Superparticle Masses and Super. Phenomenology beyond mSUGRA

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SUSY IS A MATURE SUBJECT

Many SUSY analyses w/in mSUGRA framework with R-parity conservation

UNIVERSAL PARAMETERS @ HIGH SCALE (usually taken as M_{GUT})

- Scalar masses
- Gaugino masses
- A (and B) parameters

Predictive, FCNC OK, FALSIFIABLE

Models with Non-universal parameters possible

Scalars (Soni-Weldon 1983)

Gauginos [Even GUT may not protect universality if SUSY breaking VEV breaks GUT 1984-85]

Gauge-mediated SUSY Breaking

$M_i \propto g_{gauge}^2$

FCNC OK because sparticles with same gauge Q.Nos have same mass

MANY OTHER MODELS WHERE GUT SCALE UNIVERSALITY IS LOST DUE TO ONE REASON OR ANOTHER.

- IMPORTANT TO KEEP IN MIND WHEN ASSESSING CAPABILITIES OF EXPT. FACILITIES

- MSUGRA MAY WELL PROVE TO BE THE INCORRECT PICTURE, AND WE WILL HAVE TO FIGURE OUT THE RIGHT DIRECTION

Recent upgrades of ISAJET make it possible to simulate a wide variety of scenarios.

NUSUGi Options

i=1 Non-universal gaugino masses

2 3rd Generation A-parameters

3 H_u, H_d masses

4 First & Second Generation Sfermions

5 Third Generation Sfermions

NON UNIVERSALITY AT $Q = M_{GUT}$

SUSY BOUNDARY CONDITION SCALE "SSBCSC OPTION

USER CHOOSES SCALE @ WHICH BOUNDARY CONDITIONS FOR MSSM SOFT PARAMETERS ARE ENTERED!

$Q = M_{string}$; $Q = M_{\nu_R}$ in models with RHN. etc.

Models With Non-Universality

JHEP 4 : 16 (2006)

- Gauge-mediated models
- Universality @ M_{Pl} ⇒ RGE-induced non-universality @ M_{GUT}
- Models with "D-terms"
- "Missing partner" models with hypercolor
- Anomaly mediated SUSY Breaking
- "Effective SUSY" Models (only light 3rd generation & light inos)
  - Dynamical Inverted Mass hierarchy
  - "By hand" Inverted Mass hierarchy
- String-based Models

D-term Contributions to Scalar Masses

If the GUT group breaks to one of lower rank, there are new contributions to scalar masses [Drees 1986]

$$SO(10) \to SU(3) \times SU(2) \times U(1)$$

One additional parameter

In SO(10) only one Yukawa / gen. ⊙

M_{GUT} ⇒ Large $\tan\beta$.

⇓

Problems with radiative EWSB

Extra D-term contributions facilitate EWSB ($m_{H_u}^2 < m_{H_d}^2$)

⇓

Calculable SO(10) Model with Yukawa coupling unification

Baer, Diaz, Ferrandis XT
PRD61, 111701 (2000)

Phenomenology

tanβ ~ 50. $\mu < 0$ for Yukawa Unif & RewSB

- $\tilde{b}_1$ almost always lightest squark (sometimes even w/in Tevatron reach)
- Relic density OK.
- Direct $\tilde{\chi}_1^0$ detection rate $> 10^{-2}$ cr/kg/day in ^{73}Ge
- $b \to s\gamma$ (Generically a problem OK in special regions of parameter space with small $A_b \Rightarrow m_{\tilde{b}_1} > 1$ TeV)
- Tevatron Signals possible if we are lucky
  - $b\bar{b}A$, $b\bar{b}H$
  - $\tilde{W}_1\tilde{Z}_2 \to 3\ell$
  - $\tilde{b}_1\tilde{b}_1$

But sparticles are generically heavy for exploration
So we need LHC

[hep-ph/0005027]

Inverted Mass Hierarchy Models

First two generations of sparticles much heavier than 3rd Generation

first two generations couple weakly to EWSB sector so do not destabilize weakscale @ 1 loop.

