Using OpenMC to Model Time-of-Flight Quasi-Differential Scattering Experiments

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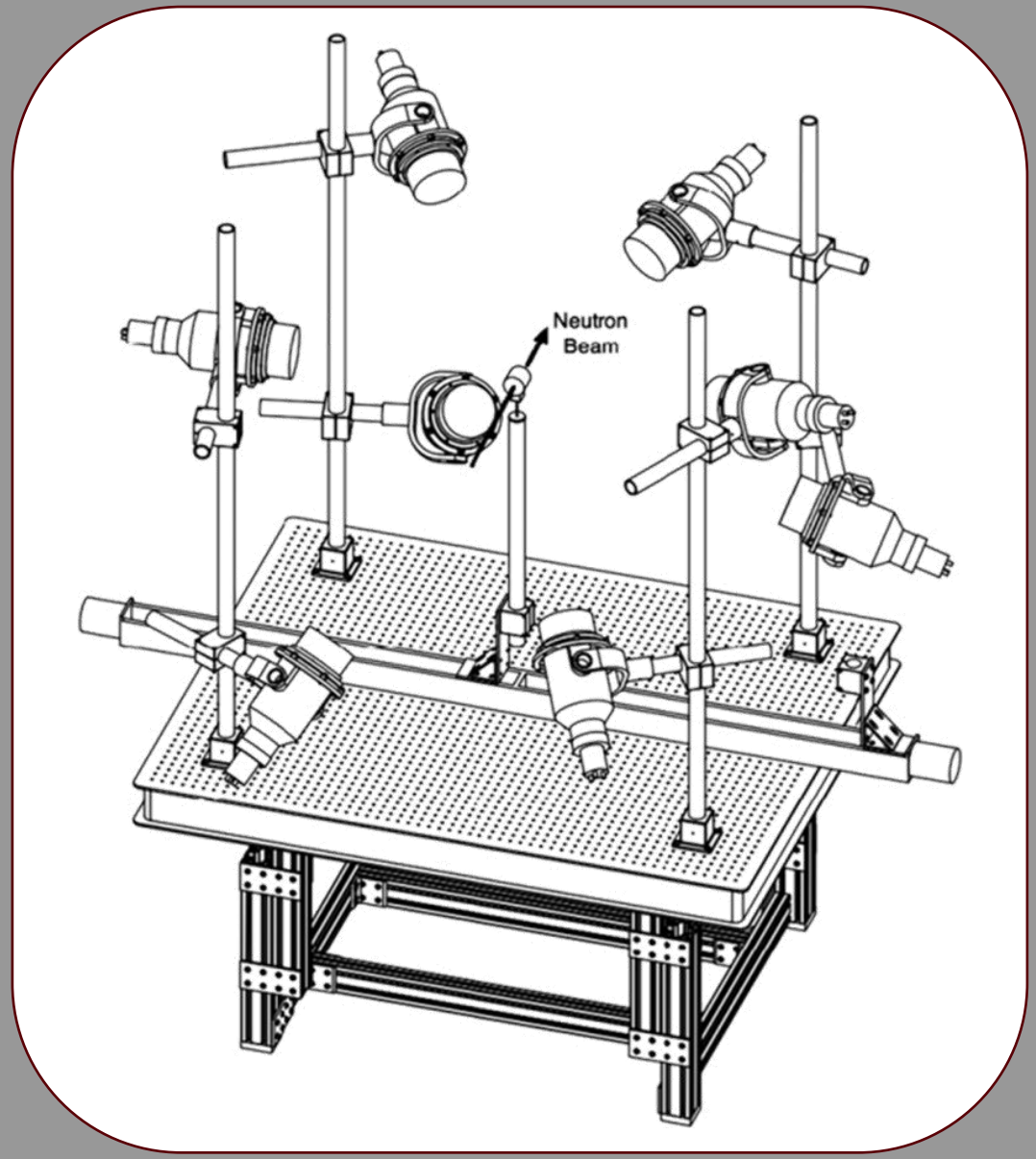
Contents

High Energy Scattering (HES) System

- RPI LINAC has a HES system for quasi-differential scattering measurements
- Uses the Time-of-Flight (ToF) method for determining neutron energies
- Useful energy interval of 0.5 MeV to 20 MeV

