

Top Quark Mass determination
from
 $t \bar{t}$ DiLepton events at Linear Collider

Jaroslav Antoš

Slovak Academy of Sciences
Academia Sinica

G. P. Yeh

Fermi Lab
Academia Sinica

M_{top}

• CDF	176.0 ± 6.5	
Lepton + jets	$175.9 \pm 4.8 \pm 5.3$	
DiLepton	$167.4 \pm 10.3 \pm 4.8$	
All-Hadronic	$186.0 \pm 10.0 \pm 5.7$	
• D0	172.1 ± 7.1	
Lepton + jets	$173.3 \pm 5.6 \pm 5.5$	
DiLepton	$168.4 \pm 12.3 \pm 3.7$	
• Tevatron	174.3 ± 5.1	GeV/c ²

$P\bar{P}$ ($q\bar{q}$ [90%], gg [10%]) $\rightarrow t\bar{t}$

Future

much higher statistics

uncertainty dominated by systematics

DiLepton events

$$t\bar{t} \rightarrow W^+b W^- \bar{b} \rightarrow \ell^+ \nu b \ell^- \bar{\nu} \bar{b}$$

may provide the smallest uncertainty in M_{top}

LHC

- $PP \rightarrow X$ $\sqrt{s} = 14 \text{ TeV}$
- luminosity
 - initial (low) = $10^{33}/\text{cm}^2/\text{s}$ $10 \text{ fb}^{-1}/\text{year}$
 - design (high) = 10^{34} $100 \text{ fb}^{-1}/\text{year}$

CMS or ATLAS

- $PP (q\bar{q}[10\%], gg[90\%]) \rightarrow t\bar{t}$
- $\sigma(t\bar{t}) \approx 800 \text{ pb}$
 - 8 million $t\bar{t}$ per low luminosity year $\approx 1 \text{ Hz}$
 - 100k DiLepton events
 - 600k Lepton + jets events with b-tag
- $\sigma(t\bar{b}) \approx 300 \text{ pb}$
 - , (t)

Linear Collider

$$\sigma_{e^+e^- \rightarrow t \bar{t}} \approx 700 \text{ fb} \quad (E_{cm} \approx 2m_t)$$

$$N_{\text{events}}(t\bar{t}) \approx 35,000 \quad \text{for } L = 50 \text{ fb}^{-1}$$

$$\sigma_{e^+e^- \rightarrow W W} \approx 5 \text{ pb} \quad \text{background}$$

Threshold Scan

- Fujii, Matsui, Sumino '94
- ECFA/DESY LC Studies '97
 - 11 - 50 fb⁻¹
 - $\Delta M_{\text{top}}^{\text{Pole}} \approx 120 - 200 \text{ MeV}$
 - $\Delta \alpha_s(M_{\text{top}}) \approx .003$
 - $\Delta, t/, t \approx 0.20 - 0.04$
 - recent studies Hoang, Kuhn, Sumino, Teubner, ...
 - “200 MeV” resolution ?
 - threshold uncertainties
 - $\Delta M_{\text{top}}^{\text{Pole}}$
 - $\Delta \alpha_s(M_{\text{top}})$
 - factor 2-3 larger than previous estimates
 - mass definition
 - NNLO corrections large

M_{top}

- direct M_{top} reconstruction
 - 2 GeV resolution at hadron colliders
 - independent of Luminosity, Cross Section
 - M_{top} measurement at \sqrt{s} beyond $t\bar{t}$ threshold

- DiLepton events

$$e^+e^- \rightarrow t\bar{t} \rightarrow W^+b W^-\bar{b} \rightarrow \ell^+\nu b \ell^-\bar{\nu}\bar{b}$$

known beam energy \Rightarrow constraint system
minimize the number of solutions

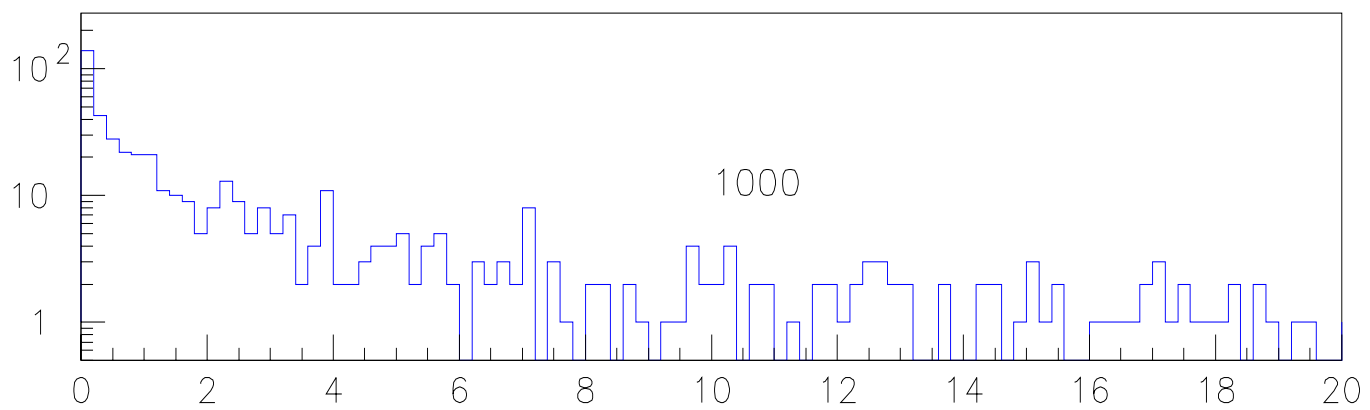
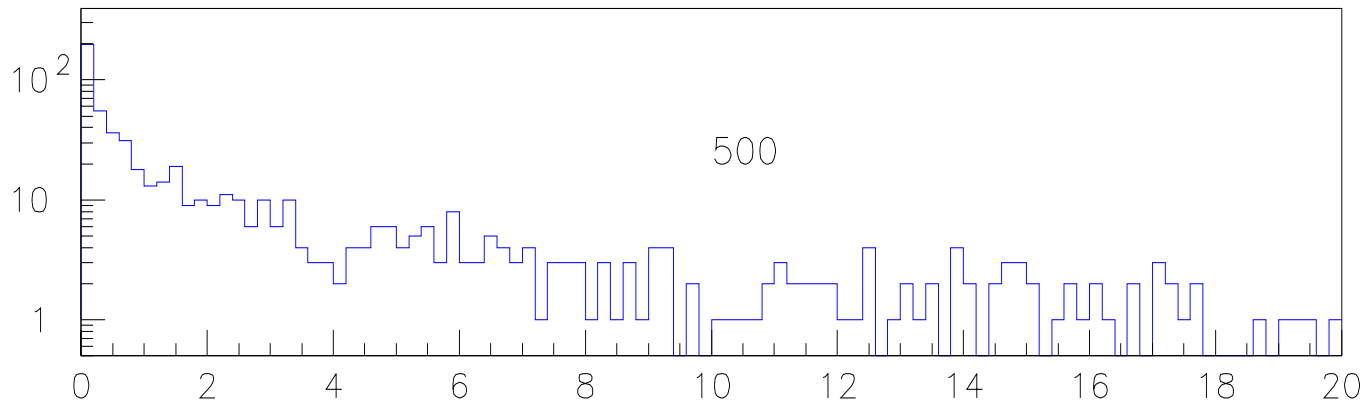
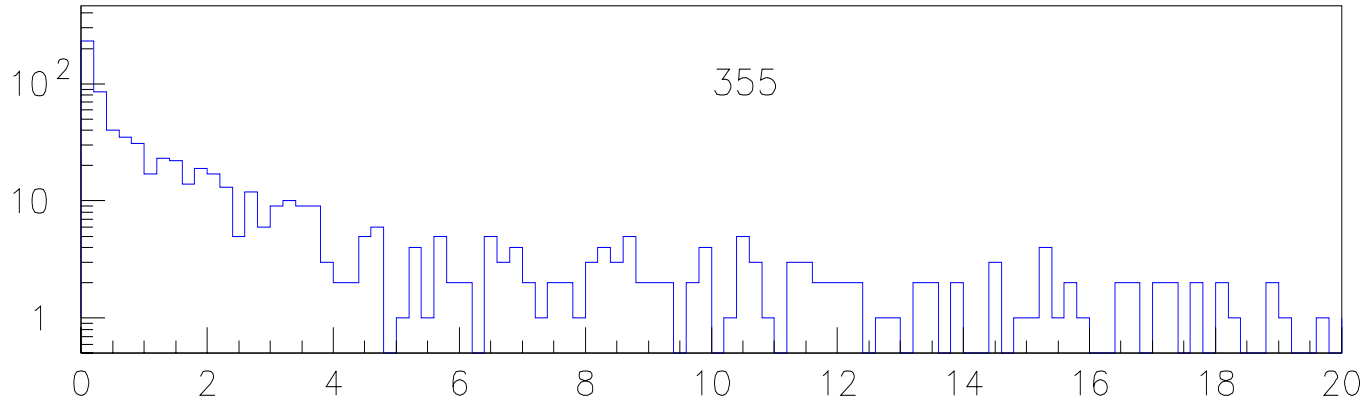


