Effective Lagrangian analysis of observed Higgs-like boson

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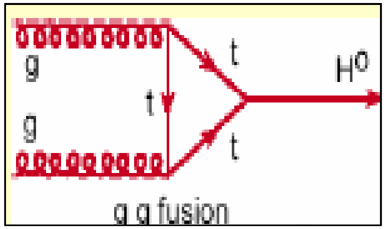
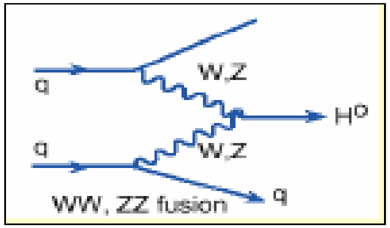
Higgs-like Boson

M = 125 GeV

Production of Higgs-boson:

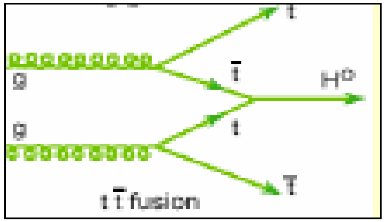


Gluon fusion



Vector boson fusion

Assotiated production



Top quark fusion

Higgs Signals:

γγ

$$gg \longrightarrow H \longrightarrow \gamma\gamma$$
$$pp \longrightarrow t\bar{t}H \longrightarrow t\bar{t}\gamma\gamma$$
$$pp \longrightarrow WH \setminus ZH \longrightarrow W\gamma\gamma \setminus Z\gamma\gamma$$

γγ(vbf)

$$pp \longrightarrow Hjj \longrightarrow \gamma\gamma jj$$

WW

$$gg \longrightarrow H \longrightarrow W^+W^- \longrightarrow 2l, 2\nu$$
$$pp \longrightarrow Hjj \longrightarrow W^+W^- jj \longrightarrow 2l, 2\nu, jj$$

τ τ

$$gg \longrightarrow H \longrightarrow \tau\tau$$
$$pp \longrightarrow Hjj \longrightarrow \gamma\gamma jj$$
$$pp \longrightarrow t\bar{t}H \longrightarrow t\bar{t}\tau\tau$$
$$pp \longrightarrow WH \setminus ZH \longrightarrow W\tau\tau \setminus Z\tau\tau$$

b b

$$pp \longrightarrow WH \setminus ZH \longrightarrow Wb\bar{b} \setminus Zb\bar{b}$$

ZZ

$$gg \longrightarrow H \longrightarrow ZZ \longrightarrow 4l$$
$$pp \longrightarrow Hjj \longrightarrow ZZjj \longrightarrow 4l, jj$$

Signal strength

Available experimental data provides the signal strength:

$$\mu_i = \frac{[\sum_j \sigma_{j\to h} Br(h \to i)]_{obs}}{[\sum_j \sigma_{j\to h} Br(h \to i)]_{SM}}$$

where i is a number of Higgs boson decay channel and
j is the number of Higgs production process for a given final state.

Best fit value of a signal strength can be expressed using
the observed number of signal events $\mathbf{N}_{\mathbf{obs}}$,
the number of background events $\mathbf{N}_{\mathbf{backgr}}$ and
the number of signal events calculated in the SM $\mathbf{N}_{\mathbf{signal,i}}$

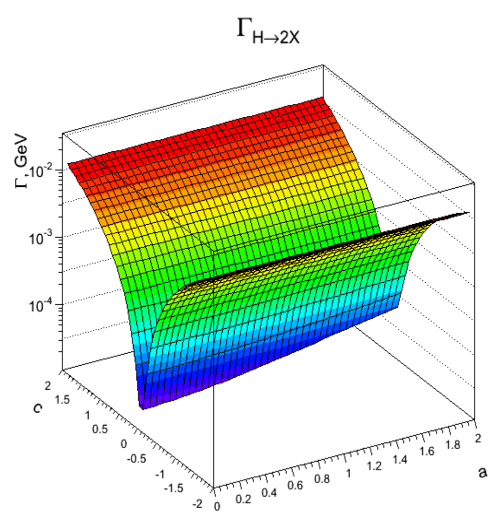
$$\hat{\mu}_i = \frac{N_{obs,i} - N_{backgr,i}}{N^{SM}_{signal,i}}$$

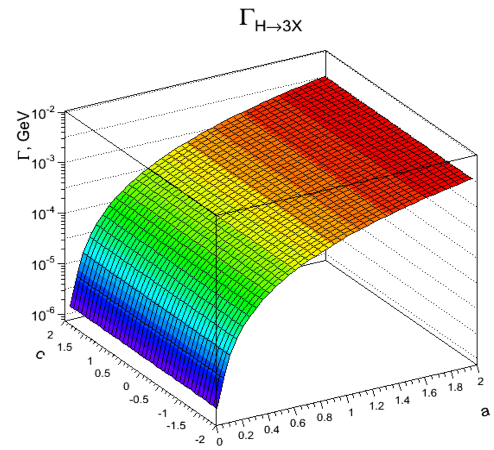
Global χ^2 defined as:

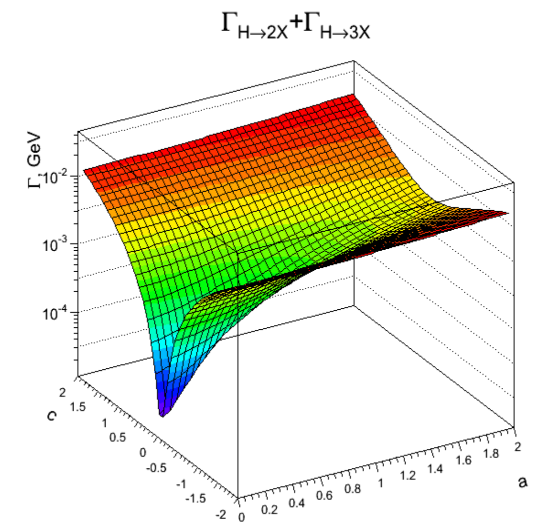
$$\chi^2(\mu_i) = \sum_{i}^{N_{ch}} \frac{(\mu_i - \hat{\mu}_i)^2}{\sigma_i^2}$$

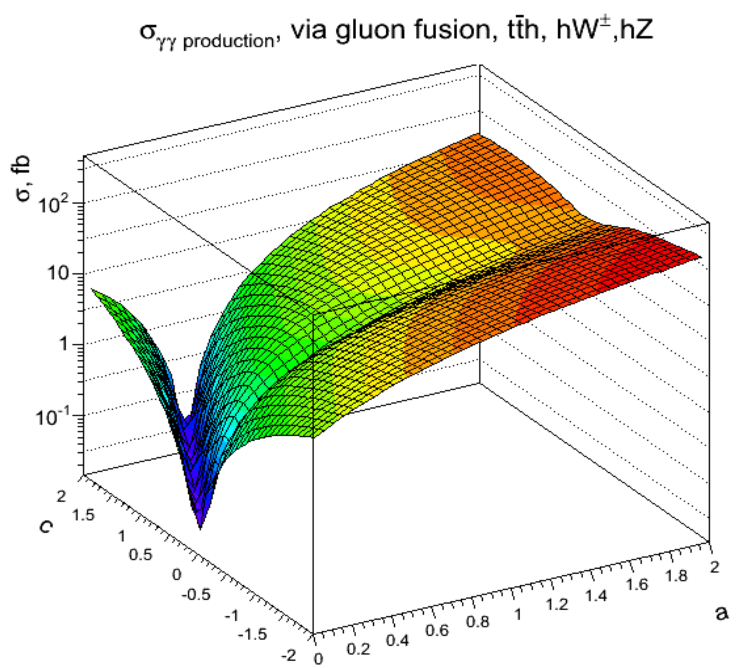
for the number of production channels N_{ch} . Theoretical predictions for $\sigma_{j \to h}$ and related errors can be found on the LHC Higgs Cross Sections WG webpage
Minimization of $\chi 2 \rightarrow \chi 2$ gives us the 1σ, 2σ and 3σ regions $\chi 2 = \chi 2_{min} + \Delta\chi 2$ where $\Delta\chi 2$ is defined by cumulative distribution function.

