Presentation at the LCWS 2005 Meeting

The Importance of Positron Polarization and the Deleterious Effects of Beam/Bremmstrahlung on the Measurement of Supersymmetric Particle Masses and other Parameters

March 2005

THE POSITRON POLARIZATION GROUP

CERN-PH-TH/2005-036, DCPT-04-100, IPPP-04-50

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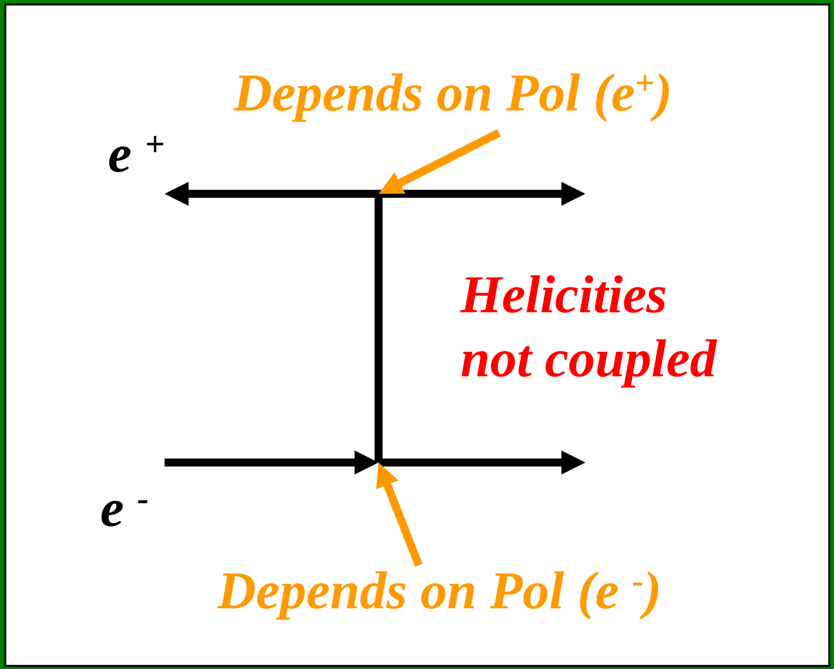
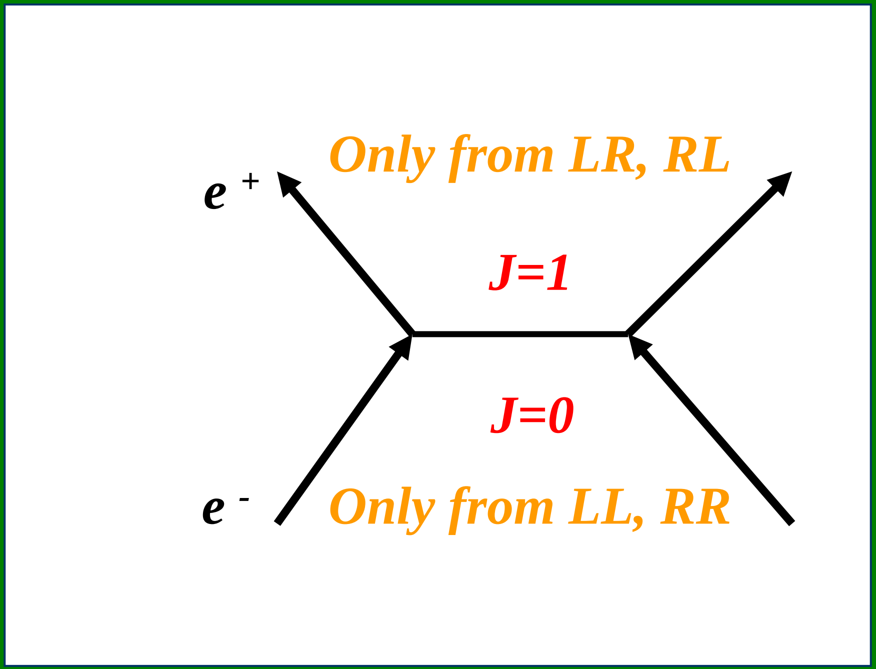
ACTIVITIES

- *The Importance of Positron Polarization in Determining SUSY Masses and other Parameters.*

- *Simulation of Supersymmetry. New method to overcome the negative effects of beamstrahlung and bremmstrahlung.*

Positron Polarization Helps

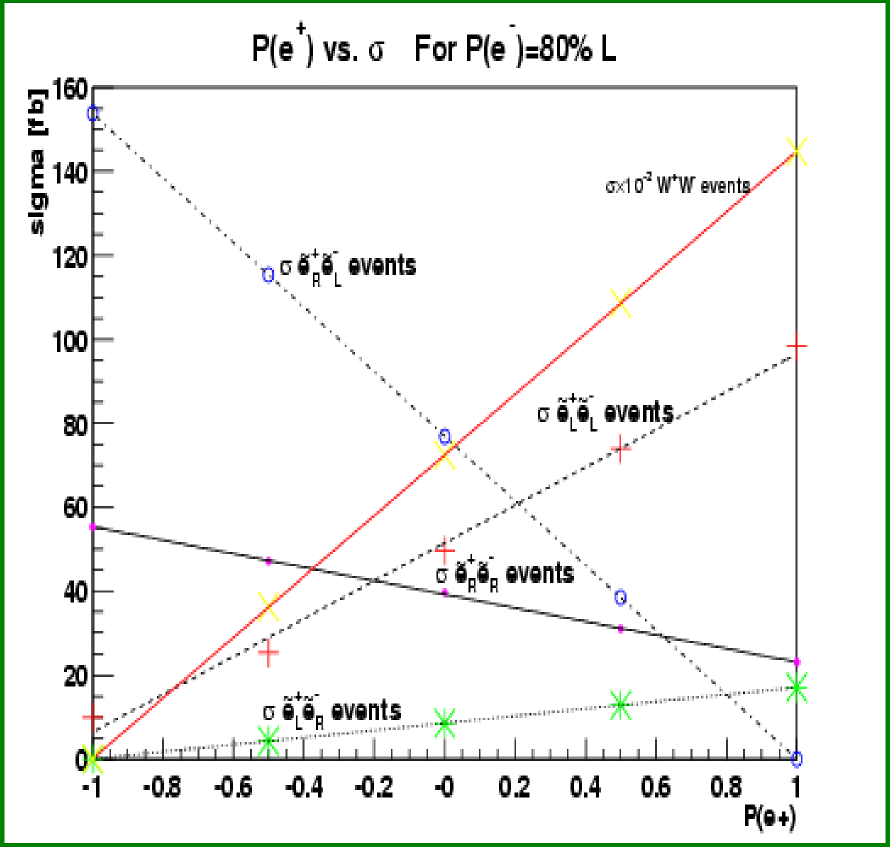




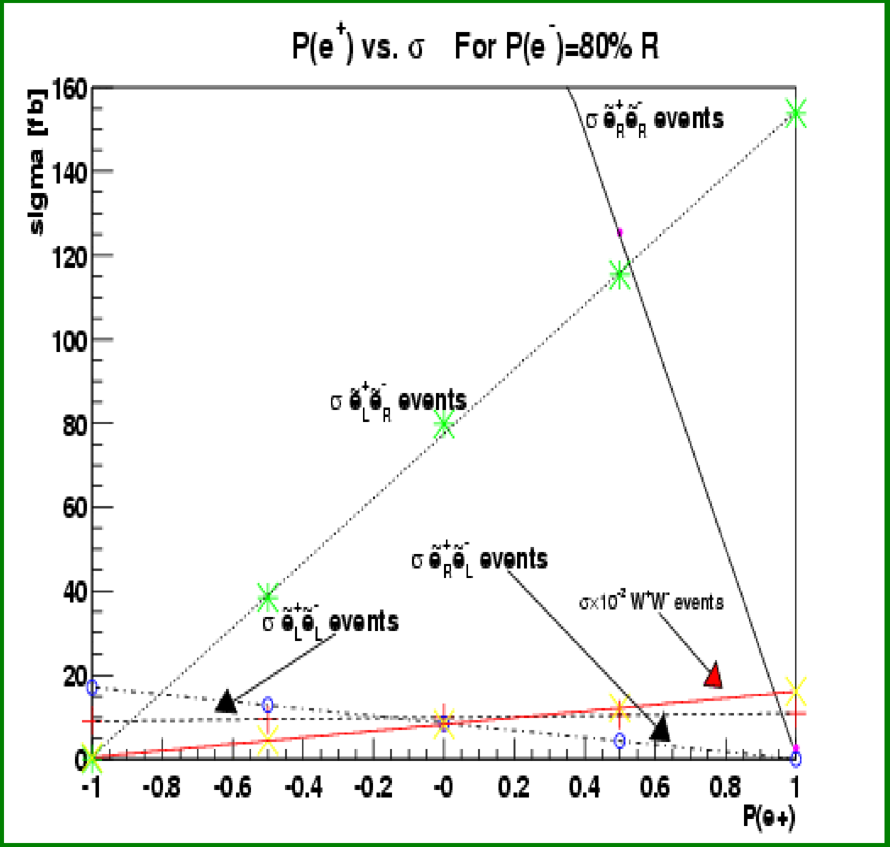
LCD-LCWS

NLC – The Next Linear Collider Project

electron Left Pol 80%

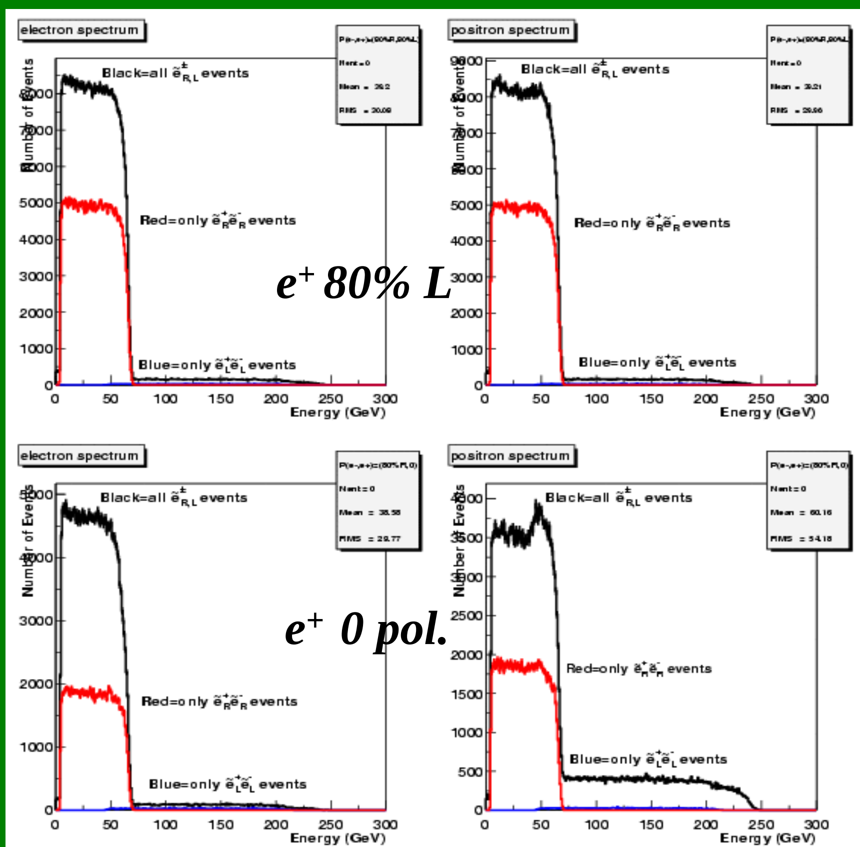


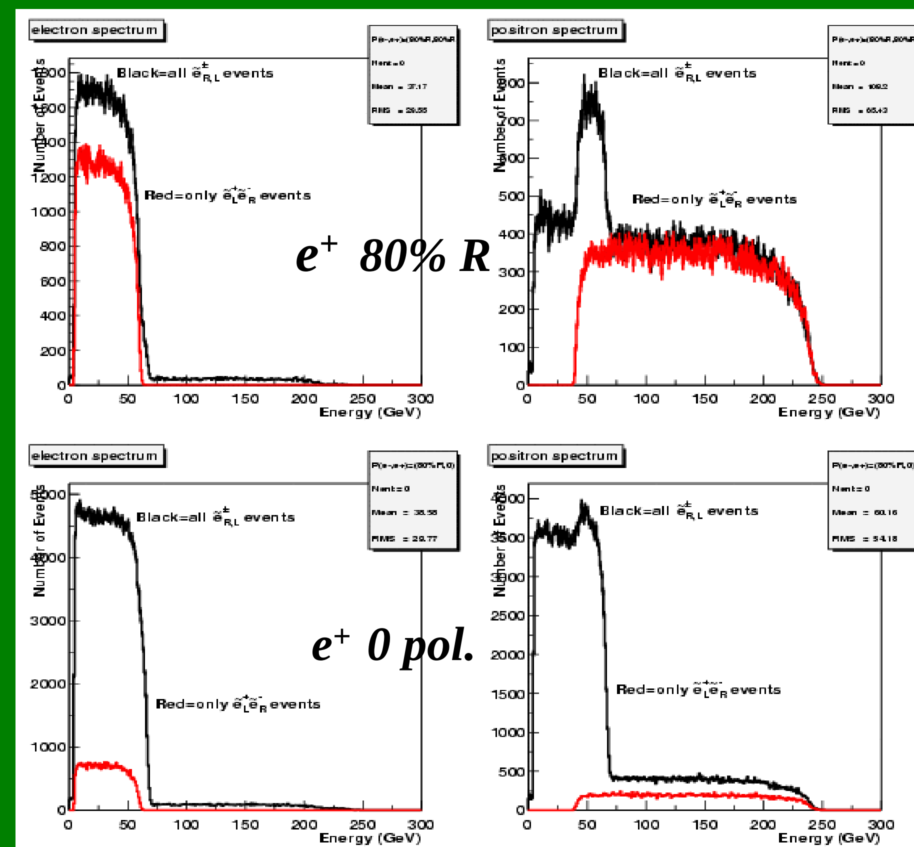
electron Right Pol 80%



Electron, Positron Energy Spectrum from $\tilde{e}^+\tilde{e}^- \to$ all e e

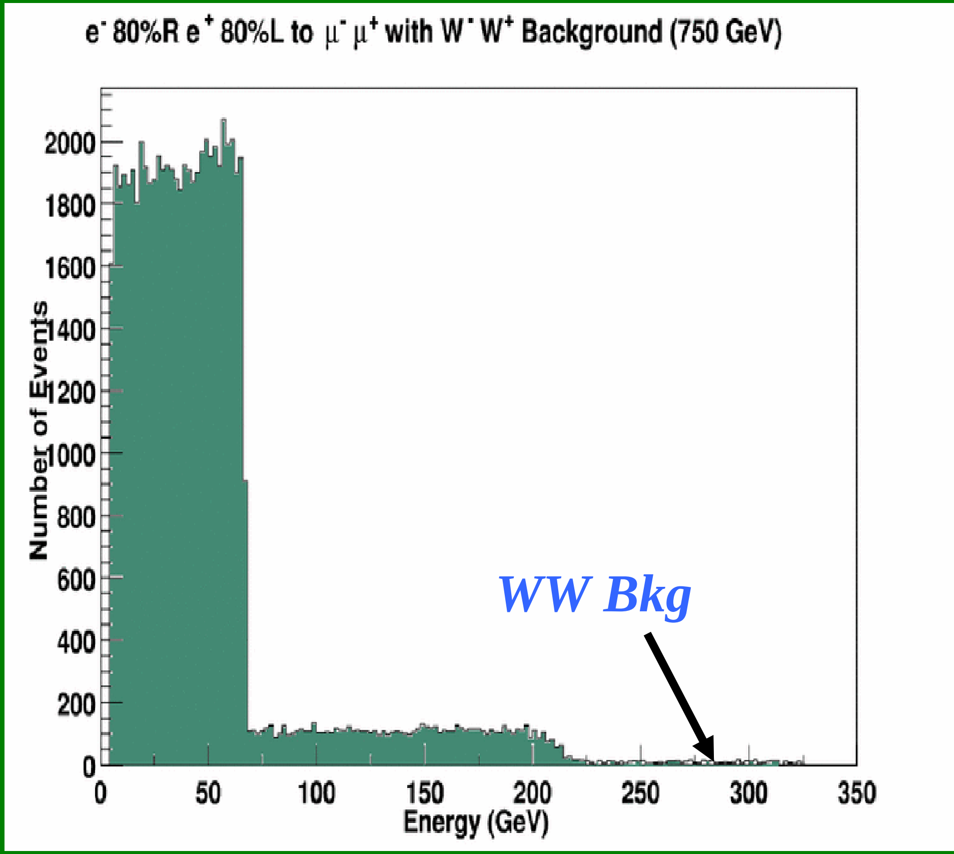
e^- Spect. e^- 80%R e^+ Spect. *e^- Spect. e^- 80%R e^+ Spect.*



