Higgs di-photon rate as an indirect probe of susy scalars

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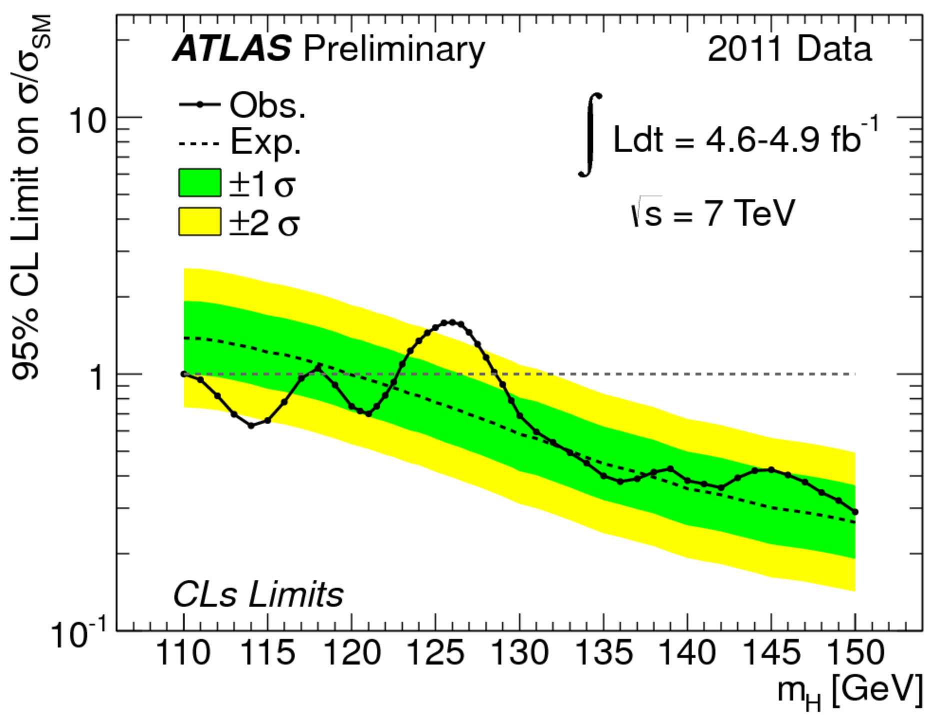
What we have learned after (5+5) fb^{-1}

