Jet energy corrections and impact on the top mass measurement in CDF at the Tevatron Run II

http://www-cdf.lbl.gov/∼currat/talks/

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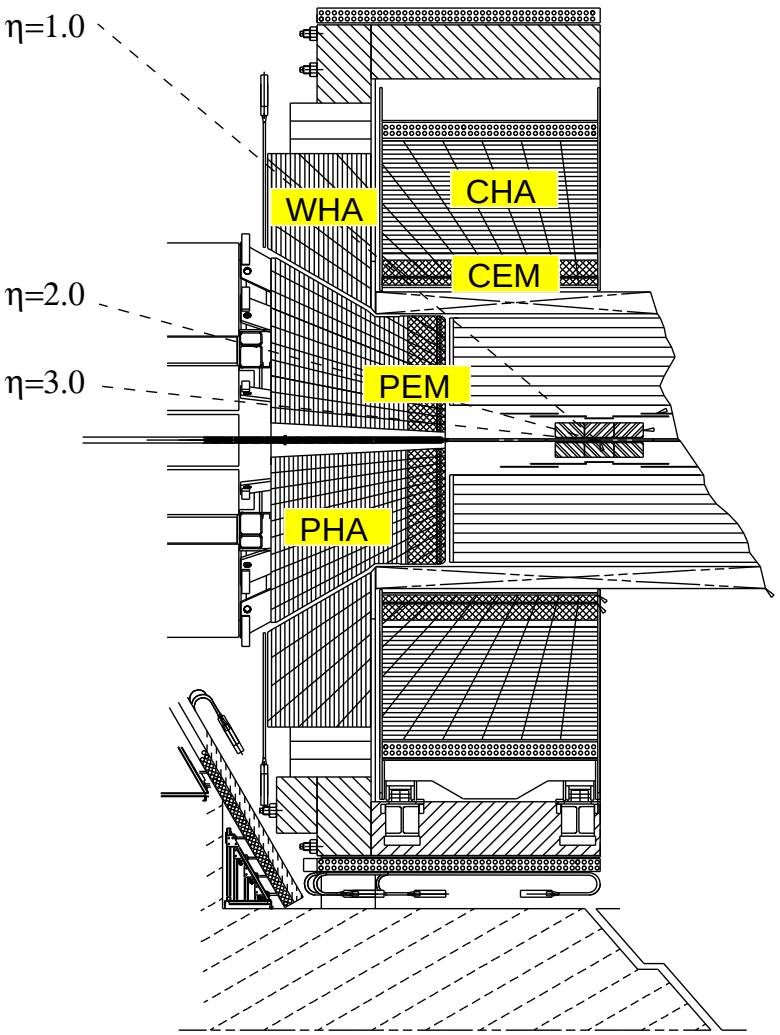
April 8, 2003

- Jet corrections why/what & review (current)
- Prospects on top mass uncertainty reduction

CDF calorimetry

CDF calorimetry is pretty diverse... 1512 towers of 12 different types



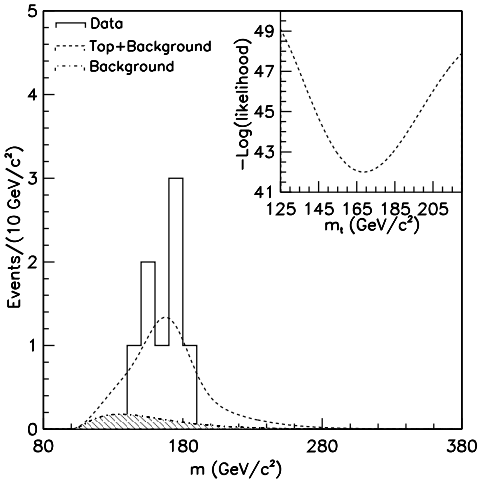
Calorimeter type	Thickness
Central EM	19 X_0, 1 λ
Central HAdronic	4.5 λ
Wall HAdronic	4.5 λ
Plug EM	21 X_0, 1 λ
Plug HAdronic	7 λ

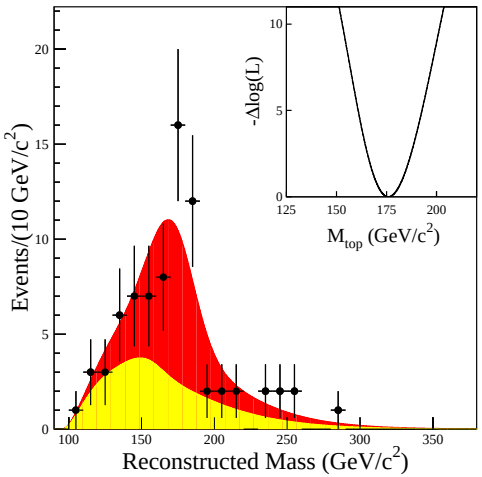
E-resolution	$\sigma/E_{(T)}$
CEM	$13.5\%/\sqrt{E_T} \oplus 2\%$
CHA	$50\%/\sqrt{E_T} \oplus 3\%$
WHA	$75\%/\sqrt{E_T} \oplus 4\%$
PEM	$16\%/\sqrt{E} \oplus 1\%$
PHA	$70\%/\sqrt{E} \oplus 5\%$

