THE MASS AND WIDTH OF THE W BOSON

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Precision determination of the W-mass is of great importance in testing the internal consistency of the Standard Model and, together with other electroweak data, in constraining the mass of the undiscovered Higgs boson. From the time of its discovery in 1983, the W-boson has been studied and its mass determined in $p\bar{p}$ and e^+e^- interactions; it is currently studied in pp interactions at the LHC. The W mass and width definition used here corresponds to a Breit-Wigner with mass-dependent width.

Production of on-shell W bosons at hadron colliders is tagged by the high p_T charged lepton from its decay. Owing to the unknown parton-parton effective energy and missing energy in the longitudinal direction, the collider experiments reconstruct 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.

In the e^+e^- collider (LEP) a precise knowledge of the beam energy enables one to determine the $e^+e^- \to W^+W^-$ cross section as a function of center of mass energy, as well as to reconstruct the W mass precisely from its decay products, even if one of them decays leptonically. Close to the W^+W^- threshold (161 GeV), the dependence of the W-pair production cross section on M_W is large, and this was used to determine M_W. At higher energies (172 to 209 GeV) this dependence is much weaker and W-bosons were directly reconstructed and the mass determined as the invariant mass of its decay products, improving the resolution with a kinematic fit.

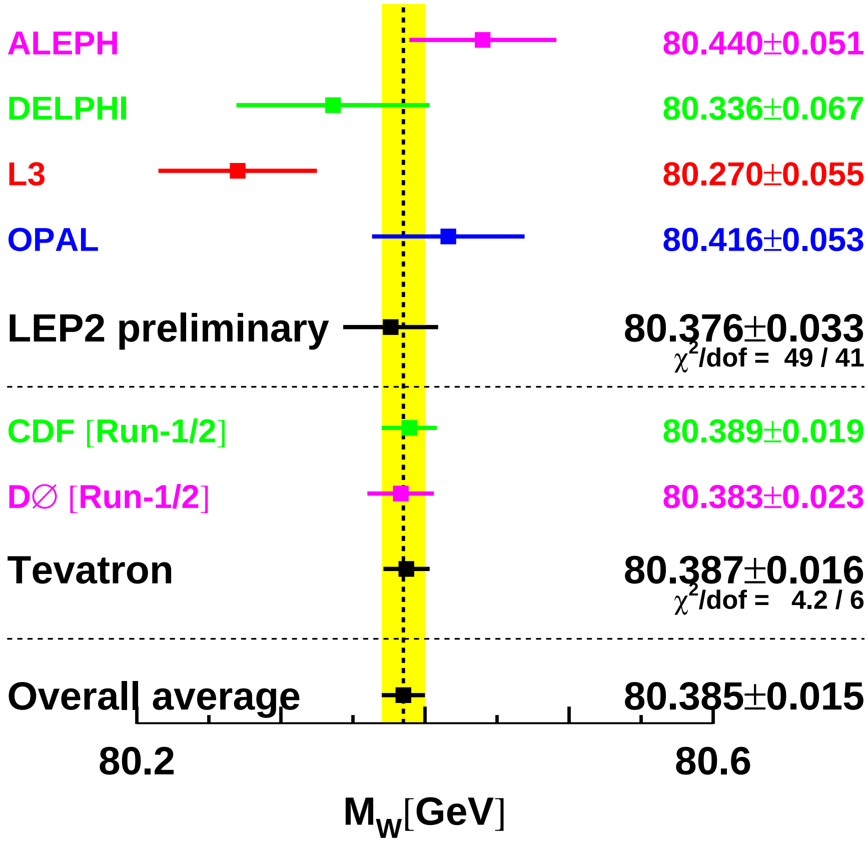

Figure 1: Measurements of the W-boson mass by the LEP and Tevatron experiments.

In order to compute the LEP average W mass, each experiment provided its measured W mass for the $q\overline{q}q\overline{q}$ and $q\overline{q}\ell\overline{\nu_\ell}$, $\ell = e, \mu, \tau$ channels at each center-of-mass energy, along with a detailed break-up of errors: statistical, uncorrelated, partially correlated and fully correlated systematics [1]. These have been combined to obtain a LEP W mass of $M_W = 80.376 \pm 0.033$ GeV. 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 $q\overline{q}q\overline{q}$ and $q\overline{q}\ell\overline{\nu_\ell}$ 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].

