Snowmass'21

Joint AF-EF Meeting on Future Colliders

"Day 1" and "Day 2"

Summary: Machine Parameter "Standard Tables"

https://indico.fnal.gov/event/43871/
https://indico.fnal.gov/event/43872/

June 24 and July 1 AF-EF talks (10 am EST)

Day 1: 10 min + 5 min Q&A = 15 min total/talk

Day 2: 10 min + 10 min Q&A = 20 min total/talk

Day 1: https://indico.fnal.gov/event/43871/

Day 2: https://indico.fnal.gov/event/43872/

Facility "Standard Table"

Facility / Your name*	Particle species	* Contact email for Qs
Beam Energy	GeV	
Peak Luminosity (10^34)	cm-2 s-1	
Int. Luminosity	ab-1/yr	
Beam dE/E at IP		
Transv. Beam sizes at IP x/y	um	
Rms bunch length / beta*	cm	
Crossing angle	urad	
Rep./Rev. frequency	Hz	
Bunch spacing	ns	
# of IPs		
# of bunches		
Length/Circumference	km	
Facility site power	MW	
Cost range	$B US	(day 2 speakers – feel free to skip)
Timescale till operations		

FCCee – Katsunobu Oide

	e^+e^-	katsunobu.oide@cern.ch			
Beam Energy, range	GeV	45.6, ±2	80, ±2	120, -10+5	182.5, -12+2
Peak Luminosity (10^34)	cm-2 s-1	460 / 2IP	56 / 2IP	17 / 2IP	3.1 / 2IP
Int. Luminosity	ab-1/yr	48 / 2IP	6 / 2IP	1.7 / 2IP	0.34 / 2IP
Beam dE/E at IP		3.8×10^{-6}	10×10^{-6}	26×10^{-6}	73×10^{-6}
Transv. Beam sizes at IP x/y	um	6.4 / 0.028	13.0 / 0.041	13.7 / 0.036	38.2 / 0.068
Rms bunch length /length of interaction area/ beta*	cm	1.21/0.042/0.08	0.60/0.085/0.1	0.53/0.09/0.1	0.25/0.18/0.16
Crossing angle	urad	±15000			
Rep./Rev. frequency	Hz	3066.7			
Bunch spacing	ns	17.5	160	990	3400
# of IPs		2			
# of bunches		16640 / ring	2000 / ring	328 / ring	48 / ring
Length/Circumference	km	97.756			
Facility site power	MW	259	277	282	340
Cost range	$B US	10.5 (BCHF)			+1.1 (BCHF)
Timescale till operations	yr	19	+4	+2	+4

CepC – Yu Chenghui

Beam Energy	GeV	120
Peak Luminosity (10^34)/IP	cm-2 s-1	3.0
Int. Luminosity	ab-1/year	1.4
Beam dE/E at IP		0.00134
Transv. Beam sizes at IP x/y	um	20.9 / 0.06
Rms bunch length / betaY*	mm	4.4 / 1.5
Crossing angle	mrad	33
Rep./Rev. frequency	Hz	3000
Bunch spacing	ns	680
# of IPs		2
# of bunches		242
Length/Circumference	km	100
Facility site power	MW	300
Cost range	$B US	5.0
Timescale till operations		2030

ILC – Shinichiro Michizono

ILC	electron/positron	ILC250
Beam Energy	GeV	125 (e-) and 125 (e+)
Peak Luminosity (10^34)	cm-2 s-1	1.35
Int. Luminosity	ab-1/yr	0.24*
Beam dE/E at IP		0.188% (e-), 0.150% (e+)
Transv. Beam sizes at IP x/y	nm	515/7.66
Rms bunch length /	cm	0.03 (σ_z)
beta*	mm	bx*=13mm, by*=0.41mm
Crossing angle	mrad	14
Rep./Rev. frequency	Hz	5
Bunch spacing	ns	554
# of IPs		1
# of bunches		1,312
Length/Circumference	km	20.5
Facility site power	MW	111
Cost (value) range	$B US	~5 (tunnel and accelerator)
Timescale till operations	years	(~1) + 4(prep.) + 9(construction)

