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SDC
SOLENOIDAL DETECTOR NOTES

IMPACT OF TRACKNG MATERIAL ON ELECTROMAGNETIC CALORIMETER CALIBRATION

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1 Impact of Tracking Material on Electromagnetic Calorimeter Calibration

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The large cross section for Z production at the SSC provides many electrons for use in a tower-by-tower calibration of the EM calorimeter. Although it may be possible to perform the calibration using only the measured electron energies to reconstruct the Z mass, the simplest method will be to calibrate the calorimeter to the tracking system by using E/p. The material in the tracking volume produces Bremsstrahlung, which modifies the measured electron momentum and possibly the calorimeter energy. This section quantifies the subsequent impact on detector calibration.

1.1 Simulation Description

The tracking system and other material used in the simulation are summarized in Table 1. The "internal Bremsstrahlung" of the Z decay is equivalent to $0.025X_0$ and is included in the beampipe material. Several variations of this base design are considered, but the number of tracking layers and the tracking resolution is held constant in all cases.

Table 1. Material in the tracking volume, baseline.

	Radius (cm)	Tracking Layers	Thickness (X_0)
Beampipe	4–5	0	0.029
Silicon	6–41	8	0.051
Outer Tracker	68–164	7	0.086
Total		15	0.166

The two components of the E/p measurement—momentum and energy—have been handled differently. EGS has been used to track electrons and photons in the 2T solenoid field until they reach the coil. The position of the highest p_t electron is recorded at each tracking plane and the transverse momentum is extracted by a

circular fit. The effects of multiple scattering and Bremsstrahlung are simulated by EGS and, therefore, are included in the fit; detector resolution is included by an explicit Gaussian smearing, where $\sigma_{p_t} = 0.00015 p_t^2$ (p_t in GeV).

The energies of electrons and photons reaching the coil are smeared with a calorimeter resolution of $13\%/\sqrt{E_t}$, then distributed among the 0.05×0.05 towers using a parameterized shower generator. The assumption in this calculation is that the calorimeter includes massless gaps or is otherwise capable of correcting for energy lost in the coil; a 40 GeV electron incident on the coil is measured in the calorimeter as having 40 GeV.

Forty GeV transverse momentum electrons have been simulated for $|\eta| < 0.3$ and for all values of phi. The detector material has been thinned at larger η to ensure that all particles traverse the same material thickness. The thinning is less than 5% for $|\eta| < 0.3$. The selected p_t is typical for electrons from Z decays. Bremsstrahlung effects are greater for low momentum (~ 10 GeV) tracks, but the Z rate is sufficiently high that these tracks will not be needed for calibration.

1.2 Impact on E/P

Even a perfectly calibrated detector will measure an E/p distribution with a peak greater than 1.0. The true E/p distribution is peaked at 1.0 with a high side tail from Bremsstrahlung (the tracker measures only the electron p_t while the calorimeter measures both the electron and photon energies). The convolution of the true distribution with the detector resolution shifts the peak to a higher values. The size of the shift depends on the amount of Bremsstrahlung, the momentum and energy resolutions, and on the cell size used to enclose the EM shower energy. This analysis uses a 0.1×0.1 cell consisting of four 0.05×0.05 towers.

Figure 1 shows the E/p distribution for the standard amount of material (case A) and for three times this amount (case C). The curves are Gaussian fits to the region [0.90,1.07]. The various cases studied are summarized in Table 2. Figure 2 shows the peak value of E/p as a function of total material thickness. Note that although the distribution of material is different in each case, the peak E/p depends approximately linearly on the amount of material. The calibration relies on knowing the correct value for the peak; the material thickness preceding a tower must, therefore, be known to within $0.05X_0$ to ensure a systematic calibration error of less than 0.2%. Given that the total thickness at $\eta = 0$ is $0.166X_0$, this accuracy should be achievable from blueprints.

Table 2. Description of the different cases studied.

