CYCLING AND INJECTION IMPROVEMENTS ON THE ESRF BOOSTER

J.P.Perrine, G.Schmidt, U.Weinrich, ESRF, Grenoble, France

ABSTRACT

The ESRF injector complex achieves the storage ring injection energy of 6 GeV with a linear accelerator as a 165 MeV preinjector and a fast cycling booster synchrotron [1]. During the last two and a half years several improvements ahve been made leading to an increased transfer efficiency and stability of the whole injector system. Additionally new possibilities like storing beam for a long time in different booster cycles were achieved.

1 GUN CATHODE 352 MHZ MODULATION

During booster injection a part of the electrons arriving from the LINAC are lost due to the longitudinal structure. The electron bunches are formed by the 3 GHz operation frequency of the LINAC whereas the booster RF is operating at 352 MHz. To improve the situation a 352 MHz signal from the booster RF master source was applied to the cathode of the electron gun to give the electron bunches an additional 352 component.

The signal from the master source was amplified by a pulsed power amplifier with a gain of 55 dB. Due to the negative polarization of the cathode an isolated pulse transformer is used to transfer the pulse to the cathode.

The original gun modulator was changed to accept this mode of operation. Choke inductances were added and the cathode load had to be rebuilt.

The switching between the different modes of gun operation is made by an opto-coupler driven RF relay.

As a consequence of these modifications the booster injection efficiency was increased. For the same booster intensity it is now possible to operate the LINAC with smaller electron intensity with the effect of gain in energy and pulse shape stability.

2 WORK DONE ON THE BOOSTER

2.1 Main Parameter

length	299.62 m
structure	FODO with missing dipole
number of cells	39
number of dipoles	66
dipole bending radius	21.996 m
number of foc. sext.	24
number of defoc. sext.	30
maximum energy	6 GeV
repetition rate	10 Hz (white circuit)
nominal hor. tune	11.8
nominal ver. tune	9.8
6 GeV emittance	1.2e-07 m rad
6 GeV energy spread	1.1e-03
mom. comp. factor	9.6e-03

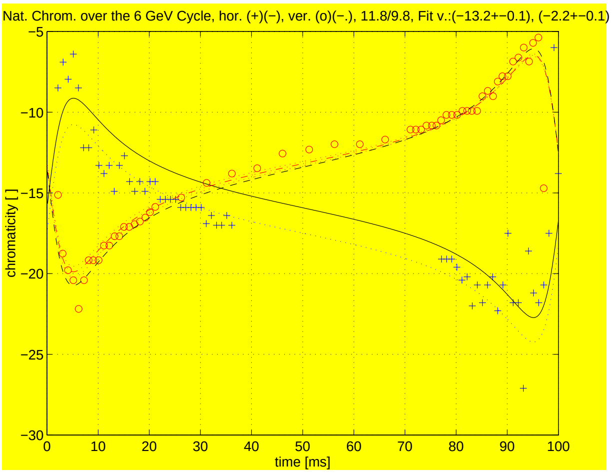
2.2 Alignment

The booster closed orbit length is fixed via the RF frequency which, in itself , is determined by the storage ring closed orbit correction. The booster lattice was found to be too short resulting in a systematic horizontal closed orbit offset all along the machine. Lengthening by 7 mm reduced the average closed orbit offset in the booster from 1.1 mm down to 0.1 mm. Since then it has been possible to inject into the booster and ramp up to 6 GeV without any steerer on.

A second improvement was achieved by fully analysing the magnet position measurements. It turned out that several small quadrupole misalignments acted in phase on the closed orbit distortions. By correcting only three to four quadrupole positions per plane the uncorrected closed orbit could be improved by a factor of two. A set of software tools is now available to predict from quadrupole position measurements a few number of quadrupoles guaranteeing a maximum uncorrected closed orbit distortion of less than four mm.

2.3 *Chromaticity Measurements*

The total chromaticity in the booster is a sum of three components [1]. The first part is the natural chromaticity due to the lattice. The second part concerns eddy current induced sextupole fields in the dipole chambers due to the fast 10 Hz cycle. The chromaticity correction is then performed with two sextupole circuits. To achieve good correction along the cycle of the natural chromaticities, the eddy current induced chromaticities and the chromaticity correction from the sextupoles were measured [2].



2.4 *Working point studies*

The booster tunes were measured and optimized along the full cycle [2]. It was found that the optimum injection efficiency into the booster can be achieved with a working point on the coupling resonance. For standard operation the vertical and the horizontal tunes are then separated during acceleration leading to a natural coupling of less than 1 % at extraction energy.

It was also possible to achieve a tune stability of 0.05 along a full cycle.

