Nuclear Instruments and Methods in Physics Research A 487 (2002) 381-395

Intercalibration of the longitudinal segments of a calorimeter system

Alessandra Betti and Julien Beyer
Tutor: Guido Volpi

HASCO 2014 - Göttingen

07.25.2014

Content

1. Introduction
2. Calibration methods
3. Results

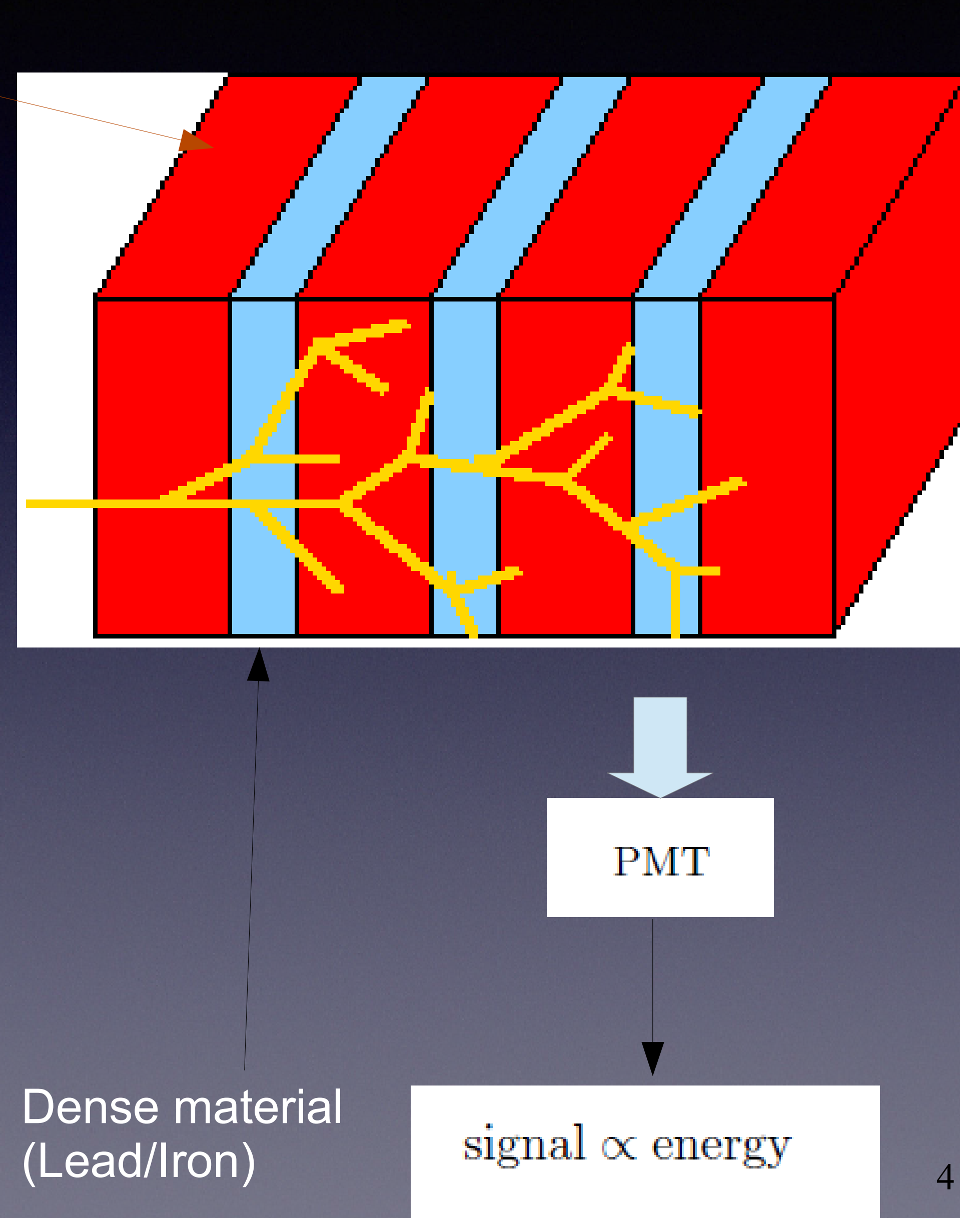
1. Introduction

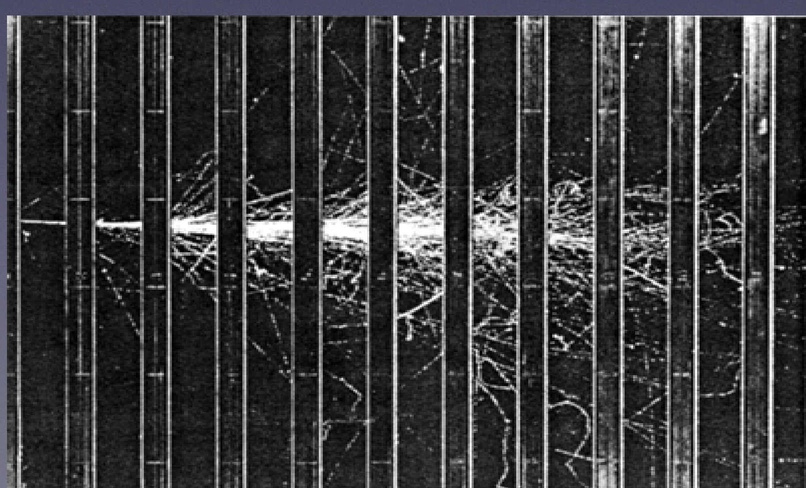
Structure of a calorimeter

A calorimeter is a detector that measures the energy of particles.
Particles deposit their energy in the calorimeter producing showers by EM and HAD interactions.

