Reactor Physics & Particle Transport Computation Simulation Lab.

Verification of MCS particle transport calculations using the Sky-shine experiment in the SINBAD benchmark

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Part I. Introduction

Skyshine Benchmark

- Ra-Reactor
- Tokamak Fusion Test Reactor

MCS Code

MCS code is a **particle transport simulation program** developed by UNIST.

Validation Method

The validation methodology for MCS code features is the so-called V&V process (**verification** and **validation**— **MCNP** and **Benchmark**).

Evaluation of experimental configuration and material data was made based on calculations performed mainly with **MCNP6**, using **ENDF/B-VII.1** continuous-energy cross sections.

All the measurement uncertainties are assumed to be at 3 standard deviations (3σ) since it is not clearly stated in the benchmark documentation.

Part II. Skyshine Model

Skyshine Model

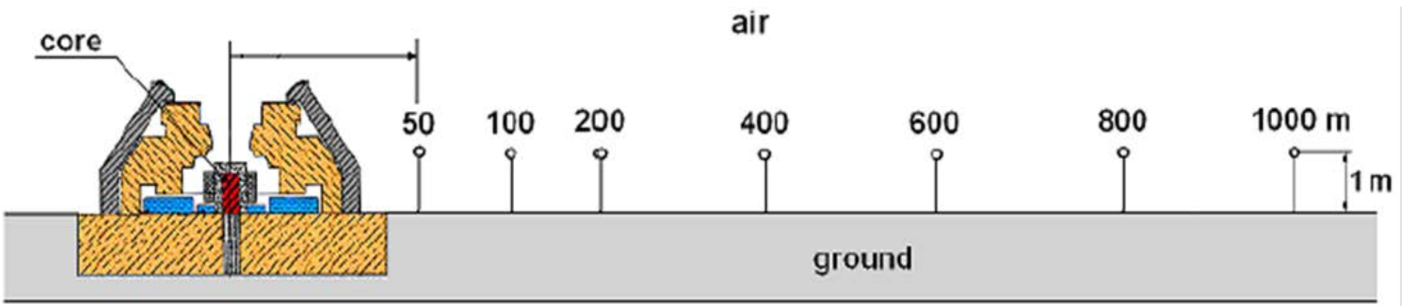
Skyshine RA-reactor

This experiment was carried out in the **RA reactor** in Kazakhstan.

The position of the detector is 1m above the ground and **50, 100, 200, 300, 400, 500, 600, 800 and 1000m** from the axis.

The statistical data in the experiment are **Neutron Flux, Neutron Dose Rate, and Neutron Spectra**.

Uncertainties (1σ) of the on-site measurements:**(10-20%)**



Model figure of Ra-reactor and detector locations.

