Same−sign pair production of singly charged Higgs bosons at hadron colliders

(in preparation)

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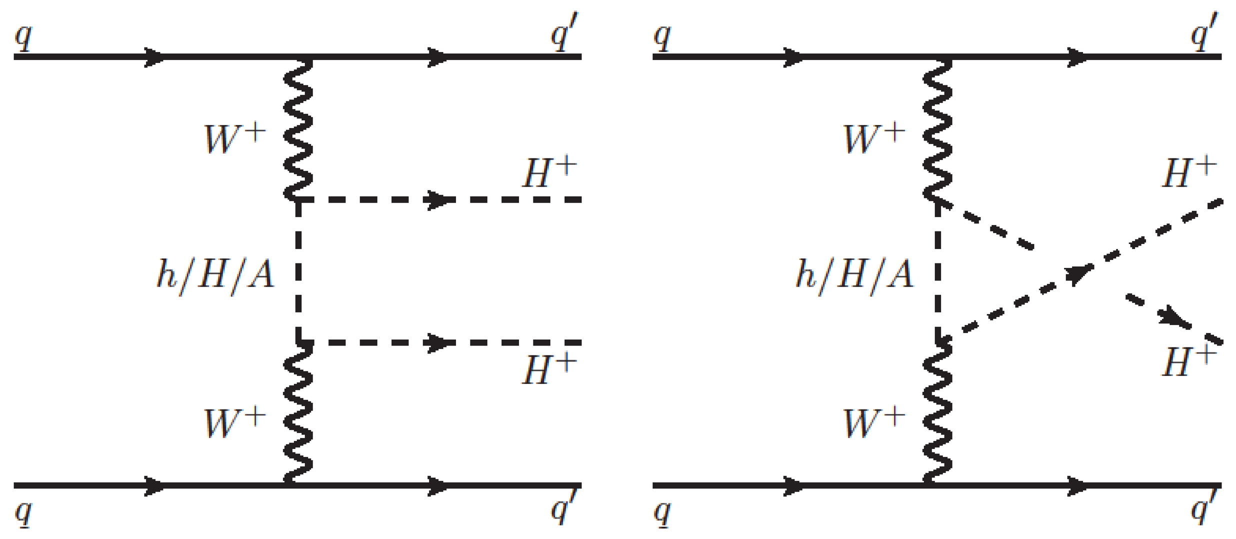
[I] 1 minute summary

We propose the same-sign process (pp $\to H^{\pm}H^{\pm}jj$) in Two-Higgs doublet Models.



What is interesting?

New Process.

Relatively free from the background

→ can be measured at the HL-LHC and future colliders.

In the alignment and custodial limit,

this process relates to global $O(4)\times O(4)$ symmetry in the Higgs potential.

[II] Symmetry

We impose three conditions.

1. Softly broken Z_2 symmetry
2. Custodial symmetry
3. Alignment limit

There are two cases which satisfy above conditions in Higgs basis.

A. Pomarol, R. Vega (1994); H. E. Haber, D. O'Neil (2011)
B. Grzadkowski, M. Maniatis, J. Wudka (2011)

1. $m^2_{H^\pm}=m^2_A,\ \ \sin(\beta-\alpha)=1$

$$V(H_1,H_2)=m'^2_1|H_1|^2+m'^2_2|H_2|^2+\frac{1}{4}\lambda'_1|H_1|^4+\frac{1}{4}\lambda'_2|H_2|^4+\frac{1}{4}\lambda'_3|H_1|^2|H_2|^2+\frac{1}{2}\lambda'_4(H_1^\dagger H_2+H_2^\dagger H_1)^2+\lambda'_7|H_2|^2(H_1^\dagger H_2+H_2^\dagger H_1)$$

2. $m^2_{H^\pm}=m^2_H,\ \ \sin(\beta-\alpha)=1$

$$V(H_1,H_2)=m'^2_1|H_1|^2+m'^2_2|H_2|^2+\frac{1}{4}\lambda'_1|H_1|^4+\frac{1}{4}\lambda'_2|H_2|^4+\frac{1}{4}\lambda'_3|H_1|^2|H_2|^2+\frac{1}{2}\lambda'_4(H_1^\dagger H_2+H_2^\dagger H_1)^2$$

Black parts are $O(4)\times O(4)$ symmetric.

N. G. Deshpande, E. Ma (1978)

$$|H_1|^2=\frac{1}{2}(h_1^2+z^2+w_1^2+w_2^2)$$

$$|H_2|^2=\frac{1}{2}(h_2^2+a^2+\xi_1^2+\xi_2^2)$$

Red parts are $O(4)$ symmetric.

