$\tilde{t}$ parameters from $\Gamma_{\gamma\gamma}$

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Background – Results – Conclusion

(delivered by M.Schmitt)

Background

This application illustrates how $\Gamma_{\gamma\gamma}$ can reveal heavy charged particles.

In this study we show that the mass of the heavier stop, $\tilde{t}_2$, can be inferred from $\Gamma_{\gamma\gamma}$, if the mass of the lighter stop, $\tilde{t}_1$, and the mixing angle, $\cos\theta_{\tilde{t}}$, are already known.

This particular case is interesting because

- Large enhancements to $\Gamma_{\gamma\gamma}$ are not generic in the MSSM, esp. with M_A large.
- The $\tilde{t}_i$ are scalars, which have normally a very small impact on $\Gamma_{\gamma\gamma}$
  – importance arises from large Yukawa couplings.

Scenario:

We assume a 500 GeV e^+e^- LC with a $\gamma\gamma$ collider running concurrently.

Furthermore we assume that the e^+e^- LC has furnished the data to measure the mass of the lightest stop $\tilde{t}_1$ and the mixing angle, $\cos\theta_{\tilde{t}}$, though the heavier stop $\tilde{t}_2$ is too heavy to be observed.

See: Choi *et al.*, hep-ph/002033, and Kalinowski & Moortgart-Pick, hep-ph/0202084

We consider the case of large M_A, for which the $h\,\tilde{t}\,\tilde{t}^*$ coupling can be written in terms of $m_{\tilde{t}_1}$, $m_{\tilde{t}_2}$, $\cos\theta_{\tilde{t}}$.

$$g_{h\tilde{t}\tilde{t}} \simeq g_D - \frac{g m_t^2}{m_W} \mp \frac{g m_t}{2 m_W}(A_t - \mu\cot\beta)\,\sin 2\theta_{\tilde{t}}$$

In principle, the reaction $e^+e^- \to h\,\tilde{t}_1\,\tilde{t}_1^*$ could be used to extract $m_{\tilde{t}_2}$.

But it fails if $\cos\theta_{\tilde{t}}$ happens to be close to 0 or 1, or the cross section is too small.

$\Downarrow$

Consider, instead, $\Gamma_{\gamma\gamma}$.

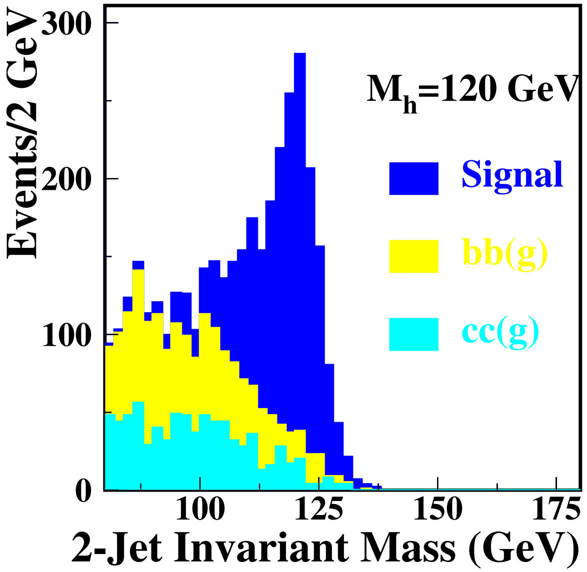
It can be extracted from data taken at a $\gamma\gamma$ collider to good precision.

$\Downarrow$

Measurements of the rate of $\gamma\gamma \to h \to b\bar{b}$, when combined with $BR(h \to b\bar{b})$ from e^+e^-, **give $\Gamma_{\gamma\gamma}$ to 2%.**

See:

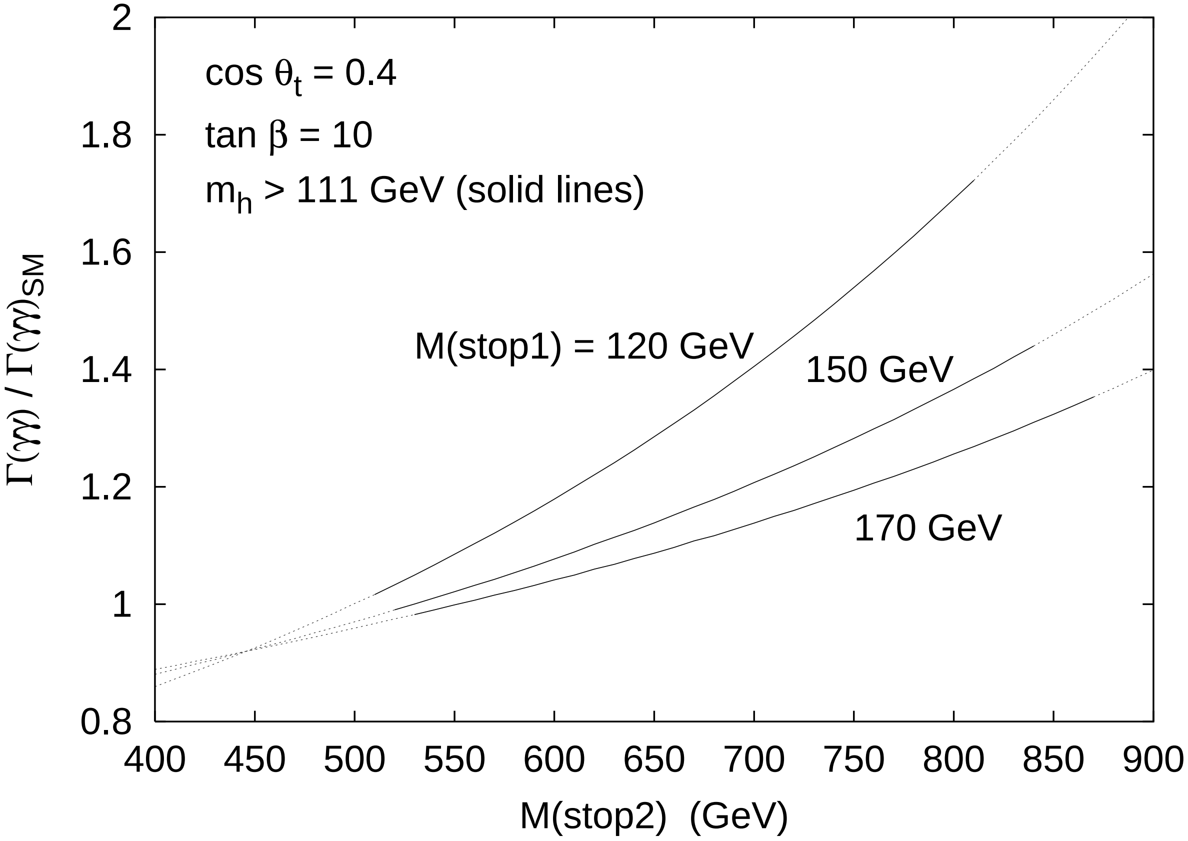
- Jikia & Söldner-Rembold: hep-ex/0101056
- Asner, Gronberg & Gunion: hep-ph/0110320
- Niezurawski, Zarnecki & Krawczyk: hep-ph/0207294



