Light Higgs at LEP and EW Precision Data

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work in progress with
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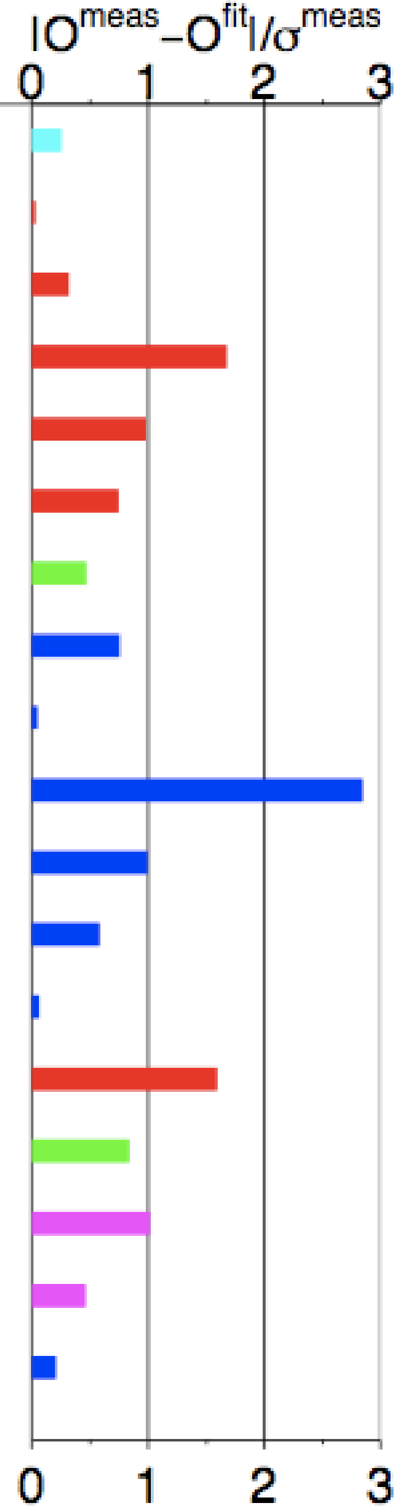
Contents

- Nonstandard Higgs Decay
- Ab and Rb
- Leptonic nonuniversality

LEP EWWG

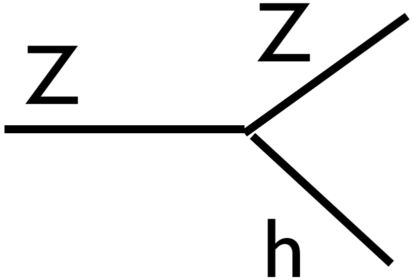
	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ_{had}^{0} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01643
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21579
R_c	0.1721 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1038
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.410 ± 0.032	80.377
Γ_W [GeV]	2.123 ± 0.067	2.092
m_t [GeV]	172.7 ± 2.9	173.3



		Measurement with Total Error	Systematic Error	Standard Model fit	Pull
	$\Delta\alpha^{(5)}_{\mathrm{had}}(m_Z^2)$ [221]	0.02758 ± 0.00035	0.00034	0.02766	−0.2
a)	LEP-I				
	line-shape and				
	lepton asymmetries:				
	m_Z [GeV]	91.1875 ± 0.0021	$^{(a)}0.0017$	91.1875	0.0
	Γ_Z [GeV]	2.4952 ± 0.0023	$^{(a)}0.0012$	2.4957	−0.2
	σ^0_{had} [nb]	41.540 ± 0.037	$^{(b)}0.028$	41.477	1.7
	R^0_ℓ	20.767 ± 0.025	$^{(b)}0.007$	20.744	0.9
	$A^{0,\ell}_{\mathrm{FB}}$	0.0171 ± 0.0010	$^{(b)}0.0003$	0.0164	0.8
	+ correlation matrix [2]				
	τ polarisation:				
	$\mathcal{A}_\ell$ ($\mathcal{P}_\tau$)	0.1465 ± 0.0033	0.0016	0.1479	−0.4
	$\mathrm{q\overline{q}}$ charge asymmetry:				
	$\sin^2\theta^{\mathrm{lept}}_{\mathrm{eff}}(Q^{\mathrm{had}}_{\mathrm{FB}})$	0.2324 ± 0.0012	0.0010	0.23141	0.8
b)	SLD				
	$\mathcal{A}_\ell$ (SLD)	0.1513 ± 0.0021	0.0010	0.1479	1.7
c)	LEP-I/SLD Heavy Flavour				
	R^0_{b}	0.21629 ± 0.00066	0.00050	0.21585	0.7
	R^0_{c}	0.1721 ± 0.0030	0.0019	0.1722	0.0
	$A^{0,\mathrm{b}}_{\mathrm{FB}}$	0.0992 ± 0.0016	0.0007	0.1037	−2.8
	$A^{0,\mathrm{c}}_{\mathrm{FB}}$	0.0707 ± 0.0035	0.0017	0.0741	−1.0
	$\mathcal{A}_{\mathrm{b}}$	0.923 ± 0.020	0.013	0.935	−0.6
	$\mathcal{A}_{\mathrm{c}}$	0.670 ± 0.027	0.015	0.668	0.1
	+ correlation matrix [2]				

