FCAL Calibration Procedure

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1 Introduction

The response of the Forward Calorimeter to cosmic rays may be used to calibrate the response to collision particles. Most cosmic tracks traverse the Fcal vertically from top to bottom. Using a simple cosmic reconstruction algorithm we attempt isolate this sample from noise and cosmic at large angles from the vertical. The response of each module to this sample provides a measurement of channel-by-channel gain differences as well as a rough estimate of the absolute gains. In the d+Au recorded data of run 3 we utilize an observed cross-talk from the ZDC to extract channel-by-channel gains for comparison only.

2 Cosmic Calibrations

2.1 Cosmic Sample

Cosmic particles provide a calibration source to the extent that we can accurately characterize the cosmic sample. The mean energy of cosmic muons at sea-level is 4 GeV according to the PDG. At this energy the angular distribution of muons follows a $P(\theta) \propto \cos^2\theta$. The average path length of the tracks will therefore depend on the angular distribution as well as any trigger cuts that further restrict the sample distribution. There are nine columns of hadronic calorimeter modules each column a stack of ten modules. Each module is 10 cm x 10 cm x 117 cm and constructed of 48 Pb plates layered with a ribbons of 47 fibers to form a 47 x 47 fiber array within each module. For vertical tracks, the path length is 10 cm. The density of lead is 11.35 g/cm^3 and the dE/dx for lead is 1.123 $MeV \cdot cm^2/g$ resulting in an expected MIP energy of 127.5 MeV.

The recorded cosmic events are triggered by a 2x2 module sum of the analogue signals in the front-end electronics. For run 69946 the threshold was set to 26. The trigger signals of both North and South calorimeters are logically or'ed before the result is input into their common granule timing module (GTM). The resulting data files contain many events for which no signal was triggered in one of the calorimeters. An example of a cosmic triggered event is shown in Figure 1.

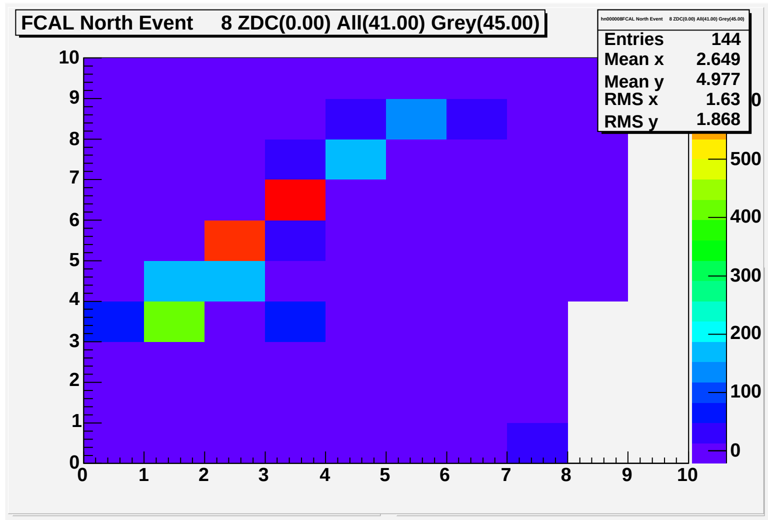

Figure 1: A typical cosmic event in the Forward Calorimeter.

2.2 Cosmic Reconstruction

Offline the FCAL Oncal module examines each event and performs a crude reconstruction to isolate vertical tracks. Isolating vertical tracks limits the variation in path length resulting from a track crossing from one column to another. Furthermore, we require minimum number of modules in that column have valid TDC values to ensure that it was a penetrating track. For each module in that column, the difference of the post and pre ADC samples is recorded in a corresponding module-by-module histogram. The mean of the distribution for each module is extracted and scaled from the high gain to the corresponding low-gain using measured gain differences (16x). This scaling is a characteristic of the readout electronics and therefore is not susceptible to changes in the HV supply, swapping of PMT, etc. However, when one ASIC card is swapped with another, it may be necessary to measure the low-high gain ratio for the new card. The quantity thus extracted for each module is in units of low gain ADC counts.

