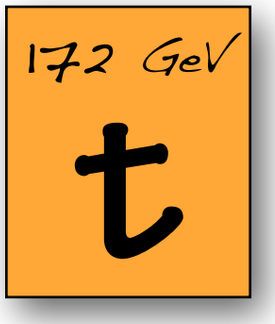
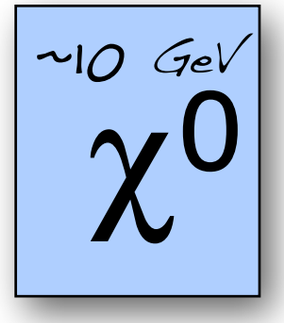
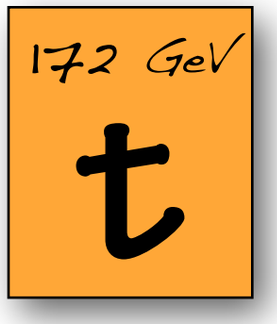
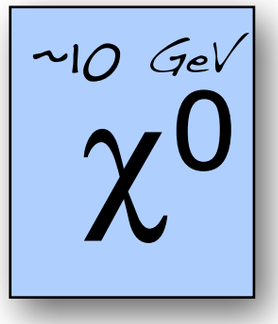


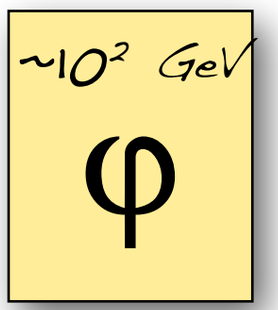


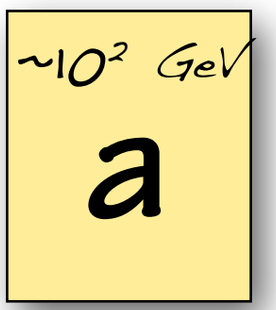
Dark matter plus top quark(s) searches at HL/HE-LHC

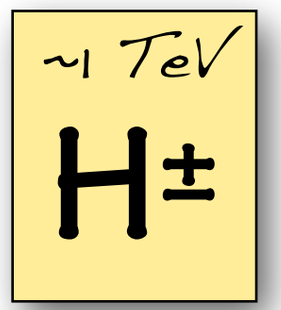




Ulrich Haisch, Priscilla Pani
& Giacomo Polesello

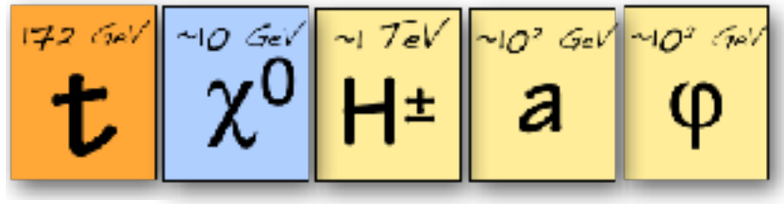


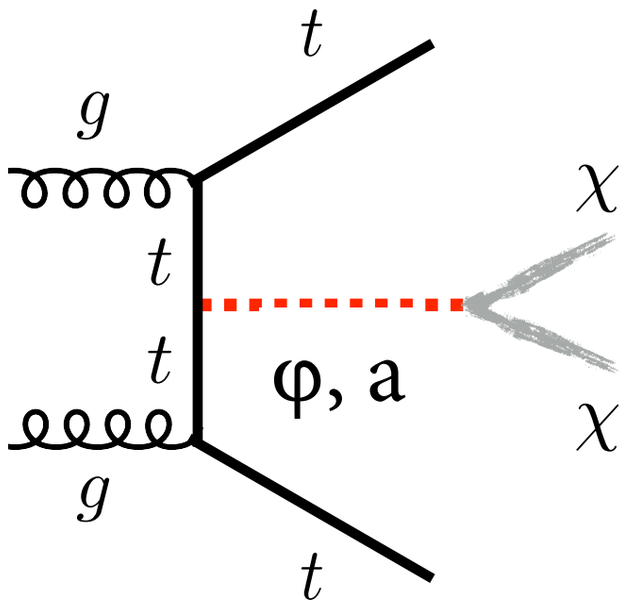


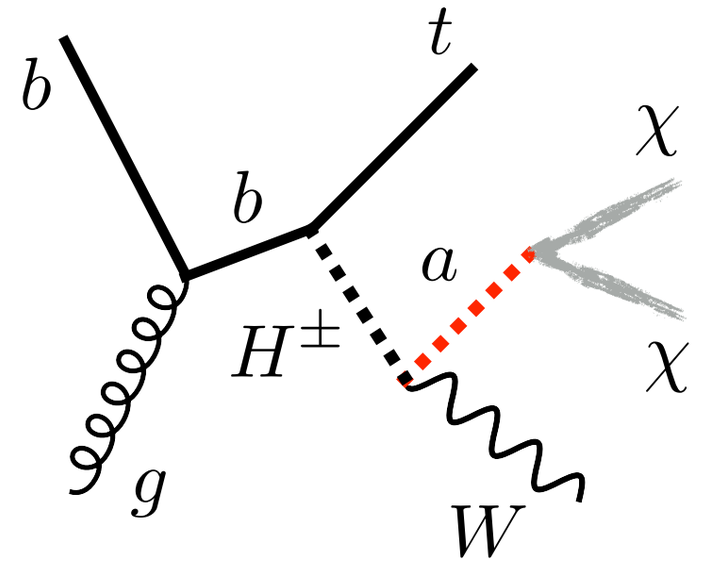


Workshop on the physics of HL-LHC, and perspectives at HE-LHC
19-20 June 2018, CERN

Contribution overview



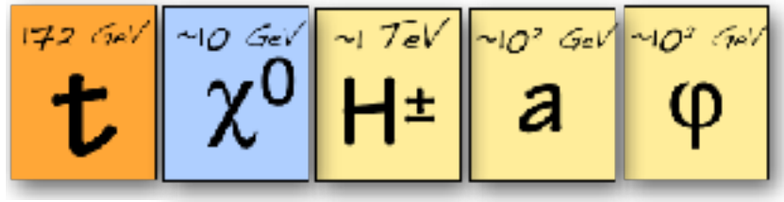




Sensitivity studies of the HL/HE-LHC prospects for searches of spin-0 mediators in $E_{T,miss}$+tt & $E_{T,miss}$+single-top production

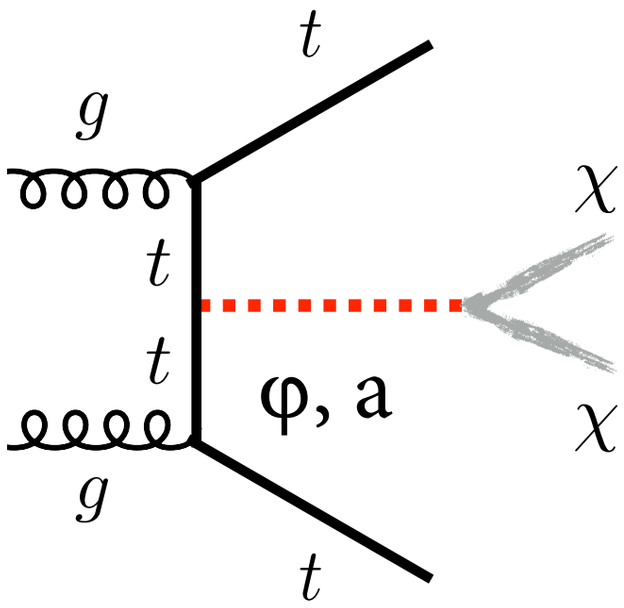
[studies based on Haisch, PP & Polesello, 1611.09841; PP & Polesello, 1712.03874]

Simplified models

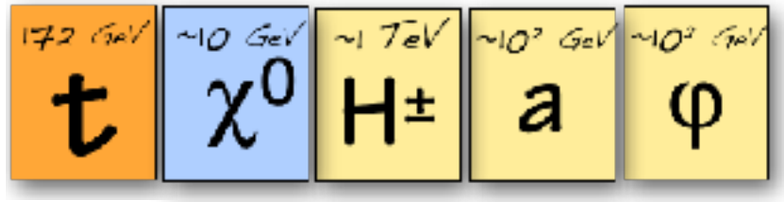


$$\mathcal{L} \supset \frac{g_q y_q}{\sqrt{2}} S\bar{q}q + g_\chi S\bar{\chi}\chi$$

[e.g. Abercrombie et al., 1507.00966]



Simplified models



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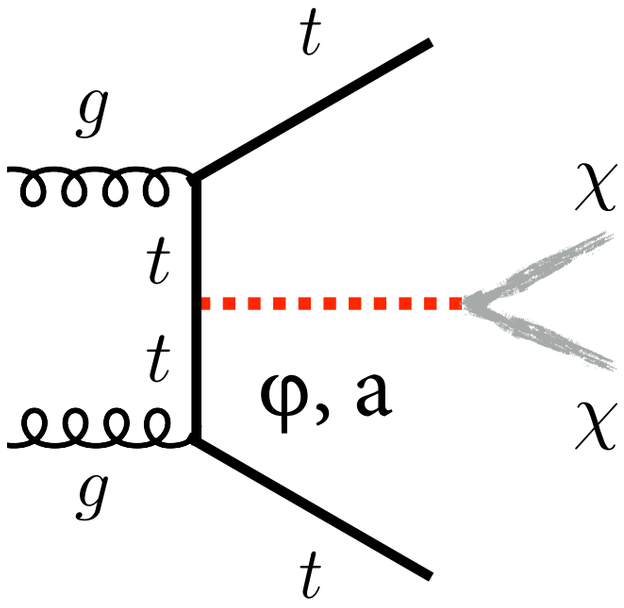
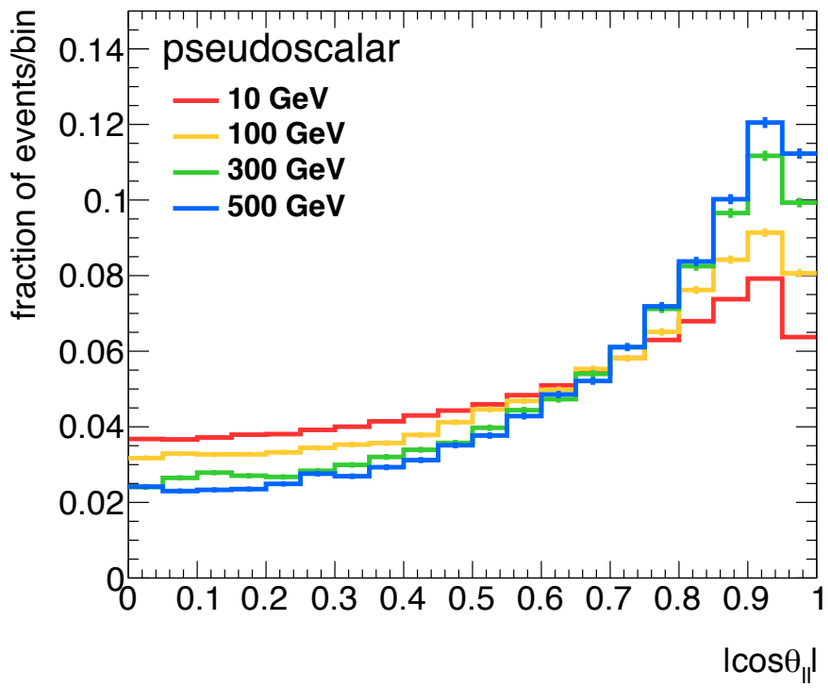
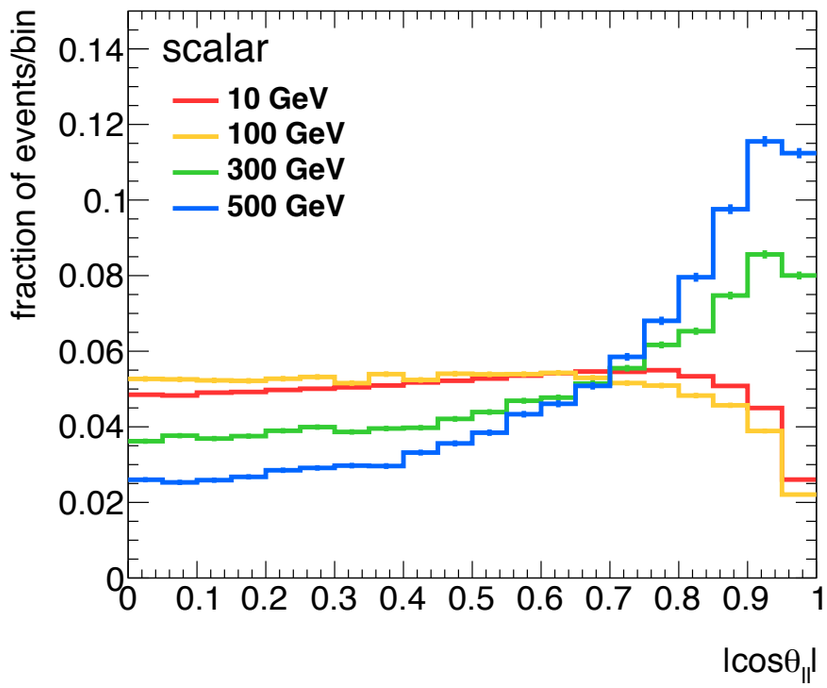
[e.g. Abercrombie et al., 1507.00966]

- ★ Typical Yukawa structure for spin-0 mediatorst
- ★ Enhanced cross sections for top quarks
- ★ Angular correlation gives a handle on the CP properties of the mediator

