The $h \rightarrow \mu\tau$ decay in a two Higgs doublets model with a fourth generation of fermions

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The four family of leptons has survived analyses from EWPOs and flavor observables, but it has been put under serious pressure from Higgs searches. To maintain the viability of a leptonic heavy fourth family (hff), it is necessary to extend the scalar sector of the SM. A version of the Two Higgs Doublet Model able to accommodate the hff, where only one of the Higgs doublets couples to the hff. Then the $h \rightarrow \mu\tau$ decay is induced by flavor changing processes associated with heavy scalar bosons and heavy fourth lepton. We present the contribution of the CP-even neutral scalar boson and we find that for particular values of the free parameters, the respective branching fraction is the order 10^{-5}-10^{-7}. While the current upper bound reported by CMS is $Br(h \rightarrow \mu\tau) \approx 0.84_{-0.37}^{+0.39}$.

Fourth generation of fermions?

At the LHC Higgs boson production via gluon fusion is the dominant production mode, can be enhanced strongly if extra heavy quarks exist[1]. But, the data from ATLAS [2] and CMS [3] seems to indicate a Higgs boson that may be consistent with the standard model with three fermion generations. On other hand, the fourth generation is severely constrains on the invisible width of Z boson at the LEP, where the number of light neutrinos is N=2.9840±0.0084. However, a small mixing with the fourth family is favored in flavor changing neutral current processes and K, D, B_d, B_S mixing and other precision observables[4]. The bounds on masses of the charged lepton, heavy neutrino and the mass splitting are given by:

$$m_{\ell_4} > 100.8 GeV, \qquad m_{\nu_4} > (80.5-101.5) GeV,$$
$$|m_{\ell_4} - m_{\nu_4}| > 140 GeV$$

2HDM with four fermion generations

The possibility of extended scalar sectors that could remove the tension between Higgs physics at the LHC and a heavy fourth generation. The idea is the following[5]: In the type II two Higgs doublets model with four fermion generations (4G2HDM), the heavy Higgs field couple only to heavy fermionic state, while the lighter Higgs boson field is responsible for the mass generation of all other lighter fermions. Applying this principle, the Yukawa interaction between the CP-even neutral scalar boson and leptonic states is given by:

$$H^0 \ell_i \ell_j \sim \frac{g f_\beta^H}{\sqrt{2} m_W} \bar{\ell}_i \left[m_{\ell_i} \Sigma_{ij}^{\ell} P_R + m_{\ell_j} \Sigma_{ji}^{\ell *} P_L \right] \ell_j H^0$$

Where $f_\beta^H = \cos(\alpha)/\sin(\beta) + \sin(\alpha)/\cos(\beta)$, while Σ is a new mixing matrix in the charged leptonic sectors. The Higgs potential is a general 2HDM one, where the Higgs coupling to charged scalar bosons is the following:

$$\lambda_{hH^0H^0} = \frac{c_{\beta-\alpha}}{2v}\Big((2M^2 - 2m_{H^0}^2 - m_h^2) s_{\beta-\alpha}^2 - (4M^2 - 2m_{H^0}^2 - m_h^2) c_{\beta-\alpha}^2 + 2(3M^2 - 2m_{H^0}^2 - m_h^2)\cot(2\beta) s_{\beta-\alpha} c_{\beta-\alpha} \Big)$$

$M^2 (= m_\Phi^2 - v\lambda^2)$ describes the soft breaking scale of the Z_2 symmetry. It is convenient to introduce a parameter x defined as $x = \pi/2 - (\beta-\alpha)$, where $x \rightarrow 0$ corresponds to the SM-like limit.

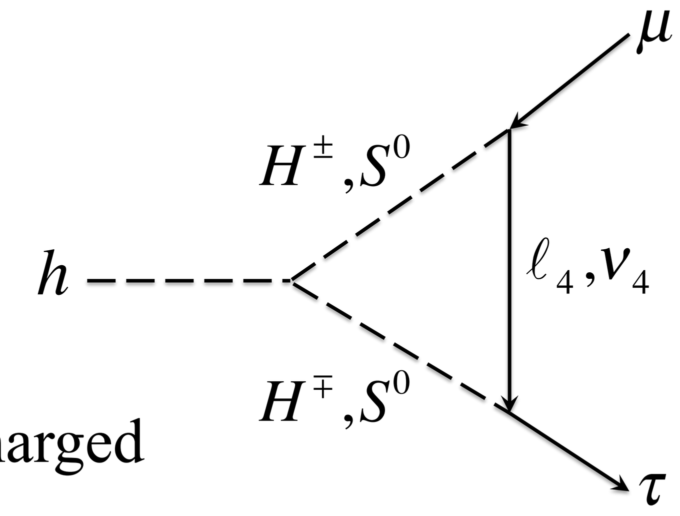
The $h \rightarrow \mu\tau$ decay

CMS experiment has reported a 2σ excess in a search for $h \rightarrow \mu\tau$, corresponding to a integrated luminosity of 19.7 fb^{-1} at $s^{1/2}$=8 TeV. The corresponding branching ratio reported is [6]:

$$Br(h \rightarrow \mu\tau) = 0.84_{-0.37}^{+0.39}\%$$

In the 4G2HDM the $h \rightarrow \mu\tau$ decay is induced at one loop level only by Higgs coupling to heavy scalar bosons.

