Interfacing Fittino with HiggsBounds

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HiggsBounds, a computer code that confronts theoretical predictions of models with arbitrary Higgs sector against exclusion bounds obtained from direct searches at LEP and the Tevatron has been included in Fittino. Fittino is a program for determining parameters of the Supersymmetric (SUSY) Lagrangian from observables that will be provided by future collider experiments like the Large Hadron Collider (LHC) at CERN and the future International Linear Collider (ILC).
Besides the implementation of the HiggsBounds library a preliminary test for the m_h-max scenario has been performed and compared to the results published by the LEP Working Group for Higgs Boson Searches.

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1 Introduction

Although the Standard Model of high energy physics (SM) is a extremely successful description of all presently known phenomena it seems clear that it will have to be extended when trying to describe physics at higher energies.[1]
One of the best motivated Standard Model extensions is Supersymmetry. It introduces a new type of symmetry between bosons and fermions. In the Minimal Supersymmetric Standard Model (MSSM) every SM particle gets a superymmetric partner whose spin differs by $\frac{1}{2}$. Hence the amount of observable particles compared to the Standard Model is more than doubled. This leads to a theory with more than 100 parameters (masses, decay widths, branching ratios, etc.) as well as parameters concerning the character of the symmetry breaking mechanism. If Supersymmetry is realized in nature it is a crucial task to obtain those parameters from observables supplied from collider experiments like the LHC at CERN or the future Linear Collider ILC.
This is where the program Fittino[2] sets in. Fittino uses an iterative approach to obtain the best set of parameters from the given input observables. As it is impossible to fit 100 parameters simultaneously, some assumptions on the structure of the SUSY Lagrangian is made, leading to a model with 24 parameters (MSSM-24).

HiggsBound[3] on the other hand uses the constraints on cross-sections obtained by the non-observation of the Higgs boson at LEP and the Tevatron to confronts them again model predictions. With HiggsBounds it is possible to exclude specific regions in the SUSY parameter space that we are not interested in anymore, because they have already been ruled out.

2 The Fit Program Fittino

Fittino's aim is to determine parameters without assuming any a priori knowledge of SUSY parameters at any step. It tries to find the the best values for the parameters by minimising a χ^2 function. The workflow of Fittino is shown in fig. 1

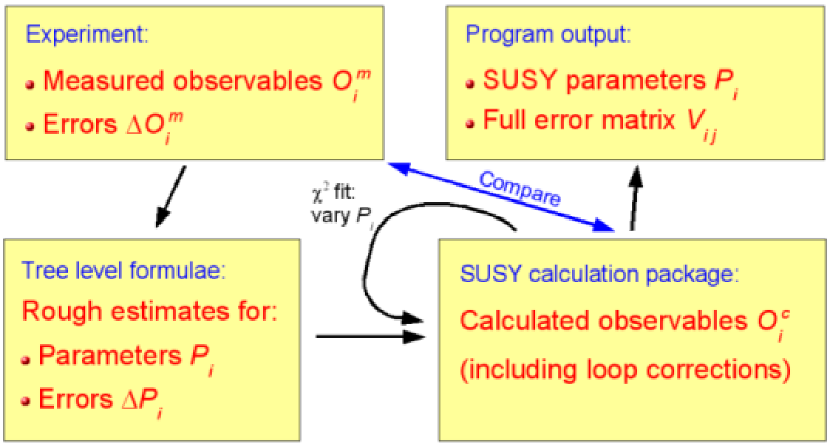

Figure 1: a schematic view of the fittino workflow (from [2])

First start values for all the parameters are derived via tree level formulae. After that the real iterative procedure starts by varying the parameters, calculating the observables and compare them to the input observables. If a set of parameters is better than the one before it is kept, otherwise it is thrown away. A lot more details about the fitting procedure as well as an overview over all the possible input variables of fittino can be found in [4].