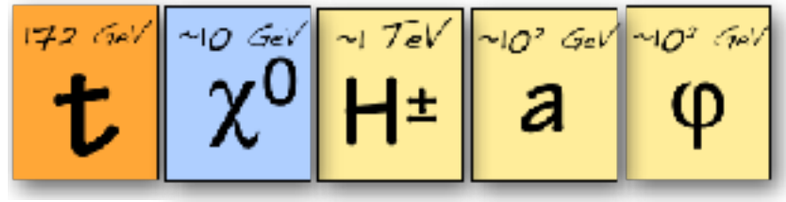


$$\cos\theta_{t\bar{t}} \equiv \tanh\left(\Delta\eta_{t\bar{t}}/2\right)$$





Simplified spin-0 models



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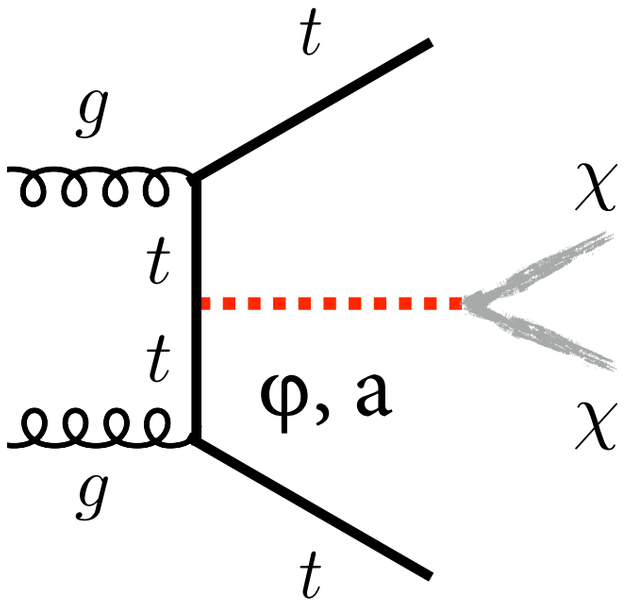
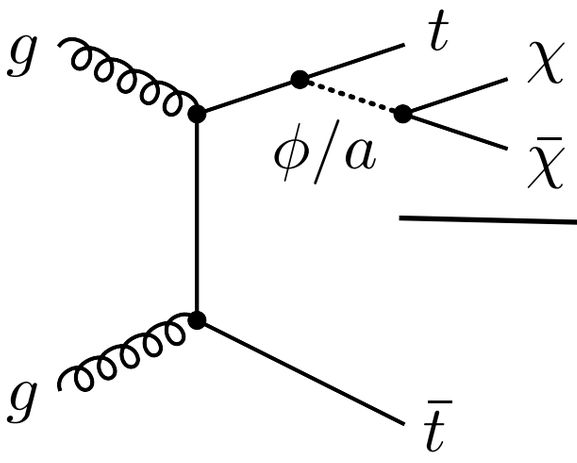
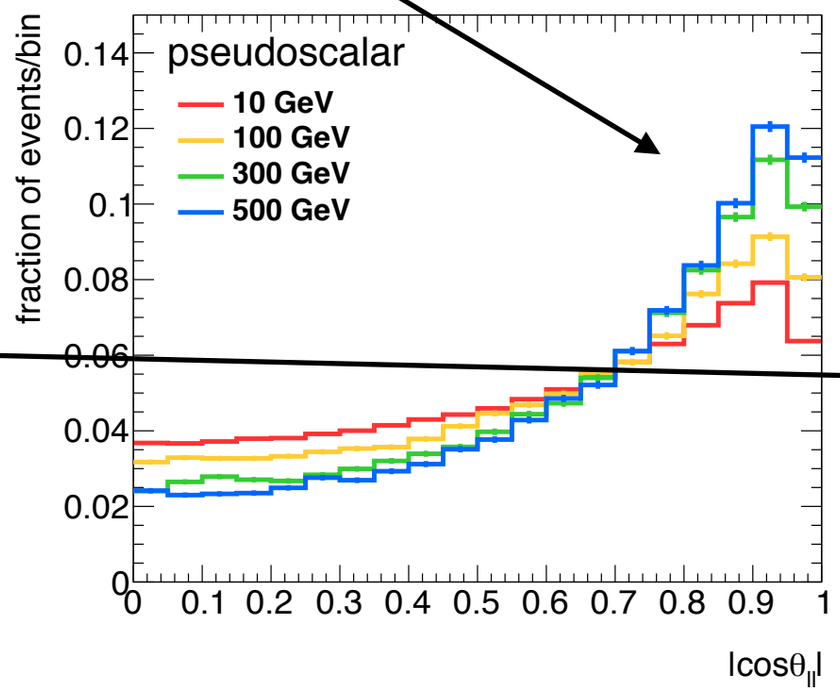
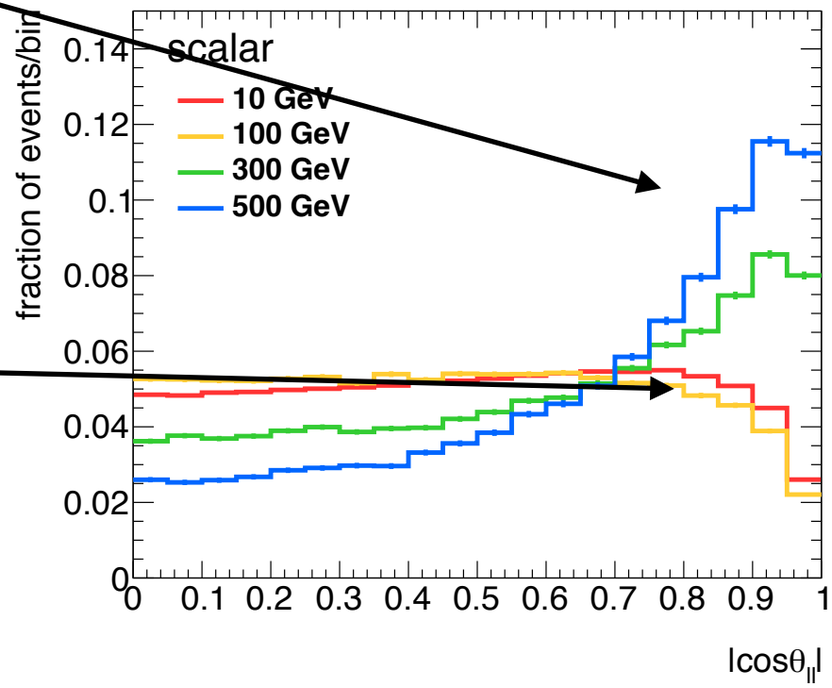


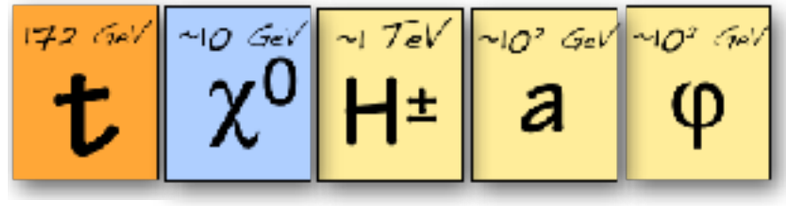


$$\cos\theta_{t\bar{t}} \equiv \tanh\left(\Delta\eta_{t\bar{t}}/2\right)$$



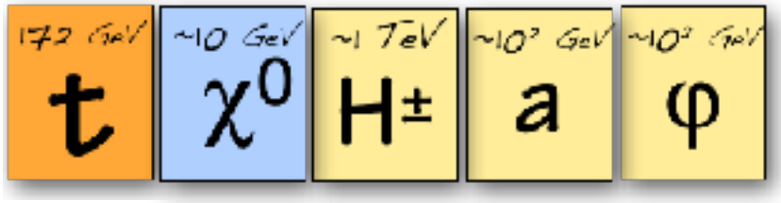


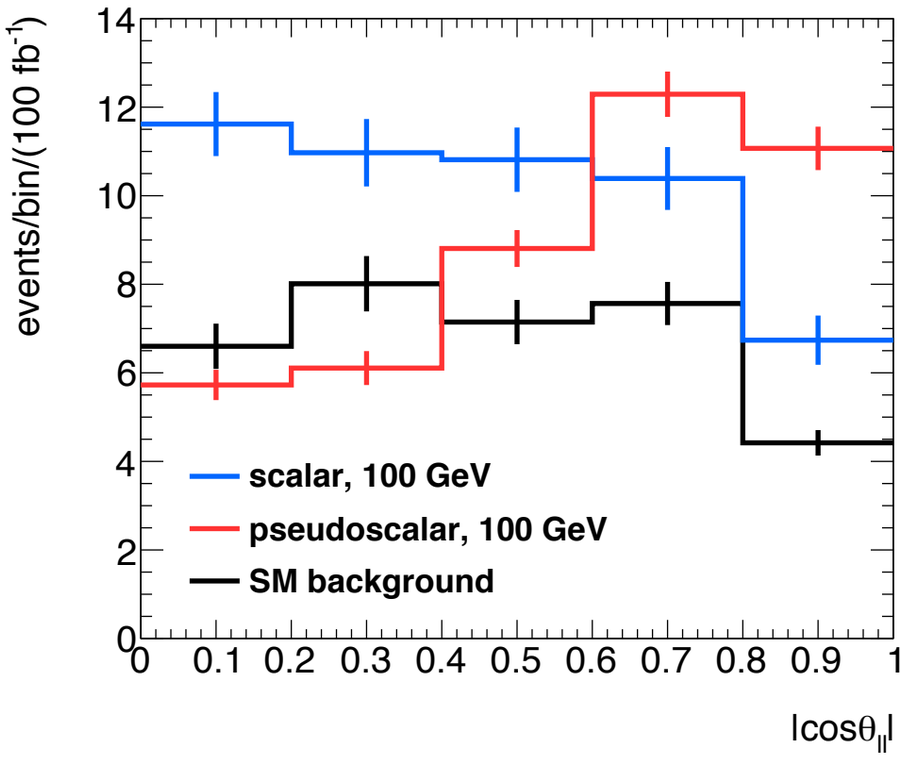
Sensitivity forecast



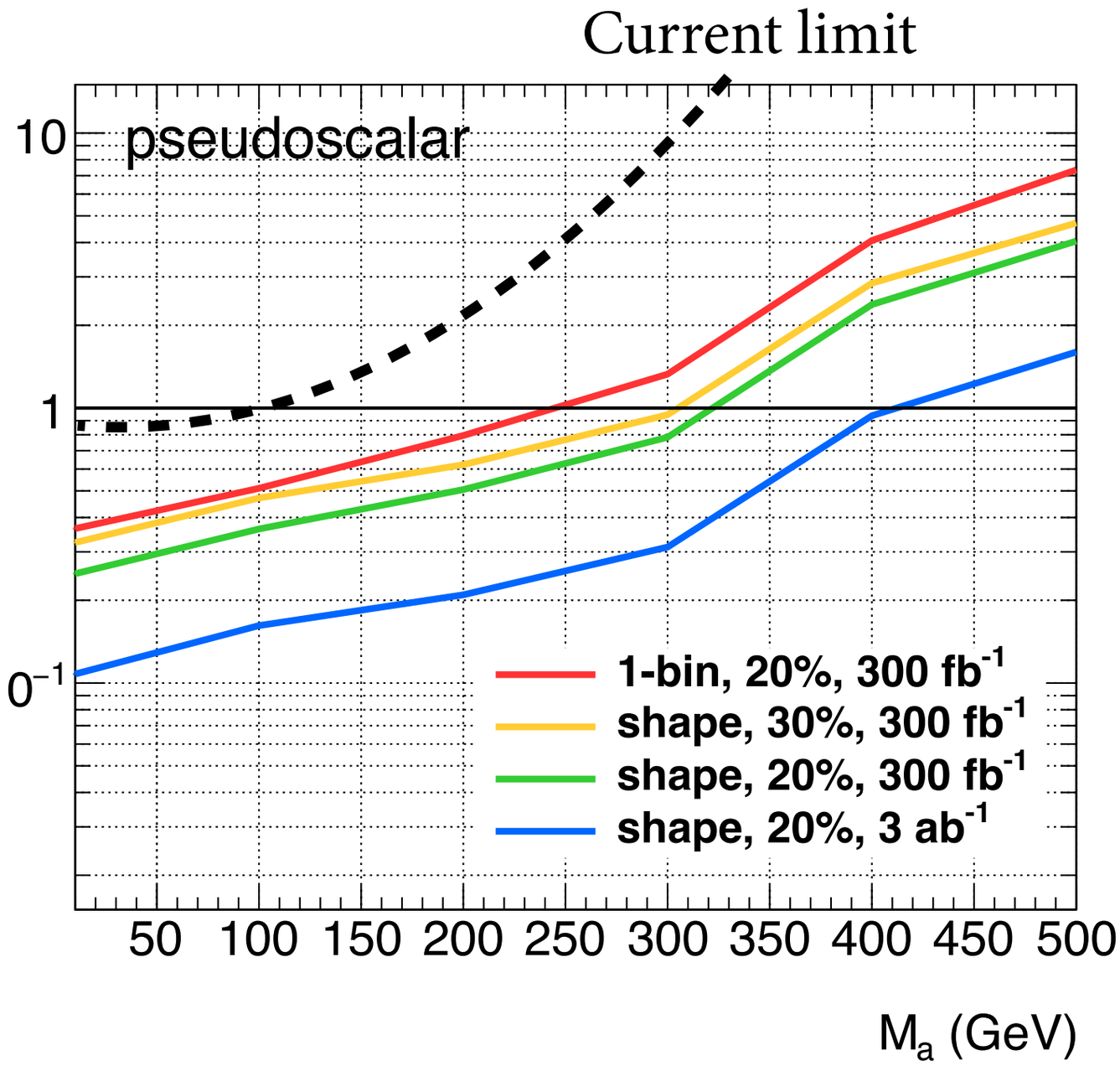
- ★ Study experimental sensitivity with simulated samples and parametrized detector smearing.
- ★ Considered *2-lep* final state.
- ★ Backgrounds: tt, tV, single-t, ttV, VV, V+jets.
- ★ Signal (Madgraph+Pythia8, DMSimp UFO)
- ★ Systematic uncertainties: 20% background.
- ★ Dataset: 300 fb-1/3ab-1 @ 14 TeV

