Young Scientists Forum

Moriond 2012 ElectroWeak Interactions and Unified Theories

A vectophobic 2HDM in the light of the LHC

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Accidental Symmetries

The Custodial Symmetry

SM

Accidental symmetry of the scalar potential

$$SU(2)_L \times SU(2)_R \xrightarrow{SSB} SU(2)_V$$

Broken by $Y_b \ll Y_t$

Protects the tree-level mass relation

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = 1$$

2HDM

$$\Phi_1 \ni \left\{ \begin{array}{c} G^+ \\ G^0 \\ G^- \end{array} \right\} \oplus \{h^0 + \frac{v}{\sqrt{2}}\};$$

$$\Phi_2 \ni \left\{ \begin{array}{c} H^+ \\ A^0 \\ H^- \end{array} \right\} \oplus \{H^0\} \text{ or } \left\{ \begin{array}{c} H^+ \\ H^0 \\ H^- \end{array} \right\} \oplus \{A^0\}$$

$\leftrightarrow$

The Flavour Symmetry

SM

Accidental symmetry of the matter lagrangian

$$U(3)^3 = U(3)_Q \times U(3)_u \times U(3)_d$$

Broken by $Y_{u,d} \neq 0$.

Flavour Conservation in NC

2HDM

$$\mathcal{L}_{Yukawa} = -\bar{Q}_L(Y_d\Phi_1 + Z_d\Phi_2)d_R - \bar{Q}_L(Y_u\tilde{\Phi}_1 + Z_u\tilde{\Phi}_2)u_R$$

$Y_{u,d}$ = SM-like, $Z_{u,d}$ generate FCNC (A^0, H^0)

MFV $\Rightarrow$ Sources of Flavour Violation = SM ($Y_{u,d}$)
$\Rightarrow$ Suppressed FCNCs

$$\begin{aligned} Z_d &= \{\delta_0 + \delta_1 Y_u Y_u^\dagger + \delta_2 (Y_u Y_u^\dagger)^2\} Y_d \\ Z_u &= \{\upsilon_0 + \upsilon_1 Y_u Y_u^\dagger + \upsilon_2 (Y_u Y_u^\dagger)^2\} Y_u \end{aligned}$$

Flavour Constraints

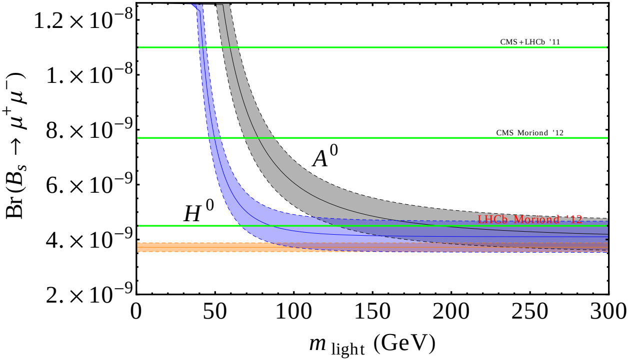

Figure: $\mathcal{B}(B_s \to \mu^+\mu^-)$ as a function of the H^0 and A^0 masses

LHC Constraints

Diphoton channel: H^0 and A^0 are vectophobic ($g_{HVV} = g_{AVV} = 0$ with $V = W^{\pm}, Z^0$)

$$R = \frac{\sigma \times \mathcal{B}(H^0, A^0 \to \gamma\gamma)}{\sigma \times \mathcal{B}(h^0 \to \gamma\gamma)^{SM}}$$

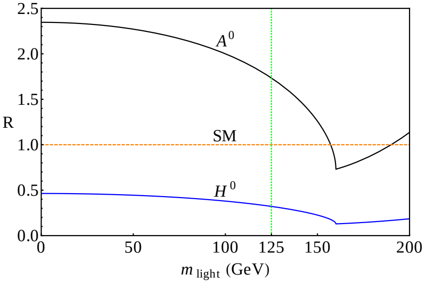

Figure: The ratio R as a function of m_{H^0, A^0} masses

Two possible hierarchies

1. $m_{A^0(H^0)} < m_{H^0(A^0)} \approx m_{H^\pm} < m_{h^0}$

   $m_{h^0} > 2m_{H^0(A^0)}$

   one resonance in the diphoton channel

   no resonance in the W^+W^- and Z^0Z^0 decays

2. $m_{h^0}, m_{A^0(H^0)} < m_{H^0(A^0)} = m_{H^\pm}$

   two resonances in the diphoton channel

   one in the W^+W^- and Z^0Z^0 decays

W^+W^- and Z^0Z^0 production and decay observations $\to$ crucial!!!

THANK YOU!

