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Utilizing the Slowing-Down-Time Technique for Benchmarking Neutron Thermalization in Graphite

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Objective

- Investigate the application of a pulsed slowing-down neutron experiment to obtain information on the behavior of neutrons as they slow down and thermalize in graphite

Outline

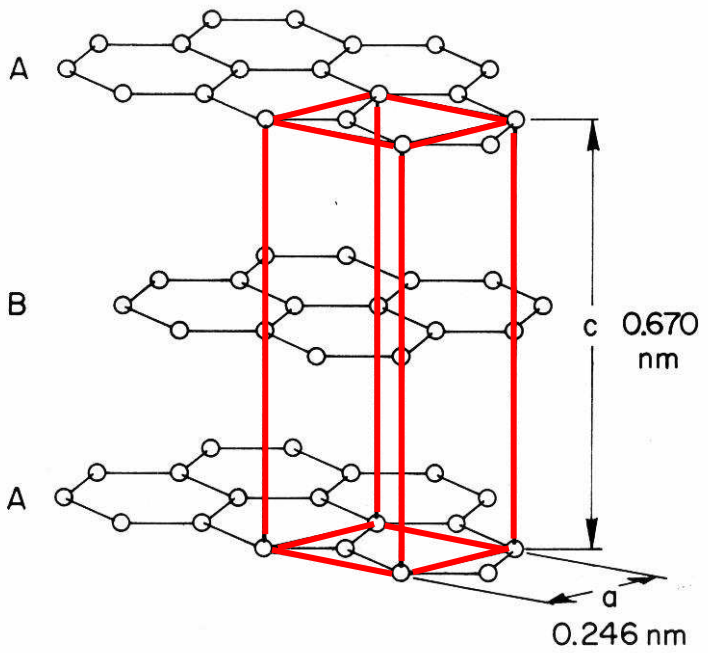
- Motivation and background
- Graphite
- Status of graphite thermal scattering cross sections
- Slowing-Down-Time (SDT) method
- Experiment at the ORELA facility of ORNL
- Initial results
- Conclusions

Motivation & Background

- The VHTR (prismatic or pebble bed) is designed as a gas cooled and graphite moderated reactor
  - Thermal spectrum reactor
- Neutron slowing-down and thermalization in graphite will define the thermal neutron spectrum.
- Thermal scattering cross sections that are not accurate will clearly produce biased predictions of the reaction rates
- Will affect reactor design analysis including estimations of fuel loading needs and cycle energy/length prediction ($$)

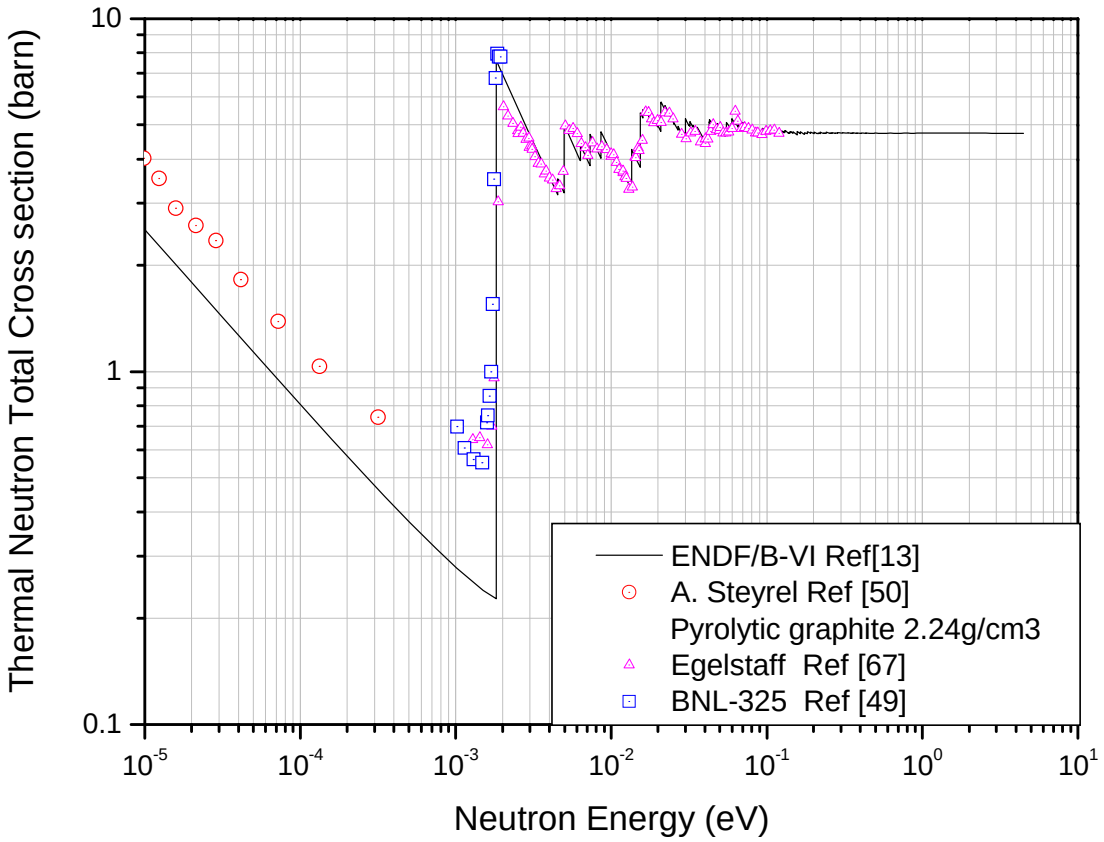
Graphite

Perfect graphite consists of planes (sheets) of carbon atoms arranged in a hexagonal lattice. Covalent bonding exits between intraplaner atoms, while the interplaner bonding is of the weak Van der Waals type. The planes are stacked in an “abab” sequence.

