Higgs, Heavy Bosons, WIMPs, Other Searches

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Higgs bosons

30 years of Higgs searches

20 years of encoding Higgs section (personally)

Higgs Bosons

- Minireview by G. Bernardi, M. Carena, T. Junk
  (27 pages, Updated May 2010) → G. Bernardi's talk
- Data Listings (Overseer: G. Weiglein, Encoder: K. Hikasa)
  - Standard Model H^0
  - MSSM H_1^0, A^0
  - Nonstandard H^0 (doublet)
  - Charged $H^\pm$ (doublet)
  - $H^{\pm\pm}$ (triplet/singlet)

Higgs searches: RPP history

- 1982: First appearance in the data listing, but located in ‘Other stable particle searches’ section

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H        HIGGS BOSON MASS LIMIT (GEV)                                          1/82*
H     A    0  0.409    CR MORE            DZHELYADI 81      ETAPRIM-->ETA HIGGS  1/82*
H
H     A   DZHELYADIN 81 OBTAINED BR(ETA PRIM-->ETA MU+MU-)<1.5E-5 (CL=.90)     1/82*
H     A   WHICH EXCLUDES A LIGHT HIGGS BOSON IN MU+MU- CHANNEL.                1/82*

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Higgs searches: RPP history

- 1982: First appearance in the data listing
- 1988: Separate 'Higgs searches' section, H^+, minireview

SEARCHES FOR NEUTRAL AND CHARGED HIGGS BOSONS

SEARCHES FOR NEUTRAL AND CHARGED HIGGS BOSONS

NOTE ON THE HIGGS BOSON

The Standard Model[1] contains one neutral scalar Higgs

would seem to be ruled out The experimental limit[13] on $BF(K^+ \to \pi^+ \mu\mu)$ is too weak to constrain the Higgs mass

H^0 (HIGGS BOSON) MASS LIMIT

For early higgs search papers see J Ellis M K Gaillard, D V Nanopoulos, Nucl Phys B106, 292 (1976)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>0.100	90	[1] BAKER 87	CALO	$K^\pm \to \pi^\pm H^0$ ($H^0 \to e^+e^-$)
none 0 6–3 9	90	[2] LEE FRANZINI 87	RVUE	Υ (1S 3S) $\to \gamma H^0$
none 0 003–0 014	95	[3] FREEDMAN 84	CNTR	$He^* \to He H^0$ ($H^0 \to e^+e^-$)
none 0 00103–0 00584		[4] MUKHOPAD 84	RVUE	$O^* \to O H^0$ ($H^0 \to e^+e^-$)
>0.013		[5] BARBIERI 75	RVUE	$nN \to nN$
• • • We do not use the following data for averages fits limits etc • • •				
		[6] DRUZHININ 87	CALO	$\phi \to \gamma H^0$ ($H^0 \to \pi^0\pi^0$)
>0 010		BELTRAMI 86	SPEC	Muonic atoms
none 0 05–0 211		[7] WILLEY 86	RVUE	$K^\pm \to \pi^\pm H^0$ ($H^0 \to e^+e^-$)
		[8] HOFFMAN 83	CNTR	$\pi p \to n H^0$ ($H^0 \to e^+e^-$)
none 0 25–0 409		[9] DZHELYADIN 81		$\eta' \to \eta H^0$ ($H^0 \to \mu^+\mu^-$)
		[10] WITTEN 81	COSM	
>9		[10] GUTH 80	COSM	
>9		[10] SHER 80	COSM	

Higgs searches: RPP

- 1982: First appearance in the data li
- 1988: Separate ‘Higgs searches’ sec
- 1990: H^0 entries tripled, first limits from LEP

H^0 (Higgs Boson) MASS LIMIT

These limits apply to the Higgs boson of the three-generation Standard Model with the minimal Higgs sector. Limits that depend on the $Ht\bar{t}$ coupling may also apply to a Higgs boson of an extended Higgs sector whose couplings to up-type quarks are comparable to or larger than those of the standard one-doublet model H^0 couplings.

