Linac-Ring Colliders with High Disruption Parameters – a First Test of Principle*

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ABSTRACT

Linac-Ring colliders are considered as one approach to an asymmetric B-factory. The beam-beam effect in a superconducting linac is different from the beam-beam effect in a storage ring or linear collider[1]. The electron beam is guided through the positron beam and disrupted. The aim of this paper is to discuss possible test facilities to study this effect.

INTRODUCTION

Recently several papers were published discussing the features of linac-ring colliders. In order to obtain luminosities of the order of 10^{34} and higher, the (positron) storage ring is operated at its linear tune shift limit of 0.05. In a practical design the number of particles in the positron bunch is 3 orders of magnitude higher than the electron bunch from the linac. As a result the disruption parameter of the electrons

$$D_e = \frac{2r_0 N_p \sigma_{pz}}{\gamma_e \sigma_{p,x} \sigma_{p,y}} \tag{1}$$

can be about 300, and the main concern is the stability of the positron beam in the storage ring. The consequences for the electron beam are shown in Figure 1. The electrons oscillate through the positron bunch and are disrupted. In several papers,[1][2][3] it is shown that under certain circumstances the beam-beam limit can be affected by position and intensity fluctuations (random walk limit). The severity of this effect depends highly on the assumed spectrum of the random noise.

It has been proposed to test the high disruption interaction with a superconducting linac and a low energy positron storage ring. In this paper, a preliminary design of two test facilities is presented. One is a 500 MeV positron storage ring, and the other is an 85 MeV positron storage ring.

DESIGN GOALS

The electron beam from CEBAF can have up to 10^9 e^- per bunch with a normalized emittance of $10^{-6}\pi$ m-rad. The two storage rings were designed in such a way that the equilibrium transverse emittance is as small as possible to produce a high electron disruption. The lattice chosen for these two rings is the FODO cell lattice which has been widely used in the design of storage rings for its superior dynamic aperture characteristics and the ease of local chromatic correction. The design work is based on the DIMAD[4] and ZAP[5] computer codes.

500 MeV STORAGE RING

The bending angle for each dipole in the 500 MeV ring is 9°. With two dipoles for each FODO cell, altogether twenty cells are needed. The minimum emittance is obtained at 144° phase advance per cell. In order to avoid excessively strong quadrupoles and sextupoles, betatron phase advances per cell of 117° for β_x and 58.5° for β_y were chosen. Some of the DIMAD output data are used in the ZAP code to find the effects of intrabeam scattering. The parameters of the 500 MeV ring are:

500 MeV Storage Ring

Energy	500 MeV
Circumference	26 m
Revolution frequency (including straight section)	10 MHz
RF	1500 MHz
Harmonic number	150
Trans. damping time	7.7 msec
Equil. emittance	10^{-8} rad-m
Equil. energy spread	4×10^{-3}
Momentum comp. factor	0.0282
Energy loss/turn	0.48 KeV
Bending angle	0.05π rad
RF voltage	800 KV
Synchrotron frequency	1.1 MHz
Tune	0.0094
Equil. bunch length	1 cm
Num. of e^+ in bunch	4×10^{11}
Max. current	1.3 A
e^- disruption D_e	116
Touschek lifetime	0.22 h

Assuming an equal-energy collision, the maximum electron disruption parameter D_e for the 500 MeV ring is 116. A schematic layout of the ring is presented in Figure 2.

85 MeV STORAGE RING

The bending angle of a dipole for the 85 MeV storage ring is 22.5°. Altogether 8 cells are needed. The betatron phase advances per cell are again 117° for β_x and 58.5° for β_y. The size of the ring is pretty small, with a diameter of about 2.44 meter. Again, some of the DIMAD output data are used in ZAP to compute the effects of intrabeam scattering.

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85 MeV Storage Ring

Energy	85 MeV
Circumference	7.68 m
Revolution frequency (including straight section)	20 MHz
RF	800 MHz
Harmonic number	40
Trans. damping time	400 msec
Equil. emittance	10^{-7} rad-m
Equil. energy spread	4×10^{-3}
Momentum comp. factor	0.1576
Energy loss/turn	1.2 eV
Bending angle/dipole	0.125π rad
Bending radius	0.46 m
Bending field	6.19 kG
RF voltage	800 kV
Synchrotron frequency	3.8 MHz
Tune	0.097
Equil. bunch length	1 cm
Num. of e^+ in a bunch	1.5×10^{11}
Max. current	0.5 A
e^- disruption D_e	24
Touschek lifetime	0.83 h

If the beams have equal energy, the maximum electron disruption parameter D_e is 24. A schematic layout of the 85 MeV ring is shown in Figure 3.

INTERACTION REGION FOR THE 85 MeV STORAGE RING (Equal Energy Case)

The interaction region for the 85 MeV ring consists of a missing-magnet FODO cell dispersion suppressor and a two-dimensional telescopic system.[6] The total length of the interaction region is 0.8 m, and the β function at the arc is reduced to 1 cm in both planes at the interaction point (IP). An electric septum is used to separate the electron and positron beams, and a magnetic septum bends the positron beam back to the ring. The angle of separation is 1.72°, and the length is:[7]

$$l = \frac{p\beta}{E}\tan\theta, \tag{2}$$

where β is v/c. With a maximum value of $E = 20$ kV/cm and $\theta = 1.72°$, the length of the septum for the 85 MeV storage ring is calculated to be 1.275 m. The lattice for the interaction region is shown in Figure 4.