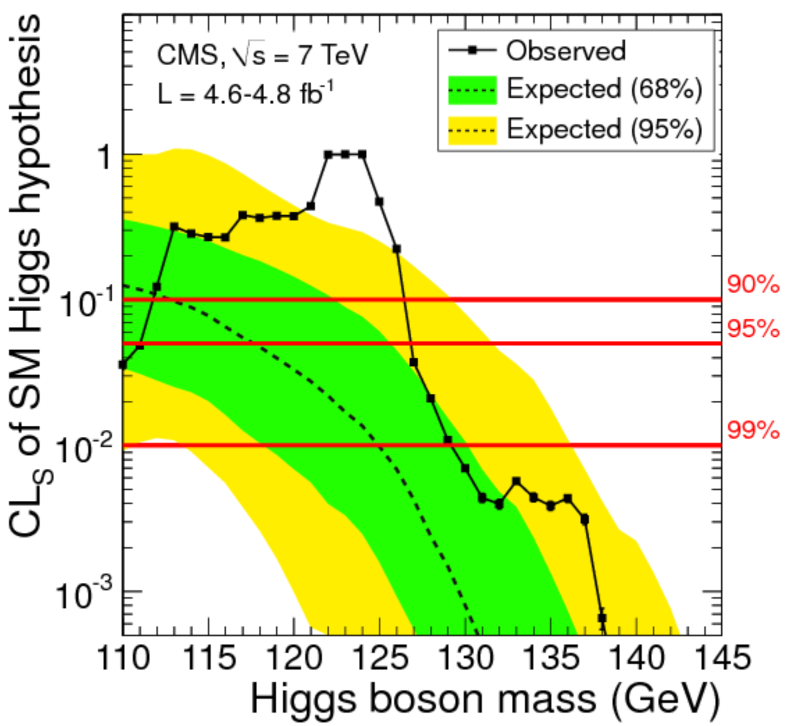
ATLAS

arXiv:1202.1408



CMS

arXiv:1202.1488

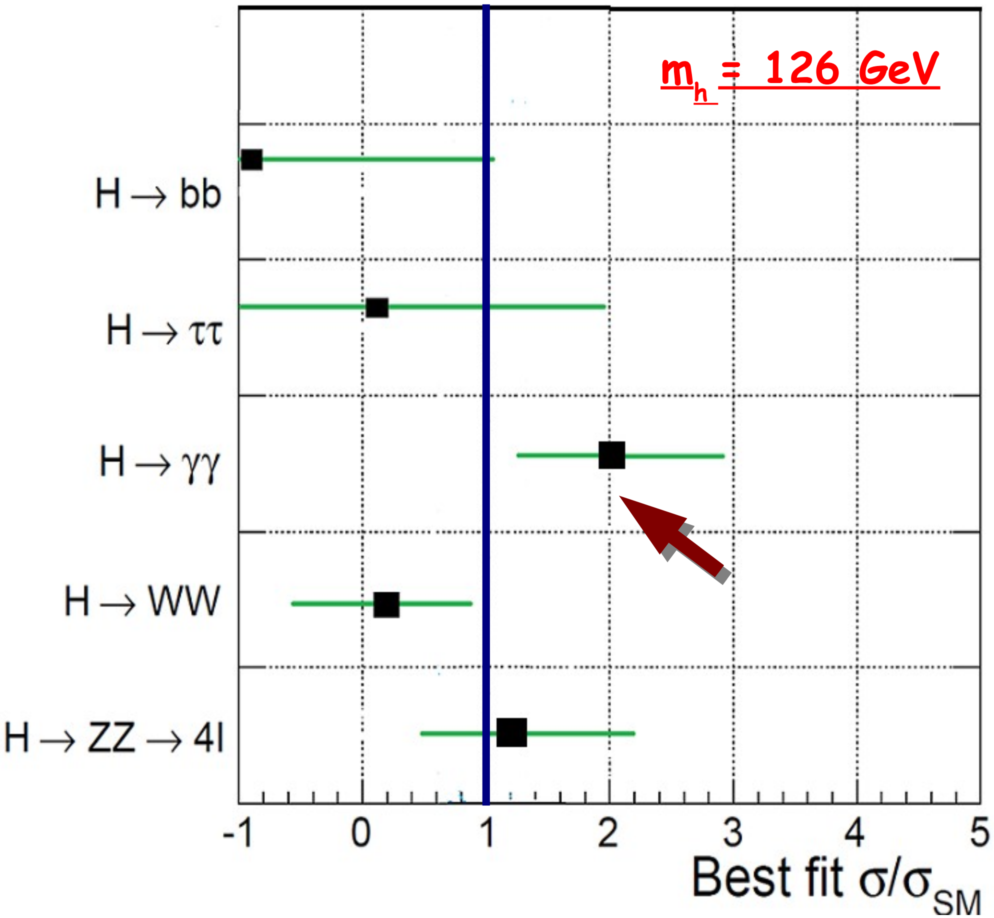


Hints of a SM-like Higgs at around 125 GeV

The Higgs of the SM?

ATLAS

arXiv:1202.1408



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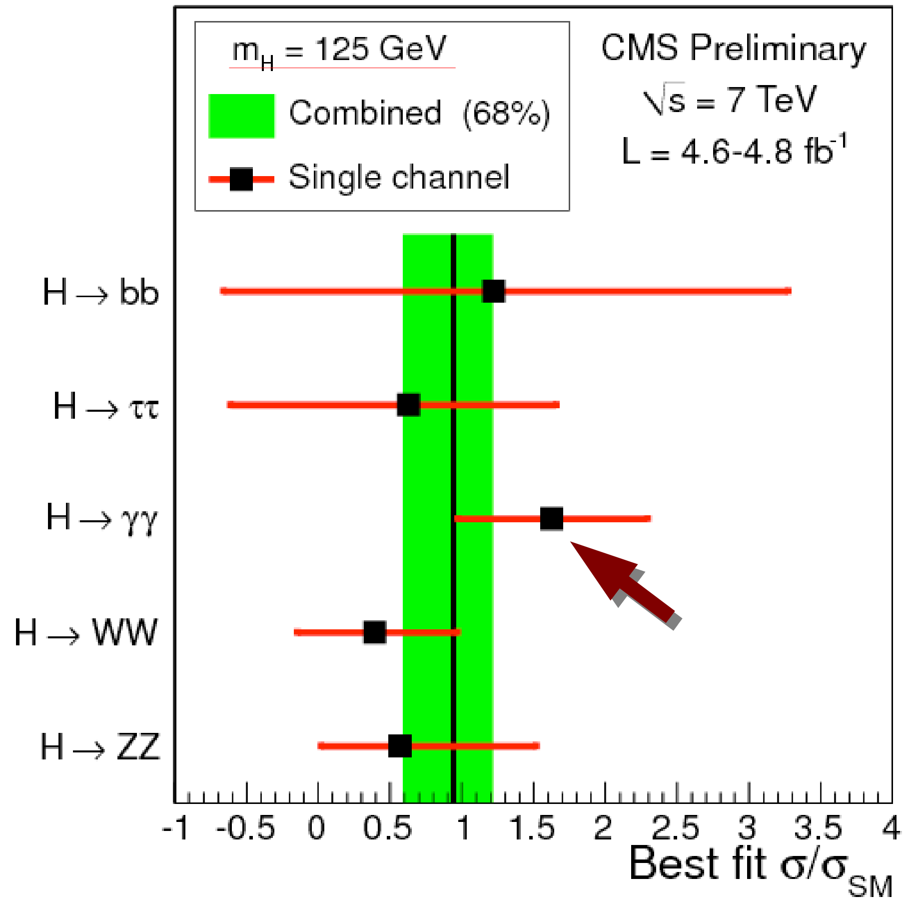


