SUSY-Breaking Parameters Fit and Models Comparison

Shehu S. AbdusSalam

DAMTP, University of Cambridge

IPPP Seminar, Durham University
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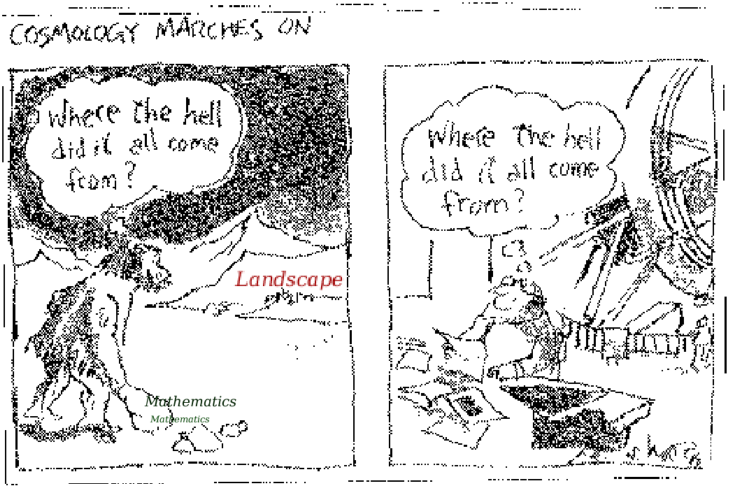
Collaborators

This talk is based on some work to be released and:

- SSA, **arXiv:0809.0284** to appear in SUSY08 proceedings
- F.Feroz, B.C.Allanach, M.Hobson, SSA, R.Trotta, A.Weber **JHEP 0810:064,2008**
- SSA, J.P.Conlon, F.Quevedo, K.Suruliz **JHEP 0712:036,2007**
- J.P.Conlon, SSA, F.Quevedo, K.Suruliz **JHEP 0701:032,2007**

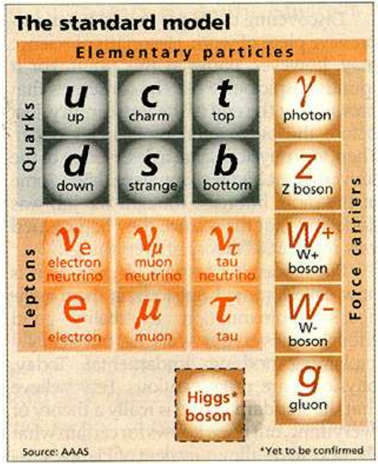
Outline

From Where.. & to Where?



Standard Models of Particle Physics & Cosmology

- Universe = 4*D* space-time + matter + interactions
- Matter is fermions
- Interactions mediated by bosons
- Dark matter and interaction
- Higgs gives masses



The Standard Models Must be Extended

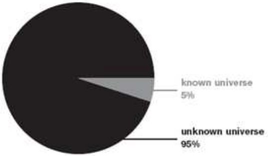
Why 3 generations?

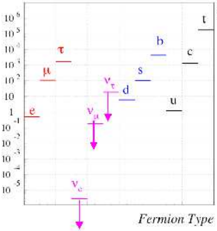
$<$ 5% of the Universe known

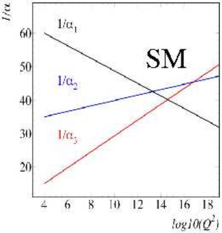
Fermion masses hierarchy

Interactions do not unify

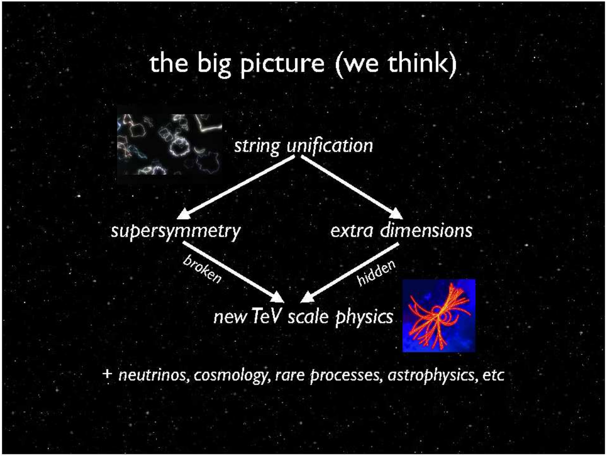
Higgs radiative corrections





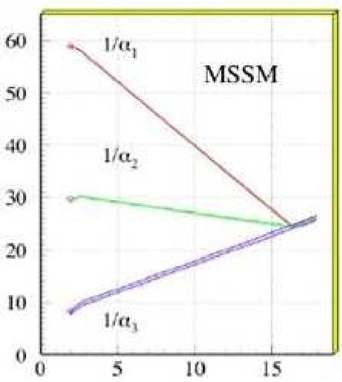


A Plan..


