Phenomenology of Twin Higgs at Colliders

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Mirror Twin Higgs Model

- The Twin Higgs framework is an elegant approach to the hierarchy problem of the Standard Model (SM).

Chacko, Goh, Harnik (2005)

- In Mirror Twin Higgs model, the SM is extended to include a complete mirror copy of the SM, with its own particle content and gauge groups.
- By a discrete Z_2 twin symmetry, the SM and twin particles are related .
- The mirror particles are not charged under SM gauge symmetry.

Mirror Twin Higgs Models

- The quadratic divergences of the SM and Twin Higgs model cancel each other exactly. In fact they are cancelled by states that carry no charge under the SM gauge groups. Discovery of these states at LHC is therefore difficult.
- The SM and twin sector interact through the Higgs portal, $|H_A|^2|H_B|^2$. For cancellation of quadratic divergences this interaction is needed.
- A soft Z_2 symmetry breaking ensures that twin Higgs VEV f is greater than the SM Higgs VEV v. Current bound from Higgs coupling measurements is $f/v \geq 3$.
- Twin fermions are heavier than SM fermions by a factor of f/v. To solve hierarchy problem it is required to have $f/v \leq 5$, i.e. the twin top should not be too heavy.

The Twin Higgs Portal

$$V(H_A,H_B) = -\mu^2\left(H_A^\dagger H_A + H_B^\dagger H_B\right) + \lambda\left(H_A^\dagger H_A + H_B^\dagger H_B\right)^2 + m^2\left(H_A^\dagger H_A - H_B^\dagger H_B\right) + \delta\left[\left(H_A^\dagger H_A\right)^2 + \left(H_B^\dagger H_B\right)^2\right].$$

- This potential depends on 4 parameters, μ, λ, m and δ.
- The potential must reproduce the electroweak VEV and the observed mass of the light Higgs, 125 GeV. That fixes 2 combinations of the 4 parameters. At a lepton collider, Higgs production cross section and invisible decay width can both be determined to high precision. This would fix a third combination. Then a measurement of the mass of twin sector Higgs fixes all 4 parameters!

- Once all 4 parameters are known, the production cross section, width and branching ratios of the twin sector Higgs are all predicted.
- A measurement of twin sector Higgs events to any SM final state then overdetermines the system. Can establish global symmetry of Higgs potential!

Fine Tuning in the Model

- m^2 and δ in the Twin Higgs potential, must be small compared to their $SU(4)$ invariant counterparts, μ^2 and λ.
- Moreover, we require $m_+ > m_T$ in order to obtain significant improvement in fine tuning with respect to the SM.

$$2\frac{m_+^2}{m_-^2}\frac{m_t^2}{m_T^2} \ .$$

Higgs Couplings

- For stable vacuum, we require

$$\frac{m_H}{m_h} \geq \frac{m_T}{m_t} = \frac{f}{v} = \cot(\vartheta)$$

where $\vartheta = \frac{f}{\sqrt{2}\,v}$.

