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Reading TeV BPMs with a Recycler Board

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Abstract

A look at Tevatron BPM information, processed by the recycler board, for data taken during the shot on the evening of Feb 18, 2004. For reference a BPM readout using the damper board is also provided. The data from the recycler boards was difficult to interpret and the problem was eventually traced to a problem with the readout.

The accompanying figures show both damper board data and recycler Echotek data taken during the shot on Wed. Feb 18, 2004 from 9PM to 11 PM. Presume that this is 36 on 36 but I have not checked.

The damper board was set up to log data from BPM HA15 . A recycler Echotek board (or boards?) was setup to log data from BPMs HA15 and VA14. To achieve this the signals from HA15 were split and half of the power sent to each board. The damper boards were configured to record I and Q values for each of the 4 cables on the BPM about once every 8 seconds. The bandwidth of each measurement corresponds to about 9.7 turns. The recycler Echotek board was modified to data log the I and Q signals for each of the 4 cables on each BPM once per second. The bandwidth of each measurement is about 1 kHz.

The data processing for damper boards follows the algorithms described in Beams-doc-988. That document describes the conversion of I and Q to position and sum; it also describes the cancellation of the proton signal on the Pbar plate. For the recycler data, the final I and Q values are taken directly from the data logger; after that the processing continues as for the damper board data.

Figure 1 shows the raw A and B signals for protons and antiprotons, for each of the three BPMs. The horizontal axis is time in hours since midnight on Feb 18 and the vertical axis is the magnitude of the signal, in the units of I and Q as produced by the two boards. In all cases one can clearly see the proton injection, the helix open, the protons coasting during antiproton injection, the energy ramp and the low beta squeeze. The antiproton signals have significant contamination from the protons but the same general features are present.

Figure 2 shows the proton A+B sum signal and the proton position signal. These make sense.

Figure 3 shows the sum and position signals, for antiprotons, for each of the three boards. These plots use the cancellation method described in Beams-doc-988. I choose points just before and just after the helix opening to calibrate the correction function. I did not use a correction for movement in the orthogonal transverse plane. The damper board intensity signal shows relatively poor cancellation during the proton injection, giving rise to the bump at times less than 21.5. The antiproton injection in 9 steps is clear. The damper board antiproton position signal has an odd behaviors at the time of the ramp — it initially moves in the same direction as the protons, not in the opposite direction.

The recycler board plots are horribly noisy.

Figure 4 shows a blow up of the HA15 recycler A+B signal near t=22 hours. from this we can see that the noise has a structure. The origin of this noise is discussed in the next section. This noise was not present on the recycler data of Feb 7, Feb 10 and Feb 13. I have not yet published those data but will soon.

Figure 5 is a repeat of figure 3 but the recycler board quantities are plotted without any attempt to cancel the proton signal. This gets rid of the horrible noise but the standard diseases due to the proton contamination are present.

1 Looking at the Phases

To investigate the structure seen in Figure 4, I made Figures 6 and 7. These show the magnitudes and phases of the signals for about one third of the data in Figure 4. From Figure 6 we see that phase of the raw signals has a regular pattern, with occasional irregularities. The pattern of the phases survives in the Pbar signals after cancellation of the proton signal. According to Jim Steimel:

> The recycler board is not triggered synchronously with the beam during closed orbit measurements. The samples are taken relative to an internal clock on the processor. That is why the phase moves around on each sample.

Figure 7 shows that the source of the magnitudes of the raw signals are stable over the period of interest. The corrected Pbar A signal carries almost all of the noise; only a little is present on the corrected Pbar B signal.

The noise on the corrected Pbar A signal is clearly correlated with the oscillations in the phase.

2 A Guess at the Root of the Problem

Figure 9 is a repeat of figure 6 except that I rotated the phases as follows. For each time point I rotated all 4 phases by a constant chosen to make arg(Proton A+B)=0. We see that, relative to this phase, the phases of Proton A and B are constant but the phases of Pbar A and B are bi-stable. The oscillation in the Pbar position and intensity measurements arises because of this bi-stability.

There is also a second issue and I will need to deal with in the correction for the proton signal on the Pbar cables. There is a cut in phase at $\pm\pi$. I have not yet checked to see if the correction deals properly with this cut. My guess is that it is OK.

3 The Full Explanation

The recycler board produces 8 quantities for each measurement, I and Q for each of 4 cables. The data logger system reads these out one at a time, using 8 separate ACNET calls. There is no guarantee that all 8 quantities come from a single measurement. Presumably the observed instability arises when some of the 8 quantities are read from one beam crossing and the remainder from a different beam crossing. The software is being modified to fix this problem. When that is done we will redo this exercise.

