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Comparative assessment of different approaches for the use of CAD geometry in Monte Carlo transport calculations

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Objectives

- Single (unique) CAD geometry: ITER CAD benchmark model.
- Three different approaches for use of CAD geometry in MC transport calculations:

McCad: Current standard approach, conversion of CAD geometry into MCNP representation using McCad developed at KIT.

MCNP6&TT: Using MCNP6's unstructured mesh geometry feature, meshing of CAD geometry with the tesselation-tetrahedralization (TT) approach developed at KIT.

DAGMC: Direct particle tracking on the CAD geometry using a patched version of MCNP developed at UW-Madison.

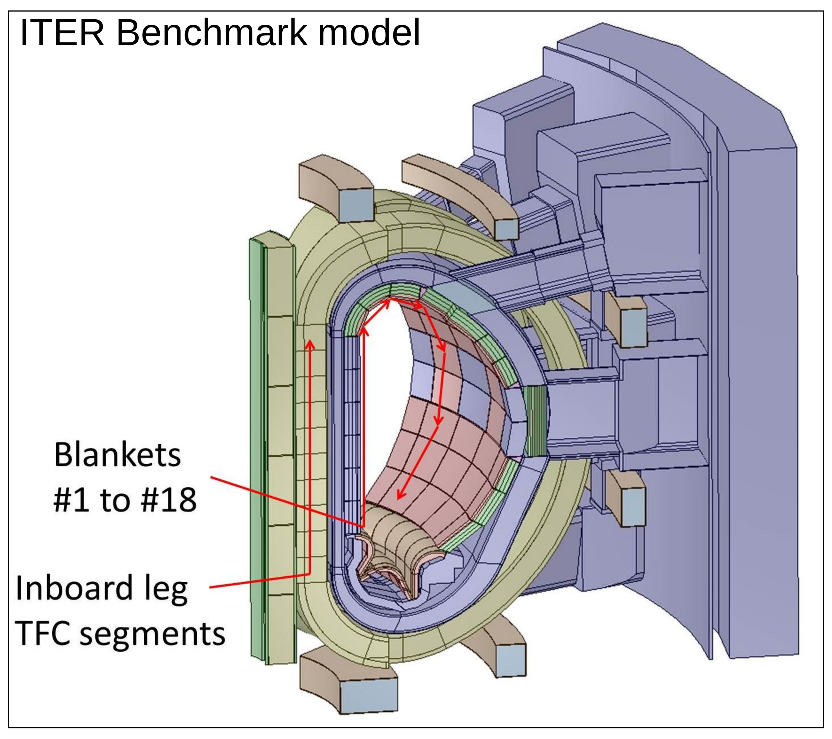
- Comparison with respect to performance and user-friendliness:

Installation (Installation guide, needed software, installation complexity).

Model preparation (repairing geometry error, time needed, user expertise).

Computation performance (calculation speed, accuracy).

ITER Benchmark model



	McCad	MCNP6&TT	DAGMC
Installation	Good installation guide. Only one additional software package required. Open Source software (except MCNP). Simple installation.	New development, up to now no installation guide. several software packages needed but not interdependent. Open Source Software (except MCNP). Moderate installation	Installation guide available, but not sufficient. Interdependent software packages. Dependent on specific, older versions. Cubit and MCNP under license control. Complex installation.
Model preparation	Decomposition into convertible solids. Substitution of spline surface with analytical surfaces mandatory. Iterative and time intensive. Extensive user expertise required.	Removing overlaps/gaps of solids. Fast conversion. User expertise required for optimization of meshing. Tally definition difficult due to meshing of cells and surfaces.	No user guide for repairing geometrical errors. Moderate speed, iterative steps required. User expertise essential. Tally definition very convenient, more user-friendly than standard MCNP.
Computation performance	Fastest calculation. Current standard approach for MCNP calculations, chosen as reference.	Slowest calculation; speed depends mainly on mesh resolution. Superimposed mesh gives large deviation for deep penetration calculations. Cell tallys agree with McCad results within statistical errors.	Moderate calculation speed. If model preparation done correctly, very good agreement with McCad results. First wall cell tallys within 1% of McCad results.

Comparison of 14 MeV neutron flux at First Wall (FW)