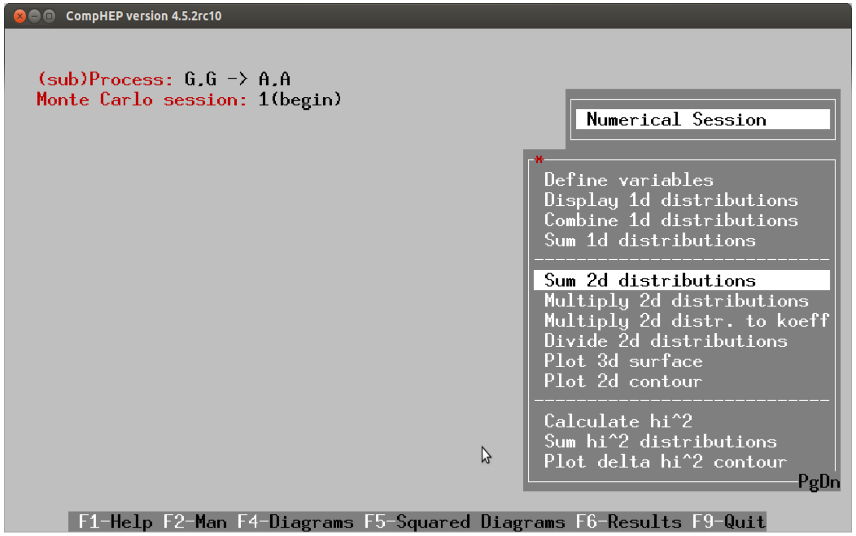
Table calculations in CompHEP



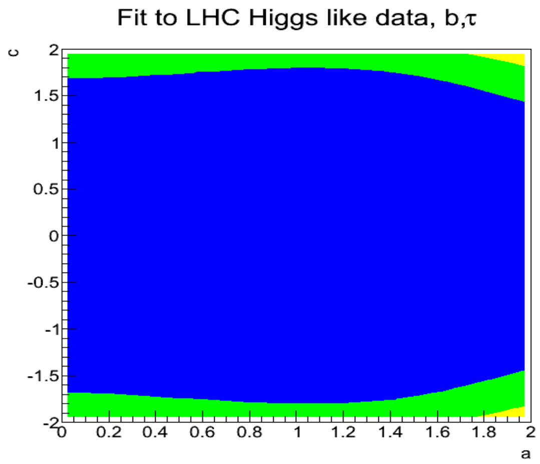


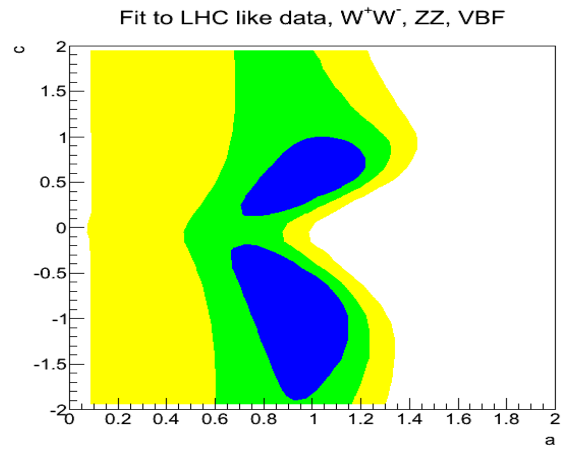


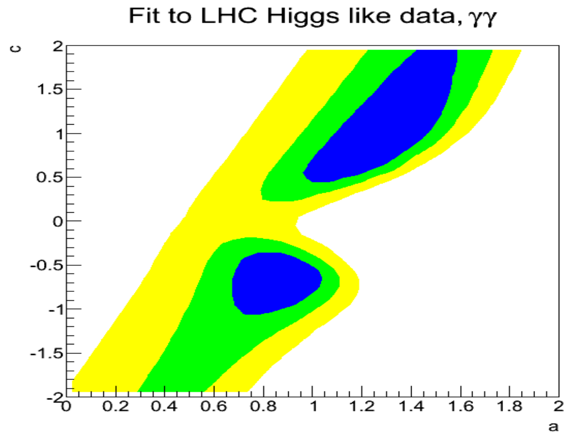


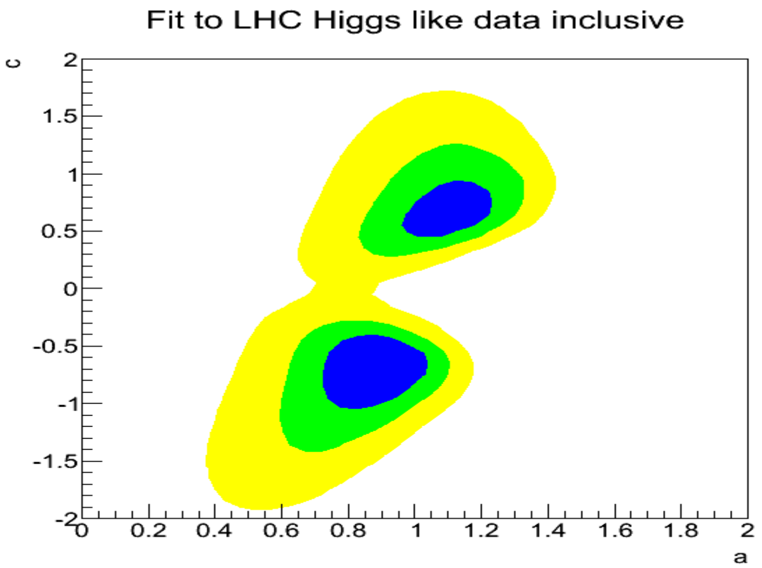