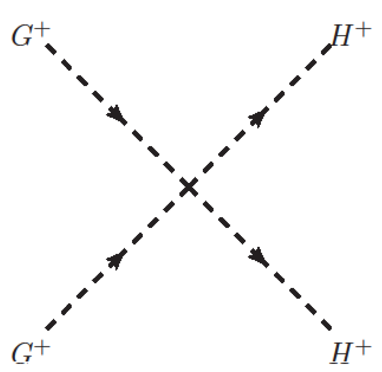
$$H_1^\dagger H_2+H_2^\dagger H_1=h_1h_2+za+w_1\xi_1+w_2\xi_2$$

Red parts includes same-sign vertices.

$$\frac{1}{2}\lambda'_4(H_1^\dagger H_2+H_2^\dagger H_1)^2\ni G^-G^-H^+H^+$$

Same-sign process measures the violation of $O(4)\times O(4)$ symmetry.

Key point: Same-sign process is proportional to the mass difference.

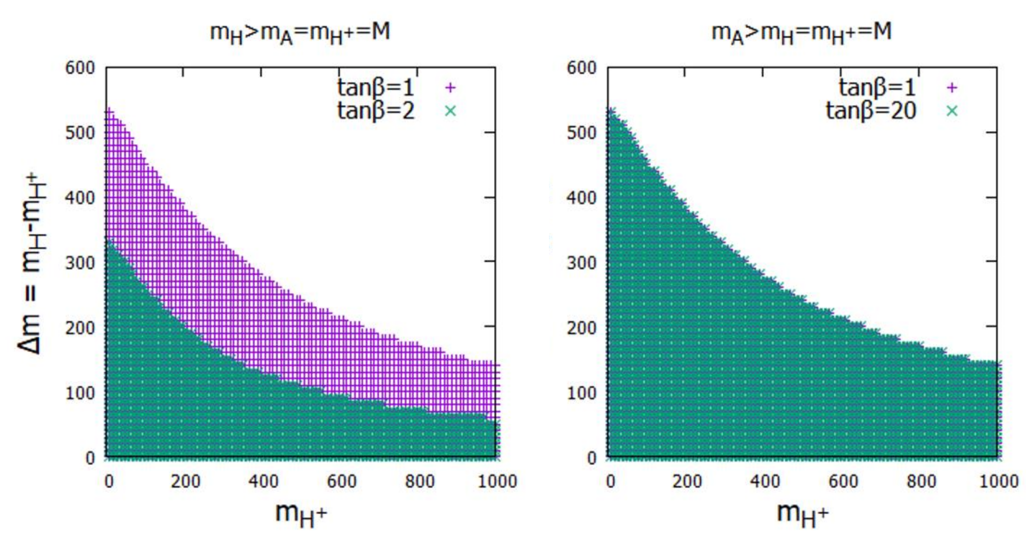


$$=i\frac{2}{v^2}(m_A^2-m_H^2)$$

[III] Numerical study

■ Unitarity bound and vacuum stability.

S. Kanemura, T. Kubota, E. Takasugi (1993); N. G. Deshpande, E. Ma (1978)
A. G. Akeroyd, A. Arhrib. E. M. Naimi (2000)



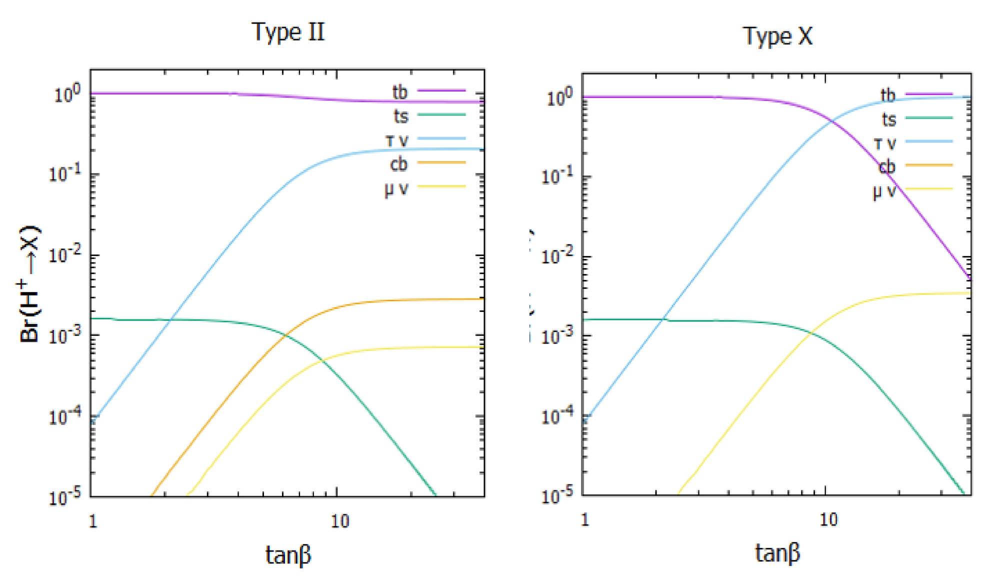
Colored region are allowed.

