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Beam Position Monitor Electronics Testing, Summer 2009

Initial ADC tests

These tests were performed on a number of analogue to digital converters (ADCs) to determine the amount of background noise intrinsic within its circuitry and from other adjacent electronics, etc. During the the first round of these tests, all channel inputs were terminated with resistors of ~50 Ohms, so that the voltage read, in absence of noise, would be exactly zero. The gate signal for integration was approximately 4ms thus 1940 samples/integration event.

The yield, difference, and asymmetry across individual channels and different ADCs were analyzed using a quartet of 4 events. The yield represents the sum of these four events, the difference the pattern of events (1+4)-(2+3), and the asymmetry is the difference divided by the yield. To determine the level of noise present, the value of the difference RMS/sample was taken, shown in illustrations 2 & 3. These values, between both channels within each ADC and between different ADCs showed good agreement within an appropriate statistical distribution.

Run 806 **module 023**

Yield		Difference		Asymmetry	
mean	RMS	mean	RMS	mean	RMS
-1.19E+6	4062.3	.124	898.3	-1.49E-8	1.89E-4
-1.60E+6	4923.7	5.460	926.8	-3.31E-6	5.79E-4
-2.19E+6	4560.7	4.929	915.9	-2.19E-6	4.17E-4
-2.55E+6	5160.8	5.661	907.2	-2.18E-6	3.56E-4
-1.47E+6	5152.1	3.751	918.0	-2.40E-6	6.24E-4
-2.23E+6	6457.0	-5.727	968.7	2.64E-6	4.35E-4
-3.41E+6	5080.5	-3.441	864.2	1.03E-6	2.53E-4
-1.26E+6	5206.2	-4.873	860.7	4.03E-6	6.85E-4

Illustration 1 - Yield, Difference, and Asymmetry data from a typical run, with 37,001 quartets/channel.

The RMS/sample measurement is in ADC units of 76.3uV/count, and the average noise level for all modules(see illustrations 2 &3) is .4695*76.3uV/count= 35.8uV. The lower limit for noise from digital integrators, as set by the Qweak 2007 Proposal[2], was 0.7uV/sqrt(Hz), and our measurements translate to 2.23uV/sqrt(Hz), [35.8uV / (1 / (4*1940samples*2usec.)]. This level is comparable to the limits set, and two orders of magnitude less than the expected noise from the beam operation, thus the noise from these electronics will play a negligible role in lessening the precision of the final measurements.

A number of the ADC modules were found to be missing small components on the main circuit board, due to shipping damage. Of the 26 modules tested, seven of these were found to be missing at least one component. Our testing showed no discernible difference in performance for broken modules, but they have already been repaired, but have yet to be re-tested.

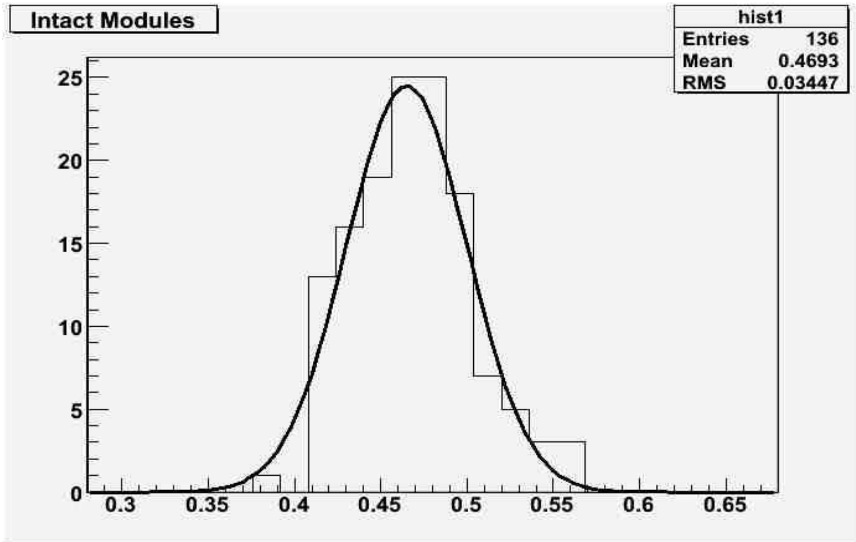

Illustration 2 - This histogram shows the distributions of the difference RMS per integration event for each channel of each intact module tested.

