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ANS Winter Meeting 2016
Transitions From Stochastic to Point Kinetics Models in Fissile Solutions

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EPSRC
Engineering and Physical Sciences Research Council

Introduction – Fissile Solutions

- Solution of uranyl salts
- Used throughout the fuel cycle
- Used in Aqueous Homogeneous Reactors
- Complex physics
  - Neutronics
  - Fluid flow
  - Chemistry
  - Radiolytic gas production
- Simulation useful for
  - Accident scenarios
  - AHR operation

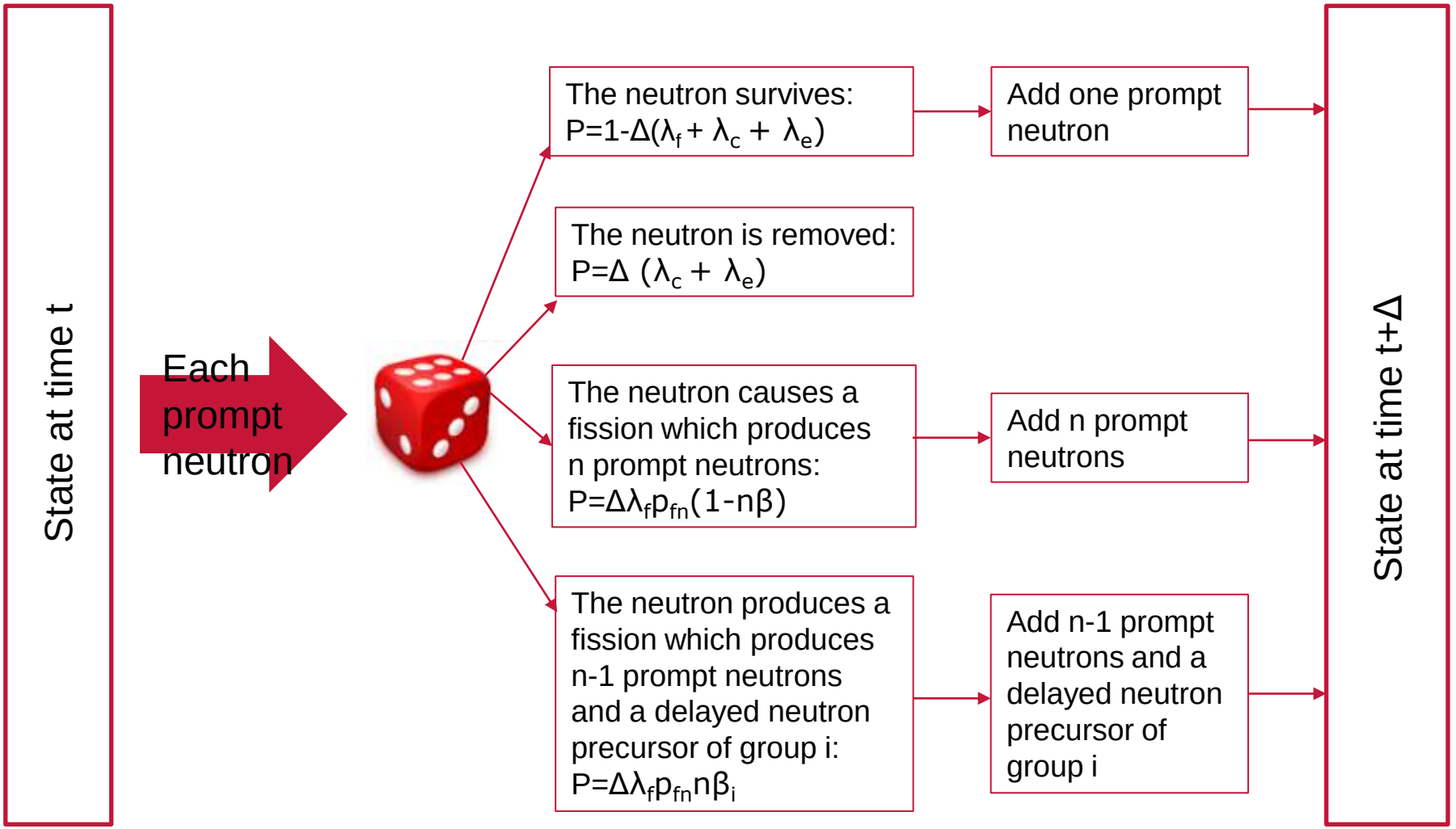
Introduction – Low Neutron Population Systems

- Start up scenarios
- Behaviour deviates from mean behaviour
- High relative variance in neutron population
- Non-deterministic response to reactivity changes
- Discussed further in *C.M. Cooling, M.M.R. Williams and M.D. Eaton,* ***Coupled Probabilistic and Point Kinetics Modelling of Fast Pulses in Nuclear Systems****, Annals of Nuclear Energy, Volume 94, pp.655-671, 2016*

Low Population Representation – Overall Strategy

- Perform a number of realisations
- Iteratively and probabilistically find state of system at time $t+\Delta$ from state at time t
- Nuclear parameters change as the system evolves
- Transition to point kinetics model once neutron population high enough
- Examine ensemble of realisations
- Each realisation may be simulated in parallel

