Cavity Monitor Performance in 2005

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I. INTRODUCTION

This report describes the performance of the new cavity monitors in Hall A and discusses needs for future improvements. Each cavity monitor assembly is a triplet of three cavities measuring current and position in two orthogonal directions (Q, X, Y). We had three monitor assemblies which we will call "cav1", "cav2", and "cav3". "cav1" was located in the BSY area and will not be discussed. "cav2" and "cav3" were located near the target in Hall A, about 8 m and 3 m from the target respectively. They are in between the last two stripline monitors 4A and 4B.

The purpose of the cavity monitors is to provide high precision and an important redundancy. In addition, they should give an increased sensitivity at low currents (50 nA) necessary for some special runs – although the striplines are said to be usable at such low current too, but they are not yet in Hall A. The cavity monitors are needed primarily by parity experiments, of which there are three currently approved for future running in Hall A. These experiments need a position resolution of 1μm integrated over 30 msec and must have accuracies of 1 nanometer in the helicity correlated difference measurements averaged over a month. The striplines already work approximately this well, but the cavities are necessary for a crucial redundancy check with an independent method to make convincing such extraordinarily small errors.

A possible side benefit of the cavity monitor system is the increased bandwidth of the electronics, desirable to have undistorted measurements of the rastered beam position at 25 kHz. However, this could also be accomplished by an upgraded, faster stripline electronics.

II. GENERALLY GOOD PERFORMANCE

Although this report will highlight some problems and the request for future improvements, we point out first that the performance was generally good. Figure 1 shows the correlation of beam current measurements between the new cavity monitors and the old, existing monitors. The linearity is excellent. Figure 2 shows the "double differences" of the various monitors (new and old). The double difference DD is defined as the difference between the charge asymmetry A_Q in one monitor (1) versus another (2), i.e.

$$DD = A_Q^{(1)} - A_Q^{(2)} \tag{1}$$

where

$$A_Q = \frac{Q_R - Q_L}{Q_R + Q_L} \tag{2}$$

for charges Q measured for helicities R and L in 30 msec (helicity period). DD is an indicator of the noisiness of the monitors. For the new cavity monitors the noise (RMS) in DD was 100 ppm which was only slightly worse than the DD for the old monitors (80 ppm).

The resolution of the cavity monitors was measured by a linear regression analysis using all BPMs including striplines to take out the correlated motion due to the beam. Looking at the final resolution of the regressed position differences gives a resolution that varied between 1.3 and 1.7 μm , which is close to the design goal of 1.0 μm at 30 Hz.

Although there were problems with cavities (documented in the next section), they apparently provided an excellent redundancy check of the helicity correlated position differences at the 1 nanometer level during HAPPEX-2 in 2005, see fig 4. The reason this worked out is that the 1-day averages somehow "average over" the problems listed in the next section.

III. PROBLEMS WITH CAVITY MONITORS

The following problems were observed for the cavity monitors during the 2005 HAPPEX running.

- Reliability: About once a week the cavity monitors simply stopped working, providing no usable information. We eventually became proficient at recovering from this (reboot the crate and restore the phases). It is speculated that this problem would be solved by moving the electronics out of the radiation zone.
- Glitches: During some runs, large excursions were observed in all signals (Q,X,Y) of cav2, see fig 5. Of course these events are rare and easy to cut out, but they are worrisome since we don't know what caused them and have no way of predicting how often they might happen, nor how to avoid them. They are an anomalous behavior of the system.
- Crosstalk: There are two kinds of crosstalk observed : 1) Crosstalk between the two cavity assemblies cav2 and cav3; and 2) An unphysical crosstalk between position and charge. The demonstrations of these are in the figs 7 and 8. At some point during the experiment the crosstalk between cavities disappeared, for no clear reason. For example, it was not correlated with the usage of the external clock that had been advocated to reduce noise. There was, however, a reboot of the crate (required for when the cavities stop working) prior to the disappearance of the crosstalk.

  Despite the crosstalk, the 1-day averages of helicity correlated position differences were apparently good, probably because we used a feedback on the charge asymmetry to keep it small (≤ 1 ppm) for most 1-hour periods of the experiment. This minimized the impact of the crosstalk, but it is still a dangerous effect.

IV. REQUESTED IMPROVEMENTS

The following improvements are requested for future running of the cavity monitor system in Hall A.

- Improve the reliability of stable operation.
- Understand the glitches mentioned above, and eliminate them.
- Eliminate the crosstalk between cavities and between charge and position. There may be physical correlations, of course, but the unphysical ones must be eliminated.
- Ensure that the cavities may work in a mode whereby they can measure beam position and current at low (50 nA) for some specialized runs. The accuracy requirements at 50 nA are 50 μm resolution in 1 minute (beam drift is acceptable but not included in this specification). The switchover between high current and low current running should take less than 30 minutes.
- It is desirable but not required that the frequency bandpass be $f \geq 200$ khz in order to have accurate BPM measurements of the rastered beam.