the big picture (we think)
string unification
supersymmetry
extra dimensions
broken
hidden
new TeV scale physics
+ neutrinos, cosmology, rare processes, astrophysics, etc

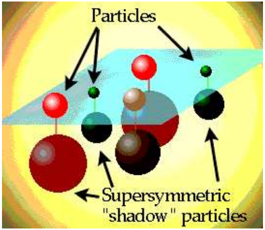
Supersymmetry is very important

- Theory meets experiment $\longrightarrow$ phenomenology
- SUSY is very important on both ends... it connects
- It solves the hierarchy problem
- Provides a dark matter candidate
- Compatible with grand unifications



SUSY-breaking models

- SUSY: superpartner to each SM particle
- No superpartner observed yet
- SUSY broken at higher energy
- Source of SUSY-breaking not understood
- Make models: two ways round..
  - From fundamental theory: LVS, mSUGRA, AMSB, GMSB, ...
  - Parametrise our ignorance: MSSM-124, CMSSM, ...
- Then scan parameters for phenomenology



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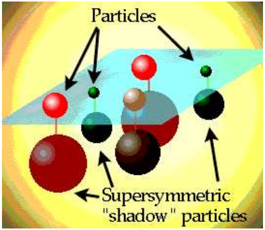
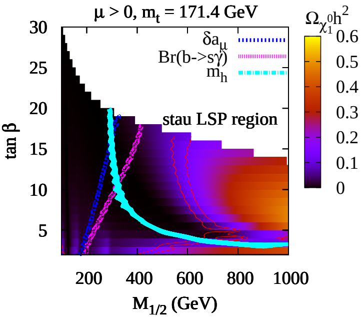


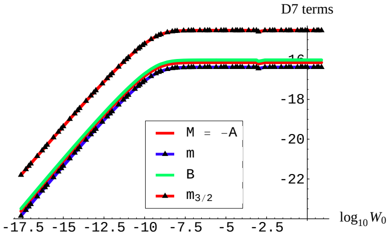
LARGE volume scenario

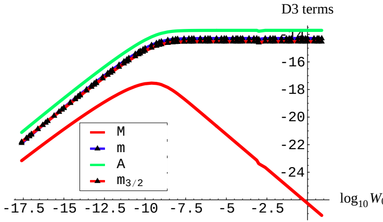
- Different structures on D3/D7-branes
- On D7 $\longrightarrow$ LVS, $M{:}m{:}A = 1{:}\frac{1}{\sqrt{3}} : -1$
- On D3 $\longrightarrow$ LV Split SUSY $M{:}m{:}A = \frac{1}{\mathcal{V}} : 1 : \mathcal{O}(1)$



W_0 Scanning

Flux parameter, W_0, affects the SUSY-breaking pattern





mSUGRA/CMSSM & other models

- Model SUSY broken in hidden sector
- Different mediation mechanisms
- Gravity, Anomaly (AMSB), Gauge (GMSB)
- mSUGRA/CMSSM most famous among the models
- Universality relations at GUT energy drastically reduce number of soft-breaking free parameters to:
- $m_0, M_{1/2}, A_0, \tan\beta, sign(\mu)$ or $m_0, M_{1/2}, A_0, B, \mu$
- Easier for phenomenological studies
- Used to provide bench mark points

