MTM Blessing

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Outline

- Overview of our method
- Q+A
- Plots + numbers to be blessed

Signal Likelihood Formula

$$L = \frac{1}{N(m_t)} \frac{1}{A(m_t, \text{JES})} \sum_{i=1}^{24} w_i \int \frac{f(z_1)f(z_2)}{FF} \, \text{TF}(\vec{y} \cdot \text{JES} \mid \vec{x}) \, |M_{eff}(m_t, \vec{x})|^2 \, d\Phi(\vec{x})$$

$$\text{with} \quad L = L(\vec{y} \mid m_t, \text{JES})$$

- For every event, calculate a likelihood as function of m_t and JES assuming its signal
- Given quantities measured in the detector ($\vec{y}$) integrate over the kinematic phase space ($\vec{x}$)
- Each point in the phase space has a weight which includes a transfer function between $\vec{x}$ and $\vec{y}$, a matrix element with an effective propagator, and PDFs for the incoming partons
- Each possible quark-jet match is assigned a weight

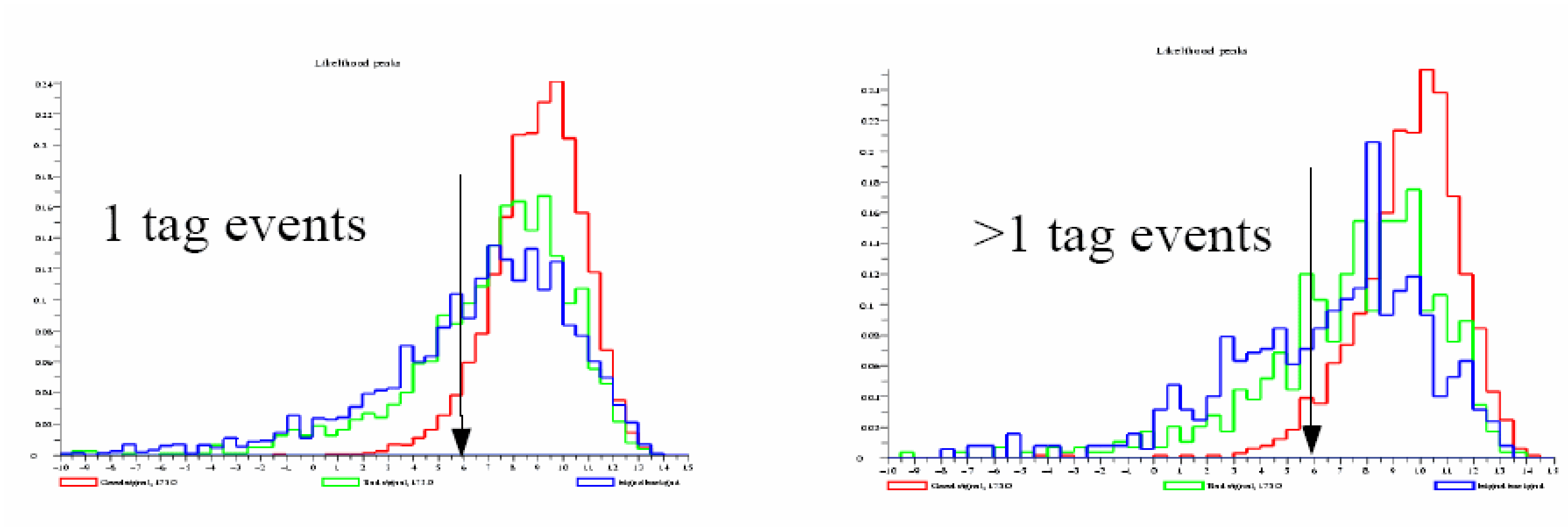
Full Likelihood Formula

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

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

- Here, $L(m_t, \text{JES}\,|\text{signal})$ is the signal likelihood for the event
- $\overline{L(m_t, \text{JES}\,|\text{background})}$ 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)

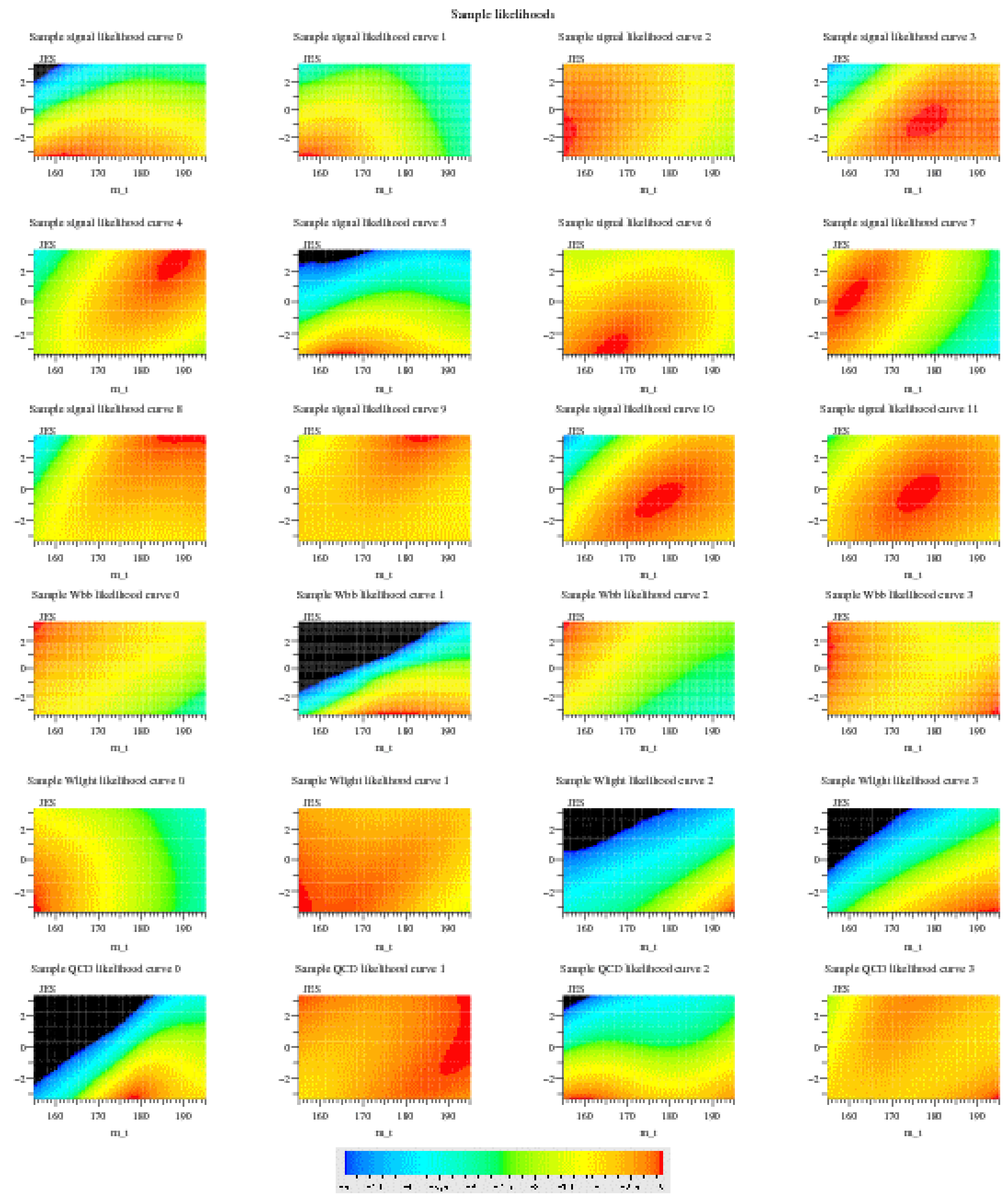
Likelihood Cut



- Our signal likelihood formula works best on good signal events – events with a good match between the four decay quarks and four tight jets in our event
- Cutting on the value of the peak of the likelihood curve, we can eliminate ~25% of non-good signal, as well as ~40% of background, while only eliminating 5% of good signal

Sample Likelihoods

- Individual event likelihoods: m_t (X-axis) vs. JES (Y-axis)
- Rows 1-3: signal
- Row 4: W+heavy flavor
- Row 5: W+light flavor
- Row 6: QCD



John Freeman

Q+A #1

What is the systematic due to the expected charm mistag rate used in your permutation weighting procedure?

