Scalar Top Mass Measurements at a Future LC

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Four different methods:

- 'IDA' based selection -
  Optimum Signal/Background ratio:
  - Cross Section with different polarizations
  - Threshold dependence of Cross Section
- Cuts based selection -
  Minimum distortion of final state observables
  - Endpoint of Jet Energy Spectrum
  - Minimum Mass of Jets

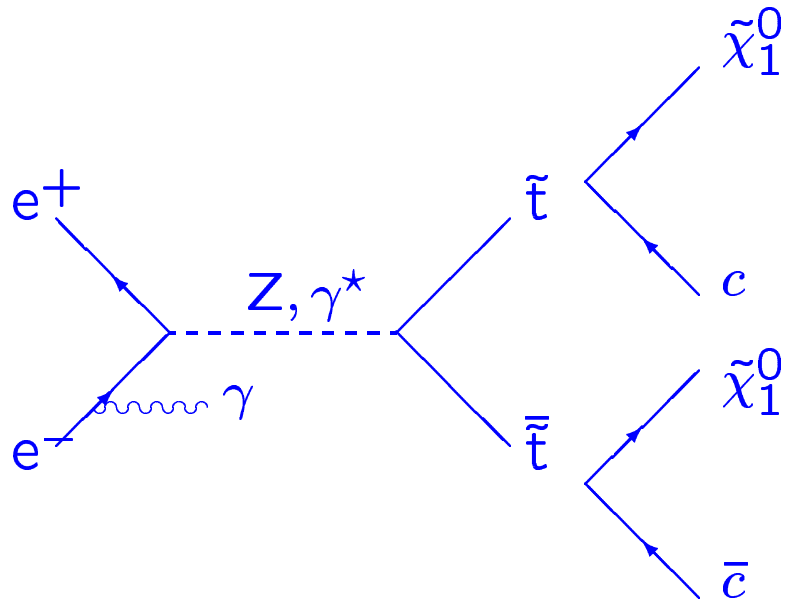
Benchmark point 'SPS5'

At SPS5 point:

$m_{\tilde{t}_1}$ = **220.7 GeV**
$M_{\tilde{\chi}_1^0}$ = **120 GeV**
$\cos\theta_{\tilde{t}} = 0.5377$

Only decays into $\tilde{\chi}_1^0 c$

Signal:
2 charm jets + E_{miss}



Expected Rates - Signal + Background

Polarisation of e^-	of e^+	$\tilde{t}_1\bar{\tilde{t}}_1$	$We\nu$	WW	$q\bar{q}$	$t\bar{t}$	ZZ
−0.8	0.6	0.0252	10.7	22.6	21.5	1.11	0.909
0	0.0	0.0163	5.59	7.86	12.1	0.574	0.864
0.8	−0.6	0.0232	1.78	0.786	13.0	0.542	0.464

Signal and background cross sections (pb) for different e^- and e^+ polarization states

Note the difference in the W cross sections.

The Analysis in Brief

- Signal and Background generated for:
  $500 fb^{-1}$ $\sqrt{s} = 500$GeV
- Detector Simulation -
  Simdet 4.03
- T.Kuhl's b/c tagging
- Either:
  Use 'IDA' program for optimum selection -
  measure Cross Sections
- Or:
  Use a conventional 'cuts based' selection -
  measure Jet Properties

IDA analysis - Preselection

- $25 <$ **No. Energy Flow objects** < 80
- $0.2 < \frac{\text{Visible Energy}}{\sqrt{s}} < 0.52$
- **Net longitudinal momentum** $< \frac{\text{Visible Energy}}{2}$
- **Thrust** < 0.95
- **Cosine theta of thrust axis** < 0.7

Selection efficiency $\sim 50\%$

Channel	$\tilde{\chi}_1^0 c \tilde{\chi}_1^0 \bar{c}$	$q\bar{q}$	WW	$eW\nu$	$t\bar{t}$	ZZ	eeZ
Events	4090	11000	19000	240000	5400	150	3500

Iterative Discriminant Analysis - 'IDA'

A method to weight each event to optimize signal / background separation using n discriminant variables.

Construct: vector x containing the n variables and $(n^2 - n)/2$ products of those variables.

Calculate:	V	Variance matrix
	$\Delta\mu$	Difference in the mean values between signal and background
	$a = V^{-1}\Delta\mu$	
	$D^0 = x^T \cdot a \cdot x$	provides the maximum separation between Signal and Background.

Weighted such that signal and background have equal importance.

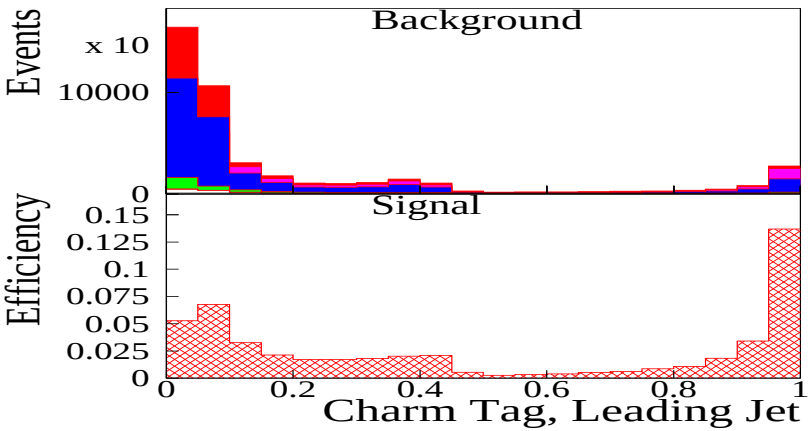
Find the value of D^0 which selects a predetermined fraction of the signal (e.g. 50%), and cut on it.

Do this process once again for events passing the cut.

