BSM (pMSSM) with new Higgs limits

Outline of my master thesis

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January 5, 2011

Outline

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Motivation

Experimental results from LHC:

- No apparent particle candidates from BSM (SUSY, $\cdots$)
- But: Higgs candidate at 125 GeV

How can we use the higgs candidate to probe SUSY?

MSSM

Minimal Supersymmetric Standard Model (MSSM) is the minimal way of implementing SUSY.

- Makes few assumptions $\rightarrow$ many degrees of freedom

It's convenient to simplify the MSSM:

- minimal SUperGRAvity (mSUGRA, cMSSM) is the most common model. Constrained by having only 5 parameters.
- Less constrained models: Less excluded from data.
  - Phenomenological MSSM (pMSSM)

pMSSM

pMSSM (or MSSM-19, MSSM-24) is a balanced way of looking at MSSM.

- Most general model with conservation of CP and R-parity (stable $\tilde{\chi}_1^0$)
- 19 parameters at weak scale ($\sim \mathrm{TeV}$)
- No assumption about the symmetry breaking or unification at high energies

Problem: Still too many parameters to make any quick conclusions. Will need to do random scans over a selected part of the parameter range.

Higgs mechanism

The equations for the electroweak theory breaks down with inclusion of mass terms.
Solution: Introduce a complex scalar doublet Φ to break the electroweak symmetry, obtain mass terms.

- 4 DoF in Φ: 3 DoF to get massive vector bosons, 1 DoF to get a scalar higgs particle

This is the minimal higgs mechanism, which works nicely for the SM.

Higgs sector in MSSM (and in 2 Higgs Doublet Model)

In MSSM we need two doublets Φ_1 and Φ_2 to break the electroweak symmetry.

- 8 DoF in Φ_1, Φ_2: 3 DoF to get massive vector bosons, 5 DoF for higgs particles:
  - 2 CP-even neutral higgs particles: h^0 (light) and H^0 (heavy)
  - 1 CP-odd neutral pseudoscalar: A^0
  - 2 charged ones: $H^{\pm}$

Both h^0 and H^0 can be treated in mostly the same way as the SM higgs.

Outline

pMSSM scans

The analysis is done as a random scan over all the parameters. For each model:

1. 19 random numbers between 0 and 1 are chosen, and scaled to each of the parameter ranges in pMSSM
2. The FORTRAN code SuSpect is given with these numbers
   - Note that SuSpect (and other software) needs other parameters as well, eg. from the standard model
3. Mass matrices are solved to give the tree level masses
4. Loops and radiative corrections improve these values
5. Apply constraints: $(g-2)_\mu, \Delta\rho, b \to s\gamma, \mathrm{DM}, \cdots$

The final output is given as sets of the masses of the supersymmetric particles, including the five higgs particles.

This process is repeated until enough models have been collected.

Higgs masses with pMSSM scans

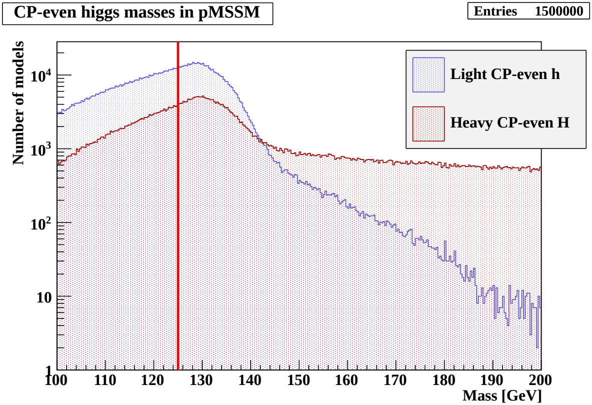


Figure: The masses of h^0 and H^0 to dominant 2-loop contributions from scan over pMSSM.

