ESR11: Interplay of Higgs phenomenology and new physics

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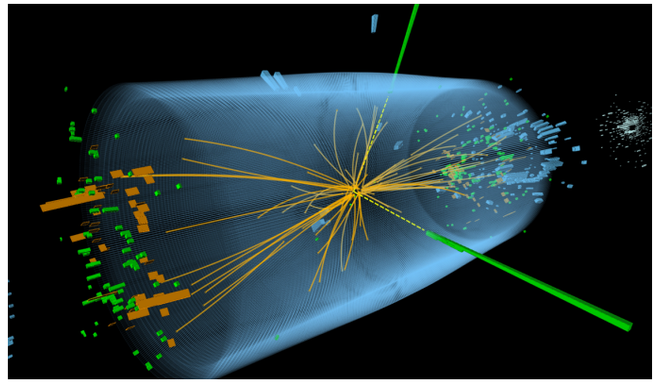
HiggsTools Kick-Off Meeting, UCL, 04 / 2014



- ESR (junior), 18 + 18 months
- Supervisor: GW
- Hiring in progress
- Planned secondments: UGR (Santander), CERN

Goals:

- Interpretation of the signal at 126 GeV and phenomenology of additional states of extended Higgs sectors

- Explore possible interplay of Higgs and new physics (NP) states:

  - H(126) --> NP, H(126) --> invisible (-> dark matter), H(126) --> $h_i + h_i$

  - NP --> H(126) + X, H(126) + NP production

  - H_i --> NP, H_i --> H(126) + H(126), ...

  - NP --> h_i + X

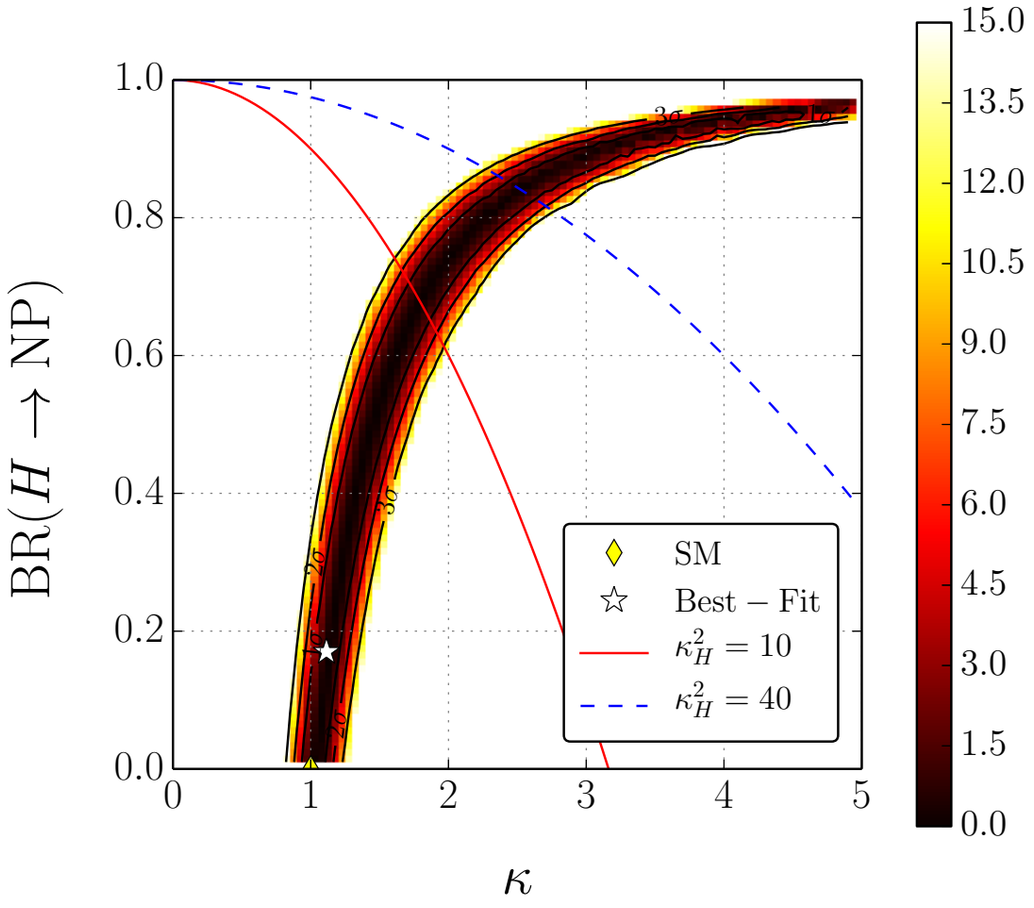
- Incorporate experimental information on the total width into the analysis of the coupling structure of H(126): goes beyond κ scale factor formalism

