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SDC Preshower Depth and Weighting Factor using Hanging File Data

Dan Green

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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1. Introduction

Often inert material exists in front of a calorimeter. If an electromagnetic (EM) shower initiates in this material, and energy is not sampled by the calorimeter, then energy resolution will be degraded. It is crucial to minimize the amount of inert material. Algorithms using a separate readout of the energy early in the shower (a "preshower" detector) can also be used to alleviate the reduced performance [1].

This problem has previously been studied using CDF test beam data [2]. In addition, an EGS simulation was used to look at the methods of using the preshower (PS) readout to reduce the energy error [3].

2. Induced Energy Error and Inert Material

For this study, test beam data using the Hanging File (HF) apparatus was used [4]. The HF stack consisted of 40 plates of 1/8" Pb, followed by 55 plates of 1" Fe. Each depth layer (95) was read out by a distinct phototube and ADC channel. The data used in this study consists of the subset of HF data with 170 GeV electrons incident on the stack [5].

The effect of inert material in front of an EM calorimeter can be simulated using HF data by dropping a variable number of layers from the EM energy sum. In what follows, n refers to the number of layers which are dropped from the sum (E). The "preshower energy" (Eps) is defined to be the energy sampled at depth n. Hence, Eps samples the energy of the EM shower as it exits the inert material which consists of n plates, or ~ n/2 radiation lengths (Xo) of material.

The first 2 moments of the energy distribution of the EM calorimeter are shown in Fig. 1 as a function of the number of dropped layers, n. In Fig. 1a the mean is seen to drop smoothly, exhibiting an ~ 9% drop if the number of layers dropped is 8. The full EM stack exhibits a 1.5% fractional energy error. That error was unfolded in quadrature from the observed fractional energy error in Fig 1b. The "induced" error reaches 0.5% at depth n = 4. This error exceeds the SDC requirements [1], and indicates that ~ 2 Xo of inert material in front of an EM calorimeter leads to unacceptable degradation in performance if it were to remain uncorrected.

3. Preshower Correction to EM Energy

The energy at plate n, (Eps), can be used to alleviate this problem. Shown in Fig. 2a is the mean of Eps, while Fig. 2b contains the rms of Eps as a function of the location, in depth, of the preshower sample. Since n = 1 has only 1 Pb plate proceeding it, the energy in the

PS sample is small. Both the mean and rms of the PS sample rise rapidly with the depth location of the sample.

Clearly, the total energy sum downstream of the PS sample (E), and the PS energy sample (Eps) are expected to be correlated. That correlation is shown in Fig. 3 for four depth locations of the PS sample. Obviously, the correlation increases with PS depth.

The PS energy can be added into the total energy sum. Since the sampling fraction for the PS is not necessarily that of the rest of the EM calorimeter, the PS sample is added in with an arbitrary weight, WT.

$$E' = E + WT * Eps \tag{1}$$

The obvious limiting case is a PS at depth, n = 1. When added to the EM energy sum with WT = 1, the original HF stack is obtained. The fractional energy error for that case, 1.5%, is unfolded in quadrature from the observed fractional energy error to yield the induced energy error. That quantity is plotted in Fig. 4 and Fig. 5 as a function of the weight factor, WT, for four different depth locations of the PS sample.

Clearly, the optimal weight changes with depth of the PS sample. As noted above, for n = 1, the optimal WT is = 1, by definition. At plate depth = 2, 4, 6, 8 the optimal weight is, roughly, WT = 1, 1.5, 2.25, and 3.25 respectively. Note also that the SDC requirement of < 0.5% induced error can be maintained up to n = 6, or ~ 3 Xo of inert material upstream of the PS sample.

The induced fractional energy error (in %) as a function of the PS depth sample location is shown in Fig. 6 to summarize the uncorrected error and the corrected error at optimal PS weight, WT. Clearly, the uncorrected errors exceed 0.5% at ~ 2.2 Xo, while the correction allows one to go to ~ 3.5 Xo before the error exceeds 0.5%.

