The Higgs boson: buried or charming

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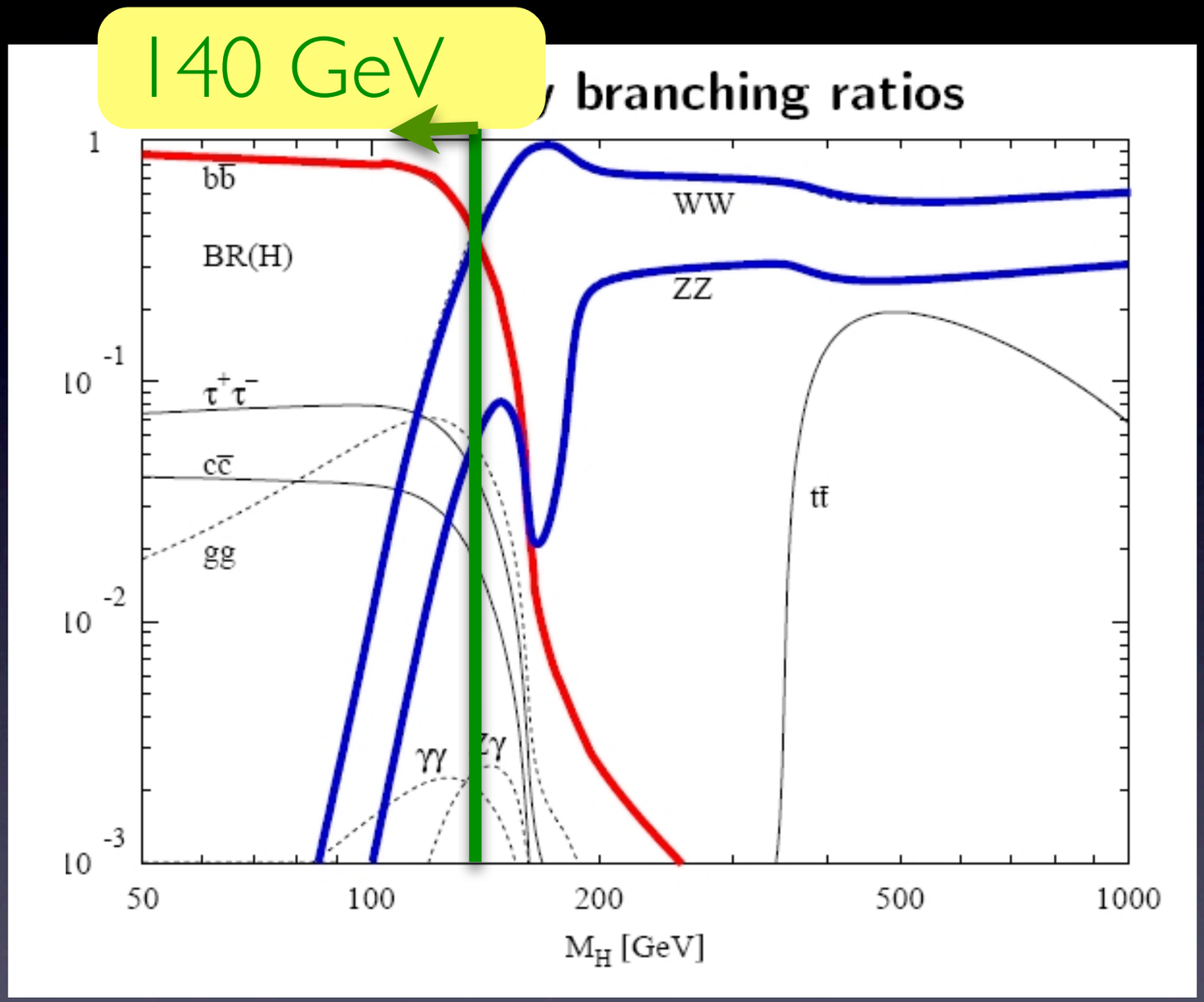
(CERN)

w/ Brando Bellazzini, Csaba Csaki,
and Adam Falkowski

Standard Higgs decays

- Coupling ~ mass, decays into heaviest available
- For light Higgs, dominant decay into 2b.

