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

The numbers here were received from representatives of the colliders in late 1999 (contact C.G. Wohl, LBNL). 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. Parameters for the defunct SPEAR, DORIS, PETRA, PEP, and TRISTAN colliders may be found in our 1996 edition (Phys. Rev. **D54**, 1 July 1996, Part I).

| | VEPP-2M (Novosibirsk) | VEPP-2000* (Novosibirsk) | VEPP-4M (Novosibirsk) | BEPC (China) | DAΦNE (Frascati) |
|---|---|---|---|---|---|
| Physics start date | 1974 | 2001 | 1994 | 1989 | 1999 |
| Maximum beam energy (GeV) | 0.7 | 1.0 | 6 | 2.2 | 0.510 (0.75 max.) |
| Luminosity ($10^{30}$ cm$^{-2}$s$^{-1}$) | 5 | 100 | 50 | 10 at 2 GeV 5 at 1.55 GeV | 50(→500) |
| Time between collisions ($\mu$s) | 0.03 | 0.04 | 0.6 | 0.8 | 0.0027–0.0054 |
| Crossing angle ($\mu$ rad) | 0 | 0 | 0 | 0 | $\pm$(1.0 to 1.5)$\times 10^4$ |
| Energy spread (units $10^{-3}$) | 0.36 | 0.64 | 1 | 0.58 at 2.2 GeV | 0.40 |
| Bunch length (cm) | 3 | 4 | 5 | $\approx$ 5 | 2(→3) |
| Beam radius ($10^{-6}$ m) | $H$: 300 $V$: 10 | 125 (round) | $H$: 1000 $V$: 30 | $H$: 890 $V$: 37 | $H$: 2100 $V$: 21 |
| Free space at interaction point (m) | $\pm$1 | $\pm$1 | $\pm$2 | $\pm$2.15 | $\pm$0.46 ($\pm$157 mrad cone) |
| Luminosity lifetime (hr) | continuous | continuous | 2 | 7–12 | 2 |
| Filling time (min) | continuous | continuous | 15 | 30 | 2 (topping up) |
| Acceleration period (s) | — | — | 150 | 120 | — |
| Injection energy (GeV) | 0.2–0.6 | 0.2–1.0 | 1.8 | 1.55 | 0.510 |
| Transverse emittance ($10^{-9}\pi$ rad-m) | $H$: 110 $V$: 1.3 | $H$: 250 $V$: 250 | $H$: 400 $V$: 20 | $H$: 660 $V$: 28 | $H$: 1000 $V$: 10 |
| $\beta^*$, amplitude function at interaction point (m) | $H$: 0.45 $V$: 0.045 | $H$: 0.06 $V$: 0.06 | $H$: 0.75 $V$: 0.05 | $H$: 1.2 $V$: 0.05 | $H$: 4.5 $V$: 0.045 |
| Beam-beam tune shift per crossing (units $10^{-4}$) | $H$: 200 $V$: 500 | $H$: 750 $V$: 750 | 500 | 350 | 400 |
| RF frequency (MHz) | 200 | 172 | 180 | 199.53 | 368.25 |
| Particles per bunch (units $10^{10}$) | 2 | 16 | 15 | 20 at 2 GeV 11 at 1.55 GeV | 3(→ 9) |
| Bunches per ring per species | 1 | 1 | 2 | 1 | 50–120 |
| Average beam current per species (mA) | 50 | 300 | 80 | 40 at 2 GeV 22 at 1.55 GeV | 800(→5000) |
| Circumference or length (km) | 0.018 | 0.024 | 0.366 | 0.2404 | 0.0977 |
| Interaction regions | 2 | 2 | 1 | 2 | 1(→2) |
| Utility insertions | 1 | 2 | 1 | 4 | $2 \times 2$ |
| Magnetic length of dipole (m) | 1 | 1.2 | 2 | 1.6 | $e^+$: 1.21/0.99 $e^-$: 1.21/0.99 |
| Length of standard cell (m) | 4.5 | 12 | 7.2 | 6.6 | — |
| Phase advance per cell (deg) | 280 | $H$: 738 $V$: 378 | 65 | $\approx$ 60 | — |
| Dipoles in ring | 8 | 8 | 78 | 40 + 4 weak | $e^+$: 8(+4 wigglers) $e^-$: 8(+4 wigglers) |
| Quadrupoles in ring | 20 | 20 | 150 | 68 | $e^+/e^-$: 53/53 |
| Peak magnetic field (T) | 1.8 | 2.4 | 0.6 | 0.9028 at 2.8 GeV | 1.2(→1.76) dipoles 1.8 wigglers |

*VEPP-2000 is a major upgrade of VEPP-2M.