References

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2. D. Green, "Effect of Inert Material on ZZ Mass Resolution for H → ZZ → eeee", Fermilab-TM-1736, SDC-92-00025, April 1991.

3. J. Marraffino et al., " 'Massless Gaps' for Solenoid Plus Calorimeter", Fermilab-TM-1766, November 1991.

4. A. Beretvas, et al., "Beam Tests of Composite Calorimeter Configurations from Reconfigurable-Stack Calorimeter", accepted by Nuc. Inst. Meth.

5. A. Byon, private communication.

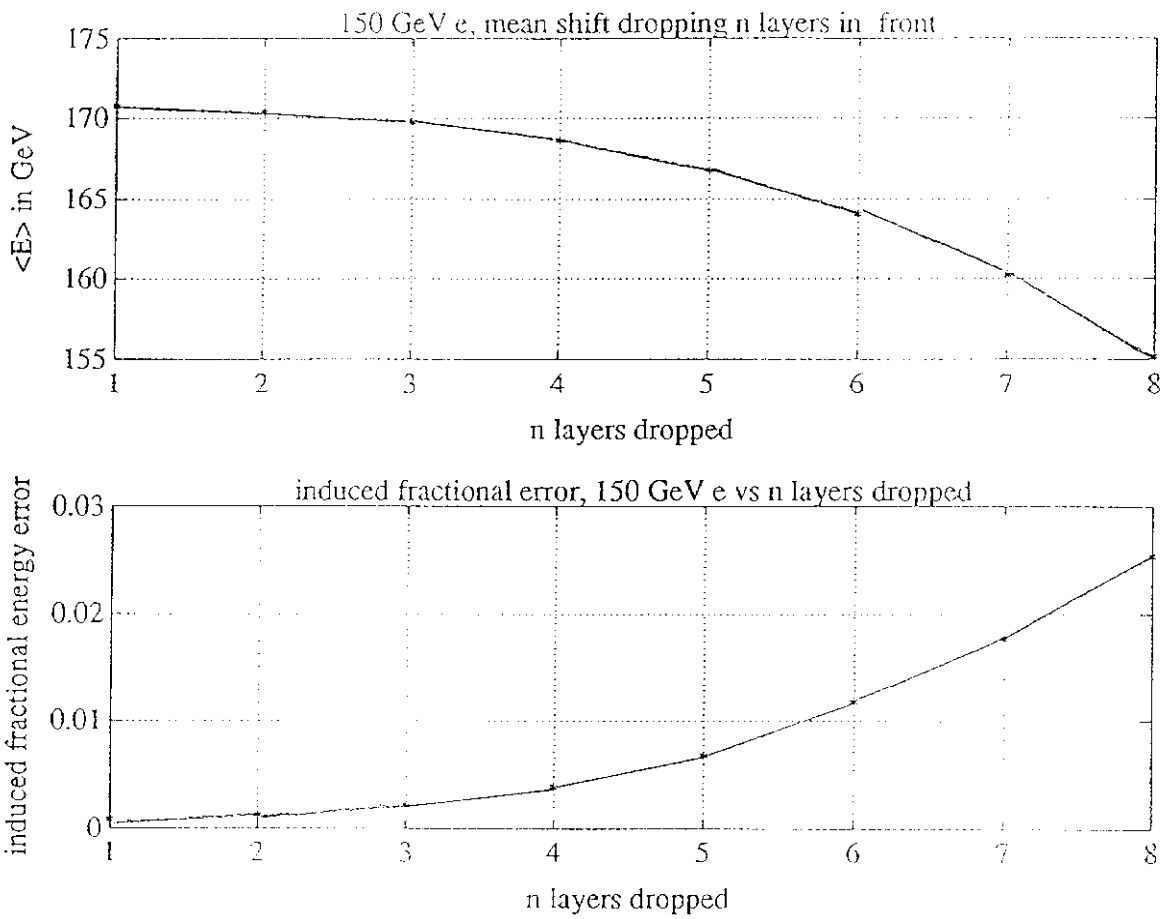


Fig. 1 HF data with 170 GeV incident electrons. The HF stack consists of 40 Pb plates 1/8" thick followed by 55 Fe plates 1" thick. The stack is degraded by removing n front samples from the energy sum. The sample at depth n is defined to be Eps = the preshower energy.

a. Mean energy observed in the truncated stack as a function of n.

b. Additional fractional energy error induced by stack truncation vs n.

