Charged Higgs Benchmarks

update

Warszawa Sept 2013

Per Osland

Work with:

almost everybody

Preamble

• A Higgs particle is found! SM?

Everything fits very nicely!



or perhaps...



room for new physics...

Preamble

- Higgs particle found! SM?
- In particular: 2HDM excluded?

Preamble

- Higgs particle found! SM?
- In particular: 2HDM excluded?
- not quite
- Hard evidence: charged Higgs!



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- 2013 It's Now or Never!

Conveners for 2HDM part: Maria K, PO

What's needed?

- Identify viable channels
- $t \to H^+ b$ $H^+ \to W^+ H_1$ $H^+ \to \tau^+ \nu$
- others?
- Identify non-excluded parameter regions
- with manageable rates and backgrounds

Numbers

- Experimentalists need numbers for observables
- Otherwise:

Model is just "Theoretical Playground"

Classifications of scenaria

Three orthogonal choices:

- Below or above t-threshold
- Different models (Yukawa sectors)
- Different decay channels

Yukawa terminology

Fermion		D		U		L
Model	VEV	\mathcal{F}^D	VEV	\mathcal{F}^{U}	VEV	\mathcal{F}^L
Ι	2	$-\cot\beta$	2	$+\cot\beta$	2	$-\cot\beta$
II	1	$+\tan\beta$	2	$+\cot\beta$	1	$+\tan\beta$
\mathbf{X}	2	$-\cot\beta$	2	$+\cot\beta$	1	$+\tan\beta$
\mathbf{Y}	1	$+\tan\beta$	2	$+\cot\beta$	2	$-\cot\beta$

Table 6: Relevant vacuum expectation values, for Φ_1 or Φ_2 , denoted 1 and 2, and reduced Yukawa couplings \mathcal{F} , as defined by Eq. (B.3) for models without tree-level FCNC.

Yukawa terminology

Φ_1	Φ_2	This work	HHG	BHP	G, AS	ARS	AKTY	BFLRSS
	u, d, ℓ	Ι	Ι	Ι	I (*)		Ι	Ι
d,ℓ	u	II	II	II	II		II	II
u, d, ℓ	u, d, ℓ	III				III		III
ℓ	u, d	X		IV	I' (*)		Х	lepton specific
d	u,ℓ	Y		III	II'		Y	flipped

Table 7: Dictionary of notations. "HHG": Higgs Hunter's Guide [1]. "BHP": Barger, Hewett, Phillips [142]. "G": Grossman [130], "AS": Akeroyd, Stirling [5]. The (*) denotes interchange $\Phi_1 \leftrightarrow \Phi_2$. "ARS": Atwood, Reina, Soni [180]. "AKTY": Aoki, Kanemura, Tsumura, Yagyu [181]. "BFLRSS": Branco, Ferreira, Lavoura, Rebelo, Sher, Silva [182].

Draft structure

- Introduction
- Potential and states
- Theoretical constraints
- Yukawa interaction
- H[±]decays
- Charged Higgs production at the LHC
- Experimental constraints



- Models with several charged scalars
- Models with DM candidates

Below top Relevant only for Models I and X

- $t \to H^+ b$,
- $H^+ \to \tau \bar{\nu}_{\tau}$
- $H^+ \to c\bar{s}$

Studied by Aoki et al, arXiv:1104.3178

Benchmarks: M=100, 150 GeV tanbeta=3, 10, 30

Perhaps update required in view of recent LHC constraints?

Below top

are we then done with the low-mass case?

Above top

- Model I: Mader et al, $H^+ \rightarrow \tau^+ \nu_{\tau}$ arXiv:1205.2692
- Model II: Basso et al, $H^+ \rightarrow W^+H_1$ arXiv:1205.6569
- Model II: Basso et al, $H^+ \rightarrow \tau^+ \nu_{\tau}$ promised soon

Marco Pruna \subset "et al"

Above top

cont

Other cases of interest?

Ideally: we should have independent confirmations

Volunteers?

Multi-doublet models

Enhanced $H^+ \rightarrow c\bar{b}$ Branching Ratios

Benchmarks: 90, 100, 130 GeV

Akeroyd et al

Models with DM candidates

- IDM Cao, Ma, Rajasekaran; Dolle et al; MK
- IDM2 cross sections, no background studies
- SO(10) Raidal et al benchmarks, 160-225 GeV singlet admixture, displaced vertices

Updates

- Some of these studies must be characterized as "surveys", not explicit benchmark studies
- Latest LHC results not accounted for

2013 vs 2012

- 2013: More exclusion in heavy-Higgs region
- 2012 $0.5 \le R_{\gamma\gamma} \le 2.0$
- 2013 ATLAS $1.03 \le R_{\gamma\gamma} \le 2.33$ (2σ)
- 2013 CMS $0.26 \le R_{\gamma\gamma} \le 1.34$ (2σ)

