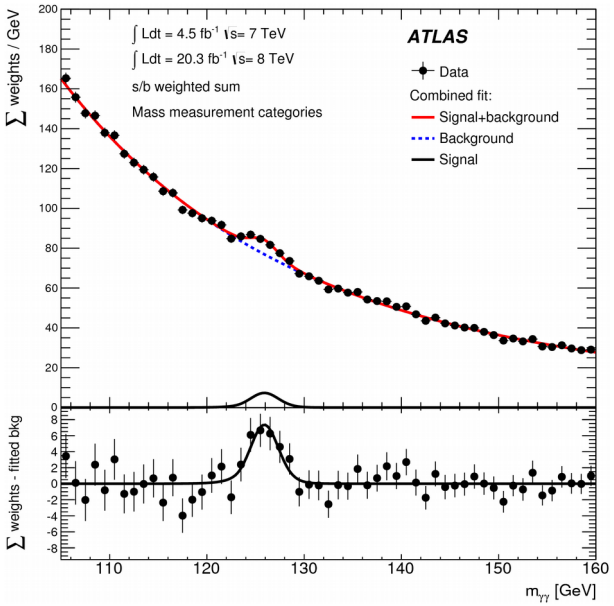
Improved τ-weapons for Higgs hunting

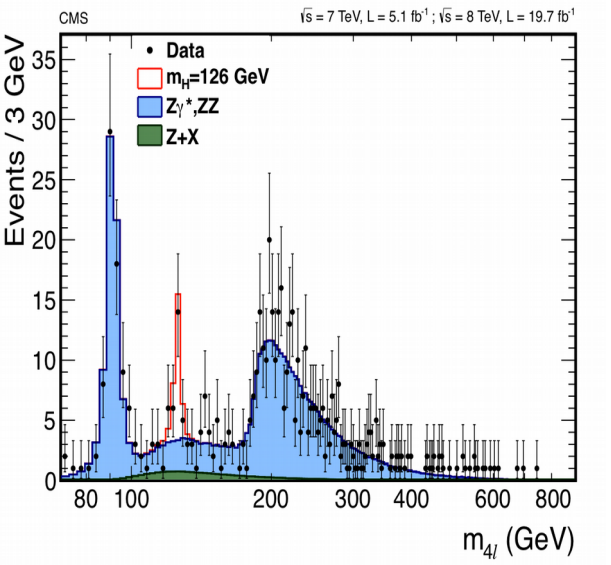
Oscar Vives

SUSY 2014

Manchester 21-26 July

4th July 2012





"Higgs" boson discovered...

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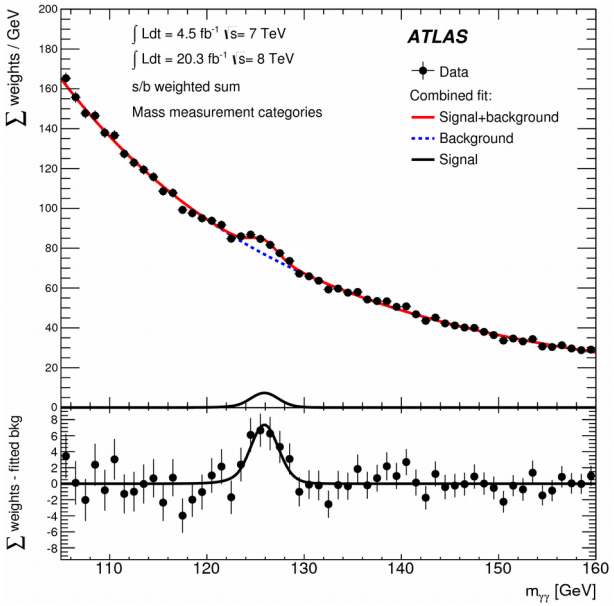

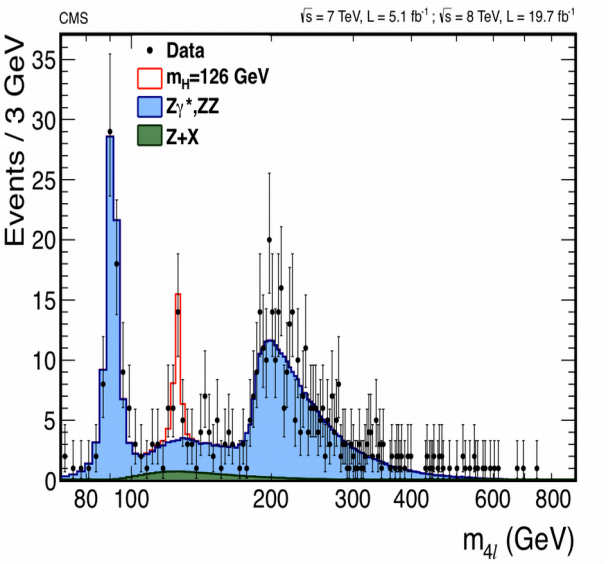

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But... what is it??, SM Higgs??, MSSM??, other ??

