[137] HYKAWY 91 gives new mass spectrometer determination of the ^{76}Ge–^{76}Se mass difference, which for given input for the nuclear matrix elements gives information on limits on Majorana masses. Application to recent ^{76}Ge decay experiments produces no new evidence for $\beta\beta(0\nu)$ decay.

[138] TURKEVICH 91 observes activity in old U sample. The authors compare their results with theoretical calculations. They state "Using the phase-space factors of Boehm and Vogel (BOEHM 87) leads to matrix element values for the ^{238}U transition in the same range as deduced for ^{130}Te and ^{76}Ge. On the other hand, the latest theoretical estimates (STAUDT 90) give an upper limit that is 10 times lower. This large discrepancy implies either a defect in the calculations or the presence of a faster path than the standard two-neutrino mode in this case." See BOEHM 87 and STAUDT 90.

[139] WONG 91 replaced by VUILLEUMIER 93.

[140] MILEY 90 claims only "suggestive evidence" for the decay. Error is 2σ.

[141] VASENKO 90 limit based on background statistics. Maximum likelihood solution is $>$2000.

[142] MORALES 88 notes a 2.5 sigma coincidence rate between electrons with energy 1483.7 ± 0.5 keV in the Ge detector and photons with energy 558 ± 15 keV in the NaI detector, close to the region where neutrinoless $0^+ \rightarrow 2^+$ ^{76}Ge decay should be expected. However, a further sutdy reported in in MORALES 91 rejects this peak at the 95% CL.

[143] BELLOTTI 87 searches for γ rays for 2^+ state decays in corresponding Xe isotopes. Limit for ^{130}Te case argues for dominant $0^+ \rightarrow 0^+$ transition in known decay of this isotope.

[144] ELLIOTT 86 limit agrees with the geochemical limit and strongly disagrees with nuclear theory calculations, casting doubt on their application to derive limits on Majorana neutrino masses and η parameters from limits on neutrinoless double β decay.

[145] HUBERT 85 gives lifetime limits on neutrinoless double β decay of ^{76}Ge to excited states of ^{76}Se.

[146] KIRSTEN 83 reports "2σ" error. References are given to earlier determinations of the ^{130}Te lifetime.

$\langle m_\nu \rangle$, The Effective Weighted Sum of Majorana Neutrino Masses Contributing to Neutrinoless Double β Decay

$\langle m_\nu \rangle = |\Sigma\, U^2_{1j} m_{\nu_j}|$, where the sum goes from 1 to n and where n = number of neutrino generations, and ν_j is a Majorana neutrino. Note that U^2_{1j}, not $|U_{1j}|^2$, occurs in the sum. The possibility of cancellations has been stressed.

VALUE (eV)	CL%	ISOTOPE		TRANSITION	METHOD	DOCUMENT ID	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$<$ 6.6	68	^{100}Mo	0ν	$0^+ \rightarrow 0^+$	Si(Li)	[147] ALSTON-...	93
$<$ 2.8–4.3	90	^{136}Xe	0ν	$0^+ \rightarrow 0^+$	TPC	[148] VUILLEUMIER	93
$<$ 1.5	90	^{76}Ge			Enriched HPGe	[149] BALYSH	92
$<$ 1.1–1.5		^{128}Te			Geochem	[150] BERNATOW...	92
$<$ 5	68	^{82}Se			TPC	[151] ELLIOTT	92
$<$ 1.9–6.7	68	^{76}Ge		$0^+ \rightarrow 0^+$	HPGe	[152] REUSSER	92
$<$ 11–30	95	^{136}Xe	0ν	$0^+ \rightarrow 0^+$	Prop cntr	[153] BELLOTTI	91
$<$ 3.3–5.0		^{136}Xe	0ν	$0^+ \rightarrow 0^+$	TPC	[154] WONG	91
$<$ 8.3	76	^{48}Ca	0ν		CaF_2 scint.	YOU	91
$<$ 1.4–8	68	^{76}Ge	0ν	$0^+ \rightarrow 0^+$	Enriched Ge(Li)	[155] VASENKO	90
$<$4.3–28		^{136}Xe	0ν	$0^+ \rightarrow 0^+$	Prop chamber	[156] BELLOTTI	89
$<$12	68	^{116}Cd	0ν		$^{116}CdWO_4$ scint	[157] DANEVICH	89
$<$3.4–23		^{76}Ge	0ν	$0^+ \rightarrow 0^+$	HPGe	[158] FISHER	89
$<$ 1.8		^{76}Ge	0ν	$0^+ \rightarrow 0^+$	HPGe	[159] CALDWELL	87
$<$ 2.7	68	^{76}Ge	0ν	$0^+ \rightarrow 0^+$	HPGe	BELLOTTI	86
$<$ 6	68	^{76}Ge	0ν	$0^+ \rightarrow 0^+$	HPGe	[160] CALDWELL	86
$<$ 6	68	^{76}Ge	0ν		HPGe	[161] CALDWELL	85
$<$20	68	^{76}Ge	0ν		Ge(Li)	[162] HUBERT	85
$<$ 3.8	68	^{76}Ge	0ν	$0^+ \rightarrow 0^+$	Ge(Li)	[163] BELLOTTI	84
$<$22		^{76}Ge	0ν	$0^+ \rightarrow 0^+$	Ge	FORSTER	84
$<$10	90	^{76}Ge	0ν		Intrinsic Ge	AVIGNONE	83
$<$22	68	^{76}Ge	0ν	$0^+ \rightarrow 0^+$	Ge(Li)	[164] BELLOTTI	83
$<$ 8.3	68	^{76}Ge	0ν	$0^+ \rightarrow 0^+$	Ge(Li)	[164] BELLOTTI	83
$<$ 5.6	95	^{128}Te			Geochem	KIRSTEN	83

