LLNL-PRES-770146

NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

# Inherently Safe Subcritical Assembly (ISSA) Benchmark Evaluation

Presented at the Nuclear Criticality Safety Program (NCSP) Technical Program Review
March 26-27 2019

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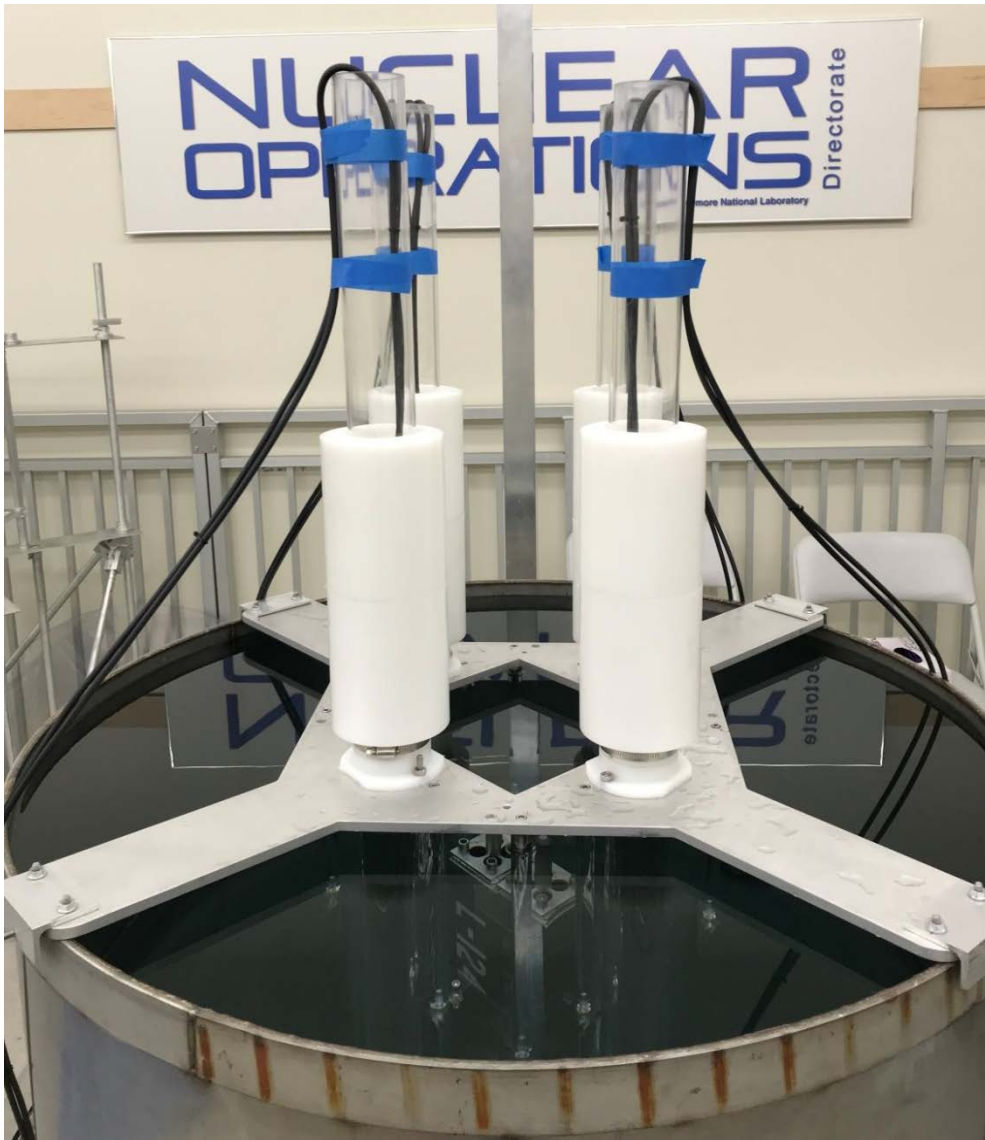
**This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344**

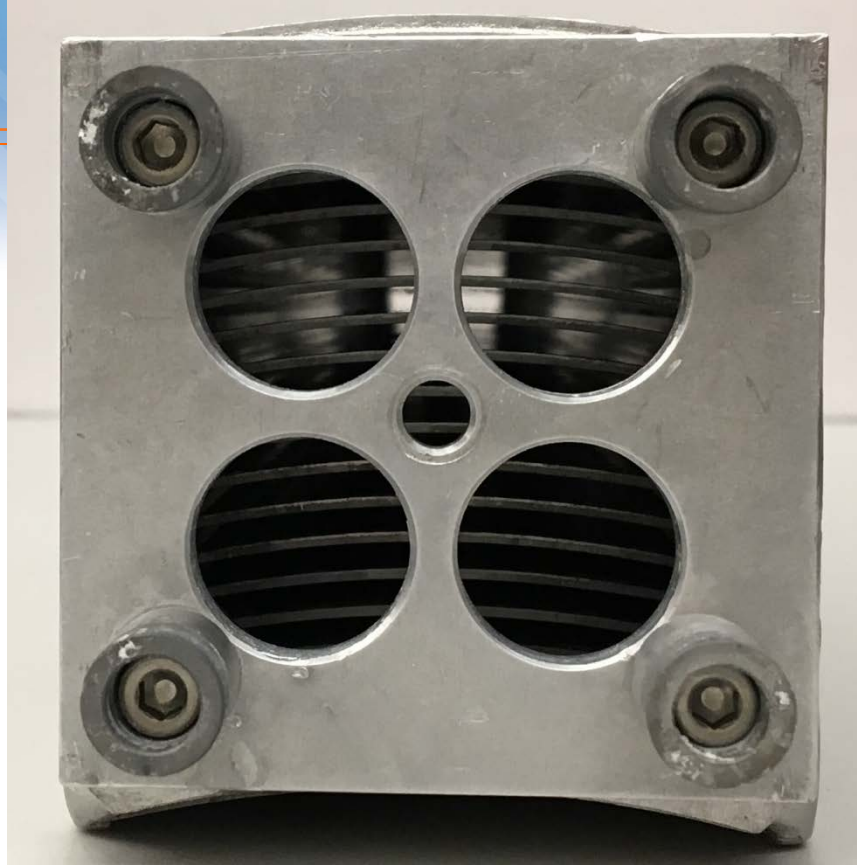
# *Inherently Safe Subcritical Assembly (ISSA)*

- Subcritical benchmark experiments for ICSBEP
- Existing asset as a training assembly
- Validate time dependent radiation transport modules
- Validate nuclear data
- Subcritical multiplication monitoring



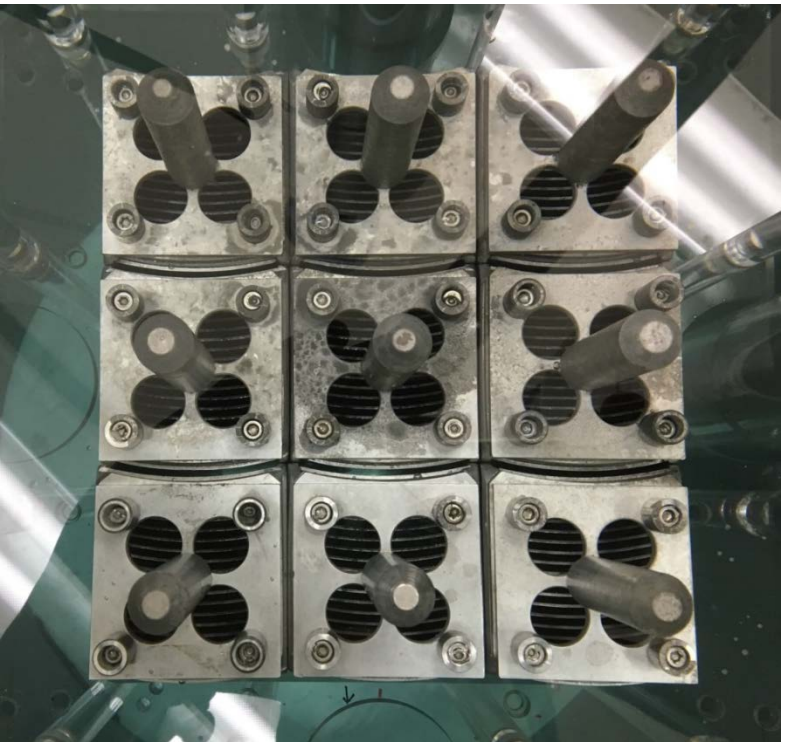
# ISSA Fuel

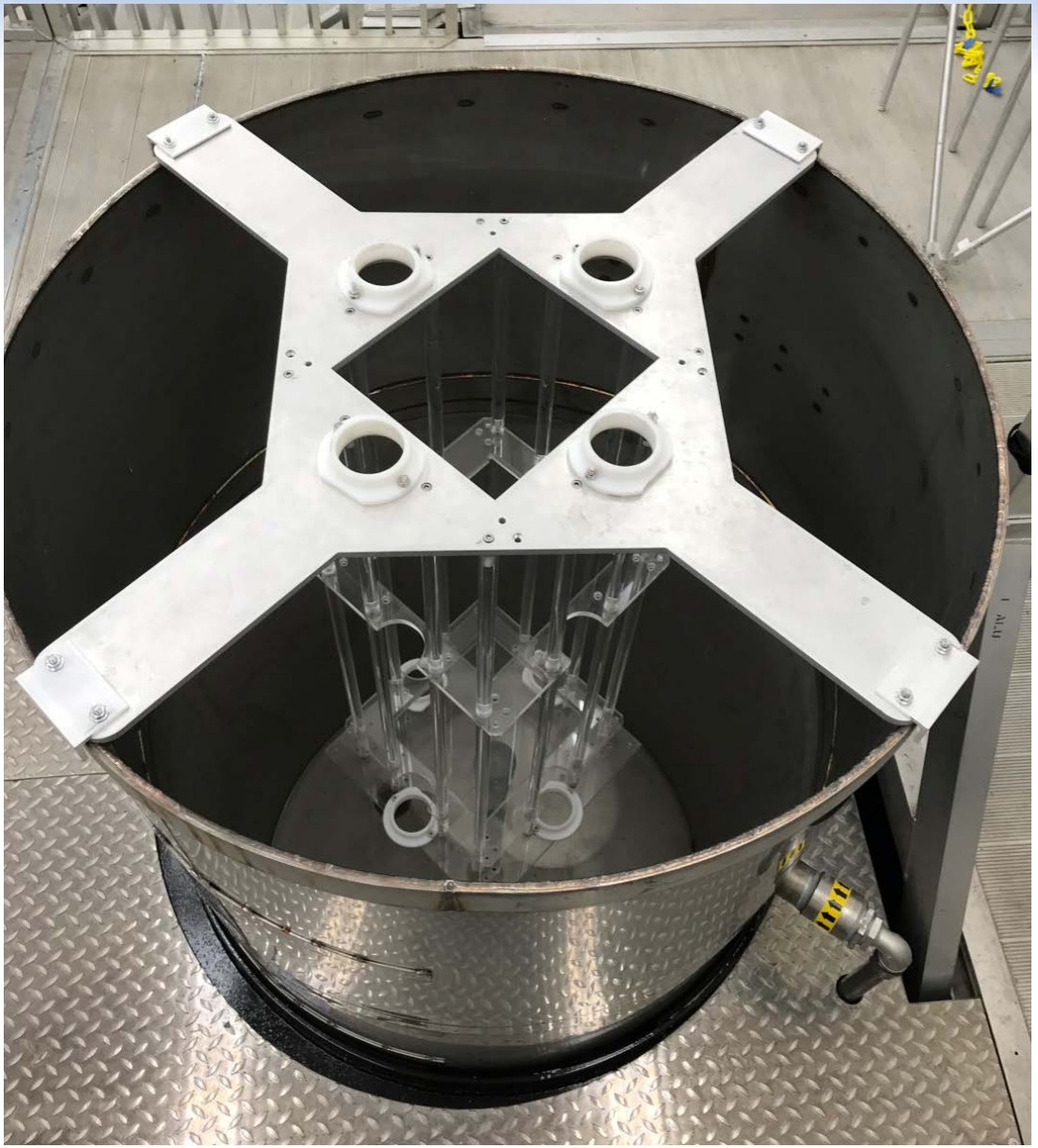
- Originally fabricated for the Omega West Reactor
- Modified at LLNL
- 93.16% $^{235}U$
- $U_3O_8$ powder + aluminum powder
- Sandwiched between aluminum plates
- 19 curved plates per assembly
- 232 g $^{235}U$ per assembly



