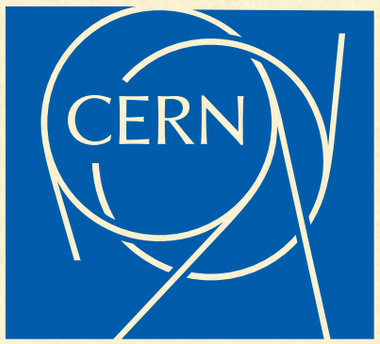
BSM HIGGS @ 100 TEV: PROGRESS REPORT

Andrey Katz (with D. Curtin and M. J. Ramsey-Musolf)



UNIVERSITÉ
DE GENÈVE

EXOTIC HIGGS DECAYS

SM allowed:

- higgs ➜ b's
- higgs ➜ gluons
- higgs ➜ gauge bosons (W's and Z's)
- higgs ➜ taus
- higgs ➜ photons
- higgs ➜ γZ
- light flavors (small)

Exotic Higgs: any channel which is disallowed or negligibly small in the SM. Examples:

- higgs ➜ invisible (not necessarily neutrinos)
- higgs ➜ 4 b (prompt or coming from displaced vertices — usually 2)
- higgs ➜ 2 b's and 2 taus (also prompt or coming from displaced vertices)
- higgs ➜ many leptons (e.g. 4 or 6)
- ……..

DEVIATION FROM THE SM HIGGS COUPLINGS

SM predicted couplings:

- $hb\bar{b}$
- hgg
- hVV (HWW and hZZ)
- hττ
- hγγ
- hγZ
- $ht\bar{t}$
- self-coupling

How well can we measure each of these couplings and what do deviations tell us about the BSM?

Ratios between the couplings can be measured more precisely than absolute values. What are the interesting ratios from the BSM point of view?

Particularly interesting and challenging couplings, which might be very informative about the new 100 GeV sterile scalars coupling to the higgs

EXTENDED HIGGS SECTOR AND NEW EXOTIC HIGGSES

Can we produce new scalar particles which are also part of the non-minimal higgs sector. What are (resonance) production rates? What are the decay modes? What is 100 TeV reach?

- Poster child — A^0, H^0 and $H^{\pm}$
- Slightly less known — "radial mode" higgses in the twin Higgs scenario
- New scalars which couple to the higgs but do not participate in EWSB (do not get VEV)

OVERVIEW OF THE BSM HIGGS THEORY

Why is this interesting? Can this compete with the direct searches for NP?

- Light particles in the higgs sector — hidden valleys. Possible motivations: neutral naturalness, (non-thermal) baryogenesis, "darkogenesis"…
  - Generic signatures — exotic higgs decays. h → light sector → something
  - Non generic, but often happens— deviation of the higgs from the SM couplings due to the extended higgs sector
  - Sometimes happens — new higgs states (e.g. radial higgs mode)
  - Quite generic — not necessarily new heavy colored states (or might demand high luminosity)
- SUSY and 2HDM:
  - Generic signatures — new higgses and deviations from the SM higgs couplings. Unclear what will be easier to spot.
- New scalars which couple to the higgs — EW baryogenesis and folded SUSY.
  - Generic — deviation in hZZ rate @ ~ 1% level and in higgs self-coupling

"STANDARD" NATURALNESS

AK, David Curtin and Raman Sundrum

SUSY and Partially composite higgs

SUSY — type II 2HDM. Can be augmented with extra scalars (NMSSM, nMSSM…) or effective hard SUSY breaking.