Charm Mistag Rate	Measured Mt (GeV)
25.3%	174.32
18.70%	174.43

- When weighting the jet-quark permutations, we take the mistag rate of the charm quark from W decays as 0.22
- Shifting this rate up and down by 15% on the Herwig mt = 175 GeV sample yields a systematic of 0.06 GeV

Q+A #2

You have a systematic for the total JES shift; could we see the effect of shifts for individual jet reconstruction levels?

Correction	Systematic (GeV)
Total	0
L7	0.24
L5	0.20

- L7 and L5 systematics are consistent with the total systematic
- Comparison has limited usefulness as errors have large effect on the values

Q+A #3

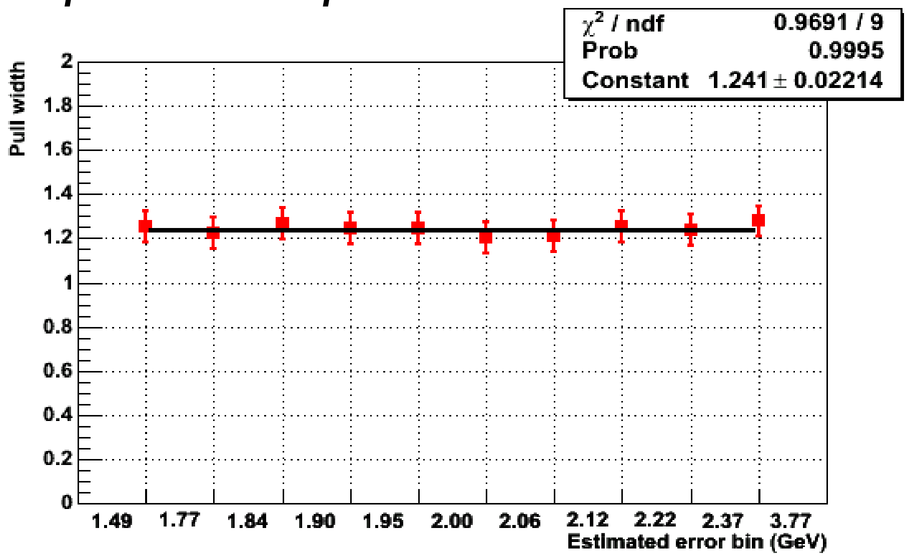
What is the effect of the # of vertices in an event on your measurement?

# of event vertices	Measured Mt (GeV)
1	175.72 +/- 0.69
2	175.83 +/- 0.76
>2	175.53 +/- 0.52

- Ran PEs on the events in the Pythia ttopzl sample with 1, 2, and >2 vertices
- Although errors on reconstructed masses are large, their reconstructed masses are quite close
- We take the largest difference between the 3 as our systematic – 0.29 GeV

Q+A #4

You have pull widths calculated as a function of top mass; what do they look like as a function of the nominal error in a given PE?



- We took the 2000 PEs each run at mt = 167.5, 170.0 and 172.5, divided the PE ensemble into ten equally sized ensembles based on the nominal error, and calculated the pull width
- Pull width of 1.24 appears independent of error, and consistent with pull width as function of mass (1.22 +/- 0.02)

Q+A #5

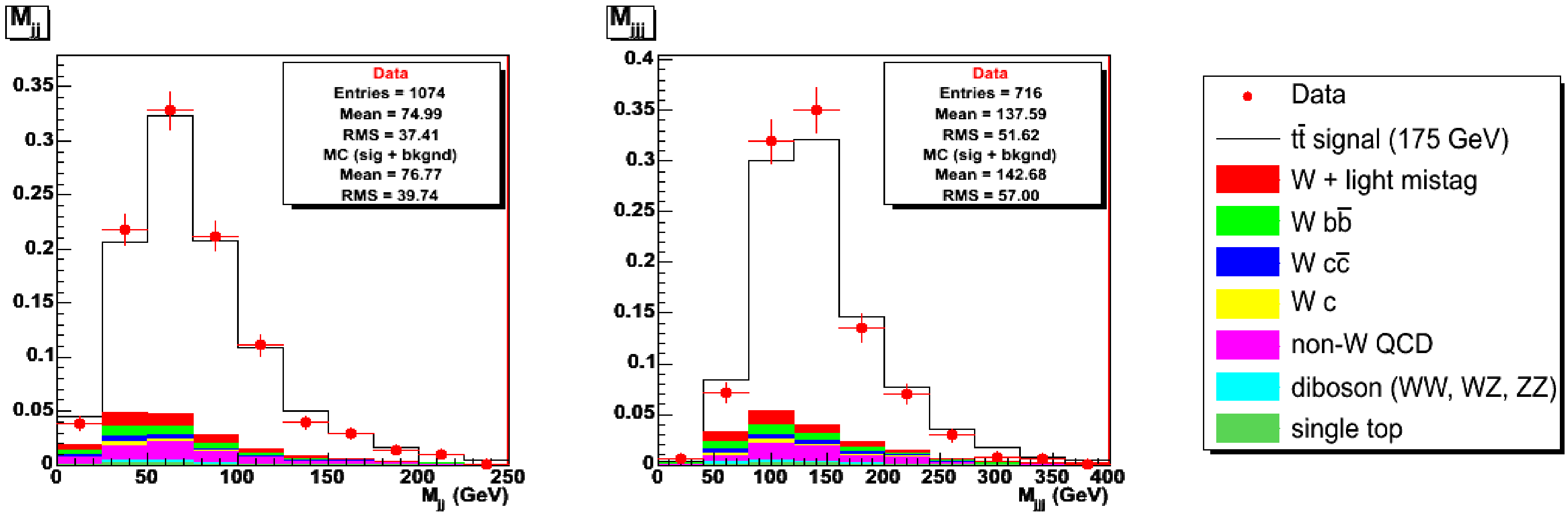
Can you show that, with everything in the integration consistent, you can get unit pull widths and no bias?

Mass	*Bias (GeV)*	*Range (GeV)*	*Pull Width*
175.0	-0.25	2.25	1.028

- Have results from fall in which events with TF-smeared partons were input into the integration at Mt = 175
- Only 80 evts/PE were run; error on bias ~ 0.35 GeV, error on pull width ~ 0.03 => bias consistent with 0 and pull width consistent with 1