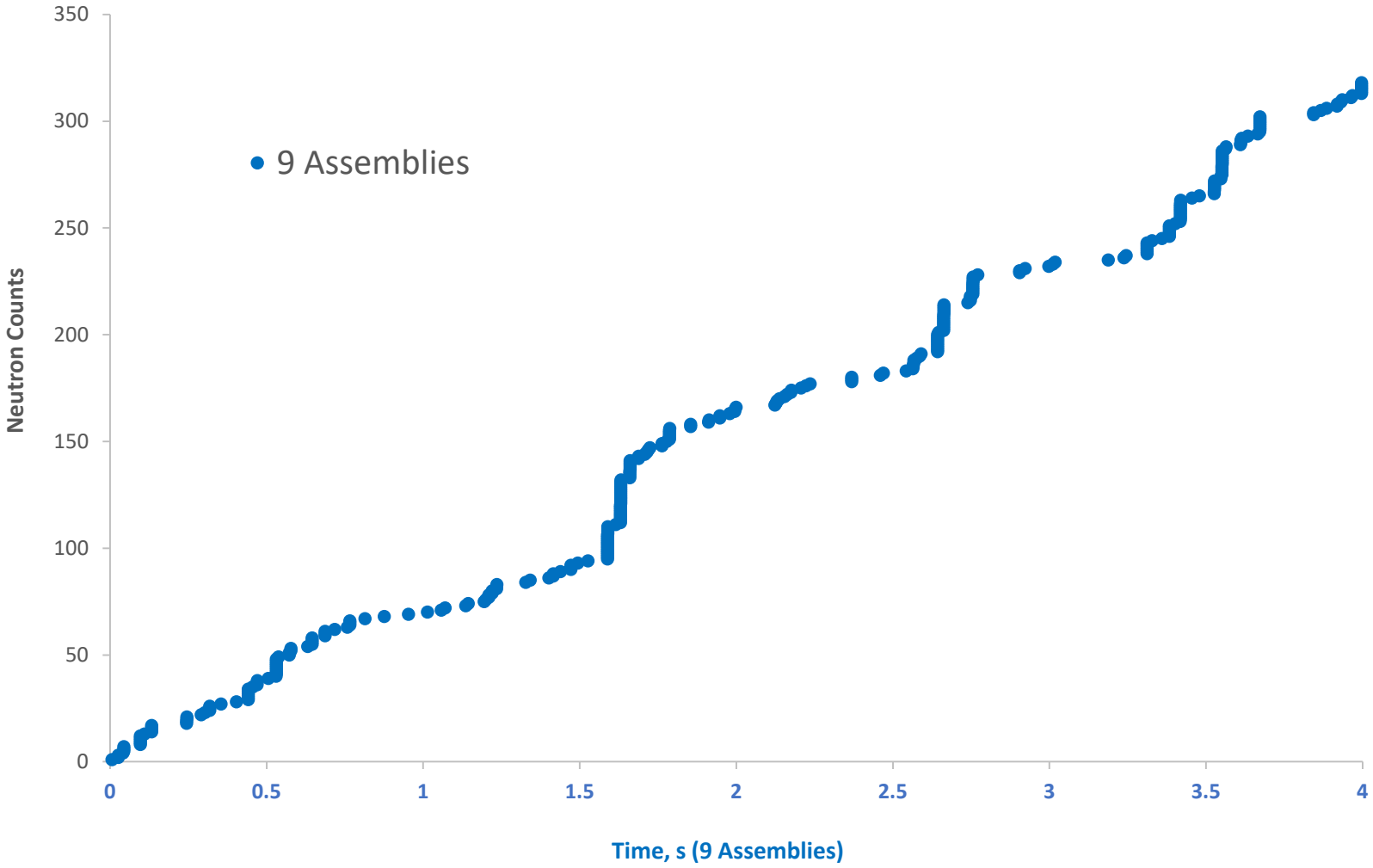
# Experiments

- 5 experiments:
  - 1, 2, 4, 6, and 9 fuel assemblies
- Multiplication ranging from 1.2-10

