Chargino and Neutralino Masses

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Outline

- Introduction
- Samples
- Analysis methods
  - Background suppression cuts
  - Chargino/Neutralino events separation
  - Kinematic fitting
- Chargino/Neutralino mass extraction
- Summary and plan

Introduction

- Physics process:

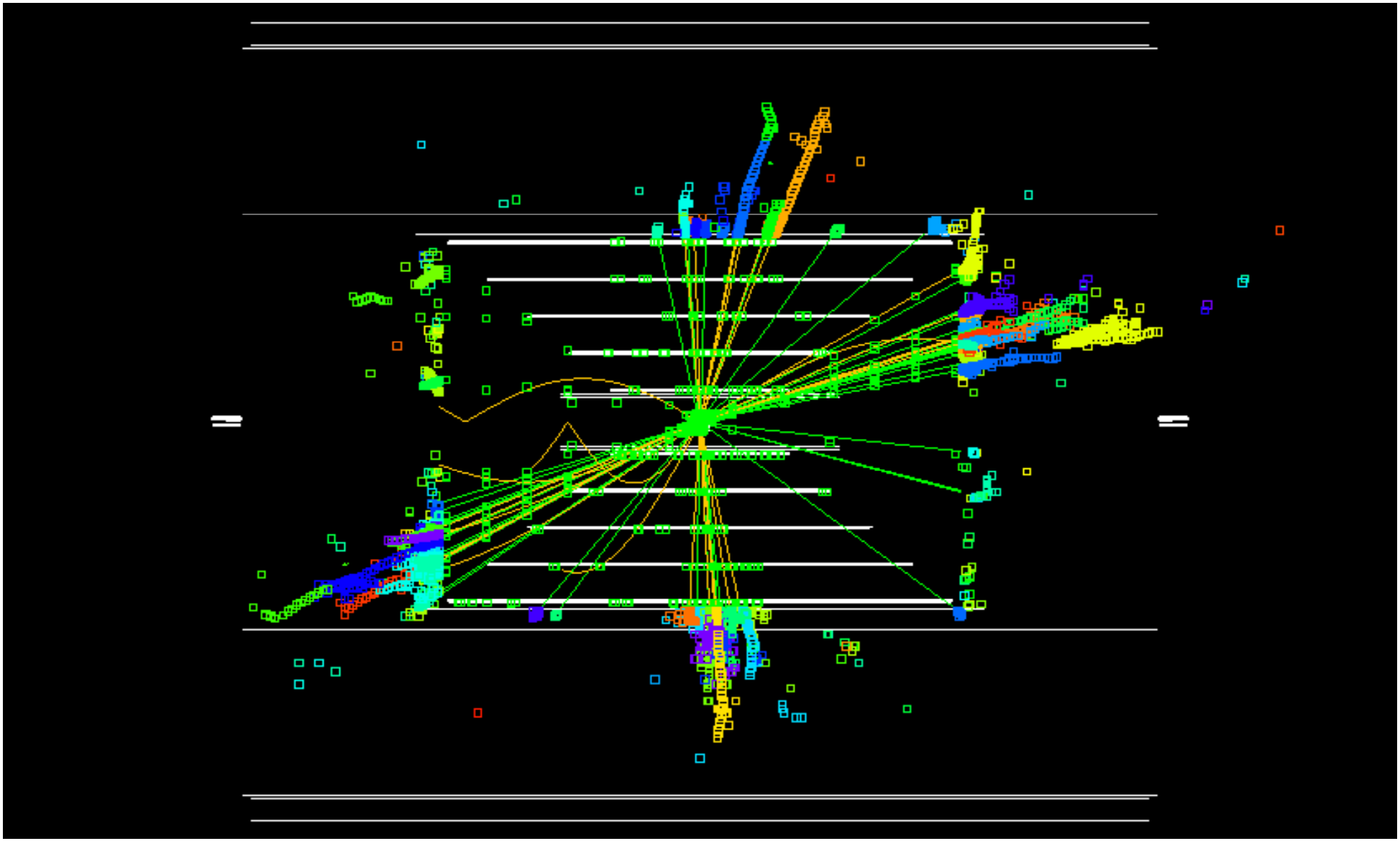
$$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 q\bar{q}q\bar{q}$$
$$e^+e^- \rightarrow \tilde{\chi}_2^0\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 Z^0Z^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0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

  - Cross-section not too small
    - Chargino pair production: ~ 100 fb
    - Neutralino pair production: ~ 10 fb
  - The gauge boson energy depends on the parent and LSP mass
  - All hadronic decay channel of gauge boson

    => signature: 4 jets + missing energy

Introduction

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
  - Cross section (all boson decay channels included):
    - Chargino events: 132.0 fb
    - Neutralino events: 23.28 fb
  - Backgrounds: e+e- -> ne1ne2, slepton pair production

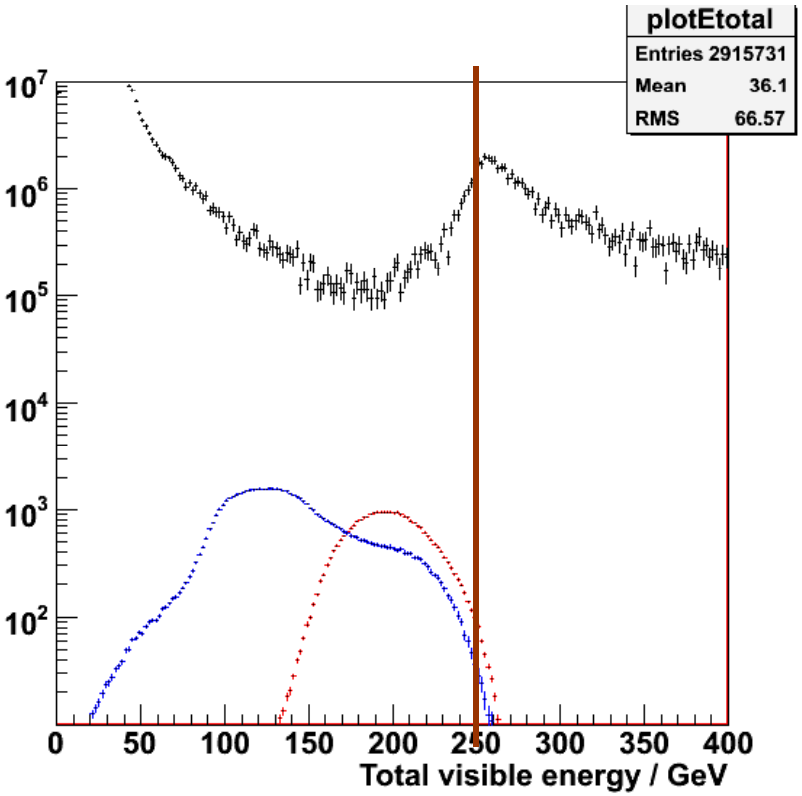
sample	$m_{\tilde{\chi}_1^0}$ (GeV)	$m_{\tilde{\chi}_1^\pm}$ (GeV)	$m_{\tilde{\chi}_2^0}$ (GeV)
Reference	115.7	216.7	216.5
$m_{\tilde{\chi}_1^0} + 0.5$	117.2	216.7	216.5
$m_{\tilde{\chi}_1^\pm} + 0.5$	115.7	217.2	216.5
$m_{\tilde{\chi}_2^0} + 0.5$	115.7	216.7	217.0

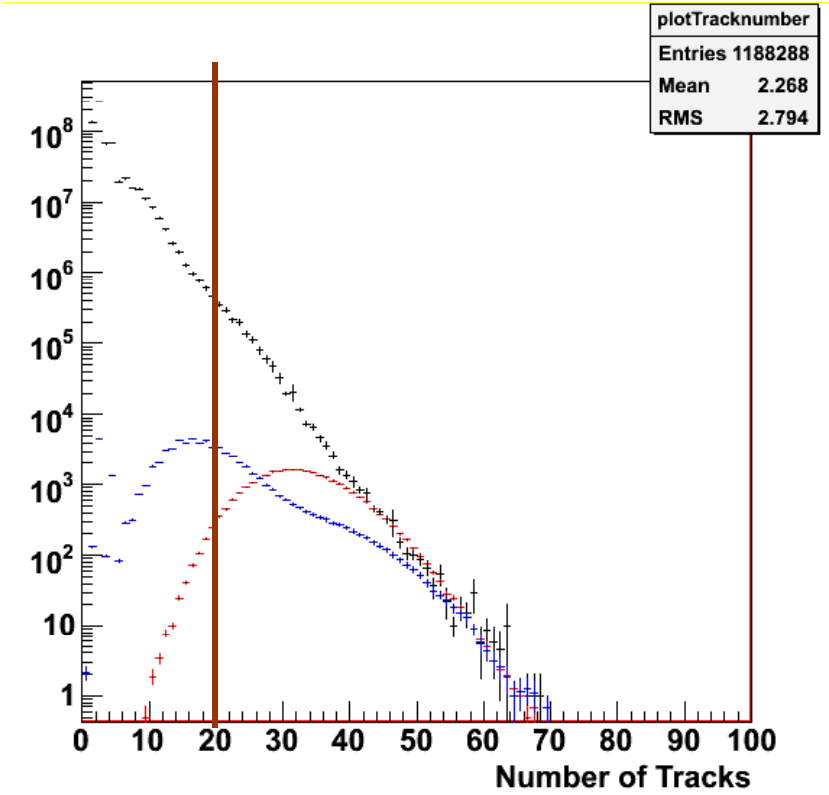
- SM background: 500 GeV, ~ 4.7 M events

Selection cuts

Number of jets	4
Total visible energy	< 250 GeV
Number of tracks	>20
Thrust	< 0.85
Cos θ_{thrust}	< 0.9
E(jet)	> 10 GeV
No isolated lepton	
E_lepton (in jet i)	$E_{lepton,\,1}$< 40 GeV, $E_{lepton,\,2}$< 40 GeV, $E_{lepton,\,3}$< 40 GeV, $E_{lepton,\,4}$< 40 GeV
f(EM)	< 80%
Angle between jets	θ 12 < 60°; θ13, θ14, θ23 < 40°; θ 24, θ34 < 20°
Acollinearity of two reco bosons	> 10 degree