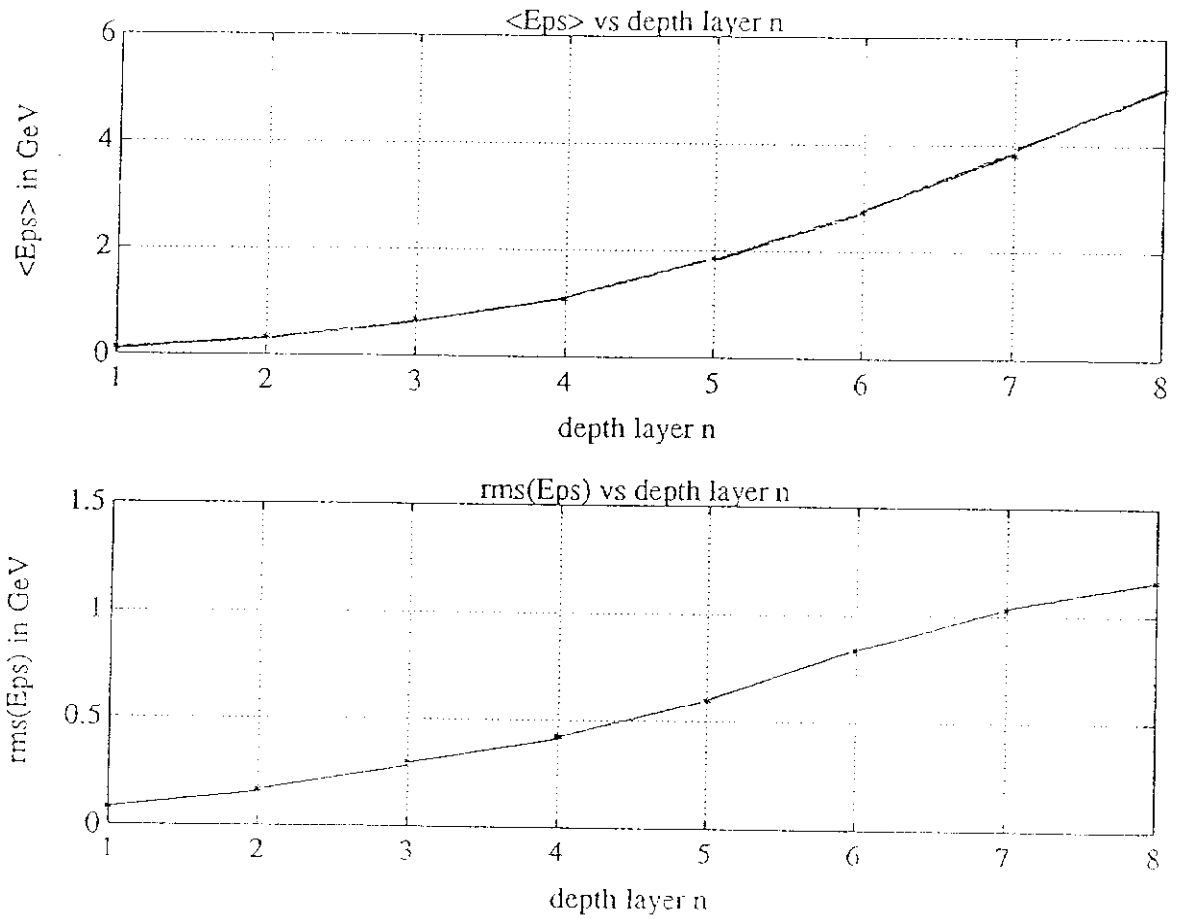


Fig. 2 HF data with 170 GeV incident electrons. The truncated stack is defined as in Fig. 1 by the number of inert layers = n.
a. Mean energy in depth sample = n, defined to be the preshower energy.
b. Rms of the energy at depth sample = n.

