21. HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (I)

None of the colliders on this page are any longer working in elementary-particle physics. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions. Many of the numbers of course changed over the lifetimes of the colliders; only the end-of-service values are given here.

	SPEAR (SLAC)	DORIS (DESY)	PETRA (DESY)	PEP (SLAC)	TRISTAN (KEK)
Physics start date	1972	1973	1978	1980	1987
Physics end date	1990	1993	1986	1990	1995
Maximum beam energy (GeV)	4	5.6	23.4	15	32
Luminosity (10^{30} cm^{-2}s^{-1})	10 at 3 GeV	33 at 5.3 GeV	24 at 17.5 GeV	60	40
Time between collisions (μs)	0.75	0.965	3.8	2.44	5
Crossing half angle (μ rad)	0	0	0	0	0
Energy spread (units 10^{-3})	1	1.2 at 5 GeV	1.1 at 17.5 GeV	1	2.3
Bunch length (cm)	$\sigma_z \approx 4$	$\sigma \sim 2$ at 5 GeV	$\sigma \sim 1.3$ at 17.5 GeV	$\sigma_z = 2$	1.5
Beam radius (10^{-6} m)	H: 700 V: 50	H: 740 V: ~ 30 } at 5 GeV	H: 430 V: 13 } at 17.5 GeV	H: 340 V: 14	H: 280 V: 8
Free space at interaction point (m)	±2.5	±1.2	±4.5	±3.7	±2.51
Luminosity lifetime (hr)	≈ 3	1.0–1.5	4 at 17.5 GeV	4	2
Filling time (min)	15	≈ 15	20	15	40
Acceleration period (s)	≤ 100	—	—	≤ 100	300
Injection energy (GeV)	2.5	up to 5.6	7	15	8
Transverse emittance ($10^{-9}\pi$ rad-m)	$H \approx 430$	H: 500 V: 5–50 } at 5 GeV	H: 140 V: 2	$H \approx 120$	H: 80 at 29 GeV
β^*, amplitude function at interaction point (m)	H: 1.2 V: 0.08	H: 0.59/12.3 V: 0.04/0.79	H: 1.3 V: 0.08	H: 1.0 V: 0.05	H: 1.0 V: 0.04
Beam-beam tune shift per crossing (units 10^{-4})	300	≤ 280 (space charge limit at 5.3 GeV)	H: 160 V: 400 } at 17.5 GeV	550	340
RF frequency (MHz)	358	500	500	352	508.5808
Particles per bunch (units 10^{10})	15	27	26	35	22
Bunches per ring per species	1	1	2	3	2
Average beam current per species (mA)	30	45 at 5.3 GeV	11 at 17.5 GeV	21	7
Circumference (km)	0.234	0.2892	2.304	2.2	3.02
Interaction regions	2	2	4	1	4
Utility insertions	18	10	4	5	8
Magnetic length of dipole (m)	2.35	3.2/1.1	5.38	5.4	5.86
Length of standard cell (m)	11.4	13.2	14.4	14.35	16.1
Phase advance per cell (deg)	H: 79 V: 90	H: 140 V: 50	H: 47 V: 40	H: 56 V: 33	60
Dipoles in ring	36	H: 28 V: 6	224	192	264 +8 weak
Quadrupoles in ring	46	68	360	248	392
Peak magnetic field (T)	1.1	1.5	0.4 at 23 GeV	0.36	0.41 at 30 GeV

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (II)

The numbers here were received from representatives of the colliders in 1996. Many of the numbers of course change with time, and only the latest values (or estimates) are given here; those in brackets are for coming upgrades. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions.

