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TeV BPM Upgrade: Dependence of Position and Resolution on Intensity

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Abstract

This note looks at the proton position and the resolution on the proton position during proton injection. The goal is to study how these two quantities depend on beam intensity. Data from both HA34 and VA35 are shown.

The data in this note were taken on August 22, 2004 during the shot which started around 2:30 PM. In all cases the data shown here started from the I and Q values data logged at 15 Hz to the Lumberjack data base using logger TevSA. Positions and intensities were computed offline from these I and Q values. The sum signal is defined as $|A| + |B|$ and the position is given by,

$$\text{Position} = 26 \frac{|A| - |B|}{|A| + |B|} \tag{1}$$

The top plot in figure 1 shows, for HA34, the proton sum signal plotted vs time starting from the time that the first proton bunch was injected until just after the last proton bunch was injected. The 36 proton bunch injections are evident. There are also two short pauses during injection during which no bunches were injected. The lower plot shows the proton position during this same time. The large deviations of about 1 mm are the injection bumps. Note that injection bumps are presented even when no bunch was injected. The data for VA35 for this same time looks similar.

For further analysis, groups of 51 consecutive data points were selected, one group following each injection bump. Each group corresponds to about 3.4 seconds of data. Because there are missed injections, 40 groups of points, not 36; I did not both to edit out the extra points. For each group of points, the following quantities were computed:

- The mean value of $|A| + |B|$.
- The mean value of the position.
- The mean value of the position resolution; this is the RMS spread of the 51 individual position measurements.

For each of the last two quantities, the statistical error was also computed.

- Error on position = $\text{RMS}/\sqrt{N}$,

- Error on RMS = RMS/$\sqrt{2N}$,

where N is the number of measurements. Each group of points was inspected

The upper left plot in Figure 2 shows the mean proton position plotted against the mean proton sum signal, for the 40 groups. The upper right plot shows the resolution on the proton position plotted against the proton sum signal. On both plots the vertical bars show the statistical errors. The bottom two plots show the same information for VA35. On both left hand plots the full vertical scale is 100 μm and on both right hand plots the full vertical scale is 120 μm.

Consider the upper left plot. The first data point is about 50 μm from the main body of the data. This is a statistically significant deviation but it is small on the scale of the resolution of that point, about 105 μm. This effect can also be seen at the left edge of the lower point of Figure 1. The next few points on the upper left plot of Figure 2 are also systematically shifted but from the main body of the data but the effect is much smaller, decreasing with intensity. Similar comments are true for the first few points in the lower right plot. My guess is that this is an instrumental effect caused by some aliasing or noise which is always present at about a constant level; this contamination is important when the signal level is low and less important when the signal level is high. However I cannot prove that this is the case and I cannot exclude true beam motion as the reason. In any case the size of the effect is small enough that it is not a serious concern.

The HA34 data appears to reach an asymptote for intensities greater than about 2000 Echotek Units while the vertical data does not approach an asymptote. Is this an indication of true beam motion for the vertical position?

Consider the two right hand plots. In both cases the resolution improves with increasing intensity. The vertical resolution has reached an asymptote by about 2000 Echotek units but the horizontal resolution never really reaches an asymptote.

1 Conclusions

The position measured with just one bunch has a significant offset from the main body of the data, about 50 μm for the HA34 data and about 30 μm for the VA35 data. This deviation is small compared to the resolution and small compared to the required accuracy.

When more bunches are in the machine, there are statistically significant effects which remain but they are at the level of about 20 μm, which is smaller than many other things that we are worried about.

I should also check to see if the behavior of the resolution for low intensities is consistent with the discretization error from the ADCs or if it is consistent with some other source.

