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Effect of Dead Material in a Calorimeter

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Introduction

The existence of dead material in any practical calorimeter system is simply a fact of life. The task for the designer, then, is to understand the impact on the Physics in question, and strive to minimize it. The aim of this note is to use the “Hanging File” test data [1] , which has fined grained individual readout of about 100 depth segments, to explore this question. What is the impact of dead material on the mean and r.m.s. of the hadronic distribution? The amount and location of the dead material is varied.

It is important to remember in what follows that the Hanging File data was calibrated, EM to HCAL compartment, so as to minimize the electron to pion energy dependence. In practical terms e/pie was made = 1.0 at an incident energy of about 100 GeV. Note that the Pb(EM) + Fe(HCAL) calorimeter was not a compensating device. This fact will have implications in what follows.

The Shift of the Mean and Corrections

The data set used here was a small number of pions in a beam prepared at 250 GeV. The calorimeter consisted of 40 plates of 1/4” Pb followed by 55 plates of 1” Fe. The 95 samples of this particular array were each sampled by a 4 mm plastic scintillator read out by a separate phototube. The depth in ECAL, 0.57 Xo sampling, is 0.74 absorption lengths. The depth in HCAL, 1.45 Xo or 0.15 lambda sampling, gives a total HCAL depth of 8.35 absorption lengths (9.1 with ECAL in front)

One, two, or three contiguous layers were then dropped from the energy sum at various locations within the HCAL compartment. The resulting distributions were then characterized by their means and second moments, the r.m.s. The first and second moment were scaled to those for no dead material anywhere.

A first attempt to correct for the dead layer was made. The first active layer was given a weight so as to compensate for the dead material. For example, for 1 dead layer the next layer in the stack contributed to the energy sum with weight 2, while for 2 dead layers the weight was 3. This scheme gives a uniform samping fraction throughout the calorimeter. If the hadronic shower is uniform on the scale of the dead material, then this method will restore the spread seen in the energy sum. In contrast, if there are fluctuations on the scale of 2.5, 5, or 7.5 cm, then the distribution will indicate poorer measurement capability.

The results for 2.5, 5.0, and 7.5 cm unsampled (or “dead”) Fe are shown in Figs. l, 2 and 3 respectively. The 2 sets of data points correspond to no corrections, o , and a correction which restores uniform sampling fraction, *. The magnitude of the loss of energy depends on the location of the of the dead material. Basically, it corresponds to the mean energy deposition “profile”. The peak loss is ~ 4%, 8%, and 12% for 2.5, 5.0, and 7.5 cm dead fe respectively. That peak occurs at - hadronic shower maximum, or layer 5 to 10 in HCAL. Since ECAL is - 0.74 absorption lengths, the location of maximum sensitivity to dead material is - 1.5 - 2.6 absorption lengths.

The weighting correction restores the unsampled energy to the sum so as to restore the average response. For 2.5, 5.0, and 7.5 cm dead Fe, the mean is restored to 1%, 2%, and 4% respectively, as seen in Figs. 1, 2, and 3. It is clear that the average response can be restored by adjusting sampling.

The Increase in the r.m.s.

The question remains as to the effect of dead material on the spread of the energy measurements. In Figs. 4, 5, and 6 we show the ration of rms/mean , normalized to the case of no dead material, for dead material of 2.5, 5.0, and 7.5 cm of Fe respectively as a function of the location within HCAL of the dead material. The 2 sets of data points refer to uncorrected distributions, o , and corrections made to achieve uniform sampling fraction, *.

There are several points of interest in these plots. First, the percentage effect is large w.r.t:. that on the mean. The maximum uncorrected degradation of resolution is ~ 25, 60, 95 % for 2.5, 5.0, and 7.5 cm dead Fe. The location of the most sensitive region for dead material is at the ECAL/HCAL boundary. That fact can be understood because the “hanging file” data comes from a noncompensating calorimeter array. Finally, the correction does not restore the energy resolution, although it does somewhat alleviate it. Thus there are fluctuations in hadronic showers which are substantial on the scale of the depth of dead material, and they cannot be recovered by simply reweighting. This fact is evident when one examines the energy deposition plots in the 95 sampling layers event by event.

Finally, one can ask if the weight to give uniform sampling is also that to give the best resolution. The rms/mean plot for 5.0 cm dead Fe as a function of the weight of the first activer layer downstream of the dead material is shown in Fig.7. The index is such that the weight varies from 1 to 11. There is a soft minimum at the expected uniform sampling point, WT = 3. Thus, we confrim that the overweighting strategy is correct and that the exact value of the weight is not particularly critical.

Dependence on Calibration, Noncompensation

As stated above, the relative calibration of the ECAL and HCAL compartments was set by the desire to make the e to pie response ~ 1 over a substantial energy range. This condition does not give a minimum resolution, and is the cause of the fact that the rms/mean ratio for dead material in Fig.4 falls below .0 in places.

