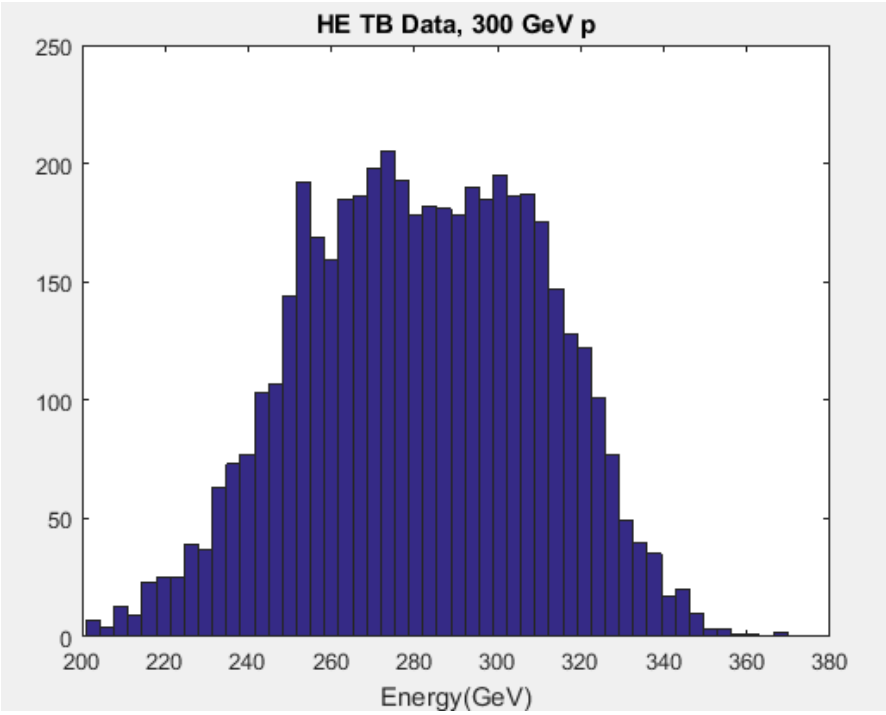
Single Particle Test Beam Response:

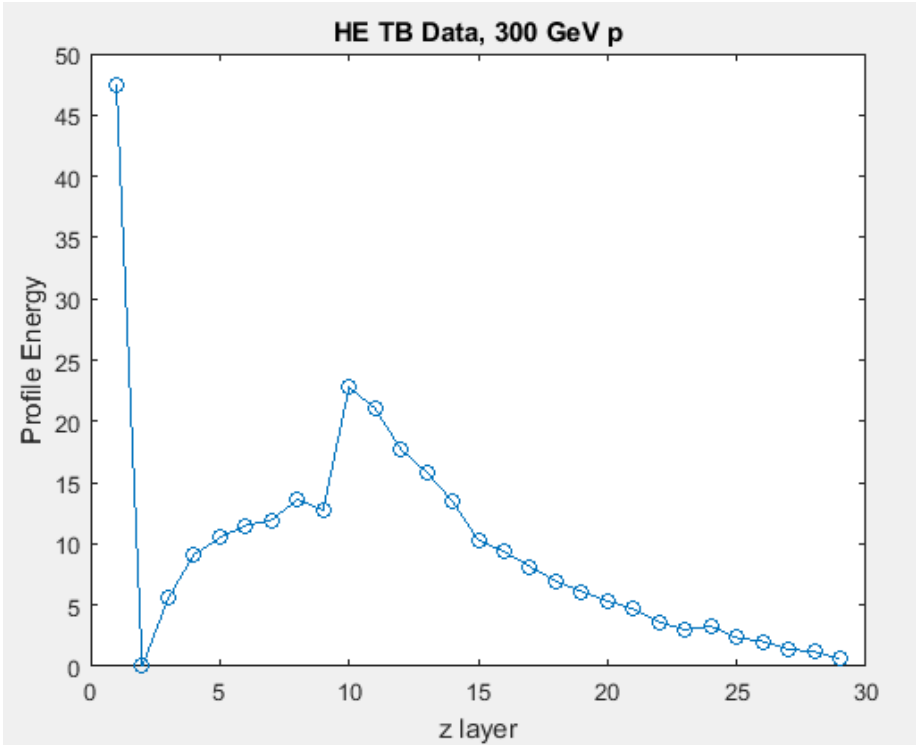
There is old H2 test beam data on e, mu, pi and p beams incident on test calorimeters. The data looked at here was ~ 300 GeV incident diffractive protons. The relationship of a single p to a 300 GeV jet is not strong; the jets have 1/3 energy in neutrals (into EE not HE) and the energy is partitioned in a set of lower energy neutrals and charged pions described by a fragmentation function which peaks at low energy, D(z) ~ 1/z. Nevertheless, some insight can perhaps be gained.

