Chargino and Neutralino Masses at ILC

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IoP HEPP Annual Meeting, Oxford
08 Apr, 2009

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  - Signal selection
  - Chargino/Neutralino events separation
  - Kinematic fitting
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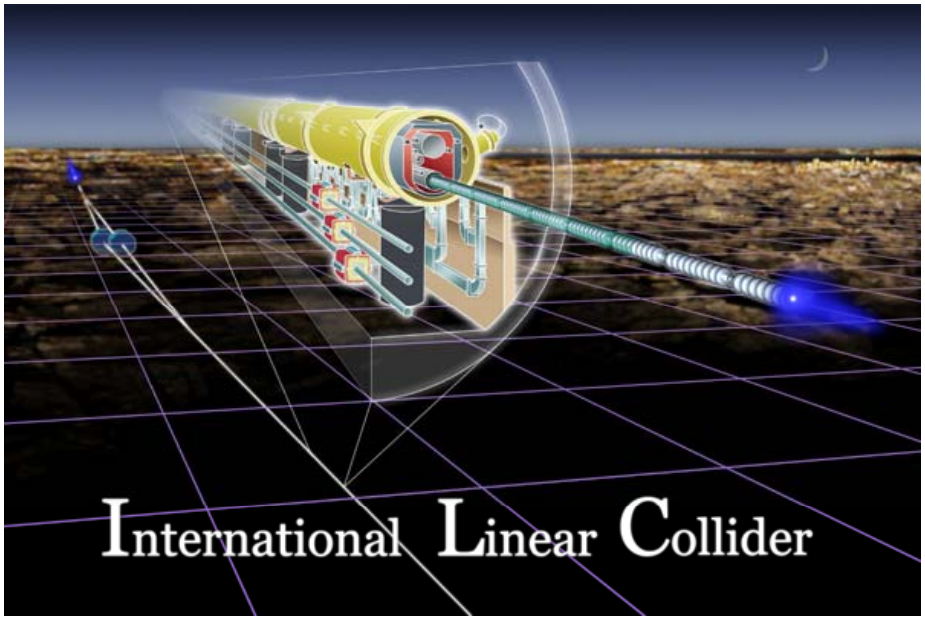
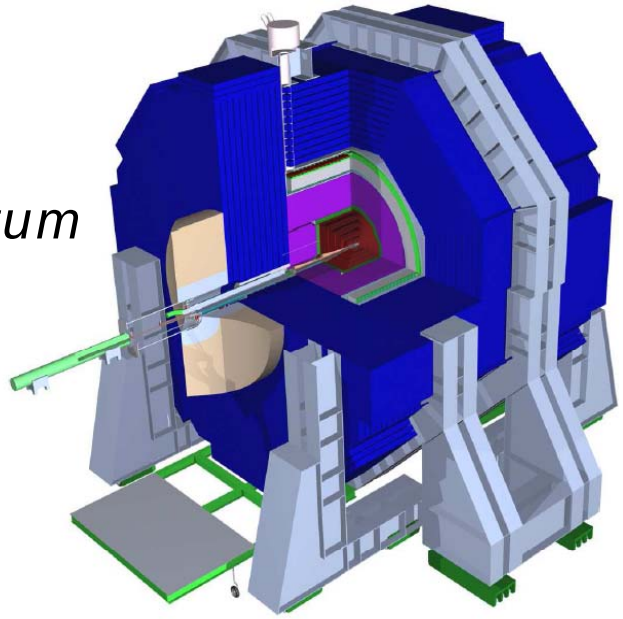
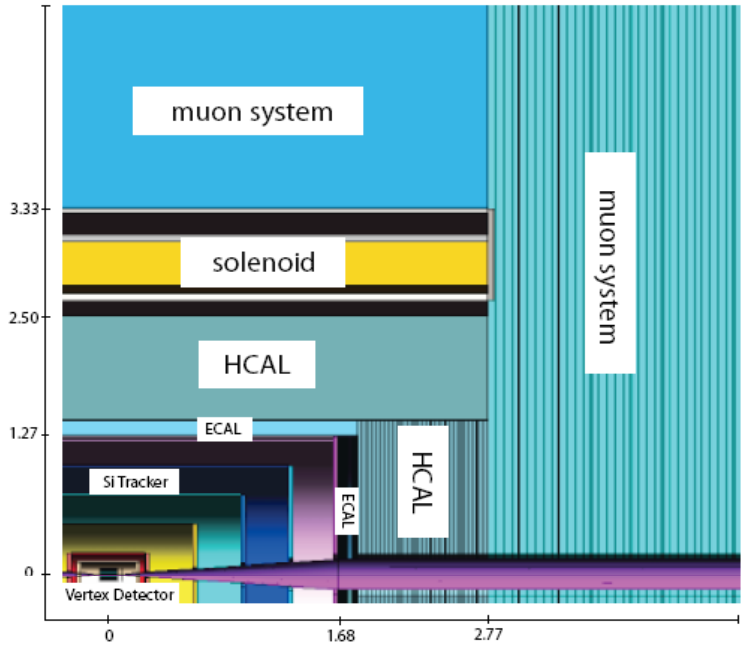
ILC and SiD



- International Linear Collider
  - e+e- , √s 500 GeV
- The Silicon Detector (SiD)
  - Particle Flow Algorithm (PFA)
  - Si vertexing & tracking,
    Si-W ECal, finely segmented HCal
  - High field (5T)

Superb energy/momentum resolution expected!