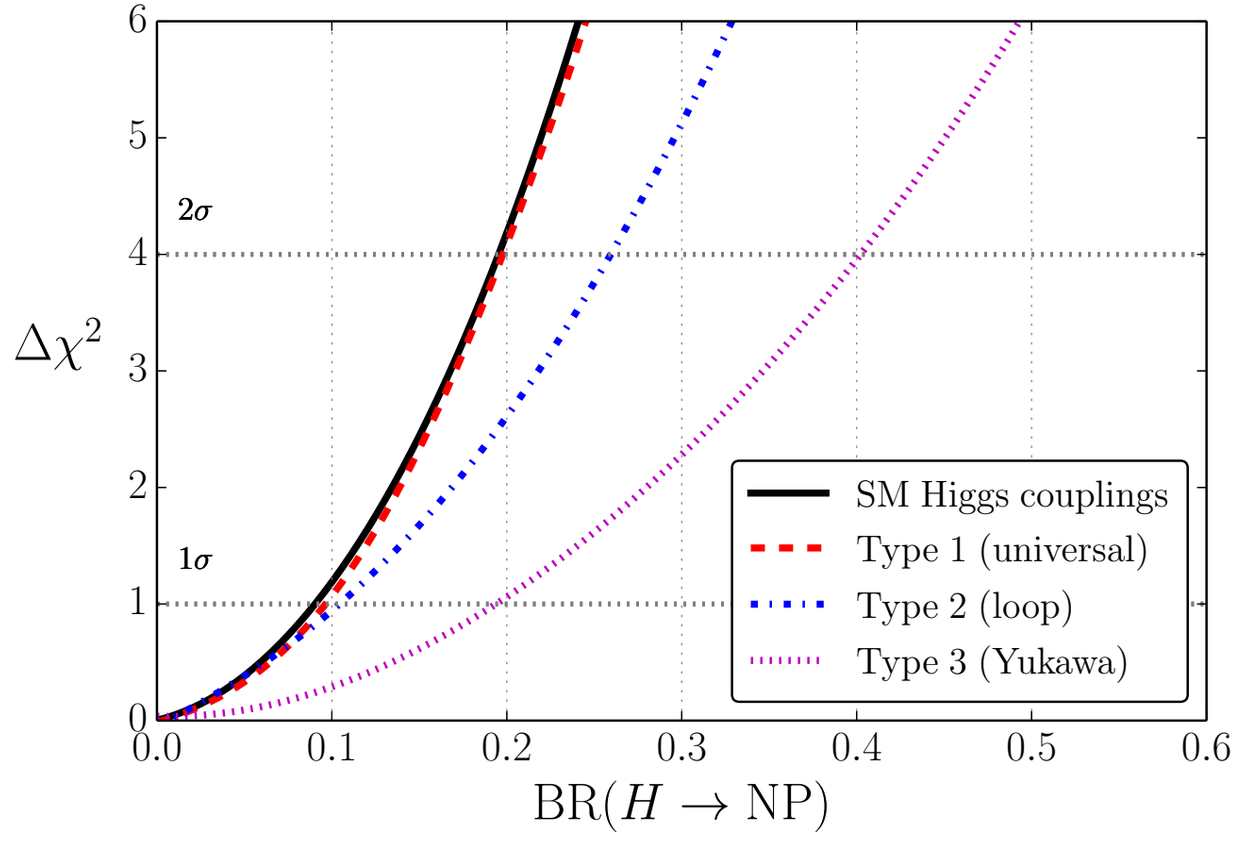
Example: current bounds on H(126) → NP from ATLAS + CMS

