University Activities 2004 Results and 2005 Plan

Except for

Laser: Prof. Izawa

Plan of new ST device at Kyushu Univ. and Tokyo Univ.:
Prof. Takase

S. Sudo
National Institute for Fusion Science
March 4, 2005

Outlines of General Objectives

- ***Physics Mechanism Investigations*** of **Potential Formation** and **Potential (or Electric Field) Effects** on **Plasma Confinement Improvement.**

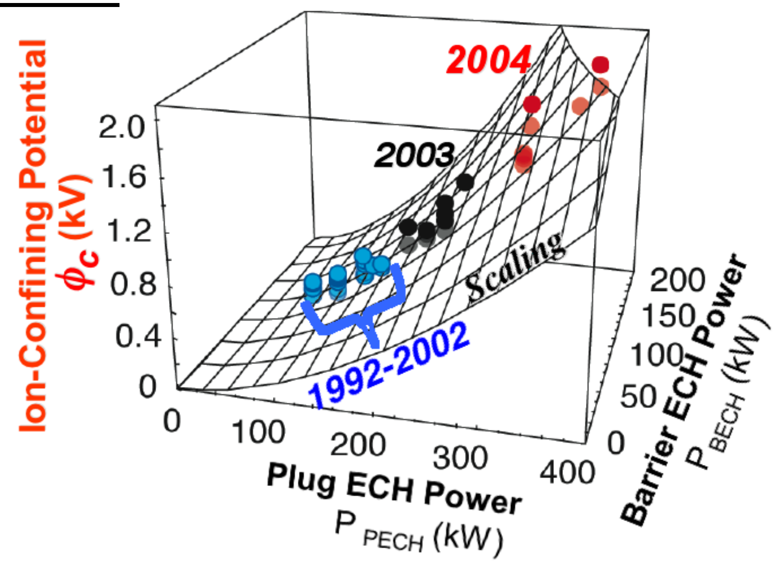
- **Its Extended Generalization covering Physics of H mode and ITB** on the basis of the Effects of ***Radially Sheared Electric-Field*** **(*dE_r/dr*)** *Formation.*

[These Investigations *are* ***based on*** **the Characteristic Advantage of Mirror Devices;** namely, ***the Ease of Control of Radial Potential Profile*** due to Locally Heated *Electron* ***Flow into the Open-Ended Region***.]

Activities and Main Results in 2004

● Objectives :

・Investigations of **Potential Formation** and the **Effects** of **Produced Radially Sheared Electric Field** dE_r/dr.



● Main Results :

[1] **Three-times Progress** in **Ion-Confining Potentials** ϕ_c as compared to ϕ_c **in 1992-2002 is achieved** in the hot-ion mode.

[2] ***Turbulent Vortex Structures*** are observed with a **Weak** E_r **Shear** formation.

[3] ***Suppression of the Turbulent Vortex Structures*** **due to a *Strong*** E_r ***Shear*, dE_r/dr, along with** *Confinement Improvement* in the **transverse direction**.

[4] **Potentials** are Extended along our Proposed **Theoretical Scaling**.

Activities and Main Plans in 2005

● Objectives :

Physics Mechanisms Investigations of **Plasma Confinement** due to **Potential** or **Sheared Electric Field** ***dE_r/dr*** **Formation**.

● Plans and Targets :

(1) ***The first Experiments*** **by the use of Both Plug 500-kW ECH for High Potential Confinement**.

[*No Experiments with both plug ECH over 200 kW through Mirror History*]

(2) **Investigations of the Shear Effects (*dE_r/dr*)** on **the Suppression of Turbulent Vortex-like Phenomena** with **Improved** Confinement in relation to **H-mode and ITB Mechanisms**.

(3) Extension and Verification of **"Our Proposed Theory and Scaling" of *Potential Formation and Confinement***.

(4) **High-power Gyrotron Development** ***for the first Central ECH***.

