Interpretation of the Higgs signal in supersymmetric models

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MSSM Higgs sector

In the minimal supersymmetric Standard Model (MSSM) two Higgs doublets are needed to give mass to up- and down-type quarks.

This leads to five physical Higgs bosons:

Two CP-even Higgs | CP-odd Higgs | Two charged Higgs

The MSSM Higgs sector is described by two parameters: $M_A, \ \tan\beta$

The discovered Higgs boson at ~ 126 GeV can be interpreted as the lightest (h) CP-even Higgs of the MSSM. Also the interpretation of the signal as the heavier CP-even Higgs (H) is generally possible. This interpretation is very constrained in the MSSM, however a viable option in other SUSY models.

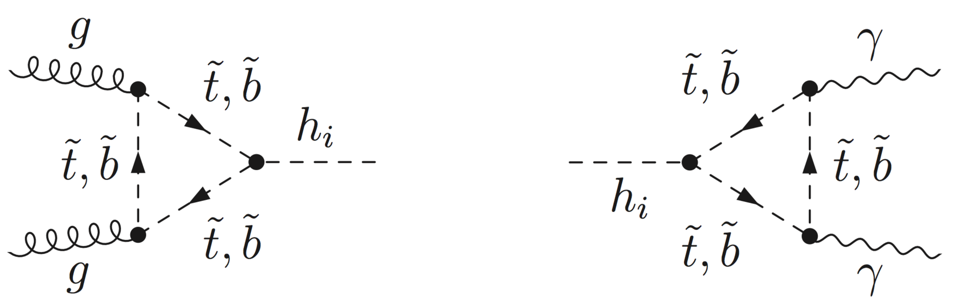
Measurement of the Higgs signal strengh

For each decay channel the LHC experiments provide the best fit signal strength:

$$\mu_i = \frac{\sigma(pp \to H) \times BR(H \to i)}{\sigma^{\mathrm{SM}}(pp \to H) \times BR^{\mathrm{SM}}(H \to i)}$$

The observation is compatible with the SM so far, but deviations from 1 are measured (even though not statistically significant at present) and many other 'new physics' explanations are possible.

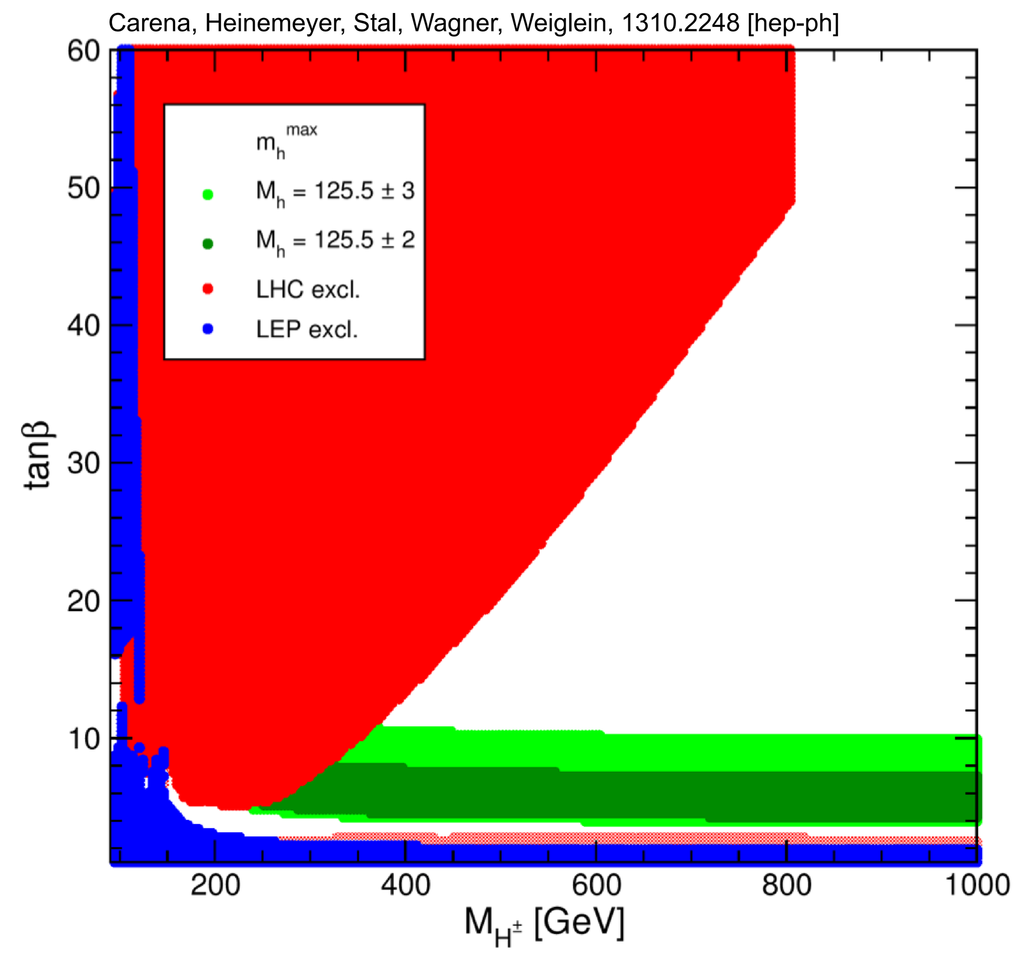
In the MSSM the Higgs couplings are different than in the SM and supersymmetric (SUSY) particles can occur in loop diagrams. This leads to changes in the predictions for the Higgs production cross-sections and the Higgs boson decay rates compared to the SM.



