LONGITUDINAL MATCHING BETWEEN THE LEB AND THE MEB FOR THE SSC

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Abstract

Longitudinal matching of bunches between the Low Energy Booster (LEB) and the Medium Energy Booster (MEB), if done by controlling the rf voltage alone, requires too low a voltage to be practicable. Here we investigate the possibility of matching dynamically by bunch rotation in the longitudinal phase space at the end of the LEB cycle. First, the bunches are sheared by an rf phase-jump into the unstable region. Next, the bunch is matched by jumping back to the synchronous phase. Sensitivity to errors in phase and timing are studied.

1 Introduction

The limit on the space charge tune shift at injection determines the bunch parameters at injection. For a given longitudinal emittance this determines the required rf voltage during the fill time for the MEB; another consideration in the choice of rf voltage is that the synchrotron tune is not an integer multiple of 60 Hz[1]. If we do not want tumbling and further increase in the longitudinal emittance in the MEB, the bunch in the LEB at extraction must conform to the bucket in the MEB. One way to do this, of course, is to match the LEB bucket at extraction to the MEB bucket at injection. For the present parameters this requires too low an rf voltage in the LEB. There are three possible options. We may blow up the longitudinal emittance in the LEB and thus make higher rf voltages in the MEB and the LEB acceptable. This has a detrimental effect if we wish to choose Griffin's scheme for transition crossing[2]. Alternatively, we may let the bunch tumble in the MEB and let the emittance increase. In addition to the above disadvantage for transition crossing this may cause dilution of transverse emittance during the fill time. The alternative presented here is to match the bunch dynamically.

2 Matching Requirements

Let η be the slip factor, V the rf voltage and h the harmonic number. Then—since the synchronous phase in the LEB at extraction and in the MEB at injection are zero —the buckets will be matched if $\eta h/V$ has the same value for two machines. Table 1 gives the various parameters for the two machines based on the particle momentum of 12 GeV/c.

Parameter	The LEB	The MEB
Harmonic Number	108	792
Transition Gamma	21.26	24.0
Slip Factor	0.003864	0.004340
Rf Voltage	80 kV	170 kV
Matching Voltage	20.64 kV	170 kV
	80 kV	659 kV

Table 1: Matching Parameters

The matching value of 20.64 kV in the LEB corresponding to the value of 170 kV in the MEB is deemed too low to be practicable and the value of 80 kV is chosen. The matching value of 659 kV in the MEB corresponding to the value of 80 kV in the LEB will exceed the space charge tune shift limit in the MEB. However, the higher value is acceptable if we increase the LEB longitudinal emittance. Since the synchronous phase is zero, for a given emittance the bunch height scales as $V^{\frac{1}{4}}$ while bunch width scales as $V^{-\frac{1}{4}}$. Therefore we need to double the longitudinal emittance from the nominal value of .038 eV s (95%). Here, however, we match the rms spreads of the bunch as described in the next section.

3 Matching Mechanism

The idea is to jump the phase near the end of the LEB cycle to the unstable synchronous phase and back to the stable synchronous phase. While at the unstable phase, the bunch shears. Then after some time we bring back the phase to the stable point. The timings have to be adjusted such that at the end of the LEB cycle a proper bunch is obtained. It is, of course, not possible to obtain an exactly matching bunch. We, however, match the rms values of bunch height and width to that of the matched bunch. The scaling of the height and width mentioned above requires that the bunch width/height be increased/decreased by a

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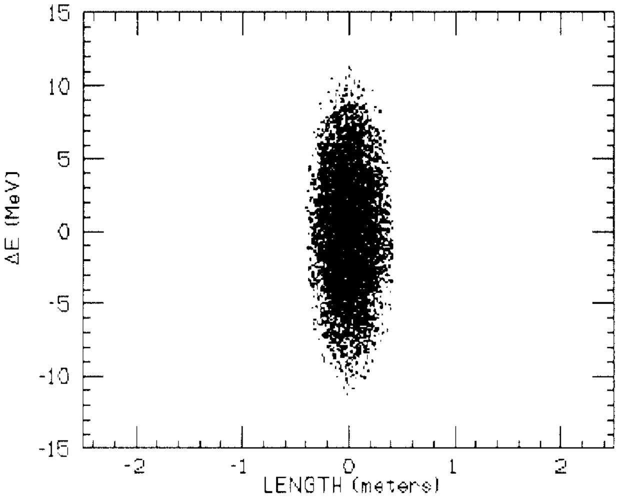

Figure 1: Phase Space Distribution at 49.5ms

factor of the fourth root of the ratio of matching voltage to the actual voltage in the LEB; this factor is 1.404 for the present case.

The idea of jumping between stable and unstable synchronous points is essential only if the synchronous energy curve needs to be traced with a good accuracy. Since the process is executed at the end of the cycle, the energy gain during this process is negligible and could be compensated by other adjustments. This allows, as shown below, a considerable degree of latitude in the magnitude of the phase jump.

4 The Simulation Results

The LEB is a 10 Hz resonant machine with an injection momentum of 1.219 GeV/c and extraction momentum of 12 GeV/c. The procedure requires .5 ms. At 49.5 ms a phase jump to the unstable synchronous point was initiated. The phase was brought to the stable synchronous point at 49.65 ms. Figure 1 shows the bunch at 49.5 ms when the phase was changed to the unstable synchronous point. At 49.65 ms the phase was shifted back to the stable point. Figure 2 shows the bunch at 49.65 ms. Figure 3 shows the bunch at 50 ms, the end of the LEB cycle.

