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A Plan for In Situ Calibration of the DØ Calorimeters

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ABSTRACT An overview of a self contained plan for calibrating the DØ calorimeters using collider data is presented. The scheme first obtains the relative calibration using phi symmetry and then calibrates the electromagnetic shower counters with various resonances. The problems of calorimeter modules being radially displaced from the beam axis is discussed. It is shown that radial displacements of up to a centimeter produce insignificant biases (less than 0.5%) in the Central Calorimeter. The End Calorimeters are more sensitive to radial displacements but a linear expansion in radial displacement of the expected energy distribution is derived. This formula is suitable for correcting known displacements out to eta=3.5 or alternatively surveying the detector using these large eta towers. A detailed discussion of using "high energy" pi0's (~ 4 GeV) to calibrate the electromagnetic sections is included. The direct photon method of transferring the EM calibration to hadronic towers is presented. It is shown that this method can be used to determine the absolute jet energy to between 2 and 3% and is insensitive to fragmentation schemes. There are also indications that the calibration for cells near the EC/CC transition will depend on the event vertex's z coordinate. Using dijet events to cross check the direct photon calibration is also discussed. Unfortunately, the dijets suffer from a large (~12%) systematic bias associated with the threshold cut. A discussion of what is the "acceptable" fraction of dead calorimeter read out sections is given and the implications for what the resulting calibration means.

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1 Introduction The setting of an absolute energy scale for the calorimeters will be of vital importance for many of the DØ physics goals. These include precision W mass measurements, jet cross sections, and, by implication, supersymmetry (because of the missing energy dependence of this measurement.) When DØ turns on there will be an energy scale based on test beam studies of the ECEM, IH and CC modules with hopefully GEANT extrapolations to less uniform regions of the calorimeter. However, there will be a nagging uncertainty, at the few percent level, to these numbers. This will be the case even for the modules that have been both exposed at the NWA beam line and inserted into the actual DØ cryostat because of changes in the electronics, differences in the amount and composition of dead material in front, absolute argon purity measurement differences, as well as totally unforeseen and unknown factors.

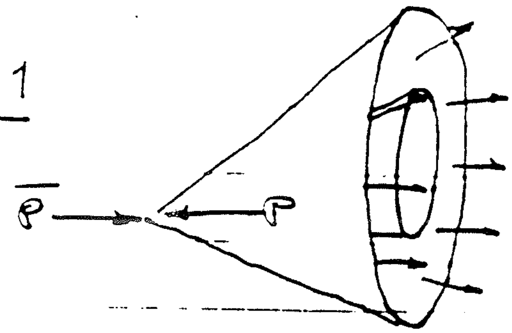
The impact of those presentations by the DØ collaboration which strongly depend on the absolute energy scale will be greatly strengthened if we can demonstrate, using collider data, that we understand the calibration of the actual modules to the stated accuracy. This is equivalent to calibrating the calorimeter using collider data. In fact, it seems reasonable to assume that any disagreements between in situ calibration and GEANT or test beam based calibrations will be settled by using the in situ calibration. This note presents the outline of a complete in situ calibration scheme and reports on the status of our understanding of this method. The rest of this section will be used to give a brief over-view of the entire proposed calibration scheme. The sections following that will give a detailed status report of the progress to date. The final section will talk about proposed triggers for a dedicated calibration run lasting roughly 24 running hours.

Figure 1.1 presents a schematic overview of the proposed method. It assumes that the electronics calibration, turning ADC counts into integrated charge, has been done removing any time dependent corrections.[1] The lack of a central magnetic field forces the use of any kinematic constraint or symmetry that is available. The first stage in the calibration is using the azimuthal (or phi) symmetry of the collider events. The sum of energy deposited in each calorimeter read-out section is compared with the average of all of the equivalent cells, i.e. all those with the same pseudo-rapidity (eta) and at the same depth. This will remove phi dependencies caused by asymmetric dead material distributions (such as structural supports like dog bones etc.) It will also build in a correction factor for those cells adjacent to phi cracks. This will be particularly

[1] It is possible that there will be time dependencies which can not be removed by the electronics calibration, such as changes in argon purity etc. These will have to be constantly monitored separately. They can be cross checked, as will be shown, periodically using phi symmetry.

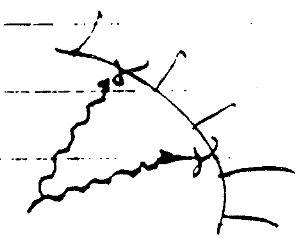
Figure 1.1

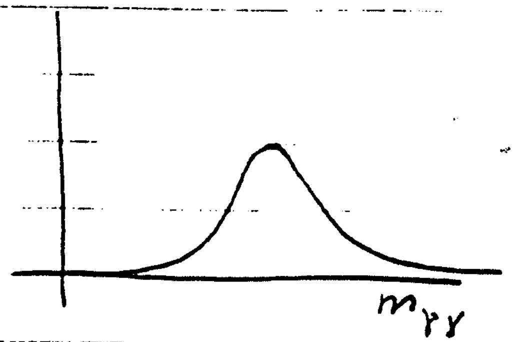
Step 1



Phi symmetry is used to determine the relative calibration for all cells with the same η and depth

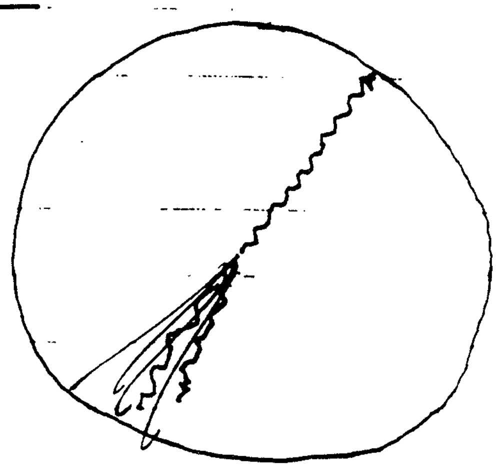
Step 2





Resonences decaying into either 2 photons or 2 electrons will be used to calibrate the EM sections

Step 3



direct photon events will be used to transfer the EM calibration to hadronic towers by using total event P_t conservation.

significant for those readout sections in the CCEM"3" layer where half the cells are adjacent to inter-module cracks and half are not. This can be modified to better suite the H-matrix algorithms if so desired. However, for jet or missing Et studies, it is believed that individual showers will not be reconstruct and an average approach is best.

Once the phi degree of freedom has been calibrated away, the EM section will be calibrated, as a function of depth and eta, using the reconstruction of resonances. The Z^0 mass, accurately determined by LEP, can be used as a calibration resonance. Ulrich Heinz has shown[1] that we can expect an accuracy of 2 to 3% by adjusting the gains to give the expected Z^0 line width with the expected number of Z^0's produced in run 1a. This resonance has the advantage of calibrating electrons in an energy range very close to the one of interest from $W^{\pm}$ decays. However, it could be hoped to get a higher accuracy in the calibration and using resonances which are produced more copiously. Ulrich is also investigating using the J/psi resonance which is at least produced more plentifully than the Z^0. Unfortunately, the J/psi's produced in B decays and have an associated muon trigger are also very rare and so Ulrich is investigating triggering on the J/psi's themselves using electron triggers. It is still too early to assess the utility of using this resonance. A third possibility is to use "high energy" pi0's. A quick calculation of the minimum opening angle for reconstructing two photons gives a maximum pi0 energy of less than 1 GeV in the central region. However, various tricks have been developed which allow the reconstruction of symmetric decays to much higher energies. We have successfully reconstructed central calorimeter pi0's with energies up to 4 GeV without significant calorimeter granularity biases showing up. These pi0's are certainly produced copiously with 10 million passing the level 1 EM(1,2) trigger (after pre-scaling) and isolation cuts. However, their energy is still regrettably small and they must be combined with the higher mass resonances to get the final calibration.

Now, assuming that at least the central calorimeters electromagnetic section has now been calibrated, direct photon events can be used to transfer the CCEM calibration to all layers of the hadronic calorimeters. This is done by adjusting the gains of all cells so that the direct photon's transverse momentum is balanced by the entire rest of the event. There will of course be shower fluctuations and losses down the beam pipe which would mean that even for a perfectly calibrated calorimeter the measured photon's transverse momentum would not balance the measured transverse momentum sum of the rest of the event. However, a least squares algorithm can handle this by keeping track of the expected measurement error for all cells and introducing an additional error to represent Pt lost down the beam pipe. This method has been tested using GEANTed ISAJET Monte Carlo direct photon events with complete detector simulation, including losses

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[1] Ulrich Heinz, private communication.

down the beam pipe. It has successfully corrected hadron towers for the known errors, then present in DØGEANT for charged pion shower energies, at least in the central region. The gains thus determined were tested by sending PYTHIA generated single jets. This also showed that the average jet energy scale could be determined to 2 to 3% and was insensitive to the details of the fragmentation scheme.