3 HiggsBounds

Neither at LEP nor at the Tevatron signals of the Higgs boson have been found. This non-observation of the signal has been turned into constraint on individual signal topologies. HiggsBounds takes user-provided input for all neutral Higgs bosons (like masses, total decay widths, couplings to SM particles and branching ratios) and calculates the model cross section for each Higgs signal topology. After that HiggsBounds determines the search topology with the highest statistical sensitivity and compares the model prediction for this channel with the observed one and then decides whether a parameter point is excluded at 95% confidence level or not.
HiggsBounds has three different operation modes:

- Online version[5]
- command line version
- subroutine version

for this purpose we use HiggsBounds as an external library and apply the provided subroutines from within Fittino. When new results from the Tevatron are published and those results are put in HiggsBounds, the user only has to compile the new version of the library to benefit from the latest results, without changing anything inside fittino

4 The interface

The general operation method of the interface is as follows:

1. After starting fittino the subroutine `initialize_HiggsBounds` is called from the external HiggsBounds library, reading in all the needed tables holding the information about the constraints on different crosssections.

2. In every single iteration step the routine `run_HiggsBounds_effC` is invoked using the values predicted by the theory calculator and returning either `0, 1` or `2`, whereas `0` means parameter point is excluded at 95% C.L., `1` means parameter point is not excluded, and `2` means that there was a problem calling the function (mostly because of a problem in the calculator run).

3. If the parameter point is exluded, χ^2 is set to $1.1111111 \cdot 10^{10}$. This high value assures that Fittino will not try to fit on that point again and because we exactly know the value of χ^2 at the excluded parameter points we can seperate them from the unexcluded regions (see chapter 5).

One problem was, that HiggsBounds expects the passed arrays or matrices to be in the right order, starting with the lowest Higgs mass. Therefore every array and matrix-element has to be swapped in respect to the higgs masses.

4.1 How to use it

To use HiggsBunds in fittino the user just has to set the switch `UseHiggsBounds` to `On` and specify whether he wants to include only LEP results, only Tevatron results or both, assigning it to the value `HBWhichExpt`. If it is not set, both experiments are used.
After fittino is finished running the user obtaines a ROOT-ntuple storing the masses of the neutral Higgs bosons, $\tan\beta$ and the values for χ^2. At the moment it is not possible to include more / other output variables without making changes in the sourcecode.

5 Test in the m_h-max benchmark scenario

To fully describe the Higgs sector in the MSSM only a few parameters are needed. The m_h-max scenario defines a set of those parameters. It's nice property is that it maximises the upper limit on m_{h^0} and therefore has a large theoretically allowed parameter space. Table 1 shows the particular values I used throughout this analysis.

parameter	value
$\tan\beta$	0.4 - 40
M_A (GeV)	0.1 - 1000
M_{SUSY} (GeV)	1000
M_2 (GeV)	200
μ (GeV)	-200
$m_{\tilde{g}}$ (GeV	800
X_t (GeV)	2 M_{SUSY}
A (GeV)	$X_t + \mu \cot\beta$

Table 1: Parameters of the $_h$-max scenario (cp. [6])

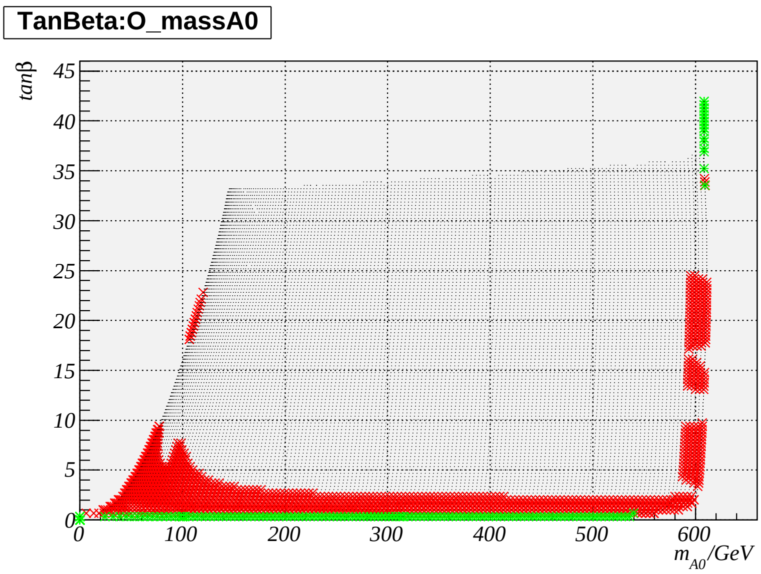

Figure 2: Result from test run in the m_h-max scenario. Sampled points are black, theoratically inaccessible points green and points excluded by HiggsBounds are red