Skyshine Model

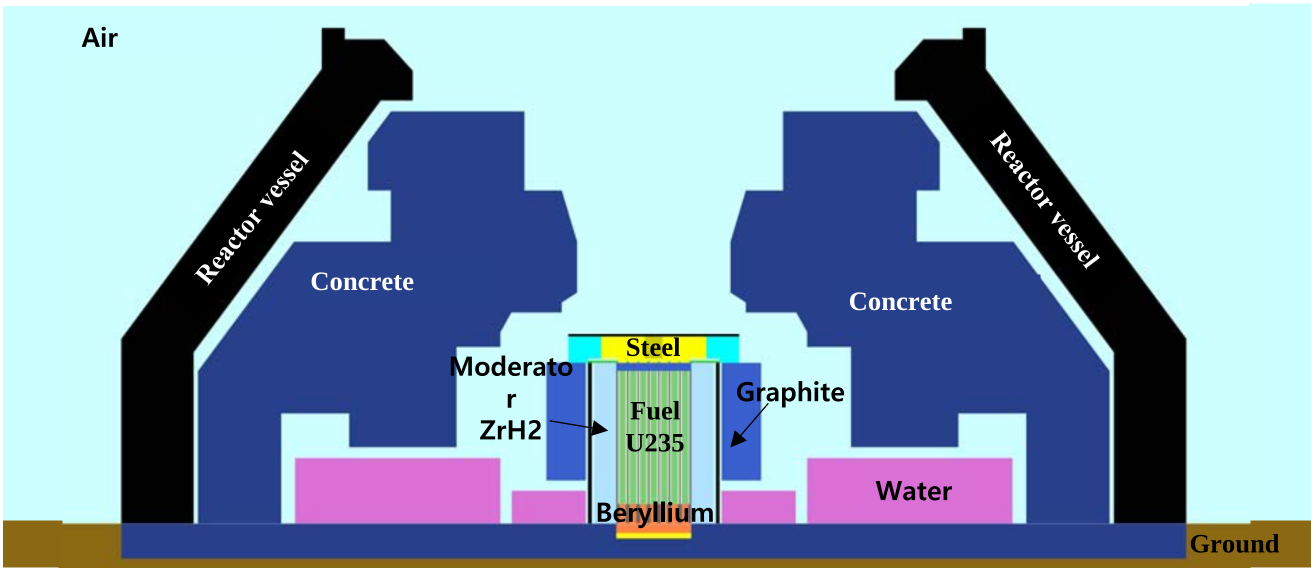
RA reactor experimental detector type

Detector	Characteristics of the Detector	Approximate Energy Range	Function obtained from Measurements
Scintillation counter with a LiF+ZnS(Ag) pellet	⌀25×2mm pellet (⌀40×200mm counter)	Thermal neutrons	Thermal neutron flux
LiF+moderator	⌀150mm polyethylene	0.5eV – 10MeV	Intermediate and fast neutron flux
LiF+moderator	⌀240mm polyethylene	0.5 – 10MeV	Neutron dose rate
Plastic+ZnS(Ag)	⌀80×6mm pellet	1 – 10MeV	Fast neutron flux
H counter	⌀32×150mm; 3atm (H_2-90%, CH_4-9.4%, ^{3}He-0.4%)	20-400KeV	Neutron flux
^{3}He counter	⌀32×150mm; 12atm (^{3}He-33%, Kr-67%)	100KeV-5MeV	Neutron flux
Scintillation counter with a stilbene crystal	⌀40×40mm	0.8-10MeV	Neutron flux
Bonner multispheres, scintillation counter with a B+ZnS(Ag) pellet	6 sizes of polyethylene moderato rs, their diameters being 5.1,7.6, 12.7 ,17.8,20.3,30.5 cm	Thermal neutrons – 10MeV	Neutron flux

Skyshine Model

Skyshine RA-reactor

The size of the simulation model is the same as the size of the actual reactor. Detector geometry is not modelled. **Neutron source** modelled as cylinder source with energy distribution and run in **fixed-source mode**.



Ra-Reactor model

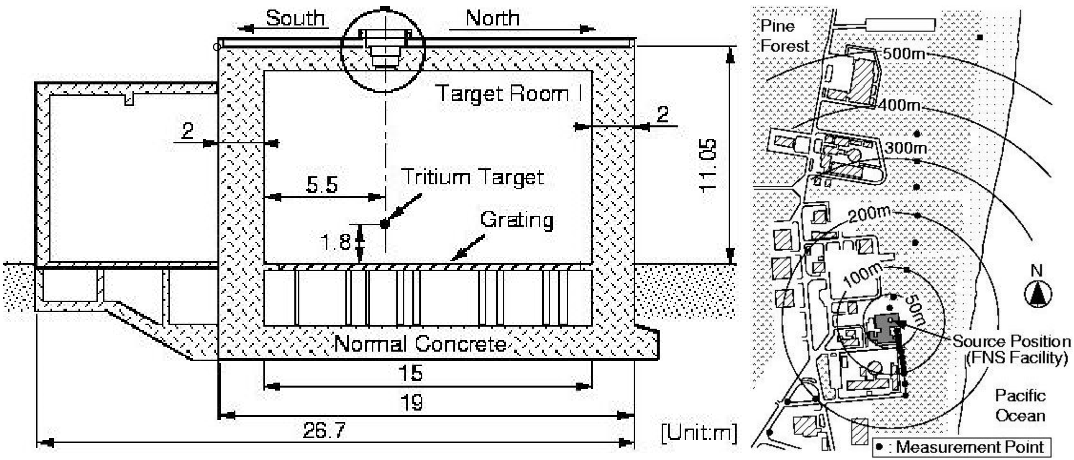
Skyshine Model

Skyshine TFTR(Tokamak Fusion Test Reactor)

The experiment was conducted at **the Tokamak Fusion Test Reactor** in the Princeton Plasma Physics Laboratory. The D-T neutron source is used as the source information. The **neutron dose rate** was measured.