Standard Higgs decays



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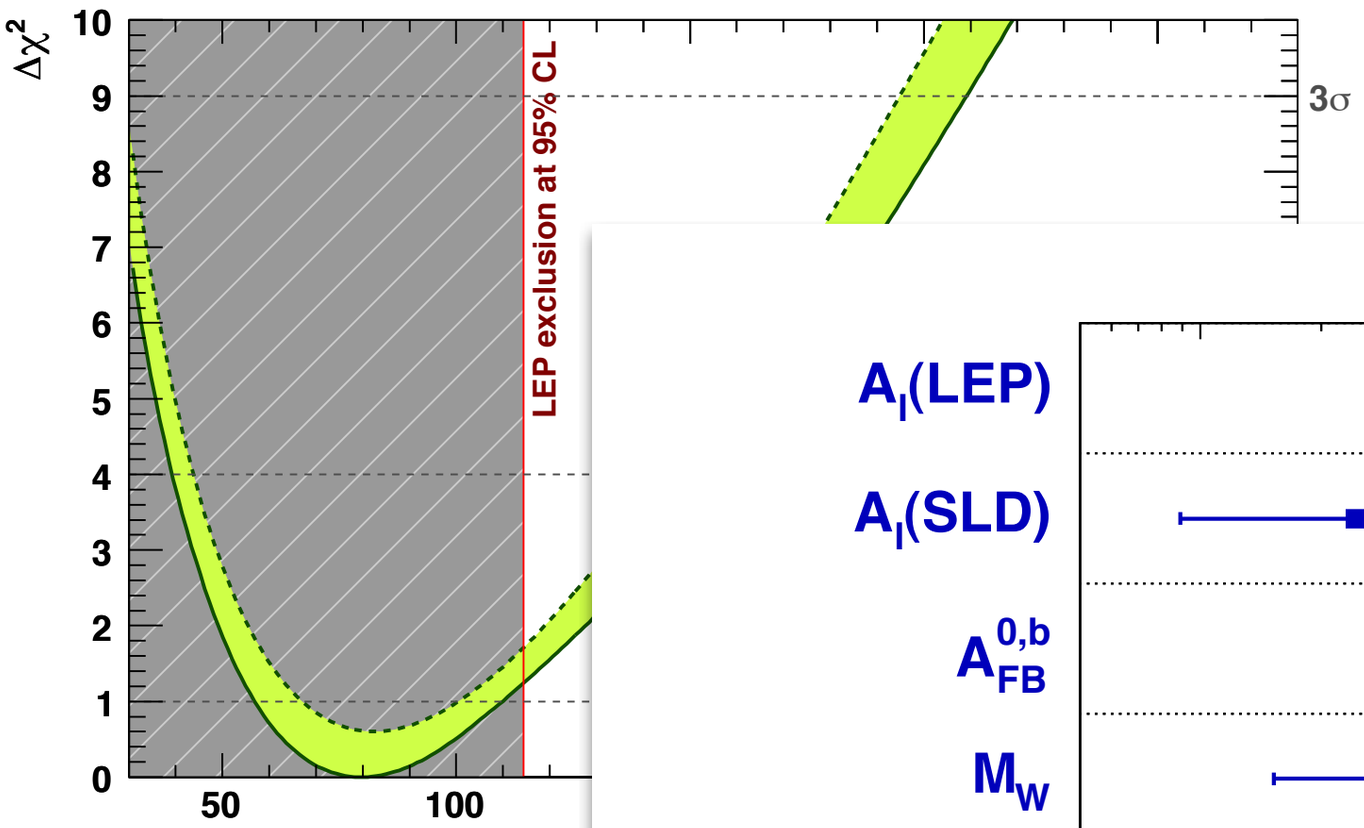
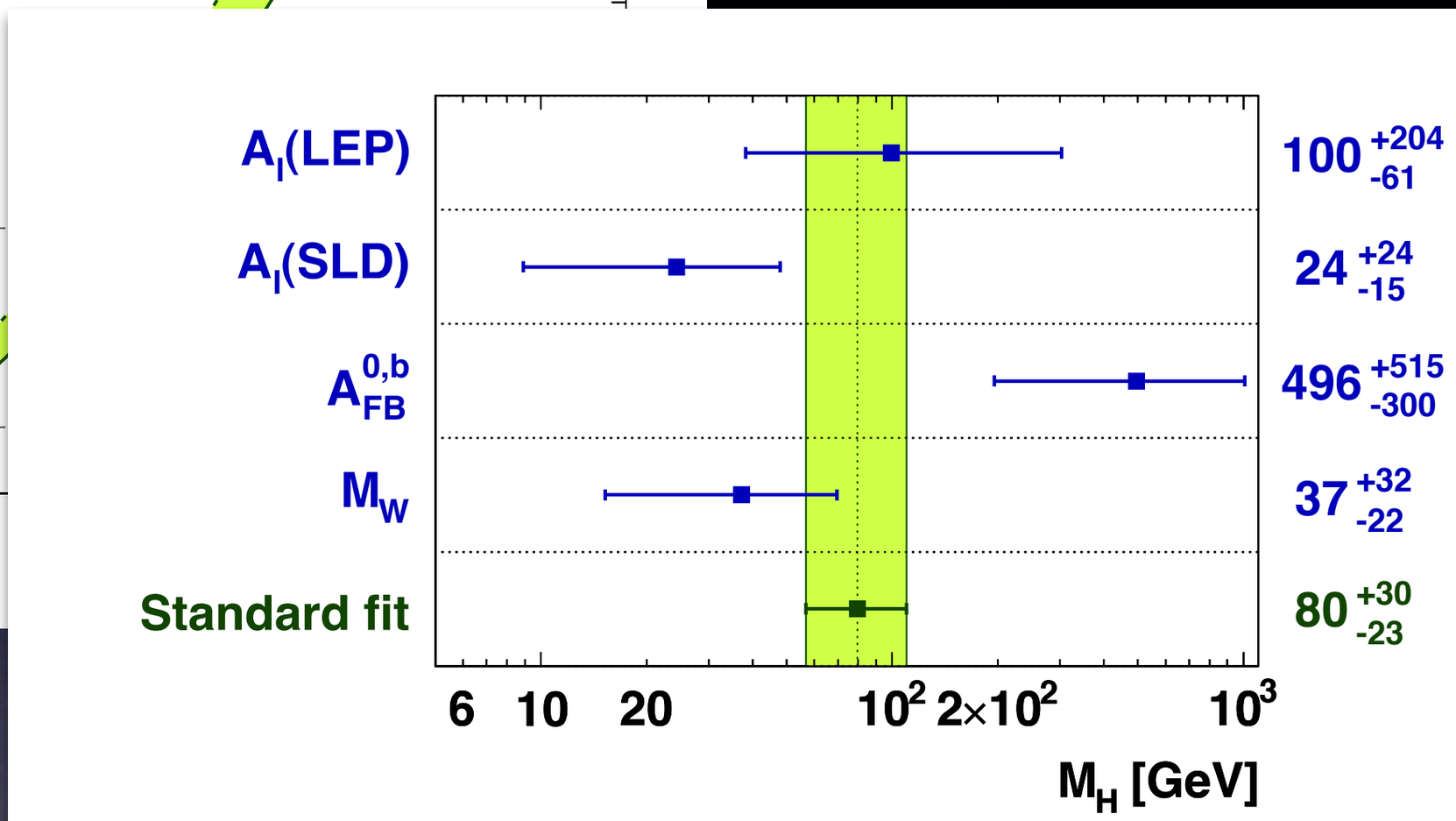
- For light Higgs, dominant decay into 2b.

