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Tevatron BPM Upgrade:
Comparison of Long Gate Mode and Short Gate Mode

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Abstract

This document shows a comparison of the two different operating modes which are proposed for the upgraded Tevatron BPM system. The two modes, long gate mode and short gate mode, give the same answer for the proton position to within 50 μm. However they give very different answers for the Pbar position; the measurements differ by about 600 μm.

1 Change Log

v1 First release.

2 Introduction

The idea behind these measurements is to find a period of stable Tevatron operation and to measure the beam position first using the long gate mode and then using the short gate mode. Under the assumption that the beam did not move during this time, this allows a direct comparison of the position reported by the two techniques.

In long gate mode, the Echotek board is configured to acquire data over many turns of the Tevatron to produce a single measurement on each cable with a resolution bandwidth of about 1 KHz.

In short gate mode the Echotek board is configured to acquire data for about 800 ns. The time window for the Pbar cables is chosen such that there is no contamination from signals which come from the proton beam. During the time window for the proton cables, there are both protons and Pbars passing through the BPM. The resolution bandwidth of this measurement is more than 1 MHz. This mode is discussed in more detail in Beams-doc-1124.

3 Data Sample

The data were taken from the shot which started at about 3:00 PM on June 2, 2004. Before the shot started, Jim Steimel set up the modified recycler Echotek board in long gate mode and read it out with the data logger at 1 Hz. Once a stable store was achieved, he changed the recycler Echotek board to work in short gate mode. This data was also data logged at 1 Hz.

4 The Data

Figure 1 shows a summary of the data for the BPM HA15. The upper left plot shows the proton sum signal for the full time period. For all plots in this document the the horizontal axis is time in hours since the start of the day. A step in the sum signal is present when the data processing was switched from short gate mode to long date mode. The other features present are the proton injection at a time of 15.0 hours and the energy ramp at about 15.6 hours. I don't know of any reason for the small step at a time near 17.5 hours.

The upper right plot shows the sum signal for the Pbar cables, after correction for the proton contamination. The correction coefficients were computed from the proton signals immediately before and after the helix opened and before the start of antiproton injection. This is described in more detail as Model 2 in Beams-doc-988. The Pbar sum plot is noisier than the proton sum plot. At the time of the change in processing modes, a step is seen in the Pbar sum signal. One can also clearly see the Pbar injection in this plot.

The lower left plot shows the proton position computed as

$$P = 26\frac{|B| - |A|}{|A| + |B|}, \tag{1}$$

where A and B are the complex numbers (I,Q) reported by the Echotek. In this plot one can see the helix open and the changes in the orbit during the ramp, squeeze and the start of collisions. The vertical dashed red line shows the time at which the processing mode was changed to short gate. Only a small change in the measured position is seen.

The lower right plot shows the Pbar position computed using the same equation as for protons but after A and B have been corrected to remove the proton contamination. The vertical dashed red line shows the time at which the processing mode was changed to short gate. At this time there is a marked step in the measured Pbar position. Because the proton position did not change at this time, we presume at th that step in the Pbar position is an artifact of the instrumentation, not real beam motion.

I should check this by looking at other BPMs.

Figure 2 shows the same plots as the previous page but zoomed in to better see the time near the change in processing mode. At the time of the change, the step in the proton position is less than about 50 μm and the step in the Pbar position is about 500 μm.

Figure 3 shows the same information as in Figure 1 but for the BPM VA14. These plots are qualitatively the same as the plots for HA15. Figure 3 shows the same plots as the previous figure but zoomed into the time near the change in processing mode. In the lower left figure one can see a small, but statistically significant step in the proton position of about 50 μ and, in the lower right plot, one can see a step in the Pbar position of about 700 μm.

The average of the two Pbar step sizes is 600 μm.

4.1 Understanding the Proton Plots

There are several possible explanations for the change in the proton sum signal when the processing mode is changed. One possibility is that the Echotek board is programmed to have slightly different gain in the two cases. A second possibility is that the timing of the gates cuts out part of the tail from the last bunch. In long gate mode many bunches are seen and this is a small effect. In short gate mode only two bunches are seen so this should be a larger effect. Neither of these effects should change the central value of the measured position, although they might cause a change in the position resolution. No significant change is seen in the measured proton position so both explanations are allowed by the data.

