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SOLENOIDAL DETECTOR NOTES

EFFECT OF TILE-TO-TILE VARIATIONS AND CALIBRATION IMPERFECTIONS ON THE EM CALORIMETER RESOLUTION

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1 Introduction

This note presents an attempt to study the effect of tile-to-tile variations and imperfections of tower-to-tower calibration on the energy resolution of the SDC EM calorimeter.

GEANT was used to simulate electron showers in a model of the SDC calorimeter assuming several kinds of tile-to-tile variations. The energy resolutions as a function of energy were fit to estimate the constant term.

Section 2 describes GEANT simulation. Section 3 presents the values of constant term induced with tile-to-tile variations that are intrinsic to each tower, and that take into account tower-to-tower intercalibrations. Section 4 discusses tower-to-tower calibration and imperfections of of the calibration coefficient assigned to each tower. Section 5 gives the conclusions.

2 GEANT simulation of EM showers

Two kinds of design were used to study the problem. The calorimeter was assumed to consist of 100 layers in depth . For the first design each layer contained a 0.3175cm lead plate followed by a 0.25cm scintillating plate (Central Calorimeter Conceptual Design Report), and for the second case each layer contained a 0.4cm lead plate and 0.4cm scintillating plate (TDR).

In transverse direction, there were 7x7 towers, each of 10x10cm^2.

There was no material in front of calorimeter. Also there were no cracks between towers, transverse leakage, or longitudinal leakage.

For each tile (total number 49000), a response was randomly selected from a gaussian distribution with mean 1 and width σ_t. Tile-to-tile variations of σ_t=0, 0.05, 0.10 and 0.20 (0, 5%, 10%, 20%) were used.

500 showers induced by e^- were simulated for each value of energy of 2, 5, 10, 20, 50, and $100GeV$. The 'signal' was the energy deposited in the scintillating plates. The energy cutoff in GEANT was $1MeV$ for e^- and $100keV$ for γ.

A center of the calorimeter (actually it was a center of a central tower) was assumed to be the point of e^- beam incidence for studying a contribution to the constant term in the

energy resolution due to 'intrinsic' tower nonuniformity. To study the effect of tower-to-tower intercalibration, points of incidence were randomly chosen within ±30cm in x and y across the calorimeter face (so no transverse leakage was expected).

3 Effect on Energy Resolution

The energy resolution of a real EM calorimeter is usually approximated by a sum

$$\frac{\sigma_E}{E} = \frac{A}{\sqrt{E}} \oplus B$$

where $\oplus$ means a sum in quadrature, A is the stochastic term, and B is the constant term.

The stochastic term is defined by

- shower fluctuations
- sampling rato.

Under the influence of a stochastic type errors the detector response stays gaussian, has no tails, and exhibits a perfect linearity with respect to energy scale.

The constant term reflects the intrinsic imperfections of a calorimeter which induce such effects as

- increased width of a gaussian curve describing detector response
- non-gaussian tails in the response curve
- nonlinearity of the detector response with respect to energy scale.

The effect of tile-to-tile variations is on the constant term.

Here it should be mentioned that the results on the constant term obtained using the two kinds of calorimeter design are in a perfect agreement.

The values of constant and stochastic term were obtained from a fit by a function $A^2 + B^2 E_{e^-}$ of dependense $(\sigma_E/E)^2 E_{e^-}$ vs E_{e^-}.

The values of the constant term induced only due to 'intrinsic' nonuniformity inside a tower are summarized below

$\sigma_t(\%)$	0	5	10	20
$B(\%)$	0.00±0.16	0.35±0.07	0.60±0.08	1.00±0.08

Assuming no tower-to-tower calibration one has

$\sigma_t(\%)$	5	10	20
$B(\%)$	0.95±0.07	1.68±0.07	3.67±0.09

Figure 1 shows a plot of the intrinsic constant term as well as the constant term which accounts for tower intercalibrations as functions of tile-to-tile variations. Linear fits to the data in figure 1 yield intercept of $(0.06 \pm 0.01)\%$ and $(0.00 \pm 0.01)\%$ and slopes (0.049 ± 0.005) and (0.182 ± 0.006).