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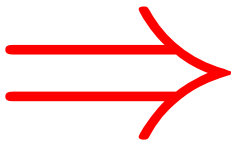

New couplings, extra scalar states...

- G. Barenboim, C. Bosch, M. L. Lopez-Ibañez and O. Vives, Phys. Rev. D90 (2014) 015003, arXiv:hep-ph/1311.7321.
- G. Barenboim, C. Bosch, M. L. Lopez-Ibañez and O. Vives, JHEP 1311, 051(2013), arXiv:hep-ph/1307.5973.

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- Lightest Higgs corresponds to the observed scalar state at LHC
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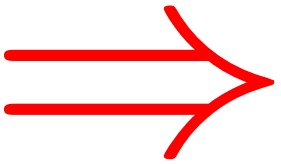

General model including all possible MSSMs

2 Higgs doublets with CP violating phase

$$\Phi_1 = \begin{pmatrix} \frac{1}{\sqrt{2}}\left(v_1 + \phi_1 + i a_1\right) \\ \phi_1^- \end{pmatrix}; \qquad \Phi_2 = e^{i\xi} \begin{pmatrix} \phi_2^+ \\ \frac{1}{\sqrt{2}}\left(v_2 + \phi_2 + i a_2\right) \end{pmatrix}$$

Generic 3 x 3 Higgs mass matrix.

$$M_H^2 = (\phi_1, \phi_2, a) \begin{pmatrix} M^2_{S_{2\times 2}} & M^2_{SP_{1\times 2}} \\ M^2_{PS_{2\times 1}} & M^2_P \end{pmatrix} \begin{pmatrix} \phi_1 \\ \phi_2 \\ a \end{pmatrix}$$

Diagonalized by an unknown unitary matrix $\mathcal{U}$:

$$\mathcal{U} \cdot M_H^2 \cdot \mathcal{U}^T = \mathrm{Diag}\left(M^2_{H_1}, M^2_{H_2}, M^2_{H_3}\right) .$$

Experimental Constraints

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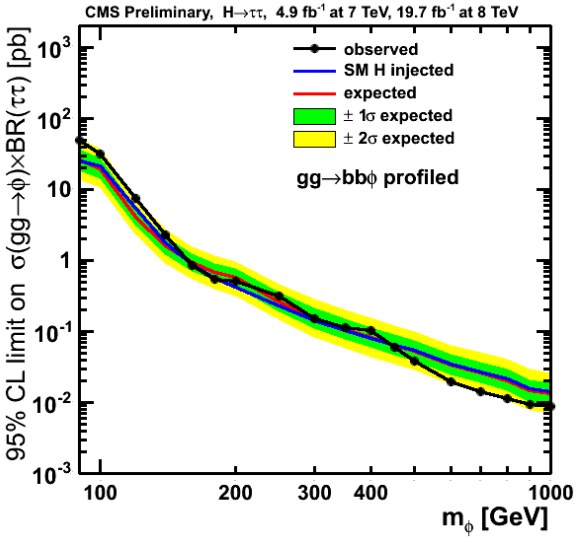
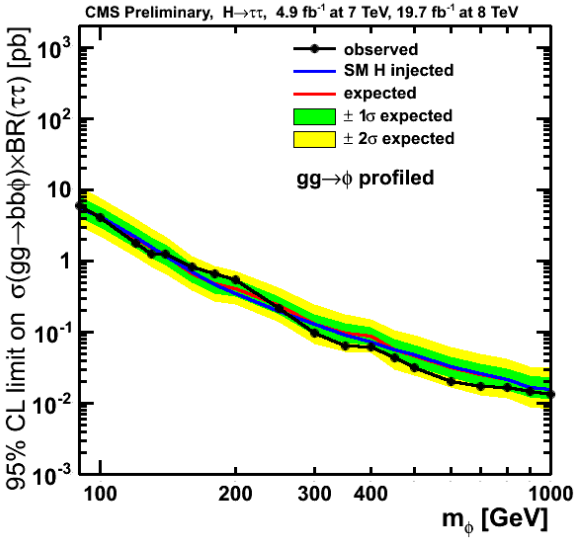
- LHC constraints:

At 95% C.L. $$0.75 \leq \mu_\gamma = \frac{\sigma(pp \to H) \times \mathrm{BR}(H \to \gamma\gamma)}{\sigma(pp \to H)_{\mathrm{SM}} \times \mathrm{BR}(H \to \gamma\gamma)_{\mathrm{SM}}} \leq 1.55$$

