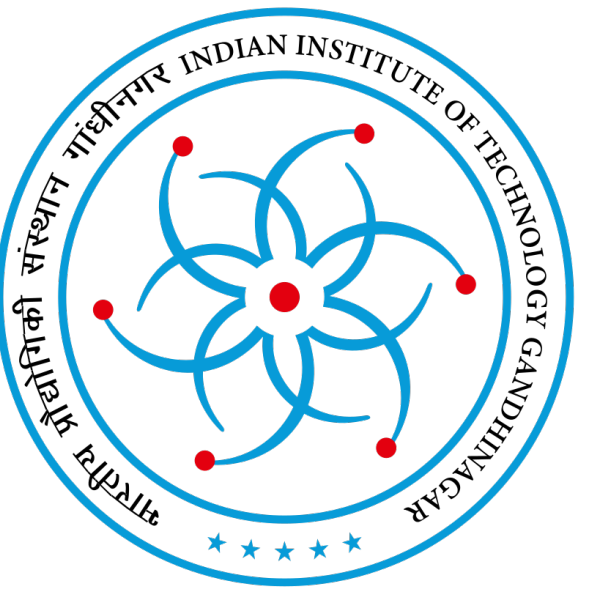


Constraining the 3HDM parameter space using Active Learning



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Model

The most general $SU(2)_L \times U(1)_Y$ invariant potential that admits Z_3 symmetry is given by,

$$V = m_{11}^2(\Phi_1^\dagger \Phi_1) + m_{22}^2(\Phi_2^\dagger \Phi_2) + m_{33}^2(\Phi_3^\dagger \Phi_3) + \lambda_1(\Phi_1^\dagger \Phi_1)^2 + \lambda_2(\Phi_2^\dagger \Phi_2)^2 + \lambda_3(\Phi_3^\dagger \Phi_3)^2 \\ + \lambda_4(\Phi_1^\dagger \Phi_1)(\Phi_2^\dagger \Phi_2) + \lambda_5(\Phi_1^\dagger \Phi_1)(\Phi_3^\dagger \Phi_3) + \lambda_6(\Phi_2^\dagger \Phi_2)(\Phi_3^\dagger \Phi_3) + \lambda_7(\Phi_1^\dagger \Phi_2)(\Phi_2^\dagger \Phi_1) + \lambda_8(\Phi_1^\dagger \Phi_3)(\Phi_3^\dagger \Phi_1) \\ + \lambda_9(\Phi_2^\dagger \Phi_3)(\Phi_3^\dagger \Phi_2) + [\lambda_{10}(\Phi_1^\dagger \Phi_2)(\Phi_1^\dagger \Phi_3) + \lambda_{11}(\Phi_1^\dagger \Phi_2)(\Phi_3^\dagger \Phi_2) + \lambda_{12}(\Phi_1^\dagger \Phi_3)(\Phi_2^\dagger \Phi_3) + h.c.].$$

Democratic Yukawa : $\mathcal{L}_{Yukawa} = -[\bar{L}_L \Phi_1 \mathcal{G}_l l_R + \bar{Q}_L \Phi_2 \mathcal{G}_d d_R + \bar{Q}_L \tilde{\Phi}_3 \mathcal{G}_u u_R + h.c.]$.