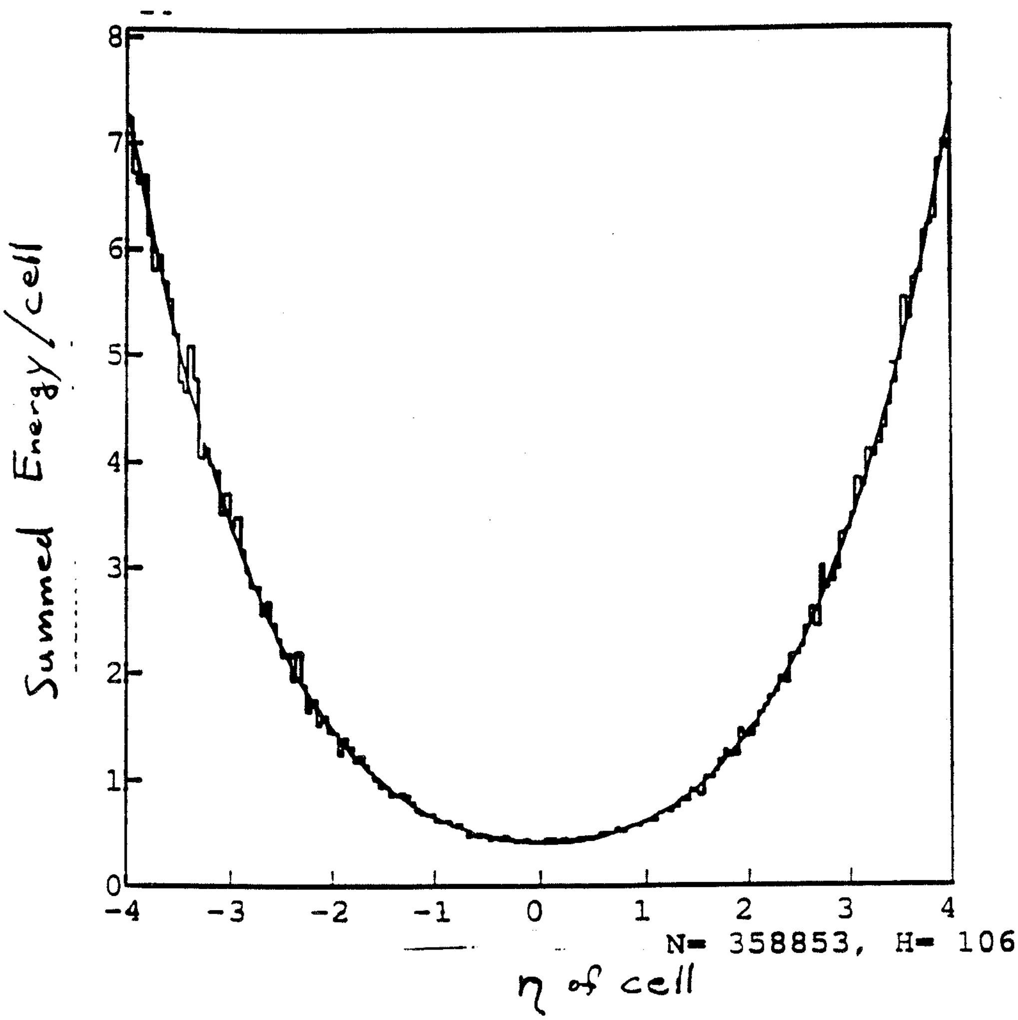
The schemes outlined above are still being developed. Recently, a considerable amount of time has gone into understanding what triggers we would want for a dedicated calibration run. The next sections go into the details of the individual steps in the calibration process.

2 Phi Symmetry The actual collider events are expected to be phi symmetric, there will, however, be asymmetric effects on the energy sums discussed above which are not related electronics or argon purity. The most important is the displacement of the beam axis to the symmetry axis of the calorimeters. Considerable effort has gone into making as phi symmetric a detector and positioning it as accurately as possible. There will be unavoidable uncertainties in this position if for no other reason than the unpredictable shrinking of the large assemblies of modules causing a vertical displacement. If an arbitrary radial displacement is made to the beam position (in a coordinate system fixed by the calorimeter modules) then the net energy deposited in a calorimeter cell (which covers the range from η_1 to η_2, in the calorimeter coordinate system) is given by

$$\int_{\eta_1}^{\eta_2} E\left(-\ln\left[\tan\left\{\tan^{-1}\left(\frac{\sqrt{r^2+R^2-2rR\cos\phi}}{z}\right)/2\right\}\right]\right) \qquad \text{eq. 2.1}$$

Where r is the radial displacement, R is the radius of the calorimeter cell at eta, z is the distance from the event vertex to the calorimeter cell, ϕ is the azimuthal angle of the calorimeter cell, and E is the energy distribution of minimum bias events as a function of eta (in the events coordinate system.) This is nothing more than expressing the integral of the energy flow into the calorimeter cell in terms of the displaced calorimeter coordinates. Since the calorimeter cell covers a small range in eta this integral can be replaced by a product of $\Delta\eta$ $E(\eta_{average})$. For fitting purposes we want to expand this integral in a power series in r and only keep the terms up to those linear in r.

Figure 2.1



Summed Energy/cell
8
7
6
5
4
3
2
1
0
-4
-3
-2
-1
0
1
2
3
4
N= 358853, H= 106
η of cell

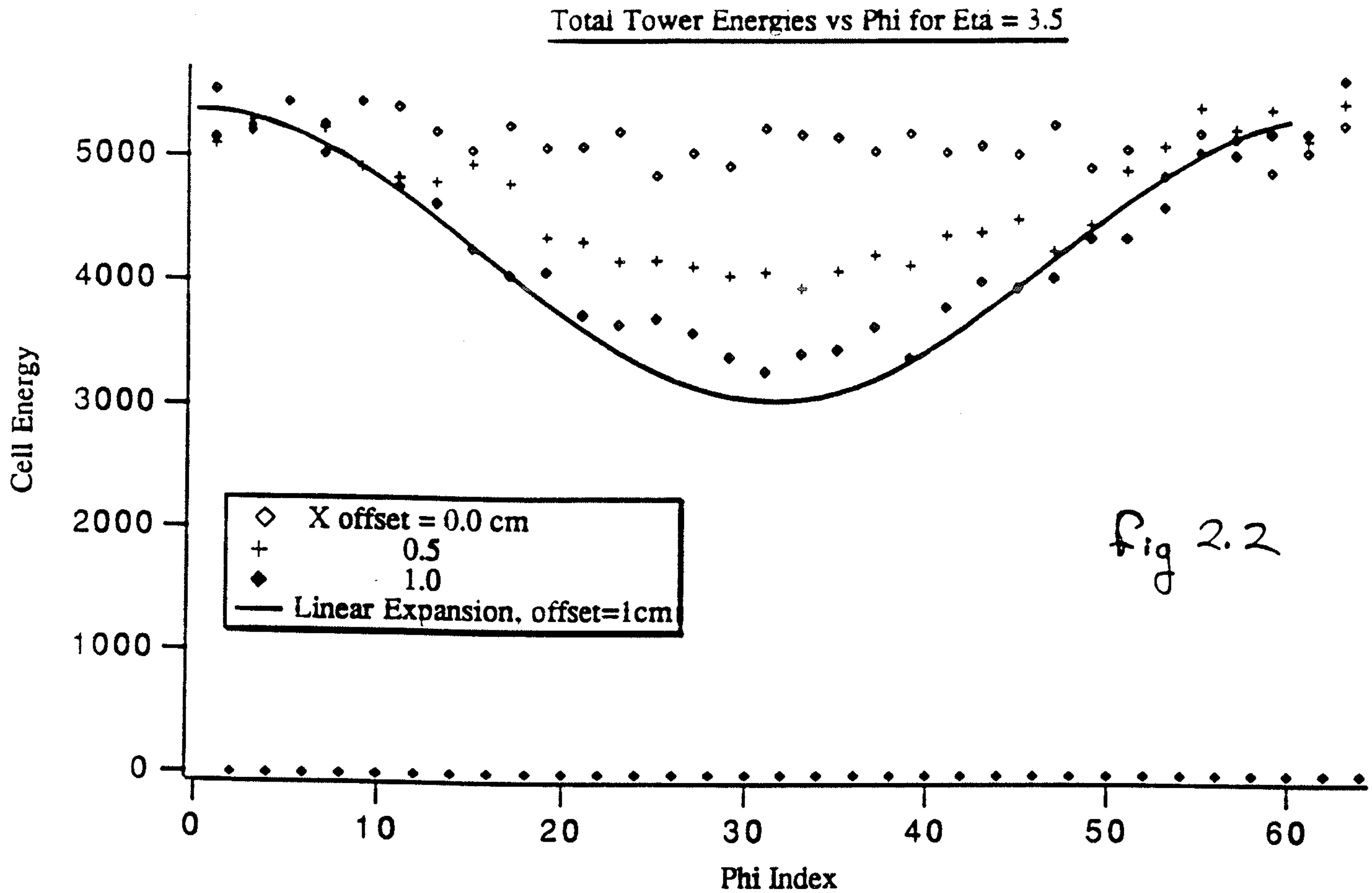

Total Tower Energies vs Phi for Eta = 3.5
Cell Energy
5000
4000
3000
2000
1000
0
X offset = 0.0 cm
0.5
1.0
Linear Expansion, offset=1cm
0
10
20
30
40
50
60
Phi Index

fig 2.2

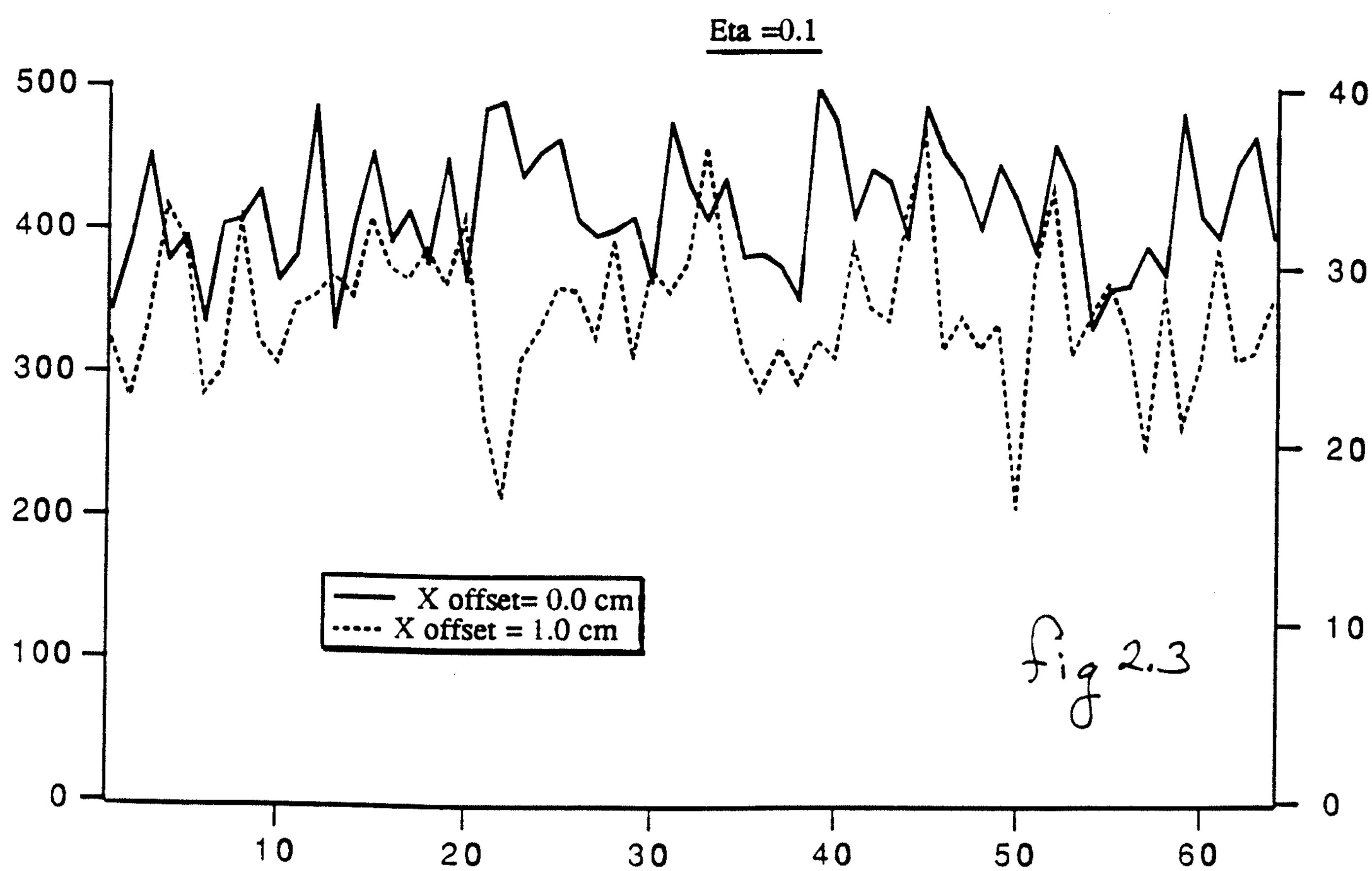

Eta =0.1
500
400
300
200
100
0
40
30
20
10
0
X offset= 0.0 cm
X offset = 1.0 cm
10
20
30
40
50
60

