Z

$J = 1$

THE Z BOSON

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Precision measurements at the Z-boson resonance using electron–positron colliding beams began in 1989 at the SLC and at LEP. During 1989–95, the four CERN experiments have made high-statistics studies of the Z. The availability of longitudinally polarized electron beams at the SLC since 1993 has enabled a precision determination of the effective electroweak mixing angle $\sin^2\overline{\theta}_W$ that is competitive with the CERN results on this parameter.

The Z-boson properties reported in this section may broadly be categorized as:

- The standard 'lineshape' parameters of the Z consisting of its mass, M_Z, its total width, Γ_Z, and its partial decay widths, Γ(hadrons), and $\Gamma(\ell\overline{\ell})$ where $\ell = e, \mu, \tau, \nu$;
- Z asymmetries in leptonic decays and extraction of Z couplings to charged and neutral leptons;
- The b- and c-quark-related partial widths and charge asymmetries which require special techniques;
- Determination of Z decay modes and the search for modes that violate known conservation laws;
- Average particle multiplicities in hadronic Z decay;
- Z anomalous couplings.

Details on Z-parameter determination and the study of $Z \to b\overline{b}, c\overline{c}$ at LEP and SLC are given in this note.

The standard 'lineshape' parameters of the Z are determined from an analysis of the production cross sections of these final states in e^+e^- collisions. The $Z \to \nu\overline{\nu}(\gamma)$ state is identified directly by detecting single photon production and indirectly by subtracting the visible partial widths from the total width. Inclusion in this analysis of the forward-backward asymmetry of charged leptons, $A_{FB}^{(0,\ell)}$, of the τ polarization, $P(\tau)$, and its forward-backward asymmetry, $P(\tau)^{fb}$, enables the separate determination of the effective vector ($\overline{g}_V$) and axial vector ($\overline{g}_A$) couplings of the Z to these leptons and the ratio ($\overline{g}_V/\overline{g}_A$) which is related to the effective electroweak mixing angle $\sin^2\overline{\theta}_W$ (see the "Electroweak Model and Constraints on New Physics" Review).

Determination of the b- and c-quark-related partial widths and charge asymmetries involves tagging the b and c quarks. Traditionally this was done by requiring the presence of a prompt lepton in the event with high momentum and high transverse momentum (with respect to the accompanying jet). Precision vertex measurement with high-resolution detectors enabled one to do impact parameter and lifetime tagging. Neural-network techniques have also been used to classify events as b or non-b on a statistical basis using event–shape variables. Finally, the presence of a charmed meson (D/D^*) has been used to tag heavy quarks.

Z-parameter determination

LEP was run at energy points on and around the Z mass (88–94 GeV) constituting an energy 'scan.' The shape of the cross-section variation around the Z peak can be described by a Breit-Wigner *ansatz* with an energy-dependent total width [1–3]. The **three** main properties of this distribution, viz., the **position** of the peak, the **width** of the distribution, and the **height** of the peak, determine respectively the values of M_Z, Γ_Z, and $\Gamma(e^+e^-) \times \Gamma(f\overline{f})$, where $\Gamma(e^+e^-)$ and $\Gamma(f\overline{f})$ are the electron and fermion partial widths of the Z. The quantitative determination of these parameters is done by writing analytic expressions for these cross sections in terms of the parameters and fitting the calculated cross sections to the measured ones by varying these parameters, taking properly into account all the errors. Single-photon exchange (σ^0_γ) and γ-Z interference ($\sigma^0_{\gamma Z}$) are included, and the large ($\sim$25 %) initial-state radiation (ISR) effects are taken into account by convoluting the analytic expressions over a 'Radiator Function' [1–6] $H(s,s')$. Thus for the process $e^+e^- \rightarrow f\overline{f}$:

$$\sigma_f(s) = \int H(s,s')\ \sigma^0_f(s')\ ds' \tag{1}$$

$$\sigma^0_f(s) = \sigma^0_Z + \sigma^0_\gamma + \sigma^0_{\gamma Z} \tag{2}$$

$$\sigma^0_Z = \frac{12\pi}{M_Z^2}\ \frac{\Gamma(e^+e^-)\Gamma(f\overline{f})}{\Gamma_Z^2}\ \frac{s\ \Gamma_Z^2}{(s-M_Z^2)^2\ +\ s^2\Gamma_Z^2/M_Z^2} \tag{3}$$

$$\sigma^0_\gamma = \frac{4\pi\alpha^2(s)}{3s}\ Q_f^2 N_c^f \tag{4}$$

$$\begin{aligned}\sigma^0_{\gamma Z} = & -\frac{2\sqrt{2}\alpha(s)}{3}\ (Q_f G_F N_c^f \mathcal{G}_{Ve}\mathcal{G}_{Vf}) \\ & \times \frac{(s-M_Z^2)M_Z^2}{(s-M_Z^2)^2 + s^2\Gamma_Z^2/M_Z^2}\end{aligned} \tag{5}$$

where Q_f is the charge of the fermion, $N_c^f = 3(1)$ for quark (lepton) and $\mathcal{G}_{Vf}$ is the neutral vector coupling of the Z to the fermion-antifermion pair $f\overline{f}$.

Since $\sigma^0_{\gamma Z}$ is expected to be much less than σ^0_Z, the LEP Collaborations have generally calculated the interference term in the framework of the Standard Model. This fixing of $\sigma^0_{\gamma Z}$ leads to a tighter constraint on M_Z and consequently a smaller error on its fitted value.

In the above framework, the QED radiative corrections have been explicitly taken into account by convoluting over the ISR and allowing the electromagnetic coupling constant to run [10]: $\alpha(s) = \alpha/(1-\Delta\alpha)$. On the other hand, weak radiative corrections that depend upon the assumptions of the electroweak theory and on the values of the unknown M_{top} and M_{Higgs} are accounted for by **absorbing them into the couplings**, which are then called the *effective* couplings $\mathcal{G}_V$ and $\mathcal{G}_A$ (or alternatively the effective parameters of the $\star$ scheme of Kennedy and Lynn [11]).

$\mathcal{G}_{Vf}$ and $\mathcal{G}_{Af}$ are complex numbers with a small imaginary part. As experimental data does not allow simultaneous extraction of both real and imaginary parts of the effective couplings, the convention $g_{Af} = \text{Re}(\mathcal{G}_{Af})$ and $g_{Vf} = \text{Re}(\mathcal{G}_{Vf})$ is used and the imaginary parts are added in the fitting code [4].

Defining

$$A_f = 2\frac{g_{Vf}\cdot g_{Af}}{(g^2_{Vf}+g^2_{Af})} \tag{6}$$

the lowest-order expressions for the various lepton-related asymmetries on the Z pole are [7–9] $A^{(0,\ell)}_{FB} = (3/4)A_e A_f$, $P(\tau) = -A_\tau$, $P(\tau)^{fb} = -(3/4)A_e$, $A_{LR} = A_e$. The full analysis takes into account the energy dependence of the asymmetries. Experimentally A_{LR} is defined as $(\sigma_L - \sigma_R)/(\sigma_L + \sigma_R)$ where $\sigma_{L(R)}$ are the $e^+e^- \rightarrow Z$ production cross sections with left-(right)-handed electrons.

The definition of the partial decay width of the Z to $f\overline{f}$ includes the effects of QED and QCD final state corrections as well as the contribution due to the imaginary parts of the couplings:

$$\Gamma(f\overline{f}) = \frac{G_F M_Z^3}{6\sqrt{2}\pi} \; N_c^f (\left|\mathcal{G}_{Vf}\right|^2 R_A^f + \left|\mathcal{G}_{VA}\right|^2 R_V^f) + \Delta_{ew/\mathrm{QCD}} \quad (7)$$

where R_V^f and R_A^f are radiator factors to account for final state QED and QCD corrections as well as effects due to nonzero fermion masses, and $\Delta_{ew/\mathrm{QCD}}$ represents the non-factorizable electroweak/QCD corrections.

S-matrix approach to the Z

While practically all experimental analyses of LEP/SLC data have followed the 'Breit-Wigner' approach described above, an alternative S-matrix-based analysis is also possible. The Z, like all unstable particles, is associated with a complex pole in the S matrix. The pole position is process independent and gauge invariant. The mass, $\overline{M}_Z$, and width, $\overline{\Gamma}_Z$, can be defined in terms of the pole in the energy plane via [12–15]

$$\overline{s} = \overline{M}_Z^2 - i\overline{M}_Z\overline{\Gamma}_Z \quad (8)$$

leading to the relations

$$\begin{aligned} \overline{M}_Z &= M_Z/\sqrt{1+\Gamma_Z^2/M_Z^2} \\ &\approx M_Z \; - 34.1 \text{ MeV} \quad (9) \\ \overline{\Gamma}_Z &= \Gamma_Z/\sqrt{1+\Gamma_Z^2/M_Z^2} \\ &\approx \Gamma_Z \; - 0.9 \text{ MeV} \; . \quad (10) \end{aligned}$$

Some authors [16] choose to define the Z mass and width via

$$\overline{s} = (\overline{M}_Z - \frac{i}{2}\overline{\Gamma}_Z)^2 \quad (11)$$

which yields $\overline{M}_Z \approx M_Z - 26$ MeV, $\overline{\Gamma}_Z \approx \Gamma_Z - 1.2$ MeV.

The L3 and OPAL Collaborations at LEP (ACCIARRI 97K and ACKERSTAFF 97C) have analyzed their data using the S–matrix approach as defined in Eq. (8), in addition to the conventional one. They observe a downward shift in the Z mass as expected.

Handling the large-angle e^+e^- final state

Unlike other $f\overline{f}$ decay final states of the Z, the e^+e^- final state has a contribution not only from the s-channel but also from the t-channel and s-t interference. The full amplitude is not amenable to fast calculation, which is essential if one has to carry out minimization fits within reasonable computer time. The usual procedure is to calculate the non-s channel part of the cross section separately using the Standard Model programs ALIBABA [17] or TOPAZ0 [18] with the measured value of M_{top}, and $M_{\text{Higgs}} = 150$ GeV and add it to the s-channel cross section calculated as for other channels. This leads to two additional sources of error in the analysis: firstly, the theoretical calculation in ALIBABA itself is known to be accurate to $\sim 0.5\%$, and secondly, there is uncertainty due to the error on M_{top} and the unknown value of M_{Higgs} (100–1000 GeV). These additional errors are propagated into the analysis by including them in the systematic error on the e^+e^- final state. As these errors are common to the four LEP experiments, this is taken into account when performing the LEP average.

Errors due to uncertainty in LEP energy determination [19–23]

The systematic errors related to the LEP energy measurement can be classified as:

- The absolute energy scale error;
- Energy-point-to-energy-point errors due to the nonlinear response of the magnets to the exciting currents;
- Energy-point-to-energy-point errors due to possible higher-order effects in the relationship between the dipole field and beam energy;
- Energy reproducibility errors due to various unknown uncertainties in temperatures, tidal effects, corrector settings, RF status, *etc.*

Precise energy calibration was done outside normal data taking using the resonant depolarization technique. Run-time energies were determined every 10 minutes by measuring the relevant machine parameters and using a model which takes into account all the known effects, including leakage currents produced by trains in the Geneva area and the tidal effects due to gravitational forces of the Sun and the Moon. The LEP Energy Working Group has provided a covariance matrix from the determination of LEP energies for the different running periods during 1993–1995 [5].

Choice of fit parameters

The LEP Collaborations have chosen the following primary set of parameters for fitting: M_Z, Γ_Z, σ^0_{hadron}, $R(\text{lepton})$, $A^{(0,\ell)}_{FB}$, where $R(\text{lepton}) = \Gamma(\text{hadrons})/\Gamma(\text{lepton})$, $\sigma^0_{\text{hadron}} = 12\pi\Gamma(e^+e^-)\Gamma(\text{hadrons})/M^2_Z\Gamma^2_Z$. With a knowledge of these fitted parameters and their covariance matrix, any other parameter can be derived. The main advantage of these parameters is that they form the **least correlated** set of parameters, so that it becomes easy to combine results from the different LEP experiments.

Thus, the most general fit carried out to cross section and asymmetry data determines the **nine parameters**: M_Z, Γ_Z, σ^0_{hadron}, $R(e)$, $R(\mu)$, $R(\tau)$, $A^{(0,e)}_{FB}$, $A^{(0,\mu)}_{FB}$, $A^{(0,\tau)}_{FB}$. Assumption of lepton universality leads to a **five-parameter fit** determining M_Z, Γ_Z, σ^0_{hadron}, $R(\text{lepton})$, $A^{(0,\ell)}_{FB}$. The use of **only** cross-section data leads to six- or four-parameter fits if lepton universality is or is not assumed, *i.e.*, $A^{(0,\ell)}_{FB}$ values are not determined.

In order to determine the best values of the effective vector and axial vector couplings of the charged leptons to the Z, the above mentioned nine- and five-parameter fits are carried out with added constraints from the measured values of A_τ and A_e obtained from τ polarization studies at LEP and the determination of A_{LR} at SLC.

Combining results from the LEP and SLC experiments [24]

Each LEP experiment provides the values of the parameters mentioned above together with the full covariance matrix. The statistical and experimental systematic errors are assumed to be uncorrelated among the four experiments. The sources of **common** systematic errors are i) the LEP energy uncertainties, ii) the effect of theoretical uncertainty in calculating the small-angle Bhabha cross section for luminosity determination and in estimating the non-s channel contribution to the large-angle Bhabha cross section, and iii) common theory errors. Using this information, a full covariance matrix, V, of all the input parameters is constructed and a combined parameter set is obtained by minimizing $\chi^2 = \Delta^T V^{-1} \Delta$, where Δ is the vector of residuals of the combined parameter set to the results of individual experiments.

Non-LEP measurement of a Z parameter, (*e.g.,* $\Gamma(e^+e^-)$ from SLD) is included in the overall fit by calculating its value using the fit parameters and constraining it to the measurement.

Study of $Z \to b\overline{b}$ and $Z \to c\overline{c}$

In the sector of c- and b-physics the LEP experiments have measured the ratios of partial widths $R_b = \Gamma(Z \to b\overline{b})/\Gamma(Z \to \text{hadrons})$ and $R_c = \Gamma(Z \to c\overline{c})/\Gamma(Z \to \text{hadrons})$ and the forward-backward (charge) asymmetries $A_{FB}^{b\overline{b}}$ and $A_{FB}^{c\overline{c}}$. Several of the analyses have also determined other quantities, in particular the semileptonic branching ratios, $\mathrm{B}(b \to \ell)$, $\mathrm{B}(b \to c \to \ell^+)$, and $\mathrm{B}(c \to \ell)$, the average $B^0\overline{B}^0$ mixing parameter $\overline{\chi}$ and the probabilities for a c–quark to fragment into a D^+, a D_s, a D^{*+} , or a charmed baryon. The latter measurements do not concern properties of the Z boson and hence they do not appear in the listing below. However, for completeness, we will report at the end of this minireview their values as obtained fitting the data contained in the Z section. All these quantities are correlated with the electroweak parameters, and since the mixture of b hadrons is different from the one at the $\Upsilon(4S)$, their values might differ from those measured at the $\Upsilon(4S)$.

All the above quantities are correlated to each other since:

- Several analyses (for example the lepton fits) determine more than one parameter simultaneously;
- Some of the electroweak parameters depend explicitly on the values of other parameters (for example R_b depends on R_c);
- Common tagging and analysis techniques produce common systematic uncertainties.

The LEP Electroweak Heavy Flavour Working Group has developed [25] a procedure for combining the measurements taking into account known sources of correlation. The combining procedure determines twelve parameters: the four parameters of interest in the electroweak sector, R_b, R_c, $A_{FB}^{b\overline{b}}$, and $A_{FB}^{c\overline{c}}$ and, in addition, $\mathrm{B}(b \to \ell)$, $\mathrm{B}(b \to c \to \ell^+)$, $\mathrm{B}(c \to \ell)$, $\overline{\chi}$, $f(D^+)$, $f(D_s)$, $f(c_{\text{baryon}})$ and $P(c \to D^{*+}) \times \mathrm{B}(D^{*+} \to \pi^+ D^0)$, to take into account their correlations with the electroweak parameters. Before the fit both the peak and off-peak asymmetries are translated to the common energy $\sqrt{s} = 91.26$ GeV using the predicted dependence from ZFITTER [6].

Summary of the measurements and of the various kinds of analysis

The measurements of R_b and R_c fall into two classes. In the first, named single-tag measurement, a method for selecting b and c events is applied and the number of tagged events is counted. The second technique, named double-tag measurement, is based on the following principle: if the number of events with a single hemisphere tagged is N_t and with both hemispheres tagged is N_{tt}, then given a total number of $N_{\rm had}$ hadronic Z decays one has:

$$\frac{N_t}{2N_{\rm had}} = \varepsilon_b R_b + \varepsilon_c R_c + \varepsilon_{uds}(1 - R_b - R_c) \tag{12}$$

$$\frac{N_{tt}}{N_{\rm had}} = \mathcal{C}_b \varepsilon_b^2 R_b + \mathcal{C}_c \varepsilon_c^2 R_c + \mathcal{C}_{uds} \varepsilon_{uds}^2 (1 - R_b - R_c) \tag{13}$$

where ε_b, ε_c, and ε_{uds} are the tagging efficiencies per hemisphere for b, c, and light quark events, and $\mathcal{C}_q \neq 1$ accounts for the fact that the tagging efficiencies between the hemispheres may be correlated. In tagging the b one has $\varepsilon_b \gg \varepsilon_c \gg \varepsilon_{uds}$, $C_b \approx 1$. Neglecting the c and uds background and the hemisphere correlations, these equations give:

$$\varepsilon_b = 2N_{tt}/N_t \tag{14}$$

$$R_b = N_t^2/(4N_{tt}N_{\rm had}) \ . \tag{15}$$

The double-tagging method has thus the great advantage that the tagging efficiency is directly derived from the data, reducing the systematic error of the measurement. The backgrounds, dominated by $c\overline{c}$ events, obviously complicate this simple picture, and their level must still be inferred by other means. The rate of charm background in these analyses depends explicitly on the value of R_c. The correlations in the tagging efficiencies between the hemispheres (due for instance to correlations in momentum between the b hadrons in the two hemispheres) are small but nevertheless lead to further systematic uncertainties.

The measurements in the b- and c-sector can be essentially grouped in the following categories:

- Lifetime (and lepton) double-tagging measurements of R_b. These are the most precise measurements of R_b and obviously dominate the combined result. The main sources of systematics come from the charm contamination and from estimating the hemisphere b-tagging efficiency correlation. The charm rejection has been improved (and hence the systematic errors reduced) by using either the information of the secondary vertex invariant mass or the information from the energy of all particles at the secondary vertex and their rapidity;
- Analyses with $D/D^{*\pm}$ to measure R_c. These measurements make use of several different tagging techniques (inclusive/exclusive double tag, exclusive double tag, reconstruction of all weakly decaying charmed states) and no assumptions are made on the energy dependence of charm fragmentation;
- Lepton fits which use hadronic events with one or more leptons in the final state to measure $A_{FB}^{b\overline{b}}$ and $A_{FB}^{c\overline{c}}$. Each analysis usually gives several other electroweak parameters. The dominant sources of systematics are due to lepton identification, to other semileptonic branching ratios and to the modeling of the semileptonic decay;
- Measurements of $A_{FB}^{b\overline{b}}$ using lifetime tagged events with a hemisphere charge measurement. Their contribution to the combined result has roughly the same weight as the lepton fits;

- Analyses with $D/D^{*\pm}$ to measure $A_{FB}^{c\overline{c}}$ or simultaneously $A_{FB}^{b\overline{b}}$ and $A_{FB}^{c\overline{c}}$;
- Measurements of A_b and A_c from SLD, using several tagging methods (lepton, kaon, D/D^*, and vertex mass). These quantities are directly extracted from a measurement of the left–right forward–backward asymmetry in $c\overline{c}$ and $b\overline{b}$ production using a polarized electron beam.

Averaging procedure

All the measurements are provided by the LEP Collaborations in the form of tables with a detailed breakdown of the systematic errors of each measurement and its dependence on other electroweak parameters.

The averaging proceeds via the following steps:

- Define and propagate a consistent set of external inputs such as branching ratios, hadron lifetimes, fragmentation models *etc.* All the measurements are also consistently checked to ensure that all use a common set of assumptions (for instance since the QCD corrections for the forward–backward asymmetries are strongly dependent on the experimental conditions, the data are corrected before combining);
- Form the full (statistical and systematic) covariance matrix of the measurements. The systematic correlations between different analyses are calculated from the detailed error breakdown in the measurement tables. The correlations relating several measurements made by the same analysis are also used;

- Take into account any explicit dependence of a measurement on the other electroweak parameters. As an example of this dependence we illustrate the case of the double-tag measurement of R_b, where c-quarks constitute the main background. The normalization of the charm contribution is not usually fixed by the data and the measurement of R_b depends on the assumed value of R_c, which can be written as:

$$R_b = R_b^{\text{meas}} + a(R_c)\frac{(R_c - R_c^{\text{used}})}{R_c} \ , \tag{16}$$

  where R_b^{meas} is the result of the analysis which assumed a value of $R_c = R_c^{\text{used}}$ and $a(R_c)$ is the constant which gives the dependence on R_c;
- Perform a χ^2 minimization with respect to the combined electroweak parameters.

After the fit the average peak asymmetries $A_{FB}^{c\overline{c}}$ and $A_{FB}^{b\overline{b}}$ are corrected for the energy shift from 91.26 GeV to M_Z and for QED (initial state radiation), γ exchange, and γZ interference effects to obtain the corresponding pole asymmetries $A_{FB}^{0,c}$ and $A_{FB}^{0,b}$.

