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Dead Material and Energy Measurements in Hadronic Calorimeters

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DEAD MATERIAL AND ENERGY MEASUREMENTS IN HADRONIC CALORIMETERS

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1. Introduction

Often the question arises as to where is the optimal place to locate "dead" material in a calorimeter. This material may be needed for structural reasons, for example. There needs to be a quantified answer to the question of what damage this "dead" material does to the performance of a calorimeter. For the purposes of this note, a hadronic calorimeter (HAD) is characterized by the mean and standard deviation of the energy measurement made by that detector.

2. Depth Truncation

It may happen that in certain regions of detection, the active depth of the calorimeter is limited. An example would be the existence of nonprojective cracks between calorimeter modules or "doglegs" [1]. It is also possible that fiscal requirements force a thinner design than first intended [2]. In that case, it is useful to quantify the loss in performance (characterized here by induced nonlinearities in the mean and increased errors in the energy measurement).

Data from the Hanging File (HF) test calorimeter is used in this study. The HF arrangement used here consists of 40 plates of 1/8" Pb (EM compartment), followed by 55 plates of 1" Fe (HAD compartment) [3]. The maximum energy available in the HF data set is 250 GeV, which is the energy studied here. Only the HAD compartment is considered. The EM compartment is left intact in all the measurements presented in this note.

In Fig. 1 is shown the shift in the mean caused by a truncated HAD depth. The energy mean divided by the mean at full HF depth is shown for 250 GeV incident pions as a function of the depth of the truncated HAD compartment. The relative mean ranges from ~ 0.15 to 1.0 as the HAD depth ranges from 0 (EM depth ~ 0.8 inelastic interaction

lengths) to 8.3 interaction lengths. Clearly, at 250 GeV, a lesser depth is sufficient for good containment.

In Fig. 2 is shown the increase in the error caused by a truncated HAD depth. The energy error divided by the mean and normalized to the full HAD depth is given as a function of the depth of the truncated HAD compartment. As in Fig. 1, it is clear that an energy of 250 GeV is well measured in the calorimeter for depths up to 15" less than the full depth.

In fact, the SDC total depth of 10 interaction lengths was chosen to measure 10 TeV mass dijets (~ 5 TeV Pt jets, ~ 1 TeV kt leading particles) well [2]. The present study confirms that single particles of lower energy are well measured. This study also allows one to scale. A glance at Fig. 2 shows that single particles of 250 GeV are well measured for depths 15" less than the full HAD compartment. Thus, if one wished only to measure 2.5 TeV dijets (~ 1.25 TeV Pt jets, ~ 0.25 TeV leading particles) well, the calorimeter could be made ~ 2 absorption lengths shorter.

3. "Dead" Tiles

A second problem which might occur would be dead tiles due to mechanical failures of splices or other connections. How might such a problem be treated? First, one needs to recalibrate the mean. Shown in Fig. 3 is the mean response with 1 broken tile relative to the undamaged mean as a function of the location of the "dead" tile. Clearly, the tile location is important. Figure 4 shows the same plot as Fig. 3 except that there are 2 contiguous broken tiles in this case. Looking at the 2 Figures, one can see that the loss in the mean is roughly linear; with 2 broken tiles, one loses a fraction of the mean about twice the loss due to 1 broken tile. The maximum loss occurs near hadronic shower maximum; it is 4% per tile. Losses for broken tiles in the rear of the HAD compartment are benign.

In Fig. 5 is shown the error divided by the mean normalized to the undamaged value for 1 broken tile as a function of the location of that tile. The statistical error on each data point is roughly 10%. The analogous results for 2 broken tiles are shown in Fig. 6. Again, the degradation in performance is roughly linear. For 1 broken tile the fractional energy error is increased by ~ 20% for a tile near hadronic shower maximum. For 2 broken tiles, the largest fractional increase in energy error is ~ 50%. The tile location is important only for tiles in the first 3-4 absorption lengths of the HAD compartment (HAD1 in the SDC calorimeter is 4 absorption lengths thick). As with the measurement of the mean, "dead" tiles in the rear are unimportant. This fact also gives one a guide as to the placement of inert material (supports, etc.). Dead material should be placed as deep as

possible within the HAD compartment. The scale for depth is set roughly by the HAD1/HAD2 boundary.

