The Higgs to gamma-gamma rate as a probe of Susy

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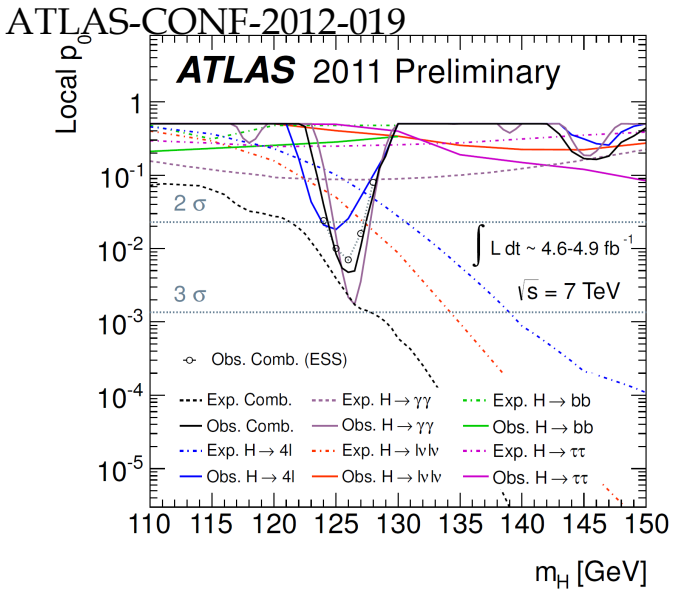
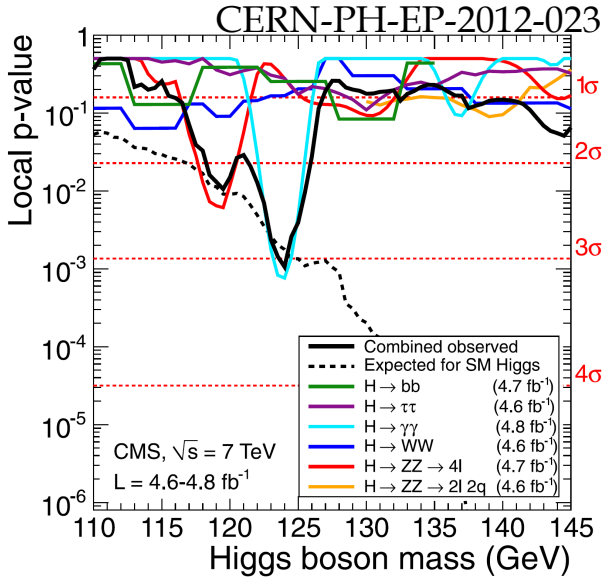
Hints for a Higgs at ~125 GeV

