Are Slepton Masses Universal?

Why do we care, and how might we know?

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Weak Interactions & Neutrinos 2002

Supersymmetry is "quite mature"

Idea dates back at least to 1971-74

Phenomenological interest took off ~ 1981-82

- SUSY can stabilize the electroweak scale if $|m_p - m_{\tilde{p}}| \lesssim O(1\,\mathrm{TeV})$

SPARTICLES MUST BE PRESENT AT THE TEV SCALE ☺

SUSY BREAKING "LOW ENERGY" PHENOMENON

MODELS WITH TeV SCALE ~~SUSY~~

$$\sum_{\text{bosons}} (2j+1) M_j^2 - \sum_{\text{fermions}} (2j+1) M_j^2 = 0!$$

Valid in each charge Secta of Theory

$\Downarrow$

There must be a squark lighter than a quark! ☹

- In theories with gravity, RHS $\neq 0$ even in the "flat space limit" with fixed $m_{3/2}$ (Supergravity)

- Sum Rules are tree-level results. If masses only result at the loop level these don't apply (Gauge-Mediation)

We don't know how SUSY is broken

$\Downarrow$

We don't really know what sparticle masses should be

$\Downarrow$

Parametrize this by allowing all soft SUSY breaking operators consistent with symmetries
[Poincaré + $SU(3) \times SU(2) \times U(1)$]

MSSM (Conserved R-parity)

124 parameters.

Theorists make assumptions about high scale physics to reduce this number.

ASSUMPTIONS MAY BE WRONG

Differing assumptions lead to different masses

⇓

Assumptions are experimentally testable

SUSY MODELS

Models take care that sparticles with same gauge Q. Nos. are (approximately) degenerate

FCNC constraints require this for first two generations if sparticles are in reach of machines!

Sparticle masses can be anything except for "gauge" invariance constraints

$$m_{\tilde{e}_L} = m_{\tilde{\nu}_L} \quad \text{(up to } SU(2)\times U(1) \text{ D-terms)}$$

$\tilde{e}_L$ & $\tilde{\nu}_L$ are part of a Lepton doublet & so have <u>same mass</u> except for EWSB effects!

$$m^2_{\tilde{\nu}} = m^2_{\tilde{e}_L} + \frac{1}{2} M_Z^2 \cos 2\beta$$

Focus on Slepton and Chargino Masses

- Precision measurements of these possible at Linear Colliders

- Clean experimental environment
- Well-defined initial state
- Availability of longitudinal beam polarization

Some precise mass info also possible from LHC but that is a different issue.

mSUGRA model

Universal Mass parameter for all scalars

$m_{\tilde{L}} = m_{\tilde{e}_R}$ [$Q \simeq M_{GUT}$]

Renormalization effects split them

Gauge-Mediated SUSY Breaking

Sparticle mass $\propto \frac{\alpha_i}{4\pi} \Lambda$

Gauge coupling

$m_{\tilde{L}} \simeq 2\, m_{\tilde{e}_R}$ [Q = Messenger Scale]

Anomaly Mediation

Sparticle mass determined by gauge β (and γ) functions

$m_{\tilde{e}_L} \simeq m_{\tilde{e}_R}$ (Weak Scale)

accident?

mSUGRA & Gauge mediation easily distinguishable!

From Spectrum as well as signals.

What about mSUGRA & Anomaly Mediation?

Distinguishable because chargino/neutralino masses are distinct in these models!

In mSUGRA $m_{\tilde{W}_1} \simeq m_{\tilde{Z}_2} \simeq 2 m_{\tilde{Z}_1}$ almost always.

In AMSB $m_{\tilde{W}_1} \simeq m_{\tilde{Z}_1}$ because the SU(2) gaugino is lighter than U(1) gaugino.

WHY BOTHER ABOUT MASSES THEN?

$m_{\tilde{e}_R} \stackrel{?}{=} m_{\tilde{\mu}_R}$; $m_{\tilde{e}_L} \stackrel{?}{=} m_{\tilde{\mu}_L}$

HIGH DEGREE OF DEGENERACY EXPECTED IN THESE MODELS

But this is not trivial! No a priori symmetry reason for universality among generations!

What about staus?

(Non)-Degeneracy of $\tilde{\tau}_1, \tilde{\tau}_2$ with selectrons & smuons says something about τ-Yukawas?

MOREOVER, ...

THERE ARE "REASONABLE" MODELS WHERE GUT SCALE MASSES MAY BE SPLIT!

SO(10) GUTS

$$m_{\tilde{L}}^2 = m_{16}^2 - 3M_D^2$$
$$m_{\tilde{e}_R}^2 = m_{16}^2 + M_D^2$$

Intra-generation splitting

[Same M_D^2 determines splitting of other particles]

Right-handed Neutrino Yukawa interactions CAN affect $m_{\tilde{L}}$ but not $m_{\tilde{e}_R}$ - most important for 3rd Gen. in hierarchical See-saw framework

Inter-generation splitting

Gaugino-Mediated SUSY Breaking

Higher dimensional theory

Gauge fields directly feel SUSY breaking sector ⇒ Gauginos get a mass

Matter scalars (approx) massless

Conditions valid at Compactification Scale.

In SU(5) model m_{10} and m_5 evolve differently from M_C to M_{GUT}

[Intrageneration splitting at M_{GUT}]

Looks like mSUGRA with small m_0.

Baer, Balazs, Mizukoshi XT (PRD 63, 055011)

Impact of Yukawa Interactions

$$\frac{d}{d\ln Q}\left(m^2_{\tilde{e}_R} - m^2_{\tilde{\tau}_R}\right) = \frac{2}{16\pi^2}\left(2 f_\tau^2 X_\tau\right)$$

Δ_R

Gauge Contrib^{ns} cancel
– universality.

$$\frac{d}{d\ln Q}\left(m^2_{\tilde{e}_L} - m^2_{\tilde{\tau}_L}\right) = \frac{2}{16\pi^2}\left(f_\tau^2 X_\tau + f_\nu^2 X_\nu\right)$$

Δ_L

$X_\tau = m^2_{\tilde{\tau}_L} + m^2_{\tilde{\tau}_R} + m^2_{H_d} + A_\tau^2$; $X_\nu = m^2_{\tilde{\tau}_L} + m^2_{\tilde{\nu}_R} + m^2_{H_u} + A_\nu^2$

