

Discovery of the Heavy Top Partner in the LR-Twin Higgs Model at the LHC

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Outline

➡ Twinhiggs Model

- Twin Higgs Mechanism
- Introduce the Heave Top quark
- New Particles

➡ Heavy Top Quark @ LHC

- Production
- Decay
- Background
- Signal + Background @LHC

Twinhiggs Mechanism: Linear Realization

$$H = \begin{pmatrix} H_L \\ H_R \end{pmatrix}$$

SM Higgs doublet
EWSB \rightarrow SM Higgs
3 higgses: ϕ^0, ϕ^\pm

$$\langle H \rangle = \begin{pmatrix} 0 \\ 0 \\ 0 \\ f_1 \end{pmatrix}$$

$$U(4) \times U(4) \rightarrow U(3) \times U(3)$$

$$SU(2)_L \times SU(2)_R \times U(1)_{B-L} \rightarrow SU(2)_L \times U(1)_Y$$

$$\hat{H} = \begin{pmatrix} \hat{H}_L \\ \hat{H}_R \end{pmatrix}$$

$SU(2)_L$ Higgs doublet
 H_1^\pm, H_1^0
 Dark matter candidate
3 eaten by heavy gauge bosons

$$\langle \hat{H} \rangle = \begin{pmatrix} 0 \\ 0 \\ 0 \\ f_2 \end{pmatrix}$$

$f_2 > f_1$

Only couples to Gauge bosons.

TH Mechanism: Linear Realization Contd ...

$$\Delta V = \frac{9g_L^2}{64\pi^2} \Lambda^2 H_L^\dagger H_L + \frac{9g_R^2}{64\pi^2} \Lambda^2 H_R^\dagger H_R \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} H = \begin{pmatrix} H_L \\ H_R \end{pmatrix}$$

$$\downarrow \quad \boxed{g_L = g_R = g}$$

$$\Delta V = \frac{9g^2}{64\pi^2} \Lambda^2 (H_L^\dagger H_L + H_R^\dagger H_R) = \frac{9g^2}{64\pi^2} \Lambda^2 H^\dagger H$$

U(4) invariant,
Doesn't contribute to GB mass

$$\Delta V = \frac{g^4}{16\pi^2} \log\left(\frac{\Lambda}{gf}\right) (|H_L|^4 + |H_R|^4)$$

$$m_H \sim \frac{g^2 f}{4\pi} \quad \boxed{\text{Natural for } f \sim \text{TeV}}$$

Heavy Top Quark: t_H

$$Q_L = (u, d)_L = [2, 1, 1/3] \quad L_L = (v, e)_L = [2, 1, -1]$$

$$Q_R = (u, d)_R = [1, 2, 1/3] \quad L_R = (v, e)_R = [1, 2, -1]$$

Yukawa coupling ~ 1 for SM top quark.

$$T_L = [1, 1, 4/3] \quad T_R = [1, 1, 4/3]$$

$$y\bar{Q}_R H_R^\dagger T_L + y\bar{Q}_L H_L^\dagger T_R + M\bar{T}_L T_R + h.c.$$

M: mixing parameter of t_L with T_L .

