jh180080-MDJ
森高　外征雄（核融合科学研究所）

Gyrokinetic simulation of divertor heat-load in magnetic fusion devices

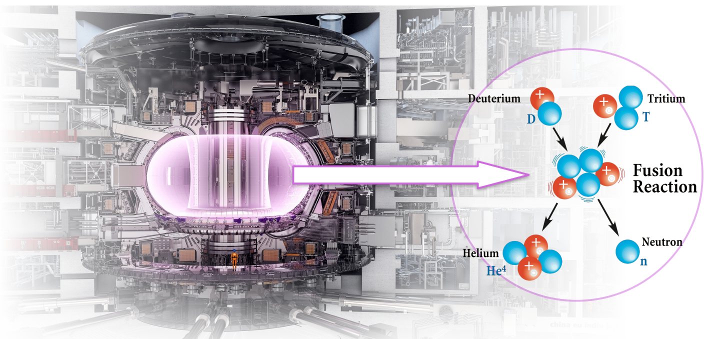
Collaborating Researchers

T. Aoki (GSIC, Tokyo Institute of Technology)
C-S. Chang, S. Ethier, S. Ku, R. Hager and A. Scheinberg (PPPL)
S. Klasky, J. Choi and E. D'Azevedo (ORNL)
E. Yoon (UNIST) Y. Idomura (JAEA)   S. Ishiguro (NIFS)

Summary

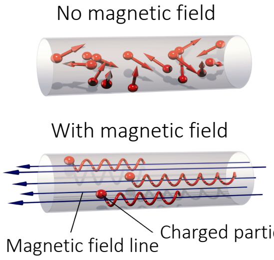
- Gyrokinetic code, XGC, and I/O framework, ADIOS, have been combined for whole device modeling of magnetic fusion devices.
- These will be optimized to cutting edge super computers toward a comparative study of divertor heat load in various fusion devices.

Introduction

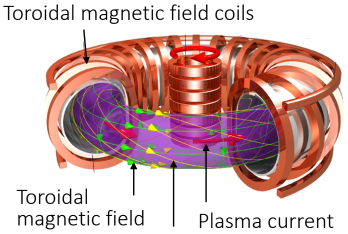


International Thermonuclear Experimental Reactor (ITER) under construction

- Nuclear fusion reactions, e.g., D-T reaction, can be a sustainable energy source to meet world-wide energy demands.
- To produce net power from the reactions, we have to confine the fuels with high temperature (> 10^8 ℃) in the reactor.
- Strong magnetic fields can be employed to confine the fuels in plasma states.
- Torus-type magnetic configurations with twisting field lines have been proposed for the magnetic fusion devices.



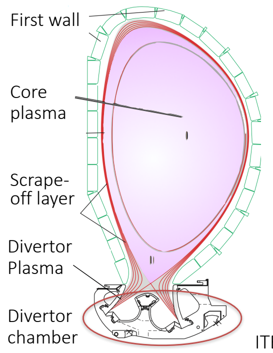
http://iter.rma.ac.de/



Max-Planck-Institut für Plasmaphysik

Motivation

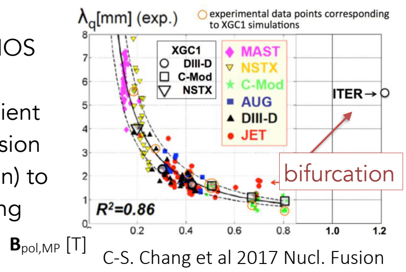
- Precise prediction of divertor heat load by means of whole device kinetic modeling has a critical importance in ITER operation and future reactor designs.
- Robust computational model and large computational resources are required for multi-physics simulation including core and edge regions.



- Core plasma - slow evolution
  - *burning plasma in closed field lines*
  - *nearly equilibrium states*
  - *collisionless / cross-field transport*
  - *wave-particle interaction in turbulence*
- Edge plasma - fast evolution
  - *interface to the wall in open field lines*
  - *highly non-thermal states*
  - *collisional / field-aligned transport*
  - *plasma-wall (neutral) interaction*

ITER Physics Basis Editors et al 1999 Nucl. Fusion

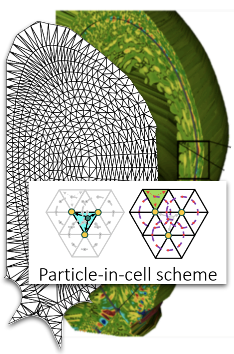
- XGC and ADIOS have been used to estimate the heat-load width in the present Tokamaks in USA and ITER. For the ITER case 90% of TITAN, the world's largest GPU machine, was occupied for a few days.
- We will optimize XGC and ADIOS to the latest GPU machine, TSUBAME3, toward more efficient computations for remaining fusion devices such as JT60-SA (Japan) to understand the size and shaping effects on divertor heat load.



C-S. Chang et al 2017 Nucl. Fusion

X-point Gyrokinetic Code (XGC)

- A gyrokinetic particle-in-cell code designed for whole device modeling of magnetic fusion devices.

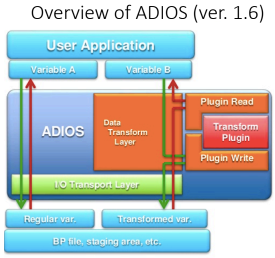


1. Kinetic description of magnetized plasma
2. Hybrid use of marker particle and phase-space grid
   - Low-noise treatment of non-thermal dynamics [1]
   - Fokker-plank and Monte-Carlo approaches for collisional interactions [2]
3. Finite element field solver on unstructured mesh generated based on the structures of field lines and vessel components [3]

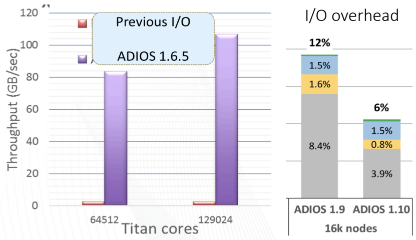
ADaptable I/O System (ADIOS)

- Componentization for fast & scalable I/O framework [4]

Overview of ADIOS (ver. 1.6)



Performance of ADIOS in XGC on TITAN



- Optimal "on-the-fly" data aggregation, relocation and reduction among massive parallel computational, staging and I/O nodes.
- Applications : Large scale computing (1~ 10PB / day for XGC), real-time data analysis, visualization, code coupling and so on

[1] S. Ku et al, JCP (2016) [2] E. Yoon et al, PoP (2014), D. Stotler et al, CSD (2013) [3] F. Zhang et al, Eng. with Computers (2016), PETSc : https://www.mcs.anl.gov/petsc/ [4] https://www.olcf.ornl.gov/center-projects/adios/ [5] S.Klasky, HPC Advisory Council China Workshop (2016)