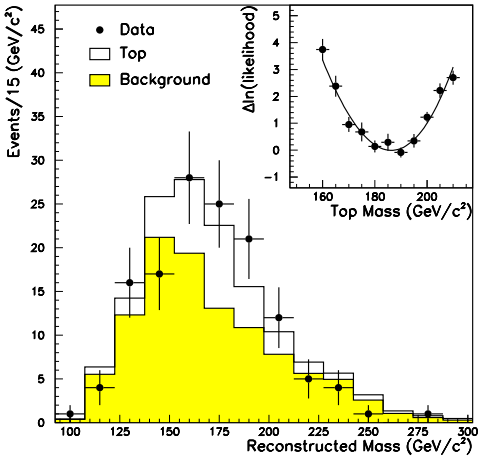
- New in Run II: end plug calorimeters (PEM+PHA), PMTs
- New in Run II: all of the electronics (108 bunches @ 132 ns crossing time ultimately)

☞ ... new calibrations!

Top mass measurement in Run I







dilepton | ℓ+jets | all hadronic

Final CDF result: $176.0 \pm 4.0 \pm 5.1$ GeV/c^2

Systematic errors (in GeV/c^2)

Channel	dilepton	ℓ+jets	all-had.
Jet E-scale	3.8	4.4	5.0
ISR,FSR	2.7	2.6	1.8
MC (PDF, b-tag)	0.6	0.5	0.2
Generator	0.6	0.1	0.8
Backgd shape	0.3	1.3	1.7
MC stats	0.7	n.a.	0.6
Total	4.8	5.3	5.7

Run II: about $50\times$ Run I yield ($\int \mathcal{L} = 2$ fb^{-1})...

- Stat error is going to be very low
- Smart work to be done to reduce systematics

Correction scheme

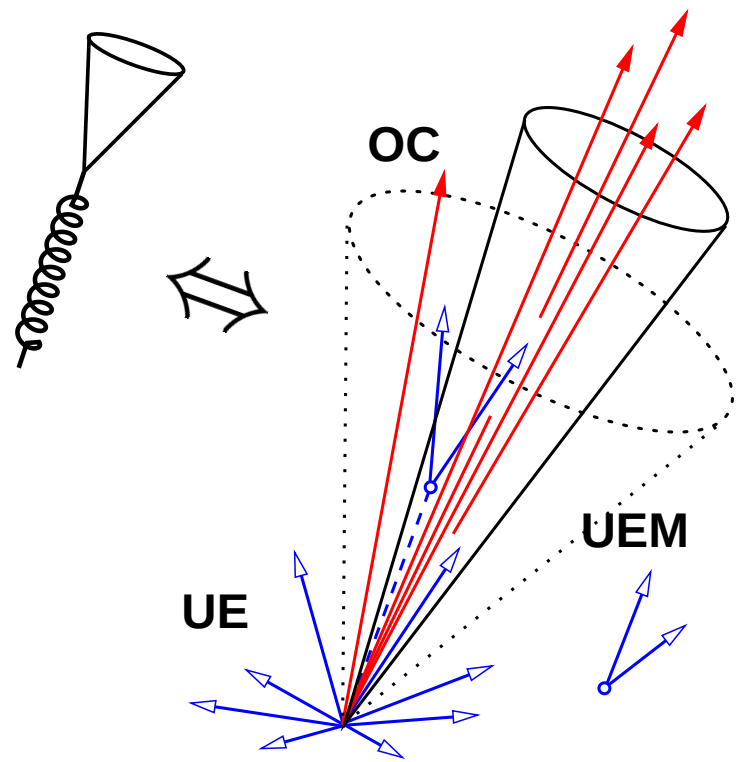
- Correction applied to raw cluster energies:

$$p_T(R) = [p_T^{raw}(R) \times f_{rel} - UEM(R)] \times f_{abs}(R) - UE(R) + OC(R)$$

with $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ the cone radius chosen for jet measurement (cone algorithm with $R = 0.4$ for top analysis)

f_{rel} relative E-scale: correct for non-uniformities in calorimeter response as $f(\eta)$

$f_{abs}(R)$ absolute E-scale: maps raw jet E observed in cone of radius R into average true jet E