Some of the experiments for a light Higgs utilize its coupling with nucleons. We parameterize the Higgs-nucleon coupling (which is dominantly isosclar) as $g_{HNN} = \eta_{HNN}(\sqrt{2}G_F)^{1/2}\, m(N)$. The limits depend on the value of η_{HNN} used. Shifman *et al.* [Phys. Lett. **78B**, 443 (1978)] obtained $\eta_{HNN} = 0.22$ assuming three heavy flavors. More recently, T.P. Cheng [Phys. Rev. **D38**, 2869 (1988)], H.-Y. Cheng [Phys. Lett. **B219**, 347 (1989)], and Barbieri and Curci [Phys. Lett. **B219**, 503 (1989)] took into account the strange-quark content of the proton as well as the heavy quark effects, and derived $\eta_{HNN} = 0.56$.

For early Higgs search papers, see J. Ellis, M.K. Gaillard, D.V. Nanopoulos, Nucl. Phys. **B106**, 292 (1976).

For recent and comprehensive reviews, see Gunion, Haber, Kane, and Dawson, "The Higgs Hunter's Guide," (Addison-Wesley, Menlo Park, CA, 1990), M. Sher, Phys. Rep. **179**, 273 (1989), and R.N. Cahn, Rep. Prog. Phys. **52**, 389 (1989).

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>24 (CL = 95%) OUR LIMIT					
none 3.0–19.3	95	[1,2] AKRAWY	90C	OPAL	$Z \to H^0 + (e^- e^-, \mu^+\mu^-, \nu\bar{\nu})$
> 0.026	90	[3] ATIYA	90	CNTR	$K^\pm \to \pi^\pm H^0$
none 0.012–0.211	90	[4] BARR	90	CNTR	$K_L^0 \to \pi^0 H^0$ $(H^0 \to e^+e^-)$
> 0.32		[5] DAWSON	90	RVUE	K decays
none 0.032–15	95	[2,6] DECAMP	90	ALEP	$Z \to H^0 + (e^+e^-, \mu^+\mu^-, \tau^+\tau^-, \nu\bar{\nu}, q\bar{q})$
none 11–24	95	[7] DECAMP	90H	ALEP	$Z \to H^0 + (e^+e^-, \mu^+\mu^-, \nu\bar{\nu})$
none 0.0012–0.052	90	DAVIER	89	BDMP	$e^- Z \to e H^0 Z$ $(H^0 \to e^+e^-)$
none 0.010–0.10	90	[8] EGLI	89	CNTR	$\pi^+ \to e^+ \nu H^0$ $(H^0 \to e^+e^-)$
> 0.010	68	[9] BELTRAMI	86	SPEC	Muonic atoms
none 0.003–0.012	95	[10] FREEDMAN	84	CNTR	$He^* \to He H^0$ $(H^0 \to e^+e^-)$
none 0.00103–0.00584		[11] MUKHOPAD...	84	RVUE	$O^* \to O H^0$ $(H^0 \to e^+e^-)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 0.21–3.57		[12] DAWSON	90	RVUE	$B \to \mu^+\mu^- X$; $B \to K(\mu^+\mu^-, \pi^+\pi^-, K^+K^-)$
> 0.3		[13] LEUTWYLER	90	RVUE	$K^+ \to \pi^+ H^0$
none 0.21–1.0	90	[14] ALAM	89B	CLEO	$B \to H^0 K$, $(H^0 \to \mu^+\mu^-, \pi^+\pi^-)$
none 1.0–3.6	90	[14] ALAM	89B	CLEO	$B \to H^0 X$ $(H^0 \to \mu^+\mu^-)$
none 0.29–0.57	90	[15] ALBRECHT	89	ARG	$\Upsilon(1S) \to H^0 \gamma$ $(H^0 \to \pi^+\pi^-)$
none 0.22–0.32		[16] ATIYA	89	CNTR	$K^+ \to \pi^+ H^0$ $(H^0 \to \mu^+\mu^-)$
> 0.28		[17] CHENG	89	RVUE	$K^\pm \to \pi^\pm H$
none 3.6–4.6		[18] EILAM	89	RVUE	$B \to H^0 X$, $(H^0 \to \mu^+\mu^-)$
> 0.018		[19] GRIFOLS	89	RVUE	$\sigma_{tot}(nPb)$
		[20] LINDNER	89	THEO	Vacuum stability
none 0.211–0.700		[21] RABY	89	RVUE	$B \to \mu^+\mu^- X$ $m(top) > 80$ GeV
none 0.07–0.21	90	[22] SNYDER	89	MRK2	$B \to H^0 X$ $(H^0 \to e^+e^-)$
none 0.015–0.04	90	[23] YEPES	89	RVUE	$\pi^\pm \to e^\pm \nu H^0$ $(H^0 \to e^+e^-)$
none 0.03–0.20		[24] YEPES	89B	RVUE	$pN \to H^0 X$ $(H^0 \to e^+e^-)$
> 0.36		[25] CHIVUKULA	88	RVUE	$K \to \pi^+ H^0$
none 0.00103–3.57		[21] CHIVUKULA	88	RVUE	$B \to H^0 X$, $m(top) > 80$ GeV
none 2–3.7		[21] GRINSTEIN	88	RVUE	$B \to H^0 X$, $m(top) > 80$ GeV
none 0.21–5	90	[26] LEE-FRANZINI	88	CUSB	$\Upsilon(1S,3S) \to \gamma H^0$
	90	[27] BAKER	87	CALO	$K^\pm \to \pi^\pm H^0$ $(H^0 \to e^+e^-)$
		[28] DRUZHININ	87	ND	$\phi \to \gamma H^0$ $(H^0 \to \pi^0\pi^0)$
none 0.05–0.211		[29] WILLEY	86	RVUE	$K^\pm \to \pi^\pm H^0$ $(H^0 \to e^+e^-)$
		[30] HOFFMAN	83	CNTR	$\pi p \to n H^0$ $(H^0 \to e^+e^-)$
		[31] DZHELYADIN	81		$\eta' \to \eta H^0$ $(H^0 \to \mu^+\mu^-)$
		[32] WITTEN	81	COSM	
		[32] GUTH	80	COSM	
		[32] SHER	80	COSM	
> 0.006		[33] BARBIERI	75	RVUE	$nN \to nN$

