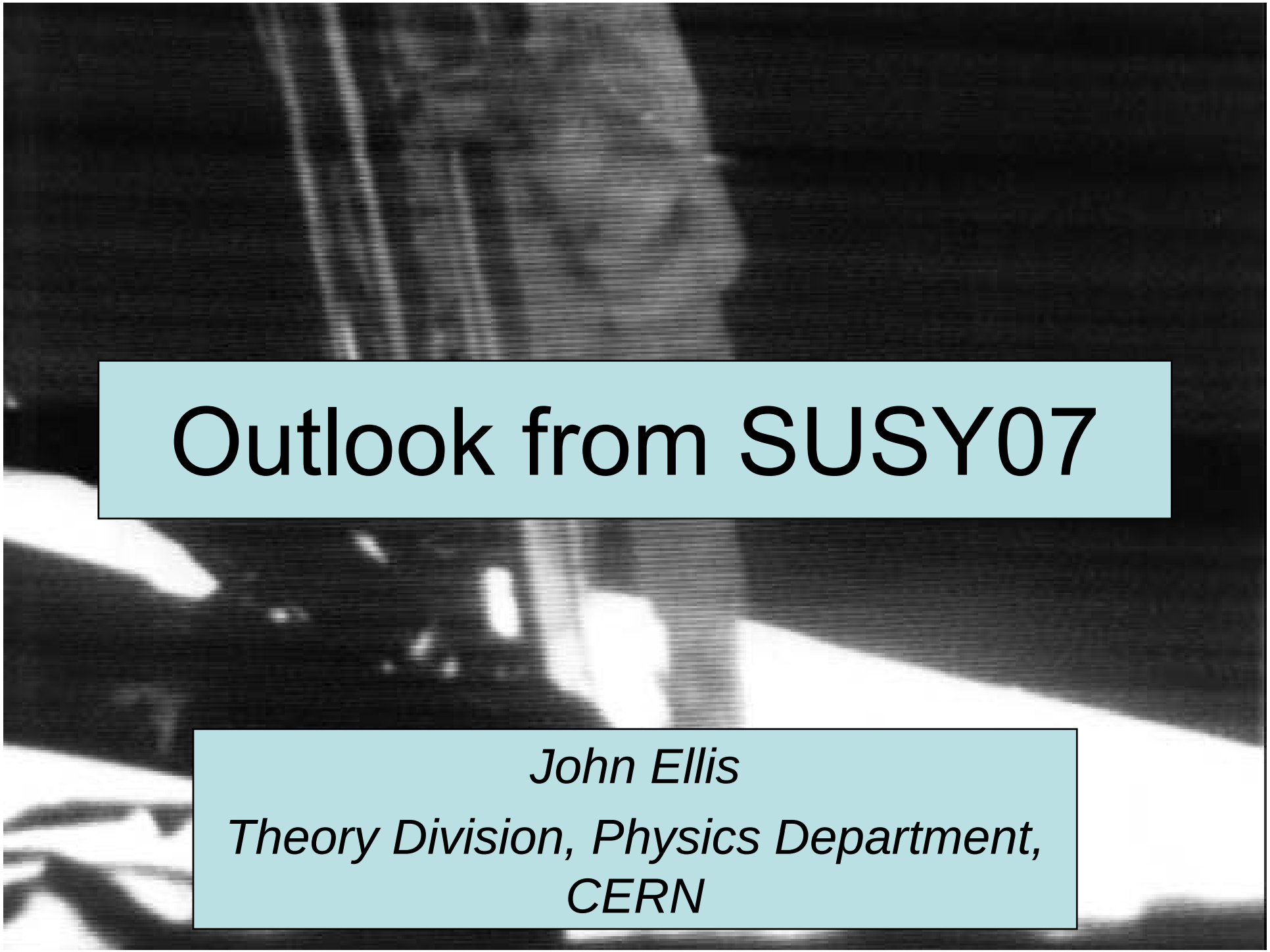


Outlook from SUSY07

John Ellis

Theory Division, Physics Department, CERN

A Historical Parallel?

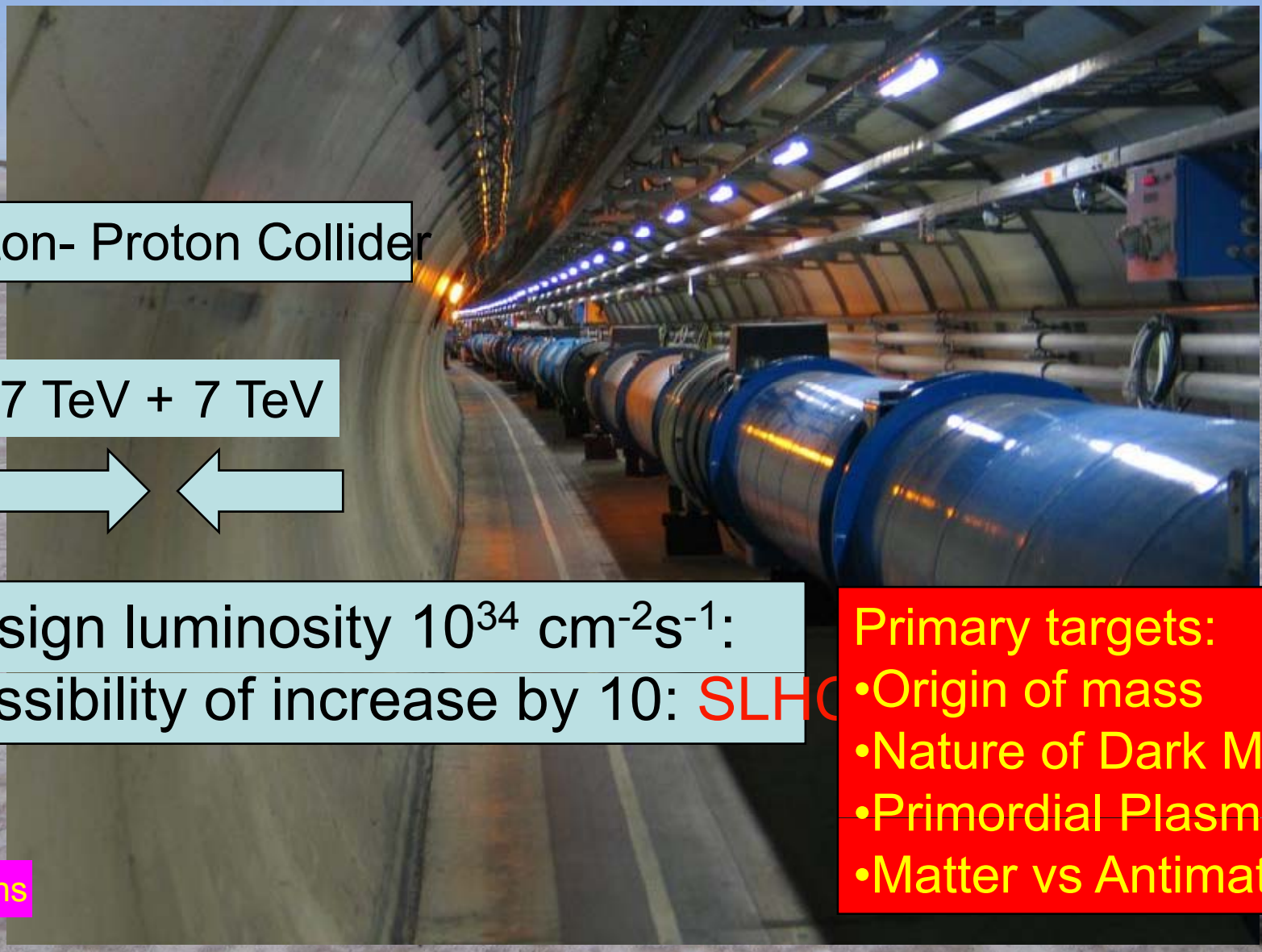
- President Kennedy:

  "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the earth"

- CERN Council:

  “We believe that this organization should commit itself to achieving the goal, before this decade is out, of discovering the Higgs boson and supersymmetry”

The Large Hadron Collider (LHC)



Proton- Proton Collider

7 TeV + 7 TeV

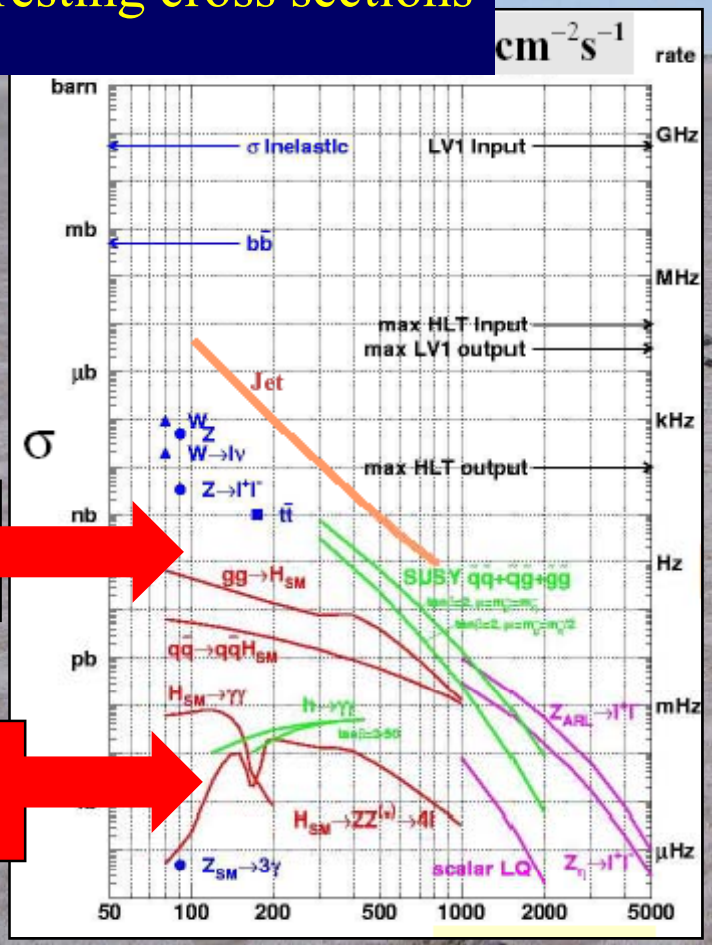
Design luminosity 10^{34} $cm^{-2}s^{-1}$:
Possibility of increase by 10: SLHC

Primary targets:
- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter

Evans

The LHC Physics Haystack(s)

Interesting cross sections



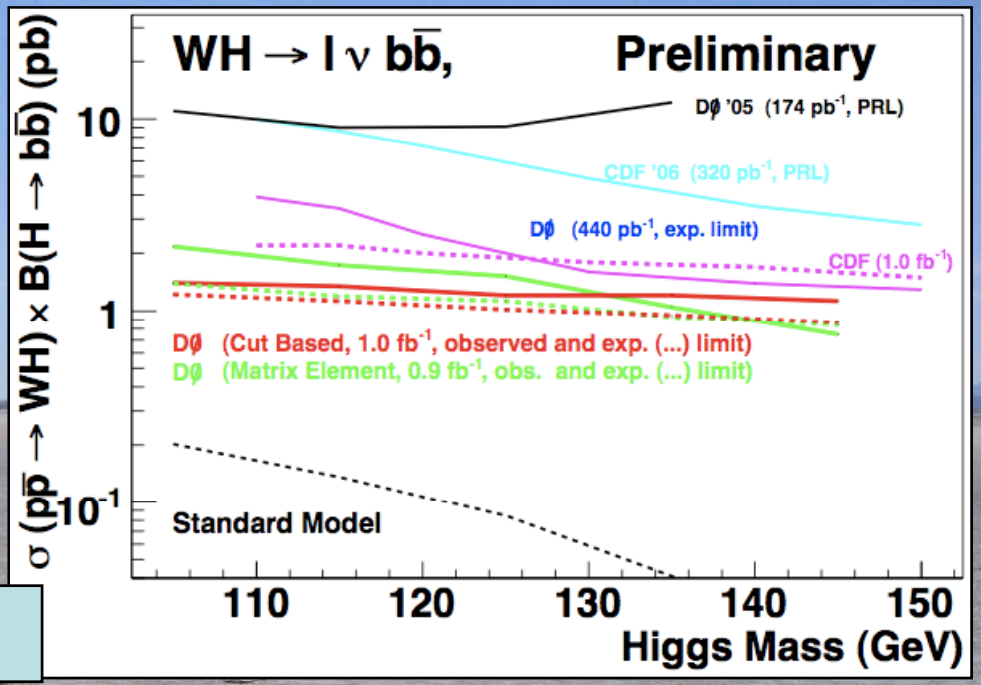
Susy

Higgs

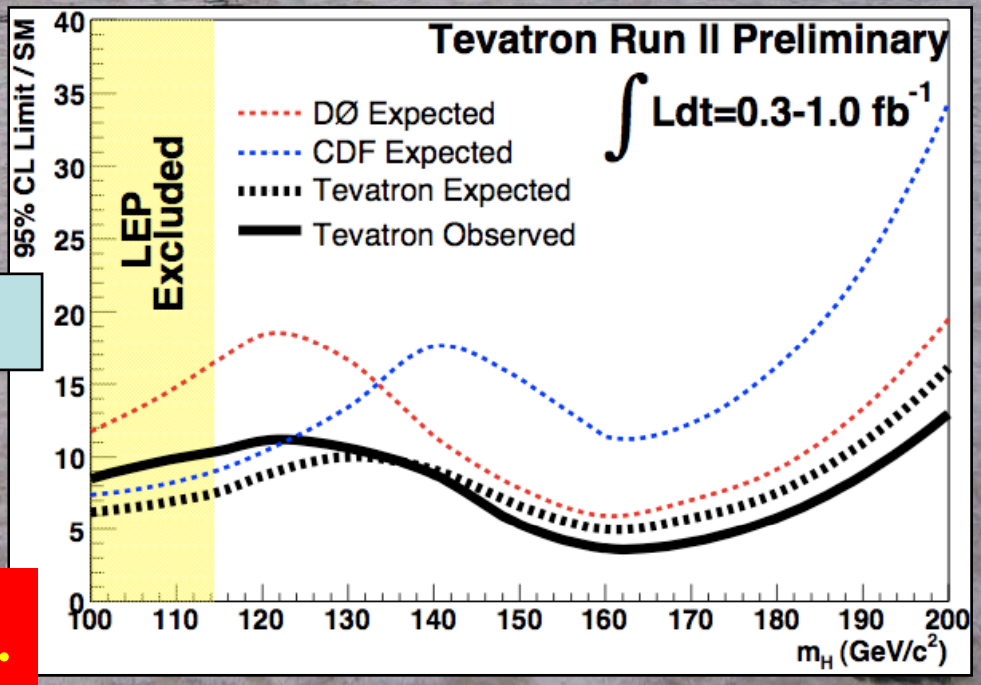
- Cross sections for heavy particles
  ~ 1 /(1 TeV)^2
- Most have small couplings ~ α^2
- Compare with total cross section
  ~ 1/(100 MeV)^2
- Fraction ~ 1/1,000,000,000,000
- Need ~ 1,000 events for signal
- Compare needle
  ~ 1/100,000,000 m^3
- Haystack ~ 100 m^3
- Must look in ~ 100,000 haystacks

Status of Higgs Search @ Tevatron

Status of one search channel



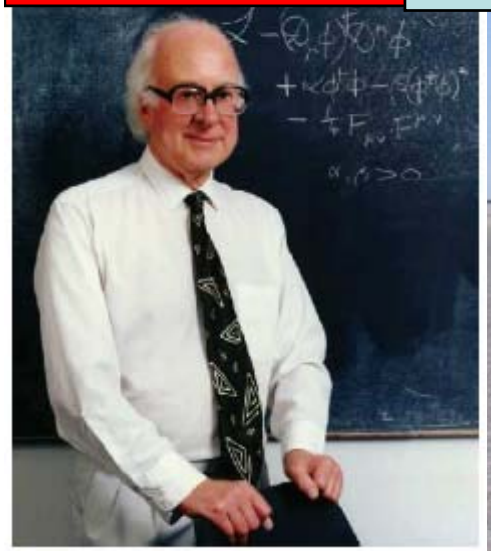
Combined search status



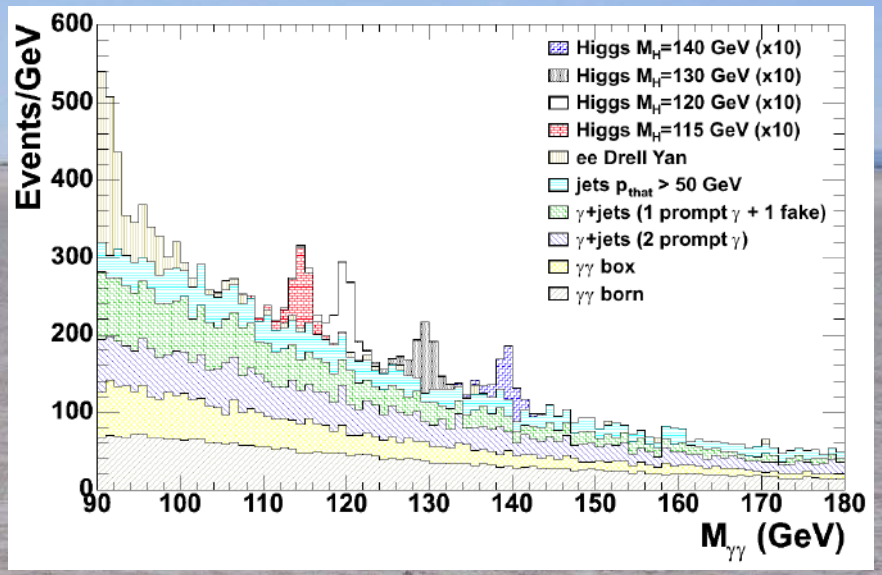
Not very far away …

A la recherche du Higgs perdu ..

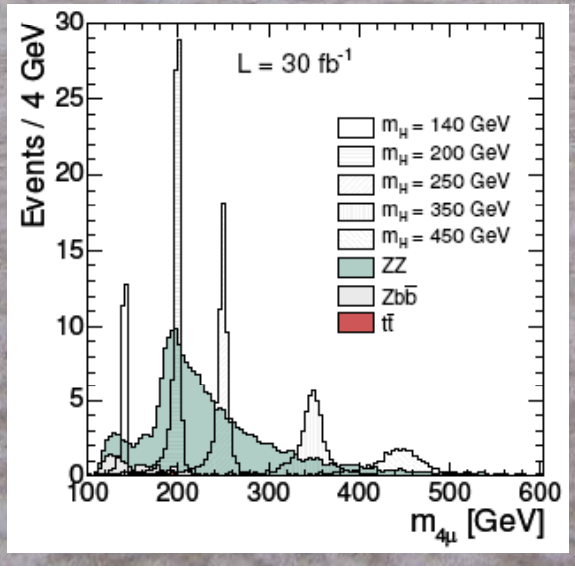
Some Sample Higgs Signals



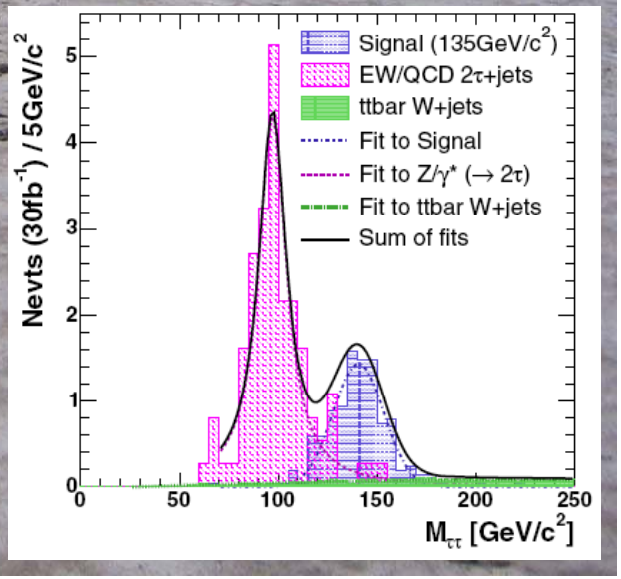
$\gamma\gamma$



ZZ* -> 4 leptons

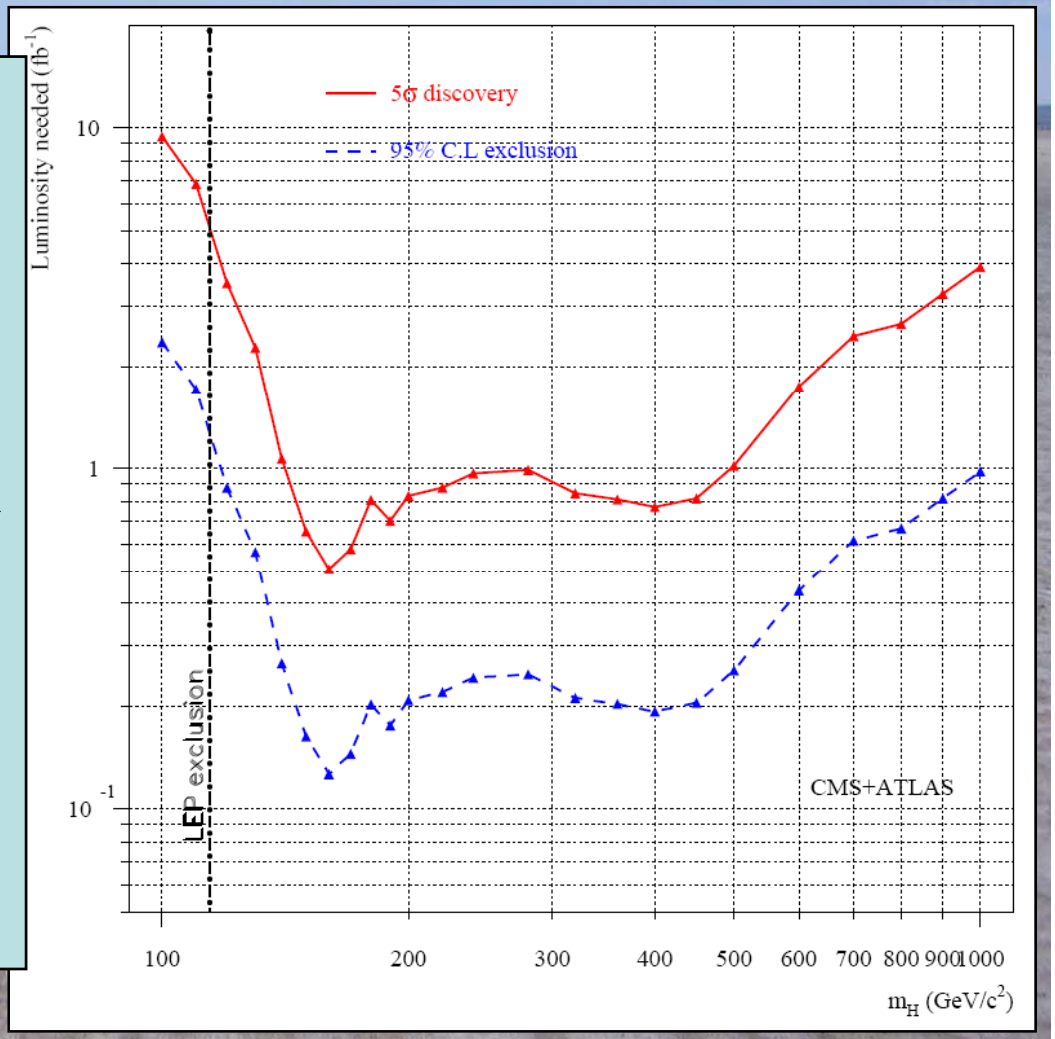


$\tau\tau$



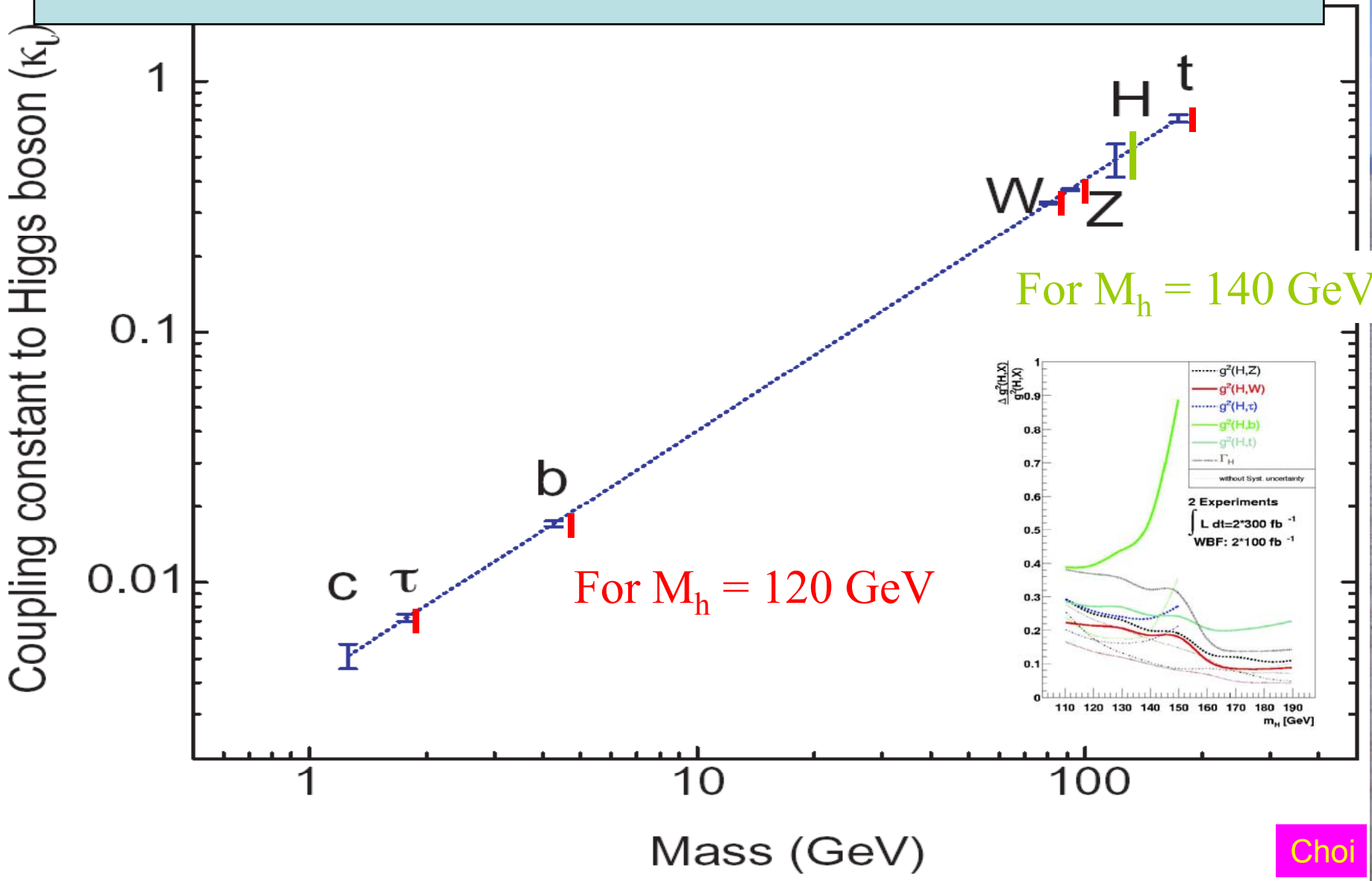
Potential of Initial LHC running

- A Standard Model Higgs boson could be discovered with 5-σ significance with $5fb^{-1}$, $1fb^{-1}$ would be sufficient to exclude a Standard Model Higgs boson at the 95% confidence level
- Signal would include ττ, γγ, bb, WW and ZZ
- Will need to understand detectors very well