Projections

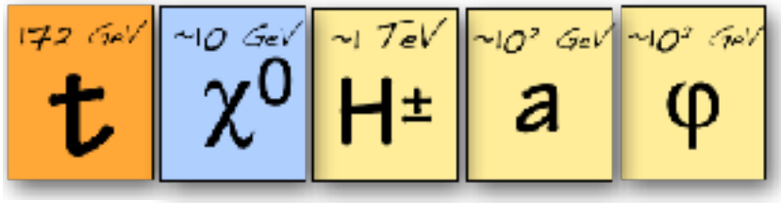


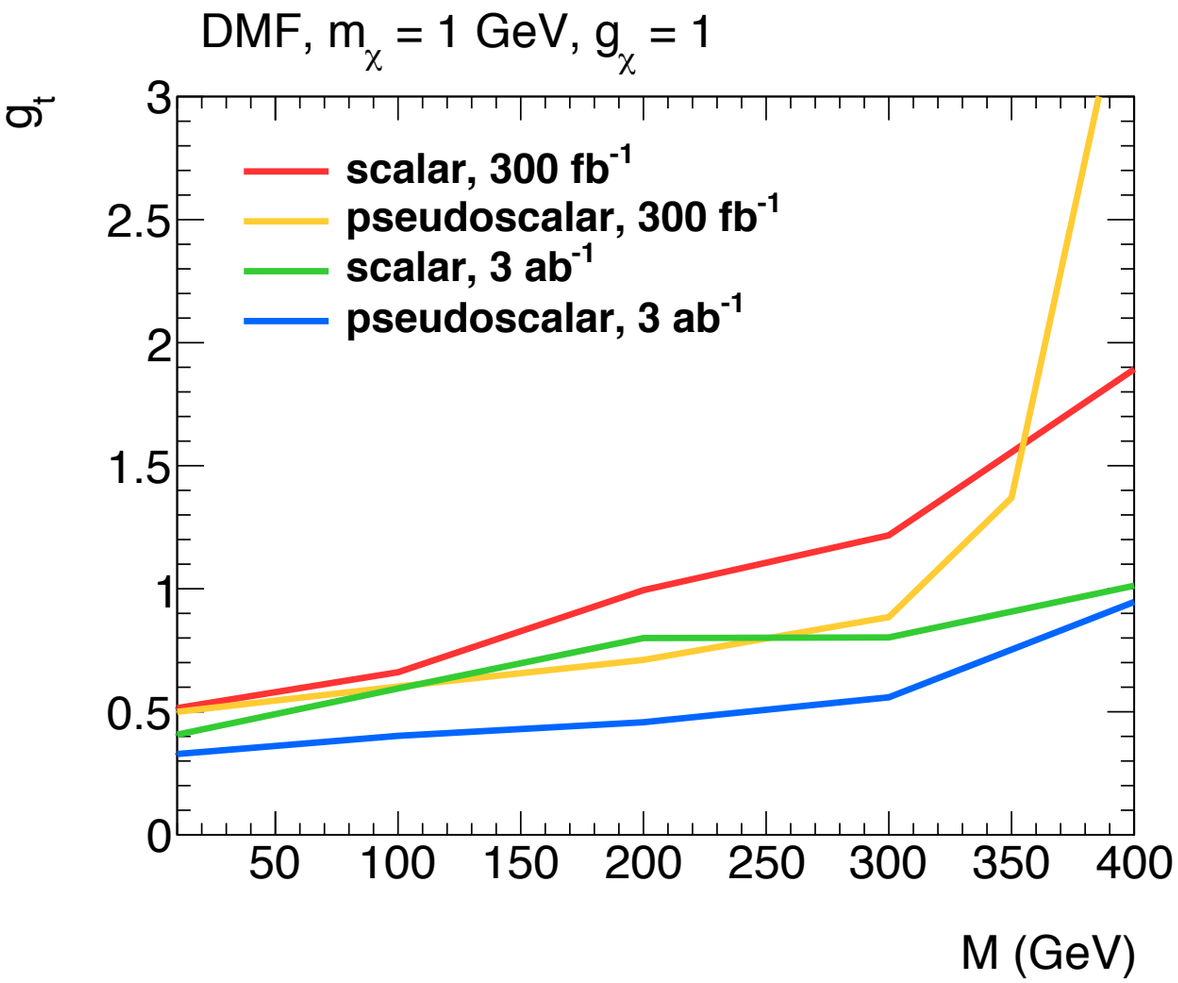


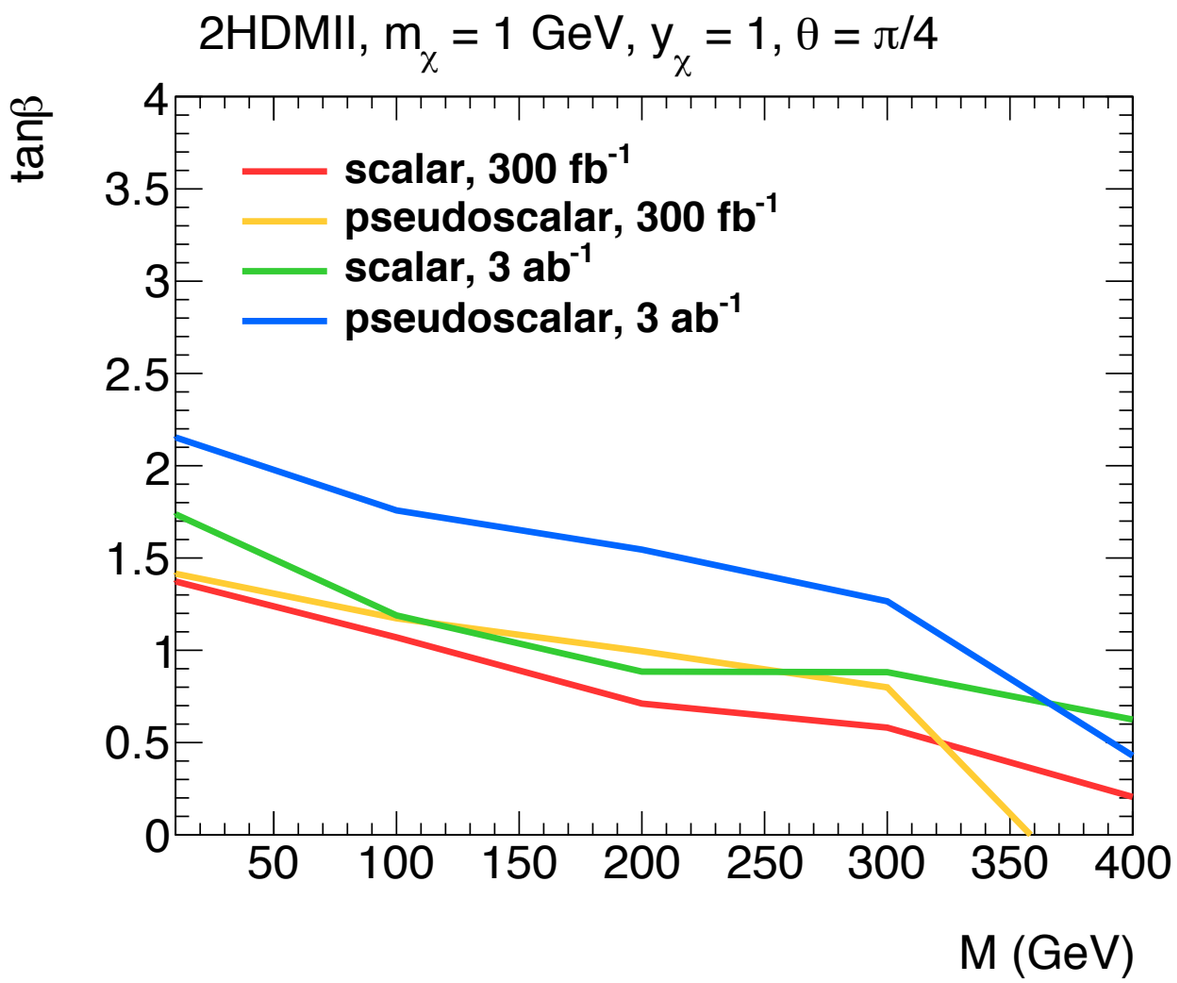
Multi-bin fit



Projections (II)

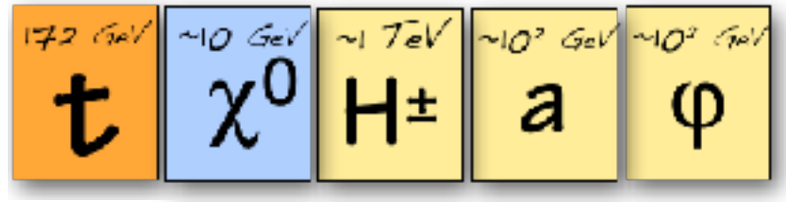


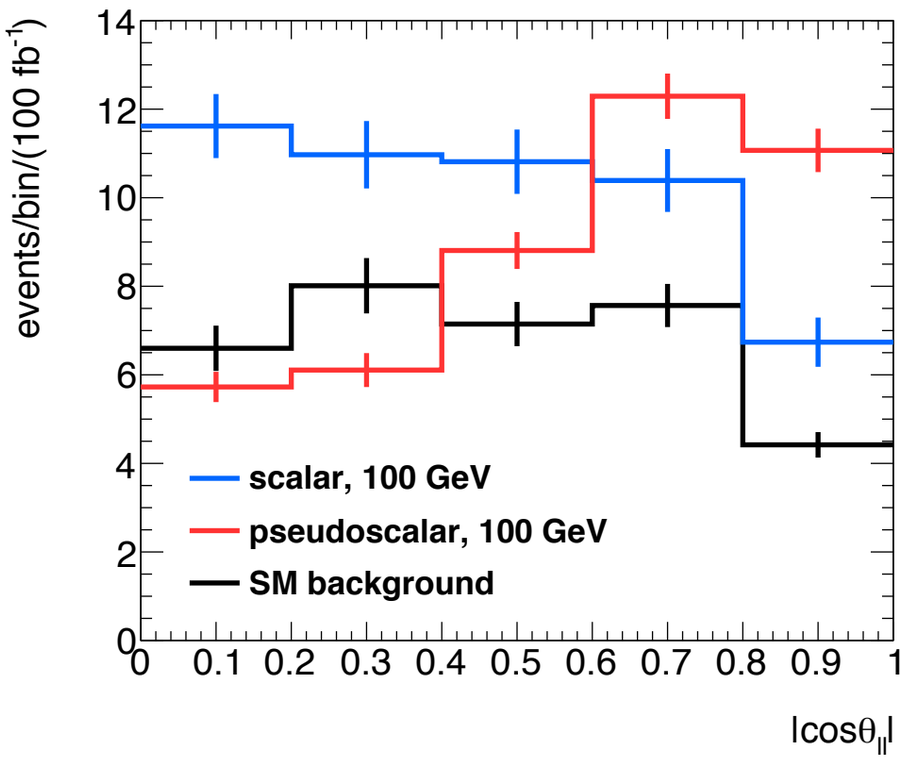




Spin-0 mediators with an effective coupling strength of O(1) to tops can be tested for masses up to 350 GeV (or even above) at future LHC runs

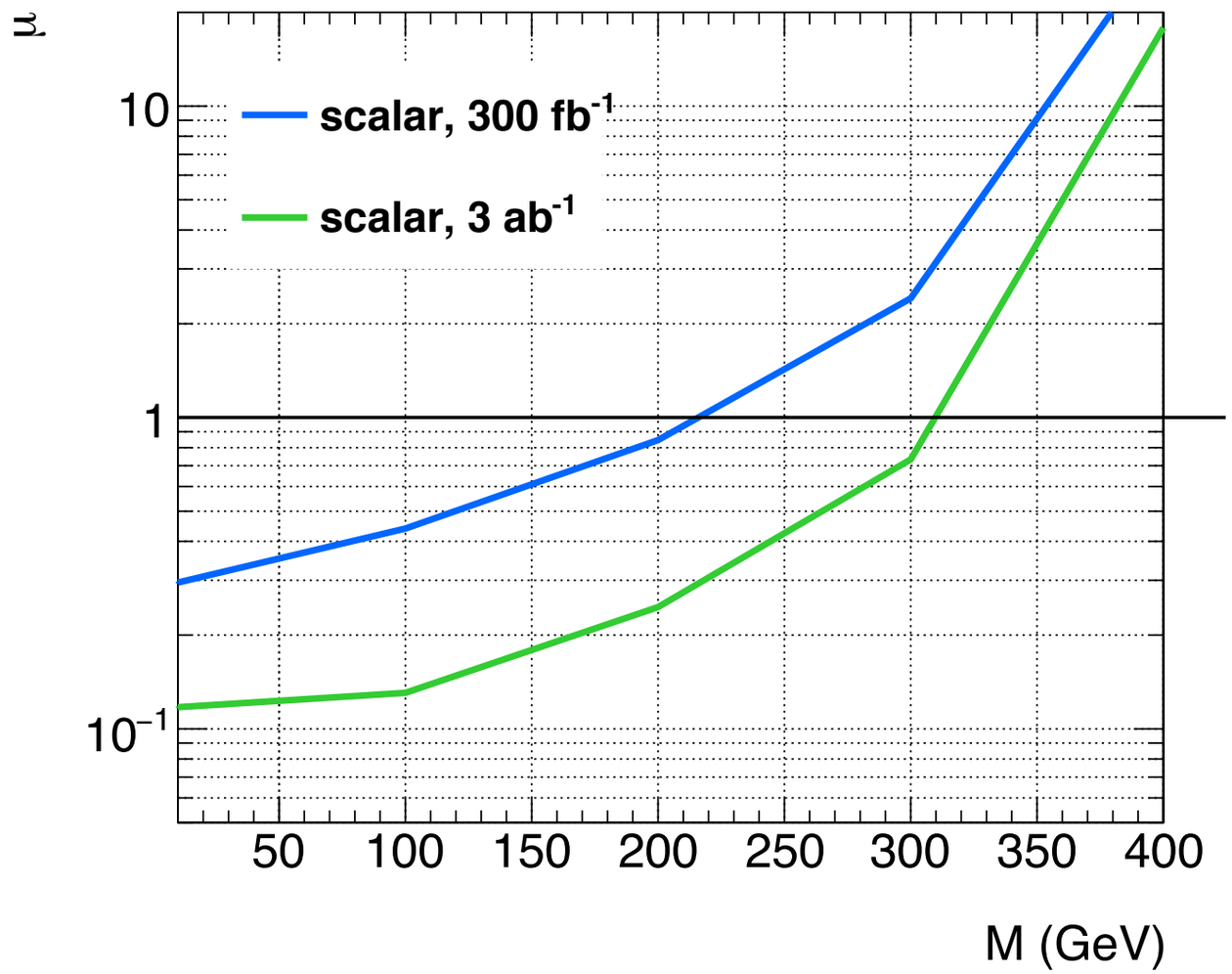
CP measurement



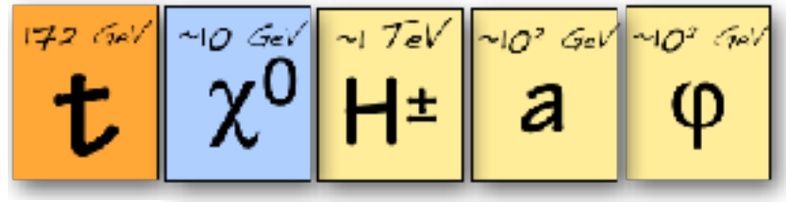


Scalar hypothesis can be excluded at 95% CL in favour of pseudoscalar one (& vice versa) up to ~200 GeV (300 GeV) with 300 fb^{-1} (3 ab^{-1})

Multi-bin fit

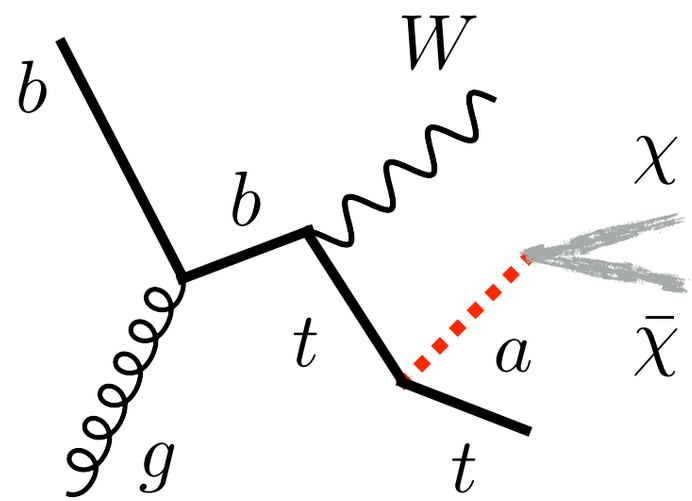


2HDM+a models

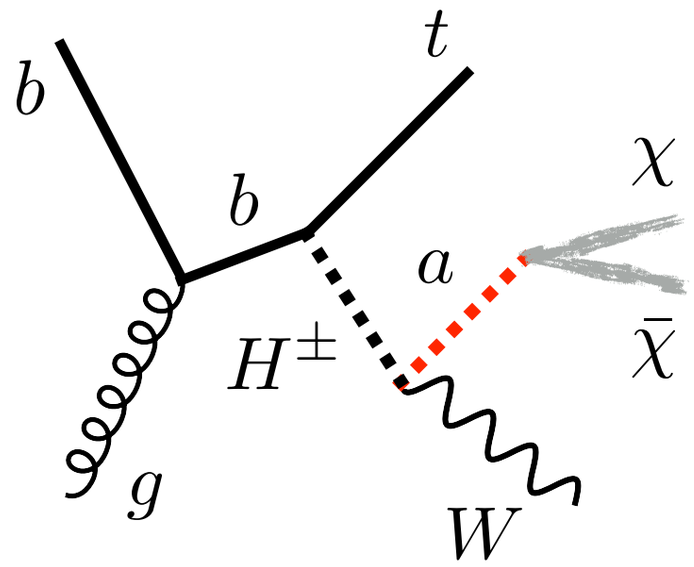


[Bauer et al., 1701.07427]

