T-Anomaly Indeced Decays in Little Higgs Model with T-Parity

Yu Gao, UW - Madison

V. Barger , Y. Gao, Wai-Yee Keung
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Little hierarchy and the little Higgs

SM:

Higgs mass = 115~ 200 GeV requires: $\left|\frac{\delta_q m^2}{m^2}\right| \leq 10 \;\Rightarrow\; \Lambda_{\rm SM} \lesssim 2-3 \text{ TeV}$

Precision Electroweak data requires: $\Lambda_{\rm SM} \gtrsim 10 \text{ TeV}$

A Little Higgs:

a pseudo-Goldstone boson protected by collective symmetry breaking

The SU(5)/SO(5) construction

Arkani-Hamed, Cohen, Kalz, Nelson, 2002

SU(5) with gauged $[SU(2)_1 \times U(1)_1] \times [SU(2)_2 \times U(1)_2]$

Each SU(2)×U(1) leaves a SU(3) symmetry intact

Higgs mass needs both SU(2)×U(1) groups

$\Rightarrow$ leading vector boson loop diagrams lead no worse than logarithmic divergence

Top sector

Top contribution canceled by a new fermion t_p $\Rightarrow$ reduced effective top Yukawa

New particles

$$SU(5) \xrightarrow{\Sigma_0} SO(5)$$

$$[SU(2) \times U(1)]^2 \qquad SU(2)_L \times U(1)$$

* Massive complex triplet Higgs f
  Massive partners of EW gauge fields
  Another top quark

The LH model doesn't solve the little hierarchy problem

* Naturalness: $f \sim 1$ TeV (Casa et.al, 2005)

* precision EW: $f > 4.6$ TeV (2σ) (Csaki et.al., 2003)

T parity (Chern and Low, 2004)

$\Rightarrow$ * triplet f odd, doublet h even under T

* $H^\dagger f\ H$ term forbidden, no triplet vev

* extended fermion sector:
T-odd partner to every LH fermion

* no mixing between W / W_H or Z / Z_H or between f / f_H:
(*T*-odd particles leave EW physics alone)

OK with precision EW (Casa et.al.,2005)

NOT that OK with fine tuning (J. Hubisz, P. Meade, 2005)

Production rate

Tree level @ LHC, f =1.5 TeV, m_H=200 GeV

Final state	σ [fb]
q^+q^-	5.2
q^+q^+	2.6
$T_-\bar{T}_-$	1.5
$q_-W_H^+ + q_-W_H^-$	1.8
q_-Z_H	0.90
$Z_HW_H^+ + Z_HW_H^-$	1.6
$W_H^+W_H^-$	1.0

Final state:	σ [fb]
$q_- q_-$	9.7
f X	0.005
A_H X	0.33
A_H A_H	0.003

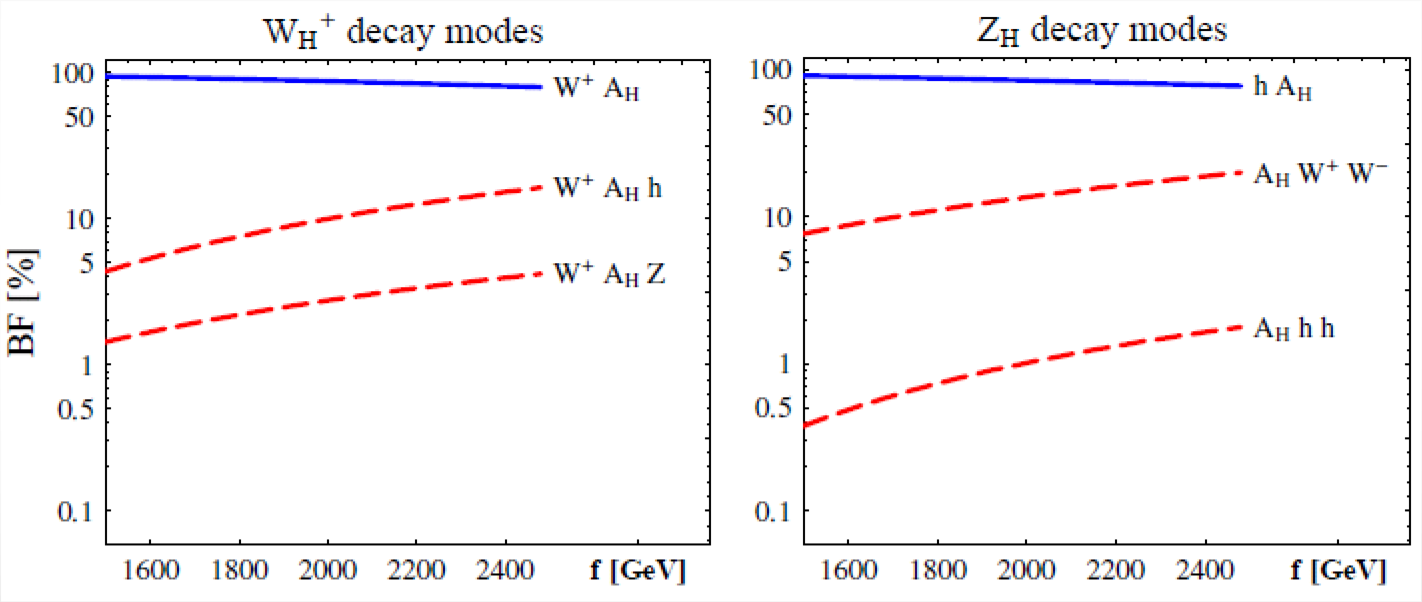
T conservation means:

T-odd particles must be produced in pairs

T_+ is *T* even and can be produced with SM quarks

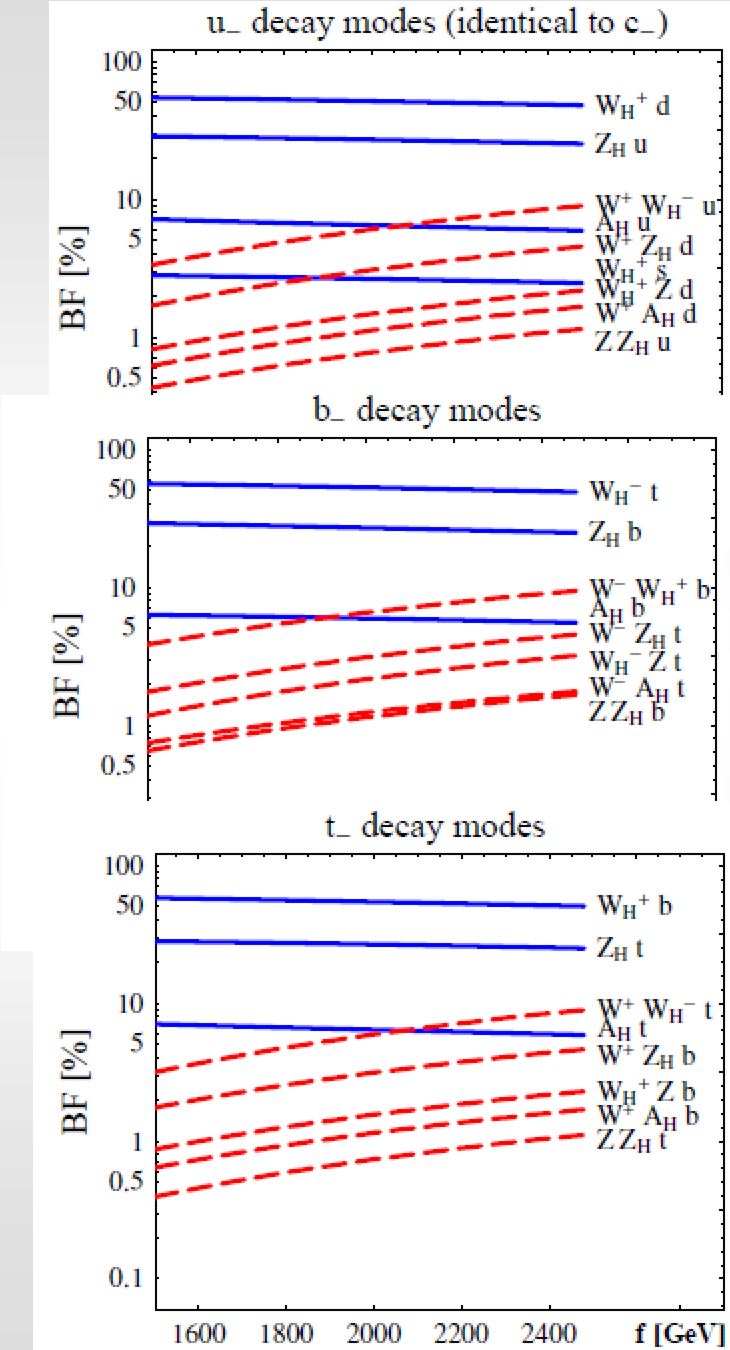
All T-odd particles decay into A_H

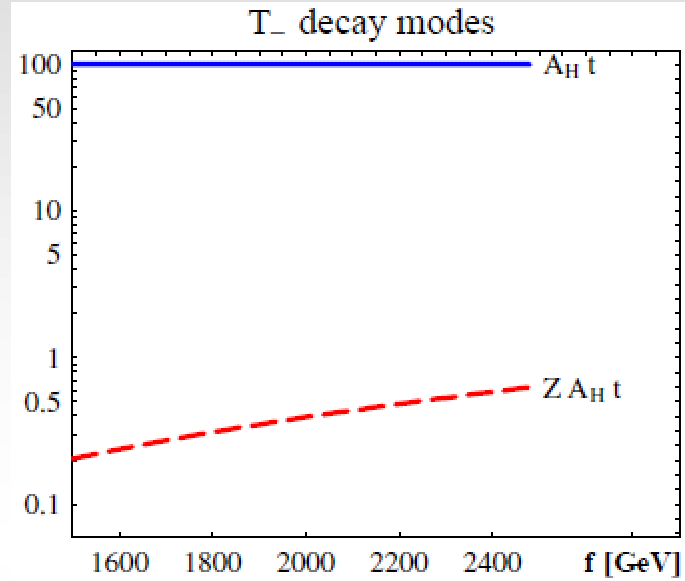
$\not{E}_T$ factory at LHC?