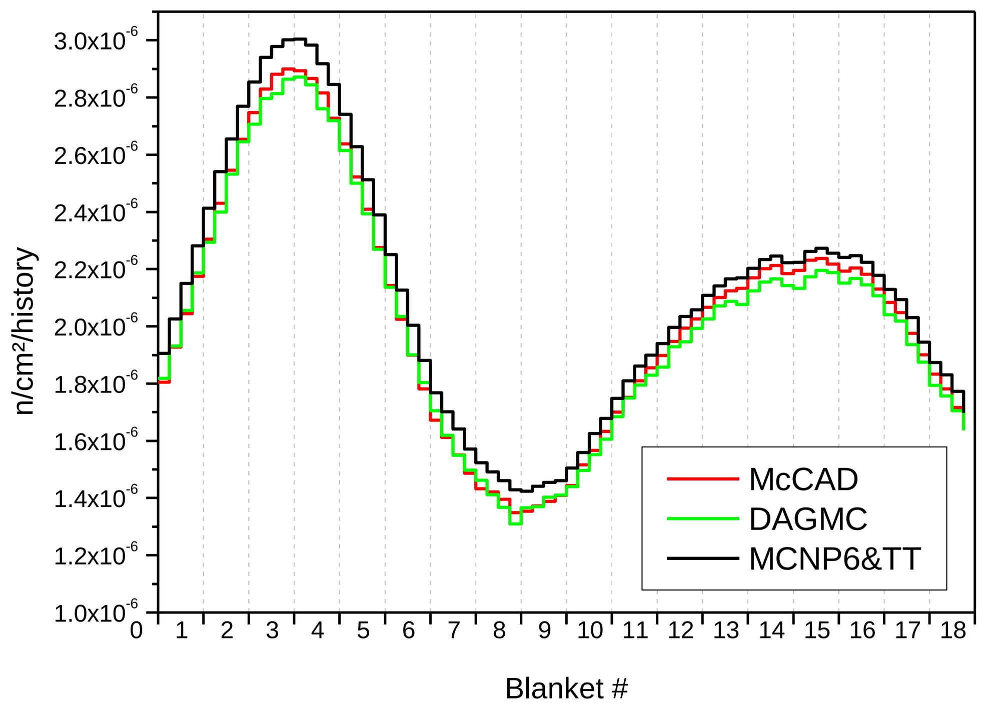
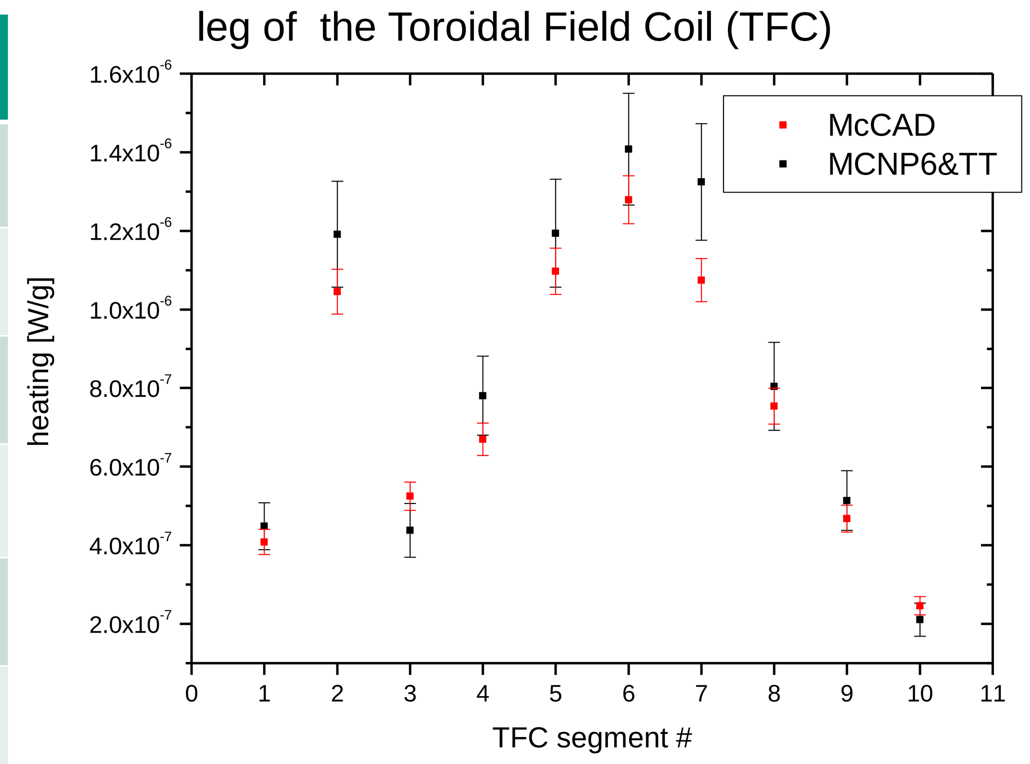


Table: Comparison of calculation performances.

	McCAD	MCNP6 & TT	DAGMC
Lost particles	$4e^{-6}$ %	$2e^{-4}$ %	$3e^{-4}$ %
CPU time per 1e5 histories (voided)	23 s	550 s	134 s
CPU time per 1e5 histories	294 s	1004 s	630 s
Deviation from McCad FW 14 MeV neutron current	-	3.4 %*	1.0 %*
Deviation from McCad heating inboard TFC	-	9.8 %*	too many lost particles
Deviation from McCad Neutron flux mesh at equatorial port	-	27 %	too many lost particles

*within statistical error

Comparison of nuclear heating in the inboard leg of the Toroidal Field Coil (TFC)



Conclusions

- McCad most useful for simple models or if model preparation has to be done only once. Small changes to the geometry can be done directly in the MCNP input file.
- MCNP6&TT model preparation extremely fast and reliable. Problematic with regard to nuclear responses; for meshtally the deviation to McCad approach lager than statistical error. Statistical error in general larger than for McCad approach (same number of histories).
- DAGMC most useful for complex models that need to be changed regularly.