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Seeing AntiProtons with the New Echotek Board

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Abstract

This note describes data taken on Aug 11, 2004 using the new Echotek board in the A3 house. It includes the first look at the corrected anti-proton signals using the new board. The resolutions are: VA35 protons, 9.2 μm; VA35 anti-protons, 14.5 μm; HA34 protons, 29 μm; HA34 anti-protons, 38 μm. These are not corrected for a small beam drift during the measurement period.

1 Introduction

The data shown in this note were taken in the A3 house using the new echotek board during the shot which took place starting at about 5:30 AM on August 11, 2004. The Echotek board was configured in long gate mode (aka narrow band mode). The I and Q data were datalogged at 15 Hz and extracted from the data logger to do this study. I did not check whether or not the phase problem identified in Beams-doc-1300 is still present; but I presume that it is.

Figures 1 through 4 show the results for BPM VA35 while figures 5 through 8 show the corresponding plots for HA34.

2 Intensity Data

The upper two plots of Figure 1 show one continuous time series of the proton sum signal, $|A|+|B|$, for VA35. The horizontal axis is time of the day, in hours, and the vertical axis is Echotek units. Note the scale difference between the left and the right plots. The rightmost point on the left plot is the last point before the start of proton injection. The leftmost point on the right plot is the point taken 1/15 of a second later, the first point with protons in the machine. The left most point on the right plot has a value of 210. This suggests that a sensible threshold to define the presence of a valid proton signal is between 50 and 100 Echotek units.

The lower two plots of Figure 1 show one continuous time series of the corrected anti-proton sum signal, $|A| + |B|$. By corrected I mean that the proton contamination on the antiproton cables has been subtracted. Note the scale difference between the left and the right plots. The rightmost point on the left plot is the last data point before the start of anti-proton injection. The leftmost point on the right plot is the point taken 1/15 of a second later, the first point with anti-protons in the machine. It has a value of 389. This suggests that a sensible threshold to define the presence of a valid anti-proton signal is between 50 and 100 Echotek units.

In this representation the time axes of the upper and lower plots do not match.

In the upper right plot one can discern the following events:

- The start of proton injection.
- A pause in proton injection from about 5:10 AM to about 5:30 AM.
- Continued proton injection.
- Coasting protons from about 5:45 AM to about 6:45 AM. During part of this time the anti-proton injection takes place.
- The step near 6:45 AM corresponds to the energy ramp. The change in bunch shape during the energy ramp causes a change in the power spectrum of each bunch, increasing the power at 53.1 HHz. This is not calibrated out of the $|A| + |B|$ signal.

In the lower right plot one can discern the following:

- The 9 steps of the antiproton injection.
- The energy ramp.

In both plots one can see the coasting beam during HEP running at the right edge of the plot. Figure 5 shows the same information for HA34.

3 Position Time Series

The upper left plot of figure 2 shows a time series of the proton postion and the upper right plot shows a time series of the antiproton position. Only data points for which the sum signal is above 100 Echotek units are shown. The horizontal axes of these two plots cover the same time period of time. On both plots the vertical axes cover 8 mm. The red vertical lines mark the regions which will be used to measure the resolution; see the next section.

On the upper left plot one can discern:

- The proton injection up to about 5:45 AM. It appears that there is poor resolution during this time. But that is not the case as will be discussed below.
- The opening of the helix about 5:45 AM.
- Nine small proton position glitches during antiproton injection.
- Beam motion during the ramp, squeeze and start of collisions.

- A stable position for HEP running.

On the upper right plot the last three of these effects can be seen.

The middle plot shows a detail of the proton position signal during the time of proton injection. The injection bumps are visible. It is these bumps which cause the illusion of poor resolution in the upper left plot. There are more than 36 injection bumps but remember that there was a pause of about 20 minutes during proton injection. It appears that the injection bumps continued throughout the pause.

The bottom plot shows a detail of the first few injection bumps. The left edge of the middle plot and the left edge of the bottom plot correspond to the same time. The horizontal axis of the bottom plot is time, in seconds from the left edge of the plot.

Figure 6 shows the same information for HA34.

4 Position Resolution

The upper left plot of figure 3 shows a detail from the upper left plot of figure 2. It shows the time between the vertical read lines on an expanded scale. During this time the beam motion is small compared to the resolution. The lower left plot shows a histogram of the data from the upper left plot projected onto the postion axis. The RMS of this distribution corresponds to the proton position resolution, 9.1 μm. The quoted resolution is not corrected for the small but significant slope of the data in the upper left plot.

The right two plots in figure 3 show the same information for the antiprotons. The antiproton resolution is 14.4 μm.

Figure 7 shows the same information for HA34. The resolutions for all four measurements are summarized in table 1. One might worry that using the raw RMS of the distribution overweights the tails. To check this I fitted each of the four resolution histograms using a gaussian. In all cases, the σ returned by the fit was the same as the RMS to ± 1 in the third signficant figure.