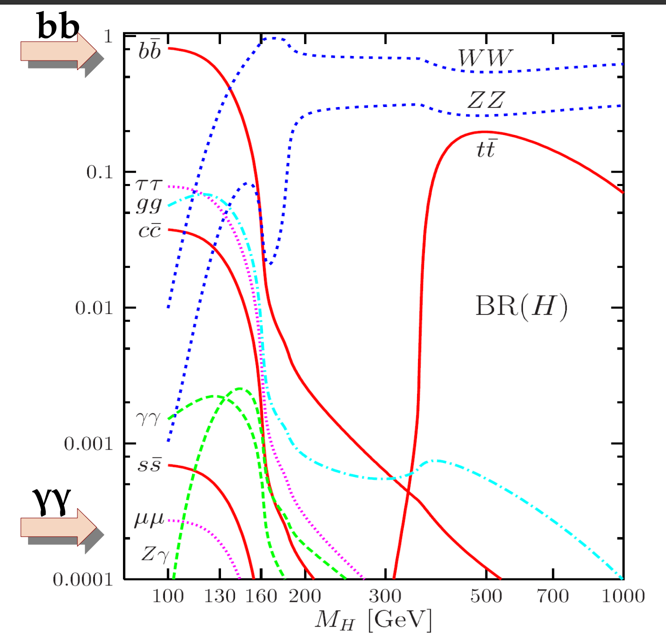
Pretty **SM-like** but still large room for **surprises**

The Gamma Gamma Channel

LHC golden channel in the Higgs low mass range

Only arising at the <u>one loop</u> level in the SM

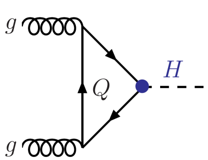
$$\sigma(pp \to h \to \gamma\gamma) = \sigma(pp \to h)\frac{\Gamma(h \to \gamma\gamma)}{\Gamma_{\rm tot}}$$

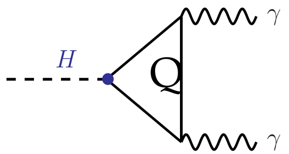


A. Djouadi, 0503172

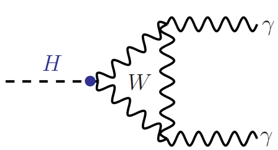
Main contribution coming from gluon gluon fusion,
also arising only at the one loop level in the SM

$$\hat{\sigma}(\hat{s})^{\rm LO}_{(gg\to h)_{\rm SM}} = \frac{\alpha_s^2 m_h^2}{9216\pi}\left|\sum \frac{g_{hf\bar{f}}}{m_f} N_c^f A_{1/2}(\tau_f)\right|^2 \delta(\hat{s} - m_h^2)$$





$$\Gamma(h \to \gamma\gamma)^{\rm LO}_{\rm SM} \simeq \frac{\alpha^2 m_h^3}{1024\pi^3}\left|\frac{g_{hWW}}{m_W^2} A_1(\tau_W) + 2\sum_f \frac{g_{hf\bar{f}}}{m_f} N_c^f Q_t^2 A_{1/2}(\tau_f)\right|^2$$



