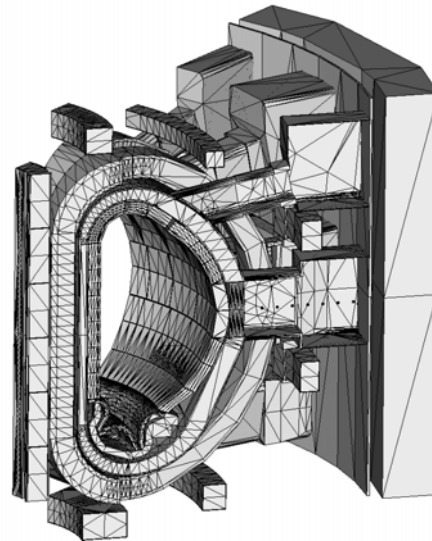


An advanced MC modeling and multi-physics coupling system for fusion applications

Yuefeng Qiu, Ulrich Fischer, Lei Lu.

Institute for Neutron Physics and Reactor Technology, KIT



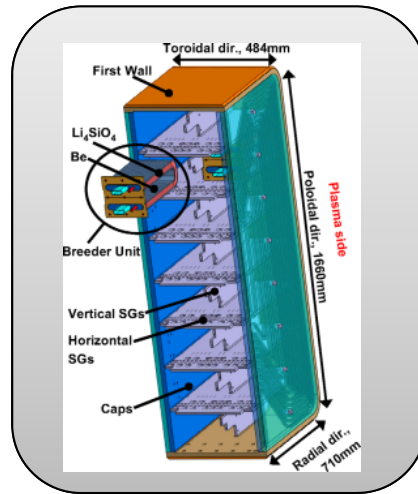
Outline

- Introduction
- The integrated system
- Advanced MC modeling
- Multi-physics coupling
- Summary

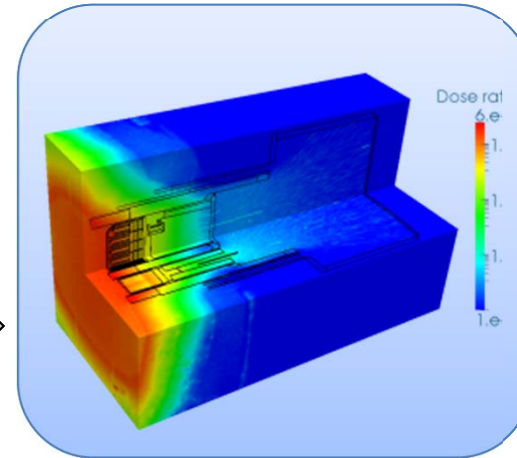
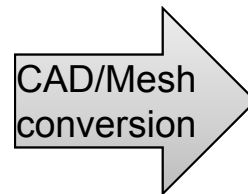
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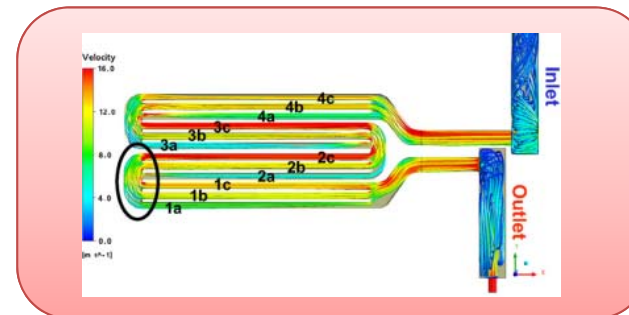
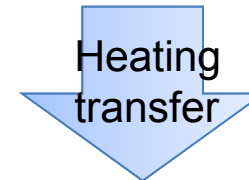
Introduction



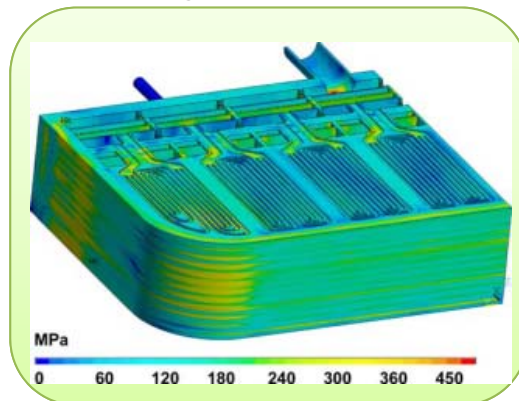
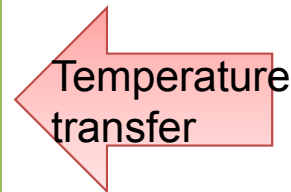
CAD Design