5 Autocorrelation Function

The top plot in figure 4 shows a histogram of the nearest neighbour autocorrelation function of the proton position. This is computed using the data displayed in figure 3. The autocorrelation function is defined as:

$$A(n) \quad = \quad P(n) - P(n-1) \tag{1}$$

where n is an index which runs over the data points, $P(n)$ is the position at the n^{th} measurement, and where $A(n)$ is the autocorrelation function. The lower plot in figure 4 shows a histogram of the nearest neighbour autocorrelation function for the antiproton position. It too uses the data used for in figure 3

Figure 8 shows histograms of the autocorrelation function for protons and antiprotons measured at HA34. The RMS widths of all four autocorrelation

	Resolution (σ) (μm)	$\sqrt{2}\sigma$ (μm)	RMS of $A(n)$ (μm)
VA35 Proton	9.1	12.9	11.6
VA35 Antiproton	14.4	20.4	18.5
HA34 Proton	29.	41.	45.
HA34 Antiproton	38.	54.	59.

Table 1: The second column gives the measured position resolution from figures 3 and 7. The third column gives $\sqrt{2}$ times this number. The third column gives the RMS width of the autocorrelation functions in figures 4 and 8. A comparison of the last two columns is given in the text. All of the numbers in this table have errors which are 0.7% of themselves.

histograms are recorded in table 1. As for the position resolutions, I worried that the raw RMS might overweight the tails but it does not: when the autocorrelation histograms were fitted using gaussians, the fit returned a σ which matches the RMS to ± 1 in the third significant figure. These histograms were made with 10000 data points and they are well described as guassians. Therefore the fractional error on the σ of these distributions is about $1/\sqrt{20000}$, or $\pm 0.7\%$.

If all of the data points are independent measures of the same quantity then the RMS of $A(n)$ should be $\sqrt{2}$ times the resolution of the proton position. That is, the last two columns of table 1 should be equal. While these columns are close on the scale of the specs on the resolution, they are statistically inconsistent. Both measurements at VA35 have an autocorrelation which is narrower than expected while both measurments at HA34 have an autocorrelation which is broader than expected. I would like to see data from other BPM locations before concluding that the H and V measurements are systematically different in this respect.

I am not yet sure what to make of this but the effect is small enough that it is irrelevant for operational use of the BPMs.

5.1 Checking the Easy Things

I decided to have a quick look check a few obvious possiblities for the differences between the last two columns of table 1. The naive interpreation is that there is some modulation in the position which causes the observed effects. I tried to look for this by compting the Fourier transform of the 10000 position measurements used for the resolution measurement (this corresponds to about 11 minutes). I did this for all four of HA34, VA35, protons and antiprotons. The only lines in any of the Fourier transforms are the 15 Hz sampling frequency and its aliases. So what ever modulations exist, they are not coherent over 10 minutes; or the 15 Hz rate is too slow to catch them; or the 15 Hz sampling clock has too much phase jitter; or ....

A second interpretation of the autocorrelation resolution for the V data is that successive position measurements are not actually independent.

In the near term don't plan to investigate this further.

6 Conclusions

The new Echotek boards are working well and are able to catch all of the expected details in a shot. The subtraction of the proton contamination on the antiproton cables is also working well. However much work remains on calibration and there remain some outstanding problems which do not affect the data shown here. The most important of these is the continuous value of the phases of the raw A and B measurements.