fig 2.3

This expansion is

$$\Delta\eta\, E(\eta_{ave}) + \frac{r}{2}\, z \cos\varphi \left\{ \frac{\left(1+e^{-2\eta_1}\right)\cot\frac{\vartheta_1}{2}}{\left(R_1^2 + z^2\right)} - \frac{\left(1+e^{-2\eta_2}\right)\cot\frac{\vartheta_2}{2}}{\left(R_2^2 + z^2\right)} \right\} \left\{ E(\eta_{ave}) + \eta_{ave} \left(\frac{\partial E(\eta)}{\partial \eta} \right)_{\eta_{ave}} \right\}$$

eq. 2.2

The first term is just the energy flow for no displacements. The second term involves small displacements in radius and depends on the derivative of the energy flow. The cosine is with respect to the azimuthal direction of the radial displacement. The energy flow for minimum bias events (as determined using ISAJET) is shown in Figure 2.1. A fourth order polynomial gives a very nice fit to this function and its derivative. This parameterization than be used in the expansion above. It should be pointed out that since this is a linear expansion we can determine the energy flow and its derivative experimentally (i.e. independent of ISAJET) by simply binning events in terms of the z of their primary vertex and solving the system of linear equations for E and $dE/d\eta$! However, for the time being we can use the ISAJET simulation of the energy flow to estimate the size of the effect of the radial displacement.

Using the parameterized energy flow, as determined above, we can estimate that a radial displacement of the beam from the symmetry axis of the central calorimeter of 6.4 mm causes a phi dependent systematic shift of at most 0.44%, if the first order term in the expansion above is not used. The average systematic shift would be roughly half that. Even the maximum bias associated with this (quite large) radial displacement is acceptable and we conclude that phi symmetry in the central calorimeter can proceed without radial displacement corrections. A similar analysis for random displacements in z of the CCEM modules indicates that these are insensitive also to displacements on the order of 6mm.

The End Calorimeter modules, on the other hand, are sensitive to radial displacements of the beam. This is especially true of the higher eta (smaller radius) towers. Figure 2.2 shows the summed energy deposited into calorimeter towers at eta=3.5 for zero, 0.5cm, and 1.0cm radial offset. The solid curve is the linear expansion in equation 2.2 assuming an average event vertex z coordinate of 220 cm (which corresponds to the middle of the IFH1 layer) and normalizing the value of the curve at phi=0. to the data. The minimum bias events were generated with a smeared event vertex and because of the CPU time to GEANT an event it was impractical to cut on the z vertex. This presumably accounts for the deviation of the data from the expected curve. This assumption will be checked in the near future.

Figure 2.3 shows the similar quantity for a tower at eta=0.1. While there is quite a bit of structure of the summed energy in phi (due to the low statistics of ~1300 minimum bias events in the central region) there is no indication of a systematic shift similar to the one seen at large eta even for radial offsets of 1cm. This is in agreement with our expectations from the linear expansion, eq. 2.2. This sensitivity of the EC to radial displacement relative to the beam axis can be corrected for if the position is determined by some other method (from crack positioning for instance) or it can be used to both calibrate and survey the calorimeter by using events at different primary vertex z values as alluded to above.

3 Resonance Calibration of EM Sections The electromagnetic section plays a crucial role in physics and in the in situ calibration scheme presented here. The relevant energy scale for the physics is half the mass of the W/Z bosons, roughly 50 GeV/c P_t. Luckily the $Z^0 \rightarrow e^+e^-$ channel provides a calibration standard to use with an energy close to the W mass which is of physical interest. Unfortunately, we can expect to reconstruct only several hundred such Z's during the entire 20 pb^{-1} 1a run. The calibration transfer to the hadronic towers using direct photons, as detailed below, is dominated by those events with photon energies just above the acceptance threshold, typically 10 to 20 GeV/c P_t. It is clear that the calibration requirements for these tow electromagnetic shower energy ranges are different. In particular, a high statistics, high precision calibration at energies in the 4 to 5 GeV/c^2 range would be acceptable for the calibration transfer and could be accomplished before enough higher mass resonances were accumulated.

An algorithm for reconstructing high energy π^0 's has been developed. This routine was designed with the goal of reconstructing a small fraction of well isolated pi0's specifically for calibration of the calorimeter EM. The efficiency can afford to be small since the cross section for production of these particles is very large. Figure 3.1 shows the cross section for single π^0 production as a function of Pt in the central region ($-0.5 < \eta < 0.5$.) The π^0 is required to be well isolated. These curves represent requiring less than 100 MeV in a cone centered around the π^0 of $\Delta R = \sqrt{(\Delta\phi^2 + \Delta\eta^2)}$ less than 0.4 and 0.6 respectively in minimum bias events. Figure 3.2 shows the level 1 EM(1,2) trigger efficiency[1] of isolated π^0 's. If it is assumed that these events are triggered in level 1 with the EM(1,2) trigger and even including its pre-scaling of 50,000 we can expect 10 million such π^0 's with Pt > 4 GeV/c in run 1a. The question remains on how to reconstruct the highest energy π^0 's possible.

The most obvious method of reconstructing π^0 's, i.e. to reconstruct the individual decay photons, only works up to energies close to 1 GeV/c^2. We have adapted a trick from previous experiments to work for DØ's central calorimeter. The individual photons are not reconstructed.

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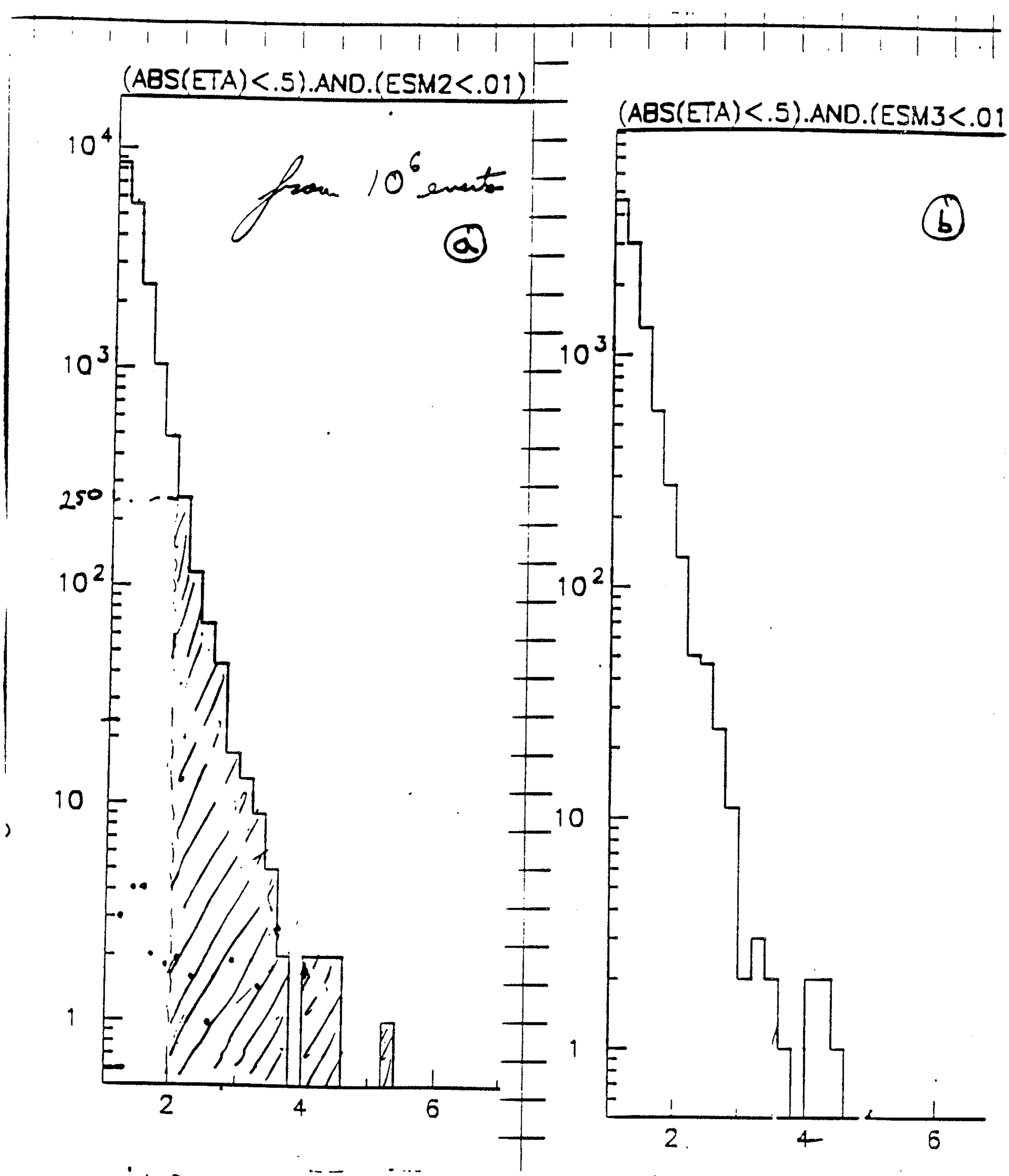
[1] These efficiencies were determined by Andy Milder using the Level 1 emulator.