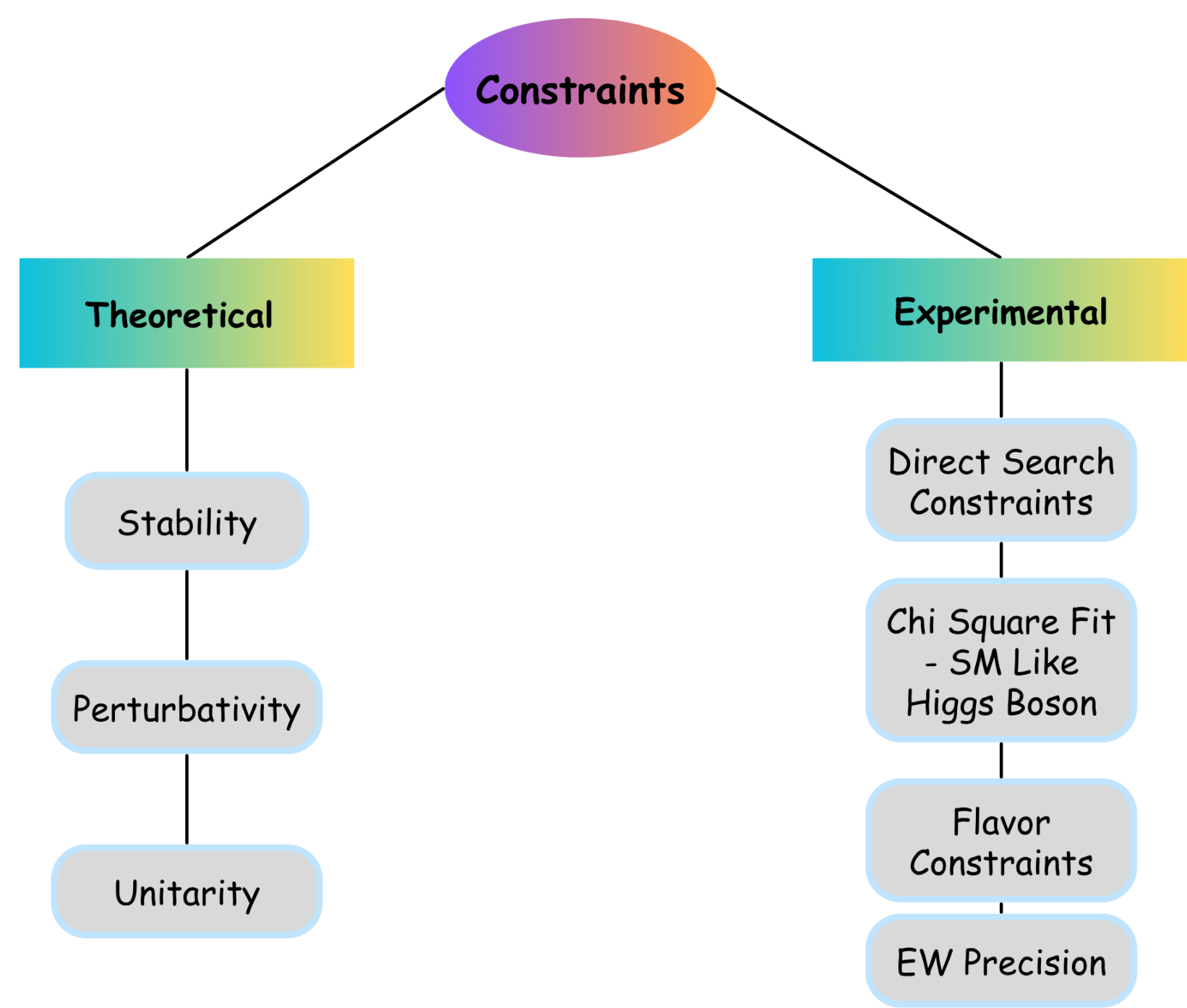
Field Definitions

$$\Phi_k = \left(\frac{\phi_k^+}{\frac{v_k + p_k + i n_k}{\sqrt{2}}} \right) \quad \text{where } k = 1, 2, 3$$