As an illustration, the energy distribution was sorted on interaction point. For interaction points in the ECAL, the mean was ~ 5 % lower than for conversions in the HCAL. The rms/mean was ~ 4% for the former, while it was ~ 5% for the latter events. The rms/mean was 5.3 % for the full event set. Since the energy ratio was <Eecal/Ehcal> = 0.32, we recalibrated the ECAL by a 15% upward adjustment. For this calibration option the mean was almost independent of conversion point, as was the rms. The global data set had a rms/mean of 4.9%, showing how this calibration improves the energy resolution.

A plot of the mean for 5.0 cm dead Fe placed at various depths in HCAL for the revised calibration is shown in Fig.8a. Clearly, the plot is essentially the same as that of Fig.2. A plot of the rms/mean is given in Fig.8b. This plot shows different ehavior from that of Fig.5. The general scale of the effect of dead material is reduced. The effect is always a degradation, as is intuitively plausible. There is clearly an alleviation of the effect using the weighting scheme. Still, the effect is largest at ECAL/HCAL boundary due to the noncompensation of such a device.

References

1. HF NIM paper

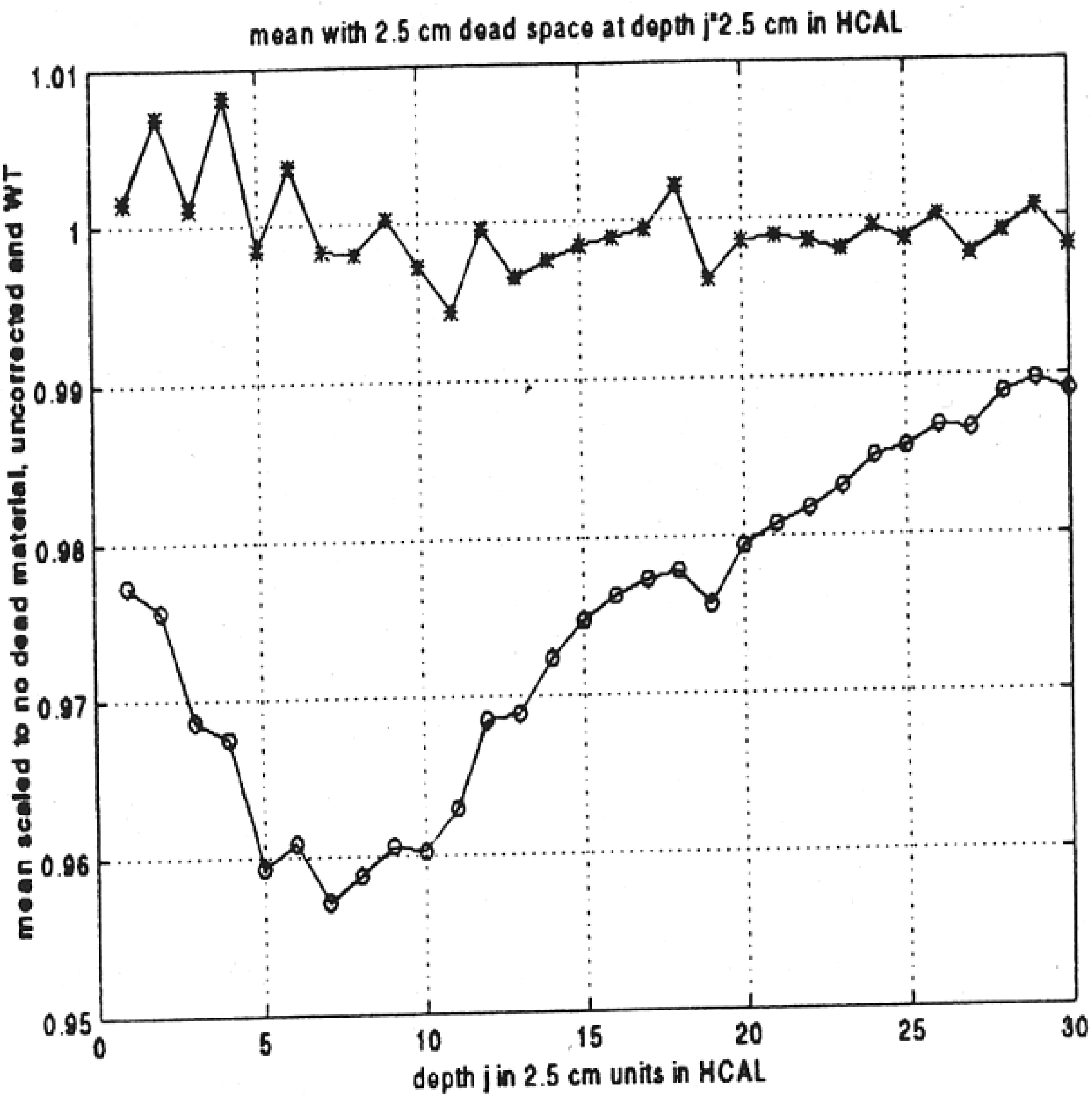

Fig.1: The effect of a dead 2.5 cm layer of Fe in a calorimeter at a depth in HCAL idenfified by index j (2.5 cm Fe units). The HCAL

segment is behind an EM segment consisting of 40 layers of 0.635 cm Pb sampled with 4 mm scintillator. The points, o , are for no correction. The points, * , are corrected by oversampling the layer just downstream of the dead material such as to have uniform sampling fraction.