Interpretation of the Higgs signal as the light CP-even Higgs

The interpretation of the light CP-even Higgs as the state at 126 GeV leads to a lower bound on the CP-odd Higgs mass M_A of around 200 GeV.

As a consequence, the MSSM is in the "decoupling limit", where the state at 126 GeV has SM- like couplings. Therefore no deviation of the measured properties from SM is expected at the present level of accuracy. The properties of the observed signal have to be measured very precisely.



Fitting the MSSM to the Higgs and low-energy data

A random scan over the pMSSM parameter space is performed (10 million points) and for each point a χ^2 value is calculated:

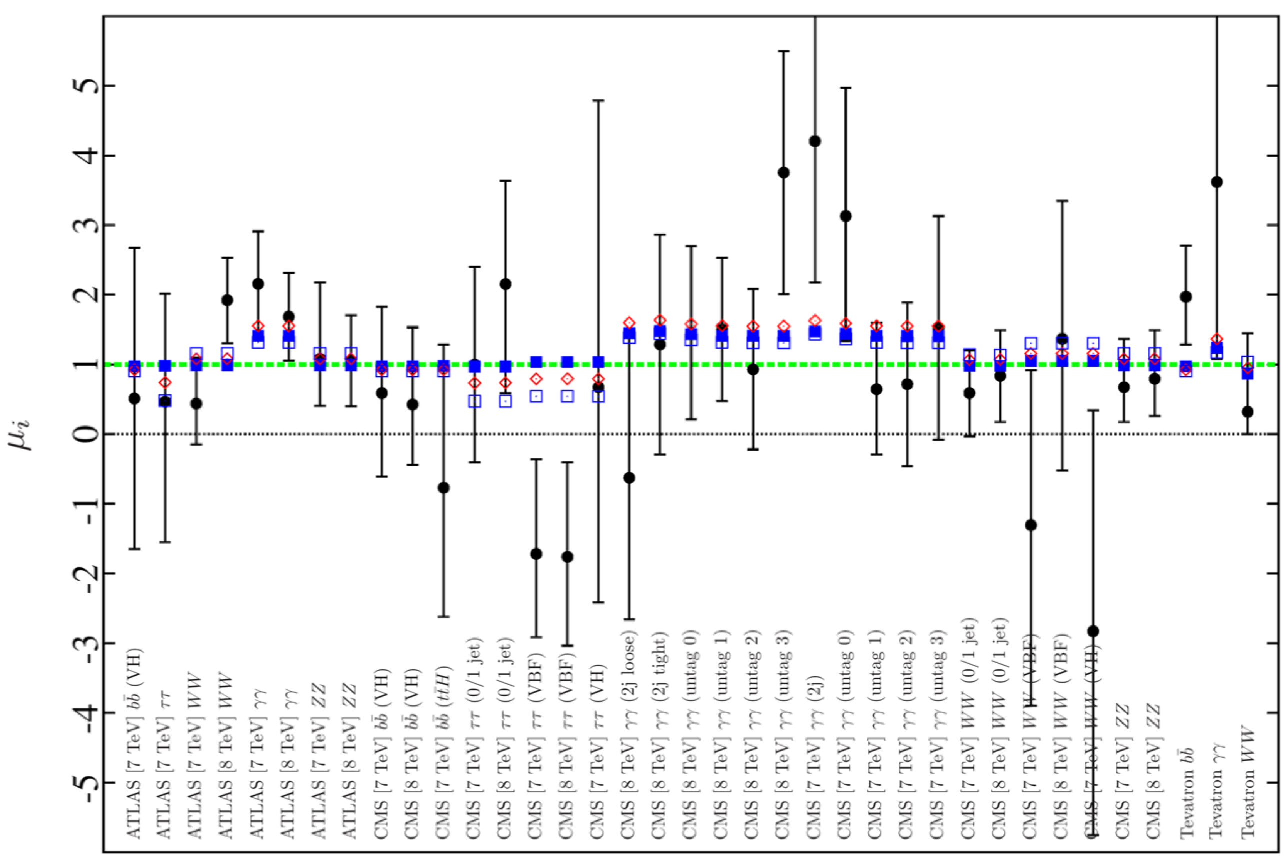
$$\chi^2 = \sum_{i=1}^{n_{\mathrm{LHC}}+n_{\mathrm{Tev}}} \frac{(\mu_i - \hat{\mu}_i)^2}{\sigma_i^2} + \frac{(M_{h,H} - \hat{M}_H)^2}{\sigma_{\hat{M}_H}^2} + \sum_{i=1}^{n_{\mathrm{LEO}}} \frac{(O_i - \hat{O})^2}{\sigma_i^2}$$

