4.1 Motivation

As discussed in Sect. 2, fixed-order calculations allow to capture all corrections at a given order in a straightforward way by evaluating self-energy corrections and are therefore expected to be accurate for low SUSY scales. If however several or all non-SM particles are much heavier than the electroweak scale, large logarithms appear in the calculation spoiling the convergence of the perturbative expansion. In such situation EFT calculations (see Sect. 3) allow to resum these large logarithmic corrections. Without the inclusion of higher dimensional operators into the EFT framework (see [94] for a work in this direction), terms suppressed by the SUSY scale are however missed. In consequence, the EFT calculation might become inaccurate for low SUSY scales.

For intermediary scales around the TeV scale (0.5 – 2 TeV) – a region which is of particular interest in view of LHC phenomenology –, it is hard to decide which of the two approaches is more accurate. This led to the development of so-called hybrid approaches combining both methods into a single calculation. They are designed in order to profit from the advantages of both methods, namely high accuracy for low SUSY scales in case of the fixed-order calculation and high accuracy for high SUSY scales in the case of the EFT calculation. In consequence, these hybrid approaches should provide high accuracy predictions for all possible SUSY scales.

Before explaining the different methods used for the hybrid approach, we illustrate these statements exemplary in Fig. 2, in which we compare the results of the codes `FeynHiggs` and `FlexibleSUSY` in two scenarios. In all plots the soft-breaking masses of the slepton and squark sector are chosen equal to M_S. Also the gluino mass is set equal to M_S. The stop mixing parameter, defined in the $\overline{\text{DR}}$ scheme, is set equal to $-\sqrt{6}M_S$.

The result for the first scenario are shown in the upper row. Here, $m_{1,2} = \mu = 200$ GeV, $m_A = M_S/8$ and $\tan\beta = 8$ is chosen. In the upper left plot, showing the results of `FeynHiggs` for this scenario, we clearly see the interpolating behaviour of the hybrid result. It is close to the fixed-order result for $M_S \sim 1$ TeV, whereas it converges to the EFT result for rising M_S. In the region of 1 TeV $\lesssim M_S \lesssim 2.5$ TeV, the hybrid method yields arguably the most precise result. In the upper right plot, showing the results of `FlexibleSUSY` for the same scenario, a very similar behaviour is visible. In the case of `FlexibleSUSY` the pure fixed-order result (including `Himalaya`) however better captures the logarithmic behaviour of the pure EFT calculation in the shown M_S interval.

The main region for the large numerical significance of suppressed term is the low M_A value. For comparison, we investigate a second scenario with $m_A = m_{1,2} = \mu = M_S$ and $\tan\beta = 20$. As we observe in the related plots in the lower row of Fig. 2, the suppressed terms are completely negligible already for very low scales ($M_S \gtrsim 700$ GeV in the case of `FeynHiggs`, $M_S \gtrsim 400$ GeV in the case of `FlexibleSUSY`).

We want to stress that even in such a scenario the hybrid approach yields valuable information. I.e., it allows to assess the size of suppressed terms. The fact that they are negligible in the phenomenologically interesting region is an important input for the estimation of the remaining theoretical uncertainties (see [HB: ref unc. section]).

For both scenarios, we observe discrepancies between the results of `FeynHiggs` and `FlexibleSUSY` of up to ~ 2 GeV. This can be explained by differences in the involved fixed-order calculations which are formally of higher order. Both codes however agree within the corresponding uncertainty estimates (see [HB: ref unc. section]).