For $m_A > m_H = m_{H^+} = M$, constraints are $\tan\beta$ independent.

Flavor experiments($\bar{B}\to s\gamma$) favors $\tan\beta>1$ for light $H^\pm$.

■ Decay pattern of the H^+

S. Kanemura, K. Tsumura, K. Yagyu, H. Yokoya (2014)

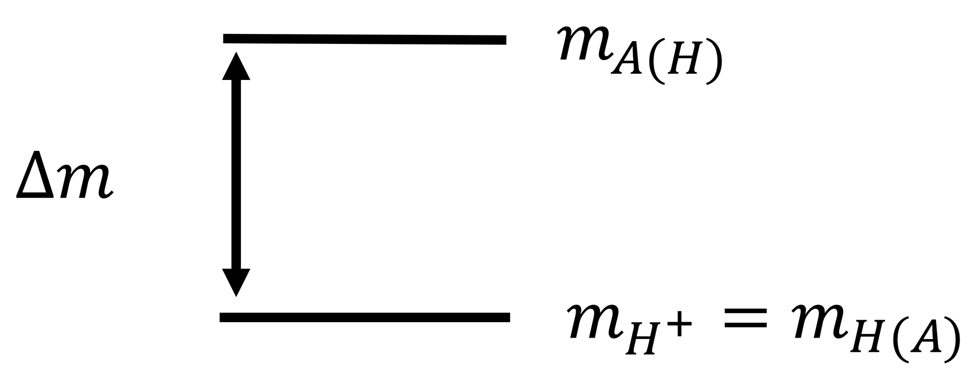


Type X, $\tan\beta\geq 20$
$\to\bar{\tau}\nu$ decay

Other cases→ $t\bar{b}$ decay

■ Our scenario

Mass hierarchy



Decay mode

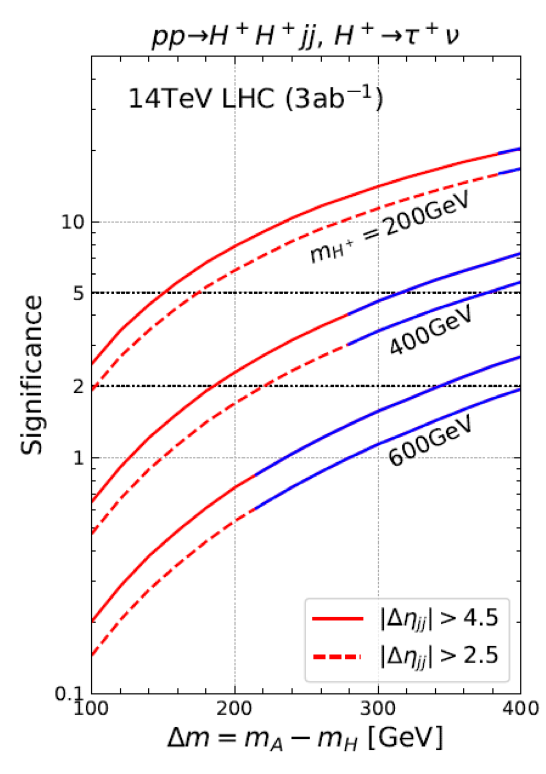
$H^+\to\bar{\tau}\nu$ or $H^+\to t\bar{b}$

Depending on the Type and $\tan\beta$

■ $H^+\to\bar{\tau}\nu$

For $m_{H^+}\leq 400$ GeV, We can test the mass difference $\Delta m=200$ GeV in 2σ confidence level at HL-LHC(14TeV, $3ab^{-1}$).

* Blue line isn't allowed theoretically.
* $\Delta\eta_{jj}$ is rapidity separation.



■ $H^+\to t\bar{b}$

For $m_{H^+}\leq 400$ GeV, We can test the mass difference $\Delta m=150$ GeV in 2σ confidence level at HL-LHC(14TeV, $3ab^{-1}$).

We can test This same-sign process at the HL-LHC.