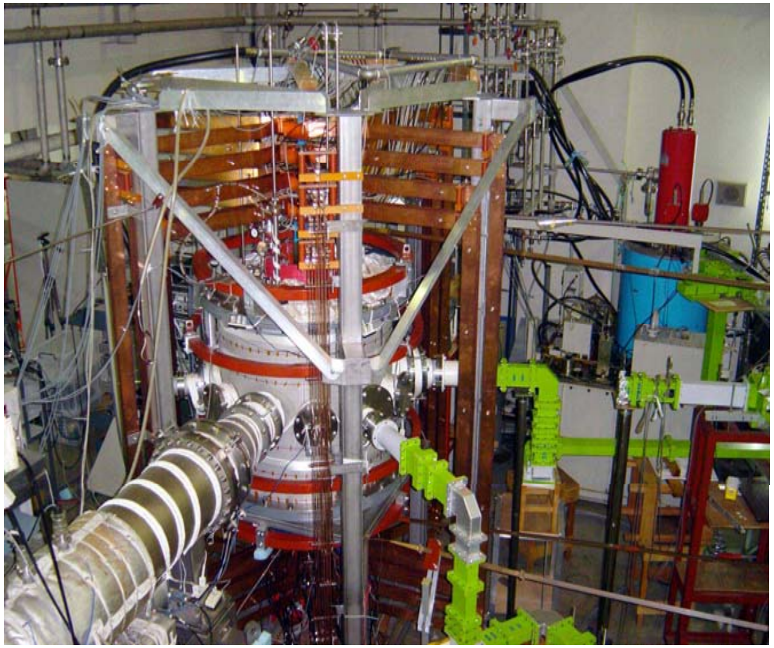
Outline of Low Aspect ratio Torus Experiment

T. Maekawa , *Graduate School of Energy Science, Kyoto University, Japan*

Objective: **Formation of Spherical Tokamak plasma by ECH without central solenoid . Central structure of ST reactor is greatly simplified without Central Solenoid. ECH is potentially an attractive method since plasma initiation, and current ramp-up might be simultaneously realized by injecting microwave power from a small launcher remote from the plasma.** ***Small scale experiments are useful to establish the physical base for formation of ST plasma by ECH , which may encourage larger scale experiments.***

LATE Parameters:

Vacuum vessel (diameter = height = 1m)
Center post (diameter=11.4 cm)
Toroidal coils operation (achieved):
60 kAT, 10 s. or 90 kAT, 0.2 s.
Microwave Power (achieved):
2.45 GHz(10kW, 4s and 30 kW, 2s.)
5.0 GHz (160 kW, 0.06 s.)
Diagnostics:
4mm interferometer (2channels), Video camera, Flux loops, Langmuir probes, Spectrometer, Four SX cameras.



The LATE Devise

Results in 2004

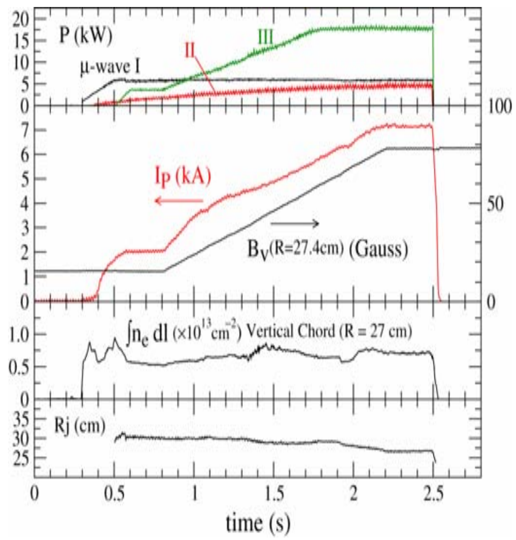
Two Modes of Discharges are Effective for ST formation

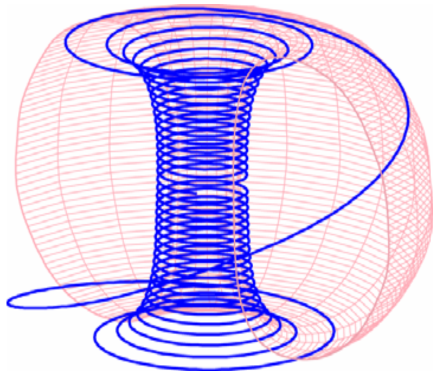
(1) Slow formation with a slow ramp of Bv field.

Ip reaches 7 .2 kA during a 2 seconds discharge by 2.45 GHz 30 kW. Line of magnetic force (blue line) on the last closed flux surface shows the production of a spherical tokamak configuration.