Jakobs

Higgs Measurements @ ILC & LHC

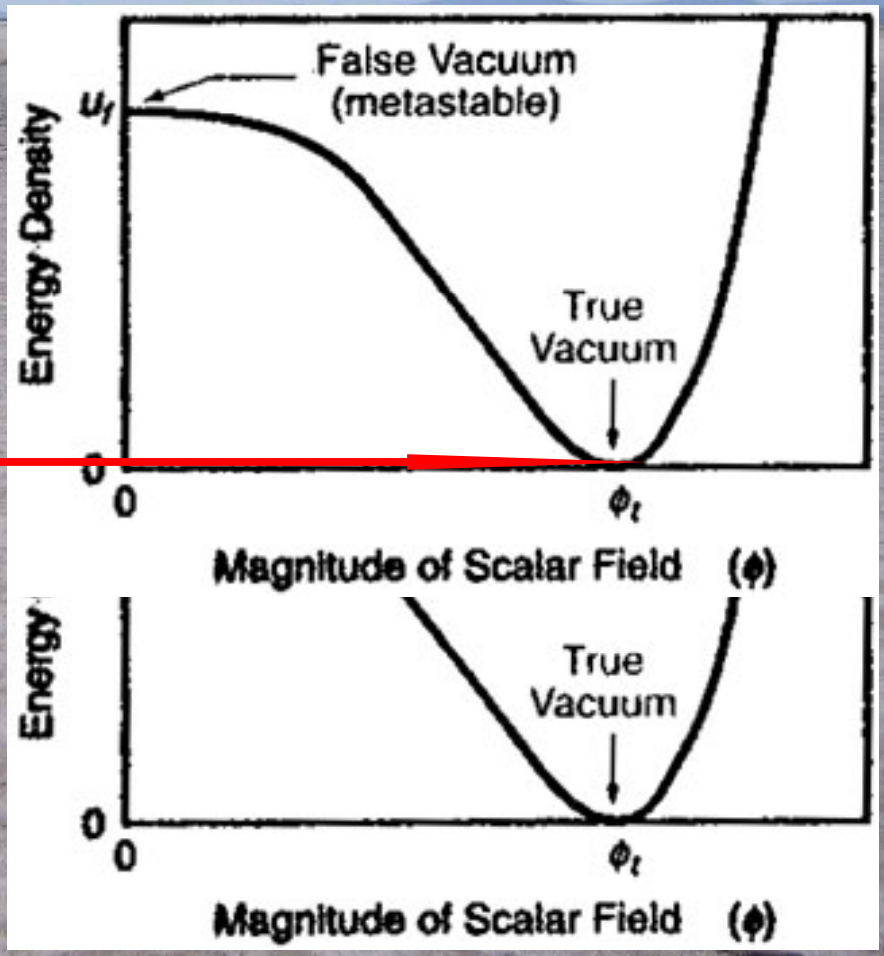


Choi

The Higgs and Vacuum Energy

- Must add a constant to the effective potential so that net value in true vacuum ~ 0
- Physical value

  ~ 10^{-60}



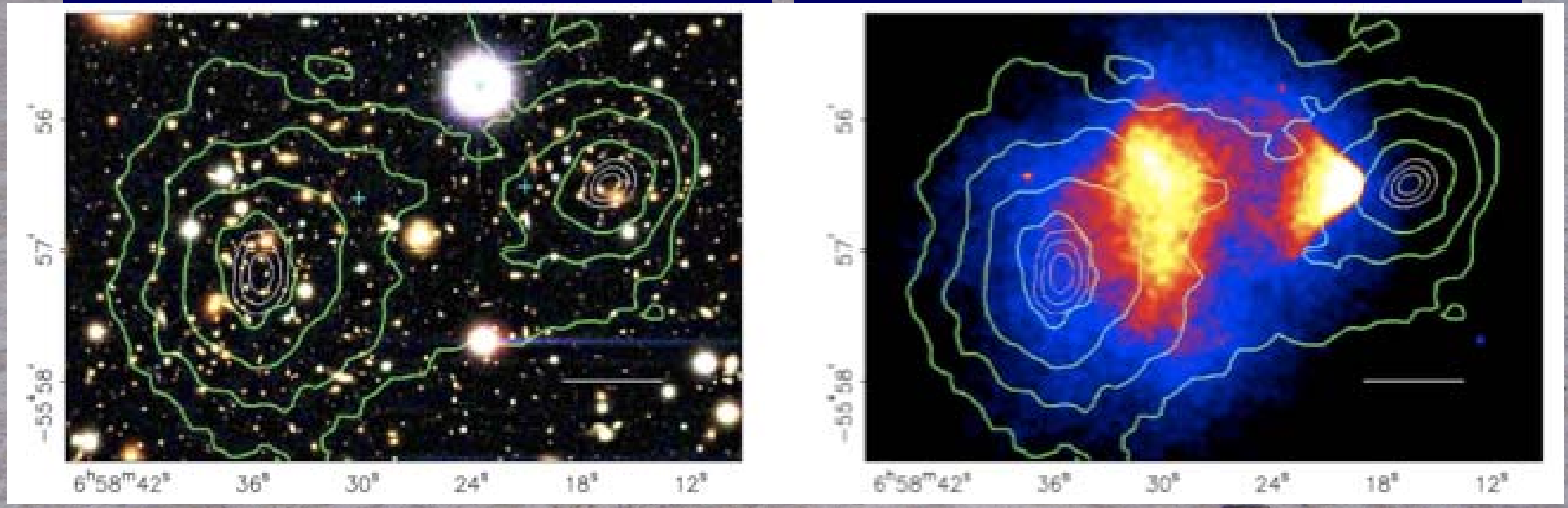
Why Supersymmetry (Susy)?

- Intrinsic beauty
- Hierarchy/naturalness problem
- Unification of the gauge couplings
- Predict light Higgs < 150 GeV
  - As suggested by precision electroweak data
- Cold dark matter
- Essential ingredient in string theory (?)

Direct Evidence for Collisionless Dark Matter

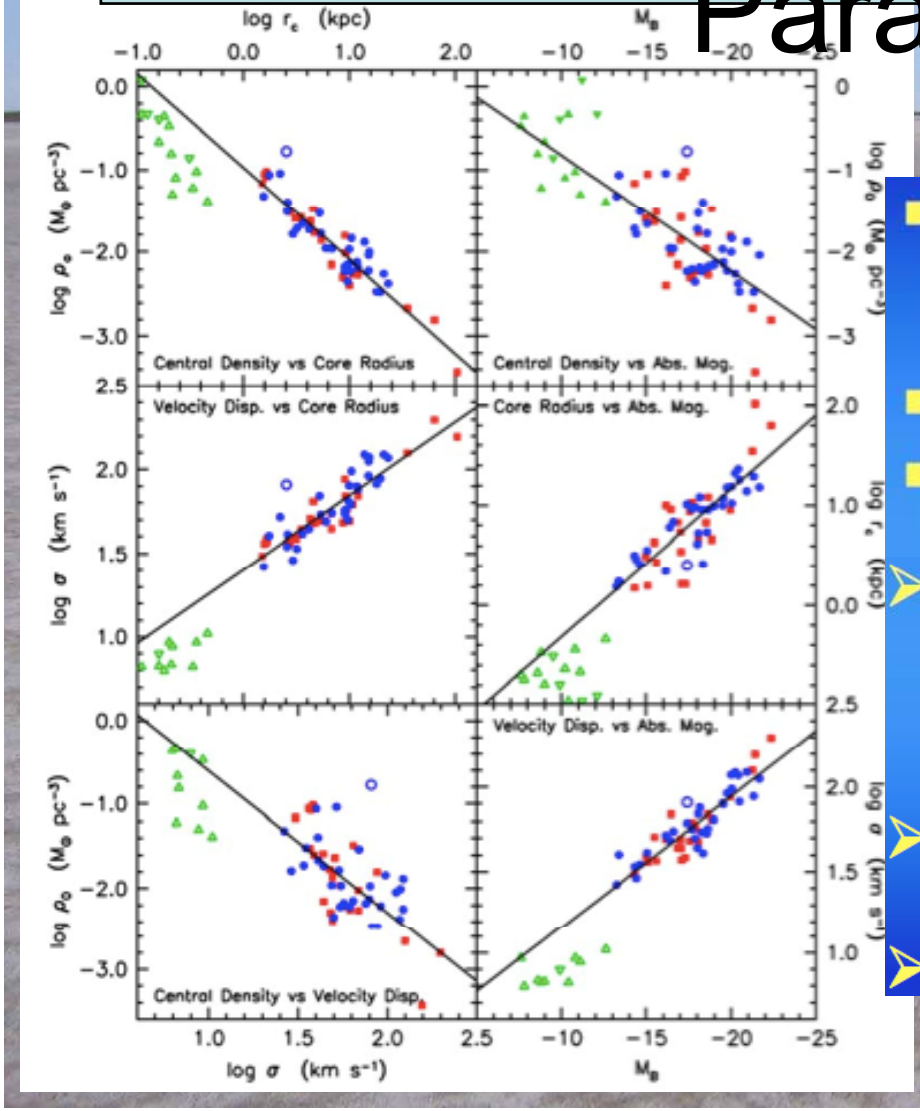
Collision of two galaxies:
dark matter lumps pass through

Collision of two galaxies:
gaseous matter stuck in between



Clowe et al, 2006

Dwarf Spheroidal Galaxies: Problems for the CDM Paradigm?



- A minimum size for galaxies, ~100pc
  - Mass size scale somewhat larger (?), expected since baryons dissipate energy?
- Velocity dispersions of ~10km/s, ~ flat profile
- Cored mass profiles, with similar mean mass densities ~0.1$M_\odot$/pc^3, ~5GeV/cc

➢ Characteristic Scale above 100pc, several $10^7 M_\odot$
  - ➢ power-spectrum scale break?
  - ➢ This would (perhaps!) naturally solve the substructure and cusp problems

➢ Number counts low relative to CDM

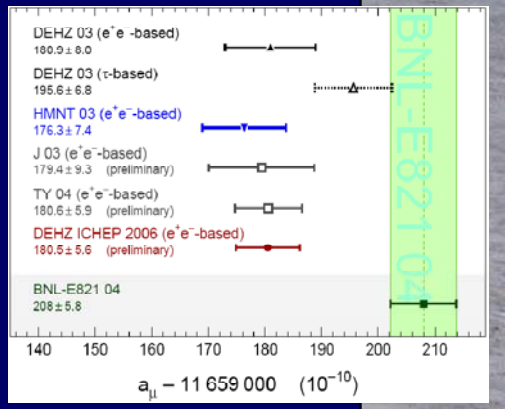
➢ Need to consider seriously non-CDM candidates

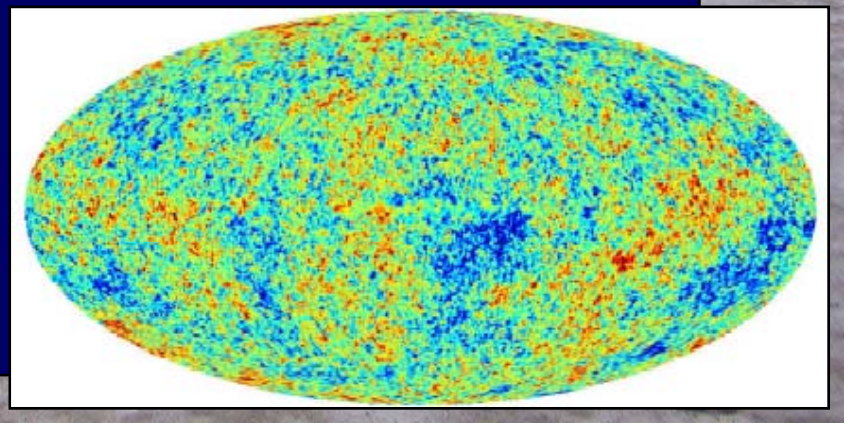
Gilmore et al, 2007

Constraints on Supersymmetry

- Absence of sparticles at LEP, Tevatron
  - selectron, chargino > 100 GeV
  - squarks, gluino > 300 GeV
- Indirect constraints
  - Higgs > 114 GeV, $b \rightarrow s\,\gamma$
- Density of dark matter
  - lightest sparticle χ:
  - $0.094 < \Omega_\chi h^2 < 0.124$

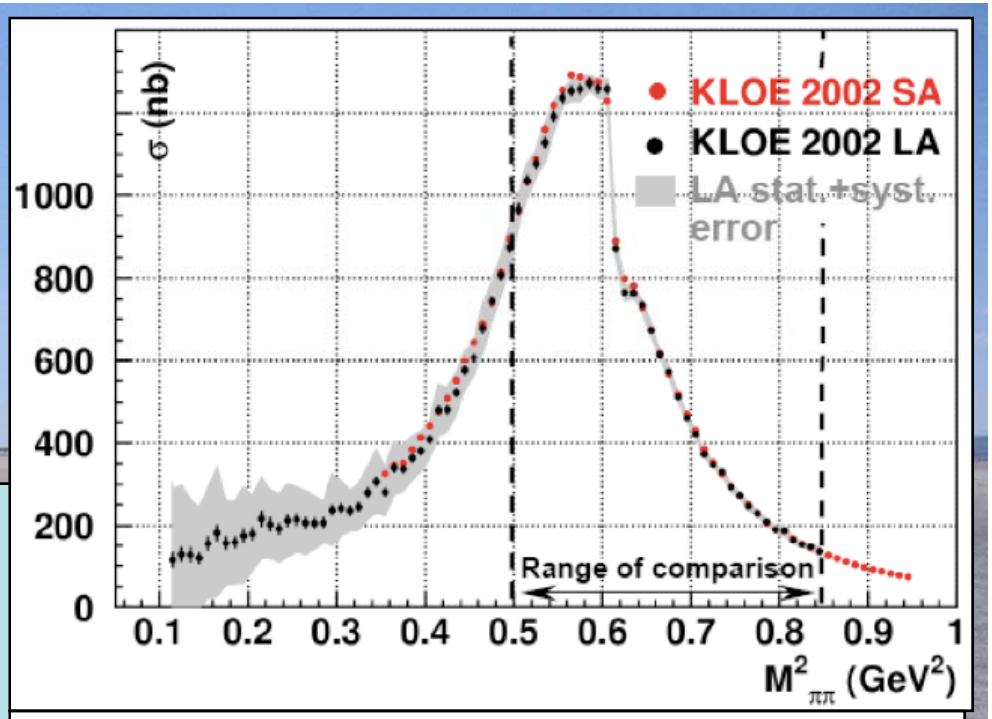
3.3 σ effect in $g_\mu - 2$?

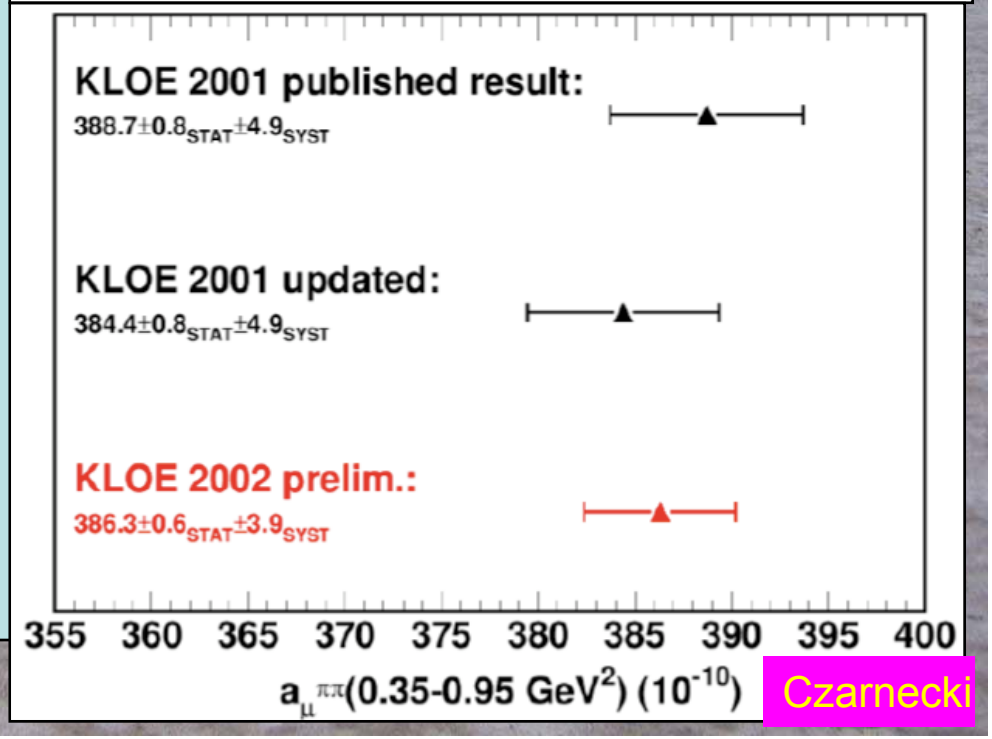




Quo Vadis $g_\mu - 2$?

- New e^+e^- data agree with previous
- Strengthen discrepancy
  - now 3.4 σ
- New τ decay data apparently disagree with previous
- Still preliminary?





Possible Nature of LSP

- No strong or electromagnetic interactions
  - Otherwise would bind to matter
  - Detectable as anomalous heavy nucleus
- Possible weakly-interacting scandidates
  - Sneutrino
    - (Excluded by LEP, direct searches)
  - Lightest neutralino χ (partner of Z, H, γ)
  - Gravitino
    - (nightmare for astrophysical detection)

Minimal Supersymmetric Extension of Standard Model (MSSM)

- Particles + spartners

$$\begin{pmatrix} \frac{1}{2} \\ 0 \end{pmatrix} \; e.g., \; \begin{pmatrix} \ell \; (lepton) \\ \tilde{\ell} \; (slepton) \end{pmatrix} \; or \; \begin{pmatrix} q \; (quark) \\ \tilde{q} \; (squark) \end{pmatrix} \quad \begin{pmatrix} 1 \\ \frac{1}{2} \end{pmatrix} \; e.g., \; \begin{pmatrix} \gamma \; (photon) \\ \tilde{\gamma} \; (photino) \end{pmatrix} \; or \; \begin{pmatrix} g \; (gluon) \\ \tilde{g} \; (gluino) \end{pmatrix}$$

- 2 Higgs doublets, coupling μ, ratio of v.e.v.'s = $\tan \beta$
- Unknown supersymmetry-breaking parameters:
  - Scalar masses m_0, gaugino masses $m_{1/2}$,
  - trilinear soft couplings A_λ, bilinear soft coupling B_μ
- Assume universality? constrained MSSM = CMSSM
  - Single m_0, single $m_{1/2}$, single A_λ, B_μ: not string?
- Not the same as minimal supergravity (mSUGRA)
- Gravitino mass, additional relations

$$m_{3/2} = m_0, \; B_\mu = A_\lambda - m_0$$

Current Constraints on CMSSM

Assuming the lightest sparticle is a neutralino

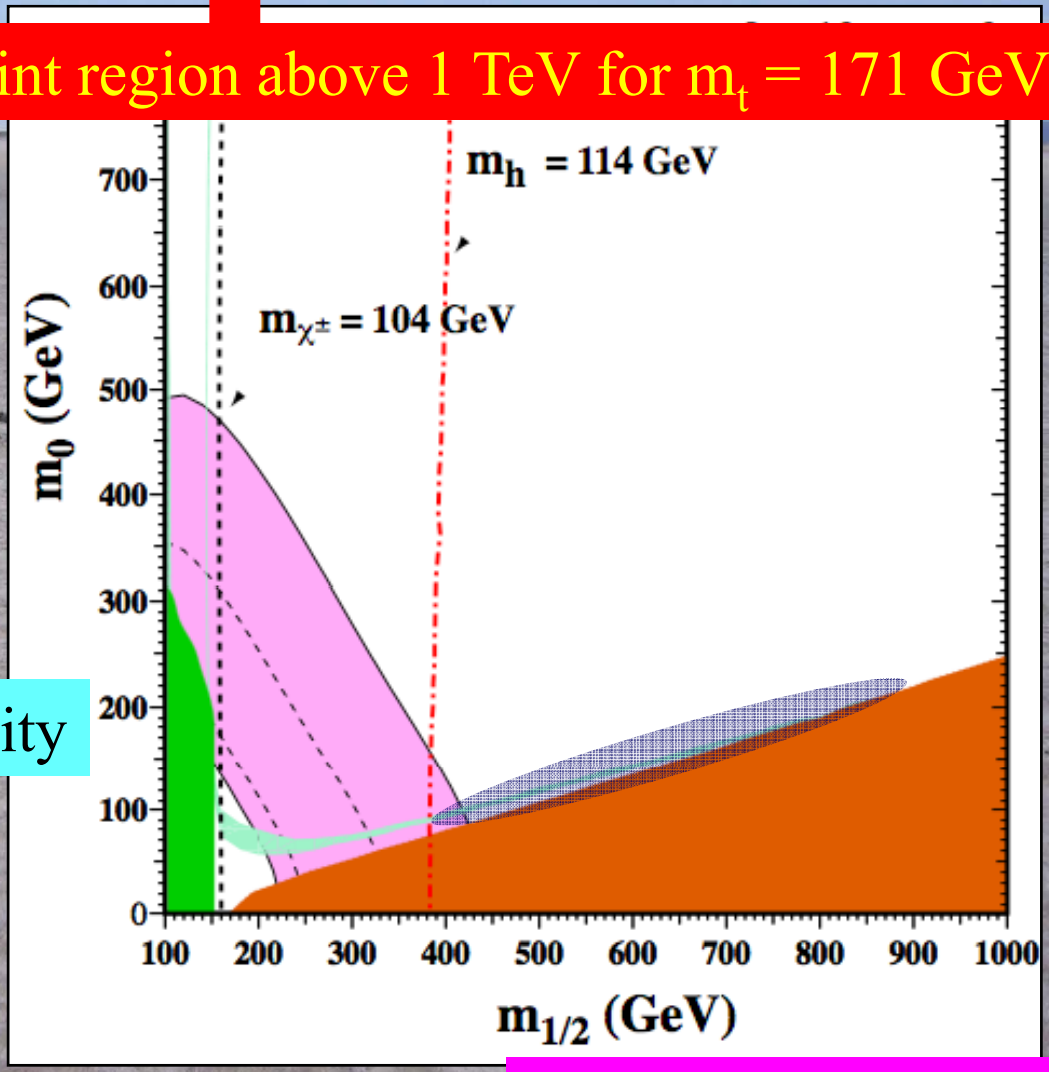
Focus-point region above 1 TeV for m_t = 171 GeV

