Low Current Cavity Monitor Tests

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I. INTRODUCTION

In May 29, 2008 a 2.5 hour test was performed to check the Hall A cavity monitors at low current (50 nA). This report discusses the data analysis and proposes new tests for Fall 2008.

II. SETUP AND GOALS

Each cavity monitor assembly is a triplet of cavities measuring current and position in two orthogonal directions (X, Y, Q). We have two monitor assemblies near the target in Hall A which we call "4A" and "4B" , see fig 1. More information about the cavities is available elsewhere.

For parity experiments the cavity monitors must operate at very low currents for calibration runs. For example, in PREX we will have rates of approximately 20 $\frac{\text{MHz}}{\mu A}$, so at 50 nA we will have ∼1 MHz in each spectrometer. Based on experience with HAPPEX, we know we'll need to keep the current below 50 nA for good Q^2 measurements and background analysis that require the VDCs. It looks like the cavities will work down to 10 nA. At 10 nA we'll have 200 kHz in the HRS and the systematic error should be $\frac{dQ^2}{Q^2} \leq 0.5\%$.

Other experiments in hall A may benefit from low current running. Also, the cavity monitor electronics is faster than the stripline electronics, making raster corrections simpler.

The test we performed on May 29 consisted of moving the beam with steering coils (MAT1H01H and MCZ1H04V) and observing the position in the cavities. This scan was repeated at beam currents of 9.5 μA, 1.0 μA, 100 nA, and 50 nA. At currents $\geq 1\mu$A the old current monitors and stripline monitors work well and we can cross calibrate. At currents $\leq 1\mu$A we used the triggers in the Bigbite spectrometer as a relative measure of the beam current (8.8 $\frac{\text{kHz}}{\mu A}$).

There two goals were:

- To observe good stability (± 0.2 mm) of the absolute calibration for currents $50\text{nA} \leq I \leq 10\mu\text{A}$.
- To observe good resolution ($\leq$ 0.5 mm) at 50 nA.

SUMMARY OF RESULTS :

- Between the runs at 1 μA and 100 nA, the calibration was stable, but above and below this range it changed drastically. We've realized this was because we had changed gains in those intervals. It will be important to repeat the test without changing the gains.
- To determine the resolution we had to subtract the natural beam noise, which at low current was about ±0.5mm. (There was no feedback to stabilize position.) The result was a resolution of $\sim 150\mu$m at currents $\geq 1\mu$A and $\sim 450\mu$m at 50 nA. This is for spectrometer-DAQ events integrating for 200 nsec. Averaging over several thousand such events data should make the position error $\ll$0.5 mm which is adequate for the experiments.

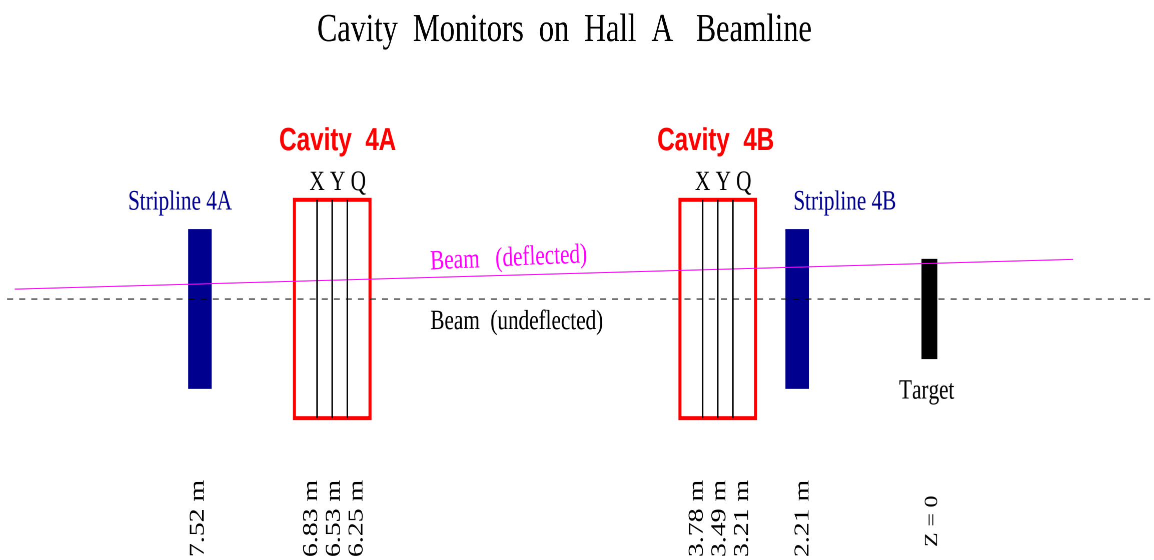

FIG. 1: Cavity monitors on the Hall A beamline near the target. Also shown are the stripline monitors and all the Z locations. The beam was deflected by steering coils.

TABLE I: **Cavity Position Calibration at 1μA**

Monitor	ADC channels per mm
4A X	106
4A Y	113
4B X	410
4B Y	526

III. ANALYSIS PROCEDURE

We had separate CODA runs at each magnet setting (position of beam) and each beam current. For each run a "beam on" cut was determined using the cavity current monitor. The runs at $I \geq 1\mu$A were calibrated against the stripline monitors. The stripline monitors were first calibrated, in the usual way, against the EPICS data, to know how many ADC channels corresponds to 1 mm. For the cavity monitors the calibration at 1 μA is shown in table I. This calibration surely changed when we changed the gains, by possibly a factor of ∼2 below 1μA, but we could not account for that. This illustrates why it was a mistake to change the gain and phases (note that the phases are thought to have had a relatively minor affect on the calibration).

Using the position calibration at 1μA we can check the positions in the scans at the other currents. This is shown in figures 2-9. One can see that between the 1μA run and the 100 nA run, the absolute positions in the cavities were repeatable, which is a good sign. As far as we know the gains and phases were not changed between those runs, but our online notes indicate they were changed between 1μA and 9.5μA and between 100 nA and 50 nA which explains the large change in "apparent" position in the cavities.

To determine the monitor resolution, we must subtract the beam movement. Two methods were tried: (a) Use the correlation between cavities as a measure of the beam noise and subtract this off; (b) To probe a particular cavity, say 4AX, use the striplines and other cavity (4BX) to construct a line and look at the residual to this line.

Method (a) is the only one that works below 1μA. It yielded the results in figures 10-25. Obviously, since the calibration changed the low current results could be off by a factor of ∼2. Nevertheless, there was a good separation between the points of the scan and it looks like can get good position information down to 10 nA.

Method (b) was only applied to 1 uA because the calibration between striplines and cavities was set at this current. For an unknown reason the resolutions found using this method were larger than those found in method (a) by about a factor of 2. See figure 26 for resulting histograms.

IV. FUTURE RUN PLAN

We'd like to return in Fall 2008 for another test run. The procedure will be the same, except at the frontend we perform the following steps.

