CONNECTING LOW-SCALE PHENOMENOLOGY TO HIGH-SCALE THEORY

SUPERPARTNER, MASSES / YUKAWAS ETC

LISA EVERETT
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INTRODUCTION

TOP-DOWN?

BOTTOM-UP?

OBSERVABLES VS PARAMETERS

NOT AS BAD AS IT LOOKS?

OBSTACLES TO DEDUCING THE HIGH SCALE THEORY

$\Longrightarrow$ OPPORTUNITIES

NOT AS BAD AS IT LOOKS?

FIRST FIND SUPERPARTNERS

-- AT TEVATRON

-- BENCHMARK MODELS (THEORY-MOTIVA

- BASICALLY -- ONE DAY THERE WILL BE A SUPERPARTNER SIGNAL -- THEN WHAT?
- SMALL EXTRA DIMENSIONS -- TRADITIONAL CONTEXT

G. KANE
SUSY 02
DESY

• CENTRAL PROBLEM IN PARTICLE PHYSICS CONTINUES TO BE UNDERSTANDING EWSB

-- FIND, STUDY h^0

• THEN -- CENTRAL PROBLEM BECOMES SUPERSYMMETRY BREAKING

-- FIND, STUDY SUPERPARTNERS

-- HOW IS ~~SUSY~~? -- HIDDEN SECTOR?

-- TRANSMISSION?

• IN PARALLEL -- WHAT IS THE UNDERLYING, MORE FUNDAMENTAL THEORY?

-- 4D EFFECTIVE FIELD THEORY AT HIGH SC

-- 10D STRING THEORY?

• APPROACH?

-- TOP-DOWN? YES -- BUT NOT ENOUGH

-- BOTTOM-UP? YES -- BUT NOT ENOUGH

-- MUCH WORK, THINKING NEEDED TO GO FROM $\sigma_i \times BR_j$, m_i TO

$W(\text{UNIF})$, $\mathcal{L}_{\text{SOFT}}(\text{UNIF})$

$\Rightarrow$ T^OP M^OTIVATED B^OTTOM U^P -- AS FOR PAST 400 YEARS

• OBSTACLES?

• TOP-DOWN? TO DETERMINE ANY OBSERVABLE, NEED TO CALCULATE:

-- $\tan\beta$ (NOT IN HIGH SCALE THEORY -- ONLY ARISES IF BREAK EW SYMMETRY)

-- μ

* $\mu = 0$ AT HIGH SCALE (NATURAL IN STRING THEO[RY]
* ORIGIN?
* ENTERS $\tilde{C}, \tilde{N}, \tilde{Q}$ MASS, CROSS SECTIONS

-- PHASES OF SOFT PARAMETERS, μ

-- ALL PARAMETERS IN NEEDED RGEs

-- SMALL ELEMENTS OF YUKAWA MATRICES, AND PHASES -- MAY DEPEND ON HIGHER DIMENSIONAL OPERATORS

AND ......

$\Rightarrow$ CAN GUIDE THINKING -- BUT SERIOUS PREDICTIONS UNLIKELY

INCLUDE ν SECTOR TOO BUT FOCUS ON COLLIDERS

• BOTTOM-UP?

-- ONCE DATA EXISTS, MUST MEASURE WITHOUT AD HOC ASSUMPTIONS ABOUT SOFT PARAMETERS, μ

AT TEVATRON

-- UNLESS LUCKY [e.g. $\ell^\pm \gamma\gamma \not{E}_T$ EVENTS, TINY SM BACKGROUNDS], WILL SEE SMALL, SLOWLY INCREASING EXCESSES IN FEW CHANNELS

e.g. $\not{E}_T + \geq 3$ JETS, $\ell^\pm + \not{E}_T$ + JETS, ...

$\lesssim 1$ OBSERVABLE IN $\mathcal{L}_{SOFT}$

-- EXPERIMENTERS MEASURE (AT TEVATRON, LHC, ...) INFO ON MASSES FROM KINEMATICS (e.g. END POINTS OF $\partial\sigma/\partial p_T^X$, $\partial\sigma/\partial \not{E}_T$, ...)

-- CAN COUNT OBSERVABLES, PARAMETERS FOR ANY PROCESS

$$\sigma_i \times BR_j = F_{ij}(M_1, M_2, m_3, \mu, \varphi_1, \ldots)$$
$$m_i = F_i'(\qquad\qquad)$$

-- AT **HADRON** COLLIDERS **ALWAYS** FEWER OBSERVABLES THAN LAGRANGIAN PARAMETERS

-- SO MEASURING μ, $\tan\beta$, ... NOT IN GENERAL POSSIBLE AT HADRON COLLIDERS! -- CAN DO ASSUMPTION DEPENDENT OR MODEL-DEPENDENT "MEASUREMENTS"
-- MAY BE LUCKY SO EXTREME EFFECTS DOMINATE (e.g. LARGE $\tan\beta$)

$\hookrightarrow B_s \to \mu^+\mu^-$ OR $b\bar{b}h$

$\sqrt{s} \gtrsim 500$ GeV

⇒ NEED LC ABOVE THRESHOLD FOR A FEW SUPERPARTNERS

• GETTING MORE OBSERVABLES THAN PARAMETER[S] IS MAJOR REASON WE NEED LC

-- 1 POLARIZED BEAM ⇒ "DOUBLE" NUMBER OBSERVAB[LES]

-- 2 " " ⇒ EVEN MORE (NO COUNT[ING])

-- 2 ENERGIES ⇒ ANOTHER "DOUBLING" OF OBSERVABLES (NO COUNT[ING])

BARGER, FALK, HAN, JIANG, PALLER

-- COUNTING DONE FOR $\tilde{C}+\tilde{N}$ AT LC -- BUT PROBABLY NEED MORE OBSERVABLES TO DEAL WITH OBSTACLES SUCH AS FIXED POINTS, EXPERIMENTAL ERRORS, ASSUMPTIONS ABOUT THEORY

CHOI, KALINOWSKI, MOORTGAT-PICK, ZERWAS (CKMZ)

• SO -- EVENTUALLY THE LAGRANGIAN PARAMETERS CAN BE MEASURED

-- UNTIL THEN, INCOMPLETE SET OF OBSERVABLE[S] IS AN OBSTACLE TO LEARNING HIGH SCALE THEOR[Y]

• ACTUALLY -- NOT SO BAD (?)
-- SUSY A REAL THEORY, SO VERY CONSTRAINED, CAN DO A LOT WITH INCOMPLETE INFO

• SUPPOSE FIND TEVATRON "SIGNAL" -- NOT DRAMATIC SINCE 2 ESCAPING LSPs -- SEVERAL CHANNELS WITH EXCESSES, PROBABLY ONLY INCLUSIVE CHANNELS