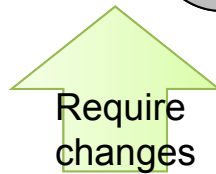
Neutron physics



Thermal hydraulics



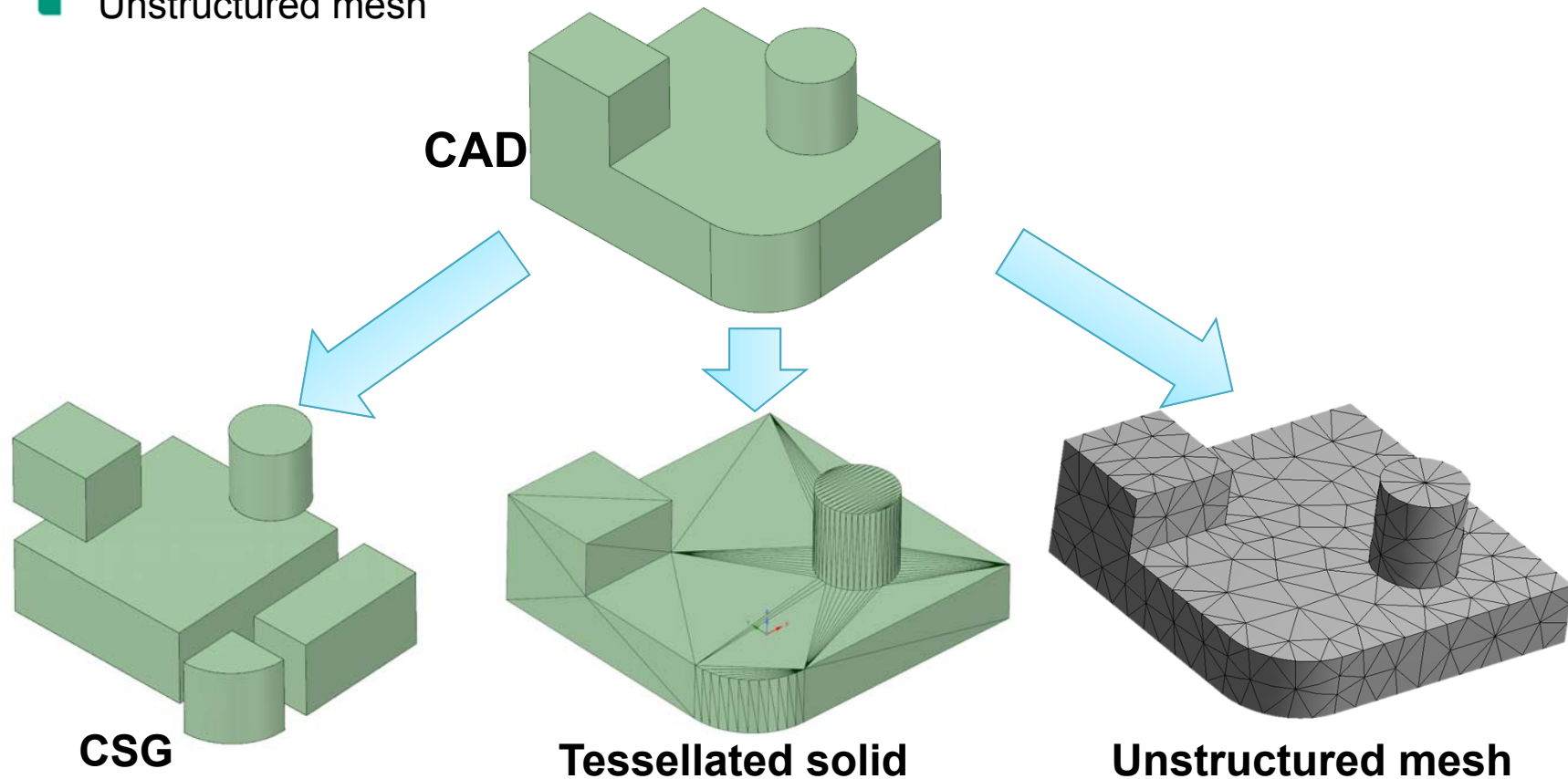
Structural mechanics



Courtesy of P. Pereslavl'tsev, F. Cismondi

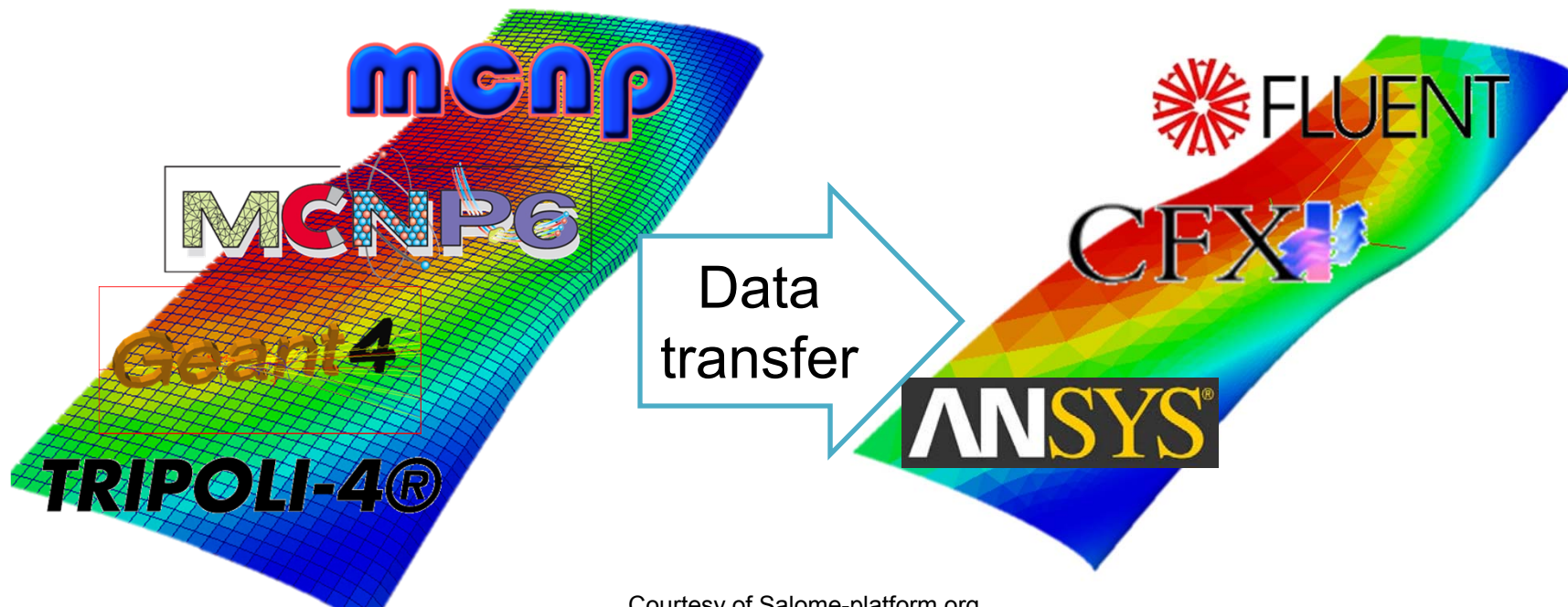
Introduction – Monte Carlo (MC) modeling

- CAD based MC modeling
 - Constructive solid geometry (CSG)
 - Tessellated (faceted) solid
 - Unstructured mesh



Introduction – Multiphysics coupling

- General data mapping
 - Flexible for any kind of meshes
 - Accurately preserved physical field
- Interfaces
 - Import data from MC codes
 - Export data for TH/SM codes



