Triplet Explanation of the 95 GeV Excess

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- Based on *arXiv.2306.15722*

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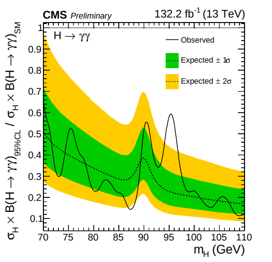
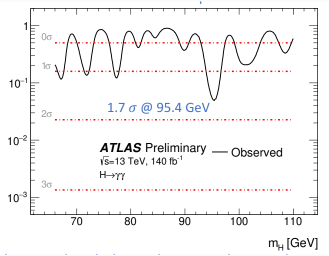
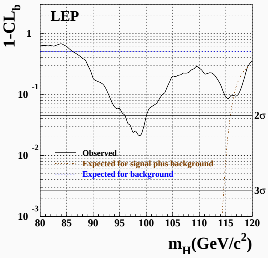
Outline

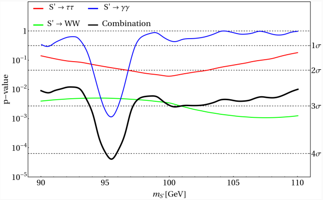
Motivation

- CMS, ATLAS and LEP hints for a new resonance decaying to $\gamma\gamma$, bb and $\tau\tau$ at 95 GeV.



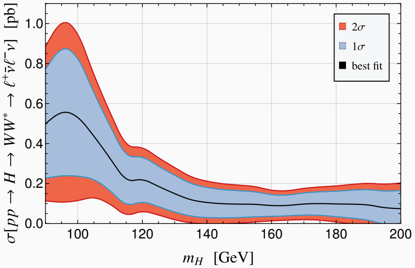






Why Triplet?

- Positive shift in the W mass as suggested by the experimental average (LEP+LHC+CDF II).
- Non-zero $\sigma[pp \to H \to WW^* \to l^+\,\bar{\nu}\,l^-\,\nu]$ preferred: [arXiv:2302.07276] by G. Coloretti, A. Crivellin, S. Bhattacharya, B. Mellado.



- Triplet dominantly decays to WW.

Scalar sector

- The Lagrangian of our model is

$$V = -\mu_\Phi^2 \Phi^\dagger \Phi + \frac{\lambda_\Phi}{4}\left(\Phi^\dagger\Phi\right)^2 - \mu_\Delta^2 \mathrm{Tr}\left(\Delta^\dagger \Delta\right) + \frac{\lambda_\Delta}{4}\left[\mathrm{Tr}\left(\Delta^\dagger\Delta\right)\right]^2 + \mu \Phi^\dagger \Delta \Phi + \lambda_{\Phi\Delta} \Phi^\dagger \Phi \mathrm{Tr}\left(\Delta^\dagger \Delta\right),$$

- We define

$$\Phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}, \quad \Delta = \frac{1}{2}\begin{pmatrix} \delta^0 & \sqrt{2}\delta^+ \\ \sqrt{2}\delta^- & -\delta^0 \end{pmatrix},$$

- ϕ^0 and δ^0 acquire the VEVs: $\langle \sqrt{2}\phi^0 \rangle = v \approx 246\,\mathrm{GeV}$, $\langle \delta^0 \rangle = v_\Delta$.
- Gauge bosons mass:

$$m_W^2 = \frac{g^2}{4}(v^2 + 4v_\Delta^2), \qquad m_Z^2 = \frac{g^2}{4\cos\theta_W^2} v^2.$$

- Preferred experimental values of v_Δ, (with and without CDF II)

$$v_\Delta = 4.60^{+0.58}_{-0.66}\,\mathrm{GeV}, \qquad v_\Delta^{(\mathrm{w/o\ CDF\ II})} = 2.89^{+0.59}_{-0.75}\,\mathrm{GeV}.$$

Particles and parameters

- Particle content: Two CP-even scalars (h, H), one charged Higgs $(H^{\pm})$.
- Four free parameters.
    1. α: CP-even mixing angle.
    2. m_H and $m_H^{\pm}$: mass of CP-even and charged Higgses.
    3. v_Δ: VEV of the triplet.
- The mass-splitting, $\Delta_m = m_{H^\pm} - m_H$, is small

$$m_{H^\pm}^2 - m_H^2 \simeq O(v_\Delta)$$

for small v_Δ.