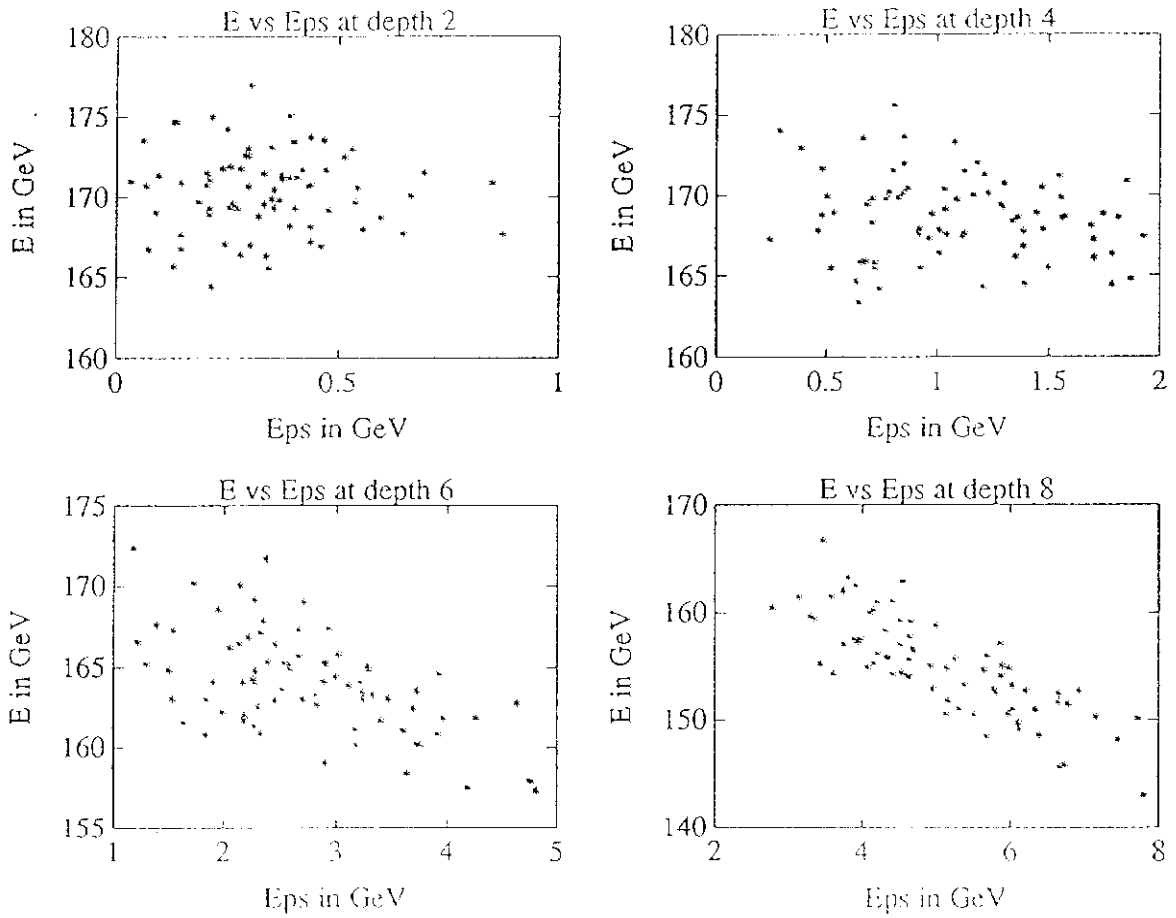


Fig. 3 Correlation between the energy observed in a truncated HF stack with n plates dropped from the energy sum and the energy observed at depth n.

a. 2 plates of inert material, ~ 1 Xo.
b. 4 plates of inert material, ~ 2 Xo.
c. 6 plates of inert material, ~ 3 Xo.
d. 8 plates of inert material, ~ 4 Xo.

