Exotic (non-standard) Higgs Decays

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"Exotic Higgs Decay Working Group"

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D. McKeen, J. Shelton, M. Strassler, Z. Surujon, B. Tweedie, Y. Zhong

Snowmass on the Pacific @ KITP

5/29/2013

Post discovery

- 125 GeV state is a new particle discovered at LHC

$\Longrightarrow$ must study *everything* about it

- Important to e.g.
  - measure SM decays
  - look for non-SM production
  - look for Higgs partners
  - look for non-standard decays

e.g. $h \to 4\gamma, 4b, \gamma + \not{E}_T, \ldots$

should be an important component of current & future LHC research program (or any other collider's)

Non-standard ("exotic") Higgs decays

- Higgs is one of only two SM fields that can have renormalizable couplings to SU(3)xSU(2)xU(1) singlet fields

$\Longrightarrow$ • Higgs may be leading window into BSM physics
• trivial to have non-standard decays

e.g. $\Delta\mathcal{L} = \frac{\lambda}{4} S^2 |H|^2$ (common building block in extended Higgs sectors)

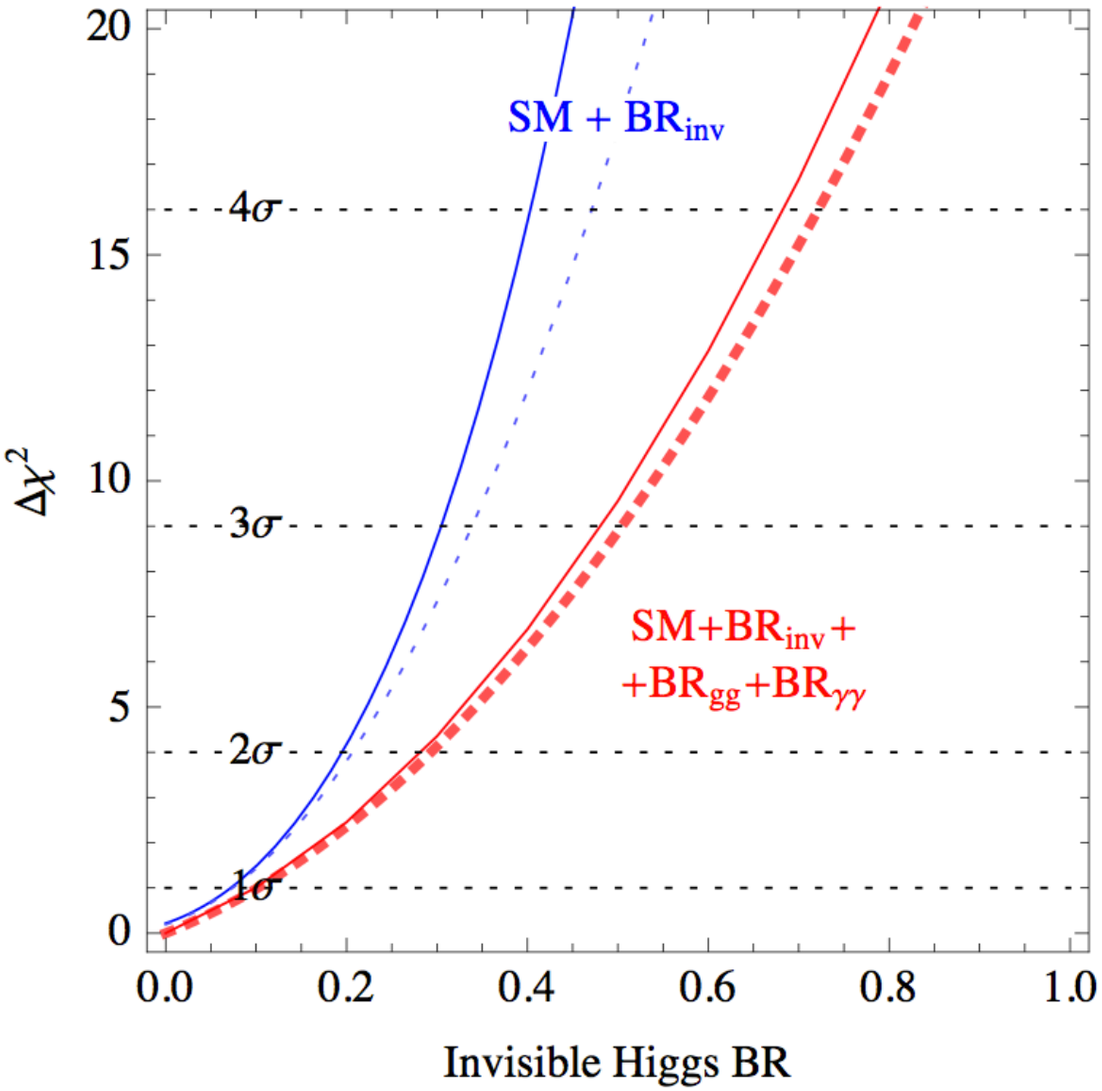
can give BR(H→SS)~O(10%) for λ~0.005

Non-standard ("exotic") Higgs decays

- could easily be missed by *all* other searches
- require dedicated analyses
- discovery potential w/ existing data

"Invisible" Higgs width

$\mathrm{BR}_{\mathrm{inv}} < 0.28$ at 95% C.L. (w/ assumptions)



plenty of room for exotic decays

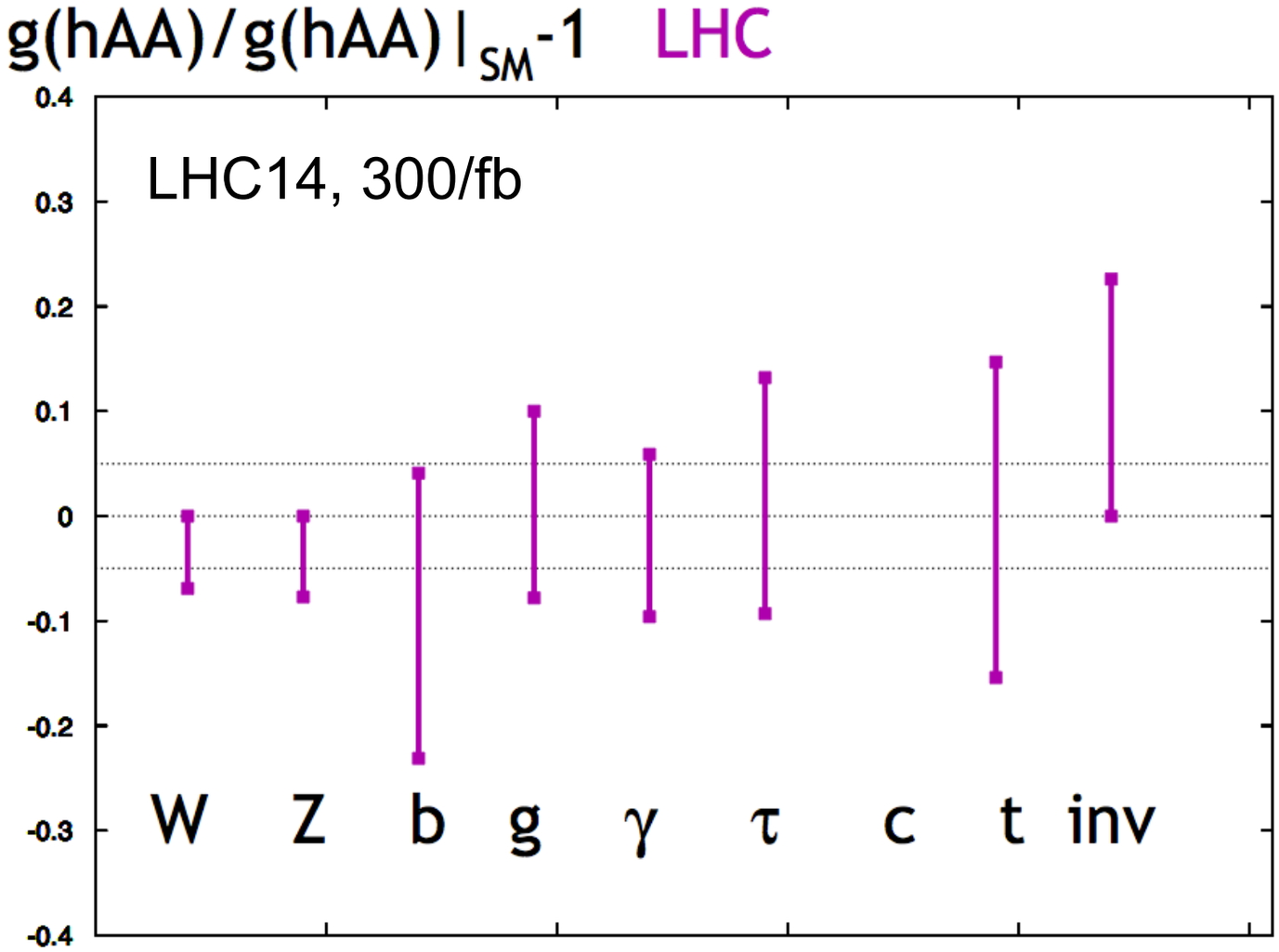
could be much more common than $h \to \gamma\gamma$, $h \to ZZ^*$