[147] ALSTON-GARNJOST 93 use the "conservative matrix elements of Engel *et al.* (ENGEL 88).

[148] VUILLEUMIER 93 mass range from parameter range in the Caltech calculations (ENGEL 88). On the basis of these calculations, the BALYSH 92 mass range would be $<$ 2.2–4.4 eV.

[149] BALYSH 92 uses the MUTO 89 matrix elements.

[150] BERNATOWICZ 92 finds these majoron mass limits assuming that the measured geochemical decay width is a limit on the 0ν decay width. The range is the range found using matrix elements from HAXTON 84, TOMODA 87, and SUHONEN 91. Further details of the experiment are given in BERNATOWICZ 93.

[151] ELLIOTT 92 uses the matrix elements of HAXTON 84.

[152] REUSSER 92 contains the final results for the search for neutrinoless double beta decay of ^{76}Ge in the Gotthard tunnel underground laboratory. Range comes from range of nuclear matrix elements used to relate neutrino mass to lifetime limit (ENGEL 88, HAXTON 84, and MUTO 89).

[153] BELLOTTI 91 range of limits comes from range of theoretical calculations considered. Analysis uses difference between natural and enriched ^{136}Xe runs to obtain the $\beta\beta 0\nu$ limits, leading to "less stringent, but safer limits."

[154] WONG 91 uses the quasiparticle random phase approximation of ENGEL 88 to extract the above limit for the case of a transition caused by a Majorana neutrino mass.

[155] VASENKO 90 range comes from range of nuclear matrix elements of HAXTON 84, ENGEL 88. On the basis of the MUTO 89 matrix element, the limit will be $<$ 1.3 eV.

[156] BELLOTTI 89 gives model-dependent upper bounds on Majorana neutrino masses and on the admixture of right-handed lepton-number-violating currents.

[157] DANEVICH 89 uses calculations of GROTZ 86.

[158] FISHER 89 model-dependent bounds are for Majorana neutrino masses.

[159] CALDWELL 87 least stringent limit (using HAXTON 84) is listed. Limits given using other nuclear matrix element calculations are 1.5 eV and 0.7 eV.

[160] CALDWELL 86 gives several limits depending on which calculation of nuclear matrix elements is used; we quote the most conservative, i.e., least stringent. Other limits are 1.0 eV and 1.9 eV. Authors note that the overall uncertainty due to the serious disagreement between nuclear calculations and both lab and geochemical measurements for regular 2-neutrino double β decay is also present in these limits.

[161] CALDWELL 85 uses results of HAXTON 81, HAXTON 82. Authors state that limit could be "two or three times larger."

[162] HUBERT 85 limit is obtained from analysis of data using theoretical calculations by HAXTON 81, HAXTON 82.

[163] See Table 1 of BELLOTTI 84 for their assessment of previous bounds.

[164] BELLOTTI 83 limits are obtained from analysis of data using theoretical calculations by DOI 83 and ROSEN 81.

Limits on Lepton-Number Violating ($V+A$) Current Admixture

For reasons given in the discussion at the beginning of this section, we list only results from 1989 and later.

η_{RR} (10^{-6})	CL%	η_{LR} (10^{-8})	CL%	ISOTOPE	METHOD	DOCUMENT ID	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$<$2.3	90	$<$1.5	90	^{76}Ge	Enriched HPGe	[165] BALYSH	92
		$<$5.3		^{128}Te	Geochem	[166] BERNATOW...	92
$<$3.6	68	$<$2.2	68	^{76}Ge	HPGe	[167] REUSSER	92
$<$9	68	$<$8	68	^{76}Ge	Ion chamber	BELLOTTI	89

[165] BALYSH 92 uses the MUTO 89 matrix elements.

