Di-photon decay of a light Higgs state in the BLSSM

HPNP2021, Higgs as a probe of NP

Ahmed Ali Abdelalim[1,2], Biswaranjan Das[3], Shaaban Khalil[1], Stefano Moretti[4]

[1] *Center for Fundamental Physics, Zewail City of Science and Technology, Giza, Egypt.*
[2] *Physics Department, Faculty of Science, Helwan University, Cairo, Egypt.*
[3] *East African Institute for Fundamental Research (ICTP−EAIFR), University of Rwanda, Kigali, Rwanda.*
[4] *School of Physics and Astronomy, University of Southampton, Southampton, UnitedKingdom.*

March 26, 2021

UNIVERSITY OF Southampton

Motivation

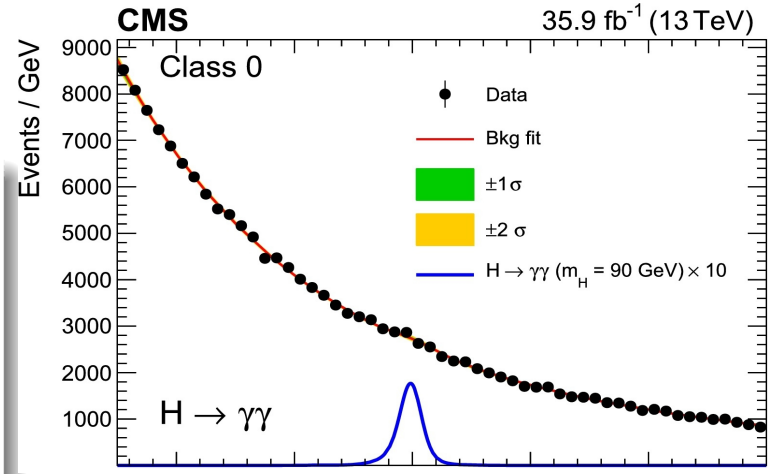
We investigate

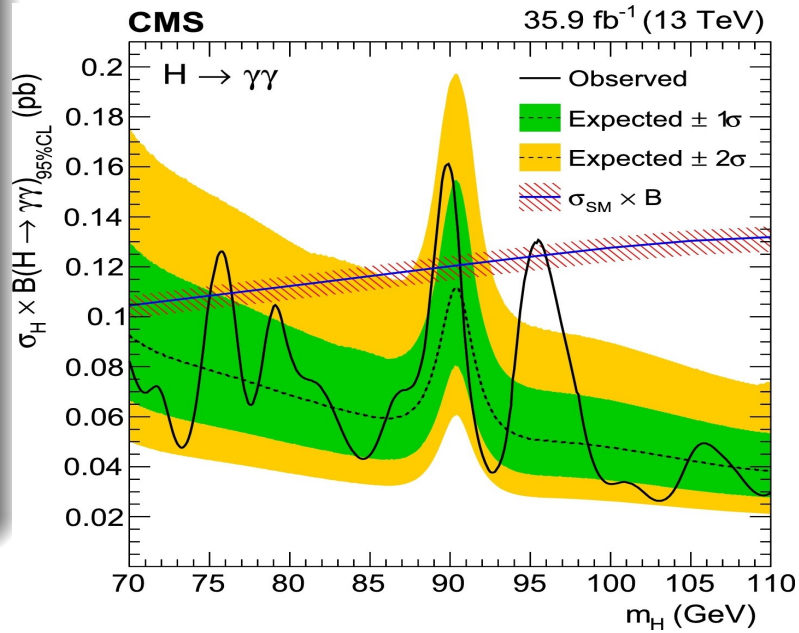
In the context of the $B - L$ Supersymmetric Standard Model (BLSSM), we investigate the consistency of a light Higgs boson, with mass around $90 - 95$ GeV, with the results of a search performed by the CMS collaboration in the di-photon channel at the integrated luminosity of 35.9 fb^{-1} and $\sqrt{s} = 13$ TeV.

CMS Collaboration, Phys. Lett. B 793, 320 (2019).

Based data-sets of size 19.7 and 35.9 fb^{-1} at $\sqrt{s} = 8$ and 13 TeV respectively, the CMS collaboration found potential signals for another neutral Higgs boson, h', with a mass of 90 to 95 GeV, precisely in the $gg \to h' \to \gamma\gamma$ channel.