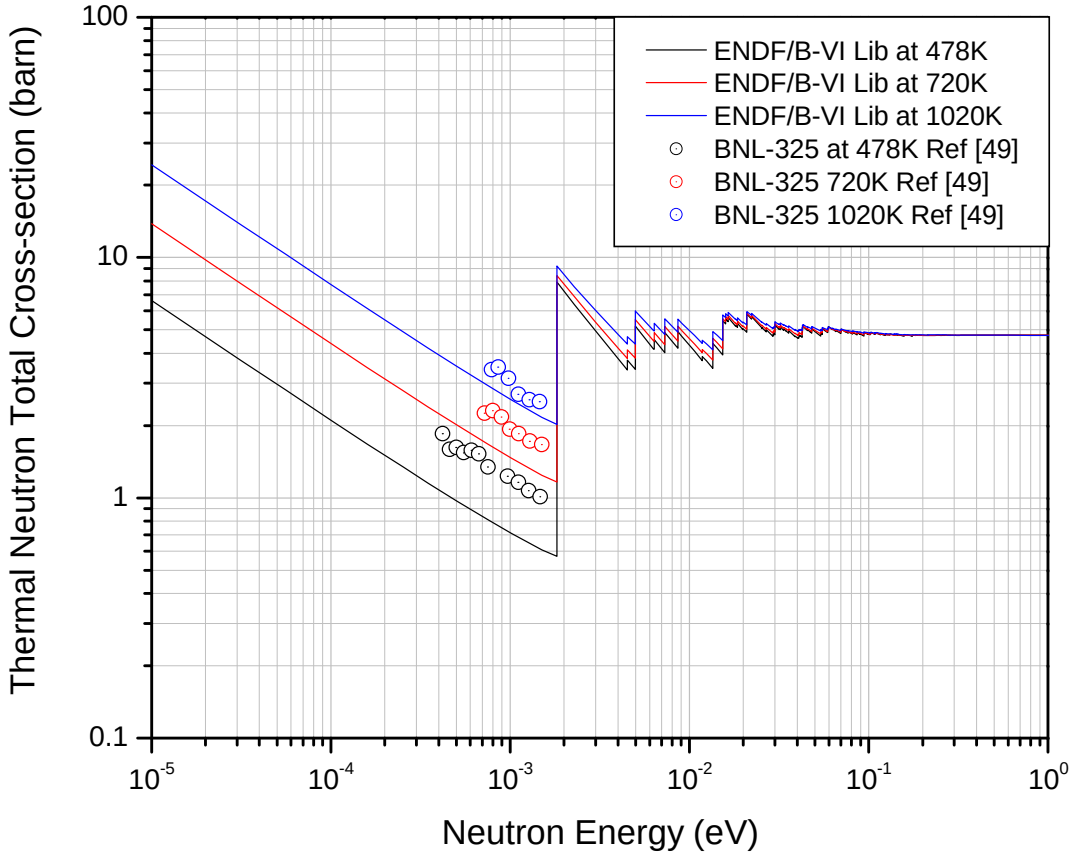


- Hexagonal Structure
- 4 atoms per unit cell
- a=b=6.7 Å
- c=2.46 Å

Status of Graphite Cross-Section Libraries



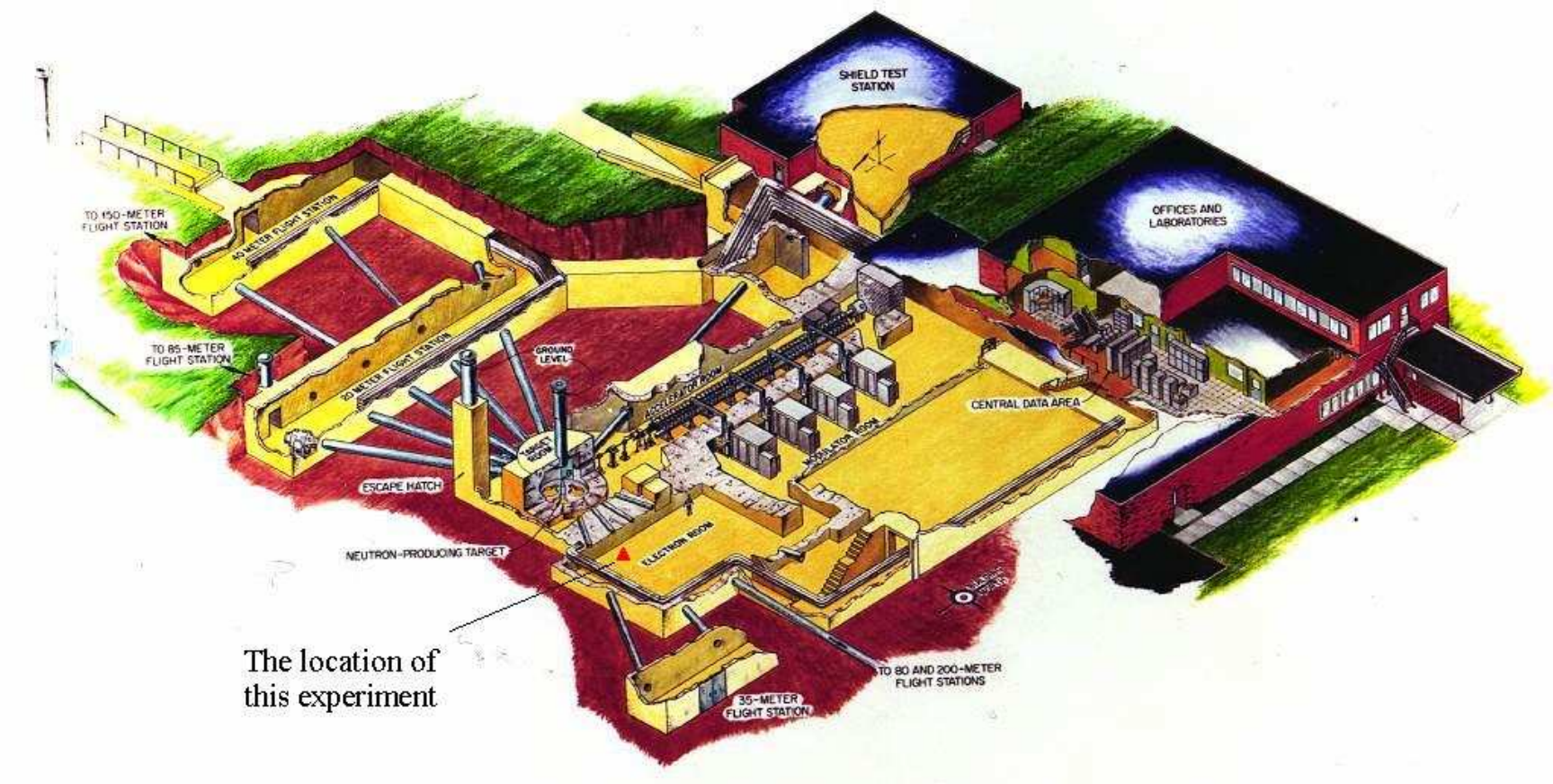
Status of Graphite Cross-Section Libraries cont.



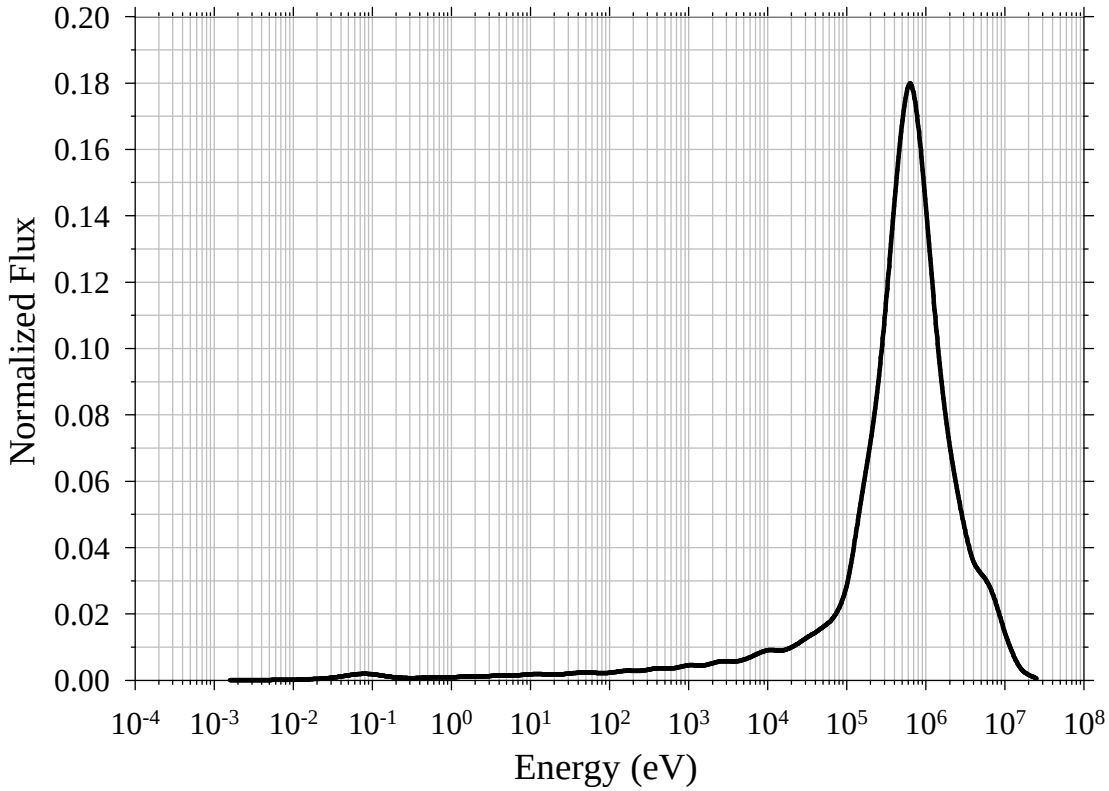
Slowing-Down-Time Method

- The integral reaction rate in a detector is measured as a function of Slowing-Down-Time
- The average energy of neutrons in a moderator is related to the time after the neutron pulse, which is call the Slowing-Down-Time
- The evolution (in time) of the neutron energy spectrum in the moderator from the source energy down to the thermal energy range can be monitored
- With minimum processing, the measured response points can be directly compared with theoretical prediction

