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CESR-B, Upgrading the CESR Facility to B-Factory Capability[1]

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Abstract

With the design goal of $3 \times 10^{33} cm^{-2} s^{-1}$ luminosity a concept design for an upgrade to the CESR electron-positron facility has been created[1]. Capable of operating with unequal beam energies of 8 and 3.5 GeV, the two ring machine will also be operable at equal beam energies up to 6 GeV per beam with minor changes to the interaction region. The design provides for extraction of synchrotron radiation from both electron and positron beams. Parameters and major features of the design are presented.[1]

INTRODUCTION

The possibility for determining if the KM mechanism is responsible for CP violation has inspired the development of this high luminosity upgrade design. The luminosity required is about 15 times the present CESR luminosity and must be achieved with beams of unequal energies so that B mesons created at the $\Upsilon(4S)$ resonance are lorentz boosted in the lab frame. Both of these requirements result in need for the two independent rings. Collision of electron beams of unequal energies has not been attempted heretofore, bringing with it the concern that the achievable beam-beam parameter may be limited to values lower than achieved in equal energy machines. Operating experience over the past 25 years indicates that radiation damping decrement or radiation fluctuation induced energy spread may both be important variables[2]. Accordingly the ring for the low energy beam is designed to keep the damping decrement and energy spread of the low energy beam equal to or greater than that for current CESR at 5.3 GeV. A beam-beam parameter equal to present CESR, i.e. 0.03, with the same optical parameters at the crossing point has been adopted. The desired luminosity increase is achieved by increasing the number of bunches to 230 and crossing beams at a small angle to avoid parasitic beam crossings. Having chosen the single bunch parameters to be the same as currently achieved, the challenge lies in reducing the ring impedance, to assure beam stability, improving the ring vacuum pumping speeds to handle the high gas loads and devising an IR geometry and optics that controls beam engendered detector background to acceptable occupancy levels. In addition the crossing angle needs to be compensated by the use of crab crossing[3].

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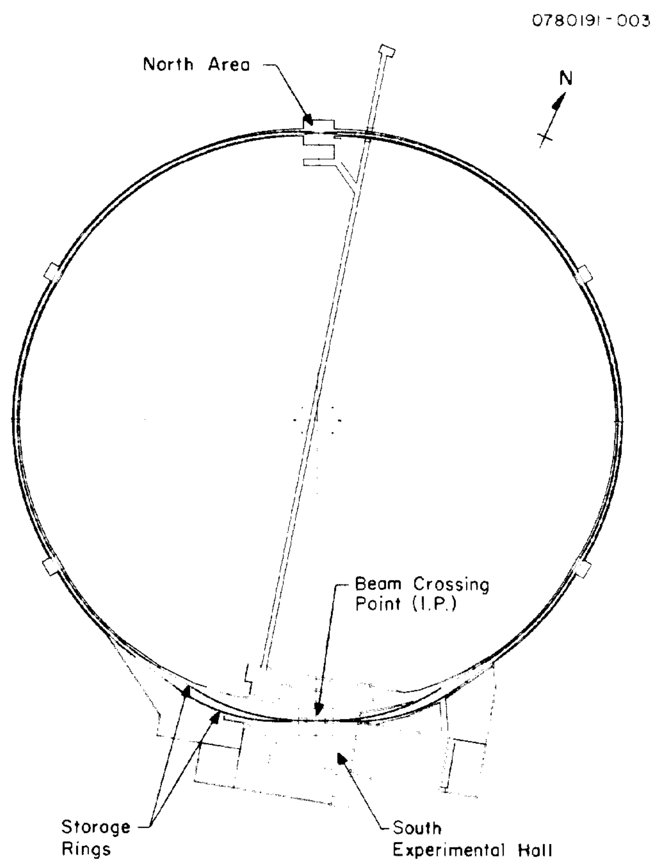

Figure 1: Overall view of the CESR-B accelerators.

LAYOUT OF THE FACILITY AND PARAMETERS

Figure 1 shows the overall layout of the current facility with the new, low energy, ring added. both high energy and low energy beams lie in the same plane with collisions arranged in the south experimental hall. A collisionless cross over is arranged in the north.

Figure 2 shows the cell structure in the arcs.

The interaction region layout is shown in Figure 3. Note that the beams approach from the outside, throwing their synchrotron radiation focus outward thereby easing background control.

Compensation of the detector solenoid is done locally and is common to both beams as is the superconducting final focusing quad. for both beams. In this way control of the IR optics of the two beams is kept flexible while minimizing the needed crossing angle.