Comments on updates for Type II

Overview ATLAS constraints









Model II Benchmarks (Basso et al)

	α_1/π	α_2/π	α_3/π	aneta	M_2	$M_{H^{\pm}}^{\min}, M_{H^{\pm}}^{\max}$
P_1	0.23	0.06	0.005	1	300	300,325
P_2	0.35	-0.014	0.48	1	300	$300,\!415$
P_3	0.35	-0.015	0.496	1	350	$300,\!450$
P_4	0.35	-0.056	0.43	1	400	$300,\!455$
P_5	0.33	-0.21	0.23	1	450	$300,\!470$
P_6	0.27	-0.26	0.25	1	500	$300,\!340$
P_7	0.39	-0.07	0.33	2	300	$300,\!405$
P_8	0.34	-0.03	0.11	2	400	$300,\!315$
P_9	0.47	-0.006	0.05	10	400	400,440
<i>P</i> ₁₀	0.49	-0.002	0.06	10	600	600,700

half of them are now excluded (2σ) by ATLAS

but not by CMS

Mini-review of Basso et al

Proposed channel:

 $pp \to W^{\pm}H^{\mp}(+X)$ $\rightarrow W^+W^-H_1$ $\rightarrow jj \ell^{\pm} \nu b\bar{b}$ W H_1

Branching ratios:

Dominant production mechanisms

Coupling may depend on details

irreducible background

small

- cross section larger by factor 10³
- impose generic cuts, BG reduction by factor 40, signal reduction by 2-3

Generic cuts

1) **Kinematics:** standard detector cuts

$$p_{\ell}^{T} > 15 \text{ GeV}, \qquad |\eta_{\ell}| < 2.5,$$

 $p_{j}^{T} > 20 \text{ GeV}, \qquad |\eta_{j}| < 3,$
 $\Delta R_{jj}| > 0.5, \qquad |\Delta R_{\ell j}| > 0.5;$

2) light Higgs reconstruction:

 $\left| M(b\overline{b}) - 125 \text{ GeV} \right| < 20 \text{ GeV};$

3) hadronic W reconstruction $(W_h \rightarrow jj)$:

|M(jj) - 80 GeV| < 20 GeV;

Generic cuts

4) top veto: if $\Delta R(b_1, W_h) < \Delta R(b_2, W_h)$, then

 $M(b_1 j j) > 200 \text{ GeV}, \qquad M_T(b_2 \ell \nu) > 200 \text{ GeV},$ otherwise 1 \leftrightarrow 2; disfavor top, for each b-quark separately

5) same-hemisphere b quarks:

$$\frac{\mathbf{p}_{b_1}}{|\mathbf{p}_{b_1}|} \cdot \frac{\mathbf{p}_{b_2}}{|\mathbf{p}_{b_2}|} > 0 \,.$$

Additional anti-top cut

Idea: Since $M_{H^\pm} > m_t$

One of the W's should form high invariant mass with $b\bar{b}$ pair

Possible cuts

"squared cut": "single cut":

$$C_{squ} = \max \left(M(b\bar{b}jj), M_T(b\bar{b}\ell\nu) \right) > M_{lim}$$
$$C_{sng} = M_T(b\bar{b}\ell\nu) > M_{lim}.$$

Choose:

$$C_{\rm sng}$$

 $\dot{M}_{\rm lim} = 600 \,\,{\rm GeV}$

$$P_2: \tan \beta = 1, \quad M_2 = 300 \text{ GeV}, \quad \alpha_i = \{0.35, -0.014, 0.48\}$$

$$P_7: \tan \beta = 2, \quad M_2 = 300 \text{ GeV}, \quad \alpha_i = \{0.39, -0.07, 0.33\}$$

	$M_{H^{\pm}} =$	310 GeV	$M_{H^{\pm}} = 390 \text{ GeV}$		
	Events	S/\sqrt{B}	Events	S/\sqrt{B}	
$t\overline{t}$		24	1.9		
peak	11.9	_	9.9	_	
P_1	3.8	0.8	—	—	
peak	2.6	0.8	—	—	
P_2	4.7	1.0	8.8	1.8	
peak	3.3	1.0	7.3	2.3	
P_3	11.3	2.3	22.0	4.4	
peak	7.7	2.3	17.2	5.4	
P_4	10.0	2.0	20.3	4.1	
peak	7.8	2.3	16.0	5.1	
P_5	21.1	4.2	30.2	6.1	
peak	13.9	4.1	25.0	7.9	
P_6	14.0	2.8	—	_	
peak	9.4	2.8	_	—	
P_7	3.1	0.6	7.4	1.5	
peak	2.8	0.8	7.3	2.3	
P_8	1.2	0.2	—		
peak	1.2	0.4	_	—	

Summary

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- Hope to soon have results on tau decay mode for Model II
- Confirmations/cross checks most welcome
- Some work (updates) left on models with DM

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- Join us!