COMPENSATION BY SOFTWARE – SINGLE PARTICLES AND JETS IN THE H 1 CALORIMETER

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ABSTRACT

The method of software compensation for the intrinsically non-compensating H 1 calorimeter is described both for single particles and jets. It is based on the π^0-weighting technique. Only the e.m. fraction f_{em} of the jet energy has an impact on the weighting function. The incorporation of an estimator for f_{em} into the weighting ansatz yields results on energy normalization and energy resolution for jets similar to those obtained for single particles.

The H1 calorimeter group has studied the π^0-weighting technique in detail for single particles using beam calibration data of the H1 calorimeter prototype or standard modules [2,3,4,5]. Typically a hadronic energy resolution of (45 - 50) % / $\sqrt{E}$ has been achieved even though the H1-calorimeter - a lead/stainless steel liquid argon calorimeter - is intrinsically non-compensating. One of the crucial questions is, to which extent these results can be transfered to ep events at HERA, where the calibration of jets rather than for single particles is the issue of primary importance.

This question has been studied using final state particles from the fragmentation of u-quark jets generated with the LUND code [6]. To simulate the response of electromagnetic particles the EGS4 code [7] has been used, which yields a good description of the data. On the other hand the hadron simulation programs used so far did not describe the single pion data at the level of accuracy required to extract the weighting constants. Therefore the response of the hadronic particles in the jet has been taken from the single particle measurements done at CERN.

The lateral segmentation of the 1987 test set-up calorimeter has been used, which was not yet the final one used in the H1 calorimeter, even though rather similar. To have a reasonable angular coverage for jets, this calorimeter structure has been extended horizontally and vertically up to a size of 2 × 2 m, with the interaction vertex being 2 m in front. Thus jets have been simulated in an angular region corresponding to the forward region (i.e. proton direction) in the H1 calorimeter.

To obtain the pion response at different energies and impact angles, we had to scale between the energies, where beam data were available, and rotate the single pion event relative to the normal impact angle (90°) used in the beam. To do so, a scaling and rotation algorithm [8] has been developed. which preserves the charge fluctuations in the pads. This algorithm has been extensively tested with MC events. From the comparison of directly simulated MC events and MC events obtained via the identical interpolation and rotation algorithm as used for the test data, we get good agreement in longitudinal and lateral charge distributions for hadronic showers up to rotation angles of 35° and down to energies of 10 GeV.

The main difference between single particles and jets is the larger fraction of electromagnetic energy in the jet. This leads to a significant different e/π-ratio in the e.m. calorimeter as can bee seen in Fig.1. This larger amount of e.m. energy yields also a better energy resolution even without any weighting (Fig.2). Assuming $\frac{\sigma}{E} = \sqrt{A^2/E + B^2}$ one obtains for jets $A = 0.535 \pm 0.035$ GeV$^{1/2}$ and $B = 0.034 \pm 0.002$ and for pions $A = 0.604 \pm 0.004$ GeV$^{1/2}$ and $B = 0.064 \pm 0.001$.

As shown previously [2,3,4,5] the charge deposited in a single channel offers the possibility to identify the underlying showering process: E.m. showers deposit locally more charge than hadronic showers. A non-linear dependence $E(Q)$ of the energy on the charge deposited in an individual channel, which takes into account both the e/π-ratio and the tagging efficiency for charge deposits from electromagnetic particles will effectively compensate for the different e and π response and thus improve the energy