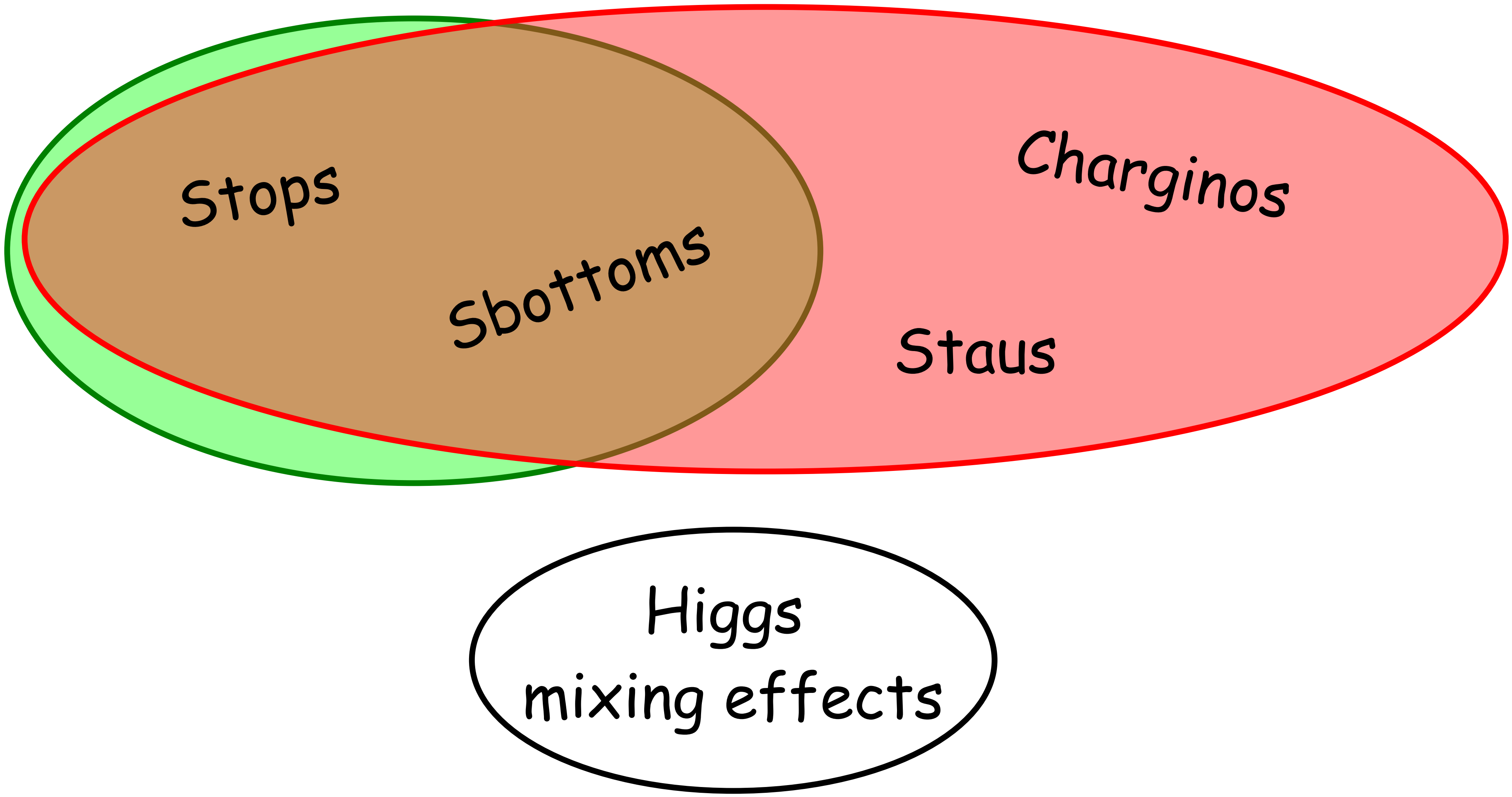
$$\tau = \frac{4m^2}{m_h^2}$$

Opposite sign contributions

NP particles charged under the SM gauge group at
the few hundred GeV scale can naturally produce large effects

Susy Effects in the Gamma Gamma Channel

$$\sigma(pp \to h \to \gamma\gamma) = \sigma(pp \to h)\frac{\Gamma(h \to \gamma\gamma)}{\Gamma_{\rm tot}}$$



