Figure 3 shows a detail of Figure 2b) during antiproton injection. This provides a another check on the quality of the cancellation of the proton contamination. When that cancellation is poor, the antiproton position trace will show large steps at each antiproton injection, as will be shown in Figure 5. In Figure 3, the antiproton position is stable to better than 100 µm throughout the antiproton injection. The conclusion is that the cancellation is excellent.

Figure 3 also provides evidence for antiproton contamination on the proton position. The effect is about 300 µm, well below the accuracy specification of 1 mm. It is understood in principle how to correct for this contamination but doing so would not result in significant operational improvements at the current antiproton intensities. Moreover, calibrating this correction would probably require antiproton only stores, a profligate use of antiproton's unless a significant operational improvement is promised. The injection bumps and the cogging operations are also clearly seen in Figure 3.

One of the Tevatron tune up steps is to inject a proton bunch and then energize the separators with the opposite polarity, which places the proton bunch on the antiproton helix. Figure 4a) shows the measured proton position during one of these reverse helix stores. Horizontal dashed lines are drawn at the positions of the measured central and antiproton orbits. Figure 4b) shows the measured beam positions for a shot which followed soon after. The two horizontal lines drawn on 4a) have been repeated in 4b). A third horizontal line has been drawn on 4b) at the predicted position of the proton helix. Inspection of the figure shows that the central orbit has moved by about 50 µm between the two data sets. It also shows that the antiproton's are measured to be at the predicted position to better than 100 µm and that the proton's are at the mirror image position with an accuracy of about 150 µm. These deviations are within the specified tolerances.

In order to further test the self consistency of the upgraded BPM electronics, there is a plan for a proton only store with the separators off. During this store the measured proton position will trace out the central orbit from initial proton injection to the initiation of collisions. Immediately following this study, a normal physics shot will be done and the measured proton and antiproton positions will be compared to the central orbit determined in the proton only store. If there are significant deviations from the expected mirror image model, a correction scheme will be developed.

The cancellation coefficients vary from one BPM to the next, presumably due to material and construction tolerances. The coefficients for a given BPM also vary from store to store. The main source of this effect is believed to be changes in the vertical beam position at a horizontal-measuring BPM, and vice versa.

The scale of the store to store variation is illustrated in Figure 5, in which the red points show the antiproton position for a particular shot using the cancellation coefficients computed using the helix opening of that shot. The blue points show the positions for the same shot, but computed using the cancellation coefficients from a shot 7 days earlier. The older cancellation coefficients do a much poorer job, particularly at low

Comparison of Antiprotons with Reverse Helix Protons

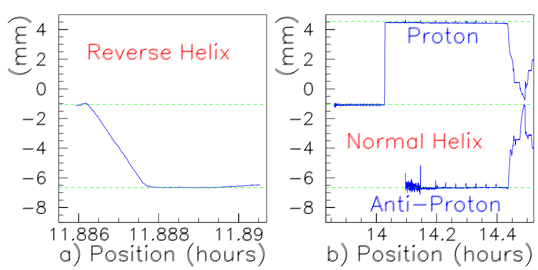

Figure 4. Comparison of antiproton position with that of protons on the reversed helix, for BPM VA35. The time axis is time of day, in hours

Antiproton Data from August 18, Old and Current Calibrations

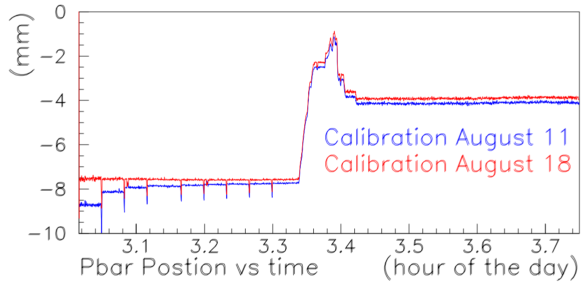

Figure 4. Antiproton data from August 18, processed using two different calibrations for the cancellation coefficients. The time axis is time of day, in hours

antiproton currents, when the residual contamination is a much larger fraction of the total signal. When all antiproton bunches have been injected, the bias from the stale calibration is about 500 µm, which is within requirements. When only a few bunches have been injected, however, the bias is outside of the requirements. To address this an automated procedure to re-compute the cancellation coefficients every shot is being developed.

CONCLUSIONS

This poster has described the frequency domain method for measuring the antiproton position using the upgraded Tevatron BPM system. Using data taken during the commissioning period, the method has been shown to meet the requirements for resolution and accuracy, the accuracy tests being performed relative to the measured proton position.

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