PDG Japan

K. Hikasa (Tohoku U.)

Current Status

- Encoding team
  - K. Hikasa (Tohoku U)
  - K. Nakamura (U Tokyo/KEK)
  - Y. Sumino (Tohoku U)
  - F. Takahashi (Tohoku U)
  - M. Tanabashi (Nagoya U)
  - J. Tanaka (U Tokyo)
- Review authors
- Financial support: Japan-US Program (KEK)

Pre-History

- KEK-PDG (1974-)
  - Kasuke Takahashi, Yoshio Oyanagi and others

  - Compilation of πN Scattering Cross Section
  - Photoproduction Data
  - Magnetic Tape Library

PDG Japan (1986-)

- Financed by KEK in the framework of Japan/US High Energy Program
  - PI: Kasuke Takahashi
- Encoding of a major part of searches
  - Initially by Kaoru Hagiwara, S. Kawabata
  - New sections created for 1988 edition

Search Sections in 1986

- ν mass, mixing
- Heavy leptons
- Free quarks
- Monopoles
- Top hadrons
- Axion
- Supersymmetry
- Others

Higgs limits in `Other Stable Particle Searches' section: Only 5 entries

HIGGS BOSON MASS LIMIT (GeV)

```
H     A   D  0.409   OR MORE                DZHELYADI 81        ETAPRIM-->ETA HIGGS
H     B   D  0.325   OR MORE                WILLEY    82 RVUE K+-->DILEPTON+PI+
H     C                                     HOFFMAN   83 CNTR PI-P-->N(HO-->E+E-)
H     D   NONE .003   TO .014  CL=.95       FREEDMAN  84 CNTR HE*-->HE(HO-->E+E-)
H     E   NONE .00103 TO .00584             MUKHOPADH 84 RVUE  O*--> O(HO-->E+E-)
H
H     A  DZHELYADIN 81 OBTAINED BR(ETA PRIM-->ETA MU+MU-)<1.5E-5 (CL=.90)
H     A  WHICH EXCLUDES A LIGHT HIGGS BOSON IN MU+MU- CHANNEL.
H
H     B  WILLEY 82 CALCULATED BR(K+-->HO+PI+) BY ONE-LOOP S-->D HO AND QUARK
H     B  MODEL. EXCLUDE M(HO) < M(K)-M(PI).
H
H     C  HOFFMAN 83 LOOKED FOR E+E- PEAK FROM HIGGS PRODUCED IN PI-P CEX AT
H     C  300MEV/C. SET CL=.90 LIM. DSIGMA/DT*BR(E+E-)<3.5 E-32 CM**2/GEV**2
H     C  FOR  140 < M(HO) < 160 MEV.
H
H     D  FREEDMAN 84 IS ANL EXP WITH DYNAMITRON PROTON BOMBARDING TRITIUM TO
H     D  FORM HE*. THEY ALSO REANALYZE KOHLER 74 HE* DATA TO FIND NO MASS
H     D  REGION IS EXCLUDED BY THAT DATA.  SEE ALSO COMMENT CARDS E BELOW.
H
H     E  MUKHOPADHYAY 84 EXAMINE KOHLER 74 HE* AND C* DATA. CLAIM THAT NO
H     E  MASS REGION CAN BE EXCLUDED BY 74 HE* DATA AS PROTON DECAY WIDTH OF
H     E  HE* IS LARGE (BR(HE*-->HIGGS HE)=3.4 E-11 IS VERY SMALL). ABOVE
H     E  LIMIT IS FROM KOHLER 74 O* DECAY DATA. (KOHLER 74, PRL 33, 1628).
H
H                                COMMENT
H        FOR EARLY HIGGS SEARCH PAPERS, SEE
H         J.ELLIS, M.K.GAILLARD, D.V.NANOPOULOS, NUCL. PHYS. B106, 292, 1976
```

Line Printer Output!

