MINI-BUNCHING THE AGS SLOW EXTERNAL BEAM*

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Abstract

Test and modeling toward providing a continuos string of proton bursts of a few nano-seconds every 3 to 10 micro-seconds for the two second BNL AGS spill are presented.

1 INTRODUCTION

Two new proposed experiments at the AGS require well bunched beam. The specification for a muon to electron conversion experiment is a burst of a few nano-seconds every few micro-seconds with only a part in 10^8 leakage between bursts. Another experiment to measure the muon lifetime needs 10 micro-seconds between bursts. The AGS started extracting mini-bunches in 1974 for Fainberg and Kalogerapoulos to measure anti-neutrons. Bunches were <~4 ns spaced every 220 ns. This technique kept the beam bunched in the main RF buckets and moved only the edge of the bunch into the extraction transverse resonance by slowly shifting the RF frequency[1,2]. There has been no further interest in this technique until a new crop of proposals developed from the AGS 2000 Workshop [3].

1.a Mini Bunches every 3 Micro-seconds.

The plan for this rate of delivery is to only fill one of the eight RF buckets in the AGS. This bunch is then accelerated to full energy and, as the RF is left on, kept bunched. After the extraction resonance is established, the radius is slowly moved out, using a signal from the servo that controls the spill rate to modify the rate of radial change, until all the beam has kissed the resonance and been extracted. The actual beam bursts in the slow beam are much shorter than the bunches in the AGS as only the edge of the rotating bunch touches the resonance.

Mini Bunches Every 10 Micro-seconds.

The approach to achieve 10 micro-seconds between bursts is to use an RF dipole as is used to spin flip on intrinsic resonances during polarized proton acceleration[4]. This dipole will kick horizontally and be "tuned" to one third the rotation frequency of those particles being extracted or ~124 kilo Hertz. The phase of the kick will be such as to enhance only one of the three separatrixes of those particles being extracted within the one populated bucket in the accelerator. This will prevent particles from passing the fixed unstable points on two corners of the stable area and enhance escape on to the separatrix at the remaining one.

2 LONGITUDINAL MODELING

The equation modeled is:

$$\ddot{\phi} = W_o^2 * (\sin\phi - \sin\phi_s)$$

$$[W_o^2 = \frac{eV\eta f_{RF}^2\, 2\pi}{\beta^2 Eh}]$$

where ϕ and equivalent W_o^2 were calculated using equations in Ref 5. Normal conditions used were: RF voltage = 20 KV & $\dot{B}/B$ = 0.001 /Sec., producing buckets with the following: stable phase = 0.17^o , half height = 68 MeV.

An ensemble of particles were started for all phases within a bunch that fills 10% of the bucket and the "resonance", $\dot{\phi}$ where the particle makes a "first crossing", is moved down. Each time a particle exceeds a new $\dot{\phi}$, a point is plotted on to the screen at the current phase and $\dot{\phi}$. The resultant plot shows the phase extent of beam as it is extracted. As the bunch only fills the bucket to 10% on flattop, particle population is contained within less than ~40% of peak amplitude. The full width of bunches here is less than 20 nano-seconds.

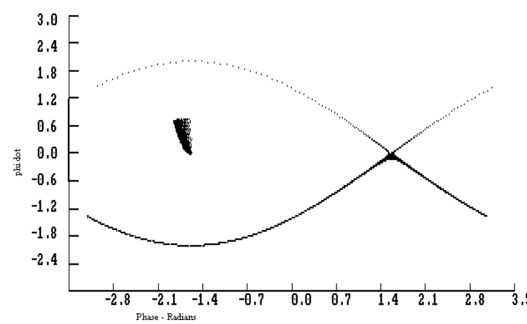

Figure 1 Phase of Extraction for Various Amplitudes of Synchrotron Oscillations.

3 TRANSVERSE MODELING

Behavior was tracked using equations from Ref 6. They are for tracking position in an "*XY*" space every three revolutions and were modified to be Symplectic by M Blaskowitz. They are:

$X_{n+1} = (X_n + \varepsilon * Y_n)/(1 - 6 * E * Y_n)$

$Y_{n+1} = Y_n - \varepsilon * X_{n+1} + 3 * E * [(X_{n+1})^2 - (Y_n)^2]$

[Where eta space variables *X* is related to displacement by $\sqrt{\beta}$ and *Y* to angle, both rotated to match the phase of the sextuples; ε is the tune difference from the resonance

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and E to drive sextuple strength. which is normalized to make X_o, the size of the stable region, unity.]