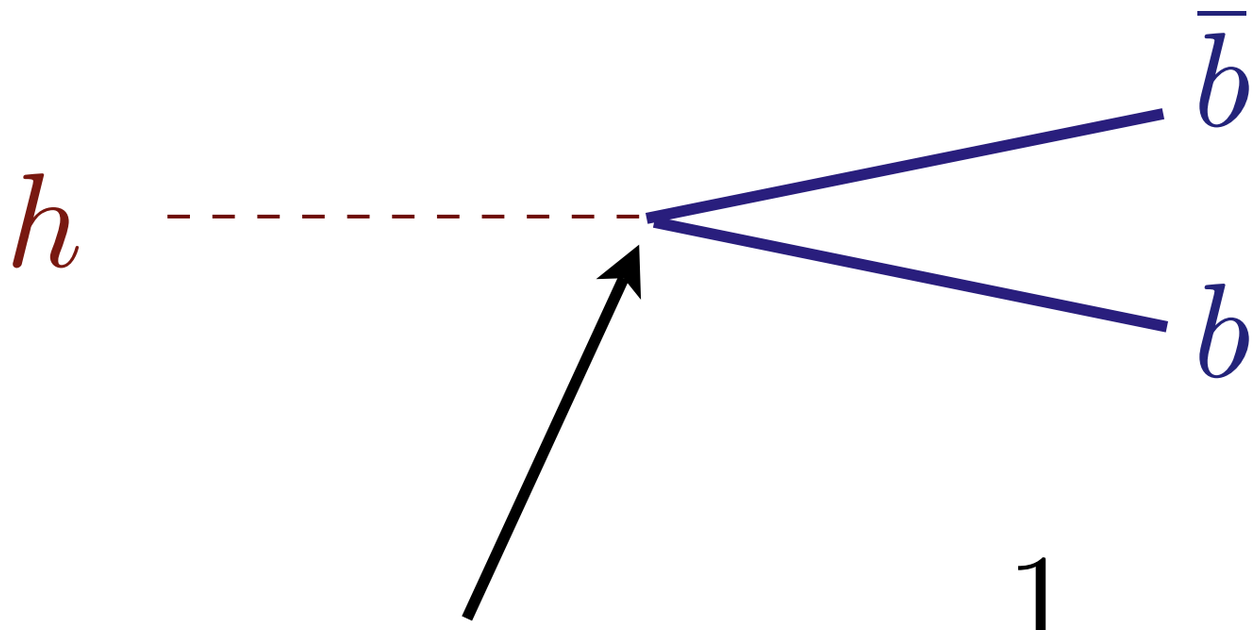
Gfitter '08





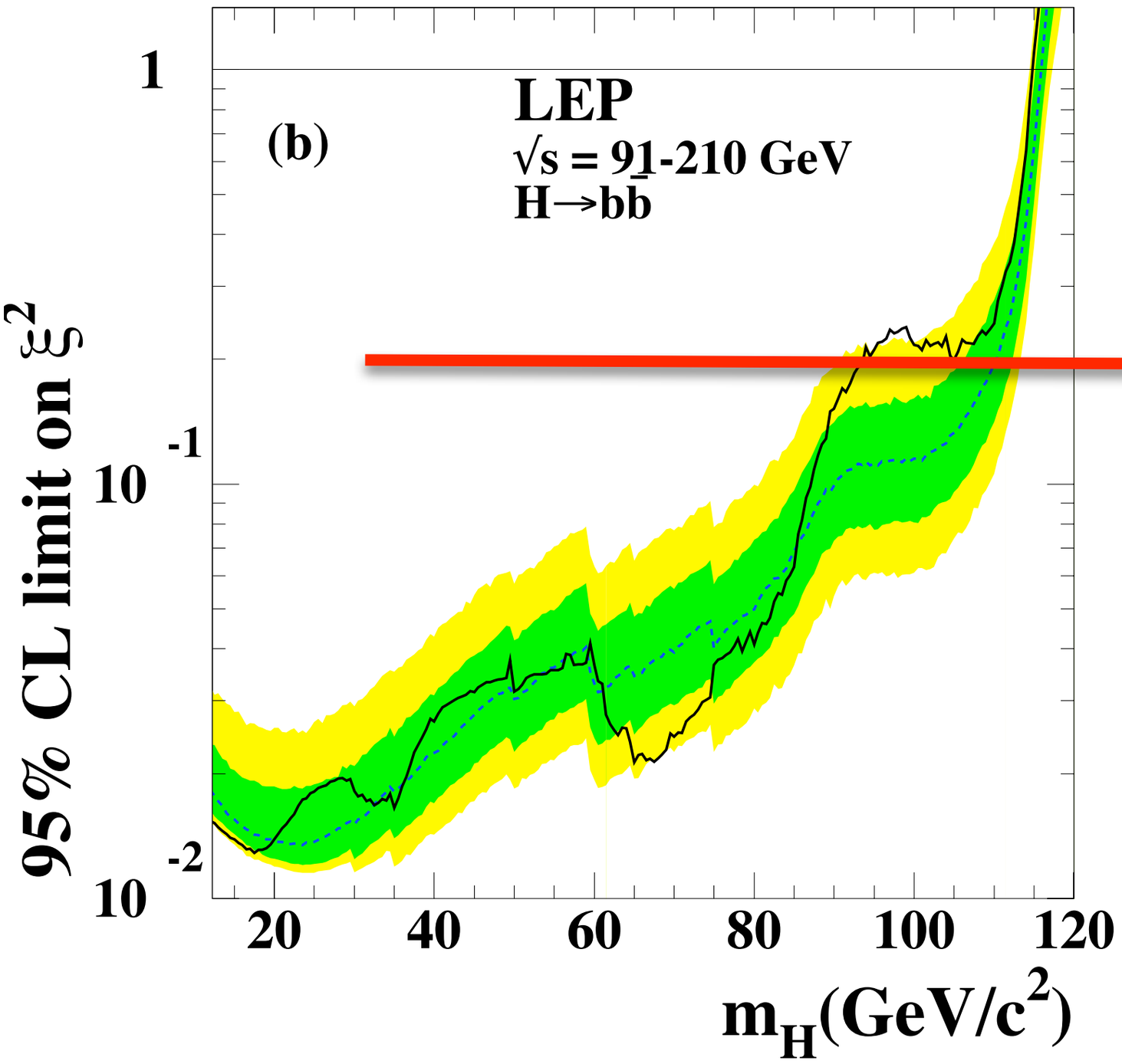
- Indirect tests suggest light scalar < 158 GeV (95%cl)
- without A^b_{FB}, $\quad m_H = 55^{+32}_{-21}\,\mathrm{GeV}$

