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Revision A

SDC
SOLENOIDAL DETECTOR NOTES

SOURCE CALIBRATIONS AND SDC CALORIMETER REQUIREMENTS

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1. Introduction

Several studies of the problem of calibration of the SDC calorimeter exist [1]. In this note the attempt is made to give a connected account of the requirements on the source calibration from the point of view of the desired, and acceptable, constant term induced in the EM resolution. It is assumed that a "local" calibration resulting from exposing each tower to a beam of electrons is not feasible. It is further assumed that an "in situ" calibration is either not yet performed, or is unavailable due to tracking alignment problems or high luminosity operation rendering tracking inoperative. Therefore, the assumptions used are rather conservative. In this scenario, each scintillator plate of each tower is exposed to a moving radioactive source. That reading is used to "mask" an optical "cookie" in a grey code chosen so as to make the response uniform [2]. The source is assumed to be the sole calibration of the tower. Therefore, the phrase "global" calibration of towers by movable radioactive sources is adopted.

2. Source Location Requirements

The requirements on the source have been given elsewhere [3]. In this note a simple model is made and evaluated by Monte Carlo techniques. The source is assumed to be Cs, with a 0.66 MeV gamma line. The absorption in plastic is by way of the Compton effect. The absorption length is taken to be 20 cm. The recoil range of the Compton e is neglected as is the source size. The square plate geometry is assumed with a plate of 10 cm full width and 4 mm thickness. The results are shown in Fig. 1 for the signal as a function of source position with respect to the scintillator tile. The effect of Pb in the vicinity of the source/tile was ignored.

There were 5 locations studied. Typically, 2% of all isotropically emitted photons interacted in the plate. As is obvious geometrically, the first derivative of the source response vanishes for displacements of the source from the plate center line along the plate width., i.e. x or y. Displacements perpendicular to the long dimension of the plate, z, have a non zero first derivative. As seen in Fig. 1, the sensitivity of the tile response to plate displacement is 0.06%/mm for "horizontal" motion and 6%/mm for "vertical" motion. As expected, only "vertical" motion is important [3]. These results are in rough agreement to those found in previous studies [1]. In conclusion, if a 2% rms error on tile response uniformity is required, then the source location must be controlled to an accuracy of 0.3 mm.

3. Relationship of Calorimeter Resolution and Tile Uniformity

Clearly, the calorimeter must be a uniform medium. If it is nonuniform, then fluctuations in the shower location within the calorimeter will lead to errors in the energy measurement. These errors will appear as a contribution to the "constant term" in the resolution. To set the scale, the SDC EM calorimeter was given a budget of ~ 0.5% constant term due to nonuniformities in construction [1]. Previous studies, [2], have indicated that this requirement implies (in a "global" calibration scheme) controlling the tile uniformity to an rms of ~ 2%. The results of Section 2 then imply that the source must be controlled to 0.3 mm rms. Other studies [4,5] confirm this result.

In order to reproduce the results, and to deepen the study, a simple minded Monte Carlo model was made. The EM showers were assumed to be of a fixed shape, as given in Ref. 6, and all fluctuations in showers come from variations in the location of the conversion point. The SDC calorimeter was assumed to consist of 70 samples of 4 mm Pb, 50 Xo deep. An ensemble of 20 towers with sampling smeared by an rms of 5% was "constructed" and illuminated by 20 photon showers of 50 GeV incident on the towers.

The mean conversion point was, <to> ~ 1, with an rms in to of ~ 1. A figure of merit was chosen to be the fractional energy error, dE/E = (E-Eo)/Eo. Note that no sampling fluctuations exist to confuse the issues. The "shower maximum", SM, sample was taken to be at plate 9, depth ~ 6 Xo. The mean value of the SM energy was 1.65 GeV with a rms of 0.52 GeV due to fluctuations in the conversion point.

The observed mean of dE/E and the rms for dE/E for the 20 towers is shown in Fig. 2. Clearly, the rms of the mean over all towers is large with respect to the rms of any given tower. Summing all towers "globally", one has a mean in dE/E of -0.0034 and an rms of 0.0115. The mean rms of all towers is 0.0013. "Local" and "global" calibrations are illustrated also in Fig. 3. The sum of all tower values for dE/E is shown in Fig. 3a, while the sum with the tower mean first subtracted is shown in Fig. 3b. Clearly, if the tower mean can be separately determined, the sensitivity of the calorimeter to tile nonuniformity can be dramatically reduced. This fact has been noted previously [4,5].