$H \to \tau\tau$
Searches of extra Higgs





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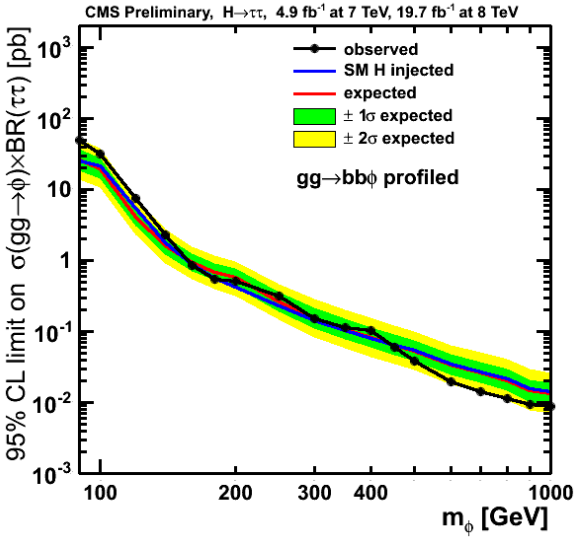

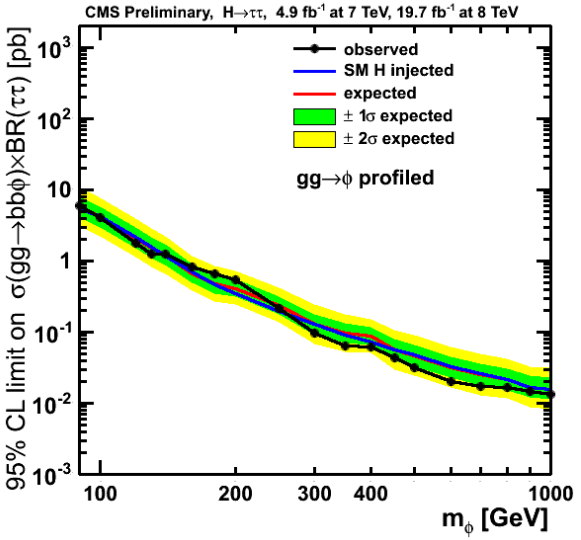

- Indirect constraints:

At 95% C.L. $\quad 2.99 \times 10^{-4} \leq \mathrm{BR}(B \to X_s\gamma) \leq 3.87 \times 10^{-4}$

also $\quad B_s \to \mu^+\mu^-, \;$ and at low masses, $\quad t \to H^+ b$

Model Analysis

Higgs to γγ at LHC

$$\sigma(pp \to H \to \gamma\gamma) = \sigma(pp \to H_1) \times \Gamma(H_1 \to \gamma\gamma)/\Gamma_{H_1}$$

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1.- Decay width

$$\Gamma\left(H_a \to \gamma\gamma\right) = \frac{M_{H_a}^3 \alpha^2}{256\pi^3 v^2}\left[\left|S_a^\gamma\left(M_{H_a}\right)\right|^2 + \left|P_a^\gamma\left(M_{H_a}\right)\right|^2\right]$$

$$\begin{aligned} S_{H_1^0}^\gamma \simeq\ & \mathcal{U}_{11}\left(\frac{-8.3}{\tan\beta} + (-0.025 + i\,0.034)\ \mathrm{Re}\left\{\frac{\tan\beta}{1+\kappa_d\tan\beta}\right\} - 0.45\left(\frac{m_{\tilde{t}_2}^2}{m_{\tilde{t}_1}^2} - 1\right)\mathrm{Re}\left\{\frac{\mu m_t \mathcal{R}_{11}^* \mathcal{R}_{21}}{m_{\tilde{t}_2}^2}\right\}\right) + \\ & \mathcal{U}_{12}\left(-6.5 + 0.45\left(\frac{m_{\tilde{t}_2}^2}{m_{\tilde{t}_1}^2} - 1\right)\mathrm{Re}\left\{\frac{A_t^* m_t \mathcal{R}_{11}^* \mathcal{R}_{21}}{m_{\tilde{t}_2}^2}\right\} + 0.45\left(\frac{m_t^2\left|\mathcal{R}_{11}\right|^2}{m_{\tilde{t}_1}^2} + \frac{m_t^2\left|\mathcal{R}_{12}\right|^2}{m_{\tilde{t}_2}^2}\right)\right) + \\ & \mathcal{U}_{13}\left((-0.025 + i\,0.034)\ \mathrm{Im}\left\{\frac{\kappa_d\tan^2\beta}{1+\kappa_d\tan\beta}\right\} + 0.45\left(\frac{m_{\tilde{t}_2}^2}{m_{\tilde{t}_1}^2} - 1\right)\mathrm{Im}\left\{\frac{\mu m_t \mathcal{R}_{11}^* \mathcal{R}_{21}}{m_{\tilde{t}_2}^2}\right\}\right) \end{aligned}$$