HiggsSignals *[P. Bechtle, S. Heinemeyer, O. Stål, T. Stefaniak, G. W. '14]*

No assumptions on undetectable / invisible decays, common scale factor $\varkappa$

$$\kappa_V \leq 1 \ (V = W, Z)$$





⇒ There is significant room for decay modes of the signal at 126 GeV into new physics final states

Method

- Theoretical predictions for the relevant quantities
- Work out phenomenology of possible new signatures
- Suggest analysis strategies to enhance experimental sensitivity
- Close collaboration with A. Raspereza (CMS)
- Milestones: M1.1.3, M1.3.1, M1.4.1, M2.2.2, M2.2.3, M2.2.4

Backup

Present status

- The properties of the signal are so far compatible with the predictions for the Higgs boson of the SM, but many other interpretations are possible, corresponding to very different underlying physics:
  - Lightest or next-to-lightest state of an extended Higgs sector
  - Pseudo-Goldstone boson, composite Higgs, ...
  - Mixed state: Higgs-radion mixing, ...
  - Dilaton, ...

⇒ Need to discriminate between the different possible options in order to identify the nature of electroweak symmetry breaking!

Higgs physics: shedding light on dark matter?

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- If dark matter consists of one or more particles with a mass below about 63 GeV, then the decay of the signal at 126 GeV into a pair of dark matter particles is kinematically open

- Non-zero branching ratio into invisible particles could manifest itself via:

  - Direct search for $H \rightarrow$ invisible

  - Suppression of all other branching ratios

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⇒ Higgs physics could provide a ``window" to dark matter

Search for non-standard heavy Higgses

"Typical" features of extended Higgs sectors:

- A light Higgs with SM-like properties, couples with about SM-strength to gauge bosons
- Heavy Higgs states that decouple from the gauge bosons

For “non-standard” Higgs states:

$\Rightarrow$ Cannot use weak-boson fusion channels for production

$\Rightarrow$ Possible production channels: $gg \to H$, $b\bar{b}H$, . . .

Cannot use LHC “gold plated” decay mode $H \to ZZ \to 4\mu$

$\Rightarrow$ Search for heavy Higgs bosons $H, A, H^{\pm}$ is very different from the SM case

What if the signal at 126 GeV corresponds to a state of an extended Higgs sector which is not the lightest one?

Extended Higgs sector where the second-lightest Higgs at $\sim 126\ \mathrm{GeV}$ has SM-like couplings to gauge bosons

$\Rightarrow$ Lightest neutral Higgs with heavily suppressed couplings to gauge bosons, may have mass below the LEP limit of $M_{\mathrm{H_{SM}}} > 114.4\ \mathrm{GeV}$ (in agreement with LEP bounds)

Possible realisations: 2HDM, MSSM, NMSSM, ...

Example: "Low M_{H} benchmark scenario" of the MSSM

$\Rightarrow$ Observation of a SM-like signal at $\sim 126\ \mathrm{GeV}$ provides a strong motivation to look for non SM-like Higgses elsewhere

$\Rightarrow$ The best way of experimentally proving that the observed state is not the SM Higgs would be to find in addition (at least one) non-SM like Higgs!

Would such a light Higgs be detectable at the LHC?

- Not in decays of the state at $\sim 126\ \mathrm{GeV}$ if mass of lightest Higgs $\gtrsim 63\ \mathrm{GeV}$

- This possibility has not been explored at the LHC so far; first LHC searches for light Higgses in this mass range are in progress

- In case of SUSY, such a light Higgs could be produced in a SUSY cascade, e.g. $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h$; could be similar for other types of BSM physics