

Contents

FCC Collaboration	3
Executive Summary	5
1 Physics Discovery potential	13
1.1 Introduction	13
1.2 Precision electroweak measurements	13
1.3 The Higgs Boson	13
1.4 Rare processes	13
1.5 New particle discovery potential	13
1.6 Requirements for the collider	13
1.7 Requirements for the detector	13
1.8 Requirements for theory	14
2 Collider Design and Performance	15
2.1 Design goals and basic choices	15
2.2 Parameter Optimisation	17
2.3 Design Challenges and Approaches	17
2.3.1 Synchrotron radiation	17
2.3.2 Tapering	17
2.3.3 Dynamic aperture, beam lifetime, top-up injection	17
2.3.4 Low emittance tuning and optics correction	19
2.3.5 Energy efficiency	20
2.4 Optics Design and Beam Dynamics	20
2.4.1 Modified FODO cell in the arc	20
2.4.2 Interaction Region	21
2.4.3 RF section and other straight sections	22
2.4.4 Dynamic Aperture	24
2.4.5 Tolerances and optics tuning	26
2.5 Machine detector interface	26
2.6 Collective effects	26
2.6.1 Introduction	26
2.7 Impedance budget	27
2.7.1 Resistive wall	27
2.7.2 RF cavities and tapers	27
2.7.3 SR absorbers	28
2.7.4 Collimators	28
2.7.5 Beam Position Monitors	28
2.7.6 RF shielding	29
2.7.7 Summary	29

2.8	Single bunch instabilities	30
2.8.1	Microwave instability	30
2.8.2	TMCI	31
2.9	Multi bunch instabilities	32
2.9.1	Transverse resistive wall coupled bunch instability	32
2.9.2	Bunch-by-bunch feedback requirements	32
2.10	Interaction region impedance budget	34
2.10.1	IP resistive wall	34
2.10.2	SR masks	34
2.10.3	Trapped modes	35
2.11	Electron cloud	35
2.11.1	Electron density threshold for the single bunch head-tail instability	35
2.12	Energy calibration and polarization	36
2.13	Injection and extraction	38
2.14	Machine performance and operation aspects	38
2.15	Monochromatization	40
2.16	Running at other energies	40
3	Collider Technical Systems	43
3.1	Main RF systems including staging and RF R and D	43
3.2	Main Magnet System	43
3.2.1	Introduction	43
3.2.2	Main Dipole Magnets	43
3.2.3	Quadrupoles	43
3.2.4	Interaction Region and Final Focus	43
3.2.5	Auxiliary Magnets	43
3.3	Vacuum system and e-cloud mitigation	43
3.4	Beam instrumentation and feedback systems	43
3.5	Beam dumping, beam injection and beam transfer systems	43
3.6	Other key technologies	43
3.7	Radiation Environment	44
4	Civil Engineering	45
4.1	Requirements and Design Considerations	45
4.2	Layout and Placement	45
4.2.1	Collider Layout	46
4.2.2	Collider Placement	46
4.3	Underground Structures	46
4.3.1	Tunnels	46
4.3.2	Shafts	46
4.3.3	Alcoves	46
4.3.4	Experiment Caverns	46

4.3.5	Service Caverns	46
4.4	Surface Points	46
4.4.1	Experiment Surface Site	46
4.4.2	Technical Surface Site	46
4.4.3	Access Roads	46
5	Technical Infrastructures	47
5.1	Requirements and Design Considerations	47
5.2	Piped Utilities	47
5.2.1	General introduction to piping systems	47
5.2.2	Cooling plants	47
5.2.3	Chilled water	49
5.2.4	Drinking water	50
5.2.5	Fire fighting network	50
5.2.6	Reject water	50
5.2.7	Compressed air	51
5.3	Heating, Ventilation, Air Conditioning	51
5.3.1	Design	51
5.3.2	Indoor conditions	51
5.3.3	Ventilation of underground premises	51
5.3.4	Machine tunnels	52
5.3.5	Experimental caverns	52
5.3.6	Other premises	52
5.3.7	Operational modes	52
5.3.8	Working parameters	52
5.3.9	Ventilation of surface buildings	53
5.3.10	Safety	53
5.4	Electricity Distribution	54
5.5	Emergency Power	54
5.6	Cryogenic System	54
5.6.1	Overview	55
5.6.2	Proximity Cryogenics and Heat Loads	55
5.6.3	Cryogenic Plants	55
5.6.4	Cryogen Inventory and Storage	55
5.7	Equipment Transport and Handling	55
5.8	Person Transport	55
5.9	Geodesy, Survey and Alignment	55
5.10	Communications, Computing and Data Services	55
5.11	Safety and Access Management Systems	55
6	Injector complex	57
6.1	Electron gun	57

6.2	Linac	57
6.3	Positron source and capture system	57
6.4	Damping ring	57
6.5	Energy and bunch compressors	57
6.6	Pre-booster	57
6.7	Booster	57
6.8	Transfer Lines	57
7	Experiments and Detectors	59
7.1	Experimental environment	59
7.2	The luminometer	59
7.3	The vertex detector	59
7.4	The all-silicon detector design	59
7.5	The IDEA concept	59
7.6	Magnet System	59
7.7	Constraints on readout systems	59
7.8	Infrastructure Requirements	59
8	Safety	61
8.1	Safety Policy and Regulatory Framework	61
8.1.1	Legal Context of CERN	61
8.1.2	Hazard Register and Safety Performance Based Design	62
8.2	Occupational Health and Safety	62
8.2.1	Fire Hazard	63
8.2.2	Oxygen Deficiency	63
8.3	Radiation Protection	64
8.3.1	Particle Beam Operation	64
8.3.2	Activation of Solids	65
8.3.3	Activated or contaminated liquids	65
8.3.4	Activated or radioactive gases and radioactive aerosols	65
9	Energy Efficiency	67
9.1	Requirements and Design Considerations	67
9.2	Power Consumption	67
9.3	Energy Management and Saving	67
9.4	Waste Heat Valorisation	67
10	Environment	69
10.1	Requirements and Approach Considerations	69
10.1.1	Legal Requirements	69
10.1.2	Environmental Compatibility Management Concept	69
10.2	Environmental Impacts	69

10.2.1	Radiological Impacts	69
10.2.2	Conventional Impacts	69
10.3	Waste Management	69
10.3.1	Radioactive Waste Management	69
10.3.2	Conventional Waste Management	69
11	Education, Economy and Society	71
11.1	Requirements and Approach Considerations	71
11.2	Host State Realization Concept	71
11.2.1	France	71
11.2.2	Switzerland	71
11.3	Socio-Economic Opportunities	71
11.3.1	Scientific Publications	71
11.3.2	The Value of Training	71
11.3.3	Opportunities for Industries	71
11.3.4	Cultural Effects	71
11.3.5	The Value of Knowledge	71
12	Strategic Research and Development	73
12.1	Strategic Considerations	73
12.2	Accelerator Related R&D	73
12.3	Detector Related R&D	73
12.4	Infrastructures Related R&D	73
12.5	Risks	73
	Appendices	75
A	Collider Parameter Tables	75
A	Collider	75
B	LHC as Injector	75
C	Superconducting SPS	75
B	Experiment Parameter Tables	77
C	Infrastructures Parameter Tables	79
A	Layout	79
B	Civil Engineering	79
C	Resource Use	79
	Glossary	79
	References	84