Future of SFitter

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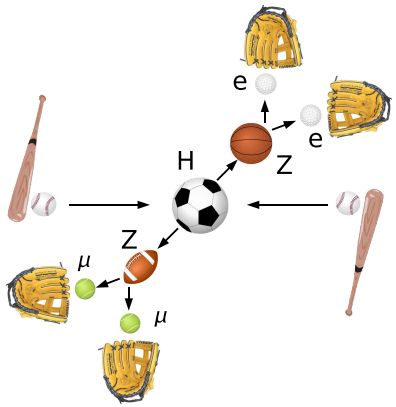
Physics questions



1. What are the quantum numbers?

- CP-even spin-0 scalar expected, which operators?
  spin-1 vector unlikely
  spin-2 graviton unexpected
- experimental task, ask flavor colleagues [Cabibbo–Maksymowicz–Dell'Aquila–Nelson angles]

2. What are the coupling values?

- 'coupling' after fixing operator basis
- renormalizable vs anomalous couplings to Standard Model
- anomalous decays means couplings to new particles
- effective theory only way to exploit distributions?
- interface experiment–theory

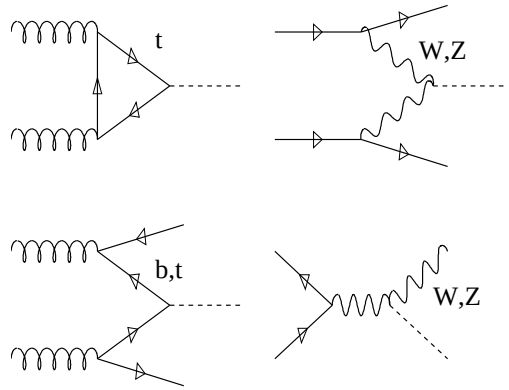
3. What does all this tell us?

- strongly interacting models?
- weakly interacting two-Higgs-doublet models, even SUSY?
- Higgs portal including dark matter, baryogenesis, etc?
- TeV-scale new physics?
- theory task

SFitter

Standard Model operators only [SFitter 2009]

- assume: narrow CP-even scalar
  Standard Model operators
- production & decay rates as input
- focus SM-like [secondary solutions possible]
- multi-dimensional likelihood map [couplings & nuisance]



$$\boxed{\begin{array}{l} gg \to H \\ qq \to qqH \\ gg \to t\bar{t}H \\ qq' \to VH \end{array}} \quad \longleftrightarrow \quad \boxed{g_{HXX} = g_{HXX}^{\text{SM}} \; (1 + \Delta_X)} \quad \longleftrightarrow \quad \boxed{\begin{array}{l} H \to ZZ \\ H \to WW \\ H \to b\bar{b} \\ H \to \tau^+\tau^- \\ H \to \gamma\gamma \end{array}}$$

Possible choice: total width [SFitter 2009]

- coupling extraction impossible without width assumption
- observed partial widths: $\sum \Gamma_i(g^2) < \Gamma_{\text{tot}} \quad \to \Gamma_H|_{\text{min}}$
- $WW \to WW$ unitarity: $g_{WWH} \lesssim g_{WWH}^{\text{SM}} \quad \to \Gamma_H|_{\text{max}}$ [HiggsSignals]
- SFitter assumption $\Gamma_{\text{tot}} = \sum_{\text{obs}} \Gamma_j$ [plus generation universality]