- Do a quick scan from 2μA to 10 nA and find the set of gains and phases which provide reasonable signals in the EPICS interface.
- Need a more reliable readback of magnet settings.
- Do the magnet scan for various currents, but this time *without any adjustment of gains or phases.*

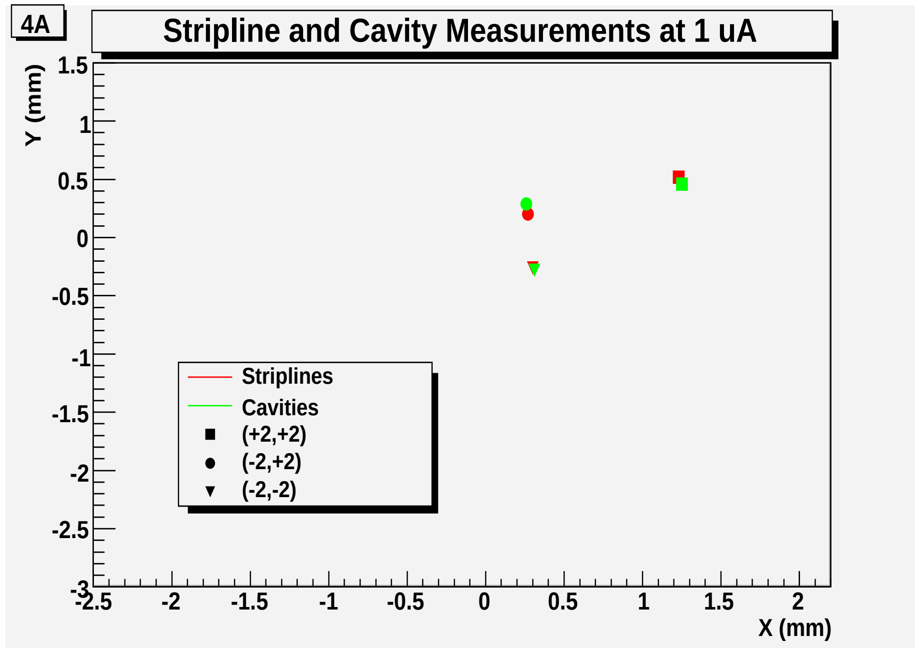

FIG. 2: Positions of striplines and cavities 4A at 1μA. This was the current we choose to pin down the cavity calibration.

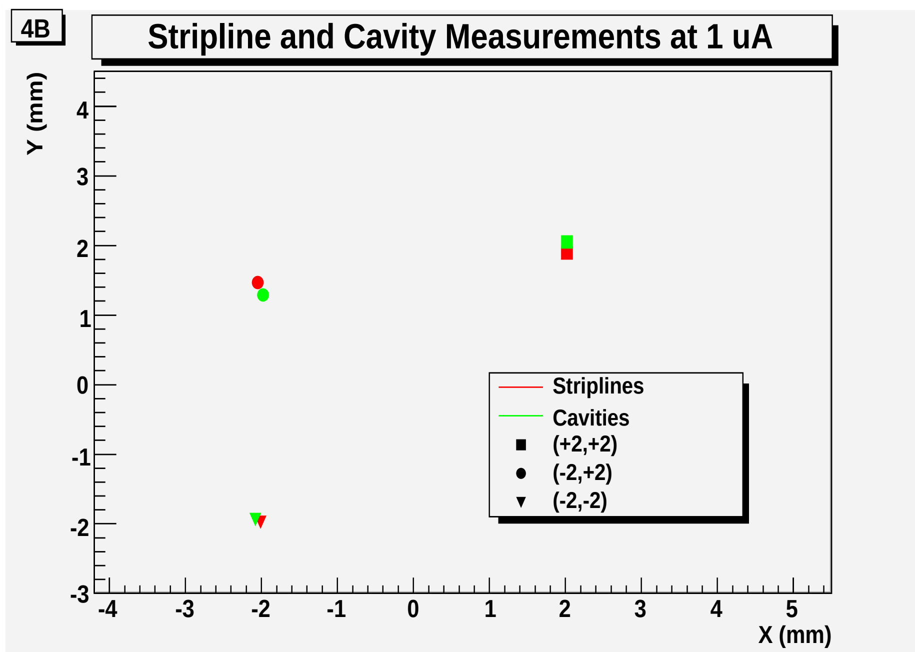

FIG. 3: Same as fig 2 except for 4B.

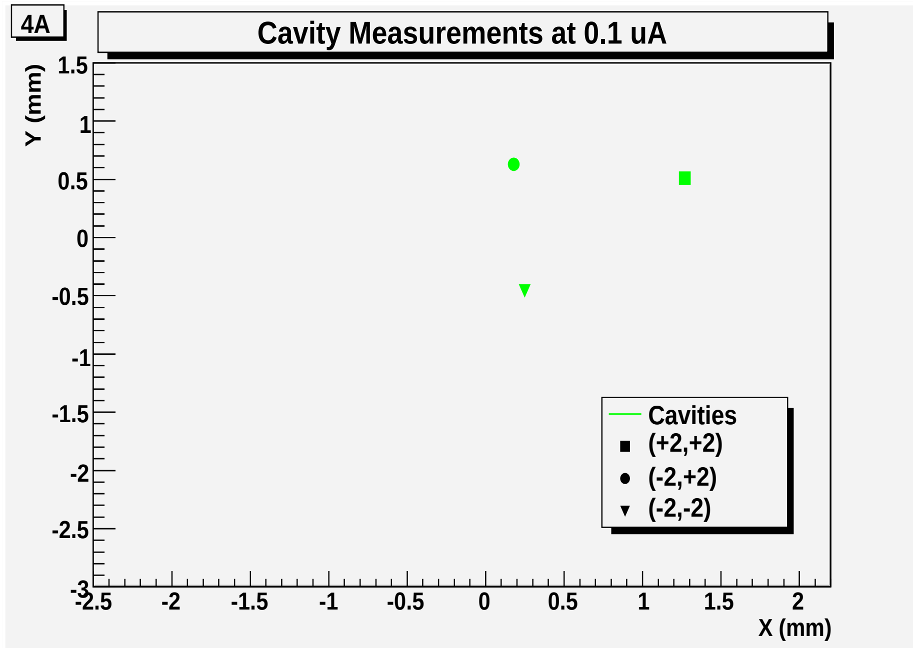

FIG. 4: Positions of cavities 4A at 100 nA. The striplines no longer work at this current. Note, the absolute calibration didn't change much compared to fig 2. No gains were touched between 1 μA and 100 nA.

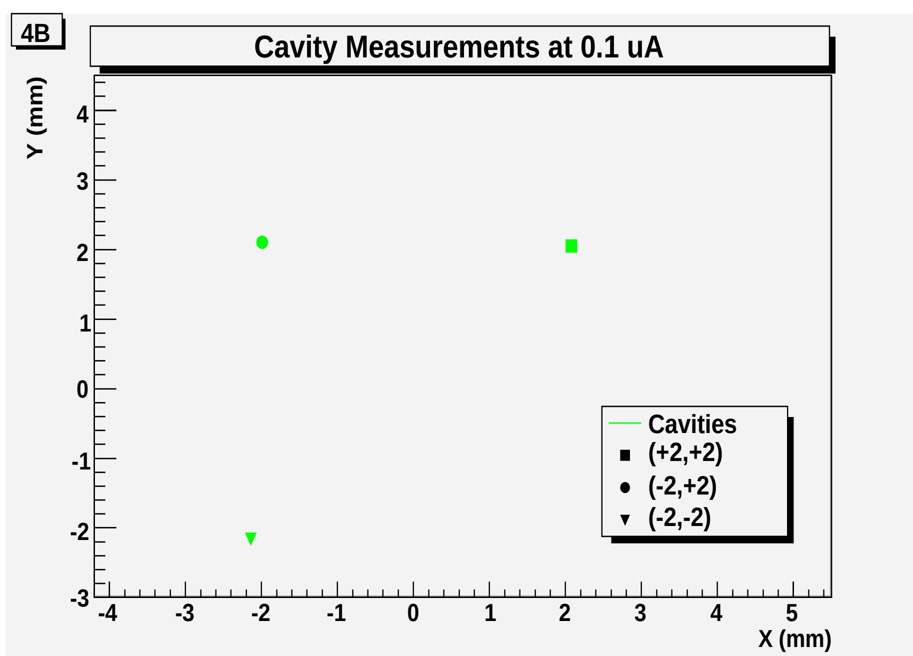

FIG. 5: Same as fig 4 except for 4B.

