(1) The Higgs Singlet Extension at LHC Run 2

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based on

G.M. Pruna, TR (PRD 88 (2013) 115012)
D. Lopez-Val, TR (PRD 90 (2014) 114018)
TR, T. Stefaniak (EPJC (2015) 75:105, EPJC76 (2016) no.5, 268)
F. Bojarski, G. Chalons, D. Lopez-Val, TR (JHEP 1602 (2016) 147)

IKTP, TU Dresden

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(2) Higgs Singlet extension (aka The Higgs portal)

The model

- Singlet extension:
  simplest extension of the SM Higgs sector
- add an **additional scalar**, singlet under SM gauge groups
  (further reduction of terms: impose additional symmetries)

$\Rightarrow$ potential (H doublet, χ real singlet)

$$\mathbf{V = -m^2 H^\dagger H - \mu^2 \chi^2 + \lambda_1 (H^\dagger H)^2 + \lambda_2 \chi^4 + \lambda_3 H^\dagger H \chi^2},$$

- collider phenomenology studied by many authors: Schabinger, Wells; Patt, Wilzcek; Barger ea; Bhattacharyya ea; Bock ea; Fox ea; Englert ea; Batell ea; Bertolini/ McCullough; ...
- our approach: **minimal:** no hidden sector interactions
- equally: **Singlet acquires VeV**

(3) Singlet extension: Characteristics

VeVs: $H \equiv \begin{pmatrix} 0 \\ \frac{\tilde{h}+v}{\sqrt{2}} \end{pmatrix}$, $\chi \equiv \frac{h'+x}{\sqrt{2}}$.

- potential: 5 free parameters: 3 couplings, 2 VeVs
  $\lambda_1, \lambda_2, \lambda_3, v, x$
- rewrite as
  $\mathbf{m_h}, \mathbf{m_H}, \sin\alpha, \mathbf{v}, \tan\beta$
- **fixed**, **free**
  $\sin\alpha$: mixing angle, $\tan\beta = \frac{v}{x}$
- physical states ($m_h < m_H$):
  $$\begin{pmatrix} \mathbf{h} \\ \mathbf{H} \end{pmatrix} = \begin{pmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} \tilde{h} \\ h' \end{pmatrix},$$
- SM-like couplings of **light/ heavy** Higgs:
  rescaled by $\sin\alpha, \cos\alpha$
- in addition: **new physics channel:** $H \to h\,h$

$$\Gamma_{\rm tot}(H) = \sin^2\alpha\, \Gamma_{\rm SM}(H) + \Gamma_{H\to h\,h},$$

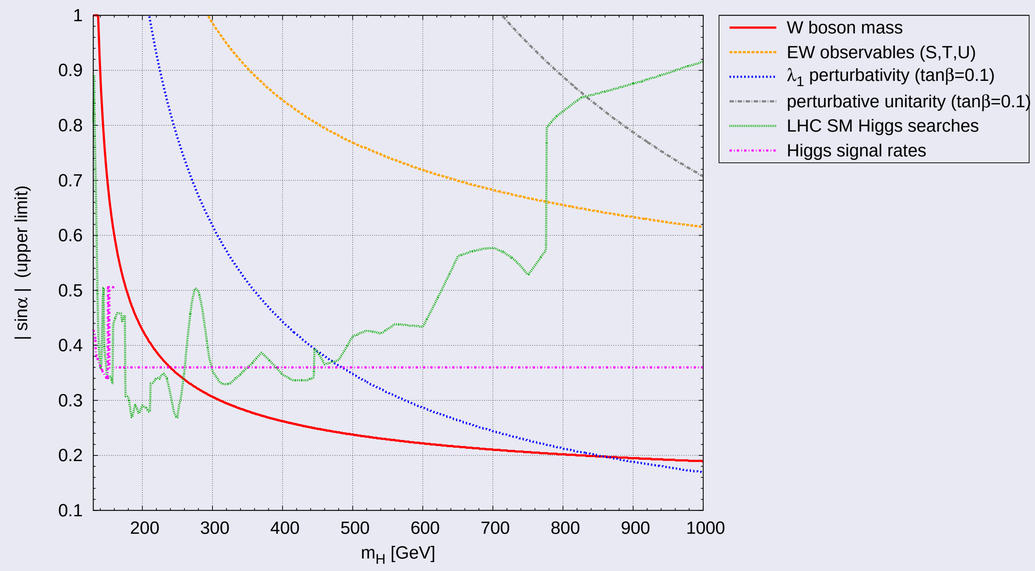
(4) Theoretical and experimental constraints on the model

our studies: $m_{h,H} = 125.09\,\mathrm{GeV}$, $0\,\mathrm{GeV} \le m_{H,h} \le 1\,\mathrm{TeV}$

1. limits from **perturbative unitarity**
2. limits from EW precision observables through S, T, U
3. special: **limits from W-boson mass** as precision observable
4. **perturbativity** of the couplings (up to certain scales*)
5. **vacuum stability and minimum condition** (up to certain scales*)
6. **collider limits** using HiggsBounds [Bechtle ea, '08-'15]
7. measurement of **light Higgs signal rates** using HiggsSignals [Bechtle ea, '13] and ATLAS-CONF-2015-044 [signal strength combination]

(*): only for $m_h = 125.09\,\mathrm{GeV}$

(5) Combined limits on $|\sin\alpha|$ (TR, T. Stefaniak, EPJC76 (2016) no.5, 268)