This averaging procedure, using the twelve parameters described above and applied to the data contained in the Z particle listing below, gives the following results:

$$\begin{aligned} R_b^0 &= 0.21644 \pm 0.00075 \\ R_c^0 &= 0.1671 \pm 0.0048 \\ A_{FB}^{0,b} &= 0.1003 \pm 0.0022 \\ A_{FB}^{0,c} &= 0.0701 \pm 0.0045 \end{aligned}$$

$$B(b \to \ell) = 0.1056 \pm 0.0026$$

$$\mathrm{B}(b \to c \to \ell^+) = 0.0807 \pm 0.0034$$

$$B(c \to \ell) = 0.0990 \pm 0.0037$$

$$\overline{\chi} = 0.1177 \pm 0.0055$$

$$f(D^+) = 0.239 \pm 0.016$$

$$f(D_s) = 0.116 \pm 0.025$$

$$f(c_{\mathrm{baryon}}) = 0.084 \pm 0.023$$

$$P(c \to D^{*+}) \times \mathrm{B}(D^{*+} \to \pi^+ D^0) = 0.1657 \pm 0.0057$$

References

1. R.N. Cahn, Phys. Rev. **D36**, 2666 (1987).
2. F.A. Berends *et al.*, "*Z* Physics at LEP 1", CERN Report 89-08 (1989), Vol. 1, eds. G. Altarelli, R. Kleiss, and C. Verzegnassi, p. 89.
3. A. Borrelli *et al.*, Nucl. Phys. **B333**, 357 (1990).
4. D. Bardin and G. Passarino, "Upgrading of Precision Calculations for Electroweak Observables," `hep-ph/9803425`; D. Bardin, G. Passarino, and M. Grünewald, "Precision Calculation Project Report," `hep-ph/9902452`.
5. R. Billen *et al.* (Working Group on LEP Energy), Eur. Phys. J. **C6**, 187 (1999).
6. D. Bardin *et al.*, Nucl. Phys. **B351**, 1 (1991).
7. M. Consoli *et al.*, "*Z* Physics at LEP 1", CERN Report 89-08 (1989), Vol. 1, eds. G. Altarelli, R. Kleiss, and C. Verzegnassi, p. 7.
8. M. Bohm *et al.*, *ibid*, p. 203.
9. S. Jadach *et al.*, *ibid*, p. 235.
10. G. Burgers *et al.*, *ibid*, p. 55.

11. D.C. Kennedy and B.W. Lynn, SLAC-PUB 4039 (1986, revised 1988).
12. R. Stuart, Phys. Lett. **B262**, 113 (1991).
13. A. Sirlin, Phys. Rev. Lett. **67**, 2127 (1991).
14. A. Leike, T. Riemann, and J. Rose, Phys. Lett. **B273**, 513 (1991).
15. See also D. Bardin *et al.*, Phys. Lett. **B206**, 539 (1988).
16. S. Willenbrock and G. Valencia, Phys. Lett. **B259**, 373 (1991).
17. W. Beenakker, F.A. Berends, and S.C. van der Marck, Nucl. Phys. **B349**, 323 (1991).
18. K. Miyabayashi *et al.* (TOPAZ Collaboration) Phys. Lett. **B347**, 171 (1995).
19. R. Assmann *et al.* (Working Group on LEP Energy), Z. Phys. **C66**, 567 (1995).
20. L. Arnaudon *et al.* (Working Group on LEP Energy and LEP Collaborations), Phys. Lett. **B307**, 187 (1993).
21. L. Arnaudon *et al.* (Working Group on LEP Energy), CERN-PPE/92-125 (1992).
22. L. Arnaudon *et al.*, Phys. Lett. **B284**, 431 (1992).
23. R. Bailey *et al.*, 'LEP Energy Calibration' CERN-SL 90-95.
24. The LEP Collaborations: ALEPH, DELPHI, L3, OPAL, the LEP Electroweak Working Group, and the SLD Heavy Flavour Group:
    CERN-EP/2000-016 (1999); CERN-EP/99-15 (1998);
    CERN-PPE/97-154 (1997); CERN-PPE/96-183 (1996);
    CERN-PPE/95-172 (1995); CERN-PPE/94-187 (1994);
    CERN-PPE/93-157 (1993).
25. The LEP Experiments: ALEPH, DELPHI, L3, and OPAL Nucl. Instrum. Methods **A378**, 101 (1996).

Z MASS

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the *Z* boson"). The fit is performed using the *Z* mass and width, the *Z* hadronic pole cross section, the ratios of hadronic to leptonic partial widths, and the *Z* pole forward-backward lepton asymmetries. This set is believed to be most free of correlations.

The *Z*-boson mass listed here corresponds to a Breit-Wigner resonance parameter. The value is 34 MeV greater than the real part of the position of the pole (in the energy-squared plane) in the *Z*-boson propagator. Also the LEP experiments have generally assumed a fixed value of the $\gamma - Z$ interferences term based on the standard model. Keeping this term as free parameter leads to a somewhat larger error on the fitted *Z* mass. See ACCIARRI 97K and ACKERSTAFF 97C for a detailed investigation of both these issues.

VALUE (GeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
91.1882±0.0022 OUR FIT				
91.1863±0.0028	4.08M	[1] ABREU 00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
91.1898±0.0031	3.96M	[2] ACCIARRI 00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
91.1885±0.0031	4.57M	[3] BARATE 00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
91.193 ±0.010	1.2M	[4] ACCIARRI 97K	L3	$E^{ee}_{\rm cm}$= LEP1 + 130–136 GeV + 161–172 GeV
91.185 ±0.010		[5] ACKERSTAFF 97C	OPAL	$E^{ee}_{\rm cm}$= LEP1 + 130–136 GeV + 161 GeV
91.162 ±0.011	1.2M	[6] ACCIARRI 96B	L3	Repl. by ACCIARRI 97K
91.192 ±0.011	1.33M	[7] ALEXANDER 96X	OPAL	Repl. by ACKERSTAFF 97C
91.151 ±0.008		[8] MIYABAYASHI 95	TOPZ	$E^{ee}_{\rm cm}$= 57.8 GeV
91.187 ±0.007 ±0.006	1.16M	[9] ABREU 94	DLPH	Repl. by ABREU 00F
91.195 ±0.006 ±0.007	1.19M	[9] ACCIARRI 94	L3	Repl. by ACCIARRI 00C
91.182 ±0.007 ±0.006	1.33M	[9] AKERS 94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
91.187 ±0.007 ±0.006	1.27M	[9] BUSKULIC 94	ALEP	Repl. by BARATE 00C
91.74 ±0.28 ±0.93	156	[10] ALITTI 92B	UA2	$E^{p\overline{p}}_{\rm cm}$= 630 GeV
89.2 $^{+2.1}_{-1.8}$		[11] ADACHI 90F	RVUE	
90.9 ±0.3 ±0.2	188	[12] ABE 89C	CDF	$E^{p\overline{p}}_{\rm cm}$= 1.8 TeV
91.14 ±0.12	480	[13] ABRAMS 89B	MRK2	$E^{ee}_{\rm cm}$= 89–93 GeV
93.1 ±1.0 ±3.0	24	[14] ALBAJAR 89	UA1	$E^{p\overline{p}}_{\rm cm}$= 546,630 GeV

[1] The error includes 1.6 MeV due to LEP energy uncertainty.

[2] The error includes 1.8 MeV due to LEP energy uncertainty.

[3] BARATE 00C error includes approximately 2.4 MeV due to statistics, 0.2 MeV due to experimental systematics, and 1.7 MeV due to LEP energy uncertainty.

[4] ACCIARRI 97K interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix formalism with a combined fit

to their cross section and asymmetry data at the Z peak (ACCIARRI 94) and their data at 130, 136, 161, and 172 GeV. The authors have corrected the measurement for the 34.1 MeV shift with respect to the Breit-Wigner fits. The error contains a contribution of ±3 MeV due to the uncertainty on the γZ interference.

[5] ACKERSTAFF 97C obtain this using the S-matrix formalism for a combined fit to their cross-section and asymmetry data at the Z peak (AKERS 94) and their data at 130, 136, and 161 GeV. The authors have corrected the measurement for the 34 MeV shift with respect to the Breit-Wigner fits.

[6] ACCIARRI 96B interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix ansatz. The 130–136 GeV data constrains the γZ interference terms. As expected, this result is below the mass values obtained with a standard Breit-Wigner parametrization.

[7] ALEXANDER 96X obtain this using the S-matrix formalism for a combined fit to their cross-section and asymmetry data at the Z peak (AKERS 94) and their data at 130 and 136 GeV. The authors have corrected the measurement for the 34 MeV shift with respect to the Breit-Wigner fits.

[8] MIYABAYASHI 95 combine their low energy total hadronic cross-section measurement with the ACTON 93D data and perform a fit using an S-matrix formalism. As expected, this result is below the mass values obtained with the standard Breit-Wigner parametrization.

[9] The second error of 6.3 MeV is due to a common LEP energy uncertainty.

[10] Enters fit through W/Z mass ratio given in the W Particle Listings. The ALITTI 92B systematic error (±0.93) has two contributions: one (±0.92) cancels in m_W/m_Z and one (±0.12) is noncancelling. These were added in quadrature.

[11] ADACHI 90F use a Breit-Wigner resonance shape fit and combine their results with published data of PEP and PETRA.

[12] First error of ABE 89 is combination of statistical and systematic contributions; second is mass scale uncertainty.

[13] ABRAMS 89B uncertainty includes 35 MeV due to the absolute energy measurement.

[14] ALBAJAR 89 result is from a total sample of 33 $Z \rightarrow e^+ e^-$ events.

Z WIDTH

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson").

VALUE (GeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.4952±0.0026 OUR FIT				
2.4876±0.0041	4.08M	[15] ABREU 00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
2.5024±0.0042	3.96M	[16] ACCIARRI 00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
2.4951±0.0043	4.57M	[17] BARATE 00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.494 ±0.010	1.2M	[18] ACCIARRI 97K	L3	$E^{ee}_{\rm cm}$= LEP1 + 130–136 GeV + 161–172 GeV
2.50 ±0.21 ±0.06		[19] ABREU 96R	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
2.492 ±0.010	1.2M	[20] ACCIARRI 96B	L3	Repl. by ACCIARRI 97K
2.483 ±0.011 ±0.0045	1.16M	[21] ABREU 94	DLPH	Repl. by ABREU 00F
2.494 ±0.009 ±0.0045	1.19M	[21] ACCIARRI 94	L3	Repl. by ACCIARRI 00C
2.483 ±0.011 ±0.0045	1.33M	[21] AKERS 94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV

2.501	± 0.011	± 0.0045	1.27M	[21] BUSKULIC	94	ALEP	Repl. by BARATE 00C
3.8	± 0.8	± 1.0	188	ABE	89C	CDF	$E^{p\overline{p}}_{\mathrm{cm}}$= 1.8 TeV
2.42	$^{+0.45}_{-0.35}$		480	[22] ABRAMS	89B	MRK2	E^{ee}_{cm}= 89–93 GeV
2.7	$^{+1.2}_{-1.0}$	± 1.3	24	[23] ALBAJAR	89	UA1	$E^{p\overline{p}}_{\mathrm{cm}}$= 546,630 GeV
2.7	± 2.0	± 1.0	25	[24] ANSARI	87	UA2	$E^{p\overline{p}}_{\mathrm{cm}}$= 546,630 GeV

[15] The error includes 1.2 MeV due to LEP energy uncertainty.

[16] The error includes 1.3 MeV due to LEP energy uncertainty.

[17] BARATE 00C error includes approximately 3.8 MeV due to statistics, 0.9 MeV due to experimental systematics, and 1.3 MeV due to LEP energy uncertainty.

[18] ACCIARRI 97K interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix formalism with a combined fit to their cross section and asymmetry data at the Z peak (ACCIARRI 94) and their data at 130, 136, 161, and 172 GeV. The authors have corrected the measurement for the 0.9 MeV shift with respect to the Breit-Wigner fits.

[19] ABREU 96R obtain this value from a study of the interference between initial and final state radiation in the process $e^+ e^- \to Z \to \mu^+ \mu^-$.

[20] ACCIARRI 96B interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix ansatz. The 130–136 GeV data constrains the γZ interference terms. The fitted width is expected to be 0.9 MeV less than that obtained using the standard Breit-Wigner parametrization (see 'Note on the Z Boson').

[21] The second error of 4.5 MeV is due to a common LEP energy uncertainty.

[22] ABRAMS 89B uncertainty includes 50 MeV due to the miniSAM background subtraction error.

[23] ALBAJAR 89 result is from a total sample of 33 $Z \to e^+ e^-$ events.

[24] Quoted values of ANSARI 87 are from direct fit. Ratio of Z and W production gives either $\Gamma(Z) < (1.09 \pm 0.07) \times \Gamma(W)$, CL = 90% or $\Gamma(Z) = (0.82^{+0.19}_{-0.14} \pm 0.06) \times \Gamma(W)$. Assuming Standard-Model value $\Gamma(W) = 2.65$ GeV then gives $\Gamma(Z) < 2.89 \pm 0.19$ or $= 2.17^{+0.50}_{-0.37} \pm 0.16$.

Z DECAY MODES

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$e^+ e^-$		(3.367 ± 0.005) %	
Γ_2	$\mu^+ \mu^-$		(3.367 ± 0.008) %	
Γ_3	$\tau^+ \tau^-$		(3.371 ± 0.009) %	
Γ_4	$\ell^+ \ell^-$	[*a*]	(3.3688 ± 0.0026) %	
Γ_5	invisible		(20.02 ± 0.06) %	
Γ_6	hadrons		(69.89 ± 0.07) %	
Γ_7	$(u\overline{u}+c\overline{c})/2$		(10.1 ± 1.1) %	
Γ_8	$(d\overline{d}+s\overline{s}+b\overline{b})/3$		(16.6 ± 0.6) %	
Γ_9	$c\overline{c}$		(11.68 ± 0.34) %	
Γ_{10}	$b\overline{b}$		(15.13 ± 0.05) %	
Γ_{11}	$b\overline{b}b\overline{b}$		(4.2 ± 1.6) $\times 10^{-4}$	
Γ_{12}	ggg		$<$ 1.1 %	CL=95%
Γ_{13}	$\pi^0 \gamma$		$<$ 5.2 $\times 10^{-5}$	CL=95%
Γ_{14}	$\eta \gamma$		$<$ 5.1 $\times 10^{-5}$	CL=95%

Γ_{15}	$\omega\gamma$			$<$ 6.5		$\times 10^{-4}$	CL=95%
Γ_{16}	$\eta'(958)\gamma$			$<$ 4.2		$\times 10^{-5}$	CL=95%
Γ_{17}	$\gamma\gamma$			$<$ 5.2		$\times 10^{-5}$	CL=95%
Γ_{18}	$\gamma\gamma\gamma$			$<$ 1.0		$\times 10^{-5}$	CL=95%
Γ_{19}	$\pi^{\pm} W^{\mp}$		[b]	$<$ 7		$\times 10^{-5}$	CL=95%
Γ_{20}	$\rho^{\pm} W^{\mp}$		[b]	$<$ 8.3		$\times 10^{-5}$	CL=95%
Γ_{21}	$J/\psi(1S)X$			(3.51	$^{+0.23}_{-0.25}$	) $\times 10^{-3}$	S=1.1
Γ_{22}	$\psi(2S)X$			(1.60	$\pm$0.29	) $\times 10^{-3}$	
Γ_{23}	$\chi_{c1}(1P)X$			(2.9	$\pm$0.7	) $\times 10^{-3}$	
Γ_{24}	$\chi_{c2}(1P)X$			$<$ 3.2		$\times 10^{-3}$	CL=90%
Γ_{25}	$\Upsilon(1S)\,X + \Upsilon(2S)\,X + \Upsilon(3S)\,X$			(1.0	$\pm$0.5	) $\times 10^{-4}$	
Γ_{26}	$\Upsilon(1S)X$			$<$ 4.4		$\times 10^{-5}$	CL=95%
Γ_{27}	$\Upsilon(2S)X$			$<$ 1.39		$\times 10^{-4}$	CL=95%
Γ_{28}	$\Upsilon(3S)X$			$<$ 9.4		$\times 10^{-5}$	CL=95%
Γ_{29}	$(D^0/\overline{D}^0)\,X$			(20.7	$\pm$2.0	) %	
Γ_{30}	$D^{\pm}X$			(12.2	$\pm$1.7	) %	
Γ_{31}	$D^*(2010)^{\pm}X$		[b]	(11.4	$\pm$1.3	) %	
Γ_{32}	BX						
Γ_{33}	B^*X						
Γ_{34}	B^0_sX			seen			
Γ_{35}	B^+_cX			searched for			
Γ_{36}	anomalous $\gamma+$ hadrons		[c]	$<$ 3.2		$\times 10^{-3}$	CL=95%
Γ_{37}	$e^+e^-\gamma$		[c]	$<$ 5.2		$\times 10^{-4}$	CL=95%
Γ_{38}	$\mu^+\mu^-\gamma$		[c]	$<$ 5.6		$\times 10^{-4}$	CL=95%
Γ_{39}	$\tau^+\tau^-\gamma$		[c]	$<$ 7.3		$\times 10^{-4}$	CL=95%
Γ_{40}	$\ell^+\ell^-\gamma\gamma$		[d]	$<$ 6.8		$\times 10^{-6}$	CL=95%
Γ_{41}	$q\overline{q}\gamma\gamma$		[d]	$<$ 5.5		$\times 10^{-6}$	CL=95%
Γ_{42}	$\nu\overline{\nu}\gamma\gamma$		[d]	$<$ 3.1		$\times 10^{-6}$	CL=95%
Γ_{43}	$e^{\pm}\mu^{\mp}$	*LF*	[b]	$<$ 1.7		$\times 10^{-6}$	CL=95%
Γ_{44}	$e^{\pm}\tau^{\mp}$	*LF*	[b]	$<$ 9.8		$\times 10^{-6}$	CL=95%
Γ_{45}	$\mu^{\pm}\tau^{\mp}$	*LF*	[b]	$<$ 1.2		$\times 10^{-5}$	CL=95%
Γ_{46}	pe	*L,B*		$<$ 1.8		$\times 10^{-6}$	CL=95%
Γ_{47}	$p\mu$	*L,B*		$<$ 1.8		$\times 10^{-6}$	CL=95%

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

[b] The value is for the sum of the charge states or particle/antiparticle states indicated.

[c] See the Particle Listings below for the γ energy range used in this measurement.

[d] For $m_{\gamma\gamma} = (60 \pm 5)$ GeV.

Z PARTIAL WIDTHS

$\Gamma(e^+ e^-)$ Γ_1

For the LEP experiments, this parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the *Z* Boson.'

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
84.015±0.139 OUR FIT					
83.54 ±0.27	117.8k	ABREU	00F	DLPH	E^{ee}_{cm}= 88–94 GeV
84.16 ±0.22	124.4k	ACCIARRI	00C	L3	E^{ee}_{cm}= 88–94 GeV
83.88 ±0.19		BARATE	00C	ALEP	E^{ee}_{cm}= 88–94 GeV
82.89 ±1.20 ±0.89		[25] ABE	95J	SLD	E^{ee}_{cm}= 91.31 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
83.63 ±0.53	42k	AKERS	94	OPAL	E^{ee}_{cm}= 88–94 GeV

[25] ABE 95J obtain this measurement from Bhabha events in a restricted fiducial region to improve systematics. They use the values 91.187 and 2.489 GeV for the *Z* mass and total decay width to extract this partial width.

$\Gamma(\mu^+ \mu^-)$ Γ_2

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the *Z* Boson.'

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
84.003±0.210 OUR FIT					
84.48 ±0.40	157.6k	ABREU	00F	DLPH	E^{ee}_{cm}= 88–94 GeV
83.95 ±0.44	113.4k	ACCIARRI	00C	L3	E^{ee}_{cm}= 88–94 GeV
84.02 ±0.28		BARATE	00C	ALEP	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
83.83 ±0.65	57k	AKERS	94	OPAL	E^{ee}_{cm}= 88–94 GeV

$\Gamma(\tau^+ \tau^-)$ Γ_3

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the *Z* Boson.'

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
84.113±0.245 OUR FIT					
83.71 ±0.58	104.0k	ABREU	00F	DLPH	E^{ee}_{cm}= 88–94 GeV
84.23 ±0.58	103.0k	ACCIARRI	00C	L3	E^{ee}_{cm}= 88–94 GeV
84.38 ±0.31		BARATE	00C	ALEP	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
82.90 ±0.77	47k	AKERS	94	OPAL	E^{ee}_{cm}= 88–94 GeV

$\Gamma(\ell^+ \ell^-)$ Γ_4

In our fit $\Gamma(\ell^+ \ell^-)$ is defined as the partial *Z* width for the decay into a pair of massless charged leptons. This parameter is not directly used in the 5-parameter fit assuming lepton universality but is derived using the fit results. See the 'Note on the *Z* Boson.'

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
84.057±0.099 OUR FIT					
83.85 ±0.17	379.4k	ABREU	00F	DLPH	E^{ee}_{cm}= 88–94 GeV
84.14 ±0.17	340.8k	ACCIARRI	00C	L3	E^{ee}_{cm}= 88–94 GeV
84.02 ±0.15	500k	BARATE	00C	ALEP	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
83.55 ±0.44	146k	AKERS	94	OPAL	E^{ee}_{cm}= 88–94 GeV

Γ(invisible) Γ_5

We use only direct measurements of the invisible partial width using the single photon channel to obtain the average value quoted below. OUR FIT value is obtained as a difference between the total and the observed partial widths assuming lepton universality.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
499.4± 1.7 OUR FIT					
503 ±16 OUR AVERAGE Error includes scale factor of 1.2.					
498 ±12 ±12	1791	ACCIARRI	98G	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
539 ±26 ±17	410	AKERS	95C	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
450 ±34 ±34	258	BUSKULIC	93L	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
540 ±80 ±40	52	ADEVA	92	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
498.1± 3.2		[26] ABREU	00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
499.1± 2.9		[26] ACCIARRI	00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
499.1± 2.5		[26] BARATE	00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
490.3± 7.3		[26] AKERS	94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
524 ±40 ±20	172	[27] ADRIANI	92E	L3	Repl. by ACCIARRI 98G

[26] This is an indirect determination of Γ(invisible) from a fit to the visible Z decay modes.

