Supersymmetry – THIS IS PART 4 OF 4

To reduce the size of this section's PostScript file, we have divided it into three PostScript files. We present the following index:

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MINIMAL SUPERSYMMETRIC STANDARD MODEL ASSUMPTIONS

All results shown below (except where stated otherwise) are based on the Minimal Supersymmetric Standard Model (MSSM) as described in the Note on Supersymmetry. This includes the assumption that R-parity is conserved. In addition the following assumptions are made in most cases:

1) The $\widetilde{\chi}_1^0$ (or $\widetilde{\gamma}$) is the lightest supersymmetric particle (LSP).
2) $m_{\widetilde{f}_L} = m_{\widetilde{f}_R}$ where $\widetilde{f}_L$ and $\widetilde{f}_R$ refer to the scalar partners of left-and right-handed fermions.

Limits involving different assumptions either are identified with comments or are in the miscellaneous section.

When needed, specific assumptions of the eigenstate content of neutralinos and charginos are indicated (use of the notation $\widetilde{\gamma}$ (photino), $\widetilde{H}$ (Higgsino), $\widetilde{W}$ (w-ino), and $\widetilde{Z}$ (z-ino) indicates the approximation of a pure state was made).

$\widetilde{\chi}_1^0$ (Lightest Neutralino) MASS LIMIT

$\widetilde{\chi}_1^0$ is likely to be the lightest supersymmetric particle (LSP). See also the $\widetilde{\chi}_2^0$, $\widetilde{\chi}_3^0$, $\widetilde{\chi}_4^0$ section below.

We have divided the $\widetilde{\chi}_1^0$ listings below into three sections: 1) Accelerator limits for $\widetilde{\chi}_1^0$, 2) Bounds on $\widetilde{\chi}_1^0$ from dark matter searches, and 3) Other bounds on $\widetilde{\chi}_1^0$ from astrophysics and cosmology.

Accelerator limits for $\widetilde{\chi}_1^0$

These papers generally exclude regions in the $M_2-\mu$ parameter plane based on accelerator experiments. Unless otherwise stated, these papers assume minimal supersymmetry and GUT relations (gaugino-mass unification condition). $\Delta m_0 = m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0}$.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>24.9	95	[1] ABREU	98	DLPH	
>10.9	95	[2] ACCIARRI	98F	L3	$\tan\beta > 1$
>13.3	95	[3] ACKERSTAFF	98L	OPAL	$\tan\beta > 1$
>12.5	95	[4] ALEXANDER	96L	OPAL	$\tan\beta > 1.5$
>12.8	95	[5] BUSKULIC	96A	ALEP	$m_{\widetilde{\nu}} > 200$ GeV
>23	95	[6] ACCIARRI	95E	L3	$\tan\beta > 3$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>17	95	[7] ELLIS	97C	RVUE	All $\tan\beta$
		[8] ABREU	96O	DLPH	
		[9] ACCIARRI	96F	L3	
>12.0	95	[10] ALEXANDER	96J	OPAL	$1.5 < \tan\beta < 35$
≥ 0		[11] FRANKE	94	RVUE	$\widetilde{\chi}_1^0$ mixed with a singlet
>20	95	[12] DECAMP	92	ALEP	$\tan\beta > 3$
>5	90	[13] HEARTY	89	ASP	$\widetilde{\gamma}$; for $m_{\widetilde{e}} < 55$ GeV

[1] ABREU 98 bound combines the chargino and neutralino searches at $\sqrt{s}$=161, 172 GeV with single-photon-production results at LEP-1 from ABREU 97J. The limit is based on the same assumptions as ALEXANDER 96J except m_0=1 TeV.

[2] ACCIARRI 98F evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The limit is obtained for $0 < M_2 < 2000$, $|\mu| < 500$, and $1<\tan\beta < 40$, but remains valid outside this domain. No dependence on the trilinear-coupling parameter A is found. The limit holds for all values of m_0 consistent with scalar lepton contraints. It improves to 24.6 GeV for $m_{\widetilde{\nu}} > 200$ GeV. Data taken at $\sqrt{s}$ = 130–172 GeV.

[3] ACKERSTAFF 98L evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The bound is determined indirectly from the $\widetilde{\chi}_1^+$ and $\widetilde{\chi}_2^0$ searches within the MSSM. The limit is obtained for $0 < M_2 < 1500$, $|\mu| < 500$ and $\tan\beta > 1$, but remains valid outside this domain. The limit holds for the smallest value of m_0 consistent with scalar lepton constraints (ACKERSTAFF 97H). It improves to 24.7 GeV for m_0=1 TeV. Data taken at $\sqrt{s}$=130–172 GeV.

[4] ALEXANDER 96L bound for $\tan\beta$=35 is 26.0 GeV.

[5] BUSKULIC 96A puts a lower limit on $m_{\widetilde{\chi}_1^0}$ from the negative search for neutralinos, charginos. The bound holds for $m_{\widetilde{\nu}} > 200$ GeV. A small region of (μ,M_2) still allows $m_{\widetilde{\chi}_1^0}$=0 if sneutrino is lighter. This analysis combines data from e^+e^- collisions at $\sqrt{s}$=91.2 and at 130–136 GeV.

[6] ACCIARRI 95E limit for $\tan\beta > 2$ is 20 GeV, and the bound disappears if $\tan\beta \sim 1$.

[7] ELLIS 97C uses constraints on $\chi^{\pm}$, χ^0, and $\widetilde{\ell}$ production obtained by the LEP experiments from e^+e^- collisions at $\sqrt{s}$ = 130–172 GeV. It assumes a universal mass m_0 for scalar leptons at the grand unification scale.

[8] ABREU 96O searches for possible final states of neutralino pairs produced in e^+e^- collisions at $\sqrt{s}$ = 130–140 GeV. See their Fig. 3 for excluded regions in the (μ,M_2) plane.

[9] ACCIARRI 96F searches for possible final states of neutralino pairs produced in e^+e^- collisions at $\sqrt{s}$= 130–140 GeV. See their Fig. 5 for excluded regions in the (μ,M_2) plane.

[10] ALEXANDER 96J bound is determined indirectly from the $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ searches within MSSM. A universal scalar mass m_0 at the grand unification scale is assumed. The bound is for the smallest possible value of m_0 allowed by the LEP $\widetilde{\ell}$, $\widetilde{\nu}$ mass limits. Branching fractions are calculated using minimal supergravity. The bound is for $m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0} > 10$ GeV. The limit improves to 21.4 GeV for m_0=1 TeV. Data taken at $\sqrt{s}$ = 130–136 GeV. ACKERSTAFF 96C, using data from $\sqrt{s}$ = 161 GeV, improves the limit for m_0 = 1 TeV to 30.3 GeV.

[11] FRANKE 94 reanalyzed the LEP constraints on the neutralinos in the MSSM with an additional singlet.

[12] DECAMP 92 limit for $\tan\beta > 2$ is $m > 13$ GeV.

[13] HEARTY 89 assumed pure $\widetilde{\gamma}$ eigenstate and $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$. There is no limit for $m_{\widetilde{e}} > 58$ GeV. Uses $e^+e^- \rightarrow \gamma\widetilde{\gamma}\widetilde{\gamma}$. No GUT relation assumptions are made.

Bounds on $\widetilde{\chi}^0_1$ from dark matter searches

These papers generally exclude regions in the $M_2-\mu$ parameter plane assuming that $\widetilde{\chi}^0_1$ is the dominant form of dark matter in the galactic halo. These limits are based on the lack of detection in laboratory experiments or by the absence of a signal in underground neturino detectors. The latter signal is expected if $\widetilde{\chi}^0_1$ accumlates in the Sun or the Earth and annihilates into high-energy ν's.

VALUE	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	[14] BOTTINO	97	DAMA
	[15] LOSECCO	95	RVUE
	[16] MORI	93	KAMI
	[17] BOTTINO	92	COSM
	[18] BOTTINO	91	RVUE
	[19] GELMINI	91	COSM
	[20] KAMIONKOW..	91	RVUE
	[21] MORI	91B	KAMI
none 4–15 GeV	[22] OLIVE	88	COSM

[14] BOTTINO 97 points out that the current data from the dark-matter detection experiment DAMA are sensitive to neutralinos in domains of parameter space not excluded by terrestrial laboratory searches.

[15] LOSECCO 95 reanalyzed the IMB data and places lower limit on $m_{\widetilde{\chi}^0_1}$ of 18 GeV if the LSP is a photino and 10 GeV if the LSP is a higgsino based on LSP annihilation in the sun producing high-enery neutrinos and the limits on neutrino fluxes from the IMB detector.

[16] MORI 93 excludes some region in M_2–μ parameter space depending on tanβ and lightest scalar Higgs mass for neutralino dark matter $m_{\widetilde{\chi}^0} > m_W$, using limits on upgoing muons produced by energetic neutrinos from neutralino annihilation in the Sun and the Earth.

[17] BOTTINO 92 excludes some region M_2-μ parameter space assuming that the lightest neutralino is the dark matter, using upgoing muons at Kamiokande, direct searches by Ge detectors, and by LEP experiments. The analysis includes top radiative corrections on Higgs parameters and employs two different hypotheses for nucleon-Higgs coupling. Effects of rescaling in the local neutralino density according to the neutralino relic abundance are taken into account.

[18] BOTTINO 91 excluded a region in $M_2-\mu$ plane using upgoing muon data from Kamioka experiment, assuming that the dark matter surrounding us is composed of neutralinos and that the Higgs boson is not too heavy.

[19] GELMINI 91 exclude a region in $M_2 - \mu$ plane using dark matter searches.

[20] KAMIONKOWSKI 91 excludes a region in the M_2–μ plane using IMB limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the sun, assuming that the dark matter is composed of neutralinos and that $m_{H^0_1} \lesssim$ 50 GeV. See Fig. 8 in the paper.

[21] MORI 91B exclude a part of the region in the M_2–μ plane with $m_{\widetilde{\chi}^0_1} \lesssim$ 80 GeV using a limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the earth, assuming that the dark matter surrounding us is composed of neutralinos and that $m_{H^0_1} \lesssim$ 80 GeV.

[22] OLIVE 88 result assumes that photinos make up the dark matter in the galactic halo. Limit is based on annihilations in the sun and is due to an absence of high energy neutrinos detected in underground experiments. The limit is model dependent.

Other bounds on $\widetilde{\chi}^0_1$ from astrophysics and cosmology

Most of these papers generally exclude regions in the $M_2-\mu$ parameter plane by requiring that the $\widetilde{\chi}^0_1$ contribution to the overall cosmological density is less than some maximal value to avoid overclosure of the Universe. Those not based on the cosmological density are indicated. Many of these papers also include LEP and/or other bounds.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
>40		[23] ELLIS	97C	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>21.4	95	[24] ELLIS	96B	RVUE	$\tan\beta > 1.2$, $\mu < 0$
		[25] FALK	95	COSM	*CP*-violating phases
		DREES	93	COSM	Minimal supergravity
		FALK	93	COSM	Sfermion mixing
		KELLEY	93	COSM	Minimal supergravity
		MIZUTA	93	COSM	Co-annihilation
		ELLIS	92F	COSM	Minimal supergravity
		KAWASAKI	92	COSM	Minimal supergravity, $m_0=A=0$
		LOPEZ	92	COSM	Minimal supergravity, $m_0=A=0$
		MCDONALD	92	COSM	
		NOJIRI	91	COSM	Minimal supergravity
		[26] OLIVE	91	COSM	
		ROSZKOWSKI	91	COSM	
		ELLIS	90	COSM	
		[27] GRIEST	90	COSM	
		[28] GRIFOLS	90	ASTR	$\widetilde{\gamma}$; SN 1987A
		KRAUSS	90	COSM	
		[26] OLIVE	89	COSM	
> 100 eV		[29] ELLIS	88B	ASTR	$\widetilde{\gamma}$; SN 1987A
none 100 eV – (5–7) GeV		SREDNICKI	88	COSM	$\widetilde{\gamma}$; $m_{\widetilde{f}}$=60 GeV
none 100 eV – 15 GeV		SREDNICKI	88	COSM	$\widetilde{\gamma}$; $m_{\widetilde{f}}$=100 GeV
none 100 eV–5 GeV		ELLIS	84	COSM	$\widetilde{\gamma}$; for $m_{\widetilde{f}}$=100 GeV
		GOLDBERG	83	COSM	$\widetilde{\gamma}$
		[30] KRAUSS	83	COSM	$\widetilde{\gamma}$
		VYSOTSKII	83	COSM	$\widetilde{\gamma}$

[23] ELLIS 97C uses in addition to cosmological constraints, data from e^+e^- collisions at 170–172 GeV. It assumes a universal scalar mass for both the Higgs and scalar leptons, as well as radiative supersymmetry breaking with universal gaugino masses. ELLIS 97C also uses the absence of Higgs detection (with the assumptions listed above) to set a limit on $\tan\beta > 1.7$ for $\mu < 0$ and $\tan\beta > 1.4$ for $\mu > 0$. This paper updates ELLIS 96B.

[24] ELLIS 96B uses, in addition to cosmological constraints, data from BUSKULIC 96K and SUGIMOTO 96. It assumes a universal scalar mass m_0 and radiative Supersymmetry breaking, with universal gaugino masses.

[25] Mass of the bino (=LSP) is limited to $m_{\widetilde{B}} \lesssim 350$ GeV for $m_t = 174$ GeV.

[26] Mass of the bino (=LSP) is limited to $m_{\widetilde{B}} \lesssim 350$ GeV for $m_t \le 200$ GeV. Mass of the higgsino (=LSP) is limited to $m_{\widetilde{H}} \lesssim 1$ TeV for $m_t \le 200$ GeV.

[27] Mass of the bino (=LSP) is limited to $m_{\widetilde{B}} \lesssim 550$ GeV. Mass of the higgsino (=LSP) is limited to $m_{\widetilde{H}} \lesssim 3.2$ TeV.

[28] GRIFOLS 90 argues that SN1987A data exclude a light photino ($\lesssim$ 1 MeV) if $m_{\widetilde{q}} < 1.1$ TeV, $m_{\widetilde{e}} < 0.83$ TeV.

[29] ELLIS 88B argues that the observed neutrino flux from SN 1987A is inconsistent with a light photino if 60 GeV $\lesssim m_{\widetilde{q}} \lesssim$ 2.5 TeV. If m(higgsino) is O(100 eV) the same argument leads to limits on the ratio of the two Higgs v.e.v.'s. LAU 93 discusses possible relations of ELLIS 88B bounds.

[30] KRAUSS 83 finds $m_{\widetilde{\gamma}}$ not 30 eV to 2.5 GeV. KRAUSS 83 takes into account the gravitino decay. Find that limits depend strongly on reheated temperature. For example a new allowed region $m_{\widetilde{\gamma}}$ = 4–20 MeV exists if $m_{\text{gravitino}}$ <40 TeV. See figure 2.

$\widetilde{\chi}^0_2$, $\widetilde{\chi}^0_3$, $\widetilde{\chi}^0_4$ (Neutralinos) MASS LIMITS

Neutralinos are unknown mixtures of photinos, z-inos, and neutral higgsinos (the supersymmetric partners of photons and of Z and Higgs bosons). The limits here apply only to $\widetilde{\chi}^0_2$, $\widetilde{\chi}^0_3$, and $\widetilde{\chi}^0_4$. $\widetilde{\chi}^0_1$ is the lightest supersymmetric particle (LSP); see $\widetilde{\chi}^0_1$ Mass Limits. It is not possible to quote rigorous mass limits because they are extremely model dependent; i.e. they depend on branching ratios of various $\widetilde{\chi}^0$ decay modes, on the masses of decay products ($\widetilde{e}$, $\widetilde{\gamma}$, $\widetilde{q}$, $\widetilde{g}$), and on the $\widetilde{e}$ mass exchanged in $e^+e^- \rightarrow \widetilde{\chi}^0_i\widetilde{\chi}^0_j$. Often limits are given as contour plots in the $m_{\widetilde{\chi}^0} - m_{\widetilde{e}}$ plane vs other parameters. When specific assumptions are made, e.g, the neutralino is a pure photino ($\widetilde{\gamma}$), pure z-ino ($\widetilde{Z}$), or pure neutral higgsino ($\widetilde{H}^0$), the neutralinos will be labelled as such.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 45.3	95	[31] ACKERSTAFF	98L	OPAL	$\widetilde{\chi}^0_2$, $\tan\beta > 1$
> 75.8	95	[31] ACKERSTAFF	98L	OPAL	$\widetilde{\chi}^0_3$, $\tan\beta > 1$
>127	95	[32] ACCIARRI	95E	L3	$\widetilde{\chi}^0_4$, $\tan\beta > 3$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 92	95	[33] ACCIARRI	98F	L3	$\widetilde{H}^0_2$, $\tan\beta$=1.41, $M_2 <$ 500 GeV
		[34] ABACHI	96	D0	$p\overline{p} \rightarrow \widetilde{\chi}^\pm_1\widetilde{\chi}^0_2$
		[35] ABE	96K	CDF	$p\overline{p} \rightarrow \widetilde{\chi}^\pm_1\widetilde{\chi}^0_2$
		[36] ACCIARRI	96F	L3	$\widetilde{\chi}^0_2$
> 86.3	95	[37] ACKERSTAFF	96C	OPAL	$\widetilde{\chi}^0_3$
> 45.3	95	[38] ALEXANDER	96J	OPAL	$\widetilde{\chi}^0_2$1.5 <$\tan\beta$ <35
> 33.0	95	[39] ALEXANDER	96L	OPAL	$\widetilde{\chi}^0_2$, $\tan\beta > 1.5$
> 68	95	[40] BUSKULIC	96K	ALEP	$\widetilde{\chi}^0_2$
> 52	95	[32] ACCIARRI	95E	L3	$\widetilde{\chi}^0_2$, $\tan\beta > 3$
> 84	95	[32] ACCIARRI	95E	L3	$\widetilde{\chi}^0_3$, $\tan\beta > 3$
> 45	95	[41] DECAMP	92	ALEP	$\widetilde{\chi}^0_2$, $\tan\beta > 3$
		[42] ABREU	90G	DLPH	$Z \rightarrow \widetilde{\chi}^0\widetilde{\chi}^0$
		[43] AKRAWY	90N	OPAL	$Z \rightarrow \widetilde{\chi}^0\widetilde{\chi}^0$
> 57	90	[44] BAER	90	RVUE	$\widetilde{\chi}^0_3$; $\Gamma(Z)$; $\tan\beta > 1$

		[45] BARKLOW	90	MRK2	$Z \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_2, \widetilde{\chi}^0_2 \widetilde{\chi}^0_2$
		[46] DECAMP	90K	ALEP	$Z \rightarrow \widetilde{\chi}^0 \widetilde{\chi}^0$
>41	95	[47] SAKAI	90	AMY	$e^+ e^- \rightarrow \widetilde{H}^0_1 \widetilde{H}^0_2$ $(\widetilde{H}^0_2 \rightarrow f \overline{f} \widetilde{H}^0_1)$
>31	95	[48] BEHREND	87B	CELL	$e^+ e^- \rightarrow \widetilde{\gamma} \widetilde{Z}$ $(\widetilde{Z} \rightarrow q \overline{q} \widetilde{\gamma})$, $m_{\widetilde{e}} <$ 70 GeV
>30	95	[49] BEHREND	87B	CELL	$e^+ e^- \rightarrow \widetilde{\gamma} \widetilde{Z}$ $(\widetilde{Z} \rightarrow q \overline{q} \widetilde{g})$
>31.3	95	[50] BEHREND	87B	CELL	$e^+ e^- \rightarrow \widetilde{H}^0_1 \widetilde{H}^0_2$ $(\widetilde{H}^0_2 \rightarrow f \overline{f} \widetilde{H}^0_1)$
>22	95	[51] BEHREND	87B	CELL	$e^+ e^- \rightarrow \gamma \widetilde{\gamma} \widetilde{Z}$ $(\widetilde{Z} \rightarrow \widetilde{\nu} \nu)$
		[52] AKERLOF	85	HRS	$e^+ e^- \rightarrow \widetilde{\gamma} \widetilde{\chi}^0$ $(\widetilde{\chi}^0 \rightarrow q \overline{q} \widetilde{\gamma})$
none 1–21	95	[53] BARTEL	85L	JADE	$e^+ e^- \rightarrow \widetilde{H}^0_1 \widetilde{H}^0_2$, $\widetilde{H}^0_2 \rightarrow f \overline{f} \widetilde{H}^0_1$
		[54] BEHREND	85	CELL	$e^+ e^- \rightarrow$ monojet X
>35	95	[55] ADEVA	84B	MRKJ	$e^+ e^- \rightarrow \gamma \widetilde{Z}$ $(\widetilde{Z} \rightarrow \ell \overline{\ell} \widetilde{\gamma})$
>28	95	[56] BARTEL	84C	JADE	$e^+ e^- \rightarrow \gamma \widetilde{Z}$ $(\widetilde{Z} \rightarrow f \overline{f} \widetilde{\gamma})$
		[57] ELLIS	84	COSM	

[31] ACKERSTAFF 98L is obtained from direct searches in the $e^+ e^- \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_{2,3}$ production channels, and indirectly from $\widetilde{\chi}^\pm_1$ and $\widetilde{\chi}^0_1$ searches within the MSSM. See footnote to ACKERSTAFF 98L in the chargino Section for further details on the assumptions. Data taken at $\sqrt{s}$=130–172 GeV.

