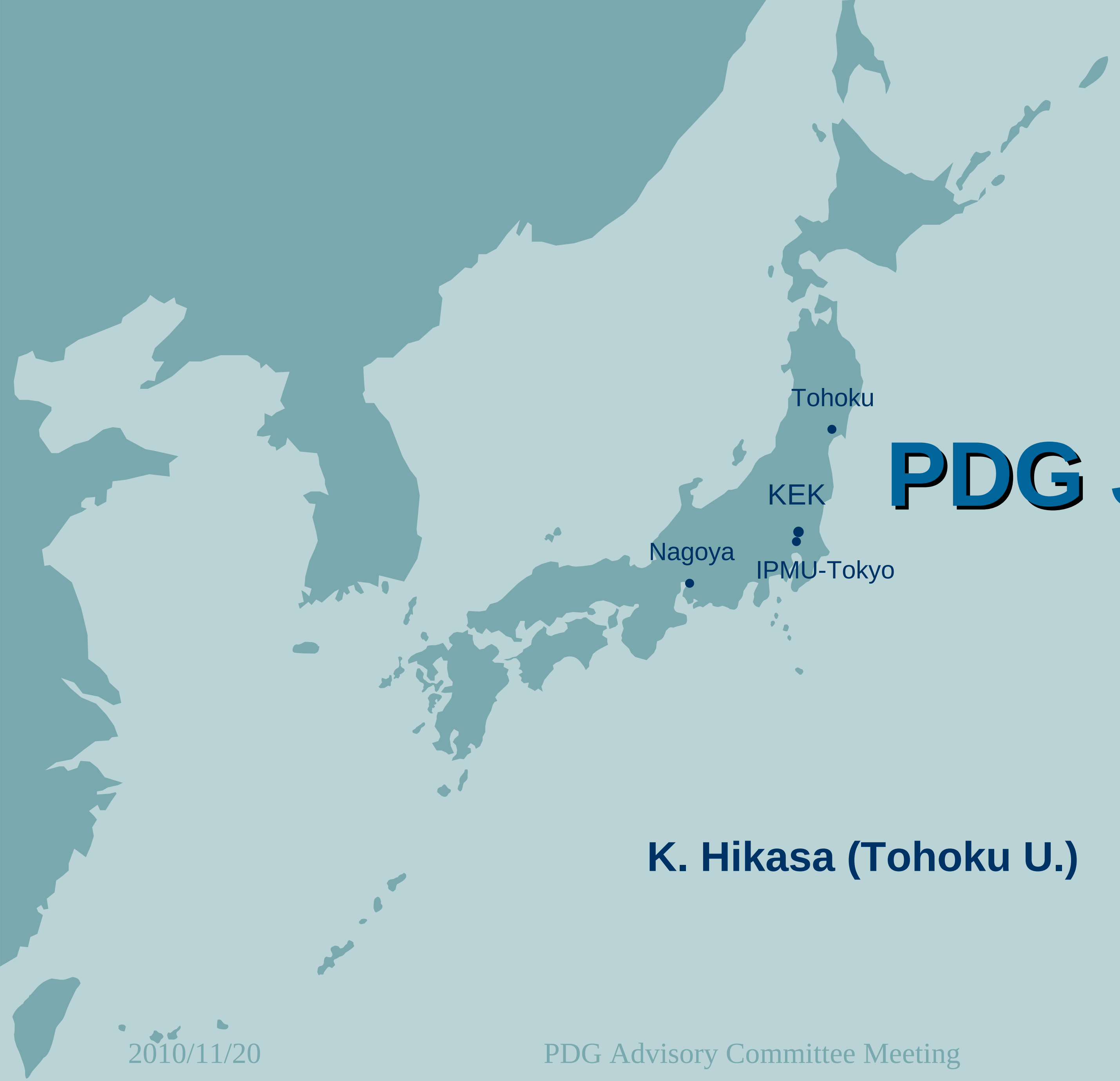
PDG Japan



K. Hikasa (Tohoku U.)

Brief history

1974 KEK-PDG

1986 RPP activity started (K. Hagiwara, S. Kawabata)

1986 Funding from KEK (Japan-US Program)

- 1986-90 Kasuke Takahashi
- 1991-96 Yoshio Oyanagi
- 1997- Ken-ichi Hikasa

1997 Mirror site at KEK

Present Encoders/Overseers: K. Hagiwara (KEK), K. Hikasa (Tohoku), H. Murayama, K. Nakamura (IPMU Tokyo), M. Tanabashi (Nagoya), T. Watari (Tokyo - retired)

RPP Sections in charge

- Neutrinos (astrophysical)
- Top quark
- 4th generation quarks
- Higgs bosons
- Axions and light bosons
- Heavy bosons (W', Z', leptoquarks, etc.)
- Technicolor
- Compositeness (contact int., excited q/l, etc.)
- WIMPs and other searches
- (formerly Supersymmetry)

Current Encoders

Name	Period	Present responsibility
K. Hagiwara	1986-91, 94-	Top, 4th Gen. Quarks
K. Hikasa	1989-	Higgs, WIMPs, Other Searches
H. Murayama	1992-	Axions
M. Tanabashi	1994-	Heavy Bosons, Technicolor, Compositeness
K. Nakamura	1995-	Neutrinos (astrophysical)

In addition, T. Watari oversees the Heavy Boson section.