Light Higgs' Small Width



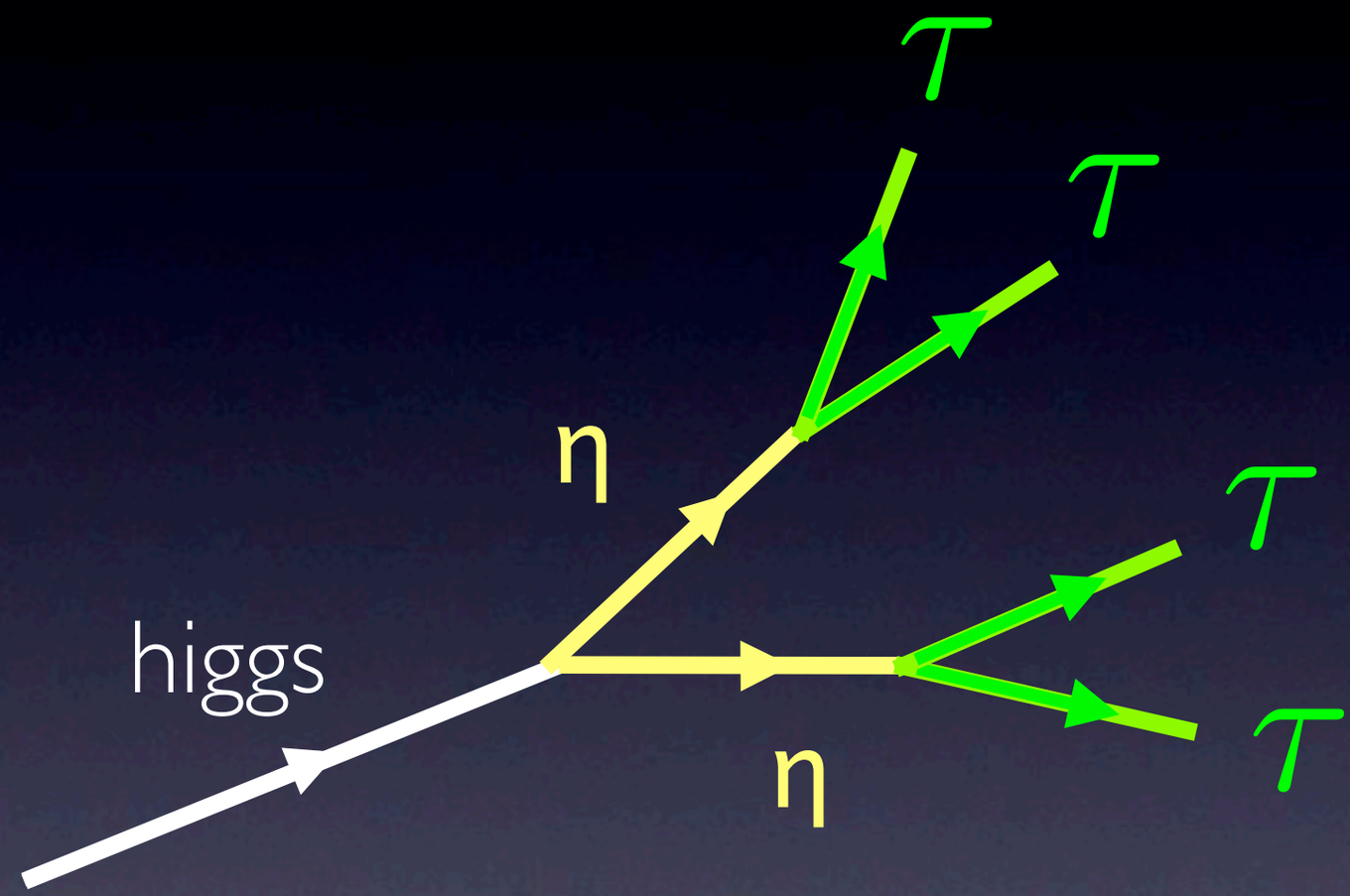
$$y_b(m_h) \sim \frac{1}{60}$$

$$\Gamma_{h \to b\bar{b}} \sim y_b^2$$



Suppress SM BR to 20 %

NMSSM = MSSM + singlet η



assume $m_\eta < 2m_b$

Dermisek & Gunion '06

Non-standard Higgs decays

Decay Channel	**Limit**
$h \to b\bar{b}$ or $\tau\bar{\tau}$	115 GeV
$h \to jj$	113 GeV
$h \to WW^*$ or ZZ^*	110 GeV
$h \to \gamma\gamma$	117 GeV
$h \to \not{E}$	114 GeV
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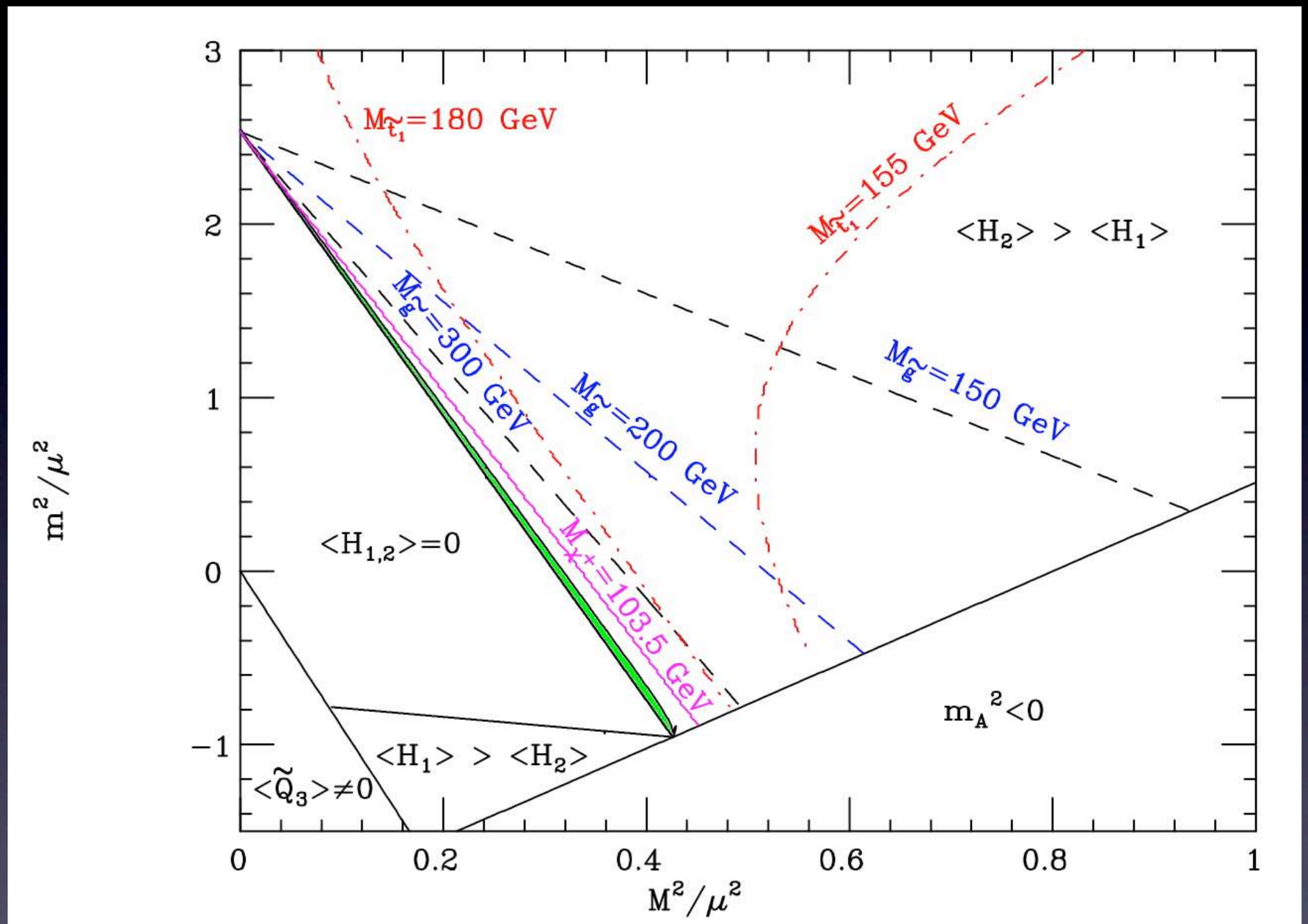
$h \to AA \to 4\tau, 4c, 4g$	86 GeV
$h \to$ anything	82 GeV

Constraints on 4- (or more) body decays typically as weak as model-independent bound of 82 GeV

Little Hierarchy problem of the MSSM

Giudice, Rattazzi '06



No natural MSSM after LEP2.