The mathematical expression for the branching fraction is given by:



$$Br(h \rightarrow \mu\tau) \simeq \frac{m_h}{8\pi}(|A|^2 + |B|^2)$$

A and B are form factors, for charged scalar boson are given by:

$$A = \lambda_{hH^0H^0} U_{4i}^* U_{j4} \frac{m_h s_{\nu_4} g^2}{16\pi^2 m_W^2} [f_\beta^2 (s_{\ell_4}^2 + s_{\nu_4}^2) + t_\beta s_{\nu_4}^2 (t_\beta - 2f_\beta)] \Xi$$

$$B = \lambda_{hH^0H^0} U_{4i}^* U_{j4} \frac{m_h s_{\nu_4} g^2}{16\pi^2 m_W^2} [f_\beta (s_{\ell_4} + s_{\nu_4}) - s_{\nu_4} t_\beta][f_\beta (s_{\ell_4} - s_{\nu_4}) + s_{\nu_4} t_\beta] \Xi$$

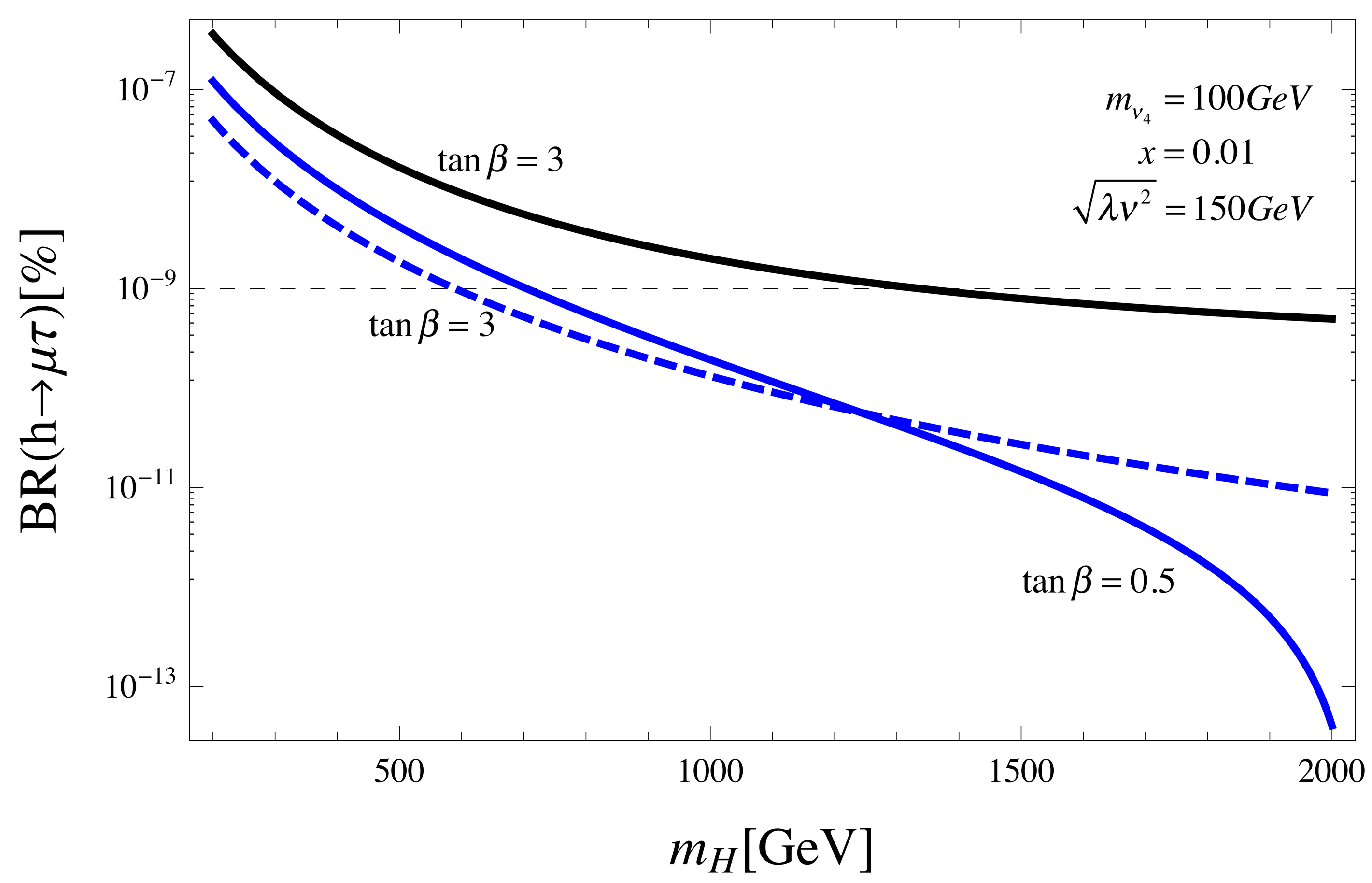
Where it ha been assumed that $U \sim \Sigma$, $s_4 = m_4/m_h$ and the Feynman parameter is the following:

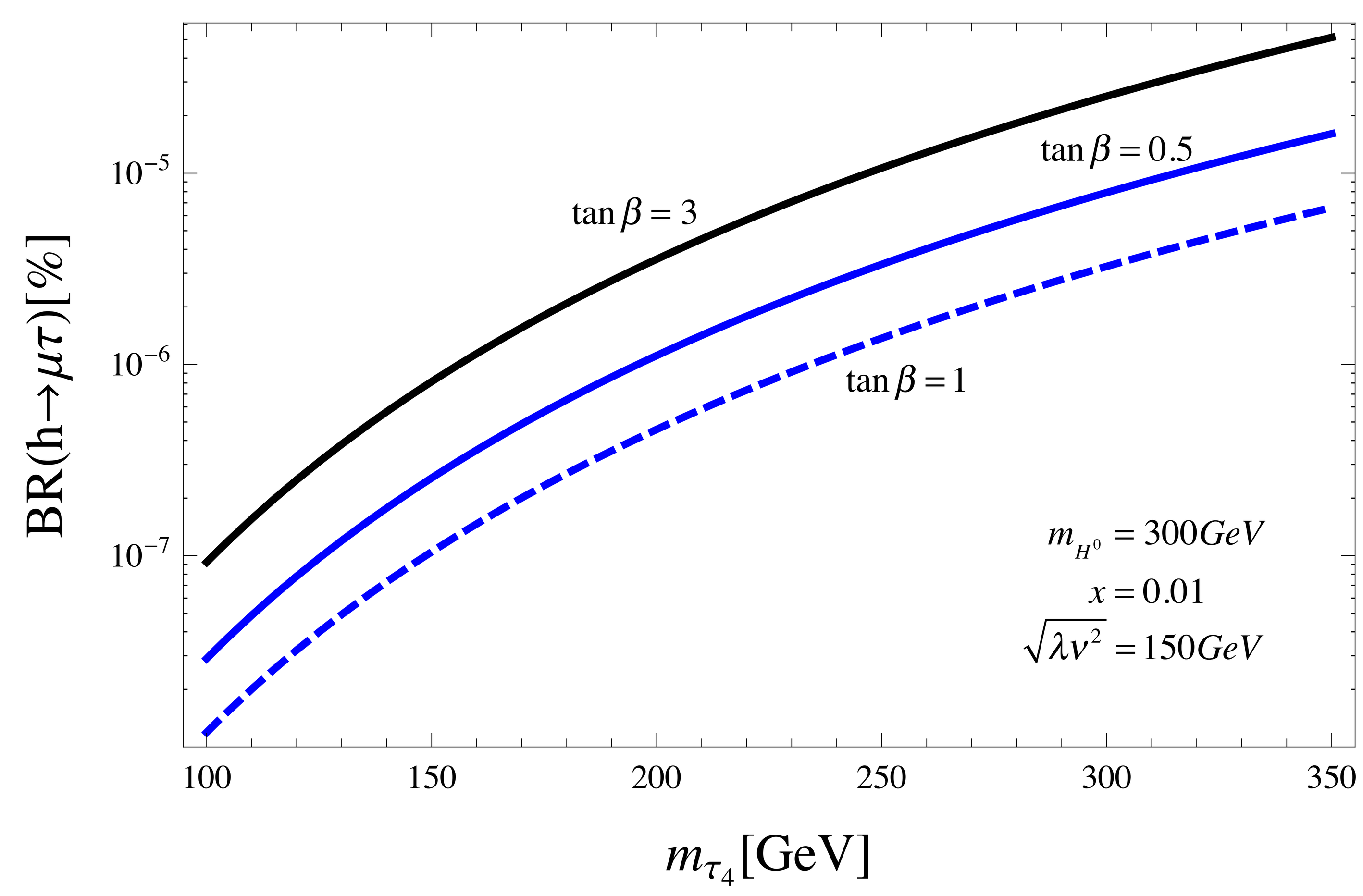
$$\Xi(s_{H^0}^2, s_{\nu_4}^2) = \int_0^1 \frac{\log[s_{H^0}^2 + (y-1)y] - \log[s_{H^0}^2 y + s_{\nu_4}^2 (y-1)]}{4(s_{H^0}^2 - s_{\nu_4}^2 - y)} dx$$

Also $s_\tau = m_\tau/m_h \approx 0$ and $s_\mu = m_\mu/m_h \approx 0$.

Results

From $\tau \rightarrow \gamma\mu$ decay [Phys.Lett.B 709 (2012) 207], we take the bound $U_{4\mu}^* U_{\tau 4} \sim 10^{-3}$ for our analysis.





References

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