Ameliorate FCNC Problems if heavy

Dine, Kagan, Samuel 1990
Pomarol + Tomasini 1995
Cohen, Kaplan, Nelson 1996

Hierarchy at high mass scale dangerous - RGE's make $\tilde{t}, \tilde{b}$ heavy @ weak scale

Arkani-Hamed + Murayama
Agashe + Graesser
[Re-visit]

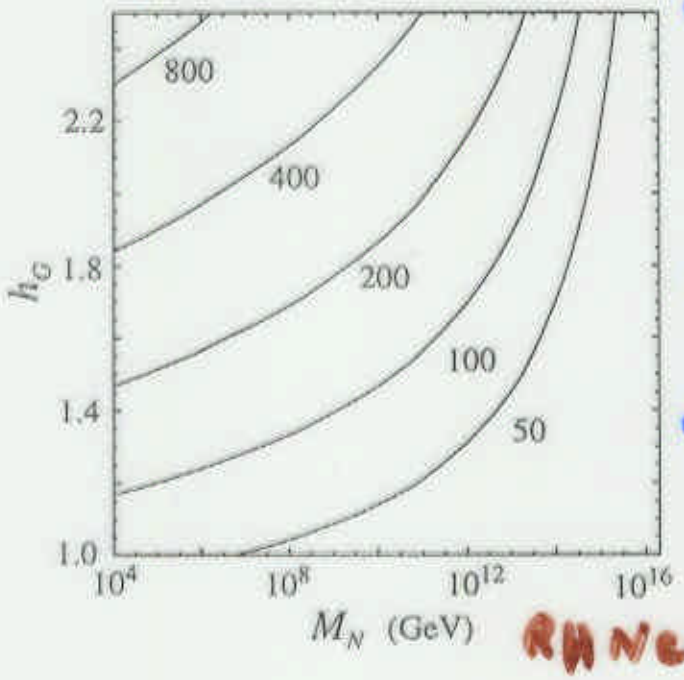
Dynamically Generate hierarchy
[Bagger, Feng, Kolda, Polonsky, Zhang]
1999-2000

Bagger et. al.

Simple SO(10) symmetric boundary Conditions, $4\,m_{16}^2 : 2\,m_{10}^2 = A_0^2$

⇓

Large $S \equiv \dfrac{\langle m_{1,2}^2 \rangle}{\langle m_3^2 \rangle}$



GUT Scale → Yukawa

"get $\dfrac{m_3}{m_1} \sim 10$ ⇒ O(10 TeV) masses for first two generations"

RH Neutrino

- BUT - problems with EWSB
- "Approximations Rug"

- Including D-terms ameliorates this ⇒ Calculable spectra!

[Barr, Mercadante xT PL B 475, 289 (2000)]

How big is the hierarchy?

$S_{max} < 10$ for us.

What happened?

- We insist on $m_t = 175$ GeV* (not a fixed pt)

⇓

GUT scale Yukawa Σ 0.7

- Correction from "sub-dominant" terms neglected by Bagger et al.

* Can get $S \sim 20$ with higher m_t

Illustration of IMH Scenario

$\tan\beta = 50$, $m_D = 0.2\, m_{16}$

$m_{10} = m_{16}$ $\quad$ $m_{\tilde{L}} = 0.2\, m_0$

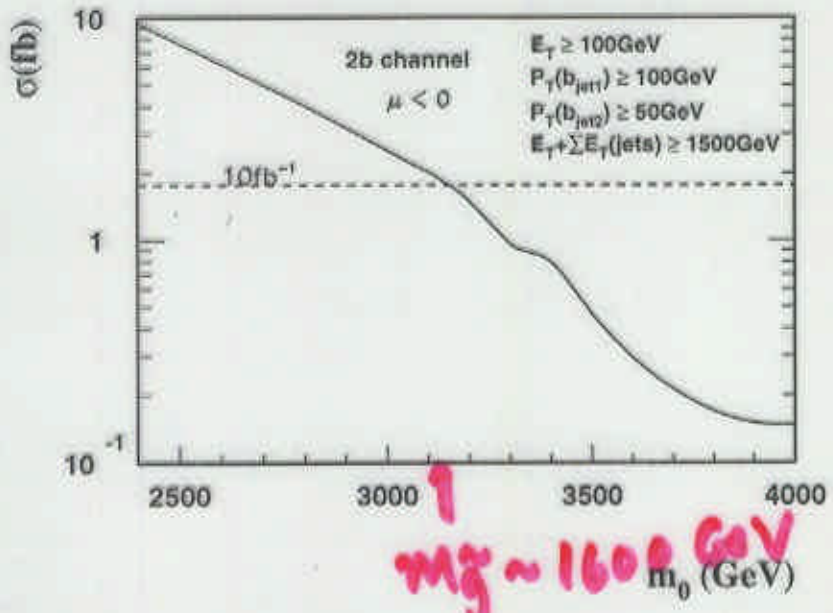
LHC reach maximized in the channel with tagged b-jets