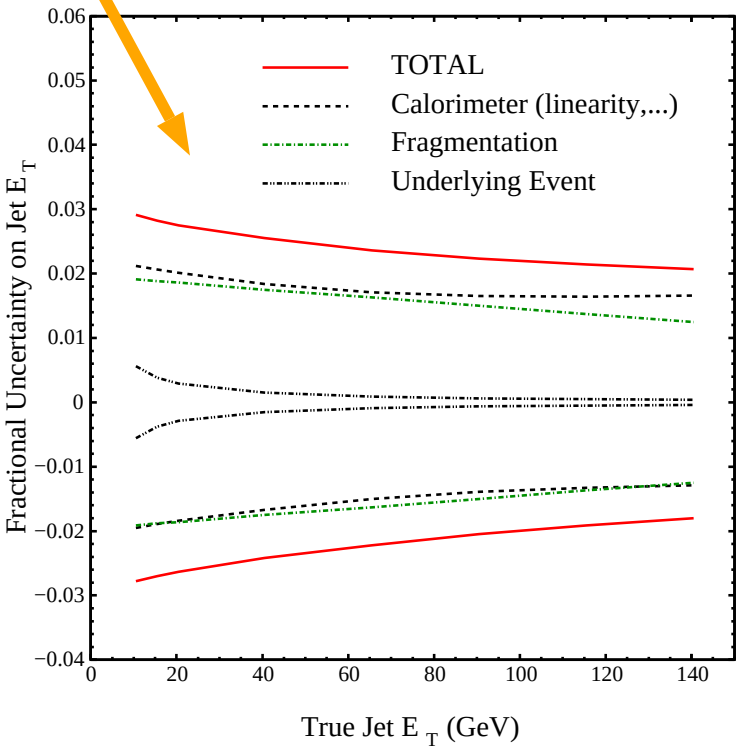
☞ jets corrected back to parton level, assuming flat p_T spectrum

- $t\bar{t}$ specific corrections:
  - applied on $t\bar{t}$ event candidates
  - specific p_T spectrum
  - different correction for b-jets

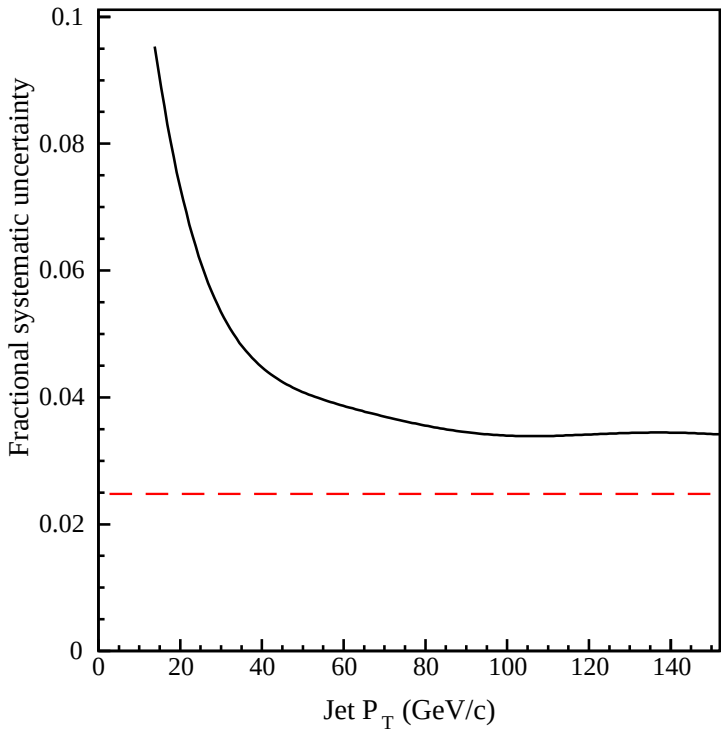
Top mass in Run I review

Run I: jet E-scale source of the largest systematic uncertainty in m_t measurement

Stability	1%	$\Delta m_t \simeq 1.2$
Absolute corr. (+UE)	2.5%	$\Delta m_t \simeq 3$
Relative corr.	0.2%, 4% in cracks	$\Delta m_t \simeq 2$ [GeV/c^2]
UEM (UE from mult. int.)	100 MeV/vertex	
OOCC	6–1.4%	