The Higgs measurements from ATLAS, CMS and Tevatron are taken into account as well as low energy observables:

$$b \to s\gamma, B_s \to \mu\mu, B \to \tau\nu, (g_\mu - 2), M_W$$

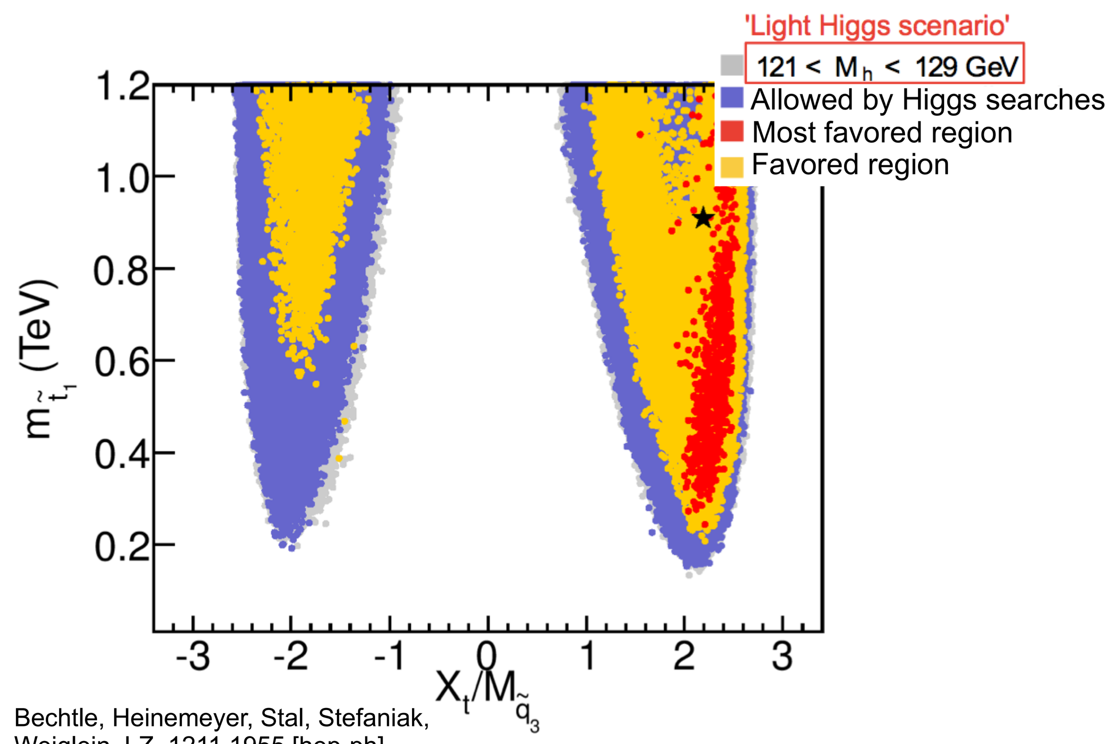
The MSSM has the flexibility to describe deviations of the measurements from the SM prediction. However large deviations cannot be explained (SM-like behavior in the decoupling limit).

The MSSM provides a good fit to the observables, similar to the SM. For the light Higgs case the MSSM provides a slightly better description of the measurements than the SM.



