Top Quark Mass Measurement in the Lepton + Jets Channel Using a Multivariate Technique

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Overview

- Currently, our CDF group is developing a matrix-element based likelihood calculation to measure the top mass in the $t\bar{t} \rightarrow bq\bar{q}\,\bar{b}l\nu$ decay channel
- *Features which will be discussed include*:
  - A novel approach to our integration designed to account for limitations from not using all kinematic information
  - Use and optimization of an event observable which will discriminate between background and signal events

The Signal Likelihood

$$L_{t\bar{t}}(\vec{y} \mid m_t) = \frac{1}{N(m_t)} \int \frac{1}{A(m_t, S)} \frac{f(z_1) f(z_2)}{FF} TF(S * \vec{y} \mid \vec{x}) \, |M(m_t, \vec{x})|^2 \, d\Phi(\vec{x})$$

- To formulate a likelihood for an event:
  - For a range of assumed true top masses (m_t), given what's measured in the detector ($\vec{y}$), integrate over all possible parton-level kinematic configurations for l+jets production and decay ($\vec{x}$)
  - Each $\vec{x}$ has a weight, proportional to the matrix element squared, the "transfer function" between parton and jet Pt's, and the incoming parton distribution functions
  - For a given event, sum the likelihoods for all possible jet-parton matches

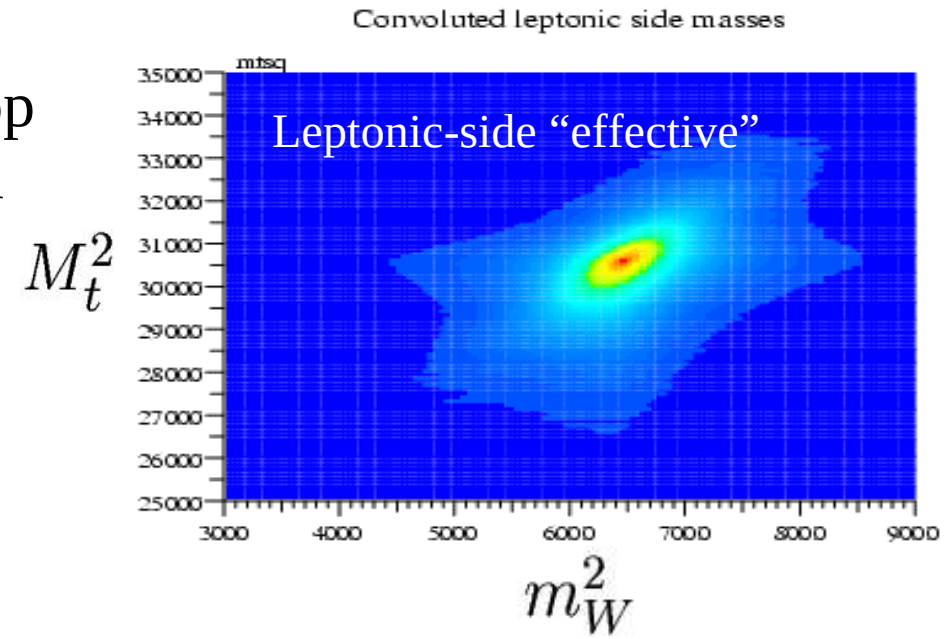
A Challenge

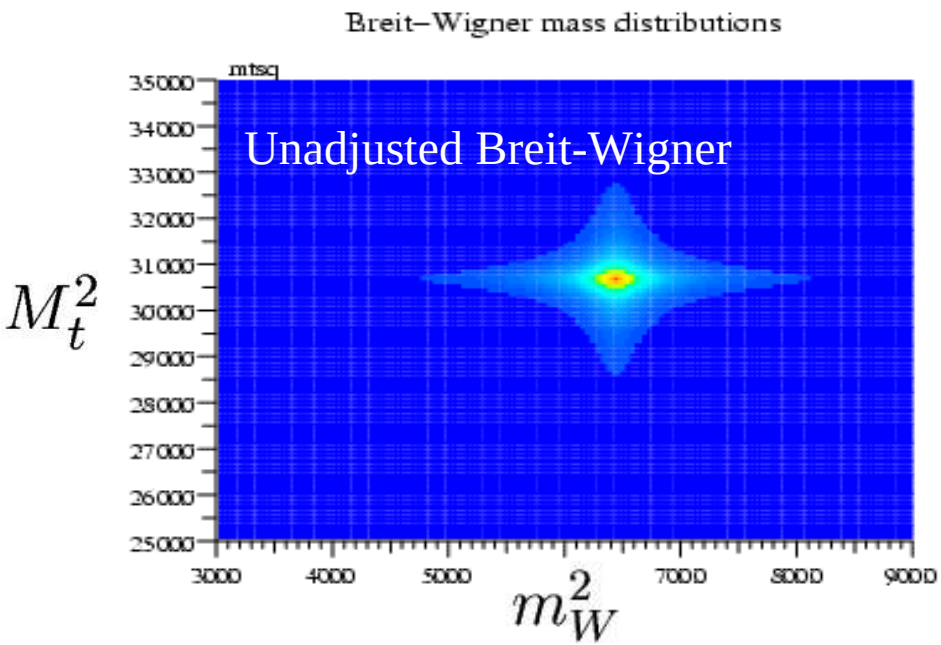
- In reality: only have CPU time to integrate on a subset of $\vec{x}$
- Have to make some assumptions: quark masses always on-shell, quark angles are jet angles, lepton is perfectly measured
- Problems arise:
  - M_t^2 *and* m_W^2 *distributions are no longer physical Breit-Wigners*
  - *Quarks in solution have high momenta*