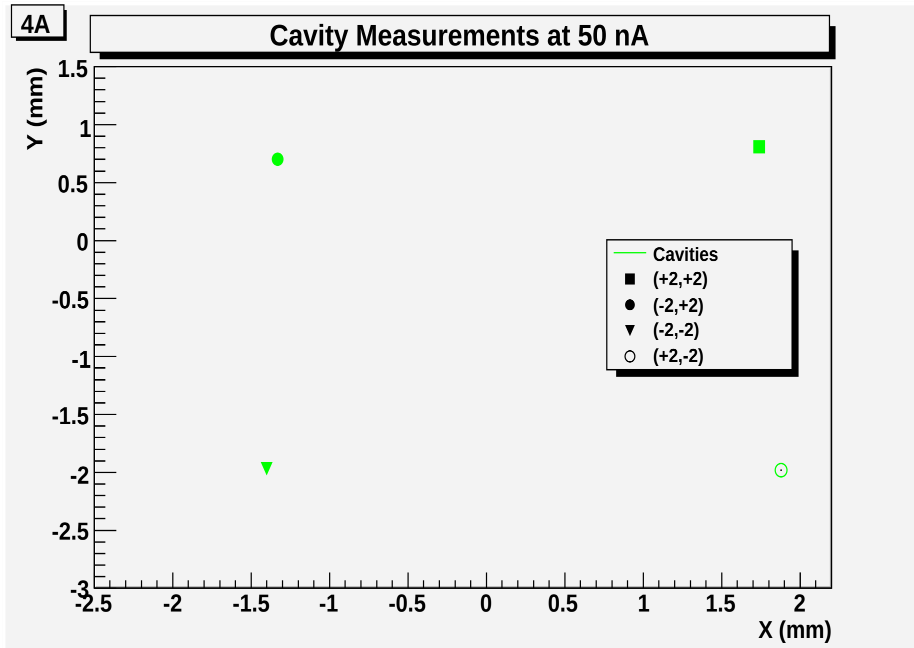

FIG. 6: Positions of cavities 4A at 50 nA. The absolute calibration changed a large amount compared to fig 2, but this is due to changes in the gain, which was a mistake.

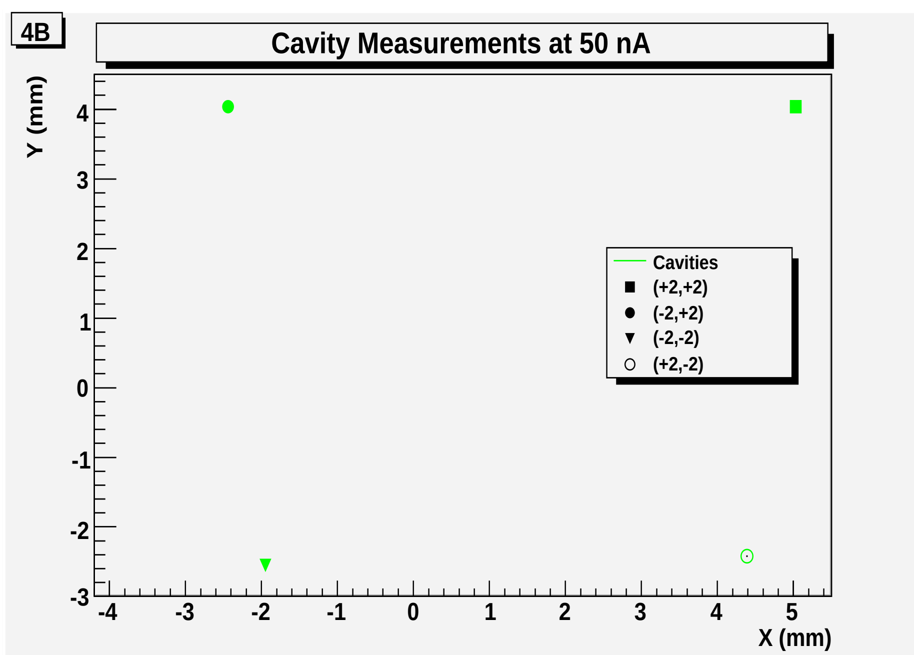

FIG. 7: Same as fig 6 except for 4B.

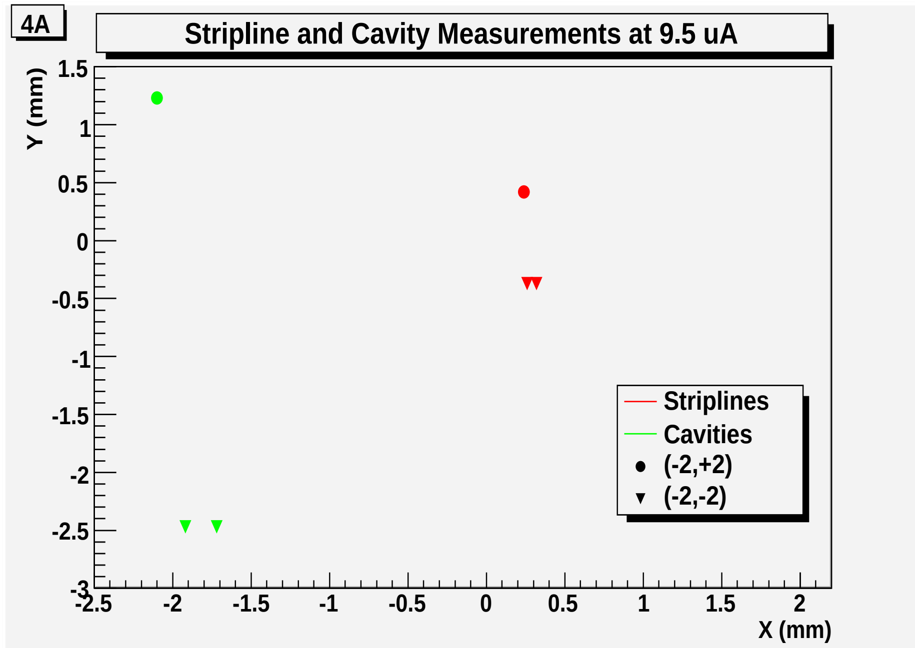

FIG. 8: Positions of cavities 4A at 9.5 μA. The calibration is affected by the same problem as fig 6.

