

Simulation Study of Top Full Reconstruction Near the $t\bar{t}$ Threshold

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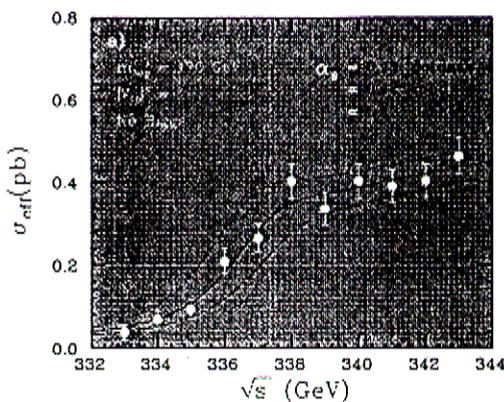
LCWS 2000 @ FNAL (25 Oct. 2000)

Top Physics at JLC

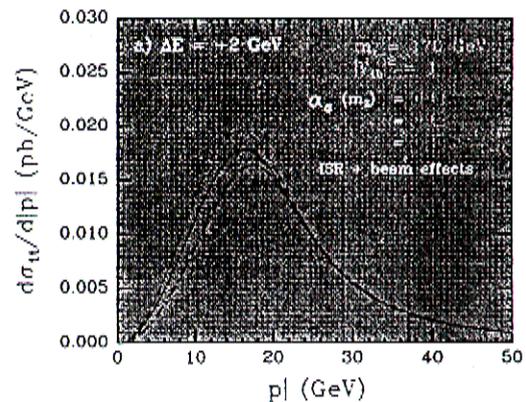
Top physics is promising & interesting for LC

Previous studies

Threshold scan of tot. cross section



Measurement of mom. distribution



Information on

$$\Delta m_t \quad \Delta \alpha_s \quad \Delta \Gamma_t / \Gamma_t \quad \Delta \beta_H, \quad \beta_H \equiv \frac{g_{ttH}}{g_{ttH}(SM)}$$

PRD50 (1994) 4341

Current studies

Physics with precision measurements

Property of production and decay vertices

Target Study of CP violation in top-sector

More realistic MC analysis

Event generation & Detector sim.
(VTX)

CP Violation in Top

Top is heavy and has almost no mixing with other generations
 = SM CP violation is extremely small

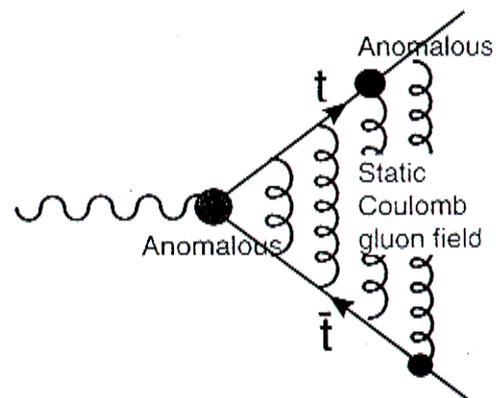
Discovery of CP violation in $e^+e^- \rightarrow t\bar{t} \rightarrow bW^+\bar{b}W^-$
 = Beyond the SM !

We focus on $t\bar{t}$ threshold region

CPV Scenario: EDM coupling

$$\mathcal{L}_{CPV} = \frac{ed}{2m_t} (\bar{t} i \sigma^{\mu\nu} \gamma_5 t) F_{\mu\nu}$$

d : Electric dipole mom.



Theoretical Advantage

- Multiple gluon exchange
enhances the CPV eff.
- Highly (~90%) polarized top samples
improve sensitivity to CPV eff.
- Control of beam polarization
allows WEDM, CEDM separation
- Large cross section
provides large event samples

Experimental Advantage

- Well-known kinematics (Small ISR + Beamstrahlung eff.)
- Well-defined top rest frame
- Smaller BG processes (Small cross section of multiple gauge boson processes)

