Fit of Electroweak Parameters to Precision Data

Within the Standard Model the Z mass, \( m_Z \), the W mass, \( m_W \), and the weak mixing angle, \( \theta_w \), are related by

\[
\cos \theta_w = \frac{m_W}{m_Z},
\]

(7.1)

which is a prediction of the Higgs mechanism. As presented in Sect. 3.2 the mass of the Z boson, \( m_Z \), is known to a very high accuracy of \( 2.3 \times 10^{-5} \). The measurement of the weak mixing angle from electroweak precision observables, as explained in Sect. 3.6, allows to predict the mass of the W boson using equation (7.1). After applying the proper radiative corrections this prediction of the W mass can be compared to the result of the direct measurement. This tests not only the validity of Equation (7.1) on Born level, but also the corresponding electroweak radiative corrections.

7.1 Direct W-Mass Measurement Facing Precision Data

The W mass is measured at LEP 2 studying the W-pair production \( e^+e^- \rightarrow W^+W^- \rightarrow f\bar{f}f\bar{f} \), as presented in detail in the previous Chap. 6. At hadron colliders the leptonic decays of singly produced W bosons with electrons or muons in the final state are selected. From the momentum measurement of the leptons the transverse mass is calculated. The transverse mass, i.e. the invariant mass of the transverse momentum of the charged lepton and the missing momentum vector in the plane transverse to the beam, is not affected by the unknown missing momentum along the beam axis. The experiments CDF and D0 have performed a precise measurement [1] of the W mass using the Run I data set of the Tevatron collider. The precision of the Tevatron W mass measurement is currently limited by data statistics. The uncertainty in the lepton energy scale gives the largest contribution to the systematic error. To improve the accuracy of the energy measurement of the leptons, leptonic
Fig. 7.1. Measurement of the W mass at LEP and Tevatron and comparison with the Standard Model prediction as function of the Higgs mass. The theory uncertainty is dominated by the uncertainties in $m_t$ and $\Delta \alpha$ and shown as a band whose width represents the quadratic sum of both effects.

Z decays are selected and calibrated using the precise Z mass from the Z resonance scan at LEP.

The results of the Tevatron and LEP experiments on the W mass are in good agreement as shown in Fig. 7.1. All direct W-mass measurements, of which some are still preliminary, result in a world average of:

$$m_W = 80.392 \pm 0.029 \text{ GeV}.$$  \hspace{1cm} (7.2)

Additionally the W mass calculated within the Standard Model from the Fermi constant $G_F$ is shown as a function of the Higgs mass. The measured W-mass values prefer a light Higgs boson.