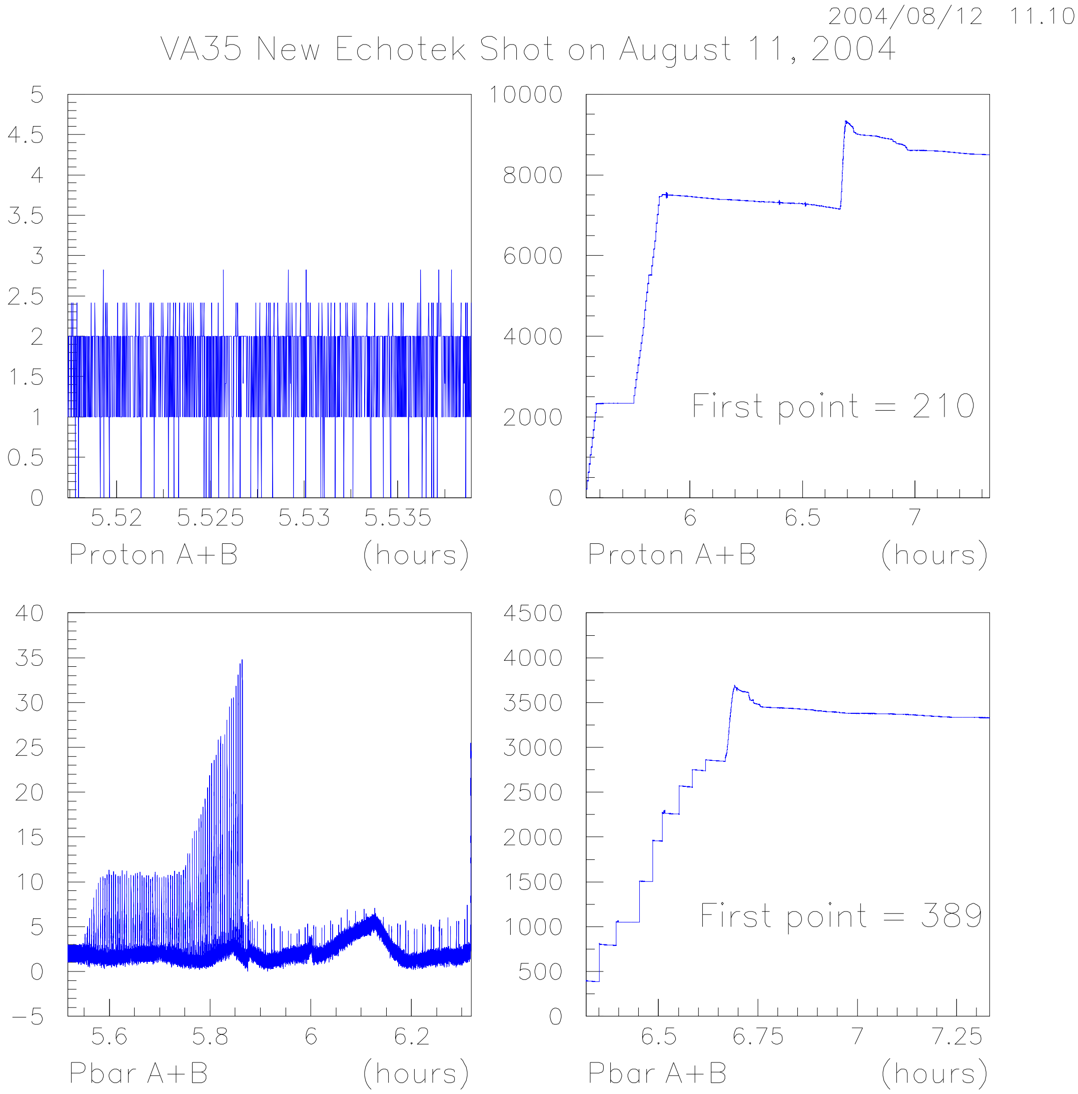

Figure 1: Study of proton and antiproton sum signals at BPM VA35 using the new Echotek board. The plots are described in the text.

