Studies of Particle Motions During Slow Resonant Extraction

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(Dated: August 22, 2014)

Abstract

We present here

I. INTRODUCTION

II. PHASESPACE CORRECTIONS WITH DYNAMIC BUMPS

In the previous paper [1], we discussed that a septum foil plane should be aligned with particles' x' coordinates when they are entering the field region of the septum. This alignment of the septum foil plane along with x''s should be optimized to reduce particle losses due to crossing the plane from outside to inside the field region or vice versa. However, particles' angle coordinates at the entrance of the first septum are changing in time when a separatrix is being squeezed during an extraction period. Fig. 1 shows a normalized phase space of unstable particles for 4 different stages of extractions. Streams of unstable particles on the rightmost separatrix branch are entering the septum field region by crossing the vertical line (color:purple). As the separatrix is squeezed, these branch arms are moving downward. If the septum foil plane is aligned with Therefore, the alignment is only valid for a few turns at the beginning, and there will be misalignments of the septum foil plane with respect to x''s later. These result in increasing of beam losses in time. Moreover, one can expect that an angular spread of extracted particles at the entrance of the septum will be large.

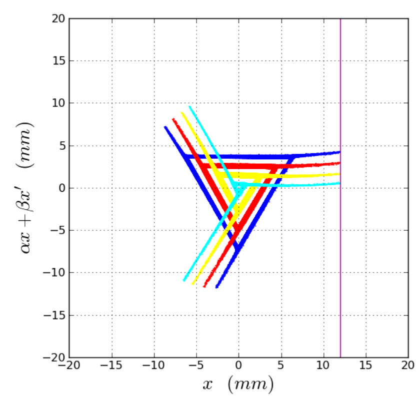


FIG. 1. Normalized phase space plots of particles around separatrices.

In order to mitigate these effects, orbit corrections are applied using 4 dynamic angle bumps. Fig. 2 shows a schematic drawing of 4 dynamic bump locations in the extraction beamline. 2 bumps are located at the upstream of septa, and the other 2 are at the downstream. Upstream bumps kick particles so that outgoing particles' angles are aligned at the

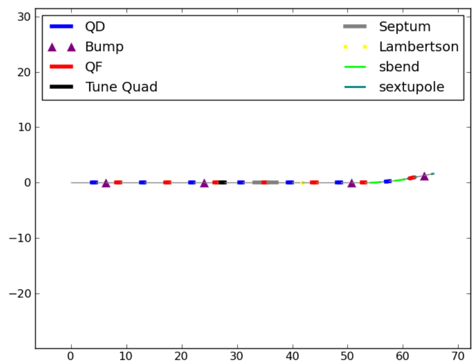


FIG. 2. Schematic drawing of the external beamline with 4 dynamic bumps.

entrance end of the first septum during the entire extraction period. Then, downstream bumps will kick them back to original positions.

Using simple Bump strengths, θ_i for $i = 1, 2, 3, 4$, are given by

$$\begin{aligned} \theta_1(t) &= \sqrt{\frac{\beta_s}{\beta_1}} \frac{\sin(\psi_s - \psi_2)}{\sin(\psi_2 - \psi_1)} \left(-\Delta x'_s(t)\right), & \theta_2(t) &= \sqrt{\frac{\beta_s}{\beta_2}} \frac{\sin(\psi_s - \psi_1)}{\sin(\psi_2 - \psi_1)} \Delta x'_s(t), \\ \theta_3(t) &= \sqrt{\frac{\beta_s}{\beta_3}} \frac{\sin(\psi_s - \psi_4)}{\sin(\psi_4 - \psi_3)} \Delta x'_s(t), & \theta_4(t) &= \sqrt{\frac{\beta_s}{\beta_4}} \frac{\sin(\psi_s - \psi_3)}{\sin(\psi_4 - \psi_3)} \left(-\Delta x'_s(t)\right), \end{aligned} \tag{1}$$

where β_i's are betatron functions at the septum(s) and bumps($1, 2, 3, 4$), ψ_i's are betatron phase advances, and $\Delta x'_s(t)$ is required changes of angle coordinates at the septum as a function of time. Fig. 3 shows changes of bump strengths in time. Since particles' angles are aligned to the initial angle, bump strengths are zero at the beginning and are maximum at the end of extraction.

Before applying dynamic bumps, phase space of circulating particles are centered at the origin as shown in Fig. 1. As the separatrix is squeezed by increaing tune-quad strengths, phase space areas are shrinking in time and outgoing branches.