4. Using SM to Reduce Errors due to Nonuniformities

Previously it was noted, [7], that, using longitudinal segmentation, one could reduce the effects of radiation induced nonuniformities by essentially measuring the shower conversion point. That perception can be extended to the problem of nonuniformities induced by manufacturing imperfections. The idea is to use SM in a given tower with respect to the total EM energy to measure the location of the conversion point on an event by event basis. Some representative distributions for a given tower are shown in Fig. 4. The value of SM energy and shower conversion point, to, was recorded for each tower and shower.

Clearly, the SM energy is well correlated to the conversion point, to. Larger values of SM energy mean that to is less deep in the calorimeter as shown in Fig. 5. Therefore, a measure of SM energy is a measure of the major fluctuation in the nonuniform EM calorimeter. Hence, we expect that SM energy will correlate with dE/E for the tower. Shown in Fig. 6a is the correlation of dE/E and SM energy for a particular tower "built" as shown in Fig. 6b. Clearly, on a tower by tower basis, the SM/EM energy ratio correlates to dE/E. Therefore, if a "local" calibration has been performed, the residual error can be driven down even lower using the ratio of SM/EM energy.

The values of dE/E as a function of SM energy for 8 towers is shown in Fig. 7. Clearly, the specific tower construction dictates the nature of the correlation. Therefore, good knowledge of the individual tower plate response is needed to realize the reduced errors implied by Fig. 6. In particular, a "local" calibration is needed. If a "local" calibration exists, and if the tower "construction" is well understood, then errors in fractional energy of < 0.0005 appear to be feasible. If only a "global" calibration exists, then 5% rms scintillator tile errors induce a ~ 1% constant term in the energy resolution.

References

1. Solenoidal Detector Collaboration Technical Design Report, April 1, 1992, SDC-92-201.

2. Calorimeter Conceptual Design, Tile/Fiber Scintillator Option, Sept. 3, 1991.

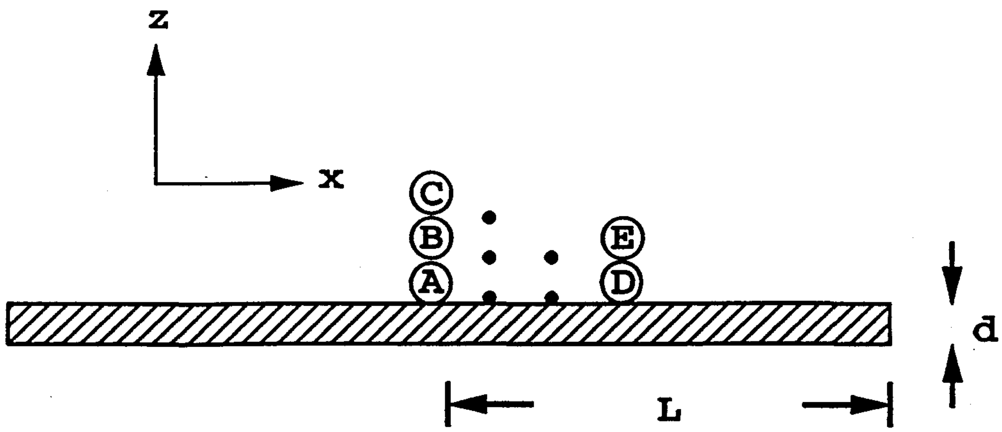
3. C. Blocker, SDC Calorimeter Calibration Requirements, SDC Note.

4. J. Yarba, Presentation to the SDC Calorimeter Group, SSCL, May, 1992.

5. J. Budagov et al., Tile-To-Tile Nonuniformity: How It Affects the Calorimeter Response, JINR, Duba Note.

6. Review of Particle Properties Phys. Rev. D 45 11 (1992).

7. D. Green, J. Hauptman, A. Para, "Radiation Damage, Calibration and Depth Segmentation in Calorimeters, Fermilab FN565, May 1991.