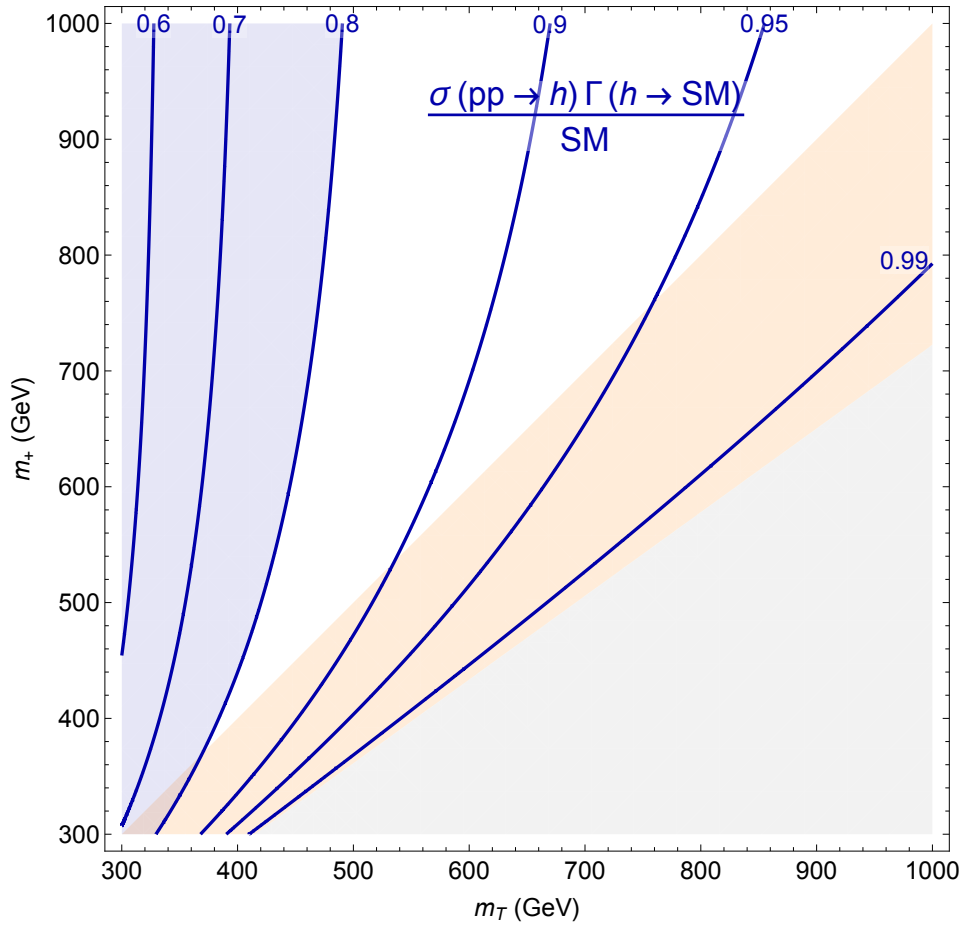
- Twin Higgs mixes with the light Higgs, with mixing angle θ. So Higgs couplings are reduced, similar to any pNGB models,

- Coupling deviations,

$$g_h^A = g_{SM}\cos(\vartheta - \theta)$$

$$g_H^A = g_{SM}\sin(\vartheta - \theta)$$

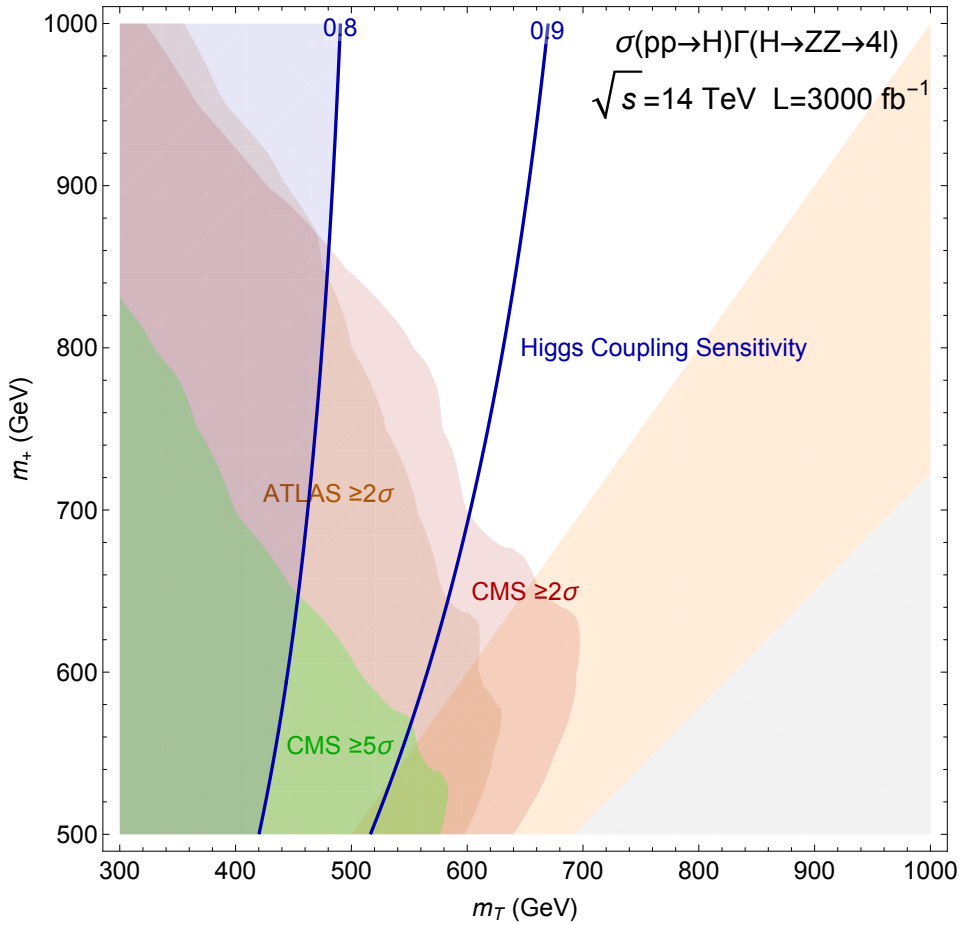
- about 10% after HL-LHC.