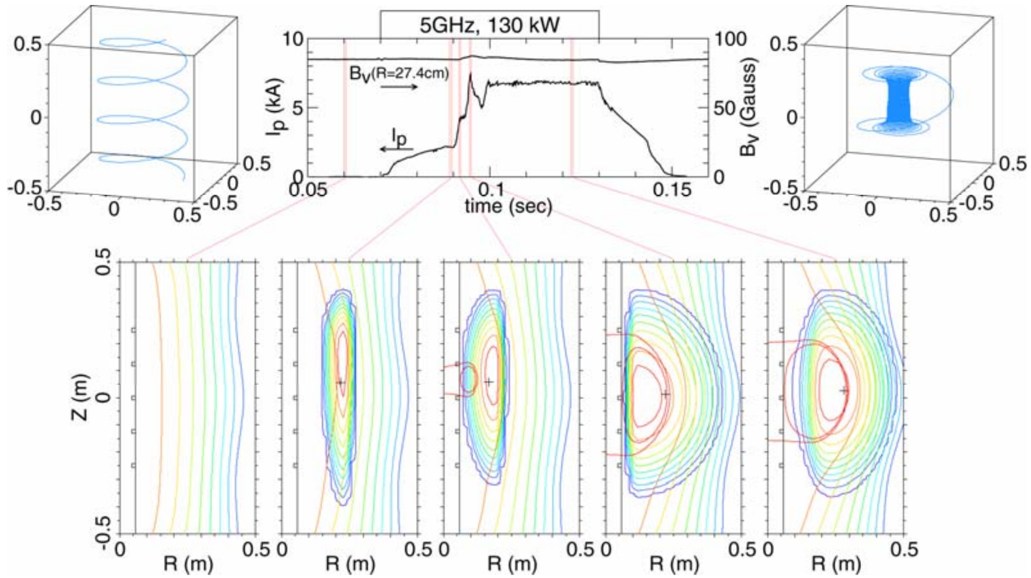
(2) Spontaneous formation under steady Bv field.

Ip up to 7 kA is obtained by a 5 GHz, 130 kW, 60 ms pulse. Closed flux surfaces are formed by spontaneous evolution of plasma current profile under steady Bv field.





Slow Formation



Spontaneous Formation

Plan in 2005

[A] Production and Sustainment of Spherical Tokamak Plasma

- ◎ **Formation of ST by higher microwave power (5 GHz and 2.45 GHz) and at higher toroidal fields (5GHz).**
- ◎ **Realization of diverted discharges for 2.45 GHz slow formation experiments with divertor configuration to reduce impurity out flux.**

[B] Reinforcement of Toroidal Field

- ◎ **Reinforcement of toroidal field coil for higher current operation.**

[C] Diagnostics

- ◎ **Measurement of Electron Velocity Distribution by Soft X-ray and Hard X-ray PHA.**
- ◎ **Equipment of imaging spectroscopy at visible light range and SX-CT with 4 SX cameras.**

[D] Microwave Power Source and Injection System for ECH

- ◎ **<u>Reinforcement of 5GHz ECH system (200 kW, 100msec)</u> and 2.45 GHz ECH system (50 kW, 10 sec) for higher currents.**

Overview of FRC Plasma Experiment (FY2004)

Plasma Experiment

- ***Comparison of H-NB and He-NB injection effects on FIX-FRC plasma***

  Confinement times elongated by H-NB injection.
  These elongations are consistent with the empirical scaling law.

- ***Formation ans sustainment of FRC plasma using RMF(Rotating Magnetic Field)***

  Application of RMF to pre-ionized gas inside SUS chamber.

  Construction of small FRC apparatus for process application.

- ***Experimental study of equibrium of high-beta plasma***

  Thomson scattering measurement of radial distribution of electron temperature.
  Small magnetic probe array to measure internal Bz profile .

Development Research

- ***Measurement of temperature and speed of ion using ICCD camera***

  Mutipoint measurements with optical fibers.

Research Issues (FY2005)

Plasma Experiment

- ***Investagation of FRC plasma formed by RMF***
  - ***Large volume plasma is formed at FIX apparatus***

    Examination of influences of RMF parameters (frequency, magnitude) to equilibrium of formed FRC.
  - ***Small size plasma for process application***

    Steady plasma with small size is formed to form thin film with various parameters.