[32] ACCIARRI 95E limits go down to 0 GeV ($\widetilde{\chi}^0_2$), 60 GeV ($\widetilde{\chi}^0_3$), and 90 GeV ($\widetilde{\chi}^0_4$) for tanβ=1.

[33] ACCIARRI 98F is obtained from direct searches in the $e^+ e^- \rightarrow \widetilde{\chi}^0_{1,2} \widetilde{\chi}^0_2$ production channels, and indirectly from $\widetilde{\chi}^\pm_1$ and $\widetilde{\chi}^0_1$ searches within the MSSM. See footone to ACCIARRI 98F in the chargino Section for futher details on the assumptions. Data taken at $\sqrt{s}$ = 130–172 GeV.

[34] ABACHI 96 searches for 3-lepton final states. Efficiencies are calculated using mass relations and branching ratios in the Minimal Supergravity scenario. Results are presented as lower bounds on $\sigma(\widetilde{\chi}^\pm_1 \widetilde{\chi}^0_2) \times$ B$(\widetilde{\chi}^\pm_1 \rightarrow \ell \nu_\ell \widetilde{\chi}^0_1) \times$ B$(\widetilde{\chi}^0_2 \rightarrow \ell^+ \ell^- \widetilde{\chi}^0_1)$ as a function of $m_{\widetilde{\chi}^0_1}$. Limits range from 3.1 pb ($m_{\widetilde{\chi}^0_1}$ = 45 GeV) to 0.6 pb ($m_{\widetilde{\chi}^0_1}$ = 100 GeV).

[35] ABE 96K looked for tripleton events from chargino-neutralino production. They obtained lower bounds on $m_{\widetilde{\chi}^0_2}$ as a function of μ. The lower bounds are in the 45–50 GeV range for gaugino-dominant $\widetilde{\chi}^0_2$ with negative μ, if tanβ <10. See paper for more details of the assumptions.

[36] ACCIARRI 96F looked for associated production $e^+ e^- \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_2$. See the paper for upper bounds on the cross section. Data taken at $\sqrt{s}$ = 130–136 GeV.

[37] ACKERSTAFF 96C is obtained from direct searches in the $e^+ e^- \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_{2,3}$ production channel, and indirectly from $\widetilde{\chi}^\pm_1$ searches within MSSM. Data from $\sqrt{s}$ = 130, 136, and 161 GeV are combined. The same assumptions and constraints of ALEXANDER 96J apply. The limit improves to 94.3 GeV for m_0 = 1 TeV.

[38] ALEXANDER 96J looked for associated $e^+ e^- \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_2$. A universal scalar mass m_0 at the grand unification scale is assumed. The bound is for the smallest possible value of m_0 alowed by the LEP $\widetilde{\ell}$, $\widetilde{\nu}$ mass limits, 1.5 $<\tan\beta<$35. Branching fractions are calculated using minimal supergravity. The bound is for $m_{\widetilde{\chi}^0_2} - m_{\widetilde{\chi}^0_1}$ >10 GeV. The limit improves to 47.5 GeV for m_0=1 TeV. Data taken at $\sqrt{s}$ = 130–136 GeV. ACKERSTAFF 96C, using data from $\sqrt{s}$ = 161 GeV, improves the limit for m_0 = 1 TeV to 51.9 GeV.

[39] ALEXANDER 96L bound for $\tan\beta$=35 is 51.5 GeV.

[40] BUSKULIC 96K looked for associated $e^+ e^- \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_2$ and assumed the dominance of off-shell Z-exchange in the $\widetilde{\chi}^0_2$ decay. The bound is for $m_{\widetilde{\chi}^0_2} - m_{\widetilde{\chi}^0_1}$ >9 GeV. Data taken at $\sqrt{s}$ = 130–136 GeV.

[41] For $\tan\beta$ >2 the limit is >40 GeV; and it disappears for $\tan\beta < 1.6$.

[42] ABREU 90G exclude B($Z \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_2$) $\geq 10^{-3}$ and B($Z \rightarrow \widetilde{\chi}^0_2 \widetilde{\chi}^0_2$) $\geq 2 \times 10^{-3}$ assuming $\widetilde{\chi}^0_2 \rightarrow \widetilde{\chi}^0_1 f \overline{f}$ via virtual Z. These exclude certain regions in model parameter space, see their Fig. 5.

[43] AKRAWY 90N exclude B($Z \rightarrow \widetilde{\chi}^0_1 \widetilde{\chi}^0_2$) $\gtrsim$ 3–5 $\times 10^{-4}$ assuming $\widetilde{\chi}^0_2 \rightarrow \widetilde{\chi}^0_1 f \overline{f}$ or $\widetilde{\chi}^0_1 \gamma$ for most accessible masses. These exclude certain regions in model parameter space, see their Fig. 7.

[44] BAER 90 is independent of decay modes. Limit from analysis of supersymmetric parameter space restrictions implied by $\Delta\Gamma(Z) <$ 120 MeV. These result from decays of Z to all combinations of $\widetilde{\chi}^\pm_i$ and $\widetilde{\chi}^0_i$. Minimal supersymmetry with $\tan\beta > 1$ is assumed.

[45] See Figs. 4, 5 in BARKLOW 90 for the excluded regions.

[46] DECAMP 90K exclude certain regions in model parameter space, see their figures.

[47] SAKAI 90 assume $m_{\widetilde{H}^0_1} = 0$. The limit is for $m_{\widetilde{H}^0_2}$.

[48] Pure $\widetilde{\gamma}$ and pure $\widetilde{Z}$ eigenstates. B($\widetilde{Z} \rightarrow q\overline{q}\widetilde{\gamma}$) = 0.60 and B($\widetilde{Z} \rightarrow e^+ e^- \widetilde{\gamma}$) = 0.13. $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} <$ 70 GeV. $m_{\widetilde{\gamma}} <$ 10 GeV.

[49] Pure $\widetilde{\gamma}$ and pure $\widetilde{Z}$ eigenstates. B($\widetilde{Z} \rightarrow q\overline{q}\widetilde{g}$) = 1. $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} <$ 70 GeV. $m_{\widetilde{\gamma}} = 0$.

[50] Pure higgsino. The LSP is the other higgsino and is taken massless. Limit degraded if $\widetilde{\chi}^0$ not pure higgsino or if LSP not massless.

[51] Pure $\widetilde{\gamma}$ and pure $\widetilde{Z}$ eigenstates. B($\widetilde{Z} \rightarrow \widetilde{\nu}\nu$) = 1. $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$ = 26 GeV. $m_{\widetilde{\gamma}}$ = 10 GeV. No excluded region remains for $m_{\widetilde{e}}$ >30 GeV.

[52] AKERLOF 85 is $e^+ e^-$ monojet search motivated by UA1 monojet events. Observed only one event consistent with $e^+ e^- \rightarrow \widetilde{\gamma} + \widetilde{\chi}^0$ where $\widetilde{\chi}^0 \rightarrow$ monojet. Assuming that missing-p_T is due to $\widetilde{\gamma}$, and monojet due to $\widetilde{\chi}^0$, limits dependent on the mixing and $m_{\widetilde{e}}$ are given, see their figure 4.

[53] BARTEL 85L assume $m_{\widetilde{H}^0_1} = 0$, $\Gamma(Z \rightarrow \widetilde{H}^0_1 \widetilde{H}^0_2) \gtrsim \frac{1}{2}\Gamma(Z \rightarrow \nu_e \overline{\nu}_e)$. The limit is for $m_{\widetilde{H}^0_2}$.

[54] BEHREND 85 find no monojet at $E_{\rm cm}$ = 40–46 GeV. Consider $\widetilde{\chi}^0$ pair production via Z^0. One is assumed as massless and escapes detector. Limit is for the heavier one, decaying into a jet and massless $\widetilde{\chi}^0$. Both $\widetilde{\chi}^0$'s are assumed to be pure higgsino. For these very model-dependent results, BEHREND 85 excludes m = 1.5–19.5 GeV.

[55] ADEVA 84B observed no events with signature of acoplanar lepton pair with missing energy. Above example limit is for $m_{\widetilde{\gamma}}$ <2 GeV and $m_{\widetilde{e}}$ <40 GeV, and assumes B($\widetilde{Z} \rightarrow \mu^+ \mu^- \widetilde{\gamma}$) = B($\widetilde{Z} \rightarrow e^+ e^- \widetilde{\gamma}$) = 0.10. BR = 0.05 gives 33.5 GeV limit.

[56] BARTEL 84C search for $e^+ e^- \rightarrow \widetilde{Z} + \widetilde{\gamma}$ with $\widetilde{Z} \rightarrow \widetilde{\gamma} + e^+ e^-$, $\mu^+ \mu^-$, $q\overline{q}$, etc. They see no acoplanar events with missing-p_T due to two $\widetilde{\gamma}$'s. Above example limit is for $m_{\widetilde{e}}$ = 40 GeV and for light stable $\widetilde{\gamma}$ with B($\widetilde{Z} \rightarrow e^+ e^- \widetilde{\gamma}$) = 0.1.

[57] ELLIS 84 find if lightest neutralino is stable, then $m_{\widetilde{\chi}^0}$ not 100 eV – 2 GeV (for $m_{\widetilde{q}}$ = 40 GeV). The upper limit depends on $m_{\widetilde{q}}$ (similar to the $\widetilde{\gamma}$ limit) and on nature of $\widetilde{\chi}^0$. For pure higgsino the higher limit is 5 GeV.

Unstable $\widetilde{\chi}_1^0$ (Lightest Neutralino) MASS LIMIT

Unless stated otherwise, the limits below assume that the $\widetilde{\gamma}$ decays either into $\gamma\widetilde{G}$ (goldstino) or into $\gamma\widetilde{H}^0$ (Higgsino).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>77	95	[58] ABBOTT	98	D0	$p\overline{p} \to \gamma\gamma \not{E}_T$+X
		[59] ABREU	98	DLPH	$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0$ ($\widetilde{\chi}_1^0 \to \gamma\widetilde{G}$)
		[60] ACKERSTAFF	98J	OPAL	$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0$ ($\widetilde{\chi}_1^0 \to \gamma\widetilde{G}$)
	95	[61] ACCIARRI	97V	L3	$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0$ ($\widetilde{\chi}_1^0 \to \gamma\widetilde{G}$)
		[62] ELLIS	97	THEO	$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0$, $\widetilde{\chi}_1^0 \to \gamma\widetilde{G}$
		[63] BUSKULIC	96U	ALEP	$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0$ ($\widetilde{\chi}_1^0 \to \nu\ell\overline{\ell}'$)
>40	95	[64] BUSKULIC	95E	ALEP	$e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0$ ($\widetilde{\chi}_1^0 \to \nu\ell\overline{\ell}'$)
		[65] BUSKULIC	95E	ALEP	$e^+e^- \to \widetilde{\gamma}\widetilde{\gamma}$ ($\widetilde{\gamma} \to \nu\ell\overline{\ell}'$)
		[66] ACTON	93G	OPAL	$e^+e^- \to \widetilde{\gamma}\widetilde{\gamma}$ ($\widetilde{\gamma} \to \tau^\pm\ell^\mp\nu_{\ell'}$)
		[67] ABE	89J	VNS	$e^+e^- \to \widetilde{\gamma}\widetilde{\gamma}$ ($\widetilde{\gamma} \to \gamma\widetilde{G}$ or $\gamma\widetilde{H}^0$)
>15	95	[68] BEHREND	87B	CELL	$e^+e^- \to \widetilde{\gamma}\widetilde{\gamma}$ ($\widetilde{\gamma} \to \gamma\widetilde{G}$ or $\gamma\widetilde{H}^0$)
		[69] ADEVA	85	MRKJ	
		[70] BALL	84	CALO	Beam dump
		[71] BARTEL	84B	JADE	
		[71] BEHREND	83	CELL	
		[72] CABIBBO	81	COSM	

[58] ABBOTT 98 studied the chargino and neutralino production, where the lightest neutralino in their decay products further decays into $\gamma\widetilde{G}$. The limit assumes the gaugino mass unification.

[59] ABREU 98 uses data at $\sqrt{s}$=161 and 172 GeV. Upper bounds on $\gamma\gamma\not{E}$ cross section are obtained. Similar limits on $\gamma\not{E}$ are also given, relevant for $e^+e^- \to \widetilde{\chi}_1^0\widetilde{G}$ production.

[60] ACKERSTAFF 98J looked for $\gamma\gamma\not{E}$ final states at $\sqrt{s}$=161–172 GeV. They set limits on $\sigma(e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0)$ in the range 0.22–0.50 pb for $m_{\widetilde{\chi}_1^0}$ in the range 45–86 GeV. Mass limits for explicit models from the literature are given in Fig. 19 of their paper. Similar limits on γ+missing energy are also given, relevant for $\widetilde{\chi}_1^0\widetilde{G}$ production.

[61] ACCIARRI 97V looked for $\gamma\gamma\not{E}$ final states at $\sqrt{s}$=161 and 172 GeV. They set limits on $\sigma(e^+e^- \to \widetilde{\chi}_1^0\widetilde{\chi}_1^0)$ in the range 0.25–0.50 pb for masses in the range 45–85 GeV. The lower limits on $m_{\widetilde{\chi}_1^0}$ vary in the range of 64.8 GeV (pure bino with 90 GeV slepton) to 75.3 GeV (pure higgsino). There is no limit for pure zino case.

[62] ELLIS 97 reanalyzed the LEP2 ($\sqrt{s}$=161 GeV) limits of $\sigma(\gamma\gamma+E_{\rm miss})<$ 0.2 pb to exclude $m_{\widetilde{\chi}^0_1} <$ 63 GeV if $m_{\widetilde{e}_L}=m_{\widetilde{e}_R} <$ 150 GeV and $\widetilde{\chi}^0_1$ decays to $\gamma\widetilde{G}$ inside detector.

[63] BUSKULIC 96U extended the search for $e^+e^- \rightarrow \widetilde{\chi}^0_1\widetilde{\chi}^0_1$ in BUSKULIC 95E under the same assumptions. See their Fig. 5 for excluded region in the neutralino-chargino parameter space. Data taken at $\sqrt{s}$ = 130–136 GeV.

[64] BUSKULIC 95E looked for $e^+e^- \rightarrow \widetilde{\chi}^0_1\widetilde{\chi}^0_1$, where $\widetilde{\chi}^0_1$ decays via R-parity violating interaction into one neutrino and two opposite-charge leptons. The bound applies provided that B($Z \rightarrow \widetilde{\chi}^0_1\widetilde{\chi}^0_1$)$>$ $3 \times 10^{-5}\beta^3$, β being the final state $\widetilde{\chi}^0_1$ velocity.

[65] BUSKULIC 95E looked for $e^+e^- \rightarrow \widetilde{\gamma}\widetilde{\gamma}$, where $\widetilde{\gamma}$ decays via R-parity violating interaction into one neutrino and two opposite-charge leptons. They extend the domain in the ($m_{\widetilde{e}}$,$m_{\widetilde{\gamma}}$) plane excluded by ACTON 93G to $m_{\widetilde{e}}$ >220 GeV/c^2 (for $m_{\widetilde{\gamma}}$=15 GeV/c^2) and to $m_{\widetilde{\gamma}}$ >2 GeV/c^2 (for $m_{\widetilde{e}}$ <220 GeV/c^2).

[66] ACTON 93G assume R-parity violation and decays $\widetilde{\gamma} \rightarrow \tau^\pm\ell^\mp\nu_\ell$ (ℓ= e or μ). They exclude $m_{\widetilde{\gamma}}$ = 4–43 GeV for $m_{\widetilde{e}_L}$ <42 GeV, and $m_{\widetilde{\gamma}}$ = 7–30 GeV for $m_{\widetilde{e}_L}$ <100 GeV (95% CL). Assumes $\widetilde{e}_R$ much heavier than $\widetilde{e}_L$, and lepton family number violation but L_e-L_μ conservation.

[67] ABE 89J exclude $m_{\widetilde{\gamma}}$ = 0.15–25 GeV (95%CL) for d = (100 GeV)^2 and $m_{\widetilde{e}}$ = 40 GeV in the case $\widetilde{\gamma} \rightarrow \gamma\widetilde{G}$, and $m_{\widetilde{\gamma}}$ up to 23 GeV for $m_{\widetilde{e}}$ = 40 GeV in the case $\widetilde{\gamma} \rightarrow \gamma\widetilde{H}^0$.

[68] BEHREND 87B limit is for unstable photinos only. Assumes B($\widetilde{\gamma} \rightarrow \gamma(\widetilde{G}$ or $\widetilde{H}^0$)) =1, $m_{\widetilde{G}\,{\rm or}\,\widetilde{H}^0} \ll m_{\widetilde{\gamma}}$ and pure $\widetilde{\gamma}$ eigenstate. $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} <$ 100 GeV.

