

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

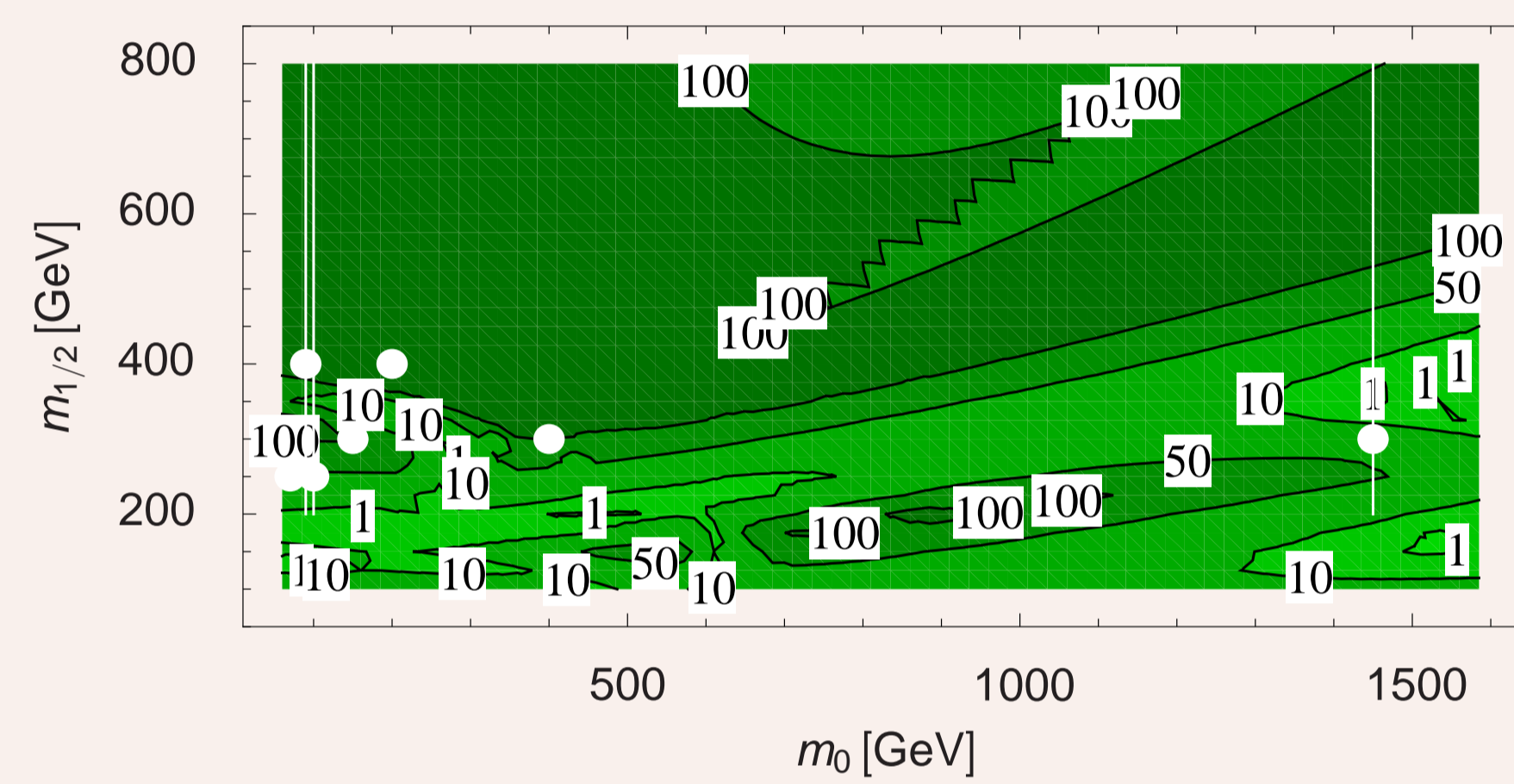
MSSM Higgs sector: 2 Higgs doublet model

