Fermi National Accelerator Laboratory

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A Simple Analog Clock Used for Reducing Pedestal Noise

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Introduction

Experimental facilities are inherently noisy places! Try as one might to eliminate it [1,2,3,4], there always seems to be some residual low frequency electronic hum that works its way into low level analog signals, such as calorimetry into analog-to-digital converters (ADC)[5]. At the Fermilab Wide Band Lab, the predominant noise (between experimental hall and counting room, and between electronics racks within experimental hall and within counting room) consists of a combination of 60 Hz plus 180 Hz adding together with equal amplitudes and identical phase. The noise contributions at these low frequencies are easily removed by capacitor-coupling or isolation transformers. This approach works well for most detector systems. However, for the highest rate analog detector systems, e.g. the calorimeters within the beam stops for the electron (RESH-0), positron (POSH-0), and photon (BGM) beams for E-831/FOCUS, these AC couplers introduce unacceptable signal distortion and rate-dependent analog baseline shifts.

The residual 60/180 Hz hum, between these detectors and their ADCs, is typically on the order of 10 mvolt peak-to-peak at the Wide Band Laboratory, which drastically smears the pedestal spectra and constitutes the major contribution to the resolution for these detector systems.

Rather than continue to beat my head against the wall in trying to eliminate all this noise, I implemented a simple 60 Hz analog clock ramp which was read into an ADC channel simultaneously as part of the data event record and which indicated the instantaneous *phase* relative to the 60 Hz AC power at Wide Band Laboratory. The pedestal was then monitored and parameterized as a function of this phase. During analysis, the digitized analog system had its phase-dependent pedestal subtracted, thereby substantially reducing the low-frequency pedestal noise.

Circuit Description

The 60 Hz analog clock circuit is a simple saw-tooth ramp generator shown in Figure 1. It is packaged in two NIM modules to provide additional isolation between the 120 VAC and 6 VAC and the output ramp. The 74121 Schmitt-trigger one-shot multi-vibrator fires at approximately 1/3 of the (positive) amplitude of the clipped 6 VAC, providing a 4 μ-sec TTL reset pulse at this specific phase of the AC line voltage. No additional phase-locking or missing cycle compensation was included. (See what I mean by "simple"?). The 4 μ-sec pulse was used to reset the charging capacitor via the 75452 switch. The 741 op amp provided buffering and offset adjustment, producing the desired saw-tooth ramp from –30 mvolt to –90 mvolt into the 50 ohm input of the ADC. The analog ramp, along with the half-rectified 6 VAC phase is shown in Figure 2. Although the analog ramp is fairly linear, for off-line correction of pedestal noise, the only requirement is that there be a one-to-one correspondence between the analog ramp and the phase of the line power.

Performance

Figure 3 shows the input 60/180 Hz analog noise and the smeared pedestals for the three high-rate calorimeters before offline correction using this analog clock/ramp. Figure 4 shows the correlation between the pedestal distribution for the BGM calorimeter and the phase of the line power as represented by the analog clock ramp (in the ADC named BGMX). Figure 5 shows the averages and standard deviations for the pedestals as a function of analog clock. The parameterization of the average pedestal as function of analog clock reading was used to correct the pedestals in Figure 6. For this pedestal run, the first half of the data set was used to plot the upper raw pulse-height distributions and to determine the average pedestals as a function of analog clock ramp. This phase-dependent average pedestal was then subtracted from each ADC for the second half of the pedestal run, giving the corrected pedestal distributions with reduced standard deviations.

The phase dependent correction parameters were determined in March, 1997 and continued to be optimal through the end of the data run in August, 1997 indicating excellent phase and ramp-shape stability for the analog clock ramp over this 6 month time scale.

Figure 7 shows the application of this pedestal noise reduction technique applied to the electron (and negative hadron) beam energy spectrum (that's why its called the *Wide Band* Beam) as measured by the BGM calorimeter.

This analog clock ramp allowed monitoring and diagnosis of other expermiment parameters, such as some efficiencies and trigger rates, which were also demonstrated to be correlated to the phase of the 60 Hz electrical power service.

