PLAN B

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1. Introduction

We propose conversion of the CESR storage ring to a low emittance configuration with 10 xray beam lines in L0, including 5 undulator straights and 5 hard bend lines. In order to achieve the low emittance in the CESR tunnel we split the bending magnets and add nearly 200 quadrupoles and sexutpoles. In addition to the five zero dispersion straights for undulators in L0 there is a sixth 5m long zero dispersion straight for RF. We assume that the electron beam circulates counterclockwise (as it does now) so that the x-rays are directed to the east.

We describe the machine magnet layout and lattice including the layout of x-ray beam lines, dynamic aperture, RF requirements and injection, and estimate the cost of the conversion of the storage ring.

2. Lattice & Layout

The arc cell is very simple, consisting of a single 3.287m bend and a pair each of horizontally and vertically focusing quadrupoles. The magnet layout and lattice functions of the cell are shown in Figure 1. The optics through the L0 region is designed with 6 zero dispersion straights. One of the straights is 5m long with space for 3 RF cavities. The remaining 5 can be laid out to accommodate 5 - 2m undulators as in Figures 2 and 4, or with one 5m undulator, two 1m undulators, and two 2m undulators as in Figures 5 and 6. The optical functions for the entire ring are Figure 3.

3. Parameters

The ring parameters are summarized in Table 1.

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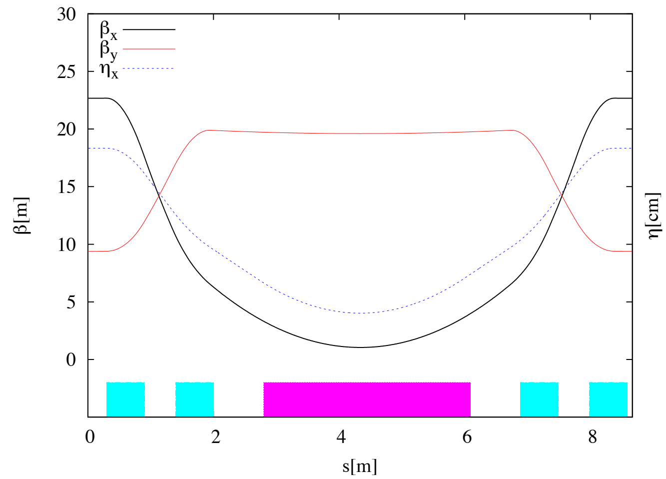

FIGURE 1. Arc cell.

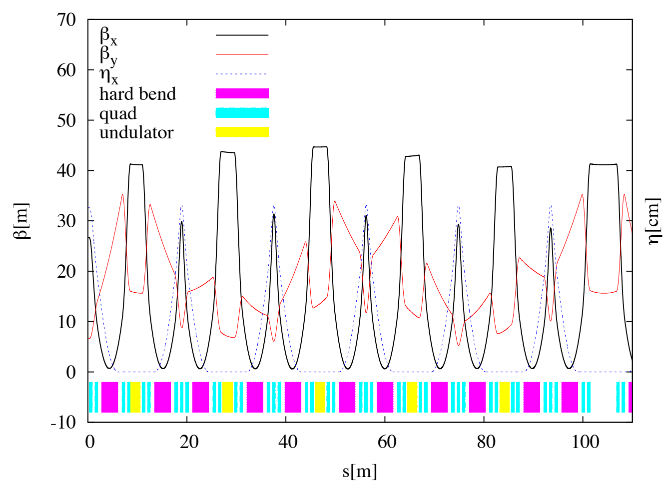

FIGURE 2. L0 region layout and optics with 5 2m undulator straights.

4. X-RAY BEAM LINES

The layout of x-ray beam lines is shown in Figure 4 for the 5 2m undulator configuration and in Figure 6 in the configuration with one 5m undulator etc.

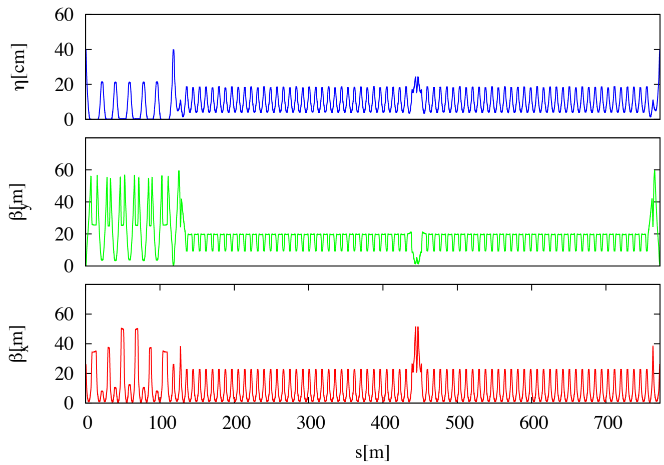

FIGURE 3. Ring optics. The zero corresponds to the start of the insertion region in the west. (Electrons travel west to east.)

