Fitting the Two-Higgs-Doublet model of type II

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see arXiv:1403.1246

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Theory

Scalar potential of the 2HDM of type II:

$$
\begin{aligned}
V_H^{\text{2HDM}} =& m_{11}^2 \Phi_1^\dagger \Phi_1 + m_{22}^2 \Phi_2^\dagger \Phi_2 - m_{12}^2 \left(\Phi_1^\dagger \Phi_2 + \Phi_2^\dagger \Phi_1 \right) \\
&+ \frac{\lambda_1}{2} \left(\Phi_1^\dagger \Phi_1 \right)^2 + \frac{\lambda_2}{2} \left(\Phi_2^\dagger \Phi_2 \right)^2 + \lambda_3 \left(\Phi_1^\dagger \Phi_1 \right) \left(\Phi_2^\dagger \Phi_2 \right) \\
&+ \lambda_4 \left(\Phi_1^\dagger \Phi_2 \right) \left(\Phi_2^\dagger \Phi_1 \right) + \frac{\lambda_5}{2} \left[\left(\Phi_1^\dagger \Phi_2 \right)^2 + \text{h.c.} \right]
\end{aligned}
$$

2HDM II: 8 real parameters assuming CP conserving scalar sector and additional Z_2 symmetry $\Phi_1 \to -\Phi_1$ and $u \to -u$

Theory

Physical parameters of the 2HDM II:

v, m_h, m_H, m_A, m_{H^+}, $\beta - \alpha$, $\tan\beta$, m_{12}^2

Theoretical constraints:

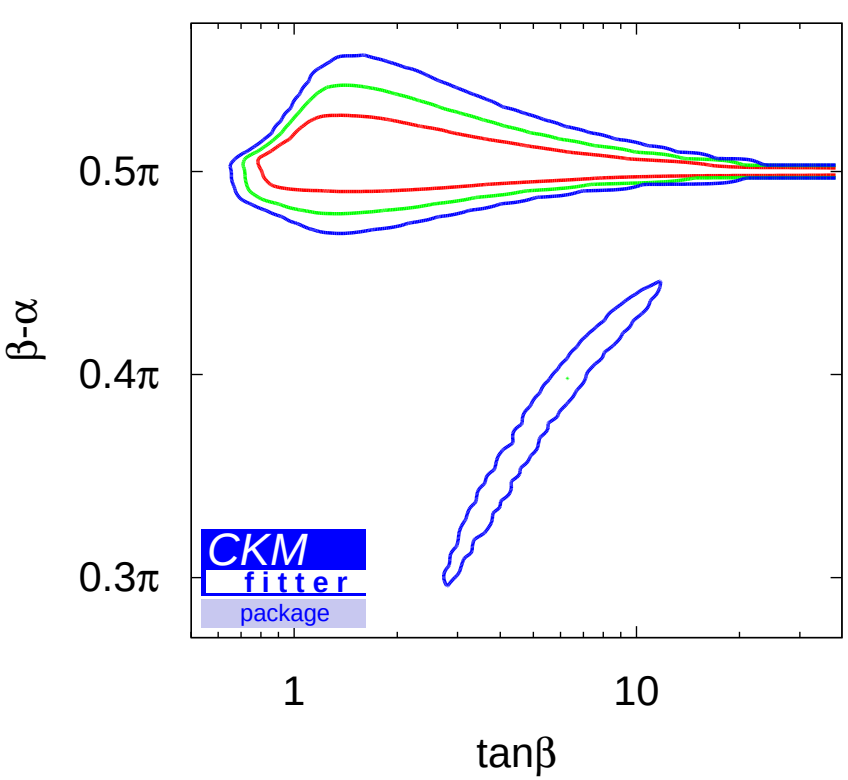
- Positivity of the scalar potential [Deshpande, Ma '78]
- Perturbativity of the quartic couplings ($\|S\| < \frac{1}{8}$)
  [Nierste, Riesselmann '96; Ginzburg, Ivanov '05;
  Baglio, OE, Nierste, Wiebusch '14]
- Stable vacuum at 243 GeV [Barroso, Ferreira, Ivanov, Santos '13]