Selection cuts – visible energy, multiplicity



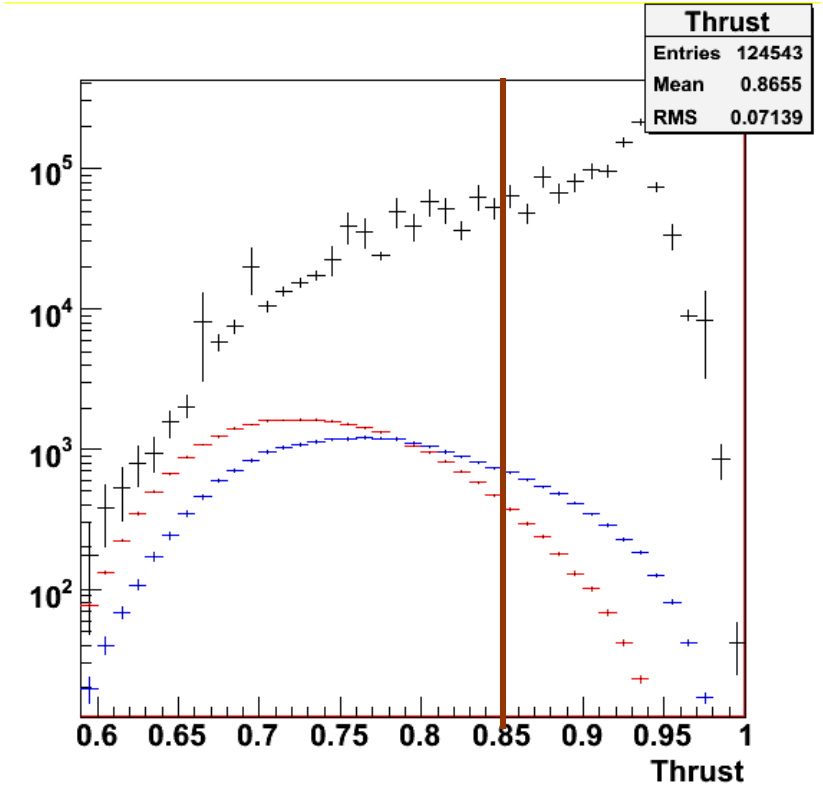


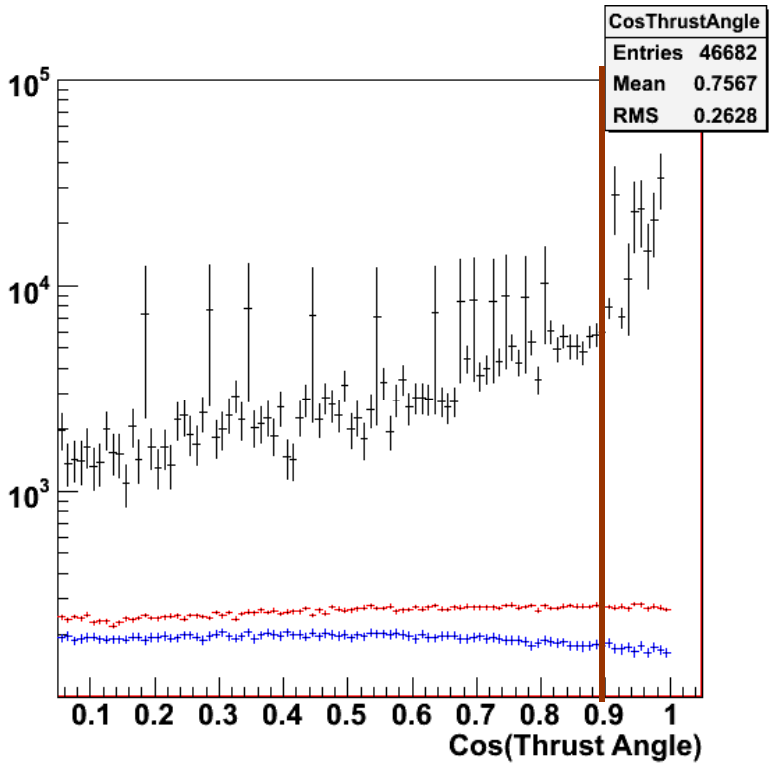
Red: Chargino signal (all hadronic channel)

Blue: SUSY background

Black: SM background

Selection cuts - thrust, thrust angle





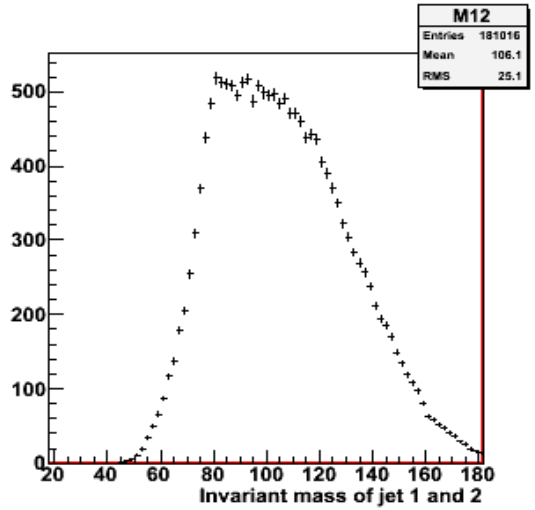
Red: Chargino signal (all hadronic channel)

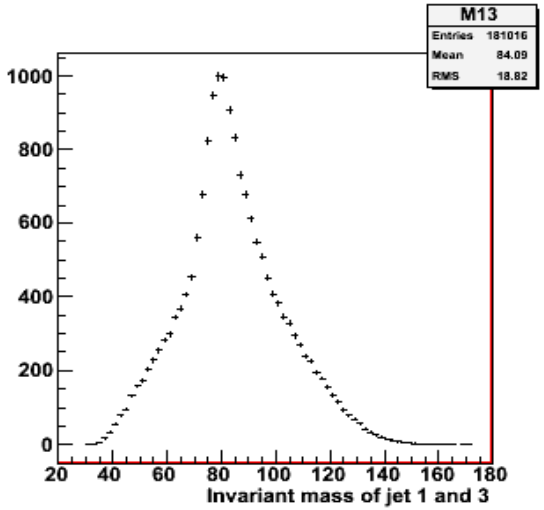
Blue: SUSY background

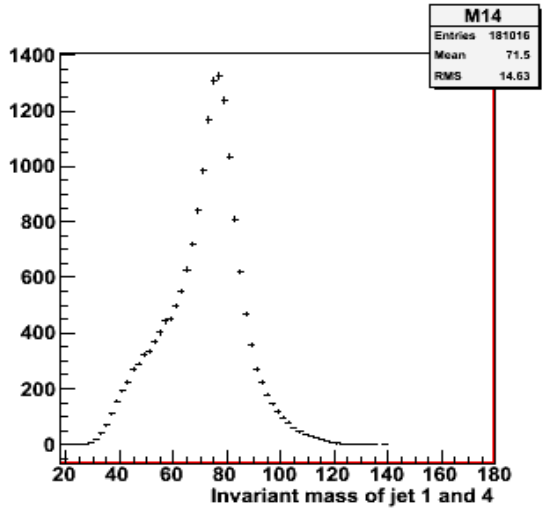
Black: SM background

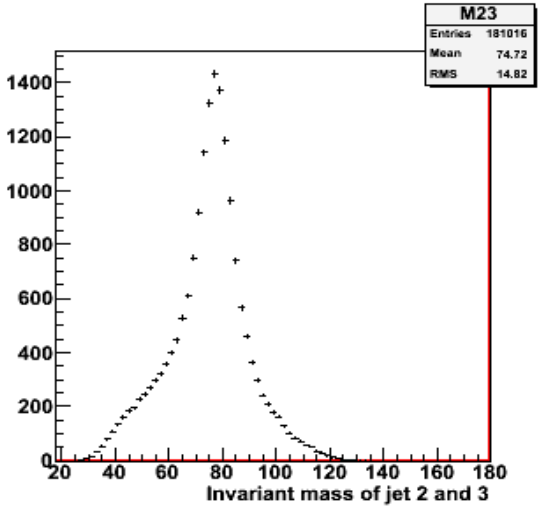
Chargino/ Neutralino Separation

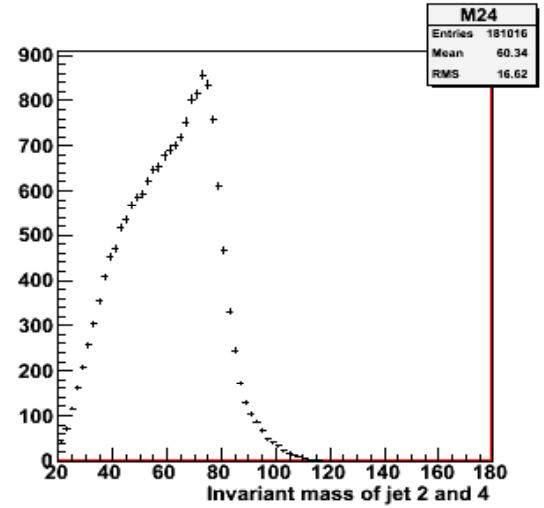
- Based on the two reconstructed boson mass: W or Z
- Need to pair jets correctly
- All jet combinations for chargino selection:

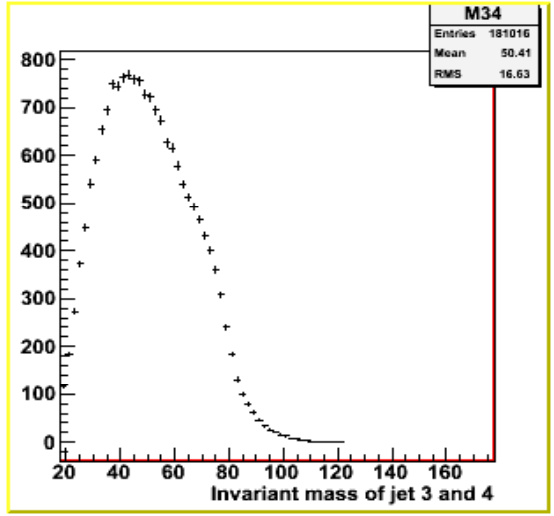






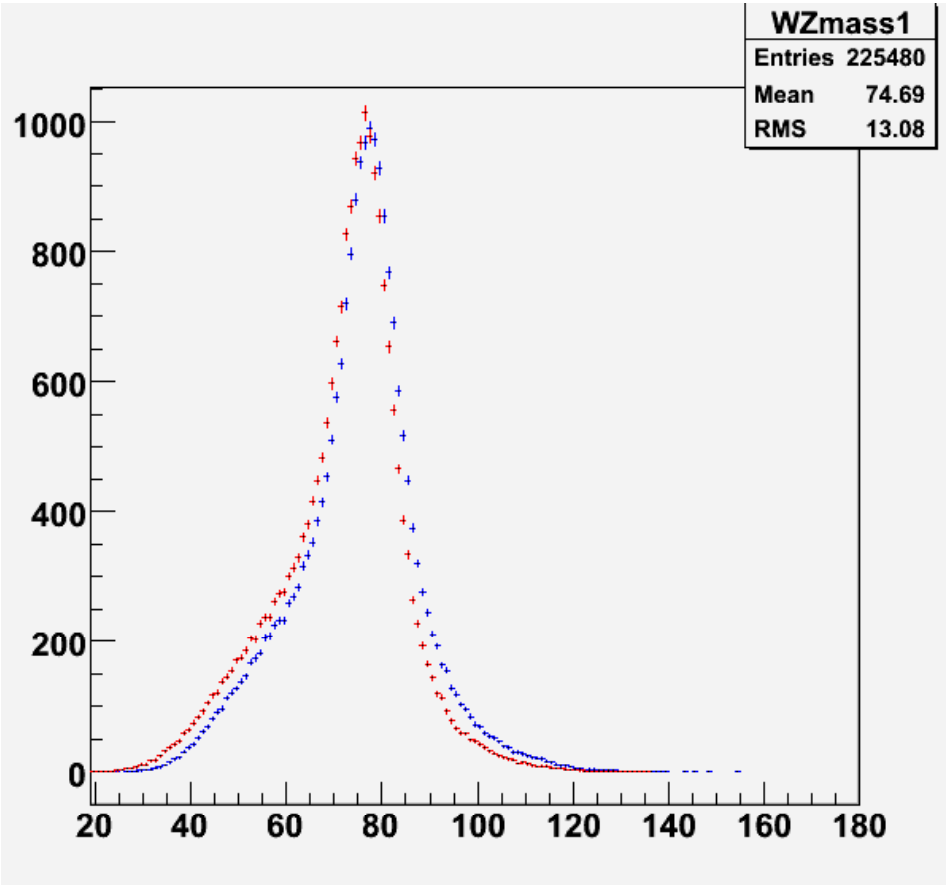






Chargino/ Neutralino Separation

- Jet pairing optimization:
- Choose the combination minimizing:
- $(m_{j1,j2} - m_W)^2 + (m_{j3,j4} - m_W)^2$