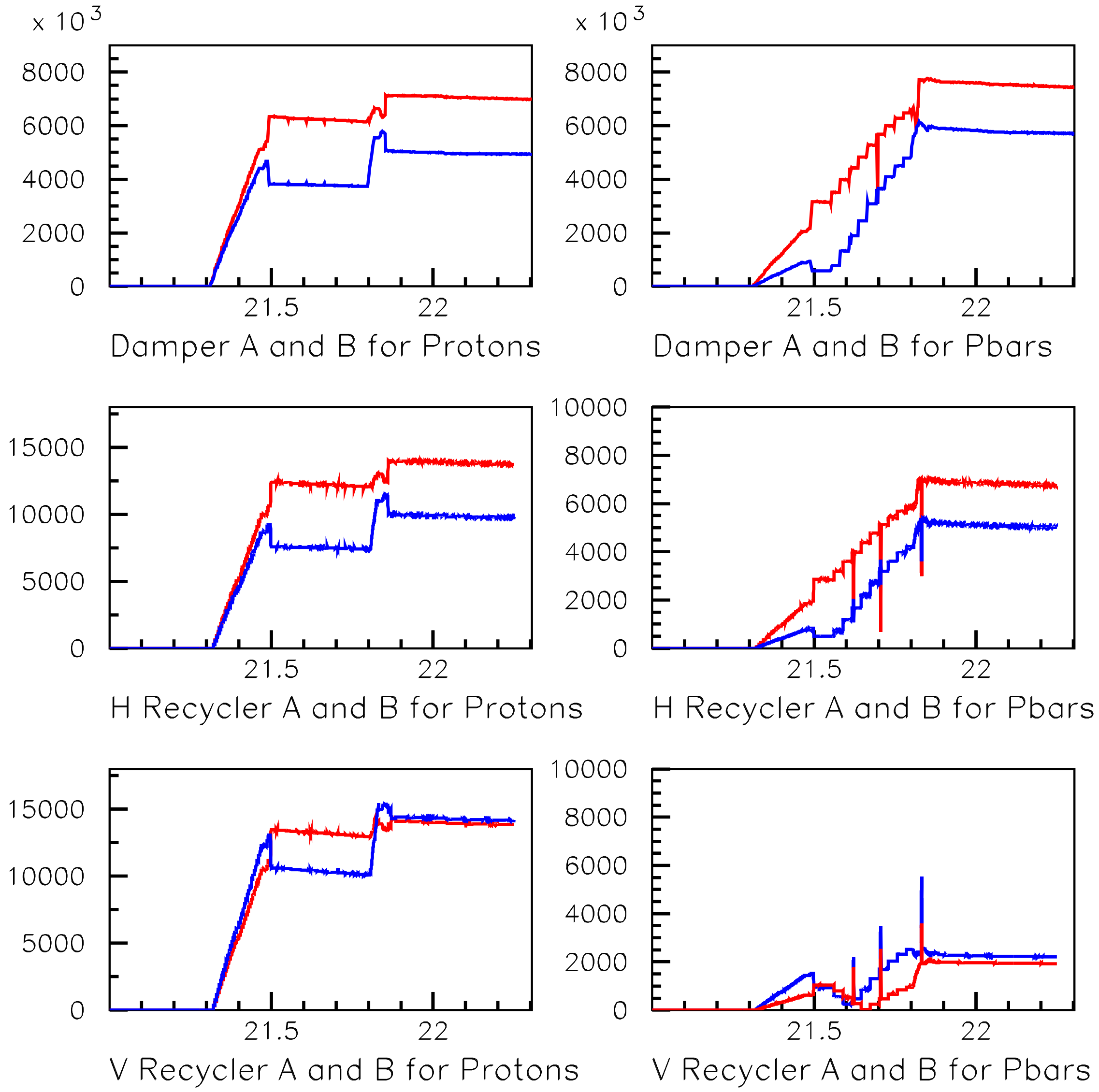

Figure 1: Raw $|A|$ and $|B|$ signals for protons and antiprotons, for each of the three boards.

