

Contents

I	Executive Summaries	2
1	Introduction and Overview	4
1.1	Motivation	4
1.2	The muon collider concept	4
1.3	The muon collider challenges	6
1.4	Developing the muon collider study	9
1.5	R&D Progress and Status	10
1.6	Key future R&D Objectives	11
1.7	R&D Programme	13
1.8	Synergies	13
1.9	Site development	14
1.10	Timeline and staging	14
1.11	Sustainability and environnement	15
1.12	Conclusion	15
II	Evaluation Report	16
2	Physics	18
2.0.1	Exploring the energy frontier	19
2.0.2	Synergies and staging	25
3	Interface	31
3.1	Physics and detector needs	31
3.2	MDI	34
3.2.1	Overview	34
3.2.2	Key challenges	35
3.2.3	Recent achievements	36
4	Detector concepts	39
4.1	Overview	39
4.2	MUSIC	39
4.3	MAIA	41
4.4	Performance	42
4.5	Technologies	46

4.6	Software & Computing	46
4.6.1	System Overview	46
4.6.2	Requirements	47
5	Accelerator complex concepts	49
5.1	Proton driver	49
5.1.1	Overview	49
5.2	Muon production & cooling	54
5.2.1	Key challenges	55
5.2.2	Recent Achievements - Target & Front End	55
5.2.3	Recent Achievements - Rectilinear Cooling	55
5.2.4	Recent Achievements - Final Cooling	58
5.3	Acceleration	60
5.3.1	Low-energy acceleration	60
5.3.2	High-energy acceleration	61
5.4	Collider	65
5.4.1	Collective Effects and Integration	66
6	Accelerator Technologies	67
6.1	Magnets	67
6.2	Power converters	67
6.2.1	Power converters for the muon accelerator	67
6.3	Radiofrequency	67
6.3.1	RF system for muon cooling	68
6.3.2	RF system for acceleration	71
6.4	Target	73
6.5	Radiation shielding	76
6.6	Muon cooling cell	79
6.7	Cryogenics	81
6.8	Vacuum	84
6.9	Absorber	87
6.10	Instrumentation	87
6.11	Radiation protection	87
6.12	Movers	91
6.13	Technical infrastructure	91
6.14	Safety	91

III	R&D Proposal and Implementation	92
7	R&D Objectives	93
7.1	Overview	93
7.2	Focus 2025-2035	93
7.3	Timeline	93
7.4	Plan & Cost	93
8	Physics R&D	94
8.1	Introduction	94
8.2	Expanding and consolidating the physics case	95
8.3	Physics at the muon collider facility	96
8.4	Theoretical tools	96
8.5	The future muon collider physics community	96
9	Detector R&D	97
9.1	Detector concept and performance	97
9.2	Detector technologies	98
9.3	Software & computing for detectors	98
9.3.1	Next Steps	99
9.3.2	Thoughts from K. KRIZKA	99
9.3.3	Thoughts from W. HOPKINS	101
9.3.4	Thoughts form T. MADLENER	101
10	Magnets R&D	102
11	Accelerator R&D	103
11.1	Accelerator design	103
11.1.1	Proton complex	103
11.1.2	Muon cooling systems	103
11.1.3	Low-energy acceleration	103
11.1.4	High-energy complex	104
11.1.5	Collider ring	106
11.1.6	Collective effects	106
11.2	Machine-detector interface	106
11.3	Neutrino flux mitigation system	106
11.4	RF systems	106
11.4.1	Muon cooling RF	106

11.4.2	High energy complex RF	106
11.4.3	RF test stand and test cavities	107
11.5	Target system	107
11.6	Instrumentation	108
11.7	Radiation shielding	108
11.8	Cryogenics	108
11.9	Vacuum	109
11.10	Radiation protection	109
11.11	Infrastructure	110
11.12	General safety	110
11.13	Other technologies	111
11.14	Software for the accelerator	111
12	Muon cooling demonstration	112
12.1	Cooling demonstrator programme	112
12.2	RF Test Stand	112
12.2.1	RF Testing at SLAC	112
12.3	Muon cooling test module	112
12.4	Demonstrator implementation at CERN	112
12.4.1	Demonstrator system description	112
12.4.2	Civil engineering	112
12.4.3	Infrastructure	113
12.4.4	Cost and timeline	113
12.5	Demonstrator implementation at Fermilab	113
12.5.1	Fermilab Accelerator Complex Evolution	113
12.5.2	Fermilab Demonstrator Sites options	113
12.5.3	Demonstrator Design	114
13	Other test infrastructure	115
14	R&D Programme Synergies	116
14.1	Technologies	116
14.1.1	Magnets	116
14.1.2	SRF technology	117
14.1.3	Other technologies	117
14.2	Technology applications	118
14.2.1	Accelerator magnets	118

14.2.2	Fusion	118
14.2.3	Material and life science in high magnetic field	119
14.2.4	Nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI)	119
14.2.5	Low-consumption magnets for nuclear and particle physics, and medical applications	119
14.2.6	Magnets for neutron spectroscopy	120
14.2.7	Detector magnets for physics search	120
14.2.8	Superconducting motors and generators	120
14.2.9	Targets for spallation neutron sources	120
14.2.10	Microwave RF sources	121
14.3	Facilities	121
14.3.1	Colliders	121
14.3.2	Charged lepton flavour violation experiments	122
14.3.3	$g-2$	122
14.3.4	nuSTORM and precision neutrino experiments	122
14.3.5	muSR and low-energy muon beams	123
14.3.6	High power proton sources	123
14.4	Synergies—summary	123
15	Sustainability Environmental considerations	124
15.1	Cost drivers and cost scale	124
15.2	Power drivers and power scale	124
16	Muon Collider implementation	125
16.1	Overview	125
16.2	Timeline	125
16.3	Implementation at CERN	125
16.3.1	Timeline	125
16.3.2	Civil Engineering	125
16.3.3	Infrastructure	126
16.3.4	Accelerator	126
16.4	Implementation at Fermilab	126
16.4.1	Timeline	127
16.4.2	Civil Engineering	127
16.4.3	Infrastructure	127
16.4.4	Accelerator	127