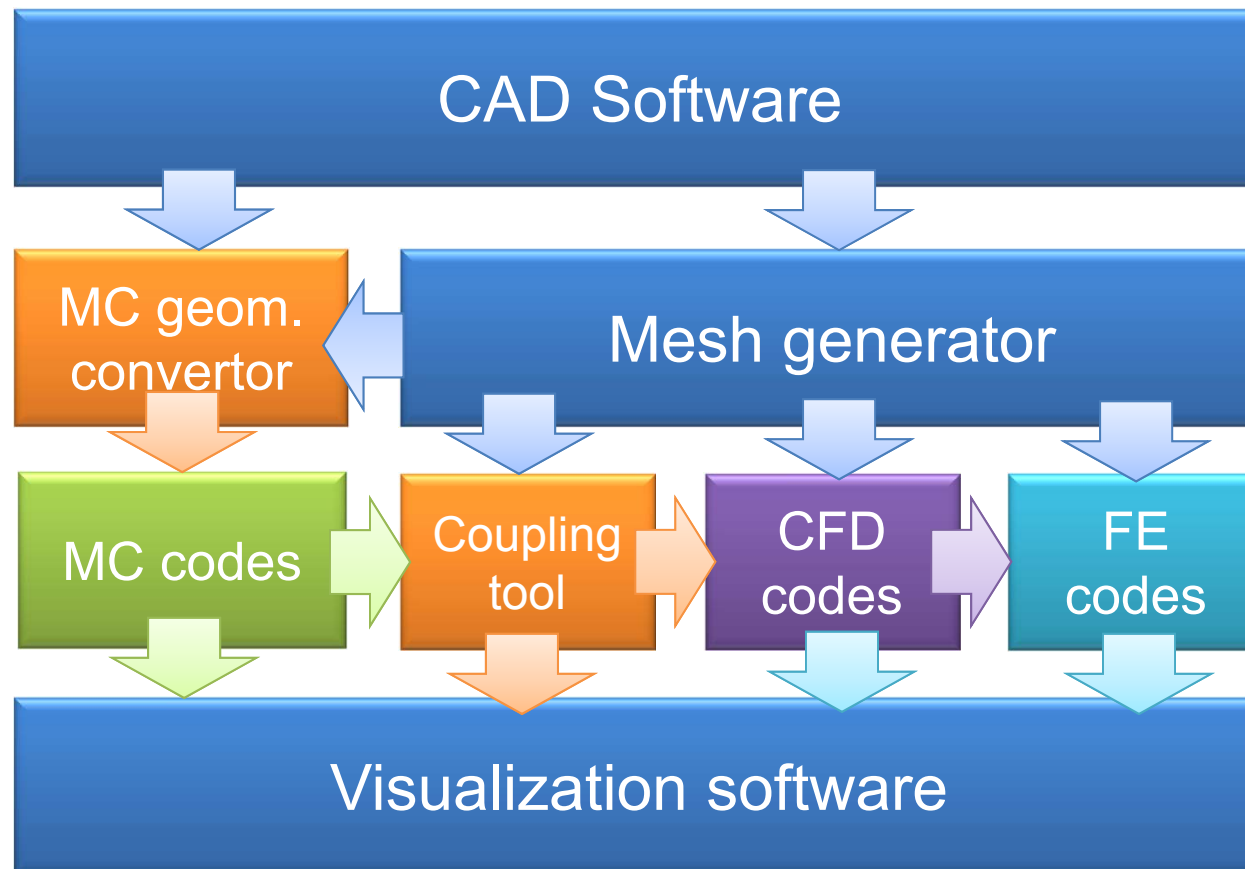
Courtesy of Salome-platform.org

Outline

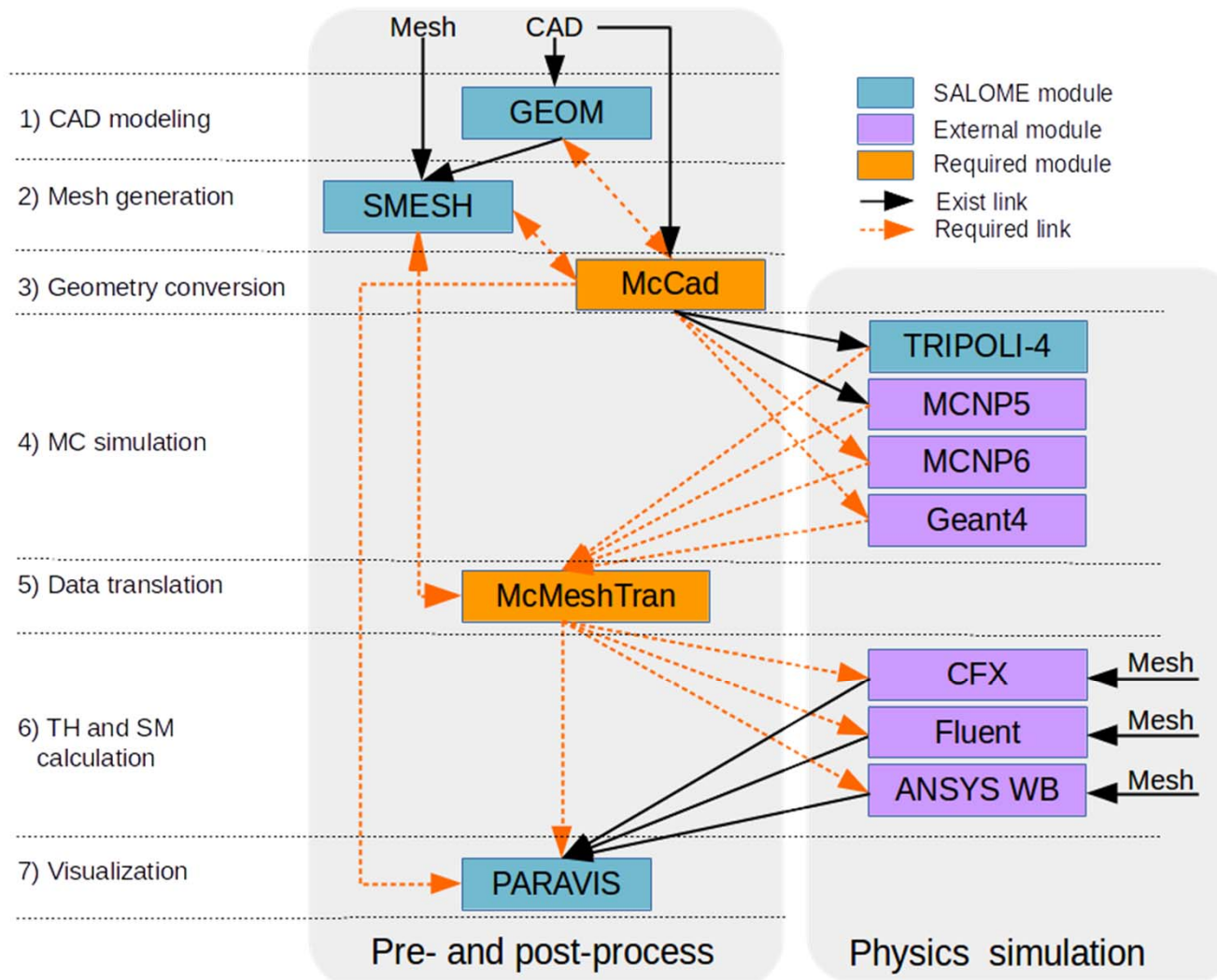
- Introduction
- **The integrated system**
- Advanced MC modeling
- Multi-physics coupling
- Summary

The integrated system

- Functions modules



The integrated system

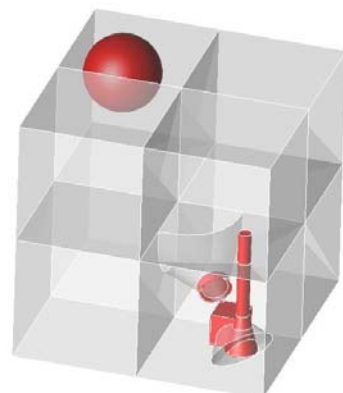
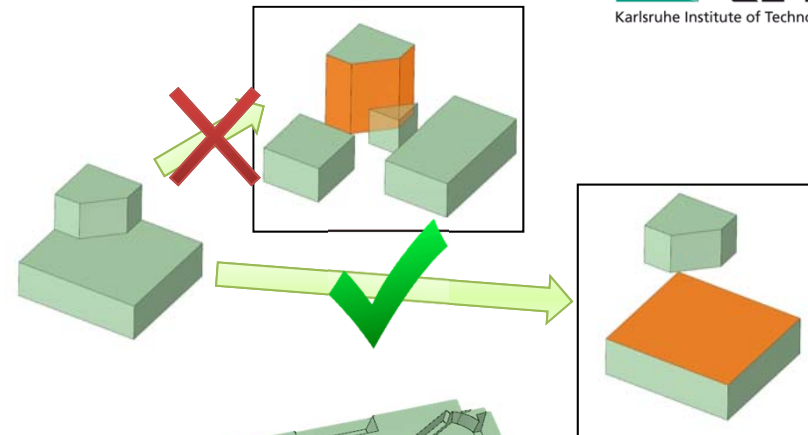


Outline

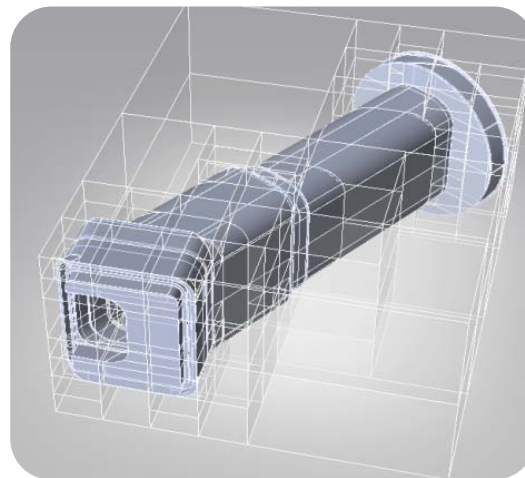
- Introduction
- The integrated system
- **Advanced MC modeling**
- Multi-physics coupling
- Summary

Advanced MC modeling

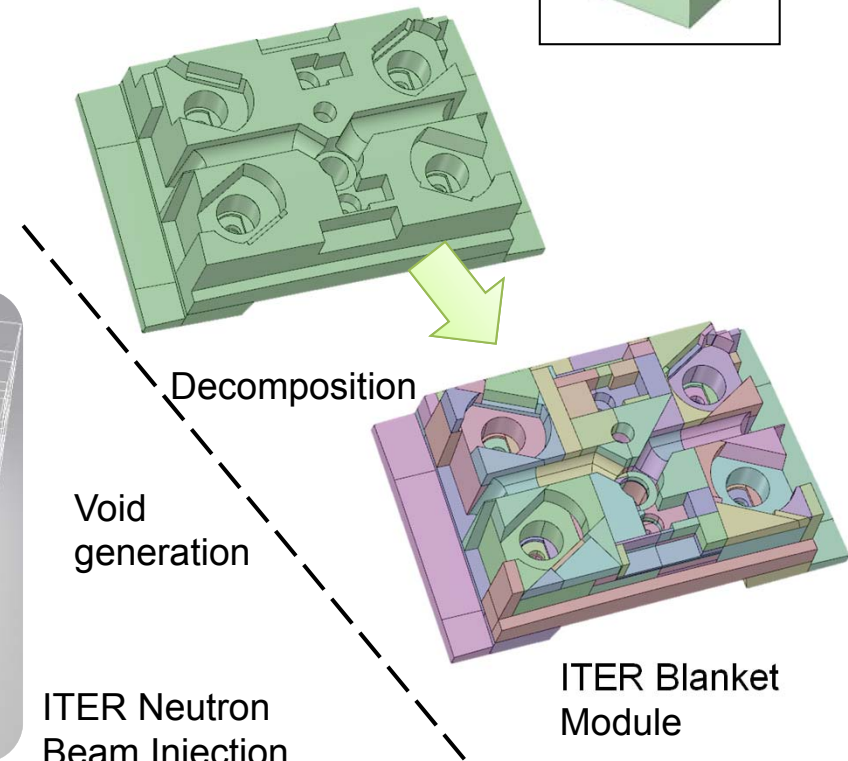
- McCad
 - Developed in KIT Based on Open CASCADE
 - Well validated and widely used in ITER, DEMO, IFMIF, ...
- CAD to CSG conversion for MC codes
 - Step 1: decomposing to CSG
 - Step 2: describing void space
 - Support MCNP, TRIPOLI