$m_{\tilde{g}} \lesssim 1600\,\text{GeV}$, $m_{\tilde{u}} = 3300\,\text{GeV}$

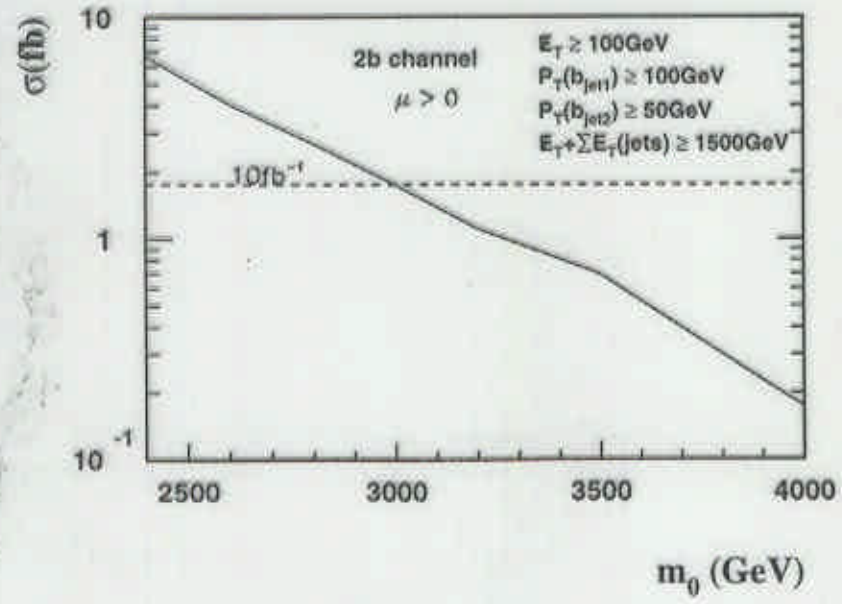
Other phenomenological aspects under study