Nonstandard Higgs Decay

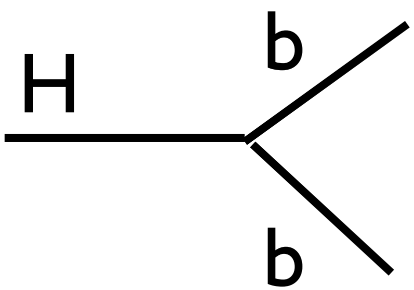
There are two ways to modify Higgs events.



1. Production

ZZh coupling is small

$$g^2 = 0.04 g_{\mathrm{SM}}^2 \rightarrow m_h > 75\mathrm{GeV}$$

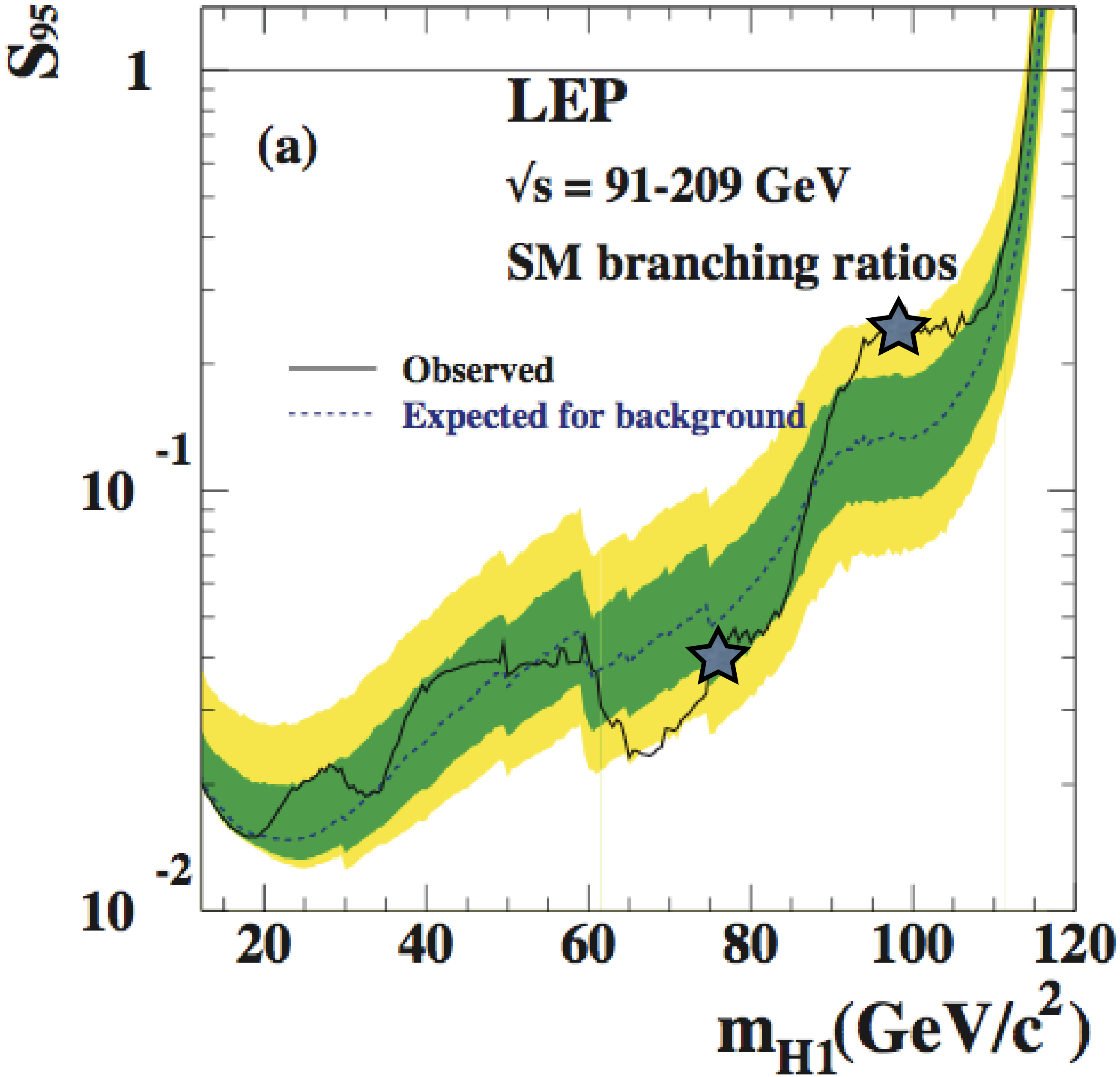


2. Decay