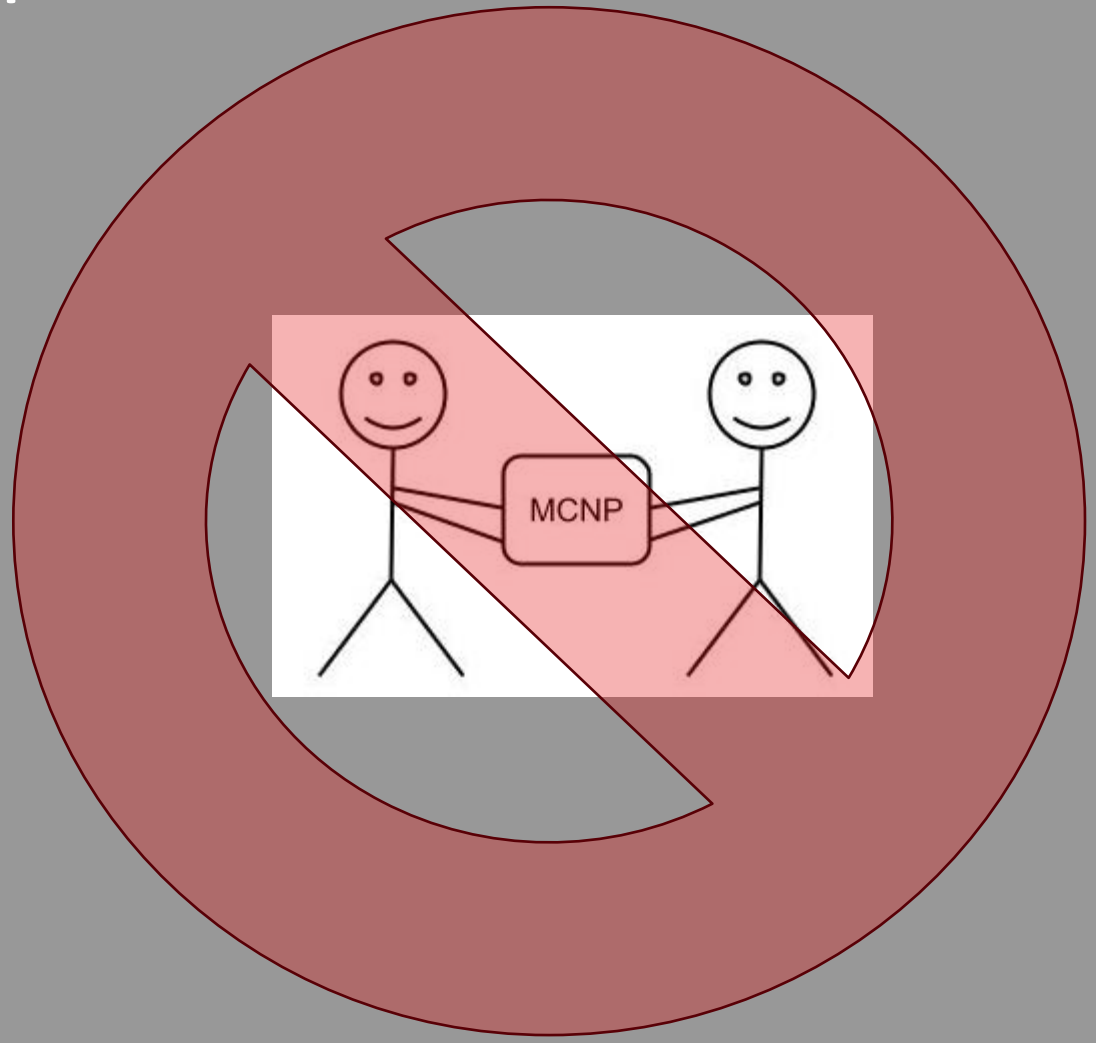


Monte Carlo Simulations of HES System

- Monte Carlo simulations are used for both evaluation validation and experiment design
- At the RPI LINAC, MCNP6 is generally used for these simulations
- All researchers and students know how to use MCNP
- F5 point detectors allow for reasonable statistics in a short period of time

Difficulties with MCNP

- Only US citizens can get it
- Export control rules make cluster management tedious
- Modifications can’t be shared



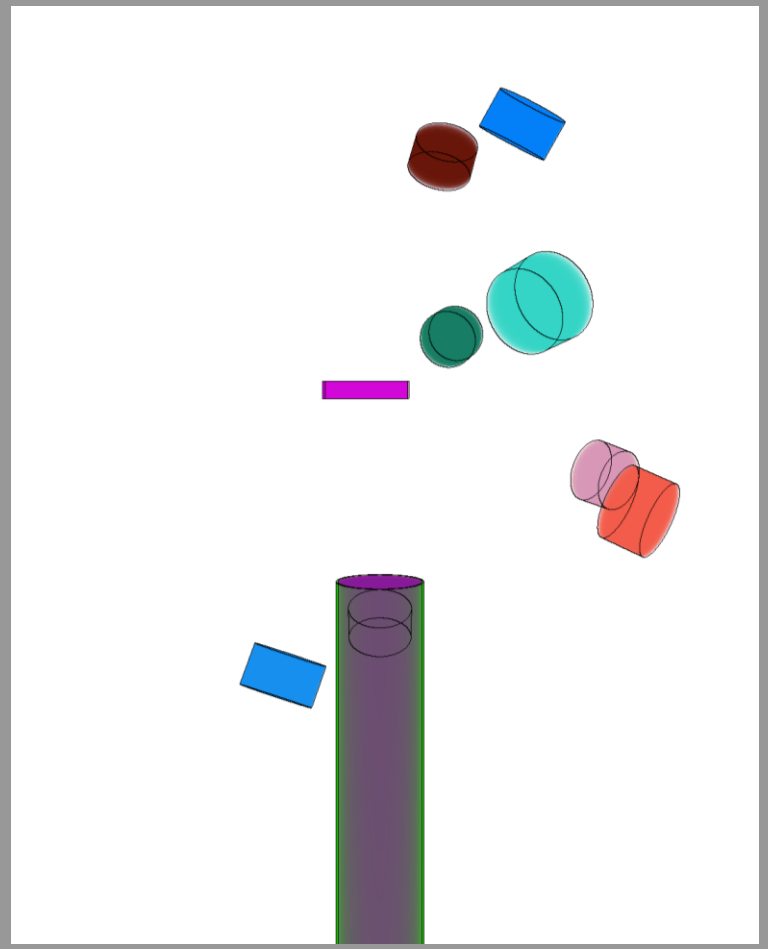
OpenMC

- Continuous energy Monte Carlo simulations for neutrons and photons
- General 3D geometries
- Tallies include flux, reaction rates, currents, heating, and pulse-height
- Can share modifications to source code (or even contribute !)
- Anyone is allowed access
- But no point-detectors… yet

Modeling HES System with OpenMC

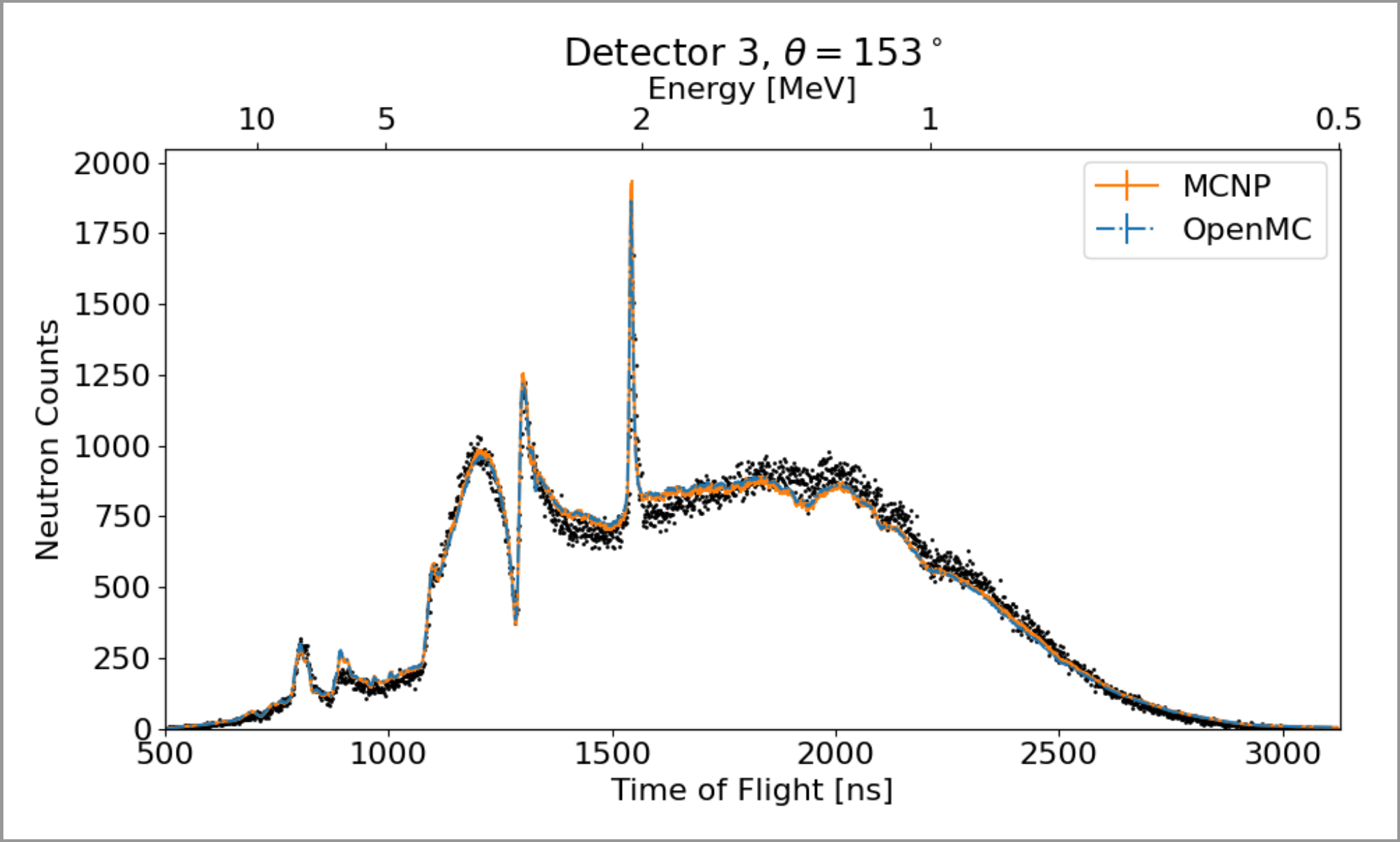
Due to the possible advantages of using OpenMC over MCNP, we wanted to test the performance and agreement of the two codes on the HES system here at the RPI LINAC.