Case	Thickness (X_0)	Description
A	0.166	Baseline
B	0.332	Twice baseline
C	0.498	Three times baseline
D	0.140	Silicon 50% thinner
E	0.123	Outer tracker 50% thinner
F	0.097	Tracker 50% thinner

1.3 EM Calorimeter Calibration

As shown in Fig. 1, extra material results in a wider E/p peak containing fewer events. More luminosity is required to achieve the same statistical error on the calibration. A calibration procedure using E/p has been simulated to analyse this effect.

Forty GeV electrons are simulated using EGS and parameterized showers as described above, except that a "calibration error" (α_{cal}) is applied to each tower before the four-tower sum is performed. The value of (α_{cal}) for each tower is selected from a Gaussian distribution of mean 1 and sigma 0.02. Varying the sigma from 0. to 0.06 does not significantly change the results given below.

Electrons with measured E/p between 0.90 and 1.07 are used. Although the measurement reflects to some extent the response of four different towers, the electron is assigned to the tower with the highest energy. The correction for each tower is selected to give the correct value for the average E/p for electrons assigned to that tower. The averages for the towers are not independent, so several iterations are required to obtain a consistent set of correction factors, α_{cor}. The error in the correction is $(\alpha_{cor} - \alpha_{cal})/\alpha_{cal}$. The rms of this quantity—the calibration error—is plotted in Fig. 3 as a function of the number of electrons in each tower (N_e), for cases A, B, C, and F. This is total number of electrons, not just those with $0.90 < E/p < 1.07$. The errors scale as $1/\sqrt{N_e}$.

The number of electrons per tower required to achieve a calibration error of 0.3% increases approximately exponentially with the amount of preceding material (Fig. 4). The specific values are N_e = 180, 220, 520 and 950 for cases F, A, B and C. The expected rate of $p_t > 20$ GeV electrons from Z decays is 3000 per tower per year, with a factor of 2 uncertainty. Thus, two months is sufficient to accumulate the required data for thicknesses up to twice that in the standard $\eta = 0$ case and four

months for three times ($0.5X_0$). Electrons from W decays are produced at a rate approximately five times higher, but may be more difficult to trigger on.

1.4 Summary

The material in the tracking volume does not seriously impair the calibration of the calorimeter. The amount of material preceding each tower must be know to within $0.05X_0$ to establish the correct peak value of E/p. The calorimeter is calibrated by ensuring that the average E/p is correct for each tower individually. The number of electrons required increases exponentially with the amount of material, but remains at a reasonable level for up to $0.5X_0$, the maximum thickness in the baseline design.

Figure Captions

Fig. 1. Observed E/p distribution for (a) the baseline tracking system at $\eta = 0$ ($0.166X_0$), and (b) three times this thickness. The curves are Gaussian fits to the region $0.90 < E/p < 1.07$. Fig. 1a and 1b do not correspond to the same luminosity.

Fig. 2. Peak value of E/p as a function of material thickness for the six cases listed in Table 2. The dashed line has slope $0.043/X_0$.

Fig. 3. Tower-to-tower calibration error vs number of electrons per tower. Lines are of the form $\beta/\sqrt{N_e}$. Dashed is case F (half tracker-material), $\beta = 0.040$; solid is case A (baseline), $\beta = 0.046$; dotdashed is case B (twice baseline), $\beta = 0.068$; dotted is case C (three times baseline), $\beta = 0.093$.

Fig. 4. Number of electrons required to achieve 0.3% relative calibration vs preceding material thickness. The four points correspond to cases F, A, B and C. The dashed line is $N = 116 \cdot e^{X/0.234}$.