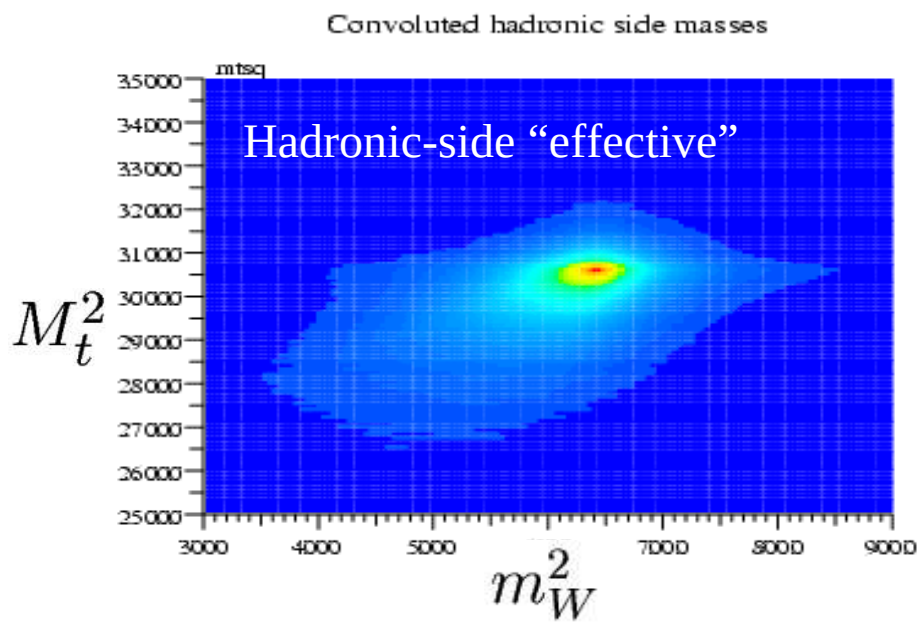
The Q: How do we compensate for this?

Effective Propagators

- Our approach: Be consistent - use top and W propagators which have been constructed off of our assumptions!

