W

$J = 1$

A REVIEW GOES HERE – Check our WWW List of Reviews

W MASS

OUR FIT uses the W and Z mass, mass difference, and mass ratio measurements.

To obtain OUR EVALUATION the correlation between systematics is properly taken into account.

VALUE (GeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
80.396 ± 0.061 OUR EVALUATION				
80.42 ± 0.05 OUR FIT				
80.43 ± 0.06 OUR AVERAGE				
80.38 ± 0.12 ±0.05	701	[1] ABBIENDI 99C	OPAL	$E^{ee}_{\rm cm}$= 161+172+ 183 GeV
80.61 ± 0.15	801	[2] ACCIARRI 99	L3	$E^{ee}_{\rm cm}$= 161+172+ 183 GeV
80.423 ± 0.112 ±0.054	812	[3] BARATE 99	ALEP	$E^{ee}_{\rm cm}$= 161+172+ 183 GeV
80.44 ± 0.10 ±0.07	28323	[4] ABBOTT 98O	D0	$E^{p\overline{p}}_{\rm cm}$= 1.8 TeV
80.22 ± 0.41 ±0.07	72	[5] ABREU 98B	DLPH	$E^{ee}_{\rm cm}$= 172.14 GeV
80.40 ± 0.44 ±0.095	29	[6] ABREU 97	DLPH	$E^{ee}_{\rm cm}$= 161.3 GeV
80.35 ± 0.14 ±0.23	5982	[7] ABACHI 96E	D0	$E^{p\overline{p}}_{\rm cm}$= 1.8 TeV
80.41 ± 0.18	8986	[8] ABE 95P	CDF	$E^{p\overline{p}}_{\rm cm}$= 1.8 TeV
79.91 ± 0.39	1722	[9] ABE 90G	CDF	$E^{p\overline{p}}_{\rm cm}$= 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
80.32 ± 0.30 ±0.094	96	[10] ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99C
$80.5\ {}^{+1.4}_{-2.2}\ {}^{+0.5}_{-0.6}$	104	[11] ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99C
80.80 ± 0.32 ±0.114	95	[12] BARATE 98B	ALEP	Repl. by BARATE 99
$80.80\ {}^{+0.48}_{-0.42}\ \pm 0.03$	20	[13] ACCIARRI 97	L3	Repl. by ACCIARRI 99
$80.5\ {}^{+1.4}_{-2.4}\ \pm 0.3$	94	[14] ACCIARRI 97M	L3	Repl. by ACCIARRI 99
$80.71\ {}^{+0.34}_{-0.35}\ \pm 0.09$	101	[15] ACCIARRI 97S	L3	Repl. by ACCIARRI 99
80.14 ± 0.34 ±0.095	32	[16] BARATE 97	ALEP	Repl. by BARATE 99
$81.17\ {}^{+1.15}_{-1.62}$	106	[17] BARATE 97S	ALEP	Repl. by BARATE 99
$80.40\ {}^{+0.44}_{-0.41}\ {}^{+0.09}_{-0.10}$	23	[18] ACKERSTAFF 96B	OPAL	Repl. by ABBIENDI 99C

84	$^{+10}_{-7}$		13	[19] AID	96D	H1	$e^{\pm}p \to \nu_e(\overline{\nu}_e) + X$ $\sqrt{s} \approx 300$ GeV
80.84	± 0.22	±0.83	2065	[20] ALITTI	92B	UA2	See W/Z ratio below
80.79	± 0.31	±0.84		[21] ALITTI	90B	UA2	$E_{\text{cm}}^{p\overline{p}}$= 546,630 GeV
80.0	± 3.3	±2.4	22	[22] ABE	89I	CDF	$E_{\text{cm}}^{p\overline{p}}$= 1.8 TeV
82.7	± 1.0	±2.7	149	[23] ALBAJAR	89	UA1	$E_{\text{cm}}^{p\overline{p}}$= 546,630 GeV
81.8	$^{+6.0}_{-5.3}$	±2.6	46	[24] ALBAJAR	89	UA1	$E_{\text{cm}}^{p\overline{p}}$= 546,630 GeV
89	± 3	±6	32	[25] ALBAJAR	89	UA1	$E_{\text{cm}}^{p\overline{p}}$= 546,630 GeV
81.	± 5.		6	ARNISON	83	UA1	E_{cm}^{ee}= 546 GeV
80.	$^{+10.}_{-6.}$		4	BANNER	83B	UA2	Repl. by ALITTI 90B

[1] ABBIENDI 99C obtain this value properly combining results from a direct W mass reconstruction at 172 and 183 GeV with that from the measurement of the total W-pair production cross section at 161 GeV. The systematic error includes an uncertainty of ±0.02 GeV due to the possible color-reconnection and Bose-Einstein effects in the purely hadronic final states and an uncertainty of ±0.02 GeV due to the beam energy.

[2] ACCIARRI 99 obtain this value properly combining results obtained from a direct W mass reconstruction at 172 and 183 GeV with those from the measurements of the total W-pair production cross sections at 161 and 172 GeV. The value of the mass obtained from the direct reconstruction at 172 and 183 GeV is $M(W)= 80.58 \pm 0.14 \pm 0.08$ GeV.

[3] BARATE 99 obtain this value properly combining results from a direct W mass reconstruction at 172 and 183 GeV with those from the measurements of the total W-pair production cross sections at 161 and 172 GeV. The systematic error includes ±0.023 GeV due to LEP energy uncertainty and ±0.021 GeV due to theory uncertainty on account of possible color reconnection and Bose-Einstein correlations.

[4] ABBOTT 98O fit the transverse mass distribution of 28323 $W \to e\nu_e$ events. The systematic error includes a detector related uncertainty of ±60 MeV and a model uncertainty of ±30 MeV. Combining with ABACHI 96E DØ obtain a W mass value of 80.43 ± 0.11 GeV.

[5] ABREU 98B obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. The systematic error includes ±0.03 GeV due to the beam energy uncertainty and ±0.05 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with ABREU 97 authors find: $M(W) = 80.33 \pm 0.30 \pm 0.06 \pm 0.03$ (LEP) GeV.

[6] ABREU 97 derive this value from their measured W-W production cross section $\sigma_{WW} = 3.67^{+0.97}_{-0.85} \pm 0.19$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. The systematics include an error of ±0.03 GeV arising from the beam energy uncertainty.

[7] ABACHI 96E fit the transverse mass distribution of 5982 $W \to e\nu_e$ decays. An error of ±160 MeV due to the uncertainty in the absolute energy scale of the EM calorimeter is included in the total systematics.