Two other possible explanations can be eliminated. One might think that that the broader resolution bandwidth includes information from more frequencies, which causes a shift in the measurement. It seems unlikely that such an effect would conspire to give such a large step in the sum signal but such a small effect in the position signal. This this explanation seems unlikely. One might also think that the short gate mode somehow has a worse problem than the narrow gate mode with the Pbar bunches contaminating the proton signal. However Figure 4 in Beams-doc-1124 shows that the effect is well understood and is much too small to explain the size of the step in the sum signal.

4.2 Understanding the Pbar Plots

In the Pbar data, a large step is seen in both the sum and the position signals. The leading explanation for the step in position is that the measurements in long gate mode have imperfect cancellation of the proton signal, which gives a bias to the measurement of the Pbar position. In the short gate mode, this contamination is not present and the Pbar position measurement is clean. Therefore one is tempted to say that that short gate mode gives the "right" answer. However the short gate mode has a wider resolution bandwidth which introduces different sources of bias and we do not have a control for these. Perhaps any bias from this source can be bounded using the proton data?

The above explanations can also explain the step in the Pbar intensity. However that step presumably also has contributions from whatever causes the step in the proton intensity.

5 Summary and Conclusions

The short and long gate modes give the same answer for the proton position within about 50 μm. However they give very different answers for the Pbar position; the two measurements differ by about 600 μm. At present we cannot say which of these two answers, if either, is correct. However I am working under the assumption that the short gate mode is likely to be more correct.

If we do this exercise again it would be smart to return to long gate mode at the end in order to verify that the beam did not move during the short gate measurements.