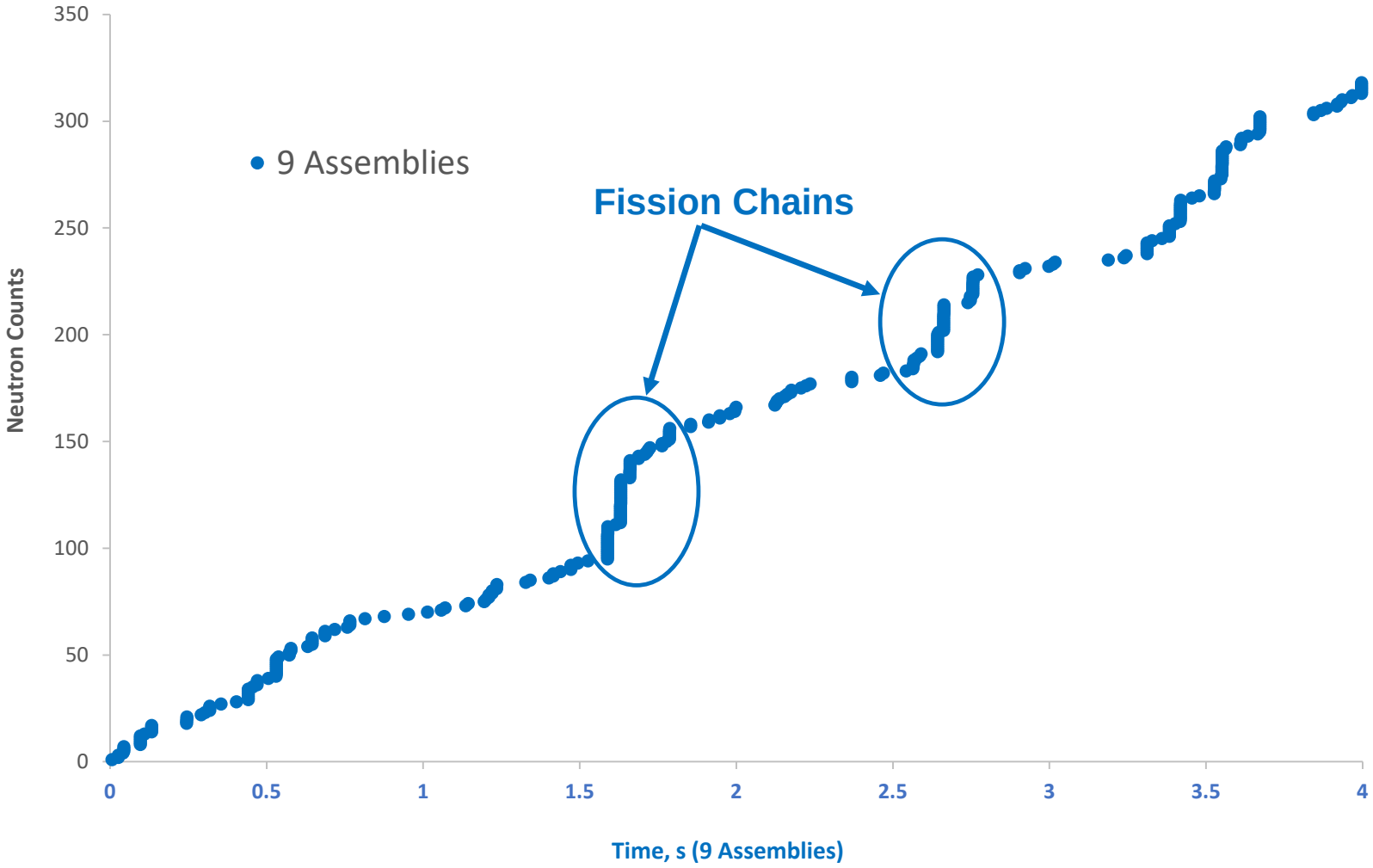




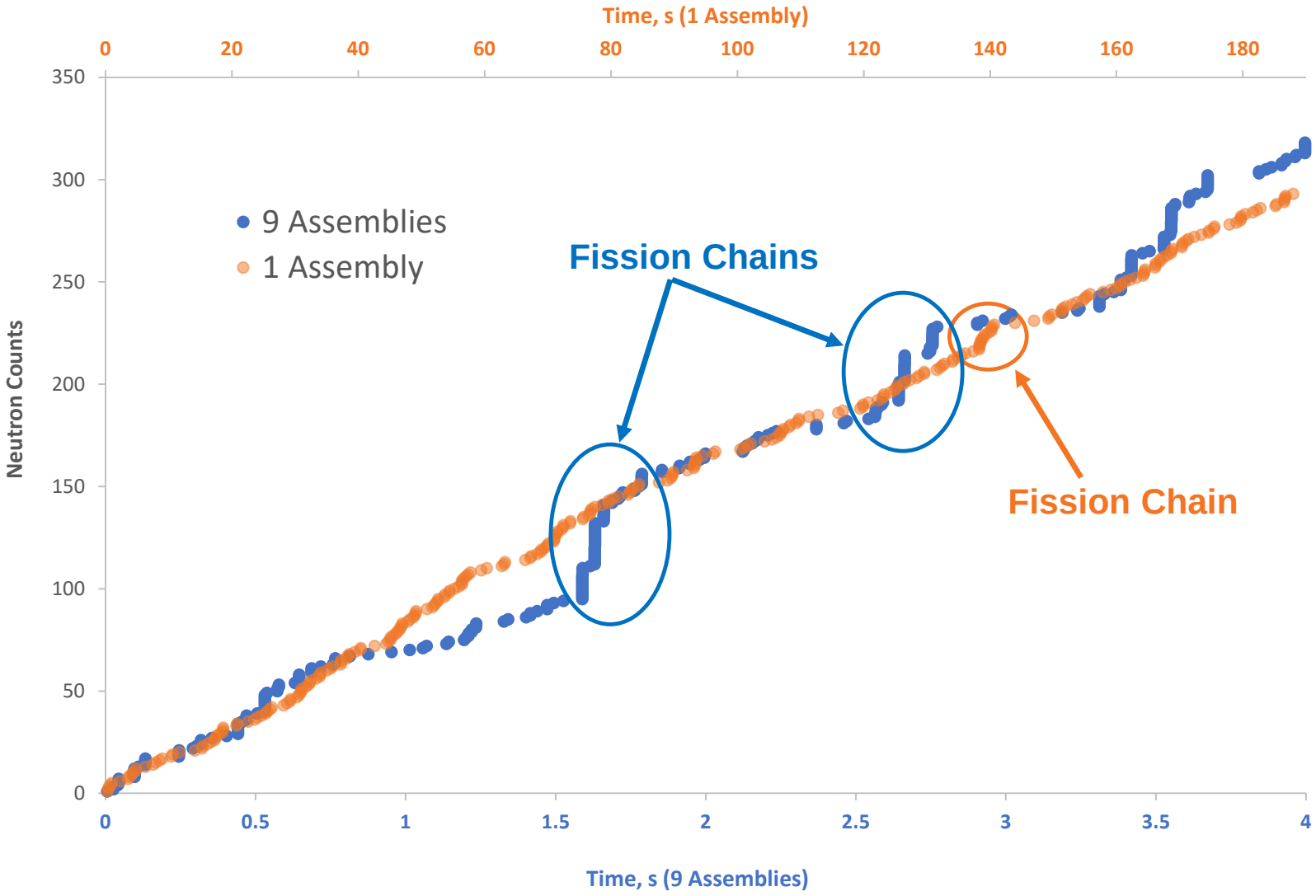
# Experimental Results



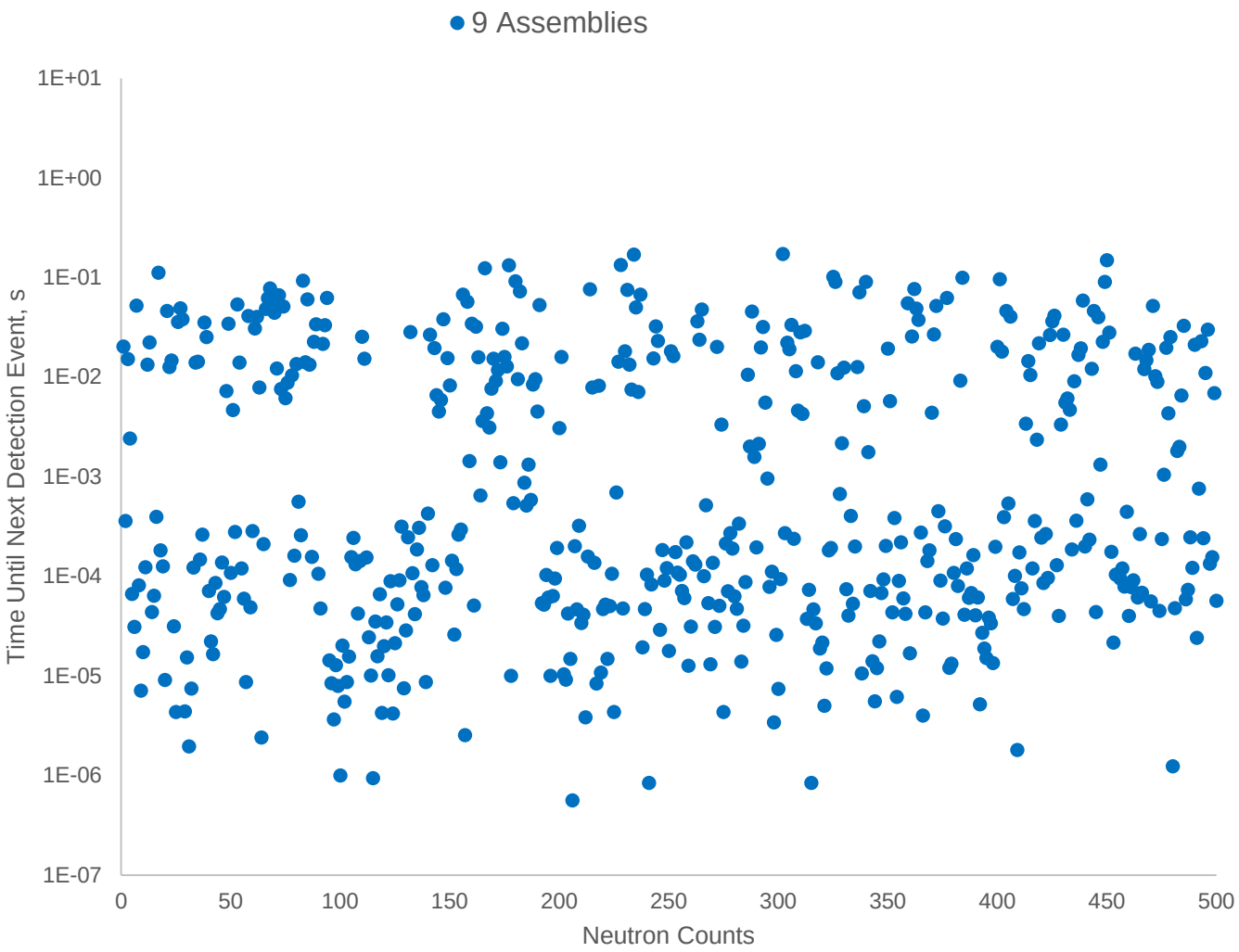
# Experimental Results



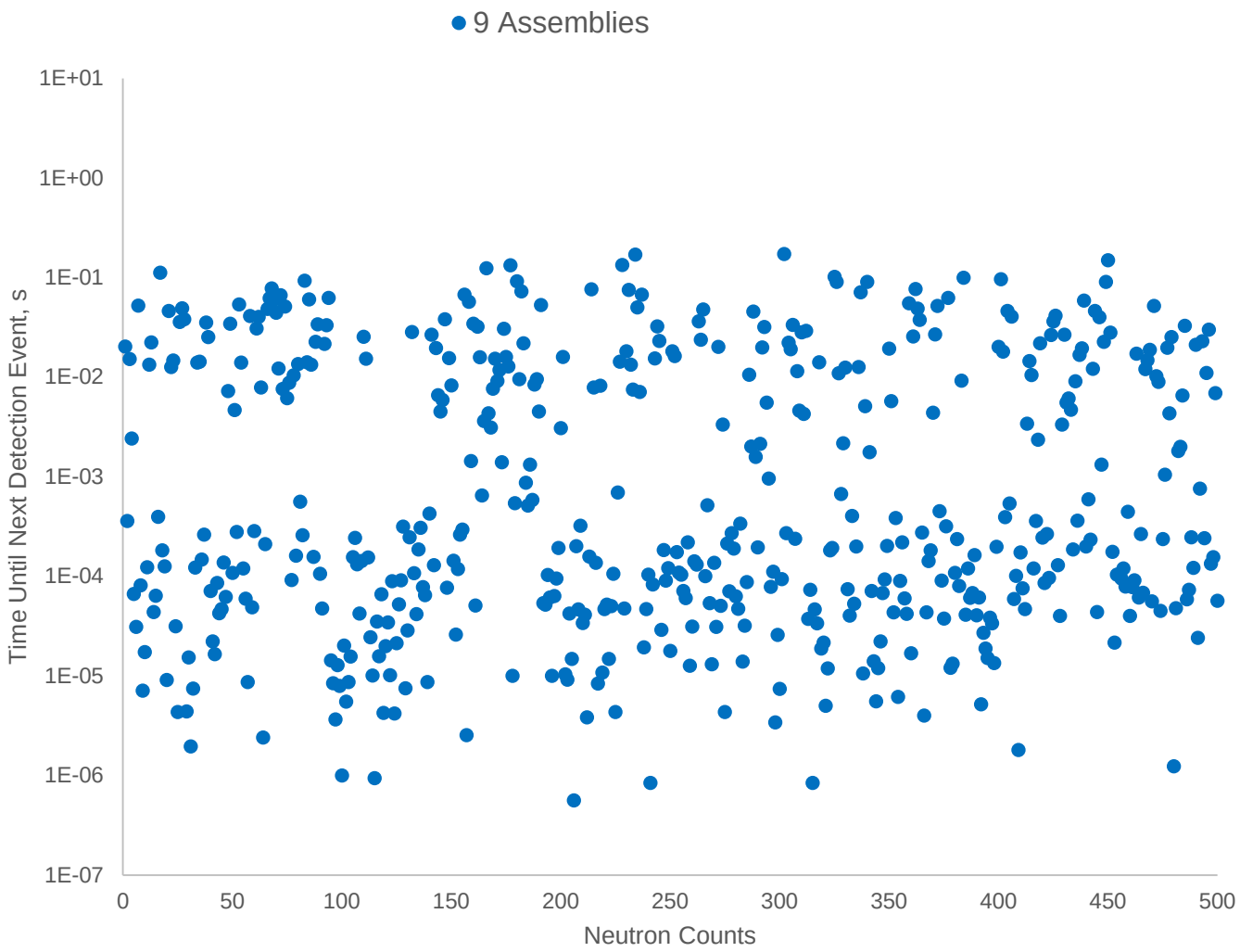
# Experimental Results



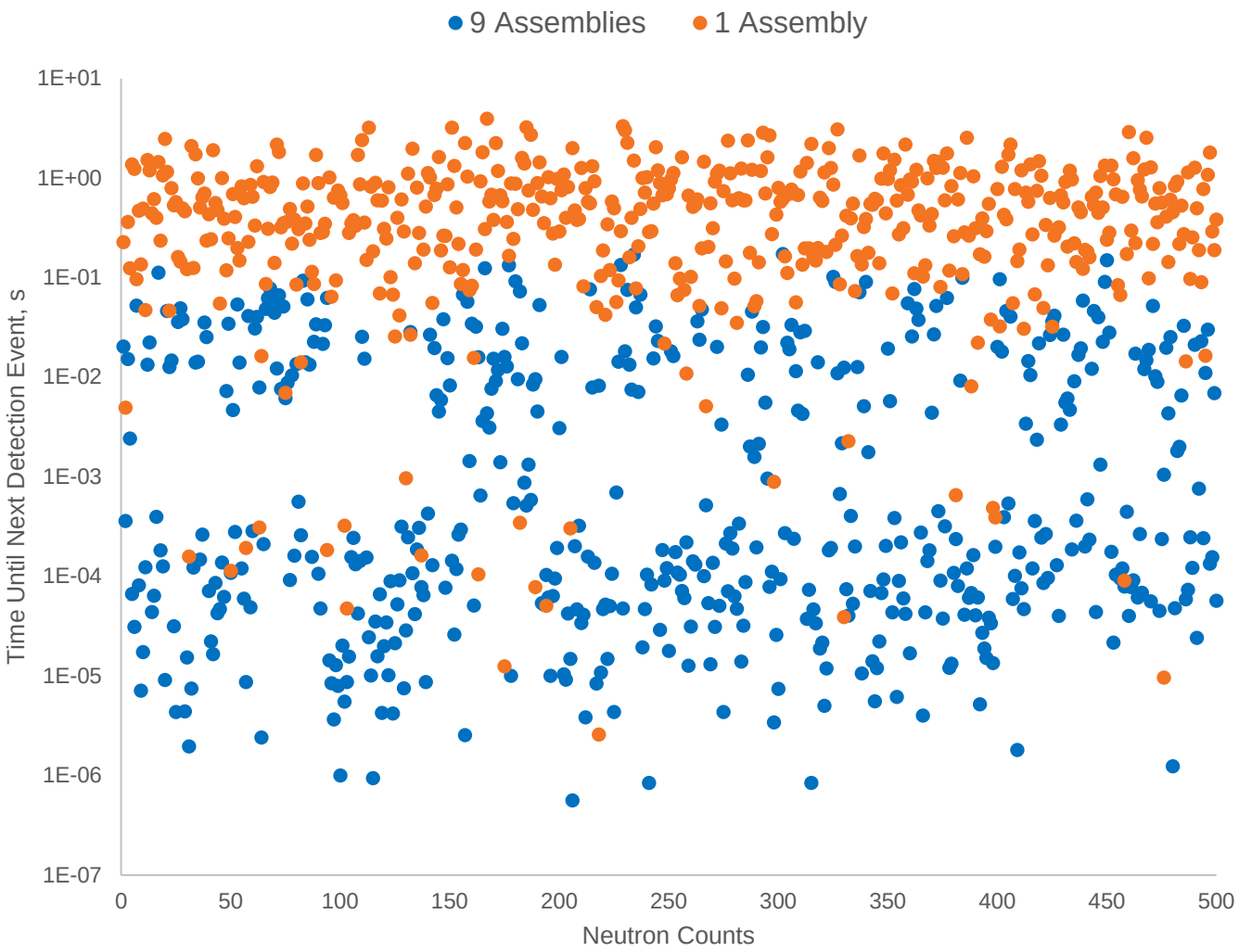
# Experimental Results



# Experimental Results



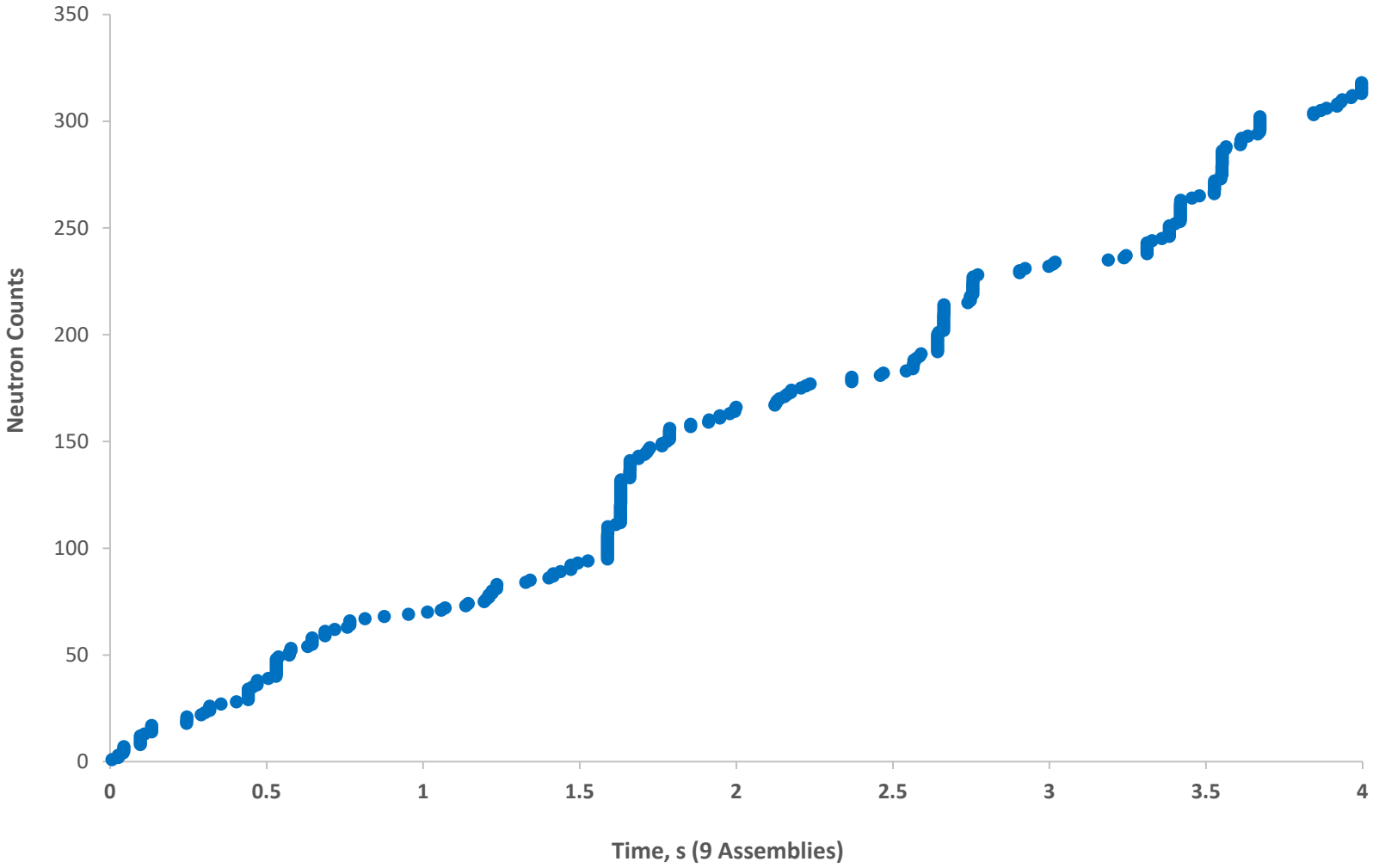
# Experimental Results



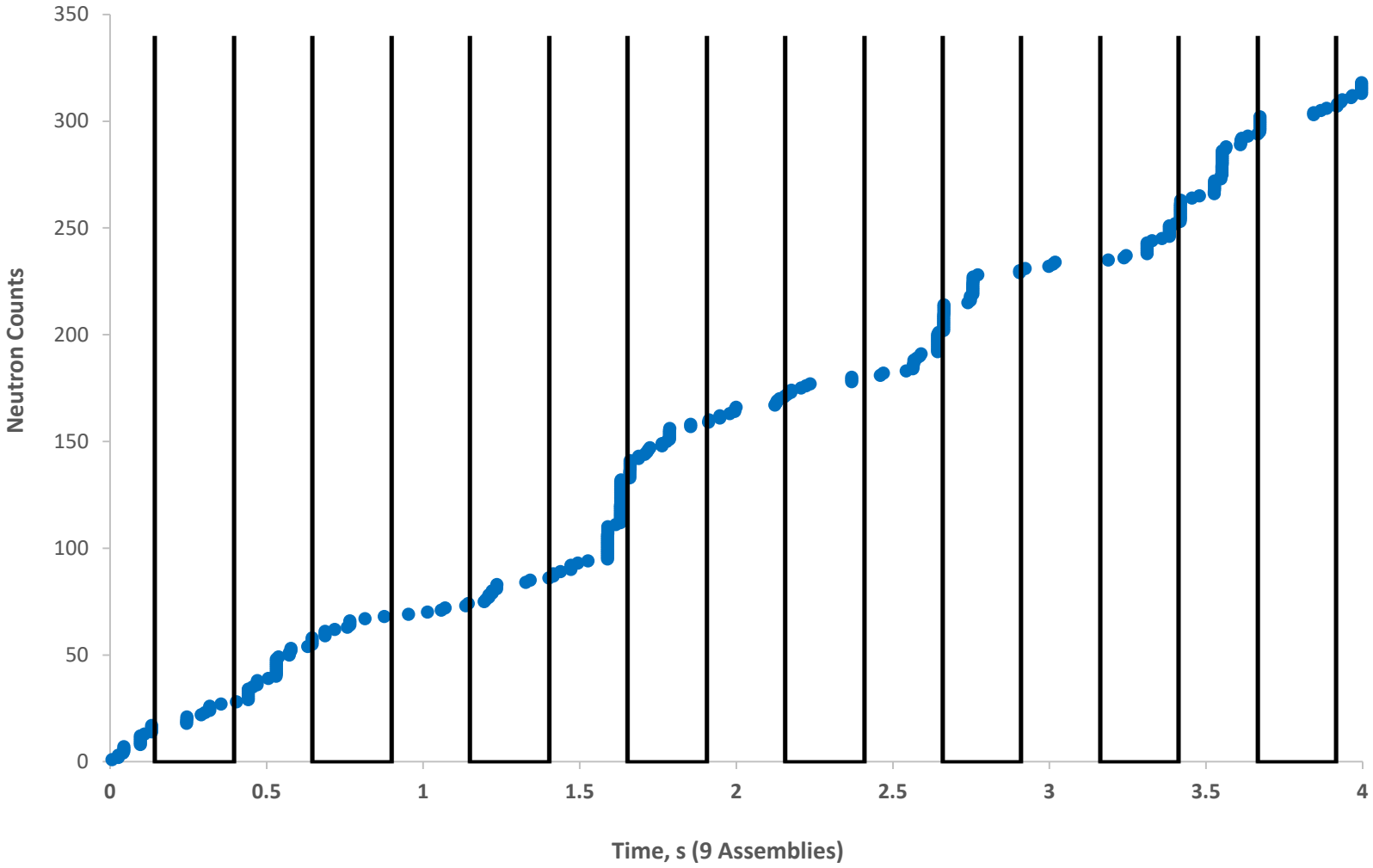

**Random Source**

**Fission Chains**

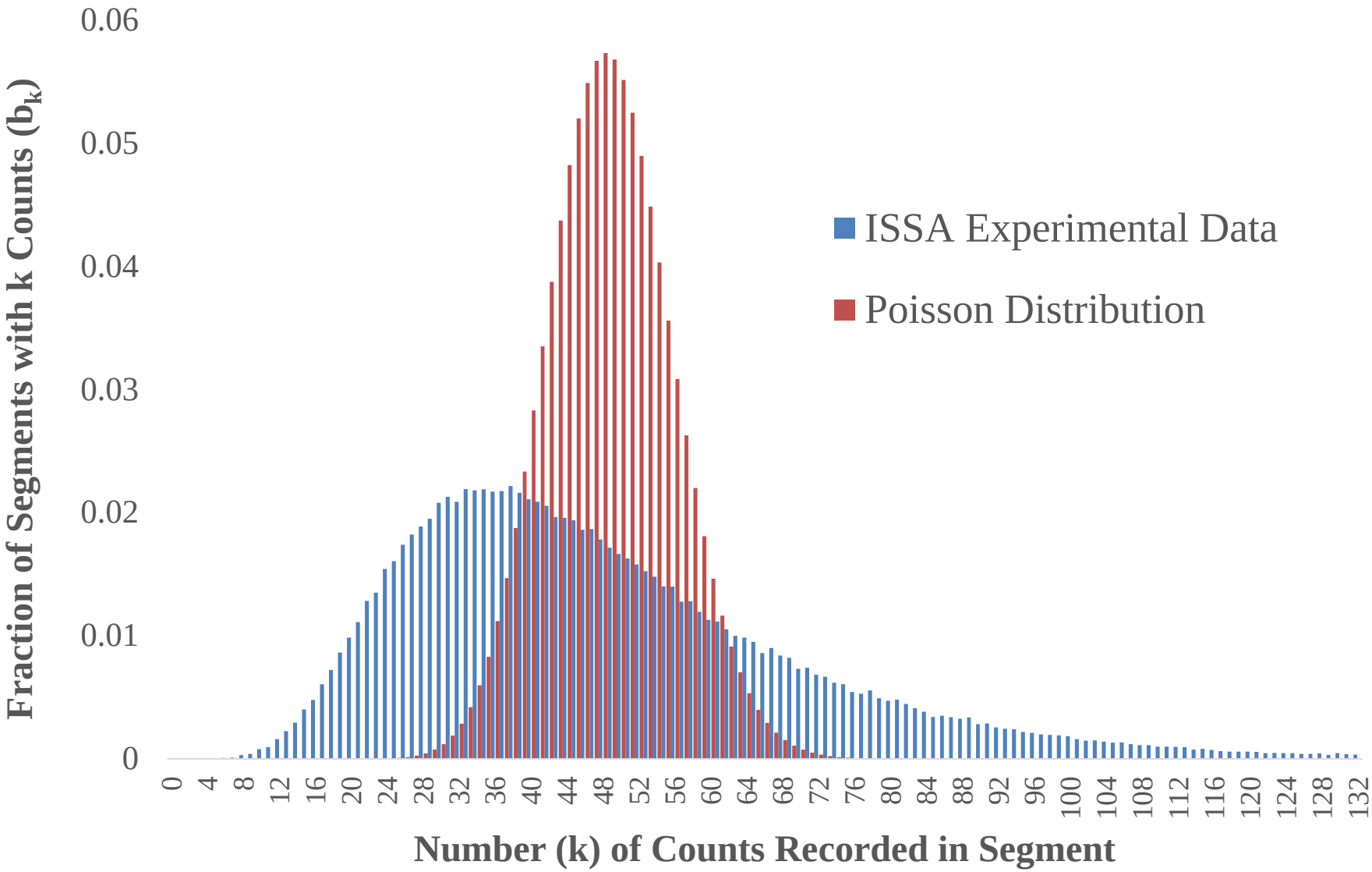
