Stacking and SY120 Pulses

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This is a short note that outlines a simple calculation to estimate how many pulses can be sent to SY120 while running mixed mode operations.

Introduction

The primary focus of the Accelerator division in the beginning of FY05 will be to maximize the stacking rate. Also, the complexity of running the Collider in Mixed Pbar Source mode with the Recycler encourages keeping operational scenarios as simple as possible.

Interleaved Mixed Mode SY120 Cycles Scenario

The scenario that would achieves both of these goals is to interleave single pbar stacking cycles with Mixed Mode SY120 cycles for the first part of the stacking period. During the second part of the stacking period, we would run Mixed Mode SY120 cycles every pulse. During both periods, the cycle period will be adjusted to accommodate the natural slowdown of stacking as the pbar stack grows. The boundary between these two periods is determined when the natural stacking cycle length equals the minimum Mixed Mode cycle length.

The stacking rate as a function stack size is given as:

$$R(S) = R_o \frac{S_m - S}{S_m} \tag{1}$$

where R_o is the stack rate when the with no core in the Accumulator and S_m is the stack size at which the stacking rate falls to zero. This equation can be integrated to get the stack size as a function of time.

$$S(t) = S_m - (S_m - S_o)e^{-\frac{R_o t}{S_m}} \tag{2}$$

where S_o is the stack size at t=0. The time it takes to reach a given stack size is:

$$T_{stack}(S) = \frac{S_m}{R_o} \ln\left(\frac{S_m - S_o}{S_m - S}\right) \tag{3}$$

The time between stacking pulses (stacking cycle) for a given stack rate is:

$$\Delta\tau_c(t) = \frac{R_o}{R(t)} \Delta\tau_o \tag{4}$$

where $\Delta\tau_o$ is the cycle time when the stack size is zero. Because of the ramping of the P2 line or Main Injector correctors, there is a minimum stacking cycle time that can be used for mixed mode operations. The amount of time that is spent stacking before this minimum stacking cycle time is reached is:

$$T_{mix}(\Delta\tau_{c_{min}}) = \frac{S_m}{R_o} \ln\left(\frac{(S_m - S_o)}{S_m} \frac{\Delta\tau_{c_{min}}}{\Delta\tau_o}\right) \tag{5}$$

This time as a function of minimum Mixed Mode cycle time is shown in Figure 1. For Figure 1, the initial stack rate R_o is 14mA/hr, the maximum stack size S_m is 270mA and the initial pbar cycle time $\Delta\tau_o$ is 2.0 seconds.

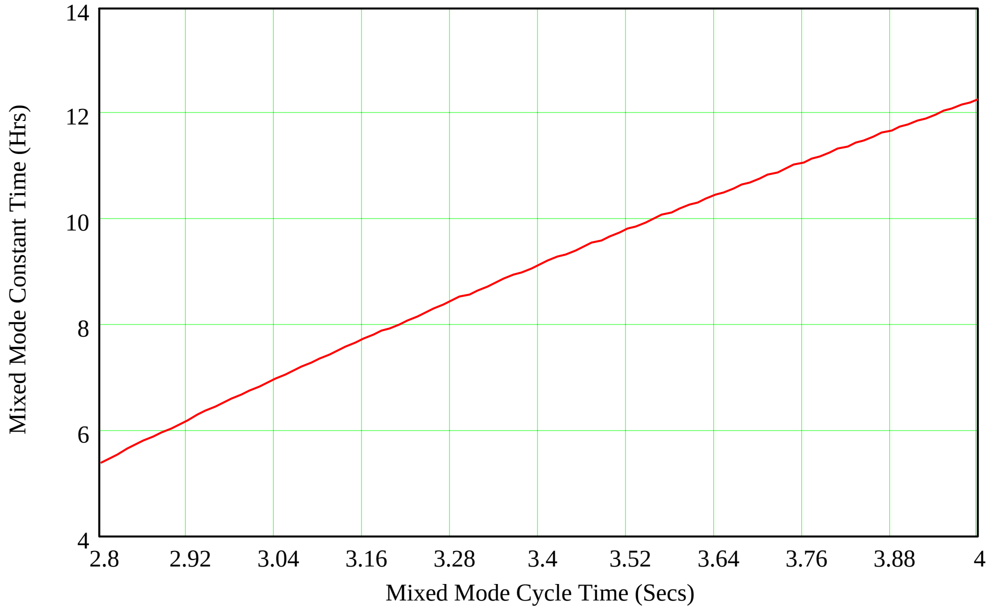

Figure 1. Time it takes for the natural cycle time to reach the minimum Mixed Mode cycle time as a function of the minimum Mixed Mode cycle time.

