Theory issues

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- SUSY interpretation of the observed signal?
- LHC Higgs XS WG, properties of a light Higgs: couplings, spin and $\mathcal{CP}$ properties

SUSY interpretation of the observed signal?

SUSY interpretation is possible both for the lightest $\mathcal{CP}$-even Higgs (has SM-like behaviour in the decoupling limit, $M_A \gg M_Z$) and for the second-lightest neutral Higgs

Interpretation of the observed signal at ~ 125 GeV in terms of the second-lightest Higgs of the MSSM and the NMSSM:

The light Higgs h in this scenario has a mass that is often below the LEP limit of $M_{H_{SM}} > 114.4$ GeV (with reduced couplings to gauge bosons, in agreement with LEP bounds)

$\Rightarrow$ It is important to extend the LHC Higgs searches to the region below 114 GeV!

How about a possible enhancement of the $\gamma\gamma$ rate?

An enhanced rate in the $\gamma\gamma$ channel,

$$R^{h_i}_{\gamma\gamma} = \frac{\sigma(pp \to h_i) \times \mathrm{BR}(h_i \to \gamma\gamma)}{\sigma(pp \to H_{\mathrm{SM}}) \times \mathrm{BR}(H_{\mathrm{SM}} \to \gamma\gamma)}$$

could be accomodated for a 125 GeV Higgs

– both in the MSSM and the NMSSM

– for the lightest and the second-lightest Higgs

[*R. Benbrik, M. Gomez Bock, S. Heinemeyer,O. Stål, G. W., L. Zeune '12*]

Possible mechanisms for enhancing the $\gamma\gamma$ rate in the MSSM

- Enhancement of $\Gamma(h, H \to \gamma\gamma)$:
  loop contributions from light staus

- Suppression of Higgs (h, H) coupling to $b\bar{b}$:
  $\Rightarrow$ Enhancement of $\mathrm{BR}(h, H \to \gamma\gamma)$

$$\frac{g_{hb\bar{b}}}{g_{H_{\mathrm{SM}}b\bar{b}}} = \frac{1}{1+\Delta_b}\left(-\frac{\sin\alpha_{\mathrm{eff}}}{\cos\beta} + \Delta_b \frac{\cos\alpha_{\mathrm{eff}}}{\sin\beta}\right)$$

  Suppression of $g_{hb\bar{b}}$ because of large Higgs propagator-type corrections ($\to$ small α_{eff}) or large correction to the relation between m_{b} and the bottom Yukawa coupling (Δ_b) [similar for H]

  Experimental situation for $\tau^+\tau^-$ and $b\bar{b}$ channels still inconclusive

Additional mechanism in the NMSSM

Additional mechanism for suppression of Higgs coupling to $b\bar{b}$ in the NMSSM:

Mixing of Higgs singlet to doublet fields can result in small H_d component

$\Rightarrow$ coupling to down-type fermions suppressed

LHC Higgs XS WG, properties of a light Higgs: couplings, spin and $\mathcal{CP}$ properties

- Mass: finite width effects assumed to be negligible

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- Couplings:

  What is actually meant by a Higgs coupling measurement?

  A coupling is not a directly measurable quantity

  $\Rightarrow$ Need “unfolding” procedure to extract information on the couplings from the actually measured quantities, i.e. $\sigma \times \mathrm{BR}$

  $\Rightarrow$ Gives rise in general to a model dependence

Approaches to determine possible deviations from the SM couplings

- Use tree-level relations

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- Use tree-level relations
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  Compatibility of the results with the SM?

- Full SM predictions $+$ anomalous couplings
  $\Rightarrow$ Appropriate tools needed

  Anomalous couplings would in general change kinematic distributions

  $\Rightarrow$ no simple rescaling of MC predictions possible

Recommendations of the LM subgroup of the LHC Higgs XS WG for analyses of 2012 data (draft)

Assumptions:

- Signal corresponds to only one state, no overlapping resonances, etc.

- Narrow-width approximation

- Only modifications of coupling strenghts (absolute values of the couplings) are considered, no modification of the tensor structure as compared to the SM case

  $\Rightarrow$ Assume that the observed state is a $\mathcal{CP}$-even scalar

Recommendations of the LM subgroup of the LHC Higgs XS WG for analyses of 2012 data (draft)

Use state-of-the-art predictions in the SM and recale the predictions with "leading order inspired" scale factors C_i ($C_i = 1$ corresponds to the SM case)

Note: scaling of couplings is in general not possible if higher-order electroweak corrections are included

$\Rightarrow$ Need in general scale factors for couplings of new state to t, b, τ, W, Z, ...

- $+$ extra loop contribution to $\sigma(gg \to H)$, $\Gamma(H \to gg)$
- $+$ extra loop contribution to $\Gamma(H \to \gamma\gamma)$
- $+$ additional contributions to total width, Γ_H, from undetectable final states

Total width Γ_H cannot be measured at the LHC without further assumptions (otherwise only coupling ratios can be determined, not absolute values of couplings)

Recommendations of the LM subgroup of the LHC Higgs XS WG for analyses of 2012 data (draft)

Different "benchmarks" for scale factors C_i: simplifying assumptions to reduce the number of free parameters

Current experimental data is sensitive to variations of only one or two parameters:

1 parameter: overall coupling strength μ

2 parameters: e.g. common scale factor C_V for W, Z, and common scale factor for all fermions, C_F

Higgs spin and $\mathcal{CP}$ properties

Spin: need to discriminate between hypotheses for spin 0, (1), (2)

$\mathcal{CP}$-properties: Observed state can be any admixture of $\mathcal{CP}$-even and $\mathcal{CP}$-odd components

Observables investigated at the LHC ($H \to ZZ^*, WW^*$ and H production in weak boson fusion) involve HVV coupling

$\Rightarrow$ little sensitivity to $\mathcal{CP}$-odd components: would be loop-induced and heavily suppressed in most BSM models

$\Rightarrow$ Discrimination between the hypotheses of a pure $\mathcal{CP}$-even and a pure $\mathcal{CP}$-odd state is not sufficient to determine the $\mathcal{CP}$ properties of the new state