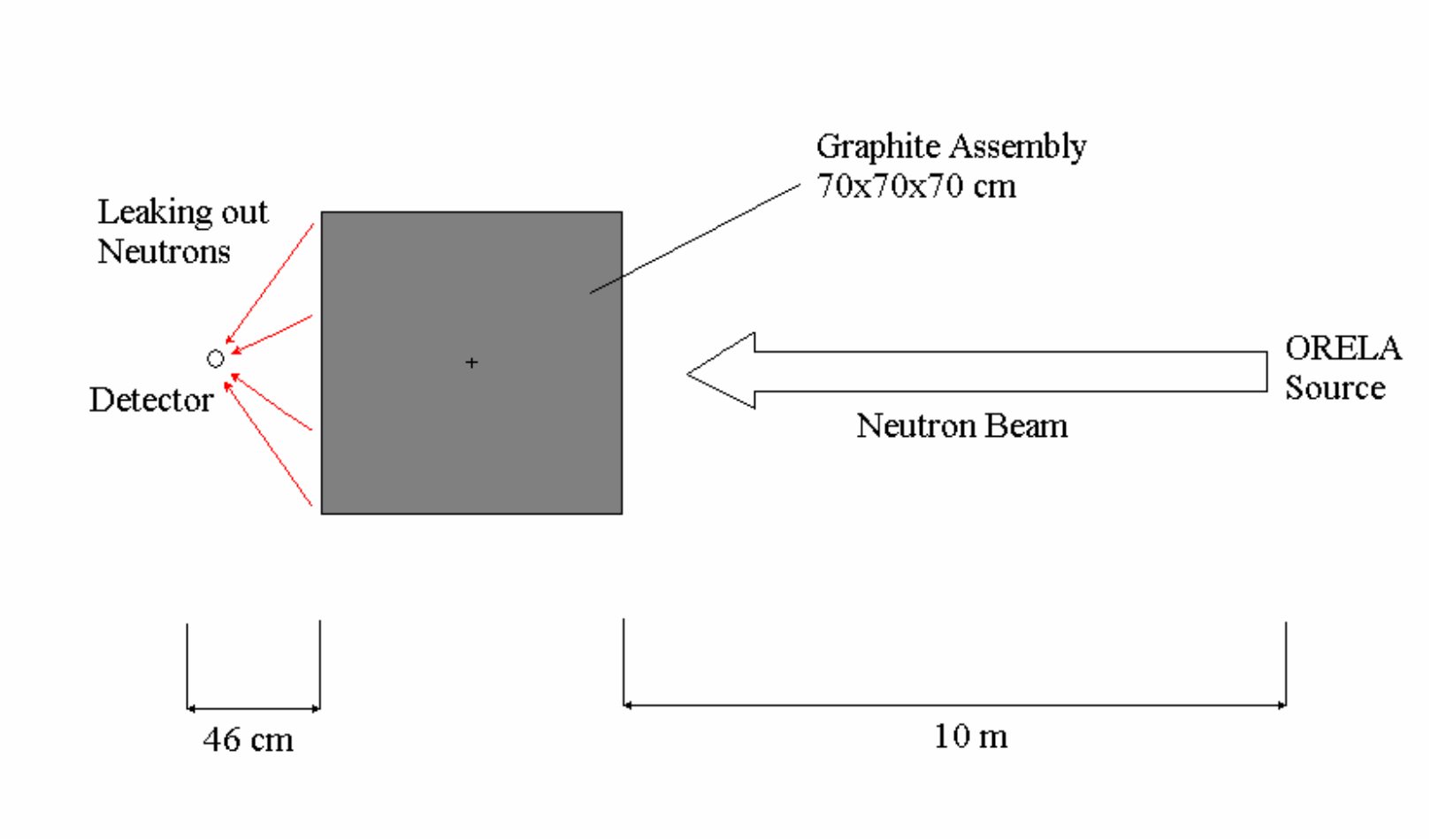
ORELA Facility

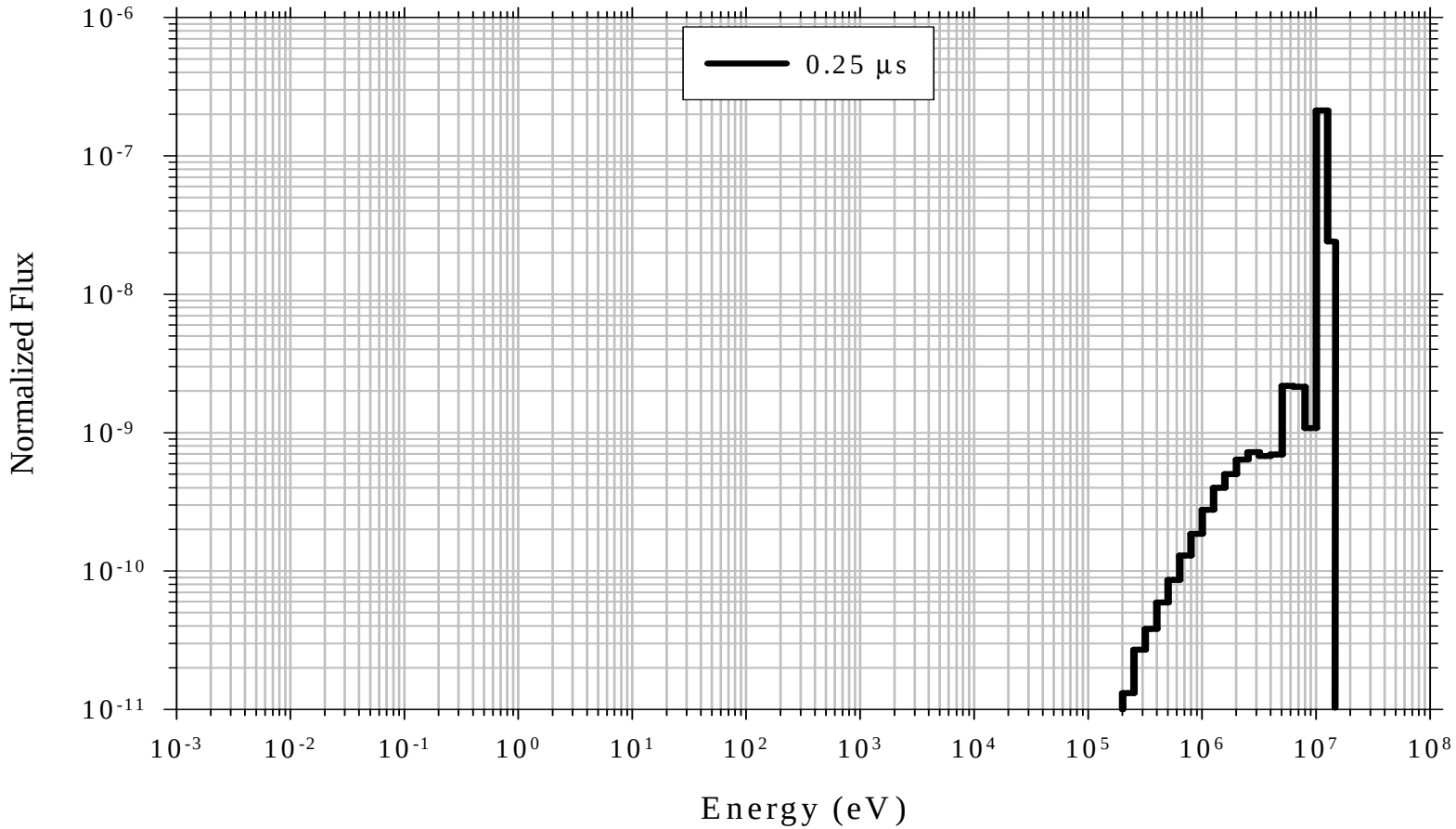


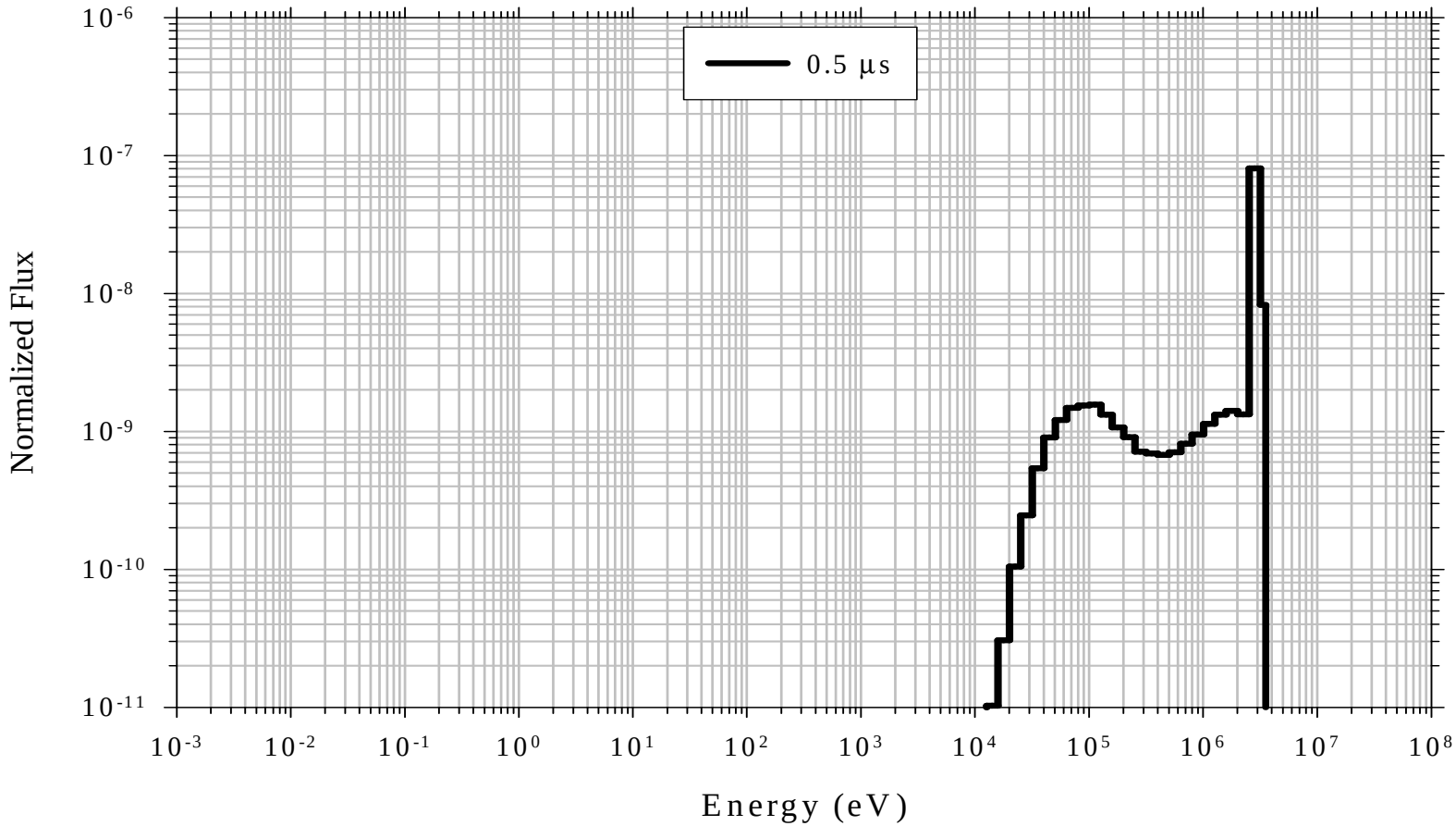
Source Energy Distribution



MCNP Simulation Model




0.25 µs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
100
101
102
103
104
105
106
107
108


0.5 µs
Normalized Flux
Energy (eV)
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10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
100
101
102
103
104
105
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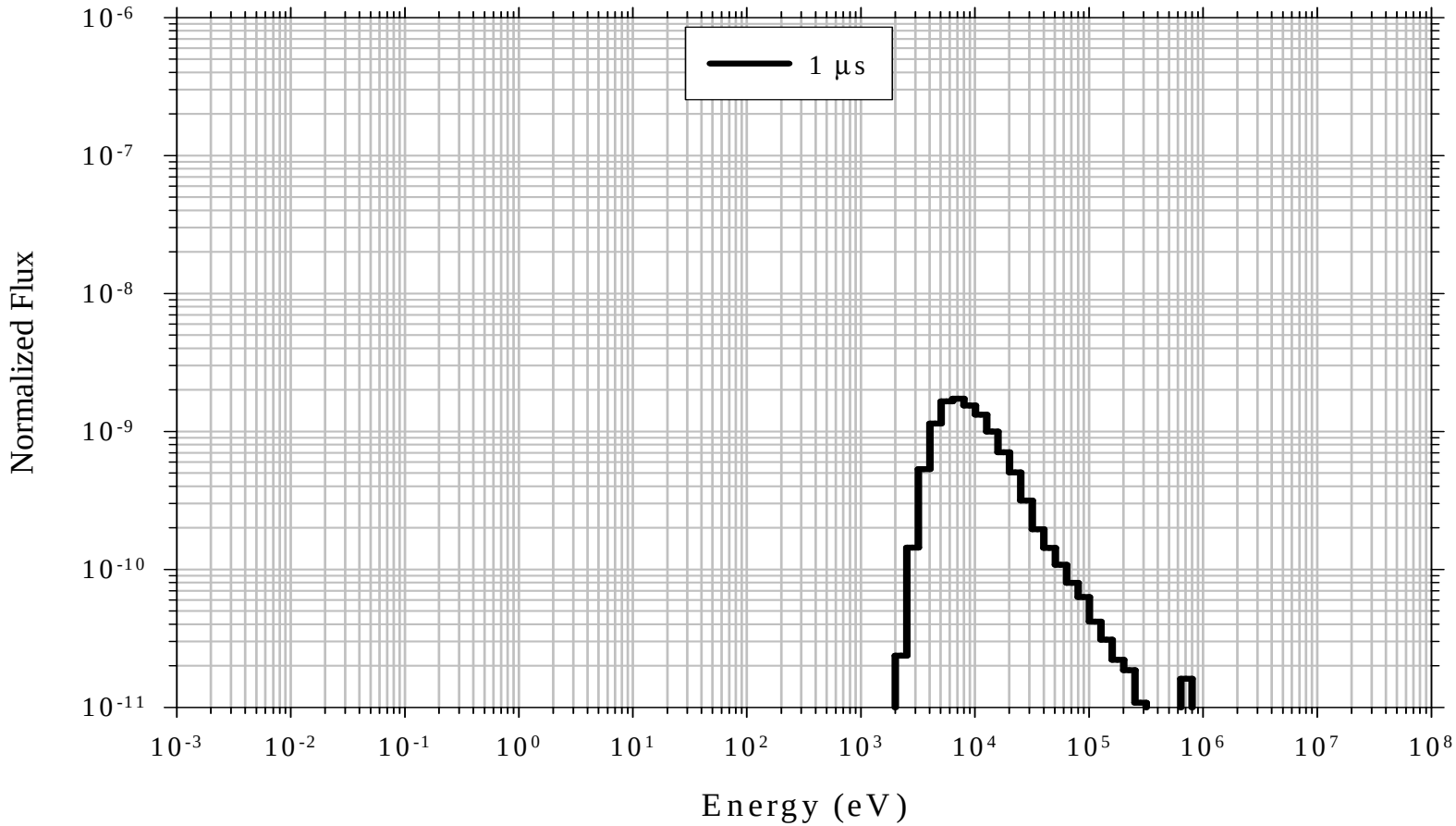
107
108