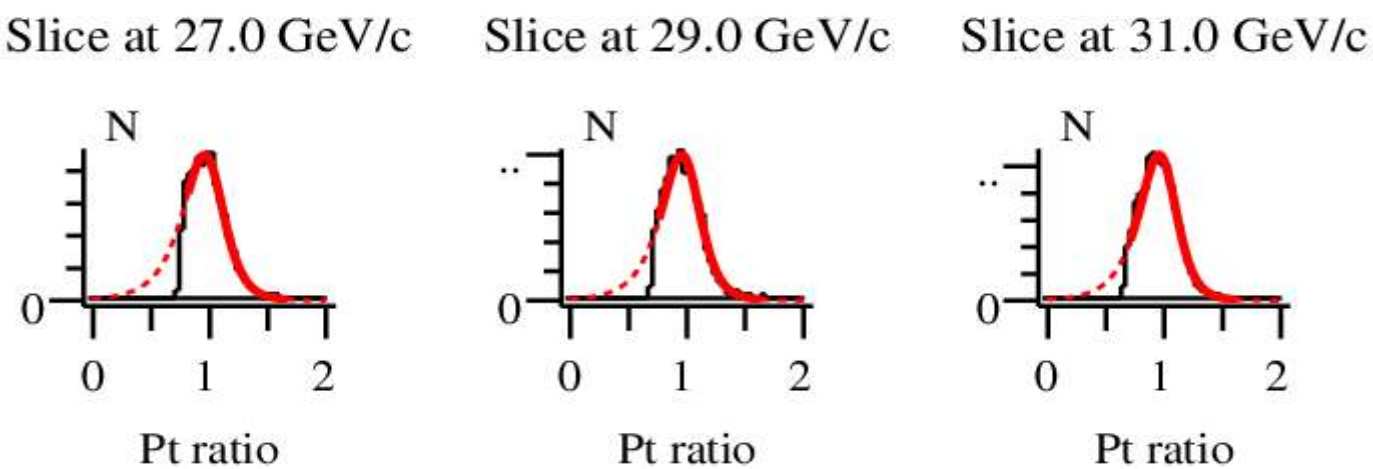






Transfer Functions

- Give probability that a quark with a given p_T will result in a measured jet p_T
- Constructed off of quarks which adhere to our integration assumptions - “effective” TF's
- Functions are parametrized as function of quark p_T through family of “Johnson curves” - can achieve all values of mean, sigma, skewness and kurtosis!



Background Handling

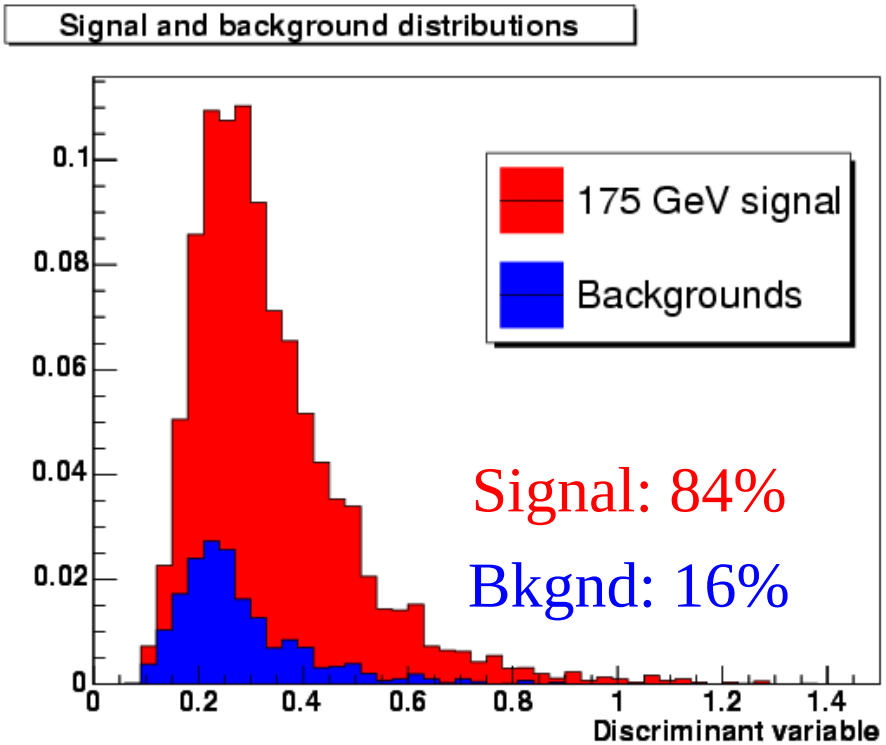
Full likelihood: $\mathrm{L}_{total}(m_t) = (1 - f_i)L_{t\bar{t}}(m_t) + f_i U(m_t)$

...where $U(m_t)$, the background likelihood, is the uniform distribution

- Event selection for our data sample is the standard set of CDF cuts for $t\bar{t} \rightarrow bq\bar{q}\,\bar{b}l\nu$ with a few additional requirements
  - From 680 pb^{-1} of data, expect 82 events, 16% of which is background
- f_i is calculated using an event observable...

Background Handling

- Use bkgnd/signal discrimination variable, "V"; linear combination of
  - Aplanarity
  - $D_{\mathrm{R}} = \Delta R_{ij}^{(\min)} \times \min(p_T^{(i,j)})/p_{\mathrm{T}}(l^{\pm})$
  - $H_{\mathrm{TZ}} = \sum_{i=2}^{4} |p_{\mathrm{T}}^{(i)}| / (\sum_{i=1}^{4} |p_z^{(i)}| + p_z^{(l\pm)} + |p_z^{(\nu)}|)$