[27] ADRIANI 92E improves but does not supersede ADEVA 92, obtained with 1990 data only.

Γ(hadrons) Γ_6

This parameter is not directly used in the 5-parameter fit assuming lepton universality, but is derived using the fit results. See the 'Note on the Z Boson.'

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1743.8± 2.2 OUR FIT					
1738.1± 4.0	3.70M	ABREU	00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
1751.1± 3.8	3.54M	ACCIARRI	00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
1744.0± 3.4	4.07M	BARATE	00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1741 ±10	1.19M	[28] AKERS	94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV

[28] AKERS 94 assumes lepton universality. Without this assumption, it becomes 1742 ± 11 MeV.

Z BRANCHING RATIOS

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson").

Γ(hadrons)/$\Gamma(e^+e^-)$ Γ_6/Γ_1

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
20.766± 0.056 OUR FIT					
20.88 ± 0.12	117.8k	ABREU	00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
20.816± 0.089	124.4k	ACCIARRI	00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
20.677± 0.075		[29] BARATE	00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

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

20.74 ± 0.18	31.4k	ABREU	94	DLPH	Repl. by ABREU 00F
20.96 ± 0.15	38k	ACCIARRI	94	L3	Repl. by ACCIARRI 00C
20.83 ± 0.16	42k	AKERS	94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
20.59 ± 0.15	45.8k	BUSKULIC	94	ALEP	Repl. by BARATE 00C
$27.0\ {}^{+11.7}_{-\ 8.8}$	12	[30] ABRAMS	89D	MRK2	$E^{ee}_{\rm cm}$= 89–93 GeV

[29] BARATE 00C error includes approximately 0.062 due to statistics, 0.033 due to experimental systematics, and 0.026 due to the theoretical uncertainty in t-channel prediction.

[30] ABRAMS 89D have included both statistical and systematic uncertainties in their quoted errors.

$\Gamma(\text{hadrons})/\Gamma(\mu^+\mu^-)$ Γ_6/Γ_2

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson").

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
20.769±0.041 OUR FIT					
20.65 ±0.08	157.6k	ABREU	00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
20.861±0.097	113.4k	ACCIARRI	00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
20.799±0.056		[31] BARATE	00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

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

20.54 ±0.14	45.6k	ABREU	94	DLPH	Repl. by ABREU 00F
21.02 ±0.16	34k	ACCIARRI	94	L3	Repl. by ACCIARRI 00C
20.78 ±0.11	57k	AKERS	94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
20.83 ±0.15	46.4k	BUSKULIC	94	ALEP	Repl. by BARATE 00C
$18.9\ {}^{+7.1}_{-5.3}$	13	[32] ABRAMS	89D	MRK2	$E^{ee}_{\rm cm}$= 89–93 GeV

[31] BARATE 00C error includes approximately 0.053 due to statistics and 0.021 due to experimental systematics.

[32] ABRAMS 89D have included both statistical and systematic uncertainties in their quoted errors.

$\Gamma(\text{hadrons})/\Gamma(\tau^+\tau^-)$ Γ_6/Γ_3

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson").

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
20.742±0.051 OUR FIT					
20.84 ±0.13	104.0k	ABREU	00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
20.792±0.133	103.0k	ACCIARRI	00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
20.707±0.062		[33] BARATE	00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

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

20.68 ±0.18	25k	ABREU	94	DLPH	Repl. by ABREU 00F
20.80 ±0.20	25k	ACCIARRI	94	L3	Repl. by ACCIARRI 00C
21.01 ±0.15	47k	AKERS	94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
20.70 ±0.16	45.1k	BUSKULIC	94	ALEP	Repl. by BARATE 00C
15.2 $^{+4.8}_{-3.9}$	21	[34] ABRAMS	89D	MRK2	$E^{ee}_{\rm cm}$= 89–93 GeV

[33] BARATE 00C error includes approximately 0.054 due to statistics and 0.033 due to experimental systematics.

[34] ABRAMS 89D have included both statistical and systematic uncertainties in their quoted errors.

Γ(hadrons)/$\Gamma(\ell^+\ell^-)$ Γ_6/Γ_4

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

Our fit result is obtained requiring lepton universality.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
20.744±0.029 OUR FIT					
20.730±0.060	379.4k	ABREU	00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
20.810±0.060	340.8k	ACCIARRI	00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
20.725±0.039	500k	[35] BARATE	00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

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

20.62 ±0.10	102k	ABREU	94	DLPH	Repl. by ABREU 00F
20.93 ±0.10	97k	ACCIARRI	94	L3	Repl. by ACCIARRI 00C
20.835±0.086	146k	AKERS	94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
20.69 ±0.09	137.3k	BUSKULIC	94	ALEP	Repl. by BARATE 00C
18.9 $^{+3.6}_{-3.2}$	46	ABRAMS	89B	MRK2	$E^{ee}_{\rm cm}$= 89–93 GeV

[35] BARATE 00C error includes approximately 0.033 due to statistics, 0.020 due to experimental systematics, and 0.005 due to the theoretical uncertainty in t-channel prediction.

Γ(hadrons)/$\Gamma_{\rm total}$ Γ_6/Γ

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
69.886±0.065 OUR FIT					

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

69.83 ±0.23	1.14M	BUSKULIC	94	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

$\Gamma(e^+e^-)/\Gamma_{\rm total}$ Γ_1/Γ

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.3671±0.0047 OUR FIT					

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

3.383 ±0.013	45.8k	BUSKULIC	94	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

$\Gamma(\mu^+\mu^-)/\Gamma_{\rm total}$ Γ_2/Γ

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.3666±0.0079 OUR FIT					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3.344 ±0.026	46.4k	BUSKULIC	94	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

$\Gamma(\tau^+\tau^-)/\Gamma_{\rm total}$ Γ_3/Γ

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.3710±0.0094 OUR FIT					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3.366 ±0.028	45.1k	BUSKULIC	94	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

$\Gamma(\ell^+\ell^-)/\Gamma_{\rm total}$ Γ_4/Γ

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

Our fit result assumes lepton universality.

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.3688±0.0026 OUR FIT					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3.375 ±0.009	137.3k	BUSKULIC	94	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

$\Gamma(\text{invisible})/\Gamma_{\rm total}$ Γ_5/Γ

See the data, the note, and the fit result for the partial width, Γ_5, above.

VALUE (%)	*DOCUMENT ID*
20.016±0.063 OUR FIT	

$\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$ Γ_2/Γ_1

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE	*DOCUMENT ID*
0.9999±0.0032 OUR FIT	

$\Gamma(\tau^+\tau^-)/\Gamma(e^+e^-)$ Γ_3/Γ_1

This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE	*DOCUMENT ID*
1.0012±0.0036 OUR FIT	

$\Gamma\big((u\overline{u}+c\overline{c})/2\big)/\Gamma\big(\text{hadrons}\big)$ Γ_7/Γ_6

This quantity is the branching ratio of $Z \rightarrow$ "up-type" quarks to $Z \rightarrow$ hadrons. Except ACKERSTAFF 97T the values of $Z \rightarrow$ "up-type" and $Z \rightarrow$ "down-type" branchings are extracted from measurements of Γ(hadrons), and $\Gamma(Z \rightarrow \gamma+$ jets) where γ is a high-energy (>5 GeV) isolated photon. As the experiments use different procedures and slightly different values of M_Z, Γ(hadrons) and α_s in their extraction procedures, our average has to be taken with caution.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.145±0.015 OUR AVERAGE				
0.160±0.019±0.019	[36] ACKERSTAFF	97T	OPAL	E^{ee}_{cm}= 88–94 GeV
$0.137^{+0.038}_{-0.054}$	[37] ABREU	95X	DLPH	E^{ee}_{cm}= 88–94 GeV
0.139±0.026	[38] ACTON	93F	OPAL	E^{ee}_{cm}= 88–94 GeV
0.137±0.033	[39] ADRIANI	93	L3	E^{ee}_{cm}= 91.2 GeV

[36] ACKERSTAFF 97T measure $\Gamma_{u\overline{u}}/(\Gamma_{d\overline{d}}+\Gamma_{u\overline{u}}+\Gamma_{s\overline{s}}) = 0.258 \pm 0.031 \pm 0.032$. To obtain this branching ratio authors use $R_c+R_b = 0.380 \pm 0.010$. This measurement is fully negatively correlated with the measurement of $\Gamma_{d\overline{d},s\overline{s}}/(\Gamma_{d\overline{d}}+\Gamma_{u\overline{u}}+\Gamma_{s\overline{s}})$ given in the next data block.

[37] ABREU 95X use $M_Z = 91.187 \pm 0.009$ GeV, Γ(hadrons) = 1725 ± 12 MeV and $\alpha_s = 0.123 \pm 0.005$. To obtain this branching ratio we divide their value of $C_{2/3} = 0.91^{+0.25}_{-0.36}$ by their value of $(3C_{1/3} + 2C_{2/3}) = 6.66 \pm 0.05$.

[38] ACTON 93F use the LEP 92 value of Γ(hadrons) = 1740 ± 12 MeV and $\alpha_s = 0.122^{+0.006}_{-0.005}$.

[39] ADRIANI 93 use $M_Z = 91.181 \pm 0.022$ GeV, Γ(hadrons) = 1742 ± 19 MeV and $\alpha_s = 0.125 \pm 0.009$. To obtain this branching ratio we divide their value of $C_{2/3} = 0.92 \pm 0.22$ by their value of $(3C_{1/3} + 2C_{2/3}) = 6.720 \pm 0.076$.

$\Gamma\big((d\overline{d}+s\overline{s}+b\overline{b})/3\big)/\Gamma\big(\text{hadrons}\big)$ Γ_8/Γ_6

This quantity is the branching ratio of $Z \rightarrow$ "down-type" quarks to $Z \rightarrow$ hadrons. Except ACKERSTAFF 97T the values of $Z \rightarrow$ "up-type" and $Z \rightarrow$ "down-type" branchings are extracted from measurements of Γ(hadrons), and $\Gamma(Z \rightarrow \gamma+$ jets) where γ is a high-energy (>5 GeV) isolated photon. As the experiments use different procedures and slightly different values of M_Z, Γ(hadrons) and α_s in their extraction procedures, our average has to be taken with caution.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.237±0.009 OUR AVERAGE				
0.230±0.010±0.010	[40] ACKERSTAFF	97T	OPAL	E^{ee}_{cm}= 88–94 GeV
$0.243^{+0.036}_{-0.026}$	[41] ABREU	95X	DLPH	E^{ee}_{cm}= 88–94 GeV
0.241±0.017	[42] ACTON	93F	OPAL	E^{ee}_{cm}= 88–94 GeV
0.243±0.022	[43] ADRIANI	93	L3	E^{ee}_{cm}= 91.2 GeV

[40] ACKERSTAFF 97T measure $\Gamma_{d\overline{d},s\overline{s}}/(\Gamma_{d\overline{d}}+\Gamma_{u\overline{u}}+\Gamma_{s\overline{s}}) = 0.371 \pm 0.016 \pm 0.016$. To obtain this branching ratio authors use $R_c+R_b = 0.380 \pm 0.010$. This measurement is fully negatively correlated with the measurement of $\Gamma_{u\overline{u}}/(\Gamma_{d\overline{d}}+\Gamma_{u\overline{u}}+\Gamma_{s\overline{s}})$ presented in the previous data block.

[41] ABREU 95X use $M_Z = 91.187 \pm 0.009$ GeV, Γ(hadrons) = 1725 ± 12 MeV and $\alpha_s = 0.123 \pm 0.005$. To obtain this branching ratio we divide their value of $C_{1/3} = 1.62^{+0.24}_{-0.17}$ by their value of $(3C_{1/3} + 2C_{2/3}) = 6.66 \pm 0.05$.

[42] ACTON 93F use the LEP 92 value of Γ(hadrons) = 1740 ± 12 MeV and $\alpha_s = 0.122^{+0.006}_{-0.005}$.

[43] ADRIANI 93 use $M_Z = 91.181 \pm 0.022$ GeV, Γ(hadrons) = 1742 ± 19 MeV and $\alpha_s = 0.125 \pm 0.009$. To obtain this branching ratio we divide their value of $C_{1/3} = 1.63 \pm 0.15$ by their value of $(3C_{1/3} + 2C_{2/3}) = 6.720 \pm 0.076$.

$R_c = \Gamma(c\overline{c})/\Gamma(\text{hadrons})$ Γ_9/Γ_6

OUR FIT is obtained by a simultaneous fit to several *c*- and *b*-quark measurements as explained in the "Note on the *Z* boson." As a cross check we have also performed a weighted average of the R_c measurements taking into account the various common systematic errors. Assuming that the smallest common systematic error is fully correlated, we obtain $R_c = 0.1683 \pm 0.0049$.

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. Combining published and unpublished preliminary LEP and SLD electroweak results (as of March 2000) yields $R_c = 0.1674 \pm 0.0038$. The Standard Model predicts $R_c = 0.1723$ for $m_t = 174.3$ GeV and $M_H = 150$ GeV.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.1671±0.0048 OUR FIT				
0.1665±0.0051±0.0081	[44] ABREU	00	DLPH	E^{ee}_{cm}= 88–94 GeV
0.1698±0.0069	[45] BARATE	00B	ALEP	E^{ee}_{cm}= 88–94 GeV
0.180 ±0.011 ±0.013	[46] ACKERSTAFF	98E	OPAL	E^{ee}_{cm}= 88–94 GeV
0.167 ±0.011 ±0.012	[47] ALEXANDER	96R	OPAL	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.1675±0.0062±0.0103	[48] BARATE	98T	ALEP	Repl. by BARATE 00B
0.1689±0.0095±0.0068	[49] BARATE	98T	ALEP	Repl. by BARATE 00B
0.1623±0.0085±0.0209	[50] ABREU	95D	DLPH	E^{ee}_{cm}= 88–94 GeV
0.142 ±0.008 ±0.014	[51] AKERS	95O	OPAL	Repl. by ACKERSTAFF 98E
0.165 ±0.005 ±0.020	[52] BUSKULIC	94G	ALEP	Repl. by BARATE 00B

[44] ABREU 00 obtain this result properly combining the measurement from the D^{*+} production rate (R_c= 0.1610 ± 0.0104 ± 0.0077 ± 0.0043 (BR)) with that from the overall charm counting (R_c= 0.1692 ± 0.0047 ± 0.0063 ± 0.0074 (BR)) in $c\overline{c}$ events. The systematic error includes an uncertainty of ±0.0054 due to the uncertainty on the charmed hadron branching fractions.

[45] BARATE 00B use exclusive decay modes to independently determine the quantities $R_c \times$f($c \to$ X), X=D^0, D^+, D^+_s, and Λ_c. Estimating $R_c \times$f($c \to \Xi_c / \Omega_c$)= 0.0034, they simply sum over all the charm decays to obtain R_c= 0.1738 ± 0.0047 ± 0.0088 ± 0.0075(BR). This is combined with all previous ALEPH measurements (BARATE 98T and BUSKULIC 94G, R_c= 0.1681 ± 0.0054 ± 0.0062) to obtain the quoted value.

[46] ACKERSTAFF 98E use an inclusive/exclusive double tag. In one jet $D^{*\pm}$ mesons are exclusively reconstruced in several decay channels and in the opposite jet a slow pion (opposite charge inclusive $D^{*\pm}$) tag is used. The *b* content of this sample is measured by the simultaneous detection of a lepton in one jet and an inclusively reconstructed $D^{*\pm}$ meson in the opposite jet. The systematic error includes an uncertainty of ±0.006 due to the external branching ratios.

[47] ALEXANDER 96R obtain this value via direct charm counting, summing the partial contributions from D^0, D^+, D^+_s, and Λ^+_c, and assuming that strange-charmed baryons account for the 15% of the Λ^+_c production. An uncertainty of ±0.005 due to the uncertainties in the charm hadron branching ratios is included in the overall systematics.

[48] BARATE 98T perform a simultaneous fit to the p and p_T spectra of electrons from hadronic Z decays. The semileptonic branching ratio B($c \to e$) is taken as 0.098 ± 0.005 and the systematic error includes an uncertainty of ± 0.0084 due to this.

[49] BARATE 98T obtain this result combining two double-tagging techniques. Searching for a D meson in each hemisphere by full reconstruction in an exclusive decay mode gives $R_c = 0.173 \pm 0.014 \pm 0.0009$. The same tag in combination with inclusive identification using the slow pion from the $D^{*+} \to D^0 \pi^+$ decay in the opposite hemisphere yields $R_c = 0.166 \pm 0.012 \pm 0.009$. The R_b dependence is given by $R_c = 0.1689 – 0.023 \times (R_b – 0.2159)$. The three measurements of BARATE 98T are combined with BUSKULIC 94G to give the average $R_c = 0.1681 \pm 0.0054 \pm 0.0062$.

[50] ABREU 95D perform a maximum likelihood fit to the combined p and p_T distributions of single and dilepton samples. The second error includes an uncertainty of ± 0.0124 due to models and branching ratios.

[51] AKERS 95O use the presence of a $D^{*\pm}$ to tag $Z \to c\overline{c}$ with $D^* \to D^0 \pi$ and $D^0 \to K \pi$. They measure $P_c * \Gamma(c\overline{c})/\Gamma(\text{hadrons})$ to be $(1.006 \pm 0.055 \pm 0.061) \times 10^{-3}$, where P_c is the product branching ratio B($c \to D^*$)B($D^* \to D^0 \pi$)B($D^0 \to K \pi$). Assuming that P_c remains unchanged with energy, they use its value $(7.1 \pm 0.5) \times 10^{-3}$ determined at CESR/PETRA to obtain $\Gamma(c\overline{c})/\Gamma(\text{hadrons})$. The second error of AKERS 95O includes an uncertainty of ± 0.011 from the uncertainty on P_c.

[52] BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and dilepton events.

$R_b = \Gamma(b\overline{b})/\Gamma(\text{hadrons})$ Γ_{10}/Γ_6

OUR FIT is obtained by a simultaneous fit to several c- and b-quark measurements as explained in the "Note on the Z boson." As a cross check we have also performed a weighted average of the R_b measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. For $R_c = 0.1671$ (as given by OUR FIT above), we obtain $R_b = 0.21653 \pm 0.00070$. For an expected Standard Model value of $R_c = 0.1723$, our weighted average gives $R_b = 0.21631 \pm 0.00070$.

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. Combining published and unpublished preliminary LEP and SLD electroweak results (as of March 2000) yields $R_b = 0.21642 \pm 0.00073$. The Standard Model predicts $R_b = 0.21581$ for $m_t = 174.3$ GeV and $M_H = 150$ GeV.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.21644±0.00075 OUR FIT					
0.2174 ±0.0015 ±0.0028		[53] ACCIARRI	00	L3	E^{ee}_{cm}= 89–93 GeV
0.2178 ±0.0011 ±0.0013		[54] ABBIENDI	99B	OPAL	E^{ee}_{cm}= 88–94 GeV
0.21634±0.00067±0.00060		[55] ABREU	99B	DLPH	E^{ee}_{cm}= 88–94 GeV
0.2142 ±0.0034 ±0.0015		[56] ABE	98D	SLD	E^{ee}_{cm}= 91.2 GeV
0.2159 ±0.0009 ±0.0011		[57] BARATE	97F	ALEP	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.2175 ±0.0014 ±0.0017		[58] ACKERSTAFF	97K	OPAL	Repl. by ABBIENDI 99B
0.2167 ±0.0011 ±0.0013		[59] BARATE	97E	ALEP	E^{ee}_{cm}= 88–94 GeV
0.229 ±0.011		[60] ABE	96E	SLD	Repl. by ABE 98D
0.2216 ±0.0016 ±0.0021		[61] ABREU	96	DLPH	Repl. by ABREU 99B
0.2145 ±0.0089 ±0.0067		[62] ABREU	95D	DLPH	E^{ee}_{cm}= 88–94 GeV
0.219 ±0.006 ±0.005		[63] BUSKULIC	94G	ALEP	E^{ee}_{cm}= 88–94 GeV
0.251 ±0.049 ±0.030	32	[64] JACOBSEN	91	MRK2	E^{ee}_{cm}= 91 GeV

[53] ACCIARRI 00 obtain this result using a double-tagging technique, with a high p_T lepton tag and an impact parameter tag in opposite hemispheres.

[54] ABBIENDI 99B tag $Z \rightarrow b\overline{b}$ decays using leptons and/or separated decay vertices. The b-tagging efficiency is measured directly from the data using a double-tagging technique.

[55] ABREU 99B obtain this result combining in a multivariate analysis several tagging methods (impact parameter and secondary vertex reconstruction, complemented by event shape variables). For R_c different from its Standard Model value of 0.172, R_b varies as $-0.024\times(R_c$–$0.172)$.

[56] ABE 98D use a double tag based on 3D impact parameter with reconstruction of secondary vertices. The charm background is reduced by requiring the invariant mass at the secondary vertex to be above 2 GeV. The systematic error includes an uncertainty of ± 0.0002 due to the uncertainty on R_c.

[57] BARATE 97F combine the lifetime-mass hemisphere tag (BARATE 97E) with event shape information and lepton tag to identify $Z \rightarrow b\overline{b}$ candidates. They further use c- and uds-selection tags to identify the background. For R_c different from its Standard Model value of 0.172, R_b varies as $-0.019\times(R_c - 0.172)$.

[58] ACKERSTAFF 97K use lepton and/or separated decay vertex to tag independently each hemisphere. Comparing the numbers of single- and double-tagged events, they determine the b-tagging efficiency directly from the data.

[59] BARATE 97E combine a lifetime tag with a mass cut based on the mass difference between c hadrons and b hadrons. Included in BARATE 97F.

[60] ABE 96E obtain this value by combining results from three different b-tagging methods (2D impact parameter, 3D impact parameter, and 3D displaced vertex).

[61] ABREU 96 obtain this result combining several analyses (double lifetime tag, mixed tag and multivariate analysis). This value is obtained assuming $R_c=\Gamma(c\overline{c})/\Gamma(\text{hadrons}) = 0.172$. For a value of R_c different from this by an amount ΔR_c the change in the value is given by $-0.087 \cdot \Delta R_c$.