The number of stacking pulses from t=0 until T_{mix} is given as:

$$2N_1\left(\Delta\tau_{c_{min}}\right)=\int_0^{T_{mix}(\Delta\tau_{c_{min}})}\frac{dt}{\Delta\tau_c(t)}=\frac{1}{R_o\Delta\tau_o}\left[S_m\left(1-\frac{\Delta\tau_o}{\Delta\tau_{c_{min}}}\right)-S_o\right] \qquad (6)$$

Where N_1 is the number of slow spill cycles. The factor of 2 in front of N_1 in Eqn. 6 is to account for the interleaving of the cycles with the stacking cycles. After the minimum cycle time for mixed-mode is reached the number of stacking pulses between this time and when the desired stack size is achieved is:

$$N_2\left(S,\Delta\tau_{c_{min}}\right)=\int_{T_{mix}(\Delta\tau_{c_{min}})}^{T_{stack}(S)}\frac{dt}{\Delta\tau_c(t)}=\frac{S_m}{R_o\Delta\tau_{c_{min}}}-\frac{S_m-S}{R_o\Delta\tau_o} \qquad (7)$$

The average number of pulses per hour for SY120 in this mode is:

$$n_{12}\left(S,\Delta\tau_{c_{min}}\right)=\frac{N_1\left(\Delta\tau_{c_{min}}\right)+N_2\left(S,\Delta\tau_{c_{min}}\right)}{T_{stack}} \qquad (8)$$

The number of pulses per hour for an initial stack rate R_o of 14mA/hr, the maximum stack size S_m of 270mA and the initial pbar cycle time $\Delta\tau_o$ of 2.0 seconds is shown in Figure 2. Figure 2 shows the pulses per hour for two final stack sizes and the scenario if a constant pbar cycle time equal to the Mixed Mode cycle time is used.

