Theoretical uncertainties in the MSSM Higgs boson mass calculation

[based on 1912.04199]

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Motivation

- SM is not able to explain Dark Matter, hierarchy problem, ...,
- the Minimal Supersymmetric Standard Model (MSSM) addresses (some of) these questions,
- it does not only associate a superpartner to each SM degree of freedom, but also extends the Higgs sector by a second doublet.

$\rightarrow$ Use Higgs measurement/searches to constrain the MSSM.

The SM-like Higgs mass as a precision observable

Special feature of the MSSM

Mass of lightest $\mathcal{CP}$-even Higgs, M_h, is calculable in terms of model parameters $\Rightarrow$ can be used as a precision observable

- at tree-level $M_h^2 \simeq M_Z^2 \cos^2(2\beta) \leq M_Z^2$,
- M_h is, however, heavily affected by loop corrections,
- directly sensitive to the SUSY scale.

Experimentally measured mass: [Aad et al.,1503.07589]

$$M_h^{\text{exp}} = 125.08 \pm 0.21 \text{ (stat.)} \pm 0.11 \text{ (sys.) GeV}$$

To fully profit from experimental precision, higher order calculations are crucial!

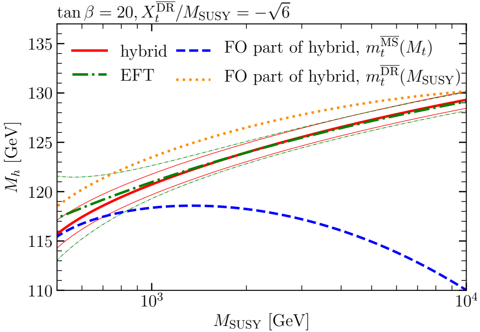
Calculation of the SM-like Higgs mass

Three approaches are used:

- Fixed-order (FO) approach:
  - \+ Precise for low SUSY scales,
  - − but for high scales $\ln(M_{\text{SUSY}}^2/M_t^2)$ terms spoil convergence of perturbative expansion.
- effective field theory (EFT) approach:
  - \+ Precise for high SUSY scales (logs resummed),
  - − but for low scales $\mathcal{O}(M_t/M_{\text{SUSY}})$ terms are missed if higher-dimensional operators are not included.
- hybrid approach combining FO and EFT approaches:
  - ++ Precise for low and high SUSY scales.

Remaining theoretical uncertainty

Single-scale scenario with all non-SM particles at M_{SUSY} (SM as EFT)

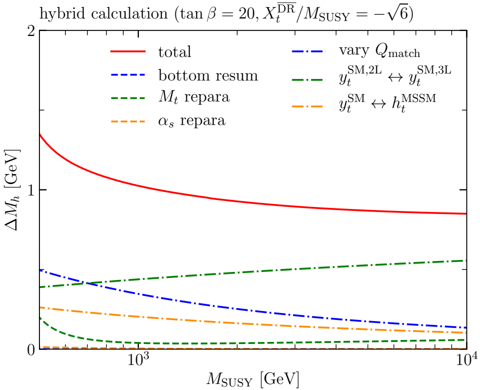


"Rule of thumb"

Remaining theoretical uncertainties (for $\overline{\text{DR}}$ stop input parameter):
$X_t/M_{\text{SUSY}} = 0 \;\to\; \Delta M_h \sim$ 0.5 GeV,
$X_t/M_{\text{SUSY}} = \sqrt{6} \;\to\; \Delta M_h \sim$ 1 GeV

Slightly higher for OS stop input parameters.

Remaining uncertainties – individual sources



Uncertainty estimate dominated by:

- Uncertainty from higher order threshold corrections:
  - vary matching scale between SM and MSSM,
  - reexpress treshold correction in terms of h_t^{MSSM} instead of y_t^{SM}.
- Uncertainty of SM input couplings:
  - $y_t(M_t)$ extracted at the 2- or 3-loop level out of OS top mass.

Conclusions

- The SM-like Higgs mass is a unique observable in the MSSM directly sensitive to the SUSY scale,
- to fully profit from experimental precision, the calculation of higher order corrections **and** an estimation of the remaining theoretical uncertainties is crucial,
- combining fixed-order and EFT approaches allows for precise prediction for low and high SUSY scales,
- remaining theoretical uncertainty: $\Delta M_h \sim 0.5 - 1$ GeV.

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Thanks for your attention!