Probing Exotic Charged Higgs Decays in the Type-II 2HDM through Top Rich Signal at a Future 100 TeV *pp* Collider

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Outline

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1. Motivation and Objective

- Many Beyond Standard Models (BSM) contain charged Higgs. Two Higgs Doublet Models (2HDM) provides the simplest option.
- Observation of charged Higgs gives direct evidence of BSM physics.
- Conventional Higgs search channels are challenging.
- We search Charged Higgs in type-II 2HDM via exotic decay mode $H^{\pm} \rightarrow AW^{\pm}/HW^{\pm}$ with $A/H \rightarrow tt$ using top tagging technique in a future 100 TeV *pp* collider.

2. Charged Higgs in Type-II 2HDM

- Two $SU(2)_L$ Higgs doublets

$$\Phi_a = \begin{pmatrix} \phi_a^+ \\ (v_a + \rho_a + i\eta_a)/\sqrt{2} \end{pmatrix}, \quad a = 1, 2.$$

- Five Higgs bosons: two charged (H^+,H^-), two neutral CP-even (h, H), one neutral CP-odd (A), after electroweak symmetry breaking.
- Six free parameters: tan β, cos(β–α), m_{12}^2, m_H, m_A, $m_{H\pm}$.
- h be the SM-like 125 GeV Higgs → cos(β–α)=0;
  to respect unitarity for heavy Higgs → $m_{12}^2 \cos\beta \sin\beta = m_H^2$;
  to allow exotic charged Higgs decay → $m_A = m_{H\pm} > m_H$.