The upper limit on $(\sigma \times BR)$, normalized to that for a standard model-like Higgs boson, is in the range 0.7-0.2, with two notable exceptions : (1) in the region around the Z boson peak, where the limit rises to 1.1, which may be due to Drell–Yan dielectron production where electrons could be misidentified as isolated photons, (2) due to an observed excess with respect to the SM prediction, which is maximal for a mass hypothesis of 95.3 GeV with a local (global) significance of 2.8 (1.3) standard deviations.





The $B - L$ Supersymmetric SM (BLSSM)

- The BLSSM gauge structure is

$$SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_{B-L}$$

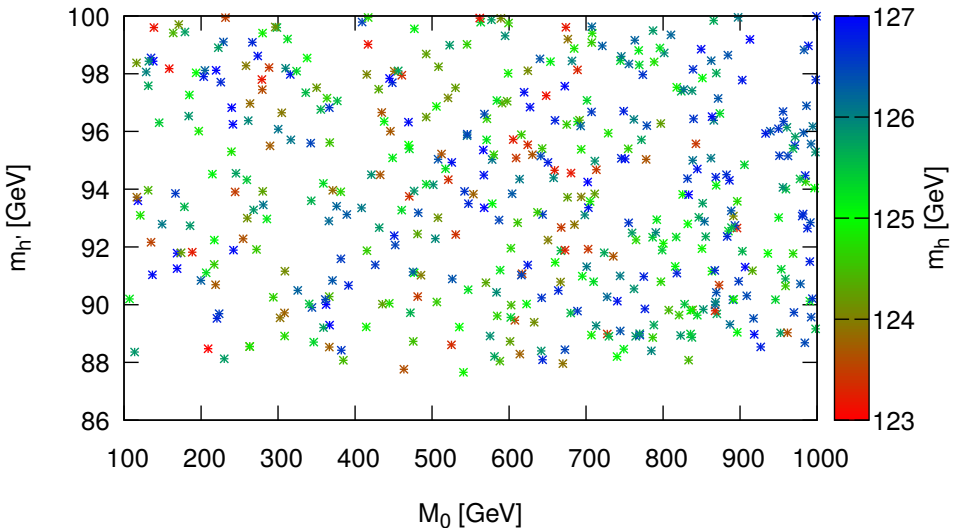
  which is an extension of the MSSM obtained by adopting an additional $U(1)_{B-L}$ gauge group.
- The BLSSM has a rich Higgs sector, consisting of two Higgs doublets and two Higgs singlets. Among those, the CP-even Higgs bosons can act as the potential h' state behind the observed excess in $M_{\gamma\gamma}$, with the model still providing a SM-like Higgs state with 125 GeV.

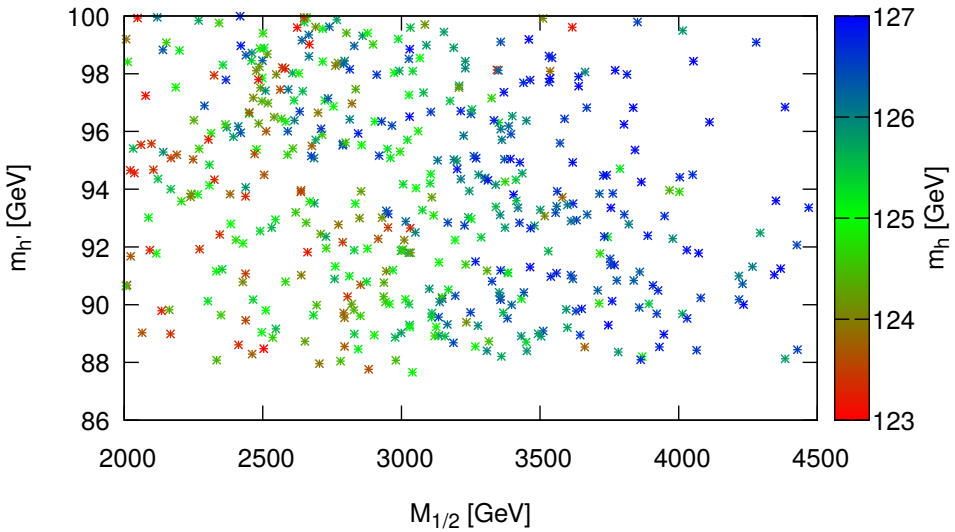
Scanning the Parameters Space

The scan was done at the GUT scale by varying four input parameters :

