

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

Updated in early 2010 with numbers received from representatives of the colliders (contact J. Beringer, LBNL). For existing (future) colliders the latest achieved (design) values are given. Quantities are, where appropriate, r.m.s.; H and V indicate horizontal and vertical directions; s.c. stands for superconducting. Parameters for the defunct SPEAR, DORIS, PETRA, PEP, SLC, TRISTAN, and VEPP-2M colliders may be found in our 1996 edition (Phys. Rev. **D54**, 1 July 1996, Part I).

	VEPP-2000 (Novosibirsk)	VEPP-4M (Novosibirsk)	BEPC (China)	BEPC-II (China)	DAΦNE (Frascati)
Physics start date	2008	1994	1989	2008	1999
Physics end date	—	—	2005	—	2013
Maximum beam energy (GeV)	1.0	6	2.2	1.89 (2.3 max)	0.700
Luminosity ($10^{30} \text{ cm}^{-2}\text{s}^{-1}$)	100	20	12.6 at 1.843 GeV/beam 5 at 1.55 GeV/beam	330	450 (1000 achievable)
Time between collisions (μs)	0.04	0.6	0.8	0.008	0.0027
Full crossing angle ($\mu \text{ rad}$)	0	0	0	2.2×10^4	5×10^4
Energy spread (units 10^{-3})	0.64	1	0.58 at 2.2 GeV	0.52	0.40
Bunch length (cm)	4	5	≈ 5	1.3	low current: 1 high current: 2
Beam radius (10^{-6} m)	125 (round)	H : 1000 V : 30	H : 890 V : 37	H : 380 V : 5.7	H : 800 V : 4.8
Free space at interaction point (m)	± 1	± 2	± 2.15	± 0.63	± 0.40
Luminosity lifetime (hr)	continuous	2	7–12	1.5	0.3
Turn-around time (min)	continuous	18	32	26	3
Injection energy (GeV)	0.2–1.0	1.8	1.55	1.89	on energy
Transverse emittance ($10^{-9}\pi \text{ rad}\cdot\text{m}$)	H : 250 V : 250	H : 200 V : 20	H : 660 V : 28	H : 144 V : 2.2	H : 260 V : 0.52
β^* , amplitude function at interaction point (m)	H : 0.06 – 0.11 V : 0.06 – 0.10	H : 0.75 V : 0.05	H : 1.2 V : 0.05	H : 1.0 V : 0.015	H : 0.25 V : 0.009
Beam-beam tune shift per crossing (units 10^{-4})	H : 750 V : 750	500	350	200	250
RF frequency (MHz)	172	180	199.53	499.8	368
Particles per bunch (units 10^{10})	16	15	20 at 2 GeV 11 at 1.55 GeV	3.6	e^- : 3.3 e^+ : 2.4
Bunches per ring per species	1	2	1	93	120 (incl. 10 bunch gap)
Average beam current per species (mA)	150	80	40 at 2 GeV 22 at 1.55 GeV	580	e^- : 1800 e^+ : 1300
Circumference or length (km)	0.024	0.366	0.2404	0.23753	0.098
Interaction regions	2	1	2	1	1
Magnetic length of dipole (m)	1.2	2	1.6	Outer ring: 1.6 Inner ring: 1.41	1
Length of standard cell (m)	12	7.2	6.6	Outer ring: 6.6 Inner ring: 6.2	12
Phase advance per cell (deg)	H : 738 V : 378	65	≈ 60	60–90 non-standard cells	360
Dipoles in ring	8	78	40 + 4 weak	84 + 8 weak	8
Quadrupoles in ring	20	150	68	134+2 s.c.	48
Peak magnetic field (T)	2.4	0.6	0.903 at 2.8 GeV	Outer ring: 0.677 Inner ring: 0.766	1.7