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2.- Production cross section

$$\sigma\left(pp \to H_1\right) \simeq \left[0.16 \frac{\tan^2\beta}{\left(1+\kappa_d \tan\beta\right)^2}\left(\left|\mathcal{U}_{11}\right|^2 + \left|\mathcal{U}_{13}\right|^2\right) + \right.$$

$$\frac{0.1\tan^2\beta}{\left(1+\kappa_d\tan\beta\right)^2}\,\mathcal{U}_{11}^2 - \frac{1.4\tan\beta}{1+\kappa_d\tan\beta}\,\mathcal{U}_{11}\mathcal{U}_{12} + 13\,\mathcal{U}_{12}^2$$

$$\left. + \left(\frac{2}{\left(1+\kappa_d\tan\beta\right)} + \frac{0.1\tan^2\beta}{\left(1+\kappa_d\tan\beta\right)^2} + \frac{27}{\tan^2\beta}\right)\mathcal{U}_{23}^2\right] \text{ pb}$$

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3.- Total width

$$\Gamma_{H_1} \simeq \frac{g^2 M_{H_1}}{32\pi M_W^2} \left[\tan^2\beta \left(\mathcal{U}_{11}^2 + \mathcal{U}_{13}^2\right)\left(3m_b^2 + m_\tau^2\right) + 6.7 \times 10^{-4} M_{H_1}^2 \left(\mathcal{U}_{12} + \frac{\mathcal{U}_{11}}{\tan\beta}\right)^2\right]$$

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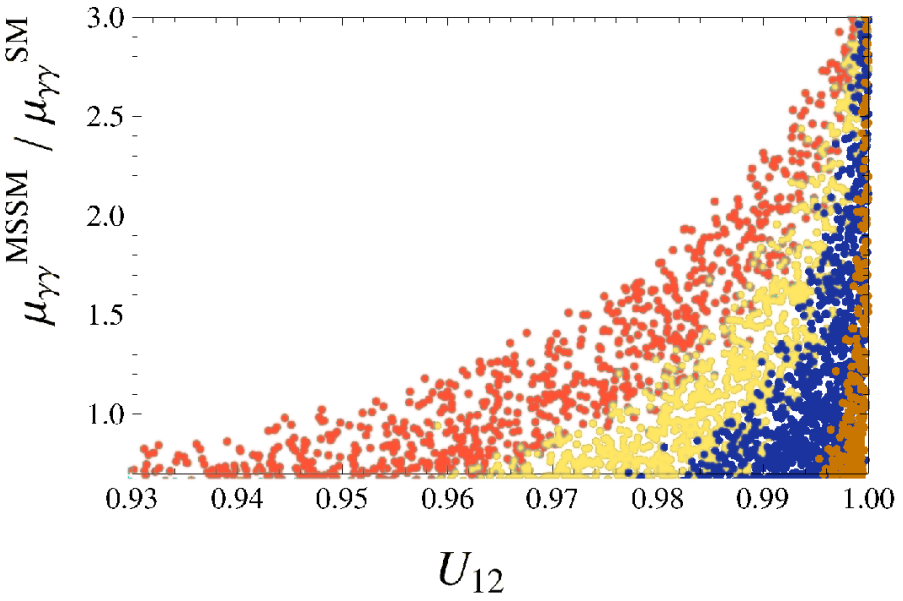

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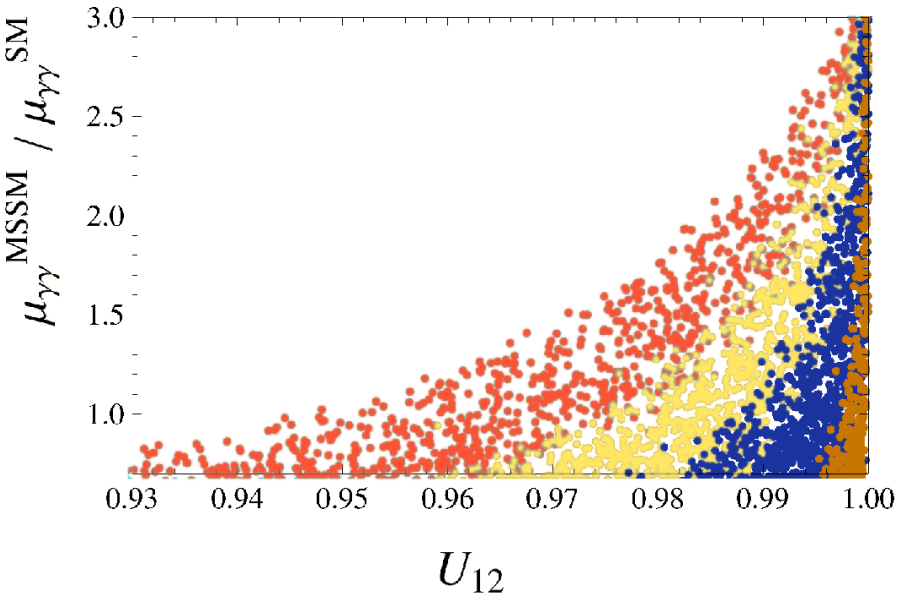