• PROVE SUSY? -- NO -- BUT GAMBLE

INCLUSIVE SIGNATURES, CLUES	$\widetilde{G}$MSB, LARGE μ	$\widetilde{G}$MSB SMALL μ	GMSB, LOW SCALE	UNSTABLE LSP	$\widetilde{\text{SUSY}}$ GUINO CONDENSATION	$\widetilde{\text{SUSY}}$ $\langle F \rangle$
LARGE $\not{E}_T$	YES	YES	YES	NO	·	·
PROMPT γ's	NO	SOMETIMES	YES (BUT...)	NO	·	·
TRILEPTON EVENTS	YES	NO	NO	NO		
SAME-SIGN DILEPTON EVENTS	·	·				
LONG-LIVED NLSP	·	·				
τ-RICH	·	·				
b-RICH	·	·				
⋮						

PLUS CONSTRAINTS FROM HIERARCHY, EWSB, GAUGE COUPLING UNIFICATION, NO SIGNAL AT LEP, TEVATRON HIGGS SIGNA[L] ν's, $g_\mu - 2$, $b \to s\gamma$ .... AND RELATE LSP TO CDM DETECT[ION]

• STUDY TOP-DOWN MODELS TO FILL IN TABLE, RELATE CONSTRAINTS

• DON'T NEED TO MEASURE EVERY SOFT PARAMETER
-- LOOK FOR PATTERNS, ORDERING OF MASSES ETC

• EACH INCLUSIVE OBSERVABLE ALLOWS ONE TO CARVE AWAY PART OF PARAMETER AND THEORY SPACE -- REMAINING PART POINTS TOWARD HIGH SCALE THEORY

• FOR SM, DIDN'T NEED SO MUCH DATA:
-- V-A CURRENTS, NOT S, P, T
-- CHIRAL FERMIONS
-- WEAK INTERACTIONS WEAK
-- HADRON SPECTRUM
-- EARLY SCALING

• WHAT WILL WE NEED TO KNOW TO "GUESS" THE SSM?
-- VERY INTERESTING TO STUDY THIS IN MODELS

• SO SOME OPTIMISM REASONABLE

• DIFFERENT STRING THEORIES, DIFFERENT SUSY, ETC
⇒ DIFFERENT WORLD

BUT....

• MORE OBSTACLES :

EXTRAPOLATING TO HIGH SCALE NEVER MODEL-INDEPENDENT

-- EFFECTS OF INTERMEDIATE SCALE MATTER CAN BE LARGE -- NATURAL IN STRING THEORIES

-- DON'T KNOW AT WHAT SCALES TO START/END RGE RUNNING -- SCALE FOR INTERMEDIATE MATTER? -- ~~SUSY~~ SCALE? -- FUNDAMENTAL THEORY SCALE

-- FIXED POINTS (INFRARED)

- m_{top} (ROSS EL AL)
- SFERMIONS
- YUKAWAS (NELSON, STRASSLER)

RANGE OF HIGH SCALE INPUT PARAMETERS FLOW TO SAME LE VALUE ⇒ PRECISE KNOWLEDGE OF LE VALUE VERY IMPORTANT TO RECONSTRUCT HIGH SCALE THEORY

⇒ EXAMINE WHAT MEASUREMENT ACCURACY IS NEEDED/ POSSIBLE WITH LHC/LC, WHAT OBSERVABLES MOST HELPFUL

BLAIR, POROD, ZERWAS

ALLANACH, GRELLSCHEID, QUEVEDO

-- UV FIXED POINTS? (MARTIN, WELLS)

-- D-TERMS, FROM ADDITIONAL U(1)'S UNDER WHICH VISIBLE SECTOR PARTICLES CHARGED -- AFFECT SFERMIONS, m_{H_u}, m_{H_d} -- SO CHANGE EWSB -- SO AFFECT μ, GAUGINO MASSES, CDM, ...

-- EXTENDED GAUGE GROUP? -- EXTRA U(1)'S, LARGER GROUP -- ADDITIONAL SOFT TERMS -- LARGER NEUTRALINO, HIGGS MASS MATRICES -- NEW GAUGE COUPLINGS, KINETIC MIXING -- ETC -- MISINTERPRET LE DATA IF IGNORE