X^2 analysis and contour plots in CompHEP

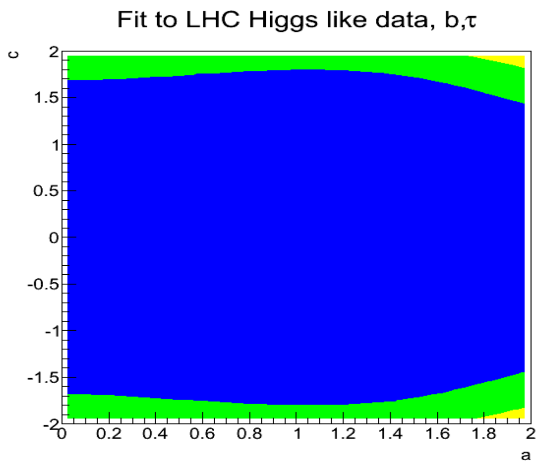


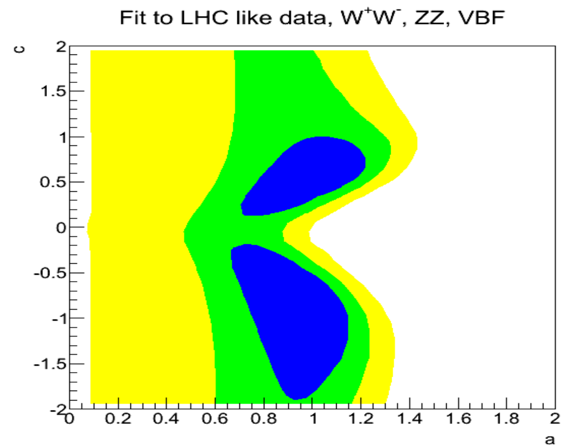


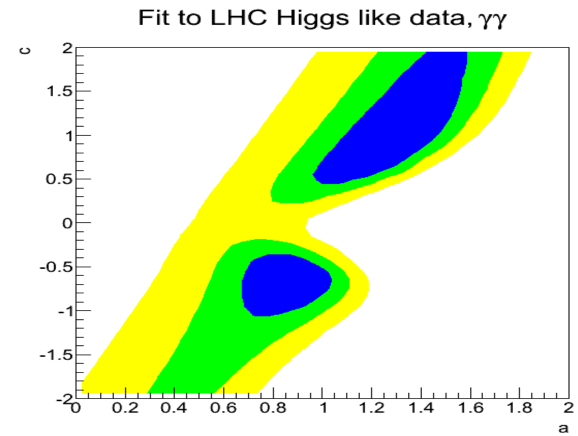


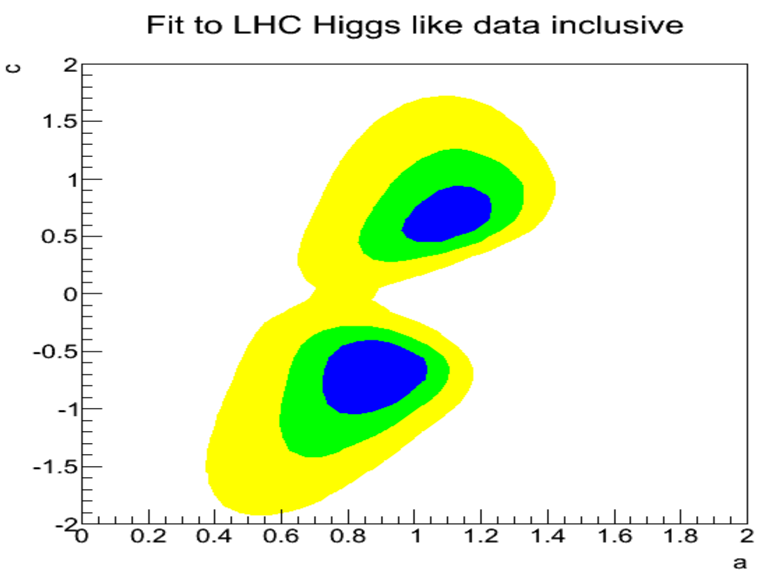


