

Contents

1	Introduction	1
2	Research with Neutrons	5
2.1	The science case	6
2.1.1	Solid state physics	7
2.1.2	Materials science and Engineering	7
2.1.3	Chemical structure, kinetics and dynamics	7
2.1.4	Soft condensed matter	8
2.1.5	Biology and biotechnology	8
2.1.6	Earth and environmental science	8
2.1.7	Fundamental neutron physics	9
2.1.8	Muons as probes for condensed matter	9
2.2	Research reactors or pulsed spallation sources?	10
2.3	The European Spallation Neutron Source ESS	13
2.3.1	Short history of ESS	14
2.3.2	Technical design of ESS	15
	The Ion-source and the linear accelerator	16
	The compressor-rings	17
	The target stations	17
	The instruments and modes of operations	22
	Costs, time schedule and location	23
2.4	Concepts of transmutation	25
2.5	The “Energy-Amplifier”	27
2.6	Conclusion “Research with Neutrons”	29
3	Neutron production	30
3.1	The Spallation Process	31
3.2	Calculations of hadronic showers	33
4	Theory/Models	35
4.1	Transport equation	35
4.2	Nuclear physics models	37
4.3	Modeling of transport processes	38
4.4	Parameter discussion	44
4.4.1	Level density description	45

4.4.2	Coulomb Barriers for charged particle emission and feedback on neutrons	46
4.4.3	Equilibration time	48
4.5	Particular decay modes of hot nuclei	49
4.5.1	Fission	49
4.5.2	Vaporization and multifragmentation	53
5	Why nuclear physics experiments?	57
5.1	Application driven motivation	57
5.2	Astrophysics driven motivation	58
5.3	Nuclear physics driven motivation	59
6	Experiments	63
6.1	The COoler SYnchrotron COSY	63
6.2	The NESSI experiment	65
6.2.1	Objective	65
	Experiments at LEAR, PS (CERN) and COSY (FZJ)	66
6.2.2	Experimental setup	67
	The 4π sr neutron-detector	68
	Efficiency of the BNB-Detector	70
	Additional neutrons produced in the scintillator liquid	71
	The 4π sr Silicon-Detector	74
	Efficiency of the Si-Detectors	75
6.2.3	Corrections on the data	75
6.2.4	Trigger conditions	75
	The Targets	76
6.2.5	Plan of anticipated research	77
6.3	The PISA experiment	77
6.3.1	Objective	77
6.3.2	Experimental setup	78
	The channelplate detectors	79
	The Bragg curve detector	80
	The phoswich detectors	82
6.4	The JESSICA experiment	82
6.4.1	Objective	82
6.4.2	Advanced moderators at JESSICA	83
6.4.3	Experimental setup and method	86
7	Results and comparison with theory	89
7.1	Results NESSI Experiment/Theory	89
7.1.1	Thick targets	90
	The light signal of the BNB	90
	Reaction cross section and hadronic interaction length	90
	Neutron multiplicities	92
	Mean neutron multiplicities	92

Neutron multiplicity distributions	93
The economy of neutron production	99
Neutron production by π, K, \bar{p}, p, d projectiles	100
The GCCI level density and the MPM	103
Coulomb barriers in thick targets	104
7.1.2 Thin targets	106
Thermal excitation energy E^*	106
Neutron multiplicity M_n -distributions for thin targets	115
Particle production cross sections σ_n, σ_H and σ_{He} for thin targets	116
Composite Particle Emission	119
Fission	123
Vaporization and Multifragmentation	127
7.1.3 Conclusion NESSI	130
7.2 Results PISA Experiment/Theory	132
7.3 Data Library of H- and He in p-induced reactions	137
7.4 Results JESSICA Experiment/Theory	137
8 Conclusion	142
References	146