- The universal Soft SUSY-Breaking (SSB) scalar mass term, M_0 $(= M_{Q_{1,2,3}} = M_{U_{1,2,3}} = M_{D_{1,2,3}} = M_{L_{1,2,3}} = M_{E_{1,2,3}})$, range [100-1000] GeV.
- The universal SSB gaugino mass term $M_{\frac{1}{2}}$ $(= 2M_1 = M_2 = \frac{1}{3}M_3)$, range [1000-4500] GeV.
- $\tan\beta$ range [1-60] GeV.
- The universal Higgs to sfermion trilinear coupling A_0 $(= A_{\widetilde{t}} = A_{\widetilde{b}} = A_{\widetilde{\tau}})$, range [1000-4000] GeV.
- All other model parameters are kept fixed, e.g., $m_{Z'} = 2500$ GeV, $\tan\beta' = 1.15$ and $\mu = \mu' = B_\mu = B_{\mu'} = 0$.
- The lightest neutral Higgs boson mass in the range 90 GeV $\geq m_{h'} \geq$ 95 GeV. the second lightest (SM-like) Higgs boson with a mass m_h which allows ± 2 GeV uncertainty in its theoretical model prediction, about the experimental measurement of $m_h = 125.09 \pm 0.32$.

Moreover, the scanned points are tested to be consistent with the Higgs boson experimental measurements performed by the LEP, TeVatron and the LHC. They also need to satisfy the experimental constraints on the Branching Ratios (BRs) of the most stringent B-meson decay channels within a 2σ error, which are given by $\mathrm{BR}(B \to X_s\gamma) = (3.32 \pm 0.15) \times 10^{-4}$, $\mathrm{BR}(B_s \to \mu^+\mu^-) = (3.1 \pm 0.6) \times 10^{-9}$ and $\mathrm{BR}(B_u \to \tau^\pm\nu_\tau) = (1.06 \pm 0.19) \times 10^{-4}$.



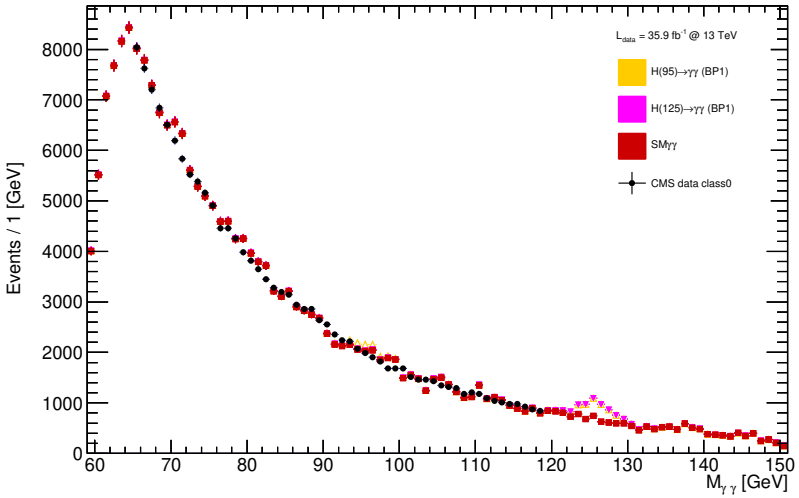


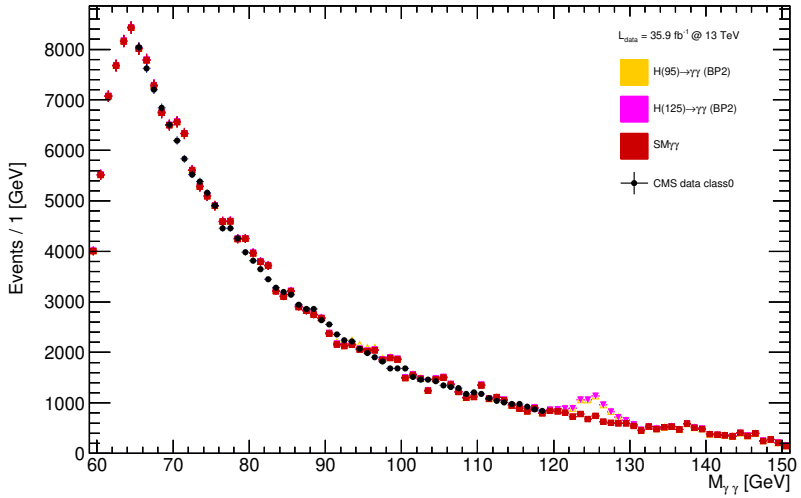
BP	$m_{h'}$	m_h	$\sigma(pp \to h' \to \gamma\gamma)$	$\sigma(pp \to h \to \gamma\gamma)$
1	95.3	125.9	13.1	43.5
2	94.2	125.3	8.6	49.3
3	89.7	125.7	9.7	49.3
4	90.0	127.2	8.7	47.6