χ^2 analysis and contour plots in CompHEP



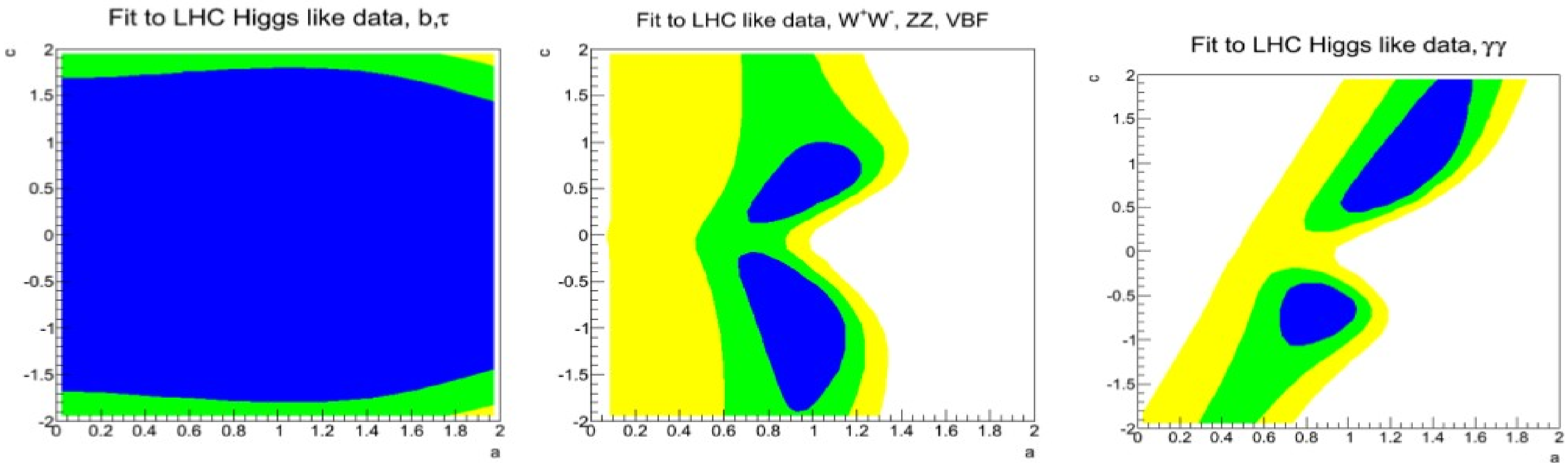




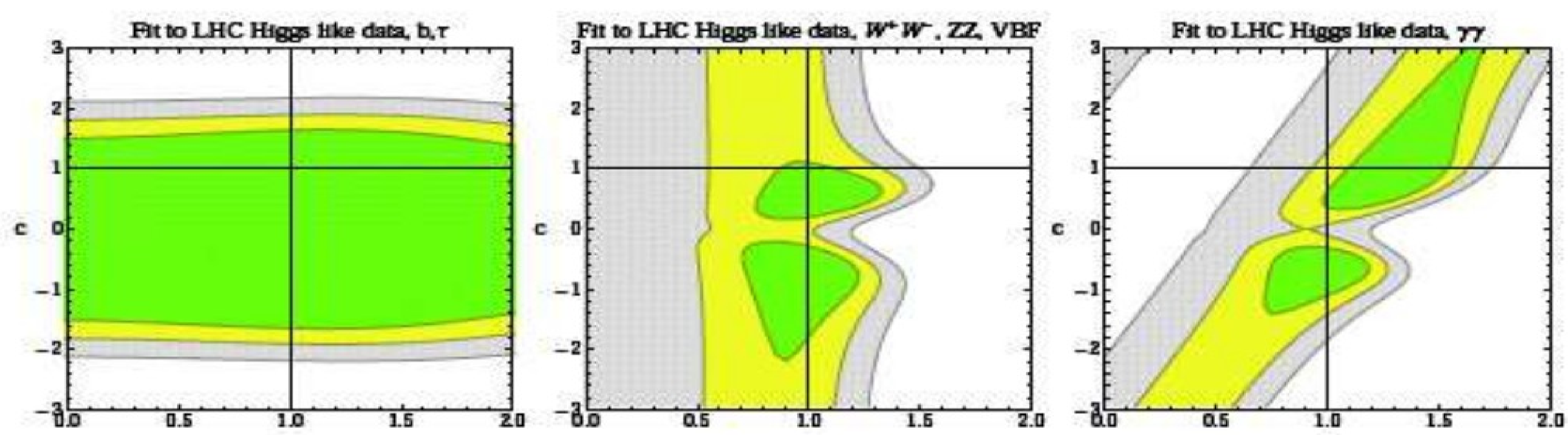


Comparison of CompHEP calculations with well known results

Partial χ2 fit in the (a, c) plane

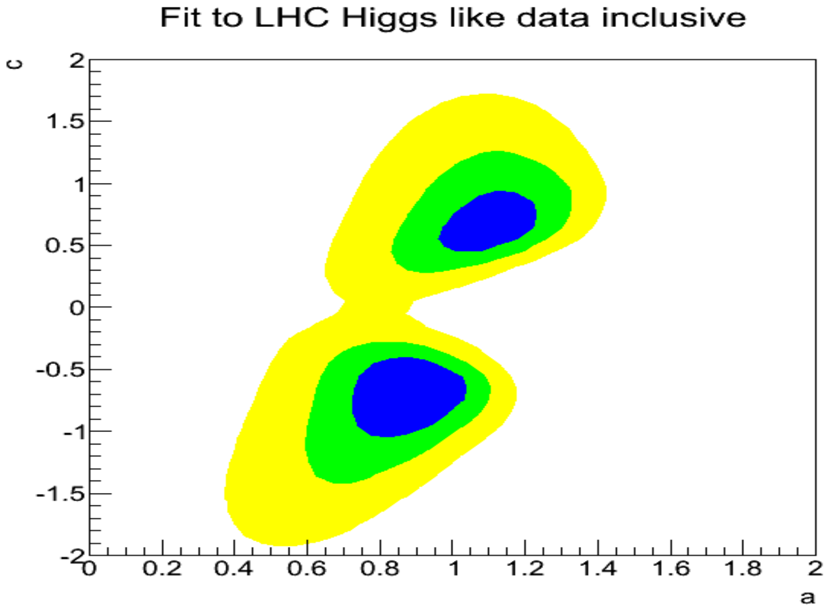