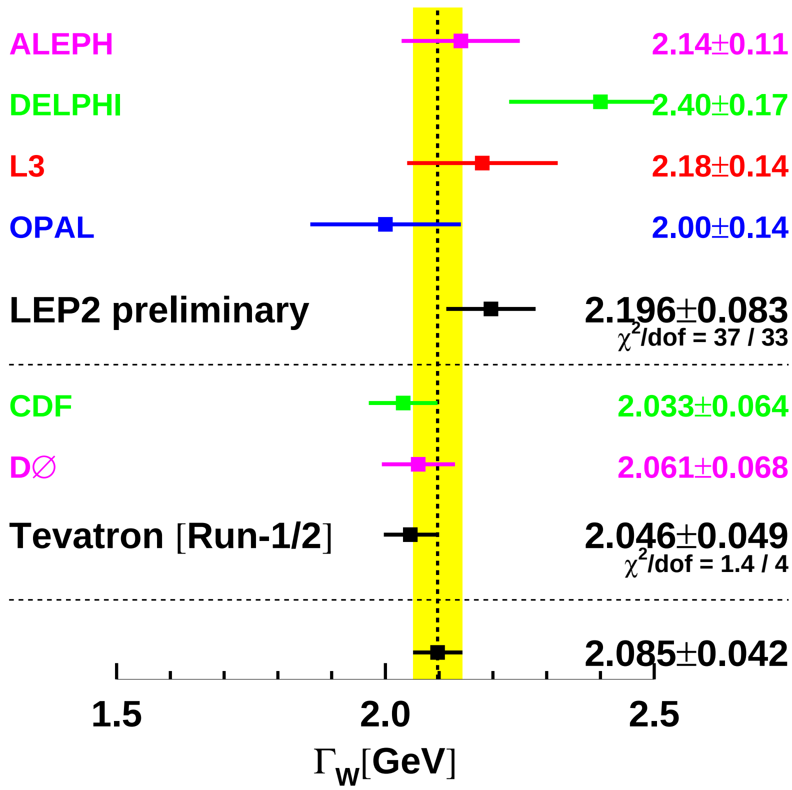

Figure 2: Measurements of the W-boson width by the LEP and Tevatron experiments.

The two Tevatron experiments have also identified common systematic errors. Between the two experiments, uncertainties due to the parton distribution functions, radiative corrections, and choice of mass (width) in the width (mass) measurements 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. Errors of 12 MeV (20 MeV) and 9 MeV (7 MeV) accounting for PDF and radiative correction uncertainties in the mass (width) combination dominate the correlated uncertainties.

At the 2012 winter conferences, the CDF and D0 experiments have presented new results for the mass of the W boson based on $2 - 4$ fb^{-1} of Run-II data, 80.387 ± 0.019 GeV [4] and 80.375 ± 0.023 GeV [5], respectively. The W-mass determination from the Tevatron experiments has thus become very precise. Combining all Tevatron results from Run-I and Run-II using an improved treatment of correlations, a new average of

80.387 ± 0.016 GeV is obtained [6], with common uncertainties of 10 MeV (PDF) and 4 MeV (radiative corrections).

The LEP and Tevatron results on mass and width, which are based on all results available, are compared in Fig. 1 and Fig. 2. Good agreement between the results is observed. Combining these results, assuming no common systematic uncertainties between the LEP and the Tevatron measurements, yields an average W mass of $M_W = 80.385 \pm 0.015$ 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 $m_{\rm top}$ measurement, gives a W-boson mass of $M_W = 80.365 \pm 0.020$ GeV and a W-boson width of $\Gamma_W = 2.091 \pm 0.002$ GeV [7].

References

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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]`.
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6. The Tevatron Electroweak Working Group, for the CDF and DØ Collaborations: *2012 Update of the Combination of CDF and DØ Results for the Mass of the W Boson*, March 2012, `arXiv:1204.0042 [hep-ex]`.
7. 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/2010-095, `arXiv:1012.2367 [hep-ex]` (December 2010).