IMPROVEMENTS IN BUNCH COALESCING IN THE FERMILAB MAIN RING

J. Dey, I. Kourbanis, D. Wildman, Fermi National Accelerator Laboratory*, P.O Box 500, Batavia, IL. 60510, USA

Abstract

In Fermilab's Main Ring bunch coalescing is used to produce intense proton and antiproton bunches for the Tevatron. For the bunch coalescing, 11 proton or antiproton bunches are rotated first in the fundamental rf harmonic of 53 MHz to reduce the momentum spread, then are rotated for a quarter of a period in a lower harmonic (h=53 or 2.5 MHz) and recaptured in a single 53 MHz bucket[1]. The 2.5 voltage available for coalescing is 22 KV. Recently 3 new 2.5 MHz coalescing cavities were installed[2] and the available 2.5 voltage was tripled. The coalescing improvements from this upgrade will be described.

I. INTRODUCTION

Recent injector improvements and upgrades helped increased the Main Ring intensity by 50% since the last collider run. The higher proton intensities resulted in higher longitudinal emittances before coalescing. Typical long. emittances of the highest intensity proton bunches are 0.30-0.32 eV-sec.

Also higher antiproton stacking efficiencies resulted in higher antiproton stacks and larger antiproton bucket sizes, for more antiprotons extracted. The 11 antiproton bunches have a parabolic distribution in emittances and intensities, the middle bunches having the greater intensities and emittances. The pbar emittances typically vary between 0.14 eV-sec for the end bunches to 0.30 eV-sec for the bunches in the middle.

With the larger proton and antiproton long. emittances, even with the introduction of a second harmonic cavity, the coalescing efficiency was in the 70-80% range resulting in satellites and DC beam. In Fig. 1 an ESME[3] simulation is shown of 11 (typical long. emittance) antiproton bunches at the moment of recapture in an 800 KV 53 MHz bucket. In Fig. 1 the distribution at recapture is wider than the standard 53 MHz bucket (18.9 nsec). Some of the particles spill into the two neighboring buckets resulting in satellites, and some are not captured and lost as DC beam.

In Fig.2 the same 11 antiproton bunches are shown at recapture rotated this time with 60 KV of 2.5 MHz. The width of the distribution is now narrow enough to fit in the single 53 MHz bucket and there are almost no satellites.

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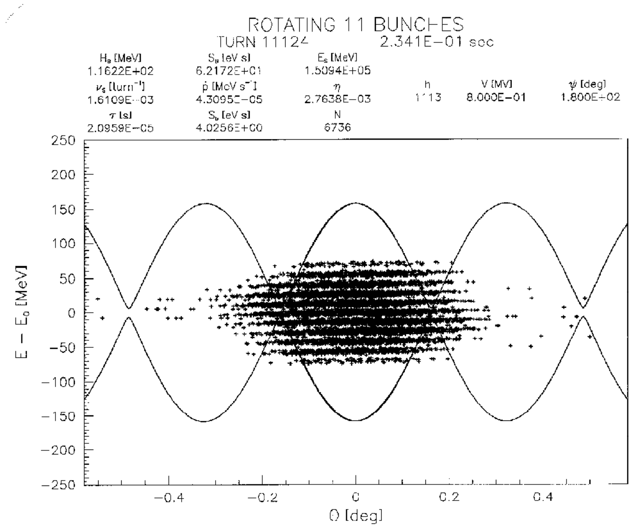


Figure 1: 11 pbar bunches rotated with 21 KV of 2.5 MHz and 4 KV of 5 MHz at the moment of recapture.

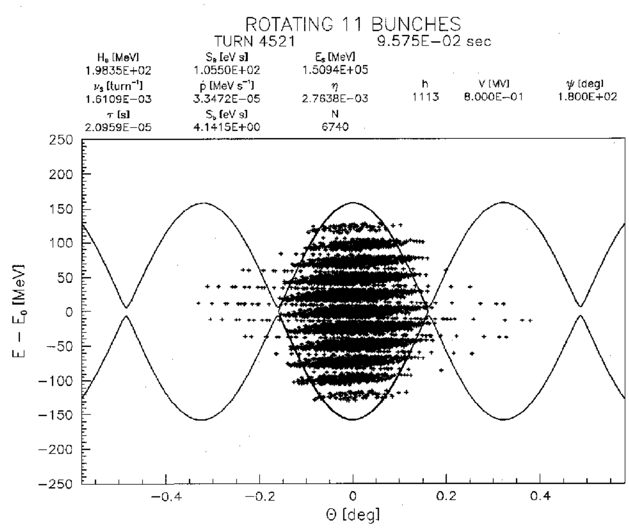


Figure 2: 11 typical pbar bunches rotated with 60 KV of 2.5 MHz and 11 KV of 5.0 MHz at the moment of recapture.