Projected LHC Reach with ZZ

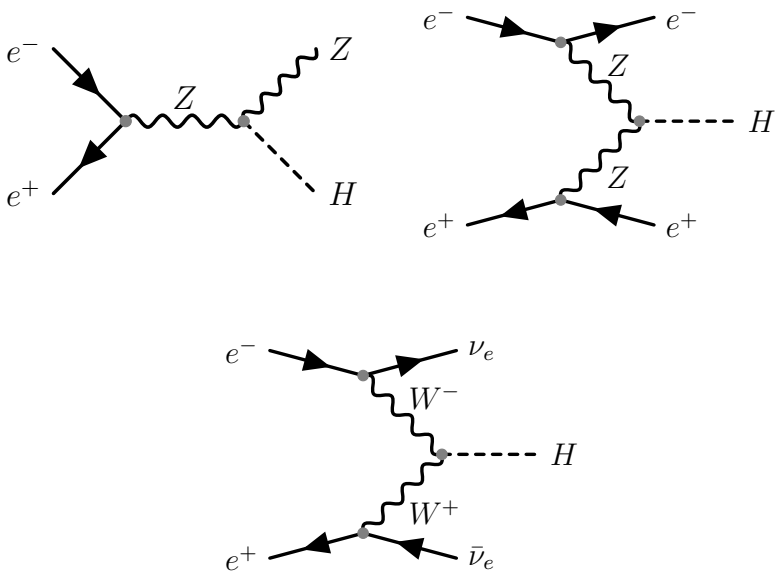
see also A. Ahmed, arXiv:1711.03107

- Using CMS-PAS-FTR-13-024 and ATL-PHYS-PUB-2013-016 we find the projected reach for $pp \to H \to ZZ \to \ell\ell\ell\ell$
- Clearly, the LHC can test the Twin Higgs for some parameter regions
- How does it improve for a linear collider?