There was an EE compartment followed by 28 active layers of Cu absorber and scintillator in the test beam. The Cu sampling fraction changed, getting coarser as the HE layer went deeper. Layer calibrations were made using a muon beam.

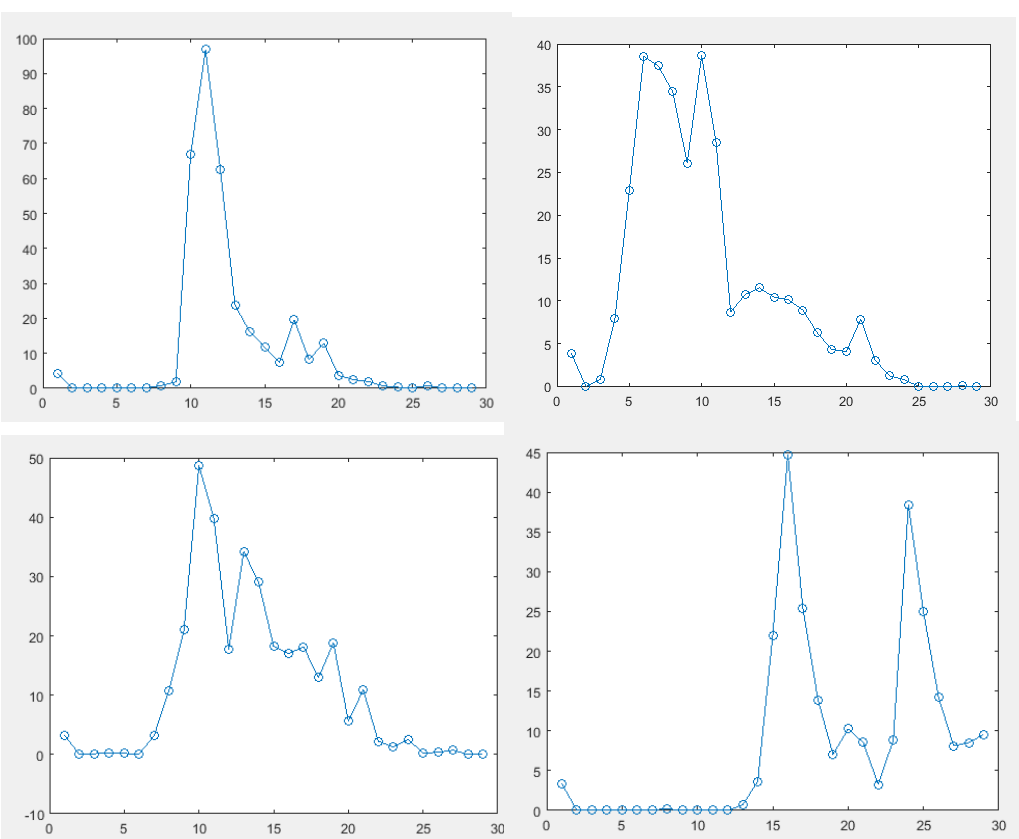
The total energy when the device was calibrated with muons appears below. The mean p energy was 282 GeV with a r.m.s. of 28.7 GeV. No beam energy spread was subtracted so the intrinsic energy error is not known well. There was a "constant term" in the energy resolution because the EE+HE system was non-compensating.