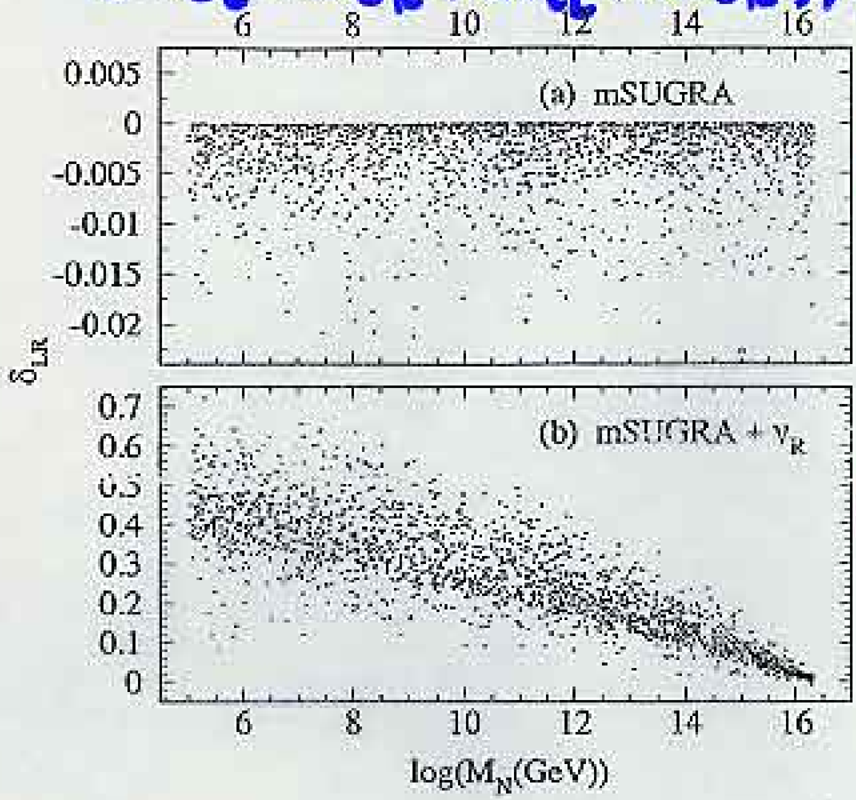
$2\Delta_L - \Delta_R = 0$ in mSUGRA!
SUM-RULE!

$$\frac{d}{d\ln Q}\left(2\Delta_L - \Delta_R\right) = \frac{4}{16\pi^2} f_\nu^2 X_\nu$$

mSUGRA Sum rule violated!

$$\delta_{LR} = \frac{2\Delta_L - \Delta_R}{(m_{\tilde{e}_L}^2 + m_{\tilde{e}_R}^2 + m_{\tilde{e}_L}^2 + m_{\tilde{e}_R}^2)/4}$$

LOOK AT SCALE



TINY

$M_N \approx M_{GUT}$

$\Rightarrow$ No effect of RHN

O(1)

☺

Problem

$m_{\tilde{e}_L}, m_{\tilde{e}_R} \neq$ Physical masses $m_{\tilde{e}_1}, m_{\tilde{e}_2}$ due to Yukawa coupling + mixing effects.

$$\Delta_1 = m_{\hat{e}_R}^2 - m_{\tilde{e}_1}^2$$

$$\Delta_\nu = m_{\tilde{\nu}_e}^2 - m_{\hat{\tilde{\nu}}_e}^2 = \Delta_L \text{ for mSUGRA}$$

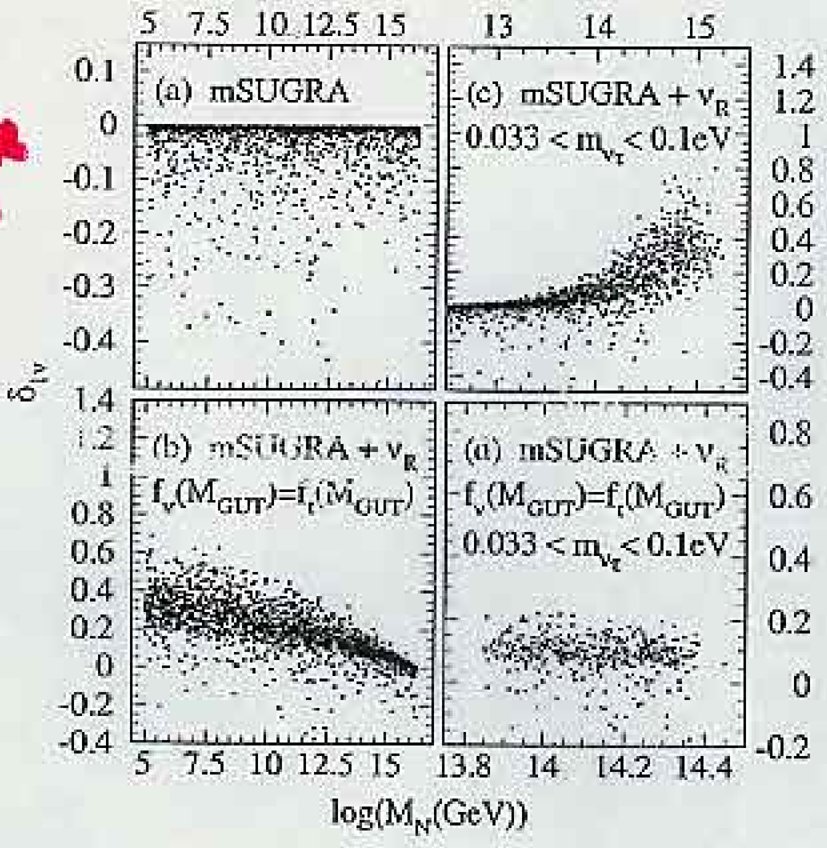
$\Rightarrow \delta_{12}$ dimensionless variable

DIRECTLY MEASURE

$\frac{f_{\nu_\tau}^2 v_u^2}{M_N}$ fixed.

BIGGER SPREAD $\delta_{b\tau\nu}$

If f_ν is not too small, BIG EFFECT



+ve $\delta_{b\tau}$

PROBLEM

δm_ν^2 IS ALL WRONG!

CAN WE DISTINGUISH $\delta_{12} \simeq 0.1$ from $\delta_{12} \simeq 0$?