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Limits from Coupling to $Z/W^{\pm}$

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>48 (CL = 95%) OUR LIMIT					
>48	95	[1] DECAMP	92	ALEP	$Z \to H^0 Z^*$
>38	95	[2] ABREU	91C	DLPH	$Z \to H^0 Z^*$
>11.3	95	[3] ACTON	91	OPAL	$H^0 \to$ anything
>41.8	95	[4] ADEVA	91	L3	$Z \to H^0 Z^*$
none 3–44	95	[5] AKRAWY	91	OPAL	$Z \to H^0 Z^*$
none 0.21–14	95	[6] ABREU	90C	DLPH	$Z \to H^0 Z^*$
none 2–32	95	[7] ADEVA	90H	L3	$Z \to H^0 Z^*$
> 2	99	[8] ADEVA	90N	L3	$Z \to H^0 Z^*$
none 0.032–15	95	[9] DECAMP	90	ALEP	$Z \to H^0 Z^*$
> 0.057	95	[10] DECAMP	90M	ALEP	$Z \to H^0 ee$, $H^0 \mu$
none 11–41.6	95	[11] DECAMP	90N	ALEP	$Z \to H^0 Z^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 0.21	99	[12] ABREU	91B	DLPH	$Z \to H^0 Z^*$
		[13] ADEVA	91D	L3	$Z \to H^0 \gamma$
none 3–25.3	95	[14] AKRAWY	91C	OPAL	$Z \to H^0 Z^*$
> 1.4	68	[15] ELLIS	91B	RVUE	Electroweak
		[16] HIOKI	91	RVUE	Electroweak
none 0.21–0.818	90	[17] ABE	90E	CDF	$p\bar{p} \to (W^{\pm}, Z) + H^0 + X$
none 0.846–0.987	90	[17] ABE	90E	CDF	$p\bar{p} \to (W^{\pm}, Z) + H^0 + X$
none 3.0–19.3	95	[18] AKRAWY	90C	OPAL	$Z \to H^0 Z^*$
> 0.21	95	[19] AKRAWY	90P	OPAL	$Z \to H^0 Z^*$
none 11–24	95	[20] DECAMP	90H	ALEP	$Z \to H^0 Z^*$
> 1.8	68	[21] ELLIS	90B	RVUE	Electroweak