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

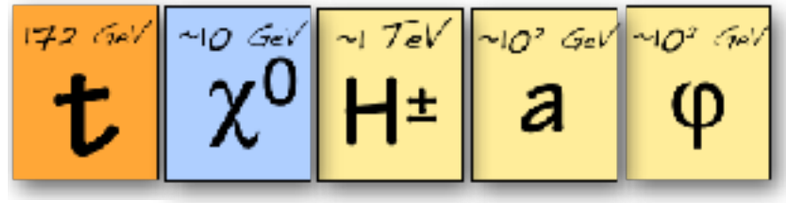


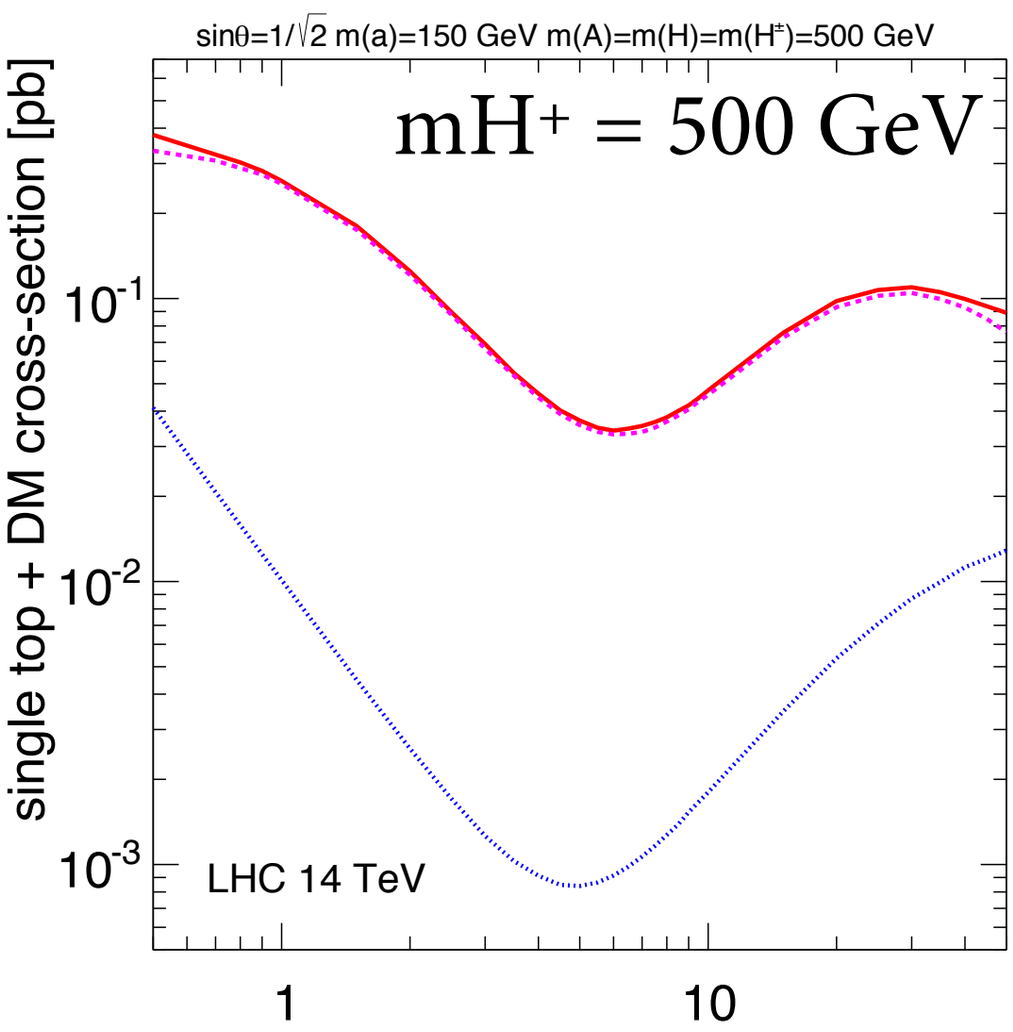
Simplified models only have this diagram

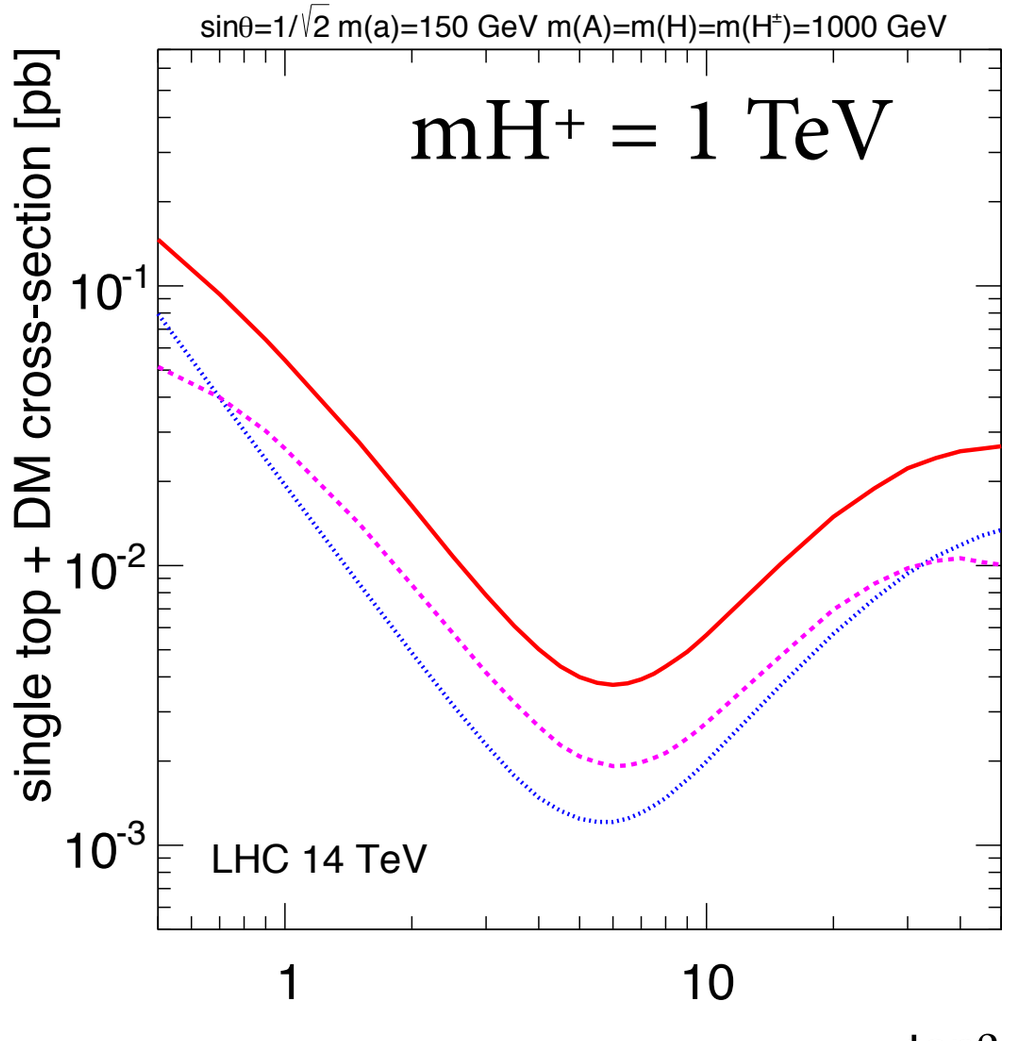


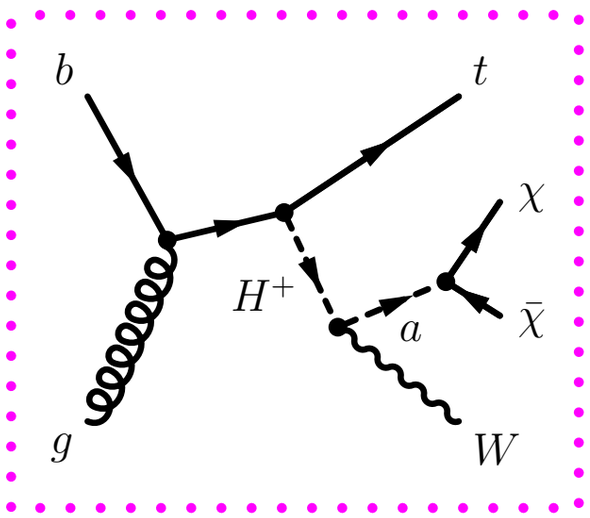
additional in 2HDM+a model; restores unitarity & can lead to resonant enhancement of E_T^{miss}+tW signal

Single top+a production





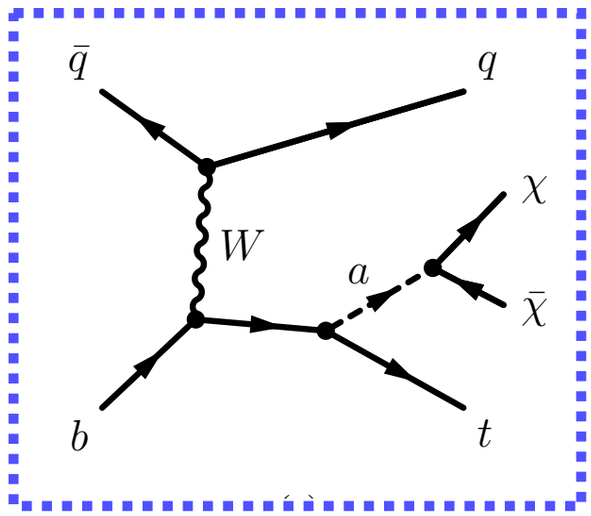




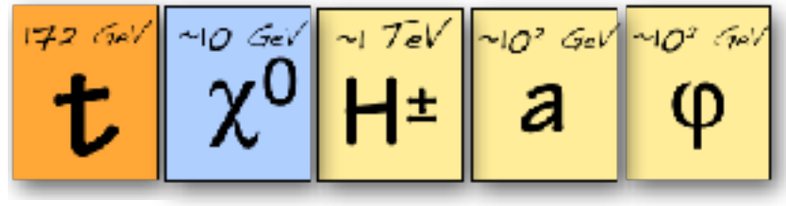
pp → tWχχ inclusive

pp → tH±, H± → Wχχ

pp → tjχχ (t-channel)