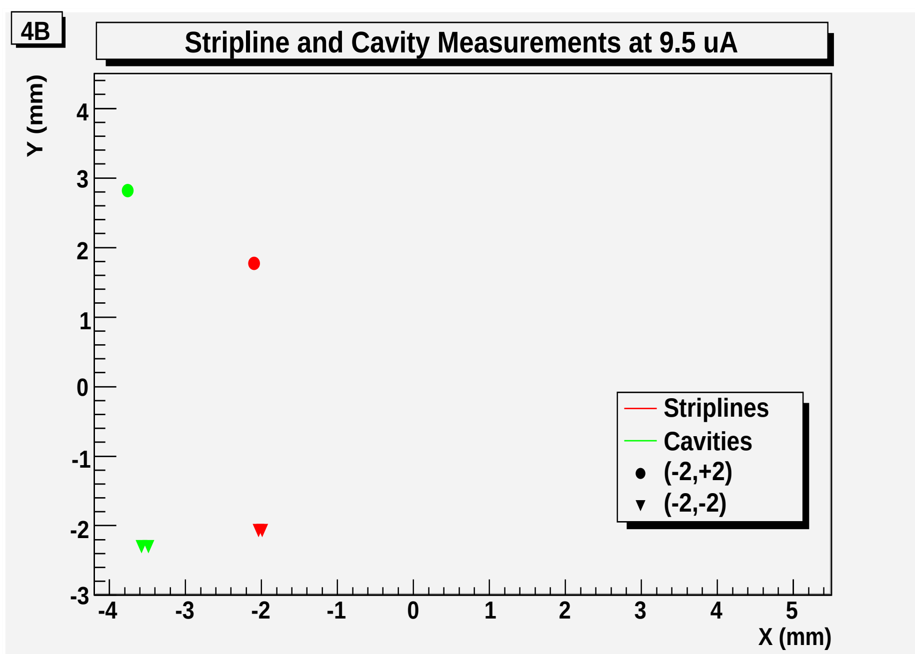

FIG. 9: Same as fig 8 except for 4B.

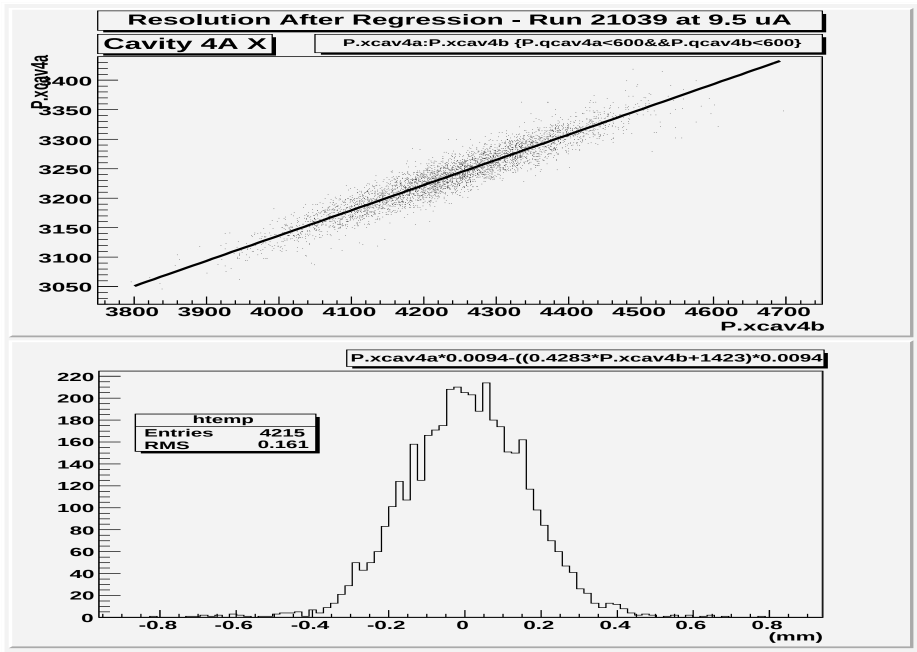

FIG. 10: Resolution analysis of 4AX position at 9.5 μA. A correlation between cavity monitors is used to crudely subtract the beam noise, leaving a residual (bottom fig) with a width of 161 μm.

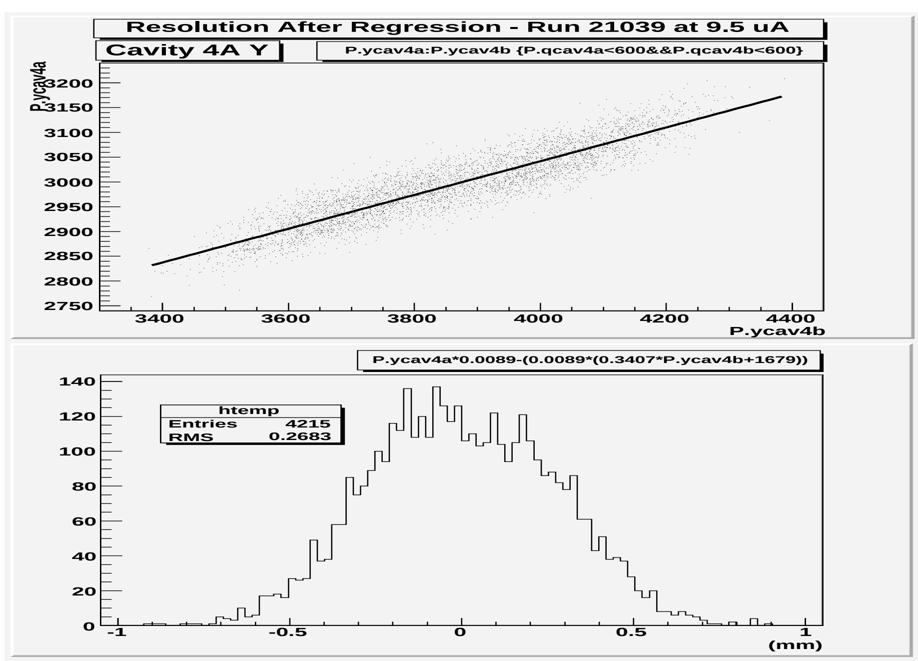

FIG. 11: Resolution analysis 4AY at 9.5 μA.

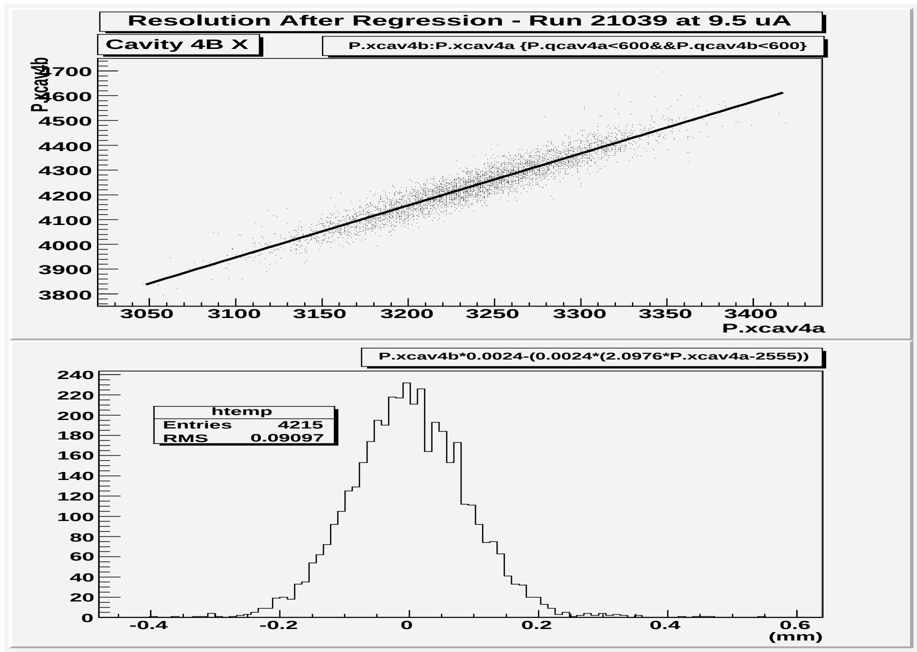

FIG. 12: Resolution analysis of 4BX at 9.5 μA.

