Use of the tracker information to check the jet energy scale

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Introduction

Linearity of the jet energy scale affected by

- Non-compensation of the calorimeters :
  E(reco)[$\pi^{\pm}$, *p*...]< E(reco)[γ, *e*...]
- Gaps and dead material (η dependence of the jet response)

jet calibration algorithm : (H1, local hadron calibration...)

- Correction for non compensation, dead material and gaps
- ex : after H1 calibration : E(reco)/E(truth)<1-2%

Use of tracker information

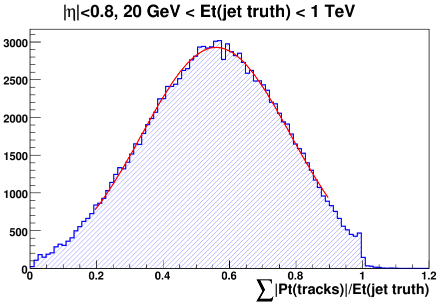
- Independent of the calorimeter system,
- Gives information on the jet composition (Pt of the charged part of the jet...)
- $\Rightarrow$ Possible to check the calibration uniformity on jets with different composition, using data only.

Outline

1. **Preliminary study**
   - Tracks in jets
   - Sensitivity of the method
2. **Propositions using real data**
   - General considerations
   - An unbiased method
   - Some results
3. **Conclusions**
   - About this talk...
   - Application to data...

Tracks in jets

- Tracker acceptance : $|\eta| < 2.5$; p_T>500 MeV
- $\sum$|Pt(tracks)|= sum of tracks Pt within a cone ΔR around the direction of the reco jet
- f(tracks)=$\sum$|Pt(tracks)|/Et(jet truth) : independent (in average) of Et(jet truth)
- f(tracks) varies from $\approx$ 20% to 90%



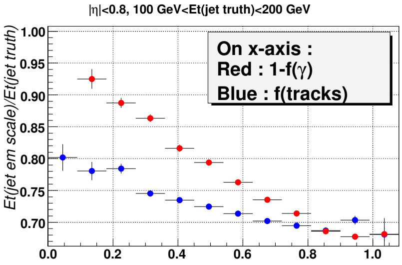
- f(tracks)$\approx$90% : jet with lot of $\pi^{\pm}$, p... $\rightarrow$ large hadronic component
- f(tracks)$\approx$20% : jet with lot of γ $\rightarrow$ large electromagnetic component
- $\Rightarrow$ f(tracks)= probe for jet composition

Sensitivity of the method

WARNING !

- neutral particles that give a hadronic contribution in the calo (n, K_l^0...) : invisible in tracker

$\Rightarrow$ limited sensitivity of the method...

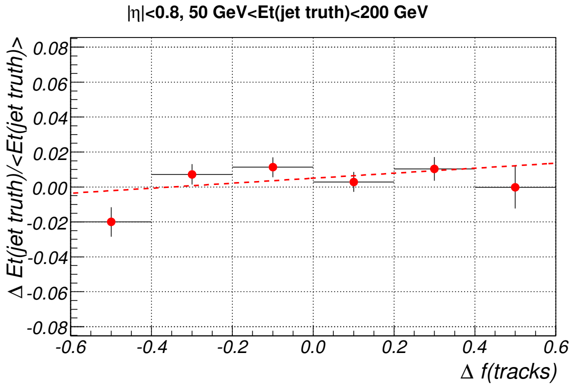


- $1 - f(\gamma)$: fraction of energy brought by all particles but γ $\Rightarrow$ ΔE(jet uncalib.)/E(jet truth)≈30%
- f(tracks) : fraction of energy brought by visible tracks $\Rightarrow$ ΔE(jet uncalib.)/E(jet truth)≈10%
  smaller visible effect of the non-compensation

General considerations for application to data

Possible strategy :

- Balancing between Et(jet) and f(tracks) for QCD di-jets events
- Test on truth jets
  - x-axis : Δf(tracks)= f(tracks jet 1) - f(tracks jet 2) with f(tracks jet i)=$\sum$|Pt(tracks jet i)|/Et(jet i truth)
  - No correlation, as expected

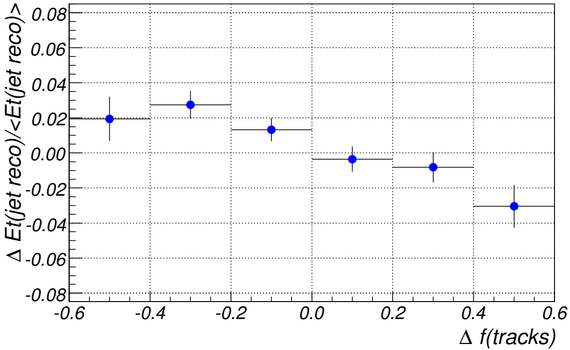


$\Delta E/E < 1\%$

General considerations for application to data

Possible strategy :

- Balancing between Et(jet) and f(tracks) for QCD di-jets events
- Test on calibrated jets (H1)
    - x-axis : Δf(tracks)= f(tracks jet 1) - f(tracks jet 2) with f(tracks jet i)=$\sum$|Pt(tracks jet i)|/Et(jet i truth)
    - correlation = remaining effect of the non-compensation