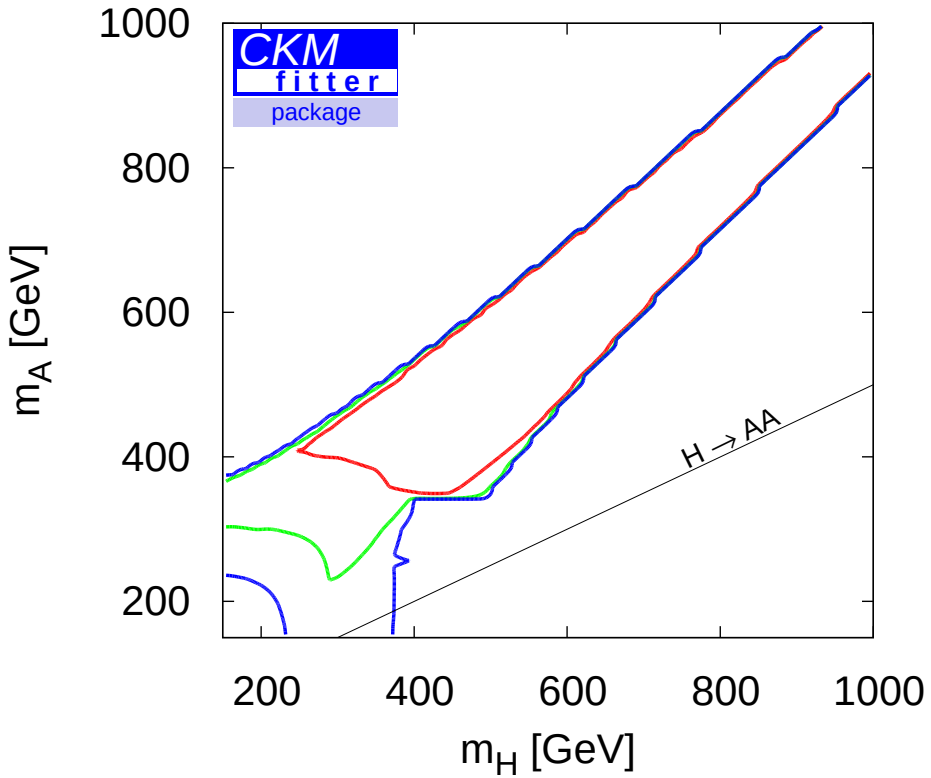
Experiment

Experimental constraints:

- Electroweak precision data
  [LEP & SLD '06]
- $b \to s\gamma$ and Δm_{B_s}
  [Hermann, Misiak, Steinhauser '12; Deschamps, Descotes-Genon, Monteil, Niess, T'Jampens, Tisserand '09]
- Light Higgs signal strengths
  [ATLAS-CONF-2013-034; CMS-PAS-HIG-13-005]
- Heavy Higgs exclusion limits
  [CMS '13; CMS-PAS-HIG-13-021; CMS-PAS-HIG-13-025]

Results

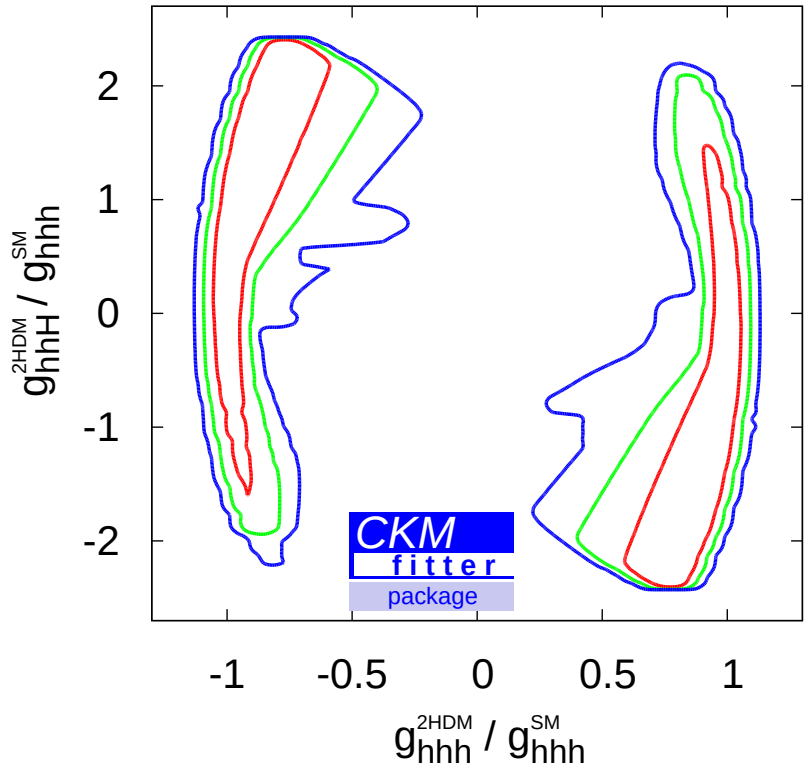




The 2HDM II parameter space is strongly constrained.

