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Optimizing the Top Mass Measurement

Kirsten Tollefson, Paul Tipton, Josh Cassada
The University of Rochester

Richard Hughes
Fermilab

Abstract

We present a method for optimizing the top mass measurement in the lepton + jets mode. This method makes use of the additional information contained in the pretagged sample as well as the different signal-to-background ratio for SVX and SLT tagged events. When we apply this method to the data we obtain a top mass of $176.8 \pm 3.7(stat.)^{+5.1}_{-4.0}(sys.)\ GeV/c^2$.

1 Introduction

The standard top mass measurement for the lepton + jets channel, in 110 pb^{-1} of data, is $175 \pm 5.7(stat) \pm 7.1(syst)\ GeV/c^2$. The method for measuring the top mass in the lepton + jets channel uses a sample of events which have 4 or more jets where at least one of these jets must have a b-tag [1, 2]. This method neglects information that is in the untagged sample and in the differences in the signal-to-background ratio for SVX and SLT tagged samples. We would like to make optimal use of our present data sample. In this note, we investigate changes to the top mass measurement when we incorporate information from the untagged sample and distinguish between the types of b-tags. We want to do this *a priori*, using Monte Carlo, before looking at the data. We attempt to optimize the mass measurement by first looking at the method which gives the greatest reduction in the statistical uncertainty. Finally, we have applied this method to the data and evaluated the systematic uncertainties associated with it.

2 Finding the Optimal Method in Monte Carlo

Table 1 gives a list of possible sub-samples of the pretagged mass data sample. Table 1 also gives the number of observed events in the data and the number of expected background and top events for these subsamples [3]. Most of the background numbers in Table 1 come from Brian Harral's background note[4]. The background numbers for the SVX single tagged and the SLT tagged (no SVX tags) subsamples were calculated by scaling the background numbers from the SVX tagged and SLT tagged subsamples, respectively. The background number for the SVX double tagged subsample comes from a preliminary calculation done by Rob Roser. To reduce the amount of background in the top sample we also tried changing the kinematic cuts. In particular, we changed the E_T and η cuts on the fourth jet to match the cuts of the three highest E_T jets; $E_T > 15\ GeV$ and $\eta < 2.0$. The efficiencies of the tighter kinematic requirements on the fourth jet are 31% on background and 68% on top. Table 2 shows the number of expected events for background and top when the four mass jets all have $E_T > 15\ GeV$ and $\eta < 2.0$. The

Subsample	$N_{observed}$	N_{back}	N_{top}
Pretag	153	$98\ ^{+11}_{-11}$	55
No tag	119	$91.6\ ^{+10}_{-10}$	27.4
SVX tag	20	$1.6\ ^{+0.65}_{-0.43}$	18.4
SVX single tag	15	$1.2\ ^{+0.49}_{-0.32}$	13.8
SVX double tag	5	$0.14\ ^{+0.04}_{-0.04}$	4.9
SLT tag	21	$5.0\ ^{+1.56}_{-1.07}$	16
SLT tag (No SVX)	14	$3.5\ ^{+1.09}_{-0.75}$	10.5
SVX and SLT tag	7	$0.15\ ^{+0.09}_{-0.06}$	6.9
SVX or SLT tag (Standard Method)	34	$6.4\ ^{+2.1}_{-1.4}$	27.6

Table 1: The number of observed top events in 110 pb^{-1} of data and the expected number of background and top events for the various subsamples.

expectation numbers in Table 2 are obtained by scaling the number of background and top in Table 1 by their measured efficiencies.

We run 500 pseudo-experiments for each of the subsamples listed in Table 1. For each pseudo-experiment of a particular subsample, we input the number of observed events and the expected background. The pseudo-experiment is compared to templates of various top masses which were generated from Herwig. The Minuit mass fitter[5, 6] returns a log likelihood value for each of the template masses. This log likelihood function is then minimized [7] to obtain a top mass value and its statistical uncertainty [8]. Table 3 gives the median mass and median statistical uncertainty from the 500 pseudo-experiments generated for various subsamples.

The last line of Table 3 shows the mass and statistical uncertainty for the untagged subsample where the four highest E_T jets must have $E_T > 15$ GeV and $\eta < 2$. We found that raising the E_T cut on the fourth jet only improved the statistical uncertainty for the untagged and pretagged cases. In the tagged subsamples the tighter kinematic cuts reduce the number of events in the sample appreciably enough that the statistical uncertainty for these samples increased. The more restrictive kinematic cuts help reduce the amount of background in the untagged sample without severely reducing the statistics. For the remainder of this analysis we will apply the more restrictive kinematic cuts only to the untagged sample.

Table 1 shows that the amount of background is significantly less in the SVX tagged sample than the SLT tagged sample and that the tagging efficiency is higher for SVX than SLT. Based on the improved signal to noise of the SVX we considered using only the SVX tagged sample and discarding the SLT tagged sample. From Table 3 we notice that we cannot improve the mass measurement by using the SVX tagged sample or the SVX double tagged sample alone. We reduce the amount of background by using only SVX tagged samples but we also lose a sufficient number of events to cause the statistical uncertainty to increase instead of decrease. In fact the subsample with the smallest expected statistical uncertainty is our current method of using SVX or SLT tags. However, by using this sample we are not using all of our available information. We are not making use of the information stored in the larger pretagged sample and we are not taking into account the differences between the signal-to-background ratio for the SVX and SLT tagged samples.

Subsample	N_{back} Expected	N_{top} Expected
Pretag	$31\ ^{+3.5}_{-3.5}$	38
No tag	$29.3\ ^{+3.2}_{-3.2}$	18.9
SVX tag	$0.5\ ^{+0.21}_{-0.14}$	12.7
SVX single tag	$0.4\ ^{+0.16}_{-0.10}$	9.5
SVX double tag	$0.04\ ^{+0.01}_{-0.01}$	3.4
SLT tag	$1.6\ ^{+0.5}_{-0.3}$	11
SLT tag (No SVX)	$1.1\ ^{+0.35}_{-0.24}$	7.2
SVX and SLT tag	$0.05\ ^{+0.03}_{-0.02}$	4.7
SVX or SLT tag (Standard Method)	$2.1\ ^{+0.7}_{-0.5}$	19

Table 2: The expected number of background and top events for the various categories when all 4 jets used in the mass fitter have $E_T > 15$ GeV and $\eta < 2$.

In order to use all of the available information, we can divide the pretagged sample up into non-overlapping (exclusive) subsamples. The subsamples are therefore uncorrelated and their likelihoods can then be multiplied together. As an example, we could combine the SVX tagged sample, the SLT tagged sample[9] and the not tagged sample. We take the 500 pseudo-experiments generated for each of these subsamples and multiply their likelihood values together for each pseudo-experiment. We fit each of the 500 combined likelihoods to obtain a mass and statistical uncertainty. We compare the median mass and median statistical uncertainty for different combinations of uncorrelated subsamples to determine which combination is the best.

Table 4 shows the masses and statistical uncertainties for several different combinations of uncorrelated subsamples. The combination which gives the smallest expected statistical uncertainty uses the following four subsamples:

- SVX single tagged
- SVX double tagged
- SLT tagged (No SVX)
- Not tagged with the tighter kinematic requirement that all 4 jets have $E_T > 15$ GeV and $\eta < 2$.

