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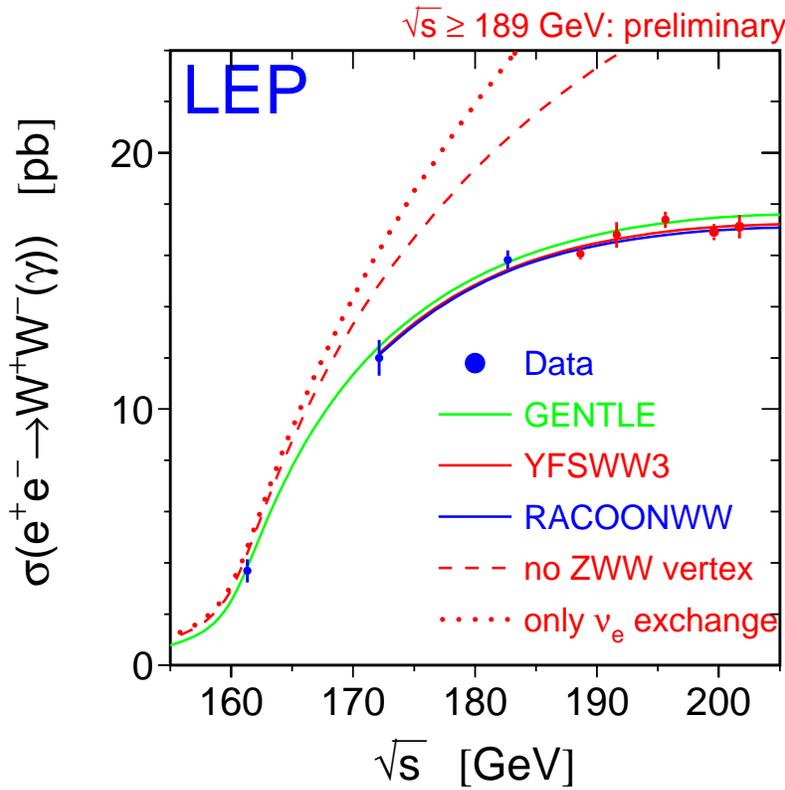
## THE MASS OF THE $W$ BOSON

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Till 1995 the production and study of the  $W$  boson was the exclusive domain of the  $\bar{p}p$  colliders at CERN and FNAL.  $W$  production in these hadron colliders is tagged by a high  $p_T$  lepton from  $W$  decay. Owing to unknown parton-parton effective energy and missing energy in the longitudinal direction, the experiments reconstruct only the transverse mass of the  $W$  and derive the  $W$  mass from comparing the transverse mass distribution with Monte Carlo predictions as a function of  $M_W$ .

Beginning 1996 the energy of LEP increased to above 161 GeV, the threshold for  $W$ -pair production. A precise knowledge of the  $e^+e^-$  centre of mass energy enables one to reconstruct the  $W$  mass even if one of them decays leptonically. At LEP two methods have been used to obtain the  $W$  mass. In the first method the measured  $W$ -pair production cross sections,  $\sigma(e^+e^- \rightarrow W^+W^-)$ , have been used to determine the  $W$  mass using the predicted dependence of this cross section on  $M_W$  (see Fig. 1). At 161 GeV, which is just above the  $W$ -pair production threshold, this dependence is a much more sensitive function of the  $W$  mass than at the higher energies (172 to 202 GeV) at which LEP has run during 1996–99. In the second method, which is used at the higher energies, the  $W$  mass has been determined by directly reconstructing the  $W$  from its decay products.

Each LEP experiment has combined their own mass values properly taking into account the common systematic errors. In order to compute the LEP average  $W$  mass each experiment



**Figure 1:** The  $W$ -pair cross section as a function of the center-of-mass energy. The data points are the LEP averages. The solid lines are predictions from different models of  $WW$  production. For comparison the figure contains also the cross section if the  $ZWW$  coupling did not exist (dashed line), or if only the  $t$ -channel  $\nu_e$  exchange diagram existed (dotted line).

has provided its measured  $W$  mass for the  $qqqq$  and  $qql\nu$  channels at each center-of-mass energy along with a detailed break-up of errors (statistical and uncorrelated, partially correlated and fully correlated systematics [1]). These have been properly combined to obtain a *preliminary* [2] LEP  $W$  mass

=  $80.401 \pm 0.048$  GeV. Errors due to uncertainties in LEP energy (17 MeV) and possible effect of color reconnection (CR) and Bose–Einstein (BE) correlations between quarks from different  $W$ 's (18 MeV) are included. The mass difference between  $qqqq$  and  $qq\ell\nu$  final states (due to possible CR and BE effects) is  $35 \pm 55$  MeV.

The two Tevatron experiments have also carried out the exercise of identifying common systematic errors and averaging with CERN UA2 data to obtain an average  $W$  mass =  $80.448 \pm 0.062$  GeV.

Combining all the published and unpublished  $p\text{-}\bar{p}$  Collider and LEP results (as of mid-March 2000) yields an average  $W$ -boson mass of  $80.419 \pm 0.038$  GeV assuming no common systematics between LEP and hadron collider measurements.

The Standard Model prediction from the electroweak fit, excluding the direct  $W$  mass measurements from LEP and Tevatron, gives a  $W$ -boson mass of  $80.382 \pm 0.026$  GeV.

OUR EVALUATION in the listing below is obtained by combining only published LEP and  $p\text{-}\bar{p}$  Collider results using the same procedure as above.

## References

1. The LEP Collaborations: ALEPH, DELPHI, L3, OPAL, the LEP Electroweak Working Group, and the SLD Heavy Flavour and Electroweak Groups, CERN-EP-2000-016 (January 21, 2000).
  2. A. Straessner and C. Sbarra, talks presented at the XXXV Rencontres de Moriond, "Electroweak Interactions and Unified Theories," (Les Arcs, France, 11–18 March 2000).
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**W MASS**

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

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

<u>VALUE (GeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>80.419 ± 0.056 OUR EVALUATION</b>				
<b>80.43 ± 0.05 OUR FIT</b>				
80.482 ± 0.091	45394	1 ABBOTT	00 D0	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
80.38 ± 0.12 ± 0.05	701	2 ABBIENDI	99C OPAL	$E_{cm}^{ee} = 161+172+ 183 \text{ GeV}$
80.270 ± 0.137 ± 0.048	809	3 ABREU	99T DLPH	$E_{cm}^{ee} = 161+172+ 183 \text{ GeV}$
80.61 ± 0.15	801	4 ACCIARRI	99 L3	$E_{cm}^{ee} = 161+172+ 183 \text{ GeV}$
80.423 ± 0.112 ± 0.054	812	5 BARATE	99 ALEP	$E_{cm}^{ee} = 161+172+ 183 \text{ GeV}$
80.41 ± 0.18	8986	6 ABE	95P CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
79.91 ± 0.39	1722	7 ABE	90G CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
80.49 ± 0.43 ± 0.095	871	8 ABREU	99K DLPH	Repl. by ABREU 99T
80.44 ± 0.10 ± 0.07	28323	9 ABBOTT	98O D0	Repl. by ABBOTT 00
80.22 ± 0.41 ± 0.07	72	10 ABREU	98B DLPH	Repl. by ABREU 99T
80.32 ± 0.30 ± 0.094	96	11 ACKERSTAFF	98D OPAL	Repl. by ABBIENDI 99C
80.5 + 1.4 + 0.5 - 2.2 - 0.6	104	12 ACKERSTAFF	98D OPAL	Repl. by ABBIENDI 99C
80.80 ± 0.32 ± 0.114	95	13 BARATE	98B ALEP	Repl. by BARATE 99
80.80 + 0.48 ± 0.03 - 0.42	20	14 ACCIARRI	97 L3	Repl. by ACCIARRI 99
80.5 + 1.4 ± 0.3 - 2.4	94	15 ACCIARRI	97M L3	Repl. by ACCIARRI 99
80.71 + 0.34 ± 0.09 - 0.35	101	16 ACCIARRI	97S L3	Repl. by ACCIARRI 99
80.14 ± 0.34 ± 0.095	32	17 BARATE	97 ALEP	Repl. by BARATE 99
81.17 + 1.15 - 1.62	106	18 BARATE	97S ALEP	Repl. by BARATE 99
80.35 ± 0.14 ± 0.23	5982	19 ABACHI	96E D0	Repl. by ABBOTT 00
80.40 + 0.44 + 0.09 - 0.41 - 0.10	23	20 ACKERSTAFF	96B OPAL	Repl. by ABBIENDI 99C
84 + 10 - 7	13	21 AID	96D H1	$e^{\pm} p \rightarrow \nu_e (\bar{\nu}_e) + X$ $\sqrt{s} \approx 300 \text{ GeV}$
80.84 ± 0.22 ± 0.83	2065	22 ALITTI	92B UA2	See $W/Z$ ratio below
80.79 ± 0.31 ± 0.84		23 ALITTI	90B UA2	$E_{cm}^{p\bar{p}} = 546,630 \text{ GeV}$
80.0 ± 3.3 ± 2.4	22	24 ABE	89I CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
82.7 ± 1.0 ± 2.7	149	25 ALBAJAR	89 UA1	$E_{cm}^{p\bar{p}} = 546,630 \text{ GeV}$
81.8 + 6.0 ± 2.6 - 5.3	46	26 ALBAJAR	89 UA1	$E_{cm}^{p\bar{p}} = 546,630 \text{ GeV}$
89 ± 3 ± 6	32	27 ALBAJAR	89 UA1	$E_{cm}^{p\bar{p}} = 546,630 \text{ GeV}$
81. ± 5.	6	ARNISON	83 UA1	$E_{cm}^{ee} = 546 \text{ GeV}$
80. + 10. - 6.	4	BANNER	83B UA2	Repl. by ALITTI 90B