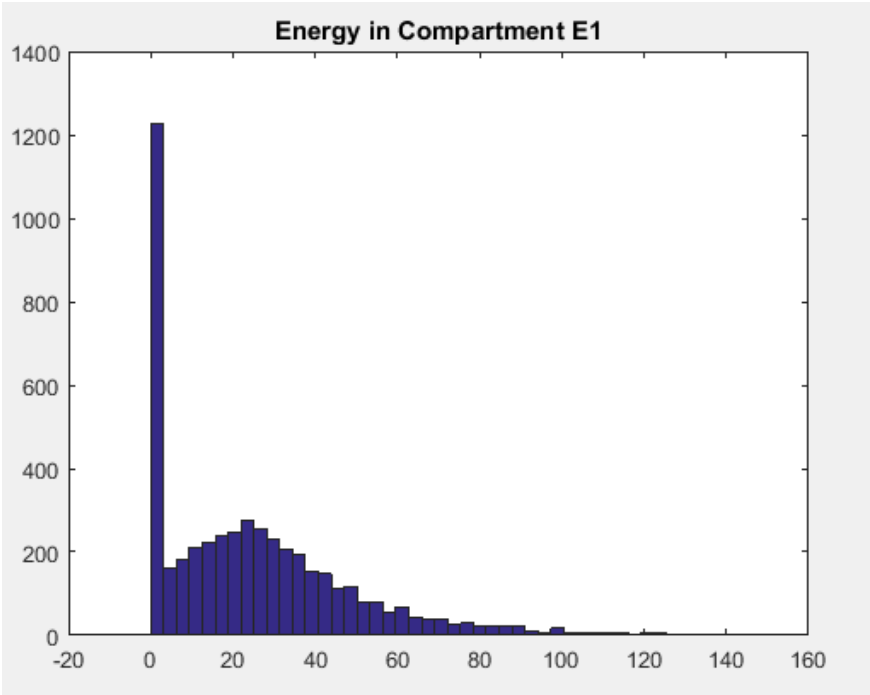
A profile in depth of the average energy deposit is shown below. The EE is at layer 1. Note that EE does not contain 1/3 of the energy because a p is incident, not a jet. Nevertheless, for early p interactions, neutral pions are produced and captured in EE, which has the highest layer energy. Layer 2 was dead. The change in sampling fraction of the Cu is quite apparent at layer 10.



The profile is misleading because of the large fluctuations in a hadron shower. Several individual events appear below. It is these fluctuations that cause the problems with radiation damage since in their absence the shower shape in depth is well known and early and damaged layers can be interpolated.



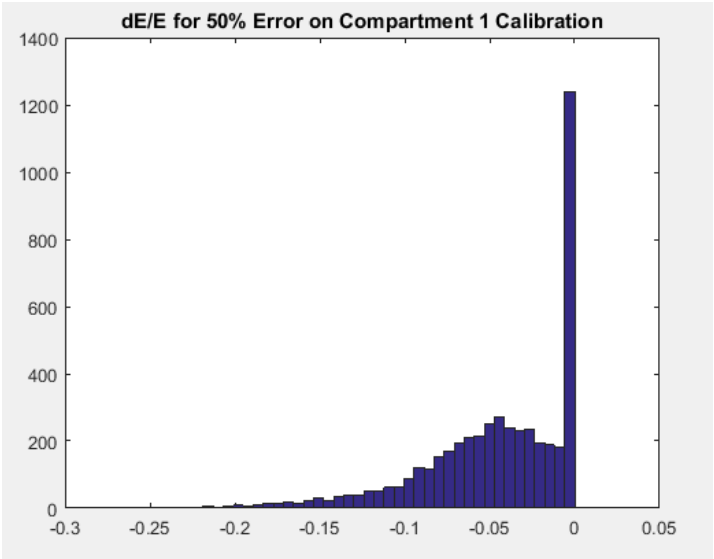
Some longitudinal “compartments” were defined below. EE is layer 1, E1 is layer 3-5, E2 is 6-9, E3 is 10-14 and E4 is 15-29. The mean energies in the compartments are; 48, 25, 50, 91 amd 68 GeV respectively. As might be expected,there are large fluctuations about these means. An example of the energy spectrum deposited in E1 appears below. There is a substantial probability, ~ 25 %, of a late developing shower where there is no energy in E1. However, in the case of a jet, being an ensemble of lower energy particles, these fluctuations are decreased.