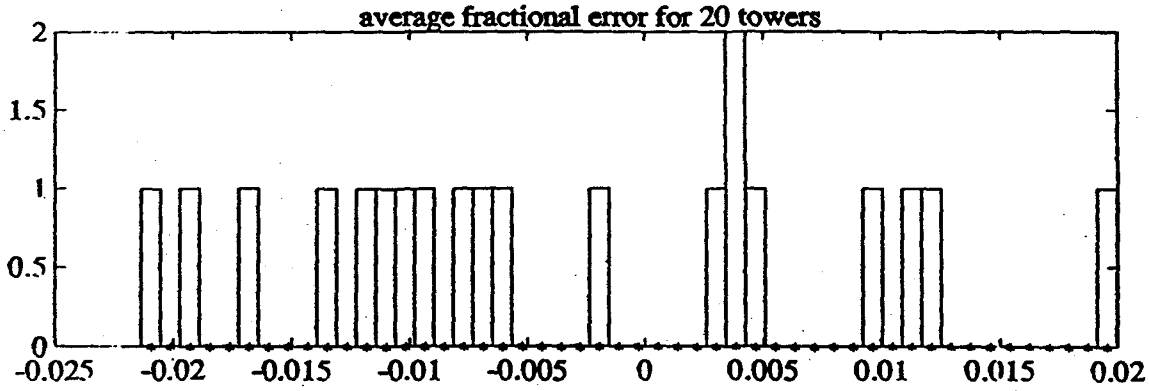


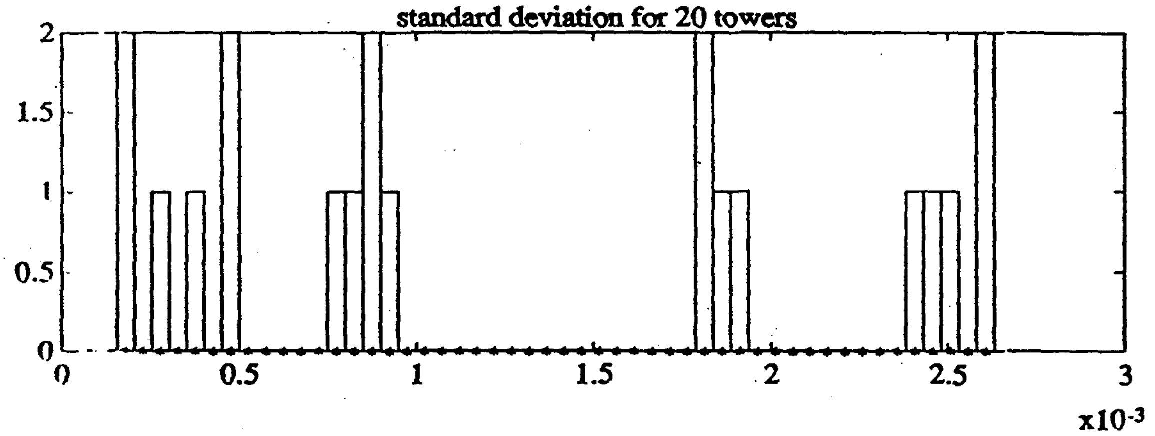
POSITION	PROB	x,y,z(cm)
A	0.0247	0,0,0
B	0.0201	0,0,0.3
C	0.01698	0,0,0.6
D	0.02459	0.5,0,0
E	0.02006	0.5,0,0.3

$$\left(\frac{1}{\mathcal{P}}\frac{\partial \mathcal{P}}{\partial x}\right) \cong 0.06\%/\mathrm{mm}$$