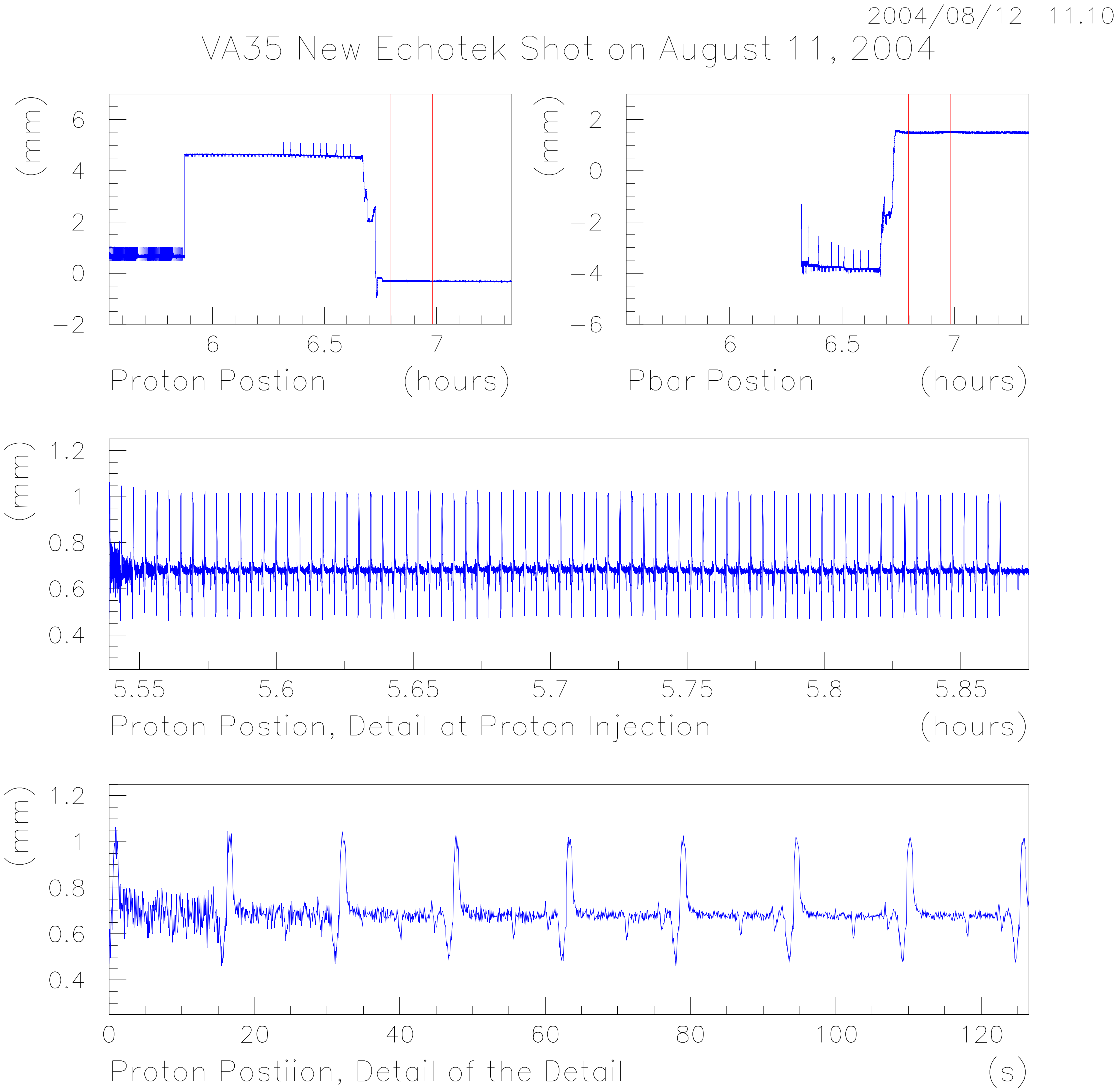

Figure 2: Study of proton and antiproton position signals at BPM VA35 using the new Echotek board. The plots are described in the text.

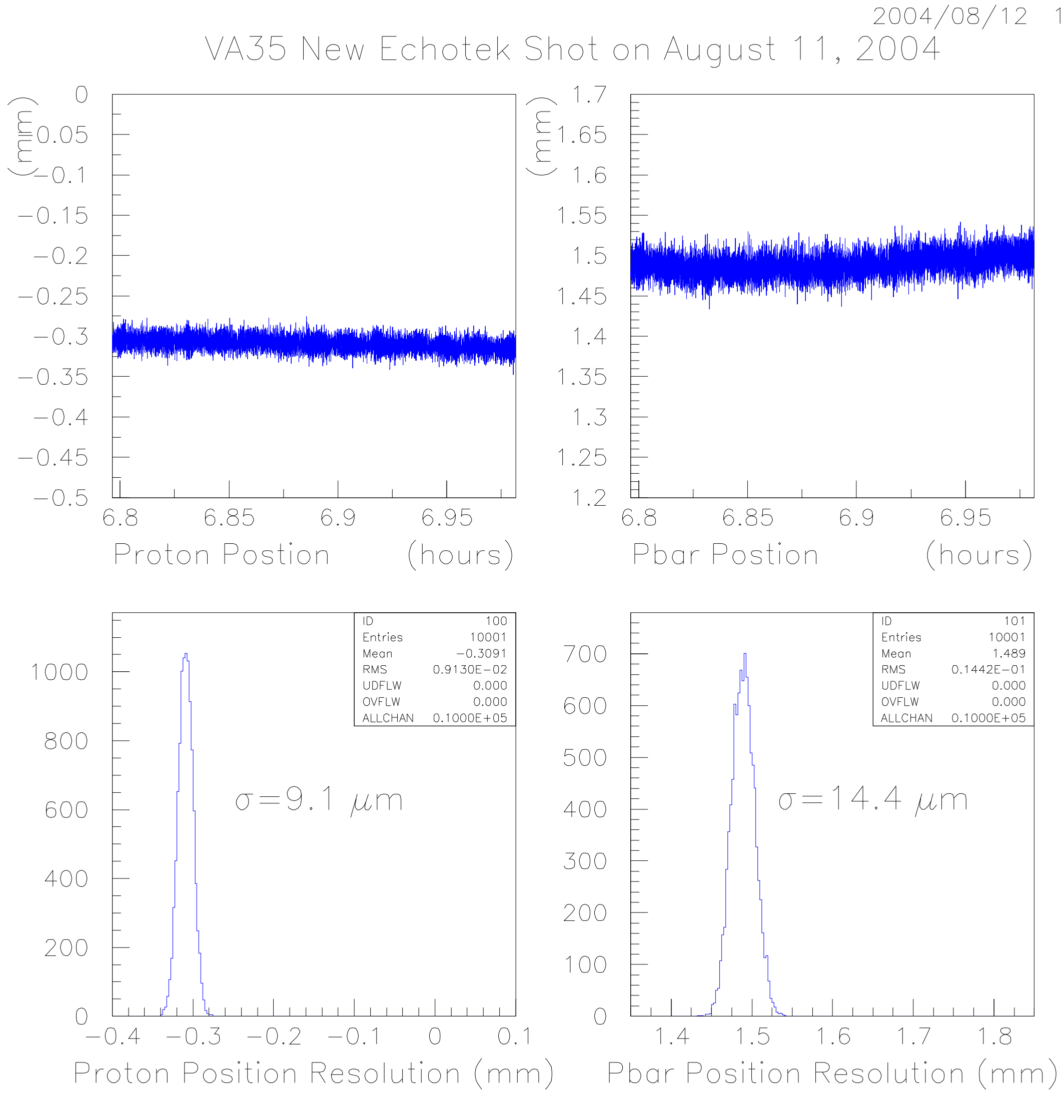

Figure 3: Study of proton and antiproton position resolutions at BPM VA35 using the new Echotek board. The plots are described in the text.

