BEAM TRANSFER FROM THE DEBUNCHER TO THE STACKING ORBIT OF THE ACCUMULATOR RING AT FERMILAB

V.K.Bharadwaj, J.E.Griffin, D.J.Harding, J.A.MacLachlan,
Fermi National Accelerator Laboratory*
P.O. Box 500, Batavia, Illinois 60510, USA.

Introduction

This paper describes the transfer of a cooled beam of antiprotons from the Debuncher Ring to the stacking orbit of the Accumulator Ring at the Fermilab Pbar Source. Overviews and descriptions of this Pbar Source and its use for pbar-p colliding physics may be found in references 1-4. Some parameters relevant to this paper for the Debuncher and Accumulator are given in Table 1. The properties of the two RF systems relevant to this paper are listed in Table 2, and additional information on these systems are given in references 5,6. At the end of a Debuncher beam cycle - currently every 2.8 seconds - a cooled debunched beam of antiprotons circulates in the Debuncher Ring. Horizontally and vertically this beam is smaller than 7 pi mm-mrad[7]. Longitudinally the beam is cooled to a Dp/p of 0.2%.[8]

TABLE 1 : RING PARAMETERS

	Debuncher	Accumulator
Kinetic Energy (Gev)	8.0	7.9
Transition Energy (Gev)	7.648	5.43
Average Radius (meters)	80.42	75.45
Momentum Compaction Factor	0.006	0.023
Betatron Acceptance (mm-mrad)	20 pi	10 pi
Momentum Aperature (%)	4.0	2.5
Revolution Period (microsec)	1.694	1.590

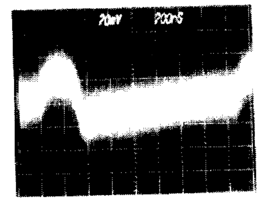
TABLE 2 : RF PARAMETERS

	DRF2	ARF1
Frequency (MHz)	2.36	52.8
Harmonic Number	4	84
RF Voltage (kVolts)	.9	105.0

Gap Preservation

There is a suppressed bucket RF system, DRF2, that makes a gap of about 240 nanoseconds in the debunched beam in the Debuncher Ring. This gap in the beam is shown in Figure 1. The gap is used to accommodate the risetime of the Debuncher extraction kicker - without a gap the beam that lies in this risetime would be lost. The most dramatic way of illustrating this effect is to show the stacking rate with and without this system. Figure 2 shows this and one can see that the stacking rate is approximately 10% better with DRF2 on than with it off.

*Operated by Universities Reasearch Association Inc. under contract with the United States Department of Energy.



200 nanoseconds/divison

Figure 1. Gap in Debuncher beam held by DRF2

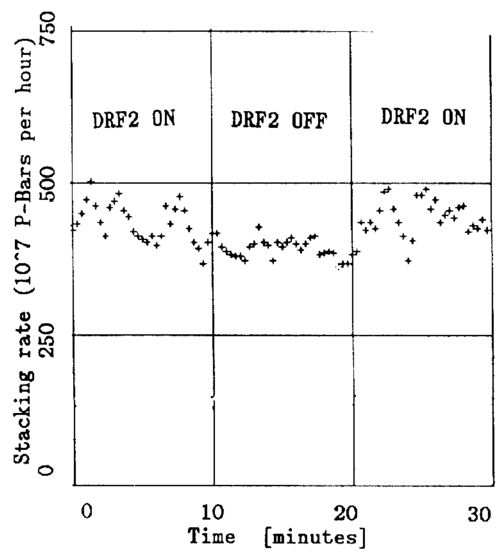


Figure 2. Stacking rate with and without DRF2

Debuncher To Accumulator Beamline Transfer

The antiprotons are transferred from the Debuncher to the Accumulator through a short beamline known as the D-to-A line.

Beam is extracted from the Debuncher in a single turn. The extraction point is at the upstream end of the long straight section D10 in a region of zero dispersion. A pulsed horizontal kicker magnet[9] is fired by a signal synchronized to the gap in the beam. This gives the beam a 4.6 mr deflection. About 13 meters downstream (0.25 betatron oscillation) the beam enters a pulsed septum magnet[10]. The septum magnet gives the beam an

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additional horizontal bend. The beam then passes through the edge of the good gradient region of a large aperture quadrupole, receiving one more horizontal bend.

