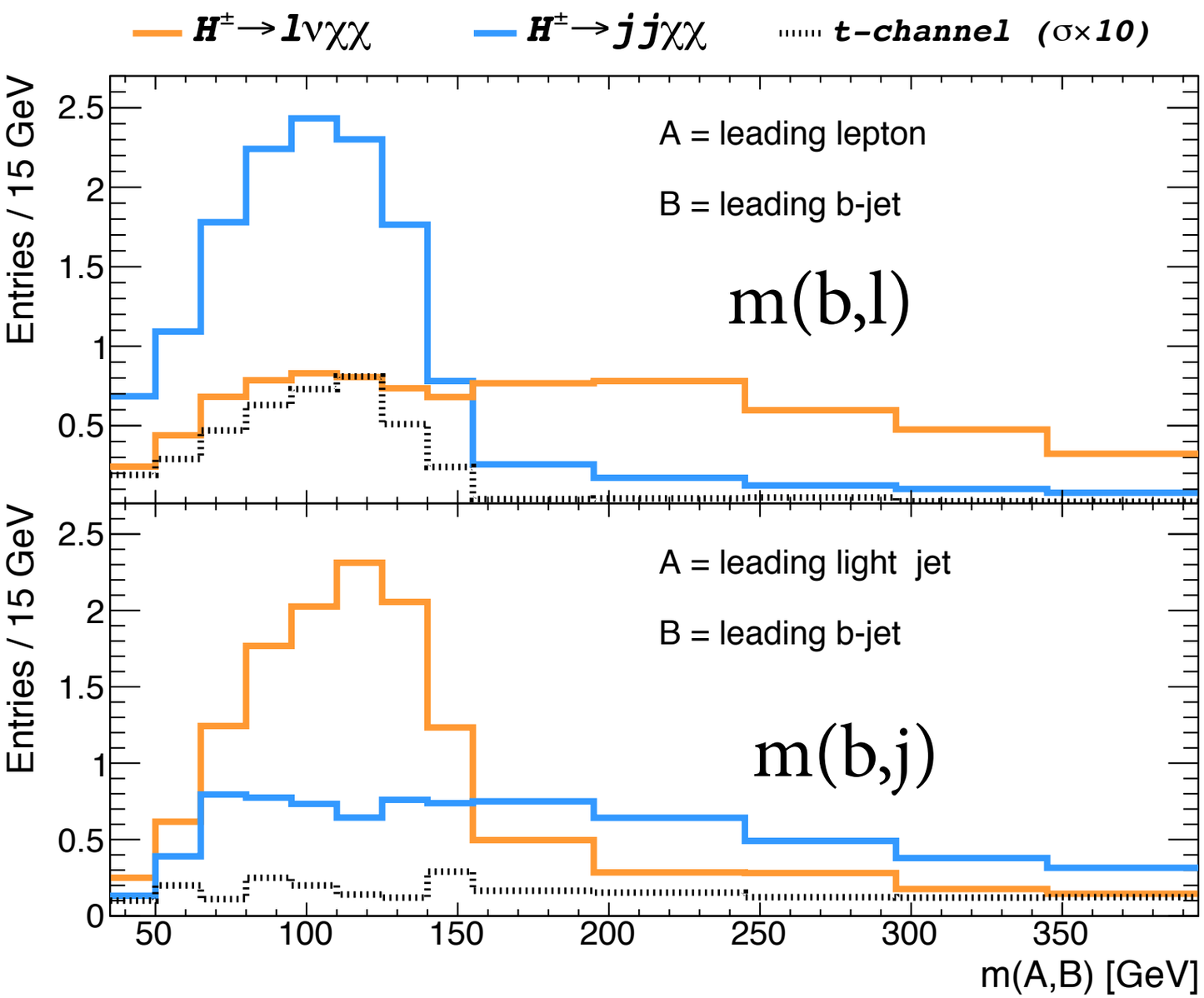
$$m_T^\ell = M_T(\vec{p}_T^{\,\ell}, \vec{p}_T^{\,miss})^2 \equiv 2|\vec{p}_T^{\,\ell}||\vec{p}_T^{\,miss}|(1 - \cos\Delta\phi_{\vec{p}_T^{\,\ell}\,\vec{p}_T^{\,miss}})$$