$$\Rightarrow \quad U_{12} \sim 1$$

$$U_{11}, U_{13} \sim 1/\mathrm{tg}\,\beta$$

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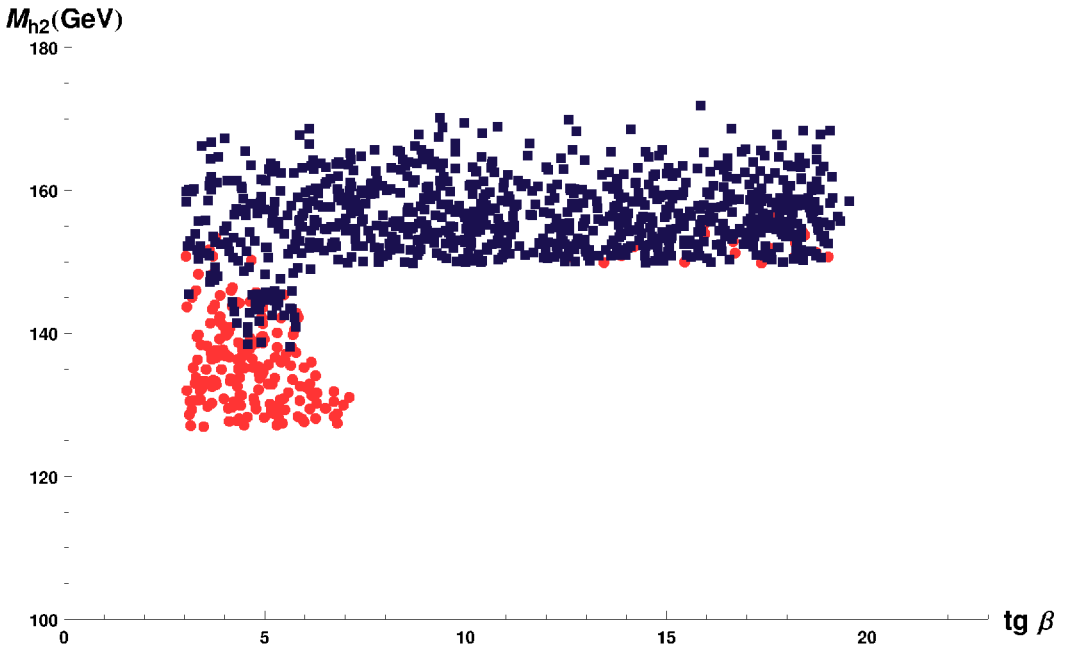
1. Light extra Higgs states. $m_{H+} \leq m_t$

"Old" ATLAS/CMS ττ searches



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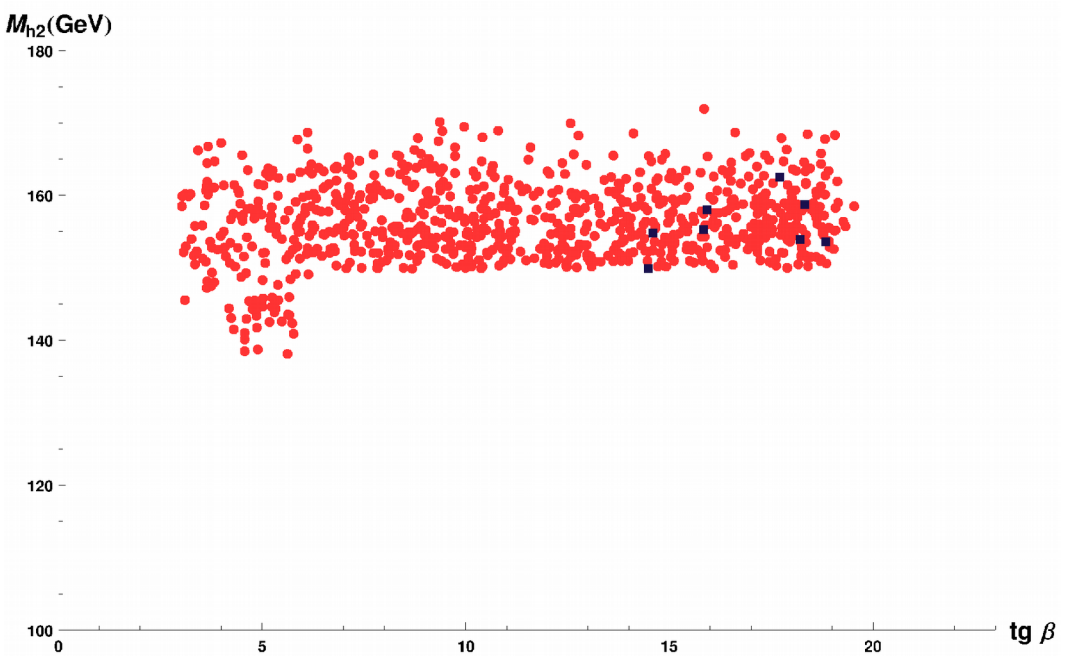

