

Higgs phenomenology in the MSSM

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DESY theory fellow's meeting
19.11.2018, Hamburg

About me...

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- ▶ 25.3.2018: Birth of my daughter!



Physics...

Current situation:

- ▶ Higgs discovery at LHC fixed last free parameter of the Standard Model (SM),

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

→ Need beyond SM physics

- ▶ No direct evidence for beyond SM physics at LHC so far

Need to use all available information to constrain BSM models

- ▶ Direct searches
- ▶ Indirect constraints (Higgs signal strengths, precision observables, ...)

During my PhD I worked on the

Minimal Supersymmetric Standard Model

- ▶ Many theoretical motivations
- ▶ But also interesting phenomenology (i.e. Higgs sector)

MSSM Higgs sector: 2 Higgs doublets

- ▶ Corresponds to a type II Two-Higgs-doublet model (THDM)
- ▶ Two Higgs doublets results in five physical Higgs states: \mathcal{CP} -even: h, H ; \mathcal{CP} -odd: A ; Charged: H^\pm
- ▶ SUSY reduces Higgs potential parameters to 2 non-SM parameters (M_A and $\tan \beta = v_2/v_1$)

Special feature of 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 $M_h^2 \simeq M_Z^2 \cos(2\beta)^2 \leq M_Z^2$
- ▶ M_h is however heavily affected by loop corrections (up to $\sim 100\%$)

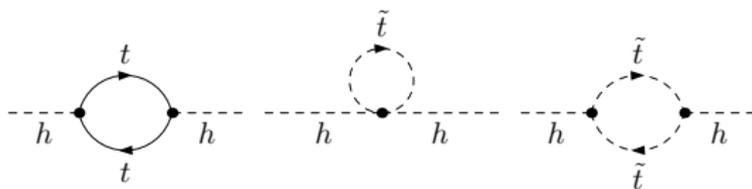
\rightarrow Higher order calculations are essential

Two standard approaches:

- ▶ Fixed-order techniques
- ▶ Effective field theories

Fixed-order approach

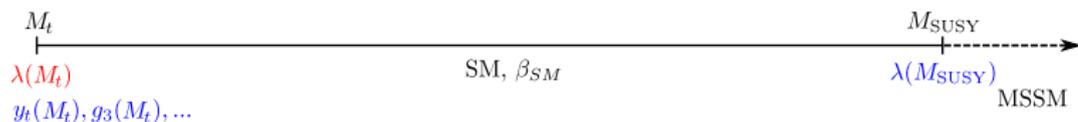
Calculate Higgs self-energy diagrams:



→ Precise for low SUSY scales ✓

But: For high scales large logarithms appear, $\ln(M_{\text{SUSY}}/M_t)$,
spoil convergence of perturbative expansion ✗

EFT calculation



- ▶ Simplest case: integrate out all SUSY particles
→ SM as EFT
- ▶ Higgs self-coupling fixed at matching scale
- ▶ Run λ down to electroweak scale using SM RGEs
- ▶ Calculate Higgs mass in the EFT

→ Precise for high SUSY scales (logarithms resummed) ✓

But: Inaccurate for low scales (misses $\mathcal{O}(M_t/M_{SUSY})$ terms) ✗

How to deal with intermediary SUSY scales?

- ▶ For superpartners in the LHC range, both large logarithms and $\mathcal{O}(M_t/M_{\text{SUSY}})$ terms might be relevant