# Analysis


Neutron Counts
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Time, s (9 Assemblies)

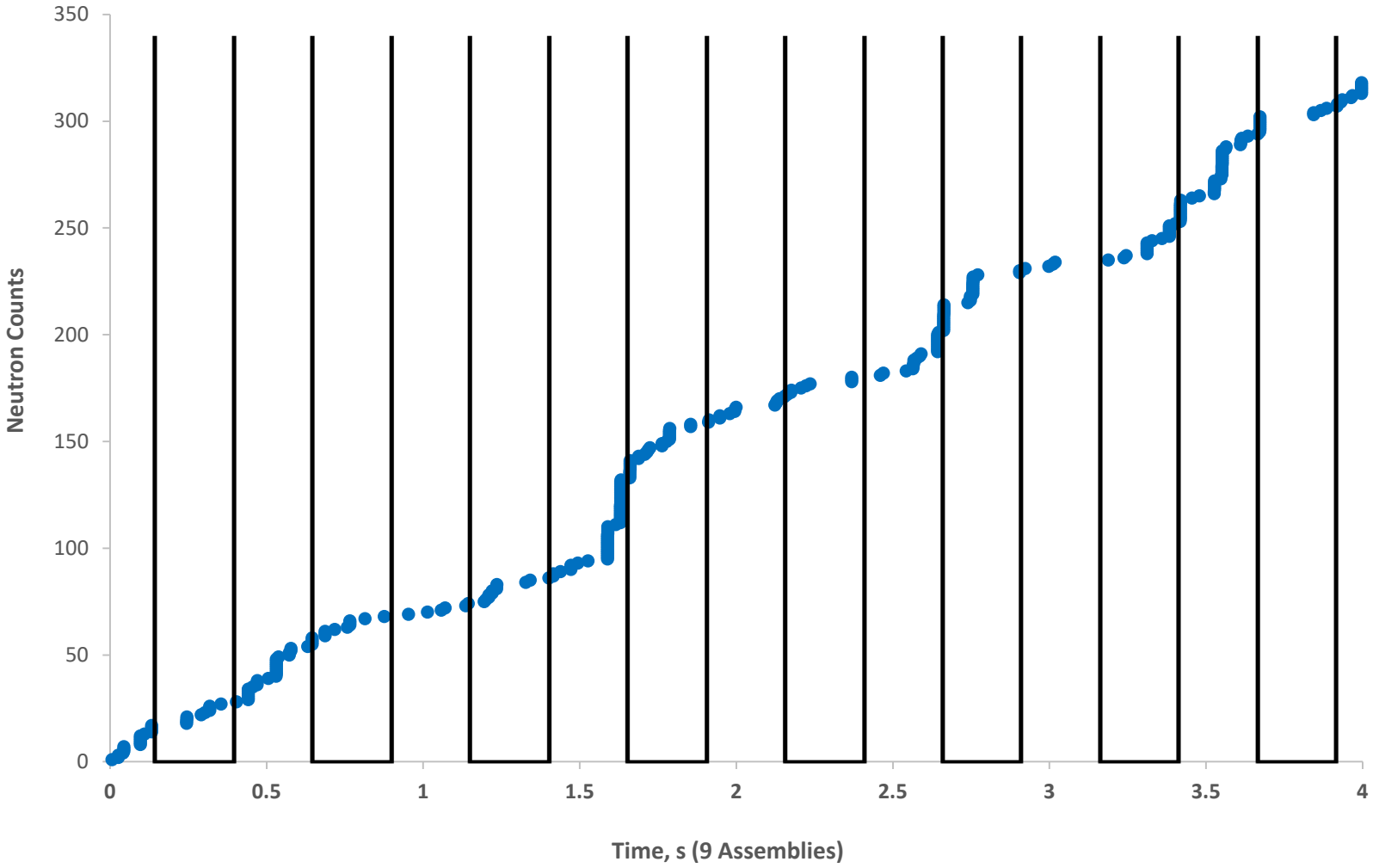
# Analysis


Neutron Counts
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Time, s (9 Assemblies)

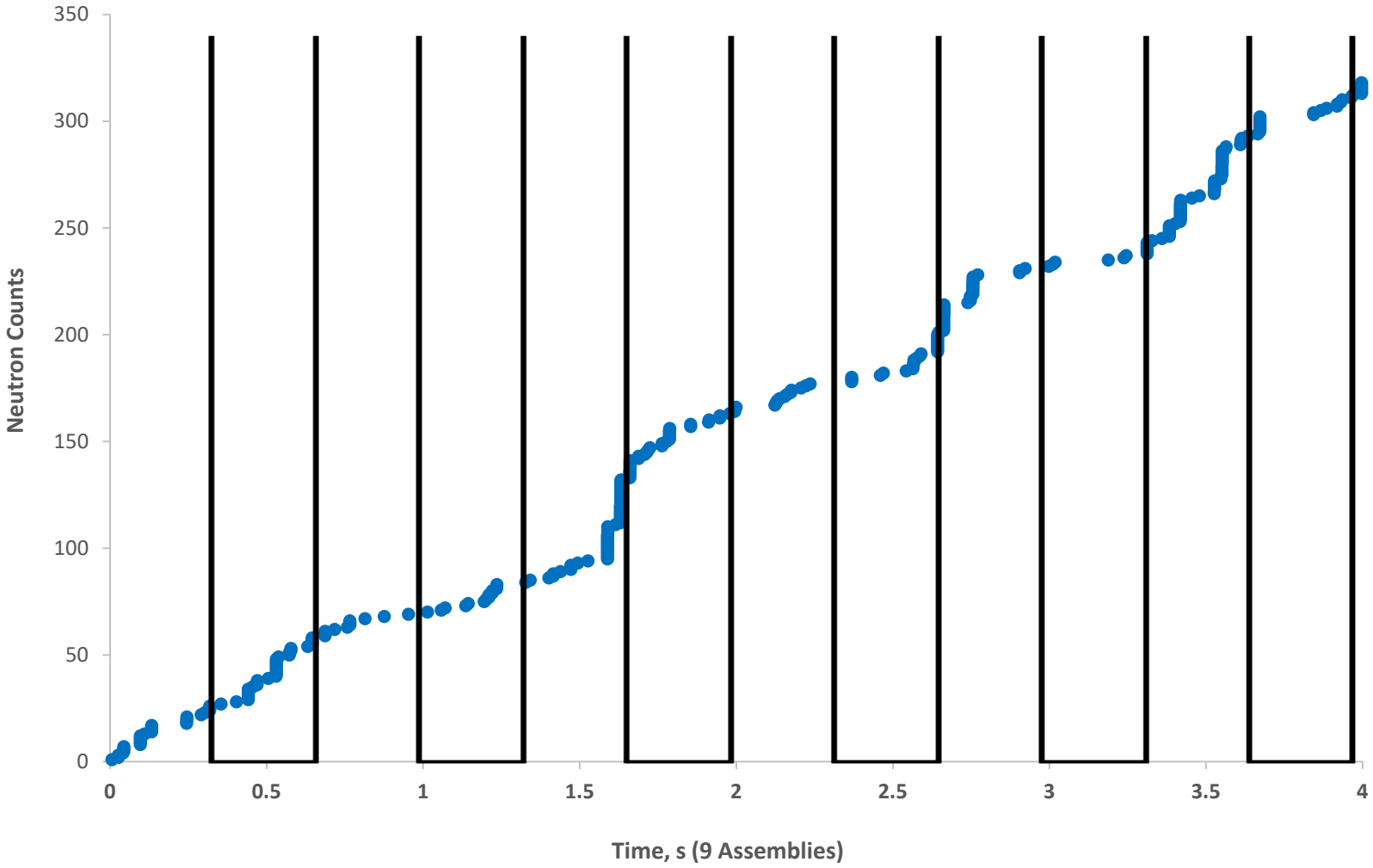
# Analysis


0.06
0.05
0.04
0.03
0.02
0.01
0
Fraction of Segments with k Counts ($b_k$)
ISSA Experimental Data
Poisson Distribution
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100 104 108 112 116 120 124 128 132
Number (k) of Counts Recorded in Segment

