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Anti-proton Transfers with the New MI BPMs

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Abstract

This note shows closed orbit data taken during the transfer of anti-protons from the Accumulator to the Recycler, MI state 20.

1 Introduction

The data shown in this note were taken during cycles of MI state 20, between about 3:30 PM and 4:30 PM on Wednesday January 11, 2006. In this MI state, anti-protons are injected from the Accumulator into the MI, circulated for a while and then extracted into the Recycler. This data shows information from six such transfers, which took place at about 10 minute intervals.

Throughout the study period, the MI was sending beam to NUMI and doing the anti-proton transfers to the Accumulator. The front end was programmed to enter closed orbit mode at the start of MI state 20 and exit closed orbit mode at the end of the state. At the end of each cycle of state 20 the closed orbit buffer (4096 points) was written to disk.

For the data shown here the Echotek was in 2.5 MHz closed orbit mode. I believe, but have not independently verified, that the transition board was putting out both the 2.5 MHz and the 53 MHz signals.

In the requirements document, Beams-doc-1786-v7, Table 8 gives the required resolution for measuring anti-protons with a 2.5 MHz bunch structure. The document specifies that for nominal intensity, $> 20 \times 10^9$/bunch, the BPM should have a 3 sigma resolution of 300 μm. It also specifies that when the intensity is less than nominal, the BPM should have a 3 sigma resolution of 500 μm.

Table 1 gives the intensity recorded in the MI scrap book for these six transfers. So the first four cycles should have a 1 sigma resolution less than 100 μm while the last two should have a 1 sigma resolution less than 167 μm.

2 The Data

Each saved closed orbit buffer contained the most recent cycle of state 20 plus stale information. For each buffer, the last cycle was extracted and the data for all six buffers were concatenated into a single data set. The sum and position

Cycle	Intensity ($\times 10^{10}$/batch)	Intensity ($\times 10^{9}$/bunch)
1	25	62.5
2	18	45.0
3	13	32.5
4	10	25.0
5	7	17.5
6	5	12.5

Table 1: Reported anti-proton intensities for each of the cycles. The second column gives the intensity read by Dave Capista from a graph in the MI scrap book; this is the intensity for sum of the 4 bunches in the transfer. The third column gives this same number divided by 4, to give intensity per bunch. The first four cycles are above the nominal intensity and, therefore, are required to meet the nominal resolution requirement. The last two cycles are below nominal intensity and must only meet the relaxed requirement.

signals for the combined data set are shown in Figure 1. The gap of about 10 minutes between each cycle is not indicated on this plot. The data are ordered so that the earlier cycles have the lower tick numbers. The main feature of these data is the fall off of intensity for later transfers.

I do not have a reference cycle of a proton state that can be used as a reference for the position.

Figures 2 and 3 show details of the data in Figure 1. In both plots vertical red lines are drawn at ticks 385 and 415; the data between these ticks was used to compute the mean value and RMS spread of the sum and position signals. The values of mean sum, mean position and RMS position resolution are summarized in Table 2. Figure 4 shows a finer detail of the position data; it is included to show that the measured RMS position resolution is not contaminated by a slope or large jumps in the data. The resolution requirements, expressed as to 1 sigma values, are also included in Table 2.

The data from Table 2 is displayed graphically in Figure 5. For reference the required resolution is overlayed as the horizontal red lines; none of the data points meets the resolution requirements.

