A Social Higgs?

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HIGGS HUNTING WORKSHOP
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Introduction

- How do we test the hypothesis of a non-minimal Higgs sector?
  - Indirectly: deviations of Higgs(125) couplings from SM
  - Directly: look for other Higgs-like bosons

- This talk:
  - Simplest extension of SM Higgs sector: SM Higgs + singlet
  - Improved sensitivity from combining Higgs(125) couplings + higher mass limits

'The Social Higgs' , D.B. and Matthew McCullough
JHEP 1212:118 (2012), arXiv:1207.4209

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An extended Higgs sector

- h = SM Higgs, s = gauge singlet

$$\begin{pmatrix} h \\ s \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \cdot \begin{pmatrix} \tilde{h} \\ \tilde{s} \end{pmatrix}$$

- s might also couple to additional charged particles leading to

$$\mathcal{L} \supset \alpha c_{h\gamma\gamma} s F^{\mu\nu} F_{\mu\nu}$$

- If $m_{\tilde{s}} \geq 2m_{\tilde{h}}$, $\tilde{s}$ can decay to $2\tilde{h}$

$$\mathrm{BR}(\tilde{s} \to 2\tilde{h}) = \kappa \sqrt{1 - \frac{4m_{\tilde{h}}^2}{m_{\tilde{s}}^2}}$$

Analysis

Parameters: $\{\theta,\ \alpha,\ \kappa,\ m_{\tilde{h}}, m_{\tilde{s}}\}$

- Pick $m_{\tilde{h}} \simeq 126$ GeV
- Fix κ
- Fit α, θ to data for $m_{\tilde{s}} \in [200, 1000]$ GeV (avoid $\tilde{h}$ contamination)

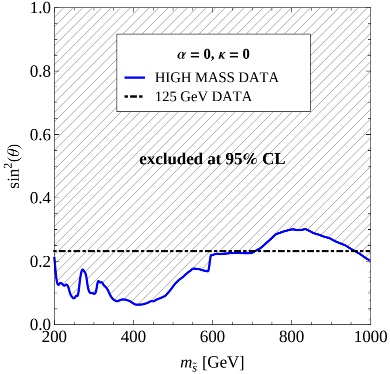
$\boxed{\mu_i = \frac{\sigma \times \mathrm{BR}_i}{(\sigma \times \mathrm{BR}_i)_{\mathrm{SM}}} \text{ 'signal strength'}}$

$$\lambda(\mu, m) \simeq e^{-[\mu - \hat{\mu}(m)]^2 / 2\sigma^2(\mu, m)}$$

$$\lambda_{\mathrm{C}}(\mu_{\tilde{h}}, \mu_{\tilde{s}}, m_{\tilde{h}}, m_{\tilde{s}}) = \lambda(\mu_{\tilde{h}}, m_{\tilde{h}}) \times \lambda(\mu_{\tilde{s}}, m_{\tilde{s}})$$

μ	$\tilde{h}$	$\tilde{s}$
$\gamma\gamma$	$(\cos\theta + \alpha \sin\theta)^2$	$(\sin\theta - \alpha\cos\theta)^2(1 - \mathrm{BR}_{2\tilde{h}})$
$ZZ, WW, bb, \tau\tau$	$\cos^2\theta$	$\sin^2\theta(1 - \mathrm{BR}_{2\tilde{h}})$

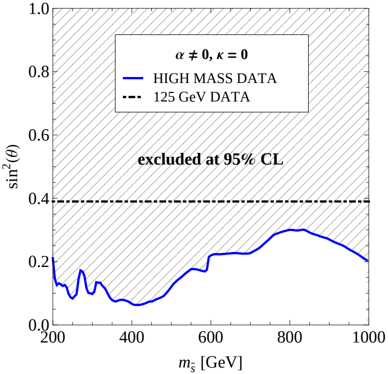
Excluded regions, $\alpha = 0$

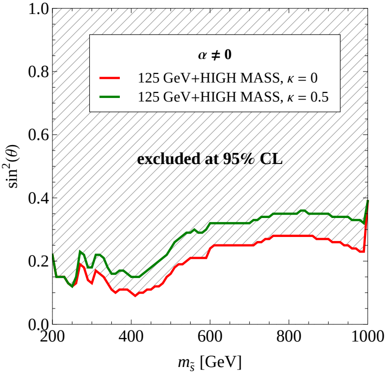


ATLAS and CMS $\gamma\gamma$, *ZZ*, *bb*, $\tau\tau$, *WW* with $\mathcal{L} = 5$ fb^{-1}(7 TeV) + $\mathcal{L} \leq 20$ fb^{-1}(8 TeV)

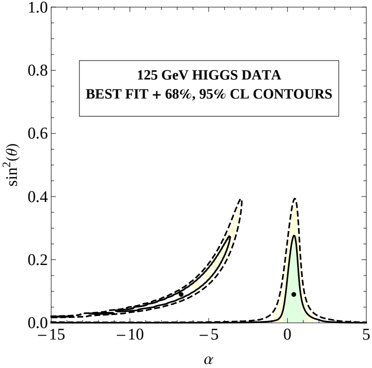
(includes newest EPS-HEP 2013 data) + Tevatron $\gamma\gamma$, *bb*, *WW*

Excluded regions, $\alpha \neq 0$





Decoupled $\tilde{s}$



If $m_{\tilde{s}} > 1$ TeV, $\tilde{s}$ doesn't contribute any signal in the search window

Best fit for α and $\sin^2\theta$ shows no significant improvement over the SM fit

Conclusions

- SM Higgs $+$ singlet scenario already strongly constrained.
  $\sin^2(\theta) \lesssim 0.2$ for $m_{\tilde{s}} \in [200, 1000]$ GeV
- Improved sensitivity by combining 125 GeV data
  & higher mass limits

Next questions:

- To which degree will we be able to discriminate signatures of different extended Higgs sectors?
- What is the best way to do it?

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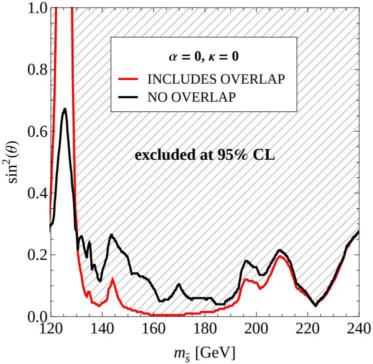
Backup, signal overlap



Likelihood for multiple scalars:

$$\lambda_C(\mu_{\tilde{h}}, \mu_{\tilde{s}}, m_{\tilde{h}}, m_{\tilde{s}}) = \lambda(\mu_{\tilde{h}}, m_{\tilde{h}}) \times \lambda(\mu_{\tilde{s}}, m_{\tilde{s}})$$

$\lambda =$ two-sided gaussian

$$\mu_{i,\tilde{h}}(m_{\tilde{h}}) = \mu_{i,\tilde{h}} + \mu_{i,\tilde{s}}\, e^{-(m_{\tilde{s}} - m_{\tilde{h}})^2 / 2\sigma^2_{\text{res},i}(m_{\tilde{h}})}$$

$$\mu_{i,\tilde{s}}(m_{\tilde{s}}) = \mu_{i,\tilde{s}} + \mu_{i,\tilde{h}}\, e^{-(m_{\tilde{h}} - m_{\tilde{s}})^2 / 2\sigma^2_{\text{res},i}(m_{\tilde{s}})}$$