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TeV BPM Upgrade: A Look at Uncoalesced Batches

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Abstract

This note looks at the proton position and the resolution on the proton position during an injection tune up, at which time the Tevatron contained a batch of uncoalesced bunches. The results are compared with similar measurements made a few minutes later, during injection for normal collider operations. The quality of the cancellation of the proton contamination on the anti-proton cables is also shown for both of these running conditions.

The data in this note were taken on August 21, 2004 during and just before the shot which started around 8:45 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.[1] Positions and intensities were computed offline from these I and Q values. The sum signal is defined as $|A| + |B|$ and the position, in mm, is given by,

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

In the top plot in figure 1, the blue curve shows the proton sum signal, $|A| + |B|$, on HA34. The horizontal axis is the time of day, in hours, and the full horizontal scale corresponds to just more than 30 minutes. This curve has two main features, a constant, low intensity signal from about 20.3 hours to just after 20.7 hours and a stair case at the right edge of the plot. The red curve shows the value of the ACNET variable V:COALP, which indicates the status of coalescing in the Main Injector. The first of feature in the blue curve shows the response of the BPM system when the Tevatron contains a batch of uncoalesced bunches. The second feature shows BPM response during the injection of the first 6 proton bunches in a normal shot. The rest of the shot is not shown but it proceeded normally. The measured sum signal for an uncoalesced batch is close to the the sum signal for a single bunch. This is discussed further in the discussion section.

The second plot in figure 1 shows the measured beam position during the same time interval as the top plot. The horizontal beam motion during the

[1] These data were taken during daylight savings time but analyzed during normal time. Lumberjack does not know about this transition and the data had to be corrected by hand so that the times shown are in CDT.

orbit tuning is evident. The injection bumps are also visible near the right hand edge of the plot. The red horizontal line near the right edge of the plot shows a region which was selected to be shown on an expanded horizontal scale.

The third plot in figure 1 shows a detail of the selected region from the previous plot. In this plot the feature near 20.7 hours and the injection bumps are resolved more clearly. It is also clear that the measured proton position is very close to the same for all bunch patterns investigated. The red vertical lines mark regions selected for measurement of the mean position and the resolution of the position measurement. These will be presented in figure 3.

The bottom plot in figure 1 shows the anti-proton sum signal, $|A| + |B|$, after cancellation of the proton contamination. The cancellation of is the same quality for all of the data. For reference, the true anti-proton sum signal after the first 4 anti-proton bunches have been injected is about 500 Echotek Units.

The coefficients used to cancel the proton contamination on the anti-proton cables were computed using (I,Q) data just before and just after the opening of the helix, a few minutes after the last data shown in these figures.

Figure 2 shows the same information as figure 1 but for BPM VA35. All plots have the same horizontal scale as the corresponding plots in the previous figure. The middle two plots have the same full vertical scale, but different offsets, as the corresponding plots in the previous figure.

Consider the third plot in figure 2. The pairs of red vertical lines mark groups of 50 data points. For each of the groups, the mean and RMS of the 50 position measurements were computed. The corresponding groups of 50 points in the top plot were used to compute the mean proton sum signal for these same times. These data are plotted in the upper left plot of figure 3, which shows the mean proton position as a function of the mean proton sum signal. The red box shows the data point for the uncoalesced batch and the blue triangles show the data points for one, two and three coalesced bunches. The error bars are the statistical error on the mean. The upper right plot in figure 3 shows the the proton resolution (RMS of the groups of 50 points), plotted as a function of proton sum signal.

The blue points in these plots follow the trends which were established in Beams-doc-1319: the resolution improves with increasing intensity and there appears to be a bias in the position measurement at low intensities; this bias is reduced at higher intensities.

The bottom two plots show the same information but using the data from HA34 shown in figure 1. The upper and lower plots have the same horizontal scale and the same full vertical scale.

1 Discussion

Assuming that actual orbit was unchanged between the uncoalesced and coalesced data, the instrument has the same response for both types of data: the measured positions are the same to within ten microns, which is much smaller than the statistical error on the measurement. The resolutions are also the same within 1.5 standard deviations of the statistical error.

The one puzzle which remains is the magnitude of the sum signal for the uncoalesced beam. Normally uncoalesced beam contains 30 bunches. The process of coalescing combines 9 uncoalesced bunches into one coalesced bunch. This process is highly efficient so my naive expectation is that the uncoalesced batch beam should have a sum signal which matches that of about 3.3 coalesced bunches. Instead it is a good match to one coalesced bunch.