- Neutrons scattering with graphite and iron
- Gamma production from neutron interactions with iron
- Used surface current tallies
- ENDF/B-VIII.0 Library

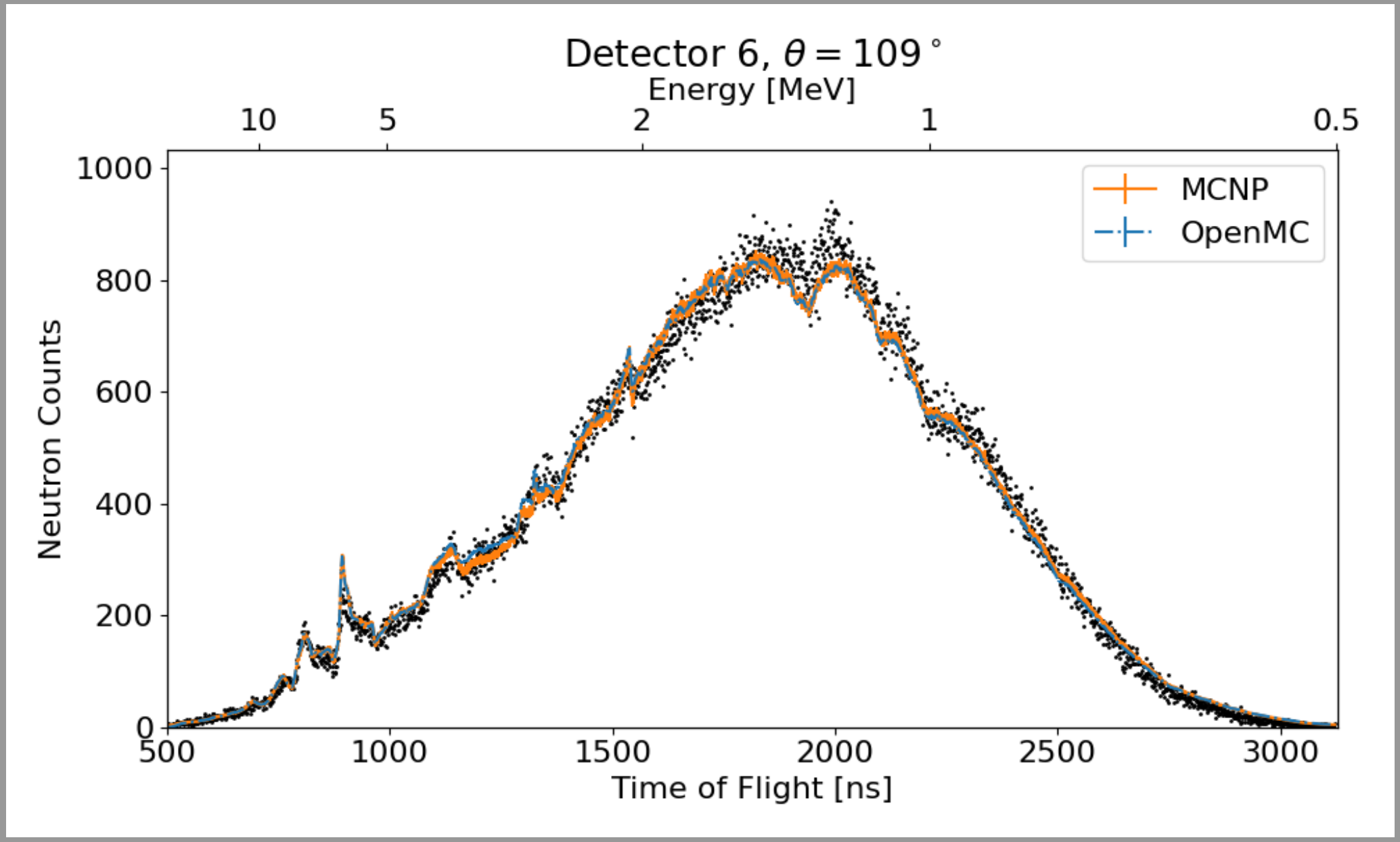


Neutrons Scattering with Graphite

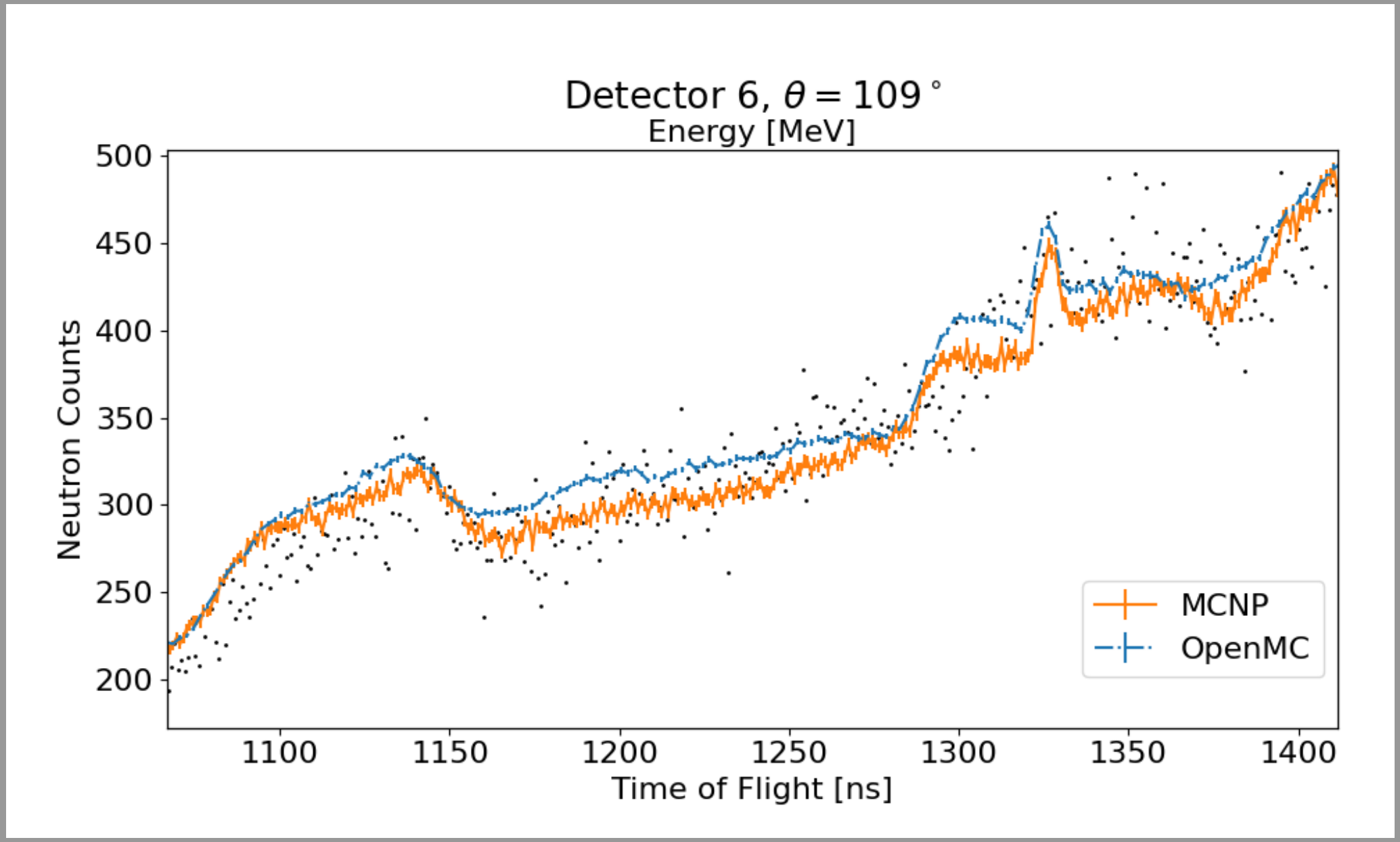
Graphite


Detector 3, $\theta = 153^\circ$
Energy [MeV]
10