Search Sections in 1988

- ν mass, mixing
- Heavy leptons
- Free quarks
- Monopoles
- Top hadrons
- Axions
- Supersymmetry
- Other searches

- Top & 4th generation
- Axions & light bosons
- Supersymmetry
- Higgs bosons
- Heavy bosons (W' etc)
- Compositeness
- Other searches

Other Searches Section Divided and Expanded

Higgs Section in 1988

- Separate 'Higgs searches' section, H^+, minireview

See key on page 129

Stable Particle Full Listings

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 from this process However, there is the possibility of a

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	$\Upsilon(1S\ 3S) \to \gamma H^0$
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 Section in 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	$K^0_L \to \pi^0 H^0$ $(H^0 \to e^+e^-)$
> 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	$nN \to nN$

Higgs Section in 1992

- Organized according to the relevant coupling (Z/W, quarkonium, B, K, N, other), MSSM Higgs, H^{++}

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	$H^0 \to$ anythin
>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	$p\overline{p} \to (W^{\pm}, Z)$ + $H^0 + X$
none 0.846–0.987	90	[17] ABE	90E	CDF	$p\overline{p} \to (W^{\pm}, Z)$ + $H^0 + X$
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** 2869 [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	pN
>0.018		[41] GRIFOLS	89	RVUE	σ_{t}
none 0.03–0.20		[42] YEPES	89B	RVUE	pN $(H^0 \to e^+ e^-)$
>0.010	68	[43] BELTRAMI	86	SPEC	Muonic atoms
none 0.003–0.012	95	[44] FREEDMAN	84	CNTR	$\mathrm{He}^* \to \mathrm{He}\,H^0$ $(H^0 \to e^+ e^-)$
none 0.00103–0.00584		[45] MUKHOPAD...	84	RVUE	$\mathrm{O}^* \to \mathrm{O}\,H^0$ $(H^0 \to e^+ e^-)$
		[46] HOFFMAN	83	CNTR	$\pi p \to n H^0$ $(H^0 \to e^+ e^-)$
>0.006		[47] BARBIERI	75	RVUE	$nN \to nN$

From Other Techniques

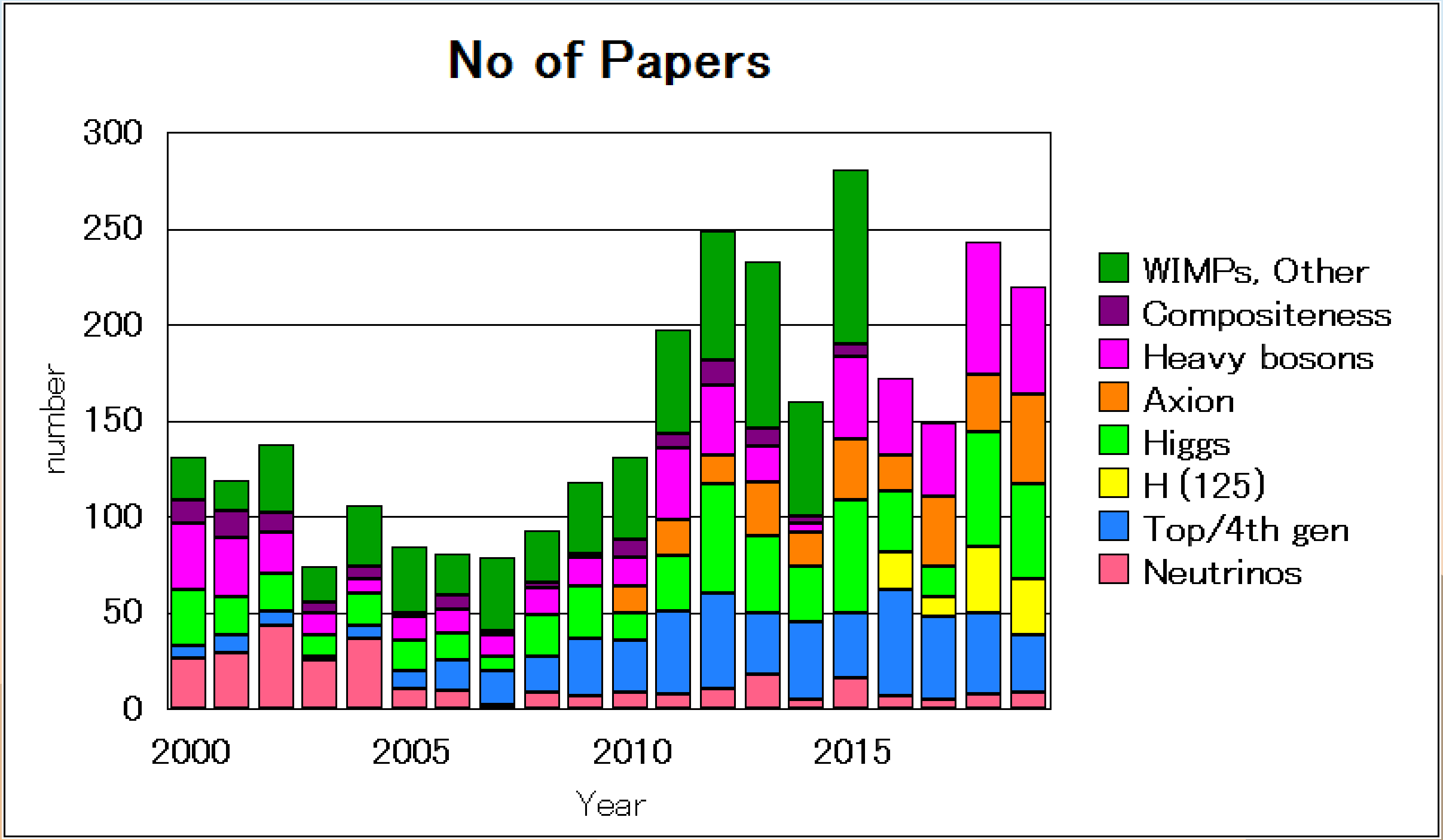
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
none 0.0012–0.052	90	DAVIER	89	BDMP	$e^- Z \to e H^0 Z$ $(H^0 \to e^+ e^-)$
none 0.010–0.10	90	[48] EGLI	89	CNTR	$\pi^+ \to e^+ \nu H^0$ $(H^0 \to e^+ e^-)$
		[49] LINDNER	89	THEO	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	