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

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

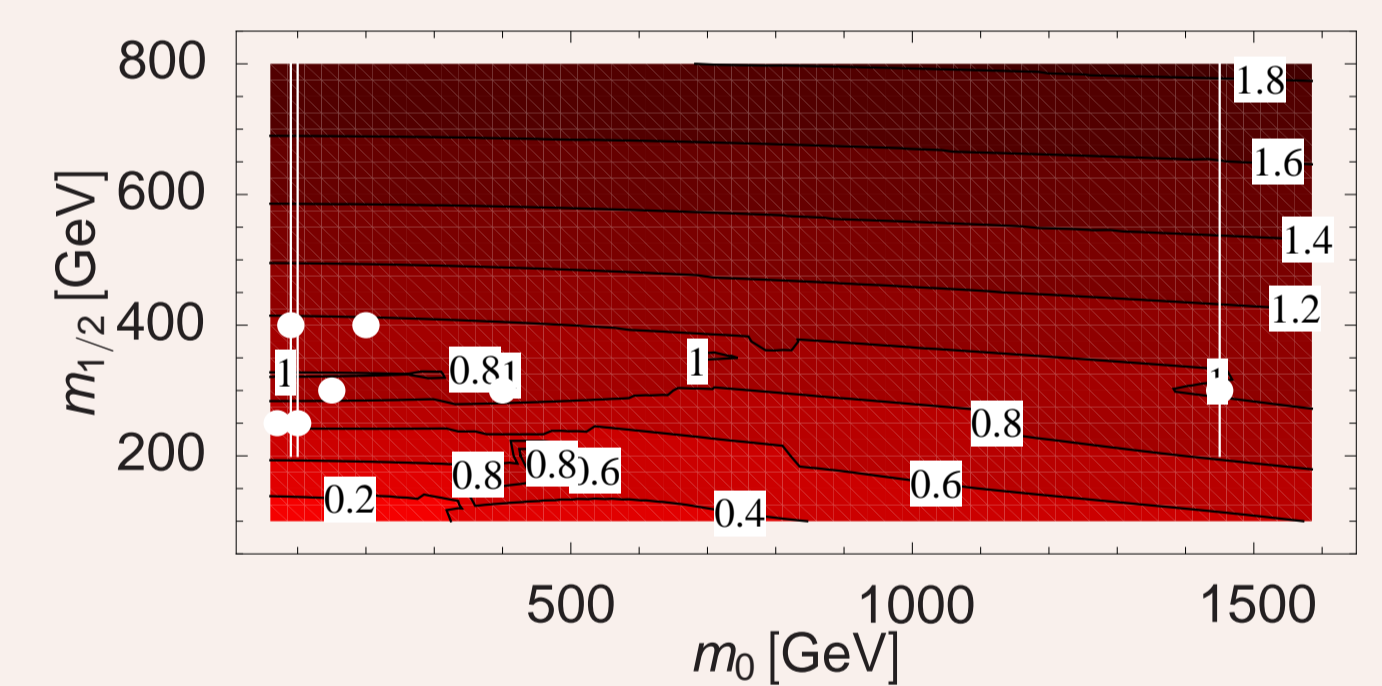
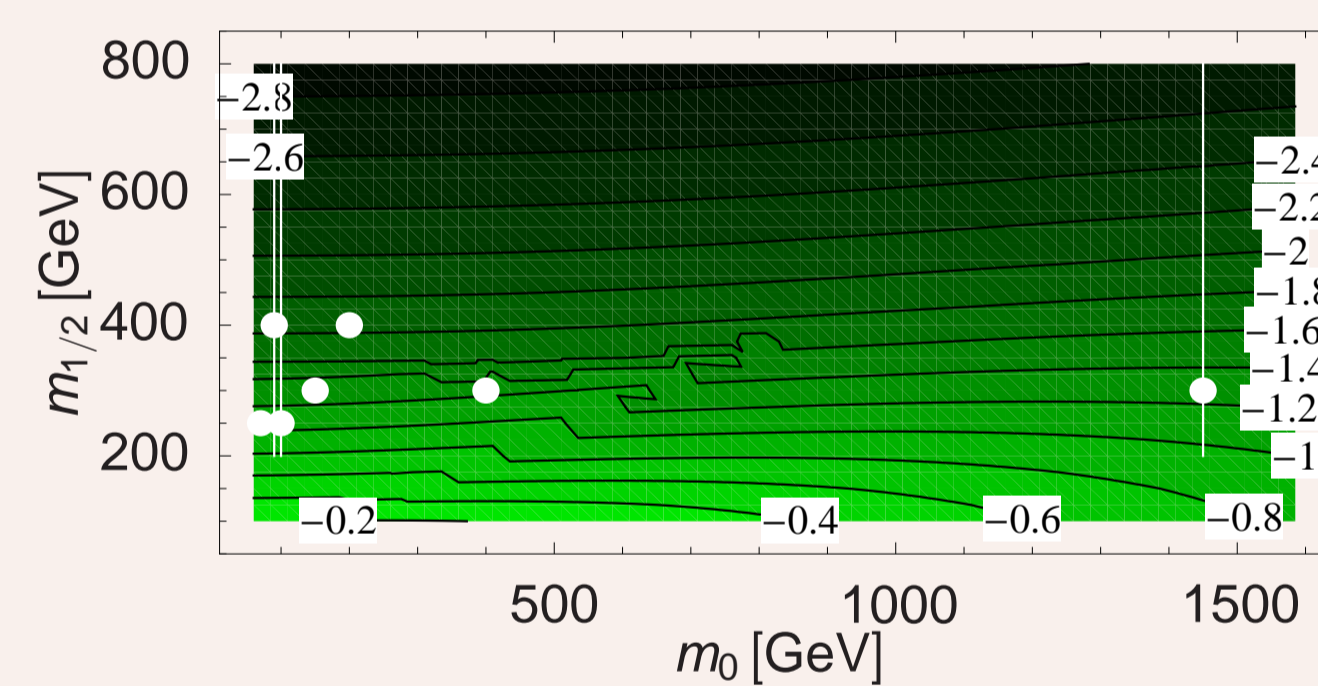
Error Estimate