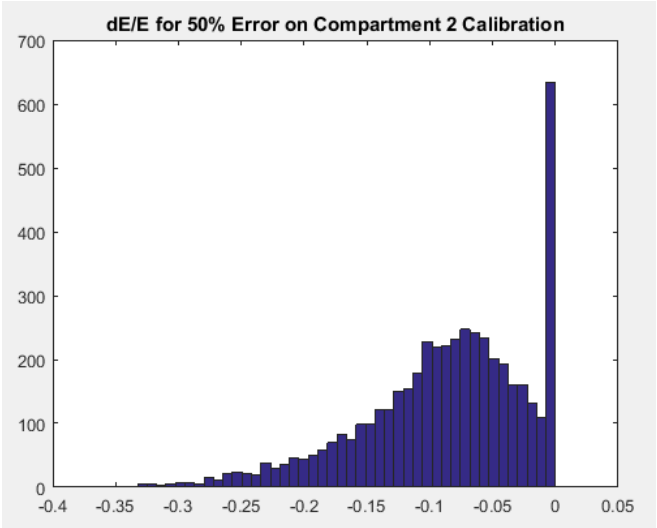


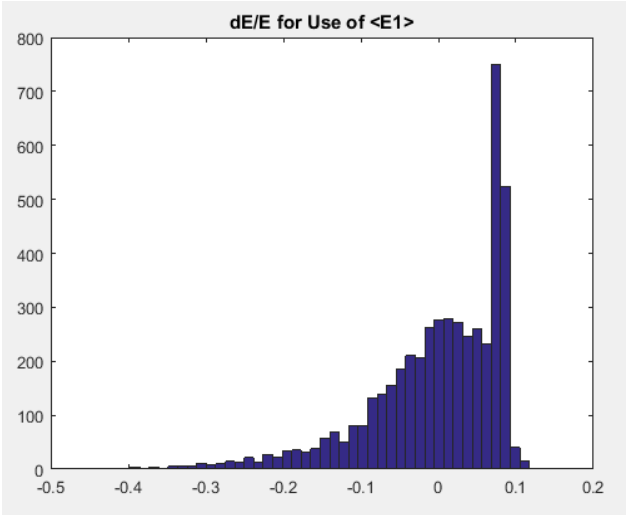
The compartments will become miscalibrated and/or inoperable due to radiation damage. The E1 will be the most damaged . The fractional change in energy due to a 50% miscalibration of E1 appears below. For those showers with no energy in E1 there is no error. The mean error induced by the miscalibraion is 4.6 % for E1. In the case of E2, also shown below, the mean induced error is 8.8%. Depending on the details of the SiPM signal and noise parameters, a 50% misestimate of the number of p.e. might occur when the mip signal has ~ 1-2 mean p.e. Deeper compartments should not be heavily affected by radiation damage.

In the case where a compartment like E1 is “lost” due to signal reduction below 1 p.e., one can still resort to using the mean E1 deposit. If E1 is dropped from the enrgy sum a 9.3 % energy shift is induced with a 9 % rms. If the mean E1 energy is added in there is no shift in the mean but the induced rms remains ~ 8.7 %. The strange shape shown below is caused by p showers without any E1 energy for which a ~ 10% error is made using the mean E1 energy.

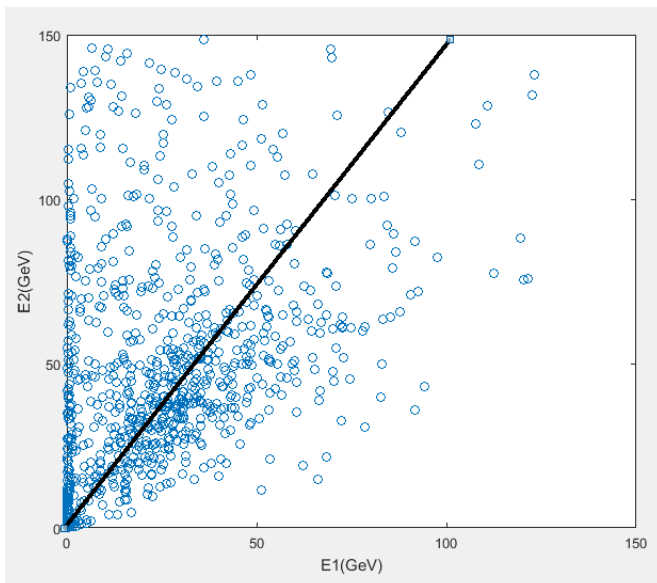
In order to quantify better the response to a Pt ~ 30 GeV jet into |y| ~ 2.5 a Monte Carlo is needed with access to all the layers of HE and the EE signal. More signal will be in EE which will make HE less crucial. For HE the ensemble of jet hadrons will smooth out the single particle fluctuations seen here. Finally, the extent of the miscalibration depends on the SiPM and FEE noise and signal and the dose rate model for the radiation damage to the scintillator.