$h \to \gamma\gamma$ in the SM

- $h \to \gamma\gamma$ is a clean channel to study
- Decays through triangle diagrams (with loop contributions)

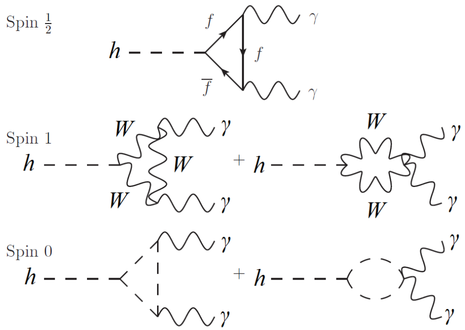
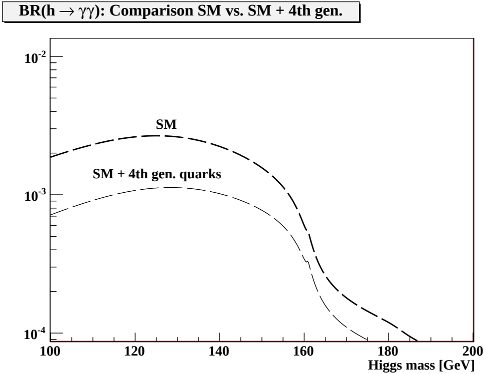


Figure: Tree level contributions to $h \to \gamma\gamma$.

$h \to \gamma\gamma$ in the SM

$$\Gamma(h \to \gamma\gamma) = \frac{\alpha^2 G_F}{128\sqrt{2}\pi^3} \left| \sum_i \text{triangle}_i \right|^2$$

Repeat for all channels to get normalization Γ_{tot} and branching ratio $\text{BR} = \Gamma_{\gamma\gamma}/\Gamma_{\text{tot}}$.



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Further work

My plan for the spring:

- Introduce more experimental constraints for the pMSSM scans
- $h \to \gamma\gamma$ in the pMSSM, not just SM
- Compare the full BR with LHC results, make exclusions in the parameter space

Last slide

Thank you for listening!

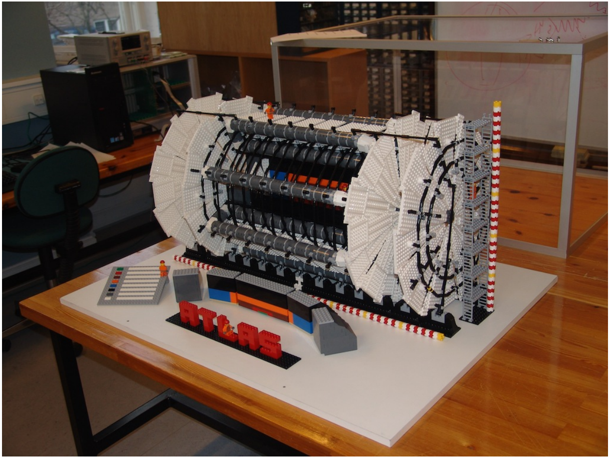

Figure: Lego ATLAS, courtesy of the good people at Niels Bohr Institute

Backup slide: Scan limits

For the higgs mass plot, the pMSSM limits are as follows:

$$1 \leq \tan\beta \leq 60,\ 50\text{GeV} \leq M_A \leq 3\text{TeV},\ |A_f| \leq 9\text{TeV}$$

$$100\text{GeV} \leq m_{\tilde{f}_{L,R}}, M_3 \leq 3\text{TeV},\ 10\text{GeV} \leq M_1, M_2, |\mu| \leq 1.5\text{TeV}$$

A log prior is used, with SuSpect 2.41. Other parameters:

- LSP $\tilde{\chi}_1^0$
- 2-loop RGE for gauge, yukawas, gauginos
- no SUSY radiative corrections to (s)particle masses (only wanted higgs masses for now)
- For higgs mass, full one-loop (PBMZ) and dominant 2-loop

Backup slide: Higgs masses with $m_h \in [120, 127]$ GeV