MANY STUDIES IN MID '90'S SHOW 1st Generation Slepton masses will be determined to $\lesssim 1\%$ at Linear colliders

T. Tsukamoto, K. Fujii, H. Murayama, K. Yamaguchi & Y. Okada (PRD '95)

H. Baer, R. Munroe, XT (PRD '96) [Cascade Decays]

JLC Group; Snowmass '96, SLAC ZDR ....

$$\Delta \delta_{12} = 4\sqrt{\left(\frac{\Delta m_{\tilde{\nu}_\tau}}{m_{\tilde{\nu}_\tau}}\right)^2 + \frac{1}{16}\left(\frac{\Delta m_{\tilde{\tau}_1}}{m_{\tilde{\tau}_1}}\right)^2}$$

$\Rightarrow$ $m_{\tilde{\nu}_\tau}$ determination with a precision of 2.5% needed!

M. Nojiri, K. Fujii & T. Tsukamoto have shown $m_{\tilde{\tau}_1}$ can be determined to $\simeq 2\%$ with $100\,fb^{-1}$ & just $\tau \to \rho$ decays (other decays $\Rightarrow$ factor 2 better?)

BEYOND UNIVERSAL MODELS

Take all sparticles at m_0 except

$m^2_{\tilde{\ell}_R} = m_0^2 + \delta m^2$ @ $Q = M_{GUT}$

$\Rightarrow S_{GUT} = 3\,\delta m^2$

$\Delta \quad \propto \quad \delta m^2$

How well can Δ be measured?

$\delta\Delta \simeq 3\,\frac{\delta m}{m} \cdot m^2$ if $m_{\tilde{W}_1} \simeq m_{\tilde{e}_L} \simeq m_{\tilde{e}_R}$

for $m = 250$ GeV, $\delta\Delta \simeq 1875\ \text{GeV}^2$

150 GeV $\quad \delta\Delta \simeq 675\ \text{GeV}^2$

Representative value $\sim 1000\ \text{GeV}^2$

Probing GUT Scale Intra-generation non-universality

Baer, Balázs, Kesselbach, Mizukoshi, XT
PRD 63, 095008

$$\frac{d}{dt}\left(m^2_{\tilde{e}_R}-m^2_{\tilde{e}_L}\right)=\frac{1}{2\pi}\frac{M_2^2}{\alpha_2^2}\left(\frac{9}{5}\alpha_1^3-3\alpha_2^3\right)+\frac{9}{20\pi}\alpha_1 S$$

$$S=\left(m^2_{H_u}-m^2_{H_d}\right)+\sum_{Gen}\left(m^2_{\tilde{q}_L}-m^2_{\tilde{\ell}_L}-2m^2_{\tilde{u}_R}+m^2_{\tilde{d}_R}+m^2_{\tilde{e}_R}\right)$$

$$S(Q)=S_{GUT}\frac{\alpha_1(Q)}{\alpha_1(GUT)}$$

$$m^2_{\tilde{e}_R}-m^2_{\tilde{e}_L}+\frac{M_2^2}{2\alpha_2^2(M_2^2)}\left[\frac{3}{11}\left(\alpha_1^2(m^2_{\tilde{e}})-\alpha_1^2(GUT)\right)-3\left(\alpha_2^2(m^2_{\tilde{e}})-\alpha_2^2(GUT)\right)\right]$$

$$=\underbrace{\left(\frac{1}{2}-2\sin^2\theta_W\right)M_Z^2}_{<(20\,GeV)^2}\cos 2\beta+\delta m^2-\frac{9}{10b_1}S_{GUT}\left(1-\frac{\alpha_1(m_Z)}{\alpha_1(GUT)}\right)$$

Everything except M_2 observable (or calculable) on LHS

Construct Δ

$$\Delta \equiv m^2_{\tilde{e}_R} - m^2_{\tilde{e}_L} + \frac{m^2_{\tilde{W}_1}}{2\alpha_2(m_{\tilde{W}_1})} \times \left[\frac{3}{11}\left(\alpha_1^2(m_{\tilde{e}}) - \alpha_1^2(GUT)\right) - 3\left(\alpha_2^2(m_{\tilde{e}}) - \alpha_2^2(GUT)\right)\right]$$

In Models with universal mass, Δ is small $\left(< (20\,\mathrm{GeV})^2\right)$ if

- $m_{\tilde{W}_1}$ not very different from M_Z
- 2 loop effects are small.
- $\alpha_i(Q) \equiv \dfrac{\alpha_i(M_Z)}{1 - \frac{b_i}{2\pi}\alpha_i(M_Z)\ln\frac{Q}{M_Z}}$

$b_1 = \frac{33}{5}$, $b_2 = 1$

Assume $\tilde{e}_L, \tilde{e}_R, \widetilde{W}_1$ produced at NLC.

