MTM Full Status

John Freeman
Lina Galtieri, Jeremy Lys, Jason Nielsen, Igor Volobouev, Pedro Movilla Fernandez

LBNL/Texas Tech/UC Santa Cruz

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Overview

- Discussion of signal likelihood curve calculation
- Background technique
- Event selection / MC events used
- PE results
  - Ideal signal
  - Signal+background
  - JES linearity checks

Conclusions / to-do list

Signal Likelihood Overview

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

- To formulate a likelihood for an event:
  - For a range of assumed true top masses (m_t) and jet energy scales (S), 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 using a weighting

Signal Likelihood Components

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

- $N(m_t)$ is the normalization of the likelihood
- $A(m_t, S)$ is the acceptance (corrects for event selection effect on normalization)
- $f(z_1) f(z_2)$ are the incoming parton PDF's – CTEQ5L
- $TF(S * \vec{y} \mid \vec{x})$ are the transfer functions
- $|M(m_t, \vec{x})|^2$ are the Kleiss-Stirling ttbar matrix elements
- $d\Phi(\vec{x})$ is the phase space factor
- FF is the flux factor of the incoming partons

A Challenge

- In reality: we only integrate on a subset of $\vec{x}$ - the hadronic and leptonic side M_t^2 and m_W^2 distributions, the ratio of the hadronic side light quark momenta, and the Pt of the ttbar system
- 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?

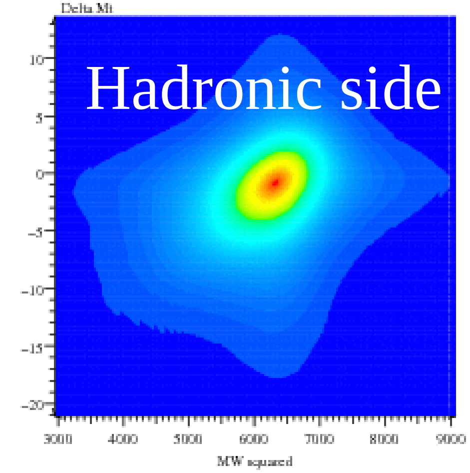
Accounting for Assumptions

- *Modify MC events used in analysis construction to adhere to the assumptions in the integration*
  - Take the quarks in a ttbar MC event decay chain, and remove the step in which they're taken off-mass-shell
  - Rotate the resulting quarks into daughter jet angles
  - Use these “effective” quarks to
    - Construct effective propagators for the top and W masses integrated on
    - Construct the transfer functions used in the calculation

Effective Propagators

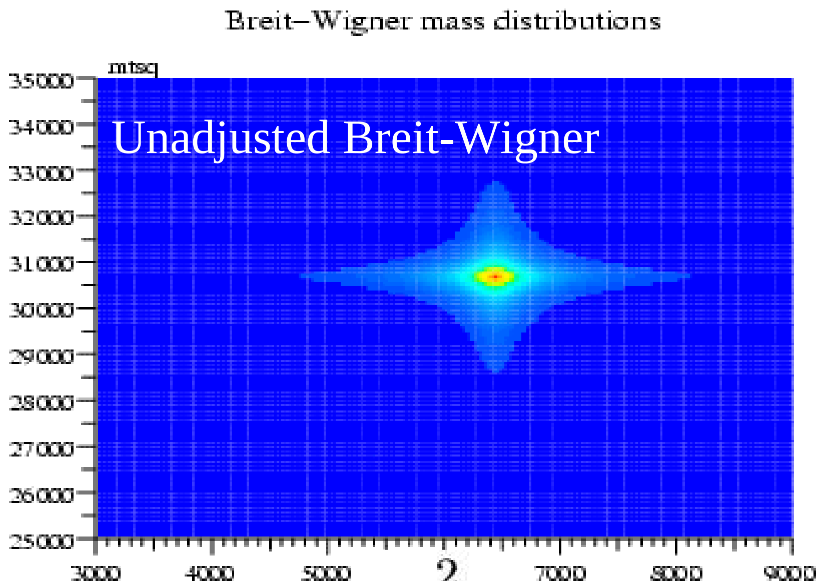
- Our effective W and top propagators are built off the invariant masses of the effective quarks