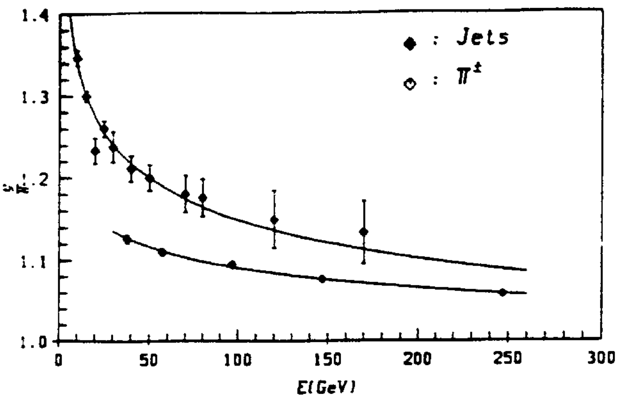

Figure 1: *e/π ratio for pions and jets*

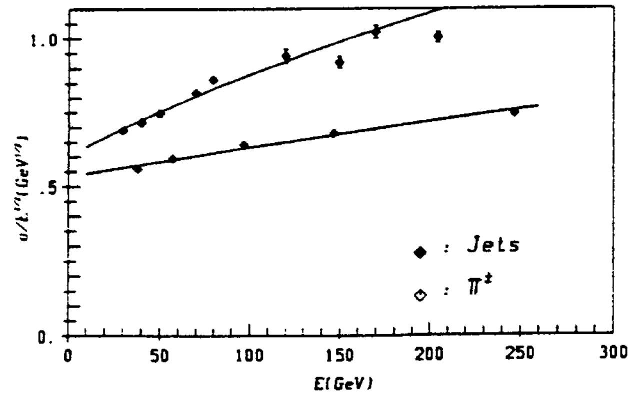

Figure 2: *Energy resolution for pions and jets*

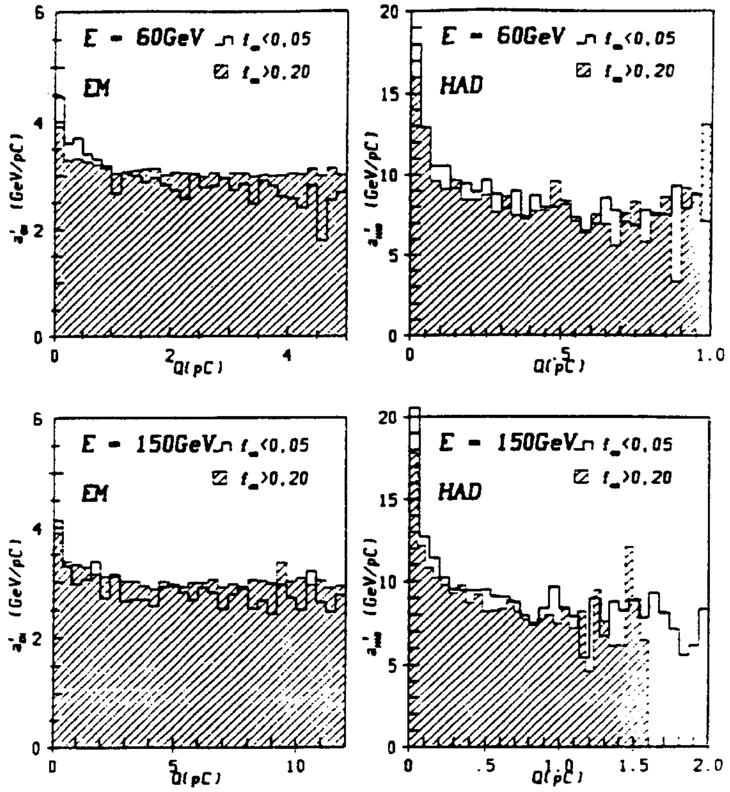

Figure 3: *Distribution of* $a^i = \frac{E(Q_i)}{Q_i}$ *for pions and jets*

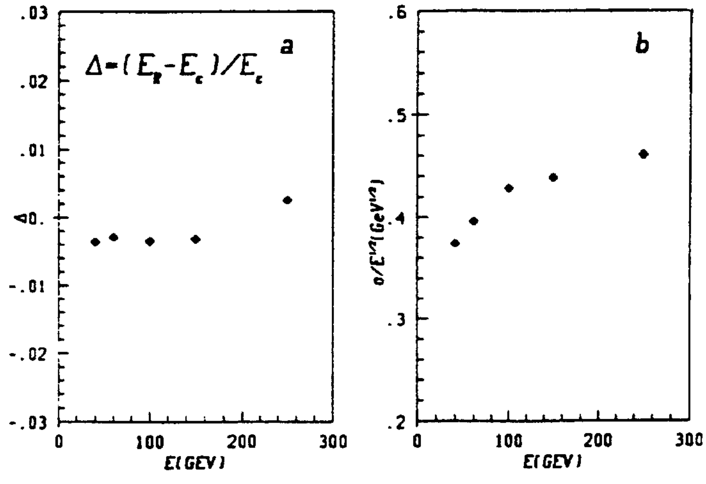

Figure 4: *Deviation from the nominal jet energy (a) and energy resolution for jets (b) using π°-weighting (see text)*

resolution.

The functional form of $E(Q)$ can be extracted directly from the data. Each individual charge bin Q_i for the e.m. and hadronic calorimeter is multiplied by a separate calibration constant a^i to obtain the total energy E:

$$E = \sum_{i=1}^{N_{EM}} a^i_{EM} Q_i + \sum_{i=1}^{N_{HAD}} a^i_{HAD} Q_i$$

The parameters a^i_{EM} and a^i_{HAD} are determined from a least square fit by minimizing the energy resolution. They yield the optimal numerical values $E(Q_i)/Q_i$ of the calibration function at a given value Q_i. This distribution is shown in Fig.3 for pions and jets at two different energies for the e.m. and hadronic calorimeter. With the larger amount of e.m. energy deposited in the e.m. calorimeter, the difference between jets and pions is mainly pronounced in the electromagnetic calorimeter: Jets require a substantially softer weighting function than pions. The strong impact of the e.m. energy fraction f_{em} in a jet on the weighting function has to be considered in the ansatz. With $f_h = 1 - f_{em}$ and using an estimator for f_{em} [8,?] based on the charge deposited in the e.m. calorimeter, we arrive finally at the following ansatz for the weighting function [8,?]:

$$\frac{E_{EM}(Q)}{Q} = < C^e_{EM} > + f_h[A \cdot e^{-(\alpha_1 \cdot f_h + \alpha_2) \cdot Q} - 1]$$

$$\frac{E_{HAD}(Q)}{Q} = < C^e_{HAD} > + f_h[B \cdot e^{-(\beta_1 \cdot f_h + \beta_2) \cdot Q} - 1]$$

$< C^e_{EM} >, < C^e_{HAD} >$ are the calibration constants for electrons for the e.m. and hadronic calorimeter respectively. The parameters α_1, α_2, β_1 and β_2 are almost energy independent. They have been determined from a fit minimizing the energy resolution in a similar way as described in ref. [5].

Using this ansatz we have studied the energy normalization and energy resolution for jets. The resulting deviation $\Delta = (E_R - E)/E$ from the nominal jet energy and the resolution $\sigma/\sqrt{E}$ are shown in Figs. 4a and 4b. The maximum deviation from the jet energy is 0.5 %. The energy resolution varies from 37 $\%/\sqrt{E}$ to 46 $\%/\sqrt{E}$ in the energy range studied.

A detailed study of the dependence of the energy normalization and energy resolution on other jet variables like particle multiplicity or thrust did not reveal any significant variation [8,?].

In conclusion, the π^o-weighting technique, used so far for single particles, has been applied to jets. Only the e.m. fraction f_{em} of jet energy has an impact on the weighting function. The incorporation of an estimator for f_{em} into the weighting ansatz yields results on energy normalization and energy resolution similar to the results obtained for single particles.

References

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