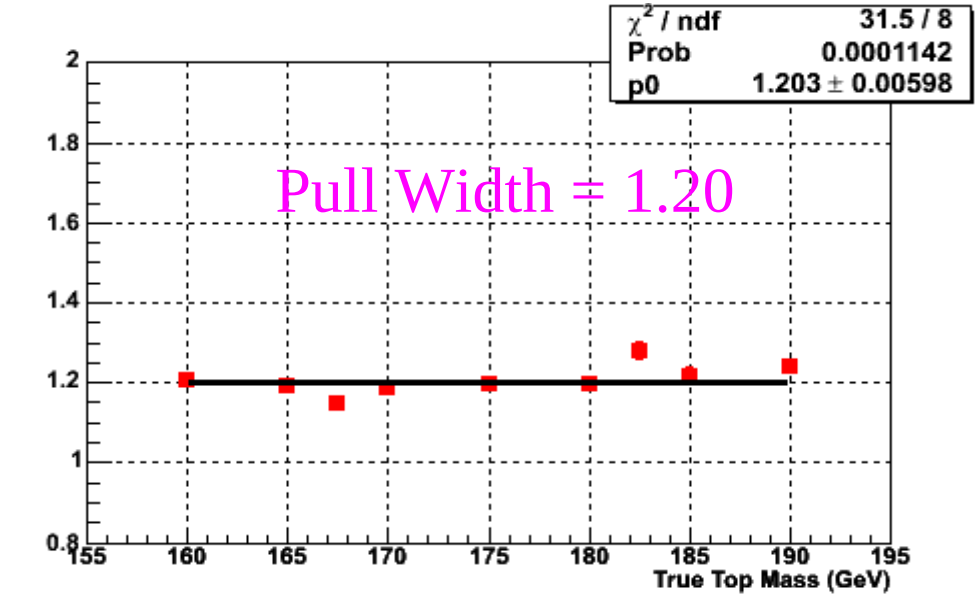


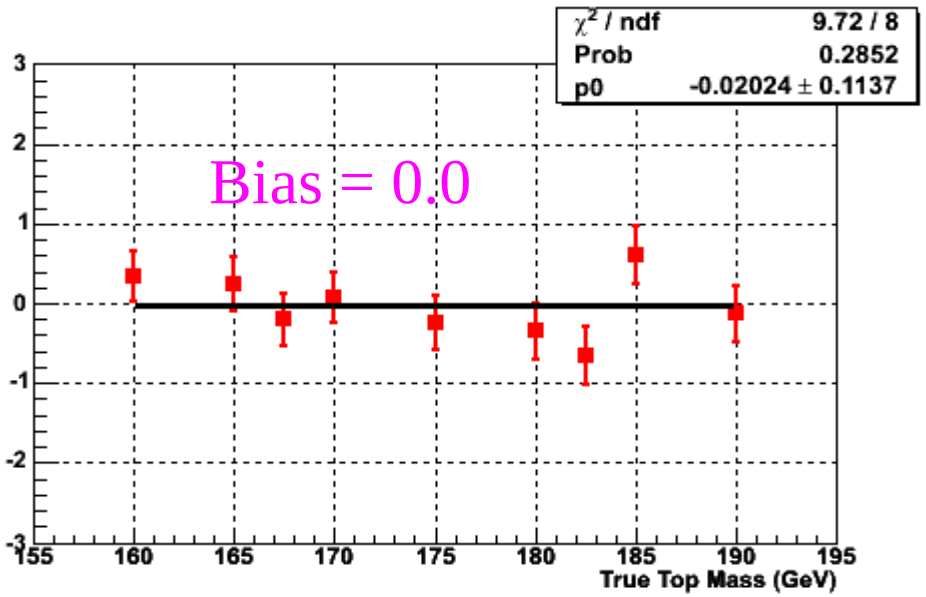
V

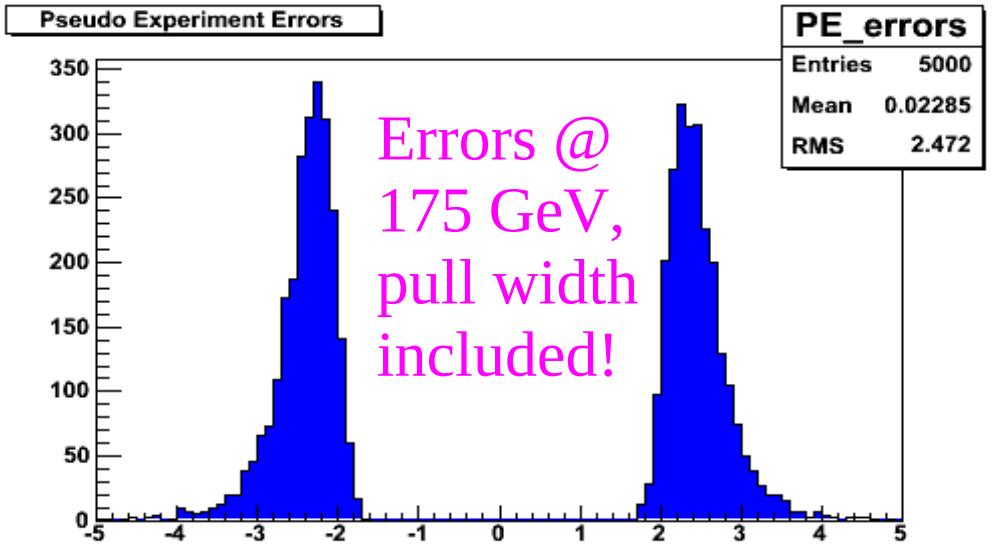
- Optimize V: adjust linear combination to
  - Maximize background/signal discrimination
  - Minimize V's dependence on m_t and jet energy systematic