Using this combination of subsamples and running 500 pseudo-experiments of Herwig top 175, we obtain a top mass of $175.3 \pm 5.5(stat)$ GeV/c^2. From Monte Carlo, the standard top mass analysis, using an SVX or SLT tag, gives a top mass of $175.1 \pm 6.4(stat)$ GeV/c^2. Comparing the standard method to the new optimized method we notice that the statistical uncertainty on the top mass has been significantly reduced. This reduction in the statistical uncertainty is equivalent to increasing the size of our current SVX or SLT tagged data sample by approximately 35%.

Subsample	Median Mass GeV/c^2	Stat. Uncertainty GeV/c^2
Pretag	175.3	7.4
No tag	173.8	12.9
SVX tag	176.2	7.2
SVX single tag	176.0	8.4
SVX double tag	177.1	9.9
SLT tag	177.4	9.6
SLT tag (No SVX)	175.9	11.8
SVX and SLT tag	176.2	11.1
SVX or SLT tag (Standard Method)	175.1	6.4
No tag ($E_t > 15$)	175.0	11.8

Table 3: The median mass and median statistical uncertainty from 500 pseudo-experiments for various subsamples.

3 Applying the Optimal Method to the Data

After finding the optimal method in the Monte Carlo we can now apply it to our full 110 pb^{-1} data sample. Table 5 shows the mass and its statistical uncertainty in the data [7] for the same categories of subsamples that were used in the Monte Carlo study. When we combine the SVX single tagged, SVX double tagged, and SLT tagged sample with the not tagged sample, where the fourth jet must have $E_T > 15$ GeV and $\eta < 2$, the top mass is:

$$176.8 \pm 3.7(stat) GeV/c^2.$$

Figure 1 shows the combined likelihood fit for the data.

4 Systematic Uncertainties

Table 6 contains the types of systematic uncertainties and their values for the standard lepton + jets mass analysis. We have evaluated each of these sources of systematic uncertainty for our analysis, using similar or identical methods. In addition we have re-evaluated the systematics for the standard analysis. They are found in Table 14. The following sections explain the calculation of each systematic uncertainty.

4.1 Jet E_T Shift Systematics

The systematic uncertainties, jet E_T scale and soft gluon radiation, are obtained by shifting the jet energies and measuring the shift in the top mass. For our analysis we have combined these two systematics into an overall jet E_T shift systematic.

The jet E_T shift systematic contains many different jet shifts. We apply a jet shift for each of the following effects:

- Absolute Corrections

Combined Subsamples	Median Mass GeV/c^2	Stat. Uncertainty GeV/c^2
(SVX or SLT) + No Tag	175.9	5.9
(SVX or SLT) + No Tag ($E_t > 15$)	176.1	5.9
SVX + SLT (No SVX) + No Tag	175.8	5.9
SVX + SLT (No SVX) + No Tag ($E_t > 15$)	176.1	5.8
SVX single + SVX double + SLT (No SVX) + No Tag	175.8	5.5
SVX single + SVX double + SLT (No SVX) + No Tag ($E_t > 15$)	175.3	5.5

Table 4: The median mass and median statistical uncertainty from 500 pseudo-experiments for various subsamples.

Subsample	Median Mass GeV/c^2	Stat. Uncertainty GeV/c^2
Pretag	186.1	8.4
No tag	188.0	10.1
No tag ($E_t > 15$)	182.1	7.2
SVX tag	178.6	5.2
SVX single tag	178.6	5.7
SVX double tag	174.4	9.8
SLT tag (No SVX)	140.0	22.8
SVX or SLT tag (Standard Method)	174.3	5.8

Table 5: The median mass and median statistical uncertainty for the various subsamples in $110 pb^{-1}$ of data.

  - Behrends curve
  - Calorimeter Stability
  - Underlying Event

- Relative Corrections
- QFL Shift - only applied when shifting jet energies upward
- Annulus Study - difference in how data and MC model the energy between cones of 0.4 and 1.0
- Energy Outside Cone of 1.0

In the standard lepton + jets analysis a separate jet shift was applied for each effect. The mass shifts for each effect where then added in quadrature. We have written an analysis control module which can implement these shifts separately as was done previously or can do a single overall jet shift. We calculate the size of jet shift needed for each of the above effects and add them in quadrature. We then apply this total jet shift in both the positive and negative directions. The shifts are applied to the raw 4-vector of the jets. Once the jet energies have been shifted the $\not{E}_T$ of the event is recalculated.

We checked that adding all the jet E_T shifts in quadrature and obtaining a single mass shift was equivalent to applying separate jet E_T shifts and adding the mass shifts in quadrature. Table 7 shows the jet E_T shift systematic uncertainties for the standard mass analysis from CDFNOTE 3501 by Galtieri and Lys compared to values obtained from using our new analysis control module. The bottom line of the table is the systematic uncertainty we obtain when we do all the jet shifts at once and get a single mass shift as compared to the line above it which is all of the jet shifts done separately and the mass shifts added in quadrature. We see that the two values are equivalent within their uncertainties. Table 8 shows the jet E_T shift systematic uncertainties for the optimization method. Once again the bottom line of the table is the systematic uncertainty when all jet shifts are applied together.

When we combine all the jet E_T shifts together and a apply a single, overall upward and downward shift to the jet E_T's we get the following systematic uncertainty for the optimization method:

$$^{+4.1}_{-2.5}\ GeV/c^2$$

When we use this same method on the standard SVX or SLT tagged mass sample we get a systematic uncertainty due to jet shifts of:

$$^{+4.0}_{-2.7}\ GeV/c^2$$

4.2 Different Generators

To study the effects of different Monte Carlo generators we generate our pseudo-experiments from Isajet Monte Carlo instead of Herwig. We compare 500 Isajet pseudo-experiments to the standard Herwig templates. We obtain the systematic uncertainty by taking the difference in the median masses of the two distributions, the mass distribution for Isajet pseudo-experiments with Herwig templates and the mass distribution for Herwig pseudo-experiments with Herwig templates. The shift in the median masses is $0.3 \pm 0.3\ GeV/c^2$.

4.3 Hard Gluon Radiation

We repeated the procedure which was used to measure the hard gluon systematic for the standard lepton + jets analysis [12]. We measured the fraction of gluon events in each of the subsamples and then generated new subsamples which had $\pm$ 30% of the measured gluon fraction. We combined the likelihoods for all of the subsamples which had the 30% higher gluon percentages and got a combined mass and statistical uncertainty. We repeated this for the subsamples which had the 30% lower gluon percentages. Table 9 shows the median mass and median statistical uncertainty for the optimized method with varying amount of gluon radiation. The statistical uncertainty has two components which are added in quadrature. The size of the mass shift from the standard case to the higher gluon percentage case and the value needed to be added in quadrature with the statistical uncertainty from the standard case to get the larger statistical uncertainty for the higher gluon percentage case. The hard gluon systematic for the optimized case is 2.2 GeV/c^2. In the standard mass analysis the hard gluon systematic is 3.6 GeV/c^2. The large decrease in the size of the hard gluon systematic was not expected but can be explained by the method in which this systematic is measured. When this systematic was measured for the standard mass analysis we did not notice a sizeable mass shift but we did see a large change in the width of the top mass distribution which is reflected in the size of the statistical uncertainty. We decided to quote a systematic which took into account the change in the statistical uncertainty on the top mass. When we combine the subsamples together we decrease the statistical uncertainty so the hard gluon systematic, which is based on the statistical uncertainty, must also decrease.