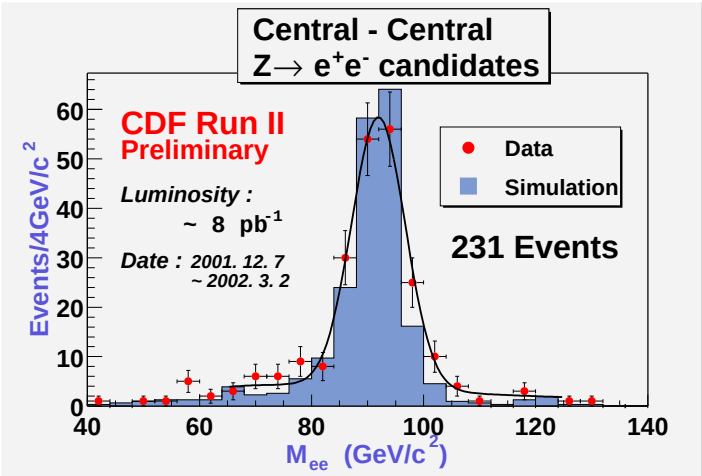
Absolute E-scale

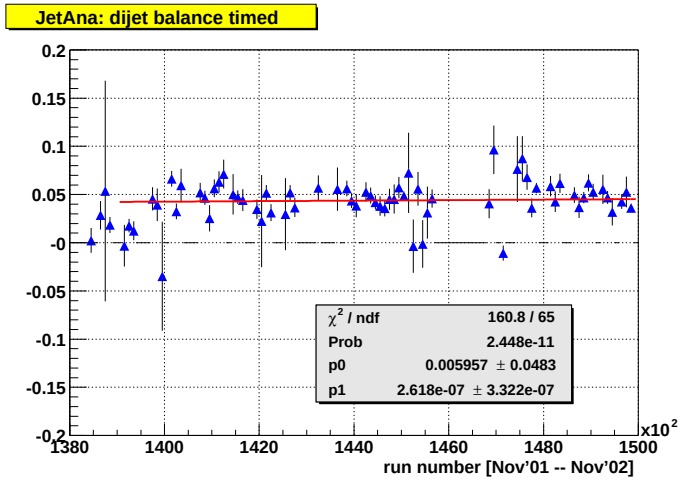


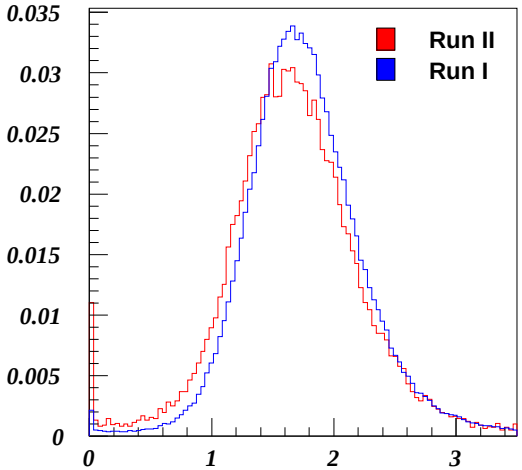
Total systematics on jets

Scale stability

- Stability (central): source/laser runs on towers (PMTs), checked by data ($Z^0, J/\psi$) ☞ must be kept below 1%
- Stability (plugs): source/laser runs, dijet balancing (limited tracking)







$$\frac{MIP_{II}}{MIP_I} = 0.960 \pm 0.005$$

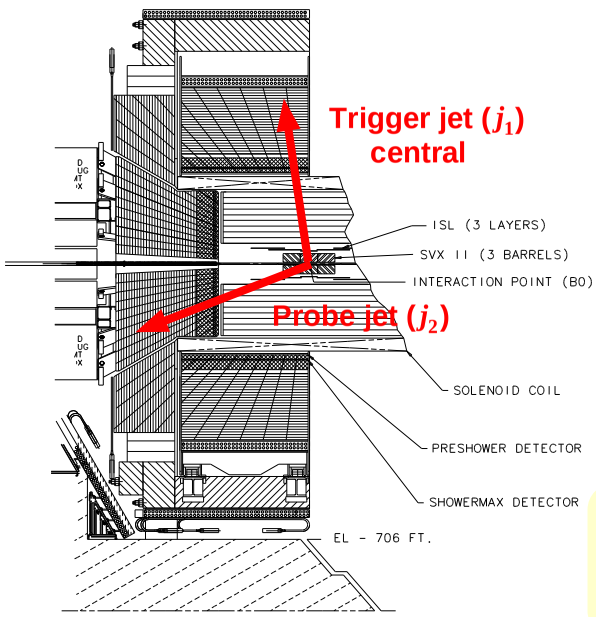
Absolute E-scale in central calorimetry

☞ different electronics, detectors...

- Quick "back in business" method...
- Using run I scale as is (out of former MC tuning to test beam data)
- Overall check with photon-jet balancing ➪ run II/run I comparison

Relative corrections

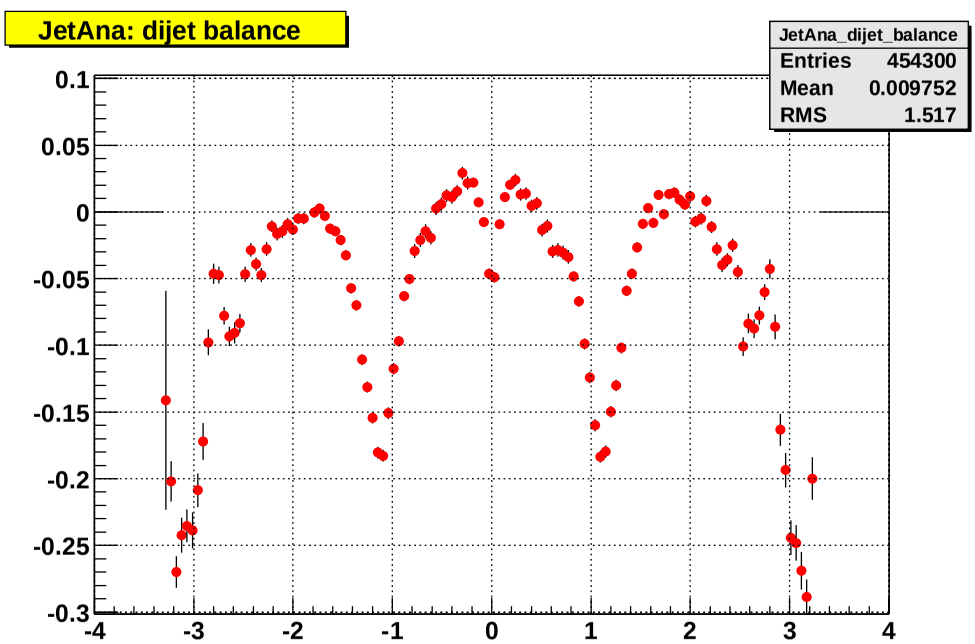
Dijet p_T-balancing technique used to determine relative corrections: transfer calibrations to the central one.