f_i = B(V) / (B(V) + S(V))

Pseudo-Experiment Results







- PEs constructed using expected numbers of background + signal in data sample
- Expected error @ 175 GeV : 2.4 GeV – comparable to other CDF top measurements

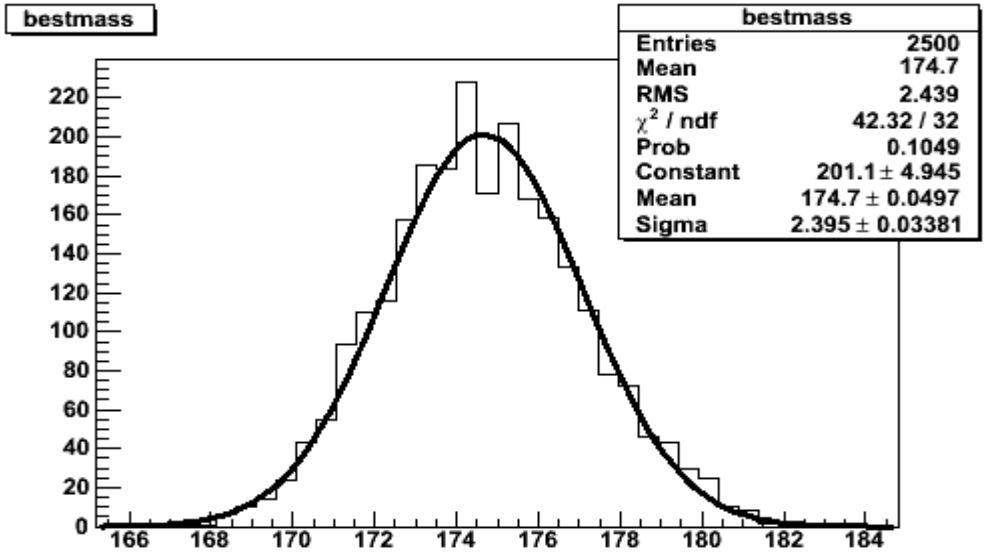
Conclusions

- We've been working on developing a likelihood calculation with some interesting features
  - Through construction of effective propagators / transfer functions, we attempt to compensate for time-saving assumptions we're forced to make
  - A discrimination variable allows us to weight events according to background probability
  - Also - currently working on a method to handle the systematic error on the jet energy measurement
- Monte Carlo results are promising; data measurement should be in the near future