Papers examined

code	section	encoder	2005	2006	2007	2008	2009
S005etc.	neutrinos	Nakamura	11	10	2	9	7
Q007	top quark	Hagiwara	9	16	16	17	27
Q008	fourth generation	Hagiwara	0	0	2	2	3
S055	Higgs bosons	Hikasa	16	14	8	21	27
S029	Axions	Murayama			9	8	18
S056	heavy bosons	Tanabashi	12	12	11	14	15
S054	compositeness	Tanabashi	1	6	1	3	1
S057	technicolor	Tanabashi	1	1	1	0	1
S030	other searches	Hikasa	35	22	38	27	37
total # of papers examined			85	81	88	101	136

Review authors

- Review authors
  - Y. Sakai (CKM)
  - T. Sumiyoshi (γ detectors)
  - A. Yamamoto (SC magnets)
  - K. Nakamura (ν)
  - M. Tanabashi (leptoquark)
  - K. Hagiwara/K. Hikasa
- Past authors
  - A.I. Sanda
  - M. Fukugita

13. Neutrino mixing 1

13. NEUTRINO MASS, MIXING, AND OSCILLATIONS

Written May 2010 by K. Nakamura (IPMU, U. Tokyo, KEK) and S.T. Petcov (SISSA/INFN Trieste, IPMU, U. Tokyo, Bulgarian Academy of Sciences).

The experiments with solar, atmospheric, reactor and accelerator neutrinos have provided compelling evidences for oscillations of neutrinos caused by nonzero neutrino masses and neutrino mixing. The data imply the existence of 3-neutrino mixing in vacuum. We review the theory of neutrino oscillations, the phenomenology of neutrino mixing, the problem of the nature - Dirac or Majorana, of massive neutrinos, the issue of CP violation in the lepton sector, and the current data on the neutrino masses and mixing parameters. The open questions and the main goals of future research in the field of neutrino mixing and oscillations are outlined.

13.1. Introduction: Massive neutrinos and neutrino mixing

It is a well-established experimental fact that the neutrinos and antineutrinos which take part in the standard charged current (CC) and neutral current (NC) weak interaction are of three varieties (types) or flavours: electron, ν_e and $\bar{\nu}_e$, muon, ν_μ and $\bar{\nu}_\mu$, and tauon, ν_τ and $\bar{\nu}_\tau$. The notion of neutrino type or flavour is dynamical: ν_e is the neutrino which is produced with e^+, or produces an e^- in CC weak interaction processes; ν_μ is the neutrino which is produced with μ^+, or produces μ^-, *etc.* The flavour of a given neutrino is Lorentz invariant. Among the three different flavour neutrinos and antineutrinos, no two are identical. Correspondingly, the states which describe different flavour neutrinos must be orthogonal (within the precision of the corresponding data): $\langle \nu_{l'} | \nu_l \rangle = \delta_{l'l}$, $\langle \bar{\nu}_{l'} | \bar{\nu}_l \rangle = \delta_{l'l}$, $\langle \bar{\nu}_{l'} | \nu_l \rangle = 0$.

It is also well-known from the existing data (all neutrino experiments were done so far with relativistic neutrinos or antineutrinos), that the flavour neutrinos ν_l (antineutrinos $\bar{\nu}_l$), are always produced in weak interaction processes in a state that is predominantly left-handed (LH) (right-handed (RH)). To account for this fact, ν_l and $\bar{\nu}_l$ are described in the Standard Model (SM) by a chiral LH flavour neutrino field $\nu_{lL}(x)$, $l = e, \mu, \tau$. For massless ν_l, the state of ν_l ($\bar{\nu}_l$) which the field $\nu_{lL}(x)$ annihilates (creates) is with helicity (-1/2) (helicity +1/2). If ν_l has a non-zero mass $m(\nu_l)$, the state of ν_l ($\bar{\nu}_l$) is a linear superposition of the helicity (-1/2) and (+1/2) states, but the helicity +1/2 state (helicity (-1/2) state) enters into the superposition with a coefficient $\propto m(\nu_l)/E$, E being the neutrino energy, and thus is strongly suppressed. Together with the LH charged lepton field $l_L(x)$, $\nu_{lL}(x)$ forms an $SU(2)_L$ doublet. In the absence of neutrino mixing and zero neutrino masses, $\nu_{lL}(x)$ and $l_L(x)$ can be assigned one unit of the additive lepton charge L_l and the three charges L_l, $l = e, \mu, \tau$, are conserved by the weak interaction.

At present there is no evidence for the existence of states of relativistic neutrinos (antineutrinos), which are predominantly right-handed, ν_R (left-handed, $\bar{\nu}_L$). If RH neutrinos and LH antineutrinos exist, their interaction with matter should be much weaker than the weak interaction of the flavour LH neutrinos ν_l and RH antineutrinos $\bar{\nu}_l$, *i.e.*, ν_R ($\bar{\nu}_L$) should be "sterile" or "inert" neutrinos (antineutrinos) [1]. In the formalism of the Standard Model, the sterile ν_R and $\bar{\nu}_L$ can be described by $SU(2)_L$ singlet RH neutrino fields $\nu_R(x)$. In this case, ν_R and $\bar{\nu}_L$ will have no gauge interactions, *i.e.*, will not couple to the weak $W^\pm$ and Z^0 bosons. If present in an extension of

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Finance (Japan-US Program)

PDG-Japan Budget: Rather stable for ten years, despite the total budget of the program was much reduced

budget for JFY2010: JPY12.5M

*Japanese fiscal year 2010: April 2010-March 2011

Continuing effort to keep this level at least