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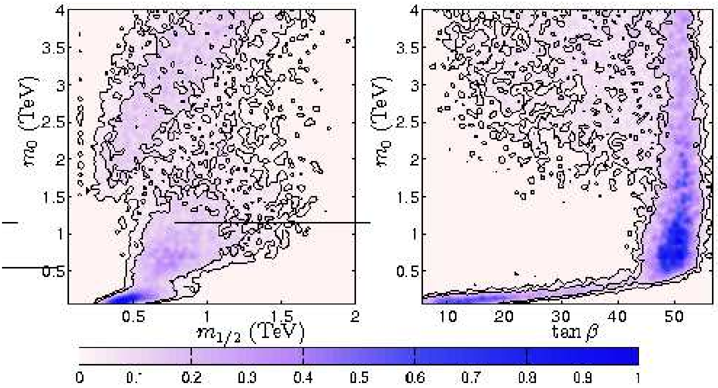
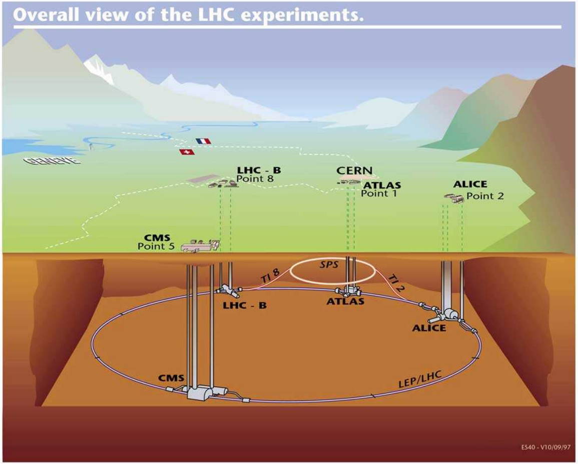
mSUGRA/CMSSM 2 parameters map ($\mu > 0$)



The Large Hadron Collider (LHC)



The night before LHC...

- Bottom-up approach very important
- Need model independent guide for the colliders
- Probe, in maximal manner, of parameter space
- Important... but missing..
- Computationally expensive
- Problem solvable with advanced sampling technique
- Multinest implements Nested Sampling
- Bayesian inference.. in action!

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Bayes theorem and nested sampling

- Nested sampling prioratise getting the Bayesian evidence
- **prior** $\times$ **likelihood** = **evidence**, Z $\times$ **posterior**, $P(\theta|D,H)$.

$$P(\theta|D,H) = P(D|\theta,H)P(\theta,H)/P(D,H)$$

- Model evidence in light data, is the **n**-dimensional integral

$$Z = P(D,H) = \int P(D|\theta,H)P(\theta,H)\, d\theta.$$

- The algorithm converts this **n**d to 1d integration!
- Use this to explore a **phenoMSSM**

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Phenomenological MSSM

- Most natural and model independent approach
- Scan over all regions of parameter space at weak-scale
- Most general: covers all scenarios for SUSY breaking
- Blind to hidden sector physics, mediation mechanisms and renormalisation group runnings
- Provide more realistic bench mark points
- Guiding map for colliders and DM searches
- Make better SUSY (MSSM) predictions

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24 parameters, θ, and prior, $\pi(\theta)$

- **phenoMSSM** = MSSM124 - extra{CP-violating, FCNC}
- Real soft SUSY-breaking terms, diagonal sfermion masses and trilinear couplings, degenerate 1st/2nd generation
- $\tan\beta$, $m^2_{H_1}$ and $m^2_{H_2}$ from the Higgs sector
- Gaugino mass terms $M_{1,2,3}$; 10 sfermion masses.
- Trilinear couplings A_t, A_b, A_τ, and $A_\mu = A_e$
- Most important SM parameters: masses m_t, m_b, M_τ, electroweak and strong parameters G_F, m_Z, α_{em}, and α_s
- **phenoMSSM** prior: $\pi(\theta) = P(\theta|H) = \pi(\theta_1)\pi(\theta_2)\ldots\pi(\theta_{24})$

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Observables (Data), D_i: $\{\mu_i, \sigma_i\}$

Observable, D_i	Mean value(μ_i)	Uncertainty(σ_i)
m_W	80.398 GeV	0.0025 GeV
Γ_Z	2.4952 GeV	0.0023 GeV
$\sin^2\ \theta_{eff}^{lep}$	0.23149	0.000173
$\delta a_\mu \times 10^{10}$	29.5	8.8
$Br(b \to s\gamma) \times 10^4$	3.55	0.72
$Br(B \to \mu^+\mu^-)$	5.8×10^{-8}	upper limit
$R_{\Delta M_{B_s}}$	0.85	0.11
$R_{Br(B_u \to \tau\nu)}$	1.2589	0.4758
Δ_{0-}	0.0375	0.0289
$\Omega_{CDM}h^2$	0.1143	0.02

HEP and MultiNest Softwares

phenoMSSM predictions, O_i, are computed using:

- **SOFTSUSY-2.0.17**, B. C. Allanach arXiv:hep-ph/0104145
- **micrOMEGAs-2.1**, arXiv:0803.2360
- **superISO-2.0**, F. Mahmoudi arXiv:0710.2067
- **susyPOPE**, A. Webber, private

MultiNest sampler, F.Feroz and M.P.Hobson arXiv:0704.3704

Likelihood and posterior maps

Likelihood: predicted values (non)deviation from observed

For each prediction, O_i, of data, D_i compute
$L_i = P(D_i|\theta, H) = \left(2\pi\sigma_i^2\right)^{-1/2} \exp\left[-(O_i - \mu_i)^2/2\sigma_i^2\right]$

Then **phenoMSSM** posterior, $P(\theta|D_i, H) = p_i = \frac{1}{Z} L_i \pi_i$

Z for models comparison and
p_i for parameters map and fit to data

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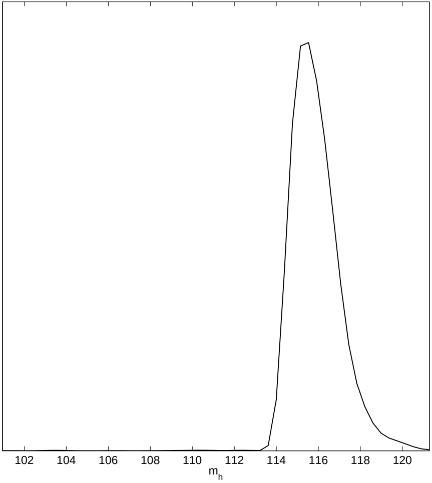
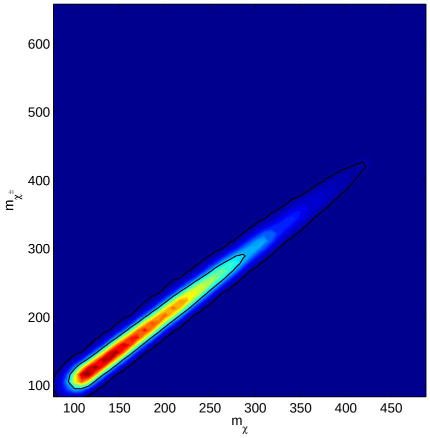
Runs!

Super Run Codes...

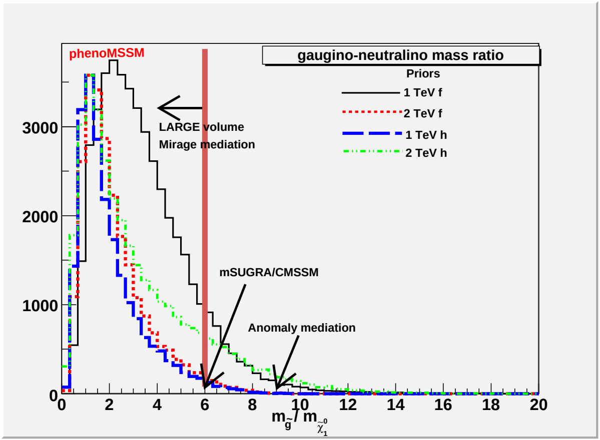
phenoMSSM Higgs masses



Neutralino-chargino mass



Gluino-neutralino mass ratio



Summary and Outlook

- First phenomenological SUSY parameters global fit
- Weak-scale parameters scan, independent of SUSY-breaking models
- Cleaner guide for SUSY and DM search experiments
- Do **phenoMSSM** SUSY and DM phenomenology
- Use **phenoMSSM** for better MSSM predictions
- Neutrino masses, CP-violating and FCNC sources
- Underconstrained..? LHC data on the way
- Generic techniques; can be applied to other problems

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Thanks for Listening!