An ensemble of 2000 particles with an initial gaussian distribution in this space were tracked. Particles motion was starting with a large ε. Tune difference was slowly shifted to zero, ε shrank to zero, and the location of the particle plotted every 36 turns (12 passes through the above equations). [Without tune shift, the particle path did not change during 1.9 seconds of simulated coasting (sixty thousand passes); on a 586, this took less than two minutes (only 5 times the time of travel of particles in the AGS)]. Figure 2 shows trajectories for normal 1/3 integer extraction, Figure 3 shows the trajectories for particles with the RF dipole on with 1.5 gauss-meters of field. The dipole is simulated by a .003 increment in Y every three turns.

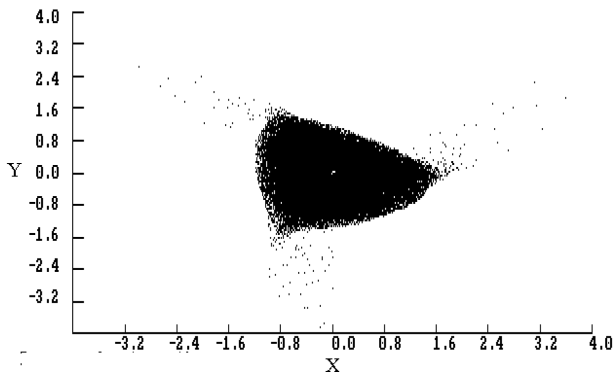

Figure 2 Extraction Separatrixes, RF Dipole Off

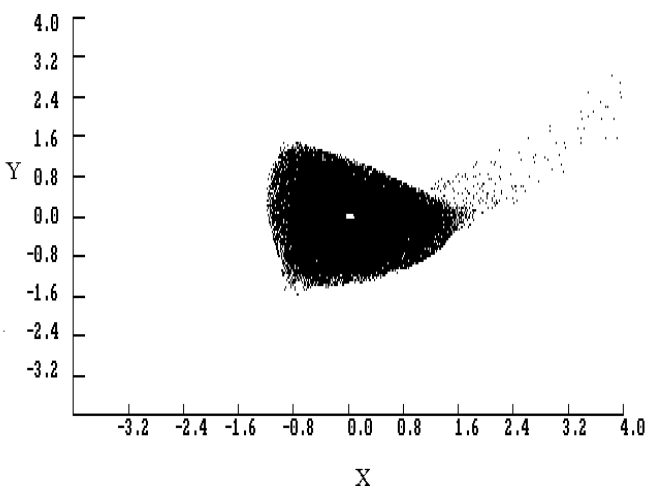

Figure 3 Extraction Separatrixes, RF Dipole On

4 BEAM TESTS

Bunched Slow Extraction from the AGS was tested quickly with one of the two buckets filled in the Booster. The kickers for transferring beam between the Booster and the AGS were miss-timed to only both be on when the one bunch was transferred. With only one RF bucket filled beam was accelerated, left bunched on flat top, extracted and targeted. The arrival time of secondaries from the target was compared to the time of a rotation clock signal from the RF system that divides the RF by eight (buckets) starting with the first injected bunch. Secondaries show an RMS bunch widths of ~6 nano-seconds occurring every 3 micro-seconds. There was a few parts in 10^5 "leakage" between buckets as seen in Fig 4.

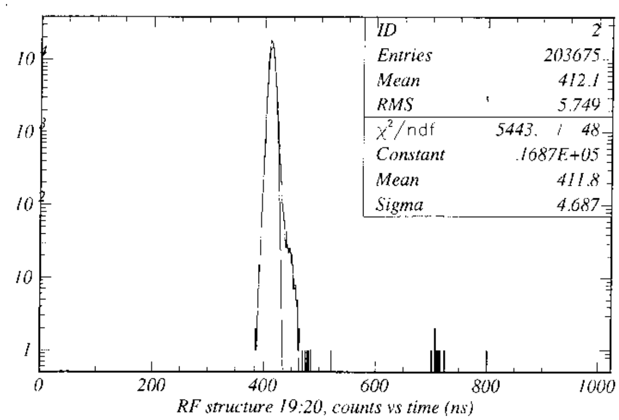

Figure 4 Single Mini-Bunch - Data

This small amount of beam trickled into the adjacent bucket during the zero $\dot{B}$ time on the AGS magnet reserved for injection. This leakage may be stemmed by better RF control and shortening the time beam is stored here, also if there remains beam in the adjacent bucket after this effort, this bucket will be emptied by extracting it with the Fast Beam kicker during acceleration.

Beam tests for 10 micro-second structure may be done this summer using the tune meter kicker

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