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Direct measurement of m_{W}

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Measurement of the mass of the W boson using direct reconstruction

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Abstract

From data corresponding to an integrated luminosity of 157.6 pb^{-1} taken during the 189 GeV run in 1998, DELPHI has measured the W mass from direct reconstruction of WW $\to \ell\bar{\nu}\mathrm{q}\bar{\mathrm{q}}$ and WW $\to \mathrm{q}\bar{\mathrm{q}}\mathrm{q}\bar{\mathrm{q}}$ events. Combining these channels, a value of $m_{\mathrm{W}} = 80.331 \pm 0.090(stat) \pm 0.035(syst) \pm 0.034(fsi) \pm 0.017(LEP)$ GeV/c^2 is obtained, where *fsi* denotes final state interaction. The combination with previous DELPHI measurement gives the value of $m_{\mathrm{W}} = 80.316 \pm 0.076(stat) \pm 0.047(syst) \pm 0.017(LEP)$ GeV/c^2.

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1 Introduction

During the 189 GeV run in 1998 DELPHI collected a sample of e^+e^- collisions corresponding to an integrated luminosity of 157.6 pb^{-1}. At this energy a high precision measurement of m_W can be made by reconstructing the W mass spectrum using constrained fitting techniques. This direct measurement of m_W provides an important test of the Standard Model by comparison with the indirect measurement from precise electroweak results at lower energies [1] and helps constrain the mass of the Higgs boson.

This paper describes the analysis using events in which one W decays into leptons and the other into quarks, WW $\rightarrow l\bar{\nu}q\bar{q}$ ("semileptonic" events), and events in which both Ws decay hadronically, WW $\rightarrow q\bar{q}q\bar{q}$ ("hadronic" events). These analyses are detailed in [2]

The paper is organised as follows. In section 2, the DELPHI detector setup and the event generators are briefly reviewed. In section 3, the measurement of the W mass in the semileptonic channel is presented, while section 4 describes this measurement in the fully hadronic channel. In section 5, the combined result is presented, as well as combinations with previous DELPHI results.

2 Apparatus and Simulations

Detailed descriptions of the DELPHI apparatus and its performance can be found in [3].

The response of the detector to various physics processes was modelled using the simulation program DELSIM [4], which incorporates the resolution, granularity and efficiency of the detector components. The event generator EXCALIBUR [5] was used for the simulation of all four-fermion final states (signal and background), while the background from $e^+e^- \rightarrow q\bar{q}(\gamma)$ was generated with the PYTHIA [6] event generator. For the generation of the EXCALIBUR events, the fragmentation was performed using JETSET 7.4 [7] tuned to the DELPHI LEP1 data [8], and the initial state radiation (ISR) was generated using the QEDPS program [9].

For the signal part, a sample of 270,000 events was generated with a reference W mass of 80.35 GeV/c^2, while two other smaller samples of 180,000 events each were generated with masses of 79.35 and 81.35 GeV/c^2. At each of these masses, the simulated width was the one predicted by the standard model. The W mass and width used in this paper correspond to a W propagator with an s-dependent width.

3 Analysis of the semileptonic decay channel

Events were selected from the data sample recorded, requiring all detectors essential for this measurement to be fully efficient. These comprise the central tracking detectors and the electromagnetic calorimeters. The selected sample corresponds to an integrated luminosity of 152.9 pb^{-1}.

The analysis follows closely that presented in [2] for the electron and muon channels. In addition, we present here an analysis of the $\tau\bar{\nu}q\bar{q}$ channel.

Only events which failed the electron and muon selections were used as $\tau\bar{\nu}q\bar{q}$ candidates. They were required to be clusterised in 3 or more jets using LUCLUS with $ycut$ = 5 GeV/c^2, and they were then forced into a 3-jet configuration, in which the tau jet was chosen as the jet with the lowest charged multiplicity. As the tau mainly decays into a final state with 1 or 3 charged particles, only events where the tau jet contained between 1 and 4 charged tracks were selected. The selection, tuned on samples of signal and background Monte Carlo, was based on properties of tau jets (fraction of charged to total energy, isolation) and of global WW events (acollinearity, acoplanarity, b-tagging, missing energy). Cuts were optimised separately for tau candidates with one and more than one charged tracks. The composition of the tau sample after selection was estimated to be 64% $\tau\bar{\nu}$q$\bar{\text{q}}$, 19% e$\bar{\nu}$q$\bar{\text{q}}$, 5% of $\mu\bar{\nu}$q$\bar{\text{q}}$ and the remainder to come mainly from $q\bar{q}(\gamma)$, corresponding to a 35% selection efficiency for $\tau\bar{\nu}$q$\bar{\text{q}}$ events.

After the selection, 265 electron, 315 muon and 218 tau candidates remained in the data, while the numbers of expected events from simulation were respectively 290.8, 335.8 and 200.2 respectively.