Delta Mt



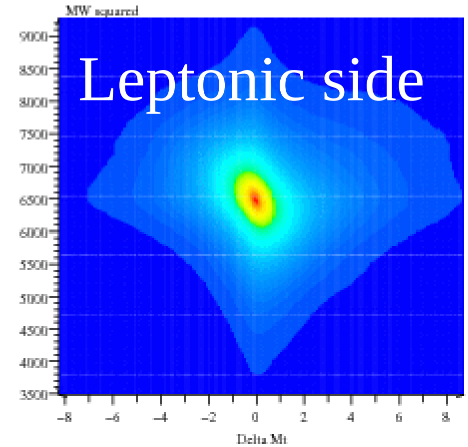
m_W^2

M_t^2



m_W^2

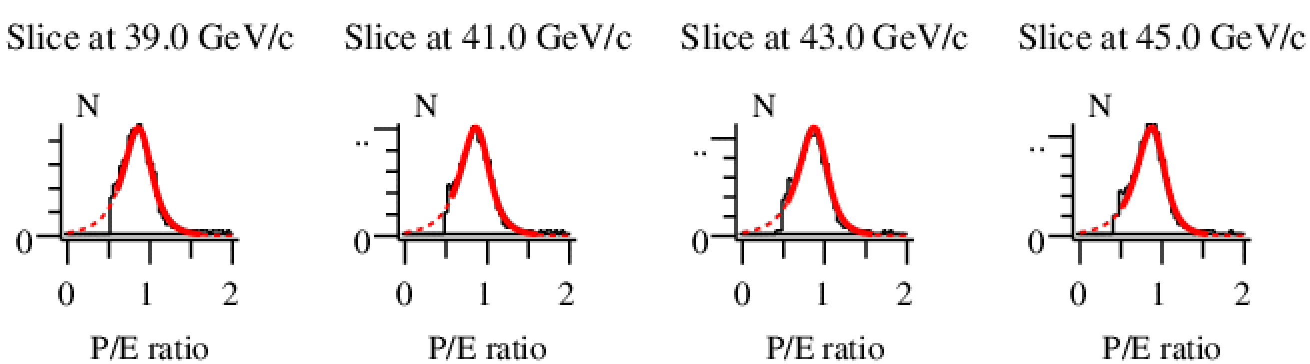
m_W^2



Delta Mt

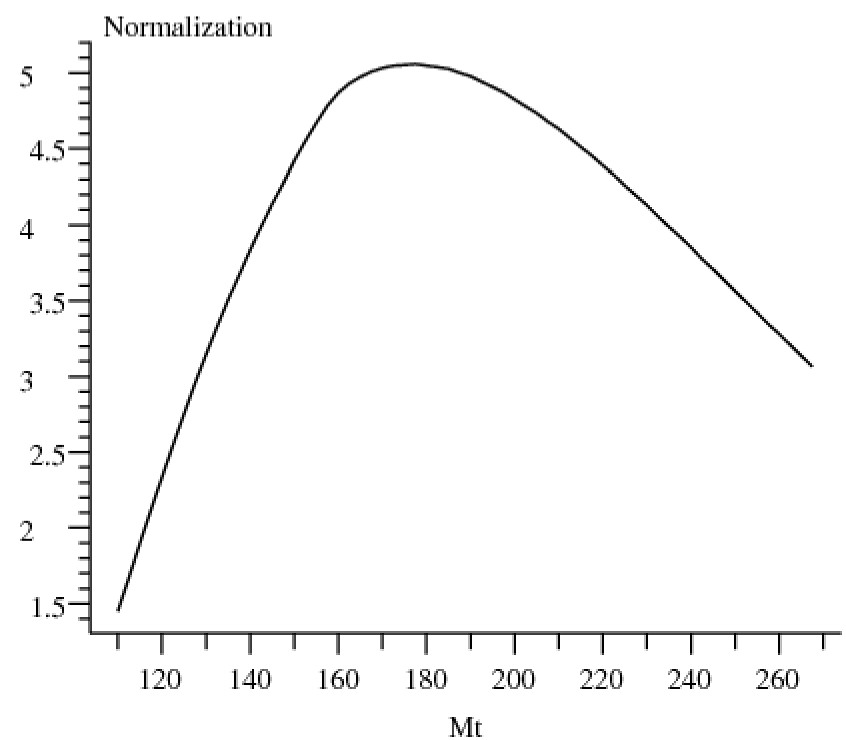
Transfer Functions

- Give probability that a quark with a given p_T will result in a measured jet p / parton E
- Constructed off of quarks which adhere to our integration assumptions - “effective” TF's
- Functions are parametrized as function of quark through family of “Johnson curves” - can achieve all val p_T of mean, sigma, skewness and kurtosis!
- Eta regions 0-0.15, 0.15-0.85, 0.85-1.4, 1.4-2.0, as well as b and light quarks, have their own TF's



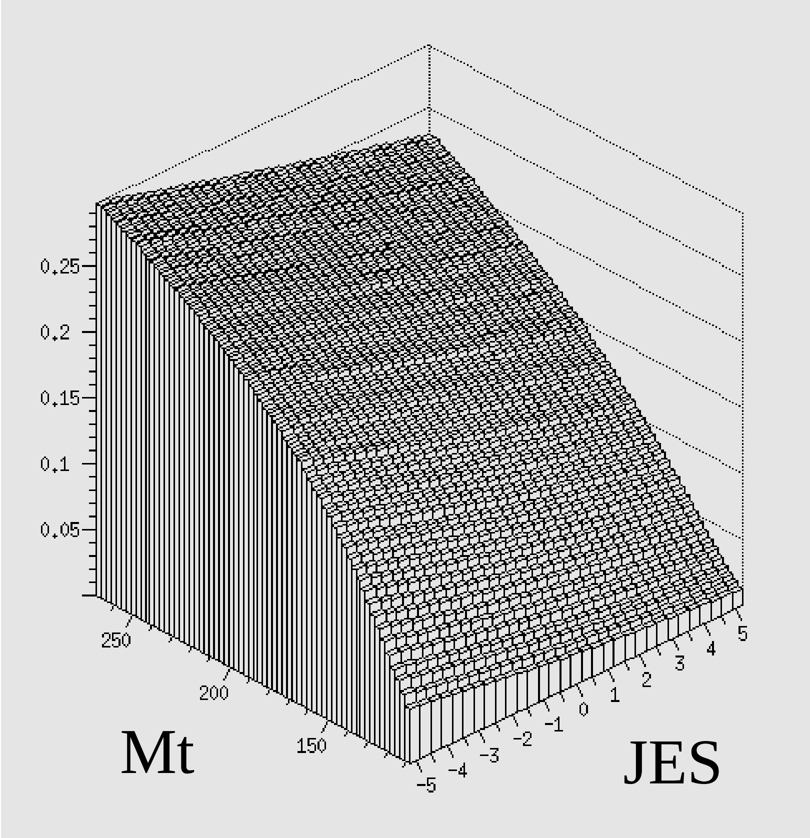
Normalization

- For our likelihood to be properly normalized, given a JES and top mass it should integrate to unity over the y's – the detector level quantities
- The normalization we use is proportional to $\sigma_{t\bar{t}} \cdot \Gamma_t^2 / m_t^2$



Acceptance

- The acceptance is designed to complete the normalization of the likelihood through accounting for the effect of event selection cuts
- The TF's we build are normalized wrt ALL jet momenta – not just those which pass selection cuts!
- By smearing effective quarks from MC signal events by the TFs and then applying our selection cut to the result, we ensure our TF's – and thus our likelihood – is properly normalized



Background Handling

- In our calculation of the likelihood curve, we assume we have a ttbar signal event (we use ttbar signal matrix elements, etc.)
- Of course, we have background to deal with as well. We incorporate background into a given event's log likelihood through the following formula (to be explained the next couple of slides):

$$L_{mod}(m_t, \mathrm{JES}) = \sum_{\mathrm{events}} [\log\{L(m_t, \mathrm{JES}\,|\mathrm{signal})(1 - f_{bg}(q)\kappa(m)) + f_{bg}(q)\kappa(m)U\}$$

$$- f_{bg}(q)\log\{\overline{L(m_t, \mathrm{JES}\,|\mathrm{background})}(1 - f_{bg}(q)\kappa(m)) + f_{bg}(q)\kappa(m)U\}]$$

Background Handling (cont'd)

$$L_{mod}(m_t, \mathrm{JES}) = \sum_{\mathrm{events}} [\log\{L(m_t, \mathrm{JES}\,|\mathrm{signal})(1 - f_{bg}(q)\kappa(m)) + f_{bg}(q)\kappa(m)U\}$$

$$-f_{bg}(q)\log\{\overline{L(m_t, \mathrm{JES}\,|\mathrm{background})}(1 - f_{bg}(q)\kappa(m)) + f_{bg}(q)\kappa(m)U\}]$$

- Here, $L(m_t, \mathrm{JES}\,|\mathrm{signal})$ is the signal likelihood for the event
- $\overline{L(m_t, \mathrm{JES}\,|\mathrm{background})}$ is the average shape of a background likelihood curves
- $f_{bg}(q)$ is the calculated probability that the event is background
- U is the uniform distribution over mt-JES
- $\kappa(m)$ is a parameter we can adjust to alter the smoothing effects of U (we leave at 1 for now)