4.4 Fit Configuration

Traditionally the systematic uncertainty due to fit configuration was taken as the difference between the SQUAW and MINUIT fit results. We now we have several different mass fitting techniques which use approximately the same data sample. They are:

- **Velev et al.** - Uses a different likelihood
- **Galtieri et al.** - Uses SQUAW and smooths the templates
- **Eddy et al.** - Uses MINUIT and smooths the templates but in a slightly different way
- **Kirsten et al.** - Uses Minuit but does not smooth

These results are given in Table 10.

We propose estimate the systematic due to different fitting methods by using the largest difference between the above results. Using this method we obtain a systematic of: ± 1.4 GeV/c^2. It has been noted that the current difference between SQUAW and MINUIT is most likely *not* due to differences in the kinematic fitting of each event. Rather the differences are most likely due to differences in the smoothing algorithms in the top mass templates. Thus we may consider re-grouping this systematic with the likelihood systematic uncertainty.

4.5 b-tagging Bias

The b-tagging bias systematic is meant to estimate the top mass uncertainty due to the uncertainty in:

- the efficiency vs. Et for SVX and SLT tagging
- the rate of tagging of non-B jets in real top events
- the effect of the b-tagging E_T bias on the W+jets background

In the PRD, it is stated that the last effect causes a negligible change in the top mass. The first two sources led to a top mass systematic of 2.4 GeV/c^2.

In the past, the uncertainty in the SVX and SLT tagging turn-on curve was modeled in the following way. In GENP, real b's matched to found jets passing the kinematics criteria ($E_t > 15$ GeV, $|\eta| < 2.0$) are called tagged and treated as such in the mass fitting routines. For SLT tags, real semileptonic b decays were selected. This changes the gradual turn-on above 15 GeV to a step function at 15 GeV. It has been suggested that we examine in greater detail our true uncertainty in the tagging efficiency instead of using this rather *ad hoc* approach. We have attempted to do this, first for SVX tagging, then for SLT tagging.

The SVX tagging efficiency is determined by Monte Carlo, then corrected by a scale factor, determined from data. Recently Unal and others (CDF3563) have determined the scale factor from CTC tracking studies. This scale factor is determined as a function of jet E_T, as shown in Figure 2. The uncertainties are statistical and systematic, where the latter are determined from reasonable variations in the tracking dependance on Q, the track quality variable. The first variation assumed no Q dependence and the second variation assumed a one standard deviation stronger Q dependence than the standard for the CTC tracking efficiency.

In all top analyses, the scale factor is assumed to be flat with E_T. We estimated the systematic uncertainty due to SVX b tagging by using the maximum deviation from flat allowed by Figure 2. This deviation was used to sculpt the standard Monte Carlo for SVX tagging. The resultant Monte Carlo $M_{top} = 175\ GeV/c^2$ pseudo experiments were then processed with the standard Minuit fitting routines. The deviation in the top mass from the nominal is given in Table 11.

The SLT efficiency is determined from data. The SLT muon selection is studied in detail with the very large $\psi \rightarrow \mu\mu$ sample. Systematic effects like how isolated the muon is have been studied and are flat with tagged jet E_T. SLT electron tags are studied with the high statistics $\gamma \rightarrow ee$ sample. Again, tagging rate vs. track isolation variables have been studied and residual uncertainties are negligible. Also small are the uncertainties in the had/Em cut efficiency vs. E_T.

One uncertainty in the SLT tagging is relevant. The exact ratio of real-to-fake SLT tags in top events is uncertain (at perhaps the 10-20% level). In order to estimate the effect of this on the top mass, we generate top pseudo experiments which have 100 % fake SLT tags in top events. We also generate pseudo experiments with 100 % real SLT tags in top events. The distribution is more broad for fake SLT tags. Half the difference between these two extremes is clearly a conservative estimate of this systematic error, and it is given in Table 11

We add the mass shift due to SVX tagging bias in quadrature with the SLT tagging bias to obtain the total b-tagging bias systematic uncertainty of 0.4 GeV/c^2 for the optimized analysis.

4.6 Background Spectrum

To measure the effect of different background shapes on the top mass we vary the Q^2 scale in Vecbos. The mass group decided previously that the standard Q^2 value to use in Vecbos would be P_T^2. We changed the Q^2 value in Vecbos to M_W^2 and generated new background templates. We then refit the data using the background templates with $Q^2 = M_W^2$. The results are shown in Figure 3. We take the shift in the mass value as the systematic uncertainty due to the background spectrum. Table 12 shows the mass values for the data using the two different Q^2 scales. We measure a systematic uncertainty due to the background spectrum of 0.7 GeV/c^2.

We use Vecbos to model the QCD $W + jets$ backgrounds. A small amount of non-W background is also expected. Previous studies done by Lina et al. (Need reference) have shown that the non-W background shapes are similar to Vecbos. So we make the assumption that all backgrounds are adequately modeled by Vecbos background templates. We intend to revisit this study, with larger data samples, and look at the following distributions:

- Non-isolated lepton + 4 jets
- Lepton + 4 low $\mathrm{E_T}$ jets
- Z + 4 jets

4.7 Likelihood Method

In determining a top mass from the data, we separated the data into the four subsamples listed in Section 2 and constrained the background to be within errors of the calculated value. By fitting the mass distribution from data to the appropriate HERWIG Monte Carlo templates, we determined, for each subsample, a log likelihood value for each of 11 top masses ranging from 140-210 GeV/c^2. Because the four subsamples are statistically independent, the *combined* log likelihood for each mass was determined by simply adding the log likelihoods for each of the individual subsamples. Using the point with the minimum combined log likelihood value and the three points to either side, a seven-bin fit to a parabola was performed on the plot of log likelihood values versus mass. As shown in Figure 1, the minimum of this parabola was taken to correspond to the most probable top mass for what we call the standard optimal method. The change in mass corresponding to a change in 0.5 units of log likelihood was taken to be the uncertainty on this value for the top mass.

In order to investigate the systematic uncertainty of this analysis, we considered other possible methods of using the optimal method to determine a top mass. Allowing the background to be unconstrained in the mass fitter, we performed an otherwise identical analysis on the data and found that the mass had shifted 0.3 GeV/c^2 from the standard central value to 177.1 GeV/c^2, as shown in Figure 4. The results for the individual subsamples are shown in Table 12.

Secondly, we performed the optimal method with the background constrained to be within the calculated errors, but instead of the nominal seven-bin fit of the log likelihood values, we required the parabolic fit to include the nine points corresponding to top masses of 150-200 GeV/c^2. The effect of this fixed range fit was to shift the mass value by 0.4 GeV/c^2 to 177.2 GeV/c^2. See Figure 5. Adding in quadrature the effects of these variations, we arrived at a likelihood method systematic error of 0.5 GeV/c^2.

4.8 Monte Carlo Statistics

The top mass is determined by comparing masses observed in the data to templates for top (at different masses) and background as determined from Monte Carlo. These templates have finite statistics, and thus there is some dependence on the fitted top mass.