4. Calibration Issues

The SDC plans to mount an extensive system of movable radioactive sources so that each tile will "see" a source for calibration purposes [4]. There are various schemes of using the data itself to also perform "in situ" calibrations. What is the interaction between calibration and "dead" tiles? Clearly, the radioactive sources can identify the existence of a dead tile. Then, one can use the knowledge of the location in depth of the tile (e.g. Fig. 3) to correct the mean of the distribution by a predicted amount. Obviously, the correction for only 1 broken tile is < 4%.

One can extract a bit more information. Given the location of the bad tile one can weight the error of the energy measurement made by that tower. If the bad tile is in HAD2, the error is not adversely effected. If it is in HAD1, the location of the bad tile (see Fig. 5) allows one to estimate the reduced weight of energy measurements made by that tower.

References

1. D. Green, "The Effects of Cracks on Calorimeter Response in the SDC "Dogleg" Design", Fermilab-TM-1810 (1992).

2. D. Green, J. Hauptman, and A. Para, "Radiation Damage, Calibration and Depth Segmentation in Calorimeters", Fermlab-FN-565, May 1991.

3. A. Beretvas, et al., "Beam Tests of Composite Calorimeter Configurations from Reconfigurable-Stack Calorimeter", submitted to Nuc. Inst. Meth.