Figure 1: χ^2 distribution for "true" combination of reconstructed $t\bar{t}$ events, for $E_{cms} = 355, 500, 1000$ GeV.

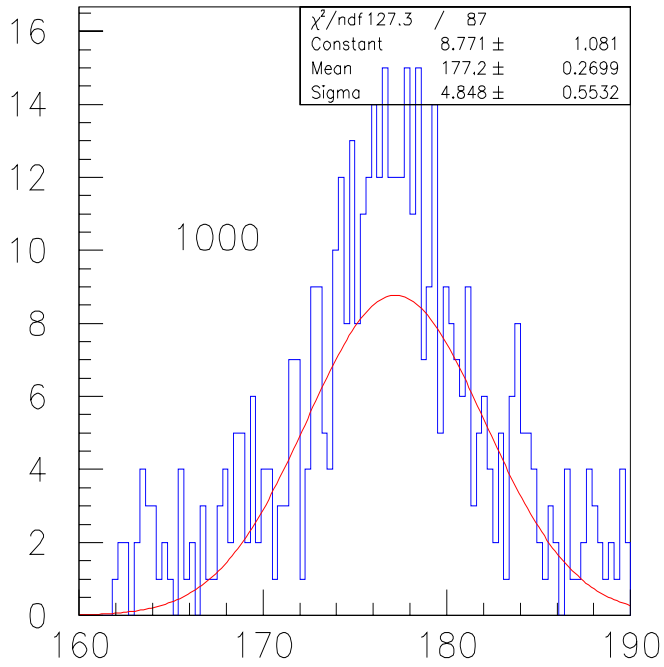
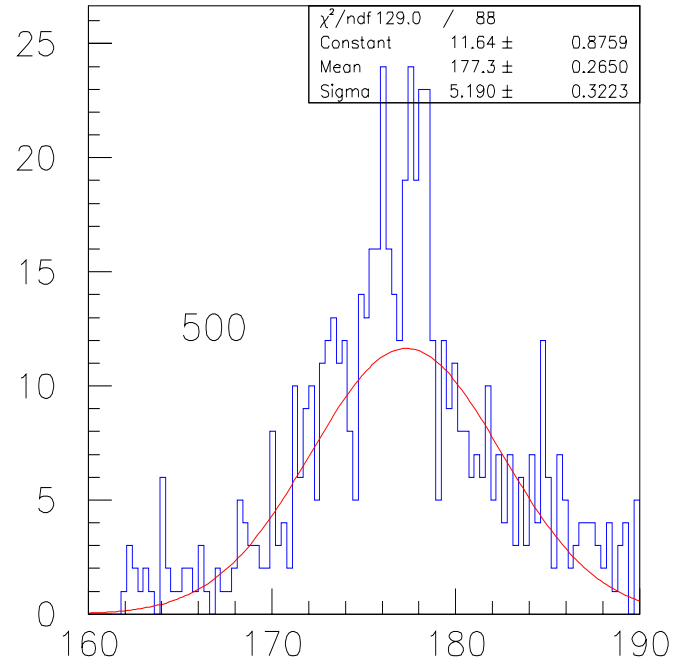
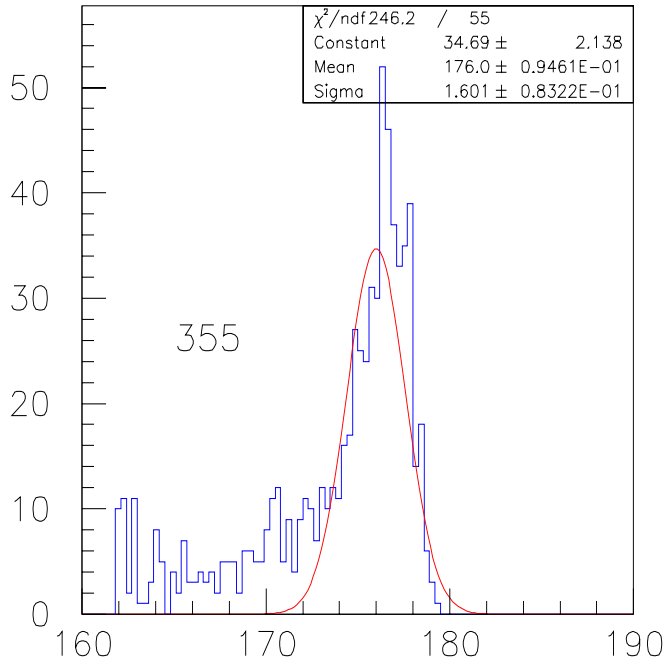


Figure 2: Reconstructed (raw) top mass distribution and Gaussian fit, for $E_{cms} = 355, 500, 1000$ GeV.