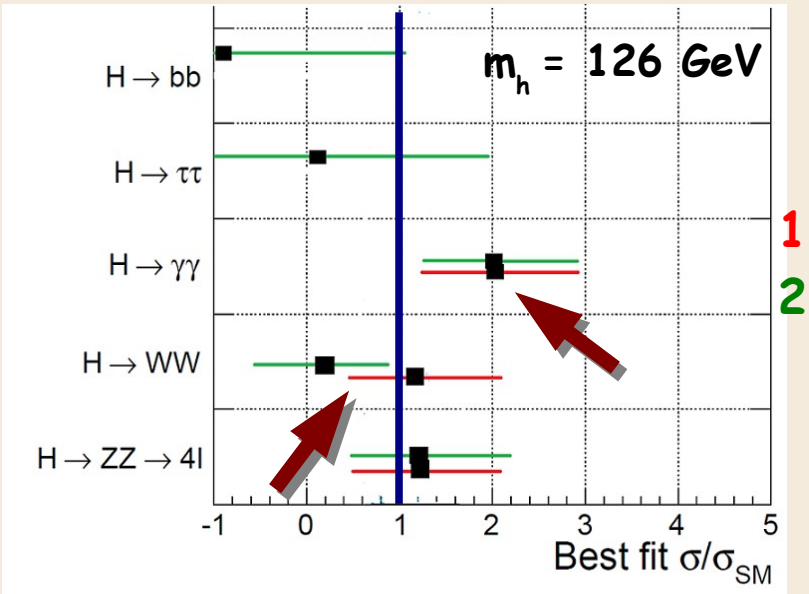
ATLAS



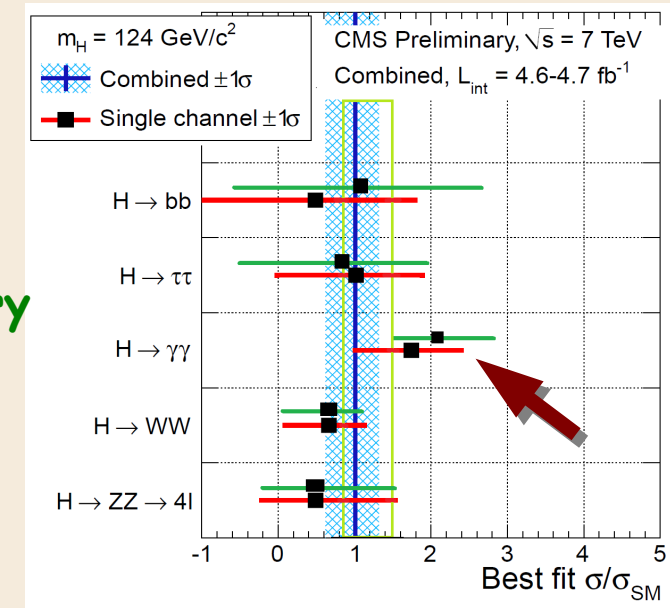
+ broad excess
in the bb channel
at Tevatron
in (120-135)GeV