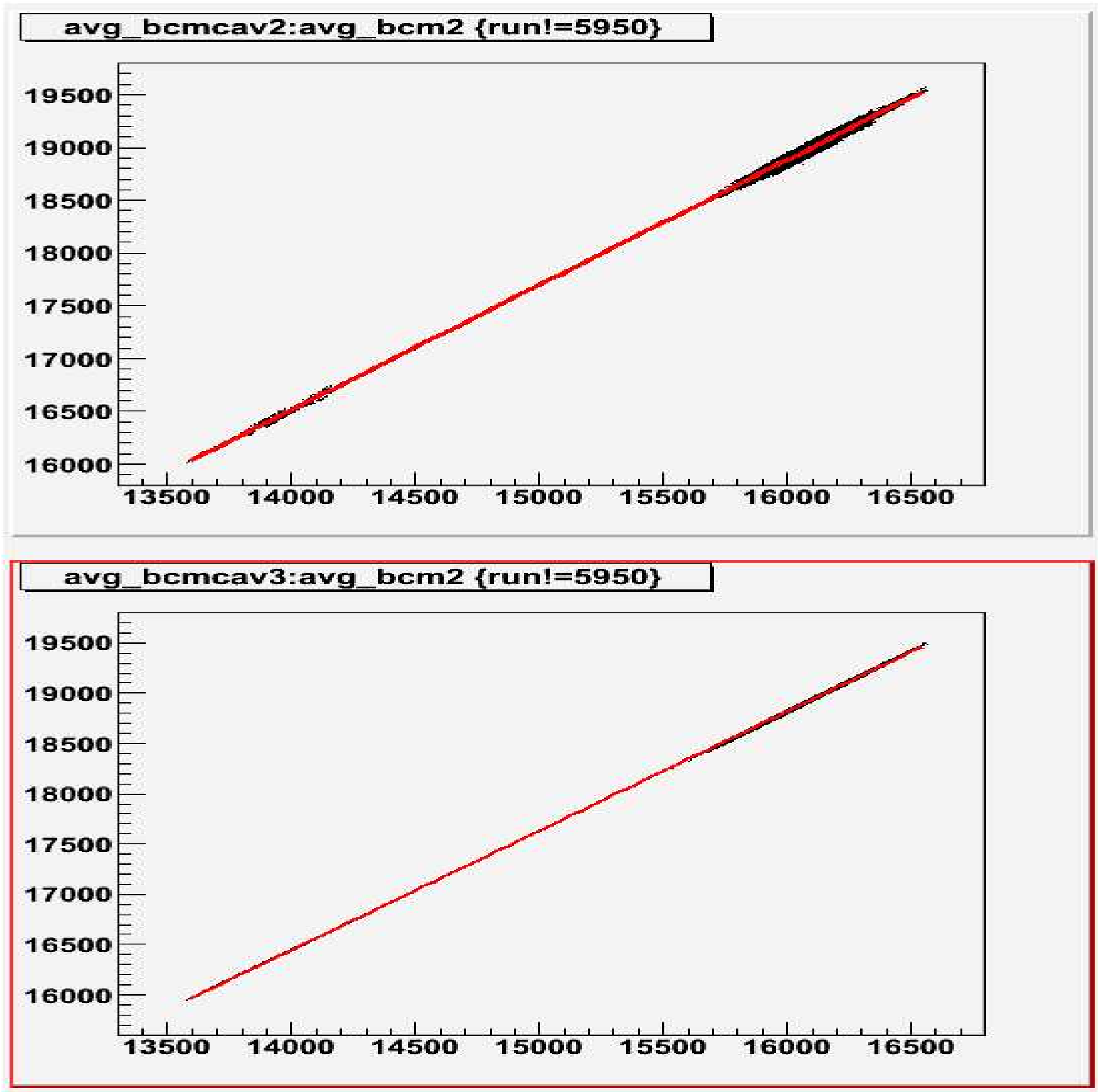

FIG. 1: The beam current measured in the new cavities ("cav2" and "cav3" which are located near the target, see text) are well correlated to the old BCM ("bcm2") current measurements. The linearity is excellent.