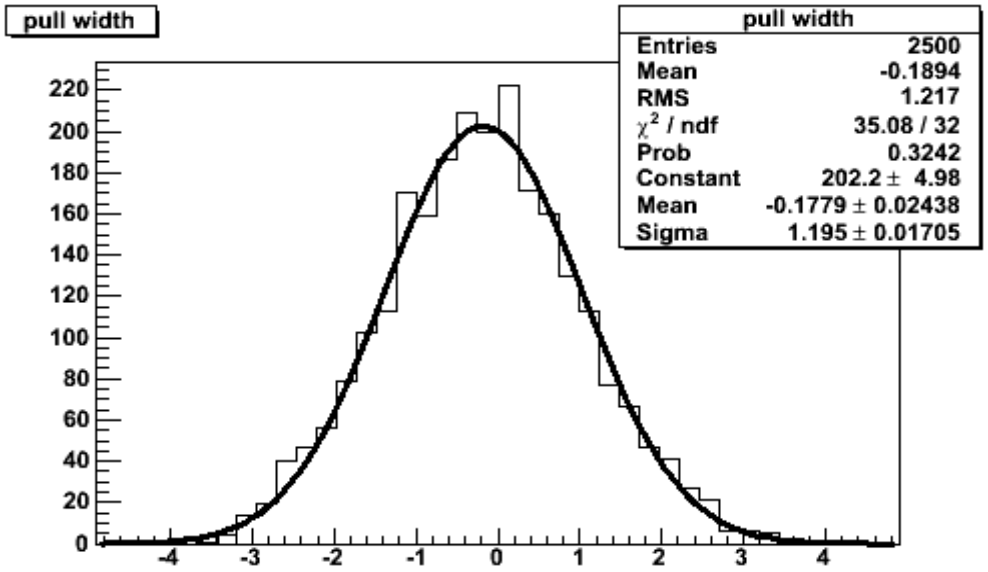
BACKUP SLIDES

PEs at top mass of 175 GeV

PE measurements @ 175 GeV:
mean = 174.7, sigma = 2.4



PE pulls @ 175 GeV:
sigma = 1.2



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Background Handling Performance

PE configuration	*<Bias> (GeV)*	*Sigma @ 180 GeV (GeV)*	*<Pull Width>*
With background handling	-0.02 +/- 0.11	2.40 +/- 0.03	1.20 +/- 0.01
Without background handling	0.64 +/- 0.12	2.58 +/- 0.04	1.42 +/- 0.01