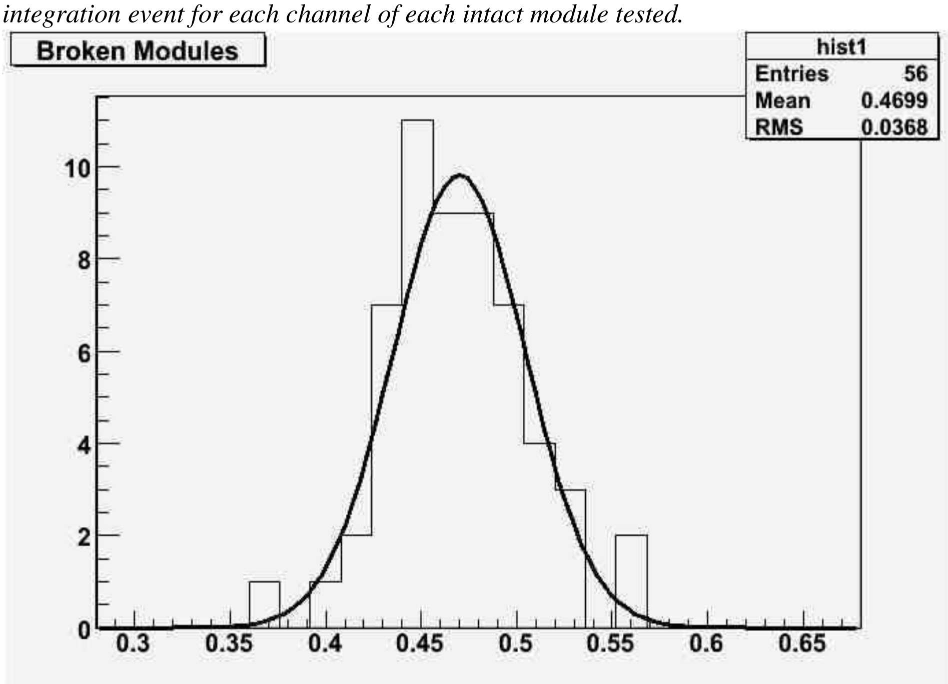

Illustration 3 - The broken modules. Aside from the number of entries, the difference between the broken and intact modules is negligible.

Battery Tests

These were performed to directly test the differences between nominal noise levels in empty, unterminated channels of the ADCs and channels with voltage inputs, from both 60Hz and DC batteries. The yields and differences between individual channels and different ADCs were again analyzed. The empty, unterminated channels gave yields and differences indistinguishable from the tests with terminated inputs. Though the yields for channels with voltage inputs increased by a factor of ~100, compared to empty channels, the mean & RMS values for the differences were only slightly larger, indicating that the signals input had little noise. However, as can be seen in Illustration 7, the distribution of the difference RMS among the battery test runs is not Gaussian, for reasons as yet unknown, though each peak does fall within the bounds of the error of the mean

(~5ppm). Longer runs that restrict the error on the mean could show this odd distribution to be unimportant.

ADC 1: battery with resistor through current-> voltage amplifier
ADC 2: empty, unterminated
ADC 3: current -> battery with resistor through voltage through hall patch panel then current-> voltage amplifier
ADC 4: empty, unterminated
ADC 5: OU battery source, 3v
ADC 6: empty, unterminated
ADC 7: JLAB battery source, 9v
ADC 8: empty, unterminated