Excluded because stau LSP

Excluded by b → s gamma

WMAP constraint on relic density

Preferred (?) by latest g - 2



JE + Olive + Santoso + Span

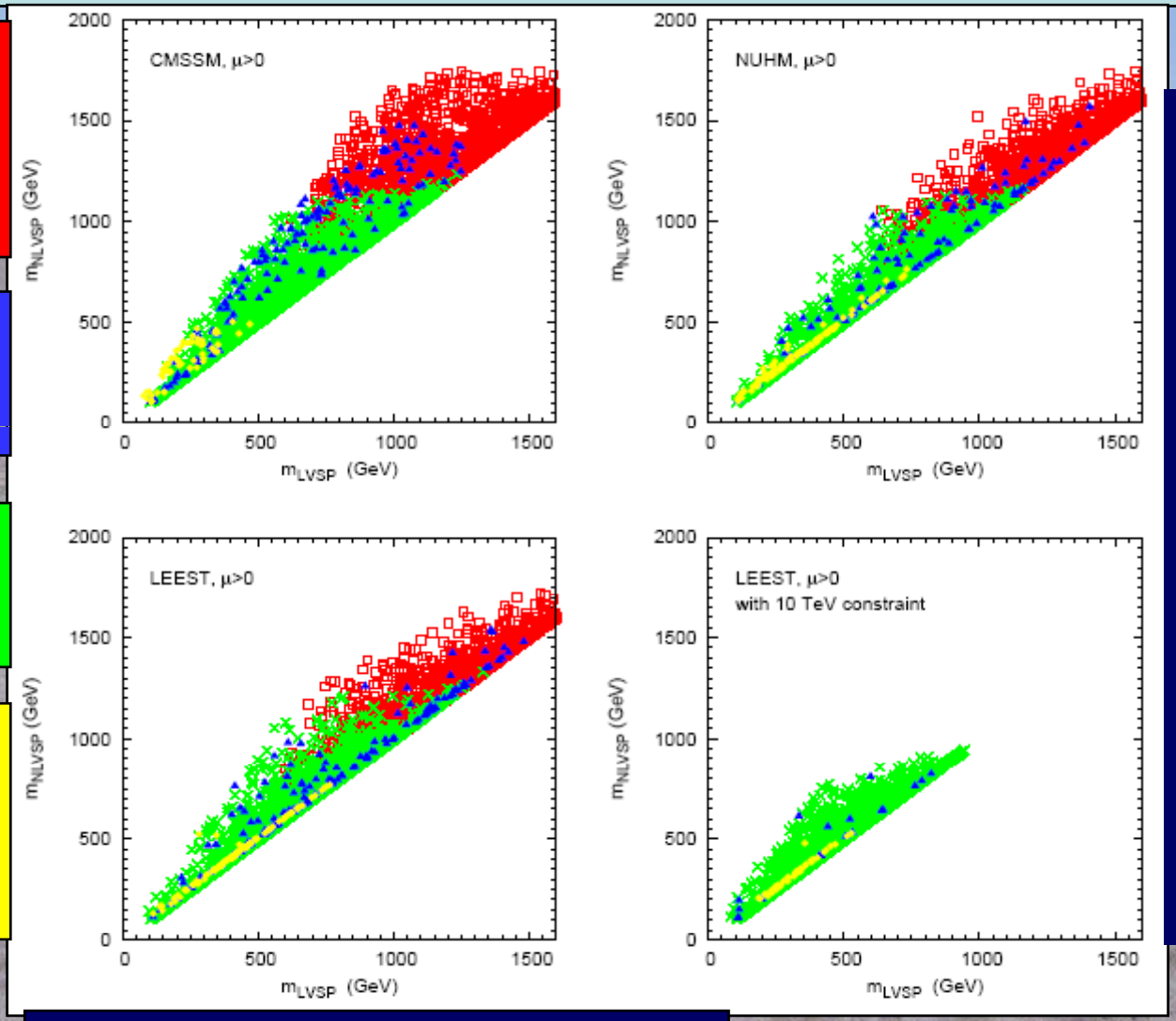
Sparticles may not be very light

Full Model samples

Provide Dark Matter

Detectable @ LHC

Dark Matter Detectable Directly



← Second lightest visible sparticle

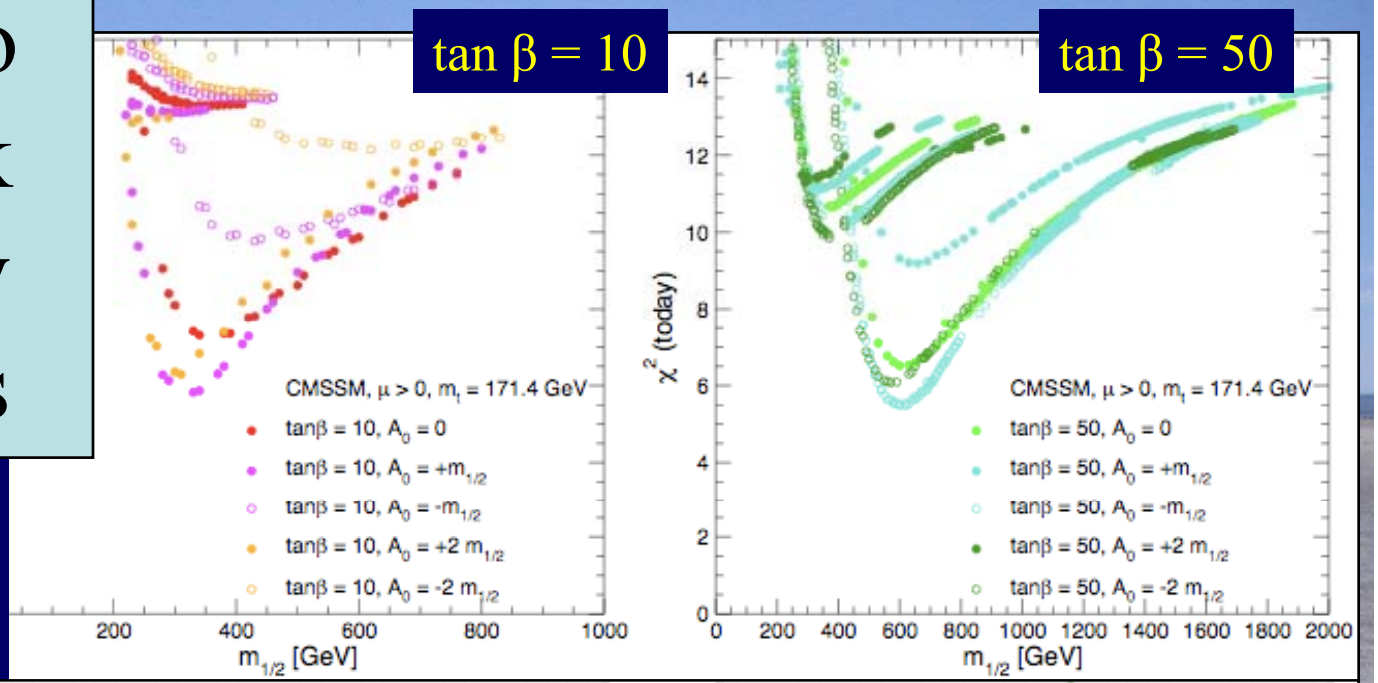
Lightest visible sparticle →

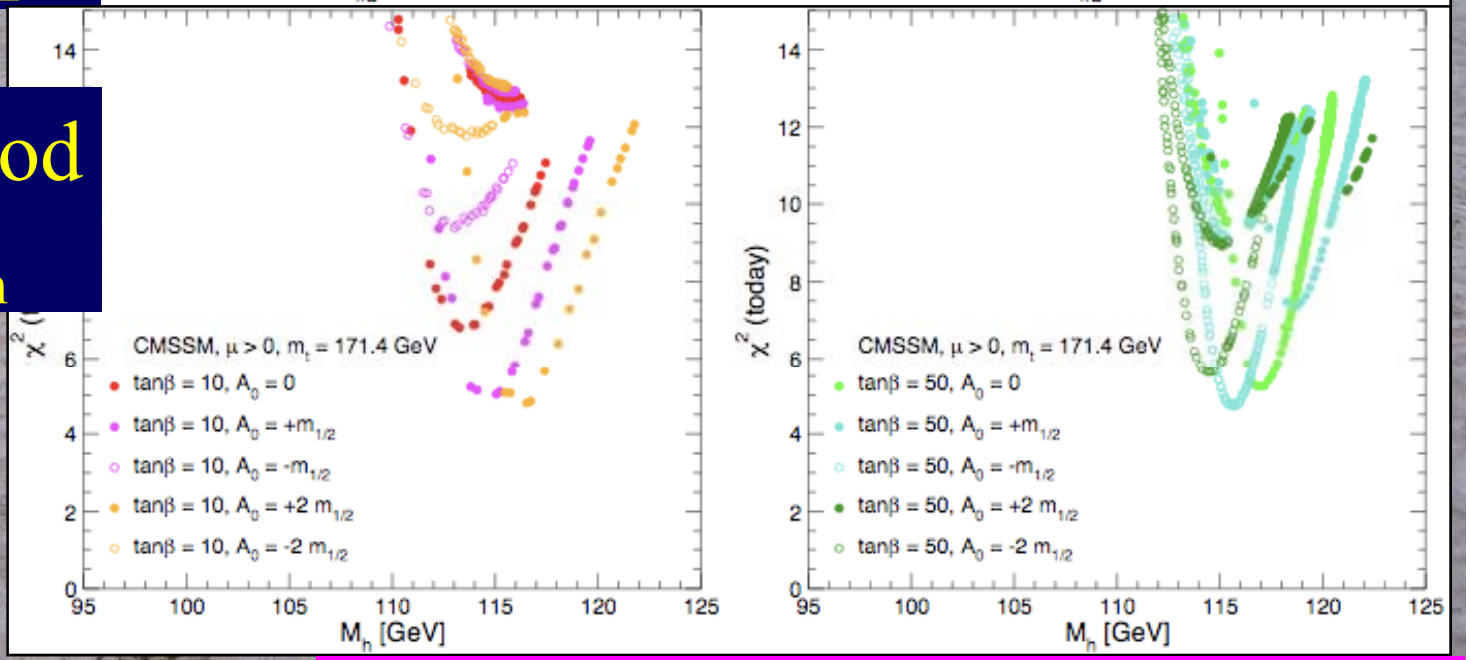
JE + Olive + Santoso + Span

Global Fit to Electroweak and B decay Observables

Likelihood for $m_{1/2}$

Likelihood for M_h





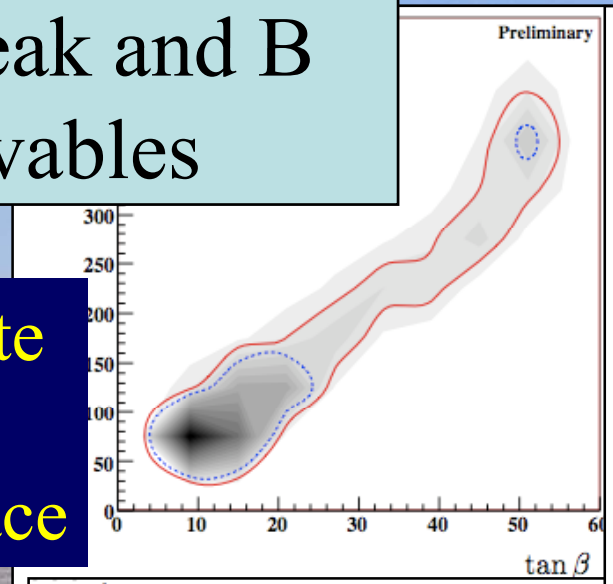
JE + Heinemeyer + Olive + Weber + Weiglein, arXiv:0706.0652

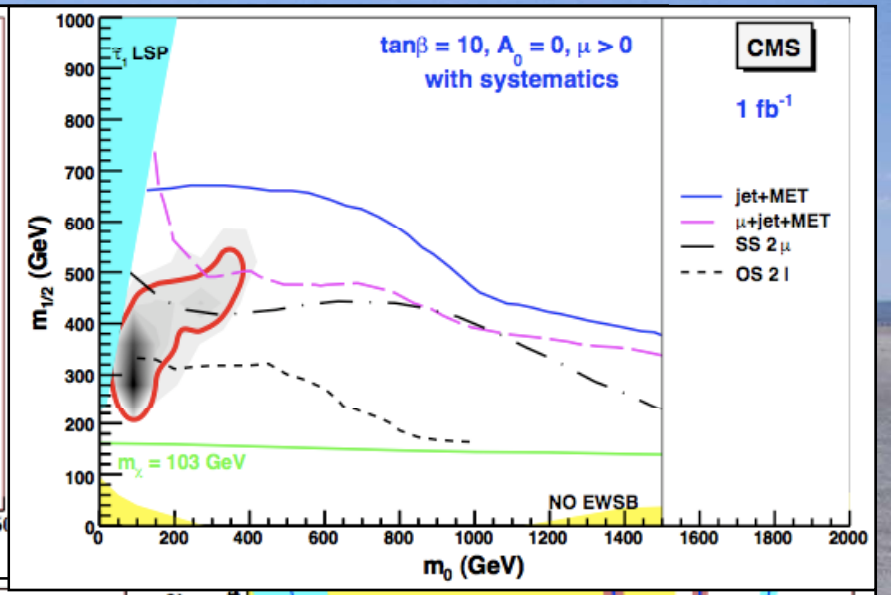
More Complete Fit to Electroweak and B Observables

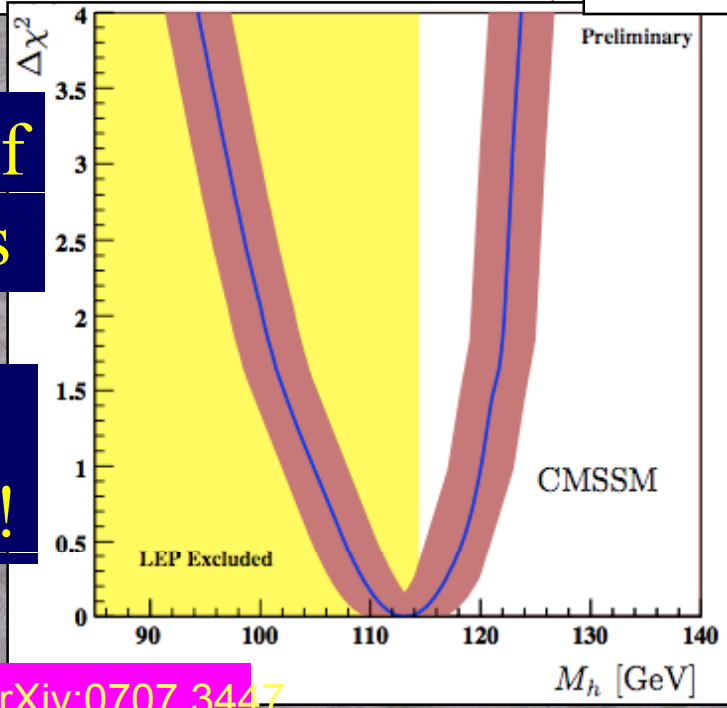
More complete analysis of parameter space

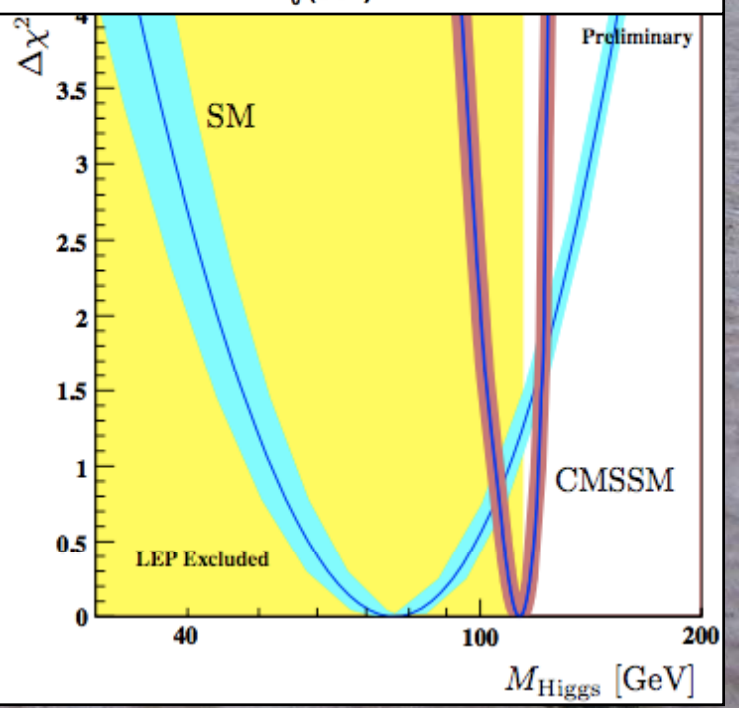
Larger set of observables

Better Graphics!



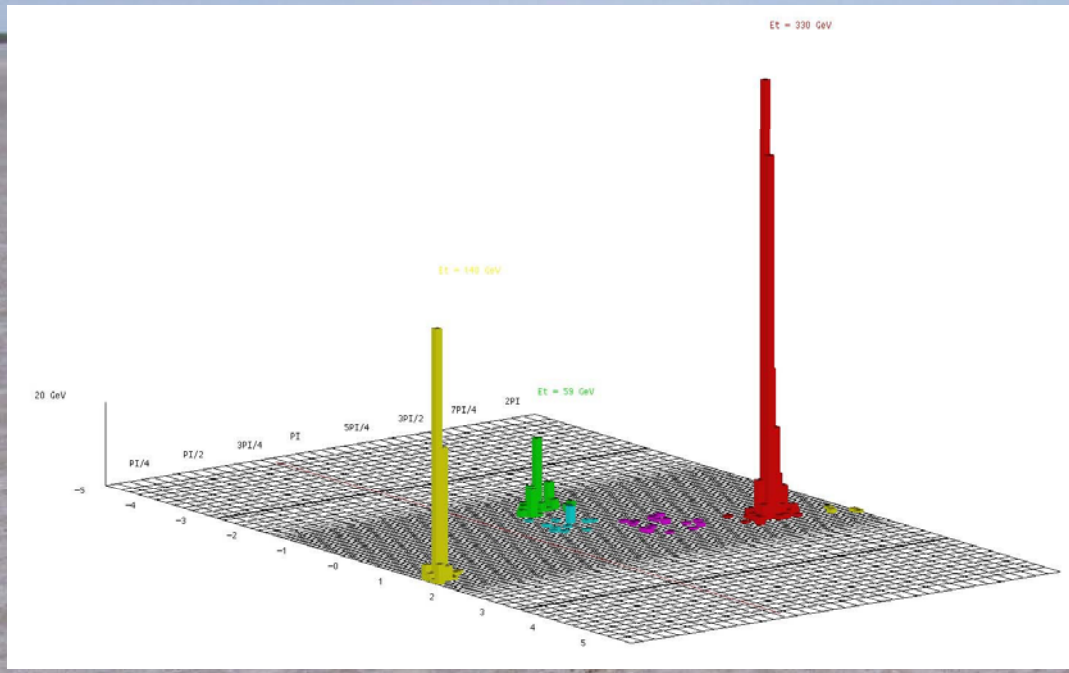


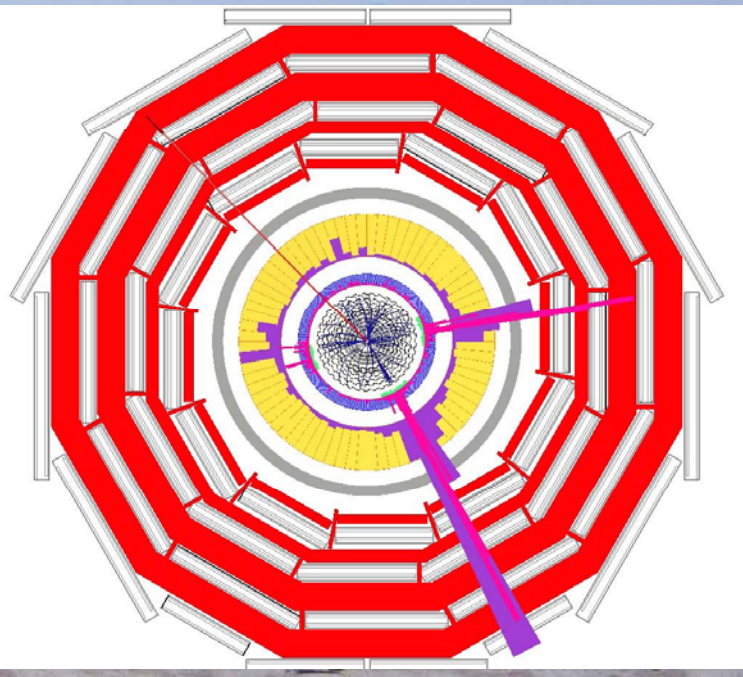




O. Buchmueller et al, arXiv:0707.3447

Classic Supersymmetric Signature



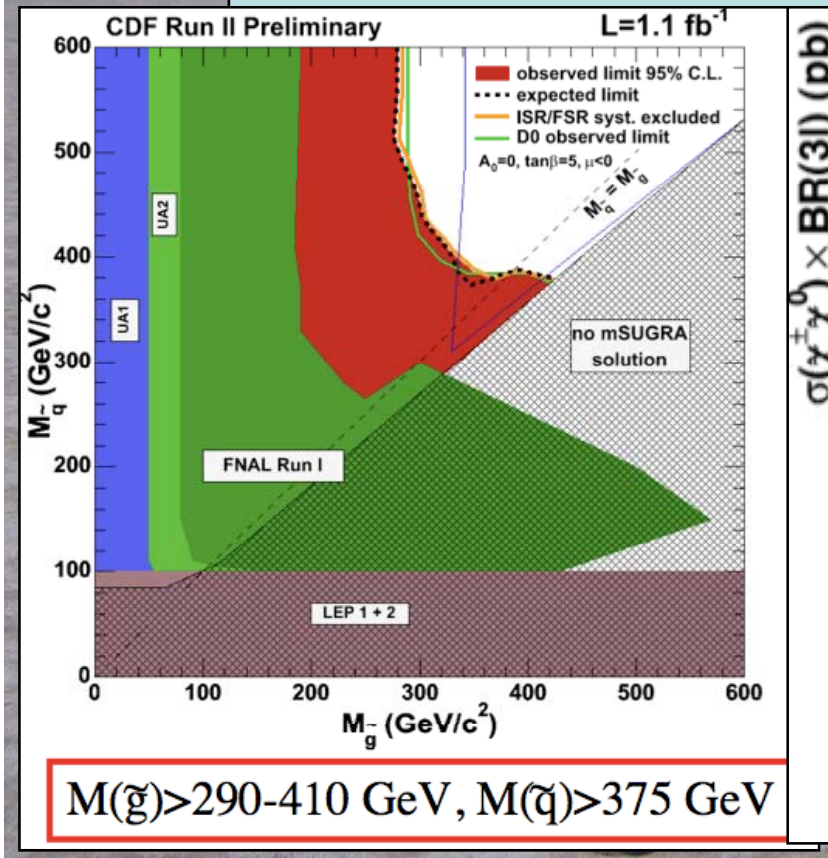


Missing transverse energy

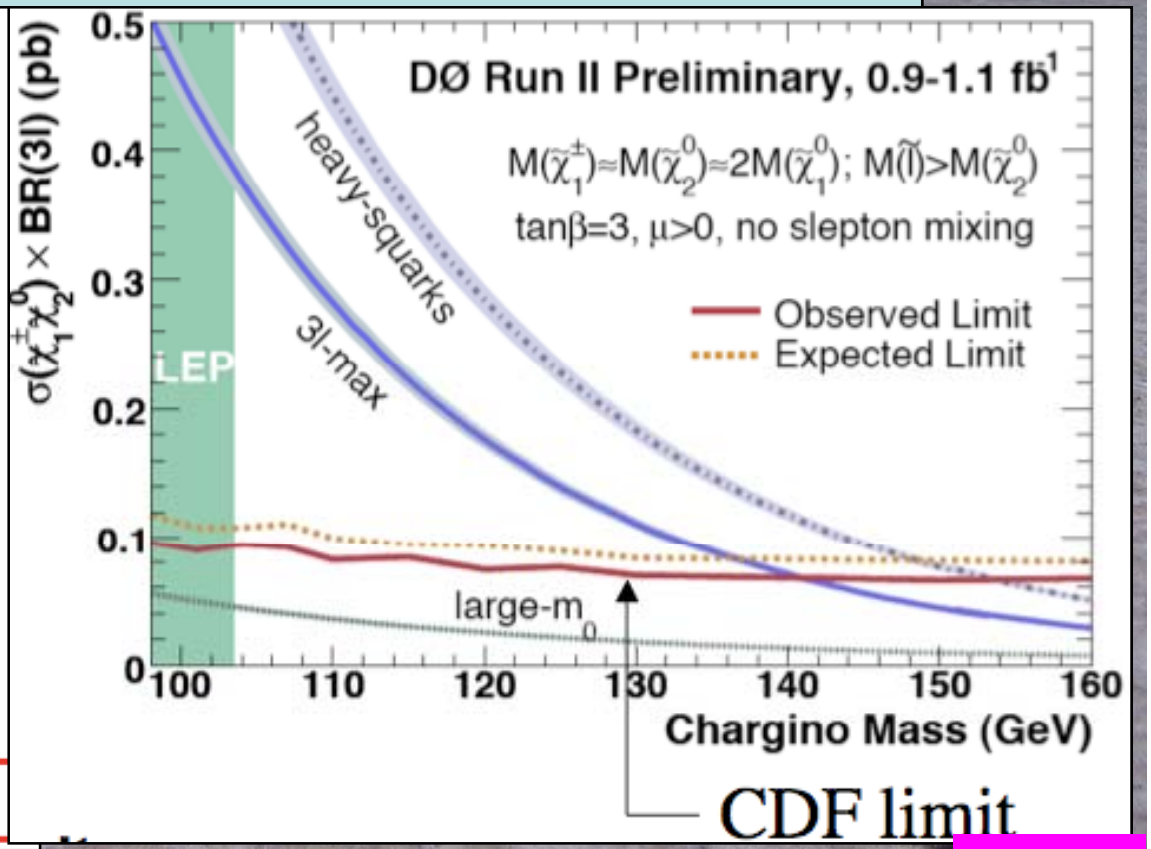
carried away by dark matter particles

Search for SUSY @ Tevatron

Limits on squarks, gluinos, trileptons,



M(g̃)>290-410 GeV, M(q̃)>375 GeV



Duperrin

The LHC's First Discovery?