The measurement **uncertainty** of the neutron dose rate is **within 30%.**

Detector: **^{3}He proportional detector**, Fuji Electric NSN10002**.**

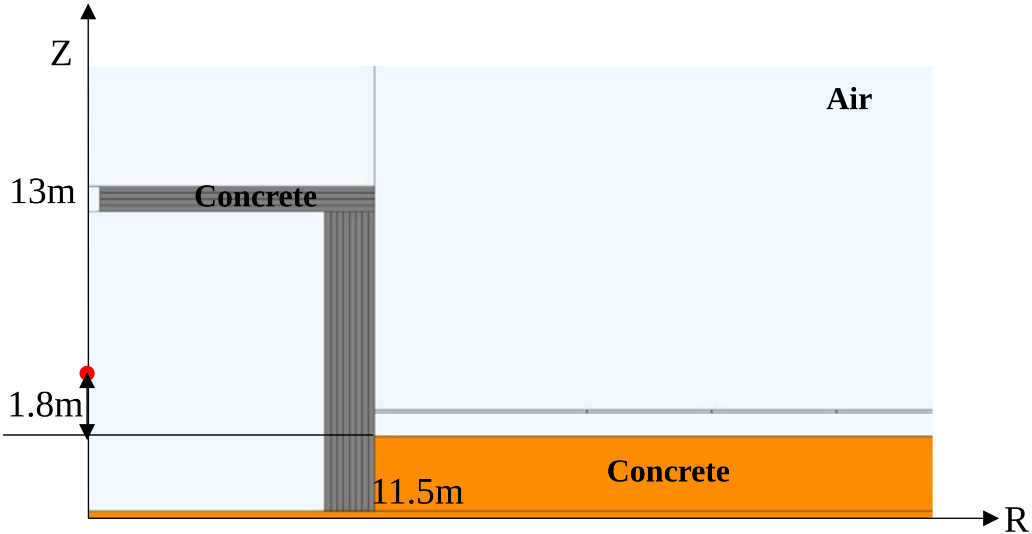


Model figure of TFTR and detector locations.

Skyshine Model

Skyshine TFTR(Tokamak Fusion Test Reactor)

The actual reactor model is simplified. The **source is located at a height of 1.8 meters** from the horizontal. The shape of the reactor is a cylinder with a height of 13 meters, a radius of 11.5 meters, and a thickness of about 3 meters. The main shielding material is concrete. Detector geometry is not modelled. Neutron source modelled as **point source** with **energy & angular distribution** and run in fixed-source neutron-photon mode.