5
2
1
0.5
2000
1750
1500
1250
1000
750
500
250
0
Neutron Counts
MCNP
OpenMC
500
1000
1500
2000
2500
3000
Time of Flight [ns]

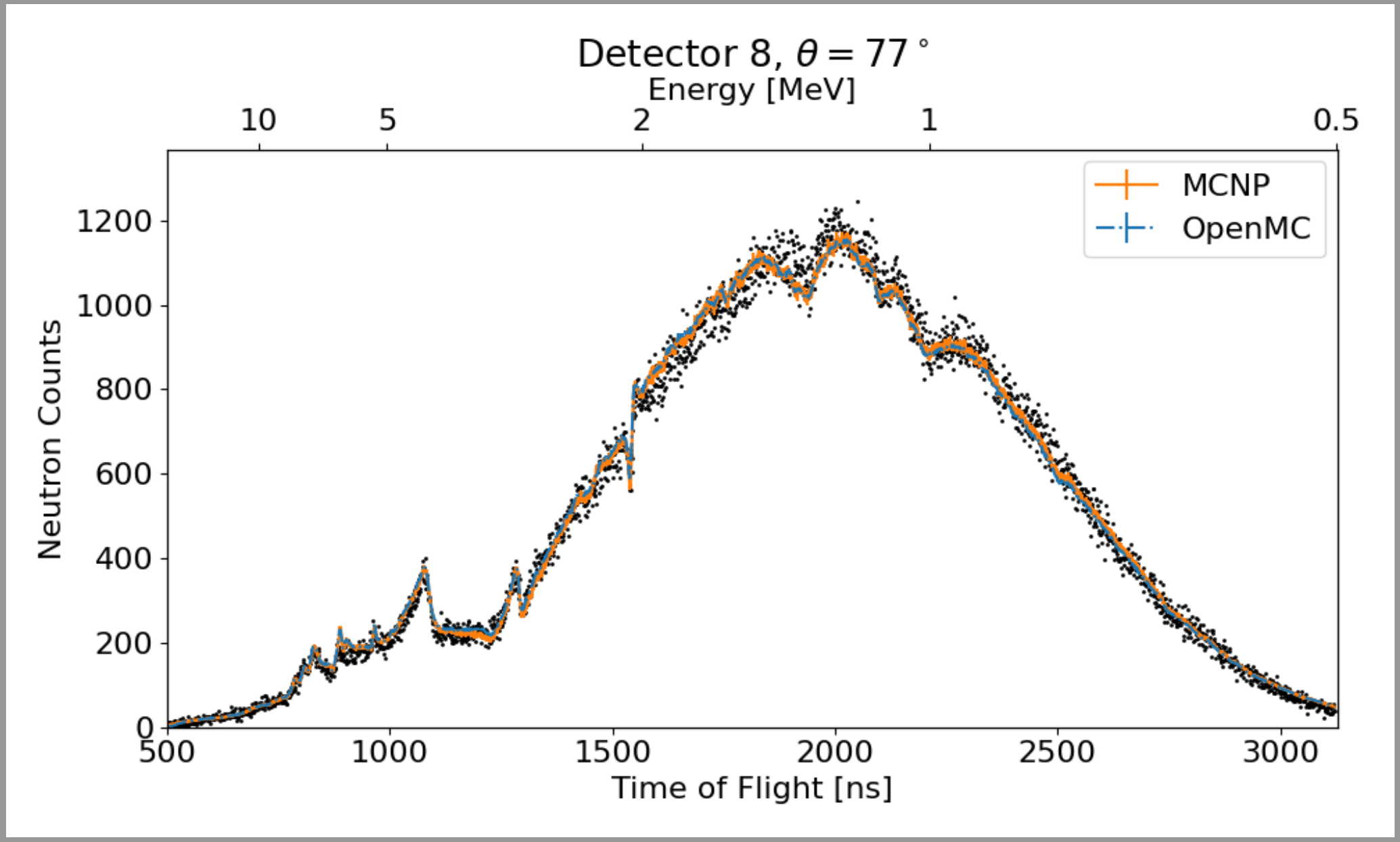
Graphite


Detector 6, $\theta = 109^\circ$
Energy [MeV]
10
5
2
1
0.5
MCNP
OpenMC
Neutron Counts
0
200
400
600
800
1000
500
1000
1500
2000
2500
3000
Time of Flight [ns]

