Tevatron Proton Injection Kicker Waveform Analysis

G. Annala, B. Hanna

On July 25, 1995 a shift of Tevatron beam studies was devoted to examining the shape of the E17 kicker waveform. The purpose of this study was to determine how the kicker may effect the emittance of the Protons once collider operation changed to 36 bunch operation. The kicker was setup to give the most uniform flattop with approximately the correct flattop length. To do this, all 22 cells of the pulse forming network were connected and the predets for the tube timing were set as follows:

Main = 1.0 μ sec

Clip = 6.0 μ sec

Dump = 4.0 μ sec

The data was collected by varying the trigger of the kicker and observing the response of the beam with the BPM system. This timer, the beam synch delay out of a 279 module, only has 7 bucket resolution. Thus any waveform variation smaller than 131 nsec (or greater than 7.6 MHz) will not be observed. The data for the flattop was collected in a different way than the data for the rising edge and falling edge.

To collect the flattop data the injection closure was tuned to give a minimum turn by turn oscillation. Under these conditions, a first turn flash frame was recorded as a reference. As the kicker timing was varied, the positions at E17, E19 and E26 were recorded. Also, the amplitude of turn by turn oscillation as measured by the beam line tuner system at D49 was recorded. The effect of the kick given by the timing change was recorded for times that map out the complete flattop of the kicker wave form. In figure 1, the turn by turn amplitude is shown vs kicker trigger setting (in units of MREV). Because the kicker is being delayed, and the beam is always arriving at the same time, the rising edge of the kicker is actually on the right side of the plot, and the end of the flattop is on the left. The x's show the points in time that Protons will pass during 36 bunch operation. The first bunch will pass as the initial transient has stabilized at

1.925 MREV. It can be seen that the flattop is about 400 nsec short, so the clip tube timing will have to be adjusted. Note that this is feasible in that the maximum allowable rise time is 2.617 micro-sec while the rise time to where the oscillation dies out is 2.605 micro-sec.

Figure 1

The data indicates that if the kicker is tuned up so that bunch 1 has no injection oscillation, about 4 of the bunches would have an oscillation amplitude of about .2 mm, and the other bunches amplitude would be negligible. Beta at E17 is only 10% different than at the BPM at D49, so the oscillation amplitude at that location would be similar. A typical transverse beam measurement at E17 with the flying wires gives a sigma of at least 2 mm. The formula for emittance dilution

$$(\epsilon + \Delta\epsilon)/\epsilon = 1 + 1/2(\Delta x/\sigma)^2$$

would predict an emittance growth of only 0.5% for 1/3 of the bunches in the train. This is absolutely acceptable.

The data for the bottom of the kicker wave form was compiled somewhat differently. For this data, a closed orbit was taken for circulating beam. The kicker was then fired near in time to the circulating bunch, and the BPM system was used to look at the deflection of the beam. A one turn flash triggered on the circulating beam was used to observe the deflection. Also, the normal turn by turn system was used to measure oscillation amplitudes caused by the firing of the kicker. Figure 2 shows the deflection of the beam on the E19 BPM as a function of kicker trigger. The x's mark the times when Protons would arrive at the kicker if a trigger of 1.925 MREV is used for the trigger. This plot shows the rising edge of the kicker occurs right as the last circulating bunch passes.

Figure 2

There is no oscillation caused by the rising edge of this kick, so there is no emittance growth of the beam that passes just prior to the start of the kicker pulse.

Figure 3 is the same type of data, but the triggers show the kick given to the beam that passes after the kicker pulse. This data was taken with the clip tube firing 400 nsec too early, so figure 4 shows the Proton bunches shifted by 400 nsec to account for the later fall time once the clip and dump tube timing is adjusted. Figure 4 also uses the the amplitude of the E24 turn by turn oscillation for the BPM data.

Figure 3

**E17 kicker waveform
Falling edge
Protons shifted by 400 nsec**

Figure 4

This data shows that the batch of Protons that passes by the kicker after its pulse receives a kick of about 0.7 mm. Applying the same emittance dilution formula as done for examining the flattop gives an emittance growth of about 6%. Reducing the number of cells in the PFL will not help this problem as that will make flattop worse; from earlier data taken with only 6 cells the flattop varied by 8% while with all 21 cells the flattop varies only .5%. Since the flattop uniformity varies linearly with the number of PFN cells we can only take out 1 or 2 cells before flattop becomes a problem. Other possible solutions would include making transverse dampers work or add a "bumper" kicker at E17 to cancel the errors. Another possibility is to reduce the inductance of the magnets; this would probably take a re-work of the magnets although it may be that the old D48 magnets would work as they have lower inductance.