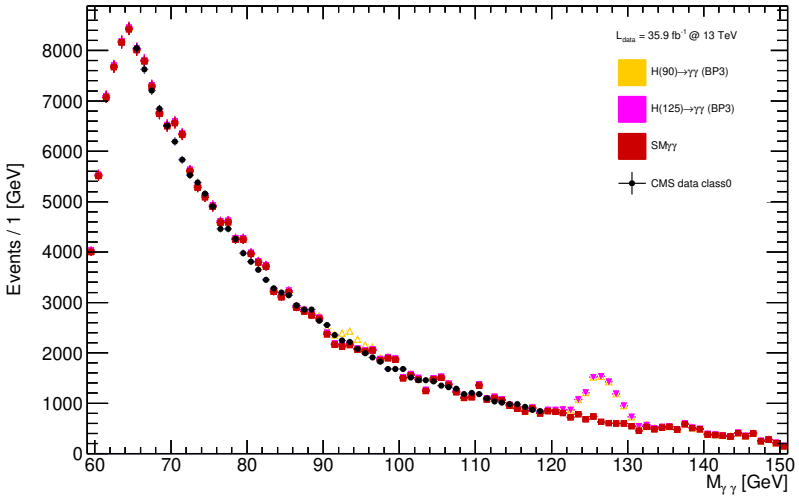
Results

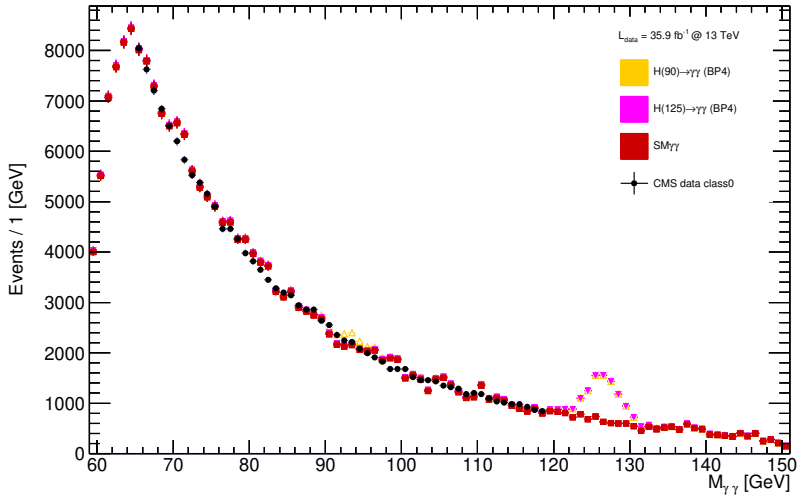
All events have to have :

- di-photon with $|\eta^{\gamma}| \leqslant 2.5$ and out of the crack region between the barrel and end-cap parts of the CMS EM-calorimeters.
- p_T leading photon in the pair has to have $p_T^{\gamma 1}/M_{\gamma\gamma} > 30.6/65.0 = 0.47$.
- p_T next-leading photon in the pair has to have $p_T^{\gamma 2}/M_{\gamma\gamma} > 18.2/65.0 = 0.28$.