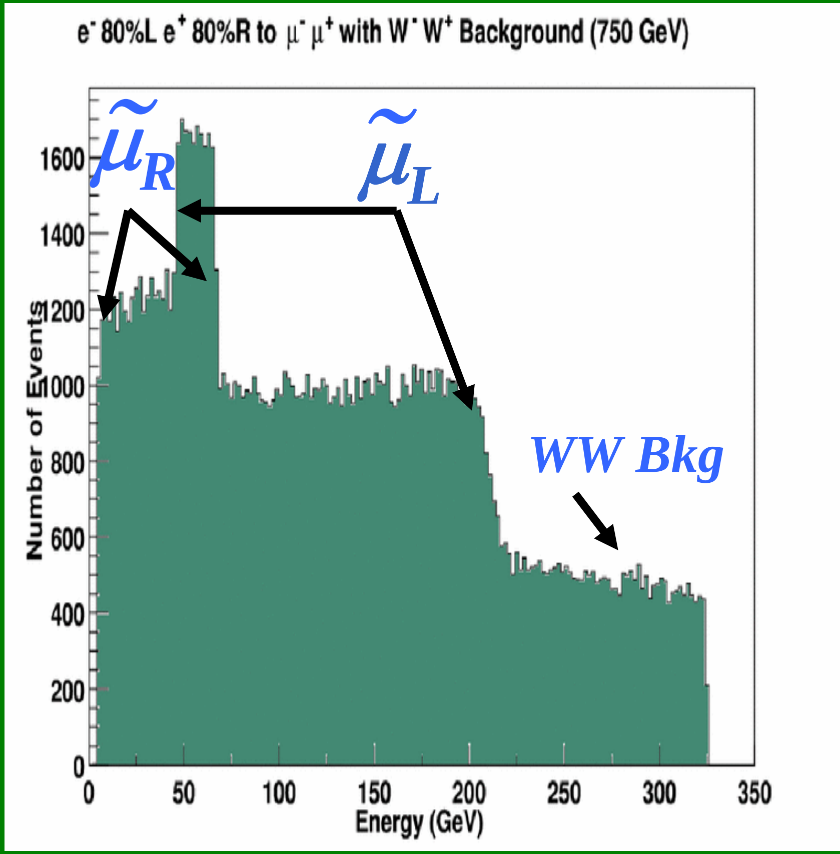


Muon Energy Spectrum from $e^+ e^- \to \tilde{\mu}^+ \tilde{\mu}^-$

e^- 80% R e^+ 80% L



e^- 80% L e^+ 80% R



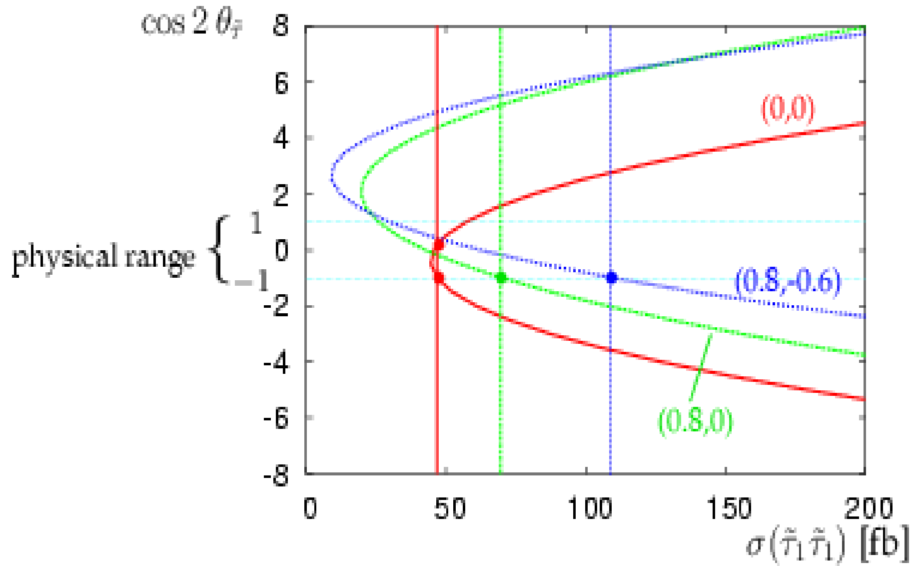
These selectron, smuon signals with various electron and positron polarization are clear evidence for supersymmetry.!!!

These energy distributions can not be produced with Standard Model processes.

Need positron polarization to observe dramatic energy distribution shape variations.

Measurement of the sfermion Mixing Angle ($\theta_{\tilde{f}}$)

Varying the electron and positron polarizations

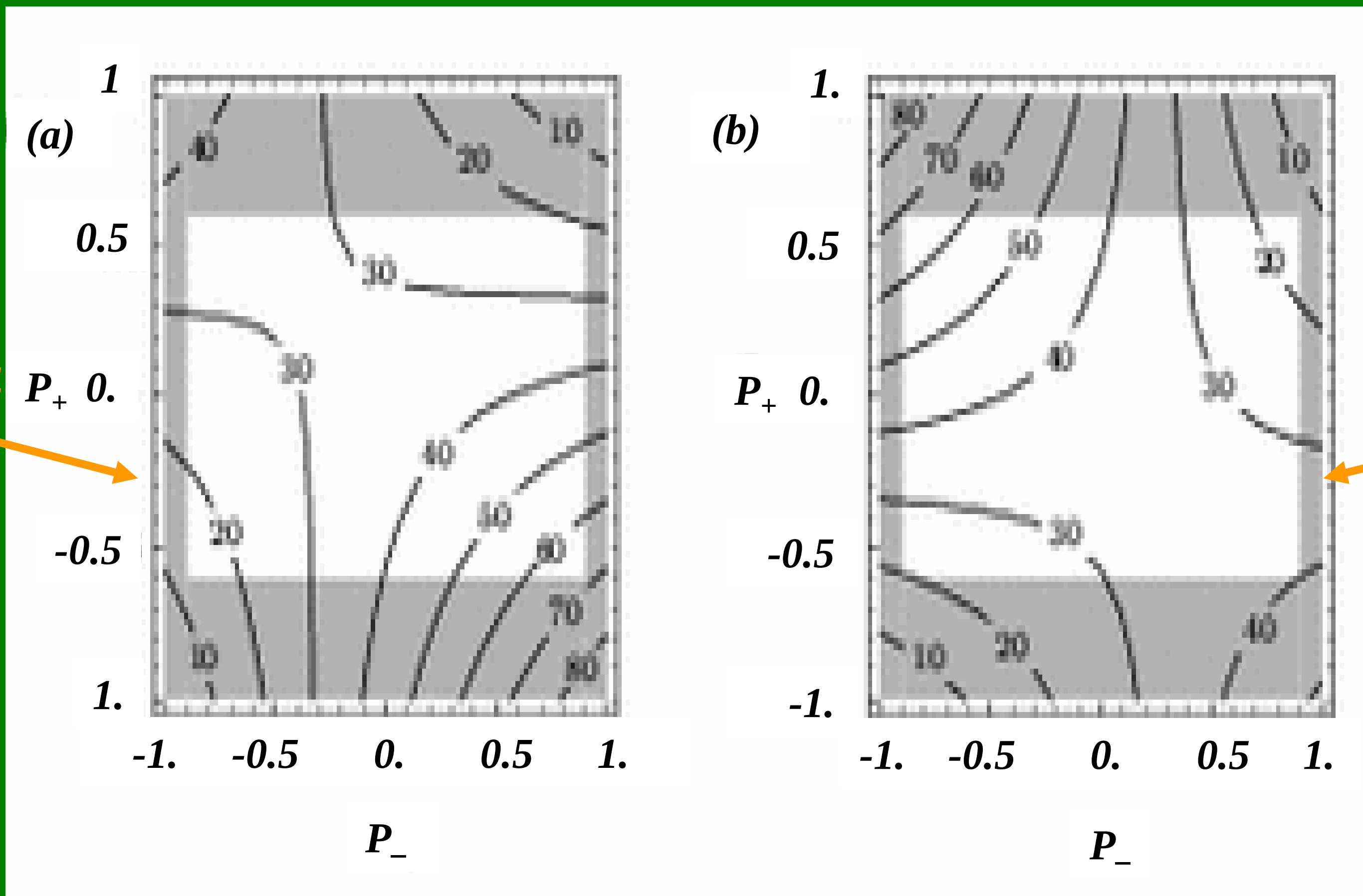


This is one case where removal of the 2 γ process is crucial

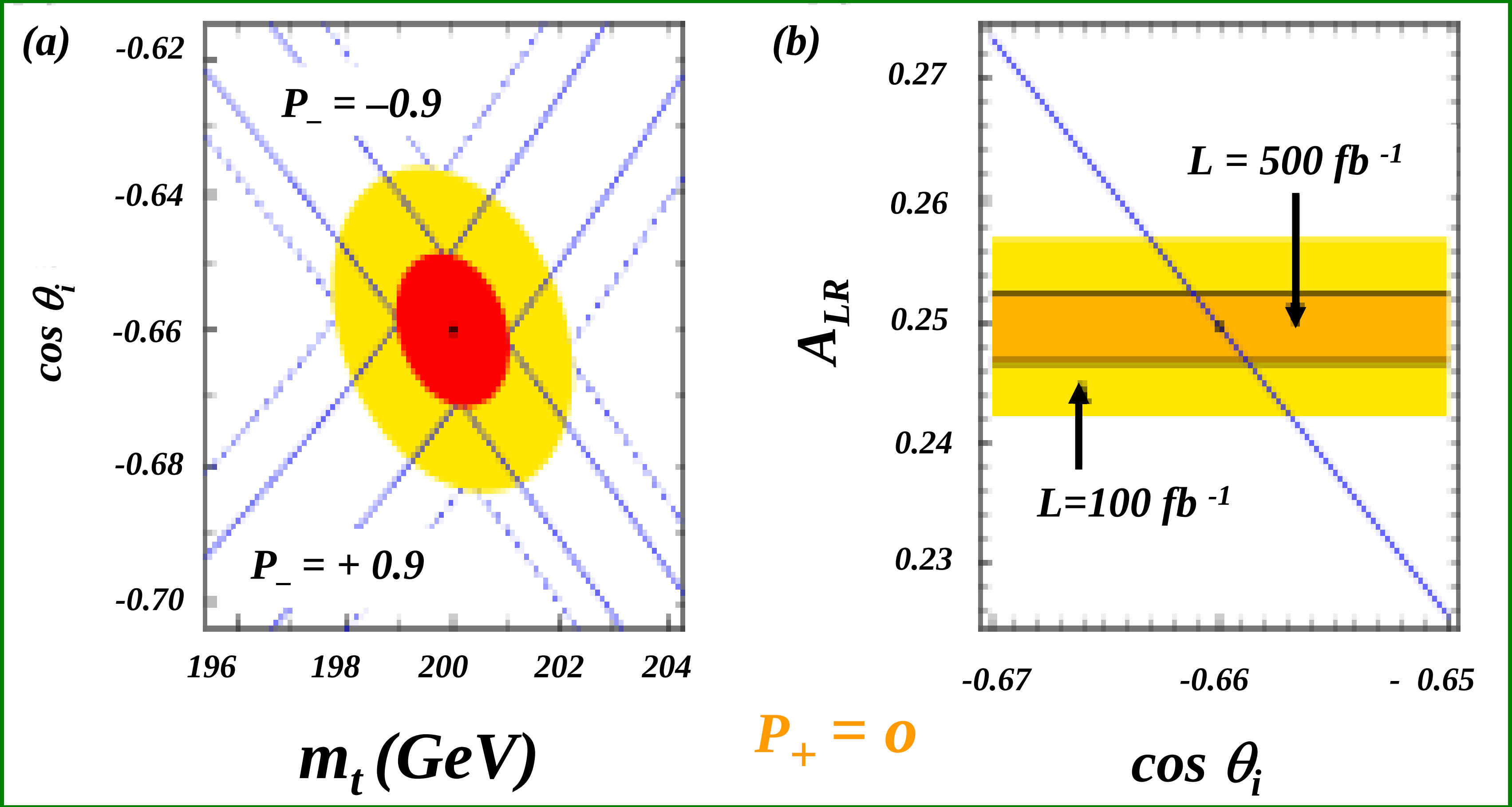
The leptons from stau decays are soft.

$E_{cm} = 500\ GeV$ $\sigma(e^+ e^- \rightarrow \tilde{t}_1 \tilde{t}_1)\ fb$ $M_{\tilde{t}_1} = 200\ GeV$

$|\cos\theta_i| = 0.4$



$|\cos\theta_i| = 0.66$


(a)
-0.62
-0.64
-0.66
-0.68
-0.70
cos θ_i
P_ = –0.9
P_ = + 0.9
196
198
200
202
204
m_t (GeV)
(b)
0.27
0.26
0.25
0.24
0.23
A_LR
L = 500 fb -1
L=100 fb -1
-0.67
-0.66
- 0.65
cos θ_i
P_+ = o

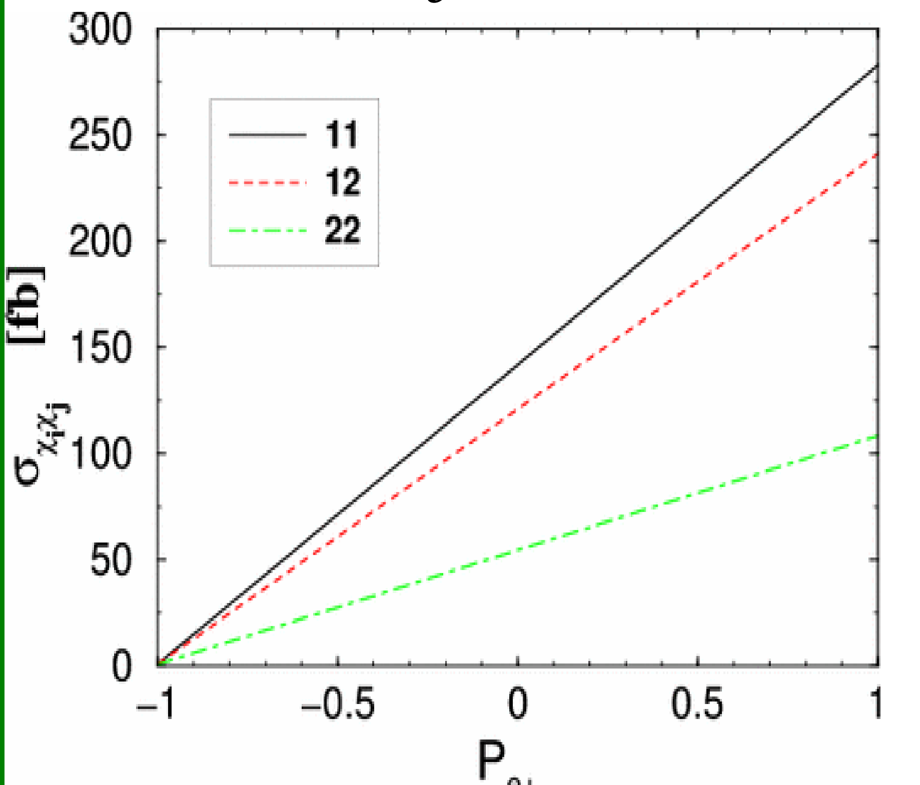
Measuring the sfermion mixing angle

The sfermion production goes via γ, Z exchange in the s-channel and the coupling constants depend on the sfermion mixing angle (θ_i). The cross section can be enhanced by varying the positron polarization and the sensitivity on the mixing angle can be determined more readily and measured.