(a) $\sum_{\Delta R \leq 0.4}^{i \neq \pi^0} E_i \leq 100$ MeV

(b) $\sum_{\Delta R \leq 0.6}^{i \neq \pi^0} E_i \leq 100$ MeV

Figure 3.1

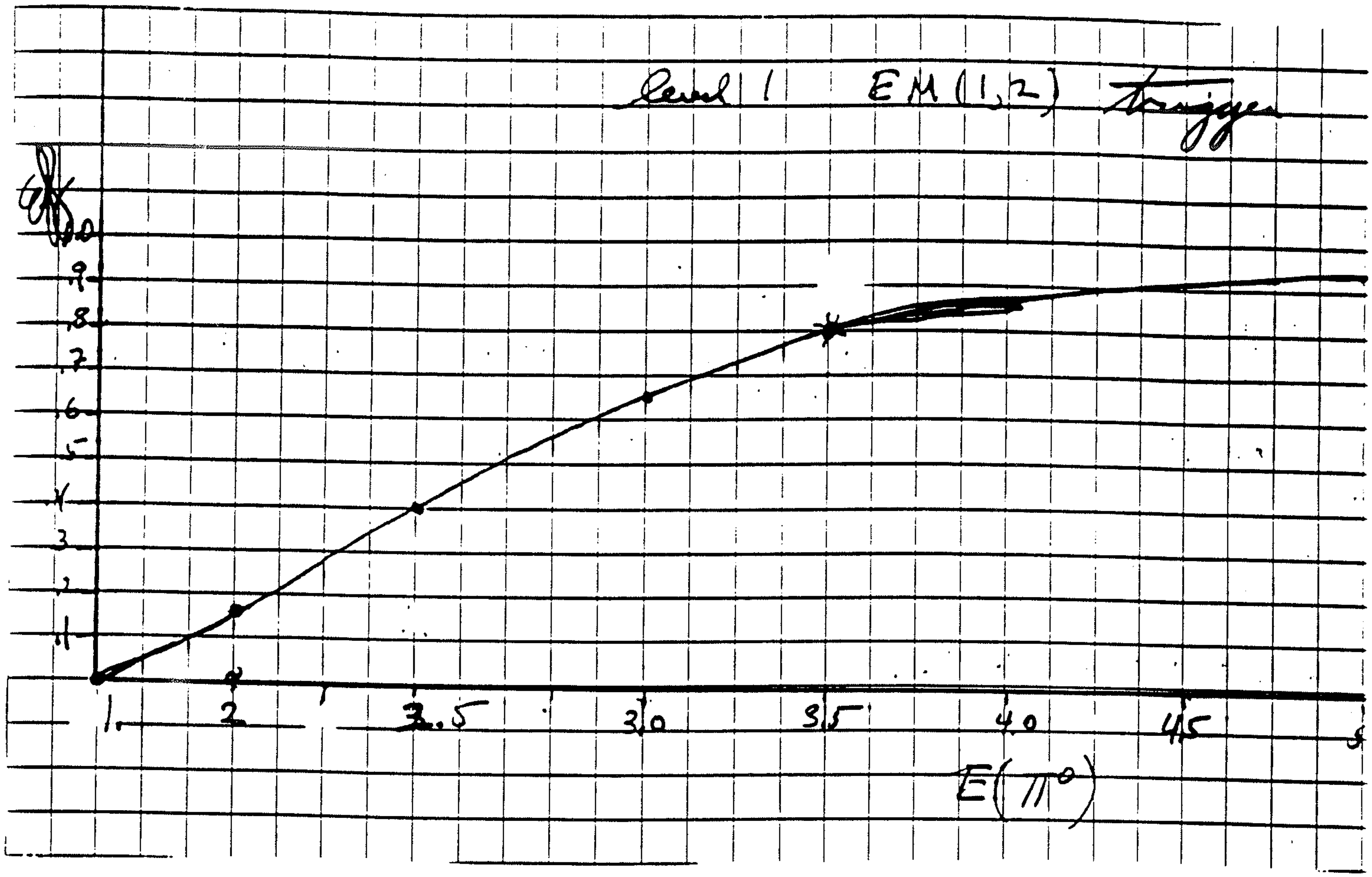


Figure 3.2

Instead that fraction of π^0 decays which are highly symmetric are used and the π^0 mass is approximated to be

$$m_{\pi^0}^2 = 2\, E_1 E_2 \left(1\text{-cos } \Gamma_{12}\right) \cong \left(\frac{1}{2} \sum_{\text{EM cells}} E_i\right)^2 \left(1\text{-cos } \Gamma_{12}\right)$$

where the sum over EM cells is over all cells associated with the π^0 shower cluster which is typically ΔR=0.2. The angle Γ_{12} is the angle between the two decay photons as determined in EM layer 3. There are technical details to this angle determination but the basic separation requirement is that the maximum layer 3 cell be at least $\sqrt{2}$ cell size (0.05 x 0.05) from the cell with the next large deposited energy. This is the same thing as saying that the two cells can be positioned diagonally from each other but not adjacent (see Figure 3.3.)

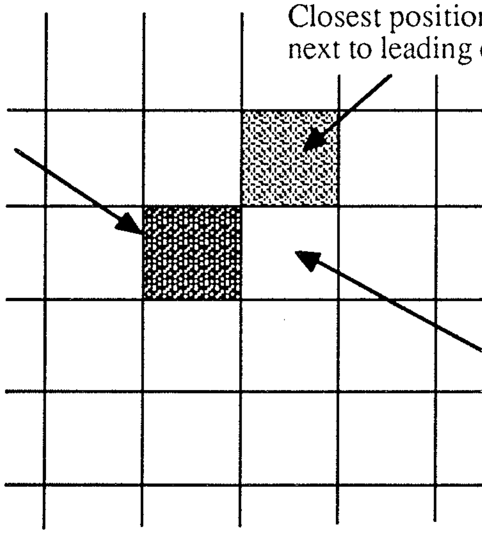


Figure 3.3 Layer EM "3"

The peak positions are refined by using an energy weighted average of their nearest neighbors.

Figure 3.4 show the resulting reconstructed π^0 mass for several different incident energies. DØGEANT with full showering but using mixtures for the calorimeter modules was used to simulate these showers. While this combination for the Monte Carlo does not do a perfect job at simulating the transverse shower shape (which is important for this algorithm) it does do a reasonable job. In fact, we can expect that the actual showers will be some what broader. Comparing the reconstruction efficiency for the full shower Monte Carlo with the reconstruction of DØGEANT parameterized cutoff showers indicates that the efficiency of determining the shower centers should actually increase with minimal decrease in the maximum reconstructed energy.

It is clear that this method has been geared to the higher energy π^0 's because if fails to reconstruct any with 1 GeV/c^2 incident energy. There is also a troubling secondary peak (at a

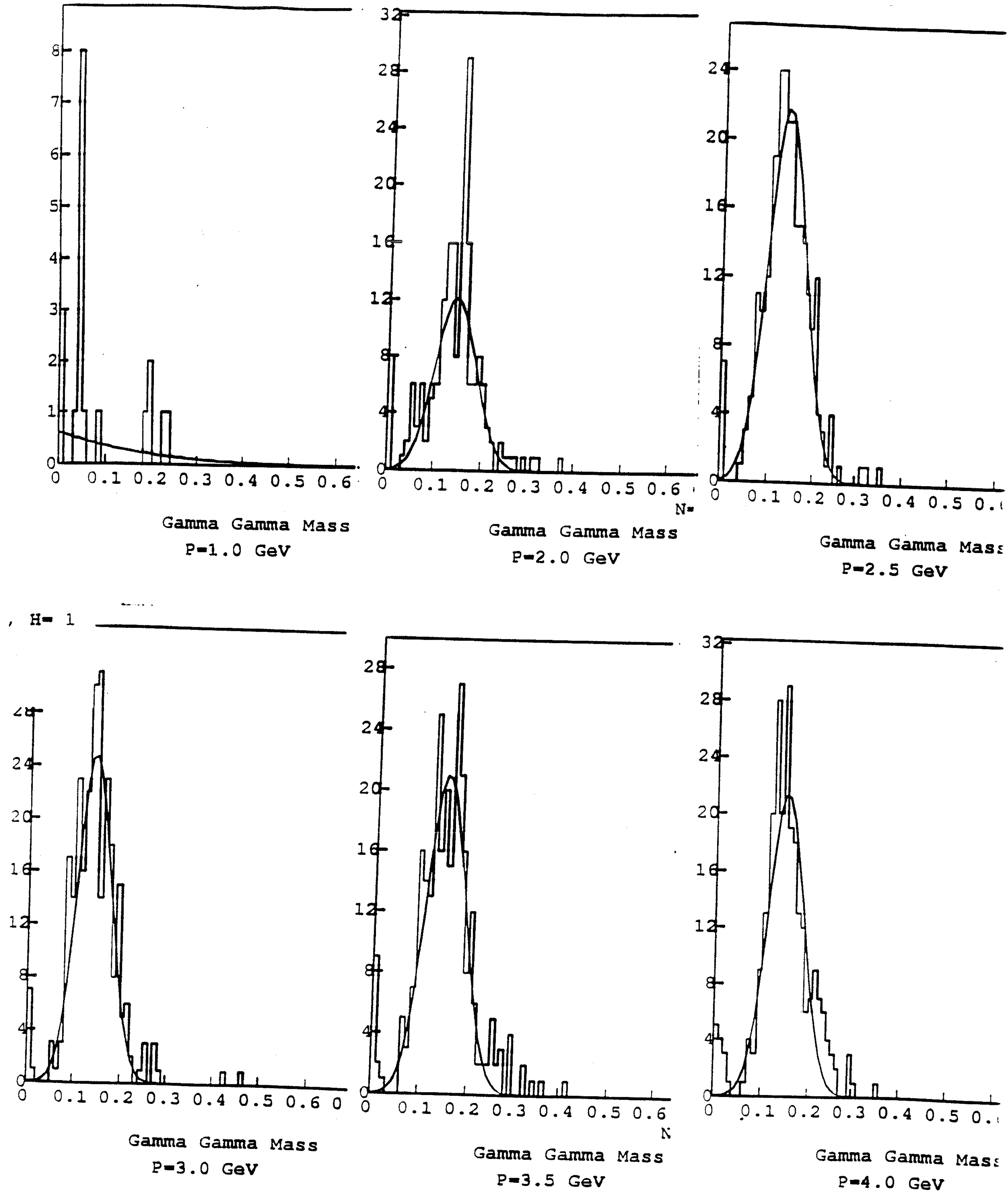

Gamma Gamma Mass
P=1.0 GeV
Gamma Gamma Mass
P=2.0 GeV
Gamma Gamma Mass
P=2.5 GeV
Gamma Gamma Mass
P=3.0 GeV
Gamma Gamma Mass
P=3.5 GeV
Gamma Gamma Mass
P=4.0 GeV