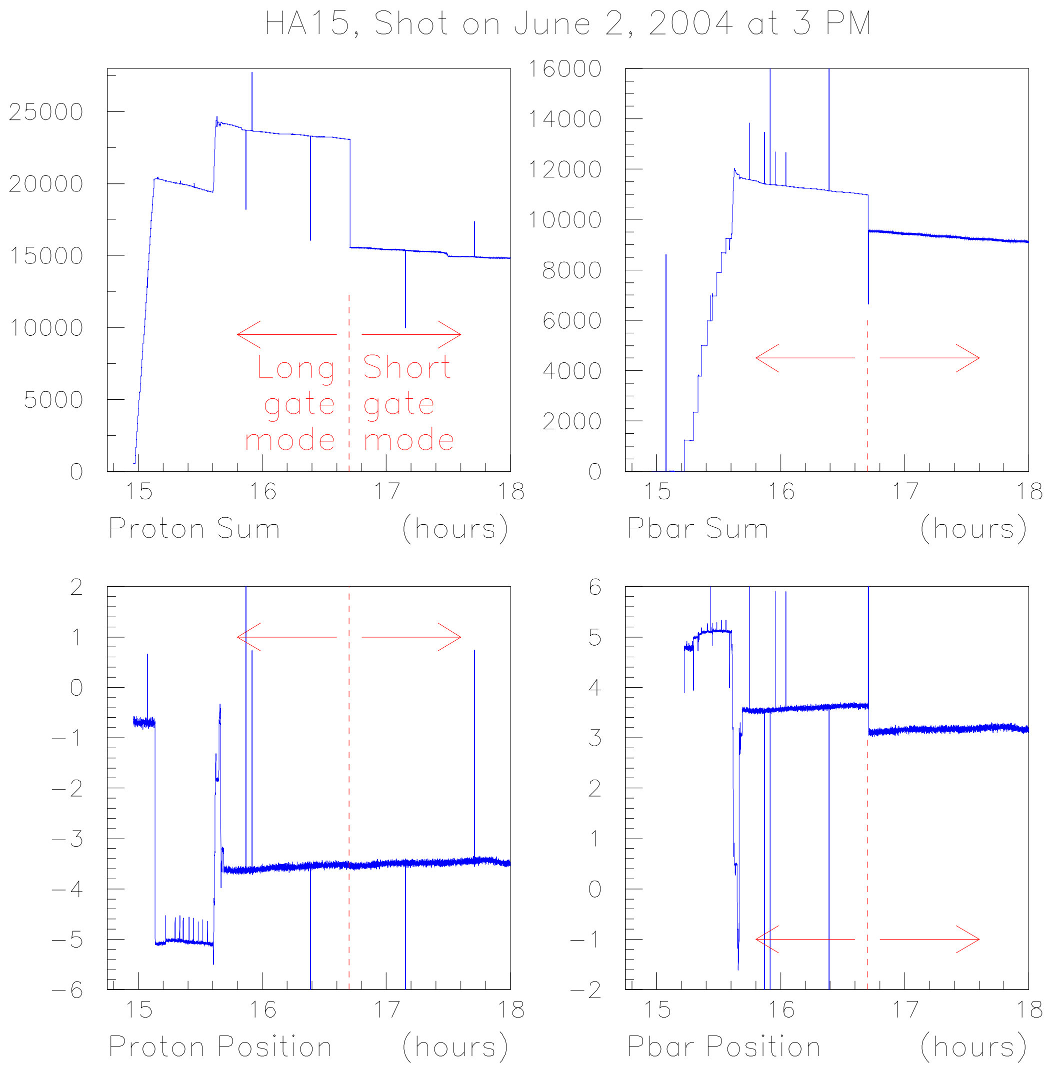

Figure 1: Sum and position signals at HA15 for the protons and Pbars for about the first three hours of the shot. The plots for the Pbars are made after the subtraction of the contamination from the protons. The horizontal axis is in hours from the start of the day. The data before about 16:42 were acquired in long gate mode while the data after that time were acquired in short gate mode. This time is marked on the plots with a vertical red dashed line and two arrows. For both bottom plots the full scale of the vertical axis is the same, 8 mm.