Recently a decision was made to upgrade our coalescing system by making new 2.5 MHz cavities capable of producing a total of 60 KV, three times the voltage available today. The new higher voltage would help us reduce the width of the recaptured distribution by a factor of $\sqrt{3}$, increase the coalescing efficiency and eliminate the satellites.

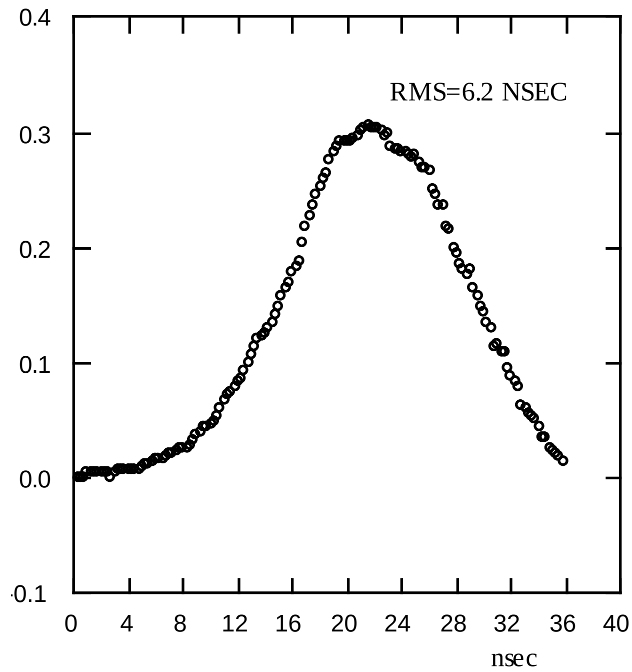
III. EXPERIMENTAL RESULTS

To test if the results with the higher 2.5 MHz voltage agree with the simulations, 5 proton bunches (to eliminate the effect of the 5.0 MHz voltage) each of 0.3 eV-sec were coalesced first with the old coalescing cavities (a total of 21 KV of 2.5 MHz) and then with the old and the new cavities together (a total of 60 KV of 2.5 MHz). The digitized beam profiles at the moment of recapture for both cases are shown in Fig. 3. The rms. spread with the 60 KV is about $\sqrt{3}$ times smaller than the rms. spread of the distribution rotated with 21 KV, as in the simulations. Also the total spread of the distribution rotated with 60 KV is 17.5 nsec and fits in the recapture 53 MHz bucket (18.9 nsec wide).

The effect of the higher 2.5 MHz voltage on the pbar coalescing efficiency is shown in Fig. 4. The predicted coalescing efficiencies are from ESME simulations for 11 pbars bunches with typical emittances rotated with 21 KV of 2.5 MHz and 4 KV of 5.0 MHz (before the upgrade) and 60 KV of 2.5 MHz (after the upgrade). The results agree with the predictions, and show a 14% improvement in pbar coalescing efficiency.

The proton coalescing efficiency also increased by about 10% after the upgrade with proton bunches as large as 3.2E11 being observed. The typical satellite bunches after the upgrade have intensities less than 2% of the main bunch intensity, compared with 8-12% before.

The proton bunch coalescing efficiency is expected to be further improved with the installation of the new 5 MHz cavity that is going to be installed in the summer of '95 along with the rest of the new 2.5 MHz cavities.



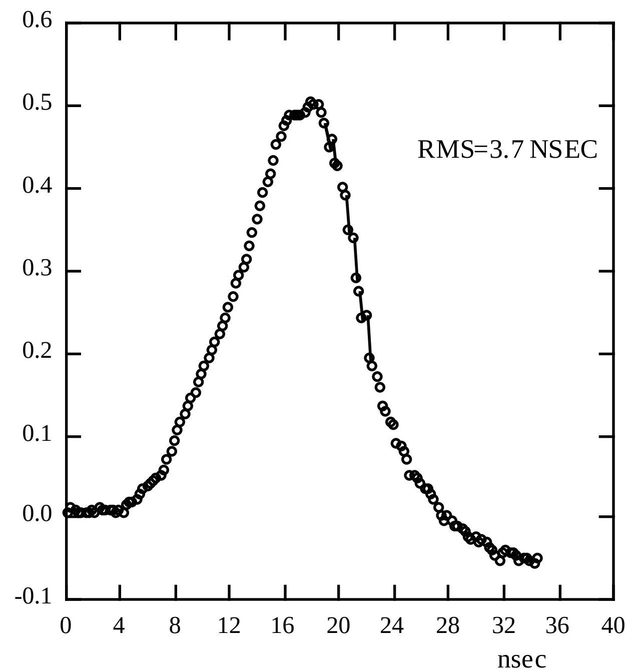


Figure 3: Profiles of the coalesced distribution of 5 proton bunches at the moment of recapture. Top: Bunches rotated with 21 KV of 2.5 MHz. Bottom: Bunches rotated with 60 KV of 2.5 MHz.