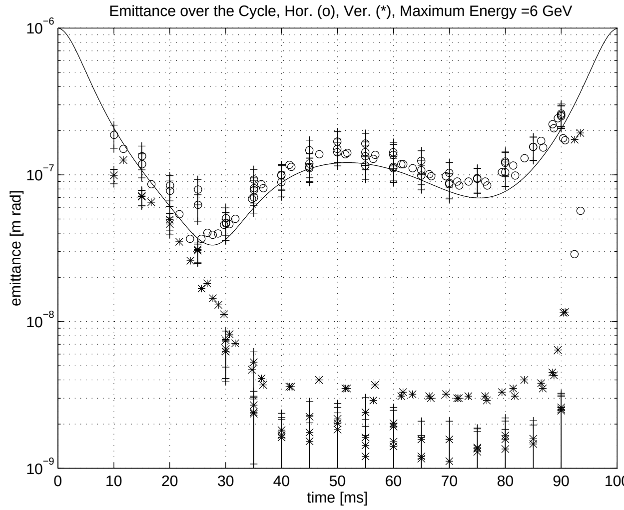
Flexibility in the working point was also proven. Several working points were successfully tested with a horizontal tune between 10.2 and 12.2 and a vertical one between 9.2 and 10.2.

Extraction out of the decelerating part at energies from 1 to 6 GeV was used for low energy studies on the storage ring [3].

Decelerating beam down to 85 MeV was proven as well as acceleration to different maximum energies.

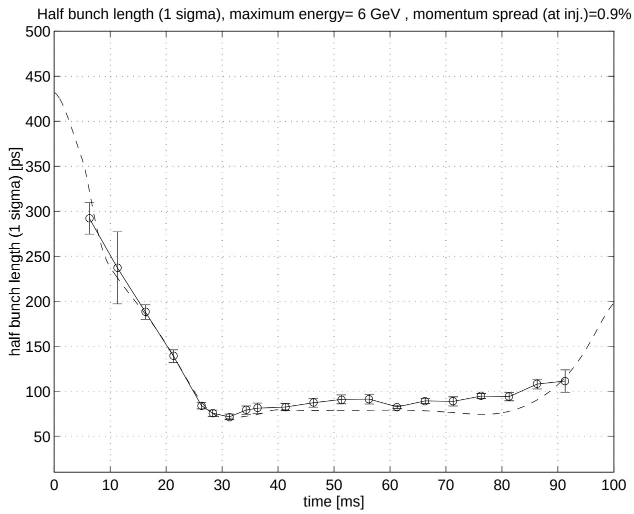
2.5 *Emittance Measurements*

The emittances were measured with a visible light monitor [2]. The emittances were followed up all through the different cycles. The emittance resolution of the light monitor is in the range of a few nm rad. It was demonstrated that the horizontal emittance damps adiabatically down until the synchrotron radiation equilibrium becomes dominant at high energies. The vertical emittance continues the damping until it reaches the few nm rad range at high energies.



2.6 *Bunch length Measurements*

The bunch length development along the cycle was measured with a streak camera [2]. The behavior is as expected along the standard operation cycle. At high energies the one sigma bunch lengths are between 65 and 80 ps.



3 ACHIEVED IMPROVEMENTS

3.1 *Injection into the booster*

The LINAC bunches are now longitudinally matched to the booster buckets. This results together with an improved energy stability, smaller energy spread and coupling of the tunes in a stable injection efficiency of about 90 %. This is an improvement of about a factor of two compared to former conditions.

The bunch purity in the booster in single bunch mode is now about 0.1 % due to the optimized gun modulator.

An injection with only 85 MeV electrons arriving from the LINAC was run in user service mode for several days with a good injection efficiency. This means that the booster is capable of boosting routinely the electron energy by a factor of more than 70 !

3.2 Extraction out of the booster

Due to the small coupling at extraction and the stable closed orbit the extraction efficiency now routinely exceeds 95 %. The overall transfer efficiency from the booster to the storage ring is now about 85 %.

The flexibility of the extraction was proven when the storage ring was served for low energy studies. Beam transfer was achieved for 1, 1.5, 2, 3, 4, 5 and 6 GeV [3]. This was either reached by extracting out of the decelerating part of the booster cycle or by varying the maximum energy of the booster cycle.

3.3 Beam Storage

The most exciting result of the different work is that it is now possible to store beam for several ten thousands of booster cycles [2]. This was achieved by the optimized alignment, the stable tunes and a well made chromaticity correction. Beam was successfully stored in cycles with maximum energy of 1, 2, 3, 4, 5 and 6 GeV.

1 minute of lifetime was reached in the standard 6 GeV cycle. In a 1 GeV cycle about 30 minutes of lifetime can be achieved. The longest lifetimes until now was achieved in a 3 GeV cycle leading to about 1 hour lifetime.

To achieve higher intensities a second injection kicker was installed in the booster allowing accumulation. In several cycles accumulation with the 165 MeV LINAC pulse was proven. The highest intensity achieved until now is 10 mA. The limitation was outgassing in the cavities - a limit which can be pushed by careful conditioning. Nevertheless, in most of the cycles the accumulation saturation occurred until now at intensities similar to one shot on axis injection.

ACKNOWLEDGMENT

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REFERENCES

[1] ESRF FOUNDATION PHASE REPORT, 1987.

[2] G. Schmidt, Beam Dynamic Studies in Cycling and Storage mode of the ESRF fast Cycling Synchrotron; Thesis at the University of Dortmund, 1996

[3] G. Schmidt, How to gain in emittance for the injection into the 1 GeV storage ring, 6/95-inj technical note, machine division, ESRF