ABEL + ALLANACH ph/9707436

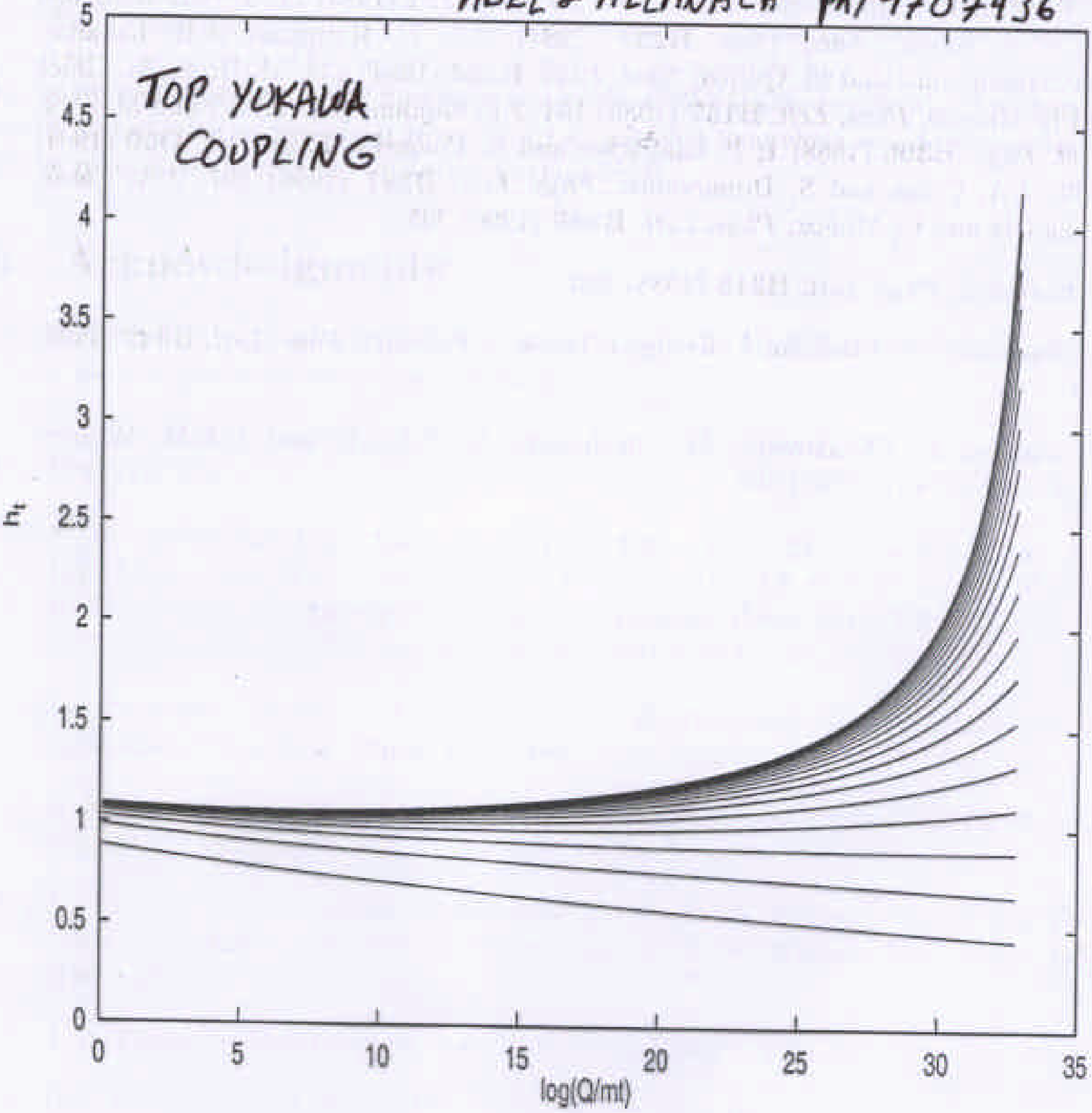


Figure 1: The two-loop renormalisation of the top Yukawa coupling, h_t, for $m_t = 140$ GeV. We have included electroweak and h_b, h_τ corrections and $\tan\beta$ is determined seperately for each line by Eq.(1). The true fixed point is $h_t/g_3 = 0.9$ and is invariant under the renormalisation group. Electroweak corrections make this higher than the naive value, $h_t = \sqrt{7/18}g_3$. The QFP limit is formally defined as the h_t trajectory for which h_t has a Landau pole at M_{GUT}.

ABLE + ALLANACH

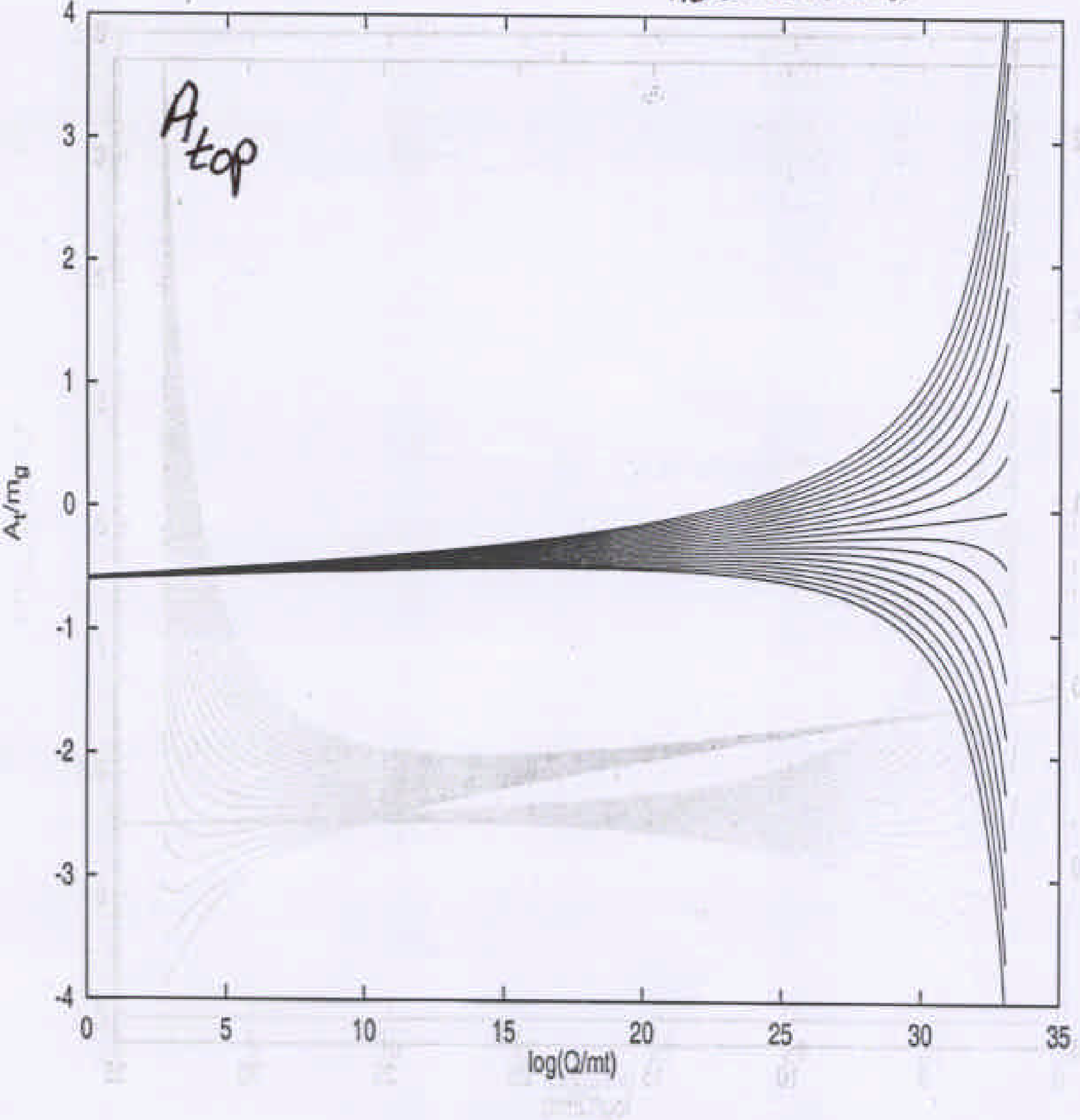
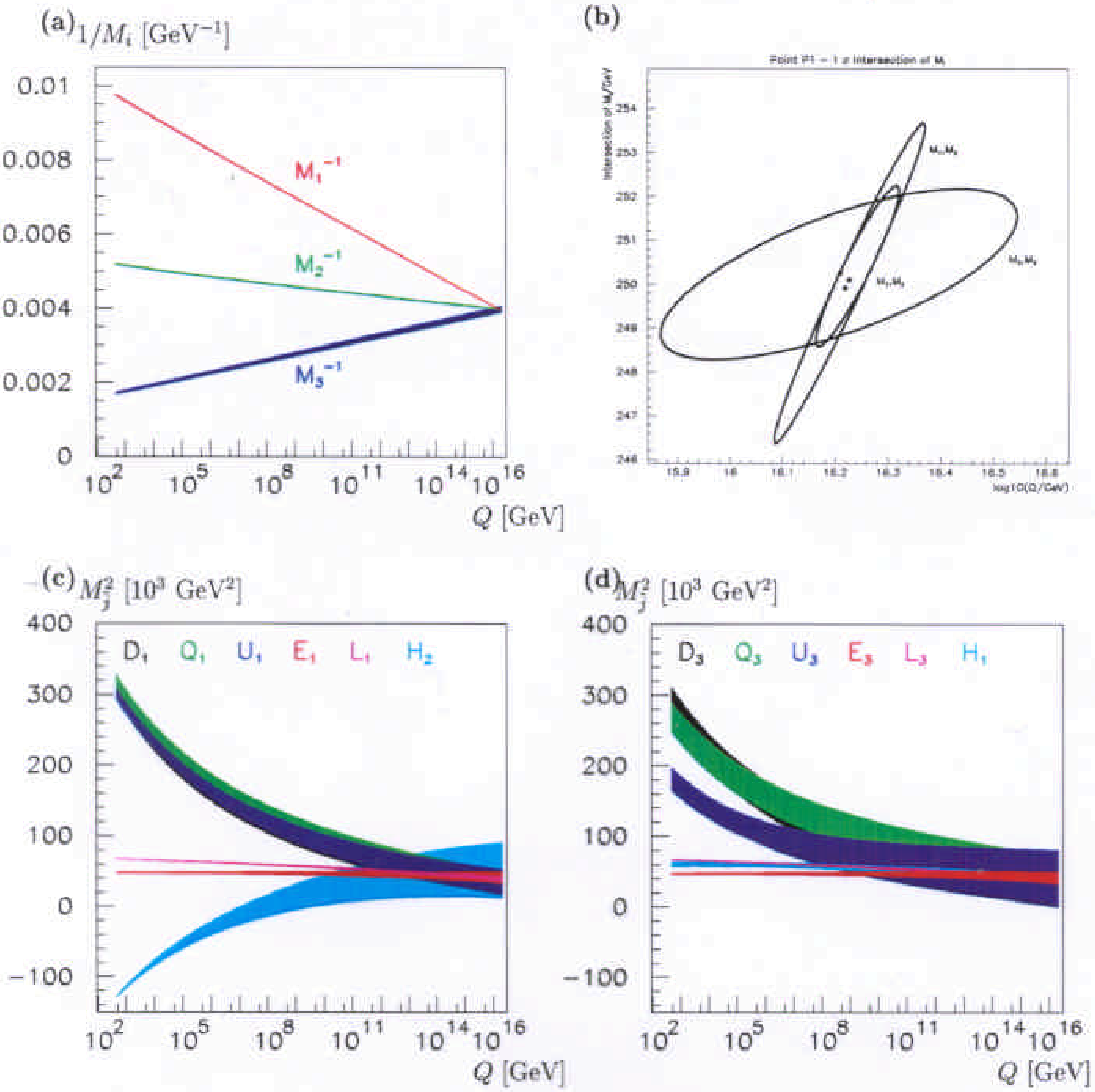