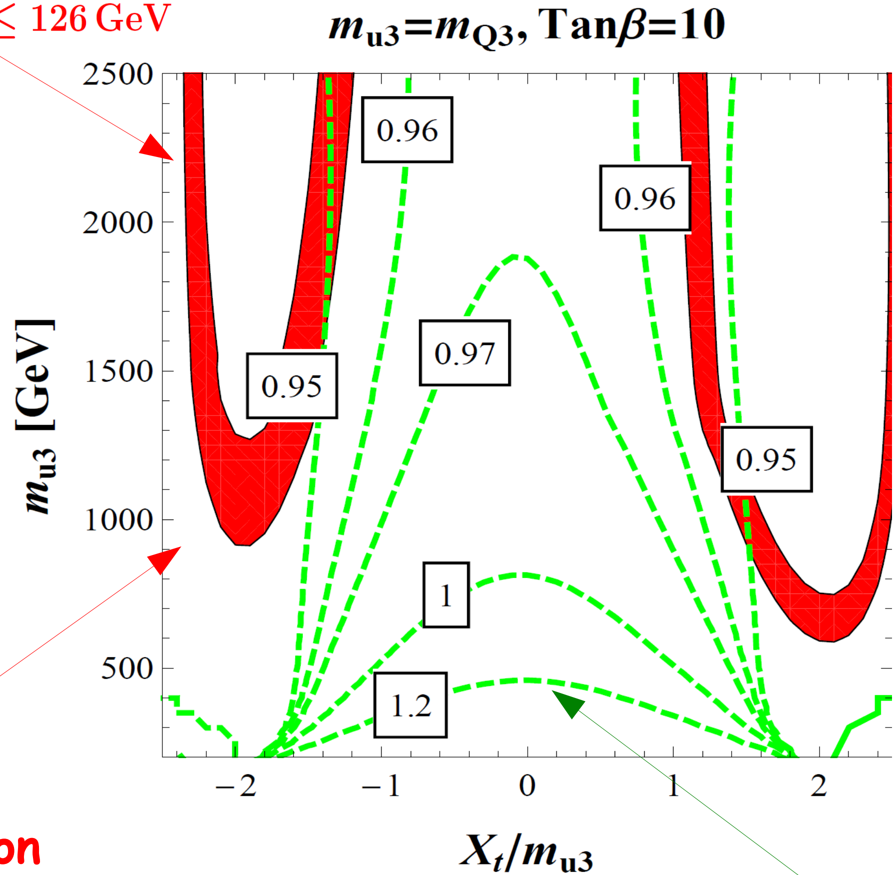
Effects on the Production and γγ Width

See also Dermisek, Low, 0701235

$$\frac{\sigma(gg \to h)}{\sigma(gg \to h)_{SM}} \cdot \frac{\Gamma(h \to \gamma\gamma)}{\Gamma(h \to \gamma\gamma)_{SM}}$$

Stop contribution

$124\,\text{GeV} \leq m_h \leq 126\,\text{GeV}$



Small suppression

Possible enhancement, but even larger enhancement of the WW and ZZ channel

$$\mathcal{M}^2_{\text{stop}} = \begin{pmatrix} m^2_{Q_3} + m_t^2 + D_L & m_t(A_t - \mu \cot\beta) \\ m_t(A_t - \mu\cot\beta) & m^2_{u_3} + m_t^2 + D_R \end{pmatrix}$$

($X_t = A_t - \mu\cot\beta$)

Sbottoms contributions

are suppressed by Ybottom, and the bound on the sbottom mass coming from direct searches is more stringent than the one for stops

In general the enhancement of the γγ rate cannot be sizable

Effects on the di-Photon Partial Width

Ellis, Gaillard, Nanopoulos, 1976

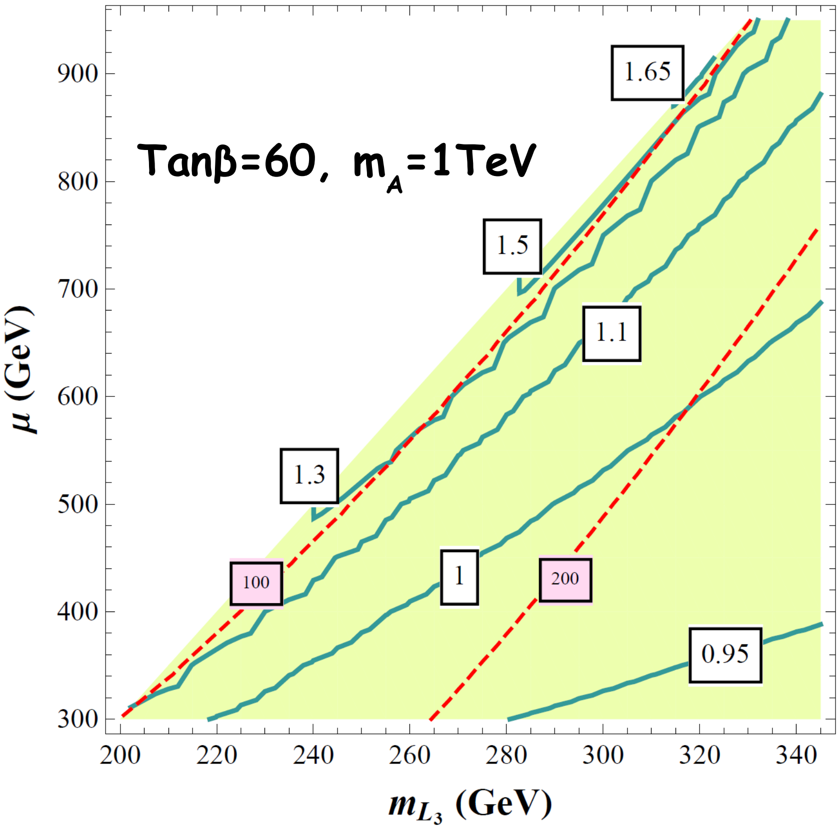
$$\Delta A_{\gamma\gamma} \propto \frac{\partial \log(\det \mathcal{M}^2(v))}{\partial \log v}$$

$$\frac{\Gamma(h \to \gamma\gamma)}{\Gamma(h \to \gamma\gamma)_{\rm SM}}$$

Stau contribution

$$\Delta A_{\gamma\gamma} \propto -\frac{(\mu \tan\beta)^2 m_\tau^2}{m_{L3}^2 m_{e3}^2 - m_\tau^2(\mu\tan\beta)^2} \sim -\frac{m_{\tilde\tau_2}^2}{m_{\tilde\tau_1}^2}\left(1 - \frac{m_{\tilde\tau_1}^2}{m_{\tilde\tau_2}^2}\right)^2$$