Background Handling (cont'd)

$$L_{mod}(m_t, \mathrm{JES}) = \sum_{\mathrm{events}} [\log\{L(m_t, \mathrm{JES}\,|\mathrm{signal})(1 - f_{bg}(q)\kappa(m)) + f_{bg}(q)\kappa(m)U\}$$

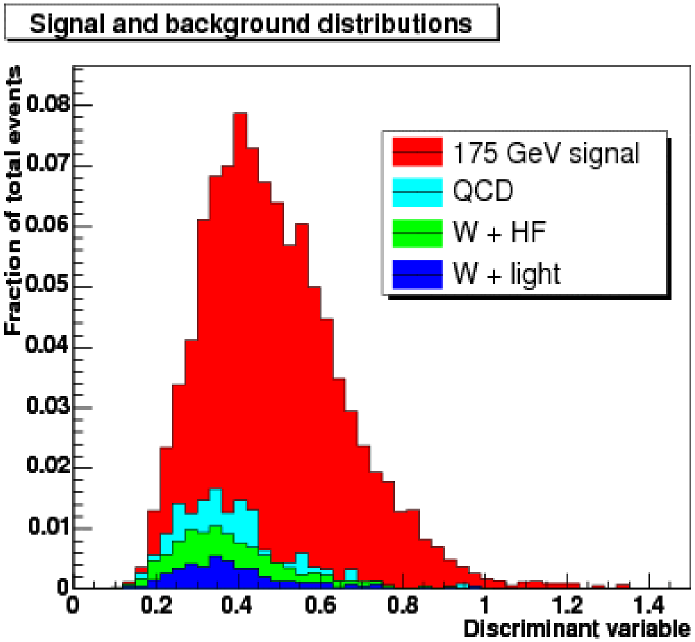
$$-f_{bg}(q)\log\{\overline{L(m_t, \mathrm{JES}\,|\mathrm{background})}(1 - f_{bg}(q)\kappa(m)) + f_{bg}(q)\kappa(m)U\}]$$

- In basic terms: for a given event, subtract off the average background log likelihood weighted by $f_{bg}(q)$ from the calculated signal log likelihood
- Smooth both the signal and background's likelihoods with the uniform distribution to reduce the effect of increasing the error on the PE measurement through the average background log likelihood not properly modeling the actual shape of the background log likelihoods in the PE

Calculating the event's background probability

- Using MC events, we create histograms of an event observable q which have different distributions for signal vs. background
- We scale the histograms according to the expected # of signal vs. background events in our sample
- For a given event, we take its observable q, calculate its value B(q) in the background histogram and S(q) in the signal histogram, and take

$$f_{bg}(q) = B(q)/(B(q) + S(q))$$



Signal: 84%
Background: 16%

Background Handling

- "q" is a linear combination of
  - Aplanarity
  - $D_{\rm R} = \Delta R_{ij}^{(\rm min)} \times \min(p_T^{(i,j)})/p_{\rm T}(l^{\pm})$
  - $H_{\rm TZ} = \sum_{i=2}^{4} |p_{\rm T}^{(i)}| / (\sum_{i=1}^{4} |p_z^{(i)}| + p_z^{(l\pm)} + |p_z^{(\nu)}|)$

The linear combination has been optimized to
-Minimize dependence on JES and top mass
-Maximize signal/background discrimination

Event Selection Cuts

- We use the standard top group requirements for ttbar -> l+jets, with the additional requirements that
  - There be exactly 4 tight jets in the event
  - There be > 0 btags
- We got rid of our 0-loose jet requirement – more to gain from the additional data than to lose from higher amount of background, ISR contamination, etc. in >0 loose events
- Expect 179 events in the data sample with these selection requirements

Expected Background #'s

- Our background fractions are taken from Harvard ttbar xsec measurement on 318 pb^-1 (Note 7536)
- We take the background fraction to be (# of expected background events)/(# of data events) = 16%

Background	318 pb^{-1}	955 pb^{-1}
non-W (QCD)	3.07 ± 1.06	9.22 ± 3.18
W + light (mistag)	2.27 ± 0.45	6.82 ± 1.35
Diboson (WW, WZ, ZZ)	0.39 ± 0.08	1.17 ± 0.24
Sum of above 2	2.66 ± 0.53	7.99 ± 1.59
W $b\bar{b}$	1.70 ± 0.79	5.11 ± 2.37
W $c\bar{c}$, W c	1.31 ± 0.63	3.93 ± 1.89
Single top	0.41 ± 0.09	1.23 ± 0.27
Sum of above 3	3.43 ± 1.41	10.30 ± 4.23
Total background	9.16 ± 0.82	27.51 ± 2.46
Expected top ($m_t = 175$)	42 ± 5	126 ± 15
Events observed	63	179

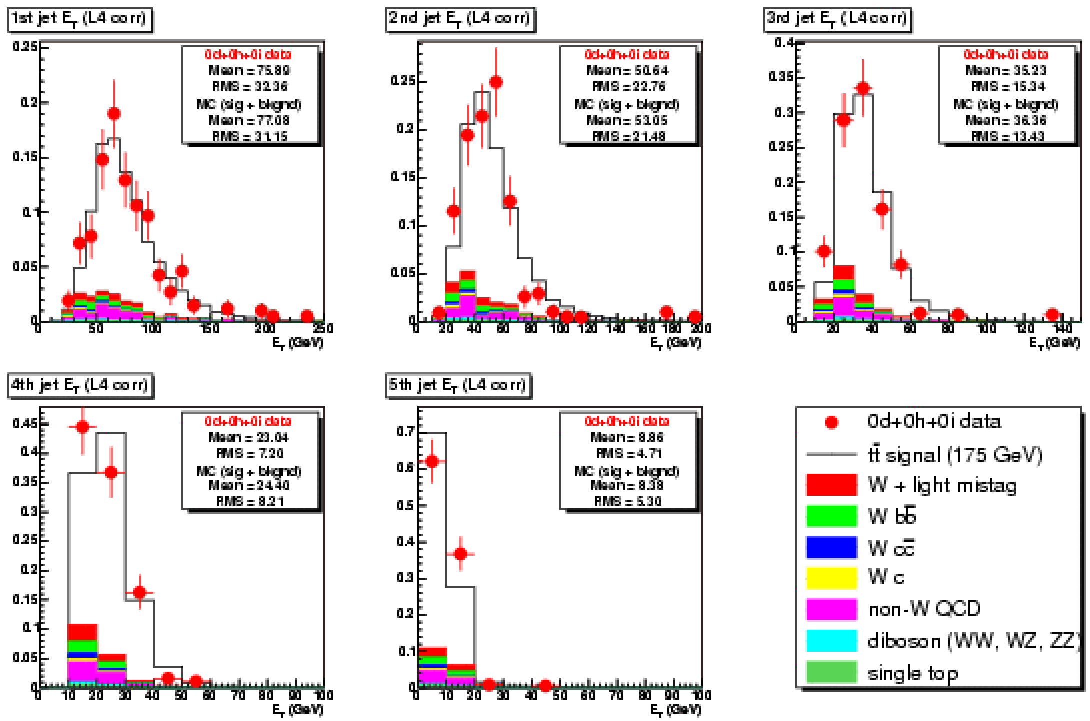
MC Events

- During this blessing iteration, we'll be using the Gen 5 MC, using jetcorr06b corrections
- For the PE's I'll show later, ttopXg samples were used as the signal MC; additionally, for backgrounds we have:

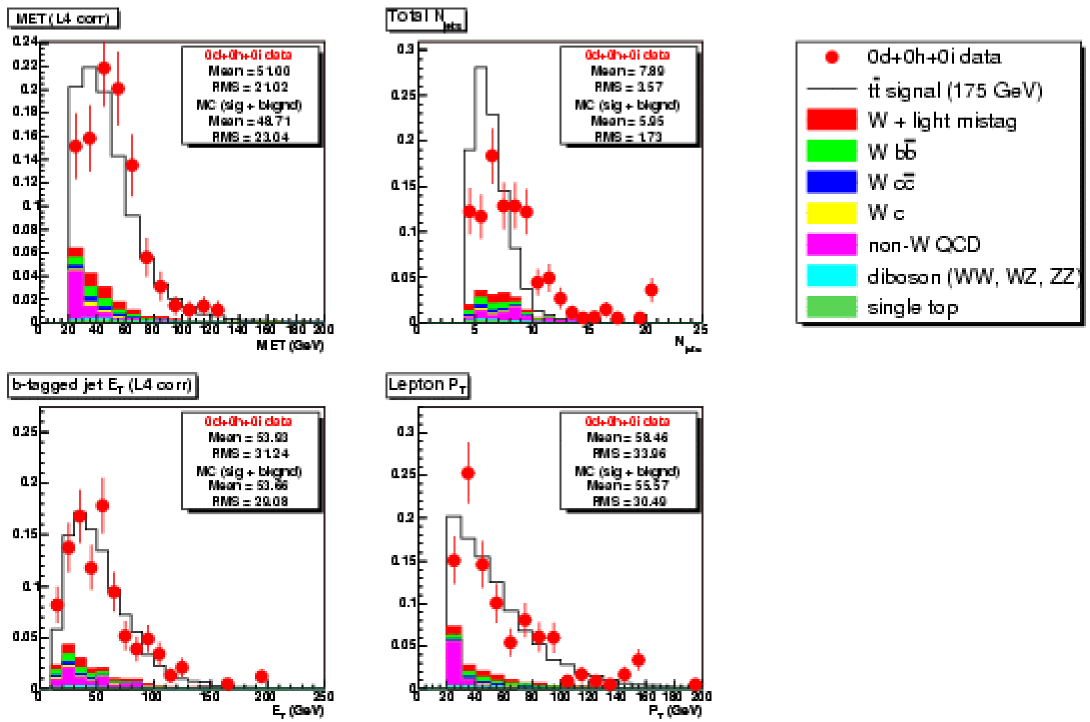
Sample Name	Description	Events	≥ 0 LJ
atop7a	$W \to e\nu + 4p$ (mistag)	243427	138
atopfb	$W \to \mu\nu + 4p$ (mistag)	287271	160
atoppb	$W \to e\nu + b\bar{b} + 2p$	235221	546
atopjb	$W \to \mu\nu + b\bar{b} + 2p$	239255	537
atoptb	$W \to e\nu + c\bar{c} + 2p$	193991	150
atopmb	$W \to \mu\nu + c\bar{c} + 2p$	254511	160
atopkc	$W \to e\nu + c + 3p$	299172	256
bhel0d_ni	non-iso e data	1255715	54*
bhmu0d_ni	non-iso μ data	552401	63*