Encoders

<table>
<tr><th colspan="2">Section</th><th>86</th><th>87</th><th>88</th><th>89</th><th>90</th><th>91</th><th>92</th><th>93</th><th>94</th><th>95</th><th>96</th><th>97</th><th>98</th><th>99</th><th>00</th><th>01</th><th>02</th><th>03</th><th>04</th><th>05</th><th>06</th><th>07</th><th>08</th><th>09</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th></tr>
<tr><td colspan="2">Solar/atmospheric neutrinos</td><td colspan="9"></td><td colspan="26">Nakamura</td></tr>
<tr><td colspan="2">Top
4th gen quarks</td><td colspan="3" rowspan="8">Hagiwara/
Kawabata</td><td colspan="5"></td><td colspan="20">Hagiwara</td><td colspan="7">Sumino</td></tr>
<tr><td rowspan="2">Higgs</td><td>H^0 (125)</td><td colspan="27" rowspan="2">Hikasa</td><td colspan="5">Tanaka</td></tr>
<tr><td>Searches</td><td colspan="5"></td></tr>
<tr><td colspan="2">Axion &
light bosons</td><td colspan="3" rowspan="4">Hikasa</td><td colspan="4">Murayama</td><td colspan="14">(Murayama)</td><td colspan="11">Takahashi</td></tr>
<tr><td colspan="2">Heavy boson searches</td><td colspan="2" rowspan="2"></td><td colspan="27" rowspan="2">Tanabashi</td></tr>
<tr><td colspan="2">Compositeness/
technicolor</td></tr>
<tr><td colspan="2">SUSY searches</td><td colspan="4">Murayama</td><td colspan="8">(Murayama)</td><td colspan="17"></td></tr>
<tr><td colspan="2">WIMPs/Other searches</td><td colspan="27">Hikasa</td><td colspan="5"></td></tr>
<tr><td colspan="2">Japan/US Program PI</td><td colspan="5">Kasuke Takahashi</td><td colspan="6">Yoshio Oyanagi</td><td colspan="24">Ken-ichi Hikasa</td></tr>
</table>

- 1995: Solar/Atmospheric Neutrinos by Kenzo Nakamura
- 1996: Top Searches → Real Particle
- 2012: Higgs Searches → Real Particle