Introduction

- Physics process: (SUSY point 5 in ILC benchmarks)

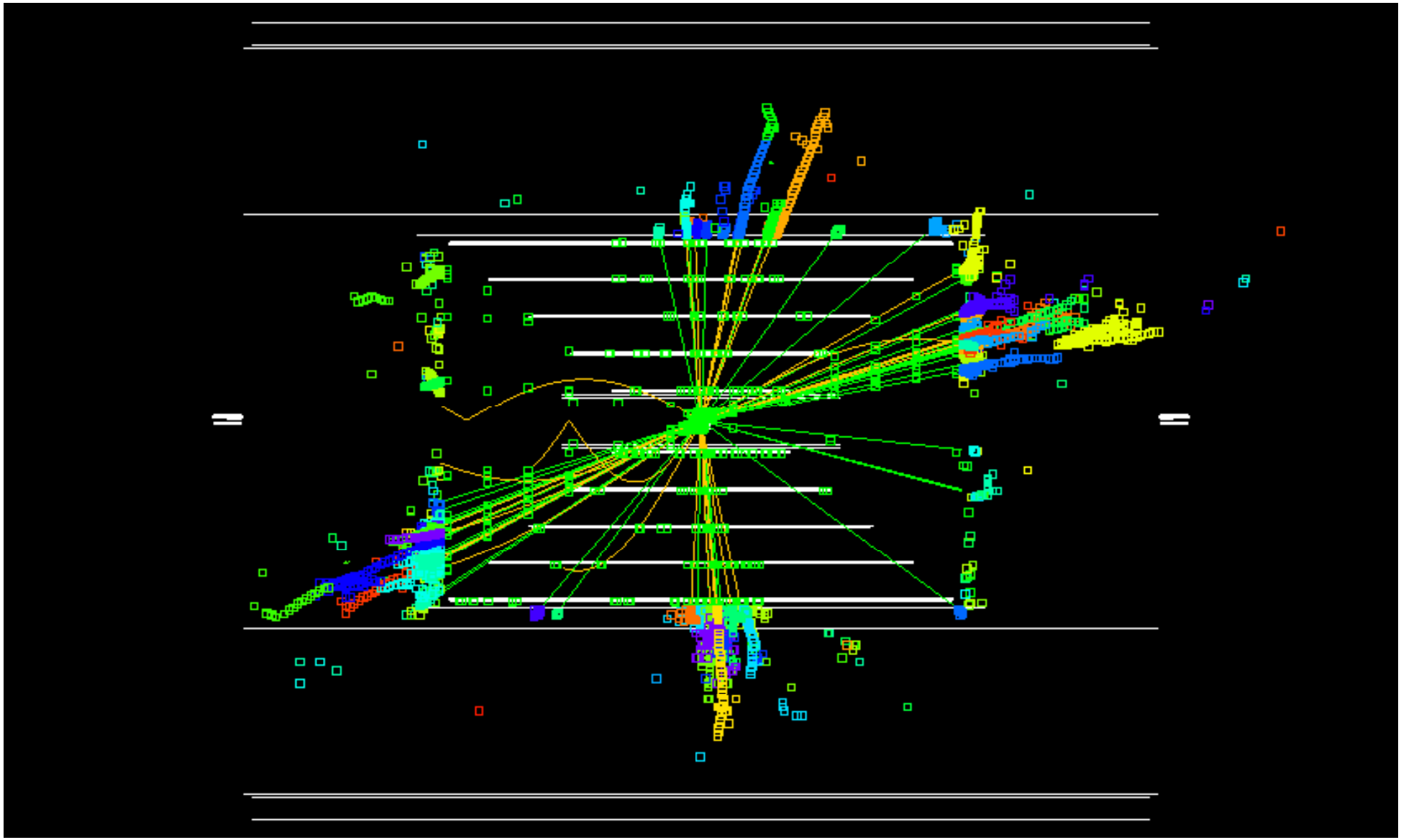
$$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 q\bar{q}q\bar{q}$$
$$e^+e^- \rightarrow \tilde{\chi}_2^0\,\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 Z^0Z^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 q\bar{q}q\bar{q}$$

parameter	value
m_0	206 GeV
$m_{1/2}$	293 GeV
$\tan\beta$	10
A	0
μ	375 GeV
$M_{\tilde{\chi}_1^0}$	115.7 GeV
$M_{\tilde{\chi}_1^\pm}$	216.5 GeV
$M_{\tilde{\chi}_2^0}$	216.7 GeV

  - $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ dominantly decay into on-shell W/Z
  - Cross-section not too small
    - $\tilde{\chi}_1^+\tilde{\chi}_1^-$ ~ 100 fb
    - $\tilde{\chi}_2^0\,\tilde{\chi}_2^0$ ~ 10 fb
  - The gauge boson energy depends on the parent and LSP mass

    Precision measurement on SUSY parameter!
- Signature: 4 jets (from 2 acoplanar W/Z) + missing energy
  - WW/ZZ seperation: good PFA performance required!

e+e- -> ne2ne2 -> ne1ne1ssdd



Samples

- SUSY samples:
  - √s = 500 GeV; 500 fb-1 luminosity; ~ 1.2M events /sample
  - Polarization: 80% e- L, 30% e+ R
  - Backgrounds: e+e- -> ne1ne2, slepton pair production