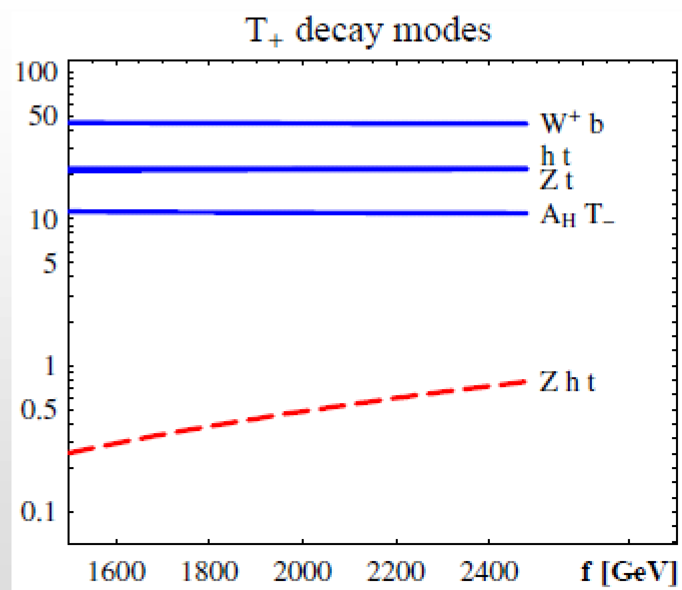


Weak gauge bosons

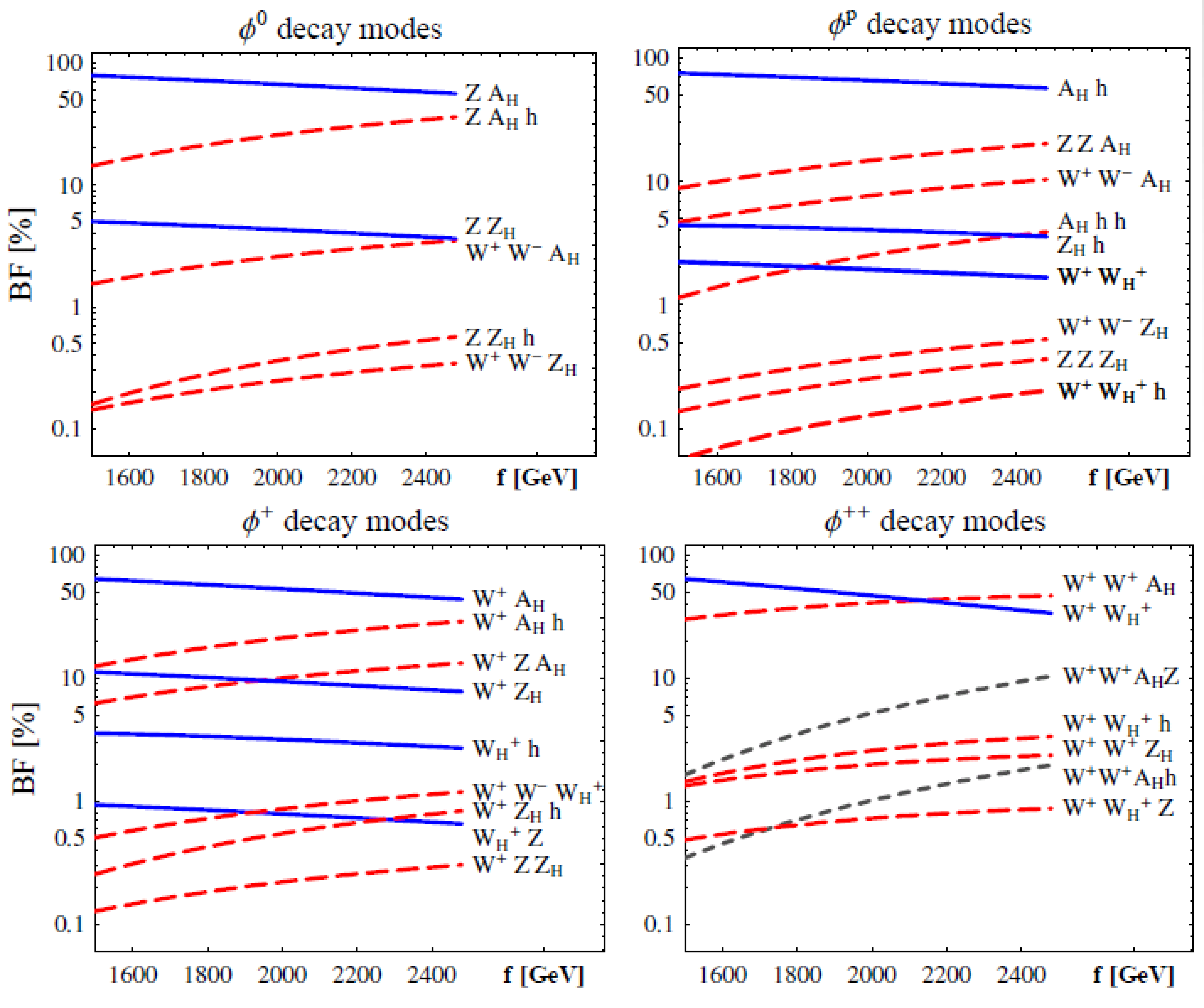
Heavy quark decays







Heavy Higgs fields



T-violation (A_H isn't stable) (C. Hill, R. Hill, 2007)

Similarity between *T* parity and KK parity

A 5D Lagrangian → The Chern-Simmons term breaks the *T*-parity

↓ 4D

Wess-Zumino-Witten term → *T* parity broken in 4D

$$\Gamma_{WZW} = \int d^4x \, \frac{\tilde{g}N}{24\sqrt{3}\pi^2} \epsilon^{\mu\nu\rho\sigma} \tilde{B}_\mu [$$

$$-\frac{1}{3} g_1^2 [B_\nu \partial_\rho B_\sigma] + 2 g_2^2 \, \mathrm{Tr}[W_\nu \partial_\rho W_\sigma] - \frac{3 i g_2^3}{2} \mathrm{Tr}[W_\nu W_\rho W_\sigma]$$

$$+ \frac{i g_1}{2F^2} F^B_{\nu\rho} [H^\dagger (D_\sigma H) - (D_\sigma H^\dagger) H] - \frac{i g_2}{F^2} [H^\dagger F^W_{\nu\rho} (D_\sigma H) - (D_\nu H^\dagger) F^W_{\rho\sigma} H]]$$

T-violation (A_H isn't stable) (C. Hill, R. Hill, 2007)