The events were reconstructed using a constrained fit, imposing conservation of 4-momentum and equality of the two W masses. The distributions of the reconstructed masses are shown in figure 1 for real and simulated data in the electron, muon and tau channels.

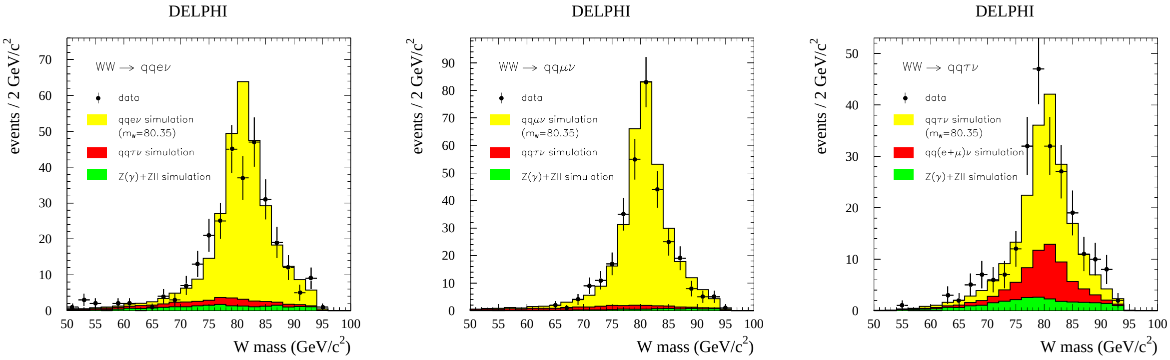

Figure 1: The distributions of the reconstructed masses for the electron, muon and tau channels.

As in [2], the W mass was extracted from an event-by-event likelihood fit using all events within the region of fitted mass 68-92 GeV/c^2, followed by a bias correction estimated from Monte Carlo events reweighted at various masses. Any imperfection in the simulation will cause a systematic error on the mass. The different sources of systematic errors are discussed in detail in [2]. The list of the relevant ones is presented in table 1.

For the lepton combination, all sources of systematic errors are taken as uncorrelated between electron, muon and tau, except for the errors coming from the jet energy, the fragmentation and the ISR which are taken as fully correlated.

The event-by-event likelihood analysis on the semileptonic channels gave the following results:

$$m_W = 80.326 \pm 0.290(stat) \pm 0.080(syst) \pm 0.017(LEP)\,\text{GeV/c}^2$$

for electron events,

$$m_W = 80.071 \pm 0.217(stat) \pm 0.068(syst) \pm 0.017(LEP)\,\text{GeV/c}^2$$

for muon events and

$$m_W = 79.892 \pm 0.324(stat) \pm 0.074(syst) \pm 0.017(LEP)\,\text{GeV/c}^2$$

Sources of systematic error ($\mathrm{MeV/c^2}$)	$\mathrm{e}\bar{\nu}\mathrm{q}\bar{\mathrm{q}}$	$\mu\bar{\nu}\mathrm{q}\bar{\mathrm{q}}$	$\tau\bar{\nu}\mathrm{q}\bar{\mathrm{q}}$	$\mathrm{l}\bar{\nu}\mathrm{q}\bar{\mathrm{q}}$	$\mathrm{q}\bar{\mathrm{q}}\mathrm{q}\bar{\mathrm{q}}$	Combined
Statistical error on calibration	30	25	27	16	13	10
Lepton energy	39	41	-	23	-	8
Jet energy	59	45	66	54	20	23
Background level	6	-	9	3	3	2
Background shape	-	-	-	-	5	3
Isolation of the lepton	13	-	-	4	-	1
Total uncorrelated	**78**	**66**	**72**	**61**	**25**	**27**
Fragmentation	10	10	10	10	20	17
I.S.R.	15	15	15	15	15	15
Total correlated	**18**	**18**	**18**	**18**	**25**	**23**
LEP energy	**17**	**17**	**17**	**17**	**17**	**17**
Colour reconnection	-	-	-	-	50	33
Bose Einstein correlations	-	-	-	-	20	13
Total final state interaction	**-**	**-**	**-**	**-**	**54**	**34**

Table 1: Contributions to the systematic error on the mass measurement. The error sources have been separated into those uncorrelated and correlated between the different LEP experiments.

for tau events. The last error[1] comes from the uncertainty on the beam energy.

The combination of the three gives the following result:

$$m_W = 80.102 \pm 0.153(stat) \pm 0.063(syst) \pm 0.017(LEP)\,\mathrm{GeV/c^2}.$$

4 Analysis of the hadronic decay channel

Requiring only that the central tracking was fully efficient, events were selected from a data sample corresponding to an integrated luminosity of $157.4\,\mathrm{pb}^{-1}$. A total of 1601 events were selected, while 1589 were expected from simulation.