CompHEP

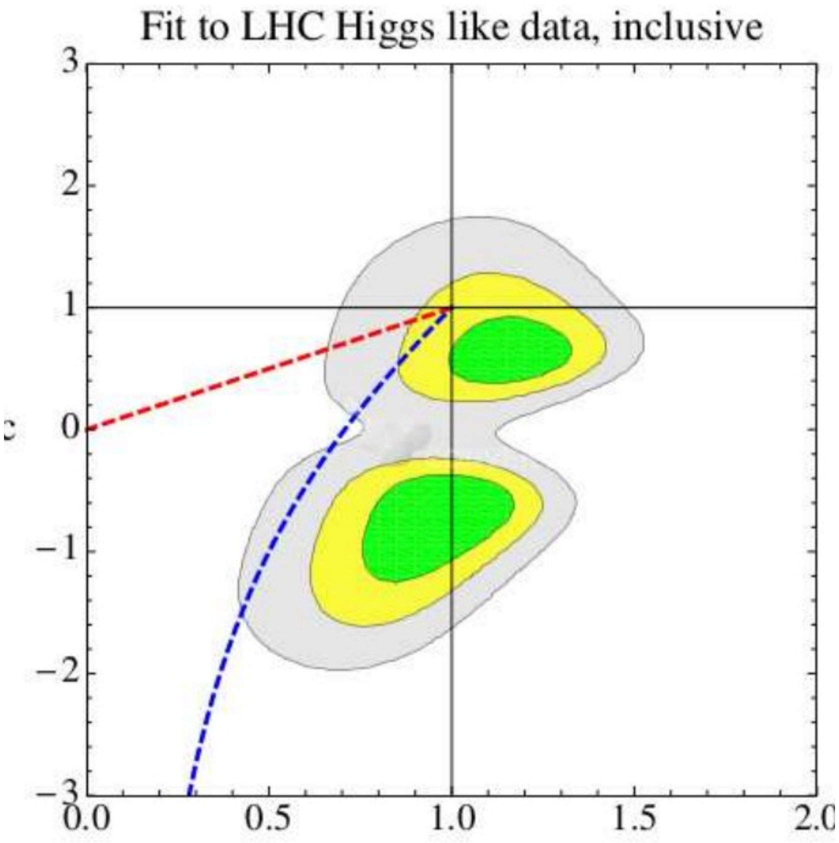


J.R. Espinosa, C. Grojean, M. Muhlleitner, M. Trott, Fingerprinting Higgs Suspects at the LHC, JHEP 1205, 097 (2012)

Global χ2 fit in the (a, c) plane (based of 2012 data)