CMS



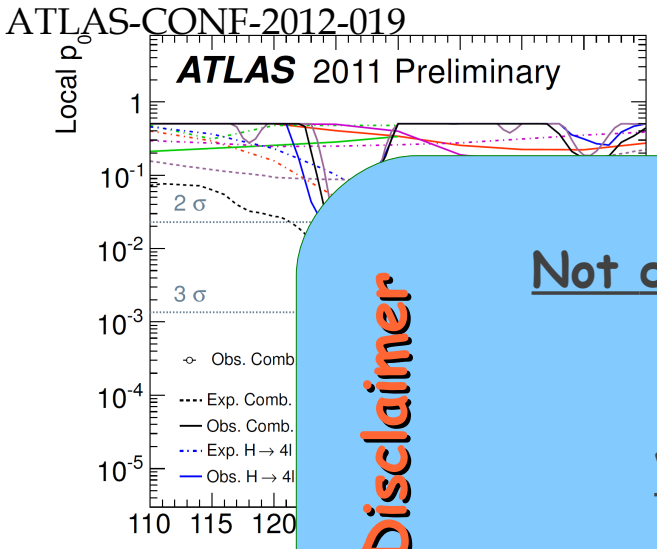


1. last December
2. Moriond/February

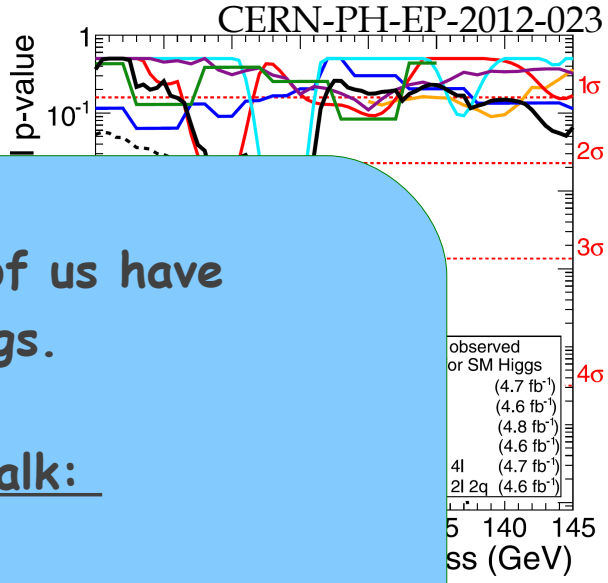


Hints for a Higgs at ~125 GeV

ATLAS



CMS

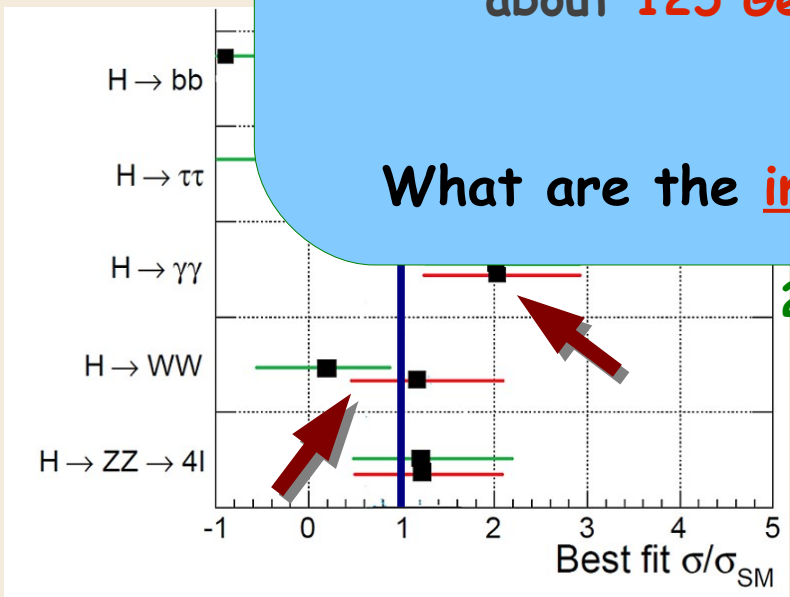


Disclaimer

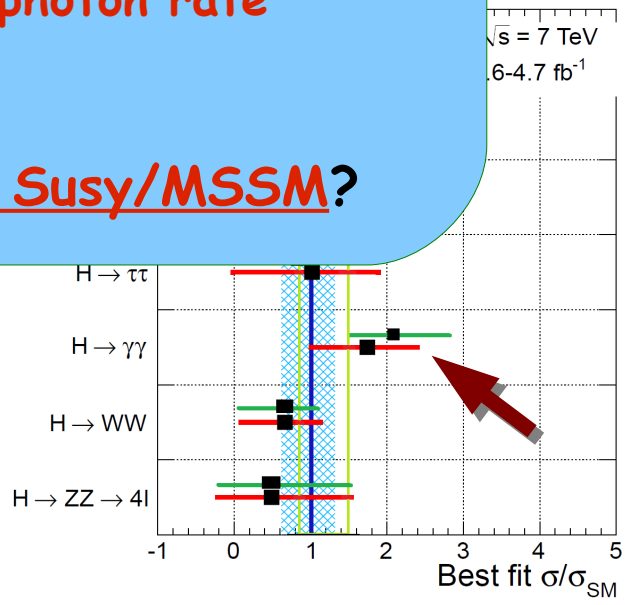
Not definitive evidence, but most of us have a strong belief this is a Higgs.

Working assumption for this talk:
there really is a Higgs at
about 125 GeV with enhanced di-photon rate

What are the implications for the Susy/MSSM?