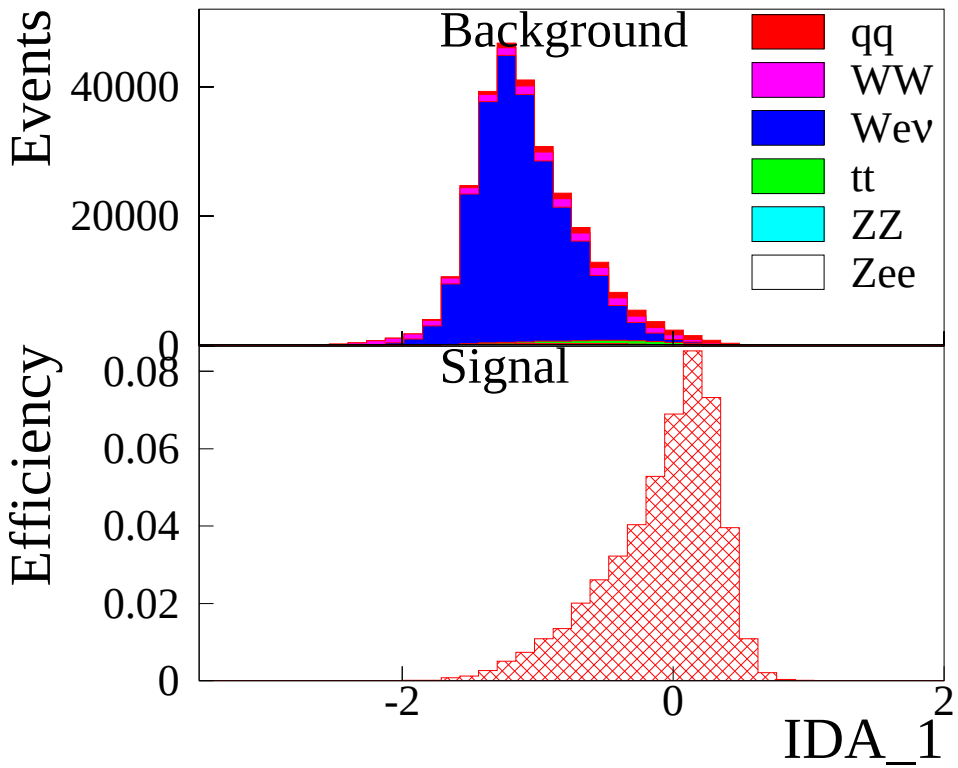
IDA Analysis

Discrimination Variables

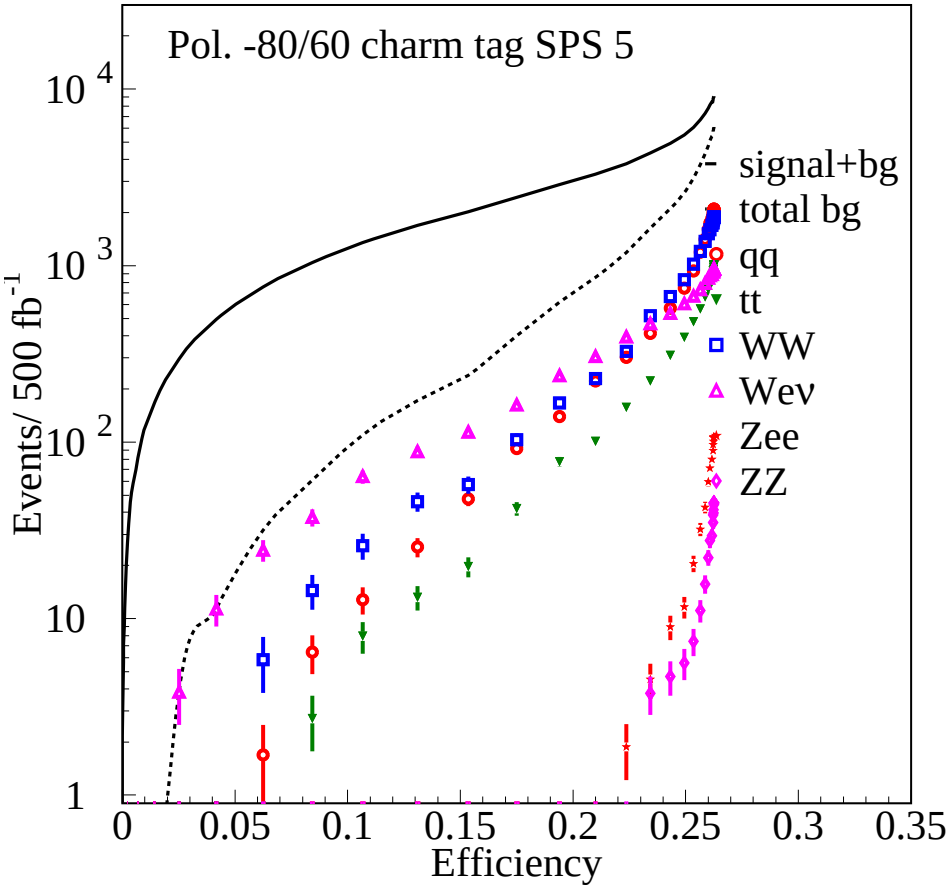
- visible energy
- number of jets
- thrust value
- thrust direction
- number of energy flow objects
- transverse momentum imbalance
- parallel momentum imbalance
- acoplanarity of the two highest energy jets.
- invariant mass of the two highest energy jets.
- Charm Tag of Jet 1
- Charm Tag of Jet 2