Figure 3.4

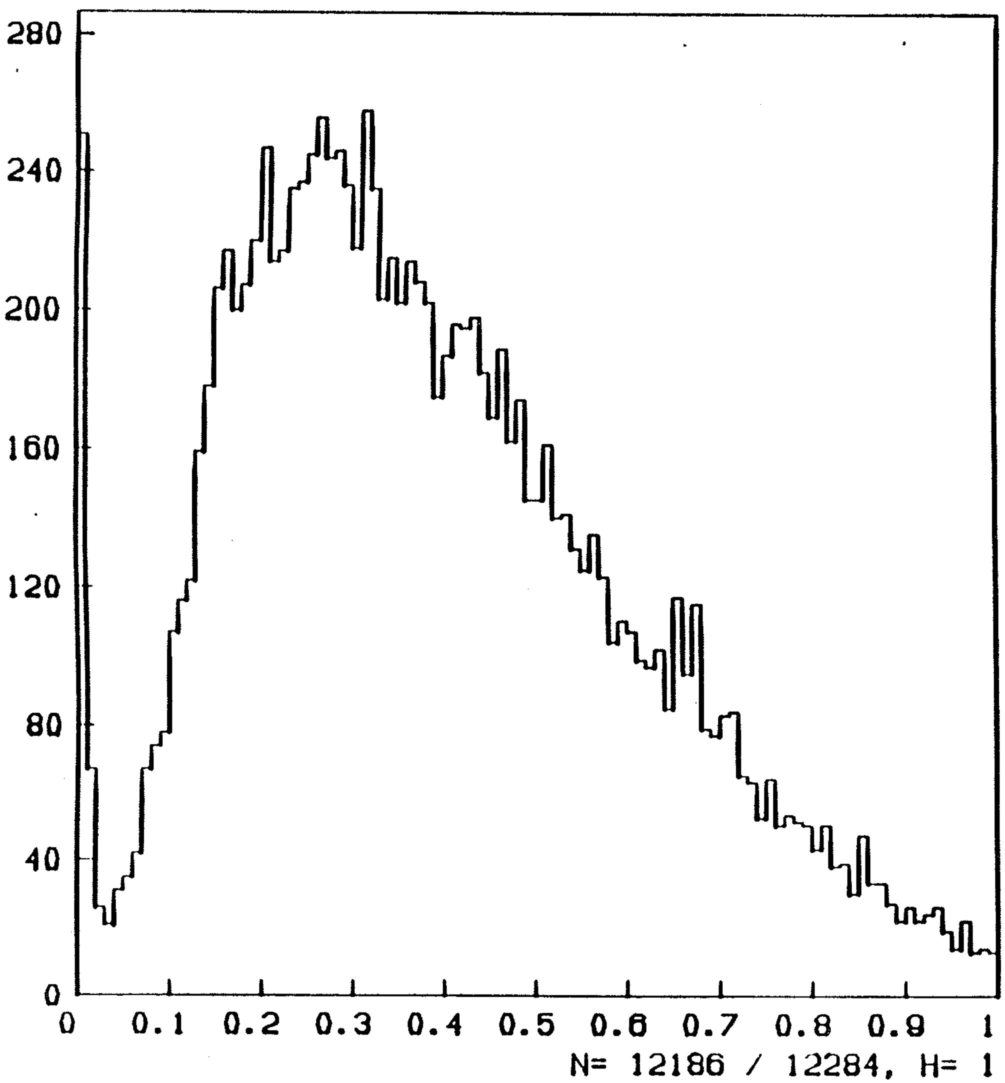
reconstructed mass of roughly 0.225 GeV/c2.) This secondary peak is related to the finite granularity of the transverse calorimeter segmentation. It is also exacerbate by the mono-energetic nature of the incident π^0 's. This effect has been studied in detail and is the factor which limits the maximum energy that π^0 's can be reconstructed. Figure 3.5 shows the resulting reconstructed masses for 50,000 pairs of photons with energies randomly picked such that the total energy of the pair is between 1 and 10 GeV/c^2. There is no indication of "special" masses due to the calorimeter geometry. Figure 3.6 shows these same reconstructed masses but weighting each by the cross section as shown in Figure 3.1. Again no biases appear which indicates that when the generated photon pair mass is allowed to have a continuous distribution then no biases are present (to the level of our statistical power.)

The code for using these reconstructed π^0 's in calibration is still being developed. It is currently envisioned that a calibration constant for each layer will be determined as a function of eta. By this we mean that a single gain constant for all cells of a fixed eta and layer (as determined by the phi symmetry calibration discussed above) will be determined. The π^0 's near (currently within ΔR=0.2) dead readout sections will be ignored. This insures that dead cells will not influence the calibration of neighboring good electromagnetic cells. Corrections for these dead cells can then be made later on in the reconstruction process based on unbiased energies in neighboring readout sections. The impact of these dead cells is discussed in further detail in section 6 where the "acceptable" fraction of dead EM readout sections is calculated. It is clear that for calibration purposes this fraction should be kept below 1%.

4 Direct Photons -Transferring EM Calibration to Hadronic Towers The mechanics for transferring the calibration from the EM sections to hadronic towers has been discussed in detail elsewhere[1]. Only the general outline of the method will be presented here along with some of the results of the recent developments.

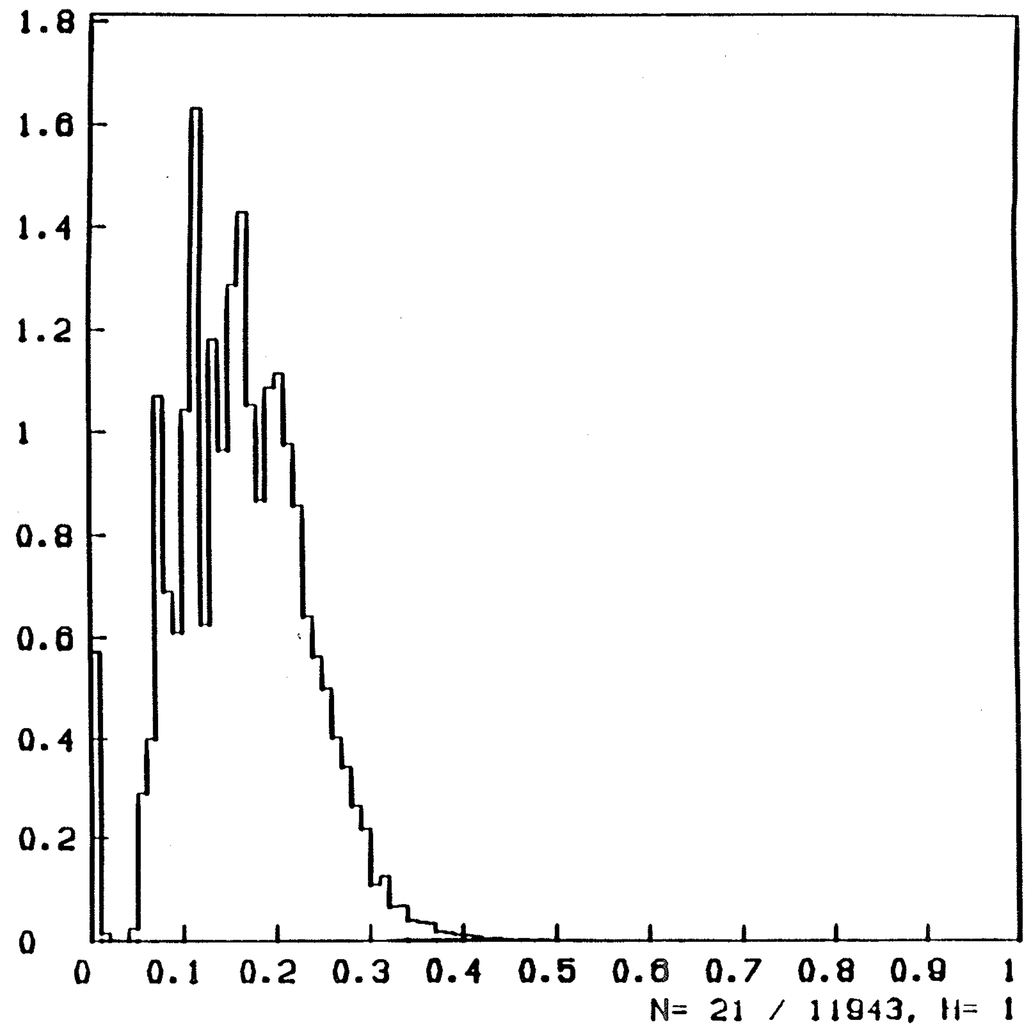
The some of the fundamental diagrams for direct photon production is shown in Figure 4.1. Since it is the partons that interact the center of mass of the hard scattering will be boosted longitudinally by some unknown amount (which for this process can be determined experimentally.) There is also some transverse momentum to the partons given by a transverse structure function. This transverse structure function is often referred to as being initial state radiation of gluons. These two points of view are equivalent to each other and both result in some transverse momentum to the photon-jet system. In general the "recoil" jet to this system is missed down the beam pipe and will result in a discrepancy for between the photon and the jet's transverse

[1]G. E. Forden. DØ note 790 Schemes for Calibrating the DØ Hadron Calorimeter 10/14/90.



GAMMA GAMMA MASS

Figure 3.5



GAMMA GAMMA MASS
WEIGHTED EVENTS, EMIN = 2 GEV

Figure 3.6

momentum. Luckily, this "beam jet" carries off a small amount of Pt and is not highly correlated with the direction of either the photon or the jet and so can be represented as a gaussian error in the least squares fit during the calibration.