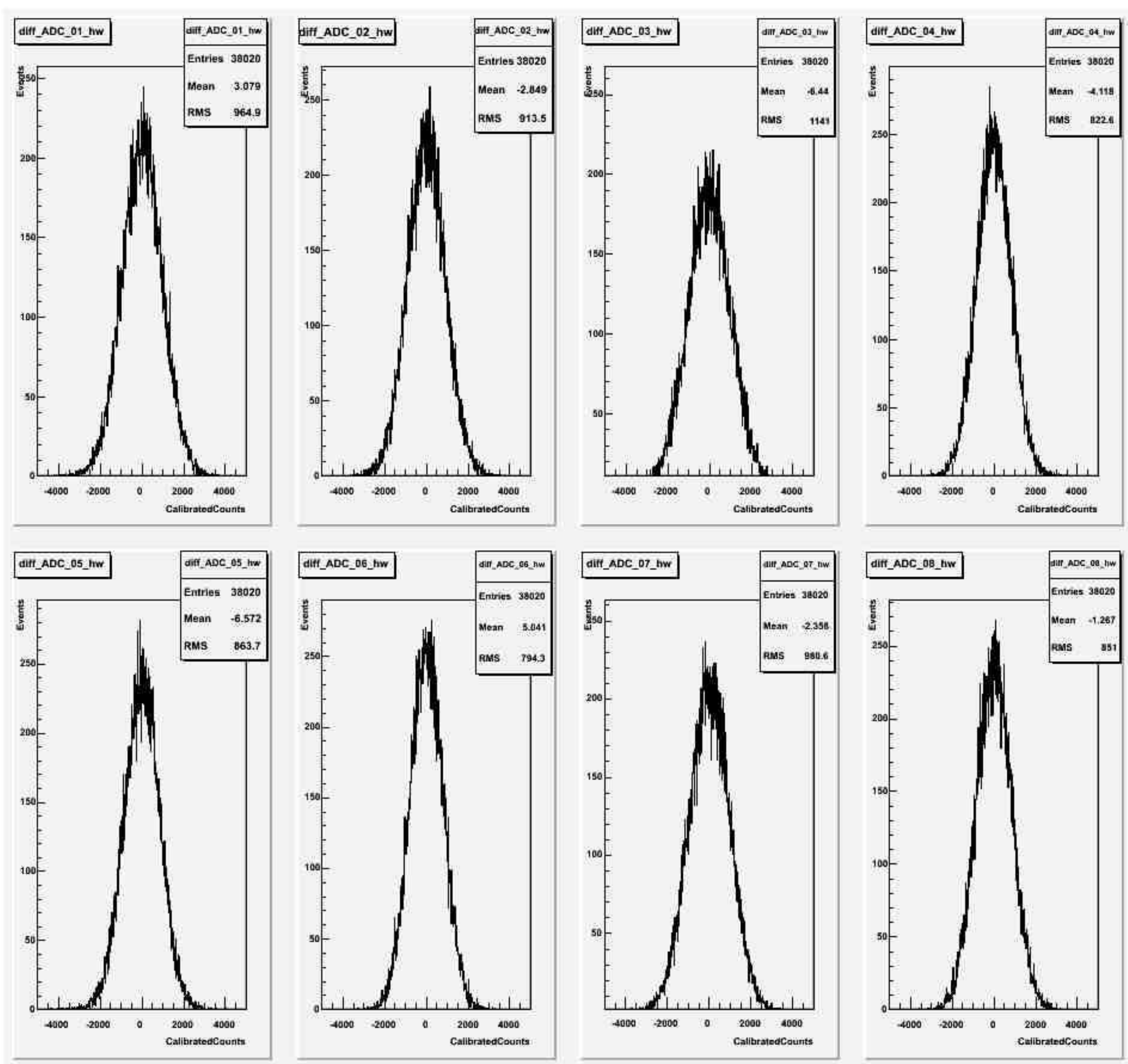

Illustration 4 - Histograms of the differences for each of the eight channels for one battery test. Five of the eight have means that fall within one standard deviation of zero.

	YIELD		DIFFERENCE	
	mean	RMS	mean	RMS
ADC 01	3.35E+8	429237	3.08	964.92
ADC 02	-3.12E+6	5839	-2.85	913.55
ADC 03	3.46E+8	443179	-6.44	1140.65
ADC 04	-4.67E+6	7571	-4.12	822.57
ADC 05	3.09E+8	395803	-6.57	863.68
ADC 06	-1.25E+6	4770	5.04	794.35
ADC 07	-9.47E+8	1221760	-2.36	980.62
ADC 08	-2.98E+6	6354	-1.27	851.04
	entries=38020			

Illustration 5 - Data, including the yield, for the same run as the above histogram. Note the much higher yield for channels with a voltage input, with negligible increase in difference.