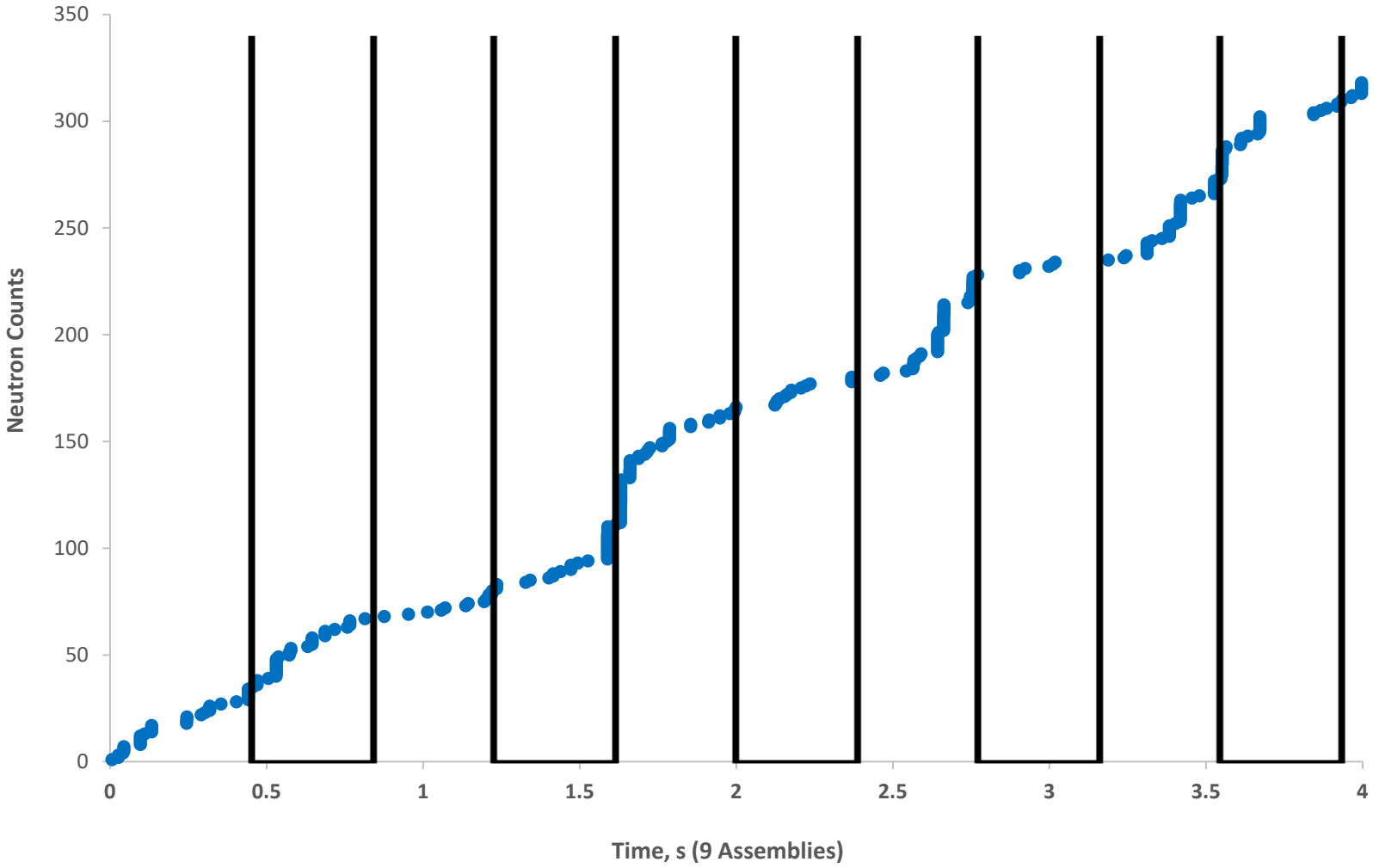
# Analysis


Neutron Counts
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Time, s (9 Assemblies)

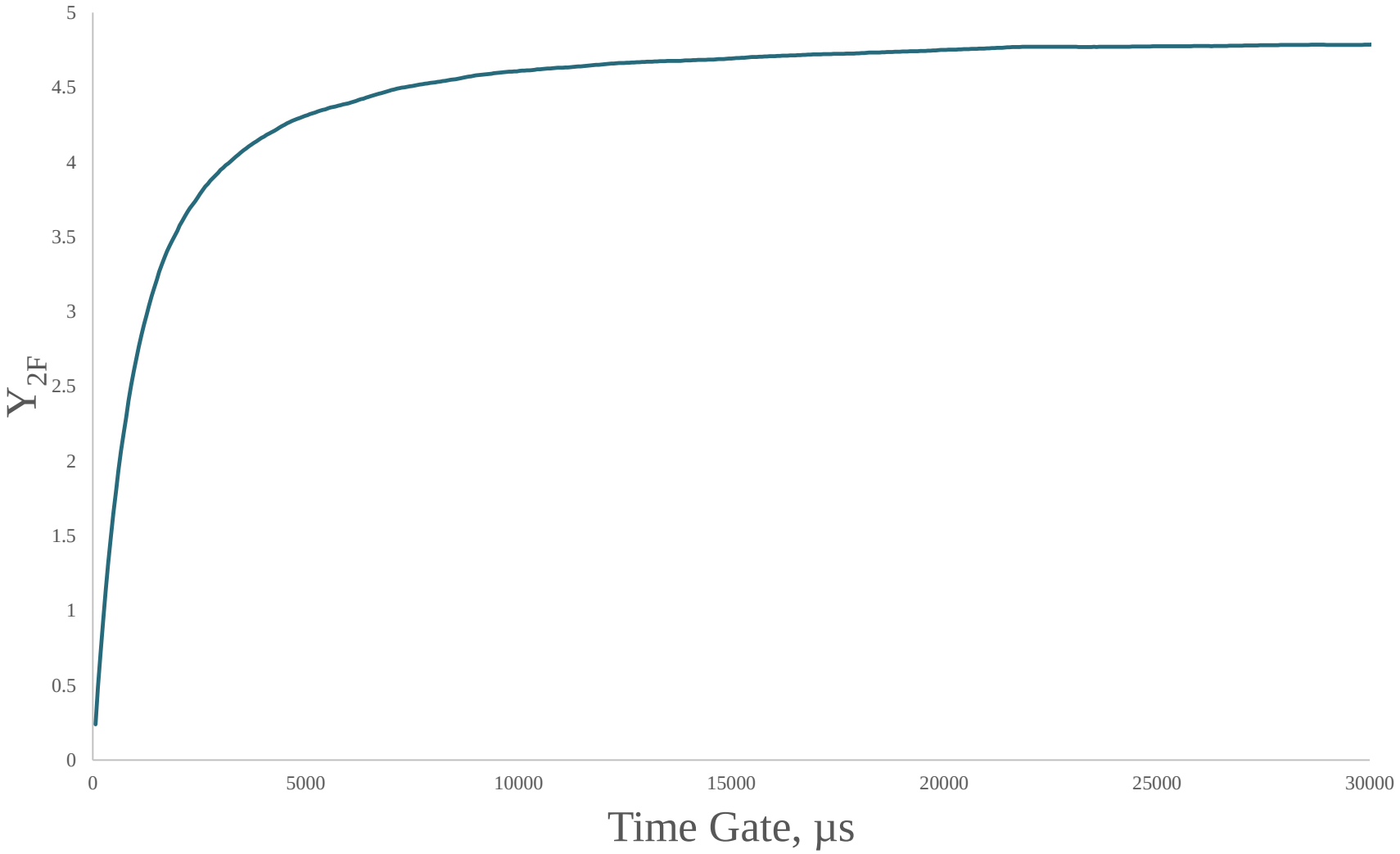
# Analysis


Neutron Counts
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Time, s (9 Assemblies)

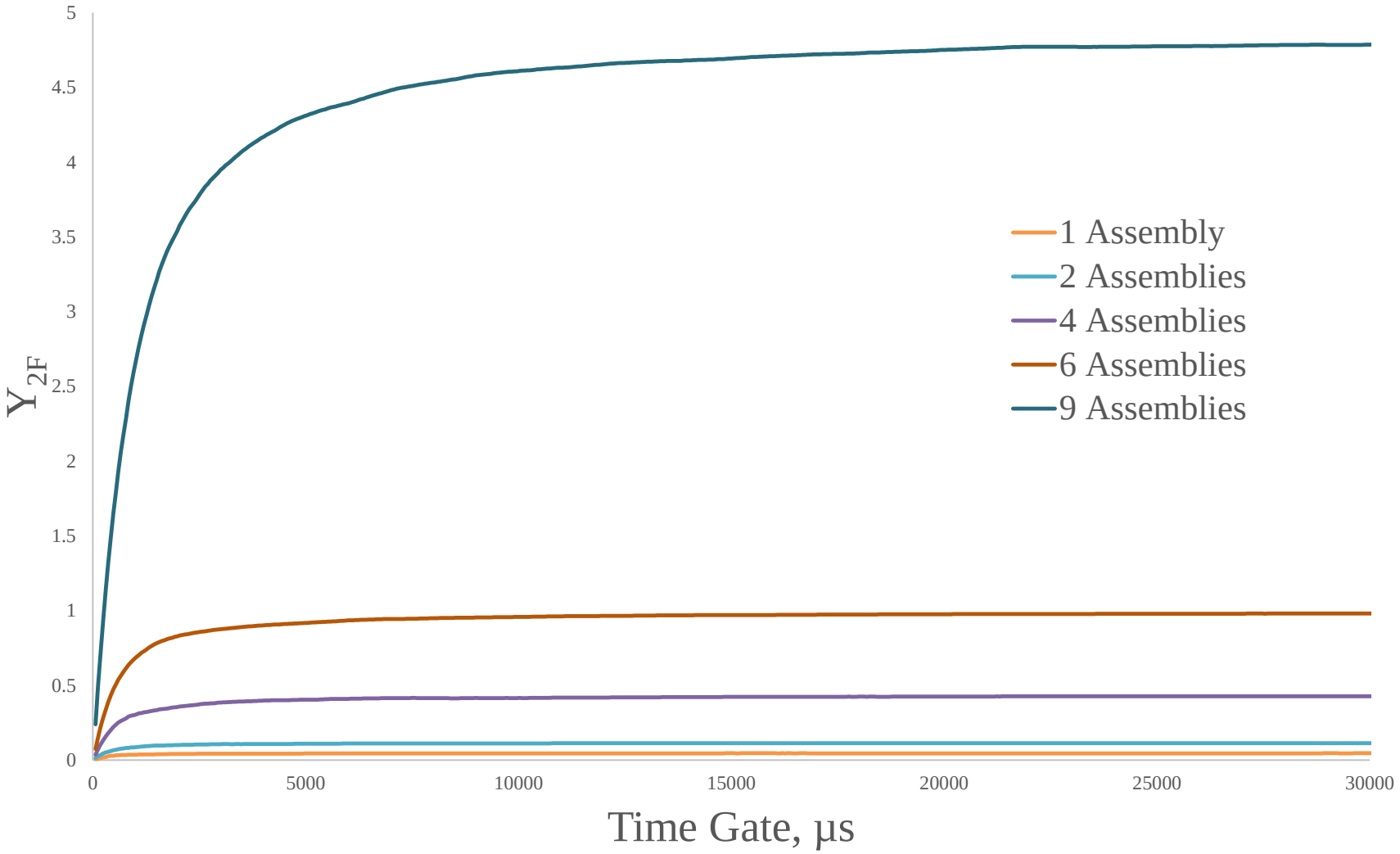
# Analysis


Neutron Counts
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Time, s (9 Assemblies)