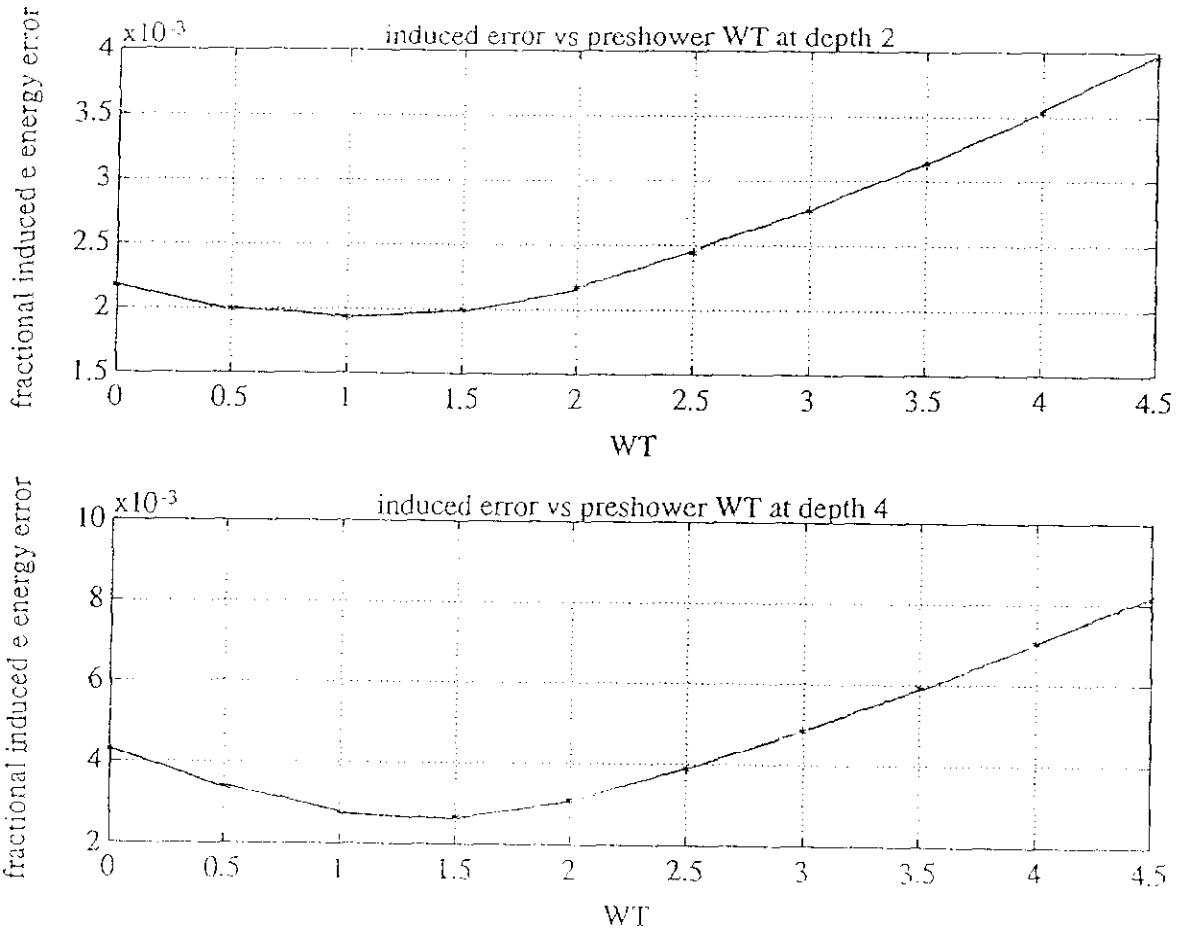
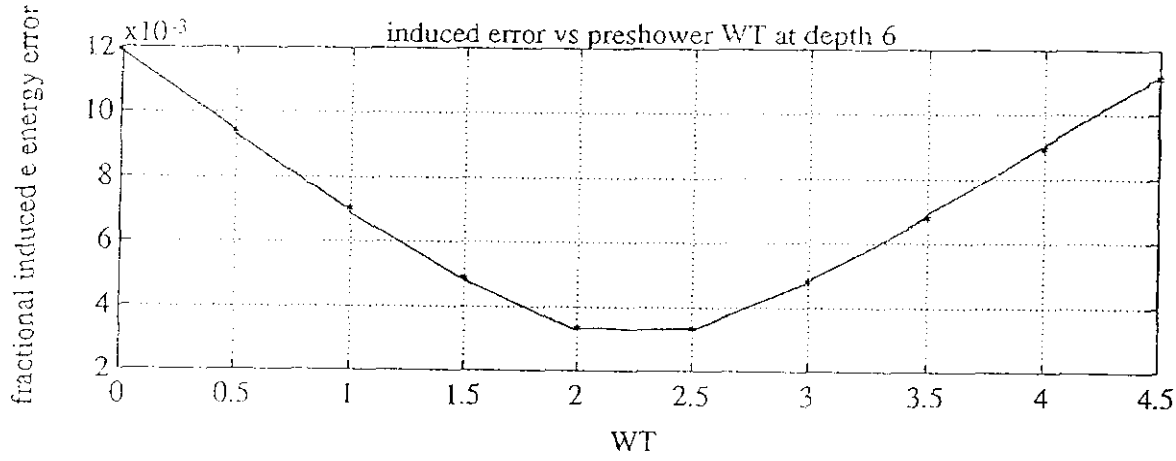