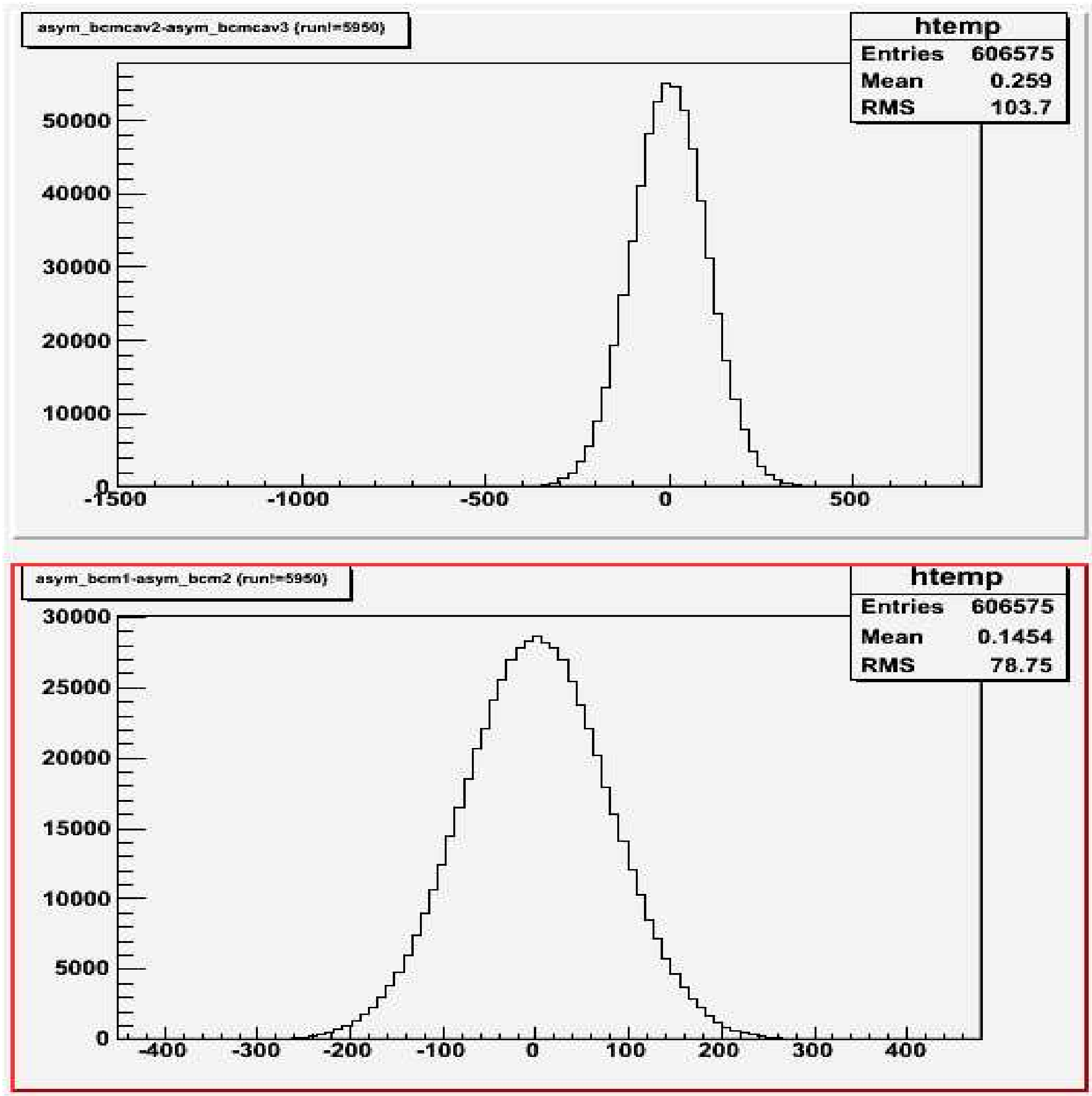

FIG. 2: The double differences (difference between charge asymmetry measured in one monitor to another monitor) is a measure of the noise of the two monitors involved. The top plot is for “cav2” and “cav3” which are the new cavity monitors. It shows an RMS of 100 ppm. The bottom plot is for the two older BCMs and shows an RMS of 80 ppm.