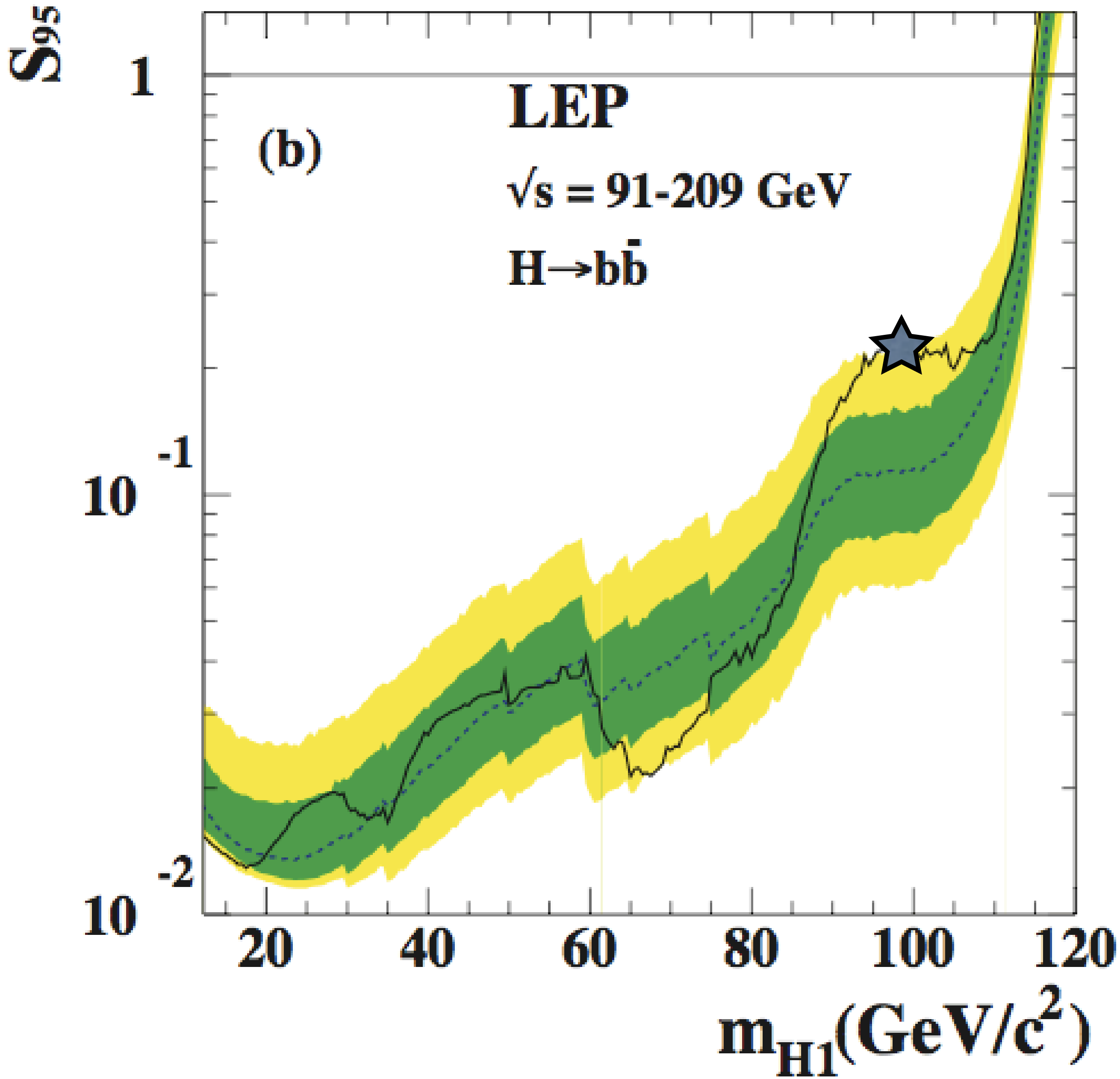
B(h ->bb) is small

$$B(H \rightarrow b\bar{b}) = 0.2 \rightarrow m_H > 100GeV$$

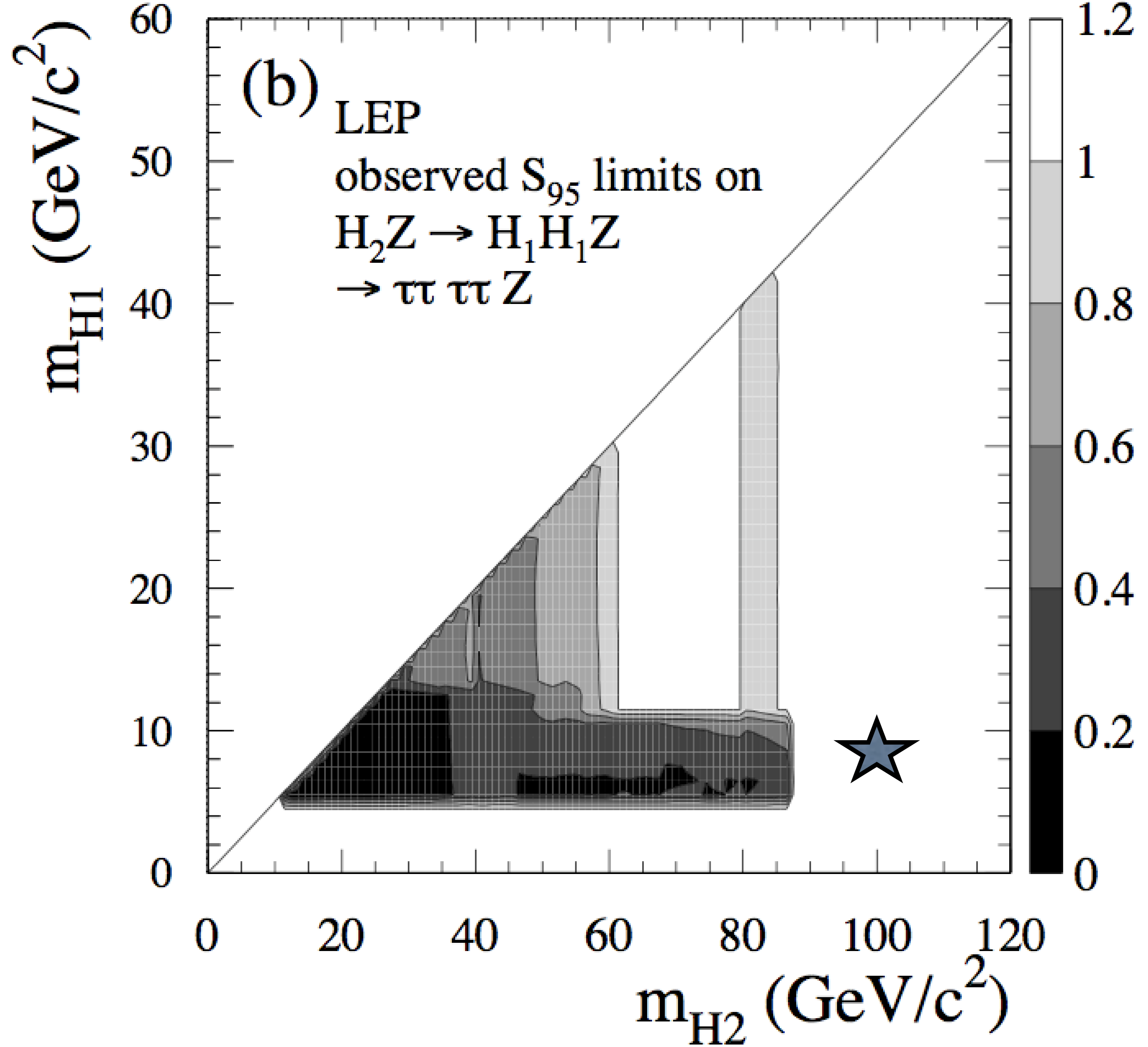
Nonstandard Higgs Decay



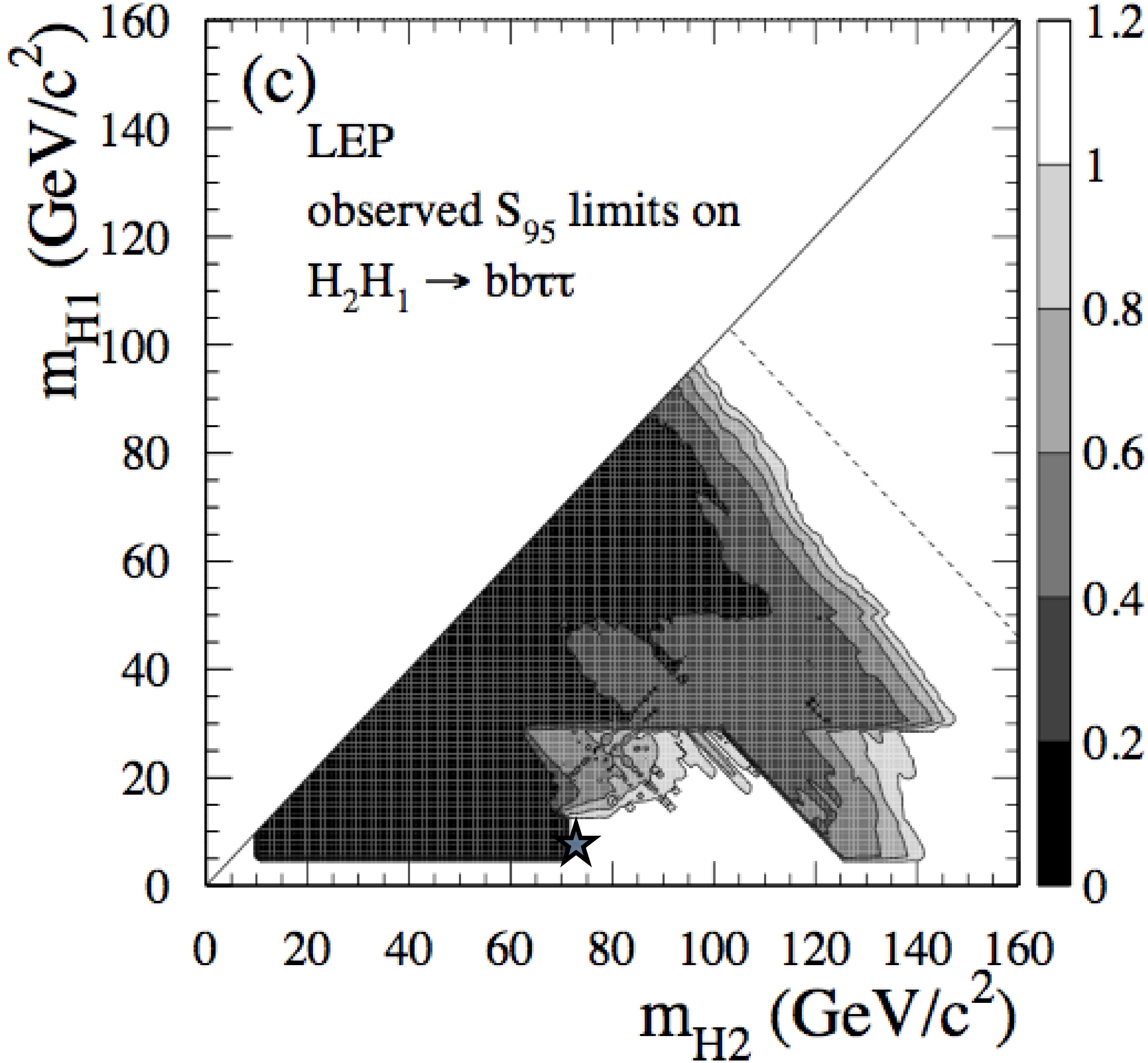
Nonstandard Higgs Decay