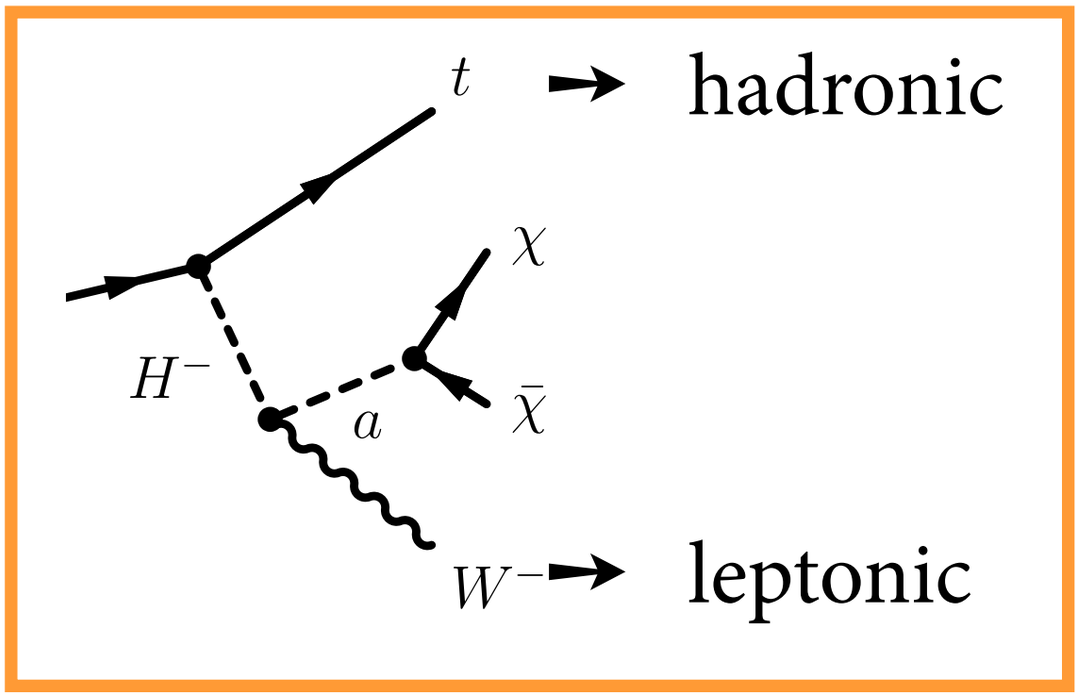
2) stransverse mass (asymmetric) **≳*200 GeV***

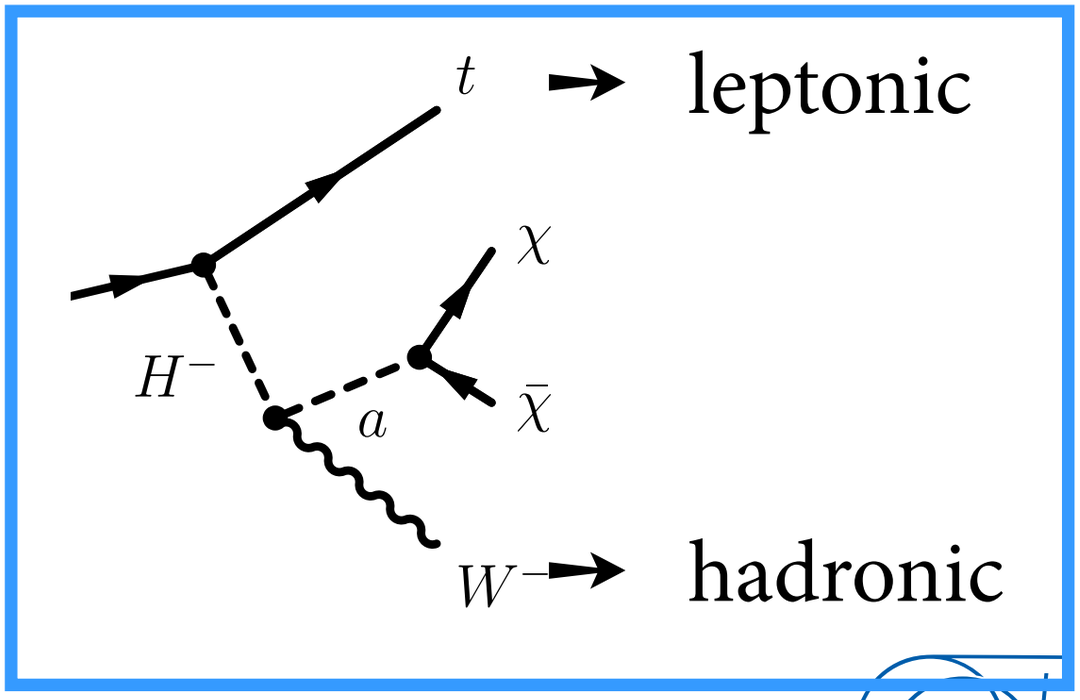
$$m_{T2} \equiv \min_{\vec{q}_T + \vec{r}_T = \vec{p}_T^{\,miss}} \{\max[m_T(\vec{p}_a, \vec{q}_T), m_T(\vec{p}_b, \vec{r}_T)]\},$$