	VEPP-2M [round beams] (Novosibirsk)	DAΦNE (Frascati)	ϕ FACTORY (Novosibirsk)	BEPC (China)	VEPP-4M (Novosibirsk)
Physics start date	1974 [1997]	1997	?	1989	1994
Maximum beam energy (GeV)	0.7 [0.55]	0.510 (0.75 max.)	0.55	2.2	6
Luminosity (10^{30} cm^{-2}s^{-1})	5 [100]	135(→540)	2500	10	50
Time between collisions (μs)	0.03	0.0108(→0.0027)	0.007	0.8	0.6
Crossing angle (μ rad)	0	$\pm(1.0$ to $1.5)\times10^4$	0	0	0
Energy spread (units 10^{-3})	0.6 [0.35]	0.40	0.5	0.58	1
Bunch length (cm)	3	3.0	1	≈ 5	5
Beam radius (10^{-6} m)	H/V: 400/10 [35 (round)]	H: 2100 V: 21	35 (beams are round)	H: 926 V: 61	H: 1000 V: 30
Free space at interaction point (m)	±1	±0.46 (±157 mrad cone)	±2	±2.5	±2
Luminosity lifetime (hr)	continuous	2	continuous	7–12	2
Filling time (min)	continuous	3 (topping up)	continuous	30	15
Acceleration period (s)	—	—	—	120	150
Injection energy (GeV)	0.2–0.7 [0.2–0.55]	0.510	—	1.3	1.8
Transverse emittance ($10^{-9}\pi$ rad-m)	H/V: 400/4 [150]	H: 1000 V: 10	125	H: 660 V: 43	H: 400 V: 20
β^*, amplitude function at interaction point (m)	H/V: 0.48/0.04 [0.05]	H: 4.5 V: 0.045	0.01	H: 1.3 V: 0.085	H: 0.75 V: 0.05
Beam-beam tune shift per crossing (units 10^{-4})	H/V: 200/500 [1000]	400	1000	420	500
RF frequency (MHz)	200	368.25	700	199.53	180
Particles per bunch (units 10^{10})	4 [6.7]	8.9	5	20 at 2 GeV	15
Bunches per ring per species	1	30(→120)	11	1	2
Average beam current per species (mA)	100 [160]	1313(→5250)	550	40 at 2 GeV	80
Circumference or length (km)	0.018	0.0977	0.047	0.2404	0.366
Interaction regions	2	2	1	2	1
Utility insertions	1	2 × 2	1	4	1
Magnetic length of dipole (m)	1	e^+: 1.21/0.99 e^-: 1.21/0.99	0.8	1.6	2
Length of standard cell (m)	4.5 [9.0]	—	—	6.6	7.2
Phase advance per cell (deg)	280 [560]	—	—	≈ 60	65
Dipoles in ring	8	e^+: 8(+4 wigglers) e^-: 8(+4 wigglers)	22	40 + 4 weak	78
Quadrupoles in ring	20 [12]	e^+/e^-: 53/53	22	68	150
Peak magnetic field (T)	1.8 [1.5]	1.2(→1.76) dipoles 1.8 wigglers	1.8	0.9028	0.6

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (III)

The numbers here were received from representatives of the colliders in 1996. Many of the numbers of course change with time, and only the latest values (or estimates) are given here. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions; s.c. indicates superconducting.