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

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	CESR (Cornell)	CESR-C (Cornell)	LEP (CERN)	ILC (TBD)
Physics start date	1979	2002	1989	TBD
Physics end date	2002	2008	2000	—
Maximum beam energy (GeV)	6	6	100 - 104.6	250 (upgradeable to 500)
Luminosity (10^{30} cm $^{-2}$ s $^{-1}$)	1280 at 5.3 GeV/beam	76 at 2.08 GeV/beam	24 at Z^0 100 at > 90 GeV	2×10^4
Time between collisions (μ s)	0.014 to 0.22	0.014 to 0.22	22	0.3^{\ddagger}
Full crossing angle (μ rad)	± 2000	± 3300	0	14000
Energy spread (units 10^{-3})	0.6 at 5.3 GeV/beam	0.82 at 2.08 GeV/beam	0.7→1.5	1
Bunch length (cm)	1.8	1.2	1.0	0.03
Beam radius (μ m)	H : 460 V : 4	H : 340 V : 6.5	H : 200 → 300 V : 2.5 → 8	H : 0.639 V : 0.0057
Free space at interaction point (m)	± 2.2 (± 0.6 to REC quads)	± 2.2 (± 0.3 to PM quads)	± 3.5	± 3.5
Luminosity lifetime (hr)	2-3	2-3	20 at Z^0 10 at > 90 GeV	n/a
Turn-around time (min)	5 (topping up)	1.5 (topping up)	50	n/a
Injection energy (GeV)	1.8-6	1.5-6	22	n/a
Transverse emittance ($10^{-9}\pi$ rad-m)	H : 210 V : 1	H : 120 V : 3.5	H : 20-45 V : 0.25 → 1	H : 0.02 V : 8×10^{-5} (at 250 GeV)
β^* , amplitude function at interaction point (m)	H : 1.0 V : 0.018	H : 0.94 V : 0.012	H : 1.5 V : 0.05	H : 0.02 V : 0.0004
Beam-beam tune shift per crossing (units 10^{-4})	H : 250 V : 620	e^- : 420 (H), 280 (V) e^+ : 410 (H), 270 (V)	830	n/a
RF frequency (MHz)	500	500	352.2	1300
Particles per bunch (units 10^{10})	1.15	4.7	45 in collision 60 in single beam	2
Bunches per ring per species	9 trains of 5 bunches	8 trains of 3 bunches	4 trains of 1 or 2	2625
Average beam current per species (mA)	340	72	4 at Z^0 4→6 at > 90 GeV	9 (in pulse)
Beam polarization (%)	—	—	55 at 45 GeV 5 at 61 GeV	e^- : > 80% e^+ : > 60%
Circumference or length (km)	0.768	0.768	26.66	31
Interaction regions	1	1	4	1
Magnetic length of dipole (m)	1.6-6.6	1.6-6.6	11.66/pair	n/a
Length of standard cell (m)	16	16	79	n/a
Phase advance per cell (deg)	45-90 (no standard cell)	45-90 (no standard cell)	102/90	n/a
Dipoles in ring	86	84	3280+24 inj. + 64 weak	n/a
Quadrupoles in ring	101 + 4 s.c.	101 + 4 s.c.	520+288 + 8 s.c.	n/a
Peak magnetic field (T)	0.3 / 0.8 at 8 GeV	0.3 / 0.8 at 8 GeV, 2.1 wigglers at 1.9 GeV	0.135	n/a

‡ Time between bunch trains: 200ms.