[8] ABE 95P use 3268 $W \to \mu\nu_{\mu}$ events to find $M = 80.310 \pm 0.205 \pm 0.130$ GeV and 5718 $W \to e\nu_e$ events to find $M = 80.490 \pm 0.145 \pm 0.175$ GeV. The result given here combines these while accounting for correlated uncertainties.

[9] ABE 90G result from $W \to e\nu$ is $79.91 \pm 0.35 \pm 0.24 \pm 0.19$(scale) GeV and from $W \to \mu\nu$ is $79.90 \pm 0.53 \pm 0.32 \pm 0.08$(scale) GeV.

[10] ACKERSTAFF 98D obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. When both W mass and width are varied they obtain $M(W) = 80.30 \pm 0.27 \pm 0.095$ GeV. The systematic error includes ±0.03 GeV due to the beam energy uncertainty and ±0.05 GeV

due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining both values of ACKERSTAFF 98D with ACKERSTAFF 96B authors find: $M(W) = 80.35 \pm 0.24 \pm 0.07 \pm 0.03$ (LEP) GeV.

[11] ACKERSTAFF 98D derive this value from their measured WW production cross section $\sigma_{WW} = 12.3 \pm 1.3 \pm 0.4$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy.

[12] BARATE 98B obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. The systematic error includes ± 0.03 GeV due to the beam energy uncertainty and ± 0.032 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with the M_W values from cross section measurements at 161 and 172 GeV (BARATE 97 and BARATE 97S) authors find: $M(W) = 80.51 \pm 0.23 \pm 0.08$ GeV.

[13] ACCIARRI 97 derive this value from their measured W-W production cross section $\sigma_{WW} = 2.89^{+0.81}_{-0.70} \pm 0.14$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. Statistical and systematic errors are added in quadrature and the last error of ± 0.03 GeV arises from the beam energy uncertainty. The same result is given by a fit of the production cross sections to the data.

[14] ACCIARRI 97M derive this value from their measured WW production cross section $\sigma_{WW} = 12.27^{+1.41}_{-1.32} \pm 0.23$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. Combining with ACCIARRI 97 authors find $M(W) = 80.78^{+0.45}_{-0.41} \pm 0.03$ GeV where the last error is due to beam energy uncertainty.

[15] ACCIARRI 97S obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. When both W mass and width are varied they obtain $M(W) = 80.72^{+0.31}_{-0.33} \pm 0.09$ GeV. The systematic error includes ± 0.03 GeV due to the beam energy uncertainty and ± 0.05 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with ACCIARRI 97 and ACCIARRI 97M authors find: $M(W) = 80.75^{+0.26}_{-0.27} \pm 0.03$ (LEP) GeV.

[16] BARATE 97 derive this value from their measured W-W production cross section $\sigma_{WW} = 4.23 \pm 0.73 \pm 0.19$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. The systematics include an error of ± 0.03 GeV arising from the beam energy uncertainty.

[17] BARATE 97S derive this value from their measured WW production cross section $\sigma_{WW} = 11.71 \pm 1.23 \pm 0.28$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. The errors quoted on the mass are statistical only. Combining with BARATE 97 authors find: $M(W) = 80.20 \pm 0.33 \pm 0.09 \pm 0.03$ (LEP) GeV.

[18] ACKERSTAFF 96B derive this value from an analysis of the predicted M_W dependence of their accepted four-fermion cross section, explicitly taking into account interference effects. The systematics include an error of ± 0.03 GeV arising from the beam energy uncertainty.

[19] AID 96D derive this value as a propagator mass using the Q^2 shape and magnitude of the $e^{\pm}$ charged-current cross sections. $Q^2 > 5000\,\mathrm{GeV}^2$ events with p_T of the outgoing lepton > 25 GeV/c are used.

[20] ALITTI 92B result has two contributions to the systematic error (± 0.83); one (± 0.81) cancels in m_W/m_Z and one (± 0.17) is noncancelling. These were added in quadrature. We choose the ALITTI 92B value without using the LEP m_Z value, because we perform our own combined fit.

[21] There are two contributions to the systematic error (± 0.84): one (± 0.81) which cancels in m_W/m_Z and one (± 0.21) which is non-cancelling. These were added in quadrature.

[22] ABE 89I systematic error dominated by the uncertainty in the absolute energy scale.

[23] ALBAJAR 89 result is from a total sample of 299 $W \to e\nu$ events.

[24] ALBAJAR 89 result is from a total sample of 67 $W \to \mu\nu$ events.

[25] ALBAJAR 89 result is from $W \to \tau\nu$ events.

W/*Z* MASS RATIO

The fit uses the *W* and *Z* mass, mass difference, and mass ratio measurements.

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.8820 ±0.0006 OUR FIT				
0.8819 ±0.0012 OUR AVERAGE				
0.8821 ±0.0011 ±0.0008	28323	[26] ABBOTT 98N	D0	$E_{\rm cm}^{p\overline{p}}$= 1.8 TeV
0.88114±0.00154±0.00252	5982	[27] ABBOTT 98P	D0	$E_{\rm cm}^{p\overline{p}}$= 1.8 TeV
0.8813 ±0.0036 ±0.0019	156	[28] ALITTI 92B	UA2	$E_{\rm cm}^{p\overline{p}}$= 630 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.8831 ±0.0048 ±0.0026		[28] ALITTI 90B	UA2	$E_{\rm cm}^{p\overline{p}}$= 546,630 GeV

[26] ABBOTT 98N obtain this from a study of 28323 $W \rightarrow e\nu_e$ and 3294 $Z \rightarrow e^+e^-$ decays. Of this latter sample, 2179 events are used to calibrate the electron energy scale.

[27] ABBOTT 98P obtain this from a study of 5982 $W \rightarrow e\nu_e$ events. The systematic error includes an uncertainty of ±0.00175 due to the electron energy scale.

[28] Scale error cancels in this ratio.

$m_Z - m_W$

The fit uses the *W* and *Z* mass, mass difference, and mass ratio measurements.

VALUE (GeV)	*DOCUMENT ID*	*TECN*	*COMMENT*
10.76±0.05 OUR FIT			
10.4 ±1.4 ±0.8	ALBAJAR 89	UA1	$E_{\rm cm}^{p\overline{p}}$= 546,630 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
11.3 ±1.3 ±0.9	ANSARI 87	UA2	$E_{\rm cm}^{p\overline{p}}$= 546,630 GeV

$m_{W^+} - m_{W^-}$

Test of *CPT* invariance.