[69] ADEVA 85 is sensitive to $\widetilde{\gamma}$ decay path <5 cm. With $m_{\widetilde{e}}$ = 50 GeV, limit (CL = 90%) is $m_{\widetilde{\gamma}}$ >20.5 GeV. Assume $\widetilde{\gamma}$ decays to photon + goldstino and search for acoplanar photons with large missing p_T.

[70] BALL 84 is FNAL beam dump experiment. Observed no $\widetilde{\gamma}$ decay, where $\widetilde{\gamma}$'s are expected to come from $\widetilde{g}$'s produced at the target. Three possible $\widetilde{\gamma}$ lifetimes are considered. Gluino decay to goldstino + gluon is also considered.

[71] BEHREND 83 and BARTEL 84B look for 2γ events from $\widetilde{\gamma}$ pair production. With supersymmetric breaking parameter d = (100 GeV)^2 and $m_{\widetilde{e}}$ = 40 GeV the excluded regions at CL = 95% would be $m_{\widetilde{\gamma}}$ = 100 MeV – 13 GeV for BEHREND 83 $m_{\widetilde{\gamma}}$ = 80 MeV – 18 GeV for BARTEL 84B. Limit is also applicable if the $\widetilde{\gamma}$ decays radiatively within the detector.

[72] CABIBBO 81 consider $\widetilde{\gamma} \rightarrow \gamma+$ goldstino. Photino must be either light enough (<30 eV) to satisfy cosmology bound, or heavy enough (>0.3 MeV) to have disappeared at early universe.

$\widetilde{\chi}^\pm_1$, $\widetilde{\chi}^\pm_2$ (Charginos) MASS LIMITS

Charginos ($\widetilde{\chi}^\pm$'s) are unknown mixtures of w-inos and charged higgsinos (the supersymmetric partners of W and Higgs bosons). Mass limits are relatively model dependent, so assumptions concerning branching ratios need to be specified. When specific assumptions are made, e.g. the chargino is a pure w-ino ($\widetilde{W}$) or pure charged higgsino ($\widetilde{H}^\pm$), the charginos will be labelled as such.

In the Listing below, we use $\Delta m_+ = m_{\widetilde{\chi}^\pm_1} - m_{\widetilde{\chi}^0_1}$ $\Delta m_\nu = m_{\widetilde{\chi}^\pm_1} - m_{\widetilde{\nu}}$, or simply Δm to indicate that the constraint applies to both Δm_+ and Δm_ν.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 67.6	95	[73] ABREU	98	DLPH	$\Delta m>$ 10 GeV
> 69.2	95	[74] ACCIARRI	98F	L3	$\tan\beta <$ 1.41

> 65.7	95	[75] ACKERSTAFF	98L	OPAL	$\Delta m_+ > 3$ GeV
> 56.3	95	[76] ABREU	96L	DLPH	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$
> 64	95	[77] ACCIARRI	96F	L3	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$, $m_{\widetilde{\chi}^0} < 43$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>150	95	[78] ABBOTT	98	D0	$p\overline{p} \to \gamma\gamma \not{E}_T$+X
		[79] ABBOTT	98C	D0	$p\overline{p} \to \widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$
> 71.8	95	[80] ABREU	98	DLPH	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$, $\widetilde{\chi}_1^0 \to \widetilde{G}\gamma$
		[81] ACKERSTAFF	98K	OPAL	$\widetilde{\chi}^+ \to \ell^+ \not{E}$
		[82] CARENA	97	THEO	$g_\mu - 2$
		[83] KALINOWSKI	97	THEO	$W \to \widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^0$
		[84] ABE	96K	CDF	$p\overline{p} \to \widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$
> 62	95	[85] ACKERSTAFF	96C	OPAL	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$
> 58.7	95	[86] ALEXANDER	96J	OPAL	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$
> 63	95	[87] BUSKULIC	96K	ALEP	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$
		[88] BUSKULIC	96U	ALEP	$e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-$; R-parity violation
> 44.0	95	[89] ADRIANI	93M	L3	$Z \to \widetilde{\chi}^+\widetilde{\chi}^-$, $\Gamma(Z)$
> 45.2	95	[90] DECAMP	92	ALEP	$Z \to \widetilde{\chi}^+\widetilde{\chi}^-$, all $m_{\widetilde{\chi}_1^0}$
> 47	95	[90] DECAMP	92	ALEP	$Z \to \widetilde{\chi}^+\widetilde{\chi}^-$, $m_{\widetilde{\chi}_1^0} <41$ GeV
> 99	95	[91] HIDAKA	91	RVUE	$\widetilde{\chi}_2^{\pm}$
> 44.5	95	[92] ABREU	90G	DLPH	$Z \to \widetilde{\chi}^+\widetilde{\chi}^-$, $m_{\widetilde{\gamma}} < 20$ GeV
> 45	95	[93] AKESSON	90B	UA2	$p\overline{p} \to Z$X $(Z \to \widetilde{W}^+\widetilde{W}^-)$
> 45	95	[94] AKRAWY	90D	OPAL	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$; $m_{\widetilde{\gamma}} < 20$ GeV
> 45	95	[95] BARKLOW	90	MRK2	$Z \to \widetilde{W}^+\widetilde{W}^-$
> 42	95	[96] BARKLOW	90	MRK2	$Z \to \widetilde{H}^+\widetilde{H}^-$
> 44.5	95	[97] DECAMP	90C	ALEP	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$; $m_{\widetilde{\gamma}} < 28$ GeV
> 25.5	95	[98] ADACHI	89	TOPZ	$e^+e^- \to \widetilde{\chi}^+\widetilde{\chi}^-$
> 44	95	[99] ADEVA	89B	L3	$e^+e^- \to \widetilde{W}^+\widetilde{W}^-$, $\widetilde{W} \to \ell\widetilde{\nu}$ or $\ell\nu\widetilde{\gamma}$
> 45	90	[100] ANSARI	87D	UA2	$p\overline{p} \to Z$X $(Z \to \widetilde{W}^+\widetilde{W}^-$, $\widetilde{W}^{\pm} \to e^{\pm}\widetilde{\nu})$

[73] ABREU 98 uses data at $\sqrt{s}$=161 and 172 GeV. The universal scalar mass at the GUT scale is assumed to compute branching fractions and mass spectrum. The limit is for 41 $< m_{\widetilde{\nu}} <$ 100 GeV, and tanβ=1–35. The limit improves to 84.3 GeV for $m_{\widetilde{\nu}} >$ 300 GeV. For Δm_+ below 10 GeV, the limit is independent of $m_{\widetilde{\nu}}$, and is given by 80.3 GeV for $\Delta m_+ = 5$ GeV, and by 52.4 GeV for $\Delta m_+ = 3$ GeV.

[74] ACCIARRI 98F evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The limit is obtained for 0 $< M_2 <$ 2000, tanβ < 1.41, and $\mu = -200$ GeV, and holds for all values

of m_0. No dependence on the trilinear-coupling parameter A is found. It improves to 84 GeV for large sneutrino mass, at μ=− 200 GeV. See the paper for limits obtained with specific assumptions on the gaugino/higgsino composition of the state. Data taken at $\sqrt{s}$ = 130–172 GeV.

[75] ACKERSTAFF 98L evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The limit is obtained for 0 $< M_2 <$ 1500, $|\mu| <$ 500 and $\tan\beta > 1$, but remains valid outside this domain. The dependence on the trilinear-coupling parameter A is studied, and found neglibible. The limit holds for the smallest value of m_0 consistent with scalar lepton constraints (ACKERSTAFF 97H) and for all values of m_0 where the condition $\Delta m_{\widetilde{\nu}} >$ 2.0 GeV is satisfied. $\Delta m_{\nu} >$ 10 GeV if $\widetilde{\chi}^{\pm} \rightarrow \ell \widetilde{\nu}_{\ell}$. The limit improves to 84.5 GeV for m_0=1 TeV. Data taken at $\sqrt{s}$=130–172 GeV.

[76] ABREU 96L assumes the dominance of off-shell W-exchange in the chargino decay and $\Delta(m)$ >10 GeV. The bound is for the smallest $\widetilde{\ell}$, $\widetilde{\nu}$ mass allowed by LEP, provided either $m_{\widetilde{\nu}} > m_{\widetilde{\chi}^{\pm}}$ or $m_{\widetilde{\chi}^{\pm}} - m_{\widetilde{\nu}}$ >10 GeV. 1<$\tan\beta$ <35. For a mostly higgsino $\widetilde{\chi}^{+}$ ($m_{\widetilde{\chi}^{\pm}} - m_{\widetilde{\chi}^0}$=5 GeV) the limit is 63.8 GeV, independently of the $\widetilde{\ell}$ masses. Data taken at $\sqrt{s}$ = 130–136 GeV.

[77] ACCIARRI 96F assume $m_{\widetilde{\nu}}$ >200 GeV and $m_{\widetilde{\chi}_1^{\pm}} < m_{\widetilde{\chi}_2^0}$. See their Fig. 4 for excluded regions in the ($m_{\widetilde{\chi}^{\pm}}$,$m_{\widetilde{\chi}^0}$) plane. Data taken at $\sqrt{s}$ = 130–136 GeV.

[78] ABBOTT 98 studied the chargino and neutralino production, where the lightest neutralino in their decay products further decays into $\gamma \widetilde{G}$. The limit assumes the gaugino mass unification.

[79] ABBOTT 98C searches for trilepton final states (ℓ=e,μ). Efficiencies are calculated using mass relations and branching ratios in the Minimal Supergravity scenario. Results are presented in Fig. 1 of their paper as lower bounds on $\sigma(p\overline{p} \rightarrow \widetilde{\chi}^{\pm}\widetilde{\chi}_2^0)\times$B($3\ell$). Limits range from 0.66 pb ($m_{\widetilde{\chi}_1^{\pm}}$=45 GeV) to 0.10 pb ($m_{\widetilde{\chi}_1^{\pm}}$=124 GeV).

[80] ABREU 98 uses data at $\sqrt{s}$=161 and 172 GeV. The universal scalar mass at the GUT scale is assumed to compute branching fractions and mass spectrum, and the radiative decay of the lightest neutralino into gravitino is assumed. The limit is for $\Delta m >$ 10 GeV, 41 $< m_{\widetilde{\nu}} <$ 100 GeV, and $\tan\beta$=1–35. The limit improves to 84.5 GeV if either $m_{\widetilde{\nu}} >$ 300 GeV, or Δm_{+}=1 GeV independently of $m_{\widetilde{\nu}}$.

[81] ACKERSTAFF 98K looked for dilepton+$\not{E}_T$ final states at $\sqrt{s}$=130–172 GeV. Limits on $\sigma(e^+e^- \rightarrow \widetilde{\chi}_1^+\widetilde{\chi}_1^-)\times$B$^2(\ell)$, with B($\ell$)=B($\chi^+ \rightarrow \ell^+\nu_{\ell}\chi_1^0$) (B($\ell$)=B($\chi^+ \rightarrow \ell^+\widetilde{\nu}_{\ell}$)), are given in Fig. 16 (Fig. 17).

[82] CARENA 97 studied the constraints on chargino and sneutrino masses from muon $g-2$. The bound can be important for large $\tan\beta$.

[83] KALINOWSKI 97 studies the constraints on the chargino-neutralino parameter space from limits on $\Gamma(W \rightarrow \widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^0)$ achievable at LEP2. This is relevant when $\widetilde{\chi}_1^{\pm}$ is "invisible," i.e., if $\widetilde{\chi}_1^{\pm}$ dominantly decays into $\widetilde{\nu}_{\ell}\ell^{\pm}$ with little energy for the lepton. Small otherwise allowed regions could be excluded.

[84] ABE 96K looked for tripleton events from chargino-neutralino production. The bound on $m_{\widetilde{\chi}_1^{\pm}}$ can reach up to 47 GeV for specific choices of parameters. The limits on the combined production cross section times 3-lepton branching ratios range between 1.4 and 0.4 pb, for 45<$m_{\widetilde{\chi}_1^{\pm}}$(GeV)<100. See the paper for more details on the parameter dependence of the results.

[85] ACKERSTAFF 96C assumes the dominance of off-shell W-exchange in the chargino decay and applies for Δm>10 GeV in the region of parameter space defined by: M_2 <1500 GeV, $|\mu|$ <500 GeV and $\tan\beta >$ 1.5. The bound is for the smallest $\widetilde{\ell}$,$\widetilde{\nu}$ mass allowed by

LEP, with the efficiency for $\widetilde{\chi}^{\pm} \rightarrow \widetilde{\nu}\nu$ decays set to zero. The limit improves to 78.5 GeV for $m_0 = 1$ TeV. Data taken at $\sqrt{s} = 130,136$, and 161 GeV.

[86] ALEXANDER 96J assumes a universal scalar mass m_0 at the grand unification scale. The bound is for the smallest possible value of m_0 allowed by the LEP $\widetilde{\ell}$, $\widetilde{\nu}$ mass limits. 1.5 <tanβ <35. Branching fractions are calculated using minimal supergravity. The bound is for $\Delta(m)$ >10 GeV. The limit improves to 65.4 GeV for m_0=1 TeV. Data taken at $\sqrt{s} = 130$–136 GeV.

[87] BUSKULIC 96K assumes the dominance of off-shell W-exchange in the chargino decay and applies throughout the (M_2,μ) plane for 1.41 <tanβ <35 provided either $m_{\widetilde{\nu}} > m_{\widetilde{\chi}^{\pm}}$ and $m_{\widetilde{\chi}^{\pm}} - m_{\widetilde{\chi}^0_1}$ >4 GeV, or $m_{\widetilde{\chi}^{\pm}} - m_{\widetilde{\nu}}$ >4 GeV. The limit improves to 67.8 GeV for a pure gaugino $\widetilde{\chi}^{\pm}$ and $m_{\widetilde{\nu}}$ >200 GeV. Data taken at $\sqrt{s} = 130$–136 GeV.

[88] BUSKULIC 96U searched for pair-produced charginos which decay into $\widetilde{\chi}^0_1$ with either leptons or hadrons, where $\widetilde{\chi}^0_1$ further decays leptonically via R-parity violating interactions. See their Fig. 5 for excluded region in the neutralino-chargino parameter space. Data taken at $\sqrt{s} = 130$–136 GeV.

[89] ADRIANI 93M limit from $\Delta\Gamma(Z)$< 35.1 MeV. For pure wino, the limit is 45.5 GeV.

[90] DECAMP 92 limit is for a general $\widetilde{\chi}^{\pm}$ (all contents).

[91] HIDAKA 91 limit obtained from LEP and preliminary CDF limits on the gluino mass (as analyzed in BAER 91).

[92] ABREU 90G limit is for a general $\widetilde{\chi}^{\pm}$. They assume charginos have a three-body decay such as $\ell^+\nu\widetilde{\gamma}$.

[93] AKESSON 90B assume $\widetilde{W} \rightarrow e\widetilde{\nu}$ with B > 20% and $m_{\widetilde{\nu}} = 0$. The limit disappears if $m_{\widetilde{\nu}}$ > 30 GeV.

[94] AKRAWY 90D assume charginos have three-body decay such as $\ell^+\nu\widetilde{\gamma}$ (i.e. $m_{\widetilde{\nu}} > m_{\widetilde{\chi}^+}$). A two-body decay, $\widetilde{\chi}^+ \rightarrow \ell\widetilde{\nu}$ would have been seen by their search for acoplanar leptons. The result is independent of the hadronic branching ratio. They search for acoplanar electromagnetic clusters and quark jets.

[95] BARKLOW 90 assume 100% $\widetilde{W} \rightarrow W^*\widetilde{\chi}^0_1$. Valid up to $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{W}} - 5$ GeV].

[96] BARKLOW 90 assume 100% $\widetilde{H} \rightarrow H^*\widetilde{\chi}^0_1$. Valid up to $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{H}} - 8$ GeV].

[97] DECAMP 90C assume charginos have three-body decay such as $\ell^+\nu\widetilde{\gamma}$ (i.e. $m_{\widetilde{\nu}} > m_{\widetilde{\chi}^+}$), and branching ratio to each lepton is 11%. They search for acoplanar dimuons, dielectrons, and μe events. Limit valid for $m_{\widetilde{\gamma}}$ < 28 GeV.

[98] ADACHI 89 assume only single photon annihilation in the production. The limit applies for arbitrary decay branching ratios with B($\widetilde{\chi} \rightarrow e\nu\widetilde{\gamma}$) + B($\widetilde{\chi} \rightarrow \mu\nu\widetilde{\gamma}$) + B($\widetilde{\chi} \rightarrow \tau\nu\widetilde{\gamma}$) + B($\widetilde{\chi} \rightarrow q\overline{q}\widetilde{\gamma}$) = 1 (lepton universality is *not* assumed). The limit is for $m_{\widetilde{\gamma}} = 0$ but a very similar limit is obtained for $m_{\widetilde{\gamma}} = 10$ GeV. For B($\widetilde{\chi} \rightarrow q\overline{q}\widetilde{\gamma}$) = 1, the limit increases to 27.8 GeV.

[99] ADEVA 89B assume for $\ell\nu\widetilde{\gamma}$ ($\ell\widetilde{\nu}$) mode that B(e) = B(μ) = B(τ) = 11% (33%) and search for acoplanar dimuons, dielectrons, and μe events. Also assume $m_{\widetilde{\gamma}}$ < 20 GeV and for $\ell\widetilde{\nu}$ mode that $m_{\widetilde{\nu}} = 10$ GeV.

[100] ANSARI 87D looks for high p_T e^+e^- pair with large missing p_T at the CERN $p\overline{p}$ collider at $E_{\rm cm}$ = 546–630 GeV. The limit is valid when $m_{\widetilde{\nu}} \lesssim 20$ GeV, B($\widetilde{W} \rightarrow e\widetilde{\nu}_e$) = 1/3, and B($Z \rightarrow \widetilde{W}^+\widetilde{W}^-$) is calculated by assuming pure gaugino eigenstate. See their Fig. 3(b) for excluded region in the $m_{\widetilde{W}} - m_{\widetilde{\nu}}$ plane.

Long-lived $\widetilde{\chi}^{\pm}$ (Chargino) MASS LIMITS

Limits on charginos which leave the detector before decaying.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>80	95	[101] ABREU	97D	DLPH
>83	95	[102] BARATE	97K	ALEP
>45	95	ABREU	90G	DLPH
>28.2	95	ADACHI	90C	TOPZ

[101] ABREU 97D bound applies only to masses above 45 GeV. Data collected in e^+e^- collisions at $\sqrt{s}$=130–172 GeV. The limit improves to 84 GeV for $m_{\widetilde{\nu}} > 200$ GeV.

[102] BARATE 97K uses e^+e^- data collected at $\sqrt{s}$ = 130–172 GeV. Limit valid for $\tan\beta = \sqrt{2}$ and $m_{\widetilde{\nu}} > 100$ GeV. The limit improves to 86 GeV for $m_{\widetilde{\nu}} > 250$ GeV.

$\widetilde{\nu}$ (Sneutrino) MASS LIMIT

The limit depends on the number, $N(\widetilde{\nu})$, of sneutrinos assumed to be degenerate in mass. Only $\widetilde{\nu}_L$ (not $\widetilde{\nu}_R$) exist. It is possible that $\widetilde{\nu}$ could be the lightest supersymmetric particle (LSP).