- <sup>1</sup> ABBOTT 00 use  $W \rightarrow e\nu_e$  events to measure the  $W$  mass with a fit to the transverse mass distribution. The result quoted here corresponds to electrons detected both in the forward and in the central calorimeters for the data recorded in 1992–1995. For the large rapidity electrons recorded in 1994–1995, the analysis combines results obtained from  $m_T$ ,  $p_T(e)$ , and  $p_T(\nu)$ .
- <sup>2</sup> ABBIENDI 99C obtain this value properly combining results from a direct  $W$  mass reconstruction at 172 and 183 GeV with that from the measurement of the total  $W$ -pair production cross section at 161 GeV. The systematic error includes an uncertainty of  $\pm 0.02$  GeV due to the possible color-reconnection and Bose-Einstein effects in the purely hadronic final states and an uncertainty of  $\pm 0.02$  GeV due to the beam energy.
- <sup>3</sup> ABREU 99T obtain this value properly combining results obtained from a direct  $W$  mass reconstruction at 172 and 183 GeV with those from measurement of  $W$ -pair production cross sections at 161, 172, and 183 GeV. The systematic error includes  $\pm 0.021$  GeV due to the beam energy uncertainty and  $\pm 0.030$  GeV due to possible color reconnection and Bose-Einstein effects in the purely hadronic final state.
- <sup>4</sup> ACCIARRI 99 obtain this value properly combining results obtained from a direct  $W$  mass reconstruction at 172 and 183 GeV with those from the measurements of the total  $W$ -pair production cross sections at 161 and 172 GeV. The value of the mass obtained from the direct reconstruction at 172 and 183 GeV is  $M(W) = 80.58 \pm 0.14 \pm 0.08$  GeV.
- <sup>5</sup> BARATE 99 obtain this value properly combining results from a direct  $W$  mass reconstruction at 172 and 183 GeV with those from the measurements of the total  $W$ -pair production cross sections at 161 and 172 GeV. The systematic error includes  $\pm 0.023$  GeV due to LEP energy uncertainty and  $\pm 0.021$  GeV due to theory uncertainty on account of possible color reconnection and Bose-Einstein correlations.
- <sup>6</sup> ABE 95P use 3268  $W \rightarrow \mu\nu_\mu$  events to find  $M = 80.310 \pm 0.205 \pm 0.130$  GeV and 5718  $W \rightarrow e\nu_e$  events to find  $M = 80.490 \pm 0.145 \pm 0.175$  GeV. The result given here combines these while accounting for correlated uncertainties.
- <sup>7</sup> ABE 90G result from  $W \rightarrow e\nu$  is  $79.91 \pm 0.35 \pm 0.24 \pm 0.19(\text{scale})$  GeV and from  $W \rightarrow \mu\nu$  is  $79.90 \pm 0.53 \pm 0.32 \pm 0.08(\text{scale})$  GeV.
- <sup>8</sup> ABREU 99K derive this value using the Standard Model dependence on  $M_W$  of the  $W$ - $W$  production cross sections measured at 161, 172, and 183 GeV. The systematics include an error of  $\pm 0.03$  GeV arising from the beam energy uncertainty.
- <sup>9</sup> ABBOTT 980 fit the transverse mass distribution of 28323  $W \rightarrow e\nu_e$  events. The systematic error includes a detector related uncertainty of  $\pm 60$  MeV and a model uncertainty of  $\pm 30$  MeV. Combining with ABACHI 96E  $D\bar{D}$  obtain a  $W$  mass value of  $80.43 \pm 0.11$  GeV.
- <sup>10</sup> ABREU 98B obtain this value from a fit to the reconstructed  $W$  mass distribution. The  $W$  width was taken as its Standard Model value at the fitted  $W$  mass. The systematic error includes  $\pm 0.03$  GeV due to the beam energy uncertainty and  $\pm 0.05$  GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state.
- <sup>11</sup> ACKERSTAFF 98D obtain this value from a fit to the reconstructed  $W$  mass distribution. The  $W$  width was taken as its Standard Model value at the fitted  $W$  mass. When both  $W$  mass and width are varied they obtain  $M(W) = 80.30 \pm 0.27 \pm 0.095$  GeV. The systematic error includes  $\pm 0.03$  GeV due to the beam energy uncertainty and  $\pm 0.05$  GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining both values of ACKERSTAFF 98D with ACKERSTAFF 96B authors find:  $M(W) = 80.35 \pm 0.24 \pm 0.07 \pm 0.03$  (LEP) GeV.
- <sup>12</sup> ACKERSTAFF 98D derive this value from their measured  $W$  production cross section  $\sigma_{WW} = 12.3 \pm 1.3 \pm 0.4$  pb using the Standard Model dependence of  $\sigma_{WW}$  on  $M_W$  at the given c.m. energy.
- <sup>13</sup> BARATE 98B obtain this value from a fit to the reconstructed  $W$  mass distribution. The  $W$  width was taken as its Standard Model value at the fitted  $W$  mass. The systematic error includes  $\pm 0.03$  GeV due to the beam energy uncertainty and  $\pm 0.032$  GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with the  $M_W$  values from cross section measurements at 161 and 172 GeV (BARATE 97 and BARATE 97S) authors find:  $M(W) = 80.51 \pm 0.23 \pm 0.08$  GeV.

- 14 ACCIARRI 97 derive this value from their measured  $W$ - $W$  production cross section  $\sigma_{WW} = 2.89^{+0.81}_{-0.70} \pm 0.14$  pb using the Standard Model dependence of  $\sigma_{WW}$  on  $M_W$  at the given c.m. energy. Statistical and systematic errors are added in quadrature and the last error of  $\pm 0.03$  GeV arises from the beam energy uncertainty. The same result is given by a fit of the production cross sections to the data.
- 15 ACCIARRI 97M derive this value from their measured  $W$   $W$  production cross section  $\sigma_{WW} = 12.27^{+1.41}_{-1.32} \pm 0.23$  pb using the Standard Model dependence of  $\sigma_{WW}$  on  $M_W$  at the given c.m. energy. Combining with ACCIARRI 97 authors find  $M(W) = 80.78^{+0.45}_{-0.41} \pm 0.03$  GeV where the last error is due to beam energy uncertainty.
- 16 ACCIARRI 97S obtain this value from a fit to the reconstructed  $W$  mass distribution. The  $W$  width was taken as its Standard Model value at the fitted  $W$  mass. When both  $W$  mass and width are varied they obtain  $M(W) = 80.72^{+0.31}_{-0.33} \pm 0.09$  GeV. The systematic error includes  $\pm 0.03$  GeV due to the beam energy uncertainty and  $\pm 0.05$  GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with ACCIARRI 97 and ACCIARRI 97M authors find:  $M(W) = 80.75^{+0.26}_{-0.27} \pm 0.03$  (LEP) GeV.
- 17 BARATE 97 derive this value from their measured  $W$ - $W$  production cross section  $\sigma_{WW} = 4.23 \pm 0.73 \pm 0.19$  pb using the Standard Model dependence of  $\sigma_{WW}$  on  $M_W$  at the given c.m. energy. The systematics include an error of  $\pm 0.03$  GeV arising from the beam energy uncertainty.
- 18 BARATE 97S derive this value from their measured  $W$   $W$  production cross section  $\sigma_{WW} = 11.71 \pm 1.23 \pm 0.28$  pb using the Standard Model dependence of  $\sigma_{WW}$  on  $M_W$  at the given c.m. energy. The errors quoted on the mass are statistical only. Combining with BARATE 97 authors find:  $M(W) = 80.20 \pm 0.33 \pm 0.09 \pm 0.03$  (LEP) GeV.
- 19 ABACHI 96E fit the transverse mass distribution of 5982  $W \rightarrow e\nu_e$  decays. An error of  $\pm 160$  MeV due to the uncertainty in the absolute energy scale of the EM calorimeter is included in the total systematics.
- 20 ACKERSTAFF 96B derive this value from an analysis of the predicted  $M_W$  dependence of their accepted four-fermion cross section, explicitly taking into account interference effects. The systematics include an error of  $\pm 0.03$  GeV arising from the beam energy uncertainty.
- 21 AID 96D derive this value as a propagator mass using the  $Q^2$  shape and magnitude of the  $e^\pm$  charged-current cross sections.  $Q^2 > 5000$  GeV<sup>2</sup> events with  $p_T$  of the outgoing lepton  $> 25$  GeV/ $c$  are used.
- 22 ALITTI 92B result has two contributions to the systematic error ( $\pm 0.83$ ); one ( $\pm 0.81$ ) cancels in  $m_W/m_Z$  and one ( $\pm 0.17$ ) is noncancelling. These were added in quadrature. We choose the ALITTI 92B value without using the LEP  $m_Z$  value, because we perform our own combined fit.
- 23 There are two contributions to the systematic error ( $\pm 0.84$ ): one ( $\pm 0.81$ ) which cancels in  $m_W/m_Z$  and one ( $\pm 0.21$ ) which is non-cancelling. These were added in quadrature.
- 24 ABE 89I systematic error dominated by the uncertainty in the absolute energy scale.
- 25 ALBAJAR 89 result is from a total sample of 299  $W \rightarrow e\nu$  events.
- 26 ALBAJAR 89 result is from a total sample of 67  $W \rightarrow \mu\nu$  events.
- 27 ALBAJAR 89 result is from  $W \rightarrow \tau\nu$  events.

