Measurement of the Mass of the Top Quark and Jet Energy Corrections

CDF-Canada Physics Workshop

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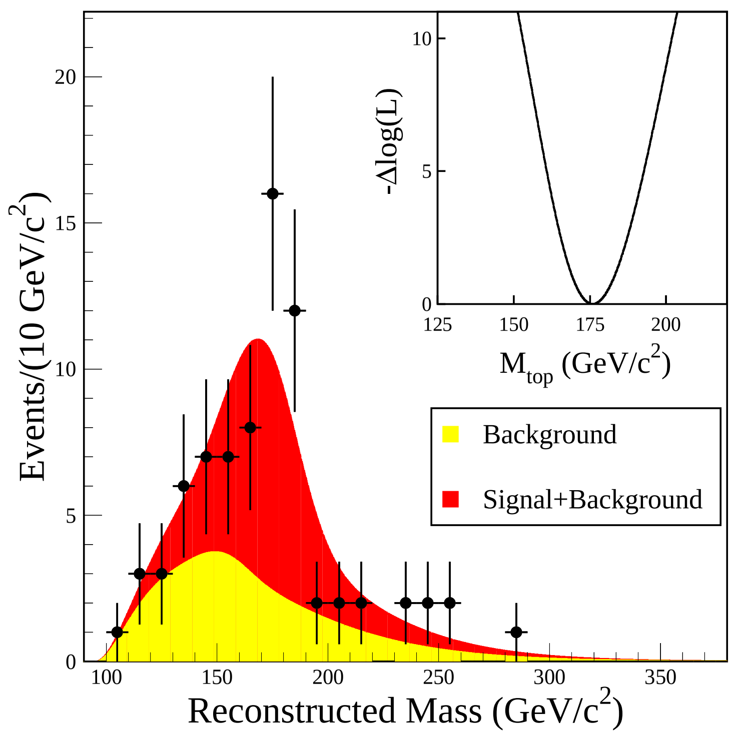
Outline:

1. Systematic Limitations in Run I
2. Contributions to Jet Energy Scale Uncertainties
3. Using Conversions to Probe the low-P_T Jet Scale
4. The Underlying Event Corrections in Run II
5. Studies on Improving the Top-Specific Corrections

Run I Lepton+jets channel: Result



Background sources:

- W+jets ______ 67%.
- QCD multijets, $b\bar{b}$ _ 20%.
- Z+jets, WW, WZ, ZZ, single-top ______ 13%.

Maximum likelihood method is used to extract the mass:

$$M_t = 175.9 \pm 4.8\ \text{(stat.)} \pm 5.3\ \text{(syst.)}\ \text{GeV}/\text{c}^2$$

The key for Run II: Systematic Uncertainties

In Run II: stat. uncertainties on M_t down to ≈ 1 GeV/c^2

$\Rightarrow$ *Measurement dominated by syst. uncertainties*.

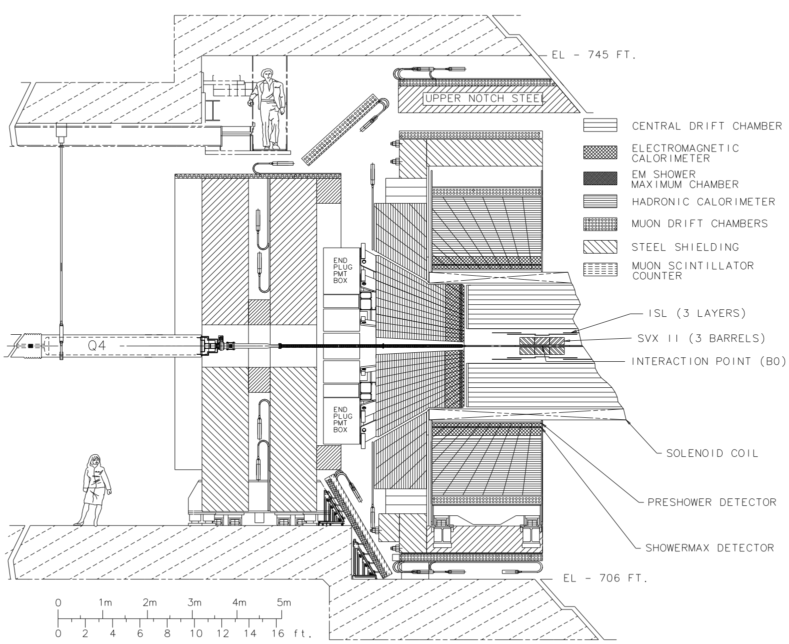
Effect	Run I (109 pb^{-1})	Run II (2 fb^{-1})	Comment
Jet energy scale	4.4	> 1.0	$1/\sqrt{\mathcal{L}}$ scaling
ISR and FSR	2.6	< 2.6	-
Shape of background	1.3	1.3	Calib. eventually?
b-tagging	0.4	0.1	$1/\sqrt{\mathcal{L}}$ scaling
Choice of PDF's	0.3	0.3	-
Total	5.3	≈ 3.1	

