

Table of content

1. Introduction	1
2. Theoretical Framework	4
2.1. The Neutron Transport Equation (NTE)	4
2.1.1. General form	4
2.1.2. NTE with fission neutrons as an external source	5
2.1.3. K-eigenvalue form	6
2.1.4. Point kinetics equations	6
2.2. Prompt and delayed neutrons	8
2.2.1. Importance of delayed neutrons	9
2.3. Nuclear data	11
2.3.1. Quantities of interest	11
2.3.2. Nuclear data libraries	12
2.4. Approaches to solve the Neutron Transport Equation	13
2.4.1. Deterministic Methods	14
2.4.2. Monte Carlo Method for solving the Transport Equation	14
2.4.3. Variance reduction methods	15
3. Methodology	17
3.1. Monte Carlo simulations with OpenMC	17
3.1.1. Benchmarks	17
3.2. Details on the inclusion of time dependence	18
3.2.1. Time evolution of the neutrons	19
3.2.2. Simulation time boundary	19
3.2.3. Time tally	19
3.3. Delayed neutron precursors	19
3.3.1. The time delay of the precursors and its consequences	19
3.3.2. Individual precursors	21
3.3.3. The precursor particle	23
3.3.4. Precursor forced decay	24
3.4. Initial transient particle source	24
3.5. Population control	26
4. Results and discussion	28
4.1. Inclusion of time dependence and individual precursors in OpenMC(TD)	29
4.1.1. Scoring of time dependent quantities in a fixed source calculation	29
4.1.2. Transport logic in a simulation divided in time intervals	30

4.1.3.	Scoring of time dependent quantities in a simulation divided in time intervals	30
4.1.4.	Activity of individual precursors	32
4.1.5.	Discussion about the use of average energies from precursor delayed neutron spectra	33
4.2.	Monoenergetic fissile system with 1-group precursor structure	34
4.2.1.	Subcritical configuration	35
4.2.2.	Slightly supercritical configuration	36
4.2.3.	Reactivity insertion	38
4.3.	Energy-dependent ^{235}U system	39
4.3.1.	Subcritical configuration	39
4.3.1.1.	i) First group with energy distribution from JEFF-3.1.1	40
4.3.1.2.	ii) First group with average energy from JEFF-3.1.1	40
4.3.1.3.	iii) 1-group with average energy from ENDF-B/VIII.0	43
4.3.1.4.	iv) 8-group with energy distribution from JEFF-3.1.1	44
4.3.1.5.	v) 6-group with average energy from ENDF-B/VIII.0	45
4.3.1.6.	vi) 50 individual precursors with average energies from ENDF-B/VIII.0	46
4.3.2.	Supercritical configuration	48
4.3.2.1.	i) First group with energy distribution from JEFF-3.1.1	48
4.3.2.2.	ii) First group with average energy from JEFF-3.1.1	49
4.3.2.3.	iii) 1-group with average energy from ENDF-B/VIII.0	51
4.3.2.4.	iv) 8-group with energy distribution from JEFF-3.1.1	52
4.3.2.5.	v) 6-group with average energy from ENDF-B/VIII.0	55
4.3.2.6.	vi) 50 individual precursors with average energies from ENDF-B/VIII.0	58
4.4.	Light-water moderated energy dependent system with individual precursor structure	59
4.4.1.	Criticality calculation using individual precursors	60
4.4.2.	Slightly supercritical configuration with 50 individual precursor structure	61
4.4.3.	Slightly supercritical configuration without the 10 most important precursors	63
5.	Summary and conclusions	67
	Glossary	70
	Bibliography	73
	Appendix A. Delayed neutron group spectra	77
	Appendix B. Solutions of the Point Neutron Kinetics Equations for 1-group precursor approximation	82
	Appendix C. Monoenergetic fissile system with 1-group precursor structure	84
	Appendix D. Summary of the simulations performed in this work	86
	Appendix E. Individual precursor data	89