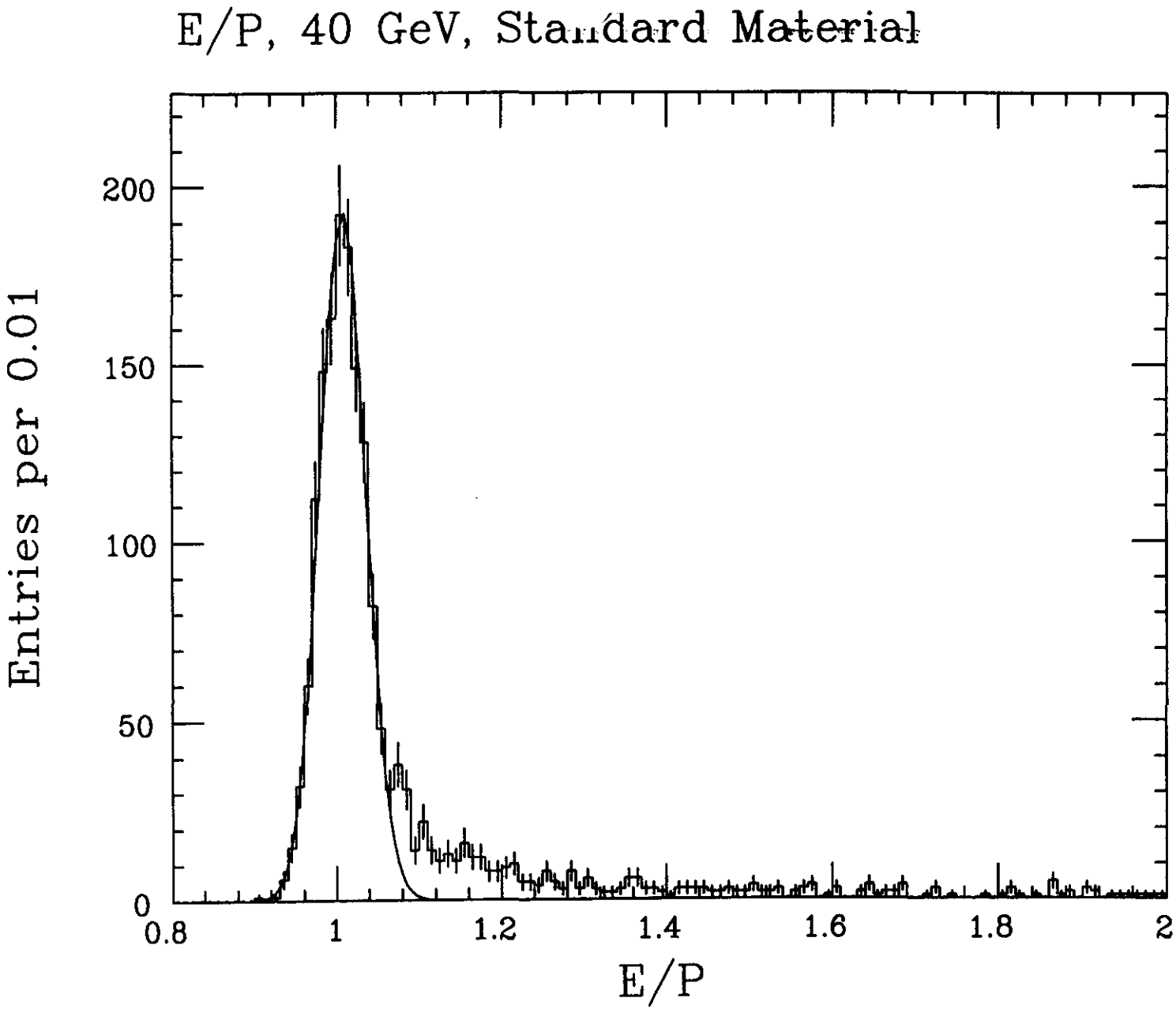