* – no tag required

Data vs. MC, Part I

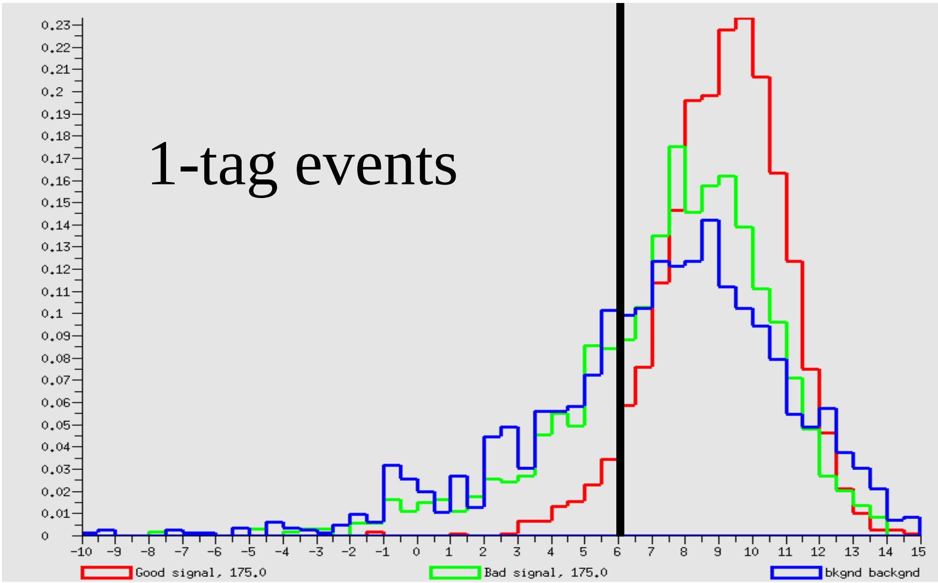


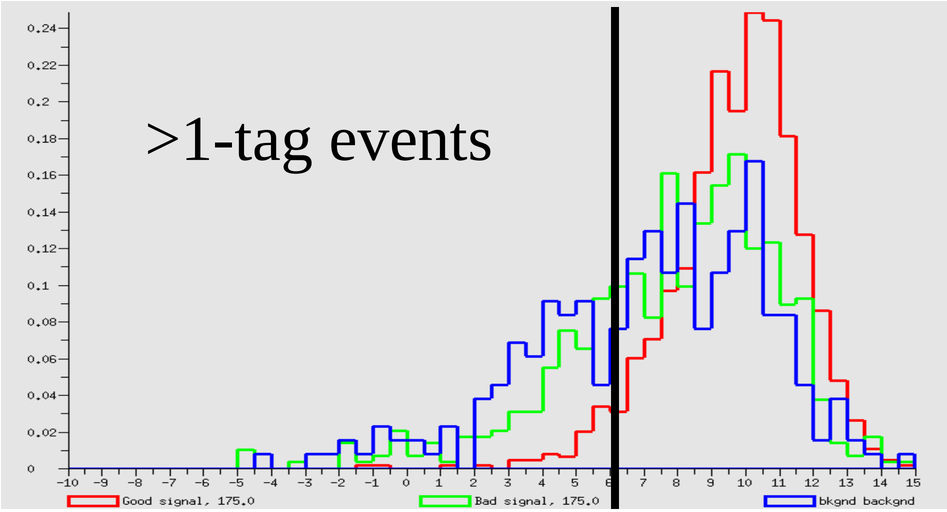
Data vs. MC, Part II



Likelihood Cut

- We've found a very effective cut for getting rid of background and "bad signal" is to eliminate events whose likelihood curve peaks are below a certain value
- We currently place the cut at 6 – although this hasn't yet been optimized (can change the value of the cut, or the mass range over which it's applied)
- At this value, we lose 4% of our l+jets events with good jet-quark match, 25% of the non-l+jets/non-good match signal, and about 1/3 of the background

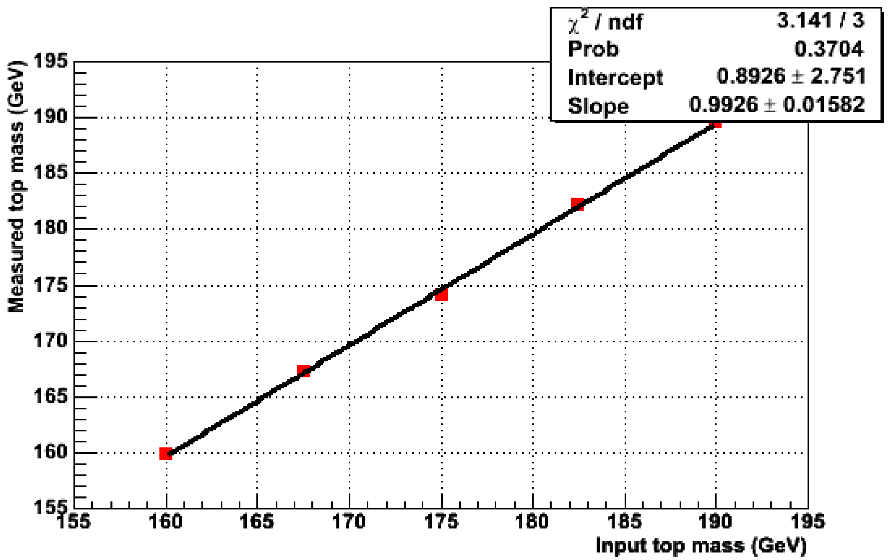


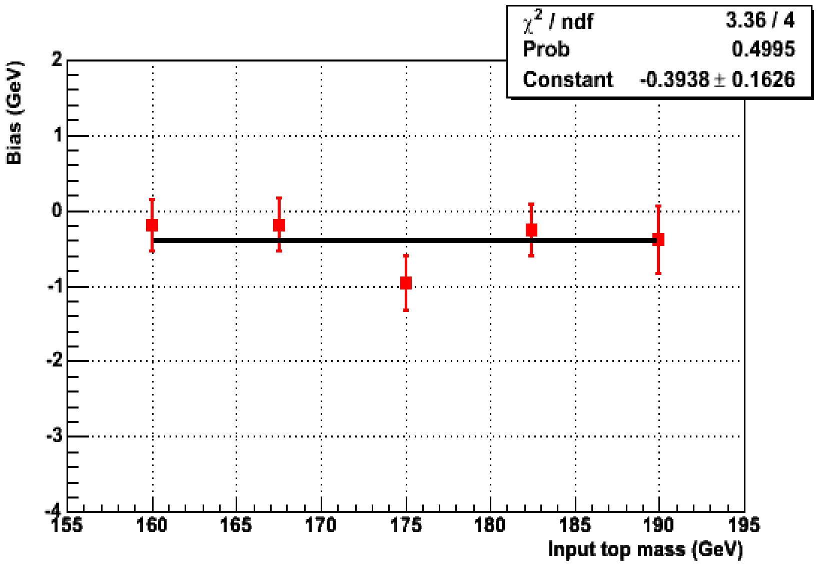


Comment on PEs

- In these PE results, 2000 PEs were run for each mass / JES point
- Measurement for a given PE was made by summing the 2-d log likelihoods of our event curves – where a profile of the resulting 2-d curve is taken along the mass axis (for mass measurement) or JES axis (for JES measurement)
- For PEs run on good signal events, 179 evts/PE were used; for PEs run on sig+background, the expected # of events given our likelihood cut efficiency - 138.4 evts/PE - were used
- Bias is (mean of the PEs – true value); its error is (RMS of PEs)/ sqrt(# of unique PEs)
- Pull width is RMS of individual PE pulls; its error is calculated empirically as the RMS of 8 pull width measurements from mt = 175 GeV sample, divided into 8 equal ensembles run with 2000 PEs using 1/8 the standard # of events