For degenerate stau soft masses



Carena, S.G., Shah, Wagner, 1112.3336

Chargino contribution

$$\Delta A_{\gamma\gamma} \propto \frac{m_W^2 s_\beta c_\beta}{M_2 \mu}$$

Contributions suppressed by tanβ

It has been shown that contributions are <u>less</u> than <u>10%</u>

Diaz, Perez, 0412066

$$\mathcal{M}_{\tilde\tau}^2 \simeq \begin{pmatrix} m_{L_3}^2 + m_\tau^2 + D_L^\tau & m_\tau(A_\tau - \mu\tan\beta) \\ m_\tau(A_\tau - \mu\tan\beta) & m_{E_3}^2 + m_\tau^2 + D_R^\tau \end{pmatrix}$$

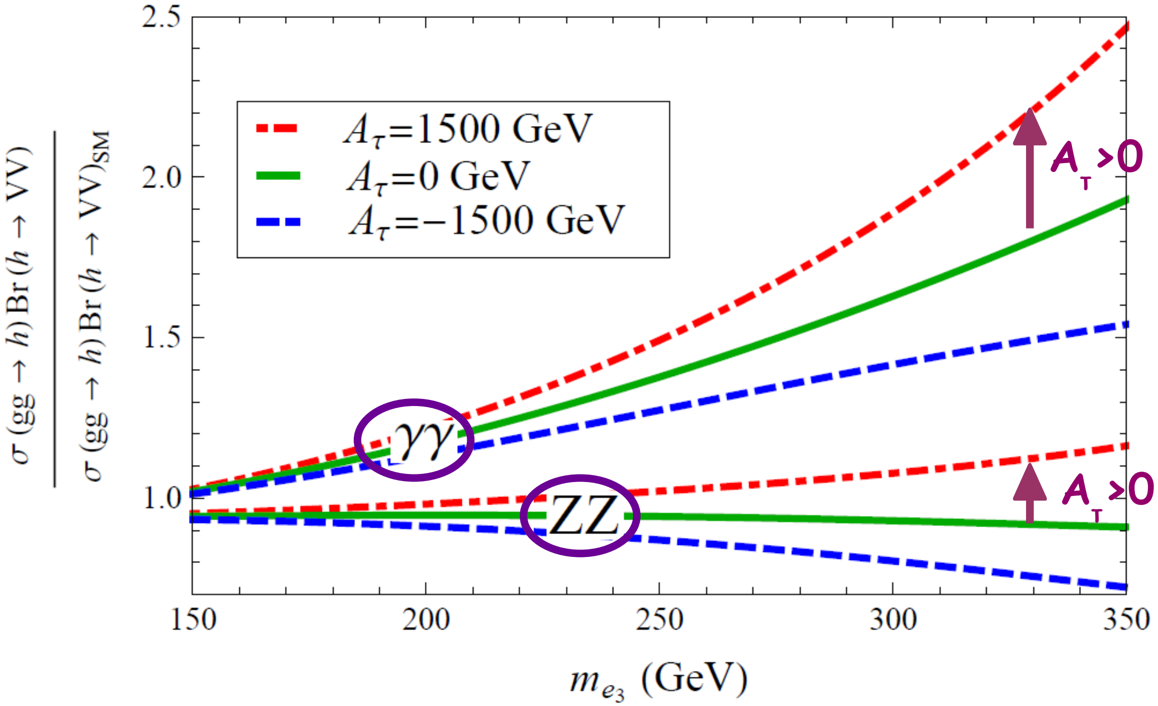
Higgs Mixing Effects

In the decoupling limit $\frac{g}{2M_W}\bar{m}_b\,(hb\bar{b})$ and $\frac{g}{2M_W}\bar{m}_b\tan\beta\,(Hb\bar{b})$

If h and H mix, the Higgs bb width may change → the Higgs total width changes

$$\frac{g}{2M_W}\bar{m}_b\tan\beta\frac{\sin\alpha}{\sin\beta}(hb\bar{b})$$

$$\begin{pmatrix} h & H \end{pmatrix}\begin{bmatrix} m_A^2 s_\beta^2 + M_Z^2 c_\beta^2 & -(m_A^2+M_Z^2)s_\beta c_\beta + \text{Loop}_{12} \\ \star & m_A^2 c_\beta^2 + M_Z^2 s_\beta^2 \end{bmatrix}\begin{pmatrix} h \\ H \end{pmatrix}$$



$$\text{Loop}_{12} = \frac{h_\tau^4 v^2}{48\pi^2}\sin^2\beta\frac{\mu^3 A_\tau}{M_{\tilde{\tau}}^4} + \cdots$$

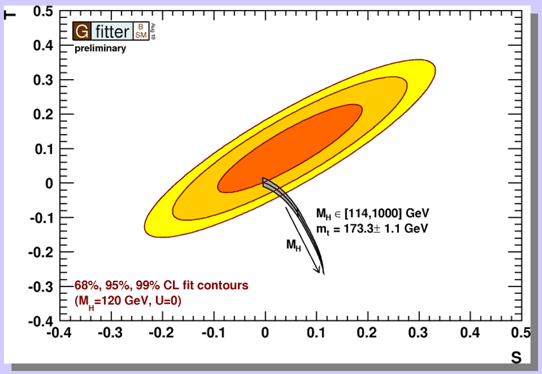
μ growing →

(we keep constant $m_{\tilde{\tau}_1} = 90\,\text{GeV}$)

