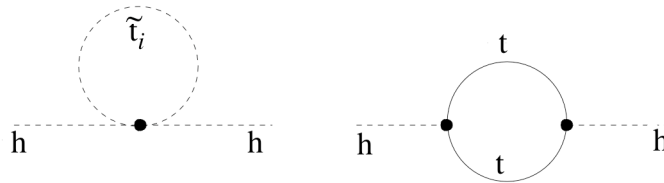# TRIUMF Summer Institute 2009
# Questions for "Beyond the Standard Model at Colliders" lecture 1
# Heather Logan

1. Show that the quadratically divergent part of the $h^0$ mass correction from the top quark loop is cancelled by the contribution from the top squark loops.



The Feynman rules for the vertices are:

$$h^0 t\bar{t} : \qquad ig_{htt}$$
$$h^0 h^0 \tilde{t}_i \tilde{t}_i : \qquad i\lambda_{hh\tilde{t}_i\tilde{t}_i},$$

where the relevant couplings are:

$$g_{htt} = -\frac{gm_t \cos\alpha}{2m_W \sin\beta}$$

$$\lambda_{hh\tilde{t}_L\tilde{t}_L} = \frac{g^2}{2}\left[-\frac{m_t^2}{m_W^2}\frac{\cos^2\alpha}{\sin^2\beta} + \cdots\right]$$

$$\lambda_{hh\tilde{t}_R\tilde{t}_R} = \frac{g^2}{2}\left[-\frac{m_t^2}{m_W^2}\frac{\cos^2\alpha}{\sin^2\beta} + \cdots\right]$$

$$\lambda_{hh\tilde{t}_L\tilde{t}_R} = 0.$$

The ellipsis in $\lambda_{hh\tilde{t}_L\tilde{t}_L}$ and $\lambda_{hh\tilde{t}_R\tilde{t}_R}$ represent electroweak terms (not proportional to $m_t$) that are cancelled among other sets of loops; you may neglect them. To show that the cancellation happens, you don't need to actually compute the loop integrals; it's enough to neglect all masses and the external momentum and write the loop integrals in the (divergent) form $\int d^4p/p^2$, where $p$ is the momentum running around the loop.

2. Consider charged Higgs boson production in association with a top quark at the LHC, $pp \to tH^-$, with the first top quark decaying semileptonically and the charged Higgs decaying according to $H^- \to \bar{t}b$ with a hadronic top decay. The final state selected in your analysis consists of $b\bar{b}\bar{b}jj\ell^+ p_T^{miss}$. Draw a Feynman diagram for the decay and assign a momentum to each particle. Write down explicit expressions in terms of the final state particle momenta for all the invariant mass peaks that should be reconstructable in this signal, i.e., the hadronically-decaying $W$, both tops, and the charged Higgs. (Ignore final-state masses. To get the $z$ component of the neutrino momentum up to a 2-fold degeneracy, you may assume that the $p_T^{miss}$ and the lepton come from a $W$ decay and that you know the $W$ mass.)