$$e^+e^- \rightarrow WWZ$$

CP-odd Observables

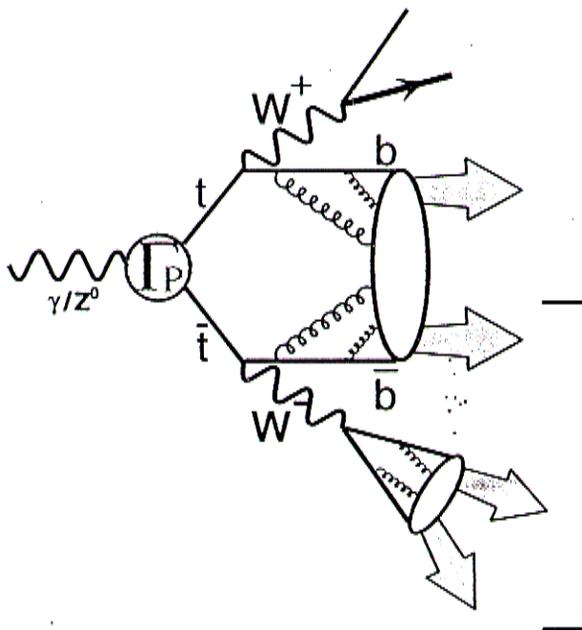
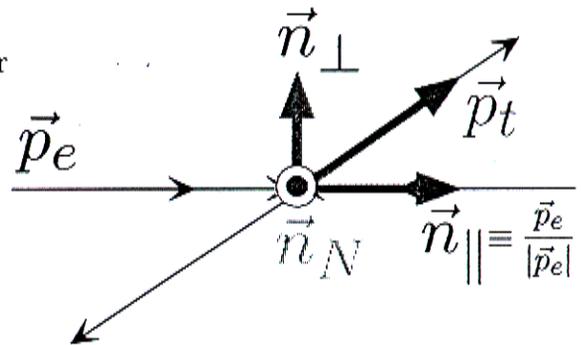
Examples of CP-odd observables taking advantage of LC experiment

Use Lepton+4Jets mode

$$(\vec{P}_t - \vec{P}_{\bar{t}}) = 2\delta\vec{P} \quad \vec{P} : \text{Polarization vector}$$

$$\langle \vec{n} \cdot (\vec{n}_{\ell^+} + \vec{n}_{\ell^-}) \rangle \simeq \frac{2}{3} \vec{n} \cdot \delta\vec{P}$$

$$\vec{n}_N \equiv \frac{\vec{p}_e \times \vec{p}_t}{|\vec{p}_e \times \vec{p}_t|}$$



Top-polarization is transferred to its daughter particles such as the lepton from W !

Top momentum is measurable as that of 3jets !

How precise can we measure the direction and magnitude of \vec{P}_{top} ?

Need realistic MC studies with detector sim. !

M.C. Simulation

Event generator (physsim-2000a)

BASES/SPRING + HELAS

Including Initial State Radiation
Beamstrahlung
S-wave & P-wave
QCD threshold corr.

JETSET 7.4 with TAUOLA

$b f_u f_d b f_d f_b$

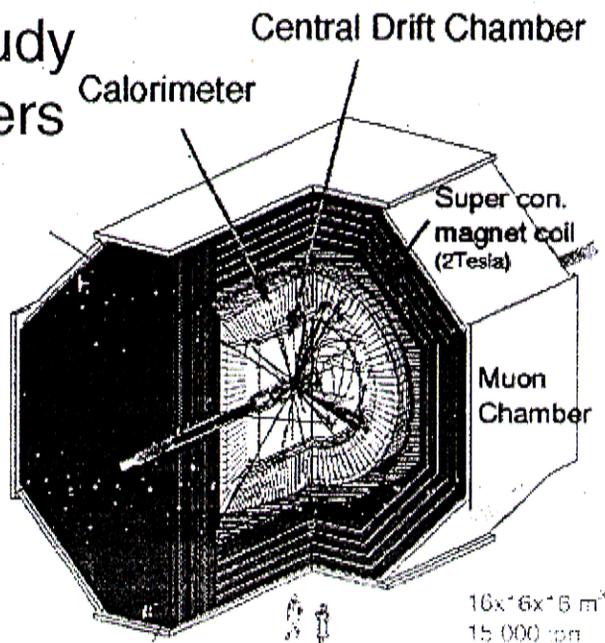


Hadrons

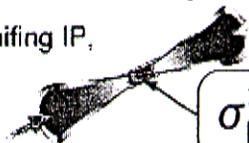
$$\begin{array}{l} \sqrt{s} = M_{1,s} + 2 \text{ GeV} \\ (m_{top} = 170 \text{ GeV}) \\ P_{e^-} = -0.8 \end{array} \xrightarrow{100 \text{ fb}^{-1}} 40\text{k events}$$

Detector simulation (JSF QuickSim)

