The relic density of the Higgs-aware MSUGRA grid

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Outline

mSUGRA

Supersymmetry is a proposed candidate for physics beyond the standard model. It introduces transformations between fermions and bosons; giving each a superpartner. In supergravity, this is taken as a local symmetry, and a spin-2 graviton appears. In the minimal case- mSUGRA - the number of parameters is reduced to 5; m_0, $m_{1/2}$, A_0, $tan\beta = v_1/v_2$ and sgnμ.
Supersymmetry provides a candidate for dark matter- the lightest supersymmetric particle cannot decay if R-parity is conserved.

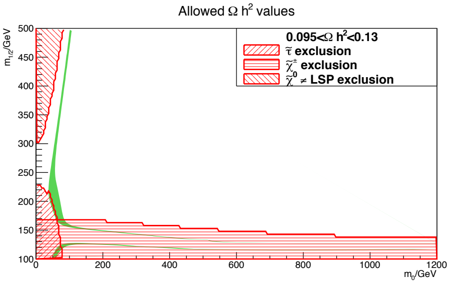
The mSUGRA parameter space

The five mSUGRA parameters are; The common sfermion mass, m_0, the common gaugino mass $m_{1/2}$, the trilinear coupling A_0, the ratio of higgs expectation values $tan\beta = v_1/v_2$ and the higgsino mass parameter, sgnμ.

When setting limits, it is common to use m_0 and $m_{1/2}$ as x and y axes, and keep the other parameters fixed.

Mass isolines will be roughly vertical for sfermions, and horizontal for gauginos. The below plot shows the Darksusy/LEP limits for charginos at the bottom and sleptons in the lower left corner.

Masses are given in GeV in all plots in this talk.



The Program Chain

Isajet 2.82/isasugra $\rightarrow$ DarkSusy 5.05 $\rightarrow$
FeynHiggs-2.9.2 $\rightarrow$ HiggsBounds 3.8.0 $\rightarrow$ Pythia-1.170
Passing a .SLHA-file along, the program packages computes masses, branching fractions and other parameters to be compared with experimental constraints.

Reasons to exclude a point

Three areas of research give excluded parameter regions; theory, accelerator experiments and astrophysics observations.

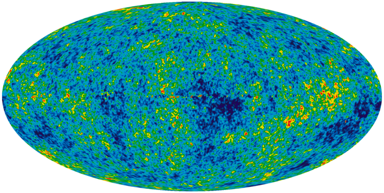
Exclusion	Program	Exclusion at	Origin
No EW symmetry breaking	IsaJet		theory
$Z^0 \neq$LSP	IsaJet		theory
stop mass	DarkSusy	$m_{stop} < 92.5$	LEP
chargino mass	DarkSusy	$m_{charg} < 103.5$	LEP
higgs	FHHB		LEP+Tevatron+LHC
$b \to \gamma$	DarkSusy	$bsg \notin (2.71 \times 10^{-4}, 4.3 \times 10^{-4})$	
$B_s \to \mu\mu$	IsaJet	$4.7 \times 10^{-9} < BR$	LHCb[1]
Ωh^2	DarkSusy	$0.13 < \Omega h^2$	WMAP[6]
σ_{LSP-p} spindep	DarkSusy		IceCube[2]
σ_{LSP-p} spinINdep	DarkSusy		Xenon[3]
$< \sigma_{LSP-LSP} v >$	DarkSusy		Fermi, CTA[5][4]

Relic Density

- Assuming R-parity conservation, the lightest supersymmetric particle will remain and contribute to the matter density.
- The WMAP experiment has set constraints on the relic density of dark matter; $\Omega h^2 = 0.1120 \pm 0.0056$[6].
- In most areas of the msugra space, the relic density is too high. The region where staus and the lsp are almost the same mass will allow a smaller relic density, since the two sparticles may coannihilate.

WMAP

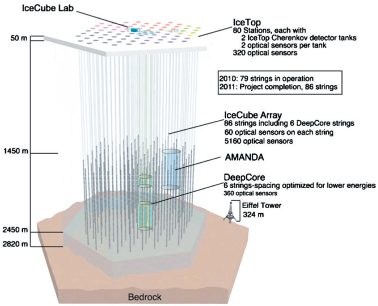
A fit to the ΛCDM constrains the dark matter density to $\Omega h^2 = 0.1109 \pm 0.0056$ [6]. Most mSUGRA points have much too high relic densities; areas that are not excluded have, for example, close LSP and stau masses to allow coannihilation.