Fig. 4 Additional fractional energy error induced by stack truncation as a function of the weight factor applied to the preshower energy = Eps.

a. preshower at depth = 2, ~ 1 Xo.

b. preshower at depth = 4, ~ 2 Xo.



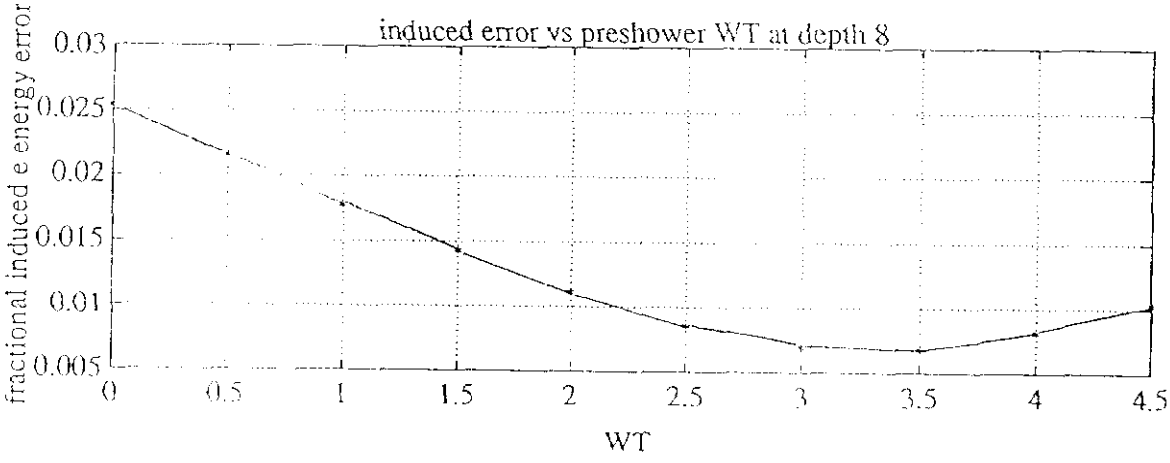


Fig. 5 As in Fig. 4 except for the depth of the preshower sample.
a. preshower at depth = 6, ~ 3 Xo.
b. preshower at depth = 8, ~ 4 Xo.