TFTR model

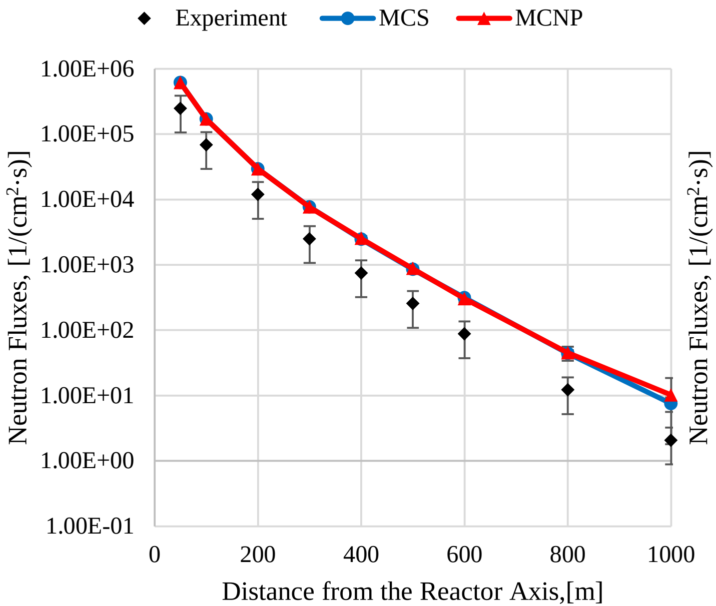
Part III. Calculation results

Calculation results

Skyshine RA-reactor

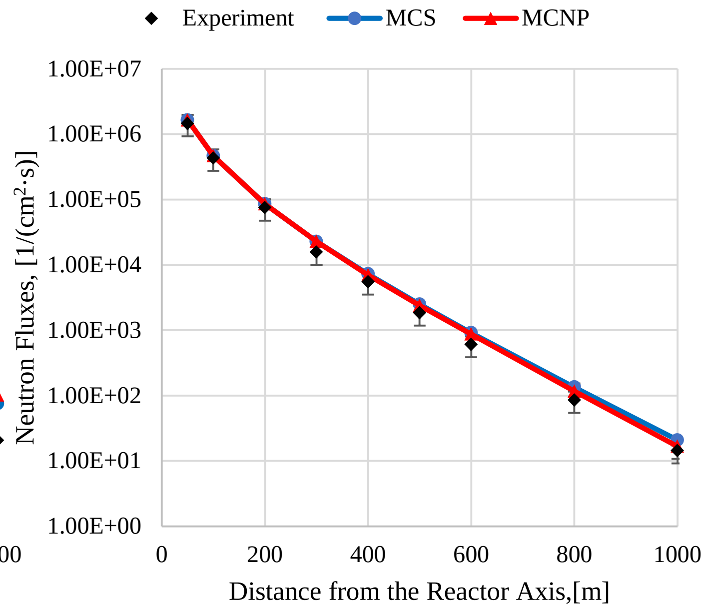
Thermal Neutron Fluxes

Φ_t ,[1/(cm²·s)]



Intermediate and Fast Neutron Fluxes

Φ_{in+f},[1/(cm²·s)]



In order to facilitate observation, the Y-axis uses a logarithmic scale.

Calculation results

RA reactor experimental detector type

Detector	Characteristics of the Detector	Approximate Energy Range	Function obtained from Measurements
Scintillation counter with a LiF+ZnS(Ag) pellet	⌀25×2mm pellet (⌀40×200mm counter)	Thermal neutrons	Thermal neutron flux
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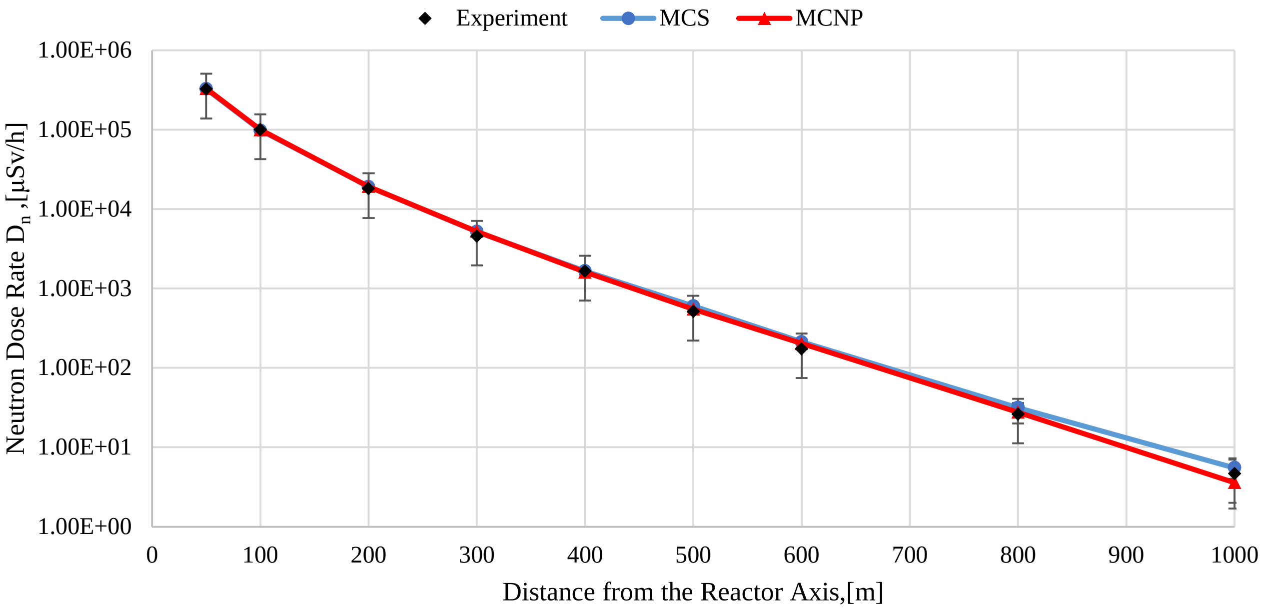
Bonner multispheres, scintillation counter with a B+ZnS(Ag) pellet	6 sizes of polyethylene moderators, their diameters being 5.1,7.6, 12.7 ,17.8,20.3,30.5 cm	Thermal neutrons – 10MeV	Neutron flux

