Fermi National Accelerator Laboratory

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Observation of the Coalescing of Beam Into an Asymmetric RF Bucket by Stochastic Cooling

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ABSTRACT

Antiprotons in the debuncher ring at Fermilab have been observed to be bunched outside of the "barrier bucket" when cooled to small $\Delta p/p$ with the stochastic cooling. This bunching occurs in the same location as a very small stable bucket in the RF wave form. The stochastic cooling appears to be causing beam that is originally uniformly distributed to be captured by this stable bucket.

I. INTRODUCTION

During normal stacking operations in the PBAR source antiprotons are injected into the debuncher storage ring and cooled in all three dimensions by stochastic cooling for several seconds before being transferred to the accumulator storage ring. While in the debuncher a barrier bucket RF system is used to preserve a gap in the beam distribution. This ensures that the beam can be injected into the smaller circumference accumulator with high efficiency.

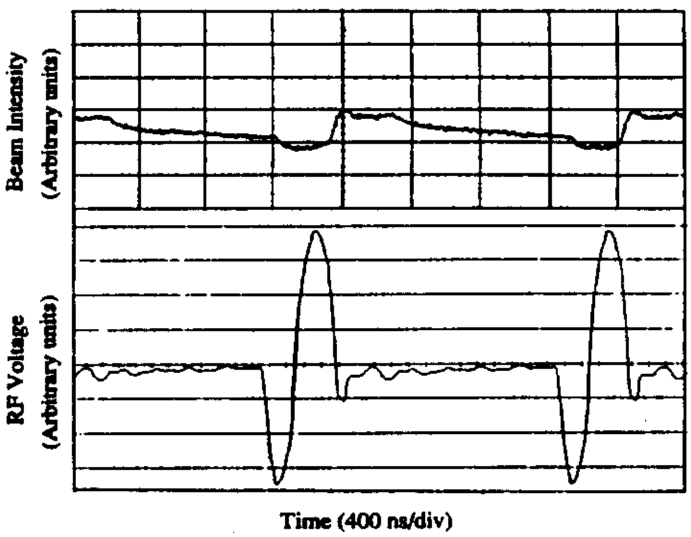

Figure 1. Beam distribution on the gap monitor after 2.4 seconds in debuncher and RF voltage wave form.

II. BEAM DISTRIBUTION AFTER 2.4 SECONDS IN DEBUNCHER

The beam is initially injected uniformly into the space outside of the barrier bucket. After 2.4 seconds of cooling the longitudinal energy distribution is roughly gaussian with a standard deviation of about $\Delta p/p = 0.08\%$. At this time the beam distribution observed on a gap monitor is shown in Figure 1. The RF voltage is also shown. The relative time of the RF with respect to the gap monitor has been adjusted in the figure to the expected location. The gaps in the beam distribution caused by the barrier bucket are clearly visible, and the distribution is noticeably asymmetric.

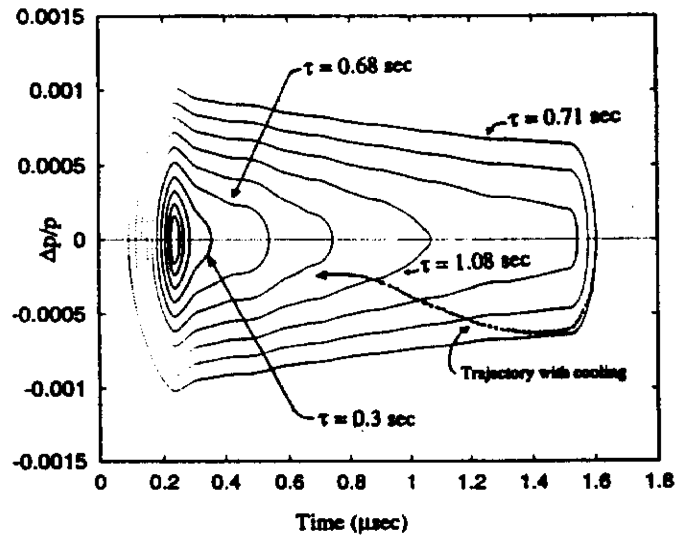

Figure 2. Particle Trajectories in the RF bucket. Contours are 0.01% apart in $\Delta p/p$. The synchrotron period is shown for a few trajectories. The dotted arrow is a possible path that a particle may take as it is cooled by the stochastic cooling.