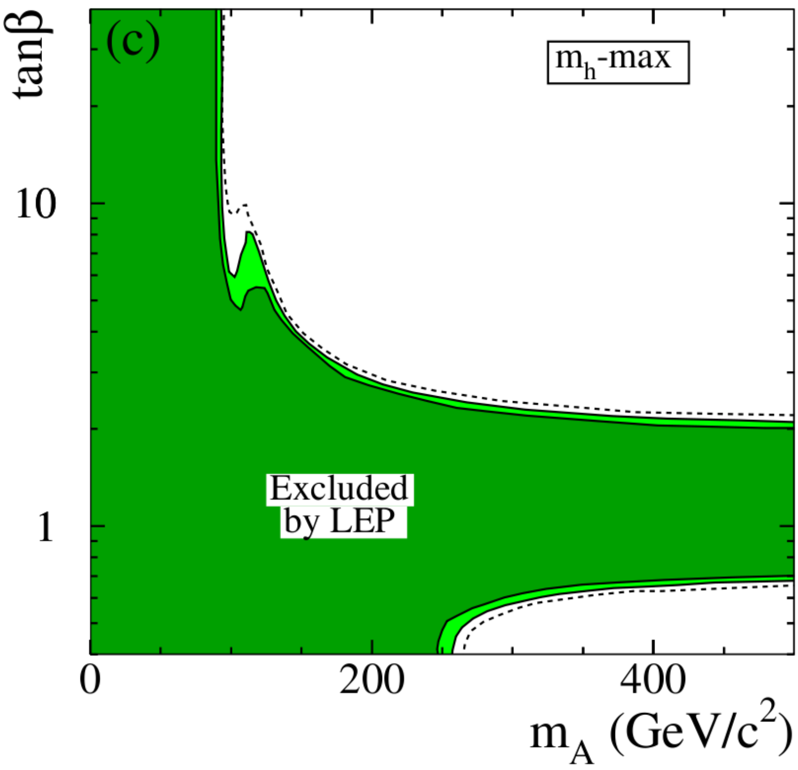

Figure 3: LEP-exclusions in the $m_A/\tan\beta$-plane (from [6])

It is obvious, that the plots don't really match. First of all there are no sampling points for low masses of m_A and high values of $\tan\beta$, but also there are points in the parameter space excluded that should not be excluded at all. If one looks at the plot m_A vs. $m_{A,obs}$ one can see that it differs a lot from the theoretical expectations.