[OE,Nierste,Wiebusch '13; Baglio,OE,Nierste,Wiebusch '14]

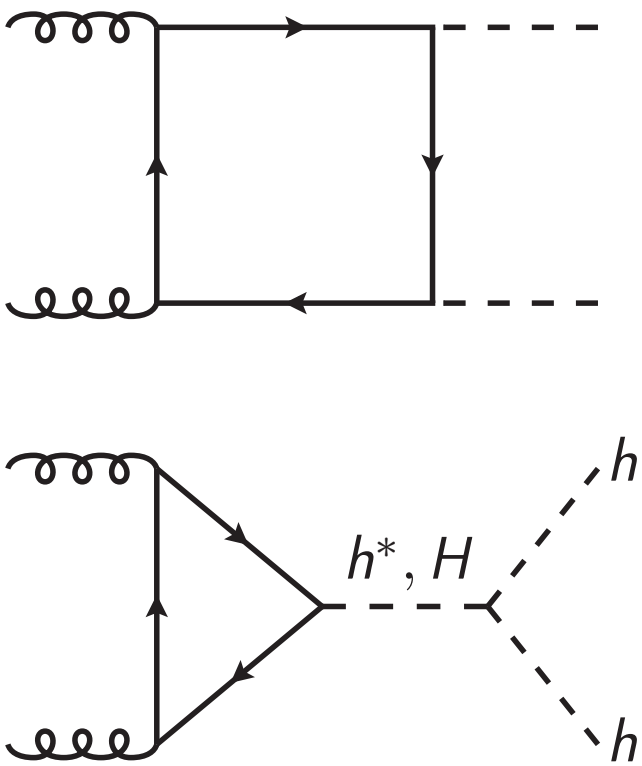
Results

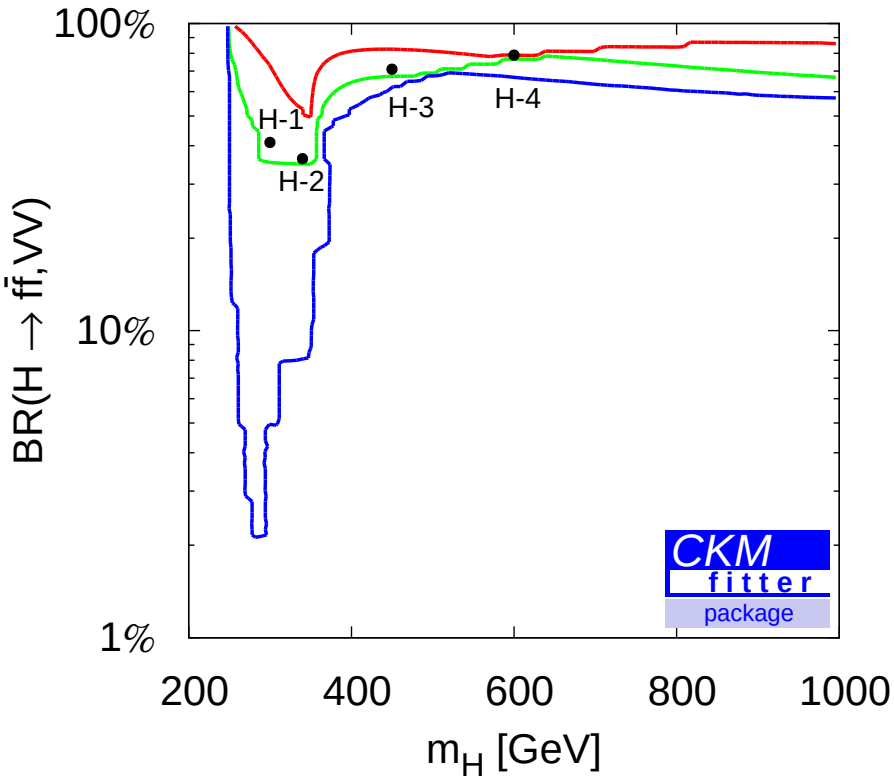


The hhh coupling in the 2HDM II cannot exceed the SM value.