2.3 Expectations

The FCAL modules were utilized in a previous experiment during which their energy dependence of their response was characterized[1]. The response is linear over the measured range from 1.5 GeV to 8.5 GeV for hadronic showers. The energy resolution above 5 GeV is better than 20%. Below this is an increasing degradation to 38% at 1.5 GeV. Variation in longitudinal distribution of energy will contribute to energy resolution. Most of the energy of these hadronic showers is deposited at the front of the calorimeter. In the case of cosmic rays, the energy is uniformly distributed along the length of the module. This is important because the attenuation length of the scintillating fibers is 220 cm so that a shower at the front of the module is 57% of that at the back of the module and about 78% of the total for a uniform distribution over the module. Therefore, we expect a mean of 99.5 MeV with an expected width of at least 40%. The variation in path length within the existing reconstruction cuts is negligible.

2.4 Cosmic Results

The cosmic calibration results are stored in the PdbCal database in the table named calib.fcl.cosmic. For each module, the extracted means of the reconstructed cosmics scaled to the low-gain ADC scale are assumed to correspond to the cosmic muon distribution with a mean of 0.1 GeV. The quantity stored in the database is in units of GeV/ADC count.

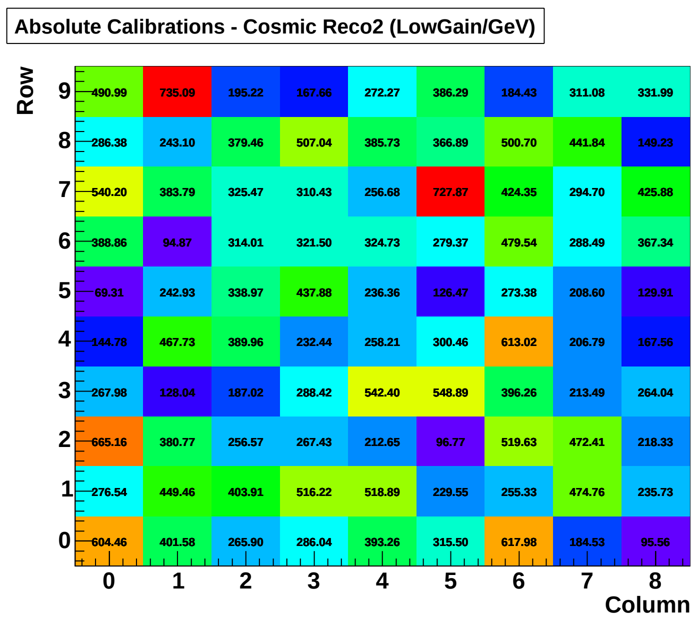

Figure 2: The Absolute Calibrations extracted for the South FCAL using cosmic triggers.

The ZDC-FCAL correlation for the deuteron side with cosmic FCAL calibrations are shown in Figure 3. There is some suspicion that the peak in the FCAL energy for protons may be in part an artifact of saturation in the readout electronics. The location of the peak seem surprisingly low, but this is not altogether inconsistent with simulation of beam energy protons. The shower of a 200 GeV proton is only partly within the FCAL acceptance.