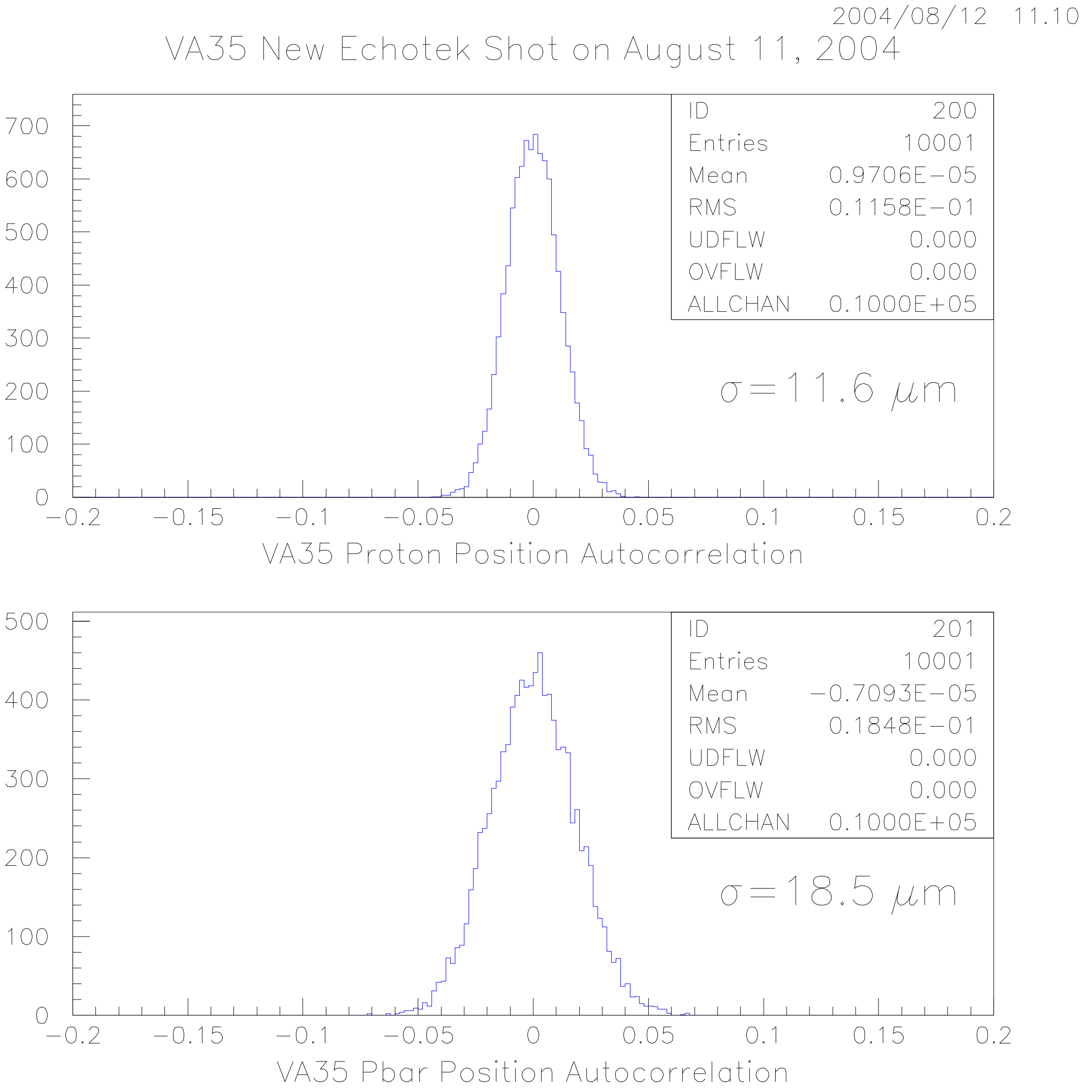

Figure 4: Study of proton and antiproton autocorrelation functions at BPM VA35 using the new Echotek board. The plots are described in the text.