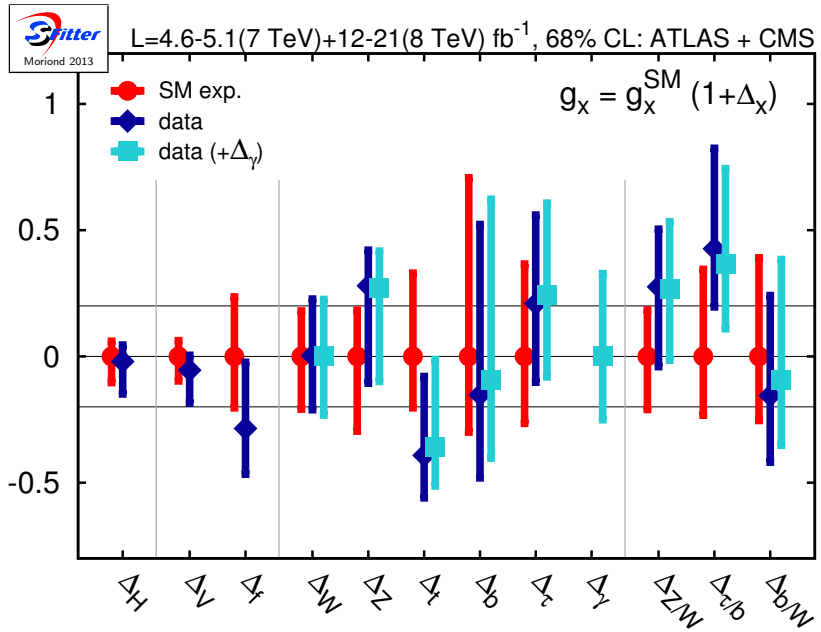
Status and challenges

Status [Lopez-Val, TP, Rauch; Cranmer, Kreiss, Lopez-Val, TP]

- publicly available input:

  signal and background event numbers
  key systematics
  theory uncertainties flat
  backwards MC engineering
- simple analyses: $\Delta_H, \Delta_V, \Delta_f$
- coupling ratios not yet an improvement

$\Rightarrow$ six couplings from data



Challenges

- correlations never 100% included
- separation of production processes vs experimental categories
- theory errors not yet limiting, but getting there

  error on the $t\bar{t}$ cross section in $H \to WW$?
  jet veto survival probabilities
  interface for new predictions in central value and error
- distributions the big problem
- profile likelihood vs Bayesian integrals

2HDM as UV completion

EFT-like approach to coupling measurements

- $\Delta_x \neq 0$ violating renormalization, unitarity,...

$\Rightarrow$ (1) define consistent 2HDM, decouple or ignore heavy states
(2) fit 2HDM parameters, plot SM couplings
(3) fit SM couplings to compare

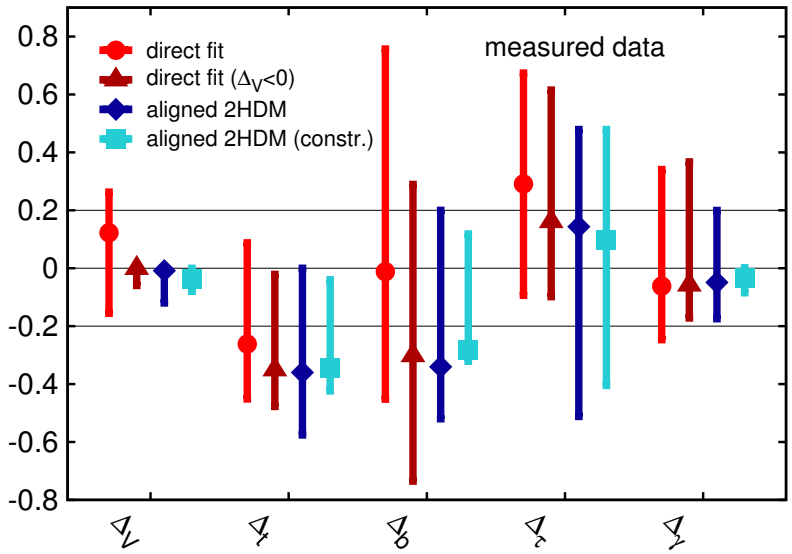
Yukawa-aligned 2HDM

- $\Delta_V \leftrightarrow (\beta - \alpha)$ $\quad \Delta_{b,t,\tau} \leftrightarrow \{\beta, \gamma_{b,\tau}\}$ $\quad \Delta_\gamma \leftrightarrow m_{H^\pm}$
- Δ_g not free parameter, top partner?
- $\Delta_V > 0$ and $\Delta_W \neq \Delta_Z$ from loops

UV-complete vs SM coupling fits

- SM fit and constrained 2HDM fit agree
- serious 2HDM fit improved

$\Rightarrow$ keep SM couplings fit!



Questions

Big questions

- is it really the Standard Model Higgs?
- is there new physics in/outside the Higgs sector?