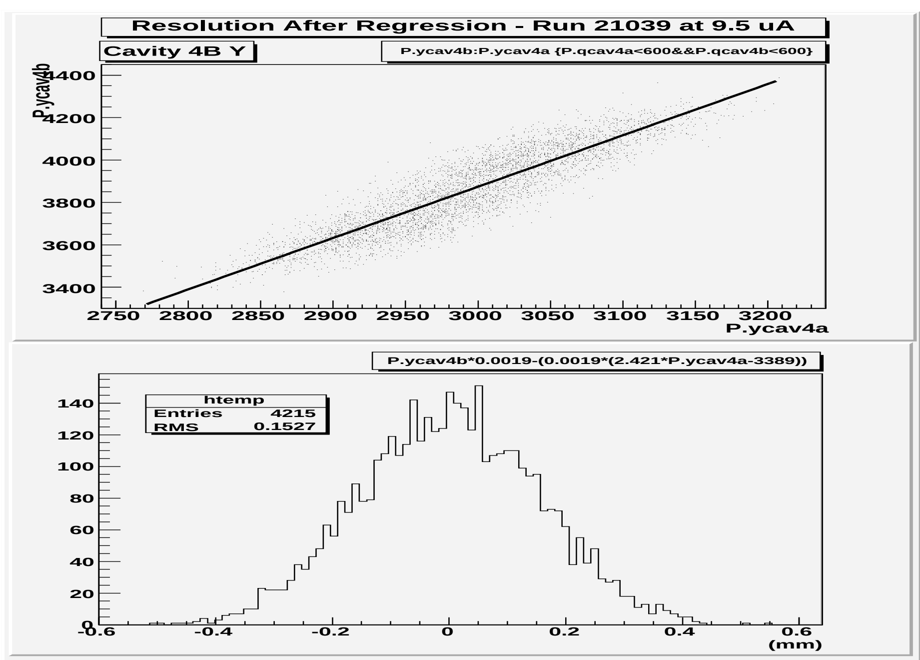

FIG. 13: Resolution analysis of 4BY at 9.5 μA.

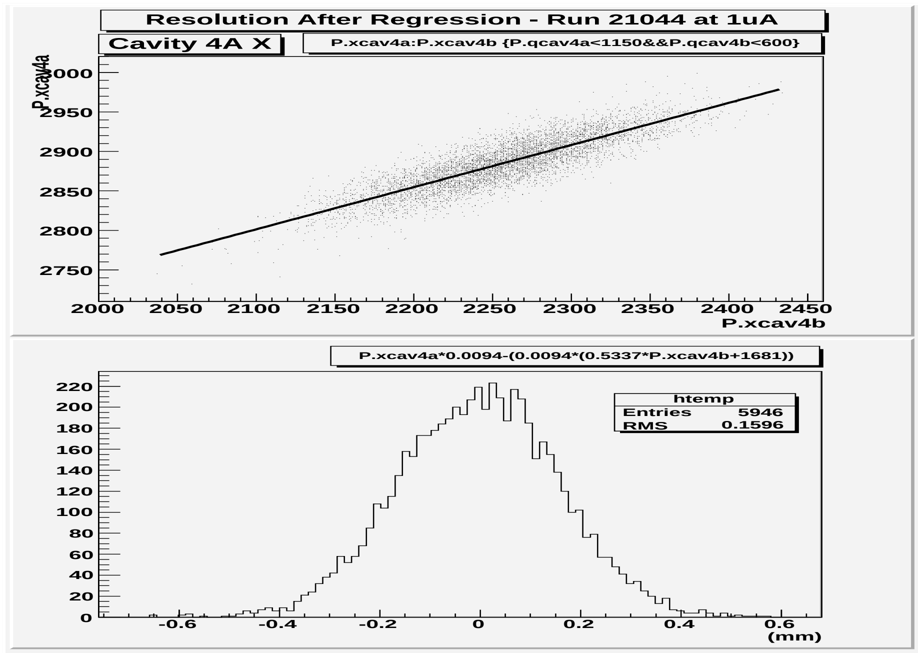

FIG. 14: Resolution analysis of 4AX at 1 μA.

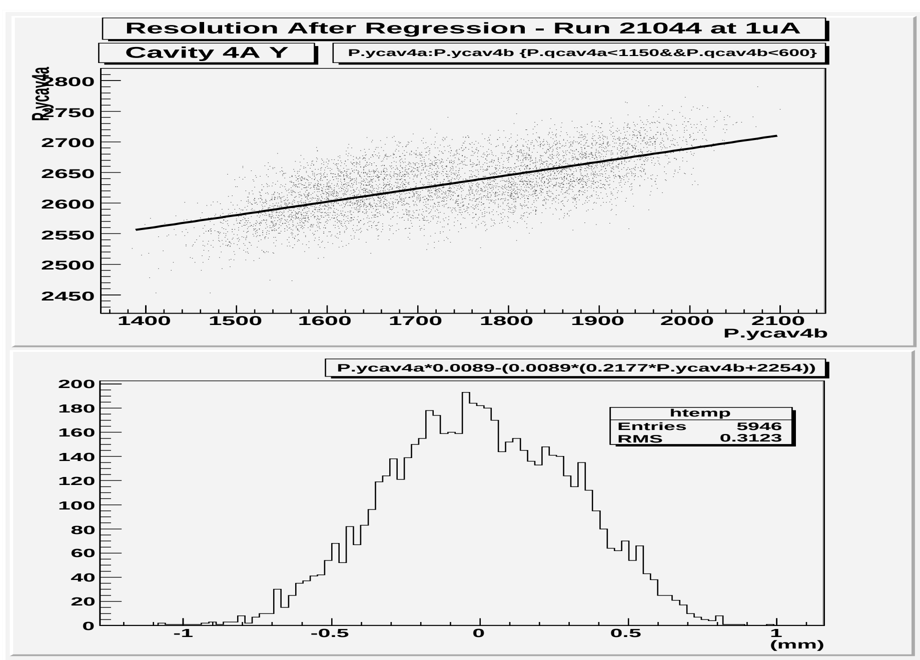

FIG. 15: Resolution analysis of 4AY at 1 μA.