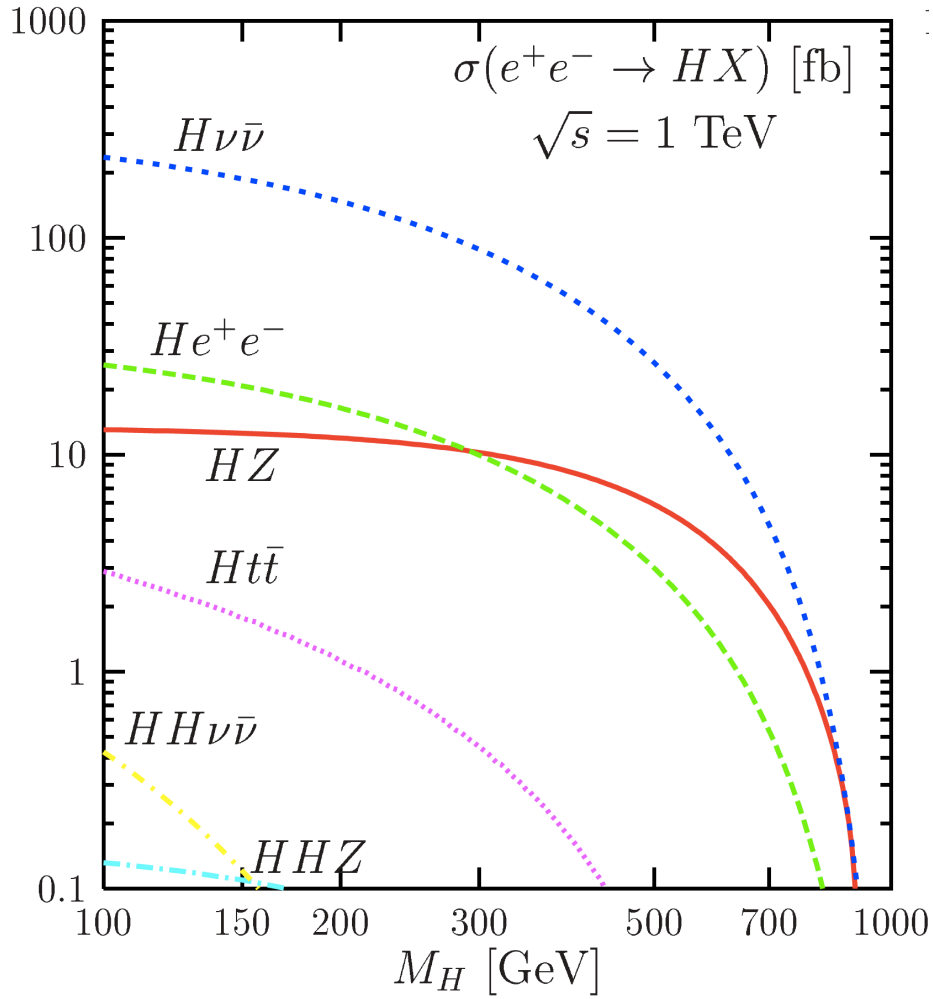


Producing of the Twin Higgs at Linear Colliders

- W fusion, Z fusion, and associated production

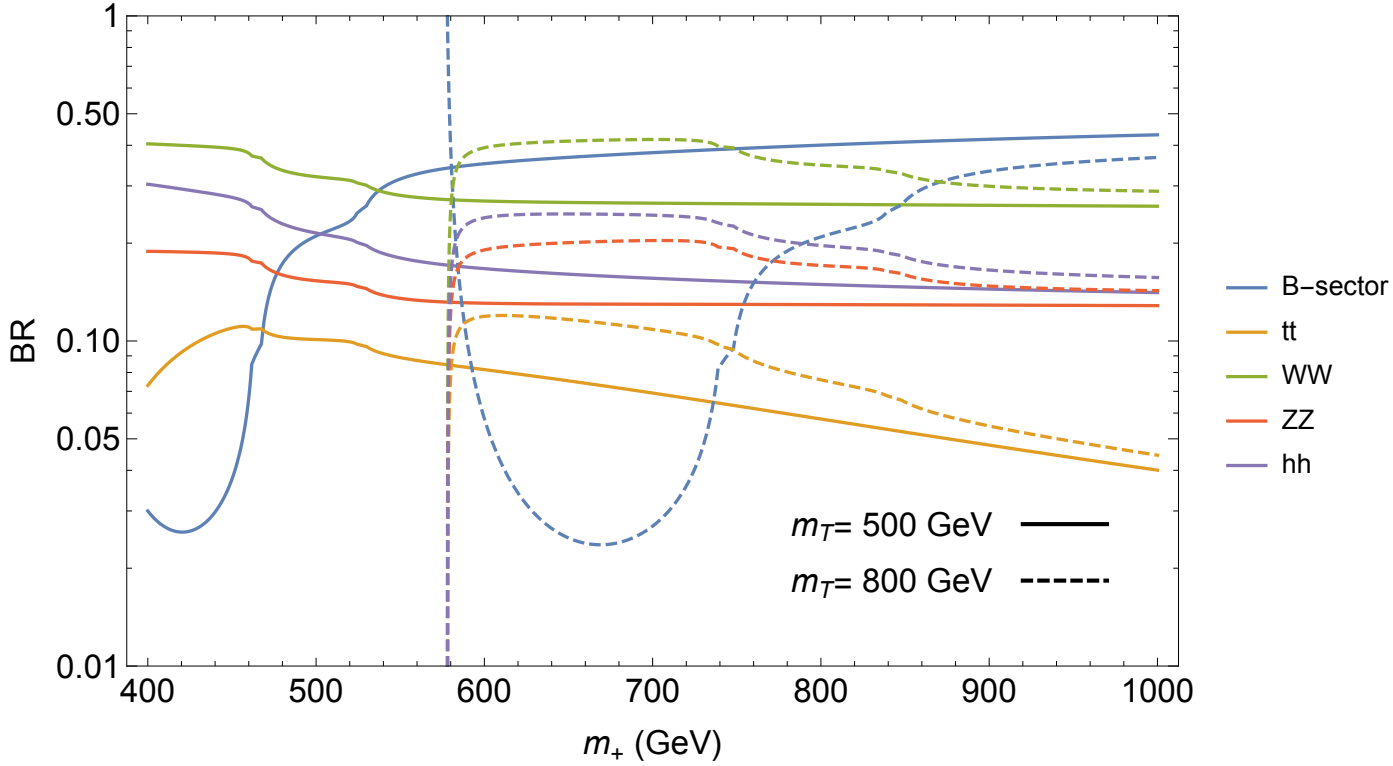


A. Djouadi, hep-ph/0503172