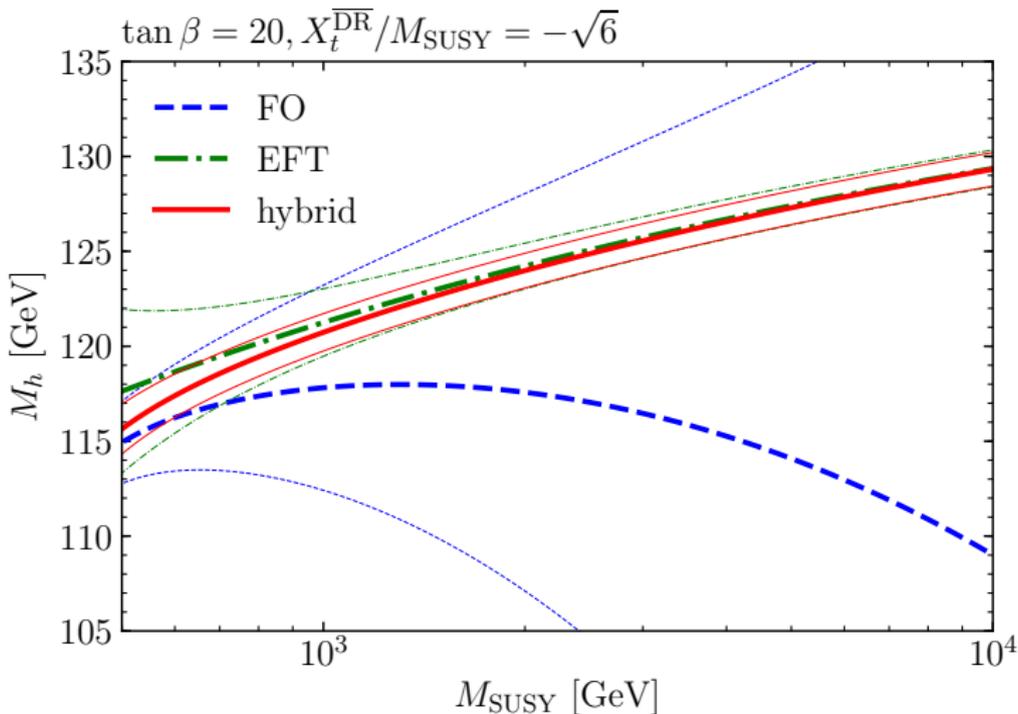


Hybrid approach

Combine both approaches to get precise results for both regimes

- ▶ Add fixed-order and EFT result
- ▶ Introduce subtraction terms to avoid double-counting of terms contained in both results

Comparison in single-scale scenario



Colored bands: Estimate of remaining theoretical uncertainty

Calculation implemented into public code FeynHiggs



- ▶ Also provides branching ratios, production cross sections, ...
- ▶ Authors: HB, S. Heinemeyer, W. Hollik, S. Paßehr, H. Rzehak, G. Weiglein

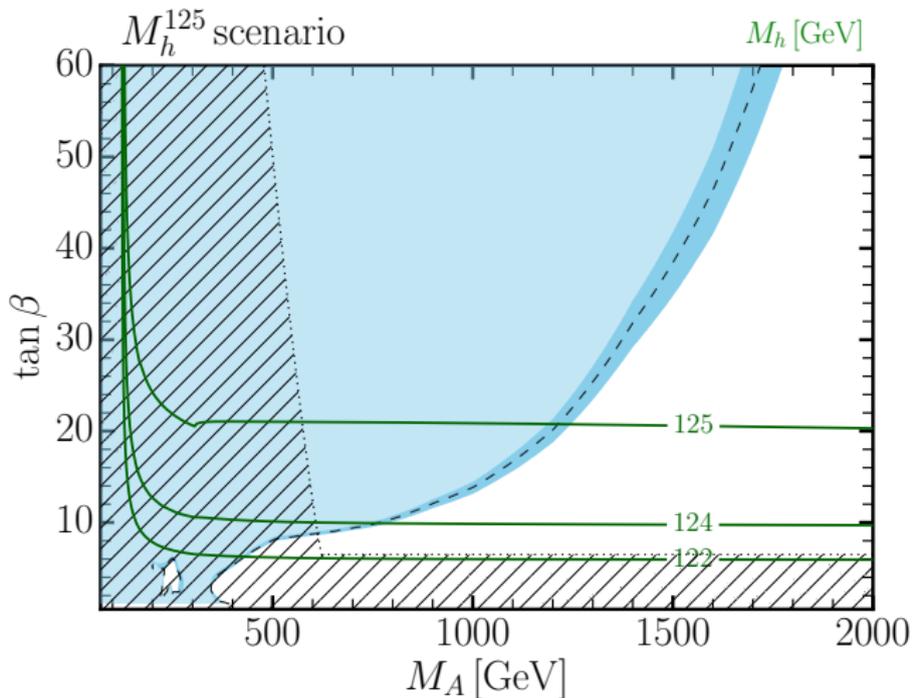
Higgs benchmark scenarios

- ▶ For ease interpretation of LHC data MSSM Higgs benchmark scenarios were developed
- ▶ Improved calculation of SM-like Higgs mass ruled out large parts of the parameter spaces