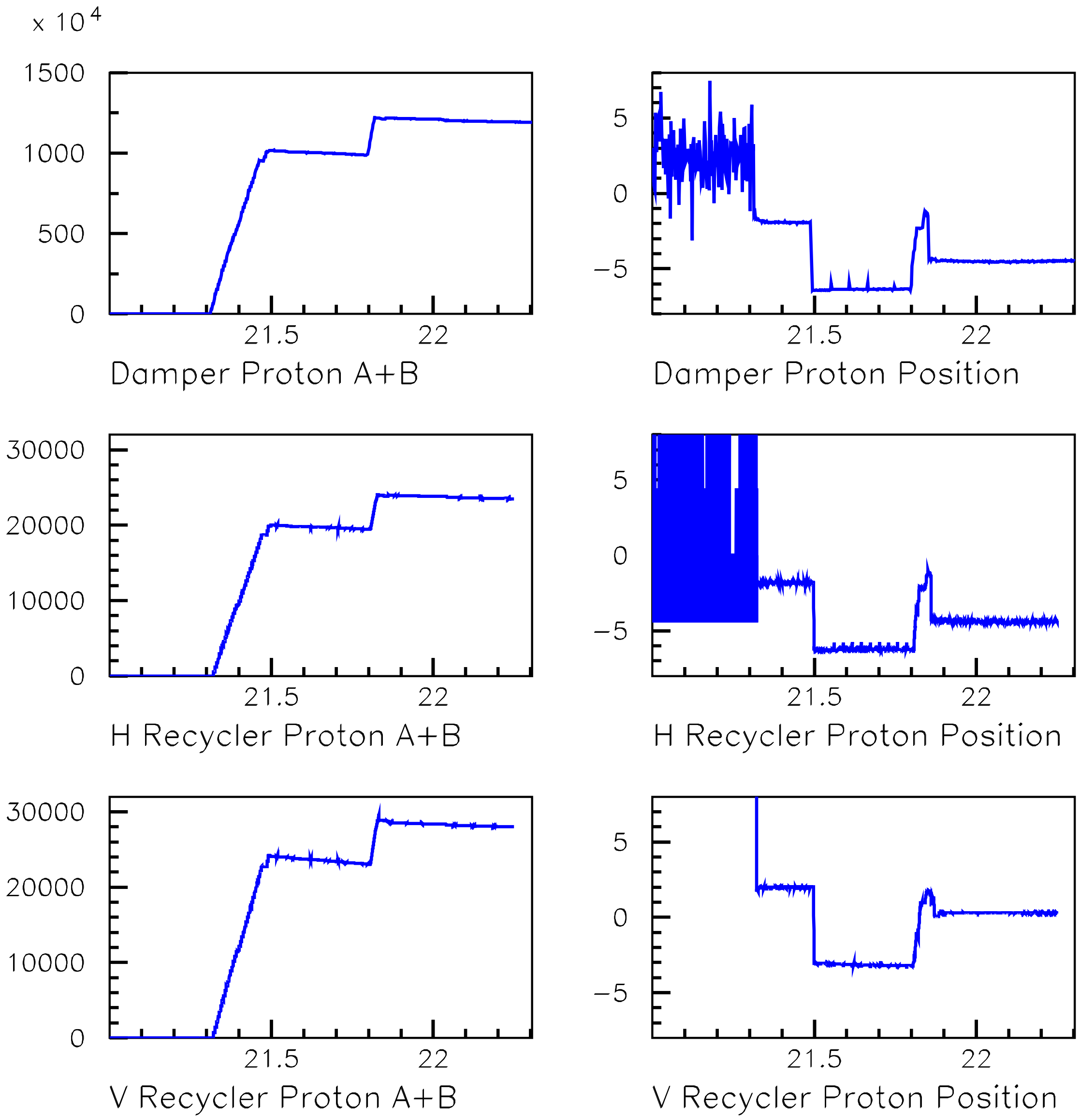

Figure 2: Proton sum and position signals, for each of the three boards.