Twin Higgs Branching

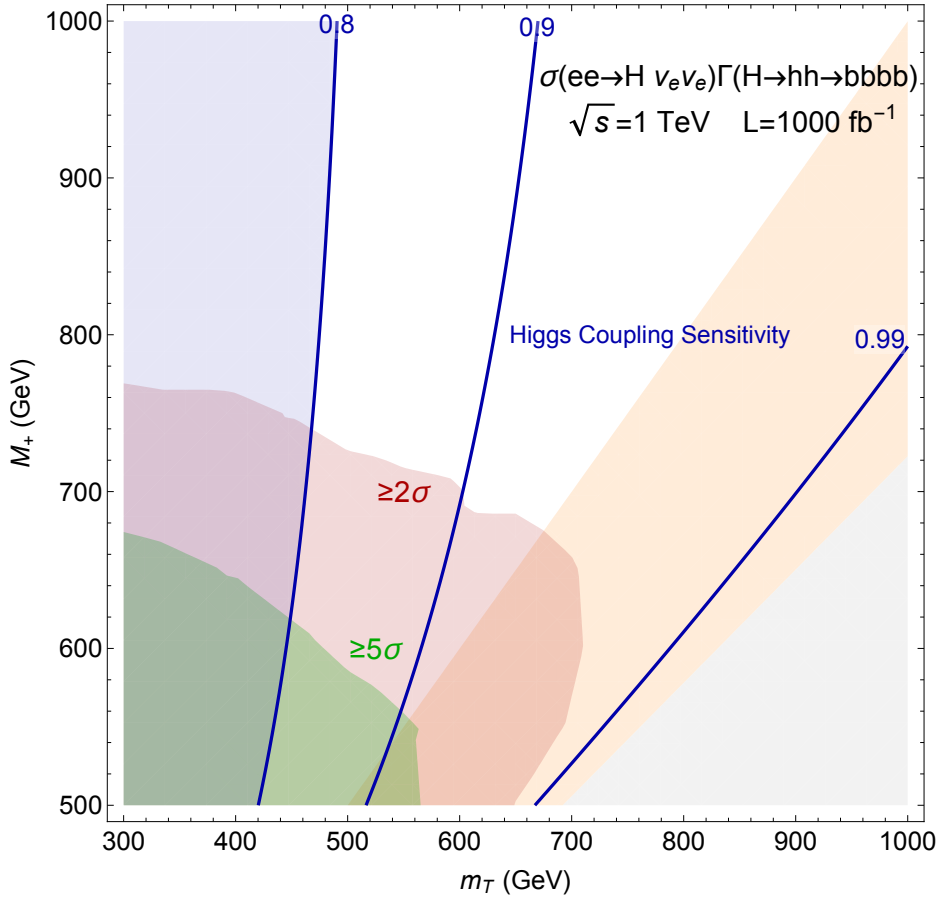
- Twin Higgs branching fraction to the Sm and twin sector EW bosons dominates.
- In the SM sector, W^+W^- branching fraction is the largest, followed by hh, ZZ.