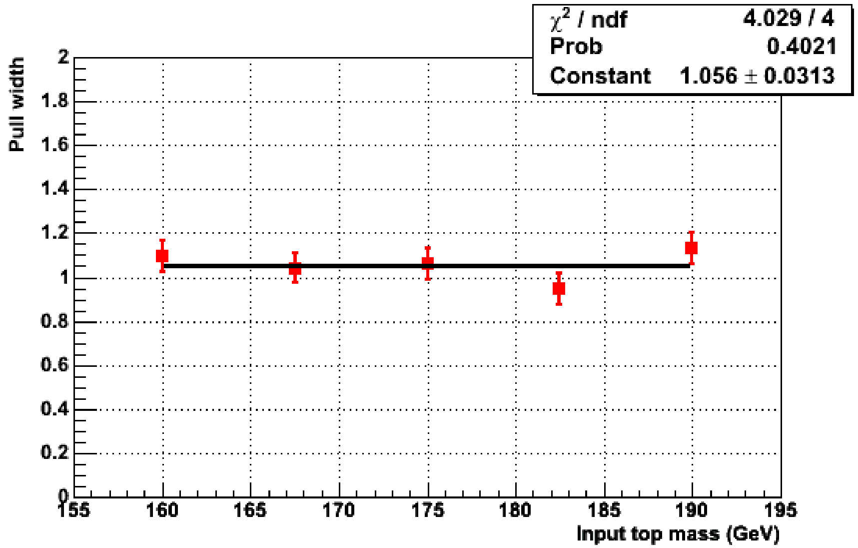
Good Signal PEs





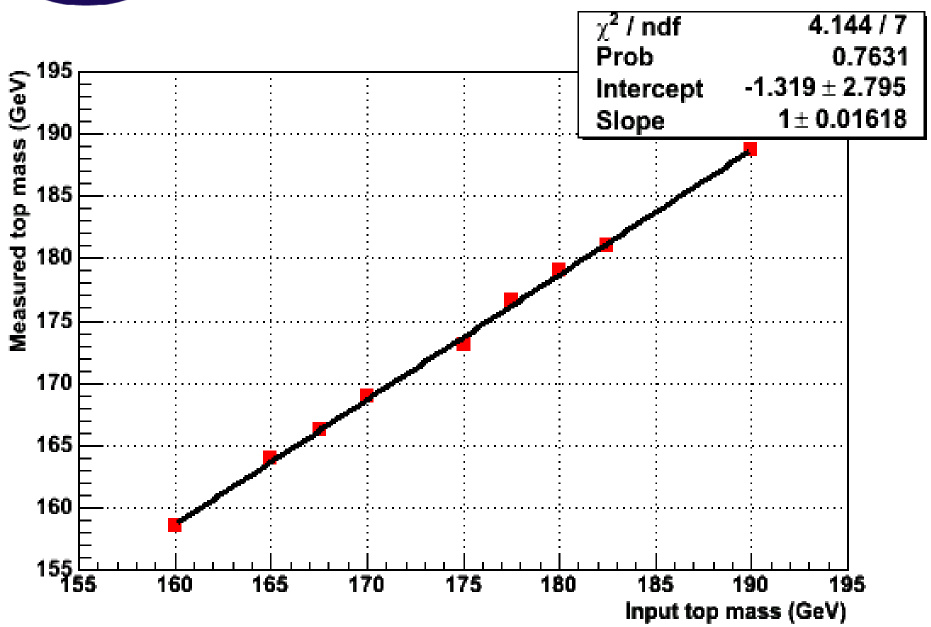
- Events used were l+jets MC events with a good chisquare match between the quarks and the 4 tight jets
- Background handling / likelihood cut not used
- 179 evts/PE run
- Bias = -0.4 GeV, mass linearity slope = 0.99 +/- 0.02

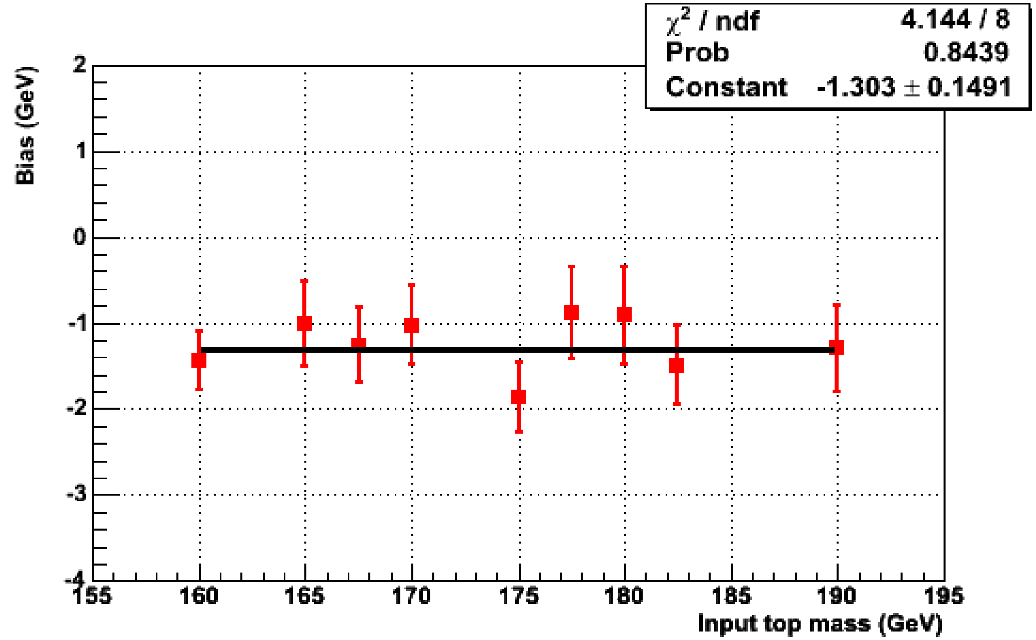
Good Signal PEs (cont'd)



- Pull width ~ 1.06
- It seems that our analysis does pretty well with ttbar events with good jet-quark matching

Sig+Bkgnd PEs

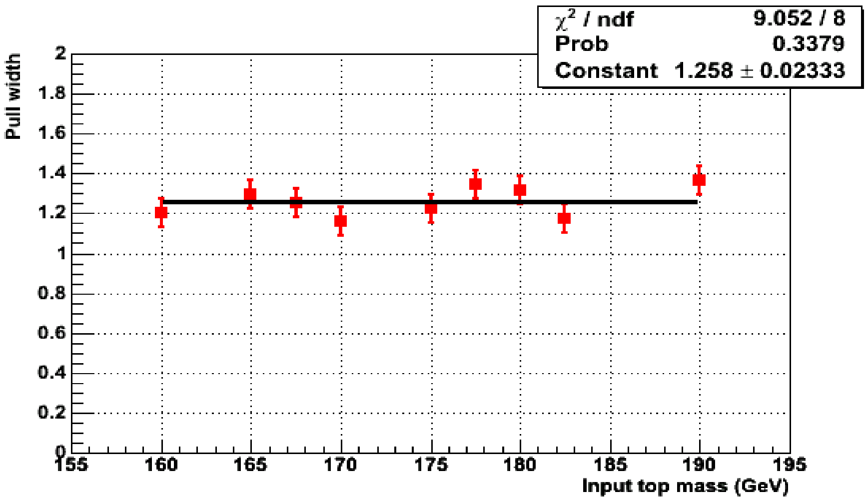




- Here, the most realistic scenario is employed:
  - Log likelihood cut at 6 used: 179 evts -> 138.4 evts/PE
  - Background handling used seperately on 1 and >1 tag events in a given PE; results then combined -> 1 tag is 14% background, >1 tag is 7%
- Bias of is ~ -1.3 GeV – but does not appear to be a function of top mass!

