THE GLOBAL
ELECTROWEAK FIT

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Abstract

We report the results of the global electroweak fit, with emphasis on the most recent results which served as input of the fit. The output of the fit sets also limits on the Standard Model Higgs mass.

1 Introduction

The Standard Model of particle physics (SM) represents certainly the biggest success of 20th century physics. Its validity over a very wide range of energies has been experimentally tested to unprecedented precision, showing a perfect agreement of theory and experiment. The use of electroweak corrections, combined with precision measurements is the main strategy used to evaluate the parameters of the model which are still unmeasured or which are measured with the poorest accuracy, such as the mass of the top, $m_t$, and of the Higgs, $m_H$. Electroweak radiative corrections to physical observables are computable in perturbation theory and they depend quadratically on $m_t$ and logarithmically on $m_H$.

The global electroweak fit combines all the information coming from many experiments into one single $\chi^2$ fit, to obtain the best evaluation of all the parameters of the SM. The fit accepts as input the following measurements from LEP: the mass and width of the Z, the hadronic pole cross section of Z exchange, the Z leptonic branching ratio, the leptonic forward backward asymmetry ($A_{FB}^{\ell\ell}$), the $\tau$ polarisation, the
charge asymmetry, and the mass and width of the W boson ($m_W$, $\Gamma_W$). Other inputs come from the combination of SLD and LEP heavy flavour measurements: the ratios of b and c partial widths of the Z to its total hadronic width ($R^0_b$, $R^0_c$), the b and c forward backward asymmetries and the coupling parameters $A_b$ and $A_c$. The other measurements used are the coupling parameter $A_\ell$ from SLD, $m_W$, $\Gamma_W$ and $m_t$ from pp colliders, the measurements of Atomic Parity Violation (APV), $\sin^2\theta_W$ from $\nu N$ scattering and the contribution of light quarks to the photon vacuum polarisation ($\Delta\alpha^{(5)}_{\text{had}}$) from low energy $e^+e^- \rightarrow q\bar{q}$.

In the following we will shortly review the inputs and the results of the global electroweak fit performed in Winter 2002.

## 2 New and updated experimental inputs

The most significant changes in the Winter 2002 global electroweak fit are the new results on $A_{FB}^{0,b}$ and $A_{FB}^{0,c}$ from Aleph, the final results from NuTeV, the inclusion of $\Gamma_W$ in the fit, and the new interpretation of the APV experiments. The Aleph measurement of $A_{FB}^{0,b}$ and $A_{FB}^{0,c}$ using leptons is described in [3]. The change induced by these results on the electroweak averages are of +1/4 of standard deviation for $A_{FB}^{0,b}$ and of +2/3 of standard deviation for $A_{FB}^{0,c}$. The NuTeV experiment has presented a final analysis of their data [4] of the scattering of $\nu_\mu$ and $\bar{\nu}_\mu$ on nuclei of iron. The value of $\sin^2\theta_W$ they obtain from the ratio

![Figure 1: Comparison of the W mass as measured by pp-colliders and LEP2 experiments and as derived by the NuTeV measurement and by LEP1 and SLD electroweak data.](image-url)
of neutral to charged current cross sections is:

\[ \sin^2 \theta_W = 0.2277 \pm 0.0013 \text{(stat)} \pm 0.0009 \text{(syst)}, \]

more than 3 standard deviations higher than the value obtained by the combination of all the other available electroweak data. In fig. 1 the value of \( m_W \) deduced by this measurement is compared to the direct measurements of LEP2 and pp colliders and to the values derived from LEP1 and SLD electroweak measurements. This discrepancy has so far not been given any satisfactory explanation, and it is therefore accepted as a statistical fluctuation. For the first time the value of \( \Gamma_W \) measured by LEP and Tevatron has been included in the electroweak global fit. The combined measurement is \( \Gamma_W = 2.13 \pm 0.07 \text{ GeV} \). Finally, a new update of the measurement of the nuclear weak charge of cesium has been included in the fit. The updated value is \( Q_W(\text{Cs}) = -72.39 \pm 0.29 \text{(exp)} \pm 0.51 \text{(theo)} \), in good agreement with the SM expectation: \( Q_W(\text{Cs})^{SM} = -72.885 \).