3) inv. mass leading light jets **~ *80 GeV***

1-lep: kinematics considerations

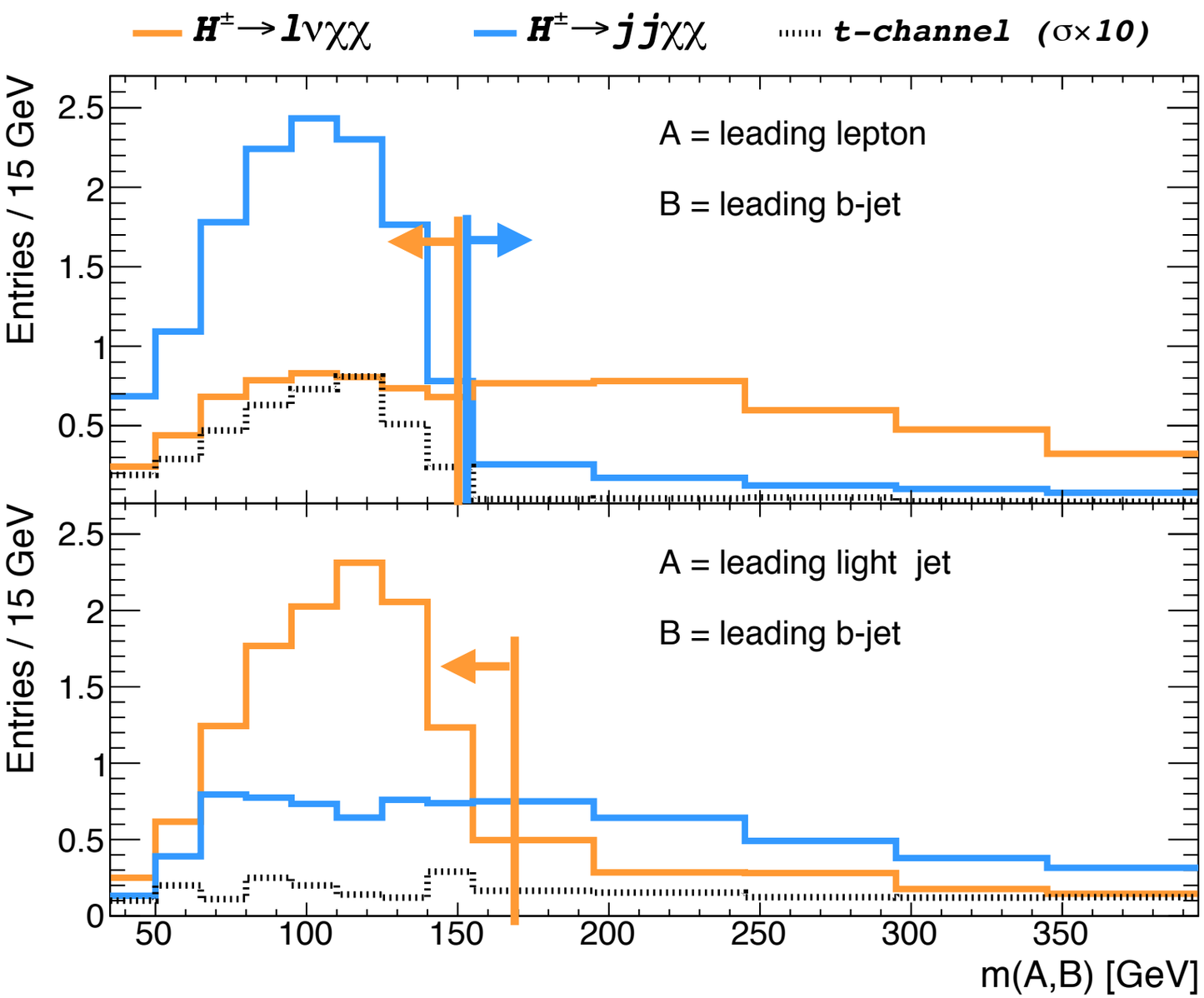






m(H±) = 1 TeV

1-lep: final selections



leptonic-H±

- lep p_T > 150 GeV
- jet p_T > 50,50,20 GeV
- m(b,l) > 160 GeV
- m(b,j) < 170 GeV