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

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| | 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 | $e^-$: 7–12 (9.0 nominal)<br>$e^+$: 2.5–4 (3.1 " )<br>(nominal $E_{cm}$ = 10.5 GeV) | 50 | 101 in 1999<br>(105=max. foreseen) |
| Luminosity ($10^{30}$ cm$^{-2}$s$^{-1}$) | 830 at 5.3 GeV | 10000 | 3000 | 2.5 | 24 at $Z^0$<br>100 at > 90 GeV |
| Time between collisions ($\mu$s) | 0.014 to 0.22 | 0.002 | 0.0042 | 8300 | 22 |
| Crossing angle ($\mu$ rad) | ±2000 | ±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 | 0.7→1.5 |
| Bunch length (cm) | 1.8 | 0.4 | $e^-/e^+$: 1.1/1.0 | 0.1 | 1.0 |
| Beam radius ($\mu$m) | $H$: 500<br>$V$: 10 | $H$: 77<br>$V$: 1.9 | $H$: 157<br>$V$: 4.7 | $H$: 1.5<br>$V$: 0.5 | $H$: 200 → 300<br>$V$: 2.5 → 8 |
| Free space at interaction point (m) | ±2.2 (±0.6 to REC quads) | +0.75/−0.58<br>(+300/−500) mrad cone | ±0.2,<br>±300 mrad cone | ±2.8 | ±3.5 |
| Luminosity lifetime (hr) | 2–3 | 2 | 2.5 | — | 20 at $Z^0$<br>10 at > 90 GeV |
| Filling time (min) | 10 (topping up) | 8 (topping up) | 3 (topping up) | — | 20 to setup<br>20 to accumulate |
| Acceleration period (s) | — | — | — | — | 600 |
| Injection energy (GeV) | 6 | $e^-/e^+$ : 8/3.5 | 2.5–12 | 45.64 | 22 |
| Transverse emittance ($\pi$ rad-nm) | $H$: 240<br>$V$: 6 | $H$: 18<br>$V$: 0.36 | $e^-$: 48 ($H$), 1.5 ($V$)<br>$e^+$: 48 ($H$), 1.5 ($V$) | $H$: 0.5<br>$V$: 0.05 | $H$: 20–45<br>$V$: 0.25 → 1 |
| $\beta^*$, amplitude function at interaction point (m) | $H$: 1.0<br>$V$: 0.018 | $H$: 0.33<br>$V$: 0.01 | $e^-$: 0.50 ($H$), 0.015 ($V$)<br>$e^+$: 0.50 ($H$), 0.015 ($V$) | $H$: 0.0025<br>$V$: 0.0015 | $H$: 1.5<br>$V$: 0.05 |
| Beam-beam tune shift per crossing (units $10^{-4}$) | 480 | $H$: 390<br>$V$: 520 | 300 | — | 830 |
| RF frequency (MHz) | 500 | 508.887 | 476 | — | 352.2 |
| Particles per bunch (units $10^{10}$) | 1.15 | $e^-/e^+$: 1.3/3.2 | $e^-/e^+$: 2.1/5.9 | 4.0 | 45 in collision<br>60 in single beam |
| Bunches per ring per species | 9 trains of 4 bunches | 5120 (5–10% gap is necessary) | 1658 | 1 | 4 trains of 1 or 2 |
| Average beam current per species (mA) | 260 | $e^-/e^+$: 1100/2600 | $e^-/e^+$: 750/2161 | 0.0008 | 4 at $Z^0$<br>4→6 at > 90 GeV |
| Beam polarization (%) | — | — | — | $e^-$: 80 | 55 at 45 GeV<br>5 at 61 GeV |
| 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 per ring | 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 | 102/90 |
| Dipoles in ring | 86 | $e^-/e^+$ : 116/112 | $e^-/e^+$: 192/192 | 460+440 | 3280+24 inj.<br>+ 64 weak |
| Quadrupoles in ring | 104 | $e^-/e^+$ : 452/452 | $e^-/e^+$: 290/326 | — | 520+288<br>+ 8 s.c. |
| Peak magnetic field (T) | 0.3 normal<br>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

The numbers here were received from representatives of the colliders in late 1999. 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. $H$, $V$, and, s.c. indicate horizontal and vertical directions, and superconducting. The SSC is kept for purposes of comparison.