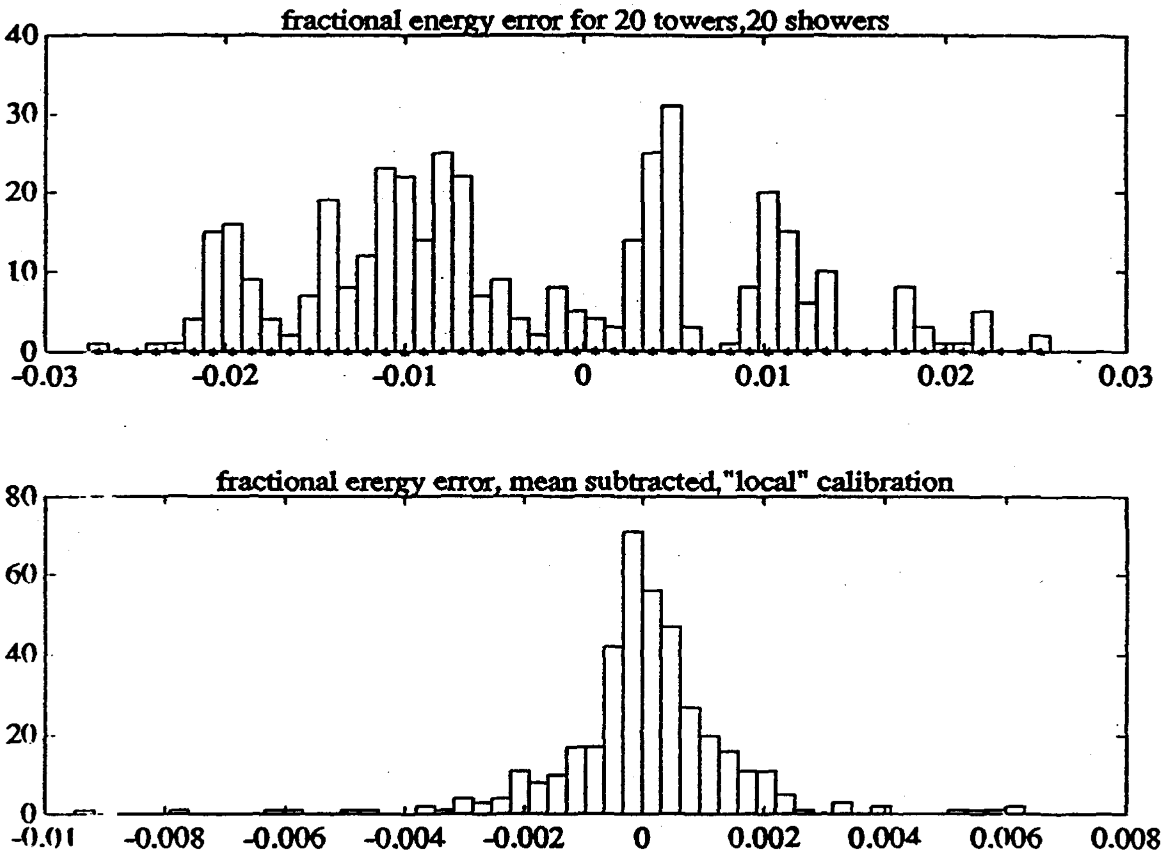
$$\left(\frac{1}{\mathcal{P}}\frac{\partial \mathcal{P}}{\partial z}\right) \cong 6\%/\mathrm{mm}$$

1. Location of the Cs source with respect to the scintillator plate. Also shown are the Monte Carlo values of the response and the derived sensitivity of the response to the source position.