[62] ABREU 95D perform a maximum likelihood fit to the combined p and p_T distributions of single and dilepton samples. The second error includes an uncertainty of ± 0.0023 due to models and branching ratios.

[63] BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and dilepton events.

[64] JACOBSEN 91 tagged $b\overline{b}$ events by requiring coincidence of ≥ 3 tracks with significant impact parameters using vertex detector. Systematic error includes lifetime and decay uncertainties (± 0.014).

$\Gamma(b\overline{b}b\overline{b})/\Gamma(\text{hadrons})$ Γ_{11}/Γ_6

VALUE (units 10^{-4})	*DOCUMENT ID*		*TECN*	*COMMENT*
6.0±1.9±1.4	[65] ABREU	99U	DLPH	E^{ee}_{cm}= 88–94 GeV

[65] ABREU 99U force hadronic Z decays into 3 jets to use all the available phase space and require a b tag for every jet. This decay mode includes primary and secondary 4b production, *e.g*, from gluon splitting to $b\overline{b}$.

$\Gamma(ggg)/\Gamma(\text{hadrons})$ Γ_{12}/Γ_6

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.6 \times 10^{-2}$	95	[66] ABREU	96S	DLPH	E^{ee}_{cm}= 88–94 GeV

[66] This branching ratio is slightly dependent on the jet-finder algorithm. The value we quote is obtained using the JADE algorithm, while using the DURHAM algorithm ABREU 96S obtain an upper limit of 1.5×10^{-2}.

$\Gamma(\pi^0\gamma)/\Gamma_{total}$ Γ_{13}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<5.2 \times 10^{-5}$	95	[67] ACCIARRI	95G	L3	E^{ee}_{cm}= 88–94 GeV
$<5.5 \times 10^{-5}$	95	ABREU	94B	DLPH	E^{ee}_{cm}= 88–94 GeV
$<2.1 \times 10^{-4}$	95	DECAMP	92	ALEP	E^{ee}_{cm}= 88–94 GeV
$<1.4 \times 10^{-4}$	95	AKRAWY	91F	OPAL	E^{ee}_{cm}= 88–94 GeV

[67] This limit is for both decay modes $Z \rightarrow \pi^0\gamma/\gamma\gamma$ which are indistinguishable in ACCIARRI 95G.

$\Gamma(\eta\gamma)/\Gamma_{total}$ Γ_{14}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<7.6 \times 10^{-5}$	95	ACCIARRI	95G	L3	E^{ee}_{cm}= 88–94 GeV
$<8.0 \times 10^{-5}$	95	ABREU	94B	DLPH	E^{ee}_{cm}= 88–94 GeV
$<5.1 \times 10^{-5}$	95	DECAMP	92	ALEP	E^{ee}_{cm}= 88–94 GeV
$<2.0 \times 10^{-4}$	95	AKRAWY	91F	OPAL	E^{ee}_{cm}= 88–94 GeV

$\Gamma(\omega\gamma)/\Gamma_{total}$ Γ_{15}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<6.5 \times 10^{-4}$	95	ABREU	94B	DLPH	E^{ee}_{cm}= 88–94 GeV

$\Gamma(\eta'(958)\gamma)/\Gamma_{total}$ Γ_{16}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<4.2 \times 10^{-5}$	95	DECAMP	92	ALEP	E^{ee}_{cm}= 88–94 GeV

$\Gamma(\gamma\gamma)/\Gamma_{total}$ Γ_{17}/Γ

This decay would violate the Landau-Yang theorem.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<5.2 \times 10^{-5}$	95	[68] ACCIARRI	95G	L3	E^{ee}_{cm}= 88–94 GeV
$<5.5 \times 10^{-5}$	95	ABREU	94B	DLPH	E^{ee}_{cm}= 88–94 GeV
$<1.4 \times 10^{-4}$	95	AKRAWY	91F	OPAL	E^{ee}_{cm}= 88–94 GeV

[68] This limit is for both decay modes $Z \rightarrow \pi^0\gamma/\gamma\gamma$ which are indistinguishable in ACCIARRI 95G.

$\Gamma(\gamma\gamma\gamma)/\Gamma_{total}$ Γ_{18}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.0 \times 10^{-5}$	95	[69] ACCIARRI	95C	L3	E^{ee}_{cm}= 88–94 GeV
$<1.7 \times 10^{-5}$	95	[69] ABREU	94B	DLPH	E^{ee}_{cm}= 88–94 GeV
$<6.6 \times 10^{-5}$	95	AKRAWY	91F	OPAL	E^{ee}_{cm}= 88–94 GeV

[69] Limit derived in the context of composite Z model.

$\Gamma(\pi^{\pm}W^{\mp})/\Gamma_{total}$ Γ_{19}/Γ

The value is for the sum of the charge states indicated.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<7 \times 10^{-5}$	95	DECAMP	92	ALEP	E^{ee}_{cm}= 88–94 GeV

$\Gamma(\rho^{\pm} W^{\mp})/\Gamma_{\text{total}}$ Γ_{20}/Γ

The value is for the sum of the charge states indicated.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<8.3 \times 10^{-5}$	95	DECAMP 92	ALEP	E^{ee}_{cm}= 88–94 GeV

$\Gamma(J/\psi(1S)X)/\Gamma_{\text{total}}$ Γ_{21}/Γ

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$3.51^{+0.23}_{-0.25}$ OUR AVERAGE Error includes scale factor of 1.1.				
$3.21 \pm 0.21^{+0.19}_{-0.28}$	553	[70] ACCIARRI 99F	L3	E^{ee}_{cm}= 88–94 GeV
$3.9 \pm 0.2 \pm 0.3$	511	[71] ALEXANDER 96B	OPAL	E^{ee}_{cm}= 88–94 GeV
$3.73 \pm 0.39 \pm 0.36$	153	[72] ABREU 94P	DLPH	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$3.40 \pm 0.23 \pm 0.27$	441	[73] ACCIARRI 97J	L3	Repl. by ACCIARRI 99F

[70] ACCIARRI 99F combine $\mu^+ \mu^-$ and $e^+ e^-$ $J/\psi(1S)$ decay channels. The branching ratio for prompt $J/\psi(1S)$ production is measured to be $(2.1 \pm 0.6 \pm 0.4^{+0.4}_{-0.2}(\text{theor.})) \times 10^{-4}$.

[71] ALEXANDER 96B identify $J/\psi(1S)$ from the decays into lepton pairs. (4.8 ± 2.4)% of this branching ratio is due to prompt $J/\psi(1S)$ production (ALEXANDER 96N).

[72] Combining $\mu^+ \mu^-$ and $e^+ e^-$ channels and taking into account the common systematic errors. $(7.7^{+6.3}_{-5.4})$% of this branching ratio is due to prompt $J/\psi(1S)$ production.

[73] ACCIARRI 97J combine $\mu^+ \mu^-$ and $e^+ e^-$ $J/\psi(1S)$ decay channels and take into account the common systematic error.

$\Gamma(\psi(2S)X)/\Gamma_{\text{total}}$ Γ_{22}/Γ

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1.60 ± 0.29 OUR AVERAGE				
$1.6 \pm 0.5 \pm 0.3$	39	[74] ACCIARRI 97J	L3	E^{ee}_{cm}= 88–94 GeV
$1.6 \pm 0.3 \pm 0.2$	46.9	[75] ALEXANDER 96B	OPAL	E^{ee}_{cm}= 88–94 GeV
$1.60 \pm 0.73 \pm 0.33$	5.4	[76] ABREU 94P	DLPH	E^{ee}_{cm}= 88–94 GeV

[74] ACCIARRI 97J measure this branching ratio via the decay channel $\psi(2S) \rightarrow \ell^+ \ell^-$ ($\ell = \mu$, e).

[75] ALEXANDER 96B measure this branching ratio via the decay channel $\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$, with $J/\psi \rightarrow \ell^+ \ell^-$.

[76] ABREU 94P measure this branching ratio via decay channel $\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$, with $J/\psi \rightarrow \mu^+ \mu^-$.

$\Gamma(\chi_{c1}(1P)X)/\Gamma_{\text{total}}$ Γ_{23}/Γ

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.9 ± 0.7 OUR AVERAGE				
$2.7 \pm 0.6 \pm 0.5$	33	[77] ACCIARRI 97J	L3	E^{ee}_{cm}= 88–94 GeV
$5.0 \pm 2.1^{+1.5}_{-0.9}$	6.4	[78] ABREU 94P	DLPH	E^{ee}_{cm}= 88–94 GeV

[77] ACCIARRI 97J measure this branching ratio via the decay channel $\chi_{c1} \rightarrow J/\psi + \gamma$, with $J/\psi \rightarrow \ell^+ \ell^-$ ($\ell = \mu$, e). The $M(\ell^+ \ell^- \gamma)$–$M(\ell^+ \ell^-)$ mass difference spectrum is fitted with two gaussian shapes for χ_{c1} and χ_{c2}.

[78] This branching ratio is measured via the decay channel $\chi_{c1} \rightarrow J/\psi + \gamma$, with $J/\psi \rightarrow \mu^+ \mu^-$.

$\Gamma(\chi_{c2}(1P)X)/\Gamma_{total}$ Γ_{24}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<3.2 \times 10^{-3}$	90	[79] ACCIARRI	97J	L3	E^{ee}_{cm}= 88–94 GeV

[79] ACCIARRI 97J derive this limit via the decay channel $\chi_{c2} \rightarrow J/\psi + \gamma$, with $J/\psi \rightarrow \ell^+ \ell^-$ ($\ell = \mu$, e). The $M(\ell^+ \ell^- \gamma)$–$M(\ell^+ \ell^-)$ mass difference spectrum is fitted with two gaussian shapes for χ_{c1} and χ_{c2}.

$\Gamma(\Upsilon(1S)X + \Upsilon(2S)X + \Upsilon(3S)X)/\Gamma_{total}$ $\Gamma_{25}/\Gamma = (\Gamma_{26}+\Gamma_{27}+\Gamma_{28})/\Gamma$

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1.0±0.4±0.22	6.4	[80] ALEXANDER	96F	OPAL	E^{ee}_{cm}= 88–94 GeV

[80] ALEXANDER 96F identify the Υ (which refers to any of the three lowest bound states) through its decay into $e^+ e^-$ and $\mu^+ \mu^-$. The systematic error includes an uncertainty of ±0.2 due to the production mechanism.

$\Gamma(\Upsilon(1S)X)/\Gamma_{total}$ Γ_{26}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<4.4 \times 10^{-5}$ **(CL = 95%)**					
$<4.4 \times 10^{-5}$	95	[81] ACCIARRI	99F	L3	E^{ee}_{cm}= 88–94 GeV

[81] ACCIARRI 99F search for $\Upsilon(1S)$ through its decay into $\ell^+ \ell^-$ ($\ell = e$ or μ).

$\Gamma(\Upsilon(2S)X)/\Gamma_{total}$ Γ_{27}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<13.9 \times 10^{-5}$	95	[82] ACCIARRI	97R	L3	E^{ee}_{cm}= 88–94 GeV

[82] ACCIARRI 97R search for $\Upsilon(2S)$ through its decay into $\ell^+ \ell^-$ ($\ell = e$ or μ).

$\Gamma(\Upsilon(3S)X)/\Gamma_{total}$ Γ_{28}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<9.4 \times 10^{-5}$	95	[83] ACCIARRI	97R	L3	E^{ee}_{cm}= 88–94 GeV

[83] ACCIARRI 97R search for $\Upsilon(3S)$ through its decay into $\ell^+ \ell^-$ ($\ell = e$ or μ).

$\Gamma((D^0/\overline{D}^0)X)/\Gamma(\text{hadrons})$ Γ_{29}/Γ_6

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.296±0.019±0.021	369	[84] ABREU	93I	DLPH	E^{ee}_{cm}= 88–94 GeV

[84] The $(D^0/\overline{D}^0)$ states in ABREU 93I are detected by the $K\pi$ decay mode. This is a corrected result (see the erratum of ABREU 93I).

$\Gamma(D^\pm X)/\Gamma(\text{hadrons})$ Γ_{30}/Γ_6

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.174±0.016±0.018	539	[85] ABREU	93I	DLPH	E^{ee}_{cm}= 88–94 GeV

[85] The $D^\pm$ states in ABREU 93I are detected by the $K\pi\pi$ decay mode. This is a corrected result (see the erratum of ABREU 93I).

$\Gamma\big(D^*(2010)^{\pm}X\big)/\Gamma\big(\text{hadrons}\big)$ Γ_{31}/Γ_6

The value is for the sum of the charge states indicated.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.163±0.019 OUR AVERAGE	Error includes scale factor of 1.3.				
0.155±0.010±0.013	358	[86] ABREU	93I	DLPH	E^{ee}_{cm}= 88–94 GeV
0.21 ±0.04	362	[87] DECAMP	91J	ALEP	E^{ee}_{cm}= 88–94 GeV

[86] $D^*(2010)^{\pm}$ in ABREU 93I are reconstructed from $D^0\pi^{\pm}$, with $D^0 \rightarrow K^-\pi^+$. The new CLEO II measurement of B($D^{*\pm} \rightarrow D^0\pi^{\pm}$) = (68.1 ± 1.6) % is used. This is a corrected result (see the erratum of ABREU 93I).

[87] DECAMP 91J report B($D^*(2010)^+ \rightarrow D^0\pi^+$) B($D^0 \rightarrow K^-\pi^+$) $\Gamma(D^*(2010)^{\pm}X)$ / Γ(hadrons) = (5.11 ± 0.34) × 10^{-3}. They obtained the above number assuming B($D^0 \rightarrow K^-\pi^+$) = (3.62±0.34±0.44)% and B($D^*(2010)^+ \rightarrow D^0\pi^+$) = (55±4)%. We have rescaled their original result of 0.26 ± 0.05 taking into account the new CLEO II branching ratio B($D^*(2010)^+ \rightarrow D^0\pi^+$) = (68.1 ± 1.6)%.

$\Gamma\big(B^0_sX\big)/\Gamma\big(\text{hadrons}\big)$ Γ_{34}/Γ_6

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	[88] ABREU	92M	DLPH	E^{ee}_{cm}= 88–94 GeV
seen	[89] ACTON	92N	OPAL	E^{ee}_{cm}= 88–94 GeV
seen	[90] BUSKULIC	92E	ALEP	E^{ee}_{cm}= 88–94 GeV

[88] ABREU 92M reported value is $\Gamma(B^0_sX)$∗B($B^0_s \rightarrow D_s\mu\nu_{\mu}X$) ∗B($D_s \rightarrow \phi\pi$)/$\Gamma$(hadrons) = (18 ± 8) × 10^{-5}.

[89] ACTON 92N find evidence for B^0_s production using D_s-ℓ correlations, with $D^+_s \rightarrow \phi\pi^+$ and $K^*(892)K^+$. Assuming R_b from the Standard Model and averaging over the e and μ channels, authors measure the product branching fraction to be $f(\overline{b} \rightarrow B^0_s)$×B($B^0_s \rightarrow D^-_s\ell^+\nu_{\ell}X$)×B($D^-_s \rightarrow \phi\pi^-$) = (3.9 ± 1.1 ± 0.8) × 10^{-4}.

[90] BUSKULIC 92E find evidence for B^0_s production using D_s-ℓ correlations, with $D^+_s \rightarrow \phi\pi^+$ and $K^*(892)K^+$. Using B($D^+_s \rightarrow \phi\pi^+$) = (2.7 ± 0.7)% and summing up the e and μ channels, the weighted average product branching fraction is measured to be B($\overline{b} \rightarrow B^0_s$)×B($B^0_s \rightarrow D^-_s\ell^+\nu_{\ell}X$) = $0.040 \pm 0.011^{+0.010}_{-0.012}$.

$\Gamma\big(B^+_cX\big)/\Gamma\big(\text{hadrons}\big)$ Γ_{35}/Γ_6

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
searched for	[91] ACKERSTAFF	98O	OPAL	E^{ee}_{cm}= 88–94 GeV
searched for	[92] ABREU	97E	DLPH	E^{ee}_{cm}= 88–94 GeV
searched for	[93] BARATE	97H	ALEP	E^{ee}_{cm}= 88–94 GeV

[91] ACKERSTAFF 98O searched for the decay modes $B_c \rightarrow J/\psi\pi^+$, $J/\psi a^+_1$, and $J/\psi\ell^+\nu_{\ell}$, with $J/\psi \rightarrow \ell^+\ell^-$, $\ell = e,\mu$. The number of candidates (background) for the three decay modes is 2 (0.63 ± 0.2), 0 (1.10 ± 0.22), and 1 (0.82 ± 0.19) respectively. Interpreting the 2 $B_c \rightarrow J/\psi\pi^+$ candidates as signal, they report $\Gamma(B^+_cX)$×B($B_c \rightarrow J/\psi\pi^+$)/$\Gamma$(hadrons) =($3.8^{+5.0}_{-2.4} \pm 0.5$)×$10^{-5}$. Interpreted as background, the 90% CL bounds are $\Gamma(B^+_cX)$∗B($B_c \rightarrow J/\psi\pi^+$)/$\Gamma$(hadrons) $< 1.06 \times 10^{-4}$, $\Gamma(B^+_cX)$∗B($B_c \rightarrow J/\psi a^+_1$)/$\Gamma$(hadrons) $< 5.29 \times 10^{-4}$, $\Gamma(B^+_cX)$∗B($B_c \rightarrow J/\psi\ell^+\nu_{\ell}$)/$\Gamma$(hadrons) $<$ 6.96×10^{-5}.

[92] ABREU 97E searched for the decay modes $B_c \rightarrow J/\psi\pi^+$, $J/\psi\ell^+\nu_\ell$, and $J/\psi(3\pi)^+$, with $J/\psi \rightarrow \ell^+\ell^-$, $\ell = e,\mu$. The number of candidates (background) for the three decay modes is 1 (1.7), 0 (0.3), and 1 (2.3) respectively. They report the following 90% CL limits: $\Gamma(B_c^+ X)*B(B_c \rightarrow J/\psi\pi^+)/\Gamma(\text{hadrons}) < (1.05\text{–}0.84) \times 10^{-4}$, $\Gamma(B_c^+ X)*B(B_c \rightarrow J/\psi\ell\nu_\ell)/\Gamma(\text{hadrons}) < (5.8\text{–}5.0) \times 10^{-5}$, $\Gamma(B_c^+ X)*B(B_c \rightarrow J/\psi(3\pi)^+)/\Gamma(\text{hadrons}) < 1.75 \times 10^{-4}$, where the ranges are due to the predicted B_c lifetime (0.4–1.4) ps.

[93] BARATE 97H searched for the decay modes $B_c \rightarrow J/\psi\pi^+$ and $J/\psi\ell^+\nu_\ell$ with $J/\psi \rightarrow \ell^+\ell^-$, $\ell = e,\mu$. The number of candidates (background) for the two decay modes is 0 (0.44) and 2 (0.81) respectively. They report the following 90% CL limits: $\Gamma(B_c^+ X)*B(B_c \rightarrow J/\psi\pi^+)/\Gamma(\text{hadrons}) < 3.6 \times 10^{-5}$ and $\Gamma(B_c^+ X)*B(B_c \rightarrow J/\psi\ell^+\nu_\ell)/\Gamma(\text{hadrons}) < 5.2 \times 10^{-5}$.

$\Gamma(B^* X)/\big[\Gamma(B X) + \Gamma(B^* X)\big]$ $\Gamma_{33}/(\Gamma_{32}+\Gamma_{33})$

As the experiments assume different values of the *b*-baryon contribution, our average should be taken with caution. If we assume a common baryon production fraction of $(10.1^{+3.9}_{-3.1})$% as given in the 1998 edition of this *Review* OUR AVERAGE becomes 0.74 ± 0.04.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.75 ±0.04 OUR AVERAGE					
0.760±0.036±0.083		[94] ACKERSTAFF	97M	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
0.771±0.026±0.070		[95] BUSKULIC	96D	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
0.72 ±0.03 ±0.06		[96] ABREU	95R	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
0.76 ±0.08 ±0.06	1378	[97] ACCIARRI	95B	L3	$E^{ee}_{\rm cm}$= 88–94 GeV

[94] ACKERSTAFF 97M use an inclusive B reconstruction method and assume a (13.2 ± 4.1)% *b*-baryon contribution. The value refers to a *b*-flavored meson mixture of B_u, B_d, and B_s.

[95] BUSKULIC 96D use an inclusive reconstruction of B hadrons and assume a (12.2 ± 4.3)% *b*-baryon contribution. The value refers to a *b*-flavored mixture of B_u, B_d, and B_s.

[96] ABREU 95R use an inclusive B-reconstruction method and assume a (10 ± 4)% *b*-baryon contribution. The value refers to a *b*-flavored meson mixture of B_u, B_d, and B_s.

[97] ACCIARRI 95B assume a 9.4% *b*-baryon contribution. The value refers to a *b*-flavored mixture of B_u, B_d, and B_s.

$\Gamma(\text{anomalous}\ \gamma + \text{hadrons})/\Gamma_{\text{total}}$ Γ_{36}/Γ

Limits on additional sources of prompt photons beyond expectations for final-state bremsstrahlung.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<3.2 \times 10^{-3}$	95	[98] AKRAWY	90J	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV

[98] AKRAWY 90J report $\Gamma(\gamma X) <$ 8.2 MeV at 95%CL. They assume a three-body $\gamma q\overline{q}$ distribution and use $E(\gamma) >$ 10 GeV.

$\Gamma(e^+e^-\gamma)/\Gamma_{\text{total}}$ Γ_{37}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<5.2 \times 10^{-4}$	95	[99] ACTON	91B	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV

[99] ACTON 91B looked for isolated photons with E>2% of beam energy (> 0.9 GeV).

$\Gamma(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$ Γ_{38}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<5.6 \times 10^{-4}$	95	[100] ACTON 91B	OPAL	$E^{ee}_{\text{cm}} = 91.2$ GeV

[100] ACTON 91B looked for isolated photons with $E>2\%$ of beam energy ($>$ 0.9 GeV).