FIGURES

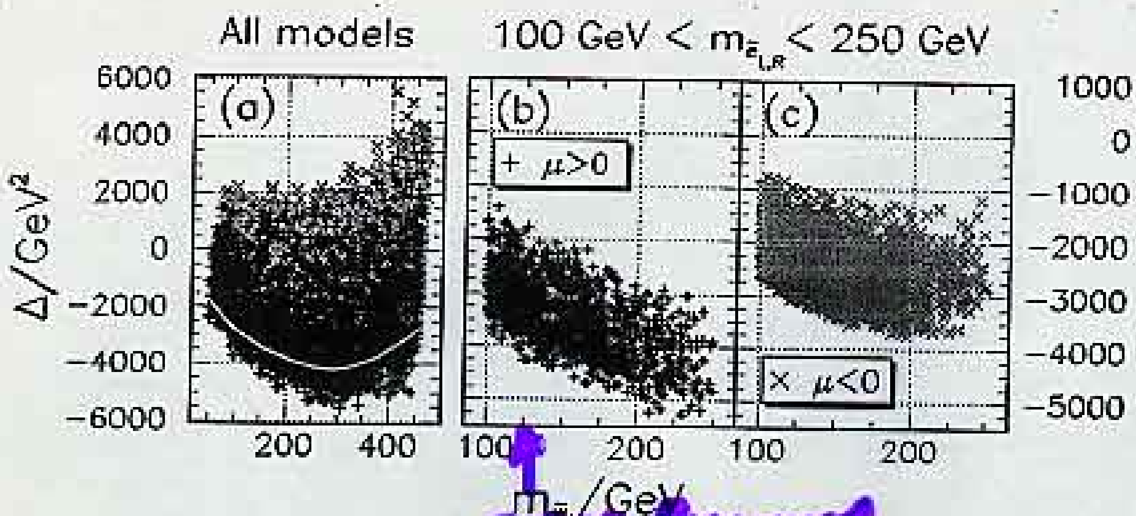


FIG. 1. A scatter plot of Δ, defined in Eq. (6), versus the chargino mass. In frame (a) we show Δ for all the generated mSUGRA models that satisfy the experimental and theoretical constraints discussed in the text. The light crosses and dark pluses denote models with negative and positive values of μ, respectively. Where these overlap, just the dark pluses are visible. The white curve shows the boundary of the band with $\mu < 0$. Frame (b) shows the same thing except that $\tilde{e}_L$, $\tilde{e}_R$ and $\widetilde{W}_1$ are each also required to be lighter than 250 GeV, with $\mu > 0$. Frame (c) is the same as frame (b) except that $\mu < 0$. Notice that the vertical scale is on the right for frames (b) and (c).

- Spread in Δ >> D-term
  but << $m^2 \sim (150-200)^2 \sim$ 20-40 K GeV^2

- Bulk of spread comes from $M_2 \to m_{\widetilde{W}_1}$

$\Downarrow$

If M_2 "directly measured" Δ spread greatly reduced

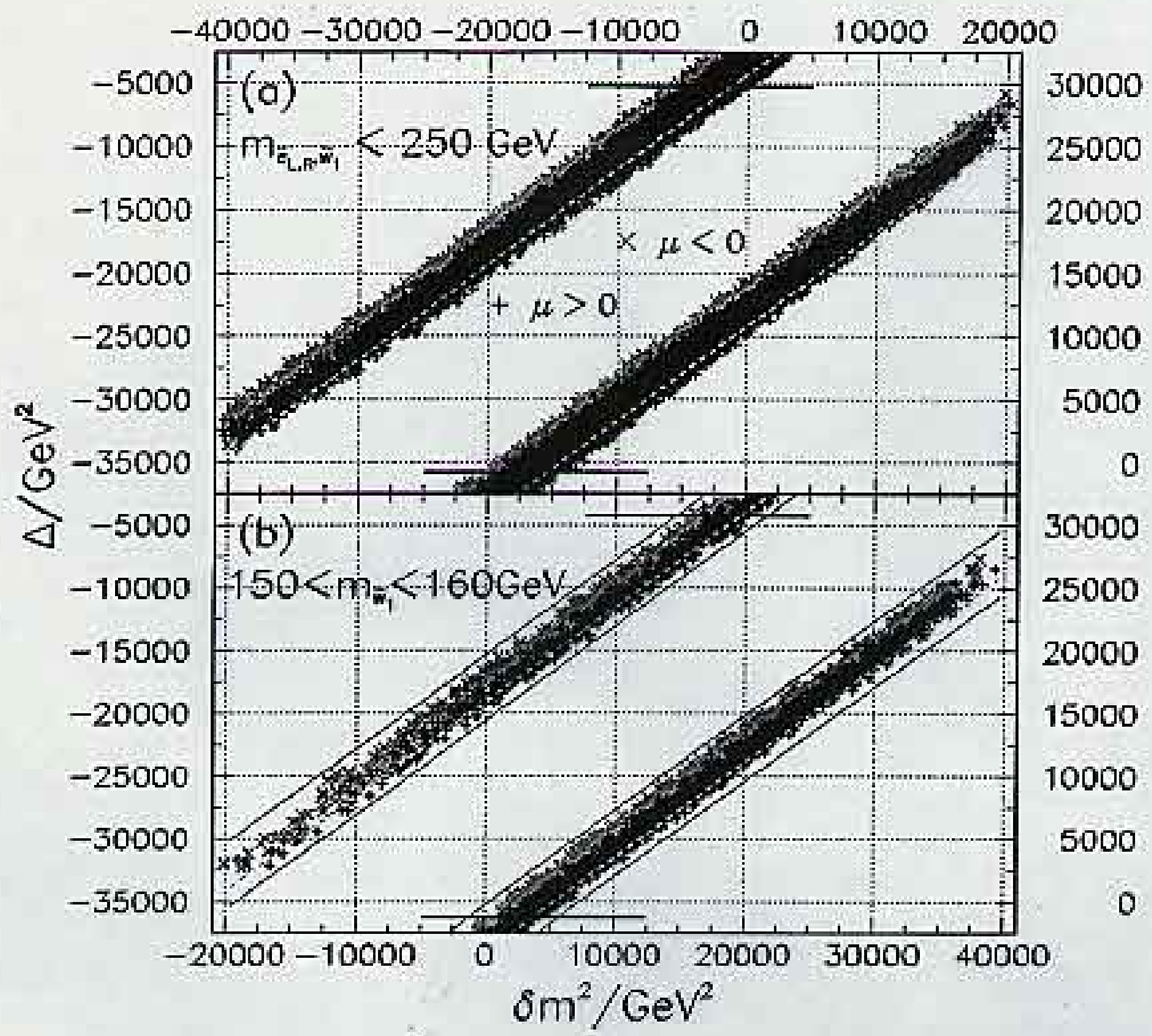


FIG. 2. A scatter plot of Δ versus $\delta m^2 \equiv m^2_{\tilde{e}_R}(M_{GUT}) - m^2_{\tilde{e}_L}(M_{GUT})$. In frame ($a$) we show Δ for the non-universal models satisfying the same experimental and theoretical constraints as in Fig. 1b,c. Models with positive (negative) values of μ are shown by a dark plus (light cross). Where these overlap, just the dark pluses are visible. The dashed line shows the lower boundary of the region with light crosses. To expand the width of the band in which all the models lie, we have broken the scale into two. The upper band shows Δ for negative values of δm^2 shown on the upper scale, while the lower band shows Δ (vertical scale on the right) for positive values of δm^2 (lower scale). The horizontal lines show the limits on Δ within the mSUGRA framework. Frame (b) shows the same scatter plot as in frame (a), except that the chargino mass is also required to lie between 150 GeV and 160 GeV. The solid lines show the boundaries of the band in frame (a) above while the dashed line shows the boundary of the new region with $\mu < 0$.