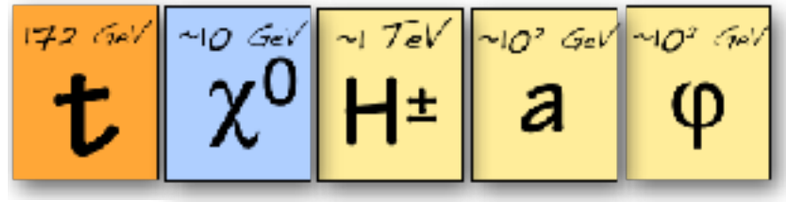


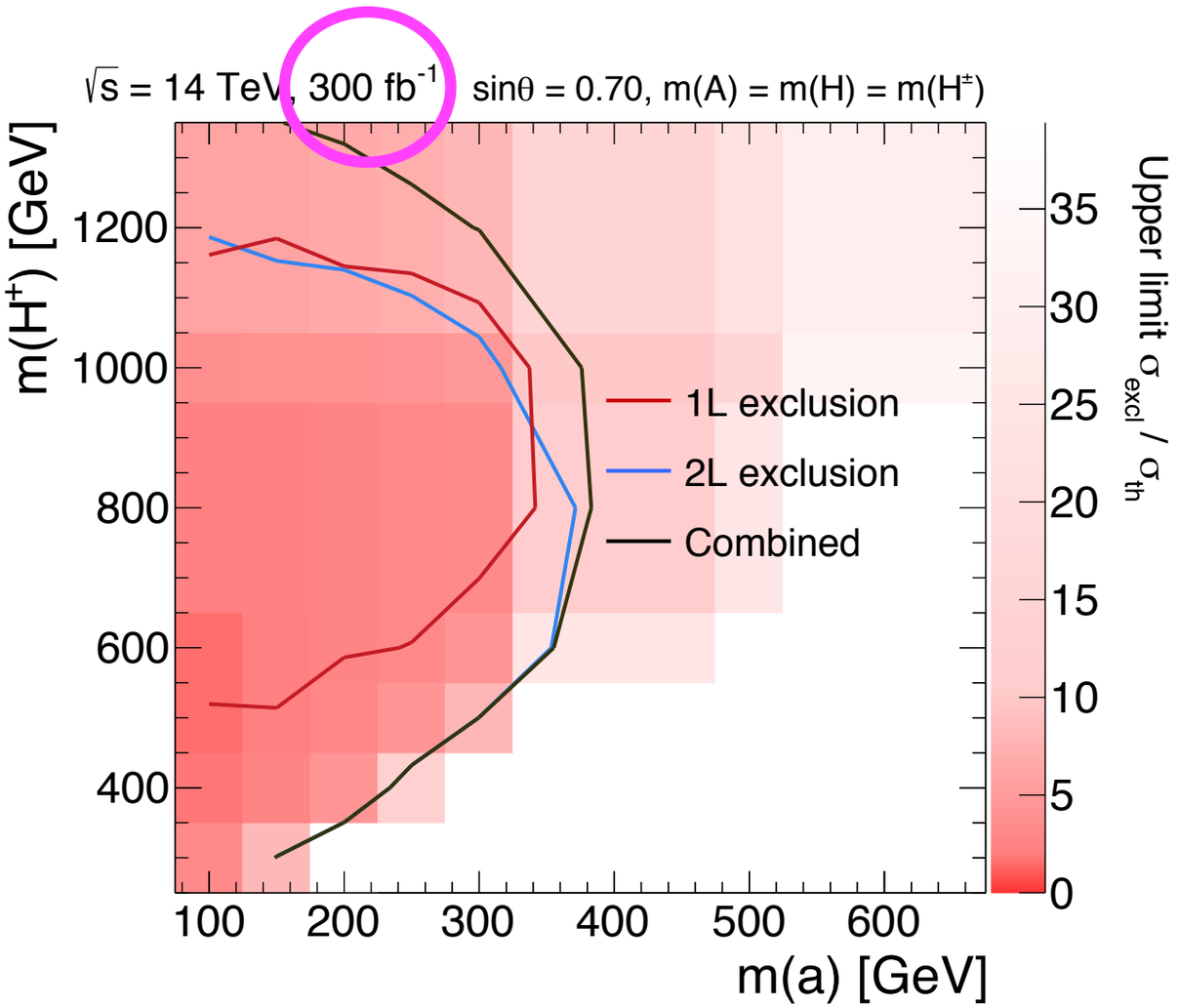
Sensitivity forecast

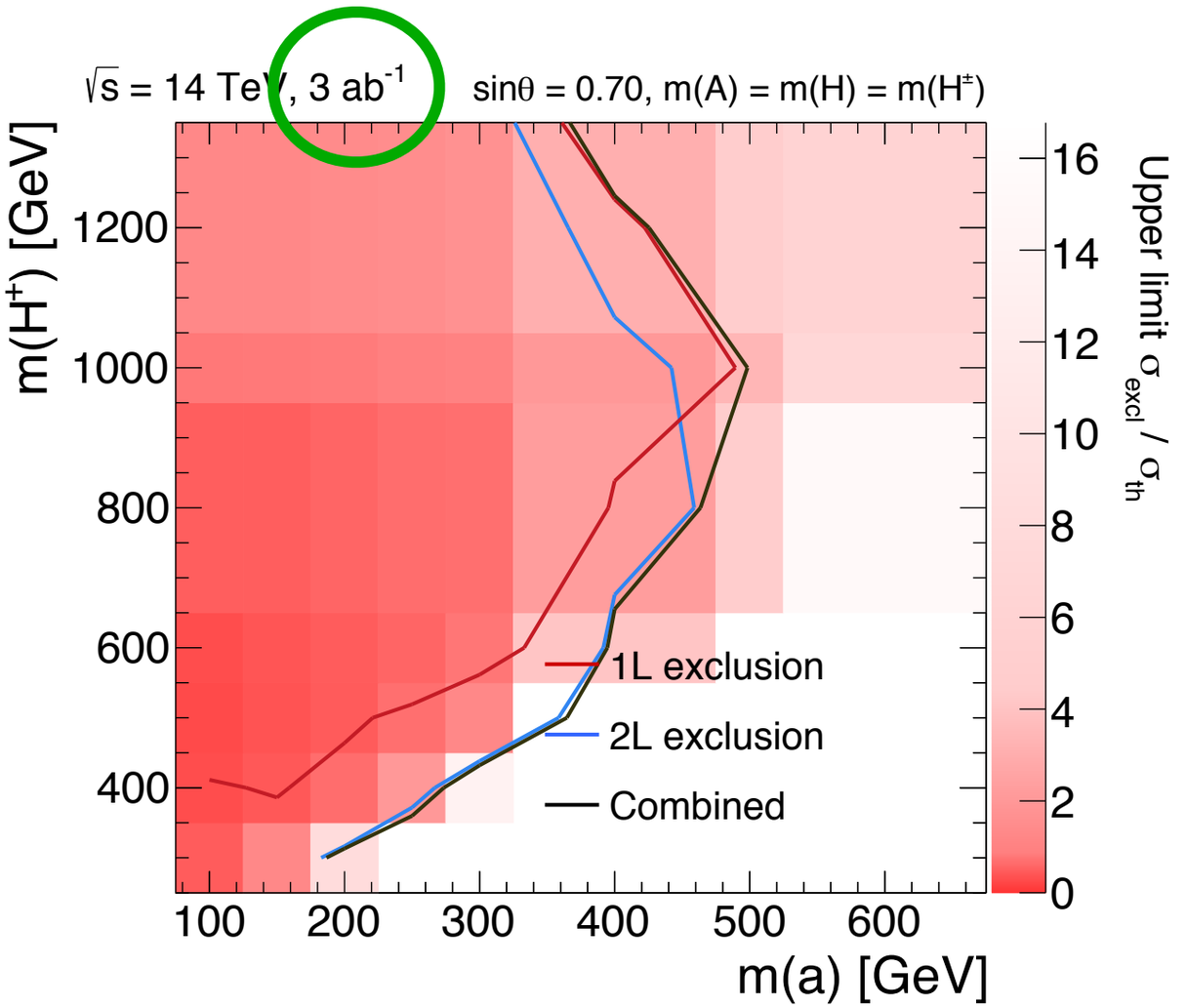


- ★ Study experimental sensitivity with simulated samples and parametrized detector smearing.
- ★ Considered both ***1-lep*** **and** ***2-lep*** final states.
- ★ Backgrounds: tt, tV, single-t, ttV, VV, V+jets.
- ★ Signal (Madgraph+Pythia8, **2HDM+a UFO**)
- ★ Systematic uncertainties: **15% background, 5% signal**.
- ★ Dataset: 300 fb-1/3ab-1 @ 14 TeV

Projections (ma-mH, sinθ = 1/√2)

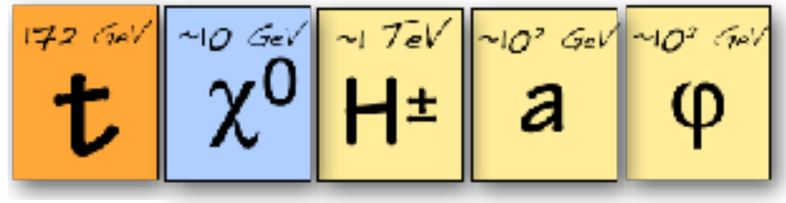


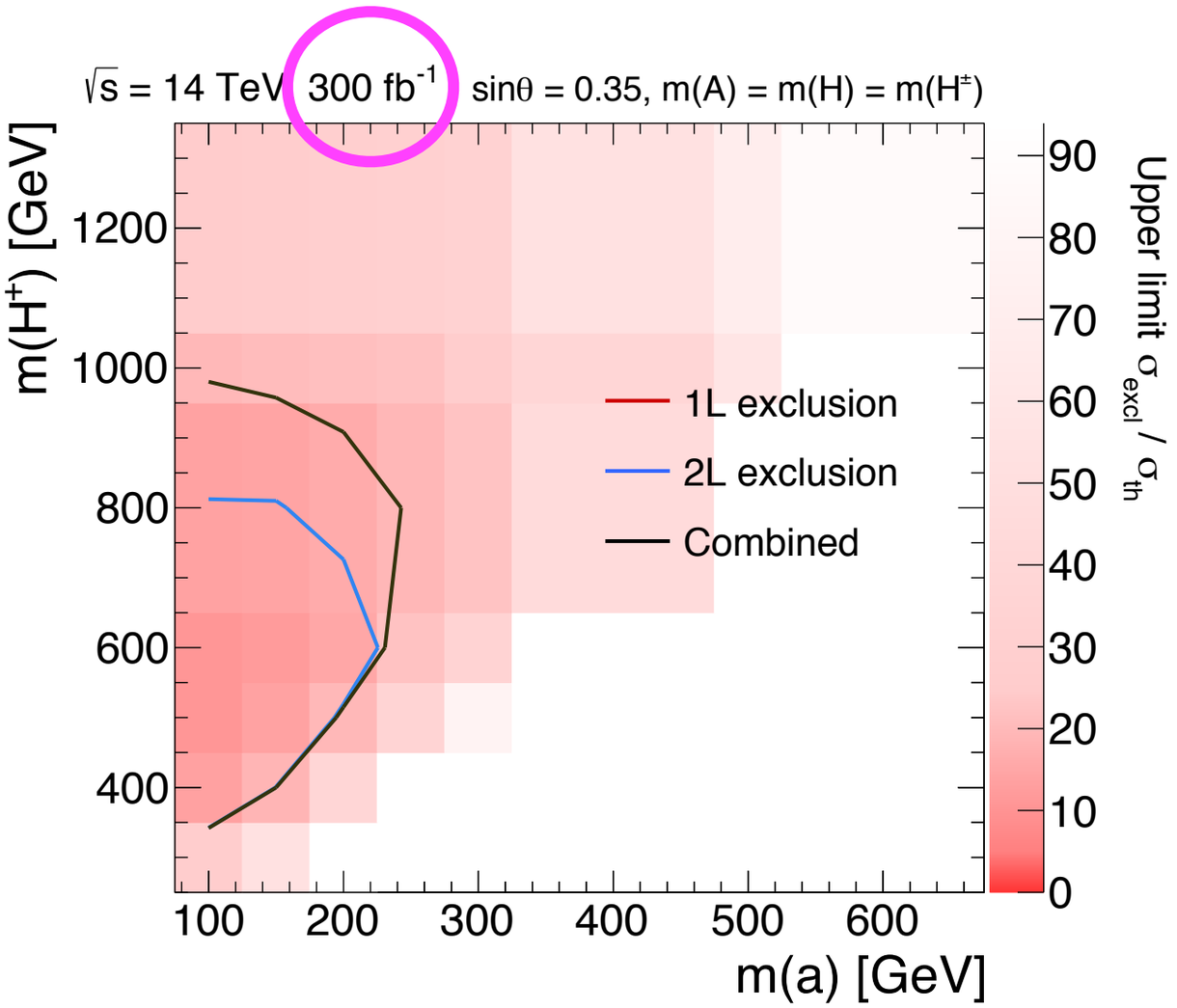


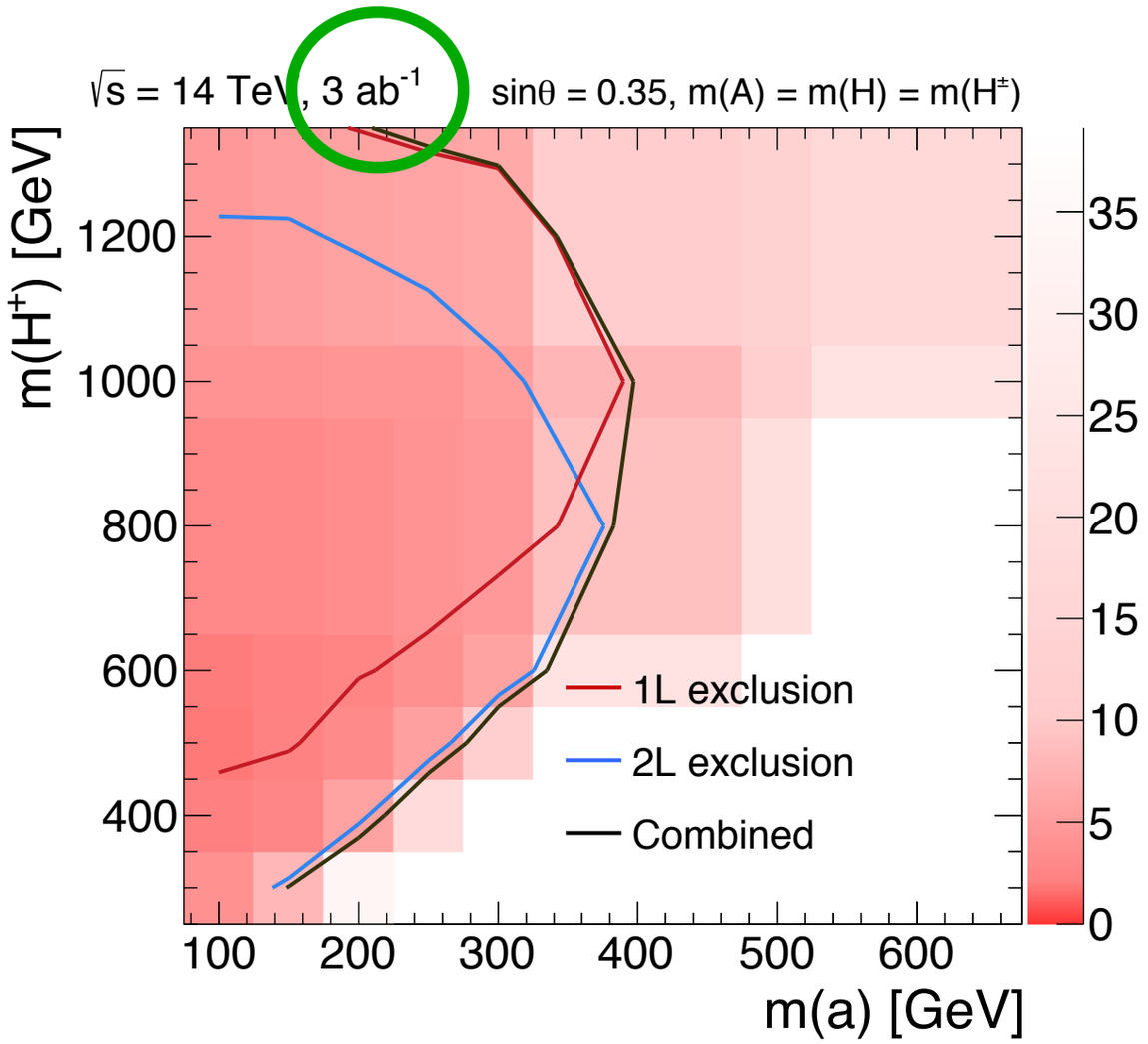


In 2HDM+a model, HL-LHC (3 ab^{-1}) search notably improves the coverage of Run 3 (300 fb^{-1}) results to higher values of charged Higgs mass

Projections (ma-mH, sinθ = 1/√8)

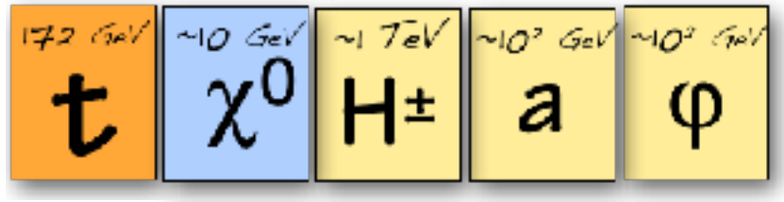


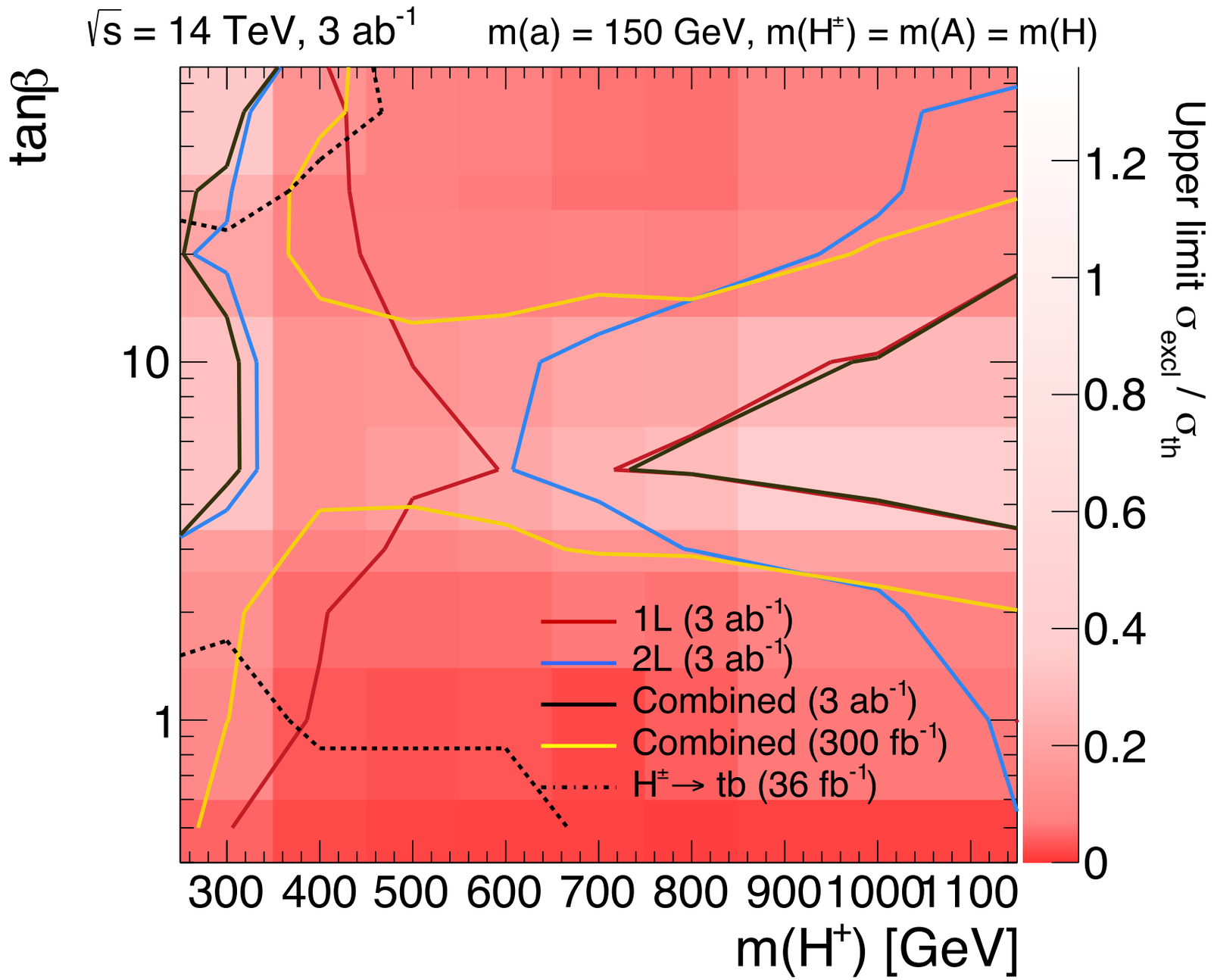




Improvements particularly large if $E_{T,miss}$+single-top signal strengths small, meaning that Run 3 searches are statistically limited