2. Charged Higgs in Type-II 2HDM

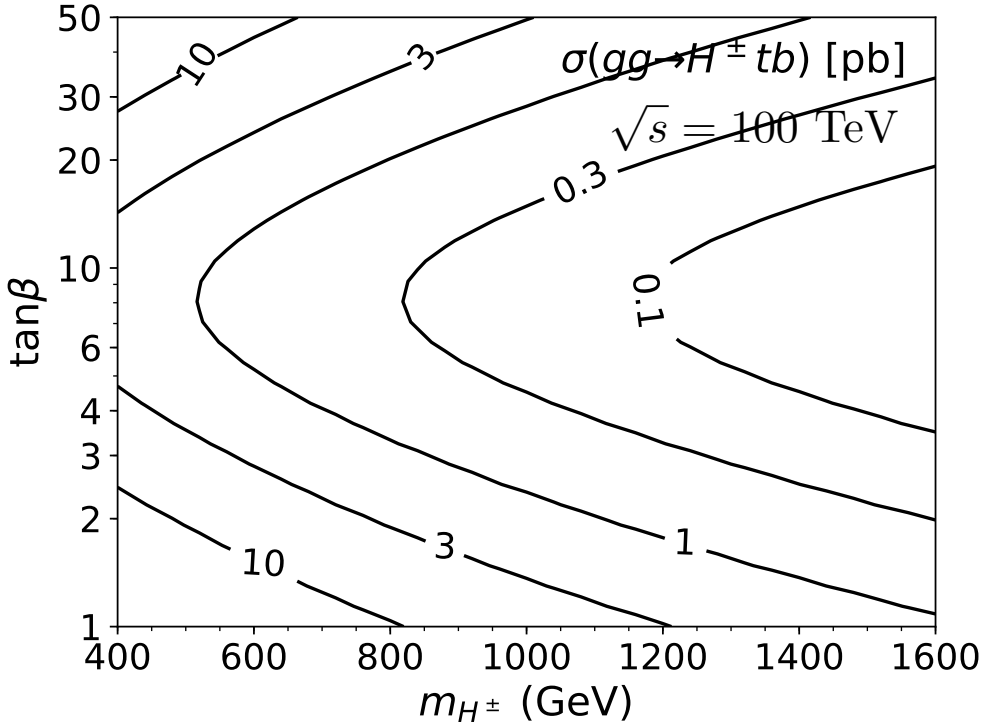
- Interactions involving charged Higgs

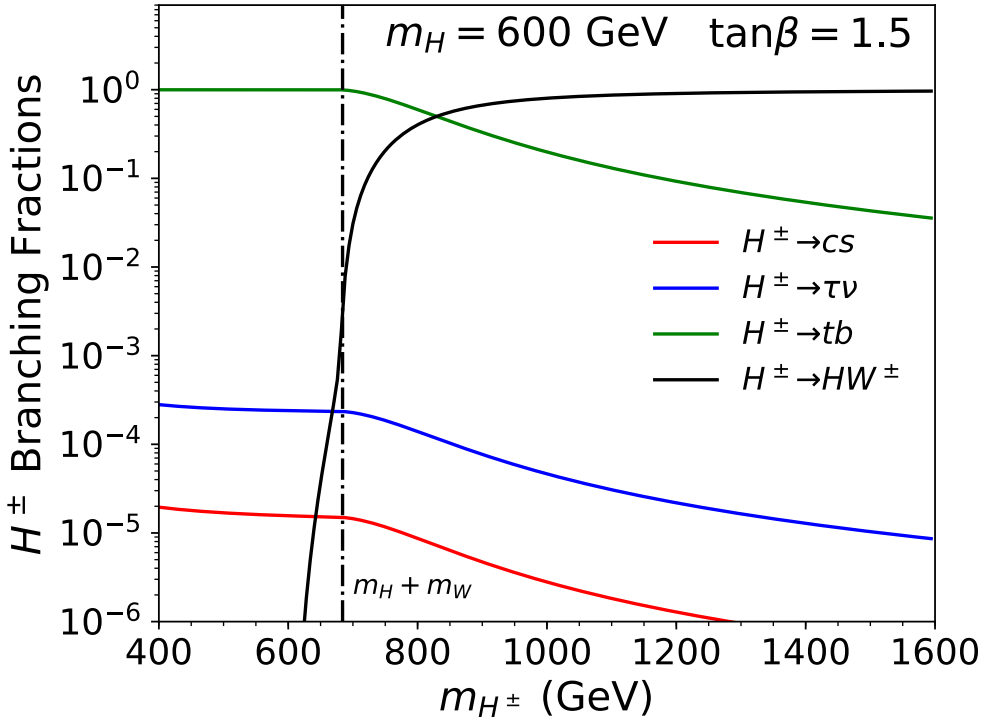
$$g_{H^\pm hW^\mp} = \frac{g\cos(\beta-\alpha)}{2}(p_h - p_{H^\pm})^\mu \simeq 0,$$

$$g_{H^\pm HW^\mp} = \frac{g\sin(\beta-\alpha)}{2}(p_h - p_{H^\pm})^\mu \simeq \frac{g}{2}(p_H - p_{H^\pm})^\mu,$$

$$g_{H^\pm u_i d_j} = \frac{V_{ij}}{\sqrt{2}}\left[(t_\beta y_d + t_\beta^{-1} y_u) + (t_\beta y_d - t_\beta^{-1} y_u)\gamma^5\right]$$