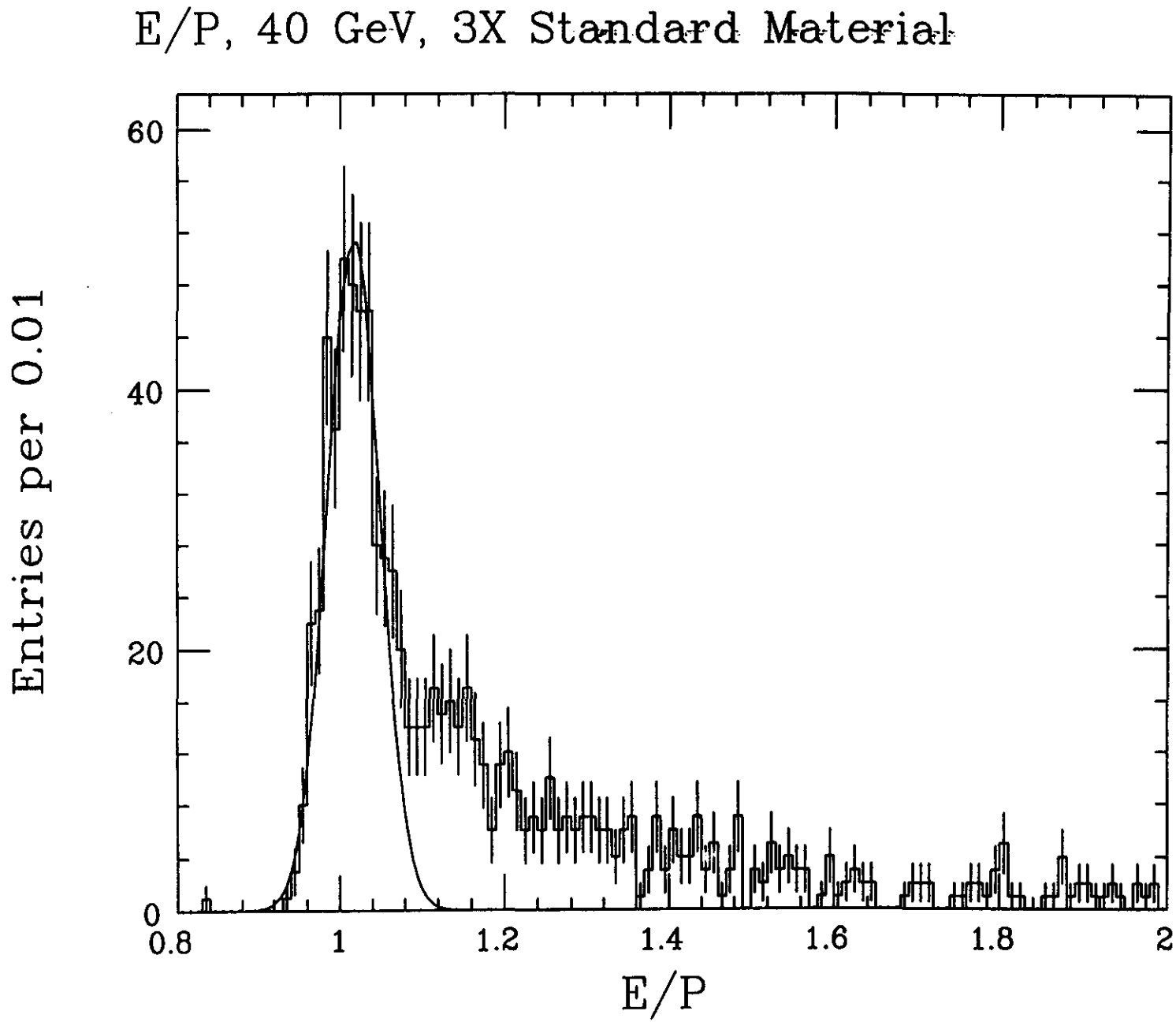