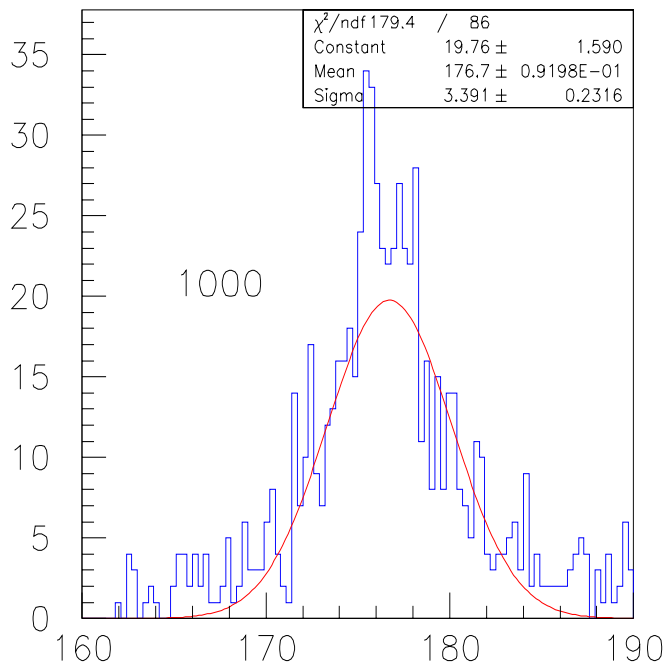
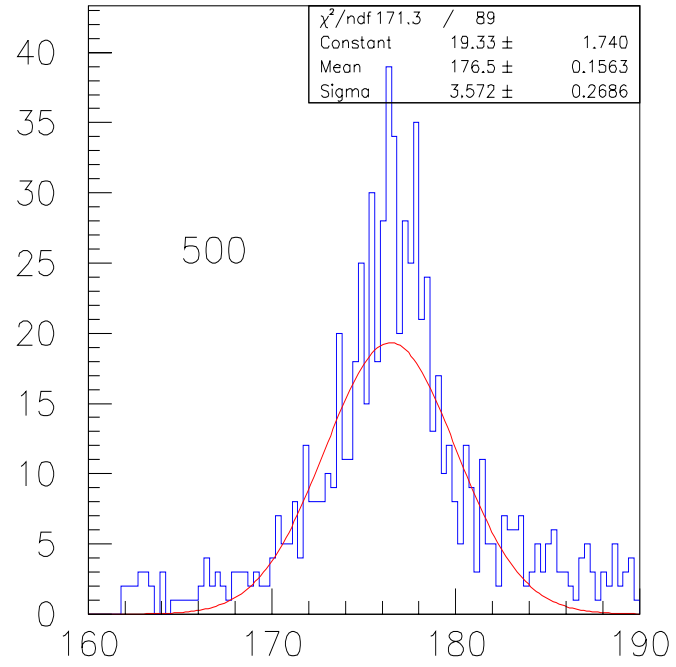
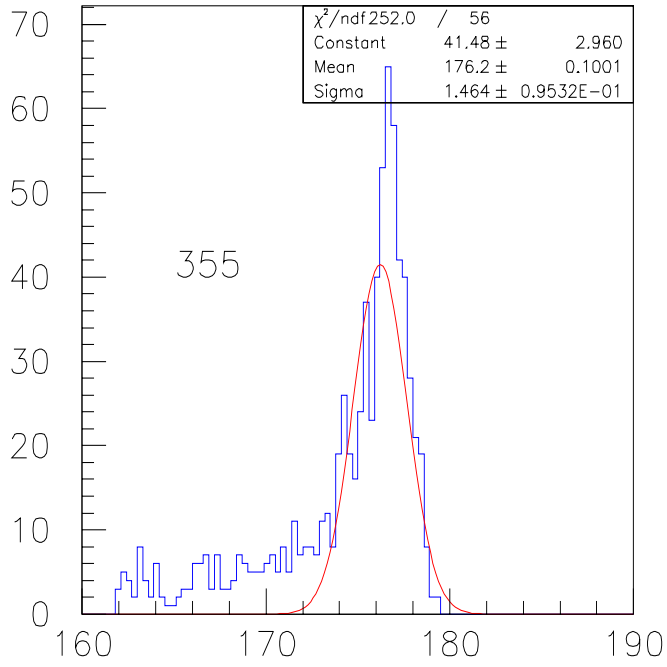


Figure 3: Reconstructed top mass distribution and Gaussian fit, with **initial, final state radiation, and beamstrahlung switched OFF**

