related analyses → Gabrielli, Ilyin, Melo, Djouadi, Holik, ...

$Z\gamma h$ and $\gamma\gamma h$

in SM and beyond

M. KRAWCZYK
WARSAW UNIV.

(collaboration with I. Ginzburg, P. Osland)

SM: Z — Z — H_{SM} ~ 1

2HDM: Z — Z — h ~ $\sin(\beta-\alpha)$ ~ 1

MSSM: $M_h < M_H$

for $\beta-\alpha = \frac{\pi}{2}$ as SM

Z — Z — H ~ $\cos(\beta-\alpha)$ ~ 0

Consider:

$Z\gamma h$ $\gamma\gamma h$ and $gg h$ for $M_h = 100$ GeV

q, W^+, H^+ q

LC (e^+e^-, $e\gamma$, $\gamma\gamma$) TEVATRON LHC

Beyond SM

2 Higgs Doublet Model

$\phi_1 = (\quad)$ $\phi_2 = (\quad)$ $V(\phi_1, \phi_2)$

$\langle \phi_1 \rangle = v_1$ $\langle \phi_2 \rangle = v_2$

5 Higgs bosons: h, H, A
H^+, H^-

few versions CP
FCNC

Model II : CP conservation

$\phi_1 \rightarrow (\bullet)$

$\phi_2 \rightarrow (\bullet)\ (\bullet)$

(as in MSSM)

parameters : $M_h, M_H, M_A, M_{H^\pm}$

α (mixing h-H), $\tan\beta = \frac{v_2}{v_1}$, $v^2 = v_1^2 + v_2^2$

λ_5 (or $g_{hH^+H^-}$)

to be constrained by data

Result: a very light h or A may exist

Couplings : 2HDM$_{II}$ /SM

Haber, hep-[ph] 9707...
Mättig, Zoch...
M...

hbb̄ : $\frac{-\sin\alpha}{\cos\beta} = \sin(\beta-\alpha) - \tan\beta\cos(\beta-\alpha)$

htt̄ : $\frac{\cos\alpha}{\sin\beta} = \sin(\beta-\alpha) + \frac{1}{\tan\beta}\cos(\beta-\alpha)$

Abb̄ : $\tan\beta$ Att̄ = $\frac{1}{\tan\beta}$

* low $\tan\beta \to$ t
* large $\tan\beta \to$

* hZZ: $\sin(\beta-\alpha)$

A: if $\cos(\beta-\alpha)=0$ ($\Leftrightarrow \sin(\beta-\alpha)=1$)

hbb̄, htt̄, hZZ ~ SM

* **B**: if $\sin(\beta-\alpha)=0$ ($\Leftrightarrow \cos(\beta-\alpha)=1$)

LEP: $\sin(\beta-\alpha)$ small for $M_h \lesssim 50$ GeV

hbb̄ opposite sign to htt̄

hZZ = 0!

|hbb̄| >> htt̄ for $\tan\beta >> 1$

very different from SM

Note: HZZ ~ ...
$M_H > 90$ GeV

in MSSM only 2 parameters indep.!

→ hep-ph/9912495

Status of 2HDM (II)

Direct searches at LEP1

- $e^+e^- \to Zh$ $\sin^2\beta-\alpha < 0.01$ for $M_h \lesssim 20$ G

- $e^+e^- \to hA$ $\cos^2\beta-\alpha$, $M_h + M_A \gtrsim 50$ GeV

→

- $e^+e^- \to f\bar{f}\,A$ (h) $\tan\beta < 20$ for $M_A \lesssim 2$ GeV; < 45 for $\lesssim 20$ GeV

- $e^+e^- \to H^+H^-$ $M_{H^+} \gtrsim 72$ GeV ($b \to s\gamma$ $M_{H^+} \gtrsim 165$ GeV) (Greub, Bourzumat 98)

Other constraints ...

- $(g-2)_\mu$ Δ_{2HDM} > 0 for light h, < 0 light A (Zochag... PR... 55 ... 199...)
- $e^+e^- \to h\gamma$ ($A\gamma$) (LEP1) $0.1 < \tan\beta \lesssim 60$ dependence on $g_{hH^+H^-}$ (Mattig, Zochowski, MK, Eur.P.J.C...)