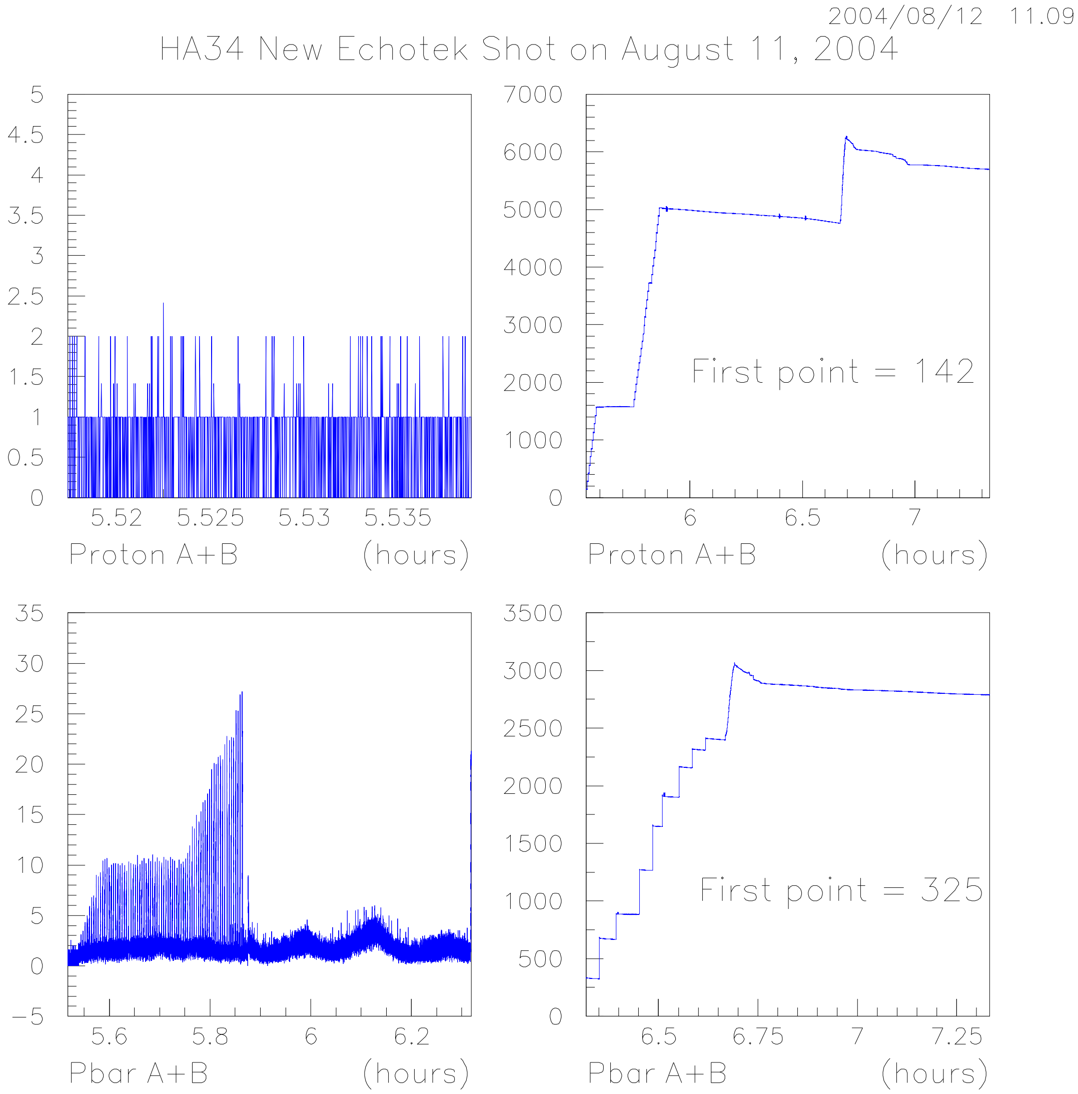

Figure 5: Study of proton and antiproton sum signals at BPM HA34 using the new Echotek board. The plots are described in the text.