- ▶ 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 $\tan \beta = 10, A_0 = 0$

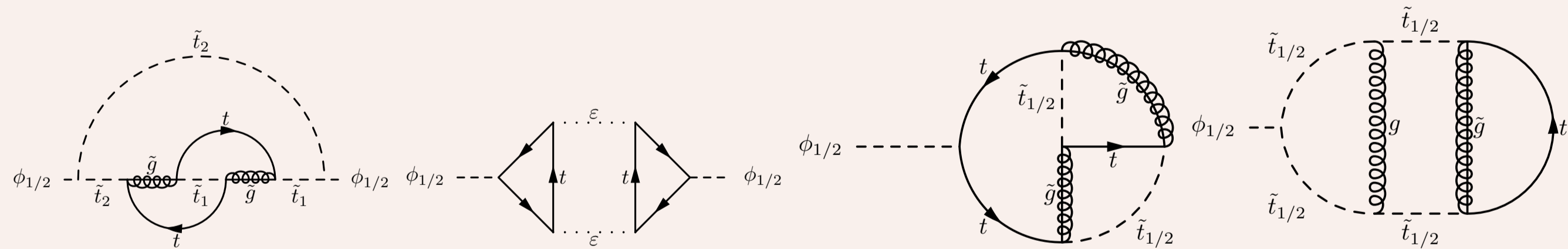
- ▷ estimate error due to higher orders by comparing the last two known terms of the expansion