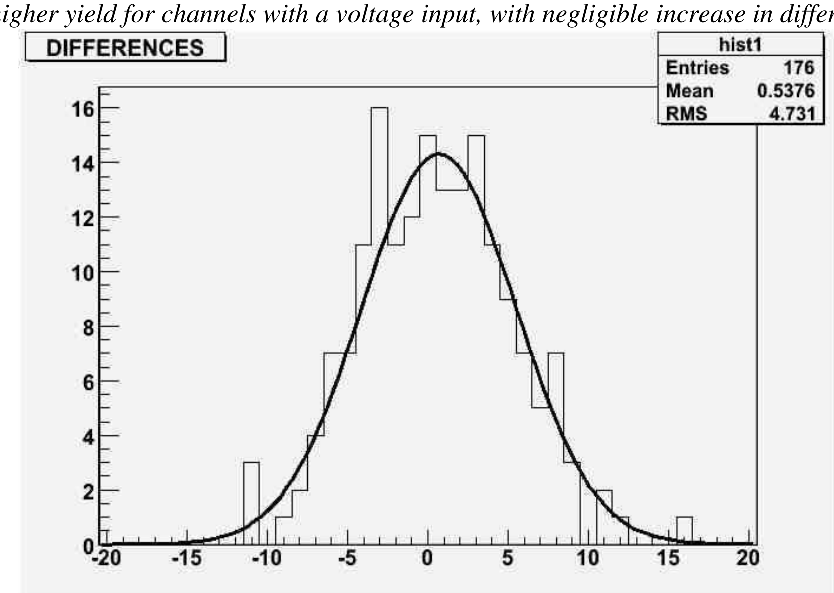

Illustration 6 - Distribution of the mean difference value for each ADC in initial, terminated testing.

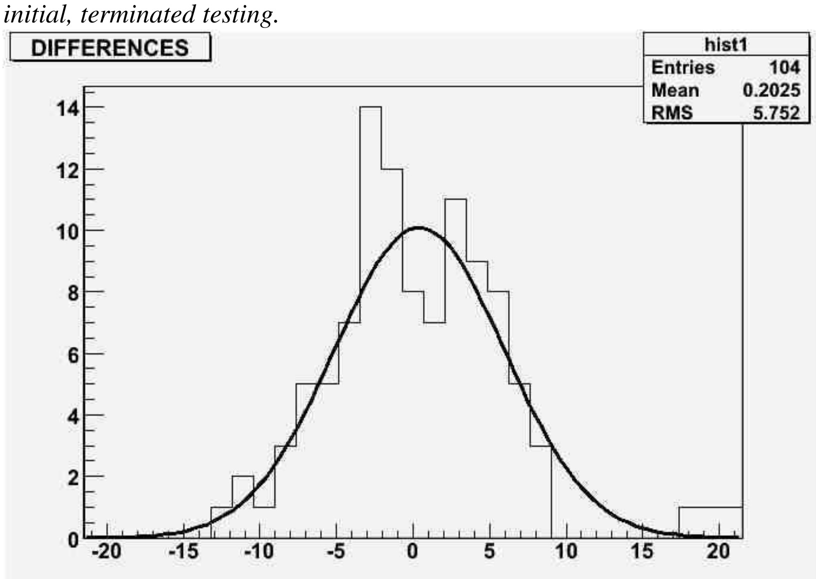

Illustration 7 - Distribution of the mean difference values for each ADC channel tested with the batteries input. The multi peak structure for batttery, as opposed to empty, channels is more pronounced, but is present to some degree in each of the eight individual channels.

Injector/Beamline Runs

These run were performed on ADC modules in the injector building, thus a more relevant location to test the effects of noise. Each channel input had a voltage signal into it, corresponding to different beam position monitors (BPMs). There are four groups of BPMs in the injector, in sequential order the 1i, 0i, 0l, and 0r, between each of which the beam energy is increased. For more details, consult the Injector Quick Reference Drawing[1.]