6 December 2008

Evidence for squark and gluino production in pp collisions at $\sqrt{s}$ = 14 TeV

CMS collaboration

Abstract

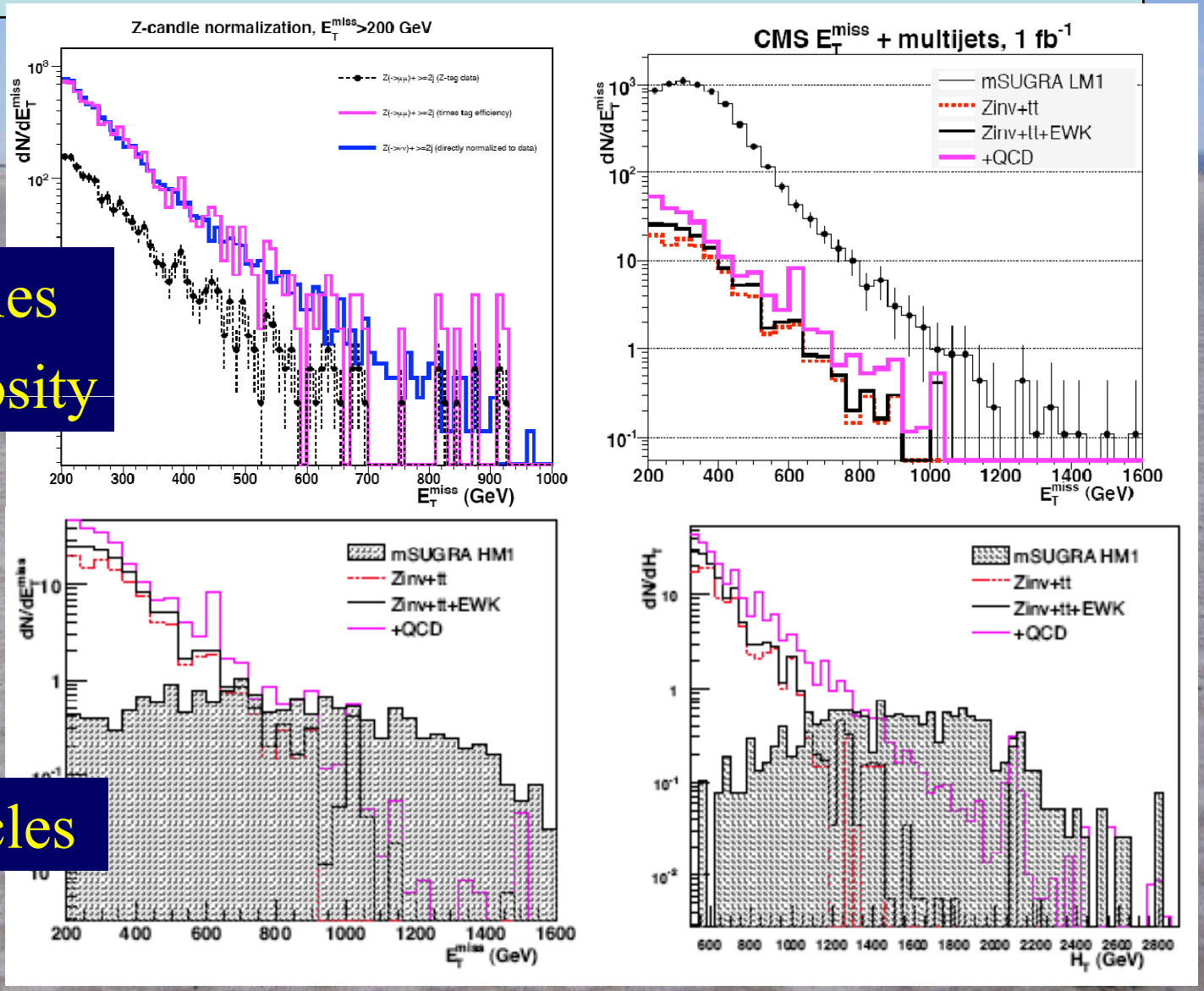
Experimental evidence for squark and gluino production in pp collisions $\sqrt{s}$ = 14 TeV with an integrated luminosity of 97 pb^{-1} at the Large Hadron Collider at CERN is reported. The CMS experiment has collected 320 events of events with several high E_T jets and large missing E_T, and the measured effective mass, i.e. the scalar sum of the four highest P_T jets and the event $\not{E}_T$, is consistent with squark and gluino masses of order of 650 GeV/c^2. The probability that the measured yield is consistent with the background is 0.26%.

Submitted to *European Journal of Physics*

Search for Supersymmetry

Light sparticles
@ low luminosity

Heavy sparticles



Supersymmetrists, Beware!

29 March 1984

EXPERIMENTAL OBSERVATION OF EVENTS WITH LARGE MISSING TRANSVERSE ENERGY ACCOMPANIED BY A JET OR A PHOTON(S) IN $p\bar{p}$ COLLISIONS AT $\sqrt{s}$ = 540 GeV

UA1 Collaboration, CERN, Geneva, Switzerland

Aachen[1]-Annecy(LAPP)[2]-Birmingham[3]-CERN[4]-Harvard[5]-Helsinki[6]-Kiel[7] Queen Mary College, London[8]-NIKHEF, Amsterdam[9]-Paris(Coll.de France)[10]-Riverside[11] Roma[12]-Rutherford Appleton Lab.[13]-Saclay(CEN)[14] Vienna[15]-Wisconsin[16] Collaboration

G. Arnison[13], O.C. Allkofer[7], A. Astbury[13,*], B. Aubert[2], C. Bacci[12], G. Bauer[16], A. Bézaguet[4], R.K. Bock[4], T.J.V. Bowcock[8], M. Calvetti[12], P. Catz[2], P. Cennini[4], S. Centro[4], F. Ceradini[12], S. Cittolin[4], D. Cline[16], C. Cochet[14], J. Colas[2], M. Corden[3], D. Dallman[4,15], D. Dau[7], M. DeBeer[14], M. Della Negra[4,*], M. Demoulin[4], D. Denegri[14], D. DiBitonto[4], A. DiCiaccio[12], L. Dobrzynski[14], J. Dowell[3], K. Eggert[1], E. Eisenhandler[8], N. Ellis[4], P. Erhard[1], H. Faissner[1], M. Fincke[7,*], P. Flynn[13], G. Fontaine[10], R. Frey[11], R. Frühwirth[15], J. Garvey[3], S. Geer[4], C. Ghesquière[14], P. Ghez[2], W.R. Gibson[8], Y. Giraud-Héraud[14], A. Givernaud[14], A. Gonidec[2], G. Grayer[13], T. Hansl-Kozanecka[1], W.J. Haynes[13], L.O. Hertzberger[9], D. Hoffmann[2], H. Hoffmann[4], D.J. Holthuizen[9], R.J. Homer[3], A. Honma[8], W. Jank[4], G. Jorat[4], P.I.P. Kalmus[8], V. Karimäki[6], R. Keeler[8,*], I. Kenyon[3], A. Kernan[11], R. Kinnunen[6], W. Kozanecki[11], D. Kryn[4,10], P. Kyberd[8], F. Lacava[12], J.-P. Laugier[14], J.-P. Lees[2], H. Lehmann[1], R. Leuchs[1], A. Lévêque[4], D. Linglin[2], E. Locci[14], M. Loret[14], T. Markiewicz[16], G. Maurin[4], T. McMahon[3], J.-P. Mendiburu[10], M.-N. Minard[2], M. Mohammadi[16], K. Morgan[11], M. Moricca[12], F. Muller[4], A.K. Nandi[13], L. Naumann[4], A. Norton[4], A. Orkin-Lecourtois[10], L. Paoluzi[12], F. Pauss[4], G. Piano Mortari[12], E. Pietarinen[6], M. Pimiä[6], D. Pitman[11], A. Placci[4], J.-P. Porte[4], E. Radermacher[1], J. Ransdell[11], H. Reithler[1], J.-P. Revol[4], J. Rich[14], M. Rijssenbeek[4], C. Roberts[13], J. Rohlf[2], P. Rossi[4], C. Rubbia[4], B. Sadoulet[4], G. Sajot[10], G. Salvini[12], J. Sass[14], A. Savoy-Navarro[10], D. Schinzel[4], W. Scott[13], T.P. Shah[13], I. Sheer[11], D. Smith[11], M. Spiro[14], J. Strauss[13], J. Streets[3], K. Sumorok[4], F. Szoncso[15], C. Tao[10], G. Thompson[8], J. Timmer[4], E. Tscheslog[1], J. Tuominiemi[6], B. Van Eijk[9], J.-P. Vialle[2], J. Vrana[14], V. Vuillemin[4], H. D. Wahl[15], P. Watkins[3], J. Wilson[3], C.-E. Wulz[15], M. Yvert[2]

Abstract

We report the observation of five events in which a missing transverse energy larger than 40 GeV is associated with a narrow hadronic jet and of two similar events with a neutral electromagnetic cluster (either one or more closely spaced photons). We cannot find an explanation for such events in terms of backgrounds or within the expectations of the Standard Model.

受入 84-9-298

CERN-TH.3968/84

IS SUPERSYMMETRY FOUND? *)

John Ellis
CERN — Geneva

and

Marc Sher **)
University of California, Irvine

ABSTRACT

Monojet events seen recently by the UA1 collaboration at the CERN $p\bar{p}$ Collider may be due to squarks or gluinos with masses O(40) GeV. The thinness of the observed jets favours the squark interpretation. In this case, we predict that sleptons should have masses between 20 and 30 GeV and that the photino should have a mass between 5 and 10 GeV. Such masses are close to the experimental lower limits and sparticles could soon be detectable in $e^+e^- \to (\tilde{\gamma}\tilde{\gamma})\gamma$ experiments and $W^\pm$ and Z^0 decay. We demonstrate that such light sparticle masses are consistent with models whose weak gauge symmetry breaking is driven by a t quark weighing O(40) GeV as recently reported, and even with no-scale models in which the supersymmetry breaking scale is also determined dynamically.

*) Supported in part by the director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Dept. of Energy under Contract #DE-AC03-76SF0098 and by N.S.F. Contract NSF-PHY-8305795.

**) Presently at CERN, Geneva. Address after September 1, 1984: Univ. of California, Santa Cruz.

CERN-TH.3968/84
July 1984

Supersymmetrists, Beware!

Typical analysis cuts (ATLAS EXAMPLE):

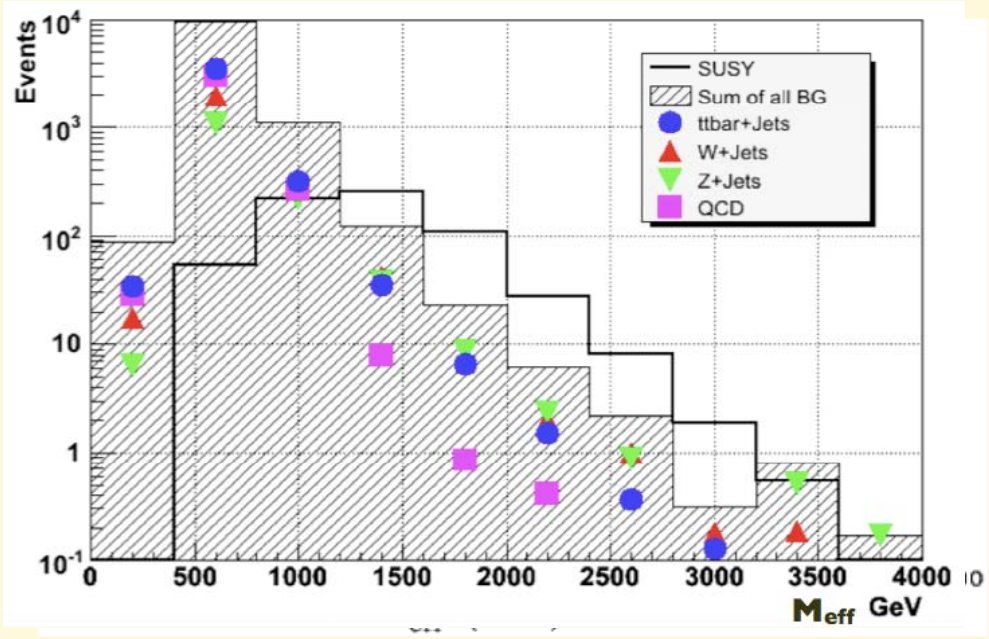
≥4jets, E_T>50 GeV leading jet E_T>100 GeV

no lepton with E_T>20 GeV

MissET> max(100, 0.2 M_{eff})

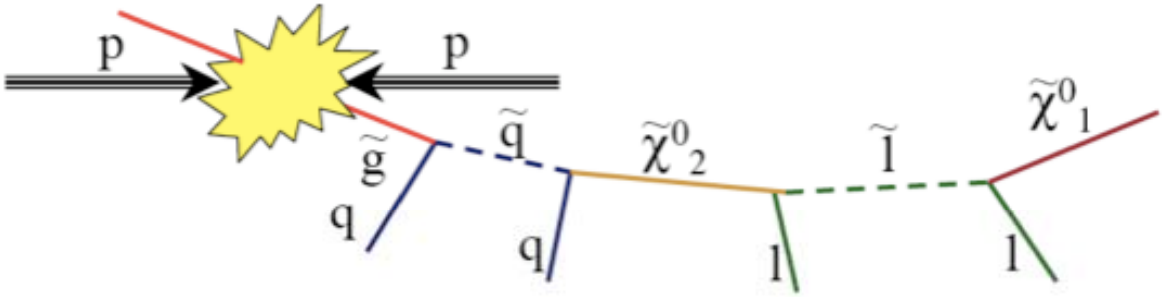
M_{eff} = MET + $\sum_{i=1,..,4} E_T^i$

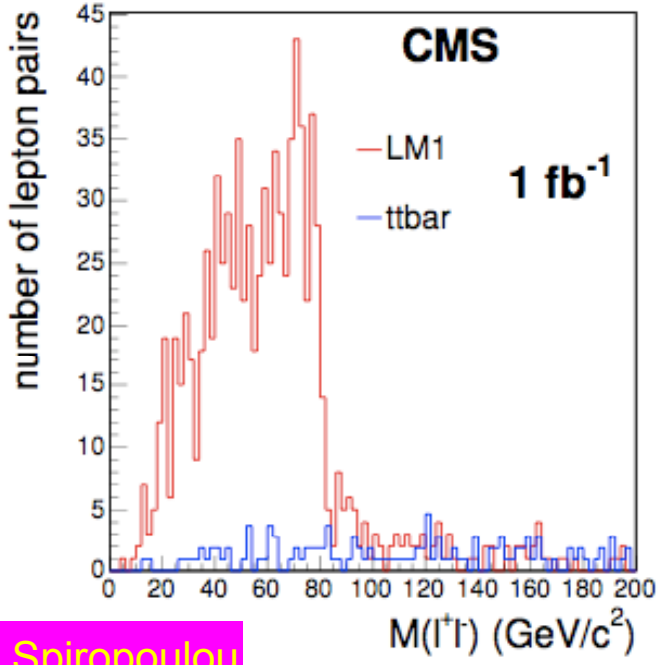
Transverse sphericity > 0.2



Mangano

Early Search for Dileptons





Spiropoulou

- SFOS dilepton+jets+E_T^{miss}
- $t\bar{t}$:WW+j:Z+j:other$\sim$ 6:1:1:1
- flavor subtraction ($e^-\mu^+ + e^+\mu^-$) to supress chargino, W, $t\bar{t}$, WW, "other"
- L1+HLT trigger path required
- overall systematic on the background 20% (JES dominated)
- 5σ discovery with $\sim$ 20 pb^{-1} (of data understood as expected with 1 fb^{-1}).

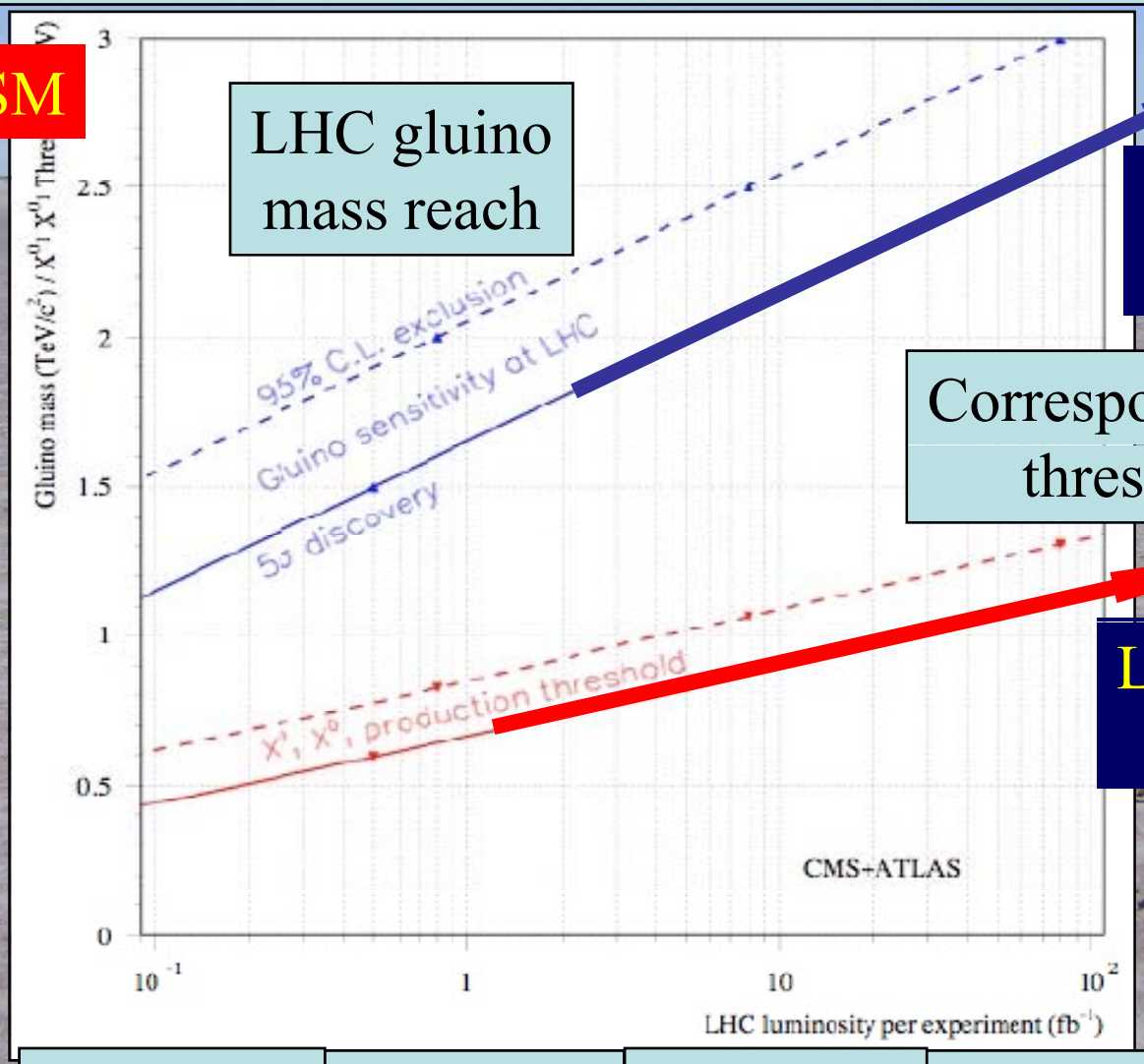
CMS SUSY Discovery Plan

- Search for SUSY (Evidence for excess) in $\geq$1 lepton+$E_{\mathrm{T}}^{\mathrm{miss}}$+jets at 14 TeV in the electron and muon channels (100 pb^{-1}).
- Search for SUSY (Evidence for excess) in opposite sign dilepton pairs+ $E_{\mathrm{T}}^{\mathrm{miss}}$+jets at 14 TeV in the electron and muon channels (20 pb^{-1})
- Search for SUSY (Evidence for excess) in same-sign dilepton pairs + $E_{\mathrm{T}}^{\mathrm{miss}}$+jets at 14 TeV in the electron and muon channels (200 pb^{-1})
- Search for SUSY (Evidence for excess) in Z^0 leptonic decays+ $E_{\mathrm{T}}^{\mathrm{miss}}$+jets at 14 TeV in the electron and muon channels (100 pb^{-1})
- Search for LVF SUSY (Evidence for excess) in $e + \mu$ final state at 14 TeV (500 pb^{-1})
- Search for SUSY (Evidence for excess) in trileptons + jets at 14 TeV. ($\sim$ fb^{-1})
- Search for SUSY (Evidence for excess) in $b\bar{b}$ + 1 lepton at 14 TeV.
- Search for SUSY (Evidence for excess) in 0 lepton + $E_{\mathrm{T}}^{\mathrm{miss}}$+ jets at 14 TeV (10 pb^{-1})
- Search for SUSY (Evidence for excess) in $b\bar{b}$ + $E_{\mathrm{T}}^{\mathrm{miss}}$ + jets at 14 TeV (100 pb^{-1})
- Search for SUSY (Evidence for excess)in top hadronic decays+ $E_{\mathrm{T}}^{\mathrm{miss}}$ at 14 TeV (200 pb^{-1})
- Serach for SUSY (Evidence for excess) in opposite-sign ditau + $E_{\mathrm{T}}^{\mathrm{miss}}$ at 14 TeV (200 pb^{-1})
- Search for GMSB (Evidence for excess) in prompt photon final states at 14 TeV (500 pb^{-1})
- Search for GMSB (Evidence for excess) in non-pointing photons at 14 TeV (1 fb^{-1})
- Search and reconstruction of heavy stable charged particles at 14 TeV using TOF and dE/dx (500 pb^{-1})
- ....

