Parameters of an e^+e^- Collider in the VLHC Tunnels

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1. Introduction

We have discussed the option of building an e^+e^- collider in the tunnels of the VLHC in a number of notes [1, 2, 3, 4, 5]. Continued study of this option has shown that the operating range of the machine can can be extended somewhat from previous papers and this note presents the most recent progress on the luminosity and high energy operation of this machine. We have assumed that this machine would be used to justify the construction of a tunnel which would eventually house the VLHC collider, and perhaps ultimately an ep collider.

2. Parameters

The operating limits of an e^+e^- collider in the VLHC tunnel [6] are determined by the allowable β_y^*, the beam beam parameter, ξ_y, and the charge per bunch that can be accelerated in the collider, which is primarily determined at injection.

The most important physics parameters are shown in Figure 1, Table I and Table II. A more complete list is on the web, [7], where the decreasing luminosity with energy is due to operation at the synchrotron power limit. The good energy resolution of this option may be a significant advantage for the study of light higgs and the $t\bar{t}$ threshold.

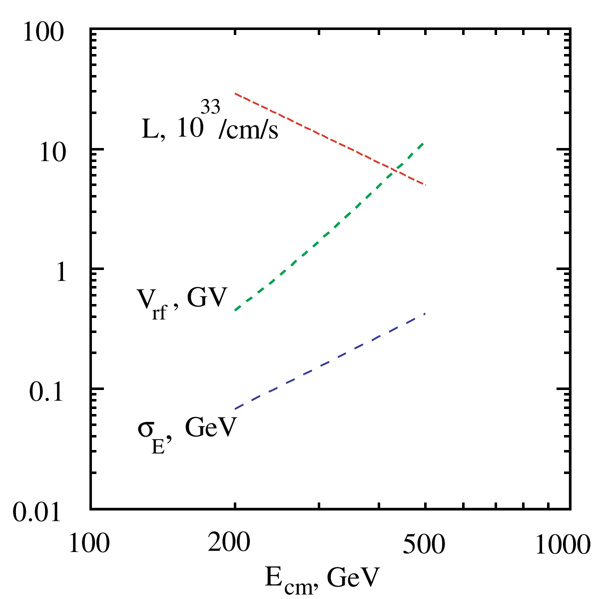

Figure 1: Luminosity, Energy resolution and rf Voltage.

Table I Overall Parameters

Circumference [km]	233
Revolution frequency, [KHz]	1.287
Bend radius, [km]	32.07
Arc Radius, [km]	34.48
Cell Length [m]	215.677
Number of IP's	1
β_x^*,β_y^*, [cm]	100,1.0
Total synchrotron power(two beams), [MW]	100
Linear power load, [kW/m/beam]	0.23

Table II At 350 GeV in the Center of Mass

Beam Energy, [GeV]	175
Luminosity, [/cm^2/s]	9.81×10^{33}
$\kappa/(\beta_y^*/\beta_x^*)$	1.0
Emittances ϵ_x, ϵ_y [nm]	4.747, 0.047
RMS at IP σ_x^*, σ_y^* [μm]	68.9, 0.689
Bunch intensity, current [mA]	4.85×10^{11}/0.10
Number of bunches per beam	193
Bunch spacing [km]	1.21
Total current (both beams) [mA]	38.6
Damping decrement	0.0148
Beam–beam tune shift ξ_y	0.133
Dipole field [T]	0.01820
Phase advance per cell μ_x, μ_y [°]	77.657
Arc tune	216.726
Total length of dipoles in a cell [m]	200.5
Quadrupole gradient times length [T]	14.55
Arc β^{max}, β^{min} [m]	359.2, 82.5
Arc $\sigma_x^{max}, \sigma_x^{min}$ [mm]	1.306, 0.63
Arc dispersion D^{max}, D^{min} [m]	1.127, 0.589
Vacuum chamber aperture, h & v, [cm]	4.8, 12
Bend radius / Machine radius $2\pi\rho/C$	0.93
Momentum compaction	2.31×10^{-5}
Energy loss /particle /turn [GeV]	2.59
Critical energy [keV]	344
Longitudinal damping time [turns]	67
RMS relative energy spread	9.85×10^{-4}
Center of Mass energy spread, [GeV]	0.207
Bunch length [mm]	7.275
Synchrotron tune	0.0988
RF Voltage [MV]	2989.3
RF frequency [MHz]	352.
e^+e^- bremmstrahlung lifetime [hrs]	23.27
Polarization time, [hrs]	5.5
Required power, [MW]	~ 200
Photon flux/length [#/m/sec/beam]	7.2×10^{15}

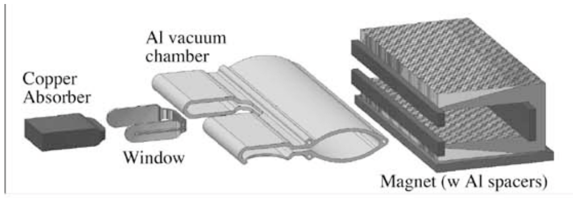

Figure 2: The magnet arcs.

3. Comments

The advantages of this facility would be that the luminosity is high, the center of mass energy resolution is very good, the machine is a comparatively conservative extrapolation from LEP and should run reliably, a GigaZ collider is being considered for the injector [8], and the combination of lepton and hadron physics in the same tunnel could maintain a large, active community at the energy frontier for many years. On the other hand, the energy reach of this ring is limited and we assume that the VLHC proton–proton collider would constitute the preferred upgrade path if limited new physics was discovered below 500 GeV. Continued study of the polarization properties of this ring has shown that it is difficult to produce and maintain polarization at high energies [9].

Although is machine would be an extension of the LEP operating modes [10], extrapolation is not straightforward. The presence of a beta wave prevented LEP from systematically exploring the minimum useful β_y^*, and the Transverse Mode Coupling Instability (TMCI) at injection prevented operating the machine at the beam-beam limit at high energy. In addition, this machine would operate with collisions at only one interaction point, where LEP always used four.

We have looked in some detail at the engineering of this machine. The rf system is fairly similar to LEP [11]. The interaction point optics uses a focus where the slope of the dispersion is nonzero at the IP [12]. The arc magnets and vacuum chamber are constrained by the large vacuum aperture required to combat transverse mode coupling instabilities at injection and the need to avoid bellows by using a no bake/no bellows option. We assume that the arcs would consist of two rings, one above the other, to minimize parasitic collisions. Electrostatic separators [13] would be used for initially separating beams. The magnet/vacuum chamber system can be designed to be simple to assemble, with the aim of having the cost approach the materials cost. Low field magnets are a concern [1], however vacuum annealed, low carbon steel may produce very low residual fields, which would improve injection without significantly raising the cost of the magnet systems [14].

Although cost arguments originally developed for LEP [15] lead to the conclusion that 25 km was an approximate cost minimum for that machine, our work has different assumptions and different conclusions. For a given energy, we find that the magnetic field, wall power loading and beam induced gas load per unit length all decrease with circumference approximately like $1/C$, so the total arc cost is not strongly related to circumference.

4. R & D Issues

Beam-beam interactions and the limitations on the beam–beam tune shift, ξ_y, operation in the regime where there is severe synchrotron beam damping, methods of minimizing the effects of Transverse Mode Coupling instability, polarization, construction of a vacuum chamber without bellows (prebaked) all require more attention.

5. Conclusions

This machine would have a high luminosity and very good energy resolution over its operating range. We have described parameters and critical issues.

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