To determine the effect of such finite statistics, we fit the data to *fluctuated* templates. To construct *fluctuated* templates, we vary the number of entries in each bin, using the standard template entry as the mean. This is done for all top mass templates, and the background template. The data is then fit using these templates, and a mass value is returned. This procedure is repeated 500 times, and the resulting distribution of returned masses is shown in Figure 6, for the standard analysis (using SVX or SLT tags). The systematic uncertainty we quote is then the sigma of the returned distribution, or 1.5 GeV/c^2.

The same method is used for the optimized analysis, in which all of the templates in each of the 4 sub-samples are *fluctuated*. The resulting distribution of returned masses is shown in Figure 7. The systematic uncertainty we quote is then the sigma of the returned distribution, or 1.3 GeV/c^2.

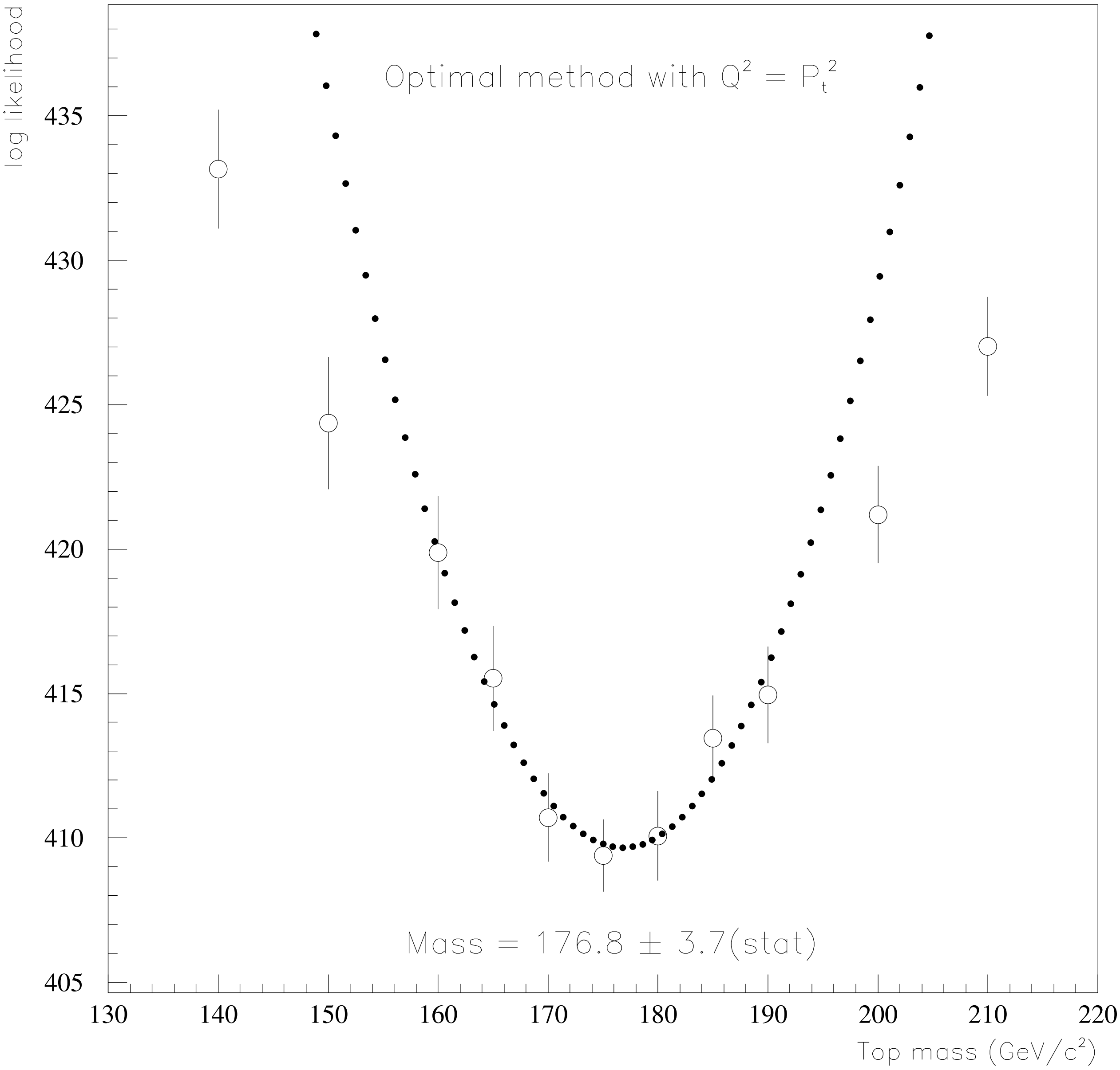

Figure 1: The likelihood fit for the optimized lepton + jets mode.

Systematic	Standard GeV/c^2
Jet E_T Scale	3.1
Soft Gluon Effects	1.9
Different Generators	0.9
Hard Gluon Effects	3.6
Fit Configuration	2.5
b-tagging Bias	2.3
Background Spectrum	1.6
Likelihood Method	2.0
Monte Carlo Statistics	2.3
Total	7.1

Table 6: The blessed systematics for the standard lepton + jets mass analysis.

Systematic	CDF3501 Values GeV/c^2	Our Values GeV/c^2
Annulus Study	1.1 ± 0.6	1.3 ± 0.4
Outside Cone 1.0	1.3 ± 0.6	1.4 ± 0.4
Total - Soft Gluon	1.7 ± 0.8	1.9 ± 0.6
Absolute	3.0 ± 0.3	2.3 ± 0.4
Relative	0.1 ± 0.3	0.5 ± 0.4
Total - Jet E_T Scale	3.0 ± 0.4	2.4 ± 0.6
Soft Gluon + Jet Scale	3.4 ± 0.9	3.1 ± 0.8
All Shifts Done Together	–	2.7 ± 0.4

Table 7: The values for the jet E_T shift systematics for the standard analysis from CDFNOTE 3501 compared to the values we get using our module for the standard analysis. The bottom line of the table is the systematic uncertainty we get when we added all the jet shifts in quadrature and apply a single overall jet shift. The numbers shown are for a downward shift only.

Systematic	Shift Down GeV/c^2
Annulus Study	1.0 ± 0.3
Outside Cone 1.0	1.1 ± 0.3
Total - Soft Gluon	1.5 ± 0.4
Absolute	1.2 ± 0.3
Relative	0.4 ± 0.3
Total - Jet E_T Scale	1.3 ± 0.4
Soft Gluon + Jet Scale	2.0 ± 0.6
All Shifts Done Together	2.5 ± 0.3

Table 8: The values of the jet E_T shift systematics for the optimization method. The bottom line is the systematic uncertainty when all jet shifts were done together. The values shown are for the shifted downward case only.

Gluon %	Median Mass GeV/c^2	Statistical Uncertainty GeV/c^2	Systematic Uncertainty GeV/c^2
Lower	176.3	5.0	2.0
Standard	175.8	5.4	–
Upper	175.0	5.8	2.1

Table 9: The median mass, median statistical uncertainty and systematic uncertainty for the optimized method when the gluon percentage is varied.

Analysis	Mass (GeV/c^2)
George Velev L**	174.2 ± 5.5
Squaw	175.6 ± 5.7
Minuit Nathan	174.4 ± 5.6
Minuit Kirsten	174.3 ± 5.8

Table 10: Mass and statistical uncertainty for various analyses of the lepton + jets data.