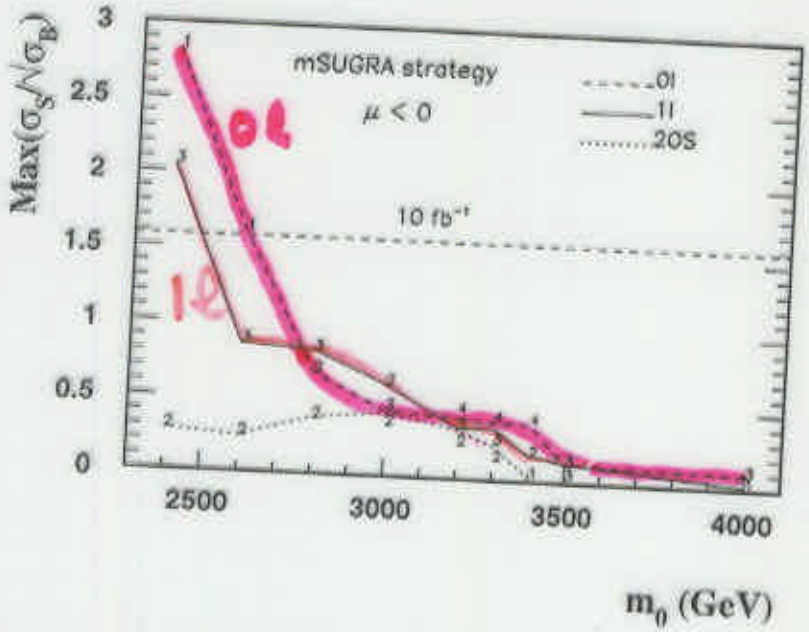
Baer
Balazs
Mercadante
Ashlie
Wang
XT

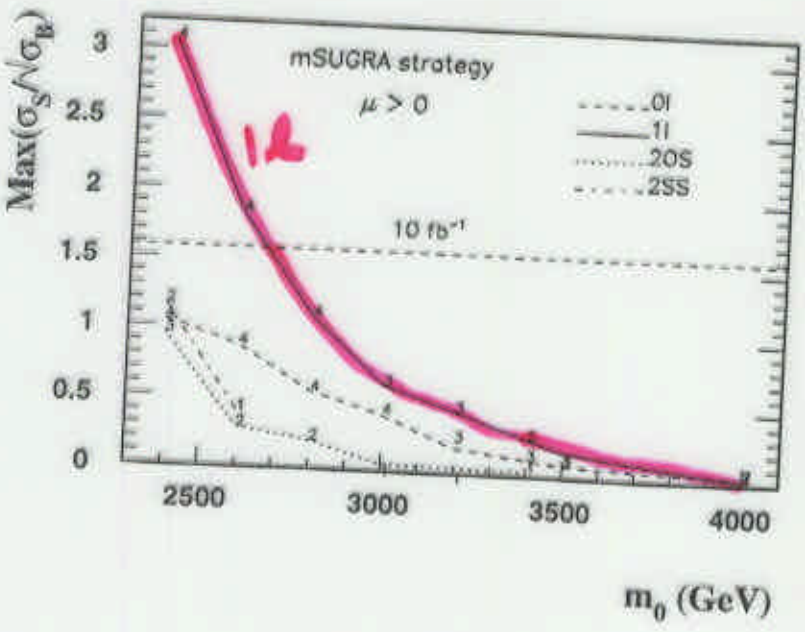
LHC Reach in Dynamical IMH Scenario



$m_{\tilde{g}} \sim 1600$ GeV

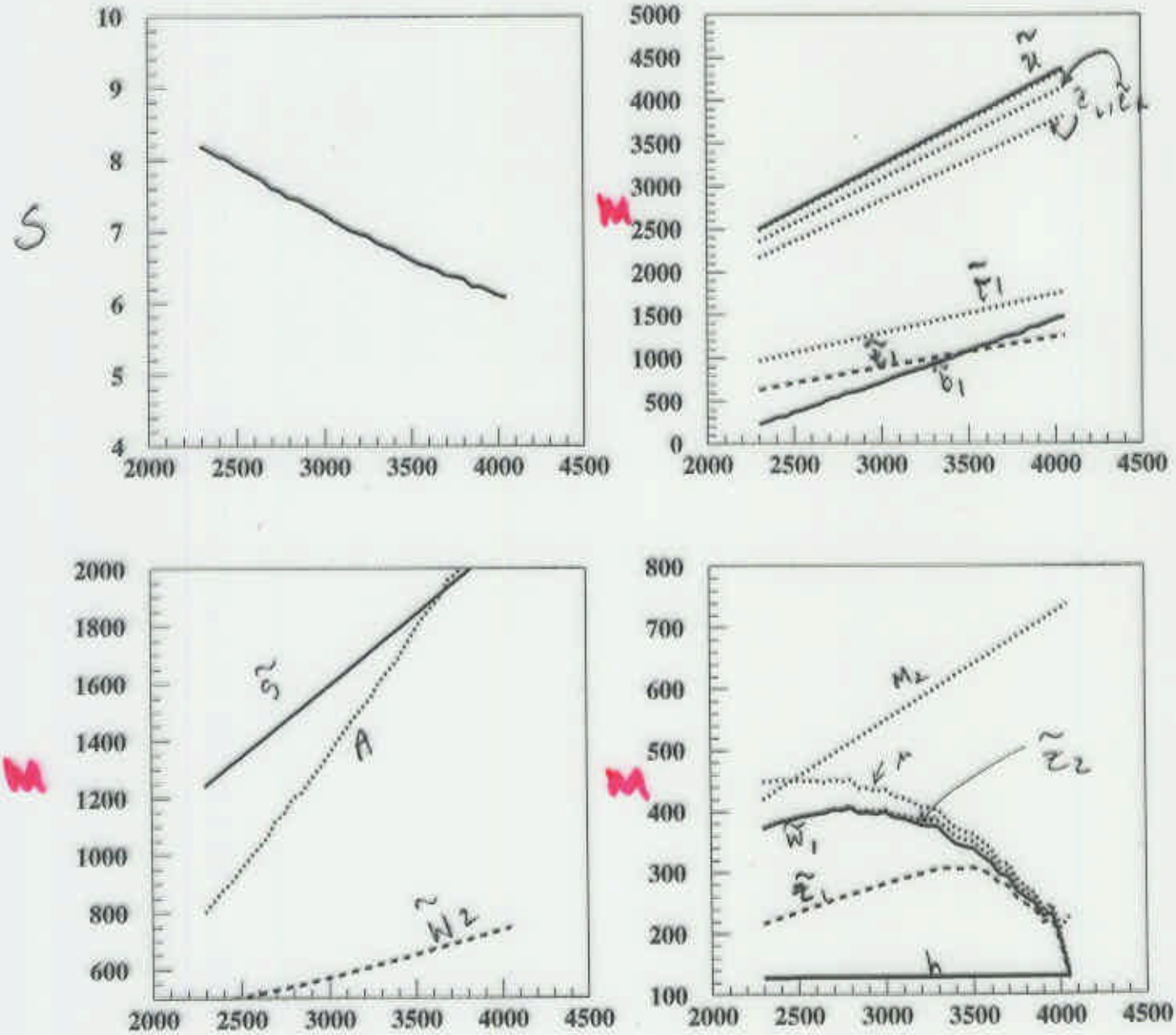



mSUGRA strategy
μ < 0
0l
1l
2OS
10 fb⁻¹
Max(σS/√σB)
m0 (GeV)