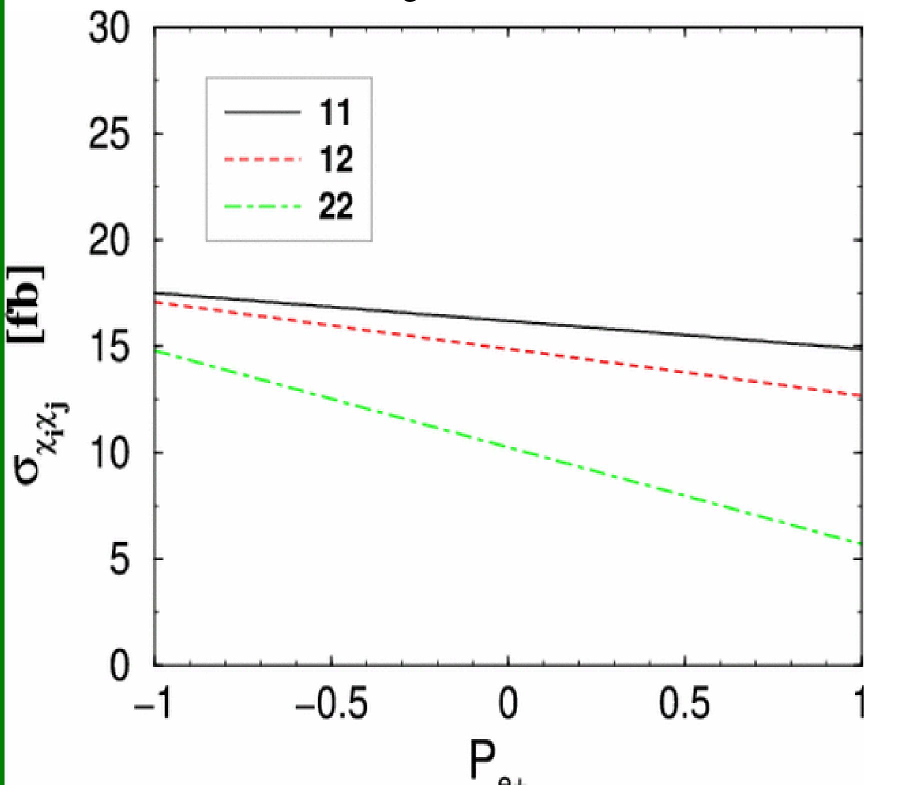
Study of Chargino and Neutralino Production with Positron Polarization.

$E_{cm} = 1$ TeV $\quad \sigma(\tilde{\chi}_i^+ \tilde{\chi}_j^-)$ fb $\quad$ SPS1a

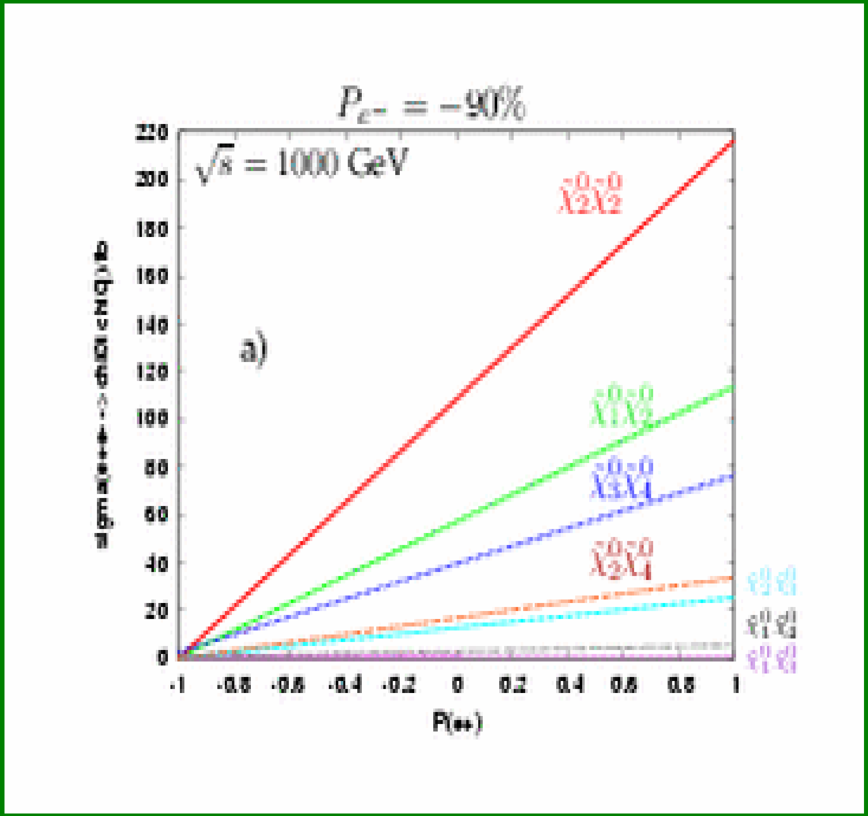
$P_{e^-} = -0.9$

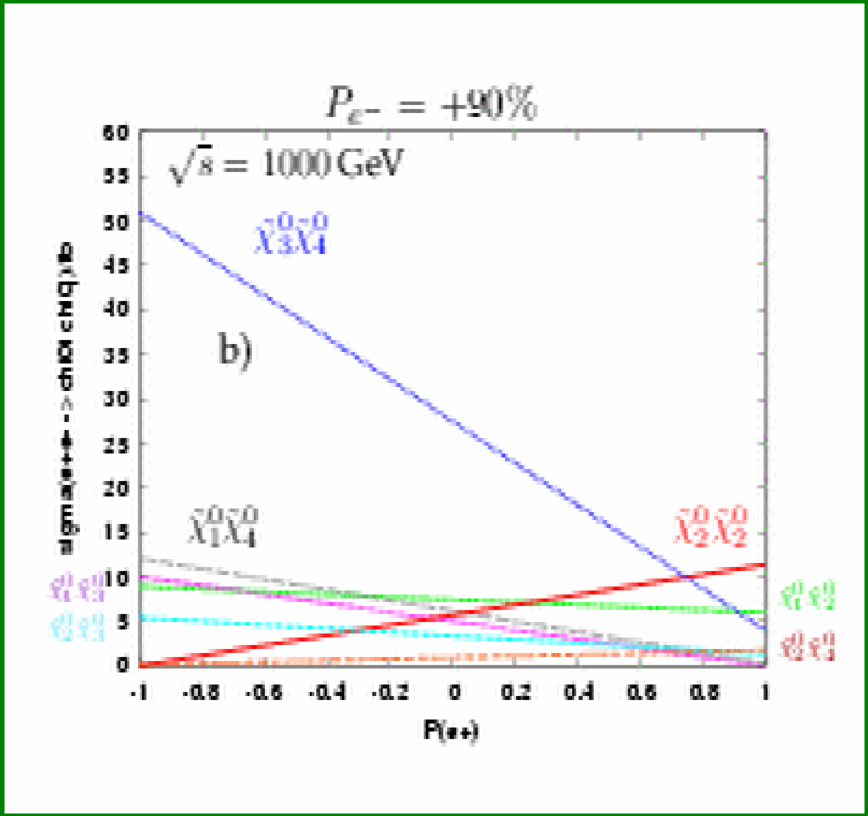


$P_{e^-} = +0.9$



E_{cm} =1 TeV $\sigma(\tilde{\chi}_i\ \tilde{\chi}_j)fb$ SPS1a





$$\sigma(\tilde{\chi}_1\,\tilde{\chi}_2) \times B.R.(\tilde{\chi}_2 \rightarrow \tilde{l}_R\, l_1) \times B.R.(\tilde{l}_R \rightarrow l_2\, \tilde{\chi}_1^0)\ fb$$

$$\text{Define } T = \{\vec{P}(e^-) \times \vec{P}(l_2)\} \cdot \vec{P}(l_1)$$

$$A(T) = \frac{\sigma(T>0) - \sigma(T<0)}{\sigma(T>0) + \sigma(T<0)}$$

A_{CP} = Diff. in Pol. of τ

Non-zero A_T, A_{CP} $\rightarrow$ CP Violation

Determined the values of σ and A(T) as a function of electron and positron polarization

for the following parameters

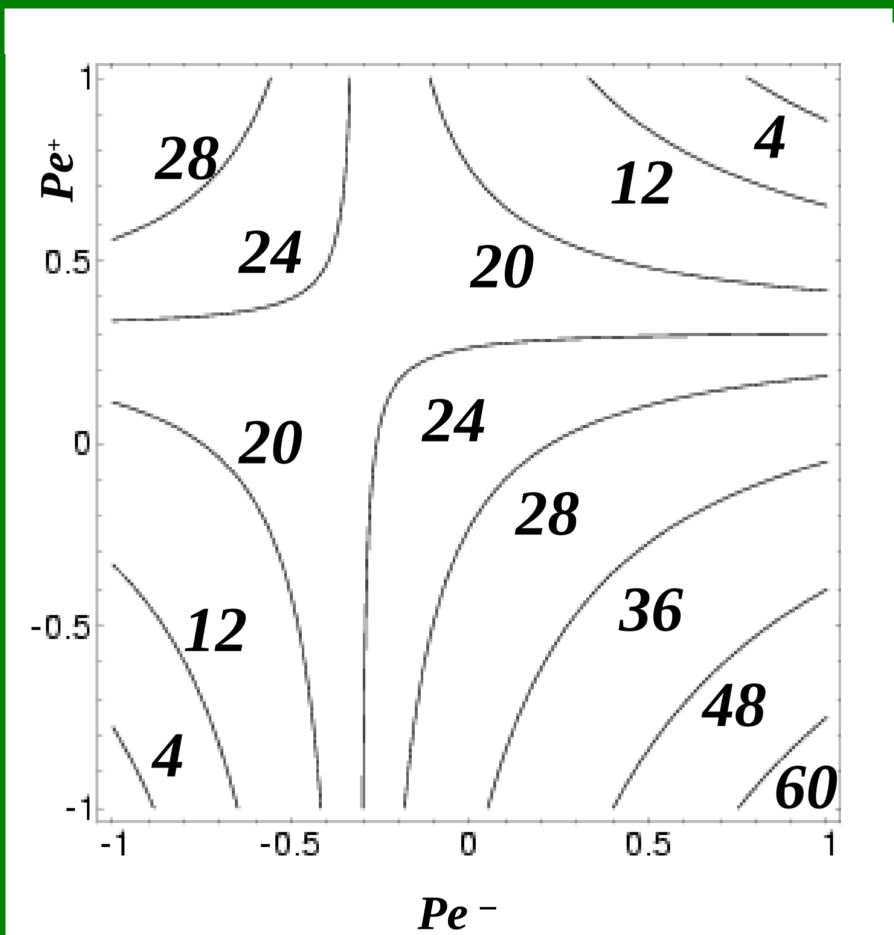
M_0 = 100 GeV $\tan(\beta) = 10$

M_2 = 400 GeV $\varphi(M_1) = 0.2\pi$

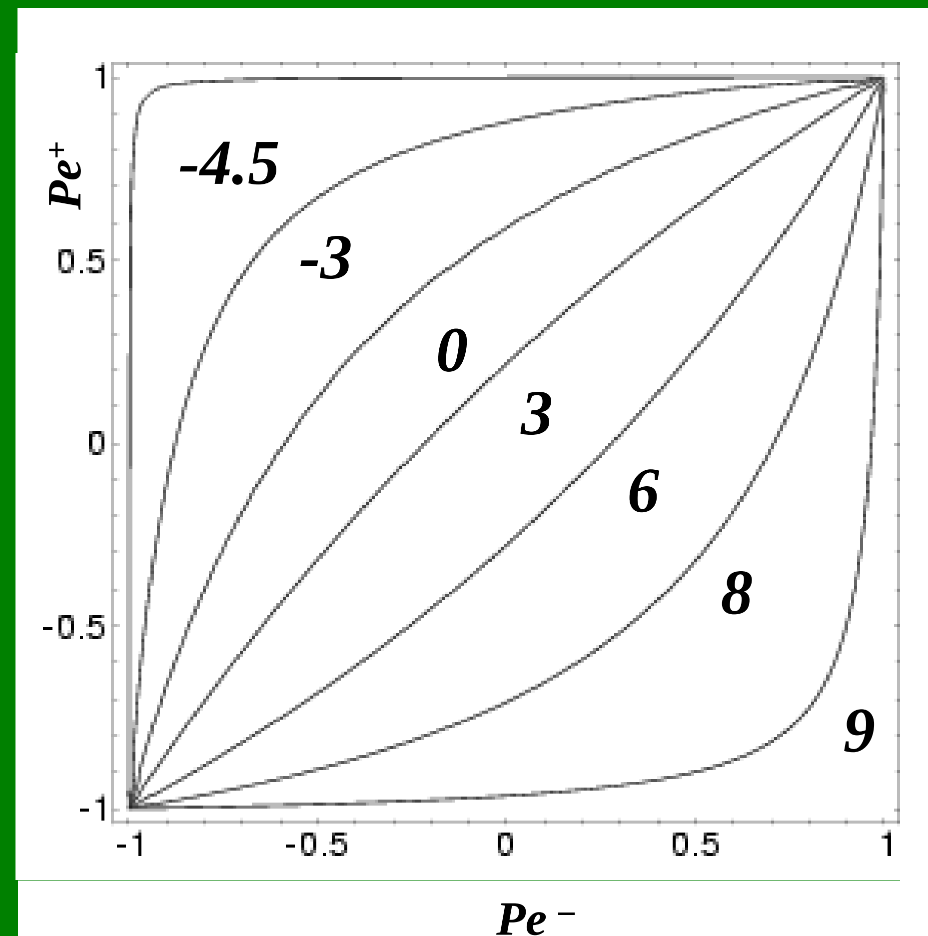
$|A_\tau|$ = 250 GeV $\varphi(A_\tau) = \varphi(\mu) = 0$

