A Higgs or Not A Higgs.........?

大阪

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OUTLINE

* A model-independent analysis of a new scalar particle

I Motivation:

.... why do this?

II Method:

..... how to do this?

III Results:

...... what do you learn?

MOTIVATION

Q: If a new scalar is discovered, what do we learn?

A:
- ☐ SUPERSYMMETRY
- ☐ COMPOSITENESS
- ☐ LARGE EXTRA DIMENSIONS

⋮

Best-motivated alternatives......
...... given the present state of knowledge

but
what if.....

☐ NOTA*

*None of the Above

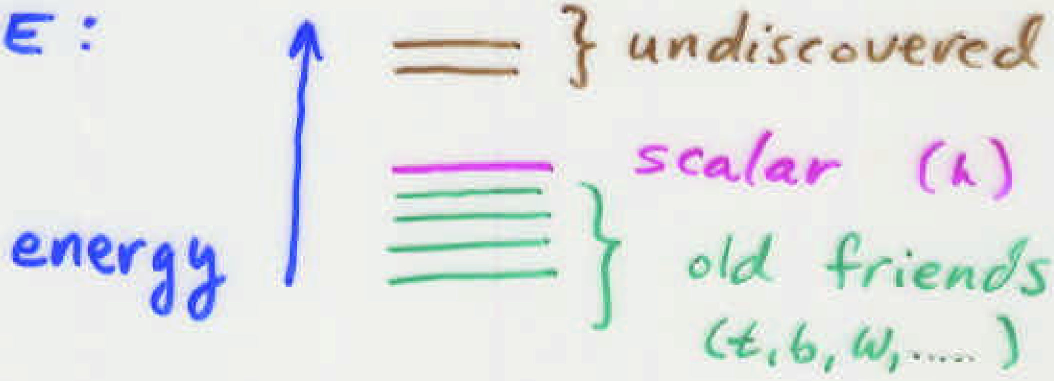
Flies in the Ointment....

* Even if right, models often difficult to distinguish from one another at accessible energies
  - 2HDMs, MSSM
* Are there signals not (yet) predicted by any model?
* What can be ruled out early on after a scalar's discovery?

METHOD

* MODELS ARE SIMILAR IF THEY DIFFER ONLY AT HIGH ENERGIES
  - heavy states decouple
  - all differences are in low energy effective couplings

➡ ASSUME:



* EXPAND IN $1/M$: Write *most* *general* possible effective h couplings
  - sufficient if $M \gtrsim 200-300$ GeV
  - can *systematically* compare low-energy properties

Effective Couplings

* Interactions organized by dimension (powers of $1/M$)

[eg: single electrically-neutral scalar]

$$\mathcal{L}_2 = -\frac{1}{2} m_h^2 h^2$$

$$\mathcal{L}_3 = -\frac{1}{3!} v h^3 - \frac{1}{2} a_z Z_\mu Z^\mu h - a_w W_\mu^* W^\mu h$$

$$\mathcal{L}_4 = -\frac{1}{4!} \lambda h^4 - \frac{1}{4} b_z Z_\mu Z^\mu h^2 - \frac{1}{2} b_w W_\mu^* W^\mu h^2 - \bar{f}\left(y_{ff'} + i \gamma_5 z_{ff'}\right) f' h$$

$$\mathcal{L}_5 = -c_\gamma F^{\mu\nu} F_{\mu\nu} h - \tilde{c}_\gamma F_{\mu\nu} \tilde{F}^{\mu\nu} h - c_g G_{\mu\nu} G^{\mu\nu} h - c_{z\gamma} Z_{\mu\nu} F^{\mu\nu} h$$

$$+ \cdots$$

THE PROGRAM

* COMPUTE OBSERVABLES FROM EFFECTIVE COUPLINGS
  - Once and for all...
  - what can be measured?
  - model-specific assumptions?

eg: $y \sim m$ ↳

* COMPUTE PREDICTIONS FOR EFFECTIVE COUPLINGS IN MODELS
  - How widely sampled is coupling space?
  - Which models are distinguishable?
  - Which observables are model-specific, which are generic to all?

RESULTS (hep-ph/9912459)

• A THEORETICAL TOOLBOX:

- expressions for observables without model-dependent assumptions (like $y_e \approx m_e$)
- expressions for effective couplings in wide variety of models.

• EXPERIMENTAL CONSEQUENCES:

- current bounds on some effective couplings

eg $y_{ee} \lesssim 0.01 - 0.1$ depending on m_h

- identify 12 experimentally distinguishable categories (popular models explore 7)

• ROBUST COMPARISON OF MODELS:

- which couplings 'see' loops $\frac{y_u/y_d}{m_u/m_d}$
- which couplings test which models

eg: $\frac{a_w}{e M_w / s_w} \lesssim 1$ for doublets, singlets only

Some Scalar Botany

* Q: What kinds of scalars can be out there?

