Measuring Mass and Cross Section Parameters at a Focus Point Region

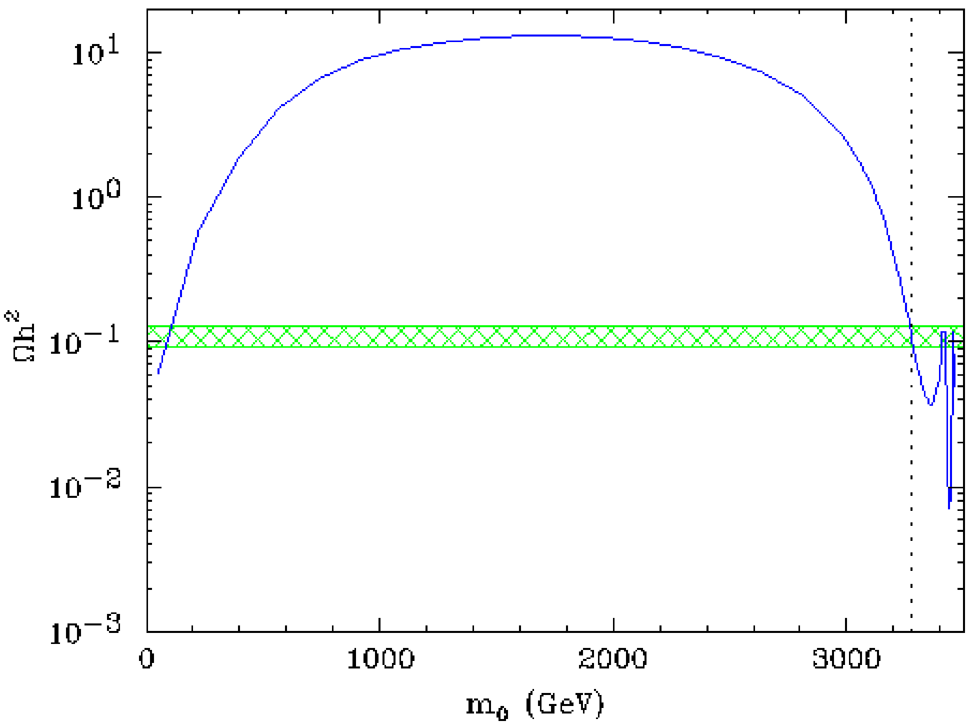
Richard Gray
Cornell University
LCWS 2005

Cornell LC Cosmology Group

Jim Alexander, Karl Ecklund,
Laura Fields, Richard Gray, Dan Hertz,
Chris D. Jones, Surik Mehrabyan, Jim Pivarski
(Cornell University)

Andreas Birkedal, Konstantin Matchev
(University of Florida)

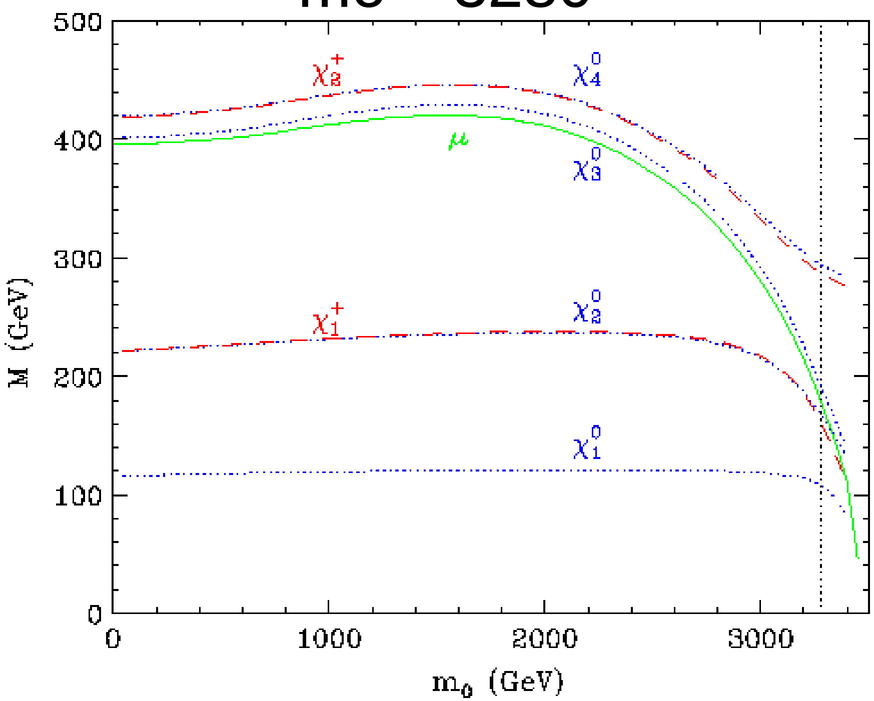
Introduction



- SUSY models have good dark matter candidates.
- But WMAP $\Omega_h h^2$ limits relic densities
- We will study an MSUGRA focus point that is consistent with WMAP