Theoretical constraints

- Vacuum stability conditions (BFB):

$$\lambda_\Phi > 0, \quad \lambda_\Delta > 0, \quad \sqrt{2}\lambda_{\Phi\Delta} + \sqrt{\lambda_\Phi \lambda_\Delta} > 0$$

- Perturbative unitarity conditions:

$$|\lambda_\Phi| \leq 2\kappa\pi, \quad |\lambda_\Delta| \leq 2\kappa\pi, \quad |\lambda_{\Phi\Delta}| \leq \kappa\pi,$$
$$|6\lambda_\Phi + 5\lambda_\Delta \pm \sqrt{(6\lambda_\Phi - 5\lambda_\Delta)^2 + 192\lambda_{\Phi\Delta}^2}| \leq 8\kappa\pi,$$

with $\kappa = 16$.

- All trilinear and quartic couplings are taken to be smaller than 4π.

Phenomenology

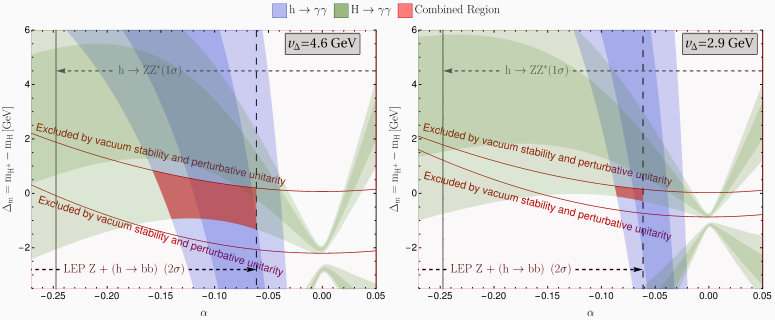
H **production:**

- GF and VBF proportional to α^2.
- DY production via $pp \to W^* \to H^\pm H$

H **decay to $\gamma\gamma$:**

- Mixing induced: $\alpha^2 \Gamma[H \to \gamma\gamma]_{SM}$.
- Modification by WW and $H^\pm$ loops (depending on Δ_m).

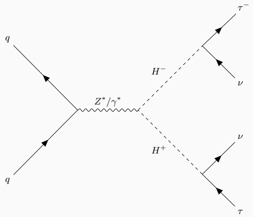
Phenomenology



- Vacuum stability and perturbative unitarity constraints imposed.
- SM signal strength of $h \to \gamma\gamma$ is modified by $H^\pm$ loop.
- Higgs signal strength of $h \to ZZ^*$ further constraints α.
- Zbb and $H \to \gamma\gamma$ can be explained.

Bounds on $H^\pm$ production and decay:

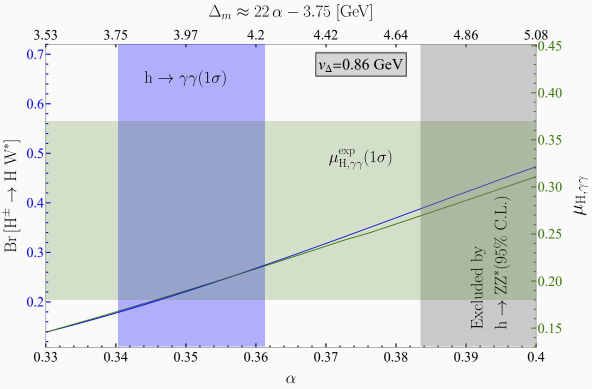
- $H^\pm$ dominantly decays to $\tau\nu$.



- It produces a collider signature similar to super-symmetric tau partners searched by CMS and ATLAS.
- Our predicted cross-section is borderline allowed.
- To eliminate the tension a lower $\mathrm{Br}[H^\pm \to \tau\nu]$ can be achieved by increasing $\mathrm{Br}[H^\pm \to HW^*]$ that requires sizable Δ_m.

Phenomenology

- Sizable Δ_m is possible for low v_Δ.



- Vacuum stability and perturbative unitarity conditions give the relation $\Delta_m \approx 22\alpha - 3.75$ GeV.

Summary

- $SU(2)_L$ triplet with Y=0 can explain several excesses at 95 GeV.
- Predicts positive shift in W-mass.
- Charged Higgs with a mass $\approx 95\,\text{GeV}$.
- Predicts stau-like excess in LHC Run 3 data.
- H is produced in association with jets and τ leptons.