Number of Neutrino Types and Sum of Neutrino Masses

The neutrinos referred to in this section are those of the Standard SU(2)×U(1) Electroweak Model possibly extended to allow nonzero neutrino masses. Light neutrinos are those with $m < m_Z/2$. The limits are on the number of neutrino mass eigenstates, including ν_1, ν_2, and ν_3.

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Number from e^+e^- Colliders

Number of Light ν Types

Our evaluation uses the invisible and leptonic widths of the Z boson from our combined fit shown in the Particle Listings for the Z Boson, and the Standard Model value $\Gamma_\nu/\Gamma_\ell = 1.9908 \pm 0.0015$.

VALUE	*DOCUMENT ID*		*TECN*
2.994±0.012 OUR EVALUATION	Combined fit to all LEP data.		
• • • We do not use the following data for averages, fits, limits, etc. • • •			
3.00 ±0.05	[1] LEP	92	RVUE

[1] Simultaneous fits to all measured cross section data from all four LEP experiments.

Number of Light ν Types from Direct Measurement of Invisible Z Width

In the following, the invisible Z width is obtained from studies of single-photon events from the reaction $e^+e^- \rightarrow \nu\overline{\nu}\gamma$. All are obtained from LEP runs in the E^{ee}_{cm} range 88–189 GeV.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
3.00±0.07 OUR AVERAGE				
2.84±0.15±0.14	ABREU	00Z	DLPH	1997–1998 LEP runs
3.01±0.08	ACCIARRI	99R	L3	1991–1998 LEP runs
2.89±0.32±0.19	ABREU	97J	DLPH	1993–1994 LEP runs
3.23±0.16±0.10	AKERS	95C	OPAL	1990–1992 LEP runs
2.68±0.20±0.20	BUSKULIC	93L	ALEP	1990–1991 LEP runs
• • • We do not use the following data for averages, fits, limits, etc. • • •				
3.1 ±0.6 ±0.1	ADAM	96C	DLPH	$\sqrt{s}$ = 130, 136 GeV

Limits from Astrophysics and Cosmology

Number of Light ν Types

("light" means < about 1 MeV). See also OLIVE 81. For a review of limits based on Nucleosynthesis, Supernovae, and also on terrestial experiments, see DENEGRI 90. Also see "Big-Bang Nucleosynthesis" in this *Review*.

VALUE	*DOCUMENT ID*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •		

$2<N_\nu<4$	LISI	99	BBN
<4.3	OLIVE	99	BBN
<4.9	COPI	97	Cosmology
<3.6	HATA	97B	High D/H quasar abs.
<4.0	OLIVE	97	BBN; high ^{4}He and ^{7}Li
<4.7	CARDALL	96B	Cosmology, High D/H quasar abs.
<3.9	FIELDS	96	Cosmology, BBN; high ^{4}He and ^{7}Li
<4.5	KERNAN	96	Cosmology, High D/H quasar abs.
<3.6	OLIVE	95	BBN; ≥ 3 massless ν
<3.3	WALKER	91	Cosmology
<3.4	OLIVE	90	Cosmology
<4	YANG	84	Cosmology
<4	YANG	79	Cosmology
<7	STEIGMAN	77	Cosmology
	PEEBLES	71	Cosmology
<16	[2] SHVARTSMAN	69	Cosmology
	HOYLE	64	Cosmology

[2] SHVARTSMAN 69 limit inferred from his equations.

Number Coupling with Less Than Full Weak Strength

VALUE	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
<20	[3] OLIVE	81C	COSM
<20	[3] STEIGMAN	79	COSM

[3] Limit varies with strength of coupling. See also WALKER 91.

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Limit on Total ν MASS, m_{tot}

(Defined in the above note), of effectively stable neutrinos (i.e., those with mean lives greater than or equal to the age of the universe). These papers assumed Dirac neutrinos. When necessary, we have generalized the results reported so they apply to m_{tot}. For other limits, see SZALAY 76, VYSOTSKY 77, BERNSTEIN 81, FREESE 84, SCHRAMM 84, and COWSIK 85.

VALUE (eV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<2.7	[4] FUKUGITA	00	COSM	
<5.5	[5] CROFT	99	ASTR	Ly α power spec
<180	SZALAY	74	COSM	
<132	COWSIK	72	COSM	
<280	MARX	72	COSM	
<400	GERSHTEIN	66	COSM	

[4] FUKUGITA 00 is a limit on neutrino masses from structure formation. The constraint is based on the clustering scale σ_8 and the COBE normalization and leads to a conservative limit of 0.9 eV assuming 3 nearly degenerate neutrinos. The quoted limit is on the sum of the light neutrino masses.

[5] CROFT 99 result based on the power spectrum of the Ly α forest. If $\Omega_{\text{matter}} < 0.5$, the limit is improved to $m_\nu < 2.4$ (Ω_{matter}/0.17–1) eV.

Limits on MASSES of Light Stable Right-Handed ν (with necessarily suppressed interaction strengths)

VALUE (eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<100–200	[6] OLIVE	82	COSM	Dirac ν
<200–2000	[6] OLIVE	82	COSM	Majorana ν

[6] Depending on interaction strength G_R where $G_R < G_F$.

Limits on MASSES of Heavy Stable Right-Handed ν (with necessarily suppressed interaction strengths)

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
> 10	[7] OLIVE	82	COSM	G_R/G_F <0.1
>100	[7] OLIVE	82	COSM	G_R/G_F <0.01

[7] These results apply to heavy Majorana neutrinos and are summarized by the equation: m_ν >1.2 GeV (G_F/G_R). The bound saturates, and if G_R is too small no mass range is allowed.

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