| | HERA (DESY) | S$p\overline{p}$S (CERN) | TEVATRON (Fermilab) | LHC (CERN) | | SSC (USA) |
|---|---|---|---|---|---|---|
| Physics start date | 1992 | 1981 | 1987 | 2005 | | 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<br>$p$: 0.92 | 0.315 (0.45 in pulsed mode) | 1.0 | 7.0 | 2.76 TeV/u | 20 |
| Luminosity ($10^{30}$ cm$^{-2}$s$^{-1}$) | 14 | 6 | 210 | $1.0 \times 10^4$ | 0.002 | 1000 |
| Time between collisions ($\mu$s) | 0.096 | 3.8 | 0.396 | 0.025 | 0.125 | 0.016678 |
| Crossing angle ($\mu$ rad) | 0 | 0 | 0 | $\geq 200$ | $\leq 200$ | 100 to 200 (135 nominal) |
| Energy spread (units $10^{-3}$) | $e$: 0.91<br>$p$: 0.2 | 0.35 | 0.09 | 0.1 | 0.1 | 0.055 |
| Bunch length (cm) | $e$: 0.83<br>$p$: 8.5 | 20 | 38 | 7.5 | 7.5 | 6.0 |
| Beam radius ($10^{-6}$ m) | $e$: 280($H$), 50($V$)<br>$p$: 265($H$), 50($V$) | $p$: 73($H$), 36($V$)<br>$\bar{p}$: 55($H$), 27($V$) | $p$: 34<br>$\bar{p}$: 29 | 16 | 15 | 4.8 |
| Free space at interaction point (m) | ±5.8 | 16 | ±6.5 | 38 | 38 | ±20 |
| Luminosity lifetime (hr) | 10 | 15 | 7–30 | 10 | 6.7 | ∼24 |
| Filling time (min) | $e$: 60<br>$p$: 120 | 0.5 | 30 | 6 | 20 | 72 |
| Acceleration period (s) | $e$: 200<br>$p$: 1500 | 10 | 86 | 1200 | | 1500 |
| Injection energy (TeV) | $e$: 0.012<br>$p$: 0.040 | 0.026 | 0.15 | 0.450 | 177.4 GeV/u | 2 |
| Transverse emittance ($10^{-9}\pi$ rad-m) | $e$: 42($H$), 6($V$)<br>$p$: 5($H$), 5($V$) | $p$: 9<br>$\bar{p}$: 5 | $p$: 3.5<br>$\bar{p}$: 2.5 | 0.5 | 0.5 | 0.047 |
| $\beta^*$, amplitude function at interaction point (m) | $e$: 1($H$), 0.7($V$)<br>$p$: 7($H$), 0.5($V$) | 0.6 (H)<br>0.15 (V) | 0.35 | 0.5 | 0.5 | 0.5 |
| Beam-beam tune shift per crossing (units $10^{-4}$) | $e$: 190($H$), 360($V$)<br>$p$: 12($H$), 9($V$) | 50 | $p$: 38<br>$\bar{p}$: 97 | 34 | — | 8 head on<br>13 long range |
| RF frequency (MHz) | $e$: 499.7<br>$p$: 208.2/52.05 | 100+200 | 53 | 400.8 | 400.8 | 359.75 |
| Particles per bunch (units $10^{10}$) | $e$: 3<br>$p$: 7 | $p$: 15<br>$\bar{p}$: 8 | $p$: 27<br>$\bar{p}$: 7.5 | 10.5 | 0.0094 | 0.8 |
| Bunches per ring per species | $e$: 189<br>$p$: 180 | 6 | 36 | 2835 | 608 | 17,424 |
| Average beam current per species (mA) | $e$: 40<br>$p$: 90 | $p$: 6<br>$\bar{p}$: 3 | $p$: 81<br>$\bar{p}$: 22 | 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<br>$p$: 8.82 | 6.26 | 6.12 | 14.3 | | Mostly 14.928 |
| Length of standard cell (m) | $e$: 23.5<br>$p$: 47 | 64 | 59.5 | 106.90 | | 180 |
| Phase advance per cell (deg) | $e$: 60<br>$p$: 90 | 90 | 67.8 | 90 | | 90 |
| Dipoles in ring | $e$: 396<br>$p$: 416 | 744 | 774 | 1232 main dipoles | | $H$: 8336<br>$V$: 88 } in 2 rings |
| Quadrupoles in ring | $e$: 580<br>$p$: 280 | 232 | 216 | 692 focussing +96 skew | | 2084 } 2 rings |
| Magnet type | $e$: C-shaped<br>$p$: s.c., collared, cold iron | $H$ type with bent-up coil ends | s.c.<br>cos $\theta$<br>warm iron | s.c.<br>2 in 1<br>cold iron | | s.c.<br>cos $\theta$<br>cold iron |
| Peak magnetic field (T) | $e$: 0.274<br>$p$: 4.65 | 1.4 (2 in pulsed mode) | 4.4 | 8.3 | | 6.790 |
| $\overline{p}$ source accum. rate (hr$^{-1}$) | — | $6 \times 10^{10}$ | $20\times10^{10}$ | — | | — |
| Max. no. $\overline{p}$ in accum. ring | — | $1.2 \times 10^{12}$ | $2.6\times10^{12}$ | — | | — |