1% measurement of masses
⇒ Model distinguishable from mSUGRA if $|\delta\Delta| \gtrsim 4000\,\mathrm{GeV}^2$

Gaugino Mediation SU(5) model with $M_c \sim M_{Pl}/10$ distinguishable from mSUGRA with 1% mass Measurements (on edge)

SO(10) model with $M_D \sim \frac{1}{5} m_0$ readily distinguishable

Measurement of Δ or Δ' allows determination of δm^2 to $\pm 2500 \text{GeV}^2$ (depends on exact masses)

DIRECT PROBE OF GUT Scale non-universality.

HOW WELL CAN WE DETERMINE $m(\tilde{\nu}_\tau)$ at A LINEAR COLLIDER?

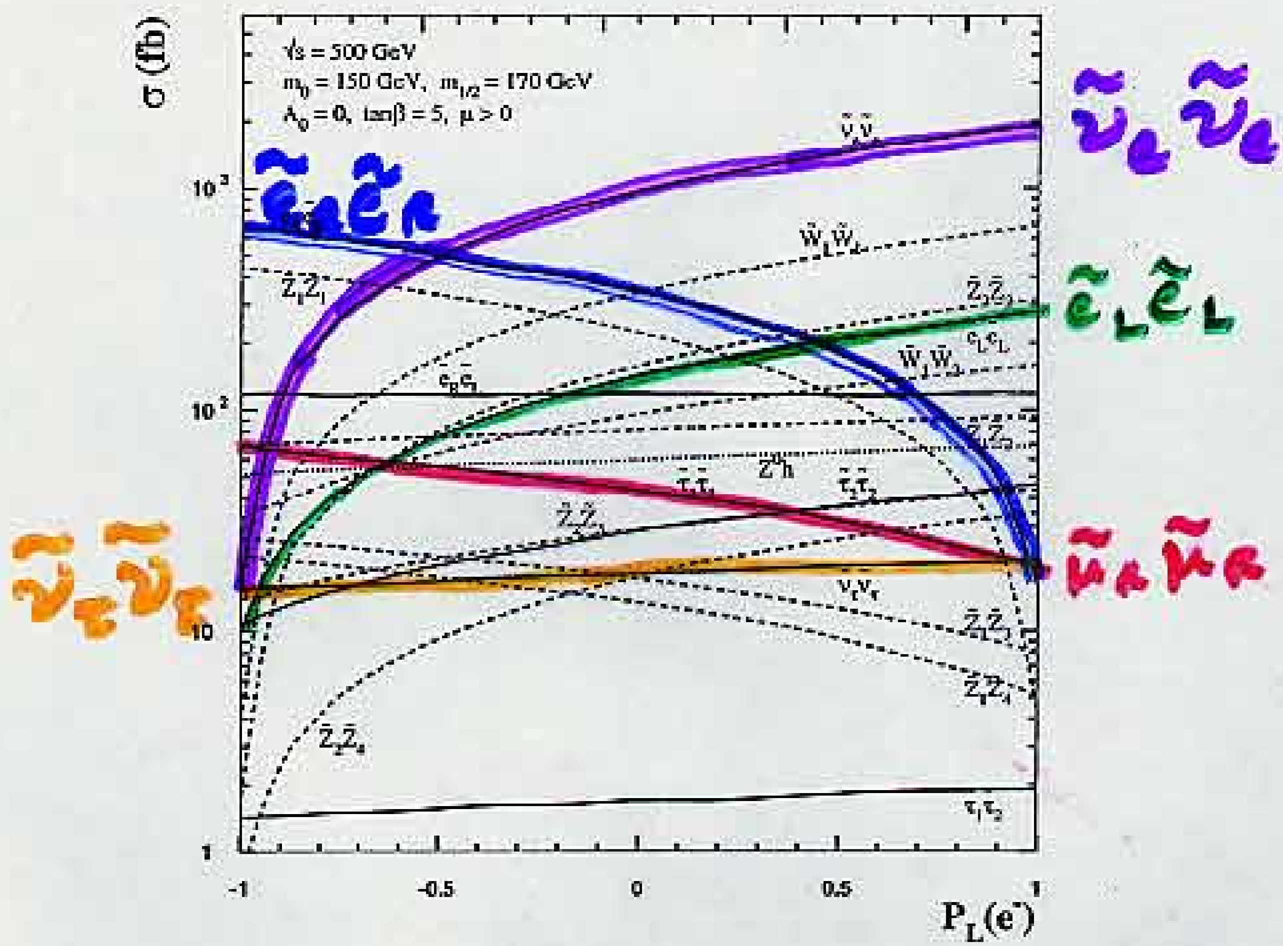


FIG. 6. Cross sections for various SUSY production processes at an e^+e^- collider with $\sqrt{s} = 500$ GeV versus the electron beam polarization parameter $P_L(e^-)$ for the case study in Sec. III. The solid lines show cross sections for sleptons, the dashed lines for charginos and neutralinos and the dotted lines for Higgs boson production mechanisms. The cross sections for Ah and ZH production are below the 1 fb level.

$\tilde{\nu}_\tau$ MASS MEASUREMENT

Following earlier strategy for $m_{\tilde{\nu}_e}$ determination

$$e^+ e^- \to \tilde{\nu}_\tau \; \tilde{\nu}_\tau$$

$\tilde{\nu}_\tau \to \tau \tilde{W}$, $\tilde{W} \to \ell \nu \tilde{Z}_1$

$\tilde{\nu}_\tau \to \tau \tilde{W}_1$, $\tilde{W}_1 \to j j \tilde{Z}_1$

$\tau \tau \ \ell j j + \not{E}_T$ final state

τ = "narrow jet" with 1-3 charged prongs

"E_τ" spectrum yields information about $m_{\tilde{\nu}_\tau}$

STRATEGY FAILS !

- $\sigma(\tilde{\nu}_e \bar{\tilde{\nu}}_e) \gg \sigma(\tilde{\nu}_\tau \bar{\tilde{\nu}}_\tau)$ $O(100)$

- $\tau \to$ hadrons costs $4/9$

- Only part of τ is visible. Upper end of E_τ distribution smeared down.
  Need E_τ^{min} cut, causes different $m_{\tilde{\nu}_\tau}$ distributions for $E > E_\tau^{min}$ to resemble one another

- SUSY Backgrounds which were insignificant for $\tilde{\nu}_e$ now matter!