Spiropoulou

Implications of LHC Search for LCs

In CMSSM



SLHC reach ~ CLIC

Corresponding sparticle thresholds @ LC

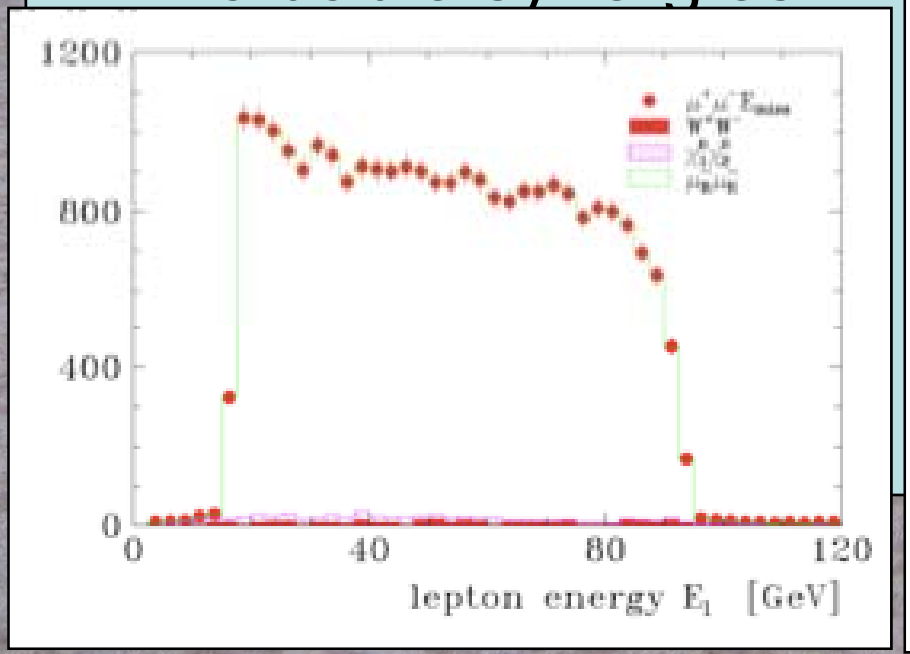
LHC will tell ILC where to look

'month' @ 10^{32} | 'month' @ 10^{33} | 1 'year' @ 10^{33} | 1 'year' @ 10^{34}

Blaising, JE et al: 2006

Precision Measurements @ ILC

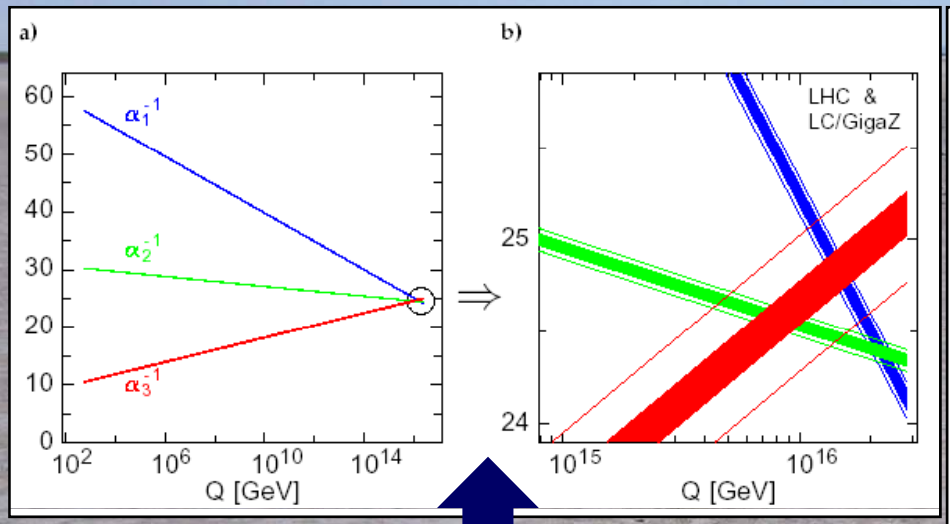
- Accurate measurements of masses, couplings
- Invaluable synergies



EXC	LHC	LC	LHC+LC	SPS1a
M_1	102.5±5.3	102.3±0.1	102.2±0.1	102.2
M_2	191.8±7.3	192.5±0.7	191.8±0.2	191.8
M_3	578.±15.	→	588.±11.	589.4
$M_{\tilde{e}_L}$	198.7±5.1	198.7±0.2	198.7±0.2	198.7
$M_{\tilde{e}_R}$	138.2±5.0	138.2±0.05	138.2±0.05	138.2
$M_{\tilde{q}_L}$	550.±13.	→	553.3±6.5	553.7
$M_{\tilde{u}_R}$	529.±20.	→	532.±15.	532.1
$M_{\tilde{d}_R}$	526.±20.	→	529.±15.	529.3
A_t	-507.±91.	-501.9±2.7	-505.2±3.3	-504.9
μ	345.2±7.3	344.3±2.3	344.4±1.0	344.3
$\tan\beta$	10.2±9.1	10.3±0.3	10.06±0.2	10

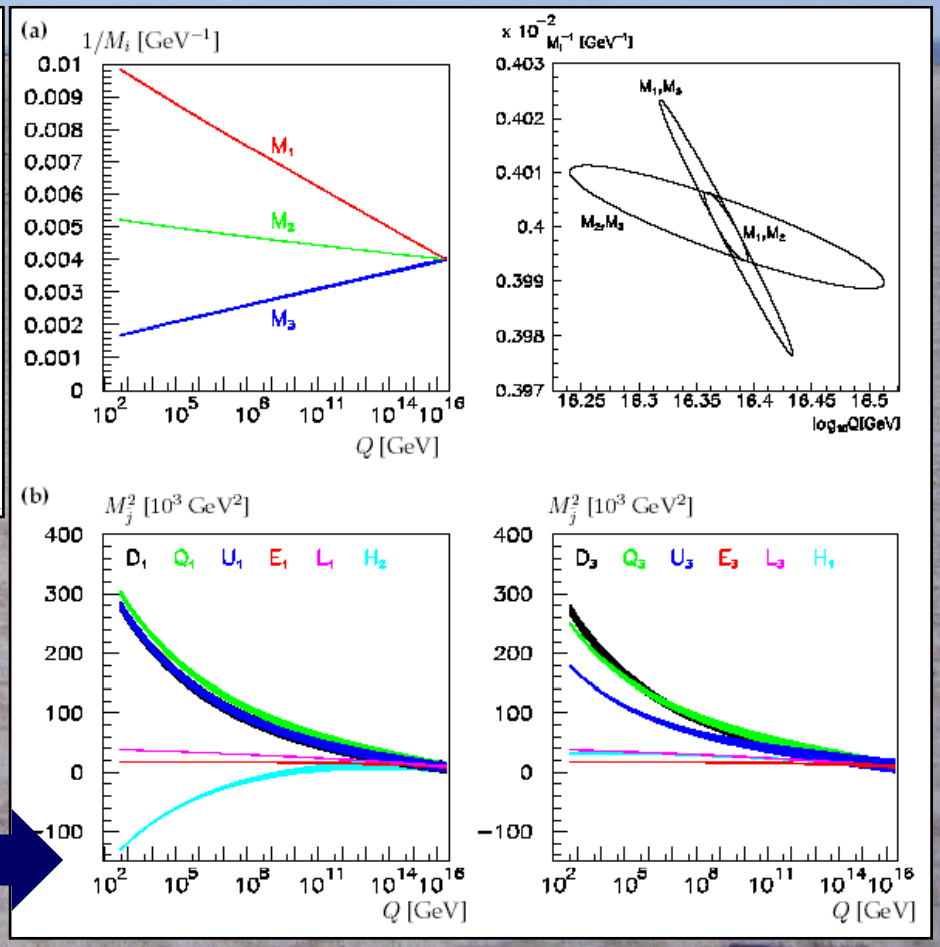
Choi

Tests of Unification @ LHC/ILC



For gauge couplings

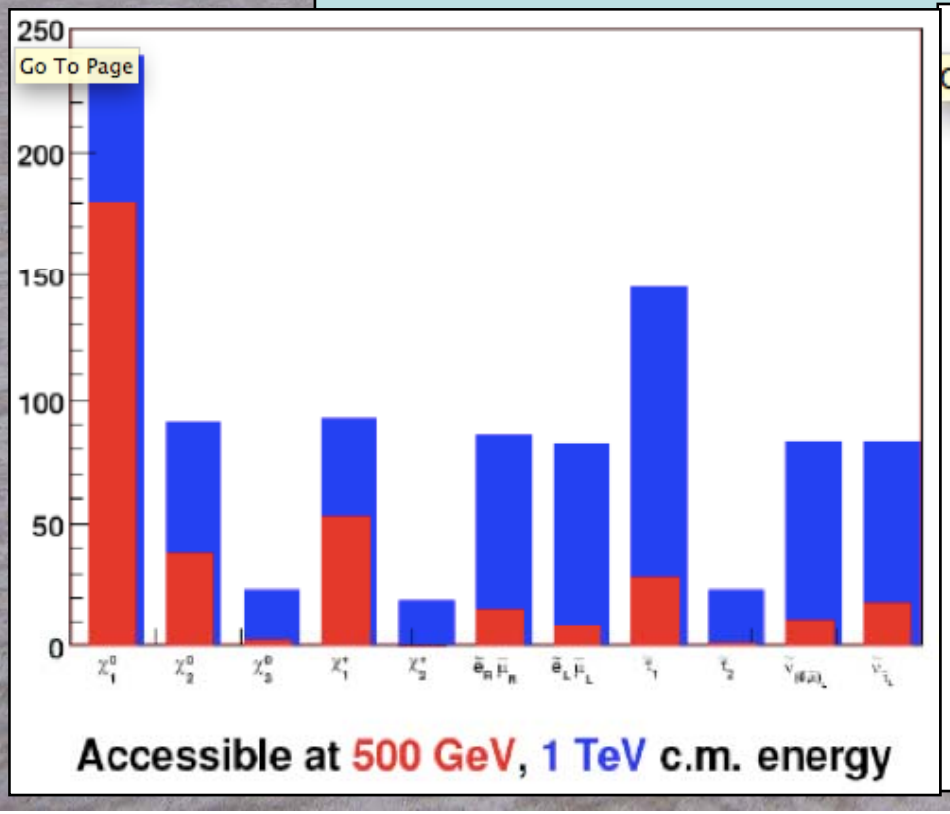
For sparticle masses



Choi

Supersymmetrists, Beware!

Preliminary study of 242 models with large cross sections @



Go To Page

★ Out of 242 models, at 500 GeV:

59+99=158/242 = 65 %

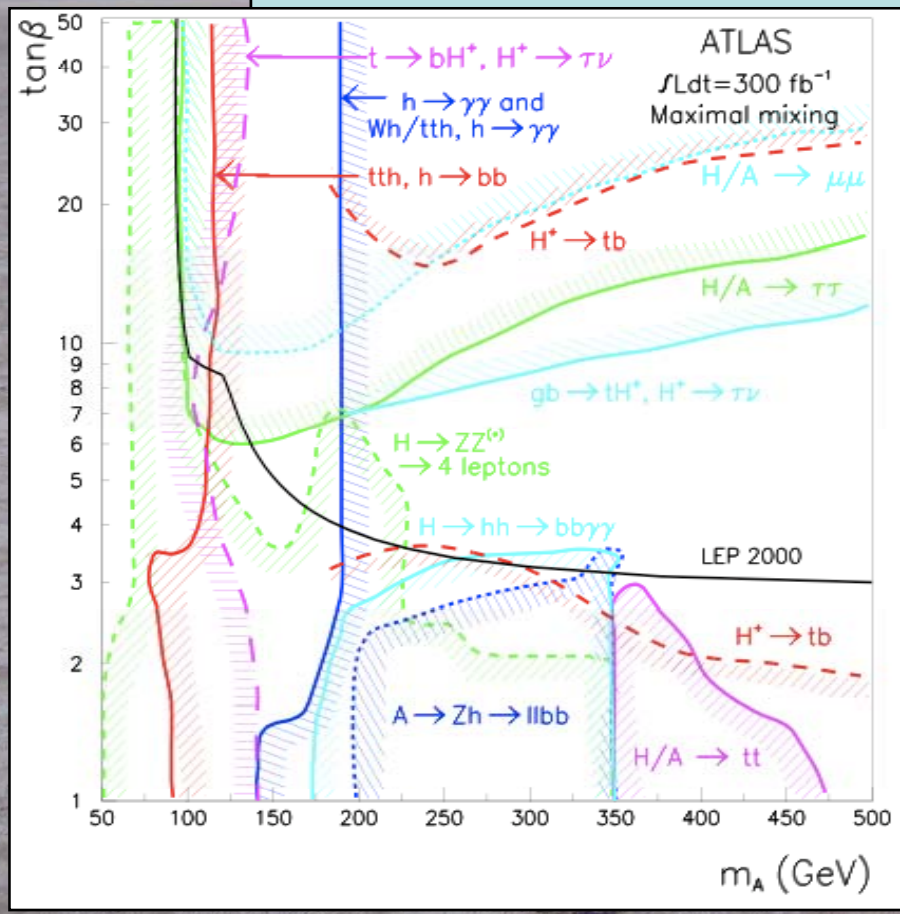
have NO signal observable…

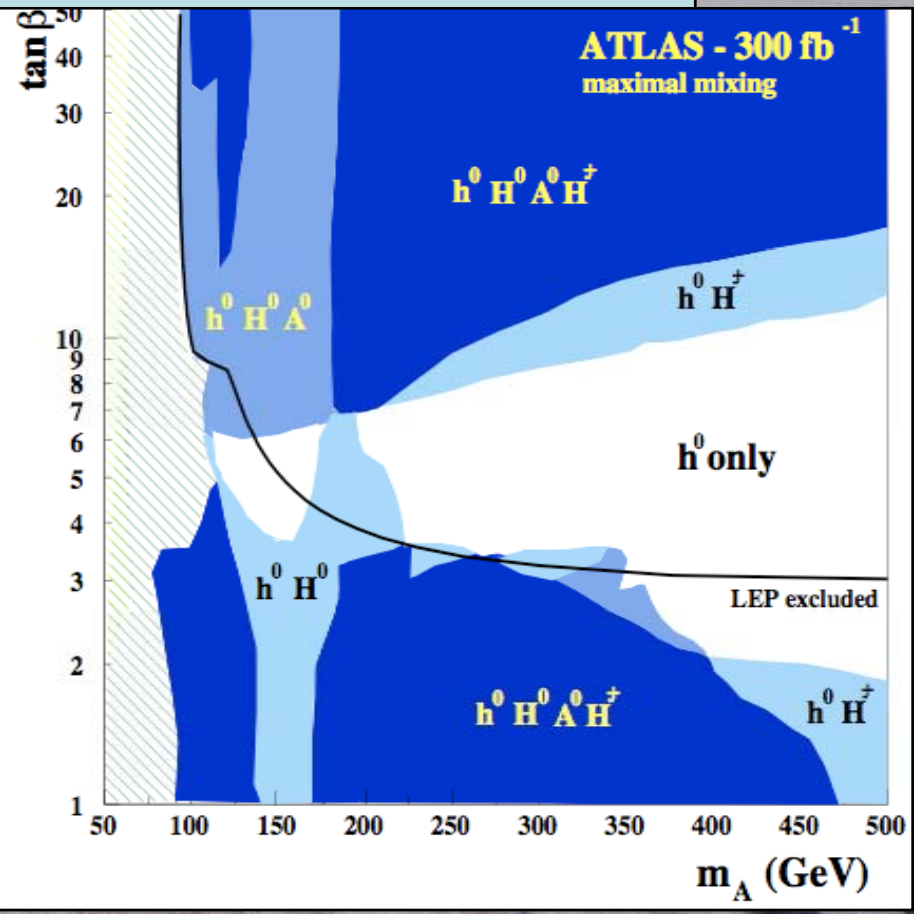
★ The percentage is actually higher (~75 % !) after some further investigation

Lillie //

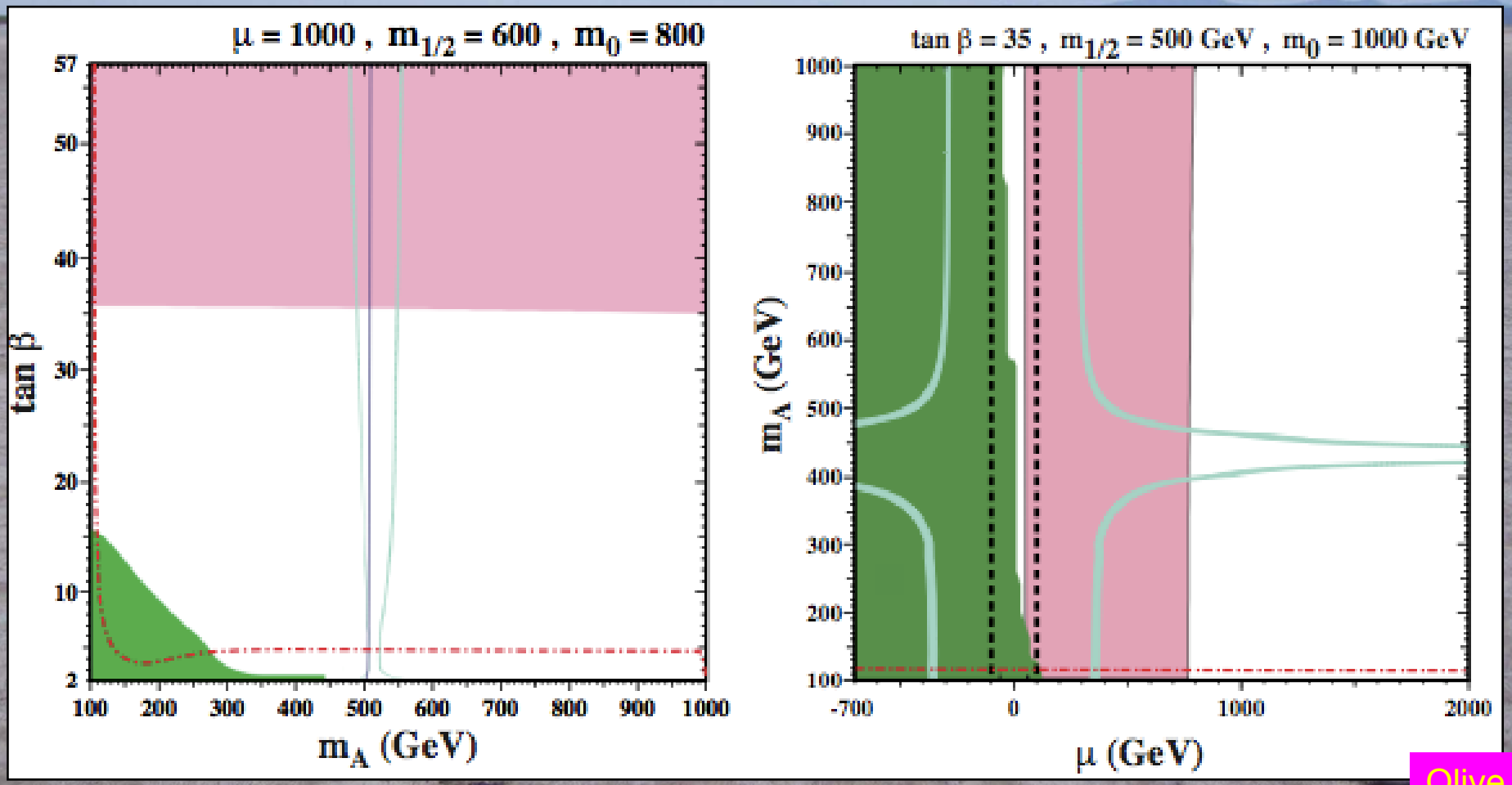
Prospects for SUSY Higgses @ LHC

Cover entire plane at least (only)





Most of (mA, tan β) Plane **NOT** WMAP-Compatible



Olive

Non-Universal Scalar Masses

- Different sfermions with same quantum #s?

  e.g., d, s squarks?

  disfavoured by upper limits on flavour-changing neutral interactions

- Squarks with different #s, squarks and sleptons?

  disfavoured in various GUT models

  e.g., $d_R = e_L$, $d_L = u_L = u_R = e_R$ in SU(5), all in SO(10)

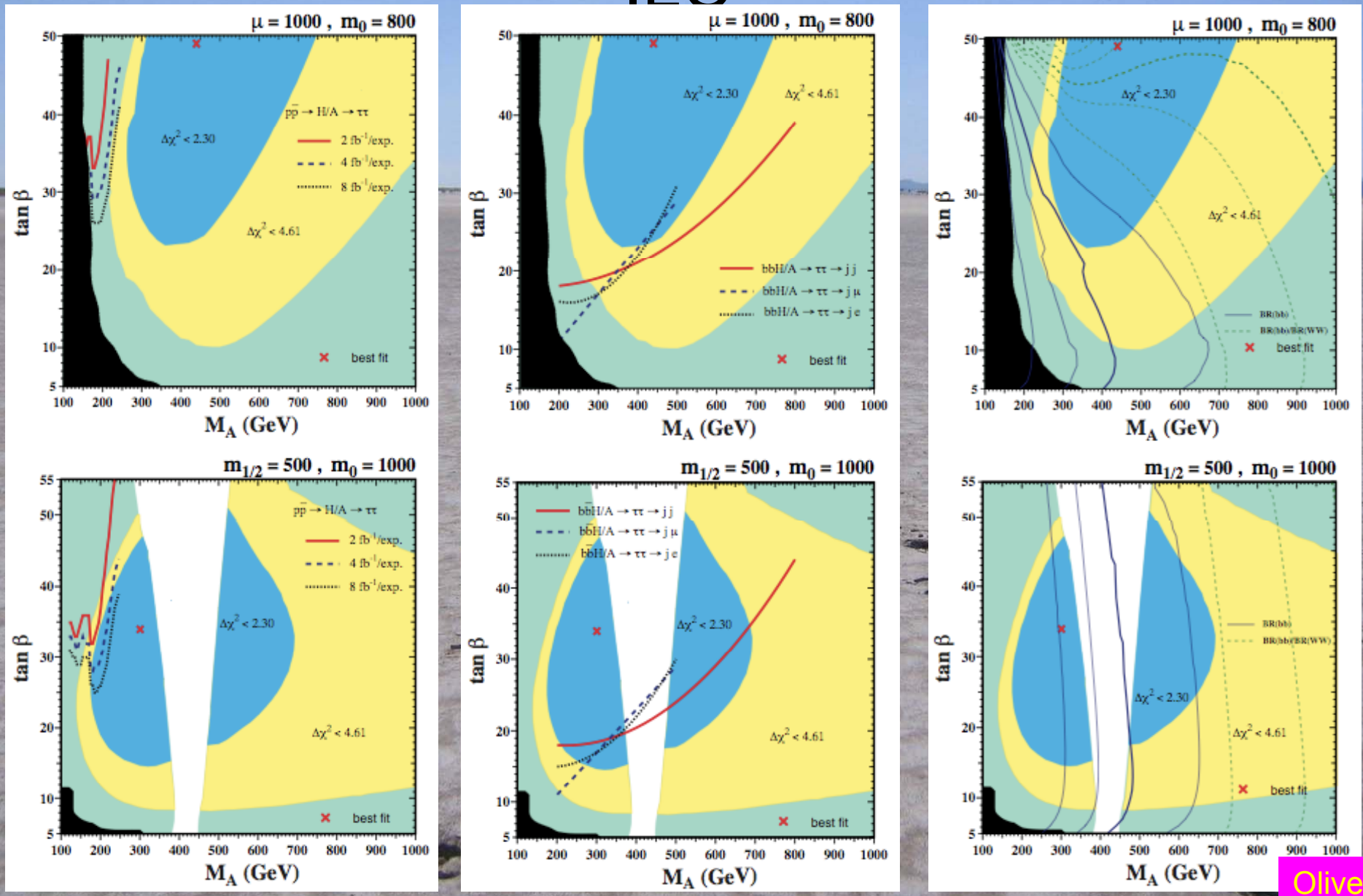
- Non-universal susy-breaking masses for Higgses?

  No reason why not!