References:

1. Marvin Johnson, Practical Electronics For Experimenters, Fermilab Academic Lecture Series, February, 1990.

2. H.W. Ott, Noise Reduction Techniques in Electronic Systems, Wiley, New York, 1976.

3. P. Horowitz and W. Hill, The Art of Electronics, Cambridge University Press, Cambridge, 1980, especially Chapter 7.

4. Age Visser's design for quiet power and super-quiet power for the Fermilab Wide Band Lab.

5. The LeCroy LRS 1885 ADC has good active low-frequency noise suppression below about 10 mvolts peak-to-peak, which gets overwhelmed above this noise level. The faster LRS 1881 ADC, which was used in E-831/FOCUS, does not have this good low frequency noise rejection feature. Pedestal smearing due to 60/180 Hz noise was the issue addressed by this analog clock ramp.

Figures:

FERMILAB
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: PHG 972: 60 Hz Analog Clock (Ramp)

NAME: Peter H. Garbincius

DATE: 21 March 97 **REVISION DATE:**

PHG 972A:

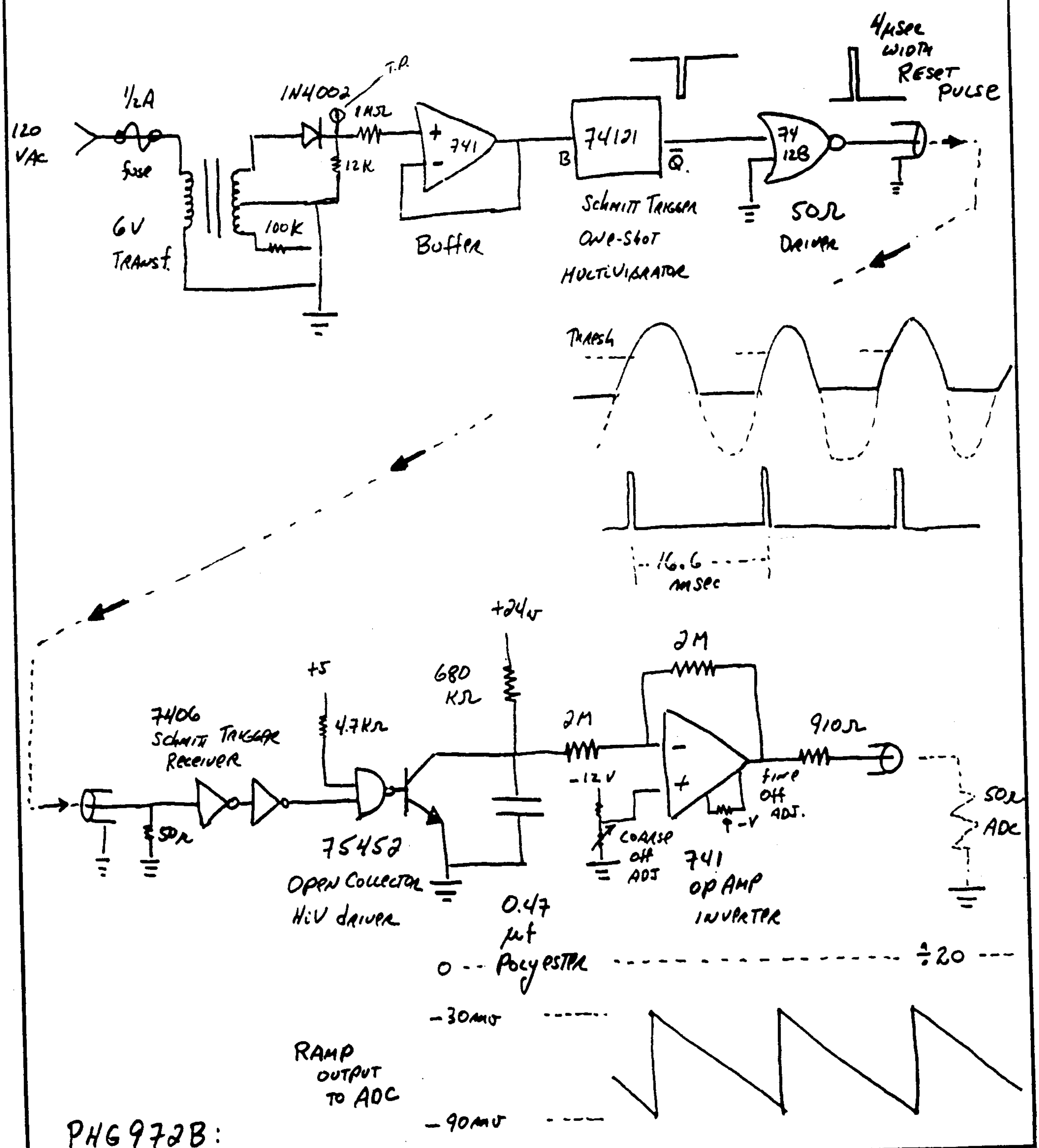

Figure 1. 60 Hz Analog Clock (Ramp) Circuit.

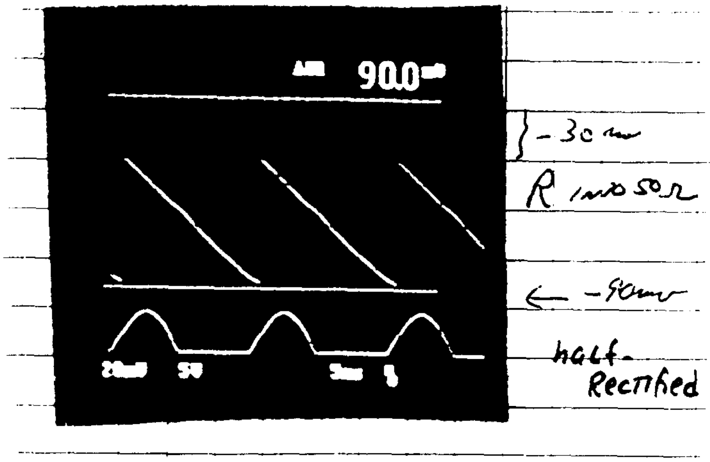

Figure 2. Oscilloscope trace of analog ramp and 60 Hz half-rectified 6 VAC.