Recursive void space



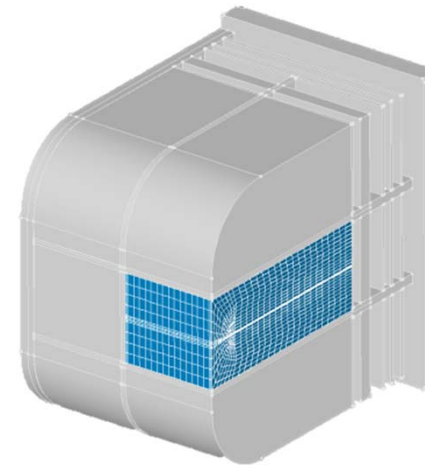
ITER Neutron Beam Injection



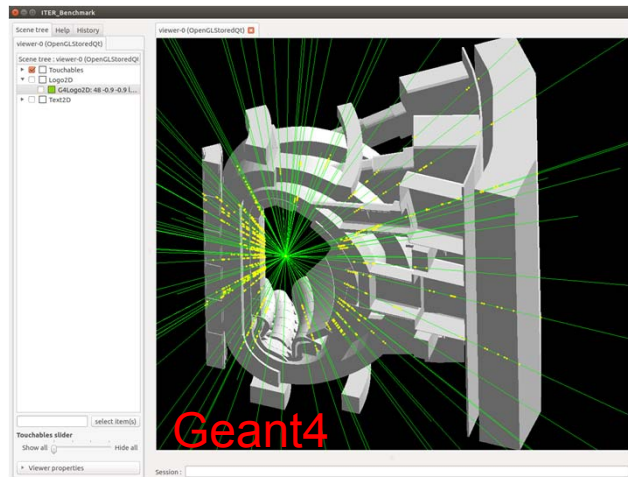
Advanced MC modeling

- CAD to 3D mesh conversion
 - Hybrid CSG and mesh conversion
 - Hybrid geometry and tally mesh
 - Supporting MCNP6 unstructured mesh geometry

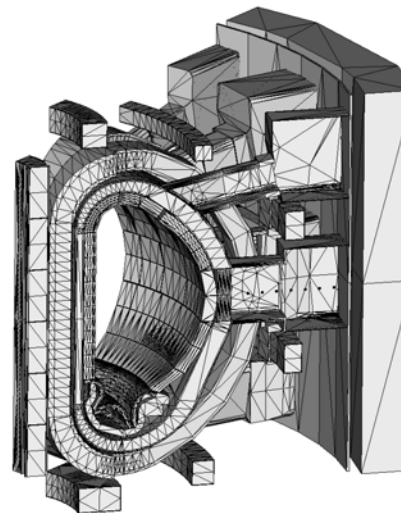
- CAD to tessellated solid conversion
 - Supporting Geant4 GDML



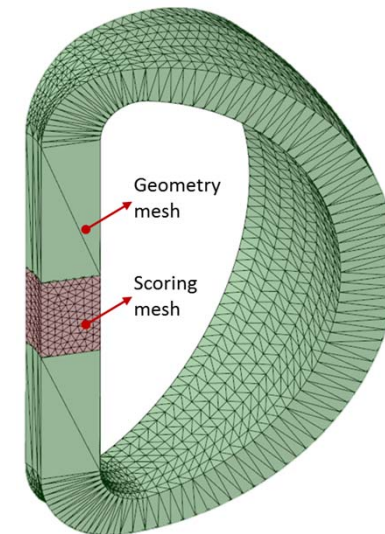
Hybrid CSG and mesh



Geant4 geometry



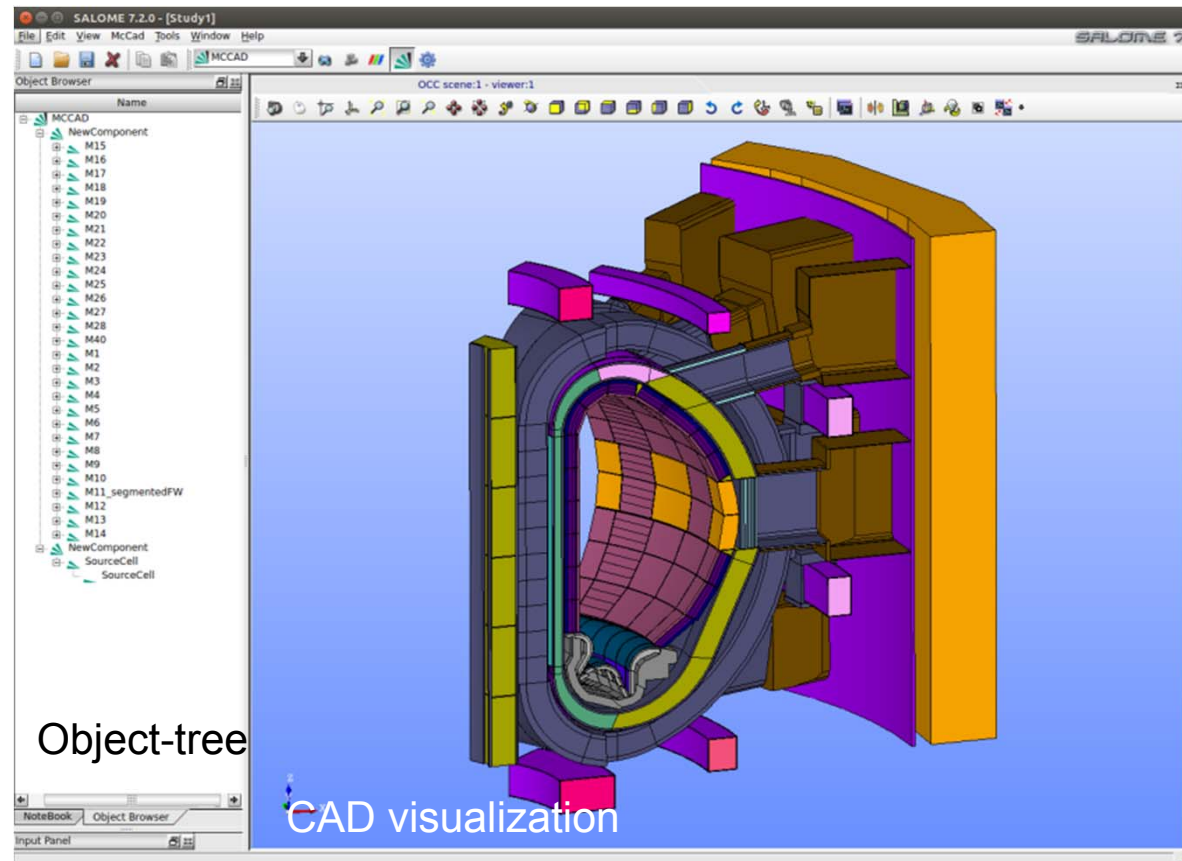
MC geometry mesh



Hybrid geometry and tally mesh

Advanced MC modeling

- SALOME version
 - New Object tree
 - Independent CAD viewer
 - MC material management
 - CAD/mesh sharing with GEOM and SMESH
 - Visualization CAD in ParaView
 - Binary version provided for Linux and Windows system.