Low Population Representation – Prompt Neutrons



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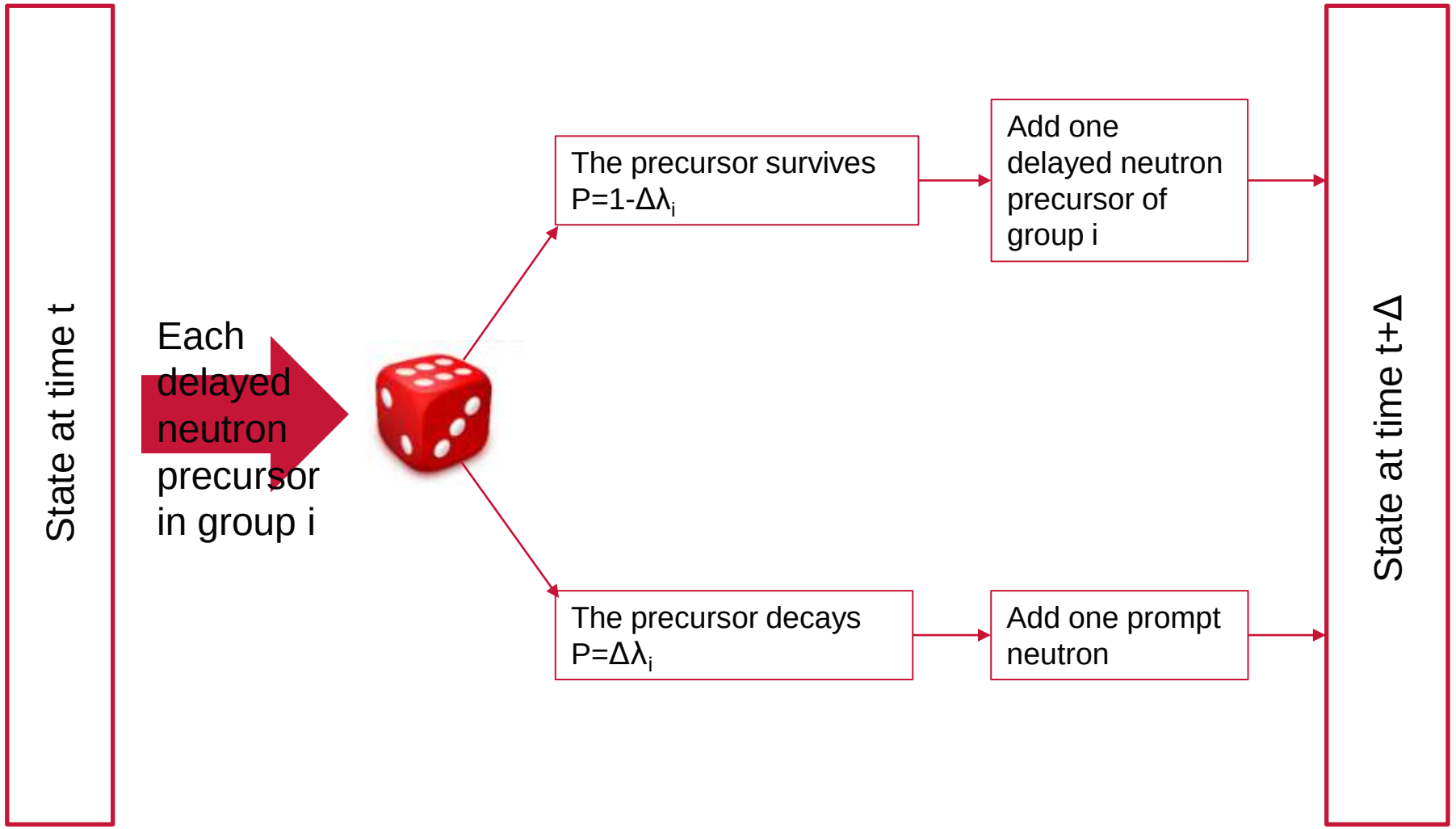
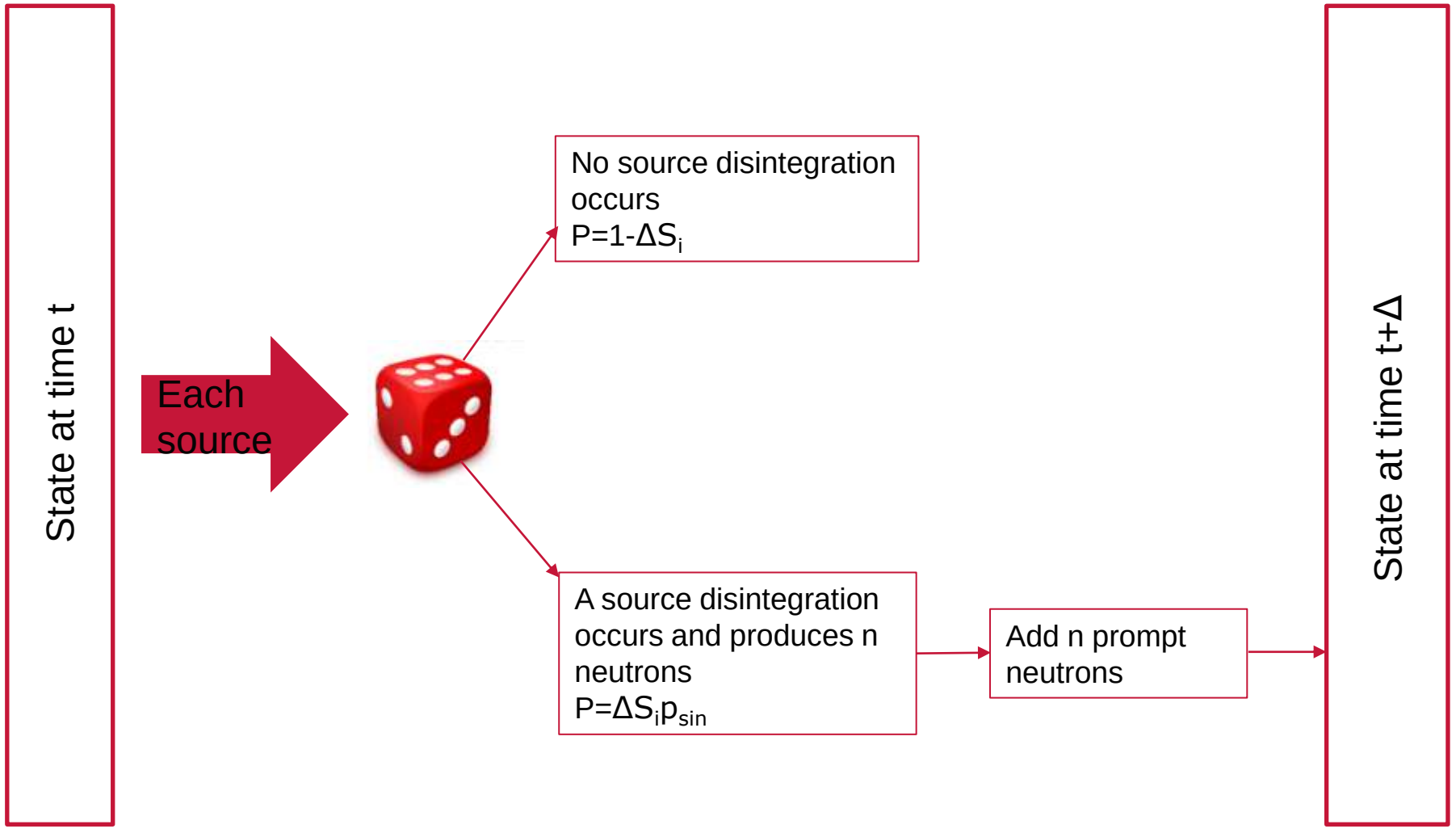
Low Population Representation – Delayed Neutron Precursors