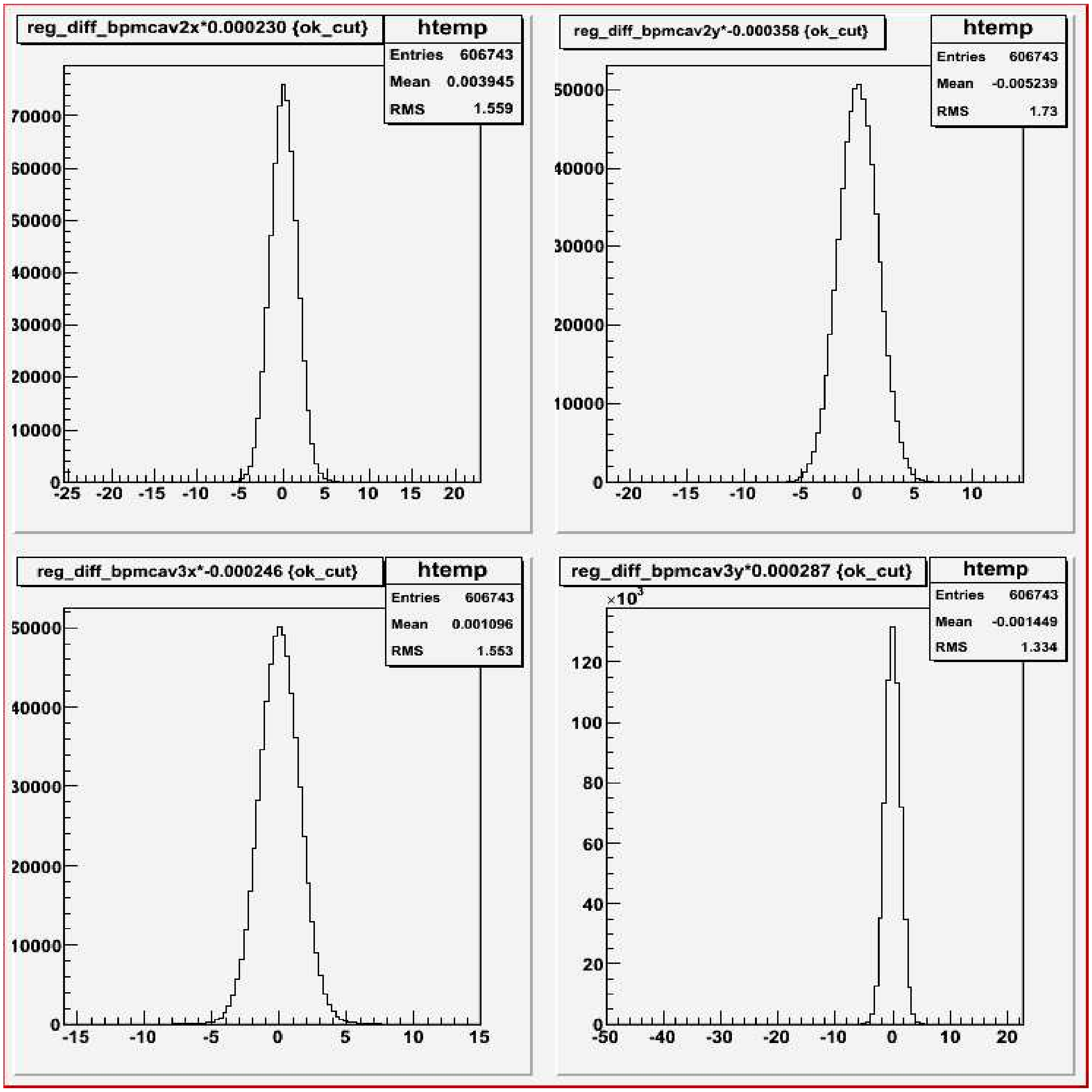

FIG. 3: The resolution of the new cavity position monitors ("cav2" and "cav3") is obtained from a linear regression analysis involving all existing BPMs. The result is a resolution of 1.3 to 1.7 μm, which is close to the design goal of 1.0 μm at 30 Hz.