Graphite

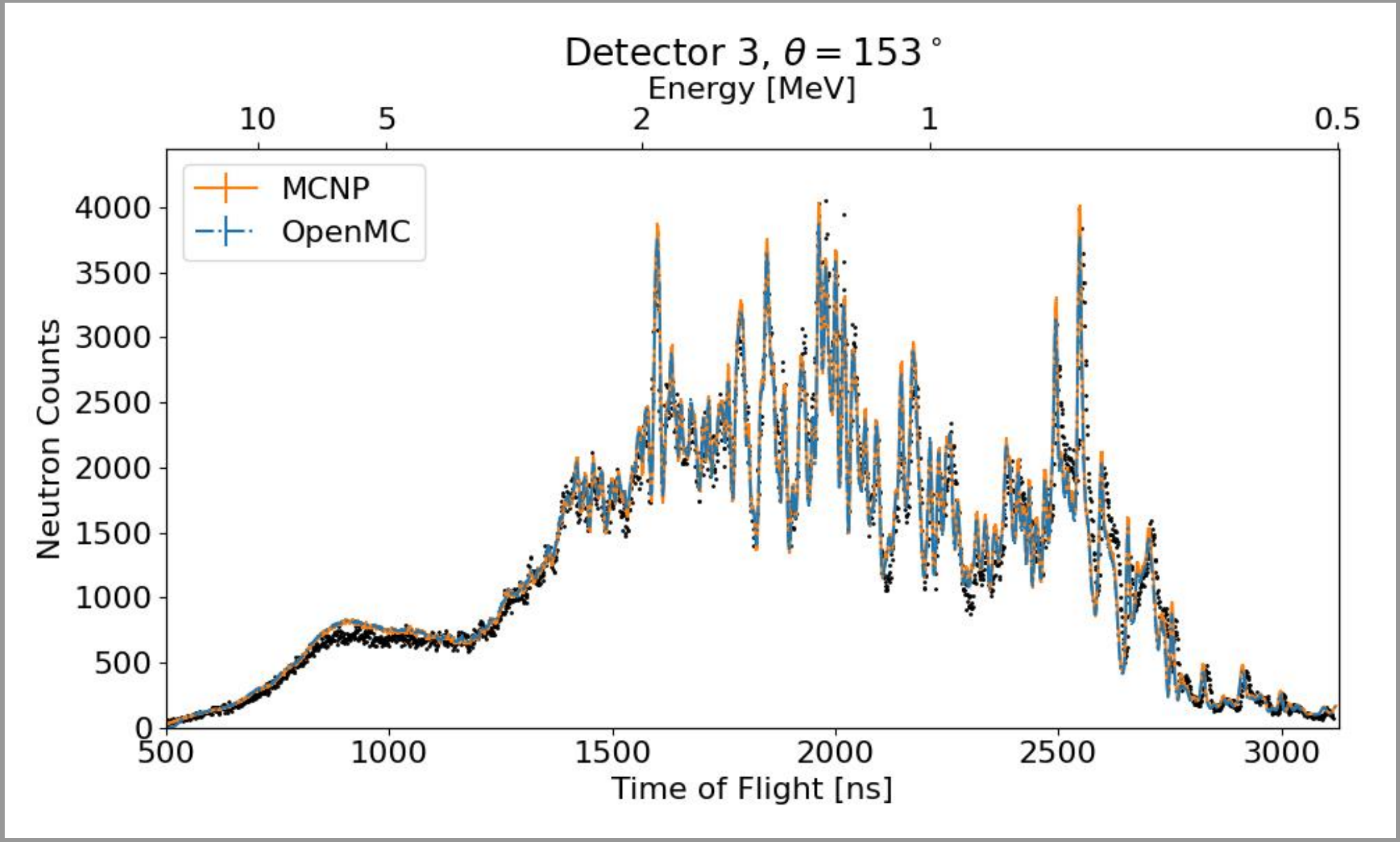

Detector 6, $\theta = 109^\circ$
Energy [MeV]
Neutron Counts
500
450
400
350
300
250
200
1100
1150
1200
1250
1300
1350
1400
Time of Flight [ns]
MCNP
OpenMC

Graphite

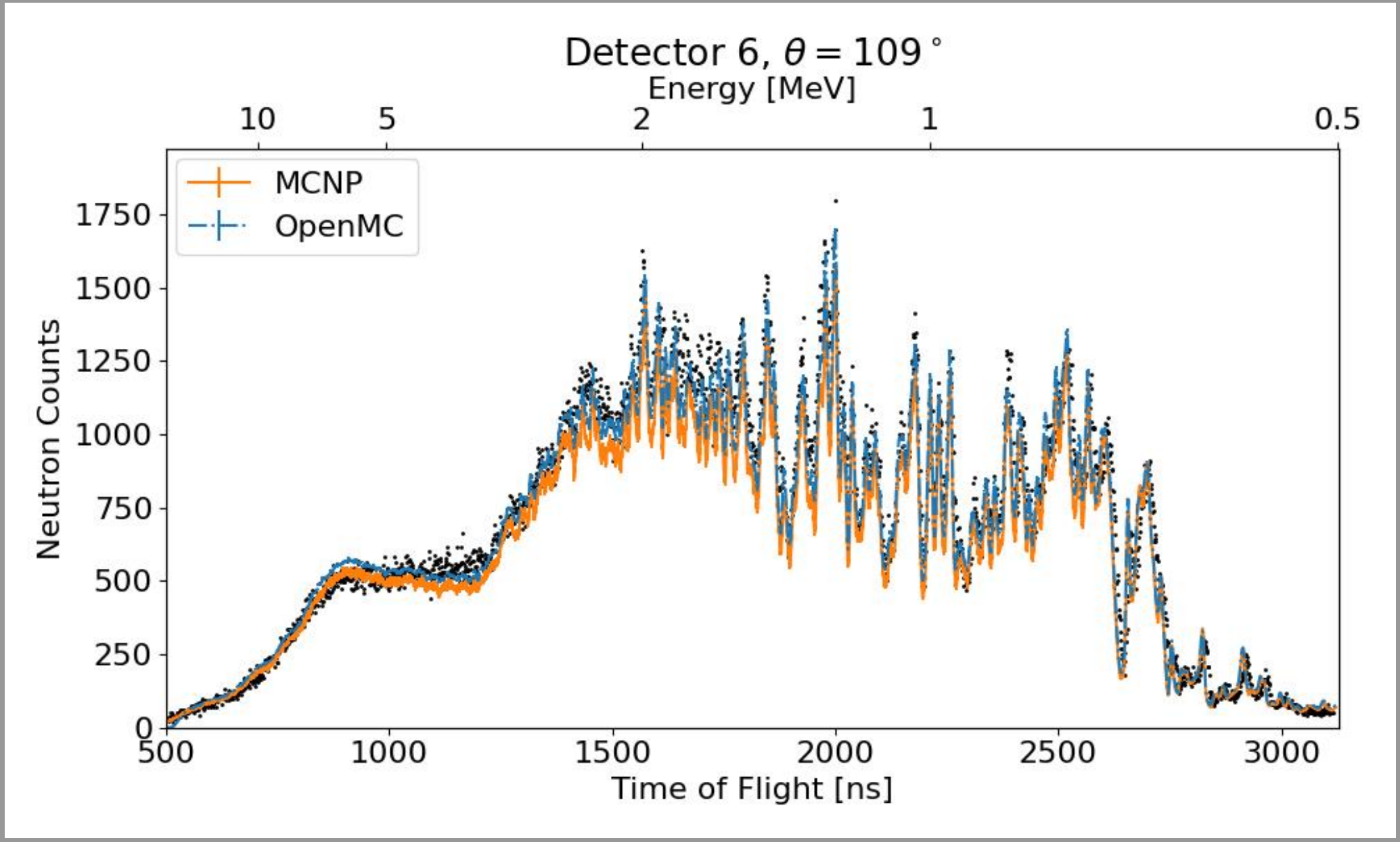

Detector 8, $\theta = 77^\circ$
Energy [MeV]
10
5
2
1
0.5
MCNP
OpenMC
Neutron Counts
0
200
400
600
800
1000
1200
500
1000
1500
2000
2500
3000
Time of Flight [ns]