WMAP-Compatible (m_A, tanβ) Surfaces in NUHM

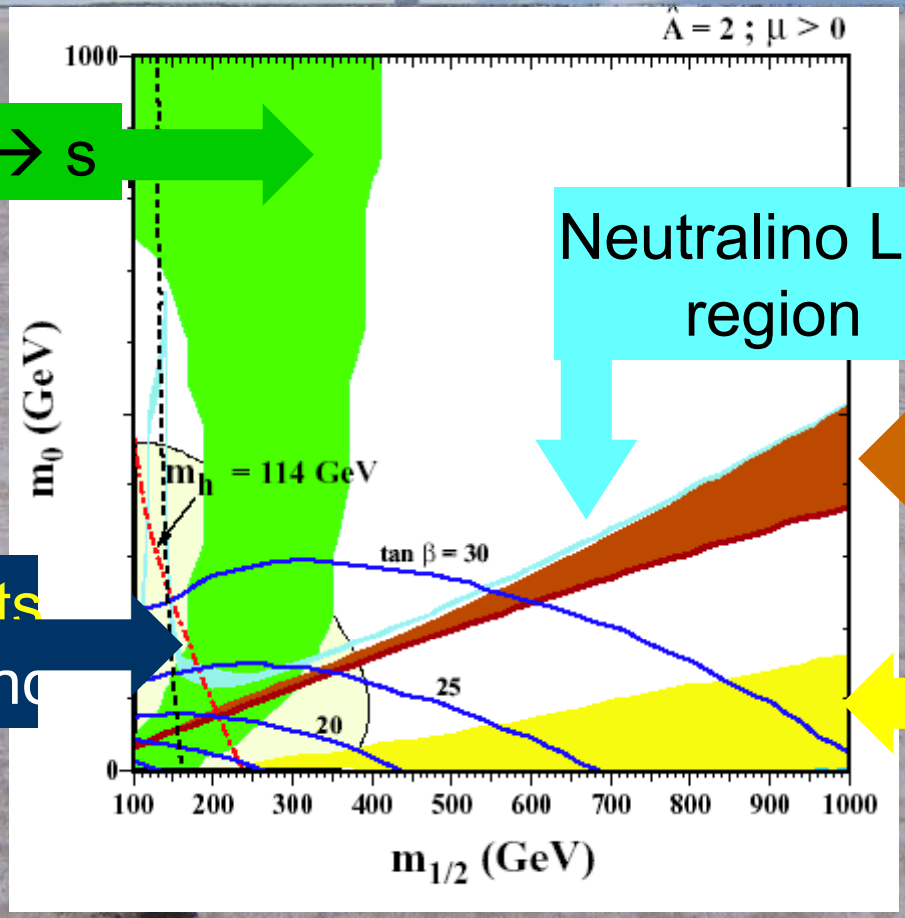
- Within CMSSM, generic choices of mA, tanβ do not have correct relic density
- Use extra NUHM parameters to keep $\Omega_\chi h^2$ within WMAP range, e.g.,
  - m_0 = 800 GeV, μ = 1000 GeV, $m_{1/2}$ ~9/8 m_A
  - $m_{1/2}$ = 500, m_0 = 1000, μ ~ 250 to 400 GeV
- Make global fit to electroweak and B observables
- Analyze detectability @ Tevatron/LHC/ILC

WMAP Surfaces @ Tevatron, LHC, ILC



Minimal Supergravity Model (mSUGRA)

More constrained than CMSSM: $m_{3/2} = m_0$, $B_\lambda = A_\lambda - 1$



Excluded by b → s

Neutralino LSP region

stau LSP (excluded)

LEP constraints On m_h, charginc

Gravitino LSP stau NLSP

Steffen

Possible Nature of NLSP if GDM

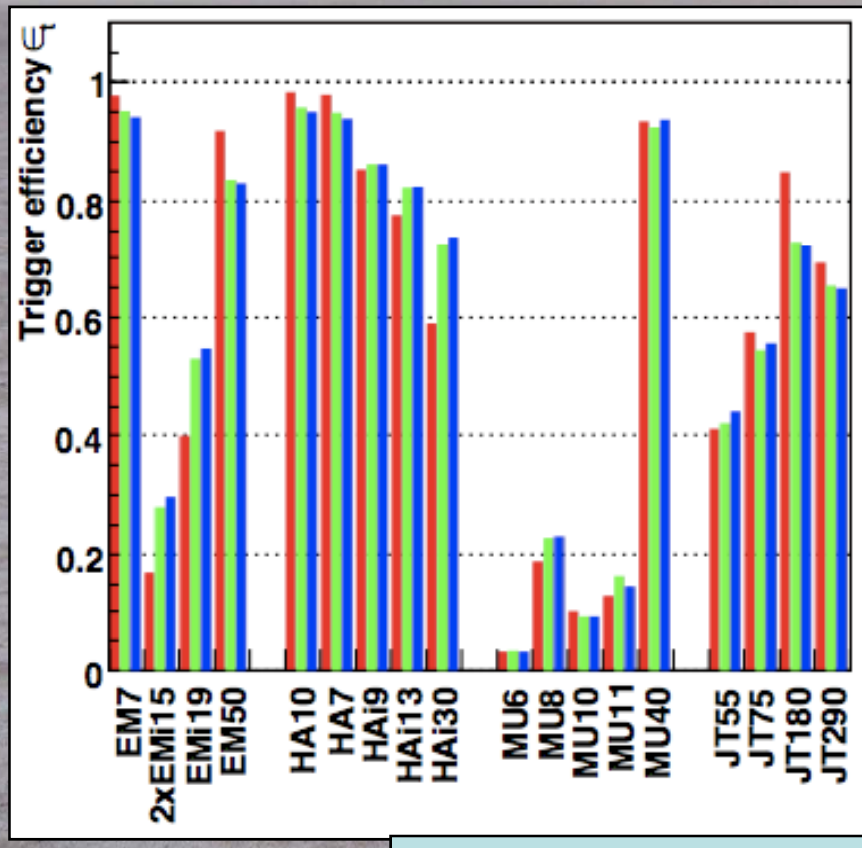
- NLSP = next-to-lightest sparticle
- Very long lifetime due to gravitational decay, e.g.:

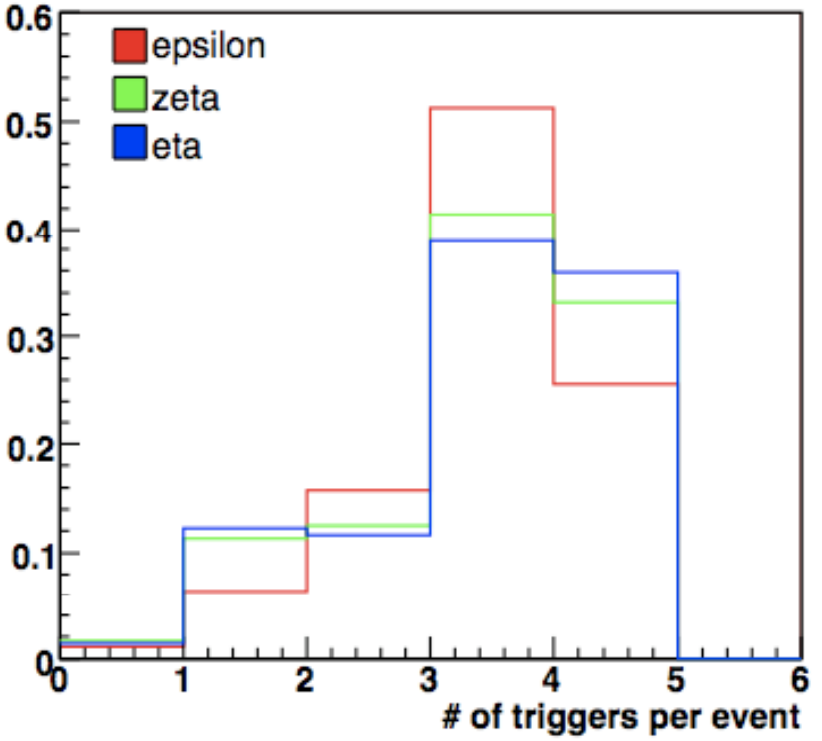
$$\Gamma_{\tilde{\tau}\to\tilde{G}\tau} = \frac{1}{48\pi}\,\frac{1}{M_P^2}\,\frac{m_{\tilde{\tau}}^5}{m_{3/2}^2}\left(1-\frac{m_{3/2}^2}{m_{\tilde{\tau}}^2}\right)^4$$

- **Could be hours, days, weeks, months or years!**
- Generic possibilities:
  - lightest neutralino χ
  - lightest slepton, lighter stau or sneutrino?
- Constrained by astrophysics/cosmology

Triggering on GDM Events

Will be selected by many separate triggers

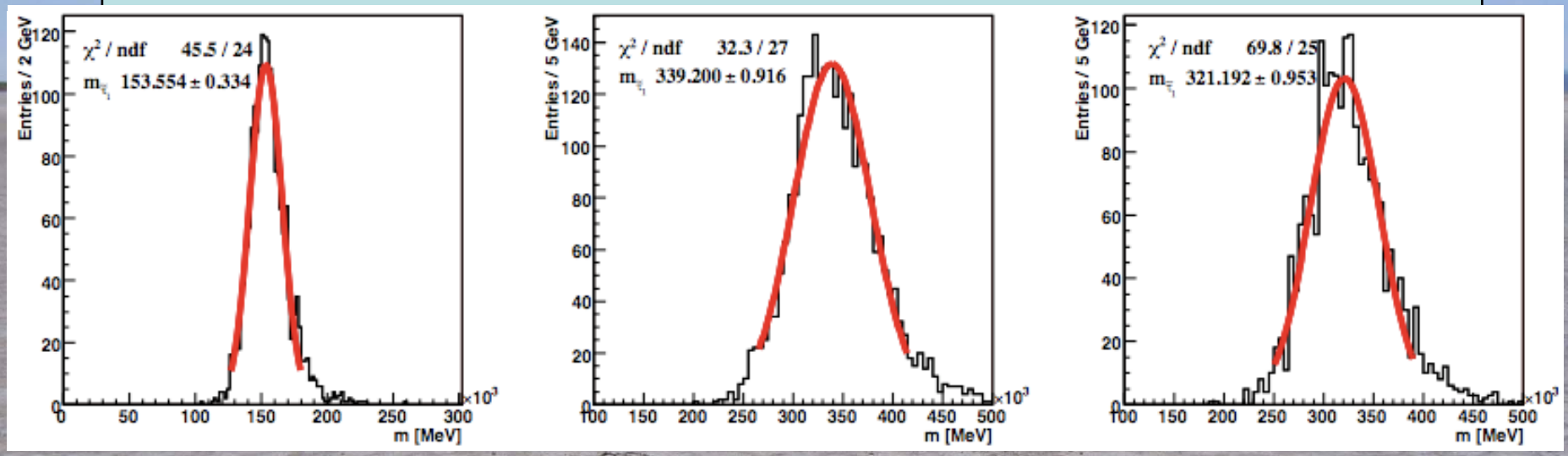




via combinations of μ, E energy, jets, τ

JE, Raklev, Øye: 2007

Stau Mass Determination



Good mass resolution

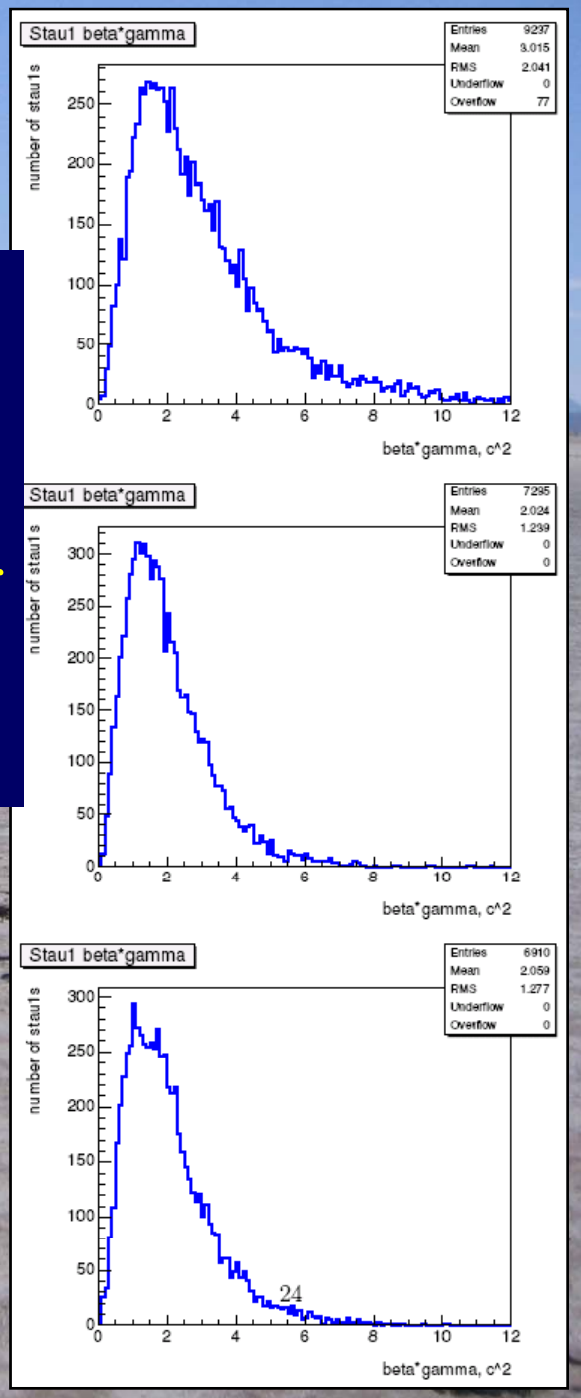
Sample	Mass	Nominal mass
ϵ	153.554 ± 0.334	152.475
ζ	339.200 ± 0.916	338.114
η	321.192 ± 0.953	318.931

JE + Raklev + Oye

Stau Momentum Spectra

- $\beta\gamma$ typically peaked ~ 2
- Staus with $\beta\gamma < 1$ leave central tracker after next beam crossing
- Staus with $\beta\gamma < ¼$ trapped inside calorimeter
- Staus with $\beta\gamma < ½$ stopped within 10m
- **Can they be dug out of cavern wall?**

Model	ϵ	ζ	η
Number of particles with $\beta\gamma < 0.25$	850	7	7
Range in C (cm)	60	136	129
Range in Fe (cm)	29	65	61
Number of particles with $\beta\gamma < 0.5$	7700	100	90
Range in C (cm)	600	1360	1290
Range in Fe (cm)	290	650	610



De Roeck, JE, Gianotti, Moortgat, Olive + Pape: hep-ph/0508198

Very little room for water tank in LHC caverns, only in forward directions where few staus

Extract Cores from Surrounding Rock?

- Use muon system to locate impact point on cavern wall with uncertainty < 1cm
- Fix impact angle with accuracy 10^{-3}
- Bore into cavern wall and remove core of size 1cm × 1cm × 10m = $10^{-3}m^3$ ~ 100 times/year
- Can this be done before staus decay?

  Caveat radioactivity induced by collisions!

  2-day technical stop ~ 1/month

- Not possible if lifetime ~10^4s, possible if ~10^6s?

De Roeck, JE, Gianotti, Moortgat, Olive + Pape: hep-ph/0508

Bound-State Effects

- Staus may bind to protons, light nuclei
- Additional effects on light-element abundances
- Big changes in some interaction rates
- New nucleosynthesis co
  - Recalculate abundances of ^{4}He, D, ^{3}He
  - May improve results for ^{6,7}Li abundances
- Potentially very important constraints on parameter space in stau NLSP/gravitino LSP scenarios

Pospelov

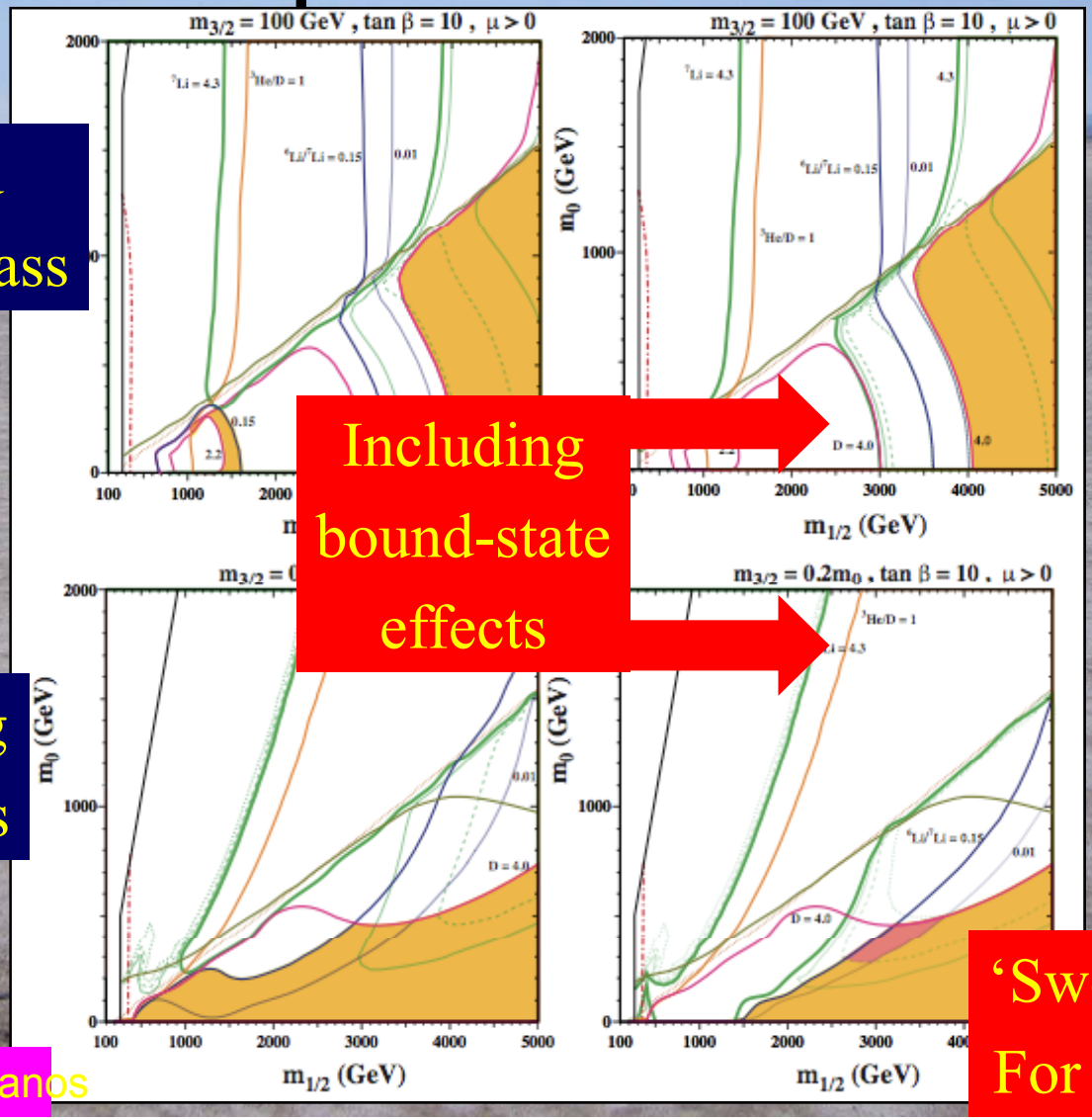
Reaction	EM Transition	$A(B,\gamma)$ $Q_{\rm SBBN}$ (MeV)	$[X^-A](B,C)X^-$ $Q_{\rm CBBN}$ (MeV)	Enhancement $\sigma_{\rm CBBN}/\sigma_{\rm SBBN}$
$d(\alpha,\gamma)^6$Li	E2	1.474	1.124	7.0×10^7
^{3}H$(\alpha,\gamma)^7$Li	E1	2.467	2.117	1.0×10^5
^{3}He$(\alpha,\gamma)^7$Be	E1	1.587	1.237	2.9×10^5
^{6}Li$(p,\gamma)^7$Be	E1	5.606	4.716	2.9×10^4
^{7}Li$(p,\gamma)^8$Be	E1	17.255	16.325	2.6×10^3
^{7}Be$(p,\gamma)^8$B	E1	0.137	-1.323	N/A

Steffen

Effects on GDM parameter Space

Scenario with fixed gravitino mass

Scenario with varying gravitino mass



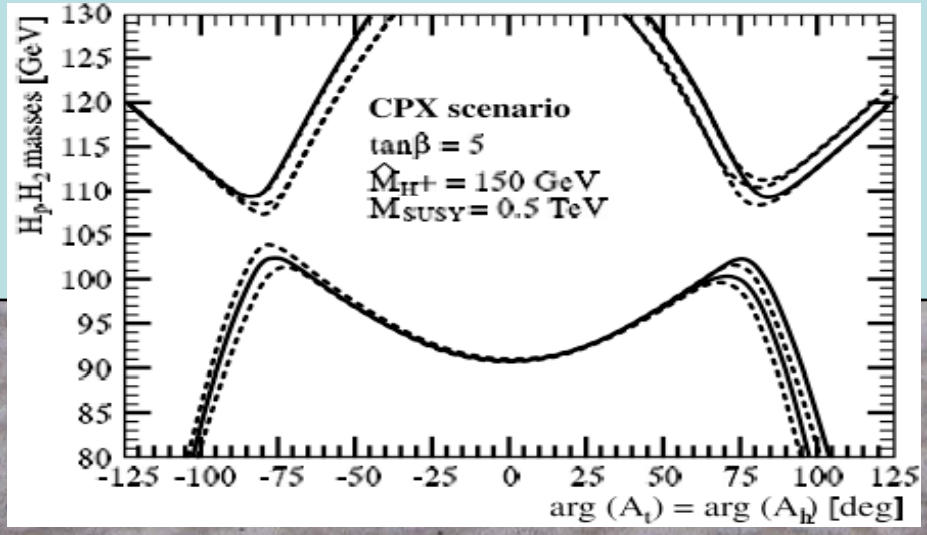
Including bound-state effects

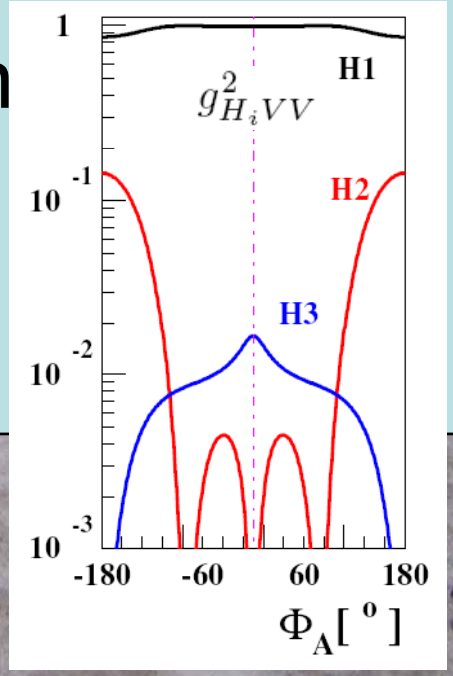
'Sweet spot' For Lithium

Cyburt, JE, Fields, Olive + Spanos

Complexification of CMSSM

- Two new CP-violating parameters:
  - Arg(M_i m), Arg(A_f m)
- Loop-induced mixing $\frac{3}{16\pi^2}\frac{\mathrm{Im}\,(A_f\mu)}{m^2_{\tilde{f}_2}-m^2_{\tilde{f}_1}}$
  - (h,H,A) → (H_1,H_2,H_3) with indefinite CP
- Effects on masses, couplin