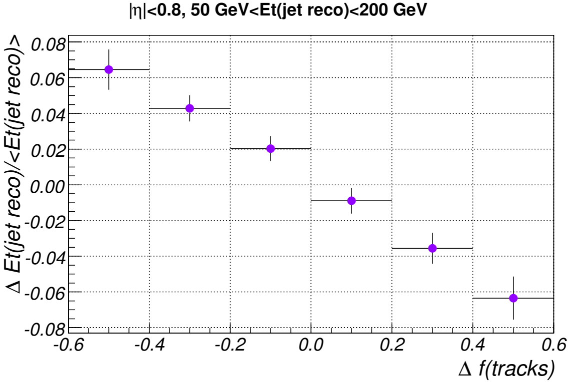


$\Delta E/E \approx 6\%$
Problem : how to measure f(tracks) ?

General considerations for application to data

Possible strategy :

- Balancing between Et(jet) and f(tracks) for QCD di-jets events
- Test on calibrated jets (H1)
    - x-axis : Δf(tracks)= f(tracks jet 1) - f(tracks jet 2) with f(tracks jet i)=$\sum$|Pt(tracks jet i)|/Et(jet i reco)
    - large correlation observed : WARNING : there is a bias

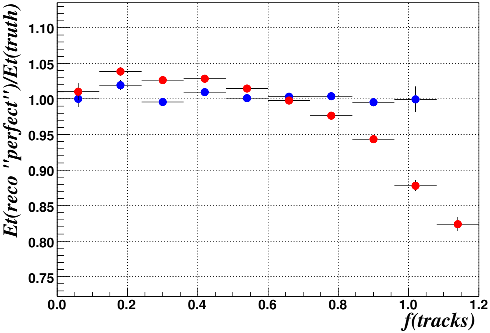


$\Delta E/E \approx 10\%$

Bias of the f(track) measurement

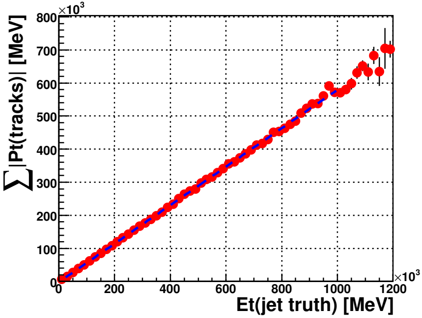
- Correct definition : f(tracks truth)=$\sum$|Pt(tracks)|/Et(jet truth)
- Measurable quantity : f(tracks reco)=$\sum$|Pt(tracks)|/Et(jet reco)
- f(tracks reco) affected by the calorimeter resolution
  - for given Et(jet truth), Et(jet reco) $\nearrow \Rightarrow$ f(tracks reco) $\searrow$
- Example : Et(reco "perfect")= Et(truth jet) + smearing

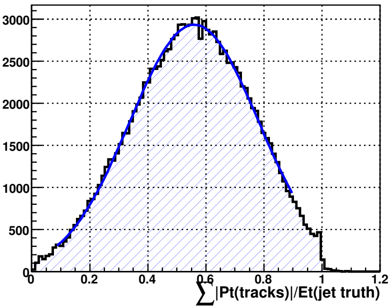
- Blue : correlation with f(tracks truth)
- Red : correlation with f(tracks reco)



An unbiased method

- Impossible to measure f(tracks) in an unbiased way
- Possibility : use the known relation between Et(jet) and $\sum |Pt(tracks)|$:
  - $\sum |Pt(tracks)| = \alpha \times$Et(jet) + gaussian fluctuation
  - $\alpha = 0.57 \pm 0.11$ (CDF measurement PhysRevLett.87.211804)

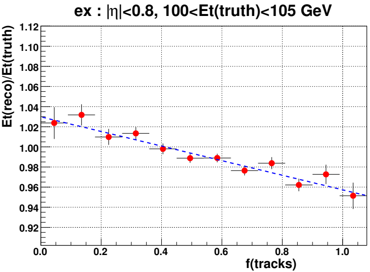




$|\eta|$<0.8

An unbiased method

- Non-uniformity of the jet calibration : correlation between Et(reco) and the jet composition (f(tracks))
- Et(reco)=Et(truth)$\times[1 - k.f(tracks)]$ with k=slope

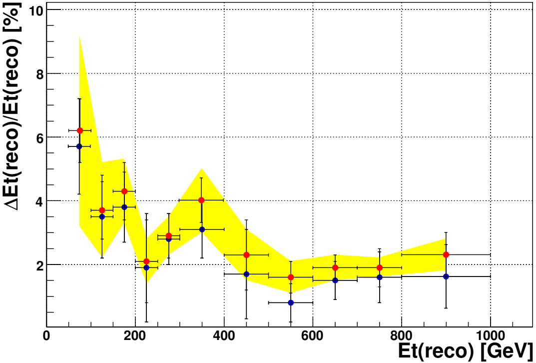


Application to data : balanced QCD jets

- ΔEt=Et(reco jet1)-Et(reco jet2); ΔPt=$\sum$Pt(tracks jet1)-$\sum$Pt(tracks jet2)
- $Cov(\Delta Et, \Delta Pt) = \alpha(1 - k\alpha).Var(\Delta Et) - k.Var(\Delta Pt)$

$$\Rightarrow k = \frac{Cov(\Delta Et, \Delta Pt) - \alpha.Var(\Delta Et)}{\alpha^2.Var(\Delta Et) + Var(\Delta Pt)}$$