3 Discussion

While the BPM system appears to be working correctly, the sum signals are low and none of the data points in the lower plot in Figure 5 satisfy the required resolution. In the prototype used for these measurements, the gains on the transition board cannot be remotely controlled. So the gains were fixed at a compromise value, with the 2.5 MHz gain low enough that it does not cause saturation in the 53 MHz digital filter. So it is possible to redo this measurement with an increased gain; this can be done once the production equipment, with

Cycle	Mean Sum (EU)	Mean Position (mm)	RMS Position (μm)
1	428.5 ± 0.4	-5.00 ± 0.02	121 ± 15
2	296.0 ± 0.3	-5.06 ± 0.03	160 ± 20
3	230.9 ± 0.5	-5.05 ± 0.04	215 ± 27
4	158.9 ± 0.4	-5.04 ± 0.04	218 ± 27
5	122.0 ± 0.4	-5.07 ± 0.07	399 ± 50
6	80.6 ± 0.4	-5.08 ± 0.08	476 ± 60
Required, $> 20 \times 10^9$/bunch:			100
Required, $< 20 \times 10^9$/bunch:			167

Table 2: The mean values of the sum and position, and the RMS position resolution, computed from the indicated regions in Figures 2 and 3. In each case the errors are 1 sigma errors. The error on the mean was computed as RMS/$\sqrt{N}$, where N is the number of points used. The error on the RMS was computed as RMS/$\sqrt{2N}$. The last two lines give the required resolution, converted to 1 sigma resolution; the first four cycles have a sufficiently high intensity that they should satisfy the nominal resolution requirement. The last two cycles have lower intensity and should satisfy the relaxed requirement.

remotely controllable gains, becomes available.

There is a clear intensity effect in the lower plot in Figure 5. With higher gains the resolution at the low intensity points will certainly be improved and should be at least as good as the resolution at the high intensity points. One cannot tell from this data if the resolution on the high intensity point will also improve with higher gain or if it has already reached an asymptote.