VALUE (GeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.19±0.58	1722	ABE 90G	CDF	$E_{\rm cm}^{p\overline{p}}$= 1.8 TeV

W WIDTH

The CDF and DØ widths labelled "extracted value" are obtained by measuring $R = [\sigma(W)/\sigma(Z)]\ [\Gamma(W \rightarrow \ell\nu_{\ell})]/(\mathrm{B}(Z \rightarrow \ell\ell)\Gamma(W))$ where the bracketed quantities can be calculated with plausible reliability. $\Gamma(W)$ is then extracted by using a value of $\mathrm{B}(Z \rightarrow \ell\ell)$ measured at LEP. The UA1 and UA2 widths used $R = [\sigma(W)/\sigma(Z)]\ [\Gamma(W \rightarrow \ell\nu_{\ell})/\Gamma(Z \rightarrow \ell\ell)]\ \Gamma(Z)/\Gamma(W)$ and the measured value of $\Gamma(Z)$. The Standard Model prediction is 2.067 ± 0.021 (ROSNER 94).

VALUE (GeV)	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.06 ±0.05 OUR AVERAGE					
1.84 ±0.32 ±0.20		674	[29] ABBIENDI 99C	OPAL	E^{ee}_{cm}= 172+183 GeV
1.97 ±0.34 ±0.17		687	[30] ACCIARRI 99	L3	E^{ee}_{cm}= 172+183 GeV
2.044±0.093		13k	[31] ABACHI 95D	D0	Extracted value
2.11 ±0.28 ±0.16		58	[32] ABE 95C	CDF	Direct meas.
2.064±0.060±0.059			[33] ABE 95W	CDF	Extracted value
$2.10\ ^{+0.14}_{-0.13}\ \pm 0.09$		3559	[34] ALITTI 92	UA2	Extracted value
$2.18\ ^{+0.26}_{-0.24}\ \pm 0.04$			[35] ALBAJAR 91	UA1	Extracted value
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1.30\ ^{+0.70}_{-0.55}\ \pm 0.18$		92	[36] ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99C
$1.74\ ^{+0.88}_{-0.78}\ \pm 0.25$		101	[37] ACCIARRI 97S	L3	Repl. by ACCIARRI 99
2.16 ±0.17			[38] ABE 92I	CDF	Repl. by ABE 95W
2.12 ±0.20			[39] ABE 90	CDF	Repl. by ABE 92I
2.30 ±0.19 ±0.06			[40] ALITTI 90C	UA2	Extracted value
$2.8\ ^{+1.4}_{-1.5}\ \pm 1.3$		149	[41] ALBAJAR 89	UA1	$E^{p\overline{p}}_{\mathrm{cm}}$= 546,630 GeV
<7	90	251	ANSARI 87	UA2	$E^{p\overline{p}}_{\mathrm{cm}}$= 546,630 GeV
<7	90	119	APPEL 86	UA2	$E^{p\overline{p}}_{\mathrm{cm}}$= 546,630 GeV
<6.5	90	86	[42] ARNISON 86	UA1	Repl. by ALBAJAR 89

[29] ABBIENDI 99C obtain this value from a fit to the reconstructed *W* mass distribution using data at 172 and 183 GeV. The systematic error includes an uncertainty of ±0.12 GeV due to the possible color-reconnection and Bose-Einstein effects in the purely hadronic final states and an uncertainty of ±0.01 GeV due to the beam energy.

[30] ACCIARRI 99 obtain this value from a fit to the reconstruced *W* mass distribution using data at 172 and 183 GeV.

[31] ABACHI 95D measured $R = 10.90 \pm 0.49$ and used the measured value $\mathrm{B}(Z \rightarrow \ell\ell) = (3.367 \pm 0.006)\%$ from LEP.

[32] ABE 95C use the tail of the transverse mass distribution of $W \rightarrow e\nu_e$ decays.

[33] ABE 95W measured $R = 10.90 \pm 0.32 \pm 0.29$. They use m_W=80.23 ± 0.18 GeV, $\sigma(W)/\sigma(Z) = 3.35 \pm 0.03$, $\Gamma(W \rightarrow e\nu) = 225.9 \pm 0.9$ MeV, $\Gamma(Z \rightarrow e^+e^-) = 83.98 \pm 0.18$ MeV, and $\Gamma(Z) = 2.4969 \pm 0.0038$ GeV.

[34] ALITTI 92 measured $R = 10.4^{+0.7}_{-0.6} \pm 0.3$. The values of $\sigma(Z)$ and $\sigma(W)$ come from $O(\alpha_s^2)$ calculations using $m_W = 80.14 \pm 0.27$ GeV, and $m_Z = 91.175 \pm 0.021$ GeV along with the corresponding value of $\sin^2\theta_W = 0.2274$. They use $\sigma(W)/\sigma(Z) = 3.26 \pm 0.07 \pm 0.05$ and $\Gamma(Z) = 2.487 \pm 0.010$ GeV.

[35] ALBAJAR 91 measured $R = 9.5^{+1.1}_{-1.0}$ (stat. + syst.). $\sigma(W)/\sigma(Z)$ is calculated in QCD at the parton level using $m_W = 80.18 \pm 0.28$ GeV and $m_Z = 91.172 \pm 0.031$ GeV along with $\sin^2\theta_W = 0.2322 \pm 0.0014$. They use $\sigma(W)/\sigma(Z) = 3.23 \pm 0.05$ and $\Gamma(Z) = 2.498 \pm 0.020$ GeV. This measurement is obtained combining both the electron and muon channels.

[36] ACKERSTAFF 98D obtain this value from a fit to the reconstructed W mass distribution.

[37] ACCIARRI 97S obtain this value from a fit to the reconstructed W mass distribution.

[38] ABE 92I report $1216 \pm 38^{+27}_{-31}$ $W \rightarrow \mu\nu$ and $106 \pm 10^{+0.2}_{-1}$ $Z \rightarrow \mu^+\mu^-$ events which are combined with 2426 $W \rightarrow e\nu$ events of ABE 91C to derive the ratio σ_W B$(W \rightarrow \ell\nu)/\sigma_Z$ B$(Z \rightarrow \ell^+\ell^-) = 10.0 \pm 0.6 \pm 0.4$. Finally the value of $\Gamma(Z)$ measured by LEP 92 is used to extract $\Gamma(W)$.