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Hep/ph/9910416

Also TESLA TDR V. III

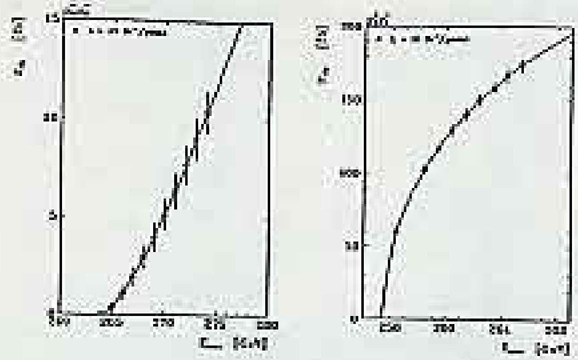


Figure 4: Visible cross sections near threshold of the reactions $e^-_R e^+_L \to \tilde{\mu}_R \tilde{\mu}_R$ (left) and $e^-_L e^+_R \to \tilde{\chi}^-_1 \tilde{\chi}^+_1$ (right). Measurements assume $\mathcal{L} = 10\ \mathrm{fb}^{-1}$ per point.

Threshold scans Further improvement on sparticle masses may be achieved through threshold scans. Such measurements are relatively simple, they essentially

Table 1: Expected precision on mass determinations using polarized e^- and e^+ beams: δm_{cont} from decay kinematics measured in the continuum ($\mathcal{L}_{cont} = 160(250)\ fb^{-1}$ at $\sqrt{s} = 320(500)$ GeV) and δm_{scan} from threshold scans ($\mathcal{L}_{scan} = 100\ fb^{-1}$). The last column indicates the sensitivity to SUSY parameters.

particle	mass [GeV]	δm_{cont} [GeV]	δm_{scan} [GeV]	SUSY parameters
$\tilde{\mu}_R$	132.0	0.3	0.09	$\Rightarrow m_0,\ m_{1/2},\ \tan\beta$
$\tilde{\mu}_L$	176.0	0.3	0.4	
$\tilde{\nu}_\mu$	160.6	0.2	0.8	
$\tilde{e}_R$	132.0	0.2	0.05	
$\tilde{e}_L$	176.0	0.2	0.18	
$\tilde{\nu}_e$	160.6	0.1	0.07	
$\tilde{\tau}_1$	131.0		0.6	
$\tilde{\tau}_2$	177.0		0.6	$\Rightarrow m_0,\ m_{1/2},\ \mu,\ \tan\beta$
$\tilde{\nu}_\tau$	160.6		0.6	
$\tilde{\chi}^\pm_1$	127.7	0.2	0.04	$\Rightarrow M_2,\ \mu,\ \tan\beta$
$\tilde{\chi}^\pm_2$	345.8		0.25	
$\tilde{\chi}^0_1$	71.9	0.1	0.05	$\Rightarrow M_1,\ M_2,\ \mu,\ \tan\beta$
$\tilde{\chi}^0_2$	130.3	0.3	0.07	
$\tilde{\chi}^0_3$	319.8		0.30	
$\tilde{\chi}^0_4$	348.2		0.52	

$\delta m_{\tilde{\nu}_e} = 70$ MeV .04%

$\delta m_{\tilde{\nu}_\tau} = 600$ MeV .4% Scaling

Vertexing helps to keep $\tau \to \ell$ decays!

We did two case studies to understand what happened.

Case I : TESLA

$m_0 = 100\,\text{GeV}$, $m_{\frac{1}{2}} = 200\,\text{GeV}$, $\tan\beta = 3$,

$A_0 = 0$, $\mu > 0$;

$B(\tilde{\nu}_\tau \tilde{\nu}_\tau \to \tau \tilde{W}_1 + \tau \tilde{W}_1 \to \tau\tau\ell jj)$

$= 4.4\%$

Case II : RHN paper case

$m_0 = 150\,\text{GeV}$, $m_{\frac{1}{2}} = 170\,\text{GeV}$

$\tan\beta = 5$, $A_0 = 0$, $\mu > 0$;

$B = 9.7\%$

$\tilde{e}_L\tilde{e}_L$ ↳ $e\tilde{W}_1$ ↳ $q\bar{q}\tilde{Z}_1$

↳ $e\tilde{W}_1$

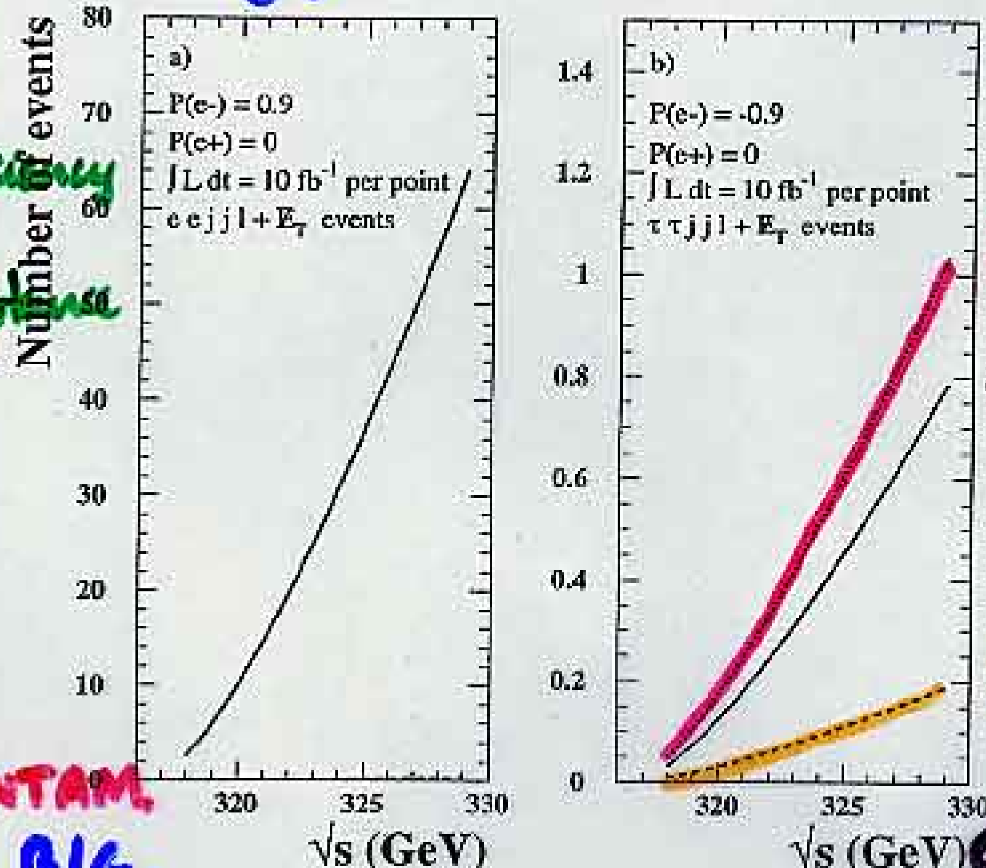
↳ $\ell\nu\tilde{Z}_1$

eejjℓ

NO RATE! ☹

100% efficiency

No acceptance cuts.