ACFA study
parameters



magnifying IP,



$$|\cos \theta| < 0.95$$

$$\sigma_{P_T}/P_T = 5 \times 10^{-5} P_T \oplus 0.1 \%$$

$$\sigma_E/\sqrt{E} = 15 \% / \sqrt{E} \oplus 1 \% \text{ (EM)}$$

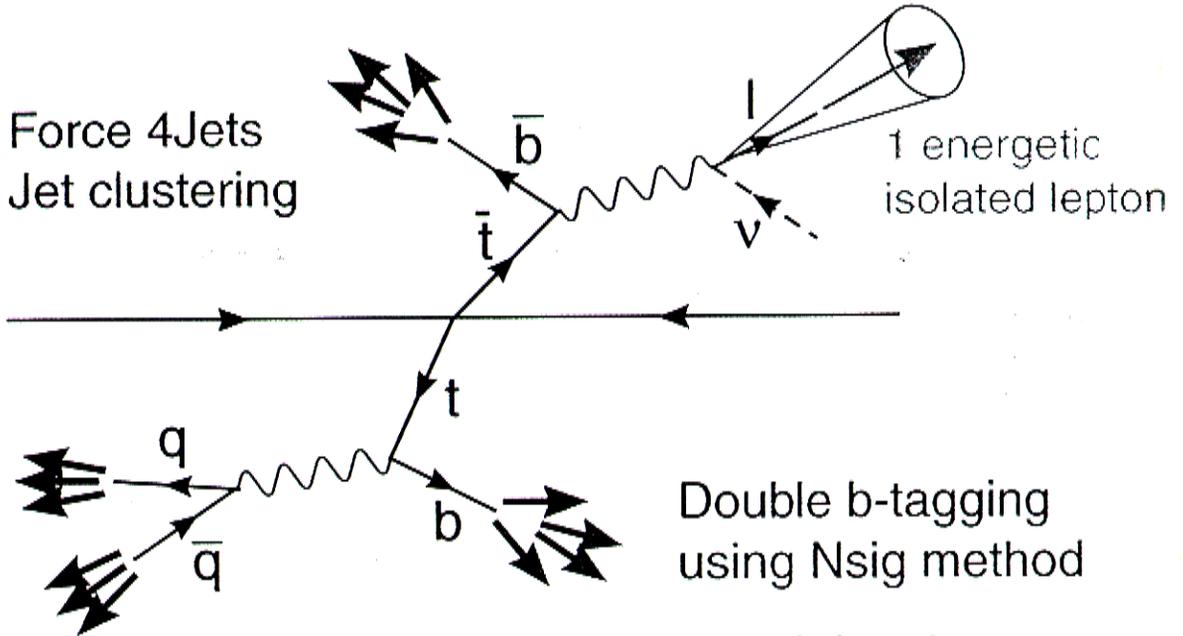
$$\sigma_E/\sqrt{E} = 40 \% / \sqrt{E} \oplus 2 \% \text{ (HAD)} \\ \text{(Unit : [GeV])}$$

$$\sigma_b^2 = 7.0^2 + (20.0/p)^2 / \sin^3 \theta \text{ [\mu m]}$$

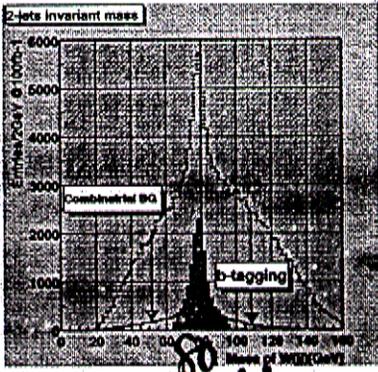
Strategy of Event Selection

$Br(L+4J) = 29\%$

lepton charge = W charge
 --> $t\bar{t}$ ID, $b\bar{b}$ ID



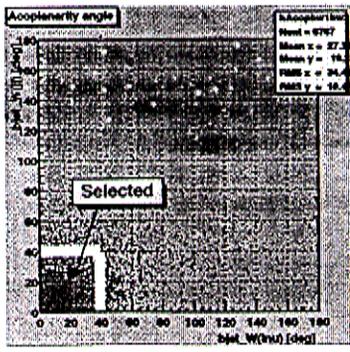
$N_{sig} : 3.5$
 $N_{off-vertex} : 2$



- Combinatorial BG = small
- No BG events

$65 < M_{W(jj)} < 95 \text{ GeV}$

b and W : back-to-back decay near threshold

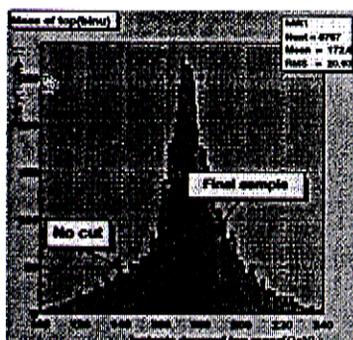
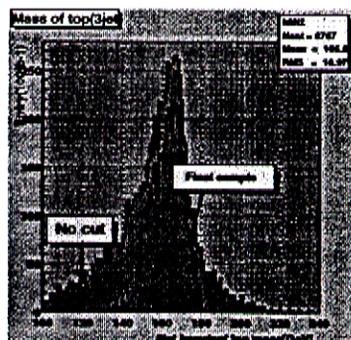