INTERACTION REGION FOR THE 85 MeV STORAGE RING (Unequal Energy Case)

In order to achieve a higher disruption it was suggested that the 85 MeV stored positron beam collides with a 20 MeV electron beam from the linac. The electron disruption parameter in this case is 100. Based on the previous 85 MeV storage ring design, the interaction region is shown in Figure 5. A dipole and a magnetic septum are used to separate the two beams.

The bending angle θ of a dipole of length l in a uniform magnetic field B is given by

$$\sin(\frac{\theta}{2}) = \frac{lBe}{2p}, \tag{3}$$

which forms the basis for the separation of the two beams. The dipole B1 is set to bend the 85 MeV positrons approaching the interaction point (IP) −3°, whereas the same dipole bends the 20 MeV electron beam leaving the IP by −12.75°. To insure a clear separation of the two beams, an additional magnetic septum gives the electron beam a further bend of −5.25° before it travels to the electron beam line. The total length of the interaction region for the positron storage ring is 2.15 meters and the length of the interaction region is 60 cm. The net bending angle for the positron beam is 22.5° taking into account B2 and B3, bending 1.5° and 24°, respectively. The two dipoles after the magnetic septum bend the electron beam by 6° and 24°, respectively.

As a summary, the β function and the dispersion functions η and η' for the whole 85 MeV ring (including the insertion for RF cavity) for unequal-energy collision are presented in Figure 6 and 7.

CONCLUSION

For the design of a Linac-Ring collider, preliminary first order optics for two storage rings of 500 MeV and 85 MeV are presented in this paper. The parameters of the rings seem well suited for the proposed experiment.

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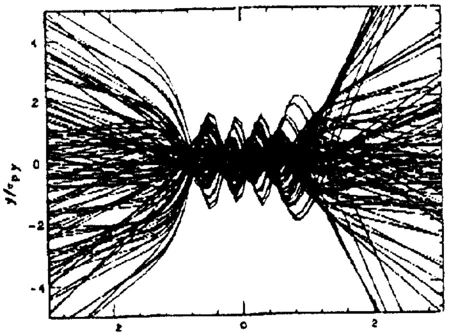
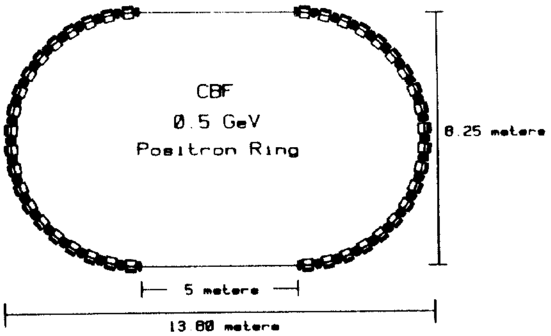
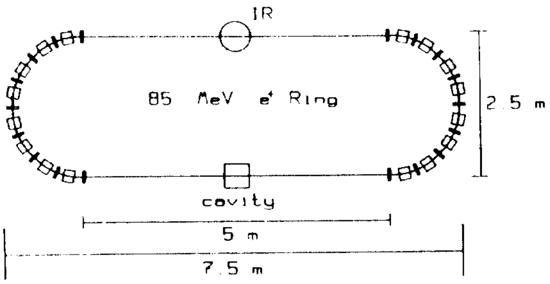


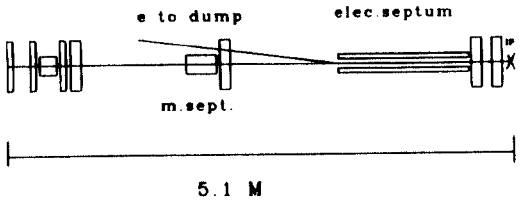
1. Disruption of the e^- beam by the $e+$ beam stored in the storage ring



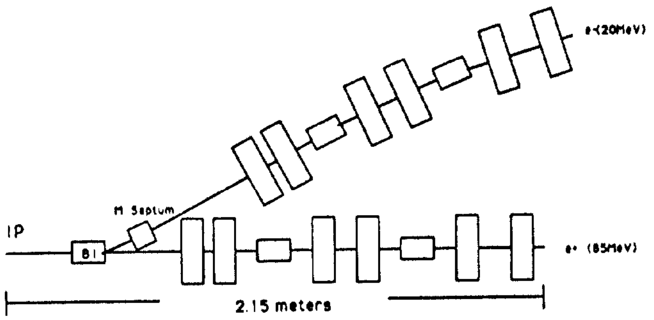
2. Schematic layout of the 500 MeV storage ring



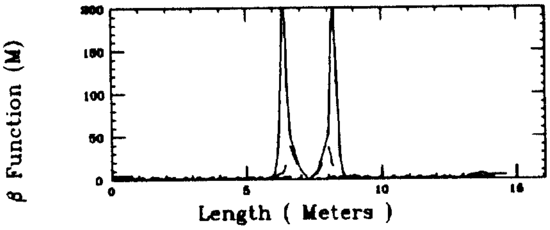
3. Schematic layout of the 85 MeV storage ring



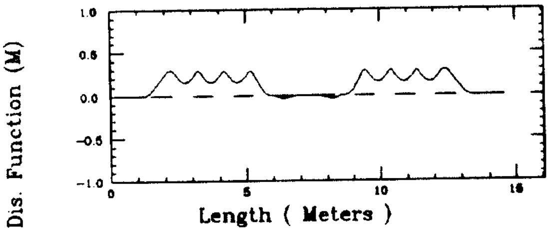
4. Interaction region of the 85 MeV storage ring



5. Asymmetric interaction region of the 85 MeV storage ring



6. β function for the 85 MeV storage ring



7. Dispersion for the 85 MeV storage ring