3 Results and conclusions

The electroweak global fit is based on the SM predictions as implemented in the ZFITTER and TOPAZ0 programs. It accepts as input all the parameters that we have listed in sec. and gives as output estimates for all the parameters of the model, including the unmeasured ones such as \( m_H \), the strong coupling constant \( \alpha_s(m_Z^2) \) and the ones with the largest experimental uncertainty, such as \( m_t \).

A summary of the fit results is shown in fig. 2. The largest pulls are given by the NuTeV result and by \( A_{FB}^{b} \). The \( \chi^2/d.o.f \) of this fit is 28.8/15, corresponding to a probability of 1.7%. The fit repeated excluding the NuTeV results yields a \( \chi^2/d.o.f \) of 19.9/14 with probability 14.3%. The most interesting output of the fit is the estimate of the Higgs mass. Figure 3 shows the \( \Delta \chi^2 \) curve for \( m_H \); the shaded band correspond to the theoretical uncertainty. The 1\( \sigma \) estimate for the mass of the SM Higgs is \( m_H = 85^{+54}_{-34} \) \text{ GeV} , with an upper limit at 95\% CL of 196 GeV. This result is changed only by a few GeV when the NuTeV result is not used in the fit.

To summarise, the SM describes very well all the data which is used to perform the electroweak global fit. The two measured parameters which show the largest disagreement with their expected values are the measurement of \( \sin^2 \theta_W \) from NuTeV and the b forward-backward asymmetry. It is possible to explain such disagreements as statistical fluctuations even though we cannot exclude that they represent hints of yet unknown physical processes not described by the Standard Model.
Figure 2: Results of the electroweak global fit. Input parameters are listed with their experimental value, and with the pull of the fit, defined by the difference between the measured and fitted value divided by the experimental uncertainty.

| Measurement          | Pull (O_{\text{max}}-O_{\text{fit}})/\sigma_{\text{exp}} | 3 2 1 0 1 2 3 |
|----------------------|-------------------------------------------------------------|------------|
| $\Delta \alpha_{\text{had}}(m_Z)$ | 0.02761 ± 0.00036 | -2.2    |
| $m_Z$ [GeV]          | 91.1875 ± 0.021   | -0.010  |
| $\Gamma_Z$ [GeV]     | 2.4952 ± 0.0023   | -1.16   |
| $\sigma_{\text{had}}$ [nb] | 41.540 ± 0.037   | 1.63    |
| $R_L$                | 20.767 ± 0.025    | 1.05    |
| $A_L^{(5)}$          | 0.01714 ± 0.00095 | -0.70   |
| $A_L(P_T)$           | 0.1465 ± 0.0033   | -0.53   |
| $R_L$                | 0.21646 ± 0.00065 | 1.06    |
| $R_L$                | 0.1719 ± 0.0031   | -1.11   |
| $A_L^{(5)}$          | 0.0994 ± 0.0017   | -2.64   |
| $A_L^{(5)}$          | 0.0707 ± 0.0034   | -1.05   |
| $A_L^{(5)}$          | 0.922 ± 0.020     | -0.64   |
| $A_L^{(5)}$          | 0.670 ± 0.026     | -0.06   |
| $A_L^{(SLD)}$        | 0.1513 ± 0.0021   | 1.50    |
| $\sin^2\theta_W(Q_0)$ | 0.2324 ± 0.0012   | 1.86    |
| $m_H$ [GeV]          | 80.451 ± 0.033    | 1.73    |
| $\Gamma_W$ [GeV]     | 2.134 ± 0.069     | -1.59   |
| $m_W$ [GeV]          | 174.3 ± 5.1       | -0.08   |
| $\sin^2\theta_W(N)$ | 0.2277 ± 0.0016   | 3.00    |
| $Q_H(C_S)$           | -72.39 ± 0.59     | 0.84    |

Figure 3: The $\Delta \chi^2$ curve for the fit of the Higgs mass. The dark shaded band corresponds to the theoretical uncertainty, while the dotted line corresponds to a different evaluation of $\Delta \alpha_{\text{had}}^{(5)}$. The mass range experimentally excluded by LEP searches is represented by the light shaded area.

References

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