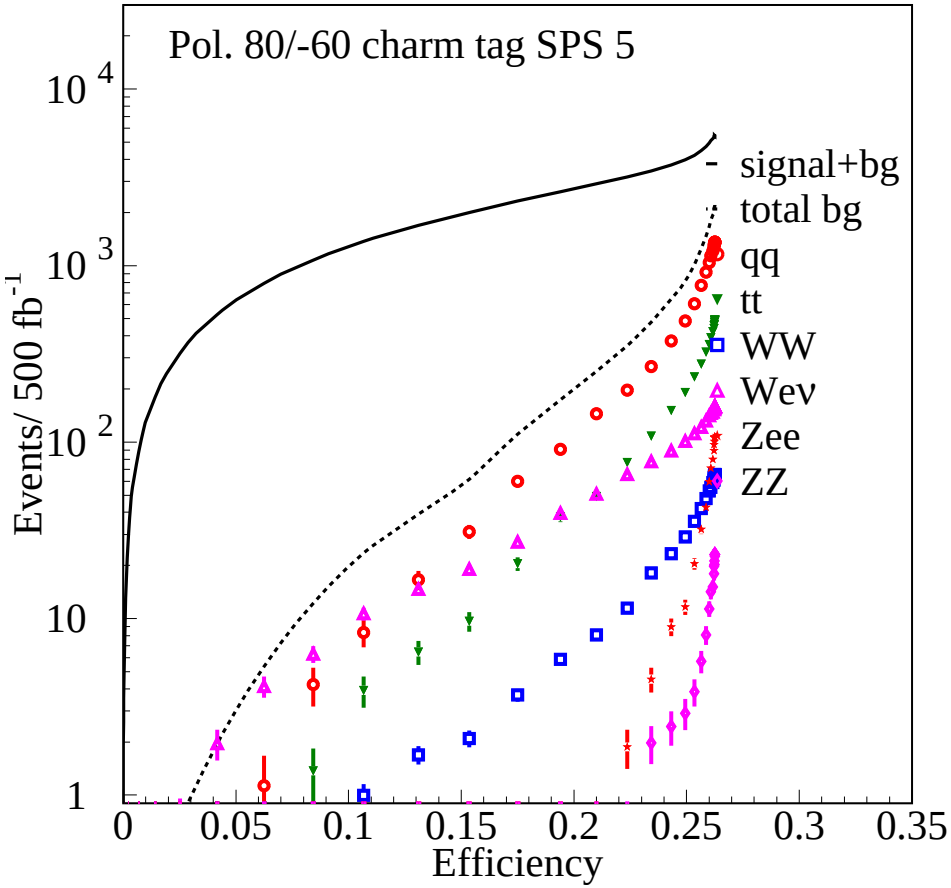


IDA values in Background and Signal



Selection Efficiency for Different Beam Polarizations

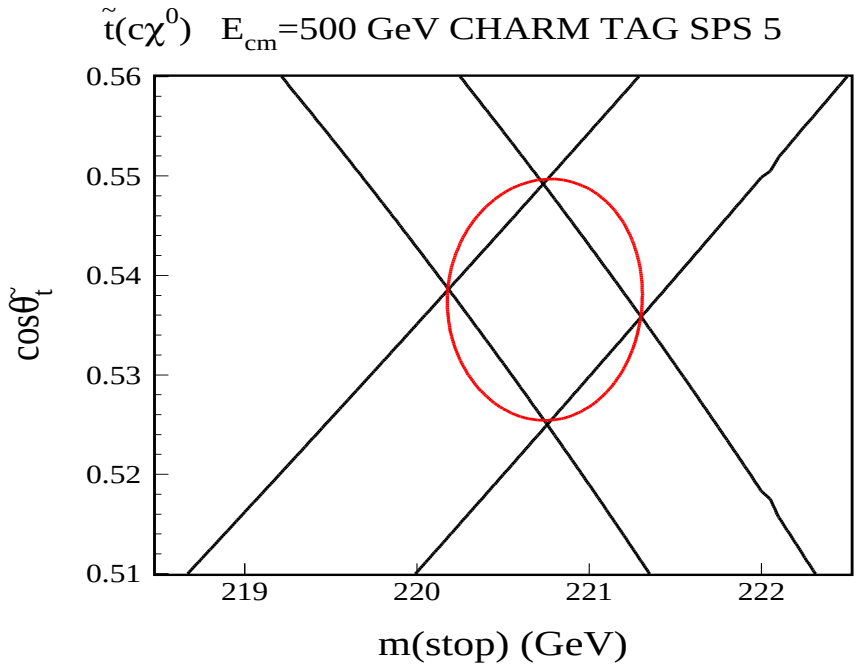




At 12% Efficiency	Signal:	1350	1500
	Background:	145	32

Results using Polarization Method

Knowing dependence of cross section on Scalar top mass and mixing angle, allows them to be measured.