$Acop(b_W) \leq 40 \text{ deg}$

Results of Reconstruction

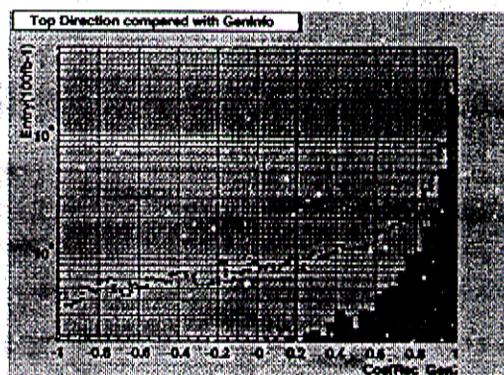
Requirement for momentum measurement

Clean sample of 3-Jet decays of top quarks without energetic missing neutrinos



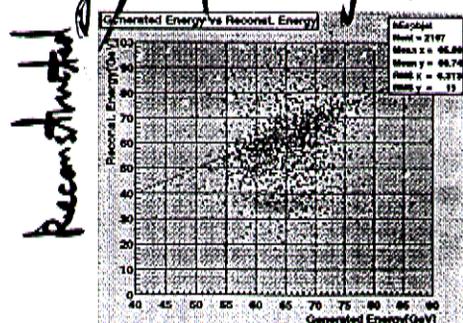
Cut on M_{3j} and $M_{j+l\nu}$

Compare the reconstructed top direction and generated one.



Overall selection eff. $\sim 8\%$

Energy of b-jet



Gen Level

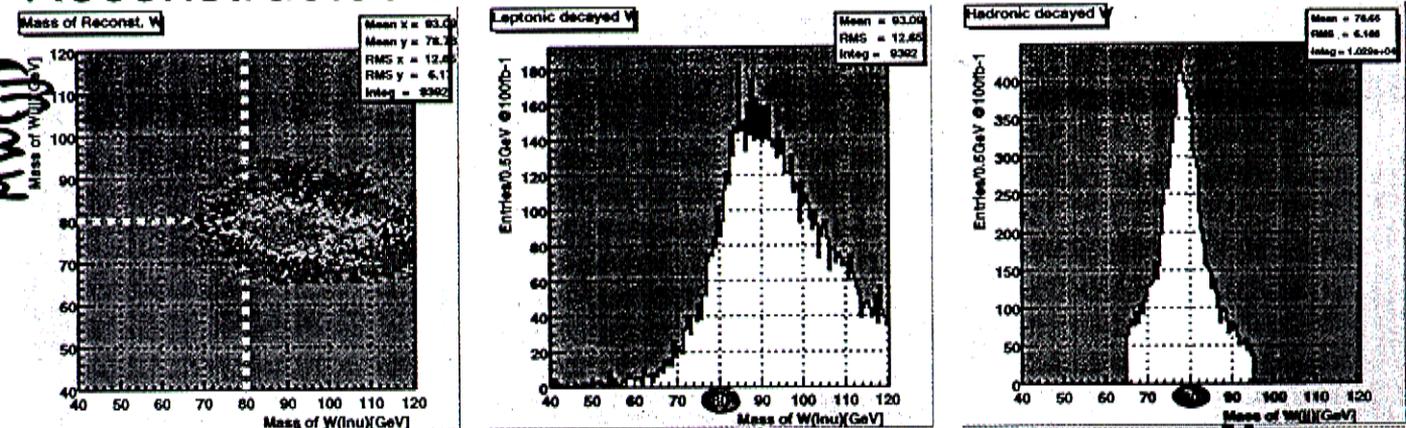
We can apply a Kinematical Fit !