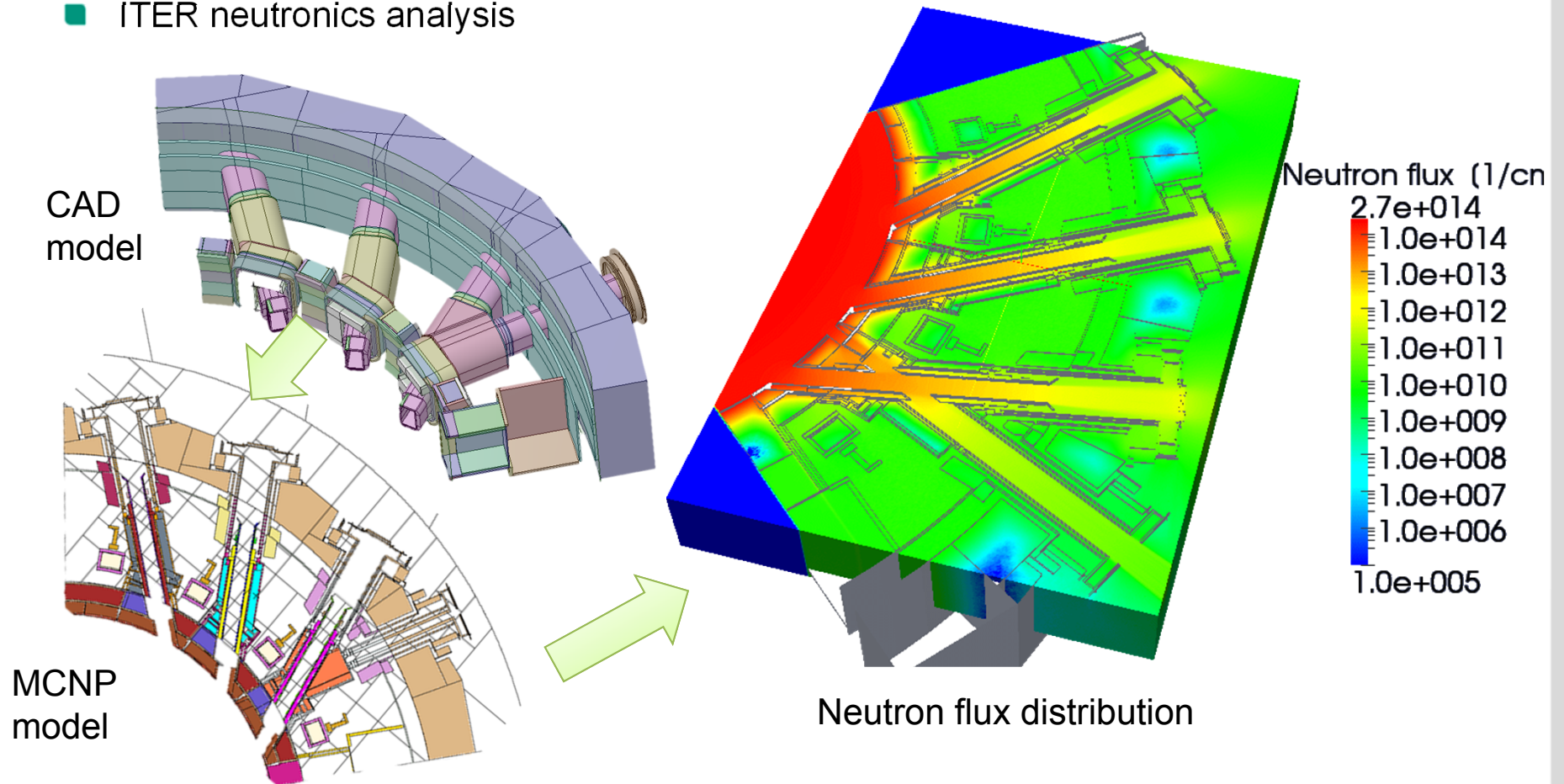
Object-tree

CAD visualization

ITER Benchmark model

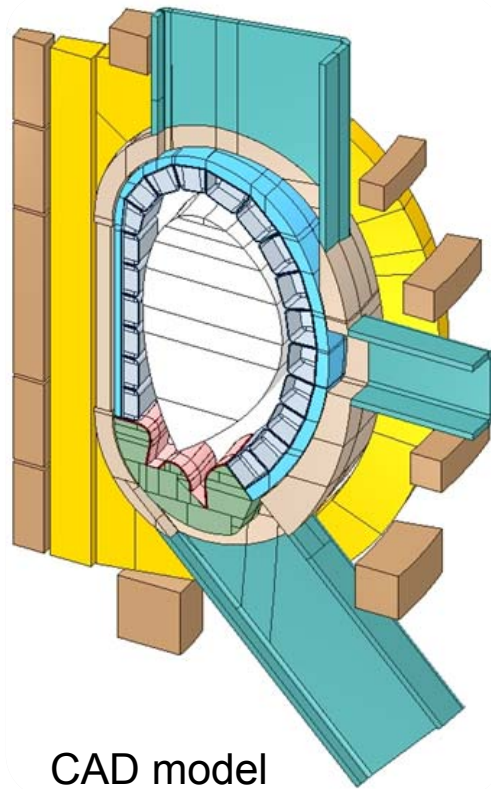
Advanced MC modeling

- Applications
 - ITER neutronics analysis

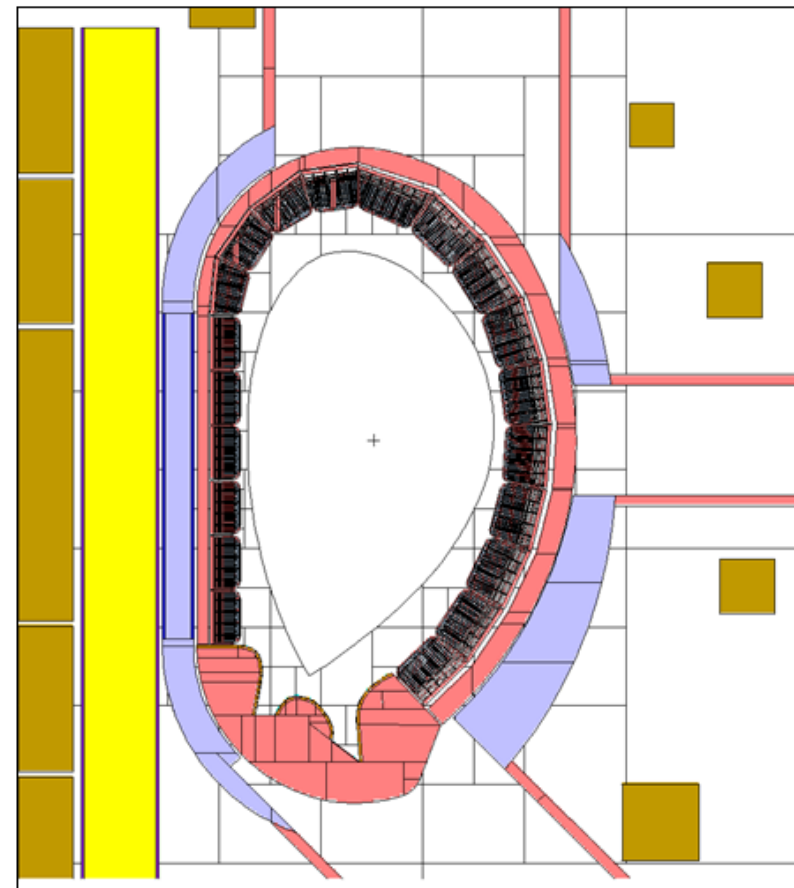


Advanced MC modeling

- Applications
 - European DEMO



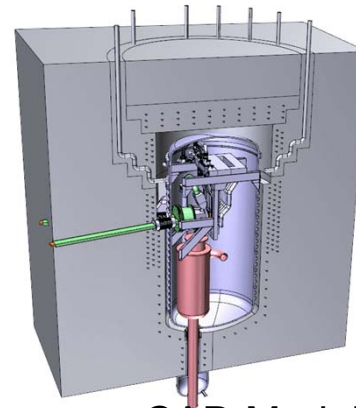
CAD model



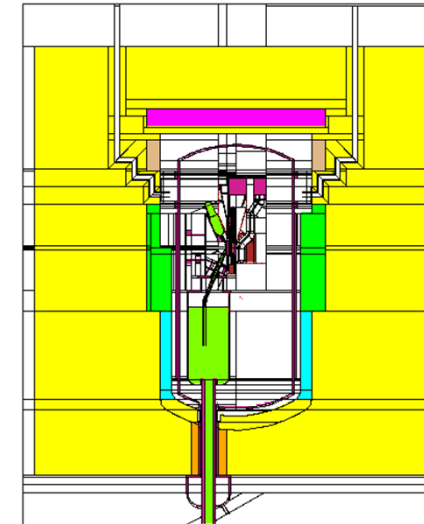
MCNP model

Advanced MC modeling

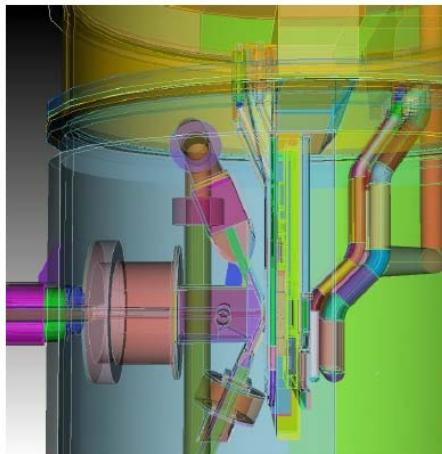
- Applications
 - International Fusion Materials Irradiation Facility (IFMIF)



