Slow Deceleration of Anti-Proton Beam in the MI:

RF Specifications

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During Run II we are planning to recycle the unused anti-proton beam from the Tevatron by decelerating it in the MI, storing and cooling the beam in the Recycler Ring [1] till the beam is needed for next collider shots. There are two main deceleration schemes [2] in the MI. Of the two schemes, the slow deceleration scheme has important advantages of no beam loss and nearly no emittance growth during the deceleration. Here, I outline the rf specifications for the slow deceleration scheme.

The anti-proton beam in the Tevatron will be decelerated to 150 GeV and at the same time the MI will be ramped to 150 GeV flat-top with empty 53 MHz rf bucket matched to the Tevatron beam bunches. At this time, one or more bunches will be transferred to the MI buckets. This will be a bucket-to-bucket transfer. Then the beam in the MI is quickly decelerated using 53MHz (h=588) rf system to 25 GeV back-proch (slightly above the MI transition energy of 20.49 GeV). At 25 GeV the bunches are transferred to rf buckets made up of ~83% of 2.5 MHz (h=28) rf wave and ~17% of 5 MHz (h=56) rf wave. Bunches are rotated for a quarter synchrotron period. At this stage the h=56 is turned off and h=28 rf bucket is matched to the bunch. The bunch length is shrunk adiabatically for ~1.9 sec by increasing the bucket height. At the end of the cycle, rf voltage is reduced and bucket is matched for further deceleration from 25 GeV to 8.889 GeV using only h=28 system.

The specifications required for the 53 MHz and 2.5 MHz rf systems for beam deceleration in MI using this scheme are described below. A typical slow deceleration ramp used in MI during deceleration is shown in Fig.1. The Table I gives the ramp parameters used in Fig. 1. Figure 2 shows the ESME simulated phase space distributions of the beam particle at various stages of deceleration of the beam in the MI obtained using the ramp. The beam loading is not a concern most of the time because the bunch intensity will be in the range of 40- 50E9. However, during the 25 GeV rf manipulation, the Vrf(28) (minimum) ~250 Volts. During this time the beam loading may pose some problem suggesting that we have to make additional efforts on developing beam loading compensation for 2.5 MHz system. In Table II rf specifications are listed at various stages of the deceleration cycle, along with the tolerance limits. All these specifications are established by ESME calculations.

References:

[1] The Fermilab Recycler Ring Technical Design Report, Gerry Jackson, FERMILAB – TM– 1991 (1996).

[2] Beam Intensity limits in the MI through the transition with a normal phase jump scheme, C.M. Bhat and J. Maclachlan, Proceeding of the 1997 PAC conference, Vancouver, B. C., Canada (1997) page 1590.

Table I: Deceleration MI Ramp for the above scenario:

t (sec)	p (GeV/c)	pdot (GeV/c/sec)	
0	150	0.0	*** Begin
0.01	150	0.0	*** Hold for 0.01 sec
0.6767	140	-30	*** decelerate with h=588
1.3017	115	-50	*** decelerate with h=588
1.7632	85	-80	*** decelerate with h=588
3.2632	25	0.0	*** Rotate the bunch with h=28
3.3132	25	0.0	Rotate the bunch with h=28+56
3.3132	25	0.0	Match the bunch with h=28+56
4.8022	25	0.0	shrink the bunch with h=28+56
11.202	17	-2.5	*** decelerate with h=28
15.031	8.96	-1.7	*** decelerate with h=28
15.114	8.889	0.0	*** decelerate with h=28

Table II: RF requirements for the Deceleration

1. Deceleration from 150GeV to 25 GeV:

   h = 588

   Vrf = 0-4 MV

   dt ~ 2.2 sec (?)

   At 25 GeV back porch, the h=588 system should be turned off and beam should be transferred to the h=28+56 rf buckets.

2. Bunch Rotation at 25 GeV :
   h = 28 + 56
   Vrf(h=28) = 50 +/- 5 kV, phis(h=28) = 180 +/- 1 deg
   Vrf(h=56) = 10 +/- 1 kV, phis(h=56) = 360 +/- 1 deg
   dt = 0.050 +/- 0.005 sec
   At the end of the bunch rotation the h=56 system will be turned off.