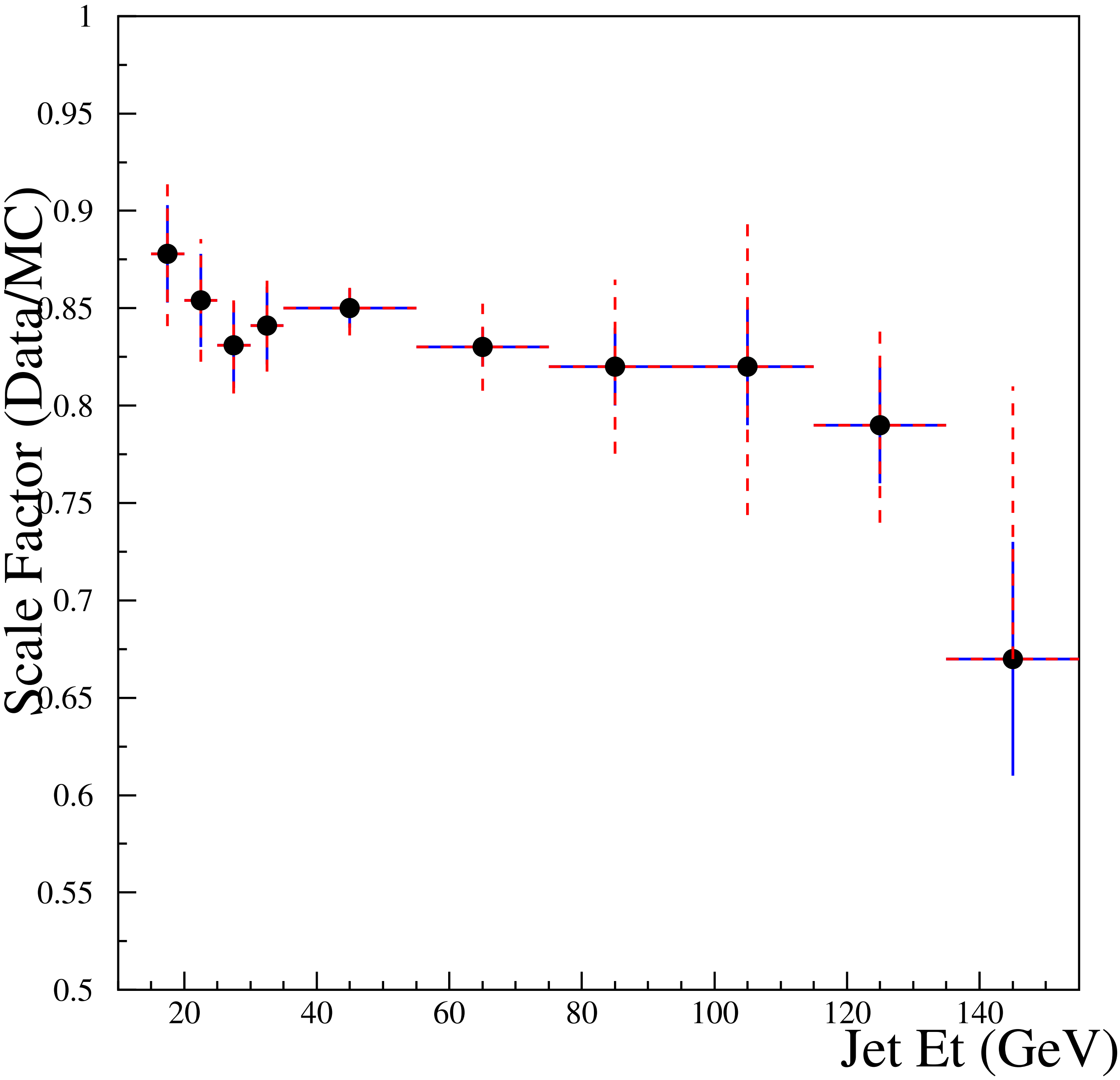

Figure 2: SVX B-tagging scale factor (data-over-Monte Carlo) vs. E_T as given in the analysis presented in CDF3563. The systematic uncertainty comes from assuming no Q dependence and a one standard deviation stronger Q dependence in the CTC tracking efficiency.

Sample Type	SVX Mass Shift	SLT Mass Shift	Combined
SLT or SVX	-0.2 $\pm$ 0.4	1.1	1.1
SVX Single	-0.5	0	0.5
SVX Double	+0.2	0	0.2
SLT	0	$\pm$2.2	2.2
Not Tagged	0	0	0
Combined	0.1	0.4	0.4

Table 11: Top Mass Shift for SVX and SLT b Tagging Bias. Shifts are given for the standard mass analysis (svx or slt), the 4 sub-samples, and the combined optimized analysis. All uncertainties are approximately 0.4 GeV/c^2.

Q^2 Value in Vecbos	Mass (GeV/c^2)
P_T^2 (Standard Value)	176.1 ± 3.8
M_W^2	176.8 ± 3.7

Table 12: The mass values for the data using different Q^2 scales to generate our Vecbos background templates.

Subsample	Constrained		Unconstrained		Calculated
	Mass	N_{back}	Mass	N_{back}	N_{back}
Not Tagged	182.1 ± 7.2	27.7 ± 3.1	177.9 ± 4.9	9.8 ± 9.0	29.3 ± 3.2
SLT (No SVX)	140.0 ± 22.8	3.7 ± 1.1	140.0 ± 30.7	9.5 ± 3.1	$3.5^{+1.09}_{-0.75}$
SVX Single	178.6 ± 5.7	1.1 ± 0.5	178.4 ± 5.6	0.01 ± 0.8	$1.2^{+0.49}_{-0.32}$
SVX Double	174.4 ± 9.8	0.14 ± 0.04	172.8 ± 11.5	0.01 ± 0.7	0.14 ± 0.04

Table 13: Results of the Constrained and unconstrained likelihood fits for the sub-samples used in the optimized method.