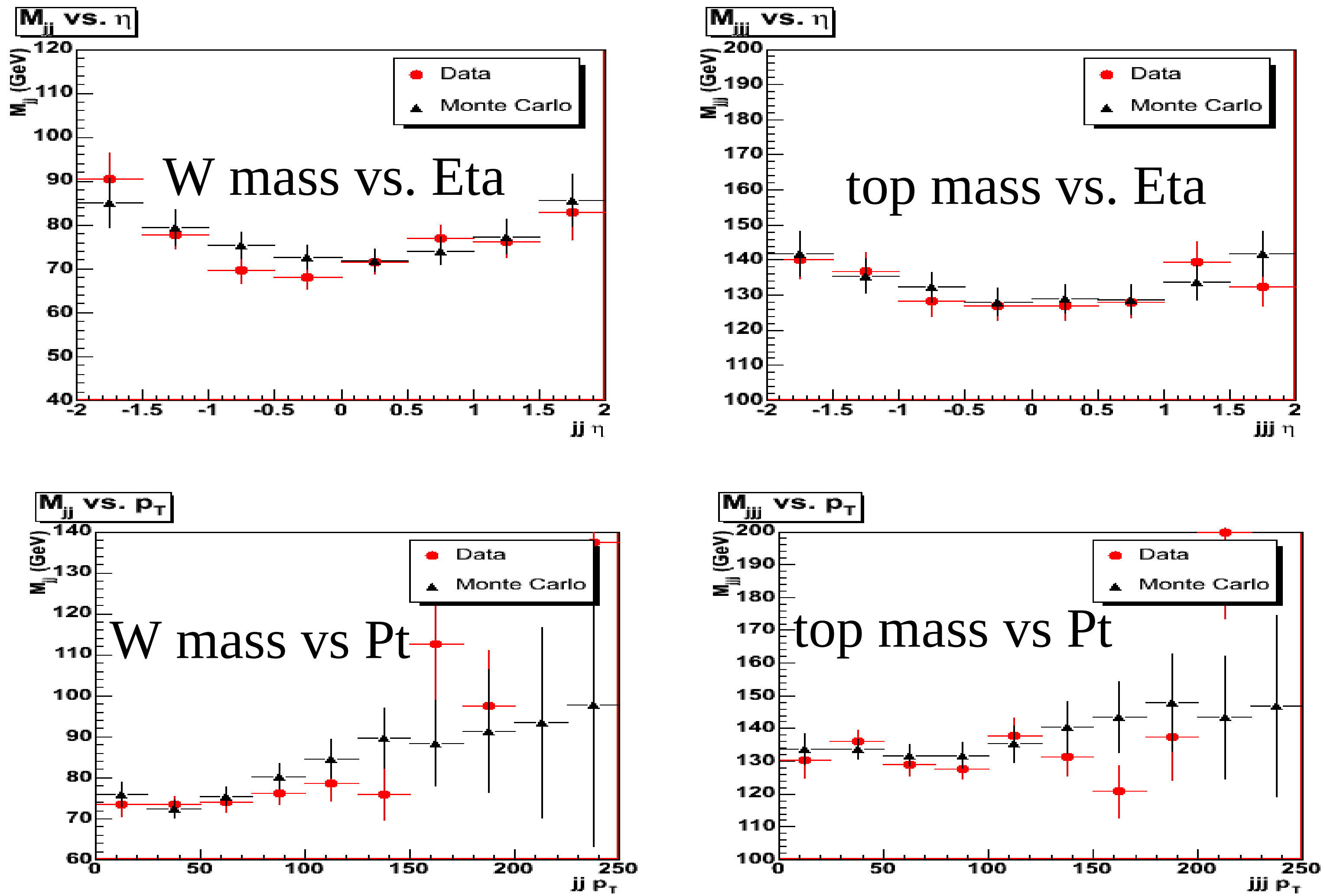
Q+A #6

Since you use a flat JES, can you compare the W mass pt and eta dependence between data and MC?



- W mass distribution appears consistent between MC and data overall

Q+A #6 (cont'd)



- Results also look OK when binned in eta and Pt

Q+A #7

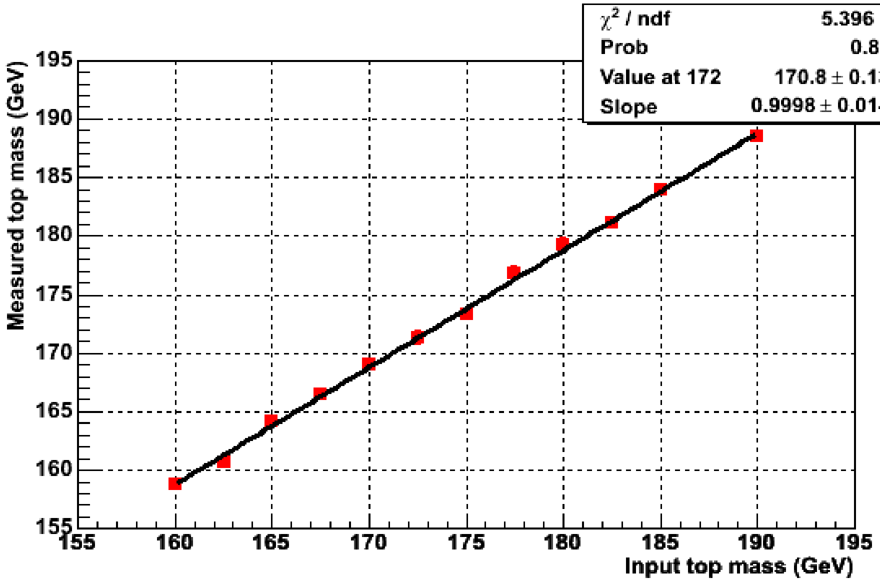
Could you show the pull widths and biases of the analysis in different situations?

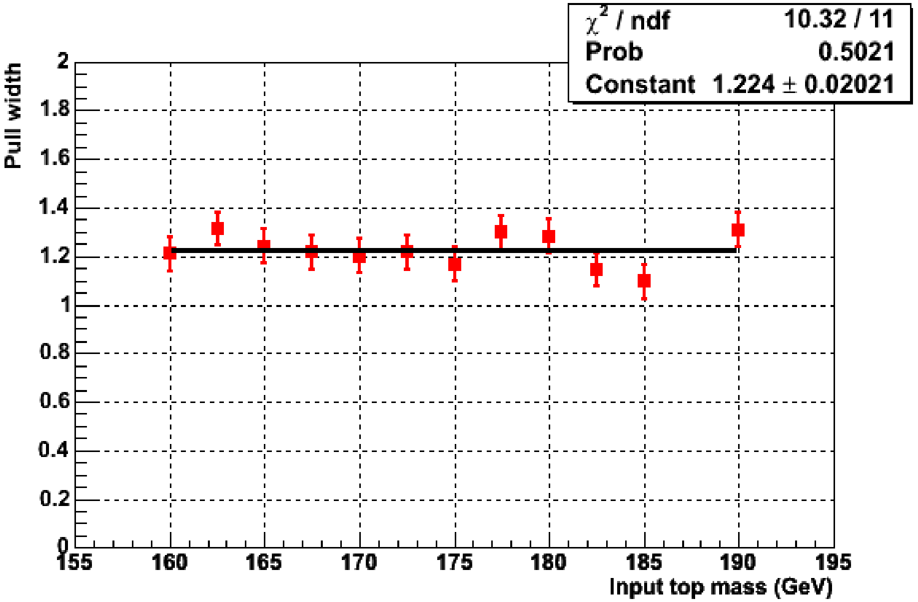
Input used	Bias	slope	σ at 172 GeV	pull
Good signal	-0.26 $\pm$ 0.12	0.99 $\pm$ 0.01	1.67 $\pm$ 0.06	1.05 $\pm$ 0.02
All signal, no cut	-3.09 $\pm$ 0.14	0.96 $\pm$ 0.02	2.50 $\pm$ 0.06	1.30 $\pm$ 0.02
All signal, cut at 6	-1.15 $\pm$ 0.13	0.99 $\pm$ 0.02	2.06 $\pm$ 0.06	1.16 $\pm$ 0.02
Sig+bkgnd, no cut	-2.14 $\pm$ 0.16	0.97 $\pm$ 0.02	2.83 $\pm$ 0.06	1.33 $\pm$ 0.02
Sig+bkgnd, cut at 6	-1.20 $\pm$ 0.14	1.00 $\pm$ 0.01	2.53 $\pm$ 0.06	1.22 $\pm$ 0.02
Sig+bkgnd, no cut or handling	-4.73 $\pm$ 0.17	0.95 $\pm$ 0.02	3.01 $\pm$ 0.06	1.42 $\pm$ 0.02
Sig+bkgnd+cut, no handling	-1.98 $\pm$ 0.14	0.98 $\pm$ 0.02	2.53 $\pm$ 0.06	1.21 $\pm$ 0.02