$|\mu|$ = 240 GeV

$\sigma(\tilde{\chi}_1^0 \tilde{\chi}_1^0 l_1 l_2)$ fb

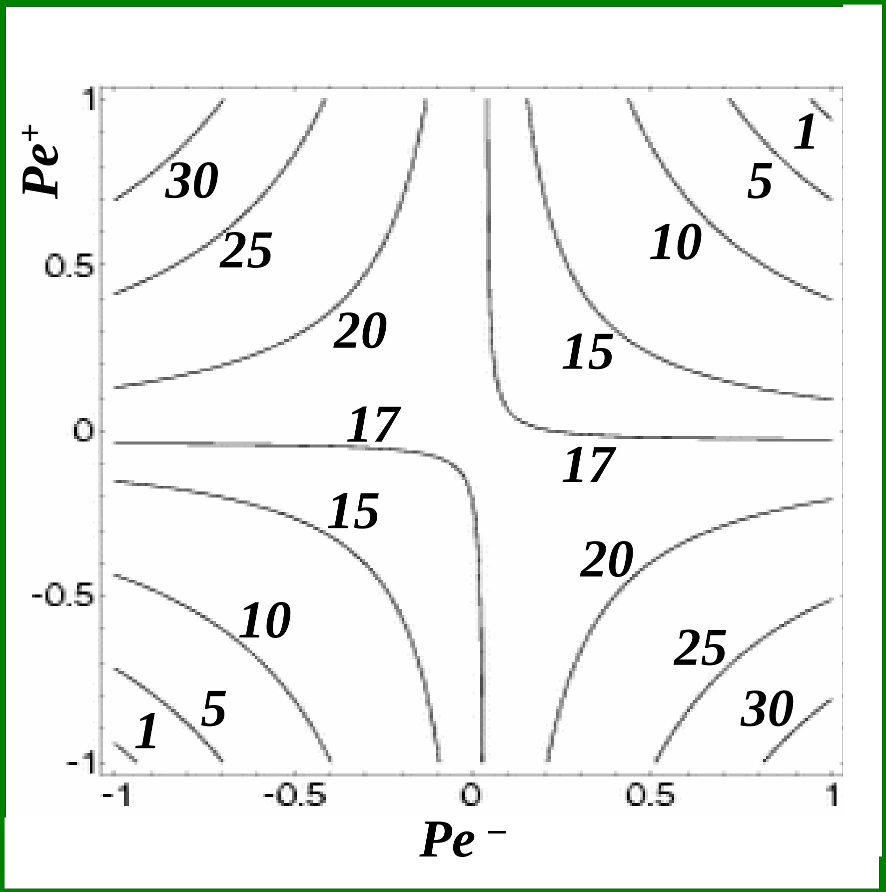


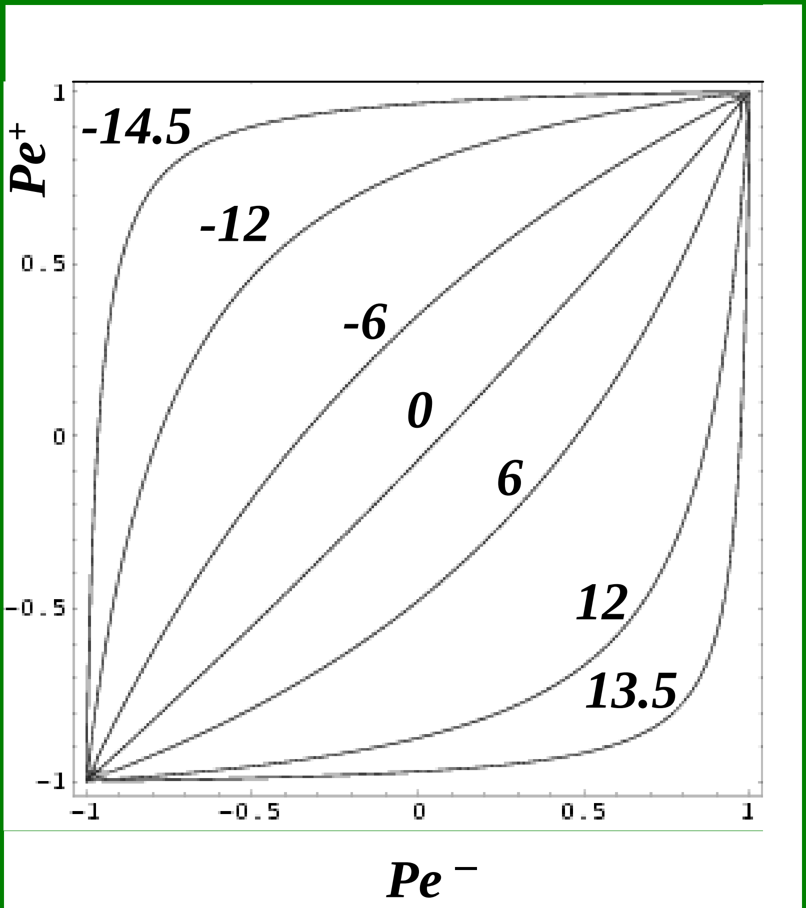
A_T in %



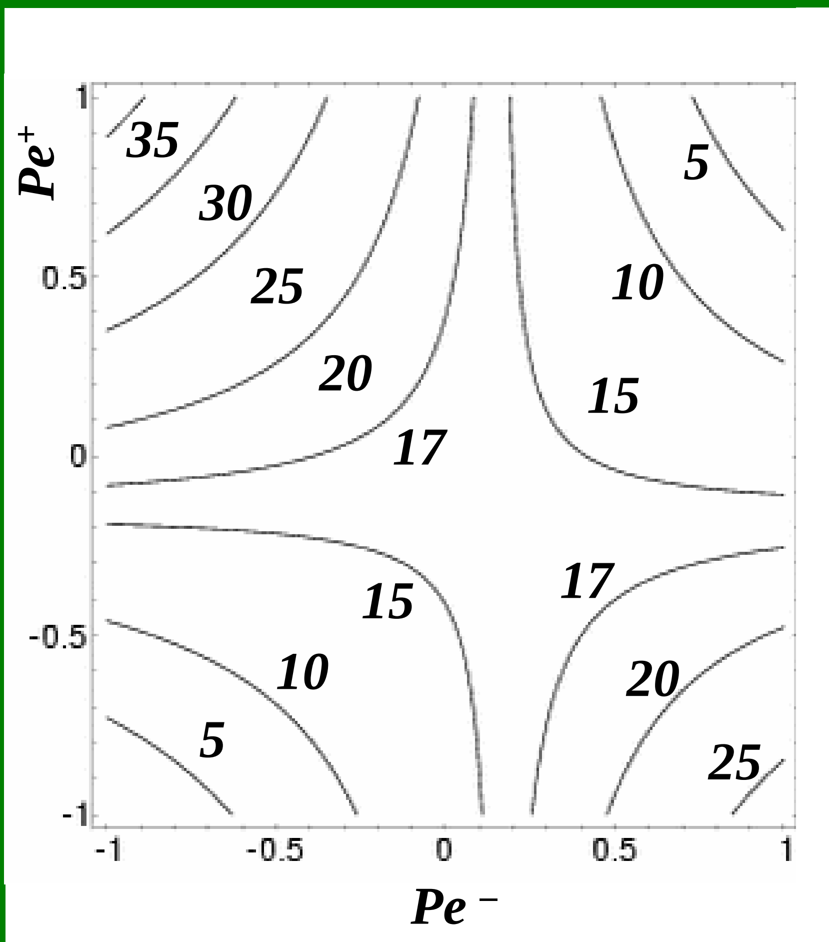
$\sigma(\tilde{\chi}_1^0\,\tilde{\tau}_1^+\tau^-)$ fb

A_{CP} %

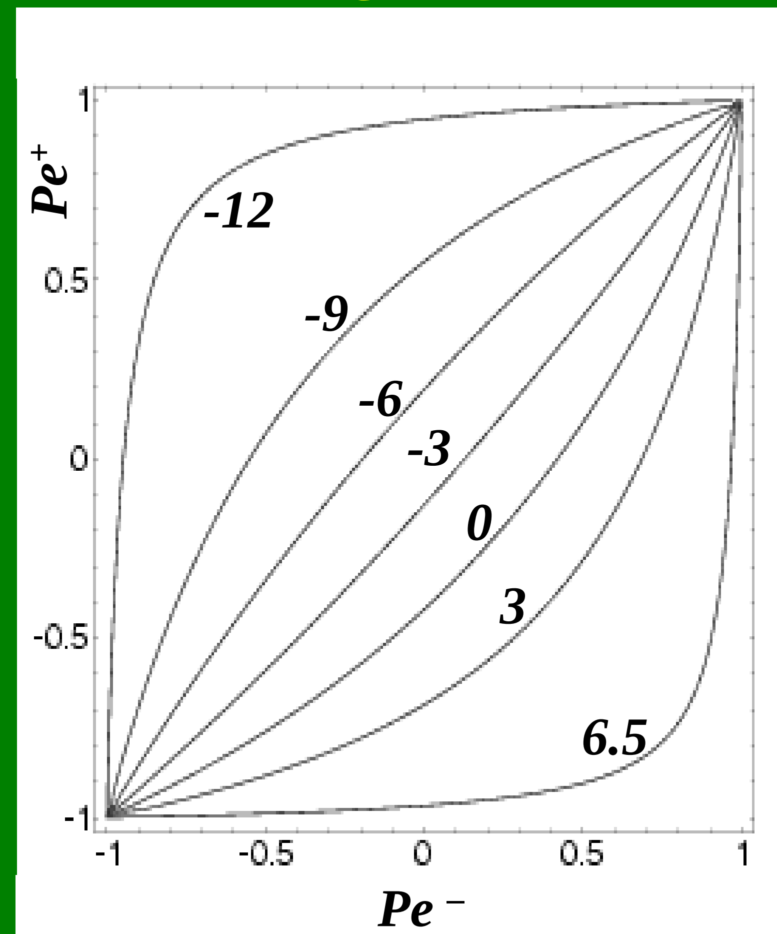




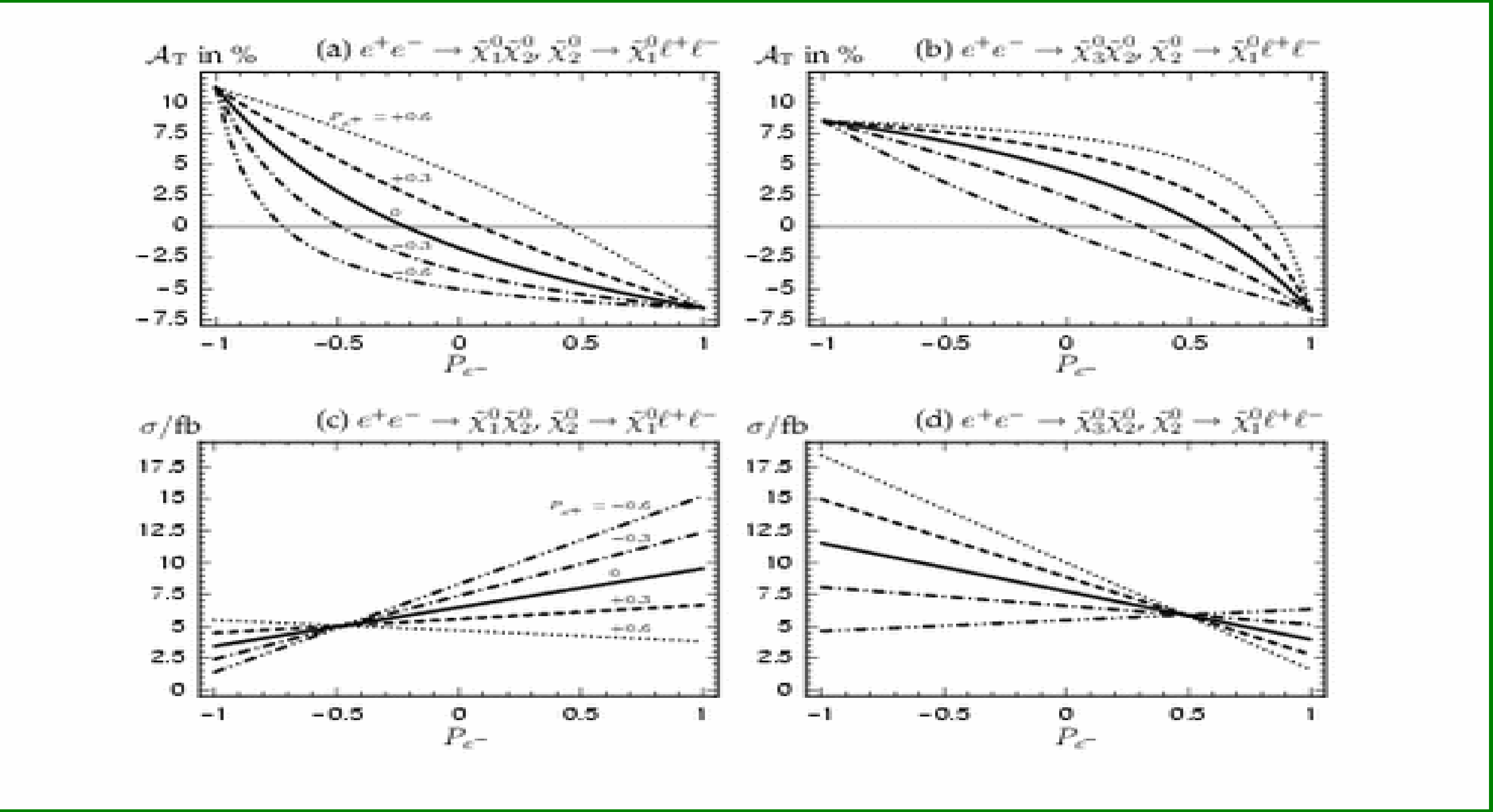
$\sigma(\tilde{\chi}_1^0\, \tilde{\tau}_1^+\, \tau^-)$ fb



A_{CP} %



$\tilde{\chi}_1^0\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\, l^+l^-$ $\quad$ $\tilde{\chi}_3^0\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\, l^+l^-$



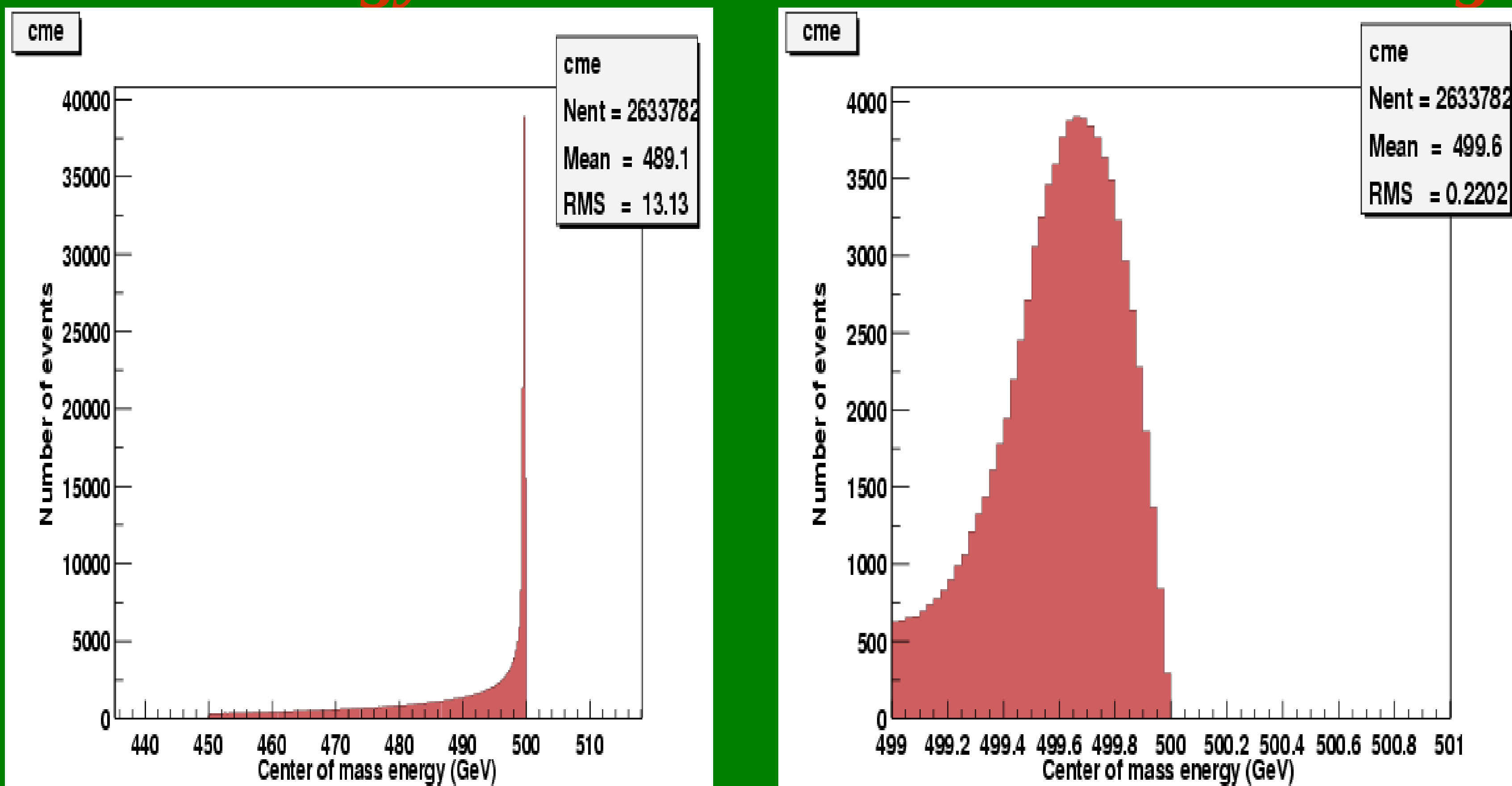
WORD OF CAUTION

All neutralino signals than end in 2 leptons without a mass constraint (like Z^0) are overwhelmed by selectron and sneutrino production channels because of t-channels and by 2 γ channels specially if the leptons come from τ decays.

Needs careful simulation. Playing with positron polarization should help.