[39] ABE 90 extract $\Gamma(W) = 2.19 \pm 0.20$ by using the value $\Gamma(Z) = 2.57 \pm 0.07$ GeV. However, in ABE 91C they update their analysis with a new LEP value $\Gamma(Z) = 2.496 \pm 0.016$; the value $\Gamma(W) = 2.12 \pm 0.20$ above reflects this update. They measured $R = 10.2 \pm 0.8 \pm 0.4$, assumed $\sin^2\theta_W = 0.229 \pm 0.007$, and took predicted values $\sigma(W)/\sigma(Z) = 3.23 \pm 0.03$ and $\Gamma(W \rightarrow e\nu)/\Gamma(Z \rightarrow ee) = 2.70 \pm 0.02$. This yields $\Gamma(W)/\Gamma(Z) = 0.85 \pm 0.08$. The quoted error for $\Gamma(W)$ includes systematic uncertainties. $E^{p\overline{p}}_{\text{cm}} = 1.8$ TeV.

[40] ALITTI 90C used the same technique as described for ABE 90. They measured $R = 9.38^{+0.82}_{-0.72} \pm 0.25$, obtained $\Gamma(W)/\Gamma(Z) = 0.902 \pm 0.074 \pm 0.024$. Using $\Gamma(Z) = 2.546 \pm 0.032$ GeV, they obtained the $\Gamma(W)$ value quoted above and the limits $\Gamma(W) < 2.56$ (2.64) GeV at the 90% (95%) CL. $E^{p\overline{p}}_{\text{cm}} = 546{,}630$ GeV.

[41] ALBAJAR 89 result is from a total sample of 299 $W \rightarrow e\nu$ events.

[42] If systematic error is neglected, result is $2.7^{+1.4}_{-1.5}$ GeV. This is enhanced subsample of 172 total events.

W^+ DECAY MODES

W^- modes are charge conjugates of the modes below.

	Mode		Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\ell^+\nu$	[a]	(10.51 ± 0.24) %	
Γ_2	$e^+\nu$		(10.78 ± 0.31) %	
Γ_3	$\mu^+\nu$		(10.2 ± 0.4) %	
Γ_4	$\tau^+\nu$		(10.2 ± 0.6) %	
Γ_5	hadrons		(68.7 ± 0.9) %	
Γ_6	$\pi^+\gamma$		$< 8 \times 10^{-5}$	95%
Γ_7	$D_s^+\gamma$		$< 1.3 \times 10^{-3}$	95%
Γ_8	$c\overline{s}$		(32^{+13}_{-11}) %	

[a] ℓ indicates each type of lepton (e, μ, and τ), not sum over them.

CONSTRAINED FIT INFORMATION

Overall fits are performed to determine the branching ratios of the W. For each LEP experiment the correlation matrix of the leptonic branching ratios is used. A first fit determines three individual leptonic branching ratios, B($W \rightarrow e\nu_e$), B($W \rightarrow \mu\nu_\mu$), and B($W \rightarrow \tau\nu_\tau$). This fit has a $\chi^2 =$ 5.8 for 17 degrees of freedom. The second fit assumes lepton universality and determines the leptonic branching ratio B($W \rightarrow \ell\nu_\ell$), from which one also derives the hadronic branching ratio, assuming B($W \rightarrow$ hadrons) = 1–3 · B($W \rightarrow \ell\nu_\ell$). This fit has a $\chi^2 = 7.8$ for 19 degrees of freedom.

W BRANCHING RATIOS

The LEP collaborations obtain the W branching ratios by a fit to their measured cross sections of the final states $e^+e^- \rightarrow W^+W^- \rightarrow q\overline{q}e\nu_e$, $q\overline{q}\mu\nu_\mu$, $q\overline{q}\tau\nu_\tau$, $q\overline{q}q\overline{q}$, $\ell\nu_\ell\ell\nu_\ell$. The leptonic branching ratios and $\sigma(e^+e^- \rightarrow W^+W^-)$ at the respective center-of-mass energies are the fitted parameters. Two fits are performed, one without and one assuming lepton universality. The hadronic branching ratio is derived from the second fit assuming B($W \rightarrow$ hadrons) = 1–3 · B($W \rightarrow \ell\nu_\ell$).

$\Gamma(\ell^+\nu)/\Gamma_{\rm total}$ Γ_1/Γ

ℓ indicates average over e, μ, and τ modes, not sum over modes.

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.1051±0.0024 OUR FIT					
0.1038±0.0028 OUR AVERAGE					
0.107 ±0.004 ±0.002	avg	461	ABBIENDI 99D	OPAL	$E^{ee}_{\rm cm}$= 161+172+ 183 GeV
0.113 ±0.012 ±0.003	avg	52	ABREU 98B	DLPH	$E^{ee}_{\rm cm}$= 161.3 + 172.14 GeV
0.100 ±0.004 ±0.001	avg	324	ACCIARRI 98P	L3	$E^{ee}_{\rm cm}$= 161+172+ 183 GeV
0.104 ±0.008	avg	3642	[43] ABE 92I	CDF	$E^{p\overline{p}}_{\rm cm}$= 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.101 $^{+0.011}_{-0.010}$ ±0.002	avg	61	ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99D
0.119 $^{+0.013}_{-0.012}$ ±0.002		51	ACCIARRI 97M	L3	Repl. by ACCIARRI 98P

[43] 1216 ± 38$^{+27}_{-31}$ $W \rightarrow \mu\nu$ events from ABE 92I and 2426$W \rightarrow e\nu$ events of ABE 91C. ABE 92I give the inverse quantity as 9.6 ± 0.7 and we have inverted.