Calculation results

Skyshine RA-reactor

Neutron Dose Rate at different Distances from the RA Reactor

D_n ,[μSv/h]

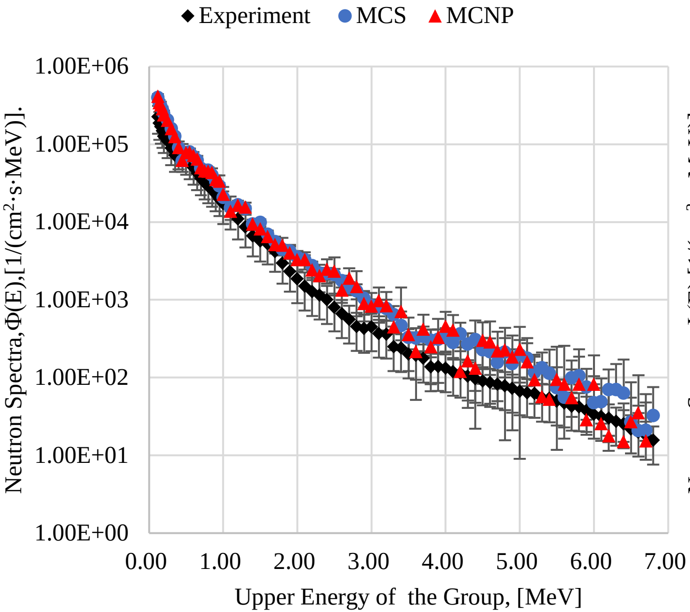


In order to facilitate observation, the Y-axis uses a logarithmic scale.

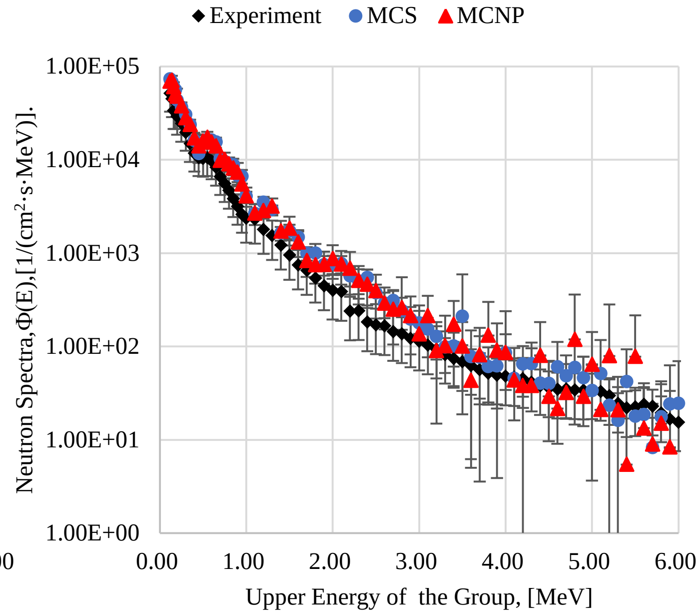
Calculation results

Skyshine RA-reactor

Differential **Neutron Spectra** at **100m** from the RA Reactor, **Φ(E),[1/(cm²·s·MeV)].**



Differential **Neutron Spectra** at **200m** from the RA Reactor, **Φ(E),[1/(cm²·s·MeV)].**

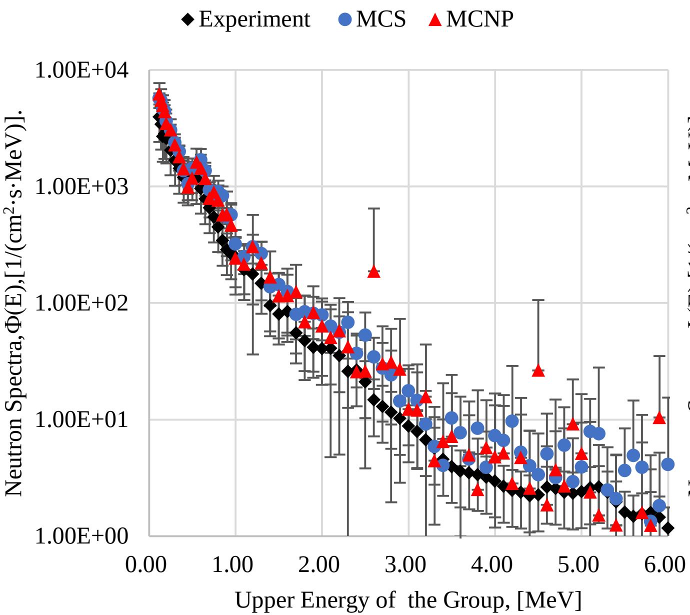


In order to facilitate observation, the Y-axis uses a logarithmic scale.