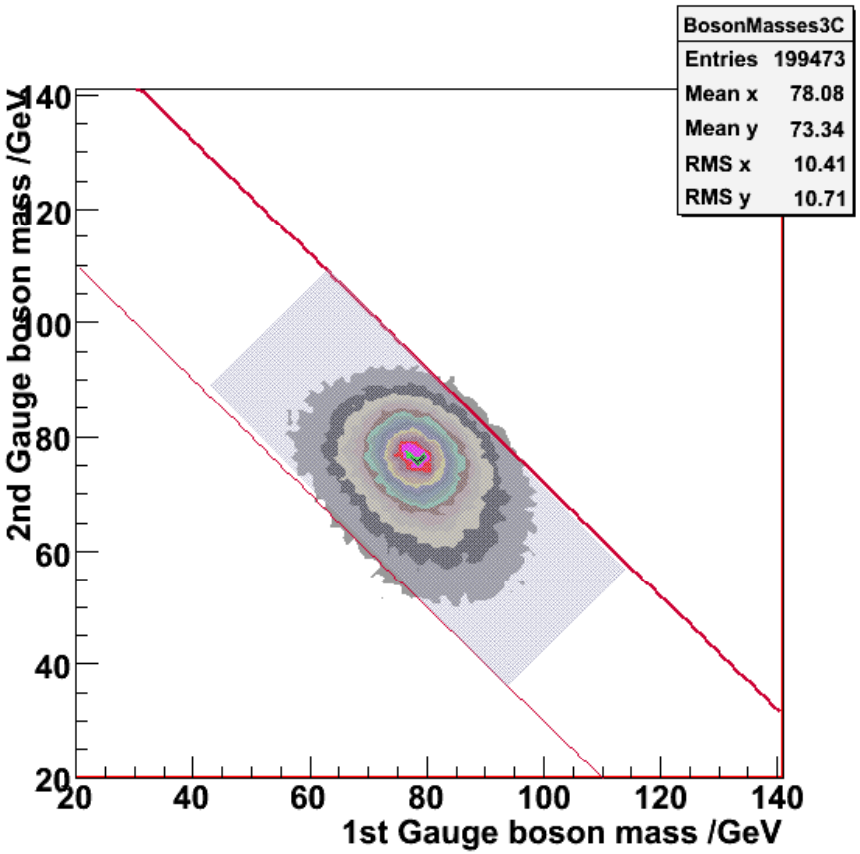


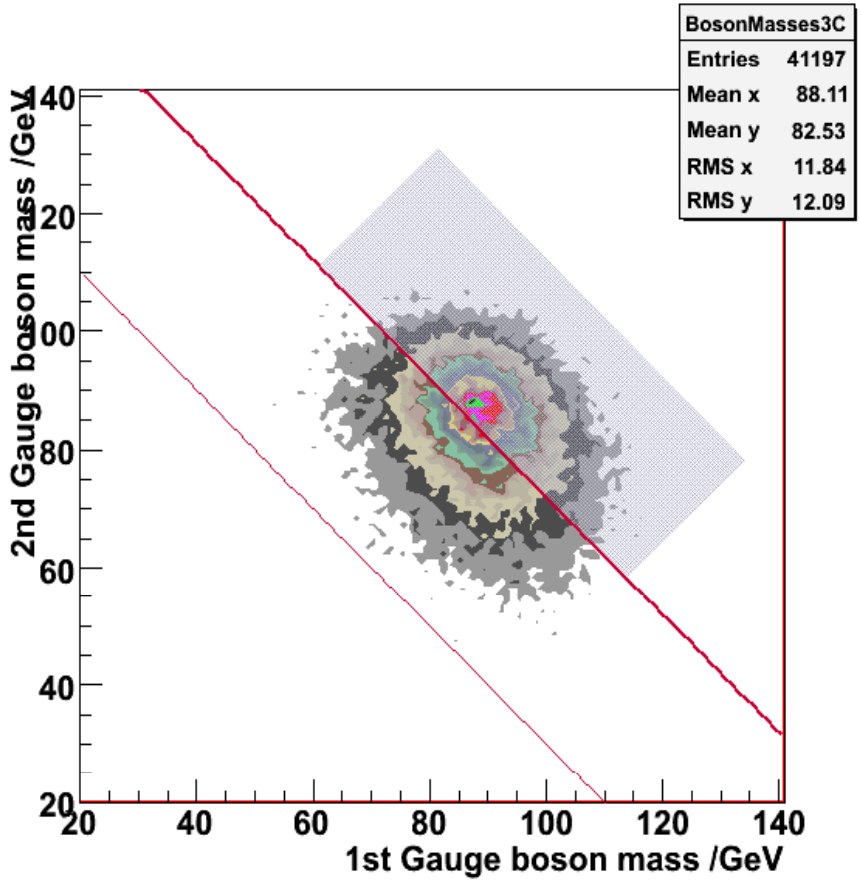
Blue: Reco'd mass of 1st W

Red: Reco'd mass of 2nd W

Chargino/ Neutralino Separation

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





Chargino events signal

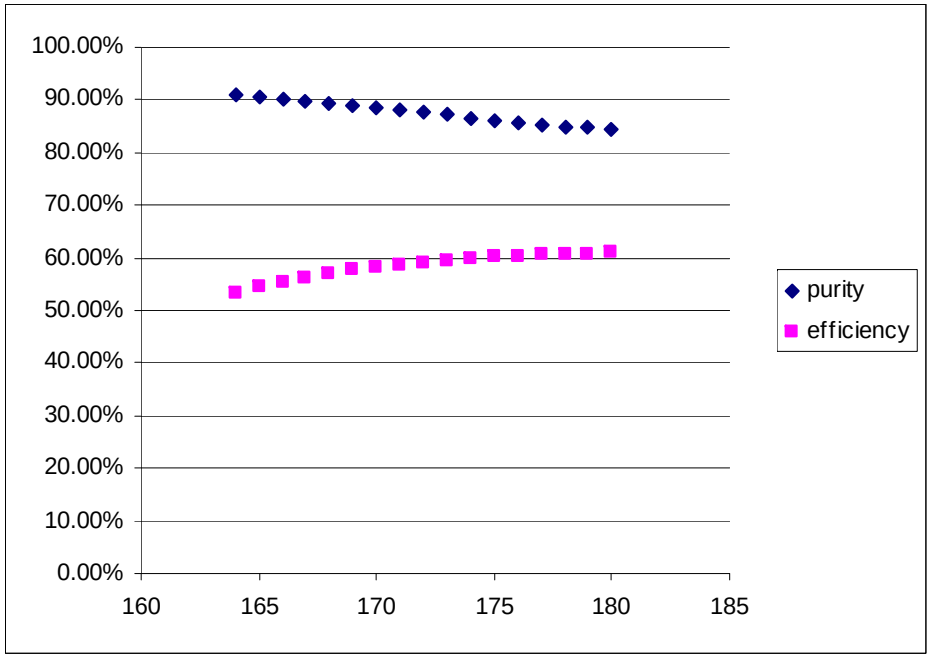
130 GeV < M(W1) + M (W2) < 172 GeV

Neutralino events signal

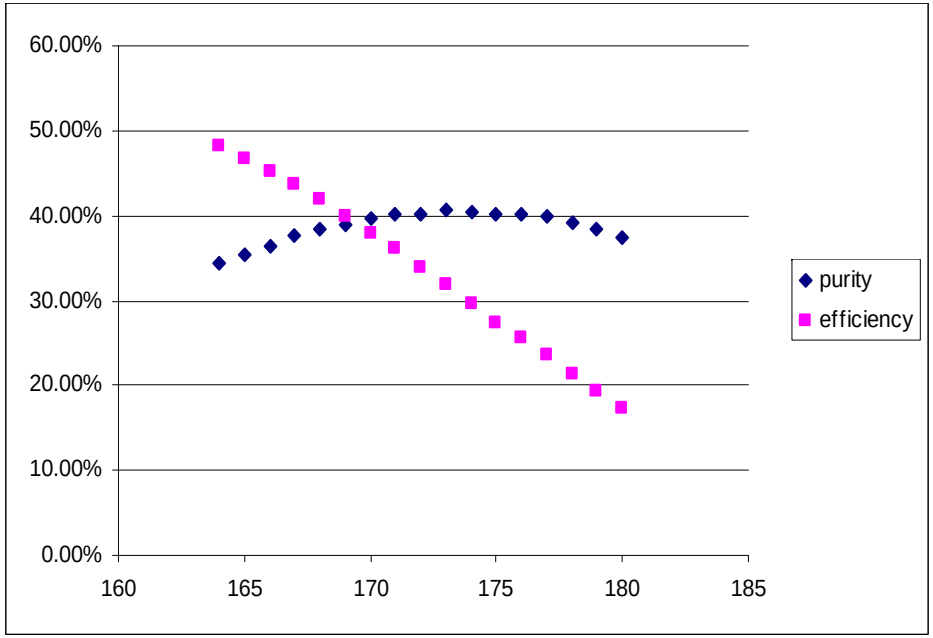
M(Z1) + M (Z2) > 172 GeV

Chargino/ Neutralino Separation

Di-jet mass correlation cut



Chargino



Neutralino

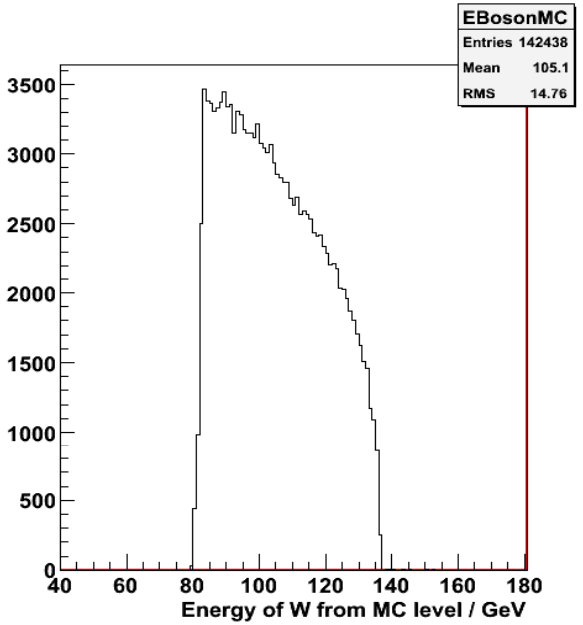
Boson energy & Chargino/Neutralino mass

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

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

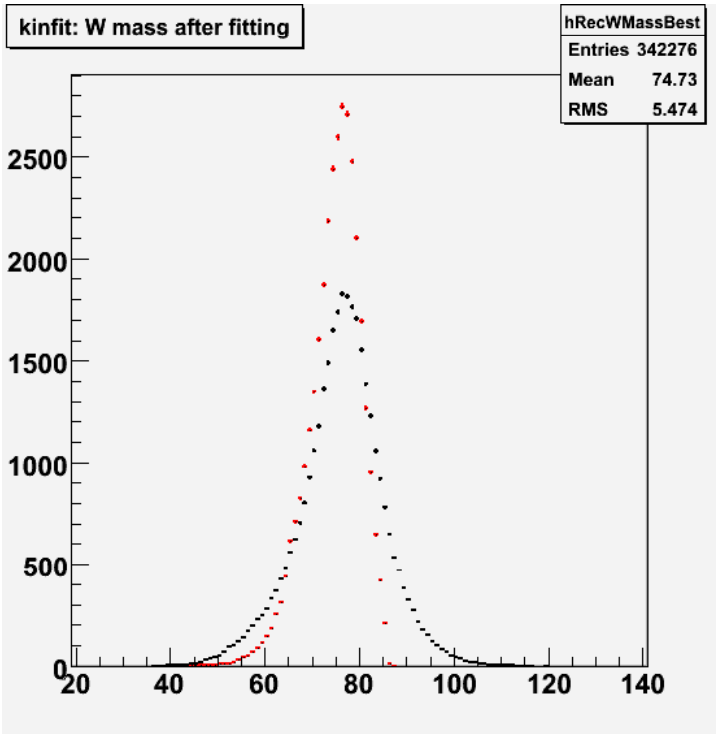
- In lab frame the W energy is boosted but still depends on the mass of chargino and neutralino.

- Therefore we can extract the chargino/neutralino energy (or their difference wrt MC sample) by comparing the W/Z energy spectrum with the template.

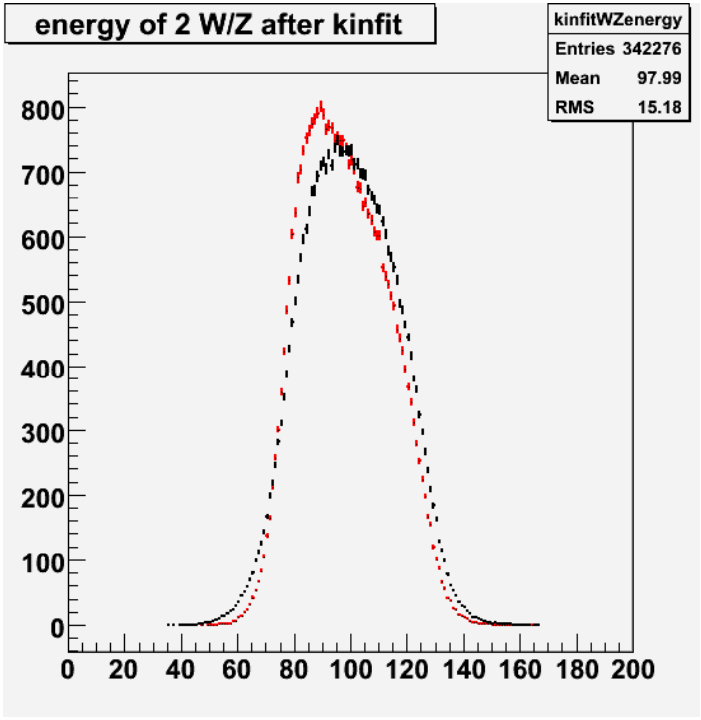


Kinematic fitting

- Kinematic fitting with one constraint (Mboson1 = Mboson2) can help improve the boson energy distribution
- Kinfit in Marlinreco package 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

Results

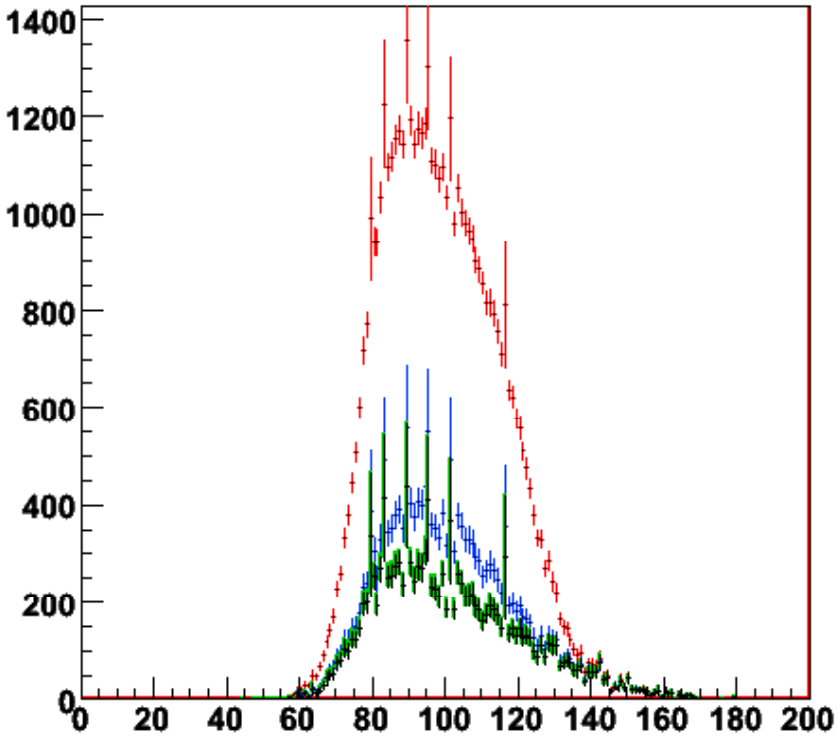
Chargino selection

---- (all hadronic) Chargino signal

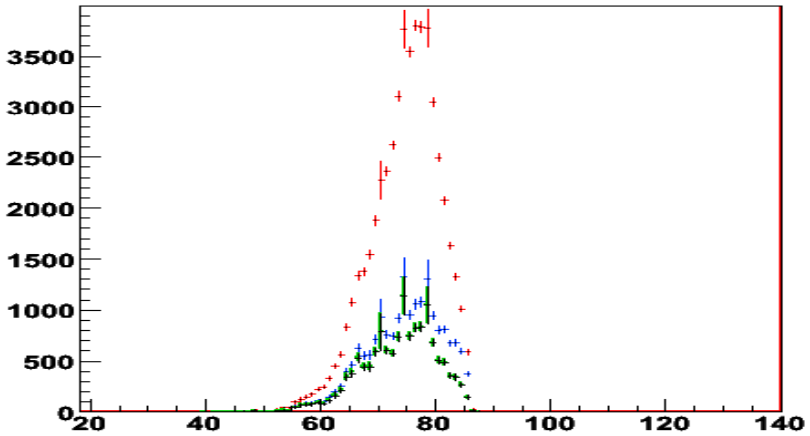
---- Neutralino events as bkg

---- Other SUSY bkg

---- SM bkg



Reco'd W energy /GeV



Reco'd W mass /GeV

Purity: 63.05%

Efficiency: 59.58%

Background:

- SM 75.46%, neu2neu2 23.82%, other SUSY bkg 0.27%

Results

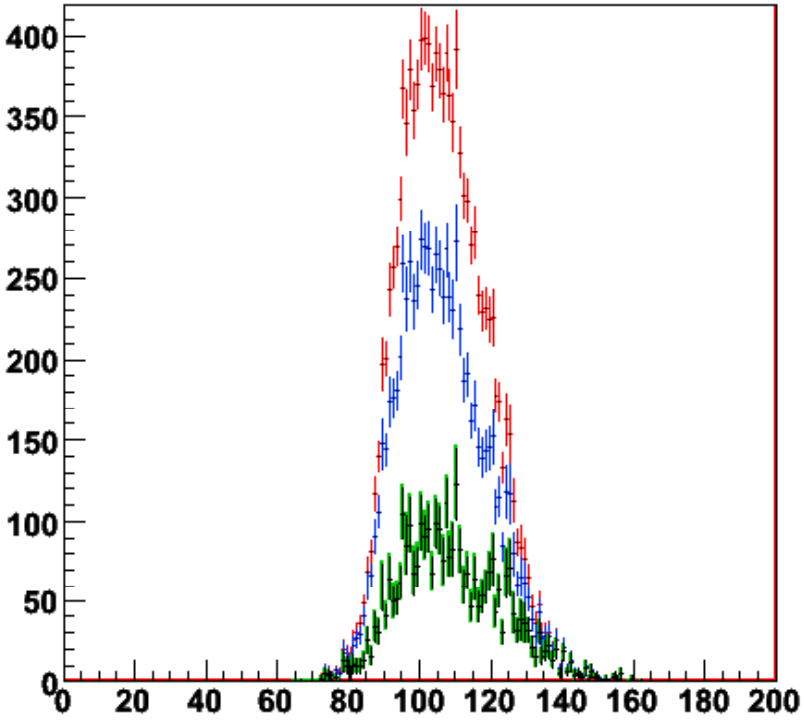
Neutralino selection

---- (all hadronic) Neutralino signal

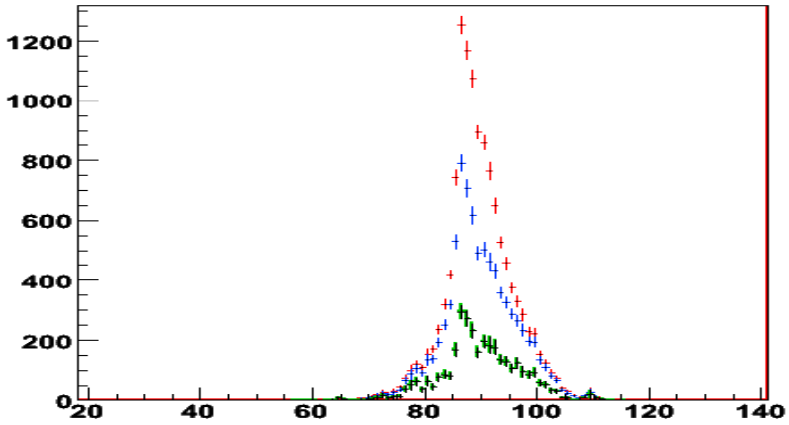
---- Chargino events as bkg

---- Other SUSY bkg

---- SM bkg



Reco'd Z energy / GeV



Reco'd Z mass / GeV

Purity: 30.77%

Efficiency: 35.68%

Background:

- SM 40.29%, chichi 59.48%, other SUSY bkg 0.24%

Template fitting

- When comparing the real data with the template, the change in *ith* bin content Δyi ~ Δm(SUSY)

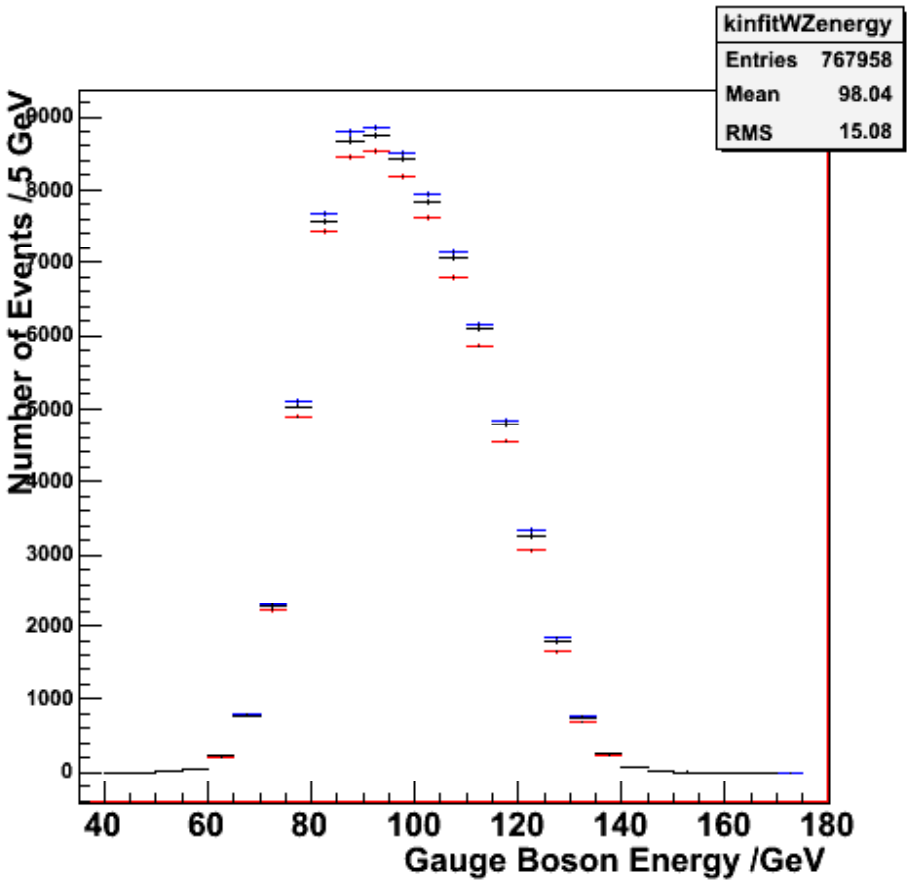
$$\Delta y_i = \left(\frac{\partial y}{\partial m_{\tilde{\chi}_1^\pm}}\right)_i \Delta m_{\tilde{\chi}_1^\pm} + \left(\frac{\partial y}{\partial m_{\tilde{\chi}_1^0}}\right)_i \Delta m_{\tilde{\chi}_1^0}$$

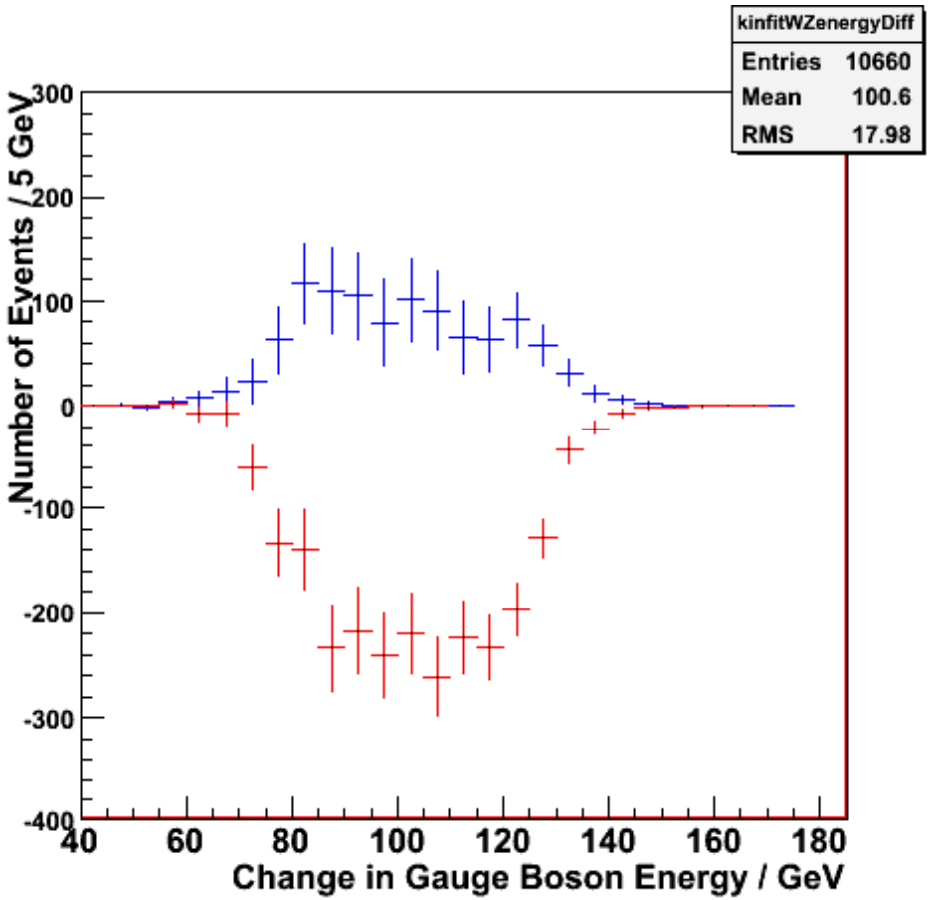
- Each derivative in the formula above is obtained by generating another sample with eg. m(chi) shifted. The mass difference from the template value can be extracted by doing least linear square fit for Δyi wrt the derivatives.

Template fitting

Error on Δm(ch): 281MeV

Error on Δm(neu1): 123 MeV





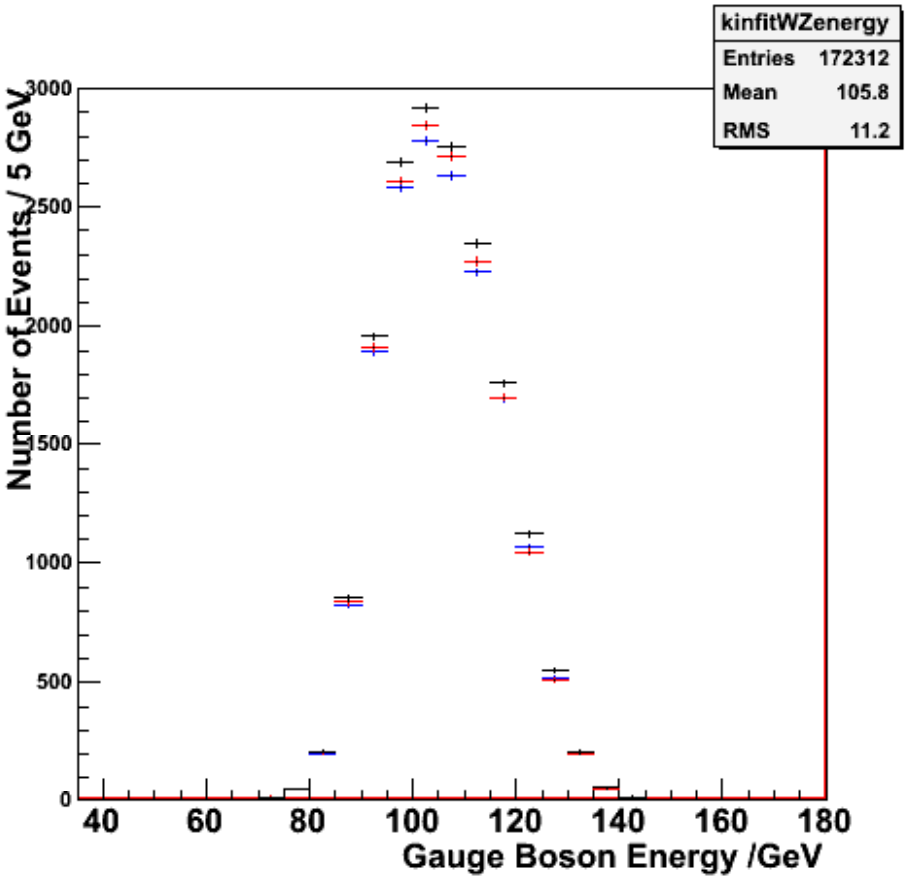
Reco'd W energy incl. all backgrounds(left) and its difference wrt the templates (right).