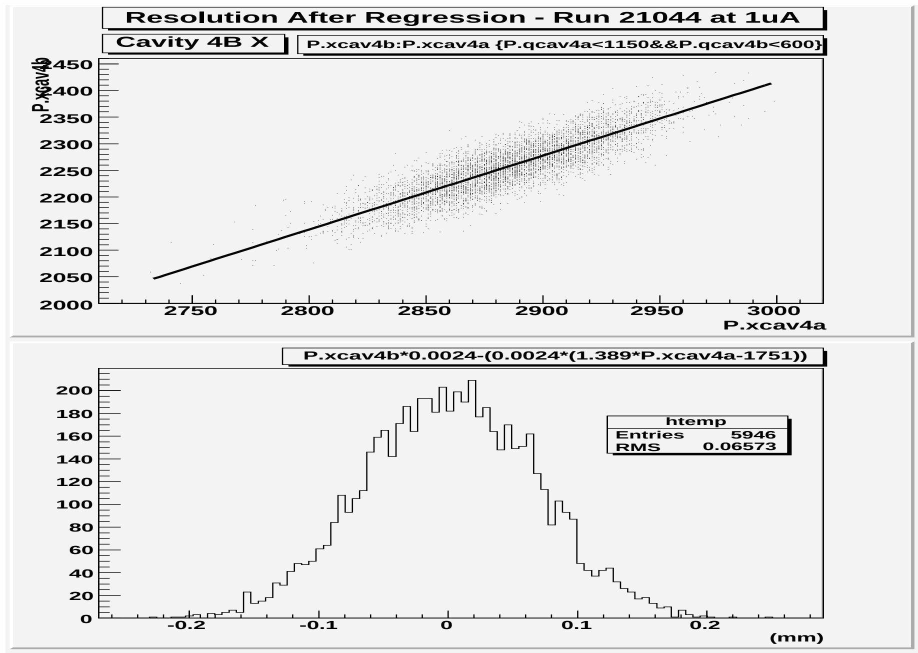

FIG. 16: Resolution analysis of 4BX at 1 μA.

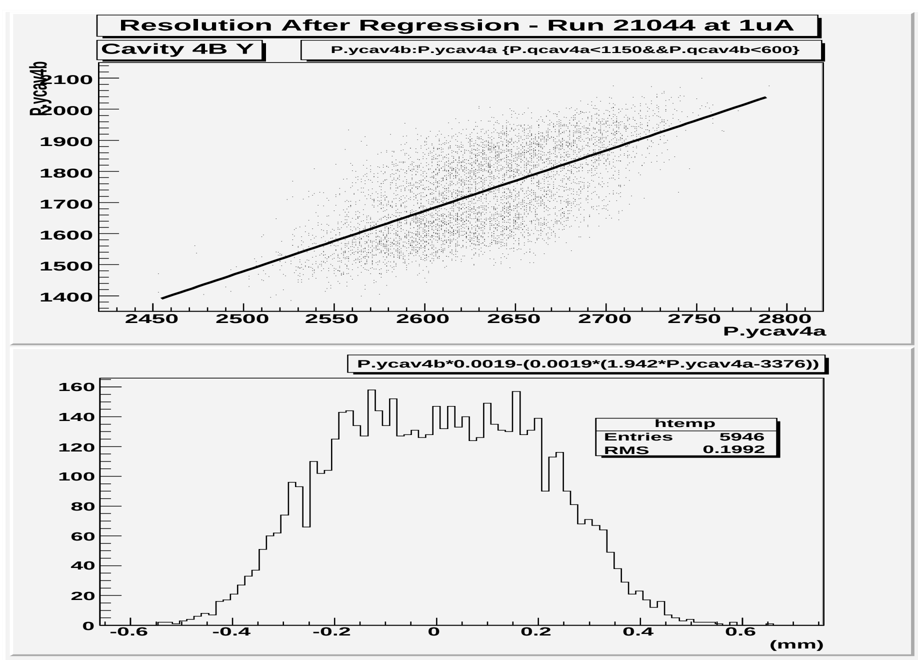

FIG. 17: Resolution analysis of 4BY at 1 μA.

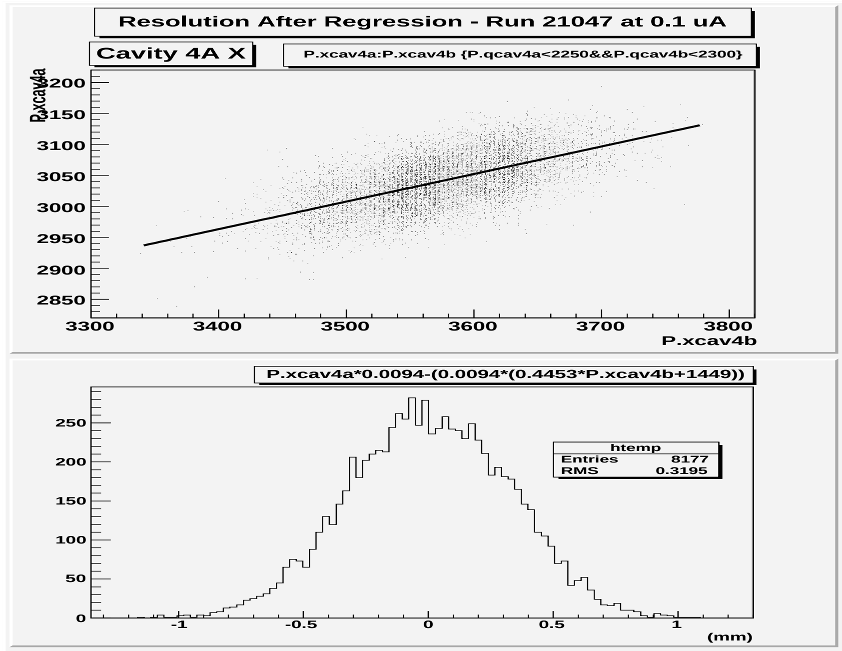

FIG. 18: Resolution analysis of 4AX at 100 nA.

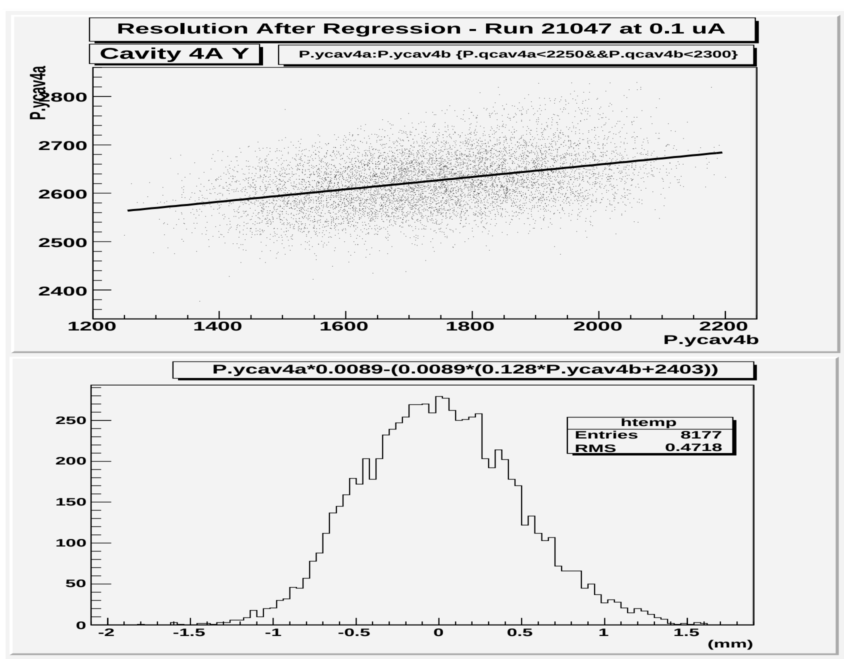

FIG. 19: Resolution analysis of 4AY at 100 nA.