Results

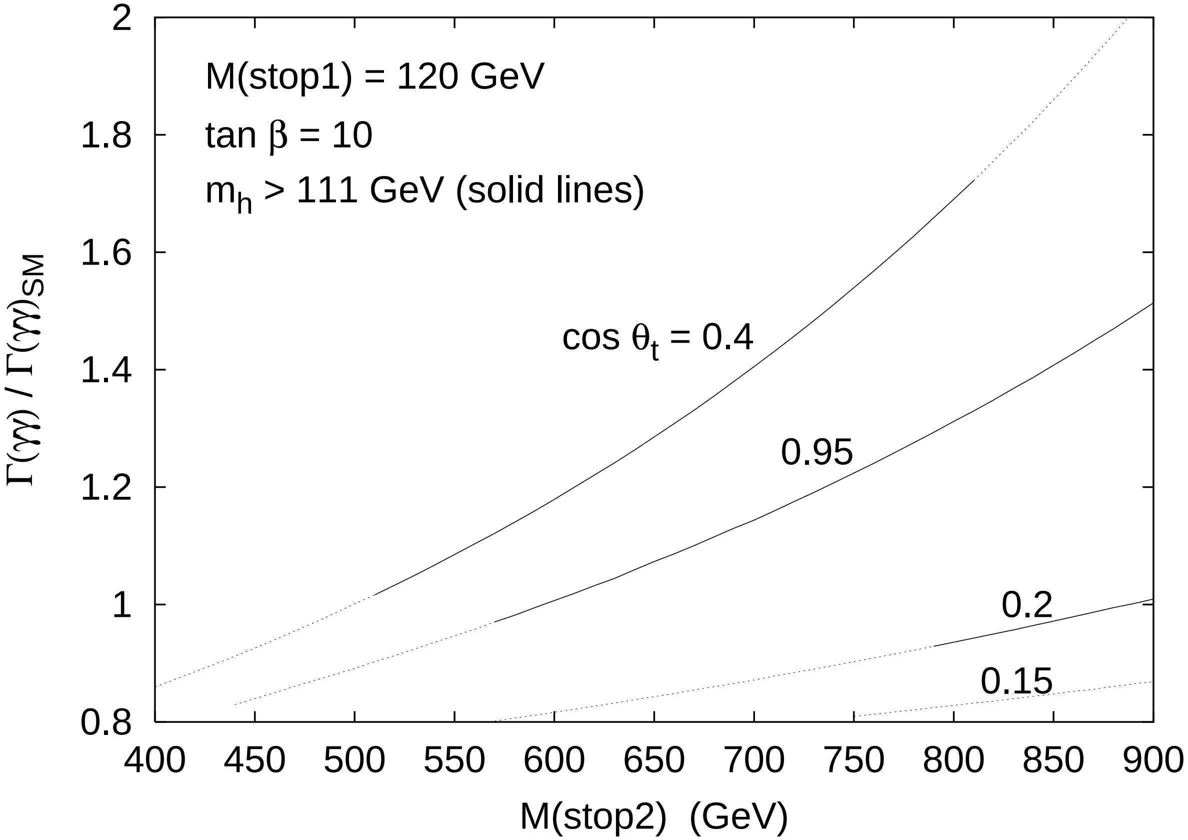
Fix $m_{\tilde{t}_1}$, $\cos\theta_{\tilde{t}}$ at representative values. Take $\tan\beta = 10$ for definiteness.

Using an improved version of HDECAY, we obtain:



Recall that the Higgs mass depends strongly on the parameters of the stop sector, and so it varies as one moves along each curve.

Here's a similar view:



The best case occurs when $\cos\theta_{\tilde{t}} \approx 0.4$ and $m_{\tilde{t}_1}$ is low.

A 2% measurement of $\Gamma_{\gamma\gamma}$ translates into an error of ± 10 GeV on $m_{\tilde{t}_2}$.

concerning parameter dependence / theoretical uncertainties:

$\longrightarrow$ We have assumed M_A large.

Allowing $M_A : 200 \longrightarrow 1000$ GeV leads to a change in the inferred $m_{\tilde{t}_2}$ of ~ 4 GeV.

Note that a low value of M_A would show up elsewhere first.

For example, $BR(W^+W^-)/BR(b\bar{b})$ will shift by $> 2\sigma$ for $M_A < 600$ GeV.

- Battaglia & Desch, hep-ph/0101165 • Carena *et al.*, hep-ph/0106116 • Velasco *et al.*, hep-ex/0111055

$\longrightarrow$ Charginos also shift $\Gamma_{\gamma\gamma}$.

If they are light, they will be observed at e^+e^- (and $\gamma\gamma$) colliders and their parameters measured, thereby removing any uncertainty in $\Gamma_{\gamma\gamma}$.

However, if they are too heavy to be observed, their influence on $\Gamma_{\gamma\gamma}$ also diminishes, leading to at most an uncertainty of ± 8 GeV (much less for large $\tan\beta$).

Conclusion

• Given knowledge of the lightest stop mass and mixing angle, the precise measurement of $\Gamma_{\gamma\gamma}$ at a $\gamma\gamma$ collider can be used to infer $m_{\tilde{t}_2}$ to an accuracy of 10–20 GeV.

$\longrightarrow$ This allows a direct deduction of fundamental SUSY parameters

$$M_{Q_3},\ M_{U_3} \text{ and } X_t = A_t - \mu \cot\beta.$$

Comment:

We have considered other rare channels, such as $h \to ZZ^*$ and $h \to \gamma Z$.

We note that the ratio of branching ratios for $BR(\gamma Z)/BR(W^+W^-)$ approaches its SM value quickly. (plot next page)

Thus it provides a stringent test of the MSSM, and would be sensitive to unexpected light charged particles in the loop.

Ratio of branching ratios compared to the SM.