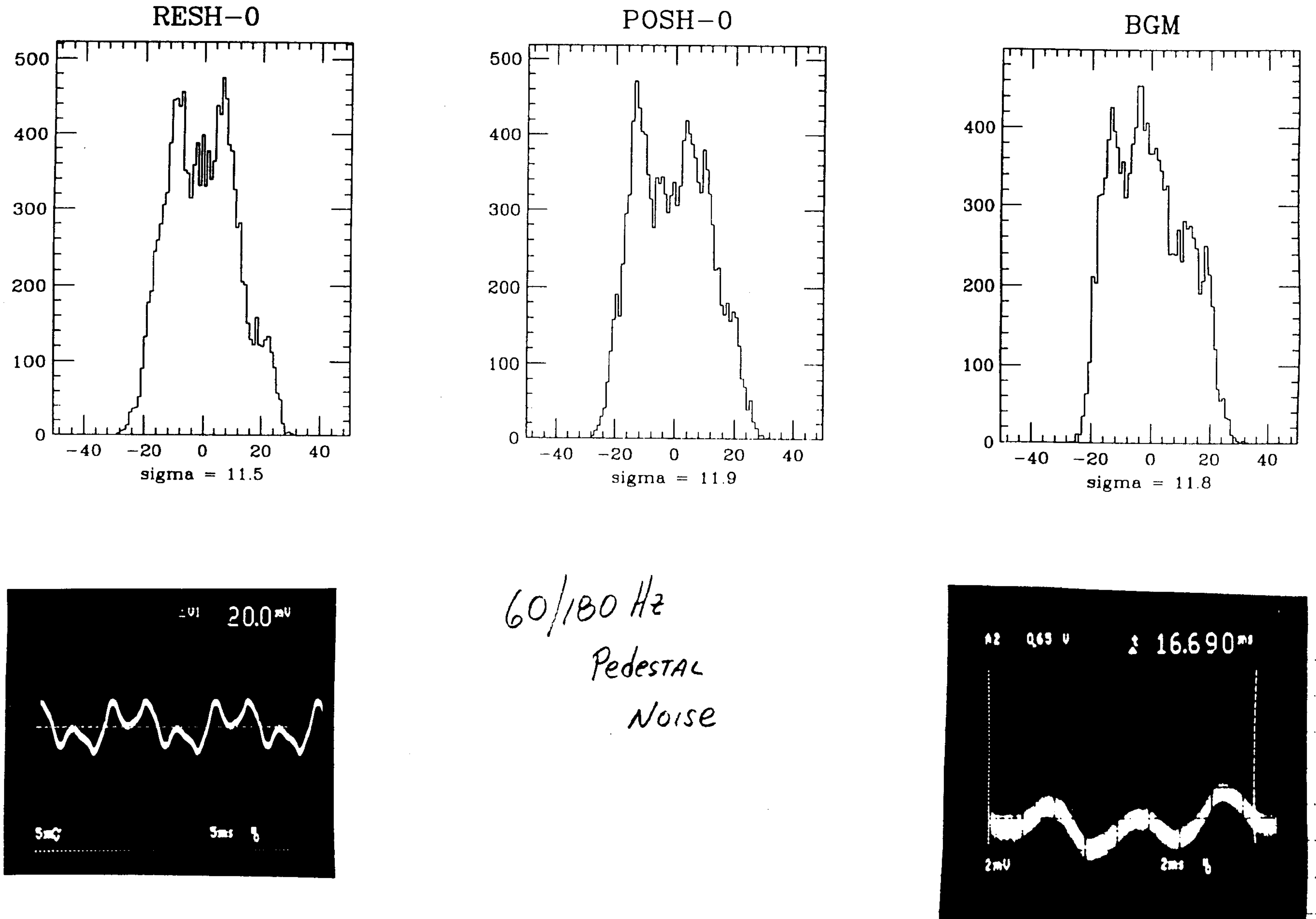

Figure 3. Oscilloscope trace of 60/180 Hz input noise and smeared pedestals before correction.

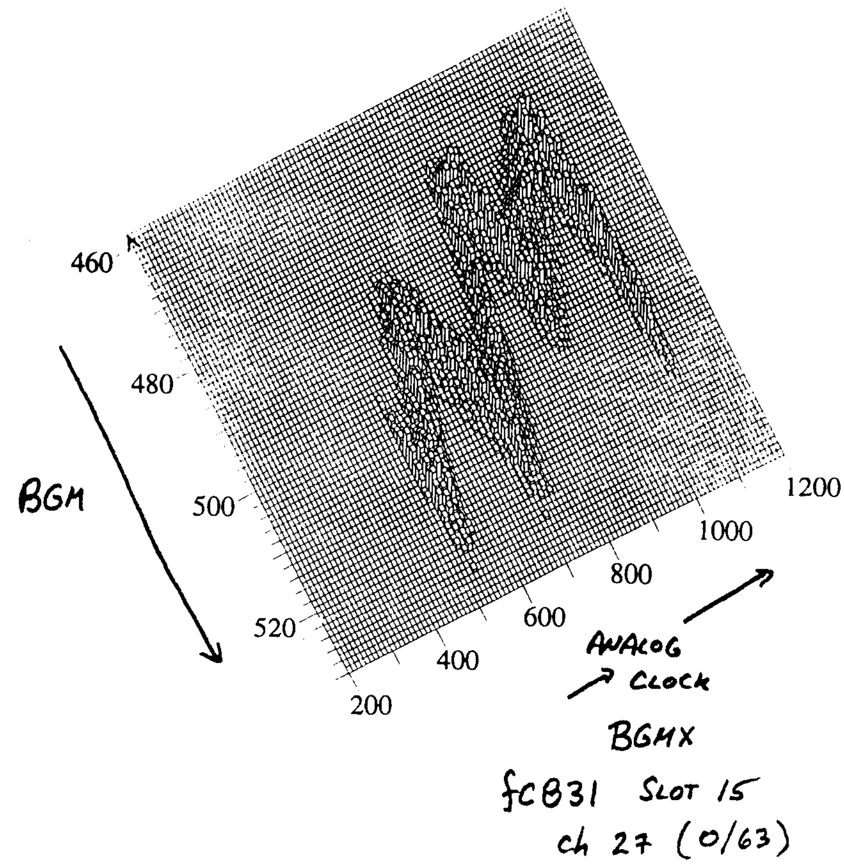

Figure 4. Two-dimensional correlation of BGM pedestal ADC counts vs. Analog Clock Ramp (named BGMX in the data record) for pulser-driven pedestal monitoring run.

