BSM: need, expectations for its scale and lessons from early LHC.

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1. State of play in HEP
2. Hymn in praise of the Standard Model(SM) of Particle physics
3. Experimental reasons and Theoretical motivations for going beyond the SM (BSM).
4. Different ways of being BSM
5. **How does LHC probe these ideas?**

The field of High Energy Physics (HEP) had been in a strange situation.

The usual road through which Science progresses:

Existing Theory and Unexplained Phenomena ⇒ New Theoretical developments ⇒ Predictions ⇒ Testing in Experiments.

State in HEP for the past decade(s) or so

Existing Theory **No Unexplained Phenomena!**, demands made by the Community on the properties of a theory ⇒ New Theoretical Developments ⇒ Predictions ⇒ Testing in Experiments.

We have strong theoretical reasons to believe that there is new physics at $\sim$ TeV scale, Dont have *any strong* experimental evidence indicating its need.

The track record of particle physicists is pretty good so far and theoretical developments based on demands of aesthetics alone have been fruitful at getting at the root of fundamental questions.

BUT

The gap between theory and experiment had never been so large!

When we say we expect new physics at the TeV scale are we theorists sure of prefactor before the TeV. How big or small can it be?.

Hope: TeV energy colliders : Large Hardon Collider (LHC) would help unravel the mystery. Data from LHC have started coming, time of reckoning has arrived!

Generalities:

The SM Lagrangian consists of 'proved' gauge sector and **yet to be proved scalar** sector:

$$\mathcal{L} = - \frac{1}{4}F^a_{\mu\nu}F^{a\,\mu\nu} + i\bar{\psi}\, \not{D}\psi$$
$$+ \psi^T \lambda \psi h + h.c.$$
$$+ |D_\mu h|^2 - V(h)$$

Gauge sector in good shape.

The beginning of the spell of the gauge principle was with QED (Feynman, Tomanaga and Schwinger), made much stronger with Non Abelian Gauge Field Theories with Spontaneous Symmetry Breaking (Electroweak: 't Hooft and Veltman) and without symmetry breaking (QCD: Gross, Wilzeck and Politzer)

All these and the idea of Spontaneous Symmetry breaking (Nambu) all have been recognised with the biggest praise: the Nobel prizes..last one coming in 2008.

But no direct evidence yet exists for the last piece of the Gauge Paradigm : the scalar sector!

Let us recall what theory has to say about it and What is the experimental information on it?

A consistent mathematical description of all – The low energy and high energy– phenomena in the world of fundamental particles, is possible in the framework of Renormalisable, Relativistic Quantum Field Theories, provided they possess gauge symmetries. The formulation based on gauge principle is what has elevated the 'model' to a 'theory' though we still call it a **Model**.

't Hooft and Veltman showed us that precise calcualtions can be done in the framework of spontaneously broken non ablelian gauge field theories.

General consensus: Renormalisable QFT's hold a lot of truth about forces of nature!

The SM is description of the *three* fundamental interactions in terms of a $SU(3) \times SU(2) \times U(1)$ invariant theory. **All these aspects have been established well enough to be text book material now.**

Is that the whole truth? Is this a time for a paradigm shift?

Quantum Field Theories are sort of a 'low energy' paradigm. 'String' theories might be the language to use once you want to include gravitation.

Jury is more than out on this point!

This may be one lesson that the LHC might teach us. That is why the LHC is a watershed!

In general Quantum Field Theories have consistency problems and calculations yield infintities.

As a matter of fact till the renormalisation procedure provided a way to compute observables in an unambiguious way, Field Theories had been put on a shelf as it were.

'Renormalisability' guranteed by symmetries of the theory.

Quantum Electro Dynamics (QED): Agreement of $(g-2)_e$ between the theoretically predicted and experimentally measured value is one of the triumphs of the theory.

Massless nature of the γ guranteed the renormalisability.

Theory of weak interaction: Rapid energy rise of (say) $\sigma(e^- \nu \to e^- \nu)$ implied unitarity vioaltion at high energy.

Problem can be solved by postulating mass for the mediator of weak interactions the W, Z.

Led to a new problem in that the theory of massive W/Z bosons does not have renormalisability.

The famous mechanism of spontaneous symmetry breaking allows one to have the cake and eat it as well! $\Rightarrow$ Electro-Weak unification.

A **renormalisable** ElectroWeak theory needs a scalar (spin=0) field (Higgs Boson), which may or may not be a fundamental particle.

The interaction of the Higgs bosons with all the other particles is decided by the symmetry breaking mechanism, the interaction of everything with W/Z and the self interactions all decided by the symmetry itself!

Note : no fundamental scalar has been found so far in nature.

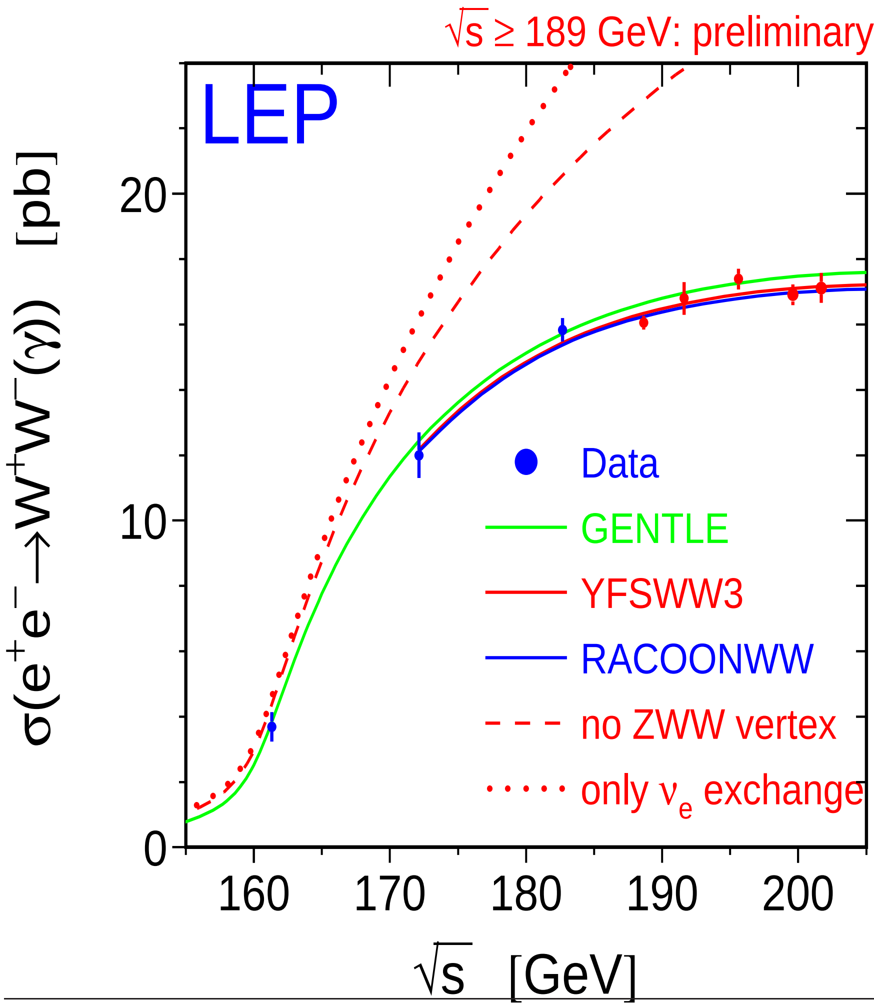
Renormalisability leads to ability to make high precision quantitative predictions in perturbation theory, if the coupling is small.

Unitarity:

The existence of the Higgs boson with precisely the same interactions as predicted in the SM can also be inferred by simply demanding that the scattering amplitudes for $W^+W^- \rightarrow W^+W^-$ etc. satisfy unitarity.

The arguments simply tell that there should be a 'S-wave' contribution to the scattering amplitude which will tame the bad high energy behaviour and hence restore unitarity. Only a rough idea on the scale of this high energy ULTRA-violet 'completion' of the theory.

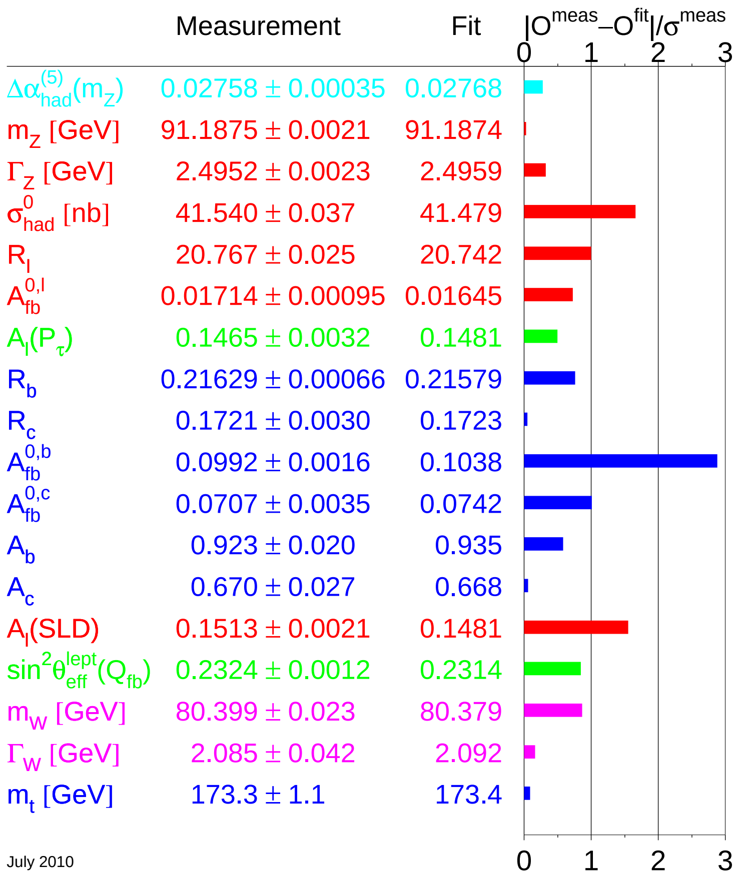
Direct 'Proof' of Symmetry and Symmetry breaking!!



Proof that electroweak symmetry exists and that it is broken.

The triple gauge boson ZWW coupling tames the bad high energy behaviour of the cross-section caused by the t-channel diagram. Direct proof for the ZWW coupling.

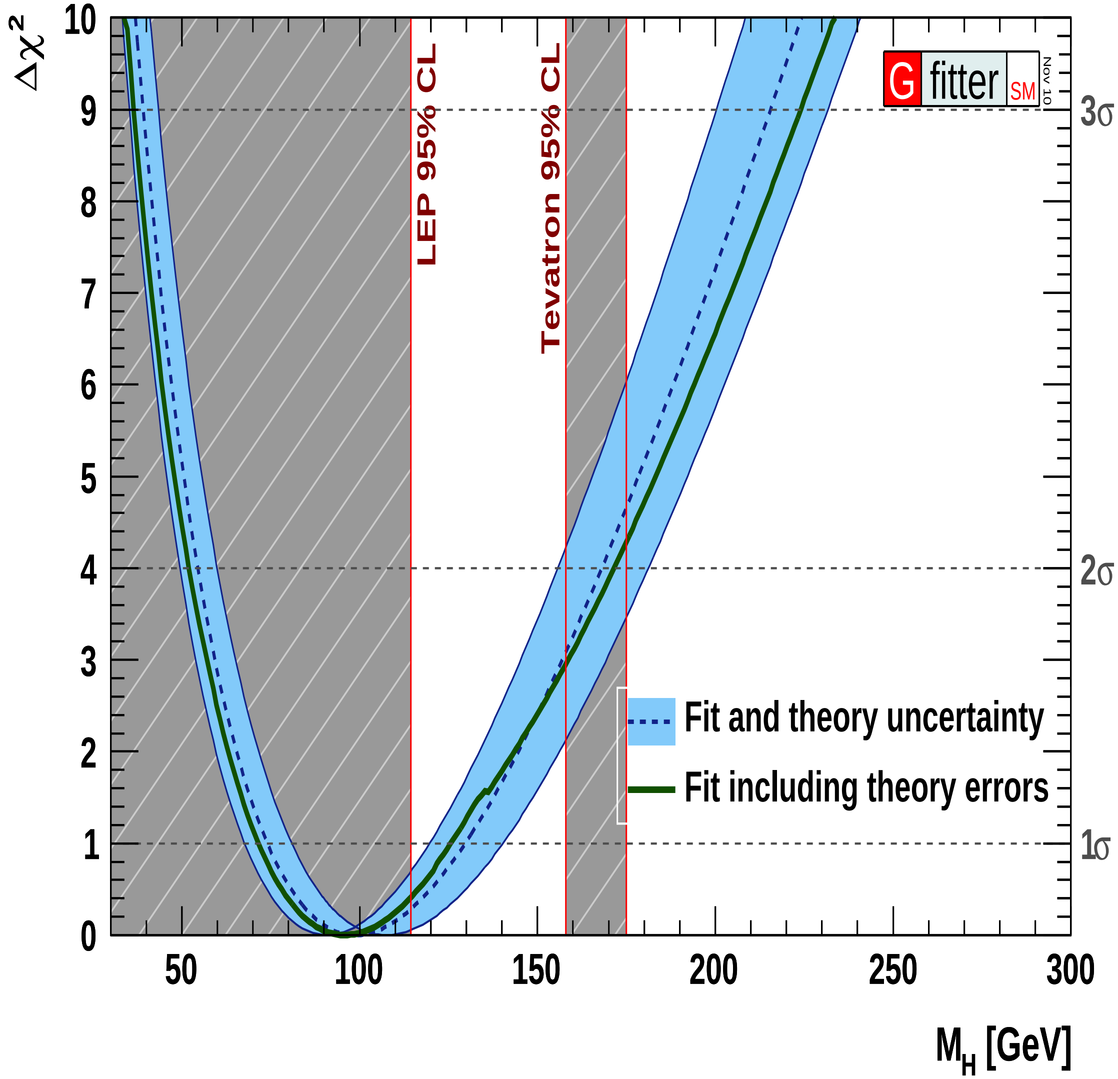
This and precision testing, confirm basics of the SM



- All the current experiments have tested the perturbative predictions of the Standard Model (SM) to an **unprecedented** accuracy.
- **May be holds also some clues of Physics beyond the SM**

see http://lepewwg.web.cern.ch

What does it mean for the Higgs? If all the current information is put together the Higgs mass should be less than 150 GeV. (**indirect experimental limit!**)

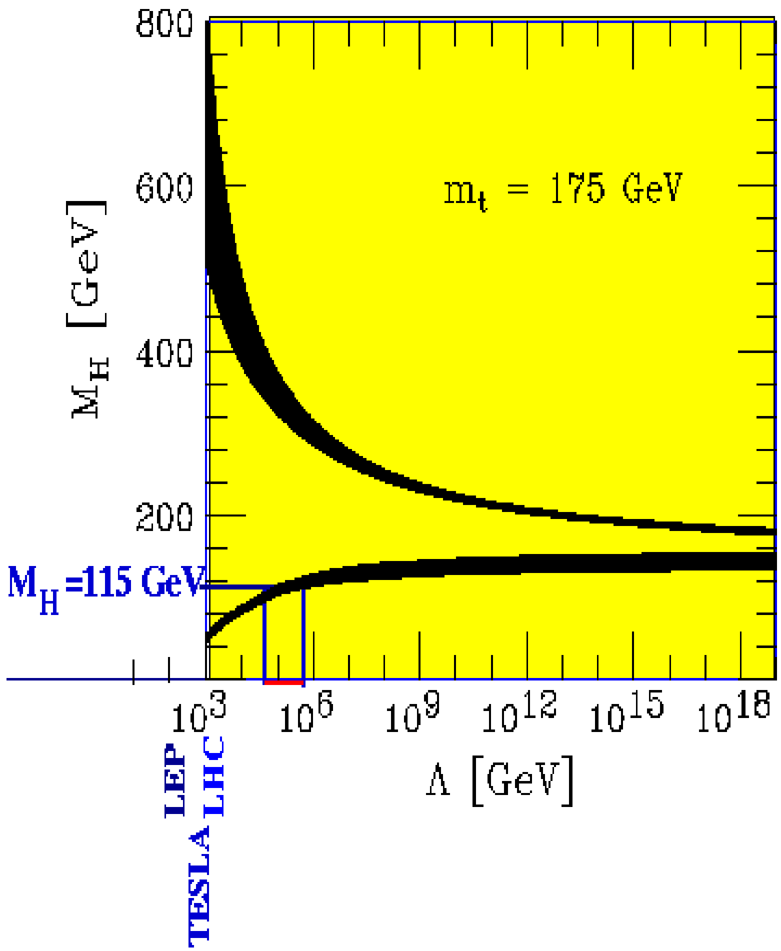


Does the SM have anything to say about what the Higgs mass should be?

Theory predicts the interactions of the Higgs boson, BUT is *completely* silent about its mass.

Note : Just the mass of the Higgs when observed can give nontrivial indication on the BSM physics!

A heavy Higgs ($\gtrsim$ 300 GeV) would mean new physics around a few TeV.



There are only limits. These come from theoretical arguments such as demanding unitarity of $WW \to WW$ scattering amplitudes and some more involved technical arguments which arise from technical issues involved with a quantum field theory for a scalar particle (Triviality).

• If there is no new physics beyond the SM upto M_{pl} then $m_h c^2$ restricted to a narrow range between 130 to 200 geV. A general bound is $\sim$ 800–900 Gev if $\Lambda = 1$ TeV.

• **If there is new physics scale > 1 TeV, the theoretical bounds on the masses may be dfferent.**

- Direct limit on the SM higgs mass is 114 GeV.

- 'Indirect limit' in the SM is 150 GeV.

In the SM, $115 < m_H < 150$ **GeV.**

- If SM is all that we have, $130 < m_h < 200$ GeV (theoretical)

Lessons:

- The EW precision data like a light higgs.

- ANY discussion of alternate scenarios of symmetry breaking MUST always pass the **precision** test.

- Models where the direct and indirect experimental Higgs mass bound can be violated quite often predicts new particles which will show up at the LHC.

- If $m_h > 700/800$ GeV then our understanding of EW symmetry breaking, based on perturbative ideas is not correct.

- Need to keep an open mind and open eye.

Last decade great progress in the flavour sector:

The correctness of CKM picture, ν oscillations...

SM needs to be augmented by

$$\mathcal{L}' = \frac{1}{M} L_i \lambda^{\nu}_{ij} L_j h^2 \text{ and/or } L_i \lambda^{\nu}_{ij} N_j h + h.c. \quad (1)$$

Neutrinos are special in that they are neutral and many new physics ideas have implications for neutrino mass generation which can *in principle* be different from other fermions. (Beyond standard model..)

1] Neutrinos have nonzero masses *and* the fermion masses have a huge hierarchy

SM has bearing on on issues cosmological and needs BSM physics as well.

2]. The contents of our periodic table seem to account for ONLY 4% of the matter in the Universe! Astrophysical evidence pretty convincing.

Dark Matter: exptal information indicates a BSM particle Dark Energy: ???Many many ideas..

3] **A** *qualitative* **explanation of the** $B - \bar{B}$ **asymmetry in the Universe, in terms of** *known* **CP violation in the SM,** *measured in laboratory*, **is possible.**

A quantitative explanation indicates need of Physics beyond the SM.

All the progress in particle physics has come by trying to 'explain' why the particles have precisely the properties they have!

One simple example:

$1/r$ dependence of the Coulomb Potential is due to the 'zero' rest mass of the photon! Zero rest mass of the photon is due to the fact that Maxwell's equations have gauge invariance.

The fact that SM works so well means

1) a Higgs OR a look alike must exist and data tell us it must be light!

2) We should also understand why it is light!! Our current theories will predict that it should be as heavy as can be!!! **One disagreement with the SM?**

This is one reason for expecting physics beyond the Standard Model!!

The hierarchy problem :

The EW theory has been tested at 1-loop level. The Higgs mass which is a free parameter in the SM, receives large quantum corrections and the mass will approach the cutoff scale of the theory.

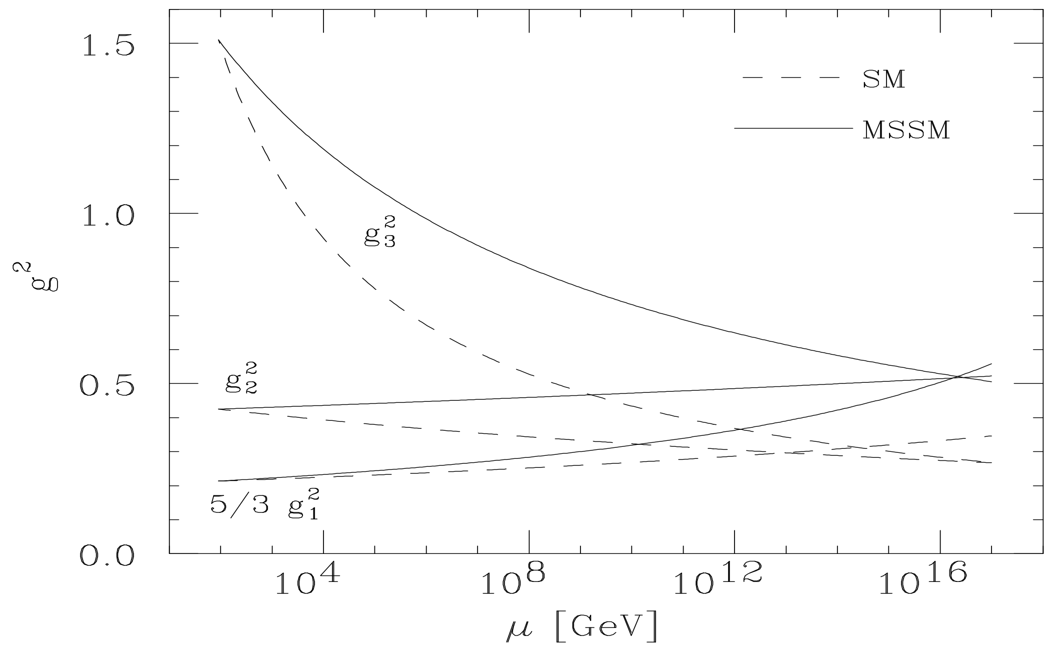
If, $m_{\mathsf{h}}^2 = m_{\mathsf{bare}}^2 + \delta m_{\mathsf{h}}^2$ the top loop (e.g.) gives

$$\delta m^2_{\mathsf{h|top}} \sim -\frac{3G_{\mathsf{F}}}{2\sqrt{2}\pi^2} m_t^2 \Lambda^2 \sim -(0.2\Lambda)^2.$$

The light higgs is 'natural' then only if $\Lambda \sim$ TeV.

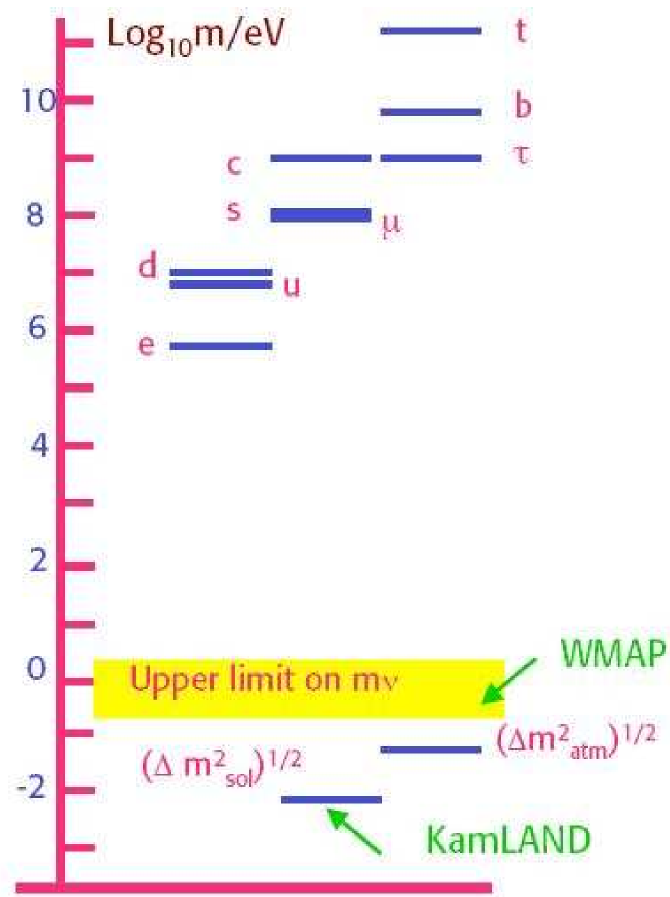
A little more 'experimentally' motivated hint for BSM?:

- Do strengths of all the interactions unify at some high energy?
- with Supersymmetry (still to be discussed) there is some evidence that they might.
- Models to explain observed mass patterns, all like unified models.



More experimentally motivated hints for Physics Beyond the SM?:

- Neutrinos have nonzero masses *and* the fermion masses have a huge hierarchy
- Aesthetics: in the SM all these masses are just arbitrary parameters. Can we have a fundamental understanding of these? This might sound esoteric, but a lot of progress actually has come from asking such questions.
- Non zero ν masses already *indicate* BSM!
- Generation of small ν masses 'naturally' possible with elegant ideas for BSM physics.
- This in turn can be tested at colliders.



- Dark Matter makes up 23% of the Universe.!
- Direct evidence for the nonzero ν masses
- Quantitative explnation of the Baryon Asymmetry in the Universe!

- **Instability of the EW scale under radiative corrections.**
- Need to get a basic understanding of the flavour Issue
- Unification of couplings
- Inclusion of Gravity in the picture?

We know at present two ways to keep the Higgs 'naturally' light:

1] Introduce a symmetry:

Supersymmetry : cancel the large top loop contribution by contributions from scalars. There exist host of new particles which we should see at the colliders, *around* TeV scale.

OR

Little Higgs models: The Higgs mass is small because its mass is protected as it is a pseudo goldstone boson. There exist many additional fermions, gauge bosons in the theory at the TeV scale.

2] The cutoff is lowered to TeV:composite models and brane-worlds. Brane Worlds postulate behaviour of the space and time different from what we understand, such as additional compactified dimensions! new developments: String theories have begun to make some statements about such models!

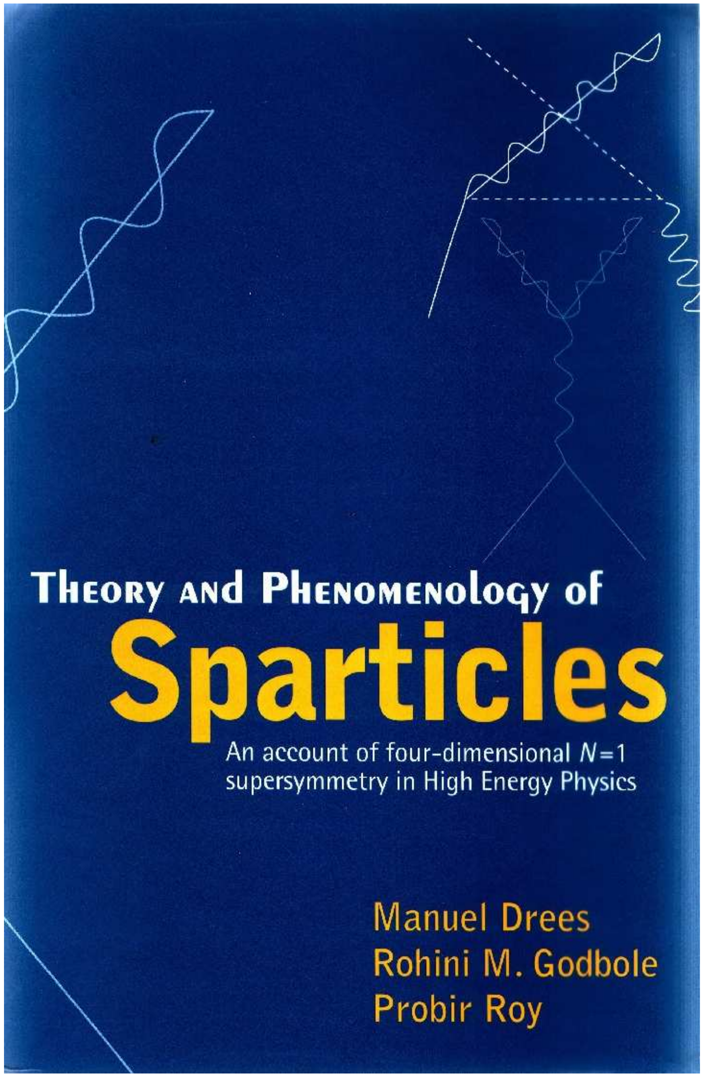
3]Higgsless models?

Little Higgs or Higgsless models in genreal have problem passing the acid test of LEP precision measurements. Issues of ultraviolet completions seem to reintroduce a high scale (much above a TeV scale) Supersymmetry.

Associated with every particle there is a supersymmetric partner! For it to solve the problems we need the partners to have a mass M such that $Mc^2 < 1000$ GeV **We see no evidence for superpartners in current experiments!**

No clue for SUSY breaking mechanisms and scale! String theory based ideas might give some directions! Interaction between phenomenologists and string theorists.

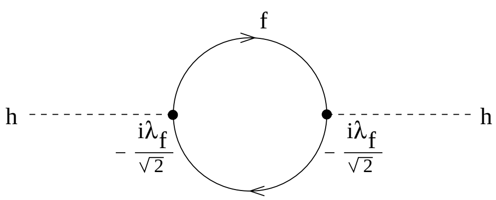
Combining SUSY with unification is the most natural and also necessary.

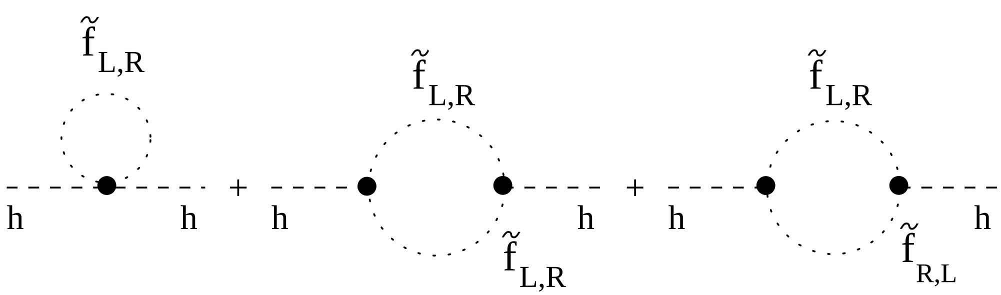


1)Supersymmetry

Theoretically extremely elegant and attractive: Spacetime symmetry, finite ultraviolet behaviour.

How is the stabilisation brought about?





Thus the sparticle loops cancel the large self energy corrections and keep the higgs mass 'naturally' small.
(R. Kaul)

Eqally important: As we saw the data seem to *like* a light Higgs.

A ready made DM candidate in case of R-parity conservation.

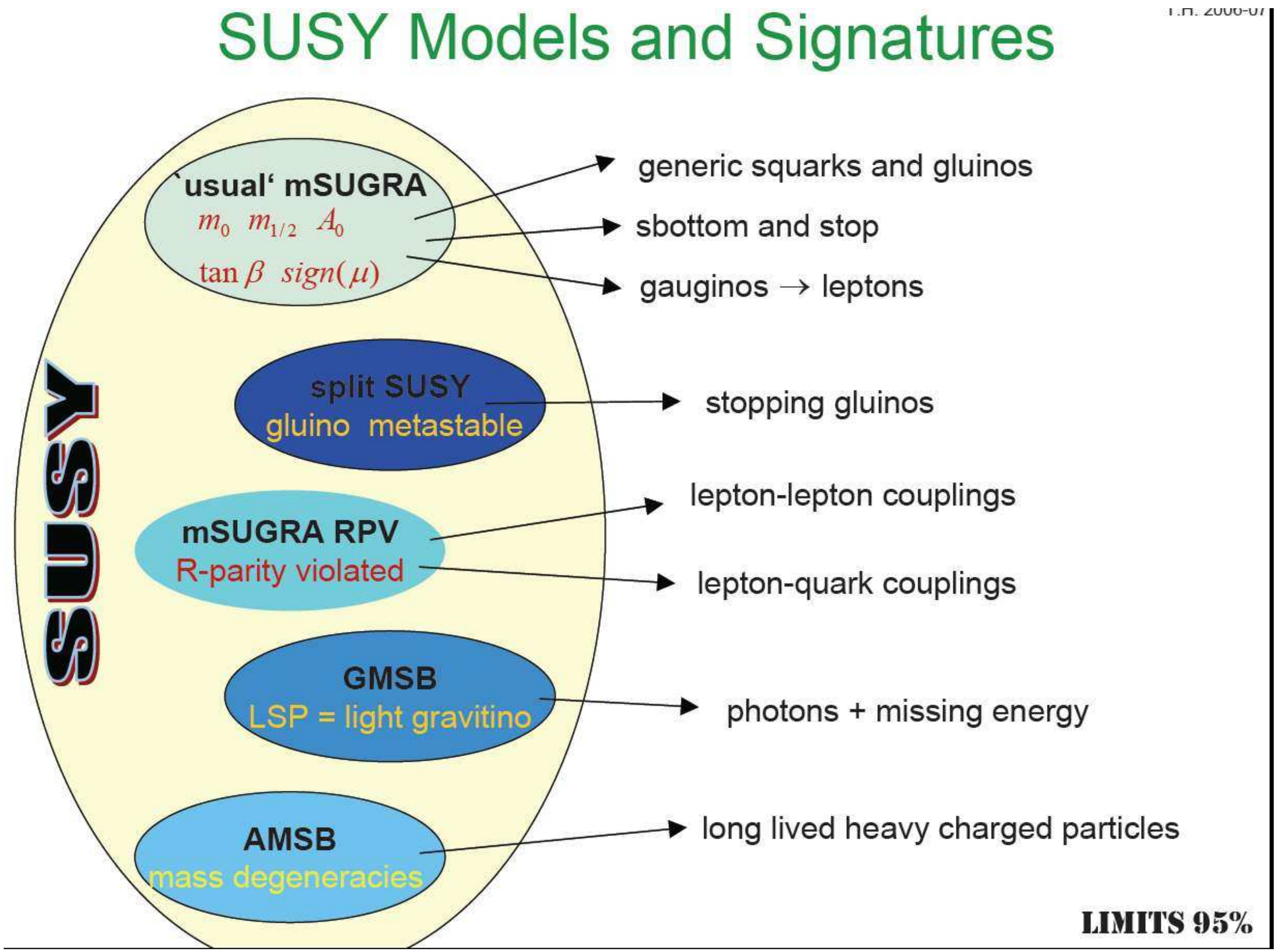
But the Higgs is not 'soo' naturally light unless sparticle masses are small.

A ready made DM candidate in case of R-parity conservation.

Search for SUSY is the case of experiments chasing a beautiful theoretical idea.

It is *clearly* broken. ALL the experiments have so far only given NEGATIVE results, giving LOWER limits on sparticle masses.

The symmetry is beautiful, the ideas of how to break it are mostly not!


SUSY Models and Signatures
T.H. 2006-07
SUSY
`usual' mSUGRA
m_0 $m_{1/2}$ A_0
$\tan\beta$ $sign(\mu)$
generic squarks and gluinos
sbottom and stop
gauginos → leptons
split SUSY
gluino metastable
stopping gluinos
mSUGRA RPV
R-parity violated
lepton-lepton couplings
lepton-quark couplings
GMSB
LSP = light gravitino
photons + missing energy
AMSB
mass degeneracies
long lived heavy charged particles
LIMITS 95%

NON-obseration of direct SUSY signal anywhere so far is not only discouraging, but also points to a problem called 'small hierarchy problem'.

The LEP Higgs mass limit implies rather heavy supersymmetric partner of the top $\sim$ TeV, if $A = 0$ which is not 'natural'. Light stop admitted with large A_t.

More generally, in SUSY models the EW symmetry breaking is radiatively induced. This means a relationship between M_Z and other SUSY parameters, masses. With sparticles as heavy as required to satisfy the LEP Higgs mass limit, a fine tuning of a percent or more is required to satisfy this relation. **Naturalness may be lost! (Guidice, Rattazi 06)** Non minimal (NMSSM) cures this problem to a large extent.

Are we being fussy?

Keeps the Higgs light! But sparticle should not be too heavy. What is 'too heavy'? When should we be worried?

Predictive: Higgs mass limits, quite robust with respect to SUSY breaking parameters.

WIMP miracle happens easily. Ready made DM candidate. But in CMSSM again it is now under great scrutiny. Good point: predictive in a given model.

Baryogenesis works. Requires NMSSM and/or additional CP violation.

Can address ν masses, but requires R-parity violaton.

Flavour physics: SUSY has no neat solution. B physics measurements put it under strain in fact.

Local supersymmetry : Supergravity contains automatically Einstein Gravity.

String theory requires Supersymmetry, BUT REMEMBER NOT TEV scale Supersymmetry.

Question:

1)Should we be worried now with the newer exclusions from CMS/ATLAS?

Is it still 'natural'? In T. Huxley's words will SUSY be a great tragedy of science: 'A beautiful theory slain by an ugly fact?'

2) Synergy between the DM experiments and LHC experiments?

3) What are the chances of SUSY detection given the current CMS/ATLAS results?

I will address this in the light of LHC data later.

Some general features of Xtra dimensional theories (idea began with Kaluza and Klein)

• Observed world has 3 space time dimensions, embedded in a higher D-dimensional spacetime, $D = 3 + \delta + 1$.

• Additional space dimensions will modify Newtonian Gravity at short distances. Experimental constraints on the *absence* of such deviation constrains the 'size' of the extra dimensions, which must be compactified.

• These theories will always have a graviton (spin 2 particle) as well as tower of Kaluza Klein (KK) excitations of which the normal SM particles are the zero modes.

• Gravity propagates into the bulk always, such that the strength of gravity on the 3-brane that is our world is the usual small value. Different Xtra dimesional models differ in the behaviour in the additional δ dimensions called the 'bulk'.

a How many extra dimensions?

b What is the size of the Xtra dimensions? What is the 'size' of the bulk? ('large' extra dimesions, TeV^{-1} dimensions)

c What is the geometry of the additional dimensions? (warped or otherwise?) (Randall Sundrum and many variations thereof)

d Which particles propagate into the bulk?

e Symmetries that the KK spectrum has (Universal Extra Dimension: UED)

f Interesting flavour physics model building possible in RS picture.

- Extra dimensions are an exciting idea. Very interesting that it is compatible with the data. Provide an intimate link with structure of spacetime and technical problems in particle physics

- None of the models is completely free from fine-tuning. RS the best and hence the template of almost all the ED phenomenology these days.

- There is no way to determine the number of the extra dimensions. We do not understand dynamically why some of the dimensions are compact

- Phenomenology is highly model- dependent: only spin-2 graviton is unique, if it (the spin) can be determined.

• Predictions for collider signals in some cases depend on the Ultra-violet completion of the theories. Counterpart of uncertainties about SUSY breaking (to some extent). In general less predictive than SUSY.

• EWPT not always easy.

• KK parity gives DM candidate.

• Does not address the different reasons for BSM as well as SUSY.

Currently we only have limits on sparticle masses (for given SUSY breaking scenarios) or on the scale Λ of the extra dimensional theories.

Interesting question: in spite of these -ve results do SUSY and ED have anything to say about the recent Tevatron anomalies.

I]

Tevatron has reported A_{FB} in $t\bar{t}$ production at a level of few σ:

Do either SUSY and/or ED have possible explanations?

i) RS KK gluons can perhaps do it..but do not quite find it easy to get the large asymmetry at the same time keeping $t\bar{t}$ spectrum unchanged!

(Djouadi, Moreau, Richard,Singh 0906.0604, Masip, Santiago et al: 1105.3333)

ii) R-parity violating SUSY: 0912.1447

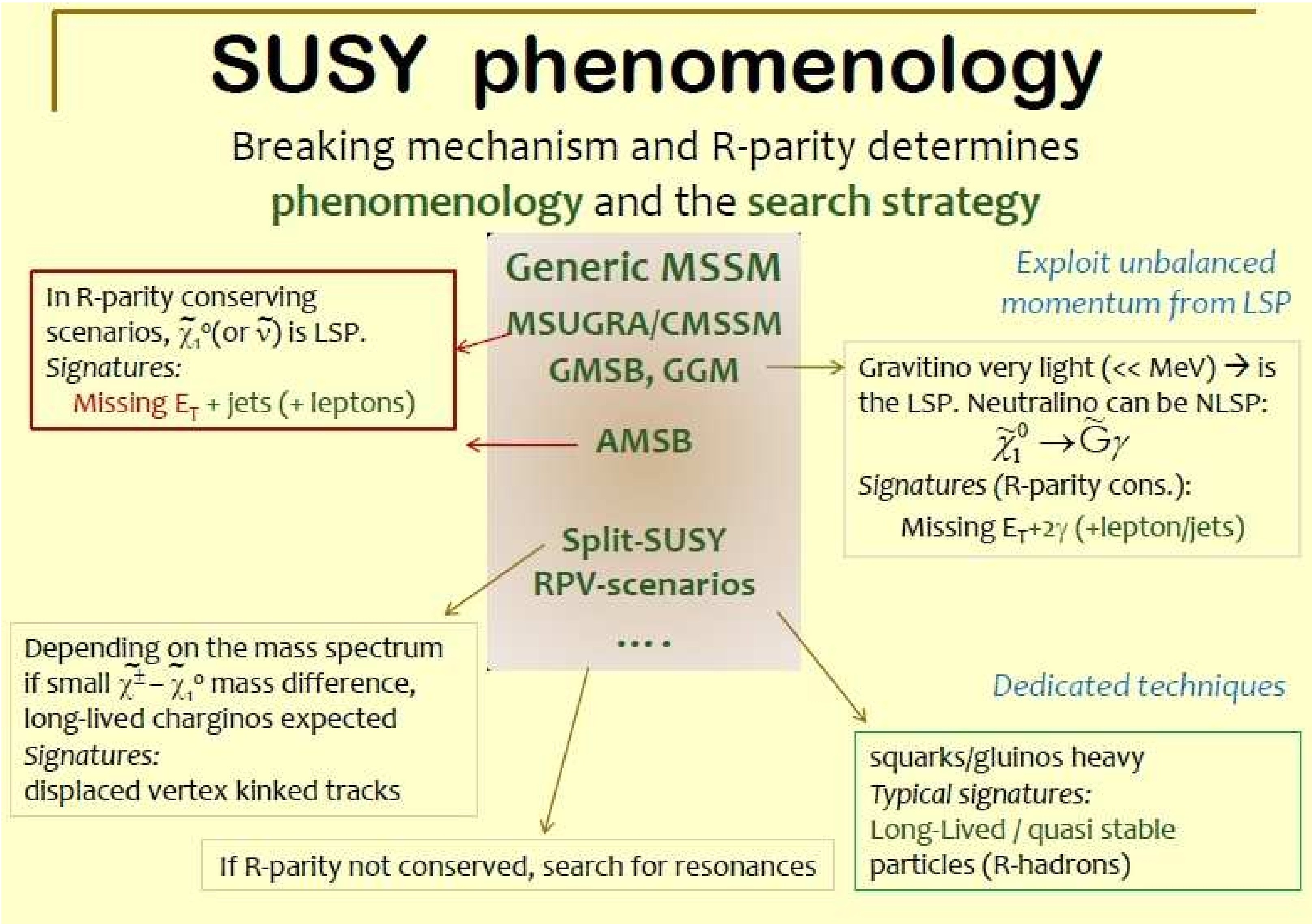
iii) Light stop: Isidori et al: 1103.0016

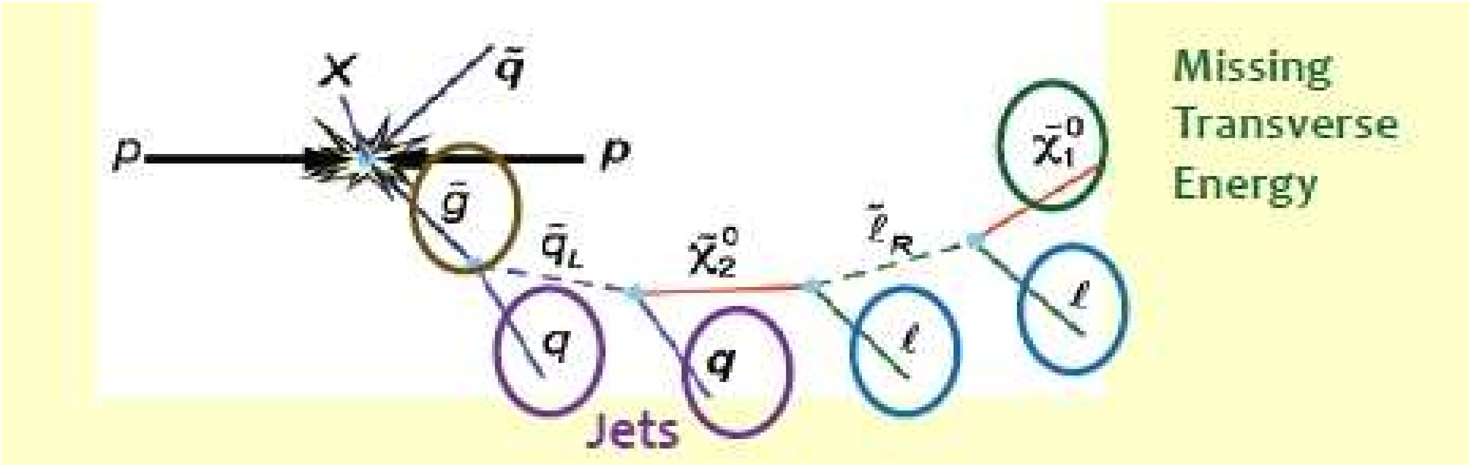
Gravitons produced in a collision can fly off into the extra dimensions, carrying energy-momentum, which would seem to disappear from the brane. (missing energy-momentum signatures).

Virtual graviton exchanges can look like neutral current interactions.

UED signatures can be similar to SUSY cascade decays. These also have a DM candidate. Spin of the DM candidate here will be zero.

RS Models: Higgs phenomenology can be affected by a possible presence of a scalar Radion. The scalar should be light. Heavy Gravitons/KK gluons resonances possible.


SUSY phenomenology
Breaking mechanism and R-parity determines
phenomenology and the search strategy
Generic MSSM
MSUGRA/CMSSM
GMSB, GGM
AMSB
Split-SUSY
RPV-scenarios
....
In R-parity conserving scenarios, $\tilde{\chi}_1^0$(or $\tilde{\nu}$) is LSP.
Signatures:
Missing E_T + jets (+ leptons)
Exploit unbalanced momentum from LSP
Gravitino very light (<< MeV) → is the LSP. Neutralino can be NLSP:
$\tilde{\chi}_1^0 \to \tilde{G}\gamma$
Signatures (R-parity cons.):
Missing E_T+2γ (+lepton/jets)
Depending on the mass spectrum if small $\tilde{\chi}^{\pm}-\tilde{\chi}_1^0$ mass difference, long-lived charginos expected
Signatures:
displaced vertex kinked tracks
Dedicated techniques
squarks/gluinos heavy
Typical signatures:
Long-Lived / quasi stable particles (R-hadrons)
If R-parity not conserved, search for resonances



A lot of work over the past decades done by theorists on

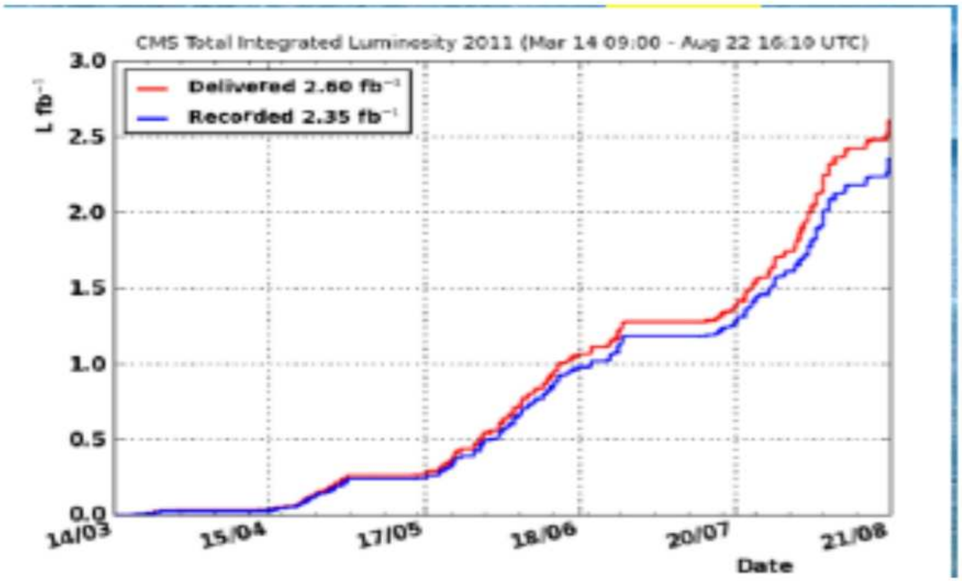
1)How to compute the expected particle spectra for a given SUSY breaking scenario

2) How to compute expected cross-sections for sparticle production

3)What are 'tell tale' final states and signatures for different SUSY models.

That needs to be used once the experimentalists tell us if they have seen any events above the background.

With the low luminosity available currently the SUSY searches are sensitive to the strongly interacting sparticles: gluinos and squarks.


CMS Total Integrated Luminosity 2011 (Mar 14 09:00 - Aug 22 16:10 UTC)
Delivered 2.60 fb⁻¹
Recorded 2.35 fb⁻¹
L fb⁻¹
3.0
2.5
2.0
1.5
1.0
0.5
0.0
14/03
15/04
17/05
18/06
20/07
21/08
Date

Direct searches:

ATLAS has seen even less events than the expected background, but consistent with it. Limits more stringent than expected. This also means: limits to evolve only somewhat slowly with increased statistics.

CMS has seen perhaps a very slight excess in one analysis. Nothing to get excited about but to keep eyes glued to the space.

Experimentalists have interpreted the results in terms of parameter space in the so called CMSSM: where the large number of MSSM parameters (105) to only 5.

At Tevatron 95% c.l. and 99% c.l. exclusions not too different. Not clear the same can not be said of the current (at least) ATLAS limits.

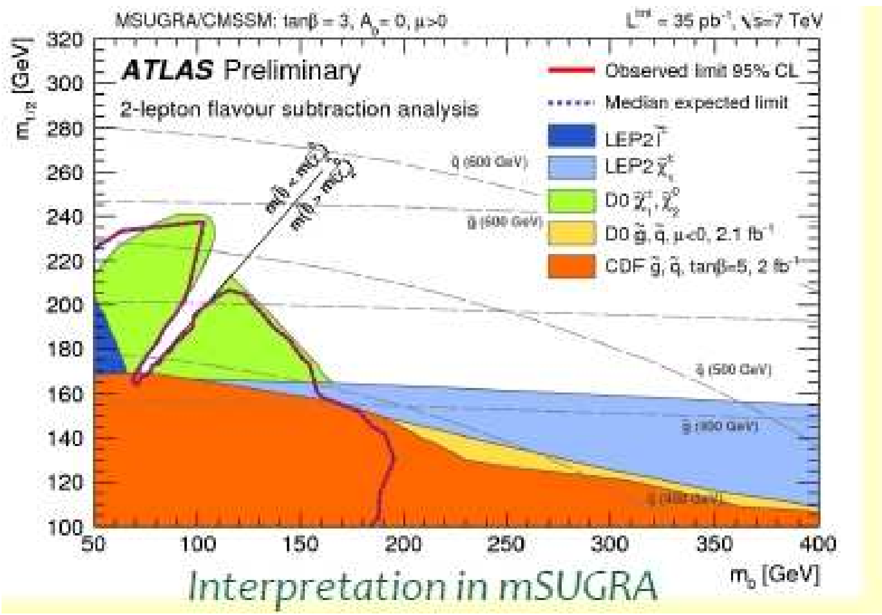
A summary: http://thp.uni-bonn.de/groups/drees/book.html

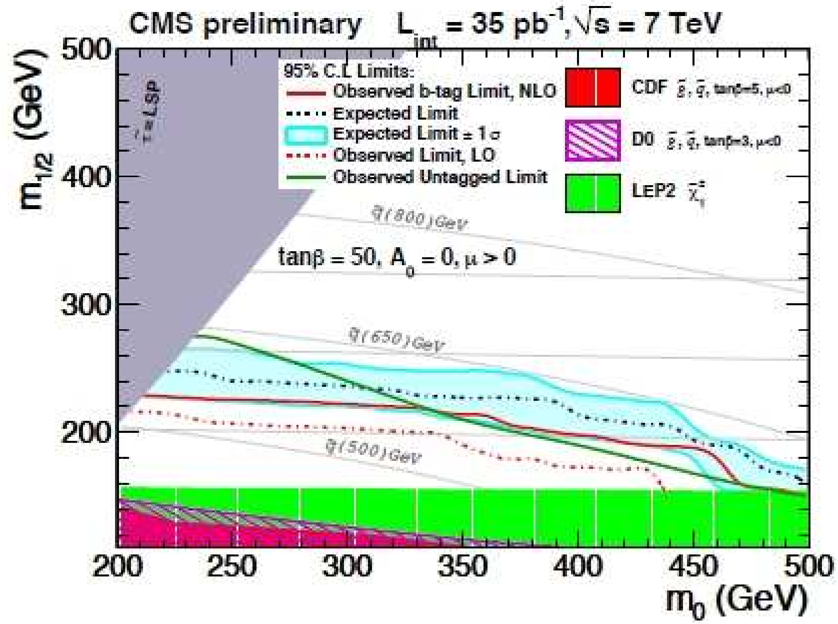
Theorists have

i) Analysed the effect of these data for the best fit to a variety of all the other data such as $(g-2)_\mu, B \to s\gamma$, requiring that SUSY gives the right amount of DM and analysed what region gives the best fit for guiding the next round of searches which are going on now (Ben Allacnach and collaborators, arXiv: 1102.3149v4, 1103.0969v3)

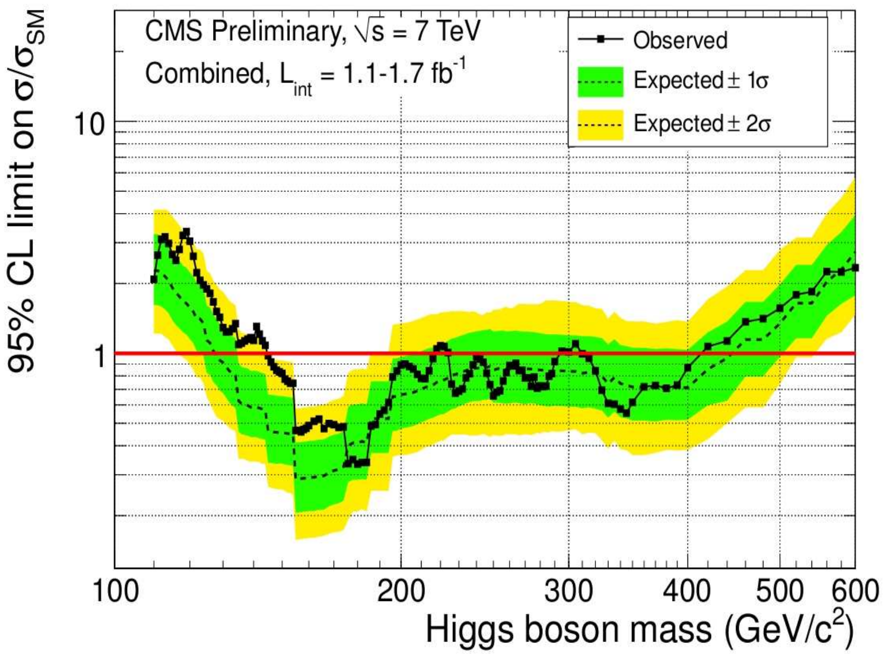
ii)interpret results in terms of a more relaxed set of parameter space than CMSSM and see whether the exclusions are still valid, J. Hewett, T. Rizzo and collaborators, SLAC-PUB-14382. They have done the exercise only for the ATALS TDR results. But now they can perhaps redo their analysis for the actual limits (PMSSM?)

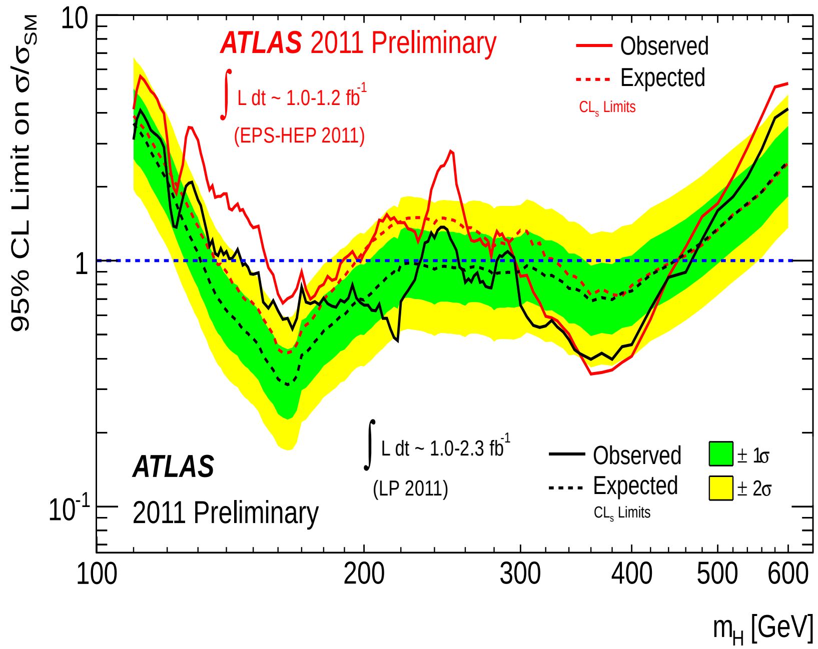
iii) See how much worse the fine tuning problem has become Strumia: 1101.2195v1



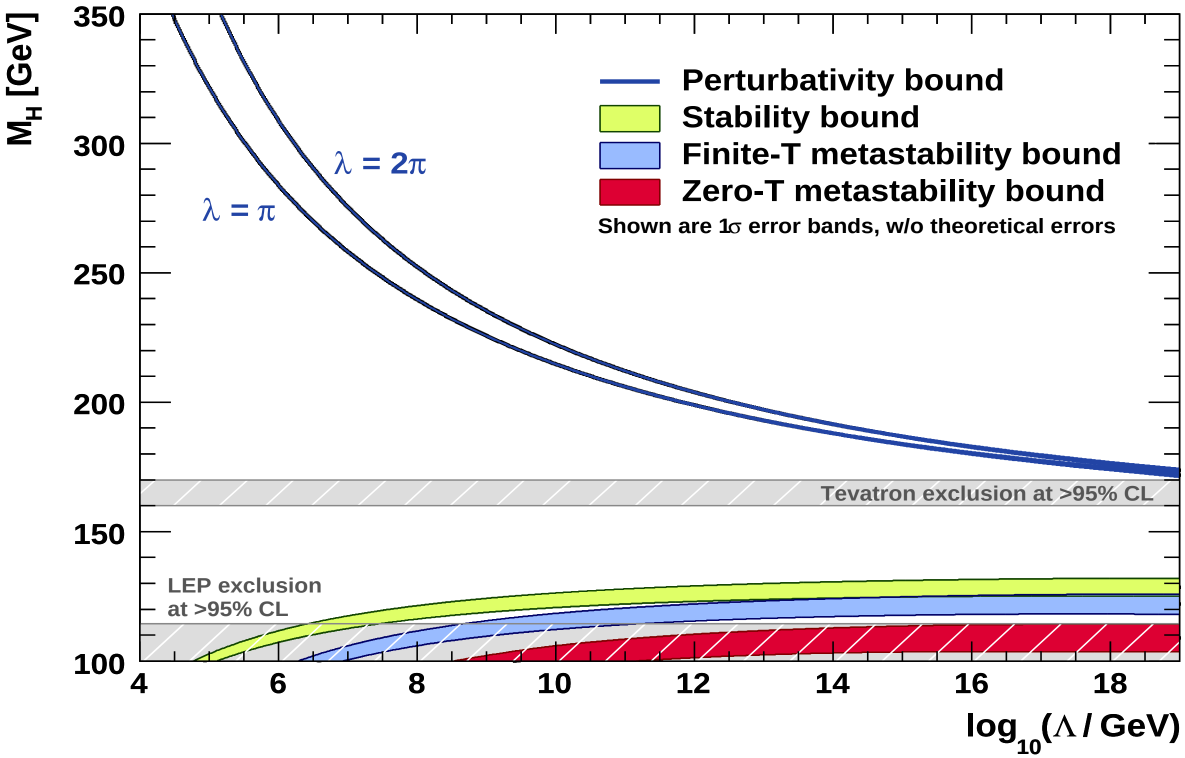


ATLAS CMS data interpreted in CMSSM



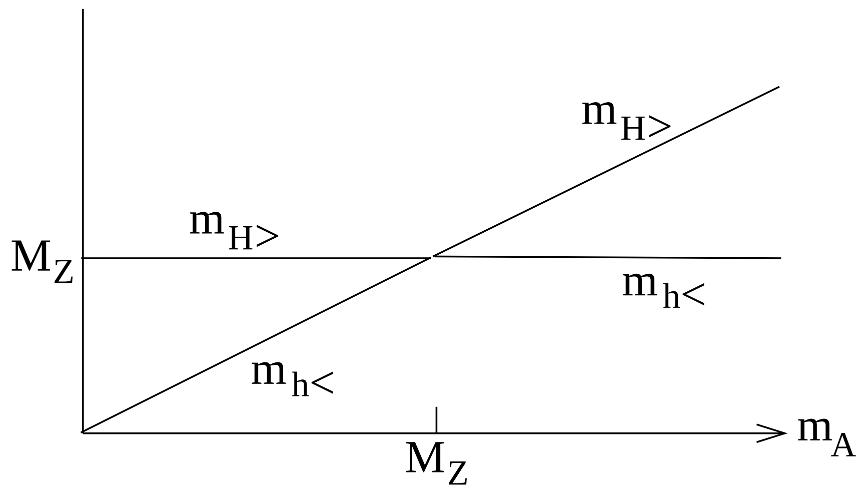


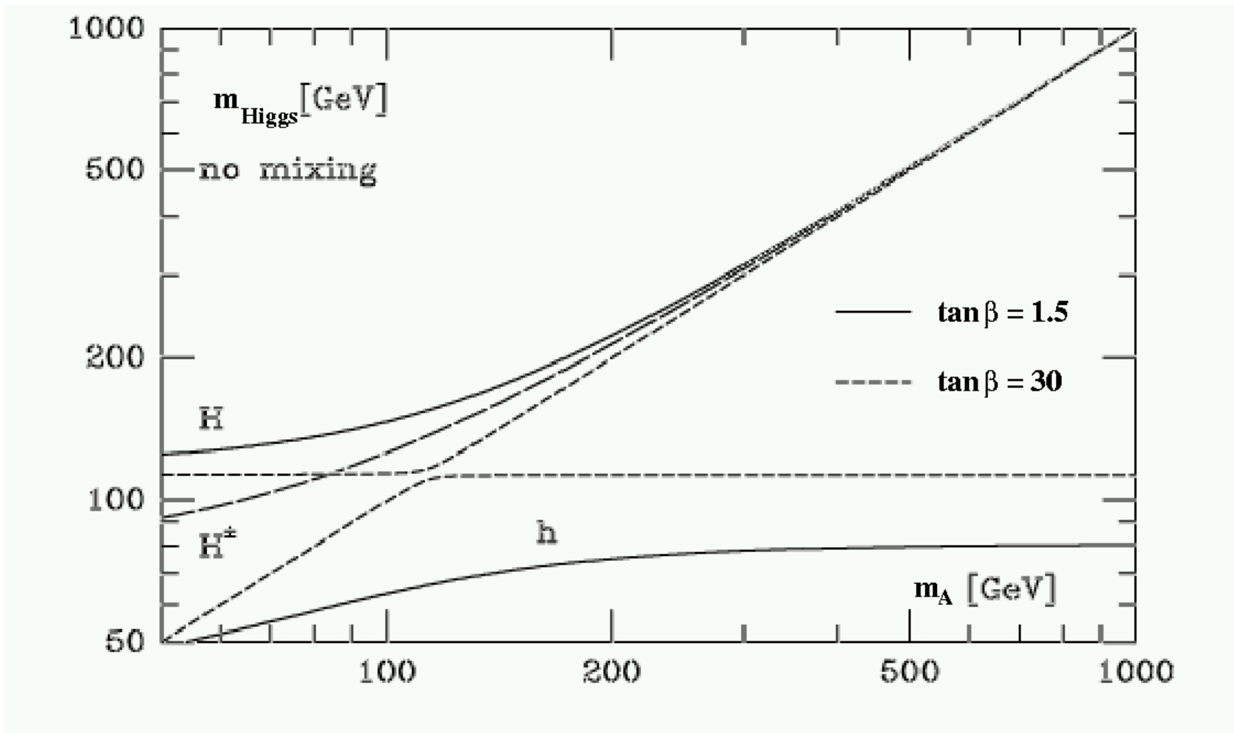
The mass of the Higgs when we see it should already help us a lot in guiding us, as much as the direct searches if not more!



Perturbativity bound
Stability bound
Finite-T metastability bound
Zero-T metastability bound
Shown are 1σ error bands, w/o theoretical errors
λ = 2π
λ = π
Tevatron exclusion at >95% CL
LEP exclusion
at >95% CL
M_H [GeV]
log_10(Λ / GeV)
350
300
250
200
150
100
4
6
8
10
12
14
16
18

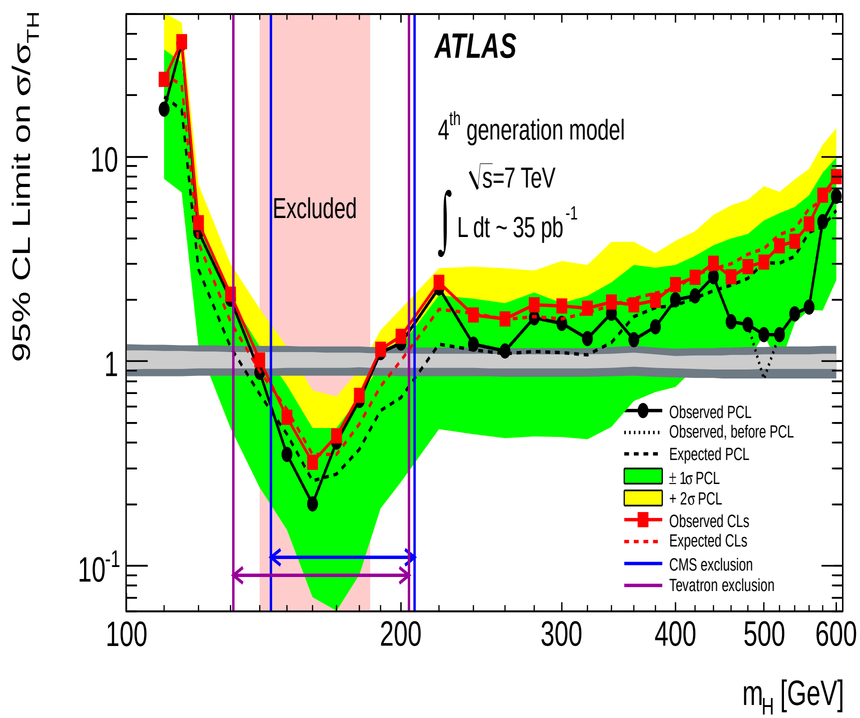
Without and with radiative corrections.

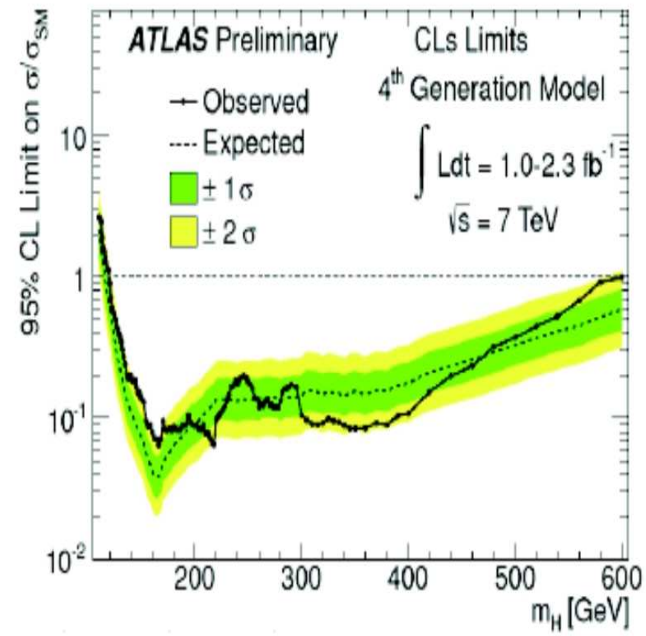


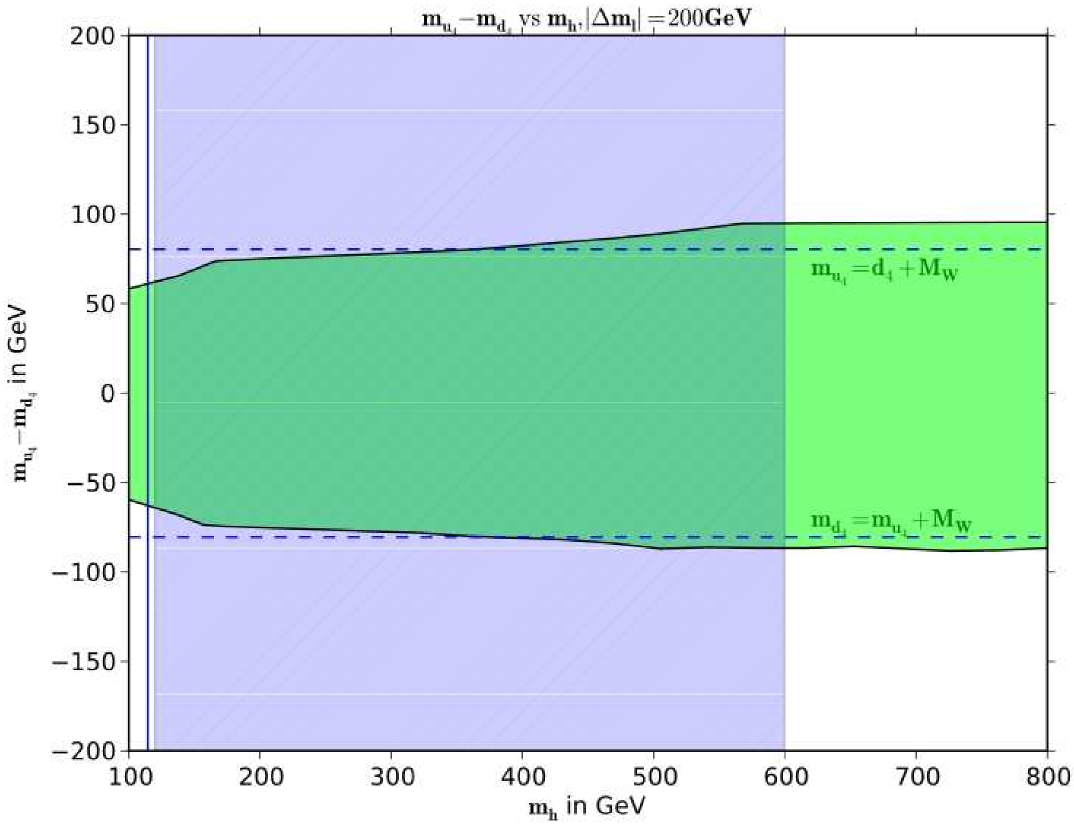


1000
500
200
100
50
m_{Higgs}[GeV]
no mixing
H
$H^{\pm}$
h
$\tan\beta = 1.5$
$\tan\beta = 30$
m_A [GeV]
100
200
500
1000

So really if the Higgs searches should rule out Existence of a light Higgs below 125 GeV or so we would have ruled out a large number of simple implementations of SUSY and SUSY breaking!

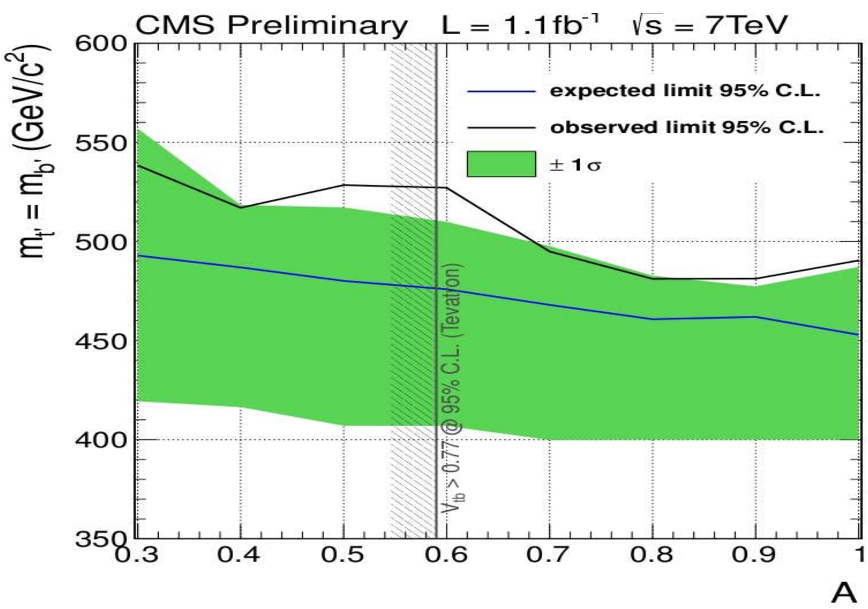

ATLAS
4th generation model
√s=7 TeV
∫ L dt ~ 35 pb-1
Excluded
Observed PCL
Observed, before PCL
Expected PCL
± 1σ PCL
+ 2σ PCL
Observed CLs
Expected CLs
CMS exclusion
Tevatron exclusion
95% CL Limit on σ/σTH
mH [GeV]


ATLAS Preliminary
CLs Limits
4th Generation Model
Observed
Expected
± 1σ
± 2σ
∫ Ldt = 1.0-2.3 fb-1
√s = 7 TeV
95% CL Limit on σ/σSM
mH [GeV]

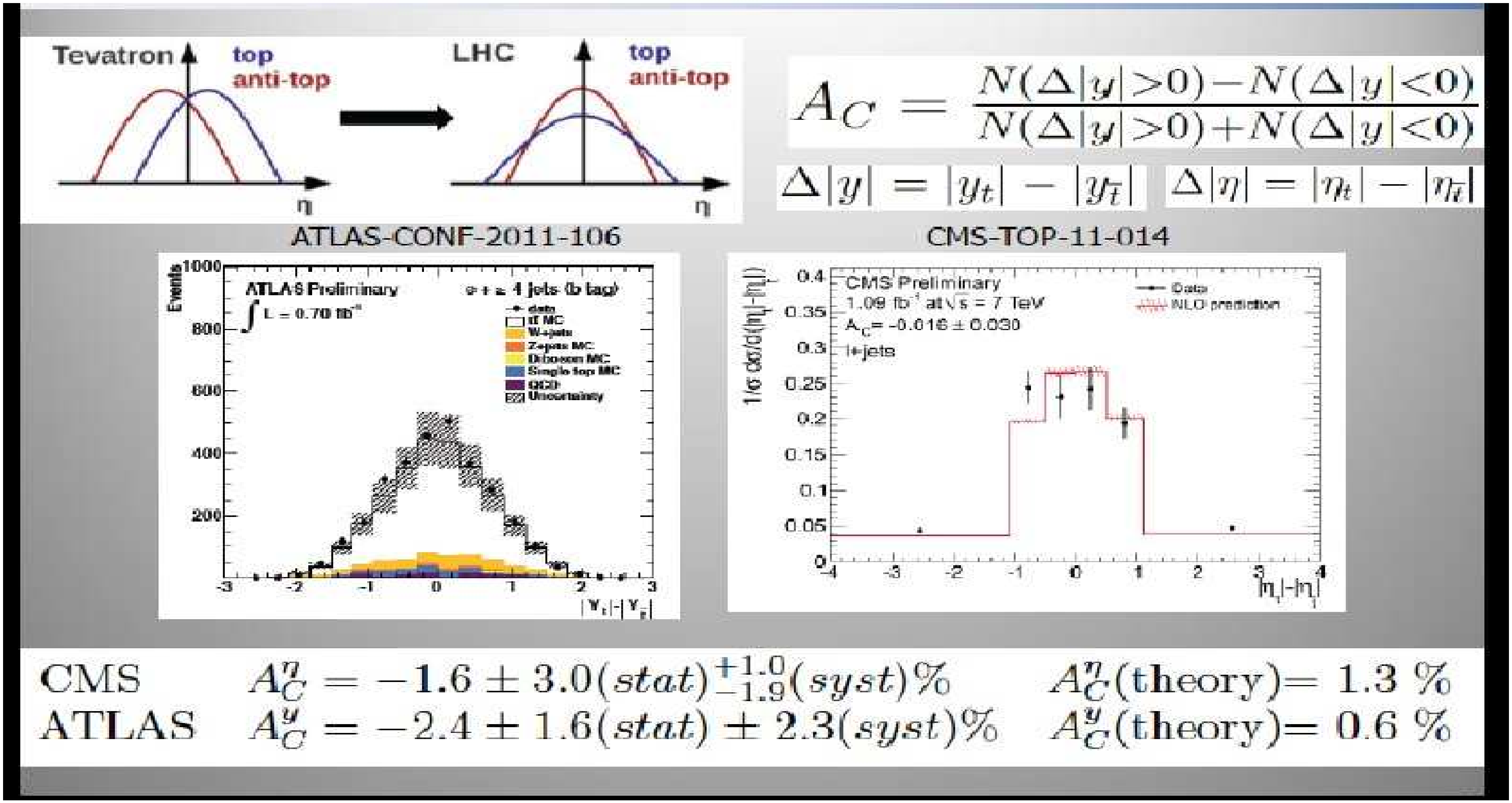


(Amold Dighe, RG, V. Arunprasath, Diptimoy Ghosh)

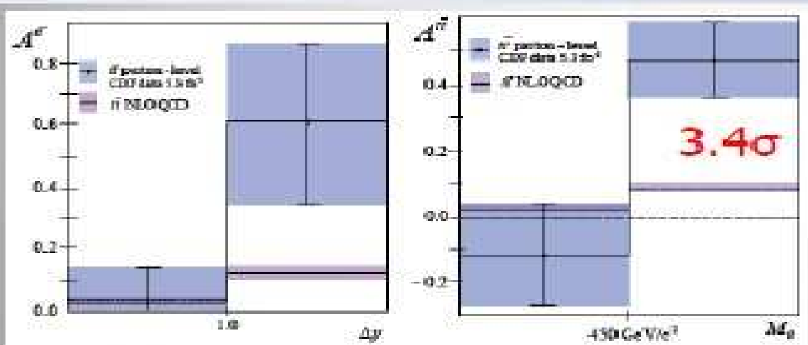
Why is this important?

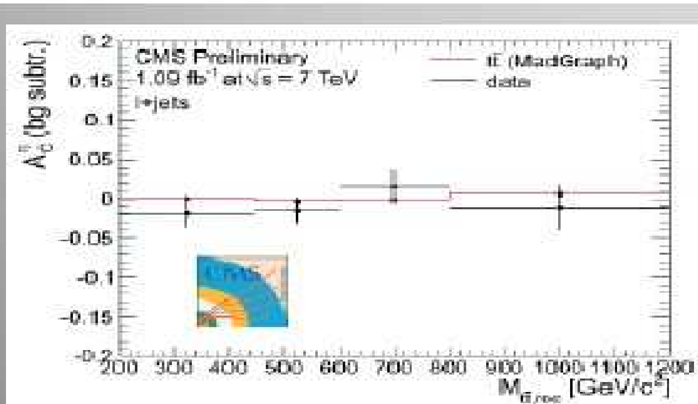


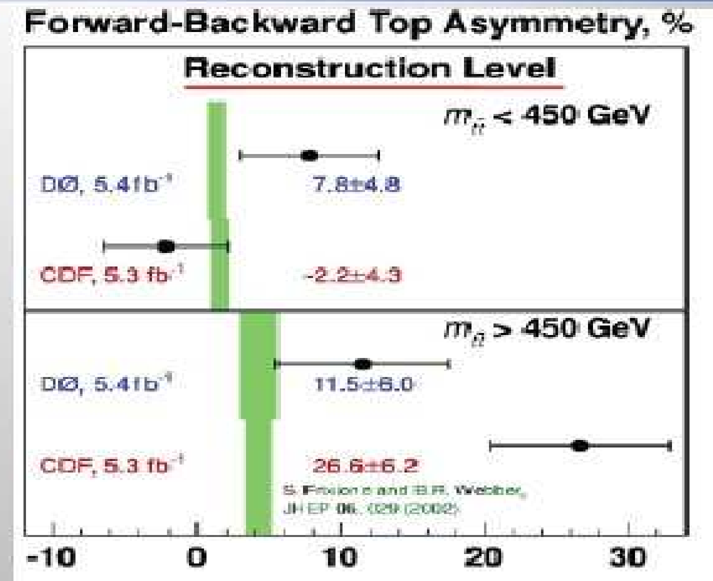
Searches at present use a final state $t' \to bW$ as the channel $t' \to b'W$ was not expected to be open. So the search strategies might have to be revisited! Nontrivial interplay between different search groups! between theory and experimental searches!


Tevatron
top
anti-top
LHC
top
anti-top
η
η
A_C = [N(Δ|y|>0) − N(Δ|y|<0)] / [N(Δ|y|>0) + N(Δ|y|<0)]
Δ|y| = |y_t| − |y_t̄|
Δ|η| = |η_t| − |η_t̄|
ATLAS-CONF-2011-106
CMS-TOP-11-014
ATLAS Preliminary
∫ L = 0.70 fb⁻¹
data
tt̄ MC
W+jets
Z+jets MC
Diboson MC
Single top MC
QCD
Uncertainty
Events
|Y_t|-|Y_t̄|
CMS Preliminary
1.09 fb⁻¹ at √s = 7 TeV
A_C = -0.016 ± 0.030
l+jets
Data
NLO prediction
|η_t|-|η_t̄|
CMS A_C^η = −1.6 ± 3.0(stat) +1.0 −1.9 (syst)% A_C^η(theory)= 1.3 %
ATLAS A_C^y = −2.4 ± 1.6(stat) ± 2.3(syst)% A_C^y(theory)= 0.6 %

High Mass Dependence?







No clear mass dependence in the D0 data, as compared to the CDF data

Interesting phenomenon! New physics? Theory issues?
Full data set analysis (~10 fb^{-1}) will be useful to shed more light

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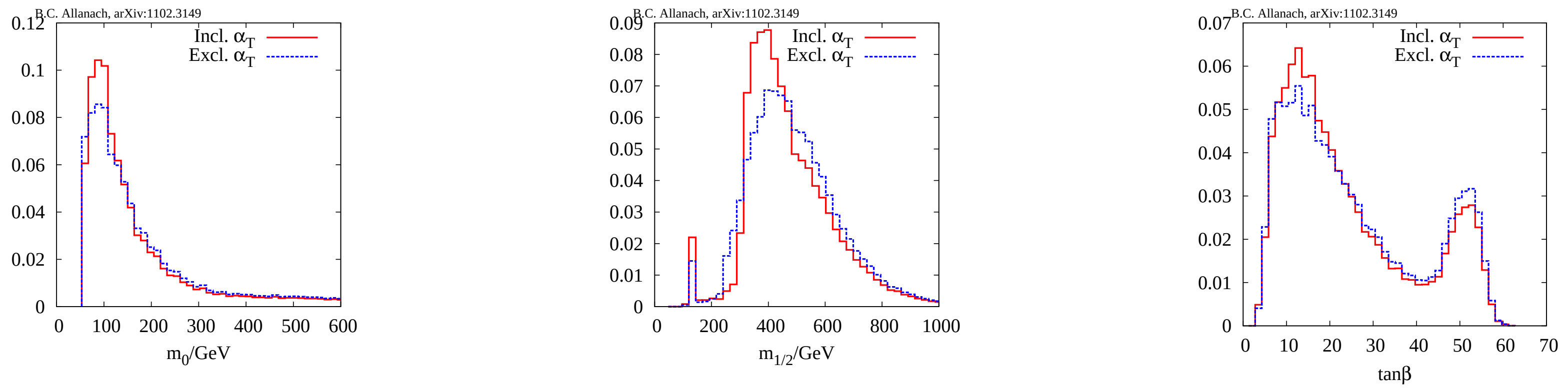
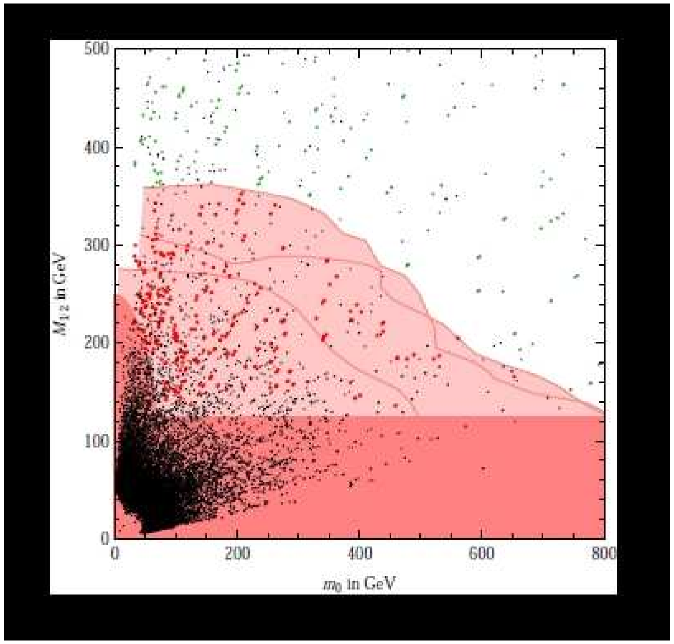


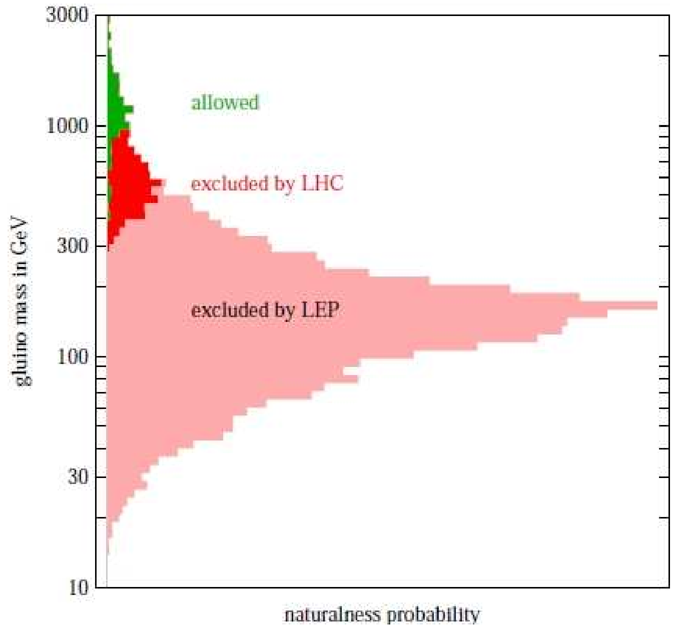
Red: Including new data, Blue: without the new data.

The changes also come from the SUSY Higgs searches which do not favour the large $\tan\beta$ values. This interplay indicates the correlation of new physics searches in different channels (Allanach: 1102.3149).

ONLY for the CMSSM.

(Belanger, R. Singh...)





In CMSSM:

$$M_Z^2 \simeq 0.2 m_0^2 + 0.7 M_3^2 - 2\mu^2$$

One can define fine tuning measures depending on the level of cancellation required to get the correct mass M_Z.

For CMSSM for $M_3 > 650$ GeV it is about 1 part in 35.

Green points correspond to allowed regions accroding to fine tuning criterion.

Plotted in the second graph is the naturalness probability. In the allowed regions fine tuning is about one part in 100.

In spite of the small luminosity the LHC is already capable of making statements in new parameter space of BSM models.

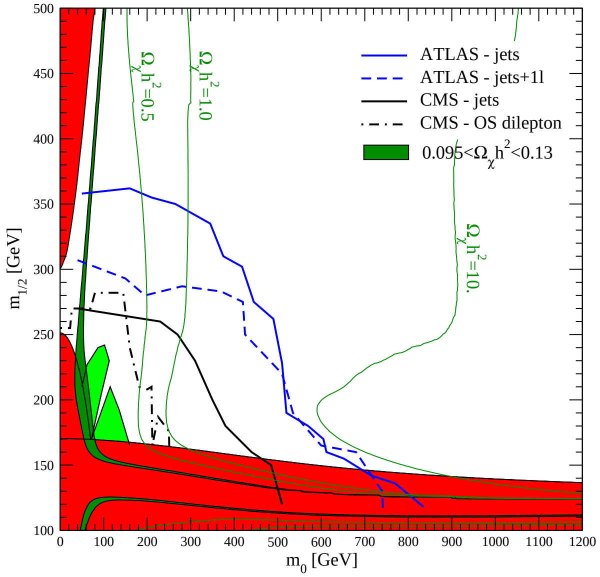
For TeV scale Supersymmetry the year 2011 will be critical. The small hierarchy problem (that is a fine tuning to about a one part in 10-100 for the Higgs mass) might be getting accentuated.

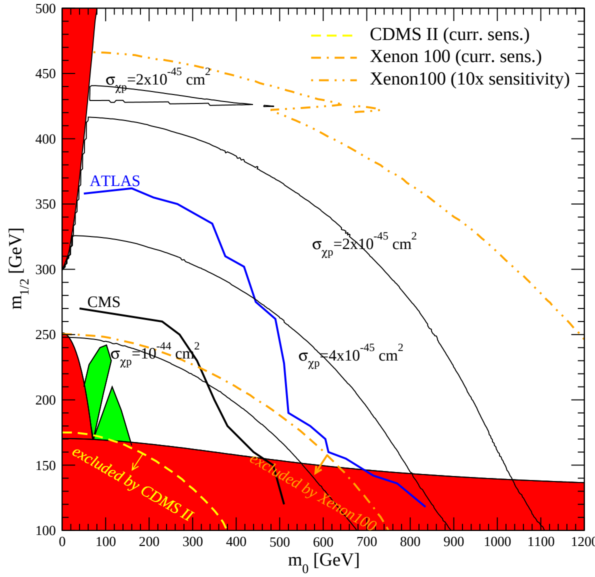
For theories with extra dimension new paramter regions begin to be explored.

Is there BSM? LHC will tell.Not just from direct searches BUT also from Higgs sector!

Many extensions of the SM, SUSY for example, has a neutral, stable particle with all the properties needed for it to be an ideal candidate for the dark matter.

The suggested solutions to cosmological questions can be tested in HEP experiments and Physics Beyond the SM can be constrained by Cosmological connections.





Profumo: 1105.5162

1) 2011-2012 is the crucial year for SUSY. Not just direct searches but Higgs physics (just its mass), results from LHCB as well as direct/indirect DM detection from XENON, CoGent putting SUSY under a scanner.

2)Results from LHCB putting different ideas again under a scanner.

3)Extra dimensions: ideas interesting..but not predicitve enough to be pushed to wall. In principle these ideas do not necessarily address the different observational facts which indicate BSM.

4)We should be infact be prepared that we are completely wrong and none of the ideas are right!

5)If Nature had been kind to us we would have seen the evidence for BSM. Now we need to work harder..that makes the game that much more fun

6)Once the Higgs is found a low energy e^+e^- collider, ILC might in fact be the way to go!