Benchmark comparison of MCNP photon interaction data

Bethany Colling [a], I. Kodeli [b] , L. W. Packer [a]

[a] *Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*
[b]*Jožef Stefan Institute, Ljubljana, Slovenia*

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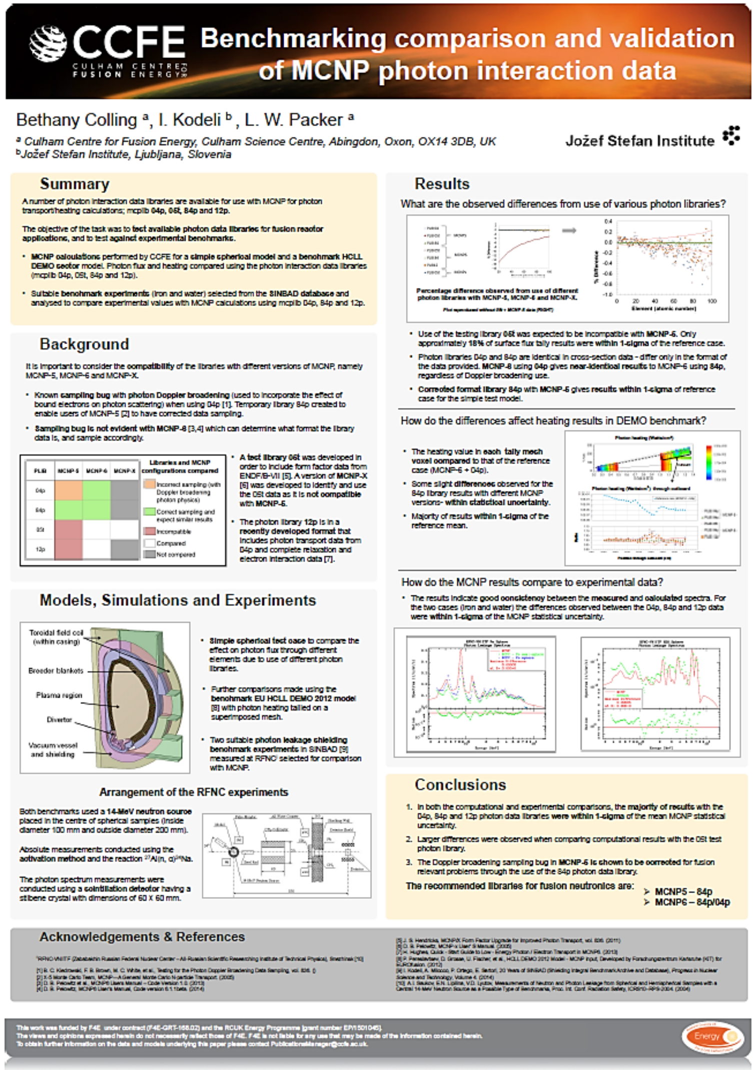
Photon Data Libraries With MCNP

The objective of the task was to **test available photon data libraries** for **fusion relevant applications**, and to test **against experimental benchmarks**

Poster 095
Witte Roos Room



Benchmarking comparison and validation of MCNP photon interaction data

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[b] *Jožef Stefan Institute, Ljubljana, Slovenia*

Jožef Stefan Institute

Summary

A number of photon interaction data libraries are available for use with MCNP for photon transport/heating calculations; mcplib 04p, 05t, 84p and 12p.

The objective of the task was to **test available photon data libraries for fusion reactor applications, and to test against experimental benchmarks.**

- **MCNP calculations** performed by CCFE for a **simple spherical model** and a **benchmark HCLL DEMO sector** model. Photon flux and heating compared using the photon interaction data libraries (mcplib 04p, 05t, 84p and 12p).
- Suitable **benchmark experiments** (iron and water) selected from the **SINBAD database** and analysed to compare experimental values with MCNP calculations using mcplib 04p, 84p and 12p.

Background

It is important to consider the **compatibility** of the libraries with different versions of MCNP, namely MCNP-5, MCNP-6 and MCNP-X.

- Known **sampling bug with photon Doppler broadening** (used to incorporate the effect of bound electrons on photon scattering) when using 04p [1]. Temporary library 84p created to enable users of MCNP-5 [2] to have corrected data sampling.
- **Sampling bug is not evident with MCNP-6** [3,4] which can determine what format the library data is, and sample accordingly.

Libraries and MCNP configurations compared

PLIB	MCNP-5	MCNP-6	MCNP-X
04p	🟧	🟩	▨
84p	🟩	🟩	▨
05t	🟥	☐	☐
12p	🟥	☐	▨

🟧 Incorrect sampling (with Doppler broadening photon physics)
🟩 Correct sampling and expect similar results
🟥 Incompatible
☐ Compared
▨ Not compared

- **A test library 05t** was developed in order to include form factor data from ENDF/B-VII [5]. A version of **MCNP-X** [6] was developed to identify and use the 05t data as it is **not compatible** with **MCNP-5**.
- The photon library 12p is in a **recently developed format** that includes photon transport data from 04p and complete relaxation and electron interaction data [7].

Models, Simulations and Experiments

- **Simple spherical test case** to compare the effect on photon flux through different elements due to use of different photon libraries.
- Further comparisons made using the **benchmark EU HCLL DEMO 2012 model** [8] with photon heating tallied on a superimposed mesh.
- Two suitable **photon leakage shielding benchmark experiments** in SINBAD [9] measured at RFNC^{i} selected for comparison with MCNP.