It is sampled with scintillator and absorber materials (lead/iron).

Each tower is connected to a PMT and produces a signal proportional to the energy deposited by the particles .





CALIBRATION CONSTANTS

The calibration constants define the relationship between the calorimeter electric signals and the energy of the particles.

They are determined by exposing the calorimeter to particle beams of known composition and energy.

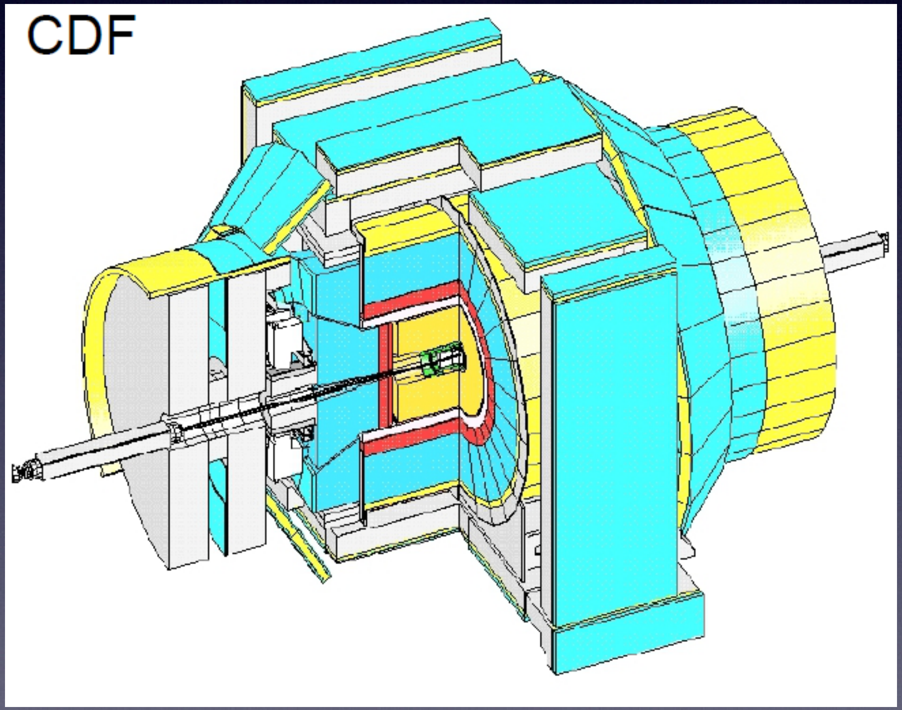
When the calorimeter is longitudinally segmented in two sections (EM and HAD) there are some complications:

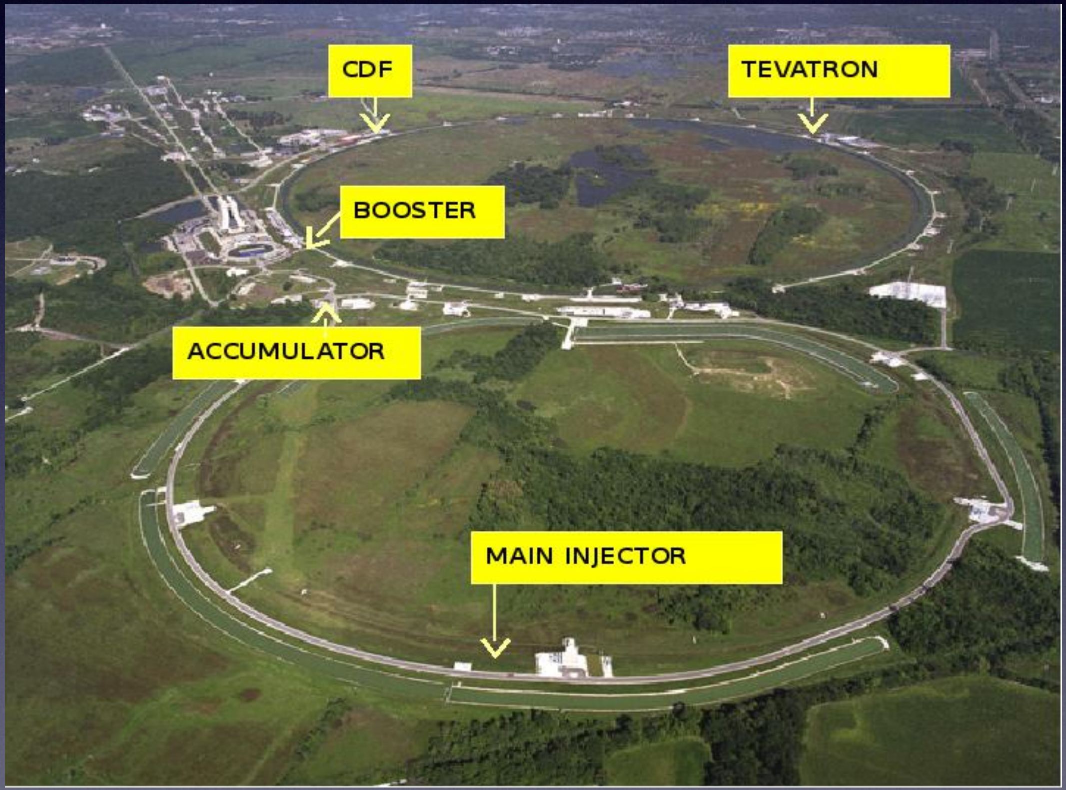
- Noncompensation: the calorimeter has different responses to electromagnetic and hadronic energy deposit ($e/h \neq 1$)
- The calorimeter response depends on the shower evolution

Motivation: Eliminate nonlinearity effects with calibration

CDF

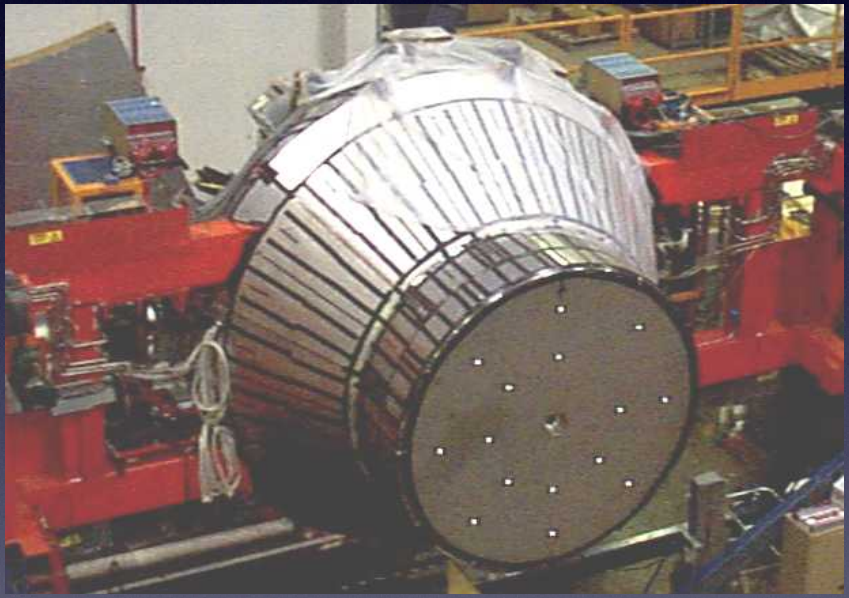
Different methods of calibration have been studied with testbeam data from the CDF Plug Upgrade Calorimeter in preparation for Tevatron Collider Run II that has worked until 2011.