The stochastic term was obtained $A = (11.76 \pm 0.23)\%$ for the first design (0.3175cm of lead followed by 0.25cm of Scintillator) and $A = (12.00 \pm 0.24)\%$ for the second design (0.4cm of lead followed by 0.4cm of Scintillator).

4 Tower-to-tower calibration

A very simple theoretical methode to set the calibration coefficient for each tower is to calculate a mean response on some 'typical' shower profile (that is an analog of a calibration in the e^- beam).

Let us assume the $10GeV$ e^- shower to be 'typical'. Each tile in stack is characterized by a response coefficient $(C_j)_i$, where j is tower number, i is tile number in a tower. The $(C_j)_i$'s are defined as described in Section 2.

A shower profile is described by formula

$$\frac{dE}{dt} \sim t^a e^{-bt}$$

where t is a depth in units of radiation length, $a = 2.284+0.7134ln(E)$, $b = 0.5607+0.0093ln(E)$, and $E = 10GeV$ as decided above. The calibration coefficient for a tower j is

$$W_j = \frac{\sum_i e_i}{\sum_i (C_j)_i e_i},$$

where $e_i = dE/dt_i$ is the energy deposited in a tile i (in a tower j). Then, $E_{real} = \sum_j W_j E_j$ where E_j is total energy measured in a tower j.

Assuming such an 'ideal calibration' (i.e. all coefficients to be defined exactly) one has

$\sigma_t(\%)$	5	10	20
$B(\%)$	0.46±0.11	0.67±0.08	1.10±0.08

But in a real experimental situation a tower response can is estimated with some precision, i.e. no calibration can be perfect. That means

$$W_j \rightarrow W_j' = W_j * CW_j$$

A reasonable way is to assume CW_j to be randomly selected from a gaussian distribution with mean 1 and σ_{CW}=0.01, 0.02, 0.03 (1%, 2%, 3%) to study the effect of the 'calibration precision' on the energy resolution of the EM calorimeter. The results are summarized below

$\sigma_{CW} = 1\%$

$\sigma_t(\%)$	5	10	20
$B(\%)$	0.98±0.07	1.07±0.09	1.32±0.10

$\sigma_{CW} = 2\%$

$\sigma_t(\%)$	5	10	20
$B(\%)$	1.91±0.08	1.93±0.08	2.26±0.10

$\sigma_{CW} = 3\%$

$\sigma_t(\%)$	5	10	20
$B(\%)$	2.91±0.09	3.02±0.10	3.07±0.10

Figure 2 shows a plot of the constant term as a function of the 'calibration precision' σ_{CW} for 10% intrinsic tile-to-tile variations.

Here it should be pointed out that actually such an imperfection of tower calibration coefficient definition is the same as a precision of measurment of every tile response with a source. For example, assuming the source calibration with a precision of 5% ($\sigma_{source} = 5\%$) and taking into account that actually about 25-30 tiles ($N_{tiles} = 25 - 30$) are involved in the process one get $\sigma_{CW} = \sigma_{source}/\sqrt{N_{tiles}} \approx 1\%$.

5 Conclusions

It's obvious that it's necessary to reduce all contributions to the constant term as much as possible. However, cost and efforts also should be optimized to best acheive our goals.

As the intrinsic constant term is given by

$$B \approx 0.05\sigma_t$$

and the light output variations of the tile/fiber assemblies is 8%, $B \approx 0.5\%$ which is an acceptable level. It means that longitunal masking ***is not necessary to reduce the contribution to the constant term from tile-to-tile variations*** for the EM calorimeter.

However, it's important to study similar effects for the hadron calorimeter. The requirements on the constant term are less severe for the hadron calorimeter but the shower fluctuations are larger, and that might make the constant term more sensitive to tile-to-tile variations.

