LHeC Ring-Ring Option

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The LHeC aims at the generation of hadron-lepton collisions with center of mass energies in the TeV scale and luminosities of the order of 10^{32}–10^{33} cm^{-2} sec^{-1} by taking advantage of the existing LHC 7 TeV proton ring and adding a high energy electron accelerator. This paper presents technical considerations and potential parameter choices for such a machine and outlines some of the challenges arising when an electron storage ring based option, constructed within the existing infrastructure of the LHC, is chosen.

1 Introduction

It was originally foreseen to allow for both an electron ring (LEP itself in the earliest versions) and a hadron ring in the LHC tunnel [1]. Interest in a lepton-hadron collider, LHeC, was rekindled recently by the proposal to add a new lepton ring to the LHC [2].

Quantity	unit	$e^{\pm}$	p
Beam energy	GeV	70	7000
Total beam current	mA	74	544
Particles/bunch N_b	10^{10}	1.40	17.0
Horiz. emittance	nm	7.6	0.501
Vert. emittance	nm	3.8	0.501
Horizontal β_x^*	cm	12.7	180
Vertical β_y^*	cm	7.1	50
Energy loss per turn	GeV	0.707	6×10^{-6}
Radiated power	MW	50	0.003
Bunch frequency	MHz	40	
CMS Energy ($\sqrt{s}$)	GeV	1400	
Luminosity /10^{33}	cm^{-2}s^{-1}	1.1	

Table 1: Main parameters for $e^{\pm}$p collisions

Here we build on that study to look more closely into aspects of the lepton ring. This could store positrons or electrons given investment in sources and polarity-switching capability. An alternative ring-linac option is discussed in [3] and more general aspects in [4].

The main parameters, from [2], are summarized in Table 1 (see also [5]) and are driven by assumptions on RF power available. Clearly there is ample scope for staging installed power and $e^{\pm}$ energy from 50–70 GeV, ultimately to approach the parameters of Table 1. If, e.g., the lepton beam current is kept constant, the $e^{\pm}$ energy scales as $E \propto P_{\mathrm{RF}}^{1/4}$.

2 Lepton Injectors

The LEP pre-injectors have been dismantled and the infrastructure re-used for the CLIC test facility CTF3. The RF cavities that accelerated leptons in the SPS have been removed to reduce its impedance. Re-installation of an injector chain similar to LEP's through the PS and SPS would be costly and potentially limit the proton performance so the LHeC needs new lepton injectors. The required bunch intensities of 1.4×10^{10} are well below the 4×10^{11} used for LEP. This should lower the injection energy from the 22 GeV of LEP and reduce the cost of new lepton injectors. A scaled-down version of ELFE [6] may be a candidate for the LHeC lepton injector.

3 Layout and bypass

The idea is to add a lepton ring to the LHC with minimal interference for the continuing high-luminosity pp program. This will require a separation bypass for the lepton ring around the high luminosity experiments ATLAS, in the interaction region IR1, and CMS in IR5. We assume that the low-luminosity LHC insertions, IR2 and IR8, can be adapted to the needs of the LHeC with RF, injection and new experiments. Fig. 1 shows the LHC underground structures and extensions considered for the LHeC while Table 2 lists the bypass tunnels considered necessary.