4. SDC Technical Design Report, SDC-92-101 (1992).

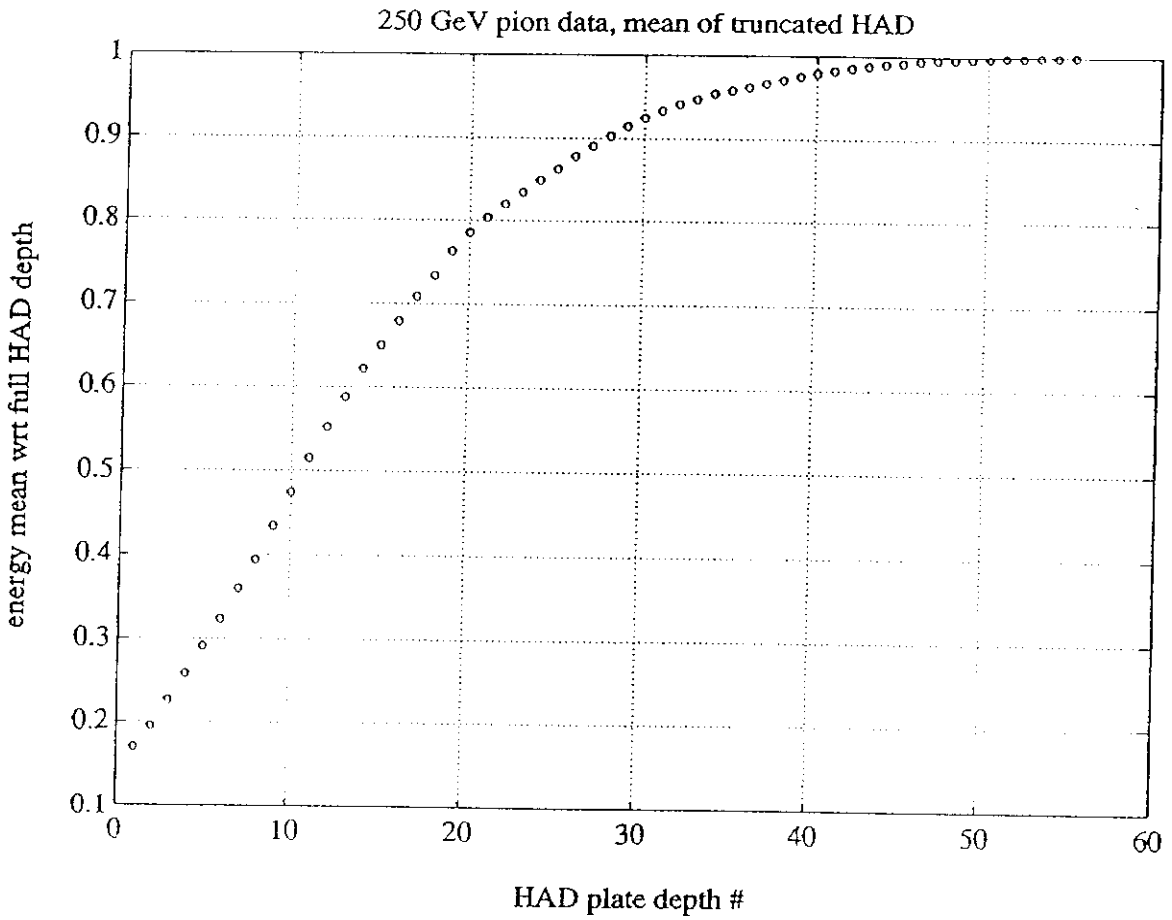

Fig. 1 Mean energy for 250 GeV incident pions for a truncated hadronic calorimeter with respect to the mean of the full depth HF module. The module consists of an EM compartment with 40 Pb plates of 1/8" and a HAD compartment consisting of 55 plates of 1" Fe. The relative mean is shown as a function of the depth of the truncated HAD compartment.