$\Gamma(\tau^+\tau^-\gamma)/\Gamma_{\text{total}}$ Γ_{39}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<7.3 \times 10^{-4}$	95	[101] ACTON 91B	OPAL	$E^{ee}_{\text{cm}} = 91.2$ GeV

[101] ACTON 91B looked for isolated photons with $E>2\%$ of beam energy ($>$ 0.9 GeV).

$\Gamma(\ell^+\ell^-\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{40}/Γ

The value is the sum over $\ell = e, \mu, \tau$.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<6.8 \times 10^{-6}$	95	[102] ACTON 93E	OPAL	$E^{ee}_{\text{cm}} =$ 88–94 GeV

[102] For $m_{\gamma\gamma} = 60 \pm 5$ GeV.

$\Gamma(q\overline{q}\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{41}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<5.5 \times 10^{-6}$	95	[103] ACTON 93E	OPAL	$E^{ee}_{\text{cm}} =$ 88–94 GeV

[103] For $m_{\gamma\gamma} = 60 \pm 5$ GeV.

$\Gamma(\nu\overline{\nu}\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{42}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.1 \times 10^{-6}$	95	[104] ACTON 93E	OPAL	$E^{ee}_{\text{cm}} =$ 88–94 GeV

[104] For $m_{\gamma\gamma} = 60 \pm 5$ GeV.

$\Gamma(e^\pm\mu^\mp)/\Gamma(e^+e^-)$ Γ_{43}/Γ_1

Test of lepton family number conservation. The value is for the sum of the charge states indicated.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.07	90	ALBAJAR 89	UA1	$E^{p\overline{p}}_{\text{cm}} =$ 546,630 GeV

$\Gamma(e^\pm\mu^\mp)/\Gamma_{\text{total}}$ Γ_{43}/Γ

Test of lepton family number conservation. The value is for the sum of the charge states indicated.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.5 \times 10^{-6}$	95	ABREU 97C	DLPH	$E^{ee}_{\text{cm}} =$ 88–94 GeV
$<1.7 \times 10^{-6}$	95	AKERS 95W	OPAL	$E^{ee}_{\text{cm}} =$ 88–94 GeV
$<0.6 \times 10^{-5}$	95	ADRIANI 93I	L3	$E^{ee}_{\text{cm}} =$ 88–94 GeV
$<2.6 \times 10^{-5}$	95	DECAMP 92	ALEP	$E^{ee}_{\text{cm}} =$ 88–94 GeV

$\Gamma(e^\pm\tau^\mp)/\Gamma_{\text{total}}$ Γ_{44}/Γ

Test of lepton family number conservation. The value is for the sum of the charge states indicated.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.2 \times 10^{-5}$	95	ABREU 97C	DLPH	$E^{ee}_{\text{cm}} =$ 88–94 GeV
$<9.8 \times 10^{-6}$	95	AKERS 95W	OPAL	$E^{ee}_{\text{cm}} =$ 88–94 GeV
$<1.3 \times 10^{-5}$	95	ADRIANI 93I	L3	$E^{ee}_{\text{cm}} =$ 88–94 GeV
$<1.2 \times 10^{-4}$	95	DECAMP 92	ALEP	$E^{ee}_{\text{cm}} =$ 88–94 GeV

$\Gamma(\mu^{\pm}\tau^{\mp})/\Gamma_{\rm total}$ Γ_{45}/Γ

Test of lepton family number conservation. The value is for the sum of the charge states indicated.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.2 \times 10^{-5}$	95	ABREU	97C	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
$<1.7 \times 10^{-5}$	95	AKERS	95W	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
$<1.9 \times 10^{-5}$	95	ADRIANI	93I	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
$<1.0 \times 10^{-4}$	95	DECAMP	92	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

$\Gamma(pe)/\Gamma_{\rm total}$ Γ_{46}/Γ

Test of baryon number and lepton number conservations. Charge conjugate states are implied.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.8 \times 10^{-6}$	95	[105] ABBIENDI	99I	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV

[105] ABBIENDI 99I give the 95%CL limit on the partial width $\Gamma(Z^0 \rightarrow pe) <$ 4.6 KeV and we have transformed it into a branching ratio.

$\Gamma(p\mu)/\Gamma_{\rm total}$ Γ_{47}/Γ

Test of baryon number and lepton number conservations. Charge conjugate states are implied.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.8 \times 10^{-6}$	95	[106] ABBIENDI	99I	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV

[106] ABBIENDI 99I give the 95%CL limit on the partial width $\Gamma(Z^0 \rightarrow p\mu) <$ 4.4 KeV and we have transformed it into a branching ratio.

AVERAGE PARTICLE MULTIPLICITIES IN HADRONIC *Z* DECAY

Summed over particle and antiparticle, when appropriate.

$\langle N_{\gamma} \rangle$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
20.97±0.02±1.15	ACKERSTAFF	98A	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV

$\langle N_{\pi^{\pm}} \rangle$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
16.99±0.20 OUR AVERAGE				
16.84±0.37	ABE	99E	SLD	$E^{ee}_{\rm cm}$= 91.2 GeV
17.26±0.10±0.88	ABREU	98L	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
17.04±0.31	BARATE	98V	ALEP	$E^{ee}_{\rm cm}$= 91.2 GeV
17.05±0.43	AKERS	94P	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV

$\langle N_{\pi^0} \rangle$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
9.76±0.26 OUR AVERAGE				
9.55±0.06±0.75	ACKERSTAFF	98A	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV
9.63±0.13±0.63	BARATE	97J	ALEP	$E^{ee}_{\rm cm}$= 91.2 GeV
9.90±0.02±0.33	ACCIARRI	96	L3	$E^{ee}_{\rm cm}$= 91.2 GeV
9.2 ±0.2 ±1.0	ADAM	96	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
9.18±0.03±0.73	ACCIARRI	94B	L3	Repl. by ACCIARRI 96

$\langle N_{\eta} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.95±0.07 OUR AVERAGE			
0.97±0.03±0.11	ACKERSTAFF 98A	OPAL	E^{ee}_{cm}= 91.2 GeV
0.93±0.01±0.09	ACCIARRI 96	L3	E^{ee}_{cm}= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.91±0.02±0.11	ACCIARRI 94B	L3	Repl. by ACCIARRI 96

$\langle N_{\rho^{\pm}} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
2.40±0.06±0.43	ACKERSTAFF 98A	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\rho^{0}} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
1.24±0.10 OUR AVERAGE Error includes scale factor of 1.1.			
1.19±0.10	ABREU 99J	DLPH	E^{ee}_{cm}= 91.2 GeV
1.45±0.06±0.20	BUSKULIC 96H	ALEP	E^{ee}_{cm}= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.21±0.04±0.15	ABREU 95L	DLPH	Repl. by ABREU 99J

$\langle N_{\omega} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
1.08±0.09 OUR AVERAGE			
1.04±0.04±0.14	ACKERSTAFF 98A	OPAL	E^{ee}_{cm}= 91.2 GeV
1.17±0.09±0.15	ACCIARRI 97D	L3	E^{ee}_{cm}= 91.2 GeV
1.07±0.06±0.13	BUSKULIC 96H	ALEP	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\eta'} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.17 ±0.05 OUR AVERAGE Error includes scale factor of 2.4.			
0.14 ±0.01 ±0.02	ACKERSTAFF 98A	OPAL	E^{ee}_{cm}= 91.2 GeV
0.25 ±0.04	[107] ACCIARRI 97D	L3	E^{ee}_{cm}= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.068±0.018±0.016	[108] BUSKULIC 92D	ALEP	E^{ee}_{cm}= 91.2 GeV

[107] ACCIARRI 97D obtain this value averaging over the two decay channels $\eta' \rightarrow \pi^{+}\pi^{-}\eta$ and $\eta' \rightarrow \rho^{0}\gamma$.

[108] BUSKULIC 92D obtain this value for $x > 0.1$.

$\langle N_{f_0(980)} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.147±0.011 OUR AVERAGE			
0.164±0.021	ABREU 99J	DLPH	E^{ee}_{cm}= 91.2 GeV
0.141±0.007±0.011	ACKERSTAFF 98Q	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{a_0(980)^{\pm}} \rangle$

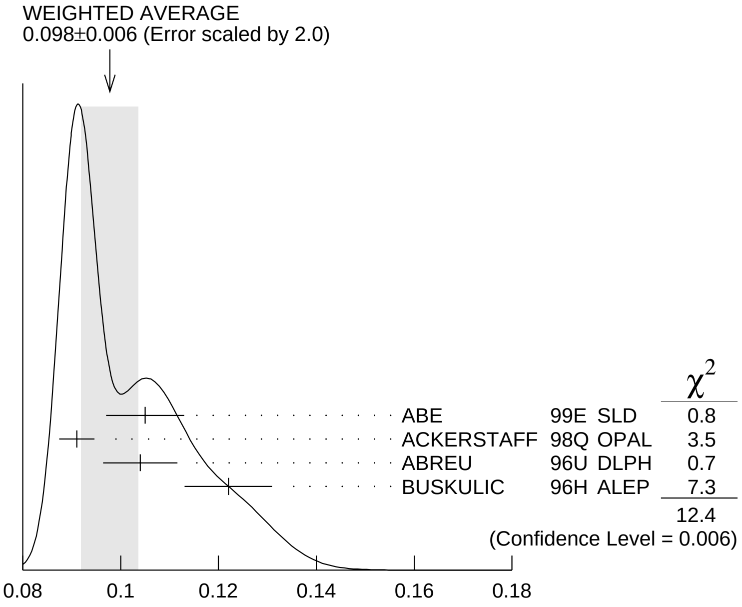
VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.27±0.04±0.10	ACKERSTAFF 98A	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\phi} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.098±0.006 OUR AVERAGE	Error includes scale factor of 2.0. See the ideogram below.		
0.105±0.008	ABE 99E	SLD	E^{ee}_{cm}= 91.2 GeV
0.091±0.002±0.003	ACKERSTAFF 98Q	OPAL	E^{ee}_{cm}= 91.2 GeV
0.104±0.003±0.007	ABREU 96U	DLPH	E^{ee}_{cm}= 91.2 GeV
0.122±0.004±0.008	BUSKULIC 96H	ALEP	E^{ee}_{cm}= 91.2 GeV

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

0.100±0.004±0.007	AKERS 95X	OPAL	Repl. by ACKERSTAFF 98Q



$\langle N_{\phi} \rangle$

$\langle N_{f_2(1270)} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.169±0.025 OUR AVERAGE	Error includes scale factor of 1.4.		
0.214±0.038	ABREU 99J	DLPH	E^{ee}_{cm}= 91.2 GeV
0.155±0.011±0.018	ACKERSTAFF 98Q	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{f'_2(1525)} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.012±0.006 OUR AVERAGE			
0.012±0.006	ABREU 99J	DLPH	E^{ee}_{cm}= 91.2 GeV

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

0.020±0.005±0.006	ABREU 96C	DLPH	Repl. by ABREU 99J

$\langle N_{K^\pm} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
2.25±0.05 OUR AVERAGE			
2.22±0.16	ABE 99E	SLD	$E^{ee}_{\rm cm}$= 91.2 GeV
2.21±0.05±0.05	ABREU 98L	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
2.26±0.12	BARATE 98V	ALEP	$E^{ee}_{\rm cm}$= 91.2 GeV
2.42±0.13	AKERS 94P	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
2.26±0.01±0.18	ABREU 95F	DLPH	Repl. by ABREU 98L

$\langle N_{K^0} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
2.013±0.022 OUR AVERAGE			
2.01 ±0.08	ABE 99E	SLD	$E^{ee}_{\rm cm}$= 91.2 GeV
2.024±0.006±0.042	ACCIARRI 97L	L3	$E^{ee}_{\rm cm}$= 91.2 GeV
1.962±0.022±0.056	ABREU 95L	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
1.99 ±0.01 ±0.04	AKERS 95U	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV
2.061±0.047	BUSKULIC 94K	ALEP	$E^{ee}_{\rm cm}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
2.04 ±0.02 ±0.14	ACCIARRI 94B	L3	Repl. by ACCIARRI 97L

$\langle N_{K^*(892)^\pm} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.72 ±0.05 OUR AVERAGE			
0.712±0.031±0.059	ABREU 95L	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
0.72 ±0.02 ±0.08	ACTON 93	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV

$\langle N_{K^*(892)^0} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.739±0.022 OUR AVERAGE			
0.707±0.041	ABE 99E	SLD	$E^{ee}_{\rm cm}$= 91.2 GeV
0.74 ±0.02 ±0.02	ACKERSTAFF 97S	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV
0.77 ±0.02 ±0.07	ABREU 96U	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
0.83 ±0.01 ±0.09	BUSKULIC 96H	ALEP	$E^{ee}_{\rm cm}$= 91.2 GeV
0.97 ±0.18 ±0.31	ABREU 93	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.74 ±0.03 ±0.03	AKERS 95X	OPAL	Repl. by ACKERSTAFF 97S

$\langle N_{K_2^*(1430)} \rangle$

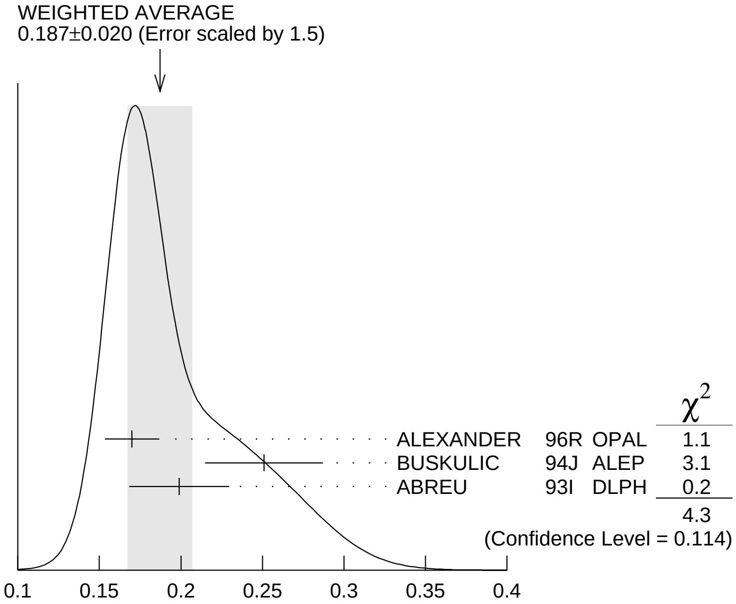
VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.073±0.023 OUR AVERAGE			
0.073±0.023	ABREU 99J	DLPH	$E^{ee}_{\rm cm}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.079±0.026±0.031	ABREU 96U	DLPH	Repl. by ABREU 99J
0.19 ±0.04 ±0.06	[109] AKERS 95X	OPAL	$E^{ee}_{\rm cm}$= 91.2 GeV

[109] AKERS 95X obtain this value for $x < 0.3$.

$\langle N_{D^\pm} \rangle$

VALUE	DOCUMENT ID	TECN	COMMENT
0.187±0.020 OUR AVERAGE	Error includes scale factor of 1.5. See the ideogram below.		
0.170±0.009±0.014	ALEXANDER 96R	OPAL	E^{ee}_{cm}= 91.2 GeV
0.251±0.026±0.025	BUSKULIC 94J	ALEP	E^{ee}_{cm}= 91.2 GeV
0.199±0.019±0.024	[110] ABREU 93I	DLPH	E^{ee}_{cm}= 91.2 GeV

[110] See ABREU 95 (erratum).



$\langle N_{D^\pm} \rangle$

$\langle N_{D^0} \rangle$

VALUE	DOCUMENT ID	TECN	COMMENT
0.462±0.026 OUR AVERAGE			
0.465±0.017±0.027	ALEXANDER 96R	OPAL	E^{ee}_{cm}= 91.2 GeV
0.518±0.052±0.035	BUSKULIC 94J	ALEP	E^{ee}_{cm}= 91.2 GeV
0.403±0.038±0.044	[111] ABREU 93I	DLPH	E^{ee}_{cm}= 91.2 GeV

[111] See ABREU 95 (erratum).

$\langle N_{D_s^\pm} \rangle$

VALUE	DOCUMENT ID	TECN	COMMENT
0.131±0.010±0.018	ALEXANDER 96R	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{D^*(2010)^\pm}\rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.183 ±0.008 OUR AVERAGE			
0.1854±0.0041±0.0091	[112] ACKERSTAFF 98E	OPAL	$E_{\rm cm}^{ee}$= 91.2 GeV
0.187 ±0.015 ±0.013	BUSKULIC 94J	ALEP	$E_{\rm cm}^{ee}$= 91.2 GeV
0.171 ±0.012 ±0.016	[113] ABREU 93I	DLPH	$E_{\rm cm}^{ee}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.183 ±0.009 ±0.011	[114] AKERS 95O	OPAL	Repl. by ACKERSTAFF 98E

[112] ACKERSTAFF 98E systematic error includes an uncertainty of ±0.0069 due to the branching ratios $B(D^{*+} \to D^0\pi^+) = 0.683\pm0.014$ and $B(D^0 \to K^-\pi^+) = 0.0383\pm0.0012$.

[113] See ABREU 95 (erratum).

[114] AKERS 95O systematic error includes an uncertainty of ±0.008 due to the $D^{*\pm}$ and D^0 branching ratios [they use $B(D^* \to D^0\pi) = 0.681 \pm 0.016$ and $B(D^0 \to K\pi) = 0.0401 \pm 0.0014$ to obtain this measurement].

$\langle N_{D_{s1}(2536)^+}\rangle$

VALUE (units 10^{-3})	*DOCUMENT ID*	*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$2.9^{+0.7}_{-0.6}\pm0.2$	[115] ACKERSTAFF 97W	OPAL	$E_{\rm cm}^{ee}$= 91.2 GeV

[115] ACKERSTAFF 97W obtain this value for $x>$ 0.6 and with the assumption that its decay width is saturated by the D^*K final states.

$\langle N_{B^*}\rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.28 ±0.01 ±0.03	[116] ABREU 95R	DLPH	$E_{\rm cm}^{ee}$= 91.2 GeV

[116] ABREU 95R quote this value for a flavor-averaged excited state.

$\langle N_{J/\psi(1S)}\rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0056±0.0003±0.0004	[117] ALEXANDER 96B	OPAL	$E_{\rm cm}^{ee}$= 91.2 GeV

[117] ALEXANDER 96B identify $J/\psi(1S)$ from the decays into lepton pairs.

$\langle N_{\psi(2S)}\rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0023±0.0004±0.0003	ALEXANDER 96B	OPAL	$E_{\rm cm}^{ee}$= 91.2 GeV

$\langle N_p\rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
1.04±0.04 OUR AVERAGE			
1.03±0.13	ABE 99E	SLD	$E_{\rm cm}^{ee}$= 91.2 GeV
1.08±0.04±0.03	ABREU 98L	DLPH	$E_{\rm cm}^{ee}$= 91.2 GeV
1.00±0.07	BARATE 98V	ALEP	$E_{\rm cm}^{ee}$= 91.2 GeV
0.92±0.11	AKERS 94P	OPAL	$E_{\rm cm}^{ee}$= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.07±0.01±0.14	ABREU 95F	DLPH	Repl. by ABREU 98L

$\langle N_{\Delta(1232)^{++}} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.087±0.033 OUR AVERAGE	Error includes scale factor of 2.4.		
0.079±0.009±0.011	ABREU 95W	DLPH	E^{ee}_{cm}= 91.2 GeV
0.22 ±0.04 ±0.04	ALEXANDER 95D	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Lambda} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.374±0.007 OUR AVERAGE			
0.395±0.022	ABE 99E	SLD	E^{ee}_{cm}= 91.2 GeV
0.364±0.004±0.017	ACCIARRI 97L	L3	E^{ee}_{cm}= 91.2 GeV
0.374±0.002±0.010	ALEXANDER 97D	OPAL	E^{ee}_{cm}= 91.2 GeV
0.386±0.016	BUSKULIC 94K	ALEP	E^{ee}_{cm}= 91.2 GeV
0.357±0.003±0.017	ABREU 93L	DLPH	E^{ee}_{cm}= 91.2 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.37 ±0.01 ±0.04	ACCIARRI 94B	L3	Repl. by ACCIARRI 97L

$\langle N_{\Lambda(1520)} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0213±0.0021±0.0019	ALEXANDER 97D	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Sigma^+} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.099±0.008±0.013	ALEXANDER 97E	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Sigma^-} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.083±0.006±0.009	ALEXANDER 97E	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Sigma^+ + \Sigma^-} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.181±0.018 OUR AVERAGE			
0.182±0.010±0.016	[118] ALEXANDER 97E	OPAL	E^{ee}_{cm}= 91.2 GeV
0.170±0.014±0.061	ABREU 95O	DLPH	E^{ee}_{cm}= 91.2 GeV

[118] We have combined the values of $\langle N_{\Sigma^+} \rangle$ and $\langle N_{\Sigma^-} \rangle$ from ALEXANDER 97E adding the statistical and systematic errors of the two final states separately in quadrature. If isospin symmetry is assumed this value becomes 0.174 ± 0.010 ± 0.015.