→ definition of new benchmark scenarios

Example: M_h^{125} scenario

- ▶ All SUSY particles at the TeV scale
- ▶ Resembles THDM type-II at low scales



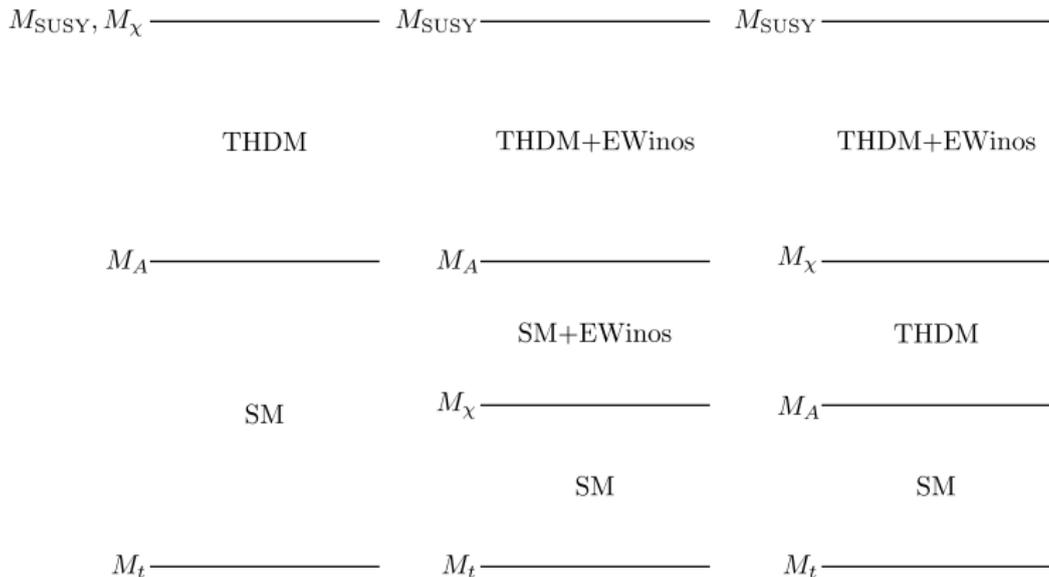
- ▶ Blue: Excluded by direct searches for heavy Higgs bosons
- ▶ Hashed: Excluded by Higgs signal strengths / Higgs mass

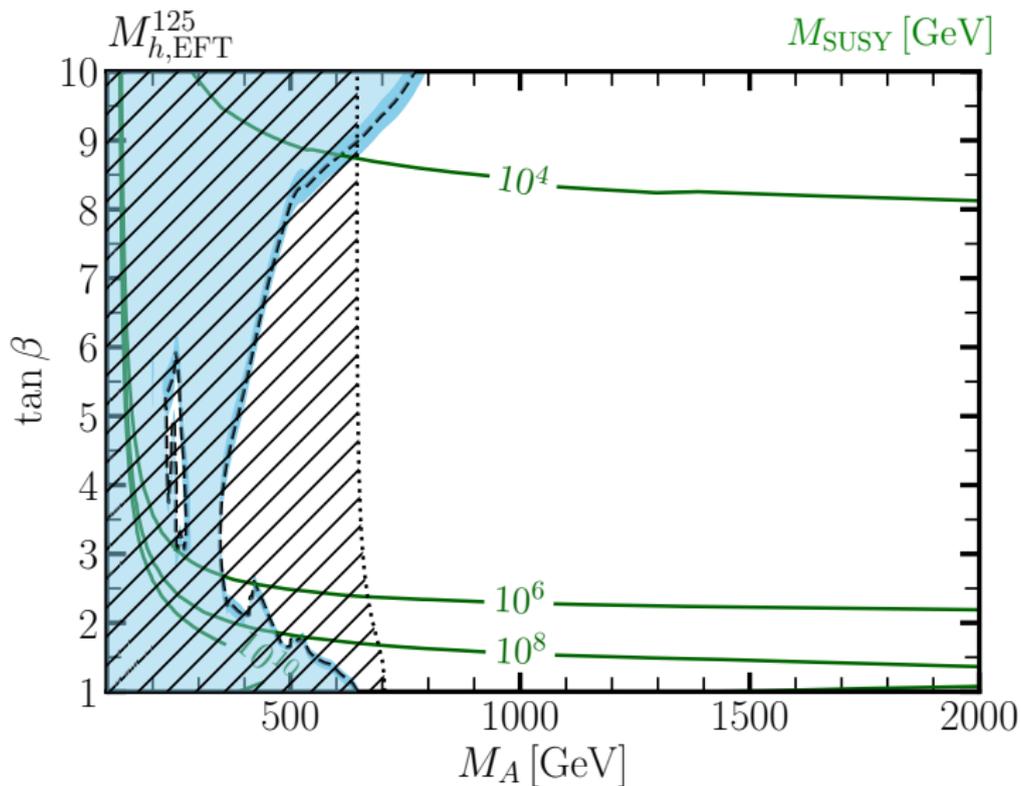
Low $\tan \beta$ region?

- ▶ Low $\tan \beta$ region excluded since M_h too small
- ▶ Can raise SUSY scale to reopen it

→ large hierarchy between heavy Higgses and SUSY particles

More complicated EFT calculation needed



$M_{h,EFT}^{125}$ 

Thanks for your attention!

P.S.: Also looking for new projects.