Apiary B Factory Lattice Design*

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Abstract
The Apiary B Factory is a proposed high-intensity electron-positron collider. This paper will present the lattice design for this facility, which envisions two rings with unequal energies in the PEP tunnel. The design has many interesting optical and geometrical features due to the needs to conform to the existing tunnel, and to achieve the necessary emittances, damping times and vacuum. Existing hardware is used to a maximum extent.

I. Introduction

The Apiary B Factory consists of two equal-sized rings in the PEP tunnel with unequal energies, offset vertically except in the IR straight section where the beams are brought into head-on collision. The rings retain the general configuration of PEP, with a geometric 6-fold periodicity. The Apiary lattice resembles that of PEP in the arcs but is quite different in the straight sections. The design of the high and low energy rings (HER and LER) differ, especially in the straight sections, but in the arcs and in some of the straight sections the quadrupoles are directly above and below each other.

For each ring, all of the arcs are identical except that in the HER the dispersion suppressors of four of them are tuned to create a beat in the dispersion function through the arc. This 'mismatched' dispersion function serves to adjust the emittance of the HER to the desired value. Each arc consists of 16 cells; twelve cells in the center have the same length, two at each end are slightly longer.

The main differences between the sextants of the rings are occasioned by the different types of long straight sections, each of which has its orbit functions matched to those of the arcs at the boundaries.

Having touched on the common features of the rings, we will now discuss their individual features.

II. Low Energy Ring

A. Arcs

The center nine cells are regular 80° phase FODO cells, and the remaining 3-1/2 cells at each end are the dispersion suppressors. The phase was chosen to achieve a suitable momentum compaction and to make an achromat of the center nine cells. The dipoles are displaced upstream from the center of each half cell to give space to extract the synchrotron radiation.

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Table I. Apiary Lattice Parameters

	Low Energy Ring	High Energy Ring	
Energy	3.1	9	GeV
Circumference	2199.32	2199.32	m
Vertical ring separation	0.895	m	
Collision mode		head on	
Luminosity		3 E 33	cm-2 s-1
Current	2.14	1.48	A
Emittance, epsx/epsy	96.5/3.9	48.2/1.9	nm-rad
Betas @ IP, $\beta x/\beta y$	37.5/1.5	75/3.0	cm
Bunch separation	1.26	1.26	m
Damping time, τ_ϵ	18.4	18.4	ms
Number straight sections	6	6	
Arc length	245.553	245.553	m
Straight section length	121	121	m
Cell length - normal	15.125	15.125	m
Cell length - suppressor	16.0125	16.0125	m
Cell phase advance	80	60	deg

B. Normal Straight Sections

The LER has two normal sextants whose long straight sections consist of eight normal-length cells without dipoles, with phase advances of 90° in their normal state. However the central seven quadrupoles can be tuned with four independent power supplies to change the global tunes while retaining the overall matching to the arcs. RF cavities can also be installed in these straight sections.

C. Injection Straight Section

One long straight section has a 40 m long drift space for injection, with βx = 80 m at the center.

D. Wiggler Straight Sections

Two straight sections are configured to house wiggler magnets. These are used to adjust the emittance and damping time of the LER. They are placed on doglegs that direct the radiation away from the ring magnets.

E. IR Straight Section

The LER beamline is brought into colinearity with that of the HER at the IP by a combination of vertical and horizontal bends. The first separation of the beams leaving the IP is horizontal, and is done with a permanent-magnet dipole 20 cm from the IP and a triplet, whose quadrupoles are suitably offset to increase the separation. These are adjusted primarily to focus the low-energy beam. The triplet is followed by a septum quadrupole that focuses the HER beam only. Next the LER beamline is bent upwards by a septum dipole. The remainder of the IR straight section contains bends to bring the beamline to the arc at the right position and direction, and quadrupoles to match the beta functions and dispersion. The horizontal bending is antisymmetric about the IP, producing an S-bend that is favorable for masking.