Non sign of deviations in the higgs sector until now — 2HDM in decoupling (or alignment) limit. What do we expect?

$$r_b \approx \left(1 - \frac{m_h^2}{m_H^2}\right)^{-1} \left(1 - \frac{\lambda_{35} v^2}{m_H^2}\right).$$

$$r_t = \frac{v g_{ht\bar{t}}}{m_t} = 1 + \frac{B^2}{2M_1^4}\left(1 - r_b^2\right),$$

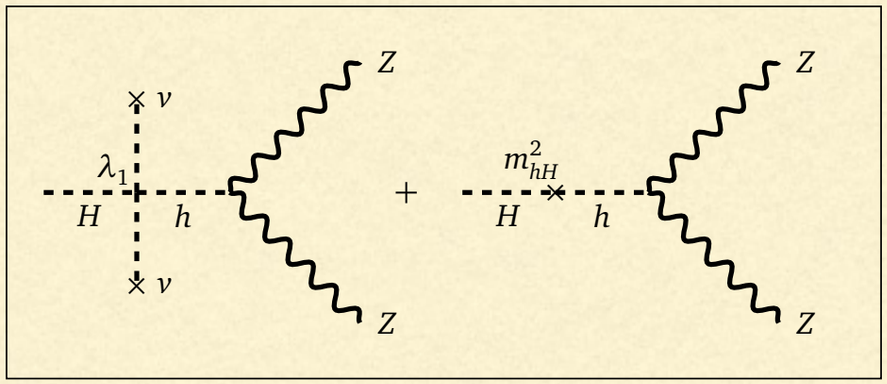
$$r_V = \frac{v g_{hVV}}{2m_V^2} = 1 - \frac{B^2}{2M_1^4}\left(1 - r_b\right)^2.$$

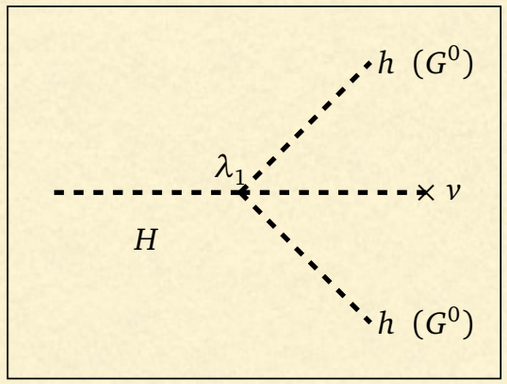
Expect dominant deviations in the down-type sector fermions, other deviations are strongly suppressed

"STANDARD" NATURALNESS 2

More SUSY signatures — direct production of the heavy higgses. Usually decay into the fermions and the light higgs - namely hh, ZZ, WW.

$$\Gamma(H \to hh) \approx 9\ \Gamma(H \to ZZ)$$





Compositeness: the generic behavior of the higgs sector — misalignment. We expect higgs couplings deviations (suppression) which is proportional to the ratio between the EW scale and the scale of the colored partners ☞

complementarity of exotic higgs searches with the direct searches for colored partners.

NEUTRAL NATURALNESS

Similar to the partial TeV-scale compositeness: misalignment and universal suppression of the higgs couplings proportional to the FT.

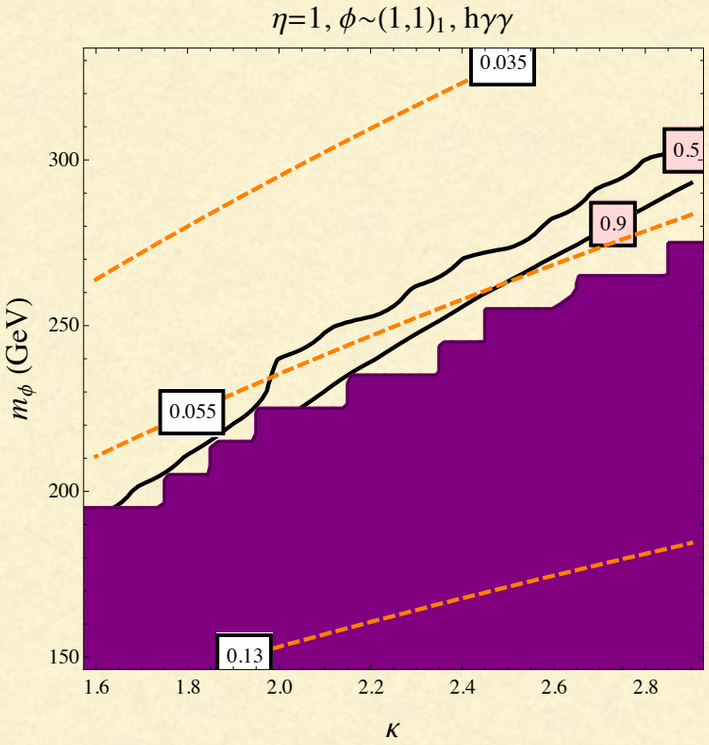
Different from TeV-scale compositeness:

- No colored particles, complementarity with the direct searches is lost, higgs couplings is the main signal
- Generically predict confining hidden valleys at the scale of ~ GeV. Higgs will have exotic decays: decays via secondary vertices or prompt decays $h \rightarrow 4b$, $h \rightarrow 4\tau$, etc.
- In folded SUSY (non generic) — complementary to the quirks searches
- In twin higgs — direct radial higgs production

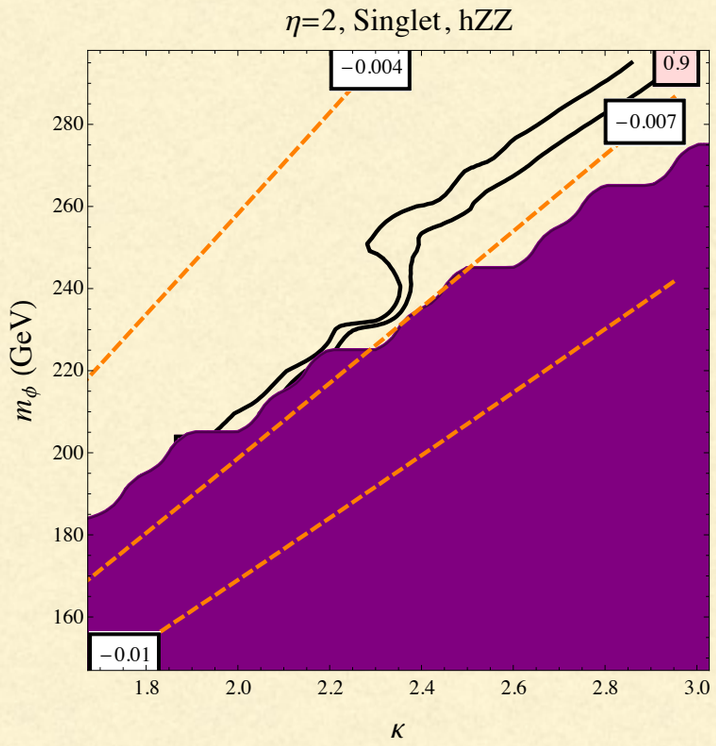
BEYOND NATURALNESS — EWPT

AK and Maxim Perelstein

In the SM the EW transition is a smooth crossover, there is no departure of equilibrium to produce the baryon asymmetry. To change the nature of the EWPT we need new states, which couple strongly to the higgs. Too light — excluded from the invisible higgs decays. Generic signature — deviation in higgs couplings



Nightmare scenario — singlets, cause deviation in hZZ coupling ~O(1%).



BEYOND NATURALNESS — MORE

- Higgs portal DM — invisible higgs decays, disappearing tracks from the higgs decay (*Matt Low, Mike Spannowski, Tim Tait*)

- Neutrino masses — triplet scalar "higgs" in type II see-saw: production decay mode and reach (*Rabi Mohapatra*)

HIGHLIGHTS OF THE "TO-DO" LIST

- Naturalness side: reach for the misaligned higgs couplings (universal suppression)
- Naturalness — production of heavy higgses, especially decaying into fermions and the "SM higgs" (with equivalence theorem)
- Measurement of hZZ coupling and higgs self-coupling
- Trigger demands