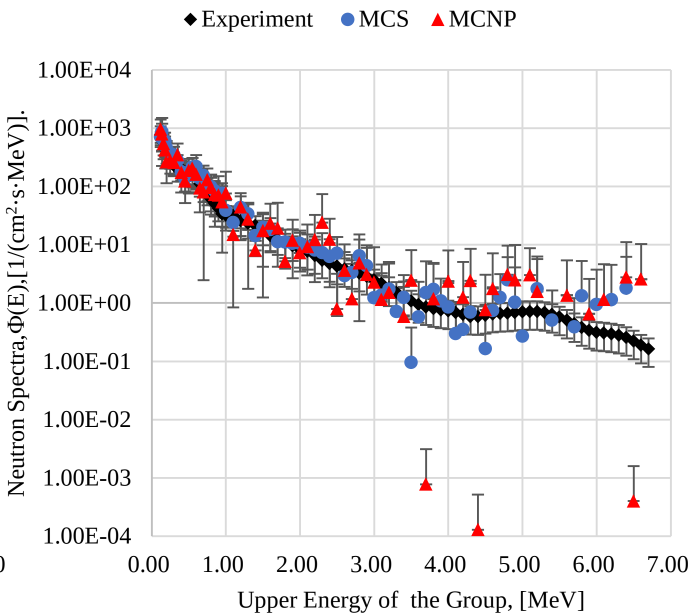
Calculation results

Skyshine RA-reactor

Differential **Neutron Spectra** at **400m** from the RA Reactor, **Φ(E),[1/(cm²·s·MeV)].**



Differential **Neutron Spectra** at **600m** from the RA Reactor, **Φ(E),[1/(cm²·s·MeV)].**

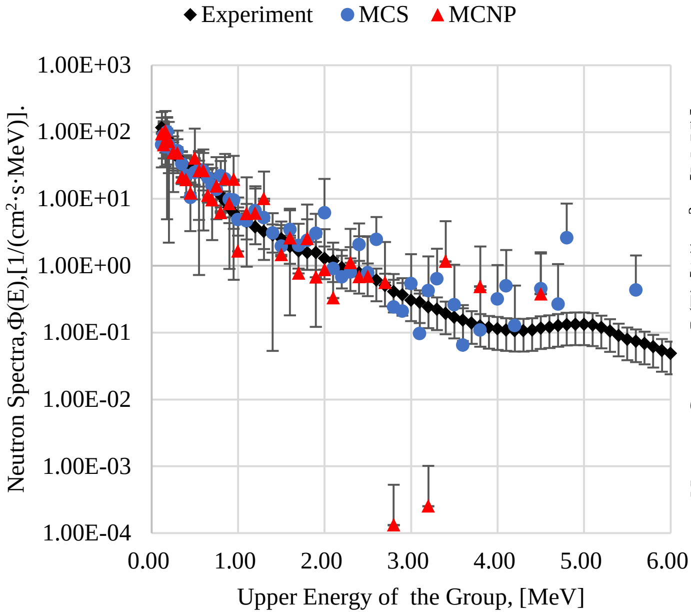


In order to facilitate observation, the Y-axis uses a logarithmic scale.