Neutrons Scattering with Iron

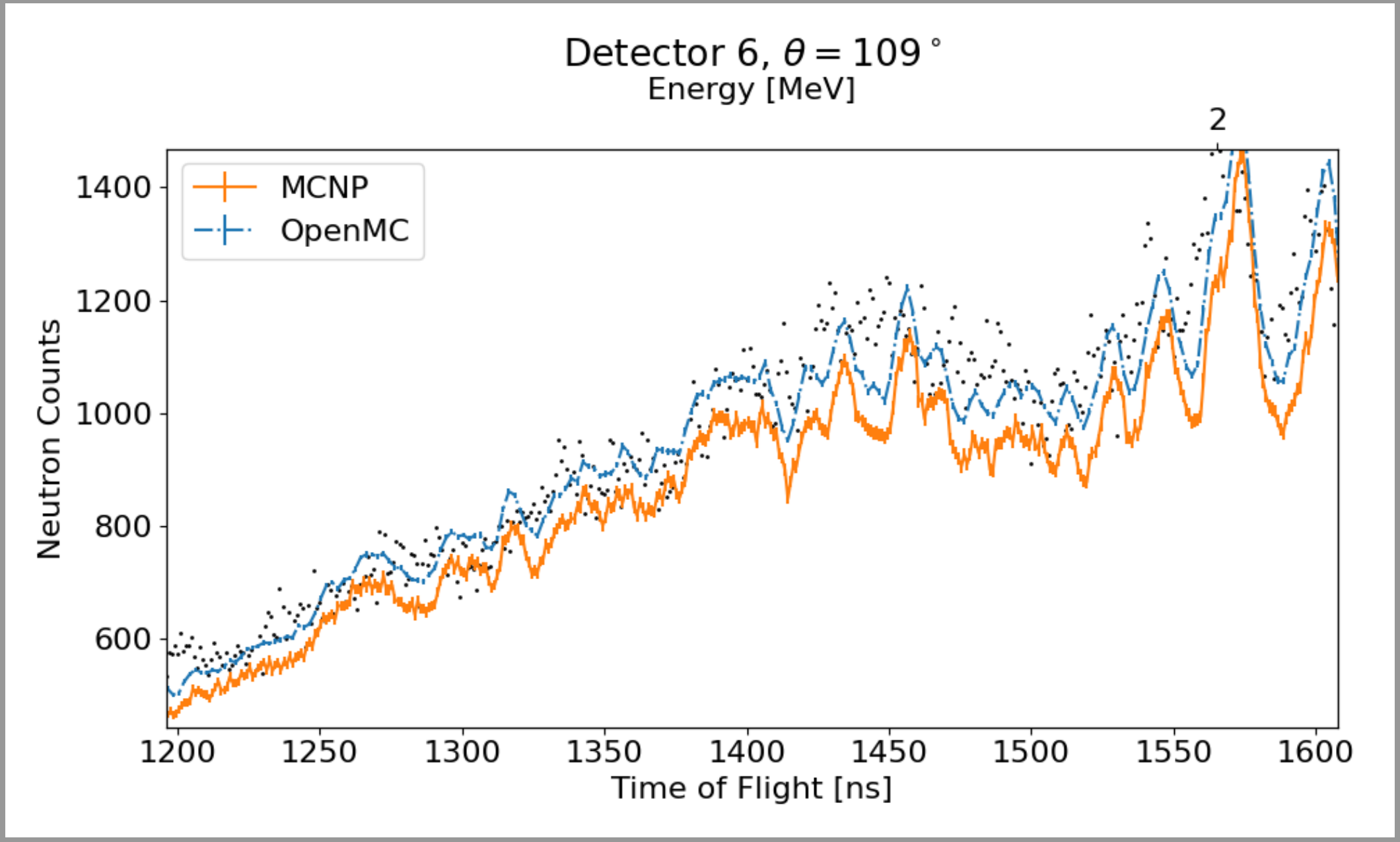
Iron


Detector 3, $\theta = 153^\circ$
Energy [MeV]
10
5
2
1
0.5
MCNP
OpenMC
Neutron Counts
4000
3500
3000
2500
2000
1500
1000
500
0
500
1000
1500
2000
2500
3000
Time of Flight [ns]

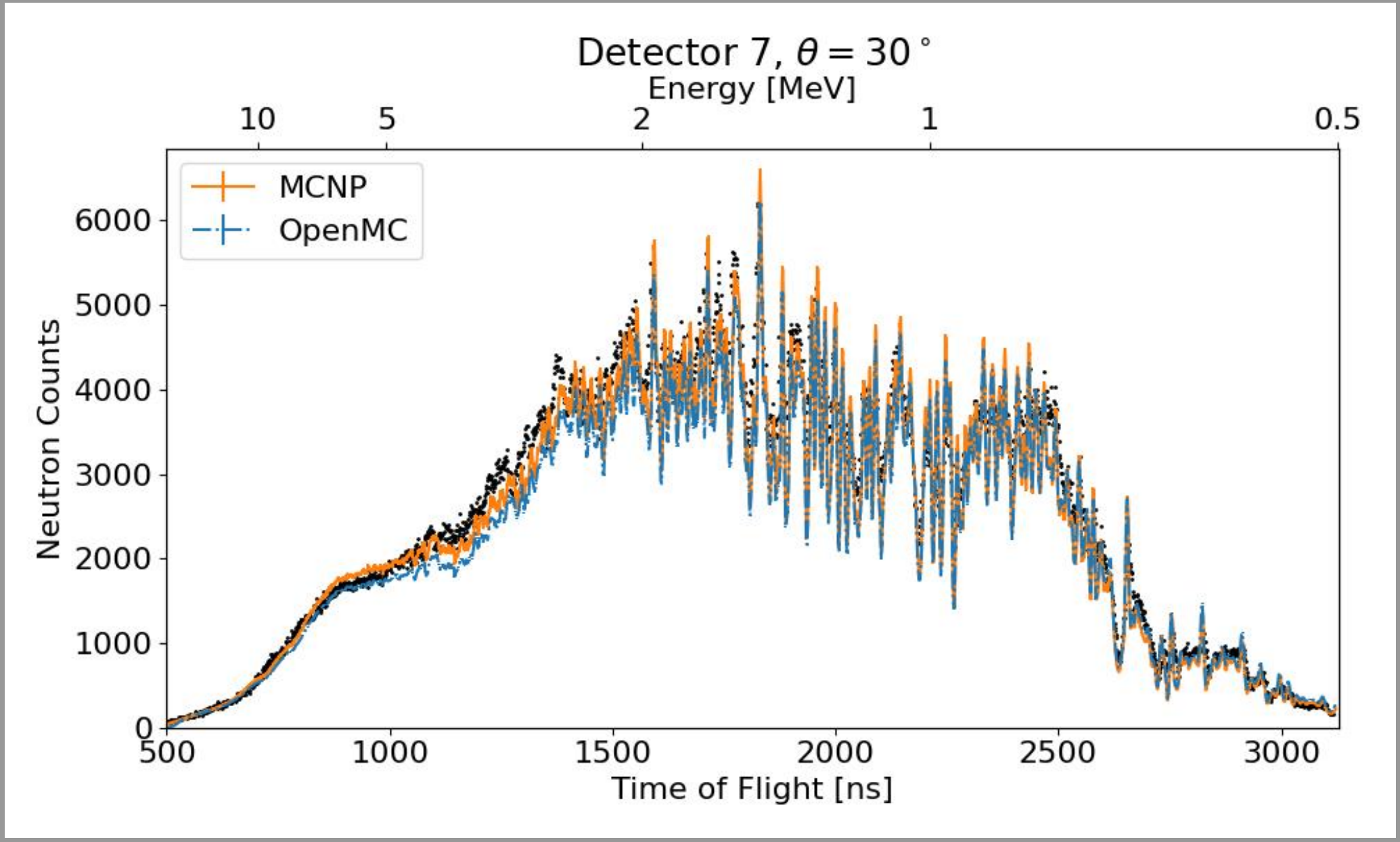
Iron


Detector 6, $\theta = 109^\circ$
Energy [MeV]
10
5
2
1
0.5
MCNP
OpenMC
Neutron Counts
0
250
500
750
1000
1250
1500
1750
500
1000
1500
2000
2500
3000
Time of Flight [ns]