During one of these runs, a beam trip occurred, allowing the analysis of the time for different electronics groups to recover and return to normal beam monitoring. It was found that the BPMs in the first electronics groups (1i0x & 0i0x) took significantly longer (~1.3 sec.) to return to normal monitoring once beam was restored, as opposed to the 0l & 0r groups, which both took ~0.3 sec. to recover. This difference can be accounted for by noting that the 0i module spent just over 1 sec. at saturation, while the other modules spend less than 0.1 sec. in this state. It was found that different BPM front-end electronics (LINAC-style IF cards for 1i and 0i BPMs, instead of TRANSPORT-style IF cards) was the cause of this discrepancy, and the IF cards have been replaced so that all the modules are consistent (all use LINAC IF cards). However, now all the modules spend over 1 sec. at saturation, which effectively means that for the first second of beam operation, it is unknown where the beam is at any point in the line. This is not regarded as an issue for the beam control, but will be investigated by accelerator division personel in case it is a symptom of some misconfiguration of the electronics.

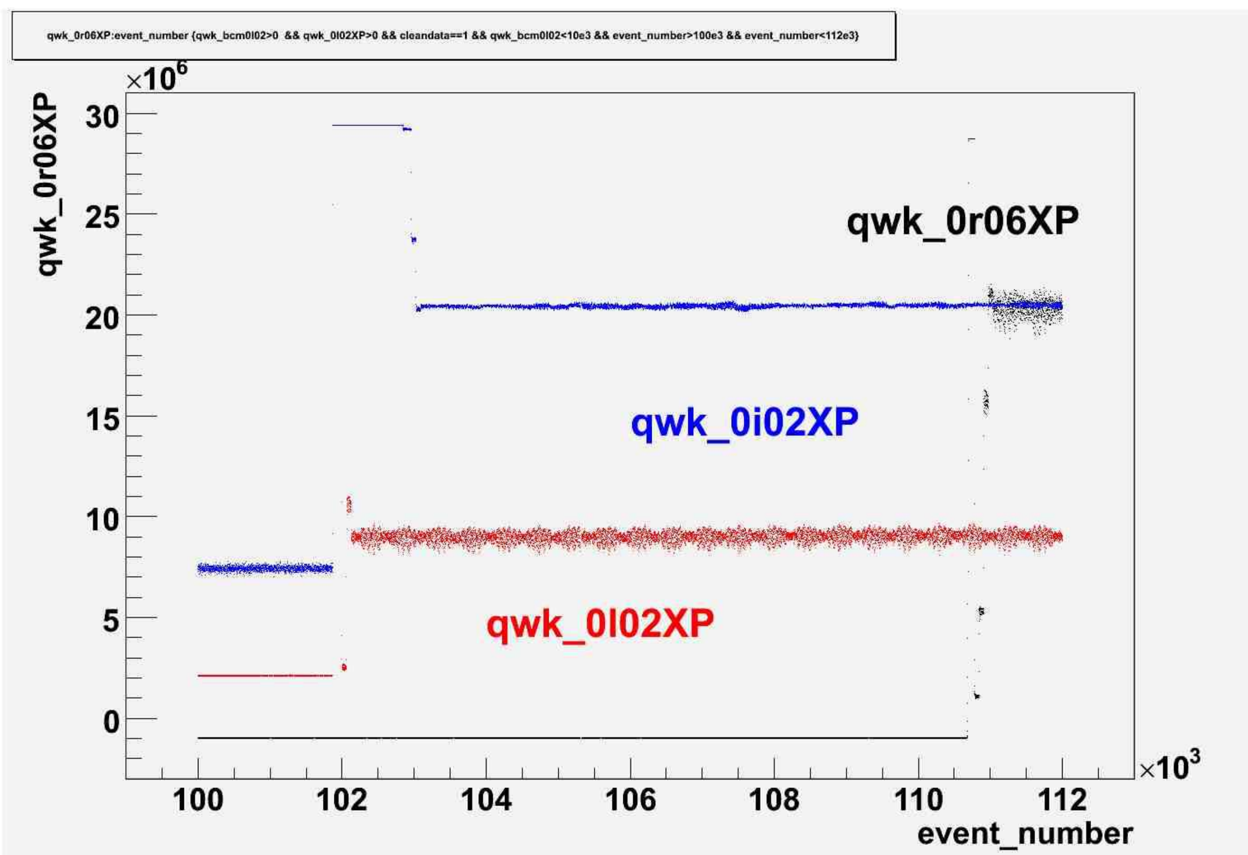