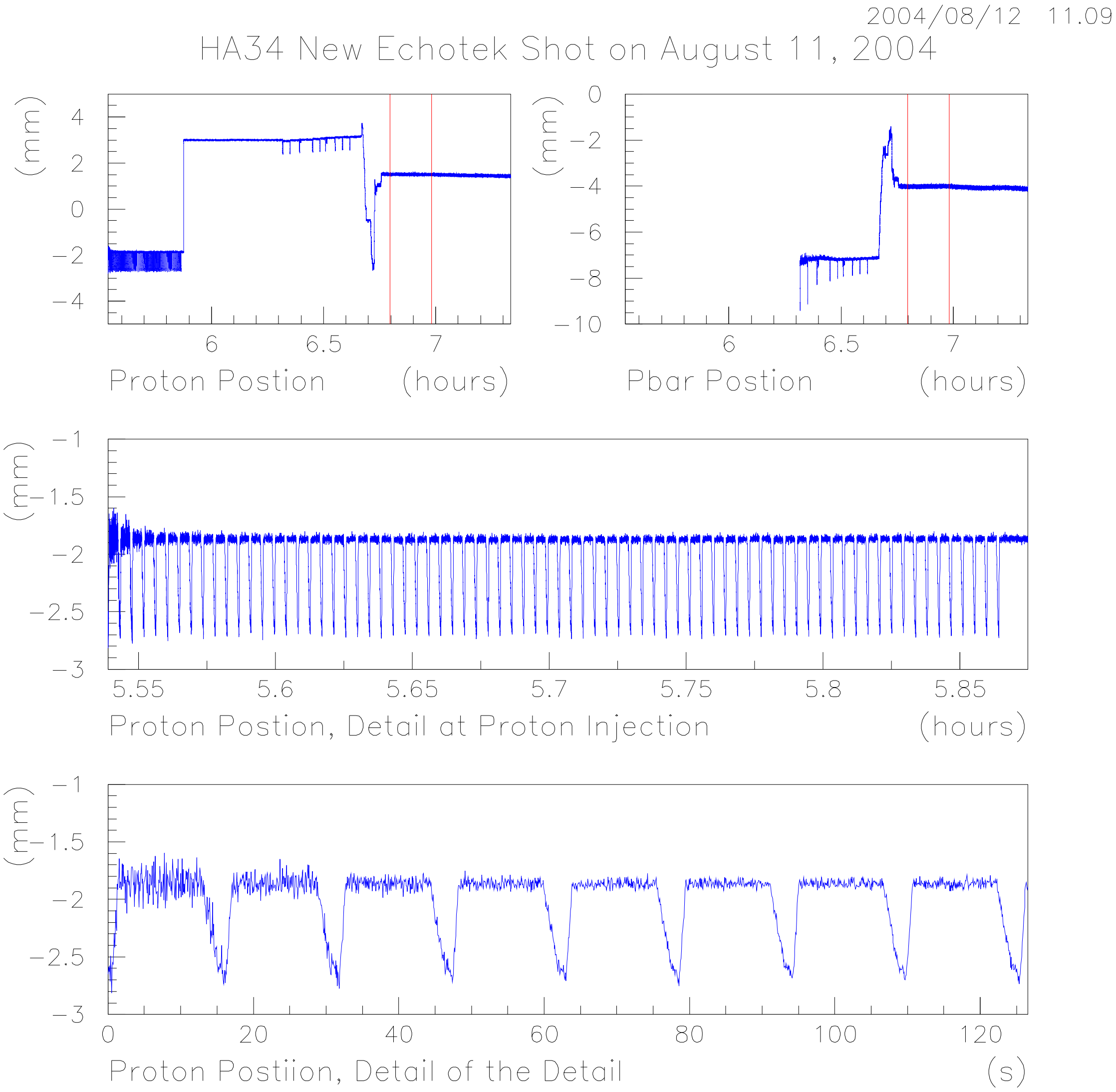

Figure 6: Study of proton and antiproton position signals at BPM HA34 using the new Echotek board. The plots are described in the text.

