

12 Global electroweak fit in the FCC-ee era

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The top quark and Higgs boson masses have been predicted before their respective discoveries by the global fit of the Standard Model to electroweak precision data. With the Higgs boson discovery and the measurement of its mass, the last missing parameter of the Standard Model has been fixed and thus the internal consistency of the Standard Model can be probed at a new level by comparing direct measurements with the indirect predictions of the global electroweak fit. In this section, we discuss the expected precisions in the most important indirect predictions that are expected in the FCC-ee era and compare them with the state of the art.

Global electroweak analyses and fits have a long history in particle physics, starting before the discovery of the W and Z bosons. The basic idea of the global electroweak fit is the comparison of the state-of-the-art calculations of the electroweak precision observables with the most recent experimental data to constrain the free parameters of the fit and to test the goodness of fit. The free parameters of the SM relevant for the global electroweak analysis are the coupling constant of the electromagnetic, weak, and strong interactions, as well as the masses of the elementary fermions and bosons. This number can be reduced by fixing parameters with insignificant uncertainties compared with the sensitivity of the fit, as well as imposing the relations of the electroweak unification. The typical floating parameters chosen in the fit are the masses of the Z and the Higgs boson, the top, the bottom, and charm quark masses, and the coupling parameters $\Delta\alpha_5$ and $\alpha_S(m_Z)$. An introduction and a review of the current status of the global electroweak fit can be found in Ref. [1].

Besides a global analysis of the consistency between observables and their relations, the global electroweak fit can be used to indirectly determine and hence predict the expected values of observables. Technically, this indirect parameter determination is performed by scanning the parameter in a chosen range and calculating the corresponding χ^2 values. It should be noted that the value of χ_{\min}^2 is not relevant for the uncertainty estimation, only its difference relative to the global minimum, $\Delta\chi^2 := \chi^2 - \chi_{\min}^2$.

These indirect determinations have been recently performed with the latest measured values of electroweak precision observables in Ref. [1] and the state-of-the-art fitting frameworks GAPP and Gfitter. While GAPP (Global Analysis of Particle Properties) [2] is a Fortran library for the evaluations of pseudo-observables, Gfitter consist of independent object-oriented C++ code [3]. Both frameworks yield consistent results. Selected input parameters of the fit, including their current experimental uncertainty, are summarised in Table C.12.1, while the $\Delta\chi^2$ distributions for the indirect determinations of M_H , M_W , and m_{top} are summarised in Figure C.12.1.

We repeat the indirect fit of these observables using the GAPP program, mainly by assuming the FCC-ee projections and target uncertainties from Refs. [4, 5], as well as non-dominant theory uncertainties from unknown higher orders. It should be noted that the uncer-

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Table C.12.1: Overview of selected observables, their values, and current uncertainties, which are used or determined within the global electroweak fit [1]. The future expected FCC-ee uncertainties are also shown [4, 5].

| Parameter | Current value | FCC-ee unc.-target | Parameter | Current value | FCC-ee unc.-target |
|---|------------------------|--------------------|--------------------------------|--------------------------|--------------------|
| M_H | 125.09 ± 0.15 GeV | ± 0.01 GeV | M_Z | 91.1875 ± 0.0021 GeV | < 0.1 MeV |
| M_W | 80.380 ± 0.013 GeV | ± 0.6 MeV | Γ_Z | 2.4952 ± 0.0023 GeV | 25 keV |
| Γ_W | 2.085 ± 0.042 GeV | ± 1.0 MeV | σ_{had}^0 | 41.540 ± 0.037 nb | 0.004 nb |
| m_{top} | 172.90 ± 0.47 GeV | ± 15 MeV | R_b | 0.21629 ± 0.00066 | < 0.00006 |
| $\Delta\alpha_{\text{had}}[\times 10^{-5}]$ | 2758 ± 10 | ± 3 | $A_{\text{LR}}^{\text{FB}}(b)$ | 0.0992 ± 0.0016 | ± 0.0001 |