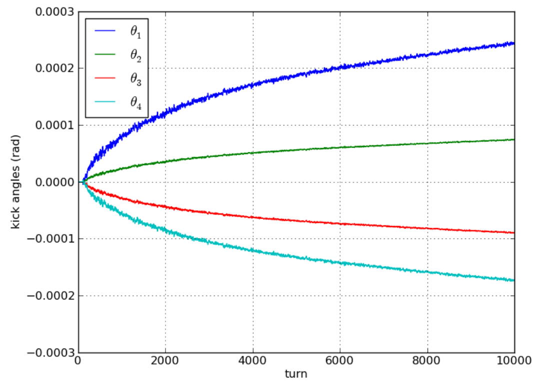
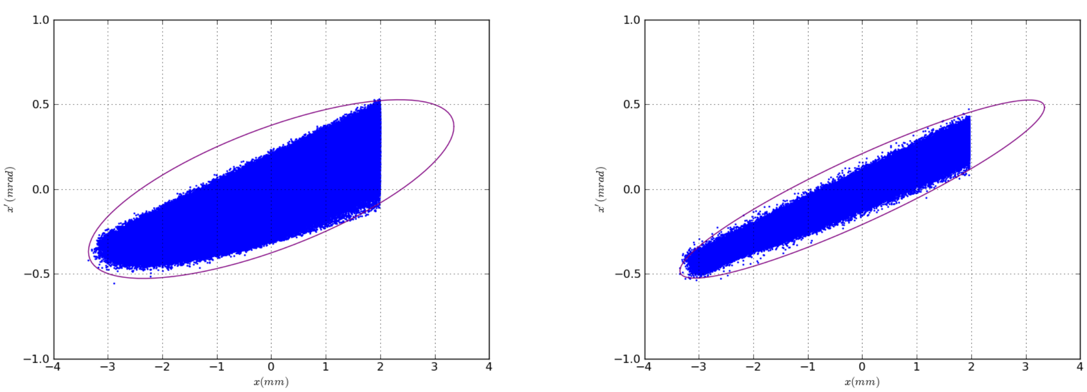


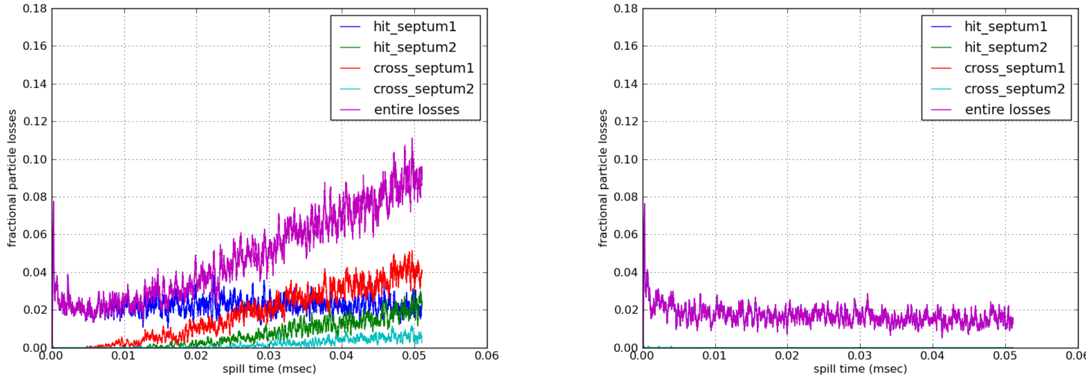
FIG. 3. Strength changes of dynamic bumps in time.



(a)Without Dynamic Bumps

(b)With Dynamic Bumps

FIG. 4. Footprints of extracted particles with/without dynamic bumps.



(a)Without Dynamic Bumps

(b)With Dynamic Bumps

FIG. 5. Particle losses in time with/without dynamic bumps.

III. TRACKING OF PARTICLE LOSSES

IV. EMITTANCE GROWTH RATES WITH RFKO BEAM HEATING

V. RFKO BEAM DISTRIBUTION FUNCTION

VI. ARRIVAL TIME DISTRIBUTION

VII. CONCLUSION

VIII. ACKNOWLEDGMENTS

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[1] C.S. Park, "Tracking Simulation of the Third-Integer Resonant Extraction for the Fermilab Mu2e Experiment," submitted to PRST-AB.