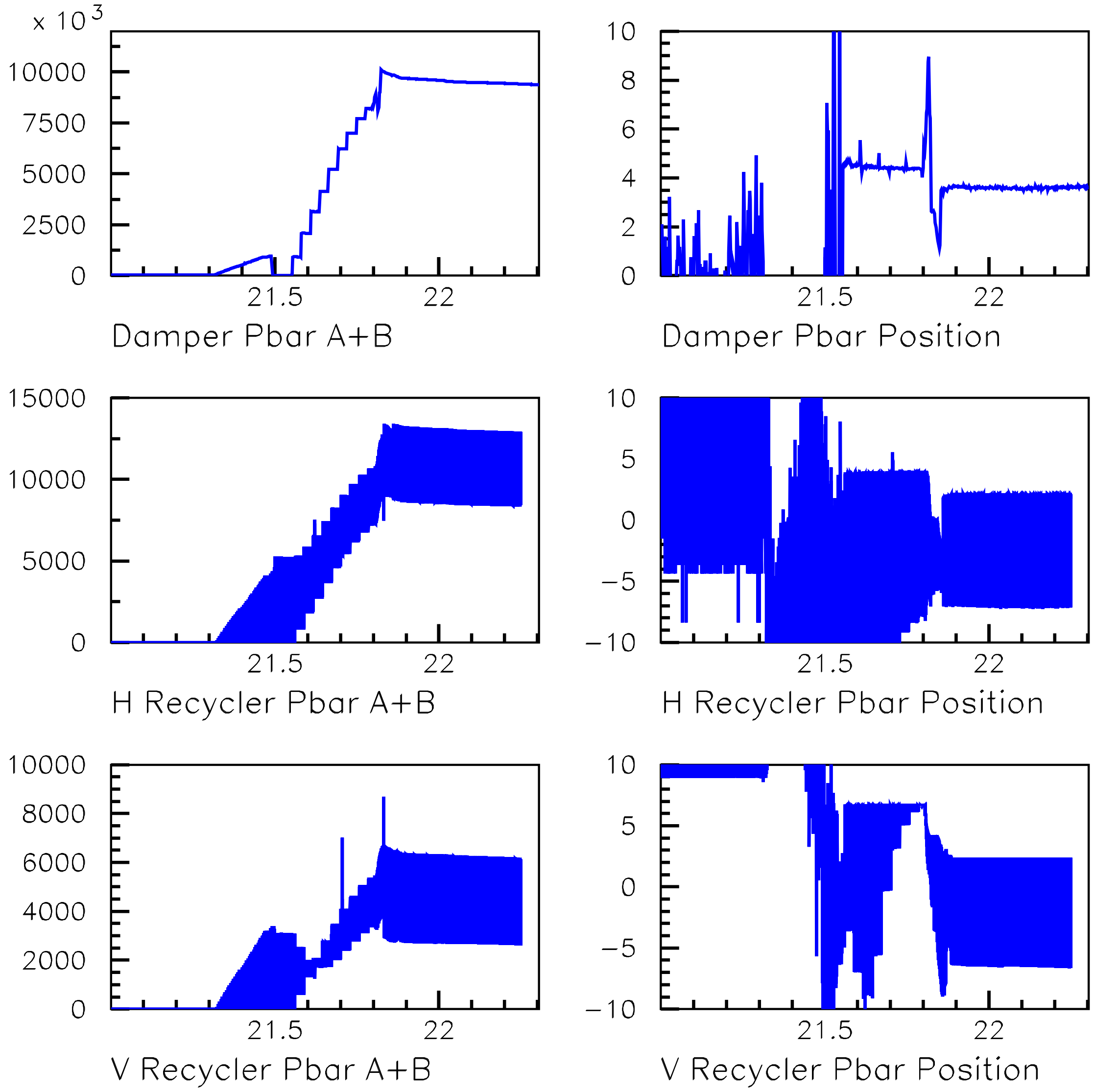

Figure 3: Antiproton sum and position signals, for each of the three boards. The proton signals on the antiproton cables were canceled as described in Beams-doc-988.

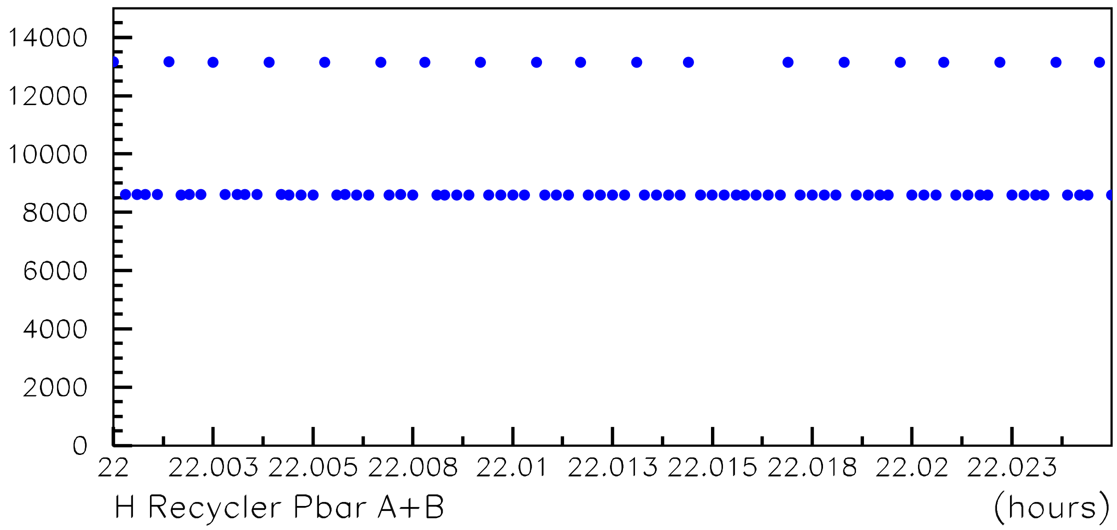

Figure 4: A detail of the noise on the HA15 sum signal.