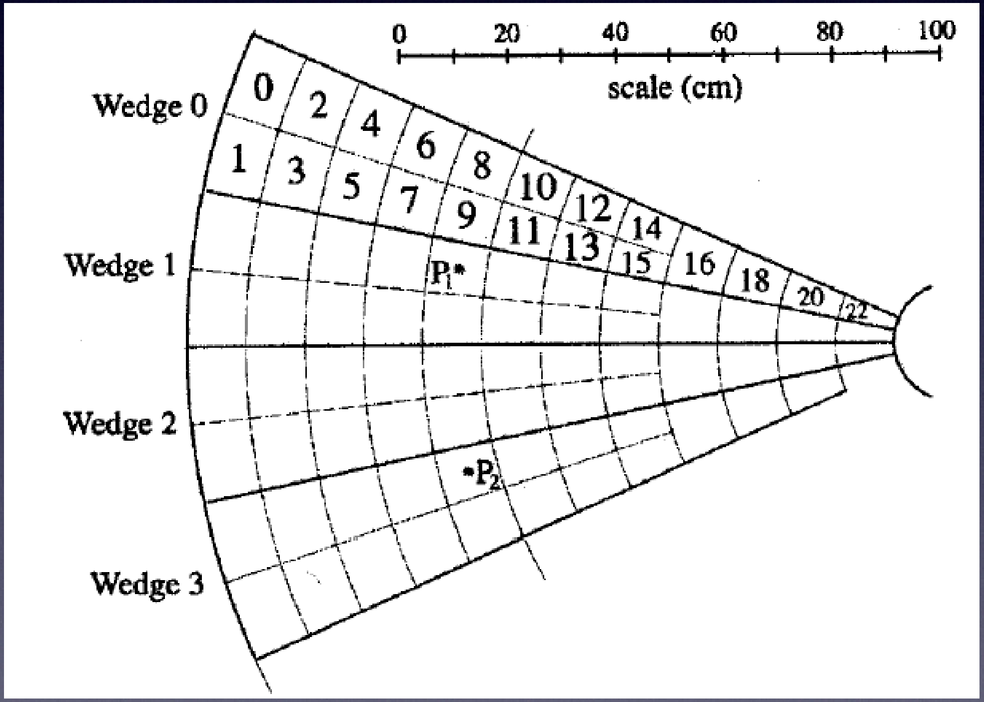




The experimental data was taken with a special module that was built for testbeam purposes.

This module consists of four sections and one of them (3) was built without the EM compartment in the way that it is possible to shoot the beam directly in the HAD compartment for testing it. The test beam particles travel perpendicular to the plane of this page and they enter the calorimeter in point P_1 and P_2 .





Each tower of the calorimeter is connected to its own PMT and it's important that the gains of all the towers are equal, so it is necessary to measure the gain of each tower and equalize them using a muon test beam.

Task

Calibrate the calorimeter

Here there are three different methods to calibrate a longitudinally segmented calorimeter

2.Methods

EM calibration

The energy scale of the EM section of the calorimeter is always determined using an electron beam (in this case with energies from 8 to 180 GeV) with this formula:

$$A = \frac{\langle \sum_i (\mathrm{em}_i - \mathrm{ped}_i^{\mathrm{em}}) \mathrm{tg}_i^{\mathrm{em}} \rangle}{E_e}$$

em_i : measured signal

$\mathrm{ped}^{\mathrm{em}}_i$: pedestal

$\mathrm{tg}^{\mathrm{em}}_i$: gain constant of the tower i

E_e : energy of the electron beam

The result is that the value of A is constant within the experimental uncertainties over a wide range of electron energies.

Method I

1. Calibrate the EM with electrons from a test beam

2. Shoot pions on EM+HAD

3. Calibrate the HAD only with data from penetrating pions
   → penetrating: no strong/weak interaction in the EM

$$B_I = \frac{\langle \sum_i \left(\mathrm{had}_i - \mathrm{ped}_i^{\mathrm{had}} \right) \mathrm{tg}_i^{\mathrm{had}} \rangle}{\langle E_\pi - E_{\mathrm{em}} - E_{\mathrm{leak}} \rangle}$$

Method II

1. Calibrate the EM with electrons from a test beam

2. Calibrate the HAD with electrons from a test beam

→ Calibrate both separately

$$B_{\mathrm{II}} = \frac{\langle \sum_i \left(\mathrm{had}_i - \mathrm{ped}_i^{\mathrm{had}}\right) \mathrm{tg}_i^{\mathrm{had}} \rangle}{E_e}$$

Method III

1. Calibrate the EM with electrons from a test beam

2. Shoot pions on EM+HAD

3. Use penetrating as well as non-penetrating pions for calibration of HAD

   → such that the average reconstructed energy for penetrating and non-penetrating pions is equal