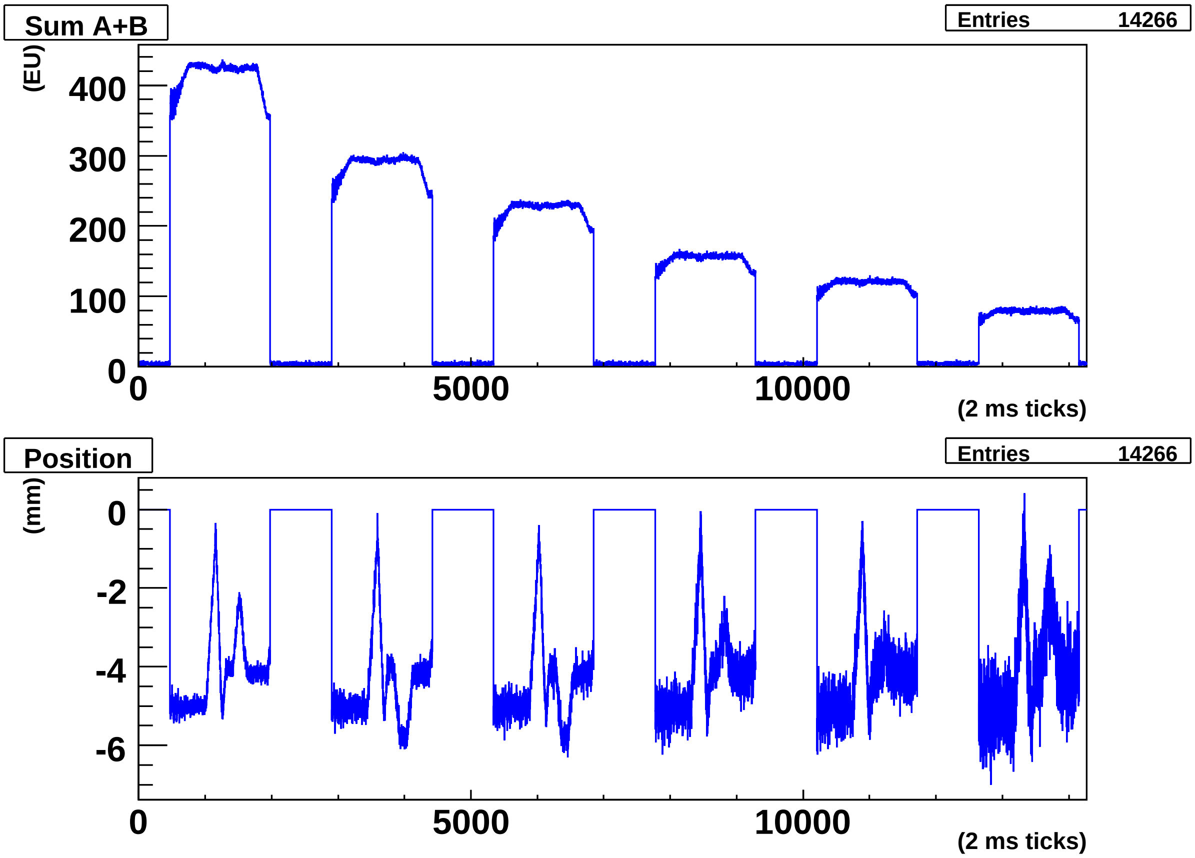

Figure 1: Closed orbit sum and position information from six cycles of MI state 20, transfer of anti-protons from the Accumulator to the Recycler. The cycles were separated by about 10 minutes but are combined here for display purposes.