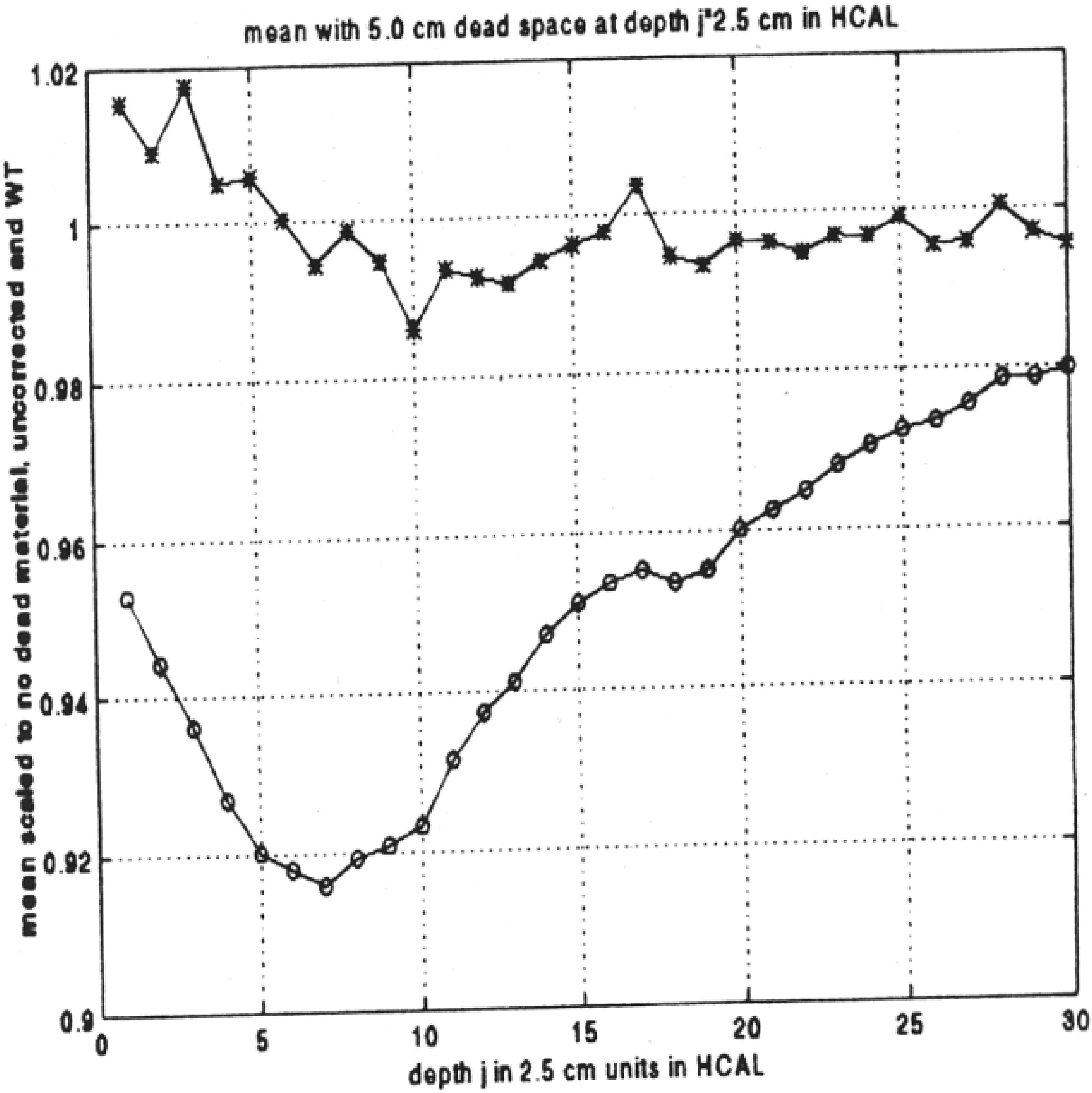

Fig.2: As in Fig.1, save that the depth of dead material is 5 cm.