Low Population Representation – Sources



The Size of Δ

- Smaller Δ results in slower simulation
- Larger Δ degrades accuracy
- Aim to limit the probability of two events of the same type in Δ to $\xi=10^{-4}$
- Prompt neutrons:
  - $P_{event}=(\lambda_f + \lambda_c + \lambda_e)\Delta$
  - $\Delta < \xi^{0.5}/(\lambda_f + \lambda_c + \lambda_e)$ if prompt neutrons present
- Delayed neutron precursors
  - $P_{event}= \lambda_i\Delta$
  - $\Delta < \xi^{0.5}/\lambda_i$ if delayed neutron precursor of group i present
- Source
  - $P_{event}=S_i\Delta$
  - $\Delta < \xi^{0.5}/S_i$ if source i present

Point Kinetics Model

- Initial conditions taken from low population model at transition
- Standard point kinetics formulation
- Thermal hydraulics model
  - Also operates alongside low population system
  - Production of radiolytic gas in dissolved or bubble phase
  - Advection of radiolytic gas out of the system
  - Heating of solution by fission
  - Cooling of solution through contact with surroundings

A Sample System

- Cylinder of uranyl nitrate of radius 0.32m and height 0.662m
- 100gU/l
- 20% enrichment
- 242kg
- -278$/$m^3$ void feedback coefficient
- -0.0368$/K temperature feedback coefficient
- 293K external temperature
- Source strength of 300n/s
- Initially cold and with no neutrons
- Linear ramp insertion of 2$ over 3s

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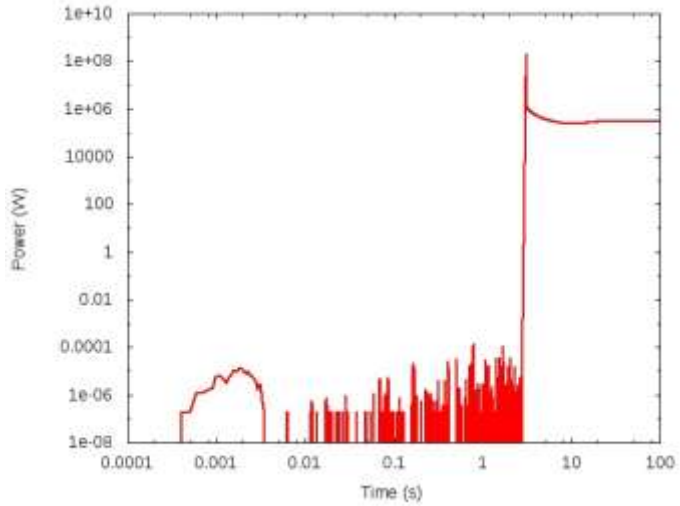
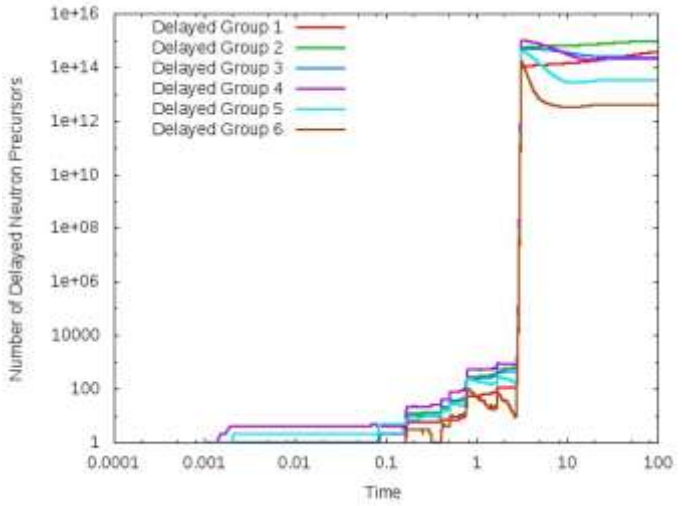
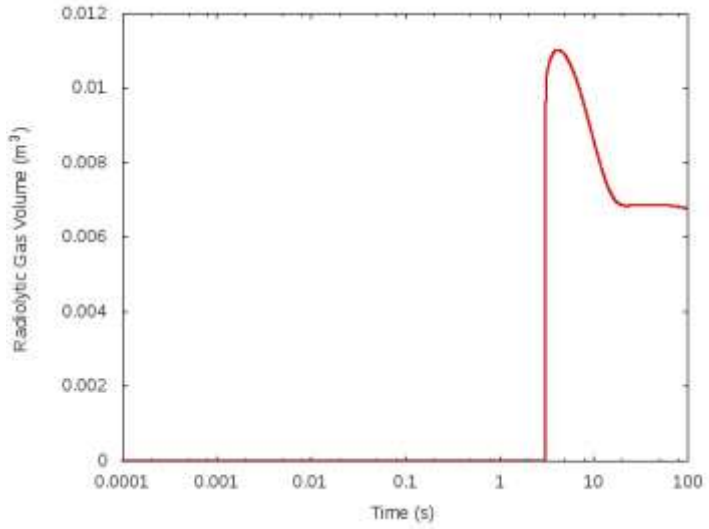
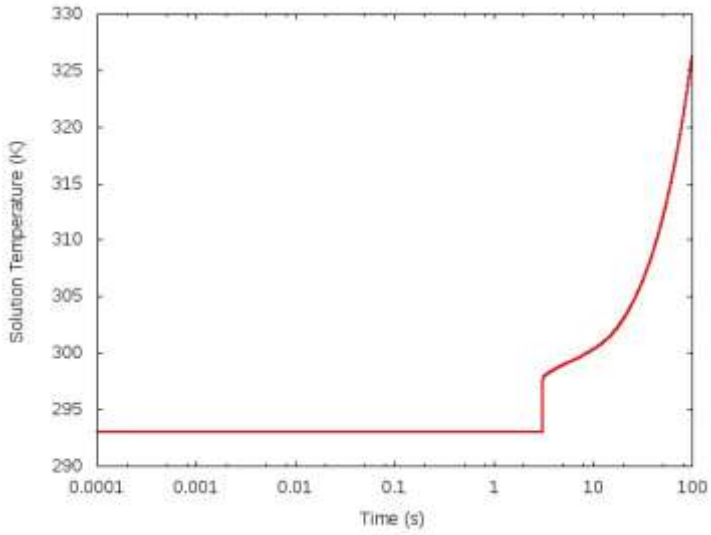
A Single Realisation