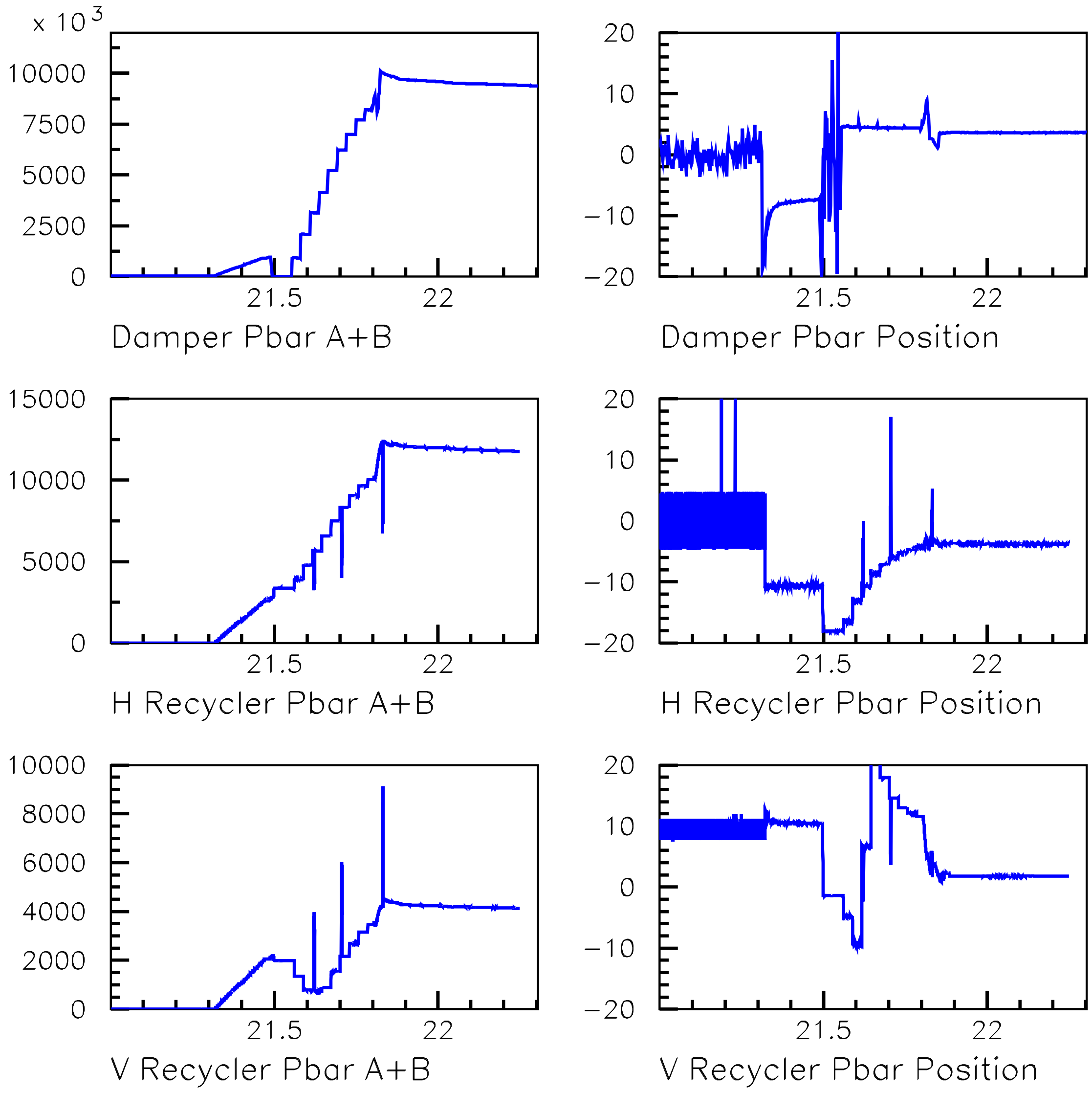

Figure 5: The damper board data is the same as figure 3. For the recycler board data, this is the same as figure 3 but without the cancellation of the proton noise on the antiproton cables.