1st Trial of Kin. Fit

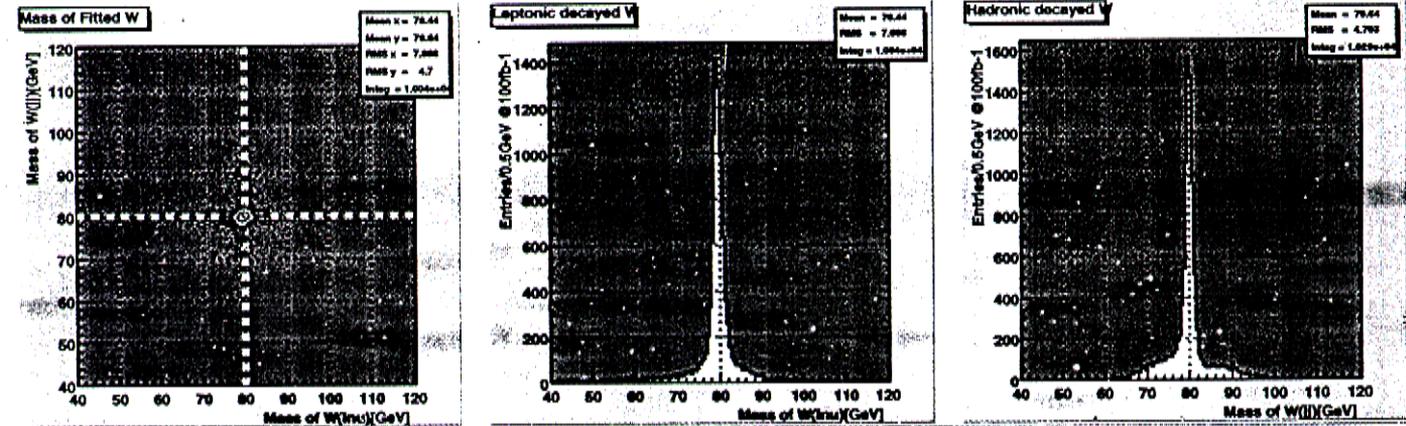
Simplification for initial trial

- ISR + Beamstrahlung : OFF
- Slightly above threshold ($2m_t + 2 \text{ GeV}$) to avoid complication due to off-shell tops