	CESR (Cornell)	KEKB (KEK)	PEP-II (SLAC)	SLC (SLAC)	LEP (CERN)
Physics start date	1979	1999	1999	1989	1989
Maximum beam energy (GeV)	6	$e^- \times e^+$: 8×3.5	$e^- \times e^+$: 9×3.1 (6.5 GeV c.m. max)	50	87 in 1996 (97=max. foreseen)
Luminosity (10^{30} cm^{-2}s^{-1})	330 at 5.3 GeV (600 in mid-1996)	10000	3000	0.8	24 at Z^0 34 at 68 GeV
Time between collisions (μs)	0.028 to 0.22	0.002	0.0042	8300	22
Crossing angle (μ rad)	± 2000	$\pm 11,000$	0	0	0
Energy spread (units 10^{-3})	0.6 at 5.3 GeV	0.7	e^-/e^+: 0.61/0.77	1.2	1.0
Bunch length (cm)	1.8	0.4	e^-/e^+: 1.1/1.0	0.08	1.8
Beam radius (10^{-6} m)	H: 500 V: 11	H: 77 V: 1.9	H: 155 V: 6.2	H: 2.1 V: 0.6	H: 200 V: 8
Free space at interaction point (m)	± 2.2 (± 0.6 to REC quads)	± 0.4, (+300/−500) mrad cone	± 0.2, ± 300 mrad cone	± 2.8	± 3.5
Luminosity lifetime (hr)	3–4	2	2.5	—	20
Filling time (min)	10 (topping up)	8 (topping up)	3 (topping up)	—	90
Acceleration period (s)	—	—	—	—	420
Injection energy (GeV)	6	e^-/e^+: 8/3.5	2.5–12	45.64	22
Transverse emittance ($10^{-9}\pi$ rad-m)	H: 240 V: 8	H: 18 V: 0.36	e^-: 48 (H), 1.9 (V) e^+: 64 (H), 2.6 (V)	H: 0.6 V: 0.1	H: $12 \rightarrow 4$ V: $0.5 \rightarrow 2$
β^*, amplitude function at interaction point (m)	H: 1.0 V: 0.018	H: 0.33 V: 0.01	e^-: 0.50 (H), 0.02 (V) e^+: 0.375 (H), 0.015 (V)	H: 0.01 V: 0.002	H: 2.5 V: 0.05
Beam-beam tune shift per crossing (units 10^{-4})	420	H: 390 V: 520	300	—	490
RF frequency (MHz)	500	508.887	476	—	352.2
Particles per bunch (units 10^{10})	11	1.3/3.2	e^-/e^+: 2.7/5.9	3.5	20 in collision 60 in single beam
Bunches per ring per species	9 trains of 2 bunches (of 3 bunches in mid-1996)	5120	1658	1	1995: 4 trains of 3 1996+: 4 trains of 2
Average beam current per species (mA)	120 (300 in mid-1996)	e^-/e^+: 1100/2600	e^-/e^+: 990/2140	0.0007	4
Beam polarization (%)	—	—	—	e^-: 80	55
Circumference or length (km)	0.768	3.016	2.2	1.45 +1.47	26.66
Interaction regions	1	1	1 (2 possible)	1	4
Utility insertions	3	3	5	—	4
Magnetic length of dipole (m)	1.6–6.6	e^-/e^+: 5.86/0.915	e^-/e^+: 5.4/0.45	2.5	11.66/pair
Length of standard cell (m)	16	e^-/e^+: 75.7/76.1	15.2	5.2	79
Phase advance per cell (deg)	45–90 (no standard cell)	450	e^-/e^+: 60/90	108	108/60
Dipoles in ring	86	e^-/e^+: 116/112	e^-/e^+: 192/192	460+440	3280+24 inj. + 64 weak
Quadrupoles in ring	104	e^-/e^+: 452/452	e^-/e^+: 290/326	—	520+288 + 8 s.c.
Peak magnetic field (T)	0.3 normal, 0.8 high field $\}$ at 8 GeV	e^-/e^+: 0.25/0.72	e^-/e^+: 0.18/0.75	0.597	0.135

