The h(125 GeV) as the h_2 of the NMSSM and prospects for h_1 detection in the diphoton mode

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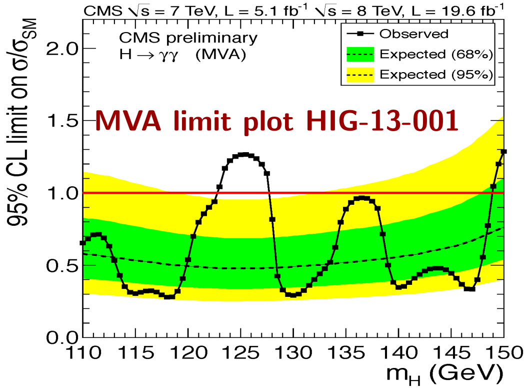
Outline

Motivation

We have found a SM-like Higgs boson around 125GeV. We searched for the Diphoton mass range 110GeV to 150GeV, how about mass range below 110GeV? From LEP, we know for SM Higgs boson this range has already been excluded. But with some BSM model, it is still allowed. arXiv:1207.1096v1



NMSSM introduction

- Supersymmetry (SUSY)–a new symmetry between fermions and bosons, a theory beyond SM.
- Minimal Supersymmetric Standard Model (MSSM), "μ problem"
- Introduce a new gauge singlet (NMSSM) only couples to the Higgs sector in a similar way as the Yukawa coupling and can give rise to an effective μ-term, solving the "μ problem" naturally.
- 7 Higgs boson, 3 CP-even, 2 CP-odd, 2-charged.

NMSSM introduction

$$
\begin{aligned}
-L_{soft} = m_{H_u}^2|H_u|^2 + m_{H_d}^2|H_d|^2 + m_S^2|S|^2 + m_Q^2|Q|^2 + \\
m_U^2|U_R|^2 + m_D^2|D_R|^2 + m_L^2|L|^2 + m_E^2|E_R|^2 + \\
h_u A_u Q \cdot H_u U_R^c - h_d A_d Q \cdot H_d D_R^c - h_e A_e L \cdot H_d E_R^c + \\
\lambda A_\lambda H_u \cdot H_d S + \frac{1}{3}\kappa A_\kappa S^3 + h.c.
\end{aligned}
\tag{1}
$$

In general, the Higgs sector of the NMSSM is described by the six parameters:

$$
\lambda, \quad \kappa, \quad A_\lambda, \quad A_\kappa, \quad \tan\beta = \langle H_u\rangle / \langle H_d\rangle, \quad \mu_{eff} = \lambda\langle S\rangle \tag{2}
$$

U. Ellwanger, C. Hugonie and A. M. Teixeira, Phys. Rept. **496** (2010):1-77

NMSSMTools

NMSSMTools is a Fortran package to compute the sparticle and Higgs masses, Higgs decay widths and couplings in the NMSSM framwork. It includes several experimental constraints: b-physics, anomalous magnetic moment of the muon $(g-2)$, relic density, direct searches for SUSY particles in LHC, and so on.
More details:
http://www.th.u-psud.fr/NMHDECAY/nmssmtools.html

All the plots I show here is only theory prediction, but we will try to compare it with data after. We use NMSSMTools410.

NMSSM Higgs boson mass

We assume h_2 corresponds to the state observed in LHC, namely its mass is around 125GeV, and the signal strength is $0.77^{+0.27}_{-0.27}$. We focus on the lightest Higgs boson h_1, the main goal is to find the proper parameter ranges which can give higher h_1 strength. We use HiggsBounds(arXiv:1311.0055, P. Bechtle) and HiggsSignal(arXiv:1305.1933, P. Bechtle) to further constrain the Higgs Boson h_2, and take all the four production modes into account.

NMSSM Higgs boson mass

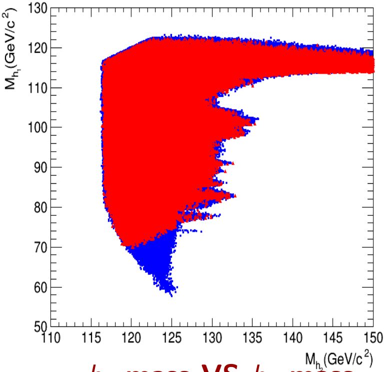
Now, after studying the property of each parameter(1-D scan), concerning the relic density, we focus on two cases:

- Suppose the LSP (with R-parity conserved) is not the single origin of dark matter, namely only upper bound considered for relic density, $relic < 0.1102$. Blue in the plots.
- Both lower and upper bound considered for relic density, $0.1102 < relic < 0.1272$. Red in the plots.
- LUX constraints are not implemented in the version we used, will update this later.

$$
\begin{aligned}
0.6 < \lambda < 0.75, \quad 0.2 < \kappa < 0.3, \quad -100 < A_\kappa < -50\mathrm{GeV} \\
165 < \mu_{eff} < 190\mathrm{GeV}, \quad 3.0 < \tan\beta < 4.0, \quad 610 < A_\lambda < 630\mathrm{GeV}
\end{aligned} \tag{3}
$$

NMSSM Higgs boson mass

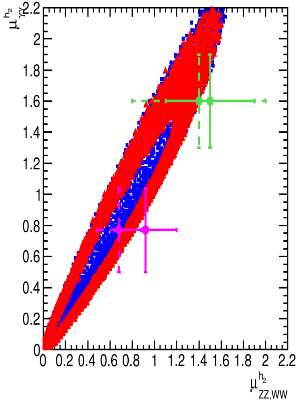
We first show the NMSSM Higgs boson mass spectrum. Our parameter set can fulfill our motivation stated above.