WMAP Seven year sky

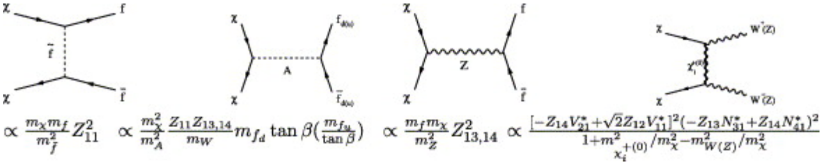
Icecube & Xenon

ICECUBE detects neutrinos with a giant array of Cherenkov detectors suspended in Antartic ice.
Assuming that the amount of dark matter captured by the sun is in equilibrium, ICECUBE looks for an excess of neutrinos from the sun, and sets limits on the rate of capture, and the spin-dependent cross section[2].
The XENON experiments look for the chance neutralino to scatter off a target of xenon, and constrains the spin-independent cross section[3].
Both experiments report experimental bounds as a function of m_{LSP}



The IceCube experiment (by Nasa-verve@wikipedia)

Fermi & CTA



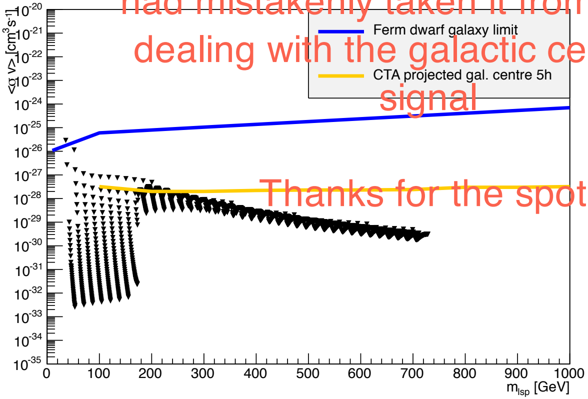
Neutralino annihilation channels from [8]

- The Fermi LAT satellite, covered in earlier talks, has put strong limits on the thermally averaged cross section of dark matter.
- This limit will be affected by the branching ratio to $\gamma\gamma$, as well as how lumpy dark matter is.
- In addition, I include a projection of the exclusion potential of the CTA.

Fermi & CTA

NOTE: the questioner at the talk was right in questioning the CTA limit- I had mistakenly taken it from a paper dealing with the galactic centre line signal

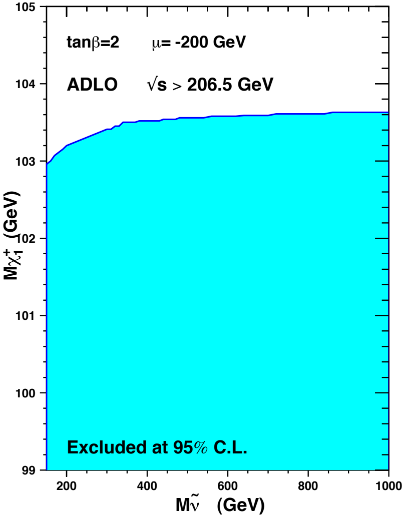
Thanks for the spot!



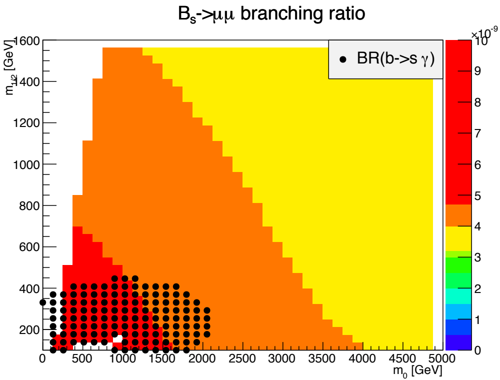
Thermally averaged annihilation cross section of models of the higgs-aware grid from DarkSusy

LEP

LEP searched for sleptons and charginos.
In my code, they are implemented as straight cuts on, for example chargino mass[2]. Except through $B_s \to \mu\mu$ and Higgsbounds, no other LHC exclusions are included; they are contours in parameter space, not bounds on a single observable.



B-physics



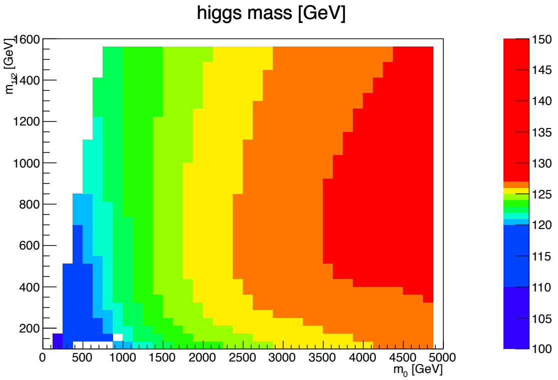
The branching ratio $B_s \to \mu\mu$ calculated by Isajet. Red corresponds to $\text{Br}(B_s \to \mu\mu > 4.7 \times 10^{-9})$.

The region with black points is excluded by the $b \to s\gamma$ calculated by DarkSusy

Requiring a Higgs Candidate

- This years discovery of a Higgs candidate needs to be taken into account when considering the mSUGRA parameter space.
- The planes previously used to interpret results do not have the required higgs-masses.
- Stephen Martin, Tapas Sarangi and Xavier Portell proposed a plane for study that achieves viable higgs masses by maximizing the stop mixing. THis is achieved at large negative A_t and a $tan\beta < 35$ (roughly)
- The proposed slice has $\tan\beta = 30$, $A_0 = -2m_0$

Higgs masses



The higgs mass from Feynhiggs, showing a broad acceptable region.

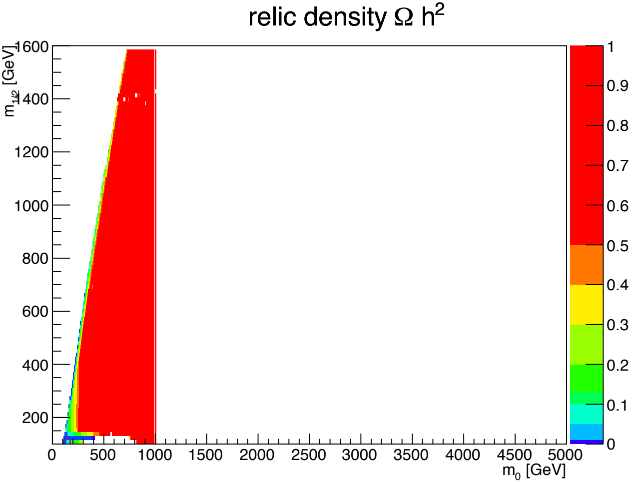
Higgs Aware grid

Progress presented by Valerio Consorti at the meeting on the 10th October:[1]

- The stau pair production branching fraction is enhanced.
- The third generation squarks and sleptons are lighter with the higher mixing.
- A stop mass lower than the gluino enables gluino to stau stau decays.
- A b-jet analysis would provide good exclusion power.

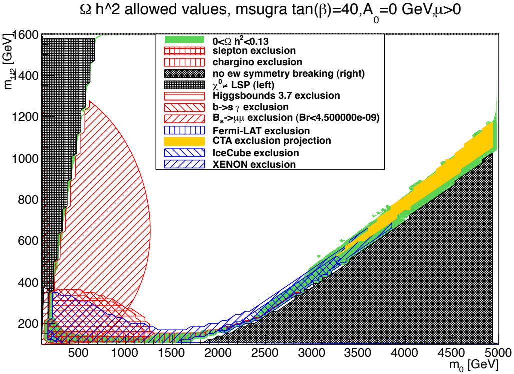
[1] https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=210747

Relic Density of the Higggs-Aware grid

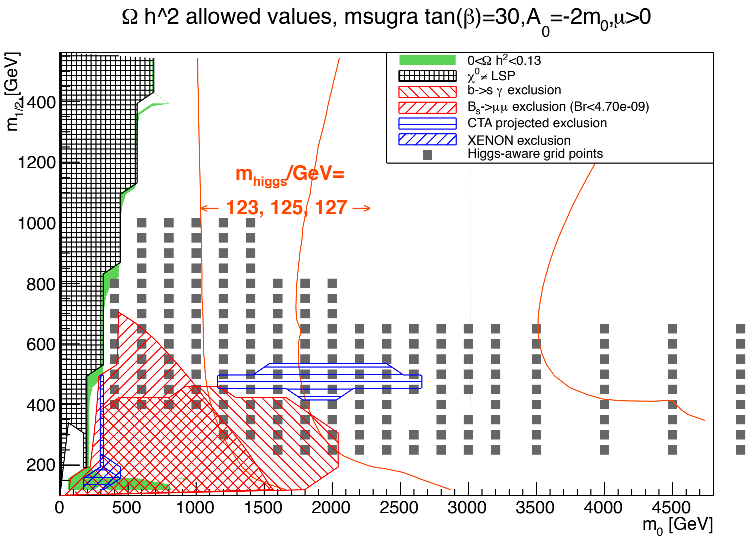


Relic density in the higgs-aware grid, computed for $m_0 < 1000$

Higgs masses



Exclusion in $tan\beta = 45$, $A_0 = 0$



Constraints on the higgs-aware plane, $tan\beta = 30$, $A_0 = -2m_0$, $\mu > 0$

Plans

- ATLAS has produced monte carlo samples for the higgs-aware grid.
- The Bergen particle physics group is working on a one-tau analysis of the 2012 data.
- My plan is to work together with the rest of the Bergen group, which is currently redoing their SUSY with tau analysis, and to compute limits in the higgs-aware plane.

Conclusions

- The Higgs-Aware grid could be of interest for astrophysics as well.
- The Coannihilation region contains viable relic denisities.
- Jan Lindroos [2] has done a markov chain analysis, and identifies a region of viable higgs masses in the same region, with somewhat smaller $A_0 = -2300$ GeV.
- An effort is underway to compute ATLAS limits on the higgs-aware plane.

[2] Burgess, Londroos, Lipniacka & Sandaker, arXiv:1210.7020v1

Questions?

Are welcome!

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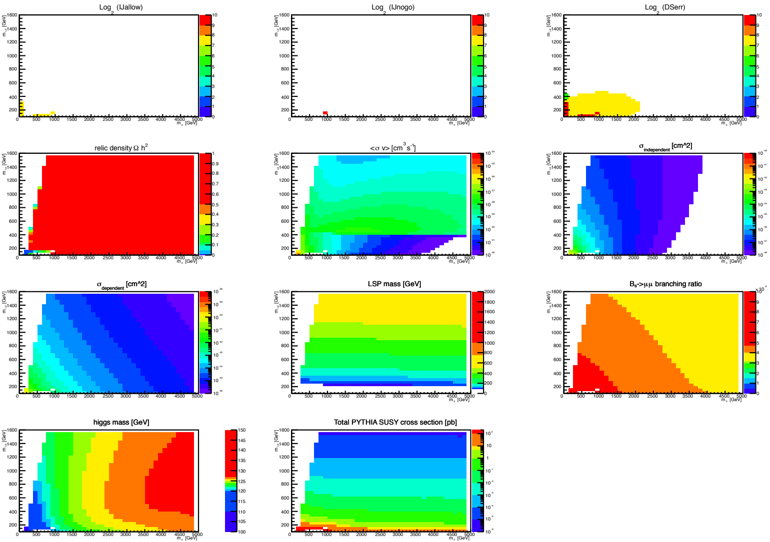
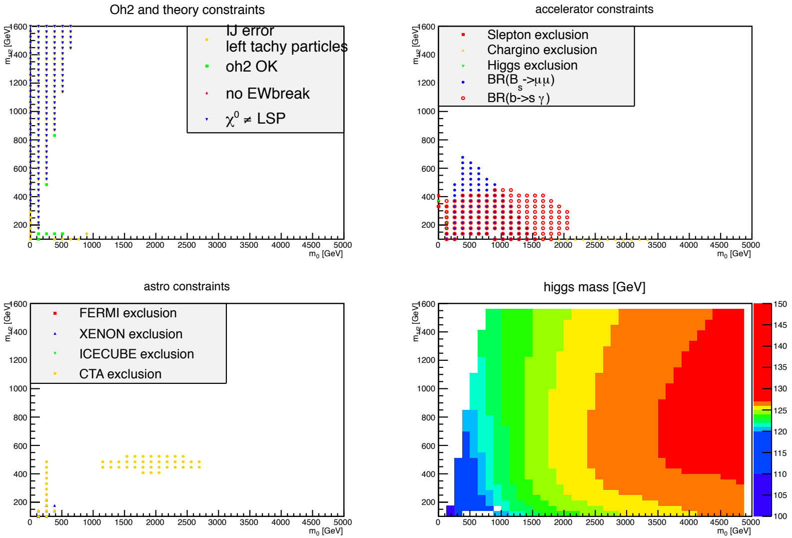