Back-to-back dijet selection:

- |z-vertex| < 60 cm
- E_T trigger jet $j_1 > 20$ GeV
- $0.2 < |\eta(j_1)| < 0.8$
- $E_T(j_1) + E_T(j_2) > 50$ GeV
- $\Delta\phi(j_1, j_2) > 2.7$
- E_T 3rd jet < 15 GeV
- $\frac{E_T(j_3)}{\frac{1}{2}[E_T(j_1)+E_T(j_2)]} < 0.25$

$$B = \frac{p_T^{probe} - p_T^{trigger}}{\frac{1}{2}(p_T^{probe} + p_T^{trigger})}$$



☞ notice crack/gap structure

Prospects

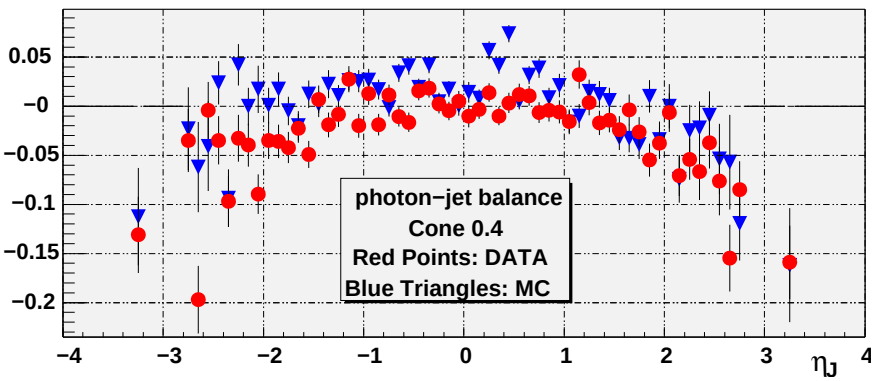
Immediate

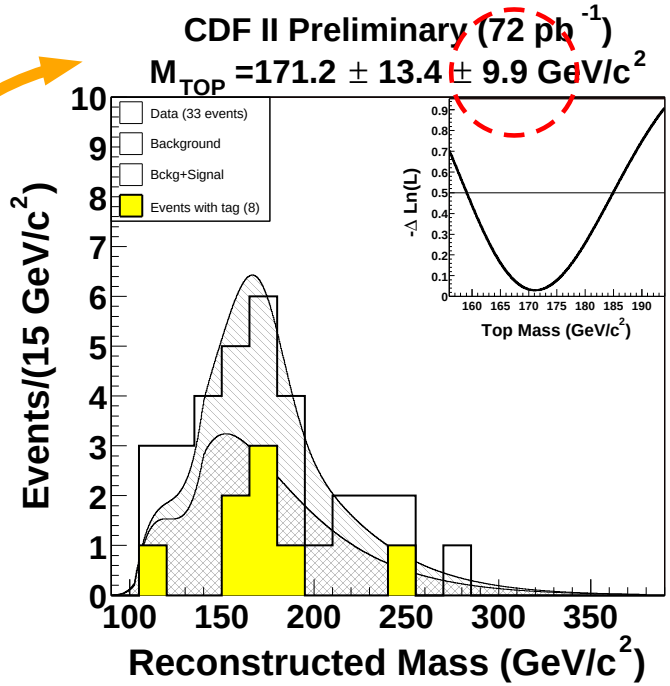
- Absolute E-scale for Run II: tuning of simulation + jet fragmentation (MC)
- Reevaluate OOCC
- Overall check with γ-jet balance $\langle f_b \rangle$

NOW

5% (scale stability w/r run I)
$\oplus$ 5% (abs scale in data-MC)

$$\langle f_b \rangle = (p_T^{jet} - p_T^{\gamma})/p_T^{\gamma}$$





Long range

- $Z - /\gamma-$jet balancing to check absolute E-scale (comparison with MC)
- W mass from 2b-tagged top event candidates ➪ next slide...
- $Z \to b\bar{b}$ to set $b-$jet specific E-scale (cf M. Baumgart's talk H13.009)