Table 1: Systematic uncertainties to M_t measurement (GeV/c^2).

Run II CDF Detector

Calorimeter in Run II:

- Same old Central Detector + Wall Detector (electronics upgraded)
- Plug scintillating calorimeter (gas calorimeter in Run I): $1.1 < |\eta| < 3.6$
- Miniplug detector covers $3.6 < |\eta| < 5.5$ (not used yet for Missing E_T and Jet reco.)
- More material in front of calorimeter:
  Run I: $\approx 7.5\%\ X_0$, Run II: $\approx 15\%\ X_0$.
- For top physics: jet are reconstructed in cone $R = \Delta\eta \times \Delta\phi = 0.4$. (Not ideal for top mass? (see note 6360: W. Fedorko *et. al*))



The Dominant Uncertainty: Jet Energy Scale

Jet in the calorimeter $\longrightarrow$ Energy of the initial parton ?

Run I Jet corrections uncertainty: **4.1%** (Z + jet balance study)

Decomposed uncertainties (substracted in quadrature):

1. **3.0%**: Soft gluon radiation leaking out of jet cone: answer is extracted from Monte Carlo simulation (includes splash-out)
2. **2.4%**: Absolute energy scale: Three components:
   (a) Jet Fragmentation (how many charged tracks in jets? How many π^0?)
   (b) Calorimeter non-linearity of response to hadronic particles
   (c) Underlying event falling in jet cones
   $\rightarrow$ (a-b) Project for S. Sabik for Run II, (c) presented later
3. **1.0%**: Relative corrections for uniform response in η
4. **0.9%**: Calorimeter stability over running period
5. **0.3%**: Multiple interactions depositing energy in jets (later)

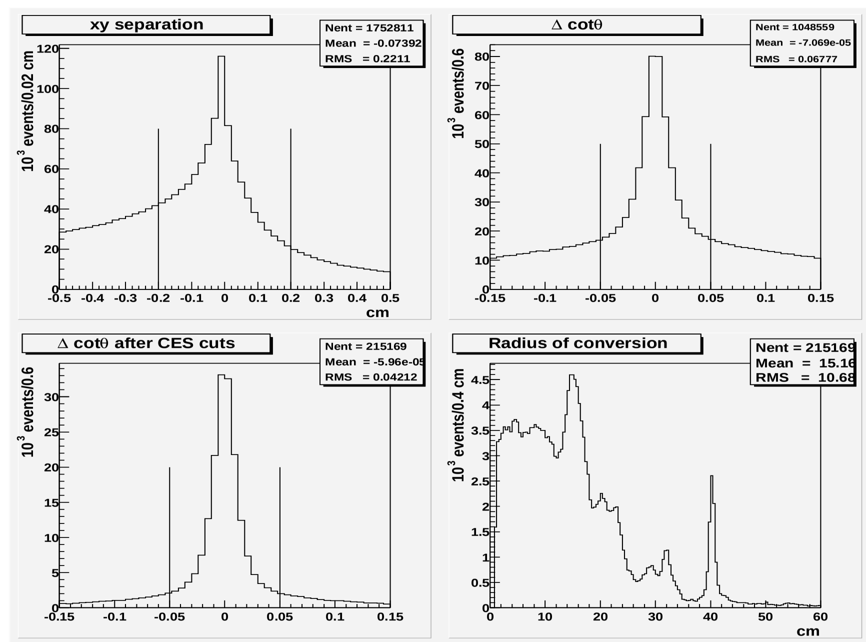
Photon-Jet Balancing

The jet energy scale can be studied "in-situ" using photon-jet events:

- Photon p_T is very well measured in CEM, events selected with 15 GeV trigger.
- Jet recoils can be studied wrt $p_T(\gamma)$
- technique is limited to $p_T > 25$ GeV $\rightarrow$ developed a technique to go lower