What's wrong with the MSSM?

$$m_h \approx m_Z^2 \cos^2 2\beta + \frac{3m_t^4}{2\pi^2 v^2} \ln \frac{m_{\rm stop}^2}{m_t^2}$$

Negative search at LEP: $m_H > 114$ GeV

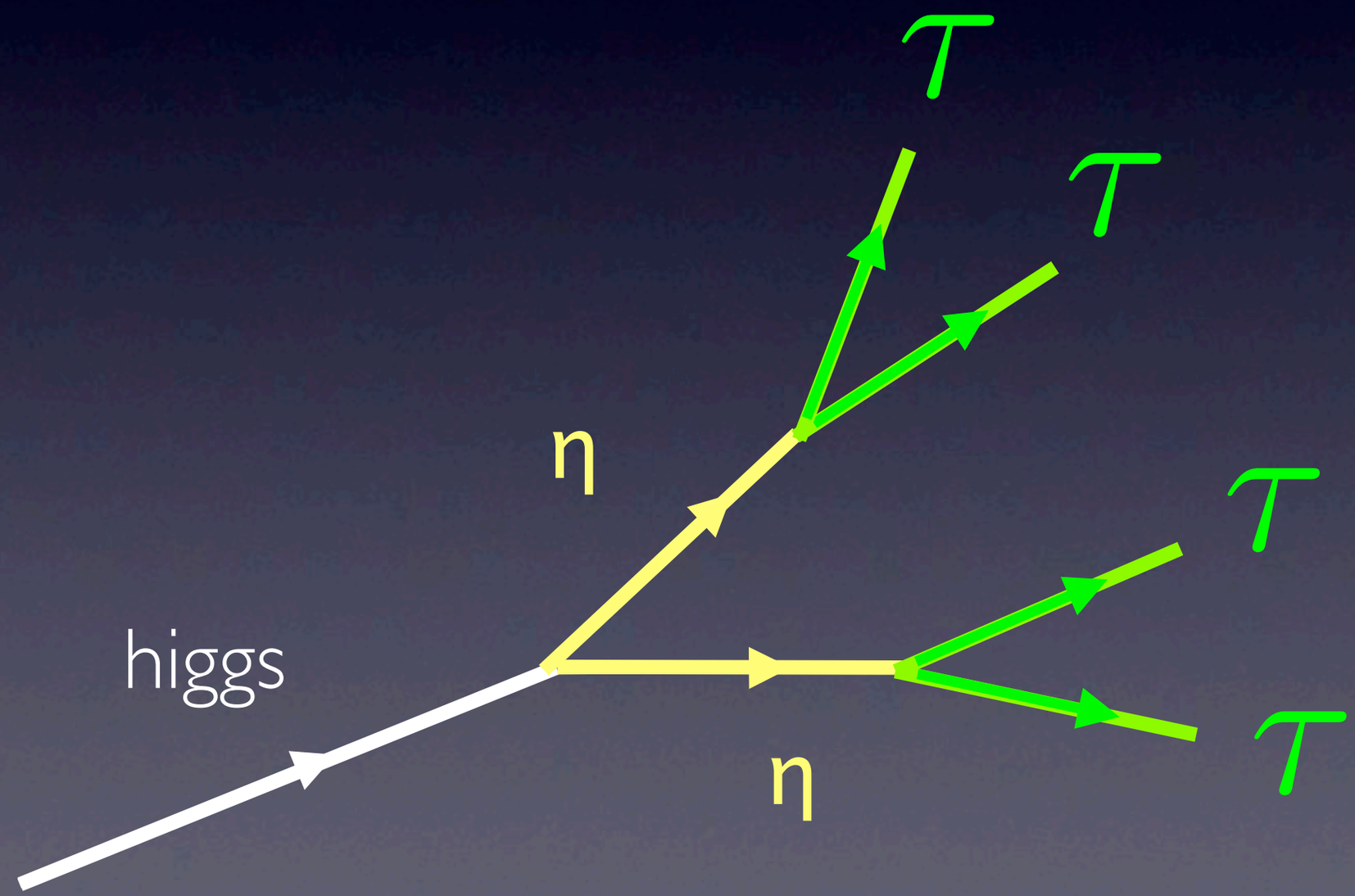
Need $m_{stop} \sim O(1\,\text{TeV})$. But at minimum satisfy:

$$\frac{m_Z^2}{2} = -|\mu|^2 - \frac{m_{H_u}^2 \tan^2\beta - m_{H_d}^2}{\tan^2\beta - 1} \approx -m_{H_u}^2$$

Fine tuning

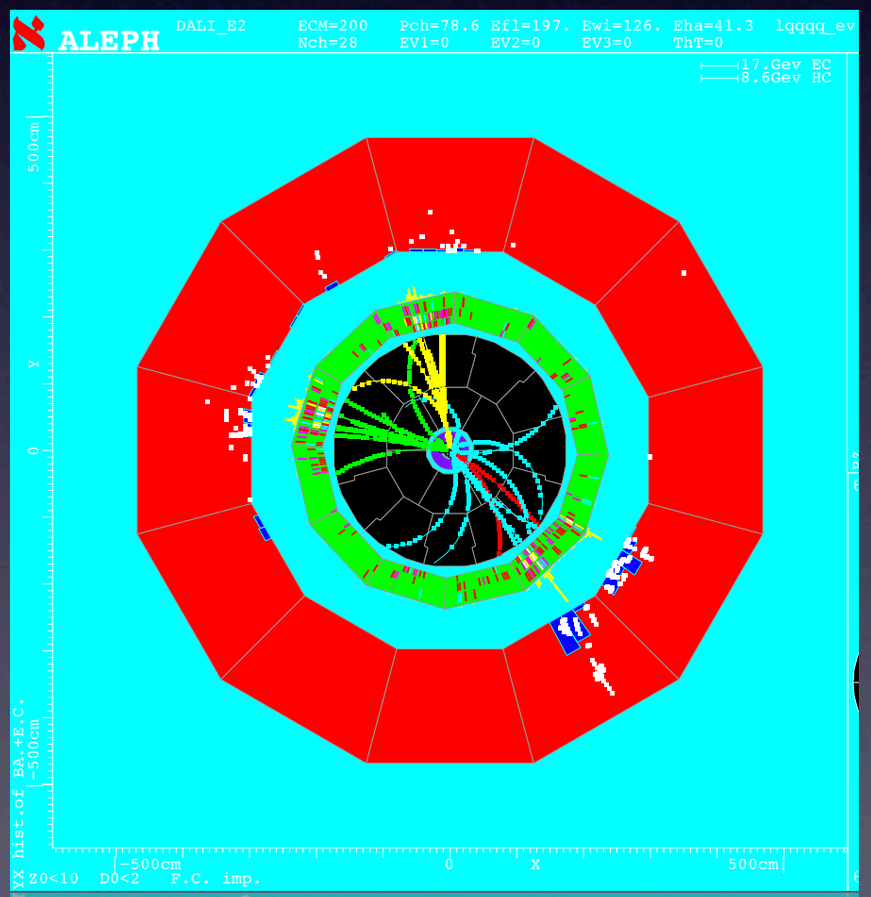
$$\delta m_{Hu}^2(\text{loop}) = -\frac{3y_t^2}{8\pi^2} m_{\rm stop}^2 \ln \frac{\Lambda^2}{m_{\rm stop}^2} \approx 600 \cdot \frac{m_Z^2}{2}$$