3. Match the bunch at 25 GeV :
   h = 28
   Vrf(h=28) = 250 +/- 15 V, phis(h=28) = 180 +/- 1 deg
   dt = 0.1 +/- 0.01 msec

4. Shrink the Bunch at 25 GeV adiabatically :
   h = 28
   Vrf(h=28) = (250 +/- 15)V to (50+/-5)kV, phis(h=28) = 180 +/- 1 deg
   dt = 1.89 +/- 0.15 sec

5. Deceleration from 25 GeV to 8.889 GeV

h = 28

Vrf(h=28) = (10+/-4)kV to (50+/-5) kV

and

270deg > phis(h=28) > 180 above 20.49 GeV (transition energy)

360deg > phis(h=28) > 270 below 20.49 GeV (transition energy)

dt = 7 +/- 1.0 sec

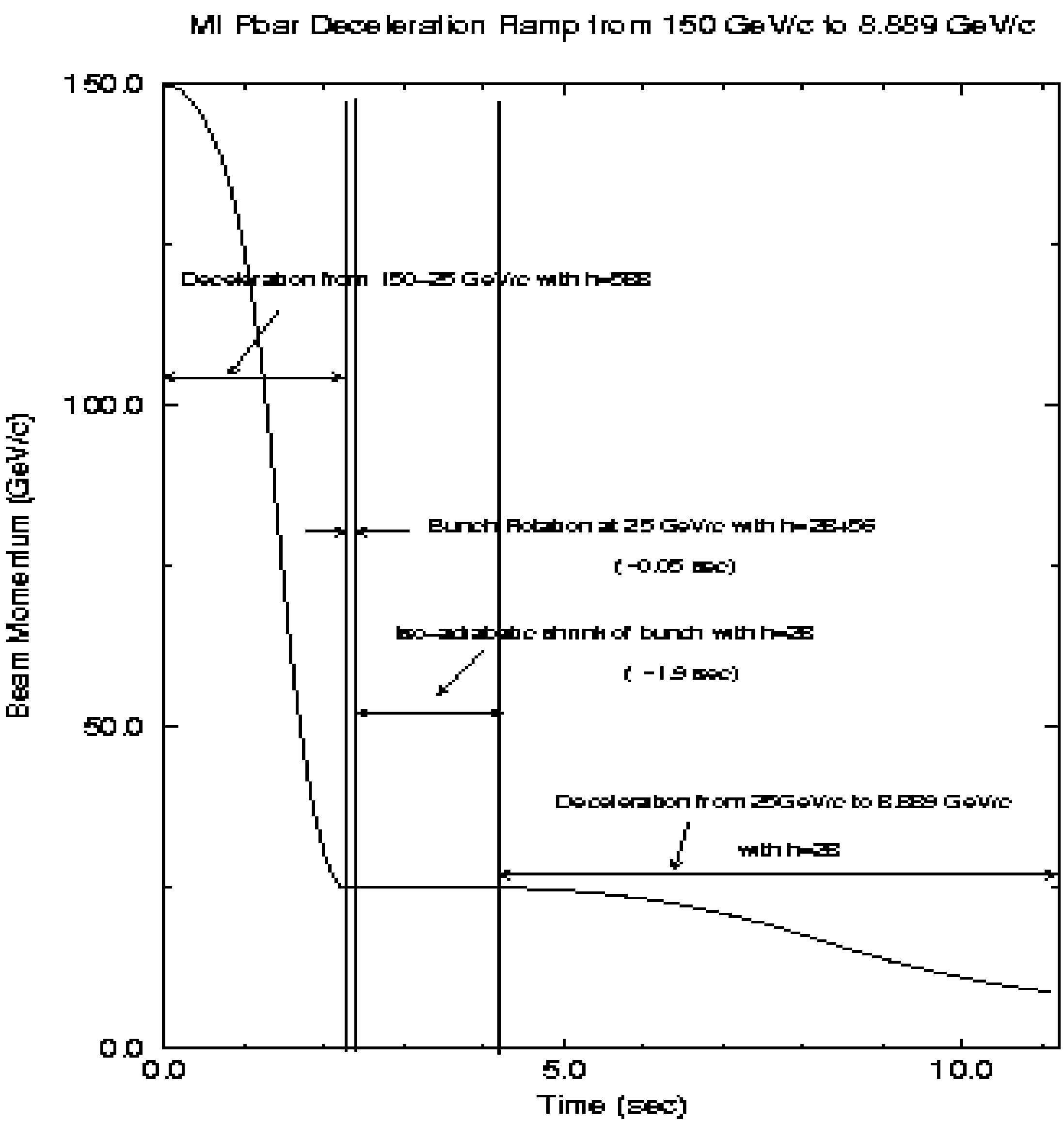

Figure 1: A typical slow deceleration ramp in the MI. Various RF manipulations to be carried out are also shown.