Conversion Photon ($\gamma \rightarrow e^+e^-$) + Jet

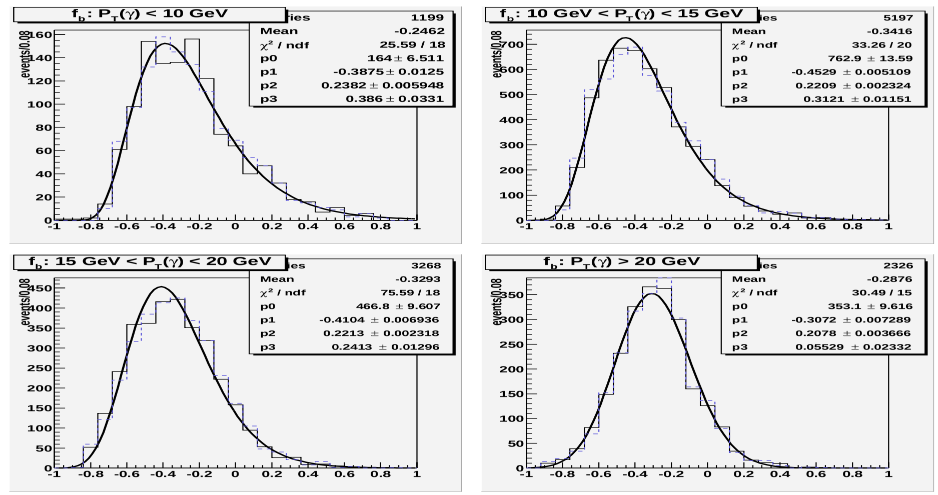
- Useful for top physics: 30% jets have $E_T < 30$ GeV
- Trigger on prescale 4 or 8 GeV e^-.
- Reconstruct Conversions (see plot $\Rightarrow$)
- Match $e^\pm$ to CEM towers

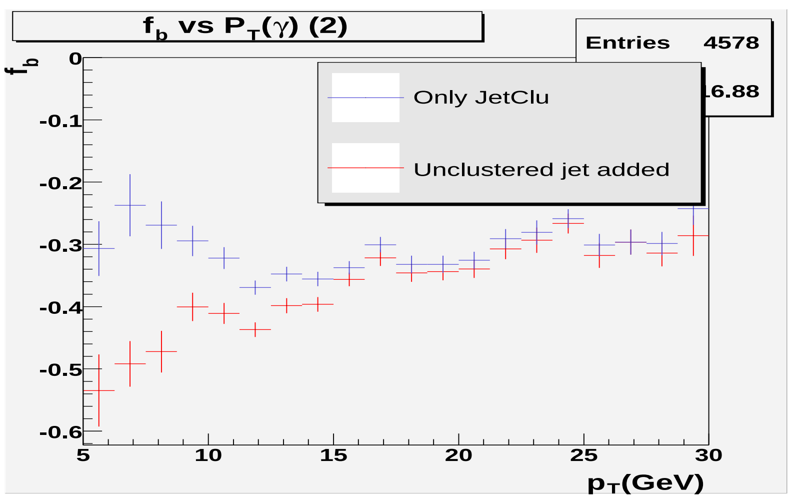


$(\gamma \rightarrow e^+e^-)$ + Jet Balancing

Reconstruction Issues

- Sliding isolation cuts for good photon ID at low-p_T
- Event-by-event UE contribution shown to be small





Results

- Secondary jet activity shown to be remaining bias using $\not{E}_T$
- Match pure photon-jet results a high-p_T
- Jet reco. seed shown to be large effect (plot $\Leftarrow$)

Underlying Event Corrections

- The underlying event deposits on average $\approx$ 0.5 GeV/cone R=0.4
- Can become a significant bias for low-p_T jets
- Furthermore, $\approx$ 2 interactions/crossing is expected at designed luminosity.
  $\therefore$ Need to extract a correction as a function of number of vertices
- For that, need to be able to count the # of vertices