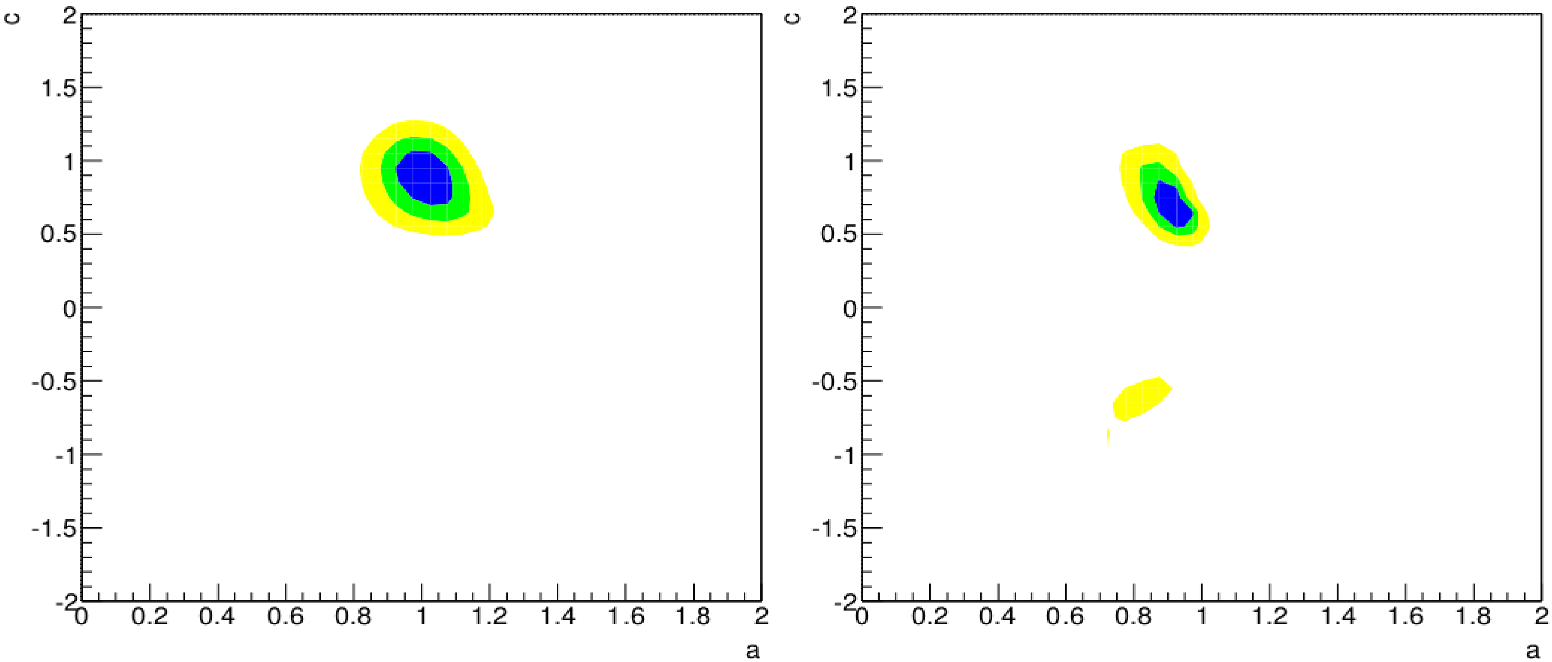


CompHEP



JHEP 1205, 097 (2012)

Global χ2 fit in the (a, c) plane
(based of 2013 data)



CompHEP

Global χ2 fits in the (a, c) plane. (left) - calculated without VBF diagrams in the γγ, WW and ZZ channels, (right) - calculated with VBF diagrams in the γγ, W W and ZZ channels
based on preliminary 2013 data

Complete set of gauge invariant dim 6 operators:

W. Buchmuller, D. Wyler, Effective lagrangian analysis of new interactins and flavour conservation, Nucl.Phys. B268 (1986) 621

- *scalar-gauge boson sector*

$$O_{\Phi G} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})G^a_{\mu\nu}G^{a\mu\nu} \qquad O_{\Phi G} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})G^a_{\mu\nu}\tilde{G}^{a\mu\nu}$$
$$O_{\Phi B} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})B_{\mu\nu}B^{\mu\nu} \qquad O_{\Phi B} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})B_{\mu\nu}\tilde{B}^{\mu\nu}$$
$$O_{\Phi W} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})W^i_{\mu\nu}W^{i\mu\nu} \qquad O_{\Phi W} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})W^i_{\mu\nu}\tilde{W}^{i\mu\nu}$$
$$O^{(1)}_{\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})D_\mu\Phi^\dagger D^\mu\Phi$$

- *scalar-fermion sector*

$$O_{t\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})(\bar{Q}_L\Phi^c t_R)$$
$$O_{b\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})(\bar{Q}_L\Phi b_R)$$
$$O_{\tau\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})(\bar{L}_L\Phi\tau_R)$$

where dual tensor $\tilde{F}_{\mu\nu} = \epsilon_{\mu\nu\gamma\delta}F_{\gamma\delta}$.

We avoid mixing in the gauge field kinetic terms by subtraction of $v^2/2$

For the same reason the a operator $O_{WB} = (\Phi^\dagger\tau^a\Phi)W^a_{\mu\nu}B^{\mu\nu}$ is excluded.