At the Accumulator end of the line two more septum magnets bring the beam close to the injection orbit in the straight section A10, also near zero dispersion. 60 meters downstream (0.75 betatron oscillations) is a shuttered pulsed kicker magnet. This point is in the short straight section A20, a high dispersion point. Here the accumulated core of antiprotons, and even the stack tail, are separated from the higher momentum injection orbit in space (figure 3). The kicker gives the beam a 4.0 mr bend, putting it in on the injection closed orbit.

The quadrupoles at each end of the line are tuned to match the accelerator parameters of the beam line to those of the rings, avoiding possible dilution of the transverse emittance. The beam position and profile in the line may be monitored at three positions with secondary emission monitor grids.

In addition to tuning the line with the antiprotons during production running, the line may be studied and tuned with 8 GeV protons running backwards from the Main Ring to the Accumulator and thence through the D-to-A line into the Debuncher.

RF Stacking In The Accumulator

Figure 3 shows various beam positions of interest in a high dispersion straight section of the Accumulator Ring. The Debuncher to Accumulator transfer injects beam onto the injection orbit of the Accumulator. The ARF1 RF system is used to decelerate the beam approximately 65 MeV onto an orbit just the other side of the injection kicker shutter. Figure 4 shows the frequency and amplitude curve of this system. The beam is captured adiabatically in 80 milliseconds, decelerated in 140 milliseconds, and then deposited at the stacking orbit. From here the stack tail stochastic cooling system moves the beam towards the core such that we can inject and decelerate another pulse of beam on the next beam cycle. How well we do in the stacking process is shown in Figures 5a,5b,5c. Here under test conditions we see the output of the longitudinal Schottky in the Accumulator. Figure 5a is the signal with the beam at the injection orbit; figure 5b is the decelerated beam; figure 5c is the Schottky signal of what is left behind. As one can see, the RF stacking efficiency is better that 99%.

	Core	Stacking orbit	Injection orbit
Distance	-63.3 mm	+14.7 mm	+80.3 mm
Momentum	-0.69 %	+0.17 %	+0.93 %
Energy	-60.5 MeV	+14.5 MeV	+81.5 MeV