Z-Vertex Finder for Run II: ZVertexColl

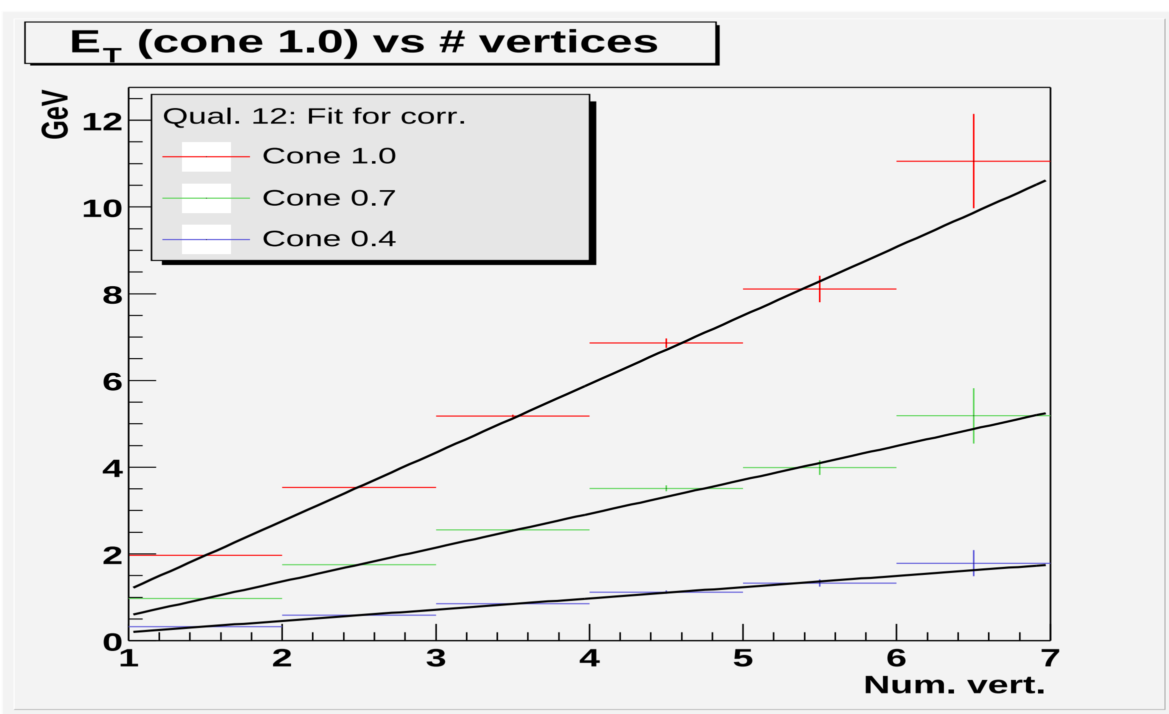
- Two purposes:
  1. Measure z position of primary vertices: E_T measurement
  2. Count the number of vertices: jet corrections, isolation cuts
- In Run II: use COT and silicon tracking
  In Run I, used specialized VTX detector only
- For same efficiency: better fake rate in Run II.

Underlying Event Corrections Measurements

Extracted by measuring the mean E_T versus the number of vertices (see plot below)

Various checks of results:

- Good fit to straight line suggest ZVertexColl parametrizes well the # of vertices
- Corrections shown to scale with cone area
- Differences with Run I shown to be understandable by different efficiency/fake rate of vertex finder.
- # of vertices shown to scale to inst. luminosity, Corrections shown to be independent of inst. luminosity
- Blessed for Winter Conferences