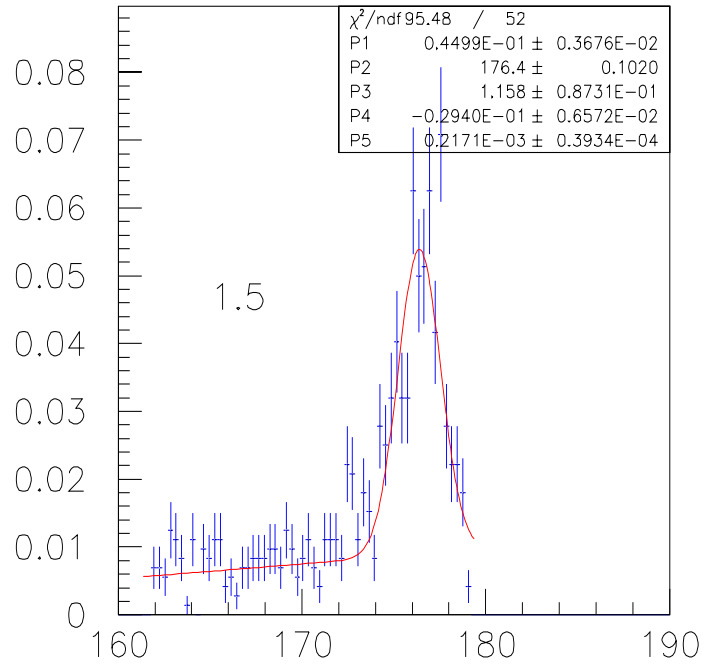
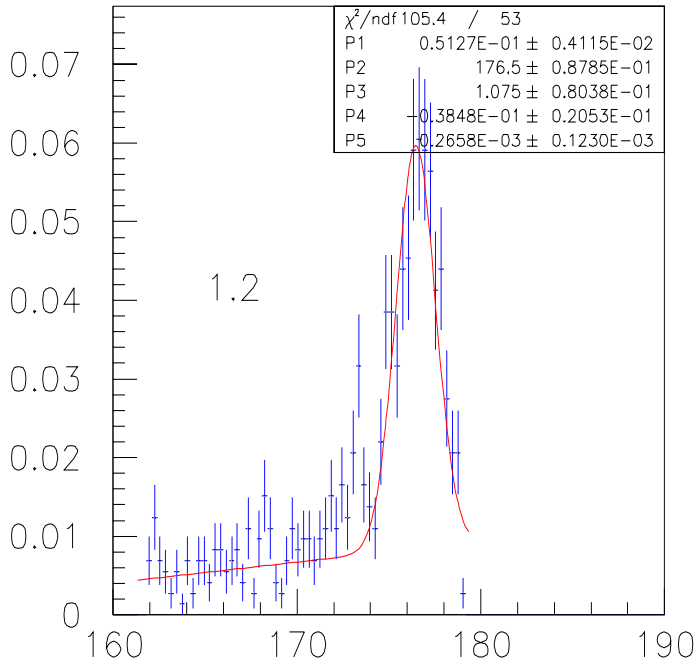
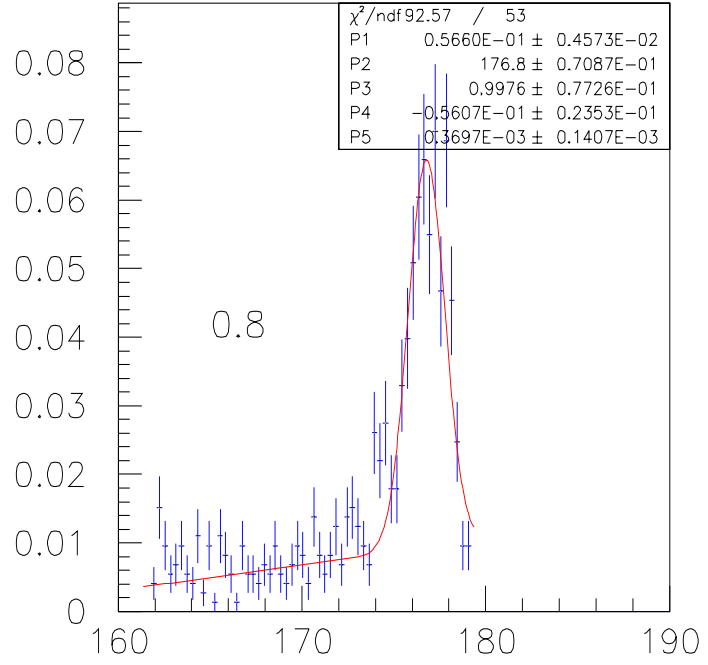
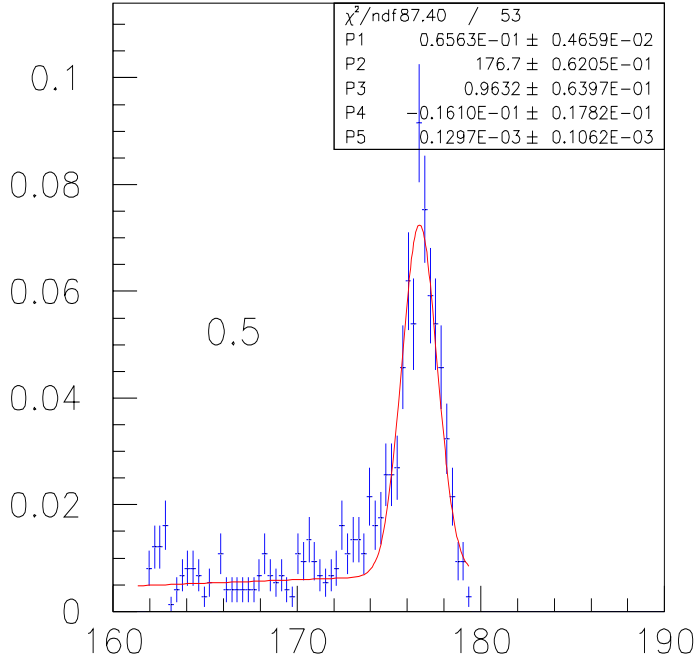


Figure 4: Reconstructed top mass distribution for $E_{cms} = 355$ GeV, for top widths 0.5, 0.8, 1.2, 1.5 times the nominal width for top mass 175 GeV/ c^2 .