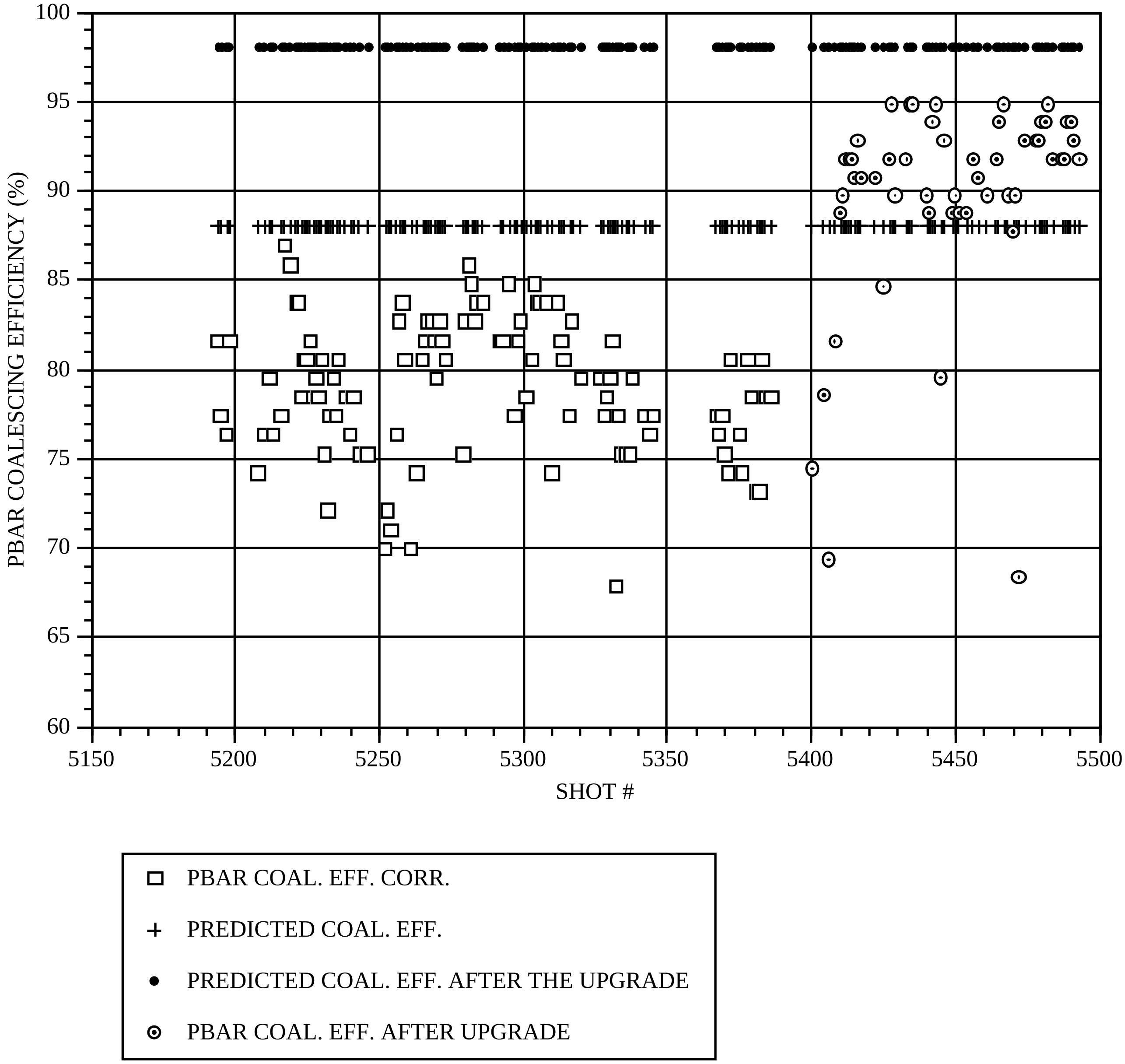


Figure 4: Pbar coalescing efficiency versus shot number before and after the coalescing upgrade.

IV. CONCLUSION

The 3 new 2.5 MHz cavities installed in Main Ring tripled the existing 2.5 MHz voltage and helped us increase the pbar coalescing efficiency by 14%, the proton coalescing efficiency by 10% and eliminate the satellite bunches.

VI. REFERENCES

[1] "Performance and Comparison of Different Coalescing Schemes Used in the Fermilab Main Ring", I. Kourbanis, G.P. Jackson, and X. Lu. Proc. of the 1993 Particle Accelerator Conf. 3799 (1993).

[2] "A New RF System for Bunch Coalescing in the Fermilab Main Ring" J. Dey, I. Kourbanis, and D. Wildman. These proceedings.

[3] "Users Guide to ESME v. 7.1", S. Stahl and J. MacLachlan, Fermilab internal note TM-1650 (2/90).