measured on each strip. The vertex finding is also sensitive to the effect, as a cluster of hits must be recognized and treated as a single track. Increasing the strip pitch from 100 μm to 200 μm improves the cluster finding, as the clusters consist of fewer strips and the larger pulse height in each strip improves the separation of true and noise hits. The occupancy in the silicon barrel is of course increased by the larger strip pitch, but vertex finding resolution and efficiency remain excellent.

5.5.3 Multiplicity Distribution

The performance of the silicon detectors in measuring the multiplicity distributions, both the average dN/dη, and event-by-event were discussed in Chapter 3. The average dN/dη can clearly be very well reconstructed from the pulse heights measured in the silicon, in a pseudorapidity range of ± 2.7. The pseudorapidity range covered in a single event is closer to 5 units, the actual coverage depending on the vertex position of that event. However, we are sensitive to fluctuations in dN/dη within that range. Of course, data collected with only partial azimuthal coverage will be very difficult to analyze for event-by-event quantities, but the average dN/dη distribution can still be measured over a large pseudorapidity range. The silicon pad endcaps will always retain full azimuthal coverage, and allow study of fluctuations in dN/dη in 0.85 units of pseudorapidity for each endcap.

The errors in the dN/dη measurements arise from several sources besides the statistical errors. The energy deposited in each silicon layer has a Landau distribution about the mean energy deposition. This is further complicated by the angle of incidence on the silicon, but can be corrected with knowledge of the vertex position. The silicon pad detectors, which see particles at angles closer to normal incidence, provide an important control to systematic errors arising from this effect. The mix of particles entering the silicon determines the mean energy loss, and corrections for this will be made offline, using the distributions of particles identified in the hadron sector of PHENIX. Clearly, the accuracy of calibration and gain matching of individual silicon pixels enters into the unfolding procedure, and hence the systematic error on dN/dη. These can be controlled by careful offline gain matching, and will be adequately addressed for trigger purposes by careful selection of the gains of preamplifier chips entering into each hardware analog sum, and application of gain match constants in the digital summing step. The systematic error on dN/dη will also be affected by our understanding of and unfolding of the noise on the silicon pixels. This can be controlled by careful study and calibration of the system with beam off, and measurement of beam-correlated noise. There will certainly be inoperative channels within the silicon system. Their effect on the multiplicity measurement will be unfolded and corrected by a Monte Carlo procedure.

5.5.4 Fluctuations

Pulse Height Analysis

The occupancy of both the pads and strips is rather high in central Au + Au collisions, in the vicinity of 40%. When the occupancy is high, the number of particles entering a single

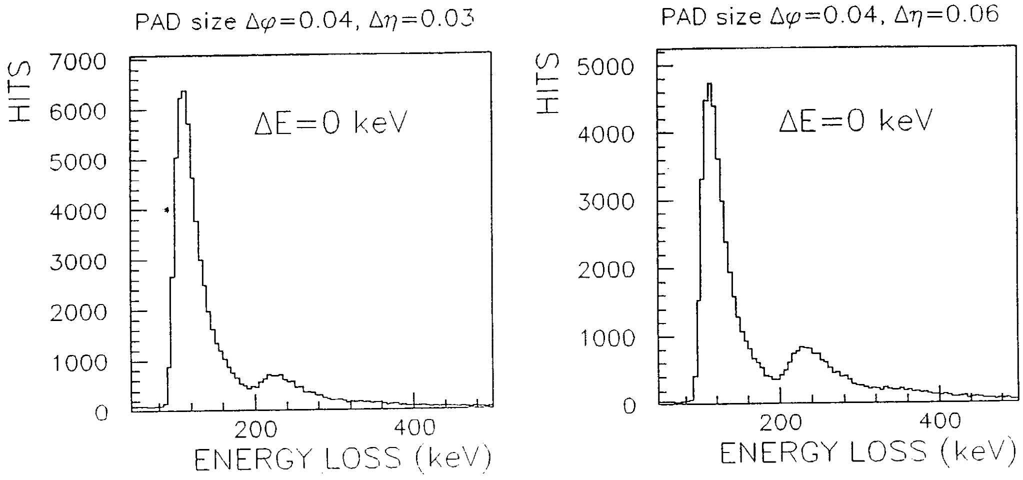

Figure 5.14: Monte Carlo simulation of pulse height spectra with GEANT using bin size $\Delta\phi$=0.04 with left) $\Delta\eta$=0.03 and right) $\Delta\eta$=0.06. The top curves are for zero detector noise, and the lower ones for 20 keV detector noise.

pixel must be unfolded from the pulse height spectrum. Uncertainties in this procedure arise from Landau fluctuations, large pulses from low energy particles, and detector and electronics effects. Figure 5.14 illustrates simulated pulse height spectra for single pads in the endcap detectors, with segmentations $\Delta\phi = 0.04$ and $\Delta\eta = 0.03$ and 0.06. The endcap pads have $\Delta\eta$ approximately 0.04 and a comparable $\Delta\phi$, so these results should simulate a typical pad. In both the perfect detector (top) and the detector with 20 keV noise level, the peaks corresponding to one and two particles entering the pad are clearly visible.