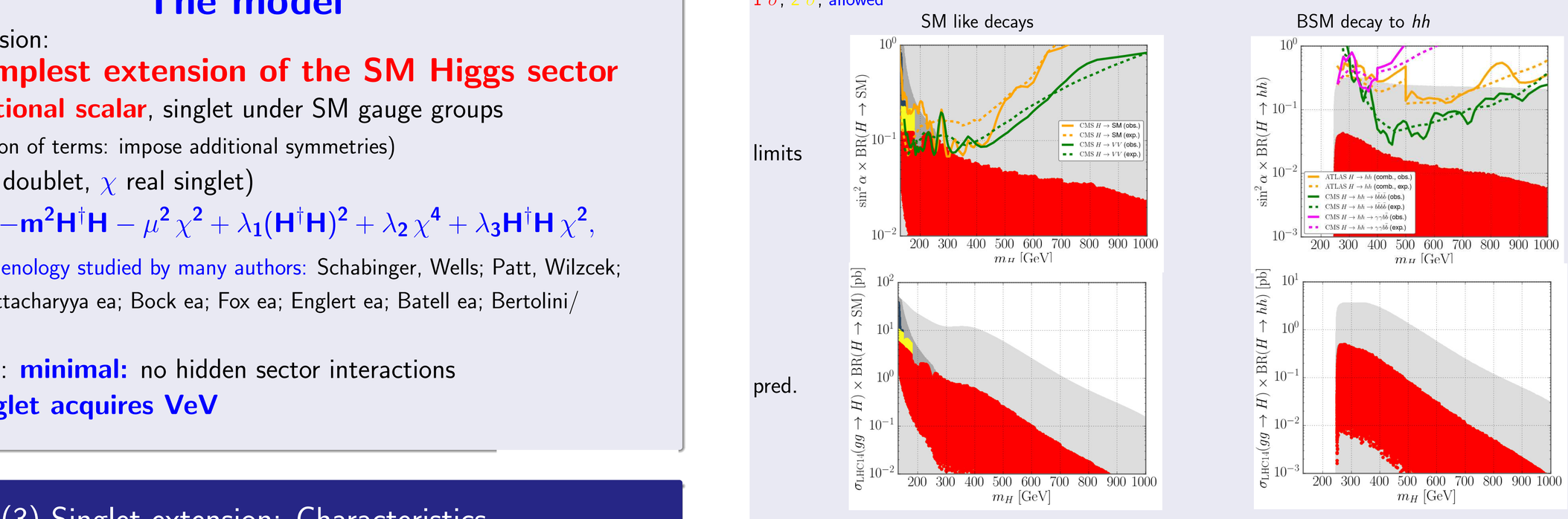


several bounds on $|\sin\alpha|$

m_W, perturbativity, LHC direct searches, Higgs Signal strength

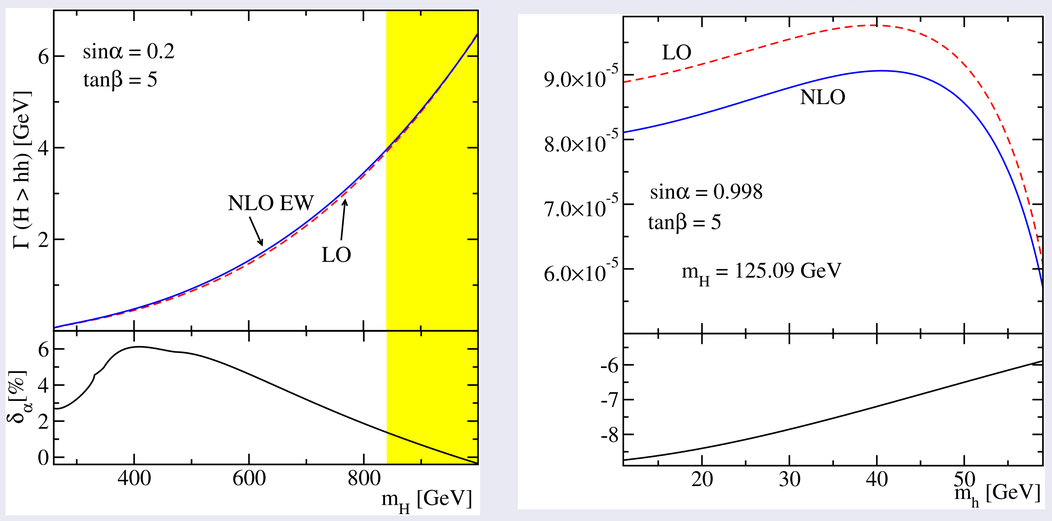
(6) Results from generic scans and predictions for LHC 14
(TR, T. Stefaniak, EPJC76 (2016) no.5, 268)

1 σ, 2 σ, allowed



(7) NLO corrections to $H \to h\,h$
(F. Bojarski, G. Chalons, D. Lopez-Val, TR, JHEP 1602 (2016) 147)

... just some numerical results for allowed regions...



$m_h = 125\,\mathrm{GeV}$ $\qquad$ $m_H = 125\,\mathrm{GeV}$

"typical" size of corrections

[beware of "inverse" $\tan\beta$ definition !!]

want to know more ?? come to Loopfest '16 !!

(8) Summary

- Singlet extension: **simplest extension of the SM Higgs sector**, easily identified with one of the benchmark scenarios of the HHXWG (cf. also YR3, Snowmass report)
- constraints on **maximal mixing** from m_W **at NLO** ($m_H \in [200\,\mathrm{GeV}; 800\,\mathrm{GeV}]$), **experimental searches and fits** ($m_{H,h} \le 200\,\mathrm{GeV}$) and/ or **running couplings** ($m_H \ge 800\,\mathrm{GeV}$)
- **quite narrow widths wrt SM-like Higgses** in this mass range
  $\Rightarrow$ **better theoretical handle**
- quite large suppression from current experimental/ theoretical constraints

!!! still, large numbers could have been produced already !!!

$\Longrightarrow$ **STAY TUNED** $\Longleftarrow$

!! Thanks to all my collaborators !!