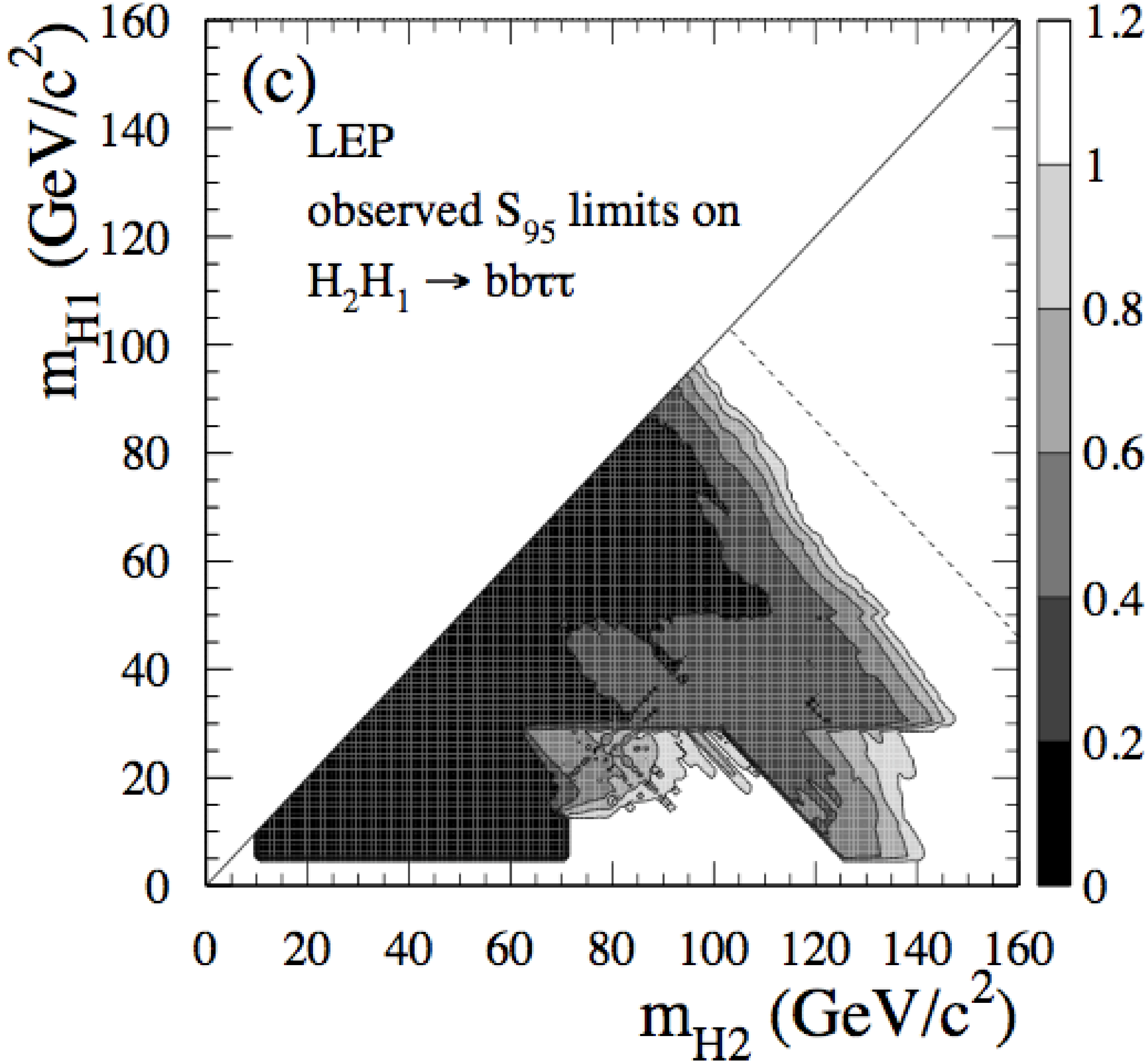
Nonstandard Higgs Decay



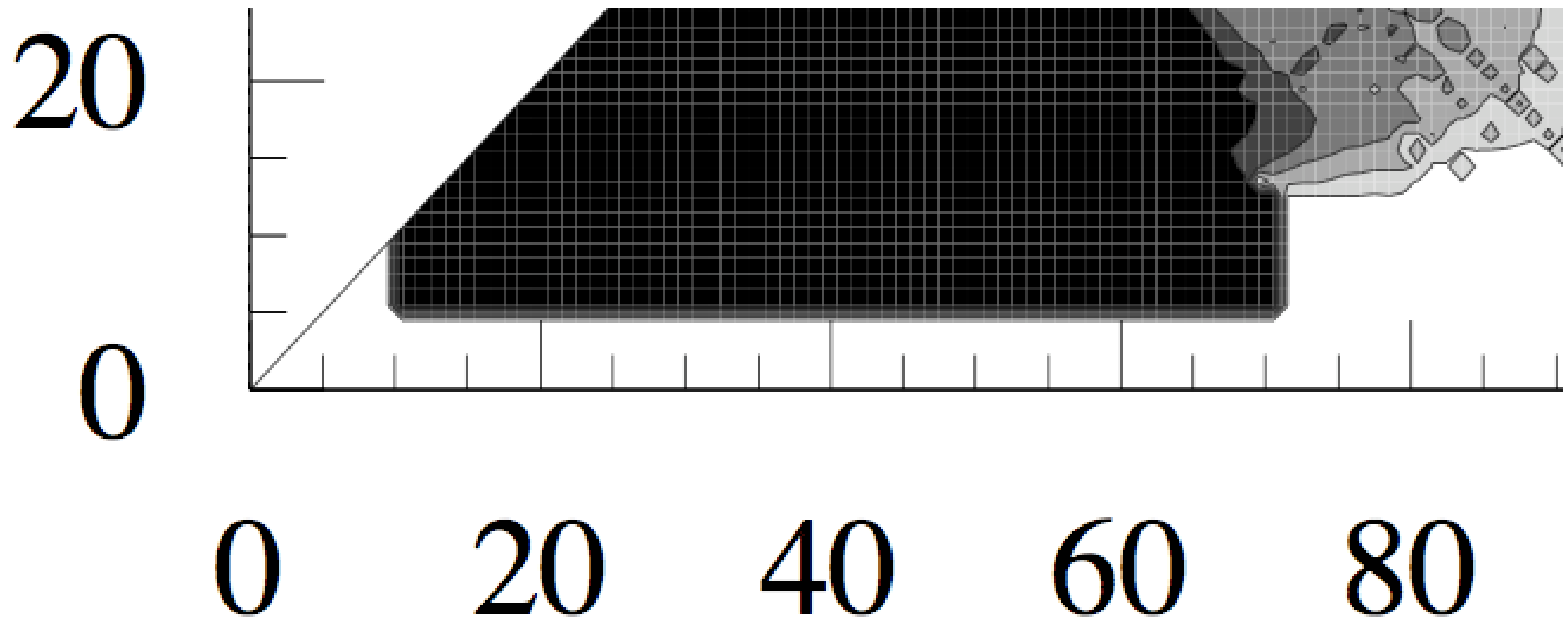
Nonstandard Higgs Decay



Nonstandard Higgs Decay



Nonstandard Higgs Decay



Ab and Rb at LEP

Ab : Forward Backward Asymmetry of b