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 43.1	95	[103] ELLIS	96B	RVUE	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=3
> 41.8	95	[104] ADRIANI	93M	L3	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=3
> 37.1	95	[104] ADRIANI	93M	L3	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=1
> 41	95	[105] DECAMP	92	ALEP	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=3
> 36	95	ABREU	91F	DLPH	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=1
> 32	95	[106] ABREU	91F	DLPH	$\Gamma(Z)$; $N(\widetilde{\nu})$=1
> 31.2	95	[107] ALEXANDER	91F	OPAL	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=1
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$\neq m_Z$	95	[108] ACCIARRI	97U	L3	R-parity violation
none 125–180	95	[108] ACCIARRI	97U	L3	R-parity violation
		[109] CARENA	97	THEO	$g_\mu - 2$
> 46.0	95	[110] BUSKULIC	95E	ALEP	$N(\widetilde{\nu})$=1, $\widetilde{\nu} \rightarrow \nu\nu\ell\overline{\ell}'$
none 20–25000		[111] BECK	94	COSM	Stable $\widetilde{\nu}$, dark matter
<600		[112] FALK	94	COSM	$\widetilde{\nu}$ LSP, cosmic abundance
none 3–90	90	[113] SATO	91	KAMI	Stable $\widetilde{\nu}_e$ or $\widetilde{\nu}_\mu$, dark matter
none 4–90	90	[113] SATO	91	KAMI	Stable $\widetilde{\nu}_\tau$, dark matter
> 31.4	95	[114] ADEVA	90I	L3	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=1
> 39.4	95	[114] ADEVA	90I	L3	$\Gamma(Z \rightarrow$ invisible); $N(\widetilde{\nu})$=3

[103] ELLIS 96B uses combined LEP data available in the Summer 1995, which constrain the number of neutrino species to N_ν=2.991 ± 0.016.

[104] ADRIANI 93M limit from $\Delta\Gamma(Z)$(invisible)< 16.2 MeV.

[105] DECAMP 92 limit is from Γ(invisible)/$\Gamma(\ell\ell)$ = 5.91 ± 0.15 (N_ν = 2.97 ± 0.07).

[106] ABREU 91F limit (>32 GeV) is independent of sneutrino decay mode.

[107] ALEXANDER 91F limit is for one species of $\widetilde{\nu}$ and is derived from Γ(invisible, new)/$\Gamma(\ell\ell)$ < 0.38.

[108] ACCIARRI 97U studied the effect of the s-channel tau-sneutrino exchange in $e^+e^- \rightarrow e^+e^-$ at $\sqrt{s}=m_Z$ and $\sqrt{s}$=130–172 GeV, via the R-parity violating coupling $\lambda_{131}L_1L_ie_1$. The limits quoted here hold for $\lambda_{131} > 0.05$. Similar limits were studied in $e^+e^- \rightarrow \mu^+\mu^-$ together with $\lambda_{232}L_2L_3e_2$ coupling.

[109] CARENA 97 studied the constraints on chargino and sneutrino masses from muon $g-2$. The bound can be important for large $\tan\beta$.

[110] BUSKULIC 95E looked for $Z \rightarrow \widetilde{\nu}\overline{\widetilde{\nu}}$, where $\widetilde{\nu} \rightarrow \nu\chi^0_1$ and χ^0_1 decays via R-parity violating interactions into two leptons and a neutrino.

[111] BECK 94 limit can be inferred from limit on Dirac neutrino using $\sigma(\widetilde{\nu}) = 4\sigma(\nu)$. Also private communication with H.V. Klapdor-Kleingrothaus.

[112] FALK 94 puts an upper bound on $m_{\widetilde{\nu}}$ when $\widetilde{\nu}$ is LSP by requiring its relic density does not overclose the Universe.

[113] SATO 91 search for high-energy neutrinos from the sun produced by annihilation of sneutrinos in the sun. Sneutrinos are assumed to be stable and to constitute dark matter in our galaxy. SATO 91 follow the analysis of NG 87, OLIVE 88, and GAISSER 86.

[114] ADEVA 90I limit is from $\Delta N_\nu < 0.19$.

$\widetilde{e}$ (Selectron) MASS LIMIT

Limits assume $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$ unless otherwise stated. When the assumption of a universal scalar mass parameter m_0 for $\widetilde{e}_L$ and $\widetilde{e}_R$ is mentioned, the relation between $m_{\widetilde{e}_R}$ and $m_{\widetilde{e}_L}$ can be found in the "Note on Supersymmetry."

In the Listings below, we use $\Delta m = m_{\widetilde{e}} - m_{\widetilde{\chi}^0_1}$.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 56	95	[115] ACCIARRI	98F	L3	$\Delta m >$ 5 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$, $\tan\beta \geq 1.41$
> 58.0	95	[116] ACKERSTAFF	98K	OPAL	$\Delta(m) >$ 5 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$
> 55	95	[117] ACKERSTAFF	97H	OPAL	$\Delta(m) >$ 5 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$
> 58	95	[118] BARATE	97N	ALEP	$\Delta(m) >$ 3 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 35	95	[119] BARATE	97N	RVUE	$\widetilde{e}_R$, $\Gamma^{\text{inv}}(Z)$
> 57	95	[120] ABREU	96O	DLPH	$\Delta(m) >$5 GeV, $\widetilde{e}^+\widetilde{e}^-$
> 50	95	[121] ACCIARRI	96F	L3	$\Delta(m) >$5 GeV, $\widetilde{e}^+\widetilde{e}^-$
> 63	95	[122] AID	96C	H1	$m_{\widetilde{q}}=m_{\widetilde{e}}$, $m_{\widetilde{\chi}^0_1}$=35 GeV
> 50	95	[123] BUSKULIC	96K	ALEP	$\Delta(m) >$10 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$, $\lvert\mu\rvert$= 1 TeV
> 63	90	[124] SUGIMOTO	96	AMY	$m_{\widetilde{\gamma}}$ <5 GeV, $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 77	90	[125] SUGIMOTO	96	RVUE	$m_{\widetilde{\gamma}}$ <5 GeV, $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 46	90	[126] ABE	95A	TOPZ	$m_{\widetilde{\gamma}}$ <5 GeV, $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 45.6	95	[127] BUSKULIC	95E	ALEP	$\widetilde{e} \rightarrow e\nu\ell\overline{\ell}'$
> 51.9	90	HOSODA	94	VNS	$m_{\widetilde{\gamma}}$=0; $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 45	95	[128] ADRIANI	93M	L3	$\Delta(m) >$5 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$
> 45	95	[129] DECAMP	92	ALEP	$\Delta(m) >$4 GeV, $\widetilde{e}^+_R\widetilde{e}^-_R$
> 42	95	ABREU	90G	DLPH	$m_{\widetilde{\gamma}}$ < 40 GeV; $\widetilde{e}^+\widetilde{e}^-$
> 38	95	[130] AKESSON	90B	UA2	$m_{\widetilde{\gamma}}$ = 0; $p\overline{p} \rightarrow ZX$ ($Z \rightarrow \widetilde{e}^+\widetilde{e}^-$)
> 43.4	95	[131] AKRAWY	90D	OPAL	$m_{\widetilde{\gamma}}$ < 30 GeV; $\widetilde{e}^+\widetilde{e}^-$

> 38.1	90	[132]	BAER	90	RVUE	$\widetilde{e}_L$; $\Gamma(Z)$; $\tan\beta > 1$
> 43.5	95	[133]	DECAMP	90C	ALEP	$m_{\widetilde{\gamma}} < 36$ GeV; $\widetilde{e}^+\widetilde{e}^-$
>830			GRIFOLS	90	ASTR	$m_{\widetilde{\gamma}} < 1$ MeV
> 29.9	95		SAKAI	90	AMY	$m_{\widetilde{\gamma}} < 20$ GeV; $\widetilde{e}^+\widetilde{e}^-$
> 29	95		TAKETANI	90	VNS	$m_{\widetilde{\gamma}} < 25$ GeV; $\widetilde{e}^+\widetilde{e}^-$
> 60		[134]	ZHUKOVSKII	90	ASTR	$m_{\widetilde{\gamma}} = 0$
> 28	95	[135]	ADACHI	89	TOPZ	$m_{\widetilde{\gamma}} \lesssim 0.85 m_{\widetilde{e}}$; $\widetilde{e}^+\widetilde{e}^-$
> 41	95	[136]	ADEVA	89B	L3	$m_{\widetilde{\gamma}} < 20$ GeV; $\widetilde{e}^+\widetilde{e}^-$
> 32	90	[137]	ALBAJAR	89	UA1	$p\overline{p} \rightarrow W^{\pm}X$ $(W^{\pm} \rightarrow \widetilde{e}_L\widetilde{\nu})$ $(\widetilde{e}_L \rightarrow e\widetilde{\gamma})$
> 14	90	[138]	ALBAJAR	89	UA1	$Z \rightarrow \widetilde{e}^+\widetilde{e}^-$
> 53	95	[139,140]	HEARTY	89	ASP	$m_{\widetilde{\gamma}}=0$; $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 50	95		HEARTY	89	ASP	$m_{\widetilde{\gamma}} <5$ GeV; $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 35	95		HEARTY	89	ASP	$m_{\widetilde{\gamma}} <10$ GeV; $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 51.5	90	[141,142]	BEHREND	88B	CELL	$m_{\widetilde{\gamma}} = 0$ GeV; $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 48	90		BEHREND	88B	CELL	$m_{\widetilde{\gamma}} < 5$ GeV; $\gamma\widetilde{\gamma}\widetilde{\gamma}$

[115] ACCIARRI 98F looked for acoplanar dielectron+$\not\!\!E_T$ final states at $\sqrt{s}$=130–172 GeV. The limit assumes μ=−200 GeV, and zero efficiecny for decays other than $\widetilde{e}_R \rightarrow e\widetilde{\chi}^0_1$. See their Fig. 6 for the dependence of the limit on Δm.

[116] ACKERSTAFF 98K looked for dielectron+$\not\!\!E_T$ final states at $\sqrt{s}$=130–172 GeV. The limit assumes $\mu < -100$ GeV, $\tan\beta$=35, and zero efficiency for decays other than $\widetilde{e}_R \rightarrow e\widetilde{\chi}^0_1$. The limit improves to 66.5 GeV for $\tan\beta$=1.5.

[117] ACKERSTAFF 97H searched for acoplanar e^+e^-, assuming the MSSM with universal scalar mass and $\tan\beta$=1.5 but conservatively did not take the possible $\widetilde{e}_L$ production into account. The limit improves to 68 GeV for the lightest allowed $\widetilde{\chi}^0_1$, while it disappears for $\Delta(m) < 3$ GeV. The study includes data from e^+e^- collisions at $\sqrt{s}$=161 GeV, as well as 130–136 GeV (ALEXANDER 97B).

[118] BARATE 97N uses e^+e^- data collected at $\sqrt{s}$=161 and 172 GeV. The limit is for $\tan\beta$=2. It improves to 75 GeV if $\Delta(m)$ >35 GeV.

[119] BARATE 97N limit from ALCARAZ 96 limit on Z invisible-decay width and N_ν=3, independent of decay mode. Limit improves to 41 GeV for degenerate right-handed sleptons.

[120] ABREU 96O bound assumes $|\mu|$ >200 GeV. The limit on $m_{\widetilde{e}_R}$ obtained by assuming a heavy $\widetilde{e}_L$ reduces to below 48 GeV. Data taken at $\sqrt{s}$ = 130–136 GeV.

[121] ACCIARRI 96F searched for acoplanar electron pairs. The limit is on $m_{\widetilde{e}_R}$, under the assumption of a universal scalar mass in the range $0<m<100$ GeV. It assumes $0<M<200$ GeV, $-200 < \mu < 0$ GeV, $\tan\beta$ = 1.5. The corresponding limit for for $m_{\widetilde{e}_L}$ is 64 GeV. The bound on $m_{\widetilde{e}_R}$ ($m_{\widetilde{e}_L}$) improves to 58 GeV (70 GeV) for $m_{\widetilde{\chi}^0_1}$=0. Data taken at $\sqrt{s}$ = 130–136 GeV.

[122] AID 96C used electron+jet events with missing energy and momentum to look for $eq \rightarrow \widetilde{e}\widetilde{q}$ via neutralino exchange with decays into $(e\widetilde{\chi}^0_1)(q\widetilde{\chi}^0_1)$. See the paper for dependences on $m_{\widetilde{q}}$, $m_{\widetilde{\chi}^0_1}$.

[123] BUSKULIC 96K searched for acoplanar electron pairs. The bound disappears for $\Delta(m)$ <10 GeV, while it improves to 59 GeV for $m_{\widetilde{\chi}^0_1}$=0. If μ is small and the LSP higgsino-dominated, no bound beyond $m_Z/2$ exists. Data taken at $\sqrt{s}$ = 130–136 GeV.

[124] SUGIMOTO 96 looked for single photon production from e^+e^- annihilation at $\sqrt{s}$= 57.8 GeV. The lower bound improves to 65.5 GeV for a massless photino.
[125] SUGIMOTO 96 combined FORD 86, BEHREND 88B, HEARTY 89, HOSODA 94, ABE 95A, and SUGIMOTO 96 results. The lower bound improves to 79.3 GeV for a massless photino.
[126] ABE 95A looked for single photon production from e^+e^- annihilation at $\sqrt{s}$= 58 GeV. The lower bound improves to 47.2 GeV for a massless photino.
[127] BUSKULIC 95E looked for $Z \to \widetilde{e}_R^+ \widetilde{e}_R^-$ where $\widetilde{e}_R \to e\chi_1^0$ and χ_1^0 decays via R-parity violating interactions into two leptons and a neutrino.
[128] ADRIANI 93M used acolinear di-lepton events.
[129] DECAMP 92 limit improves for equal masses. They looked for acoplanar electrons.
[130] AKESSON 90B assume $m_{\widetilde{\gamma}} = 0$. Very similar limits hold for $m_{\widetilde{\gamma}} \lesssim$ 20 GeV.
[131] AKRAWY 90D look for acoplanar electrons. For $m_{\widetilde{e}_L} \gg m_{\widetilde{e}_R}$, limit is 41.5 GeV, for $m_{\widetilde{\gamma}} <$ 30 GeV.
[132] BAER 90 limit from $\Delta\Gamma(Z)$ (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry and $\tan\beta > 1$ assumed.
[133] DECAMP 90C look for acoplanar electrons. For $m_{\widetilde{e}_L} \gg m_{\widetilde{e}_R}$ limit is 42 GeV, for $m_{\widetilde{\gamma}} <$ 33 GeV.
[134] ZHUKOVSKII 90 set limit by saying the luminosity of a magnetized neutron star due to massless photino emission by electrons be small compared with its neutrino luminosity.
[135] ADACHI 89 assume only photon and photino exchange and $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$. The limit for the nondegenerate case is 26 GeV.
[136] ADEVA 89B look for acoplanar electrons.
[137] ALBAJAR 89 limit applies for $\widetilde{e}_L$ when $m_{\widetilde{e}_L} = m_{\widetilde{\nu}_L}$ and $m_{\widetilde{\gamma}} = 0$. See their Fig. 55 for the 90% CL excluded region in the $m_{\widetilde{e}_L} - m_{\widetilde{\nu}_L}$ plane. For $m_{\widetilde{\nu}} = m_{\widetilde{\gamma}} = 0$, limit is 50 GeV.
[138] ALBAJAR 89 assume $m_{\widetilde{\gamma}} = 0$.
[139] HEARTY 89 assume $m_{\widetilde{\gamma}} = 0$. The limit is very sensitive to $m_{\widetilde{\gamma}}$; no limit can be placed for $m_{\widetilde{\gamma}} \gtrsim$ 13 GeV.
[140] The limit is reduced to 43 GeV if only one $\widetilde{e}$ state is produced ($\widetilde{e}_L$ or $\widetilde{e}_R$ very heavy).
[141] BEHREND 88B limits assume pure photino eigenstate and $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$.
[142] The 95% CL limit for BEHREND 88B is 47.5 GeV for $m_{\widetilde{\gamma}} = 0$. The limit for $m_{\widetilde{e}_L} \gg m_{\widetilde{e}_R}$ is 40 GeV at 90% CL.

$\widetilde{\mu}$ (Smuon) MASS LIMIT

Limits assume $m_{\widetilde{\mu}_L} = m_{\widetilde{\mu}_R}$ unless otherwise stated.

In the Listings below, we use $\Delta(m)=m_{\widetilde{\mu}} - m_{\widetilde{\chi}_1^0}$. When limits on $m_{\widetilde{\mu}_R}$ are quoted, it is understood that limits on $m_{\widetilde{\mu}_L}$ are usually at least as strong.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>55	95	[143] ACCIARRI	98F	L3	$\Delta m>$ 5 GeV, $\widetilde{\mu}_R^+\widetilde{\mu}_R^-$
>55.6	95	[144] ACKERSTAFF	98K	OPAL	$\Delta(m) >$ 4 GeV, $\widetilde{\mu}_R^+\widetilde{\mu}_R^-$
>59	95	[145] BARATE	97N	ALEP	$\Delta(m) >$ 10 GeV, $\widetilde{\mu}_R^+\widetilde{\mu}_R^-$

• • • We do not use the following data for averages, fits, limits, etc. • • •

>51	95	[146] ACKERSTAFF	97H	OPAL	$\Delta(m) > 5$ GeV, $\widetilde{\mu}^+_R \widetilde{\mu}^-_R$
>35	95	[147] BARATE	97N	RVUE	$\widetilde{\mu}_R$, $\Gamma^{\text{inv}}(Z)$
>51	95	[148] ABREU	96O	DLPH	$\Delta(m) >5$ GeV, $\widetilde{\mu}^+ \widetilde{\mu}^-$
>45.6	95	[149] BUSKULIC	95E	ALEP	$\widetilde{\mu} \rightarrow \mu \nu \ell \overline{\ell}'$
>45	95	ADRIANI	93M	L3	$m_{\widetilde{\chi}^0_1} <40$ GeV, $\widetilde{\mu}^+_R \widetilde{\mu}^-_R$
>45	95	DECAMP	92	ALEP	$m_{\widetilde{\chi}^0_1} <41$ GeV, $\widetilde{\mu}^+_R \widetilde{\mu}^-_R$
>36	95	ABREU	90G	DLPH	$m_{\widetilde{\gamma}} < 33$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>43	95	[150] AKRAWY	90D	OPAL	$m_{\widetilde{\gamma}} < 30$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>38.1	90	[151] BAER	90	RVUE	$\widetilde{\mu}_L$; $\Gamma(Z)$; $\tan\beta > 1$
>42.6	95	[152] DECAMP	90C	ALEP	$m_{\widetilde{\gamma}} < 34$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>27	95	SAKAI	90	AMY	$m_{\widetilde{\gamma}} < 18$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>24.5	95	TAKETANI	90	VNS	$m_{\widetilde{\gamma}} < 15$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>24.5	95	[153] ADACHI	89	TOPZ	$m_{\widetilde{\gamma}} \lesssim 0.8 m_{\widetilde{\mu}}$; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>41	95	[154] ADEVA	89B	L3	$m_{\widetilde{\gamma}} < 20$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$

[143] ACCIARRI 98F looked for dimuon+$\not\!\!E_T$ final states at $\sqrt{s}$=130–172 GeV. The limit assumes μ=$-$200 GeV, and zero efficiecny for decays other than $\widetilde{\mu}_R \rightarrow \mu \widetilde{\chi}^0_1$. See their Fig. 6 for the dependence of the limit on Δm.