Development Research

- ***Development of soft X-ray tomography system***

  Research for dynamic change of internal structure using 2 CT systems.

Application Research

- ***Sophisticated Micro Tokamak for application of process plasma***

  Reformation of surface and formation of thin film by Tokamak plasma with good confinement and controllable property.

Optimization Research for Helical-axis Heliotron

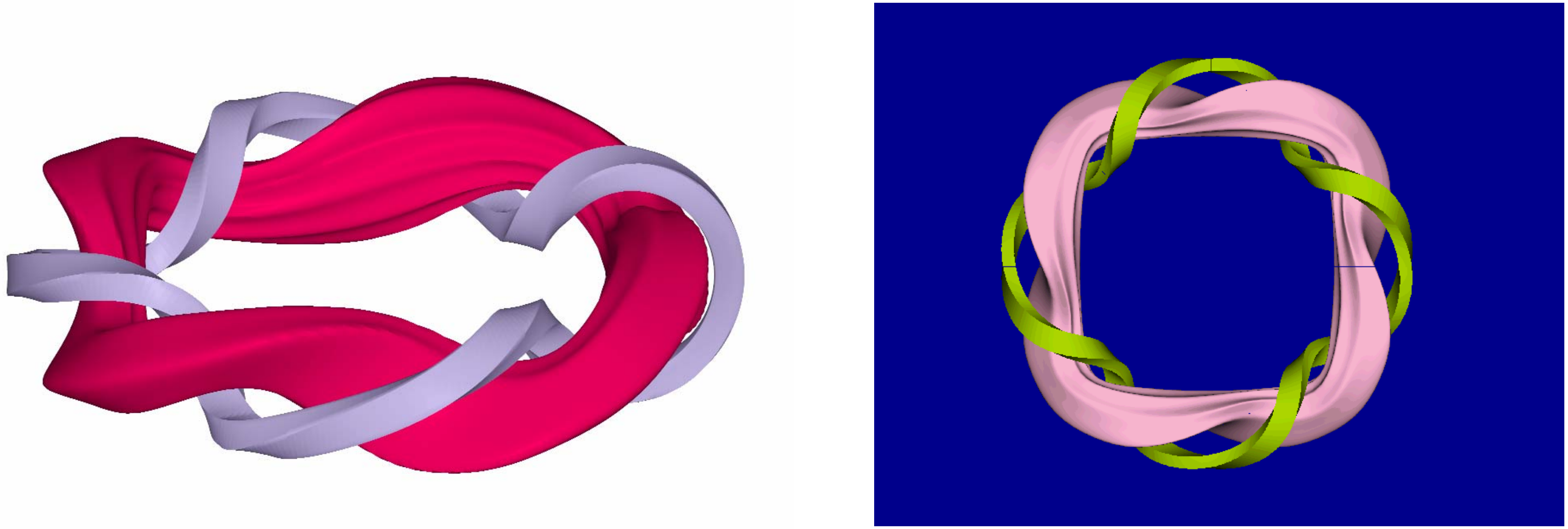
Helical-axis heliotron study is an essential part of an advanced stellarator/heliotron research and can contribute to the new concept exploration experiments.

Critical issues:

(1) Better particle confinement
(2) Higher beta (MHD stability)
(3) particle and heat control (divertor)

Proposed program:

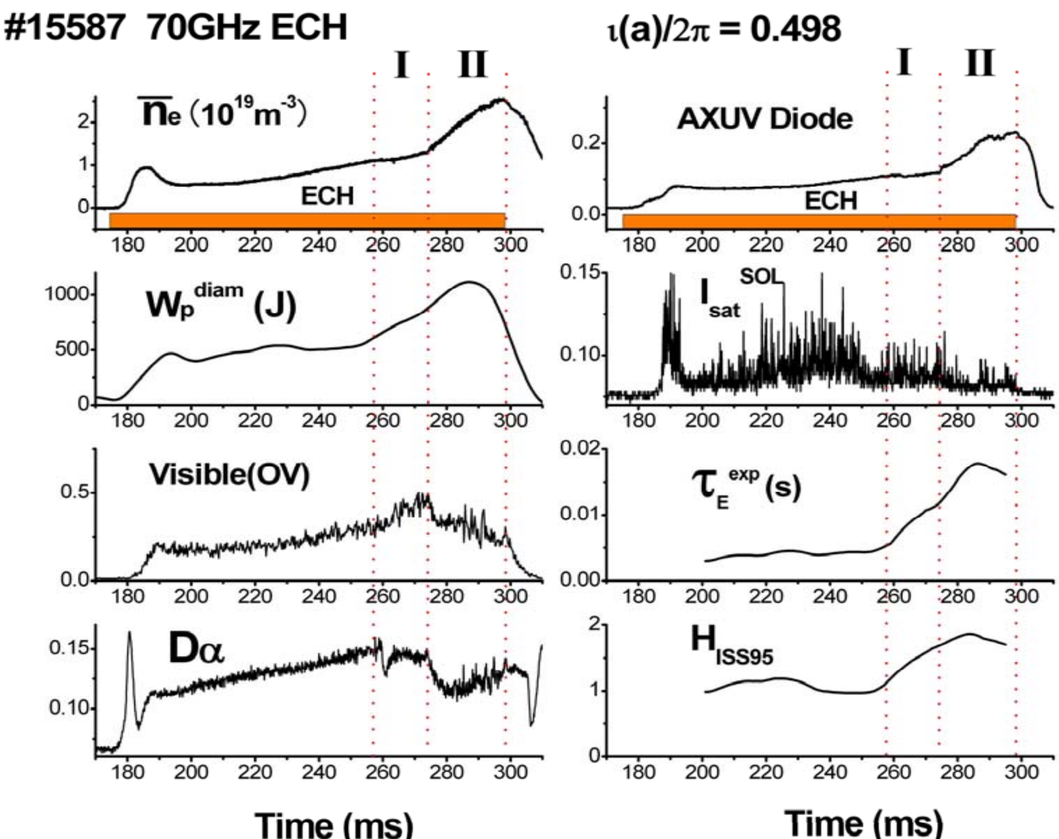
Development of a currentless quasi-isodynamic configuration with continuous helical windings

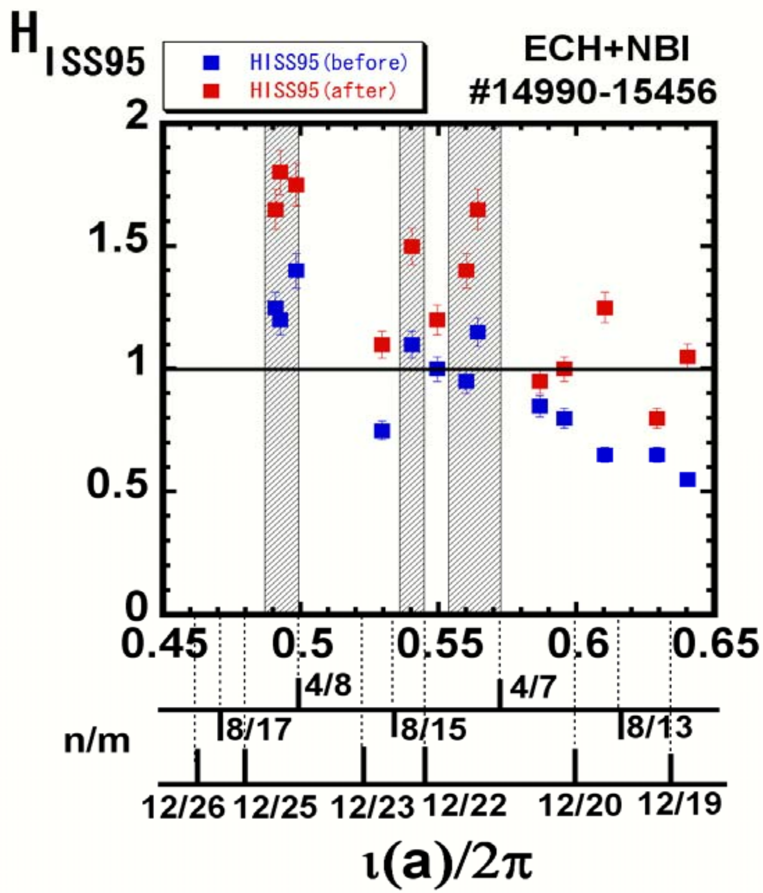


A L=1 helical coil and a plasma of Heliotron J (Oblique view and top view)