1 µs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
100
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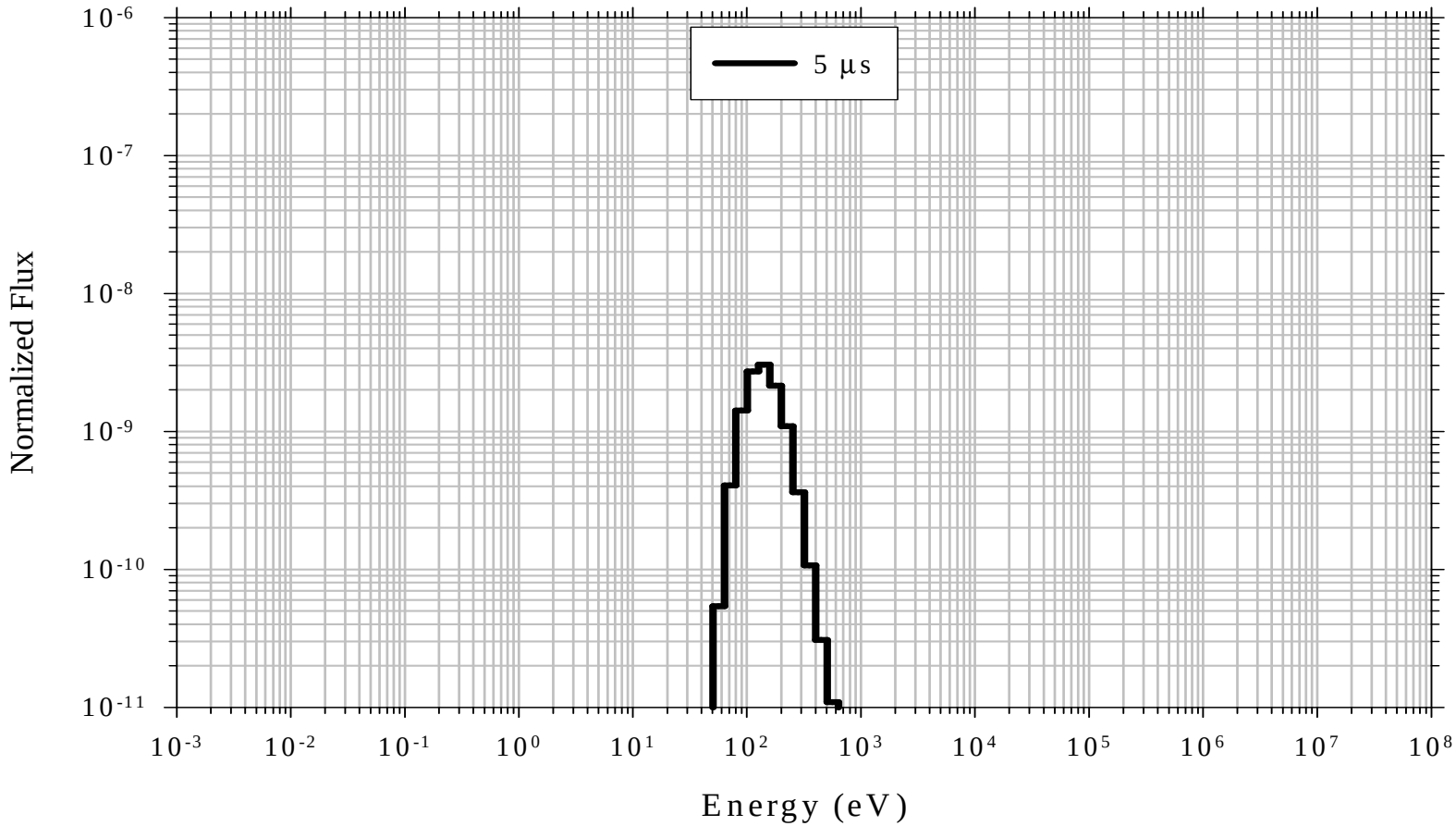
5 μs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
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10-11
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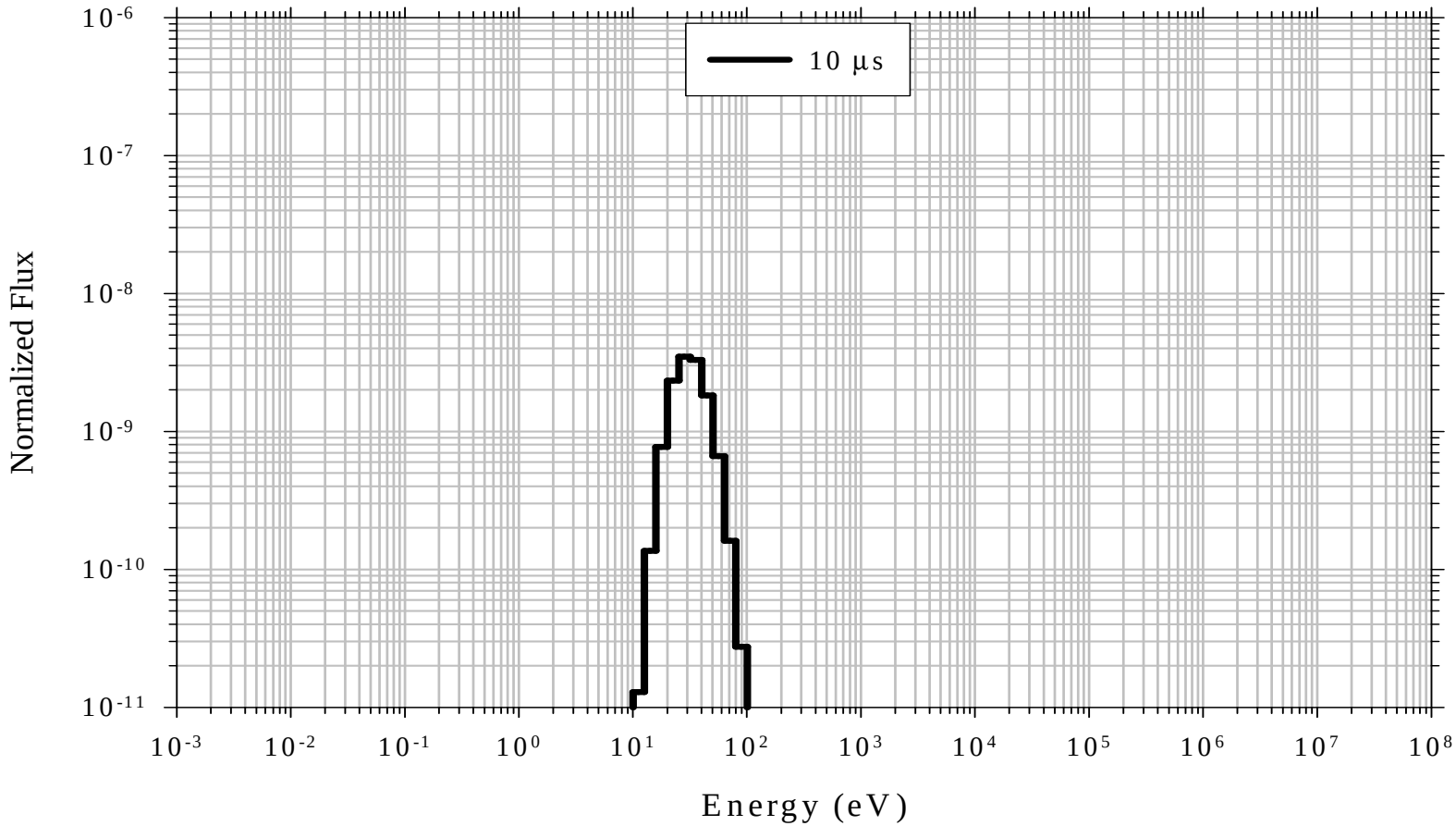