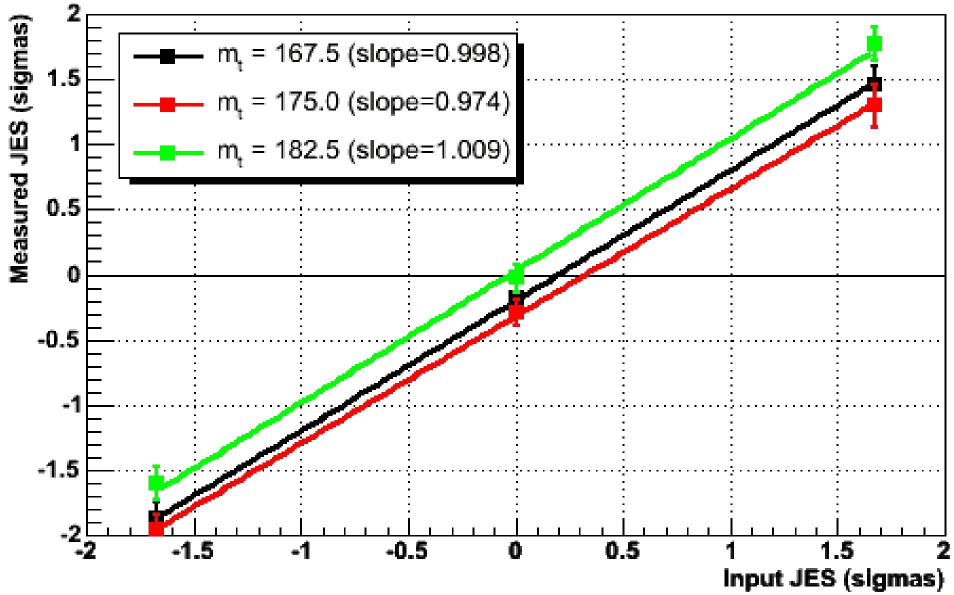
Sig+Bkgnd PEs (cont'd)

- In summary:
  - Linearity coefficient = 1.00 +/- 0.02
  - Bias = -1.30 +/- 0.15
  - Pull width = 1.26 +/- 0.02
  - Straight line fit to range -> 2.6 GeV stat+JES error
- We plan on using our pull width and bias fits to calibrate our actual measurement



JES Linearity Check (Pt I)

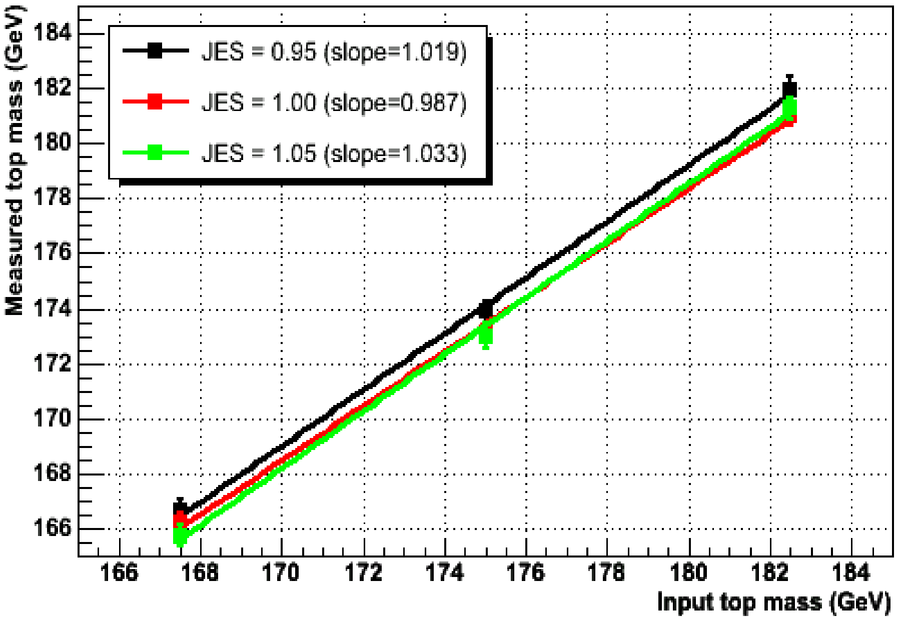
- We measured the JES using MC events at mt = 167.5, 175, 182.5, and JES values of 0.95, 1.00 and 1.05
- JES shifted sample means: input jet energies/momenta DIVIDED by JES -> expect to measure same value on JES axis!
- Fully realistic: 138.4 signal+background events / PE, likelihood cut at 6, background handling used
- The JES measurement response is linear wrt the input JES – slopes very near unity



On plot axes: JES = 1+ (0.03)*nsigmas

JES Linearity Check (Pt II)

- Looking at the input mass vs. measured mass from the same PEs, it does not appear that shifting the JES has a significant effect on the mass measurement



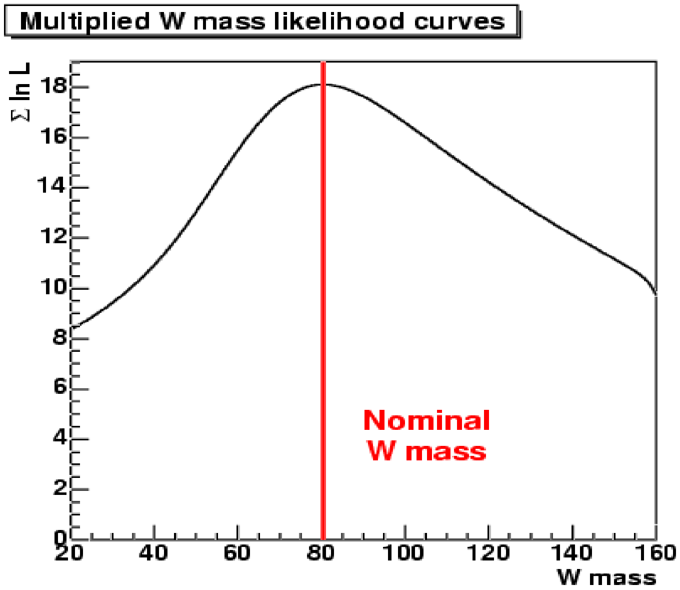
Conclusions

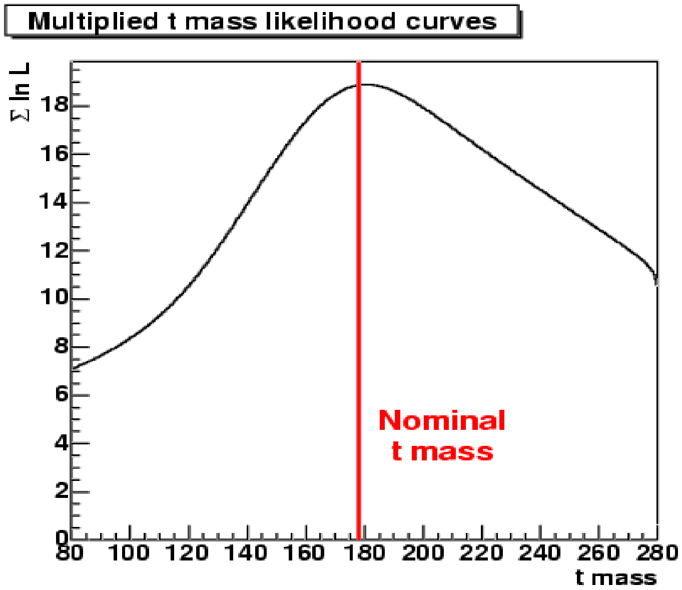
- Our analysis does a good job measuring quality signal events
- In a real-world scenario, with background, non-l+jets signal, etc., it has biases and pull widths which we plan to calibrate for in our measurement
- Currently integrating on events for preblessing; plan to look at
  - Mass and JES blind samples
  - Pythia vs. Herwig
  - ISR/FSR
  - All other systematics

-> *An updated note is coming soon!*

BACKUP SLIDES

TF Crosscheck





- Explain how the TF xcheck works
- Acknowledge that we don't think we know what the errors on the peaks are!