E/P, 40 GeV, Standard Material
Entries per 0.01
200
150
100
50
0
0.8
1
1.2
1.4
1.6
1.8
2
E/P

Fig. 1a


E/P, 40 GeV, 3X Standard Material
Entries per 0.01
60
40
20
0
0.8
1
1.2
1.4
1.6
1.8
2
E/P

1b

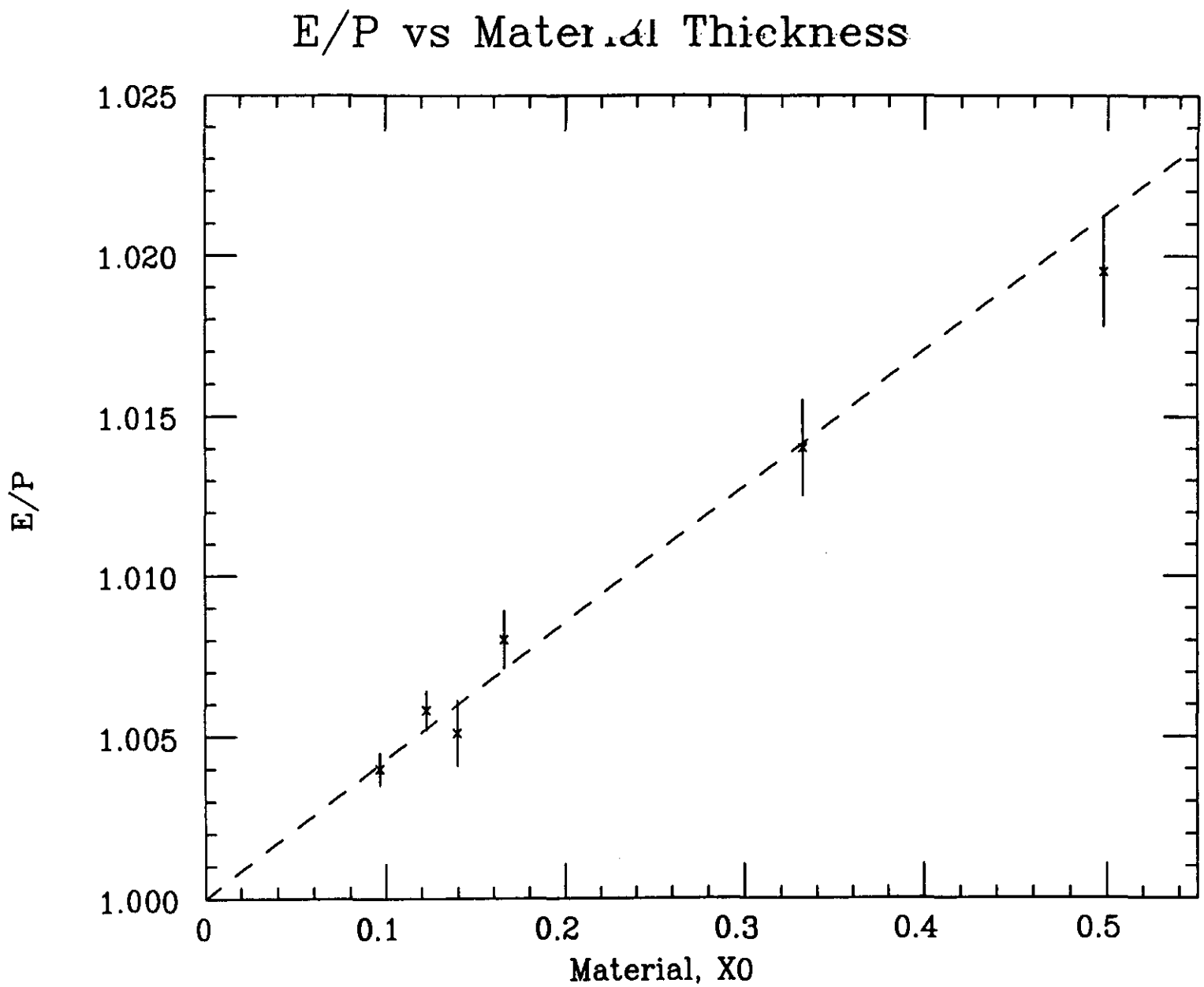

E/P vs Material Thickness
1.025
1.020
1.015
1.010
1.005
1.000
E/P
0
0.1
0.2
0.3
0.4
0.5
Material, X0