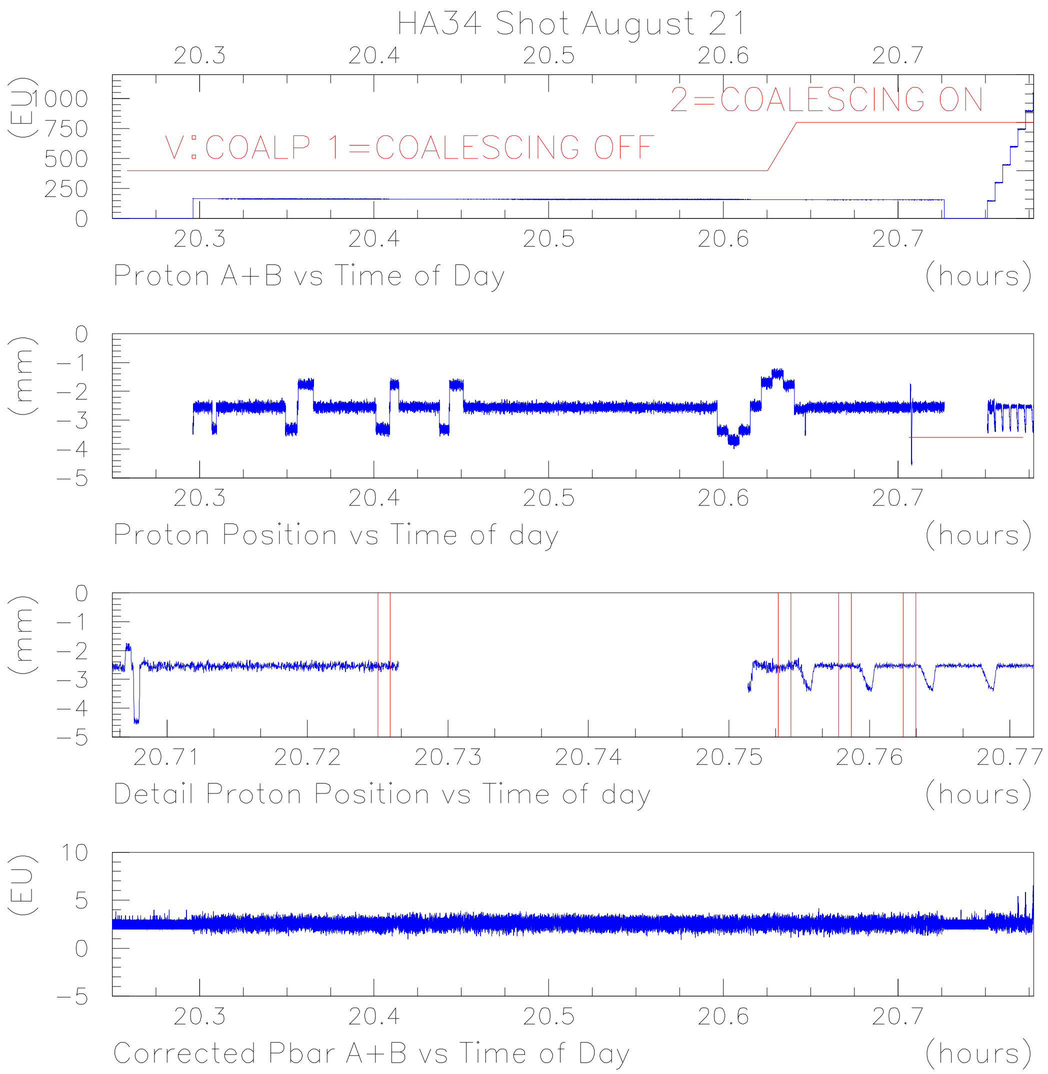

Figure 1: In the top plot, the blue curve shows the value of the proton sum signal, $|A| + |B|$, in Echotek Units (EU), from BPM HA34. The horizontal axis is time of day, in hours. The red curve and right hand scale show the value of the ACNET variable, V:COALP. The second plot shows the proton position for the same time period as the top plot. The third plot shows a selected region of the second plot, but on an expanded time scale. The bottom plot shows the corrected anti-proton sum signal for the same time interval as the top two plots. See the text for more details.