Some results



yellow band : systematic error on $\alpha = 0.57 \pm 0.11$

- From k, we get ΔEt(reco)/Et(reco) max variation when *f*(tracks) varies between $\pm 2\sigma$
- Blue : reference results (obtained using the truth)
- Red : using the covariance method (only reco variables)

Good agreement !

Conclusions

Tracker information and jet energy scale

- The tracker information can be used to study the dependence between the jet energy (before or after calibration) and its content in terms of charged particles.
- Fraction *f*(tracks) of energy brought by charged particles in a jet = 20% ("em" jet) to 90% ("had" jet)
  - at em scale : produces a ΔE(reco)/E(reco)$\approx$10%
  - after H1 calibration : ΔE(reco)/E(reco)$<\approx$5%
- Sensitivity limited by the neutral particles giving an hadronic shower in calo
- A way to measure ΔE(reco)/E(reco) using only data has been proposed : still preliminary

Conclusions

What do we learn with the described method ?

- Nothing about absolute energy scale (this would come from γ-jet and bootstrap)
- Relative information : how changes the jet reco energy for various types of jets ("em" or "had")

How to use this information on data ?

- A tool to check the calibration methods using data only: how well do we correct for non-compensation
- A handle for data-MC comparison : does the MC model reproduces the observed effect ? (before & after calibration)
- Should be included in the *JetPerformance package*

Back-up slides

Covariance computation I

In average :

Et(reco) = Et(truth)$\times(1-k.f)$ with f=$\sum$|Pt(tracks)|/Et(truth)

- f=$\sum$|Pt(tracks)|/Et(truth)
- k=miscalibration (=0 if perfect calibration)

$\Rightarrow$ Et(reco) = Et(truth)$-k\times\sum$|Pt(tracks)|

With event-by-event fluctuations :

Et(truth)= $(E_0+\delta E)$

Et(reco) = $(E_0+\delta E+\delta R)-k.[\alpha.(E_0+\delta E)+\delta Pt]$ with

- E_0 : "truth" jet energy
- δE : fluctuation due to ISR, and other effects ($\langle\delta E\rangle=0$)
- δR : fluctuation due to calo resolution; δPt : fluctuation on tracker measurement

Covariance computation II

Balancing between 2 jets:

- ΔEt(reco)=Et(reco jet1)-Et(reco jet2)
- ΔEt(reco)=$(\delta Et1 - \delta Et2).(1-\alpha k) + (\delta R1 - \delta R2) - k.(\delta Pt1 - \delta Pt2)$
- $Cov(\Delta Et, \Delta Pt) = \langle[(\delta Et1 - \delta Et2).(1-\alpha k) + (\delta R1 - \delta R2) - k.(\delta Pt1 - \delta Pt2)].[\alpha(\delta Et1 - \delta Et2) + (\delta Pt1 - \delta Pt2)]\rangle$
- $Cov(\Delta Et, \Delta Pt) = \alpha\langle(\delta Et1 - \delta Et2)^2\rangle - k\alpha^2\langle(\delta Et1 - \delta Et2)^2\rangle - k\langle(\delta Pt1 - \delta Pt2)^2\rangle$
- $Cov(\Delta Et, \Delta Pt) = \alpha Var(\Delta Et) - k\alpha^2.Var(\Delta Et) - k.Var(\Delta Pt)$

$$\Rightarrow k = \frac{Cov(\Delta Et, \Delta Pt) - \alpha Var(\Delta Et)}{\alpha^2.Var(\Delta Et) + Var(\Delta Pt)}$$

Numerical results

Et(truth)	ΔE(reco)/E(reco) [%] reference	ΔE(reco)/E(reco) [%] using covariance method
50-100	5.7 ± 1.5	6.2 ± 1.0 ± 3.0
100-150	3.5 ± 1.3	3.7 ± 0.9 ± 1.5
150-200	3.8 ± 1.1	4.3 ± 0.9 ± 1.0
200-250	1.9 ± 1.7	2.1 ± 1.3 ± 0.7
250-300	2.8 ± 0.8	2.9 ± 0.7 ± 0.6
300-400	3.1 ± 0.9	4.0 ± 0.7 ± 1.0
400-500	1.7 ± 1.4	2.3 ± 1.1 ± 0.8
500-600	0.8 ± 0.6	1.6 ± 0.5 ± 0.5
600-700	1.5 ± 0.6	1.9 ± 0.4 ± 0.4
700-800	1.6 ± 0.8	1.9 ± 0.6 ± 0.3
800-1000	1.6 ± 1.0	2.3 ± 0.7 ± 0.5