Illustration 8 - Showing the recovery time of several different BPM wires. Module 0r06 recovers later because a Faraday cup was still in place between it and the other modules after the 0i and 0l recovered.

The yields of some channels, when at their most constant, seemed to be oscillating at at least two different frequencies, with periods of approximately 450 & 12 ms. The slow oscillation is only observed starting with the 0l02 module, continuing with all subsequent modules downstream. The 12ms oscillation is present in all the modules, but increases in amplitude by a factor of five, beginning, again, at the 0l02 module. The sources of this noise appears to be a varying current in the dipole MBO0i06[1], which is a safety mechanism that can divert beam current away form the main beamline past this point at any given time. This has a current variation of ~85 Hz, which accounts for the fast oscillation, and the slow oscillation is most likely a beat frequency associated with the fast frequency. In Illustration 8, the slow oscillation can be seen in the 0l02 and 0r06 modules, but not in the 0i02 module, and the oscillation seen in this single wire is consistant with what is seen for a four wire sum. The fast oscillation is seen in Figures 9 &10.

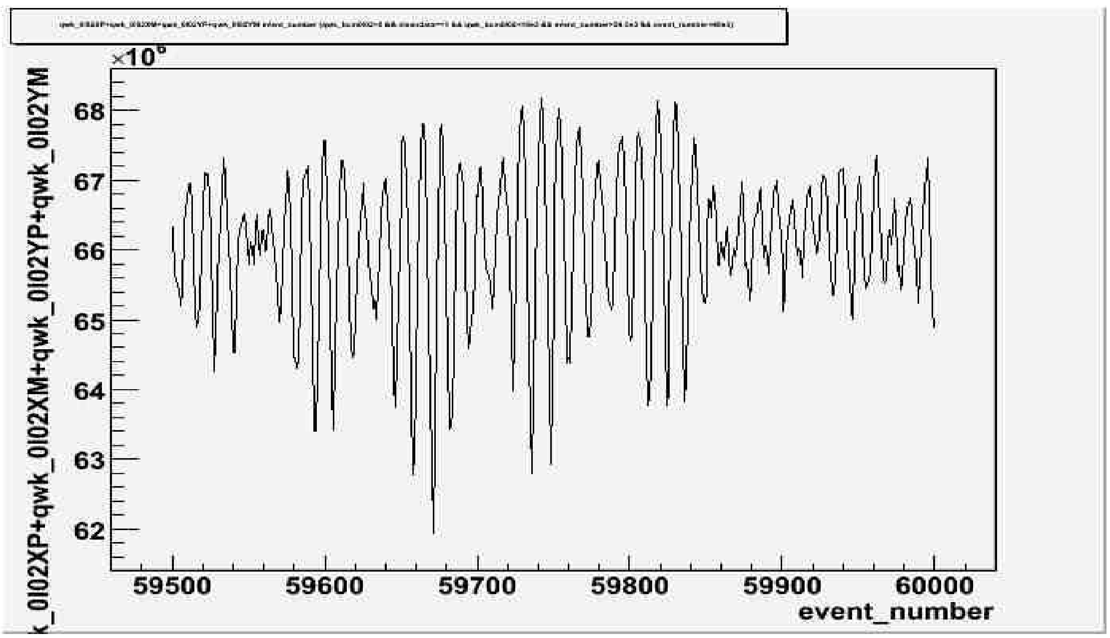

Illustration 9 - Short-period oscillations for BCM0l02.

