Z Factory at DESY – LR/RR/RC-LL

Status of Studies

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Electron-Linac 75 GeV x Positron Ring (HERA) 27.5 GeV

Electron-Ring 45 GeV x Positron Ring 45 GeV

RC-Electron Linac 45 GeV x RC-Positron Linac 45 GeV

Design Studies with updated Beta*

- used collider desing optimization program LUMIMC (A.S. 2006-2010)
- studied RL, RR, recycling Linac (RCL)
- excluded all design with unreasonable crazy chromaticities ξ>50
- chromaticities are still to high and optimistic
  but schemes (sextupoles) exist to reduce chromaticities in final focus (ILC design)

Ring-Linac Designs

Studied several concepts:

- HERA optics
- low emittance optics (D.P. last meeting)
- very low emittance optics (more optimistic phase advance)
- designs with further reduced duty cycle 12% → 2% (N.Walker)

75 GeV Electrons x 27.5 GeV Positrons

Parameter	Unit	Design "HERA"	low emitt	very low emitt
Beam Charge Ne-/e+	[1e10]/[1e10]	0.13 / 10	0.12 / 10	0.12 / 10
#Bunch e-/e+ (train/ring)		26000 / 230	26000 / 240	28000 / 250
Collision Frequency	[MHz]	10.5	11.5	11.8
Repetition Rate	[Hz]	50	50	50
Duty Cycle		0.12	0.12	0.12
Current Ie-/Ie+ (linac/ring)	[mA]/[mA]	0.20 / 170	0.21 / 180	0.26 / 190
Emittance e-	[nm rad]	0.035 / 0.0044	0.021 / 0.009	0.017 / 0.011
Emittance e+	[nm rad]	20 / 1	3.5 / 0.5	1.5 / 0.5
Beam Size at IP e-	[μm]	1.6 / 0.2	0.8 / 0.25	0.6 / 0.4
Beam Size at IP e+	[μm]	46 / 2.2	7.4 / 1.0	2.8 / 0.9
Bunch length at IP e-/e+	[mm]/[mm]	1.0 / 3.6	1.0 / 2.0	1.0 / 2.0
Beta at IP e-	[m]	0.077 / 0.010	0.030 / 0.013	0.022 / 0.014
Beta at IP e+	[m]	0.100 / 0.005	0.015 / 0.002	0.005 / 0.002
Disruption Parameters e-		0.014 / 0.12	0.28 / 0.7	1.3 / 2
Disruption Parameters e+		0.02 / 0.38	0.05 / 0.4	0.13 / 0.4
e- Power Acc./ Cryogenics	[MW] / [MW]	20 / 4	20 / 4	20 / 4
e+ Damping Power	[MW]	15	16	16
Luminosity (e-e+)	[1e32 cm-2 s-1]	**0.25**	**3.3**	**9.2**

Results Ring-Linac I

- reduction of horizontal emittance by 1/6 allows to reduce beta* (aperture limit)
- additional reduction in vertical emittance and beta*
- low emittance design increases lumi by factor 12
- further reduction of emittance (factor 2.5) increases lumi by about the same amount
- luminosities of 10^{33} are not excluded!

75 GeV Electrons x 27.5 GeV Positrons

Parameter	Unit	low emitt (LE)	low duty LE	low duty VLE
Beam Charge Ne-/e+	[1e10]/[1e10]	0.12 / 10	0.72 / 10	0.80 / 10
#Bunch e-/e+ (train/ring)		26000 / 240	4550 / 250	4550 / 250
Collision Frequency	[MHz]	11.5	11.8	11.8
Repetition Rate	[Hz]	50	25	25
Duty Cycle		0.12	0.02	0.02
Current Ie-/Ie+ (linac/ring)	[mA]/[mA]	0.21 / 180	0.27 / 190	0.26 / 190
Emittance e-	[nm rad]	0.021 / 0.009	0.100 / 0.022	0.070 / 0.044
Emittance e+	[nm rad]	3.5 / 0.5	3.5 / 0.5	1.5 / 0.5
Beam Size at IP e-	[μm]	0.8 / 0.25	2.6 / 0.45	1.5 / 0.9
Beam Size at IP e+	[μm]	7.4 / 1.0	7.4 / 1.0	2.8 / 0.9
Bunch length at IP e-/e+	[mm]/[mm]	1.0 / 2.0	1.0 / 2.0	1.0 / 2.0
Beta at IP e-	[m]	0.030 / 0.013	0.068 / 0.016	0.027 / 0.016
Beta at IP e+	[m]	0.015 / 0.002	0.015 / 0.002	0.005 / 0.002
Disruption Parameters e-		0.28 / 0.7	0.18 / 0.7	1.3 / 2
Disruption Parameters e+		0.05 / 0.4	0.05 / 0.4	0.13 / 0.4
e- Power Acc./ Cryogenics	[MW] / [MW]	20 / 4	20 / 4	20 / 4
e+ Damping Power	[MW]	16	16	16
Luminosity (e-e+)	[1e32 cm-2 s-1]	**3.3**	**3.0**	**8.0**