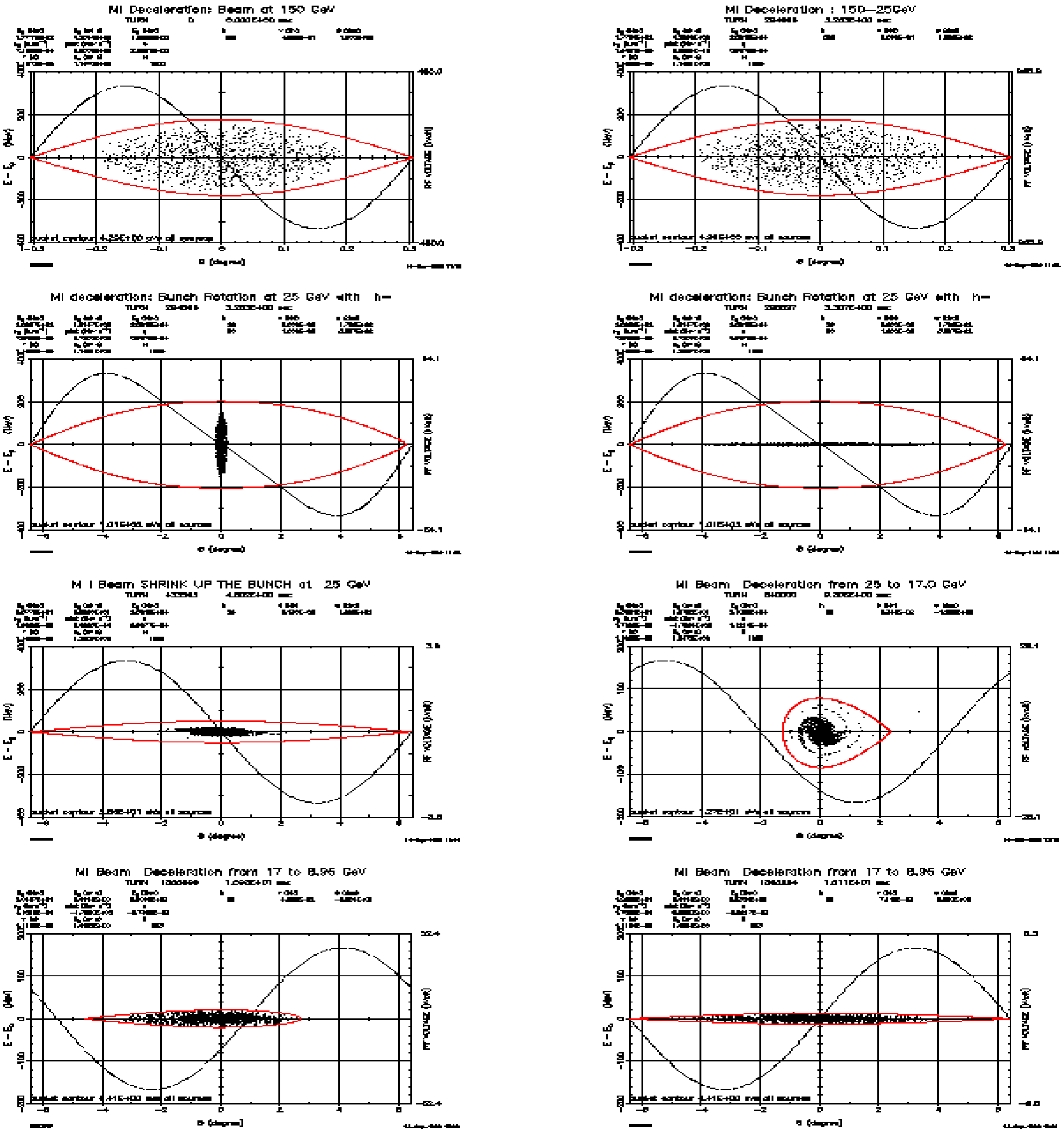

Figure 2: ESME simulation results for the first deceleration scenario. All of them represent the phase phase distributioin of the beam particles in the rf buckets. The plots are as follows: left to right, 1)beam vunch at 150 GeV, 2) at 25 GeV, 3) bunch captured in 2.5 MHz rf bucket with Vrf(28) = 60kV, 4) bunch rotation in 2.5 MHz rf bucket 5) bunch after shrinking, 6) bunch deceleration from 25 GeV to 8 GeV, 7) decelerated bunch at 17 GeV and 8) bunch at 8.9GeV, just before injection into the RR. The Initial longitudinal emittance was 3 eV-sec.