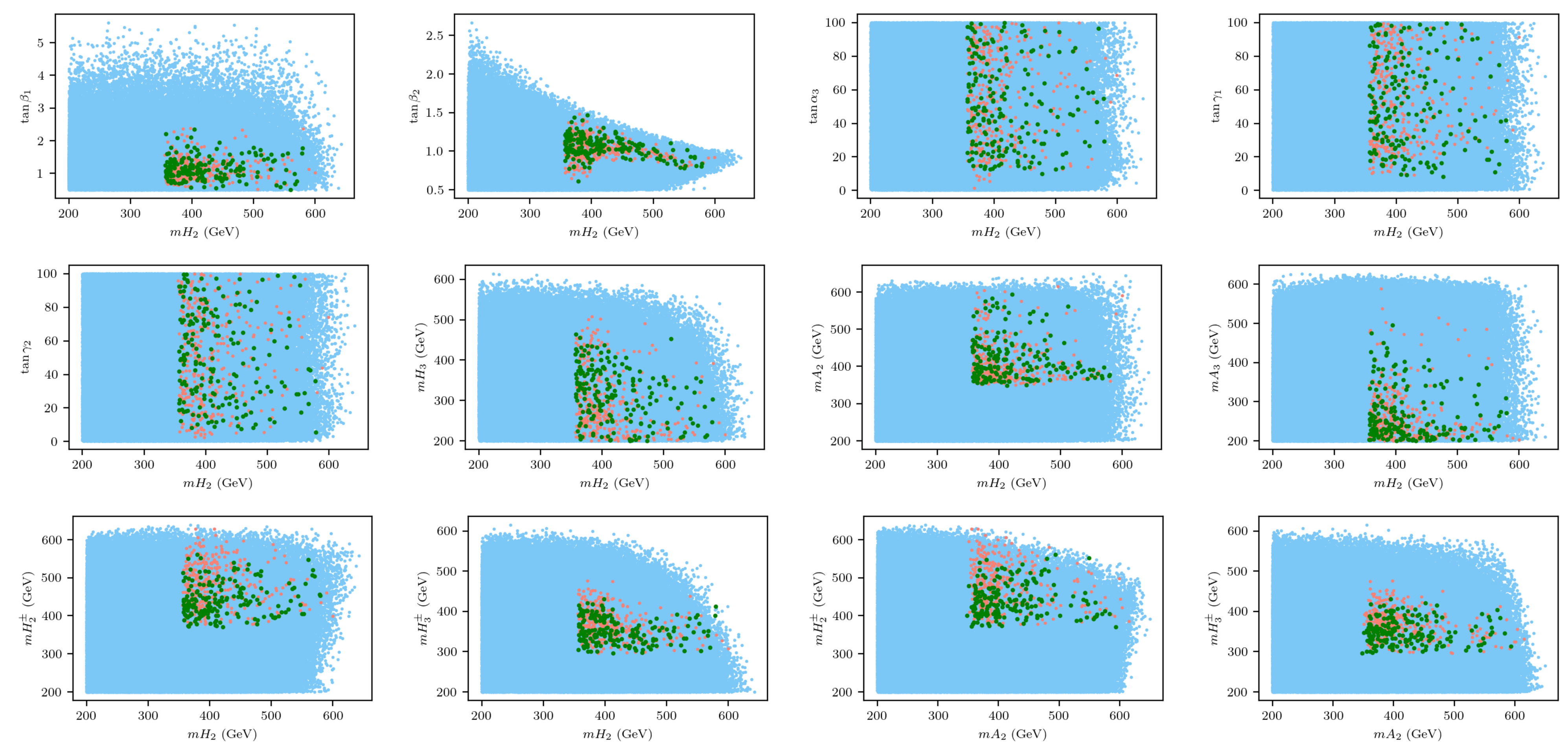
Number of independent parameters: **14**, namely

$$mH_1, mH_2, mH_3, mA_2, mA_3, mH_2^\pm, mH_3^\pm, \beta_1, \beta_2, \gamma_1, \gamma_2, \alpha_1, \alpha_2, \alpha_3$$

Constraints



Regular Hierarchy



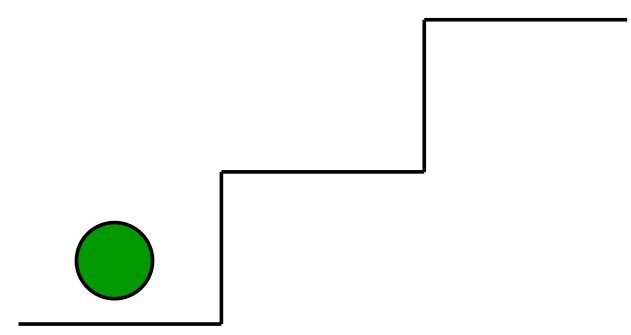
Blue region → Allowed by theoretical constraints.

