Number of Light Neutrino Types

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 $m_\nu < m_Z/2$. The limits are on the number of neutrino families or species, including ν_e, ν_μ, ν_τ

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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 Γ_ν/Γ_ℓ = 1.9908 ± 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 $e^+e^- \to \nu\overline{\nu}\gamma$. All are obtained from LEP runs in the E^{ee}_{cm} range 88–94 GeV.

VALUE	DOCUMENT ID		TECN	COMMENT
3.00±0.08 OUR AVERAGE				
2.98±0.07±0.07	ACCIARRI	98G	L3	LEP 1991–1994
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		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
< 4.9	COPI	97	COSM
< 3.6	[2] HATA	97B	COSM
< 4.0	[3] OLIVE	97	COSM
< 4.7	[2] CARDALL	96B	COSM
< 3.9	[3] FIELDS	96	COSM
< 4.5	[2] KERNAN	96	COSM
< 3.6	[4] OLIVE	95	COSM
< 3.3	WALKER	91	COSM
< 3.4	OLIVE	90	COSM
< 4	YANG	84	COSM
< 4	YANG	79	COSM
< 7	STEIGMAN	77	COSM
	PEEBLES	71	COSM
<16	[5] SHVARTSMAN	69	COSM
	HOYLE	64	COSM

[2] Limit based on high D/H from quasar absorption systems.
[3] Limit based on high ^{4}He and ^{7}Li.
[4] OLIVE 95 limit assumes the existence of at least three (massless) neutrinos.
[5] 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	[6] OLIVE	81C	COSM
<20	[6] STEIGMAN	79	COSM

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

REFERENCES FOR Limits on Number of Light Neutrino Types

ACCIARRI	98G	PL B431 199	M. Acciarri+	(L3 Collab.)
ABREU	97J	ZPHY C74 577	P. Abreu+	(DELPHI Collab.)
COPI	97	PR D55 3389	C.J. Copi, D.N. Schramm, M.S. Turner	(CHIC)
HATA	97B	PR D55 540	N. Hata, G. Steigman, S. Bludman+	(OSU, PENN)
OLIVE	97	ASP 7 27	+Thomas	(MINN, FLOR)
ADAM	96C	PL B380 471	+Adye, Agasi, Ajinenko, Aleksan+	(DELPHI Collab.)
CARDALL	96B	APJ 472 435	+Fuller	(UCSD)
FIELDS	96	New Ast 1 77	+Kainulainen, Olive+	(NDAM, CERN, MINN, FLOR)
KERNAN	96	PR D54 3681	P.S. Kernan, S. Sarkar	(CASE, OXFTP)
AKERS	95C	ZPHY C65 47	+Alexander, Allison+	(OPAL Collab.)
OLIVE	95	PL B354 357	+Steigman	(MINN, OSU)
BUSKULIC	93L	PL B313 520	+De Bonis, Decamp+	(ALEPH Collab.)
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP Collabs.)

WALKER	91	APJ 376 51	+Steigman, Schramm, Olive+	(HSCA, OSU, CHIC, MINN)
DENEGRI	90	RMP 62 1	+Sadoulet, Spiro	(CERN, UCB, SACL)
OLIVE	90	PL B236 454	+Schramm, Steigman, Walker	(MINN, CHIC, OSU, HARV)
YANG	84	APJ 281 493	+Turner, Steigman, Schramm, Olive	(CHIC, BART)
OLIVE	81	APJ 246 557	+Schramm, Steigman, Turner, Yang+	(CHIC, BART)
OLIVE	81C	NP B180 497	+Schramm, Steigman	(EFI, BART)
STEIGMAN	79	PRL 43 239	+Olive, Schramm	(BART, EFI)
YANG	79	APJ 227 697	+Schramm, Steigman, Rood	(CHIC, YALE, VIRG)
STEIGMAN	77	PL 66B 202	+Schramm, Gunn	(YALE, CHIC, CIT)
PEEBLES	71	Physical Cosmology		(PRIN)
		Princeton Univ. Press (1971)		
SHVARTSMAN	69	JETPL 9 184		(MOSU)
		Translated from ZETFP 9 315.		
HOYLE	64	Nature 203 1108	+Tayler	(CAMB)