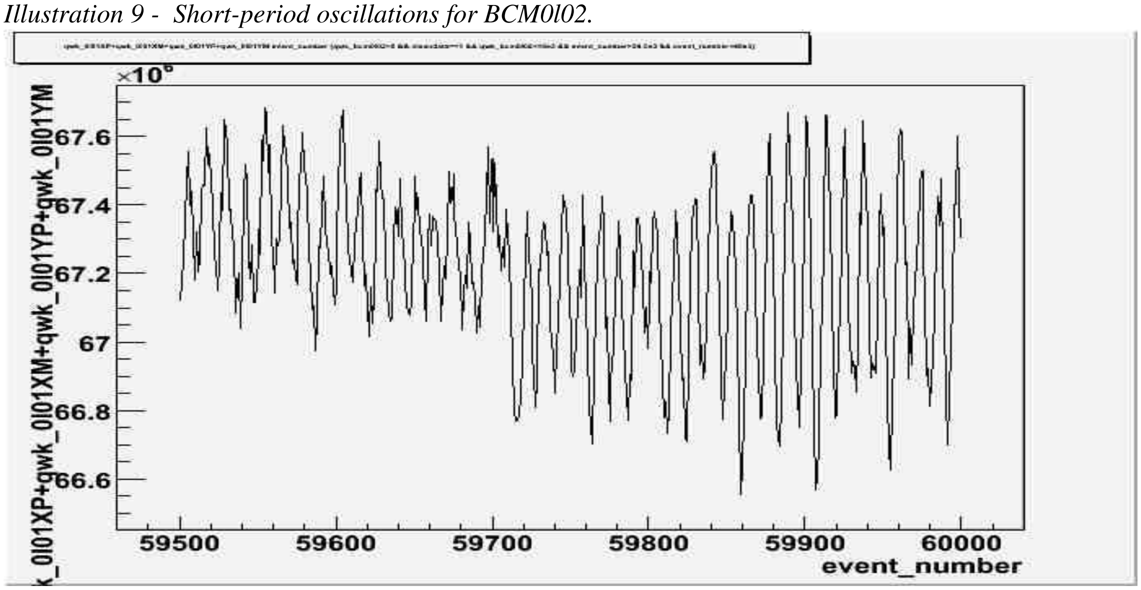

Illustration 10 - Short-period oscillations of BPM 0l02. Note the change in vertical scale compared to BPM0l01.

Pedestal problems

The pedestal that correlates the BPM values to the beam current observed by the BCM had issues. For BPMs beyond the 0i region, the currents observed did not directly correlate to the beam current, but had a more constant value. This could be do to differing sensitivities of the different electronics groups, but at this point a more probable reason for this is the loss of beam current at the apertures between 0i and 0l. The problem seems to have been corrected at this point, but it seem s to have originated from a bad injector setup, so more care needs to be taken in the future to insure a proper setup before taking data seriously.

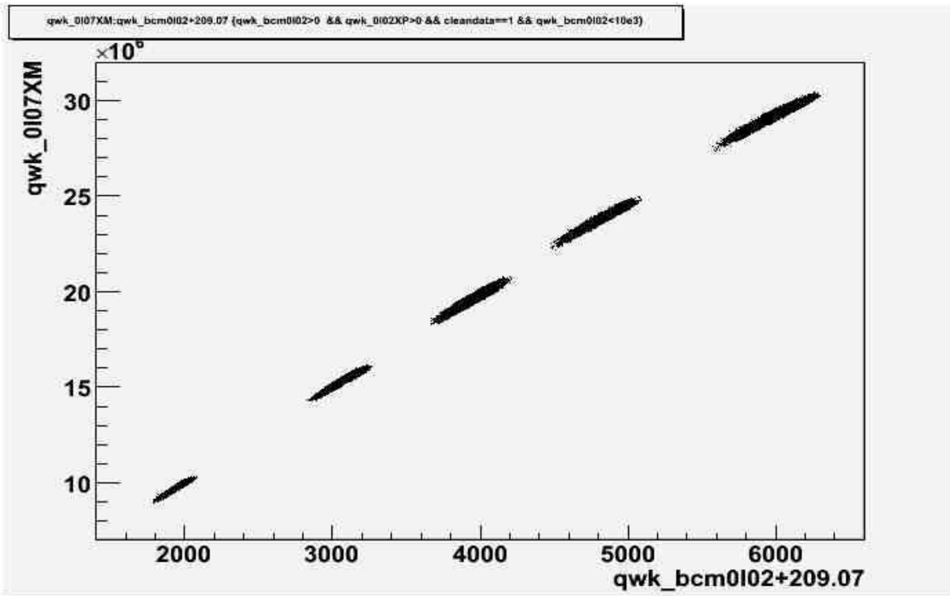

Illustration 11 - This graph represents the signal in a positive X position monitor as a function of the beam current. It shows a strong positive correlation, which is what is to be expected.