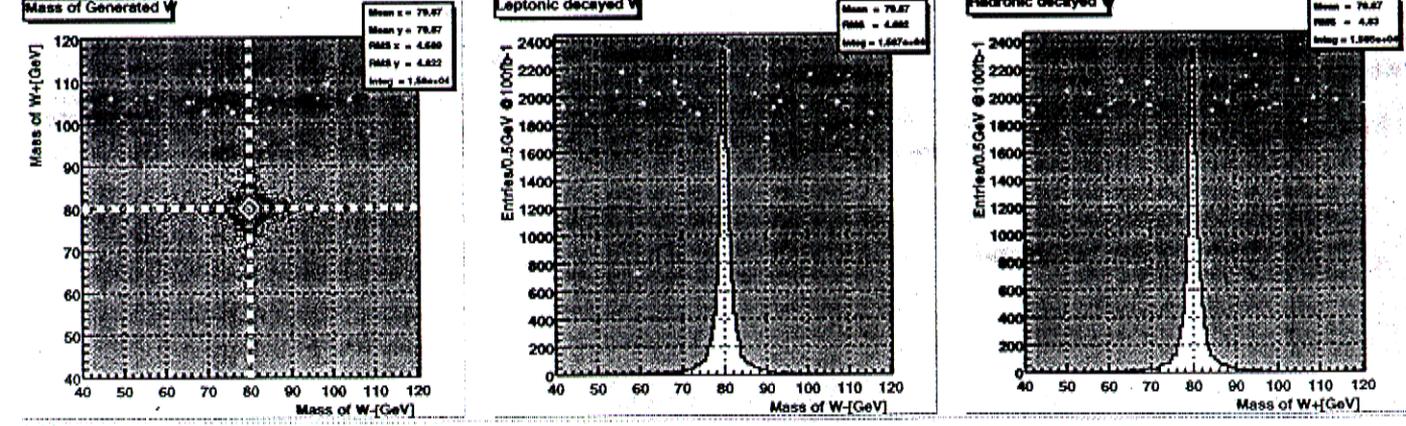
Reconstructed W



Fitted W $M_W(\ell\ell)$

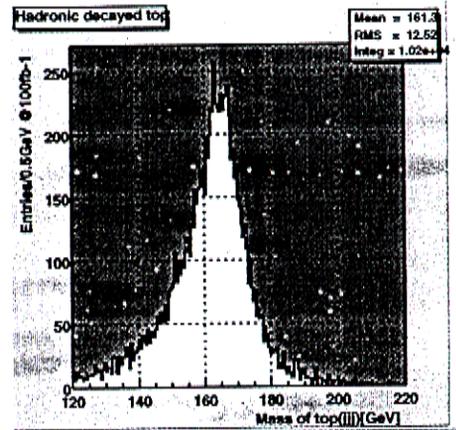
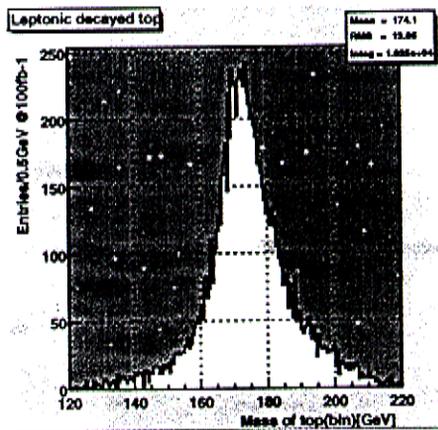
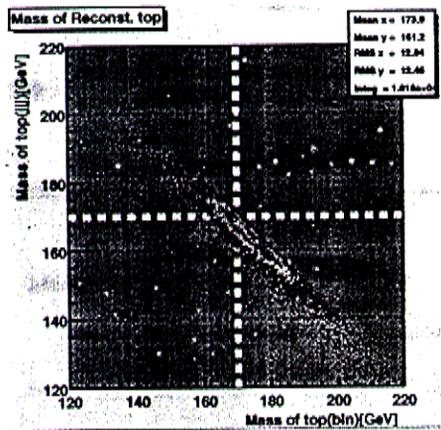


Generator level

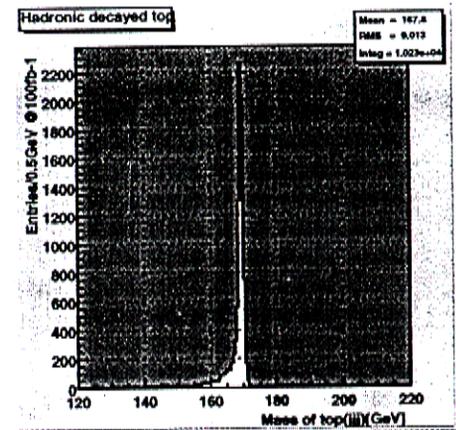
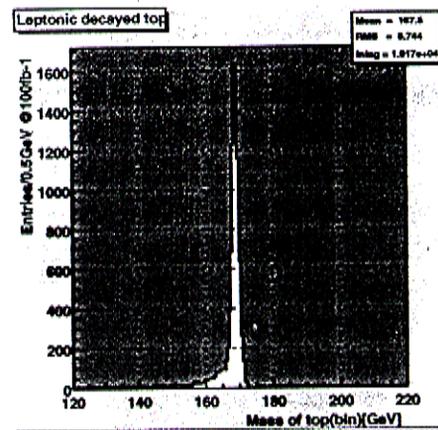
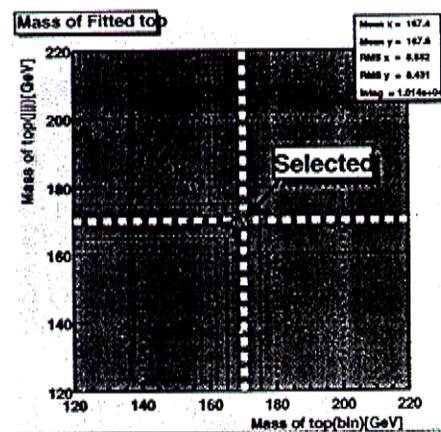


1st Trial of Kin. Fit (cont'd)

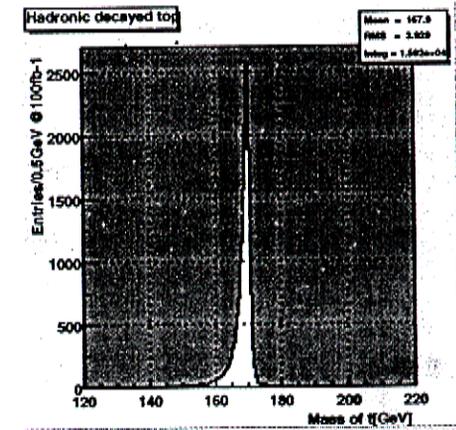
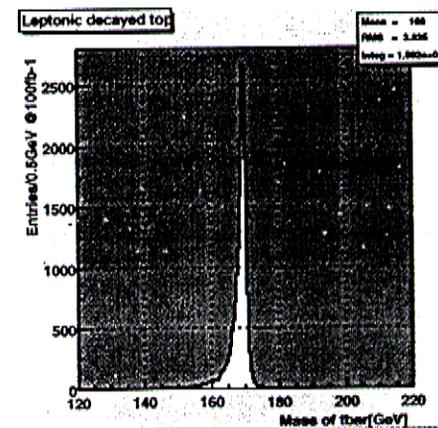
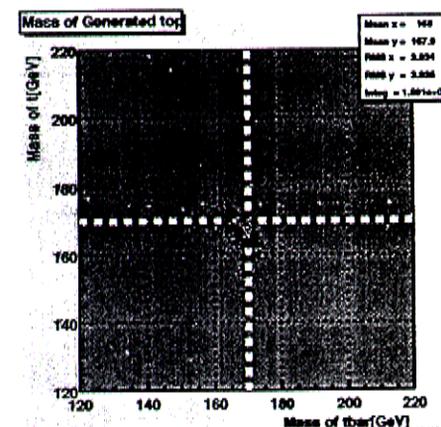
Reconstructed top



