

Contents

Introduction	1
1 Neutrino physics	3
1.1 Neutrino oscillation	3
1.1.1 Mixing and oscillation	3
1.1.2 Oscillation principle	4
1.1.3 Two flavours oscillation in vacuum	5
1.1.4 Three neutrino flavours oscillations	6
1.1.5 Oscillations in matter	7
1.2 Other properties	9
1.2.1 Helicity	9
1.2.2 Neutrino mass	9
1.3 Experimental status of neutrino oscillation	13
2 The OPERA experiment	18
2.1 The CNGS beam	19
2.1.1 CNGS beamline description	20
2.1.2 CNGS performance	21
2.2 Experimental setup	27
2.2.1 The OPERA films	28
2.2.2 Emulsion Cloud Chamber	28
2.2.3 Target Tracker	29
2.2.4 Changeable Sheet	31
2.2.5 Muon spectrometer	32
2.3 The scanning system	32
2.3.1 The European Scanning System	32
2.3.2 First example : CS scanning	33

2.3.3	X-ray marks : from the CS to the ECC	33
2.3.4	ECC scanning : from the cosmic ray to the basetrack	34
2.3.5	Scanning efficiency	35
2.4	Physics performance in τ detection in the OPERA experiment	36
2.5	Electron detection in the OPERA experiment	37
3	Analysis framework and efficiency assessment	39
3.1	Analysis framework	39
3.1.1	Analysis of the electronic detectors	39
3.1.2	Analysis of the nuclear emulsions	39
3.1.3	Monte Carlo simulation and testbeam data	39
3.1.4	Analysis tool	39
3.2	Efficiency assessment	43
3.2.1	Event location efficiency	43
3.2.2	Electron Identification Efficiency	43
4	Electromagnetic shower reconstruction in nuclear emulsions	46
4.1	Phenomenology of electromagnetic shower in the OPERA detector	46
4.1.1	Electromagnetic shower description	46
4.2	Electromagnetic shower reconstruction algorithm	48
4.2.1	Principle	48
4.2.2	Shower initiation with reconstructed tracks	48
4.2.3	Shower reconstruction	48
4.3	Electron identification	49
4.3.1	Principle of the algorithm	50
4.3.2	Performance	52
4.4	Energy estimation	52
4.4.1	Principle of the algorithm	52
4.4.2	Performance	53
4.5	Energy calibration	55
4.5.1	Parametrization of the energy on Monte Carlo (MC) sample	55
4.5.2	Test beam data analysis	55
4.6	New features of the shower reconstruction algorithm	55
4.6.1	Photon-electron separation	55
4.6.2	Electromagnetic shower reconstruction within two OPERA bricks	55

5 Electron detection in OPERA and analysis	60
5.1 Principle of the analysis	60
5.1.1 Event rates	60
5.1.2 Kinematical variables	61
5.2 ν_e oscillation study at generation level	62
5.3 Oscillated ν_e search	63
5.4 OPERA data analysis	63
5.5 Sensitivity to the $\mu \rightarrow e$ oscillation	63
5.6 $\tau \rightarrow \nu$ search	63
Conclusion	64
Appendix A Neutrinos and standard model	68
A.1 The standard model	68
Appendix B Neutrino properties	70
B.1 The neutrino discovery	70
B.2 Parity non-conservation	70
B.3 Measurement of the neutrino helicity	71
B.4 The second generation of neutrino	71
B.5 Discovery and study of electroweak currents at CERN	72
B.6 Number of neutrino generations	72
B.7 The τ discovery	73
Appendix C Addendum to neutrino properties	74
C.1 A left-handed neutrino ?	74
C.2 Seesaw mechanism	75
C.3 β -decay experiments	76
C.4 Neutrinoless double- β decay experiments	76
Appendix D Phenomenology of electromagnetic showers	78
D.1 Passage of charged particles through matter	78
D.2 Multiple Coulomb scattering	78