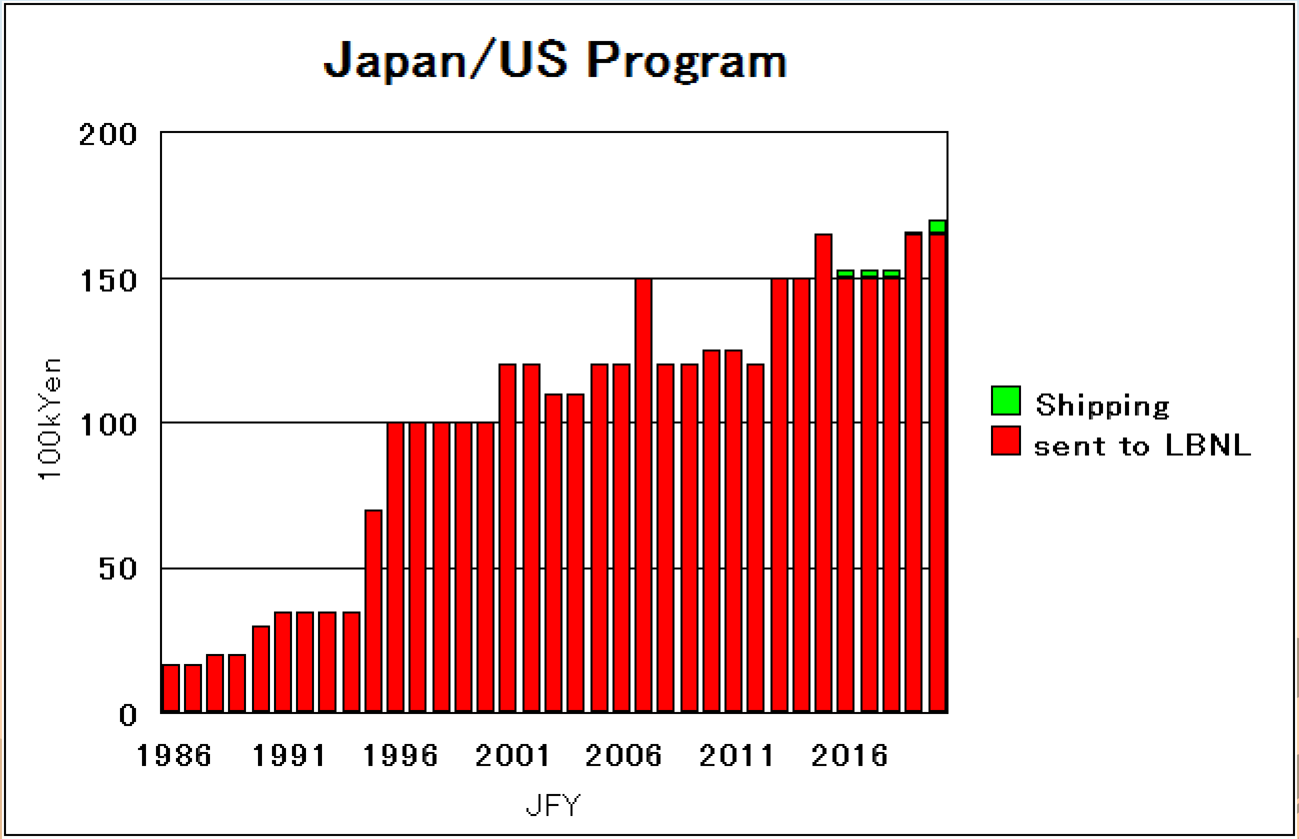
Statistics


No of Papers
300
250
200
150
100
50
0
number
2000
2005
2010
2015
Year
WIMPs, Other
Compositeness
Heavy bosons
Axion
Higgs
H (125)
Top/4th gen
Neutrinos

Review Authors

- Y. Sakai (CKM)
- M. Yokoyama (neutrino mass)
- J. Hisano (GUT)
- S. Hashimoto (lattice QCD)
- T. Sumiyoshi (detectors)
- Y. Makida (magnets)
- Y. Hayato (Monte Carlo)
- T. Hyodo ($\Lambda(1405)$)
- M. Tanabashi (leptoquark)
- M.Tanabashi/K. Hikasa/K. Terashi (compositeness)

Budget


Japan/US Program
200
150
100
50
0
100kYen
1986
1991
1996
2001
2006
2011
2016
JFY
Shipping
sent to LBNL