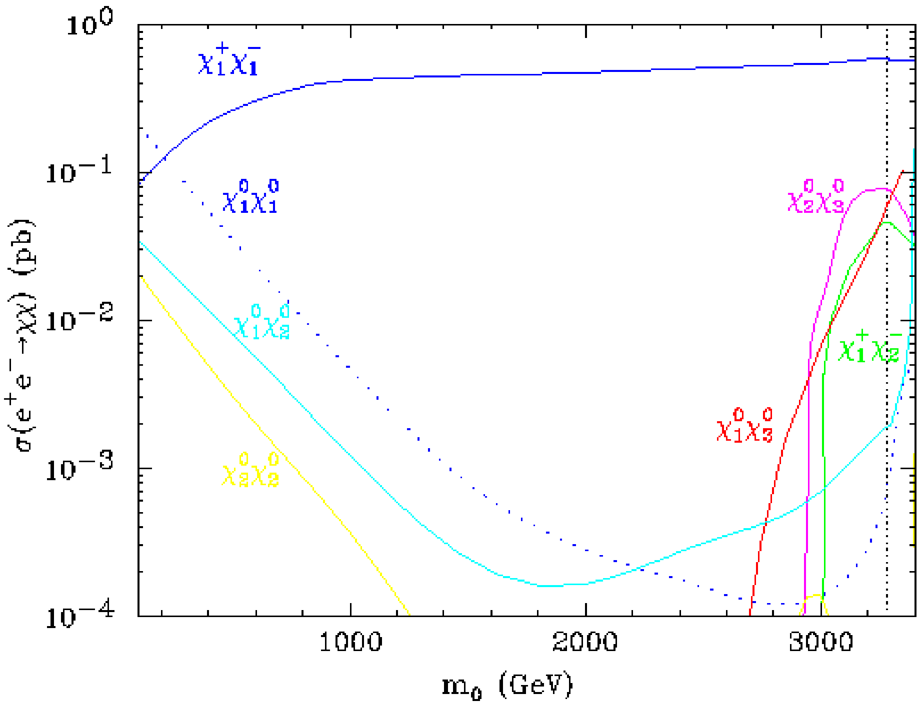
Focus Point "LCC2"

$M_{1/2}$ = 300, A_o =0, tanβ=10, μ>0, m_t = 175GeV, mo =3280



- Scalars are very heavy
- 2 Charginos (χ_i^+) 3 neutralinos (χ_j^0) will be accessible at $s^{½}$ = 500GeV
- χ_1^0 is the LSP and the Dark Matter Candidate

Pair Production Cross Sections



We expect Signals from the following Neutralino/Chargino Pairs.

- $\chi_1^+ \ \chi_1^-$
- $\chi_1^+ \chi_2^-$
- $\chi_1^0\chi_3^0$
- $\chi_2^0 \ \chi_3^0$

Cross Sections and Masses

Neutralino Mass Parameters (GeV)

- χ_1^0 : -107.7
- χ_2^0 : -166.3
- χ_3^0 : +190.0
- χ_1^+ : -159.4
- χ_2^- : -286.6

Pair	σ_L(fb)	σ_R (fb)
$\chi_1^+\chi_1^-$	940	119
$\chi_1^+\chi_2^-$	48.9	40.3
$\chi_1^0\chi_3^0$	56.8	44.1
$\chi_2^0\chi_3^0$	92.4	70.9

SUSY Decay Signatures

- $\chi_1^+ \chi_1^-$: $4J+E_{miss}$, $2J+1L+E_{miss}$
- $\chi_1^+ \chi_2^-$: $6J+E_{miss}$, $4J+2L+E_{miss}$
- $\chi_1^0 \chi_3^0$: $2J+E_{miss}$, $2L+E_{miss}$
- $\chi_2^0 \chi_3^0$: $4J+E_{miss}$, $4L+E_{miss}$, $2L+2J+E_{miss}$

Note that the number of jets could be increased by radiated gluons

Analysis Goals

- Determine expected uncertainties in cross section measurements.
- Determine uncertainties in measuring mass differences with di-lepton or di-jet invariant mass distributions
- Measure relative sign (phase) of mass parameters
- Determine mass of LSP using di-lepton or di-jet energy distributions

Monte Carlo Samples

SUSY

- Generated at Cornell by Karl Ecklund
- Isajet 7.69
- Includes : $\chi_1^+ \chi_1^-$, $\chi_1^+ \chi_2^-$, $\chi_1^0\chi_3^0$, $\chi_2^0\chi_3^0$

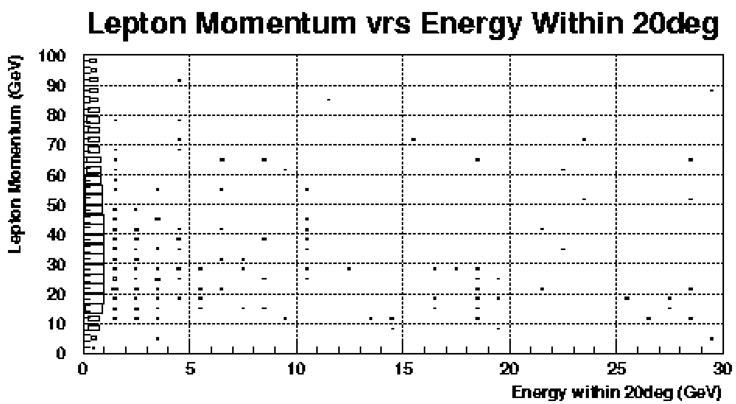
SM Backgrounds

- Generated at SLAC by Tim Barklow
- WHiZaRD 1.22
- Includes daughters from: e^+e^-, $e^-\gamma$, γe^+, $\gamma\gamma$; such as ttbar, W^+W^-, Zpair

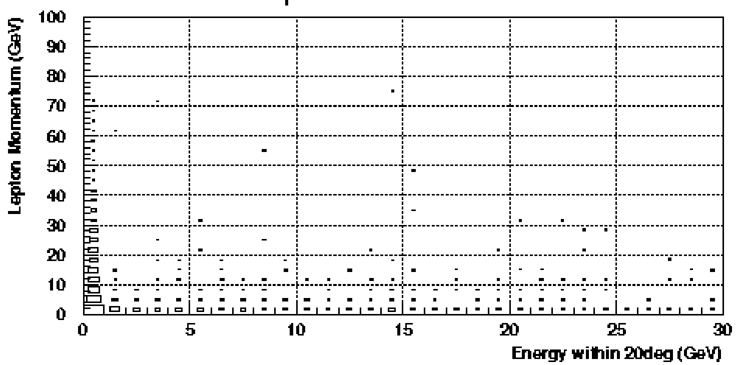
Monte Carlo (cont)

- Both SUSY and SM include Brems/Beamstrahlung (SUSY uses Isajet, SM uses CIRCE v1)
- Polarization: electron +/-95%, positron 0%
- Detector simulation done by LCD Root Fast MC, SD Mar01 (root based SLAC software)

Analysis: Signal Lepton Selection for SUSY Signature



Leptons from Neutralinos



Leptons from Jets

We want Leptons that are isolated from jets.