$\tilde{\nu}_\tau\tilde{\nu}_\tau$

$\tilde{\nu}_e\tilde{\nu}_e$

$\tilde{\nu}_\mu\tilde{\nu}_\mu$

TINY SUSY CONTAM.

NO SM BG.

SUSY CONTAM. ~O(1)

FIG. 3. Event rate at the threshold for the Case I. In a) the number of $eejj\ell$ events with 10 fb^{-1} per scanned energy with $P_L(e^-) = 0.9$. In b) for $\tau\tau jj\ell$ with the electron polarization flipped.

TESLA STRATEGY CANNOT WORK
(at least if limited to this channel)

Problem 2 With "Counting" Expt:

Cross Section is a function of <u>mass</u> as well as <u>branching ratio</u> into a particular channel.

Smaller event rate could be due to a larger mass **OR** a smaller branching ratio

$\Downarrow$

In a fit @ threshold over all normalization has to be "free"

Example : Case I

Even for $\sqrt{s} = 390$ GeV (Quite far from threshold)

$\sigma_{\tilde{\nu}_e \tilde{\nu}_e}$ reduces by 5% if $m_{\tilde{\chi}}$ is up by 1 GeV.

So counts are the same if branching ratio is 4.5% instead of 4.3%!

$\Delta\chi^2 = 4.6$

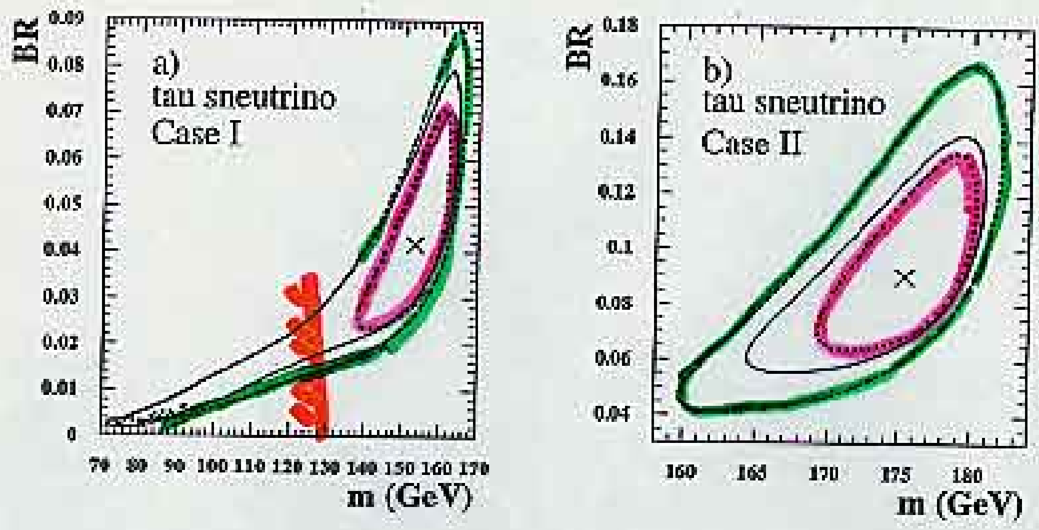


FIG. 10. 90% CL contour plot for a fixed 6 events per point (for the input theory) at lower energies, with $N = 3$, $\mathcal{L}_{low} = 400$ fb^{-1}, $\mathcal{L}_0 = 100$ fb^{-1}, and $\Delta = 60$ GeV. In both frames the solid (dashed) line stands for limits with (without) SUSY backgrounds, and the dotted line is the case with an integrated luminosity 3/2 higher and no backgrounds. The cross inside ellipsis represents the best fitted point. In a) the result for the Case I, with $D = 42$ (30) GeV for the solid and dashed (dotted), and b) the Case II, with $D = 23$ (18) GeV for the solid and dashed (dotted) line.

$$\frac{\Delta m_{\tilde{\nu}_\tau}}{m_{\tilde{\nu}_\tau}} = \frac{\pm 11 \ (8) \text{ GeV}}{176 \text{ GeV}}$$

Case II

$D_{min} = 2$ GeV $m_{\tilde{\nu}_e}$ measurement

Fixed # of evts per low Energy pt.