- Production cross section and decay branching fractions





3. Current Search

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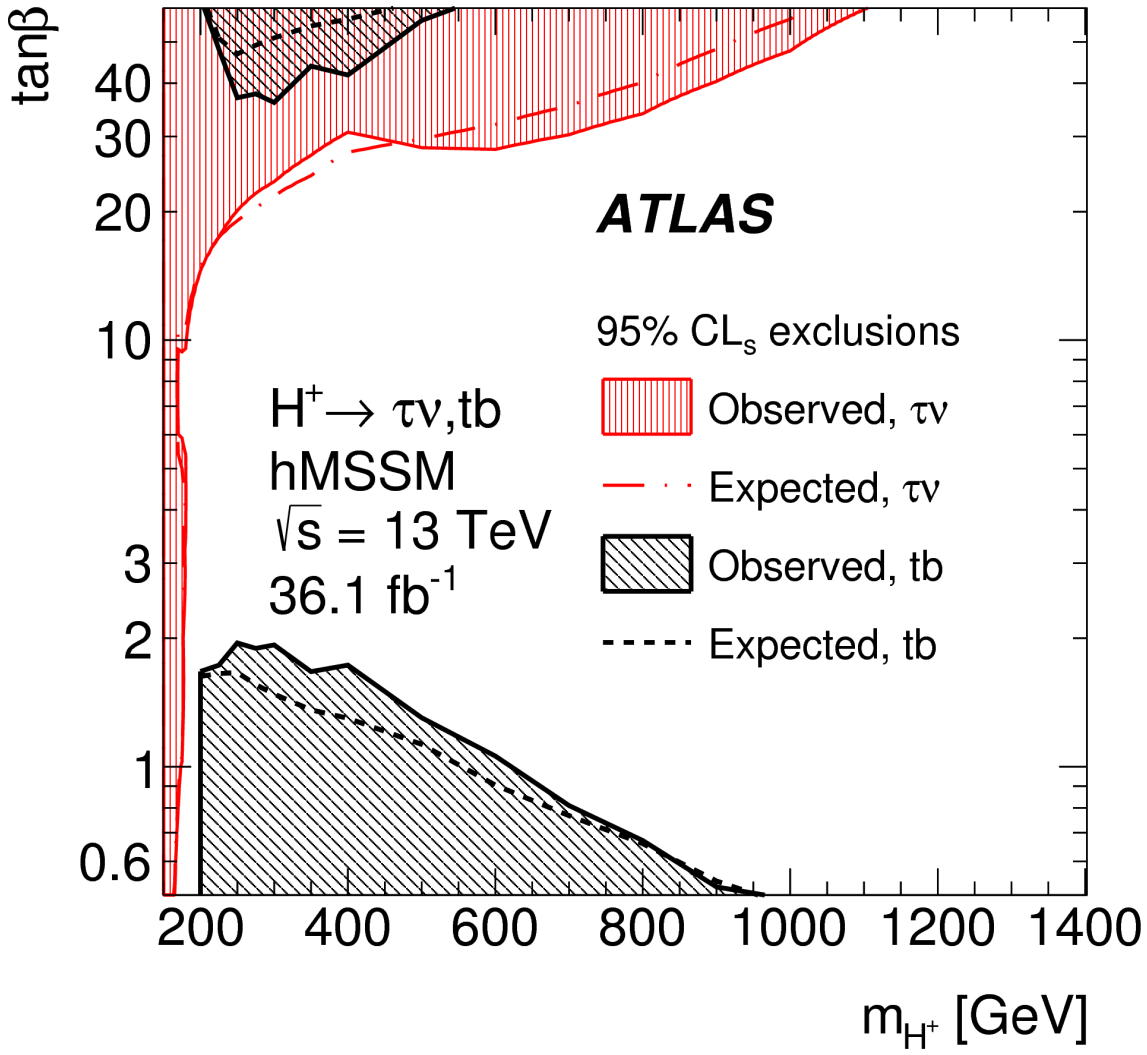


4. Search Strategy

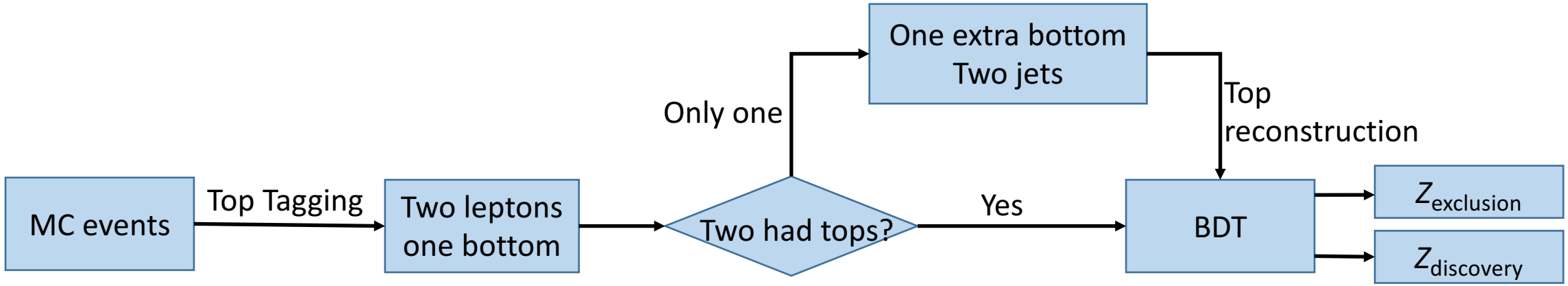
- Search exotic charged Higgs decay through $H \rightarrow tt$ channel in a future 100 TeV pp collider with integrated luminosity $\mathcal{L}$ =3000 fb^{-1},

$$gg \rightarrow tbH^{\pm} \rightarrow tbHW^{\pm} \rightarrow t\bar{t}tbW^{\pm}$$