Fig. 2

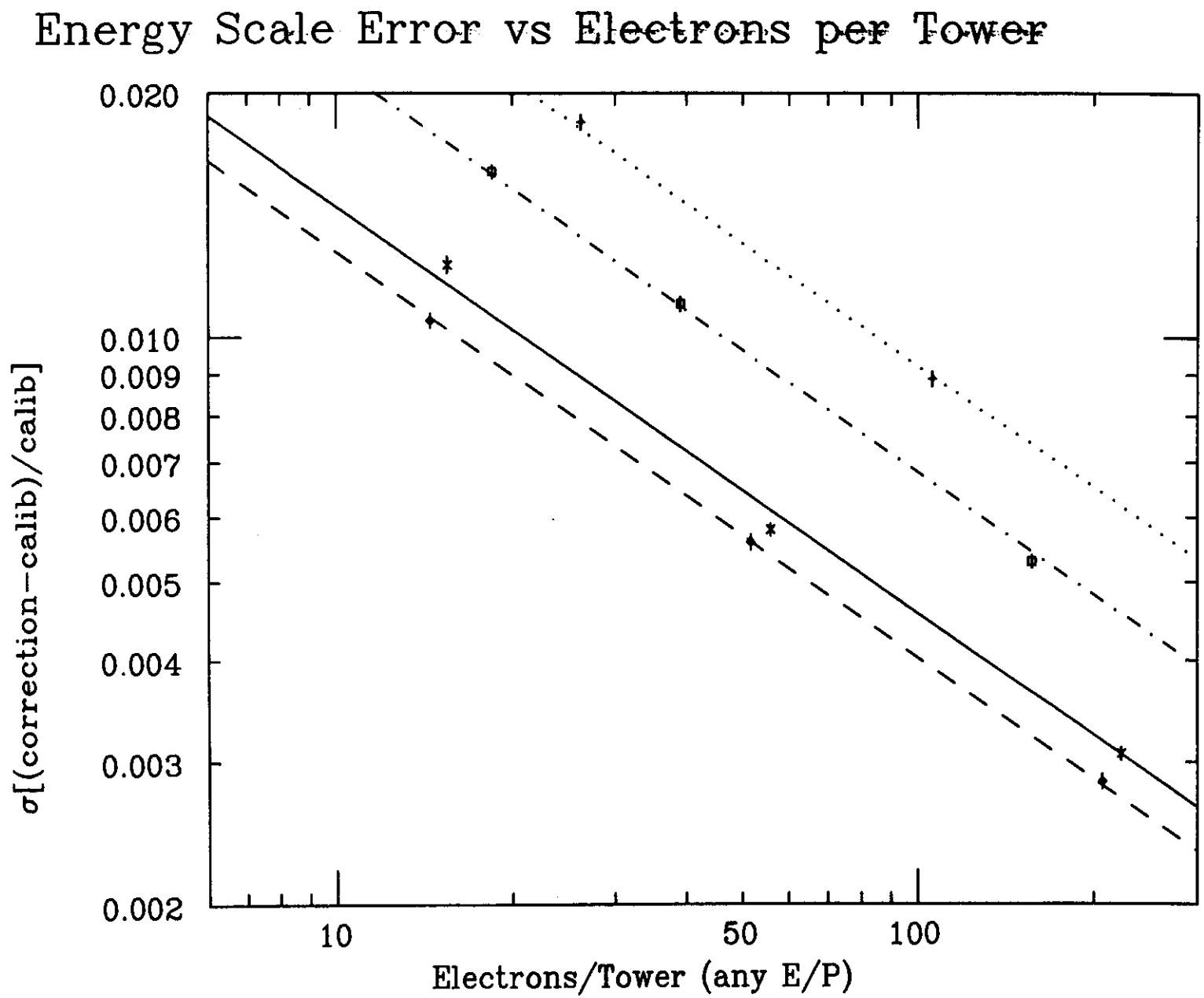

Energy Scale Error vs Electrons per Tower
0.020
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
σ[(correction−calib)/calib]
10
50
100
Electrons/Tower (any E/P)

