LINAC-RING COLLIDERS

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Electron-proton colliders with center of mass energies between 14 GeV and 100 GeV and luminosities at the 10^{33} level have been proposed recently as a means for studying hadronic structure [1]. Longitudinal polarization of the electron beam at the interaction region at the 50% to 80% level appears to be crucial for the majority of experiments. Linac-ring colliders provide an alternative to the traditional ring-ring accelerator designs [2,3]. Although linac-ring colliders are not as well understood as ring-ring colliders, comparable luminosities appear feasible, while the linac-ring option presents significant advantages with spin manipulations, reduction of synchrotron radiation load in the interaction region and wide range of continuous energy variability. Rf power and beam dump requirements make the linac-ring option viable only if the electron linac recovers the beam energy, a technology demonstrated at Jefferson Lab's IR FEL, with cw current up to 5 mA and beam energy up to 50 MeV [4].

Energy recovery is the process by which the energy invested in accelerating a beam is returned to the rf cavities by decelerating the same beam. Some of the benefits of energy recovery are: a) the required rf power becomes nearly independent of beam current, b) the overall system efficiency is increased, c) the electron beam power to be disposed of at the beam dumps is reduced by the ratio of the final to injected energy.

Self-consistent sets of parameters for electron-proton linac-ring colliders have been developed and are presented in Table 1. The first two point designs correspond to 50 GeV protons colliding with 5 GeV electrons [5], the third design, eRHIC, is based on the existing RHIC storage ring [3]. The linac technology assumed here uses TESLA cavities operating at Q_0 of $\sim 1\text{x}10^{10}$ and accelerating gradient of ~20MV/m.

Accelerator physics topics relevant to the proton ring include intrabeam scattering, collective instabilities and the emittance growth of the electron beam due to a single collision with the protons. All these effects impose limitations of the proton bunch population. The intrabeam beam scattering diffusion rates are such that electron cooling of the protons would be required.

Accelerator physics topics relevant to the energy recovery linacs include transport and beam loss issues, Higher Order Mode power dissipation, multipass, multi-bunch Beam Breakup (BBU) instabilities and the beam-beam induced head-tail instability, the latter possibly being the limiting mechanism.

Technological issues include: a) The development of a high current (~250 mA), high polarization (~80%) electron source. The present state of the art in high average current, polarized sources is ~1 mA at 80% polarization [6,7]. b) High energy electron cooling of the proton beam.

Luminosities at the 10^{33} level appear attainable in the three linac-ring scenarios presented here. No showstoppers have been found but a number of important issues have been identified that would require focused R&D before such a facility is designed and built. These topics include: a) High current polarized electron source; b) High current (~200 mA) demonstration of energy recovery, which includes understanding and controlling beam loss, possibly developing feedback for the multibunch BBU instability, and understanding of HOM power dissipation issues; c) Electron cooling and its ramifications on Laslett and beam-beam tuneshifts and d) Theoretical and, if possible, experimental investigation of the beam-beam kink instability and feedback.

Recently, recirculating, energy-recovering linacs have attracted much attention and are being considered for a number of applications, such as drivers for synchrotron radiation sources [8], and high average power FELs. In particular, Cornell University is proposing a high average current (100 mA), high Energy Recovery Linac (5 to 7 GeV) for a next generation light source [9] and is planning to address some of the technical issues of energy recovery with a smaller scale prototype (100 mA, 100 MeV).

Table 1. Parameters for linac-ring colliders

Parameter	Units	**Point Design 1**		**Point Design 2**		**eRHIC**	
		e^- Linac	p-Ring	e^- Linac	p-Ring	e^- Linac	RHIC (p)
Beam Energy	GeV	5	50	5	50	10	250
Ring Circumference	m	-	460	-	460	-	3833
N_{bunch}	ppb	1.1×10^{10}	1×10^{11}	1.1×10^{10}	1×10^{11}	3×10^{10}	$.93\times10^{11}$
f_c	MHz	150		150		56	
I_{ave}	A	0.264	2.4	0.264	2.4	0.270	0.83
σ^*	μm	25	60	25	25	33	33
ε	nm	6	36	6	6	2.5	2.5
β^*	cm	10	10	10	10	36	36
σ_z	cm	0.1	10	0.1	10	0.3	10
ξ_{pr}	-	-	0.004	-	0.004	-	0.0046
$\Delta\nu_L$	-	-	0.004	-	0.024	-	0.001
D_e	-	0.78	-	4.6	-	1.2	-
Luminosity	$cm^{-2}sec^{-1}$	6.2×10^{32}		2.1×10^{33}		1.14×10^{33}	

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