## W/Z MASS RATIO

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.8820 <math>\pm 0.0005</math> OUR FIT</b>				
0.8821 $\pm 0.0011 \pm 0.0008$	28323	28 ABBOTT	98N D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV

$0.88114 \pm 0.00154 \pm 0.00252$	5982	<sup>29</sup> ABBOTT	98P D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
$0.8813 \pm 0.0036 \pm 0.0019$	156	<sup>30</sup> ALITTI	92B UA2	$E_{cm}^{p\bar{p}} = 630$ GeV

<sup>28</sup> ABBOTT 98N obtain this from a study of 28323  $W \rightarrow e\nu_e$  and 3294  $Z \rightarrow e^+e^-$  decays. Of this latter sample, 2179 events are used to calibrate the electron energy scale.

<sup>29</sup> ABBOTT 98P obtain this from a study of 5982  $W \rightarrow e\nu_e$  events. The systematic error includes an uncertainty of  $\pm 0.00175$  due to the electron energy scale.

<sup>30</sup> Scale error cancels in this ratio.

### $m_Z - m_W$

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

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

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

Test of  $CPT$  invariance.

<u>VALUE (GeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>-0.19 \pm 0.58</math></b>	1722	ABE	90G CDF	$E_{cm}^{p\bar{p}} = 1.8$ TeV

### W WIDTH

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

<u>VALUE (GeV)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>2.12 \pm 0.05</math> OUR AVERAGE</b>					
$2.152 \pm 0.066$		79176	<sup>31</sup> ABBOTT	00B D0	Extracted value
$1.84 \pm 0.32 \pm 0.20$		674	<sup>32</sup> ABBIENDI	99C OPAL	$E_{cm}^{ee} = 172+183$ GeV
$2.48 \pm 0.40 \pm 0.10$		737	<sup>33</sup> ABREU	99T DLPH	$E_{cm}^{ee} = 183$ GeV
$1.97 \pm 0.34 \pm 0.17$		687	<sup>34</sup> ACCIARRI	99 L3	$E_{cm}^{ee} = 172+183$ GeV
$2.11 \pm 0.28 \pm 0.16$		58	<sup>35</sup> ABE	95C CDF	Direct meas.
$2.064 \pm 0.060 \pm 0.059$			<sup>36</sup> ABE	95W CDF	Extracted value
$2.10 \begin{smallmatrix} +0.14 \\ -0.13 \end{smallmatrix} \pm 0.09$		3559	<sup>37</sup> ALITTI	92 UA2	Extracted value
$2.18 \begin{smallmatrix} +0.26 \\ -0.24 \end{smallmatrix} \pm 0.04$			<sup>38</sup> ALBAJAR	91 UA1	Extracted value

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

$2.044 \pm 0.097$	11858	<sup>39</sup> ABBOTT	99H D0	Repl. by ABBOTT 00B
$2.126^{+0.052}_{-0.048} \pm 0.035$		<sup>40</sup> BARATE	99I ALEP	$E_{cm}^{ee} = 161+172+183$ GeV
$1.30^{+0.70}_{-0.55} \pm 0.18$	92	<sup>41</sup> ACKERSTAFF	98D OPAL	Repl. by ABBIENDI 99C
$1.74^{+0.88}_{-0.78} \pm 0.25$	101	<sup>42</sup> ACCIARRI	97S L3	Repl. by ACCIARRI 99
$2.30 \pm 0.19 \pm 0.06$		<sup>43</sup> ALITTI	90C UA2	Extracted value
$2.8^{+1.4}_{-1.5} \pm 1.3$	149	<sup>44</sup> ALBAJAR	89 UA1	$E_{cm}^{p\bar{p}} = 546,630$ GeV
<7	90	119 APPEL	86 UA2	$E_{cm}^{p\bar{p}} = 546,630$ GeV
<6.5	90	86 <sup>45</sup> ARNISON	86 UA1	$E_{cm}^{p\bar{p}} = 546,630$ GeV

<sup>31</sup> ABBOTT 00B measure  $R = 10.43 \pm 0.27$  for the  $W \rightarrow e\nu_e$  decay channel. They use the SM theoretical predictions for  $\sigma(W)/\sigma(Z)$  and  $\Gamma(W \rightarrow e\nu_e)$  and the world average for  $B(Z \rightarrow e e)$ . The value quoted here is obtained combining this result ( $2.169 \pm 0.070$  GeV) with that of ABBOTT 99H.

<sup>32</sup> ABBIENDI 99C obtain this value from a fit to the reconstructed  $W$  mass distribution using data at 172 and 183 GeV. The systematic error includes an uncertainty of  $\pm 0.12$  GeV due to the possible color-reconnection and Bose-Einstein effects in the purely hadronic final states and an uncertainty of  $\pm 0.01$  GeV due to the beam energy.

<sup>33</sup> ABREU 99T obtain this value using  $W W \rightarrow \ell \bar{\nu}_\ell q \bar{q}$  and  $W W \rightarrow q \bar{q} q \bar{q}$  events. The systematic error includes an uncertainty of  $\pm 0.080$  GeV due to possible color reconnection and Bose-Einstein effects in the purely hadronic final state.

<sup>34</sup> ACCIARRI 99 obtain this value from a fit to the reconstructed  $W$  mass distribution using data at 172 and 183 GeV.

<sup>35</sup> ABE 95C use the tail of the transverse mass distribution of  $W \rightarrow e\nu_e$  decays.

<sup>36</sup> ABE 95W measured  $R = 10.90 \pm 0.32 \pm 0.29$ . They use  $m_W = 80.23 \pm 0.18$  GeV,  $\sigma(W)/\sigma(Z) = 3.35 \pm 0.03$ ,  $\Gamma(W \rightarrow e\nu) = 225.9 \pm 0.9$  MeV,  $\Gamma(Z \rightarrow e^+ e^-) = 83.98 \pm 0.18$  MeV, and  $\Gamma(Z) = 2.4969 \pm 0.0038$  GeV.

<sup>37</sup> ALITTI 92 measured  $R = 10.4^{+0.7}_{-0.6} \pm 0.3$ . The values of  $\sigma(Z)$  and  $\sigma(W)$  come from  $O(\alpha_s^2)$  calculations using  $m_W = 80.14 \pm 0.27$  GeV, and  $m_Z = 91.175 \pm 0.021$  GeV along with the corresponding value of  $\sin^2\theta_W = 0.2274$ . They use  $\sigma(W)/\sigma(Z) = 3.26 \pm 0.07 \pm 0.05$  and  $\Gamma(Z) = 2.487 \pm 0.010$  GeV.

<sup>38</sup> ALBAJAR 91 measured  $R = 9.5^{+1.1}_{-1.0}$  (stat. + syst.).  $\sigma(W)/\sigma(Z)$  is calculated in QCD at the parton level using  $m_W = 80.18 \pm 0.28$  GeV and  $m_Z = 91.172 \pm 0.031$  GeV along with  $\sin^2\theta_W = 0.2322 \pm 0.0014$ . They use  $\sigma(W)/\sigma(Z) = 3.23 \pm 0.05$  and  $\Gamma(Z) = 2.498 \pm 0.020$  GeV. This measurement is obtained combining both the electron and muon channels.

<sup>39</sup> ABBOTT 99H measure  $R = 10.90 \pm 0.52$  combining electron and muon channels. They use  $M_W = 80.39 \pm 0.06$  GeV and the SM theoretical predictions for  $\sigma(W)/\sigma(Z)$ ,  $B(Z \rightarrow \ell\ell)$ , and  $\Gamma(W \rightarrow \ell\nu_\ell)$ .