- Lepton ID uses MC truth
- P_{lepton} > 10GeV
- E20 < 2 GeV; Total energy of other tracks and showers within 20º of lepton should be less than 2GeV

Analysis: Jet Identification

- $y_{cut}=0.004$
- $y_{ij}=2(\min(E_i,E_j))^2(1-\cos(\theta_{ij}))/E_{cm}^2$
- $y_{ij} < y_{cut}$ then jet-like

- Jet finding is done using the Durham Algorithm on all tracks, and unmatched showers, except for leptons identified as signal leptons

MC Truth Jet Matching (Used in B-Tagging)

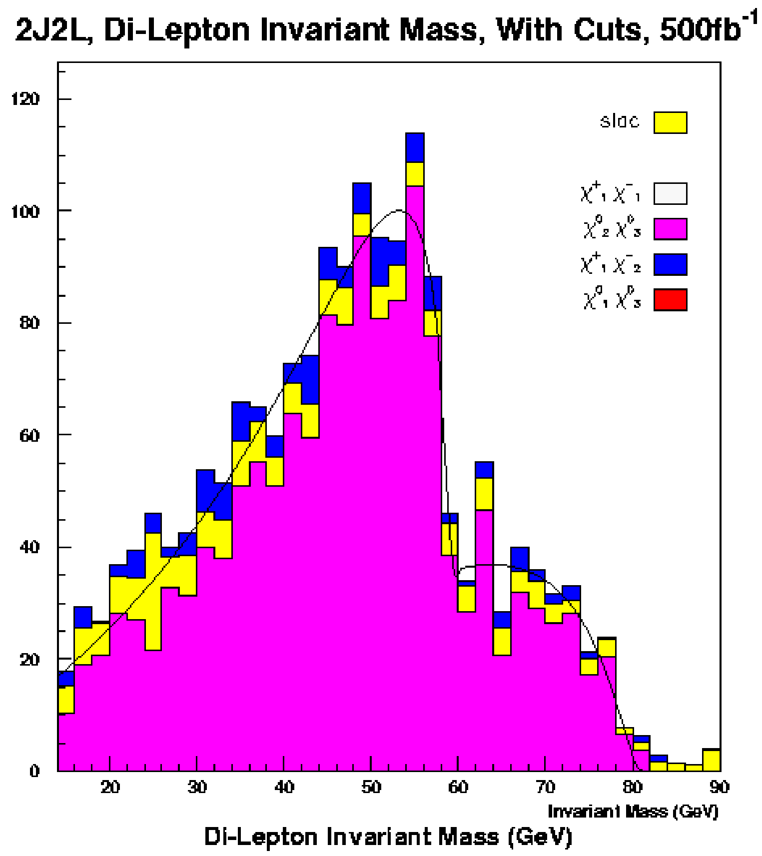
- Best match given by greatest Q_{ij}
- $Q_{ij} = (2E_{iaj} – E_{inj} - E_{jni}) / (E_i + E_j)$
- E_i=Energy in list I
- E_{iaj}=Energy in list I and j
- E_{inj}=Energy in list I but not J
- Q_{ij} = 1 Perfect match
- Q_{ij} = -1 completely different

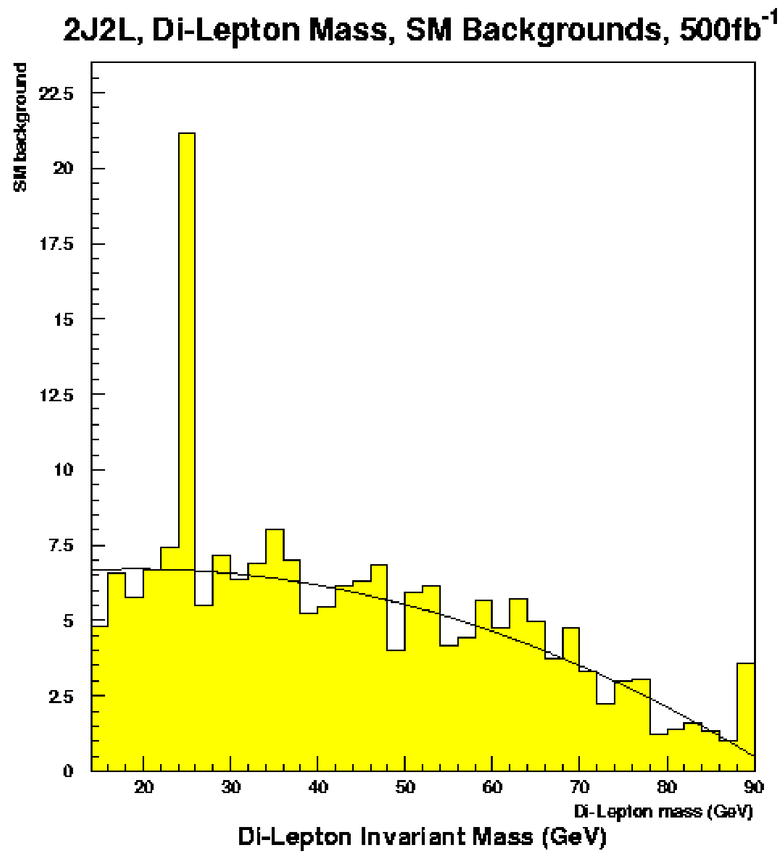
- Not able to do honest B-tag with simulation, so jets found by Durham Algorithm are given best match with MC Truth table, then use expected b-tag efficiency (~50%).