mSUGRA strategy
μ > 0
0l
1l
2OS
2SS
10 fb⁻¹
Max(σS/√σB)
m0 (GeV)

$\tan\beta = 50$, $m_{D_i} = 0.2\, m_0$

$m_{1/2} = 0.22\, m_0$, $m_N = 10^7$, $\mu < 0$



"By-hand IMH"

Put a mass hierarchy at GUT scale

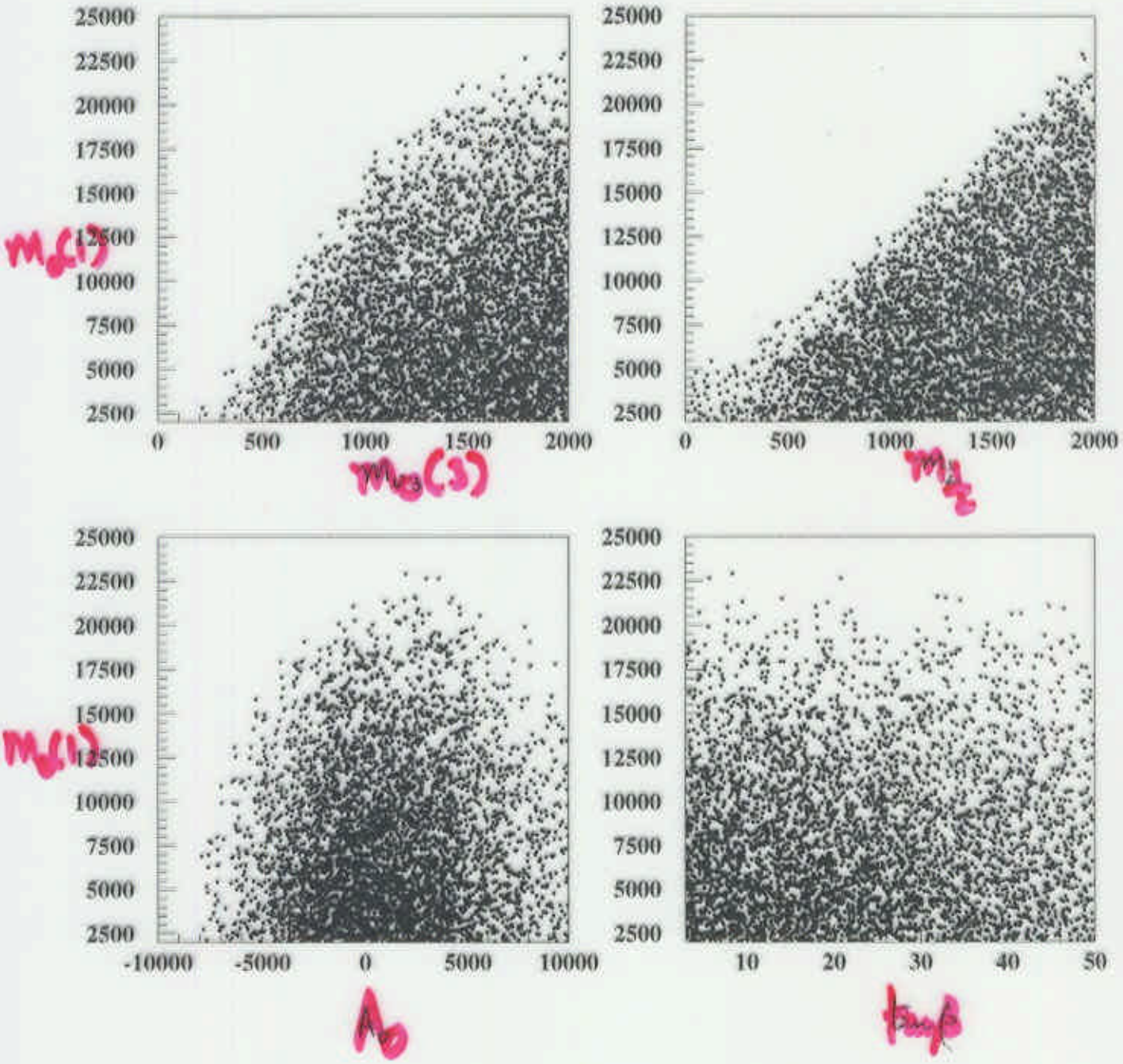
Arkani-Hamed, Murayama
Agashe + Graesser say NO!