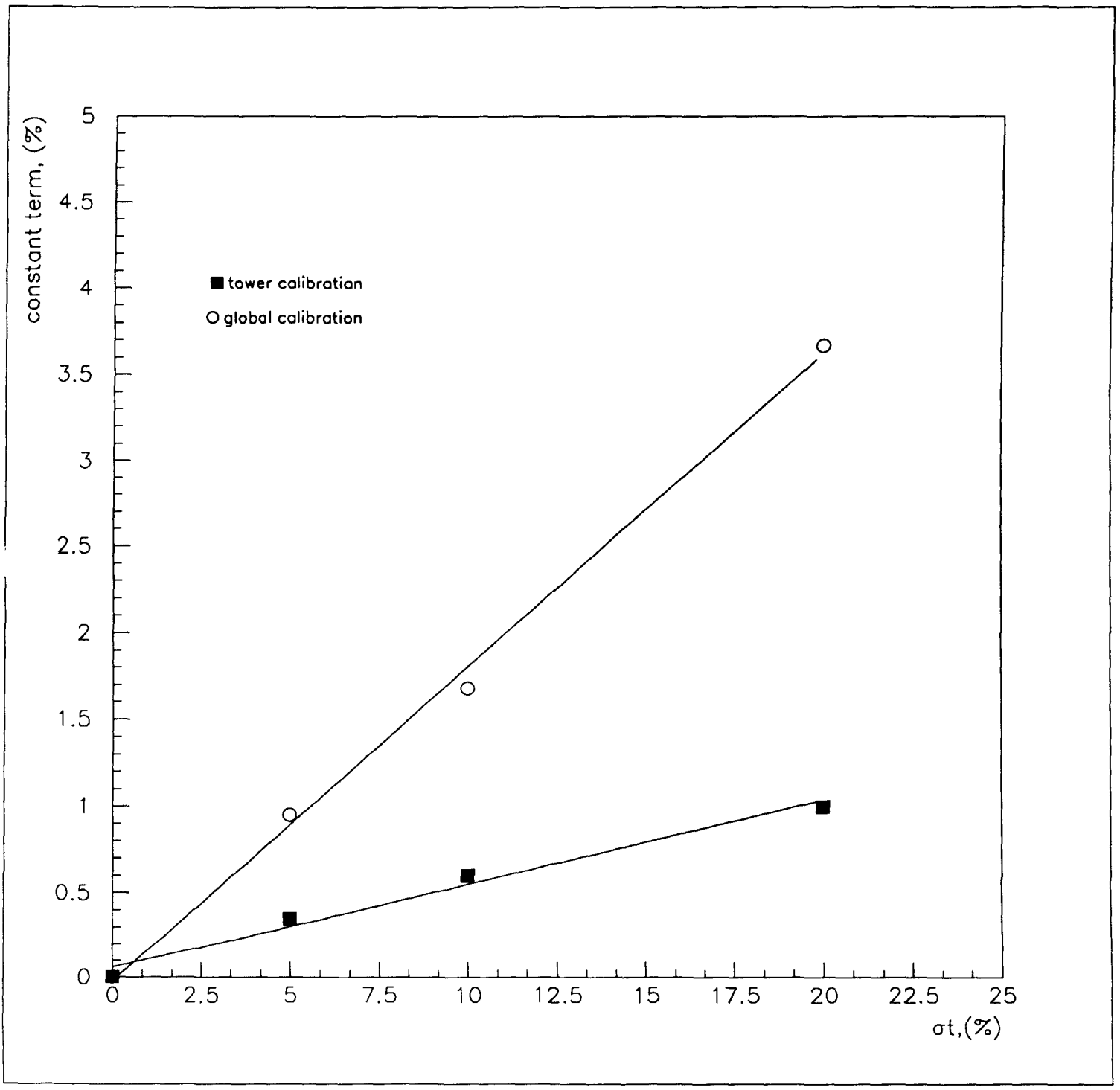
constant term, (%)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
tower calibration
global calibration
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
σt,(%)