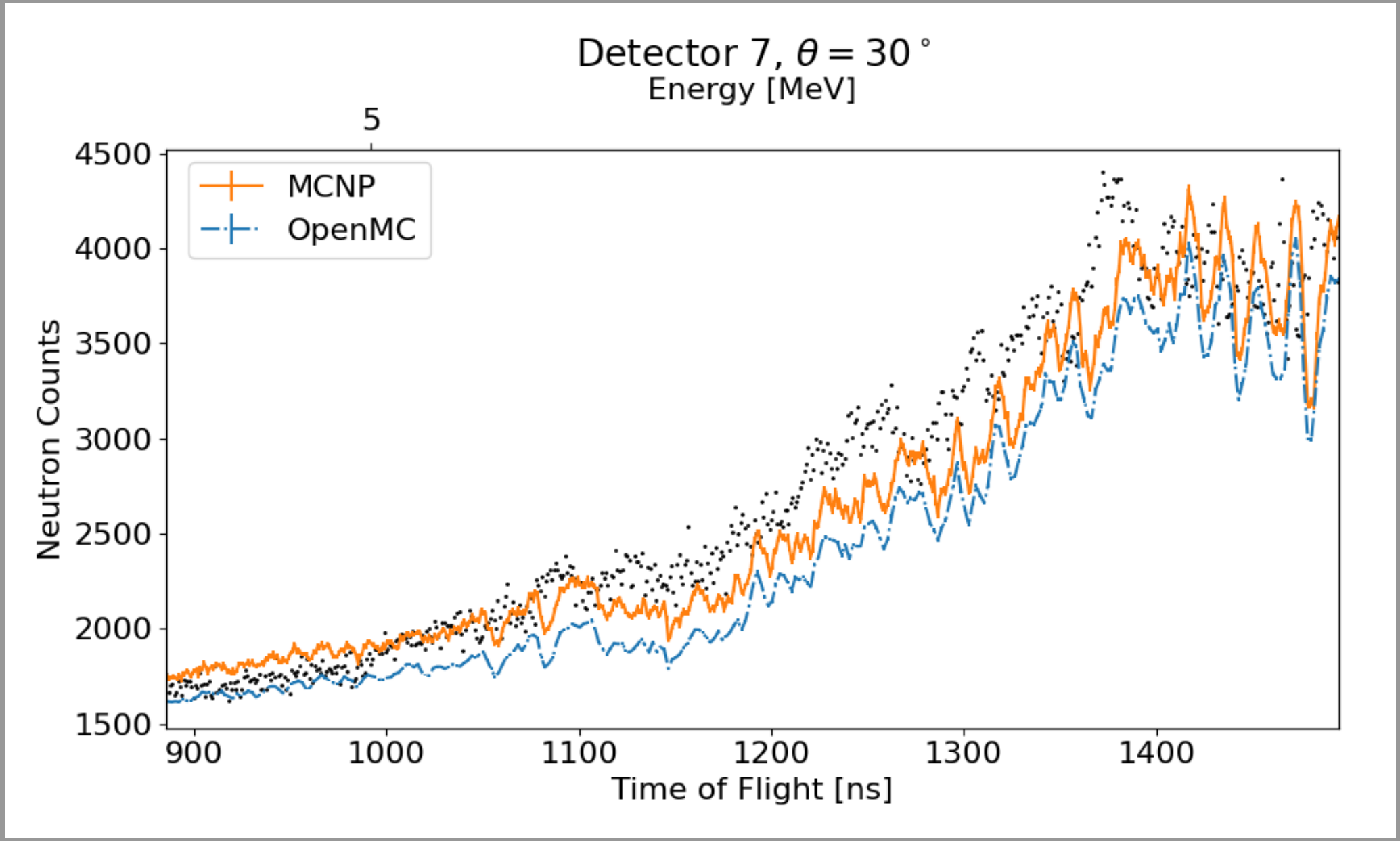
Iron


Detector 6, $\theta = 109^\circ$
Energy [MeV]
2
MCNP
OpenMC
Neutron Counts
1400
1200
1000
800
600
1200
1250
1300
1350
1400
1450
1500
1550
1600
Time of Flight [ns]