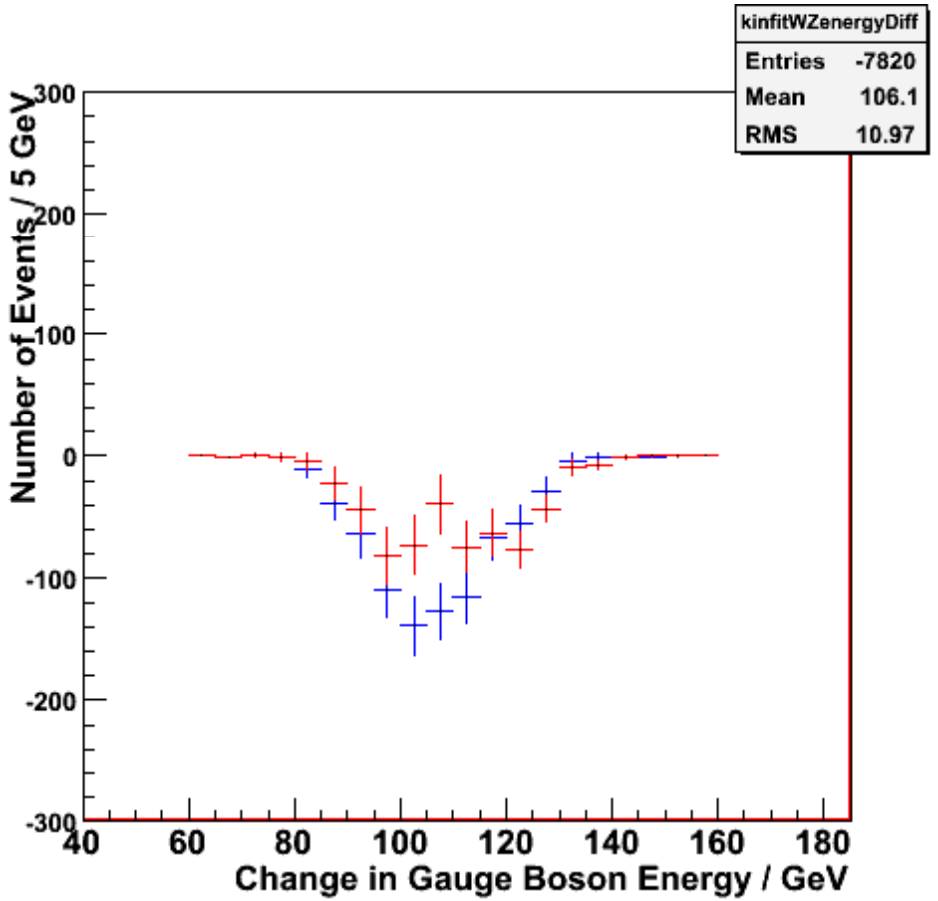
Red: m(neutrolino1) + 0.5 GeV; Blue: m(chargino) + 0.5 GeV

Template fitting

Error on Δm(neu2): 161 MeV

Error on Δm(neu1): 214 MeV





Reco'd Z energy incl. all backgrounds(left) and its difference wrt the templates (right).

Red: m(neutrolino1) + 0.5 GeV; Blue: m(neutrolino2) + 0.5 GeV

Template fitting

for the binning on previous slides:

Chargino selection:

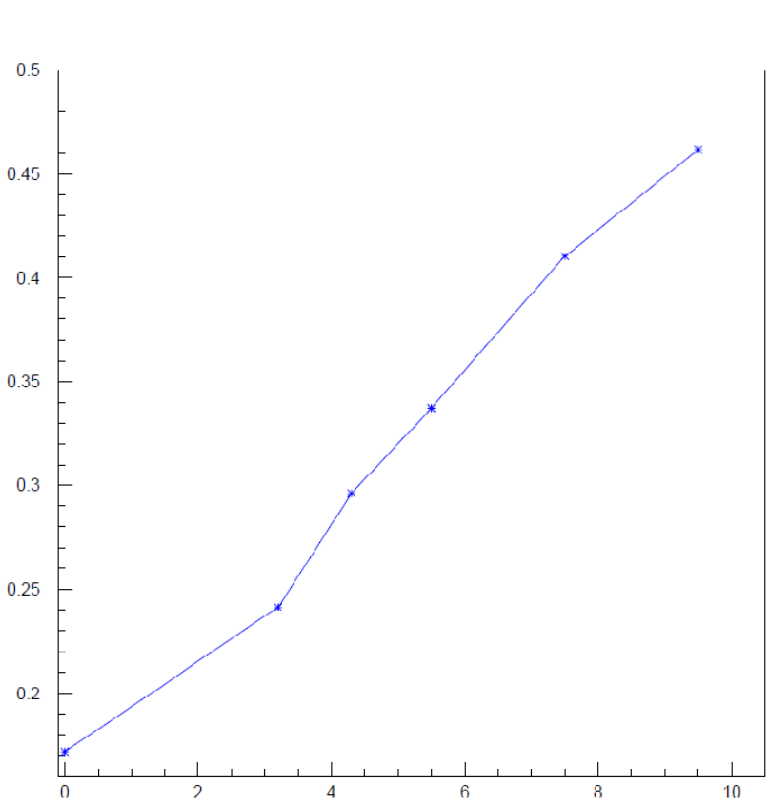
Error on Δm(ch): 281MeV

Error on Δm(neu1): 123 MeV

Neutralino selection:

Error on Δm(neu2): 161 MeV

Error on Δm(neu1): 214 MeV



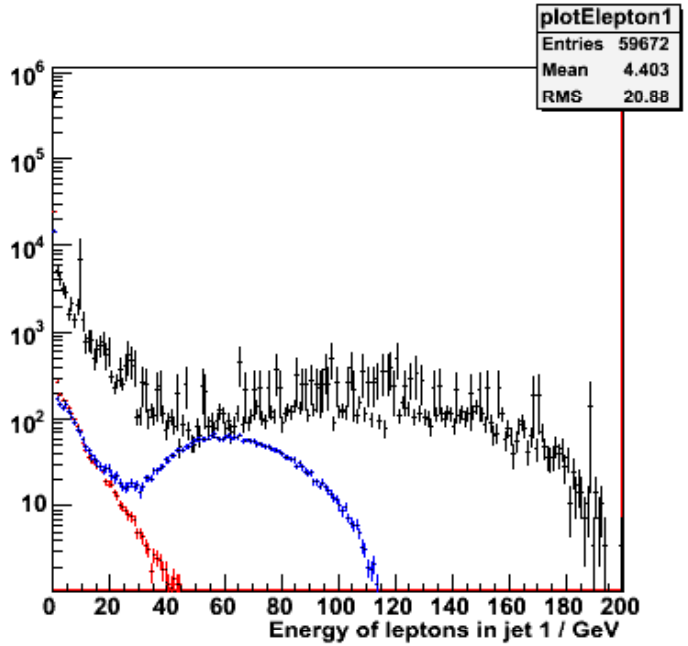
$$\left(\frac{\Delta E_{jet}}{E_{jet}}\right)_{90} \quad (\%)$$

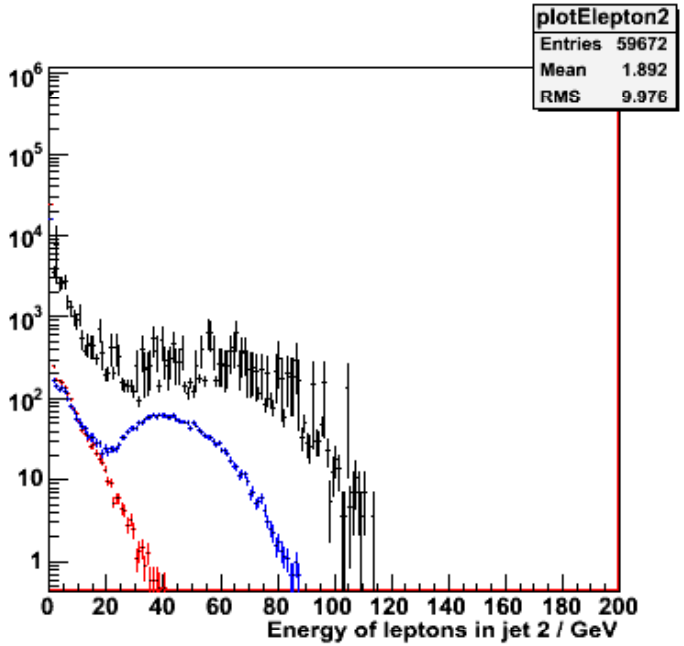
Study of error on chargino mass based on fastmc. (Tim Barklow)

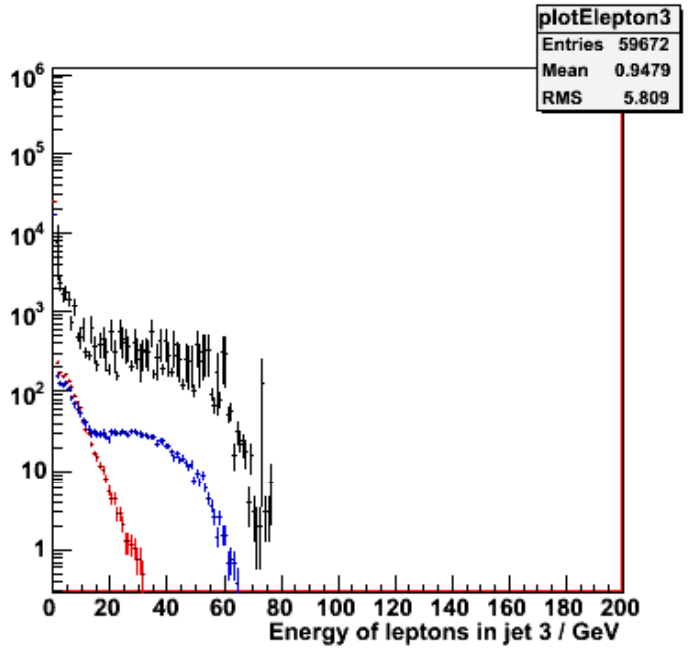
Summary and plan

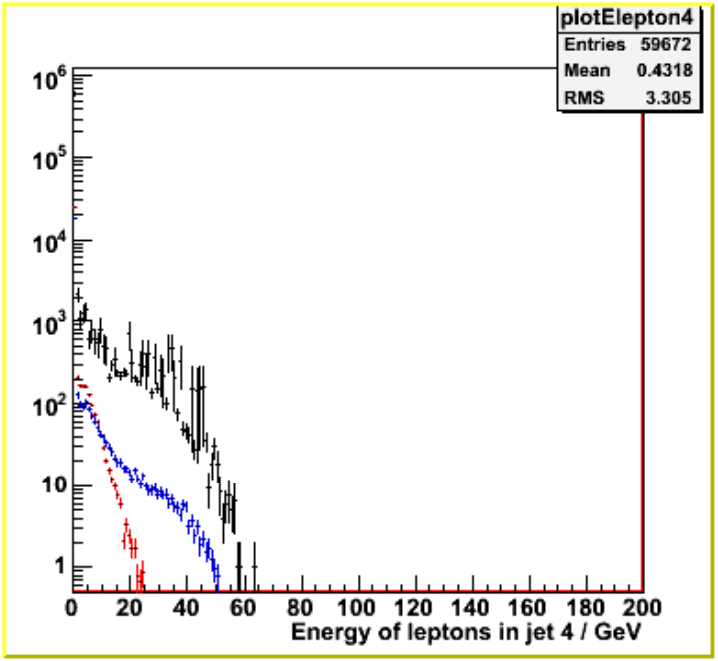
- Chargino / neutralino events can be identified at the presence of SM bkg, and separated from each other.
  - Chargino selection has much better performance
- More efforts could be made to further suppress SM background.
- Cuts have to be optimized to achieve the best purity * efficiency.
- Template fitting has provided a framework for chargino/neutralino mass extraction, but more understanding on the error estimation is needed.