Results Ring-Linac II

- reduction of duty cycle to 2% can be compensated by increasing the electron bunch charge and the electron emittance.
- almost perfect compensation in terms of luminosity!
- bunch trains are very similar to ILC design

Design Study Recycling Linac

Optimistic Design:

- acceleration to 45 GeV in 3 turns
- HF duty cycle 20% and 2%
- electrons and positrons provided with low emittance (damping ring)
- normalised positron emittance 10^{-6} rad m and 10^{-4} rad m studied

Recycling Linacs: 45 GeV Electrons x 45 GeV Positrons

Parameter	Unit	high duty	low duty	high e+ emitt
Beam Charge Ne-/e+	[1e10]/[1e10]	2 / 2	2 / 2	2 / 2
Collision Frequency	[MHz]	0.012	0.0012	0.0012
Current Ie-/Ie+ (ring/ring)	[mA]/[mA]	0.038 / 0.038	0.0038 / 0.0038	0.0038 / 0.0038
Emittance (abs) e-	[nm rad]	0.07 / 0.006	0.047 / 0.003	0.011 / 0.011
Emittance (abs) e+	[nm rad]	0.07 / 0.006	0.047 / 0.003	1.1 / 1.1
Beam Size at IP e-	[μm]	0.87 / 0.080	1.0 / 0.062	0.3 / 0.3
Beam Size at IP e+	[μm]	0.87 / 0.080	1.0 / 0.062	3.4 / 3.4
Bunch length at IP e-/e+	[mm]/[mm]	1 / 1	1 / 1	2 / 1
Beta at IP e-	[m]	0.012 / 0.001	0.022 / 0.001	0.008 / 0.008
Beta at IP e+	[m]	0.012 / 0.001	0.022 / 0.001	0.010 / 0.010
Disruption Parameters e-		1.8 / 20	1.2 / 20	0.06 / 0.06
Disruption Parameters e+		1.8 / 20	1.2 / 20	13.3 / 13.3
HF Duty Cycle		0.2	0.02	0.02
Accel/Cryo Power	[MW]	2 x 1.7 / 2 x 4.0	2 x 0.17 / 2 x 0.4	2 x 0.17 / 2 x 0.4
Luminosity (e-e+)	[1e32 cm-2 s-1]	**10.5**	**1.5**	**0.5**

Result Recycling Linac

- luminosities between 10^{32} - 10^{33} (very optimistic) might be achievable
- interesting are the very low power requirements!

Design Study Ring-Ring

- assume to separate rings for electrons and positrons (higher currents)
- ignored crossing angle in lumi calculation (optimistic)
- two different lattices: HERA, low emittance

Ring-Ring: 45 GeV Electrons x 45 GeV Positrons

Parameter	Unit	Design I ("HERA")	Design II
Beam Charge Ne-/e+	[1e10]/[1e10]	9 / 9	10 / 10
Collision Frequency	[MHz]	1.6	1.5
Current Ie-/Ie+ (ring/ring)	[mA]/[mA]	22 / 22	27 / 27
Emittance (abs) e-	[nm rad]	80 / 10	15 / 4
Emittance (abs) e+	[nm rad]	80 / 10	15 / 4
Beam Size at IP e-	[μm]	50 / 6	14 / 3
Beam Size at IP e+	[μm]	50 / 6	14 / 3
Bunch length at IP e-/e+	[mm]/[mm]	3 / 3	2 / 2
Beta at IP e-	[m]	0.030 / 0.003	0.014 / 0.003
Beta at IP e+	[m]	0.030 / 0.003	0.014 / 0.003
Disruption Parameters e-		0.006 / 0.06	0.05 / 0.25
Disruption Parameters e+		0.006 / 0.06	0.05 / 0.25
e+ Damping Power	[MW]	2 x 15	2 x 15
Luminosity (e-e+)	[1e32 cm-2 s-1]	**3.3**	**22.5**

beta* too optimistic!!!

Summary

- three different types of Z factory designs studied
- ring-ring (two rings) can achieve highest luminosities (~2 x RL)
- recycling Linac is the most complex machine and has no obvious advantage apart from the low running costs (power)
- HF duty cycle of 2% has no big impact on Ring-Linac Design

luminosities for 2% HF duty cycle:

- Ring-Linac: 3 10^{32}
- Recycling Linac: 0.5-1.5 10^{32}