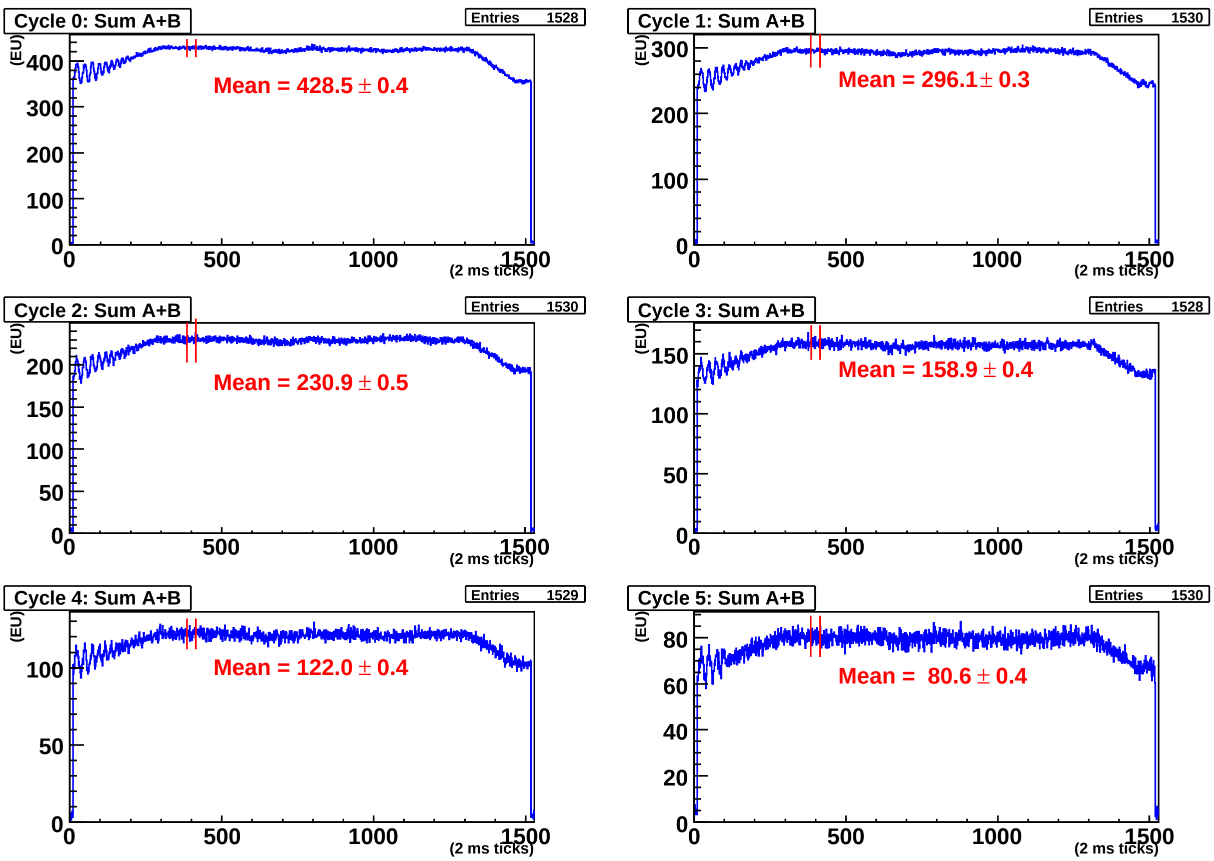

Figure 2: Detail of the sum signal for each of the six anti-proton transfers. The vertical red lines mark the region used to evaluate the mean sum signal.

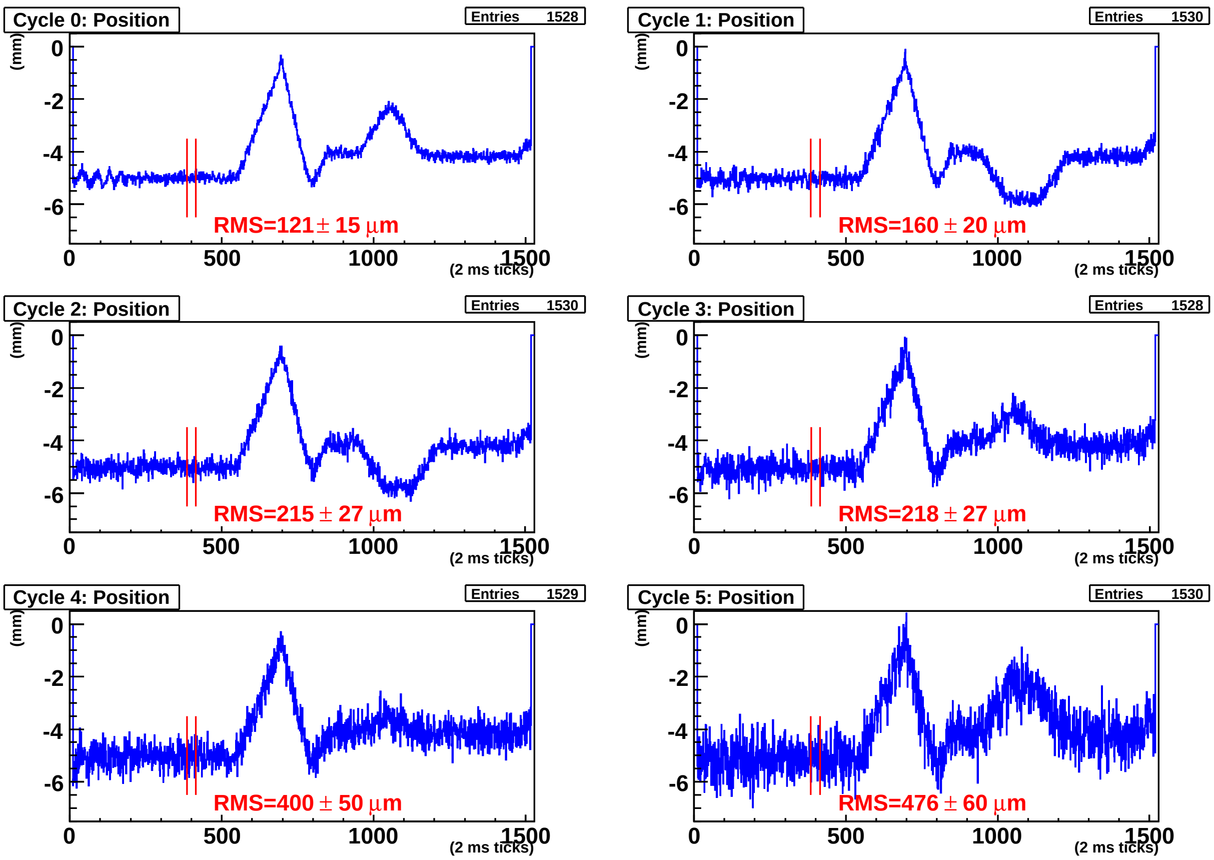

Figure 3: Detail of the anti-proton position for each of the six anti-proton transfers. The vertical red lines mark the region used to evaluate the mean position and the RMS resolution of the position.