Backups


plotElepton1
Entries 59672
Mean 4.403
RMS 20.88
Energy of leptons in jet 1 / GeV


plotElepton2
Entries 59672
Mean 1.892
RMS 9.976
Energy of leptons in jet 2 / GeV


plotElepton3
Entries 59672
Mean 0.9479
RMS 5.809
Energy of leptons in jet 3 / GeV

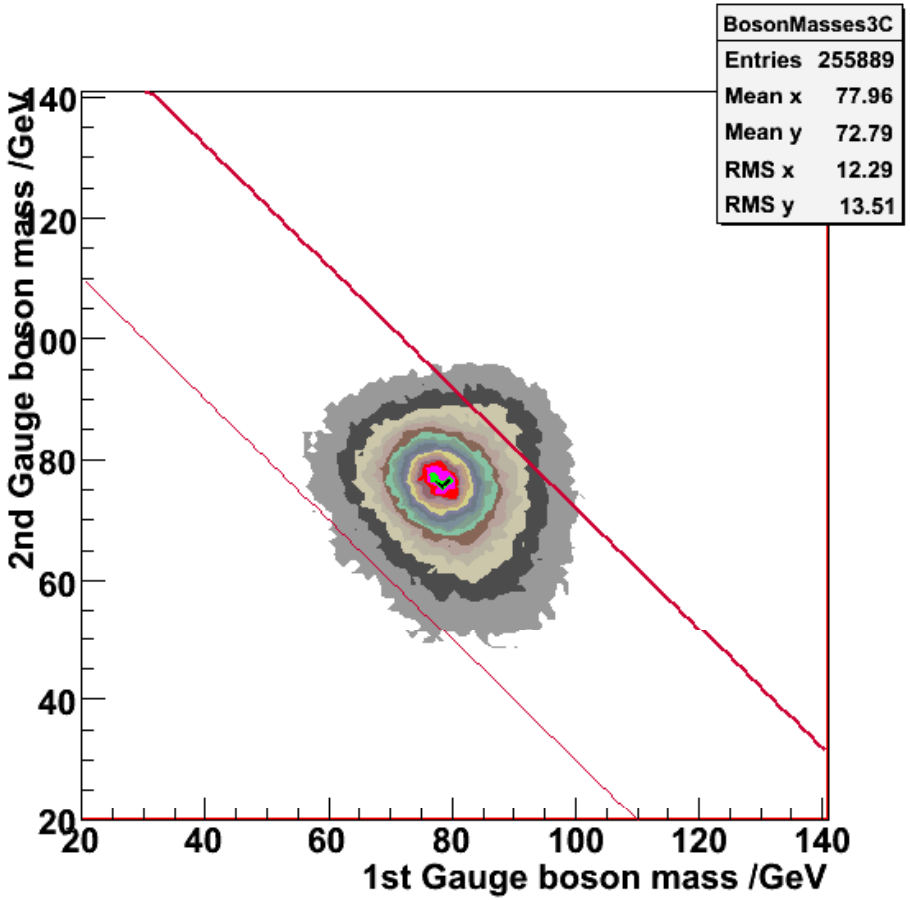

plotElepton4
Entries 59672
Mean 0.4318
RMS 3.305
Energy of leptons in jet 4 / GeV

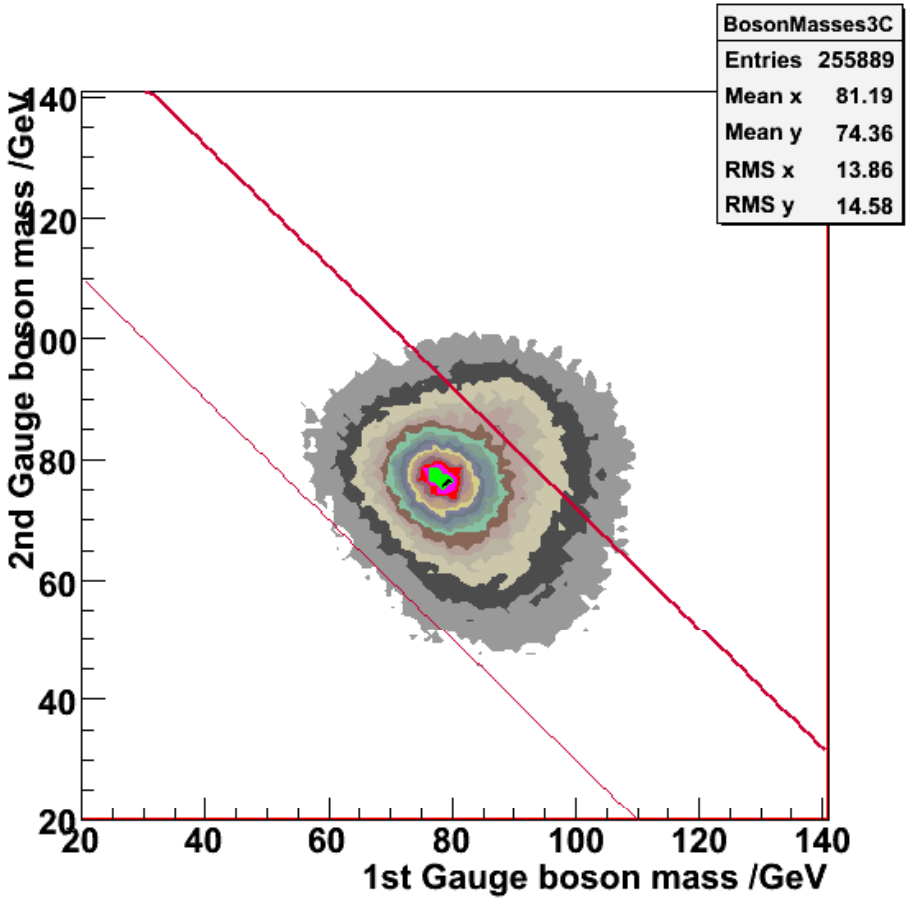
Chargino selection cuts

	ChiChi signal		Neu2Neu2 bkg		SM background	
nBeforecut Jet Number	28506	100%	11648.1	100%	6.12E+09	100%
nBeforecut E Total	28506	100%	10855.9	93.20%	1.07E+09	17.50%
nBeforecut Track Number	28189.7	98.89%	10752.2	92.31%	9.61E+08	15.70%
nBeforecut Thrust	27506	96.49%	7322.06	62.86%	1.70E+06	0.03%
nBeforecut CosThrustAngle	26038.1	91.34%	6428.18	55.19%	607485	0.01%
nBeforecut IsolatedLepton	23303.8	81.75%	5852.54	50.24%	330098	0.01%
nBeforecut fEM	23303.5	81.75%	5633.26	48.36%	324119	0.01%
nBeforecut Lepton energy	22584.1	79.23%	5318.33	45.66%	300008	0.00%
nBeforecut Jet Energy	22566.2	79.16%	5176.57	44.44%	297471	0.00%
nBeforecut Jet Angles	22360.2	78.44%	4794.56	41.16%	131883	0.00%
nBeforecut Acollinearity	19412.1	68.10%	4218.05	36.21%	38135.6	0.00%
nBeforecut 2BosonMassMax	18975.7	66.57%	3998.48	34.33%	36916.6	0.00%
nBeforecut 2BosonMassMin	18171.1	63.74%	2608.71	22.40%	36091	0.00%
nAftercut 2BosonMassMin	16983.3	59.58%	2371.4	20.36%	7511.14	0.00%