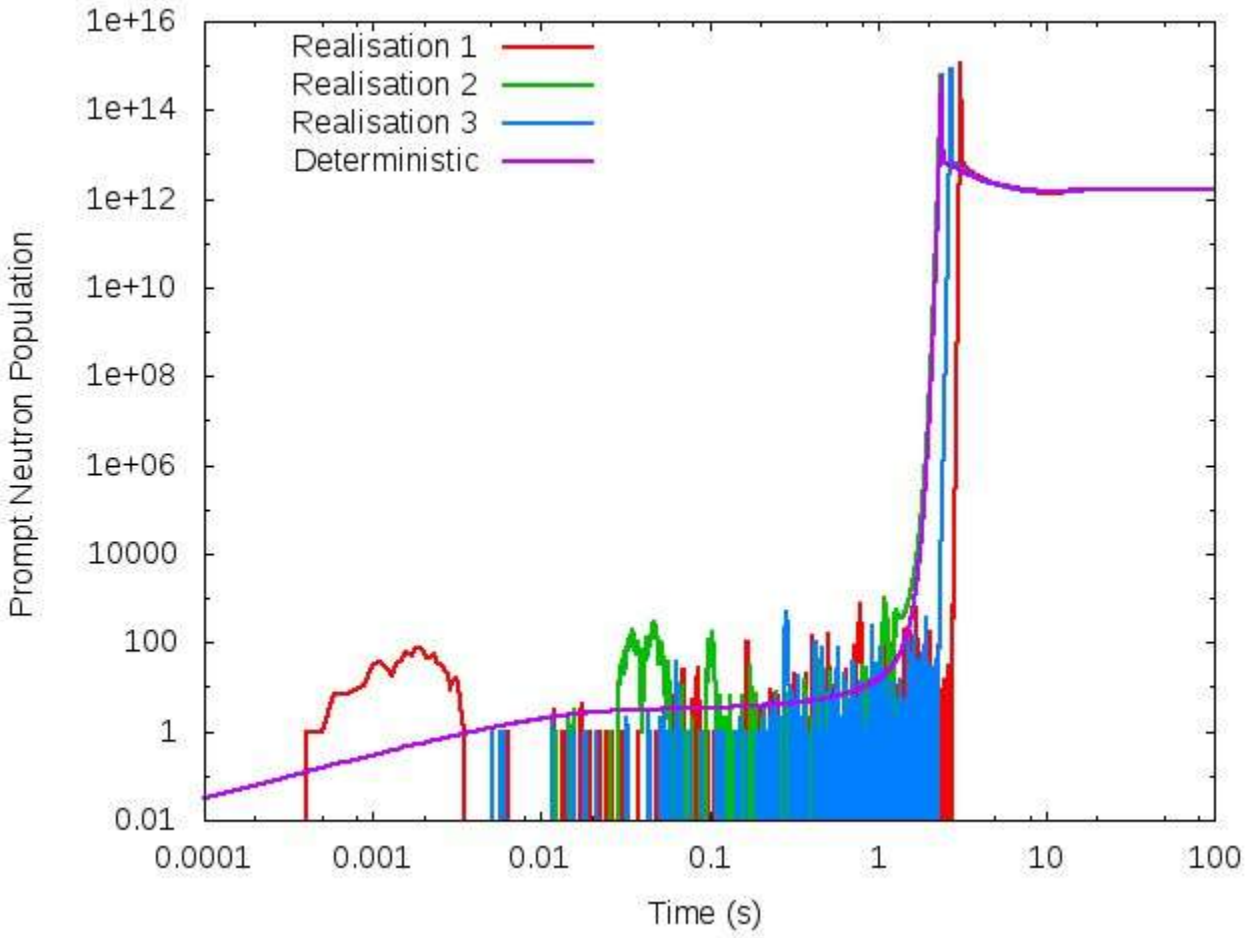








Several Realisations



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