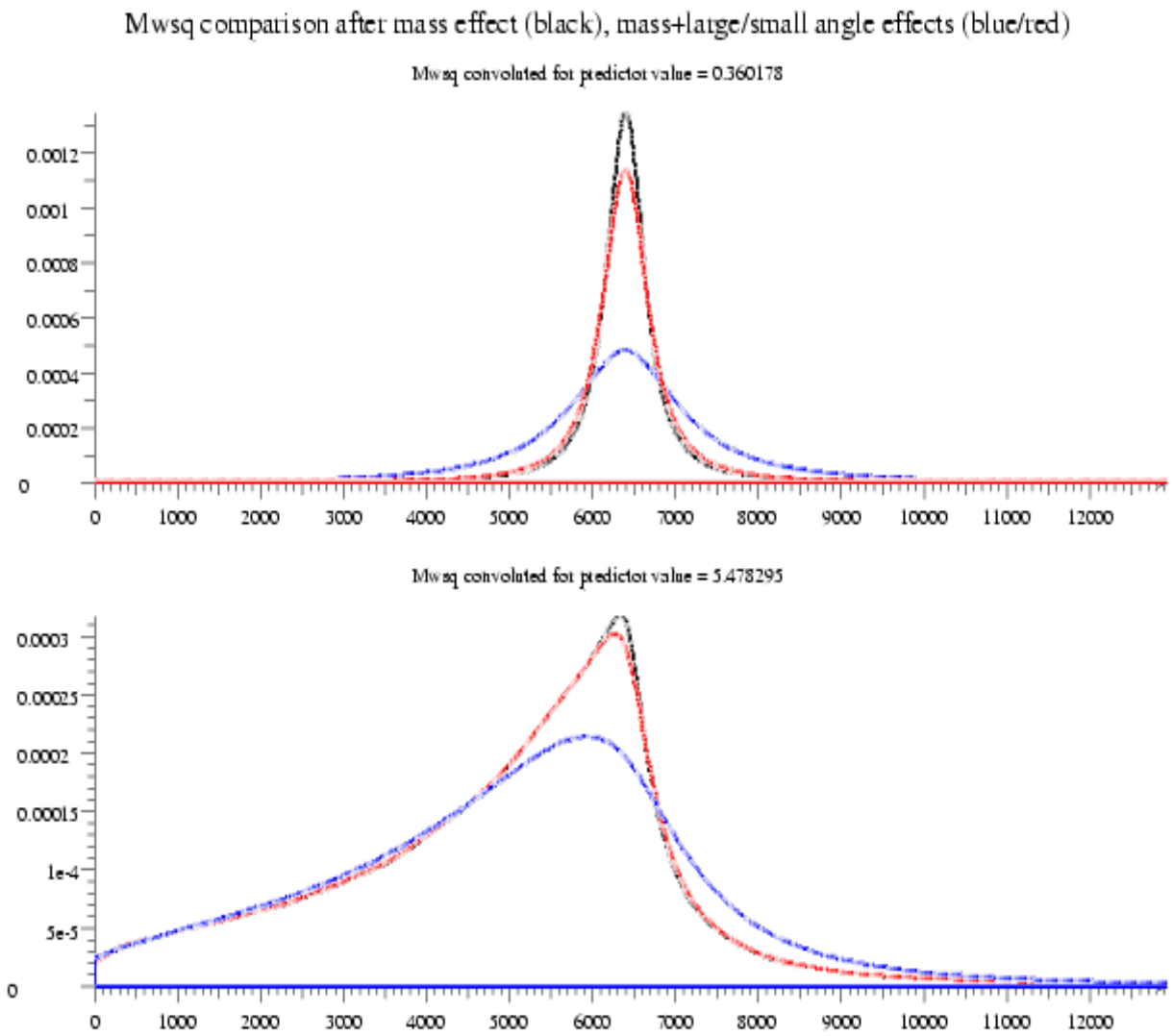
Effective Propagator Performance

PE configuration	*<Bias> (GeV)*	*Sigma @ 180 GeV (GeV)*	*<Pull Width>*
Effective Propagator	0.42 +/- 0.18	1.73 +/- 0.026	1.15 +/- 0.01
Breit-Wigner Propagator	1.29 +/- 0.21	2.02 +/- 0.031	1.33 +/- 0.02

Background	318 pb^{-1}	680 pb^{-1}	0 loose jets
non-W (QCD)	3.07 ± 1.06	6.56 ± 2.14	4.36 ± 1.42
W + light (mistag)	2.27 ± 0.45	5.14 ± 0.96	3.41 ± 0.64
Diboson (WW, WZ, ZZ)	0.39 ± 0.08	0.83 ± 0.17	0.55 ± 0.11
Sum of above 2	2.66 ± 0.53	5.97 ± 1.13	3.96 ± 0.75
W $b\bar{b}$	1.70 ± 0.79	3.63 ± 1.69	2.41 ± 1.12
W $c\bar{c}$, Wc	1.31 ± 0.63	2.82 ± 1.34	1.87 ± 0.89
Single top	0.41 ± 0.09	0.88 ± 0.19	0.58 ± 0.13
Sum of above 3	3.43 ± 1.41	7.33 ± 3.01	4.87 ± 2.00
Total background	9.16 ± 0.82	19.86 ± 3.93	13.19 ± 2.61
Expected top ($m_t = 175$)	42 ± 5	90 ± 11	60 ± 7
Events observed	63	128	85

Effect of Our Assumptions

- The uncertainty in our calculation of the hadronic W mass, for a given uncertainty on the quark masses and angles, depends on the detector-level kinematics
- This uncertainty is calculated from the partial derivatives of the W mass wrt these masses and angles, and is used to alter the width of our effective propagator