CLIC – Steinar Stapnes

Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	$\sqrt{s}$	GeV	380	1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		352	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Pulse length	τ_{RF}	ns	244	244	244
Accelerating gradient	G	MV/m	72	72/100	72/100
Total luminosity	$\mathscr{L}$	$10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$	1.5	3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathscr{L}_{0.01}$	$10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$	0.9	1.4	2
Total integrated luminosity per year	$\mathscr{L}_{\text{int}}$	fb^{-1}	180	444	708
Main linac tunnel length		km	11.4	29.0	50.1
Number of particles per bunch	N	10^9	5.2	3.7	3.7
Bunch length	σ_z	μm	70	44	44
IP beam size	σ_x/σ_y	nm	149/2.9	$\sim$ 60/1.5	$\sim$ 40/1
Normalised emittance (end of linac)	$\varepsilon_x/\varepsilon_y$	nm	900/20	660/20	660/20
Final RMS energy spread		%	0.35	0.35	0.35
Crossing angle (at IP)		mrad	16.5	20	20

EIC – Christoph Montag

EIC/Christoph Montag	e - p	Montag@bnl.gov
Beam Energy	GeV	e: 5, p: 41
Peak Luminosity (10^34)	cm-2 s-1	0.044
Int. Luminosity	ab-1/yr	4.4
Beam dE/E at IP		e: 6.8, p: 10.3
Transv. Beam sizes at IP x/y	um	198/27
Rms bunch length / beta*	cm	e: 2, p: 7.5
Crossing angle	urad	25
Rep./Rev. frequency	Hz	78000
Bunch spacing	ns	10
# of IPs		1 (up to 2)
# of bunches		1160
Length/Circumference	km	3.8
Facility site power	MW	58
Cost range	$B US	$1.6B - $2.6B
Timescale till operations		~2030

LHeC – Oliver Bruning

Facility / Your name*	Particle species	* Contact email
Beam Energy	30-60 GeV	Oliver.bruning@cern.ch
Peak Luminosity (10^34)	1 cm-2 s-1	mklein@hep.ph.liv.ac.uk
Int. Luminosity	$20fb^{-1}$ to $200fb^{-1}$ with 1 ab^{-1} over 10 years	
Beam dE/E at IP	Few 10^{-4}	
Transv. Beam sizes at IP x/y	10 μm	
Rms bunch length / beta*	0.15cm / 10cm	
Crossing angle	0 urad	
Rep./Rev. frequency	CW with 40MHz	
Bunch spacing	25ns	
# of IPs	1	
# of bunches	CW	
Length/Circumference	5.5km to 9km	
Facility site power	100 MW	
Cost range	Ca. 1 $B US	
Timescale till operations	2030-2040 LHC / 2045- 2050 FCC	

HE-LHC – Frank Zimmermann

HE-LHC	p-p (p-A, A-A)	* frank.zimmermann@cern.ch
Beam Energy	GeV	13500 (p-p)
Peak Luminosity (10^{34})	$cm^{-2}s^{-1}$	16 (p-p)
Int. Luminosity	ab^{-1}/yr	≥0.5
Beam dE/E at IP (rms)		$8x10^{-5}$
Transv. Beam sizes at IP x/y	μm	9/9 (initial)
Rms bunch length / beta*	cm	9, 45
Crossing angle	μrad	330 (full)
Rep./Rev. frequency	Hz	Rep rate = $2.7x10^{-5}$ Hz (5 h t.-a. + 5.3 h run length); rev freq.=11,245 Hz
Bunch spacing	ns	25
# of IPs		2
# of bunches		2808 / beam
Length/Circumference	km	26.7
Facility site power	MW	162
Cost range	$B US	7-8
Timescale till operation		> 2050

SPPC – Jingyu Tang

Parameter	Unit	Value		
		PreCDR	CDR	Ultimate
Circumference	km	54.4	100	100
C.M. energy	TeV	70.6	75	125-150
Dipole field	T	20	12	20-24
Injection energy	TeV	2.1	2.1	4.2
Number of IPs		2	2	2
Nominal luminosity per IP	$cm^{-2}s^{-1}$	1.2e35	1.0e35	-
Beta function at collision	m	0.75	0.75	-
Circulating beam current	A	1.0	0.7	-
Bunch separation	ns	25	25	-
Bunch population		2.0e11	1.5e11	-
SR power per beam	MW	2.1	1.1	-
SR heat load per aperture @arc	W/m	45	13	-