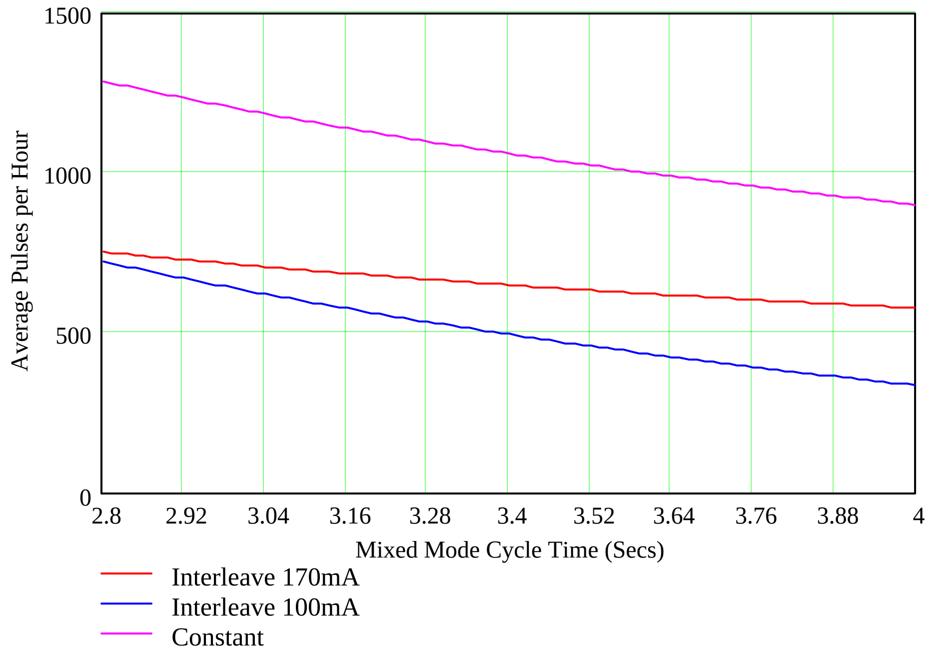

Figure 2. Number of pulses per hour as a function of the Mixed Mode cycle time

Constant Cycle Mixed Mode Cycle Time Scenario

For this scenario, we would run Mixed Mode cycles at a constant interval for the entire stacking period. In the period in which the natural stacking cycle time, given by Eqns. 1,2, &4 is smaller than the minimum Mixed Mode cycle time; the stacking rate would be reduced. The time it takes stacking at the natural cycle time to reach the minimum Mixed Mode cycle time is given by Eqn. 5. The stack size reached by stacking at the fixed minimum Mixed Mode cycle time is given as:

$$S_{mix} = R_o \frac{\Delta\tau_o}{\Delta\tau_{c_{min}}} T_{mix}(\Delta\tau_{c_{min}}) + S_o = S_m \frac{\Delta\tau_o}{\Delta\tau_{c_{min}}} \ln\left(\frac{(S_m - S_o)}{S_m} \frac{\Delta\tau_{c_{min}}}{\Delta\tau_o} \right) + S_o \qquad (11)$$

Substituting Eqn. 5 into Eqn. 2, the stack size that would have been obtained if we had stacked at the natural cycle time during this period is:

$$S_{natural} = S_m \left(1 - \frac{\Delta\tau_o}{\Delta\tau_{c_{min}}} \right) \qquad (12)$$

After the time when the natural cycle time exceeds the minimum mode cycle time, we would keep the stacking cycle time constant and equal to the minimum Mixed Mode cycle time. We would accommodate the slow down in stochastic cooling in the Stacktail system by reducing the bucket size of ARF1 in the Accumulator. That is, we would reduce the stacking rate by reducing the effective production of the Antiproton Source.

An example is shown in Figures 3. The zero-stack stack rate for this example is R_o=14 mA/Hour with an initial cycle time of $\Delta\tau_o$=2.0 seconds. The initial stack size is S_o=15 mA and the stacking duration is 22 hours which reaches a stack of 170 mA.

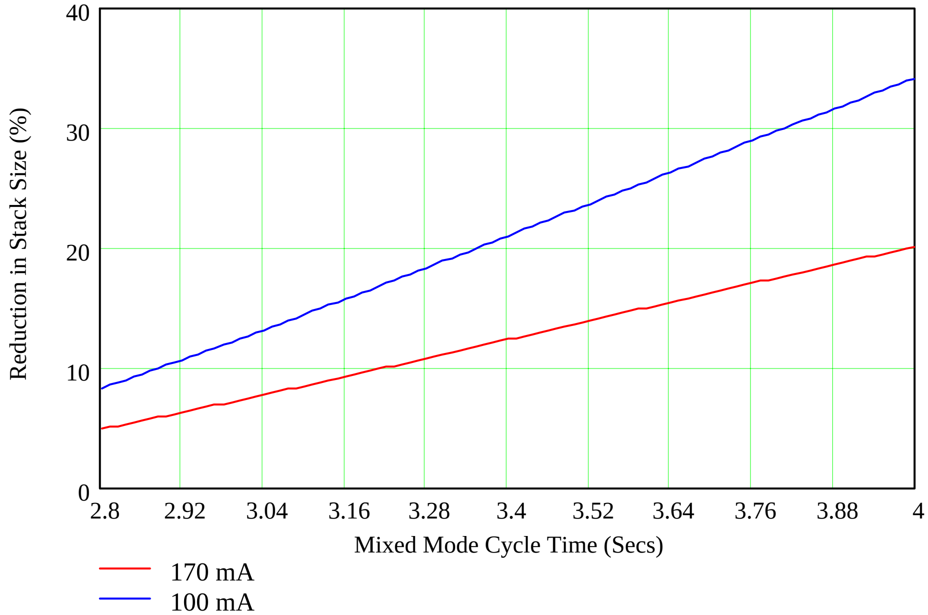

Figure 3. Reduction in Stack Size due to running at a fixed cycle time as a function of the fixed cycle time.