Verification and Validation of the Geant4 Monte Carlo Code Toolkit for DEMO Neutronics Applications

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**Motivation and Objective**
- Search for open-source alternative to MCNP for long-term future fusion neutronics applications like DEMO
- Geant4 potential option
- Fusion evaluated libraries available
- Open-source, object-oriented toolkit allows adaptation
- Validation of Geant4: Benchmarks vs. MCNP and experiments
- Extension of Geant4
- Neutron source & CAD geometry conversion
- Reflective Boundaries and Tally Multiplication
- DEMO nuclear design analyses compared to MCNP

**Re-Assessment of Previous Benchmarks**
- Geant4's suitability for fusion neutronics demonstrated
- Previous 1 MeV neutrons: Geant4 increasingly underestimates with penetration depth
- Low energy neutrons: Geant4 is consistent with MCNP
- Experimental T activity mostly underestimated for both codes
- Strong overestimation in 12th pellet of lower breeder layer by Geant4 mostly caused by 0.1 MeV energy bin
- Deviation to MCNP otherwise <5%; increasing underestimation with penetration depth
- For full pellet stack: same increasing underestimation, but only up to 2.6%
- Total tritium activity: Geant4 results deviate only by -1.3% towards MCNP
- Thermal neutron treatment should be investigated
- Geant4 produces close agreement with MCNP for tritium production

**Experimental Benchmark: HCPB Mock Up**
- >1 MeV neutrons: Geant4 increasingly underestimates with penetration depth
- Low energy neutrons: Geant4 is consistent with MCNP
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**DEMO with HCPB Blanket**
- Most of geometry converted with McCAD
- Reflective Boundary function developed for Geant4
- Fortran90 MCNP plasma neutron source converted into C++ for Geant4
- Geant4 Constructive Solid Representation allows replication only within basic shapes
- Split into basic shapes; homogenized material for left-over 8.4% of volume
- Thermal neutron treatment and better repeated structure method should be investigated
- Already good TBR agreement between Geant4 and MCNP

**Conclusions and Outlook**
- Improved basic neutron transport agreement with MCNP for newest version Geant4.10.05.p01
- McCAD to GDML geometry conversion successful
- Newly developed tally multiplication and reflective boundaries successfully used
- HCPB: slightly different volumetric distribution of T breeding, but good total agreement
- DEMO: good TBR agreement
- Geant4's suitability for fusion neutronics demonstrated
- Thermal neutron treatment should be investigated
- Better repeated structure representation method needs to be developed, possibly based on HalfSpaceSolid
- DEMO nuclear analyses other than TBR