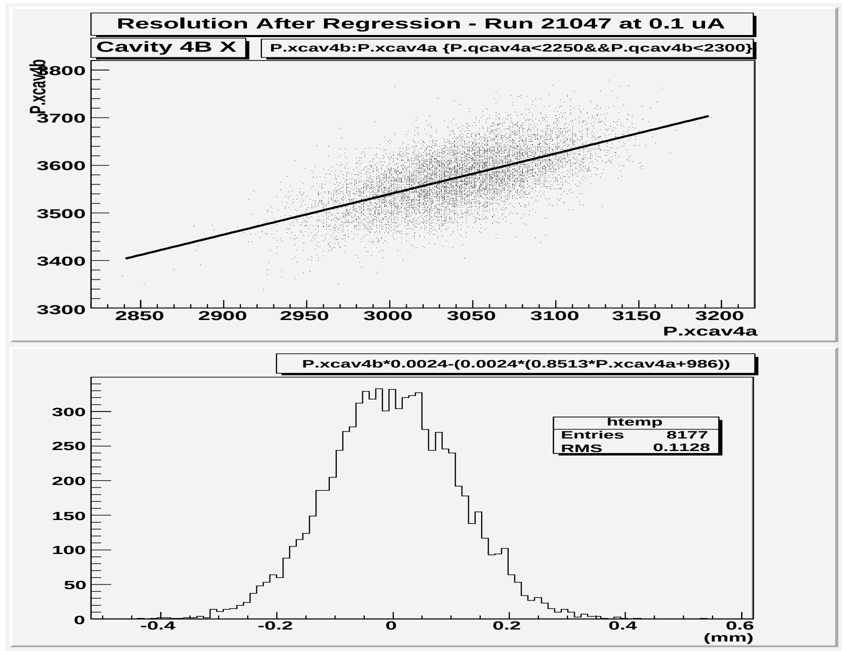

FIG. 20: Resolution analysis of 4BX at 100 nA.

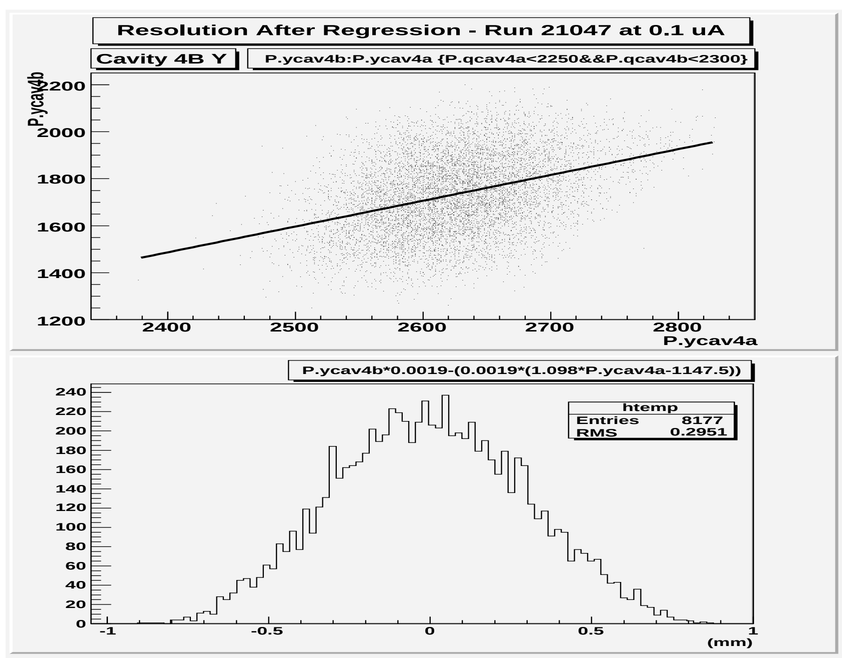

FIG. 21: Resolution analysis of 4BY at 100 nA

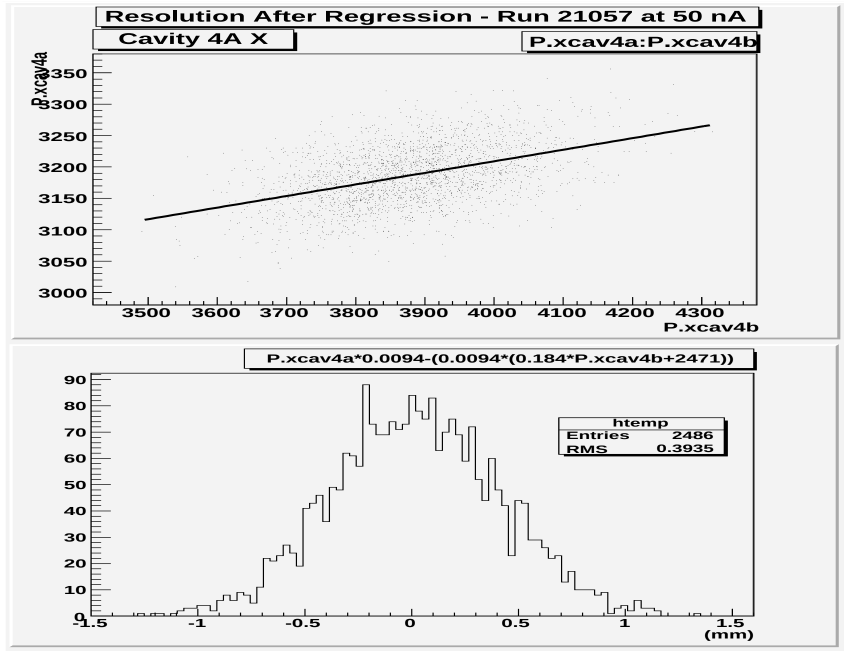

FIG. 22: Resolution analysis of 4AX at 50 nA.