Fitted top



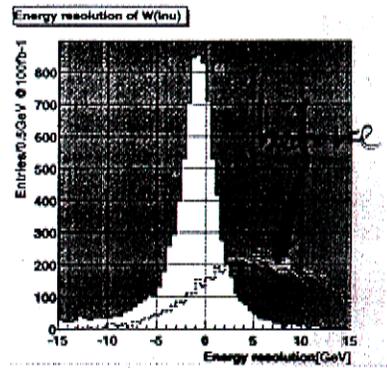
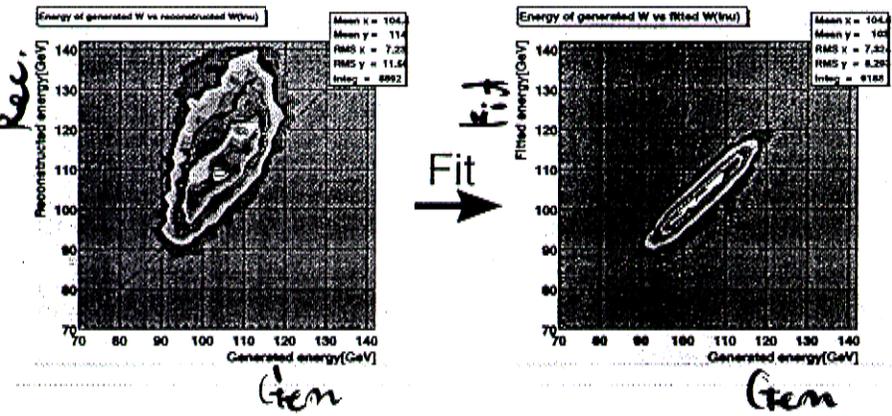
Generator level



Effects of Kin. Fit

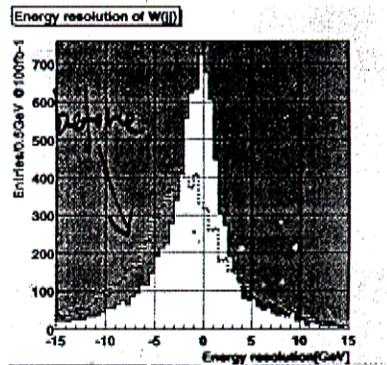
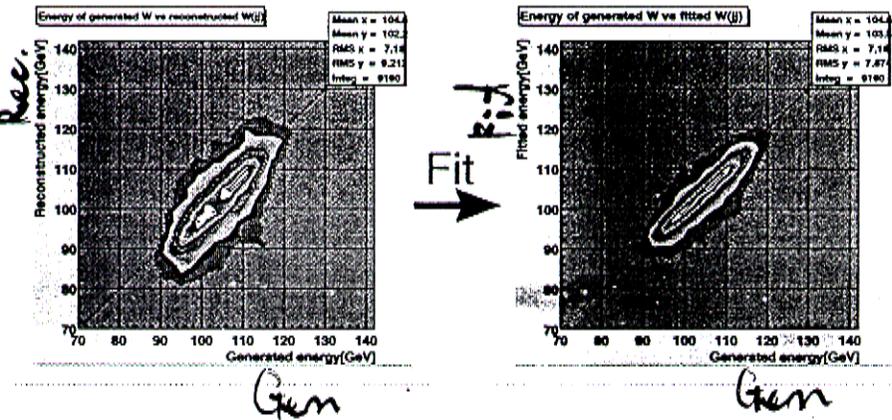
Energy of leptonic decayed W