TABLE 1. Storage Ring Parameters

Horizontal Emittance[nm]	1.3
Vertical Emittance [pm]	5
Horizontal tune	36.57
Vertical tune	8.63
Synchrotron tune	0.01
Horizontal chromaticity	-84.5
Vertical chromaticity	-17.5
Beam Energy[GeV]	5
Energy spread [%]	0.64
RF Voltage [MV]	3
Bunch length [mm]	3.2
Energy Loss/turn [MeV]	1.2
Bunch Current [mA]	0.25
Beam Current [mA]	150
Number Bunches	600
RF Power [kW]	200
Circumference [m]	768

5. Dynamic Aperture

In view of the very strong horizontal focusing and small horizontal dispersion, the sextupoles are strong and dynamic aperture tight. It is nevertheless adequate for good lifetime as shown in Figure 7. It is at least 10 times the equilibrium beam size.

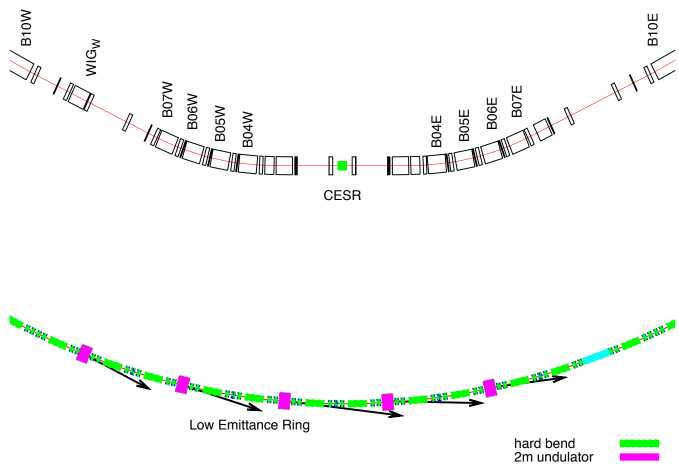

FIGURE 4. Proposed layout of x-ray undulator and hard bend beam lines in the bottom plot. Arrows indicate the orientation of the 5 undulator beam lines. The bending radius of the dipoles is 44m so they are perhaps suitable hard bend source. The existing magnet configuration is shown in the upper plot.

6. RF

A total RF voltage of 3MV at 500MHz gives a bunch length of 3.2mm and a synchrotron tune of 0.01. At 150mA, total radiated power is 180kW. This can easily be achieved with two CESR cavities. Whether there is adequate over voltage awaits a calculation of the quantum lifetime.

7. Injection

The amplitude of the injected bunch with respect to the stored beam is determined by the size of the injected bunch, the thickness of the vacuum chamber wall at the closest approach of injected beam to stored beam, and the clearance of the stored beam from the wall of the CESR vacuum chamber. We estimate that

$$A_{amp} = \sigma_{inj} + t_{wall} + 4\sigma_{stored} = 1\text{mm} + 3\text{mm} + 0.5\text{mm} = 4.5\text{mm} = 31\sigma_{stored}$$

which is just outside of the dynamic aperture. Off axis injection will be inefficient. Alternatively we propose on-axis injection where each bunch is a single shot from the injector. If we place a bunch in every other RF bucket, then there is space for 600 bunches. A beam current of 150mA corresponds to a bunch current of 0.25mA or 1.6×10^9 electrons per bunch. We have filled positrons at 100 mA/minute into 20 bunches. That corresponds to

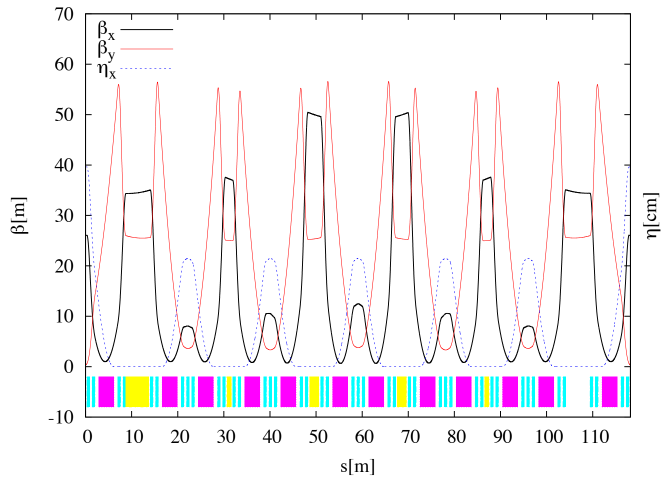

Figure 5. L0 region layout and optics with 5m undulator straight

Figure 6. Arrows indicate the orientation of the 5 undulator beam lines. There is one 5m, two 2m, and two 1m undulators.

1.4×10^{-3}mA/bunch. The efficiency for converting electrons to positions is about 1/1000.