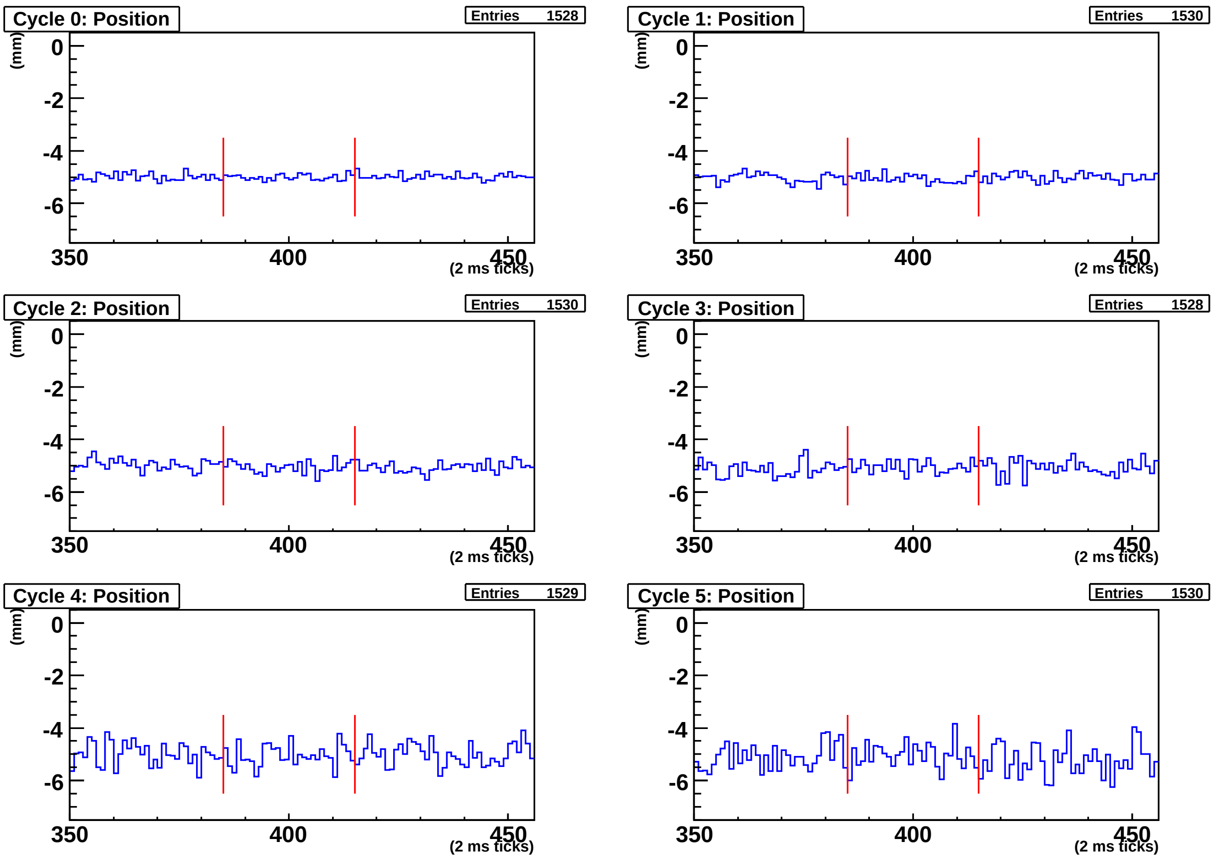

Figure 4: Finer detail of the previous figure, showing the region used to compute the mean position and the RMS resolution on the position.

