We calculate the partial widths of the light Higgs boson in the Littlest Higgs model. The loop-induced Higgs coupling to photon pairs, which is especially sensitive to effects of the new TeV-scale particles running in the loop, can be probed with high precision at a photon collider in the process $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$. Using the parameters of the Littlest Higgs model measured at the LHC one can calculate a prediction for this process, which will serve as a test of the model and as a probe for a strongly-coupled UV completion at the 10 TeV scale.

At a photon collider, the Higgs boson can be produced in the $s$-channel via $\gamma\gamma \rightarrow H$. This allows a high-precision measurement of the $\gamma\gamma H$ coupling, which is limited by systematic uncertainties at the LHC and by statistics at an $e^+e^-$ linear collider. Numerous studies [1] indicate that the rate for $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ can be measured to about 2% for a SM-like Higgs boson with $115 \text{ GeV} \leq M_H \leq 140 \text{ GeV}$. Other Higgs decay modes will be measured with lower precision.

The $\gamma\gamma H$ coupling comes from the dimension-6 operator

$$\mathcal{L} = \frac{C}{\Lambda^2} H^\dagger H F_{\mu\nu} F^{\mu\nu},$$

where $H$ is the Higgs doublet, $F^{\mu\nu}$ is the electromagnetic field strength tensor, $\Lambda$ is the mass scale that characterizes the interaction, and $C$ is a dimensionless coefficient. In the SM, this operator is induced by $W$ and $t$ loops. Taking $C = e^2/16\pi^2$ for a loop-suppressed electromagnetic interaction yields $\Lambda = 170$ GeV for the SM – the right scale for the $W$ and $t$ loops.

A 2% measurement of $\gamma\gamma \rightarrow H$ allows a probe of new physics. For weakly-coupled new physics ($C_{\text{new}} = e^2/16\pi^2$), scales up to 1.2 TeV (0.74 TeV) can be probed at the 95% confidence (5$\sigma$) level. For strongly-coupled new physics ($C_{\text{new}} = 1$), scales up to 48 TeV (31 TeV) can be probed at the 95% confidence (5$\sigma$) level. In this talk, based on [2], we apply the $\gamma\gamma \rightarrow H$ measurement to the Littlest Higgs model in order to probe for a strongly coupled UV completion at the 10 TeV scale.

The Littlest Higgs model [3] stabilizes the little hierarchy between the weak scale and the 10 TeV scale by making the SM Higgs doublet a pseudo-Nambu-Goldstone boson. At the TeV scale the model contains an SU(2) triplet of gauge bosons $Z_H, W_H$, a heavy isosinglet quark $T$, a scalar isotriplet $\Phi$, and...
a U(1) gauge boson $A_H$ (an alternate version contains no $A_H$). The model is parameterized by an overall scale $f \sim \text{TeV}$, mixing angles $\cos \theta \equiv c$ and $\cos \theta' \equiv c'$ in the extended gauge sector (these can be traded for $M_{Z^H}$ and $M_{A^H}$ once $f$ is known), a ratio of Yukawa couplings $c_t$ in the extended top sector, and a Higgs sector parameter $x$ proportional to the isotriplet vacuum expectation value [4,5]. The corrections to $\Gamma(\gamma\gamma \to H)$ in the Littlest Higgs model are shown in Fig. 1 (left) [5]. The corrections to the rest of the Higgs decay partial widths, calculated in [2], are all $\mathcal{O}(v^2/f^2)$ and are roughly the same size in each Higgs decay channel. We thus focus on the best-measured channel; the correction to the rate for $\gamma\gamma \to H \to b\bar{b}$ is shown in Fig. 1 (right).

![Figure 1](image)

**Figure 1**: (Left) Range of $\Gamma(H \to \gamma\gamma)$ accessible in the Littlest Higgs model as a function of $f$, normalized to its SM value, for $M_H = 120, 150$ and 180 GeV. (Right) Rate for $\gamma\gamma \to H \to b\bar{b}$, normalized to its SM value, as a function of $c$ for $x = 0, 0.5$ and 0.9 (solid lines), with $f = 1$ TeV, $c_t = c' = 1/\sqrt{2}$, and $M_H = 115$ GeV.

A 2% measurement of the $\gamma\gamma \to H \to b\bar{b}$ rate can be used both to test the Littlest Higgs model by probing the effects of the new weakly-coupled particles at 1–3 TeV and to search for a strongly-coupled UV completion of the model at a few tens of TeV. To do this, one must measure the model parameters (at the LHC) well enough to be able to predict the rate for $\gamma\gamma \to H \to b\bar{b}$ with sufficient precision; we take 1% parametric uncertainty as our standard. The sensitivity of $\gamma\gamma \to H \to b\bar{b}$ to $c_t$ and $M_{A^H}$ is very weak; these parameters need not be measured. The sensitivity to $x$ is also rather weak; $x$ need only be measured (from, e.g., its effect on the $W$ mass) if $f$ is low $\sim 1$ TeV and $x$ is close to 1. $f$ must be measured with a precision of several percent to several tens of percent, see Fig. 2 (left). Combining $M_{Z^H}$ with the rate for $Z_H \to e^+e^-$ at the LHC allows $f$ to be extracted, see Fig. 2 (right).

In conclusion, a future photon collider should be able to measure the rate...
for $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ with 2% precision for $115 \leq M_H \leq 140$ GeV. At the same time, the rate for this process in the Littlest Higgs model can be reliably calculated over a large range of model parameter space based on LHC measurements of the parameters. Comparing prediction with measurement then allows a probe of the UV completion of the Littlest Higgs model at 10 TeV. A strongly coupled UV completion contributes to $\gamma\gamma \rightarrow H$ at the same order as the TeV-scale particles, giving a several percent correction for $f \sim 1–3$ TeV. A weakly coupled UV completion should not affect $\gamma\gamma \rightarrow H$ at an observable level; in this case, the measurement provides a test of the model’s consistency.

References

1. D. Asner et al., Eur. Phys. J. C 28, 27 (2003); hep-ph/0308103; T. Ohgaki et al., Phys. Rev. D 56, 1723 (1997); D. Asner et al., Phys. Rev. D 67, 035009 (2003); G. Jikia et al., Nucl. Phys. Proc. Suppl. 82, 373 (2000); Nucl. Instrum. Meth. A 472, 133 (2001); P. Niezurawski et al., Acta Phys. Polon. B 34, 177 (2003); hep-ph/0307183; A. Rosca et al., hep-ph/0310036.
2. H. Logan, hep-ph/0405072.
3. N. Arkani-Hamed et al., JHEP 0207, 034 (2002).
4. T. Han et al., Phys. Rev. D 67, 095004 (2003).
5. T. Han et al., Phys. Lett. B 563, 191 (2003).