III. HIGH ENERGY RING

A. Arcs

The center twelve cells are of a regular FODO structure with 60° phase advance per cell in each plane. The dipoles are centered between the QF and QD quadrupoles. At each end of each arc are 2-cell dispersion suppressors, each cell having close to 90° phase advance. In four of the arcs the dispersion suppressors are tuned so as to create a beat in the dispersion function through those arcs.

B. Straight Sections

The normal straight sections are filled with a regular FODO lattice. The length and phase advance of these cells is the same as that in the arcs. In two of the straights the FODO lattice is tunable so as to adjust the overall betatron tune of the HER. In this case the center cells of the straight are tuned together and three quadrupoles at each end are adjusted to effect the match to the dispersion suppressor. The injection straight section is identical to that in the LER.

C. Collision Straight Section

The collision straight of the HER, being in a plane, is much simpler than that of the LER. The common permanent magnet triplet provides some focusing for the high energy beam but the main interaction region focusing is provided by a doublet placed as close as possible to the IP. The first quadrupole of this doublet has to be of a septum design so as to not interfere with the low energy beam. The dispersion function caused by the separation of the beams is controlled by two strings of very weak dipoles and another quadrupole doublet completes the focusing into the dispersion suppressor. A pair of weak dipoles adjust the angle of the beam as it enters the arc.

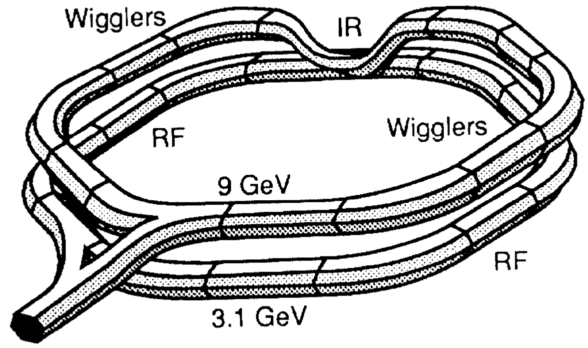

Fig. 1. Schematic of the two rings. The Low Energy Ring (LER) is elevated 0.895 m above the High Energy Ring (HER) which lies in the horizontal plane. The beams are brought into collision by a combination of vertical and horizontal bends. Wiggler magnets in some long straight sections serve to adjust the damping time and emittance of the LER.

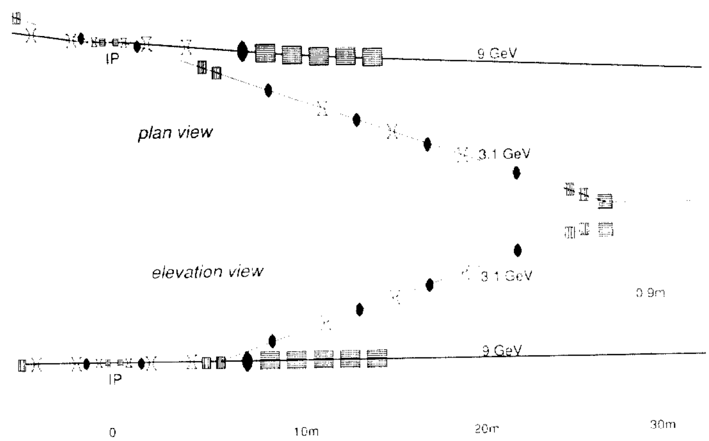

Fig. 2. Magnetic separation of the high and low energy beams. The initial horizontal separation is accomplished by a combination of a permanent magnet dipole followed by three offset permanent magnet quadrupoles. Separation is achieved by exploiting the energy difference between the beams. Once the beams are separated a system of vertically bending dipoles elevates the LER above the HER.

