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INNOVATIVE ENERGY RECONSTRUCTION ALGORITHM FOR HADRON CALORIMETER

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An hadronic shower in a calorimeter can be seen as an overlap of a pure electromagnetic and a pure hadronic component. In this case an incident hadron energy is

$$E = E_e + E_h. \tag{1}$$

The calorimeter response to these two components is usually different and can be written as

$$R = e \cdot E_e + h \cdot E_h, \tag{2}$$

where e (h) is a coefficient to rescale the electromagnetic (hadronic) energy content to the calorimeter response. A fraction of an electromagnetic energy of a hadronic shower is

$$f_{\pi^0} = E_e/E, \tag{3}$$

then

$$R = e \cdot [1 + (e/h - 1) \cdot f_{\pi^0}] \cdot E/(e/h). \tag{4}$$

From this one can gets formulae for an incident energy

$$E = 1/e \cdot (e/\pi) \cdot R, \tag{5}$$

where

$$(e/\pi) = (e/h)/(1 + (e/h - 1) \cdot f_{\pi^0}), \tag{6}$$

(e/h) is an intrinsic non-compensation of a calorimeter, the ratio of the calorimeter responses to the electromagnetic and non-electromagnetic (purely hadronic) components of hadron showers.

The dependence of f_{π^0} from the incident hadron energy can be parameterized as $0.11 \cdot \ln E$. In the case of the combined setup, the total energy is reconstructed as the sum of the energy deposit in the electromagnetic compartment E_{em}, the deposit in the hadronic compartment E_{had}, and that in the passive material between the electromagnetic and hadronic compartments E_{dm}

$$E = E_{em} + E_{dm} + E_{had}. \tag{7}$$

Using these expressions we obtain the formula for the energy reconstruction in a combined calorimeter (the e/h method) [1]:

$$E = \frac{1}{e_{em}} \left(\frac{e}{\pi}\right)_{em} \cdot R_{em} + E_{dm} + \frac{1}{e_{had}} \left(\frac{e}{\pi}\right)_{had} \cdot R_{had}, \tag{8}$$

where R_{em} and R_{had} are measured responses, $1/e_{em}$ and $1/e_{had}$ are energy calibration constants.

The method has been tested on the basis of the data of the ATLAS combined prototype calorimeter [2]. It consists of the lead-liquid argon electromagnetic calorimeter part and the hadronic tile iron-scintillator part. These data have been obtained at the CERN SPS in the energy range of 10 – 300 GeV. The term E_{dm} was taken as [3]

$$E_{dm} = (1/e_{dm}) \cdot \sqrt{E_{em,l} \cdot E_{had,f}}, \qquad (9)$$

where $E_{em,l}$ is an energy released in a last depth of an electromagnetic calorimeter and $E_{had,f}$ is an energy released in a first depth of a hadronic calorimeter.