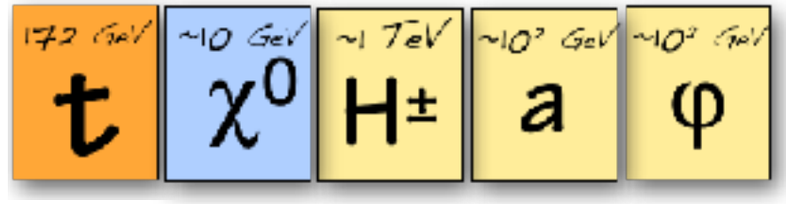
Projections (mH-tanβ)





At HL-LHC should be possible to exclude all values of tanβ for charged Higgs masses of around 300 GeV to 700 GeV for a light a of 150 GeV

In progress



- ★ Study the reach of the two signatures @27 TeV (results almost ready)
- ★ Polish and refine the existing drafts

HL-LHC prospects for determining the CP nature of spin-0 mediators in associated production of dark matter and top pairs

U.Haisch, P. Pani, G. Polesello

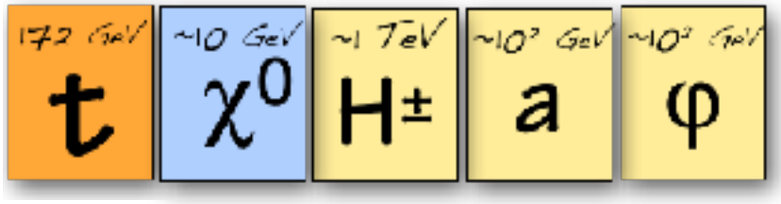
The aim of this contribution to the Yellow Report is to review and when needed extend

HL-LHC prospects for two-Higgs doublet models with a pseudo-scalar mediator in single-top quark final states

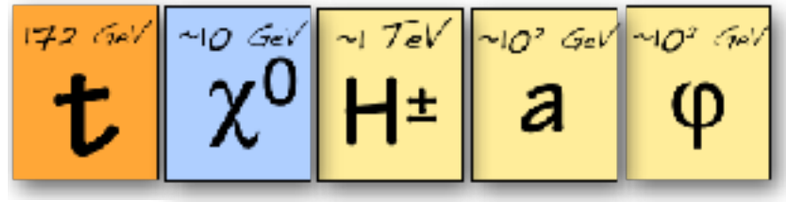
P. Pani, G. Polesello

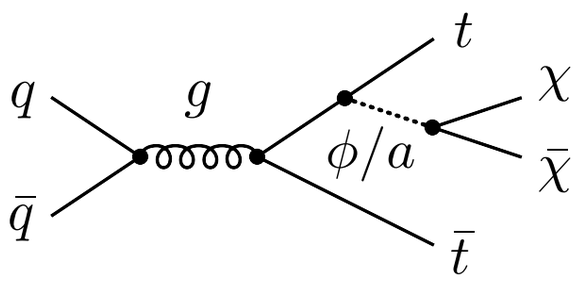
The aim of this contribution to the Yellow Report is to extend the sensitivity prospect of Refs. [1] and [2]. To this end, the single-lepton final state selection presented in Ref. [2]

Backup



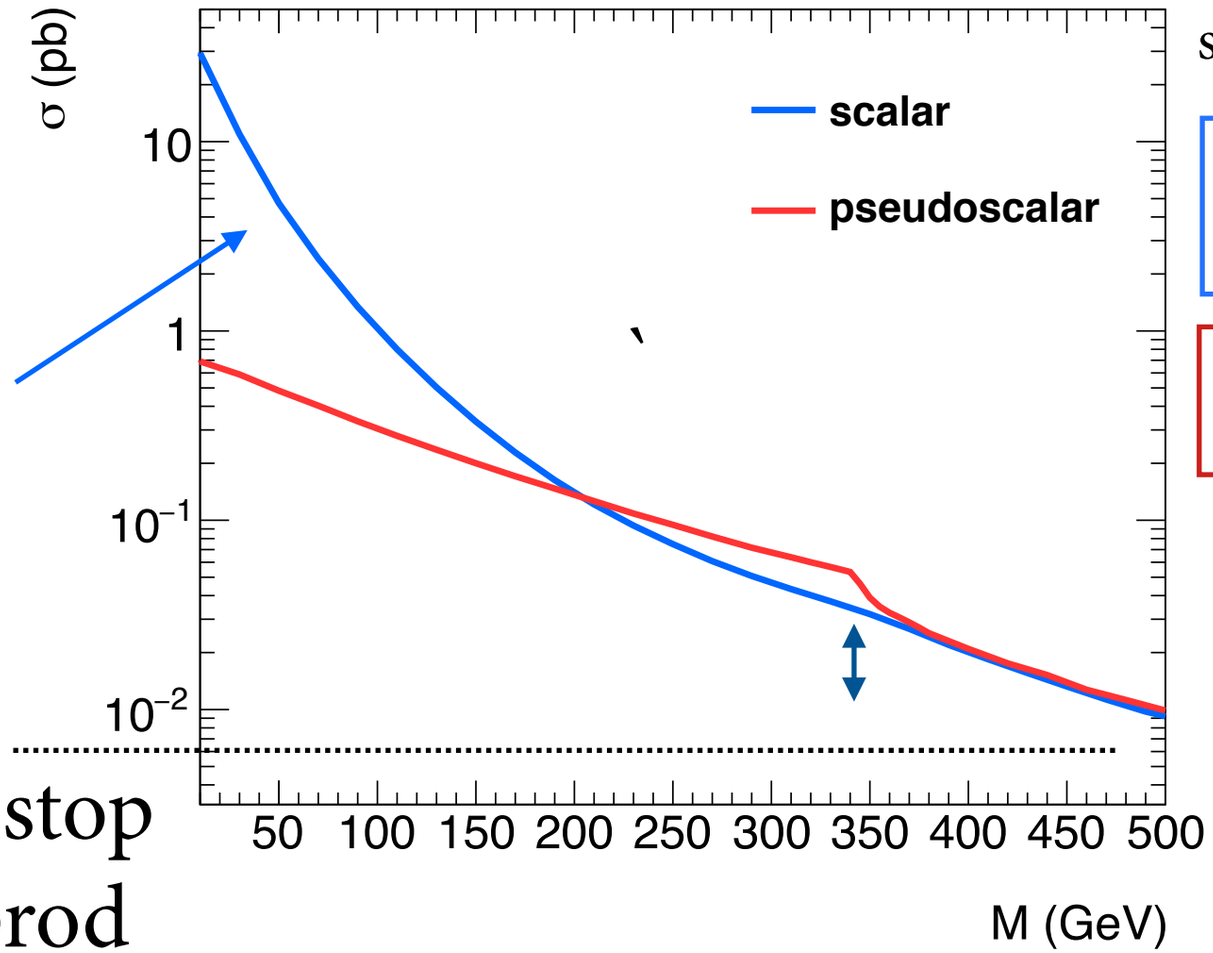
DM+tt signal





$$f_{t\to\phi}(x) \sim 1/x$$

soft-enhancement term



1 TeV stop pair prod

830 pb

σ(ttbar)

spin and color-averaged ME

$$\overline{\sum} |\mathcal{M}(t\bar{t} \to \phi)|^2 = \frac{g_t^2 s}{12} \beta^2$$

$$\overline{\sum} |\mathcal{M}(t\bar{t} \to a)|^2 = \frac{g_t^2 s}{12}$$

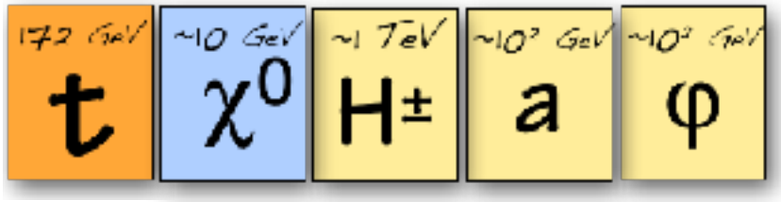
$$\beta = \sqrt{1 - 4m_t^2/s}$$

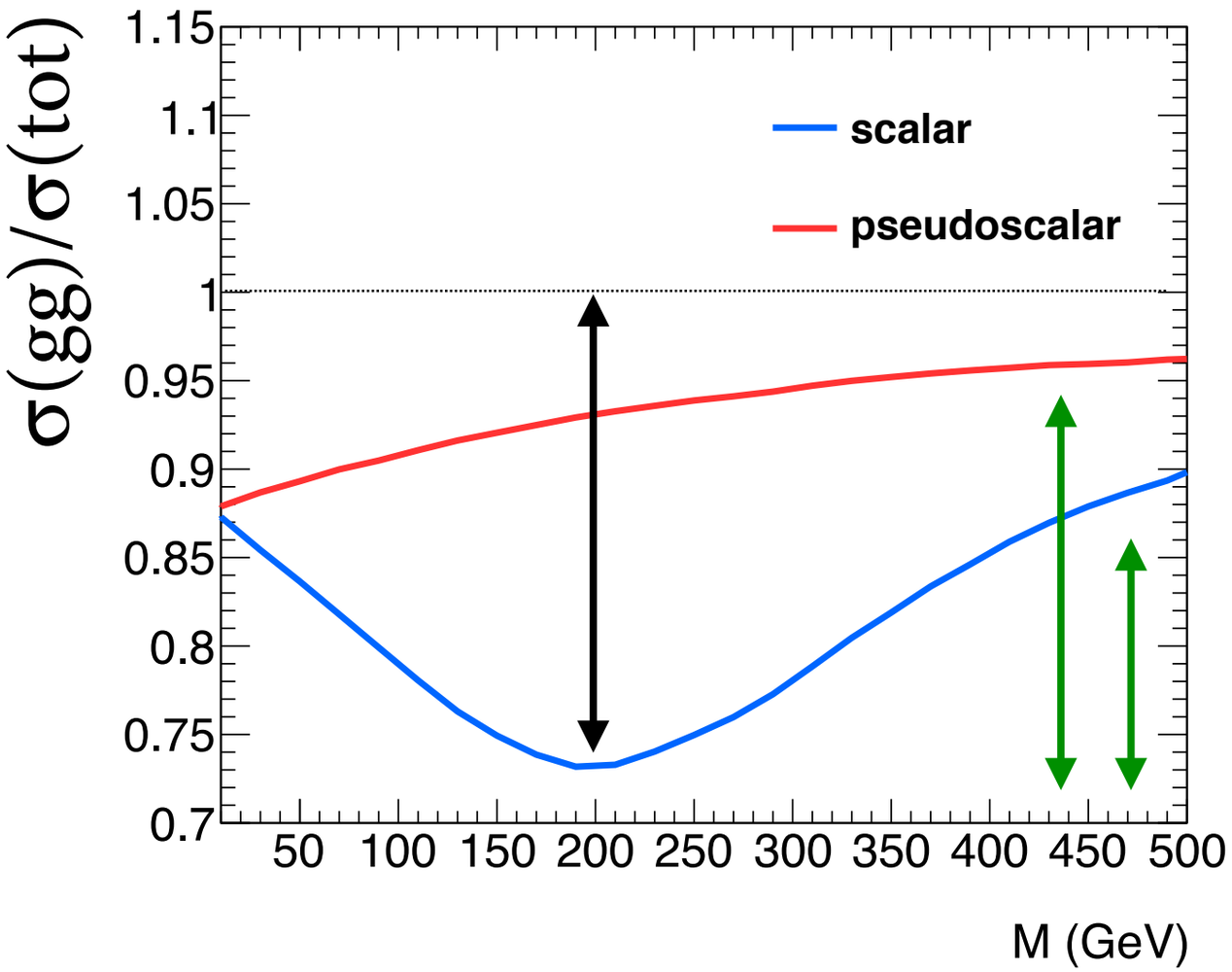
top-threshold suppression from

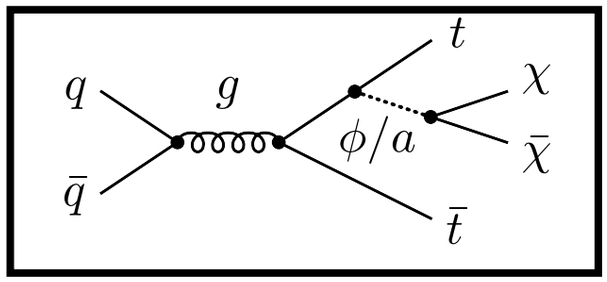
$$\phi/a \to t\bar{t}$$

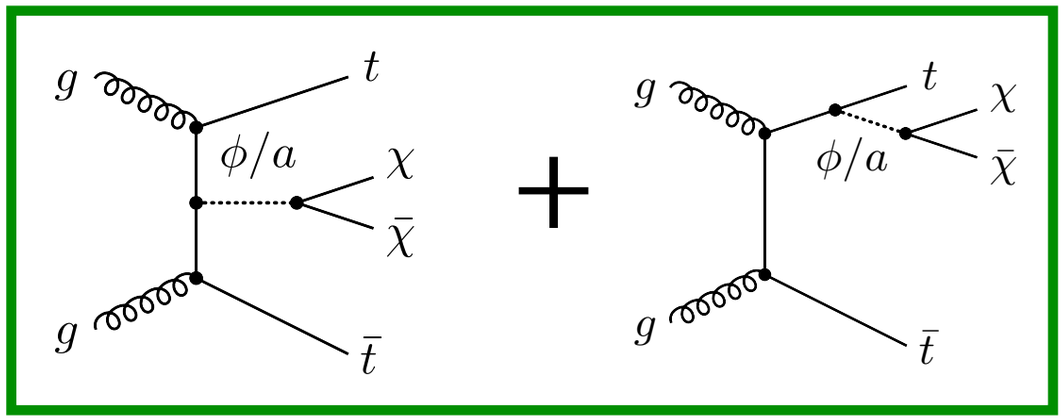
[Haisch,PP,Polesello 2017]