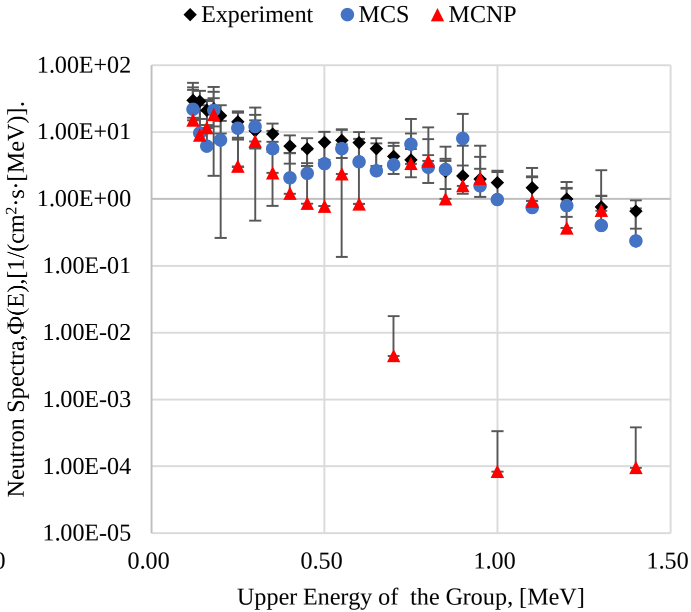
Calculation results

Skyshine RA-reactor

Differential **Neutron Spectra** at **800m** from the RA Reactor, **Φ(E),[1/(cm²·s·MeV)].**



Differential **Neutron Spectra** at **1000m** from the RA Reactor, **Φ(E),[1/(cm²·s·MeV)].**



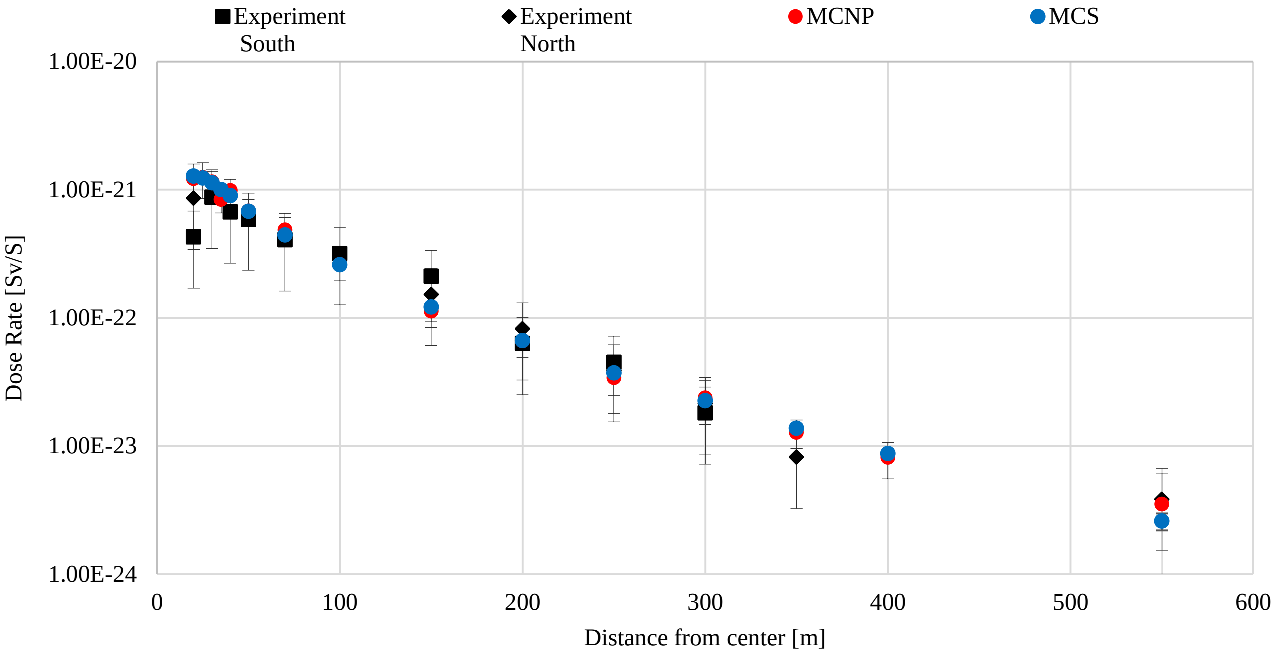
In order to facilitate observation, the Y-axis uses a logarithmic scale.

Calculation results

Skyshine TFTR(Tokamak Fusion Test Reactor)

Calculated & measured **neutron dose rate** distribution.

D_n ,[μSv/h]



In order to facilitate observation, the Y-axis uses a logarithmic scale.

Part IV. Conclusion

Conclusion

Skyshine Benchmark

The computational capability of the MCS code neutron-photon coupled transport simulation is verified by the sky-shine benchmark experiment of the SINBAD shielding benchmark. The two experimental models are one for fission source reactor experiment and one for fusion source test reactor experiment; the calculation results show good overall agreement with the experimental results, although there are some errors.

Next, other SINBAD Benchmark models will be used to verify the MCS code shielding calculations in fixed source mode.

Thank you ☺