10 µs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
100
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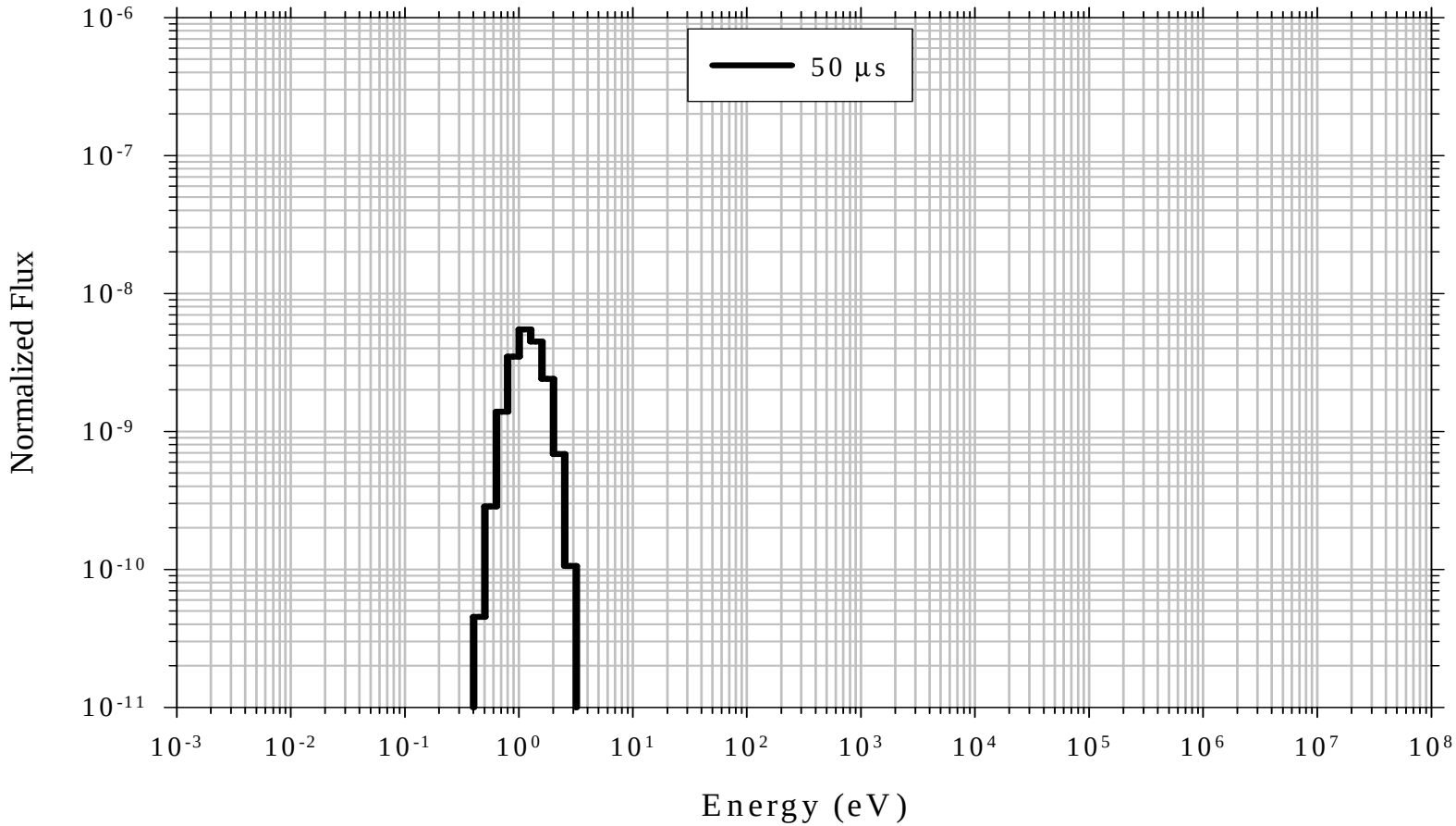
50 µs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
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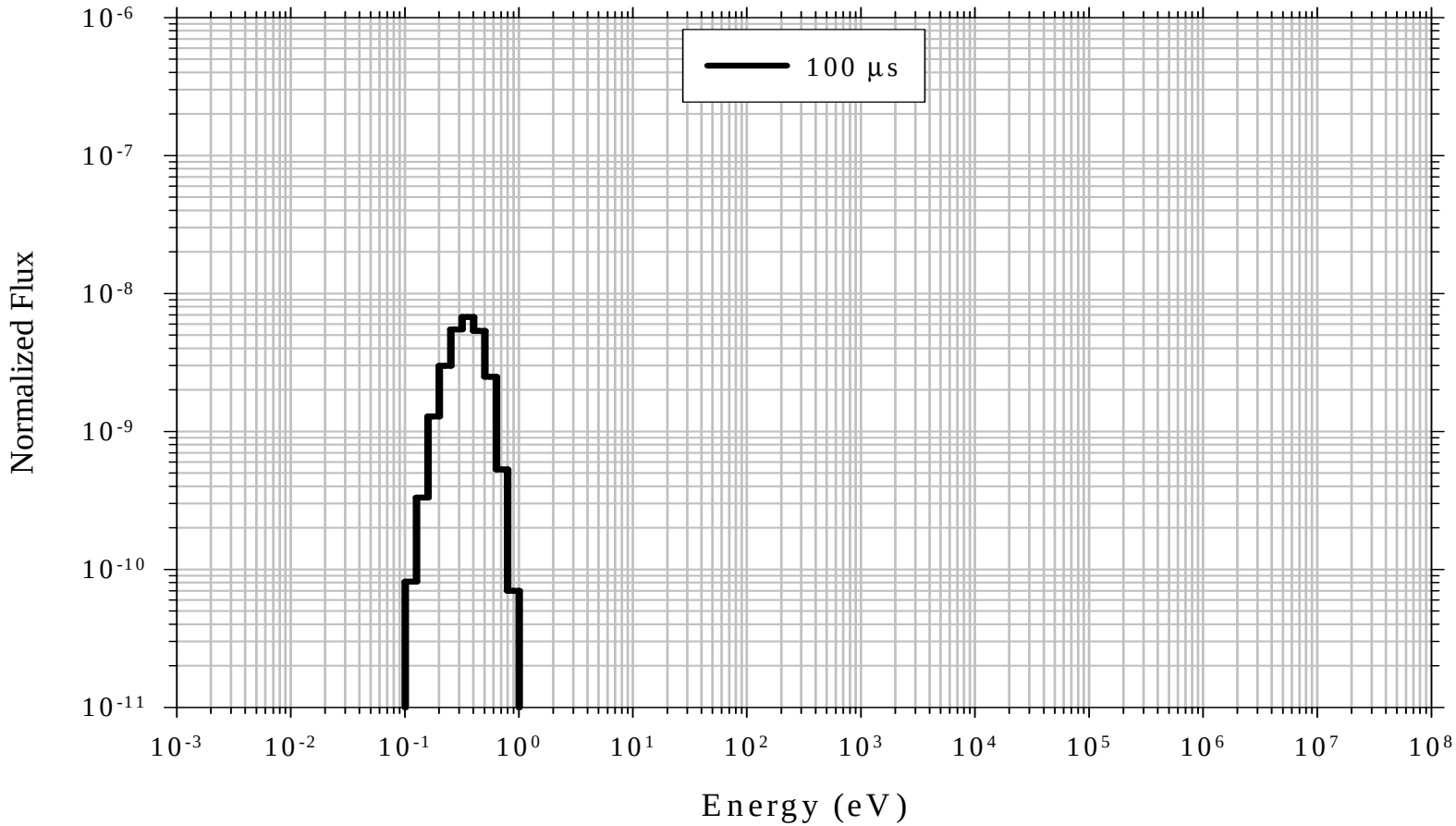
100 µs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