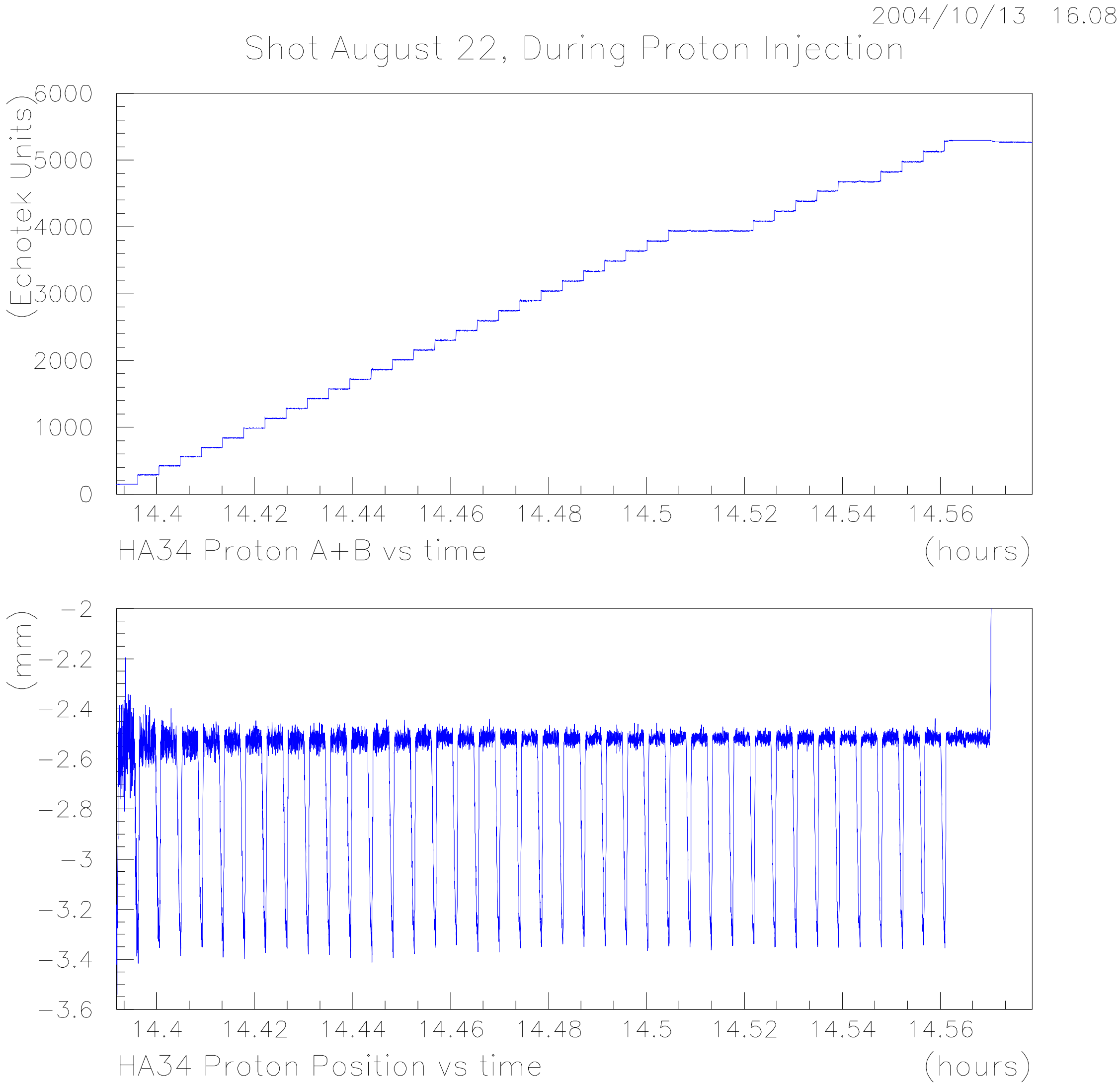

Figure 1: The upper plot shows the proton sum signal vs the time of day for data taken during proton injection during the shot starting at 2:30 PM on August 22, 2004. The lower plot shows the proton position vs time of day for these same data.