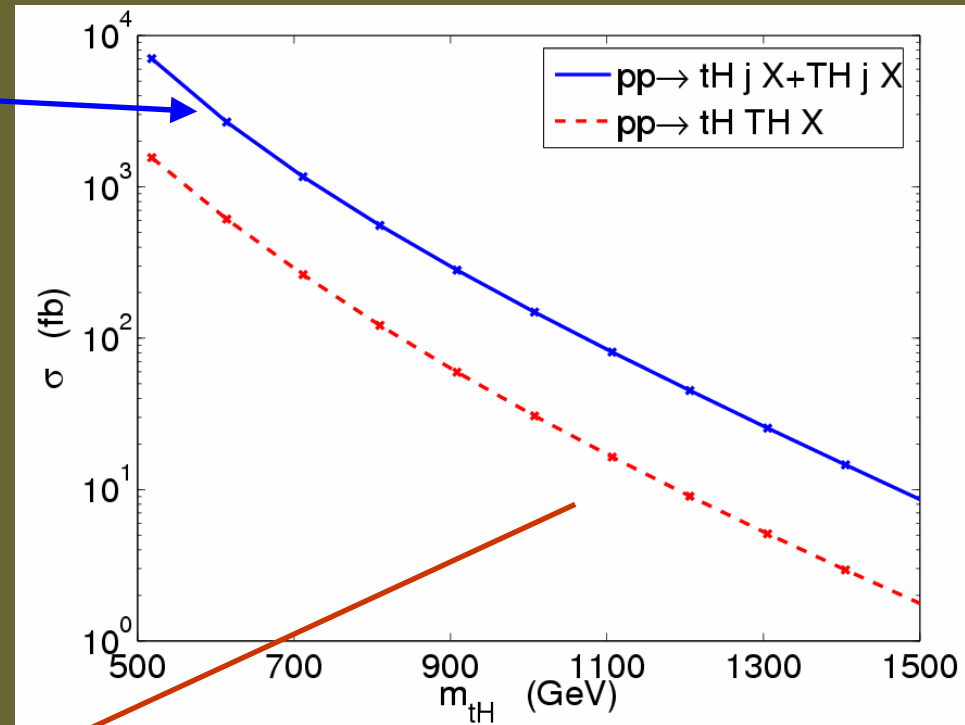
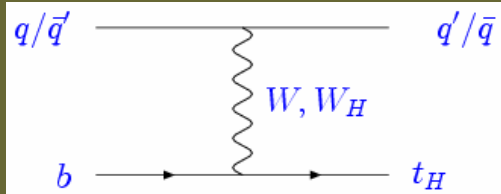
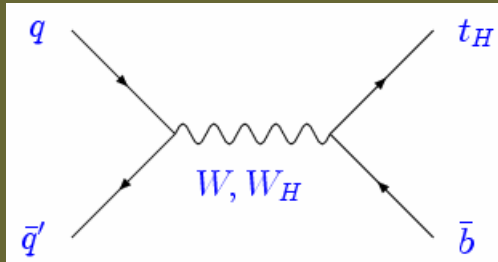
Mass eigenstates: SM top and t_H

New Particles

- Heavy gauge bosons: W_H, Z_H $m_{WH,ZH}^2 \sim g^2(f_1^2+f_2^2)$
- Heavy top: t_H $m_{tH}^2 \sim M^2+y^2f_1^2$
- Other $SU(2)_R$ Higgses: ϕ^\pm $m_{\phi^\pm}^2 \sim g^4/(16\pi^2)f_2^2 \log(\Lambda/gf_2)$
 ϕ^0 $m_{\phi^0}^2 \sim B (f_2/f_1)$
 B : small, (50-100 GeV)²
- Other $SU(2)_L$ Higgs H_{1^\pm} $m_{H_{1^\pm}, H_{2^0}}^2 \sim \mu$
 H_2^0 μ : soft symmetry breaking, $O(f_1)$