Red region → Allowed by the direct searches, the goodness-of-fit test, and the $b \rightarrow s\gamma$ constraint.

Green region → Allowed by electroweak precision constraints. (final viable region)

Alignment Limit Conditions

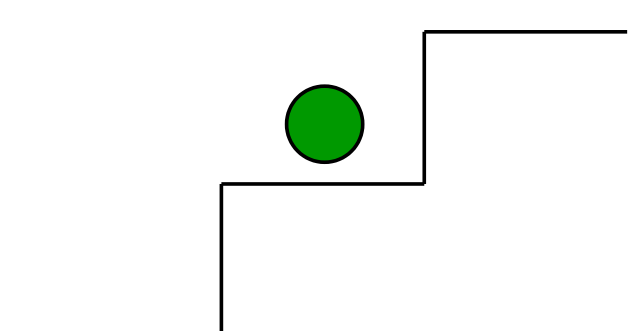
Regular Hierarchy (H_1 is SM like)



$$\alpha_1 = \beta_1 + 2n\pi$$

$$\alpha_2 = \beta_2 + 2n\pi$$

Medial Hierarchy (H_2 is SM like)

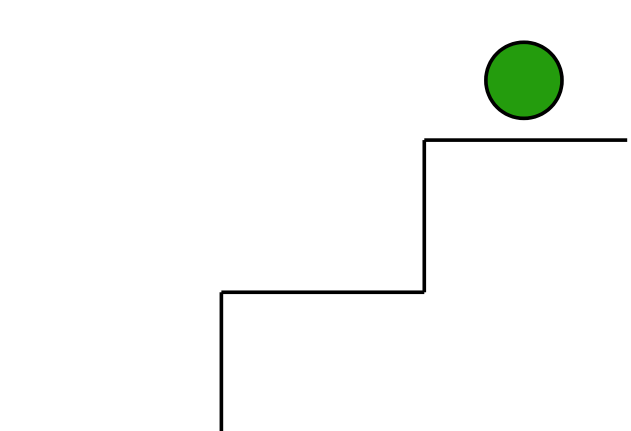


$$\alpha_1 = \beta_1 + 2n\pi$$

$$\alpha_2 = \beta_2 - \frac{\pi}{2}$$

$$\alpha_3 = \frac{\pi}{2}$$

Inverted Hierarchy (H_3 is SM like)