<sup>40</sup> BARATE 99I obtain this result with a fit to the  $W W$  measured cross sections at 161, 172, and 183 GeV. The theoretical prediction takes into account the sensitivity to the  $W$  total width.

<sup>41</sup> ACKERSTAFF 98D obtain this value from a fit to the reconstructed  $W$  mass distribution.

<sup>42</sup> ACCIARRI 97S obtain this value from a fit to the reconstructed  $W$  mass distribution.

<sup>43</sup> ALITTI 90C used the same technique as described for ABE 90. They measured  $R = 9.38^{+0.82}_{-0.72} \pm 0.25$ , obtained  $\Gamma(W)/\Gamma(Z) = 0.902 \pm 0.074 \pm 0.024$ . Using  $\Gamma(Z) = 2.546 \pm 0.032$  GeV, they obtained the  $\Gamma(W)$  value quoted above and the limits  $\Gamma(W) < 2.56$  (2.64) GeV at the 90% (95%) CL.  $E_{cm}^{p\bar{p}} = 546,630$  GeV.

<sup>44</sup> ALBAJAR 89 result is from a total sample of 299  $W \rightarrow e\nu$  events.

<sup>45</sup> If systematic error is neglected, result is  $2.7^{+1.4}_{-1.5}$  GeV. This is enhanced subsample of 172 total events.

## $W^+$ DECAY MODES

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

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level
$\Gamma_1 \ell^+\nu$	[a] $(10.56 \pm 0.14) \%$	
$\Gamma_2 e^+\nu$	$(10.66 \pm 0.20) \%$	
$\Gamma_3 \mu^+\nu$	$(10.49 \pm 0.29) \%$	
$\Gamma_4 \tau^+\nu$	$(10.4 \pm 0.4) \%$	
$\Gamma_5$ hadrons	$(68.5 \pm 0.6) \%$	
$\Gamma_6 \pi^+\gamma$	$< 7 \times 10^{-5}$	95%
$\Gamma_7 D_s^+\gamma$	$< 1.3 \times 10^{-3}$	95%
$\Gamma_8 cX$	$(35 \pm 4) \%$	
$\Gamma_9 c\bar{s}$	$(32^{+13}_{-11}) \%$	
$\Gamma_{10}$ invisible	[b] $(1.4 \pm 2.8) \%$	

[a]  $\ell$  indicates each type of lepton ( $e$ ,  $\mu$ , and  $\tau$ ), not sum over them.

[b] This represents the width for the decay of the  $W$  boson into a charged particle with momentum below detectability,  $p < 200$  MeV.

## $W$ PARTIAL WIDTHS

### $\Gamma(\text{invisible})$

$\Gamma_{10}$

This represents the width for the decay of the  $W$  boson into a charged particle with momentum below detectability,  $p < 200$  MeV.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$30^{+52}_{-48} \pm 33$	<sup>46</sup> BARATE	99I ALEP	$E_{cm}^{ee} = 161+172+183$ GeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
	<sup>47</sup> BARATE	99L ALEP	$E_{cm}^{ee} = 161+172+183$ GeV

<sup>46</sup> BARATE 99I measure this quantity using the dependence of the total cross section  $\sigma_{WW}$  upon a change in the total width. The fit is performed to the  $WW$  measured cross sections at 161, 172, and 183 GeV. This partial width is  $< 139$  MeV at 95%CL.

<sup>47</sup> BARATE 99L use  $W$ -pair production to search for effectively invisible  $W$  decays, tagging with the decay of the other  $W$  boson to Standard Model particles. The partial width for effectively invisible decay is  $< 27$  MeV at 95%CL.

## W BRANCHING RATIOS

Overall fits are performed to determine the branching ratios of the  $W$ . For each LEP experiment the correlation matrix of the leptonic branching ratios is used and the common systematic errors among LEP experiments are properly taken into account. A first fit determines three individual leptonic branching ratios,  $B(W \rightarrow e\nu_e)$ ,  $B(W \rightarrow \mu\nu_\mu)$ , and  $B(W \rightarrow \tau\nu_\tau)$ . This fit has a  $\chi^2 = 10.5$  for 20 degrees of freedom. A second fit assumes lepton universality and determines the leptonic branching ratio  $B(W \rightarrow \ell\nu_\ell)$ . This fit has a  $\chi^2=11.0$  for 22 degrees of freedom. A separate fit is performed only to hadronic branching ratio data taking into account the common systematic errors. This fit has a  $\chi^2=2.3$  for 3 degrees of freedom.

$\Gamma(\ell^+\nu)/\Gamma_{\text{total}}$

$\ell$  indicates average over  $e$ ,  $\mu$ , and  $\tau$  modes, not sum over modes.

$\Gamma_1/\Gamma$

Data marked "fit" are used for the fit. The other data is highly correlated with data appearing elsewhere in the Listings and are therefore not used in the fit.

VALUE		EVTs	DOCUMENT ID	TECN	COMMENT
<b>0.1056 ± 0.0014 OUR FIT</b>					
0.1071 ± 0.0024 ± 0.0014		1237	ABREU	00K DLPH	$E_{\text{cm}}^{ee} = 161+172+183+189$ GeV
0.107 ± 0.004 ± 0.002		461	ABBIENDI	99D OPAL	$E_{\text{cm}}^{ee} = 161+172+183$ GeV
0.1102 ± 0.0052	fit	11858	<sup>48</sup> ABBOTT	99H D0	$E_{\text{cm}}^{pp} = 1.8$ TeV
0.1036 ± 0.0040 ± 0.0017		532	BARATE	99I ALEP	$E_{\text{cm}}^{ee} = 161+172+183$ GeV
0.100 ± 0.004 ± 0.001		324	ACCIARRI	98P L3	$E_{\text{cm}}^{ee} = 161+172+183$ GeV
0.104 ± 0.008	fit	3642	<sup>49</sup> ABE	92I CDF	$E_{\text{cm}}^{pp} = 1.8$ TeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
0.1085 ± 0.0048 ± 0.0017		170	ABREU	99K DLPH	Repl. by ABREU 00K
0.101 $\begin{smallmatrix} +0.011 \\ -0.010 \end{smallmatrix}$ ± 0.002		61	ACKERSTAFF	98D OPAL	Repl. by ABBIENDI 99D
0.119 $\begin{smallmatrix} +0.013 \\ -0.012 \end{smallmatrix}$ ± 0.002		51	ACCIARRI	97M L3	Repl. by ACCIARRI 98P

<sup>48</sup> ABBOTT 99H measure  $R \equiv [\sigma_W B(W \rightarrow \ell\nu_\ell)]/[\sigma_Z B(Z \rightarrow \ell\ell)] = 10.90 \pm 0.52$  combining electron and muon channels. They use  $M_W = 80.39 \pm 0.06$  GeV and the SM theoretical predictions for  $\sigma(W)/\sigma(Z)$  and  $B(Z \rightarrow \ell\ell)$ .

<sup>49</sup>  $1216 \pm 38 \begin{smallmatrix} +27 \\ -31 \end{smallmatrix}$   $W \rightarrow \mu\nu$  events from ABE 92I and  $2426 W \rightarrow e\nu$  events of ABE 91C. ABE 92I give the inverse quantity as  $9.6 \pm 0.7$  and we have inverted.

$\Gamma(e^+ \nu)/\Gamma_{\text{total}}$   $\Gamma_2/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.1066 ± 0.0020 OUR FIT</b>				
0.1044 ± 0.0015 ± 0.0028	67318	<sup>50</sup> ABBOTT	00B D0	$E_{\text{cm}}^{p\bar{p}} = 1.8 \text{ TeV}$
0.1018 ± 0.0054 ± 0.0026	352	ABREU	00K DLPH	$E_{\text{cm}}^{ee} =$ 161+172+183 +189 GeV
0.117 ± 0.009 ± 0.002	191	ABBIENDI	99D OPAL	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
0.1115 ± 0.0085 ± 0.0024	193	BARATE	99I ALEP	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
0.105 ± 0.009 ± 0.002	128	ACCIARRI	98P L3	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
0.1094 ± 0.0033 ± 0.0031		<sup>51</sup> ABE	95W CDF	$E_{\text{cm}}^{p\bar{p}} = 1.8 \text{ TeV}$
0.10 ± 0.014 <sup>+0.02</sup> <sub>-0.03</sub>	248	<sup>52</sup> ANSARI	87C UA2	$E_{\text{cm}}^{p\bar{p}} = 546,630$ GeV

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

0.1012 ± 0.0107 ± 0.0028	56	ABREU	99K DLPH	Repl. by ABREU 00K
0.098 <sup>+0.022</sup> <sub>-0.020</sub> ± 0.003	21	ACKERSTAFF	98D OPAL	Repl. by ABBI- ENDI 99D
0.165 <sup>+0.037</sup> <sub>-0.033</sub> ± 0.005	23	ACCIARRI	97M L3	Repl. by ACCIA- RRI 98P
0.097 ± 0.02 ± 0.005	21	BARATE	97S ALEP	Repl. by BARATE 99I
seen	119	APPEL	86 UA2	$E_{\text{cm}}^{p\bar{p}} = 546,630$ GeV
seen	172	ARNISON	86 UA1	$E_{\text{cm}}^{p\bar{p}} = 546,630$ GeV

<sup>50</sup> ABBOTT 00B measure  $R \equiv [\sigma_W B(W \rightarrow e\nu_e)]/[\sigma_Z B(Z \rightarrow ee)] = 10.43 \pm 0.27$  for the  $W \rightarrow e\nu_e$  decay channel. They use the SM theoretical prediction for  $\sigma(W)/\sigma(Z)$  and the world average for  $B(Z \rightarrow ee)$ .