- Signal-only PEs: 179 evts/PE
- Sig+bkgnd PEs: 148 evts/PE with likelihood cut, 179 evts/PE without

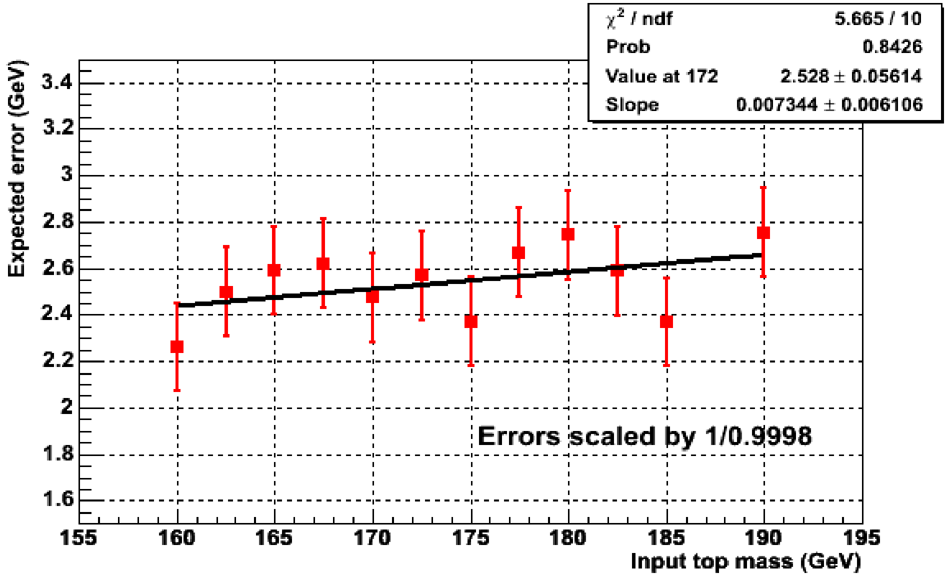
PLOTS / NUMBERS TO BE BLESSED

Signal+Background PE Results

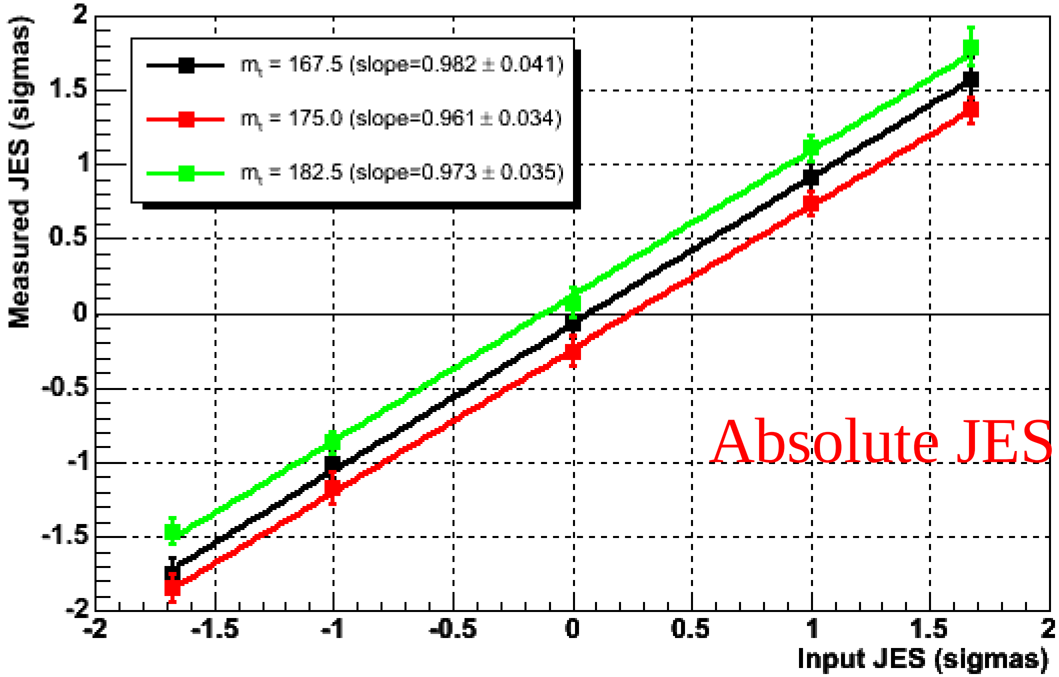




- Bias = -1.2 +/- 0.14 GeV
- Mass linearity slope: 1.000 +/- 0.014
- Pull width: 1.22 +/- 0.02
- Expected error at 172 GeV: 2.53 GeV



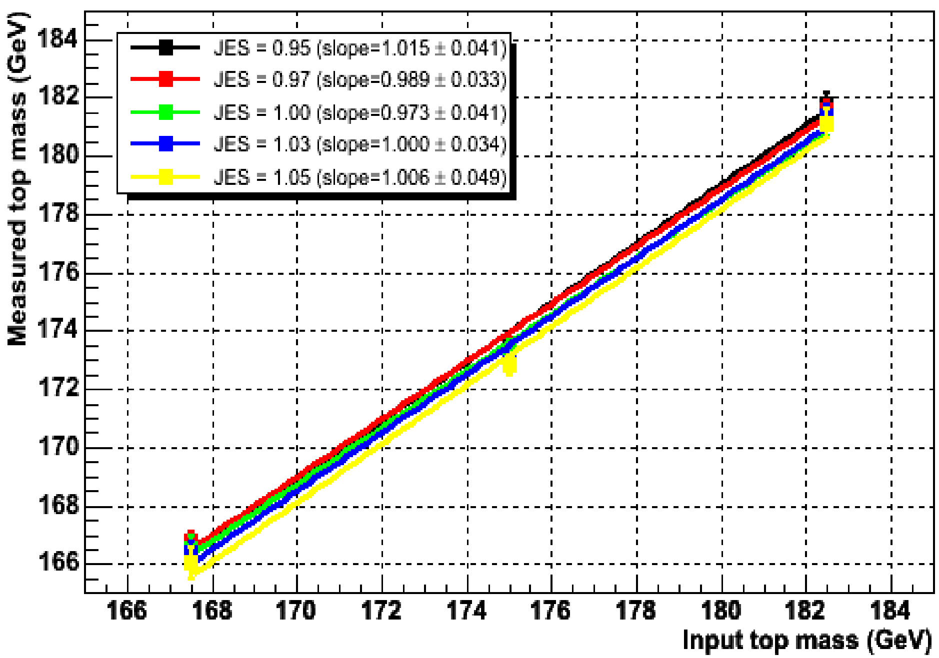
JES Linearity Results (I)