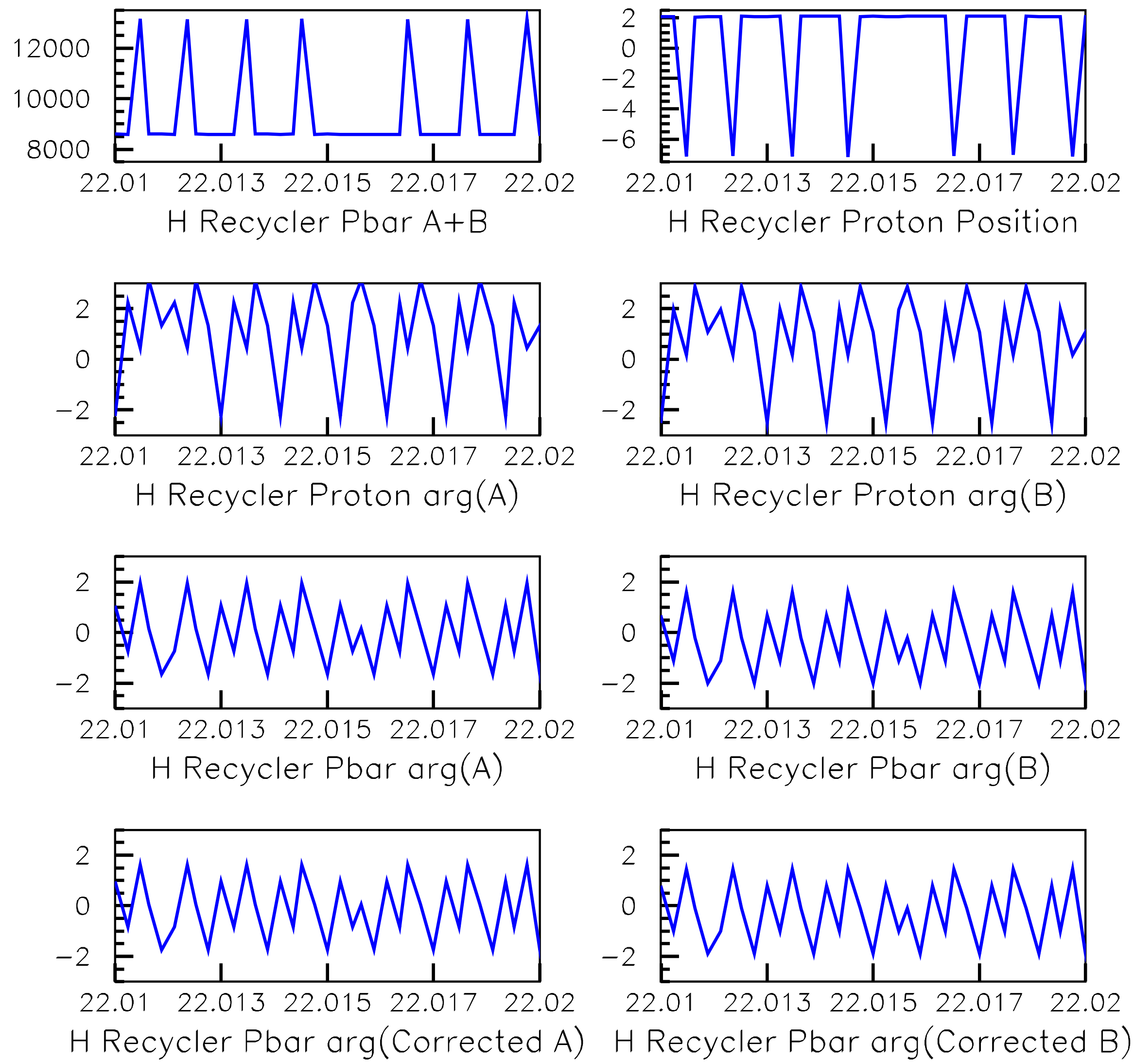

Figure 6: The top two figures are a blow up the the antiproton sum and position signals for 40 seconds near 10 PM. They show the same information as figure 4. The next 4 figures show the phase of the A and B signals on the proton and antiproton ends. Note the oscillatory behavior and the irregularity near t=22.016. The last two plots show the phase of the Pbar A and B signals after the subtraction of the proton contamination.