2 loop effects drive $m_{\tilde{t}}^2 < 0$.

$m_0(1,2)$ — A_0 — ~10TeV

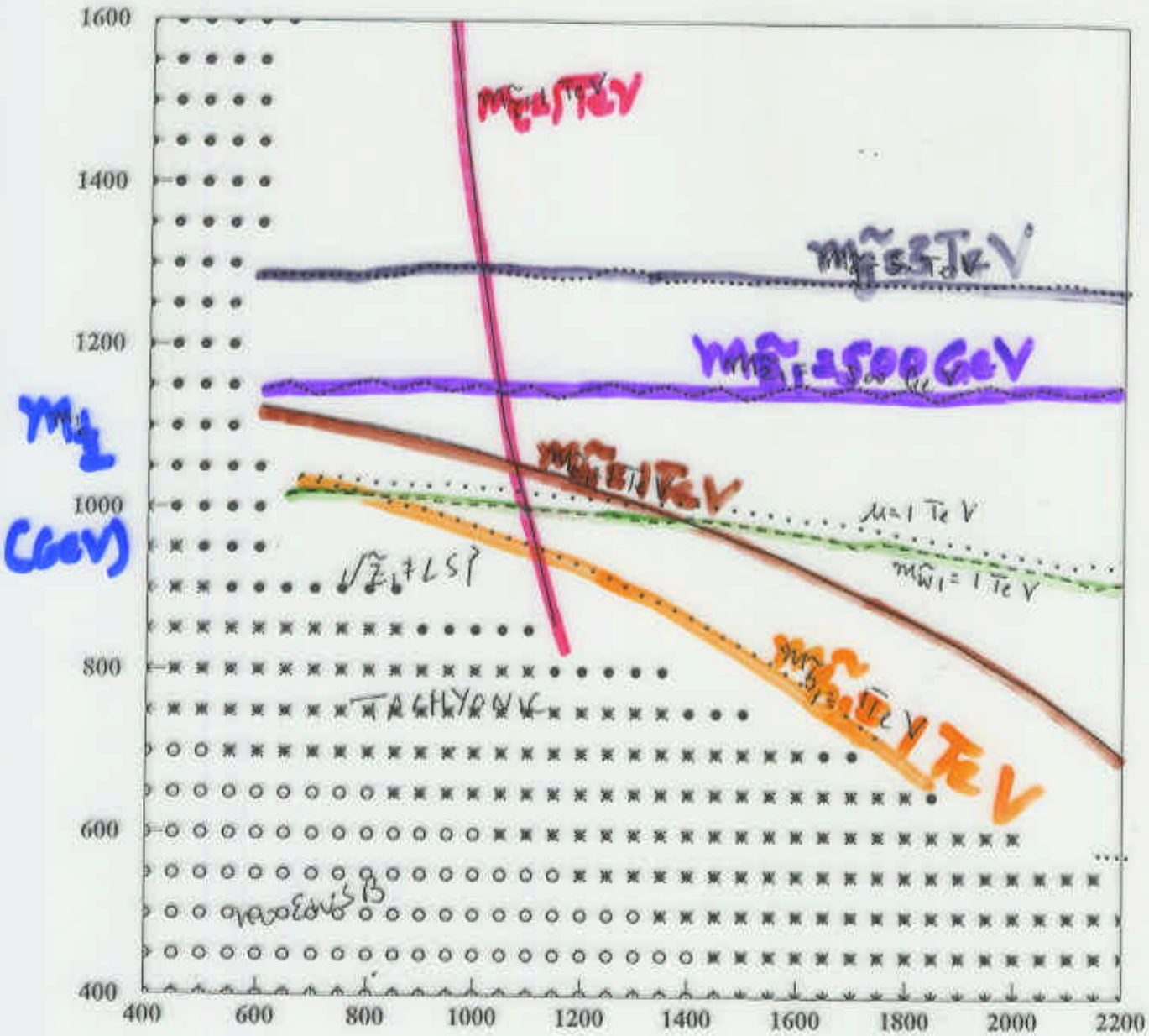
$m_0(3)$, $m_{\frac{1}{2}}$, tan β — sub-TeV
(few)