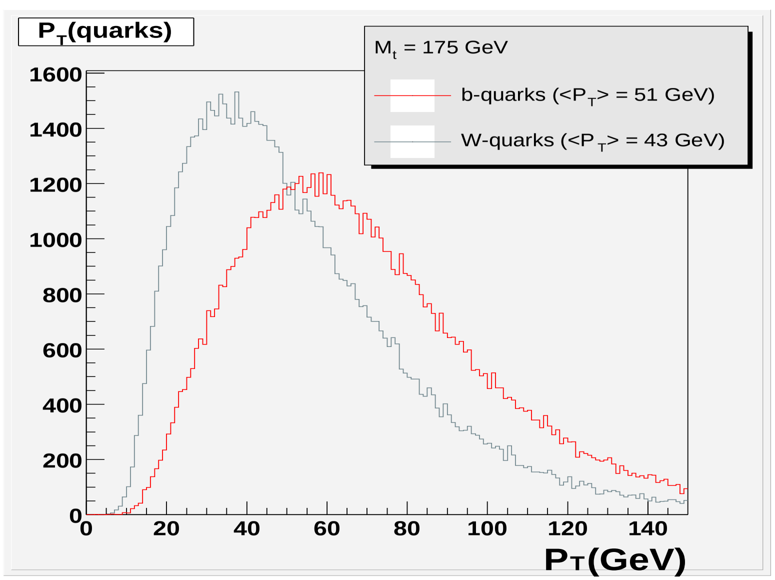
Top-Specific Jet Corrections

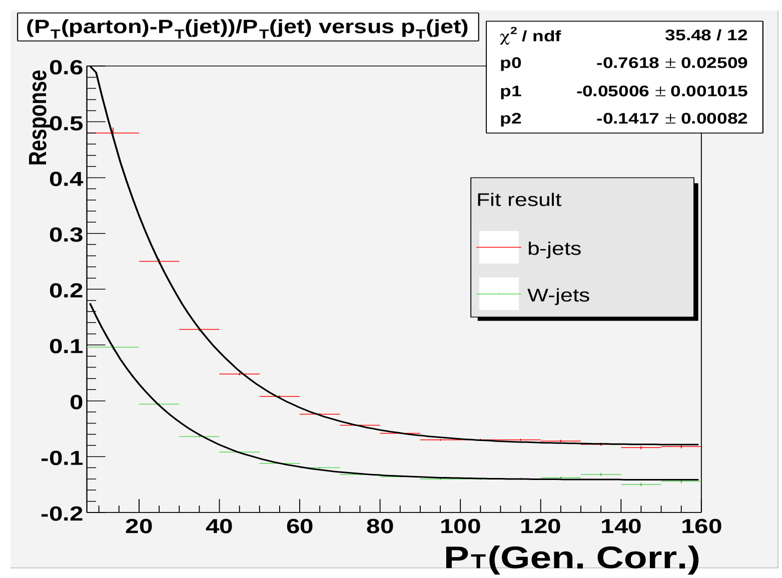
In CDF: the jet corrections are extracted for Generic Jets, i.e. with no hypothesis on the origin/flavor of the jet.

Additional corrections have to be extracted for top physics:

- b-jets: Semileptonic decays → more ν, μ, e inside jets
- W-jets: Come from colorless state → narrower jets

In addition, the AA-corrections in Run I assumed the jet p_T-spectrum to gain resolution on top mass (10-15% improvement).