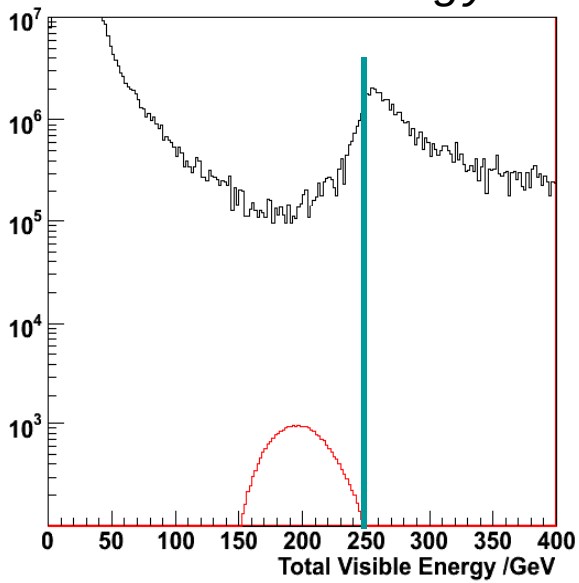
sample	$m_{\tilde{\chi}_1^0}$ (GeV)	$m_{\tilde{\chi}_1^\pm}$ (GeV)	$m_{\tilde{\chi}_2^0}$ (GeV)
Template	115.7	216.7	216.5
neu1 + 0.5	117.2	216.7	216.5
ch + 0.5	115.7	217.2	216.5
ch + 0.5	115.7	216.7	217.0

- Inclusive SM background: 500 GeV, ~ 4.7 M events

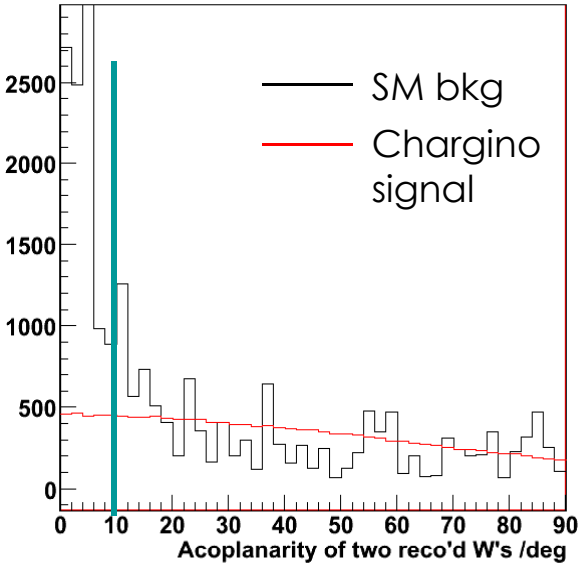
Signal selection

cut	value
E_{jet}	> 10 GeV
Fraction of EM energy in each jet	$< 80\%$
Number of tracks	> 20
Total visible energy	< 250 GeV
Thrust	< 0.85
$\cos\theta_{thrust}$	< 0.9
$\theta(1, 2)$	$> 60°$
$\theta(1, 3)$, $\theta(1, 4)$, $\theta(1, 3)$	$> 40°$
$\theta(2, 4)$, $\theta(3, 4)$	$> 20°$
Acoplanarity of two reconstructed gauge bosons	$> 10°$

Total visible energy



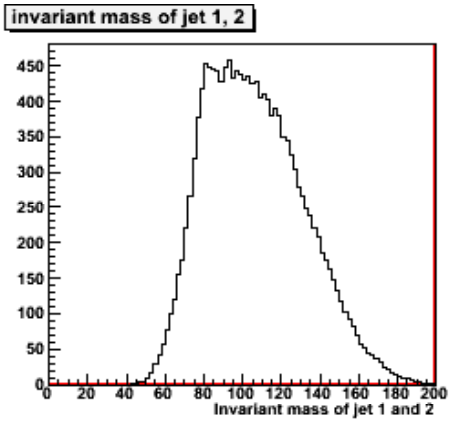
Acoplanarity btw 2 W's

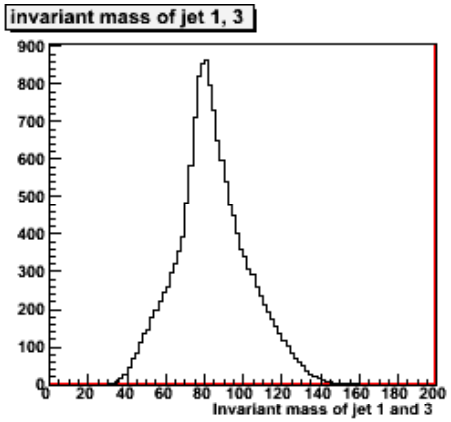


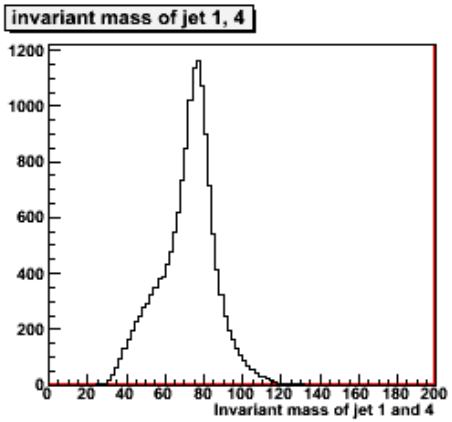
Before Chargino/Neutralino seperation:

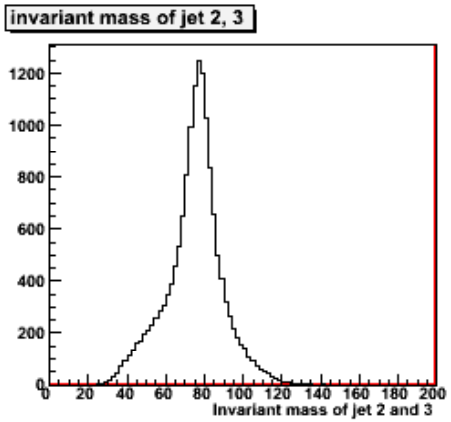
	Chargino all-haronic signal	Neutralino all-haronic signal	SM background
Efficiency	60.1%	59.3%	0.0004%
Composition	36.7%	6.9%	53.5%

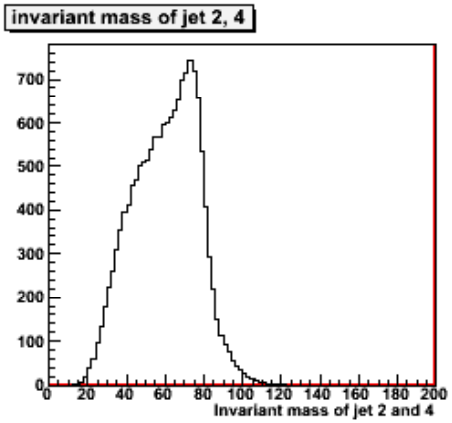
W/Z Reconstruction – Jet pairing

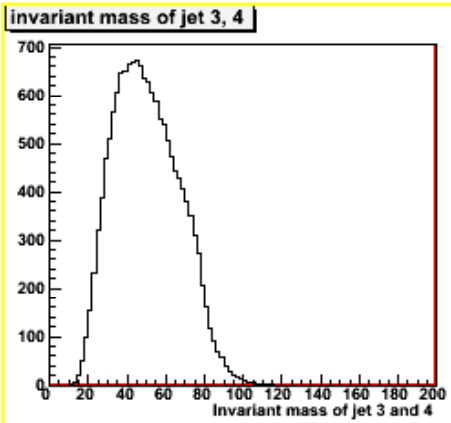








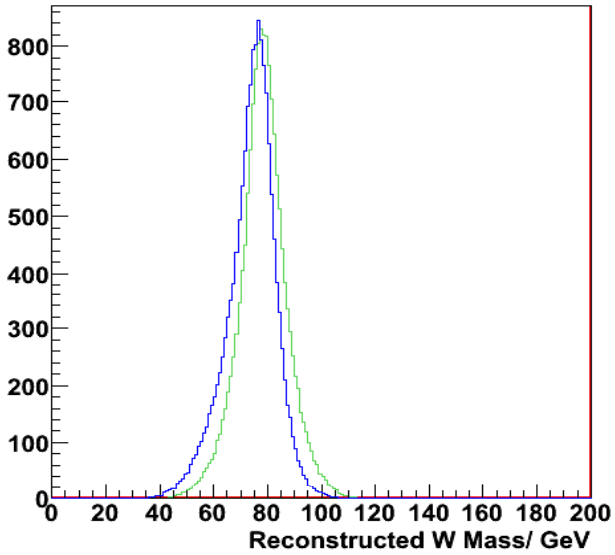




- Chargino/Neutralino signal separation is based on the two reconstructed boson mass: W or Z
- Need to pair jets correctly
- Jet pairing optimization: Choose the combination minimizing:
- $(m_{i,k} - m_W)^2 + (m_{l,n} - m_W)^2$