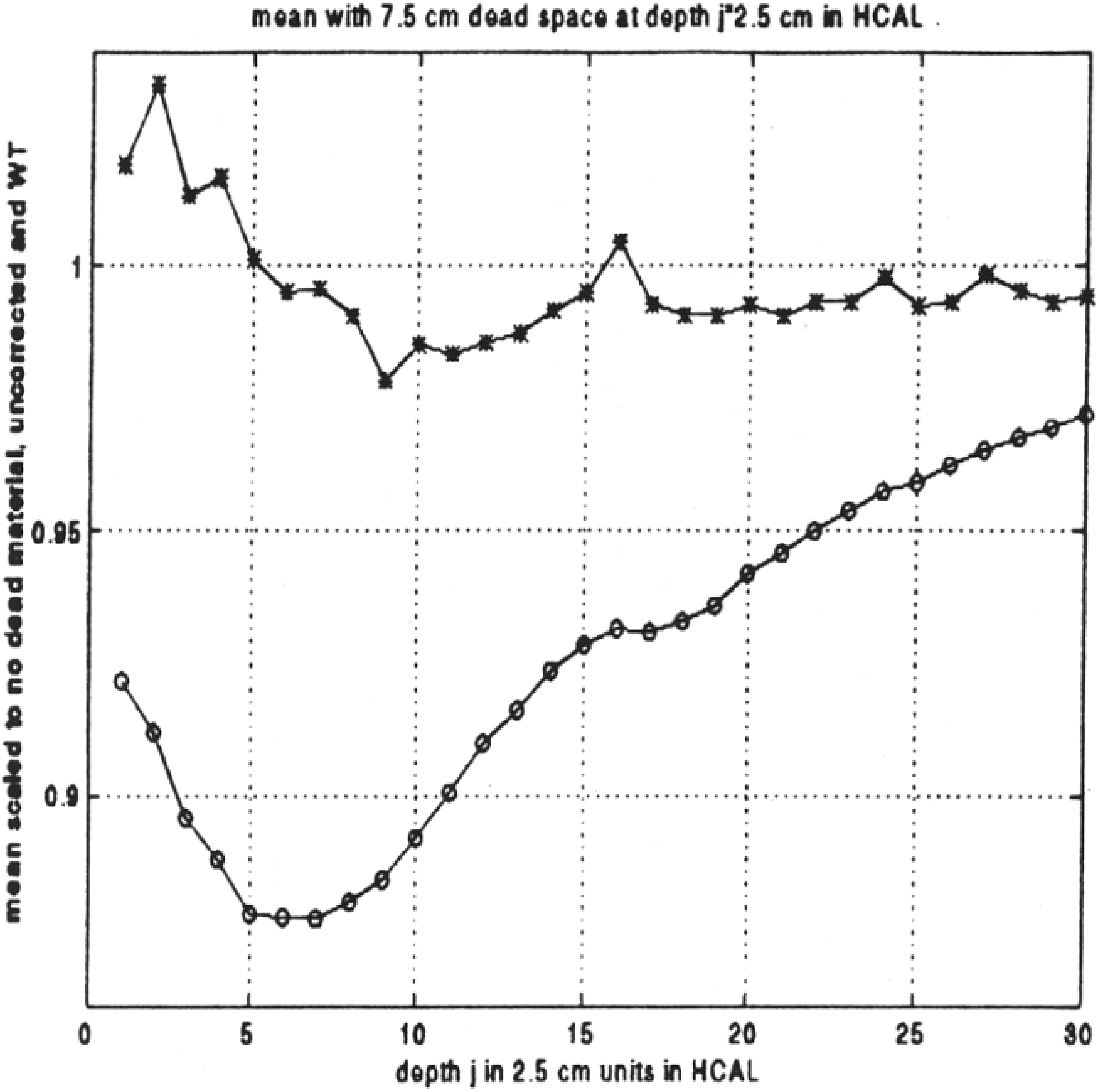

Fig.3: As in Fig.1, save that the depth of dead material is 7.5 cm.