$\Gamma(e^+\nu)/\Gamma_{\text{total}}$ Γ_2/Γ

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.1078±0.0031 OUR FIT					
0.109 ±0.004 OUR AVERAGE					
0.117 ±0.009 ±0.002	f&a	191	ABBIENDI 99D	OPAL	E^{ee}_{cm}= 161+172+ 183 GeV
0.102 $^{+0.038}_{-0.032}$ ±0.003	f&a	16	ABREU 98B	DLPH	E^{ee}_{cm}= 161.3 + 172.14 GeV
0.105 ±0.009 ±0.002	f&a	128	ACCIARRI 98P	L3	E^{ee}_{cm}= 161+172+ 183 GeV
0.097 ±0.02 ±0.005	f&a	21	BARATE 97S	ALEP	E^{ee}_{cm}= 161.3 + 172.09 GeV
0.1094±0.0033±0.0031	f&a		[44] ABE 95W	CDF	$E^{p\overline{p}}_{\text{cm}}$= 1.8 TeV
0.10 ±0.014 $^{+0.02}_{-0.03}$	f&a	248	[45] ANSARI 87C	UA2	$E^{p\overline{p}}_{\text{cm}}$= 546,630 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.098 $^{+0.022}_{-0.020}$ ±0.003	f&a	21	ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99D
0.165 $^{+0.037}_{-0.033}$ ±0.005		23	ACCIARRI 97M	L3	Repl. by ACCIARRI 98P
0.106 ±0.0096		2426	[46] ABE 91C	CDF	Repl. by ABE 94B
seen		299	[47] ALBAJAR 89	UA1	$E^{p\overline{p}}_{\text{cm}}$= 546,630 GeV
seen		119	APPEL 86	UA2	$E^{p\overline{p}}_{\text{cm}}$= 546,630 GeV
seen		172	ARNISON 86	UA1	Repl. by ALBAJAR 89

[44] ABE 95W result is from a measurement of $\sigma B(W \to e\nu)/\sigma B(Z \to e^+e^-) = 10.90\pm0.32\pm0.29$, the theoretical prediction for the cross section ratio, the experimental knowledge of $\Gamma(Z \to e^+e^-) = 83.98 \pm 0.18$ MeV, and $\Gamma(Z) = 2.4969 \pm 0.0038$.

[45] The first error was obtained by adding the statistical and systematic experimental uncertainties in quadrature. The second error reflects the dependence on theoretical prediction of total W cross section: $\sigma(546 \text{ GeV}) = 4.7^{+1.4}_{-0.7}$ nb and $\sigma(630 \text{ GeV}) = 5.8^{+1.8}_{-1.0}$ nb. See ALTARELLI 85B.

[46] ABE 91C result is from a measurement of $\sigma B(W \to e\nu)/\sigma B(Z \to e^+e^-)$, the theoretical prediction for the cross section ratio, and the experimental knowledge of $\Gamma(Z \to e^+e^-)/\Gamma(Z \to \text{all})$.

[47] ALBAJAR 89 experiment determines values of branching ratio times production cross section.

$\Gamma(\mu^+\nu)/\Gamma_{total}$ Γ_3/Γ

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.1023±0.0042 OUR FIT					
0.102 ±0.005 OUR AVERAGE					
0.102 ±0.008 ±0.002	f&a	169	ABBIENDI 99D	OPAL	E^{ee}_{cm}= 161+172+ 183 GeV
0.107 $^{+0.032}_{-0.027}$ ±0.003	f&a	20	ABREU 98B	DLPH	E^{ee}_{cm}= 161.3 + 172.14 GeV
0.102 ±0.009 ±0.002	f&a	115	ACCIARRI 98P	L3	E^{ee}_{cm}= 161+172+ 183 GeV
0.112 ±0.02 ±0.006	f&a	25	BARATE 97S	ALEP	E^{ee}_{cm}= 161.3 + 172.09 GeV
0.10 ±0.01	f&a	1216	[48] ABE 92I	CDF	$E^{p\overline{p}}_{cm}$= 1.8 TeV

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

0.073 $^{+0.019}_{-0.017}$ ±0.002	f&a	16	ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99D
0.084 $^{+0.028}_{-0.024}$ ±0.003		13	ACCIARRI 97M	L3	Repl. by ACCIARRI 98P

[48] ABE 92I quote the inverse quantity as 9.9 ± 1.2 which we have inverted.

$\Gamma(\tau^+\nu)/\Gamma_{total}$ Γ_4/Γ

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.1023±0.0057 OUR FIT					
0.099 ±0.008 OUR AVERAGE					
0.101 ±0.010 ±0.003	f&a	144	ABBIENDI 99D	OPAL	E^{ee}_{cm}= 161+172+ 183 GeV
0.134 $^{+0.050}_{-0.048}$ ±0.007	f&a	16	ABREU 98B	DLPH	E^{ee}_{cm}= 161.3 + 172.14 GeV
0.090 ±0.012 ±0.003	f&a	81	ACCIARRI 98P	L3	E^{ee}_{cm}= 161+172+ 183 GeV
0.113 ±0.027 ±0.006	f&a	37	BARATE 97S	ALEP	E^{ee}_{cm}= 161.3 + 172.09 GeV

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

0.140 $^{+0.030}_{-0.028}$ ±0.005	f&a	23	ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99D
0.109 $^{+0.042}_{-0.039}$ ±0.005		15	ACCIARRI 97M	L3	Repl. by ACCIARRI 98P

$\Gamma(\text{hadrons})/\Gamma_{\text{total}}$ $\qquad$ Γ_5/Γ

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

To obtain OUR EVALUATION the correlation between systematics is properly taken into account.

VALUE		*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.6873±0.0089 OUR EVALUATION					
0.6846±0.0073 OUR FIT					
0.687 ±0.009 OUR AVERAGE					
0.679 ±0.012 ±0.005	avg	395	ABBIENDI 99D	OPAL	E^{ee}_{cm}= 161+172+ 183 GeV
0.660 $^{+0.036}_{-0.037}$ ±0.009	avg	57	ABREU 98B	DLPH	E^{ee}_{cm}= 161.3 + 172.14 GeV
0.701 ±0.013 ±0.004	avg	462	ACCIARRI 98P	L3	E^{ee}_{cm}= 161+172+ 183 GeV
0.677 ±0.031 ±0.007	avg	65	BARATE 97S	ALEP	E^{ee}_{cm}= 161.3 + 172.09 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.698 $^{+0.030}_{-0.032}$ ±0.007	avg	52	ACKERSTAFF 98D	OPAL	Repl. by ABBIENDI 99D
0.642 $^{+0.037}_{-0.038}$ ±0.005		70	ACCIARRI 97M	L3	Repl. by ACCIARRI 98P

$\Gamma(\mu^+\nu)/\Gamma(e^+\nu)$ $\qquad$ Γ_3/Γ_2

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.949±0.043 OUR FIT					
0.97 ±0.06 OUR AVERAGE					
0.89 ±0.10	f&a	13k	[49] ABACHI 95D	D0	$E^{p\overline{p}}_{\text{cm}}$= 1.8 TeV
1.02 ±0.08	f&a	1216	[50] ABE 92I	CDF	$E^{p\overline{p}}_{\text{cm}}$= 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.00 ±0.14 ±0.08		67	ALBAJAR 89	UA1	$E^{p\overline{p}}_{\text{cm}}$= 546,630 GeV
1.24 $^{+0.6}_{-0.4}$		14	ARNISON 84D	UA1	Repl. by ALBAJAR 89

[49] ABACHI 95D obtain this result from the measured $\sigma_W \text{B}(W \to \mu\nu) = 2.09 \pm 0.23 \pm 0.11$ nb and $\sigma_W \text{B}(W \to e\nu) = 2.36 \pm 0.07 \pm 0.13$ nb in which the first error is the combined statistical and systematic uncertainty, the second reflects the uncertainty in the luminosity.