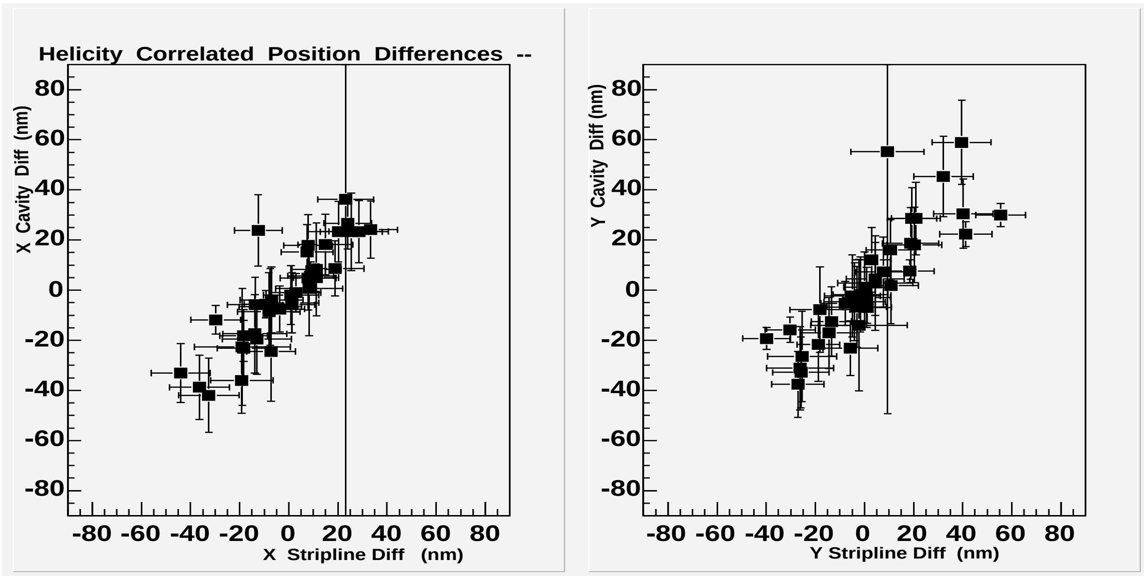

FIG. 4: Despite the problems documented subsequently, the cavity monitors did provide excellent redundancy in the the helicity correlated position differences at the 1 nm level, shown here. The cavity monitor position difference averaged over approximately 1 day of running is shown versus the stripline monitor position difference. The agreement is excellent.