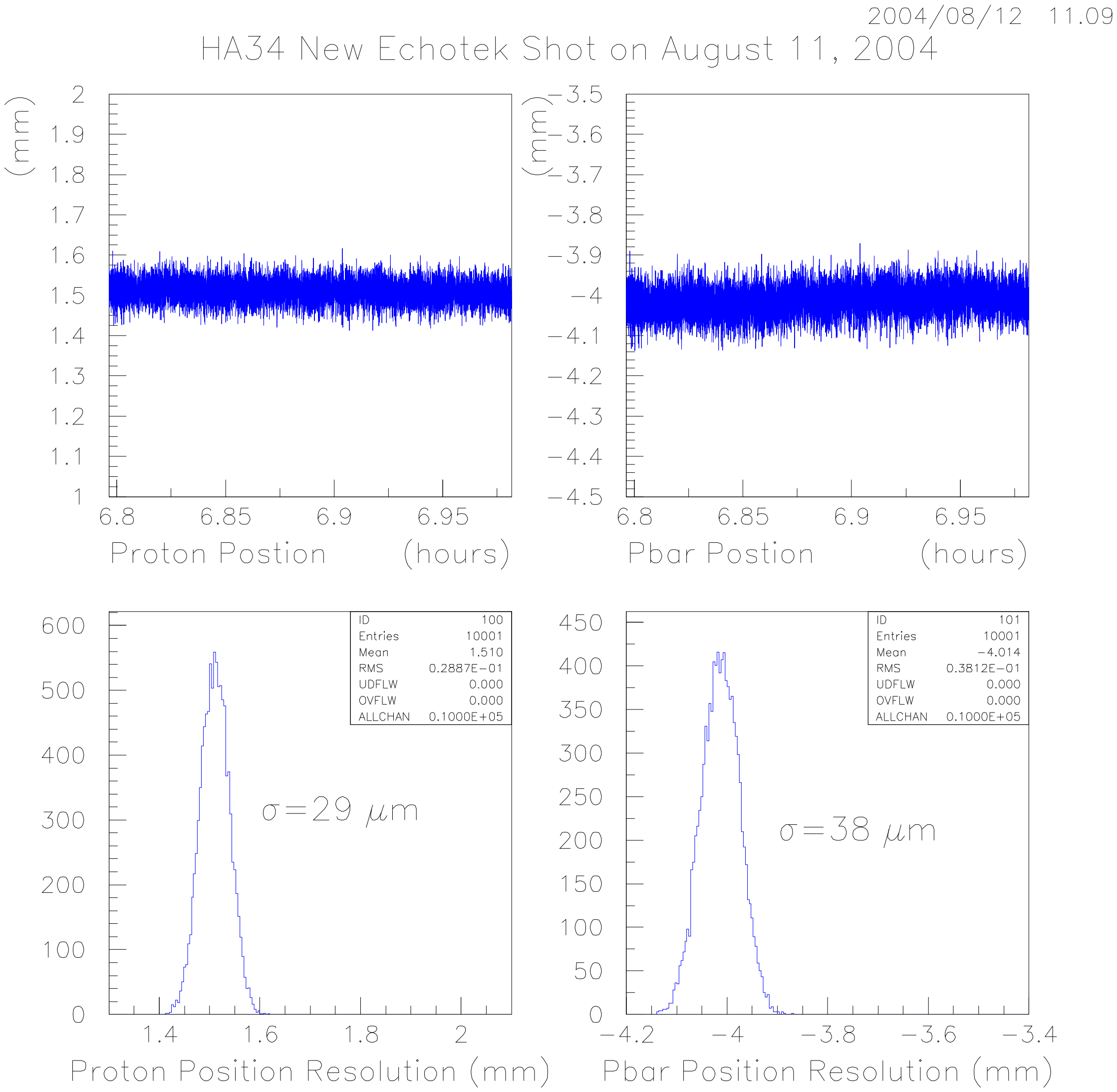

Figure 7: Study of proton and antiproton position resolutions at BPM HA34 using the new Echotek board. The plots are described in the text.

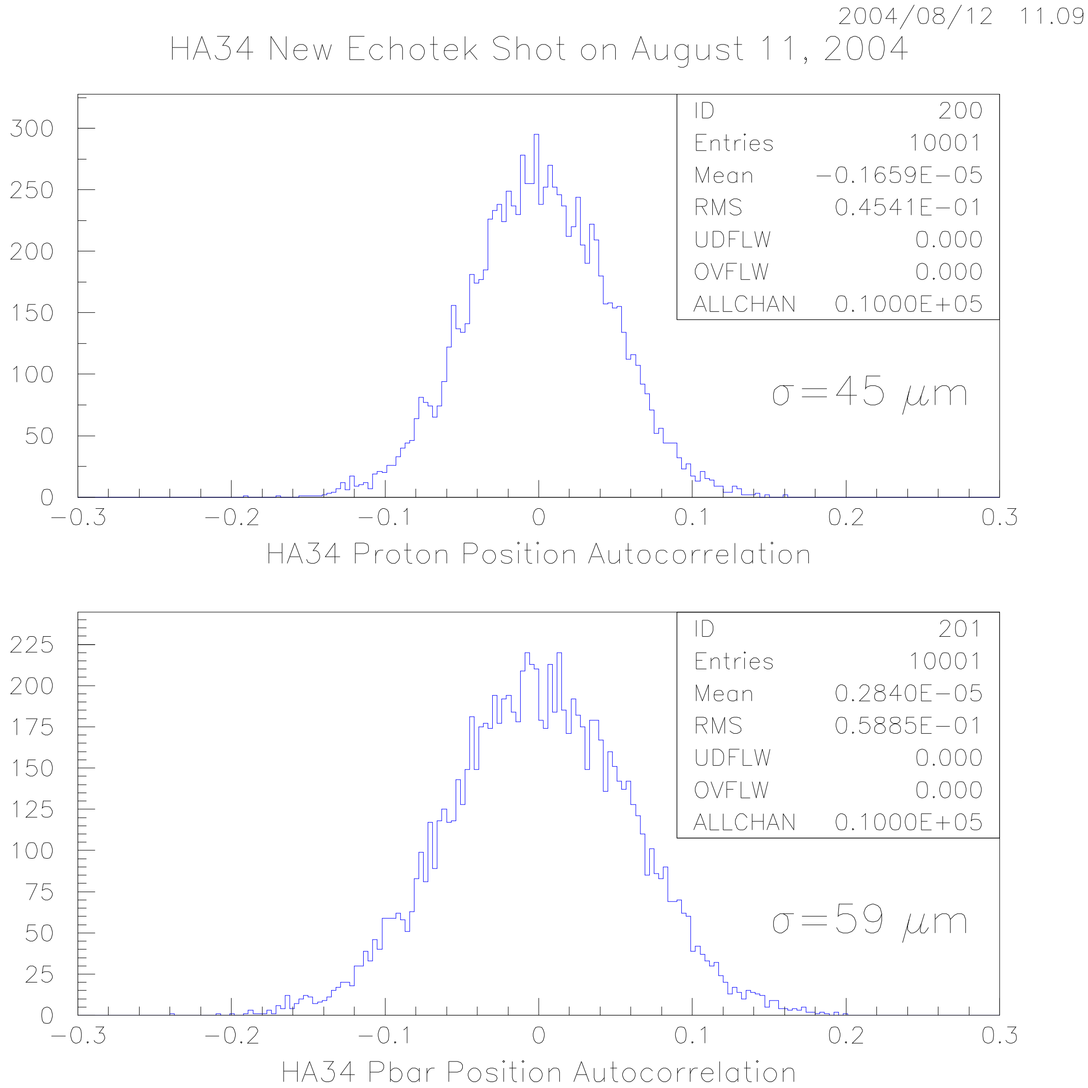

Figure 8: Study of proton and antiproton autocorrelation functions at BPM HA34 using the new Echotek board. The plots are described in the text.