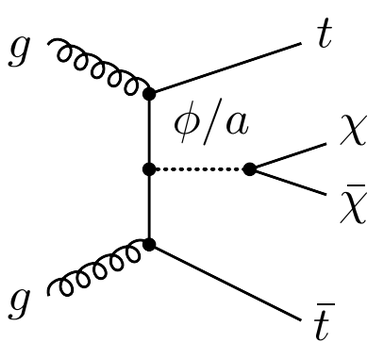
DM+tt signal



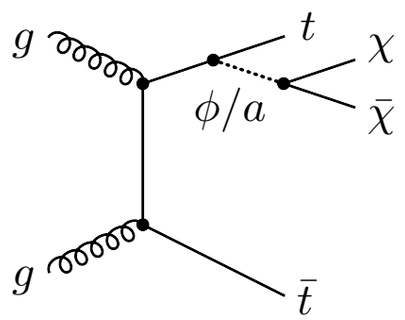






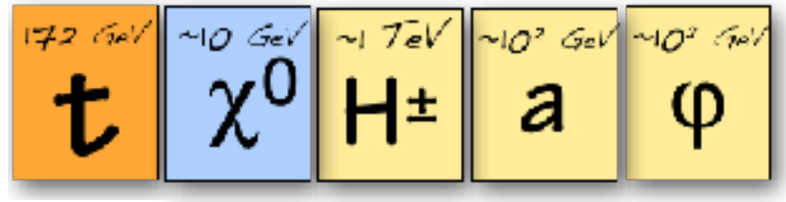


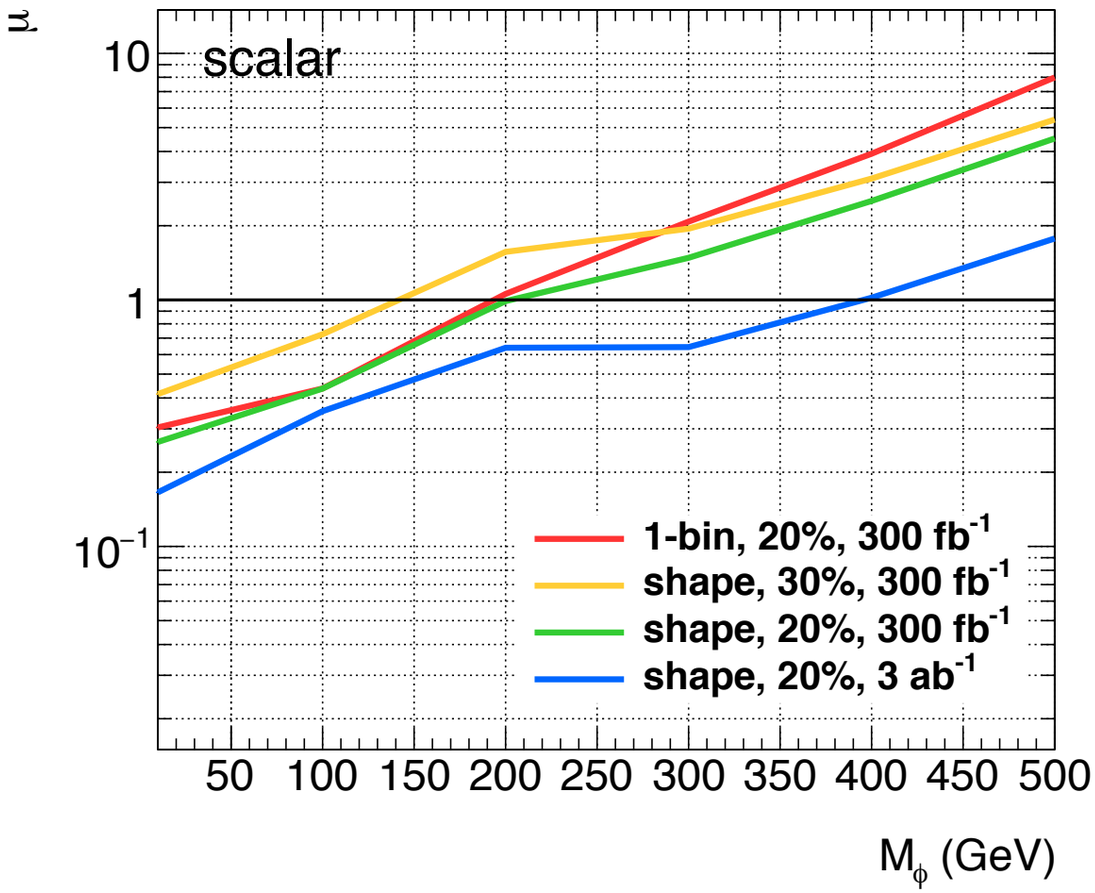
: dominant at high mass and low-mass a

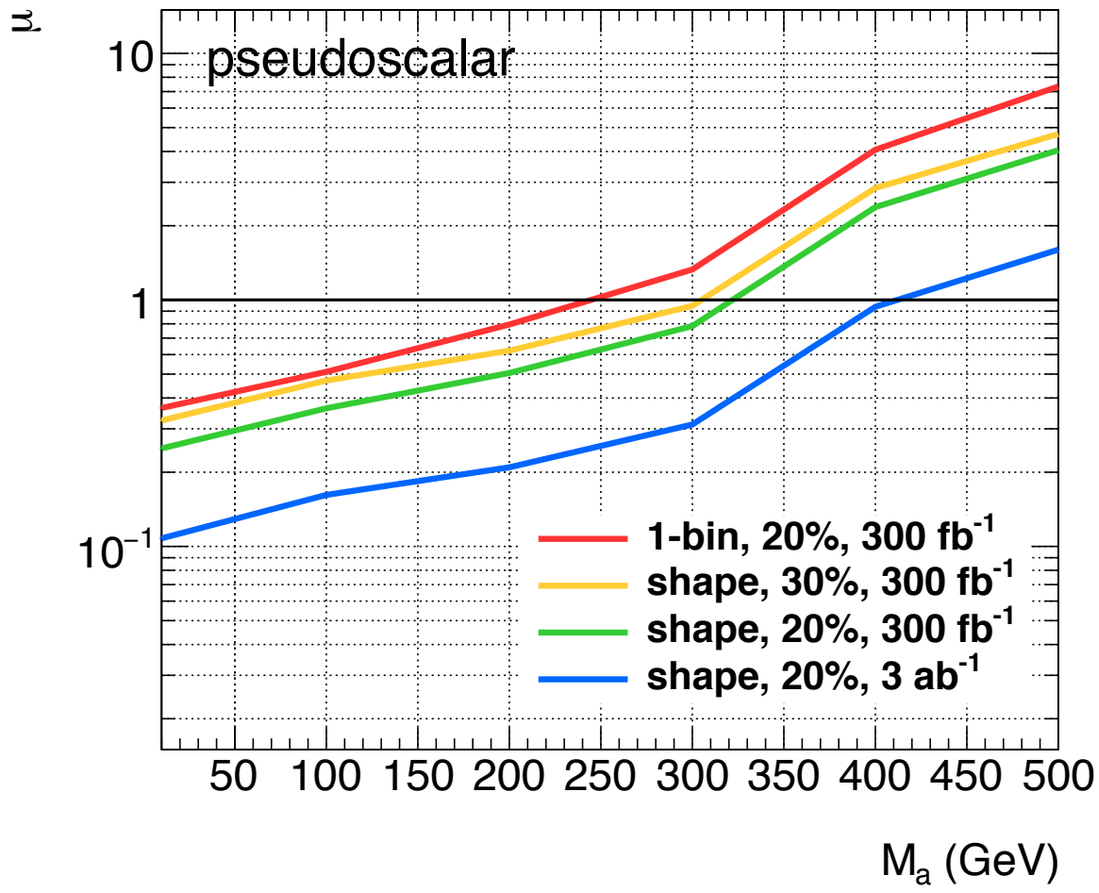


: dominant at low-mass φ

Projections DM+tt

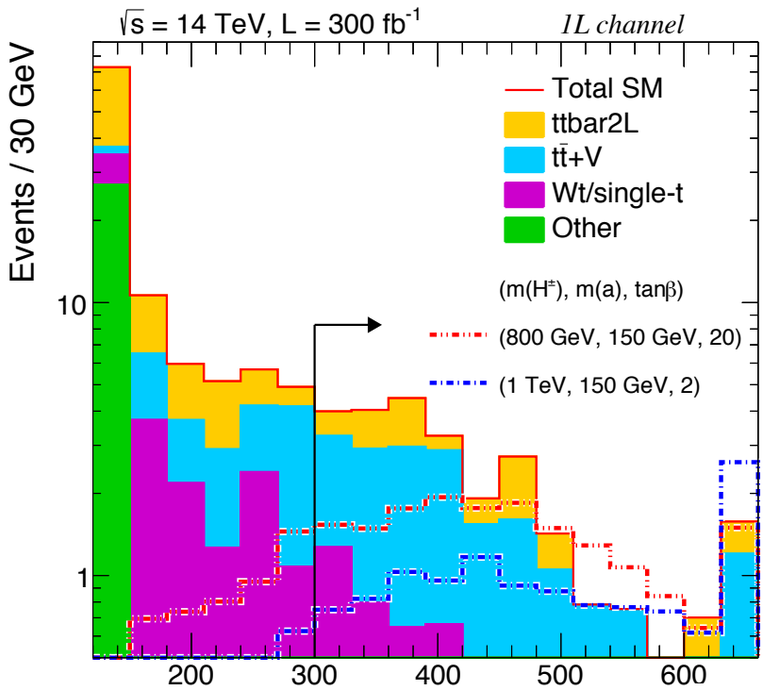






Likelihood shape fit provides a significant improvement over the counting experiment for high-mass mediators irrespectively of their CP nature

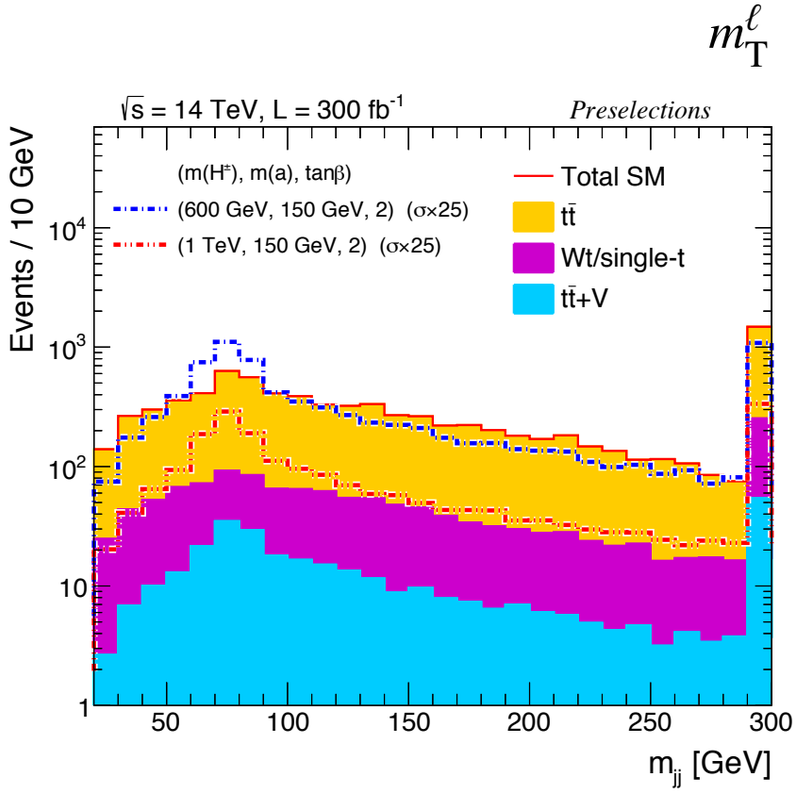
1-lep: discriminant masses



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

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

$$m_{\mathrm{T}}^{\ell} = M_{\mathrm{T}}(\vec{p}_{\mathrm{T}}^{\,\ell}, \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}})^2 \equiv 2|\vec{p}_{\mathrm{T}}^{\,\ell}||\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}|(1 - \cos\Delta\phi_{\vec{p}_{\mathrm{T}}^{\,\ell}\,\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}})$$

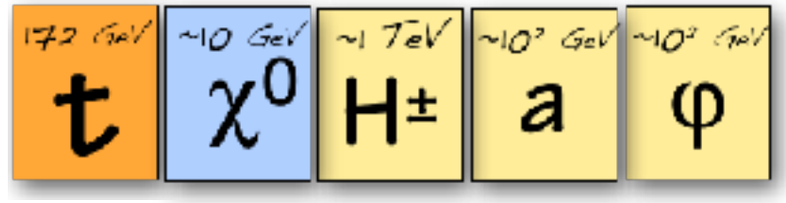


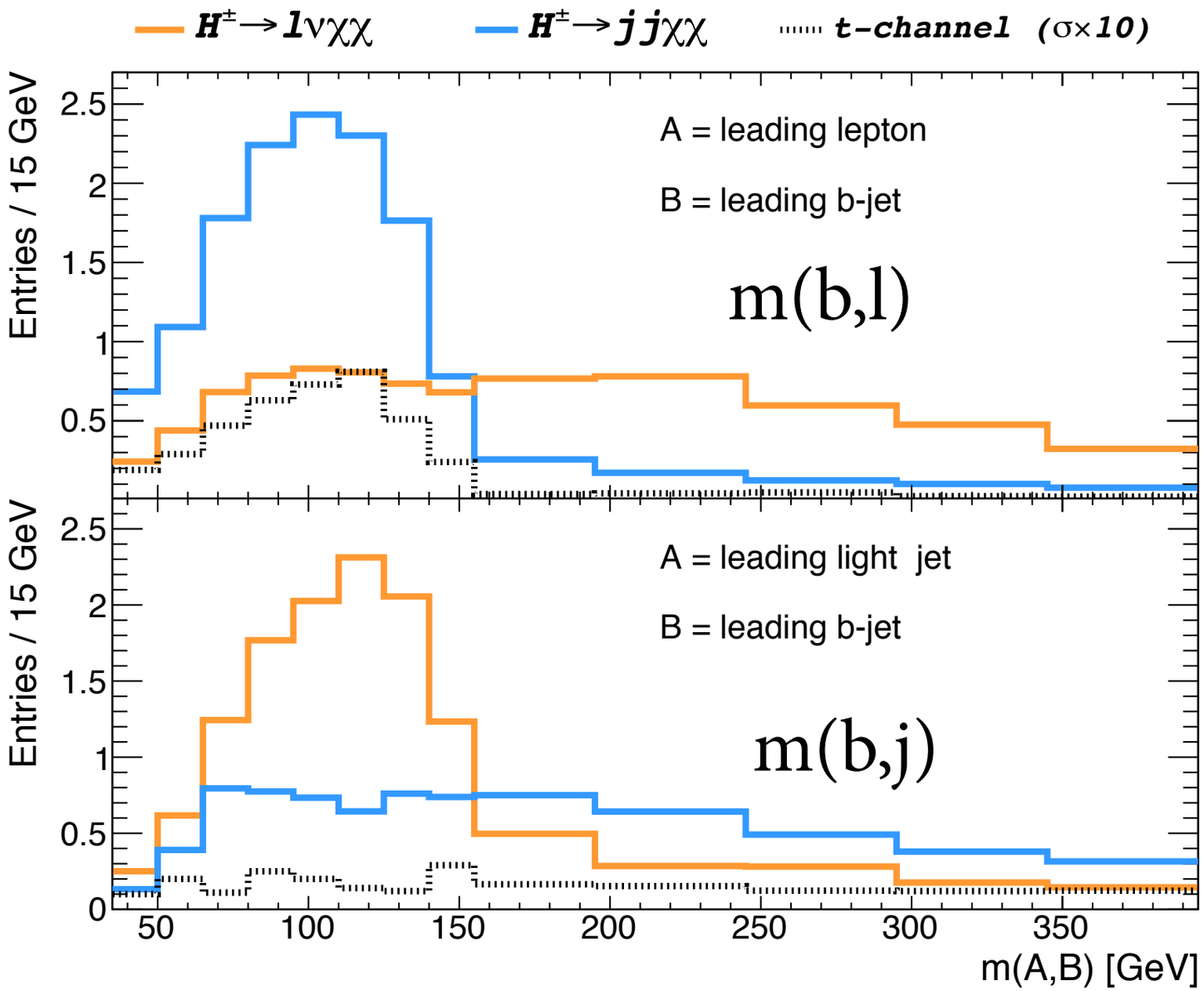
2) stransverse mass (asymmetric) **≳*200 GeV***

$$m_{\mathrm{T2}} \equiv \min_{\vec{q}_T + \vec{r}_T = \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}} \{\max[m_{\mathrm{T}}(\vec{p}_{\mathrm{a}}, \vec{q}_{\mathrm{T}}), m_T(\vec{p}_{\mathrm{b}}, \vec{r}_{\mathrm{T}})]\},$$