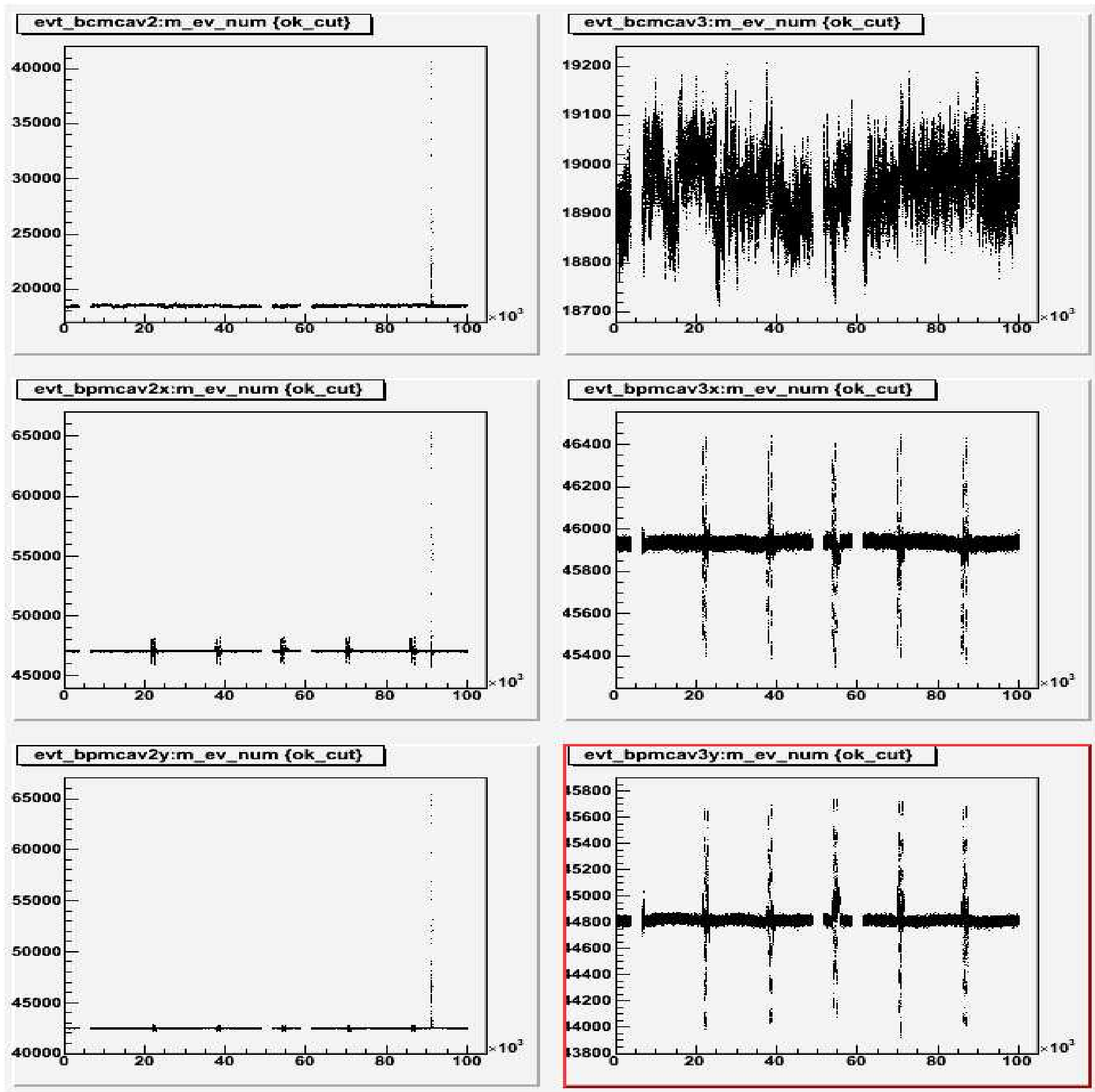

FIG. 5: The cavity position is shown as a function of event number for a run in which the "cav2" monitor had glitches. The top two plots are the beam current on cav2 (left) and cav3 (right). The bottom four plots are positions. Note, large excursions in cav3 are normal and due to our deliberate beam position modulation of order 100 μm in amplitude. However the extremely large excursion at around event 91000 for all cav2 signals is not normal (glitch in electronics).

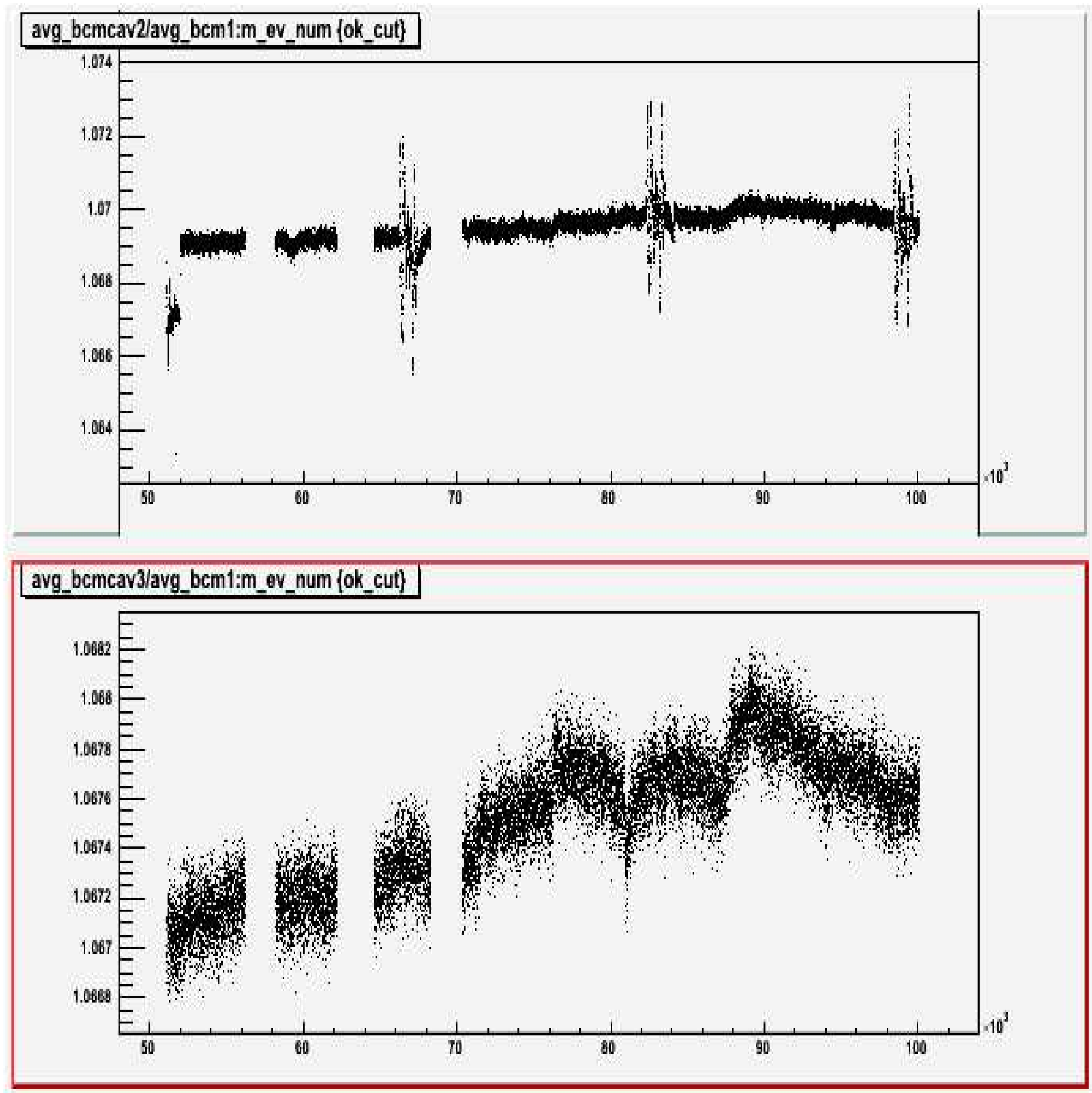

FIG. 6: The ratio of beam currents versus event number. The top plot shows the ratio of the new "cav2" cavity monitor BCM to the old cavity bcm1. The bottom plot is the same for "cav3" to bcm1. The cav3 plot looks reasonable, with small drifts in the relative gain. However the cav2 plot shows glitches due to the beam modulation (deliberate periodic beam movements of order 100 μm in amplitude). This is evidence of an undesirable crosstalk between position and charge in this monitor.