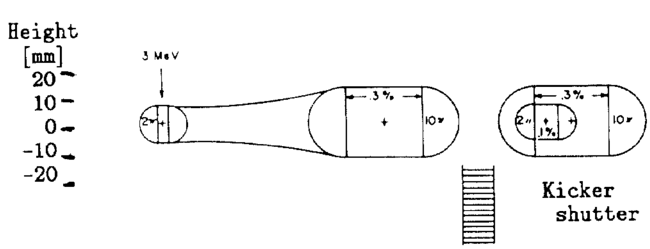

Figure 3. Accumulator beam profile in a high spersion straight section

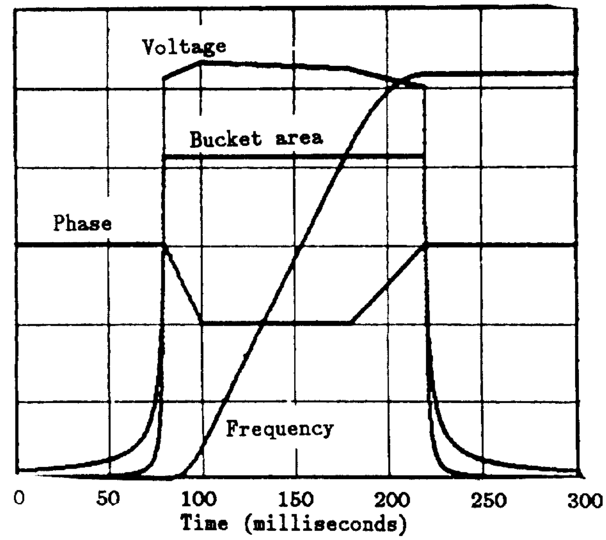

Figure 4. Accumulator RF stacking curve

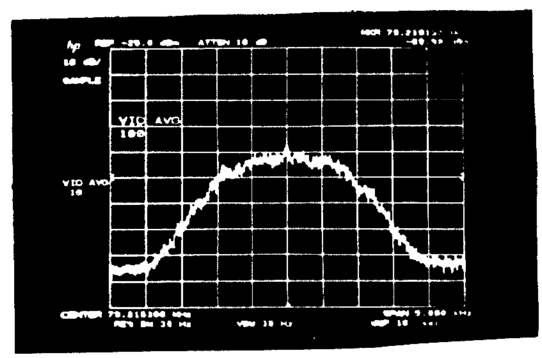

Figure 5a. Beam on injection orbit.

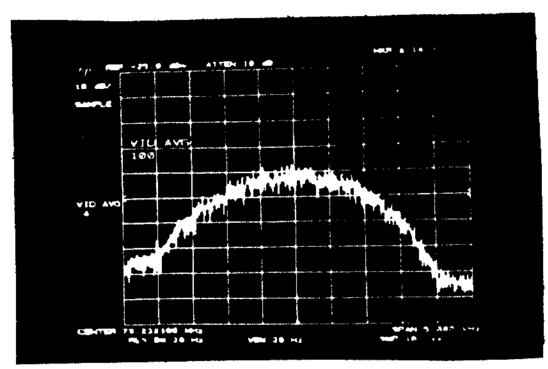

Figure 5b. Beam on stacking obit.

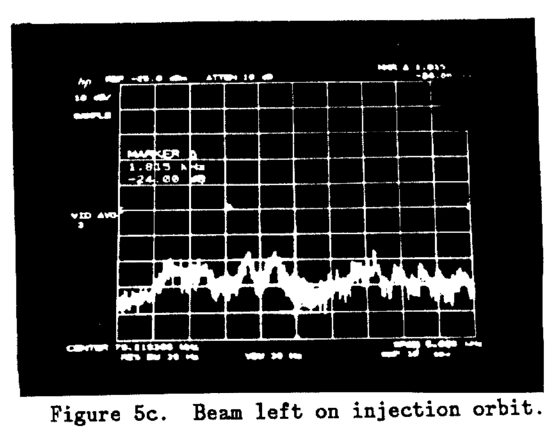

Figure 5c. Beam left on injection orbit.

Fast Fourier Transform Analyzer

We can measure various transfer efficiencies using using a Schottky pickup Fast Fourier Transform analyzer. Signals from longitudinal resonant Schottky pickups in the Debuncher and the Accumulator are separately mixed down so the frequency of interest is centered at 20kHz. These signals are then connected to an H.P. 3562A dynamic signal analyzer. The system of two RF signal mixing generators and the signal analyzer are on a single IEEE 488 bus controlled by a BASIC program running on an H.P. 9826 computer. The computer is used to control the functional mode, the timing and the I/O. The signal analyzer does all the FFT computation. For each selected spectrum, it averages the FFT spectrum from 19kHz to 21kHz, subtracts out a noise level, scales into units of beam current per hertz and integrates over frequency. Data taking is synchronized to the machine cycle with an external trigger to the analyzer. Amongst the modes of operation are to measure the efficiency of the transfer of pbars from the Debuncher to the Accumulator injection orbit, and to measure the efficiency of transfer from the Debuncher to the stacking orbit of the Accumulator Ring.

Efficiencies

The FFT analysis shows that the Debuncher to Accumulator transfer is approximately 90% efficient and there is no loss of beam during the RF stacking process. We believe that the D-to-A losses are due primarily to the acceptance of the Accumulator on the injection orbit, not in the beamline itself. These are reduced by maximizing the stochastic betatron cooling in the Debuncher, and hence minimizing the transverse size of the beam, and by tuning to reduce injection oscillations in the Accumulator with the attendant blow-up in transverse emittance. We feel that the RF capture and stacking works well. A smaller momentum spread in the beam would be the only other thing to improve the system.

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