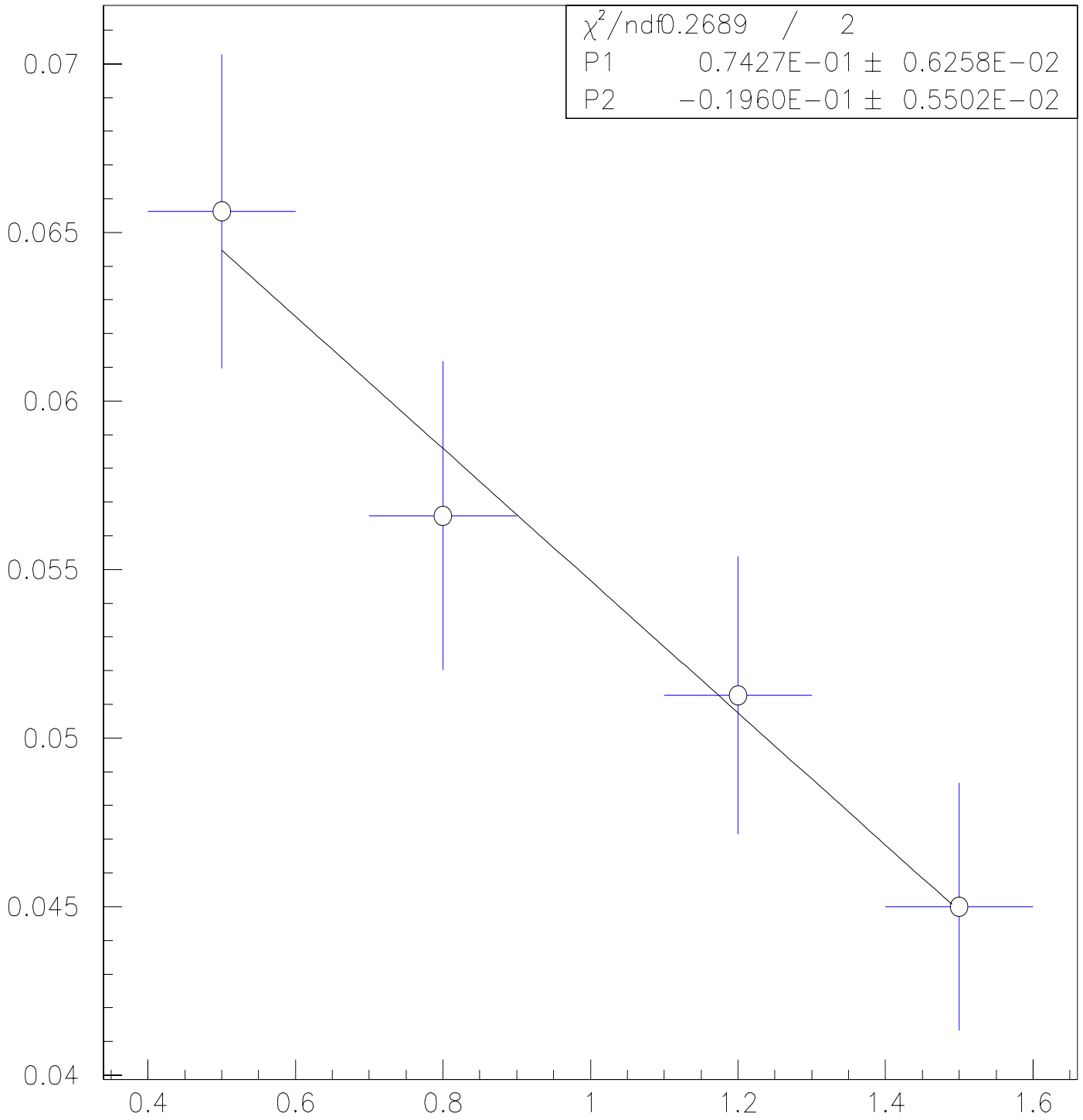


Figure 5: Dependence of p_1 parameter as a function of width ratio

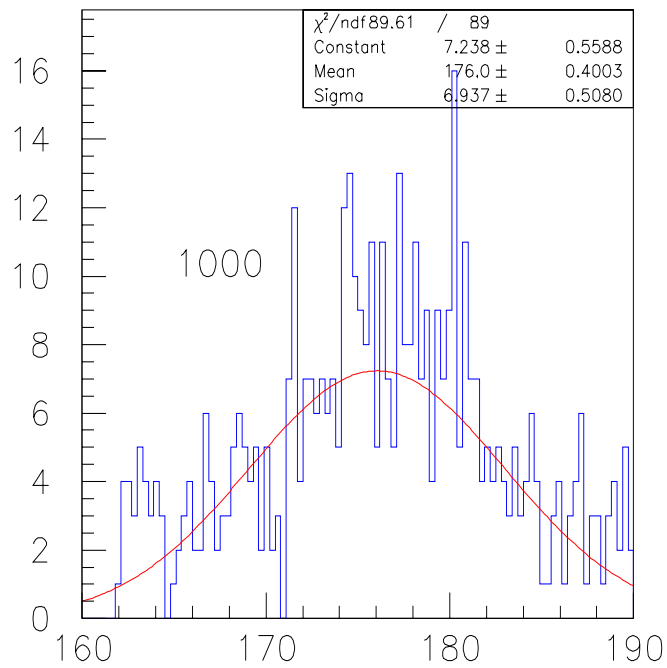
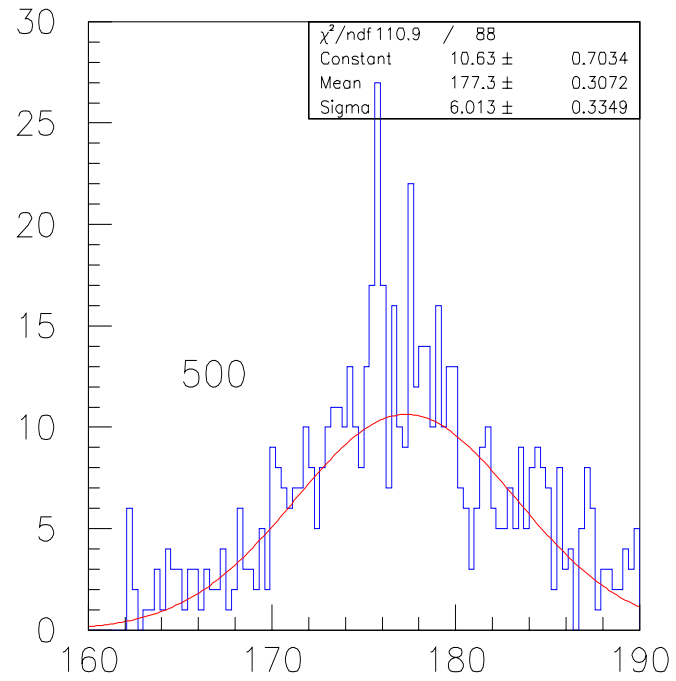
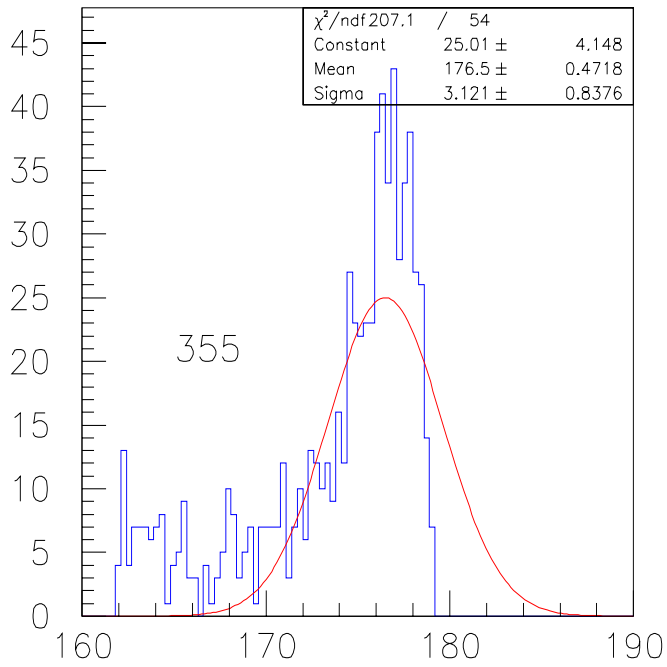


Figure 6: Reconstructed top mass distribution and Gaussian fit, with jet energy resolution degraded by a factor of 2.