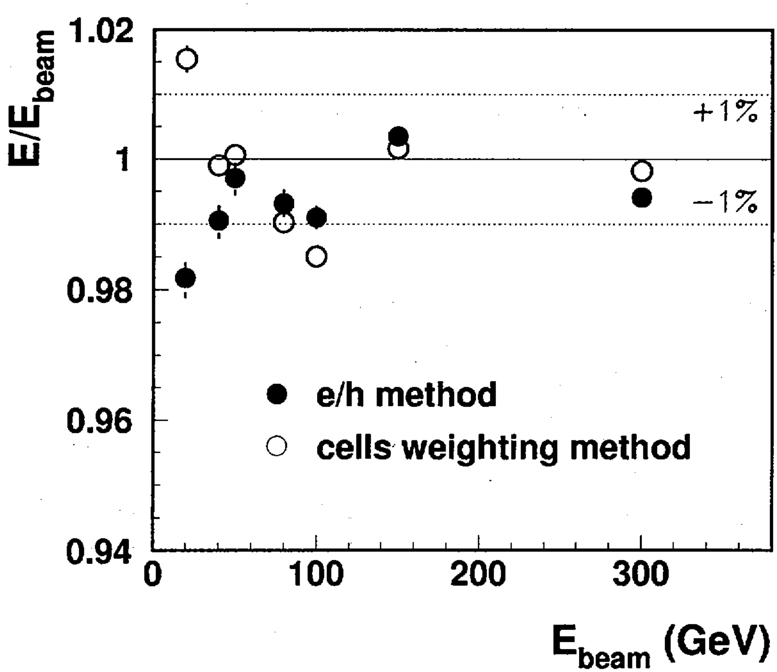

Figure 1: Energy linearity as a function of the beam energy for the e/h method (black circles) and the cells weighting method (open circles).

Fig. 1 demonstrates the correctness of the mean energy reconstruction. The mean value of energy is equal to

$$E/E_{beam} = (99.5 \pm 0.3)\% \tag{10}$$

and the spread is $\pm 1\%$. This Figure also shows the comparison of the linearity as a function of the beam energy for the e/h method and for the multiparametrical cells weighting method [3]. Comparable quality of the linearity is observed for these two methods.

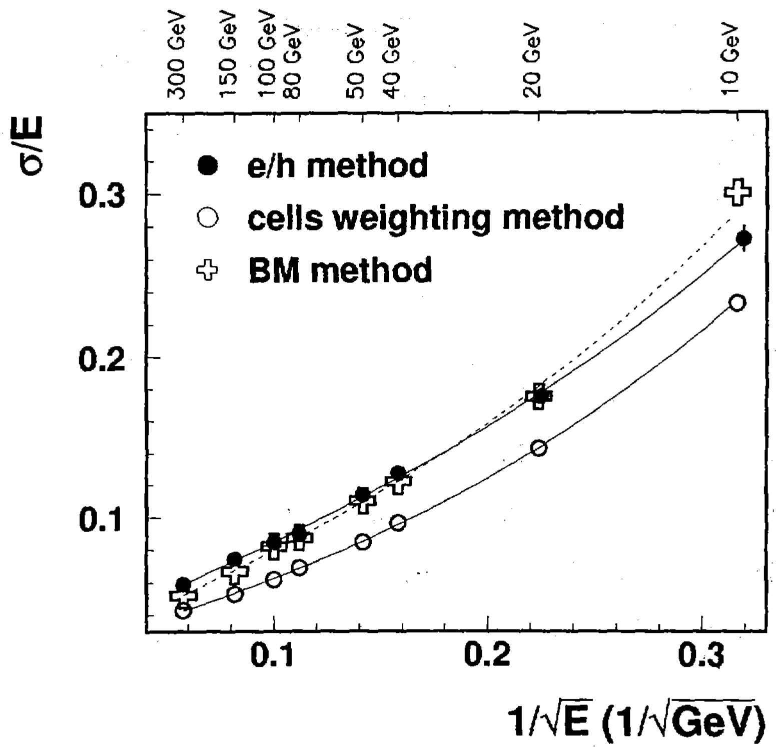

Figure 2: The fractional energy resolutions obtained with the e/h method (black circles), the benchmark method (BM, crosses) and the cells weighting method (open circles.)

Fig. 2 shows the fractional energy resolutions as a function of $1/\sqrt{E_{beam}}$ obtained by three methods: the e/h method (black circles), the benchmark method (crosses) [4] and the cells weighting method (open circles) [3]. The obtained fractional energy resolution for the e/h method is

$$\frac{\sigma}{E} = \left(\frac{(58 \pm 3)\%}{\sqrt{E}} + (2.5 \pm 0.3)\%\right) \oplus \frac{(1.7 \pm 0.2)}{E} \qquad (11)$$

This energy resolution for the e/h method is comparable with the benchmark method and only of 30% worse than for the complicated cells weighting method with about 100 parameters [5].

The proposed algorithm can be used for the fast energy reconstruction in the first level trigger and for the data analysis from modern combined calorimeters like the ATLAS and CMS detectors at the LHC.

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