Phenomenology of the Light Staus Model

Carena, Gori, Shah, Wagner, Wang,
1205.5842

Positive contribution to the T parameter



Light and heavily mixed staus

(Small) splitting between staus and smuons

Required by $(g\text{-}2)_\mu$

Imposing flavor independence at the messenger scale:
Typically
Low energy messenger scale

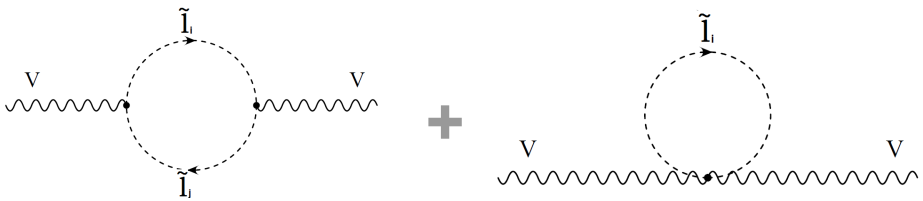
Possible new signatures at the LHC

$$pp \to \tilde{\tau}_1 \tilde{\nu}_\tau$$
$$pp \to \tilde{\tau}_1 \tilde{\tau}_1$$

Electroweak Precision Tests

Staus: very light NP states charged under SU(2) x U(1)

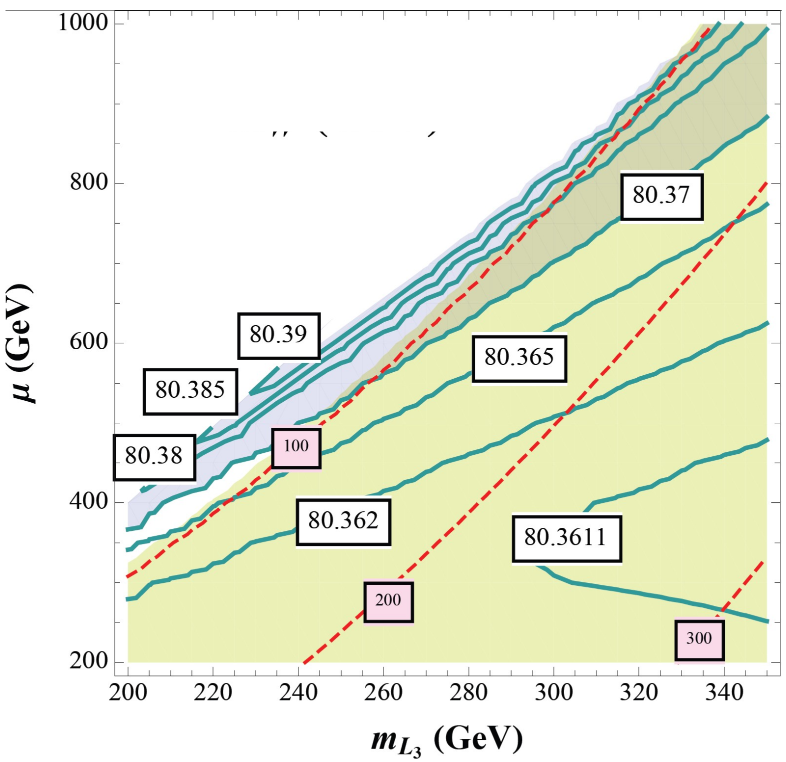
→ too large contribution to EWPTs?



New measurement of M_W:

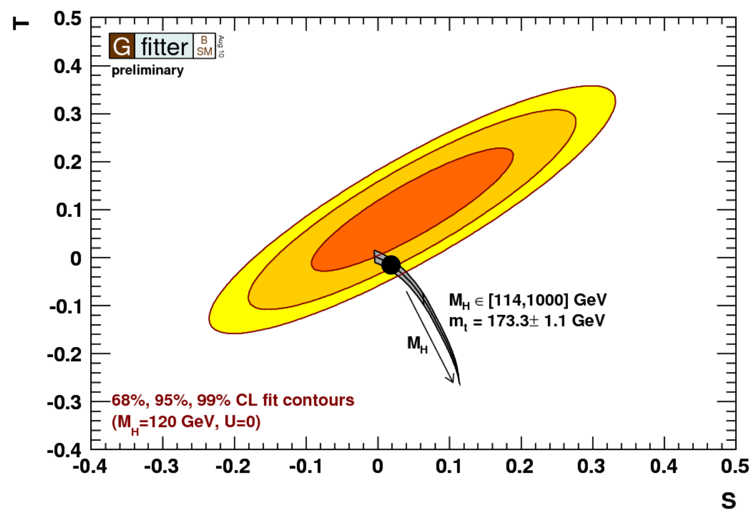
$$(80.385 \pm 0.015)\mathrm{MeV}$$

FERMILAB-TM-2532-E, 2012



$$\Delta M_W \simeq \frac{M_W}{2}\frac{\cos^2\theta_W}{\cos^2\theta_W-\sin^2\theta_W}\alpha\,\Delta T$$