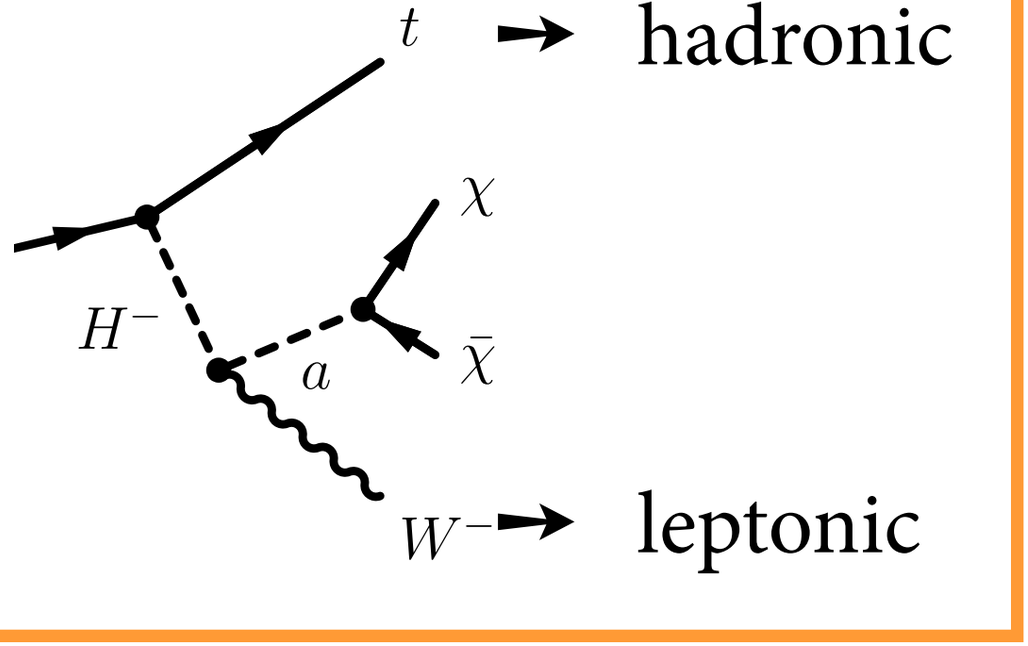
3) inv. mass leading light jets **~ *80 GeV***

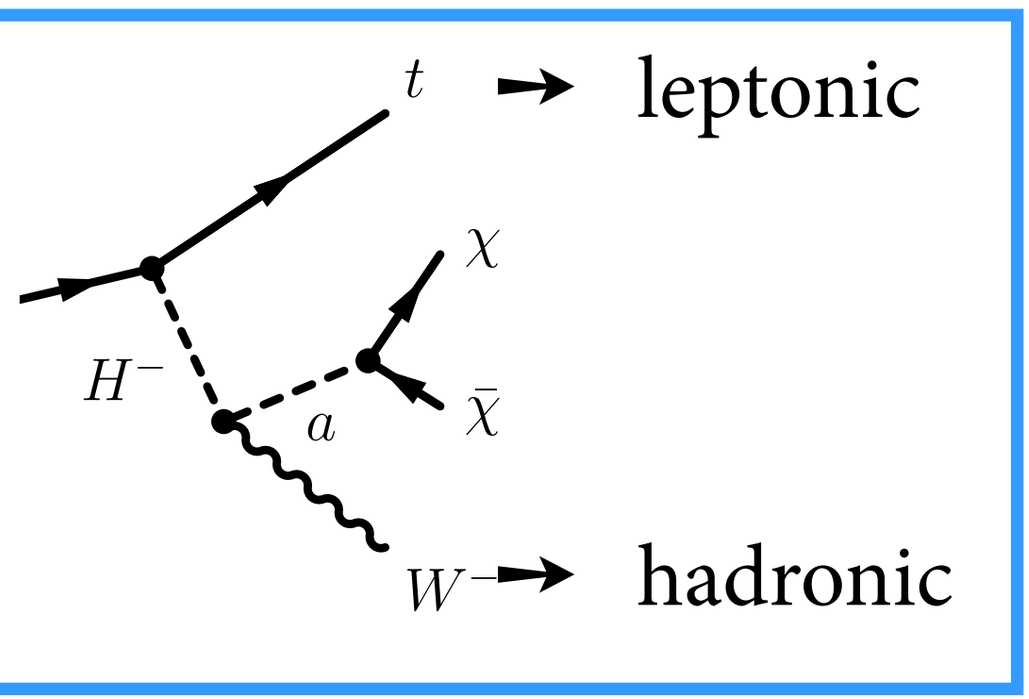
1-lep: kinematics considerations



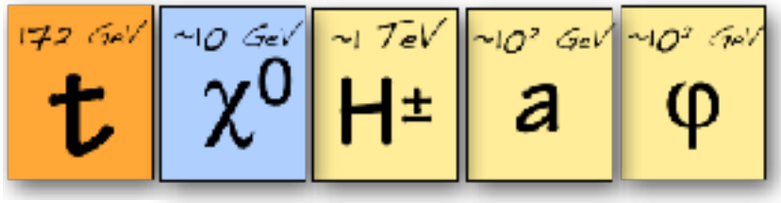


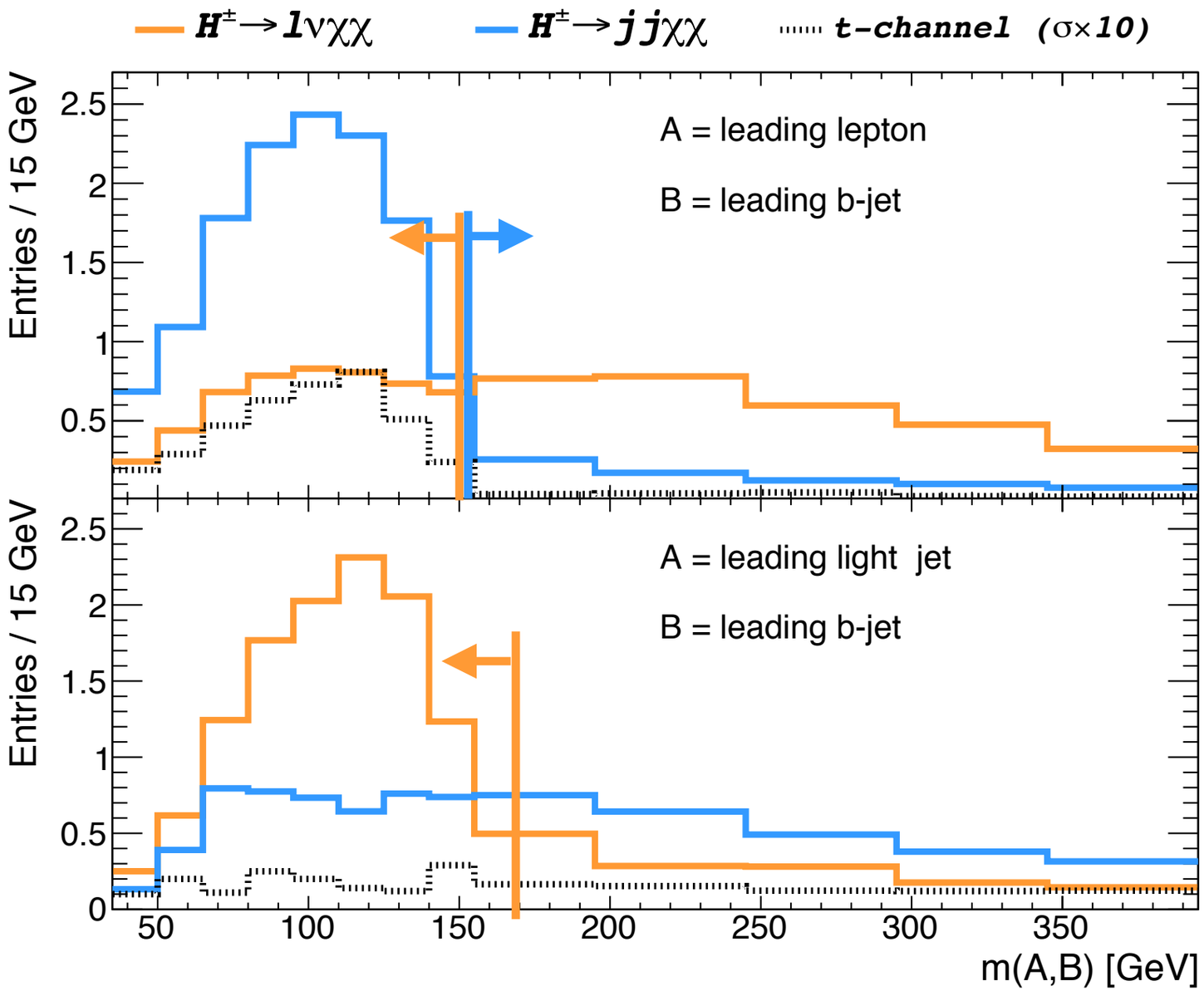
$m(H\pm) = 1$ TeV





1-lep: final selections





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

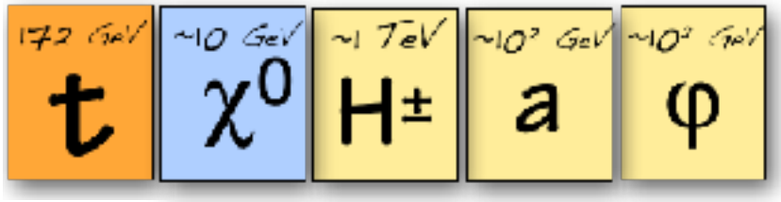
leptonic-H±

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

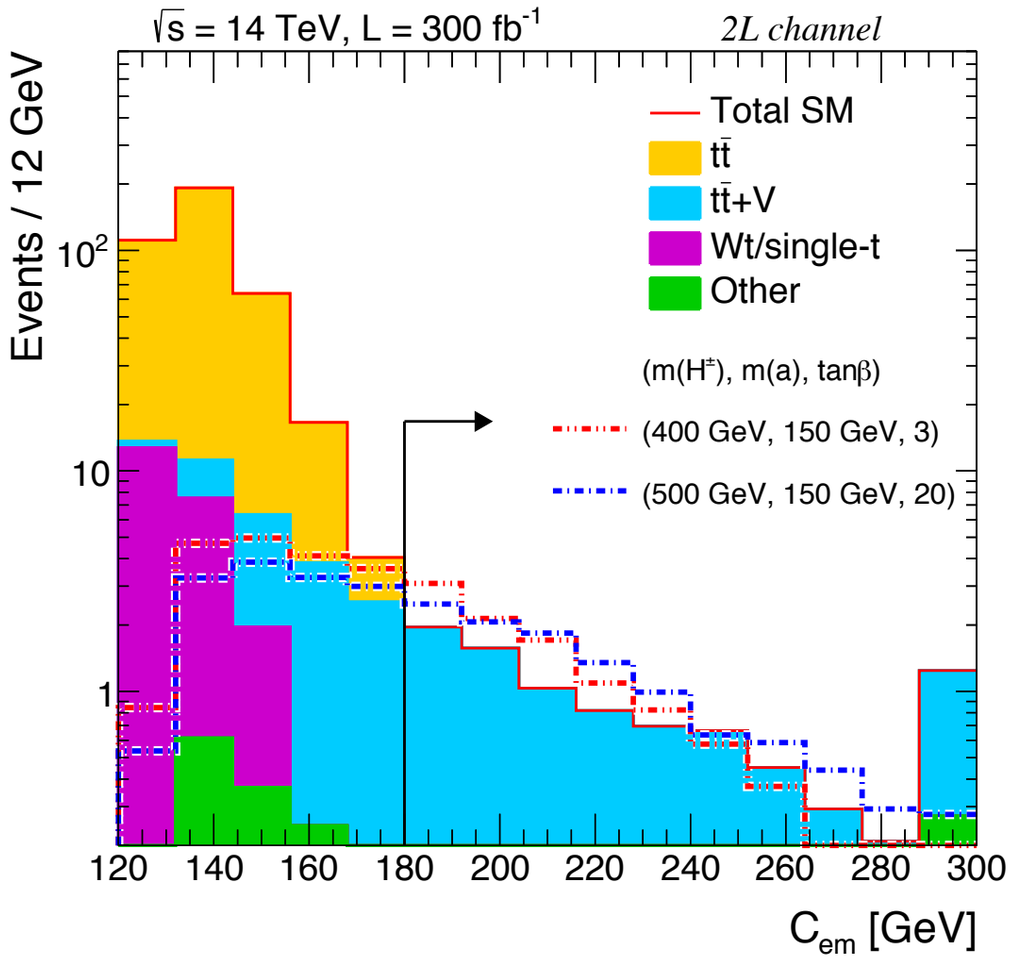
hadronic-H±

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

2-lep: discriminants and selections



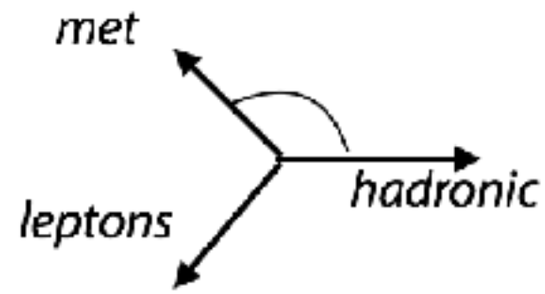
SIGNATURE: 2 *lep* + 1 *b*-jet + E_T^{miss}



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***