Inclusion of HiggsBounds

Fittino Workshop

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Table of contents

Preface

- This work was done as a project of this year's summer student program here at DESY
- supervised by Toni Hartin & Philip Bechtle
- I decided not to go into to much detail about the implementation and just give you an overview of what has been done and how to use it

HiggsBounds

- Fortran code for testing theoretical predictions of models with arbitrary Higgs sector against exclusion bounds obtained by LEP and Tevatron Higgs-searches
- No Higgs found (yet)
  → Limits on indivdual cross-sections
- HiggsBounds provides easy access to all relevant Higgs exclusion limits with about 40 implemented analyses from LEP and the Tevatron (more to come)
- Possibility to combine LEP and Tevatron results
- 3 different operation modes:
  - online version (*http://www.ippp.dur.ac.uk/HiggsBounds*)
  - command line mode
  - subroutine mode via library
- using HiggsBounds via the external library makes it possible to benefit from future upgrades and /or bugfixes without changing the fittino interface

HiggsBounds

- The basic workflow is as follows:
  - user provides model input for all neutral higgs bosons
  - HiggsBounds calculates model prediction for signal topology
  - channel with the highest statistical sensitivity is determined
  - comparison between model and observed topology for specific channel
  - decision if scenario is excluded or not
- My task: invoke the external HiggsBounds library from within fittino to decide whether a specific point in the parameter space is already excluded with 95% C.L.

HiggsBounds

- 3 different input options: But only one ("effc" - Effective couplings approximation) possible to implement
- Input required by HiggsBounds:
  - Number of neutral Higgs bosons: n_H
  - Higgs masses: m_{h_k} in the right order!
  - total widths: $\Gamma_{tot}(h_k)$
  - normalised squared effective Couplings:

$$\left(\frac{g^{model}_{h_kZZ}}{g^{SM}_{HZZ}}\right)^2, \left(\frac{g^{model}_{h_kWW}}{g^{SM}_{HWW}}\right)^2, \left(\frac{g^{model}_{h_k\gamma\gamma}}{g^{SM}_{H\gamma\gamma}}\right)^2, \left(\frac{g^{model}_{h_kgg}}{g^{SM}_{Hgg}}\right) 2,$$
$$\left(\frac{g^{model}_{h_kbb}}{g^{SM}_{Hbb}}\right)^2, \left(\frac{g^{model}_{h_k\tau\tau}}{g^{SM}_{H\tau\tau}}\right)^2, \left(\frac{g^{model}_{h_kh_jZ}}{g^{ref}_{HH'Z}}\right)^2$$

  - Branching ratios: $\mathrm{BR}_{model}(h_k \to h_j h_j)$

The implementation

- 2 new switches in the input file
  - UseHiggsBounds
  - HBWhichExpt - Which results are being taken into account (LEP, Tevatron or both). If not set `'LandT'` is assumed
- if switch *UseHiggsBounds* is set to *On* $\rightarrow$ fittino initializes HiggsBounds

```
char* whichexpt = const_cast<char*>(yyHBWhichExpt.c_str());
initialize_higgsbounds_(&nH,whichexpt);
```

- nH is the number of neutral Higgs bosons in your model (at the moment only possible for nH = 3 (MSSM))
- The subroutine `initialize_higgsbounds` reads in all the tables. This is done only once.

The implementation

- in every iteration step HiggsBounds tests if the scenario is excluded or not by invoking the function
  `int call_HiggsBounds(int nH, double* parameterVector)` that gathers all the needed information from SPheno (see above) brings them in the right order and calls the HiggsBounds subroutine `run_higgsbounds_effc`
- if HiggsBounds returns `1` (excluded) χ^2 is set to $1,11111111 \cdot 10^{10}$ (similar to the way problems with the calculator are treated)
- But distinguishable $\rightarrow$ possibility to compare exclusion plots from fittino with "official" exclusions from e.g. LEP-collaborations to test if everything works as expected

Cheat sheet

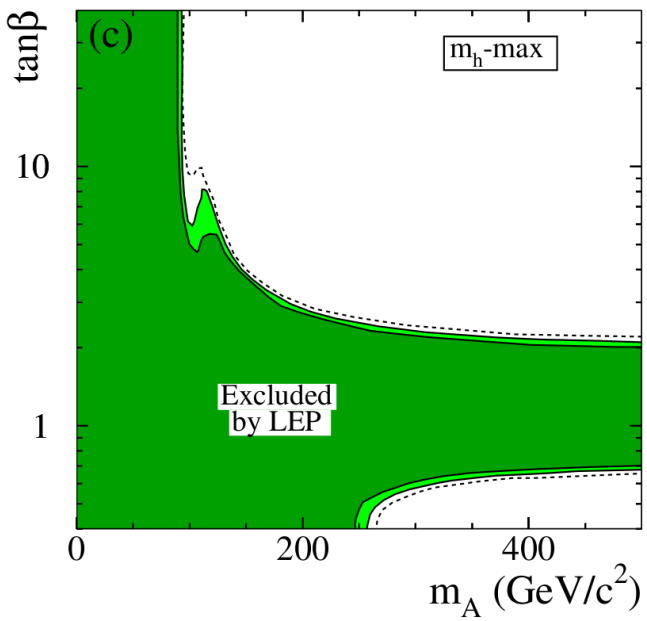
To use HiggsBounds you need to have:

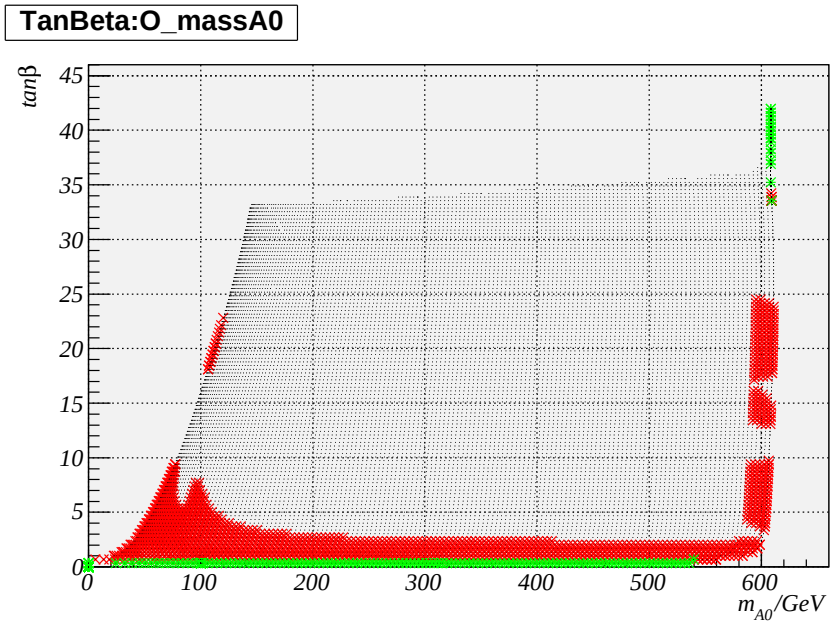
- An up-to-date version of the fittino trunk
- The compiled HiggsBounds library (either F77 or F90 version)
- both the path to `libgfortran` and `libHB` set in the Makefile
- the precompiler-flag `USELIBHB` set
- `UseHiggsBounds` switched on in your input file

If you don't want to use it, just don't set USELIBHB (Every change concerning HiggsBounds is only compiled if this is set)