The Effect of Beam-Bremmstrahlung

CM Energy Distribution with Beamstrahlung

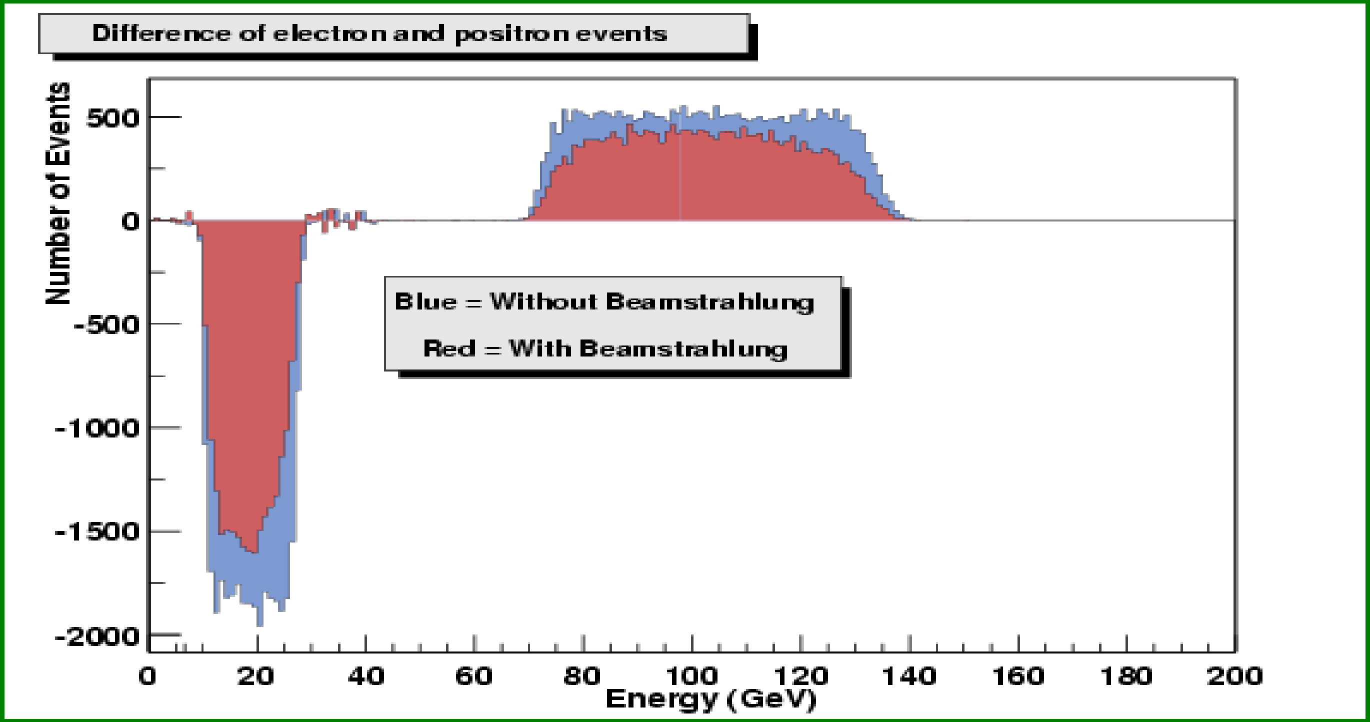


Simulation of Selectron Production Case Study

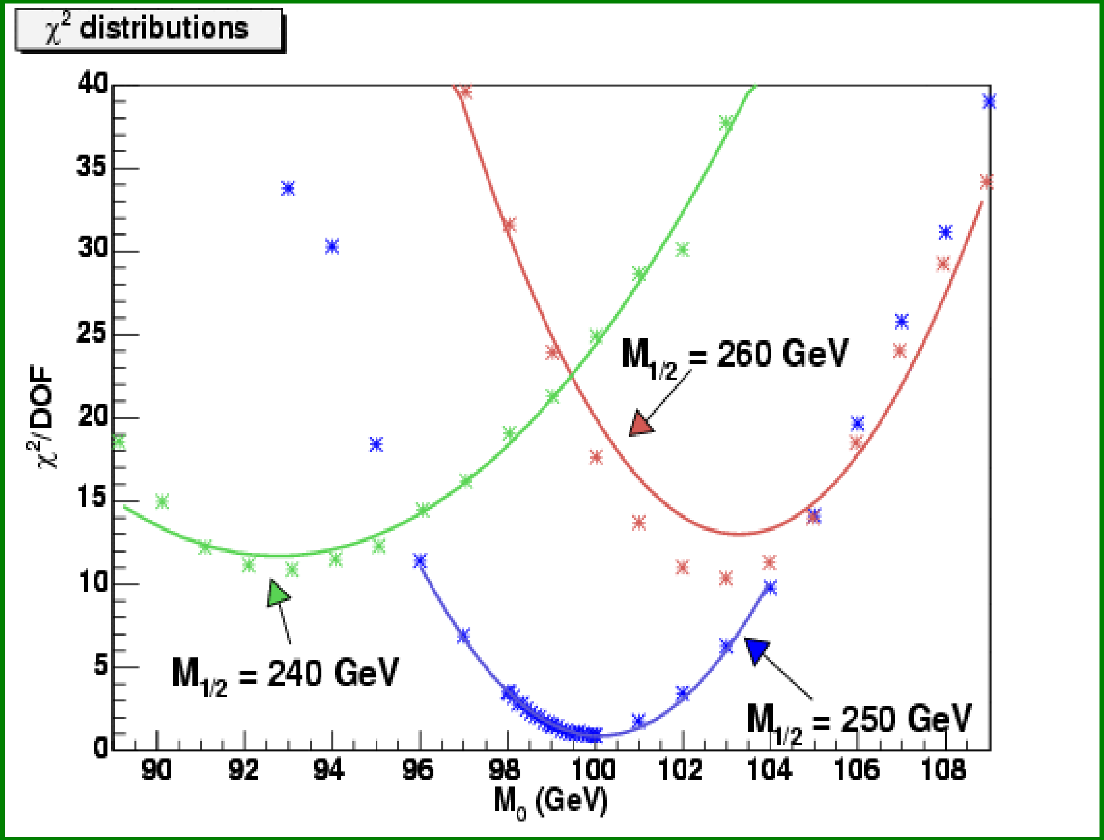
- *Consider Case SPS1 , $M_{1/2}$ = 250 GeV, M_0 = 100 GeV.*
- *Mass of e_R = 143.11GeV, Mass of e_L = 204.6 GeV, Mass of $\chi^0{}_1$ = 95.47*
- *Compare Fits with Beam and Bremmstrahlung and without.*
- *We use the e^+ - e^- Energy Spectra Substraction Technique to remove Standard Model Background.*

Selectron Production

$e^+ - e^-$ Energy Spectra



Chi-Square Fits for the SPS1 Snowmass Point



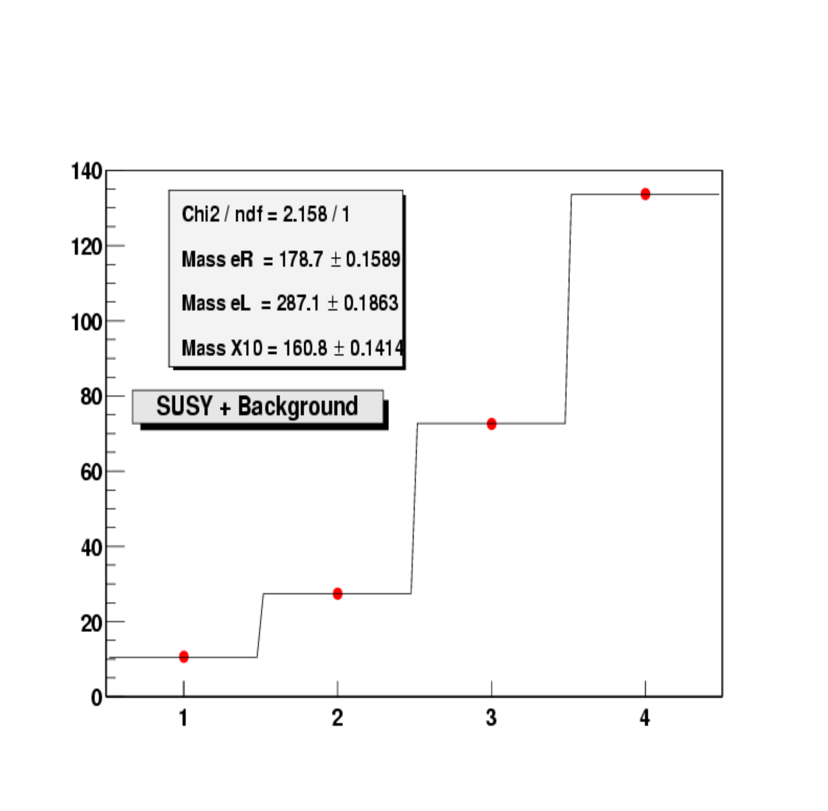
$M_{1/2}$ = 250 GeV

M_0 = 100 GeV

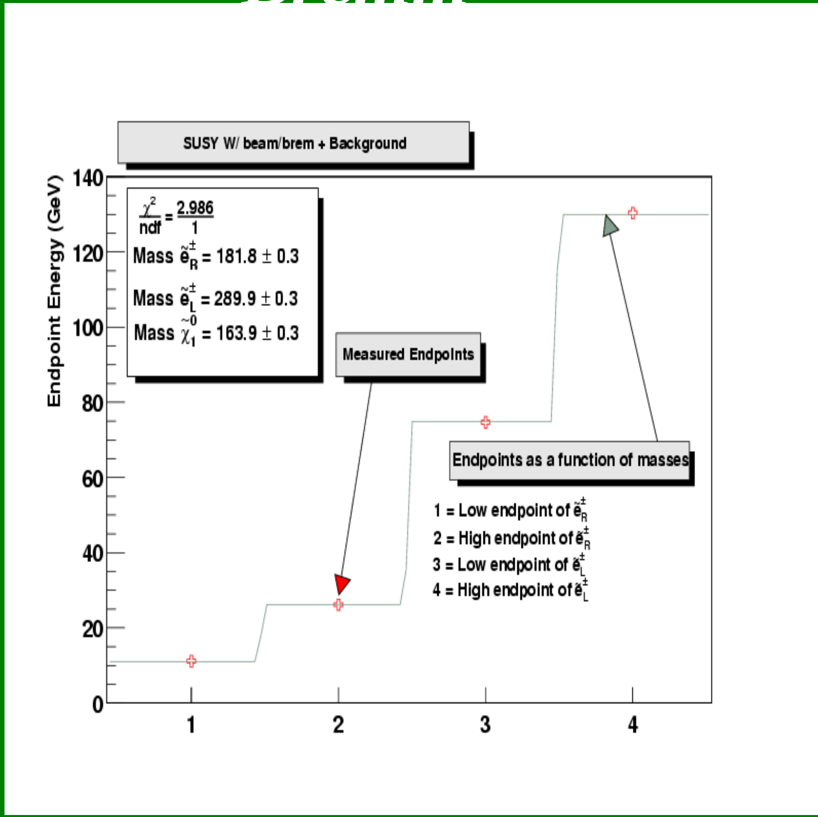
tan(β) fixed at 10

Resultant Fits to Energy Edges

No Bremm

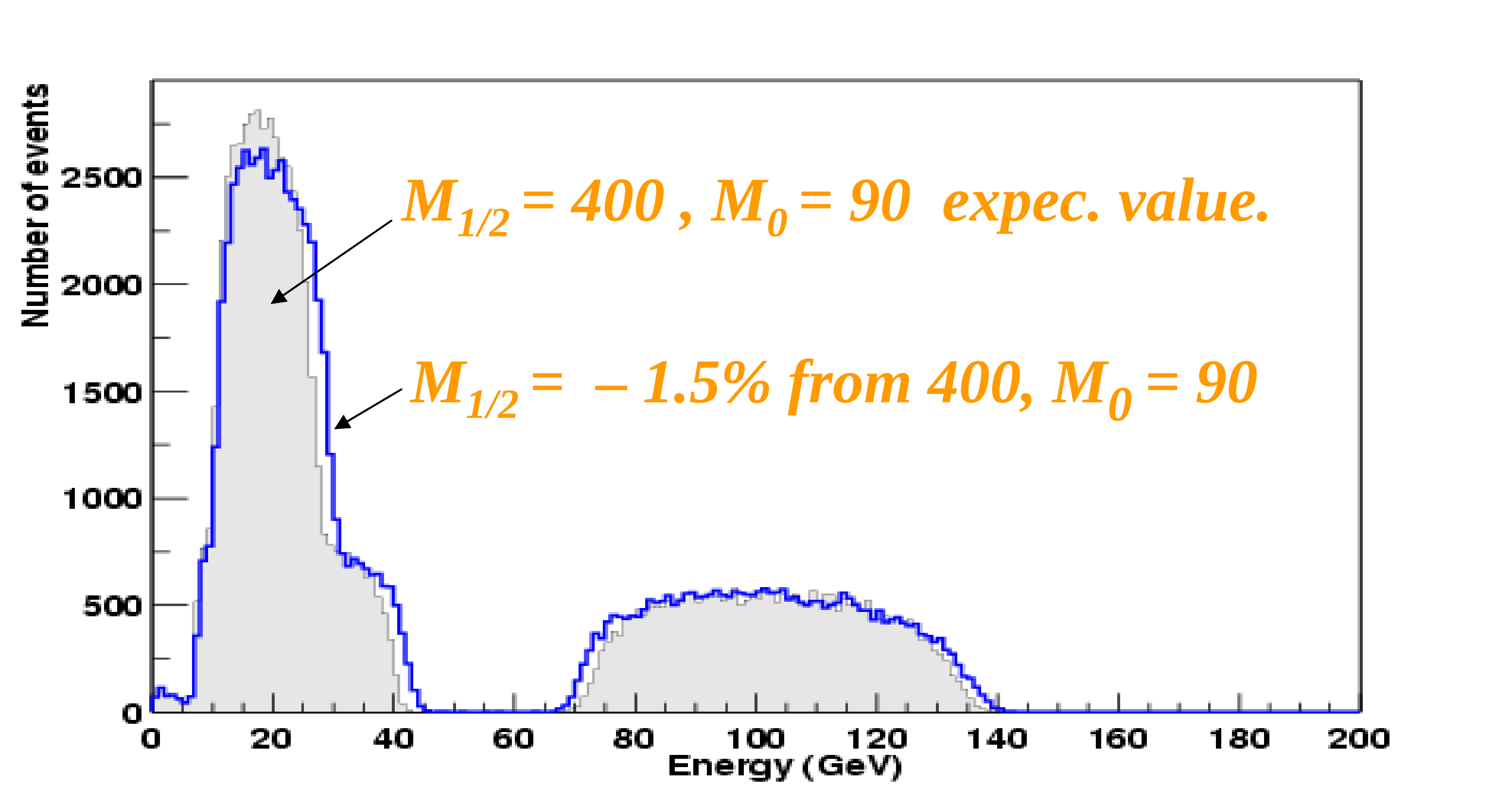


Bremm



New Method to Determine Masses

- *Compare Energy Spectrum to those Generated with different parameters encompasing the correct one.*
- *Do a Chi Square Fit to the Spectra Comparison.*
- *Choose the minimum and determine the masses.*



$M_{1/2}$ = 400 , M_0 = 90 expec. value.
$M_{1/2}$ = – 1.5% from 400, M_0 = 90
Number of events
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
180
200
Energy (GeV)