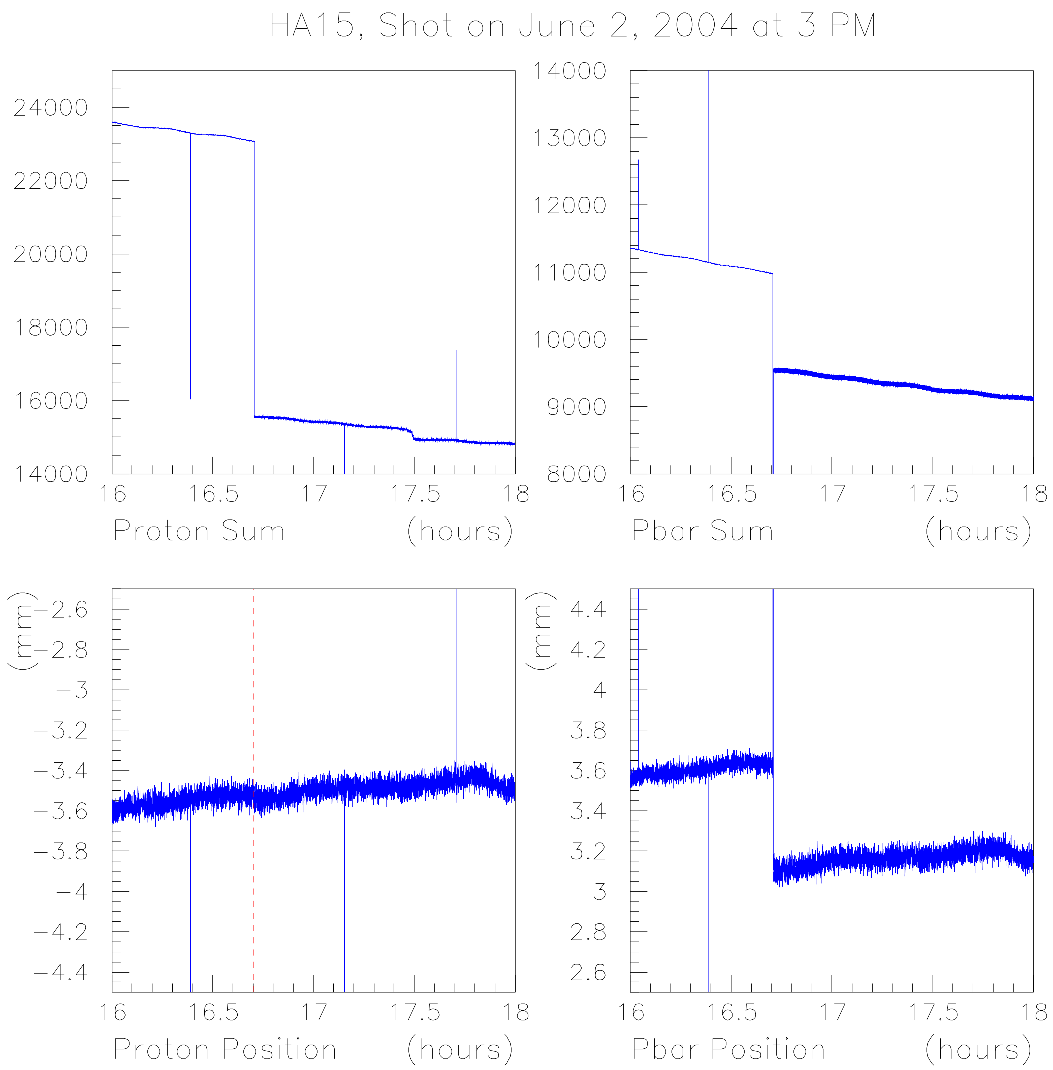

Figure 2: Detail of the plots on the previous page (for HA15) near the switch from long gate mode to short gate mode at a time of 16:42. The time of the transition is marked on the proton position figure with a vertical dashed red line; in all other plots the large step marks the time. For both bottom plots the full scale of the vertical axis is the same, 2 mm.

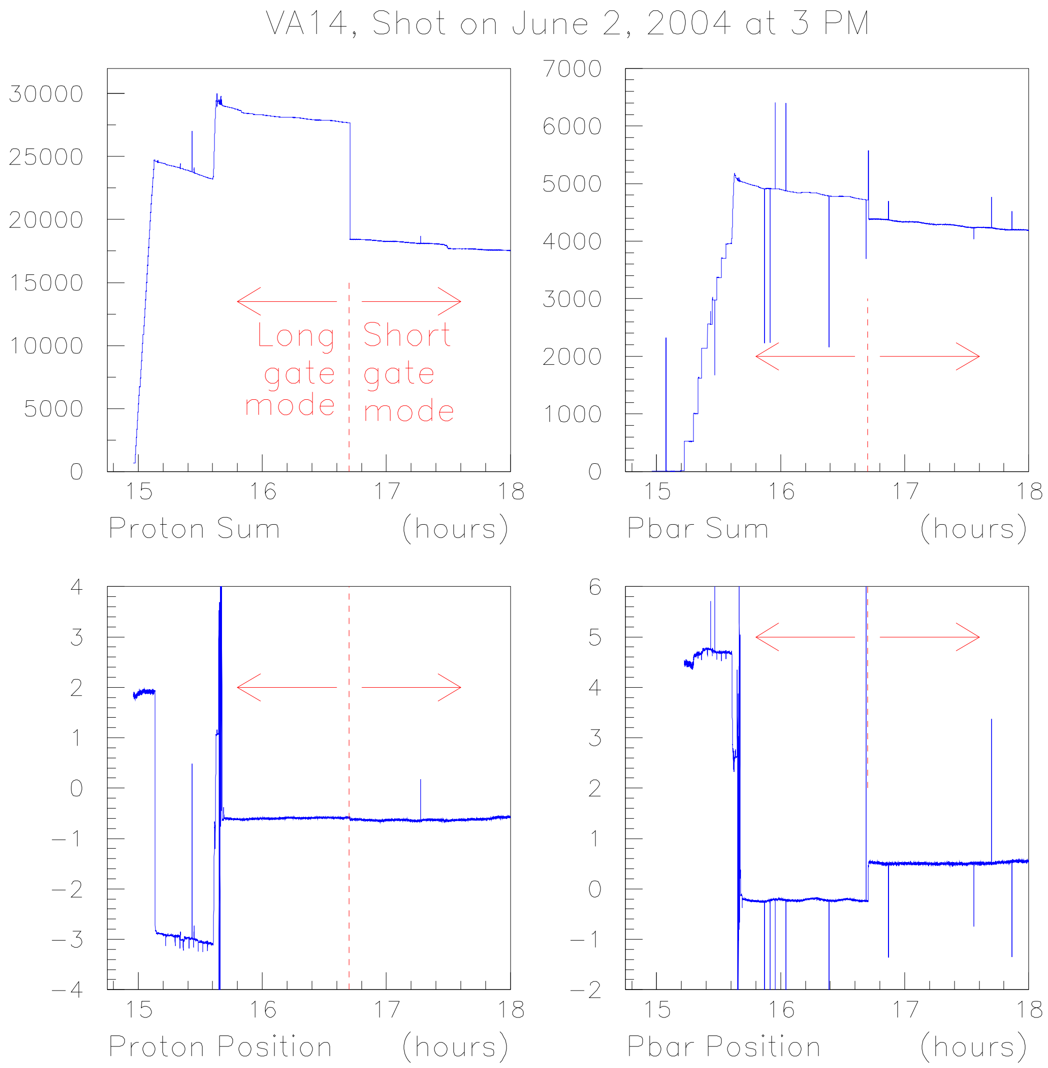

Figure 3: Sum and position signals at VA14 for the protons and Pbars for about the first three hours of the shot. The plots for the Pbars are made after the subtraction of the contamination from the protons. The horizontal axis is in hours from the start of the day. The data before about 16:42 were acquired in long gate mode while the data after that time were acquired in short gate mode. This time is marked on the plots with a vertical red dashed line and two arrows. For both bottom plots the full scale of the vertical axis is the same, 8 mm.