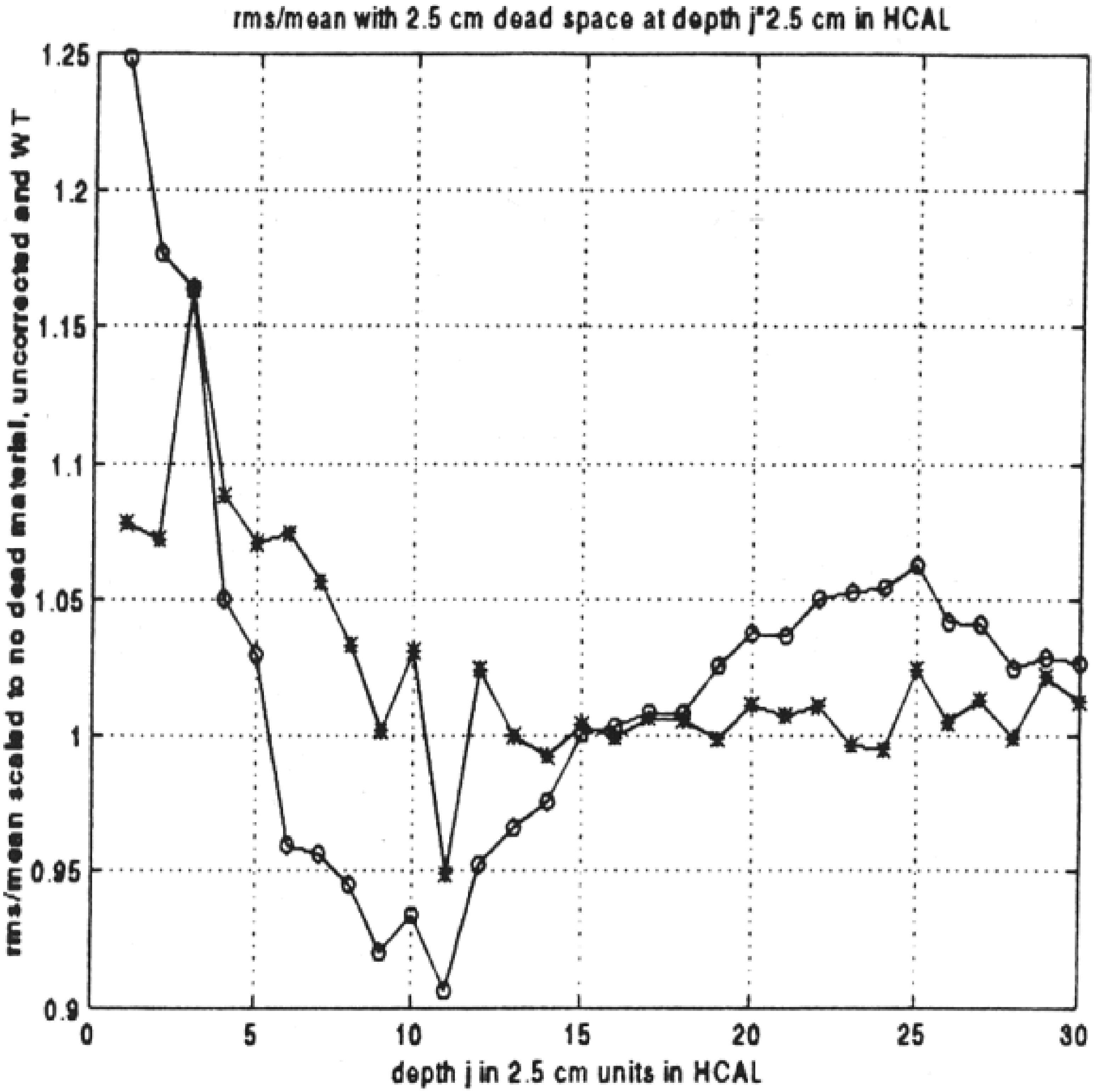

Fig.4: The ratio of r.m.s. to mean for the distribution which arises when there is a 2.5 cm dead layer of Fe in at calorimeter at a depth in HCAL labelled by index j (2.5 cm Fe units) divided by the r.m.s. to mean ratio with no dead material anywhere. The points, o , are for no corrction. The points, * , are corrected by oversampling the layer just downstream of the dead material such as to have all active layers with a locally uniform sampling fraction.