LCD-LCWS

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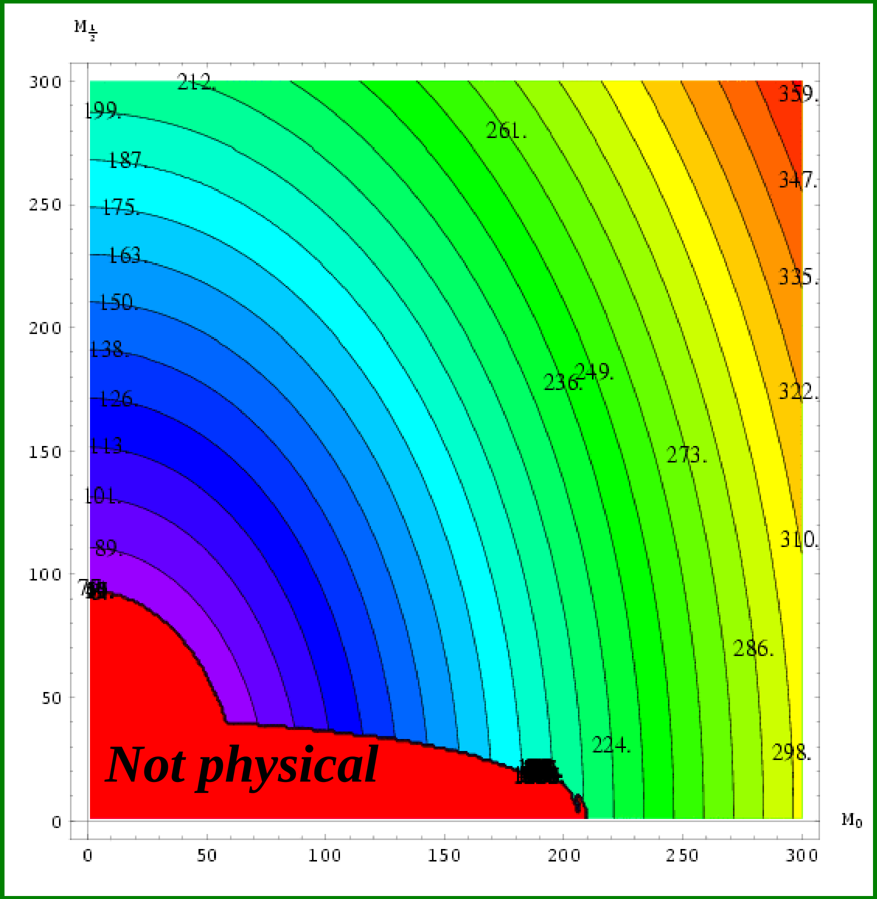
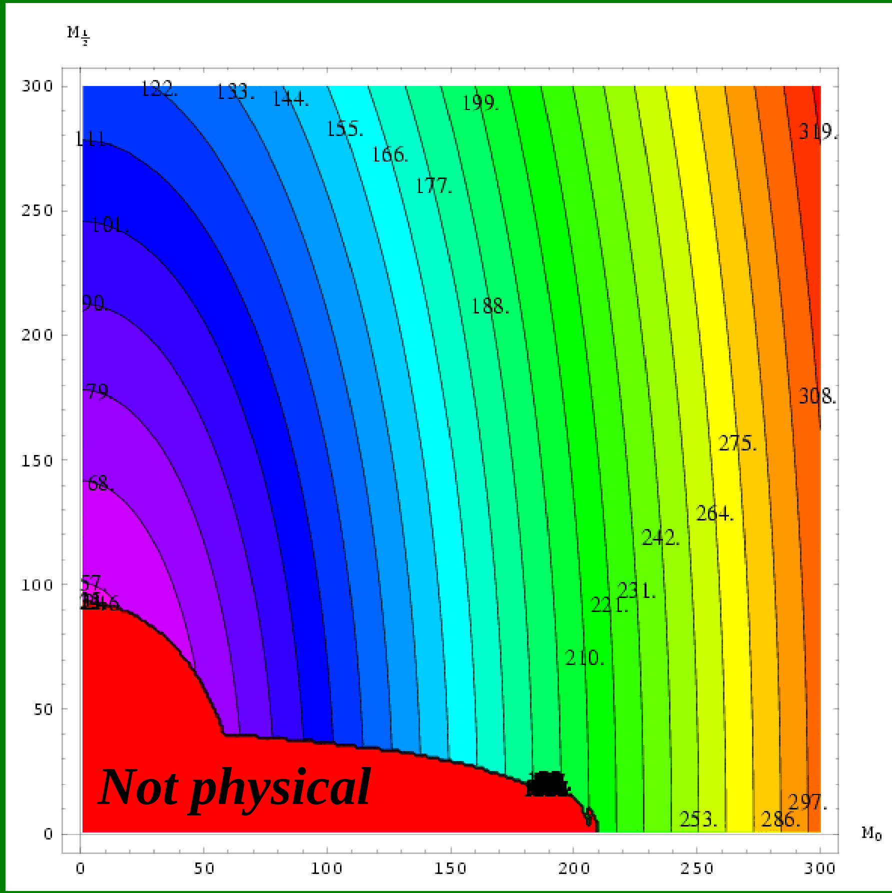
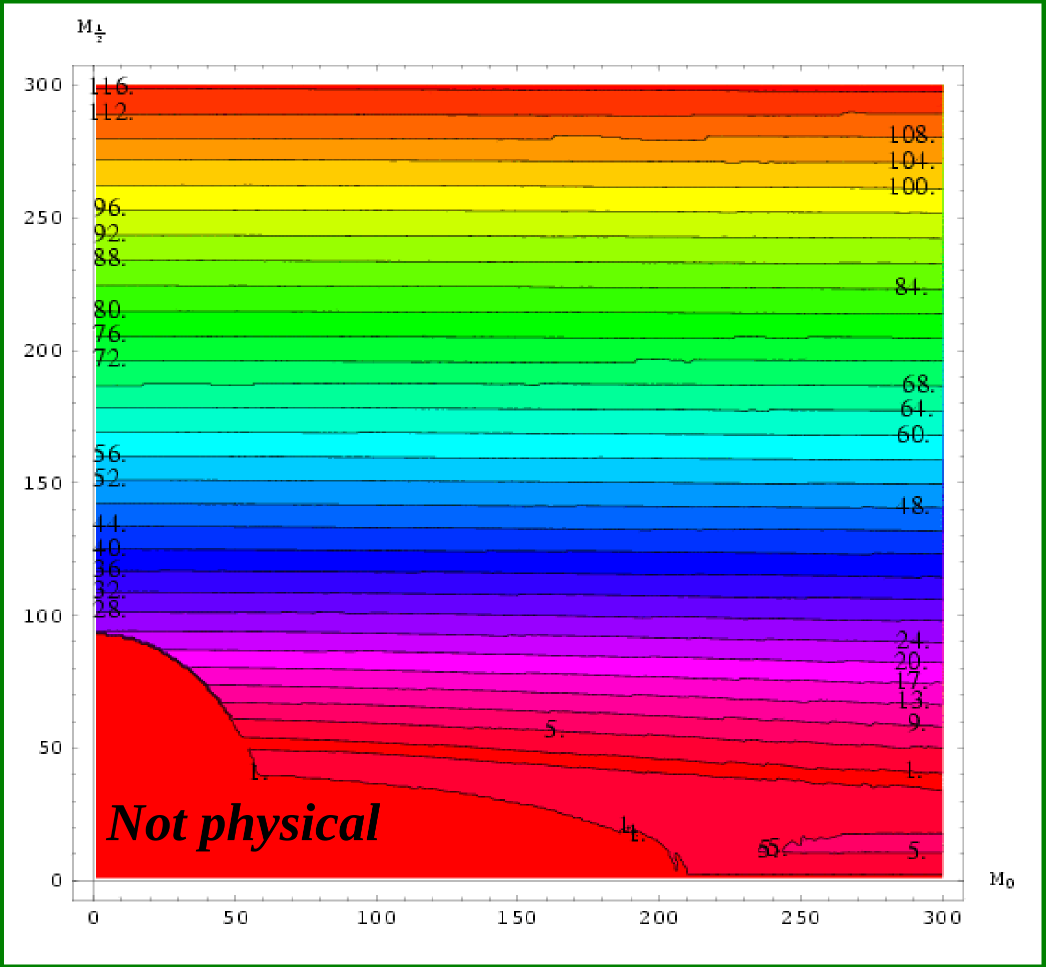
$M_{1/2}$ vs M_0 curves for $M_{sel\,L}$ values



$M_{1/2}$ vs M_0 curves for $M_{sel\,R}$ values



$M_{1/2}$ vs M_0 curves for $M(\tilde{\chi}_1^0)$

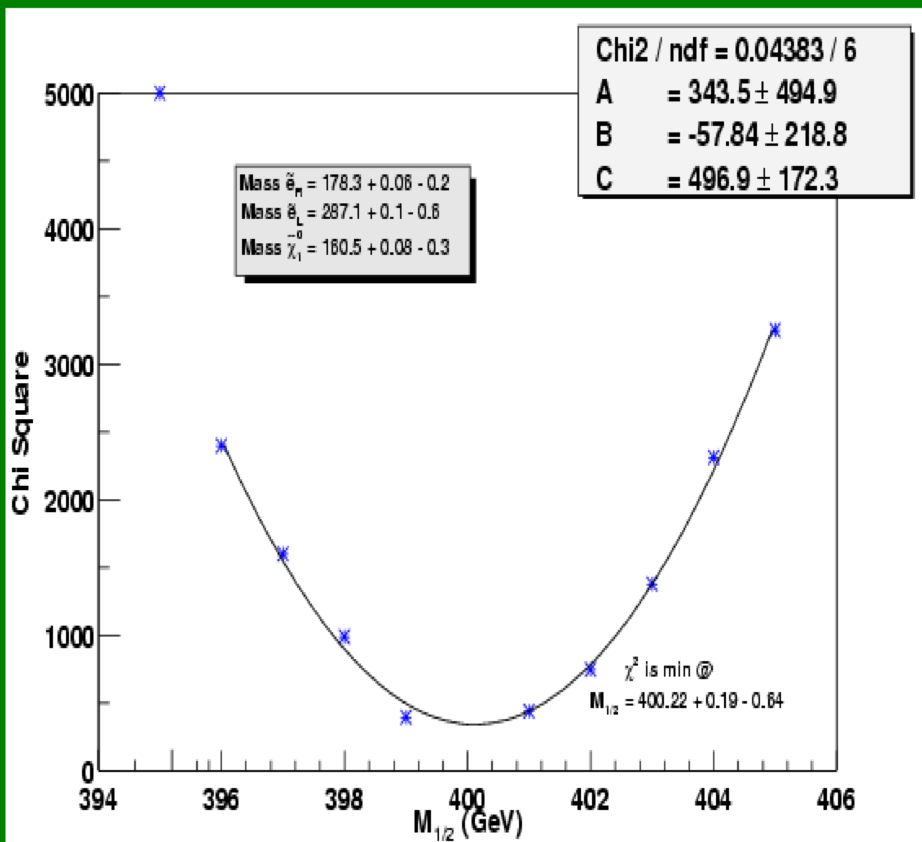


No dependence on tan(β)

Simulation of Selectron, Smuon Production Case Study

- *Consider Case SPS3 , $M_{1/2}$ = 400 GeV, M_0 = 90 GeV.*
- *Mass of e_R = 179.1 GeV, Mass of e_L = 292.5 GeV, Mass of $\chi^0{}_1$ = 158.2 GeV.*
- *Compare Fits with Beam and Bremmstrahlung and without.*
- *For selectrons we use the e^+ - e^- Energy Spectra Substraction Technique to remove Standard Model Background.*

Chi Square Fit for the SPS3 Snowmass Point



$M_{1/2}$(expec.) = 400 GeV

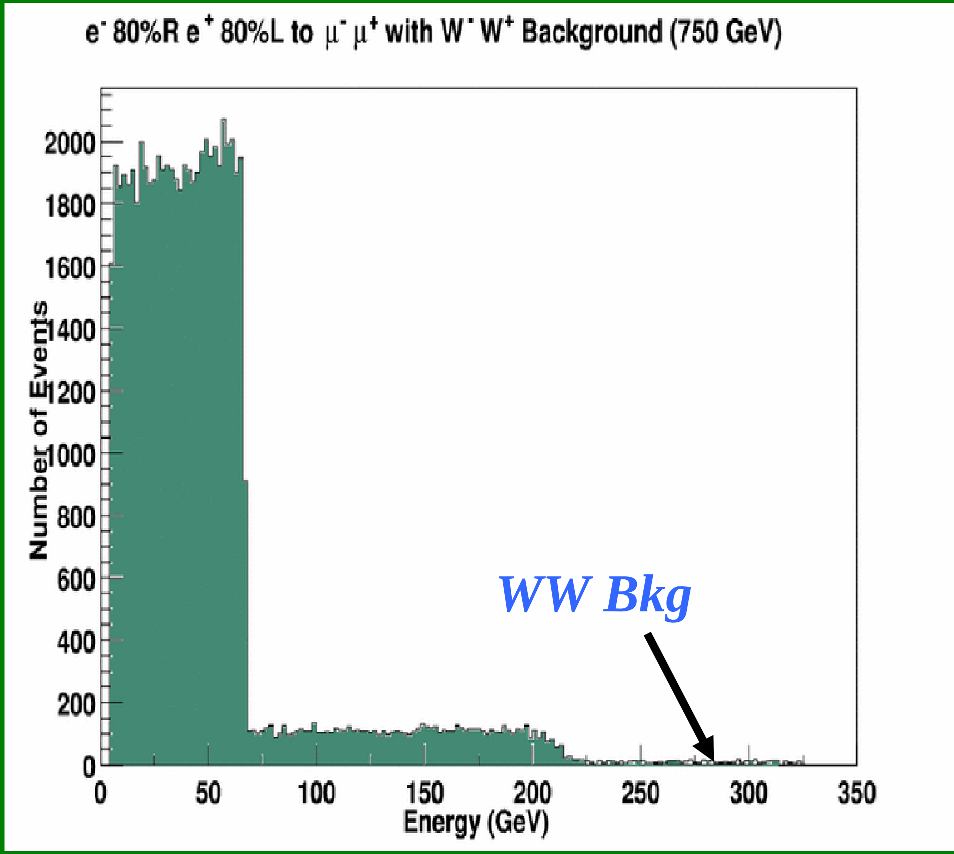
$M_{1/2}$(fit)=$400.22^{+0.19}_{-0.54}$ GeV