Heinemeyer, Hollik, Weiglein, 0412214



It corresponds to a contribution of (at most)

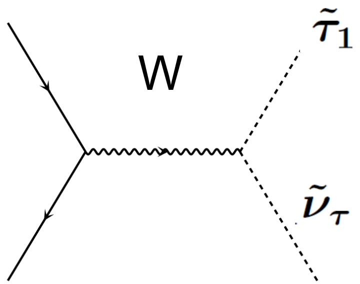
$$\Delta T \lesssim 0.1$$

Direct weak production of staus?

- LHC is looking for staus only if produced through Susy cascade decay

ATLAS-CONF-2012-005
ATLAS-CONF-2012-002

- Possible new interesting channel to look for:



$pp \to \tilde{\tau}_1 \tilde{\nu}_\tau$, with $\tilde{\tau}_1 \to \tau$, LSP and $\tilde{\nu}_\tau \to W \tilde{\tau}_1$, $\tilde{\tau}_1 \to \tau$, LSP

Final signature:
Lepton, 2 taus, missing energy

(signature also covered by multilepton Searches. These searches are however not sensitive yet)

- Main backgrounds:

Physical background: $W\gamma^*$, WZ^*
Fake background: **W+jets**

- In principle also $pp \to \tilde{\tau}_1 \tilde{\tau}_1 \to (\tau\, \mathrm{LSP})(\tau\, \mathrm{LSP})$ can be interesting, but much more challenging

Direct weak production of staus?

- Possible new interesting channel to look for:

Carena, Gori, Shah, Wagner, Wang, 1205.5842

$$pp \to \tilde{\tau}_1 \tilde{\nu}_\tau \to \ell \tau \tau \not{E}_T$$

	Total (fb)	Basic (fb)	Hard Tau (fb)
Signal	1.6	0.26	0.11
Physical background, $W + Z/\gamma^*$	27	0.32	$\lesssim 10^{-3}$
$W+$ jets background	10^4	39	0.25

14 TeV

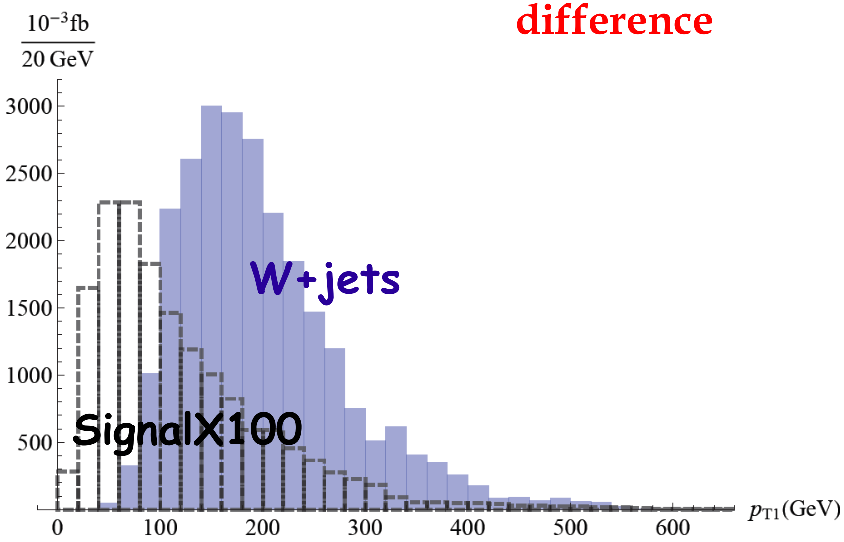
2-loose taus, $p_T^\tau > 10$ GeV, $\Delta R > 0.4$	$p_T^\ell > 85$ GeV, $\not{E}_T > 85$ GeV	$p_T^{\tau_1} < 80$ GeV

Major kinematical difference

Estimation at the parton level,
A more careful analysis would be needed

Comparable numbers (after cuts) at the 8 TeV LHC

Motivate experimentalists to perform a dedicated search to validate these results



Conclusions

If LHC will find a Higgs (at ~125 GeV) with enhanced $\gamma\gamma$ rate

→ Light staus with large mixing provide a good candidate to look for

Further enhancement due to Higgs mixing are possible

→ Little enhancement also of the other channels (WW, ZZ)

Light staus with large mixing:

Good fit of electroweak precision observables

Possibility of discovering them directly at the 14TeV LHC, through weak production, even if all the other scalars of the theory are very heavy (beyond the reach of the LHC)