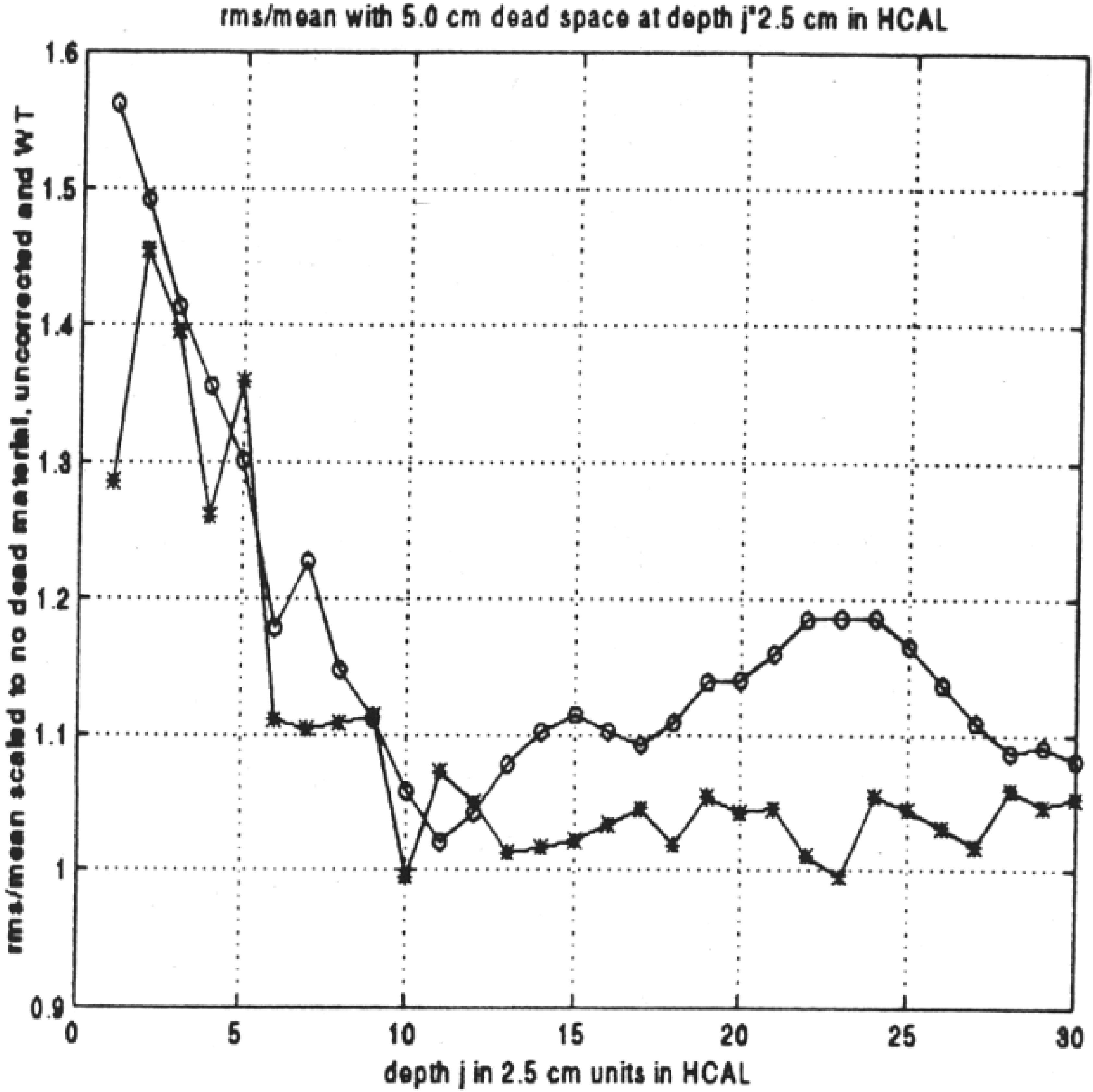

Fig.5: As in Fig.4, save that the depth of dead material is 5 cm.