$\langle N_{\Sigma^0} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.070±0.011 OUR AVERAGE			
0.071±0.012±0.013	ALEXANDER 97E	OPAL	E^{ee}_{cm}= 91.2 GeV
0.070±0.010±0.010	ADAM 96B	DLPH	E^{ee}_{cm}= 91.2 GeV

$\langle N_{(\Sigma^+ + \Sigma^- + \Sigma^0)/3} \rangle$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.084±0.005±0.008	ALEXANDER 97E	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Sigma(1385)^+} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.0239±0.0009±0.0012	ALEXANDER	97D	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Sigma(1385)^-} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.0240±0.0010±0.0014	ALEXANDER	97D	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Sigma(1385)^+ + \Sigma(1385)^-} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.046 ±0.004 OUR AVERAGE	Error includes scale factor of 1.6.			
0.0479±0.0013±0.0026	ALEXANDER	97D	OPAL	E^{ee}_{cm}= 91.2 GeV
0.0382±0.0028±0.0045	ABREU	95O	DLPH	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Xi^-} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.0258±0.0009 OUR AVERAGE				
0.0259±0.0004±0.0009	ALEXANDER	97D	OPAL	E^{ee}_{cm}= 91.2 GeV
0.0250±0.0009±0.0021	ABREU	95O	DLPH	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Xi(1530)^0} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.0053±0.0013 OUR AVERAGE	Error includes scale factor of 3.2.			
0.0068±0.0005±0.0004	ALEXANDER	97D	OPAL	E^{ee}_{cm}= 91.2 GeV
0.0041±0.0004±0.0004	ABREU	95O	DLPH	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Omega^-} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.00164±0.00028 OUR AVERAGE				
0.0018 ±0.0003 ±0.0002	ALEXANDER	97D	OPAL	E^{ee}_{cm}= 91.2 GeV
0.0014 ±0.0002 ±0.0004	ADAM	96B	DLPH	E^{ee}_{cm}= 91.2 GeV

$\langle N_{\Lambda_c^+} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
0.078±0.012±0.012	ALEXANDER	96R	OPAL	E^{ee}_{cm}= 91.2 GeV

$\langle N_{charged} \rangle$

VALUE	DOCUMENT ID		TECN	COMMENT
21.07±0.11 OUR AVERAGE				
21.21±0.01±0.20	ABREU	99	DLPH	E^{ee}_{cm}= 91.2 GeV
21.05±0.20	AKERS	95Z	OPAL	E^{ee}_{cm}= 91.2 GeV
20.91±0.03±0.22	BUSKULIC	95R	ALEP	E^{ee}_{cm}= 91.2 GeV
21.40±0.43	ACTON	92B	OPAL	E^{ee}_{cm}= 91.2 GeV
20.71±0.04±0.77	ABREU	91H	DLPH	E^{ee}_{cm}= 91.2 GeV
20.7 ±0.7	ADEVA	91I	L3	E^{ee}_{cm}= 91.2 GeV
20.1 ±1.0 ±0.9	ABRAMS	90	MRK2	E^{ee}_{cm}= 91.1 GeV

Z HADRONIC POLE CROSS SECTION

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the *Z* boson"). This quantity is defined as

$$\sigma_h^0 = \frac{12\pi}{M_Z^2} \frac{\Gamma(e^+e^-)\,\Gamma(\text{hadrons})}{\Gamma_Z^2}$$

It is one of the parameters used in the *Z* lineshape fit.

VALUE (nb)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
41.561±0.042 OUR FIT					
41.578±0.069	3.70M	ABREU	00F	DLPH	E^{ee}_{cm}= 88–94 GeV
41.535±0.055	3.54M	ACCIARRI	00C	L3	E^{ee}_{cm}= 88–94 GeV
41.559±0.058	4.07M	[119] BARATE	00C	ALEP	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
41.23 ±0.20	1.05M	ABREU	94	DLPH	Repl. by ABREU 00F
41.39 ±0.26	1.09M	ACCIARRI	94	L3	Repl. by ACCIARRI 00C
41.70 ±0.23	1.19M	AKERS	94	OPAL	E^{ee}_{cm}= 88–94 GeV
41.60 ±0.16	1.27M	BUSKULIC	94	ALEP	Repl. by BARATE 00C
42 ±4	450	ABRAMS	89B	MRK2	E^{ee}_{cm}= 89.2–93.0 GeV

[119] BARATE 00C error includes approximately 0.030 due to statistics, 0.026 due to experimental systematics, and 0.025 due to uncertainty in luminosity measurement.

Z VECTOR COUPLINGS TO CHARGED LEPTONS

These quantities are the effective vector couplings of the *Z* to charged leptons. Their magnitude is derived from a measurement of the *Z* lineshape and the forward-backward lepton asymmetries as a function of energy around the *Z* mass. The relative sign among the vector to axial-vector couplings is obtained from a measurement of the *Z* asymmetry parameters, A_e, A_μ, and A_τ. By convention the sign of g^e_A is fixed to be negative (and opposite to that of g^{ν_e} obtained using ν_e scattering measurements). The fit values quoted below correspond to global nine- or five-parameter fits to lineshape, lepton forward-backward asymmetry, and A_e, A_μ, and A_τ measurements. See "Note on the *Z* boson" for details.

g^e_V

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.03874±0.00094 OUR FIT				
−0.0412 ±0.0027	124.4k	[120] ACCIARRI 00C	L3	E^{ee}_{cm}= 88–94 GeV
−0.0400 ±0.0037		BARATE 00C	ALEP	E^{ee}_{cm}= 88–94 GeV
−0.0414 ±0.0020		[121] ABE 95J	SLD	E^{ee}_{cm}= 91.31 GeV

[120] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

[121] ABE 95J obtain this result combining polarized Bhabha results with the A_{LR} measurement of ABE 94C. The Bhabha results alone give −0.0507 ± 0.0096 ± 0.0020.

g^μ_V

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.0359±0.0033 OUR FIT				
−0.0386±0.0073	113.4k	[122] ACCIARRI 00C	L3	E^{ee}_{cm}= 88–94 GeV
−0.0362±0.0061		BARATE 00C	ALEP	E^{ee}_{cm}= 88–94 GeV

[122] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

g^τ_V

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.0366±0.0014 OUR FIT				
−0.0384±0.0026	103.0k	[123] ACCIARRI 00C	L3	E^{ee}_{cm}= 88–94 GeV
−0.0361±0.0068		BARATE 00C	ALEP	E^{ee}_{cm}= 88–94 GeV

[123] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

g^ℓ_V

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.03795±0.00071 OUR FIT				
−0.0397 ±0.0020	379.4k	[124] ABREU 00F	DLPH	E^{ee}_{cm}= 88–94 GeV
−0.0397 ±0.0017	340.8k	[125] ACCIARRI 00C	L3	E^{ee}_{cm}= 88–94 GeV
−0.0383 ±0.0018	500k	BARATE 00C	ALEP	E^{ee}_{cm}= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.034 ±0.004	146k	[124] AKERS 94	OPAL	E^{ee}_{cm}= 88–94 GeV

[124] Using forward-backward lepton asymmetries.

[125] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

Z AXIAL-VECTOR COUPLINGS TO CHARGED LEPTONS

These quantities are the effective axial-vector couplings of the Z to charged leptons. Their magnitude is derived from a measurement of the Z lineshape and the forward-backward lepton asymmetries as a function of energy around the Z mass. The relative sign among the vector to axial-vector couplings is obtained from a measurement of the Z asymmetry parameters, A_e, A_μ, and A_τ. By convention the sign of g^e_A is fixed to be negative (and opposite to that of g^{ν_e} obtained using ν_e scattering measurements). The fit values quoted below correspond to global nine- or five-parameter fits to lineshape, lepton forward-backward asymmetry, and A_e, A_μ, and A_τ measurements. See "Note on the Z boson" for details.

g^e_A

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.50133±0.00040 OUR FIT				
−0.5015 ±0.0007	124.4k	[126] ACCIARRI 00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
−0.50166±0.00057		BARATE 00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
−0.4977 ±0.0045		[127] ABE 95J	SLD	$E^{ee}_{\rm cm}$= 91.31 GeV

[126] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

[127] ABE 95J obtain this result combining polarized Bhabha results with the A_{LR} measurement of ABE 94C. The Bhabha results alone give −0.4968 ± 0.0039 ± 0.0027.

g^μ_A

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.50139±0.00066 OUR FIT				
−0.5009 ±0.0014	113.4k	[128] ACCIARRI 00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
−0.50046±0.00093		BARATE 00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

[128] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

g^τ_A

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.50223±0.00073 OUR FIT				
−0.5023 ±0.0017	103.0k	[129] ACCIARRI 00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
−0.50216±0.00100		BARATE 00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV

[129] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

g^ℓ_A

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.50145±0.00030 OUR FIT				
−0.5007 ±0.0005	379.4k	ABREU 00F	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
−0.50153±0.00053	340.8k	[130] ACCIARRI 00C	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
−0.50150±0.00046	500k	BARATE 00C	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.500 ±0.001	146k	AKERS 94	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV

[130] ACCIARRI 00C use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

Z COUPLINGS TO NEUTRAL LEPTONS

These quantities are the effective couplings of the *Z* to neutral leptons. $\nu_e e$ and $\nu_\mu e$ scattering results are combined with g^e_A and g^e_V measurements at the *Z* mass to obtain g^{ν_e} and g^{ν_μ} following NOVIKOV 93C.

g^{ν_e}

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.528±0.085	[131] VILAIN	94	CHM2	From $\nu_\mu e$ and $\nu_e e$ scattering

[131] VILAIN 94 derive this value from their value of g^{ν_μ} and their ratio $g^{\nu_e}/g^{\nu_\mu} = 1.05^{+0.15}_{-0.18}$.

g^{ν_μ}

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.502±0.017	[132] VILAIN	94	CHM2	From $\nu_\mu e$ scattering

[132] VILAIN 94 derive this value from their measurement of the couplings $g^{e\nu_\mu}_A = -0.503 \pm 0.017$ and $g^{e\nu_\mu}_V = -0.035 \pm 0.017$ obtained from $\nu_\mu e$ scattering. We have re-evaluated this value using the current PDG values for g^e_A and g^e_V.

Z ASYMMETRY PARAMETERS

For each fermion-antifermion pair coupling to the *Z* these quantities are defined as

$$A_f = \frac{2 g_V^f g_A^f}{(g_V^f)^2 + (g_A^f)^2}$$

where g_V^f and g_A^f are the effective vector and axial-vector couplings. For their relation to the various lepton asymmetries see the 'Note on the *Z* Boson.'

A_e

Using polarized beams, this quantity can also be measured as $(\sigma_L - \sigma_R)/\,(\sigma_L + \sigma_R)$, where σ_L and σ_R are the e^+e^- production cross sections for *Z* bosons produced with left-handed and right-handed electrons respectively.

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.152 ±0.004 OUR AVERAGE	Error includes scale factor of 1.2.			
0.1382±0.0116±0.0005	105000	[133] ABREU 00E	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
0.1678±0.0127±0.0030	137092	[134] ACCIARRI 98H	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
0.162 ±0.041 ±0.014	89838	[135] ABE 97	SLD	$E^{ee}_{\rm cm}$= 91.27 GeV
0.1543±0.0039	93644	[136] ABE 97E	SLD	$E^{ee}_{\rm cm}$= 91.27 GeV
0.152 ±0.012		[137] ABE 97N	SLD	$E^{ee}_{\rm cm}$= 91.27 GeV
0.129 ±0.014 ±0.005	89075	[138] ALEXANDER 96U	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
0.202 ±0.038 ±0.008		[139] ABE 95J	SLD	$E^{ee}_{\rm cm}$= 91.31 GeV
0.129 ±0.016 ±0.005	33000	[140] BUSKULIC 95Q	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.136 ±0.027 ±0.003		[134] ABREU 95I	DLPH	Repl. by ABREU 00E
0.122 ±0.030 ±0.012	30663	[134] AKERS 95	OPAL	Repl. by ALEXANDER 96U
0.1656±0.0071±0.0028	49392	[141] ABE 94C	SLD	Repl. by ABE 97E
0.157 ±0.020 ±0.005	86000	[134] ACCIARRI 94E	L3	Repl. by ACCIARRI 98H

[133] ABREU 00E obtain this result fitting the τ polarization as a function of the polar τ production angle. This measurement is a combination of different analyses (exclusive τ decay modes, inclusive hadronic 1-prong reconstruction, and a neural network analysis).

[134] Derived from the measurement of forward-backward τ polarization asymmetry.

[135] ABE 97 obtain this result from a measurement of the observed left-right charge asymmetry, $A_Q^{\rm obs} = 0.225 \pm 0.056 \pm 0.019$, in hadronic *Z* decays. If they combine this value of $A_Q^{\rm obs}$ with their earlier measurement of $A_{LR}^{\rm obs}$ they determine A_e to be $0.1574 \pm 0.0197 \pm 0.0067$ independent of the beam polarization.

[136] ABE 97E measure the left-right asymmetry in hadronic *Z* production. This value (statistical and systematic errors added in quadrature) leads to $\sin^2\theta_W^{\rm eff} = 0.23060 \pm 0.00050$.

[137] ABE 97N obtain this direct measurement using the lef-right cross section asymmetry and the left-right forward-backward asymmetry in leptonic decays of the *Z* boson obtained with a polarized electron beam.

[138] ALEXANDER 96U measure the τ-lepton polarization and the forward-backward polarization asymmetry.

[139] ABE 95J obtain this result from polarized Bhabha scattering.

[140] BUSKULIC 95Q obtain this result fitting the τ polarization as a function of the polar τ production angle.

[141] ABE 94C measured the left-right asymmetry in *Z* production. This value leads to $\sin^2\theta_W = 0.2292 \pm 0.0009 \pm 0.0004$.

A_{μ}

This quantity is directly extracted from a measurement of the left-right forward-backward asymmetry in $\mu^+\mu^-$ production at SLC using a polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.102±0.034	3788	[142] ABE	97N	SLD	$E^{ee}_{\rm cm}$= 91.27 GeV

[142] ABE 97N obtain this direct measurement using the lef-right cross section asymmetry and the left-right forward-backward asymmetry in $\mu^+\mu^-$ decays of the Z boson obtained with a polarized electron beam.

A_{τ}

The LEP Collaborations derive this quantity from the measurement of the τ polarization in $Z \rightarrow \tau^+\tau^-$. The SLD Collaboration directly extracts this quantity from its measured left-right forward-backward asymmetry in $Z \rightarrow \tau^+\tau^-$ produced using a polarized e^- beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.141 ±0.006 OUR AVERAGE					
0.1359±0.0079±0.0055	105000	[143] ABREU	00E	DLPH	$E^{ee}_{\rm cm}$= 88–94 GeV
0.1476±0.0088±0.0062	137092	ACCIARRI	98H	L3	$E^{ee}_{\rm cm}$= 88–94 GeV
0.195 ±0.034		[144] ABE	97N	SLD	$E^{ee}_{\rm cm}$= 91.27 GeV
0.134 ±0.009 ±0.010	89075	[145] ALEXANDER	96U	OPAL	$E^{ee}_{\rm cm}$= 88–94 GeV
0.136 ±0.012 ±0.009	33000	[146] BUSKULIC	95Q	ALEP	$E^{ee}_{\rm cm}$= 88–94 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.148 ±0.017 ±0.014		ABREU	95I	DLPH	Repl. by ABREU 00E
0.153 ±0.019 ±0.013	30663	AKERS	95	OPAL	Repl. by ALEXANDER 96U
0.150 ±0.013 ±0.009	86000	ACCIARRI	94E	L3	Repl. by ACCIARRI 98H

[143] ABREU 00E obtain this result fitting the τ polarization as a function of the polar τ production angle. This measurement is a combination of different analyses (exclusive τ decay modes, inclusive hadronic 1-prong reconstruction, and a neural network analysis).

[144] ABE 97N obtain this direct measurement using the left-right cross section asymmetry and the left-right forward-backward asymmetry in $\tau^+\tau^-$ decays of the Z boson obtained with a polarized electron beam.

[145] ALEXANDER 96U measure the τ-lepton polarization and the forward-backward polarization asymmetry.

[146] BUSKULIC 95Q obtain this result fitting the τ polarization as a function of the polar τ production angle.

A_c

This quantity is directly extracted from a measurement of the left-right forward-backward asymmetry in $c\overline{c}$ production at SLC using polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.66 ±0.11 OUR AVERAGE				
0.642±0.110±0.063	[147] ABE	99O	SLD	$E^{ee}_{\rm cm}$= 91.27 GeV
0.73 ±0.22 ±0.10	[148] ABE,K	95	SLD	$E^{ee}_{\rm cm}$= 91.26 GeV

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

0.37 ±0.23 ±0.21		[149] ABE	95L SLD	Repl. by ABE 99O

[147] ABE 99O tag *b* and *c* quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract simultaneously A_b and A_c.

[148] ABE,K 95 tag $Z \rightarrow c\overline{c}$ events using D^{*+} and D^+ meson production. To take care of the $b\overline{b}$ contamination in their analysis they use $A_b^D = 0.64 \pm 0.11$ (which is A_b from D^*/D tagging). This is obtained by starting with a Standard Model value of 0.935, assigning it an estimated error of ±0.105 to cover LEP and SLD measurements, and finally taking into account B-$\overline{B}$ mixing ($1-2\chi_{\text{mix}} = 0.72 \pm 0.09$).

[149] ABE 95L tag *b* and *c* quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract A_b and A_c.

A_b

This quantity is directly extracted from a measurement of the left-right forward-backward asymmetry in $b\overline{b}$ production at SLC using polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e.

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.91 ±0.05 OUR AVERAGE				
0.905±0.051		[150] ABE	99O SLD	$E^{ee}_{\text{cm}} = 91.27$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.855±0.088±0.102	7473	[151] ABE	99L SLD	Repl. by ABE 99O
0.911±0.045±0.045	11092	[152] ABE	98I SLD	Repl. by ABE 99O
0.91 ±0.14 ±0.07		[153] ABE	95L SLD	Repl. by ABE 99O

[150] ABE 99O tag *b* and *c* quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract simultaneously A_b and A_c. The value of A_b so extracted, 0.910 ± 0.068 ± 0.037, is then combined with A_b from ABE 99L and ABE 99I to obtain the resulting SLD average value quoted here.

[151] ABE 99L obtain an enriched sample of $b\overline{b}$ events tagging with an inclusive vertex mass cut. For distinguishing b and $\overline{b}$ quarks they use the charge of identified $K^{\pm}$.

[152] ABE 98I obtain an enriched sample of $b\overline{b}$ events tagging with an inclusive vertex mass cut. A momentum-weighted track charge is used to identify the sign of the charge of the underlying *b* quark.

[153] ABE 95L tag *b* and *c* quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract A_b and A_c.

TRANSVERSE SPIN CORRELATIONS IN $Z \rightarrow \tau^+\tau^-$

The correlations between the transverse spin components of $\tau^+\tau^-$ produced in Z decays may be expressed in terms of the vector and axial-vector couplings:

$$C_{TT} = \frac{|g_A^\tau|^2 - |g_V^\tau|^2}{|g_A^\tau|^2 + |g_V^\tau|^2}$$

$$C_{TN} = -2\frac{|g_A^\tau||g_V^\tau|}{|g_A^\tau|^2 + |g_V^\tau|^2}\sin(\Phi_{g_V^\tau} - \Phi_{g_A^\tau})$$

C_{TT} refers to the transverse-transverse (within the collision plane) spin correlation and C_{TN} refers to the transverse-normal (to the collision plane) spin correlation.

The longitudinal τ polarization P_τ ($= -A_\tau$) is given by:

$$P_\tau = -2\frac{|g_A^\tau||g_V^\tau|}{|g_A^\tau|^2+|g_V^\tau|^2}\cos(\Phi_{g_V^\tau} - \Phi_{g_A^\tau})$$

Here Φ is the phase and the phase difference $\Phi_{g_V^\tau} - \Phi_{g_A^\tau}$ can be obtained using both the measurements of C_{TN} and P_τ.

C_{TT}

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1.01±0.12 OUR AVERAGE				
$0.87\pm0.20^{+0.10}_{-0.12}$	9.1k	ABREU 97G	DLPH	E^{ee}_{cm}= 91.2 GeV
1.06±0.13±0.05	120k	BARATE 97D	ALEP	E^{ee}_{cm}= 91.2 GeV

C_{TN}

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.08±0.13±0.04	120k	[154] BARATE 97D	ALEP	E^{ee}_{cm}= 91.2 GeV

[154] BARATE 97D combine their value of C_{TN} with the world average $P_\tau = -0.140 \pm 0.007$ to obtain $\tan(\Phi_{g_V^\tau} - \Phi_{g_A^\tau}) = -0.57 \pm 0.97$.

$A_{FB}^{(0,e)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow e^+e^-$

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson"). For the Z peak, we report the pole asymmetry defined by $(3/4)A_e^2$ as determined by the nine-parameter fit to cross-section and lepton forward-backward asymmetry data.

ASYMMETRY (%)	*STD. MODEL*	*$\sqrt{s}$ (GeV)*	*DOCUMENT ID*	*TECN*
1.64±0.27 OUR FIT				
1.71±0.49		91.2	ABREU 00F	DLPH
1.06±0.58		91.2	ACCIARRI 00C	L3
1.88±0.34		91.2	[155] BARATE 00C	ALEP
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.5 ±0.9		91.2	ABREU 94	DLPH
1.04±0.92		91.2	ACCIARRI 94	L3
0.62±0.80		91.2	AKERS 94	OPAL
1.85±0.66		91.2	BUSKULIC 94	ALEP

[155] BARATE 00C error includes approximately 0.31 due to statistics, 0.06 due to experimental systematics, and 0.13 due to the theoretical uncertainty in t-channel prediction.

$A_{FB}^{(0,\mu)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow \mu^+\mu^-$

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson"). For the Z peak, we report the pole asymmetry defined by $(3/4)A_e A_\mu$ as determined by the nine-parameter fit to cross-section and lepton forward-backward asymmetry data.