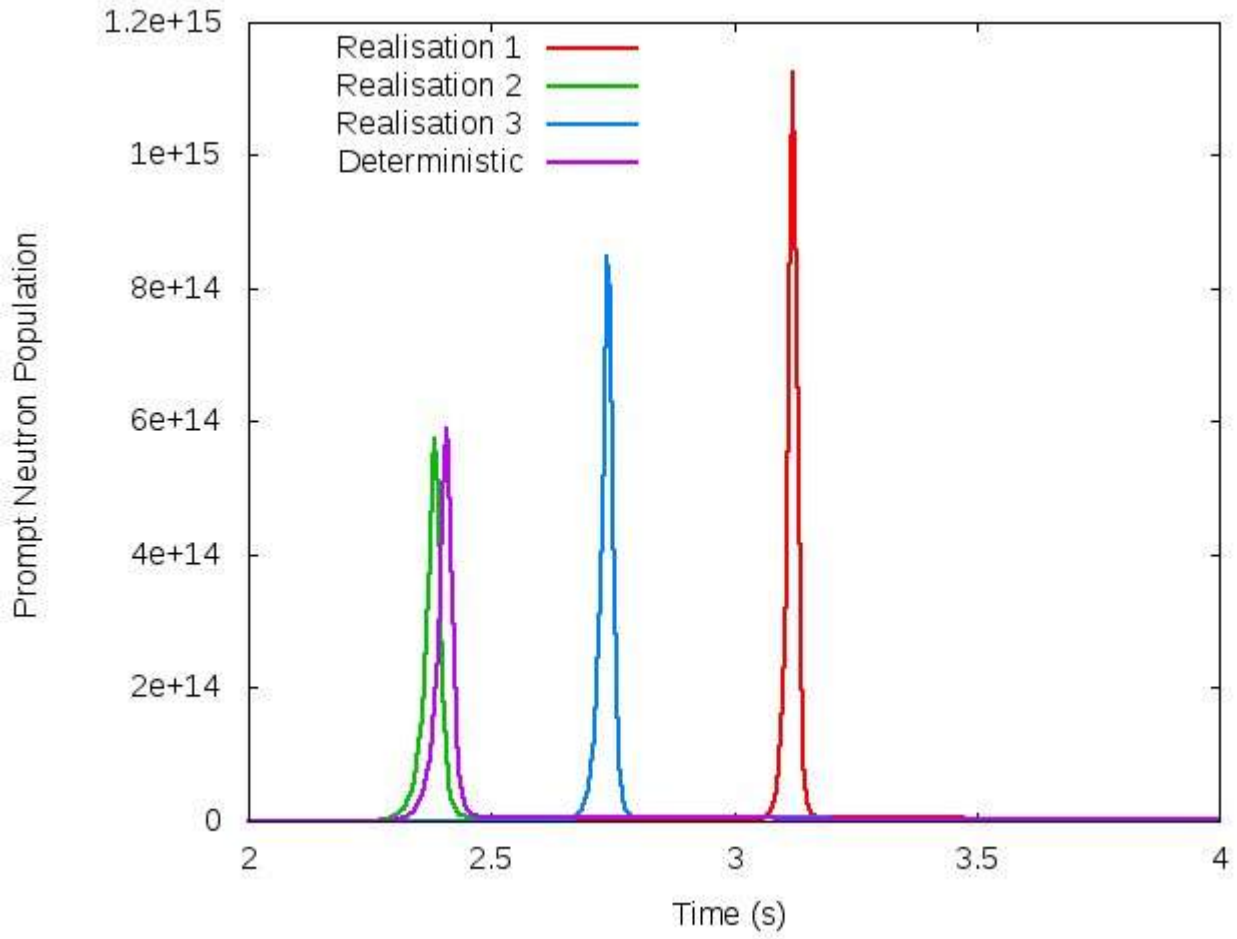
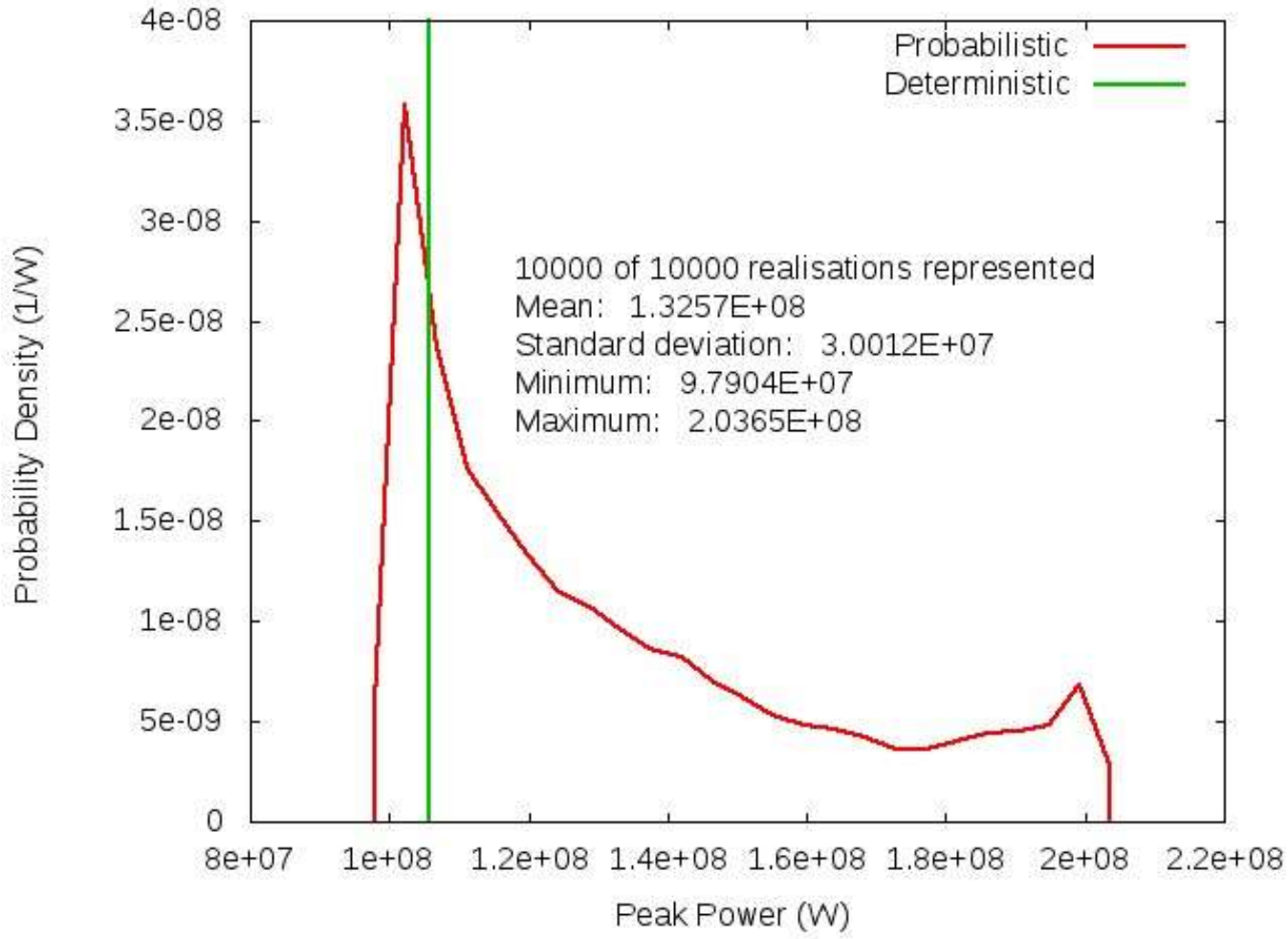