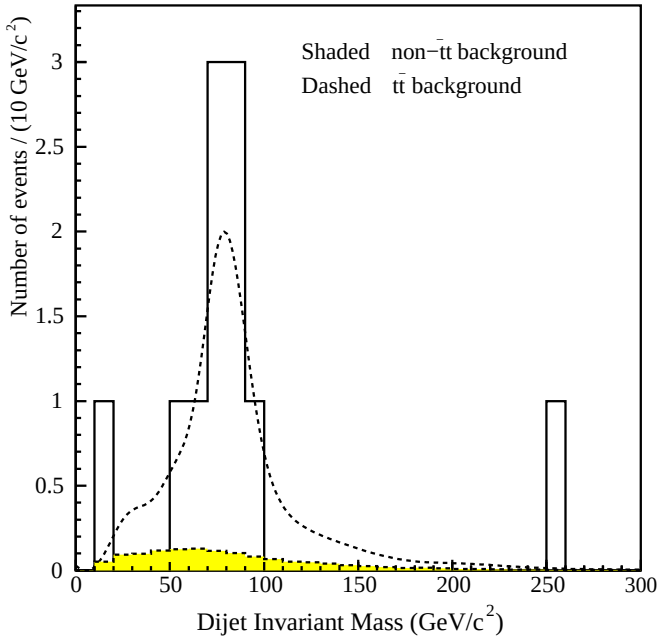
Prospects: W mass

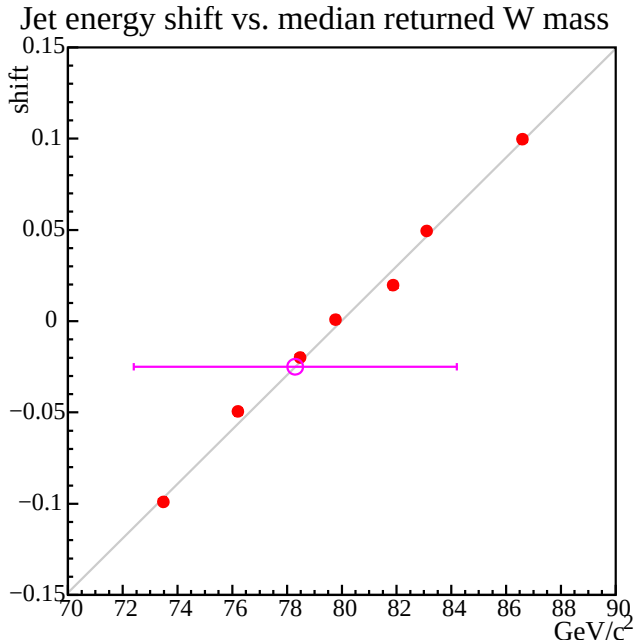
Run I: double-b tagged top event candidates

$$t \to W(\to jj)b$$
$$\bar{t} \to W(\to \ell\nu_\ell)\bar{b}$$

☞ scale set within $t\bar{t}$ environment itself!

- W mass measurement corresponds to measurement of jet E-scale of $(-2.5 \pm 8.8)\%$
- study of sidebands gives a handle on ISR/FSR (hard gluon jets)





Run II: $\geq 2b$ tags $t\bar{t}$ events yield around $50\times$ higher (increased luminosity, acceptance, improved b-tagging)

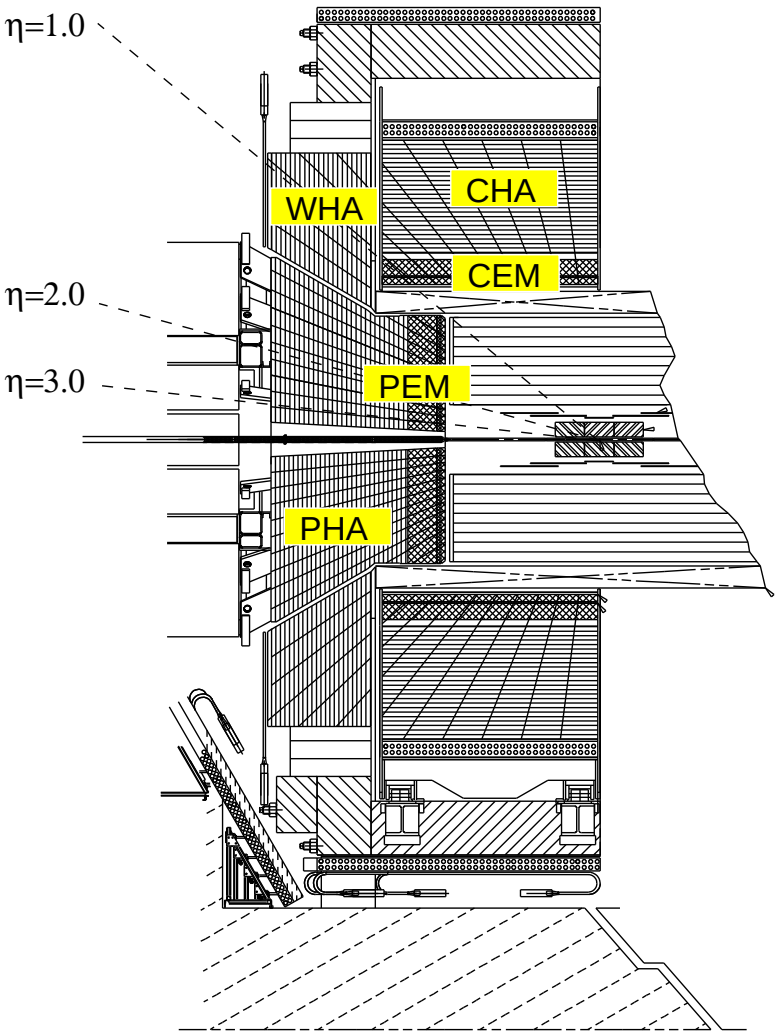
➪ $8.8\%/\sqrt{50} \simeq 1.25\%$ on E-scale (down from 2.5% in Run I)