t_H production

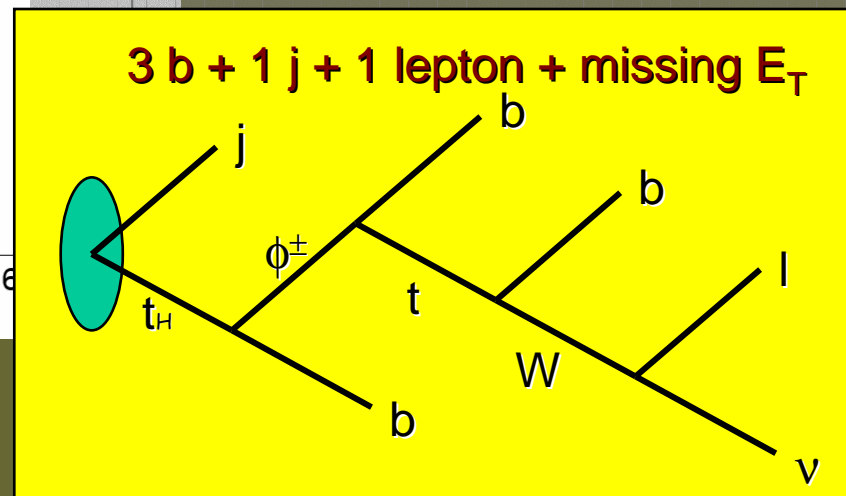
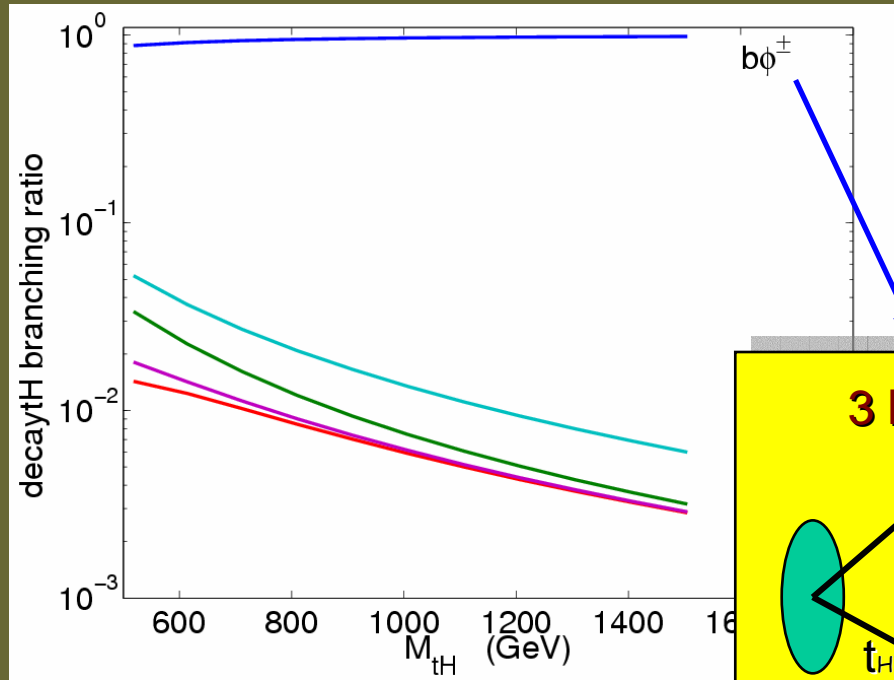
Single t_H production