<sup>51</sup> ABE 95W result is from a measurement of  $\sigma B(W \rightarrow e\nu)/\sigma B(Z \rightarrow e^+e^-) = 10.90 \pm 0.32 \pm 0.29$ , the theoretical prediction for the cross section ratio, the experimental knowledge of  $\Gamma(Z \rightarrow e^+e^-) = 83.98 \pm 0.18 \text{ MeV}$ , and  $\Gamma(Z) = 2.4969 \pm 0.0038 \text{ GeV}$ .

<sup>52</sup> The first error was obtained by adding the statistical and systematic experimental uncertainties in quadrature. The second error reflects the dependence on theoretical prediction of total  $W$  cross section:  $\sigma(546 \text{ GeV}) = 4.7^{+1.4}_{-0.7} \text{ nb}$  and  $\sigma(630 \text{ GeV}) = 5.8^{+1.8}_{-1.0} \text{ nb}$ . See ALTARELLI 85B.

$\Gamma(\mu^+ \nu)/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.1049 ± 0.0029 OUR FIT</b>				
0.1092 ± 0.0048 ± 0.0012	461	ABREU	00K DLPH	$E_{\text{cm}}^{ee} =$ 161+172+183 +189 GeV
0.102 ± 0.008 ± 0.002	169	ABBIENDI	99D OPAL	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
0.1006 ± 0.0078 ± 0.0021	179	BARATE	99I ALEP	$E_{\text{cm}}^{ee} =$ 161+172+183 GeV
0.102 ± 0.009 ± 0.002	115	ACCIARRI	98P L3	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
0.10 ± 0.01	1216	<sup>53</sup> ABE	92I CDF	$E_{\text{cm}}^{p\bar{p}} = 1.8 \text{ TeV}$

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

$0.1139 \pm 0.0096 \pm 0.0023$	67	ABREU	99K DLPH	Repl. by ABREU 00K
$0.073 \begin{smallmatrix} +0.019 \\ -0.017 \end{smallmatrix} \pm 0.002$	16	ACKERSTAFF	98D OPAL	Repl. by ABBI- ENDI 99D
$0.084 \begin{smallmatrix} +0.028 \\ -0.024 \end{smallmatrix} \pm 0.003$	13	ACCIARRI	97M L3	Repl. by ACCIA- RRI 98P
$0.112 \pm 0.02 \pm 0.006$	25	BARATE	97S ALEP	Repl. by BARATE 99I

<sup>53</sup> ABE 92I quote the inverse quantity as  $9.9 \pm 1.2$  which we have inverted.

$\Gamma(\tau^+ \nu) / \Gamma_{\text{total}}$   $\Gamma_4 / \Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.1043 ± 0.0041 OUR FIT</b>				
$0.1105 \pm 0.0075 \pm 0.0032$	424	ABREU	00K DLPH	$E_{\text{cm}}^{ee} =$ 161+172+183 +189 GeV
$0.101 \pm 0.010 \pm 0.003$	144	ABBIENDI	99D OPAL	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
$0.0976 \pm 0.0101 \pm 0.0033$	160	BARATE	99I ALEP	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
$0.090 \pm 0.012 \pm 0.003$	81	ACCIARRI	98P L3	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV

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

$0.1095 \pm 0.0149 \pm 0.0041$	47	ABREU	99K DLPH	Repl. by ABREU 00K
$0.140 \begin{smallmatrix} +0.030 \\ -0.028 \end{smallmatrix} \pm 0.005$	23	ACKERSTAFF	98D OPAL	Repl. by ABBI- ENDI 99D
$0.109 \begin{smallmatrix} +0.042 \\ -0.039 \end{smallmatrix} \pm 0.005$	15	ACCIARRI	97M L3	Repl. by ACCIA- RRI 98P
$0.113 \pm 0.027 \pm 0.006$	37	BARATE	97S ALEP	Repl. by BARATE 99I

$\Gamma(\text{hadrons}) / \Gamma_{\text{total}}$   $\Gamma_5 / \Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.6848 ± 0.0059 OUR FIT</b>				
$0.6789 \pm 0.0073 \pm 0.0043$	1773	ABREU	00K DLPH	$E_{\text{cm}}^{ee} =$ 161+172+183 +189 GeV
$0.679 \pm 0.012 \pm 0.005$	395	ABBIENDI	99D OPAL	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
$0.6893 \pm 0.0121 \pm 0.0051$	1255	BARATE	99I ALEP	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV
$0.701 \pm 0.013 \pm 0.004$	462	ACCIARRI	98P L3	$E_{\text{cm}}^{ee} = 161+172+$ 183 GeV

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

$0.6746 \pm 0.0143 \pm 0.0052$	465	ABREU	99K DLPH	Repl. by ABREU 00K
$0.698 \begin{smallmatrix} +0.030 \\ -0.032 \end{smallmatrix} \pm 0.007$	52	ACKERSTAFF	98D OPAL	Repl. by ABBI- ENDI 99D
$0.642 \begin{smallmatrix} +0.037 \\ -0.038 \end{smallmatrix} \pm 0.005$	70	ACCIARRI	97M L3	Repl. by ACCIA- RRI 98P
$0.677 \pm 0.031 \pm 0.007$	65	BARATE	97S ALEP	Repl. by BARATE 99I

### $\Gamma(\mu^+\nu)/\Gamma(e^+\nu)$

$\Gamma_3/\Gamma_2$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**0.984±0.032 OUR FIT**

0.89 ±0.10	13k	<sup>54</sup> ABACHI	95D D0	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
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1.02 ±0.08	1216	<sup>55</sup> ABE	92I CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

1.00 ±0.14 ±0.08	67	ALBAJAR	89 UA1	$E_{cm}^{p\bar{p}} = 546,630 \text{ GeV}$
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1.24 $\begin{smallmatrix} +0.6 \\ -0.4 \end{smallmatrix}$	14	ARNISON	84D UA1	Repl. by ALBAJAR 89
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<sup>54</sup> ABACHI 95D obtain this result from the measured  $\sigma_W B(W \rightarrow \mu\nu) = 2.09 \pm 0.23 \pm 0.11 \text{ nb}$  and  $\sigma_W B(W \rightarrow e\nu) = 2.36 \pm 0.07 \pm 0.13 \text{ nb}$  in which the first error is the combined statistical and systematic uncertainty, the second reflects the uncertainty in the luminosity.

<sup>55</sup> ABE 92I obtain  $\sigma_W B(W \rightarrow \mu\nu) = 2.21 \pm 0.07 \pm 0.21$  and combine with ABE 91C  $\sigma_W B(W \rightarrow e\nu)$  to give a ratio of the couplings from which we derive this measurement.

### $\Gamma(\tau^+\nu)/\Gamma(e^+\nu)$

$\Gamma_4/\Gamma_2$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**0.979±0.044 OUR FIT**

0.94 ±0.14	179	<sup>56</sup> ABE	92E CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
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1.04 ±0.08 ±0.08	754	<sup>57</sup> ALITTI	92F UA2	$E_{cm}^{p\bar{p}} = 630 \text{ GeV}$
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1.02 ±0.20 ±0.12	32	ALBAJAR	89 UA1	$E_{cm}^{p\bar{p}} = 546,630 \text{ GeV}$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.995±0.112±0.083	198	ALITTI	91C UA2	Repl. by ALITTI 92F
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1.02 ±0.20 ±0.10	32	ALBAJAR	87 UA1	Repl. by ALBAJAR 89
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<sup>56</sup> ABE 92E use two procedures for selecting  $W \rightarrow \tau\nu_\tau$  events. The missing  $E_\tau$  trigger leads to  $132 \pm 14 \pm 8$  events and the  $\tau$  trigger to  $47 \pm 9 \pm 4$  events. Proper statistical and systematic correlations are taken into account to arrive at  $\sigma B(W \rightarrow \tau\nu) = 2.05 \pm 0.27 \text{ nb}$ . Combined with ABE 91C result on  $\sigma B(W \rightarrow e\nu)$ , ABE 92E quote a ratio of the couplings from which we derive this measurement.