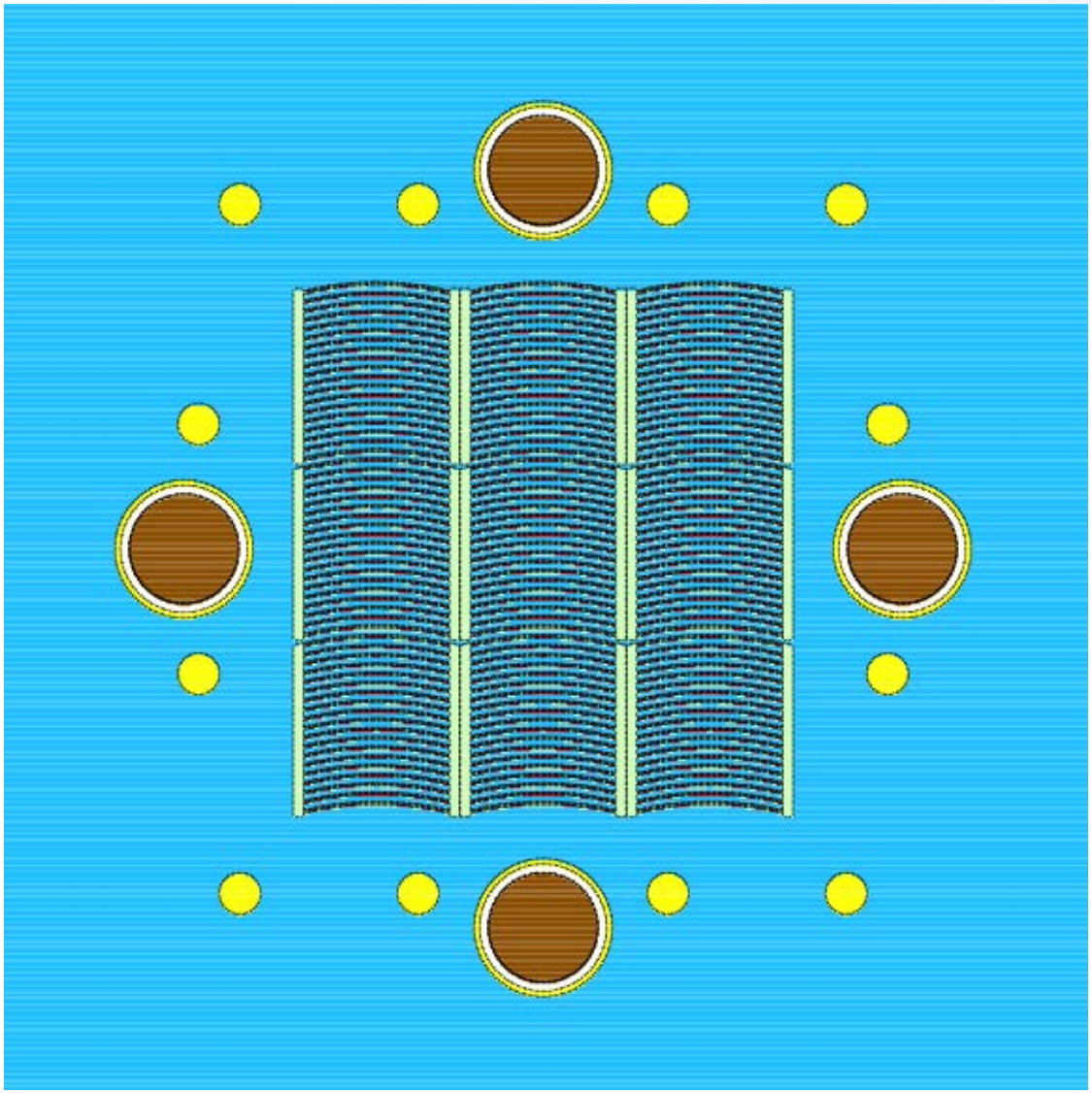
# Analysis

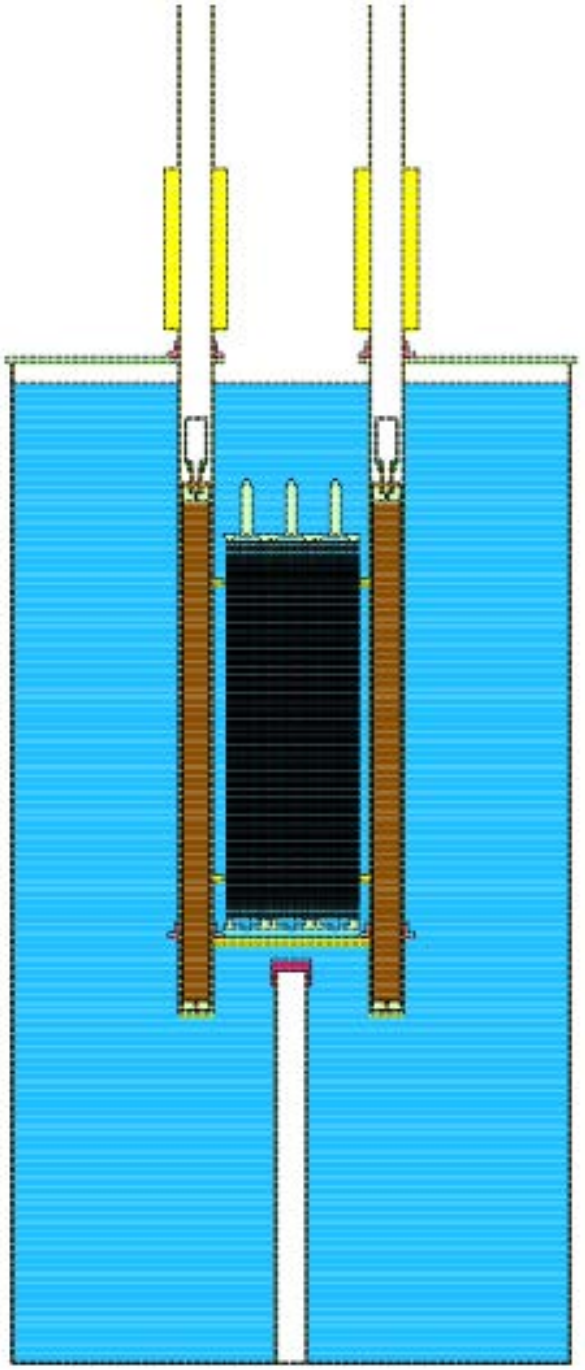

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
$Y_{2F}$
0
5000
10000
15000
20000
25000
30000
Time Gate, µs

# Analysis

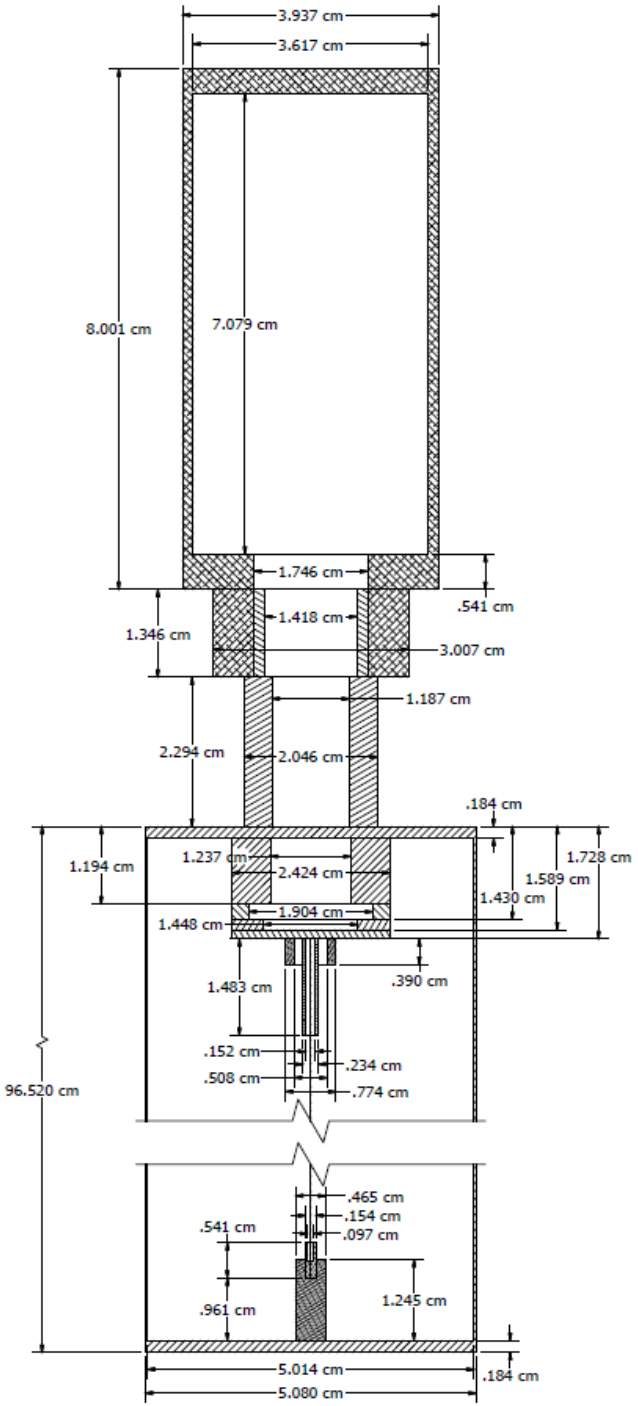

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
$Y_{2F}$
0
5000
10000
15000
20000
25000
30000
Time Gate, µs
1 Assembly
2 Assemblies
4 Assemblies
6 Assemblies
9 Assemblies

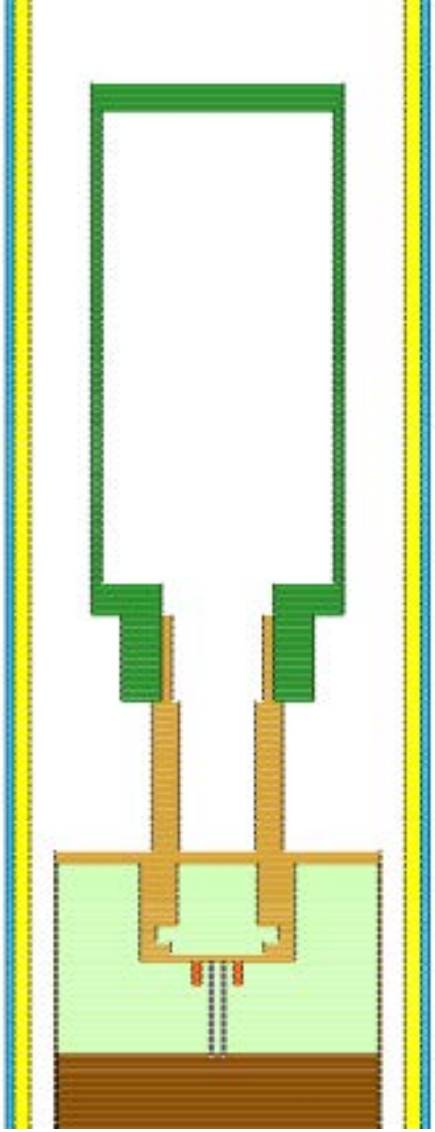
# Simulation

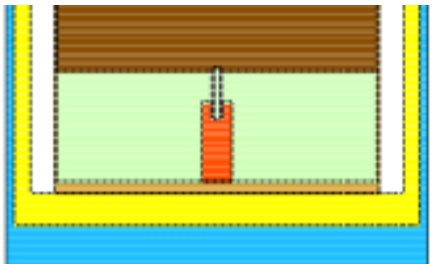




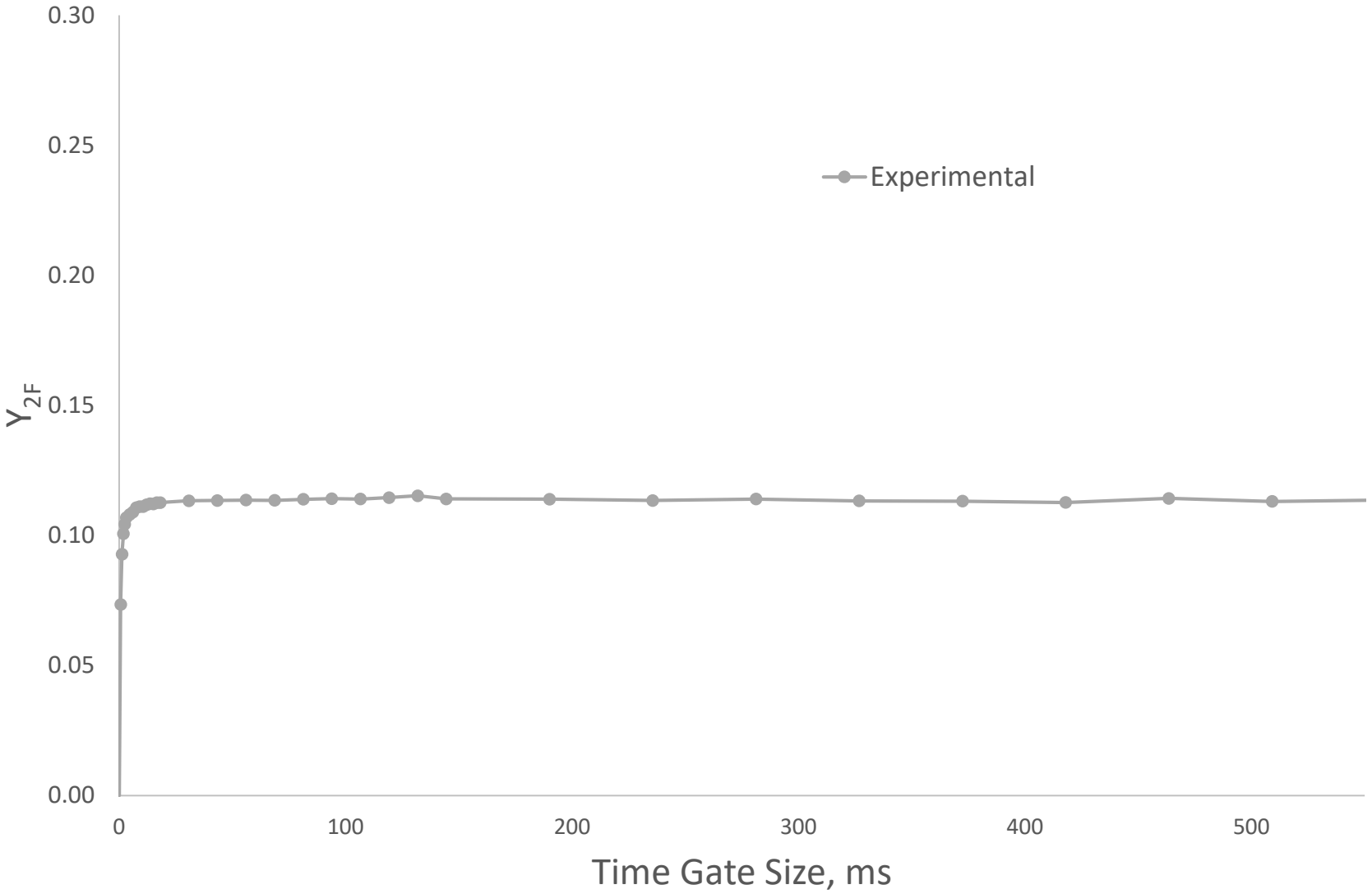

0
180
360
540
720
900


3.937 cm
3.617 cm
8.001 cm
7.079 cm
1.746 cm
.541 cm
1.346 cm
1.418 cm
3.007 cm
1.187 cm
2.294 cm
2.046 cm
.184 cm
1.194 cm
1.237 cm
2.424 cm
1.728 cm
1.589 cm
1.430 cm
1.448 cm
1.904 cm
1.483 cm
.390 cm
96.520 cm
.152 cm
.508 cm
.234 cm
.774 cm
.465 cm
.154 cm
.097 cm
.541 cm
.961 cm
1.245 cm
5.014 cm
5.080 cm
.184 cm