An Ensemble of Realisations



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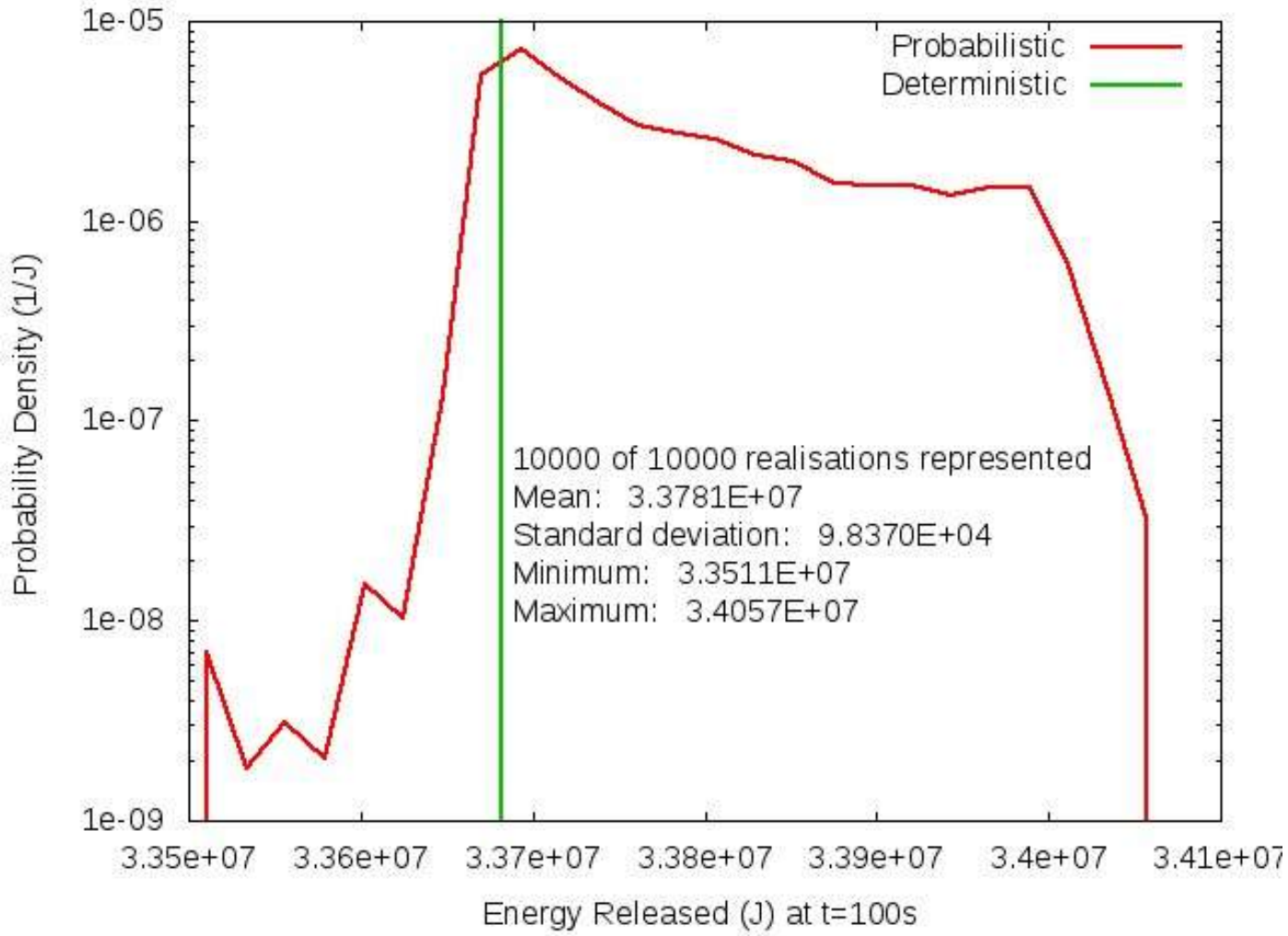

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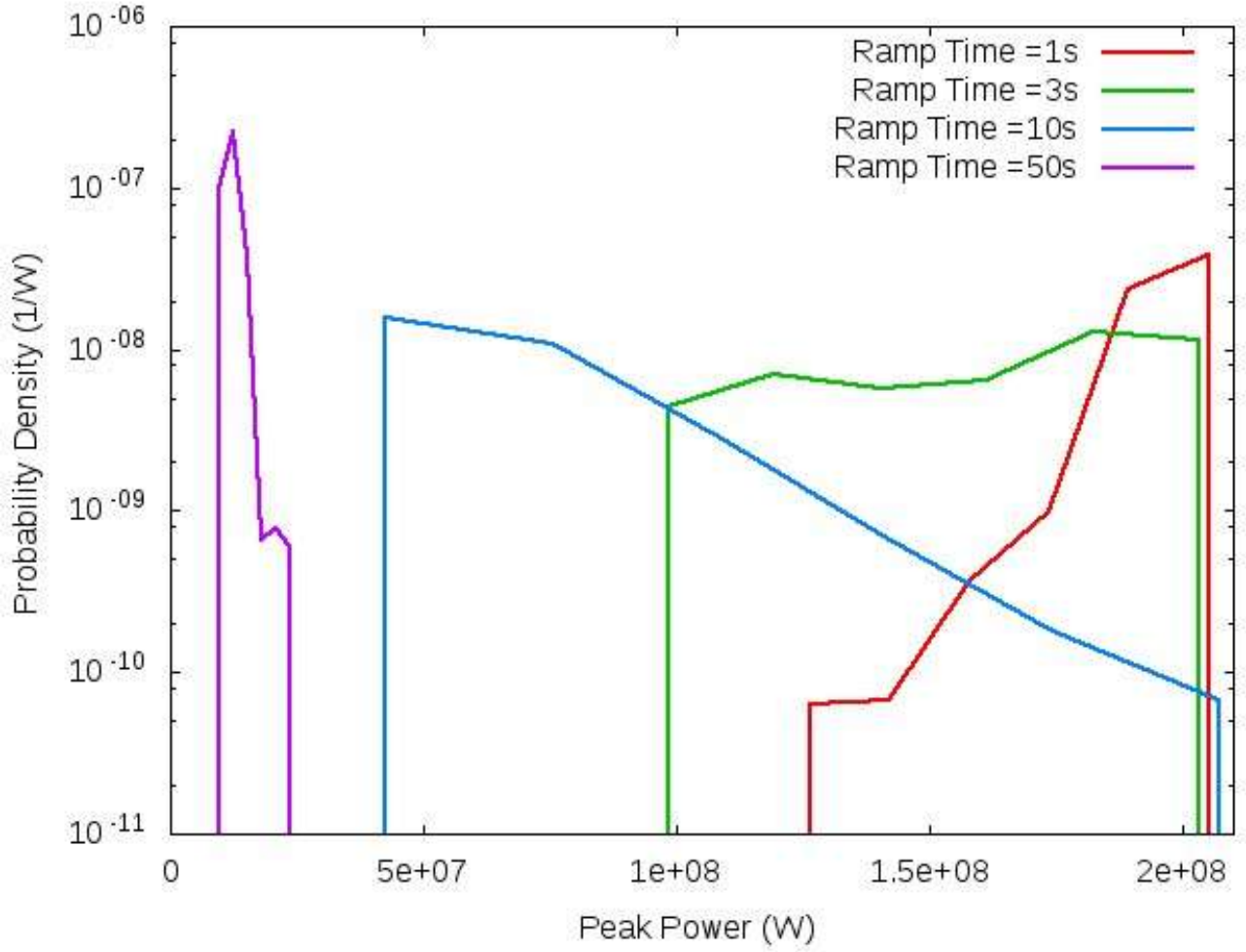
The Effect of Ramp Rate