Did we miss the Higgs at LEP ?



Currently ongoing search for exotic Higgs decays in archived LEP data h → 4 tau, ...

Kyle Cranmer presented the results this Tuesday at CERN (ALEPH's 20th birthday),



Expected limits @ m_a = 4,10 GeV

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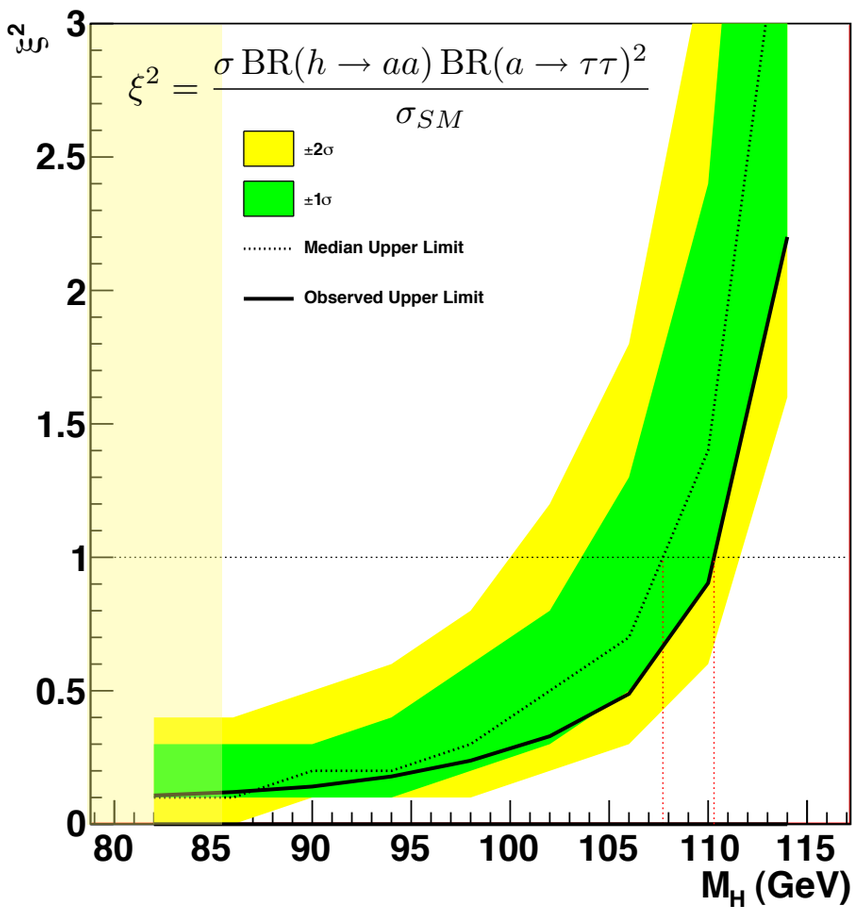
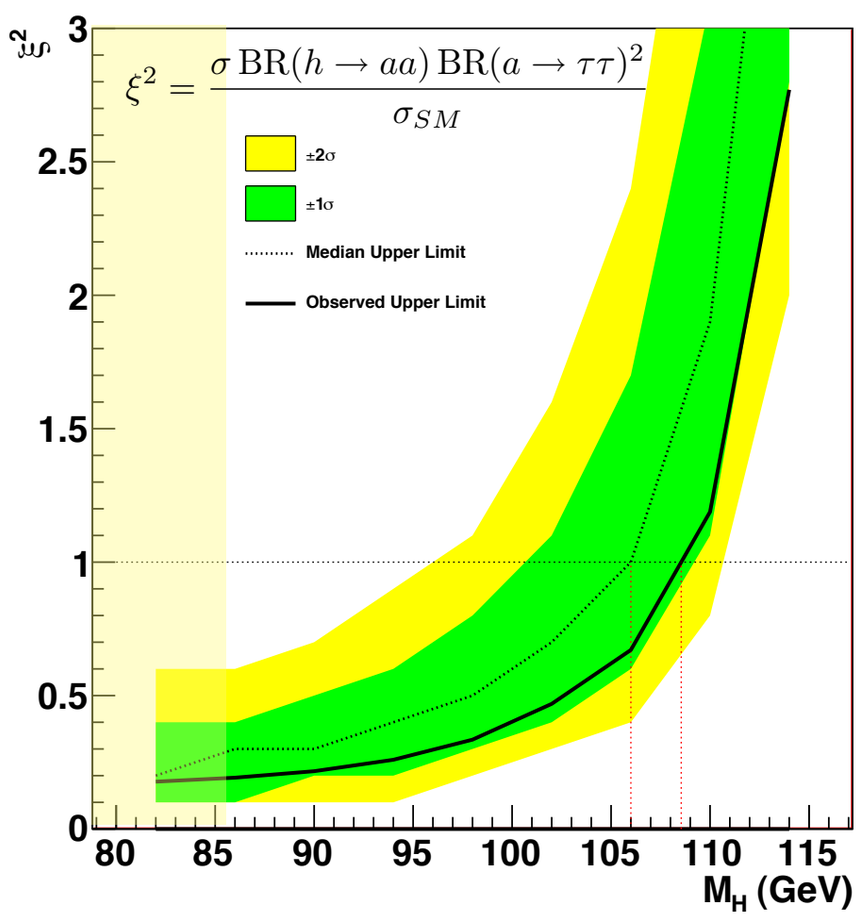
Seeing no sign of excess, we proceed to set limits