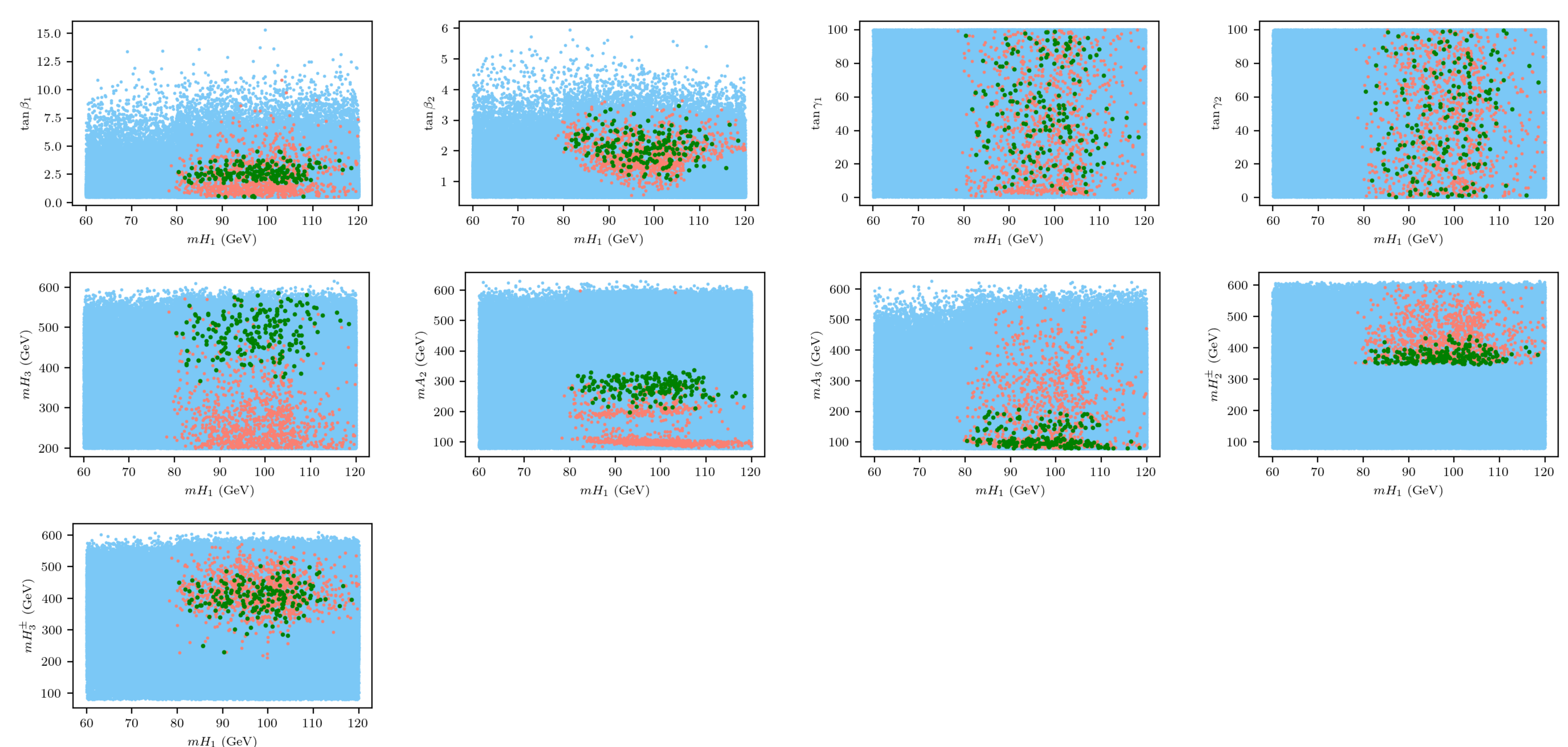


$$\alpha_1 = \beta_1 + 2n\pi$$

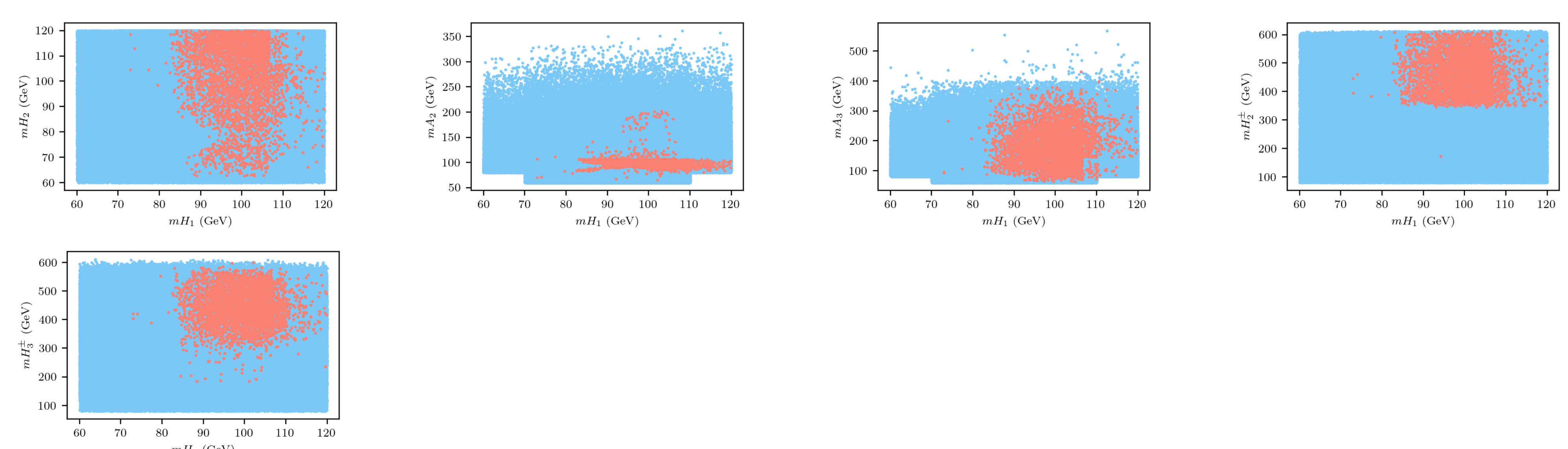