Fig. 3

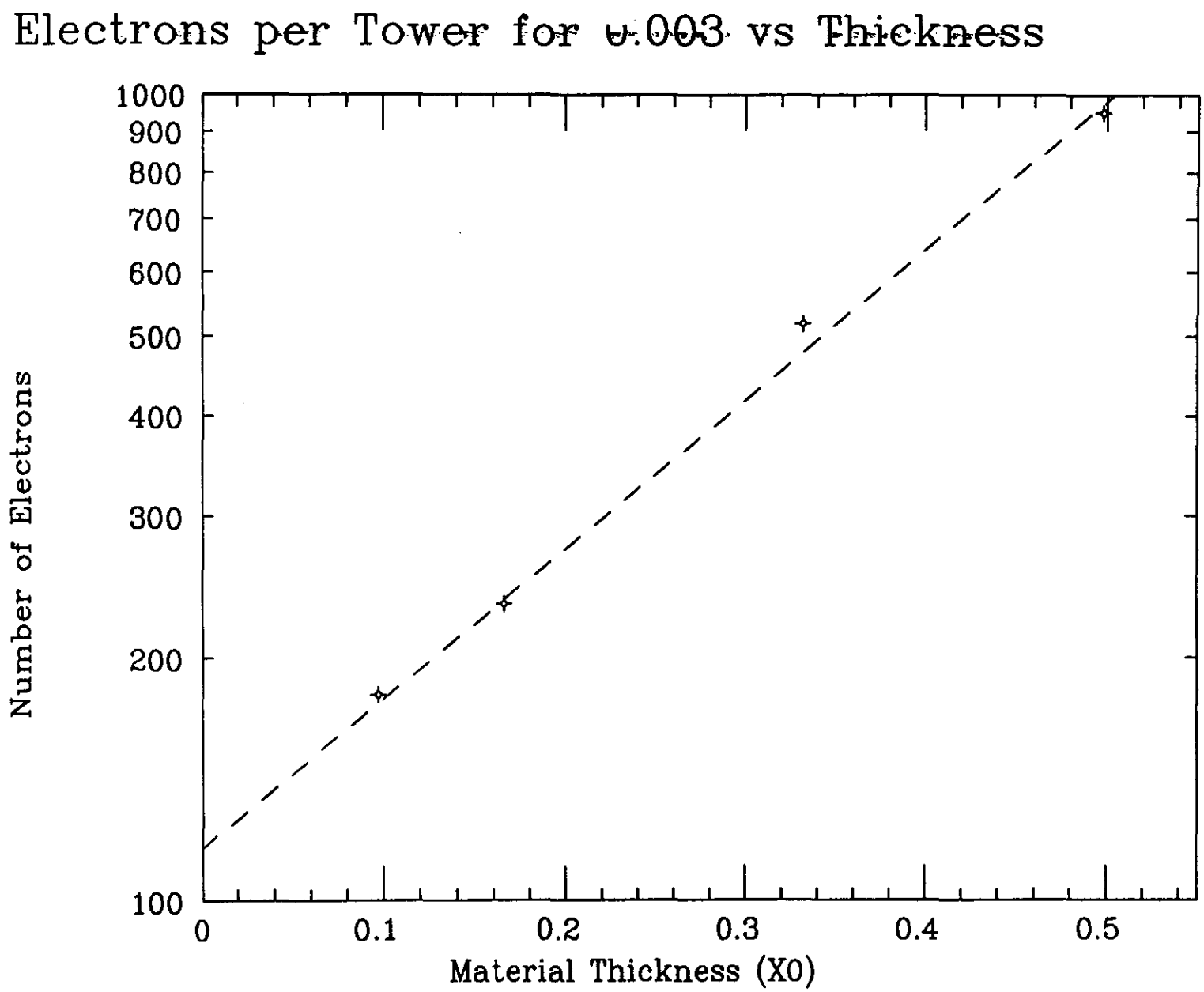

Electrons per Tower for 0.003 vs Thickness
Number of Electrons
1000
900
800
700
600
500
400
300
200
100
0
0.1
0.2
0.3
0.4
0.5
Material Thickness (X0)

Fig. 4