This method has been used with ISAJET Monte Carlo direct photon events to determine a gain constant for each hadronic tower (this coarse longitudinal binning is necessitated by the low statistics which can be generated with GEANT simulation.) Figure 4.2 shows the gain constants as determined for the DØGEANT realization of the calorimeter. The average gain constant is significantly above 1.0 which reflects the (then known) bug that a significant fraction of hadronic energy was inexplicably lost during the simulation. It should be emphasized that the Monte Carlo was used to test the method only and that the results from this test will not be used for the actual DØ calibration.[1]

A by-product of the least squares fit is an estimate for the error associated with each found gain constant. The GEANT data has been multiplied by randomly chosen constants and then the data was re-calibrated. The error, defined as the difference between the generated "gain" and the found gain, was divided by the estimated error from the fit and used to calculate a chi squared. This distribution was consistent with normal statistical fluctuations in the error. We then conclude that the predicted error is a reasonable estimate of the actual error. Figure 4.3 shows the predicted error as a function of the eta of the tower. Superimposed on this distribution is the transverse momentum sum in each ring of fixed eta. There is a strong correlation (as expected) between the size of the predicted error and the amount of energy deposited in the corresponding eta ring. It is also clear that there was insufficient transverse momentum accumulated in the EC by the roughly 1000 events used for this calibration. This was the reason for an early conclusion that dijets would be needed to calibrate the EC towers. A large amount of work went into calculating the rate we could expect for high transverse momentum jets with a single π^0 containing a large fraction of the jet energy. These events can also be used to balance Pt and calibrate the calorimeters. In the end it was concluded that 100,000 events with a high transverse momentum electromagnetic "jet" would be enough to calibrate all layers of the calorimeter to the required 5% accuracy (per eta ring, which is better than the mandated 5% over the entire calorimeter!)

Figure 4.4 shows the reconstructed jet energy for single gluon jets (as generated by the jet gun option of JETSET 7.3) both before correction with the found gain constants and after. While the calibration corrections do quite a reasonable job in the central region they fall far short of

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[1] A number of people have misunderstood this point and I apologize for not making it sufficiently clear. This method will use only data taken at the collider to determine the calibration.