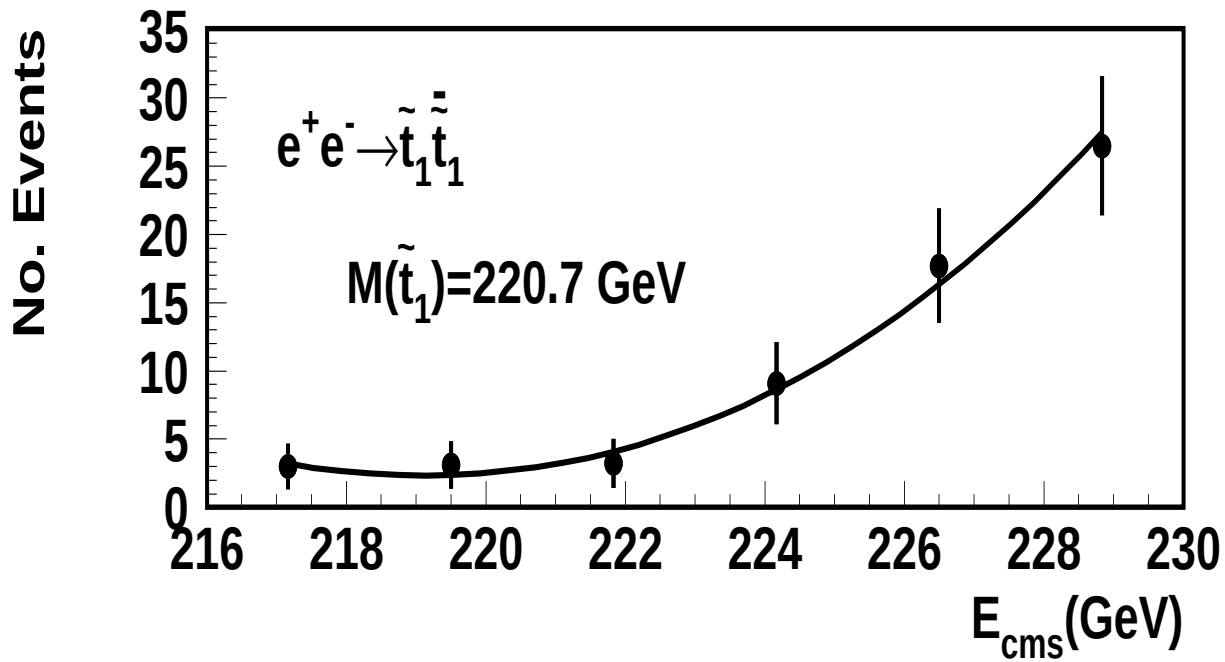


$$\Delta m_{\tilde{t}_1} = \pm 0.57\,\mathrm{GeV}$$
$$\Delta \cos\theta_{\tilde{t}} = \pm 0.012$$

N.B. Use $500\,fb^{-1}$ **for each polarization.**

Threshold Scan Method

Use 'Right Handed Polarization' to reduce backgrounds
Measure Cross Section Close to Threshold
6 points with 50 fb^{-1} per point.