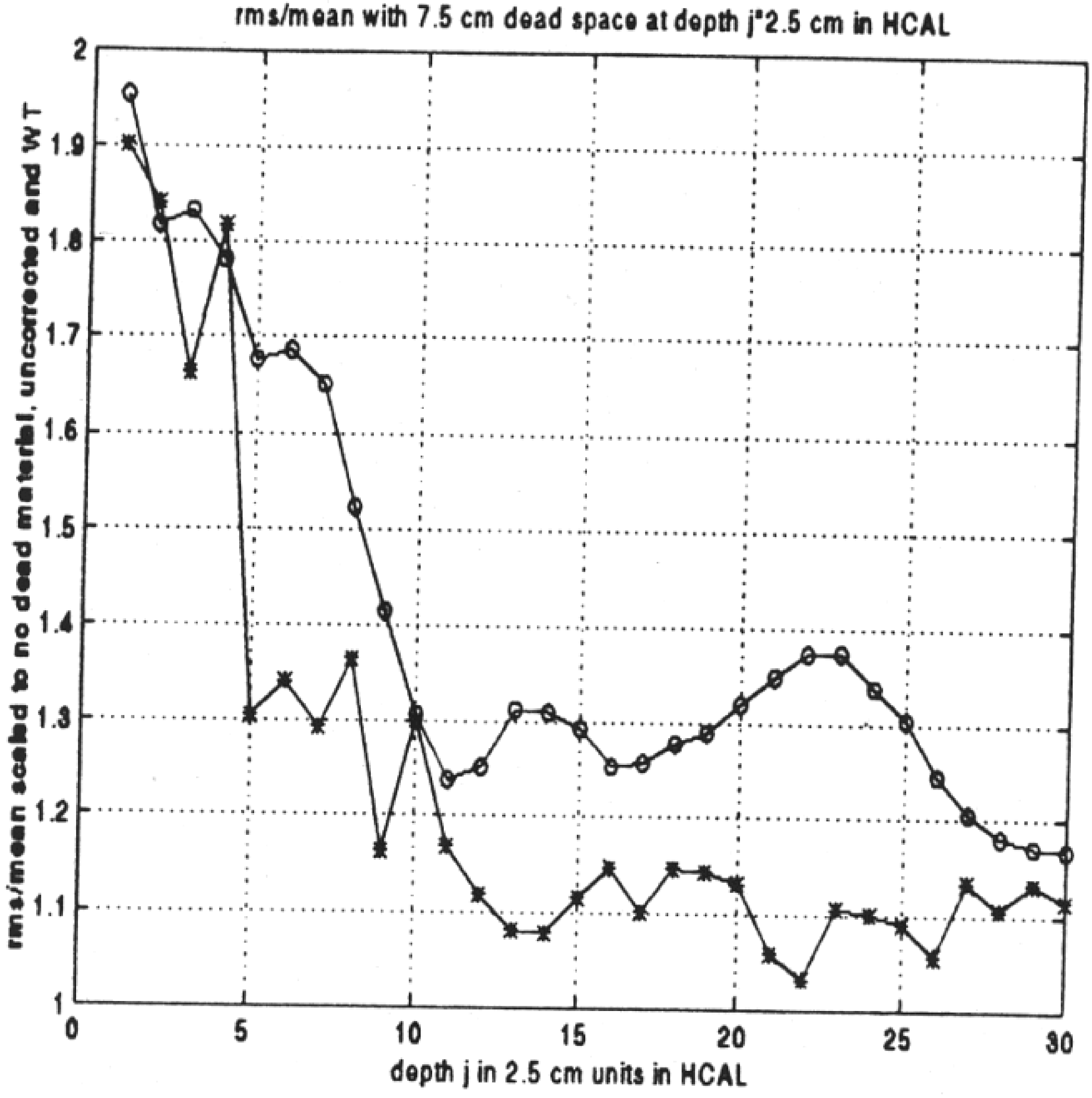

Fig.6: As in Fig.4, save that the depth of dead material is 7.5 cm.

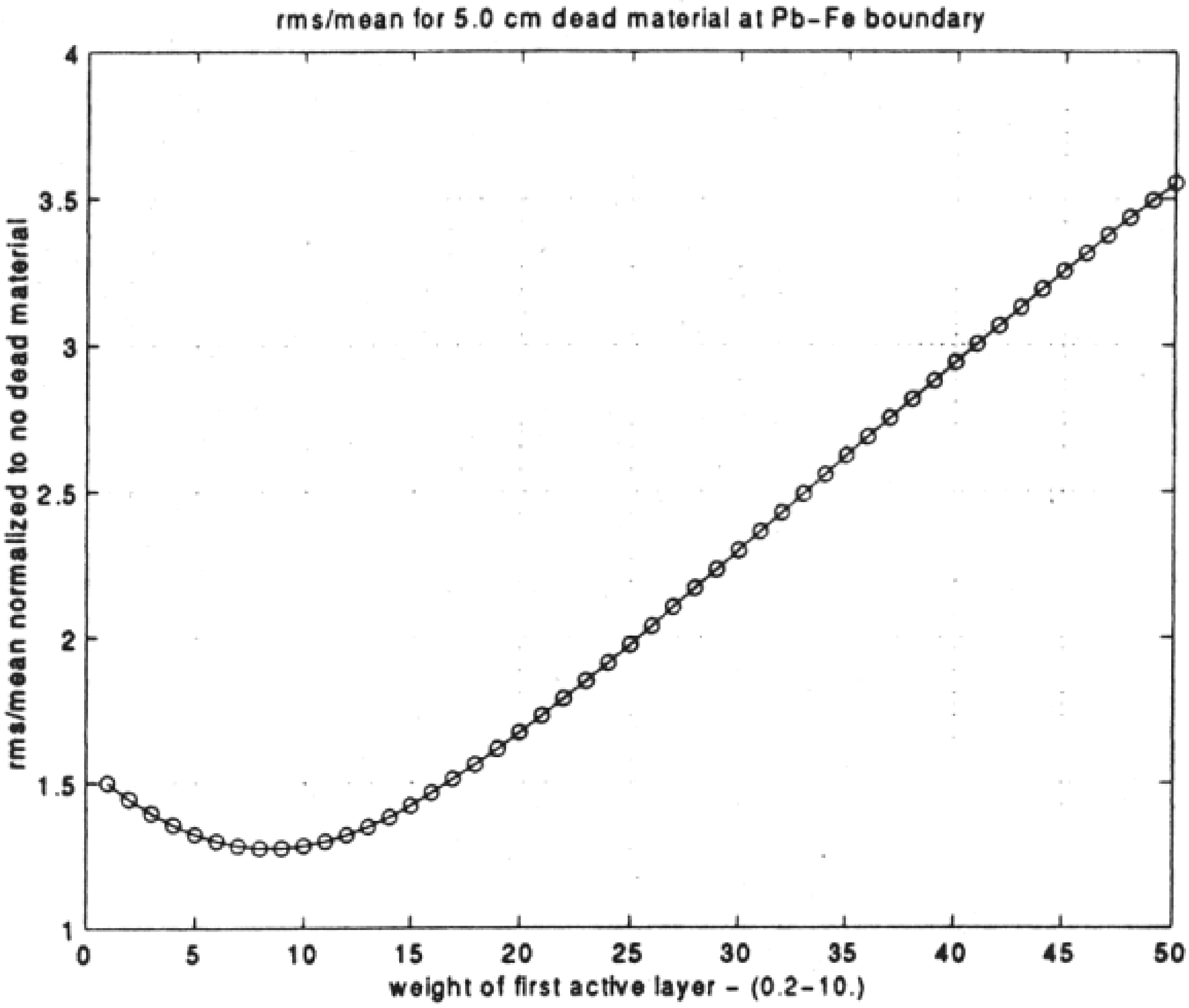

Fig.7: For the case of 5 cm dead material at the beginning of the HCAL segment a plot to check if sampling fraction is the optimal weighting. A plot of the r.m.s. to mean ration normalized to the case of no dead material as a function of the weighting of the first active layer. The index plotted is such that the weight factor varies from 1 to 11. A clear, but soft, minimum near the expected weight of 3 is seen.