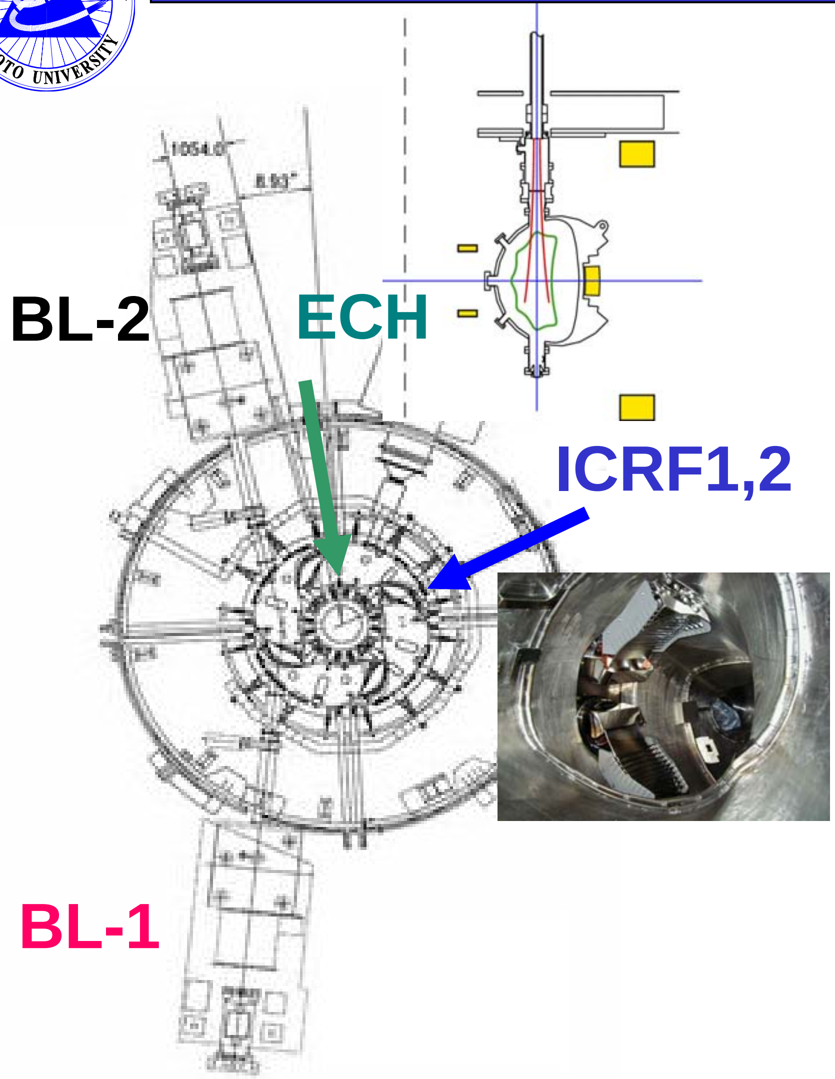
Study of Improved Confinement in Various Iota Configurations

- **The large improvement factor of confinement (1.3<H_{ISS95}<1.8) is achieved in the neighborhood of major natural resonances of n/m=4/8, 4/7 and 12/22.**
- **The region where the improvement factor stays near unity, is also found. In that region, change of Hα at the transition is slow comparing with that of high improvement case.**





Optimization Studies of Field Configuration in Extended Parameter Space



In order to progress studies of **confinement and MHD stability** of Heliotron J as an advanced helical system, the campaign of FY 2005 will be carried out focusing on the following subjects by using additional **heating devices (one NBI beam line, BL-1 and one ICRF antenna, ICRF2).**

- Production of higher-pressure plasmas
- Effective bulk and minority ion heating and the analysis of confinement of fast ions
- H-mode physics study
- Toroidal current control
- Global Alfven eigenmode study
- SOL particle and heat analysis depending on the edge field topology
- Impurity transport and shielding studies based on plasma-surface interactions