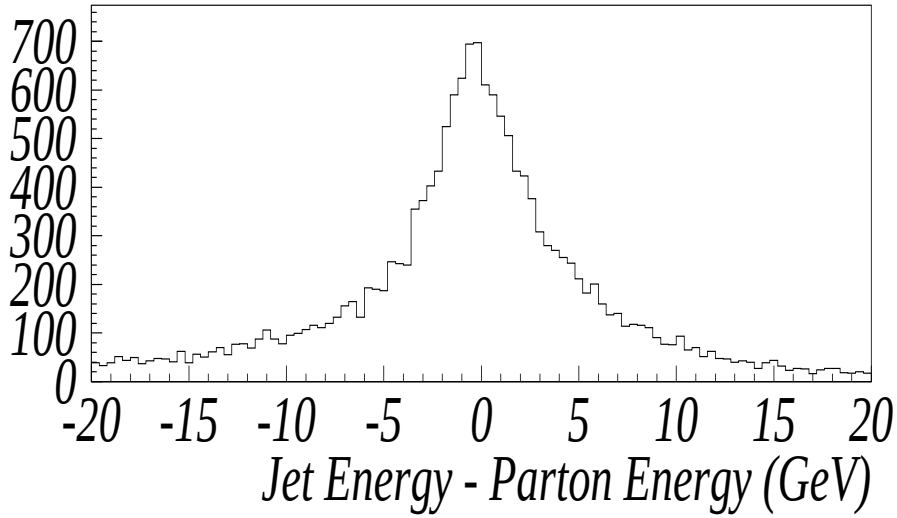


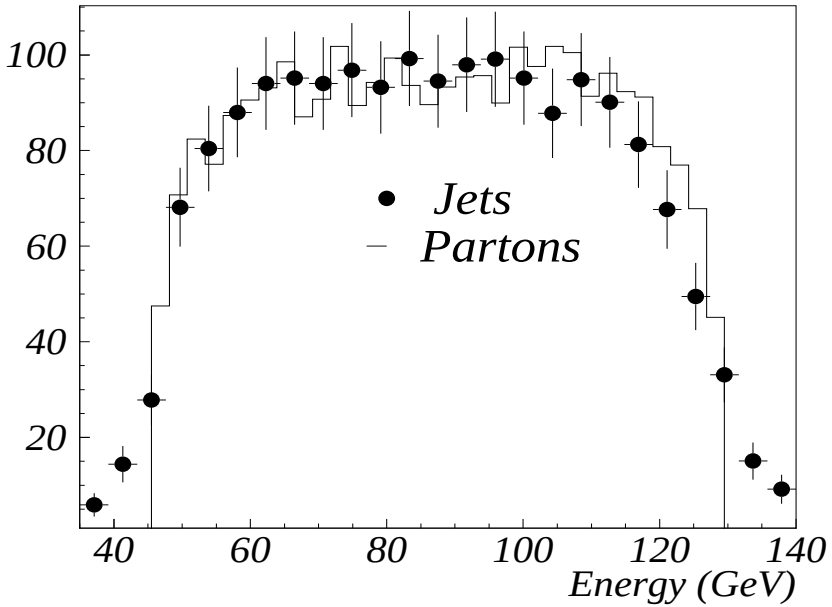
Mass from Fit to shape: 220.9 ± 1.2GeV

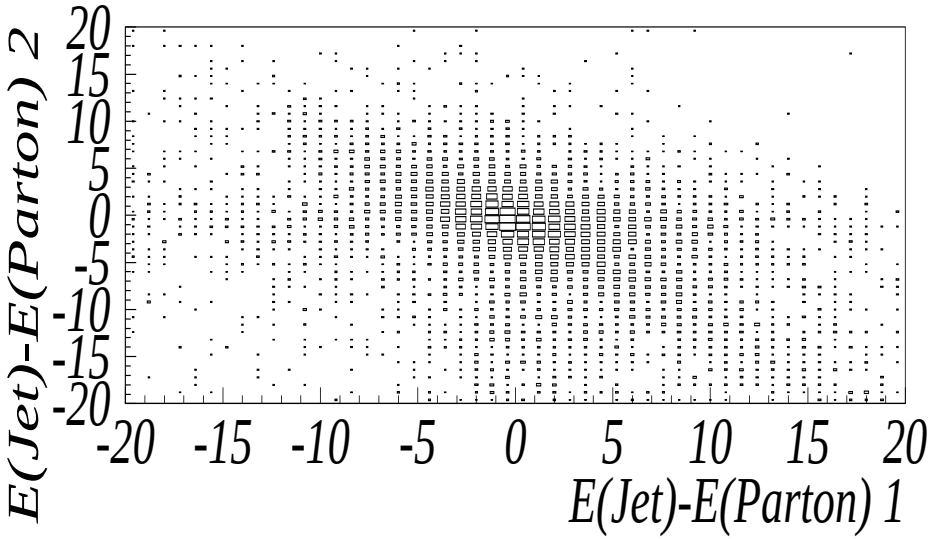
Direct Measurments from Jet Energies

'End Point Method' and 'Minimum Mass Method'

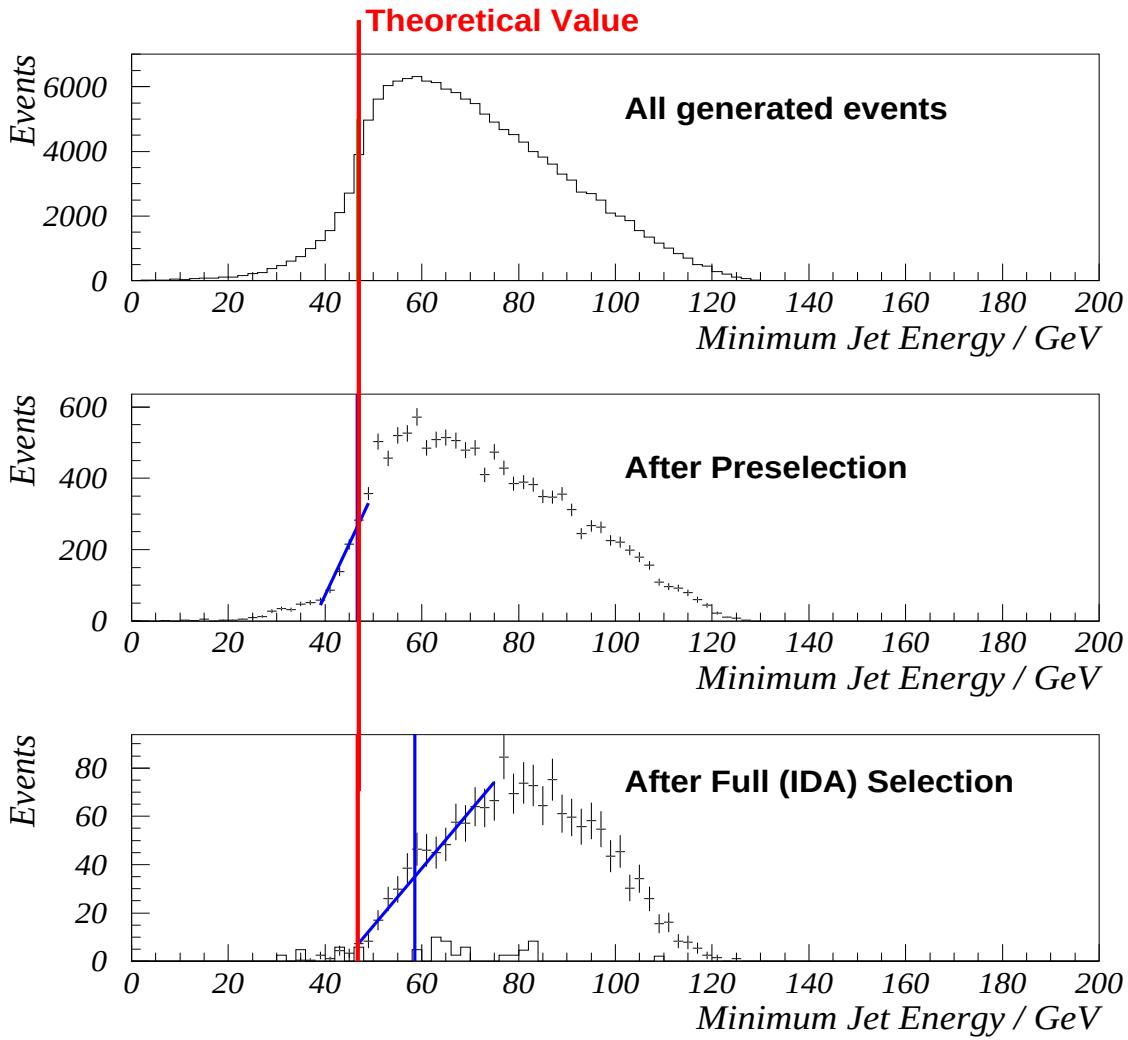
Require quark energies, but we measure jets...