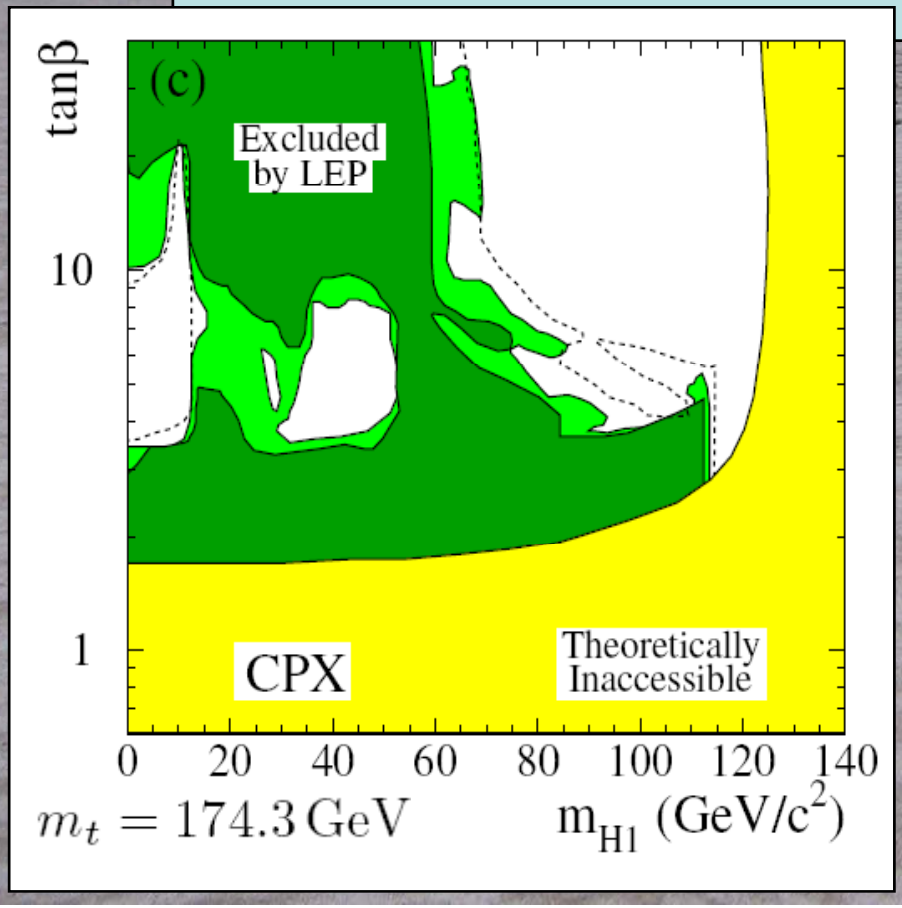


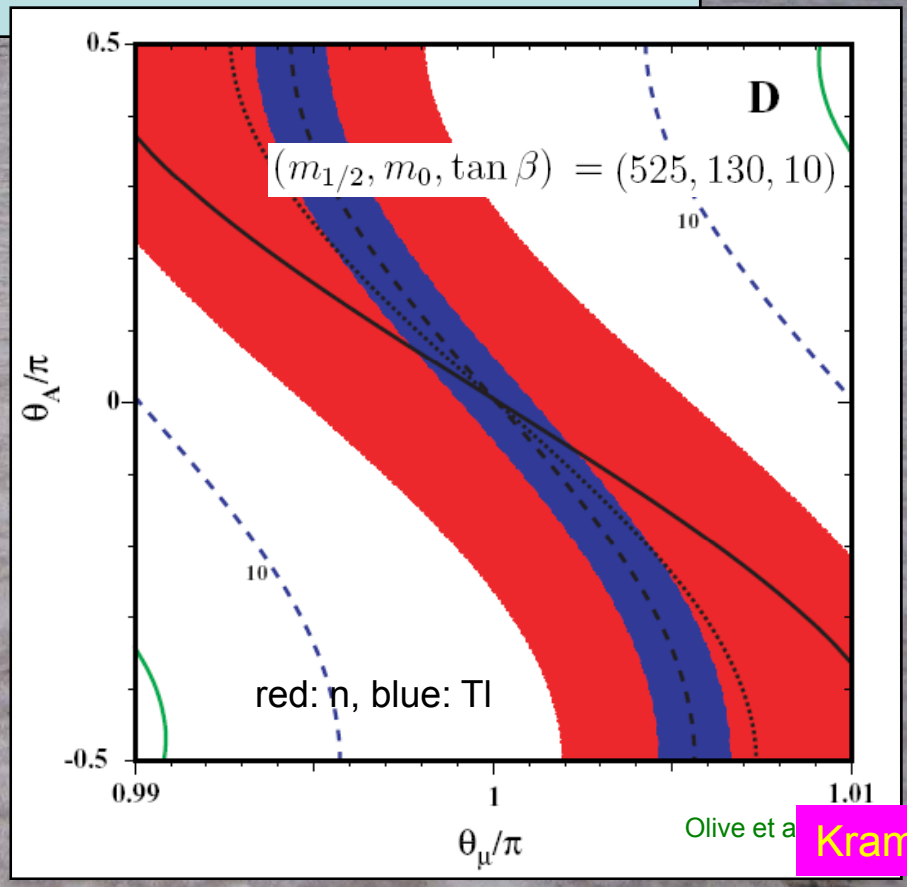


Kraml

Experimental Constraints

From LEP, from electric dipole

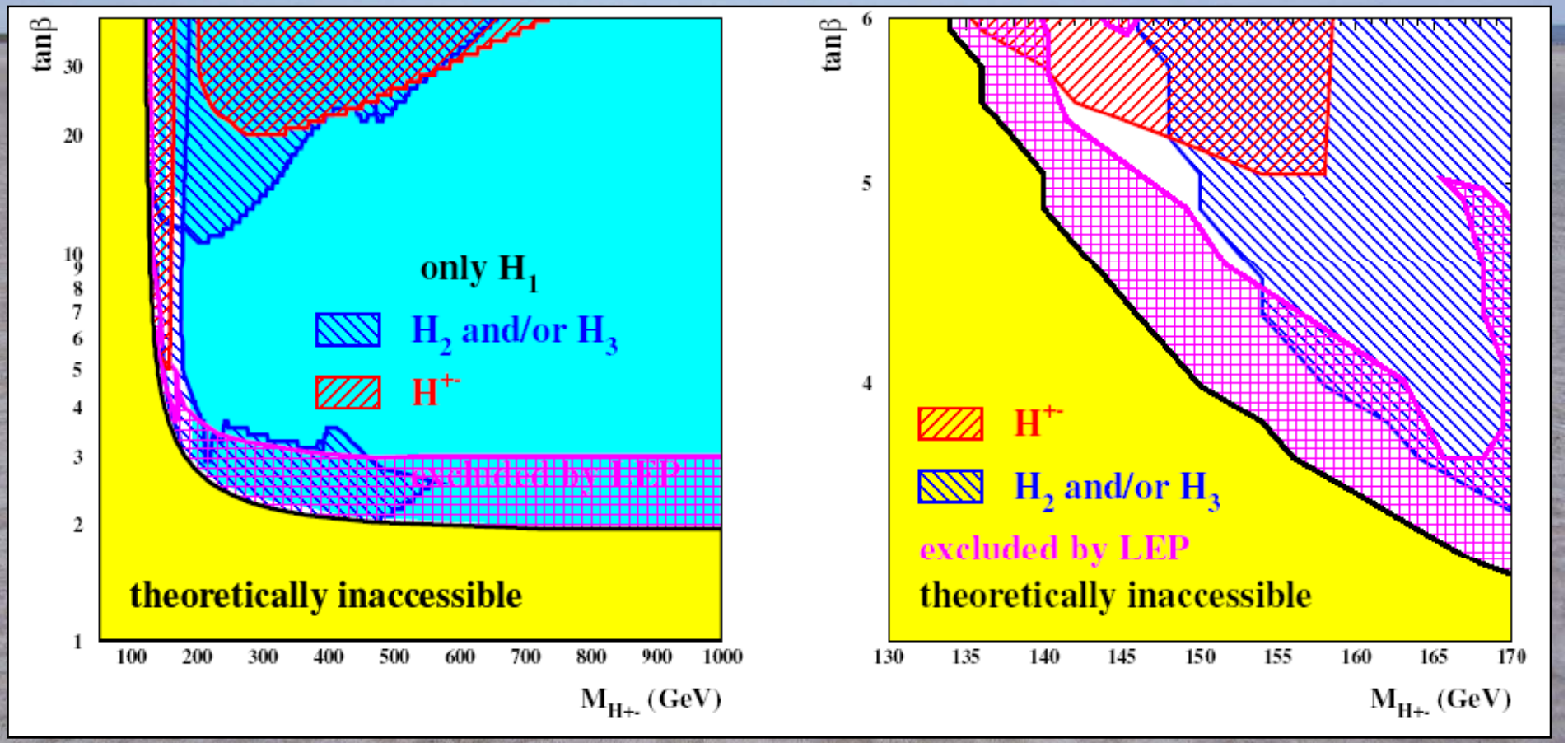




Olive et a

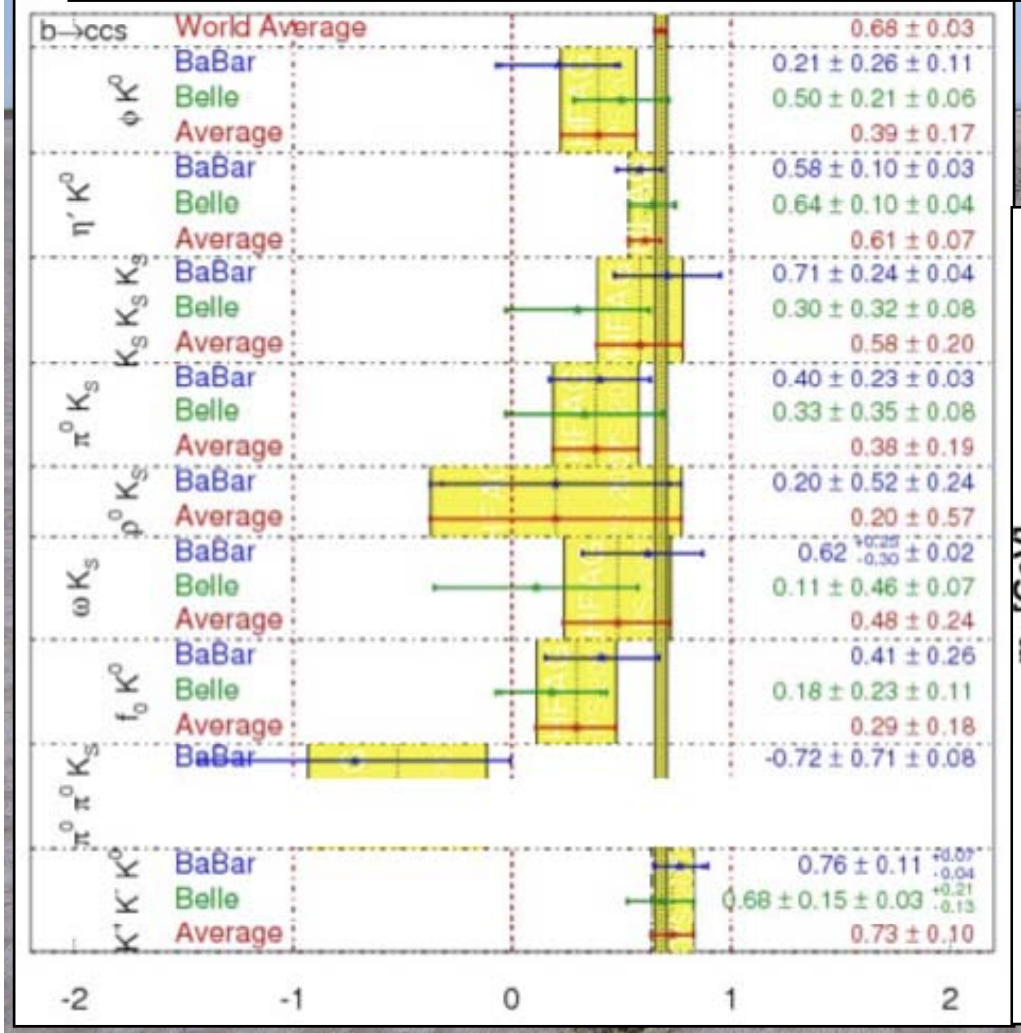
Kraml

Prospective Searches @ LHC



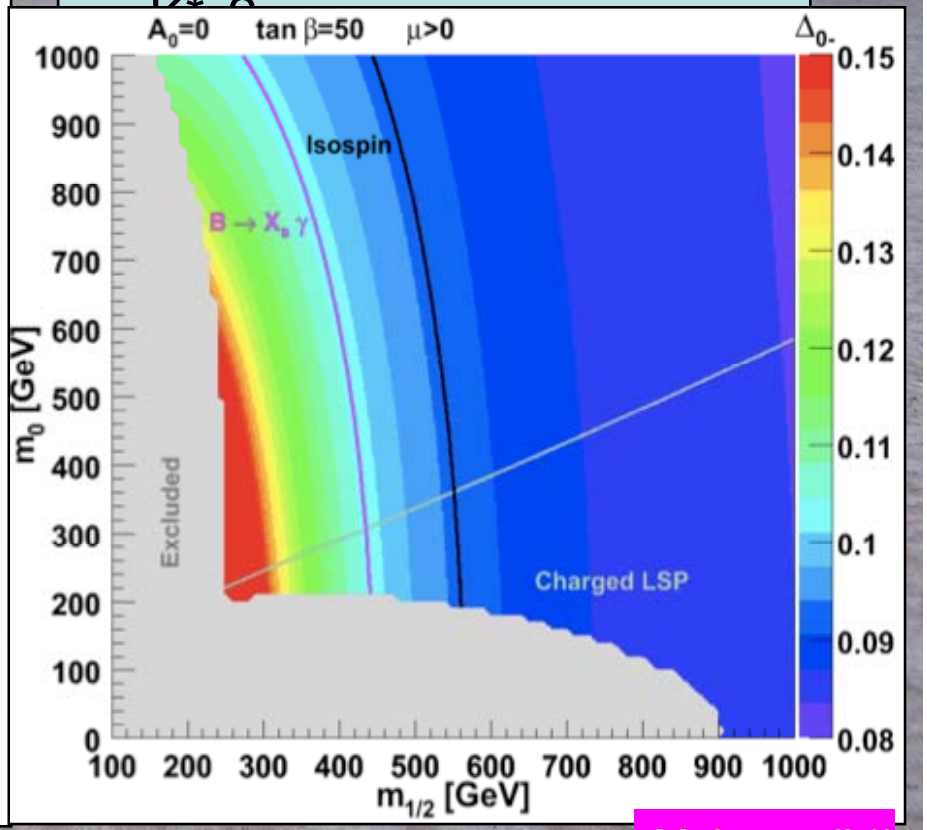
Kraml

Flavour in the LHC Era: Supersymmetric B Physics?



Discrepancies in B decays?

Isospin asymmetry in B →

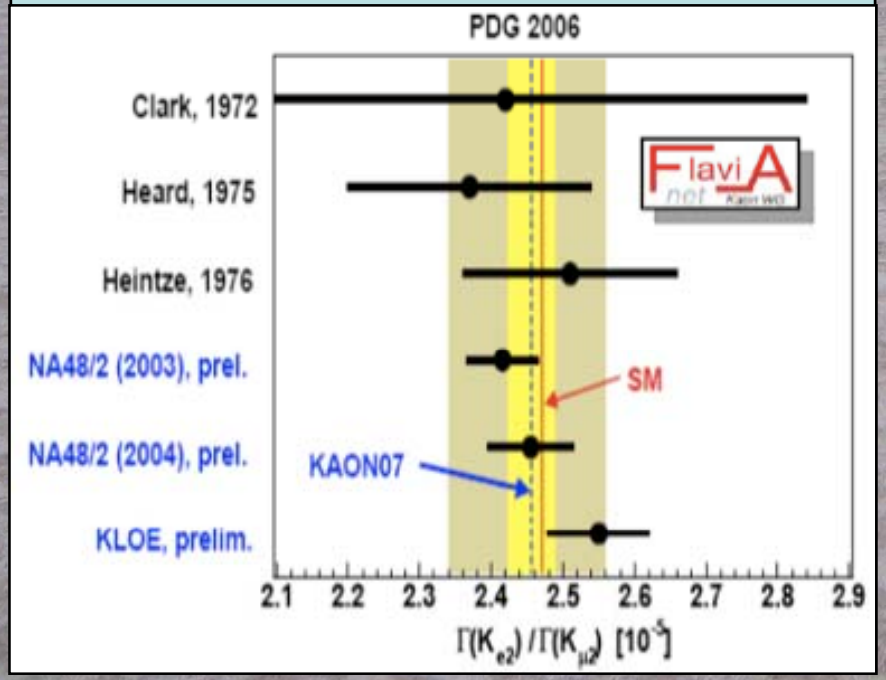


Mahmoudi //

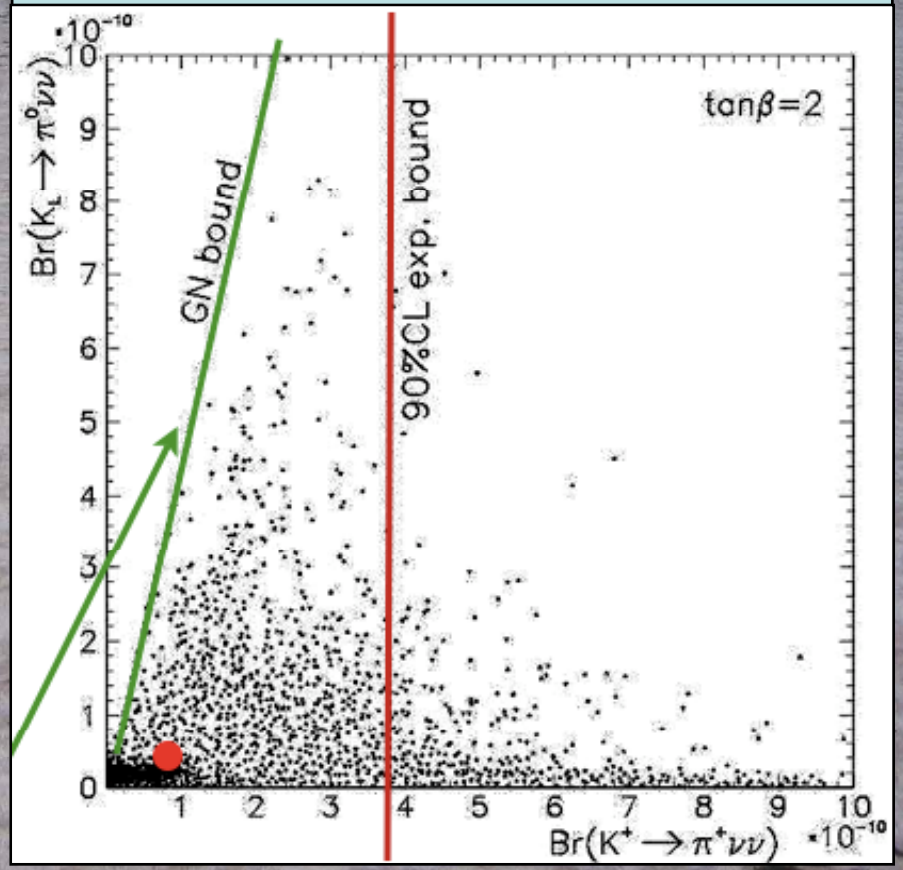
Flavour in the LHC Era: Supersymmetric K Physics?

- Violation of universality in K → e

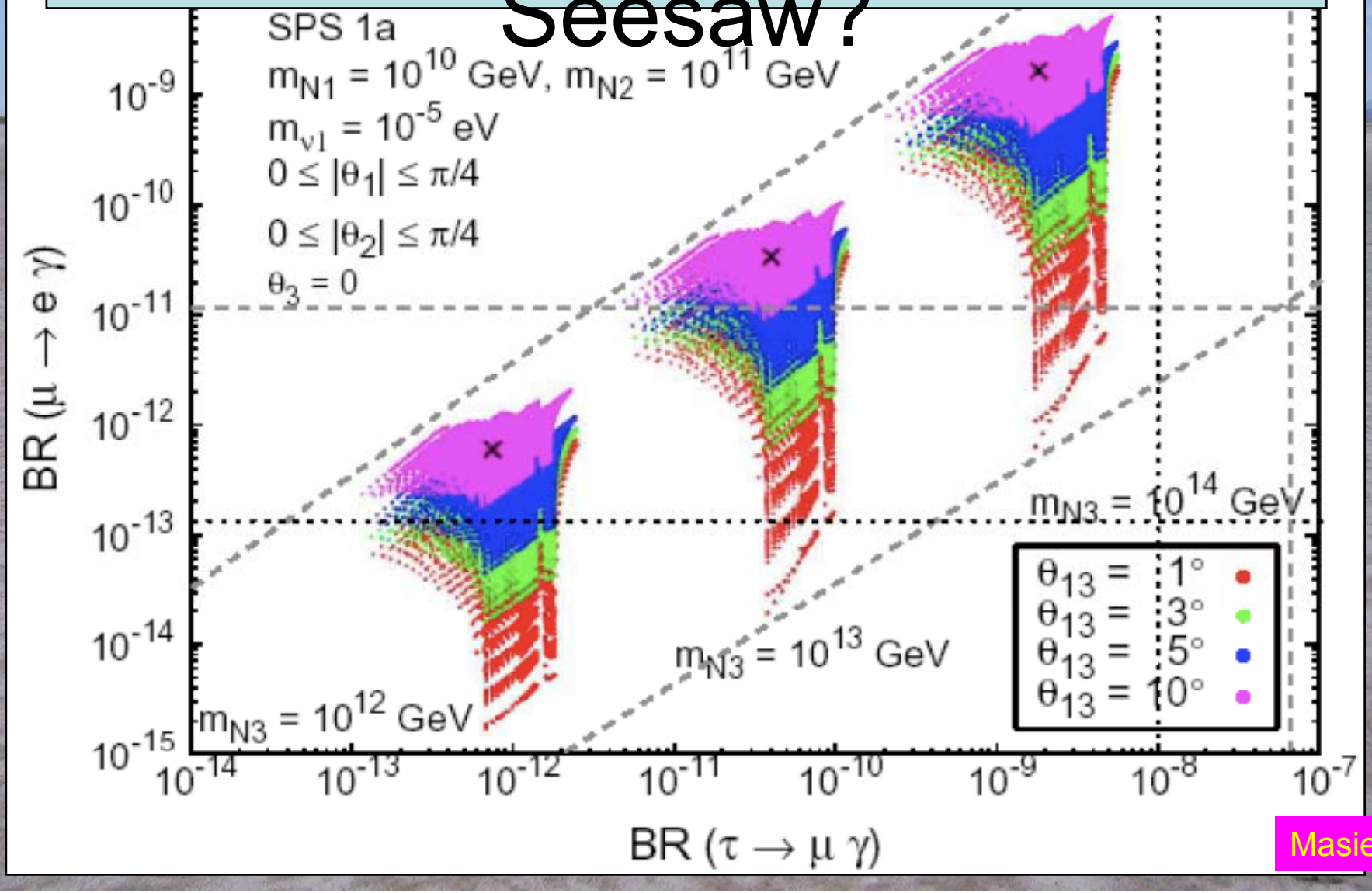
$$R_K^{LFV} \simeq R_K^{SM}\left[1+\left(\frac{m_K^4}{M_H^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right)|\Delta_R^{31}|^2\,\tan^6\beta\right]$$



- K → π νν decays?



Flavour in the LHC Era: LFV in Supersymmetric Seesaw?



Masiero

String Landscape?

- Millions (billions?) of manifolds for string compactification
- Each has dozens (hundreds) of topological cycles
- Fluxes through cycles each have O(10) possible values
- Enormous number of possible vacua
- Maybe one of them has small vacuum energy?
- How does Universe choose?
- If it happens to choose small vacuum energy, why not also choose small m_W?
- **No need for supersymmetry?**

Linde, Nilles

Unified Approach to Alternatives

The model space is continuous. There are scenarios interpolating among these categories

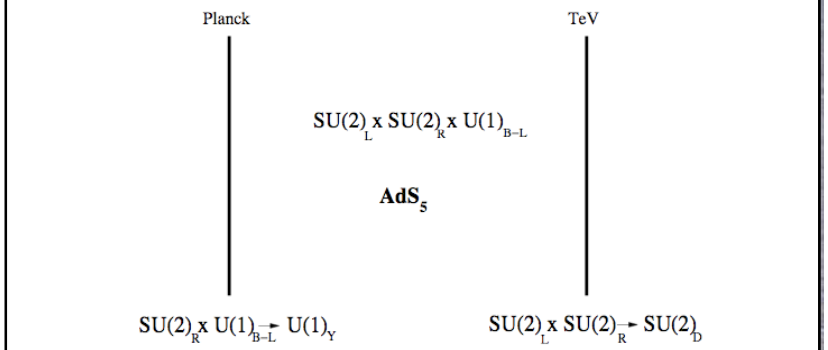
Randall-Sundrum I

Holographic PNGB Higgs

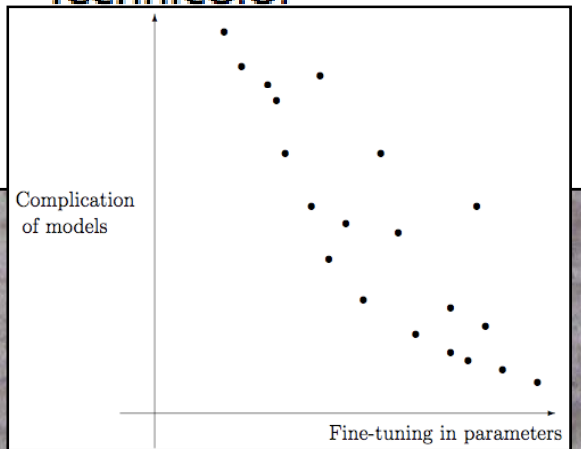
Little Higgs

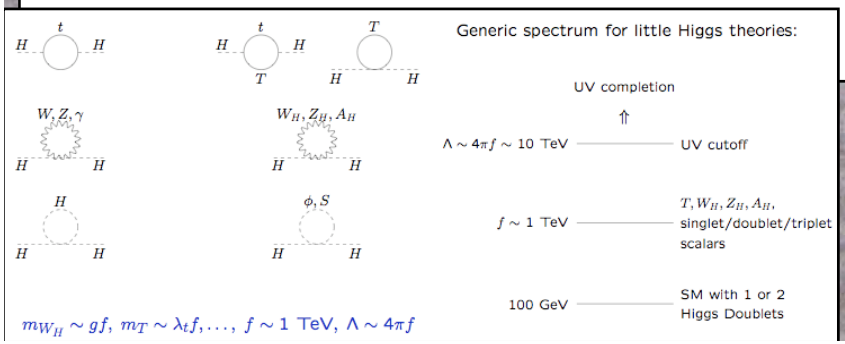
...