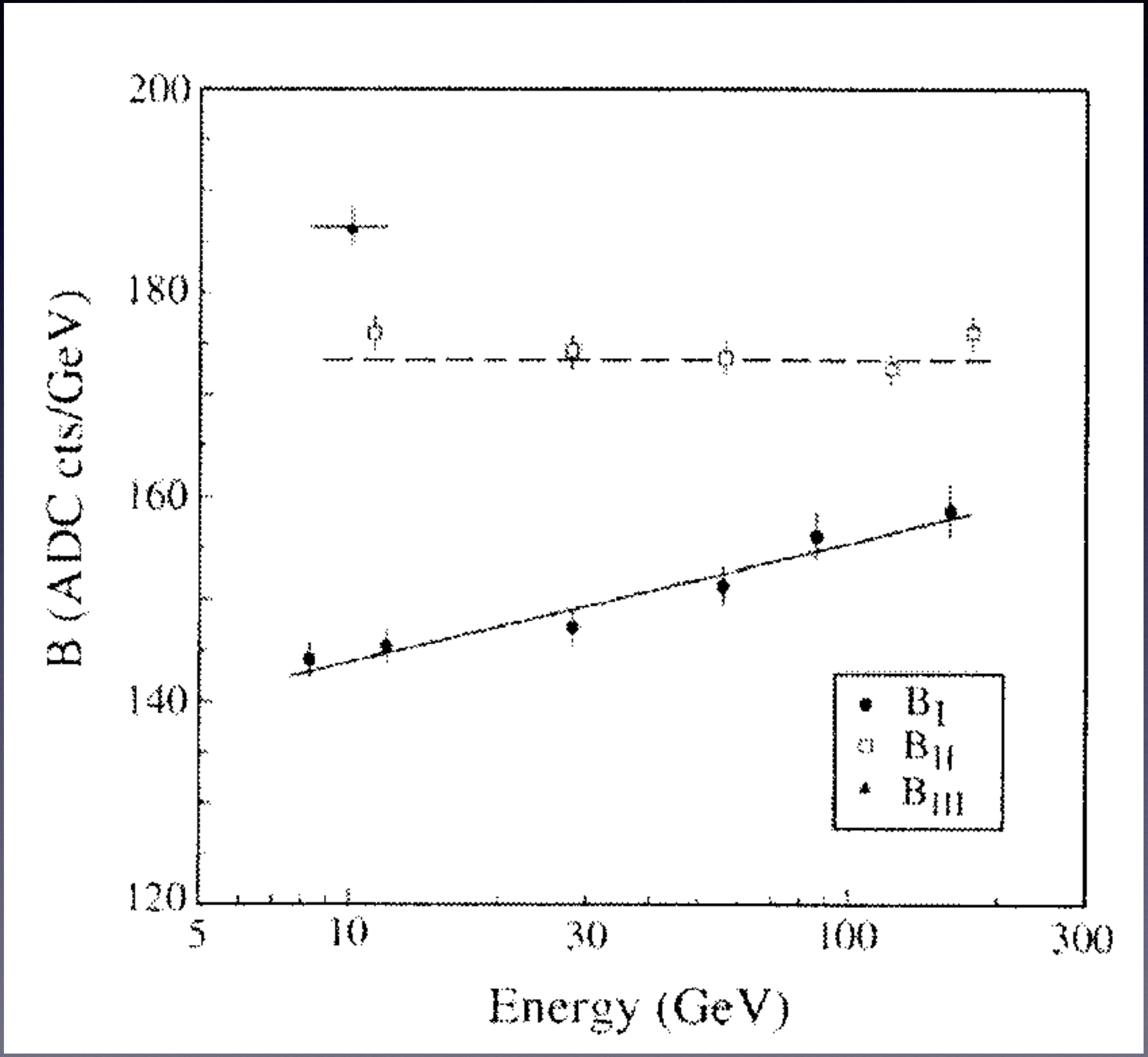
$$B_{\mathrm{III}}^{\mathrm{pen}} \stackrel{!}{=} B_{\mathrm{III}}^{\mathrm{nonpen}}$$

$$\Leftrightarrow \frac{\langle \sum_i \left(\mathrm{had}_i - \mathrm{ped}_i^{\mathrm{had}}\right) \mathrm{tg}_i^{\mathrm{had}} \rangle}{E_\pi - E_{\mathrm{em}}} = \frac{\langle \sum_i (\mathrm{em}_i - \mathrm{ped}_i^{\mathrm{em}}) \mathrm{tg}_i^{\mathrm{em}} + \sum_i \left(\mathrm{had}_i - \mathrm{ped}_i^{\mathrm{had}}\right) \mathrm{tg}_i^{\mathrm{had}} \rangle}{E_\pi}$$