Giardinoa, Kannike, Masina, Raidal, Strumia, 1303.3570

see e.g. also Belanger, Dumont, Ellwanger, Gunion, Kraml; Espinosa, Muhlleitner, Grojean, Trott

Even after LHC there will be room

LHC measurements will never determine Higgs couplings to SM particle better than 5-10%



M. Peskin, 1207.2516

How many exotic decay events possible right now?

assume BR(h→new) = 10%, LHC8, 20/fb

channel	**# events (raw)**
ggF	39000
VBF	3150
W(ℓν)+h	280
Z(ℓℓ)+h	55
ttH	260

} Associated Production (AP)

Many events in ggF/VBF, but suitability depends on *h* decays

Can always trigger w/ AP… but not many events

Many exotic decays are possible

1. h→2

e.g. h→invisible

2. h→2→3

e.g. $h \to \gamma + \not{E}_T,\ \gamma + Z',\ Z' + \not{E}_T$

3. h→2→4

e.g. $\left.\begin{array}{l} h \to 4x \\ h \to 2x2y \end{array}\right\} x, y = e, \mu, \tau, \gamma, b, j,\ \not{E}_T, \ldots$

4. h→2→6

e.g. $h \to \tilde{\chi}_1\tilde{\chi}_1 \to 6\ \mathrm{SM\ particles}$ (e.g. R-parity violation)

5. h→2→many

e.g. lepton-jets, photon-jet, … (e.g. in Hidden Valleys)

6. any of above w/ displaced vertex

Many exotic decays are possible

Need broad array of searches!

Aim of "Exotic Higgs Decay Working Group"

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- survey, systematize, prioritize non-standard decays
- an extensive literature exists, but models need reassessment: what BR can be probed? how maximize sensitivity?
- develop search strategies, assess discovery potential, provide viable benchmark models/points
- inform LHC14 trigger selection + future collider
- assemble comprehensive summary document & website to inform experimental analyses (timescale~O(few weeks))

One aim is to produce a prioritized list

(since time and resources are finite)

- distinguish between "theoretically" & "experimentally" motivated (i.e. how easy to discover)
- Challenges of prioritization:
  - theory motivation may sometimes be in eye of beholder
  - experimental motivation sometimes requires dedicated studies to evaluate
- Examples:
  - h→4b, 2b2τ: high theory/medium experiment
  - h→4e, 4μ: medium theory/high experiment

Summary

Higgs may be our (only) window to new physics

must look *explicitly* for non-standard decays

- a large array of models, so need to survey, systematize, & prioritize possibilities, & assess their discovery potential
- comprehensive summary document & website in preparation
- immediate work will be most useful for LHC8, but will inform LHC14 + future collider
  (e.g., how much better could you do w/ a linear collider?)