[144] ACKERSTAFF 98K looked for dimuon+$\not\!\!E_T$ final states at $\sqrt{s}$=130–172 GeV. The limit assumes $\mu < -100$ GeV, $\tan\beta$=1.5, and zero efficiency for decays other than $\widetilde{\mu}_R \rightarrow \mu \widetilde{\chi}^0_1$. The limit improves to 62.7 GeV for B($\widetilde{\mu}_R \rightarrow \mu \widetilde{\chi}^0_1$)=1.

[145] BARATE 97N uses $e^+ e^-$ data collected at $\sqrt{s}$=161 and 172 GeV. The limit assumes B($\widetilde{\mu} \rightarrow \mu \widetilde{\chi}^0_1$) = 1.

[146] ACKERSTAFF 97H limit is for $m_{\widetilde{\chi}^0_1}$ >12 GeV allowed by their chargino, neutralino search, and for $\tan\beta \geq 1.5$ and $|\mu| > 200$ GeV. The study includes data from $e^+ e^-$ collisions at $\sqrt{s}$=161 GeV, as well as at 130–136 GeV (ALEXANDER 97B).

[147] BARATE 97N limit from ALCARAZ 96 limit on Z invisible-decay width and N_ν=3, independent of decay mode. Limit improves to 41 GeV for degenerate right-handed sleptons.

[148] Data taken at $\sqrt{s}$ = 130–136 GeV.

[149] BUSKULIC 95E looked for $Z \rightarrow \widetilde{\mu}^+_R \widetilde{\mu}^-_R$, where $\widetilde{\mu}_R \rightarrow \mu \chi^0_1$ and χ^0_1 decays via R-parity violating interactions into two leptons and a neutrino.

[150] AKRAWY 90D look for acoplanar muons. For $m_{\widetilde{\mu}_L} \gg m_{\widetilde{\mu}_R}$, limit is 41.0 GeV, for $m_{\widetilde{\gamma}} < 30$ GeV.

[151] BAER 90 limit from $\Delta\Gamma(Z)$ (nonhadronic) $<$ 53 MeV. Independent of decay modes. Mininal supersymmetry and $\tan\beta > 1$ assumed.

[152] DECAMP 90C look for acoplanar muons. For $m_{\widetilde{\mu}_L} \gg m_{\widetilde{\mu}_R}$ limit is 40 GeV, for $m_{\widetilde{\gamma}} <$ 30 GeV.

[153] ADACHI 89 assume only photon exchange, which gives a conservative limit. $m_{\widetilde{\mu}_L} = m_{\widetilde{\mu}_R}$ assumed. The limit for nondegenerate case is 22 GeV.

[154] ADEVA 89B look for acoplanar muons.

$\widetilde{\tau}$ (Stau) MASS LIMIT

Limits assume $m_{\widetilde{\tau}_L} = m_{\widetilde{\tau}_R}$ unless otherwise stated.

In the Listings below, we use $\Delta(m)=m_{\widetilde{\tau}} - m_{\widetilde{\chi}^0_1}$. The limits depend on the potentially large mixing angle of the lightest mass eigenstate $\widetilde{\tau}_1 = \widetilde{\tau}_R \sin\theta_\tau + \widetilde{\tau}_L \sin\theta_\tau$. The coupling to the Z vanishes for $\theta_\tau = 0.82$.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>53	95	[155] BARATE	97N	ALEP	$\Delta(m) > 30$ GeV, $\theta_\tau=\pi/2$
>47	95	[155] BARATE	97N	ALEP	$\Delta(m) > 30$ GeV, $\theta_\tau=0.82$
>35	95	[156] BARATE	97N	RVUE	$\widetilde{\tau}_R$, $\Gamma^{\text{inv}}(Z)$
>44	95	[157] ADRIANI	93M	L3	$m_{\widetilde{\chi}^0_1}$ <38 GeV, $\widetilde{\tau}^+\widetilde{\tau}^-$
>45	95	[158] DECAMP	92	ALEP	$m_{\widetilde{\chi}^0_1}$ <38 GeV, $\widetilde{\tau}^+\widetilde{\tau}^-$
>43.0	95	[159] AKRAWY	90D	OPAL	$m_{\widetilde{\gamma}} < 23$ GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>45.6	95	[160] BUSKULIC	95E	ALEP	$\widetilde{\tau} \rightarrow \tau\nu\ell\overline{\ell}'$
>35	95	ABREU	90G	DLPH	$m_{\widetilde{\gamma}} < 25$ GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$
>38.1	90	[161] BAER	90	RVUE	$\widetilde{\tau}_L$; $\Gamma(Z)$; $\tan\beta > 1$
>40.4	95	[162] DECAMP	90C	ALEP	$m_{\widetilde{\gamma}} < 15$ GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$
>25	95	SAKAI	90	AMY	$m_{\widetilde{\gamma}} < 10$ GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$
>25.5	95	TAKETANI	90	VNS	$m_{\widetilde{\gamma}} < 15$ GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$
>21.7	95	[163] ADACHI	89	TOPZ	$m_{\widetilde{\gamma}}=0$; $\widetilde{\tau}^+\widetilde{\tau}^-$

[155] BARATE 97N uses e^+e^- data collected at $\sqrt{s}$=161 and 172 GeV.

[156] BARATE 97N limit from ALCARAZ 96 limit on Z invisible-decay width and N_ν=3, independent of decay mode. Limit improves to 41 GeV for degenerate right-handed sleptons.

[157] ADRIANI 93M limit is for $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$.

[158] DECAMP 92 limit is for $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$; for equal masses the limit would improve. They looked for acoplanar particles.

[159] AKRAWY 90D look for acoplanar particles. For $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$, limit is 41.0 GeV, for $m_{\widetilde{\gamma}} < 23$ GeV.

[160] BUSKULIC 95E looked for $Z \rightarrow \widetilde{\tau}^+_R \widetilde{\tau}^-_R$, where $\widetilde{\tau}_R \rightarrow \tau\chi^0_1$ and χ^0_1 decays via R-parity violating interactions into two leptons and a neutrino.

[161] BAER 90 limit from $\Delta\Gamma(Z)$ (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry and $\tan\beta > 1$ assumed.

[162] DECAMP 90C look for acoplanar charged particle pairs. Limit is for $m_{\widetilde{\tau}_L} = m_{\widetilde{\tau}_R}$. For $m_{\widetilde{\gamma}} \leq 24$ GeV, the limit is 37 GeV. For $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$ and $m_{\widetilde{\gamma}} < 15$ GeV, the limit is 33 GeV.

[163] ADACHI 89 assume only photon exchange, which gives a conservative limit. $m_{\widetilde{\tau}_L} = m_{\widetilde{\tau}_R}$ assumed.

Stable $\widetilde{\ell}$ (Slepton) MASS LIMIT

Limits on scalar leptons which leave detector before decaying. Limits from Z decays are independent of lepton flavor. Limits from continuum e^+e^- annihilation are also independent of flavor for smuons and staus. However, selectron limits from continuum e^+e^- annihilation depend on flavor because there is an additional contribution from neutralino exchange that in general yields stronger limits. All limits assume $m_{\widetilde{\ell}_L} = m_{\widetilde{\ell}_R}$ unless otherwise stated.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>65	95	[164] ABREU	97D	DLPH	$\widetilde{\mu}_r$ or $\widetilde{\tau}_R$
>67	95	[165] BARATE	97K	ALEP	$\widetilde{\mu}_R$, $\widetilde{\tau}_R$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>40	95	ABREU	90G	DLPH	
>26.3	95	ADACHI	90C	TOPZ	$\widetilde{\mu}$, $\widetilde{\tau}$
>38.8	95	AKRAWY	90O	OPAL	$\widetilde{\ell}_R$
>27.1	95	[166] SAKAI	90	AMY	
>32.6	95	SODERSTROM	90	MRK2	
>24.5	95	[167] ADACHI	89	TOPZ	

[164] ABREU 97D bound applies only to masses above 45 GeV. The mass limit improves to 68 GeV for $\widetilde{\mu}_L$, $\widetilde{\tau}_L$. Data collected in e^+e^- collisions at $\sqrt{s}$=130–172 GeV.

[165] BARATE 97K uses e^+e^- data collected at $\sqrt{s}$ = 130–172 GeV. The mass limit improves to 69 GeV for $\widetilde{\mu}_L$ and $\widetilde{\tau}_L$.

[166] SAKAI 90 limit improves to 30.1 GeV for $\widetilde{e}$ if $m_{\widetilde{\gamma}} \approx m_{\widetilde{e}}$.

[167] ADACHI 89 assume only photon (and photino for $\widetilde{e}$) exchange. The limit for $\widetilde{e}$ improves to 26 GeV for $m_{\widetilde{\gamma}} \approx m_{\widetilde{e}}$.

$\widetilde{q}$ (Squark) MASS LIMIT

For $m_{\widetilde{q}}$ > 60–70 GeV, it is expected that squarks would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included. The limits from Z decay do not assume GUT relations and are more model independent.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 224	95	[168] ABE	96D	CDF	$m_{\widetilde{g}} \leq m_{\widetilde{q}}$; with cascade decays
> 176	95	[169] ABACHI	95C	D0	Any $m_{\widetilde{g}}$ <300 GeV; with cascade decays
> 212	95	[169] ABACHI	95C	D0	$m_{\widetilde{g}} \leq m_{\widetilde{q}}$; with cascade decays
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[170] DATTA	97	THEO	$\widetilde{\nu}$'s lighter than $\widetilde{\chi}^{\pm}_1$, $\widetilde{\chi}^0_2$
> 216	95	[171] DERRICK	97	ZEUS	$ep \rightarrow \widetilde{q}$, $\widetilde{q} \rightarrow \mu j$ or τj, R-parity violation
none 130–573	95	[172] HEWETT	97	THEO	$q\widetilde{g} \rightarrow \widetilde{q}$, $\widetilde{q} \rightarrow q\widetilde{g}$, with a light gluino
none 190–650	95	[173] TEREKHOV	97	THEO	$qg \rightarrow \widetilde{q}\widetilde{g}$, $\widetilde{q} \rightarrow q\widetilde{g}$, with a light gluino
> 215	95	[174] AID	96	H1	$ep \rightarrow \widetilde{q}$, R-parity violation, λ=0.3

> 150	95	[174]	AID	96	H1	$ep \to \tilde{q}$, R-parity violation, λ=0.1
> 63	95	[175]	AID	96C	H1	$m_{\tilde{q}}$=$m_{\tilde{e}}$, $m_{\tilde{\chi}^0_1}$=35 GeV
none 330–400	95	[176]	TEREKHOV	96	THEO	$ug \to \tilde{u}\tilde{g}$, $\tilde{u} \to u\tilde{g}$ with a light gluino
		[177]	ABE	95T	CDF	$\tilde{q} \to \tilde{\chi}^0_2 \to \tilde{\chi}^0_1 \gamma$
> 45.3	95	[178]	BUSKULIC	95E	ALEP	$\tilde{q} \to q\nu\ell\overline{\ell}'$
> 239	95	[179]	AHMED	94B	H1	$ep \to \tilde{q}$; R-parity violation, λ=0.30
> 135	95	[179]	AHMED	94B	H1	$ep \to \tilde{q}$; R-parity violation, λ=0.1
> 35.3	95	[180]	ADRIANI	93M	L3	$Z \to \tilde{u}\overline{\tilde{u}}$, $\Gamma(Z)$
> 36.8	95	[180]	ADRIANI	93M	L3	$Z \to \tilde{d}\overline{\tilde{d}}$, $\Gamma(Z)$
> 90	90	[181]	ABE	92L	CDF	Any $m_{\tilde{g}}$ <410 GeV; with cascade decay
> 218	90	[182]	ABE	92L	CDF	$m_{\tilde{g}} = m_{\tilde{q}}$; with cascade decay
> 180	90	[181]	ABE	92L	CDF	$m_{\tilde{g}} < m_{\tilde{q}}$; with cascade decay
> 100		[183]	ROY	92	RVUE	$p\overline{p} \to \tilde{q}\tilde{q}$; R-parity violating
		[184]	NOJIRI	91	COSM	
> 45	95	[185]	ABREU	90F	DLPH	$Z \to \tilde{q}\overline{\tilde{q}}$, $m_{\tilde{\gamma}} < 20$ GeV
> 43	95	[186]	ABREU	90F	DLPH	$Z \to \tilde{d}\overline{\tilde{d}}$, $m_{\tilde{\gamma}} < 20$ GeV
> 42	95	[187]	ABREU	90F	DLPH	$Z \to \tilde{u}\overline{\tilde{u}}$, $m_{\tilde{\gamma}} < 20$ GeV
> 27.0	95		ADACHI	90C	TOPZ	Stable $\tilde{u}$, $\tilde{u}\overline{\tilde{u}}$
> 74	90	[188]	ALITTI	90	UA2	Any $m_{\tilde{q}}$; B($\tilde{q} \to q\tilde{g}$ or $q\tilde{\gamma}$) = 1
> 106	90	[188]	ALITTI	90	UA2	$m_{\tilde{q}} = m_{\tilde{g}}$; B($\tilde{q} \to q\tilde{\gamma}$) = 1
> 39.2	90	[189]	BAER	90	RVUE	$\tilde{d}_L$; $\Gamma(Z)$
> 45	95	[190,191]	BARKLOW	90	MRK2	$Z \to \tilde{q}\overline{\tilde{q}}$
> 40	95	[190,192]	BARKLOW	90	MRK2	$Z \to \tilde{d}\overline{\tilde{d}}$
> 39	95	[190,193]	BARKLOW	90	MRK2	$Z \to \tilde{u}\overline{\tilde{u}}$
>1100			GRIFOLS	90	ASTR	$m_{\tilde{\gamma}} < 1$ MeV
> 24	95		SAKAI	90	AMY	$e^+e^- \to \tilde{d}\overline{\tilde{d}} \to d\overline{d}\tilde{\gamma}\tilde{\gamma}$; $m_{\tilde{\gamma}} < 10$ GeV
> 26	95		SAKAI	90	AMY	$e^+e^- \to \tilde{u}\overline{\tilde{u}} \to u\overline{u}\tilde{\gamma}\tilde{\gamma}$; $m_{\tilde{\gamma}} < 10$ GeV
> 26.3	95	[194]	ADACHI	89	TOPZ	$e^+e^- \to \tilde{q}\overline{\tilde{q}} \to q\overline{q}\tilde{\gamma}\tilde{\gamma}$
		[195]	NATH	88	THEO	$\tau(p \to \nu K)$ in supergravity GUT
> 45	90	[196]	ALBAJAR	87D	UA1	Any $m_{\tilde{g}} > m_{\tilde{q}}$
> 75	90	[196]	ALBAJAR	87D	UA1	$m_{\tilde{g}} = m_{\tilde{q}}$

[168] ABE 96D searched for production of gluinos and five degenerate squarks in final states containing a pair of leptons, two jets, and missing E_T. The two leptons arise from the

semileptonic decays of charginos produced in the cascade decays. The limit is derived for fixed $\tan\beta = 4.0$, $\mu = -400$ GeV, and $m_{H^+} = 500$ GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario.

[169] ABACHI 95C assume five degenerate squark flavors with $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$. Sleptons are assumed to be heavier than squarks. The limits are derived for fixed $\tan\beta = 2.0$ $\mu = -250$ GeV, and m_{H^+}=500 GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the three fixed parameters for a large fraction of parameter space. No limit is given for $m_{\text{gluino}} > 547$ GeV.

[170] DATTA 97 argues that the squark mass bound by ABACHI 95C can be weakened by 10–20 GeV if one relaxes the assumption of the universal scalar mass at the GUT-scale so that the $\widetilde{\chi}^{\pm}_1$,$\widetilde{\chi}^0_2$ in the squark cascade decays have dominant and invisible decays to $\widetilde{\nu}$.

[171] DERRICK 97 looked for lepton-number violating final states via R-parity violating couplings $\lambda'_{ijk} L_i Q_j d_k$. When $\lambda'_{11k}\lambda'_{ijk} \neq 0$, the process $e u \rightarrow \widetilde{d}^*_k \rightarrow \ell_i u_j$ is possible. When $\lambda'_{1j1}\lambda'_{ijk} \neq 0$, the process $e\overline{d} \rightarrow \widetilde{u}^*_j \rightarrow \ell_i \overline{d}_k$ is possible. 100% branching fraction $\widetilde{q} \rightarrow \ell j$ is assumed. The limit quoted here corresponds to $\widetilde{t} \rightarrow \tau q$ decay, with λ'=0.3. For different channels, limits are slightly better. See Table 6 in their paper.

[172] HEWETT 97 reanalyzed the limits on possilbe resonances in di-jet mode ($\widetilde{q} \rightarrow q\widetilde{g}$) from ALITTI 93 quoted in "Limits for Excited q (q^*) from Single Production," ABE 96 in "SCALE LIMITS for Contact Interactions: $\Lambda(qqqq)$," and unpublished CDF, DØ bounds. The bound applies to the gluino mass of 5 GeV, and improves for lighter gluino. The analysis has gluinos in parton distribution function.

[173] TEREKHOV 97 improved the analysis of TEREKHOV 96 by including di-jet angular distributions in the analysis.

[174] AID 96 looked for first-generation squarks as s-channel resonances singly produced in ep collision via the R-parity violating coupling in the superpotential W=$\lambda L_1 Q_1 d_1$. The degeneracy of squarks $\widetilde{Q}_1$ and $\widetilde{d}_1$ is assumed. Eight different channels of possible squark decays are considered.

[175] AID 96C used electron+jet events with missing energy and momentum to look for $e q \rightarrow \widetilde{e}\widetilde{q}$ via neutralino exchange with decays into $(e\widetilde{\chi}^0_1)(q\widetilde{\chi}^0_1)$. See the paper for dependences on $m_{\widetilde{e}}$, $m_{\widetilde{\chi}^0_1}$.

[176] TEREKHOV 96 reanalyzed the limits on possible resonances in di-jet mode ($\widetilde{u} \rightarrow u\widetilde{g}$) from ABE 95N quoted in "MASS LIMITS for g_A (axigluon)." The bound applies only to the case with a light gluino.

[177] ABE 95T looked for a cascade decay of five degenerate squarks into $\widetilde{\chi}^0_2$ which further decays into $\widetilde{\chi}^0_1$ and a photon. No signal is observed. Limits vary widely depending on the choice of parameters. For $\mu = -40$ GeV, $\tan\beta = 1.5$, and heavy gluinos, the range $50 < m_{\widetilde{q}}$ (GeV)<110 is excluded at 90% CL. See the paper for details.

[178] BUSKULIC 95E looked for $Z \rightarrow \widetilde{q}\overline{\widetilde{q}}$, where $\widetilde{q} \rightarrow q\chi^0_1$ and χ^0_1 decays via R-parity violating interactions into two leptons and a neutrino.