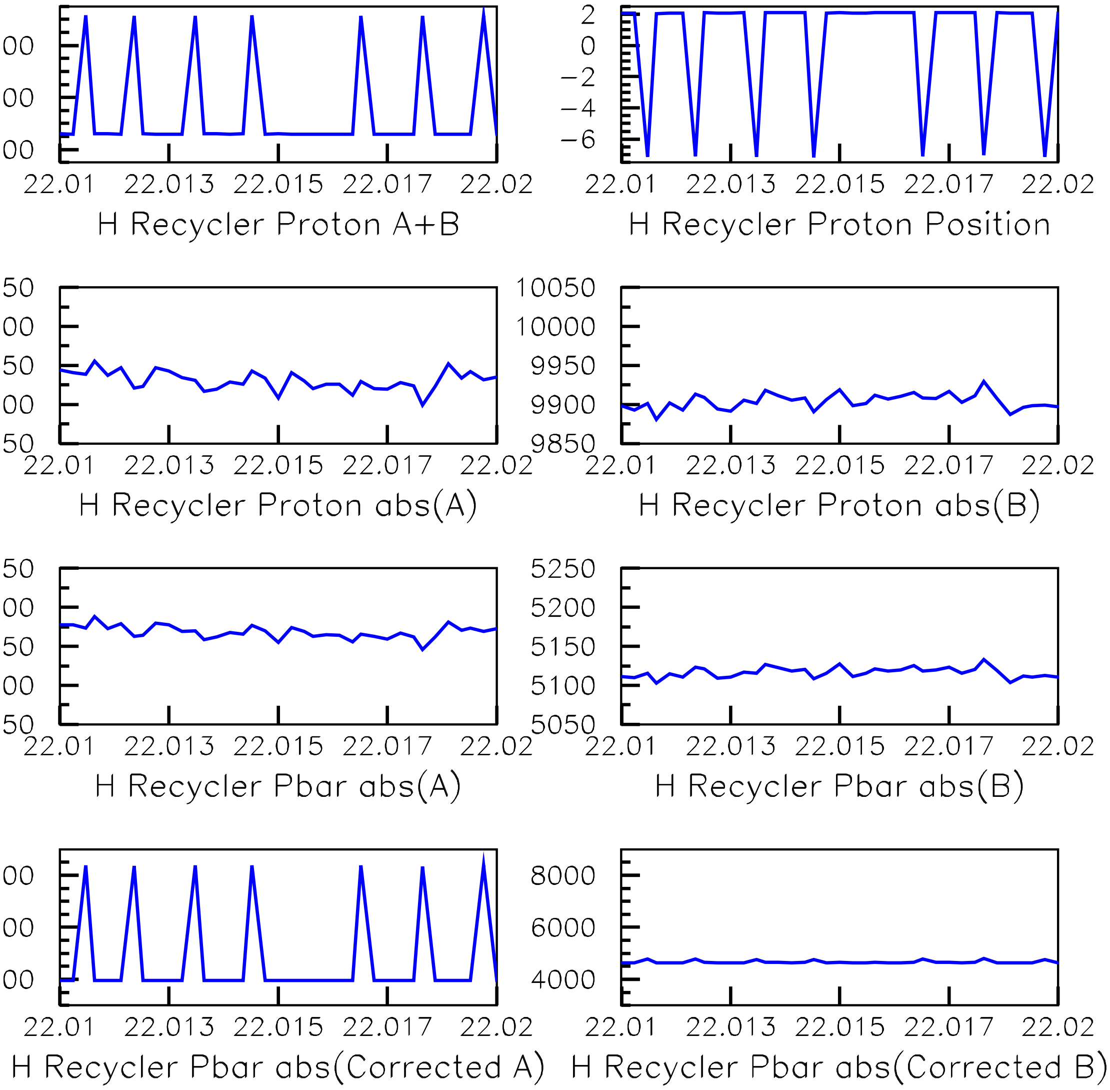

Figure 7: This figure has the same layout as figure 6 but the information plotted is the magnitude of the signals. The middle 4 plots all have different zero suppression but all 4 plots have a vertical window of 200 counts. The bottom two plots have the same vertical scale. From this we learn that the noise in the antiproton sum and position signal comes from the algorithm which removes the proton contamination on the A plate.