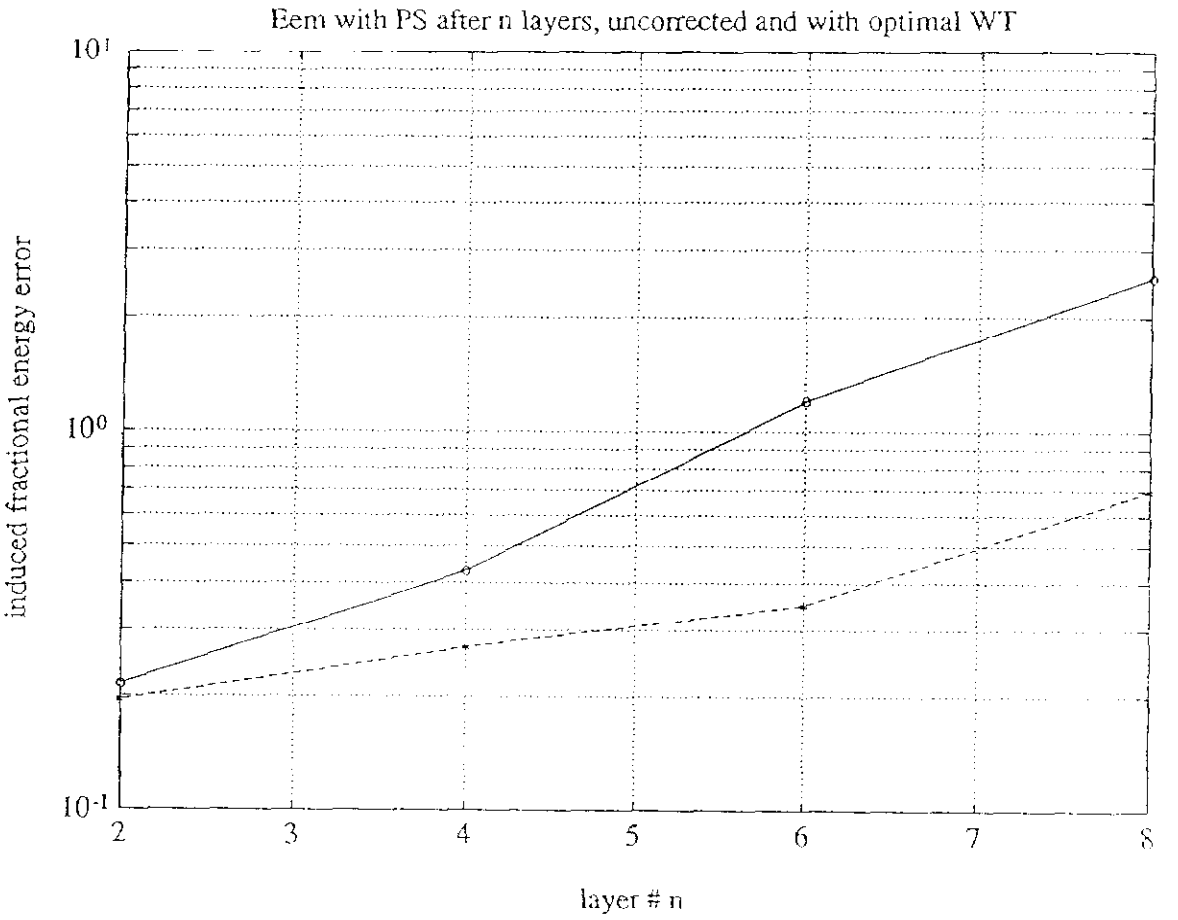


Fig. 6 Additional fractional energy error (in %) induced by stack truncation as a function of the depth of the truncation in plate number = n for 170 GeV e. The solid line represents the uncorrected error, while the dashed line represents the minimum error obtained by optimal weighting of the preshower energy in the total energy sum.