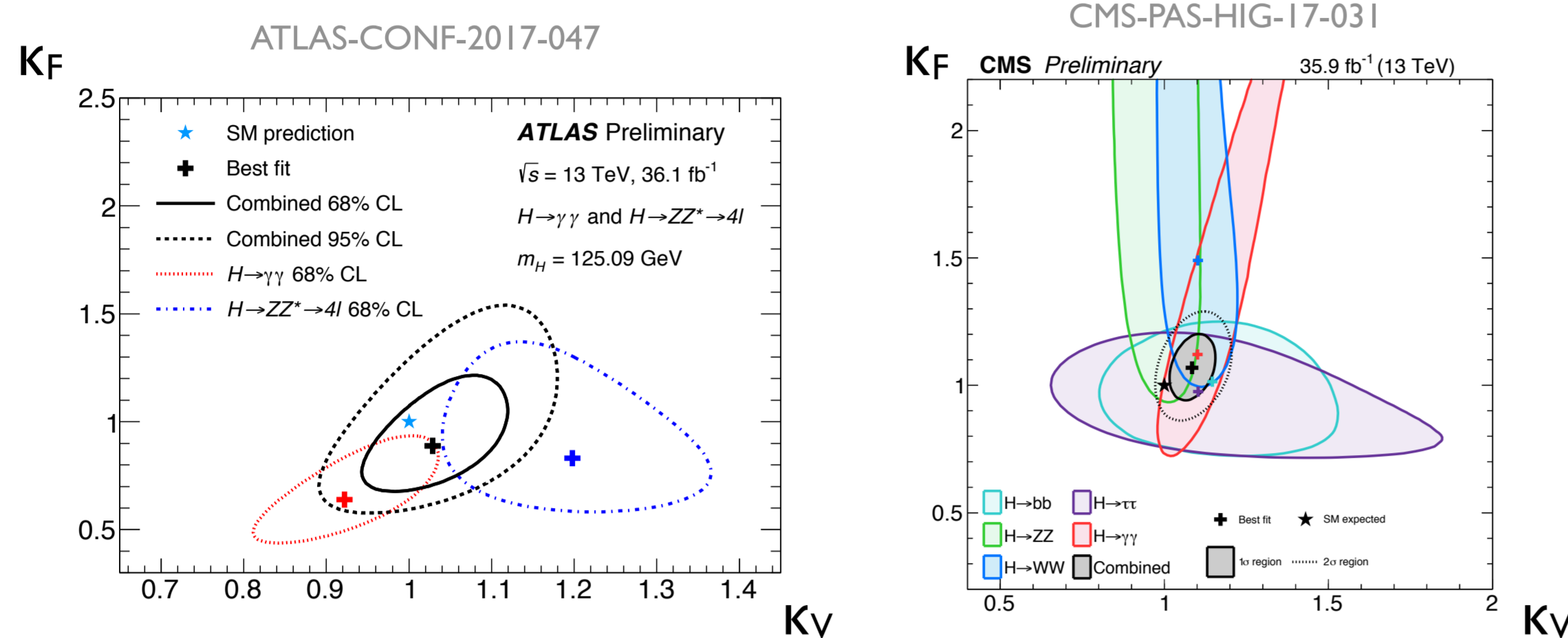


# Symmetry and Geometry in Generalized Higgs Sector

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## Higgs coupling measurements



- ~10% deviation from the SM predictions is still allowed.

## Higgs Effective Field Theory (HEFT)

“SMEFT”

$$\mathcal{L} = (D_\mu \Phi)^\dagger (D^\mu \Phi) + \frac{c}{\Lambda^2} \partial_\mu (\Phi^\dagger \Phi) \partial^\mu (\Phi^\dagger \Phi) + \dots$$

“HEFT”

$$\mathcal{L} = \frac{v^2}{4} \left( 1 + \kappa_V \frac{h}{v} + \dots \right) \text{Tr}[D_\mu U^\dagger D^\mu U] + \frac{1}{2} (\partial_\mu h) (\partial^\mu h)$$

- cannot be applied if there exist BSM particles lighter than ~ 1TeV

## Generalized HEFT

$$\mathcal{L} = \frac{1}{2} g_{ij}(\phi) D_\mu \phi^i D^\mu \phi^j$$

$$D_\mu \phi^i = \partial_\mu \phi^i + g w_a^i(\phi) W_\mu^a + g_Y y^i(\phi) B_\mu$$

$\phi = (w^a, \text{Higgs})$  SU(2)<sub>W</sub> × U(1)<sub>Y</sub> Killing vectors

- e.g. SM  $g_{ij}(\phi) : 4\text{d Flat}$
- e.g. THDM  $g_{ij}(\phi) : 8\text{d Flat}$
- e.g. SO(5)/SO(4) composite Higgs

$$g_{ij}(\phi) : S^4,$$

Curvature  $\sim v^2 / f^2$

- Detail of the Higgs sector is expressed in terms of the **geometry** ( $g_{ij}$ ) and **symmetry** ( $w_a, y$ ).

## Scattering amplitudes

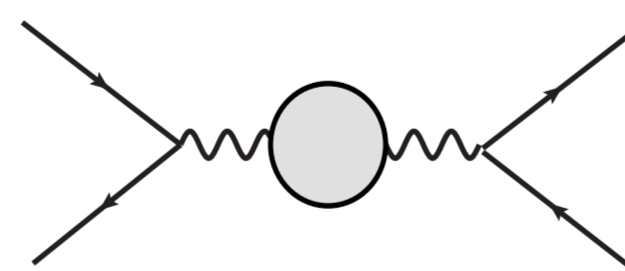


$$\mathcal{M}_{\phi_i \phi_j \rightarrow \phi_k \phi_l} \sim \frac{s}{3} (\bar{R}_{iklj} + \bar{R}_{ilkj}) + \frac{t}{3} (\bar{R}_{ijlk} + \bar{R}_{iljk}) + \frac{u}{3} (\bar{R}_{ijkl} + \bar{R}_{ikjl})$$

Perturbative unitarity :  $\bar{R}_{ijkl} = 0$

## EW oblique corrections

$$S \sim (\bar{w}_3^i)_{;j} (\bar{y}^j)_{;i} \ln \frac{\Lambda^2}{\mu^2}$$



Alonso-Jenkins-Manohar (2016)

SU(2)<sub>W</sub> × U(1)<sub>Y</sub> sym.  $[w_a, w_b] = -\epsilon_{abc} w_c$   
 $[w_a, y] = 0$   
 $v_{i;j;k} = R_{kji}^l v_l \quad (v = w_a, y)$

$$S \sim \left[ \epsilon_{3bc} (\bar{w}_b^j)_{;i} \bar{R}_{jkl}^i \bar{w}_c^k \bar{w}_3^l + \epsilon_{3bc} (\bar{y}^j)_{;i} \bar{R}_{jkl}^i \bar{w}_b^k \bar{w}_c^l \right] \ln \frac{\Lambda^2}{\mu^2}$$

## Summary and Outlook

- Physics in extended Higgs scenarios can be described by geometry and symmetry of the “scalar manifold”.

Flat → Perturbative  
Curved → Non-Perturbative

- Consistency with EWPTs does not imply the complete flatness of the scalar manifold.
- Interesting models with non-trivial scalar manifold?