Effect of IDA Selection on Min. Jet Energy

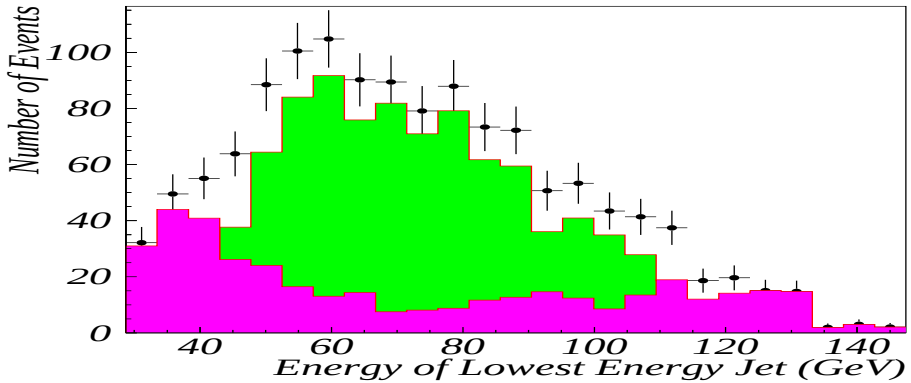


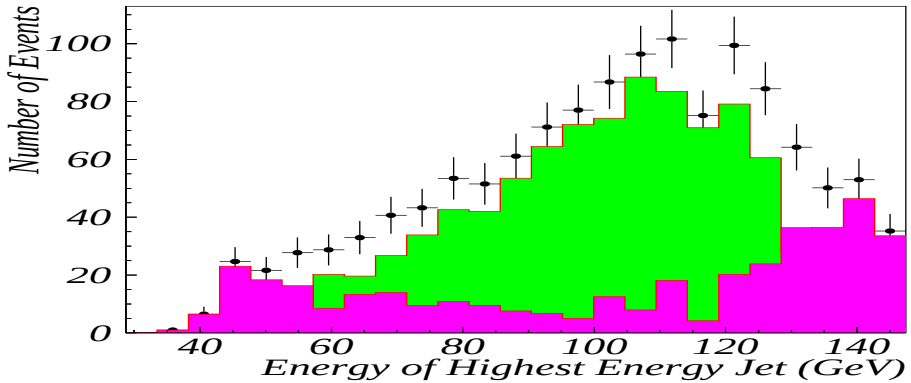
Use a Cuts based selection to reduce distortions

- 20 $<$ Number of Energy Flow Objects $<$ 90
- Visble Energy $< 0.8\sqrt{s}$
- Measured Longitudinal Momentum < 0.5 Visible Energy
- Thrust $<$ 0.95
- Cosine of Thrust Axis relative to Beam Direction $<$ 0.95
- Both Jet Charm Tags $>$ 0.3
- At Least One Jet Charm Tag $>$ 0.4
- Number of Jets $<$ 4.
- Lowest Energy Jet $>$ 35 GeV
- Highest Energy Jet $<$ 140 GeV

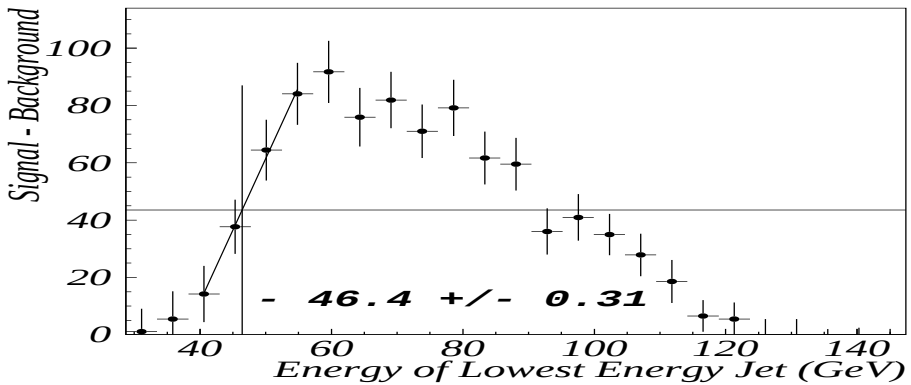
Number of Signal Events Selected = 900 (=11 % efficiency)
Number of Background Events Selected = 390 (=70% purity)

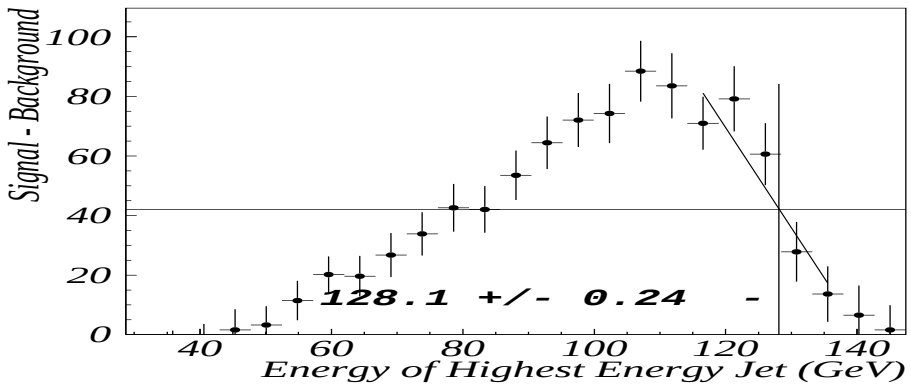
Jet Energy using Cuts Selection at SPS5





Subtract Background. Fit straight line to edges.