2. Moriond/February

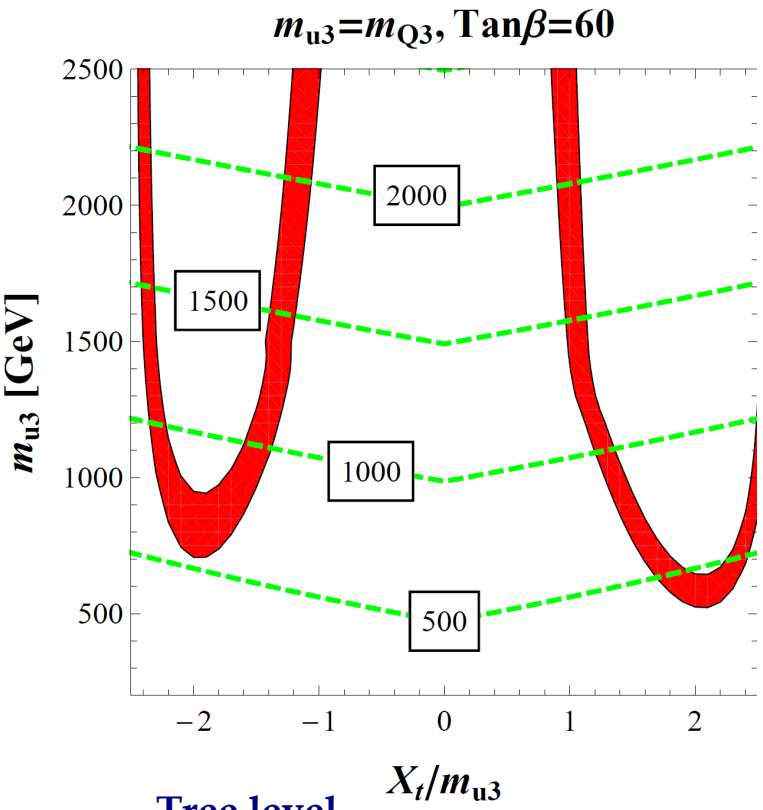


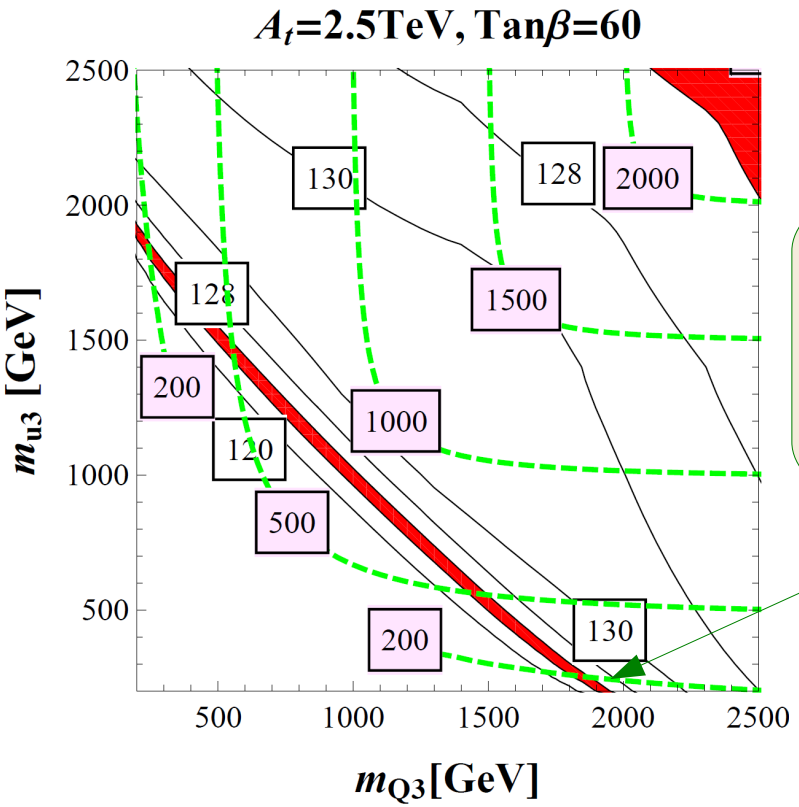
A Higgs at 125 GeV

1. First implication:

Stops generally heavy and heavily mixed

Carena, Gori, Shah, Wagner, JHEP 1203:014,2012





Still one stop at (150-200)GeV would be still allowed (if the other one is in the multiTeV range)

Tree level

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3}{4\pi^2}\frac{m_t^4}{v^2}\left[\log\left(\frac{M_{\rm SUSY}^2}{m_t^2}\right) + \frac{X_t^2}{M_{\rm SUSY}^2}\left(1-\frac{X_t^2}{12M_{\rm SUSY}^2}\right)\right]$$

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

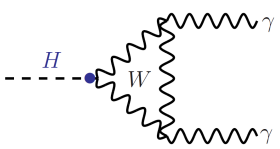
X_t

Higgs to di-photon rate

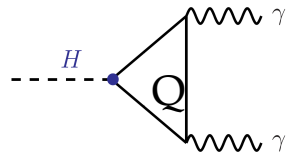
$$gg \to h \to \gamma\gamma$$

At the LO in the SM:

$$g_{hf\bar{f}} = \frac{m_f}{v},\ g_{hWW} = \frac{2m_W^2}{v},\ \tau = \frac{m_h^2}{4m^2}$$

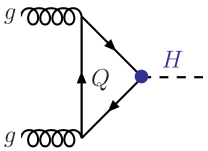


$$\Gamma(h \to \gamma\gamma)_{\rm SM} \simeq \frac{\alpha^2 m_h^3}{1024\pi^3}\left|\frac{g_{hWW}}{m_W^2}A_1(\tau_W) + 2\sum_f \frac{g_{hf\bar{f}}}{m_f}N_c^f Q_t^2 A_{1/2}(\tau_f)\right|^2$$



Dominant contribution

Opposite sign



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

Possible contributions from Susy/MSSM:

1. In the decoupling limit: $m_A \gg v$

- **sbottoms**: important if sbottoms are rather light BUT large positive contribution also to WW and ZZ
- **charginos**: very small since tan(β) suppressed (Diaz, Perez, 2005)
- **stops**
- **staus**