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



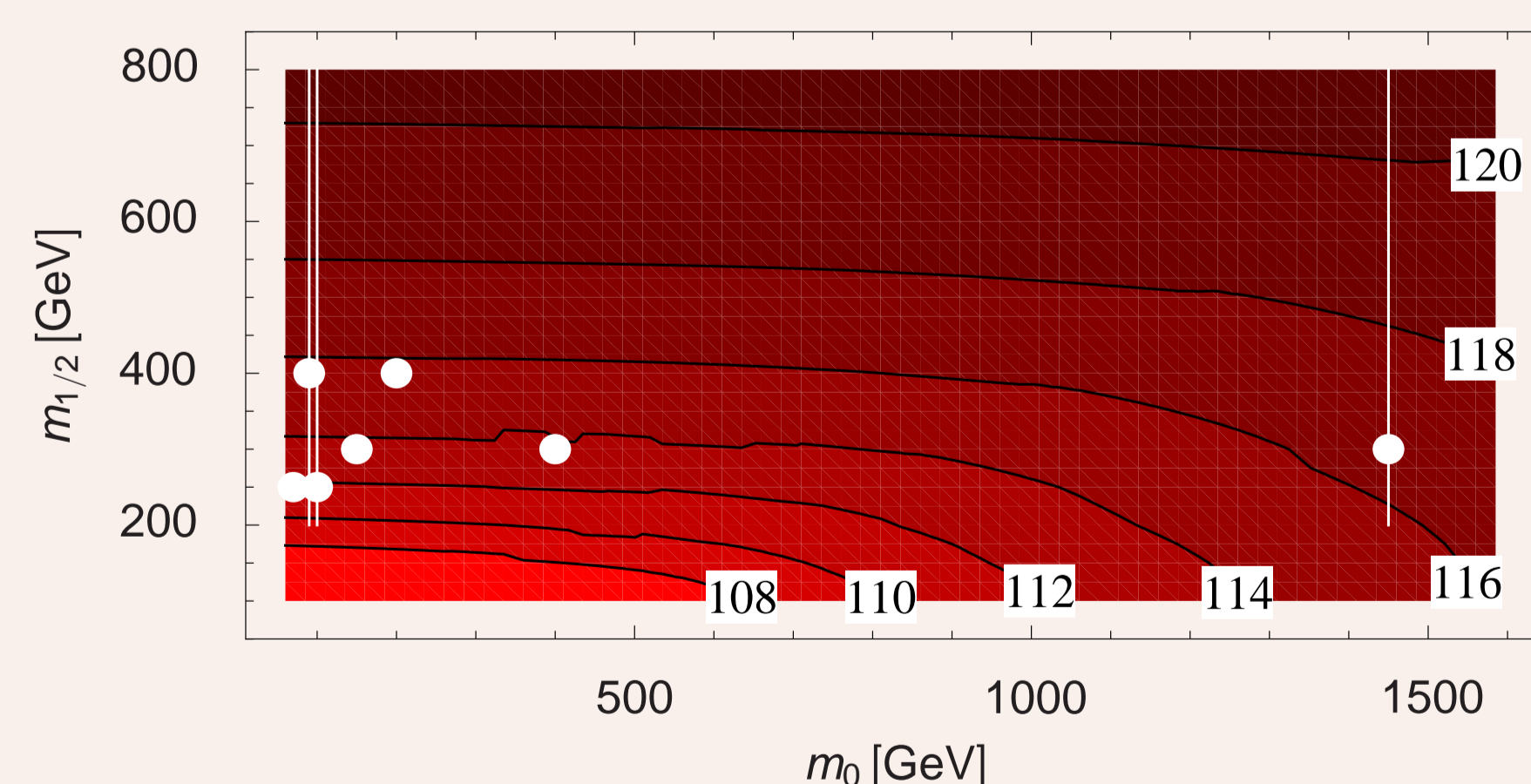
- ▶ 30.717 three-loop multi-scale diagrams, not feasible to solve directly

 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

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

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.

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, "Higgs boson mass in supersymmetry to three loops," 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>