Event Selection: $\chi_2^0\chi_3^0 \rightarrow 2J2L\chi_1^0$

- 2 Isolated Leptons, opposite charge, same flavor
- 2 or 3 jets found. (allows for a gluon jet)
- $E_{miss} > 275$ GeV
- $P_T > 10$ GeV
- $|\cos(\theta)| < 0.95$ (all jets and leptons)
- E(j or L) < 110GeV
- Anti-Btag to remove ttbar backgrounds.

2or3J2L Di-Lepton Invariant Mass Distribution





Analysis of Mass Distribution

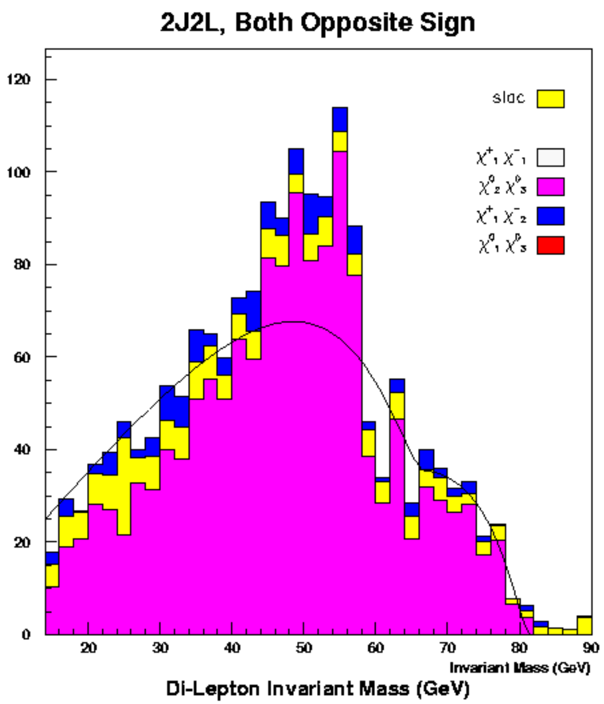
- Small Background
- Mass edges expected at 58.6GeV and 82.3GeV. Visible!
- We have a functional form for the distribution (A. Birkedal)
- The distribution is insensitive to LSP mass
- Expected Cross section uncertainty on σ_L and σ_R are each ~ +/-2.6fb (2.8%, 3.6%)
- Log Likelihood Fit to edges yields:

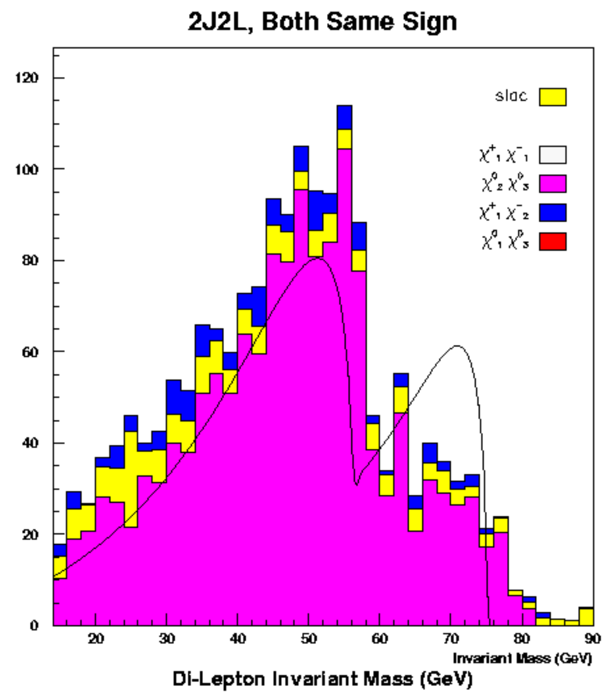
Δm21 = 58.7GeV +0.2GeV –0.1GeV

Δm31 = 82.0GeV +0.4GeV –0.1GeV

- We can also determine relative sign of mass parameters for χ_1^0 χ_2^0 χ_3^0

Determine Relative Sign of $m_{\chi 10}$, $m_{\chi 20}$, $m_{\chi 30}$

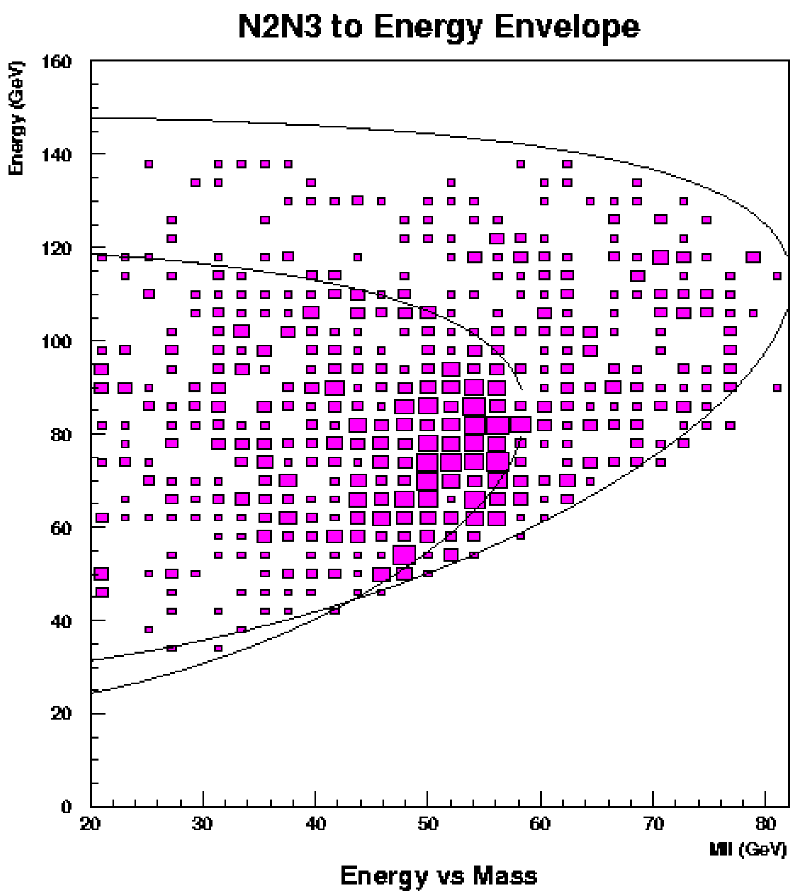




log[like(+m20,-m30)]-log[like(-m20,-m30)] =228   equivalent to 21σ

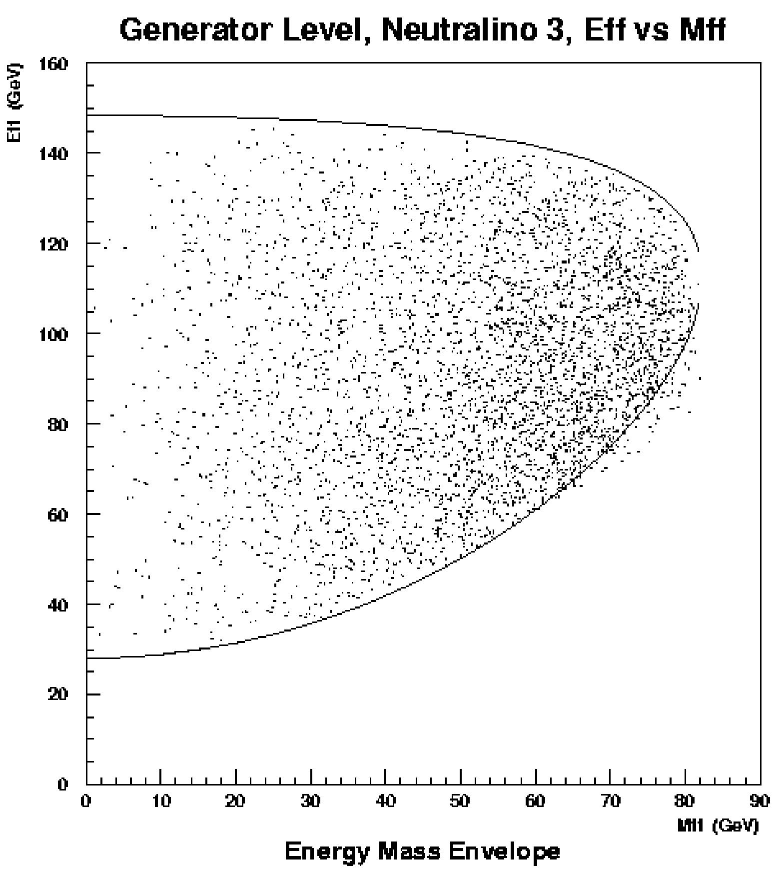
log[like(+m20,-m30)]-log[like(+m20,+m30)] =84.7 equivalent to 13σ

