Impact of a Higgs boson at a mass of 126 GeV on the standard model with three and four fermion generations

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We perform a comprehensive statistical analysis of the standard model (SM) with three and four generations using the latest Higgs search results from LHC and Tevatron, the electroweak precision observables (EWPOs) measured at LEP and SLD and the latest determinations of M_W, m_t and α_s. For the three-generation case we analyse the tensions in the electroweak fit by removing individual observables from the fit and comparing their predicted values with the measured ones. In particular, we discuss the impact of the Higgs search results on the deviations of the EWPOs from their best-fit values. Our indirect prediction of the top mass is $m_t = 175.9^{+3.1}_{-2.2}\,\mathrm{GeV}$ at 68.3% CL, in good agreement with the direct measurement. We also plot the preferred area in the M_W-m_t plane. The best-fit Higgs mass is 126.0 GeV. For the case of the SM with a perturbative sequential fourth fermion generation (SM4) we discuss the deviations of the Higgs signal strengths from their best-fit values. The $H \to \gamma\gamma$ signal strength now disagrees with its best-fit SM4 value at more than 4σ. We perform a likelihood-ratio test to compare the SM and SM4 and show that the SM4 is excluded at 5.3σ. Without the Tevatron data on $H \to b\bar{b}$ the significance drops to 4.8σ.

INTRODUCTION

Electroweak precision observables (EWPOs) played an important role in the prediction of the mass of the top quark prior to its discovery [? ?]. Later, with improving Tevatron data on m_t, EWPOs were used to constrain the mass m_H of the Higgs boson, albeit with little precision since EWPOs only depend logarithmically on this quantity [?]. Recently ATLAS and CMS have discovered a convincing candidate for the Higgs boson with a mass around 126 GeV [? ?]. With the information on m_H available, EWPOs enter a new era, as they directly test the standard model (SM) without involving otherwise undetermined fundamental parameters. In this paper we present a combined fit of the EWPOs and Higgs signal strengths in the decays to $\gamma\gamma$, WW, ZZ, $b\bar{b}$, and $\tau\tau$ studied at the LHC and the $p\bar{p} \to H \to b\bar{b}$ signal strength determined at the Tevatron [?].

The SM is minimal in several respects, e.g. the fermions belong to the smallest possible representations of the gauge groups and electroweak symmetry breaking is achieved with a single Higgs doublet. However, the fermion field content is non-minimal and organised in at least three families. There has been a tremendous interest in the phenomenology of a fourth fermion generation, with more than 500 papers in the last decade. The SM with a sequential fourth generation, SM4, had survived global analyses of EWPOs and flavour observables [? ? ? ? ? ? ?], but was put under serious pressure from the first LHC data on Higgs searches [? ? ? ?]. In this paper we show that the perturbative SM4 is the first popular model of new physics which is ruled out by the LHC at the 5σ level. This strong statement is possible because of the non-decoupling property of the SM4, as loops with 4th-generation fermions do not vanish with increasing masses. For the same reason it is difficult to compute the statistical significance at which the SM4 is ruled out: the non-decoupling property implies that the SM4 and SM are non-nested, i.e. the SM is not obtained from the SM4 by fixing the additional parameters. This complicates the statistical procedure which compares the performance of the two models at describing the data. We have solved this problem with the help of a new method for toy Monte Carlo simulations, as implemented in the *my*Fitter package [?]. A first application of *my*Fitter to the SM4 with pre-ICHEP data has been presented in [?].

METHOD AND INPUTS

We combine electroweak precision data with Higgs signal strengths provided by ATLAS, CMS and Tevatron. Our fit parameters in the SM are M_Z, m_t, α_s, $\Delta\alpha^{(5)}_{\mathrm{had}}$ and m_H. In the SM4 the additional parameters are the fourth generation quark masses $m_{t'}$ and $m_{b'}$ and the fourth generation lepton masses m_{ℓ_4} and m_{ν_4}. Mixing between the quarks of the fourth and the first three generations is neglected in this analysis, since our previous study [?] showed that such mixing is disfavoured