☆ Global fit based on EW precision dat... (LEPEWWG/98-01)

Chankowski, Zochowski, MK '99

previous analysis Grant '95

data allow for one very light Higgs h or A

Global fit : EW precision data '98

SM → best $\chi^2_{SM} \approx 15.5$

2HDM → $\chi^2_{2HDM} \lesssim \chi^2_{SM} + 4$

crucial observables:

Δg ~ intermediate tan β

R_b - especially for low & high tan β

H^+ contribution < 0

$$\sim \left(\frac{m_t}{M_2}\right)^2 \left(\frac{1}{\tan\beta}\right)^2 + \left(\frac{m_b}{M_2}\right)^2 (\tan\beta)^2$$

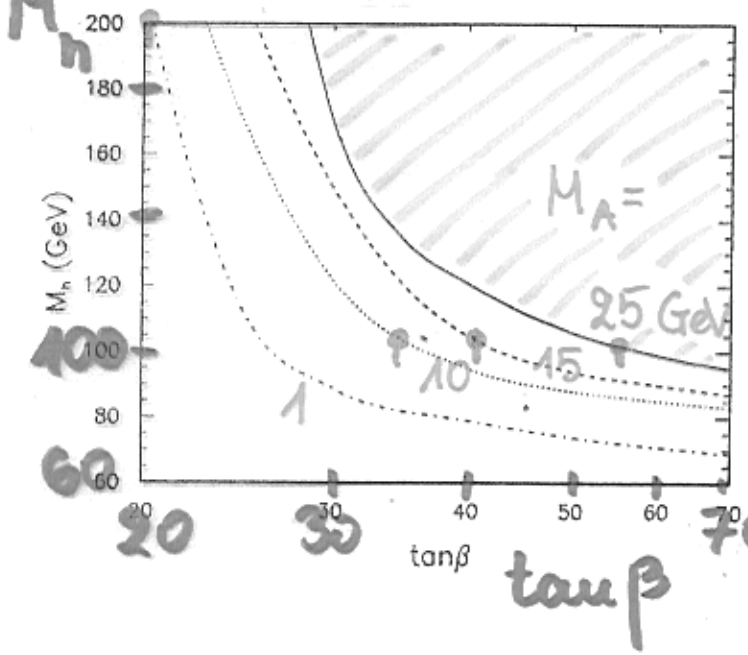
$R_b^{exp} = 0.21656 \pm 0.00074$

(0.9 standard deviation below R_b^{SM})

h, H cont's > 0 if $M_A \lesssim 100$ GeV and splitting $\Delta M(A,H)$ not too large

$b \to s\gamma$ → $M_{H^\pm} \gtrsim 165\text{-}200$ GeV

light A & large tanβ



⇔ upper limit on M_h

↑ limits from Yukawa process (LEP1)

Conclusion:

Global fit to EW precision data '98 within 2HDM (II)

good $\chi^2 \approx \chi^2_{SM}$ for $\begin{cases} \underline{M_h \leq 20\text{-}30\ \text{GeV}} \\ \underline{M_A \leq 20\text{-}30\ \text{GeV}} \end{cases}$

$\underline{H^\pm}$, $\underline{H}$ heavier and partly constrained...

$Z\gamma h$ & $gg h$

global fit Chankowski Zochowski Mc 99

2HDM (II):

- M_h — if $M_h \lesssim 20$-30 GeV → $M_{H^+} \lesssim 600$ GeV
- M_H — $\tan\beta \gtrsim 2$ $M_H \simeq 90$ GeV; $\tan\beta \lesssim 2$ $M_H \lesssim 1$ TeV
- M_{H^+} — $\gtrsim 165$ GeV { Grenob Bourzumati 98
- $\sin(\beta-\alpha)$ — $0 \lesssim \sin\beta-\alpha \lesssim 1$ for $M_h \sim 100$ GeV
- $\tan\beta$*

⇕ role of $h \leftrightarrow H$

* past. approach $2 \lesssim \tan\beta \lesssim 30$

Taking into account all constraints the main goal
→ discrimination between SM and 2HDM (also MSSM) scalar h

if h decays to $f\bar{f}$
WW/ZZ as in SM

Conclusion:

$Zh\gamma$ and $\gamma\gamma h$ couplings may help to discriminate SM - 2HDM - MSSM Higgs boson h even for $\sin(\beta-\alpha)=1$ case where h decays into $f\bar{f}$, WW/ZZ as H_{SM}