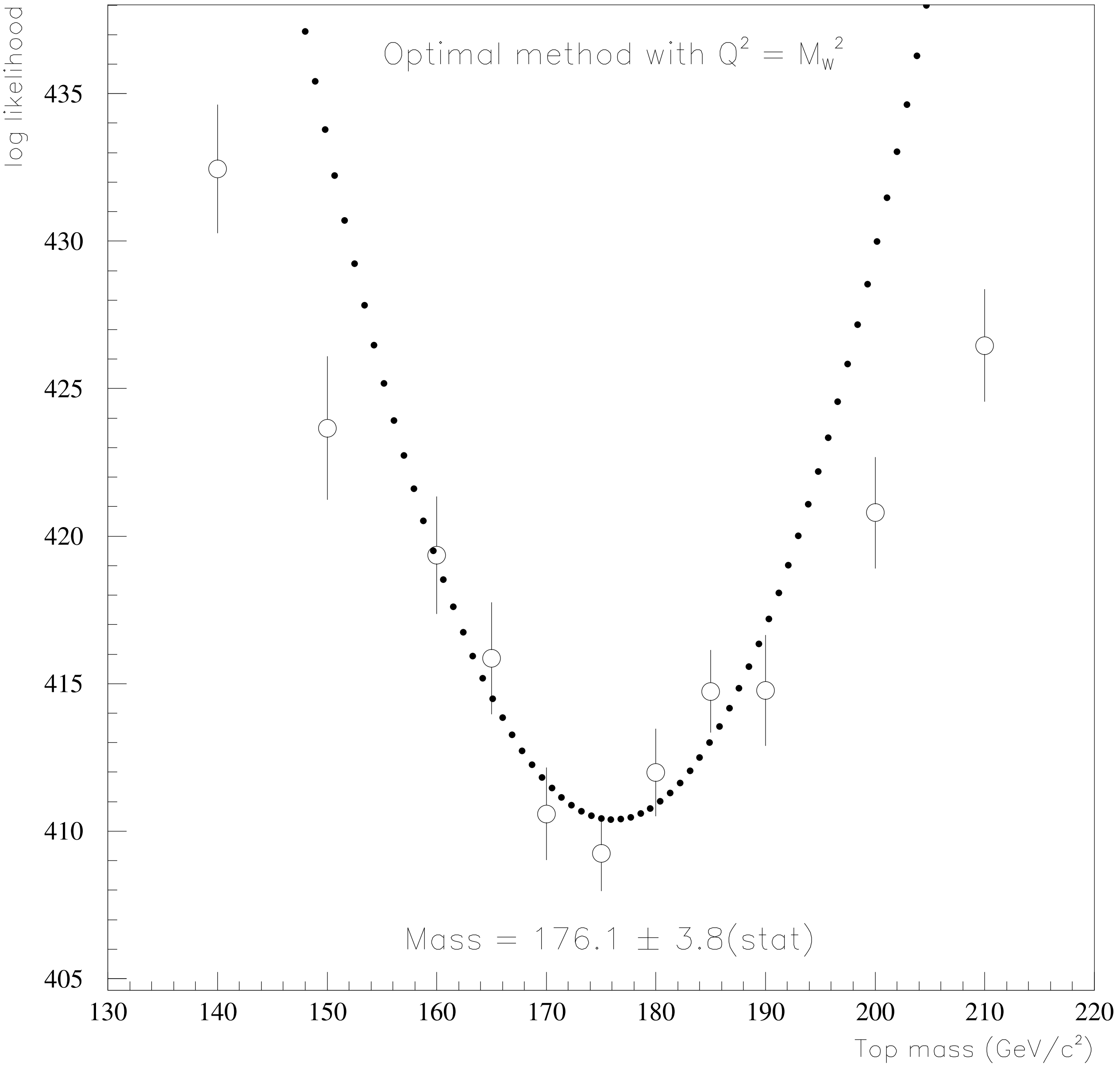

Figure 3: **The likelihood fit for the optimized lepton + jets mode with the background using $Q^2 = M_W^2$.**

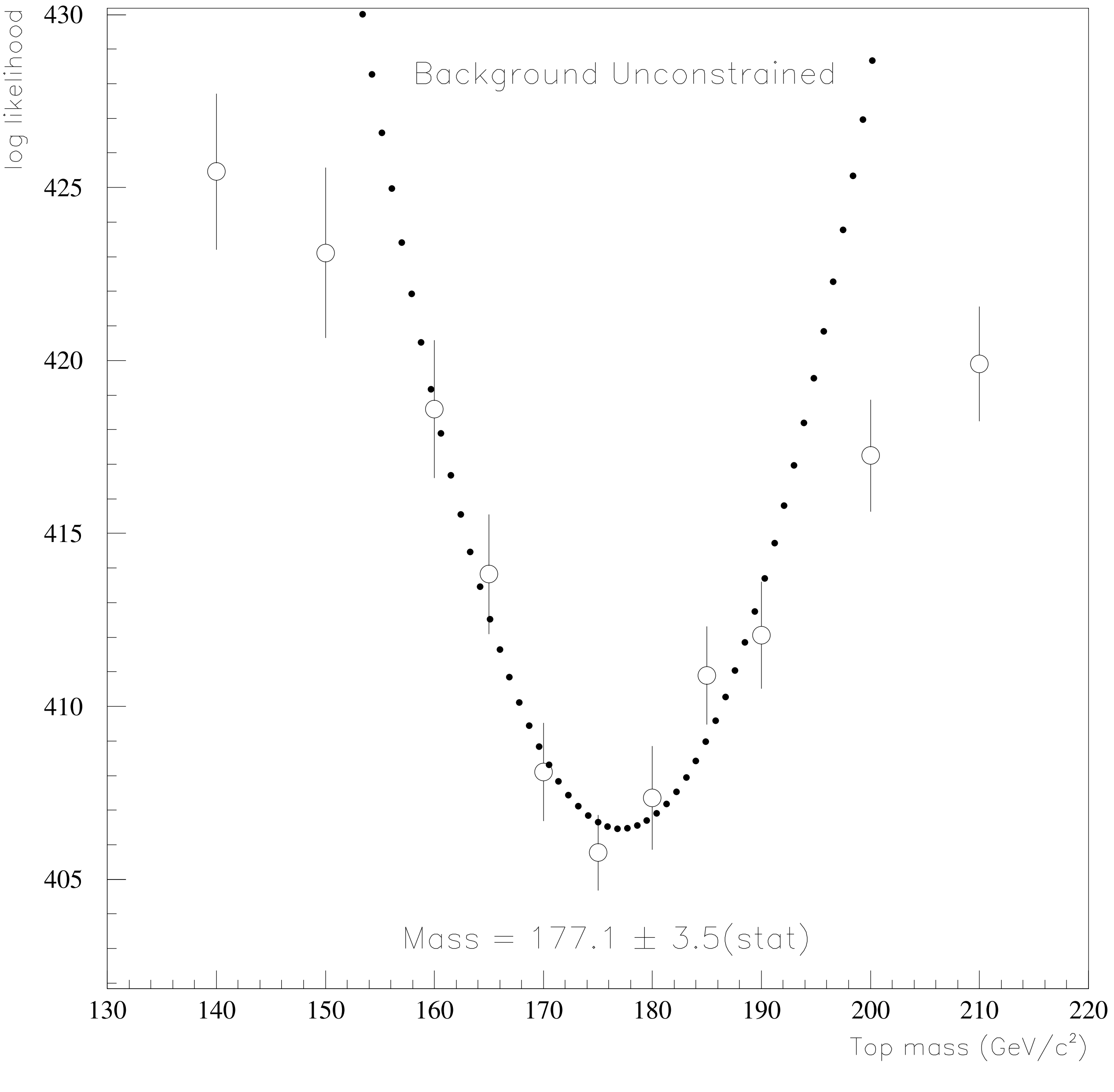

Figure 4: The likelihood fit for the optimized lepton + jets mode with the background unconstrained.