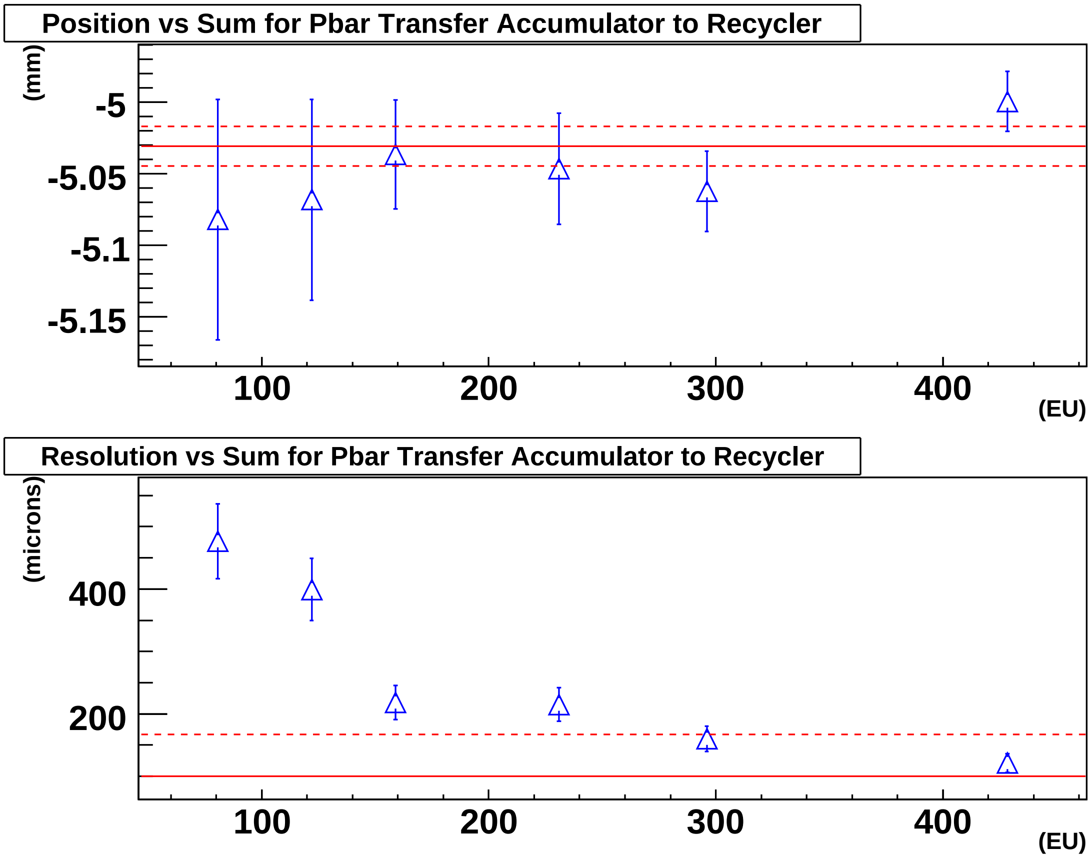

Figure 5: The upper plot shows the mean position plotted as a function the sum signal; there is one data point for each of the six cycles. The error bars are 1 sigma error bars. The error on the sum signal is too small to be interesting. The regions used to compute these data points are shown with the vertical red lines in Figures 2 through 4. In the upper plot, the solid horizontal red line shows the weighted mean of these data points and the dashed horizontal red lines show the 1 sigma error bars on the mean. The lower plot shows the position resolution as a function of sum signal, one data point for each of the six cycles. The solid red line shows the required resolution of 100 μm (1 sigma) for nominal intensity bunches; the rightmost four points should meet this requirement. The dashed red line shows the required resolution of 167 μm (1 sigma) for low intensity bunches; the leftmost two points should meet this requirement. None of the data points meets the required resolution; this is discussed in Section 3.