Linac-LHC ep Collider Options


Abstract
We describe various parameter scenarios for a linac-ring ep collider based on LHC and an independent electron linac. Luminosities between $10^{31}$ and $10^{33} \text{ cm}^{-2}\text{s}^{-1}$ can be achieved with a s.c. linac, operated either pulsed or in cw mode with optional recirculation, at a total electric wall-plug power of order 20 MW. Higher luminosities of several $10^{33} \text{ cm}^{-2}\text{s}^{-1}$ can be reached by investing more electric power or by energy recovery. Finally, merits of a linac-ring ep collider are discussed.

Scenarios

Example linac layouts

Cryogenics electric power vs. acc. gradient

Collision effect on e-: e- disruption parameter vs. $\beta^*_p$ (left)
relative rms divergence increase in collision vs. initial $\gamma_e$ (right)

Schematic interaction region

Schematic linac-ring collider with integrated e+ production (right)
and simulated e+ yield for amorphous W target of varying thickness hit by a 60-GeV e- beam $[\sigma_{x,y,e}=20 \mu m, \sigma_{x,y,e}=20 \mu m, \beta=10 m]$ (below).

Luminosity vs. e- energy for cw & pulsed linac

Table 1: Proton beam scenarios

<table>
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<th>Energy [GeV]</th>
<th>LHC</th>
<th>LHC*</th>
<th>P_{total}</th>
<th>E_{total}</th>
<th>E_{p}</th>
<th>E_{f}</th>
<th>E_{n}</th>
<th>E_{f}</th>
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Table 2: Electron-beam parameters for various (s.c.) linac-ring LHC-C scenarios. The $\beta^*$ values are calculated for a normalized e- emittance of 20 $\mu m$. Parameters marked by asterisks refer to "LHC*" of Table 1.

Merits of linac-ring ep collider:
1) Small e- emittance means luminosity can be increased for reduced $\beta^*_p$ and final e- quadrupoles far from the collision point. First elements: warm separation dipoles of 0.5-2 T
2) e-p beams can be collided head-on. No crab cavities, since e- are dumped & with assumed IR layout, residual parasitic collisions uncertain.
3) Staged construction is possible. A first stage could use the SPL as recirculator for alternating e- & p operation, bringing the electrons to some 20 GeV, which would probe physics beyond HERA. Such SPL-based recirculator could later serve as injector for e- ring or extended linac. Beam energy could be raised in steps by adding further linac segments.
4) As linac not affected by synchrotron radiation, no fundamental limit on electron beam energy.
5) Energy recovery could ultimately gain another order of magnitude in luminosity.
6) Except for collision point, linac tunnel fully separate from LHC, minimizing construction downtime.
7) The linac-ring collider would benefit from planned proton infrastructure upgrades, i.e. linac4, SPL and PS2.
8) e- beam can be 80% polarized.
9) Numerous important synergies with CLIC and ILC (beam dynamics, e+ production, tunnel, etc.) may prepare ground for future linear collider.
10) Electron-ion collisions, as well as, via laser Compton backscattering, $\gamma$-proton and $\gamma$-nucleus collisions would also be possible.

REFERENCES