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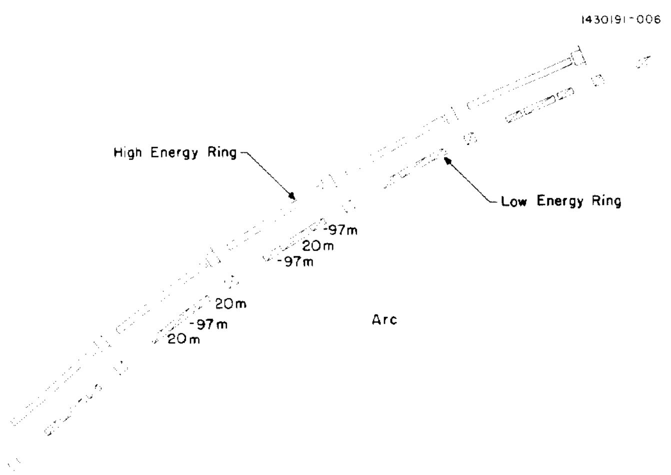

Figure 2: In the tunnel arcs, the two rings are separated by 1.5 m. Note the triplet of dipole magnets between every pair of quadrupoles in the low energy ring. The center magnet is 1.88 m long and is straddled by magnets that are 0.94 m in length. In the cells in which the longer magnet has a field corresponding to a bending radius of 20 m (-97.8 m), the shorter magnets have fields corresponding to a bending radius of -97.8 m (20 m). For operation at 5.3 GeV all three elements have a bending radius of 50.3 m.

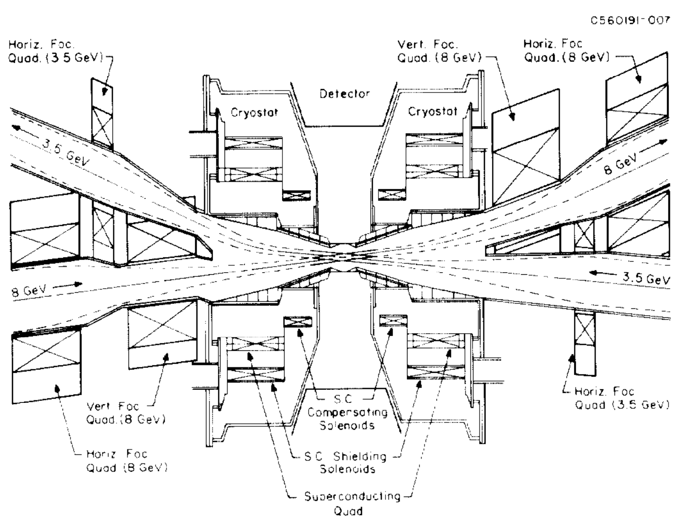

Figure 3: The accelerator layout and beam stay clear envelopes from the crossing point to just beyond the point where the beams enter their separate channels.

Table 1: The accelerator parameters for the asymmetric CESR-B option.

Parameter	HER	HER & LER	LER
E [GeV] (beam energy)	8.0		3.5
$\mathcal{L}[10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ (lumin.)		3.0	
$(\xi/\beta_V^*)(1+r)[\mathrm{m}^{-1}]$ (lumi. coeff.)		2.0	
n_b (number of bunches)		230	
r (aspsect ratio)		0.015	
$N[10^{11}]$ (e/bunch)	0.60		1.37
I_{tot} [A] (beam current)	0.87		1.98
Circumference [m]		764.84	
β_H^* [m] (IP foc, param.)		1.0	
β_V^* [cm]		1.5	
θ_c [mrad] (crossing angle)		12.0	
σ_L [cm] (bunch length)		1.0	
$\epsilon_H[10^{-7}\mathrm{m}]$ (emittance)		1.3	
$\alpha[10^{-2}]$ (momentum compac.)	0.84		1.1
η^* [m] (dispersion at IP)		0.0	
Q_s (synchrotron tune)		0.085	
Q_H (betatron tune)	12.7		11.7
$\sigma_E/E[10^{-4}]$ (energy spread)	8.4		6.5
U_o [MeV/ref] (SR loss)	5.23		0.76
P_{SR} [MW] (SR power)	4.5		1.5
V_c [MV] (cavity voltage)	35		11.9
U_c [MV] (crab voltage)	1.8		0.8
β_{crab} [m]		25	
P_{hom} [kW] (per beam)	67		180
n_c (cavities per ring)	12		4
P_{rf} [MW] (rf power)	4.8		2.4
λ_{rf} [cm] (rf wavelength)		60	
τ_ϵ [ms] (long. damp. time)	3.9		11.7
$\tau_{x,y}$ [ms] (trans. damp. time)	7.8		23.4

Minimization of both synchrotron radiation and background is a major driver in the design, pushing in the direction of low emittance and a large number of bunches. The smallest IR beta's commensurate with adequate dynamic aperture and the Siemann-Krishnagopal[4] equal tune print conditions are used. The rf parameters follow from those same conditions. The principal parameters are listed in Table 1.