From Quarkonium Decay

VALUE (GeV)	CL%
• • • We do not use the follow	
>0.086	90
none 0.29–0.57	90
none 0.21–5	90

From B Decay

VALUE (GeV)	CL%
• • • We do not use the follow	
none 0.21–3.57	
none 0.21–1.0	90
none 1.0–3.6	90

From K Decay

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>0.026	90	[31] ATIYA	90	CNTR	$K^+ \to \pi^+ H^0$
		[32] ATIYA	90B	CNTR	$K^+ \to \pi^+ H^0$, $H^0 \to \gamma\gamma$
none 0.012–0.211	90	[33] BARR	90	CNTR	$K^0_L \to \pi^0 H^0$ $(H^0 \to e^+e^-)$
>0.32		[34] DAWSON	90	RVUE	K decays
>0.3		[35] LEUTWYLER	90	RVUE	$K^+ \to \pi^+ H^0$
		[36] ATIYA	89	CNTR	$K^+ \to \pi^+ H^0$

From Coupling with Nucleons

Some of the experiments for a light Higgs utilize its couplin parameterize the Higgs-nucleon coupling (which is dominantly $\eta_{HNN}(\sqrt{2}G_F)^{1/2}\ m(N)$. The limits depend on the value of *et al.* [Physics Letters **78B** 443 (1978)] obtained $\eta_{HNN} = 0.2$ flavors. More recently, T.P. Cheng [Physical Review **D38** 286 [Physics Letters **B219** 347 (1989)], and Barbieri and Curci [Ph (1989)] took into account the strange-quark content of the prot quark effects, and derived $\eta_{HNN} = 0.56$.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	CO
• • • We do not use the following data for averages, fits, limits, etc					
none 0.001–0.08	95	BLUEMLEIN	91	BDMP	p
>0.018		[41] GRIFOLS	89	RVUE	σ_t
none 0.03–0.20		[42] YEPES	89B	RVUE	p $(H^0 \to e^+e^-)$
>0.010	68	[43] BELTRAMI	86	SPEC	Muonic atoms
none 0.003–0.012	95	[44] FREEDMAN	84	CNTR	$He^* \to He H^0$ $(H^0 \to e^+e^-)$
none 0.00103–0.00584		[45] MUKHOPAD...	84	RVUE	$O^* \to O H^0$

From Other Techniques

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 0.0012–0.052	90	DAVIER	89	BDMP	$e^- Z \to e H^0 Z$ $(H^0 \to e^+e^-)$
none 0.010–0.10	90	[48] EGLI	89	CNTR	$\pi^+ \to e^+ \nu H^0$ $(H^0 \to e^+e^-)$
		[49] LINDNER	89	THEO	Vacuum stability
none 0.015–0.04	90	[50] YEPES	89	RVUE	$\pi^{\pm} \to e^{\pm} \nu H^0$ $(H^0 \to e^+e^-)$
		[51] DZHELYADIN	81		$\eta' \to \eta H^0$ $(H^0 \to \mu^+\mu^-)$
		[52] WITTEN	81	COSM	
		[52] GUTH	80	COSM	
		[52] SHER	80	COSM	

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- 1998: First LEP2 limits, only Z/W coupling data retained
- 2000: Older (superseded) limits hidden
- 2004-2008: LEP final results, Drop in # of new papers
- 2010: New results are back in increase

New in 2010 Edition

- Standard Higgs
  - Best limit unchanged since 2004: $M_H > 114.4$ GeV (95%CL)
  - Tevatron searches: cross section limits in many modes (13 new papers)