Bechtle, Heinemeyer, Stal, Stefaniak, Weiglein, LZ, 1211.1955 [hep-ph]

Constraints on the stop sector



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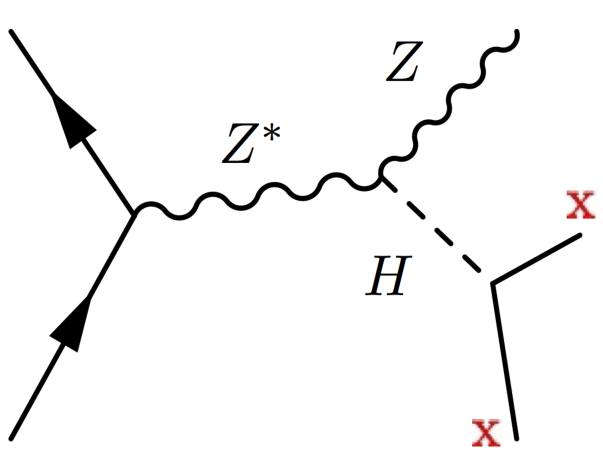
The observation of a light Higgs at 126 GeV, requires large radiative corrections in the MSSM especially from tops and stops. This implies that the mixing in the stop sector (parameterized by X_t) has to be large.

The favored region of the fit includes parameter points with stop masses down to ~ 200 GeV.

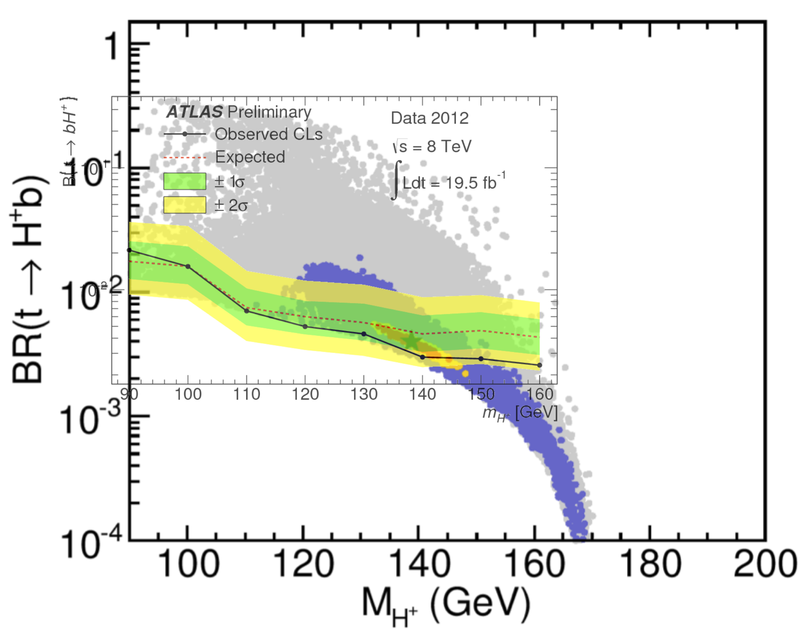
Higgs as a portal to dark matter

If dark matter consists of particles that are lighter than $M_H/2$ ~ 63 GeV, the decay of the Higgs at 126 GeV into a pair of dark matter particles (which would not interact with the detector) is kinematically open and could occur, even if the Higgs couples with SM strength to the other SM particles. Therefore searches for invisible Higgs decays are important and could provide insight into Dark Matter. In R-parity conserving SUSY models, the lightest supersymmetric particles (LSP) could be such a light dark matter particle.



Exotic interpretation of the Higgs signal

The state at 126 GeV can also be interpreted as the second-lightest state of an extended Higgs sector. The interpretation as the heavy CP-even Higgs in the MSSM implies a light charged Higgs. The new result from ATLAS has excluded most of the preferred parameter space, however the interpretation as second lightest Higgs is possible in other models, such as a 2HDM or the NMSSM.



Bechtle, Heinemeyer, Stal, Stefaniak, Weiglein, LZ, 1211.1955 [hep-ph]
ATLAS Collaboration, ATLAS-CONF-2013-090

Indirect constraints from electroweak precision data

Electroweak precision observables, such as the W boson mass, are highly sensitive to loop contributions of 'new-physics'. With a precise measurement of M_W together with a precise calculation in the SM and SUSY models, the W-boson mass provides a powerful tool to test SUSY models, to distinguish between the SM and SUSY and to constrain the SUSY parameter space.

The measurement of the W-boson mass shows a slight preference for a non-zero SUSY contribution. A more precise measurement (as one would get from the ILC) would significantly enhance the sensitivity for distinguishing between the SM and the MSSM.