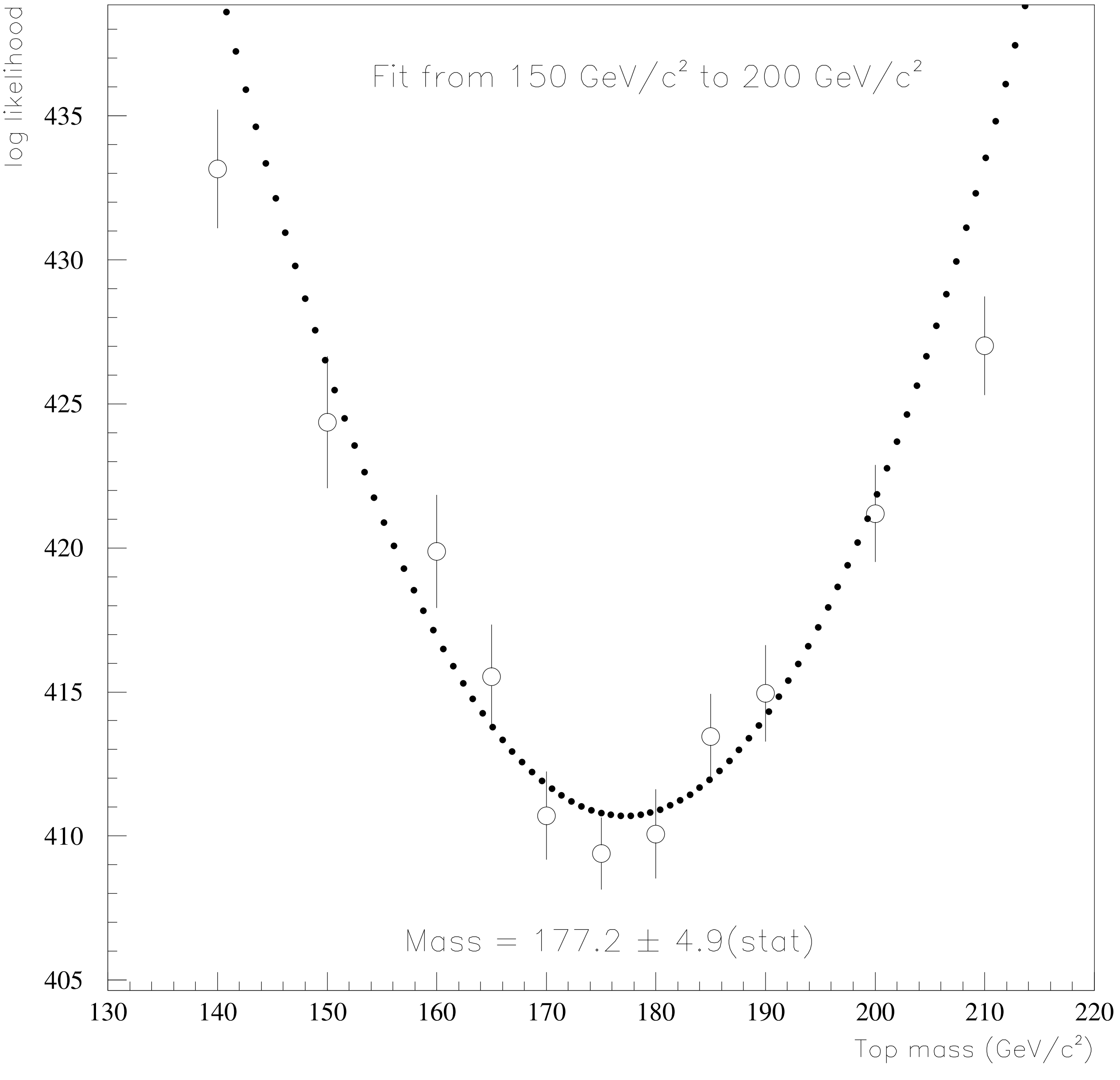

Figure 5: The likelihood fit for the optimized lepton + jets mode with the fit using nine mass points from 150 to 200 GeV/c^2.

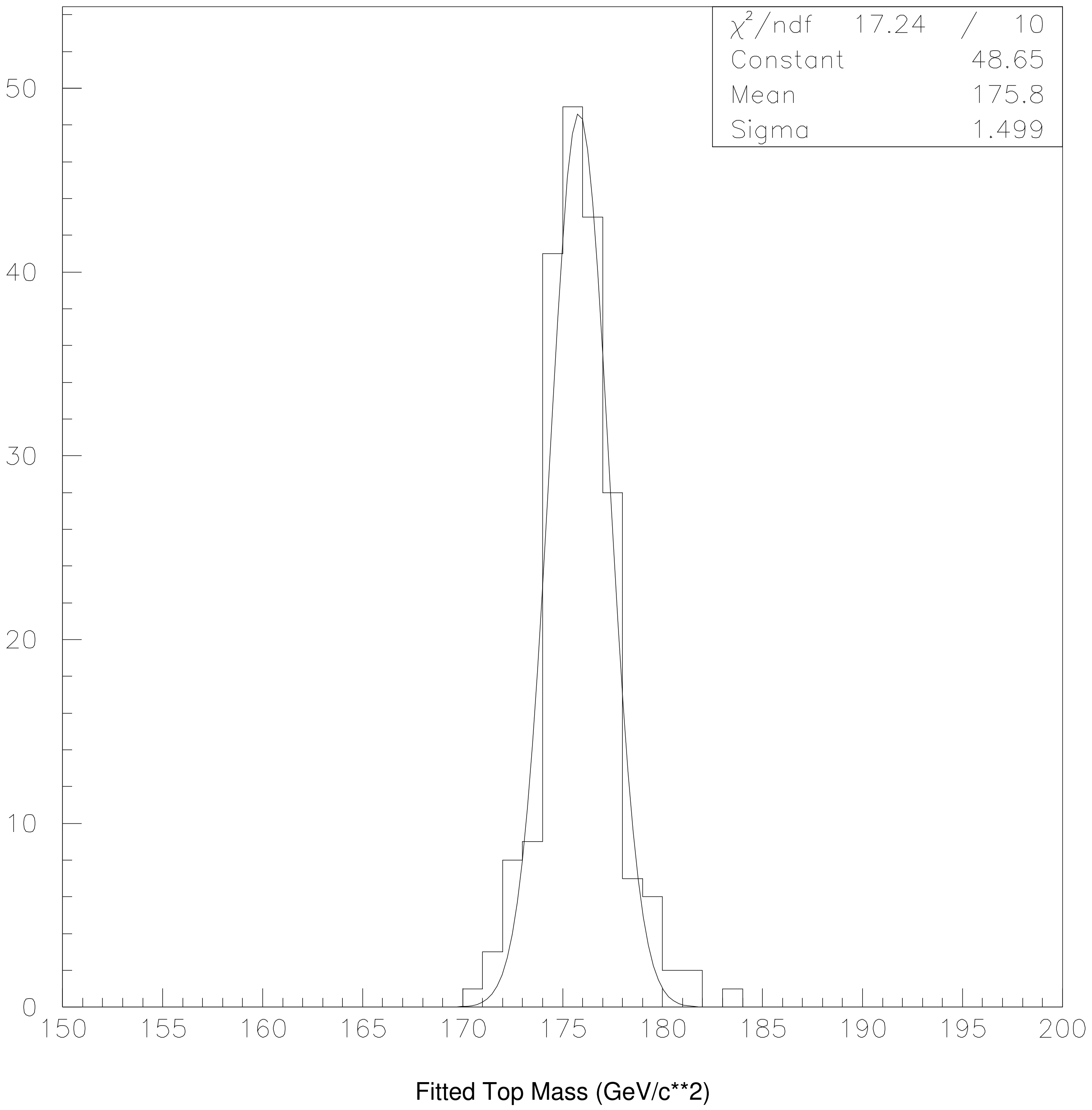

Figure 6: The distribution of fitted masses in the data, for 500 trials using fluctuated templates. The data sample is the standard SVX or SLT tagged lepton plus jets sample.

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5 Total Systematics

For completeness we list the previous and re-evaluated systematic uncertainties for the standard method, and also the systematic uncertainties for optimized top mass analysis.