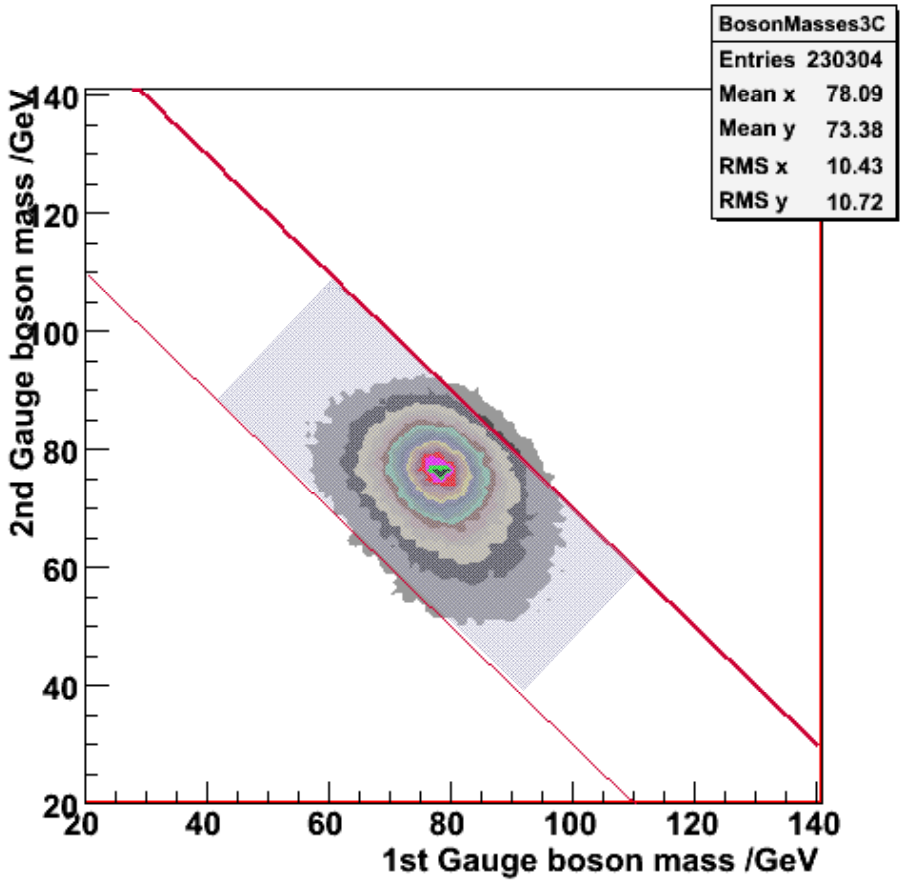
Green: Reco'd mass of 1st W

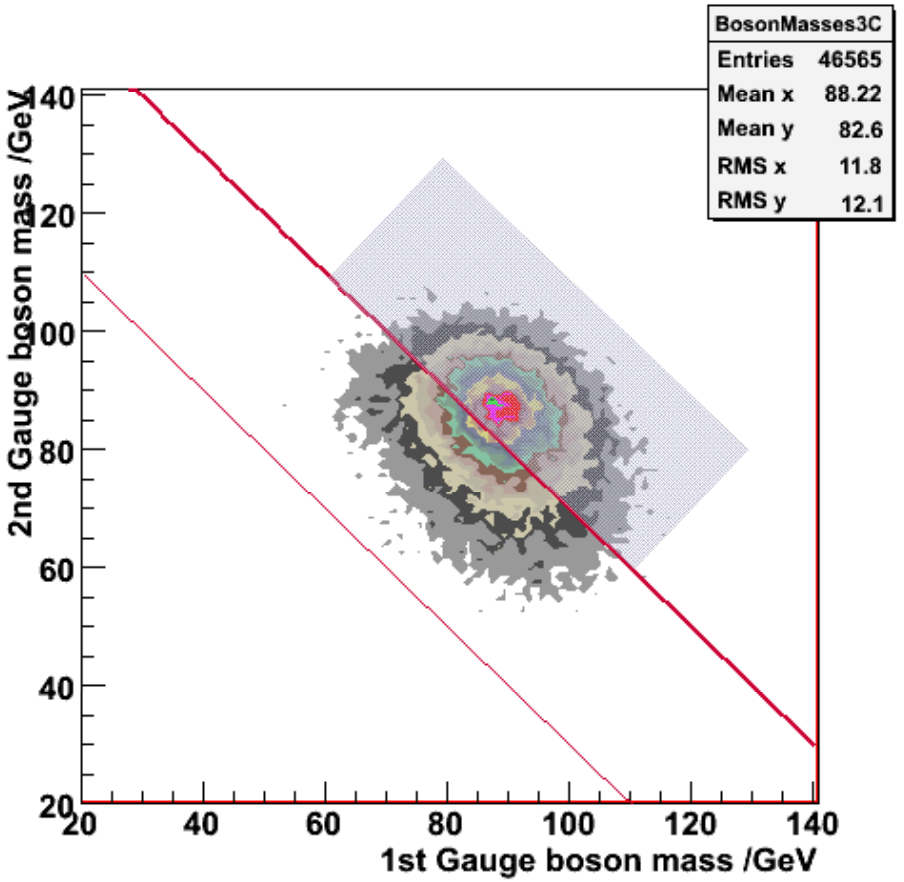
Blue: Reco'd mass of 2nd W



Chargino/ Neutralino Separation

Correlation of two di-jet masses is a powerful selection criteria





Chargino events signal

130 GeV < M(W1) + M (W2) < 172 GeV

Neutralino events signal

M(W1) + M (W2) > 172 GeV

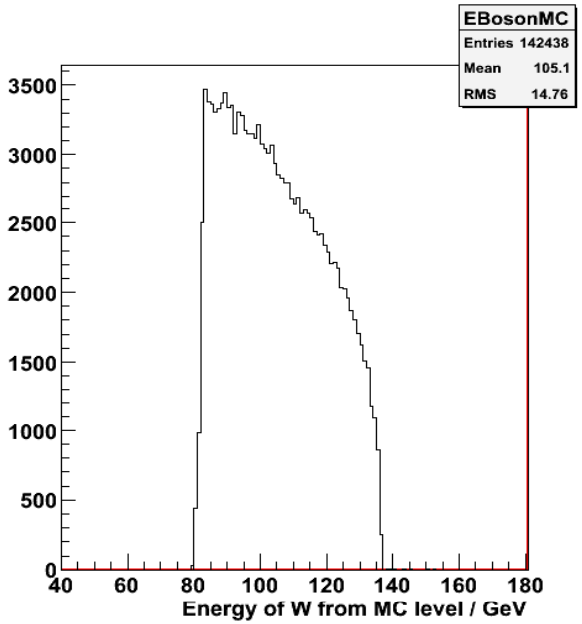
Chargino/Neutralino mass – strategy

- When chi1(ne2) -> ne1 + W(Z), in chi1 rest frame, the W is monochramatic

$$E_W = \frac{|(m_{chi}^2 + m_W^2 - m_{neu}^2)|}{2m_{chi}}$$

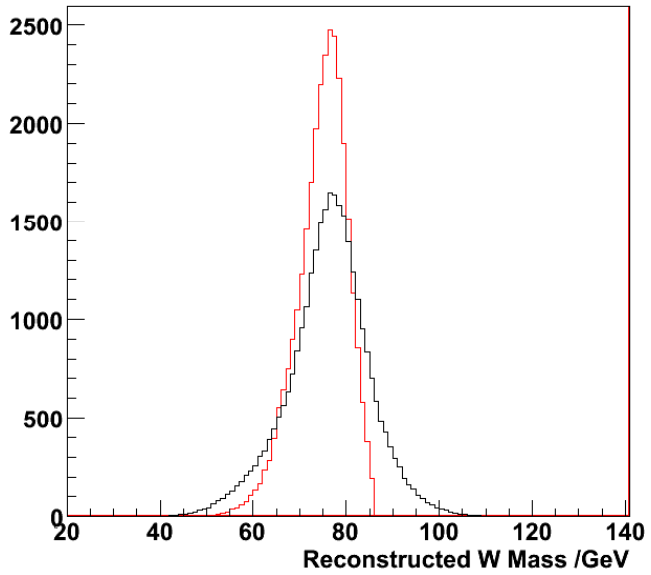