- MSSM H_1^0, A^0
  - Still new result from LEP (many ‘scenarios’)
  - Tevatron cross section limits (mostly $\tau\tau$ final states)

New in 2010 Edition (cont'd)

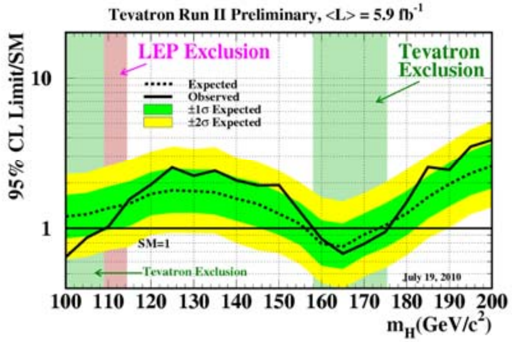
- Nonstandard H^0
  - Papers from Tevatron, LEP (still), B factories
  - Searched modes/scenarios
    - Type II two-doublet models
    - 'Invisible' H^0 (neutralino pairs)
    - Fermiophobic $H^0 \to \gamma\gamma$
    - $\Upsilon \to A^0\gamma$

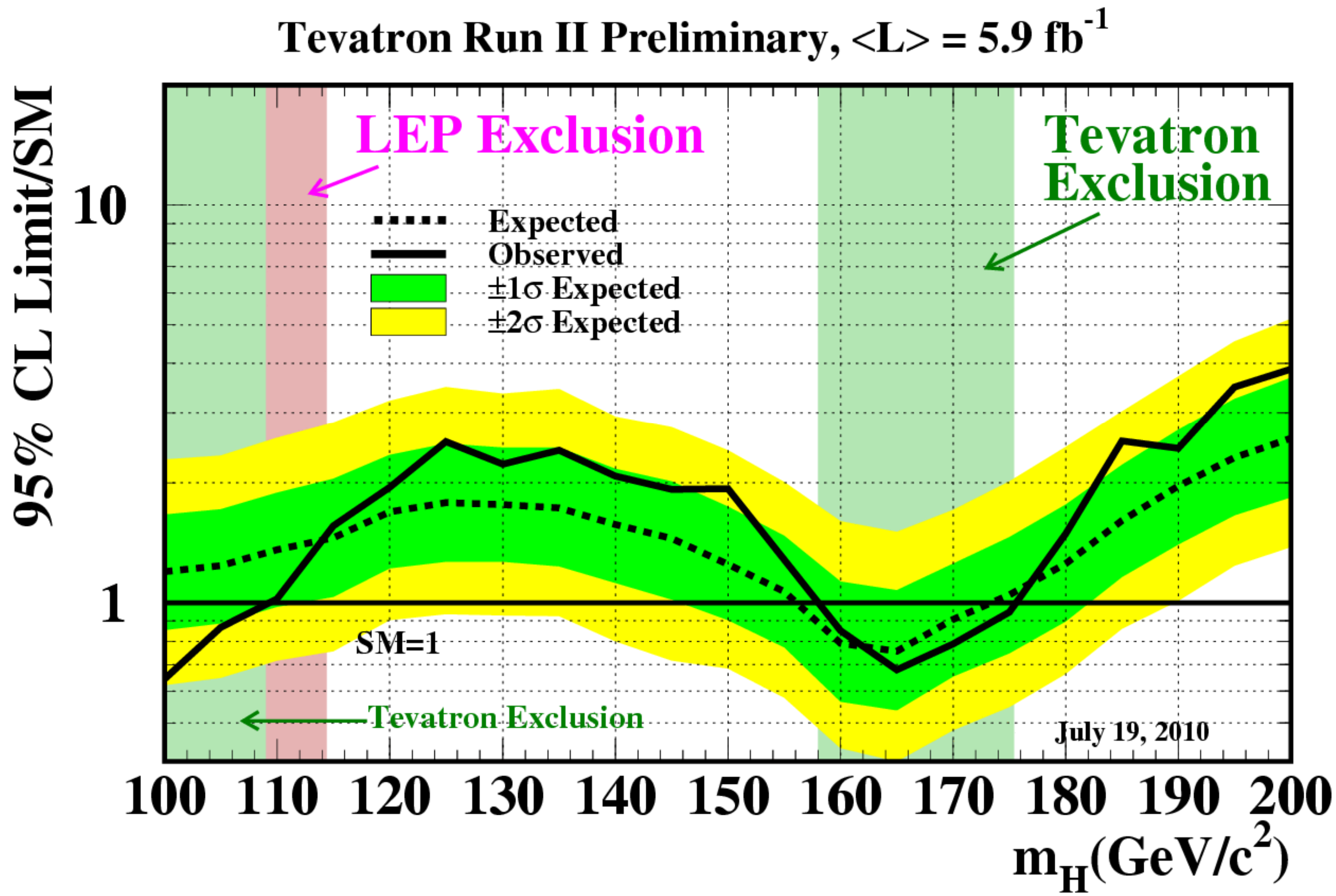
New in 2010 Edition (cont'd)