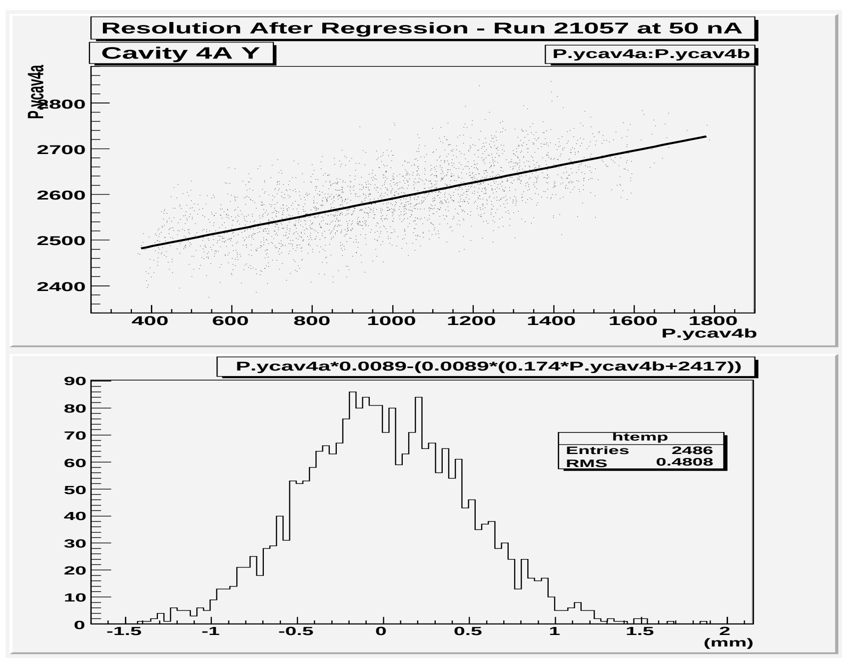

FIG. 23: Resolution analysis of 4AY at 50 nA

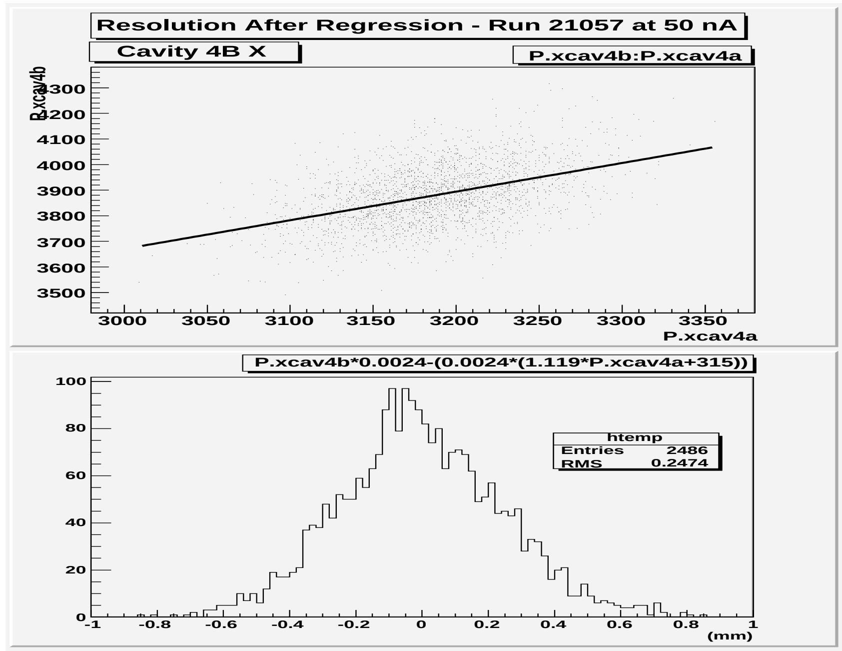

FIG. 24: Resolution analysis of 4BX at 50 nA.

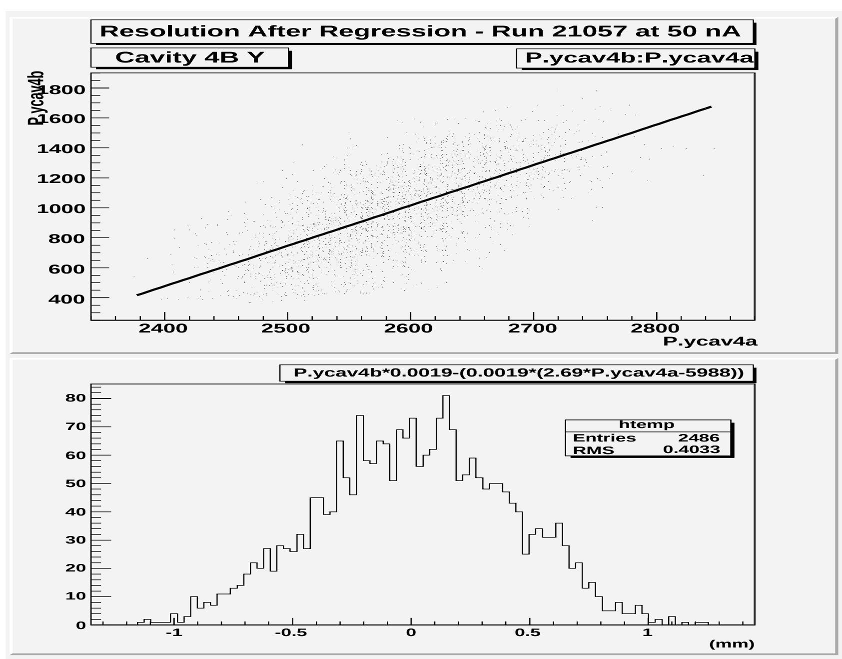

FIG. 25: Resolution analysis of 4BY at 50 nA

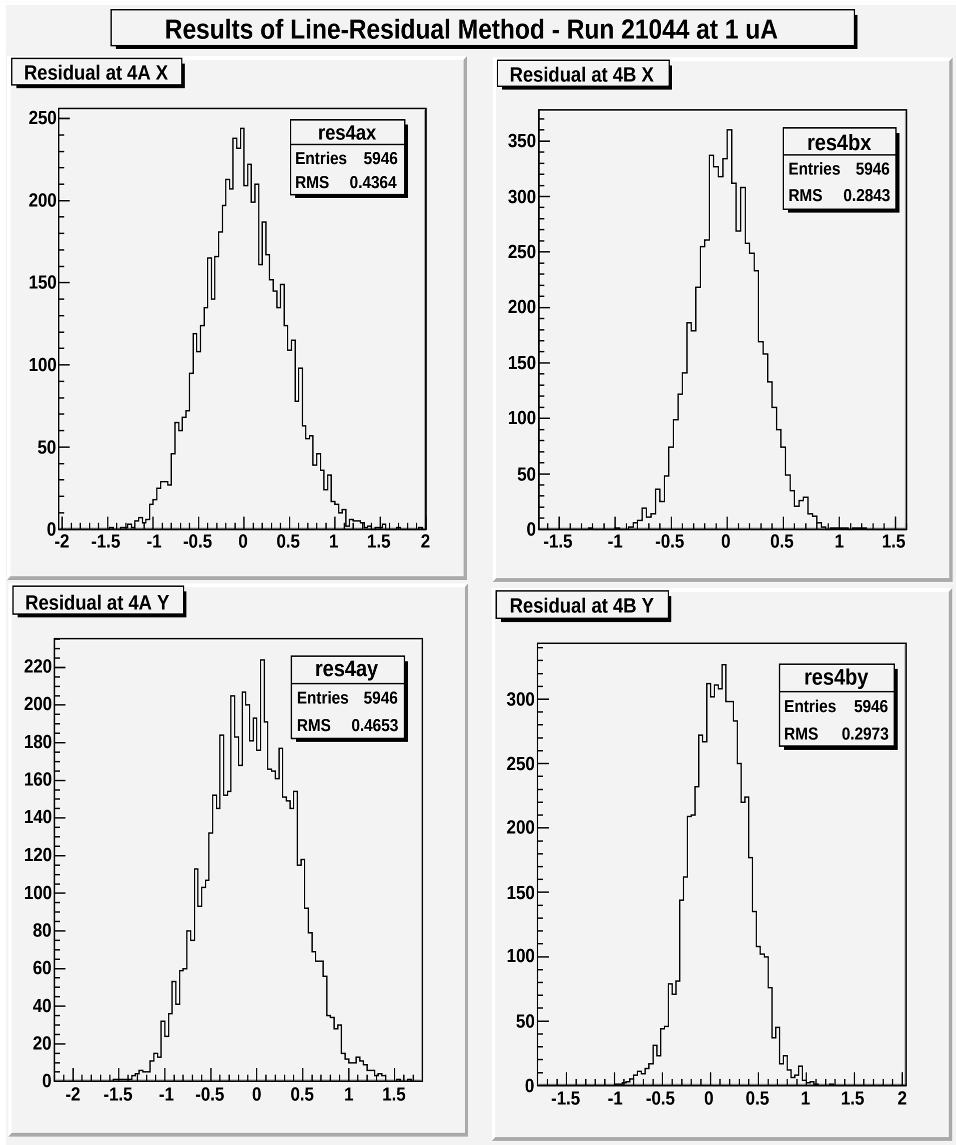

FIG. 26: Results of Method (b) for all Cavity Monitors at 1 uA