M_0 fixed at 90 GeV

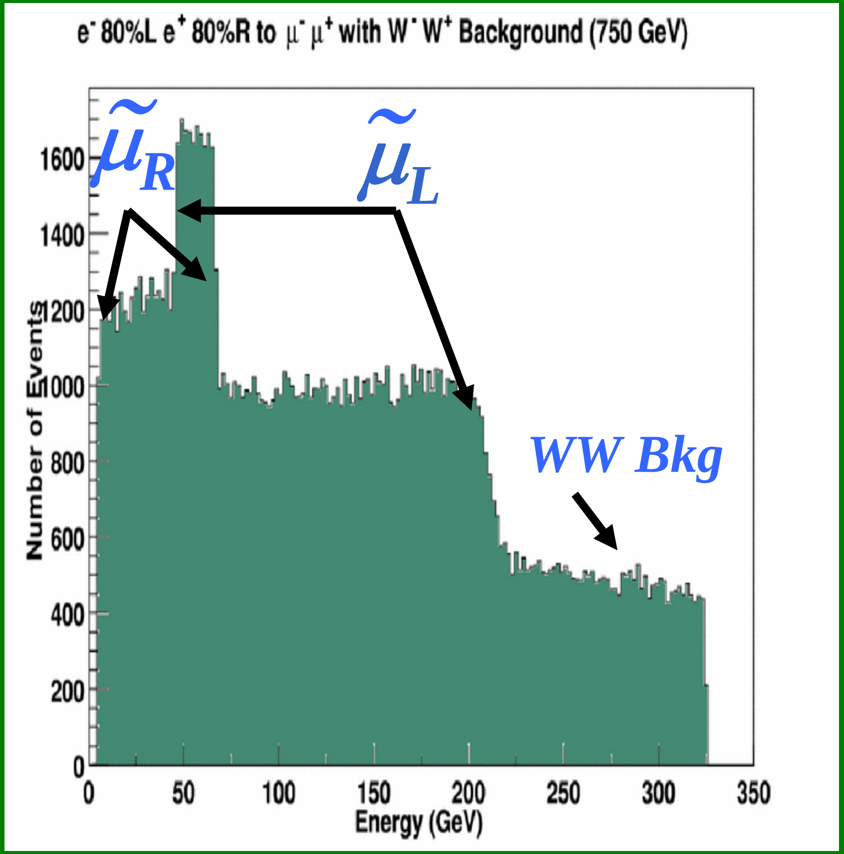
$\tan(\beta)$ fixed at 10

Muon Energy Spectrum from $e^+ e^- \to \tilde{\mu}^+ \tilde{\mu}^-$

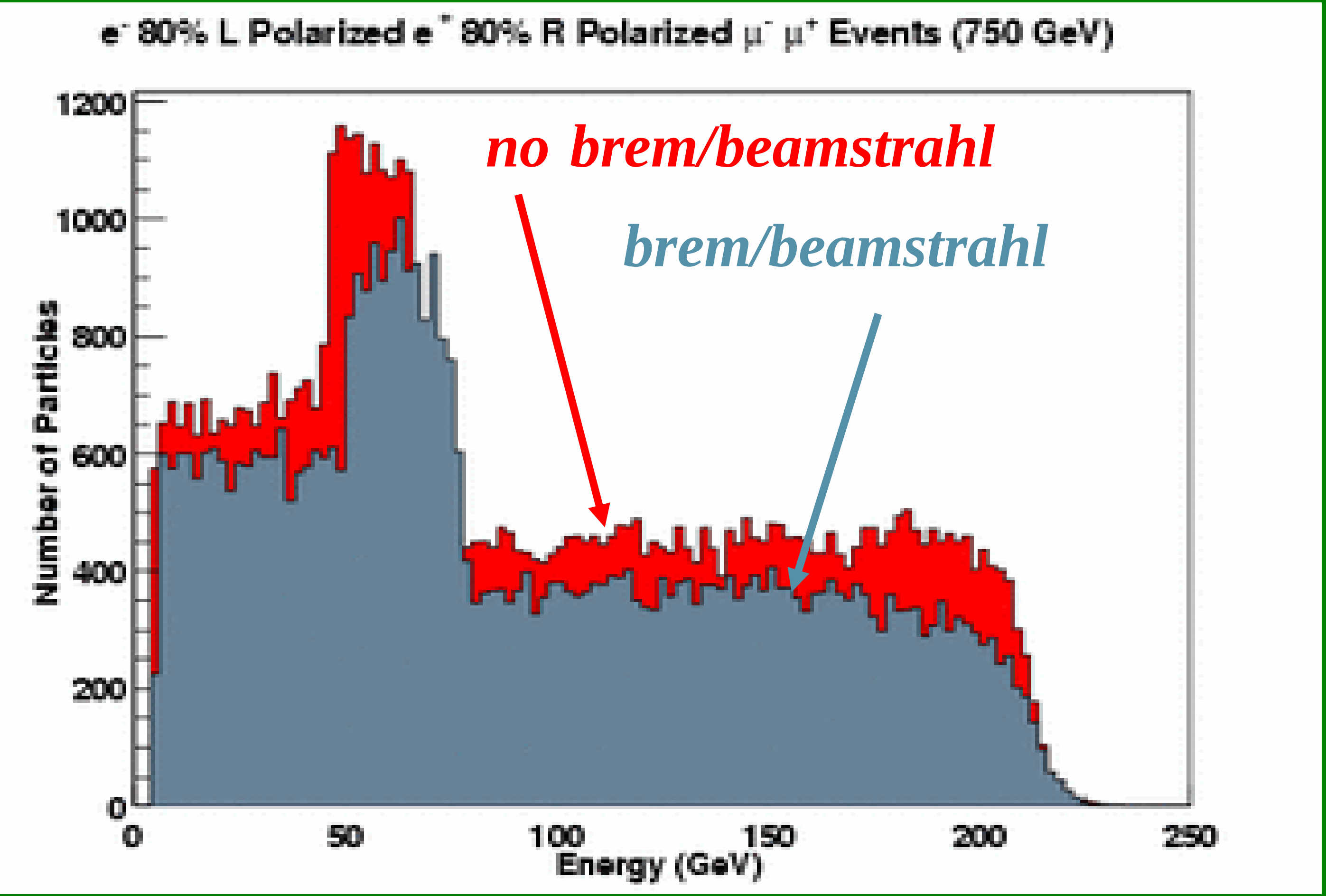
e^- 80% R e^+ 80% L



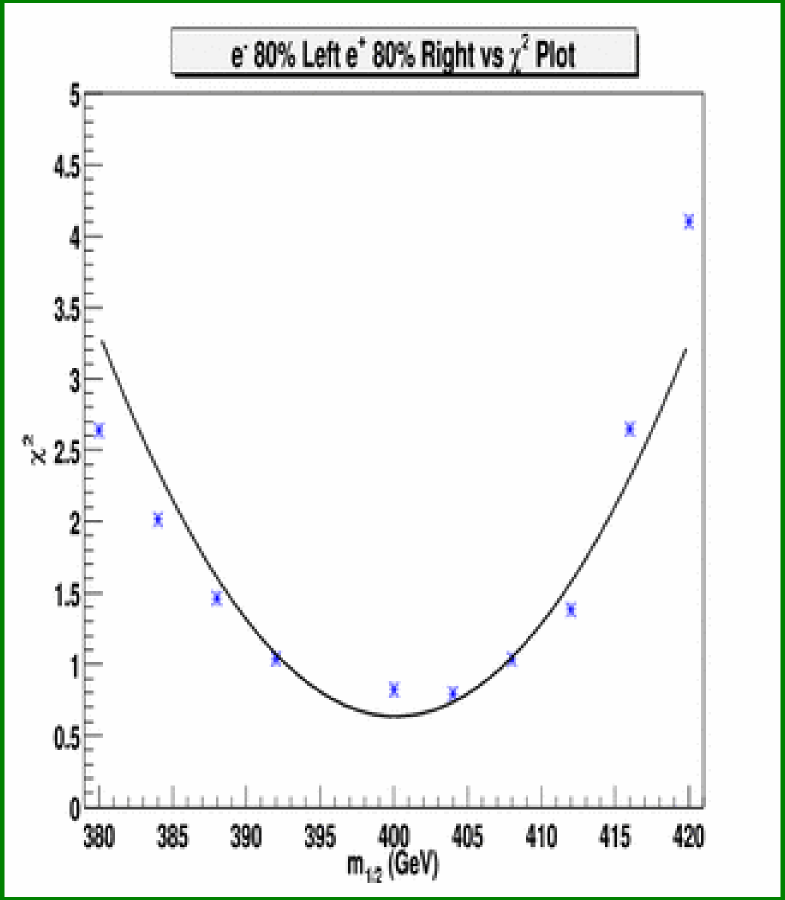
e^- 80% L e^+ 80% R

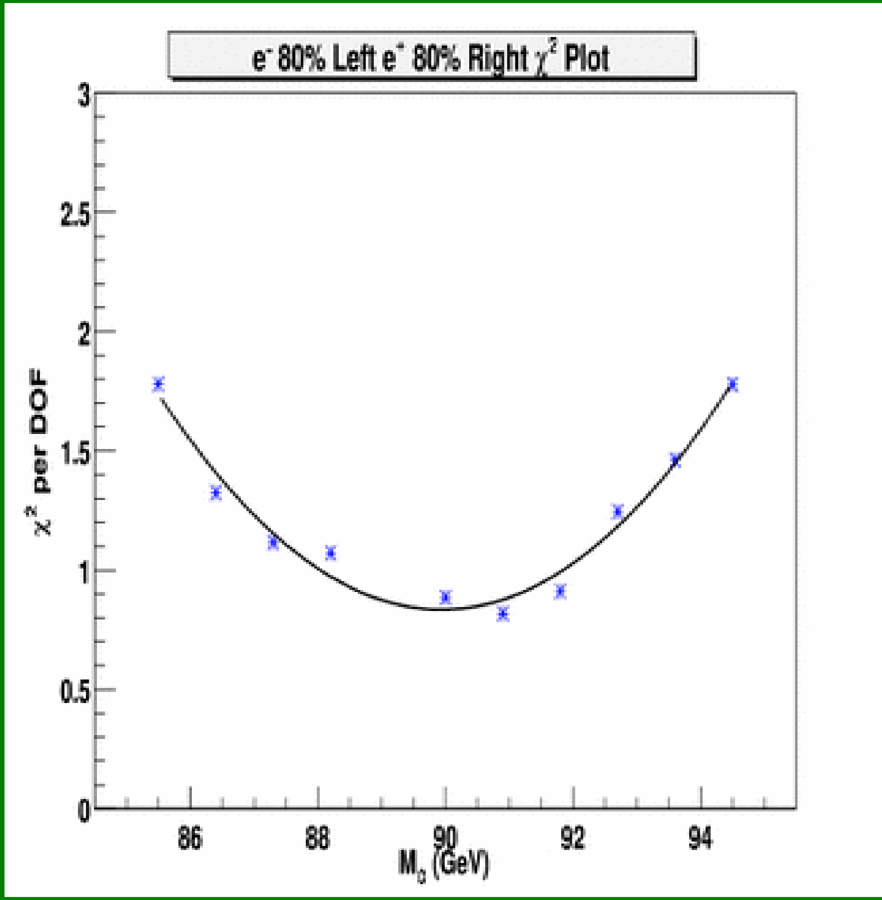


LCD-LCWS


e- 80% L Polarized e+ 80% R Polarized μ- μ+ Events (750 GeV)
no brem/beamstrahl
brem/beamstrahl
Number of Particles
Energy (GeV)
0
200
400
600
800
1000
1200
0
50
100
150
200
250

SPS3 Point; E_{cm}=750 GeV ; $M_{1/2}$=400 GeV, M_0=90 GeV





Resultant Masses from Fits

	Input Masses	Mass fit E.P.	Mas Fit ChiS.
$\tilde{\mu}_R$	179.1	171.3	179.0
$\tilde{\mu}_L$	292.5	287.4	292.0

Study of Sneutrino Productione

A Very Interesting Case

SPS6 Point

$E_{cm} = 750$ GeV

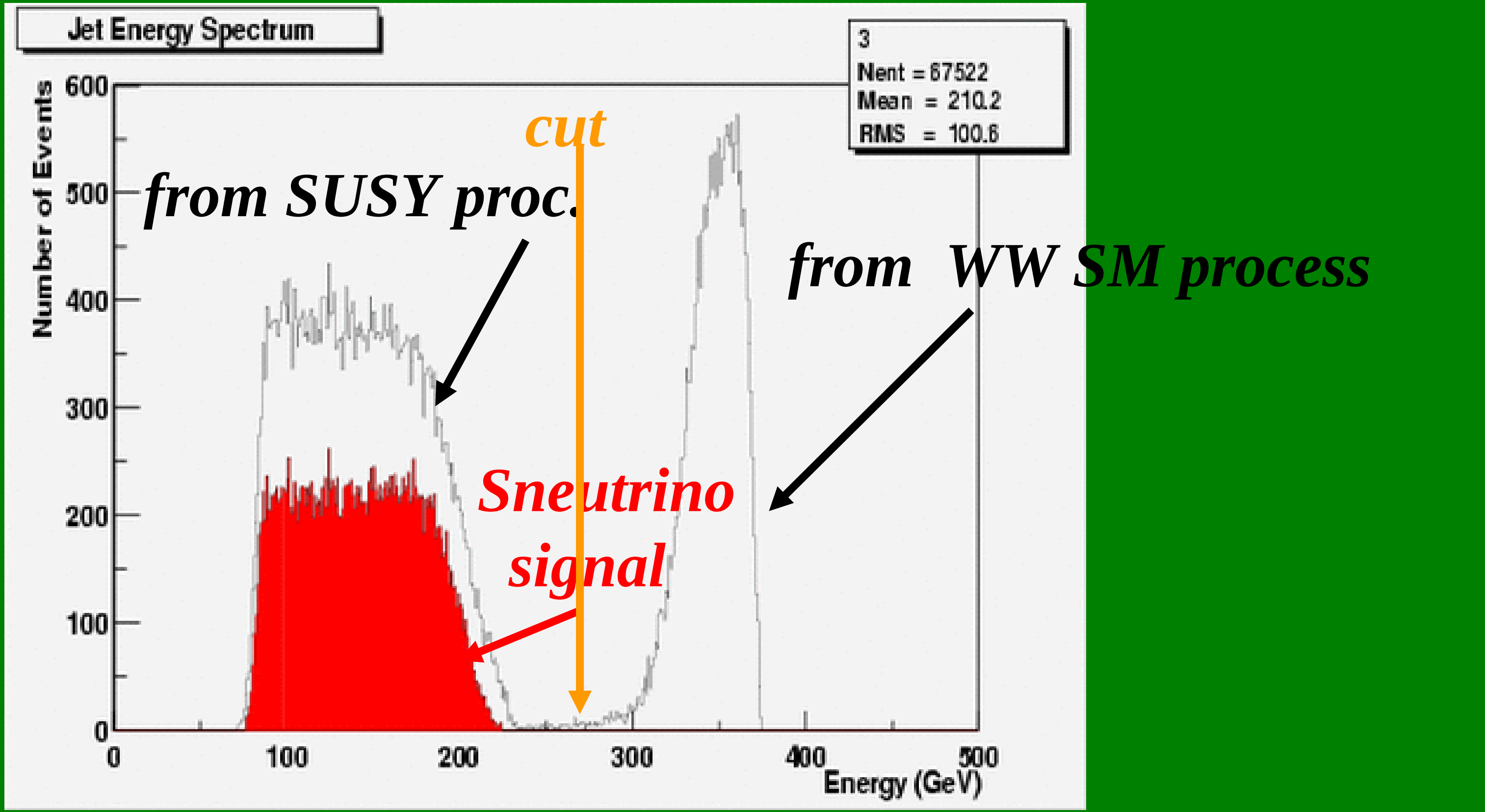
$M_0 = 150$ GeV, $M_{1/2} = 300$ GeV

$A_0 = 0$ GeV , $\tan(\beta) = 10$

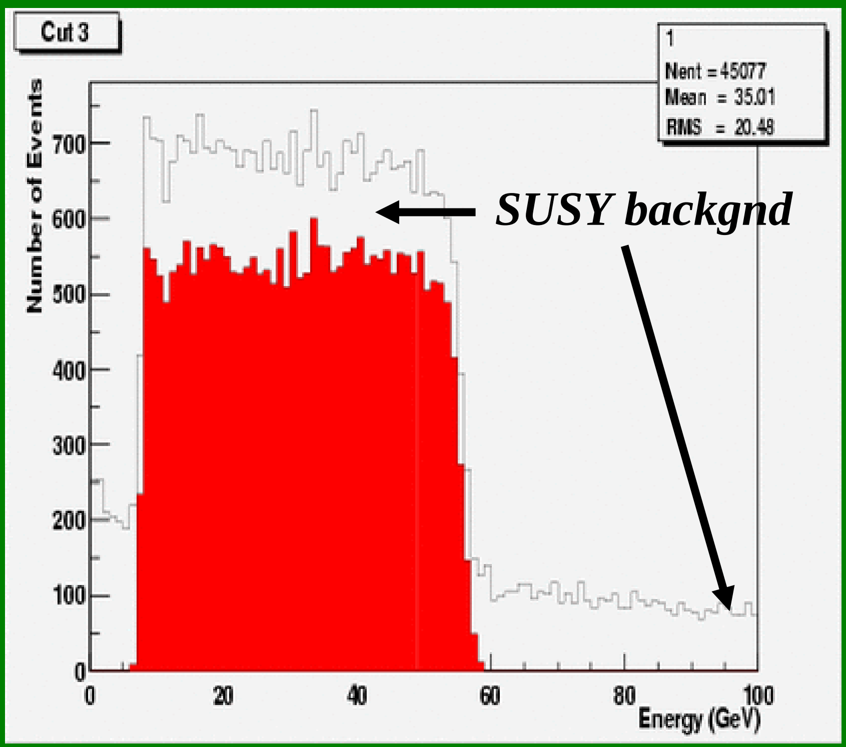
$M_{\tilde{\nu}} = 243.8$ GeV; $M_{\tilde{\chi}_1^+} = 222.4$ GeV

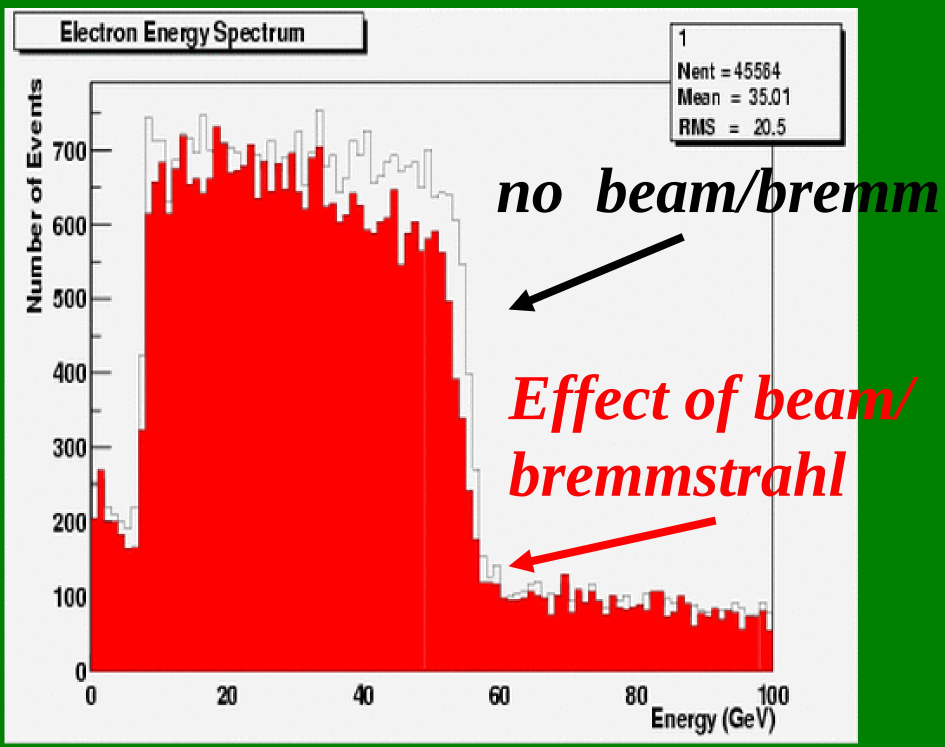
$\tilde{\nu}_e \rightarrow \tilde{\chi}_1^+ e^- ; \tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0 W^+ ; W^+ \rightarrow \text{hadrons}$

Energy Spectrum of Hadronic Jets after Hadronic Mass (W) Cut

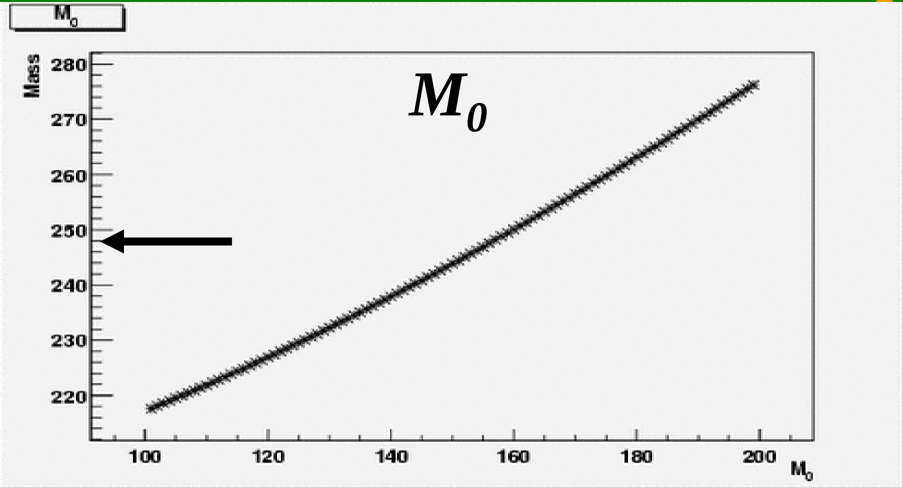


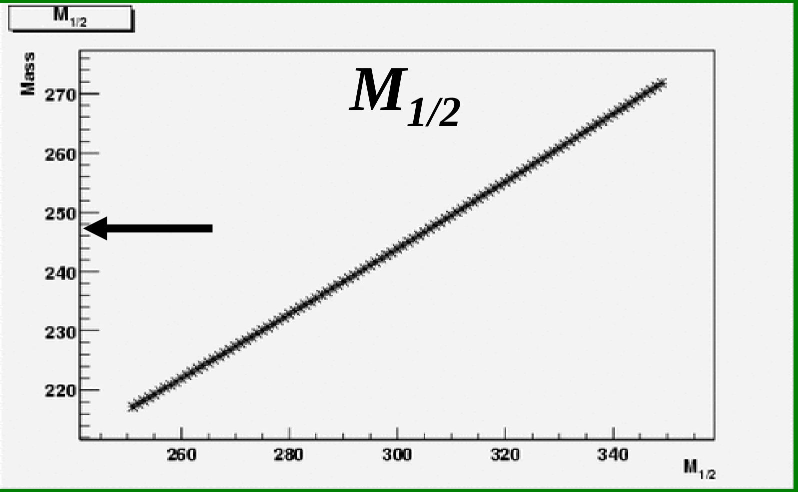
No Beam/Bremmstrahl | *Beam/Bremmstrahl*