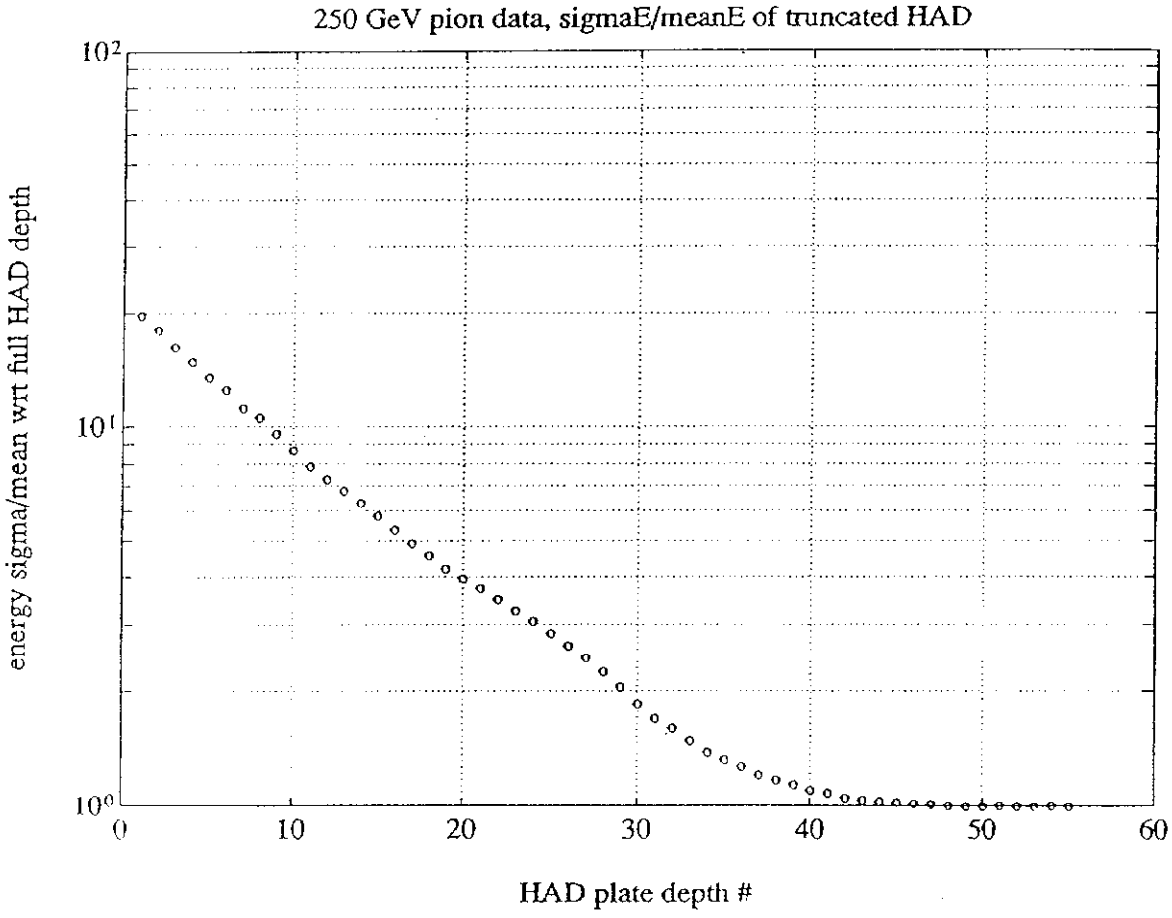

Fig. 2 Energy sigma/mean for a truncated HAD compartment with respect to the sigma/mean of the full depth HF calorimeter. The horizontal axis is the same as in Fig. 1, the number of 1" Fe plates in the truncated HAD compartment.