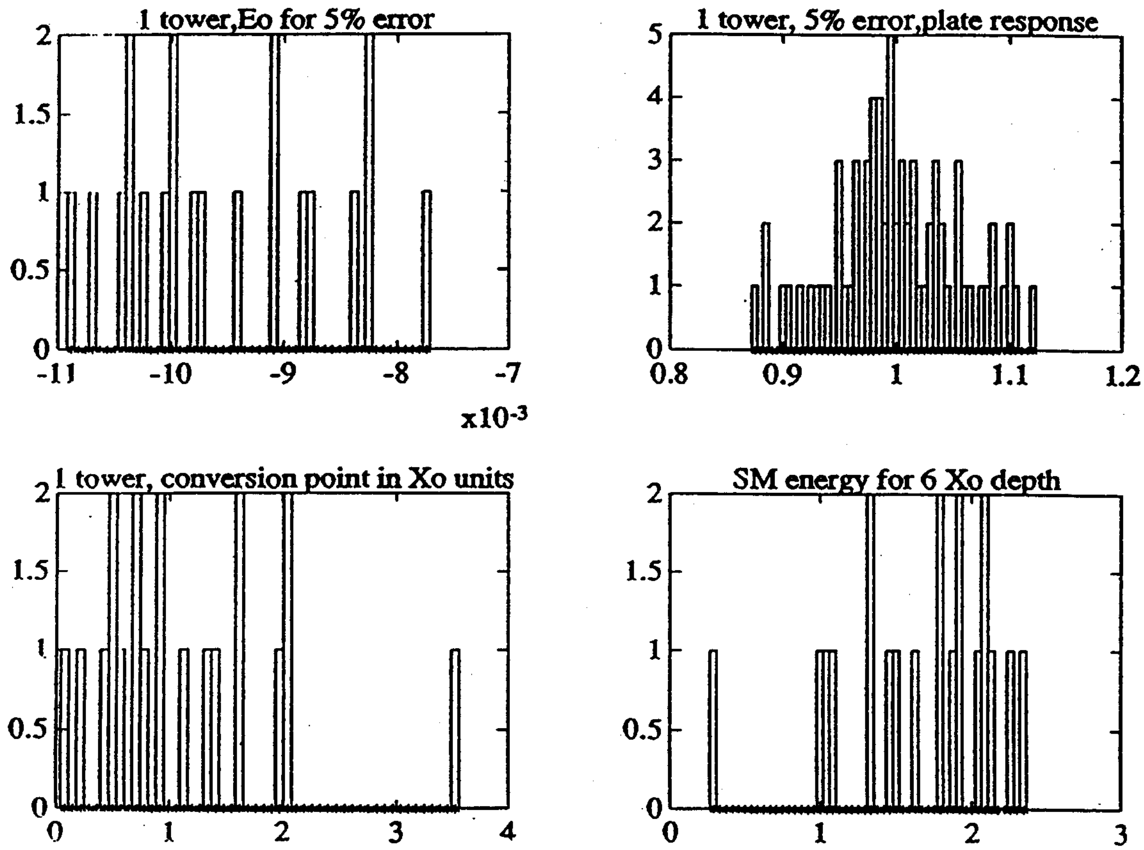




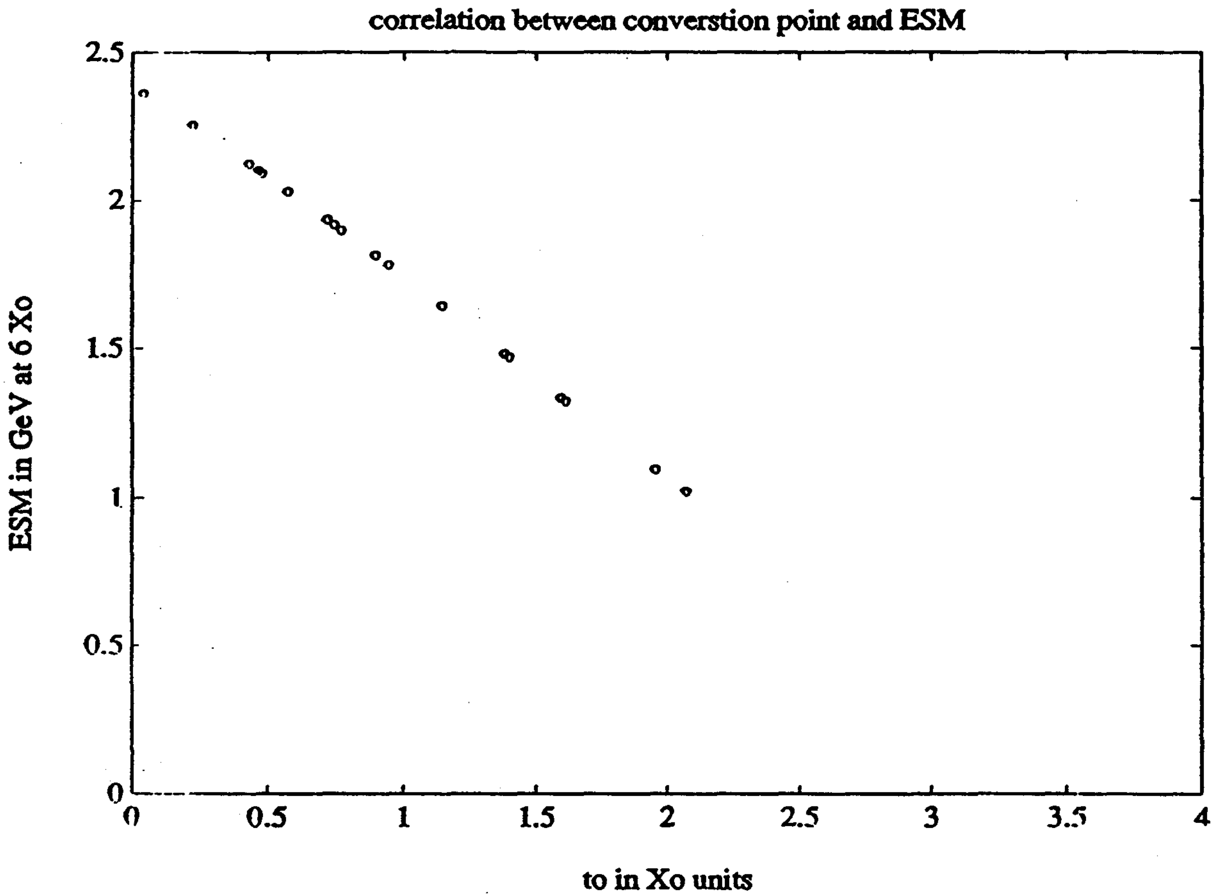
2. a. dE/E mean for 20 towers, summing over 20 showers of 50 GeV. The mean over all towers is -0.0034.
   b. dE/E rms for 20 towers. The mean over all towers is 0.00115.