BUT: just one data point in the low energetic regime to avoid bias on the result due to leakage

3. Results

Results



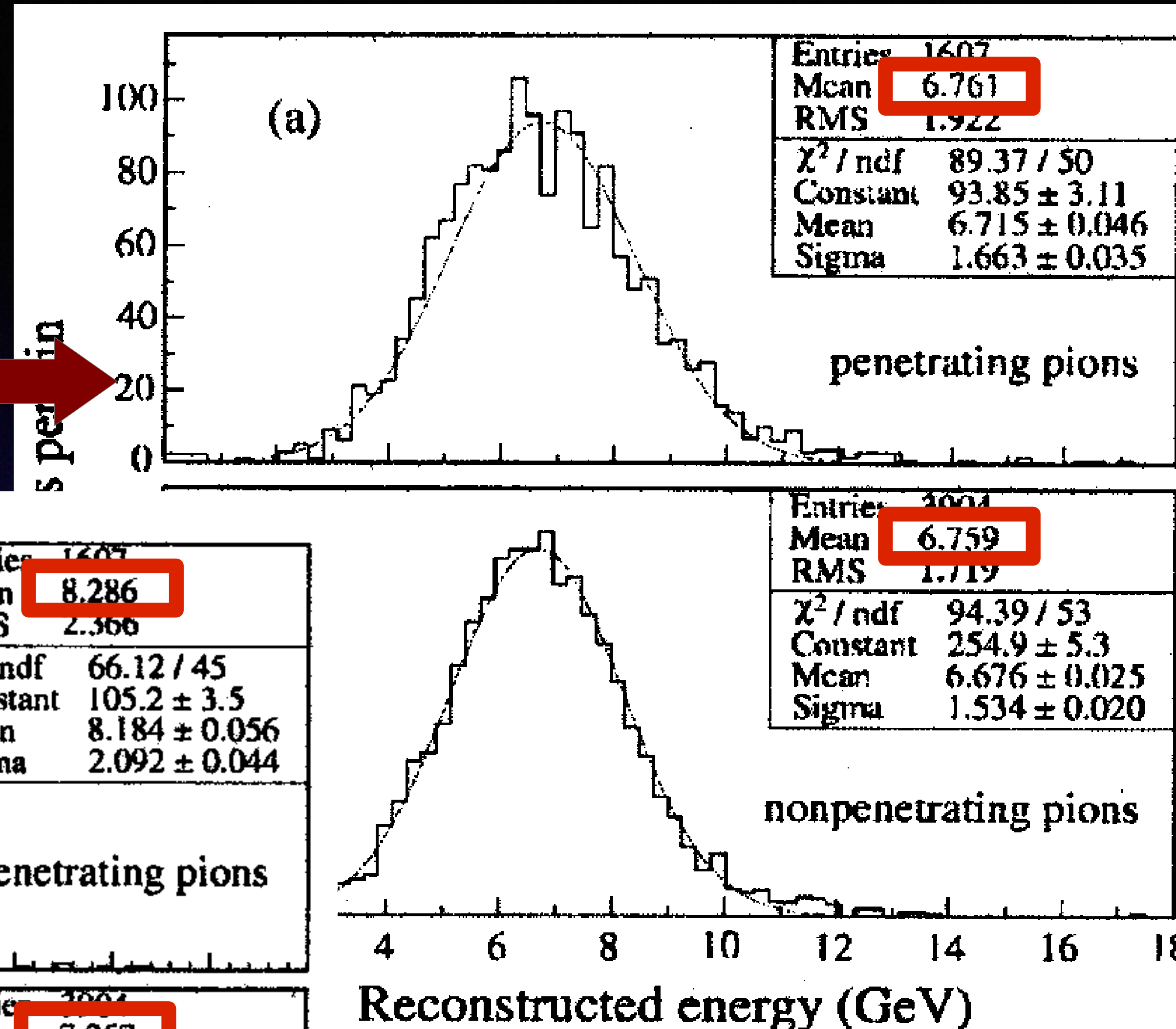
Method I:
→ non-constant behaviour of about 10% in this energy range