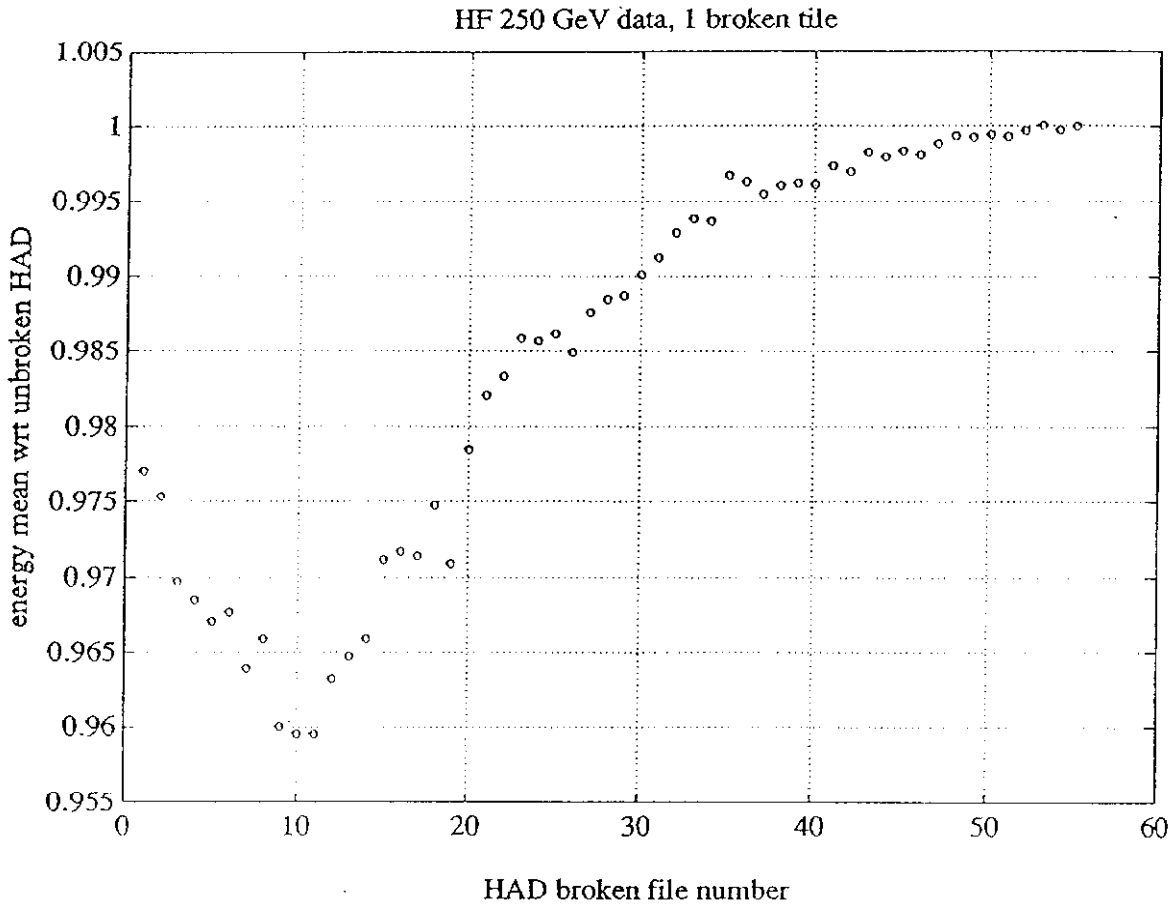

Fig. 3 Mean energy for 250 GeV incident pions for a calorimeter with 1 "dead" tile with respect to the mean of a fully functional HAD compartment as a function of the location in depth (in 1" Fe units) of the "dead" tile.

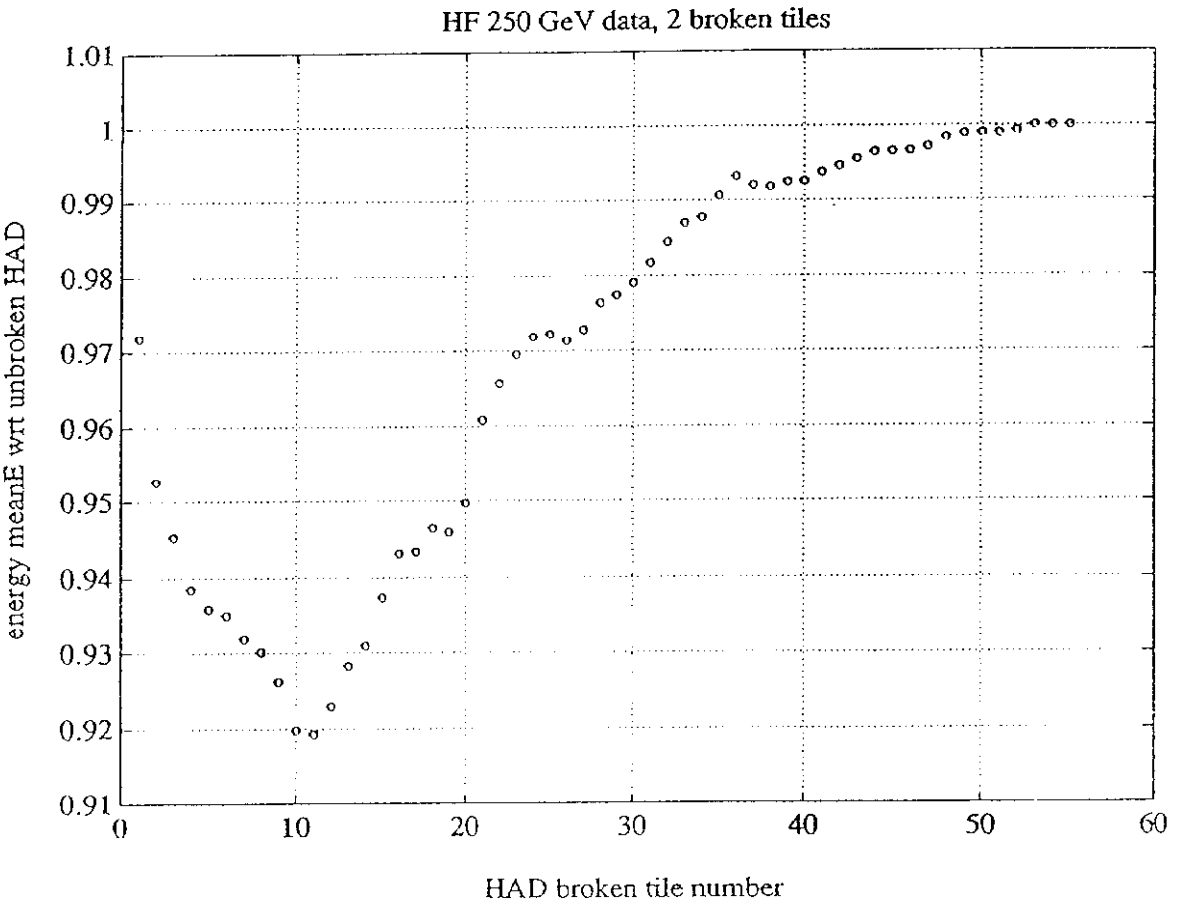

Fig. 4 Same plot as Fig.3 except that the damaged HAD calorimeter compartment now has 2 "dead" tiles. Mean as a function of the location of the 2 contiguous "dead" tiles.