Conclusion

- Statistical errors at Tevatron run II (will) become low
- The dominant source of systematic error on m_{top} is the jet E-scale
- A calibration approach based on *in situ* measurements with physics channels gives a handle
- So, taking advantage of the increased data!
- A lot of work still needs to be done to tune the simulation...
- The ultimate foreseen goal is to lower $\sigma(m_{top})$ from 5.1 GeV/c^2 (run I value) to 2–3 GeV/c^2

CDF calorimetry

- CDF calorimetry is pretty diverse... 1512 towers of 12 different kind
- All of Shashlik-type Pb$_{EM}$ (Fe$_{HAD}$)/ scintillator + WLS



Sampling	Absorber/active
CEM (Pb)	0.6 X_0 / 5 mm
CHA (Fe)	1 in/ 10 mm
WHA (Fe)	2 in/ 10 mm
PEM (Pb)	0.8 X_0 / 4.5 mm
PHA (Fe)	2 in/ 6 mm

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Correction scheme

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with $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ the cone radius chosen for jet measurement (cone algorithm with $R = 0.4$ for top analysis)

f_{rel} relative E-scale: correct for non-uniformities in calorimeter response as $f(\eta)$	$UEM(R)$ takes into account E due to multiple interactions in the event	$f_{abs}(R)$ absolute E-scale: maps raw jet E observed in cone of radius R into average true jet E	$UE(R)$ takes into account E due to the underlying event	$OC(R)$ corrects for the energy expected to be outside the cone radius

☞ jets corrected back to parton level, assuming flat p_T spectrum

- $t\bar{t}$ specific corrections:
  - applied on $t\bar{t}$ event candidates
  - specific p_T spectrum
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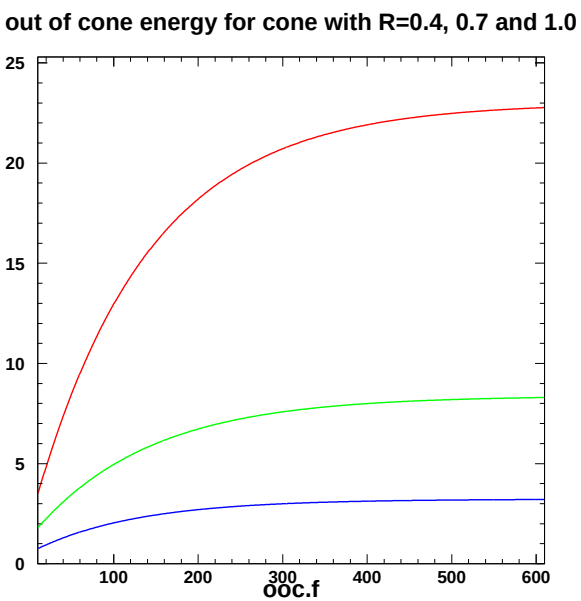
QCD & UE

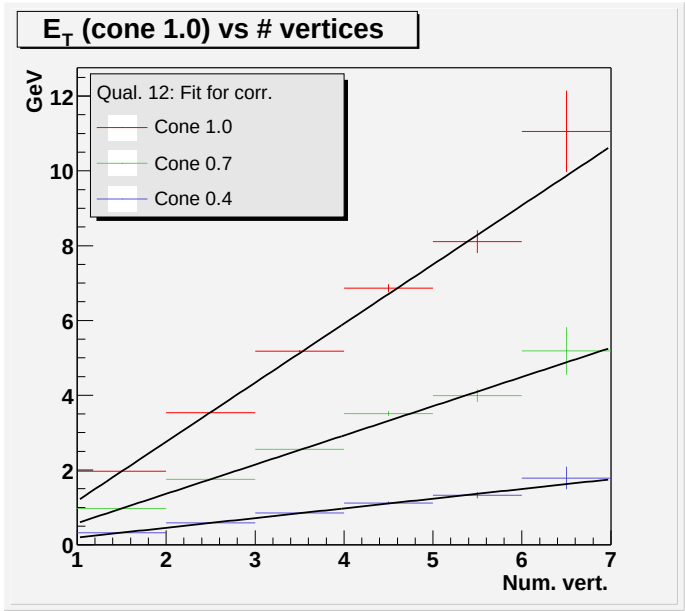
Out-of-cone correction (OOCC)