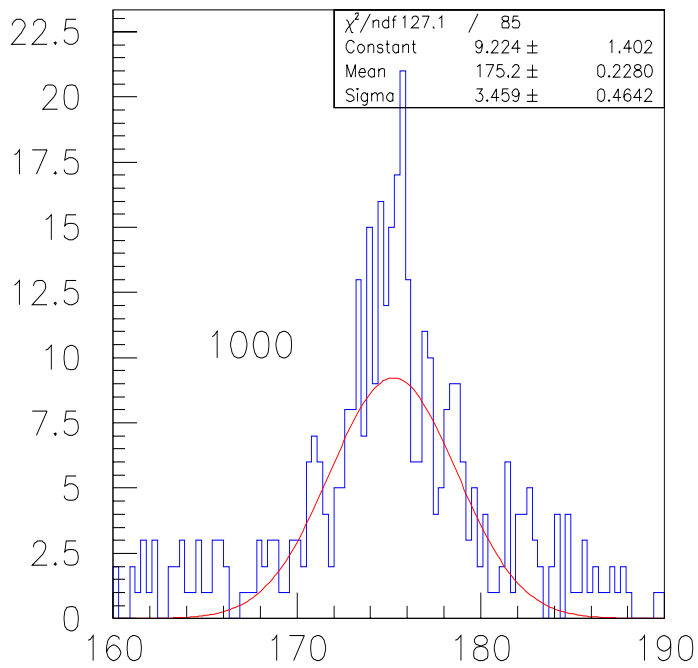
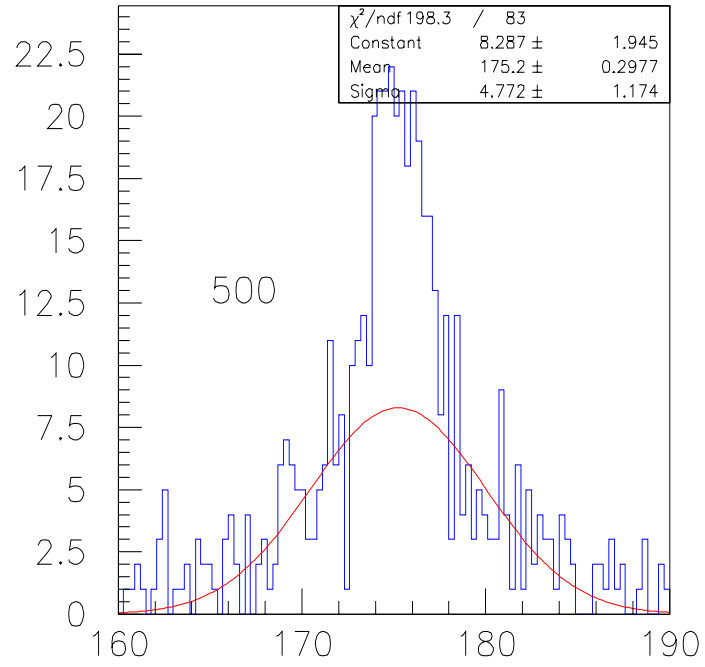
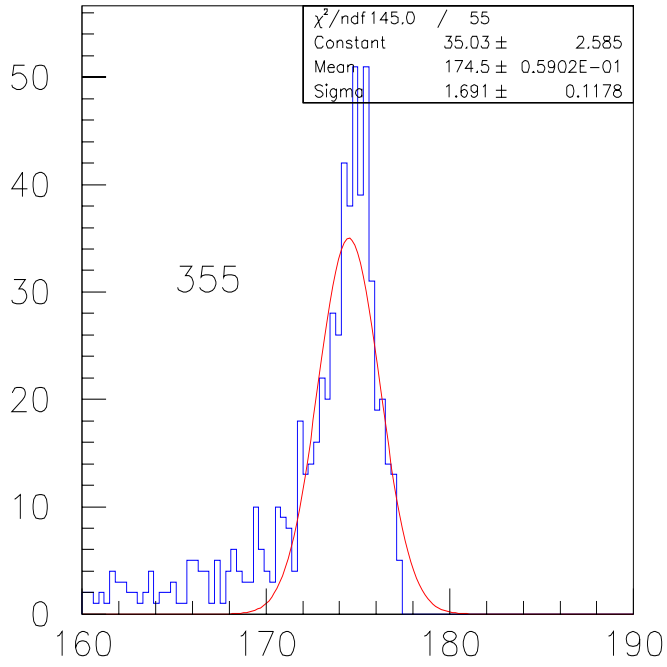


Figure 7: Reconstructed top mass distribution and Gaussian fit, with true (unsmear) quantities as input for reconstruction.

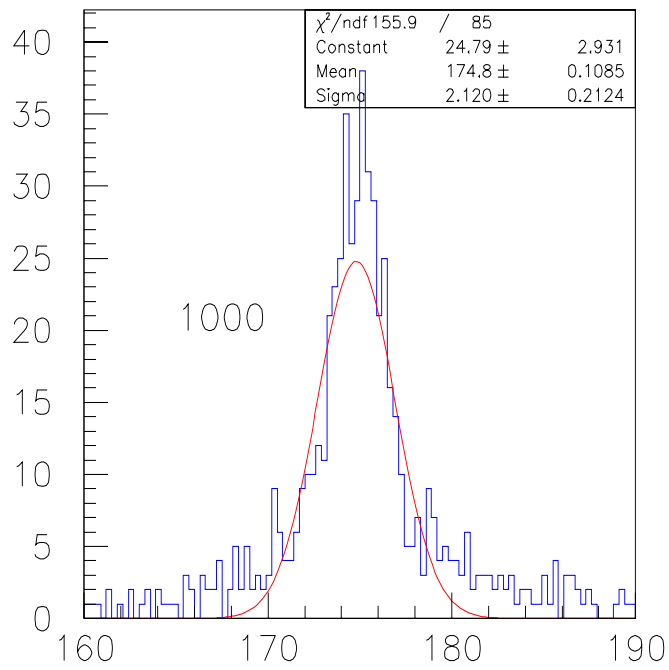
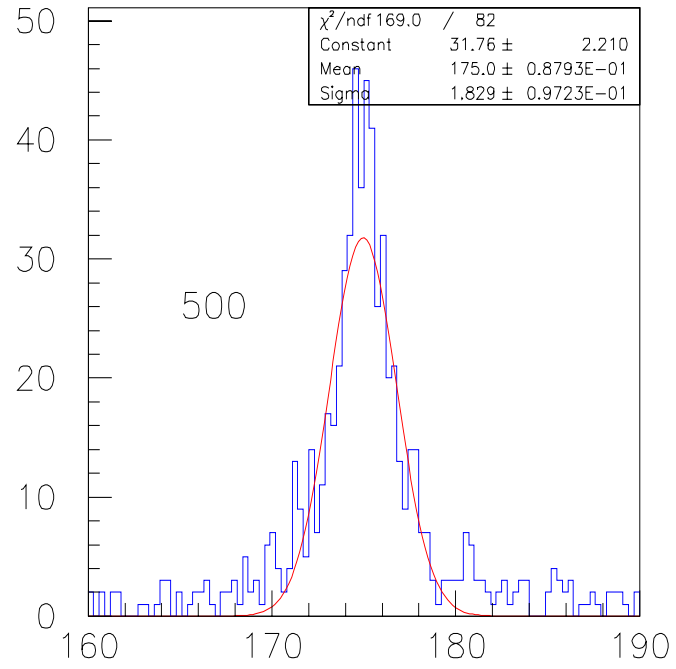
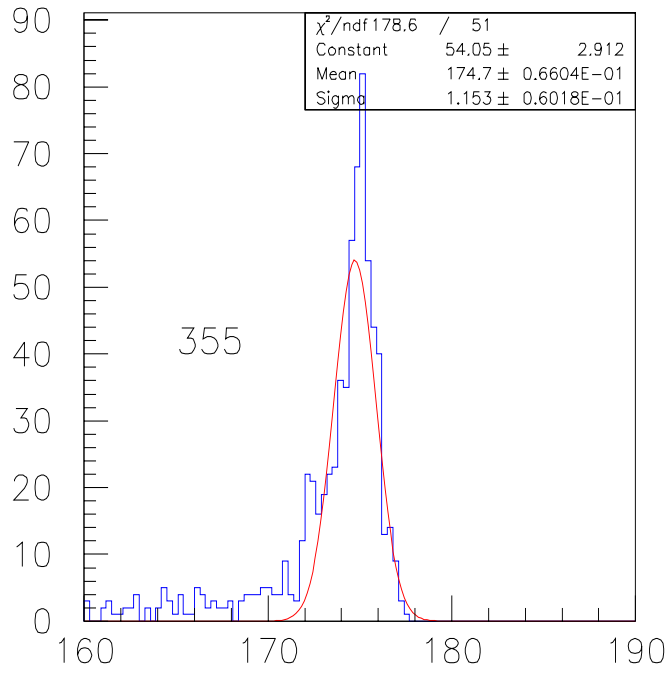


Figure 8: Reconstructed top mass distribution with true (unsmear) quantities as input for reconstruction, but with initial, final state radiation and beamstrahlung switched OFF.