- Here, we make reference to background acceptance uncertainties in MSSM Higgs analysis. (Statistical errors dominate, systematics make little difference in result)

expected limit for $m_a = 4$ GeV



expected limit for $m_a = 10$ GeV



Our first analysis of $e^+e^- \to Zh \to (ee, \mu\mu, \nu\nu)\,4\tau$ is essentially complete, and will extend the reach of the OPAL analysis

- we had sensitivity for a 5σ discovery up to ~90 GeV
- expected [observed] limits ($\xi^2 = 1$) are ~105 [110] GeV

w/ James Beacham, Paolo Spagnolo, Itay Yavin

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$\to 4\tau$ 110 GeV

Constraints on 4- (or more) body decays except 4c and 4g decays almost as strong as SM limit

Simplest Susy Little Higgs

Birkedal, Chacko, Gaillard '04
Berezhiani, Chankowsky, Falkowski, Pokorski, Wagner '04, '05
Csaki, Strumia, Marandella, Shirman '05; Roy, Schmaltz '06;
Bellazzini, Csaki, Delgado, AW '09; Bellazzini, Csaki, Falkowski, AW '09

early attempts higgs as pGB in susy:

Berezhiani, Dvali '89; Dvali, Giudice, Pomarol, 96

- Higgs as pGB of SU(3)/SU(2) at $f \approx (2-3) \times v$

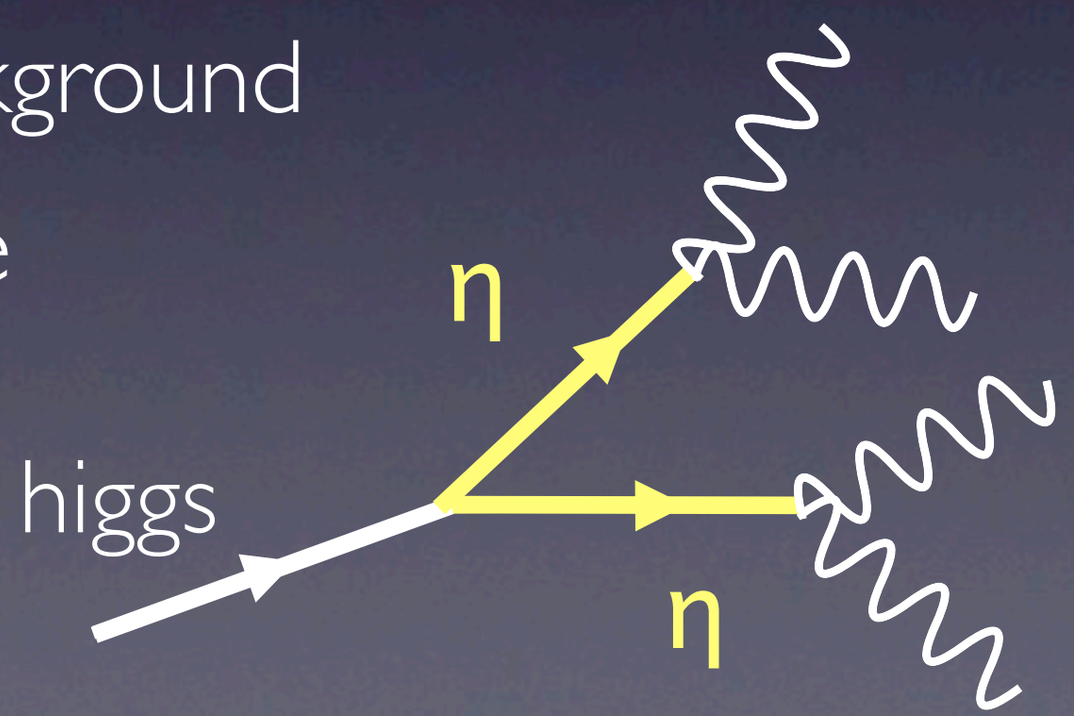
  8 - 3 = 5 broken generators

  5 = 4 (Higgs doublet) + 1 (singlet)