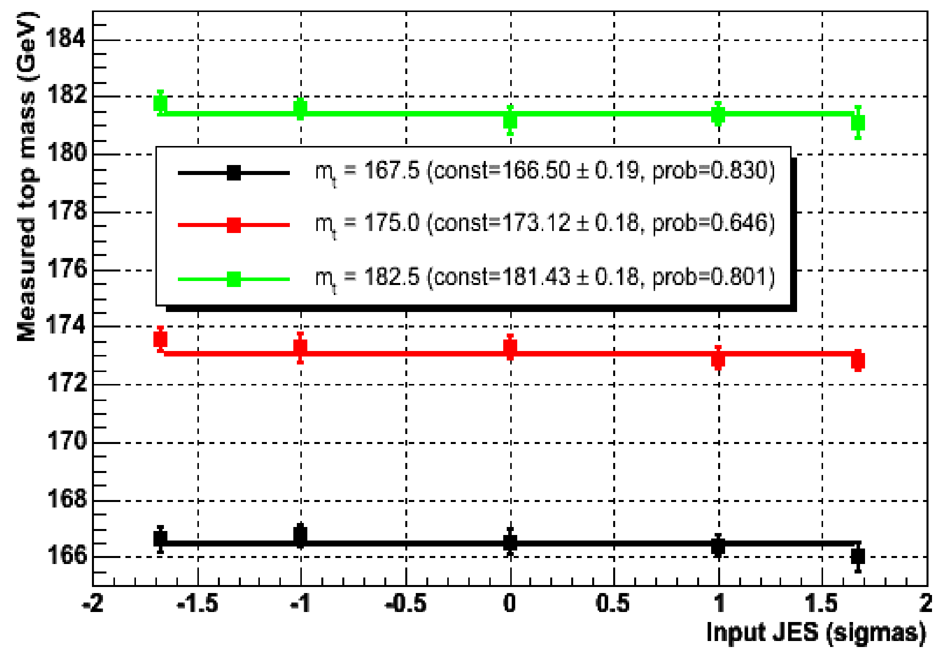


Absolute JES = 1 + 0.03 * sigma

- With more statistics, it appears the slope of reconstructed vs. input JES is ~ 0.97 for the three masses looked at
- Calibration of JES data taken by average of slopes at mt = 167.5 and 175.0: slope = 0.97, offset = -0.162
- JES data meas. error corrected by pull width of 1.14 -> average of pull widths from mt = 167.5 and mt = 175.0

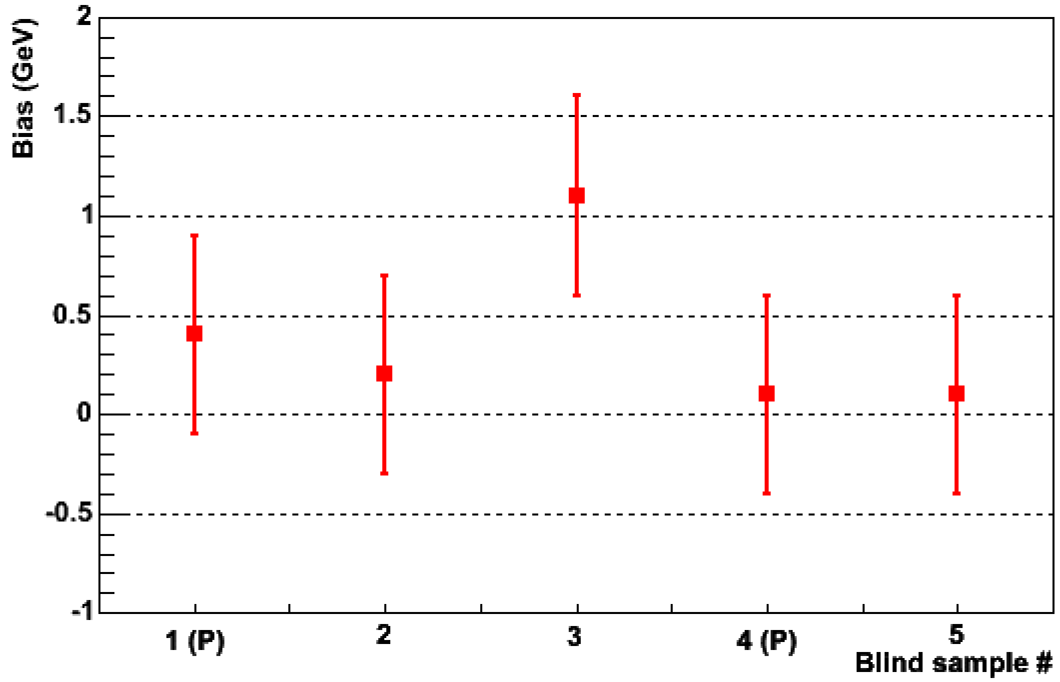
JES Linearity Results (II)





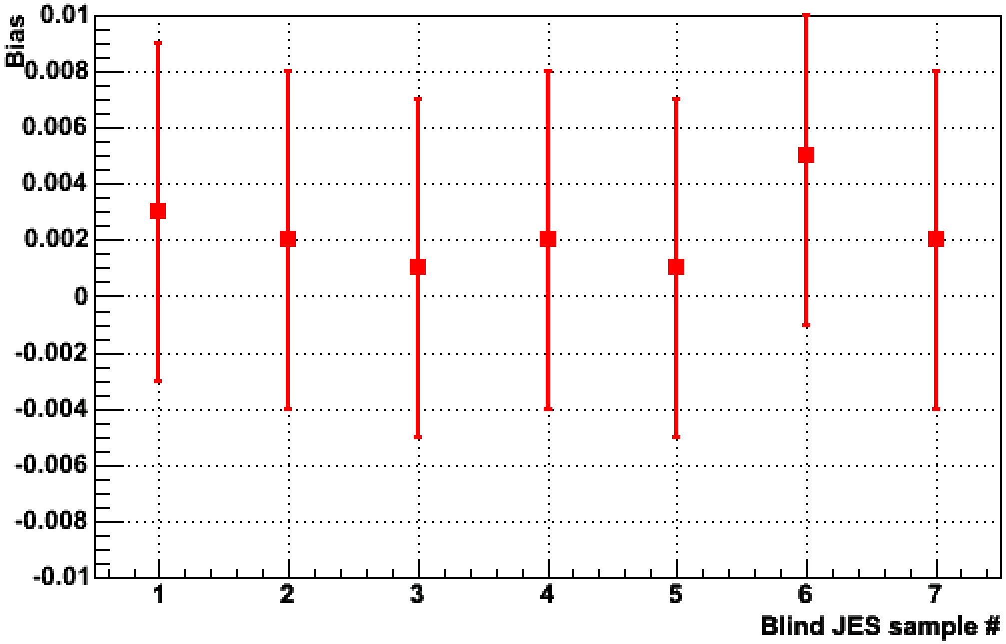
- Mass linearity looks consistent with 1 for different true values of JES
- True JES has negligible effect on measured top mass

Blind Mass Results



- Calibration of +1.20 GeV and pull width correction of 1.22 is applied to the raw blind mass sample measurements

Blind JES Results



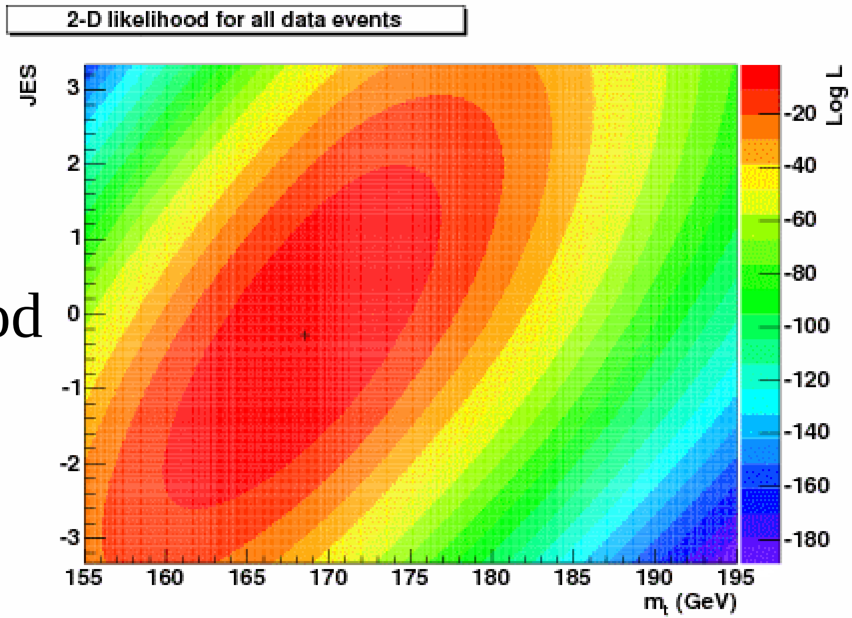
- Blind JES results have been recalibrated with the higher statistics available in the JES linearity