Iron

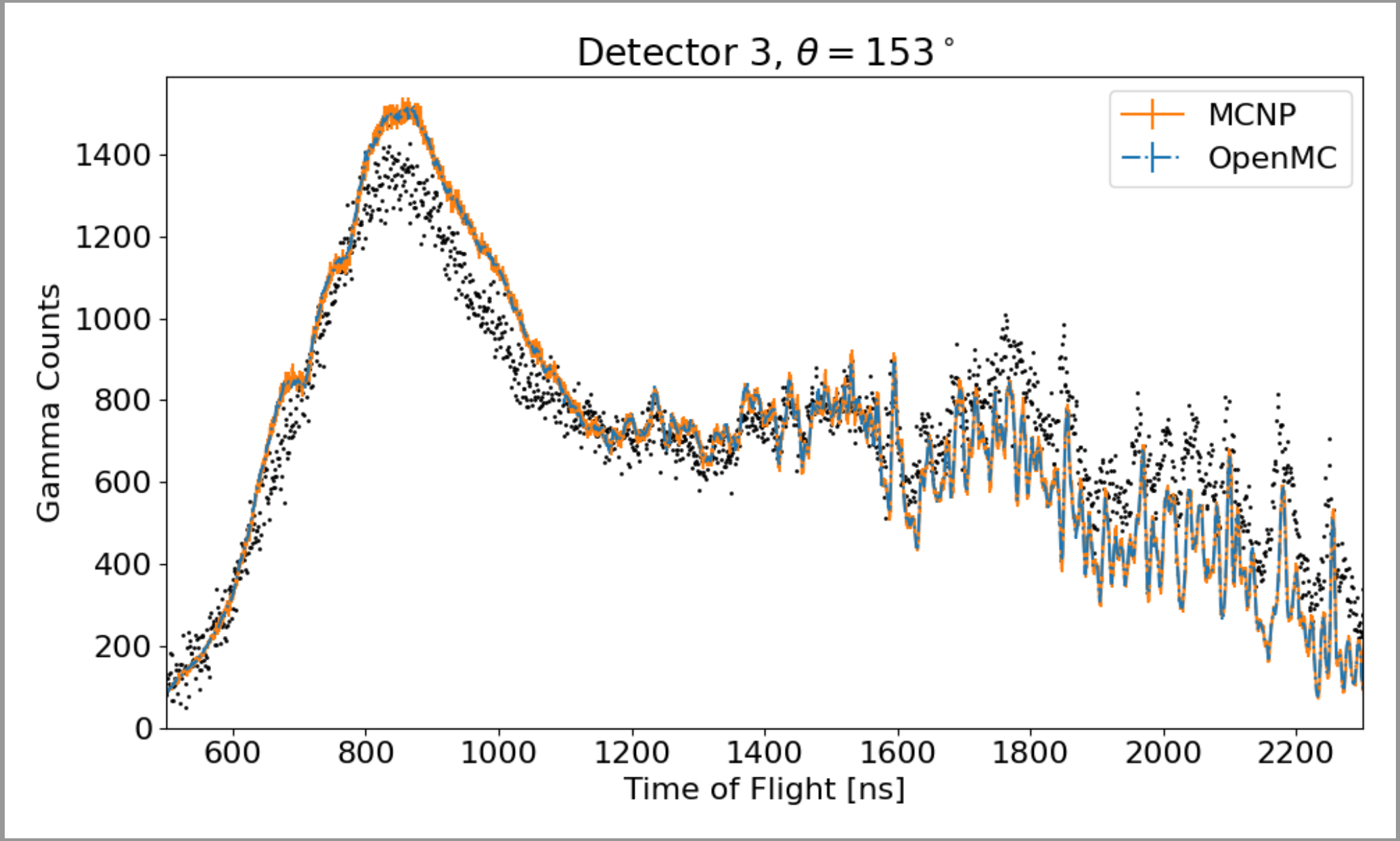

Detector 7, $\theta = 30^\circ$
Energy [MeV]
10
5
2
1
0.5
MCNP
OpenMC
Neutron Counts
0
1000
2000
3000
4000
5000
6000
500
1000
1500
2000
2500
3000
Time of Flight [ns]

Iron

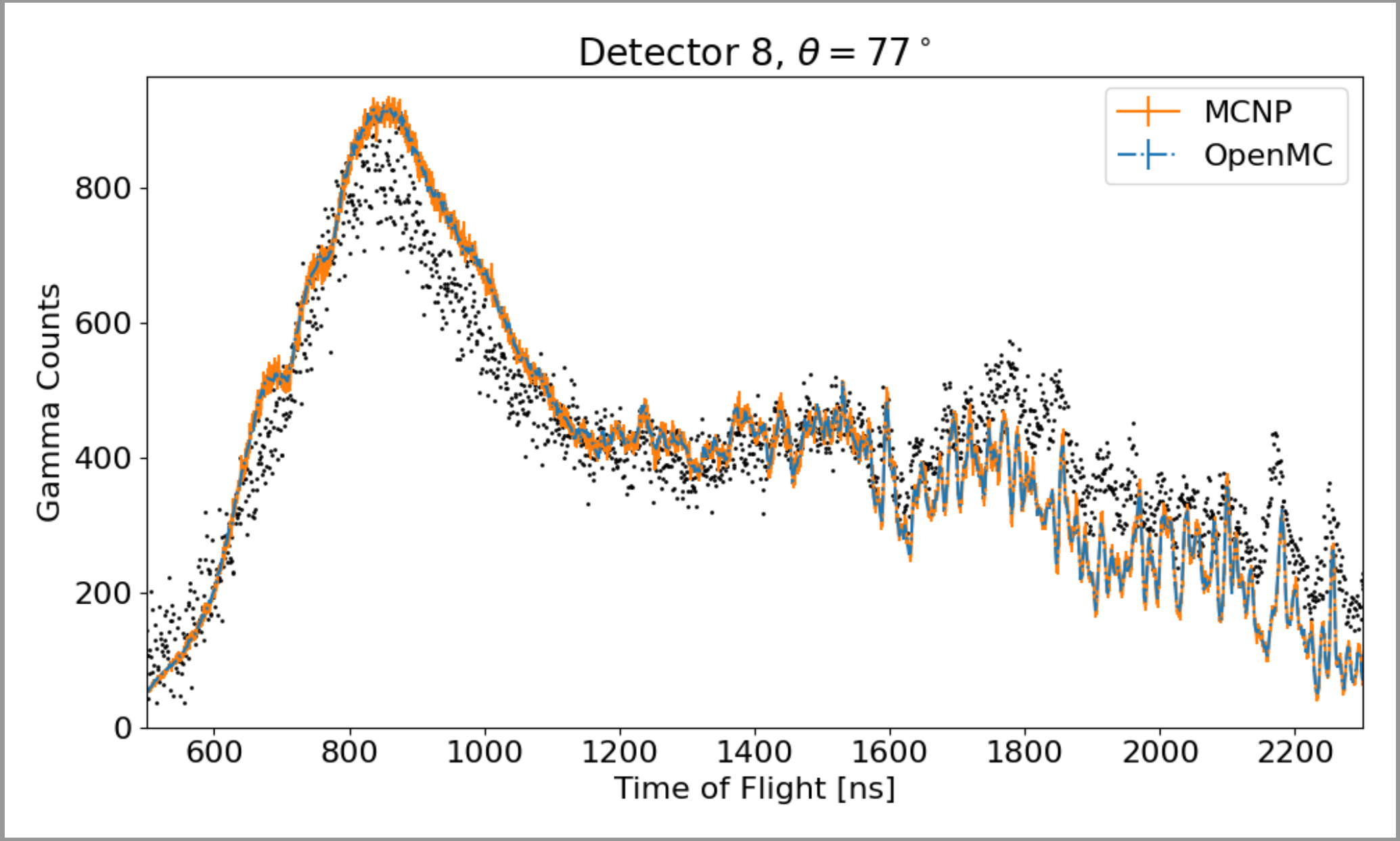

Detector 7, $\theta = 30^\circ$
Energy [MeV]
5
MCNP
OpenMC
Neutron Counts
4500
4000
3500
3000
2500
2000
1500
900
1000
1100
1200
1300
1400
Time of Flight [ns]

Gamma Production from Neutrons Scattering with Iron

Iron


Detector 3, $\theta = 153^\circ$
MCNP
OpenMC
Gamma Counts
0
200
400
600
800
1000
1200
1400
600
800
1000
1200
1400
1600
1800
2000
2200
Time of Flight [ns]

Iron


Detector 8, $\theta = 77^\circ$
MCNP
OpenMC
Gamma Counts
0
200
400
600
800
600
800
1000
1200
1400
1600
1800
2000
2200
Time of Flight [ns]

Conclusions

- OpenMC poses many potential advantages over MCNP
- Simulated HES system for Graphite and Iron using OpenMC and MCNP
- Both codes have good agreement with each other for both samples, with neutrons and gammas
  - A few small differences were observed
- Unable to give a fair performance comparison
  - OpenMC used both MPI and OpenMP
  - MCNP only used MPI
- Would like point detectors in OpenMC !
- We will be expanding use of OpenMC at the RPI LINAC moving forward

Thanks for listening !

Any questions ?