Dim 6 operators and corresponding vertices

Effective operators	Triple vertices	Feynman rules
$O_{t\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})(-\lambda_t)(\bar{Q}_L\Phi^c t_R)$	$\bar{t}\quad t\quad H$	$-M_t \cdot \frac{v}{\Lambda^2} \cdot C_{t\Phi}$
$O_{b\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})(-\lambda_b)(\bar{Q}_L\Phi b_R)$	$\bar{b}\quad b\quad H$	$-M_b \cdot \frac{v}{\Lambda^2} \cdot C_{b\Phi}$
$O_{\tau\Phi} = (\Phi^\dagger\Phi - \frac{v^2}{2})(-\lambda_\tau)(\bar{L}_L\Phi\tau_R)$	$\bar{\tau}\quad \tau\quad H$	$-M_\tau \cdot \frac{v}{\Lambda^2} \cdot C_{\tau\Phi}$
$O_{\Phi G} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})G^a_{\mu\nu}G^{a\mu\nu}$	$G_\mu\quad G_\nu\quad H$	$-2 \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi G} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
$O_{\Phi B} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})B_{\mu\nu}B^{\mu\nu}$	$A_\mu\quad A_\nu\quad H$	$-2 \cdot c_W^2 \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi B} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
	$A_\mu\quad Z_\nu\quad H$	$+2 \cdot c_W \cdot s_W \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi B} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
	$Z_\mu\quad Z_\nu\quad H$	$-2 \cdot s_W^2 \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi B} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
$O_{\Phi W} = \frac{1}{2}(\Phi^\dagger\Phi - \frac{v^2}{2})W^i_{\mu\nu}W^{i\mu\nu}$	$A_\mu\quad A_\nu\quad H$	$-2 \cdot s_W^2 \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi W} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
	$A_\mu\quad Z_\nu\quad H$	$-2 \cdot c_W \cdot s_W \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi W} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
	$Z_\mu\quad Z_\nu\quad H$	$-2 \cdot c_W^2 \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi W} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
	$W^+_\mu\quad W^-_\nu\quad H$	$-2 \cdot \frac{v}{\Lambda^2} \cdot C_{\Phi W} \cdot (g^{\mu\nu}p_1p_2 - p_1^\nu p_2^\mu)$
$O^{(1)}_\Phi = (\Phi^\dagger\Phi - \frac{v^2}{2})D_\mu\Phi^\dagger D^\mu\Phi$	$W^+_\mu\quad W^-_\nu\quad H$	$M_W^2 \cdot \frac{v}{\Lambda^2} \cdot C^{(1)}_\Phi \cdot g^{\mu\nu}$
	$Z_\mu\quad Z_\nu\quad H$	$M_Z^2 \cdot \frac{v}{\Lambda^2} \cdot C^{(1)}_\Phi \cdot g^{\mu\nu}$

Combining contributions from different operators we get a complete set of Feynman rules

Triple vertices	Feynman rules
$\bar{t} \quad t \quad H$	$-\frac{M_t}{v} \cdot \left[1 + C_{t\Phi} \cdot \frac{v^2}{\Lambda^2}\right]$
$\bar{b} \quad b \quad H$	$-\frac{M_b}{v} \cdot \left[1 + C_{b\Phi} \cdot \frac{v^2}{\Lambda^2}\right]$
$\bar{\tau} \quad \tau \quad H$	$-\frac{M_\tau}{v} \cdot \left[1 + C_{\tau\Phi} \cdot \frac{v^2}{\Lambda^2}\right]$
$G_\mu \quad G_\nu \quad H$	$-2 \cdot C_{\Phi G} \cdot \frac{v}{\Lambda^2}(g^{\mu\nu} p_1 p_2 - p_1^\nu p_2^\mu)$
$A_\mu \quad A_\nu \quad H$	$-2 \cdot (c_W^2 \cdot C_{\Phi B} + s_W^2 \cdot C_{\Phi W}) \cdot \frac{v}{\Lambda^2}(g^{\mu\nu} p_1 p_2 - p_1^\nu p_2^\mu)$
$A_\mu \quad Z_\nu \quad H$	$+2 \cdot c_W \cdot s_W \cdot (C_{\Phi B} - C_{\Phi W}) \cdot \frac{v}{\Lambda^2}(g^{\mu\nu} p_1 p_2 - p_1^\nu p_2^\mu)$
$Z_\mu \quad Z_\nu \quad H$	$+\frac{2}{v} \cdot \left[M_Z^2 \cdot (1 + \frac{v^2}{2\Lambda^2} \cdot C_\Phi^{(1)}) \cdot g^{\mu\nu} - (s_W^2 \cdot C_{\Phi B} + c_W^2 \cdot C_{\Phi W}) \cdot \frac{v^2}{\Lambda^2}(g^{\mu\nu} p_1 p_2 - p_1^\nu p_2^\mu)\right]$
${W^+}_\mu \quad {W^-}_\nu \quad H$	$+\frac{2}{v} \cdot \left[M_W^2 \cdot (1 + \frac{v^2}{2\Lambda^2} \cdot C_\Phi^{(1)}) \cdot g^{\mu\nu} - C_{\Phi W} \cdot \frac{v^2}{\Lambda^2}(g^{\mu\nu} p_1 p_2 - p_1^\nu p_2^\mu)\right]$

The Feynman rules inserted into the CompHEP
and are used for calculation the cross sections for Higgs production processes

Conclusion and results:

- We choose the basis in space of dim 6 operators.
- We significantly expanded functions of the CompHEP package for table calculations, statistical analysis and graphical representations of results.
- For validation of our machinary we compare our calculations with well known results.
- We start calculation in frame of our basis (in progress …..)