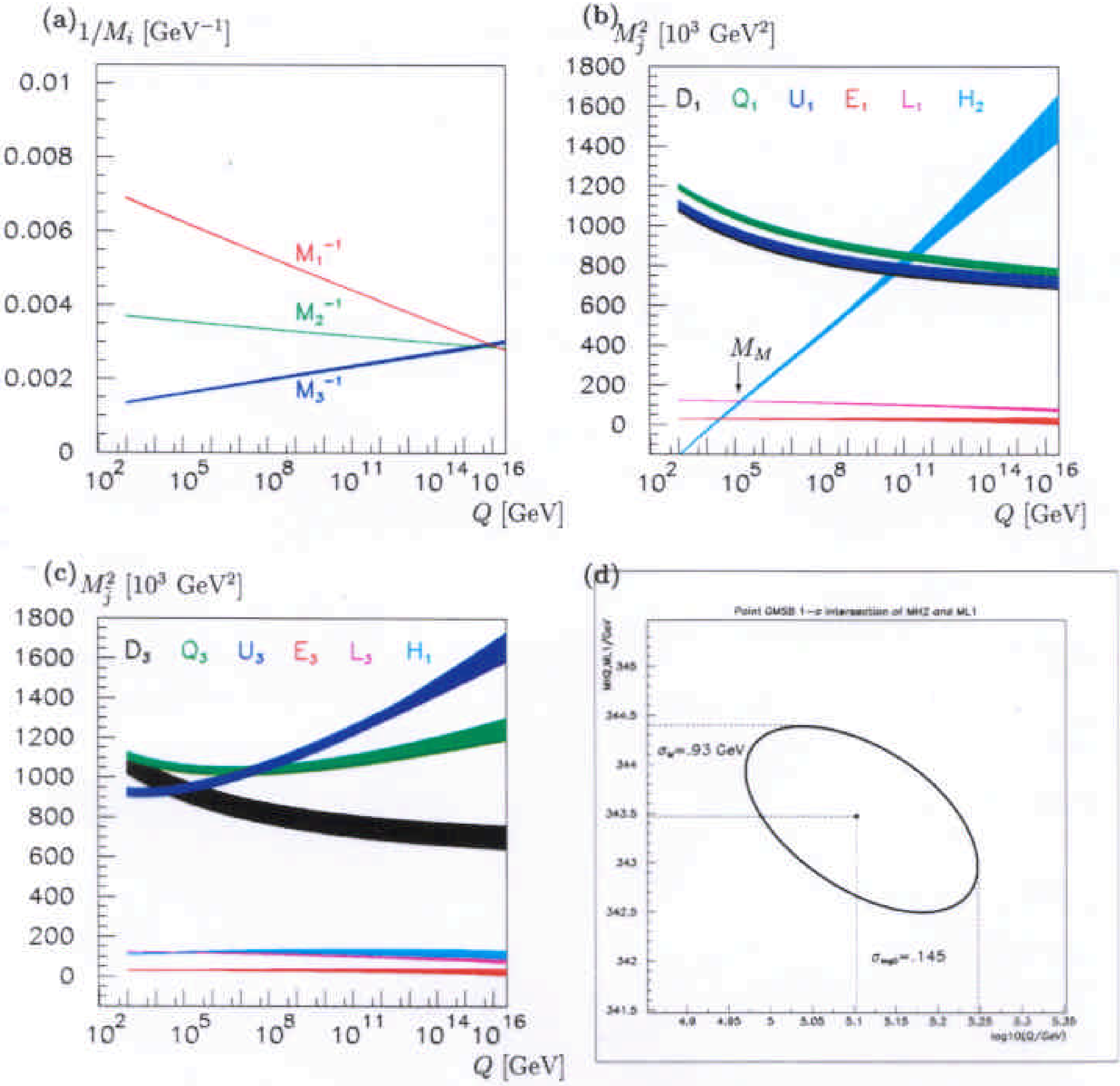
Figure 2: Two-loop renormalisation of A_t/m_g in the CMSSM for various different initial values, with $h_t(GUT) = 5g_3(GUT)$ and $m_t = 175\,\mathrm{GeV}$. All electroweak and Yukawa contributions are included.

