Three-Loop Predictions for the Light Higgs Mass in the MSSM

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Abstract

- light Higgs mass M_h is a good observable to test the MSSM
  - measurable to high precision $\mathcal{O}(100\,\text{MeV})$
  - dependence on most SUSY breaking parameters is negligible
- three-loop calculation of dominant radiative corrections is performed to match expected experimental precision
- we provide a computer code `H3m` to combine leading three-loop corrections with other contributions at lower loop order
- intrinsic theoretical uncertainty now reduced to the same order as parametric uncertainty $\mathcal{O}(1\,\text{GeV})$

Motivation

MSSM Higgs sector: 2 Higgs doublet model

$$\begin{aligned} V_H = &\left(|\mu_H|^2 + m_1^2\right)|H_1|^2 + \left(|\mu_H|^2 + m_2^2\right)|H_2|^2 \\ &- m_{12}^2\left(\epsilon_{ab}H_1^a H_2^b + \epsilon_{ab}H_1^{a*}H_2^{b*}\right) \\ &+ \frac{1}{8}\left(g_1^2 + g_2^2\right)\left[|H_1|^2 - |H_2|^2\right]^2 + \frac{1}{2}g_2^2\left|H_1^\dagger H_2\right|^2 \end{aligned}$$

- masses and mixings are very constrained: quartic terms are just the gauge couplings
- two new parameters govern the masses and mixings of five new particles: h, H, A, $H^\pm$
- $M_h \leq M_Z$ at tree level
- large radiative corrections depend on SUSY breaking: self-energy corrections shift the value of M_h

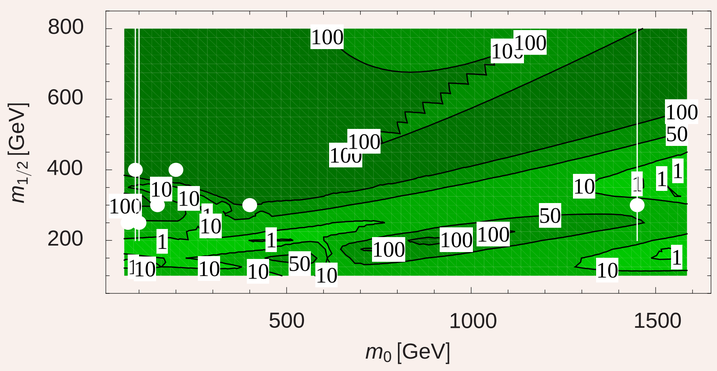
- coupling of a particle to the Higgs proportional to the mass that the particle acquires through the Higgs mechanis

⇒ heaviest particles give the largest contribution, top quark t and its superpartners $\tilde{t}$ dominate.

- experimentally: M_h precision observable $\delta M_h \approx 100 - 200\,\text{MeV}$ for light Higgs at LHC
  - need to match this precision!
    calculate leading corrections at three-loop level, i.e. $\mathcal{O}(\alpha_t\alpha_s^2)$ terms

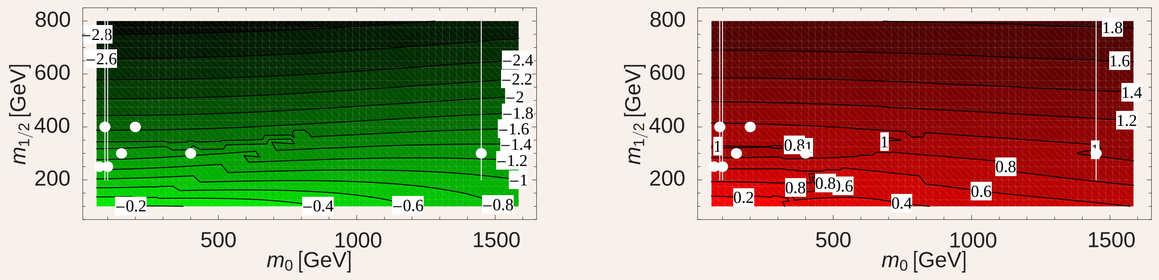
Error Estimate

- two sources of intrinsic theoretical uncertainty: asymptotic expansion and missing higher terms in α_s
  - estimate error due to asymptotic expansions by comparing, at two-loop level, with the exact result



deviation of the expansion in mass ratios from the exact results at two-loop level (in MeV) for msugra scenario with $\tan\beta = 10$, $A_0 = 0$