$\Delta F = 2$ mixings

Tree-level A^0 and H^0 mediated FCNC $\Rightarrow (Z_d)_{ij} = 4 G_F \delta_1 (V_{ti}^* V_{tj}) m_t^2 \frac{m_{d_j}}{v}$

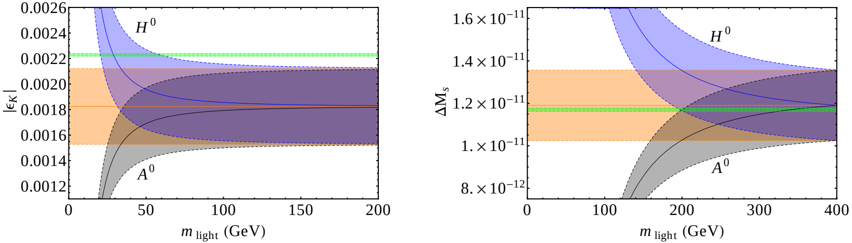

Figure: ϵ_K and ΔM_s as a function of the H^0 and A^0 masses

$$\langle \bar{M}^0 | \mathcal{H}_{eff}^{\Delta F=2} | M^0 \rangle \simeq \langle \bar{M}^0 | \mathcal{H}_{eff}^{\Delta F=2} | M^0 \rangle^{SM} \left[1 + 16\pi^2 x \delta_1^2 m_M^2 \left(\frac{1}{m_{H^0}^2} - \frac{1}{m_{A^0}^2} \right) \right]$$

$$x = \frac{2 m_t^4}{m_W^2 v^2 S_0(x_t)}$$

$B_s \to \mu^+\mu^-$ decay

SM operator $Q_A = (\bar{b}_L \gamma^\mu s_L)(\bar{\mu}\gamma_\mu\gamma_5\mu)$; new operators $\begin{cases} H^0 \to Q_S = m_b(\bar{b}_R s_L)(\bar{\mu}\mu) \\ A^0 \to Q_P = m_b(\bar{b}_R s_L)(\bar{\mu}\gamma_5\mu) \end{cases}$

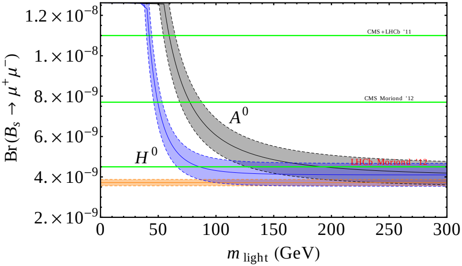

Figure: The $B_s \to \mu^+\mu^-$ branching ratio as a function of the H^0 and A^0 masses

$$\mathcal{B}(B_s \to \mu^+\mu^-) = \mathcal{B}(B_s \to \mu^+\mu^-)^{SM}\left[\left(1 + m_{B_s}^2 \frac{C_P}{C_A}\right)^2 + \left(1 - \frac{4m_\mu^2}{m_{B_s}^2}\right) m_{B_s}^4 \frac{C_S^2}{C_A^2}\right]$$

$$C_{S(P)} = \frac{\Delta}{m^2_{H^0(A^0)}}; \qquad \Delta = \frac{4\pi^2\delta_1\lambda_0 m_t^2}{M_W^2}.$$

Diphoton signal at the LHC

H^0 and A^0 are vectophobic $g_{HVV} = g_{AVV} = 0$ with $V = W^{\pm}, Z^0$

$$R = \frac{\sigma \times \mathcal{B}(H^0, A^0 \to \gamma\gamma)}{\sigma \times \mathcal{B}(h^0 \to \gamma\gamma)^{SM}}$$

$$R_{H^0/h^0}(m_{H^0} = 0 \to 125 \text{ GeV}) = (0.12 \to 0.08)\frac{(\upsilon_0 + \upsilon_1 y_t^2)^4}{(\delta_0 + \delta_1 y_t^2)^2}$$

$$R_{A^0/h^0}(m_{A^0} = 0 \to 125 \text{ GeV}) = (0.59 \to 0.44)\frac{(\upsilon_0 + \upsilon_1 y_t^2)^4}{(\delta_0 + \delta_1 y_t^2)^2}$$

Two possible hierarchies

1. $m_{A^0(H^0)} < m_{H^0(A^0)} \approx m_{H^\pm} < m_{h^0}$

   with $m_{h^0} > 2m_{H^0(A^0)}$

2. $m_{h^0}, m_{A^0(H^0)} < m_{H^0(A^0)} = m_{H^\pm}$

Role of Higgs W^+W^- and Z^0Z^0 production and decay observations

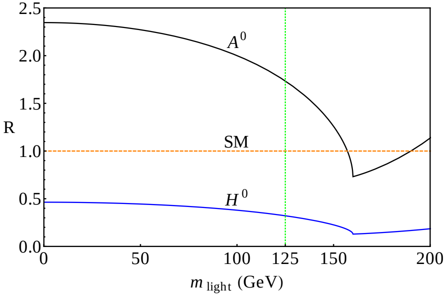

Figure: The ratio R as a function of the H^0 and A^0 masses