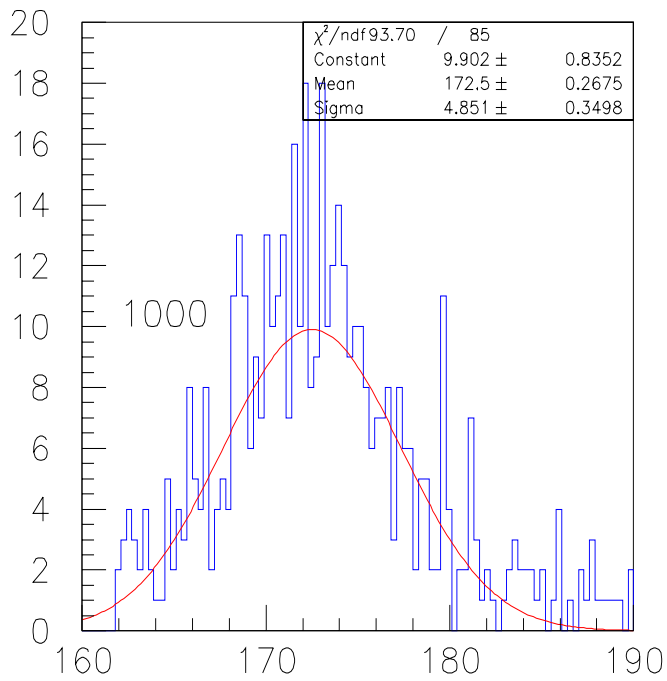
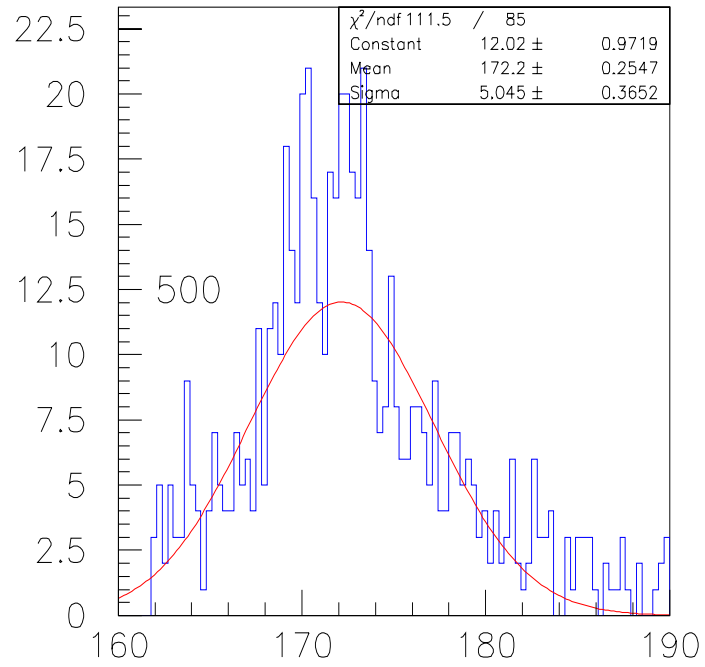
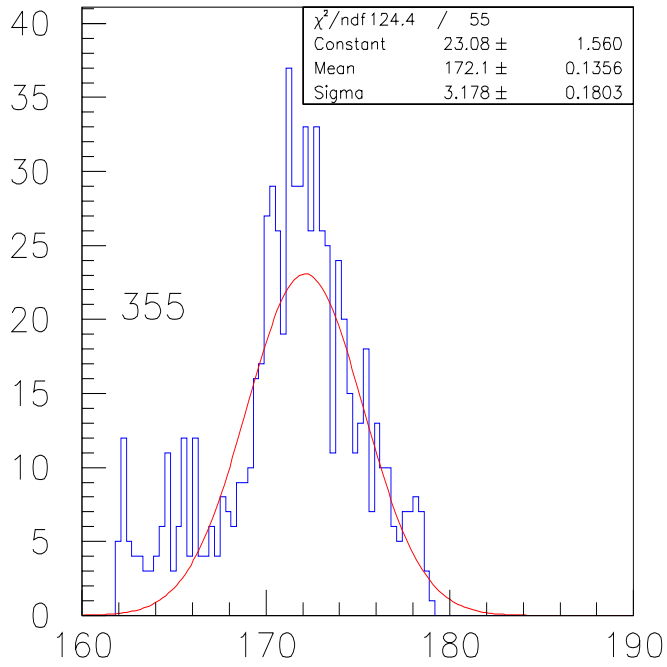


Figure 9: Reconstructed top mass distribution and Gaussian fit, with original top mass in simulation set to 170 GeV/c².

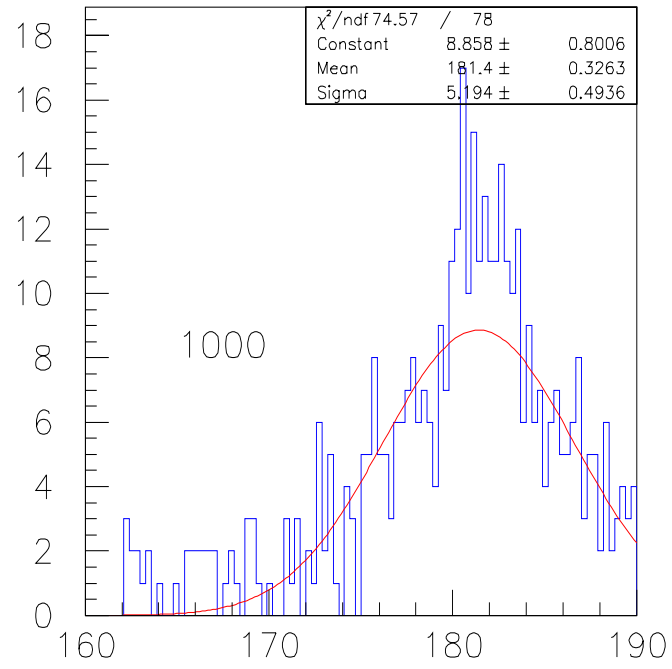
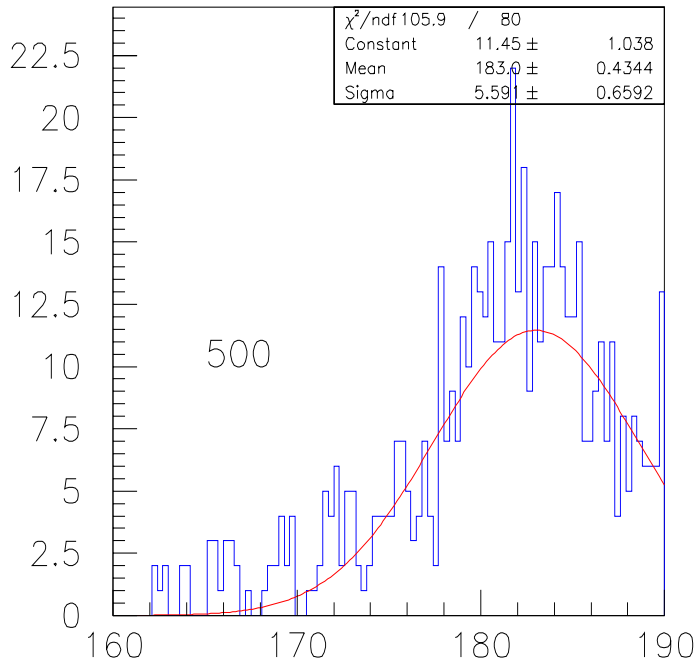


Figure 10: Reconstructed top mass distribution and Gaussian fit, with original top mass in simulation set to $180 \text{ GeV}/c^2$.

