Table S.1: Machine parameters of the FCC-ee for different beam energies. For $\mathrm{t\bar{t}}$ operation a common RF system is used.

	Z	WW	ZH	$\mathrm{t\bar{t}}$	
Circumference [km]	97.756				
Bending radius [km]	10.760				
Free length to IP l^* [m]	2.2				
Solenoid field at IP [T]	2.0				
Full crossing angle at IP θ [mrad]	30				
SR power / beam [MW]	50				
Beam energy [GeV]	45.6	80	120	175	182.5
Beam current [mA]	1390	147	29	6.4	5.4
Bunches / beam	16640	2000	328	59	48
Average bunch spacing [ns]	19.6	163	994	2763	3396
Bunch population [10^{11}]	1.7	1.5	1.8	2.2	2.3
Horizontal emittance ε_x [nm]	0.27	0.84	0.63	1.34	1.46
Vertical emittance ε_y [pm]	1.0	1.7	1.3	2.7	2.9
Horizontal β^*_x [m]	0.15	0.2	0.3	1.0	
Vertical β^*_y [mm]	0.8	1.0	1.0	1.6	
Energy spread (SR/BS) σ_δ [%]	0.038/0.132	0.066/0.131	0.099/0.165	0.144/0.186	0.150/0.192
Bunch length (SR/BS) σ_z [mm]	3.5/12.1	3.0/6.0	3.15/5.3	2.01/2.62	1.97/2.54
Piwinski angle (SR/BS) ϕ	8.2/28.5	3.5/7.0	3.4/5.8	0.8/1.1	0.8/1.0
Energy loss / turn [GeV]	0.036	0.34	1.72	7.8	9.2
RF frequency [MHz]	400			400 / 800	
RF voltage [GV]	0.1	0.75	2.0	4.0 / 5.4	4.0 / 6.9
Longitudinal damping time [turns]	1273	236	70.3	23.1	20.4
Energy acceptance (DA) [%]	±1.3	±1.3	±1.7	-2.8 +2.4	
Polarisation time t_p [min]	15000	900	120	18.0	14.6
Luminosity / IP [10^{34}/cm^{2}s]	230	28	8.5	1.8	1.55
Beam-beam ξ_x/ξ_y	0.004/0.133	0.010/0.113	0.016/0.118	0.097/0.128	0.099/0.126
Beam lifetime by rad. Bhabha scattering [min]	68	59	38	40	39
Actual lifetime incl. beamstrahlung [min]	> 200	> 200	18	24	18

accuracy for the measurements of the standard model particle properties, it opens windows to detect new rare processes, and it furnishes opportunities to observe tiny violations of established symmetries.

Technical systems

Table S.1 reveals that the FCC-ee machine faces quite different requirements in its various modes of operation. For example, on the Z pole FCC-ee is an Ampere-class storage ring, like PEP-II, KEKB and DAΦNE, with a high beam current, but a low RF voltage, of order 0.1 GV. For the $\mathrm{t\bar{t}}$ mode, the beam current is only a few mA, as for the former LEP2, while an RF voltage above 10 GV is required. In both cases a total of 100 MW RF power must be constantly supplied to the two circulating beams.

Three sets of RF cavities are proposed to cover all operation modes for the FCC-ee collider rings and booster. (1) For the high intensity operation (Z, FCC-hh) 400 MHz mono-cell cavities (4 per cryomodule) based on Nb/Cu thin-film technology at 4.5 K; (2) for higher energy (W, H, $\mathrm{t\bar{t}}$) 400 MHz four-cell cavities (4 per cryomodule) again based on Nb/Cu technology at 4.5 K, and (3), finally for the $\mathrm{t\bar{t}}$ machine a complement of 800 MHz five-cell cavities (again 4 per cryomodule) based on bulk Nb at 2 K. The installation sequence (Fig. S.4) is comparable to that of LEP, where about 30 cryomodules were installed per shutdown.

A high overall energy efficiency is achieved through a combination of different technical and operational measures, for example, by using advanced RF power sources [23] and novel low-power twin aperture magnets [24], and by top-up injection.