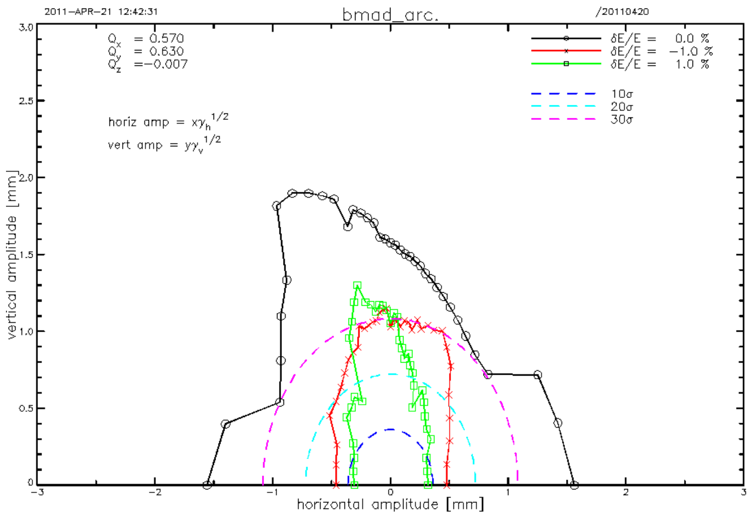

FIGURE 7. Dynamic aperture.

Therefore, we conclude that there is an equivalent current of 1.4mA per bunch of electrons on the converter target. Evidently the gun can easily deliver the requisite 1.6×10^9 electrons. All that remains is to accelerate it in the synchrotron and store it in CESR. Feedback in the synch. A new kicker to get into CESR. On axis injection into CESR requires a single kick to compensate the angle of the incoming beam as it crosses the closed orbit. If we suppose that the incoming beam exits the septum (that comes at the end of the transfer line), at $A_x = 50$mm from the center of the CESR vacuum chamber, and further that geometric mean of the horizontal β at the injection point and the kicker is $\beta_h = 30$m, then the required kick angle is $\theta = \frac{A_x}{\beta} = \frac{0.05}{30} = 1.67$mrad. The kick generated by stripline with strip separation d, length l and beam energy E is

$$\theta = \frac{e\Delta V l}{dE} = (V[kV])(l[m])$$

If we assume that the spacing of the stripline electrodes is $l = 10$cm and the beam energy is 5GeV, and the voltage is applied in equal but opposite sign to the two plates, the

$$\theta = \frac{2 \times 10^3 1}{5 \times 10^9 0.1} = 4 \times 10^{-3}\text{mrad}(V[kV])(l[m])$$

Therefore we need $Vl = \frac{1.67}{0.004} = 400[kV][m]$

At ATF, an FID pulser has been demonstrated to generate ±10kV with few ns width. Figure 8 shows the measured angular deflection in a bunch timing scan of a strip-line kicker installed in ATF[1]. Each stripline is 30cm long, corresponding to the duration of the pulse. If $V = 10$kV, then $l = 40$m. That's a lot of kickers. The manufacturer of the ATF pulser advertises a 50kV equivalent[2]. If such a pulser actually exists then $l = 8$ and at 30cm/kicker, implies 26 pulser-kicker units, a manageable number.

Alternatively, we might consider the kicker designed for the ERL[3]

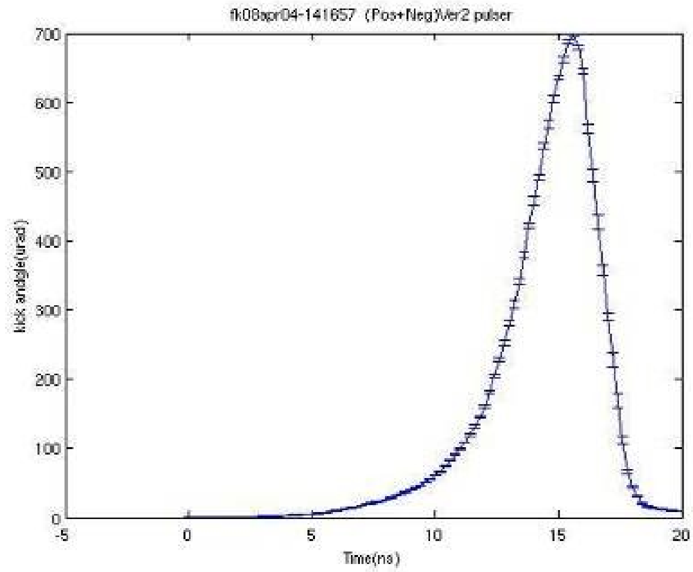

Figure 8. Measured kick vs time for ATF kicker

8. Dynamic Aperture

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References

[1] J. Urakawa, INFN, Dampng Ring Technical Baseline Review, "http://ilcagenda.linearcollider.org/getFile.py/access?contribId=6&resId=1&materialId=slides&confId=5183", 7-July-2011.
[2] http://www.fidtechnology.com/
[3] ERL kicker