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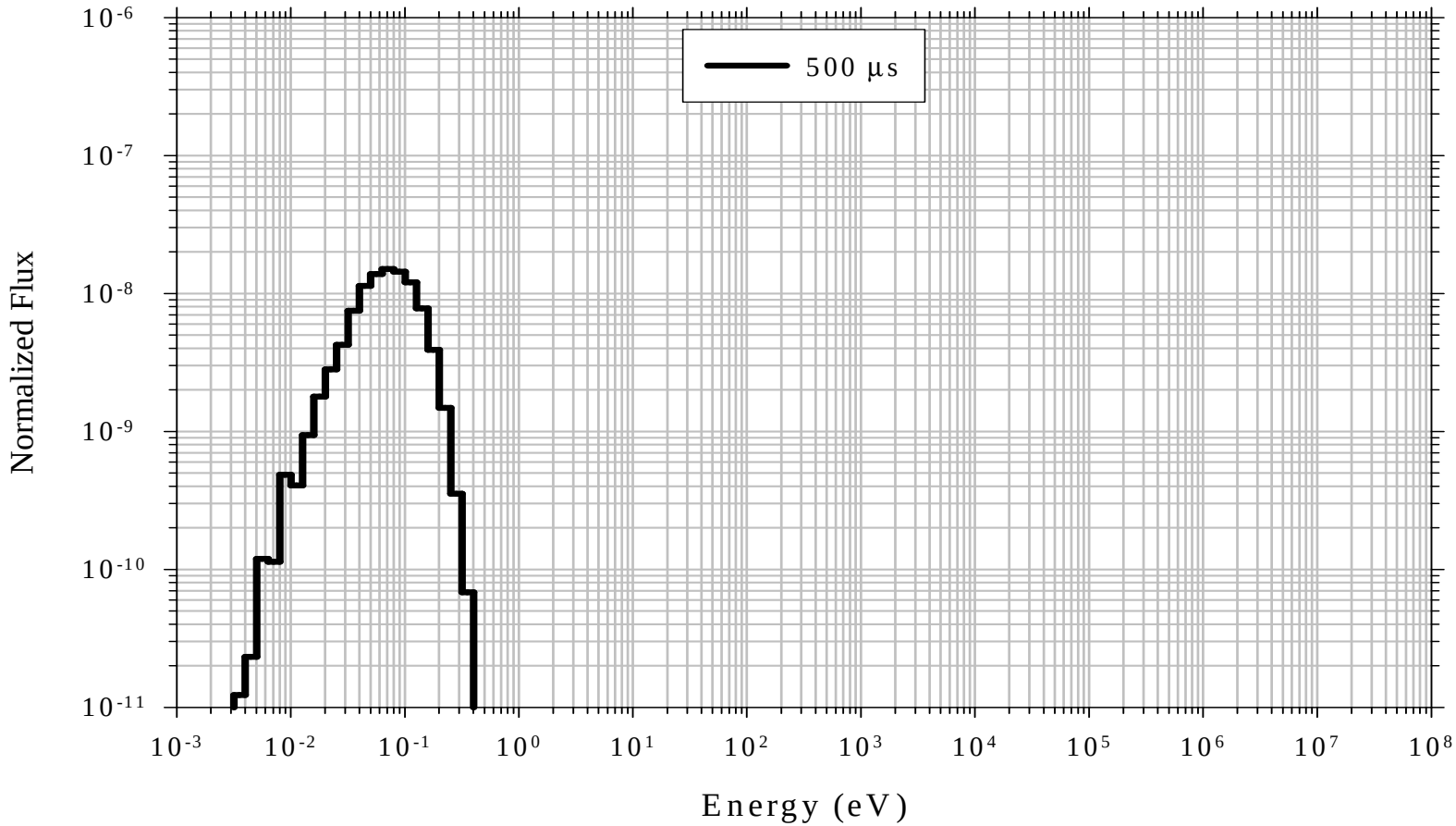
500 µs
Normalized Flux
Energy (eV)
10-6
10-7
10-8
10-9
10-10
10-11
10-3
10-2
10-1
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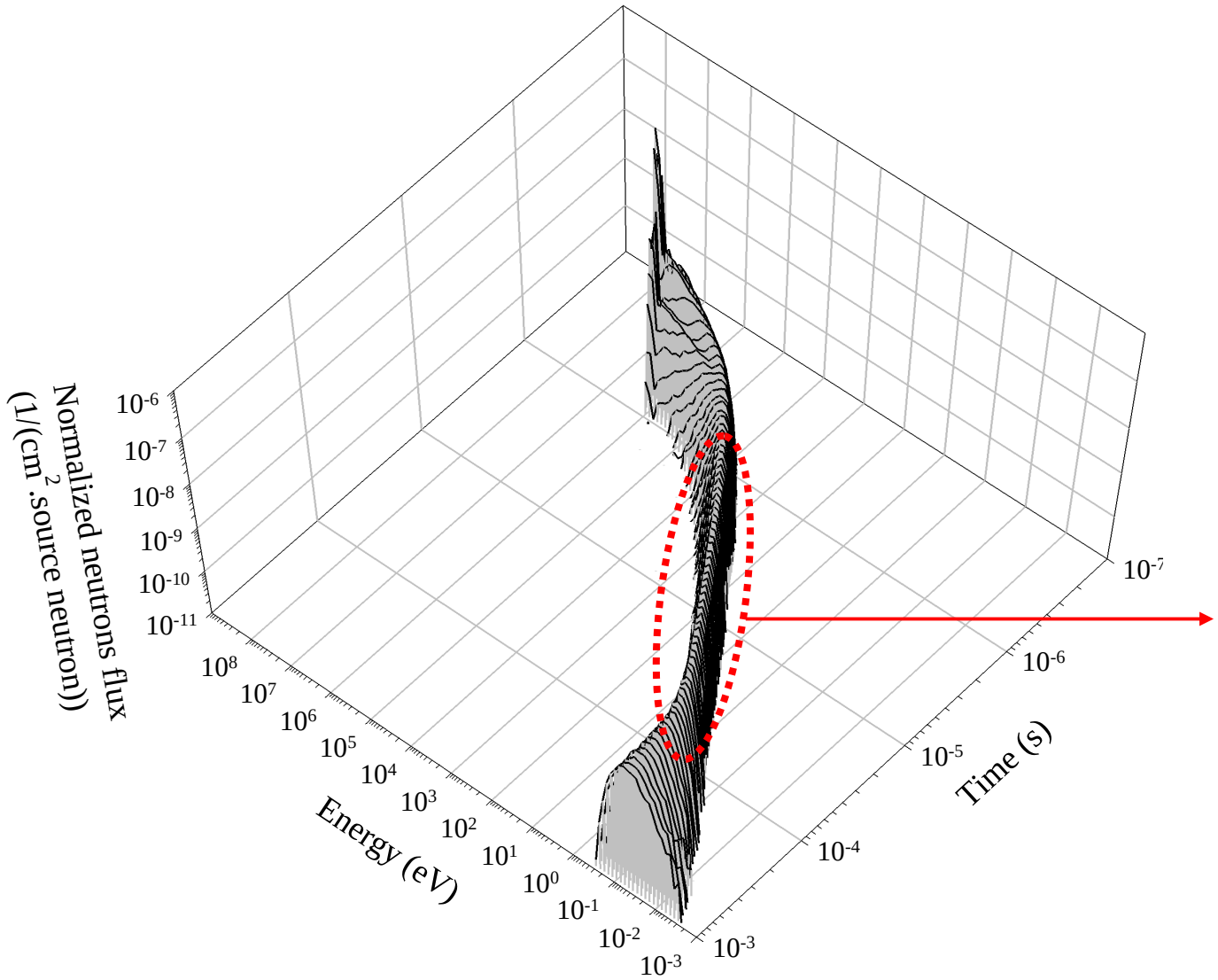
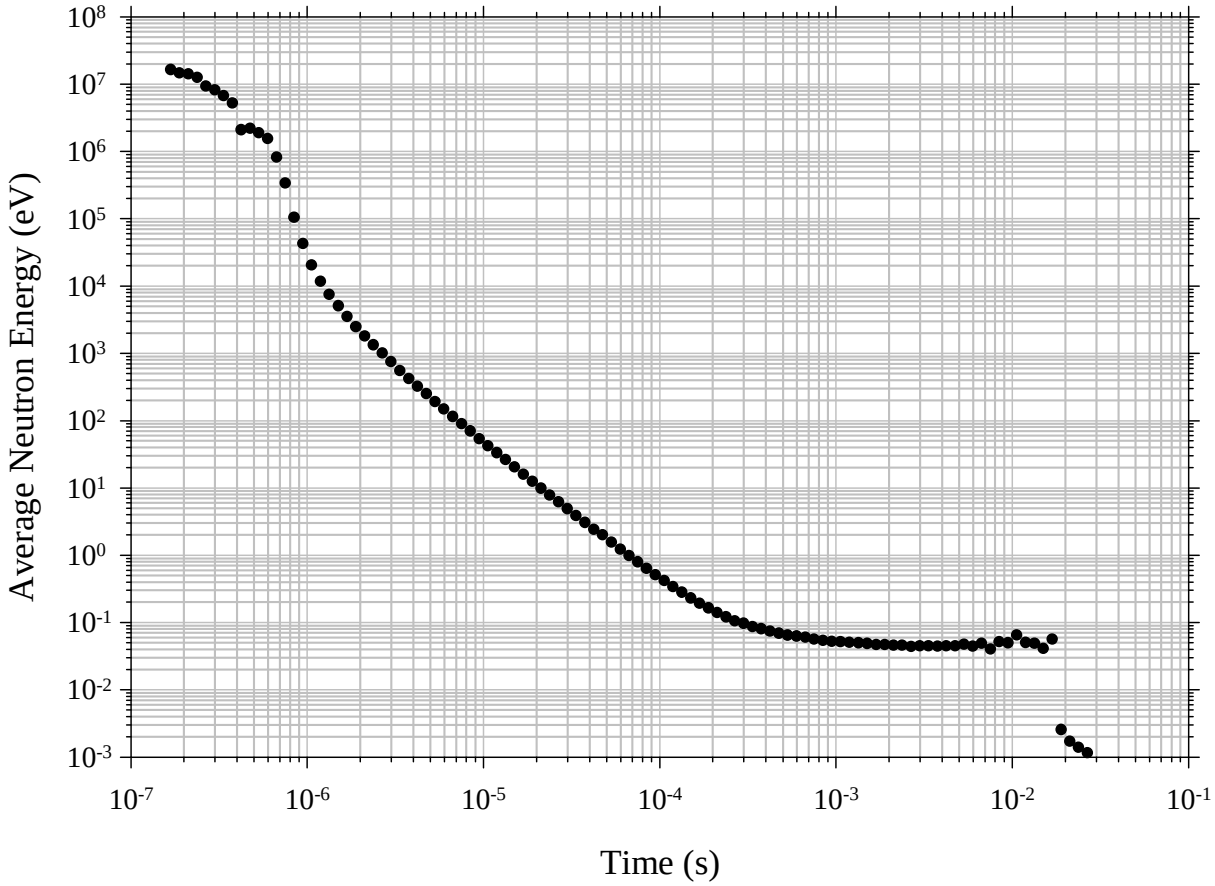
SDT Experiment