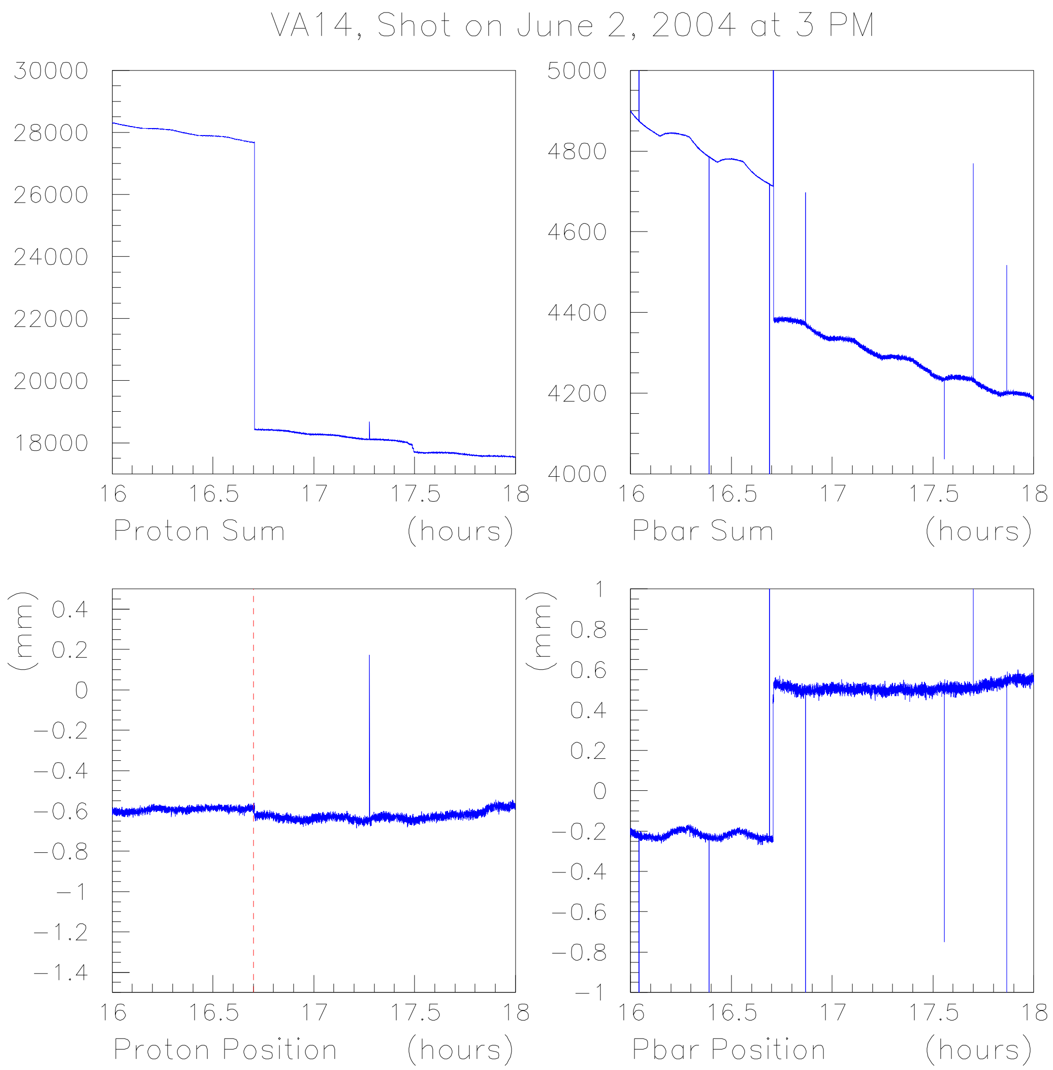

Figure 4: Detail of the plots on the previous page (for VA14) near the switch from long gate mode to short gate mode at a time of 16:42. The time of the transition is marked on the proton position figure with a vertical dashed red line; in all other plots the large step marks the time. For both bottom plots the full scale of the vertical axis is the same, 2 mm.