Arrangement of the RFNC experiments

Both benchmarks used a **14-MeV neutron source** placed in the centre of spherical samples (inside diameter 100 mm and outside diameter 200 mm).

Absolute measurements conducted using the **activation method** and the reaction ^{27}Al(n, α)^{24}Na.

The photon spectrum measurements were conducted using a **scintillation detector** having a stilbene crystal with dimensions of 60 X 60 mm.

Results

What are the observed differences from use of various photon libraries?

Percentage difference observed from use of different photon libraries with MCNP-5, MCNP-6 and MCNP-X.

- Use of the testing library 05t was expected to be incompatible with **MCNP-5**. Only approximately **18%** of surface flux tally results were **within 1-sigma** of the reference case.
- Photon libraries 04p and 84p are identical in cross-section data - differ only in the format of the data provided. **MCNP-5 using 04p gives near-identical results** to MCNP-6 using **84p**, regardless of Doppler broadening use.
- **Corrected format library 84p** with **MCNP-5 gives results within 1-sigma** of reference case for the simple test model.

How do the differences affect heating results in DEMO benchmark?

- The **heating value in each tally mesh voxel compared** to that of the reference case (MCNP-6 + 04p).
- Some slight **differences** observed for the 84p library results with different MCNP versions- **within statistical uncertainty.**
- Majority of results **within 1-sigma** of the reference mean.

How do the MCNP results compare to experimental data?

- The results indicate **good consistency** between the **measured** and **calculated** spectra. For the two cases (iron and water) the differences observed between the 04p, 84p and 12p data were **within 1-sigma** of the MCNP statistical uncertainty.

Conclusions

1. In both the computational and experimental comparisons, the **majority of results** with the 04p, 84p and 12p photon data libraries **were within 1-sigma** of the mean MCNP statistical uncertainty.
2. Larger differences were observed when comparing computational results with the 05t test photon library.
3. The Doppler broadening sampling bug in **MCNP-5 is shown to be corrected** for fusion relevant problems through the use of the 84p photon data library.

The recommended libraries for fusion neutronics are:

- MCNP5 – 84p
- MCNP6 – 84p/04p

Acknowledgements & References

^{i}RFNC-VNIITF (Zababakhin Russian Federal Nuclear Center – All-Russian Scientific Researching Institute of Technical Physics), Snezhinsk [10]

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Models, Simulations and Experiments

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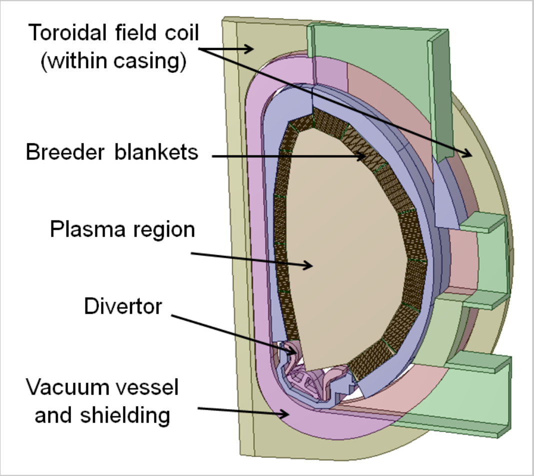
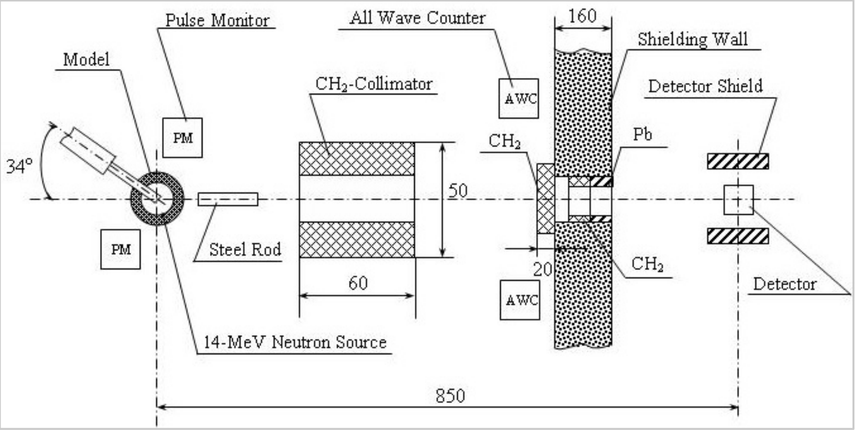


- Suitable **benchmark experiments** (iron and water) selected from the **SINBAD database** and analysed by the Jožef Stefan Institute to compare experimental values with MCNP calculations using mcplib 04p, 84p and 12p.



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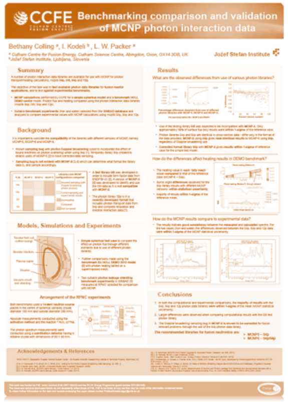

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Further detail and results on the poster (P095)

- **MCNP5 – 84p**
- **MCNP6 – 84p/04p**