$$\overline{E} \approx \frac{k}{t^2}$$

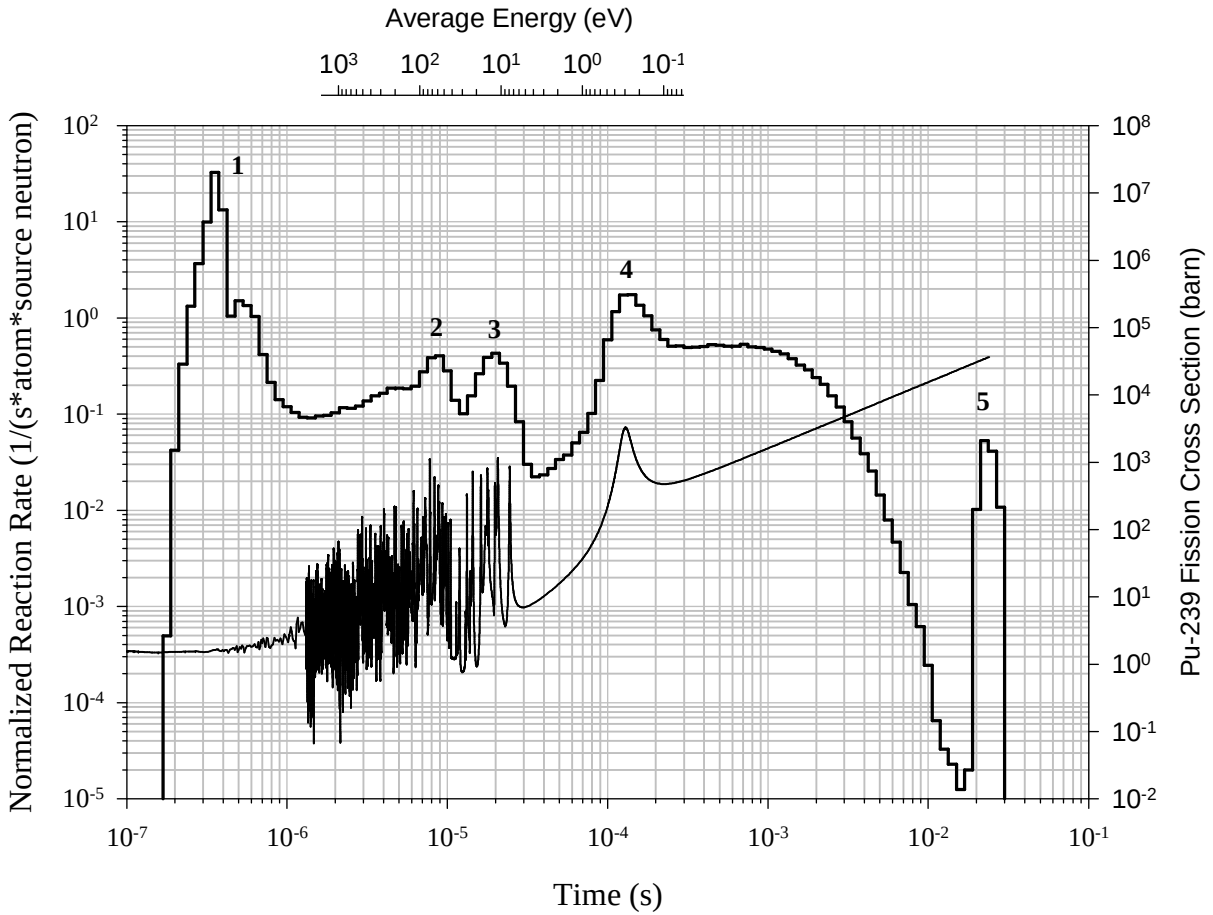
SDT and average energy

$$\overline{E}(t) = \int_E E \cdot \Psi(E,t) dE$$

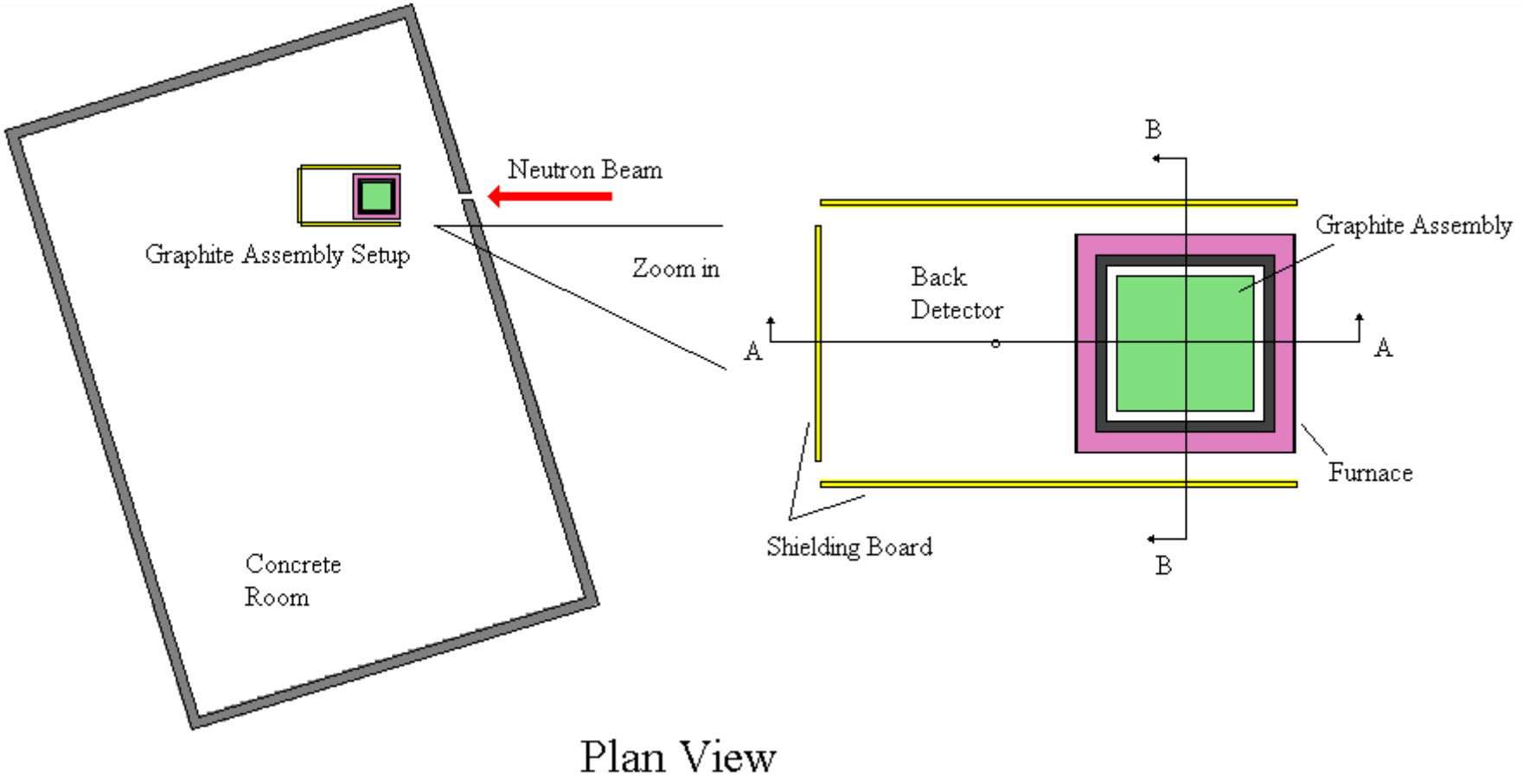


Simulated Pu-239 Time Spectrum

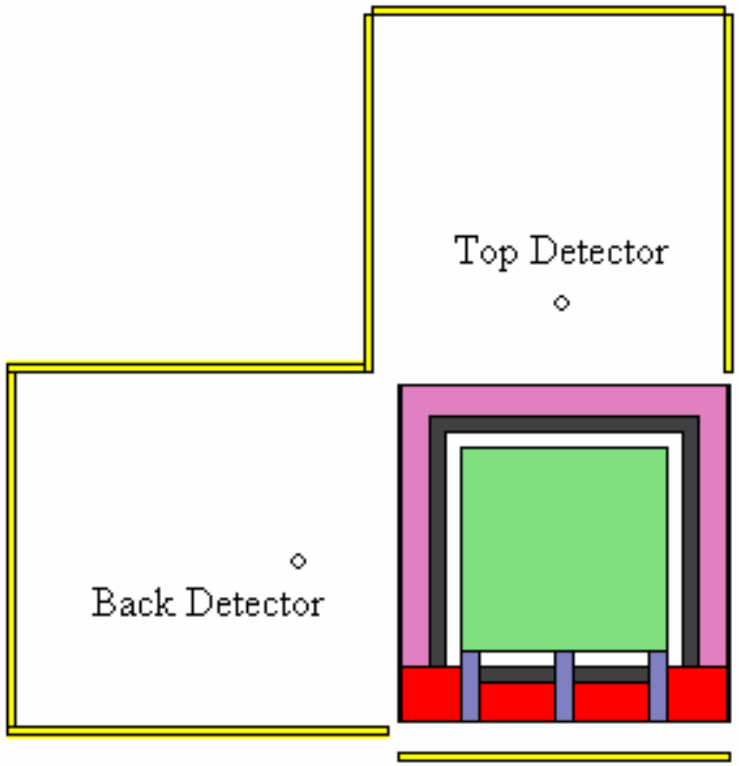
$$R(t) = \int_E \sigma(E)\,\phi(E,t)\,dE$$



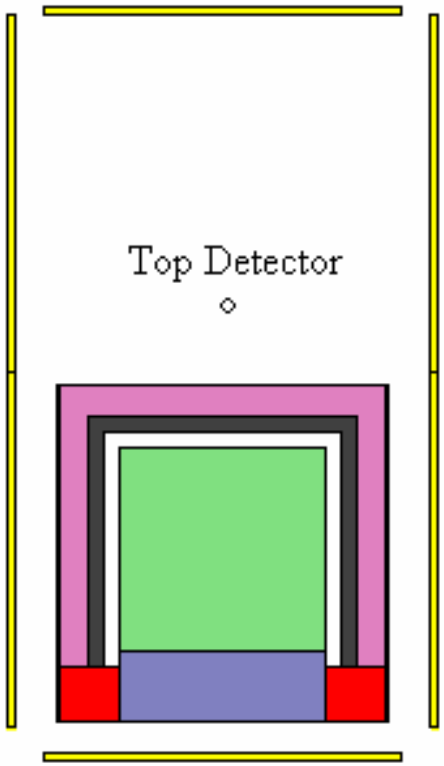
MCNP Model


Neutron Beam
Graphite Assembly Setup
Zoom in
Concrete
Room
B
Graphite Assembly
Back
Detector
A
A
Furnace
Shielding Board
B
Plan View

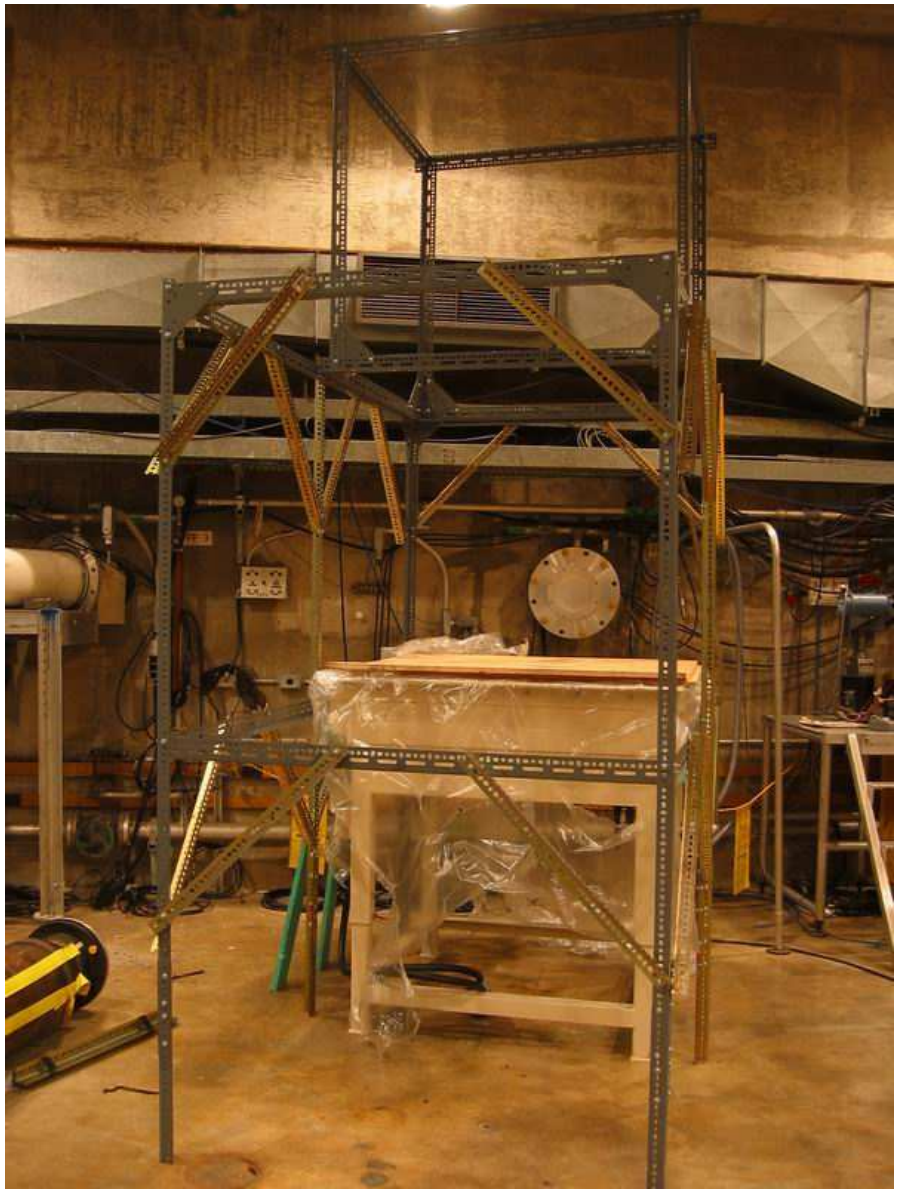
MCNP Model (cont.)