Fixed Lumi. per low Energy point

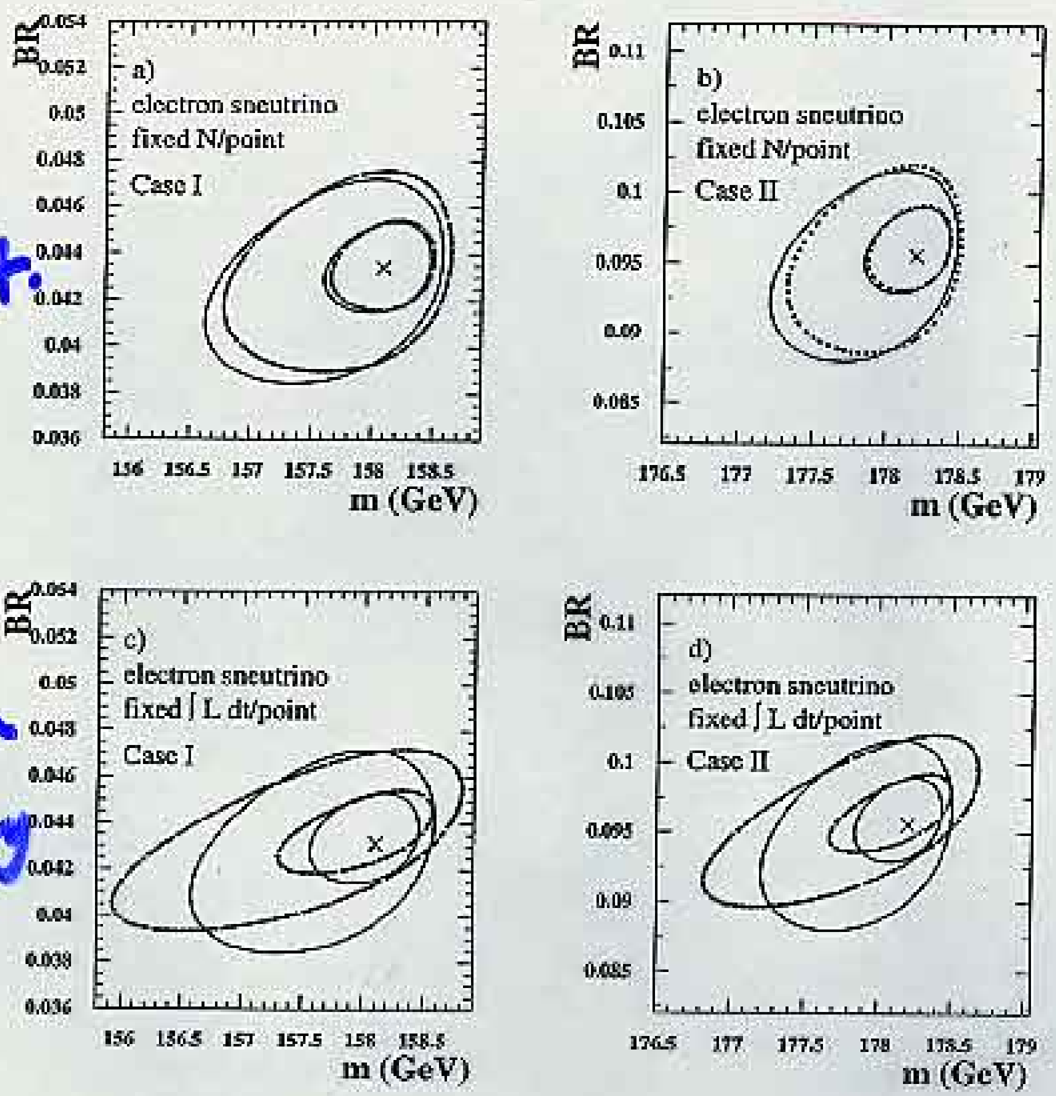


FIG. 14. 90% CL ($\Delta\chi^2 = 4.6$) contours in the $m(\tilde{\nu}_e) - BR$ plane, with $N = 3$ and a minimum of six signal events for each energy point after reconstruction efficiency, beamstrahlung and ISR for Case I (first column) and Case II (second column). The solid (dotted) contours correspond to $\Delta = 1$ GeV (30 GeV). The inner (outer) ellipses correspond to a total integrated luminosity of $500\,\mathrm{fb}^{-1}$ ($120\,\mathrm{fb}^{-1}$) of which $100\,\mathrm{fb}^{-1}$ ($20\,\mathrm{fb}^{-1}$) is at $\sqrt{s} = 500$ GeV. In the first row, the luminosity is distributed so that there are an equal number of events at each of the three low energy points, while in the second row the luminosity is equally shared between the three points. The cross shows the best fit for the $\Delta = 1$ GeV scan with $500\,\mathrm{fb}^{-1}$.

TABLE VI. A summary of our projections for sneutrino mass measurements (90% CL) [illegible] and Case II, assuming a 95% longitudinally polarized beam. For especially $\tilde{\nu}_\tau$, a significant mass measurement does not appear to be possible with 100 fb^{-1}. For each of $m(\tilde{\nu}_\tau)$ and $m(\tilde{\nu}_\mu)$, the first row shows our projection with backgrounds and SUSY contamination as discussed in the text, while the next one shows the corresponding projection if these backgrounds can be effectively eliminated without loss of signal. For $\tilde{\nu}_e$, both SM background and SUSY contamination are insignificant.

	Case I	Case II
$m(\tilde{\nu}_\tau)$ (500 fb^{-1})	$153^{+12.5}_{-24}$ GeV	$174.9^{+7.1}_{-15.4}$ GeV
	$153^{+11.5}_{-24}$ GeV	$175.4^{+5.6}_{-10.9}$ GeV
$m(\tilde{\nu}_\mu)$ (500 fb^{-1})	$156.4^{+4.2}_{-7.9}$ GeV	$175.7^{+3.9}_{-4.6}$ GeV
	$156.4^{+4.1}_{-7.4}$ GeV	$176.4^{+3.3}_{-5.2}$ GeV
$m(\tilde{\nu}_e)$ (120 fb^{-1}) *	$157.8^{+0.8}_{-1.2}$ GeV	$178.0^{+0.5}_{-0.8}$ GeV
$m(\tilde{\nu}_e)$ (500 fb^{-1}) *	$158.1^{+0.4}_{-0.5}$ GeV	$178.2^{+0.2}_{-0.4}$ GeV

* Improvement by combining other channels possible

How much depends on whether $\tilde{\nu}_e \tilde{\nu}_e$ threshold is above/below $2m_{\tilde{e}}$

These "crappy" measurements because we are analysing in a <u>model-independent</u> manner.

In a model analysis; e.g. mSUGRA or GMSB or ....

SUSY BACKGROUNDS ARE A SIGNAL

Fit to m_0, $m_{\frac{1}{2}}$ .....

$\boxed{\text{NOT } m_{\tilde{\nu}_e},\ B,}$

- Disovery of SUSY will be the start of our problems

  Establish it is SUSY

  Establish the mediator of SUSY breaking

- Super particles provide a new window to high scale physics

- Tau neutrino couplings do affect stau & $\tilde{\nu}_\tau$ masses - while possibly detectable in some models, does not seem to be the case for the naivest See-saw GUT model of m_ν

- Potential to Exploit the Δ-parameter

MASS MEASUREMENTS FROM THRESHOLD STUDIES

Counting experiments, so depend on branching ratios

Small cross-sections ⇒ few judiciously chosen points

1 Close to threshold

1 nominal energy

~ 2 spaced out in between

Good for "other" things too!