ITPA Topical Group Meeting
on Steady State and Energetic Particles
St. Petersburg, Russia
2003-07-15

Present Status of ITER Scenario Development Code in Japan

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in collaboration with

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- Transport Simulation by TASK/TR
- ECCD Analysis by TASK/WR+FP
- Summay

Integrated Code Development

- **Integrated Burning Plasma Simulation Initiative**
- **Core code: Tokamak Transport Code**
  - TOPICS: JAERI Naka
  - TASK: Kyoto Univ
- **Present status and to do's in 2003**
  - Benchmark test between TOPICS and TASK
  - Comparison with JT-60U experimental data (transport models)
  - Comparison with ITPA profile database
  - Preliminary simulation of ITER scenario

Objectives

Integrated Simulation of Burning Plasmas

- **Framework**
  for collaboration of various plasma simulation codes
- **New physics**
  in interaction between phenomena with different time and space scales
- **Advanced technique**
  of computer science, network computing and visualization

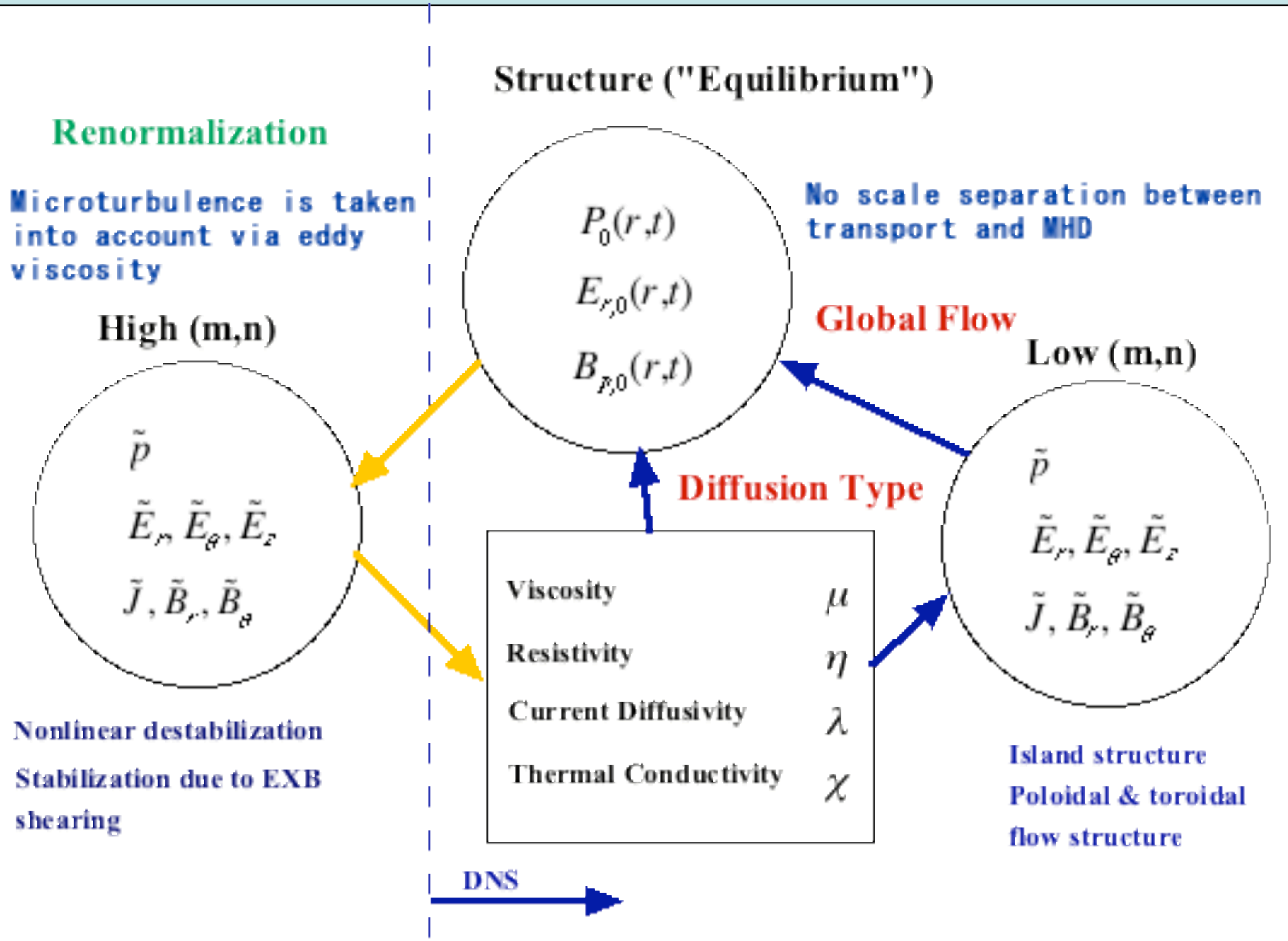
Framework

- **Core Code**
  - Based on Extended 1.5D Transport Code
    - TASK/EQ, PL, TR, DP, WR, WM, FP (Kyoto U)
  - Analysis of Experimental Data (JT-60, ITPA)
  - Predictive Simulation for Burning Plasmas
- **Common Interface for Data Transfer**
  - