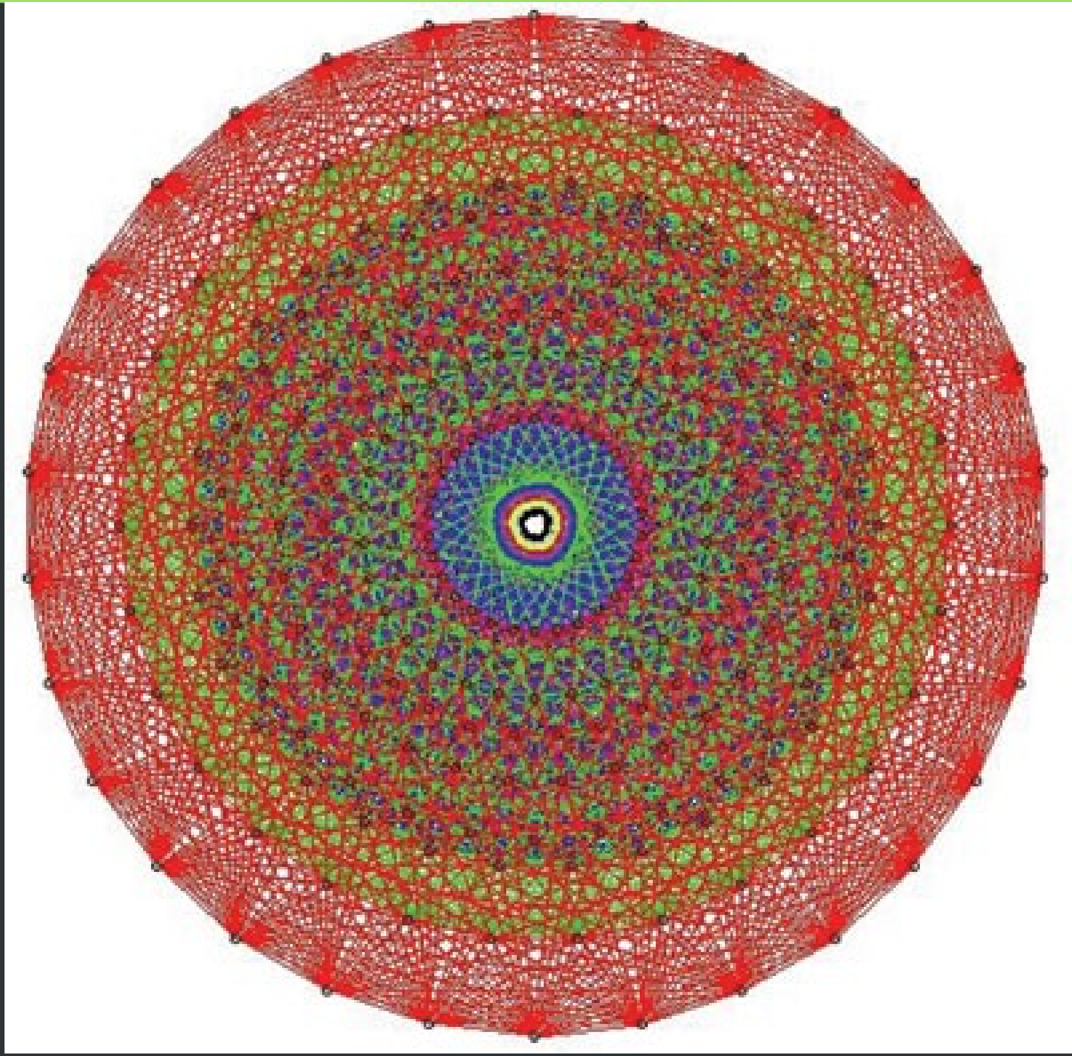
SUSY at the LHC



Rory Smith

Outline

- What is SUSY?
- Beyond the Standard Model: Motivations for finding SUSY
- Problems with SUSY
- Constraints from LEP and Tevatron
- Prospects at the LHC

What is SUSY?

- Extension of the Standard Model (SM) in which there is a correspondence between Bosons and Fermions.
- Each Boson has a Fermionic parter and vice versa, which differ by half an integer of spin. These are known as "Superpartners" or "Sparticles".

What is Susy?

- SM particles and sparticles:

gluon	gluino ($\tilde{g}$)
$W, Z, \gamma,$	chargino ($\chi_i^{\pm}$),
Higgs fields (H_i)	neutralino (χ_i^0)
quark (q)	squark ($\tilde{q}$)
lepton (l)	slepton ($\tilde{l}$)

- Supersymmetry is a "broken symmetry" meaning the SM arises as a low energy limit of the theory.
- "Sparticles" must be heavy!

Motivations for Finding SUSY

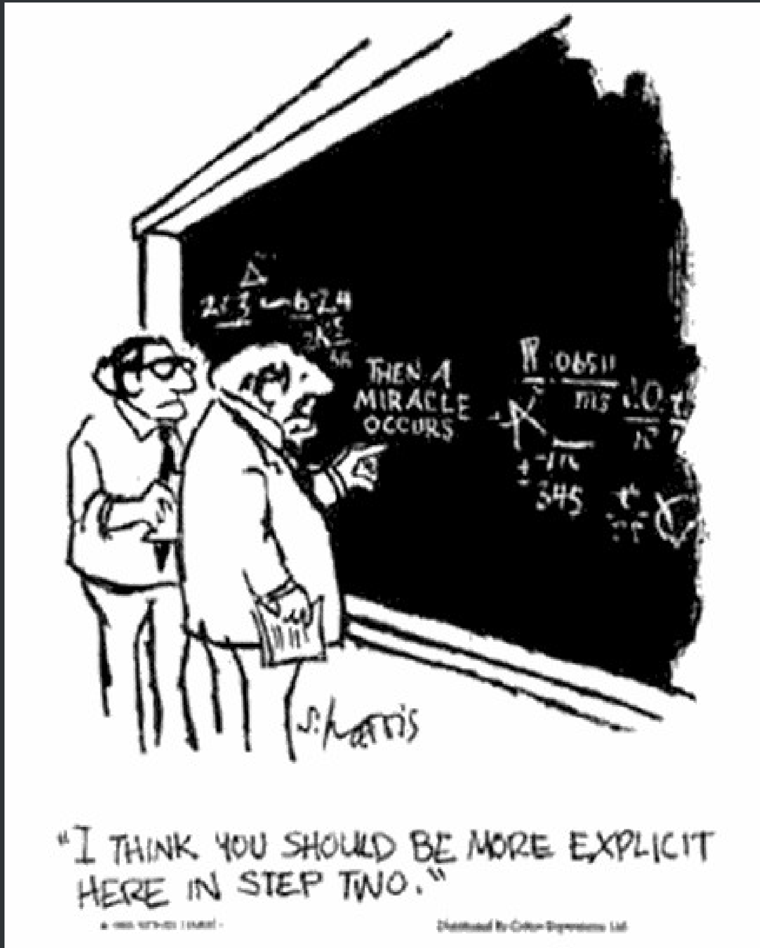
- Possible candidate for dark matter (?)
- Thought to be responsible for cosmic inflation (?)
- Step on the road to unification
- There are more fundamental reasons to find SUSY related to the Higgs mass however:

Motivations for Finding SUSY

- Not possible to calculate Higgs mass in SM.
- 1st order term from Higgs potential; quadratically divergent higher order terms from Fermoinc loops. This destroys unitarity in SM: VERY BAD!
- SM breaks down at Planck scale..if this is the divergent energy scale then the Higgs mass is some 15 orders of magnitude, above TeV scale, too high! (About the weight of a lead brick!)
- There must be new physics stabilising Higgs mass.
- SUSY eliminates quadratic divergences whilst preserving unitarity...A good candidate for the new physics!

Problems with SUSY

- There is no unique supersymmetric theory:
- MSSM, SUGRA, mSUGRA A.M.S.B., G.M.S.B. etc etc...
  all possible candidates each capable of predicting masses based on model dependent parameters. Two distinct cases of each SUSY theory (R-Parity Conserving/Violating).
- Q: Which is the correct theory?
- A: Let nature decide!



Constraints from LEP and Tevatron

- Neutrino counting experiments at LEP constrained masses of lightest neutralinos and lower limits on sleptons m_e>99GeV.
- LEP also constrained Higgs mass: m_H>114.4GeV
- Tevatron constrained SUSY partners of u,d,s,c,b quarks and gluons (for equal masses): $m_q=m_g$ >300GeV
- ...Sparticle masses cannot exceed the TeV region and still satisfy unitarity...
- Enter the LHC!

Prospects for SUSY at the LHC

- Any search at the LHC must take into account:
- Discovery reach (to what extent can SUSY be tested?)
- Reconstruction of sparticle masses
- Extraction of SUSY model parameters
- ...methods are general, but for simplicity consider SUGRA (only 4 model dependant parameters) .

Prospects for SUSY at the LHC

- For illustration, we can make things simpler still by restricting attention to the R-Parity conserving case.
- R = +1 for SM particles and R=-1 for SUSY particles.

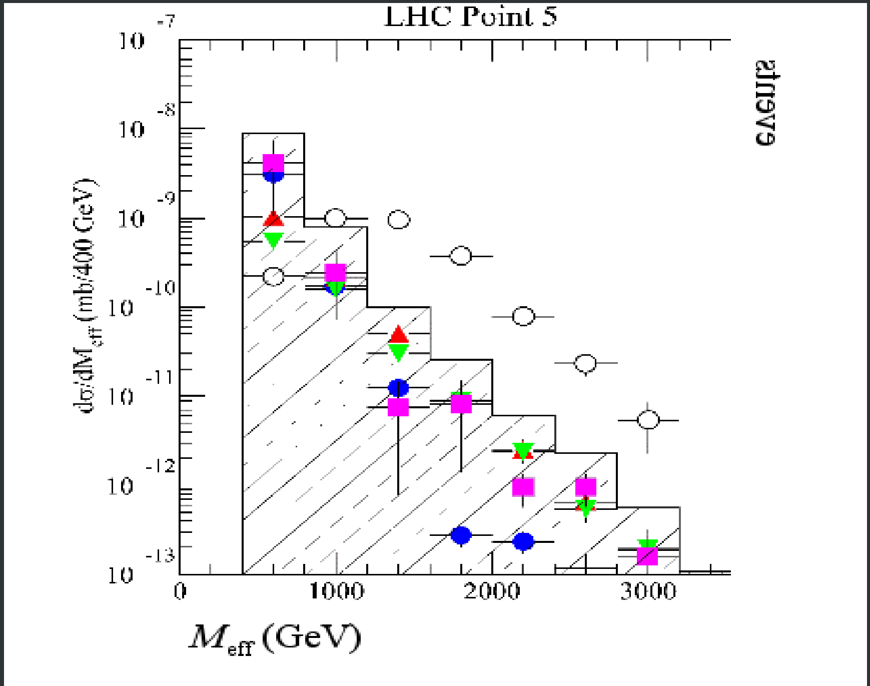
$$R = (-1)^{3(B-L)+2s}$$

- In RPC, the final state always contains two stable LSP's which are electrically neutral and weakly interacting. Hence there is a missing energy signature.

Prospects for SUSY at the LHC

$$M_{\text{eff}} = E_T^{\text{missing}} + \sum_i |\mathbf{p}_T^{\text{jet}_i}|$$

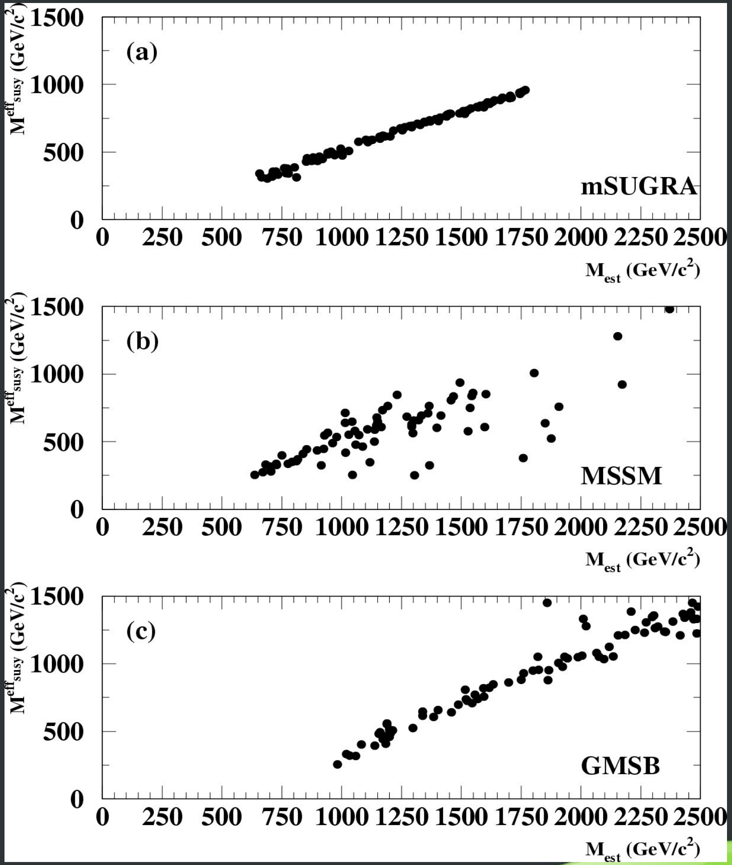
- Step One: Estimating SUSY mass scale...Full event reconstruction impossible; have to rely on effective mass of the system



- Is this a good idea?..Take a set of SUGRA parameters (m_0, $m_{1/2}$, tan β, sgn μ) chosen randomly and make an effective mass distribution:

Prospects for SUSY at the LHC

- Plots using SDECAY show strong correlation between effective mass and SUSY mass:

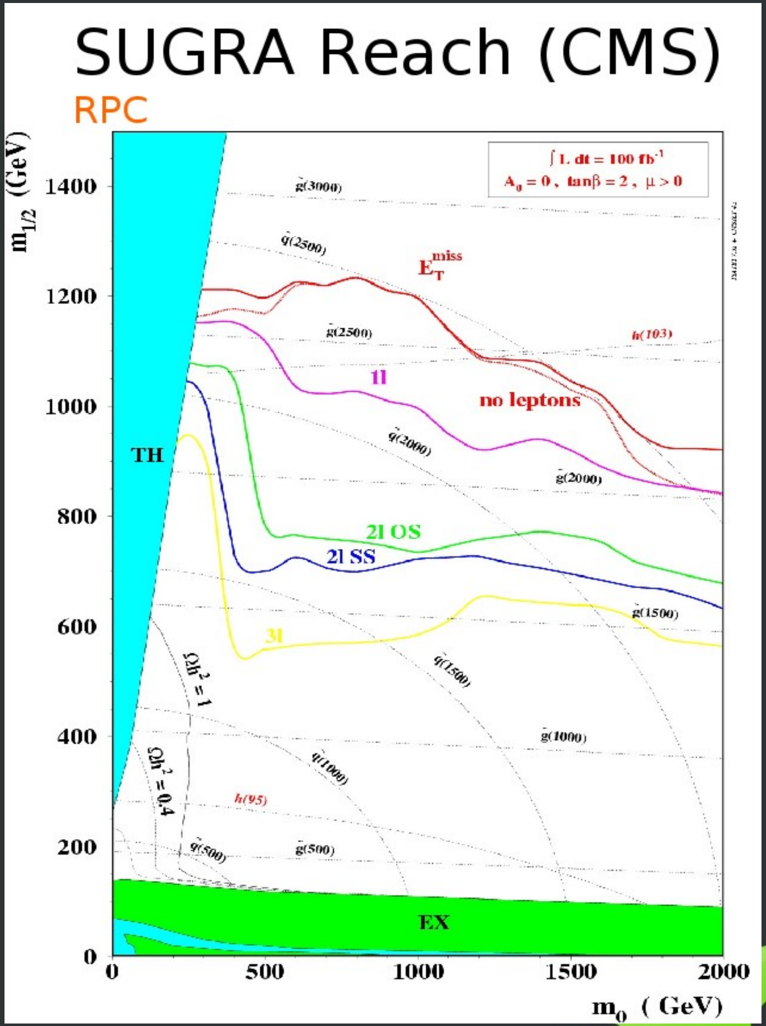


- Effective mass can be used to determine SUSY mass scale without other information!

- For any parameters then, mass spectrum can be determined by evaluating SUGRA numerically.

Prospects for SUSY at the LHC

- Search limit defined by region with acceptance > 5 and integrated luminosity 10pb^{-1} (conservative) co corresponding to 3 years ..expect to find range of dileptons, trileptons and jets..
- Reconstruction of masses, however requires favourable decay chains...
- These involve decays into SM particles to surpress SUSY background



Prospects for SUSY at the LHC

- Full event reconstruction impossible: Determining masses relies on kinematic edges.
- For a favorable decay chain, eg $\tilde{q}_L \rightarrow q\tilde{\chi}_2^0 \rightarrow ql^{\pm}\tilde{l}^{\mp} \rightarrow ql^{\pm}l^{\mp}\tilde{\chi}_1^0$
- Constraints come from dilepton edges, lq mass resolution, and two edges from llq system. Hence there are four constraints on the four unknown masses, including the neutralinos! This system can therefor be solved.
- Data from ALICE puts largest error on neutralino mass ~12%

Prospects for SUSY at the LHC

- The edge data can be used to output SUGRA parameters.
- The SUGRA parameters give the full mass spectrum, and the data can be compared to the theory.
- Note: this assumes SUGRA is the correct theory, which will be meaningless if nature has chosen a different supersymmetric theory. The mass spectrum generated from output parameters must agree with experimental results for the theory to be a viable candidate.

Conclusions

- Conservative SUSY reach at the LHC is good.
- Detecting SUSY processes (if they exist) is likely, however interpreting precisely what decay channels have been observed will be very difficult.
- Added difficulties from RPV scenarios where missing energy signatures are suppressed.

Questions?