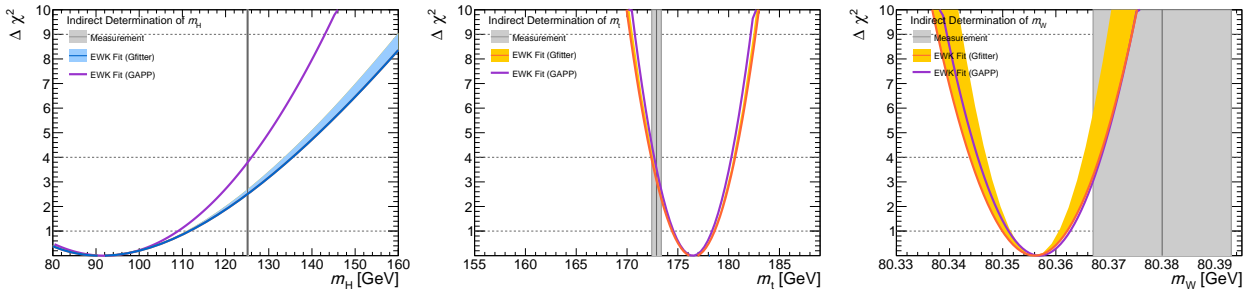


Fig. C.12.1: Comparisons of χ^2 distributions for scanning different observables using the Gitter and the GAPP, using the current experimental values and uncertainties. Theoretical uncertainties are indicated by the filled blue and yellow areas, respectively.

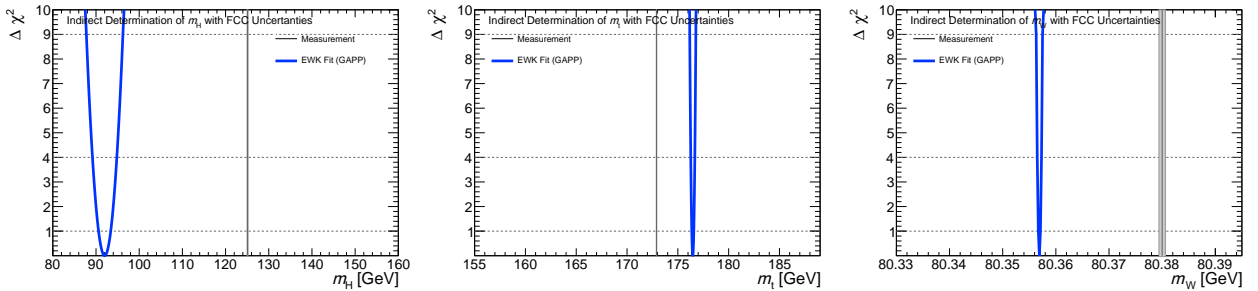


Fig. C.12.2: Comparisons of χ^2 distributions for scanning different observables using GAPP with the current experimental values but the expected uncertainties from FCC.

tainty in the weak mixing angle is assumed to be $\pm 5 \times 10^{-6}$ during the fit.[†]

Similar studies have been previously performed [6, 7]. Of special importance are the significantly lower uncertainties in m_Z , m_W , and m_{top} (Table C.12.1), which could be reduced by an order of magnitude. The $\Delta\chi^2$ distributions for M_H , M_W , and m_{top} are summarised in Figure C.12.2, yielding precisions of the indirect determinations of $\Delta M_H = \pm 1.4$ GeV, $\Delta M_W = \pm 0.2$ MeV, and $\Delta m_{\text{top}} = \pm 0.1$ GeV. Thus, the indirect test of the internal consistency of the electroweak sector would be brought to a new level. The uncertainty in m_H increases from ± 1.4 GeV to ± 5.7 GeV, if no advances are made on the theory side. Likewise, the expected uncertainty in the indirectly determined value of $\Delta\alpha_{\text{had}}$ increases from 0.05% to 0.1%. Last but

[†]This uncertainty combines the expected measurement precision of the asymmetry observables, i.e., it can be seen as a combination of $A^{\text{FB}}(\mu)$, $A^{\text{FB}}(b)$ and the τ polarisation measurements.

not least, the number of active neutrinos N_ν can be constrained at FCC-ee within ± 0.0006 , compared with the current result $N_\nu = 2.992 \pm 0.007$.

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