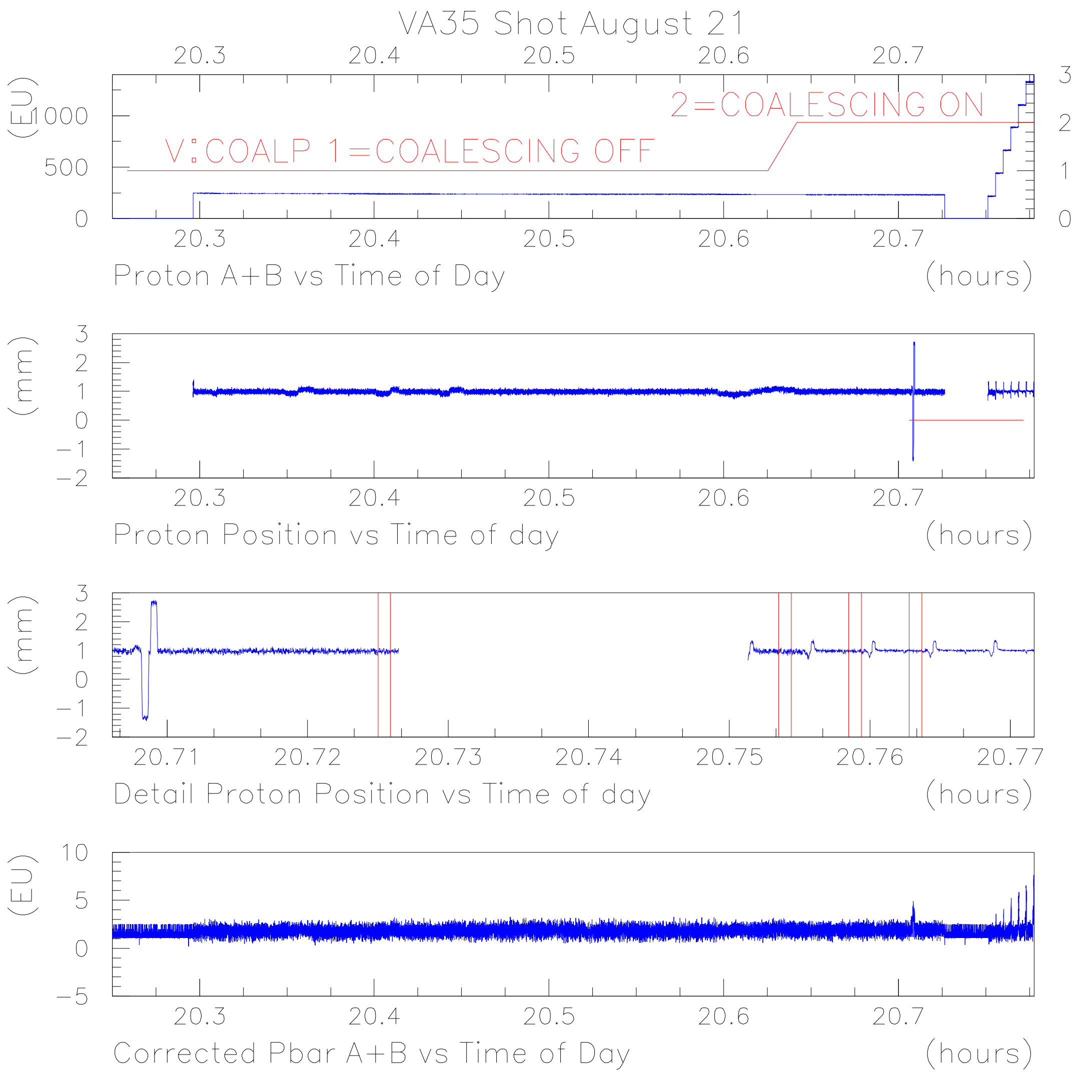

Figure 2: In the top plot, the blue curve shows the value of the proton sum signal, $|A| + |B|$, in Echotek Units (EU), from BPM VA35. The horizontal axis is time of day, in hours. The red curve and right hand scale show the value of the ACNET variable, V:COALP. The second plot shows the proton position for the same time period as the top plot. The third plot shows a selected region of the second plot, but on an expanded time scale. The bottom plot shows the corrected anti-proton sum signal for the same time interval as the top two plots. See the text for more details.