$$A^b_{FB}(M_Z) = \frac{3}{4}\frac{(Q_Z^{e_L})^2-(Q_Z^{e_R})^2}{(Q_Z^{e_L})^2+(Q_Z^{e_R})^2}\frac{(Q_Z^{b_L})^2-(Q_Z^{b_R})^2}{(Q_Z^{b_L})^2+(Q_Z^{b_R})^2} \equiv \frac{3}{4}A_e\,A_b$$

Ab FB (Exp) = 0.0992+-0.0016

Ab FB (SM) = 0.1037+-0.0008

The difference 0.0045 corresponds to the discrepancy at the level of 2.5 (or 2.8) sigma

Ab and Rb

$$R_b = \frac{B(Z \to b\bar{b})}{B(Z \to \mathrm{hadrons})}$$

Rb (Exp) = 0.21629 +- 0.00066

Rb (SM) = 0.2158

The difference 0.0005 is 0.7 sigma.

Ab and Rb

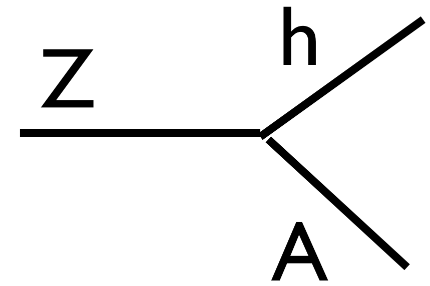
gL^2 : gR^2 ~ 30:1

1% change in L needs 30% change in R
to keep the sum invariant

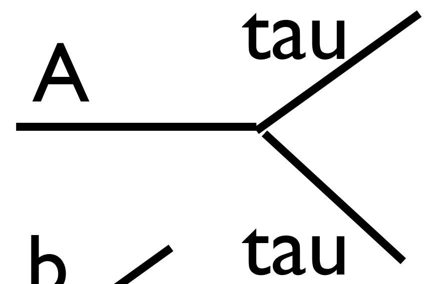
Can we see Ab anomaly as a signal of new physics?

Probably, yes.

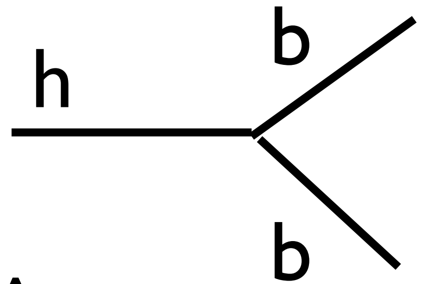
Light Higgs in MSSM-like setup
(all the Higgs < 100 GeV)