[179] AHMED 94B looked for squarks as s-channel resonance in ep collision via R-parity violating coupling in the superpotential $W = \lambda L_1 Q_1 d_1$. The degeneracy of all squarks Q_1 and d_1 is assumed. The squarks decay dominantly via the same R-violating coupling into eq or νq if $\lambda \gtrsim 0.2$. For smaller λ, decay into photino is assumed which subsequently decays into $eq\overline{q}$, and the bound depends on $m_{\widetilde{\gamma}}$. See paper for excluded region on $(m_{\widetilde{q}},\lambda)$ plane.

[180] ADRIANI 93M limit from $\Delta\Gamma(Z) <$ 35.1 MeV and assumes $m_{\widetilde{q}_L} \gg m_{\widetilde{q}_R}$.

[181] ABE 92L assume five degenerate squark flavors and $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$. ABE 92L includes the effect of cascade decay, for a particular choice of parameters, $\mu = -250$ GeV, $\tan\beta = 2$. Results are weakly sensitive to these parameters over much of parameter space. No limit for $m_{\widetilde{q}} \leq 50$ GeV (but other experiments rule out that region). Limits are 10–20 GeV higher if B($\widetilde{q} \to q\widetilde{\gamma}$) = 1. Limit assumes GUT relations between gaugino masses and the gauge coupling; in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}^0_1} \approx m_{\widetilde{g}}/6$. This last relation implies that as $m_{\widetilde{g}}$ increases, the mass of $\widetilde{\chi}^0_1$ will eventually exceed $m_{\widetilde{q}}$ so that no decay is possible. Even before that occurs, the signal will disappear; in particular no bounds can be obtained for $m_{\widetilde{g}}$ >410 GeV. m_{H^+}=500 GeV.

[182] ABE 92L bounds are based on similar assumptions as ABACHI 95C. No limits for m_{gluino} >410 GeV.

[183] ROY 92 reanalyzed CDF limits on di-lepton events to obtain limits on squark production in R-parity violating models. The 100% decay $\widetilde{q} \to q\widetilde{\chi}$ where $\widetilde{\chi}$ is the LSP, and the LSP decays either into $\ell q \overline{d}$ or $\ell\ell\overline{e}$ is assumed.

[184] NOJIRI 91 argues that a heavy squark should be nearly degenerate with the gluino in minimal supergravity not to overclose the universe.

[185] ABREU 90F assume six degenerate squarks and $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$. $m_{\widetilde{q}} < 41$ GeV is excluded at 95% CL for $m_{\mathrm{LSP}} < m_{\widetilde{q}} - 2$ GeV.

[186] ABREU 90F exclude $m_{\widetilde{d}} < 38$ GeV at 95% for $m_{\mathrm{LSP}} < m_{\widetilde{d}} - 2$ GeV.

[187] ABREU 90F exclude $m_{\widetilde{u}} < 36$ GeV at 95% for $m_{\mathrm{LSP}} < m_{\widetilde{u}} - 2$ GeV.

[188] ALITTI 90 searched for events having $\geq$ 2 jets with $E_T^1 > 25$ GeV, $E_T^2 > 15$ GeV, $|\eta| < 0.85$, and $\Delta\phi < 160°$, with a missing momentum > 40 GeV and no electrons. They assume $\widetilde{q} \to q\widetilde{\gamma}$ (if $m_{\widetilde{q}} < m_{\widetilde{g}}$) or $\widetilde{q} \to q\widetilde{g}$ (if $m_{\widetilde{q}} > m_{\widetilde{g}}$) decay and $m_{\widetilde{\gamma}} \lesssim$ 20 GeV. Five degenerate squark flavors and $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$ are assumed. Masses below 50 GeV are not excluded by the analysis.

[189] BAER 90 limit from $\Delta\Gamma(Z) <$ 120 MeV, assuming $m_{\widetilde{d}_L} = m_{\widetilde{u}_L} = m_{\widetilde{e}_L} = m_{\widetilde{\nu}}$. Independent of decay modes. Minimal supergravity assumed.

[190] BARKLOW 90 assume 100% $\widetilde{q} \to q\widetilde{\gamma}$.

[191] BARKLOW 90 assume five degenerate squarks (left- and right-handed). Valid up to $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{q}} - 4$ GeV].

[192] BARKLOW 90 result valid up to $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{d}} - 5$ GeV].

[193] BARKLOW 90 result valid up to $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{u}} - 6$ GeV].

[194] ADACHI 89 assume only photon exchange, which gives a a conservative limit. The limit is only for one flavor of charge 2/3 $\widetilde{q}$. $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$ and $m_{\widetilde{\gamma}} = 0$ assumed. The limit decreases to 26.1 GeV for $m_{\widetilde{\gamma}} = 15$ GeV. The limit for nondegenerate case is 24.4 GeV.

[195] NATH 88 uses Kamioka limit of $\tau(p \to \overline{\nu}K^+) > 7 \times 10^{31}$ yrs to constrain squark mass $m_{\widetilde{q}} > 1000$ GeV by assuming that the proton decay proceeds via an exchange of a color-triplet Higgsino of mass $< 10^{16}$ GeV in the supersymmetric SU(5) GUT. The limit applies for $m_{\widetilde{\gamma}} \equiv (8/3)\sin^2\theta_W \widetilde{m}_2 > 10$ GeV ($\widetilde{m}_2$ is the SU(2) gaugino mass) and for a very conservative value of the three-quark proton wave function, barring cancellation between second and third generations. Lower squark mass is allowed if $m_{\widetilde{\gamma}}$ as defined above is smaller.

[196] The limits of ALBAJAR 87D are from $p\overline{p} \to \widetilde{q}\overline{\widetilde{q}}X$ ($\widetilde{q} \to q\widetilde{\gamma}$) and assume 5 flavors of degenerate mass squarks each with $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$. They also assume $m_{\widetilde{g}} > m_{\widetilde{q}}$. These limits apply for $m_{\widetilde{\gamma}} \lesssim$ 20 GeV.

$\widetilde{b}$ (Sbottom) MASS LIMIT

Limits in e^+e^- depend on the mixing angle of the mass eigenstate $\widetilde{b}_1 = \widetilde{b}_L\cos\theta_b + \widetilde{b}_R\sin\theta_b$. Coupling to the Z vanishes for $\theta_b \sim 1.17$. In the Listings below, we use $\Delta m = m_{\widetilde{b}_1} - m_{\widetilde{\chi}^0_1}$.

VALUE (GeV)	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>69.7	95	[197] ACKERSTAFF 97Q	OPAL	$\widetilde{b} \rightarrow b\widetilde{\chi}^0_1$, θ_b=0, $\Delta(m) > 8$ GeV
>73	95	[198] BARATE 97Q	ALEP	$\widetilde{b} \rightarrow b\widetilde{\chi}^0_1$, θ_b=0, $\Delta(m) > 10$ GeV
>53	95	[199] ABREU 96O	DLPH	$\widetilde{b} \rightarrow b\widetilde{\chi}^0$, θ_b=0, $\Delta(m) >$20 GeV
>61.8	95	[200] ACKERSTAFF 96	OPAL	$\widetilde{b} \rightarrow b\widetilde{\chi}^0$, θ_b=0, $\Delta(m) >$8 GeV

[197] ACKERSTAFF 97Q data taken at $\sqrt{s}$=130–172 GeV. See paper for dependence on θ_b. No limit for $\theta_b \approx 1.17$.

[198] BARATE 97Q uses data at $\sqrt{s}$=161, 170, and 172 GeV. The limit disappears when $\theta_b \approx 1.17$.

[199] Data taken at $\sqrt{s}$ = 130–136 GeV.

[200] ACKERSTAFF 96 also studied θ_b dependence when there is a mixing $\widetilde{b}_1 = \widetilde{b}_L\cos\theta_b + \widetilde{b}_R\sin\theta_b$. Data taken at $\sqrt{s}$ = 130, 136, and 161 GeV. See the paper for dependence on θ_b. No limit for $\theta_b \approx 1.17$.

$\widetilde{t}$ (Stop) MASS LIMIT

Limit depends on decay mode. In e^+e^- collisions they also depend on the mixing angle of the mass eigenstate $\widetilde{t}_1 = \widetilde{t}_L\cos\theta_t + \widetilde{t}_R\sin\theta_t$. Coupling to Z vanishes when $\theta_t = 0.98$. In the Listings below, we use $\Delta m \equiv m_{\widetilde{t}_1} - m_{\widetilde{\chi}^0_1}$ or $\Delta m \equiv m_{\widetilde{t}_1} - m_{\widetilde{\nu}}$, depending on relevant decay mode. See also bounds in "$\widetilde{q}$ (Squark) MASS LIMIT."

VALUE (GeV)	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
> 73.3	95	[201] ACKERSTAFF 97Q	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m) > 10$ GeV
> 65.0	95	[201] ACKERSTAFF 97Q	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0.98, $\Delta(m) > 10$ GeV
> 67.9	95	[201] ACKERSTAFF 97Q	OPAL	$\widetilde{t} \rightarrow b\ell\widetilde{\nu}$, θ_t=0, $\Delta(m) > 10$ GeV
> 56.2	95	[201] ACKERSTAFF 97Q	OPAL	$\widetilde{t} \rightarrow b\ell\widetilde{\nu}$, θ_t=0.98, $\Delta(m) > 10$ GeV
> 66.3	95	[201] ACKERSTAFF 97Q	OPAL	$\widetilde{t} \rightarrow b\tau\widetilde{\nu}_\tau$, θ_t=0, $\Delta(m) > 10$ GeV
> 54.4	95	[201] ACKERSTAFF 97Q	OPAL	$\widetilde{t} \rightarrow b\tau\widetilde{\nu}_\tau$, θ_t=0.98, $\Delta(m) > 10$ GeV
> 67	95	[202] BARATE 97Q	ALEP	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, any θ_t, $\Delta(m) > 10$ GeV
> 70	95	[202] BARATE 97Q	ALEP	$\widetilde{t} \rightarrow b\ell\widetilde{\nu}$, any θ_t, $\Delta(m) > 10$ GeV
> 64	95	[202] BARATE 97Q	ALEP	$\widetilde{t} \rightarrow b\tau\widetilde{\nu}_\tau$, any θ_t, $\Delta(m) > 10$ GeV

• • • We do not use the following data for averages, fits, limits, etc. • • •

none 61–91	95	[203] ABACHI	96B	D0	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, $m_{\widetilde{\chi}^0_1}$ <30 GeV
> 54	95	[204] ABREU	96O	DLPH	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m)$ >5 GeV
> 52	95	[204] ACCIARRI	96F	L3	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m)$ >8 GeV
> 65.4	95	[205] ACKERSTAFF	96	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m)$ >10 GeV
> 56.8	95	[205] ACKERSTAFF	96	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0.98, $\Delta(m)$>10 GeV
> 60.6	95	[205] ACKERSTAFF	96	OPAL	$\widetilde{t} \rightarrow b\ell\widetilde{\nu}$, θ_t=0, $\Delta(m)$ >10 GeV
none 9–24.4	95	[206] AID	96	H1	$ep \rightarrow \widetilde{t}\widetilde{t}$, *R*-parity violating decays
>138	95	[207] AID	96	H1	$ep \rightarrow \widetilde{t}$, *R*-parity violation, $\lambda\cos\theta_t > 0.03$
> 48	95	[204] BUSKULIC	96K	ALEP	$t \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m)$ >18 GeV
> 57	95	[204] BUSKULIC	96K	ALEP	$t \rightarrow c\widetilde{\chi}^0_1$, $\theta_t=\pi/2$, $\Delta(m)$ >14 GeV
> 45		[208] CHO	96	RVUE	B^0-$\overline{B}^0$ and ϵ, θ_t= 0.98, $\tan\beta$ <2
none 11–41	95	[209] BUSKULIC	95E	ALEP	θ_t=0.98, $\widetilde{t} \rightarrow c\nu\ell\overline{\ell}'$
none 6.0–41.2	95	AKERS	94K	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m)$ >2 GeV
none 5.0–46.0	95	AKERS	94K	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0, $\Delta(m)$ >5 GeV
none 11.2–25.5	95	AKERS	94K	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0.98, $\Delta(m)$ >2 GeV
none 7.9–41.2	95	AKERS	94K	OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, θ_t=0.98, $\Delta(m)$ >5 GeV
none 7.6–28.0	95	[210] SHIRAI	94	VNS	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, any θ_t, $\Delta(m)$ >10 GeV
none 10–20	95	[210] SHIRAI	94	VNS	$\widetilde{t} \rightarrow c\widetilde{\chi}^0_1$, any θ_t, $\Delta(m)$ > 2.5 GeV

[201] ACKERSTAFF 97Q looked for $\widetilde{t}$ pair production. Data taken at $\sqrt{s}$=130, 136, 161, 170, and 172 GeV. Unless the $\ell=\tau$ decay mode is explicitly indicated, the same branching fractions to $\ell=e$, μ, and τ are assumed for $b\ell\widetilde{\nu}_\ell$ modes. See Table 7 and Figs. 8–10 for other choices of θ_t, $\Delta(m)$, and leptonic branching ratios.

[202] BARATE 97Q uses e^+e^- data at $\sqrt{s}$=161, 170, and 172 GeV. Unless the $\ell=\tau$ decay mode is explicitly indicated, the same branching fractions to $\ell=e$, μ, and τ are assumed for $b\ell\widetilde{\nu}_\ell$ modes. See their Figs. 4 and 5 for other choices of θ_t, $\Delta(m)$, and leptonic branching ratios.

[203] ABACHI 96B searches for final states with 2 jets and missing E_T. Limits on $m_{\widetilde{t}}$ are given as a function of $m_{\widetilde{\chi}^0_1}$. See Fig. 4 for details.

[204] Data taken at $\sqrt{s}$ = 130–136 GeV.

[205] ACKERSTAFF 96 looked for $\widetilde{t}$ pair production. See the paper for θ_t and $\Delta(m)$ dependece of the limits. Data taken at $\sqrt{s}$ = 130, 136, and 161 GeV.

[206] AID 96 considers photoproduction of $\widetilde{t}\widetilde{t}$ pairs, with 100% *R*-parity violating decays of $\widetilde{t}$ to eq, with $q=d$, s, or b quarks.

[207] AID 96 considers production and decay of $\widetilde{t}$ via the *R*-parity violating coupling in the superpotential $W=\lambda L_1 Q_3 d_1$.

[208] CHO 96 studied the consistency among the B^0-$\overline{B}^0$ mixing, ϵ in K^0-$\overline{K}^0$ mixing, and the measurements of V_{cb}, V_{ub}/V_{cb}. For the range 25.5 GeV$<m_{\widetilde{t}_1}<m_Z/2$ left by AKERS 94K for θ_t = 0.98, and within the allowed range in M_2-μ parameter space from chargino, neutralino searches by ACCIARRI 95E, they found the scalar top contribution to B^0-$\overline{B}^0$ mixing and ϵ to be too large if tanβ <2. For more on their assumptions, see the paper and their reference 10.

[209] BUSKULIC 95E looked for $Z \rightarrow \widetilde{t}\,\overline{\widetilde{t}}$, where $\widetilde{t} \rightarrow c\chi^0_1$ and χ^0_1 decays via R-parity violating interactions into two leptons and a neutrino.

[210] SHIRAI 94 bound assumes the cross section without the s-channel Z-exchange and the QCD correction, underestimating the cross section up to 20% and 30%, respectively. They assume m_c=1.5 GeV.

Heavy $\widetilde{g}$ (Gluino) MASS LIMIT

For $m_{\widetilde{g}}$ > 60–70 GeV, it is expected that gluinos would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>173	95	[211] ABE	97K	CDF	Any $m_{\widetilde{q}}$; with cascade decays
>216	95	[211] ABE	97K	CDF	$m_{\widetilde{q}}$=$m_{\widetilde{g}}$; with cascade decays
>224	95	[212] ABE	96D	CDF	$m_{\widetilde{q}} = m_{\widetilde{g}}$; with cascade decays
>154	95	[212] ABE	96D	CDF	$m_{\widetilde{g}} < m_{\widetilde{q}}$; with cascade decays
>212	95	[213] ABACHI	95C	D0	$m_{\widetilde{g}} \geq m_{\widetilde{q}}$; with cascade decays
>144	95	[213] ABACHI	95C	D0	Any $m_{\widetilde{q}}$; with cascade decays
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[214] ABE	95T	CDF	$\widetilde{g} \rightarrow \widetilde{\chi}^0_2 \rightarrow \widetilde{\chi}^0_1 \gamma$
		[215] HEBBEKER	93	RVUE	e^+e^- jet analyses
>218	90	[216] ABE	92L	CDF	$m_{\widetilde{q}} \leq m_{\widetilde{g}}$; with cascade decay
>100	90	[216] ABE	92L	CDF	Any $m_{\widetilde{q}}$; with cascade decay
>100		[217] ROY	92	RVUE	$p\overline{p} \rightarrow \widetilde{g}\widetilde{g}$; R-parity violating
>132	90	[218] HIDAKA	91	RVUE	
		[219] NOJIRI	91	COSM	
> 79	90	[220] ALITTI	90	UA2	Any $m_{\widetilde{g}}$; B($\widetilde{g} \rightarrow q\overline{q}\widetilde{\gamma}$) = 1
>106	90	[220] ALITTI	90	UA2	$m_{\widetilde{q}} = m_{\widetilde{g}}$; B($\widetilde{g} \rightarrow q\overline{q}\widetilde{\gamma}$) = 1
		[221] NAKAMURA	89	SPEC	R-Δ^{++}
none 4–53	90	[222] ALBAJAR	87D	UA1	Any $m_{\widetilde{q}} > m_{\widetilde{g}}$
none 4–75	90	[222] ALBAJAR	87D	UA1	$m_{\widetilde{q}} = m_{\widetilde{g}}$
none 16–58	90	[223] ANSARI	87D	UA2	$m_{\widetilde{q}} \lesssim$ 100 GeV

[211] ABE 97K searched for production of gluinos and five degenerate squarks in events with three or more jets but no electrons or muons and missing transverse energy $\not\!\!E_T > 60$ GeV. The limit for any $m_{\widetilde{q}}$ is for μ=$-$200 GeV and tanβ=2, and that for $m_{\widetilde{q}}$=$m_{\widetilde{g}}$ is for μ=$-$400 GeV and tanβ=4. Different choices for tanβ and μ lead to changes of the order of $\pm$10 GeV in the limits. See Footnote [16] of the paper for more details on the assumptions.

[212] ABE 96D searched for production of gluinos and five degenerate squarks in final states containing a pair of leptons, two jets, and missing E_T. The two leptons arise from the semileptonic decays of charginos produced in the cascade decays. The limits are derived for fixed tanβ = 4.0, μ = $-$400 GeV, and m_{H^+} = 500 GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the values of the three fixed parameters for a large fraction of parameter space. See Fig. 2 for the limits corresponding to different parameter choices.

[213] ABACHI 95C assume five degenerate squark flavors with with $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$. Sleptons are assumed to be heavier than squarks. The limits are derived for fixed tanβ = 2.0 μ = $-$250 GeV, and m_{H^+}=500 GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the three fixed parameters for a large fraction of parameter space.