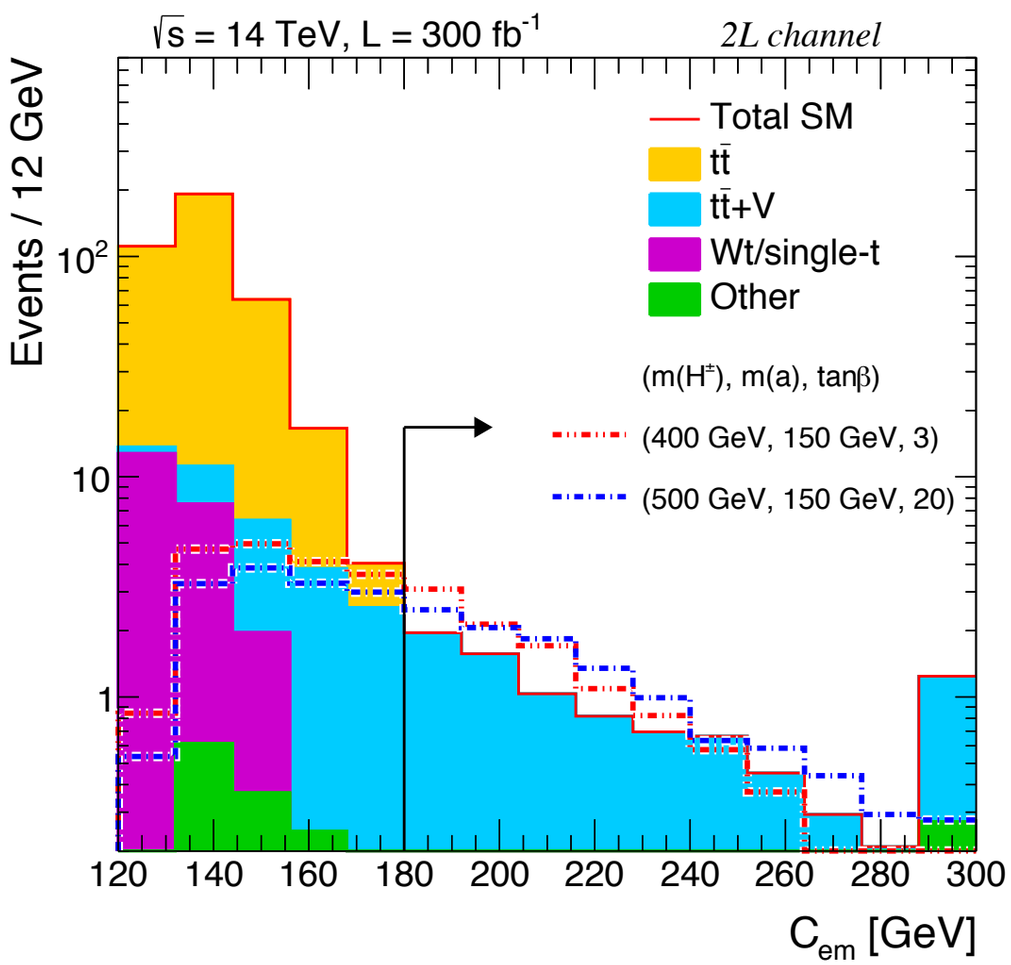
hadronic-H±

- lep p_T > 25 GeV
- jet p_T > 100,50,40 GeV
- m(b,l) < 160 GeV

+ 2nd b-jet veto, E_T^{miss}, $\Delta\varphi(E_T^{miss}$,jets)