Fig. 1

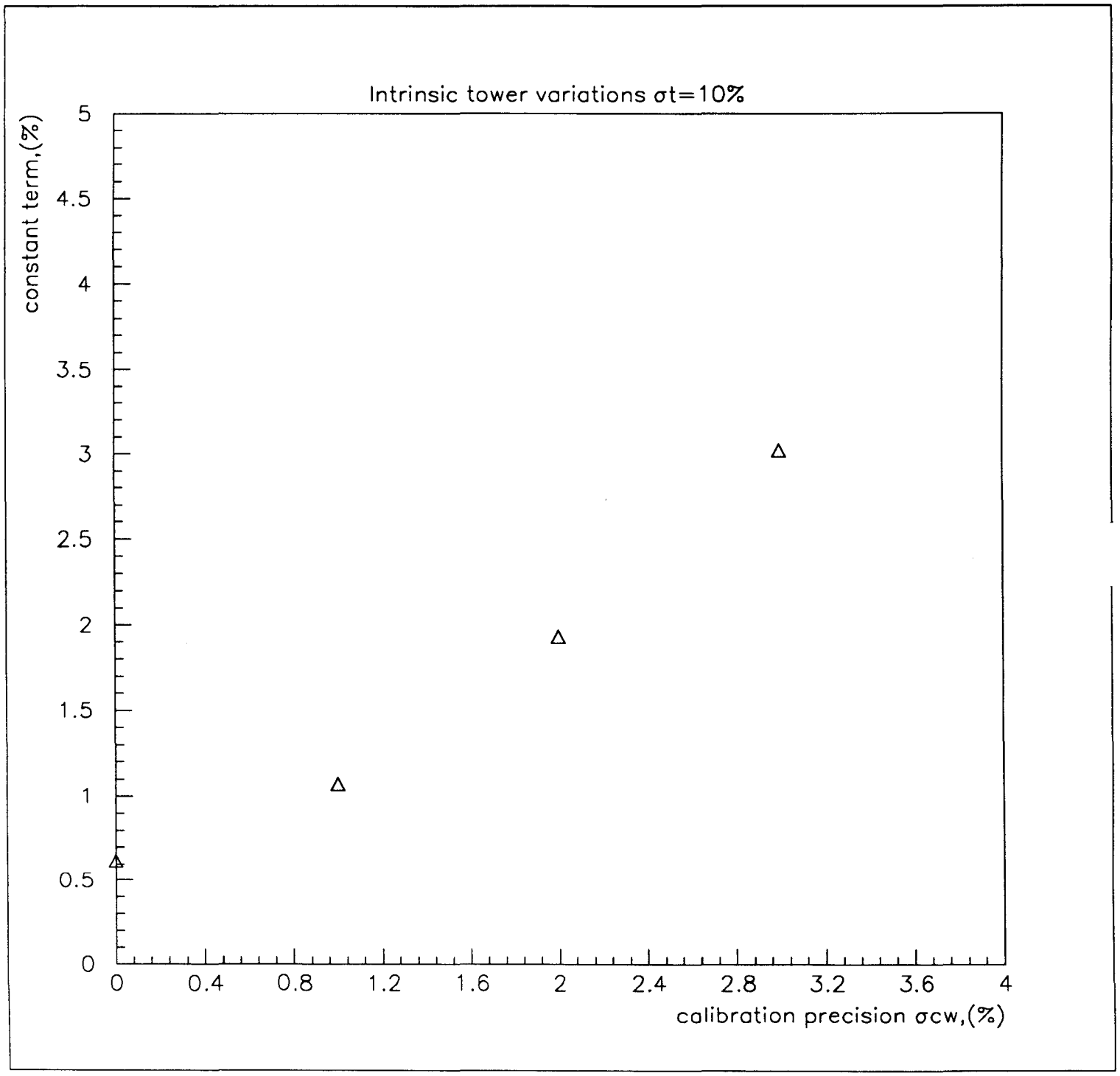
Intrinsic tower variations σt=10%
constant term,(%)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
3.6
4
calibration precision σcw,(%)

Fig. 2