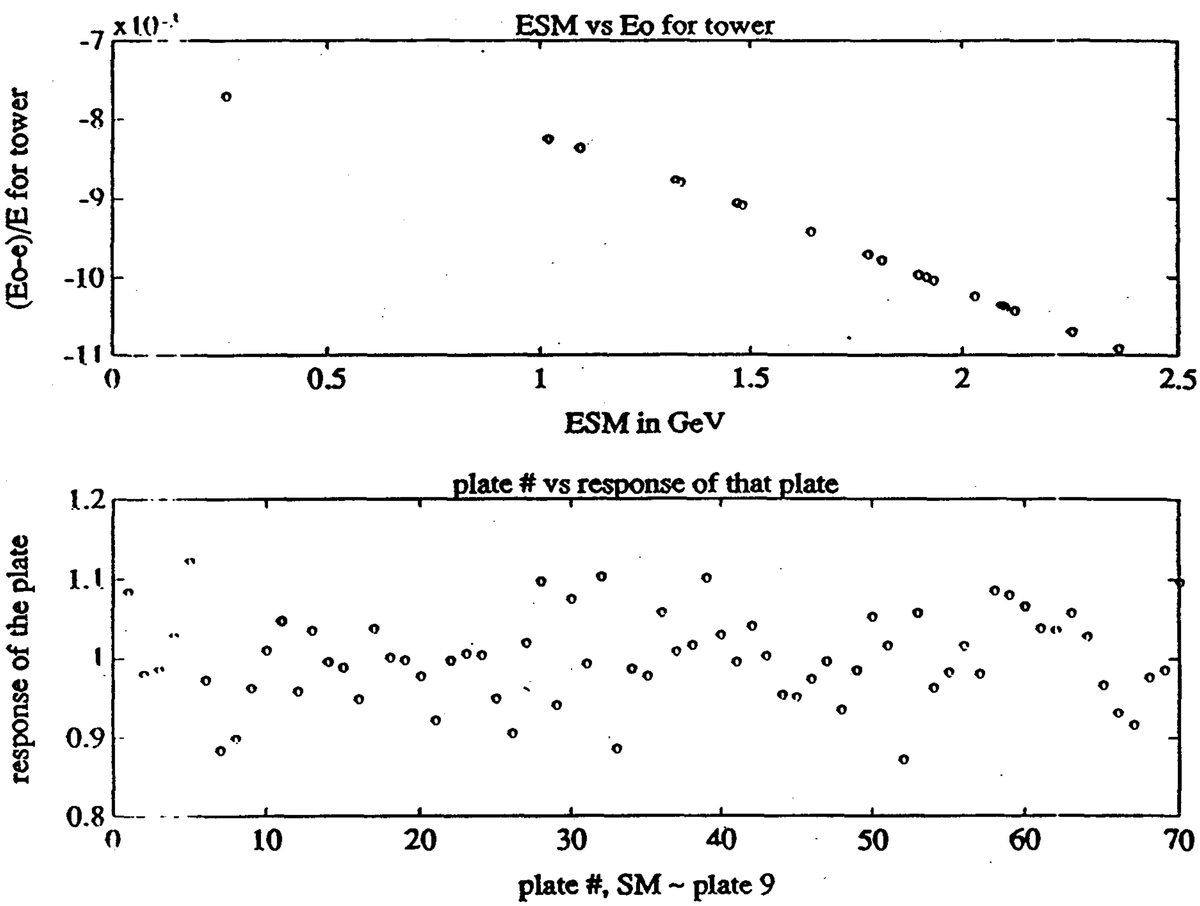
3. a. dE/E for all towers and showers. The rms of this "global" distribution is 0.0113.
b. dE/E for all towers and showers with the mean value of each tower separately, "locally", subtracted. The rms of the "local" distribution is 0.0015 or ~7 times less than that of a.