FCC-hh – Michael Benedikt

FCC-hh	p-p (p-A, A-A)	michael.benedikt@cern.ch
Beam Energy, range	TeV	50
Peak Luminosity (10^34)	cm-2 s-1	30
Int. Luminosity	ab-1/yr	1.5-2 / 2IP
Beam dE/E at IP		6.2×10^{-5}
Transv. Beam sizes at IP x/y	um	3.5
Rms bunch length / beta*	cm	8
Crossing angle	urad	200
Rep./Rev. frequency	Hz	3066.7
Bunch spacing	ns	25
# of IPs		4 (2 with high-luminosity)
# of bunches		10400 / ring
Length/Circumference	km	97.756
Facility site power	MW	560
Cost range	$B US	17 following FCC-ee in integrated program 24 standalone
Timescale till operations	yr	35-45

“Day 2”

Normal-Conducting LC – Emilio Nanni

Facility "Standard Table"

C³ / Emilio Nanni* / Sami Tantawi	Particle species	*nanni@slac.stanford.edu
Beam Energy	GeV	1000 (single beam)
Peak Luminosity (10^34)	cm-2 s-1	4.5
Int. Luminosity	ab-1/yr	TBD
Beam dE/E at IP		TBD
Transv. Beam sizes at IP x/y	um	TBD
Rms bunch length / beta*	cm	TBD
Crossing angle	urad	TBD
Rep./Rev. frequency	Hz	120
Bunch spacing	ns	3.3
# of IPs		1
# of bunches		75 (1 nC each)
Length/Circumference	km	9.4 km / linac
Facility site power	MW	340 (total for both linacs)
Timescale till operations		TBD

ERL-FCCee – Thomas Roser

ERL collider / T Roser	e+/e-	vl@bnl.ogv , roser@bnl.gov, mchamizo@bnl.gov	
Beam Energy	GeV	300 (Httbar)	120 (HZ)
Peak Luminosity	10^{34} cm^{-2} s^{-1}	8.3	73
Int. Luminosity	ab^{-1}/year	1.0	8.8
Beam dE/E at IP	%	0.32	0.23
Transv. Beam sizes at IP x/y	um	3.7 / 0.0052	5.0 / 0.0058
Rms bunch length / betay*	cm	0.2 / 0.2	0.1 / 0.1
Crossing angle	urad	0	0
Rep./Rev. frequency	Hz	9,000	99,000
Bunch spacing	ns	110,000	10,000
# of IPs		Multiple with shared luminosity	
# of bunches		Continuous beam	
Length/Circumference	km	100	
Facility site power	MW	30 MW of synchrotron radiation power	
Cost range	$B US	(day 2 speakers – feel free to skip)	
Timescale until operations		10 – 15 years	

$\gamma\gamma$ Higgs Factories – Frank Zimmermann

frank.zimmermann@cern.ch	$\gamma\gamma$	SAPPHiRE	HFiTT
e- beam energy	GeV	80	80
e- polarisation		80%	80%
Peak Luminosity (10^{34})	$cm^{-2}s^{-1}$	~2 (e^-e^- geometric)	3.2 (e^-e^-), 0.5 ($\gamma\gamma$>125 GeV)
Int. Luminosity	ab^{-1}/yr	0.05 (10k H/yr)	0.05 (10k H/yr)
Beam dE/E at IP		~0.1 (γ beam)	0.2% (e- beam)
Transv. beam sizes at IP x/y	μm	0.4, 0.018	0.48, 0.010
Rms bunch length / β^*_y	cm	0.003 / 0.01	0.035 / 0.04 ?
Crossing angle	μrad	≥20,000	25,000
Rep./Rev. frequency	Hz	200,000	47,700
Bunch spacing	ns	5000	~20000
# of IPs		1	1
# of bunches		cw	cw
Length/Circumference	km	~ 9	6.28
Facility site power	MW	100	80
Cost range	$B US	2-3	?
Timescale till operations		~2040	~2030