This analysis uses the 2D likelihood method described in [2]. After selection, a total of 1601 events remained in the data (see figure 2) while 1589 were expected from simulation. Contrary to the semi-leptonic case, the constrained fit used in the event reconstruction imposes only 4-momentum conservation. The resulting goodness-of-fit as a function of the two masses is convoluted with the theoretically expected 2D distribution to obtain an event-by-event likelihood for the W mass. This is followed by a bias correction taken from simulated events.

The calibration of the analysis depends on the accuracy of the simulation. Table 1 shows the estimated systematic errors coming from possible inaccuracies in the simulation.

The two-dimensional ideogram analysis on the hadronic channel gave the following

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[1] $\Delta m_{\mathrm{W}}/m_{\mathrm{W}} \approx \Delta \mathrm{E}_{\mathrm{beam}}/\mathrm{E}_{\mathrm{beam}}$

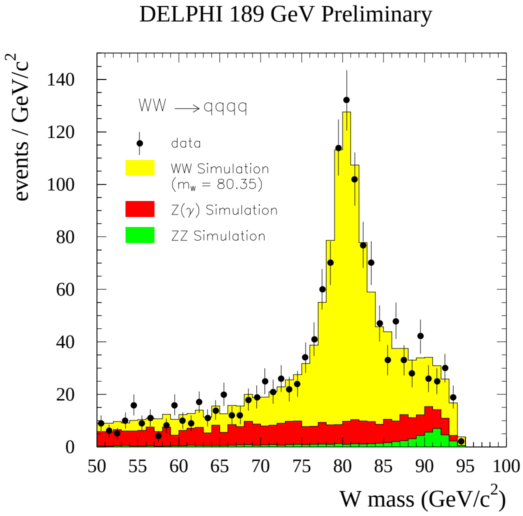

Figure 2: Mass plot for the selected WW → $q\bar{q}q\bar{q}$ candidates showing only one reconstructed mass per event (that with the best χ^2), and using an equal-mass constraint (not used in the determination of m_W, see text).

result:

$$m_{\mathrm{W}} = 80.467 \pm 0.110(stat) \pm 0.035(syst) \pm 0.054(fsi) \pm 0.017(LEP)\,,$$

where '*fsi*' denotes the possible effect from final state interactions and '*LEP*' the uncertainty on the beam energy.

5 Combination of all results

The masses measured in the semileptonic and hadronic decays analysis are in good agreement within statistics. Combining them yields

$$m_{\mathrm{W}} = 80.331 \pm 0.090(stat) \pm 0.035(syst) \pm 0.034(fsi) \pm 0.017(LEP)\,\mathrm{GeV/c^2}.$$

Our previous measurements derived from our 172 GeV data [11], and from our 183 GeV data [2] are fully compatible with this more precise value. Combining all the hadronic and semileptonic values gives the mass difference

$$m_{\mathrm{W}}(had) - m_{\mathrm{W}}(lep) = 0.128 \pm 0.159(stat) \pm 0.078(syst)\,\mathrm{GeV/c^2}$$

And combining all these measurements of the W mass yields

$$m_{\mathrm{W}} = 80.316 \pm 0.076(stat) \pm 0.047(syst) \pm 0.017(LEP)\,\mathrm{GeV/c^2}.$$

References

[1] LEP electroweak working group, *A Combination of Preliminary Electroweak Measurements and Constraints on the Standard Model*, CERN-EP/99-15.

[2] DELPHI Collaboration, P. Abreu et al., CERN-EP/99–79, submitted to Physics Letters B.

[3] DELPHI Collaboration, P. Abreu et al., Nucl. Instr. Meth. A **303** (1991) 233.
DELPHI Collaboration, P. Abreu et al., Nucl. Instr. Meth. A **378** (1996) 57.

[4] DELPHI Collaboration, *DELPHI event generation and detector simulation - User Guide*, DELPHI 89-67.

[5] F. A. Berends, R. Pittau and R. Kleiss, Comp. Phys. Comm. **85** (1995) 437.

[6] T. Sjöstrand, Comp. Phys. Comm. **82** (1994) 74.

[7] T. Sjöstrand, *PYTHIA 5.7/JETSET 7.4*, CERN-TH.7112/93 (1993).

[8] DELPHI Collaboration, P. Abreu et al., Z. Phys. C **73** (1996) 11.

[9] T. Munehisa, J. Fujimoto, Y. Kurihara and Y. Shimizu, Prog. Theor. Phys. **95** (1996) 375.

[10] DELPHI Collaboration, P. Abreu et al., Phys. Lett. B **397** (1997) 158.
DELPHI Collaboration, P. Abreu et al., *W pair production cross-section and W branching fractions in e^+e^- interactions at 183 GeV*, CERN-EP/99-47, submitted to Phys. Lett. B

[11] DELPHI Collaboration, P. Abreu et al., Phys. Lett. B **397** (1997) 158.