- Irreducible backgrounds: $tttt$, σ_{NLO}= 4.93 pb; $tttbW$, σ_{LO}= 0.623 pb.
- Use top tagging technique to detect boosted hadronic tops.
- Collect events with two leptons in the final states.
- Use boosted decision tree (BDT) to distinguish signal and background events.
- Discovery and exclusion significances are estimated assuming 10% systematic uncertainty in background cross section.

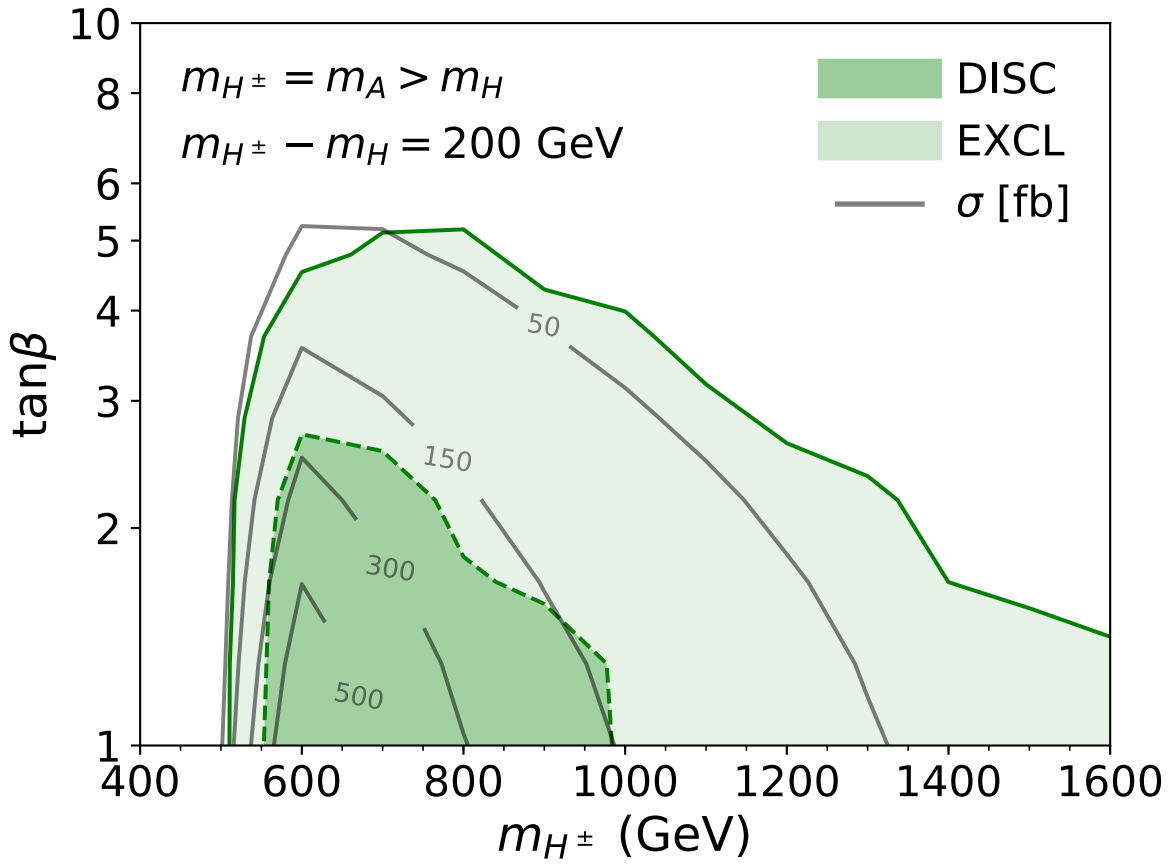
4. Search Strategy

- Cuts flow

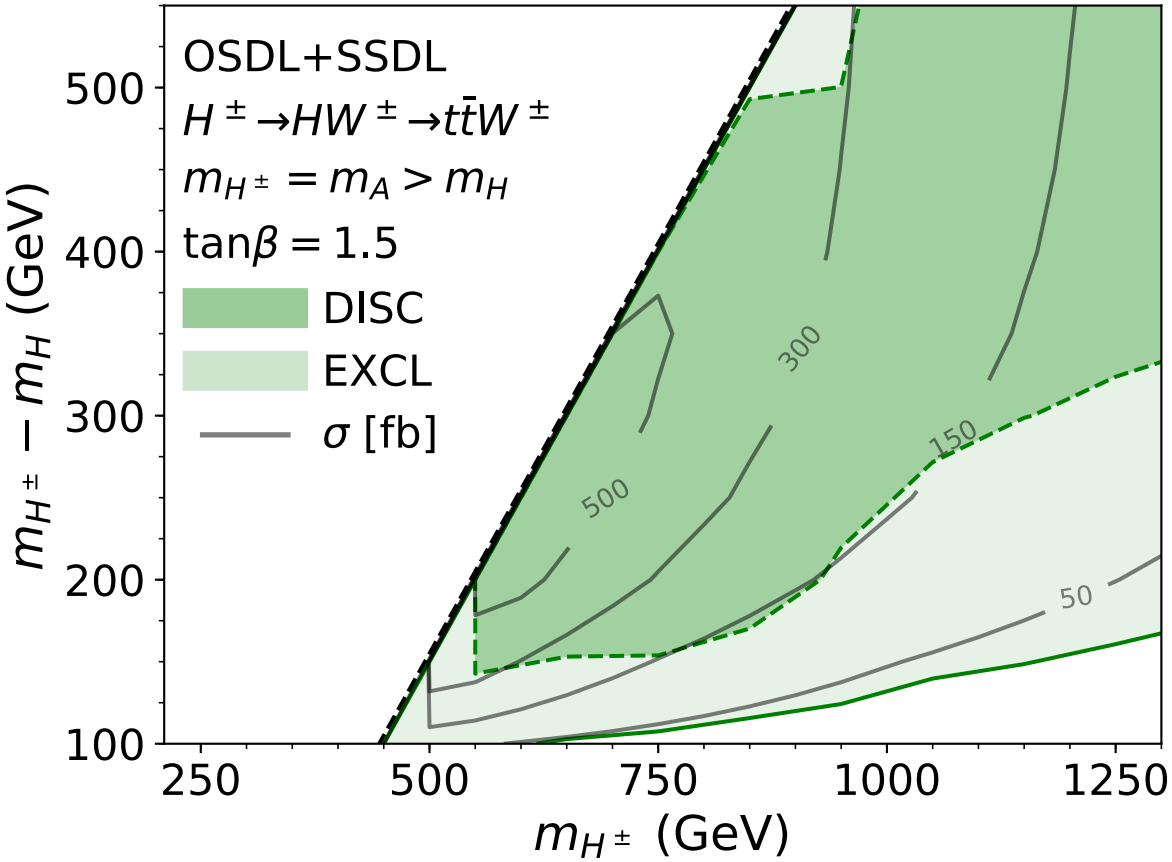