Data Measurement (Stat+JES)

Mt = 169.8 +/- 1.6 (stat.) +/- 1.7 (JES) GeV

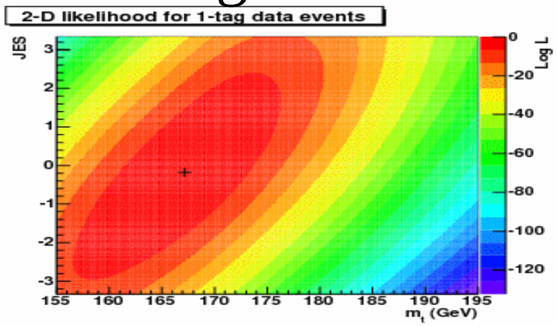
JES = 0.996 +/- 0.017

PE likelihood

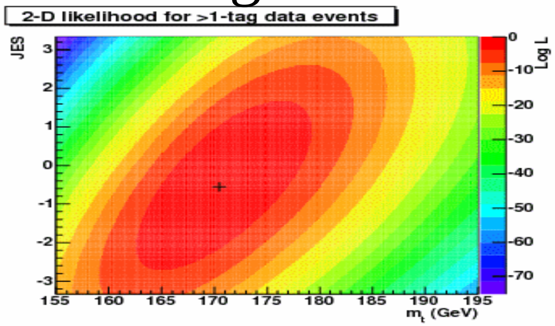


- 108 1-tag events, 41 >1 tag events
- Bias offset of +1.20 GeV and pull width of 1.22 applied to correct mass measurement and error

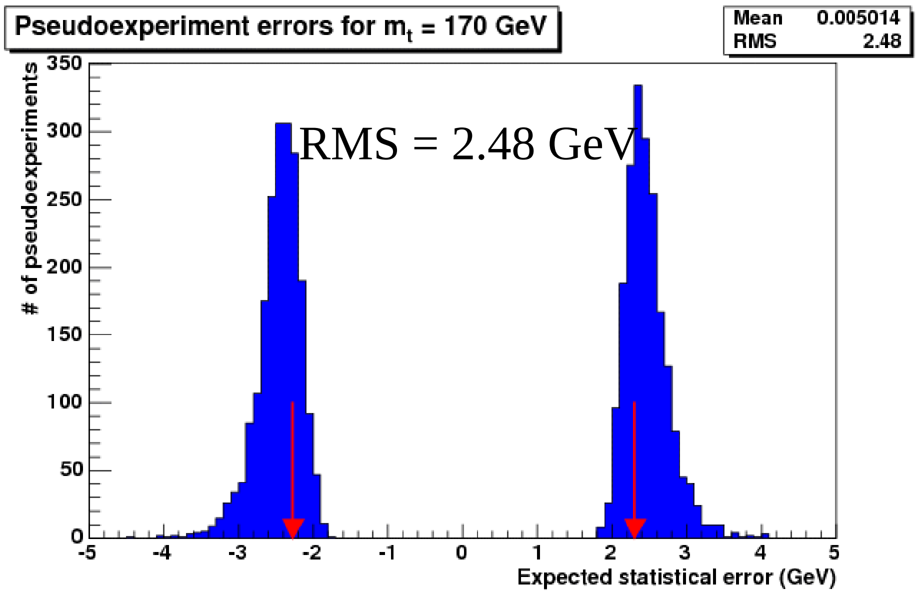
1 tag events

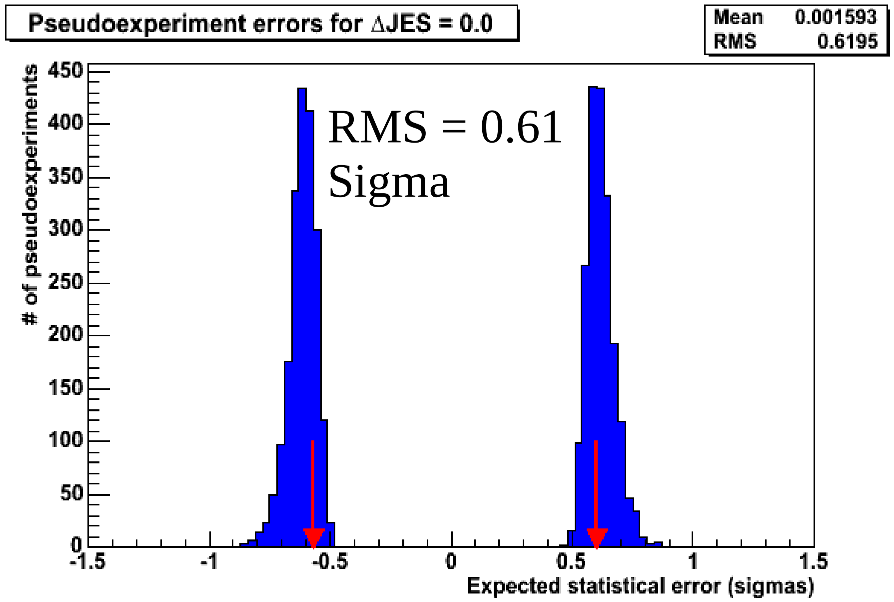


>1 tag events



Data Measurement (Stat+JES) (cont'd)





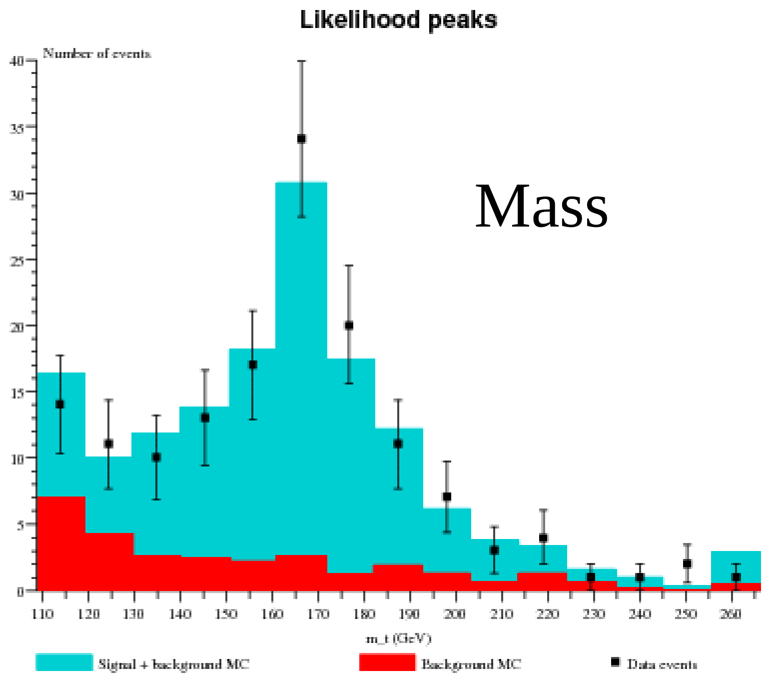
- 27% of PEs at Mt = 170.0 GeV have lower mass error than our data measurement
- 33% of PEs at Mt = 170.0 have lower JES error than our data measurement