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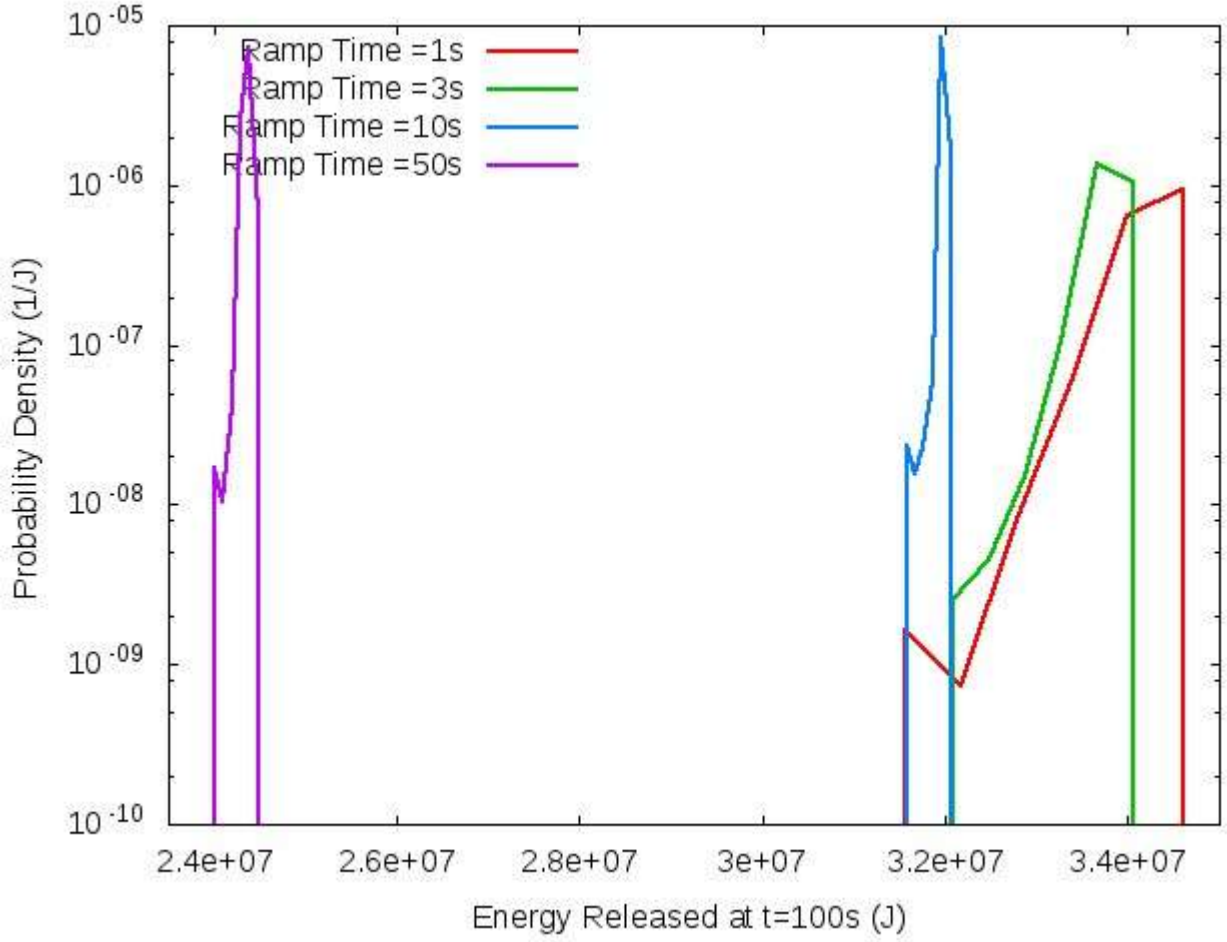
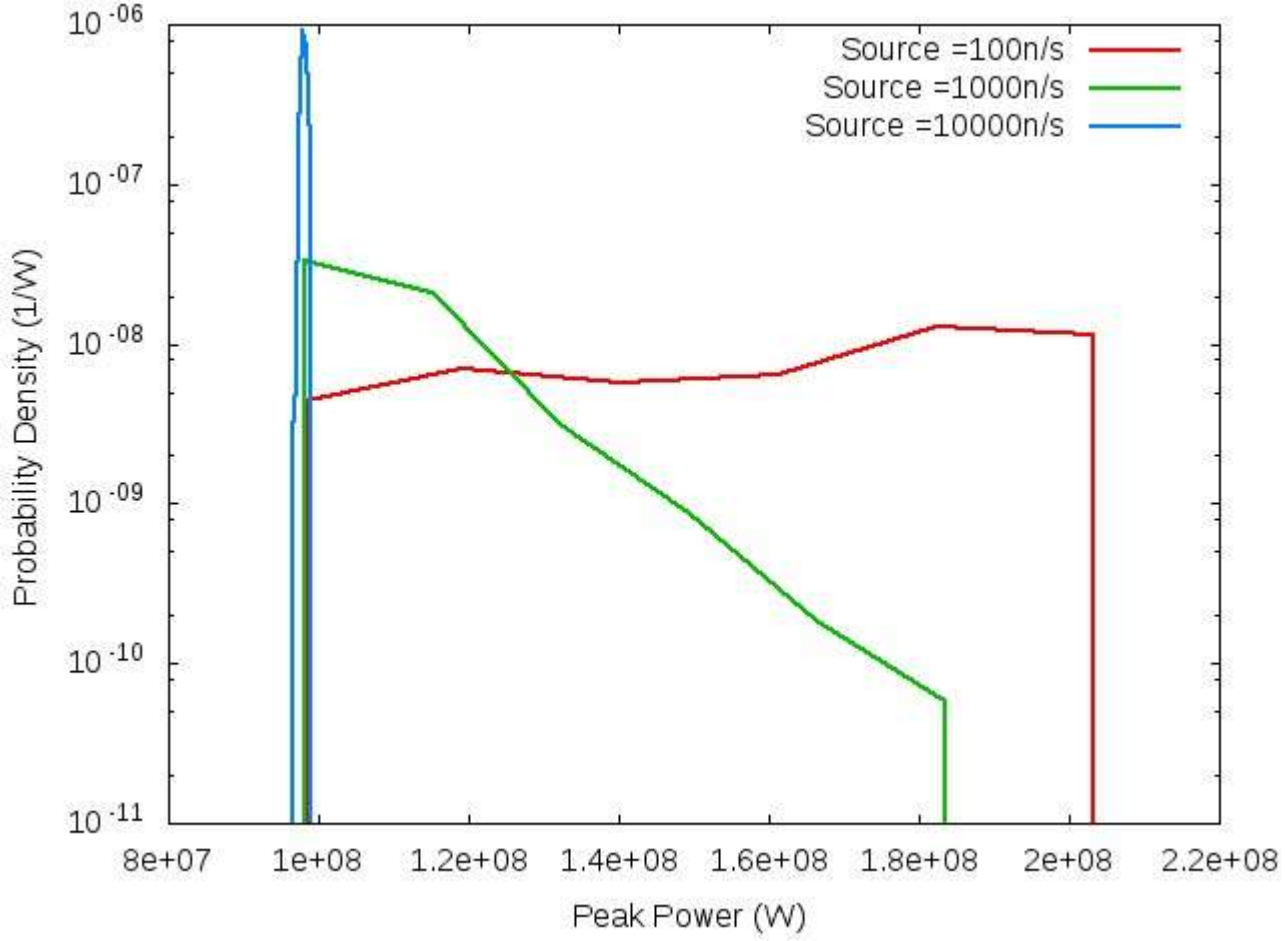


