

THE MASS AND WIDTH OF THE W BOSON

Revised March 2010 by M. W. Grünewald (University Ghent),
and A. Gurtu (Tata Inst.).

The W mass and width definition used here corresponds to a Breit-Wigner with mass-dependent width.

Until 1995, the production and study of the W boson was the exclusive domain of the $\bar{p}p$ colliders at CERN and Fermilab. W production at 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 . These analyses use the electron and muon decay modes of the W boson.

Beginning in 1996, the energy of the LEP accelerator increased to above 161 GeV, the threshold for W -pair production. A precise knowledge of the e^+e^- center-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 . 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 209 GeV) at which LEP ran during 1996–2000. In the second method, which is used at the higher energies, the W mass has been determined by directly reconstructing the W and its invariant mass 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 has provided its measured W mass for the $q\bar{q}q\bar{q}$ and $q\bar{q}\ell\bar{\nu}_\ell$, $\ell = e, \mu, \tau$ 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 LEP W mass of

$M_W = 80.376 \pm 0.033$ GeV, which includes W mass determination from W -pair production cross section variation at threshold. Errors due to uncertainties in LEP energy (9 MeV), and possible effect of color reconnection (CR) and Bose–Einstein correlations (BEC) between quarks from different W 's (8 MeV) are included. The mass difference between $q\bar{q}q\bar{q}$ and $q\bar{q}\ell\nu_\ell$ final states (due to possible CR and BEC effects) is -12 ± 45 MeV. In a similar manner, the width results obtained at LEP have been combined, resulting in $\Gamma_W = 2.196 \pm 0.083$ GeV [1].

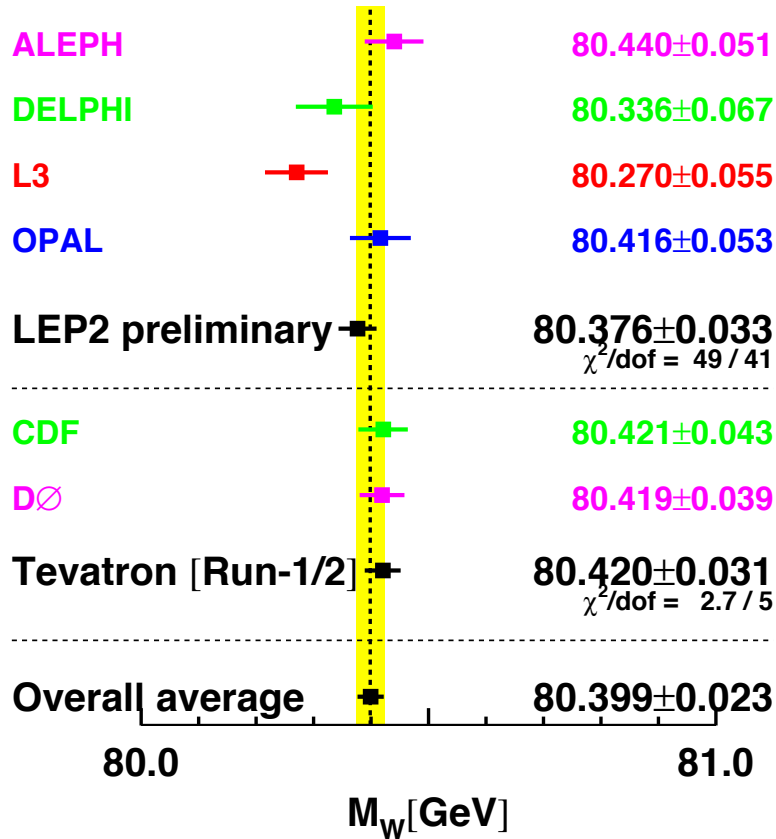


Figure 1: Measurements of the W -boson mass by the LEP and Tevatron experiments. Color version at end of book.