Resolution



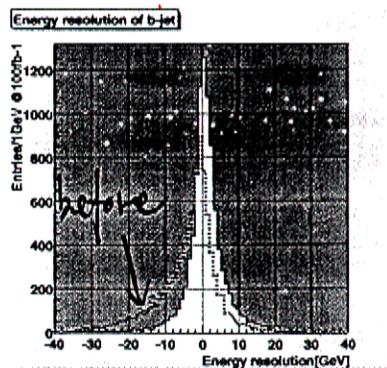
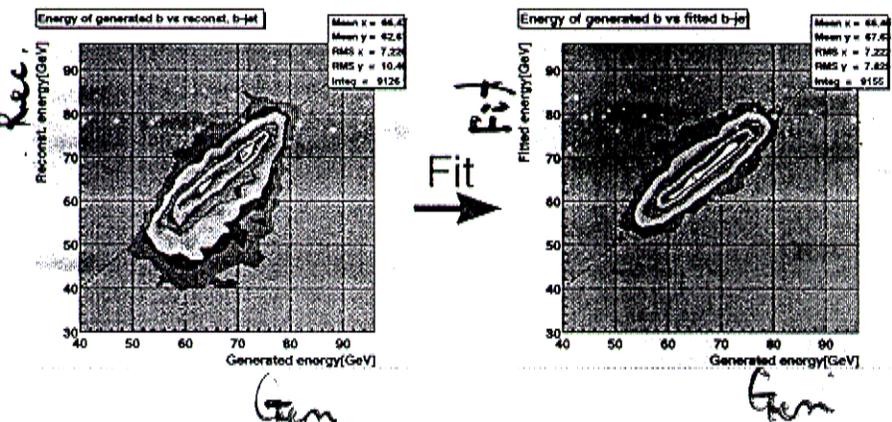
Energy of hadronic decayed W

Resolution



Energy of b-jets

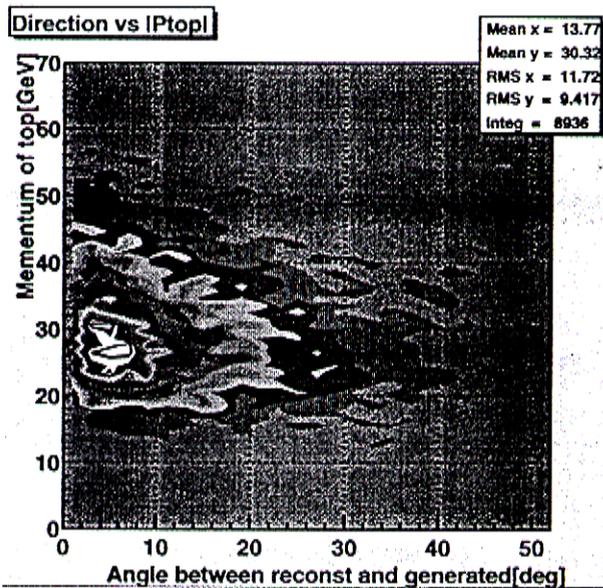
Resolution



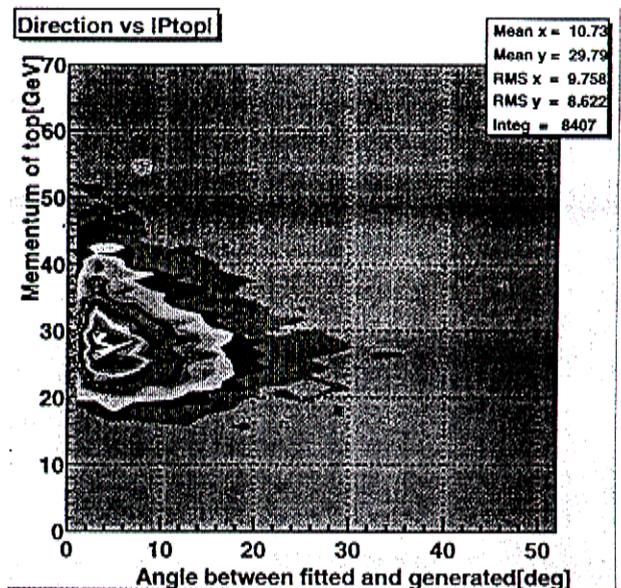
Effect on Top Direction

Angular resolution vs top momentum

Before



After



Overall Selection Eff. ~ 11 %

Appreciable improvement
of top quark direction

or

If we are to achieve the same
angular resolution for top momenta,
~ 35% gain in the selection efficiency

Summary and Plan

For L+4J mode, we developed a kinematical fit algorithm.

The fit recovers the missing energy carried away by neutrinos from bottom decays.

This results in appreciable improvement of top quark direction.

Toward further studies ...

Extension of the algorithm to below threshold region where top and anti-top cannot be simultaneously on-shell.

Inclusions of ISR and beamstrahlung effects.

For further improvements of kinematical fit performance, we need better jet clustering

~~algorithm.~~

strategy (Force 4 jets)
instead of