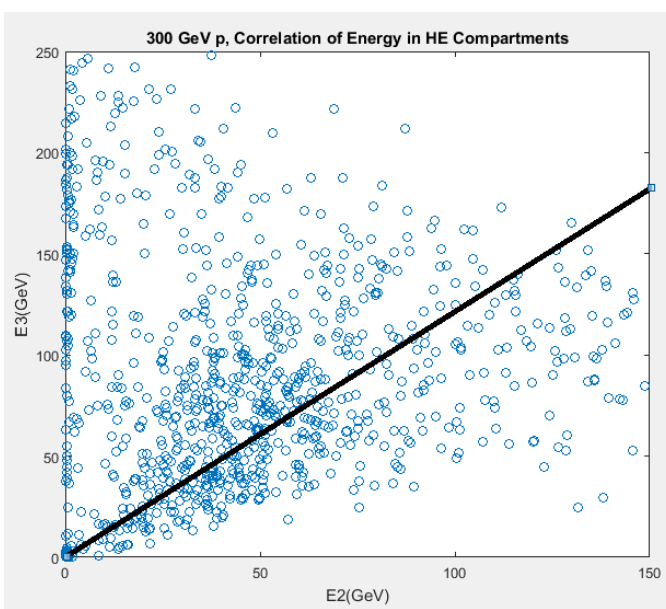

dE/E for 50% Error on Compartment 1 Calibration
1400
1200
1000
800
600
400
200
0
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05


dE/E for 50% Error on Compartment 2 Calibration
700
600
500
400
300
200
100
0
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05

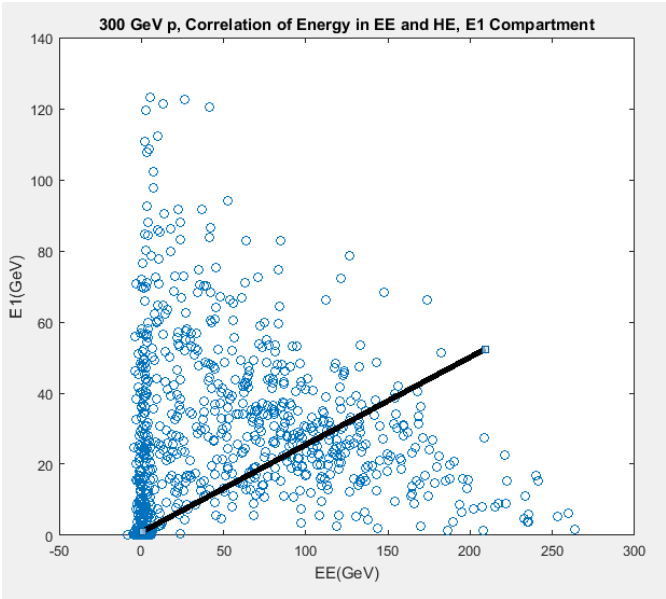

dE/E for Use of <E1>
800
700
600
500
400
300
200
100
0
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2

Another possibility is to appeal to “continuity”. As seen in the single event plots above, depths separated by an absorption length are correlated since the enrgy is propagated by charged hadrons in the hadron shower. Therefore a measurement in E3 gives an estimate of the E2 energy. Similiarly with E2 and E1. However, E2 = 0 or E1 = 0 respectively need to be avoided by making a cut to insure at least that the shower has begun. A rogh idea of the correlation would be to use the number of layers in the compartment.





Assuming a functional EE one can also try to use the correlations of EE with HE compartments. However, a large EE means that (in this case) a p interaction occurred and the first generation neutral pions give the EE signal. That signal does not correlate strongly with subsequent generations of charged pion secondaries. Nevertheless, this should be studied for jets, where one expects more correlation.


300 GeV p, Correlation of Energy in EE and HE, E1 Compartment
E1(GeV)
EE(GeV)
140
120
100
80
60
40
20
0
-50
0
50
100
150
200
250
300