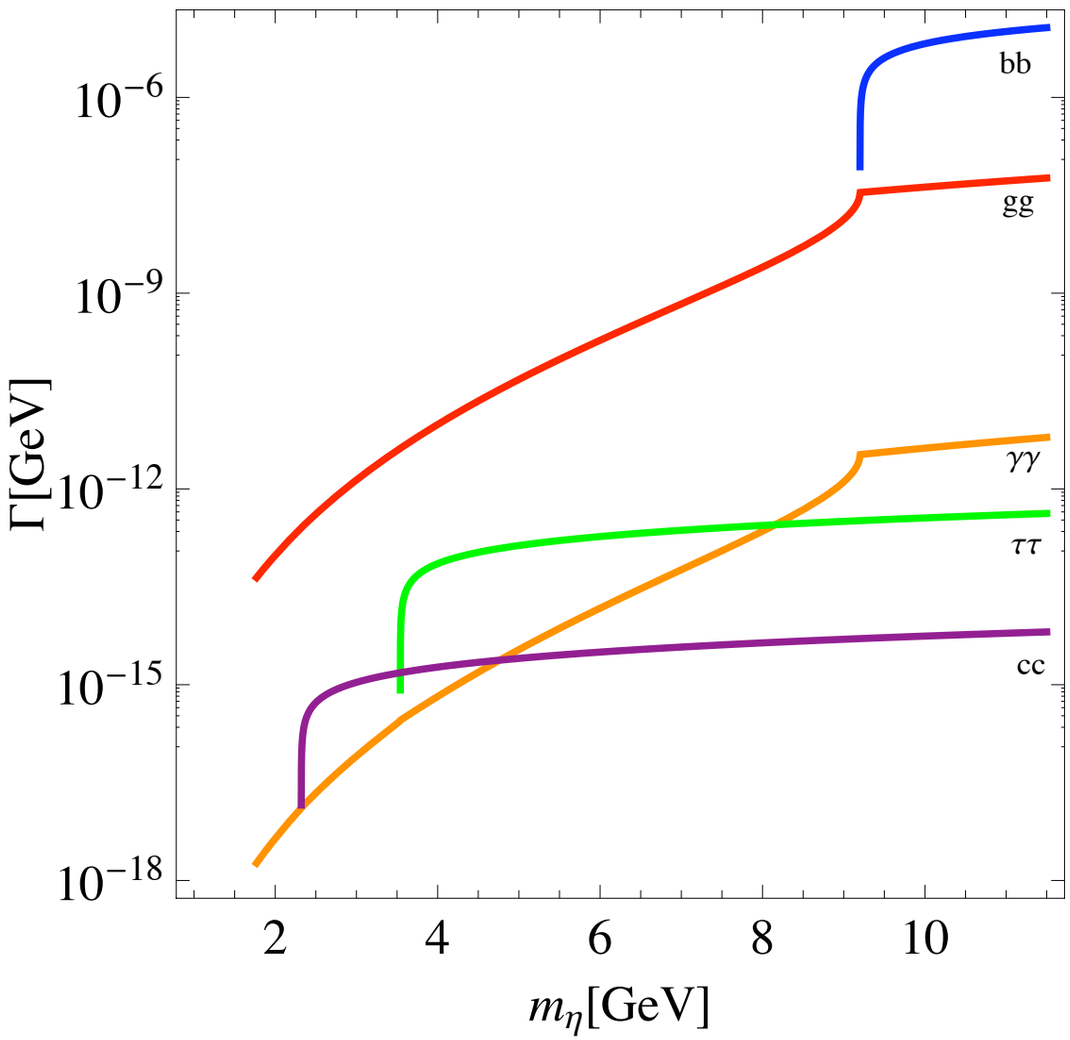
- Collective symmetry breaking

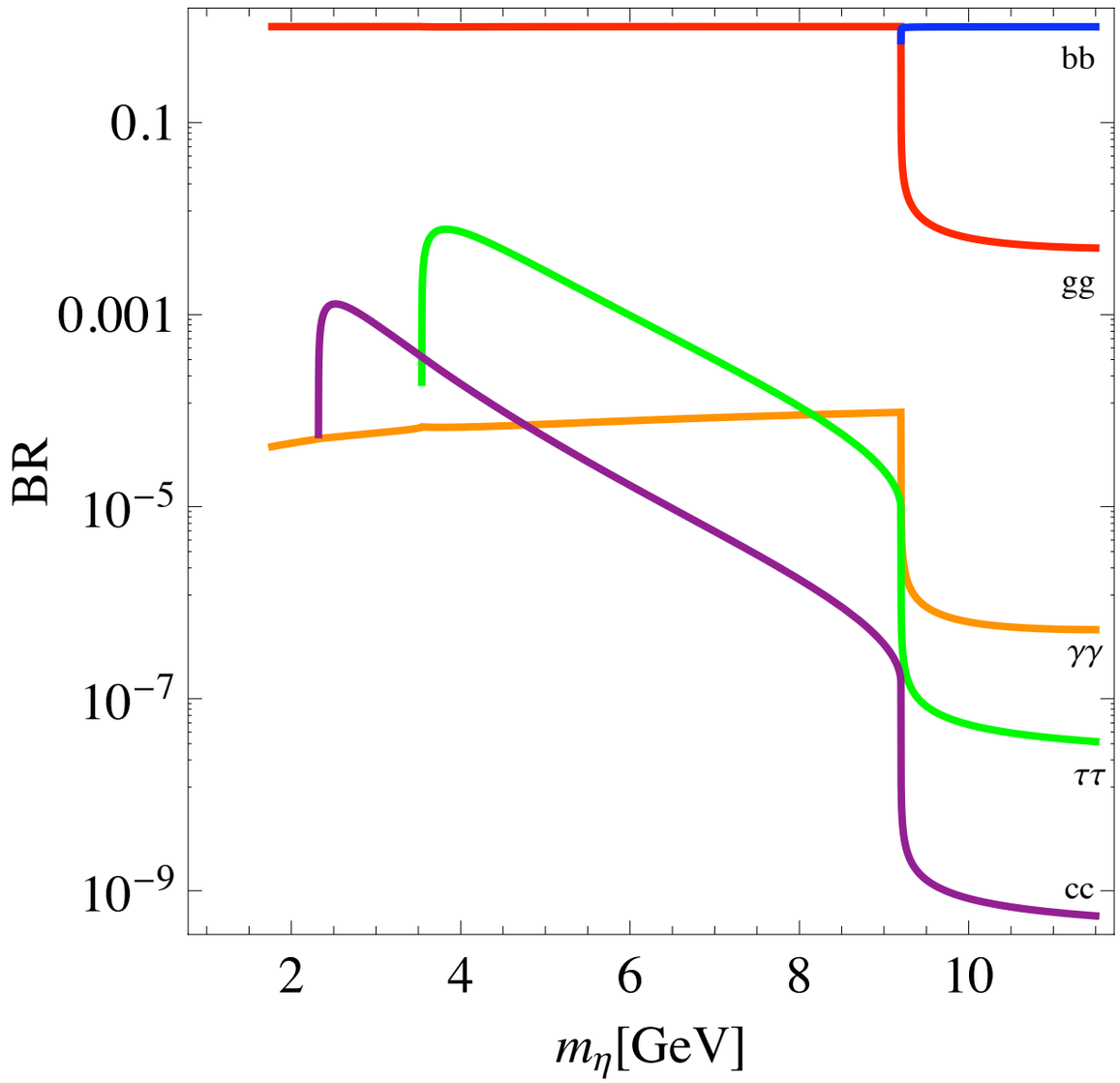
Buried / charming Higgs

- Higgs → 2 eta→4j (or 4c) cascade decay depending on fermion representation
- Higgs below SM LEP bound (~ 90 GeV)
- No little hierarchy problem
- Higgs buried in QCD background
- Fake Higgs readily available



Eta decays - buried Higgs





Fake Higgs

What completes unitarization of WW scattering?

$$\mathcal{H}_u \approx (f + r/\sqrt{2}) \sin\beta \begin{pmatrix} \sin((\tilde{v}+h)/f) \\ 0 \\ e^{i\eta/f}\cos((\tilde{v}+h)/f) \end{pmatrix}$$

→ radial excitation, oscillations around global symmetry breaking scale f

- Couples like Higgs but suppressed by $v_{ew}/f \sim 1/2$
- Cures T parameter

$$\Delta T \sim \cos^2(\tilde{v}/f)(\log m_h/\Lambda) + \sin^2(\tilde{v}/f)\log(m_r/\Lambda) \quad \rightarrow \quad m_{eff} = m_h(m_r/m_h)^{v_{EW}^2/f^2}$$

- Apparent inconsistency with EWPT and unitarization of $W_L W_L$ scattering

Summary

- Higgs and eta are pGB's of SU(3)/SU(2)
- Higgs → 2 eta → 4 j cascade decay natural
- Higgs below SM LEP bound
- No little hierarchy
- Light susy spectrum
- Higgs buried in QCD background
- Fake Higgs readily available