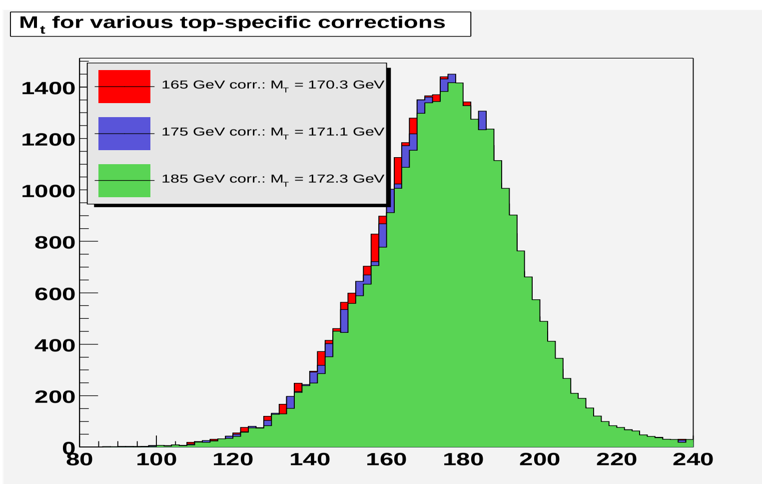


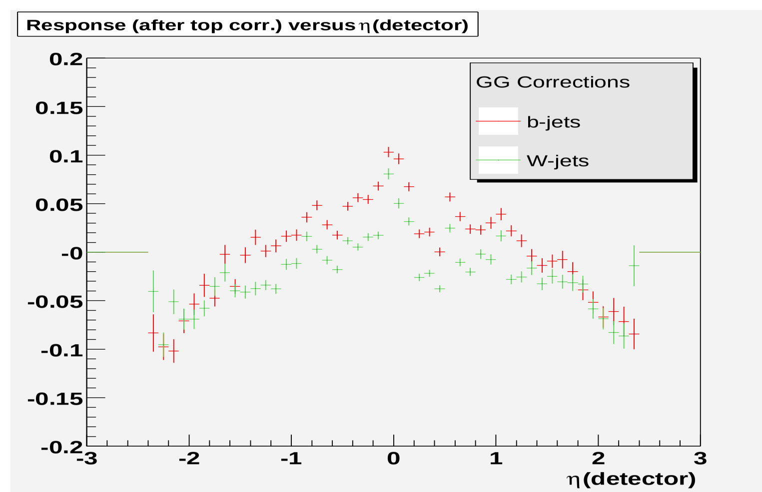


Pitfalls from Assuming p_T Distribution

→ Bias introduced if p_T spectrum is different in data

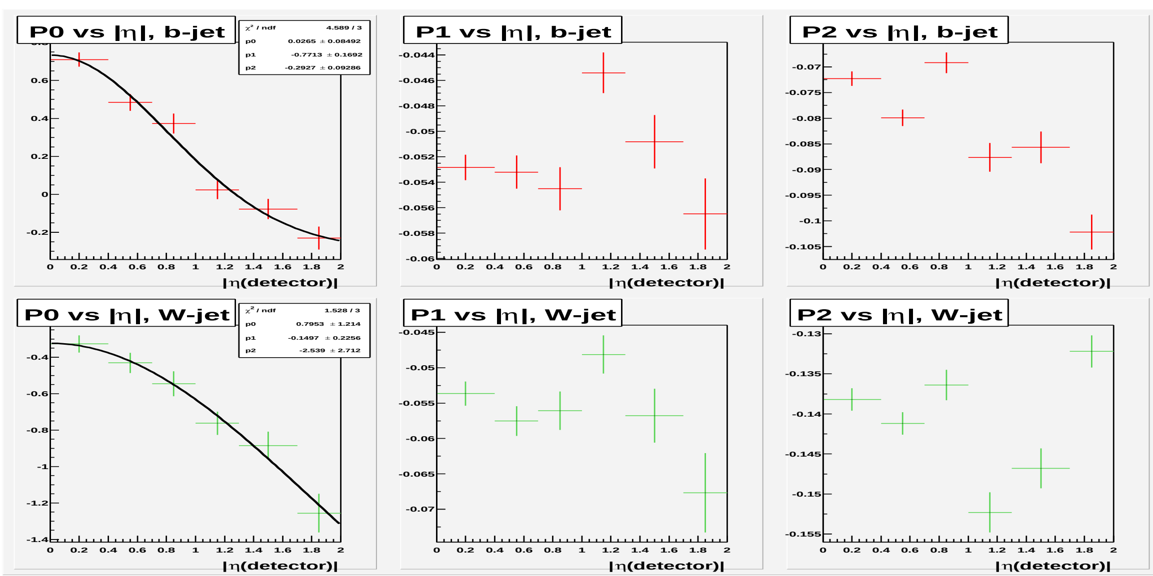
- In Run I, syst. uncert. of top-correction was put in PDF, ISR/FSR systematics (a sensible approach I believe)
- But the $p_T(top)$ spectrum is poorly constrained (A. Robinson). What if?
- One illustration of dependence is by changing M_t to extract the top-correction (see left plot). $\approx$ 1 GeV M_t shift per 10 GeV mass.
- Also, top physics is largely central → η-dependence! (not accounted for in Run I). Effect is large: 10-15% (see right plot)





New Top-Specific Jet Corrections

- Run II "GG" corrections extracted with the mean response vs p_T (argued better than median)
- After study: median of response is better estimator. The correction needed to be "calibrated" with new generators.
- Re-extracted correction for 6 η bins. Fit each template with $\boxed{f(P_T) = e^{(p_0 + p_1 P_T)} + p_2}$. Look for correlation wrt $\eta(detector$ and fit again (plot below)



Param. (GeV)	GG	Constant	f(p_T)	f(p_T,η)
σ_1 ($\pm$0.5)	26.2	29.2	24.9	23.69
σ_2 ($\pm$0.003)	-0.040	-0.056	-0.038	-0.030

Table 2: M_t resolution $\sigma(M_t) = \sigma_1 + \sigma_2 M_t$

Conclusions

Top-Specific Corrections

- More assumptions in measurement $\Rightarrow$ better statistical uncertainties
- Need to estimate if the price to pay in systematics is higher!

Generic Corrections

- Low-p_T jet response studied using new technique
- ZVertexColl: Z-Vertex Finder based on tracking
- Underlying event correction extracted

Lots of work to understand the Run II jet energy scale systematics!

$\rightarrow$ contributes 9.3 GeV/c^2 to 1st M_t measurement syst.

(Run I: 4.4 GeV/c^2)