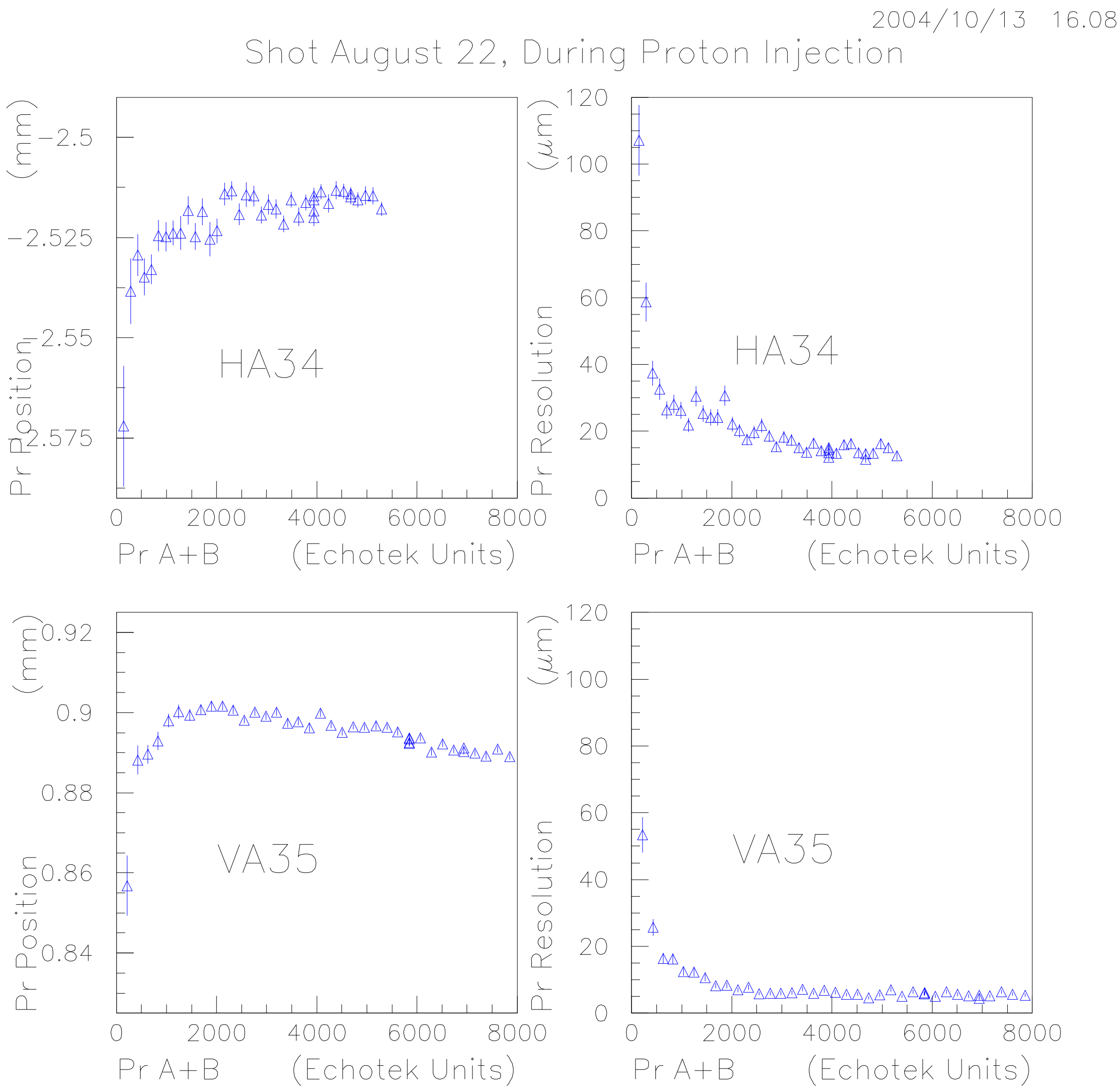

Figure 2: The upper left plot shows the mean proton position at HA34, in mm, vs the mean proton sum signal at HA34, in Echotek units, for data taken during proton injection. The error bars are the statistical error on the position measurement. The upper right plot shows the resolution on the proton position at HA34, in μm, vs the the mean proton sum signal at HA34, in Echotek units, for the same data. The lower two plots show the same information for data taken at VA35 at the same time. The plots are discussed in the text.