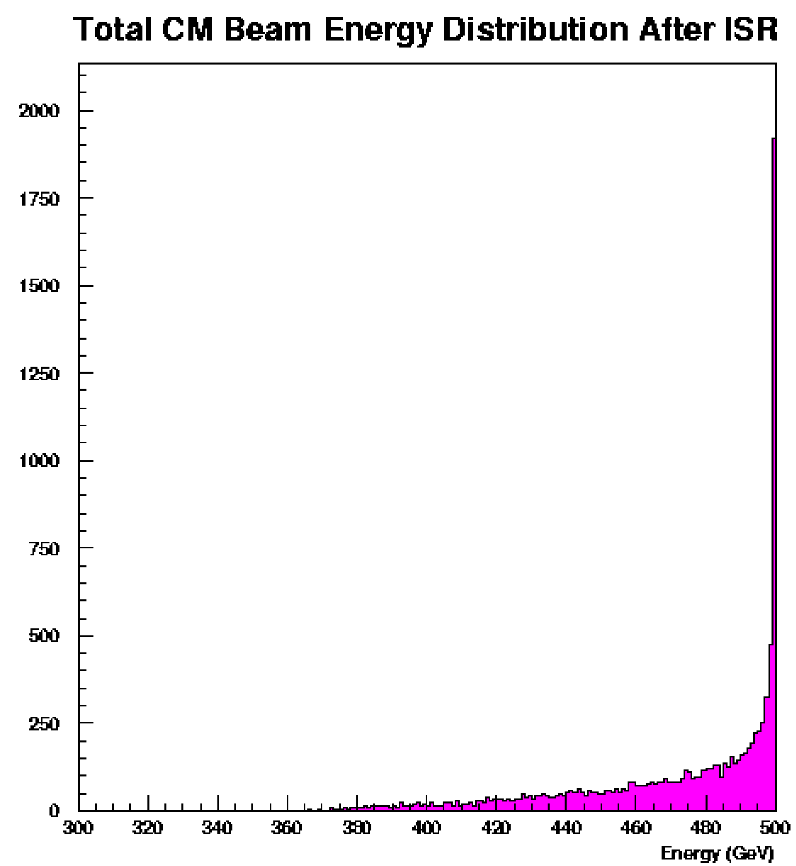
LSP Mass from E(LL) Distribution



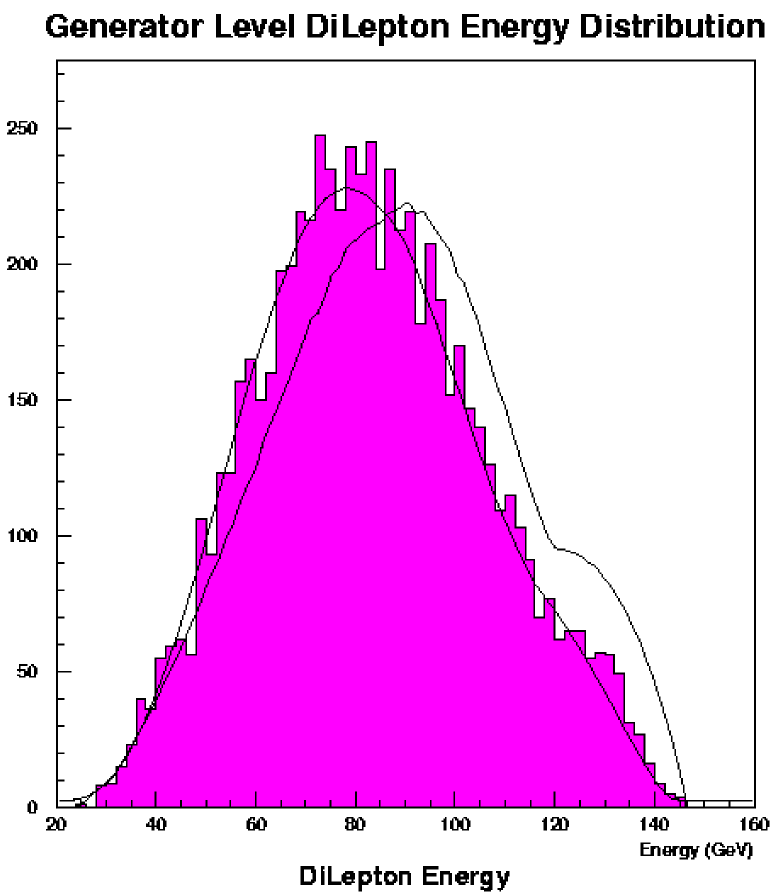
- LSP mass sets boundaries in dilepton energy vs. mass.
- Because of low stats near boundary, will fit to 1-D energy histogram.

Beam/Breamstralung distorts Energy Envelope





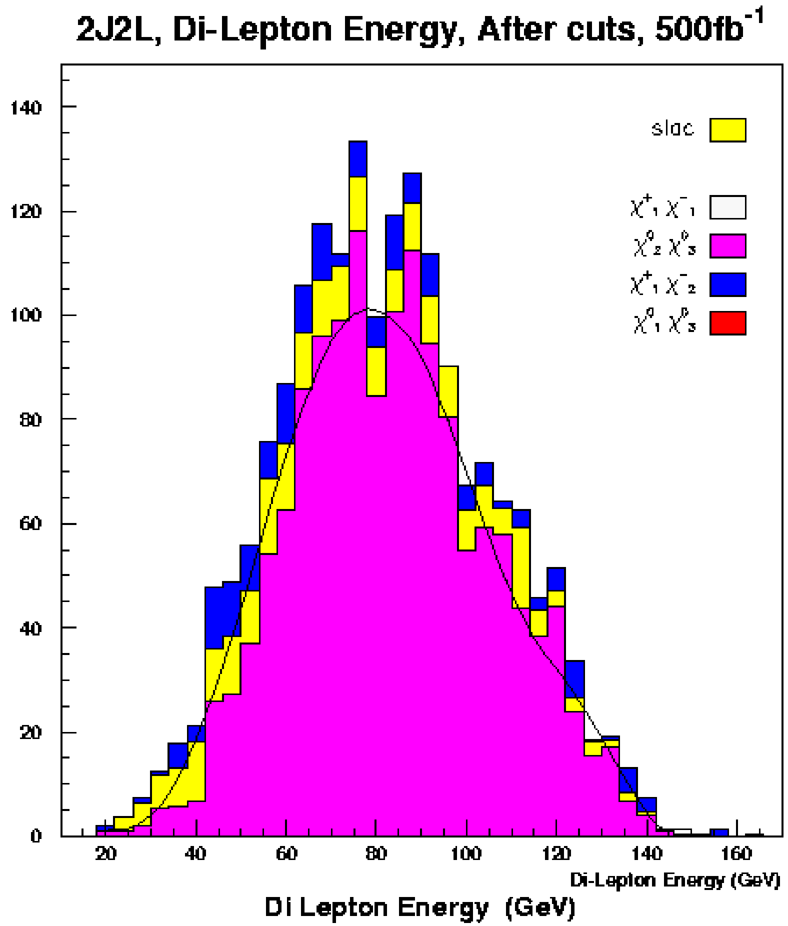
Energy Distribution Numerically Calculated