Systematic	Standard GeV/c^2	Optimized GeV/c^2	New Standard GeV/c^2
Soft Gluon + Jet E_T Scale	3.6	$^{+4.1}_{-2.5}$	$^{+4.0}_{-2.7}$
Different Generators	0.9	0.3	0.6
Hard Gluon Effects	3.6	2.2	3.6
Fit Configuration	2.5	1.4	1.4
b-tagging Bias	2.3	0.4	1.1
Background Spectrum	1.6	0.7	0.7
Likelihood Method	2.0	0.5	1.4
Monte Carlo Statistics	2.3	1.3	1.7
Total	7.1	$^{+5.1}_{-4.0}$	$^{+6.2}_{-5.4}$

Table 14: The systematic uncertainties for the blesed and re-evaluated standard analysis and also the systematic uncertainties for optimized top mass analysis.

6 Conclusion

We found a method to optimize the top mass measurement which makes use of more information than the standard analysis. We divided the pretagged sample up into non-overlapping subsamples and did a Monte Carlo study to find which combination gave the smallest statistical uncertainty. The optimized combination of subsamples used the SVX single tagged, SVX double tagged, SLT tagged and not tagged, with tighter kinematic cuts, samples. When we applied the optimal method to the data we obtained a top mass of

$$176.8 \pm 3.7(stat.)^{+5.1}_{-4.0}(sys.)\ GeV/c^2.$$

References

[1] F.Abe *et al.*, Phys. Rev. D 50, (1994) 2966

[2] F.Abe *et al.*, Phys. Rev. Lett., **74**, 14 (1995) 2626

[3] Our table does not include the category of double tags that is used by Shin Aota (see CDFNOTE 3604) and Rick Wilkinson (see CDFNOTE 3543). My double tagged sample consists of only events which have two SVX tags. Shin and Rick's double tag samples allow double b-tagged events which have SVX, SLT and jet probability tags. In the future I can include a subsample which uses their definition of double b-tagged events.

[4] B.Harral, CDF Note 3526 : Background Calculations for Mass-fit Event Selection (110 pb^{-1}), Version 1.0. I need to update my numbers to correspond with Brian's new background calculations in Version 2.0 of this note.

[5] B.Harral, CDF Note 2503 : Comments on Likelihood Method for Extracting M_{top}

[6] B.Harral, S.Kim, and S.Vejcik, CDF Note 3000 : Top Mass Determination Using the MINUIT Fitter

[7] We use a slightly different method for minimizing the log likelihood function than the Michigan and Penn groups. (For a description of their method see CDF note 2503.) We find the minimum likelihood point and then fit a parabola to 7 points, three points on each side of the minimum and the minimum. We found this method to be more robust when analyzing many Monte Carlo pseudo-experiments. This method will be also be applied to the data.

[8] The statistical uncertainty returned by the fitter is the change in the mass associated with a change in log likelihood of 0.5.

[9] If an event is SVX and SLT tagged it is included in the SVX tagged subsample and not in the SLT tagged sample. So the SLT tagged subsample has events with only SLT tags and no SVX tags.

[10] Thanks to A. Castro and P. Azzi for the all hadronic likelihood values.

[11] Thanks to C. Grosso-Pilcher and J. Konigsberg for the dilepton likelihood values.

[12] K.Tollefson, R.Hughes, P.Tipton CDF Note 3511 : Effects of Hard Gluon Radiation on the Top Mass

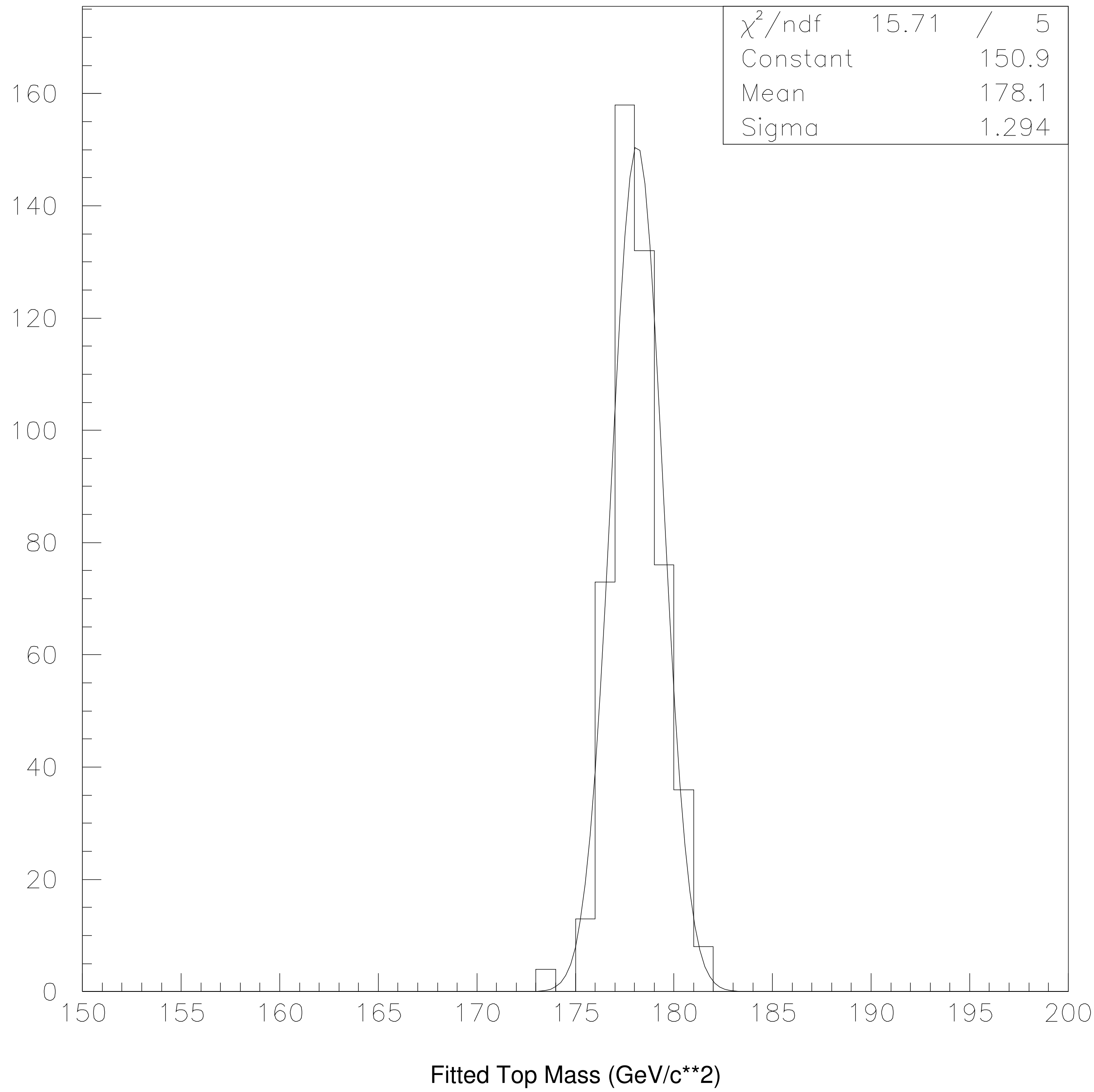

Figure 7: The distribution of fitted masses in the data, for 500 trials using fluctuated templates. The data sample is the optimized lepton plus jets sample.