TAKE VERY MINIMAL MSSM, NO EXTENSIONS -- RUN DOWN -- "OBSERVE" SPECTRA -- USE LC + LHC ERRORS -- RUN BACK UP -- REPRODUCE ORIGINAL THEORY?

BLAIR, POROD, ZERWAS -- $\tilde{G}$MSB



BLAIR, POROD, ZERWAS – GMSB



-- HIGH SCALE "THRESHOLD CORRECTIONS"

-- NON - RENORMALIZABLE OPERATORS $\sim \frac{1}{M^n} F \varphi \cdots$

-- AFFECT SMALL YUKAWAS, CKM PHASE -- HAVE TO RESCALE GAUGE COUPLINGS, GAUGINO MASSES (EVEN M_a / g_a^2) IF GAUGE KINETIC FUNCTION, KÄHLER POTENTIAL HAVE NRO] -- ETC

-- LEARNING HIGH SCALE YUKAWAS IN W -- Y_U, Y_D, Y_L, Y_ν EACH 3×3 COMPLEX FLAVOR MATRICES -- 18 PARAM EACH -- CONSIDER QUARKS -- 36 HE PARAM, BUT 10 LE OBSERVABLES (6 MASSES, 4 CKM) -- 26 UNPHYSICAL PARAM -- TECHNICAL PROBLEM SOLVED DECADE AGO (BARGER, BERGER, OHMANN; CARENA, POKORSKI, WAGNER) -- BUT RUNNING MIXES IN UNPHYSICAL PARAM -- RECENT PROGRESS (LIANTAO WANG, LISA EVERETT)

$\Rightarrow$ USE $t (= \ln Q/m_U)$ INDEPENDENT BASIS

$$\hat{Y}(t) = V_L^*(0)\, Y(t)\, V_R^T(0)$$

$\Rightarrow$ SIMPLER RGEs, ONE-TO-ONE CORRESPONDENCE BETWEEN LE INPUTS, HE OUTPUTS

$\Rightarrow$ ALGORITHM FOR TAKING ANY HIGH-SCALE THEORY AND COMPARING WITH $\hat{Y}(U)$ TO TEST

$\Rightarrow$ SIMILAR FOR TRILINEAR COUPLINGS

AND ......

OBSTACLES $\longrightarrow$ OPPORTUNITIES

- MAYBE NOT SO BAD?
- ANYTHING THAT HAS AN EFFECT LEADS TO PATTERNS, CLUES
- USE MODELS, TOP-DOWN STUDIES TO RECOGNIZE, DEAL WITH EACH OBSTACLE
- ONE CLEAR LESSON IS NEED FOR A VARIETY OF PRECISE MEASUREMENTS
- JUST AS ONLY A FEW EXPERIMENTAL CLUE PLUS UNDERSTANDING OF THEORY ⇒ SM, PERHAPS NOW A LIMITED AMOUNT OF DATA, PLUS GUIDANCE FROM TOP-DOWN THEORY, WILL ⇒ 4D EFFECTIVE HIGH SCALE THEORY (= SSM) ⇒ 10D STRING THEORY

• TO GET ANYWHERE, NEED SUPERPARTNERS

• WHEN, WHERE? REVISIT THIS OLD QUESTION ......

• WHAT DO WE KNOW THAT PROVIDES INFO?

* m_h^2 SENSITIVE TO NEW PHYSICS SCALE
  -- NOT QUANTITATIVE

* GAUGE COUPLING UNIF -- ALSO NOT QUANTITATIV

* REWSB
  -- CAN HAVE REWSB EVEN IF SUPERPARTNE $\gtrsim$ TeV

TREE LEVEL

-- BUT

IMPORTANT EQUATION, NOT YET FULLY UNDERSTOOD

$$M_Z^2 = -2\mu^2 + 2\left(\frac{m_{H_D}^2 - m_{H_U}^2 \tan^2\beta}{\tan^2\beta - 1}\right)$$

IS THE ONLY QUANTITATIVE RELATION BETWEE A KNOWN NUMBER AND SOFT PARAMETERS

• REWRITE:

GK, KING

$\tan\beta = 5$

FULL MSSM

$$\boxed{m_Z^2 = -1.9\,\mu^2 + 6.9\,M_3^2 - 0.3\,M_2^2 + 0.01\,M_1^2 - 1.2\,m_{H_U}^2 + 1.6\,m_Q^2 + \cdots}$$

-- SOFT PARAMETERS, μ^2 ARE HIGH SCALE

-- FINE TUNING NOT OK UNLESS UNDERLYING SYMMETRY

$\Longrightarrow \mu^2, M_3^2 \lesssim m_Z^2 \Longrightarrow$ LIGHT SUPERPARTNERS

LOOPHOLES? RE-EXAMINE

GK, LYKKEN, NELSON, L. WANG

BRENT NELSON, PARALLEL SESSION 6 SATURDAY

$$M_Z^2 = -1.9\mu^2 + 6.9M_3^2 - 0.3M_2^2 + 0.01M_1^2 + \cdots$$

NOTE:

-- IF ASSUME GAUGINO MASS DEGENERACY $\Rightarrow M_2^2, M_1^2$ VERY SMALL -- INCONSISTENT WITH LEP ($\to M_1, M_2 > M_Z$)

$\Rightarrow$ GAUGINO MASS DEGENERACY REQUIRES LARGE FINE TUNING -- MISLEADING?