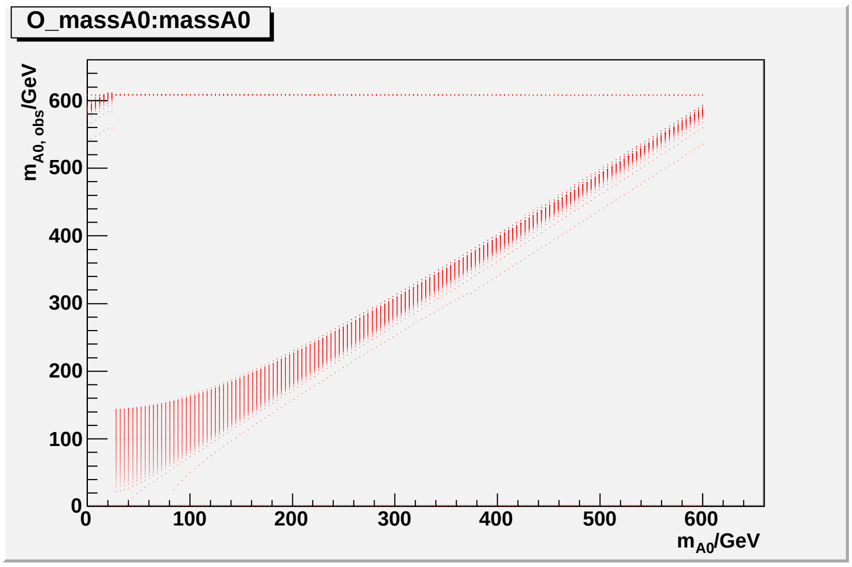

Figure 4: Input value of m_A vs. $m_{A,obs}$

It looks like the theory calculator we use in the absence of real data from experiments has problems with very low input values m_A. Also the points in $m_{A,obs}$ above 600 GeV look rather artificial.
I repeated the analysis of the data, but made two cuts:

- $m_A > 50$ GeV
- $m_{A,obs} < 600$ GeV

The result can be seen in fig. 5

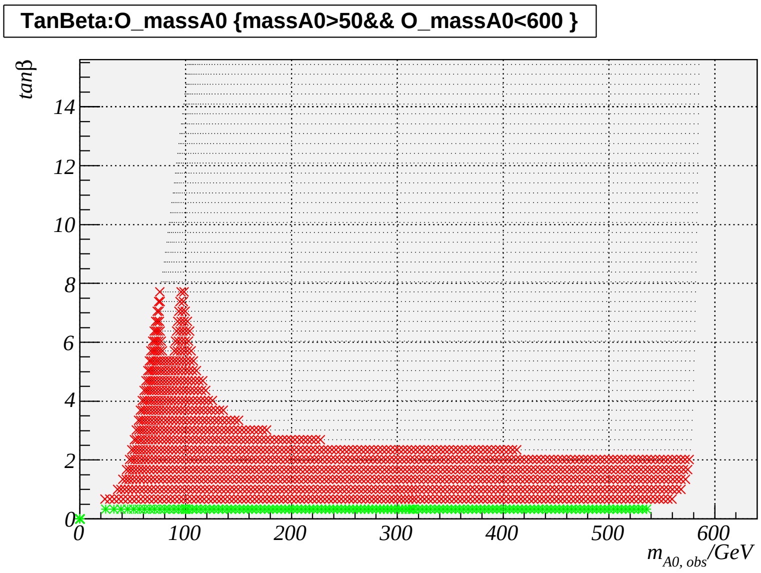

Figure 5: Revised result from fittino & HiggsBounds

One can see that after the applied cuts there is a nice agreement between fig. 3 and fig 5. This shows, that the interface between fittino and HiggsBounds is working as expected. Of course further analysis which are less model-dependent have to be made.

6 Conclusion and Outlook

This first implementation has two major drawbacks:

- Limitation to MSSM
  Although fittino in general is able to fit the Next to Minimal Supersymmetric Standard Model (NMSSM), the current HiggsBounds implementation is only capable of working with models with 3 neutral Higgs bosons
- The output is very unflexible
  At the moment there is no chance to decide what parameters are written out to the ntuple besides specifying it in the source code.

As aforementioned HiggsBounds at its current state only returns whether a parameter point is excluded at a 95% confidence level or not. Upcoming versions might include tables holding the full information of the confidence level for every single topology. It would be possible instead of setting the χ^2 artificially to a high value to really calculate the corresponding χ^2 for that specific parameter point.

7 Acknowledgements

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References

[1] S. Martin, *hep-ph/9709356v5*

[2] P. Bechtle, K. Desch and P. Wienemann *http://flc-desy.de/fittino*

[3] P. Bechtle, O. Brein, S. Heinemayer, G. Weiglein and K.E. Williams, *0811.4169v3 [hep-ph]*

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[5] P. Bechtle, O. Brein, S. Heinemayer, G. Weiglein and K.E. Williams, *http://www.ippp.dur.ac.uk/HiggsBounds*

[6] The LEP Working Group for Higgs Boson Searches, *hep-ex/0602042v1*