<sup>57</sup> This measurement is derived by us from the ratio of the couplings of ALITTI 92F.

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

$\Gamma_6/\Gamma_2$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**< 7 × 10<sup>-4</sup> (CL = 95%)**

< 7 × 10 <sup>-4</sup>	95	ABE	98H CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
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< 4.9 × 10 <sup>-3</sup>	95	<sup>58</sup> ALITTI	92D UA2	$E_{cm}^{p\bar{p}} = 630 \text{ GeV}$
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< 58 × 10 <sup>-3</sup>	95	<sup>59</sup> ALBAJAR	90 UA1	$E_{cm}^{p\bar{p}} = 546, 630 \text{ GeV}$
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<sup>58</sup> ALITTI 92D limit is  $3.8 \times 10^{-3}$  at 90%CL.

<sup>59</sup> ALBAJAR 90 obtain < 0.048 at 90%CL.

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

$\Gamma_7/\Gamma_2$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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< 1.2 × 10 <sup>-2</sup>	95	ABE	98P CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$
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### $\Gamma(cX)/\Gamma(\text{hadrons})$

$\Gamma_8/\Gamma_5$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.51 ± 0.05 ± 0.03</b>	746	<sup>60</sup> BARATE	99M ALEP	$E_{\text{cm}}^{ee} = 172 + 183 \text{ GeV}$

<sup>60</sup> BARATE 99M tag  $c$  jets using a neural network algorithm. From this measurement  $|V_{cs}|$  is determined to be  $1.00 \pm 0.11 \pm 0.07$ .

### $R_{cs} = \Gamma(c\bar{s})/\Gamma(\text{hadrons})$

$\Gamma_9/\Gamma_5$

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.46<sup>+0.18</sup><sub>-0.14</sub> ± 0.07</b>	<sup>61</sup> ABREU	98N DLPH	$E_{\text{cm}}^{ee} = 161+172 \text{ GeV}$

<sup>61</sup> ABREU 98N tag  $c$  and  $s$  jets by identifying a charged kaon as the highest momentum particle in a hadronic jet. They also use a lifetime tag to independently identify a  $c$  jet, based on the impact parameter distribution of charged particles in a jet. From this measurement  $|V_{cs}|$  is determined to be  $0.94^{+0.32}_{-0.26} \pm 0.13$ .

## AVERAGE PARTICLE MULTIPLICITIES IN HADRONIC $W$ DECAY

Summed over particle and antiparticle, when appropriate.

### $\langle N_{\text{charged}} \rangle$

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>19.3 ± 0.4 OUR AVERAGE</b>			
19.3 ± 0.3 ± 0.3	<sup>62</sup> ABBIENDI	99N OPAL	$E_{\text{cm}}^{ee} = 183 \text{ GeV}$
19.23 ± 0.74	<sup>63</sup> ABREU	98C DLPH	$E_{\text{cm}}^{ee} = 172 \text{ GeV}$

<sup>62</sup> ABBIENDI 99N use the final states  $W^+ W^- \rightarrow q\bar{q}\ell\bar{\nu}_\ell$  to derive this value.

<sup>63</sup> ABREU 98C combine results from both the fully hadronic as well semileptonic  $W W$  final states after demonstrating that the  $W$  decay charged multiplicity is independent of the topology within errors.

## TRIPLE GAUGE COUPLINGS (TGC'S)

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

Fourteen independent couplings, 7 each for  $ZWW$  and  $\gamma WW$ , completely describe the  $VWW$  vertices within the most general framework of the electroweak Standard Model (SM) consistent with Lorentz invariance and  $U(1)$  gauge invariance. Of each of the 7 TGC's, 3 conserve  $C$  and  $P$  individually, 3 violate  $CP$ , and one TGC violates  $C$  and  $P$  individually while conserving  $CP$ . Assumption of  $C$  and  $P$  conservation and electromagnetic gauge invariance reduces the independent  $VWW$  couplings to five: one common set is  $(\kappa_\gamma, \kappa_Z, \lambda_\gamma, \lambda_Z, g_1^Z)$ , where  $\kappa_\gamma = \kappa_Z = g_1^Z = 1$  and  $\lambda_\gamma = \lambda_Z = 0$  in the Standard

Model at the tree level. The  $W$  magnetic dipole moment,  $\mu_W$ , and the  $W$  electric quadrupole moment,  $q_W$ , are expressed as  $\mu_W = e (1 + \kappa_\gamma + \lambda_\gamma)/2M_W$  and  $q_W = -e (\kappa_\gamma - \lambda_\gamma)/M_W^2$ .

Precision measurements of suitable observables at LEP1 has already led to an exploration of much of the TGC parameter space. Three linear combinations of the TGC's,  $\alpha_{W\phi}$ ,  $\alpha_{B\phi}$  and  $\alpha_W$ , have been proposed to investigate the leftover "blind" directions in the  $CP$ -conserving TGC parameter space, and two linear couplings,  $\tilde{\alpha}_{BW}$  and  $\tilde{\alpha}_W$  in the  $CP$ -violating TGC parameter space (see *e.g.*, papers by Hagiwara [1], Bilenky [2], and Gounaris [3,4]). The relations between these parameters and those contained in the above set, expressed as *deviations* from the SM, are  $\Delta g_1^Z = \alpha_{W\phi}/c_w^2$ ,  $\Delta\kappa_\gamma = \alpha_{W\phi} + \alpha_{B\phi}$ ,  $\Delta\kappa_Z = \alpha_{W\phi} - t_w^2\alpha_{B\phi}$  and  $\lambda_\gamma = \lambda_Z = \alpha_W$ , where  $c_w$  and  $t_w$  are the cosine and tangent of the electroweak mixing angle. Similarly,  $\tilde{\kappa}_\gamma = \tilde{\alpha}_{BW}$ ,  $\tilde{\kappa}_Z = t_w^2\tilde{\alpha}_{BW}$  and  $\tilde{\lambda}_\gamma = \tilde{\lambda}_Z = \tilde{\alpha}_W$  within the  $CP$ -violating sector. The LEP Collaborations have recently agreed to express their results directly in terms of the parameters  $\Delta g_1^Z$ ,  $\Delta\kappa_\gamma$  and  $\lambda_\gamma$ .

At LEP2 the  $VWW$  coupling arises in  $W$ -pair production via  $s$ -channel exchange or in single  $W$  production via the radiation of a virtual photon off the incident  $e^+$  or  $e^-$ . At the TEVATRON hard photon bremsstrahlung off a produced  $W$  or  $Z$  signals the presence of a triple gauge vertex. In order to extract the value of one TGC the others are generally kept fixed to their SM values.

## References

1. K. Hagiwara *et al.*, Nucl. Phys. **B282**, 253 (1987).
2. M. Bilenky *et al.*, Nucl. Phys. **B409**, 22 (1993).
3. G. Gounaris *et al.*, CERN 96-01 525.
4. G. Gounaris *et al.*, Eur. Phys. J. **C2**, 365 (1998).

### $\Delta g_1^Z$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.01 <math>\begin{smallmatrix} +0.09 \\ -0.08 \end{smallmatrix}</math></b>				<b>OUR AVERAGE</b>
0.01 $\begin{smallmatrix} +0.13 \\ -0.12 \end{smallmatrix}$	853	64 ABBIENDI	99D OPAL	$E_{cm}^{ee} = 161+172+ 183$ GeV
-0.04 $\begin{smallmatrix} +0.14 \\ -0.12 \end{smallmatrix}$	566	65 ABREU	99L DLPH	$E_{cm}^{ee} = 183$ GeV
0.11 $\begin{smallmatrix} +0.19 \\ -0.18 \end{smallmatrix}$ $\pm 0.10$	1154	66 ACCIARRI	99Q L3	$E_{cm}^{ee} = 161+172+ 183$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	331	67 ABBOTT	99i D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
-0.017 $\pm 0.018$ $\begin{smallmatrix} +0.018 \\ -0.003 \end{smallmatrix}$		68 MOLNAR	99 THEO	LEP1, SLAC+Tevatron

64 ABBIENDI 99D combine results from  $W^+ W^-$  production at different energies. The 95% confidence interval is  $-0.23 < \Delta g_1^Z < 0.26$ .

65 ABREU 99L use  $W^+ W^-$ ,  $W e \nu_e$ , and  $\nu \bar{\nu} \gamma$  final states. The 95% confidence interval is  $-0.28 < \Delta g_1^Z < 0.24$ .