$$\alpha_2 = \beta_2 - \frac{\pi}{2}$$

$$\alpha_3 = 0$$

Medial Hierarchy



Inverted Hierarchy



Methodology

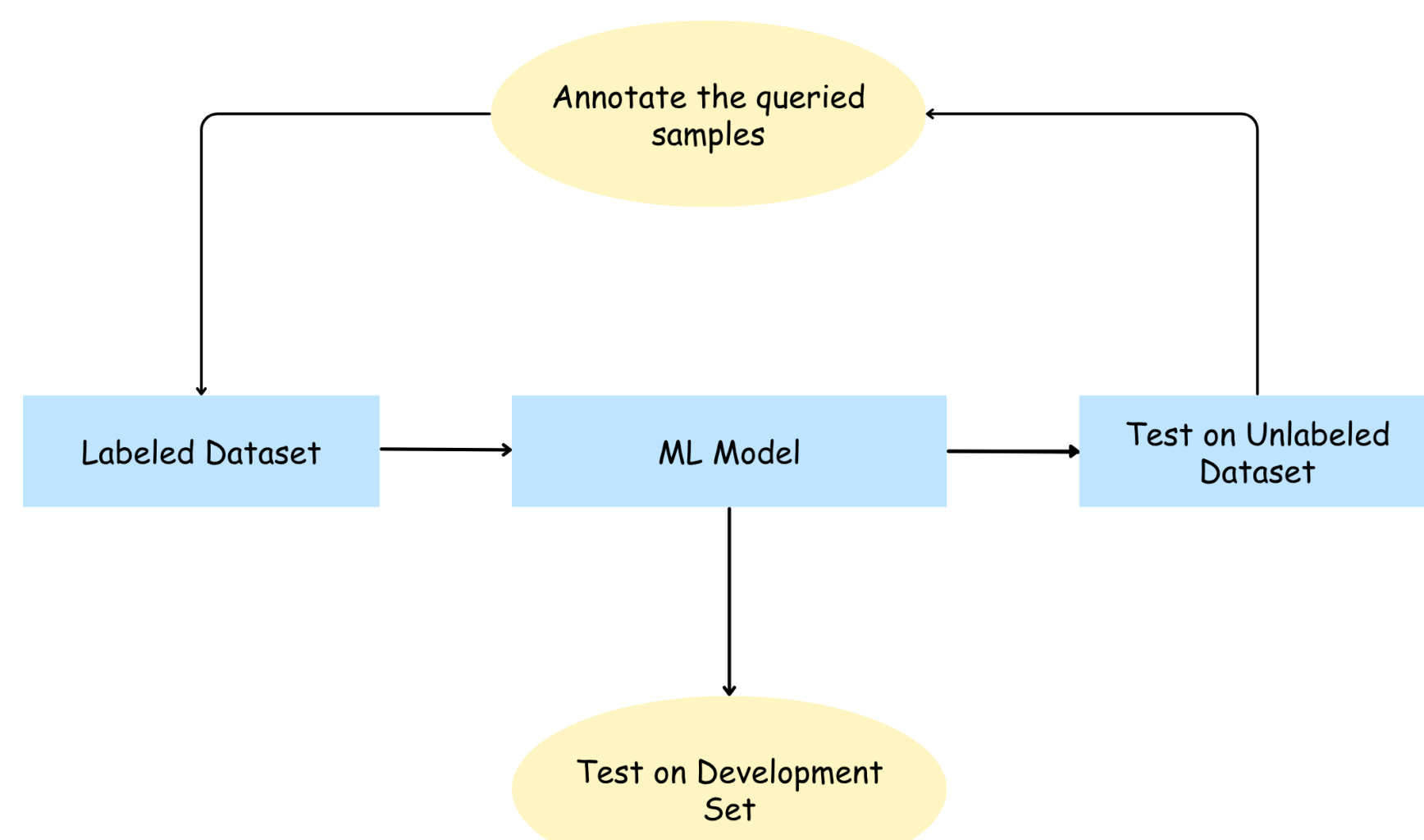


