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e^+e^- and *ep* Options for the Very Large Hadron Collider

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Abstract Although the linear collider is ultimately capable of higher energies, a circular e^+e^- collider installed in the large tunnels of a Very Large Hadron Collider (VLHC) has attractive features, including very light magnet system and unchallenging vacuum requirements. An ep collider, built either in the 3 TeV booster or the large tunnel, could extend the HERA program beyond $\sqrt{s} \sim 1$ TeV. Both machines could perhaps use the same rf system, first in the booster tunnel and then as part of the large collider.

INTRODUCTION

The possibility of installing a large electron /positron collider in the tunnels of a Very Large Hadron Collider was first considered at the 1996 Snowmass meeting (1), and studied more fully at the PAC97 conference (2). The *ep* machine has been studied fairly recently and less completely. These machines are being considered as part of the VLHC effort, and recent progress can be found on the WWW (3).

While the NLC and the Muon collider have received the primary design effort, it seems desirable to also consider the potential advantages of these machines, until the physics goals are more clearly defined by new results.

THE e^+e^- COLLIDER

Using the constraints that the total synchrotron beam loss would be 100 MW and the total circumference was 531 km, a parameter list was developed which would describe the facility. Interesting features of this machine are: 1) the luminosity, which is limited by radiated beam power and magnet aperture, has a maximum at a center of mass roughly equal to the $\bar{t}t$ threshold, decreasing at energies above or below this energy, (it is interesting to note that the energy at which the maximum luminosity occurs is proportional to $R^{0.2}$, where R is the radius of the machine, so the lepton collider parameters are comparatively independent of the VLHC parameters), 2) the energy resolution at this energy is comparatively good, $\sigma_E = 0.26$ GeV, 3) the required field for the dipole magnets is very low, $B \sim 100$ G at full field and $B \sim 10$ G at injection, requiring a good shielding against stray fields including the earth's field, 4) because the machine radius is so large, it would be difficult to evenly deposit the synchrotron power on a vacuum chamber wall, thus it seems desirable to use localized beam absorbers which would be pumped, at intervals of about 100 m. The pumping requirements on these absorbers would only be about 200 L/s at each unit. The power deposition from a 50 - 100 MW synchrotron load would be significant and would be distributed over a

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wide area. A complete design of this system will include a method of sinking this heat locally along the length of the tunnel without cooling towers.

Although the bending field is low, measurements on a prototype magnet indicated that it should be possible to use the yokes as a shield without additional active or passive components. The low field itself results in very light magnet yokes and very low excitation currents which make the magnet very light, 40 kg/m, and perhaps inexpensive.

The important parameters of the machine would be shown in the following table, taken from Reference 2.

TABLE 1 Parameters of a circular $\bar{t}t$ factory.

Beam energy	180	GeV
Circumference	531	km
Luminosity Goal	$9.15 \cdot 10^{31}$	$cm^{-2} s^{-1}$
Beam-beam tune shift, $\xi_x = \xi_y$	0.03	
Total current /beam	37	mA
Number of bunches	512	
Synchrotron loss	1.3	GeV/turn
RF voltage	1.6	GV
Beam Aperture, $A_x : A_y$	53 : 38	mm
Total Generator Power	102	MW

THE *ep* COLLIDER

This machine would be an extension of the DESY/HERA program, and the facility itself would be located in the 34 km tunnel planned for the VLHC booster synchrotron. The design constraints on this machine are 1) that the luminosity be at the 1 fb^{-1} scale, 2) that leptons polarization be possible, and 3) collisions with both electrons and positrons be possible (4). A possible parameter list is shown in Table 1, which includes the goals of the design effort. It is possible to reach $\sqrt{s} = 7$ TeV with 50 TeV protons in the large tunnel.

TABLE 2 Parameters of a large *ep* collider.

Proton beam energy	3	TeV
Electron beam energy	80	GeV
Circumference	34	km
Luminosity goal	1	fb^{-1}/y
$\sqrt{s}$	1	TeV
Total Generator Power	50	MW

A preliminary look seems to indicate that it may be possible to satisfy the requirements, however many technical questions remain.

AN ELECTRON INJECTOR CHAIN

Very preliminary work is underway to look at a possible electron injector chain utilizing the Booster and Main Injector (MI). Because of synchrotron radiation losses, it seems desirable to run the Booster below 4.5 GeV and the MI below 12 GeV. In order to produce positrons, it would be necessary to build a new electron linac and positron accumulator, modeled after those at CERN or the Argonne APS.

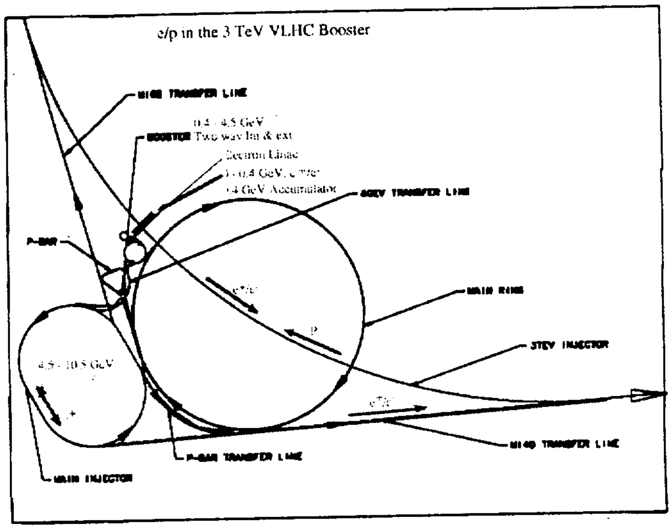

FIGURE 1, An injector chain option

CONCLUSIONS

The cost of circular colliders depends on a variety of parameters, and these very large examples are comparatively far from normal design experience, thus it seems possible that innovative designs could significantly improve the performance/cost ratio over initial expectations. The e^+e^- and *ep* colliders could considerably extend the physics capabilities of the VLHC. If the machines could share rf systems and other components, they could be built more economically. More detailed studies examining these options are underway at Fermilab and Argonne.

REFERENCES

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