[166] BERNATOWICZ 92 takes the measured geochemical decay width as a limit on the 0ν width, and uses the SUHONEN 91 coefficients to obtain the least restrictive limit on η. Further details of the experiment are given in BERNATOWICZ 93.

[167] REUSSER 92 uses the MUTO 89 matrix elements for this reduction.

REFERENCES FOR Searches for Massive Neutrinos and Lepton Mixing

ANSELMANN 94 PL B327 377 +Hampel, Heusser, Kiko, Kirsten+ (GALLEX Collab.)
ABELE 93 PL B316 26 +Helm, Kania, Schmidt+ (HEID, ILLG, MUNT)
ALSTON-... 93 PRL 71 831 Alston-Garnjost+ (LBL, MTHO, UNM, INEL)
ANSELMANN 93 PL B314 445 +Hampel, Heusser, Kiko, Kirsten+ (GALLEX Collab.)
BAHCALL 93 PR D47 1298 +Bethe (IAS, CORN)
BAHRAN 93 PR D47 R754 +Kalbfleisch (OKLA)
BAHRAN 93B PR D47 R759 +Kalbfleisch (OKLA)
BARANOV 93 PL B302 336 +Batusov, Bunyatov, Klimov+ (JINR, SERP, BUDA)
BERMAN 93 PR C48 R1 +Pitt, Calaprice, Lowry (PRIN)
BERNATOW... 93 PR C47 806 Bernatowicz, Brazzle, Cowsik+ (WUSL, TATA)
DIGREGORIO 93 PR C47 2916 +Gil, Huck, Batista+ (CNEA)
FREEDMAN 93 PR D47 811 +Fujikawa, Napolitano, Nelson+ (LAMPF E645 Collab.)
GRUWE 93 PL B309 463 +Mommaert, Vilain, Wilquet+ (CHARM II Collab.)
HAMPEL 93 JPG 19 S209 (MPIH)
HIME 93 PL B299 165 (LANL)
KALBFLEISCH 93 PL B303 355 +Bahran (OKLA)
MORTARA 93 PRL 70 394 +Ahmad, Coulter, Freedman+ (ANL, LBL, UCB)
OHSHIMA 93 PR D47 4840 + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS)
TURCK-CHI... 93 PRPL 230 57 Turck-Chieze+ (SACLD, USC, NICEA, NICEO, MEUD)
TURCK-CHI... 93B APJ 408 347 Turck-Chieze, Lopez (SACLD)
VUILLEUMIER 93 PR D48 1009 +Busto, Farine, Jorgens+ (NEUC, CIT, VILL)
WIETFELDT 93 PRL 70 1759 +Chan, da Cruz, Garcia+ (LBL, UCB, SPAUL)
ALESSAND... 92 PL B285 176 Alessandrello, Camin, Cremonesi, Fiorini+ (MILA, SASSO)
ANSELMANN 92 PL B285 376 +Hampel, Heusser+ (GALLEX Collab.)
ANSELMANN 92B PL B285 390 +Hampel, Heusser+ (GALLEX Collab.)
ARTEMJEV 92 PL B280 159 +Brakchman, Ivanovsky, Karelin+ (ITEP)
BAHCALL 92 RMP 64 885 +Pinsonneault (IAS, YALE)
BAHRAN 92 PL B291 336 +Kalbfleisch (OKLA)
BAHRAN 92B PL B294 479 (erratum) +Kalbfleisch (OKLA)
BALYSH 92 PL B283 32 +Belyaev, Bockholt, Demehin+ (MPIH, KIAE, SASSO)
BECKER-SZ... 92 PRL 69 1010 Becker-Szendy, Bratton, Casper, Dye+ (IMB Collab.)
BECKER-SZ... 92B PR D46 3720 Becker-Szendy, Bratton, Casper, Dye+ (IMB Collab.)
BEIER 92 PL B283 446 +Frank, Frati, Kim, Mann+ (KAM2 Collab.)
Also 94 PTRSL A346 63 Beier, Frank (PENN)
BERNATOW... 92 PRL 69 2341 Bernatowicz, Brannon, Brazzle, Cowsik+ (WUSL, TATA)
BLUM 92 PL B275 506 +Busto, Campagne, Dassie, Hubert+ (NEMO Collab.)
BORODOV... 92 PRL 68 274 Borodovsky, Chi, Ho, Kondakis, Lee+ (COLU, JHU, ILL)
BRITTON 92 PRL 68 3000 +Ahmad, Bryman, Burnham+ (TRIU, CARL)