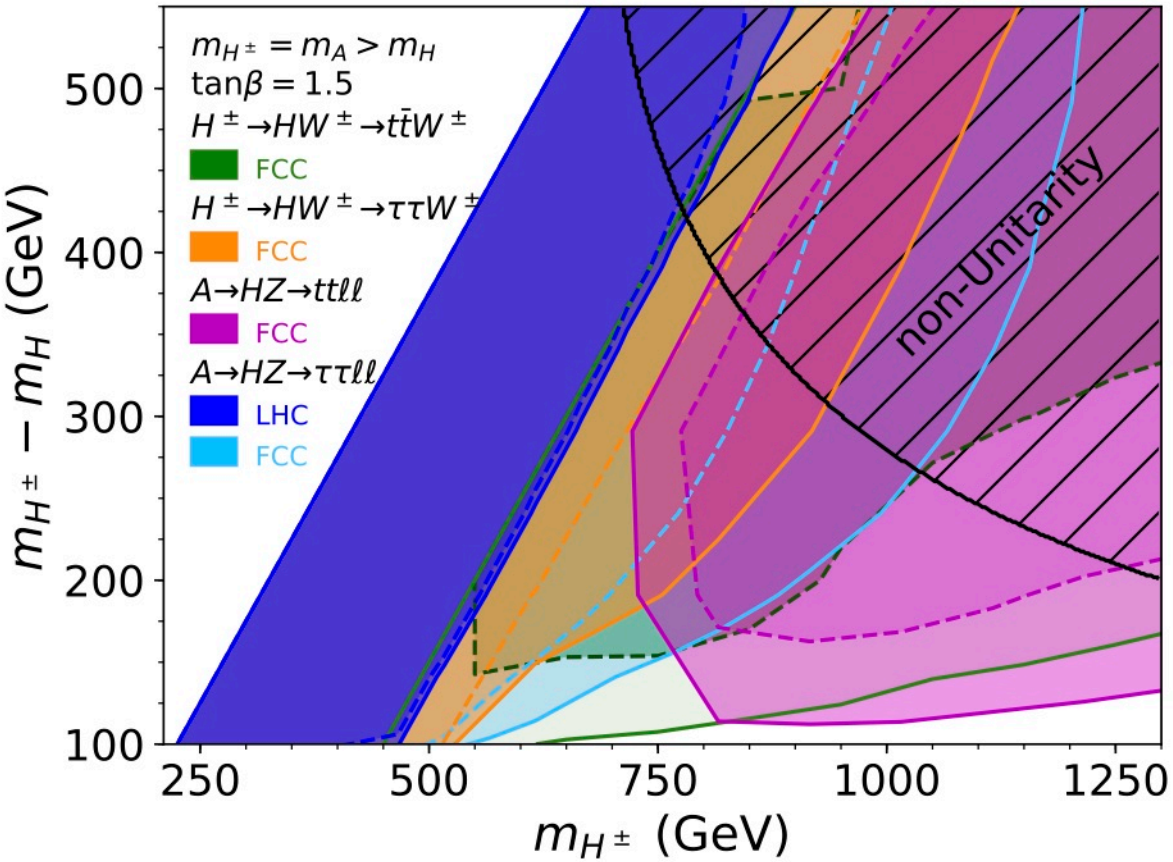
- BDT inputs: $p_{T,l1}$, $p_{T,l2}$, $p_{T,t1}$, $p_{T,t2}$, m_{t1t2}, N_j, $\Delta\eta_{l1,l2}$, H_T, miss E_T.

5. Search Results



5. Search Results





arXiv: 1812.01633

6. Summary

- Top-tagger provides a powerful tool to search non-SM heavy Higgs in the future colliders.
- Exotic decays provide new opportunities for the discovery of non-SM Higgses, which are complementary to the conventional channels.
- Combining all exotic Higgs decay channels, almost the entire parameter space in hierarchical 2HDMs can be probed at a future 100 TeV *pp* collider.

Backup slides

Channel	Divisions	Combinations	Channel	Divisions	Combinations
OSDL	OS1	$(H \to t_h\bar{t}_h)t_{\bar{\ell}}\bar{b}W_\ell^-$	SSDL		
	OS2	$(H \to t_{\bar{\ell}}\bar{t}_h)t_h\bar{b}W_\ell^-$		SS1	$(H \to \bar{t}_\ell t_h)t_h\bar{b}W_\ell^-$
	OS3	$(H \to t_h\bar{t}_\ell)t_{\bar{\ell}}\bar{b}W_h^-$		SS2	$(H \to \bar{t}_h t_{\bar{\ell}})t_{\bar{\ell}}\bar{b}W_h^-$
	OS4	$(H \to t_{\bar{\ell}}\bar{t}_\ell)t_h\bar{b}W_h^-$