Simulations with phase jump at points other than the synchronous point, with the same timing as above, were also investigated. In Case 1 the phase was kept at the stable synchronous point through out. For Case 2 the phase was altered between stable and unstable synchronous points respectively. In Case 3 the phase jump was 180 and then back to the synchronous point. The most practicable case, Case 4, is probably where the phase is locked at 180 degrees between 49.5 ms and 49.65 ms and there after until the end of the cycle the phase is locked at 0 degrees.

The extraction timing has to be decided much before the last 0.5 ms. Hence, it will not be possible to control

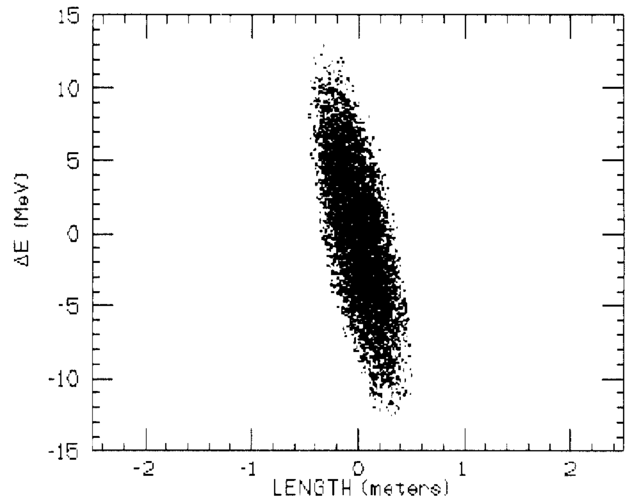

Figure 2: Phase Space Distribution at 49.65ms

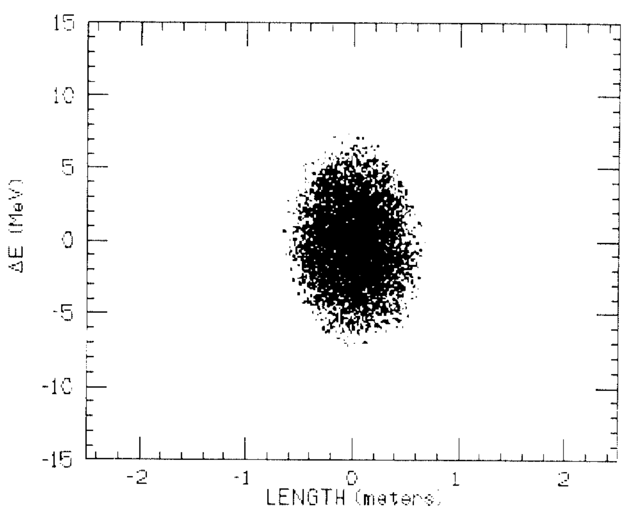

Figure 3: Phase Space Distribution at 50ms

Description	Δ E (rms) MeV	Length (rms) m
Case-1	3.564	0.1575
Case-2	2.568	.2337
Case-3	2.569	.2337
Case-4	2.566	.2345
Case-5	2.573	.2333

Table 2: Bunch at Extraction

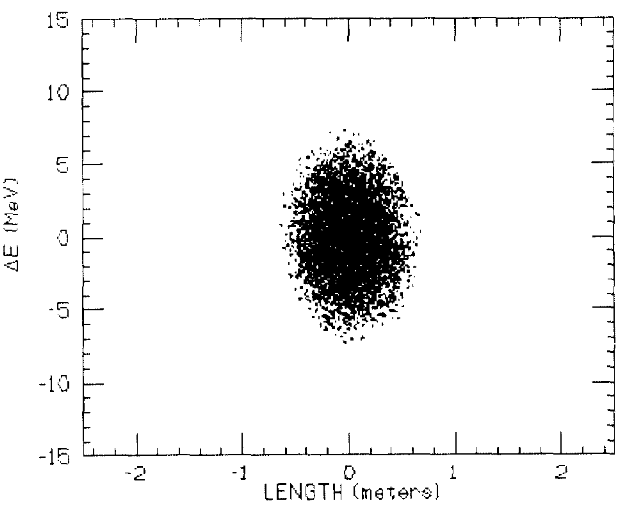

Figure 4: Case: advanced extraction

the extraction time such that the bunch has shaped properly. The extraction time itself will be known quite well in advance. Therefore a matching procedure can be triggered with a good accuracy with respect to the extraction time. The extraction itself may be some what advanced or delayed. To study this effect we have simulated the last case where the extraction is at 49.9 ms and the matching process starts at 49.4 ms. The phase jump scheme is the same as in Case 4. Figure 4 shows the bunch at extraction; the bunch looks very much like the bunch in Figure 3.

In Table 2 we give the rms length and height for the bunch at extraction for the above cases. The bunches, with 6984 particles, have been tracked through the entire LEB cycle. The simulations include space charge effects; we have used the code ESME[3].

5 Discussion

From Table 2 we observe that the rms deviation of the particle distribution in phase space about the mean is insignificantly altered by errors in the phase control. Changes in the rms value due to errors in the extraction timing of the order of .1 ms are also insignificant provided that the matching process is timed properly. From the operational point of view, Case 4, where the phase is locked at 180° and 0°, may be the best procedure. This scheme, however, will introduce an error of about 2 MeV in the synchronous energy. This systematic error can be compensated either by adjusting the injection momentum of the MEB or, the extraction momentum of the LEB. The matching scheme here is to match the rms values of the bunch to that of matched bunch. Further tracking of the bunch in the MEB shows this to be adequate; that is, tumbling of the bunch in the MEB bucket and growth in the longitudinal emittance is not observed[4]. Thus we conclude that the procedure outlined here is adequate.

Acknowledgement

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