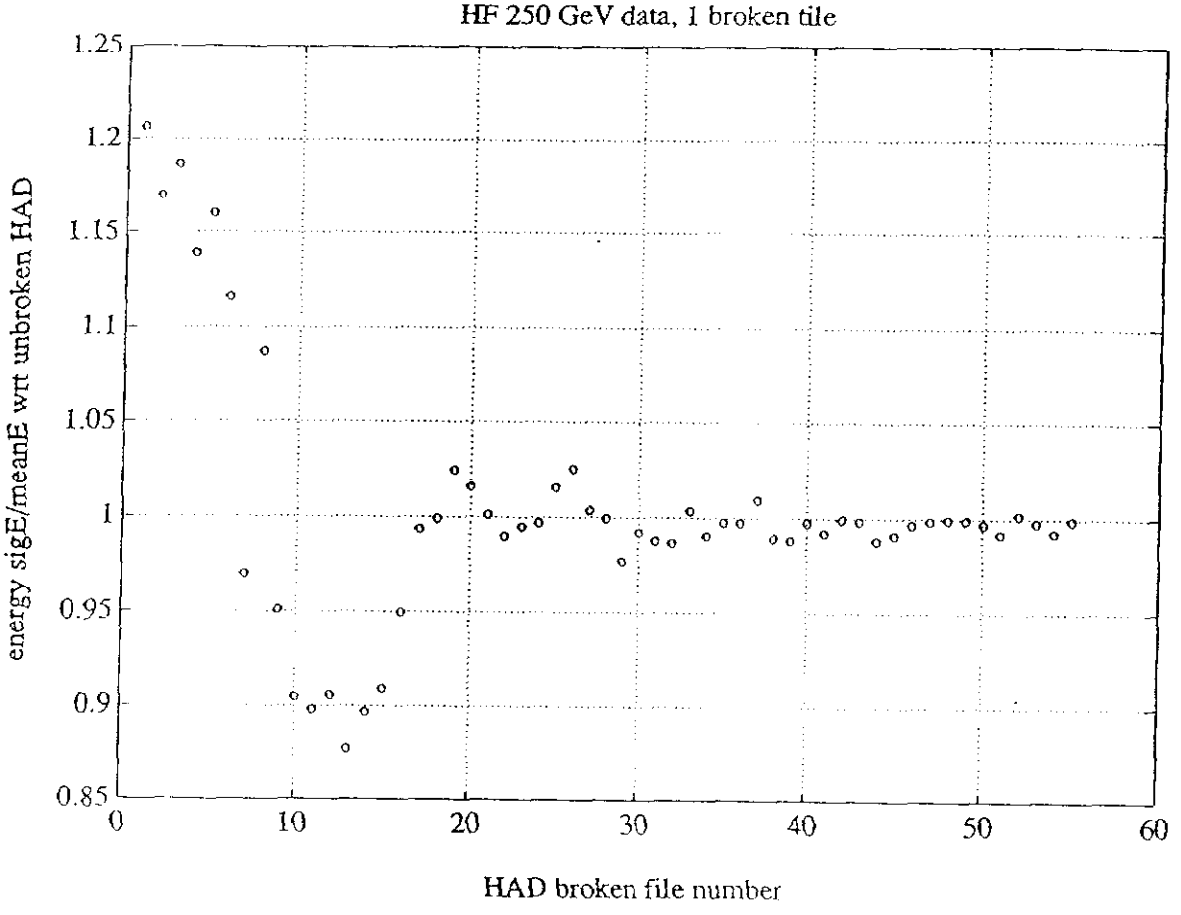

Fig. 5 Energy sigma/mean for a calorimeter with 1 "dead" tile with respect to the sigma/mean for an undamaged HAD compartment for 250 GeV incident pions. The horizontal axis is the location in depth (in 1" Fe plate units) of the "dead" tile.

