FeynHiggs(Fast):

Fortran Programs for the Evaluation of the Masses of the neutral $\mathcal{CP}$-even Higgs Bosons in the MSSM

S. Heinemeyer, DESY

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based on collaboration with
W. Hollik and *G. Weiglein*

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1. Introduction

Stringent direct test of SUSY:

Light Higgs boson h required

m_h calculable from MSSM parameters:

Tree level: $m_h < M_Z$

Large radiative corrections: $\Rightarrow m_h \lesssim 135$ GeV

$\Rightarrow$ Precise prediction needed for Higgs search:

- $\rightarrow$ Discovery/exclusion potential of LEP2 and upgraded Tevatron
- $\rightarrow$ After Higgs-boson discovery: Constraints on MSSM parameter space

$\Rightarrow$ Fast and accurate computer code necessary

Available programs differ by $\mathcal{O}(10$ GeV$)$

2. Calculations

FeynHiggs:

[S. H., W. Hollik, G. Weiglein '98]

→ Evaluation of m_h and m_H

- Full diagrammatic 1-loop calculation
  [A. Dabelstein '95]
- Leading diagrammatic 2-loop calculation in $\mathcal{O}(\alpha\alpha_s)$
  [S. H., W. Hollik, G. Weiglein '98]

Additional contributions:

- Leading term $\mathcal{O}(G_\mu^2 m_t^6)$ (RG method)
  [M. Carena, J. Espinosa, M. Quiros, C. Wagner '95]
- higher order QCD corrections (running top mass $\overline{m}_t$)

Also included:
$\Delta\rho^{\text{SUSY}}$ up to $\mathcal{O}(\alpha\alpha_s)$

[A. Djouadi, P. Gambino, S. H., W. Hollik, C. Jünger, G. Weiglein '97] [S. H., W. Hollik, G. Weiglein '98]

→ most accurate calculation for m_h based on Feynman-diagrammatic calculation
→ deviations to mostly used programs (RG) up to 5 GeV for large mixing in $\tilde{t}$-sector

FeynHiggsFast:

[S. H., W. Hollik, G. Weiglein '99]

→ Fast (and approximate) evaluation of m_h and m_H

- $t - \tilde{t}$-sector: leading logarithmic and non-logarithmic + subleading terms
- Other sectors at 1-loop: leading Log approximation
  ($t - \tilde{t}$-sector: own calculation)
  [H. Haber, R. Hempfling '91]
- Short approximation formula in $\mathcal{O}(\alpha\alpha_s)$
  [S. H., W. Hollik, G. Weiglein '99]

Additional contributions:

- Leading term $\mathcal{O}(G_\mu^2 m_t^6)$ (RG method)
  [M. Carena, J. Espinosa, M. Quiros, C. Wagner '95]
- higher order QCD corrections (running top mass $\overline{m}_t$)

Also included:
$\Delta\rho^{\text{SUSY}}$ up to $\mathcal{O}(\alpha\alpha_s)$ (no gluino)
[A. Djouadi, P. Gambino, S. H., W. Hollik, C. Jünger, G. Weiglein '97]

→ Accuracy: better that 2 GeV for most parts of MSSM parameter space
→ Also implemented in FeynHiggs

General structure:

Front-end:

→ can be manipulated at user's will

- Specification of model parameters:

  $\tan\beta$, M_A, μ

  $m_{\tilde{t}_1}$, $m_{\tilde{t}_2}$, $\theta_{\tilde{t}} \longleftrightarrow M_{\tilde{t}_L}$, $M_{\tilde{t}_R}$, M_t^{LR}

  $m_{\tilde{g}}$, M $(M \equiv M_2,\ M_1 = \frac{5}{3}\frac{s_W^2}{c_W^2} M)$

  $m_t, \ldots$

- Specification of options:

  - 1-loop: $t - \tilde{t}$ / $+ b - \tilde{b}$ / full ?
  - 2-loop improvement terms of $\mathcal{O}(G_\mu^2 m_t^6)$?
    running top mass ?
  - Comparison with short formula ?
  - $\Delta\rho^{\mathrm{SUSY}}$ maximal value ?

Main program:

→ should not be manipulated

- Evaluation of the Higgs-boson masses at
  - tree level
  - one-loop (as specified by options)
  - two-loop (as specified by options)

- Evaluation of $\Delta\rho^{\mathrm{SUSY}}$
  → Constraints on $\tilde{t}/\tilde{b}$-masses

FeynHiggs(Fast) (as a subroutine) can be linked to existing programs
(→ DELPHI collaboration, Karlsruhe
→ Members of OPAL collaboration:
work in progress)

Program parameters:

FeynHiggs:

- $\sim$ 60000 lines Fortran code
  (1/2 of the code: $\hat{\Sigma}^{(2)}_{\phi_2}(0)$)
- 3.8 MB executable file
- Runtime ca. 0.5 seconds
  (Sigma station, 600 MHz, Alpha CPU,
  512 MB)

FeynHiggsFast:

- $\sim$ 1400 lines Fortran code
- 65 KB executable file
- Runtime ca. 2×10^{-5} seconds
  (Sigma station, 600 MHz, Alpha CPU,
  512 MB)
- Accuracy: better than 2 GeV for most parts
  of MSSM parameter space

Availability:

Both programs can be obtained via WWW homepage:
www-itp.physik.uni-karlsruhe.de/feynhiggs

- Introduction to the programs
- Source code of the programs
- Information about updates
- Information about support
- Related publications

4. Conclusions

- FeynHiggs(Fast): Fortran programs for the evaluation of m_h and m_H.
- Evaluation up to $\mathcal{O}(\alpha\alpha_s)$
- can be linked to existing programs
- Accuracy:
  FeynHiggs: most precise calculation based on Feynman-diagrammatic calculation
  $\rightarrow$ deviations to existing programs up to 5 GeV for large mixing in $\tilde{t}$-sector
  FeynHiggsFast: Deviations $\leq$ 2 GeV
- Runtime: 0.5/ 2 $\times$ 10^{-5} seconds
- Available via WWW page
  www-itp.physik.uni-karlsruhe.de/feynhiggs