CRUCIAL CLUE

NOTE:

GAUGINO MASS DEGENERACY $\neq$ GAUGE COUPLING UNIFICATION

- TREE LEVEL GAUGINO MASSES DEGENERATE, BUT OFTEN SUPPRESSED -- CORRECTIONS THEN LARGE, NOT UNIVERSAL
- GAUGE COUPLING LEADING CONTRIBUTIONS UNIFY, NOT SUPPRESSED -- LOOPS SMALL
- M_a / g_a^2 IS RGE INVARIANT ONLY AT TREE LEVEL
- M_a, g_a^2 FROM DIFFERENT DILATON VEVs, UNRELATED EXCEPT FOR VERY SPECIAL FORMS OF GAUGE KINETIC FUNCTION, KÄHLER POTENTIAL

NOTE:

- CONDITIONS FOR RADIATIVE EWSB, AND <u>ALSO</u> FOR GAUGE COUPLING UNIFICATION, ARE SOFT MASSES <u>AND</u> $\mu \sim$ EW SCALE

  -- μ AFFECTS $\tilde{C}, \tilde{N}, \tilde{Q}$, HIGGS MASSES, SO AFFECTS RUNNING OF g_a^2

  -- RECALL GAUGE COUPLING UNIFICATION ANALYSES WITH SINGLE $T_{SUSY} \sim \mu$

GHILENCEA + ROSS

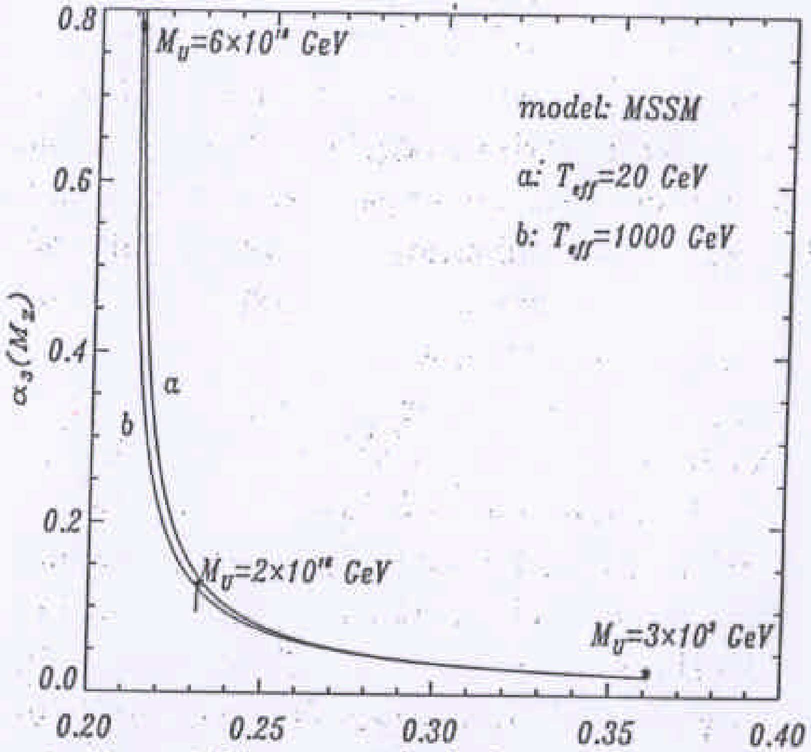


Figure 1 (a). $Sin^2\theta_W(M_Z)$

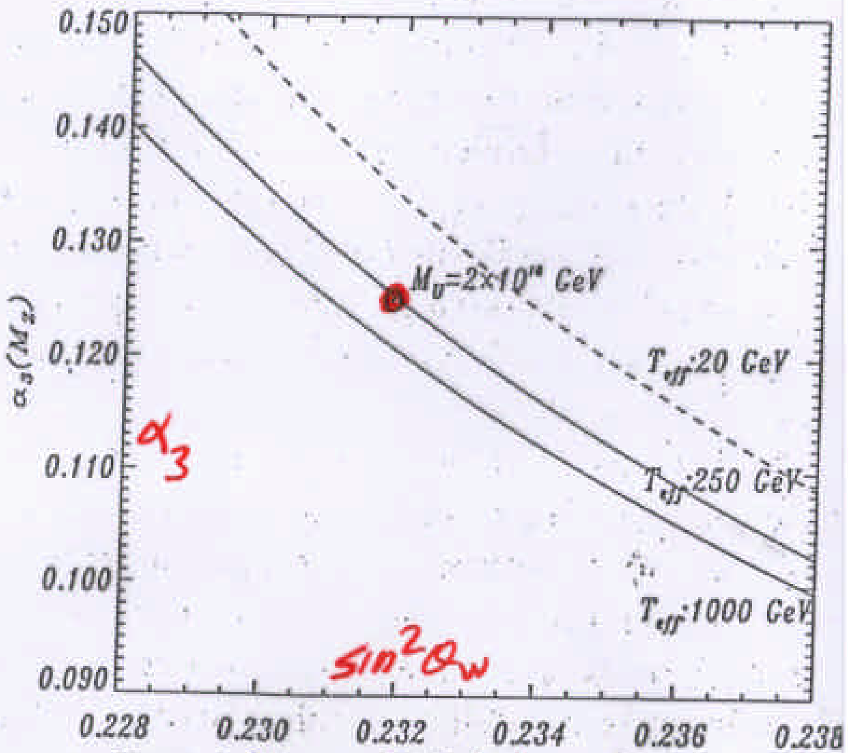


Figure 1 (b). $Sin^2\theta_W(M_Z)$

Figures 1 (a) and (b). Plots of $\alpha_3(M_Z)$ versus $\sin^2\theta_W$ calculated in the MSSM for two values of the fective supersymmetric threshold, $T_{eff} = 20$ GeV and $T_{eff} = 1000$ GeV. The limits correspond to requi $\alpha_3(M_Z)$ remains in the perturbative domain and unification occurring above the supersymmetry threshold. 'ea between the two curves provides a meas : of the predictivity of the theory. The exp(mental rang values is also shown.

- SHOULD SUPERPARTNERS HAVE ALREADY BEEN SEEN?

  LEP? TEVATRON RUN I ($\sim 100\, pb^{-1}$)

- ONLY IF WE WERE LUCKY!