ASYMMETRY (%)	*STD. MODEL*	$\sqrt{s}$ *(GeV)*	*DOCUMENT ID*	*TECN*
1.73± 0.16 OUR FIT				
1.65± 0.25		91.2	ABREU 00F	DLPH
1.88± 0.33		91.2	ACCIARRI 00C	L3
1.71± 0.24		91.2	[156] BARATE 00C	ALEP
• • • We do not use the following data for averages, fits, limits, etc. • • •				
9 ±30	−2	20	[157] ABREU 95M	DLPH
7 ±26	−10	40	[157] ABREU 95M	DLPH
−11 ±33	−25	57	[157] ABREU 95M	DLPH
−62 ±17	−45	69	[157] ABREU 95M	DLPH
−56 ±10	−58	79	[157] ABREU 95M	DLPH
−13 ± 5	−23	87.5	[157] ABREU 95M	DLPH
1.4 ± 0.5		91.2	ABREU 94	DLPH
1.79± 0.61		91.2	ACCIARRI 94	L3
0.99± 0.42		91.2	AKERS 94	OPAL
1.46± 0.48		91.2	BUSKULIC 94	ALEP
$-29.0\ ^{+\ 5.0}_{-\ 4.8}\ \pm 0.5$	−32.1	56.9	[158] ABE 90I	VNS
− 9.9 ± 1.5 ±0.5	−9.2	35	HEGNER 90	JADE
0.05± 0.22	0.026	91.14	[159] ABRAMS 89D	MRK2
−43.4 ±17.0	−24.9	52.0	[160] BACALA 89	AMY
−11.0 ±16.5	−29.4	55.0	[160] BACALA 89	AMY
−30.0 ±12.4	−31.2	56.0	[160] BACALA 89	AMY
−46.2 ±14.9	−33.0	57.0	[160] BACALA 89	AMY
−29 ±13	−25.9	53.3	ADACHI 88C	TOPZ
+ 5.3 ± 5.0 ±0.5	−1.2	14.0	ADEVA 88	MRKJ
−10.4 ± 1.3 ±0.5	−8.6	34.8	ADEVA 88	MRKJ
−12.3 ± 5.3 ±0.5	−10.7	38.3	ADEVA 88	MRKJ
−15.6 ± 3.0 ±0.5	−14.9	43.8	ADEVA 88	MRKJ
− 1.0 ± 6.0	−1.2	13.9	BRAUNSCH... 88D	TASS
− 9.1 ± 2.3 ±0.5	−8.6	34.5	BRAUNSCH... 88D	TASS
$-10.6\ ^{+\ 2.2}_{-\ 2.3}\ \pm 0.5$	−8.9	35.0	BRAUNSCH... 88D	TASS
$-17.6\ ^{+\ 4.4}_{-\ 4.3}\ \pm 0.5$	−15.2	43.6	BRAUNSCH... 88D	TASS
− 4.8 ± 6.5 ±1.0	−11.5	39	BEHREND 87C	CELL
−18.8 ± 4.5 ±1.0	−15.5	44	BEHREND 87C	CELL
+ 2.7 ± 4.9	−1.2	13.9	BARTEL 86C	JADE
−11.1 ± 1.8 ±1.0	−8.6	34.4	BARTEL 86C	JADE
−17.3 ± 4.8 ±1.0	−13.7	41.5	BARTEL 86C	JADE
−22.8 ± 5.1 ±1.0	−16.6	44.8	BARTEL 86C	JADE
− 6.3 ± 0.8 ±0.2	−6.3	29	ASH 85	MAC
− 4.9 ± 1.5 ±0.5	−5.9	29	DERRICK 85	HRS
− 7.1 ± 1.7	−5.7	29	LEVI 83	MRK2
−16.1 ± 3.2	−9.2	34.2	BRANDELIK 82C	TASS

[156] BARATE 00C error is almost entirely on account of statistics.

[157] ABREU 95M perform this measurement using radiative muon-pair events associated with high-energy isolated photons.

[158] ABE 90I measurements in the range 50 $\leq \sqrt{s} \leq$ 60.8 GeV.
[159] ABRAMS 89D asymmetry includes both 9 $\mu^+\mu^-$ and 15 $\tau^+\tau^-$ events.
[160] BACALA 89 systematic error is about 5%.

$A_{FB}^{(0,\tau)}$ CHARGE ASYMMETRY IN $e^+e^- \to \tau^+\tau^-$

OUR FIT is obtained using the fit procedure and correlations as determined by the LEP Electroweak Working Group (see the "Note on the Z boson"). For the Z peak, we report the pole asymmetry defined by $(3/4)A_e A_\tau$ as determined by the nine-parameter fit to cross-section and lepton forward-backward asymmetry data.

ASYMMETRY (%)	*STD. MODEL*	*$\sqrt{s}$ (GeV)*	*DOCUMENT ID*		*TECN*
2.07± 0.20 OUR FIT					
2.41± 0.37		91.2	ABREU	00F	DLPH
2.60± 0.47		91.2	ACCIARRI	00C	L3
1.70± 0.28		91.2	[161] BARATE	00C	ALEP
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2.2 ± 0.7		91.2	ABREU	94	DLPH
2.65± 0.88		91.2	ACCIARRI	94	L3
2.05± 0.52		91.2	AKERS	94	OPAL
1.97± 0.56		91.2	BUSKULIC	94	ALEP
$-32.8^{+6.4}_{-6.2} \pm 1.5$	−32.1	56.9	[162] ABE	90I	VNS
− 8.1 ± 2.0 ±0.6	−9.2	35	HEGNER	90	JADE
−18.4 ±19.2	−24.9	52.0	[163] BACALA	89	AMY
−17.7 ±26.1	−29.4	55.0	[163] BACALA	89	AMY
−45.9 ±16.6	−31.2	56.0	[163] BACALA	89	AMY
−49.5 ±18.0	−33.0	57.0	[163] BACALA	89	AMY
−20 ±14	−25.9	53.3	ADACHI	88C	TOPZ
−10.6 ± 3.1 ±1.5	−8.5	34.7	ADEVA	88	MRKJ
− 8.5 ± 6.6 ±1.5	−15.4	43.8	ADEVA	88	MRKJ
− 6.0 ± 2.5 ±1.0	8.8	34.6	BARTEL	85F	JADE
−11.8 ± 4.6 ±1.0	14.8	43.0	BARTEL	85F	JADE
− 5.5 ± 1.2 ±0.5	−0.063	29.0	FERNANDEZ	85	MAC
− 4.2 ± 2.0	0.057	29	LEVI	83	MRK2
−10.3 ± 5.2	−9.2	34.2	BEHREND	82	CELL
− 0.4 ± 6.6	−9.1	34.2	BRANDELIK	82C	TASS

[161] BARATE 00C error includes approximately 0.26 due to statistics and 0.11 due to experimental systematics.
[162] ABE 90I measurements in the range 50 $\leq \sqrt{s} \leq$ 60.8 GeV.
[163] BACALA 89 systematic error is about 5%.

$A_{FB}^{(0,\ell)}$ CHARGE ASYMMETRY IN $e^+e^- \to \ell^+\ell^-$

For the Z peak, we report the pole asymmetry defined by $(3/4)A_\ell^2$ as determined by the five-parameter fit to cross-section and lepton forward-backward asymmetry data assuming lepton universality. For details see the "Note on the Z boson."

ASYMMETRY (%)	*STD. MODEL*	$\sqrt{s}$ *(GeV)*	*DOCUMENT ID*		*TECN*
1.82±0.11 OUR FIT					
1.87±0.19		91.2	ABREU	00F	DLPH
1.92±0.24		91.2	ACCIARRI	00C	L3
1.73±0.16		91.2	[164] BARATE	00C	ALEP
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.77±0.37		91.2	ABREU	94	DLPH
1.84±0.45		91.2	ACCIARRI	94	L3
1.28±0.30		91.2	AKERS	94	OPAL
1.71±0.33		91.2	BUSKULIC	94	ALEP

[164] BARATE 00C error includes approximately 0.15 due to statistics, 0.04 due to experimental systematics, and 0.02 due to the theoretical uncertainty in t-channel prediction.

$A_{FB}^{(0,u)}$ CHARGE ASYMMETRY IN $e^+e^- \to u\overline{u}$

ASYMMETRY (%)	*STD. MODEL*	$\sqrt{s}$ *(GeV)*	*DOCUMENT ID*		*TECN*
4.0±6.7±2.8	**6**	**91.2**	[165] ACKERSTAFF	97T	OPAL

[165] ACKERSTAFF 97T measure the forward-backward asymmetry of various fast hadrons made of light quarks. Then using SU(2) isospin symmetry and flavor independence for down and strange quarks authors solve for the different quark types.

$A_{FB}^{(0,s)}$ CHARGE ASYMMETRY IN $e^+e^- \to s\overline{s}$

The s-quark asymmetry is derived from measurements of the forward-backward asymmetry of fast hadrons containing an s quark.

ASYMMETRY (%)	*STD. MODEL*	$\sqrt{s}$ *(GeV)*	*DOCUMENT ID*		*TECN*
9.8 ±1.1 OUR AVERAGE					
10.08±1.13±0.40		91.2	[166] ABREU	00B	DLPH
6.8 ±3.5 ±1.1	10	91.2	[167] ACKERSTAFF	97T	OPAL
• • • We do not use the following data for averages, fits, limits, etc. • • •					
13.1 ±3.5 ±1.3		91.2	[168] ABREU	95G	DLPH

[166] ABREU 00B tag the presence of an s quark requiring a high-momentum-identified charged kaon. The s-quark pole asymmetry is extracted from the charged-kaon asymmetry taking the expected d- and u-quark asymmetries from the Standard Model and using the measured values for the c- and b-quark asymmetries.

[167] ACKERSTAFF 97T measure the forward-backward asymmetry of various fast hadrons made of light quarks. Then using SU(2) isospin symmetry and flavor independence for down and strange quarks authors solve for the different quark types. The value reported here corresponds then to the forward-backward asymmetry for "down-type" quarks.

[168] ABREU 95G require the presence of a high-momentum charged kaon or Λ^0 to tag the s quark. An unresolved s- and d-quark asymmetry of $(11.2 \pm 3.1 \pm 5.4)\%$ is obtained by tagging the presence of a high-energy neutron or neutral kaon in the hadron calorimeter. Superseded by ABREU 00B.

$A_{FB}^{(0,c)}$ CHARGE ASYMMETRY IN $e^+ e^- \to c\bar{c}$

OUR FIT, which is obtained by a simultaneous fit to several c- and b-quark measurements as explained in the "Note on the Z boson," refers to the Z pole asymmetry. As a cross check we have also performed a weighted average of the "near peak" measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. Applying to this combined "peak" measurement QED and energy-dependence corrections, our weighted average gives a pole asymmetry of $(7.18 \pm 0.49)\%$.

ASYMMETRY (%)	*STD. MODEL*	*$\sqrt{s}$ (GeV)*	*DOCUMENT ID*	*TECN*
7.01 ± 0.45 OUR FIT				
6.59 ± 0.94 ± 0.35		91.235	[169] ABREU 99Y	DLPH
6.3 ± 0.9 ± 0.3		91.22	[170] BARATE 98O	ALEP
6.3 ± 1.2 ± 0.6		91.22	[171] ALEXANDER 97C	OPAL
6.00 ± 0.67 ± 0.52		91.24	[172] ALEXANDER 96	OPAL
8.3 ± 2.2 ± 1.6		91.27	[173] ABREU 95K	DLPH
9.9 ± 2.0 ± 1.7		91.24	[174] BUSKULIC 94G	ALEP
8.3 ± 3.8 ± 2.7	5.6	91.24	[175] ADRIANI 92D	L3
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−4.96 ± 3.68 ± 0.53		89.434	[169] ABREU 99Y	DLPH
11.80 ± 3.18 ± 0.62		92.990	[169] ABREU 99Y	DLPH
−1.0 ± 4.3 ± 1.0		89.37	[170] BARATE 98O	ALEP
11.0 ± 3.3 ± 0.8		92.96	[170] BARATE 98O	ALEP
3.9 ± 5.1 ± 0.9		89.45	[171] ALEXANDER 97C	OPAL
15.8 ± 4.1 ± 1.1		93.00	[171] ALEXANDER 97C	OPAL
−7.5 ± 3.4 ± 0.6	−3.5	89.52	[172] ALEXANDER 96	OPAL
14.1 ± 2.8 ± 0.9	12.0	92.94	[172] ALEXANDER 96	OPAL
7.7 ± 2.9 ± 1.2		91.27	[176] ABREU 95E	DLPH
6.99 ± 2.05 ± 1.02		91.24	[177] BUSKULIC 95I	ALEP
−12.9 ± 7.8 ± 5.5	−13.6	35	BEHREND 90D	CELL
7.7 ± 13.4 ± 5.0	−22.1	43	BEHREND 90D	CELL
−12.8 ± 4.4 ± 4.1	−13.6	35	ELSEN 90	JADE
−10.9 ± 12.9 ± 4.6	−23.2	44	ELSEN 90	JADE
−14.9 ± 6.7	−13.3	35	OULD-SAADA 89	JADE

[169] ABREU 99Y tag $Z \to b\bar{b}$ and $Z \to c\bar{c}$ events by an exclusive reconstruction of several D meson decay modes (D^{*+}, D^0, and D^+ with their charge-conjugate states).

[170] BARATE 98O tag $Z \to c\bar{c}$ events requiring the presence of high-momentum reconstructed D^{*+}, D^+, or D^0 mesons.

[171] ALEXANDER 97C identify the b and c events using a D/D^* tag.

[172] ALEXANDER 96 tag heavy flavors using one or two identified leptons. This allows the simultaneous fitting of the b and c quark forward-backward asymmetries as well as the average B^0-$\overline{B}^0$ mixing.

[173] ABREU 95K identify c and b quarks using both electron and muon semileptonic decays.

[174] BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and dilepton events.

[175] ADRIANI 92D use both electron and muon semileptonic decays.

[176] ABREU 95E require the presence of a $D^{*\pm}$ to identify c and b quarks. Replaced by ABREU 99Y.

[177] BUSKULIC 95I require the presence of a high momentum $D^{*\pm}$ to have an enriched sample of $Z \to c\overline{c}$ events. Replaced by BARATE 98O.

$A_{FB}^{(0,b)}$ CHARGE ASYMMETRY IN $e^+e^- \to b\overline{b}$

OUR FIT, which is obtained by a simultaneous fit to several c- and b-quark measurements as explained in the "Note on the Z boson," refers to the Z pole asymmetry. As a cross check we have also performed a weighted average of the "near peak" measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. Applying to this combined "peak" measurement QED and energy-dependence corrections, our weighted average gives a pole asymmetry of (10.09 ± 0.22)%. For the jet-charge measurements (where the QCD effects are included since they represent an inherent part of the analysis), we use the corrections given by the authors.

ASYMMETRY (%)	*STD. MODEL*	*$\sqrt{s}$ (GeV)*	*DOCUMENT ID*	*TECN*
10.03± 0.22 OUR FIT				
9.82± 0.47± 0.16		91.26	[178] ABREU 99M	DLPH
7.62± 1.94± 0.85		91.235	[179] ABREU 99Y	DLPH
9.60± 0.66± 0.33		91.26	[180] ACCIARRI 99D	L3
9.31± 1.01± 0.55		91.24	[181] ACCIARRI 98U	L3
10.40± 0.40± 0.32		91.25	[182] BARATE 98M	ALEP
9.94± 0.52± 0.44		91.21	[183] ACKERSTAFF 97P	OPAL
9.4 ± 2.7 ± 2.2		91.22	[184] ALEXANDER 97C	OPAL
9.06± 0.51± 0.23		91.24	[185] ALEXANDER 96	OPAL
9.65± 0.44± 0.26		91.21	[186] BUSKULIC 96Q	ALEP
10.4 ± 1.3 ± 0.5		91.27	[187] ABREU 95K	DLPH
• • • We do not use the following data for averages, fits, limits, etc. • • •				
6.8 ± 1.8 ± 0.13		89.55	[178] ABREU 99M	DLPH
12.3 ± 1.6 ± 0.27		92.94	[178] ABREU 99M	DLPH
5.67± 7.56± 1.17		89.434	[179] ABREU 99Y	DLPH
8.82± 6.33± 1.22		92.990	[179] ABREU 99Y	DLPH
6.11± 2.93± 0.43		89.50	[180] ACCIARRI 99D	L3
13.71± 2.40± 0.44		93.10	[180] ACCIARRI 99D	L3
4.95± 5.23± 0.40		89.45	[181] ACCIARRI 98U	L3
11.37± 3.99± 0.65		92.99	[181] ACCIARRI 98U	L3
7.46± 1.78± 0.24		89.43	[182] BARATE 98M	ALEP

9.24 ± 1.79 ± 0.52		92.97	[182] BARATE	98M	ALEP
4.1 ± 2.1 ± 0.2		89.44	[183] ACKERSTAFF	97P	OPAL
14.5 ± 1.7 ± 0.7		92.91	[183] ACKERSTAFF	97P	OPAL
− 8.6 ± 10.8 ± 2.9		89.45	[184] ALEXANDER	97C	OPAL
− 2.1 ± 9.0 ± 2.6		93.00	[184] ALEXANDER	97C	OPAL
5.5 ± 2.4 ± 0.3	5.5	89.52	[185] ALEXANDER	96	OPAL
11.7 ± 2.0 ± 0.3	11.4	92.94	[185] ALEXANDER	96	OPAL
− 3.4 ± 11.2 ± 0.7		88.38	[186] BUSKULIC	96Q	ALEP
5.3 ± 2.0 ± 0.2		89.38	[186] BUSKULIC	96Q	ALEP
8.9 ± 5.9 ± 0.4		90.21	[186] BUSKULIC	96Q	ALEP
3.8 ± 5.1 ± 0.2		92.05	[186] BUSKULIC	96Q	ALEP
10.3 ± 1.6 ± 0.4		92.94	[186] BUSKULIC	96Q	ALEP
8.8 ± 7.5 ± 0.5		93.90	[186] BUSKULIC	96Q	ALEP
5.9 ± 6.2 ± 2.4		91.27	[188] ABREU	95E	DLPH
11.5 ± 1.7 ± 1.0		91.27	[189] ABREU	95K	DLPH
6.2 ± 3.4 ± 0.2		89.52	[190] AKERS	95S	OPAL
9.63 ± 0.67 ± 0.38		91.25	[190] AKERS	95S	OPAL
17.2 ± 2.8 ± 0.7		92.94	[190] AKERS	95S	OPAL
8.7 ± 1.1 ± 0.4		91.3	[191] ACCIARRI	94D	L3
8.7 ± 1.4 ± 0.2		91.24	[192] BUSKULIC	94G	ALEP
9.92 ± 0.84 ± 0.46		91.19	[193] BUSKULIC	94I	ALEP
$-71 \pm 34 \, ^{+7}_{-8}$	−58	58.3	SHIMONAKA	91	TOPZ
−22.2 ± 7.7 ± 3.5	−26.0	35	BEHREND	90D	CELL
−49.1 ± 16.0 ± 5.0	−39.7	43	BEHREND	90D	CELL
−28 ± 11	−23	35	BRAUNSCH...	90	TASS
−16.6 ± 7.7 ± 4.8	−24.3	35	ELSEN	90	JADE
−33.6 ± 22.2 ± 5.2	−39.9	44	ELSEN	90	JADE
3.4 ± 7.0 ± 3.5	−16.0	29.0	BAND	89	MAC
−72 ± 28 ± 13	−56	55.2	SAGAWA	89	AMY

[178] ABREU 99M tag $Z \rightarrow b\overline{b}$ events using lifetime and vertex charge. The original quark charge is obtained from the charge flow, the difference between the forward and backward hemisphere charges.

[179] ABREU 99Y tag $Z \rightarrow b\overline{b}$ and $Z \rightarrow c\overline{c}$ events by an exclusive reconstruction of several D meson decay modes (D^{*+}, D^0, and D^+ with their charge-conjugate states).

[180] ACCIARRI 99D tag $Z \rightarrow b\overline{b}$ events using high p and p_T leptons. The analysis determines simultaneously a mixing parameter $\chi_b = 0.1192 \pm 0.0068 \pm 0.0051$ which is used to correct the observed asymmetry.

[181] ACCIARRI 98U tag $Z \rightarrow b\overline{b}$ events using lifetime and measure the jet charge using the hemisphere charge.

[182] BARATE 98M tag $Z \rightarrow b\overline{b}$ events using lifetime and measure the jet charge using the hemisphere charge. The analysis is performed as a function of the b quark purity and b polar angle.

[183] ACKERSTAFF 97P tag b quarks using lifetime. The quark charge is measured using both jet charge and vertex charge, a weighted sum of the charges of tracks in a jet which contains a tagged secondary vertex.

[184] ALEXANDER 97C identify the b and c events using a D/D^* tag.

[185] ALEXANDER 96 tag heavy flavors using one or two identified leptons. This allows the simultaneous fitting of the b and c quark forward-backward asymmetries as well as the average B^0-$\overline{B}^0$ mixing.

[186] BUSKULIC 96Q tag b-quark flavor and charge using high transverse momentum leptons. The asymmetry value at the Z peak is obtained using a charm charge asymmetry of 6.17%.

[187] ABREU 95K identify c and b quarks using both electron and muon semileptonic decays. The systematic error includes an uncertainty of ±0.3 due to the mixing correction ($\chi = 0.115 \pm 0.011$).

[188] ABREU 95E require the presence of a $D^{*\pm}$ to identify c and b quarks. Replaced by ABREU 99Y.

[189] ABREU 95K tag b quarks using lifetime; the quark charge is identified using jet charge. The systematic error includes an uncertainty of ±0.3 due to the mixing correction ($\chi = 0.115 \pm 0.011$). Replaced by ABREU 99M.

[190] AKERS 95S tag b quarks using lifetime; the quark charge is measured using jet charge. These asymmetry values are obtained using $R_b = \Gamma(b\overline{b})/\Gamma(\text{hadrons}) = 0.216$. For a value of R_b different from this by an amount ΔR_b, the change in the asymmetry values is given by $-K\Delta R_b$, where $K = 0.082$, 0.471, and 0.855 for $\sqrt{s}$ values of 89.52, 91.25, and 92.94 GeV respectively. Replaced by ACKERSTAFF 97P.

[191] ACCIARRI 94D use both electron and muon semileptonic decays. Replaced by ACCIARRI 99D.

[192] BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and dilepton events. Replaced by BUSKULIC 96Q.

[193] BUSKULIC 94I use the lifetime tag method to obtain a high purity sample of $Z \to b\overline{b}$ events and the hemisphere charge technique to obtain the jet charge. Replaced by BARATE 98M.

CHARGE ASYMMETRY IN $e^+e^- \rightarrow q\overline{q}$

Summed over five lighter flavors.