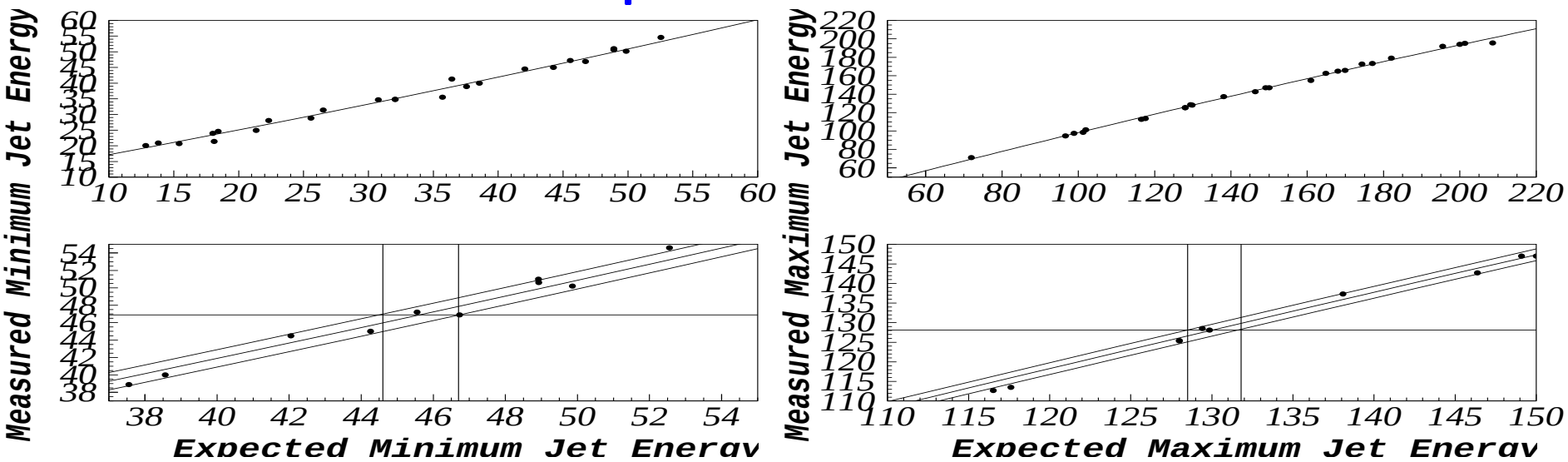




Measure Endpoints at Half Height Position

Jet Energy using Cuts Selection at SPS5

Generate several samples to obtain 'calibration curves'



Minimum Jet Endpoint $= 45.7 \pm 1.0$ **GeV**

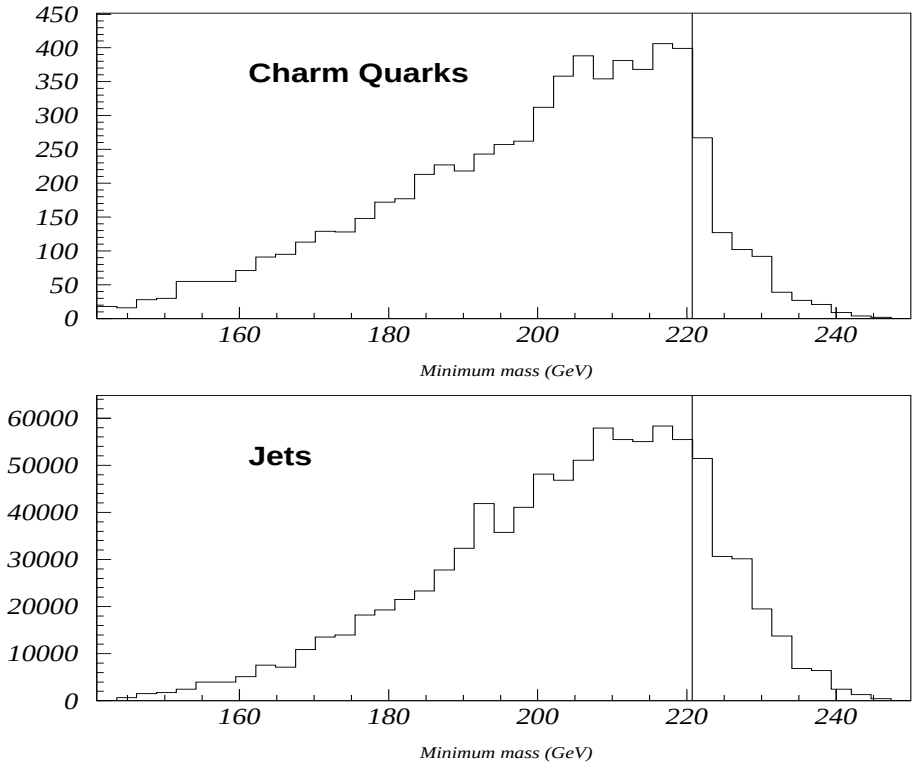
Maximum Jet Endpoint $= 130.2 \pm 1.5$ **GeV**

$m_{\tilde{t}_1} = 219.3 \pm 1.7$ **GeV**

$M_{\tilde{\chi}_1^0} = 119.4 \pm 1.6$ **GeV**

Minimum Mass Method

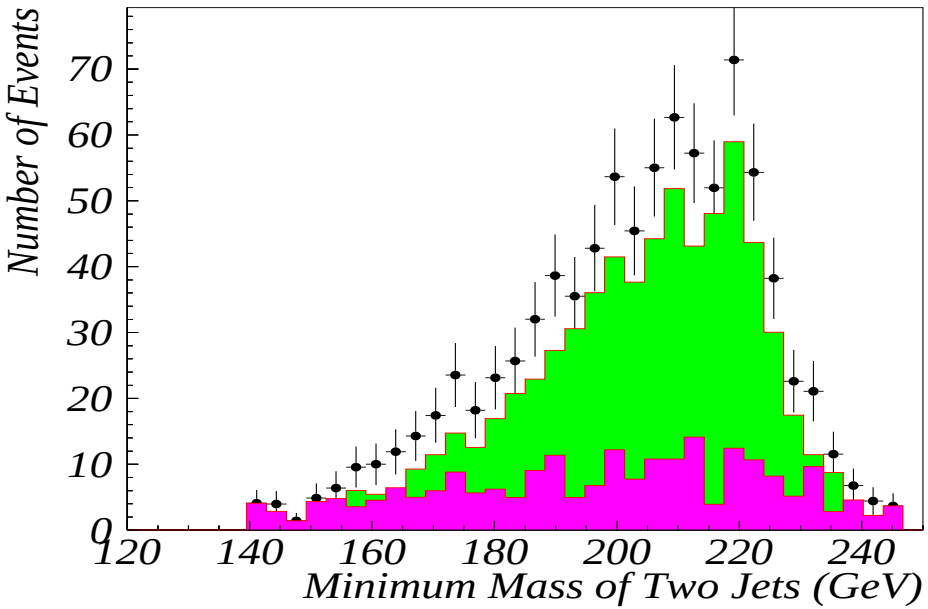
If $M_{\tilde{\chi}_1^0}$ is known, can calculate the minimum allowed mass of the two jets, this peaks at $m_{\tilde{t}_1}$.