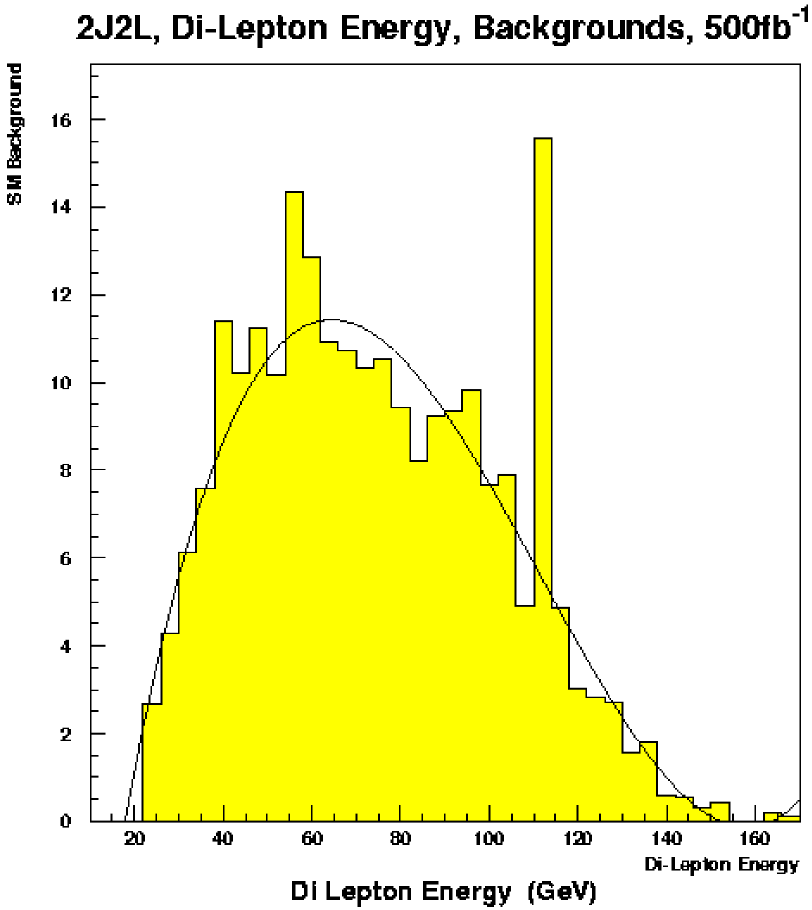


Numerically Integrate

- Isajet ISR spectrum,
- Invariant mass distribution
- Isajet angular distribution (phase space)

E(LL) Distribution





Log Likelihood Fit to E(LL)

- Using edges determined in mass analysis, results of Log Likelihood fit give:

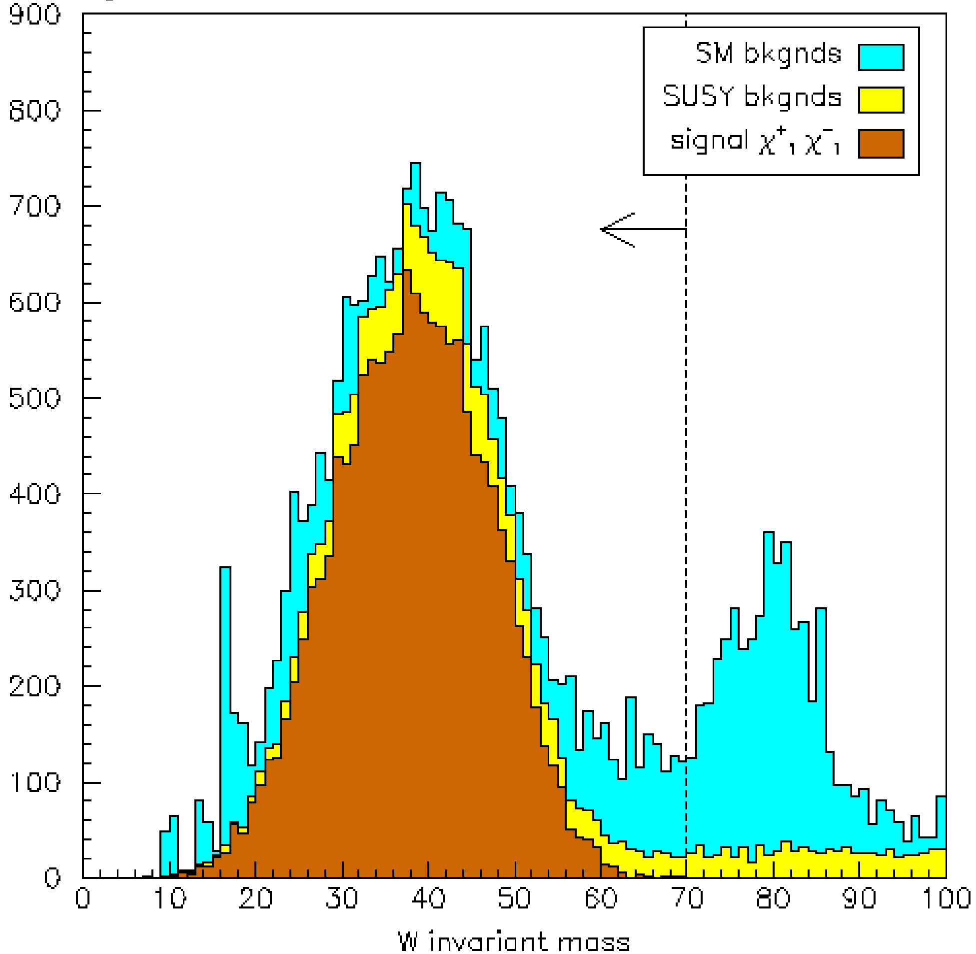
107.5GeV +0.5GeV –1.1 GeV

(true answer 107.7GeV)