Pair production

$$gg, q\bar{q} \rightarrow t_H \bar{t}_H$$

t_H decay

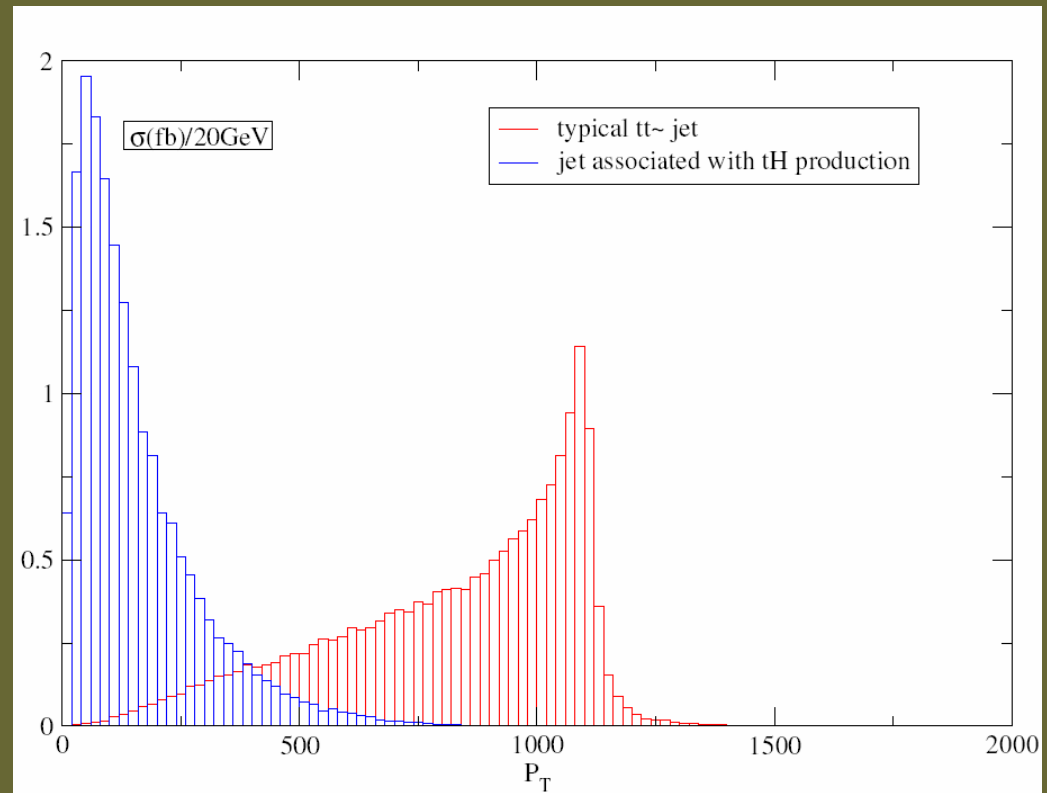


Background

$$\sigma(t\bar{t} \rightarrow wjjjj) \sim 220pb$$

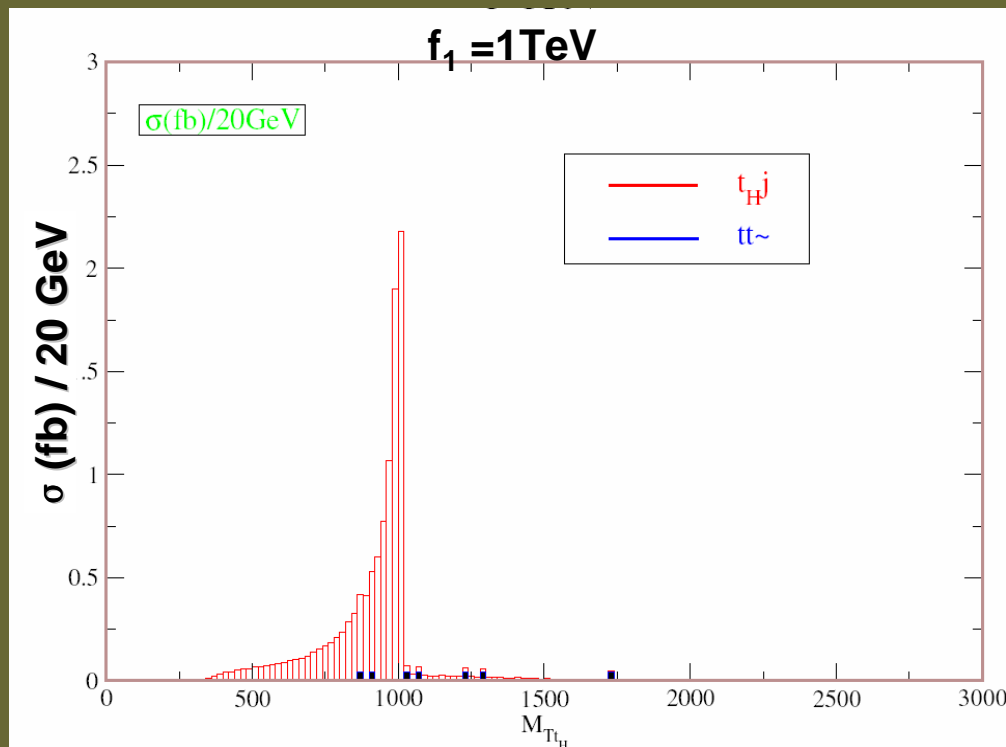
$$\sigma(w + 4jets) \sim 140pb \quad (\text{after standard cuts})$$

$$\sigma(t_H j) < 1pb$$



Signal + Background @ LHC

- lepton (e or μ) with $p_T > 30$ GeV, $|\eta| < 2.5$
- all jets with $p_T > 50$ GeV, $\Delta R_{jj} > 0.4$, $\Delta R_{jl} > 0.4$
- at least one jet with $p_T > 550$ GeV



| f_1 | S (fb) | S/B | S/ \sqrt{B} |
|-----------------|-------------|-------------|-----------------------------------|
| 700 GeV | 29.5 | 100 | 54.4 \sqrt{L} |
| 1000 GeV | 11.3 | 38.4 | 20.8 \sqrt{L} |
| 1500 GeV | 1.02 | 3.48 | 1.89 \sqrt{L} |

Need more background data.

Conclusion

➡ L-R twin Higgs model:

- Quadratic divergence forbidden by left-right symmetry

➡ New Particles:

- Heavy gauge bosons: W_H, Z_H
- Heavy top quark: t_H
- New Higgses: $\phi^\pm, \phi^0, H_1^\pm, H_1^0$

➡ Heavy top @ LHC

- Signal: 3 b + 1 j + 1 lepton + missing E_T
- Background: $t\bar{t}$, $w+4j$

➡ Future work

- Identify the left and right couplings
- Distinguish from i.e. little Higgs