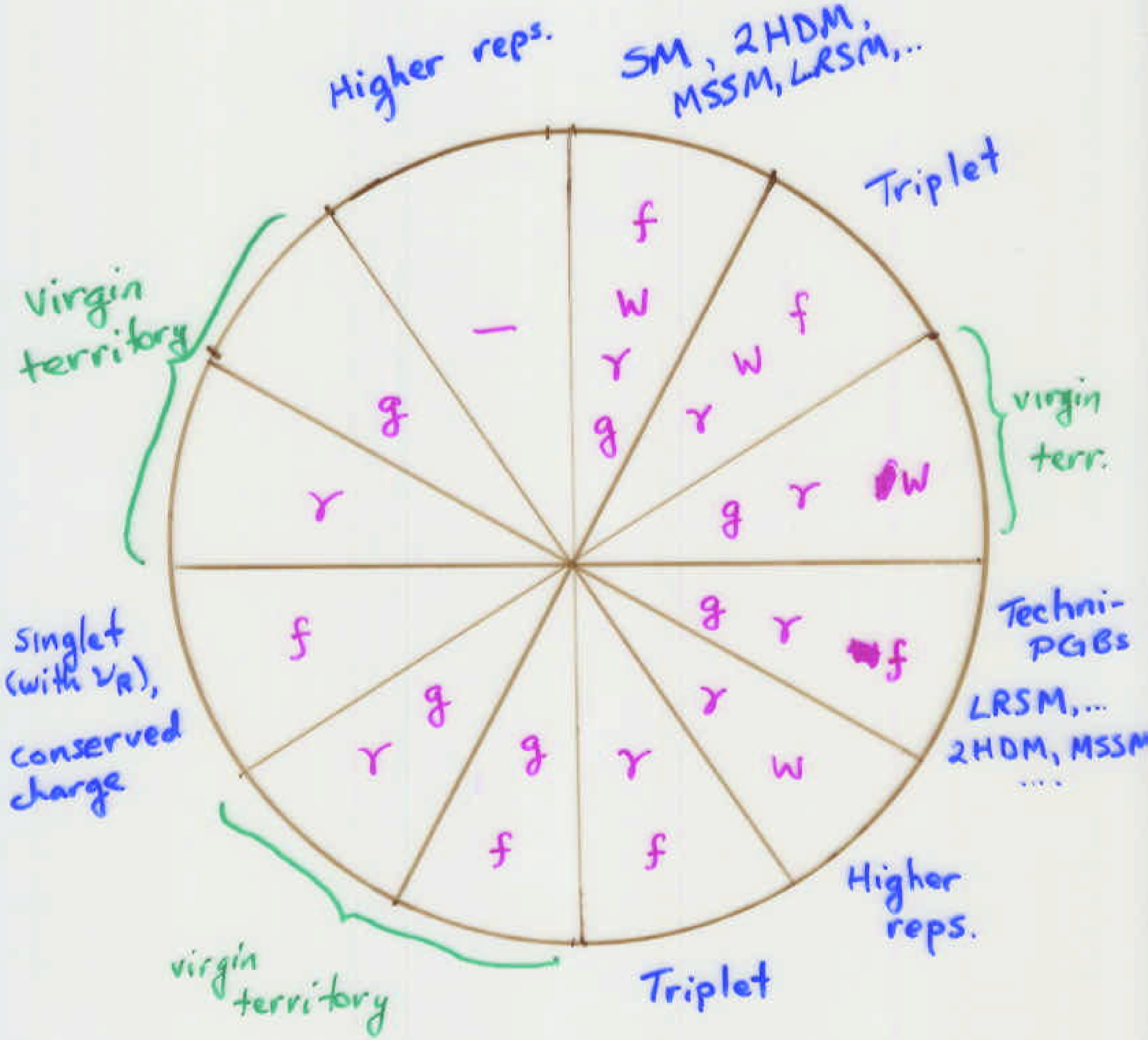
A: Can be operationally categorized by size of couplings to f, W, Z, g, γ :

	Yes	No
I Is ffh $O(e)$?	☐	☐
II Is WWh $O(e)$?	☐	☐
III Is $\gamma\gamma h$ $O\left(\frac{\alpha}{4\pi}\right)$?	☐	☐
IV Is ggh $O\left(\frac{\alpha_s}{4\pi}\right)$?	☐	☐

Since II = Y ⇒ III = Y there are 12 options....

SCALAR ROADMAP

- for which is the answer Y?



Depends on which scalar in model is observed

WHICH COUPLINGS SEE LOOPS?

* Loops bring info about higher-energy spectrum
  - need low dim" to fight decoupling
  - need small tree value to see loop

  eg: y_f, c_g, $\tilde{c}_g$, ...

- Eg: When is $(y_b/y_\tau)/(m_b/m_\tau)$ a useful discriminator?
  - proposed to tell Type II forom SUSY
    * Carena, Mrenna, Wagner
    * Babu + Kolda

  ► y_b loops $\propto m_b$ due to chiral symmetry in SM + many models

  → Big loop Requires:

  - Direct χSB couplings (SUSY partners....)

  OR

  - RH tbW couplings

Singlets and Doublets

* Multiscalar models satisfy:

$$M_W^2 = \frac{e^2}{2 s_W^2} v^T \left[\vec{T}^2 - T_3^2 \right] v$$

$$M_Z^2 = \frac{e^2}{s_W^2 c_W^2} v^T T_3^2 v$$

$$a_W^i = \frac{e^2}{s_W^2} \left[A^T (\vec{T}^2 - T_3^2) v \right]^i$$

$$a_Z^i = \frac{2e^2}{s_W^2 c_W^2} \left[A^T T_3^2 v \right]^i$$

for $\phi^i = v^i + [Ah]^i$

vev → v^i ; $[Ah]$ ← diagonaliz^{n} of masses etc

Imply: $\dfrac{a_W^h}{e M_W / s_W} \leq 1$ for doublets, singlets only

CONCLUSIONS

- MODEL INDEPENDENT ANALYSIS IS USEFUL WHEN MODELS DIFFER MOSTLY AT HIGH ENERGIES
  - COMPLEMENTS MORE PREDICTIVE MODEL BY MODEL APPROACH
  - APPROPRIATE TO SCALAR SEARCHES, B PHYSICS, PRECISION EW DATA, ...