[50] ABE 92I obtain $\sigma_W \text{B}(W \to \mu\nu) = 2.21 \pm 0.07 \pm 0.21$ and combine with ABE 91C σ_W $\text{B}((W \to e\nu))$ to give a ratio of the couplings from which we derive this measurement.

$\Gamma(\tau^+\nu)/\Gamma(e^+\nu)$ Γ_4/Γ_2

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.949±0.058 OUR FIT						
1.00 ±0.08 OUR AVERAGE						
0.94 ±0.14	f&a	179	[51] ABE	92E	CDF	$E_{\rm cm}^{p\overline{p}}$= 1.8 TeV
1.04 ±0.08 ±0.08	f&a	754	[52] ALITTI	92F	UA2	$E_{\rm cm}^{p\overline{p}}$= 630 GeV
1.02 ±0.20 ±0.12	f&a	32	ALBAJAR	89	UA1	$E_{\rm cm}^{p\overline{p}}$= 546,630 GeV

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

0.995±0.112±0.083		198	ALITTI	91C	UA2	Repl. by ALITTI 92F
1.02 ±0.20 ±0.10		32	ALBAJAR	87	UA1	Repl. by ALBAJAR 89

[51] ABE 92E use two procedures for selecting $W \rightarrow \tau\nu_\tau$ events. The missing E_T trigger leads to $132 \pm 14 \pm 8$ events and the τ trigger to $47 \pm 9 \pm 4$ events. Proper statistical and systematic correlations are taken into account to arrive at $\sigma B(W \rightarrow \tau\nu) = 2.05 \pm 0.27$ nb. Combined with ABE 91C result on $\sigma B(W \rightarrow e\nu)$, ABE 92E quote a ratio of the couplings from which we derive this measurement.

[52] This measurement is derived by us from the ratio of the couplings of ALITTI 92F.

$\Gamma(\pi^+\gamma)/\Gamma(e^+\nu)$ Γ_6/Γ_2

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{< 7 \times 10^{-4}}$	95	ABE	98H	CDF	$E_{\rm cm}^{p\overline{p}}$= 1.8 TeV
$< 4.9 \times 10^{-3}$	95	[53] ALITTI	92D	UA2	$E_{\rm cm}^{p\overline{p}}$= 630 GeV
$<58 \times 10^{-3}$	95	[54] ALBAJAR	90	UA1	$E_{\rm cm}^{p\overline{p}}$= 546, 630 GeV

[53] ALITTI 92D limit is 3.8×10^{-3} at 90%CL.

[54] ALBAJAR 90 obtain < 0.048 at 90%CL.

$\Gamma(D_s^+\gamma)/\Gamma(e^+\nu)$ Γ_7/Γ_2

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{<1.2 \times 10^{-2}}$	95	ABE	98P	CDF	$E_{\rm cm}^{p\overline{p}}$= 1.8 TeV

$R_{cs} = \Gamma(c\overline{s})/\Gamma(\text{hadrons})$ Γ_8/Γ_5

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{0.46^{+0.18}_{-0.14}\pm0.07}$	[55] ABREU	98N	DLPH	$E_{\rm cm}^{ee}$= 161+172 GeV

[55] ABREU 98N tag c and s jets by identifying a charged kaon as the highest momentum particle in a hadronic jet. They also use a lifetime tag to independently identify a c jet, based on the impact parameter distribution of charged particles in a jet. From this measurement $|V_{cs}|$ is determined to be $0.94^{+0.32}_{-0.26} \pm 0.13$.

AVERAGE PARTICLE MULTIPLICITIES IN HADRONIC *W* DECAY

Summed over particle and antiparticle, when appropriate.

$\langle N_{charged} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
19.23±0.74	[56] ABREU 98C	DLPH	E^{ee}_{cm}= 172 GeV

[56] ABREU 98C combine results from both the fully hadronic as well semileptonic $W W$ final states after demonstrating that the W decay charged multiplicity is independent of the topology within errors.

TRIPLE GAUGE COUPLINGS (TGC'S)

A REVIEW GOES HERE – Check our WWW List of Reviews

$\alpha_{W\phi}$

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.05±0.20 OUR AVERAGE				
$0.22^{+0.25}_{-0.28}\pm0.06$	89	[57] ABREU 98K	DLPH	E^{ee}_{cm}=161+172 GeV
$-0.14^{+0.27}_{-0.25}{}^{+0.14}_{-0.12}$	78	[58] BARATE 98Y	ALEP	E^{ee}_{cm}= 172 GeV

[57] ABREU 98K obtain this result using both W pair production and single W ($W e \nu_e$) production.

[58] BARATE 98Y obtain this value using semileptonic and hadronic decay modes in W pair production.

α_W

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.1 ±0.4 OUR AVERAGE				
$0.11^{+0.48}_{-0.49}\pm0.09$	89	[59] ABREU 98K	DLPH	E^{ee}_{cm}=161+172 GeV
$0.06^{+0.56}_{-0.50}{}^{+0.12}_{-0.20}$	78	[60] BARATE 98Y	ALEP	E^{ee}_{cm}= 172 GeV

[59] ABREU 98K obtain this result using both W pair production and single W ($W e \nu_e$) production.

[60] BARATE 98Y obtain this value using semileptonic and hadronic decay modes in W pair production.

$\alpha_{B\phi}$

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$0.4^{+0.5}_{-0.8}$ OUR AVERAGE				
$0.22^{+0.66}_{-0.83}\pm0.24$	89	[61] ABREU 98K	DLPH	E^{ee}_{cm}=161+172 GeV
$1.01^{+0.71}_{-1.75}\pm0.33$	78	[62] BARATE 98Y	ALEP	E^{ee}_{cm}= 172 GeV

[61] ABREU 98K obtain this result using both W pair production and single W ($W e \nu_e$) production.

[62] BARATE 98Y obtain this value using semileptonic and hadronic decay modes in W pair production.