66 ACCIARRI 99Q study  $W$ -pair, single- $W$ , and single photon events.

67 ABBOTT 99i perform a simultaneous fit to the  $W\gamma$ ,  $W W \rightarrow$  dilepton,  $W W/W Z \rightarrow e\nu jj$ ,  $W W/W Z \rightarrow \mu\nu jj$ , and  $W Z \rightarrow$  trilepton data samples. For  $\Lambda = 2.0$  TeV, the 95%CL limits are  $-0.37 < \Delta g_1^Z < 0.57$ , fixing  $\lambda_Z = \Delta\kappa_Z = 0$  and assuming Standard Model values for the  $W W\gamma$  couplings.

68 MOLNAR 99 extract this value indirectly by fitting high energy electroweak data within the framework of the Standard Model. The central value of the Higgs mass used is 300 GeV and the quoted systematic error is due to its variation between 90 to 1000 GeV.

### $\Delta\kappa_\gamma$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.08 <math>\pm 0.17</math></b>				<b>OUR AVERAGE</b>
0.11 $\begin{smallmatrix} +0.52 \\ -0.37 \end{smallmatrix}$	853	69 ABBIENDI	99D OPAL	$E_{cm}^{ee} = 161+172+ 183$ GeV
-0.08 $\pm 0.34$	331	70 ABBOTT	99i D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
0.19 $\begin{smallmatrix} +0.32 \\ -0.34 \end{smallmatrix}$	566	71 ABREU	99L DLPH	$E_{cm}^{ee} = 183$ GeV
0.11 $\pm 0.25$ $\pm 0.17$	1154	72 ACCIARRI	99Q L3	$E_{cm}^{ee} = 161+172+ 183$ GeV
0.05 $\begin{smallmatrix} +1.15 \\ -1.10 \end{smallmatrix}$ $\pm 0.25$	207	73 BARATE,R	98 ALEP	$E_{cm}^{ee} = 161+172+183$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	15	74 BARATE	99L ALEP	$E_{cm}^{ee} = 161+172+183$ GeV
0.016 $\pm 0.019$ $\begin{smallmatrix} +0.009 \\ -0.013 \end{smallmatrix}$		75 MOLNAR	99 THEO	LEP1, SLAC+Tevatron
0.06 $\begin{smallmatrix} +0.27 \\ -0.26 \end{smallmatrix}$	86	76 ACCIARRI	98N L3	Repl. by ACCIARRI 99Q

69 ABBIENDI 99D combine results from  $W^+ W^-$  production at different energies. The 95% confidence interval is  $-0.55 < \Delta\kappa_\gamma < 1.28$ .

70 ABBOTT 99i perform a simultaneous fit to the  $W\gamma$ ,  $W W \rightarrow$  dilepton,  $W W/W Z \rightarrow e\nu jj$ ,  $W W/W Z \rightarrow \mu\nu jj$ , and  $W Z \rightarrow$  trilepton data samples. For  $\Lambda = 2.0$  TeV, the 95%CL limits are  $-0.25 < \Delta\kappa_\gamma < 0.39$ .

- 71 ABREU 99L use  $W^+ W^-$ ,  $W e \nu_e$ , and  $\nu \bar{\nu} \gamma$  final states. The 95% confidence interval is  $-0.46 < \Delta\kappa_\gamma < 0.84$ .
- 72 ACCIARRI 99Q study  $W$ -pair, single- $W$ , and single photon events.
- 73 BARATE,R 98 study single photon production in  $e^+ e^-$  interactions from 161 to 183 GeV. A likelihood fit is performed to the cross section and to the photon energy and angular distributions, taking into account systematic uncertainties. The 95%CL limits are  $-2.2 < \Delta\kappa_\gamma < 2.3$ .
- 74 BARATE 99L study single  $W$  production in  $e^+ e^-$  interactions from 161 to 183 GeV. They obtain 95%CL limits of  $-1.6 < \kappa_\gamma < 1.5$ , which we convert to  $-2.6 < \Delta\kappa_\gamma < 0.5$  for  $\lambda_\gamma=0$ .
- 75 MOLNAR 99 extract this value indirectly by fitting high energy electroweak data within the framework of the Standard Model. The central value of the Higgs mass used is 300 GeV and the quoted systematic error is due to its variation between 90 to 1000 GeV.
- 76 ACCIARRI 98N study single  $W$  production in  $e^+ e^-$  interactions from 130 to 183 GeV. The 95%CL limits are  $-0.46 < \Delta\kappa_\gamma < 0.57$ .

$\lambda_\gamma$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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**$-0.04^{+0.07}_{-0.06}$  OUR AVERAGE**

$-0.10^{+0.13}_{-0.12}$	853	77 ABBIENDI	99D OPAL	$E_{cm}^{ee} = 161+172+ 183$ GeV
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$0.00^{+0.10}_{-0.09}$	331	78 ABBOTT	99i D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
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$-0.15^{+0.19}_{-0.15}$	566	79 ABREU	99L DLPH	$E_{cm}^{ee} = 183$ GeV
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$0.10^{+0.22}_{-0.20} \pm 0.10$	1154	80 ACCIARRI	99Q L3	$E_{cm}^{ee} = 161+172+ 183$ GeV
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$-0.05^{+1.55}_{-1.45} \pm 0.30$	207	81 BARATE,R	98 ALEP	$E_{cm}^{ee} = 161+172+183$ GeV
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• • • We do not use the following data for averages, fits, limits, etc. • • •

	15	82 BARATE	99L ALEP	$E_{cm}^{ee} = 161+172+183$ GeV
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$-0.48^{+0.44}_{-0.21}$	86	83 ACCIARRI	98N L3	Repl. by ACCIARRI 99Q
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77 ABBIENDI 99D combine results from  $W^+ W^-$  production at different energies. The 95% confidence interval is  $-0.33 < \lambda_\gamma < 0.16$ .

78 ABBOTT 99i perform a simultaneous fit to the  $W\gamma$ ,  $W W \rightarrow$  dilepton,  $W W/W Z \rightarrow e\nu jj$ ,  $W W/W Z \rightarrow \mu\nu jj$ , and  $W Z \rightarrow$  trilepton data samples. For  $\Lambda = 2.0$  TeV, the 95%CL limits are  $-0.18 < \lambda_\gamma < 0.19$ .

79 ABREU 99L use  $W^+ W^-$ ,  $W e \nu_e$ , and  $\nu \bar{\nu} \gamma$  final states. The 95% confidence interval is  $-0.44 < \lambda_\gamma < 0.24$ .

80 ACCIARRI 99Q study  $W$ -pair, single- $W$ , and single photon events.

81 BARATE,R 98 study single photon production in  $e^+ e^-$  interactions from 161 to 183 GeV. A likelihood fit is performed to the cross section and to the photon energy and angular distributions, taking into account systematic uncertainties. The 95%CL limits are  $-3.1 < \lambda_\gamma < 3.2$ .

82 BARATE 99L study single  $W$  production in  $e^+ e^-$  interactions from 161 to 183 GeV. The 95%CL limits are  $-1.6 < \lambda_\gamma < 1.6$  for  $\Delta\kappa_\gamma=0$ .

83 ACCIARRI 98N study single  $W$  production in  $e^+ e^-$  interactions from 130 to 183 GeV. The 95%CL limits are  $-0.86 < \lambda_\gamma < 0.75$ .

### $\Delta g_5^Z$

This coupling is *CP* conserving but *C* and *P* violating.

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$-0.44^{+0.23}_{-0.22} \pm 0.12$	1154	84 ACCIARRI	99Q L3	$E_{cm}^{ee} = 161+172+ 183$ GeV

<sup>84</sup> ACCIARRI 99Q study *W*-pair, single-*W*, and single photon events.

### $\alpha_{W\phi}$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.05 ± 0.20 OUR AVERAGE</b>				

$0.22^{+0.25}_{-0.28} \pm 0.06$	89	85 ABREU	98K DLPH	$E_{cm}^{ee} = 161+172$ GeV
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$-0.14^{+0.27+0.14}_{-0.25-0.12}$	78	86 BARATE	98Y ALEP	$E_{cm}^{ee} = 172$ GeV
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• • • We do not use the following data for averages, fits, limits, etc. • • •

331	87 ABBOTT	99I D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
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<sup>85</sup> ABREU 98K obtain this result using both *W* pair production and single *W* (*W e ν<sub>e</sub>*) production.

<sup>86</sup> BARATE 98Y obtain this value using semileptonic and hadronic decay modes in *W* pair production.

<sup>87</sup> ABBOTT 99I perform a simultaneous fit to the *Wγ*, *W W* → dilepton, *W W/W Z* → *e ν j j*, *W W/W Z* → *μ ν j j*, and *W Z* → trilepton data samples. For  $\Lambda = 2.0$  TeV, the 95%CL limits are  $-0.18 < \alpha_{W\phi} < 0.36$ , fixing  $\alpha_{B\phi} = \alpha_{W\phi} = 0$ .