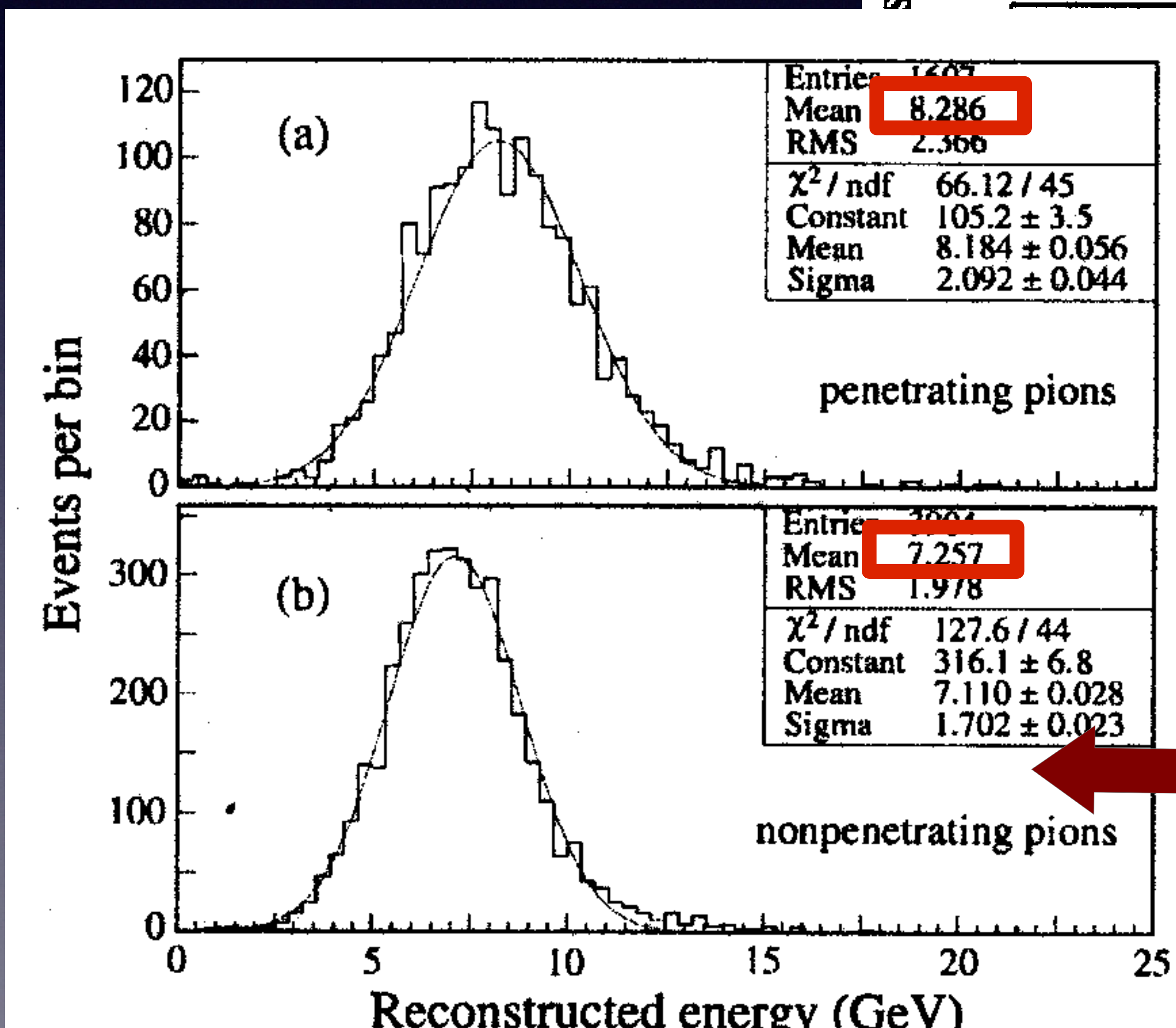
Method II:
→ constant within the uncertainties
→ due to linear behaviour in electromagnetic only regime

