

# Contents

<i>Acknowledgments</i>	vii
<i>Foreword</i>	xiii
1. Introduction	1
1.1 Neutrino Oscillations . . . . .	1
1.1.1 Experiments . . . . .	1
1.1.2 Phenomenology . . . . .	2
1.2 Three-family Oscillations and CP or T Violation . . . . .	4
1.2.1 How to measure leptonic CP violation . . . . .	5
1.2.2 The problem of degenerate solutions . . . . .	9
1.3 Experimental Setups . . . . .	9
1.3.1 Conventional neutrino beams . . . . .	9
1.3.2 First generation long-baseline experiments . . . . .	10
1.3.3 Second generation long-baseline experiments . . . . .	13
1.3.4 Next generation conventional neutrino beams . . . . .	16
1.4 Why Look For New Concepts in Neutrino Beams? . . . . .	21
1.5 New Concepts on Neutrino Beams . . . . .	23
1.5.1 Neutrino factories . . . . .	24
2. Machine Aspects	27
2.1 Introduction . . . . .	27
2.2 A Possible Beta-Beam Facility . . . . .	28
2.3 The Beta Beam Isotopes . . . . .	29
2.3.1 Which isotope to use . . . . .	29
2.3.2 Isotope production . . . . .	30

2.3.3	The ISOL method . . . . .	33
2.3.4	Direct production . . . . .	34
2.3.5	Production ring . . . . .	35
2.3.6	Production rates . . . . .	37
2.4	Ion Transfer, Ionization and Bunching . . . . .	39
2.5	Acceleration . . . . .	41
2.5.1	Linear accelerators . . . . .	42
2.5.2	Some basics about synchrotrons . . . . .	43
2.6	Stacking and Storage . . . . .	49
2.6.1	Why do we need stacking? . . . . .	49
2.6.2	Beam-cooling . . . . .	50
2.6.3	Stacking . . . . .	52
2.6.4	Annual rate of neutrinos . . . . .	55
2.6.5	Other limitations . . . . .	57
2.7	Possible Future Development . . . . .	58
2.7.1	Accumulation at low energy . . . . .	58
2.7.2	Two isotopes in the ring at the same time . . . . .	60
2.7.3	Higher gamma . . . . .	61
2.7.4	Barrier buckets in the decay ring . . . . .	62
2.7.5	Acceleration of partly stripped ions . . . . .	64
3.	CERN-Fréjus Beta Beam Physics Potential . . . . .	67
3.1	Introduction . . . . .	67
3.2	The CERN-Fréjus Configuration . . . . .	68
3.3	Data Analysis . . . . .	69
3.3.1	Backgrounds . . . . .	70
3.3.2	Signals . . . . .	73
3.3.3	Systematic errors . . . . .	75
3.4	Oscillation Analysis . . . . .	78
3.4.1	$\theta_{13}$ searches . . . . .	79
3.4.2	Leptonic CP violation searches . . . . .	84
3.4.3	Searches that cannot be done in this configuration . . . . .	86
3.5	Combined Analyses with the Atmospheric Neutrinos . . . . .	89
3.5.1	Mass hierarchy . . . . .	90
3.5.2	Degeneracy breaking . . . . .	90
3.6	Combined Analyses with the SPL Super Beam . . . . .	90
3.7	Comparison with Other Super Beam Experiments . . . . .	93

4. Physics Potential of Other Beta Beam Settings	97
4.1 Introduction . . . . .	97
4.2 High Energy Beta Beams . . . . .	98
4.3 Monochromatic Neutrino Beams . . . . .	103
4.4 Beta Beams Based on $^8\text{B}$ and $^8\text{Li}$ Ions . . . . .	105
4.5 High Energy $^8\text{B}/^8\text{Li}$ Beta Beams . . . . .	107
4.6 Comparison with Other Neutrino Facilities and Green-field Scenarios . . . . .	109
4.7 Conclusions . . . . .	114
5. Low Energy Beta Beams	119
5.1 Introduction . . . . .	119
5.2 Low Energy Setups . . . . .	120
5.2.1 Off-axis configurations . . . . .	122
5.3 Nuclear Structure, Neutrino-nucleus, Nuclear Astrophysics Applications . . . . .	127
5.4 Fundamental Interaction Studies . . . . .	132
5.4.1 Weinberg angle measurement . . . . .	132
5.4.2 Conserved vector current hypothesis . . . . .	133
5.4.3 Neutrino magnetic moment . . . . .	134
<i>Bibliography</i>	137
<i>Index</i>	153