2. What if we mix the 2 neutral Higgs bosons?

Di-photon rate in the decoupling limit

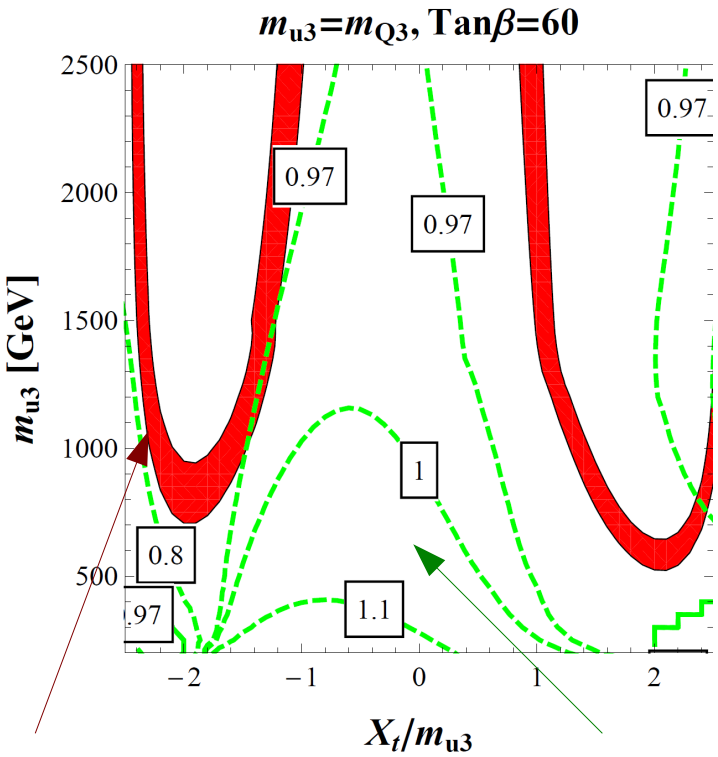
2. Second implication:

Staus generally light and heavily mixed

Carena, Gori, Shah, Wagner, JHEP 1203:014,2012

$$\frac{\sigma(gg \to h)}{\sigma(gg \to h)_{\rm SM}} \cdot \frac{\mathrm{BR}(h \to \gamma\gamma)}{\mathrm{BR}(h \to \gamma\gamma)_{\rm SM}}$$

Stop contribution



Small suppression

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

Di-photon rate in the decoupling limit

2. Second implication:

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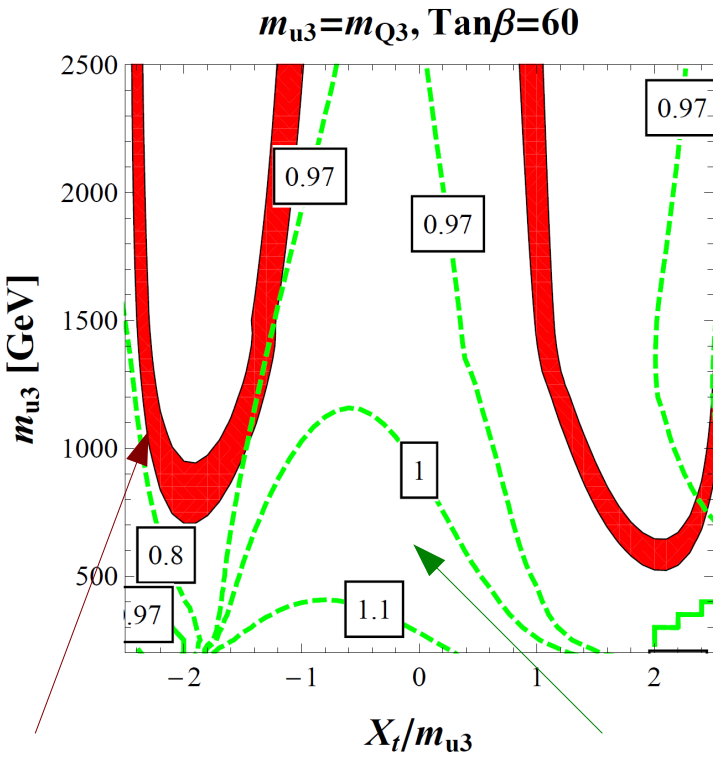
$$\frac{\sigma(gg \to h)}{\sigma(gg \to h)_{\rm SM}} \cdot \frac{\mathrm{BR}(h \to \gamma\gamma)}{\mathrm{BR}(h \to \gamma\gamma)_{\rm SM}}$$