$\widetilde{\alpha}_{BW}$

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{0.11^{+0.71}_{-0.88}\pm0.09}$	89	[63] ABREU	98K	DLPH	E^{ee}_{cm}=161+172 GeV

[63] ABREU 98K obtain this result using both W pair production and single W ($We\nu_e$) production.

$\widetilde{\alpha}_{W}$

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{0.19^{+0.28}_{-0.41}\pm0.11}$	89	[64] ABREU	98K	DLPH	E^{ee}_{cm}=161+172 GeV

[64] ABREU 98K obtain this result using both W pair production and single W ($We\nu_e$) production.

W ANOMALOUS MAGNETIC MOMENT ($\Delta\kappa$)

The full magnetic moment is given by $\mu_W = e(1+\kappa+\lambda)/2m_W$. In the Standard Model, at tree level, $\kappa=1$ and $\lambda=0$. Some papers have defined $\Delta\kappa = 1-\kappa$ and assume that $\lambda=0$. Note that the electric quadrupole moment is given by $-e(\kappa-\lambda)/m^2_W$. A description of the parameterization of these moments and additional references can be found in HAGIWARA 87 and BAUR 88. The parameter Λ appearing in the theoretical limits below is a regularization cutoff which roughly corresponds to the energy scale where the structure of the W boson becomes manifest.

VALUE ($e/2m_W$)	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	[65] ABBOTT	98I	D0
	[66] ACCIARRI	98N	L3
	[67] ABE	95G	CDF
	[68] ALITTI	92C	UA2
	[69] SAMUEL	92	THEO
	[70] SAMUEL	91	THEO
	[71] GRIFOLS	88	THEO
	[72] GROTCH	87	THEO
	[73] VANDERBIJ	87	THEO
	[74] GRAU	85	THEO
	[75] SUZUKI	85	THEO
	[76] HERZOG	84	THEO

[65] ABBOTT 98I obtain the 95% CL limits (for Λ=2.0 TeV) $-0.30 < \Delta\kappa < 0.43$ for λ=0 and $-0.20 < \lambda < 0.20$ for $\Delta\kappa$=0 from a simultaneous fit to the three final states $W\gamma$, $WW \rightarrow$ dilepton, and $WW/WZ \rightarrow e\nu_e jj$ obtained from $\overline{p}p$ collisions at $\sqrt{s} = 1.8$ TeV.

[66] ACCIARRI 98N study single W production in e^+e^- interactions at 130, 136, 161, 172, and 183 GeV. Varying freely both couplings, they report $\Delta\kappa_\gamma = 0.06^{+0.27}_{-0.26}$ with 95% CL limits $-0.46 < \Delta\kappa_\gamma < 0.57$ and $\lambda_\gamma = -0.48^{+0.44}_{-0.21}$ with 95% CL limits $-0.86 < \lambda_\gamma < 0.75$. ACCIARRI 98N define $\Delta\kappa$=$\kappa - 1$.

[67] ABE 95G report $-1.3 < \kappa < 3.2$ for λ=0 and $-0.7 < \lambda < 0.7$ for κ=1 in $p\overline{p} \rightarrow e\nu_e\gamma X$ and $\mu\nu_\mu\gamma X$ at $\sqrt{s} = 1.8$ TeV.

[68] ALITTI 92C measure $\kappa = 1^{+2.6}_{-2.2}$ and $\lambda = 0^{+1.7}_{-1.8}$ in $p\overline{p} \rightarrow e\nu\gamma + X$ at $\sqrt{s} = 630$ GeV. At 95%CL they report $-3.5 < \kappa < 5.9$ and $-3.6 < \lambda < 3.5$.

[69] SAMUEL 92 use preliminary CDF and UA2 data and find $-2.4 < \kappa < 3.7$ at 96%CL and $-3.1 < \kappa < 4.2$ at 95%CL respectively. They use data for $W\gamma$ production and radiative W decay.

[70] SAMUEL 91 use preliminary CDF data for $p\overline{p} \rightarrow W\gamma X$ to obtain $-11.3 \leq \Delta\kappa \leq 10.9$. Note that their $\kappa = 1-\Delta\kappa$.

[71] GRIFOLS 88 uses deviation from ρ parameter to set limit $\Delta\kappa \lesssim 65\ (M_W^2/\Lambda^2)$.

[72] GROTCH 87 finds the limit $-37 < \Delta\kappa < 73.5$ (90% CL) from the experimental limits on $e^+e^- \rightarrow \nu\overline{\nu}\gamma$ assuming three neutrino generations and $-19.5 < \Delta\kappa < 56$ for four generations. Note their $\Delta\kappa$ has the opposite sign as our definition.

[73] VANDERBIJ 87 uses existing limits to the photon structure to obtain $|\Delta\kappa| < 33\ (m_W/\Lambda)$. In addition VANDERBIJ 87 discusses problems with using the ρ parameter of the Standard Model to determine $\Delta\kappa$.

[74] GRAU 85 uses the muon anomaly to derive a coupled limit on the anomalous magnetic dipole and electric quadrupole (λ) moments $1.05 > \Delta\kappa\ \ln(\Lambda/m_W) + \lambda/2 > -2.77$. In the Standard Model $\lambda = 0$.

[75] SUZUKI 85 uses partial-wave unitarity at high energies to obtain $|\Delta\kappa| \lesssim 190\ (m_W/\Lambda)^2$. From the anomalous magnetic moment of the muon, SUZUKI 85 obtains $|\Delta\kappa| \lesssim 2.2/\ln(\Lambda/m_W)$. Finally SUZUKI 85 uses deviations from the ρ parameter and obtains a very qualitative, order-of-magnitude limit $|\Delta\kappa| \lesssim 150\ (m_W/\Lambda)^4$ if $|\Delta\kappa| \ll 1$.

[76] HERZOG 84 consider the contribution of W-boson to muon magnetic moment including anomalous coupling of $WW\gamma$. Obtain a limit $-1 < \Delta\kappa < 3$ for $\Lambda \gtrsim 1$ TeV.