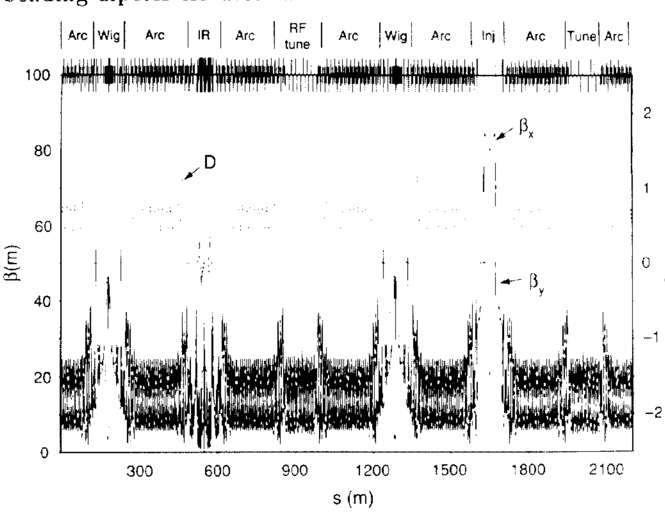

Fig. 3. Layout and optics functions for the LER. The lattice for the full ring is shown, starting and finishing at mid-arc in region 11.

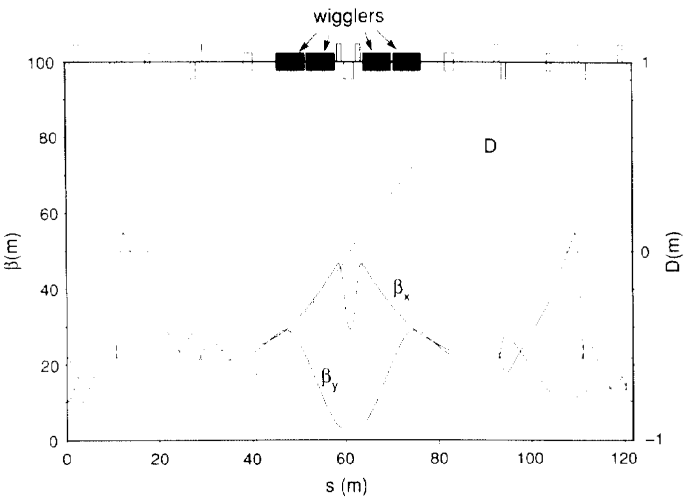

Fig. 4. Layout and optics functions for the wiggler straight sections of the LER. In conjunction with the dispersion function D, and its derivative, the wigglers increase the emittance of the low-energy beam. In addition, the wigglers can decrease the damping time of the low-energy beam so that it is equal to that of the high-energy beam.

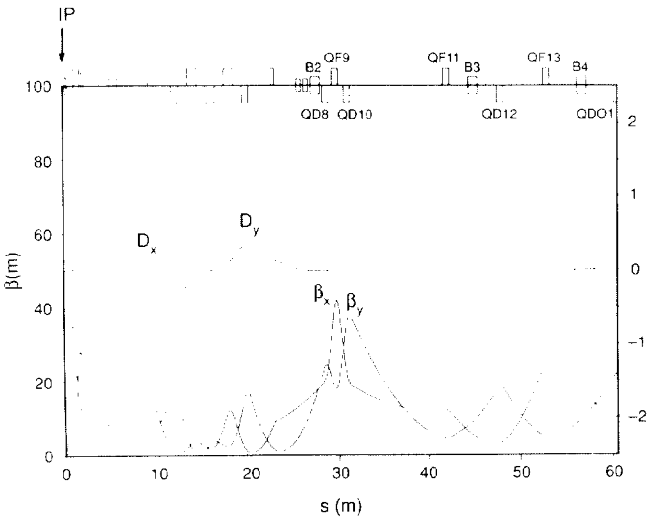

Fig. 5. Layout and optics functions for the right-hand half of the IR straight section of the LER. The quadrupoles QD8 through QF13 match the beta functions into the dispersion suppressor.