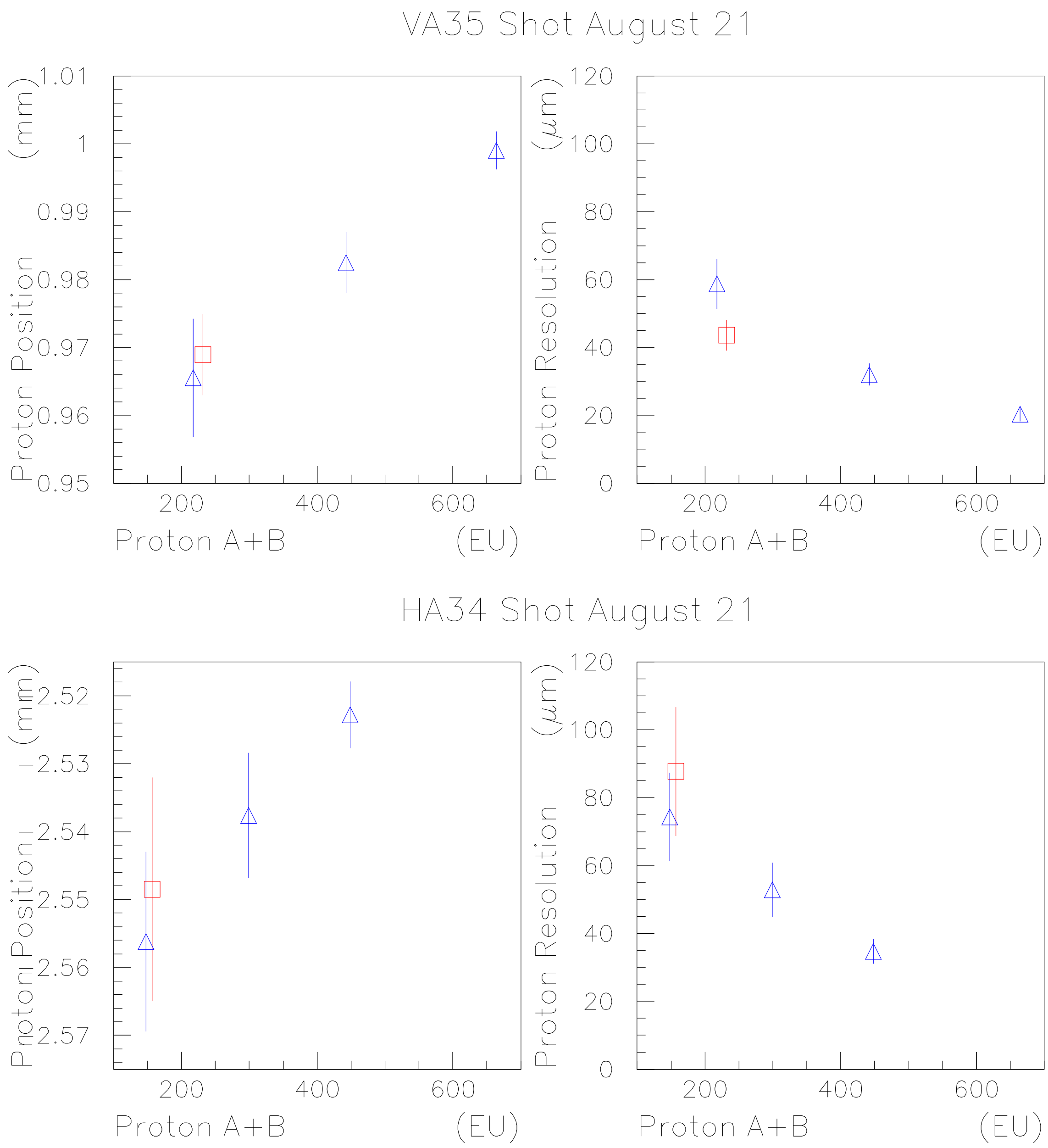

Figure 3: The left plots show the proton position plotted as a function of the BPM sum signal. The right plots show the resolution on the proton position plotted as a fucntion the BPM sum signal. The upper plots are for VA35 and lower ones for HA34. In both cases the position resolution is from the mean of 50 individual measurements and the resolution is the RMS spread of these measurements. The error bars are the statistical errors from the averaging of the 50 points.