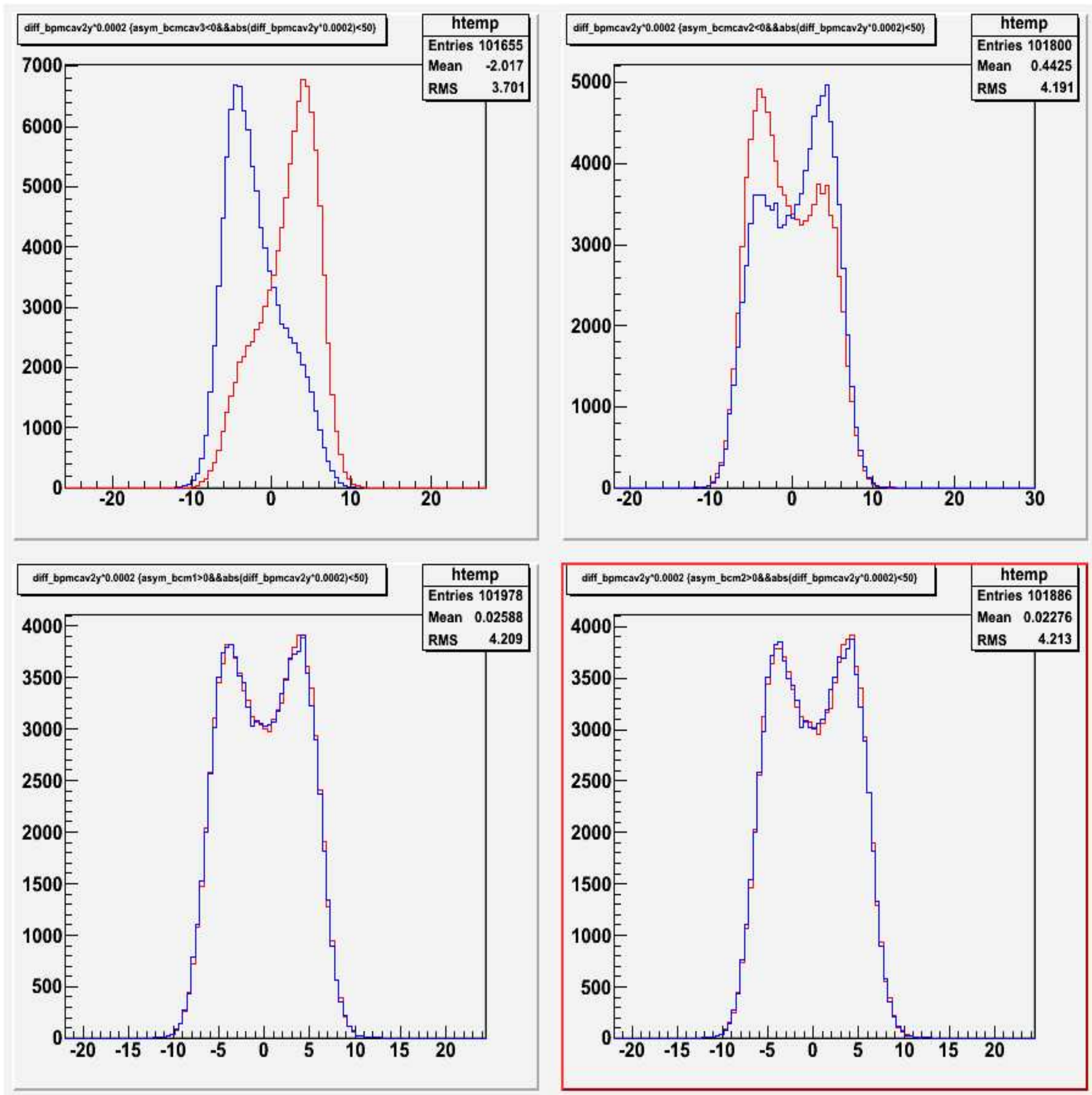

FIG. 7: The helicity correlated position difference measured in the new cavity monitors is shown with various cut conditions that demonstrate crosstalk between position and charge, and between the two monitors. The top left plot is the difference in Y on cav2 for positive (red) and negative (blue) charge asymmetry on cav3 (a separate cavity). The top right plot is the same but for cuts on cav2 charge asymmetry (same cavity). The cav3 cuts have a stronger impact, indicating crosstalk *between separate monitors*. The bottom two plots are the same position differences, but cutting on the charge asymmetry measured in an older BCM (which is far away on the beamline) which demonstrates that the correlations to charge asymmetry are *not physical* and are due to crosstalk within the new cavity monitors electronics.