- Back to parton level
- Independent of apparatus / performance
- Depends on parton fragmentation function ($\rightarrow$ Monte Carlo)



Underlying event (UE) & multiple interactions (UEM) corrections

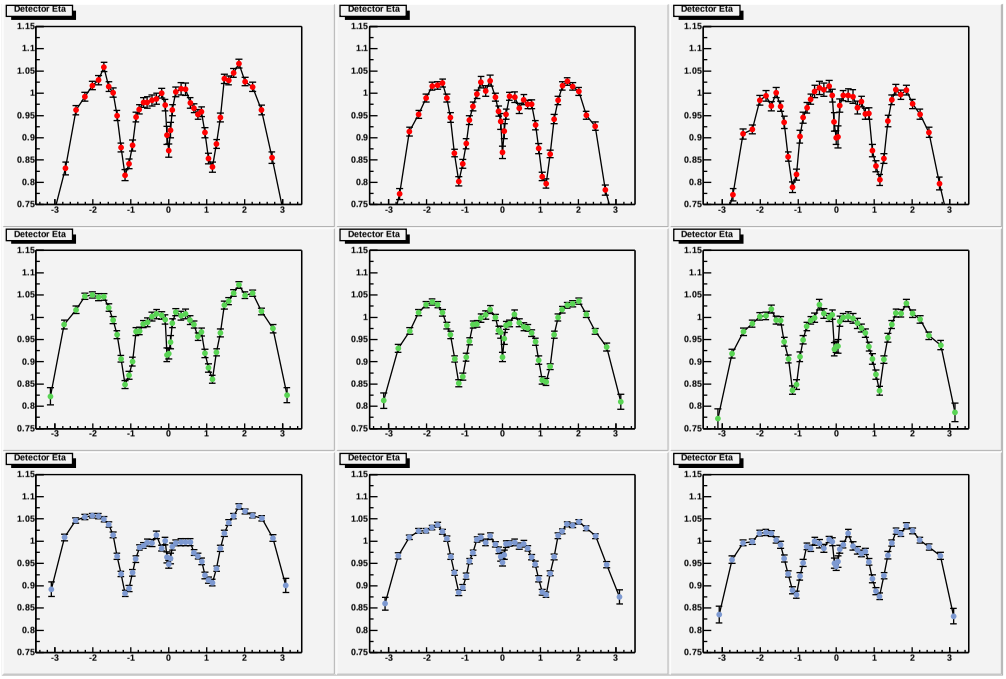
- Average E_T of random central jets in minimum bias events as f(# vertex) ➪ UEM



- Events with only 1 vertex ➪ UE

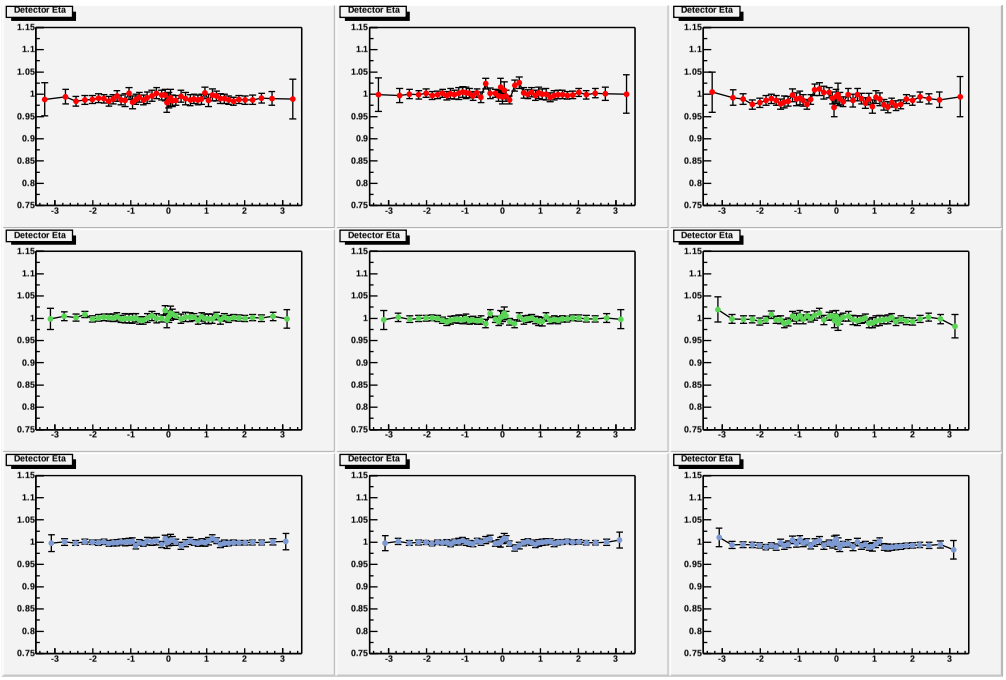
Relative E-scale before/after

Before



time ⟶

After



time ⟶

cone radius (R=0.4,0.7,1.0) ⟶

☞ Same job done in MC.