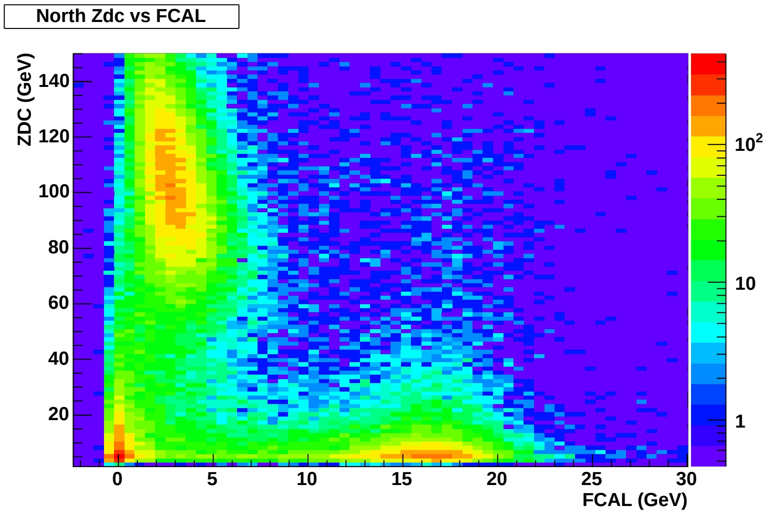

Figure 3: The ZDC-FCAL correlation on the deuteron side. The neutron signal at large ZDC corresponds to a non-zero signal in the FCAL.

3 ZDC-Crosstalk Calibrations

In the RHIC Run 3 d+Au collisions, the FCAL and ZDC have a very tight correlation at low energy. Full PISA simulations confirm a significant cross talk from the neutron showers not confined to the ZDC. A tight correlation is observed in both the simulation and real data as shown in Figure 4. The extracted slopes are compared for several runs in Figure 5 and demonstrate a significant change in the first two columns around Mar 4-6, 2003.

4 Calibration Comparison

Since the ZDC-FCAL correlation may be extracted for both the simulation and the real data, the ratio of the slopes provides an alternate means of calibration. The slope extracted from real data is in units of FCAL(ADC Counts)/ZDC(GeV). The same ratio extracted from the simulation is in units of FCAL(GeV)/ZDC(GeV). The ratio of simulation to data is then FCAL(ADC Counts)/FCAL(Simulated GeV). Obviously, this quantity depends greatly on the simulation, but with different systematic uncertainties than a calibration that might be derived by attempting to match the entire FCAL energy distribution of a module to that of simulation. In the former, we attempt to isolate only the contribution from one source in the simulation the result of which is most vulnerable in the accurate representation of the material separating the ZDC and FCAL. In the latter, one is not only limited by the accurate representation of the more complicated DX material through which protons pass at oblique angles, but also the accurate kinematic distribution of the protons. Calibrations extracted from cosmic triggers are compared with those extracted from

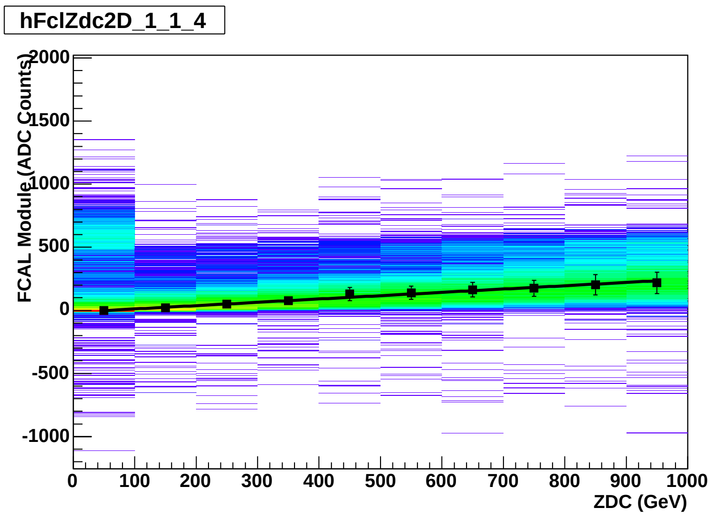

Figure 4: The FCAL-ZDC correlation for small ZDC Energy (< 1000 GeV) run 70076.