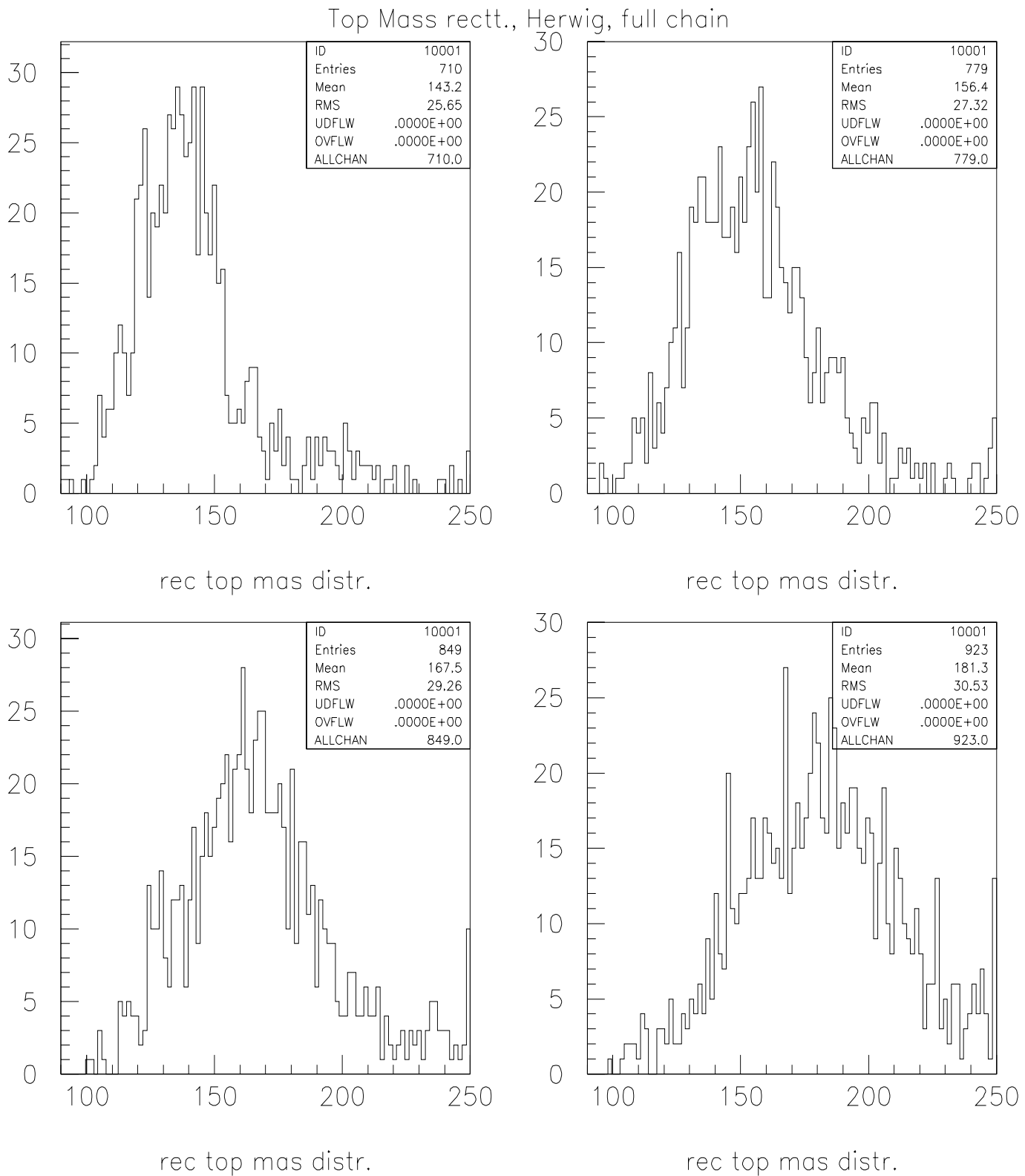


Figure 11: Reconstructed top mass distribution for CDF Monte Carlo DiLepton events, for top mass 140, 160, 180, and 200 GeV/c^2

		E (GeV)	L_{int} (pb ⁻¹)
LEP1	1989-95	M_Z	175
LEP1.5	'95	130 - 140	5
LEP2	'96	161	10
	'96	172	10
	'97	183	55
	'98	189	175
	'99-2000	196-200	150-200/yr

E method	161 GeV threshold $\sigma_{W\bar{W}}$	172 & 183 $l\nu q\bar{q}$	172 & 183 $q\bar{q}q\bar{q}$
ALEPH	$80.14 \pm 0.34 \pm 0.09 \pm 0.03$	80.34 ± 0.18	80.53 ± 0.18
DELPHI	$80.40 \pm 0.44 \pm 0.09 \pm 0.03$	80.50 ± 0.24	80.01 ± 0.22
L3	$80.80 \pm_{-0.42}^{+0.48} \pm 0.09 \pm 0.03$	80.09 ± 0.24	80.59 ± 0.23
OPAL	$80.40 \pm_{-0.41}^{+0.44} \pm_{-0.10}^{+0.09} \pm 0.10$	80.29 ± 0.19	80.40 ± 0.24
LEP		80.31 ± 0.11	80.39 ± 0.14

M_W from LEP

80.36 ± 0.09

To do

- full simulation and reconstruction
- systematic uncertainties
 - jet energy resolution
 - beam effects
 - gluon radiation
- also try $t \bar{t} \rightarrow \ell \nu b q \bar{q} \bar{b}$ Lepton + *jets* events

Summary

- M_{top} may be determined from event reconstruction

$$t \bar{t} \rightarrow \ell^+ \nu b \ell^- \bar{\nu} \bar{b} \quad \text{DiLepton events}$$

to excellent precision $\Delta M_{\text{top}} \approx 200 \text{ MeV}$

- mass determination seems most precise with a beam energy just above threshold
- also measure Γ_t to $\approx 25\%$
- These measurements are independent of luminosity & cross-section measurements
- For M_{top} measurement, not necessary to “scan” $t \bar{t}$ threshold