- In lab frame the W energy is boosted but still depends on the mass of chargino and neutralino.

- Therefore we can extract the chargino/neutralino mass by comparing the W/Z energy spectrum with the template.

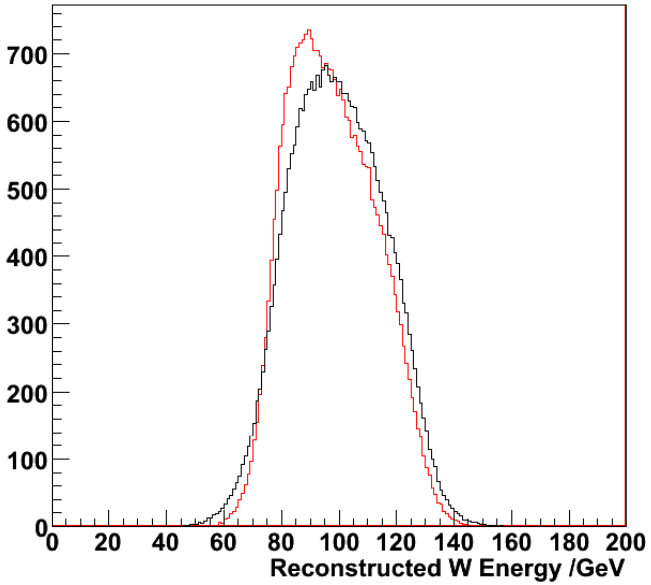


Kinematic fitting

- Kinematic fitting with one constraint (Mboson1 = Mboson2) can help improve the boson energy distribution
- Kinfit in Marlinreco package (reconstruction software based on Marlin, an ILD software framework) is used.
- The parameters used:
  - dE = 50%/√E; d\theta = 0.1 rad; d\phi = 0.1 rad



Reco'd W mass



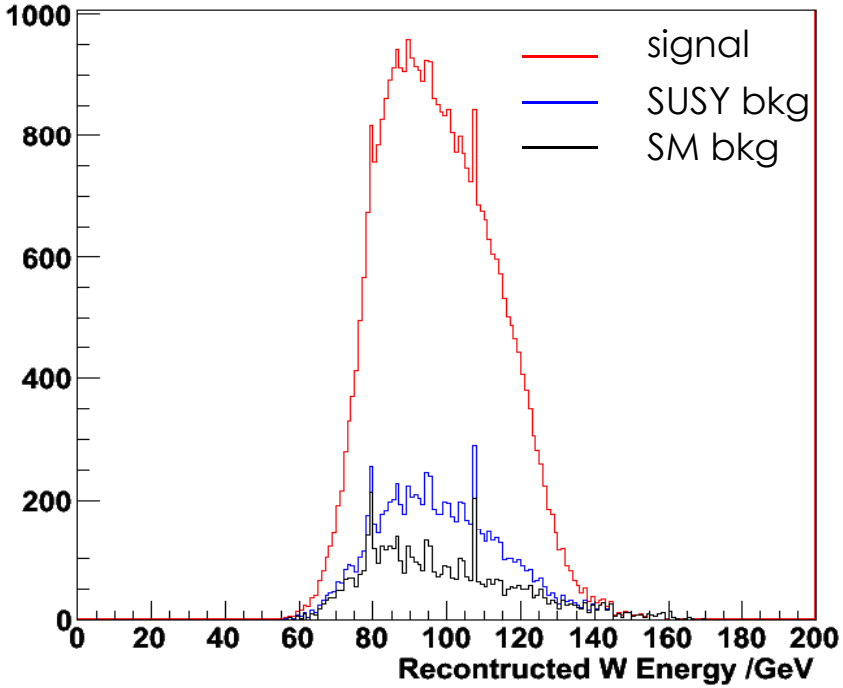
Reco'd W energy

Chargino selection:

Before/ After Kinfit

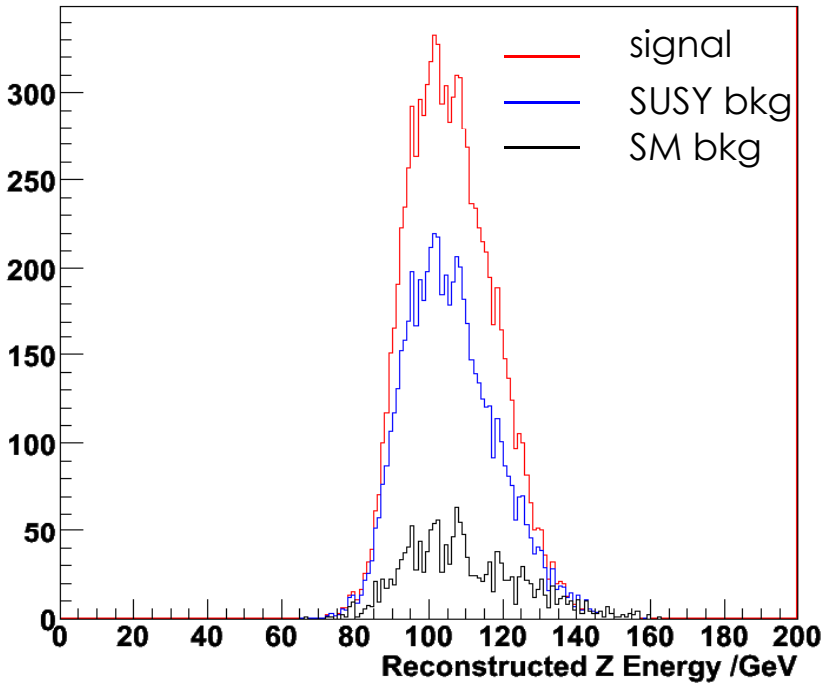
Result – boson energy spectrum

Chargino selection:



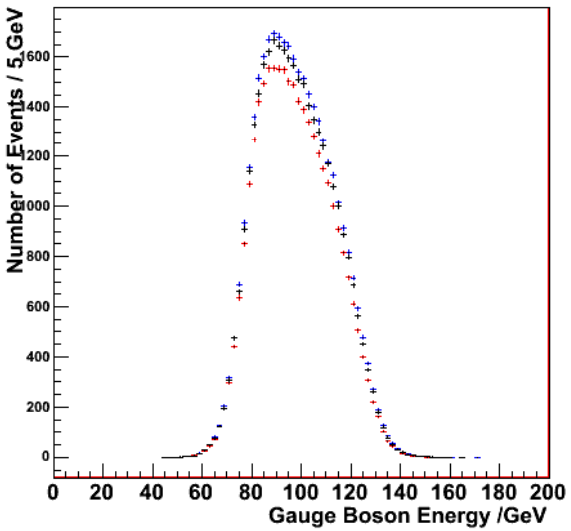
Purity :	75.3%
Efficieny :	53.8%
Xsection error:	0.9%

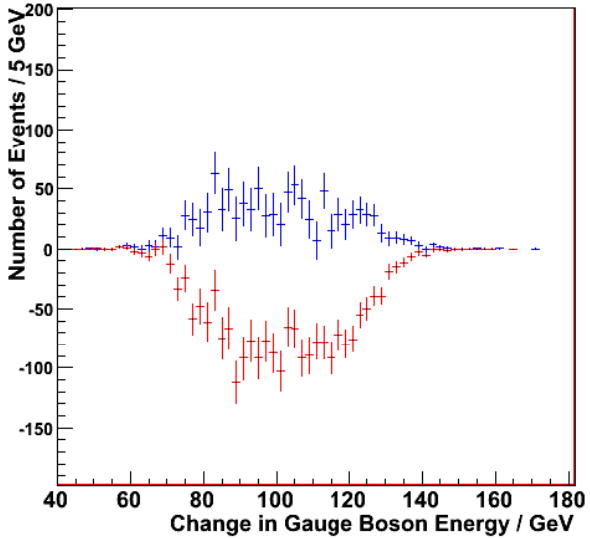
Neutralino selection:

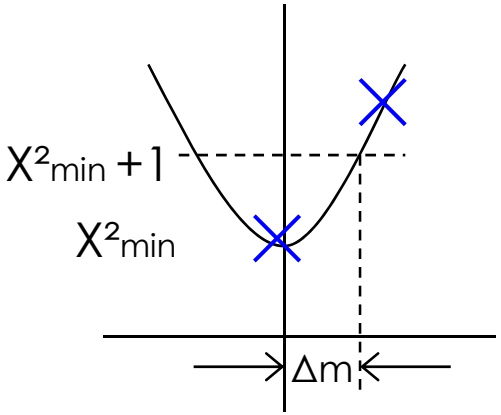


Purity :	33.7%
Efficieny :	30.2%
Xsection error:	4.2%

Result – mass uncertainty







Blue: chargino+0.5, red: neu1+0.5

Chargino signal templates (SM bkg not included)

$$\chi_1^2 = \sum_{i=0}^{Nbins} \frac{(y_{template1,i} - y_{data,i} + \delta_i)^2}{\sigma^2_{template1,i} + \sigma^2_{data,i} + \sigma^2_{SM,i}}$$