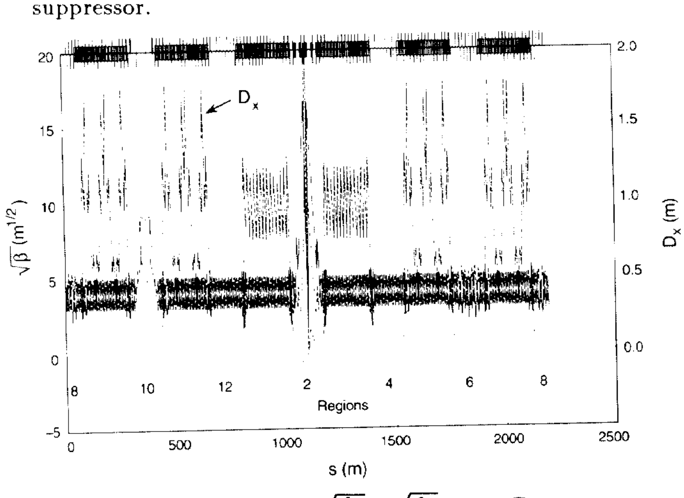

Fig. 6. Lattice functions $\sqrt{\beta_x}$, $\sqrt{\beta_y}$, and D_x (horizontal dispersion function) for the complete HER, starting at region 8. The collision region (region 2) is shown in the center of the figure.

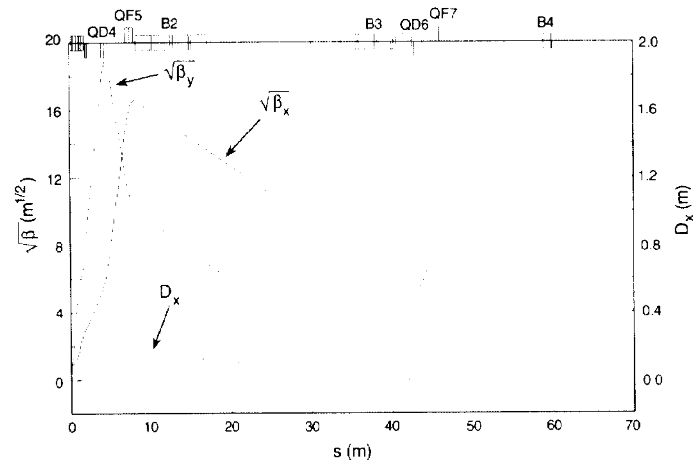

Fig. 7. Lattice functions for the first 60 m of the IR straight section of the HER. The B2 and B3 dipoles match the dispersion function to zero.

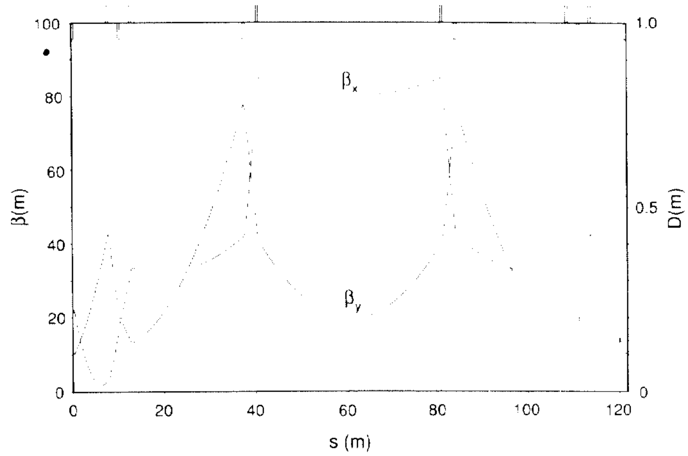

Fig. 8. Layout and optics functions for the injection straight section of the LER. The injection point is at the center of the figure, in the middle of the long straight section. Beta functions in this region are easily adjustable to match injection requirements.