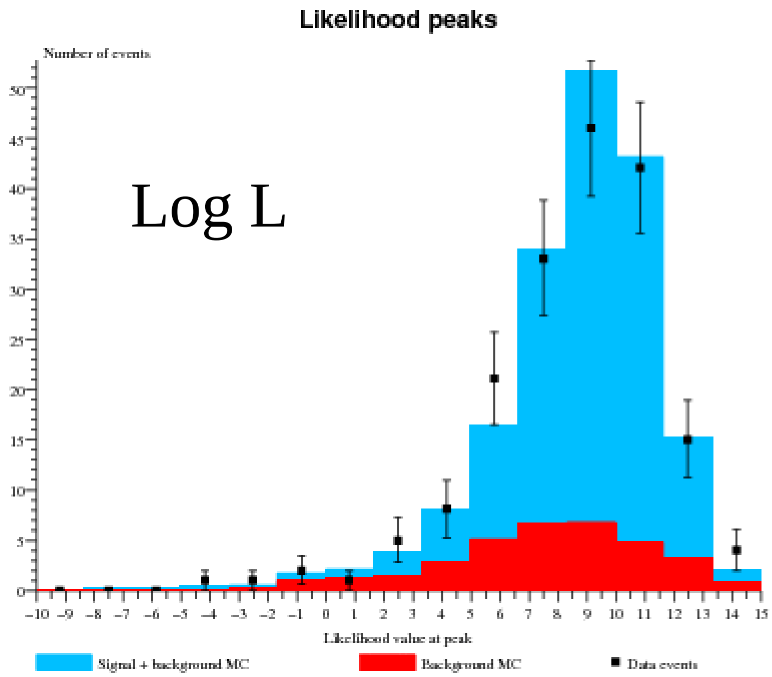
Data Measurement (Subsamples)

Subsample	Number of events	Measured m_t (GeV)
All data	149	169.75 ± 2.28
electron events	88	167.25 ± 3.31
muon events	61	175.35 ± 3.94
single-tag events	108	168.35 ± 3.26
multiple-tag events	41	171.65 ± 3.58
0d dataset	56	174.25 ± 3.55
0h dataset	50	171.55 ± 4.31
0i dataset	43	162.25 ± 3.96

- Differences consistent with effects observed by other groups

Data vs. MC





- Good agreement shown between the individual event likelihood peaks of data and MC, both for the mass and the log likelihood value

Systematics (I)

Systematic source	Systematic error (GeV)
Residual JES	0.28
PDFs	1.08
ISR	1.30 ± 0.41
FSR	1.22 ± 0.45
MC generator	0.99 ± 0.47
Gluon fraction	0.05
Background: fraction	0.20
Background: composition	0.39
Background: average shape	0.29
Calibration	0.14
b-JES	0.23
b-tag E_T dependence	0.02
permutation weighting	0.06
multiple interactions	0.30
lepton P_T	0.05
Background energy	0.30
Current total	2.44

- Systematics completely dominated by ISR/FSR/generator values

Systematics (II)

Sample	Measured m_t (GeV)	Δm_t (GeV)
Nominal Pythia (ttopel)	179.25 ± 0.29	—
Pythia more ISR (ttopdr)	178.50 ± 0.35	-0.75 ± 0.45
Pythia less ISR (ttopbr)	177.95 ± 0.29	-1.30 ± 0.41
Pythia more FSR (ttopkr)	178.81 ± 0.37	-0.44 ± 0.47
Pythia less FSR (ttopfr)	178.03 ± 0.34	-1.22 ± 0.45

Sample	Measured m_t (GeV)	Δm_t (GeV)
Nominal Herwig m_t = 178 GeV (ttophl)	178.26 ± 0.37	—
Nominal Pythia m_t = 178 GeV (ttopel)	179.25 ± 0.29	0.99 ± 0.47
Nominal Herwig m_t = 175 GeV (ttopag)	174.49 ± 0.41	—
MC@NLO m_t = 175 GeV (ptop10)	174.59 ± 0.47	0.10 ± 0.62

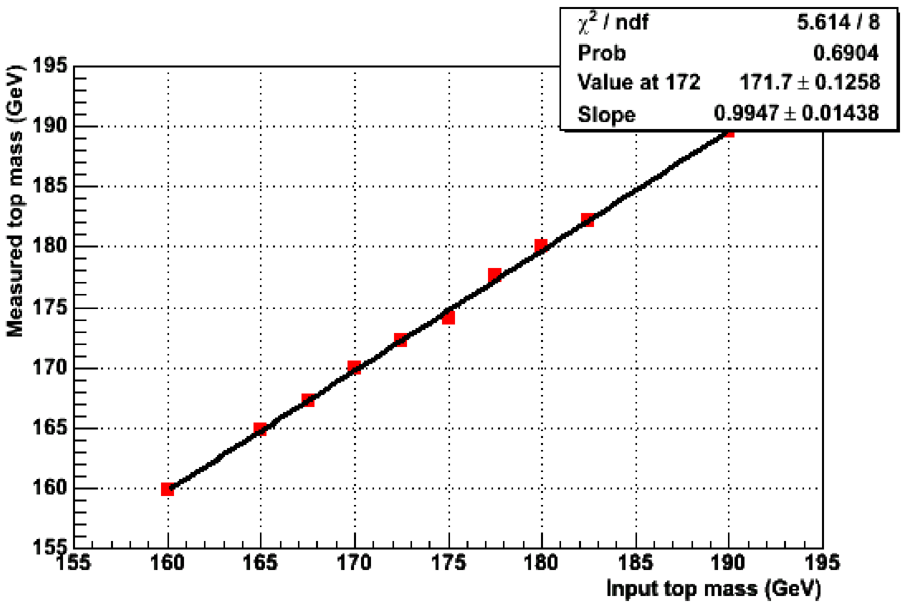
- Our ISR/FSR systematics are calculated taking the difference between nominal Pythia (ttopel) and the most different ISR/FSR sample
- High reconstructed mass of ttopel sample causes large systematics!

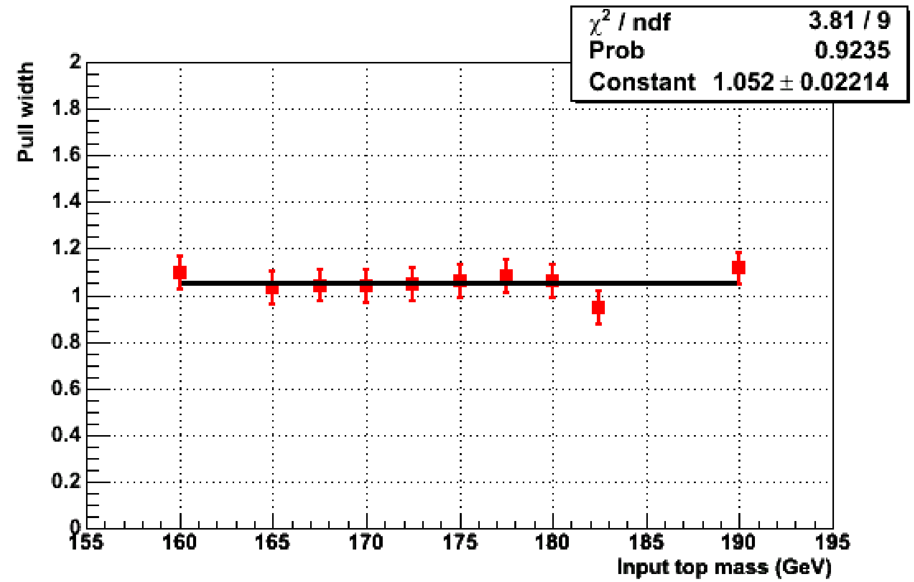
Systematics (III)

Systematic source	1-D systematic (GeV)	2-D systematic (GeV)
ISR	0.43	1.30
FSR	0.33	1.22
MC generator	0.49	0.99
Gluon fraction	0.13	0.05
PDF re-weighting	0.50	1.08
background composition	0.19	0.20
background fraction	0.22	0.39
background shape	0.55	0.29
Total	1.09	2.37