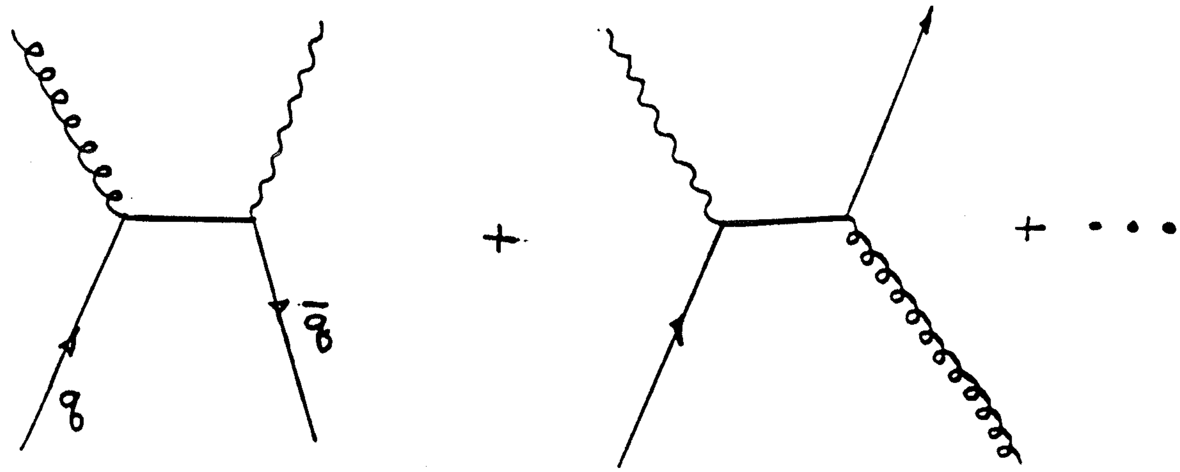

Figure 4.1

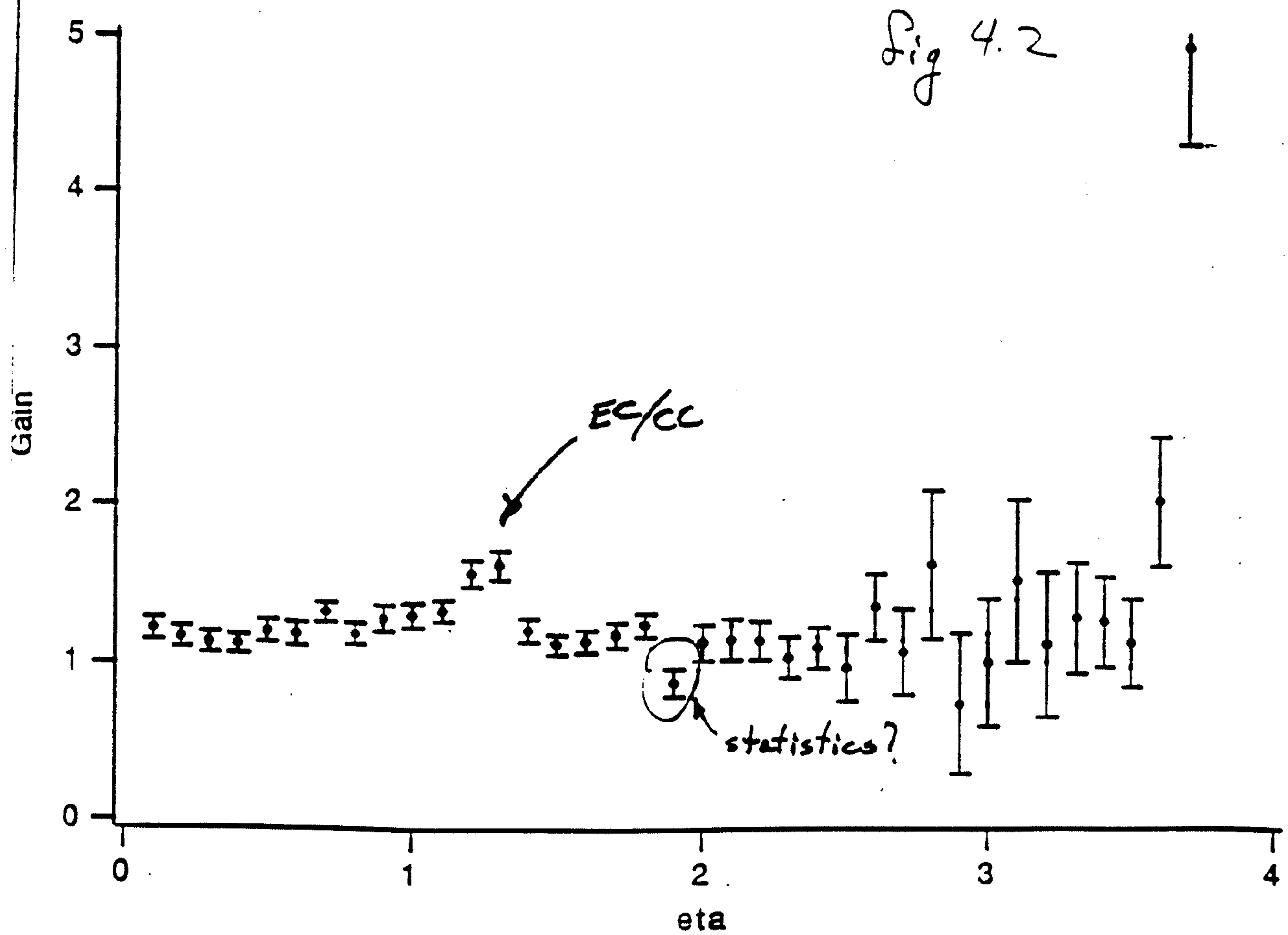

Figure 4.2

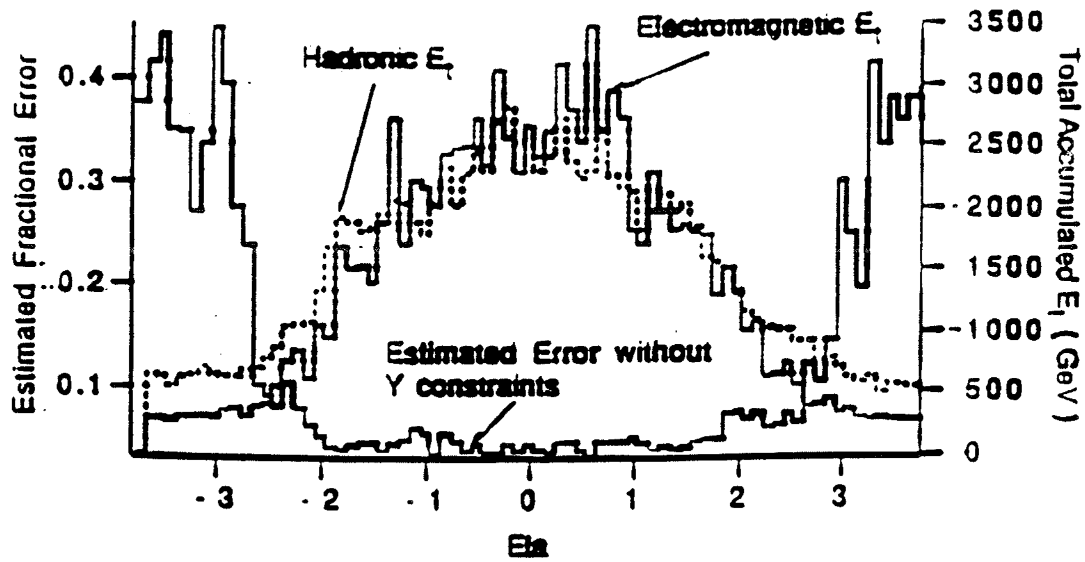

Figure 4.3

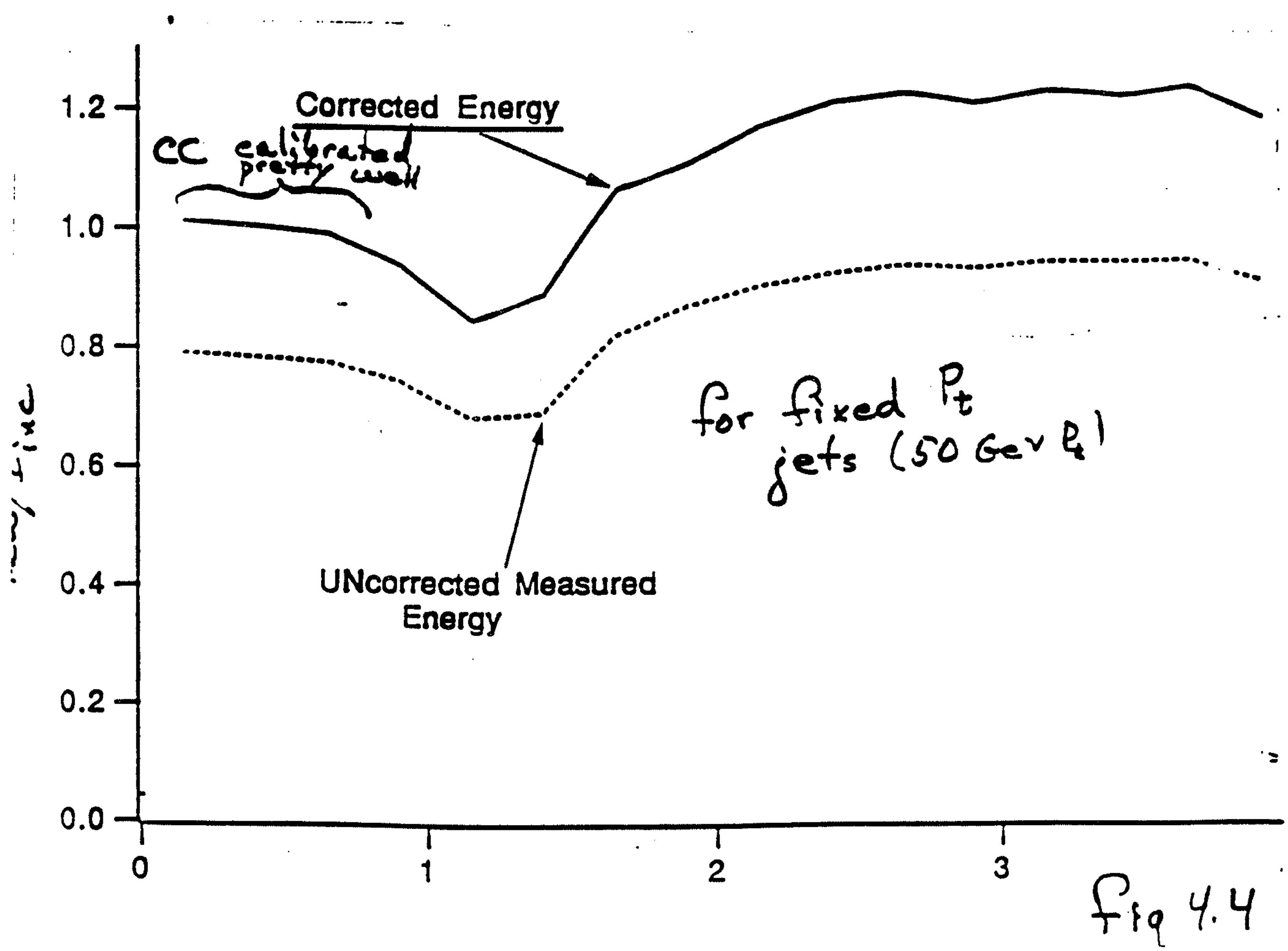

Figure 4.4

expectations in the EC/CC transition and even worse in the large eta regime. There appear to be two distance reasons for these two regions. The single jet events were inadvertently generated with a fixed event vertex of z=0 while the direct photon events (from ISAJET) were generated and simulated with a smeared z vertex. This appears to be the reason why the EC/CC transition is not corrected for. The error in the large eta range is believed to be an artifact of the single jet fragmentation function. These events were generated with fixed Pt but fragmented using an energy dependence determined by their energy. This appears to be incorrect and they should have been fragmented using a scale determined from their Pt.[1] This error resulted in a larger number of particles being generated in the jet and a correspondingly higher primary π^0 content then was present in the ISAJET direct photon events used to calibrate the simulated calorimeter. Considerable study of this method of calibration still needs to be done. This will be simplified by the fact that the actual calorimeter is more linear (e/h closer to 1) then is the case in the Monte Carlo.

<u>5 Dijet Events - A Check on Direct Photons</u> Jerry Blazey has pointed out that dijet events can be used to determine the relative calibration of the calorimeters. There are, however, considerable systematic problems with this method. One of them is associated with the unavoidable jet threshold cut[2] made on at least one of the jets. Consider an idealized sample of dijets with monochromatic energies, say 30 GeV/c^2 per jet. Jerry has determined an average jet resolution (for the Monte Carlo) of about 85%/$\sqrt{E}$. Thus each jet is smeared by a gaussian smearing by this amount. We must require that one of the jets have a <u>measured</u> energy greater than 30 GeV/c^2 (we will ignore the effects of any cone algorithm etc. on the measured jet energy.) Clearly half the jets can pass the cut and half don't. The average measured energy of the "triggering" jet is significantly higher than the generated jet, as indicated schematically in Figure 5.1. If we use the trigger jet's measured energy to balance the measured energy of the other jet (on which there were no cuts) then we induce a systematic error which would show up in the gain constants, especially if we also require that the two jets be in different regions of the calorimeter, such as the trigger jet being in the central calorimeter and the other jet being in the End calorimeter.

The fractional shift in the average measured jet energy decreases as the jet energy is increased above the selection cut. This is shown in Figure 5.2 where the measured jet distributions have been integrated from the selection cut of 30 GeV/c^2 out to infinity (or in practice since these had to numerical integrations, out to 300 GeV/c^2.) As expected the fractional error decreases as the jet energy is increased above the selection cut. At 45 GeV/c^2 the effect is completely neglectable.

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[1] Frank Paige, Private communication.

[2] Id like to thank Jerry Blazey for first bringing this problem to my attention.

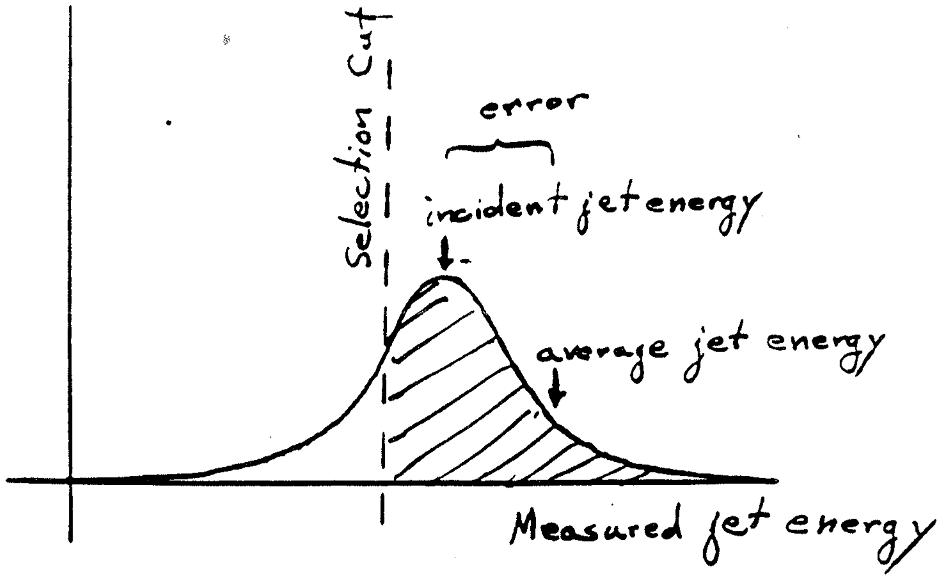

Figure 5.1

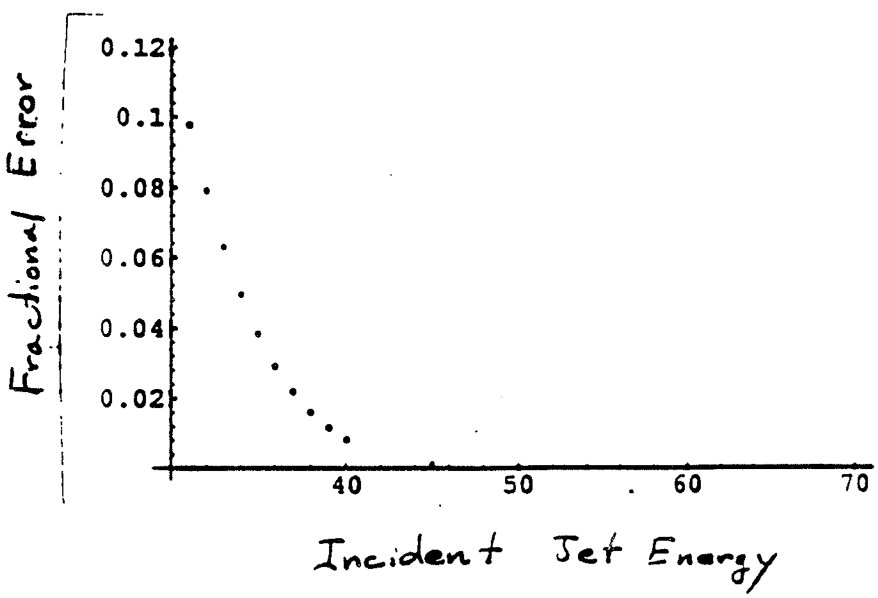

Figure 5.2

However, the dijet cross section is a fairly steeply falling function and those jets just above the selection cut will dominate the calibration. A full analysis which folds in the two jet cross section must still be done.

6 Impact of Dead Calorimeter Cells on Calibration Naturally, every attempt will be made to minimize the number of dead calorimeter cells and in that sense the acceptable fraction of dead cells is zero. In the real world accidents happen and there will be some number of calorimeter cells which are not read out. If these are assumed to be distributed at random through out the entire calorimeter then we can estimate their effects statistically. In actuality is seems more likely that they will be correlated (a cut signal cable, for instance, would wipe out a contiguous section.) We are taking the philosophical position that energy lost in dead cells should be "corrected for" latter on in the reconstruction program (perhaps some physics analysis will just throw away events which have energy near the dead cell.) That means that the dead cells surrounding neighbors must not compensate for energy lost in the dead cell. On the other hand, energy lost in dead material not normally called a calorimeter cell, should be compensated for. We chose to handle the dead cells by determining the phi averaged gain constant for each eta and layer number and avoiding those π^0 candidates which have a dead cell within ΔR=0.2 of the π^0 candidate. The "acceptable" fraction of dead cells can then be determined by requiring a reasonable chance (we have picked an arbitrary probability of 50%) for any $\Delta R \times \Delta \Phi = 0.2 \times 0.2$ EM plus 1st fine hadronic tower to not have a single dead cell in it. The 50% requirement implies that the randomly distributed dead cell rate must be less than 1%. The electromagnetic section can then be calibrated using the phi symmetric gain constants and not have an artificial compensation for the EM dead cells by just avoiding them. However, a 1% rate of dead cells implies that for a jet with ΔR=0.7 we can expect on average 34 dead cells in this cone! There is no way to avoid these cells so that we will end up compensating for the dead cells in jets (if the randomly distributed dead cell rate is 1%.) Thus isolated electrons and photons will not be corrected for dead cells in this method but jets and missing Et will. It seems to us that this is as it should be.