Neutralino selection cuts

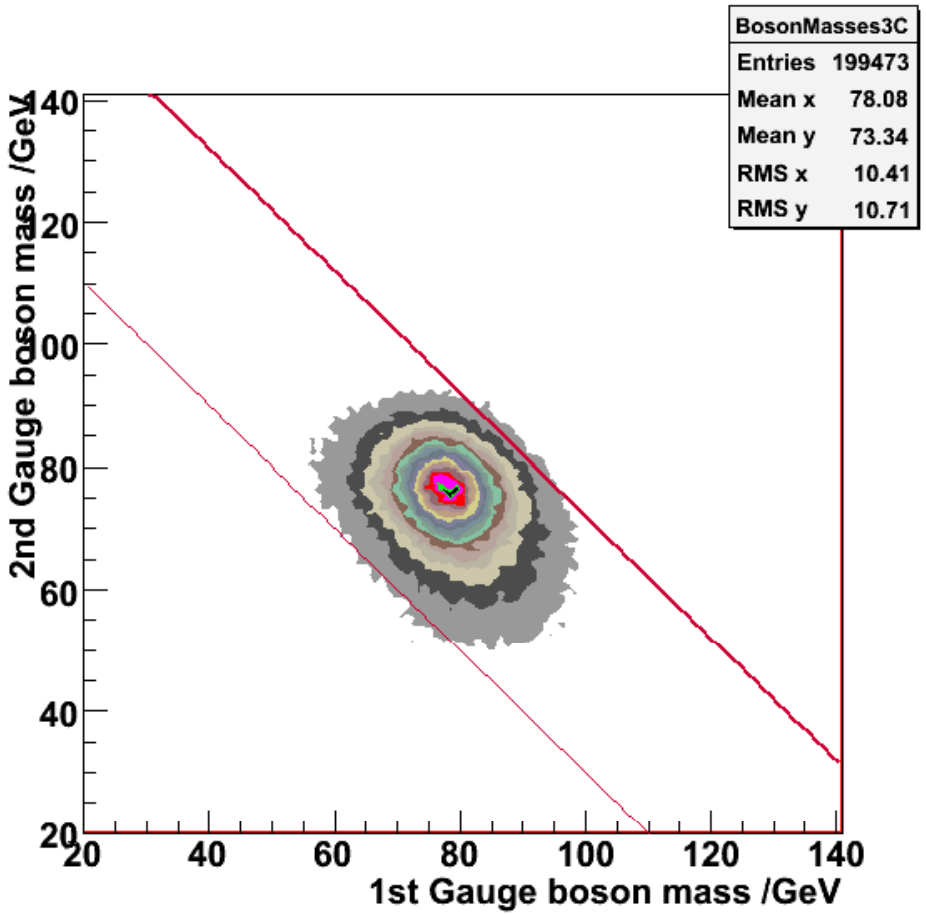
	Neu2Neu2 signal		ChiChi bkg		SM background	
nBeforecut Jet Number	5478.23	100%	66060.1	100%	6.12E+09	100%
nBeforecut E Total	5478.23	100%	61875.6	93.67%	1.07E+09	17.50%
nBeforecut Track Number	5410.57	98.76%	61536.4	93.15%	9.61E+08	15.70%
nBeforecut Thrust	5349.34	97.65%	36470.7	55.21%	1.70E+06	0.03%
nBeforecut CosThrustAngle	4929.11	89.98%	33505	50.72%	607485	0.01%
nBeforecut IsolatedLepton	4480.71	81.79%	30079.6	45.53%	330098	0.01%
nBeforecut fEM	4480.71	81.79%	28746.8	43.52%	324119	0.01%
nBeforecut Lepton energy	4373.56	79.84%	26235.3	39.71%	300008	0.00%
nBeforecut Jet Energy	4355.91	79.51%	25064.9	37.94%	297471	0.00%
nBeforecut Jet Angles	4330.46	79.05%	24140.5	36.54%	131883	0.00%
nBeforecut Acollinearity	4251.2	77.60%	22808.5	34.53%	98988.5	0.00%
nBeforecut 2BosonMassMax	4212.39	76.89%	22176	33.57%	70174.7	0.00%
nBeforecut 2BosonMassMin	4113.23	75.08%	21274.5	32.20%	56676	0.00%
nAftercut 2BosonMassMin	4043.62	73.81%	20559.4	31.12%	40959	0.00%

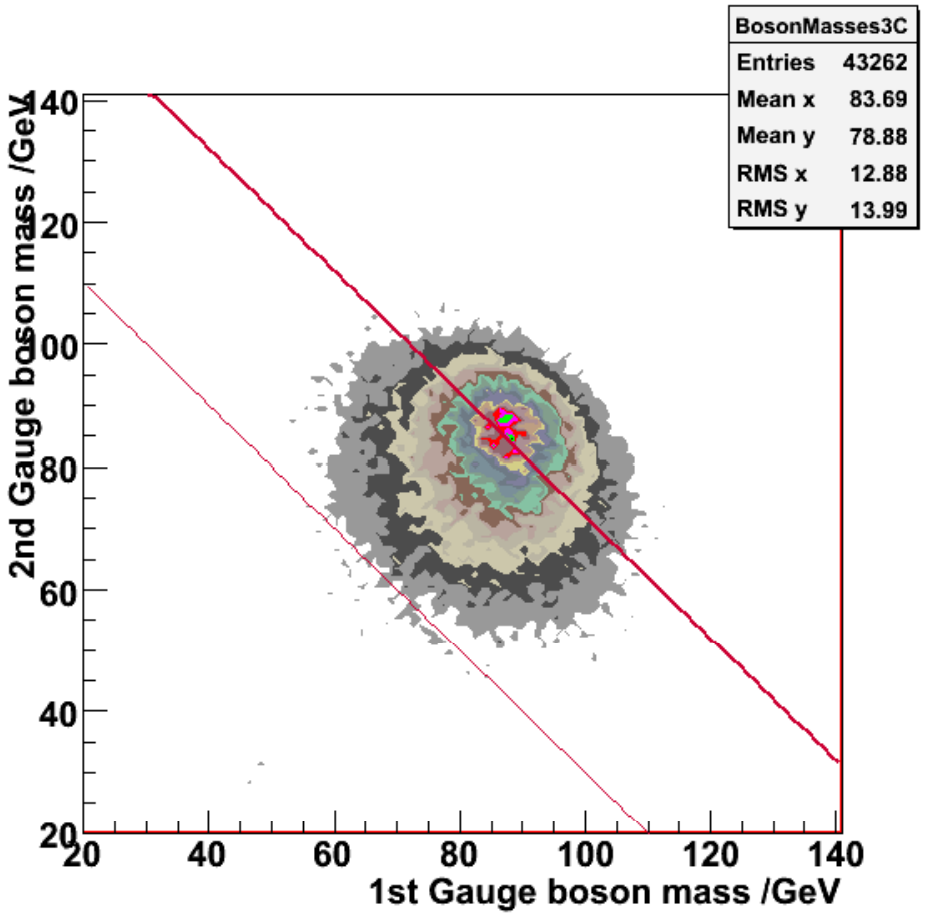




The two boson masses of all SUSY events

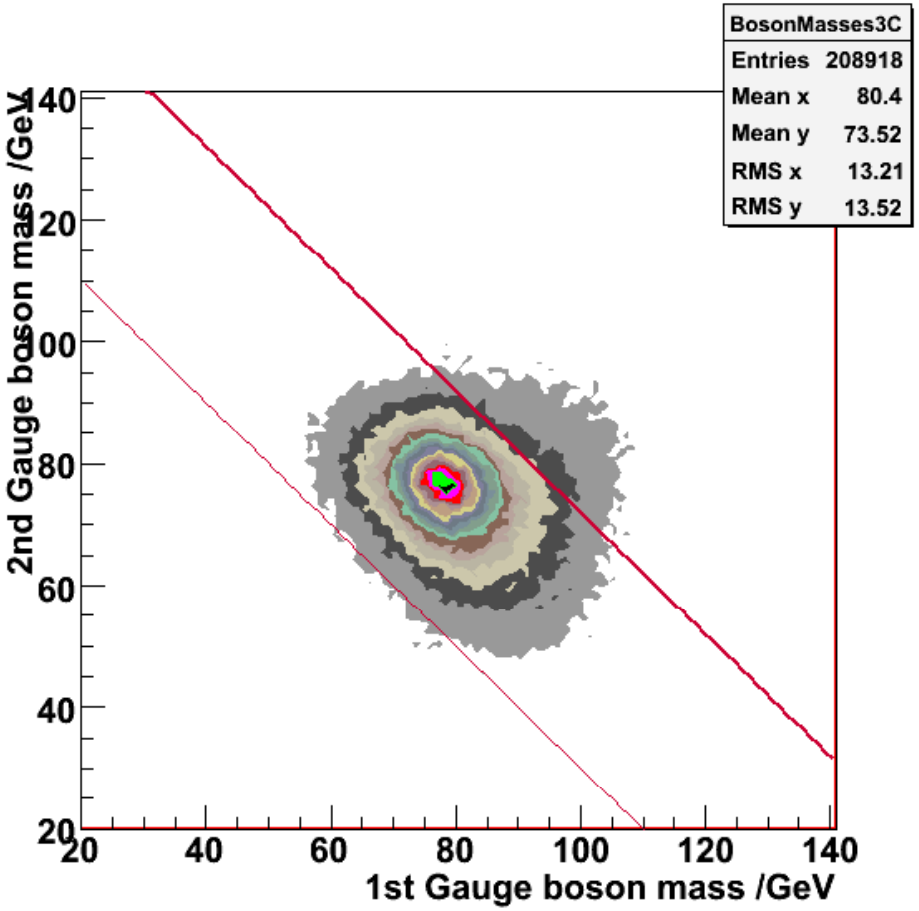
Left: chargino events selection; right: neutralino events selection

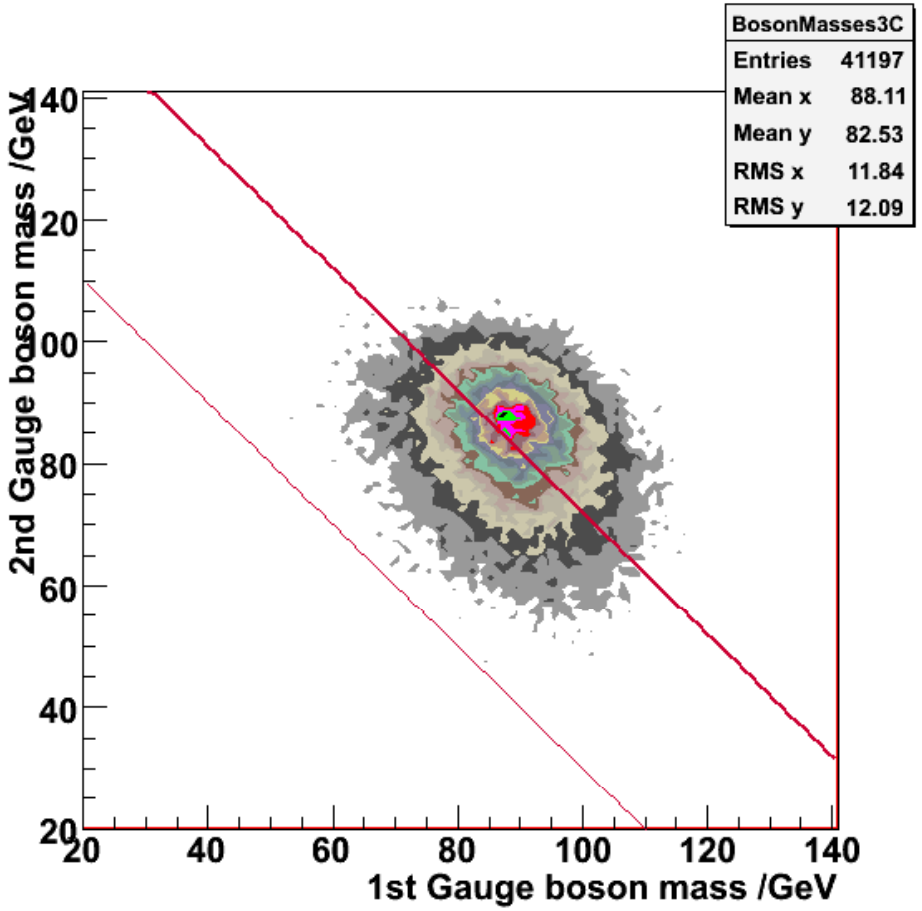




Chargino events selection:

Left: true chargino events; right: true neutralino events





Neutralino events selection:

Left: true chargino events; right: true neutralino events