Chargino selection		Neutralino selection	
Chargino	95 MeV	Neu2	369 MeV
Neu1	54 MeV	Neu1	102 MeV
		(Chargino	395 MeV)

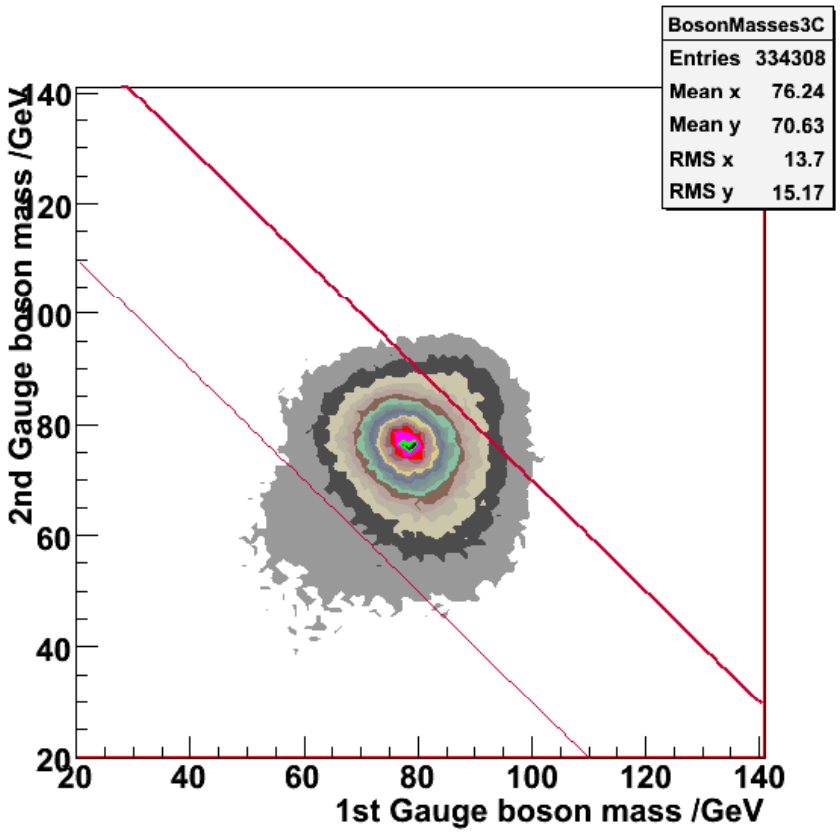
Summary

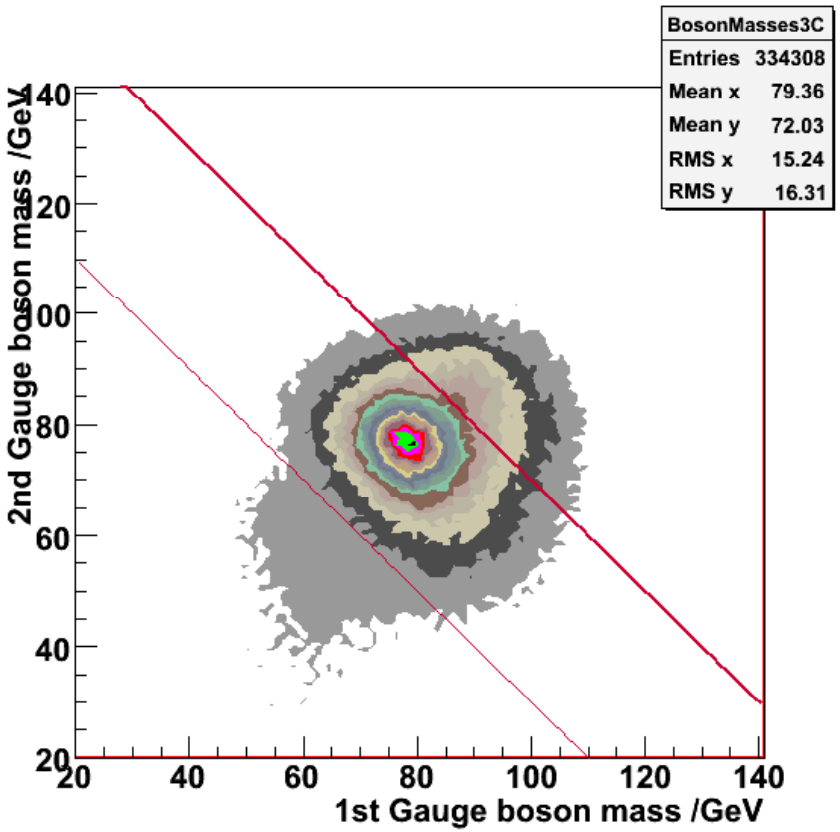
- Chargino / neutralino events can be identified at the presence of SM bkg, and separated from each other.
- The cross section uncertainty of chargino and neutralino signals are 0.9% and 4.2% respectively (without considering the uncertainty on efficiencies)
- The statistical error of chargino and neutralino 1 mass within 100MeV using template fitting method.

More details and references can be found at SiD Letter of Intent:

http://silicondetector.org/display/SiD/LOI

Backups





The two boson masses of all SUSY events

Left: chargino events selection; right: neutralino events selection