Interpretations of Higgs measurements

- Higgs couplings particularly universal for rates
- effective theories handy and well defined, but less universal
- do not trust us theorists when they offer 'big picture'

Lectures on LHC Physics, Springer, arXiv:0910.4182 updated under `www.thphys.uni-heidelberg.de/~plehn/`

Much of this work was funded by the BMBF Theorie-Verbund which is ideal for relevant LHC work

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Extended Higgs sectors

One-dimensional description of signal strengths [Cranmer, Kreiss, Lopez-Val, TP]

- decoupling defined through the massive gauge sector

$$\frac{g_V}{g_V^{\text{SM}}} = 1 - \frac{\xi^2}{2} + \mathcal{O}(\xi^3) \qquad \Leftrightarrow \qquad \Delta_V = -\frac{\xi^2}{2} + \mathcal{O}(\xi^3)$$

- dark singlet

$$\Gamma_{\text{inv}} = \xi^2 \Gamma_{\text{SM}} \qquad \mu_{p,d} = \frac{\Gamma_{\text{SM}}}{\Gamma_{\text{SM}} + \Gamma_{\text{inv}}} = 1 - \xi^2 + \mathcal{O}(\xi^3) < 1$$

- mixing singlet [no anomalous decays]

$$1 + \Delta_x = \cos\theta = \sqrt{1 - \xi^2} \qquad \mu_{p,d} = 1 - \xi^2 + \mathcal{O}(\xi^3) < 1$$

- composite Higgs

$$\xi = \frac{v}{f} \qquad \frac{\mu_{\text{WBF},d}}{\mu_{\text{GF},d}} = \frac{(1-\xi^2)^2}{(1-2\xi^2)^2} = 1 + 2\xi^2 + \mathcal{O}(\xi^3) > 1$$

- additional doublet [type-X fermion sector]

$$1 + \Delta_V = \sin(\beta - \alpha) = \sqrt{1 - \xi^2}$$

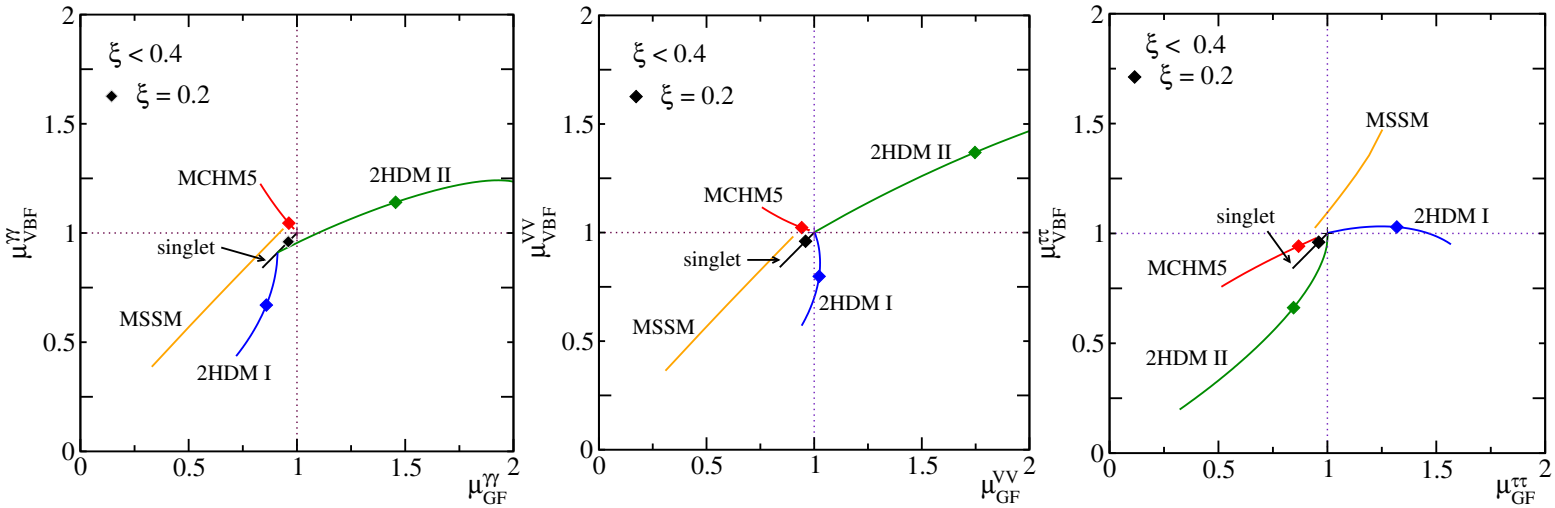
- MSSM [plus tan β]

$$\xi^2 =\simeq \frac{m_h^2\,(m_Z^2 - m_h^2)}{m_A^2 (m_H^2 - m_h^2)} \sim \frac{m_Z^4\,\sin^2(2\beta)}{m_A^4}$$

Extended Higgs sectors

Effect on signal strengths

- decay–diagonal and production–diagonal correlations
- new physics scenarios in 2 dimensions



- theory uncertainties with direction

⇒ robustness measure