One example

- comparison between the exclusion plot for the m_h-max benchmark scenario

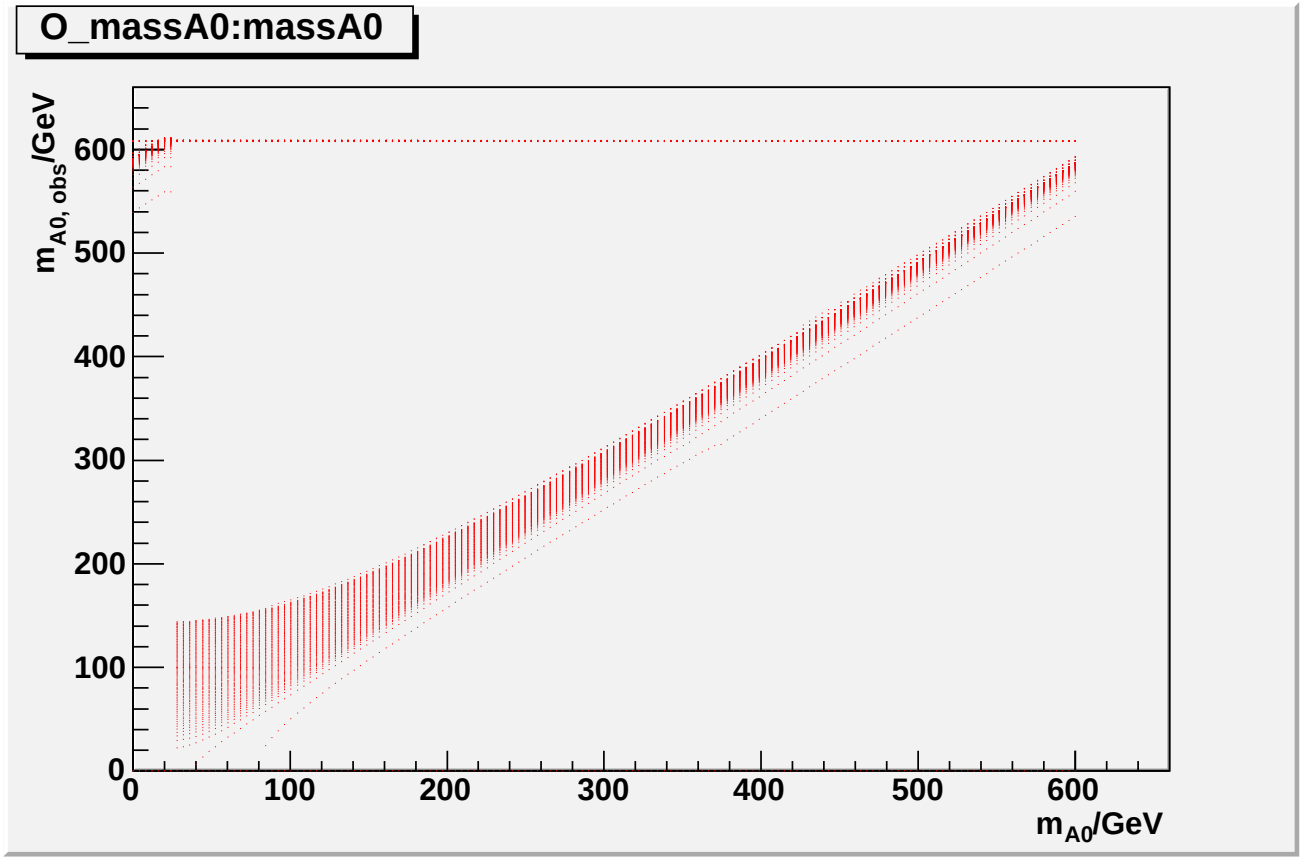




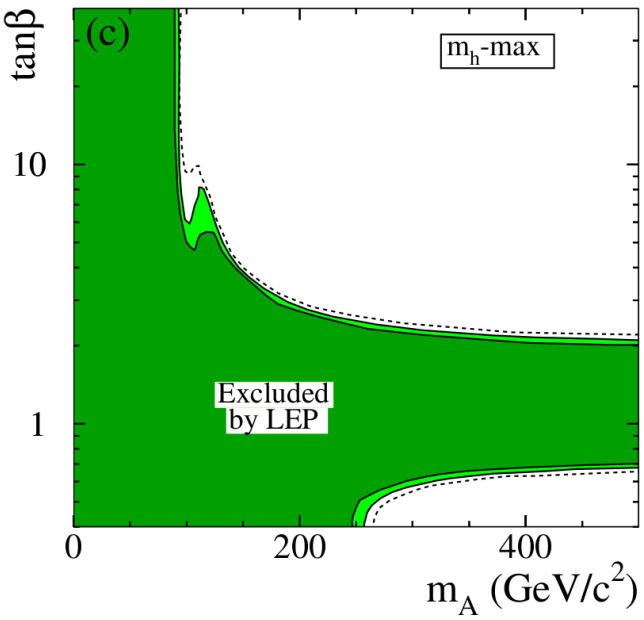
- Does not really match expectation

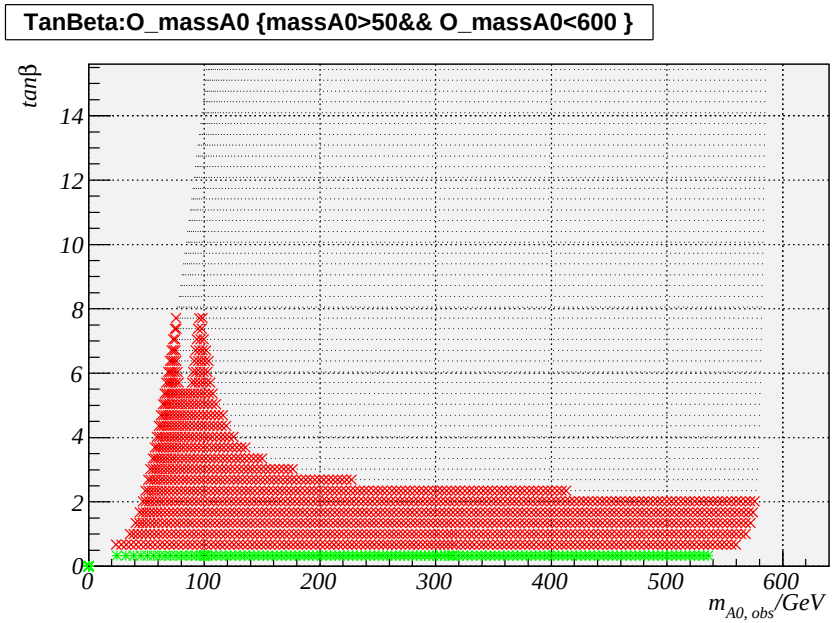
The problem

- Plot of $m_{A,run}$ vs. $m_{A,pole}$



- Cut on m_{A0}>50 GeV & $m_{A0,\ obs}$<600 GeV





- good agreement in the sampled regions

Drawbacks / Future work

- Because of the limited time I had, this is
  - not the fastest
  - not the nicest
  - and definitely not the most flexible or general implementation (Only models with 3 neutral Higgs bosons, output parameters are hardcoded, ...)
- With HiggsBounds including more analyses (new Tevatron results, charged Higgs) also changes in the implementation have to be made to benefit from them
- Inclusion of full χ^2 information from upcoming versions of HiggsBounds.

Further information

- HiggsBounds:
  - *http://www.ippp.dur.ac.uk/HiggsBounds*
  - arXiv:0811.4169v3 [hep-ph]
- MSSM neutral Higgs searches at LEP, arXiv:hep-ex/0602042v1