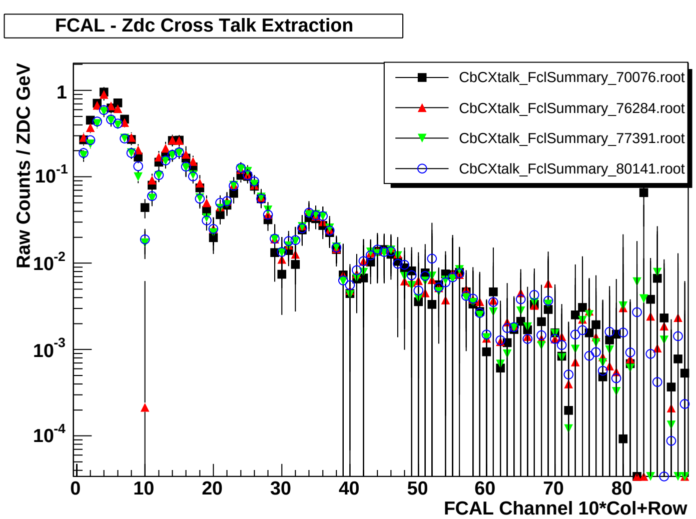

Figure 5: The FCAL-ZDC correlation slope (ZDC Energy < 1000 GeV) are compared for several runs.

matching the ZDC cross talk to simulation in Figure 6. The agreement is quite good especially in the fourth and fifth column where there are minimal hardware saturation effects and where the ZDC-Xtalk is of a significant enough contribution to be quantified above other backgrounds.

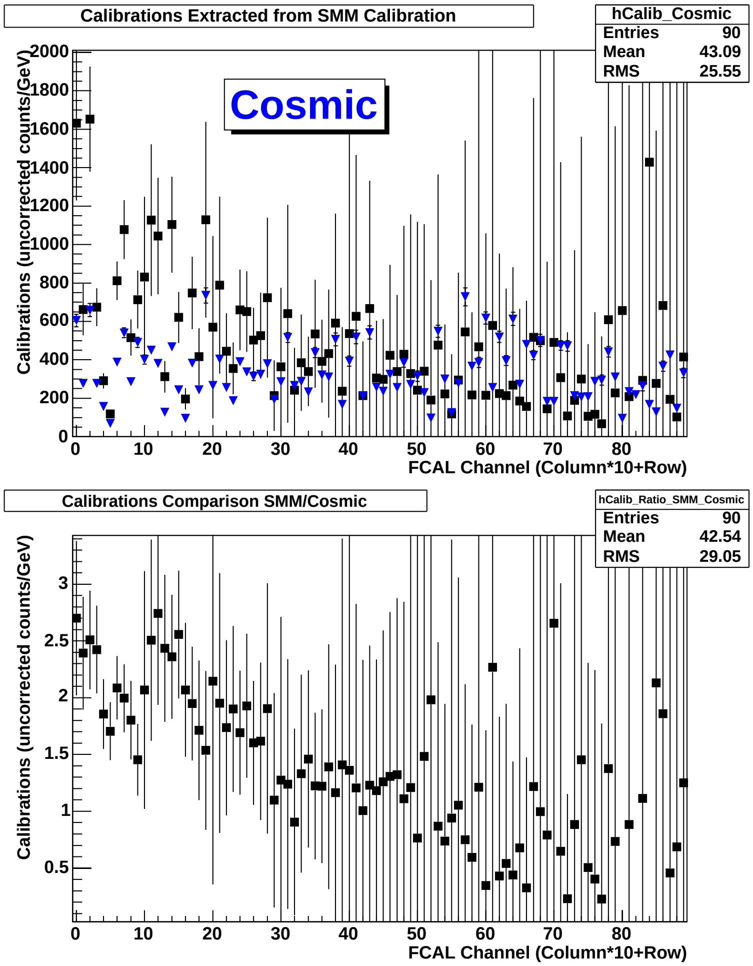

Figure 6: Upper: Calibrations extracted from simulation (black) and cosmic triggers (blue). Lower: The ratio of the the calibrations shown in the upper panel.

References

[1] C. A. Pruneau. The e864 lead/scintillating fiber hadronic calorimeter. Prepared for 6th International Conference on Calorimetry in High-energy Physics (ICCHEP 96), Rome, Italy, 8-14 Jun 1996.