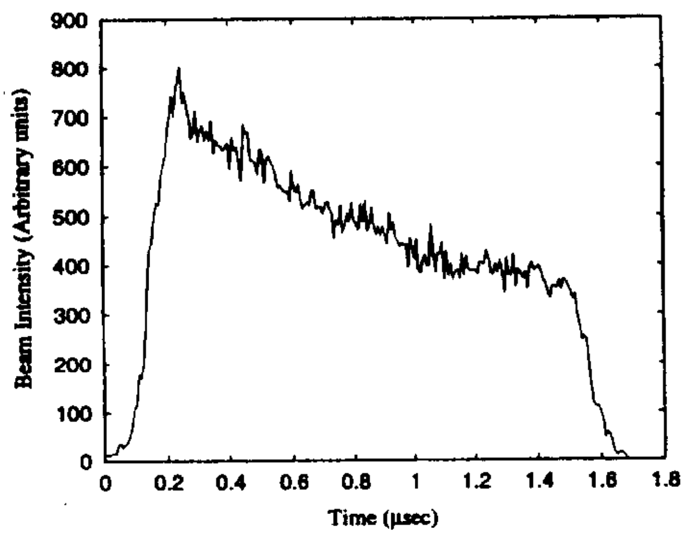

Figure 3. Predicted time distribution of beam injected uniformly into the bucket shown in Figure 2 with no cooling after 2.4 seconds.

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III. BEAM DISTRIBUTION AFTER COOLING

The asymmetry in the above distribution has been modeled using a particle tracking code similar to ESME. The initial uniform beam is injectedoff center into the asymmetric bucket shown in Figure 2. After a few seconds the time distribution of the beam is predicted to look as in Figure 3. It is asymmetric do to the fact that the bucket has more phase space area on the right hand side. There is good qualitative agreement between the two distributions.

If the beam is cooled for about 15 seconds in the debuncher the longitudinal energy distribution will stabilize with an energy spread of about $\Delta p/p = 0.03\%$. The beam on the right hand side of Figure 2 cannot be cooled if it remains on the same contour line. Therefore, as it is cooled it spirals in along a path similar to that shown by the arrow in Figure 2. The beam distribution on the gap monitor after about 15 seconds of cooling is shown in Figure 4. Almost all the antiprotons have been pushed against the edge of the barrier bucket. The large spike and two shoulders in the beam distribution closely match the details in the RF wave form.

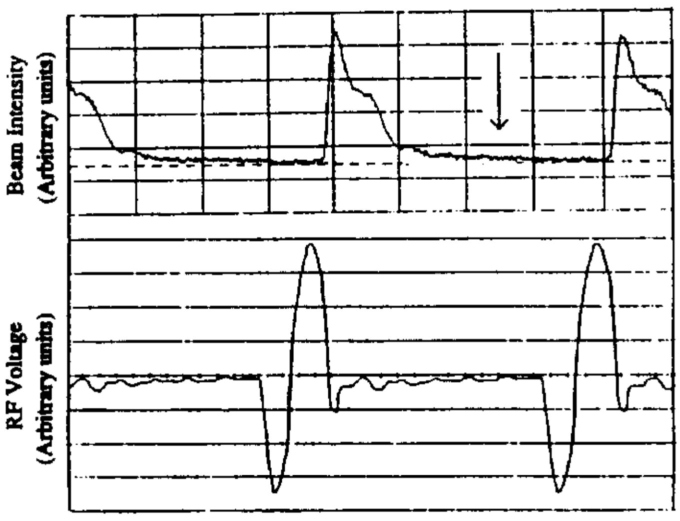

Figure 4. Time distribution of beam in Debuncher after 10-20 seconds of cooling, and the RF wave form.

A series of investigations showed that bunching depended only on how much cooling had been done to the beam, i.e. after cooling for 15 seconds the stochastic cooling could be turned off without effecting the distribution. The amount of bunching did not vary if the cooling system was tuned to give the beam a net increase or decrease in energy.

IV. POSSIBLE USES OF ASYMMETRIC RF BUCKETS FOR STACKING

The coalescing of beam by stochastic cooling opens up the possibility of stacking in the time domain rather than the energy domain, as is now done in the PBAR source at Fermilab. This could allow stacking in an accelerator with a more conventional lattice than the accumulator, where a very high dispersion section is used to physically separate the fresh injected pulse from the accumulated stack.

For instance, a 400 ns wide kicker centered in time at the point indicated by the arrow in Figure 4 could inject a fresh pulse of beam, which the stochastic cooling would then cool into the bunch at the left. In principle this is a much simpler method of stacking than is currently used, it may have some inherent advantage over the existing technique.

V. CONCLUSION

This paper documents another case of bunched beam cooling[1-2], a slowly emerging field. It appears that stochastic cooling indeed cools bunched beams, and in the presence of an asymmetric RF field can cause apparent bunching of the beam.

VI. REFERENCES

[1] J. Claus et. al., "Experimental Cooling Of Bunched Beams In FNAL'S Accumulator Ring". AD/AP-19 (Feb 1990) 75p. Fermilab Library Only.

[2] J. Marriner et. al., "Bunched Beam Cooling in the FNAL Anti-Proton Accumulator", Proc. of the 2nd European Particle Accelerator Conf. Nice, June 12-16, 1990 p 1577..