Method III:
→ no further information about the quality yet

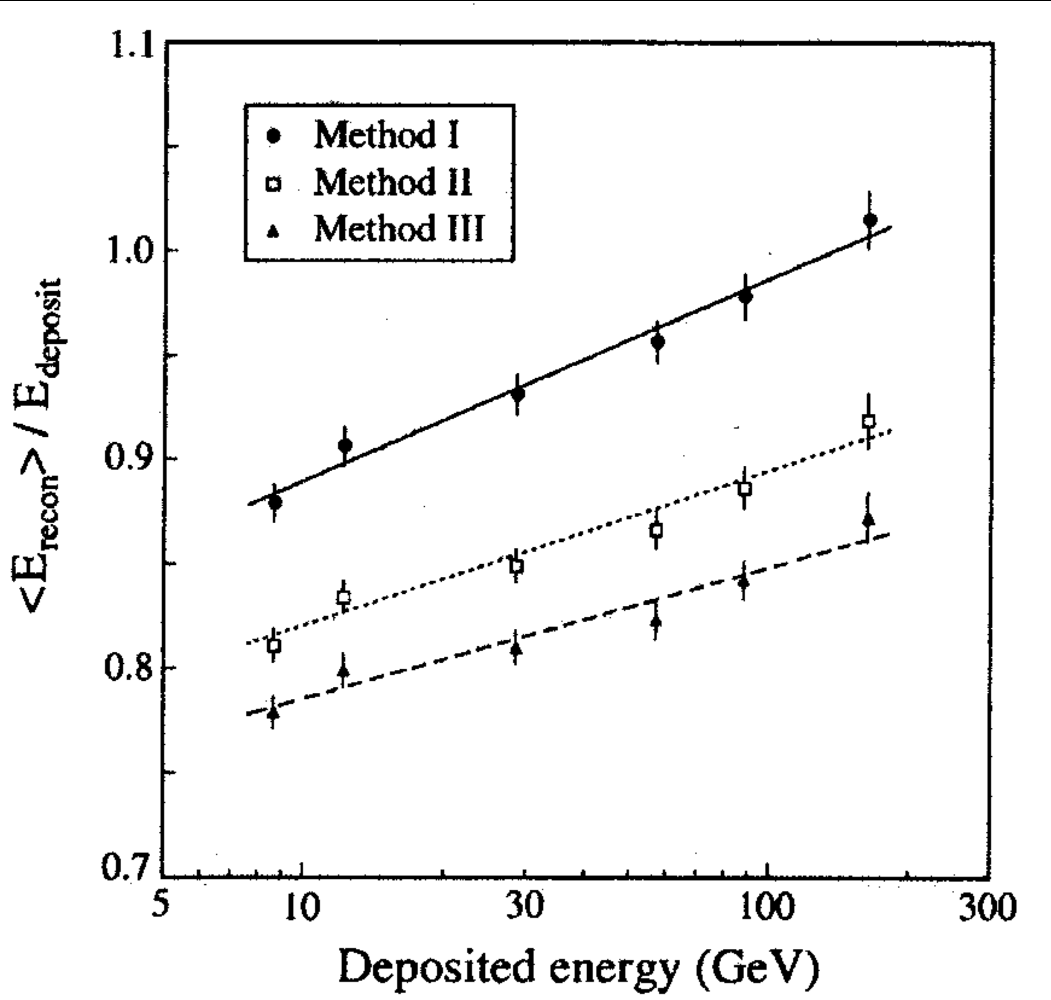
Test: pions (E=8.6 GeV) on the calorimeter and
(a) penetrating pions
(b) nonpenetrating pions

Method III:
Mean(a)-Mean(b)=0.002





Method I:
Mean(a)-Mean(b)=1.029



→ Pions with a certain energy has been shot on the calorimeter

Nonlinearity is 40% larger using Method I compared to Method III

Calibration	k_1	k_2
Method I	0.79	0.043
Method II	0.74	0.033
Method III	0.72	0.028

	8.6 GeV π beam	12.2 GeV π beam
Deposited energy (GeV)	8.6	12.2
E_{final} – Method I		
All pions	8.6 ± 0.1	12.3 ± 0.1
Penetrating	9.3 ± 0.1	13.2 ± 0.1
Nonpenetrating	8.2 ± 0.1	11.9 ± 0.1
E_{final} – Method II		
All pions	8.6 ± 0.1	12.3 ± 0.1
Penetrating	8.9 ± 0.1	12.6 ± 0.1
Nonpenetrating	8.5 ± 0.1	12.2 ± 0.1
E_{final} – Method III		
All pions	8.6 ± 0.1	12.3 ± 0.1
Penetrating	8.7 ± 0.1	12.3 ± 0.1
Nonpenetrating	8.6 ± 0.1	12.3 ± 0.1

Conclusion

Method I:
→ most common method
→ easy to do

→ dependence on the starting point
→ dependence on energy (nonlinearities)

Method II:
→ linear energy behaviour
→ same methods for EM and HAD

→ not possible if HAD and EM are connected
→ dependence on the starting point

Method III:
→ nearly no dependence on the starting point
→ possible to do in situ
→ much less nonlinearities

END

Sources

http://www-flc.desy.de/hcal/basics/calorimeter.php

http://www.hardhack.org.au/book/export/html/76

M. Albrow et al., *Intercalibration of the longitudanal segments of a calorimeter system,* Nuclear Instruments and Methods in Physics Research A 487 (2002) 381-395