Simulation of Sensitivity

Monte Carlo simulations were carried out to evaluate the silicon system capabilities for studying fluctuations. As an example of a fluctuation study, the intermittency analysis was used because its signal at RHIC may be easily estimated by extrapolating data from existing heavy ion experiments. Such a fluctuation study is a stringent test of the detector performance as a multiplicity counter, since measured signals are sensitive to local fluctuations of multiplicity densities in each event. For this reason we use it here as a performance benchmark.

A set of Monte Carlo events was generated using the α-model of intermittency introduced by Bialas and Peschanski [6]. This model can generate tracks showing the intermittency behaviors by using a series of self-similar random cascade processes. The intensity of the signal can be easily tuned by changing two free parameters. The finite resolutions and occupancies of the detector were included in the simulation. The scaled factorial moments [6] for varying pseudorapidity bin sizes were calculated for the original tracks and the reconstructed data to see the detector effects in the measurement of the intermittency.

We have extrapolated existing data to the average pseudorapidity density expected at RHIC in order to determine the input slope of the scaled factorial moments. Only one section of the barrel detector, covering 60° in azimuthal angle, and with a read-out pitch of 200 μm, was used for this study. For central Au + Au collisions, the average multiplicity per unit pseudorapidity in this detector was about 167. The two parameters (a, β) of the α-model were estimated to be 0.27 and 0.04 to give the expected slope for this system.

Using the α-model with the above parameters, tracks were generated in the pseudorapidity range $-1.0 \leq \eta \leq 1.0$. These tracks were propagated through the silicon detector and the digitized information (struck pixels and the pulse heights), was used to find pseudorapidities of the measured tracks. Due to the finite thickness of the detector (300 μm), a single track can produce a cluster of several strips firing, depending on the incident angle. Also, it is possible for different tracks to overlap and form a larger size cluster. Figure 5.15a shows the distribution of the cluster sizes with only one track entering the detector. Figure 5.15b shows the same distribution for all tracks. The number of tracks forming a cluster does not have a simple relation to the cluster size. Instead, it is necessary to use the overall energy deposition (ADC) in the cluster. As in the multiplicity density analysis above, the sum of the pulse heights was divided by the expected energy deposition from a single minimum ionizing particle to determine the track multiplicity.

Figure 5.15c shows the pulse height distribution in the clusters as a function of pseudorapidity. The lowest band corresponds to the energy deposited by single tracks and higher bands originate from higher track multiplicities. For a fixed multiplicity, the energy deposition increases with pseudorapidity, which can be expected from the increased path length through the silicon. The smearing of the multi-track resolution due to the Landau fluctuations were included in the above calculation. Pseudorapidities of the tracks were calculated by assuming random hit positions inside the cluster.

For the reconstructed and initial tracks, the second order scaled factorial moments were calculated for bin sizes varying from $\delta\eta = 2.0$ to $\delta\eta = 0.1$. In Fig. 5.16, the ideal and measured moments are presented with dotted and solid lines, respectively. For the measured

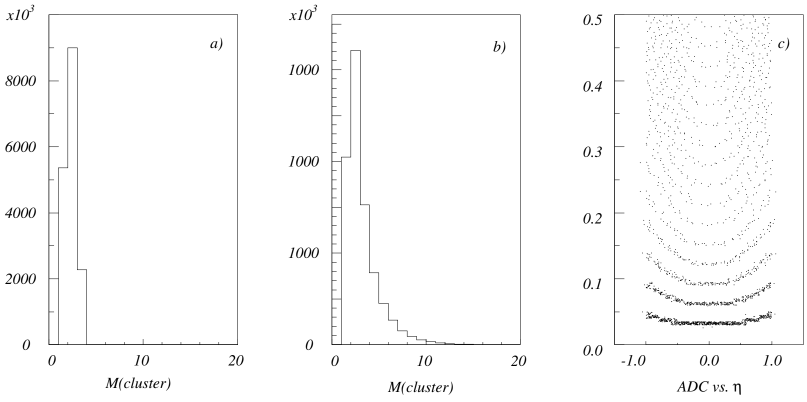

Figure 5.15: a) Strip cluster size for single tracks entering silicon barrel. b) Strip cluster size distribution for central Au + Au event. c) Pulse height in cluster, as a function of pseudorapidity.

moments, the power law behavior, $F_2 \propto (\frac{1}{\delta\eta})^{\phi_2}$ as $\delta\eta$ decreases, is clearly visible even though the slope parameter, $\phi_2 = -d(lnF_2)/d(ln\delta\eta)$, is reduced by the detector resolution. The magnitude of the detector-induced effects can be determined and corrected for via a Monte Carlo study similar to the one performed here. In this type of analysis, sensitivity to changes in the slope with scale, rather than an absolute measurement of the slope value is important. The detector effects are less important in lighter ion collisions with lower multiplicity and the signal could be measured with smaller distortions [7].