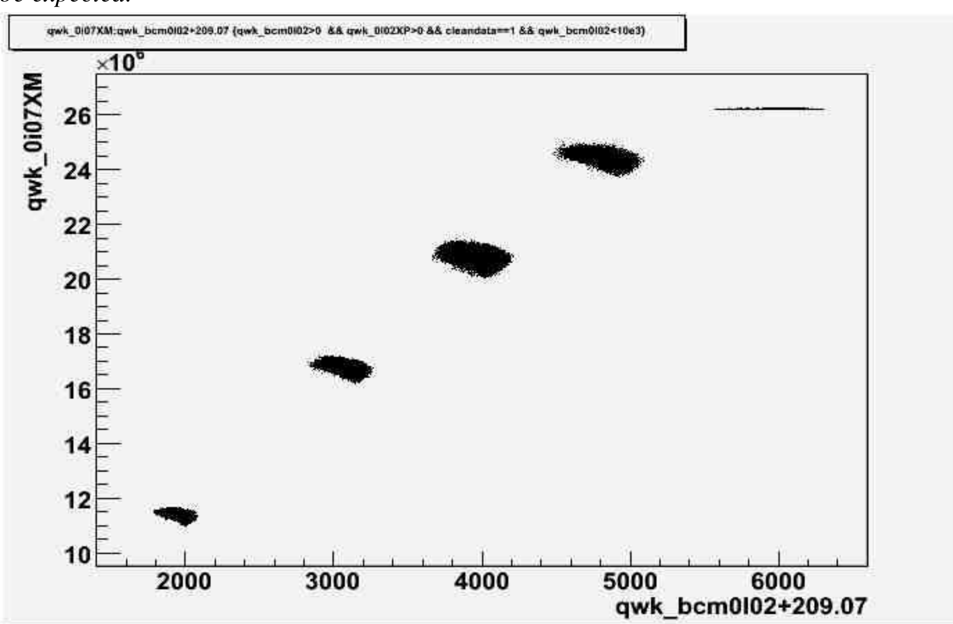

Illustration 12 - However, many of the BPMs showed a weak, or even negative correlation when compared to individual beam current values, which indicated that beam was being lost in these sections, which at this point seems to stem from the beam scraping on apertures. he narrowness of the topmost data cluster indicates that the monitor was at saturation, thus provided no useful information.

Unanswered Questions

-Why do the BPMs spend so much time at saturation when beam is turned on? This should not cause any appreciable problem for data aquisition, as ~30 after a trip is allowed for re-stabilization anyways, nor is the accelerator group concerned that this will cause any significant beam misalignments, but whether or not this is proper behavior should be investigated.

-What is the source of the slow (~2.3 Hz) beat oscillation in the beam current beyond BPM 0I02? This oscillation seems to be in changing beam intensity, rather than beam motion. The MBO0i06 dipole is one potential source, but what are others? A better injector setup is now in place, and looking at the same sort of data from new runs may show that the problem has already been eliminated.

-Why do the difference means in the battery tests show a non-Gaussian distribution (few results right at zero)? Longer runs (than the ~ten minute ones already performed) with better isolated batteries and cables may yield better data, and looking at multiple run for a single channel would be productive.

References:

Qweak general overview:

http://www.jlab.org/qweak/

Injector Quick Reference Drawing:

[1] - http://www.jlab.org/html/accel/inj_group/gun/inj_ref.pdf

Qweak 2007 Proposal:

[2] - http://qweak.jlab.org/DocDB/0007/000703/005/Qweak_Update_final2.pdf pg.31