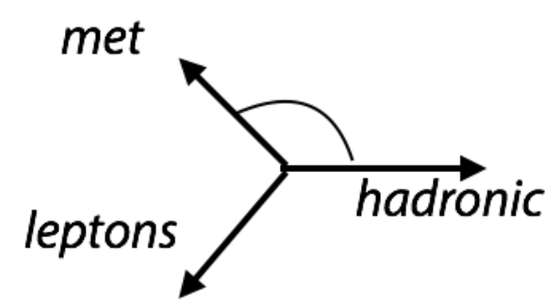
2-lep: discriminants and selections

SIGNATURE: 2 *lep* + 1 *b*-jet + E_T^{miss}



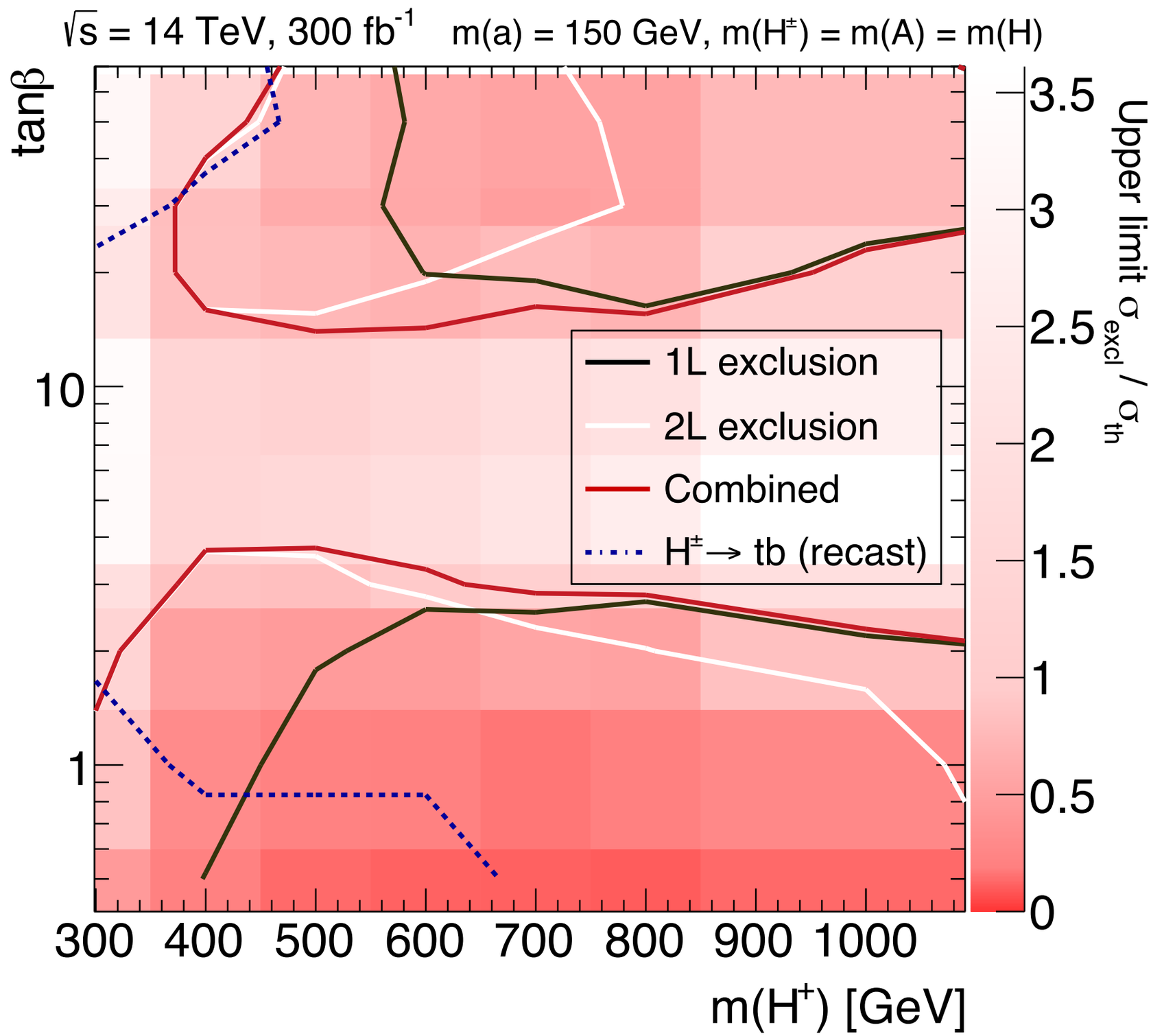
2-lep selection

- ★ mll Z-peak veto