Also 94 PR D49 28 Britton, Ahmad, Bryman+ (TRIU, CARL)
BRITTON 92B PR D46 R885 +Ahmad, Bryman+ (TRIU, CARL)
CHEN 92 PRL 69 3151 +Imel, Radcliffe, Henrickson, Boehm (CIT)
ELLIOTT 92 PR C46 1535 +Hahn, Moe+ (UCI)
GAVRIN 92 HEP-92 Conf., p. 1101 +Anosolov+ (INRM, LANL, PENN, LSU, PRIN)
Proc. XXVI Int. HEP Conf., Dallas, TX (1992) AIP Conf. Proc. No. 272, ed. J.R. Sanford
HIRATA 92 PL B280 146 +Inoue, Ishida+ (Kamiokande II Collab.)
HOLZSCHUH 92B PL B287 381 +Fritschi, Kuendig (ZURI)
KAWAKAMI 92 PL B287 45 + (INUS, KEK, SCUC, TUAT, RIKEN, ROCH, TSUK)
KETOV 92 JETPL 55 564 +Machulin, Mikaelyan+ (KIAE)
Translated from ZETFP 55 544.
KUDOMI 92 PR C46 R2132 +Ejiri, Nagata, Okada, Shibata+ (OSAK, INUS)
REUSSER 92 PR D45 2548 Reussser, Treichel, Boehm+ (CIT, NEUC, VILL)
ABAZOV 91B PRL 67 3332 +Anosov, Faizov+ (SAGE Collab.)
AVIGNONE 91 PL B256 559 +Brodzinski, Guerard+ (SCUC, PNL, ITEP, YERE)
BELLOTTI 91 PL B266 193 +Cremonesi, Fiorini, Gervasio+ (MILA, INFN)
CASPER 91 PRL 66 2561 +Becker-Szendy, Bratton, Cady+ (IMB Collab.)
DELEENER-... 91 PR D43 3611 De Leener-Rosier, Deutsch+ (LVLN, ZURI, LAUS)
EJIRI 91 PL B258 17 +Fushimi, Kamada, Kinoshita+ (OSAK)
GARCIA 91 PRL 67 3654 +Adelberger, Magnus, Swanson+ (WASH, CERN, LBL)
HIME 91 PL B257 441 +Jelley (OXF)
HIME 91B Thesis OUNP-91-21 +Jelley (OXF)
HIRATA 91 PRL 66 9 +Inoue, Kajita, Kihara+ (Kamiokande II Collab.)
HIRATA 91B PR D44 2241
HYKAWY 91 PRL 67 1708 +Nxumalo, Unger, Lander+ (MANI)
MORALES 91 NC 104A 1581 +Morales, Nunez-Lagos, Puimedon+ (ZARA)
NORMAN 91 JPG 17 S291 +Sur, Lesko+ (LBL)
SUHONEN 91 NP A535 509 +Khadkikar, Faessler (JYV, AHMED, TUBIN)
SUR 91 PRL 66 2444 +Norman, Lesko+ (LBL)
TURKEVICH 91 PRL 67 3211 +Economou, Cowan (CHIC, LANL)
WONG 91 PRL 67 1218 +Boehm, Fisher, Gabathuler+ (CIT, VILL, NEUC)
YOU 91 PL B265 53 +Zhu, Lu+ (BHEP, CAST+)
ZLIMEN 91 PRL 67 560 +Ljubicic, Kaucic, Logan (BOSK, OTTA)
ADEVA 90S PL B251 321 +Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.)
ASTIER 90 NP B335 517 +Bernardi+ (BOST, BNL, CERN, CURIN, PARIN)
BARABASH 90 PL B249 186 +Kopylov, Cherehovsky (ITEP, INRM)
BATUSOV 90B ZPHY C48 209 +Bunyatov, Kuznetsov, Pozharova+ (JINR, ITEP, SERP)
BERGER 90B PL B245 305 +Froehlich, Moench, Nisius+ (FREJUS Collab.)
BURCHAT 90 PR D41 3542 +King, Abrams, Adolphsen+ (Mark II Collab.)
DECAMP 90F PL B236 511 +Deschizeaux, Lees, Minard+ (ALEPH Collab.)
FILIPPONE 90 PL B246 546 +Vogel (CIT)
HIRATA 90 PRL 65 1297 +Inoue, Kajita+ (Kamiokande II Collab.)
HIRATA 90B PRL 65 1301 +Inoue, Kajita+ (Kamiokande II Collab.)
JUNG 90 PRL 64 1091 +Van Kooten, Abrams, Adolphsen+ (Mark II Collab.)
KOPEIKIN 90 JETPL 51 86 +Mikazlyan, Fayans (KIAE)
Translated from ZETFP 51 75.