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

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	KEKB (KEK)	PEP-II (SLAC)	SuperB (Italy)	SuperKEKB (KEK)
Physics start date	1999	1999	TBD	2014 ?
Physics end date	—	2008	—	—
Maximum beam energy (GeV)	e^- : 8.33 (8.0 nominal) e^+ : 3.64 (3.5 nominal)	e^- : 7–12 (9.0 nominal) e^+ : 2.5–4 (3.1 nominal) (nominal $E_{cm} = 10.5$ GeV)	e^- : 4.2 e^+ : 6.7	e^- : 7 e^+ : 4
Luminosity (10^{30} cm $^{-2}$ s $^{-1}$)	21083	12069 (design: 3000)	1.0×10^6	8×10^5
Time between collisions (μ s)	0.00590 or 0.00786	0.0042	0.0042	0.004
Full crossing angle (μ rad)	$\pm 11000^\dagger$	0	± 33000	± 41500
Energy spread (units 10^{-3})	0.7	e^-/e^+ : 0.61/0.77	e^-/e^+ : 0.73/0.64	e^-/e^+ : 0.58/0.84
Bunch length (cm)	0.65	e^-/e^+ : 1.1/1.0	0.5	e^-/e^+ : 0.5/0.6
Beam radius (μ m)	H: 124 (e^-), 117 (e^+) V: 0.94	H: 157 V: 4.7	H: 8 V: 0.04	e^- : 11 (H), 0.062 (V) e^+ : 10 (H), 0.048 (V)
Free space at interaction point (m)	+0.75/−0.58 (+300/−500) mrad cone	± 0.2 , ± 300 mrad cone	± 0.35	e^- : +1.20/−1.28, e^+ : +0.78/−0.73 (+300/−500) mrad cone
Luminosity lifetime (hr)	continuous	continuous	continuous	continuous
Turn-around time (min)	continuous	continuous	continuous	continuous
Injection energy (GeV)	e^-/e^+ : 8/3.5	2.5–12	e^-/e^+ : 4.2/6.7	e^-/e^+ : 7/4
Transverse emittance ($10^{-9}\pi$ rad-m)	e^- : 24 (57*) (H), 0.61 (V) e^+ : 18 (55*) (H), 0.56 (V)	e^- : 48 (H), 1.5 (V) e^+ : 24 (H), 1.5 (V)	e^- : 2.5 (H), 0.006 (V) e^+ : 2.0 (H), 0.005 (V)	5 (H), 3 (V)
β^* , amplitude function at interaction point (m)	e^- : 1.2 (0.27*) (H), 0.0059 (V) e^+ : 1.2 (0.23*) (H), 0.0059 (V)	e^- : 0.50 (H), 0.012 (V) e^+ : 0.50 (H), 0.012 (V)	e^- : 0.032 (H), 0.00021 (V) e^+ : 0.026 (H), 0.00025 (V)	e^- : 0.025 (H), 3×10^{-4} (V) e^+ : 0.032 (H), 2.7×10^{-4} (V)
Beam-beam tune shift per crossing (units 10^{-4})	e^- : 1020 (H), 900 (V) e^+ : 1270 (H), 1290 (V)	e^- : 703 (H), 498 (V) e^+ : 510 (H), 727 (V)	20 (H), 950 (V)	e^- : 12 (H), 807 (V) e^+ : 28 (H), 893 (V)
RF frequency (MHz)	508.887	476	476	508.887
Particles per bunch (units 10^{10})	e^-/e^+ : 4.7/6.4	e^-/e^+ : 5.2/8.0	e^-/e^+ : 5.1/6.5	e^-/e^+ : 6.53/9.04
Bunches per ring per species	1585	1732	978	2500
Average beam current per species (mA)	e^-/e^+ : 1188/1637	e^-/e^+ : 1960/3026	e^-/e^+ : 1900/2400	e^-/e^+ : 2600/3600
Beam polarization (%)	—	—	> 80	—
Circumference or length (km)	3.016	2.2	1.258	3.016
Interaction regions	1	1	1	1
Magnetic length of dipole (m)	e^-/e^+ : 5.86/0.915	e^-/e^+ : 5.4/0.45	e^-/e^+ : 0.9/5.4	e^-/e^+ : 5.9/4.0
Length of standard cell (m)	e^-/e^+ : 75.7/76.1	15.2	40	e^-/e^+ : 75.7/76.1
Phase advance per cell (deg)	450	e^-/e^+ : 60/90	360 (V), 1080 (H)	450
Dipoles in ring	e^-/e^+ : 116/112	e^-/e^+ : 192/192	e^-/e^+ : 186/102	e^-/e^+ : 116/112
Quadrupoles in ring	e^-/e^+ : 452/452	e^-/e^+ : 290/326	e^-/e^+ : 290/300	e^-/e^+ : 466/460
Peak magnetic field (T)	e^-/e^+ : 0.25/0.72	e^-/e^+ : 0.18/0.75	e^-/e^+ : 0.52/0.25	e^-/e^+ : 0.22/0.19

† KEKB is operating with crab crossing since February 2007.

*With dynamic beam-beam effect.