  -- ARGUMENT $\tilde{C}, \tilde{N} \lesssim 100$ GeV BASED ON GAUGINO MASS DEGENERA ASSUMPTION

  -- $\tilde{g}$ SHOULD BE LIGHT BUT

  $\sigma \sim$ FEW $\times 10^{-2}$ pb

- ONCE TEVATRON HAS $\gtrsim$ FEW fb^{-1} EXPECT SIGNALS

CAN THE FINE-TUNING CONSTRAINTS BE AVOIDED?

HOW ROBUST? -- EXAMINE MODELS, HOW μ AN

$\mathcal{L}_{SOFT}$ ARISE IN STRINGY APPROACHES

① CAN μ, M_3 BE RELATED?

$M_Z^2 = -1.9\mu^2 + 6.9M$ + ...

NO -- $\mu_W = 0$

-- μ ARISES EITHER FROM GIUDICE-MASIERO LIKE MECHANISM, OR AS SCALAR VEV -- EITHER WAY VERY DIFFERENT PHYSICS FROM M_3 -- WE CHECKED IN STRINGY AND OTHER MODELS WITH GAUGE COUPLING UNIFICATI

② COULD SOFT TERMS BE RELATED? AMONG GAUG OR GAUGINO-SCALARS?

-- NOT AMONG GAUGINOS -- NEED LARGE NON-DEGEN UNNATURAL -- IF CANCEL BY REDUCING M_3 GET LIGHT $\tilde{g}$ AS DESIRED

-- SCALARS AND M_3? -- REQUIRES LARGE SCALAR NON-DEGENERACY

-- MORE GENERALLY -- IN e.g. STRINGY APPROAC $\mathcal{L}_{SOFT}$ AFFECTED BY ~~SUSY~~, TRANSMISSION, DILATON (→ GAUGINO MASSES), MODULI (→ SCAL MASSES) -- ALL HAVE TO BE ENGINEERED TO GET CANCELLATION

-- THINK PARAMETERS -- $m_{3/2}$, DILATON VEVS, MODULI VEVS, ...

$$M_Z^2 = -\underset{\downarrow}{1.9}\,\mu^2 + \underset{\downarrow}{6.9}\,M_3^2 + \cdots$$

(3) CAN THE COEFFICIENTS BE MADE SMALLER?

YES -- RUN FROM LOWER SCALE

-- INTERMEDIATE SCALE MATTER

BUT -- COEFFICIENTS NOT VERY SMALL

-- WHATEVER PHYSICS LEADS TO SMALLER COEFFICIENTS ALSO IMPLIES LIGHTER PHYSICAL SUPERPARTNER MASSES

e.g. IN MSSM $M_{\tilde{g}} \approx 3 M_3$ (UNIF)

-- IF REDUCE $6.9 \rightarrow 6.9/10$, $M_{\tilde{g}} \approx 0.4\, M_3$ (UNIF)

$\Rightarrow$ STILL LIGHT SUPERPARTNE

-- VARIATION WITH m_{top} MILD

-- VARIATION WITH $\tan\beta$ MILD IF $\tan\beta \gtrsim$

CERN, SNOWMASS

(4) BENCHMARK MODELS -- DO THEY IMPLY
SUPERPARTNERS TOO HEAVY FOR
TEVATRON, LC 500 ?

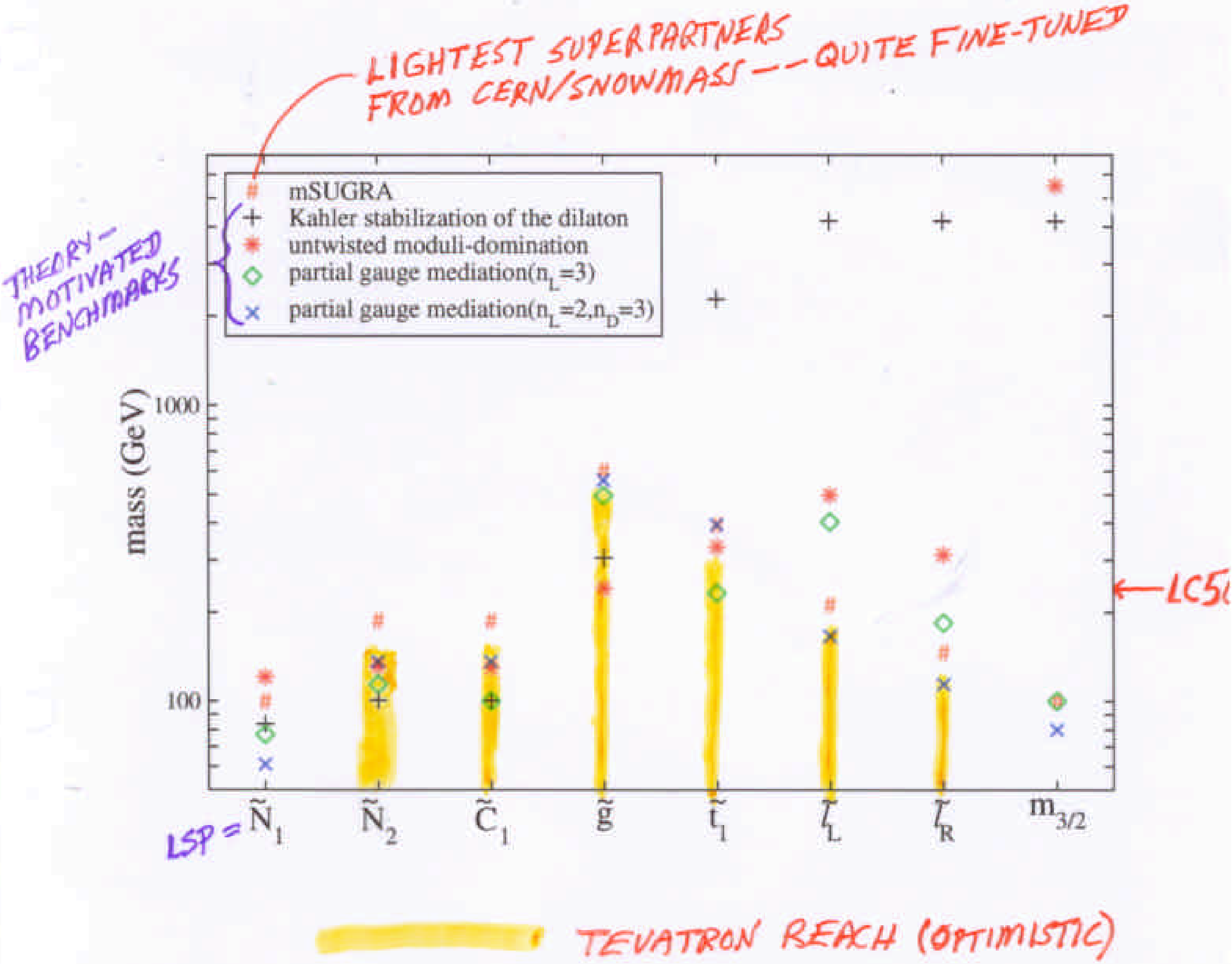
BRENT NELSON, PARALLEL SESSION 6, SAT

GK, LYKKEN, MR
BRENT NELSON,
LIANTAO WANG,
TING WANG

NO

-- CONSTRUCT THEORY MOTIVATED MODELS
BASED ON HETEROTIC STRING

- GAUGINO CONDENSATION
- KÄHLER DILATON STABILIZATION, $V = 0$
- DILATON OR MODULI DOMINATION OF SUSY
- PARTIAL HIGH SCALE GAUGE MEDIATION
- NOT FINE-TUNED
- LIGHT SUPERPARTNERS