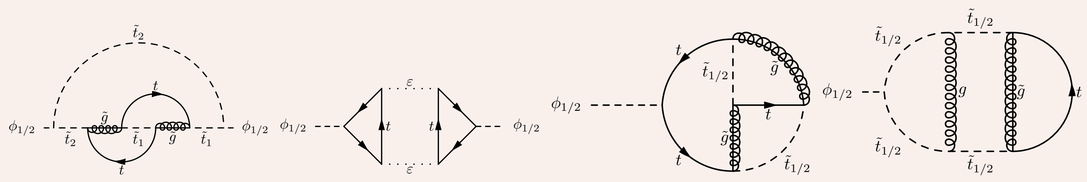
  - estimate error due to higher orders by comparing the last two known terms of the expansion



absolute size of the two-loop (left) and three-loop (right) corrections to M_h (in GeV)

- leads to a theoretic uncertainty of the Order of up to 1 GeV for large values of $m_{1/2}$
- this is comparable to the parametric uncertainty due to α_s and m_t

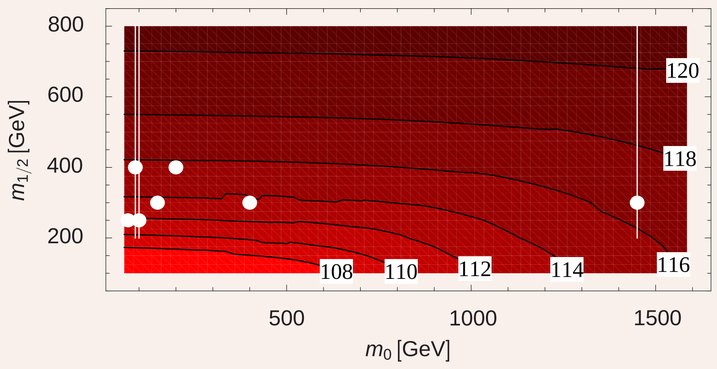
Three-Loop Corrections: Strategy



- 30.717 three-loop multi-scale diagrams, not feasible to solve directly

1. assume fixed hierarchy among the masses of the superpartners and use asymptotic expansions to reduce them to one-scale integrals
2. repeat this for many different hierarchies
3. when evaluating M_h for some point in the MSSM parameter space, use the hierarchy that fits best

Prediction for M_h in msugra scenario



prediction for the value of M_h (in GeV) for msugra scenario with $\tan\beta = 10$, $A_0 = 0$, as evaluated by `H3m`.

Computer Code: MATHEMATICA package `H3m`

- combine three-loop calculation with all available corrections at lower loop order that are available through FEYNHIGGS
- automatize the choice of the suitable hierarchy
- provide a SUSY LES HOUCHES (SLHA) interface to use input from a spectrum generator
- automatically convert between renormalization schemes used in different calculations

References

P. Kant, R. V. Harlander, L. Mihaila and M. Steinhauser,
"Light MSSM Higgs boson mass to three-loop accuracy,"
arXiv:1005.5709 [hep-ph].

R. V. Harlander, P. Kant, L. Mihaila and M. Steinhauser,
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Phys. Rev. Lett. 100 (2008) 191602 [arXiv:0803.0672 [hep-ph]].

`H3m` is available at

`http://www-ttp.particle.uni-karlsruhe.de/Progdata/ttp10/ttp10-23`