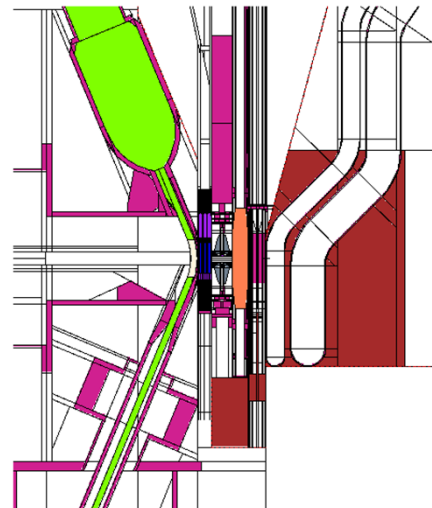
CAD Model



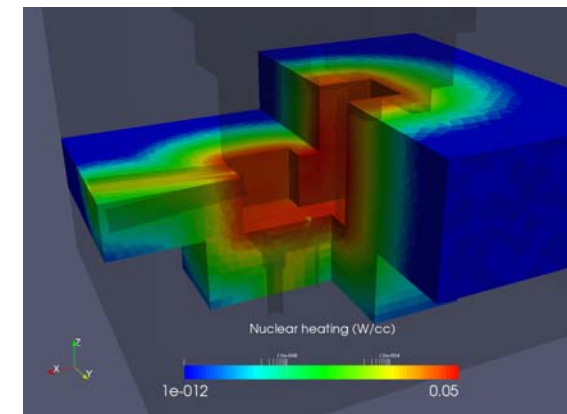
MCNP Model



CAD Model



MCNP Model



Nuclear heating distribution

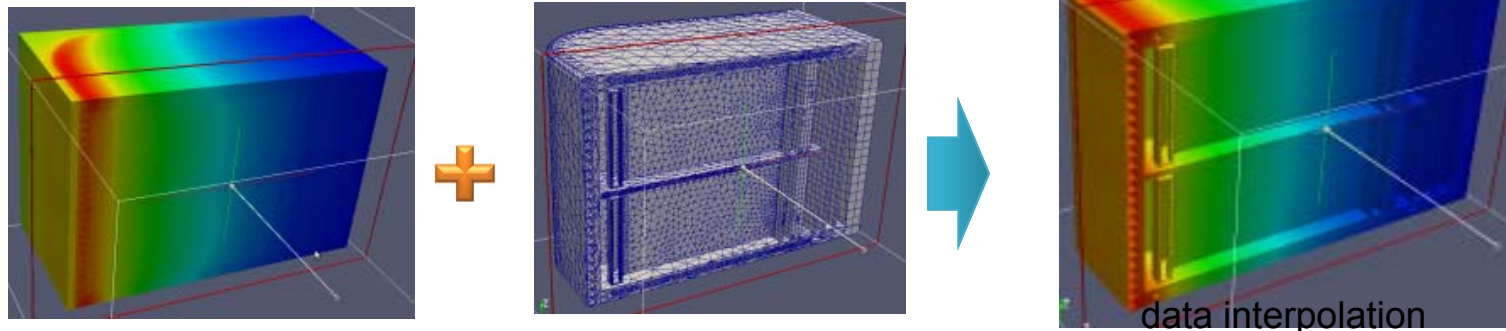
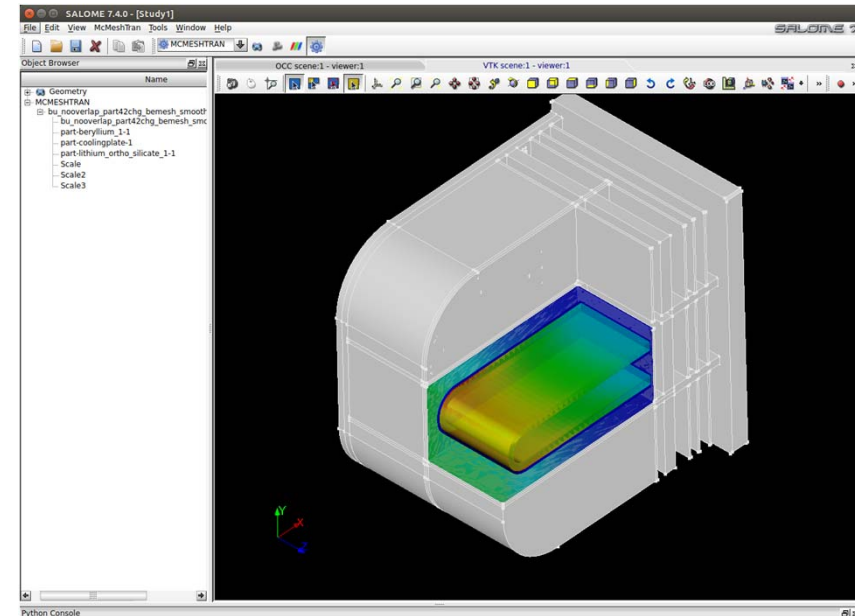
Outline

- Introduction
- The integrated system
- Advanced MC modeling
- **Multi-physics coupling**
- Summary

Multi-physics coupling

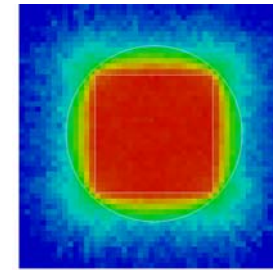
■ McMeshTran

- A MC Mesh and data Transformation/ Translation/ Transfer tool;
- Mapping data from MC to CFD/FE meshes (points and cells)
- Mesh persistency and manipulation with MED
- Mesh sharing with SMESH
- Visualize results directly on ParaView

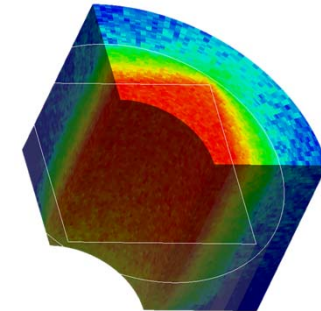


Multi-physics coupling

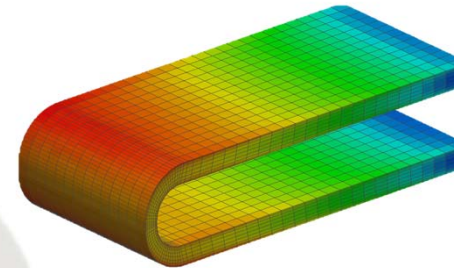
- MC code interface
 - MCNP5 rectilinear mesh tally
 - MCNP6 unstructured mesh
 - TRIPOLI-4 orthogonal mesh
 - Geant4 scoring mesh
- CFD/FE code interface
 - CFX: User Fortran
 - Fluent: User Defined Function
 - ANSYS Workbench: CSV



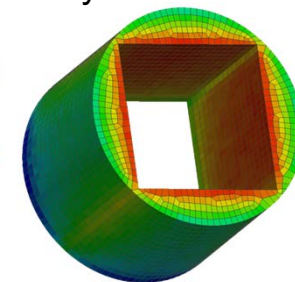
Cartesian mesh



Cylindrical mesh



Structured mesh



unstructured mesh

mcnp

MCNP6

Geant4

TRIPOLI-4®

Data
transfer

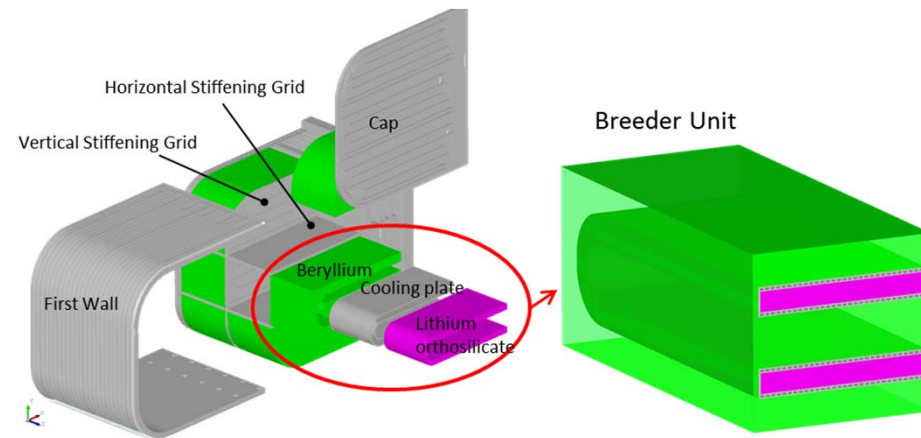
FLUENT

ANSYS®

CFX

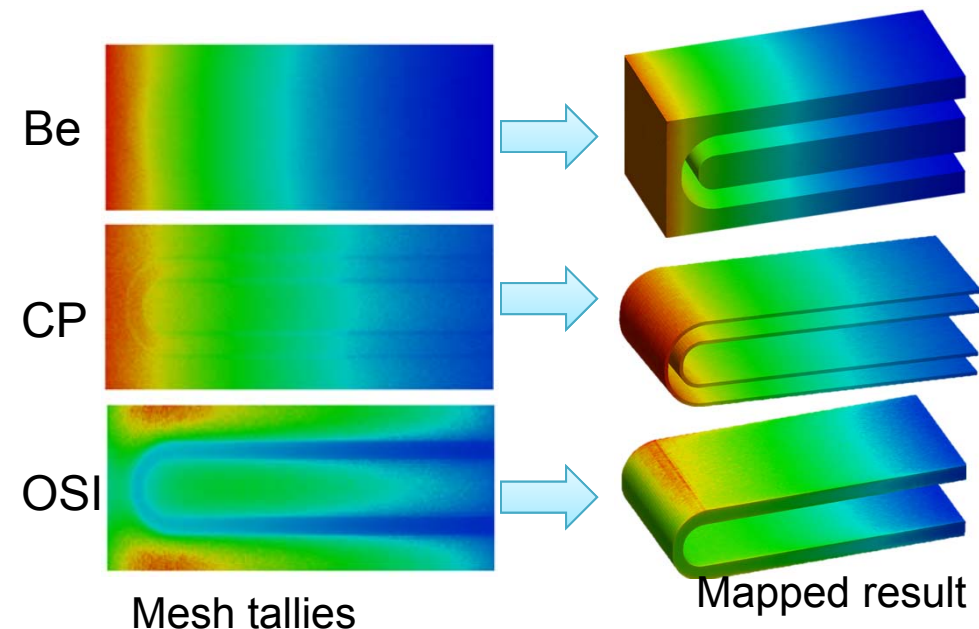
Multi-physics coupling

- MCNP mesh tally
 - Test case of TBM (Test Blanket Module which will be insert in ITER)
 - MCNP5 model



Exploded view of the HCPB TBM test case

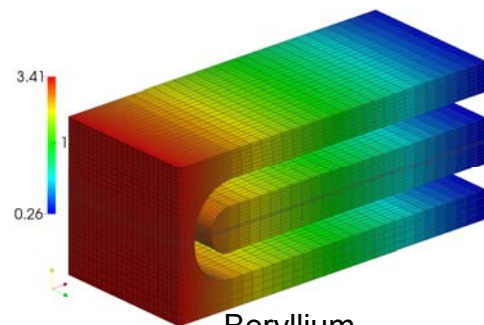
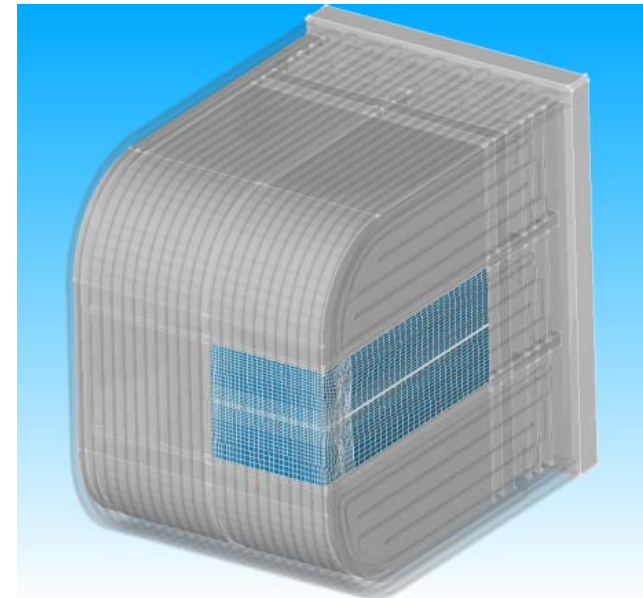
Subcom- ponent	MCNP tally result (W)	Mesh result (W)	Diff.
Beryllium	1.5555×10^4	1.5597×10^4	0.27%
Cooling plate	1.8036×10^3	1.8462×10^3	2.36%
Lithium OSI	1.0862×10^4	1.0882×10^4	0.18%



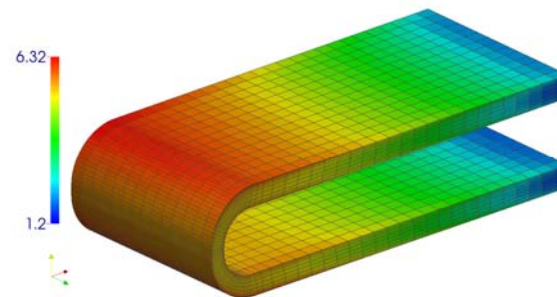
Multi-physics coupling

- MCNP6 unstructured mesh
 - Mesh of a breeder unit is generated by ANSYS ICEM;
 - Hybrid model converted by McCad;

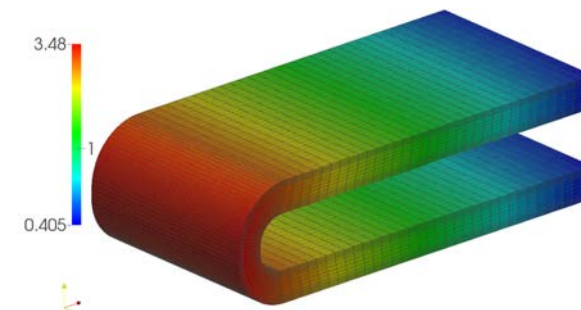
Subcomponent	MCNP tally result (W)	MCNP UM result(W)	Diff.
Beryllium	1.5555×10^4	1.5787×10^4	1.49%
Cooling plate	1.8036×10^3	1.7596×10^3	2.44%
Lithium OSI	1.0862×10^4	1.0821×10^4	0.38%



Beryllium



Lithium

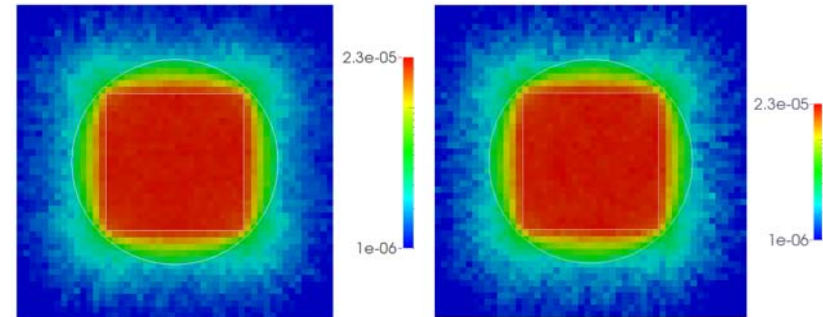
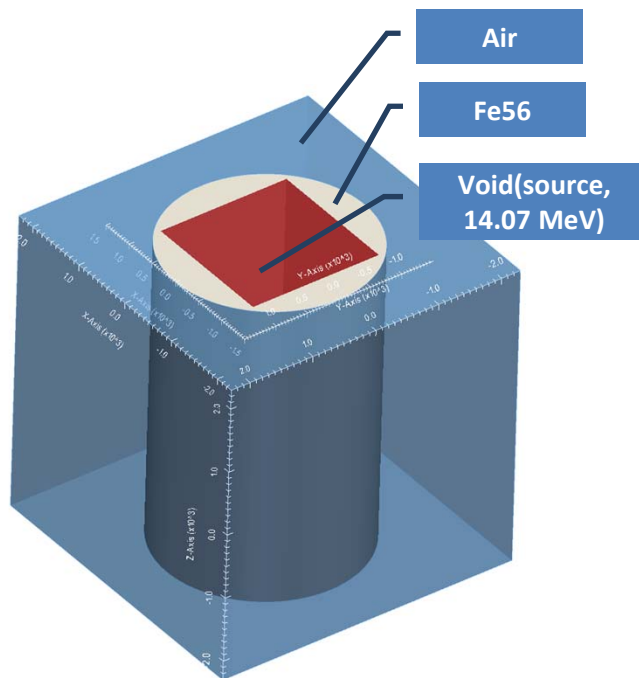


Cooling plate

Multi-physics coupling

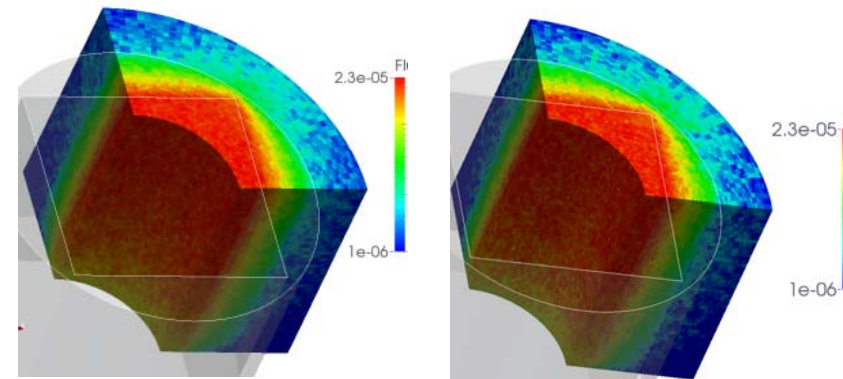
■ TRIPOLI test

- An test case has been used
- TRIPOLI Mesh tally of neutron flux is compared with MCNP mesh tally
- Results agree well.