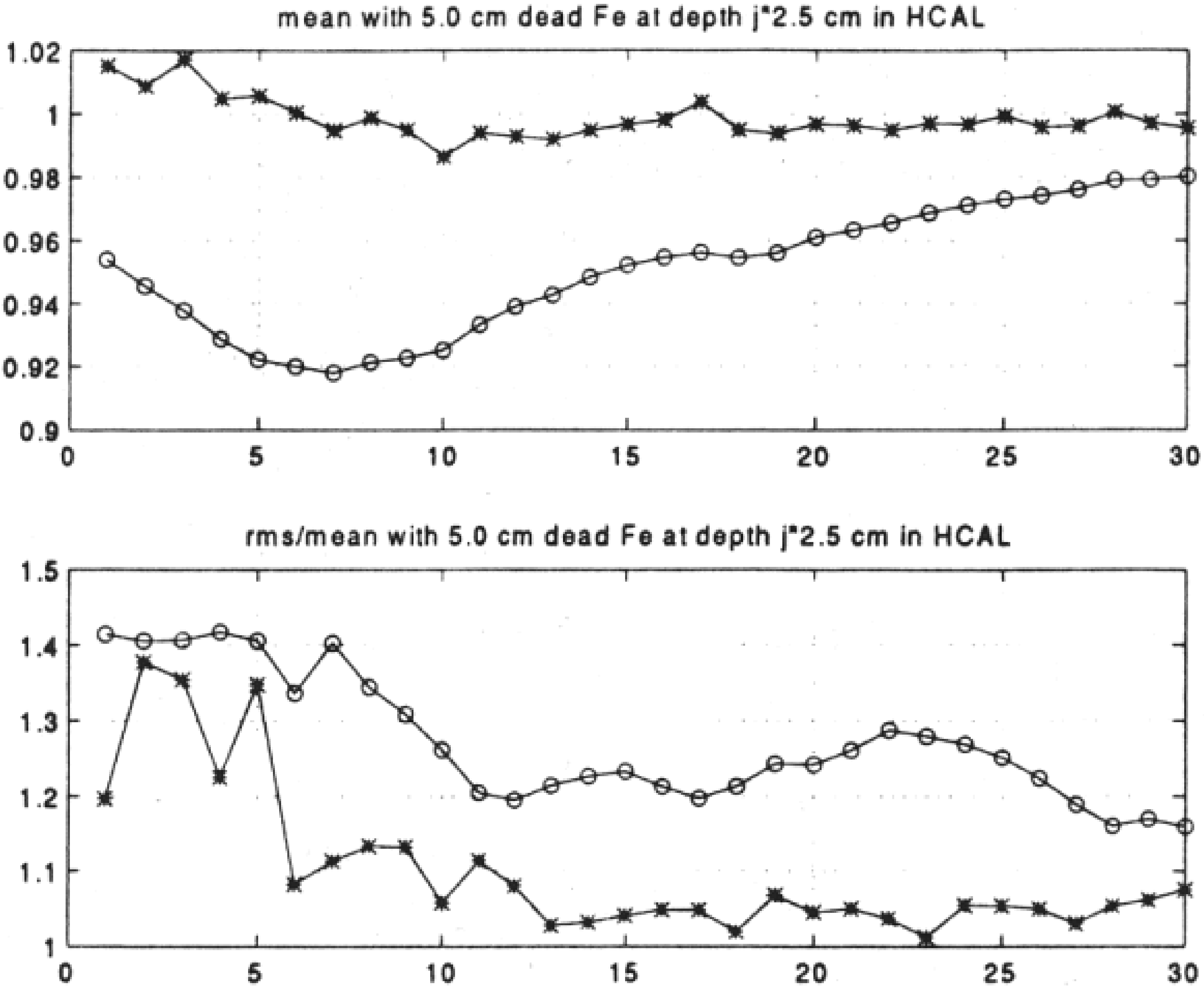

Fig.8: For the case of 5 cm dead material at different locations in HCAL with a calibration such as to minimize the energy resolution. Shown is the mean and rms/mean for no correction, o , and for a correction which retains a uniform sampling fraction.
a. mean scaled to the mean with no dead material.
b. rmd/mean scaled to the ration in the absence of dead material.