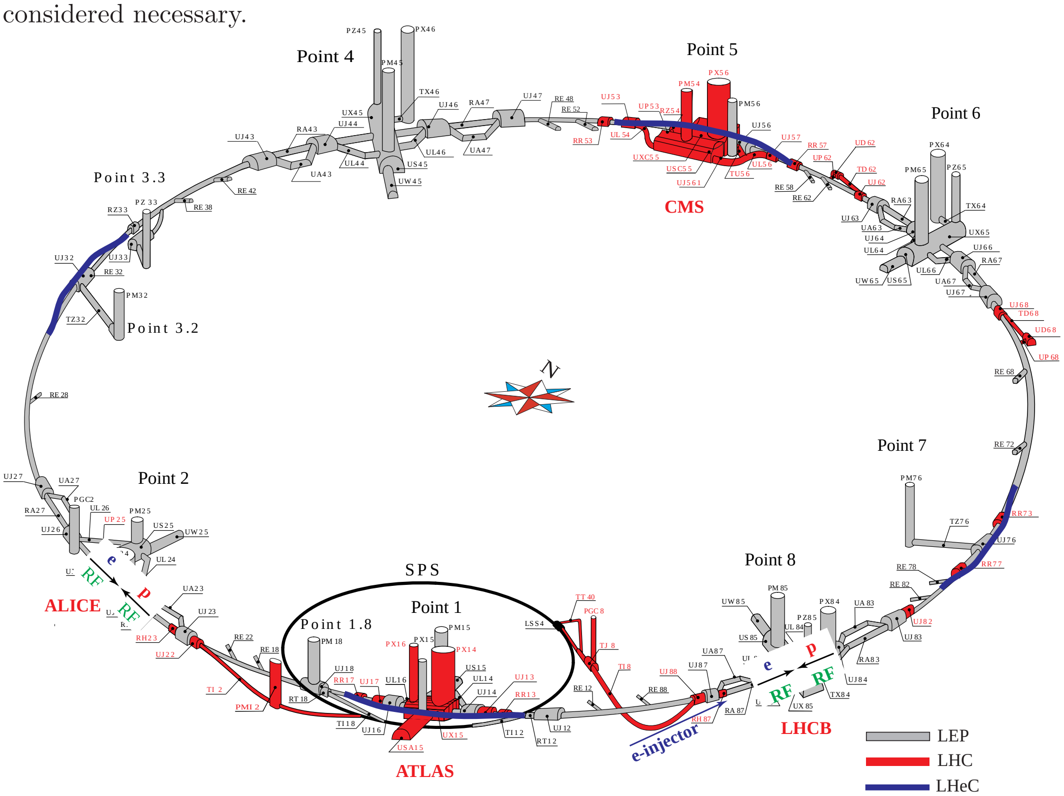

Figure 1: Civil engineering for the LHeC.

	IR1/IR5 ATLAS/CMS	IR2 and/ or IR 8	IR3/IR7
Bypass for	Experiments	RF	Collimation
Diameter	4.4/3.8 m	5.50 m	4.2/3.8 m
Length	500 m	500 m	500 m
Separation	10–13 m		

Table 2: Bypass tunnels and approximate dimensions.

The RF system will require shielded areas to house the RF power amplifiers and associated electronics. At lower energies, 50 GeV, say, the superconducting cavities (1GHz) can be accommodated at one long straight section (LSS). At higher energy it may be preferable to divide the system between two LSSs to avoid beam dynamics effects associated with high synchrotron tune and energy. The total number of cavities will depend on the RF coupler capability rather than the accelerating gradients (MV/m) achievable.

The bypasses around the experiments in IR1 and IR5 are expected to be the most demanding because they require 10–13 m of horizontal separation at the interaction point (IP). We have therefore started to look into possible designs in some detail.

Two basic alternative options have been considered for a bypass.

In the first case, the basic idea is to move part of the straight sections around the experiments to the arcs and to achieve the separation without any additional bending magnets. This was done in a layout study starting from the LEP lattice. The results is shown in Fig. 2.

The circumference is increased by $\Delta = 42\,\text{cm}$. This could be compensated by a decrease in the radius of the electron ring by $\Delta/4\pi = 6.7\,\text{cm}$. Keeping the same circumference for electron and proton rings is preferred but may not strictly be necessary. Keeping the same circumference allows synchronization of injection and abort gaps in both rings. It avoids complications in beam-beam effects between both rings and should help to minimize the emittance increase of the proton beam by the beam-beam interaction.

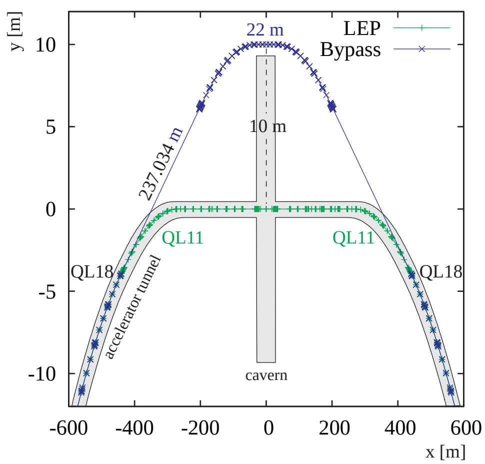

Figure 2: By-pass layout study, derived from the LEP lattice without addition of bending magnets. The y-scale is stretched by a factor of 50.

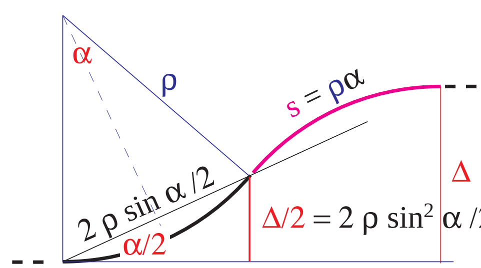

Figure 3: Geometry of a local bypass

The basic idea for the second bypass alternative considered is to not change the arc layout and to achieve all the separation needed locally, by addition of bending magnets around the interaction regions. The minimal geometry for one side of such a local bypass is illustrated in Fig. 3. If we use the same bending radius as in the arcs ($\rho = 3026\,\text{m}$), then we would need an angle $\alpha = 57\,\text{mrad}$ to get $\Delta = 10\,\text{m}$ separation by adding $4 \times 176\,\text{m}$ of extra bending magnets. This would add 3.6% in the total energy loss. In absolute, the energy loss in such a bypass at 70 GeV for a 70 mA beam would be 1.8 MW. Still stronger bends resulting in even more synchrotron radiation loss would be needed to actually fit such a bypass in the available space. Doubling the bending strength would only reduce the size to $4 \times 124.5\,\text{m}$ and increase the total power by 5.1%. Achieving a large separation like 10 m or more with a local bypass appears not to be realistic.

Combinations of both bypass options should be possible and will be studied in the future.

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