Figure: Active Learning algorithm

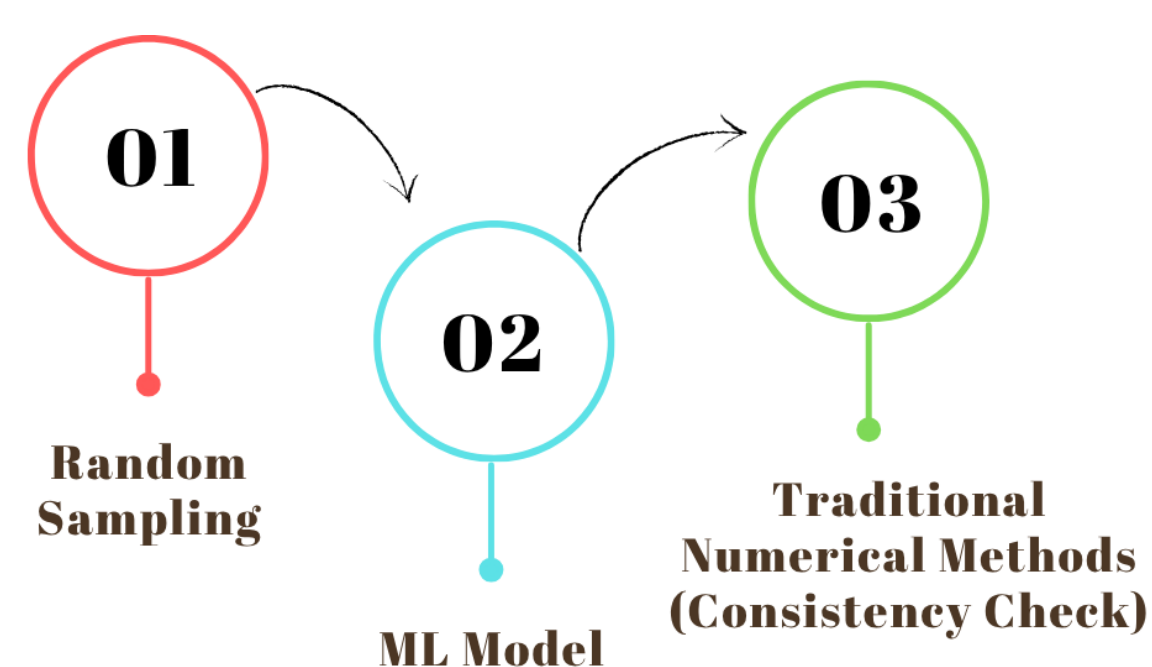


Figure: Parameter space extraction