### $\alpha_W$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.1 ± 0.4 OUR AVERAGE</b>				

$0.11^{+0.48}_{-0.49} \pm 0.09$	89	88 ABREU	98K DLPH	$E_{cm}^{ee} = 161+172$ GeV
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$0.06^{+0.56+0.12}_{-0.50-0.20}$	78	89 BARATE	98Y ALEP	$E_{cm}^{ee} = 172$ GeV
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• • • We do not use the following data for averages, fits, limits, etc. • • •

331	90 ABBOTT	99I D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
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<sup>88</sup> ABREU 98K obtain this result using both *W* pair production and single *W* (*W e ν<sub>e</sub>*) production.

<sup>89</sup> BARATE 98Y obtain this value using semileptonic and hadronic decay modes in *W* pair production.

<sup>90</sup> ABBOTT 99I perform a simultaneous fit to the *Wγ*, *W W* → dilepton, *W W/W Z* → *e ν j j*, *W W/W Z* → *μ ν j j*, and *W Z* → trilepton data samples. For  $\Lambda = 2.0$  TeV, the 95%CL limits are  $-0.18 < \alpha_W < 0.19$ , fixing  $\alpha_{B\phi} = \alpha_{W\phi} = 0$ .

### $\alpha_{B\phi}$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.4 <math>^{+0.5}_{-0.8}</math> OUR AVERAGE</b>				

$0.22^{+0.66}_{-0.83} \pm 0.24$	89	91 ABREU	98K DLPH	$E_{cm}^{ee} = 161+172$ GeV
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$1.01^{+0.71}_{-1.75} \pm 0.33$	78	92 BARATE	98Y ALEP	$E_{cm}^{ee} = 172$ GeV
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• • • We do not use the following data for averages, fits, limits, etc. • • •

331	93 ABBOTT	99I D0	$E_{cm}^{p\bar{p}} = 1.8$ TeV
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- <sup>91</sup> ABREU 98K obtain this result using both  $W$  pair production and single  $W (W e \nu_e)$  production.
- <sup>92</sup> BARATE 98Y obtain this value using semileptonic and hadronic decay modes in  $W$  pair production.
- <sup>93</sup> ABBOTT 99I perform a simultaneous fit to the  $W\gamma$ ,  $W W \rightarrow$  dilepton,  $W W/W Z \rightarrow e\nu jj$ ,  $W W/W Z \rightarrow \mu\nu jj$ , and  $W Z \rightarrow$  trilepton data samples. For  $\Lambda = 2.0$  TeV, the 95%CL limits are  $-0.67 < \alpha_{B\phi} < 0.56$ , fixing  $\alpha_{W\phi} = \alpha_W = 0$ .

### $\tilde{\alpha}_{BW}$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.11^{+0.71}_{-0.88} \pm 0.09$	89	<sup>94</sup> ABREU	98K DLPH	$E_{cm}^{ee} = 161+172$ GeV

- <sup>94</sup> ABREU 98K obtain this result using both  $W$  pair production and single  $W (W e \nu_e)$  production.

### $\tilde{\alpha}_W$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.19^{+0.28}_{-0.41} \pm 0.11$	89	<sup>95</sup> ABREU	98K DLPH	$E_{cm}^{ee} = 161+172$ GeV

- <sup>95</sup> ABREU 98K obtain this result using both  $W$  pair production and single  $W (W e \nu_e)$  production.

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

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

VALUE ( $e/2m_W$ )	DOCUMENT ID	TECN
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<sup>96</sup> ABE	<sup>95G</sup> CDF
<sup>97</sup> ALITTI	<sup>92C</sup> UA2
<sup>98</sup> SAMUEL	<sup>92</sup> THEO
<sup>99</sup> SAMUEL	<sup>91</sup> THEO
<sup>100</sup> GRIFOLS	<sup>88</sup> THEO
<sup>101</sup> GROTCH	<sup>87</sup> THEO
<sup>102</sup> VANDERBIJ	<sup>87</sup> THEO
<sup>103</sup> GRAU	<sup>85</sup> THEO
<sup>104</sup> SUZUKI	<sup>85</sup> THEO
<sup>105</sup> HERZOG	<sup>84</sup> THEO

- <sup>96</sup> ABE 95G report  $-1.3 < \kappa < 3.2$  for  $\lambda=0$  and  $-0.7 < \lambda < 0.7$  for  $\kappa=1$  in  $p\bar{p} \rightarrow e\nu_e\gamma X$  and  $\mu\nu_\mu\gamma X$  at  $\sqrt{s} = 1.8$  TeV.

- <sup>97</sup> ALITTI 92C measure  $\kappa = 1^{+2.6}_{-2.2}$  and  $\lambda = 0^{+1.7}_{-1.8}$  in  $p\bar{p} \rightarrow e\nu\gamma + X$  at  $\sqrt{s} = 630$  GeV. At 95%CL they report  $-3.5 < \kappa < 5.9$  and  $-3.6 < \lambda < 3.5$ .

- <sup>98</sup> SAMUEL 92 use preliminary CDF and UA2 data and find  $-2.4 < \kappa < 3.7$  at 96%CL and  $-3.1 < \kappa < 4.2$  at 95%CL respectively. They use data for  $W\gamma$  production and radiative  $W$  decay.
- <sup>99</sup> SAMUEL 91 use preliminary CDF data for  $p\bar{p} \rightarrow W\gamma X$  to obtain  $-11.3 \leq \Delta\kappa \leq 10.9$ . Note that their  $\kappa = 1 - \Delta\kappa$ .
- <sup>100</sup> GRIFOLS 88 uses deviation from  $\rho$  parameter to set limit  $\Delta\kappa \lesssim 65 (M_W^2/\Lambda^2)$ .
- <sup>101</sup> GROUCH 87 finds the limit  $-37 < \Delta\kappa < 73.5$  (90% CL) from the experimental limits on  $e^+e^- \rightarrow \nu\bar{\nu}\gamma$  assuming three neutrino generations and  $-19.5 < \Delta\kappa < 56$  for four generations. Note their  $\Delta\kappa$  has the opposite sign as our definition.
- <sup>102</sup> VANDERBIJ 87 uses existing limits to the photon structure to obtain  $|\Delta\kappa| < 33 (m_W/\Lambda)$ . In addition VANDERBIJ 87 discusses problems with using the  $\rho$  parameter of the Standard Model to determine  $\Delta\kappa$ .
- <sup>103</sup> GRAU 85 uses the muon anomaly to derive a coupled limit on the anomalous magnetic dipole and electric quadrupole ( $\lambda$ ) moments  $1.05 > \Delta\kappa \ln(\Lambda/m_W) + \lambda/2 > -2.77$ . In the Standard Model  $\lambda = 0$ .
- <sup>104</sup> SUZUKI 85 uses partial-wave unitarity at high energies to obtain  $|\Delta\kappa| \lesssim 190 (m_W/\Lambda)^2$ . From the anomalous magnetic moment of the muon, SUZUKI 85 obtains  $|\Delta\kappa| \lesssim 2.2/\ln(\Lambda/m_W)$ . Finally SUZUKI 85 uses deviations from the  $\rho$  parameter and obtains a very qualitative, order-of-magnitude limit  $|\Delta\kappa| \lesssim 150 (m_W/\Lambda)^4$  if  $|\Delta\kappa| \ll 1$ .
- <sup>105</sup> HERZOG 84 consider the contribution of  $W$ -boson to muon magnetic moment including anomalous coupling of  $W W\gamma$ . Obtain a limit  $-1 < \Delta\kappa < 3$  for  $\Lambda \gtrsim 1$  TeV.

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ANSARI	87	PL B186 440	R. Ansari <i>et al.</i>	(UA2 Collab.)
ANSARI	87C	PL B194 158	R. Ansari <i>et al.</i>	(UA2 Collab.)
GROTCH	87	PR D36 2153	H. Grotch, R.W. Robinett	(PSU)
HAGIWARA	87	NP B282 253	K. Hagiwara <i>et al.</i>	(KEK, UCLA, FSU)
VANDERBIJ	87	PR D35 1088	J.J. van der Bij	(FNAL)
APPEL	86	ZPHY C30 1	J.A. Appel <i>et al.</i>	(UA2 Collab.)
ARNISON	86	PL 166B 484	G.T.J. Arnison <i>et al.</i>	(UA1 Collab.)
ALTARELLI	85B	ZPHY C27 617	G. Altarelli, R.K. Ellis, G. Martinelli	(CERN+)
GRAU	85	PL 154B 283	A. Grau, J.A. Grifols	(BARC)
SUZUKI	85	PL 153B 289	M. Suzuki	(LBL)
ARNISON	84D	PL 134B 469	G.T.J. Arnison <i>et al.</i>	(UA1 Collab.)
HERZOG	84	PL 148B 355	F. Herzog	(WISC)
Also	84B	PL 155B 468 erratum	F. Herzog	(WISC)
ARNISON	83	PL 122B 103	G.T.J. Arnison <i>et al.</i>	(UA1 Collab.)
BANNER	83B	PL 122B 476	M. Banner <i>et al.</i>	(UA2 Collab.)