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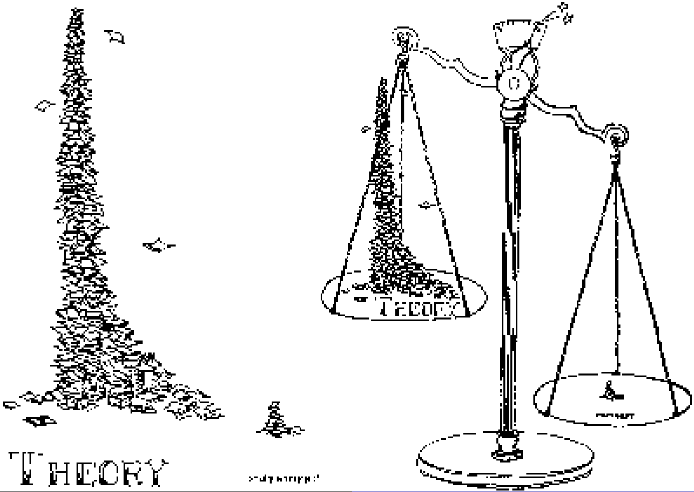
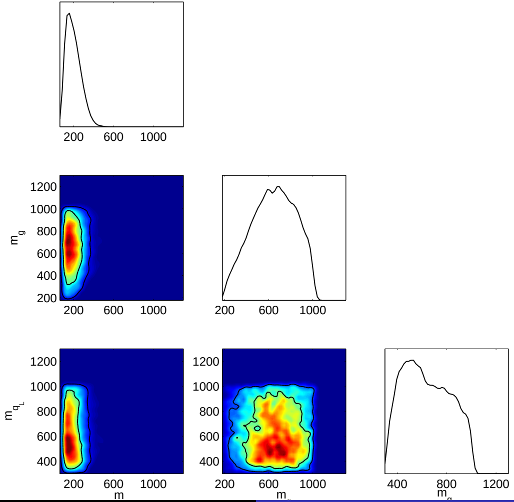
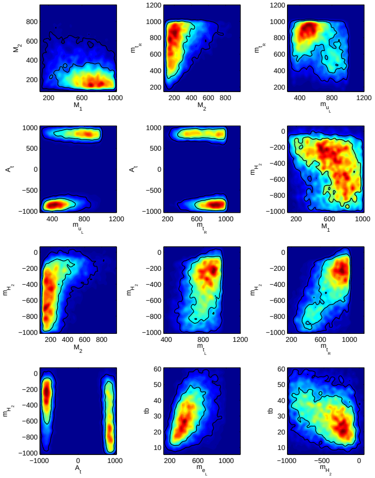
LHC will change the world



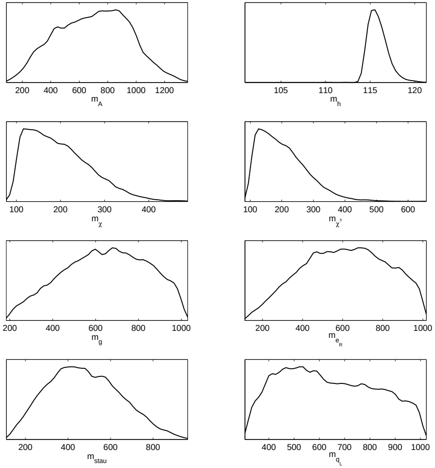
Gluino, squark and neutralino masses



The 24 input parameters



Sparticle masses



24 parameters, θ

M_1, M_2, M_3	Bino, Wino and Gluino masses
$m_{\tilde{e}_L} = m_{\tilde{\mu}_L}$	1st/2nd generation L_L slepton masses
$m_{\tilde{\tau}_L}$	3rd generation L_L slepton mass
$m_{\tilde{e}_R} = m_{\tilde{\mu}_R}$	1st/2nd generation E_R sleptons masses
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$m_{\tilde{u}_L} = m_{\tilde{d}_L} =$	
$m_{\tilde{c}_L} = m_{\tilde{s}_L}$	1st/2nd generation Q_L squark masses
$m_{\tilde{t}_L} = m_{\tilde{b}_L}$	3rd generation Q_L squark masses
$m_{\tilde{u}_R} = m_{\tilde{c}_R}$	1st/2nd generation U_R squark masses
$m_{\tilde{t}_R}$	3rd generation U_R squark mass
$m_{\tilde{d}_R} = m_{\tilde{s}_R}$	1st/2nd generation D_R squark masses
$m_{\tilde{b}_R}$	3rd generation D_R squark mass

24 parameters, θ

$A_{t,b,\tau}$	top, b- and τ- quark trilinear couplings
$A_e = A_\mu$	μ and e trilinear couplings
$m_{H_{1,2}}$	up- and down-type Higgs doublet masses
$\tan\beta$	scalar doublets **vevs** ratio
m_t	top quark pole mass
$m_b(m_b)^{\overline{MS}}$	b-quark mass
$1/\alpha_{em}(m_Z)^{\overline{MS}}$	electromagnetic coupling constant
$\alpha_s(m_Z)^{\overline{MS}}$	strong coupling constant