At SPS5 ....

Additional cut -

$p_t^{\text{Event}}/\text{Visible Energy} > 0.1$

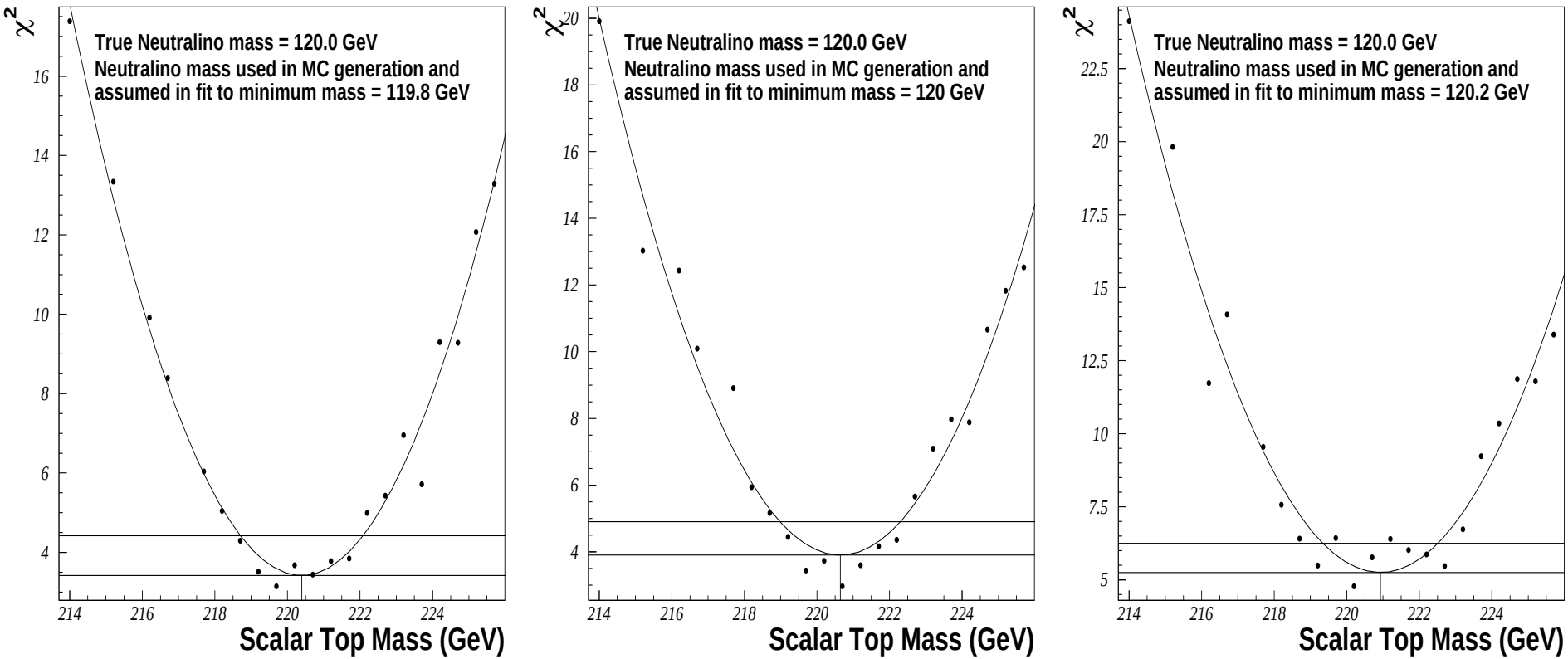


Signal: 650 Events,

Background: 190 Events

Fit to Find Error on Mass

- Generate several Monte Carlo samples - varying $m_{\tilde{t}_1}$
- Fit shape of minimum mass distribution to 'data'
- Plot χ^2 versus $m_{\tilde{t}_1}$
- Fit a parabola
- Find where χ^2 increases by 1.0 above minimum
- Check effect of uncertainty on $M_{\tilde{\chi}_1^0}$ (200 MeV, from $e^+e^- \to \tilde{\mu}\tilde{\mu}$).



$$m_{\tilde{t}_1} = 220.5 \pm 1.5 \text{ GeV}$$

Summary

- IDA selection provides high purity and efficiency.
- Allows $m_{\tilde{t}_1}$ measurement via:
  1 Combining Different Beam Polarizations
  2 Threshold Scan
- Cuts selection reduces distortions of Jet Energy Spectrum
- Allows $m_{\tilde{t}_1}$ measurement via:
  1 End Point Method
  2 Minimum Mass Method

Method	Δ_m (GeV)	luminosity	comment
Polarization	0.57	$2 \times 500 fb^{-1}$	
Threshold Scan	1.2	$300 fb^{-1}$	right hand polarization
End Point	1.7	$500 fb^{-1}$	
Minimum Mass	1.5	$500 fb^{-1}$	assumes $M_{\tilde{\chi}_1^0}$ known

To Do List (Incomplete):

Study Effects of Jet Algorithms