Light Higgs in MSSM like theory

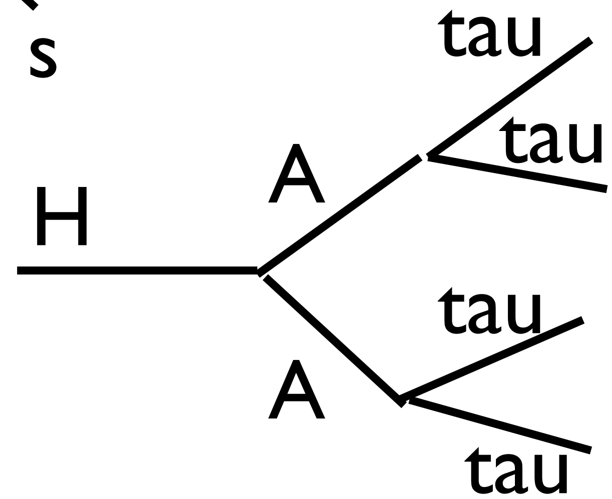


mA~7 GeV A -> tau tau

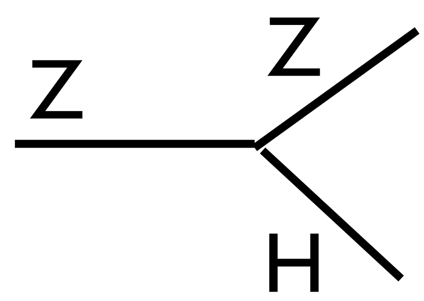


mh~70 ~ 75 GeV* h -> b b

mH+~80 GeV H+ -> W* A, tau nu, c s



mH~100 GeV H -> A A-> 4 taus



Ab and Rb

When mA < 10 GeV,
many unusual things can happen.

H => AA => 4taus
H+ => W*A, tau nu, c sbar

mA=7 GeV

$$\frac{B(Z \to hA \to b\bar{b})}{B(Z \to b\bar{b})}$$

mh=75GeV : 0.5%
mh=72GeV : 1%
mh=70 GeV : 1.5%

Ab and Rb

80 GeV charged Higgs reduces gL^2 of b by 1%
when tan beta is close to 1.
New contribution to Rb comes from Z => h A.

Rb = LL+RR+LR
-1% 0% 1%
Ab = LL - RR
-1% 0%

b to s gamma can be safe if stop mass is about 120 GeV and mu is about 100 GeV in MFV.
With sbottom-sstrange mixing, b to s gamma can be always made to be consistent.

Lepton Nonuniversality

Leptonic branching ratio of W at LEP II
has been measured with a few percent error.

$$\frac{2B(W \to \tau\nu)}{B(W \to e\nu) + B(W \to \mu\nu)} = 1.07$$

W decaying to tau is 7 % larger than to e or mu.
2.8 sigma deviation with 2~3 % error.

2B(W=>tau nu)/(B(W=>e nu)+B(W=>mu nu)) = 1.07

Lepton Nonuniversality

ex/0612034

	Lepton non–universality			Lepton universality
Experiment	$\mathcal{B}(\mathrm{W} \rightarrow \mathrm{e}\overline{\nu}_{\mathrm{e}})$ [%]	$\mathcal{B}(\mathrm{W} \rightarrow \mu\overline{\nu}_{\mu})$ [%]	$\mathcal{B}(\mathrm{W} \rightarrow \tau\overline{\nu}_{\tau})$ [%]	$\mathcal{B}(\mathrm{W} \rightarrow \mathrm{hadrons})$ [%]
ALEPH	$10.78 \pm 0.29^*$	$10.87 \pm 0.26^*$	$11.25 \pm 0.38^*$	$67.13 \pm 0.40^*$
DELPHI	$10.55 \pm 0.34^*$	$10.65 \pm 0.27^*$	$11.46 \pm 0.43^*$	$67.45 \pm 0.48^*$
L3	$10.78 \pm 0.32^*$	$10.03 \pm 0.31^*$	$11.89 \pm 0.45^*$	$67.50 \pm 0.52^*$
OPAL	10.40 ± 0.35	10.61 ± 0.35	11.18 ± 0.48	67.91 ± 0.61
LEP	10.65 ± 0.17	10.59 ± 0.15	11.44 ± 0.22	67.48 ± 0.28
χ^2/d.o.f.	6.3/9			15.4/11

Lepton Nonuniversality

ph/0607280 JH Park

0807.2135 R Dermisek

Charged Higgs with mass ~ 80 GeV can explain it.

mA ~ 7 GeV predicts mH+ ~ 80 GeV in the MSSM.

$$M_{H^+}^2 = M_A^2 + M_W^2$$ at tree level

$$\frac{\sigma(Z \to H^+ H^-)}{\sigma(Z \to W^+ W^-)} \sim 0.01$$

and charged Higgs decays dominantly to taus

Conclusion

The presence of light scalar and a slight extension of the MSSM allows new parameter space in which the anomalies in electroweak precision measurements can be explained.

The discrepancy existing in bottom and tau indicates that perhaps Higgs might have been produced at LEP I and II.

Hiding Higgs is possible (and easy).
Inconsistency in EW precision can be understood if the data is interpreted with the inclusion of light Higgs fields.

Appendix

Steps in accepting new explanations.

1. You are crazy.
It doesn't make sense.
It is already ruled out.

2. I knew it in advance.

3. It is trivial.