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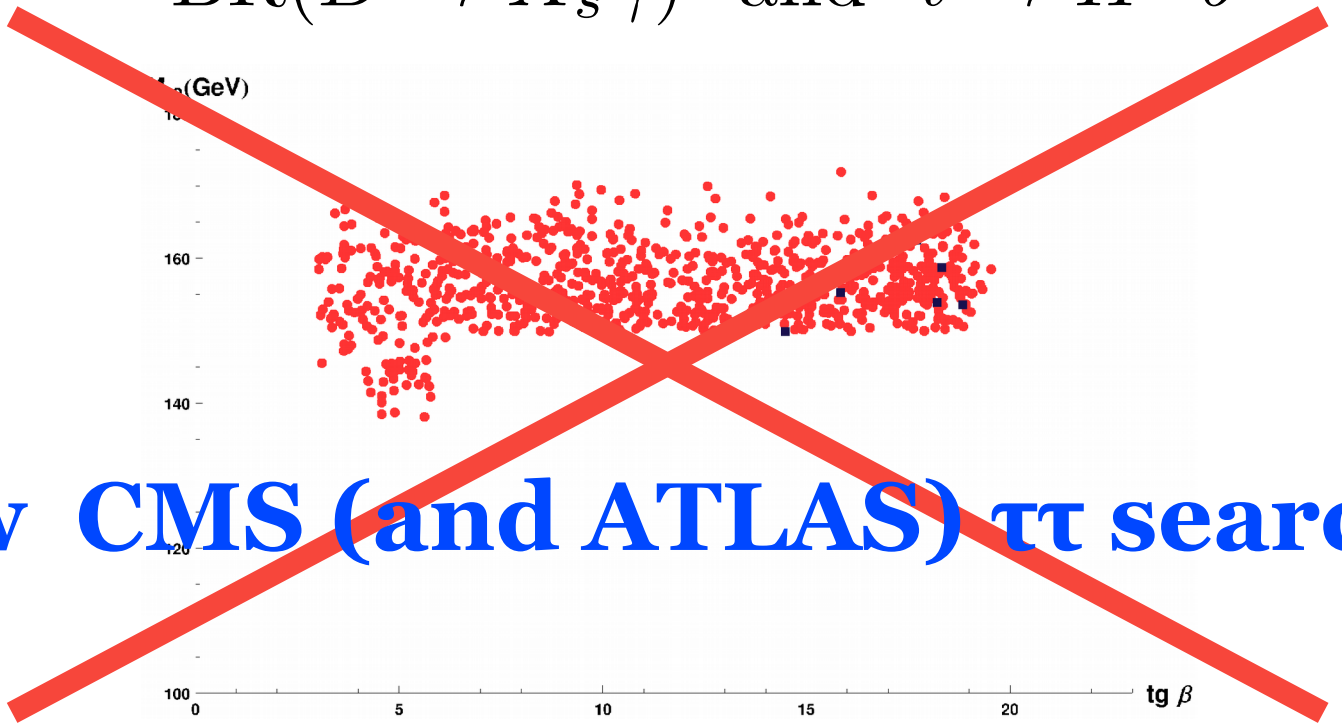

New CMS (and ATLAS) ττ searches.

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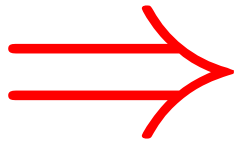
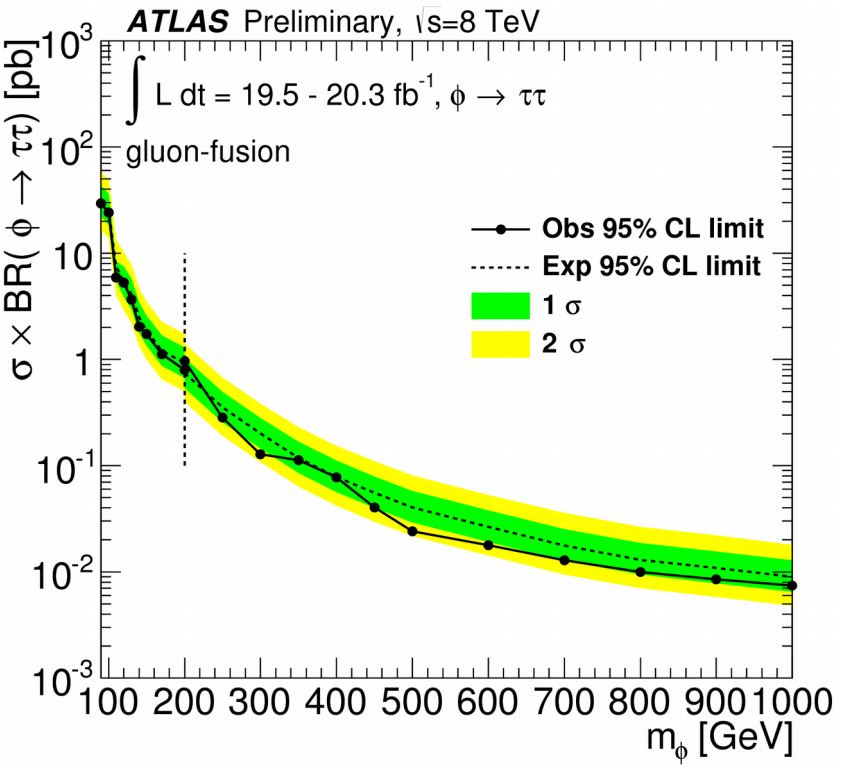


Importance of b-asociated production...