[214] ABE 95T looked for a cascade decay of gluino into $\widetilde{\chi}^0_2$ which further decays into $\widetilde{\chi}^0_1$ and a photon. No signal is observed. Limits vary widely depending on the choice of parameters. For μ = $-$40 GeV, tanβ = 1.5, and heavy squarks, the range 50<$m_{\widetilde{g}}$ (GeV)<140 is excluded at 90% CL. See the paper for details.

[215] HEBBEKER 93 combined jet analyses at various e^+e^- colliders. The 4-jet analyses at TRISTAN/LEP and the measured α_s at PEP/PETRA/TRISTAN/LEP are used. A constraint on effective number of quarks N=6.3 $\pm$ 1.1 is obtained, which is compared to that with a light gluino, N=8.

[216] ABE 92L bounds are based on similar assumptions as ABACHI 95C. Not sensitive to m_{gluino} <40 GeV (but other experiments rule out that region).

[217] ROY 92 reanalyzed CDF limits on di-lepton events to obtain limits on gluino production in R-parity violating models. The 100% decay $\widetilde{g} \rightarrow q\overline{q}\widetilde{\chi}$ where $\widetilde{\chi}$ is the LSP, and the LSP decays either into $\ell q \overline{d}$ or $\ell\ell\overline{e}$ is assumed.

[218] HIDAKA 91 limit obtained from LEP and preliminary CDF results within minimal supersymmetry with gaugino-mass unification condition. HIDAKA 91 limit extracted from BAER 91 analysis.

[219] NOJIRI 91 argues that a heavy gluino should be nearly degenerate with squarks in minimal supergravity not to overclose the universe.

[220] ALITTI 90 searched for events having $\geq$ 2 jets with E^1_T > 25 GeV, E^2_T > 15 GeV, $|\eta|$ < 0.85, and $\Delta\phi$ < 160°, with a missing momentum > 40 GeV and no electrons. They assume $\widetilde{g} \rightarrow q\overline{q}\widetilde{\gamma}$ decay and $m_{\widetilde{\gamma}} \lesssim$ 20 GeV. Masses below 50 GeV are not excluded by the analysis.

[221] NAKAMURA 89 searched for a long-lived ($\tau \gtrsim 10^{-7}$ s) charge-($\pm$2) particle with mass $\lesssim$ 1.6 GeV in proton-Pt interactions at 12 GeV and found that the yield is less than 10^{-8} times that of the pion. This excludes R-Δ^{++} (a $\widetilde{g}uuu$ state) lighter than 1.6 GeV.

[222] The limits of ALBAJAR 87D are from $p\overline{p} \rightarrow \widetilde{g}\widetilde{g}X$ ($\widetilde{g} \rightarrow q\overline{q}\widetilde{\gamma}$) and assume $m_{\widetilde{q}} > m_{\widetilde{g}}$. These limits apply for $m_{\widetilde{\gamma}} \lesssim$ 20 GeV and $\tau(\widetilde{g}) < 10^{-10}$ s.

[223] The limit of ANSARI 87D assumes $m_{\widetilde{q}} > m_{\widetilde{g}}$ and $m_{\widetilde{\gamma}} \approx 0$.

NOTE ON LIGHT GLUINO

Written March 1998 by H. Murayama (UC Berkeley).

It is controversial if a light gluino of mass below 5 GeV is phenomenologically allowed. Below we list some of the most important and least controversial constraints which need to be met for a light gluino to be viable. For reviews on the subject, see, *e.g.*, Ref. 1.

1. Either $m_{\tilde{g}} \lesssim 1.5$ GeV or $m_{\tilde{g}} \gtrsim 3.5$ GeV to avoid the CAKIR 94 limit. See also Ref. 2 for similar quarkonium constraints on lighter masses.
2. The lifetime of the gluino or the ground state gluino-containing hadron (typically, $g\tilde{g}$) must be $\gtrsim 10^{-10}$ s in order to evade beam-dump and missing energy limits [1,2].
3. Charged gluino-containing hadrons (*e.g.* $\tilde{g}u\bar{d}$) must decay into neutral ones (*e.g.* $R^0(\tilde{g}g)\pi^+$ or $(\tilde{g}u\bar{u})e^-\bar{\nu}_e$) with a lifetime shorter than about 10^{-7} s to avoid the AKERS 95R limit. Older limits for lower masses and shorter lifetimes are summarized in Ref. 1.
4. The lifetime of $R^0 \to \rho^0\tilde{\gamma}$, if allowed, must be outside the ADAMS 97B range. The $R_p^+(\tilde{g}uud)$ state, which is believed to decay weakly into $S^0(\tilde{g}uds)\pi^\pm$ (FARRAR 96), must be heavier than 2 GeV or have lifetime $\tau_{R_p} \gtrsim 1$ ns or $\tau_{R_p} \lesssim 50$ ps (*e.g.* if the strong decay into $S^0K^\pm$ is allowed), or its production cross sections must be at least a factor of 5 smaller than those of hyperons, to avoid ALBUQUERQUE 97 limit.

5. $m_{\tilde{g}} \geq 6.8$ GeV (95% CL) if the "experimental optimization" method of fixing the renormalization scale is valid and if the hadronization and resummation uncertainties are as estimated in BARATE 97L, from the D_2 event shape observable in Z^0 decay. The 4-jet angular distribution is less sensitive to renormalization scale ambiguities and yields a 90%CL exclusion of a light gluino (DEGOUVEA 97). A combined LEP analysis based on all the Z^0 data and using the recent NLO calculations [3] is warranted.
6. Constraints from the effect of light gluinos on the running of α_s apply independently of the gluino lifetime and are insensitive to renormalization scale. They disfavor a light gluino at 70% CL (CSIKOR 97), which improves to more than 99% with jet analysis.

References

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in SUSY 97, Proceedings of the Fifth International Conference on Supersymmetries in Physics," 27-31 May 1997, Philadelphia, USA, edited by M. Cvetic and P. Langacker (Nuc. Phys. B (Proc. Suppl.) 62 (1998)) p. 485. hep-ph/9710277.
2. R.M. Barnett, in SUSY 95, Proceedings of the International Workshop on Supersymmetry and Unification of Fundamental Interactions, Palaiseau, France, 15-19 May 1995, edited by I. Antoniadis and H. Videau (Editions Frontieres, Gif-sur-Yvette, France, 1996) p. 69.
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Long-lived/light $\widetilde{g}$ (Gluino) MASS LIMIT

Limits on light gluinos ($m_{\widetilde{g}}$ < 5 GeV), or gluinos which leave the detector before decaying.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[224] ADAMS	97B	KTEV	$pN \to R^0 \to \rho^0 \widetilde{\gamma}$
		[225] ALBUQUERQ...	97	E761	$R^+(uud\widetilde{g}) \to S^0(uds\widetilde{g})\pi^+$, $X^-(ssd\widetilde{g}) \to S^0\pi^-$
>6.3	95	[226] BARATE	97L	ALEP	Color factors
>5	99	[227] CSIKOR	97	RVUE	β function, $Z \to$ jets
>1.5	90	[228] DEGOUVEA	97	THEO	$Z \to jjjj$
		[229] FARRAR	96	RVUE	$R^0 \to \pi^0 \widetilde{\gamma}$
none 1.9–13.6	95	[230] AKERS	95R	OPAL	Z decay into a long-lived $(\widetilde{g}q\overline{q})^{\pm}$
<0.7		[231] CLAVELLI	95	RVUE	quarkonia
none 1.5–3.5		[232] CAKIR	94	RVUE	$\Upsilon(1S) \to \gamma +$ gluinonium
not 3–5		[233] LOPEZ	93C	RVUE	LEP
≈ 4		[234] CLAVELLI	92	RVUE	α_s running
		[235] ANTONIADIS	91	RVUE	α_s running
>1		[236] ANTONIADIS	91	RVUE	$pN \to$ missing energy
>3.8	90	[237] ARNOLD	87	EMUL	π^- (350 GeV). $\sigma \simeq A^1$
>3.2	90	[237] ARNOLD	87	EMUL	π^- (350 GeV). $\sigma \simeq A^{0.72}$
none 0.6–2.2	90	[238] TUTS	87	CUSB	$\Upsilon(1S) \to \gamma +$ gluinonium
none 1 –4.5	90	[239] ALBRECHT	86C	ARG	$1 \times 10^{-11} \lesssim \tau \lesssim 1 \times 10^{-9}$s
none 1–4	90	[240] BADIER	86	BDMP	$1 \times 10^{-10} < \tau < 1 \times 10^{-7}$s
none 3–5		[241] BARNETT	86	RVUE	$p\overline{p} \to$ gluino gluino gluon
none		[242] VOLOSHIN	86	RVUE	If (quasi) stable; $\widetilde{g}uud$
none 0.5–2		[243] COOPER-...	85B	BDMP	For $m_{\widetilde{q}}$=300 GeV
none 0.5–4		[243] COOPER-...	85B	BDMP	For $m_{\widetilde{q}}$ <65 GeV
none 0.5–3		[243] COOPER-...	85B	BDMP	For $m_{\widetilde{q}}$=150 GeV
none 2–4		[244] DAWSON	85	RVUE	$\tau > 10^{-7}$ s
none 1–2.5		[244] DAWSON	85	RVUE	For $m_{\widetilde{q}}$=100 GeV
none 0.5–4.1	90	[245] FARRAR	85	RVUE	FNAL beam dump
>1		[246] GOLDMAN	85	RVUE	Gluononium
$>$1–2		[247] HABER	85	RVUE	
		[248] BALL	84	CALO	
		[249] BRICK	84	RVUE	
		[250] FARRAR	84	RVUE	
>2		[251] BERGSMA	83C	RVUE	For $m_{\widetilde{q}}$ <100 GeV
		[252] CHANOWITZ	83	RVUE	$\widetilde{g}u\overline{d}$, $\widetilde{g}uud$
$>$2–3		[253] KANE	82	RVUE	Beam dump
$>$1.5–2		FARRAR	78	RVUE	R-hadron

[224] ADAMS 97B looked for $\rho^0 \to \pi^+\pi^-$ as a signature of R^0=$(\widetilde{g}g)$ bound states. The experiment is sensitive to an R^0 mass range of 1.2–4.5 GeV and to a lifetime range of

10^{-10}–10^{-3} sec. Precise limits depend on the assumed value of $m_{R^0}/m_{\widetilde{\gamma}}$. See Fig. 7 for the excluded mass and lifetime region.

225 ALBUQUERQUE 97 looked for weakly decaying baryon-like states which contain a light gluino, following the suggestions in FARRAR 96. See their Table 1 for limits on the production fraction. These limits exclude gluino masses in the range 100–600 MeV for the predicted lifetimes (FARRAR 96) and production rates, which are assumed to be comparable to those of strange or charmed baryons.

226 BARATE 97L studied the QCD color factors from four-jet angular correlations and the differential two-jet rate in Z decay. LImit obtained from the determination of $n_f = 4.24 \pm 0.29 \pm 1.15$, assuming T_F/C_F=3/8 and C_A/C_F=9/4.

227 CSIKOR 97 combined the α_s from $\sigma(e^+ e^- \rightarrow$ hadron), τ decay, and jet analysis in Z decay. They exclude a light gluino below 5 GeV at more than 99.7%CL.

228 DEGOUVEA 97 reaanalyzed AKERS 95A data on Z decay into four jets to place constraints on a light stable gluino. The mass limit corresponds to the pole mass of 2.8 GeV. The analysis, however, is limited to the leading-order QCD calculation.

229 FARRAR 96 studied the possible R^0=$(\widetilde{g}\,g)$ component in Fermilab E799 experiment and used its bound B$(K^0_L \rightarrow \pi^0 \nu \overline{\nu}) \leq 5.8 \times 10^{-5}$ to place constraints on the combination of R^0 production cross section and its lifetime.

230 AKERS 95R looked for Z decay into $q\overline{q}\widetilde{g}\widetilde{g}$, by searching for charged particles with dE/dx consistent with $\widetilde{g}$ fragmentation into a state $(\widetilde{g}\,q\overline{q})^{\pm}$ with lifetime $\tau > 10^{-7}$ sec. The fragmentation probability into a charged state is assumed to be 25%.

231 CLAVELLI 95 updates the analysis of CLAVELLI 93, based on a comparison of the hadronic widths of charmonium and bottomonium S-wave states. The analysis includes a parametrization of relativisitic corrections. Claims that the presence of a light gluino improves agreement with the data by slowing down the running of α_s.

232 CAKIR 94 reanalyzed TUTS 87 and later unpublished data from CUSB to exclude pseudo-scalar gluinonium $\eta_{\widetilde{g}}(\widetilde{g}\widetilde{g})$ of mass below 7 GeV. it was argued, however, that the perturbative QCD calculation of the branching fraction $\Upsilon \rightarrow \eta_{\widetilde{g}}\gamma$ is unreliable for $m_{\eta_{\widetilde{g}}} < 3$ GeV. The gluino mass is defined by $m_{\widetilde{g}}$=$(m_{\eta_{\widetilde{q}}})/2$. The limit holds for any gluino lifetime.

233 LOPEZ 93C uses combined restraint from the radiative symmetry breaking scenario within the minimal supergravity model, and the LEP bounds on the (M_2,μ) plane. Claims that the light gluino window is strongly disfavored.

234 CLAVELLI 92 claims that a light gluino mass around 4 GeV should exist to explain the discrepancy between α_s at LEP and at quarkonia (Υ), since a light gluino slows the running of the QCD coupling.

235 ANTONIADIS 91 argue that possible light gluinos ($<$ 5 GeV) contradict the observed running of α_s between 5 GeV and m_Z. The significance is less than 2 s.d.

236 ANTONIADIS 91 intrepret the search for missing energy events in 450 GeV/c pN collisions, AKESSON 91, in terms of light gluinos.

237 The limits assume $m_{\widetilde{q}} = 100$ GeV. See their figure 3 for limits vs. $m_{\widetilde{q}}$.

238 The gluino mass is defined by half the bound $\widetilde{g}\widetilde{g}$ mass. If zero gluino mass gives a $\widetilde{g}\widetilde{g}$ of mass about 1 GeV as suggested by various glueball mass estimates, then the low-mass bound can be replaced by zero. The high-mass bound is obtained by comparing the data with nonrelativistic potential-model estimates.

239 ALBRECHT 86C search for secondary decay vertices from $\chi_{b1}(1P) \rightarrow \widetilde{g}\widetilde{g}g$ where $\widetilde{g}$'s make long-lived hadrons. See their figure 4 for excluded region in the $m_{\widetilde{g}} - m_{\widetilde{g}}$ and $m_{\widetilde{g}} - m_{\widetilde{q}}$ plane. The lower $m_{\widetilde{g}}$ region below $\sim$ 2 GeV may be sensitive to fragmentation effects. Remark that the $\widetilde{g}$-hadron mass is expected to be $\sim$ 1 GeV (glueball mass) in the zero $\widetilde{g}$ mass limit.

240 BADIER 86 looked for secondary decay vertices from long-lived $\widetilde{g}$-hadrons produced at 300 GeV π^- beam dump. The quoted bound assumes $\widetilde{g}$-hadron nucleon total cross

section of 10μb. See their figure 7 for excluded region in the $m_{\widetilde{g}} - m_{\widetilde{q}}$ plane for several assumed total cross-section values.

[241] BARNETT 86 rule out light gluinos (m = 3–5 GeV) by calculating the monojet rate from gluino gluino gluon events (and from gluino gluino events) and by using UA1 data from $p\overline{p}$ collisions at CERN.

[242] VOLOSHIN 86 rules out stable gluino based on the cosmological argument that predicts too much hydrogen consisting of the charged stable hadron $\widetilde{g}uud$. Quasi-stable ($\tau > 1. \times 10^{-7}$s) light gluino of $m_{\widetilde{g}}$ <3 GeV is also ruled out by nonobservation of the stable charged particles, $\widetilde{g}uud$, in high energy hadron collisions.

[243] COOPER-SARKAR 85B is BEBC beam-dump. Gluinos decaying in dump would yield $\widetilde{\gamma}$'s in the detector giving neutral-current-like interactions. For $m_{\widetilde{q}}$ >330 GeV, no limit is set.

[244] DAWSON 85 first limit from neutral particle search. Second limit based on FNAL beam dump experiment.

[245] FARRAR 85 points out that BALL 84 analysis applies only if the $\widetilde{g}$'s decay before interacting, i.e. $m_{\widetilde{q}} < 80 m_{\widetilde{g}}^{1.5}$. FARRAR 85 finds $m_{\widetilde{g}}$ <0.5 not excluded for $m_{\widetilde{q}}$ = 30–1000 GeV and $m_{\widetilde{g}}$ <1.0 not excluded for $m_{\widetilde{q}}$ = 100–500 GeV by BALL 84 experiment.

[246] GOLDMAN 85 use nonobservation of a pseudoscalar $\widetilde{g}$-$\widetilde{g}$ bound state in radiative ψ decay.

[247] HABER 85 is based on survey of all previous searches sensitive to low mass $\widetilde{g}$'s. Limit makes assumptions regarding the lifetime and electric charge of the lightest supersymmetric particle.

[248] BALL 84 is FNAL beam dump experiment. Observed no interactions of $\widetilde{\gamma}$ in the calorimeter, where $\widetilde{\gamma}$'s are expected to come from pair-produced $\widetilde{g}$'s. Search for long-lived $\widetilde{\gamma}$ interacting in calorimeter 56m from target. Limit is for $m_{\widetilde{q}}$ = 40 GeV and production cross section proportional to $A^{0.72}$. BALL 84 find no $\widetilde{g}$ allowed below 4.1 GeV at CL = 90%. Their figure 1 shows dependence on $m_{\widetilde{q}}$ and A. See also KANE 82.

[249] BRICK 84 reanalyzed FNAL 147 GeV HBC data for R-$\Delta(1232)^{++}$ with $\tau > 10^{-9}$ s and p_{lab} >2 GeV. Set CL = 90% upper limits 6.1, 4.4, and 29 microbarns in pp, $\pi^+ p$, $K^+ p$ collisions respectively. R-Δ^{++} is defined as being $\widetilde{g}$ and 3 up quarks. If mass = 1.2–1.5 GeV, then limits may be lower than theory predictions.

[250] FARRAR 84 argues that $m_{\widetilde{g}}$ <100 MeV is not ruled out if the lightest R-hadrons are long-lived. A long lifetime would occur if R-hadrons are lighter than $\widetilde{\gamma}$'s or if $m_{\widetilde{q}}$ >100 GeV.

[251] BERGSMA 83C is reanalysis of CERN-SPS beam-dump data. See their figure 1.

[252] CHANOWITZ 83 find in bag-model that charged s-hadron exists which is stable against strong decay if $m_{\widetilde{g}}$ <1 GeV. This is important since tracks from decay of neutral s-hadron cannot be reconstructed to primary vertex because of missed $\widetilde{\gamma}$. Charged s-hadron leaves track from vertex.

[253] KANE 82 inferred above $\widetilde{g}$ mass limit from retroactive analysis of hadronic collision and beam dump experiments. Limits valid if $\widetilde{g}$ decays inside detector.