Laser-Plasma WFA – Carl Schroeder

LPWFA collider e-/e+		1 TeV cme	3 TeV cme	30 TeV cme
Beam Energy	TeV	0.5	1.5	15
Luminosity (10^34)	cm-2 s-1	1	10	1000
Int. Luminosity	ab-1/yr	0.18 (5000hrs)	1.8 (5000hrs)	18 (5000hrs)
Beam dE/E at IP				(Y>>1 regime)
Transv. Beam sizes at IP x/y	nm	50 / 1	10 / 0.5	0.2 / 0.2
Rms bunch length / beta*	mm	0.0085 / 0.1	0.0085 / 0.1	0.0085 / 0.2
Crossing angle	urad			
Rep. frequency	kHz	47	47	47
Bunch spacing	us	21	21	21
# of IPs		1	1	1
# of bunches		1	1	1
Length (2 linac tunnels)	km	0.44	1.3	13
Facility site power (2 linacs)	MW	105	315	3151
Cost range	$B US			
Timescale till operations		>30 years	>30+ years	>30++ years

Beam-Plasma WFA – Spencer Gessner

Plasma Linear Collider	Electron/Positron	Higgs Fact.	Multi-TeV
Beam Energy	GeV	250	10000
Peak Luminosity (10^34)	cm-2 s-1	1.57×10^{34}	1.05×10^{35}
Int. Luminosity	ab-1/yr	0.157	1.045
Beam dE/E at IP		0.1	0.1
Transv. Beam sizes at IP x/y	um	$0.7 / 4 \times 10^{-3}$	$0.1 / 6 \times 10^{-4}$
Rms bunch length / beta*	cm	$2 \times 10^{-3}/0.01$	$2 \times 10^{-3}/0.01$
Crossing angle	urad	1400	1400
Rep./Rev. frequency	Hz	30000	5000
Bunch spacing	ns	33333	200000
# of IPs		1	1
# of bunches		1	1
Length/Circumference	km	2.25	18
Facility site power	MW	132.92	537.22
Cost range	$B US		
Timescale till operations			

Structure-beam WFA – John Power

AFLC (beam driven SWFA)	**Particle species**	*** Contact John Power for Qs**
Beam Energy	GeV	3000
Peak Luminosity (10^34)	cm-2 s-1	5.9**
Int. Luminosity	ab-1/yr	708**
Beam dE/E at IP		0.35%**
Transv. Beam sizes at IP x/y	nm	~40/1**
Rms bunch length / beta*	µm	44**
Crossing angle	mrad	20**
Rep./Rev. frequency	Hz	5
Bunch spacing	ns	0.077
# of IPs		1
# of bunches		208 in macrobunch, 4160 in macrobunc
Length	km	18
Facility site power	MW	222
Cost range	$B US	??? See CLIC but less ???
Timescale till operations		Resource dependent

Muon Colliders (MAP design) – Daniel Schulte

Muon Collider Parameters					
		Higgs	Multi-TeV		
Parameter	***Units***	*Production Operation*			*Accounts for Site Radiation Mitigation*
CoM Energy	TeV	**0.126**	**1.5**	**3.0**	**6.0**
Avg. Luminosity	$10^{34}cm^{-2}s^{-1}$	0.008	1.25	4.4	12
Beam Energy Spread	%	0.004	0.1	0.1	0.1
Higgs Production/10^7sec		13,500	37,500	200,000	820,000
Circumference	km	0.3	2.5	4.5	6
No. of IPs		1	2	2	2
Repetition Rate	Hz	15	15	12	6
β^*	cm	1.7	1 (0.5-2)	0.5 (0.3-3)	0.25
No. muons/bunch	10^{12}	4	2	2	2
Norm. Trans. Emittance, ε_{TN}	π mm-rad	0.2	0.025	0.025	0.025
Norm. Long. Emittance, ε_{LN}	π mm-rad	1.5	70	70	70
Bunch Length, σ_s	cm	6.3	1	0.5	0.2
Proton Driver Power	MW	4	4	4	1.6
Wall Plug Power	MW	200	216	230	270

Muon Colliders (Target Parameters) – Daniel Schulte

Parameter	Unit	3 TeV	10 TeV	14 TeV
L	10^{34} cm^{-2}s^{-1}	1.8	20	40
N	10^{12}	2.2	1.8	1.8
f_r	Hz	5	5	5
P_{beam}	MW	5.3	14.4	20
C	km	4.5	10	14
<B>	T	7	10.5	10.5
ε_L	MeV m	7.5	7.5	7.5
σ_E / E	%	0.1	0.1	0.1
σ_z	mm	5	1.5	1.07
β	mm	5	1.5	1.07
ε	μm	25	25	25
$\sigma_{x,y}$	μm	3.0	0.9	0.63