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

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	HERA (DESY)	TEVATRON* (Fermilab)	RHIC (Brookhaven)				LHC† (CERN)	
	1992	1987	2001	2000	2004	2002	2009	2010
Physics start date	1992	1987	2001	2000	2004	2002	2009	2010
Physics end date	2007	—	—				—	
Particles collided	ep	$p\bar{p}$	pp (pol.)	Au Au	Cu Cu	d Au	pp	Pb Pb
Maximum beam energy (TeV)	e : 0.030 p : 0.92	0.980	0.25 34% pol	0.1 TeV/n	0.1 TeV/n	0.1 TeV/n	7.0 (3.5)	2.76 TeV/n (1.38 TeV/n)
Luminosity ($10^{30} \text{ cm}^{-2}\text{s}^{-1}$)	75	402	85 (pk) 55 (ave)	0.0040 (pk) 0.0020 (ave)	0.020 (pk) 0.0008 (ave)	0.27 (pk) 0.14 (ave)	1.0×10^4 (170)	1.0×10^{-3} (1.3×10^{-5})
Time between collisions (ns)	96	396	107	107	321	107	24.95 (49.90)	99.8 (1347)
Full crossing angle (μ rad)	0	0	0				≈ 300	≤ 100 (0)
Energy spread (units 10^{-3})	e : 0.91 p : 0.2	0.14	0.15	0.75	0.75	0.75	0.113 (0.116)	0.11
Bunch length (cm)	e : 0.83 p : 8.5	p : 50 \bar{p} : 45	55	30	30	30	7.55 (5.87)	7.94 (5.83)
Beam radius (10^{-6} m)	e : 280(H), 50(V) p : 265(H), 50(V)	p : 28 \bar{p} : 16	90	135	145	145	16.6 (45)	15.9 (45)
Free space at interaction point (m)	± 2	± 6.5	16				38	38
Initial luminosity decay time, $-L/(dL/dt)$ (hr)	10	6 (average)	2.0	1.1	1.8	1.5	14.9 (8)	10.9 - 3.6‡ (150 - 50)‡
Turn-around time (min)	e : 75, p : 135	90	200	100	145	145	≈ 180	
Injection energy (TeV)	e : 0.012 p : 0.040	0.15	0.023	0.011 TeV/n	0.011 TeV/n	0.012 TeV/n	0.450	0.177 TeV/n
Transverse emittance ($10^{-9}\pi$ rad-m)	e : 20(H), 3.5(V) p : 5(H), 5(V)	p : 3 \bar{p} : 1	11	25	23	25	0.5 (1.0)	0.5 (1.0)
β^* , ampl. function at interaction point (m)	e : 0.6(H), 0.26(V) p : 2.45(H), 0.18(V)	0.28	0.7	0.75	0.9	0.85	0.55 (2.0)	0.5 (2.0)
Beam-beam tune shift per crossing (units 10^{-4})	e : 190(H), 450(V) p : 12(H), 9(V)	p : 120 \bar{p} : 120	47	16	30	d: 21 Au: 17	34 (23)	—
RF frequency (MHz)	e : 499.7 p : 208.2/52.05	53	accel: 28 store: 28	accel: 28 store: 197	accel: 28 store: 197	accel: 28 store: 197	400.8	400.8
Particles per bunch (units 10^{10})	e : 3 p : 7	p : 26 \bar{p} : 9	11	0.12	0.45	d: 10 Au: 0.1	11.5 (7)	0.007
Bunches per ring per species	e : 189 p : 180	36	111	111	37	95	2808 (796)	592 (62)
Average beam current per species (mA)	e : 40 p : 90	p : 70 \bar{p} : 24	152	127	60	d: 119 Au: 94	584 (100)	6.12 (0.641)
Circumference (km)	6.336	6.28	3.834				26.659	
Interaction regions	2 colliding beams 1 fixed target (e beam)	2 high \mathcal{L}	6 total, 2 high \mathcal{L}				2 high \mathcal{L} +2	1 dedicated +2
Magnetic length of dipole (m)	e : 9.185 p : 8.82	6.12	9.45				14.3	
Length of standard cell (m)	e : 23.5 p : 47	59.5	29.7				106.90	
Phase advance per cell (deg)	e : 60 p : 90	67.8	84	93	84	d: 84 Au: 93	90	
Dipoles in ring	e : 396 p : 416	774	192 per ring + 12 common				1232 main dipoles	
Quadrupoles in ring	e : 580 p : 280	216	246 per ring				482 2-in-1 24 1-in-1	
Magnet type	e : C-shaped p : s.c., collared, cold iron	s.c. $\cos\theta$ warm iron	s.c. $\cos\theta$ cold iron				s.c. 2 in 1 cold iron	
Peak magnetic field (T)	e : 0.274, p : 5	4.4	3.5				8.3	

* Additional TEVATRON parameters: \bar{p} source accum. rate: $25 \times 10^{10} \text{ hr}^{-1}$; max. no. of \bar{p} stored: 3.1×10^{12} (Accumulator), 5.4×10^{12} (Recycler).

† Numbers in parentheses refer to goals for operation in 2010.

‡ For 1 - 3 experiments.