HIGH-ENERGY COLLIDER PARAMETERS: ep, $\overline{p}p$, and pp Colliders

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	HERA (DESY)	Sp$\overline{p}$S (CERN)	TEVATRON (Fermilab)	LHC (CERN)		SSC (USA)
Physics start date	1992	1981	1987	2004		Terminated
Physics end date	—	1990	—	—		—
Particles collided	ep	$p\overline{p}$	$p\overline{p}$	pp	Pb Pb	pp
Maximum beam energy (TeV)	e: 0.030 p: 0.82	0.315 (0.45 in pulsed mode)	0.9–1.0	7.0	2.76 TeV/u	20
Luminosity (10^{30} cm^{-2}s^{-1})	16	6	25 (1995) 200 (2000)	1.0×10^4	0.002	1000
Time between collisions (μs)	0.096	3.8	3.5	0.025	0.125	0.016678
Crossing angle (μ rad)	0	0	0	200	≤ 100	100 to 200 (135 nominal)
Energy spread (units 10^{-3})	e: 0.91 p: 0.2	0.35	0.15	0.1	0.1	0.055
Bunch length (cm)	e: 0.83 p: 8.5	20	50	7.5	7.5	6.0
Beam radius (10^{-6} m)	e: $280(H), 50(V)$ p: $265(H), 50(V)$	p: $73(H), 36(V)$ $\bar{p}$: $55(H), 27(V)$	36	16	15	4.8
Free space at interaction point (m)	± 5.5	16	± 6.5	38	38	± 20
Luminosity lifetime (hr)	10	15	7–30	10	6.7	~ 24
Filling time (min)	e: 30 p: 120	0.5	120	6	20	72
Acceleration period (s)	600	10	86	1200		1500
Injection energy (TeV)	e: 0.012 p: 0.040	0.026	0.15	0.450	177.4 GeV/u	2
Transverse emittance ($10^{-9}\pi$ rad-m)	e: $39(H), 2(V)$ p: $7(H), 7(V)$	p: 9 $\bar{p}$: 5	p: 4 $\bar{p}$: 2.2	0.5	0.5	0.047
β^*, amplitude function at interaction point (m)	e: $2(H), 0.9(V)$ p: $7(H), 0.7(V)$	0.6 (H) 0.15 (V)	0.35	0.5	0.5	0.5
Beam-beam tune shift per crossing (units 10^{-4})	e: $190(H), 210(V)$ p: $12(H), 9(V)$	50	p: 40 $\bar{p}$: 75	34	—	8 head on 13 long range
RF frequency (MHz)	e: 499.7 p: 208.2/52.05	100+200	53	400.8	400.8	359.75
Particles per bunch (units 10^{10})	e: 3.65 p: 10	p: 15 $\bar{p}$: 8	p: 25 $\bar{p}$: 7.5	10.5	0.0094	0.8
Bunches per ring per species	180	6	6	2835	608	17,424
Average beam current per species (mA)	e: 58 p: 158	p: 6 $\bar{p}$: 3	p: 12.5 $\bar{p}$: 3.7	536	7.8	71
Circumference (km)	6.336	6.911	6.28	26.659		87.12
Interaction regions	ep:2; e,p: 1 each, internal fixed target	2	2 high $\mathscr{L}$	2 high $\mathscr{L}$ +1	1	4
Utility insertions	4	—	4	4		2
Magnetic length of dipole (m)	e: 9.185 p: 8.82	6.26	6.12	14.2		Mostly 14.928
Length of standard cell (m)	e: 23.5 p: 47	64	59.5	106.92		180
Phase advance per cell (deg)	e: 60 p: 90	90	67.8	90		90
Dipoles in ring	e: 396 p: 416	744	774	1232 main dipoles		$\left.\begin{array}{l}H\text{: } 8336\\ V\text{: } 88\end{array}\right\}$ in 2 rings
Quadrupoles in ring	e: 580 p: 280	232	216	692 focussing +96 skew		2084 } 2 rings
Magnet type	e: C-shaped p: s.c., collared, cold iron	H type with bent-up coil ends	s.c. $\cos\theta$ warm iron	s.c. 2 in 1 cold iron		s.c. $\cos\theta$ cold iron
Peak magnetic field (T)	e: 0.274 p: 4.65	1.4 (2 in pulsed mode)	4.4	8.4		6.790
$\overline{p}$ source accum. rate (hr^{-1})	—	6×10^{10}	7×10^{10}	—		—
Max. no. $\overline{p}$ in accum. ring	—	1.2×10^{12}	2×10^{12}	—		—