Radiative corrections to the Higgs-boson decay into $b\overline{b}$ pairs

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The third and subsequent runs of the LHC will significantly increase the statistics for Higgs-boson processes. This will further improve the accuracy of important quantities, such as the coupling of the Higgs boson to the gauge bosons and the third generation of fermions. Additionally, the forthcoming measurements will allow us to study the couplings of the Higgs boson to other generations of fermions and to itself. These measurements are essential to determine if the found Higgs boson corresponds to the SM Higgs boson or if it is part of a more comprehensive Higgs sector. To match the accuracy of these measurements and improve the corresponding predictions within the SM, it is imperative to derive higher-order corrections to the Higgs-boson production and decay modes. The calculation of higher-order corrections to the $H \to b\bar{b}$ decay width, which is the dominant decay channel of the SM Higgs boson, contributes to improving the precision of the total Higgs-boson decay width and, consequently, the precision of all other branching ratios.

In this talk, I will present the results of my master's thesis, which aimed to compute the next-to-leading-order (NLO) Quantum Chromodynamics (QCD) and Electroweak (EW) corrections to the $H \to b\bar{b}$ decay width in the on-shell (OS) renormalization scheme with massive bottom quarks, as well as the mixed next-to-next-to-leading order (NNLO) QCD×EW correction of order $\mathcal{O}(N_f \alpha_s \alpha)$ in the OS scheme, where N_f stands for the number of fermion flavors. Additionally, the NLO corrections were converted from the OS scheme to the modified minimal-subtraction ($\overline{\text{MS}}$) renormalization scheme by applying a reparametrization in terms of a running $Hb\bar{b}$ Yukawa coupling based on the $\overline{\text{MS}}$ mass of the bottom quark. This allowed for a comparison of the NLO corrections in the $\overline{\text{MS}}$ scheme while treating the Higgs tadpole contributions within three different tadpole schemes.

For comparison purposes, the phase-space integration of the real NLO corrections in the OS scheme was evaluated using both the dipole subtraction method and, alternatively, the slicing method. The relative errors between the NLO corrections computed in this thesis and those obtained using the analytical expressions from the literature are below 0.0004% for the dipole subtraction method and below 0.09% for the slicing method. Furthermore, the Higgs tadpole contributions to the $\overline{\text{MS}}$ mass of the bottom quark were treated within three different tadpole schemes [1]: the Gauge-Invariant Vacuum expectation value Scheme (GIVS), the Parameter Renormalized Tadpole Scheme (PRTS), and the Fleischer–Jegerlehner Tadpole Scheme (FJTS). Subsequently, the differences between the NLO corrections in the $\overline{\text{MS}}$ scheme obtained within these three tadpole schemes were thoroughly discussed. The relative errors between the NLO corrections in the PRTS computed in this thesis and those reported in the literature under the assumption of massless bottom quarks are 1.76% for the NLO QCD correction and 2.56% for the NLO EW correction.

The NNLO correction of $\mathcal{O}(N_f\alpha_s\alpha)$ involves Feynman diagrams at order $\mathcal{O}(\alpha_s\alpha)$ containing only subdiagrams with closed fermion loops and gluon exchange or radiation. It was found that this correction depends on the NLO QCD correction and the insertions of the one-loop and two-loop renormalization constants in the $Hb\bar{b}$ vertex at $\mathcal{O}(N_f\alpha)$ and $\mathcal{O}(N_f\alpha_s\alpha)$. Therefore, the renormalization constants for this correction were evaluated using the one-loop and two-loop self-energies of the gauge and Higgs bosons at $\mathcal{O}(N_f\alpha)$ and $\mathcal{O}(N_f\alpha_s\alpha)$, respectively. The one-loop self-energies were computed using the FormCalc package [2] and the Collier library [3], and the two-loop self-energies were taken from Refs. [4, 5]. The NNLO correction to the decay width is found to be at the per-mille level.

Literatur

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