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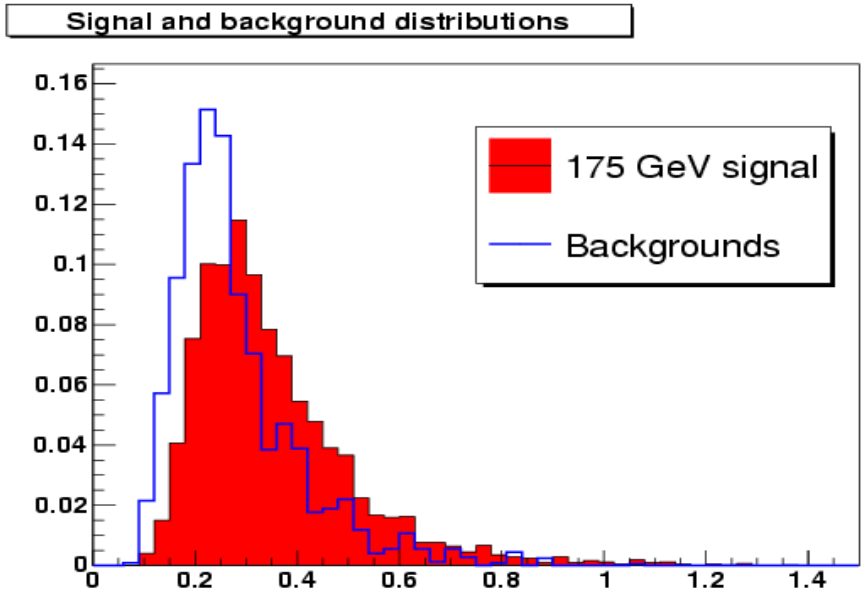
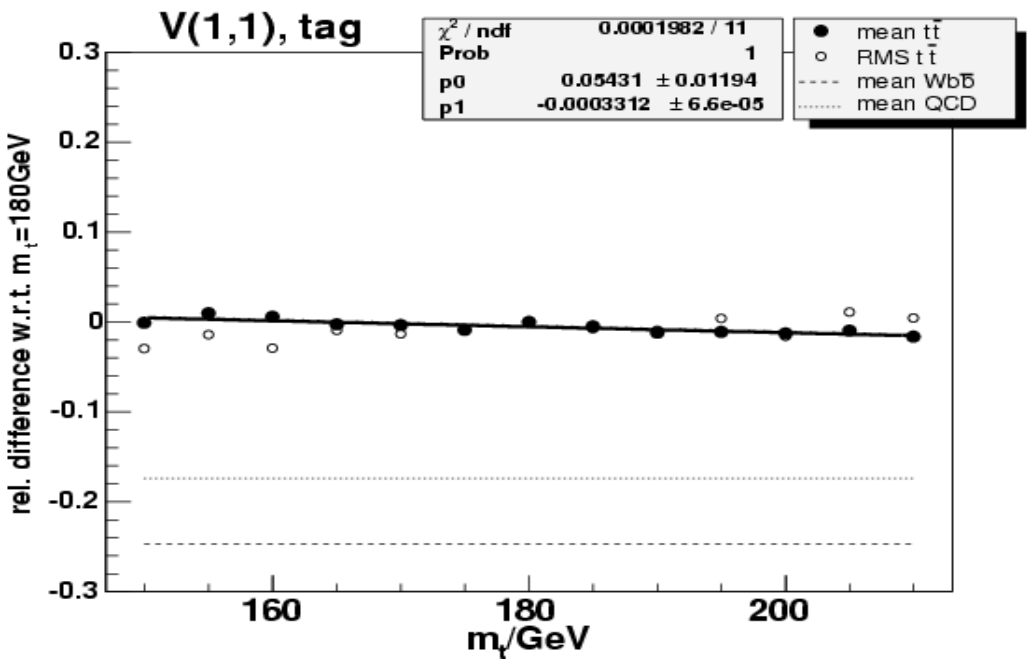
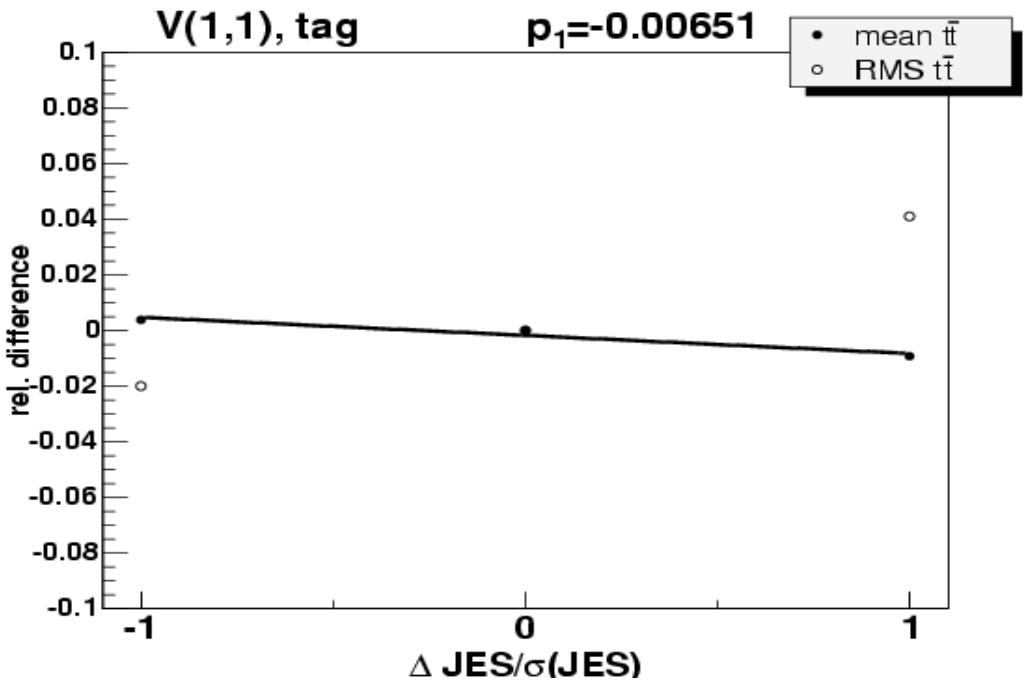
- *M* = the matrix element
- *TF* = transfer function from quark pt to jet pt
- *Phi* = the phase space factor
- *F* = flux factor
- *f* = Incoming parton distribution functions
- *A* = event selection acceptance efficiency
- *N* = normalization
- *S* = Jet Energy Scale (can adjust this to compensate for systematics in jet momenta measurements)

More on Background