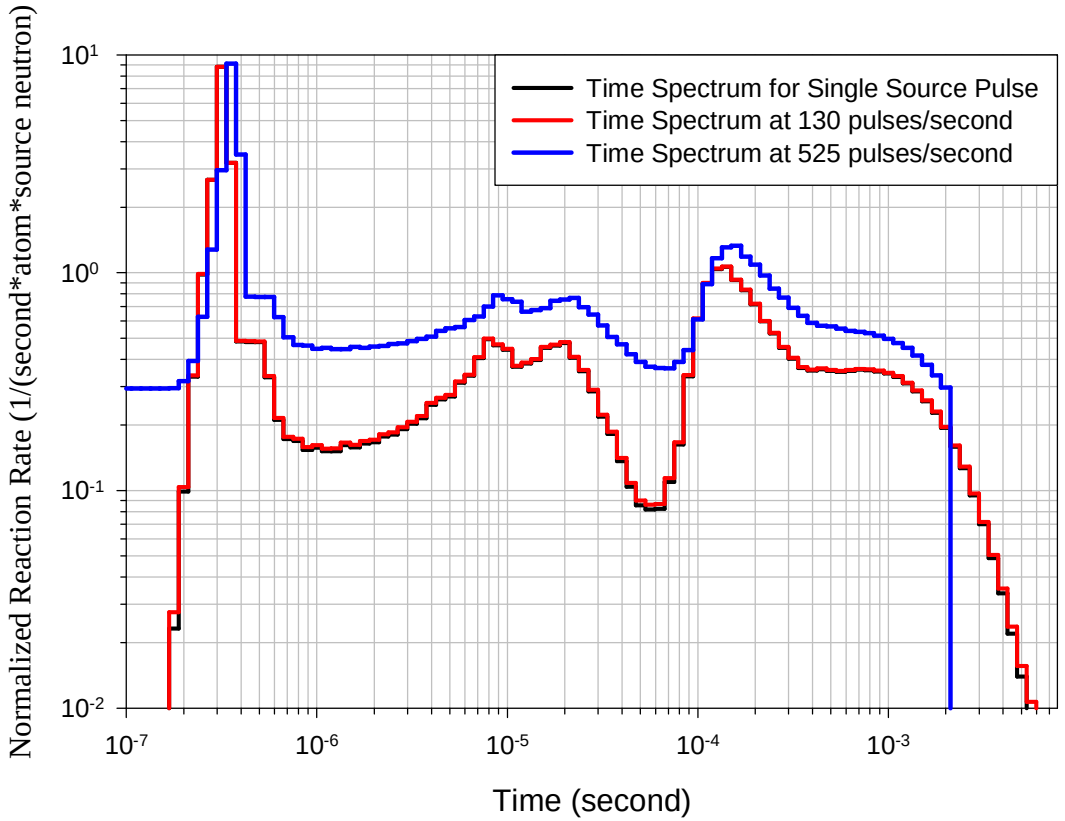
Section A-A



Section B-B

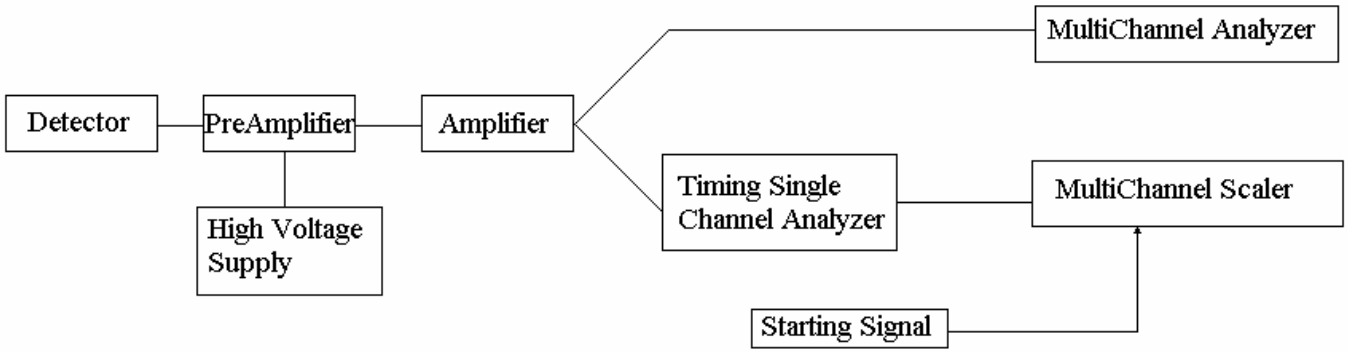


Pulse Overlap Effect



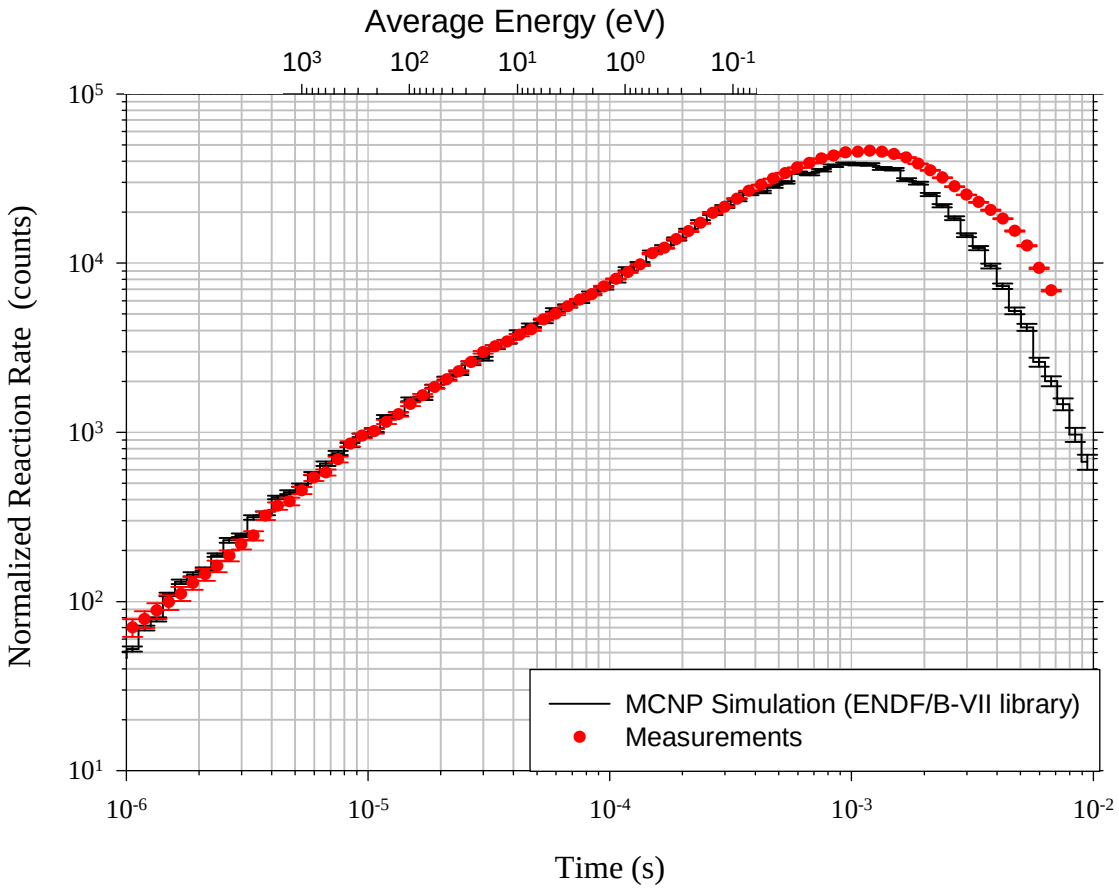
SDT Experiment

Room temperature measurement setup



Detector	Li-6 glass
Measurement time	1 hour
High Voltage	850V
Amplifier gain	0.55x100
Amplifier shaping time	1 μ s
Timing SCA window	0.9V ~ 4V
Timing SCA delay time	6 μ s
MCS channels	8192
MCS dwell time	0.9 μ s
MCA channels	2048

Top detector - Measurements



Summary

- A slowing-down-time experiment in graphite has been designed and is in its first stages of execution at the ORELA facility in Oak Ridge National Laboratory.
- The experiment aims at benchmarking the slowing down and thermalization of neutrons in graphite at temperatures extending from room temperature to approximately 1200K.
- Measurements performed so far have shown significant deviations from computational predications in the thermal energy range.
- Future measurements are planned using Cd and/or boron loaded filters to investigate the potential contribution of excess thermal and epithermal neutrons in the source pulse.