- ★ $\Delta\varphi_{boost} < 1$

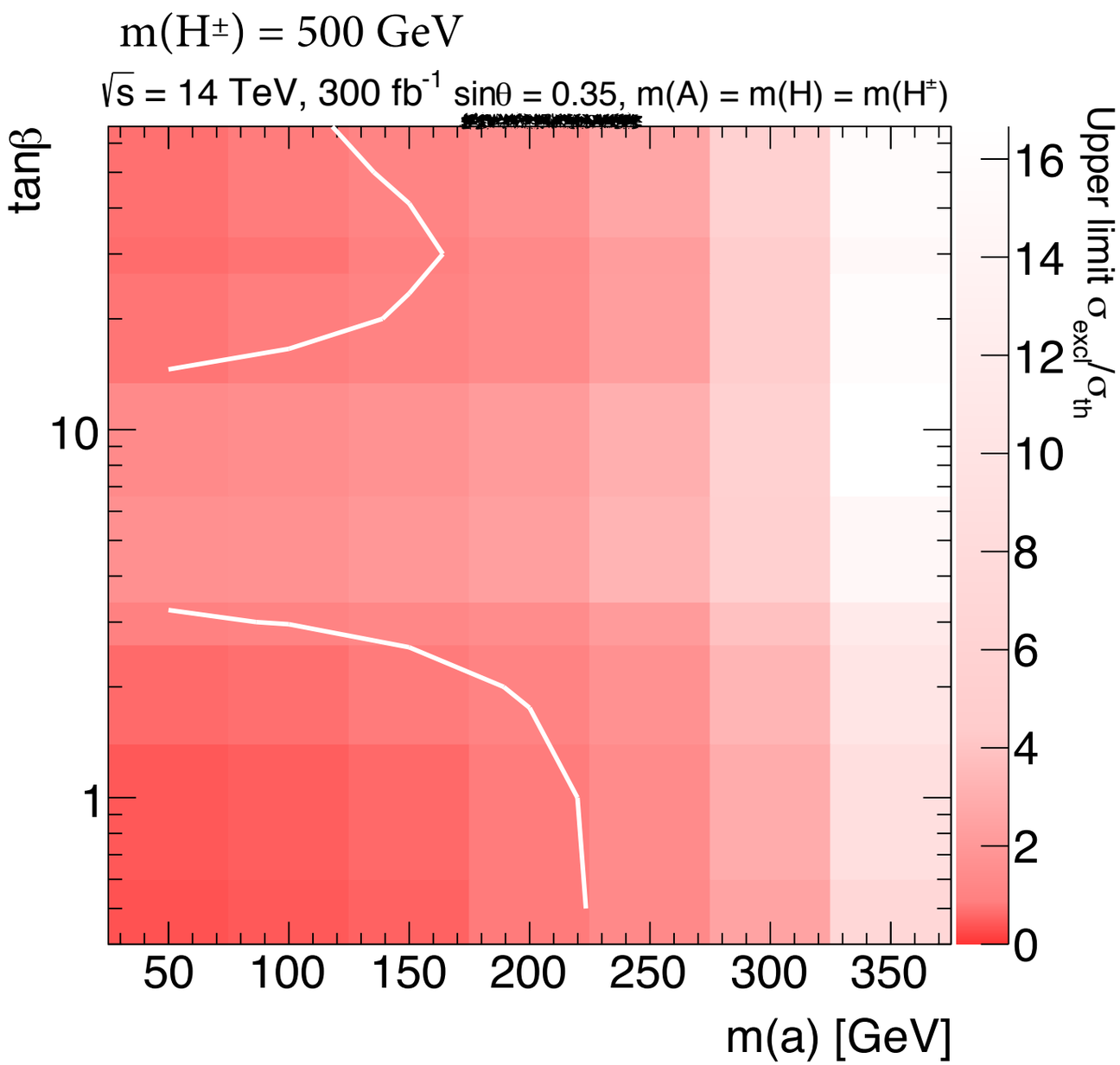


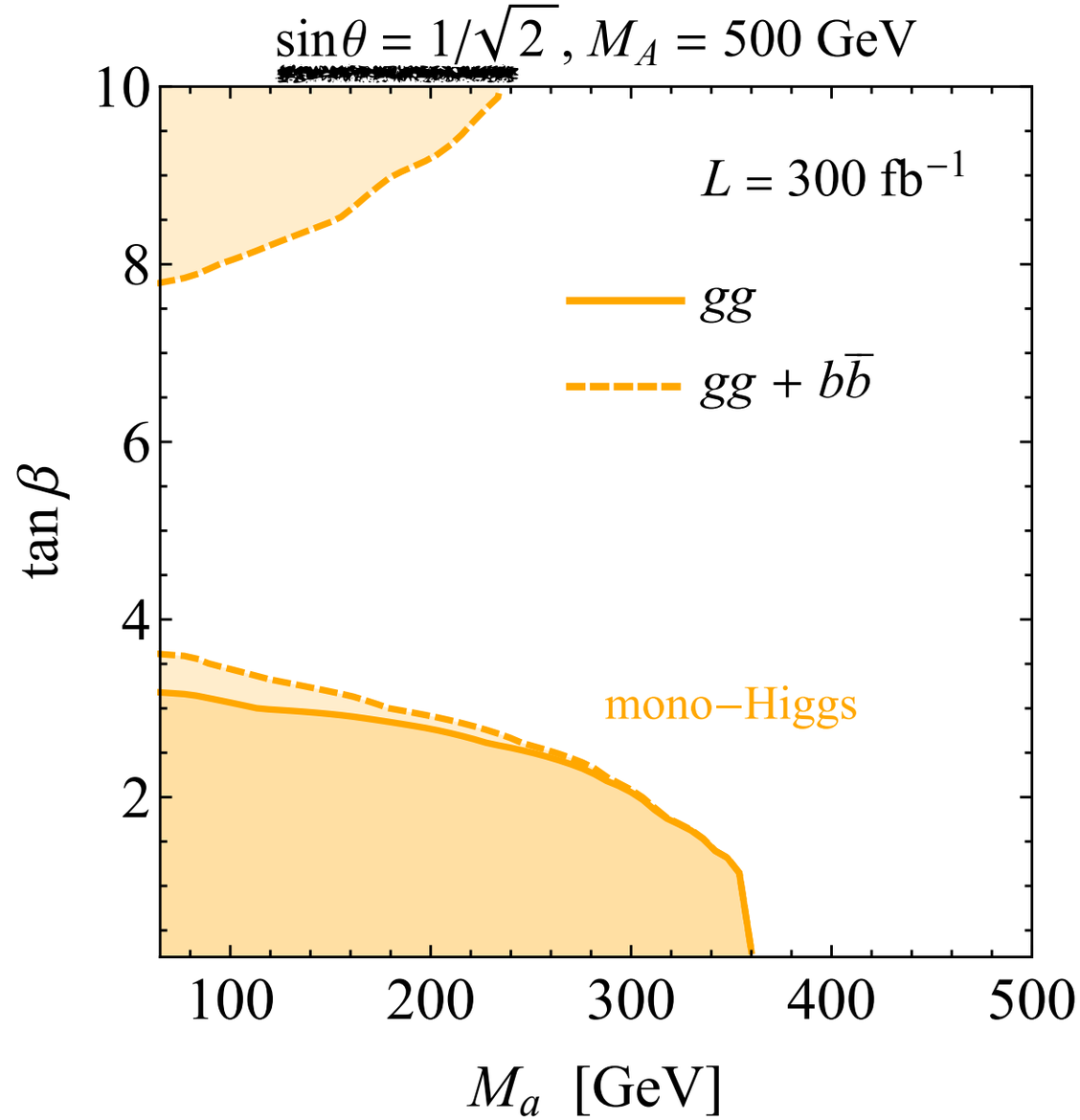
- ★ m(b,l) < 150 GeV
- ★ $H_T < 150$ GeV
- ★ $C_{em} \equiv m_{T2} + 0.2 \cdot E_T^{miss}$ ***> 180 GeV***

Results 1


√s = 14 TeV, 300 fb-1 m(a) = 150 GeV, m(H±) = m(A) = m(H)
tanβ
10
1
300 400 500 600 700 800 900 1000
m(H+) [GeV]
1L exclusion
2L exclusion
Combined
H±→ tb (recast)
Upper limit σexcl / σth
3.5
3
2.5
2
1.5
1
0.5
0