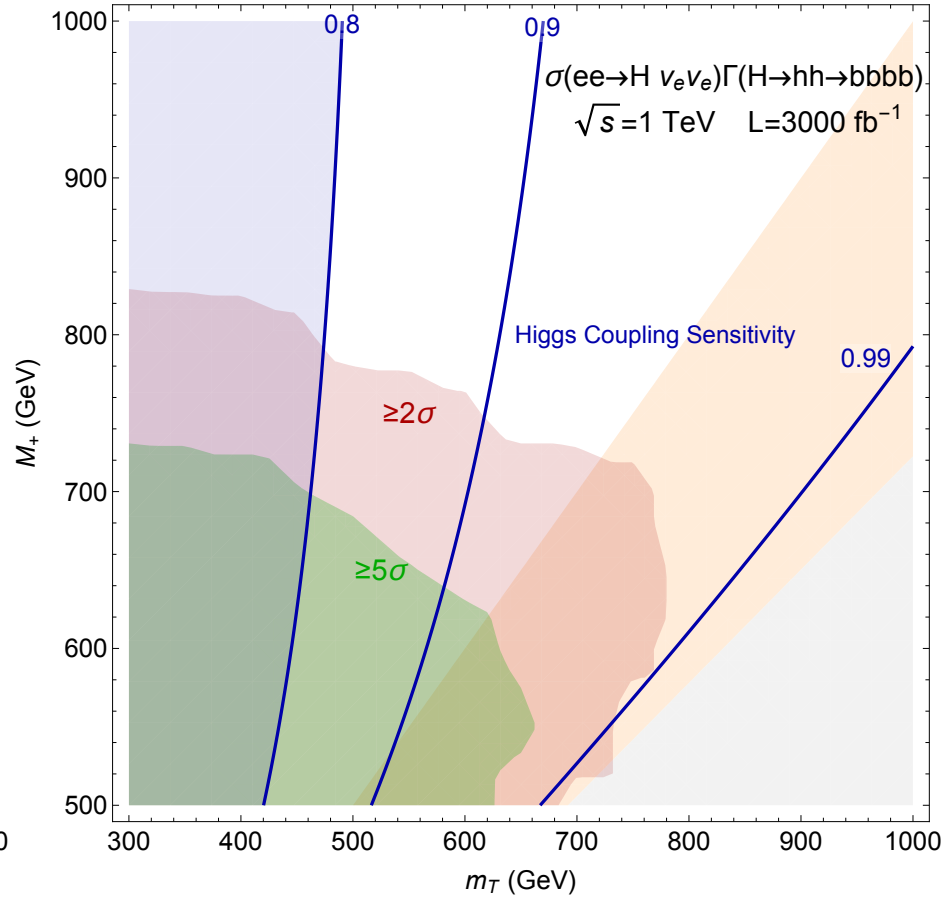


Resonant di-Higgs channel at the linear colliders

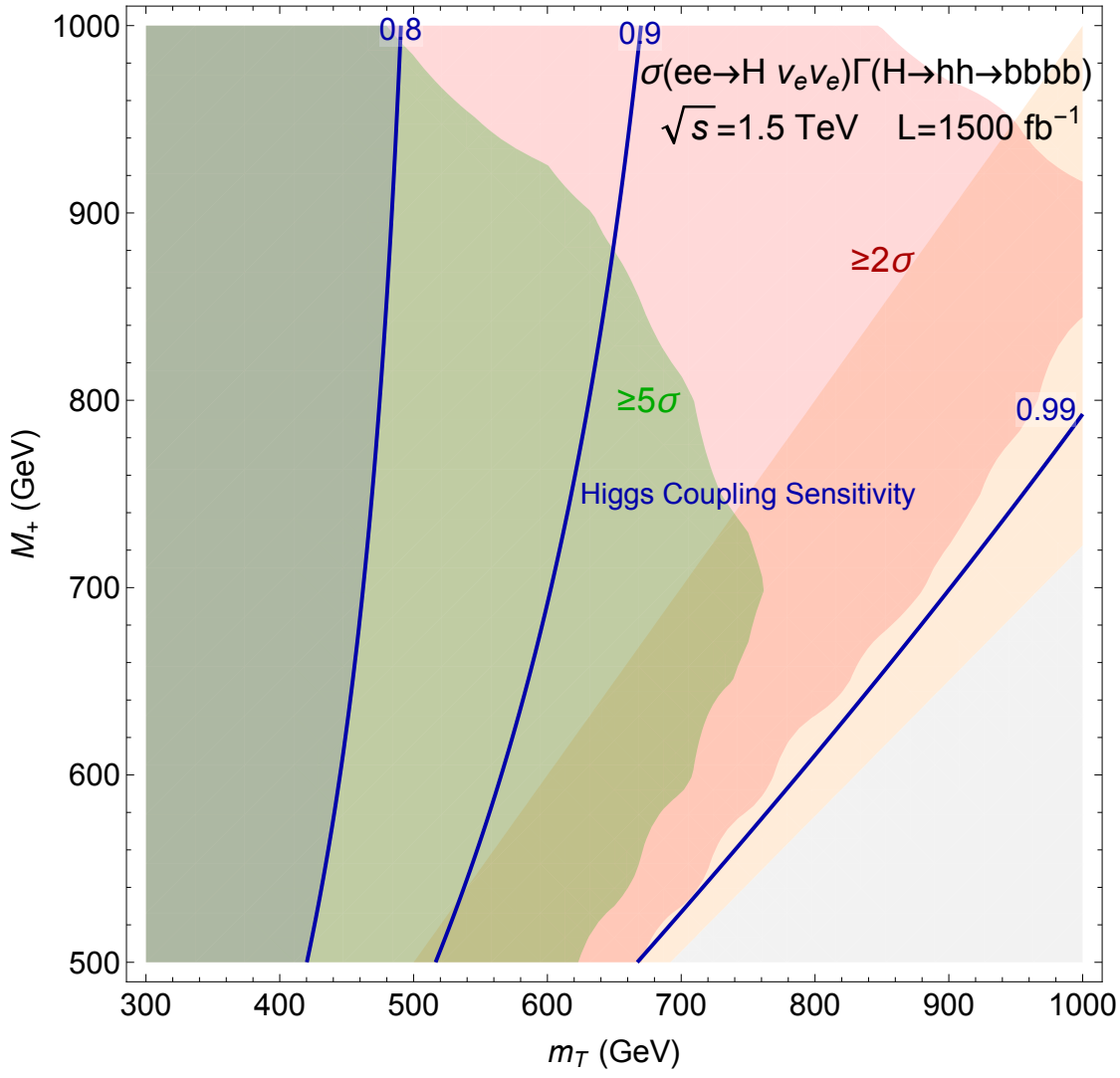
- While the WW rate is largest, the backgrounds overwhelm the signal.
- However, the di-Higgs rate to $4b$'s has much smaller background.
- Benefit of using a lepton collider!

Twin Higgs observability potential at the ILC





Twin Higgs observability potential at the CLIC



Conclusions

- The Twin Higgs framework gives an elegant solution to the hierarchy problem of the SM.
- By combining precision studies of the light Higgs with measurements of the mass and event rates of the twin sector Higgs, we can overdetermine the form of the scalar potential, and establish that it has an enhanced global symmetry.
- We found that the high luminosity LHC can potentially discover the twin sector Higgs.
- However, linear colliders such as the ILC or CLIC have much better precision and greater reach, allowing them to test the Twin Higgs mechanism.