[Baglio,OE,Nierste,Wiebusch '14]

Results

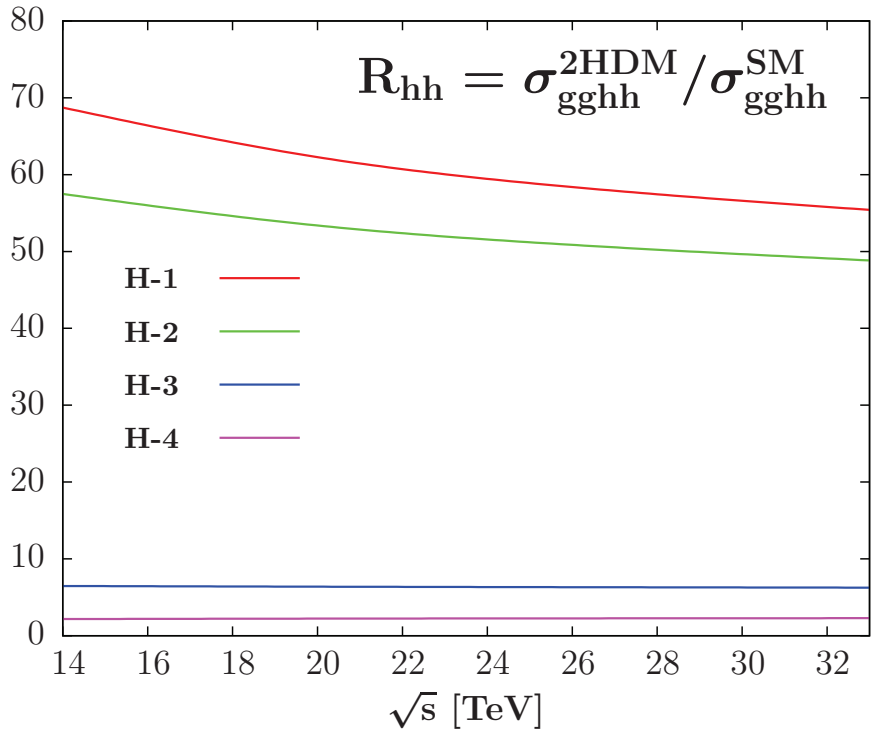




We provide benchmark scenarios featuring the largest still possible deviations from the SM.

[Baglio,OE,Nierste,Wiebusch '14]

Results



Even if the 2HDM II was "aligned",
a large enhancement of $gg \to hh$ would be possible.
[Baglio,OE,Nierste,Wiebusch '14]

Conclusions

2HDM II is strongly constrained.

Large effects in triple Higgs coupling measurements are possibile.

We provide benchmark points in arXiv:1403.1246.

Back-up slides

Tauonic B decays

The discrepancy of the measurements of $B \to \tau\nu$, $B \to D\tau\nu$ and $B \to D^*\tau\nu$ cannot by resolved in the 2HDM of type II.
Scenarios with $\tan\beta > 30$ and light m_{H^+} are disfavoured, but the rest of the parameter space receives an almost constant shift of the χ^2.

Unitarity bound

Naive perturbativity:

$$|\lambda_i| \leq 4\pi$$

More precisely in the SM:

$$|\lambda| < 2\pi$$

[Nierste, Riesselmann '96]

We take 2π value as upper limit for the magnitude of the tree-level Higgs S-matrix eigenvalues.

Literature

[Baglio,OE,Nierste,Wiebusch '14] – J. Baglio, O. Eberhardt, U. Nierste and M. Wiebusch, arXiv:1403.1264, submitted to JHEP

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[Deshpande,Ma '78] – N. G. Deshpande and E. Ma, Phys.Rev. D18 (1978) 2574

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[Ginzburg,Ivanov '05] – I. Ginzburg and I. Ivanov, Phys.Rev. D72 (2005) 115010

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[CMS '13] – Eur.Phys.J. C73 (2013) 2469