Supersymmetry Miscellaneous Results

Results that do not appear under other headings or that make nonminimal assumptions.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[254] ABACHI	97	D0	$\gamma\gamma X$
	[255] BARBER	84B	RVUE	
	[256] HOFFMAN	83	CNTR	$\pi p \rightarrow n(e^+ e^-)$

[254] ABACHI 97 searched for $p\overline{p} \rightarrow \gamma\gamma \not{E}_T + X$ as supersymmetry signature. It can be caused by selectron, sneutrino, or neutralino production with a radiative decay of their decay products. They placed limits on cross sections.

[255] BARBER 84B consider that $\widetilde{\mu}$ and $\widetilde{e}$ may mix leading to $\mu \rightarrow e\widetilde{\gamma}\widetilde{\gamma}$. They discuss mass-mixing limits from decay dist asym in LBL-TRIUMF data and e^+ polarization in SIN data.

[256] HOFFMAN 83 set CL = 90% limit $d\sigma/dt$ B(e^+e^-) $< 3.5 \times 10^{-32}$ cm^2/GeV^2 for spin-1 partner of Goldstone fermions with 140 $< m <$160 MeV decaying $\rightarrow e^+e^-$ pair.

REFERENCES FOR Supersymmetric Particle Searches

ABBOTT	98	PRL 80 442	B. Abbott+	(D0 Collab.)
ABBOTT	98C	PRL 80 1591	B. Abbott+	(D0 Collab.)
ABREU	98	EPJ C1 1	P. Abreu+	(DELPHI Collab.)
ACCIARRI	98F	EPJ C (to be publ.)	M. Acciarri+	(L3 Collab.)
CERN-PPE/97-130				
ACKERSTAFF	98J	EPJ C (to be publ.)	K. Ackerstaff+	(OPAL Collab.)
CERN-PPE/97-132				
ACKERSTAFF	98K	EPJ C (to be publ.)	K. Ackerstaff+	(OPAL Collab.)
CERN-PPE/97-124				
ACKERSTAFF	98L	EPJ C2 213	K. Ackerstaff+	(OPAL Collab.)
ABACHI	97	PRL 78 2070	S. Abachi+	(D0 Collab.)
ABE	97K	PR D56 R1357	F. Abe+	(CDF Collab.)
ABREU	97D	PL B396 315	P. Abreu+	(DELPHI Collab.)
ABREU	97J	ZPHY C74 577	P. Abreu+	(DELPHI Collab.)
ACCIARRI	97U	PL B414 373	M. Acciarri+	(L3 Collab.)
ACCIARRI	97V	PL B415 299	M. Acciarri+	(L3 Collab.)
ACKERSTAFF	97H	PL B396 301	K. Ackerstaff+	(OPAL Collab.)
ACKERSTAFF	97Q	ZPHY C75 409	K. Ackerstaff+	(OPAL Collab.)
ADAMS	97B	PRL 79 4083	J. Adams+	(KTeV Collab.)
ALBUQUERQ...	97	PRL 78 3252	I.F. Albuquerque+	(FNAL E761 Collab.)
ALEXANDER	97B	ZPHY C73 201	G. Alexander+	(OPAL Collab.)
BARATE	97K	PL B405 379	R. Barate+	(ALEPH Collab.)
BARATE	97L	ZPHY C76 1	R. Barate+	(ALEPH Collab.)
BARATE	97N	PL B407 377	R. Barate+	(ALEPH Collab.)
BARATE	97Q	PL B413 431	R. Barate+	(ALEPH Collab.)
BOTTINO	97	PL B402 113	+	(TORI, LAPP, GENO, ROMA, ROMA2, INFN)
CARENA	97	PL B390 234	M. Carena, G.F. Giudice, C.E.M. Wagner	
CSIKOR	97	PRL 78 4335	F. Csikor, Z. Fodor	(EOTV, CERN)
DATTA	97	PL B395 54	A. Datta, M. Guchait, N. Parua	(ICTP, TATA)
DEGOUVEA	97	PL B400 117	A. de Gouvea, H. Murayama	
DERRICK	97	ZPHY C73 613	M. Derrick+	(ZEUS Collab.)
ELLIS	97	PL B394 354	J. Ellis, J.L. Lopez, D.V. Nanopoulos	
ELLIS	97C	PL B413 355	J. Ellis, Falk, Olive, Schmitt	
HEWETT	97	PR D56 5703	J.L. Hewett, T.G. Rizzo, M.A. Doncheski	
KALINOWSKI	97	PL B400 112	J. Kalinowski, P. Zerwas	
TEREKHOV	97	PL B412 86	I. Terekhov	(ALAT)
ABACHI	96	PRL 76 2228	+Abbott, Abolins, Acharya+	(D0 Collab.)
ABACHI	96B	PRL 76 2222	+Abbott, Abolins, Acharya+	(D0 Collab.)
ABE	96	PRL 77 438	+Akimoto, Akopian, Albrow+	(CDF Collab.)
ABE	96D	PRL 76 2006	+Akimoto, Akopian, Albrow+	(CDF Collab.)
ABE	96K	PRL 76 4307	+Akimoto, Akopian, Albrow+	(CDF Collab.)
ABREU	96L	PL B382 323	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	96O	PL B387 651	+Adam, Adye, Agasi+	(DELPHI Collab.)
ACCIARRI	96F	PL B377 289	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ACKERSTAFF	96	PL B389 197	+Alexander, Allison, Altekamp+	(OPAL Collab.)
ACKERSTAFF	96C	PL B389 616	+Alexander, Allison, Altekamp+	(OPAL Collab.)
AID	96	ZPHY C71 211	+Andreev, Andrieu, Appuhn+	(H1 Collab.)
AID	96C	PL B380 461	+Andreev, Andrieu, Appuhn+	(H1 Collab.)
ALCARAZ	96	CERN-PPE/96-183	J. Alcaraz+	
The ALEPH, DELPHI, L3, OPAL, and SLD Collaborations and the LEP Electroweak Working Group				
ALEXANDER	96J	PL B377 181	+Allison, Altekamp, Ametewee+	(OPAL Collab.)
ALEXANDER	96L	PL B377 273	+Allison, Altekamp, Ametewee+	(OPAL Collab.)
BUSKULIC	96A	ZPHY C72 549	D. Buskulic+	(ALEPH Collab.)
BUSKULIC	96K	PL B373 246	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
BUSKULIC	96U	PL B384 461	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
CHO	96	PL B372 101	+Kizukuri, Oshimo	(TOKAH, OCH)
ELLIS	96B	PL B388 97	+Falk, Olive, Schmitt	(CERN, MINN)

FARRAR	96	PRL 76 4111	G.R. Farrar	(RUTG)
SUGIMOTO	96	PL B369 86	+Abe, Fujii, Igarashi+	(AMY Collab.)
TEREKHOV	96	PL B385 139	I. Terkhov, L. Clavelli	(ALAT)
ABACHI	95C	PRL 75 618	+Abbott, Abolins, Acharya+	(D0 Collab.)
ABE	95A	PL B361 199	+Fujii, Sugiyama, Fujimoto+	(TOPAZ Collab.)
ABE	95N	PRL 74 3538	+Albrow, Amendolia, Amidei, Antos+	(CDF Collab.)
ABE	95T	PRL 75 613	+Albrow, Amidei, Anway-Wiese+	(CDF Collab.)
ACCIARRI	95E	PL B350 109	+Adam, Adraiani, Aguilar-Benitez+	(L3 Collab.)
AKERS	95A	ZPHY C65 367	R. Akers+	(OPAL Collab.)
AKERS	95R	ZPHY C67 203	+Alexander, Allison, Ametewee, Anderson+	(OPAL Collab.)
BUSKULIC	95E	PL B349 238	+Casper, DeBonis, Decamp+	(ALEPH Collab.)
CLAVELLI	95	PR D51 1117	+Coulter	(ALAT)
FALK	95	PL B354 99	+Olive, Srednicki	(MINN, UCSB)
LOSECCO	95	PL B342 392		(NDAM)
AHMED	94B	ZPHY C64 545	+Aid, Andreev, Andrieu, Appuhn, Arpagaus+	(H1 Collab.)
AKERS	94K	PL B337 207	+Alexander, Allison, Anderson+	(OPAL Collab.)
BECK	94	PL B336 141	+Bensch, Bockholt+	(MPIH, KIAE, SASSO)
CAKIR	94	PR D50 3268	M.B. Cakir, G.R. Farrar	(RUTG)
FALK	94	PL B339 248	+Olive, Srednicki	(UCSB, MINN)
FRANKE	94	PL B336 415	+Fraas, Bartl	(WURZ, WIEN)
HOSODA	94	PL B331 211	+Abe, Amako, Arai+	(VENUS Collab.)
SHIRAI	94	PRL 72 3313	+Ohmoto, Abe, Amako+	(VENUS Collab.)
ACTON	93G	PL B313 333	+Akers, Alexander, Allison, Anderson+	(OPAL Collab.)
ADRIANI	93M	PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+	(L3 Collab.)
ALITTI	93	NP B400 3	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
CLAVELLI	93	PR D47 1973	+Coulter, Yuan	(ALAT)
DREES	93	PR D47 376	+Nojiri	(DESY, SLAC)
FALK	93	PL B318 354	+Madden, Olive, Srednicki	(UCB, UCSB, MINN)
HEBBEKER	93	ZPHY C60 63		(CERN)
KELLEY	93	PR D47 2461	+Lopez, Nanopoulos, Pois, Yuan	(TAMU, ALAH)
LAU	93	PR D47 1087		(HOUS)
LOPEZ	93C	PL B313 241	+Nanopoulos, Wang	(TAMU, HARC, CERN)
MIZUTA	93	PL B298 120	+Yamaguchi	(TOHO)
MORI	93	PR D48 5505	+(KEK, NIIG, TOKY, TOKA, KOBE, OSAK, TINT, GIFU)	
ABE	92L	PRL 69 3439	+Amidei, Anway-Wiese, Apollinari, Atac+	(CDF Collab.)
BOTTINO	92	MPL A7 733	+DeAlfaro, Fornengo, Morales, Puimedon+	(TORI, ZARA)
Also	91	PL B265 57	Bottino, de Alfaro, Fornengo, Mignola+	(TORI, INFN)
CLAVELLI	92	PR D46 2112		(ALAT)
DECAMP	92	PRPL 216 253	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
ELLIS	92F	PL B283 252	+Roszkowski	(CERN)
KAWASAKI	92	PR D46 1634	+Mizuta	(OSU, TOHO)
LOPEZ	92	NP B370 445	+Nanopoulos, Yuan	(TAMU)
MCDONALD	92	PL B283 80	+Olive, Srednicki	(LISB, MINN, UCSB)
ROY	92	PL B283 270		(CERN)
ABREU	91F	NP B367 511	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
AKESSON	91	ZPHY C52 219	+Almehed, Angelis, Atherton, Aubry+	(HELIOS Collab.)
ALEXANDER	91F	ZPHY C52 175	+Allison, Allport, Anderson, Arcelli+	(OPAL Collab.)
ANTONIADIS	91	PL B262 109	+Ellis, Nanopoulos	(EPOL, CERN, TAMU, HARC)
BAER	91	PR D44 207	+Tata, Woodside	(FSU, HAWA, ISU)
BOTTINO	91	PL B265 57	+de Alfaro, Fornengo, Mignola+	(TORI, INFN)
GELMINI	91	NP B351 623	+Gondolo, Roulet	(UCLA, TRST)
HIDAKA	91	PR D44 927		(TGAK)
KAMIONKOW...	91	PR D44 3021	Kamionkowski	(CHIC, FNAL)
MORI	91B	PL B270 89	+Nojiri, Oyama, Suzuki+	(Kamiokande Collab.)
NOJIRI	91	PL B261 76		(KEK)
OLIVE	91	NP B355 208	+Srednicki	(MINN, UCSB)
ROSZKOWSKI	91	PL B262 59		(CERN)
SATO	91	PR D44 2220	+Hirata, Kajita, Kifune, Kihara+	(Kamioka Collab.)
ABREU	90F	PL B247 148	+Adam, Adami, Adye, Alekseev+	(DELPHI Collab.)
ABREU	90G	PL B247 157	+Adam, Adami, Adye, Alekseev+	(DELPHI Collab.)
ADACHI	90C	PL B244 352	+Aihara, Doser, Enomoto+	(TOPAZ Collab.)
ADEVA	90I	PL B249 341	+Adriani, Aguilar-Benitez, Akbari, Alcarez+	(L3 Collab.)
AKESSON	90B	PL B238 442	+Alitti, Ansari, Ansorge+	(UA2 Collab.)
AKRAWY	90D	PL B240 261	+Alexander, Allison, Allport+	(OPAL Collab.)
AKRAWY	90N	PL B248 211	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
AKRAWY	90O	PL B252 290	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ALITTI	90	PL B235 363	+Ansari, Ansorge, Bagnaia, Bareyre+	(UA2 Collab.)
BAER	90	PR D41 3414	+Drees, Tata	(FSU, CERN, HAWA)
BARKLOW	90	PRL 64 2984	+Abrams, Adolphsen, Averill, Ballam+	(Mark II Collab.)

DECAMP	90C	PL B236 86	+Deschizeaux, Lees, Minard, Crespo+	(ALEPH Collab.)
DECAMP	90K	PL B244 541	+Deschizeaux, Goy, Lees+	(ALEPH Collab.)
ELLIS	90	PL B245 251	+Nanopoulos, Roszkowski, Schramm	(CERN, HARC, TAMU)
GRIEST	90	PR D41 3565	+Kamionkowski, Turner	(UCB, CHIC, FNAL)
GRIFOLS	90	NP B331 244	+Masso	(BARC)
KRAUSS	90	PRL 64 999		(YALE)
SAKAI	90	PL B234 534	+Gu, Low, Abe, Fujii+	(AMY Collab.)
SODERSTROM	90	PRL 64 2980	+McKenna, Abrams, Adolphsen, Averill+	(Mark II Collab.)
TAKETANI	90	PL B234 202	+Odaka, Abe, Amako+	(VENUS Collab.)
ZHUKOVSKII	90	SJNP 52 931	+Eminov	(MOSU)
		Translated from YAF 52 1473.		
ABE	89J	ZPHY C45 175	+Amako, Arai, Fukawa+	(VENUS Collab.)
ADACHI	89	PL B218 105	+Aihara, Dijkstra, Enomoto, Fujii+	(TOPAZ Collab.)
ADEVA	89B	PL B233 530	+Adriani, Aguilar-Benitez, Akbari+	(L3 Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
HEARTY	89	PR D39 3207	+Rothberg, Young, Johnson, Whitaker+	(ASP Collab.)
Also	87	PRL 58 1711	Hearty, Rothberg, Young, Johnson+	(ASP Collab.)
Also	86	PRL 56 685	Bartha, Burke, Extermann+	(ASP Collab.)
NAKAMURA	89	PR D39 1261	+Kobayashi, Konaka, Imai, Masaike+	(KYOT, TMTC)
OLIVE	89	PL B230 78	+Srednicki	(MINN, UCSB)
BEHREND	88B	PL B215 186	+Criegee, Dainton, Field+	(CELLO Collab.)
ELLIS	88B	PL B215 404	+Olive, Sarkar, Sciama	(CERN, MINN, RAL, CAMB)
NATH	88	PR D38 1479	+Arnowitt	(NEAS, TAMU)
OLIVE	88	PL B205 553	+Srednicki	(MINN, UCSB)
SREDNICKI	88	NP B310 693	+Watkins, Olive	(MINN, UCSB)
ALBAJAR	87D	PL B198 261	+Albrow, Allkofer+	(UA1 Collab.)
ANSARI	87D	PL B195 613	+Bagnaia, Banner+	(UA2 Collab.)
ARNOLD	87	PL B186 435	+Barth+	(BRUX, DUUC, LOUC, BARI, AICH, CERN+)
BEHREND	87B	ZPHY C35 181	+Buerger, Criegee, Dainton+	(CELLO Collab.)
NG	87	PL B188 138	+Olive, Srednicki	(MINN, UCSB)
TUTS	87	PL B186 233	+Franzini, Youssef, Zhao+	(CUSB Collab.)
ALBRECHT	86C	PL 167B 360	+Binder, Harder+	(ARGUS Collab.)
BADIER	86	ZPHY C31 21	+Bemporad, Boucrot, Callot+	(NA3 Collab.)
BARNETT	86	NP B267 625	+Haber, Kane	(LBL, UCSC, MICH)
FORD	86	PR D33 3472	+Qi, Read+	(MAC Collab.)
GAISSER	86	PR D34 2206	+Steigman, Tilav	(BART, DELA)
VOLOSHIN	86	SJNP 43 495	+Okun	(ITEP)
		Translated from YAF 43 779.		
ADEVA	85	PL 152B 439	+Becker, Becker-Szendy+	(Mark-J Collab.)
Also	84C	PRPL 109 131	Adeva, Barber, Becker+	(Mark-J Collab.)
AKERLOF	85	PL 156B 271	+Bonvicini, Chapman, Errede+	(HRS Collab.)
BARTEL	85L	PL 155B 288	+Becker, Cords, Felst, Hagiwara+	(JADE Collab.)
BEHREND	85	PL 161B 182	+Burger, Criegee, Fenner+	(CELLO Collab.)
COOPER-...	85B	PL 160B 212	Cooper-Sarkar, Parker, Sarkar+	(WA66 Collab.)
DAWSON	85	PR D31 1581	+Eichten, Quigg	(LBL, FNAL)
FARRAR	85	PRL 55 895		(RUTG)
GOLDMAN	85	Physica 15D 181	+Haber	(LANL, UCSC)
HABER	85	PRPL 117 75	+Kane	(UCSC, MICH)
ADEVA	84B	PRL 53 1806	+Barber, Becker, Berdugo+	(Mark-J Collab.)
BALL	84	PRL 53 1314	+Coffin, Gustafson+	(MICH, FIRZ, OSU, FNAL, WISC)
BARBER	84B	PL 139B 427	+Shrock	(STON)
BARTEL	84B	PL 139B 327	+Becker, Bowdery, Cords+	(JADE Collab.)
BARTEL	84C	PL 146B 126	+Becker, Bowdery, Cords+	(JADE Collab.)
BRICK	84	PR D30 1134	+	(BROW, CAVE, IIT, IND, MIT, MONS, NIJM+)
ELLIS	84	NP B238 453	+Hagelin, Nanopoulos, Olive, Srednicki	(CERN)
FARRAR	84	PRL 53 1029		(RUTG)
BEHREND	83	PL 123B 127	+Chen, Fenner, Gumpel+	(CELLO Collab.)
BERGSMA	83C	PL 121B 429	+Dorenbosch, Jonker+	(CHARM Collab.)
CHANOWITZ	83	PL 126B 225	+Sharpe	(UCB, LBL)
GOLDBERG	83	PRL 50 1419		(NEAS)
HOFFMAN	83	PR D28 660	+Frank, Mischke, Moir, Schardt	(LANL, ARZS)
KRAUSS	83	NP B227 556		(HARV)
VYSOTSKII	83	SJNP 37 948		(ITEP)
		Translated from YAF 37 1597.		
KANE	82	PL 112B 227	+Leveille	(MICH)
CABIBBO	81	PL 105B 155	+Farrar, Maiani	(ROMA, RUTG)
FARRAR	78	PL 76B 575	+Fayet	(CIT)
Also	78B	PL 79B 442	Farrar, Fayet	(CIT)