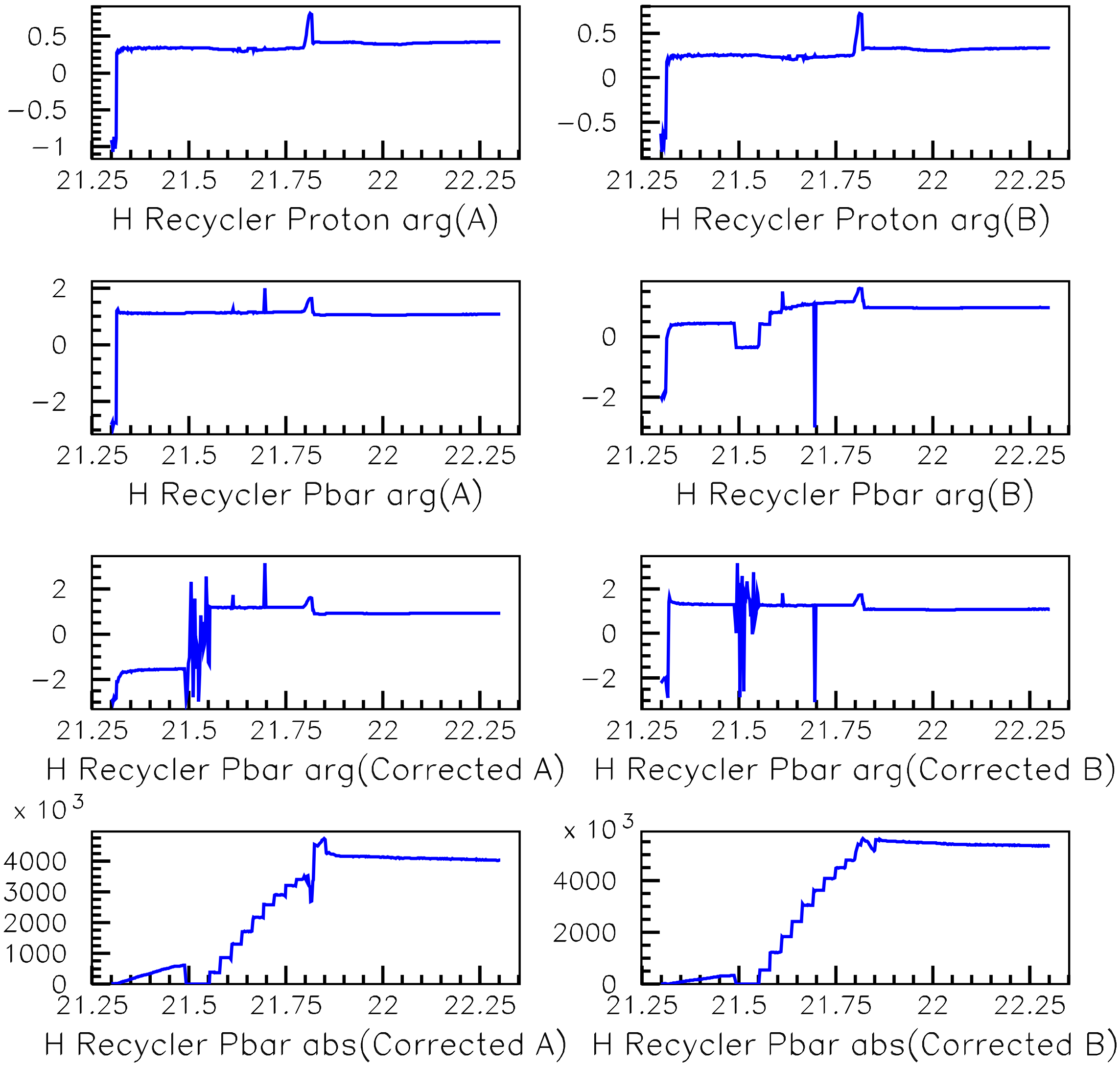

Figure 8: These plots show damper board data. The top 4 plots are the phase of the raw A and B signals from the proton and antiproton cables. The next two plots are the phase of the A and B signals, after cancellation of the proton contamination, from the Pbar cables. In all cases the phase is stable when the beam conditions are stable. The final two plots are the magnitude of the signals whose phases were plotted in the previous two plots. The magnitudes of the top 4 signals are shown in figure 1.

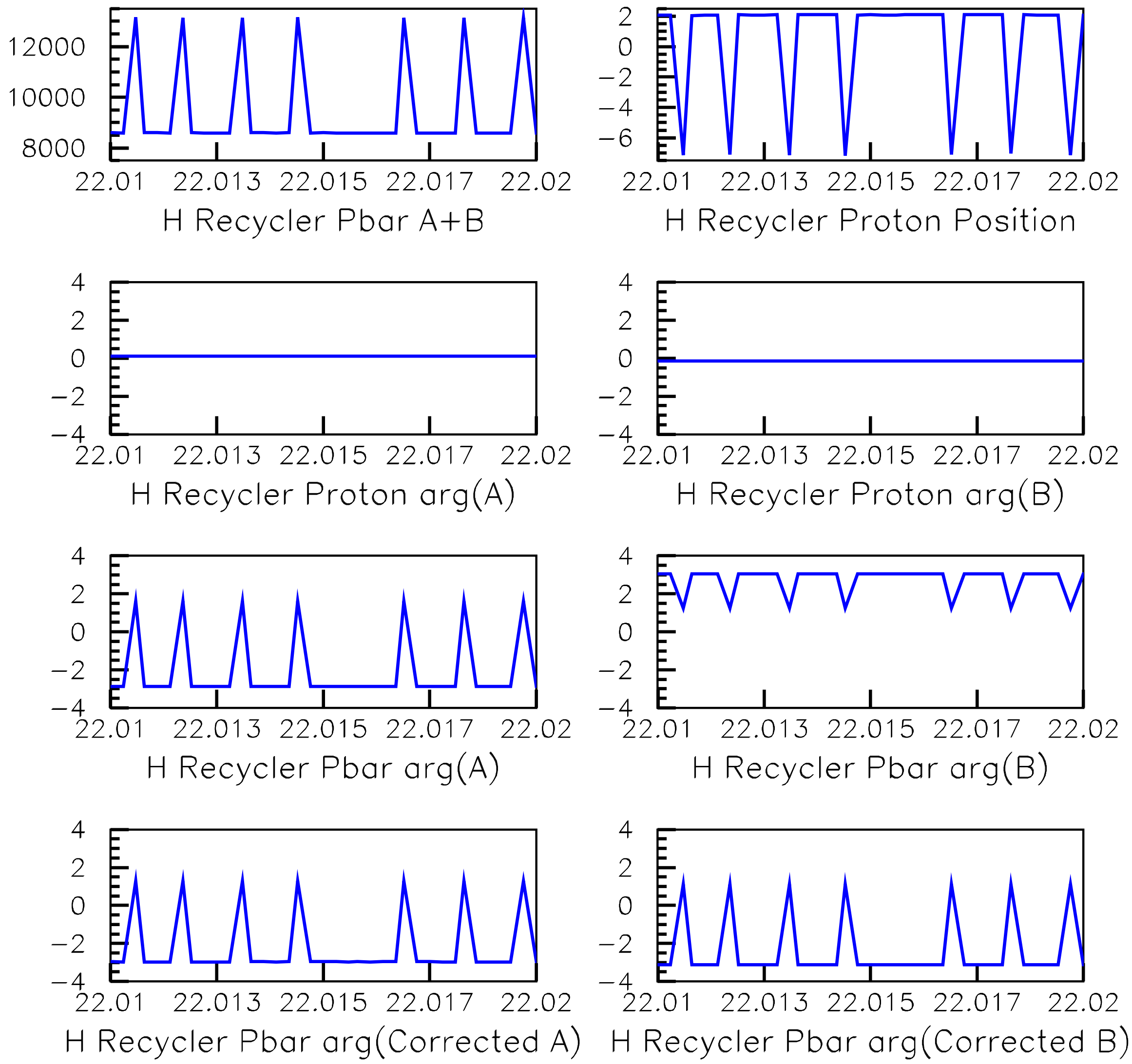

Figure 9: This figure has the same layout as figure 6 but each point has a phase rotation to make the phase of Proton A+B zero. Here we see clearly that the Pbar phases are bi-stable relative to the phase of Proton A+B.