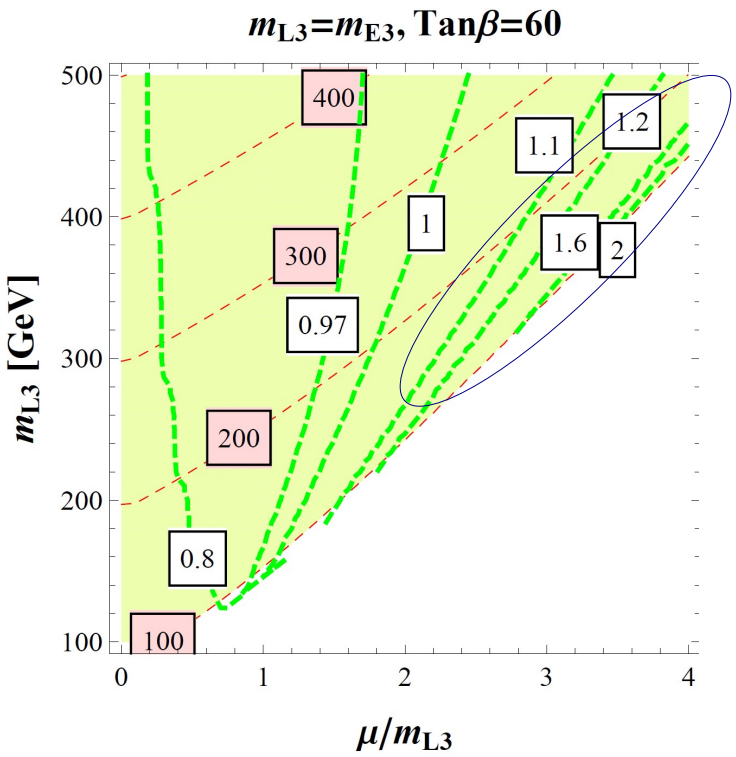
Stop contribution



Small suppression

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

Stau contribution



Sizable enhancement

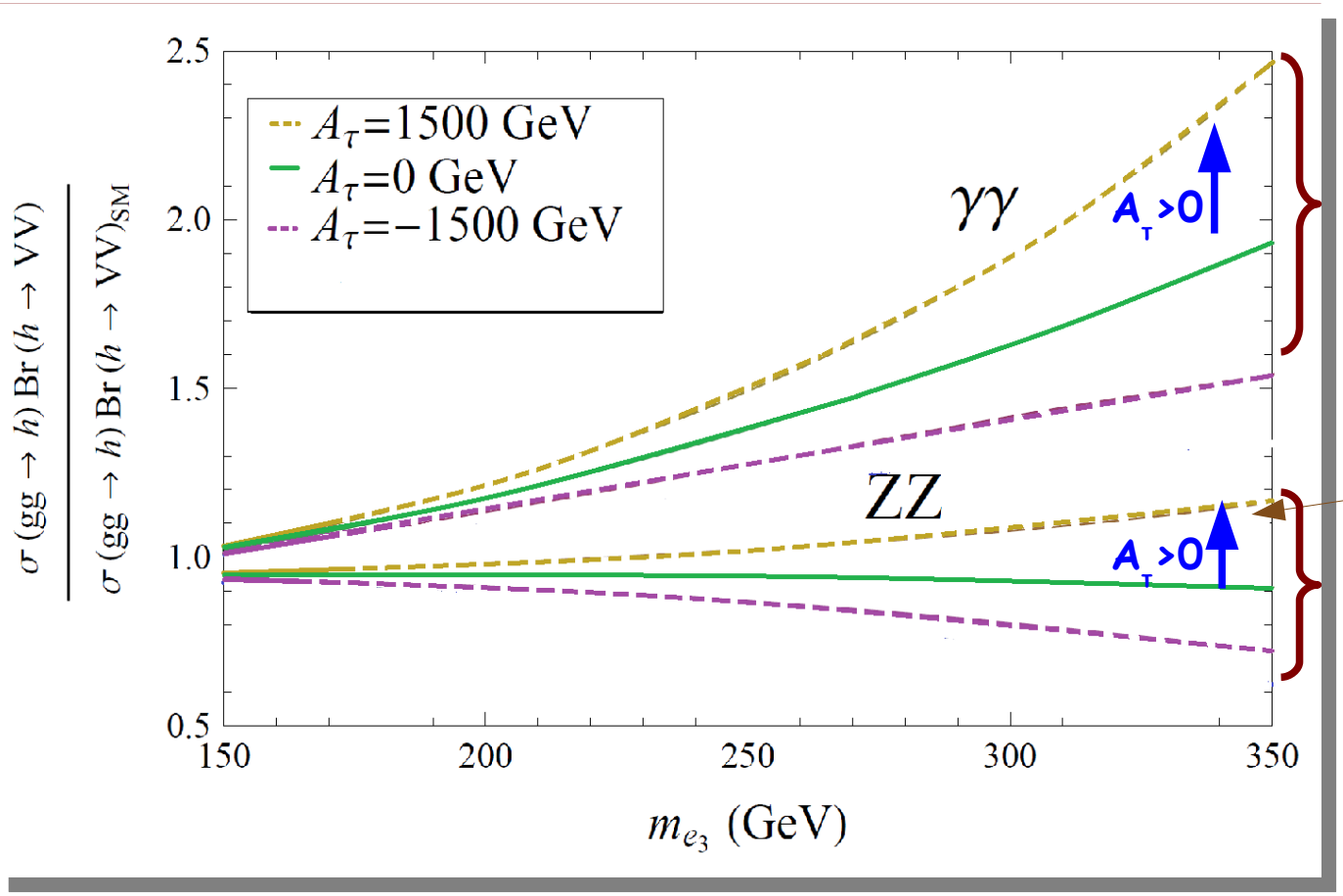
$$\mathcal{M}^2_{\tilde{\tau}} \simeq \begin{pmatrix} m^2_{L_3} + m^2_\tau + D^\tau_L & m_\tau(A_\tau - \mu \tan\beta) \\ m_\tau(A_\tau - \mu \tan\beta) & m^2_{E_3} + m^2_\tau + D^\tau_R \end{pmatrix}$$