Validating TFs Using W Mass

- To verify the transfer functions, we can reconstruct the hadronic W mass.
- For a given W mass m_W, the probability for observing jets with momenta $\vec{j_1}$ and $\vec{j_2}$ is given by

$$P(\vec{j_1}, \vec{j_2} | m_W) = \int \frac{d^3\vec{p_1}}{2E_1} \frac{d^3\vec{p_2}}{2E_2} \delta^4(P_1 + P_2 - P_W) w(\vec{j_1}|\vec{p_1}) w(\vec{j_2}|\vec{p_2}) f(\vec{p_W}) d^3\vec{p_W}$$

- $\vec{p_1}$ and P_1 are the 3- and 4-momenta of the partons
- $\vec{j_1}$ is the 3-momentum of the jet
- w are the transfer functions
- f is the prior distribution of the W momentum obtained from HEPG. (Note that this means that this is just a crosscheck.)

W Mass Calculation

- To do the integrals, we assume perfect angular resolution, zero W width, and that the W prior depends only on the magnitude of the W momentum and $\cos\theta$.

- Changing variables to P_W^2 and $\beta = \log(p_1/p_2)$, we have an integral over one variable:

$$P(j_1, j_2) \sim \int \frac{p_1^2}{E_1}\frac{p_2^2}{E_2}\frac{E_W}{p_W^2} w(j_1|p_1) w(j_2|p_2) f(p_W, \cos\theta_W) \frac{d\beta}{J}$$

  where J is a Jacobian.

- We perform this integral to obtain a likelihood curve as a function of M_W, which we then convolute with a Breit-Wigner to correct for the finite width of the W.

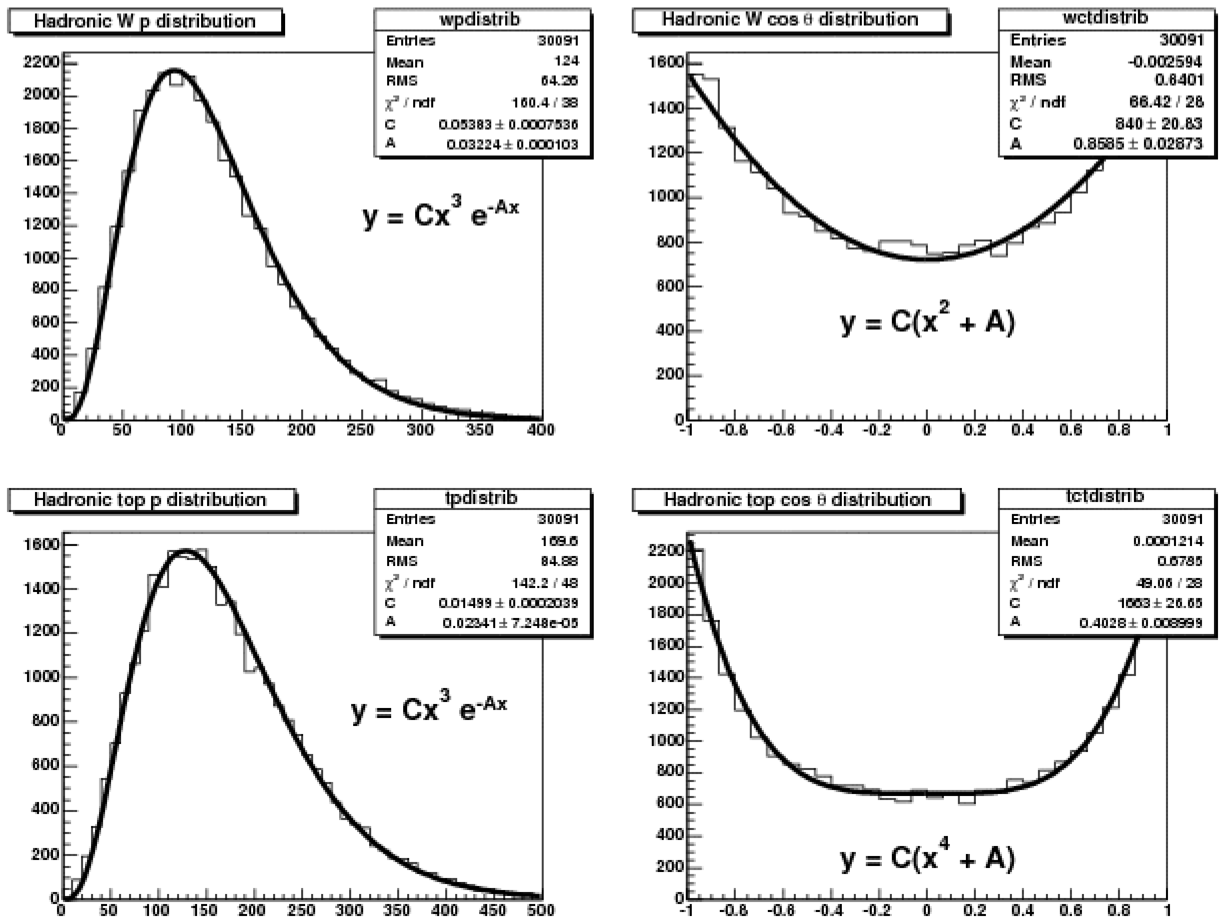
Top Mass Calculation

- By adding terms for the b quark, the t parent, and an additional prior f_t for the top momentum, we can get an integral for the top probability as well:

$$P \sim \int \frac{p_1^2}{E_1}\frac{p_2^2}{E_2}\frac{p_b^2}{E_b} w_1 w_2 w_3 \frac{E_W}{p_W^2}\frac{E_t}{p_t^2} f(p_W, \cos\theta_W) f_t(p_t, \cos\theta_t) \frac{d\beta}{J}$$

- Note that this gives us a probability as a function of M_W and M_t. In calculating our likelihood curve, we use the peak M_W value derived from the W mass integration. This produces comparable results to integrating over the whole W range.

Priors



Priors are obtained from HEPG distributions of p and $\cos\theta$ and fitted.

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