5D Higgsless Model in Warped Space



Technicolor





Cheng

Long Live Metastable Vacua!

Will the Universe become Supersymmetric?

John Ellis*
C.H. Llewellyn Smith
G.G. Ross**

Department of Theoretical Physics
University of Oxford
Oxford.

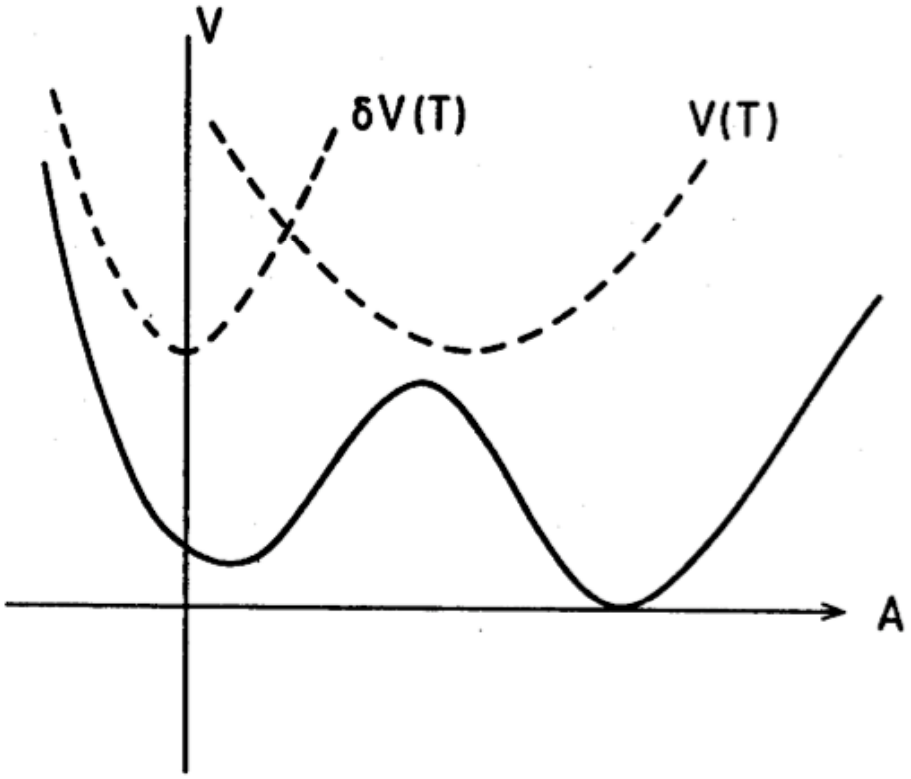
ABSTRACT

In contrast to gauge symmetries, one expects supersymmetry to be violated at finite temperatures. Perhaps the Universe as it cooled has landed in a local minimum with supersymmetry still broken and will eventually tunnel through to the global supersymmetric minimum. We present a quasi-realistic model of this type which is a modest variation on GUTs with hierarchical symmetry breaking.

*Visiting Fellow, All Souls College, Oxford.
Permanent address: CERN, 1211 Geneva 23, Switzerland.
**Also at Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX

April 1, 1982.

Modern models much more



Difficult to get good cosmology!

String adds Value to MSSM

- 200 models with the exact spectrum of the MSSM (absence of chiral exotics)
- local grand unification (by construction)
- gauge- and (partial) Yukawa unification

(Raby, Wingerter, 2007)

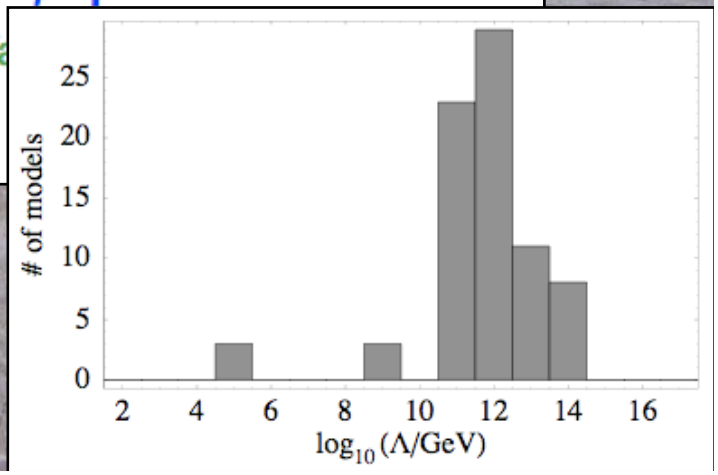
- examples of neutrino see-saw mechanism

(Buchmüller, Hamguchi, Lebedev, Ramos-Sanchez, Ratz, 2007)

- models with R-parity + solution to the μ-problem

(Lebedev, HPN, Raby, Ramos-Sanchez, Ratz, Va

- hidden sector gaugino condensation



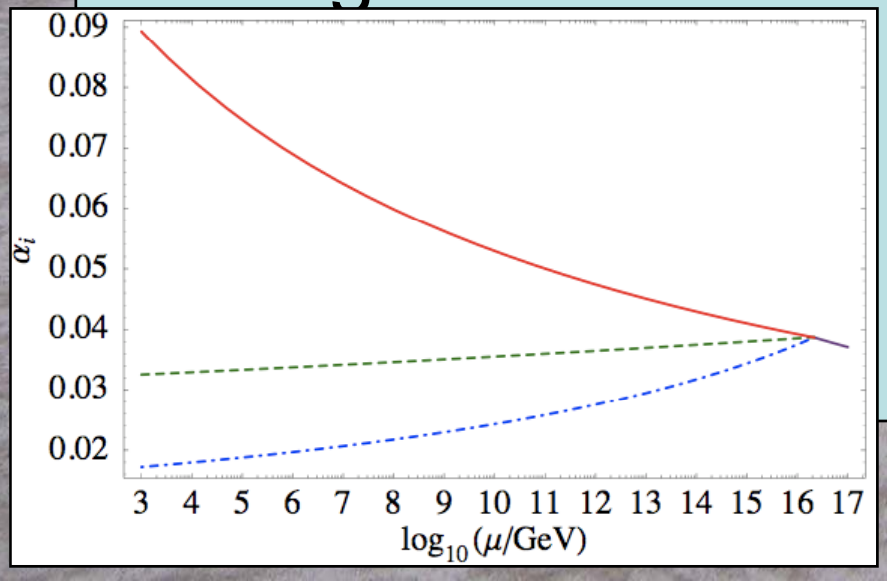
Nilles

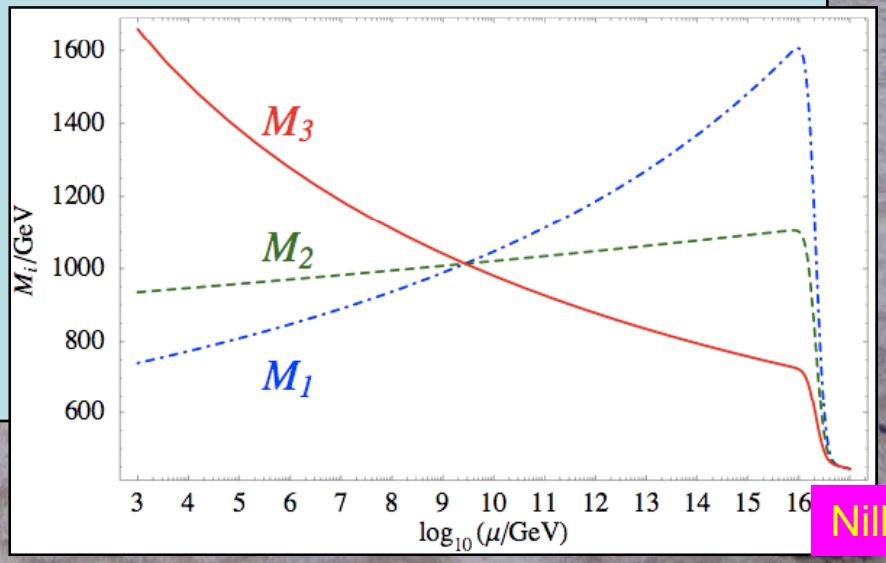
A Possible String Signature: Mirage Unification?

- Ratio of modulus/anomaly contributions to gaugino mass = ρ:

$$M_a = M_s(\rho + b_a g_a^2) = \frac{m_{3/2}}{16\pi^2}(\rho + b_a g_a^2)$$

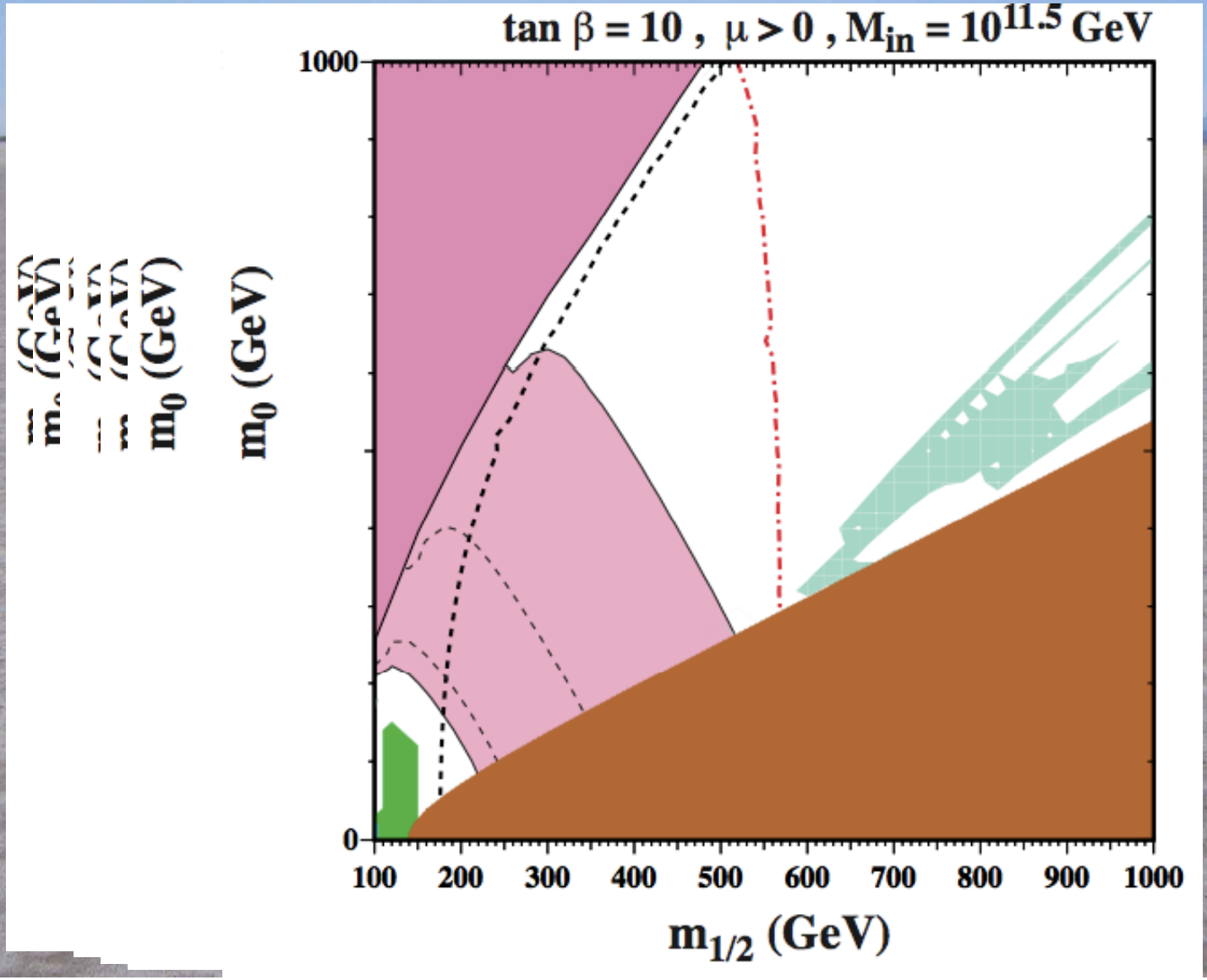
- Gaugino mass unification below GUT





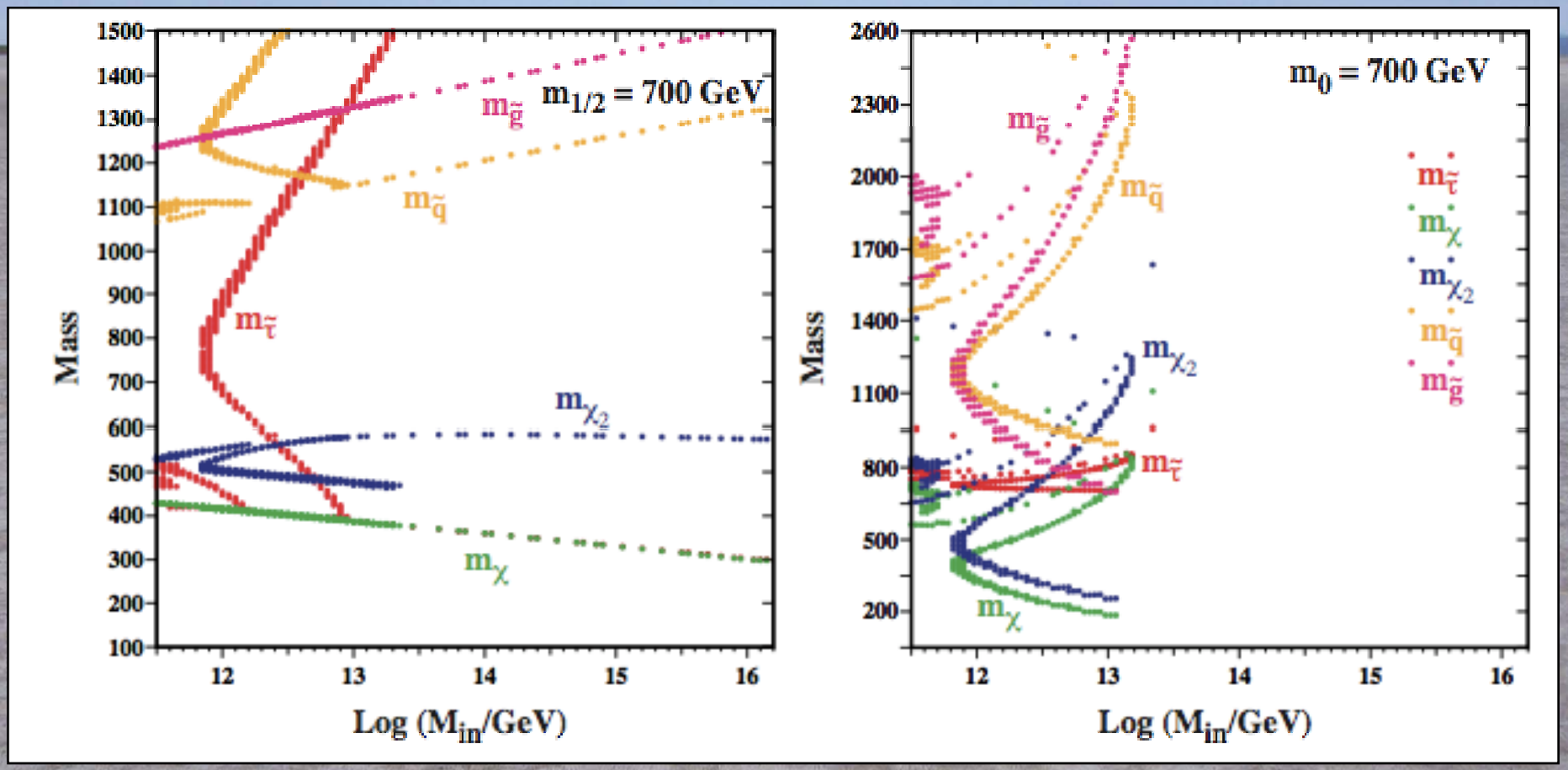
Nilles

Effects of Lowering Universality Scale



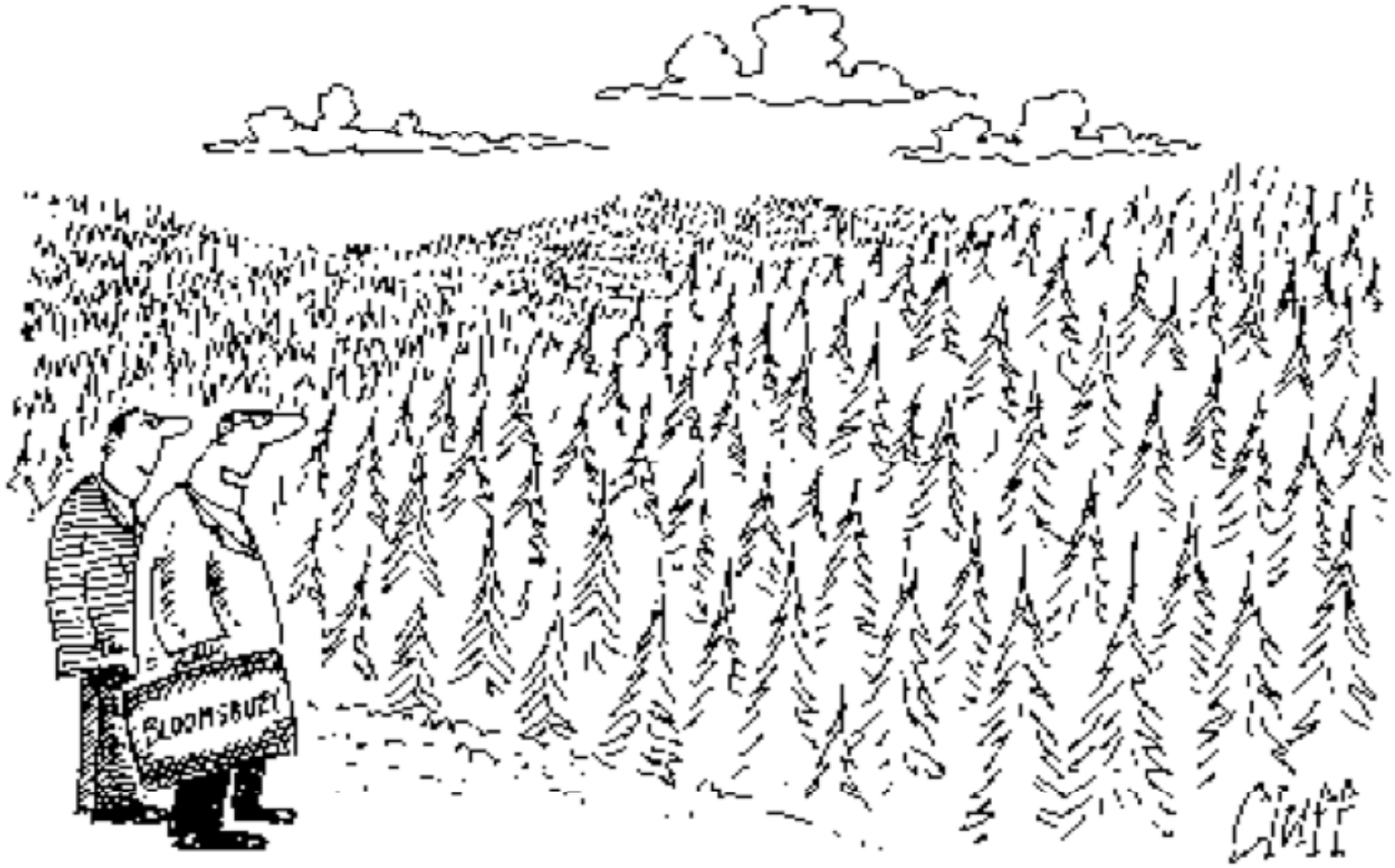
Sandick //

Effects on Allowed Sparticle Spectra

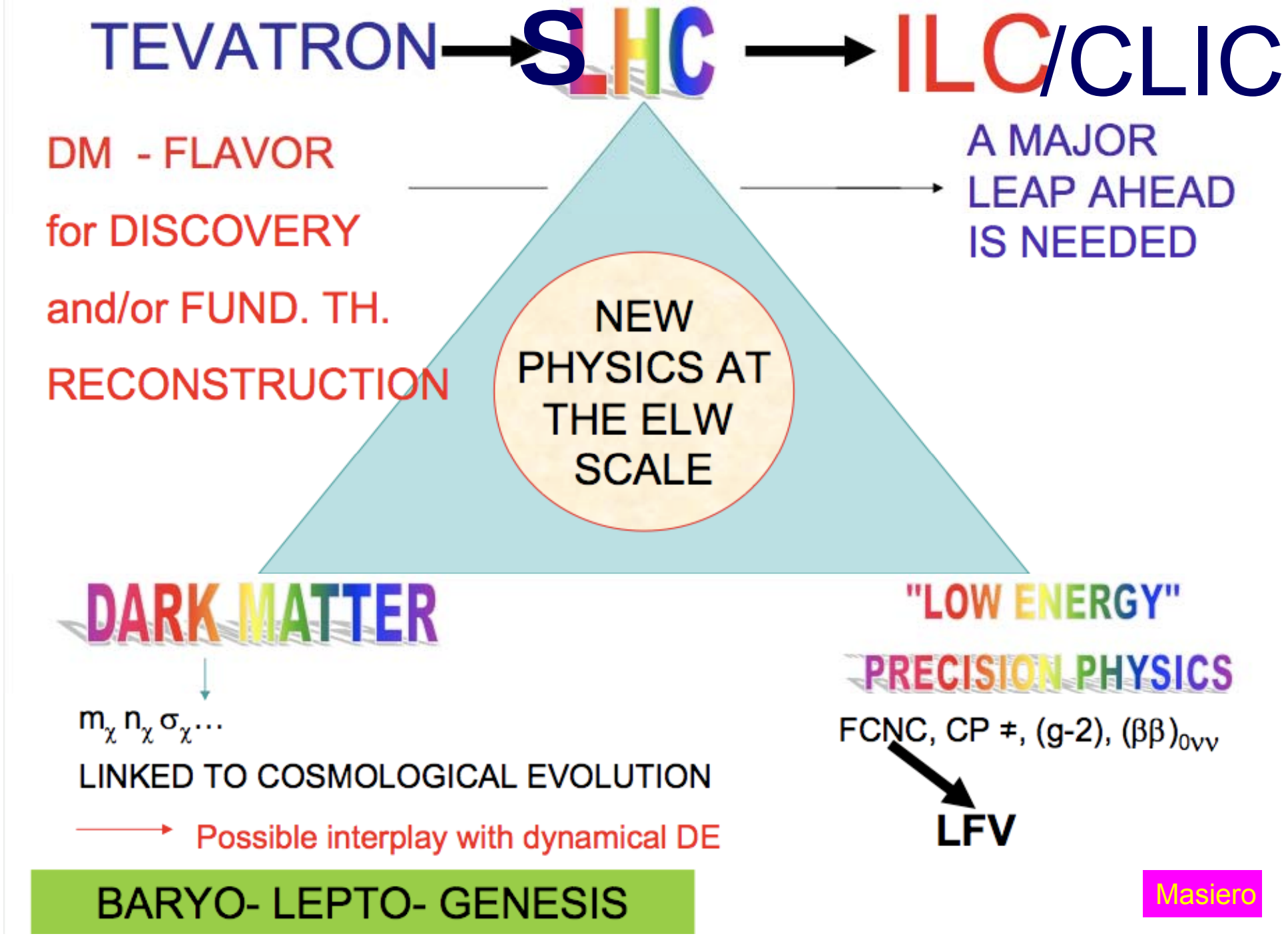


Sandick //

Search for Supersymmetry



"One day, all of these will be supersymmetric phenomenology papers."


TEVATRON
SLHC
ILC/CLIC
DM - FLAVOR
for DISCOVERY
and/or FUND. TH.
RECONSTRUCTION
A MAJOR
LEAP AHEAD
IS NEEDED
NEW
PHYSICS AT
THE ELW
SCALE
DARK MATTER
m_χ n_χ σ_χ...
LINKED TO COSMOLOGICAL EVOLUTION
Possible interplay with dynamical DE
"LOW ENERGY"
PRECISION PHYSICS
FCNC, CP ≠, (g-2), $(\beta\beta)_{0\nu\nu}$
LFV
BARYO- LEPTO- GENESIS
Masiero