- Charged Higgs
  - Tevatron limits from $t \to bH^{+}$, $H^{+} \to tb$
- Doubly charged Higgs
  - Tevatron limits in 110-150 GeV range ($H^{++} \to l^{+} l^{+}$)

Prospects

- 34 new papers in 2010 edition (10 in 2008)
- Tevatron is the current main player
  - Each search mode is not capable of giving mass limits (let alone seeing the signal)
  - Combined limits (in PRL, excl. 162-166 GeV) missed the cutoff date by one month (→ will be on in 2011 web update)
- LHC results in 201*x* edition
  - Hopefully not in the 'searches' section




Tevatron Run II Preliminary, <L> = 5.9 fb^{-1}
LEP Exclusion
Tevatron Exclusion
Expected
Observed
±1σ Expected
±2σ Expected
SM=1
Tevatron Exclusion
July 19, 2010
95% CL Limit/SM
10
1
100 110 120 130 140 150 160 170 180 190 200
m_H(GeV/c^2)

Heavy bosons other than Higgs

(W's, Z's, leptoquarks, and others)

axions etc. are somewhere else

Slides prepared by M. Tanabashi

Heavy bosons other than Higgs

- Encoder: M. Tanabashi (Nagoya U)
- Overseer: T. Watari (IPMU-Tokyo, --June '10),
  J.-F. Arguin (LBNL, Oct '10--)
- Number of reviewed papers
  - 17 papers in 2009 (5 for W'/Z', 5 for LQ)
  - 22 papers in 2010 (7 for W'/Z', 2 for LQ)
- Highlights
  - Tevatron bounds on W'/Z' decaying into tb/tt or WZ/WW
  - Improved bounds on leptoquark pair production from Tevatron

Minireviews for heavy bosons

- W' boson searches

  M.-C. Chen and B. A. Dobrescu (last update 2009)

- Z' boson searches

  M.-C. Chen and B. A. Dobrescu (last update 2009)

- Leptoquarks → S. Rolli's talk

  S. Rolli and M. Tanabashi (last update 2007)

  We plan to update the LQ minireview in the next edition to include improved LQ bounds from Tevatron

WIMPs and other particle searches

Higgs search was here 25 yrs ago

WIMPs and Other Particle Searches

- Located at the end of the book
- Contains everything which cannot be assigned to other sections
  - Extra Dim limits *used to* be here (2000)
  - WIMPs are still here, but neutralino-specific limits moved to SUSY section (2004)
- 'Minireview'
  - Just explains the structure of the section
- Data Listings (Overseer-Encoder: K. Hikasa)

WIMPs and Other Particle Searches

- Subcategories
  - WIMPs, stable particles in matter, neutral particle production, jet-jet resonances, charged particle production…
- New 2010 subsection
  - General new physics searches (no specific model)
  - Two papers from Tevatron ($3l+E_T$, $l\gamma b+E_T$)
- New 2010 entries
  - WIMPs: 7 papers
  - Long-lived charged particles (Tevatron): 2 papers