LIGHTEST SUPERPARTNERS FROM CERN/SNOWMASS -- QUITE FINE-TUNED
THEORY-MOTIVATED BENCHMARKS
mSUGRA
Kahler stabilization of the dilaton
untwisted moduli-domination
partial gauge mediation(n_L=3)
partial gauge mediation(n_L=2,n_D=3)
mass (GeV)
1000
100
LSP = $\tilde{N}_1$
$\tilde{N}_2$
$\tilde{C}_1$
$\tilde{g}$
$\tilde{t}_1$
$\tilde{l}_L$
$\tilde{l}_R$
$m_{3/2}$
←LC5
TEVATRON REACH (OPTIMISTIC)

CERN/SNOWMASS

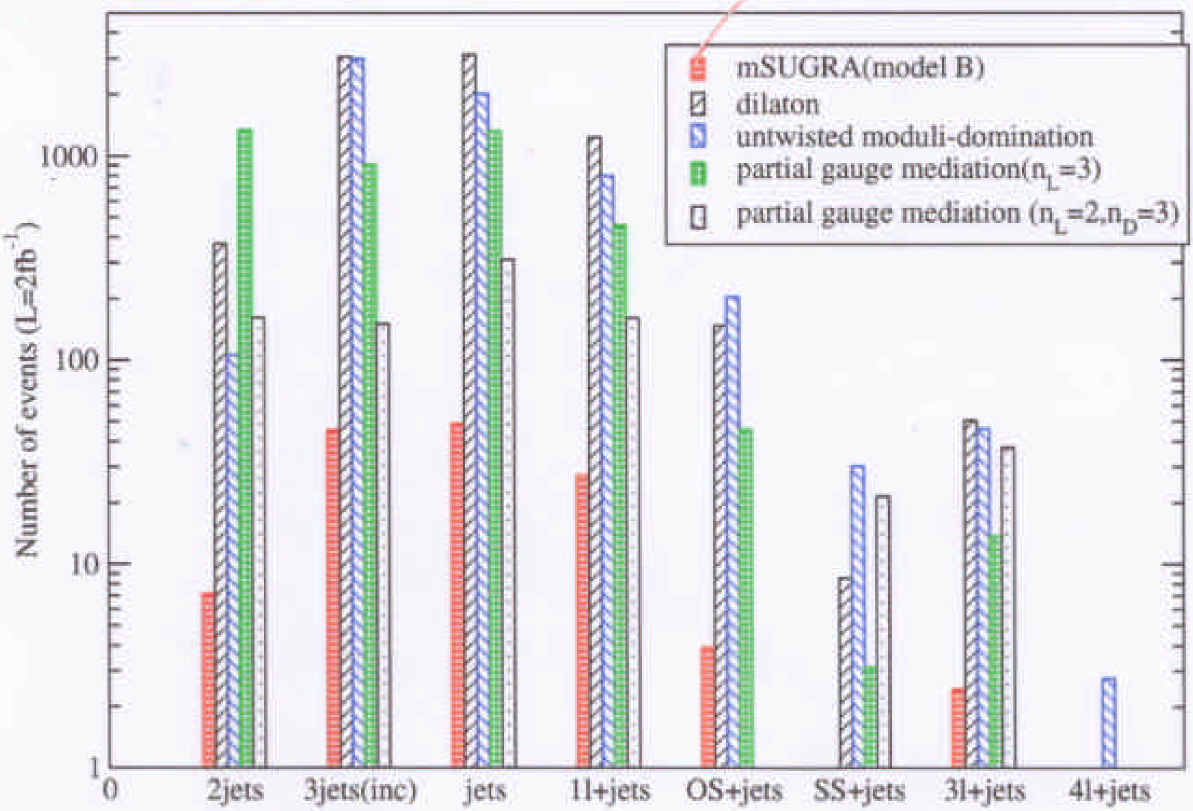


Figure 1: Number of events of different signatures for different models at Tevatron with 2fb^{-1}. Every signature has missing energy. The first one is 2 jets plus missing energy. The second one is inclusive multi-jets signauture with $n_{jets} \geq 3$. This one is used by CDF to search for gluino squark. The third one is $n_{jets} \geq 2$ without lepton. The forth one is 1 lepton plus $n_{jets} \geq 2$. The fifth is opposite sign dilepton plus $n_{jets} \geq 2$. The sixth is same-sign dilepton signature. The seventh is trilepton signature. The eighth has 4-lepton.

SIGNALS, NO BACKGROUNDS

MY SUMMARY

- IF SUPERPARTNERS ARE NOT PRODUCE[D]
  AT THE TEVATRON
  - → UNLIKELY SUPERSYMMETRY PROVIDES EXPLANATION FOR EWS[B]

  *THEN IT IS INTERESTING TO ASK WHAT ARGUMENTS SUGGEST SUPERPARTNERS AT LH[C]

- IF SUPERPARTNERS OBSERVED AT TEVATRON
  - -- NEED THINKING, ANALYSIS TO

    $$m_i,\ \sigma_i \times BR_j \longrightarrow \mathcal{L}^{EW}_{SOFT}$$

  - -- NEED INNOVATIVE THINKING, ANALYSIS FOR

    $$\mathcal{L}^{EW}_{SOFT} \longrightarrow \mathcal{L}^{UNIF}_{SOFT},$$

    IDENTIFY AND OVERCOME OBSTACLES

    OBSTACLES → OPPORTUNITIES

- PERHAPS THERE WILL BE ENOUGH CLU[ES] TO "GUESS" THE SSM AND THEN THE 10D STRING THEORY

"A NATURAL ORDER"