W REFERENCES

ABBIENDI	99C	hep-ex/9901025 CERN-EP/98-197, PL B (to be publ.)	G. Abbiendi+	(OPAL Collab.)
ABBIENDI	99D	EPJ C8 191	G. Abbiendi+	(OPAL Collab.)
ACCIARRI	99	CERN-EP/99-17 PL B (submitted)	M. Acciarri+	(L3 Collab.)
BARATE	99	PL B453 121	R. Barate+	(ALEPH Collab.)
ABBOTT	98I	PR D58 031102	B. Abbott+	(D0 Collab.)
ABBOTT	98N	PR D58 092003	B. Abbott+	(D0 Collab.)
ABBOTT	98O	PRL 80 3008	B. Abbott+	(D0 Collab.)
ABBOTT	98P	PR D58 012002	B. Abbott+	(D0 Collab.)
ABE	98H	PR D58 031101	F. Abe+	(CDF Collab.)
ABE	98P	PR D58 091101	F. Abe+	(CDF Collab.)
ABREU	98B	EPJ C2 581	P. Abreu+	(DELPHI Collab.)
ABREU	98C	PL B416 233	P. Abreu+	(DELPHI Collab.)
ABREU	98K	PL B423 194	P. Abreu+	(DELPHI Collab.)
ABREU	98N	PL B439 209	P. Abreu+	(DELPHI Collab.)
ACCIARRI	98N	PL B436 417	M. Acciarri+	(L3 Collab.)
ACCIARRI	98P	PL B436 437	M. Acciarri+	(L3 Collab.)
ACKERSTAFF	98D	EPJ C1 395	K. Ackerstaff+	(OPAL Collab.)
BARATE	98B	PL B422 384	R. Barate+	(ALEPH Collab.)
BARATE	98Y	PL B422 369	R. Barate+	(ALEPH Collab.)
ABREU	97	PL B397 158	+Adam, Adye, Adzic+	(DELPHI Collab.)
ACCIARRI	97	PL B398 223	+Adriani, Aguilar-Benitez, Ahlen+	(L3 Collab.)
ACCIARRI	97M	PL B407 419	M. Acciarri+	(L3 Collab.)
ACCIARRI	97S	PL B413 176	M. Acciarri+	(L3 Collab.)
BARATE	97	PL B401 347	+Buskulic, Decamp, Ghez+	(ALEPH Collab.)
BARATE	97S	PL B415 435	R. Barate+	(ALEPH Collab.)
ABACHI	96E	PRL 77 3309	+Abbott, Abolins, Acharya+	(D0 Collab.)
ACKERSTAFF	96B	PL B389 416	+Alexander, Allison, Altekamp+	(OPAL Collab.)
AID	96D	PL B379 319	+Andreev, Andrieu, Appuhn+	(H1 Collab.)
ABACHI	95D	PRL 75 1456	+Abbott, Abolins, Acharya+	(D0 Collab.)
ABE	95C	PRL 74 341	+Albrow, Amidei, Antos, Anway-Wiese+	(CDF Collab.)
ABE	95G	PRL 74 1936	+Albrow, Amidei, Antos+	(CDF Collab.)
ABE	95P	PRL 75 11	+Albrow, Amidei, Antos, Anway-Wiese+	(CDF Collab.)
Also	95Q	PR D52 4784	Abe, Albrow, Amidei, Antos, Anway-Wiese+	(CDF Collab.)
ABE	95W	PR D52 2624	+Albrow, Amendolia, Amidei, Antos+	(CDF Collab.)
Also	94B	PRL 73 220	Abe, Albrow, Amidei, Anway-Wiese+	(CDF Collab.)

ABE	94B	PRL 73 220	+Albrow, Amidei, Anway-Wiese+	(CDF Collab.)
ROSNER	94	PR D49 1363	+Worah, Takeuchi	(EFI, FNAL)
ABE	92E	PRL 68 3398	+Amidei, Apollinari, Atac+	(CDF Collab.)
ABE	92I	PRL 69 28	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ALITTI	92	PL B276 365	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92B	PL B276 354	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92C	PL B277 194	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92D	PL B277 203	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92F	PL B280 137	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP Collabs.)
SAMUEL	92	PL B280 124	+Li, Sinha, Sinha, Sundaresan	(OKSU, CARL)
ABE	91C	PR D44 29	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ALBAJAR	91	PL B253 503	+Albrow, Allkofer, Ankoviak, Apsimon+	(UA1 Collab.)
ALITTI	91C	ZPHY C52 209	+Ambrosini, Ansari, Autiero+	(UA2 Collab.)
SAMUEL	91	PRL 67 9	+Li, Sinha, Sinha, Sundaresan	(OKSU, CARL)
Also	91C	PRL 67 2920 erratum		
ABE	90	PRL 64 152	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
Also	91C	PR D44 29	Abe, Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	90G	PRL 65 2243	+Amidei, Apollinari, Atac+	(CDF Collab.)
Also	91B	PR D43 2070	Abe, Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ALBAJAR	90	PL B241 283	+Albrow, Allkofer+	(UA1 Collab.)
ALITTI	90B	PL B241 150	+Ansari, Ansorge, Autiero+	(UA2 Collab.)
ALITTI	90C	ZPHY C47 11	+Ansari, Ansorge, Bagnaia+	(UA2 Collab.)
ABE	89I	PRL 62 1005	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
BAUR	88	NP B308 127	+Zeppenfeld	(FSU, WISC)
GRIFOLS	88	IJMP A3 225	+Peris, Sola	(BARC, DESY)
Also	87	PL B197 437	Grifols, Peris, Sola	(BARC, DESY)
ALBAJAR	87	PL B185 233	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
ANSARI	87	PL B186 440	+Bagnaia, Banner, Battiston+	(UA2 Collab.)
ANSARI	87C	PL B194 158	+Bagnaia, Banner, Battiston+	(UA2 Collab.)
GROTCH	87	PR D36 2153	+Robinett	(PSU)
HAGIWARA	87	NP B282 253	+Peccei, Zeppenfeld, Hikasa	(KEK, UCLA, FSU)
VANDERBIJ	87	PR D35 1088	van der Bij	(FNAL)
APPEL	86	ZPHY C30 1	+Bagnaia, Banner, Battiston+	(UA2 Collab.)
ARNISON	86	PL 166B 484	+Albrow, Allkofer, Astbury+	(UA1 Collab.) J
ALTARELLI	85B	ZPHY C27 617	+Ellis, Martinelli	(CERN, FNAL, FRAS)
GRAU	85	PL 154B 283	+Grifols	(BARC)
SUZUKI	85	PL 153B 289		(LBL)
ARNISON	84D	PL 134B 469	+Astbury, Aubert, Bacci+	(UA1 Collab.)
HERZOG	84	PL 148B 355		(WISC)
Also	84B	PL 155B 468 erratum	Herzog	(WISC)
ARNISON	83	PL 122B 103	+Astbury, Aubert, Bacci+	(UA1 Collab.)
BANNER	83B	PL 122B 476	+Battiston, Bloch, Bonaudi+	(UA2 Collab.)