# Simulation Results



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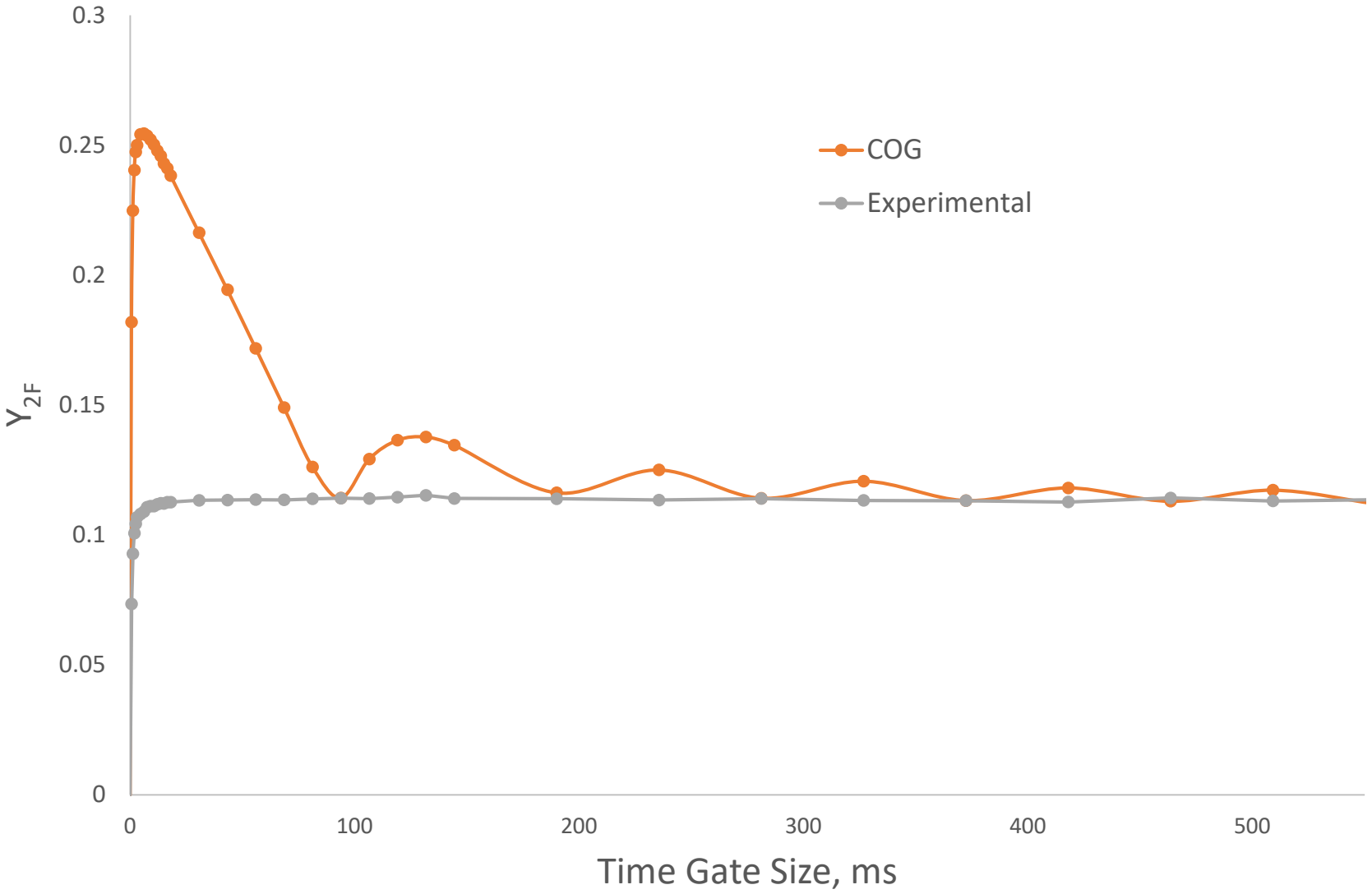

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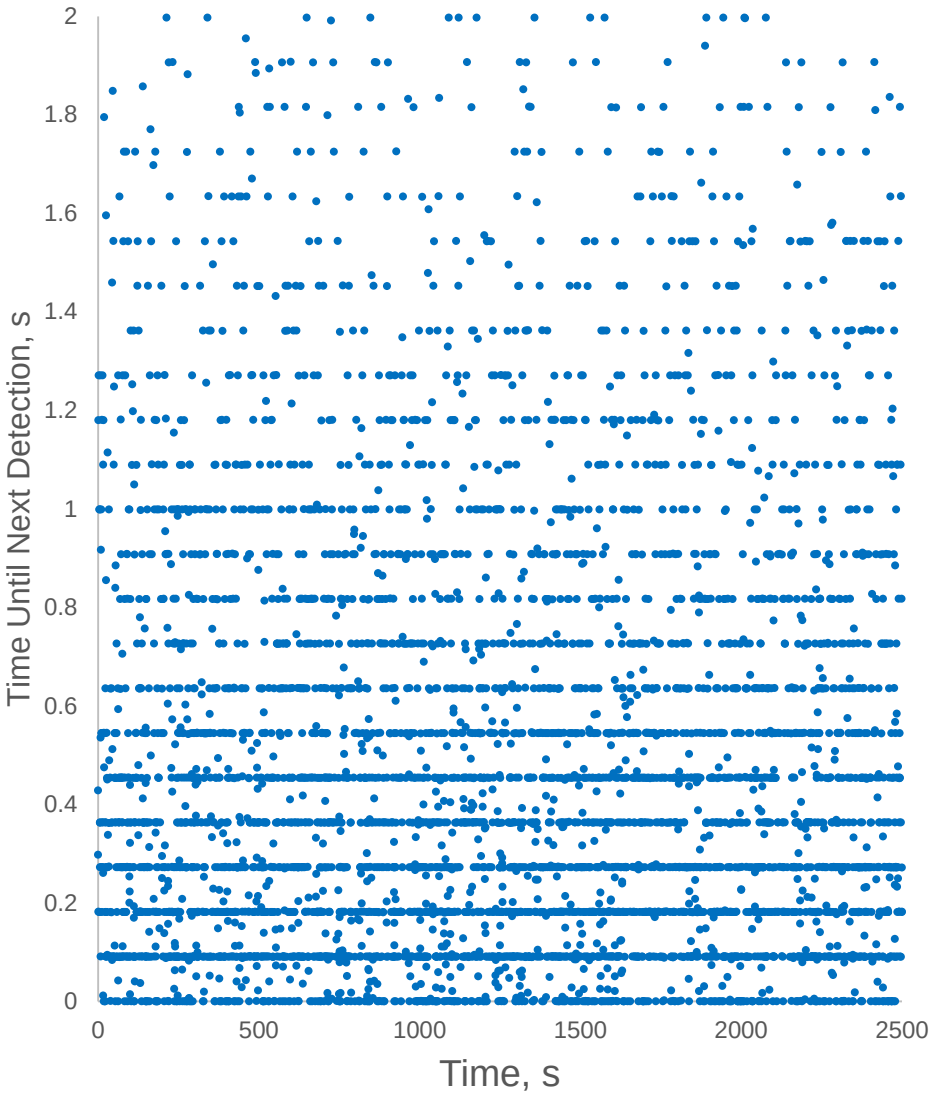



- Neutron start time determined by:

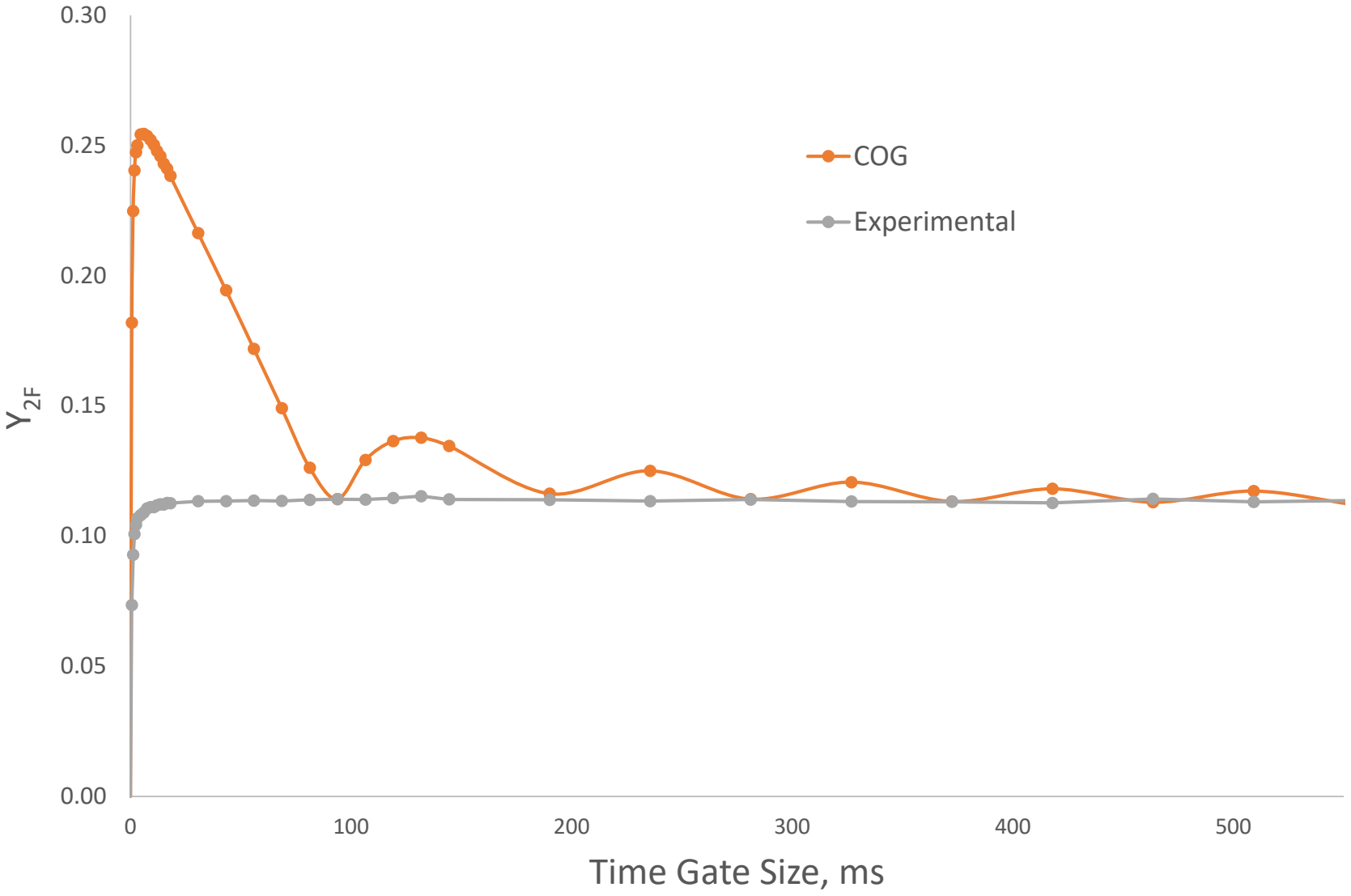
(Random Number)

X

(Total simulation duration)

- Random number generator is single precision
- Smallest difference between random numbers is ~1E-7
- For simulation duration 1E6 s, smallest time between source neutrons is 1E-7*1E6 = 0.1 s

# Simulation Results



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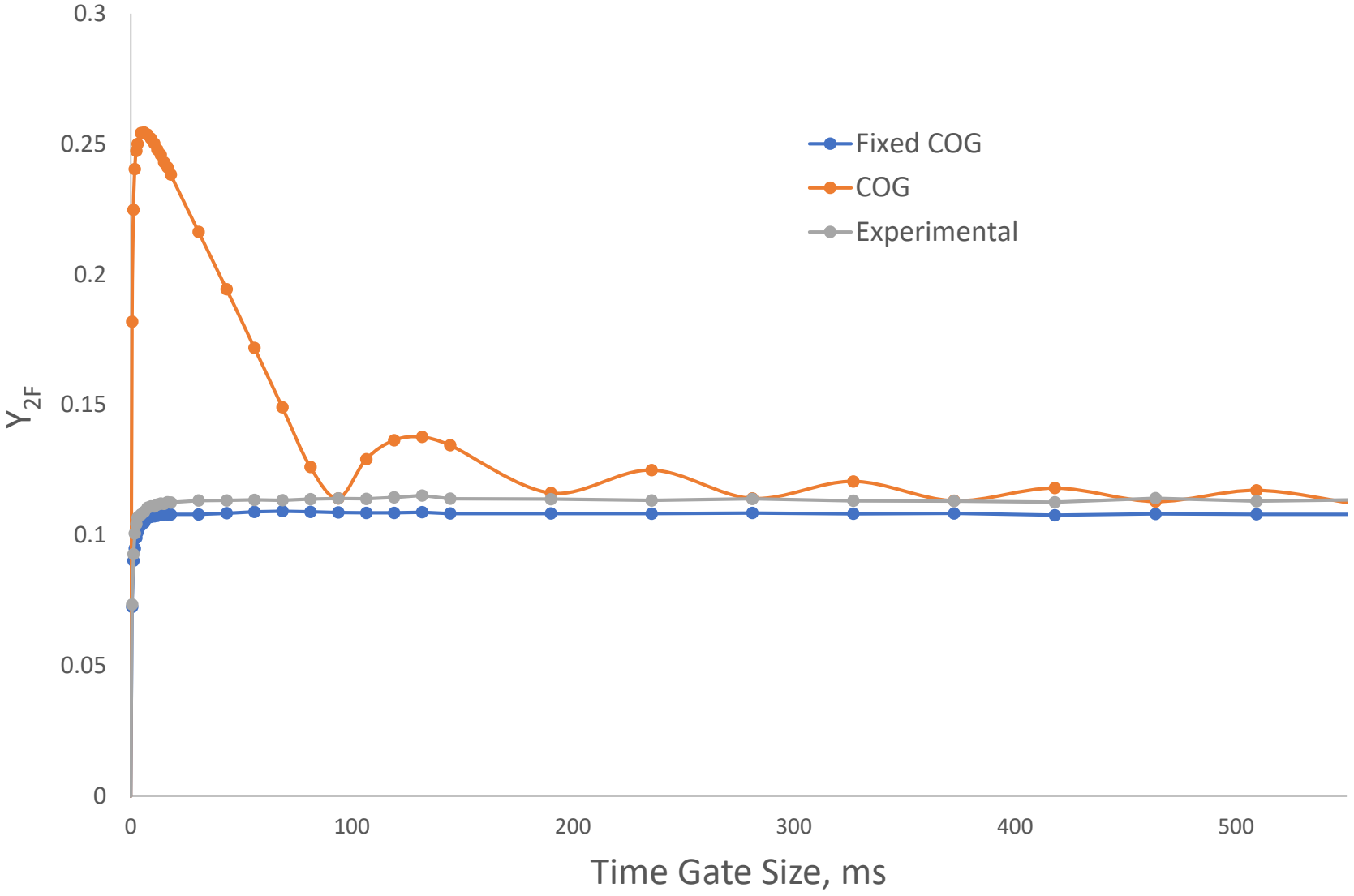