7 Conclusions A complete and self contained scheme for calibrating the DØ calorimeters has been presented. There are many questions that will have to be answered and difficulties to be over come as we proceed with this plan. Some of these difficulties have only become apparent as we have progressed (too late for inclusion in this discussion) and undoubtedly more will be uncovered. The most daunting of these appears to be the problem of what to do about dead material in front of the calorimeter during the phi symmetry phase. This problem, first brought to our attention by Bob McCarthy, arises because the low energy particles in minimum bias events will undoubtedly be more sensitive to small variations in dead material than the electrons from W and Z decay, for instance. If we proceed with a simple multiplicative relative gain constant we

would be over correcting these electrons. We are studying ways of using both the energy profiles of individual towers to enable us to use a non-linear relative gain and, perhaps alternatively, the response of EM1 to segregate the towers with similar amounts of dead material in front and only determine the relative gains inside these groups. This would result in an increase in the number of degrees of freedom but, hopefully still have a reasonable number subgroups. Clearly, 64 different subgroups for each eta would make a farce out of using phi symmetry.

We have already made progress in the alignment/survey issue of the two End Calorimeters. We were able to state that the beam spot was shifted radially from the symmetry axis of the EC's by between 0.5 and 0.7 cm BEFORE the tracking chambers announced similar findings. Since that initial announcement we have learned that it will probably be impossible for the accelerator to move the beam spot and we have had to determine the radial positions of the EC's with respect to the beam by other means (this will be discussed in detail in a forth coming DØ note.) Preliminary measurements show a displacement of the beam by -0.66 ± 0.14 cm in the X direction for the positive eta EC and -0.52 ± 0.14 cm for the negative eta EC. An unexpected spin-off of this study has enabled us to state the average z position of the event vertices. All of these measurements are done independently of the tracking chambers.

We have also already observed a phi dependent gain correction, albeit an extremely obvious one, for the eta rings at the highest eta indices as shown in Figure 7.1. This figure shows the integrated energy deposited in the towers with ieta=37. There is a clear pattern of energy depositions as a function of phi. This is caused by a considerable dead volume (with respect to the tower size) due to the presence of the spacer as shown in Figure 7.2. Naively applying phi symmetry will simply multiply the energy of each hit in the "low" cells by some factor (roughly three.) The resolution of the energy in those cells will appear worse than we would expect from say 65% $E^{-1/2}$ but we will have recovered a considerable amount of the energy lost to the spacer.

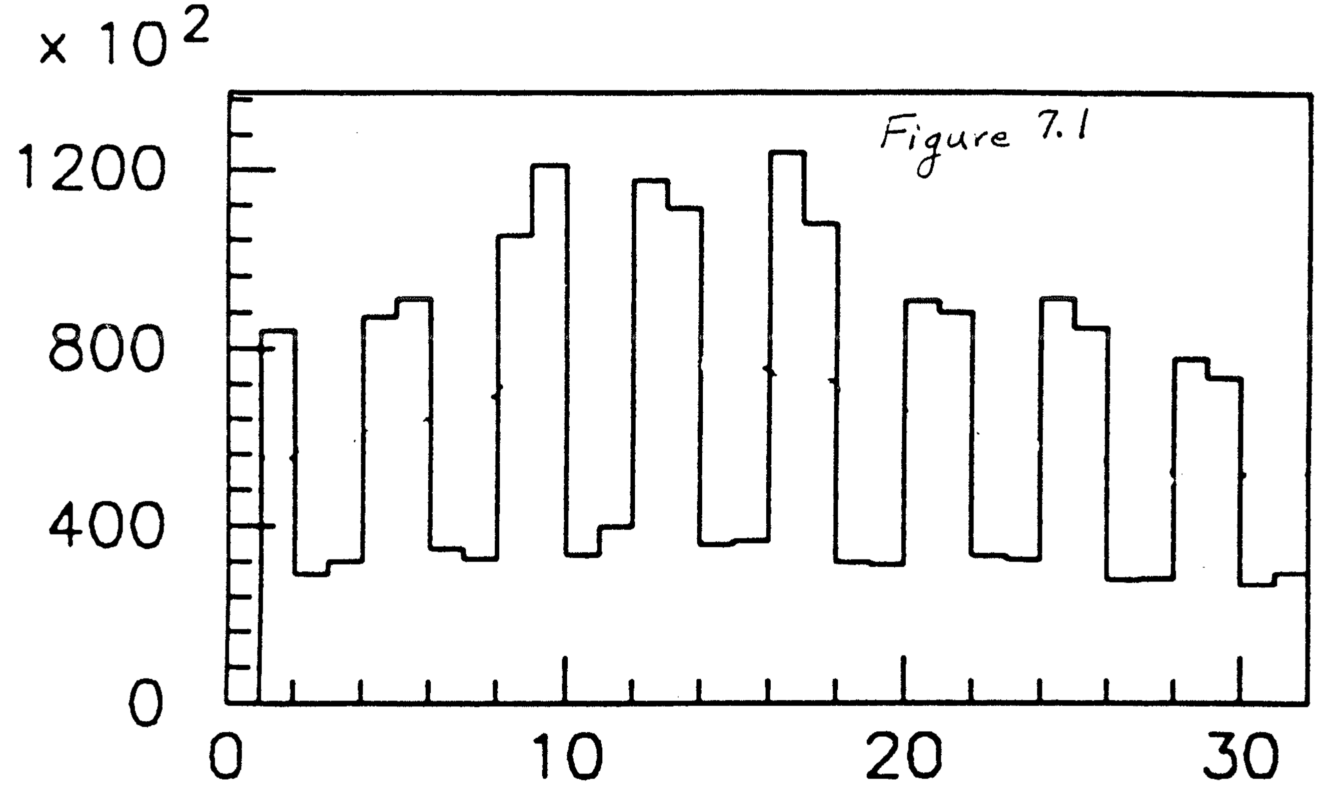

Figure 7.1

Summed Energy vs. Phi, IETA = 36

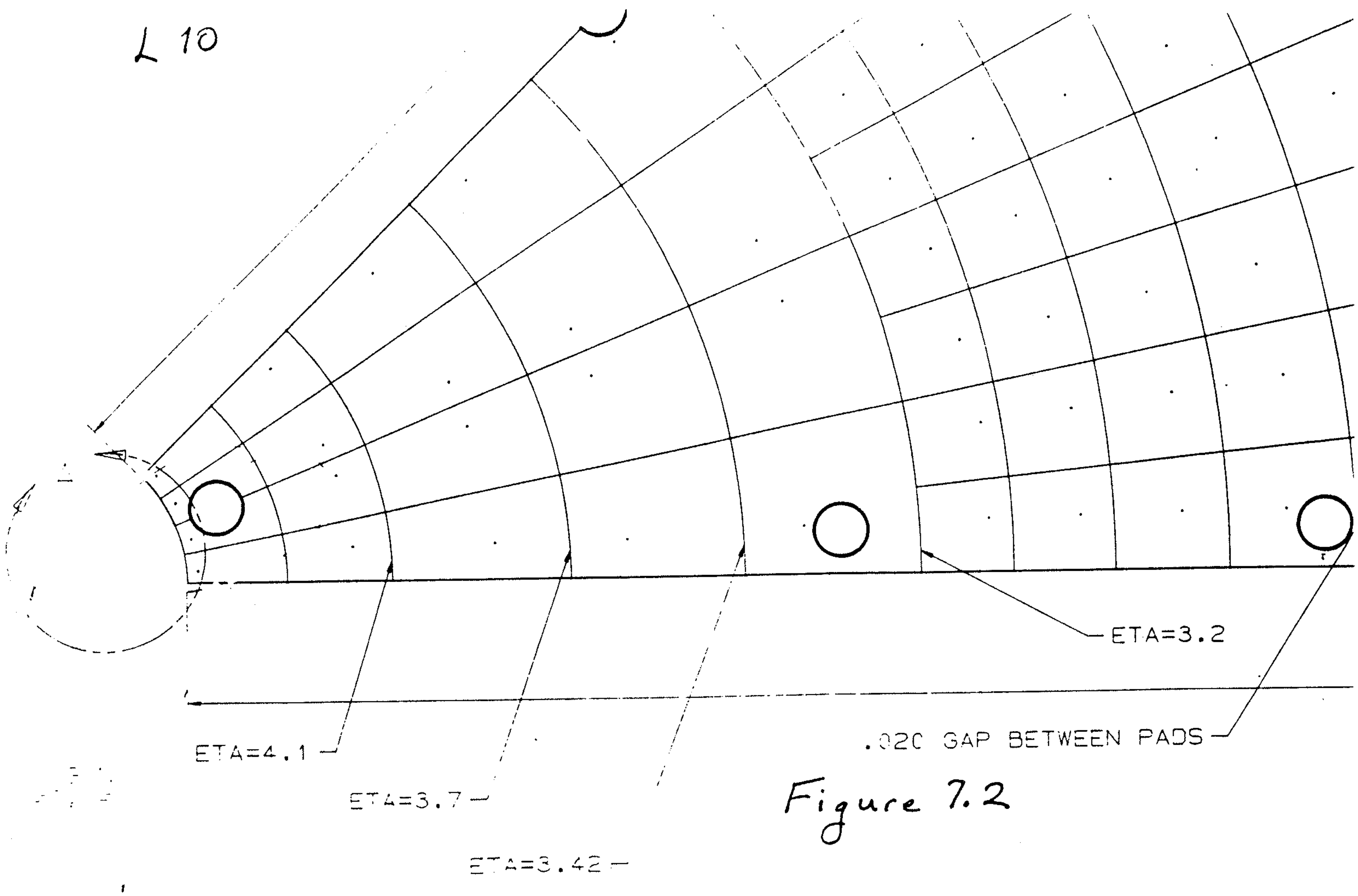

Figure 7.2