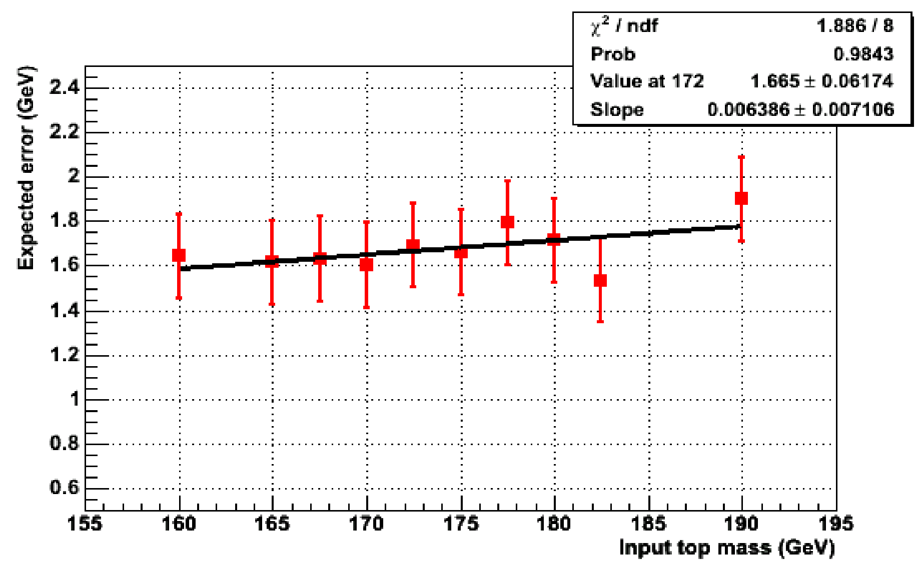
- To better understand this, we've rerun most of our systematics using just the 1-d slice at unshifted JES in our 2-d PE likelihood
- Systematic seems considerably lower; in part due to lower statistical error of measurement in 1-d case (e.g., in PDF reweighting case), in part since ttopel mass is now lower

Good Signal Only





- Bias at 172 GeV = -0.3 +/- 0.13 GeV
- Mass linearity slope = 0.995 +/- 0.014
- Pull width = 1.05 +/- 0.02
- Expected error at 172 GeV (179 evts): 1.67 GeV

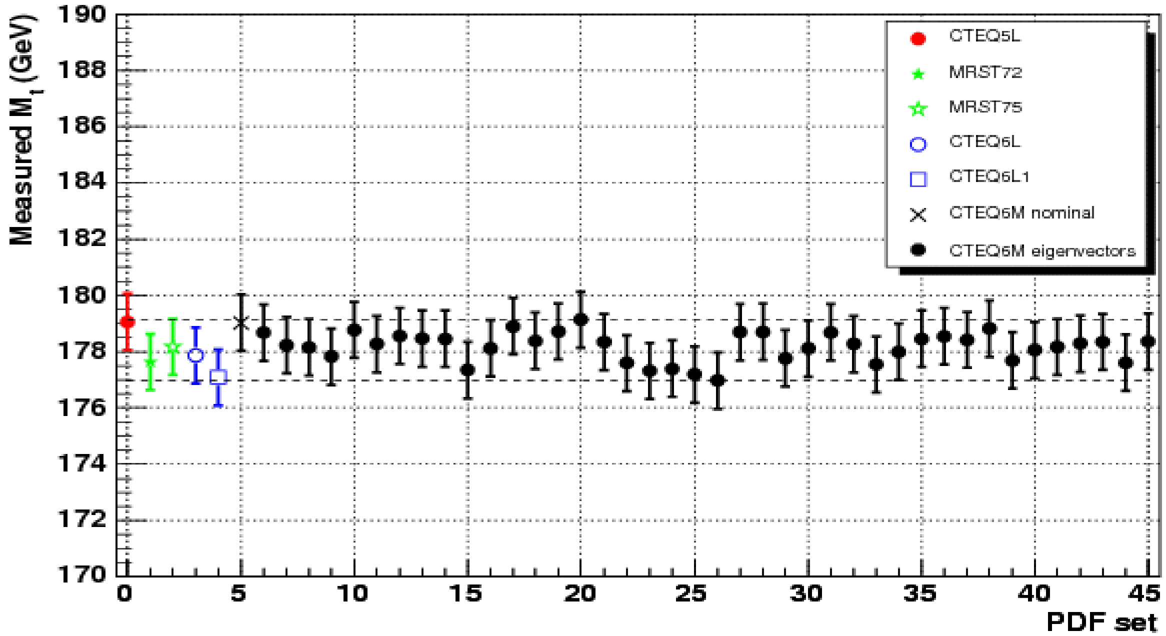


Conclusions

- A lot of interesting ideas went into this analysis
- MTM is currently working on developing ways to improve on the technique presented
- Our measurement is systematics limited in case of 2-d likelihood calculation of systematics, but would likely be statistics limited in the 1-d case with all systematics calculated
- Top mass measurement of
  - Mt = 169.8 +/- 1.6 (stat.) +/- 1.7 (JES) +/- 2.4 (syst.) GeV

BACKUP SLIDES

Systematics (IV)

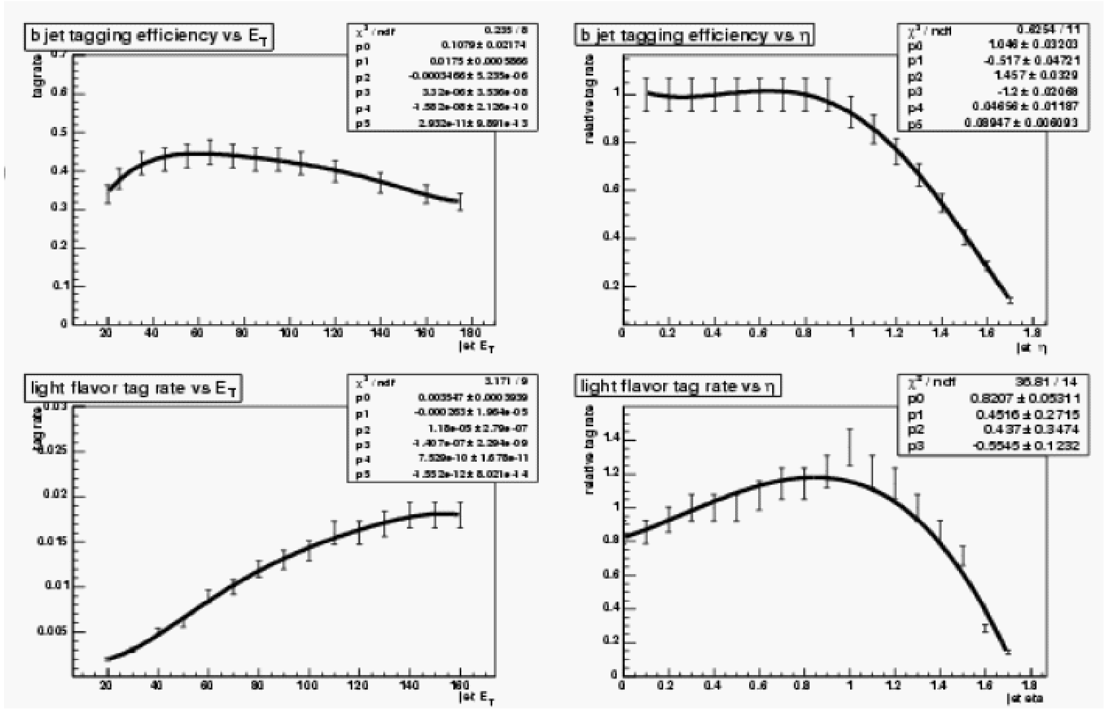


- ½ the largest difference = 1.08 GeV

Permutation Weighting

Heavy prob (P_b)

Light prob (P_l)



- For each permutation, calculate probability for each quark-jet match as function of Et and eta that the assumed quark (b, c, or l) would have produced a tagged jet
- Multiply the four probabilities together: P if tagged, (1-P) if not tagged