Mixing effects

$$\begin{pmatrix} h & H \end{pmatrix} \begin{bmatrix} m_A^2 \sin^2\beta + M_Z^2 \cos^2\beta & -(m_A^2 + M_Z^2)\sin\beta\cos\beta + \mathrm{Loop}_{12} \\ -(m_A^2 + M_Z^2)\sin\beta\cos\beta + \mathrm{Loop}_{12} & m_A^2 \cos^2\beta + M_Z^2 \sin^2\beta + \mathrm{Loop}_{22} \end{bmatrix} \begin{pmatrix} h \\ H \end{pmatrix}$$

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

Carena, Gori, Shah, Wagner, Wang, appearing soon...



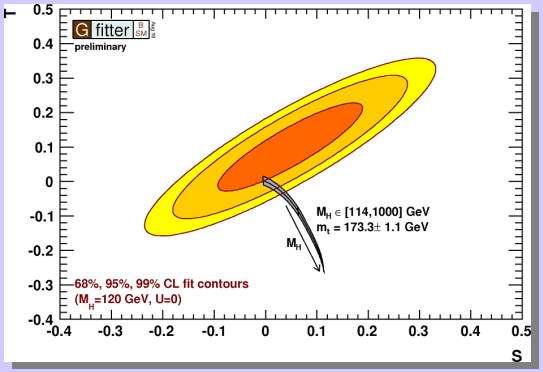
Because of the h-H mixing, the partial width in bb can be modified

All the Higgs decay channels will be affected:
In particular, if bb partial width is suppressed, then all the other channels will be enhanced

Predictions of the model

Carena, Gori, Shah, Wagner, Wang, appearing soon...

Positive contribution to the T parameter (~0.1)



Light and heavily mixed staus

Possible new signatures at the LHC

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

Splitting between staus and smuons

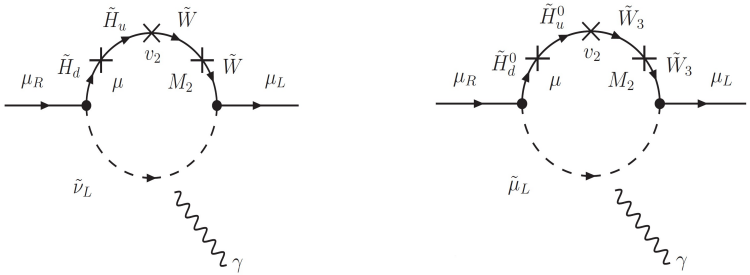
Required by $(g-2)_\mu$

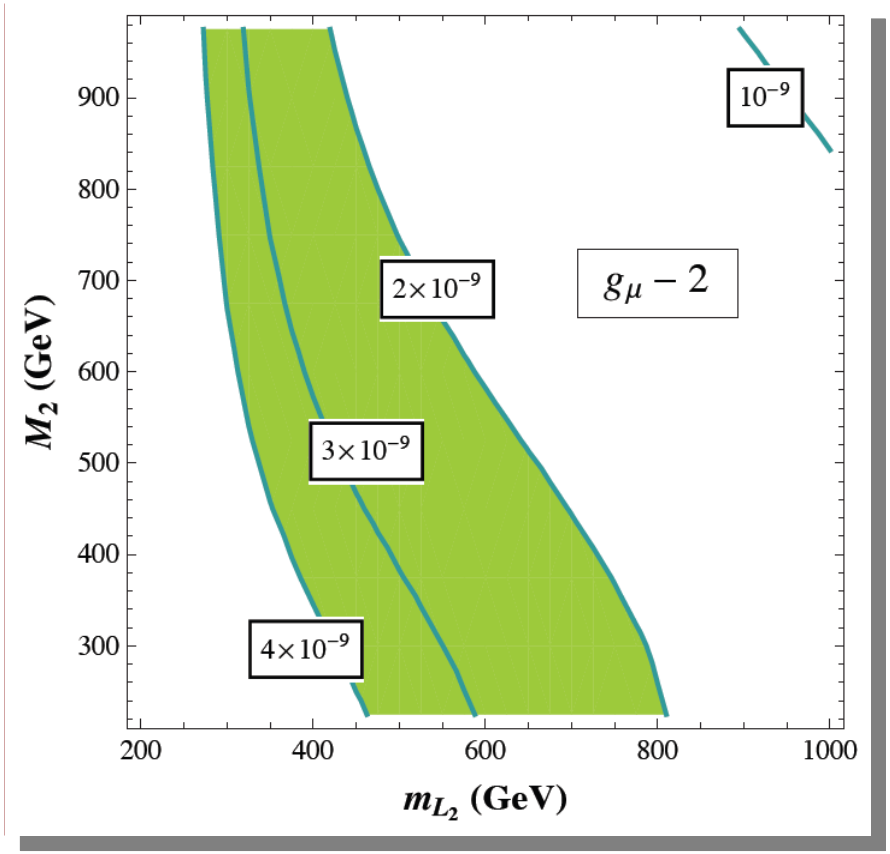
Imposing flavor independence at the messenger scale:

Low energy messenger scale

Gravitino LSP

$(g-2)_\mu$ and the messenger scale

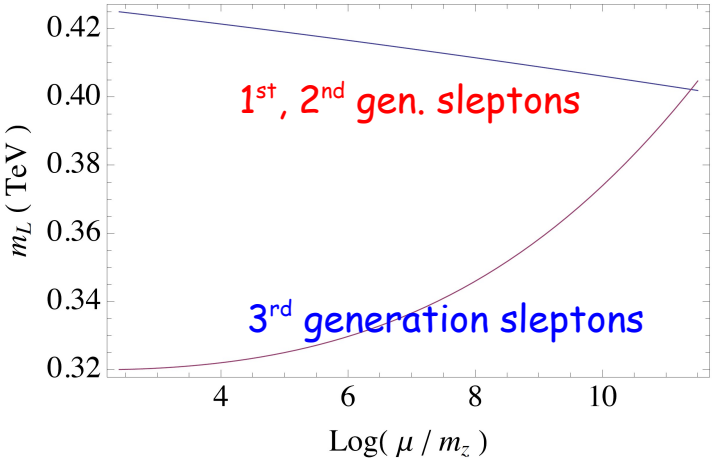




$\tan\beta = 60,\ \mu = 650\ \text{GeV}$

Light second generation left-handed sleptons with mass of about 300 to 700 GeV

Mild splitting between second and third generation sleptons



(asking flavor independence at the messenger scale)

Relatively <u>low messenger scale</u> (10^7 GeV)

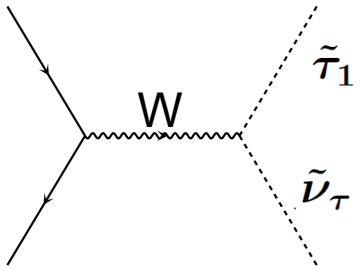
→ Gravitino LSP

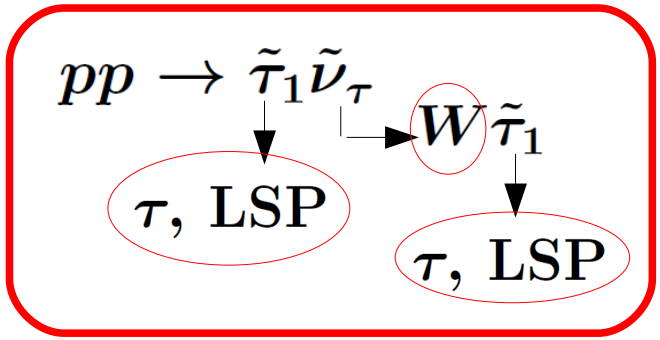
Direct weak production of staus?

- 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:





Final signature:

Lepton, 2 taus, missing energy

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

- Main backgrounds:

Physical background: Wγ*, WZ*
Fake background: W+jets

- Set of cuts:

$$\not{E}_T > 70\ \text{GeV}$$
$$p_T^{\ell} > 70\ \text{GeV}$$
$$p_T^{\tau,j} < 70\ \text{GeV}$$
$$70\ \text{GeV} < m_{12} < 130\ \text{GeV}$$

S/B~1
even if low statistics
(~10 events with 30 fb^{-1})

Still doable at the 8TeV LHC!

A dedicated experimental search should be performed to validate these 8 TeV results

Conclusions

A Higgs at ~125GeV with enhanced di-photon rate would have important implications for the MSSM

Heavy (at least one) and mixed stops

Light and mixed staus

Possibility of having mixed Higgs bosons

Rich phenomenology of the model

EWPTs

Dark matter & messenger scale

Direct searches for staus

Waiting for more statistics...!