The figures only show the performance of the barrel for this analysis. The endcaps cover the η range from 1.8 to 2.65, and do not produce clusters of hits for each track. The pad occupancy in central Au + Au collisions is around 40%, but good information on the number of particles entering each pad can be extracted as shown above. Consequently, the pad endcaps will extend the both the pseudorapidity range of intermittency analyses, and the range of scales which may be investigated.

5.5.5 Backgrounds

Simulations were performed with the LAHET (Los Alamos High Energy Transport) code system to determine the flux of charged particles and neutrons entering the silicon barrel and endcaps. This study was used to check if radiation damage may pose problems to either the silicon detectors or to the associated electronics. The simulations show that the charged particle flux is dominated by the particles produced at the vertex; there is some contribution by albedo from the magnet pole faces, but it is considerably smaller than the primary particle flux. The expected radiation dose is of the order of 1 krad per RHIC year

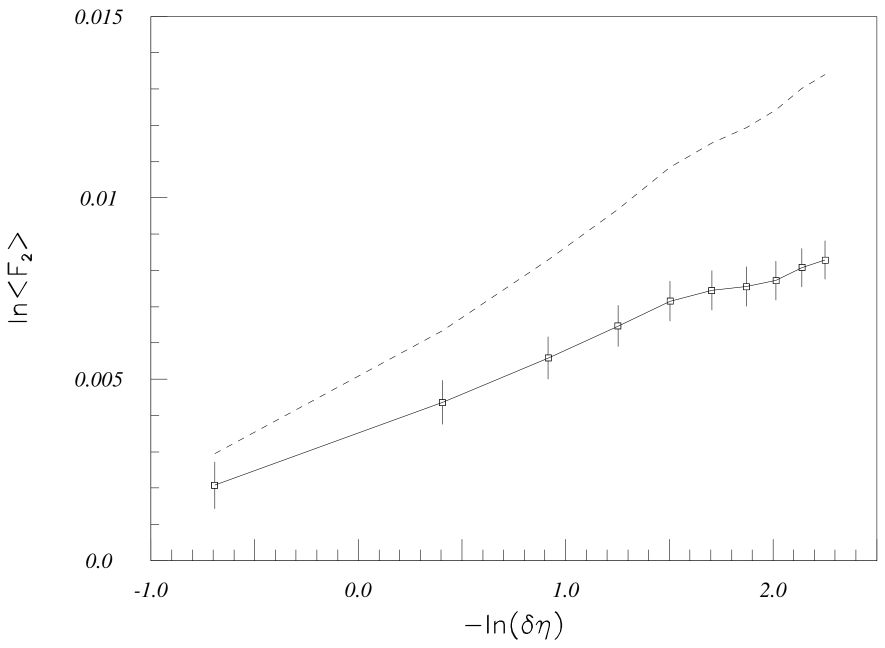

Figure 5.16: Scaled factorial moments calculated for central Au + Au collisions. Dotted line is for an ideal detector, and the solid line for data reconstructed from the silicon strips.

in the barrel detector and the endcaps will receive a very similar dose. Note that CDF tests found a factor of two increase in electronic noise after exposure of the electronics to a 20 kRad dose from ^{60}Co. [5]

Albedo particles tend to have a softer spectrum than the primary charged particles, presenting the potential problem of a large number of soft particles which deposit more energy than minimum ionizing in the silicon detectors. The LAHET spectrum of emitted protons was integrated from minimum ionizing down to the momentum at which the magnetic field prevents the protons from reaching the silicon. It was found that the number of soft protons per cm^2 is approximately 0.025, which is small compared to the number of primary charged particles.

LAHET was also used to study the neutron dose the silicon will be exposed to. Integration of the neutrons produced in the magnet, including the very soft component, showed a neutron dose of approximately 1 x 10^{11} per cm^2 per RHIC year in the barrel region, and 3 x 10^{11} per cm^2 in the endcaps. Though this is not negligible, it adds up to a total dose level below 10^{13} per cm^2, which causes significant degradation of the performance of the system.

This kind of radiation environment should not cause sufficient radiation damage to the detectors to be problematic (i.e., large increases in leakage current and degradation of detector performance). We also do not anticipate a need for special radiation-hard fabrication processes for the front-end electronics. It should be noted that the radiation environment