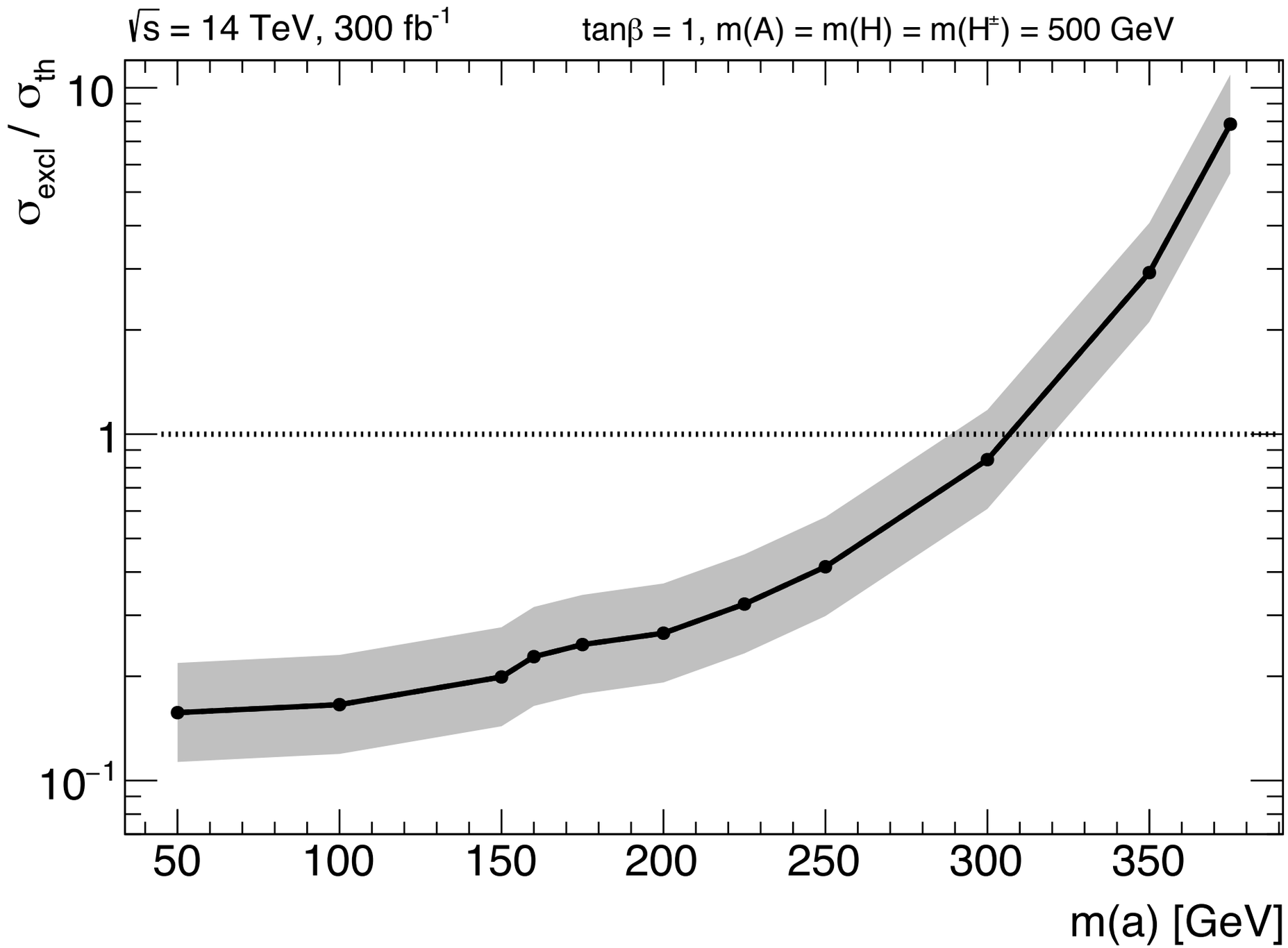
Results 2 - comparison with monoH





[Bauer,Haisch,Kahlhoefer]
arXiv:1701.07427

Results 3 - dependence on m(a)



Conclusions

- ★ tW+DM signature probes a large slice of 2HDM paramter space, complementary to DM+X signatures.

- ★ Nice example of a case where examining an UV complete extension of the simplified model suggests a signature missing from LHC searches.

- ★ **Looking forward now to dedicated searches from the experimental collaborations!**

The End

Thanks for your ~~attention~~ patience

Any question ?

Backup