RF SYSTEM

Key to maintaining a high average current staly is development of a very low impedance rf system. By use of superconducting cavities the CESR-B design minimizes both the impedance per cell by affording beam tubes above cut-off for all but the accelerating mode and the number of cells by operating at accelerating fields much higher than achievable with CW copper structures. A cell shape meeting the necessary criteria has been devised and a full scale niobium model is on order. A 500 kW window prototype has been received and is now under test. The single cell cavity unit concept is shown in Figure 4. R/Q of the fundamental is 89 ohm and for a 1 cm rms bunch length the total loss factor for all HOM's is 0.11 V/pC.

VACUUM SYSTEM

Maintenance of a beam lifetime due to beam-gas interactions requires maintenance of average pressures of about 5×10^{-9} Torr in both rings. Maintenance of sufficiently low particle backgrounds in the detector require residual gas pressures of about 1×10^{-9} Torr in the region near the IP. Average gas loads in the two rings are comparable and are too much for in-chamber distributed ion pumps. Accordingly a complex of NEG, Ti sublimation and large lumped ion pumps will be used to obtain the needed pumping speeds. Gas loading to be expected is calculated from the measured CESR desorbtion coefficient, $\eta = 5 \times 10^{-6}$ molecule/photon. This number includes desorbtion due to scattered photons as well as that due to primary hit and is based on the conservative assumption that all the gas is nitrogen. Figure 5 shows the vacuum chamber and pump configuration in the region of higtest radiation power deposition.

CONCLUSION

While challenging, it appears that extension of current storage ring technology will permit meeting the luminosity goals needed to make the next step in understanding CP violation.

References

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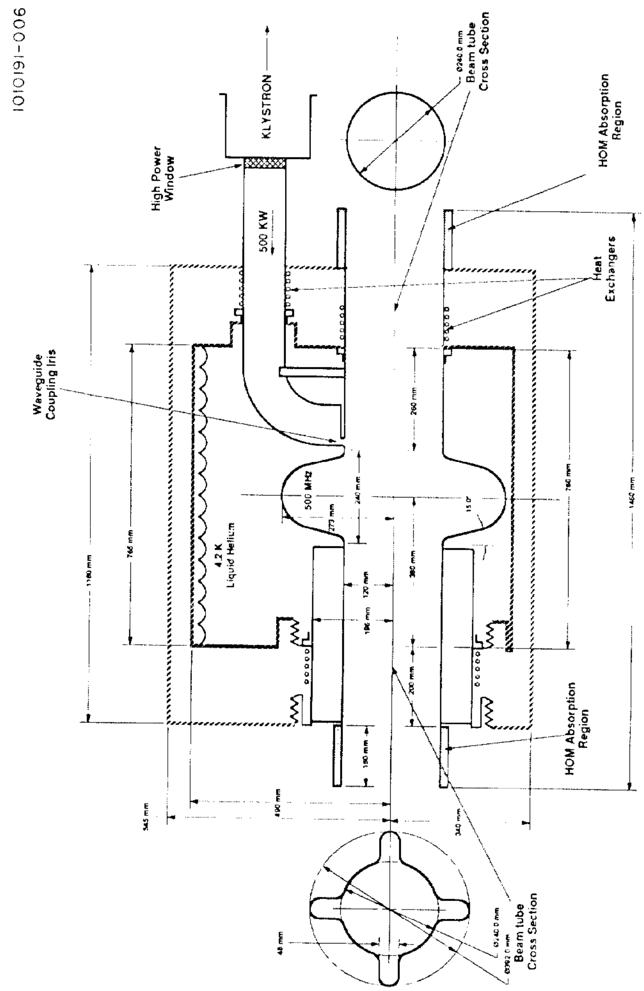

Figure 4: Accelerating cavity, coupler, mode dampers and cryostat concept.

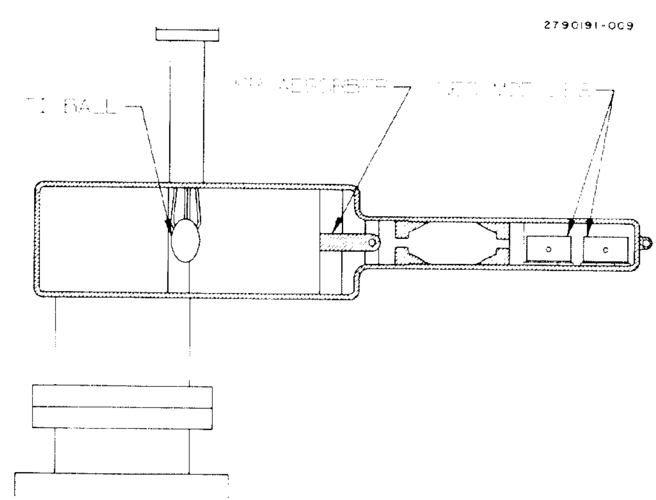

Figure 5: The vacuum chamber for the transition region where the bend radius is only 45 m and the pressure must be held to less than 1×10^{-9} Torr of CO and CO_2.