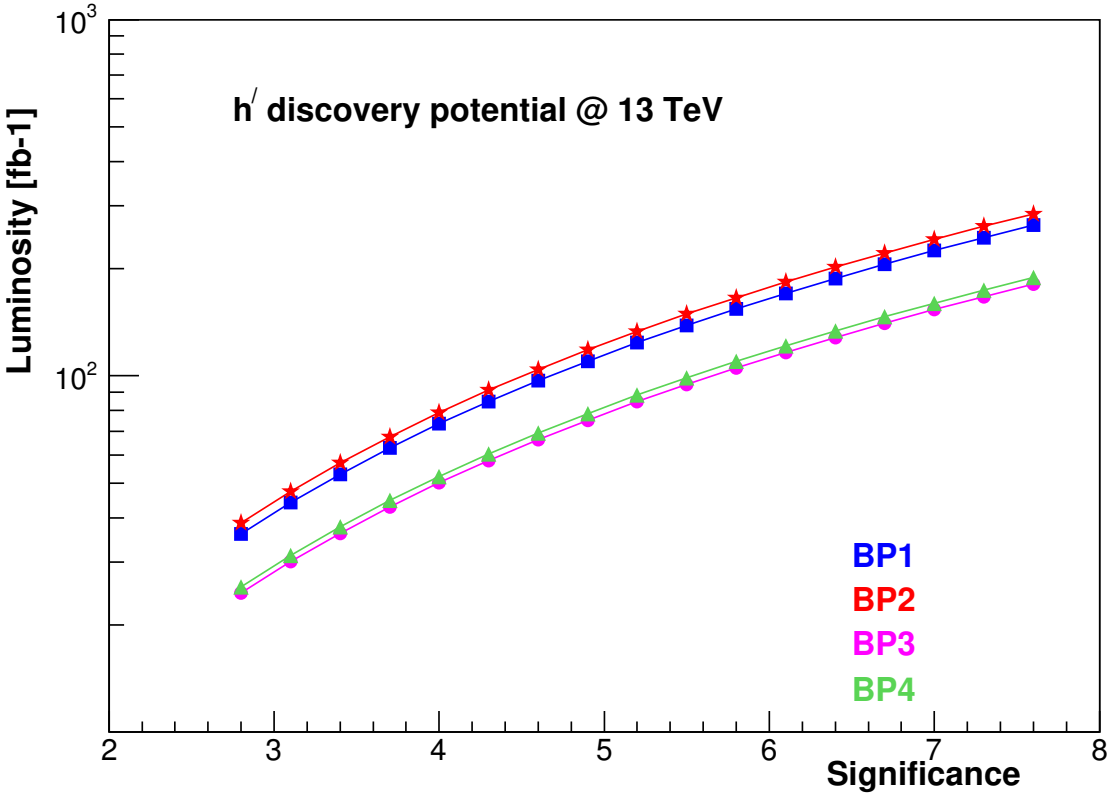



L_data = 35.9 fb^-1 @ 13 TeV
H(90)→γγ (BP3)
H(125)→γγ (BP3)
SMγγ
CMS data class0
Events / 1 [GeV]
M_γ γ [GeV]


L_data = 35.9 fb^-1 @ 13 TeV
H(90)→γγ (BP4)
H(125)→γγ (BP4)
SMγγ
CMS data class0
Events / 1 [GeV]
M_γ γ [GeV]

Range of $M_{\gamma\gamma}$ [GeV]	[65-119]	[85-100]	[92-98]	[89-98]
CMS data	170019	38159	14608	22654
SM	171337	37986	14414	22202
h' (BP1)	726	605	536	–
h (BP1)	549	167	72	–
h'+h+SM (BP1)	172612	38758	15022	–
h' (BP2)	472	396	356	–
h (BP2)	633	192	82	–
h'+h+SM (BP2)	172442	38574	14852	–
h' (BP3)	1421	1196	–	1150
h (BP3)	1380	419	–	261
h'+h+SM (BP3)	174138	39601	–	23613
h' (BP4)	1305	1098	–	1057
h (BP4)	1422	431	–	266
h'+h+SM (BP4)	174064	39515	–	23525

The empty cells in the table were not used in the significance calculation.



The integrated luminosity needed to discover the h' state of the BLSSM in di-photon events using CMS data at 13 TeV for our four BPs. The discovery is within reach of Run 2, as luminosity values of 114(123)[79]{82} fb^{-1} are needed to reach a 5σ excess in the $90 - 95$ GeV region for BP1(2)[3]{4}.

Conclusions

- We have analysed the discovery potential of a light neutral Higgs boson h' available in the context of the BLSSM at Run 2 of the LHC. We considered four BPs and showed that each of these can produce an enhancement of the di-photon cross section in the 90-95 GeV mass region through the sub-process $gg \to h' \to \gamma\gamma$ compatible with the CMS anomalous data while simultaneously producing the required amount of signal induced in the same channel by the SM-like state of the BLSSM, so as to comply with the di-photon data collected around 125 GeV.
- We also estimated the required integrated luminosity needed for a 5σ discovery of such h' state in the above channel, which turned out to be less than the total Run 2 data sample, so that we advocate new analyses using the latter.

Thank you