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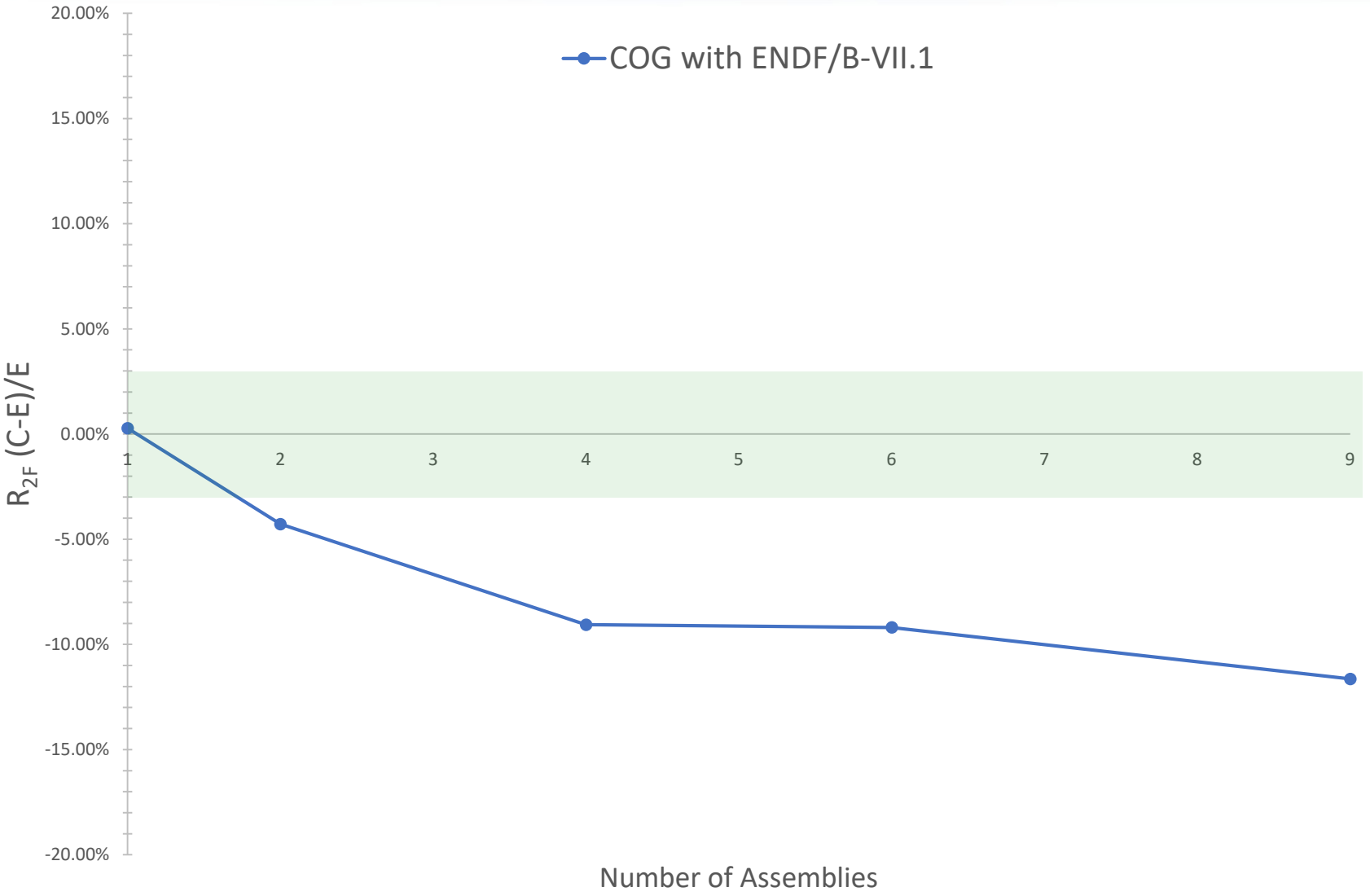

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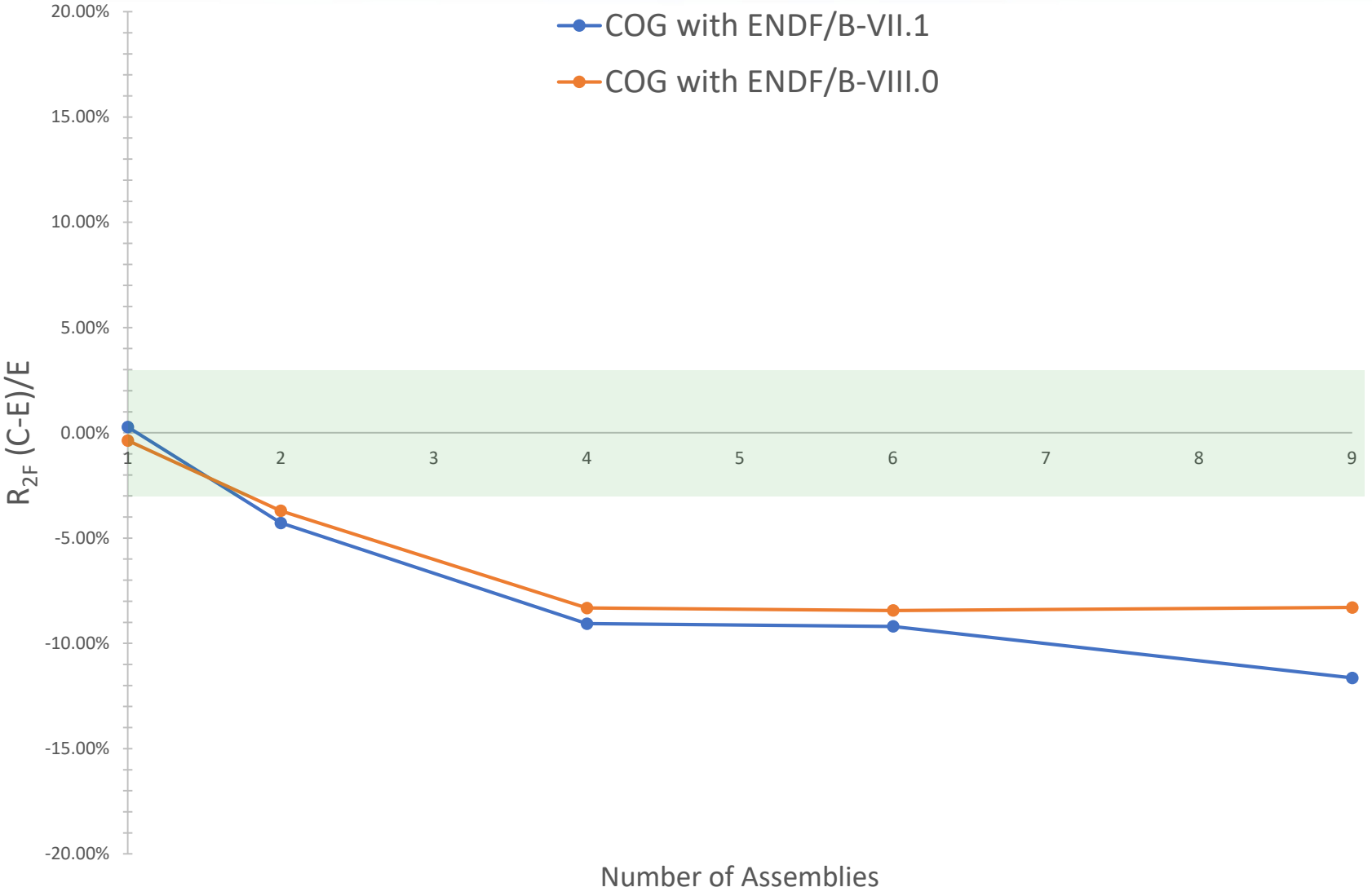

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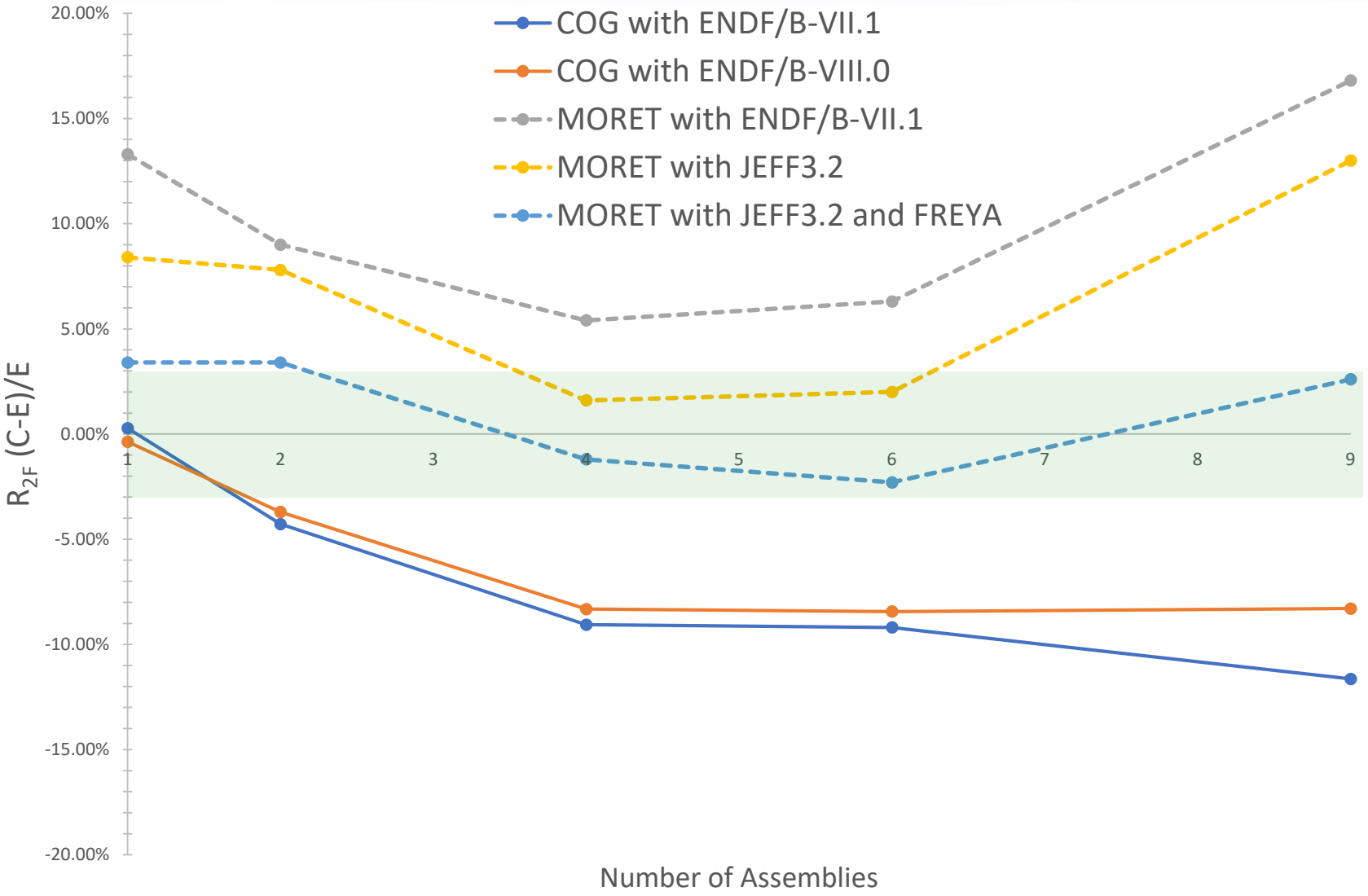

# *Conclusions*

- Identified non-physical artifact in radiation transport code
- Demonstrated improvement of nuclear data from ENDF/B-VII to ENDF/B-VIII
- Points towards further improvements from FREYA

- Provided a dataset for multiplicity community to validate new theories and techniques

# *Acknowledgements*

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA273444 and was made possible through the support of:

- Wilfried Monange, Jesson Hutchinson, Boukhmès Mechitoua
- DOE Nuclear Criticality Safety Program
- DOE Office of Fissile Materials Disposition
- DOE NNSA Livermore Field Office
- LLNL Nuclear Operations Directorate

# Questions?