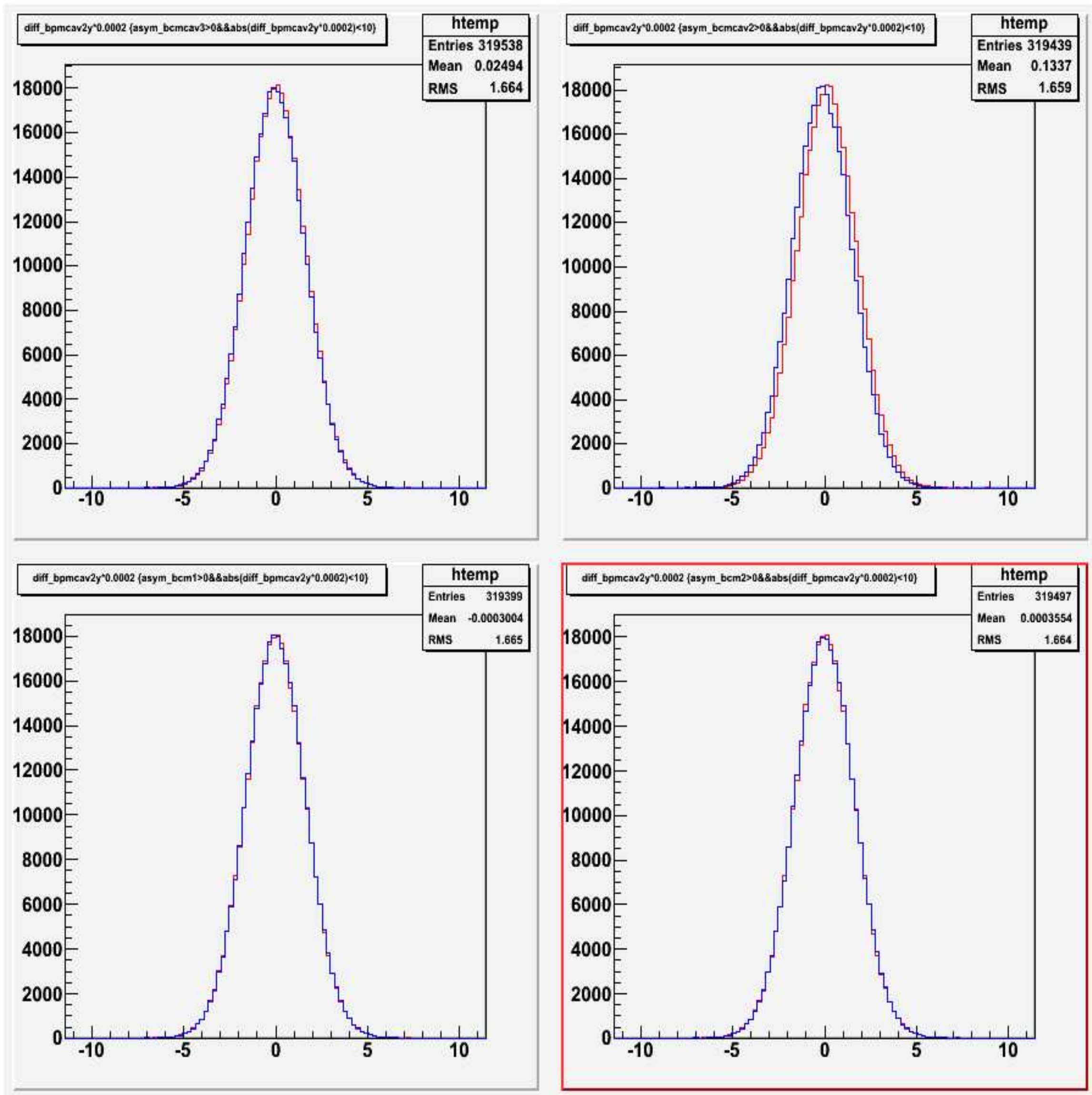

FIG. 8: This is the same plot as figure 7 except later in the experiment. The crosstalk between cav2 and cav3 is gone (top, left) and only a much smaller crosstalk between charge asymmetry and position (top, right) remains for cav2. For cav3 the crosstalks are negligible.