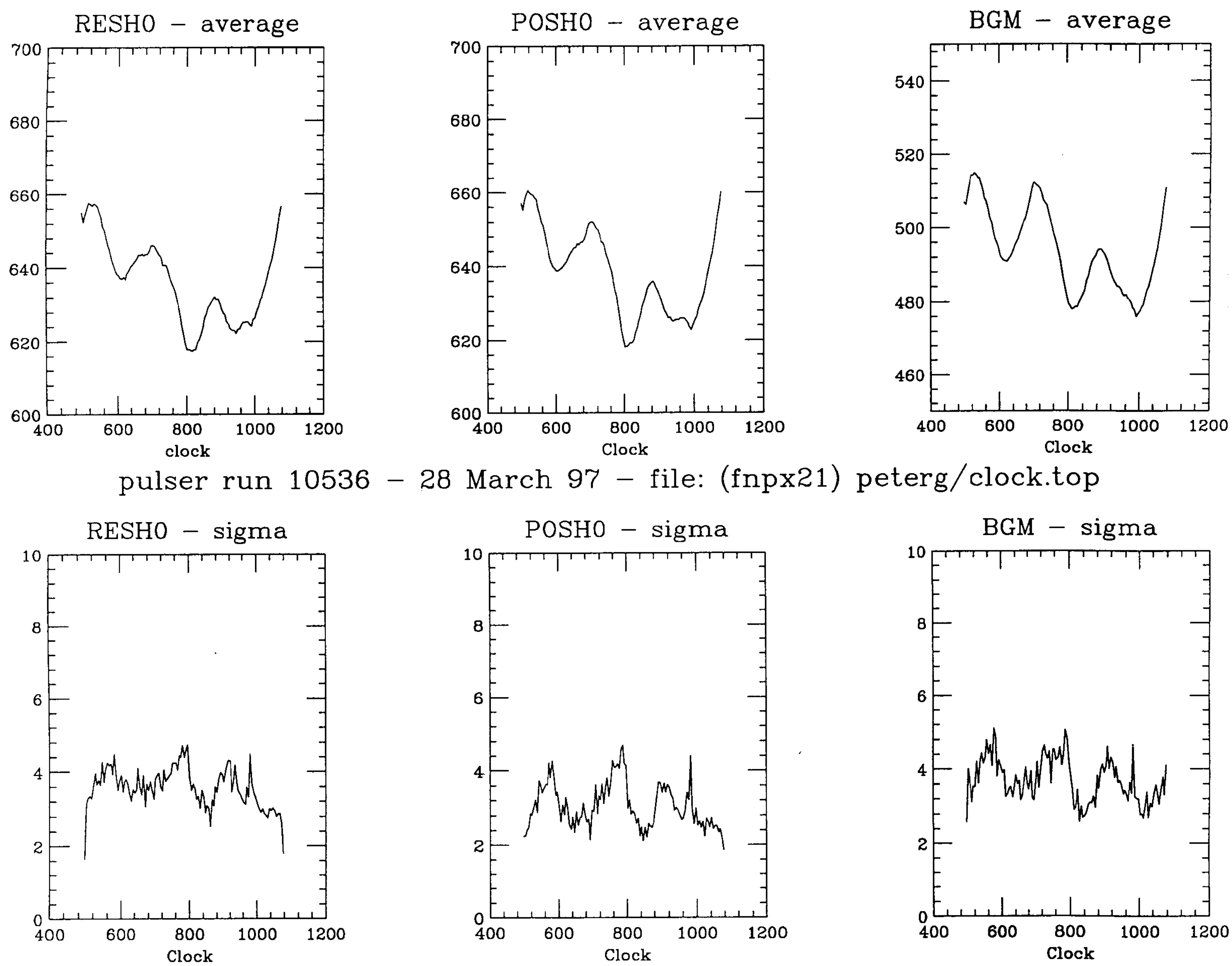

Figure 5. Averages and standard deviations for pedestal pulse height distributions for the high rate calorimeters as a function of Analog Clock Ramp ADC.

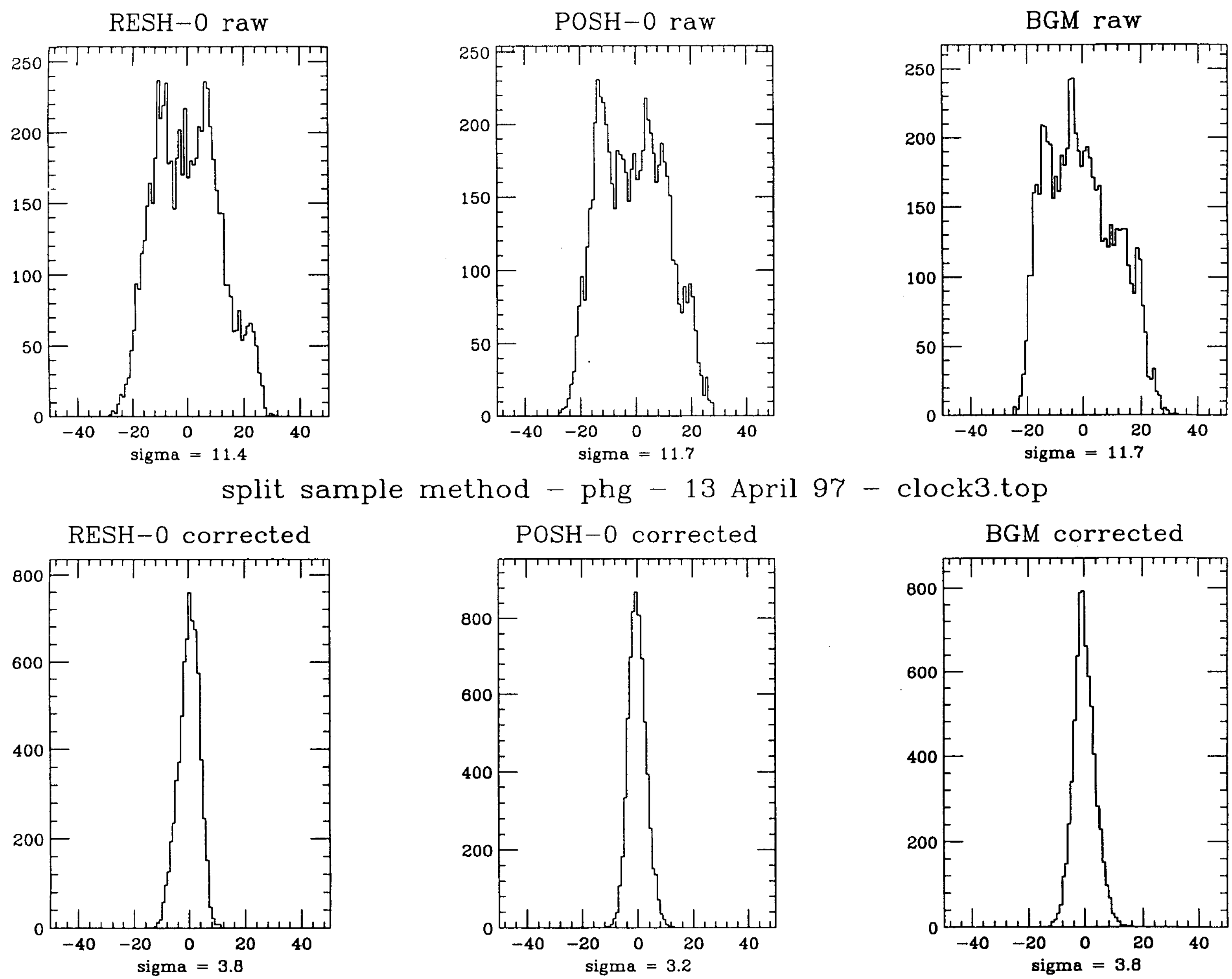

Figure 6. Correction of 60/180 Hz noise using power phase measured by analog clock ramp for three calorimeters.

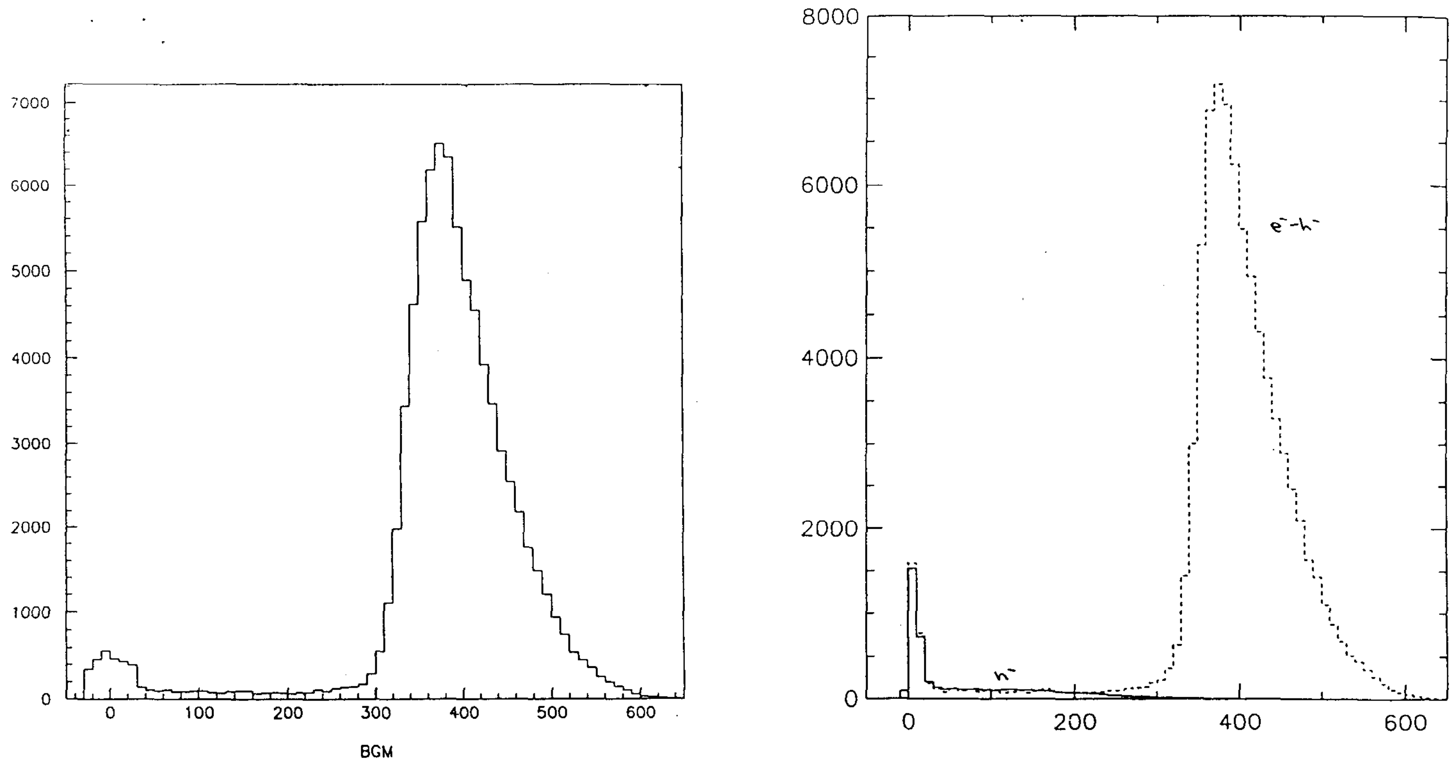

Figure 7. Analog spectrum of beams into BGM calorimeter: left: electron beam before pedestal correction, and right: electron beam (and negative hadron beam) after pedestal correction.
(Data plot provided by Kihyeon Cho of Tennessee University.)