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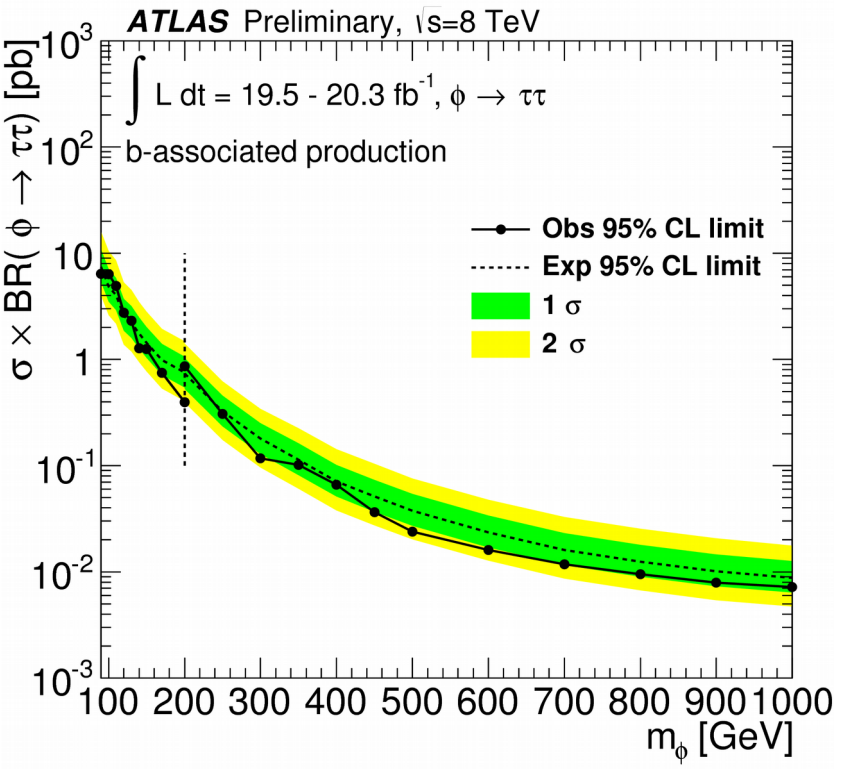

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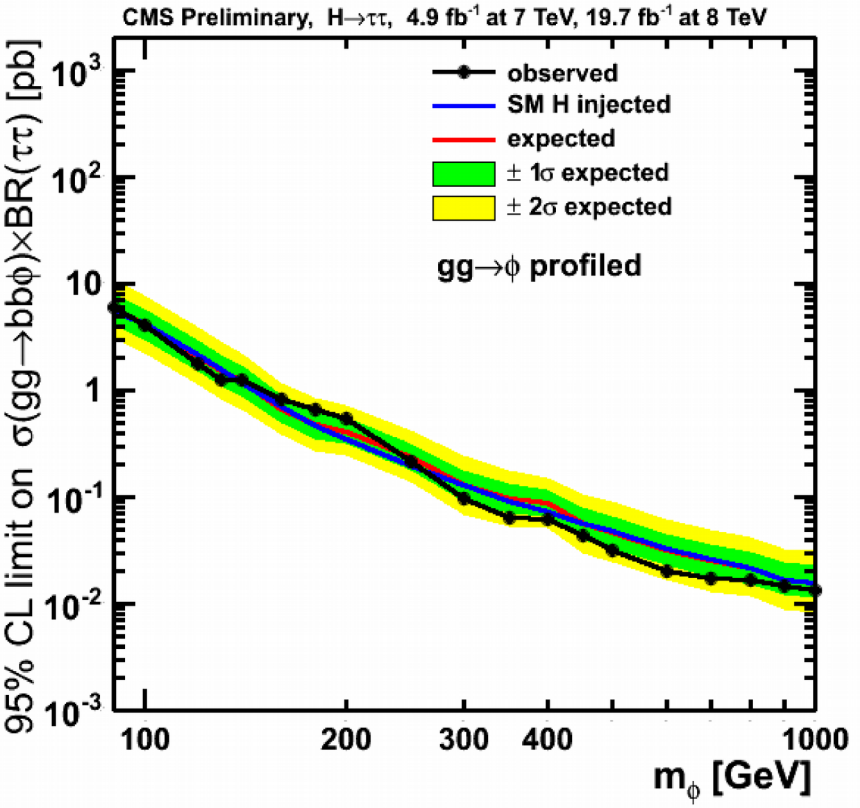