The two Tevatron experiments have also identified common systematic errors. Between the two experiments, uncertainties due to the production model, radiative corrections and parton distribution functions are treated as correlated. An average

W mass of $M_W = 80.420 \pm 0.031$ GeV [2] and a W width of $\Gamma_W = 2.046 \pm 0.049$ GeV [3] are obtained.

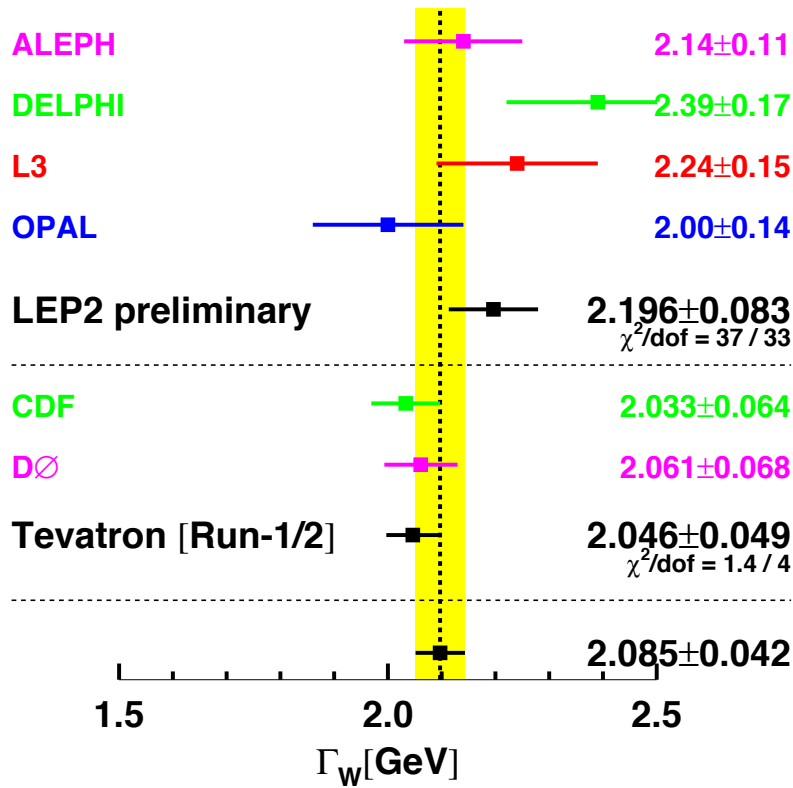


Figure 2: Measurements of the W -boson width by the LEP and Tevatron experiments. Color version at end of book.

The LEP and Tevatron results on mass and width, which are based on all results available, are compared in Fig. 1 and Fig. 2. Combining these results, assuming no common systematics between the LEP and Tevatron measurements, yields an average W mass of $M_W = 80.399 \pm 0.023$ GeV and a W width of $\Gamma_W = 2.085 \pm 0.042$ GeV.

The Standard Model prediction from the electroweak fit, using Z -pole data plus m_{top} measurement, gives a W -boson mass of $M_W = 80.364 \pm 0.020$ GeV and a W -boson width of $\Gamma_W = 2.091 \pm 0.002$ GeV [4].

References

1. The LEP Collaborations: ALEPH, DELPHI, L3, OPAL, the LEP Electroweak Working Group, CERN-PH-EP/2006-042, [hep-ex/0612034](#) (14 December 2006).
2. The Tevatron Electroweak Working Group, for the CDF and DØ Collaborations: *Updated Combination of CDF and DØ Results for the Mass of the W Boson*, August 2009, [arXiv:0908.1374](#) [hep-ex].
3. The Tevatron Electroweak Working Group, for the CDF and DØ Collaborations: *Combination of CDF and DØ Results on the Width of the W Boson*, March 2010, [arXiv:1003.2826](#) [hep-ex].
4. The ALEPH, CDF, D0, DELPHI, L3, OPAL, SLD Collaborations, the LEP Electroweak Working Group, the Tevatron Electroweak Working Group, and the SLD electroweak and heavy flavour groups, CERN-PH-EP/2009-023, [arXiv:0911.2604](#) [hep-ex] (November 2009).