Constraints on the higgs-aware plane, $tan\beta = 30$, $A_0 = -2m_0$, $\mu > 0$



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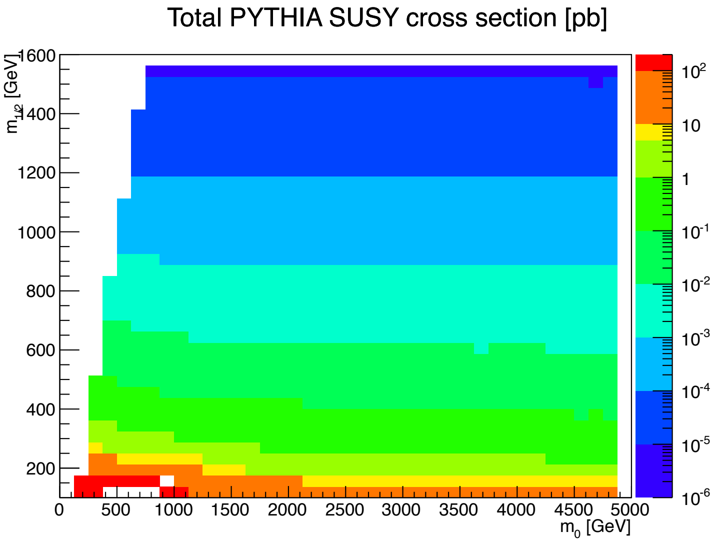
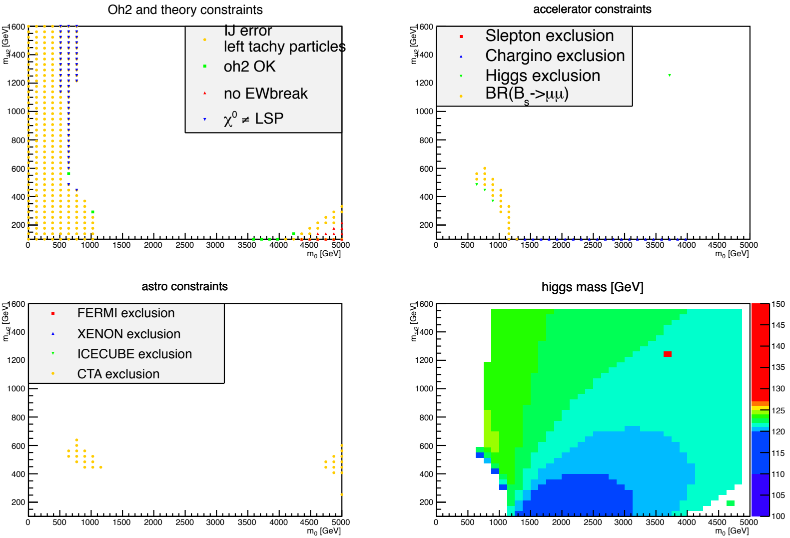


The total SUSY cross-section at 8TeV as computed with PYTHIA



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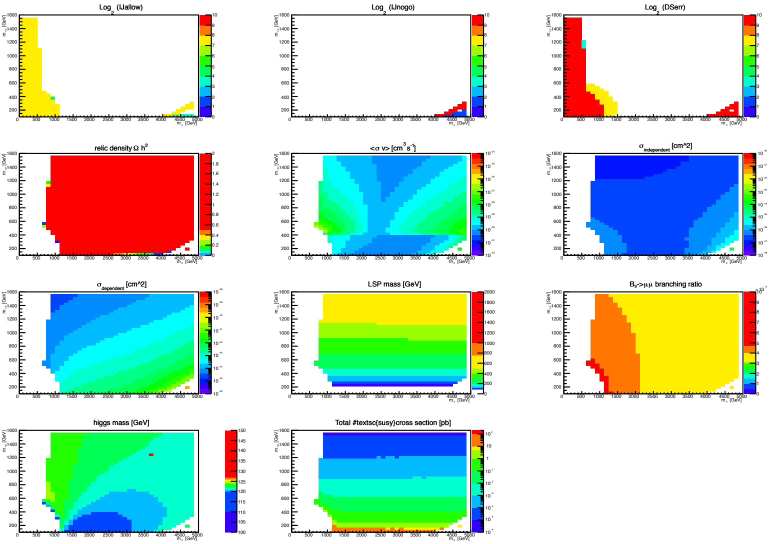

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