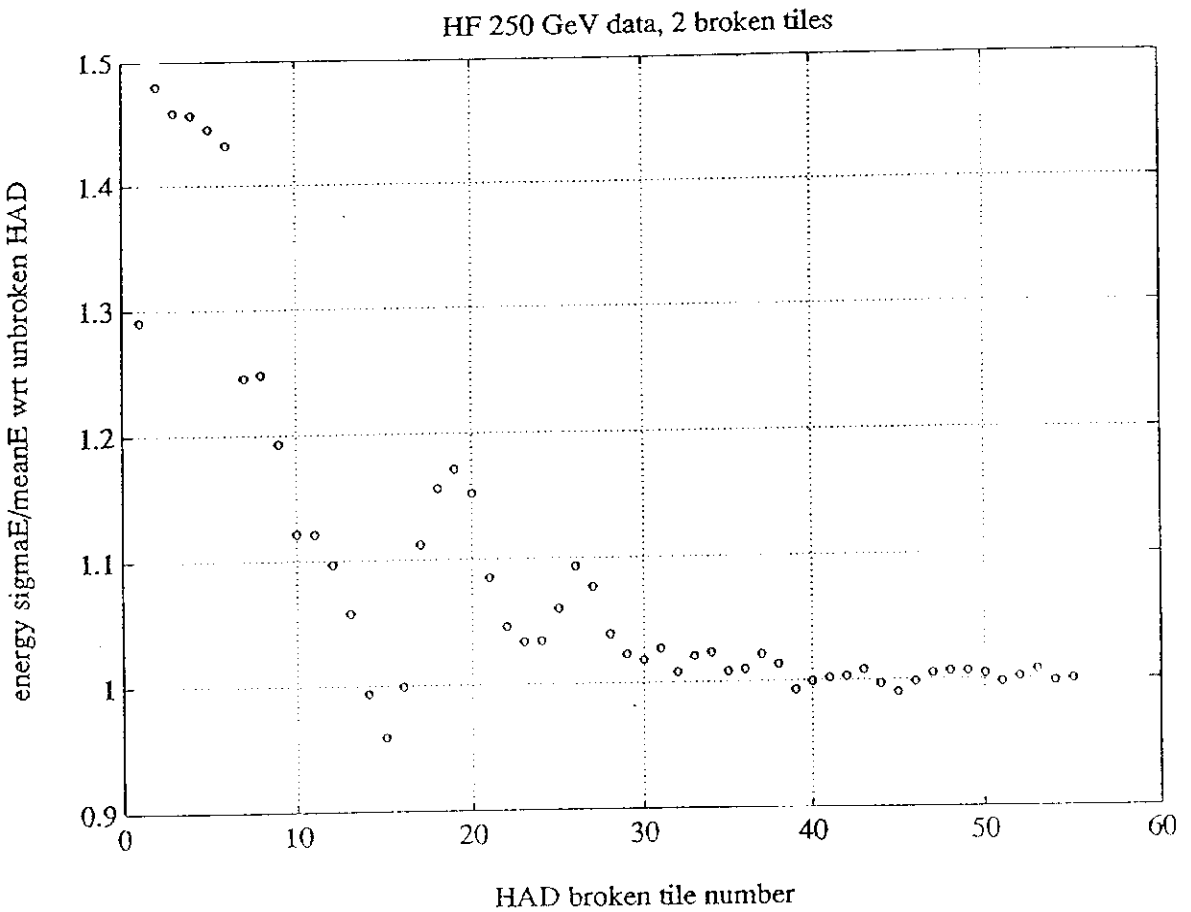

Fig. 6 Same plot as Fig. 5 except that the damaged HAD calorimeter compartment now has 2 contiguous dead tiles. Fractional energy error as a function of the location, in depth, of the 2 "dead" tiles.