Similarity between T parity and KK parity

A 5D Lagrangian → The Chern-Simmons term breaks the T-parity

↓ 4D

Wess-Zumino-Witten term → T parity broken in 4D

$$\Gamma_{WZW} = \int d^4x \, \frac{\tilde{g}N}{24\sqrt{3}\pi^2} \epsilon^{\mu\nu\rho\sigma} \tilde{B}_\mu \Big[\frac{1}{3} g_1^2 [B_\nu \partial_\rho B_\sigma] + 2 g_2^2 \mathrm{Tr}[W_\nu \partial_\rho W_\sigma] - \frac{3 i g_2^3}{2} \mathrm{Tr}[W_\nu W_\rho W_\sigma]$$

$$+ \frac{i g_1}{2F^2} F^B_{\nu\rho} [H^\dagger (D_\sigma H) - (D_\sigma H^\dagger) H] - \frac{i g_2}{F^2} [H^\dagger F^W_{\nu\rho} (D_\sigma H) - (D_\nu H^\dagger) F^W_{\rho\sigma} H] \Big]$$

The effective WZW term:

$$\mathcal{L}_{\rm WZW} \supset -\frac{K\tilde{g}g_2^2 N_{WZ} v_{SM}^2}{48\sqrt{3}\pi^2 f^2}\epsilon^{\mu\nu\rho\sigma} B_{H\mu}\left[\sec^2\theta_W Z_\sigma \partial_\nu Z_\rho + (D_\nu^A W_\rho^+)W_\sigma^- + (D_\nu^A W_\rho^-)W_\sigma^+\right]$$