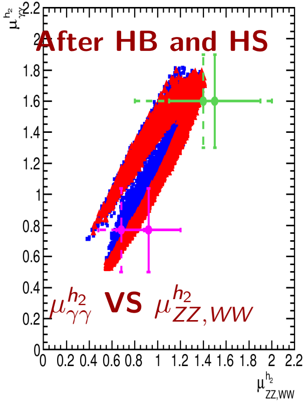


h_2 **mass VS** h_1 **mass**

h_2 compared with experiments

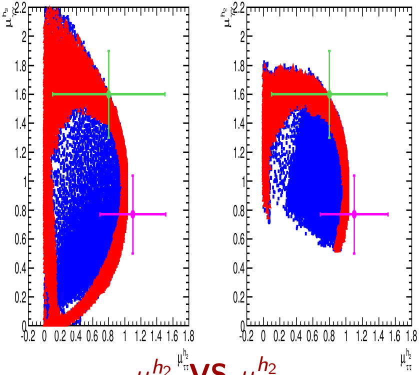
We use HiggsBounds410 and HiggsSignal110 to further constrain our parameter space. Then try to compare the signal strength in $\gamma\gamma$, ZZ, WW, $\tau\tau$ and bb decay modes with the ATLAS and CMS results. Magenta cross for CMS and green for ATLAS.





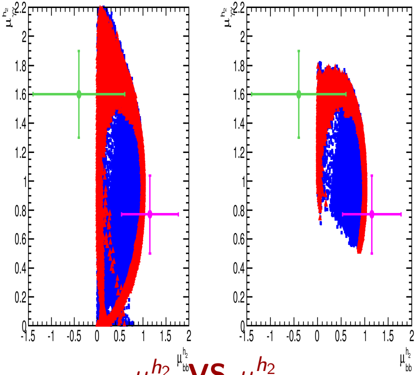
h_2 compared with experiments

After HB and HS



$\mu^{h_2}_{\gamma\gamma}$ VS $\mu^{h_2}_{tt}$

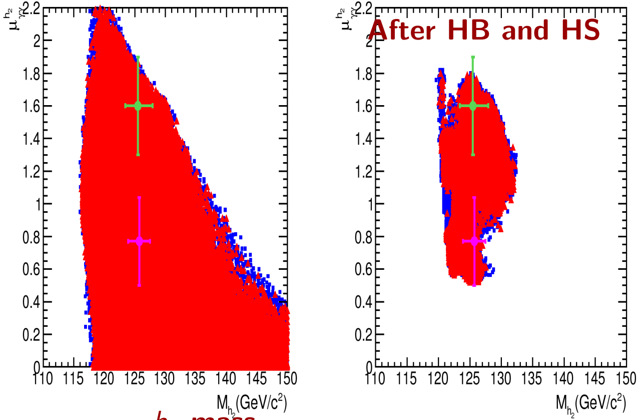
After HB and HS



$\mu^{h_2}_{\gamma\gamma}$ VS $\mu^{h_2}_{bb}$

The h_2 signal strength can be compatiable with both ATLAS and CMS results in our scanned parameter ranges.

h_2 compared with experiments

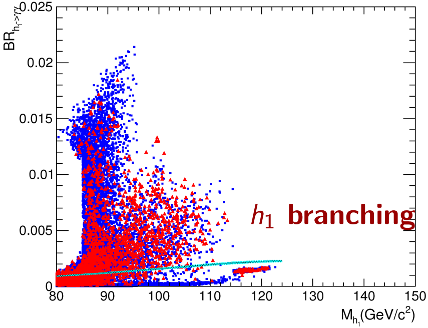


h_2 **mass**

The h_2 mass can also be compatiable with both ATLAS and CMS results in our scanned parameter ranges.

Study h_1

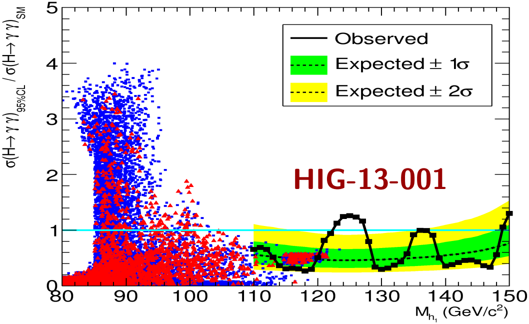
Concentrate on the $h_1 \to \gamma\gamma$ channel, we further demand signal strength $\mu_{\gamma\gamma}^{h_2}$ and h_2 mass should be within 1σ and 3σ range, namely $123.9\ GeV/c^2 < M_{h_2} < 127.5\ GeV/c^2$ and $0.5 \lesssim \mu_{\gamma\gamma}^{h_2} \lesssim 1.04$.



h_1 branching ratio to $\gamma\gamma$

Most points have enhanced branching ratio with respect to the SM value. The cyan solid line is the SM value.

Study h_1



The h_1 signal strength can be enhanced by a factor up to 3.5 compared with the corresponding SM value in mass range 85 to 95 GeV. In the mass range 110 to 122 GeV, the NMSSM points above the solid black line are almost excluded, no conclusion for the points below the line. More interesting if we extend the exclusion limit to the low mass range down to $\approx$ 80 GeV.

Conclusion and prospects

- Already many papers published on NMSSM, we based on some of the these papers, additionally study the phenomenology of h_1 when the h_2 is assumed as the observed SM-like Higgs boson whose mass is around 125 GeV.
- We find that, compared with the recent experiment, the h_1 signal strength can be enhanced by a factor up to 3.5 compared with the corresponding SM value.
- The experimental search is currently preapproved by CMS and in the procedure of approval.