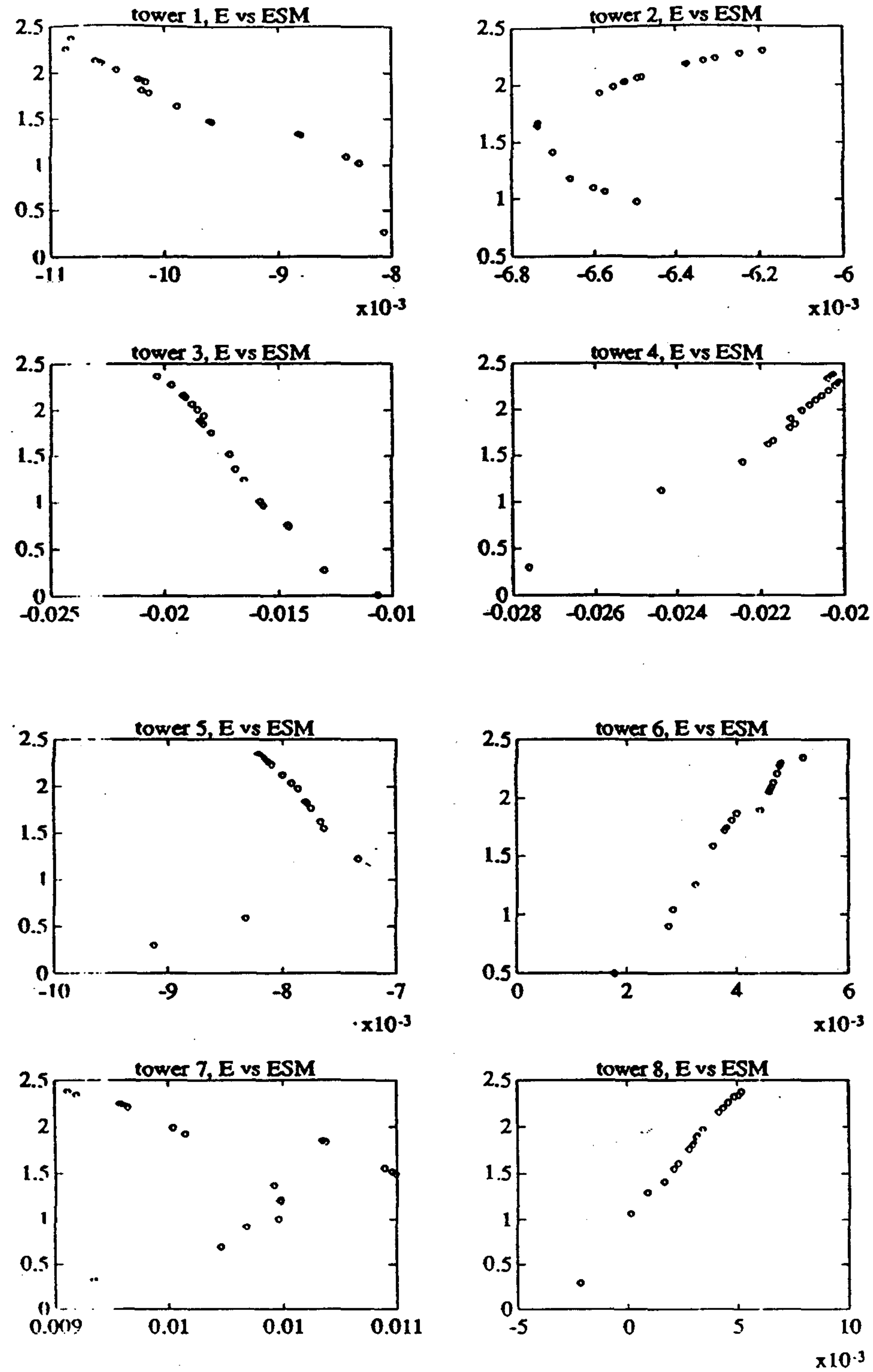
4.
a. dE/E for a single tower.
b. Plate response assuming a 5% rms manufacturing error.
c. Conversion point to for 20 showers.
d. SM energy deposit for 20 showers.



5. Scatter plot of conversion point and SM energy.



6. a. dE/E as a function of SM energy for a particular tower.
   b. Plate response as a function of plate number for the tower used in a.



7. SM energy, ESM, as a function of dE/E for 8 towers randomly "built" with scintillator tiles having a 5% rms response deviation.