A_H is the dominant component of B_H

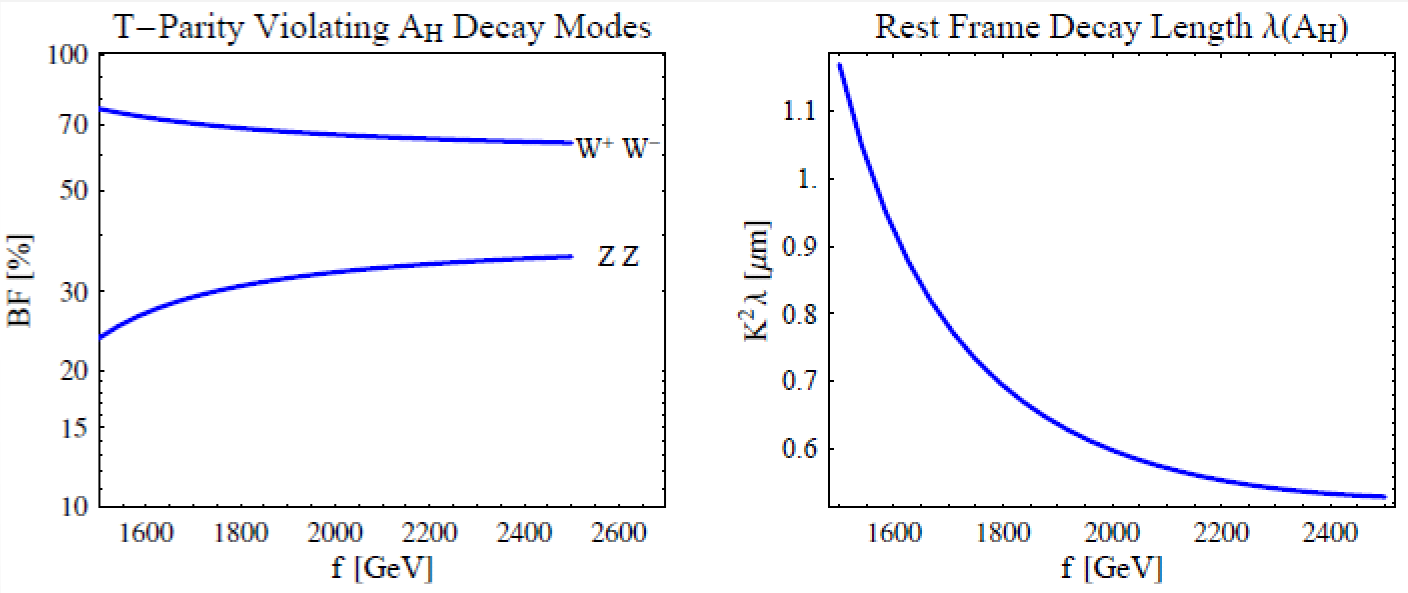
$$B_H = A_H \cos\theta_H + Z_H \sin\theta_H$$

$$\sin\theta_H = \frac{5gg'}{4(5g^2 - g'^2)}\frac{v_{SM}^2}{f^2}$$

The A_H decay widths:

$$\Gamma(B_H \to ZZ) = \frac{1}{2\pi}\left(\frac{K\tilde{g}^3 N_{WZ}}{144\pi^2}\right)^2 \frac{m_Z^2}{m_{B_H}}\left(1 - \frac{4m_Z^2}{m_{B_H}^2}\right)^{\frac{5}{2}}$$

$$\Gamma(B_H \to W^+W^-) = \frac{1}{\pi}\left(\frac{K\tilde{g}^3 N_{WZ}}{144\pi^2}\right)^2 \frac{m_W^2}{m_{B_H}}\left(1 - \frac{4m_W^2}{m_{B_H}^2}\right)^{\frac{5}{2}}$$



T−Parity Violating A_H Decay Modes
BF [%]
100
70
50
30
20
15
10
W⁺ W⁻
Z Z
1600
1800
2000
2200
2400
2600
f [GeV]
Rest Frame Decay Length λ(A_H)
K² λ [μm]
1.1
1.
0.9
0.8
0.7
0.6
1600
1800
2000
2200
2400
f [GeV]

Implications

- A_H is unstable. (decay instantaneous if kinematically allowed)

  No massive missing particle at collider from LHT model.

  A_H decays into WW or ZZ

  → multiple (4 and more) W channels