Experimental and Standard Model values are somewhat event-selection dependent. Standard Model expectations contain some assumptions on B^0-$\overline{B}^0$ mixing and on other electroweak parameters.

ASYMMETRY (%)	*STD. MODEL*	$\sqrt{s}$ *(GeV)*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
− 0.76±0.12±0.15		91.2	[194] ABREU	92I	DLPH
4.0 ±0.4 ±0.63	4.0	91.3	[195] ACTON	92L	OPAL
9.1 ±1.4 ±1.6	9.0	57.9	ADACHI	91	TOPZ
− 0.84±0.15±0.04		91	DECAMP	91B	ALEP
8.3 ±2.9 ±1.9	8.7	56.6	STUART	90	AMY
11.4 ±2.2 ±2.1	8.7	57.6	ABE	89L	VNS
6.0 ±1.3	5.0	34.8	GREENSHAW	89	JADE
8.2 ±2.9	8.5	43.6	GREENSHAW	89	JADE

[194] ABREU 92I has 0.14 systematic error due to uncertainty of quark fragmentation.

[195] ACTON 92L use the weight function method on 259k selected $Z \rightarrow$ hadrons events. The systematic error includes a contribution of 0.2 due to B^0-$\overline{B}^0$ mixing effect, 0.4 due to Monte Carlo (MC) fragmentation uncertainties and 0.3 due to MC statistics. ACTON 92L derive a value of $\sin^2\theta_W^{\rm eff}$ to be 0.2321 ± 0.0017 ± 0.0028.

CHARGE ASYMMETRY IN $p\overline{p} \rightarrow Z \rightarrow e^+e^-$

ASYMMETRY (%)	*STD. MODEL*	$\sqrt{s}$ *(GeV)*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
5.2±5.9±0.4		91	ABE	91E	CDF

ANOMALOUS $ZZ\gamma$, $Z\gamma\gamma$, AND ZZV COUPLINGS

Revised March 2000 by C. Caso (Univ. of Genova) and A. Gurtu (Tata Inst.)

In the reaction $e^+e^- \rightarrow Z\gamma$, deviations from the Standard Model for the $ZV\gamma$ couplings may be described in terms of 8 parameters, h_i^V $(i = 1,4;\ V = \gamma, Z)$ [1]. In this formalism h_1^V and h_2^V lead to CP-violating and h_3^V and h_4^V to CP-conserving effects. All these anomalous contributions to the cross section increase rapidly with center-of-mass energy. In order to ensure unitarity, these parameters are usually described by a form-factor representation, $h_i^V(s) = h_{i\circ}^V/(1 + s/\Lambda^2)^n$, where Λ is the energy scale for the manifestation of a new phenomenon and n

is a sufficiently large power. By convention one uses $n = 3$ for $h^V_{1,3}$ and $n = 4$ for $h^V_{2,4}$. Usually limits on h^V_i's are put assuming some value of Λ (sometimes ∞).

Above the $e^+e^- \to ZZ$ threshold, deviations from the Standard Model may be described by means of four anomalous couplings f^V_i $(i = 4, 5; V = \gamma, Z)$ [2]. The anomalous couplings f^V_5 lead to violation of C and P symmetries while f^V_4 introduces CP violation. These couplings are zero at tree level in the Standard Model.

Reference

1. U. Baur and E.L. Berger Phys. Rev. **D47**, 4889 (1993).
2. K. Hagiwara *et al.*, Nucl. Phys. **B282**, 253 (1987).

h^V_i

VALUE	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	[196] ABBOTT	98M	D0
	[197] ABREU	98K	DLPH
	[198] ACCIARRI	98L	L3

[196] ABBOTT 98M study $p\overline{p} \to Z\gamma$ +X, with $Z \to e^+e^-$, $\mu^+\mu^-$, $\overline{\nu}\nu$ at 1.8 TeV, to obtain 95% CL limits at Λ= 750 GeV: $|h^Z_{30}| < 0.36$, $|h^Z_{40}| < 0.05$ (keeping h^γ_i=0) and $|h^\gamma_{30}| < 0.37$, $|h^\gamma_{40}| < 0.05$ (keeping h^Z_i=0). Limits on the *CP*-violating couplings are $|h^Z_{10}| < 0.36$, $|h^Z_{20}| < 0.05$ (keeping h^γ_i=0), and $|h^\gamma_{10}| < 0.37$, $|h^\gamma_{20}| < 0.05$ (keeping h^Z_i=0).

[197] ABREU 98K determine a 95% CL upper limit on $\sigma(e^+e^- \to \gamma +$ invisible particles$) <$ 2.5 pb using 161 and 172 GeV data. This is used to set 95% CL limits on $|h^\gamma_{30}| < 0.8$ and $|h^Z_{30}| < 1.3$, derived at a scale Λ=1 TeV and with n=3 in the form factor representation.

[198] ACCIARRI 98L study 161, 172, and 183 GeV $e^+e^- \to q\overline{q}\gamma$ and $e^+e^- \to \nu\overline{\nu}\gamma$ events to derive 95% CL limits on h^V_i. For deriving each limit the others are fixed at zero. For $\Lambda = \infty$ they report: $-0.54 < h^Z_1 < 0.17$, $-0.11 < h^Z_2 < 0.37$, $-0.50 < h^Z_3 < 0.36$, $-0.12 < h^Z_4 < 0.39$, $-0.25 < h^\gamma_1 < 0.23$, $-0.18 < h^\gamma_2 < 0.18$, $-0.33 < h^\gamma_3 < 0.01$, $-0.02 < h^\gamma_4 < 0.24$.

f_i^V

VALUE	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
	[199] ACCIARRI	99O	L3

[199] ACCIARRI 99O study ZZ production in e^+e^- collisions at 183 and 189 GeV to derive 95%CL limits on f_i^V. For deriving each limit the others are fixed at zero. They report: $-1.9 < f_4^Z < 1.9$, $-5.0 < f_5^Z < 4.5$, $-1.1 < f_4^\gamma < 1.2$, $-3.0 < f_5^\gamma < 2.9$.

Z REFERENCES

ABREU 00 EPJ C12 225 P. Abreu *et al.* (DELPHI Collab.)
ABREU 00B CERN-EP/99-134 P. Abreu *et al.* (DELPHI Collab.)
EPJ C (to be publ.)
ABREU 00E CERN-EP/99-161 P. Abreu *et al.* (DELPHI Collab.)
EPJ C (to be publ.)
ABREU 00F CERN-EP/2000-037 P. Abreu *et al.* (DELPHI Collab.)
EPJ C (to be publ.)
ACCIARRI 00 EPJ C13 47 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 00C hepex-0002046 M. Acciarri *et al.* (L3 Collab.)
EPJ C (to be publ.), CERN-EP/2000-022
BARATE 00B EPJ C13 29 R. Barate *et al.* (ALEPH Collab.)
BARATE 00C EPJ C14 1 R. Barate *et al.* (ALEPH Collab.)
ABBIENDI 99B EPJ C8 217 G. Abbiendi *et al.* (OPAL Collab.)
ABBIENDI 99I PL B447 157 G. Abbiendi *et al.* (OPAL Collab.)
ABE 99E PR D59 052001 K. Abe *et al.* (SLD Collab.)
ABE 99I PR D59 092002 F. Abe *et al.* (CDF Collab.)
ABE 99L PRL 83 1902 K. Abe *et al.* (SLD Collab.)
ABE 99O PRL 83 3384 K. Abe *et al.* (SLD Collab.)
ABREU 99 EPJ C6 19 P. Abreu *et al.* (DELPHI Collab.)
ABREU 99B EPJ C10 415 P. Abreu *et al.* (DELPHI Collab.)
ABREU 99J PL B449 364 P. Abreu *et al.* (DELPHI Collab.)
ABREU 99M EPJ C9 367 P. Abreu *et al.* (DELPHI Collab.)
ABREU 99U PL B462 425 P. Abreu *et al.* (DELPHI Collab.)
ABREU 99Y EPJ C10 219 P. Abreu *et al.* (DELPHI Collab.)
ACCIARRI 99D PL B448 152 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 99F PL B453 94 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 99O PL B465 363 M. Acciarri *et al.* (L3 Collab.)
ABBOTT 98M PR D57 R3817 B. Abbott *et al.* (D0 Collab.)
ABE 98D PRL 80 660 K. Abe *et al.* (SLD Collab.)
ABE 98I PRL 81 942 K. Abe *et al.* (SLD Collab.)
ABREU 98K PL B423 194 P. Abreu *et al.* (DELPHI Collab.)
ABREU 98L EPJ C5 585 P. Abreu *et al.* (DELPHI Collab.)
ACCIARRI 98G PL B431 199 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 98H PL B429 387 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 98L PL B436 187 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 98U PL B439 225 M. Acciarri *et al.* (L3 Collab.)
ACKERSTAFF 98A EPJ C5 411 K. Ackerstaff *et al.* (OPAL Collab.)
ACKERSTAFF 98E EPJ C1 439 K. Ackerstaff *et al.* (OPAL Collab.)
ACKERSTAFF 98O PL B420 157 K. Ackerstaff *et al.* (OPAL Collab.)
ACKERSTAFF 98Q EPJ C4 19 K. Ackerstaff *et al.* (OPAL Collab.)
BARATE 98M PL B426 217 R. Barate *et al.* (ALEPH Collab.)
BARATE 98O PL B434 415 R. Barate *et al.* (ALEPH Collab.)
BARATE 98T EPJ C4 557 R. Barate *et al.* (ALEPH Collab.)
BARATE 98V EPJ C5 205 R. Barate *et al.* (ALEPH Collab.)
ABE 97 PRL 78 17 K. Abe *et al.* (SLD Collab.)
ABE 97E PRL 78 2075 K. Abe *et al.* (SLD Collab.)
ABE 97N PRL 79 804 K. Abe *et al.* (SLD Collab.)
ABREU 97C ZPHY C73 243 P. Abreu *et al.* (DELPHI Collab.)
ABREU 97E PL B398 207 P. Abreu *et al.* (DELPHI Collab.)
ABREU 97G PL B404 194 P. Abreu *et al.* (DELPHI Collab.)
ACCIARRI 97D PL B393 465 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 97J PL B407 351 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 97K PL B407 361 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 97L PL B407 389 M. Acciarri *et al.* (L3 Collab.)
ACCIARRI 97R PL B413 167 M. Acciarri *et al.* (L3 Collab.)
ACKERSTAFF 97C PL B391 221 K. Ackerstaff *et al.* (OPAL Collab.)

ACKERSTAFF	97K	ZPHY C74 1	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97M	ZPHY C74 413	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97P	ZPHY C75 385	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97S	PL B412 210	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97T	ZPHY C76 387	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97W	ZPHY C76 425	K. Ackerstaff *et al.*	(OPAL Collab.)
ALEXANDER	97C	ZPHY C73 379	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	97D	ZPHY C73 569	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	97E	ZPHY C73 587	G. Alexander *et al.*	(OPAL Collab.)
BARATE	97D	PL B405 191	R. Barate *et al.*	(ALEPH Collab.)
BARATE	97E	PL B401 150	R. Barate *et al.*	(ALEPH Collab.)
BARATE	97F	PL B401 163	R. Barate *et al.*	(ALEPH Collab.)
BARATE	97H	PL B402 213	R. Barate *et al.*	(ALEPH Collab.)
BARATE	97J	ZPHY C74 451	R. Barate *et al.*	(ALEPH Collab.)
ABE	96E	PR D53 1023	K. Abe *et al.*	(SLD Collab.)
ABREU	96	ZPHY C70 531	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	96C	PL B379 309	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	96R	ZPHY C72 31	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	96S	PL B389 405	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	96U	ZPHY C73 61	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	96	PL B371 126	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	96B	PL B370 195	M. Acciarri *et al.*	(L3 Collab.)
ADAM	96	ZPHY C69 561	W. Adam *et al.*	(DELPHI Collab.)
ADAM	96B	ZPHY C70 371	W. Adam *et al.*	(DELPHI Collab.)
ALEXANDER	96	ZPHY C70 357	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	96B	ZPHY C70 197	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	96F	PL B370 185	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	96N	PL B384 343	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	96R	ZPHY C72 1	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	96U	ZPHY C72 365	G. Alexander *et al.*	(OPAL Collab.)
ALEXANDER	96X	PL B376 232	G. Alexander *et al.*	(OPAL Collab.)
BUSKULIC	96D	ZPHY C69 393	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	96H	ZPHY C69 379	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	96Q	PL B384 414	D. Buskulic *et al.*	(ALEPH Collab.)
ABE	95J	PRL 74 2880	K. Abe *et al.*	(SLD Collab.)
ABE	95L	PRL 74 2895	K. Abe *et al.*	(SLD Collab.)
ABE,K	95	PRL 75 3609	K. Abe *et al.*	(SLD Collab.)
ABREU	95	ZPHY C65 709 erratum	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95D	ZPHY C66 323	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95E	ZPHY C66 341	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95F	NP B444 3	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95G	ZPHY C67 1	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95I	ZPHY C67 183	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95K	ZPHY C65 569	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95L	ZPHY C65 587	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95M	ZPHY C65 603	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95O	ZPHY C67 543	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95R	ZPHY C68 353	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95W	PL B361 207	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95X	ZPHY C69 1	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	95B	PL B345 589	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	95C	PL B345 609	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	95G	PL B353 136	M. Acciarri *et al.*	(L3 Collab.)
AKERS	95	ZPHY C65 1	R. Akers *et al.*	(OPAL Collab.)
AKERS	95C	ZPHY C65 47	R. Akers *et al.*	(OPAL Collab.)
AKERS	95O	ZPHY C67 27	R. Akers *et al.*	(OPAL Collab.)
AKERS	95S	ZPHY C67 365	R. Akers *et al.*	(OPAL Collab.)
AKERS	95U	ZPHY C67 389	R. Akers *et al.*	(OPAL Collab.)
AKERS	95W	ZPHY C67 555	R. Akers *et al.*	(OPAL Collab.)
AKERS	95X	ZPHY C68 1	R. Akers *et al.*	(OPAL Collab.)
AKERS	95Z	ZPHY C68 203	R. Akers *et al.*	(OPAL Collab.)
ALEXANDER	95D	PL B358 162	G. Alexander *et al.*	(OPAL Collab.)
BUSKULIC	95I	PL B352 479	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	95Q	ZPHY C69 183	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	95R	ZPHY C69 15	D. Buskulic *et al.*	(ALEPH Collab.)
MIYABAYASHI	95	PL B347 171	K. Miyabayashi *et al.*	(TOPAZ Collab.)
ABE	94C	PRL 73 25	K. Abe *et al.*	(SLD Collab.)
ABREU	94	NP B418 403	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	94B	PL B327 386	P. Abreu *et al.*	(DELPHI Collab.)

ABREU	94P	PL B341 109	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	94	ZPHY C62 551	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	94B	PL B328 223	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	94D	PL B335 542	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	94E	PL B341 245	M. Acciarri *et al.*	(L3 Collab.)
AKERS	94	ZPHY C61 19	R. Akers *et al.*	(OPAL Collab.)
AKERS	94P	ZPHY C63 181	R. Akers *et al.*	(OPAL Collab.)
BUSKULIC	94	ZPHY C62 539	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	94G	ZPHY C62 179	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	94I	PL B335 99	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	94J	ZPHY C62 1	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	94K	ZPHY C64 361	D. Buskulic *et al.*	(ALEPH Collab.)
VILAIN	94	PL B320 203	P. Vilain *et al.*	(CHARM II Collab.)
ABREU	93	PL B298 236	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	93I	ZPHY C59 533	P. Abreu *et al.*	(DELPHI Collab.)
Also	95	ZPHY C65 709 erratum	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	93L	PL B318 249	P. Abreu *et al.*	(DELPHI Collab.)
ACTON	93	PL B305 407	P.D. Acton *et al.*	(OPAL Collab.)
ACTON	93D	ZPHY C58 219	P.D. Acton *et al.*	(OPAL Collab.)
ACTON	93E	PL B311 391	P.D. Acton *et al.*	(OPAL Collab.)
ACTON	93F	ZPHY C58 405	P.D. Acton *et al.*	(OPAL Collab.)
ADRIANI	93	PL B301 136	O. Adriani *et al.*	(L3 Collab.)
ADRIANI	93I	PL B316 427	O. Adriani *et al.*	(L3 Collab.)
BUSKULIC	93L	PL B313 520	D. Buskulic *et al.*	(ALEPH Collab.)
NOVIKOV	93C	PL B298 453	V.A. Novikov, L.B. Okun, M.I. Vysotsky	(ITEP)
ABREU	92I	PL B277 371	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	92M	PL B289 199	P. Abreu *et al.*	(DELPHI Collab.)
ACTON	92B	ZPHY C53 539	D.P. Acton *et al.*	(OPAL Collab.)
ACTON	92L	PL B294 436	P.D. Acton *et al.*	(OPAL Collab.)
ACTON	92N	PL B295 357	P.D. Acton *et al.*	(OPAL Collab.)
ADEVA	92	PL B275 209	B. Adeva *et al.*	(L3 Collab.)
ADRIANI	92D	PL B292 454	O. Adriani *et al.*	(L3 Collab.)
ADRIANI	92E	PL B292 463	O. Adriani *et al.*	(L3 Collab.)
ALITTI	92B	PL B276 354	J. Alitti *et al.*	(UA2 Collab.)
BUSKULIC	92D	PL B292 210	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	92E	PL B294 145	D. Buskulic *et al.*	(ALEPH Collab.)
DECAMP	92	PRPL 216 253	D. Decamp *et al.*	(ALEPH Collab.)
LEP	92	PL B276 247	LEP *et al.*	(LEP Collabs.)
ABE	91E	PRL 67 1502	F. Abe *et al.*	(CDF Collab.)
ABREU	91H	ZPHY C50 185	P. Abreu *et al.*	(DELPHI Collab.)
ACTON	91B	PL B273 338	D.P. Acton *et al.*	(OPAL Collab.)
ADACHI	91	PL B255 613	I. Adachi *et al.*	(TOPAZ Collab.)
ADEVA	91I	PL B259 199	B. Adeva *et al.*	(L3 Collab.)
AKRAWY	91F	PL B257 531	M.Z. Akrawy *et al.*	(OPAL Collab.)
DECAMP	91B	PL B259 377	D. Decamp *et al.*	(ALEPH Collab.)
DECAMP	91J	PL B266 218	D. Decamp *et al.*	(ALEPH Collab.)
JACOBSEN	91	PRL 67 3347	R.G. Jacobsen *et al.*	(Mark II Collab.)
SHIMONAKA	91	PL B268 457	A. Shimonaka *et al.*	(TOPAZ Collab.)
ABE	90I	ZPHY C48 13	K. Abe *et al.*	(VENUS Collab.)
ABRAMS	90	PRL 64 1334	G.S. Abrams *et al.*	(Mark II Collab.)
ADACHI	90F	PL B234 525	I. Adachi *et al.*	(TOPAZ Collab.)
AKRAWY	90J	PL B246 285	M.Z. Akrawy *et al.*	(OPAL Collab.)
BEHREND	90D	ZPHY C47 333	H.J. Behrend *et al.*	(CELLO Collab.)
BRAUNSCH...	90	ZPHY C48 433	W. Braunschweig *et al.*	(TASSO Collab.)
ELSEN	90	ZPHY C46 349	E. Elsen *et al.*	(JADE Collab.)
HEGNER	90	ZPHY C46 547	S. Hegner *et al.*	(JADE Collab.)
STUART	90	PRL 64 983	D. Stuart *et al.*	(AMY Collab.)
ABE	89	PRL 62 613	F. Abe *et al.*	(CDF Collab.)
ABE	89C	PRL 63 720	F. Abe *et al.*	(CDF Collab.)
ABE	89L	PL B232 425	K. Abe *et al.*	(VENUS Collab.)
ABRAMS	89B	PRL 63 2173	G.S. Abrams *et al.*	(Mark II Collab.)
ABRAMS	89D	PRL 63 2780	G.S. Abrams *et al.*	(Mark II Collab.)
ALBAJAR	89	ZPHY C44 15	C. Albajar *et al.*	(UA1 Collab.)
BACALA	89	PL B218 112	A. Bacala *et al.*	(AMY Collab.)
BAND	89	PL B218 369	H.R. Band *et al.*	(MAC Collab.)
GREENSHAW	89	ZPHY C42 1	T. Greenshaw *et al.*	(JADE Collab.)
OULD-SAADA	89	ZPHY C44 567	F. Ould-Saada *et al.*	(JADE Collab.)
SAGAWA	89	PRL 63 2341	H. Sagawa *et al.*	(AMY Collab.)
ADACHI	88C	PL B208 319	I. Adachi *et al.*	(TOPAZ Collab.)

ADEVA	88	PR D38 2665	B. Adeva *et al.*	(Mark-J Collab.)
BRAUNSCH...	88D	ZPHY C40 163	W. Braunschweig *et al.*	(TASSO Collab.)
ANSARI	87	PL B186 440	R. Ansari *et al.*	(UA2 Collab.)
BEHREND	87C	PL B191 209	H.J. Behrend *et al.*	(CELLO Collab.)
BARTEL	86C	ZPHY C30 371	W. Bartel *et al.*	(JADE Collab.)
Also	85B	ZPHY C26 507	W. Bartel *et al.*	(JADE Collab.)
Also	82	PL 108B 140	W. Bartel *et al.*	(JADE Collab.)
ASH	85	PRL 55 1831	W.W. Ash *et al.*	(MAC Collab.)
BARTEL	85F	PL 161B 188	W. Bartel *et al.*	(JADE Collab.)
DERRICK	85	PR D31 2352	M. Derrick *et al.*	(HRS Collab.)
FERNANDEZ	85	PRL 54 1624	E. Fernandez *et al.*	(MAC Collab.)
LEVI	83	PRL 51 1941	M.E. Levi *et al.*	(Mark II Collab.)
BEHREND	82	PL 114B 282	H.J. Behrend *et al.*	(CELLO Collab.)
BRANDELIK	82C	PL 110B 173	R. Brandelik *et al.*	(TASSO Collab.)