The Effect of Source Strength



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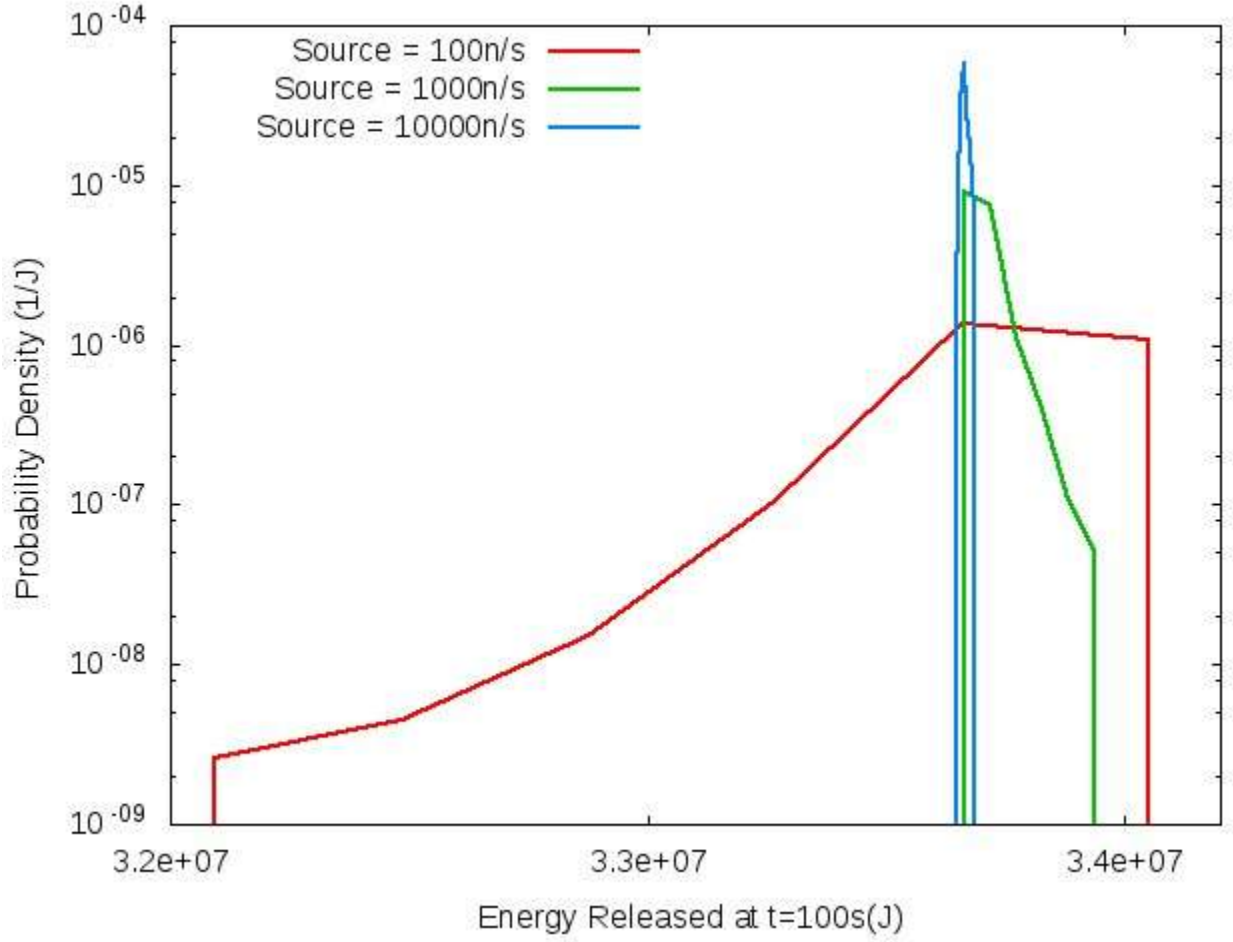

Conclusions

- Deterministic simulation is non-conservative compared to stochastic simulation
- Largest impact is on peak power
- The likely range of the peak power is related to the source strength and the rate at which reactivity increases
- The procedure for modelling the stochastic system is effective and efficient

Questions?