Competition between $m_{\tilde{t}}$ (increase $m_{\tilde{t}}$) & $m_{\tilde{\chi}^0_1}$ (decrease $m_{\tilde{t}}$)



$M_0(1) = 10\,TeV$

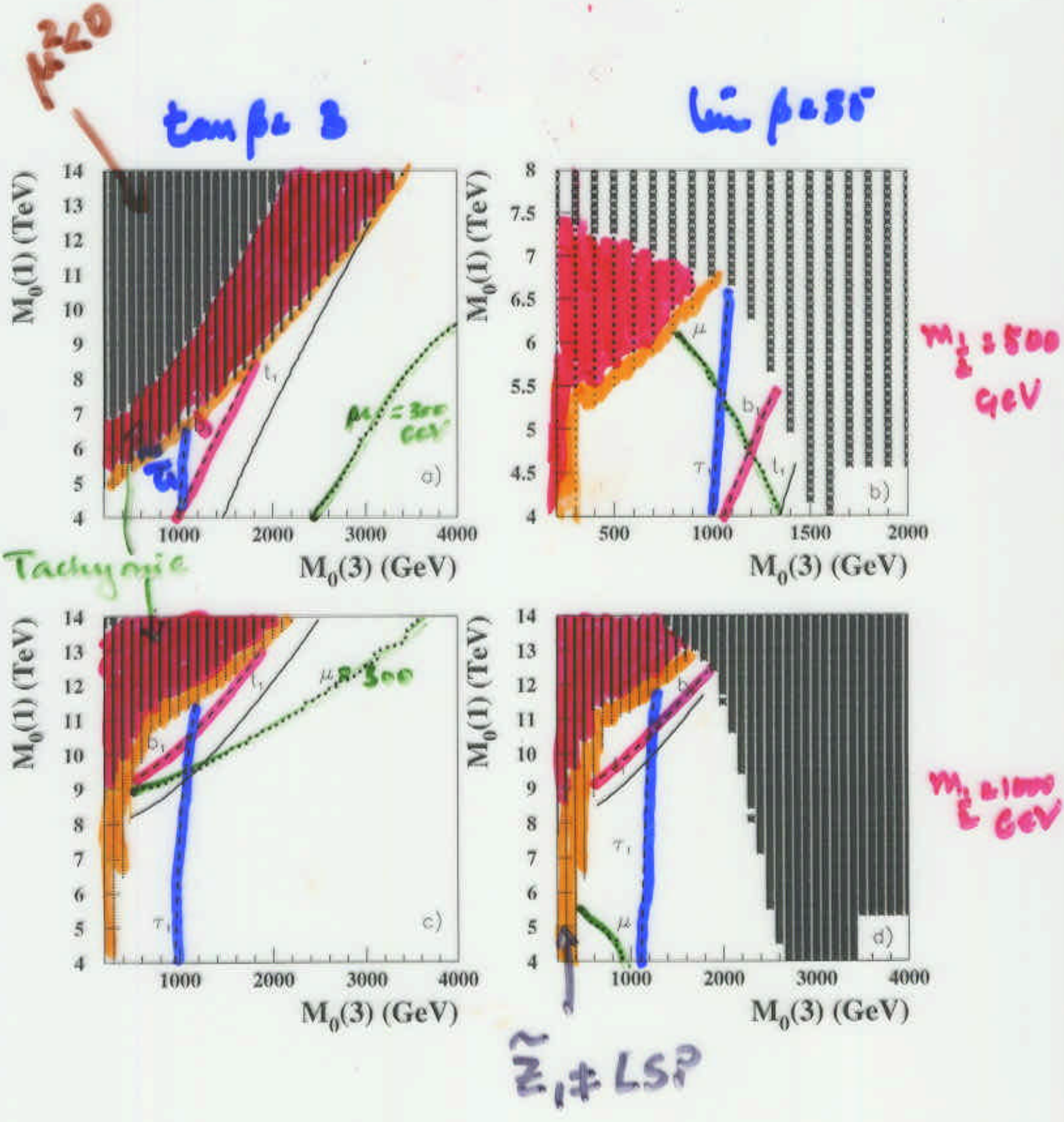
$\tan\beta = 3,\ \mu > 0$

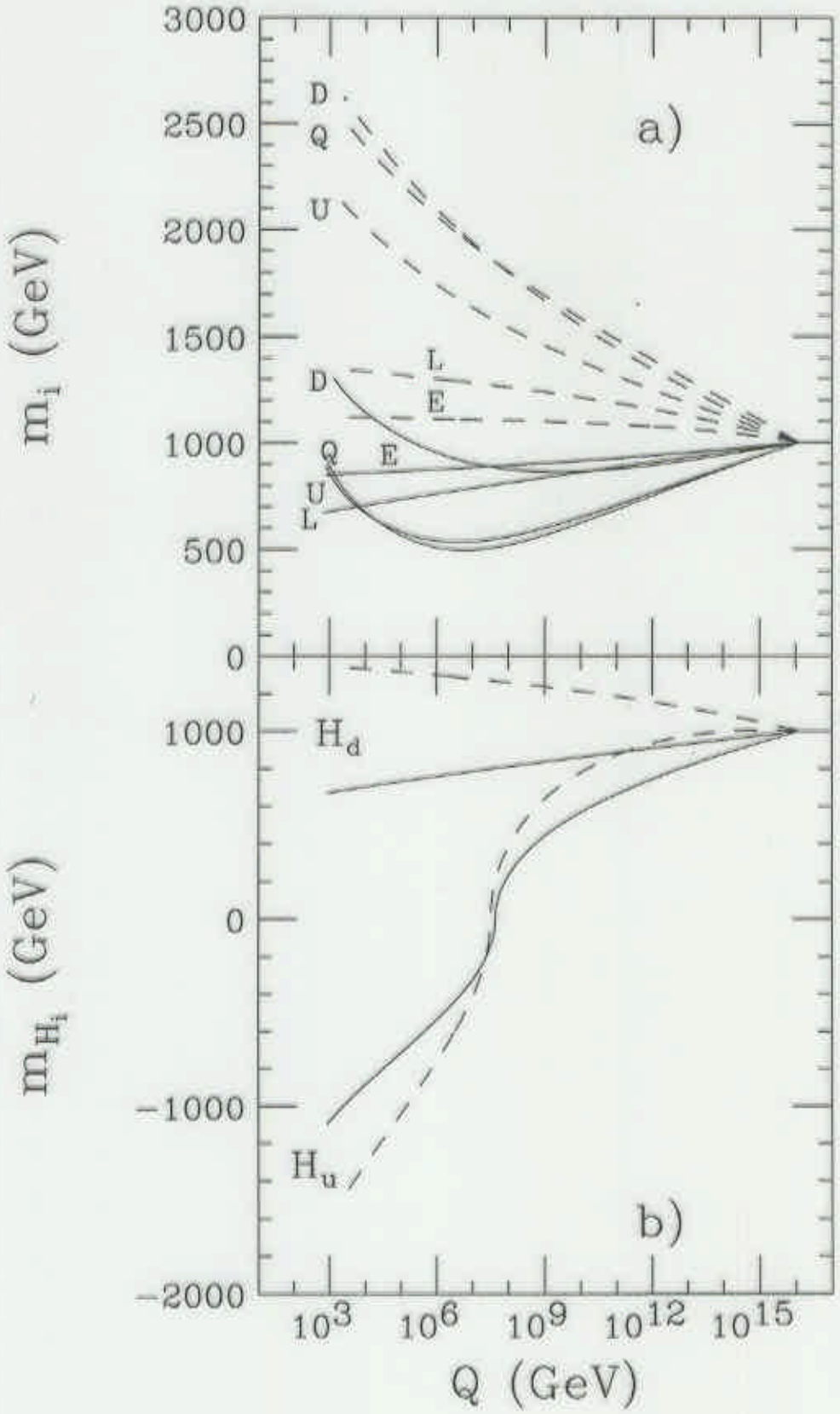


"By Hand IMH"

FINE-TUNING ISSUES ?

$A_0 = 0$; 1 TeV Mass Contours




3000
2500
2000
1500
1000
500
0
1000
0
−1000
−2000
m_i (GeV)
m_{H_i} (GeV)
D
Q
U
L
E
H_d
H_u
a)
b)
10^3
10^6
10^9
10^{12}
10^{15}
Q (GeV)

No special Conclusions except to note that there could be viable scenarios that could be phenomenologically very different