MCNP

TRIPOLI

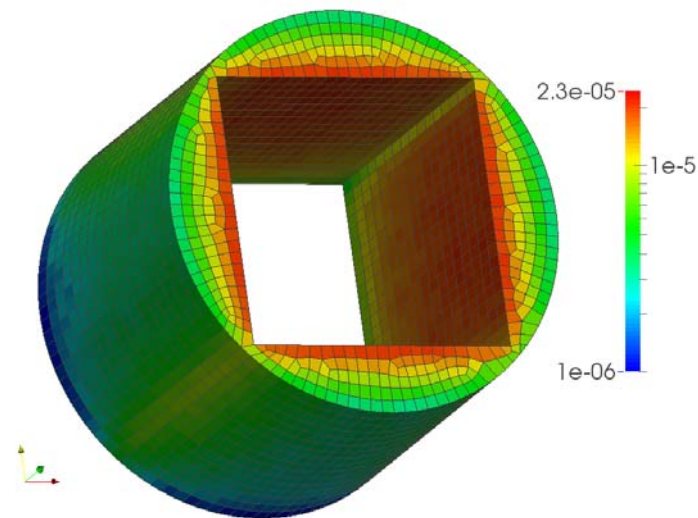


MCNP

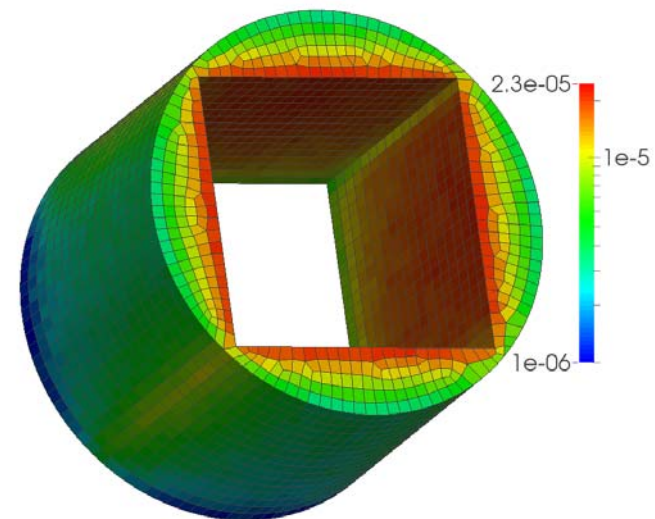
TRIPOLI

Multi-physics coupling

- Geant4 test
 - Using the same cases as TRIPOLI
 - superimposed unstructured mesh tally compared with MCNP6
 - Results agree very well.



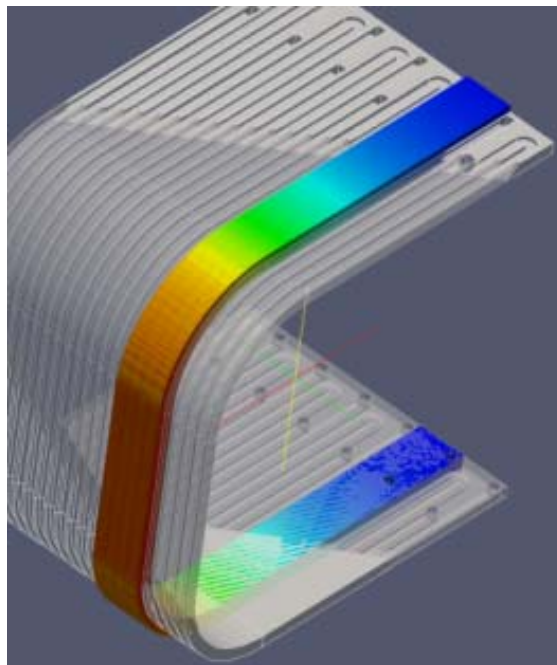
MCNP6 neutron flux



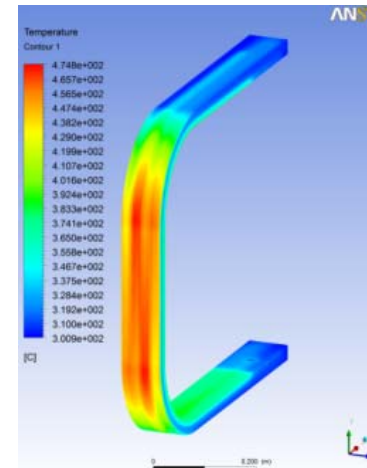
Geant4 neutron flux

Multi-physics coupling

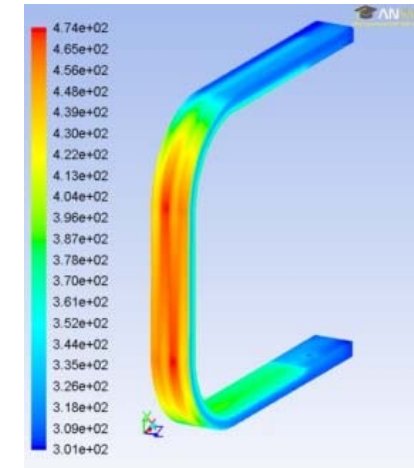
- Fluent and CFX comparison
 - The 1/6 FW model was analysis
 - Using the identical mesh and conditions
 - Temperature results agree very well.



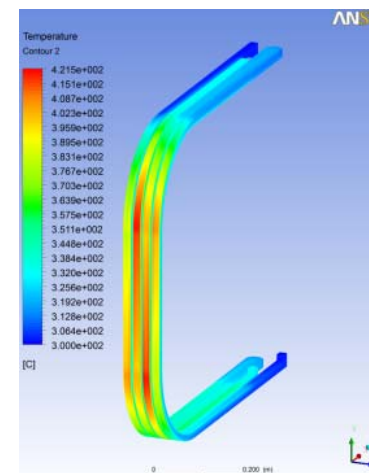
Nuclear heating



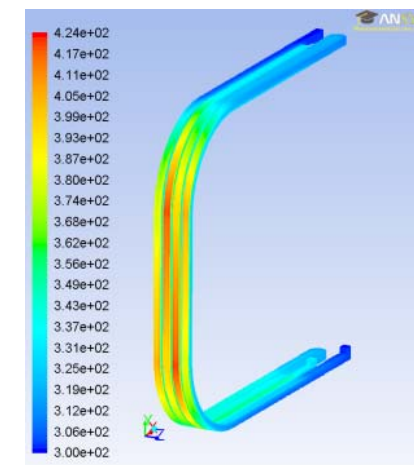
CFX-solid



Fluent-solid



CFX-Fluid



Fluent-Fluid

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Summary

- An advanced system for MC modeling and multi-physics coupling;
- McCad: Advanced hybrid CSG, tessellated solid and unstructured mesh modelling approach have been developed ;
- McMeshTran: Generic coupling between MCNP5/6, TRIPOLI-4, Geant4 and Fluent, CFX, ANSYS Workbench has been achieved.
- This system is well verified and has been applied in fusion neutronics analysis.

- General purpose tools, developed for, but not limited in fusion engineering;
- Open-source!
 - McCad binary: <https://github.com/inr-kit/McCad-Salome-Binaries>
 - McCad source: <https://github.com/inr-kit/McCad-Salome-Source>
 - McMeshTran binary: <https://github.com/inr-kit/McMeshTran-Binaries>
 - McMeshTran source: <https://github.com/inr-kit/McMeshTran-Source>

tenki ขอขอบคุณคุณ takk спасибо kam sah hamnida
дзякуй hvala dhanyavadagalu tack
gracias dijere deuf mési xièxie tanemirt
arigatô manana diolch akun bedankt blagodaram rahmet enkosi mochchakkeram trugarez dank je
dziękuje danke kop khun krap laafetai lava
ačiū shukriya ありがとう kia ora dankon dėkuji
dhanyavad barka mamnun grâce kitos spas
gracias ago tau dankie शुक्रिया sulpáy tapadh leat
teşekkür ederim bayarlalaa obrigada chnorakaloutioun
sagolun murakoze taiku mahalo didi madloba sukriya obrigado chokrane rahmat dakujem
terima kasih misaotra welain mercé najis tuke اركش
asante grazie nandri 謝謝 mersi sobodi nanni vinaka
mauruuru do raibh maith aoot merci ngiyabonga

Courtesy of hypothyroidmom.com