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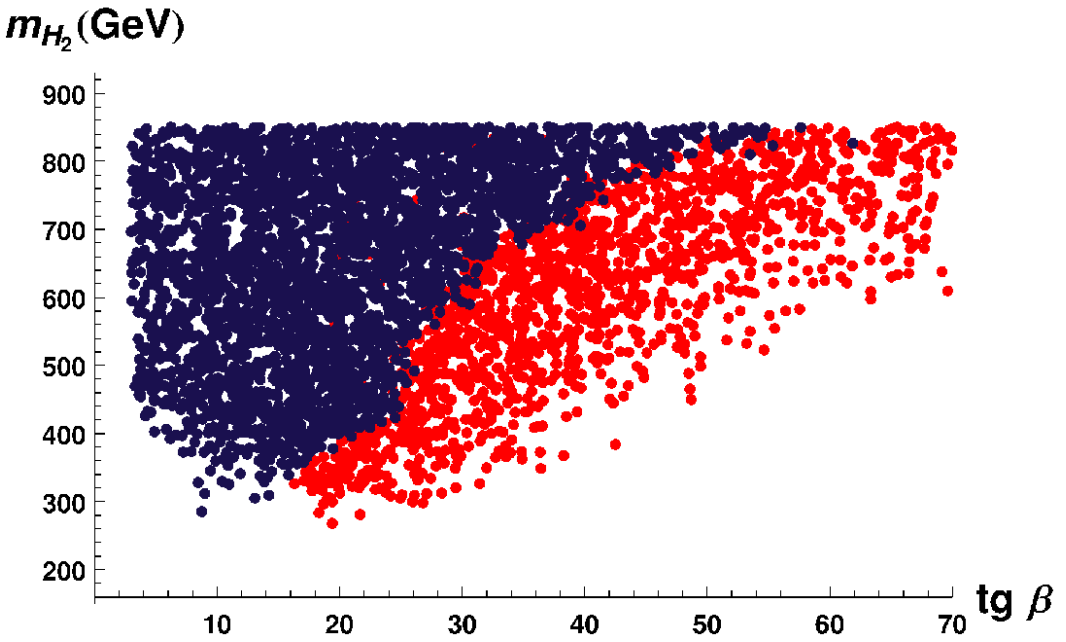

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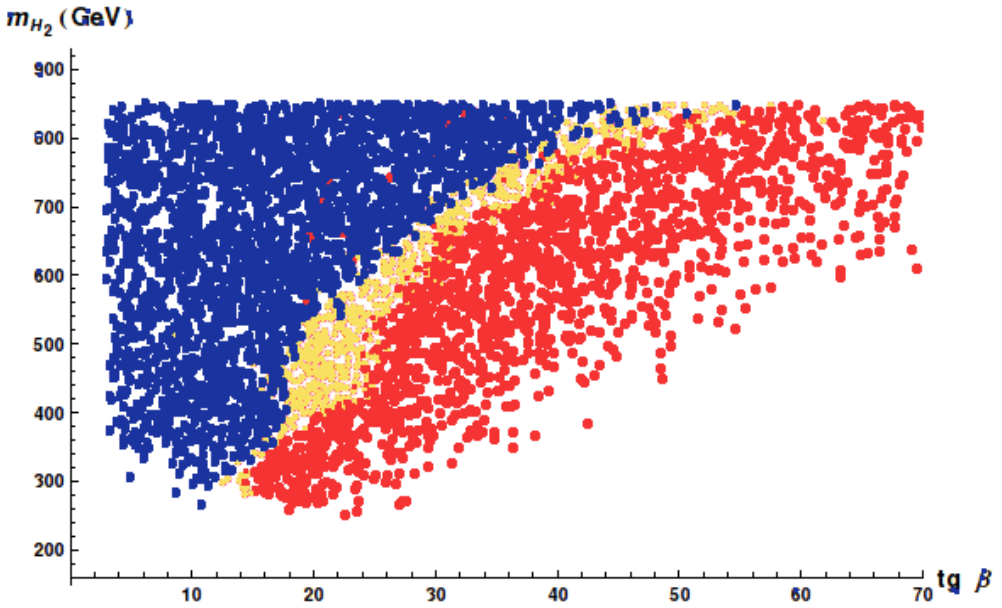

Conclusions

- Lightest Higgs at 126 GeV boson and the γγ channel provide strong constraints on Higgs mixings.
- Combination of direct searches with indirect constraints is an excellent weapon to search for additional Higgs states.
- ττ channel together with indirect constraints forbid extra Higgs states below 250 GeV.
- Strong constraints for large tg β at higher masses.
- Waiting for positive results in the ττ channel !! …