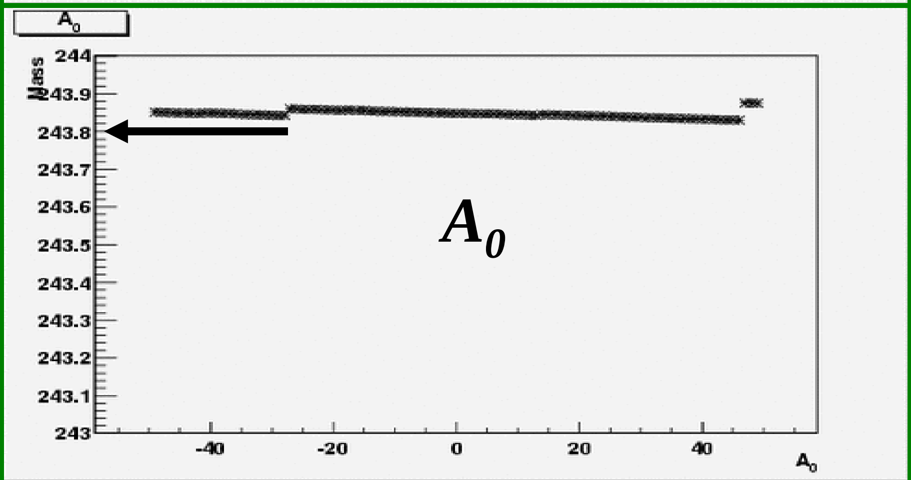


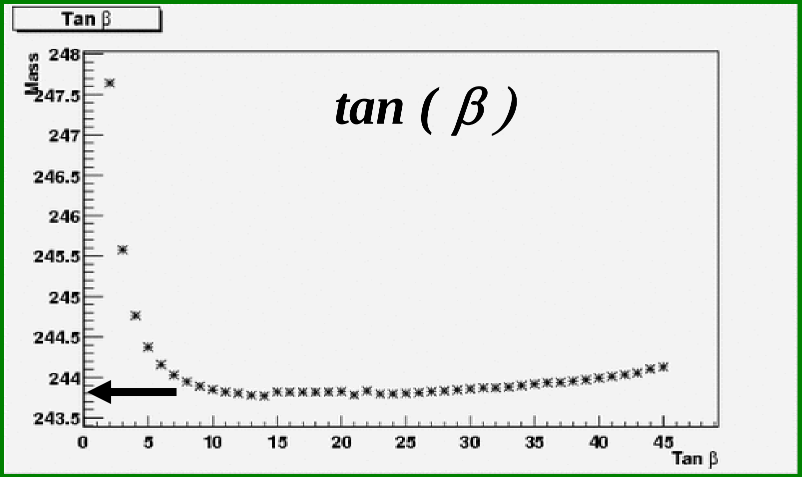


Sneutrino Mass Dependence on Parameters

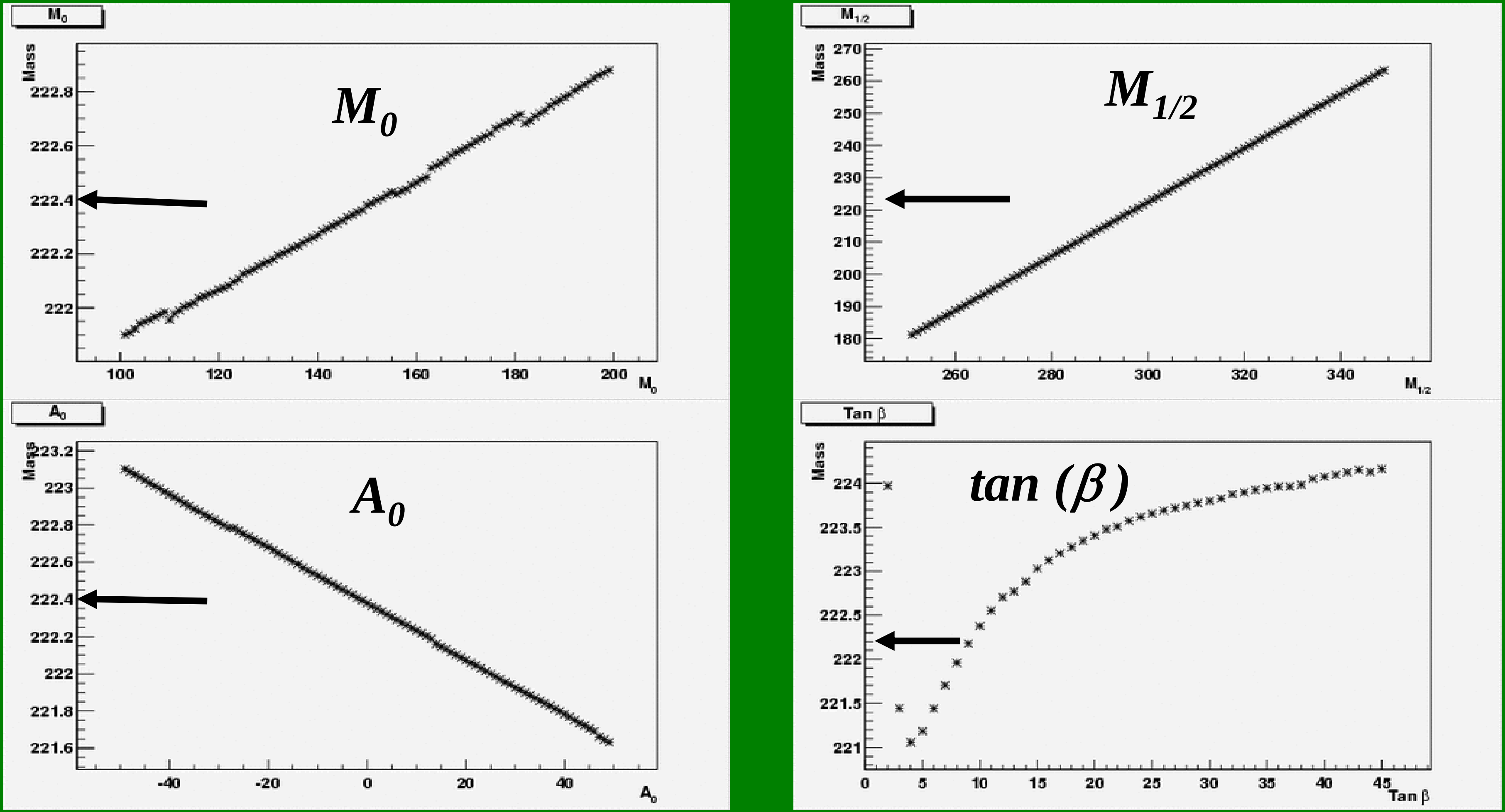




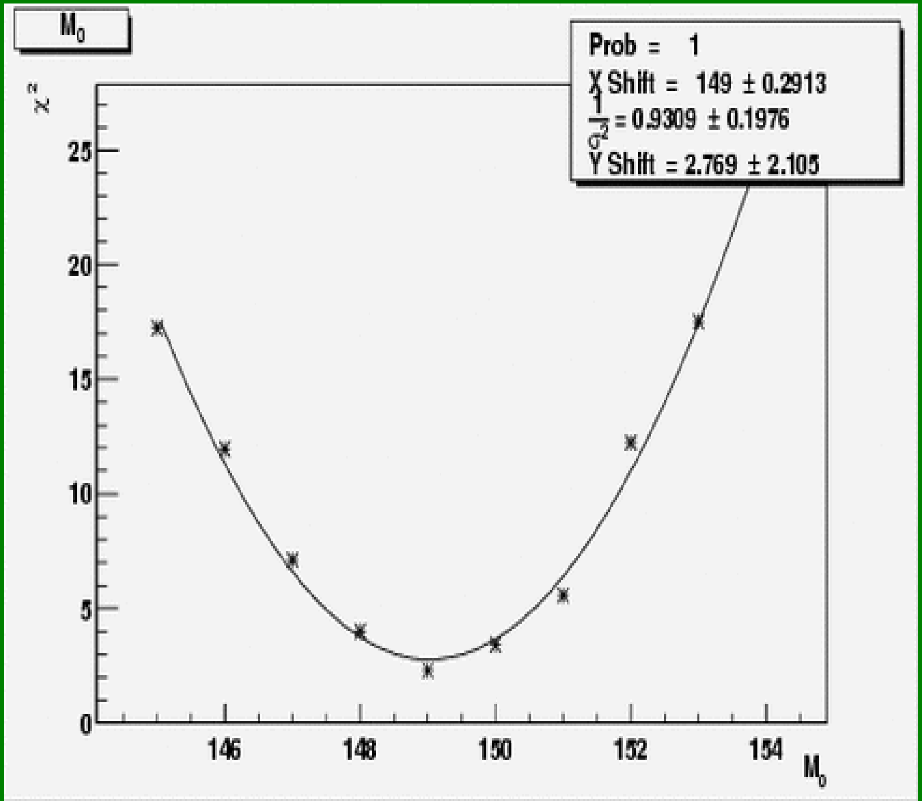


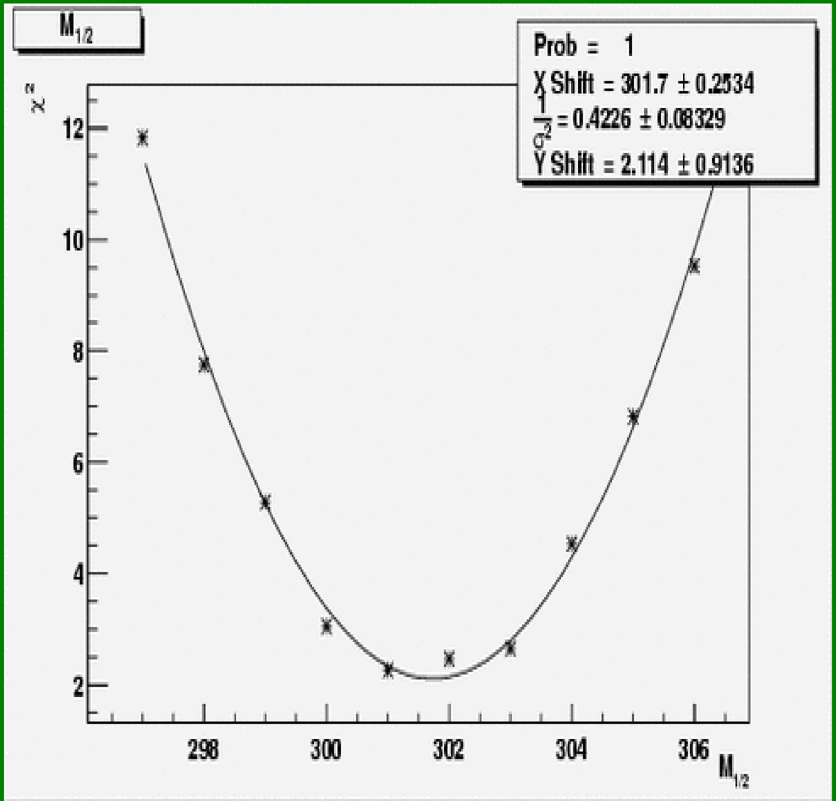


Chargino Mass Dependence on Parameters



Chi-Square fits to the Electron Energy Distribution





Resultant Masses from Fits

	Input Mass	Before Strahl End Point	After Strahl End Point	ChiS Fit
ν_e	243.8	243.6	248.9	243.5
χ_1^+	222.4	222 .1	227.4	222 .0

CONCLUSION

The slepton, sneutrino signals are easy to observe and easy to measure with positron polarization if the 2 photon process is tagged with excellent efficiency.

The masses depend on all the parameters of the SUGRA model and hence we can determine consistency of M_0 and $M_{1/2}$ with high accuracy (~ 0.2%) and determine A_0 and $\tan(\beta)$.

Neutralino Production Study

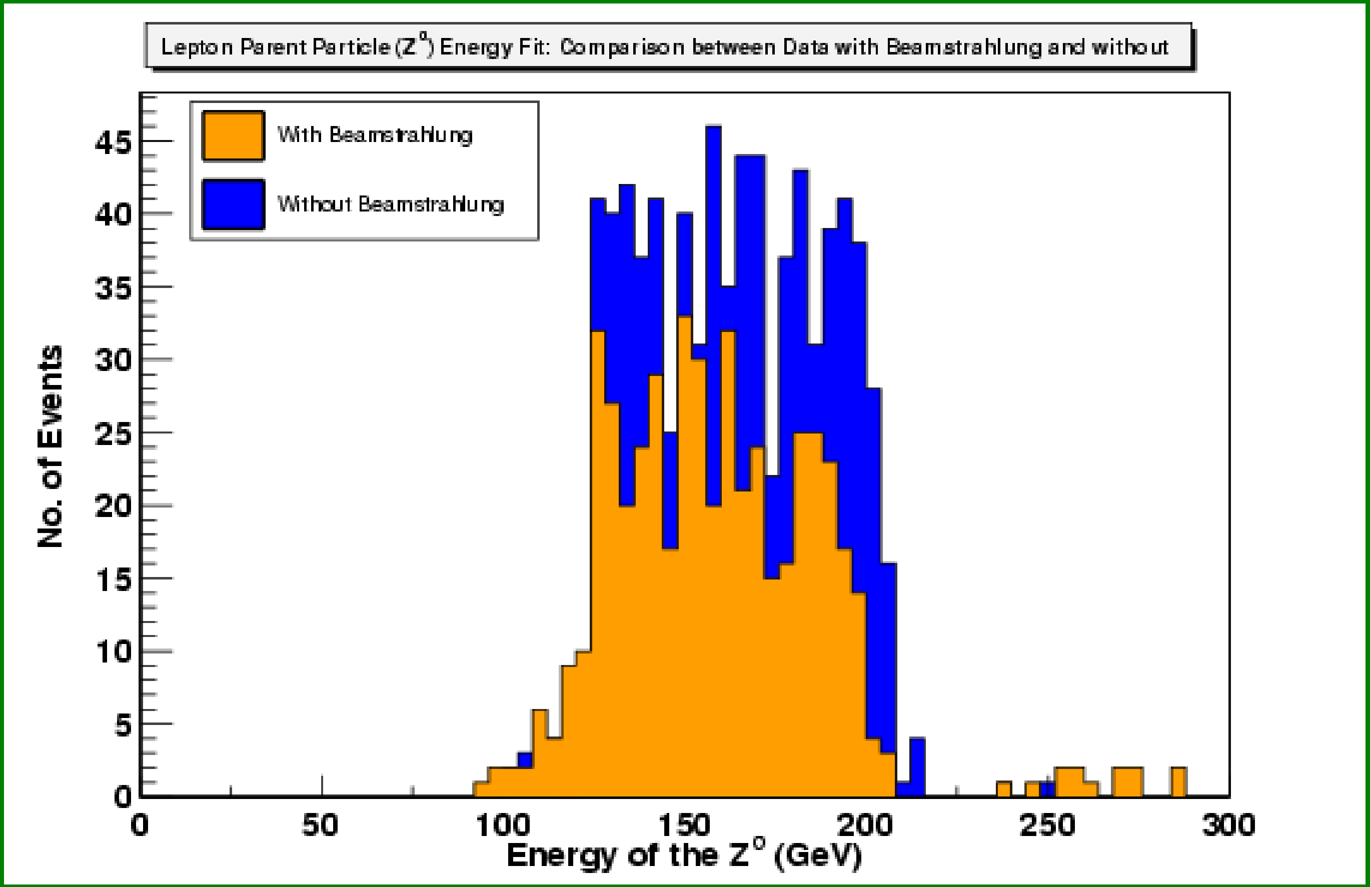
$$e^+ e^- \rightarrow \tilde{\chi}^0_2 \tilde{\chi}^0_2$$

$$\tilde{\chi}^0_2 \rightarrow Z^0 + \tilde{\chi}^0_1$$

$$Z^0 \rightarrow l^+ l^- \text{ one decay}$$

$$Z^0 \rightarrow q\,\bar{q} \text{ other decay}$$

Energy Distribution of the Z



Dependence of $\tilde{\chi}_2^0$ Mass on tan(β)