Other Modes at Cornell

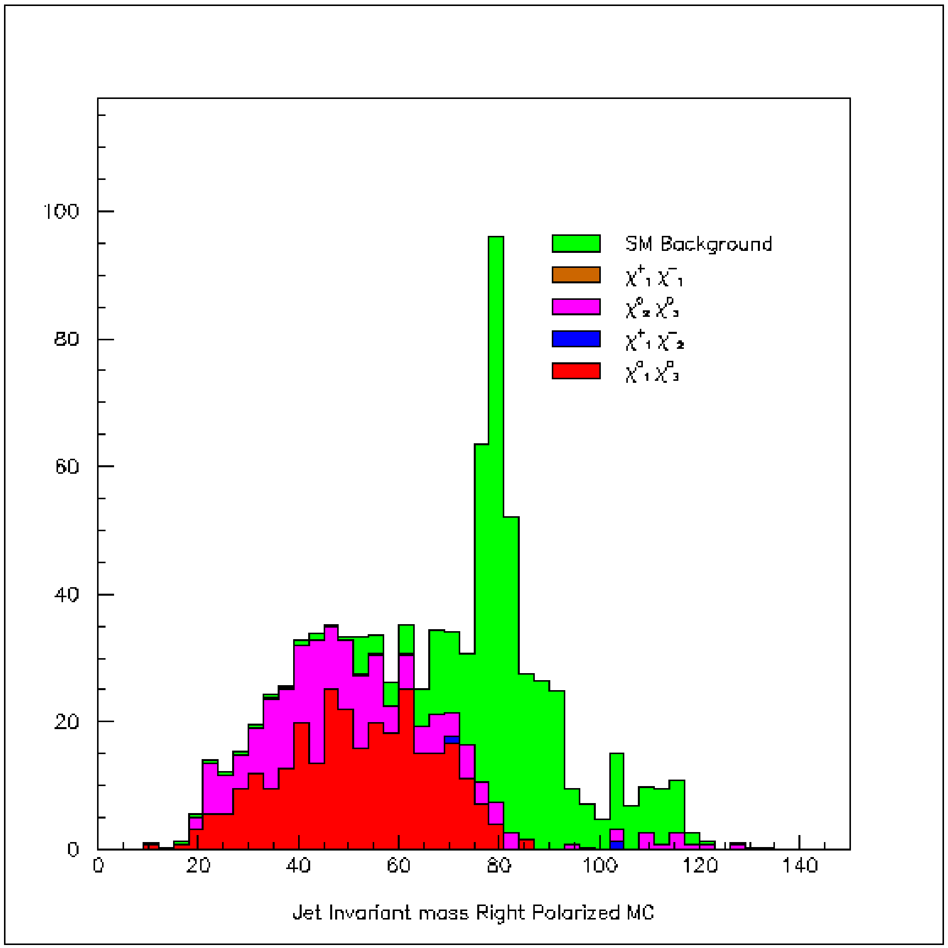
- $e^+e^- \rightarrow \chi_1^+\chi_1^- \rightarrow jjl + E_{miss}$ by Jim Pivarski
- $e^+e^- \rightarrow \chi_1^0\chi_3^0;\ \chi_2^0\chi_3^0 \rightarrow jj + E_{miss}$ by Laura Fields
- $e^+e^- \rightarrow \chi_1^+\chi_2^- \rightarrow 6j + E_{miss};\ \ 4j + 2L + E_{miss}$ by Dan Hertz

$e^+e^- \rightarrow \chi_1^+\chi_1^- \rightarrow jjl + E_{miss}$



- Study by Jim Pivarski
- will determine cross section uncertainty.
- Mass difference measurement should be possible
- Should give a second measure of M_{LSP}

$e^+e^- \rightarrow \chi_1^0\chi_3^0;\ \chi_2^0\chi_3^0 \rightarrow jj+E_{miss}$



- By Laura Fields
- W peak near edge, so no mass measurement
- Cross section of $\chi_1^0\chi_3^0$ depends on $\chi_2^0\chi_3^0$.
- $\chi_1^0\chi_3^0$: $\delta\sigma_L \sim 5fb^{-1}$ $\delta\sigma_R \sim 4fb^{-1}$, or 9%

$e^+e^- \rightarrow \chi_1^+\chi_2^- \rightarrow 6j+E_{miss}$; $4j+2L+E_{miss}$

- By Dan Hertz
- Very Preliminary
- Mode has on shell W and Z emitted during chargino decay.
- There will be too few events for mass edges to be determined. But backgrounds should be small.
- Work to determine uncertainty in cross section measurement in progress.

Conclusions

- Mass differences of χ_2^0 and χ_3^0 with LSP mass can be measured with uncertainties <0.5GeV.
- Mass of LSP can be determined with 2J2L, E(LL) distribution with uncertainty ~ 1GeV.
- Cross sections of $\chi_2^0\chi_3^0$ can be determined with uncertainty ~2.6fb ($\sigma_{\mathbf{L}}$ 2.8%, and $\sigma_{\mathbf{R}}$ to 3.6%)
- Cross sections of $\chi_1^0\chi_3^0$ can be determined with ~9% uncertainty (L. Fields).

Current and Future Tasks

- Complete $\chi_1^+\chi_1^-$ analysis for cross section, χ_1^+ mass difference, and second LSP mass measure (J. Pivarski)
- Complete $\chi_1^+\chi_2^-$ analysis for cross section (D. Hertz)
- Convert these uncertainties into uncertainties in MSUGRA parameters (M_1, M_2, μ, $\tan\beta$), and ultimately $\Omega_{DM}h^2$ (A. Birkedal, K. Matchev)

Special Thanks

- T. Barklow for generating our SM backgrounds.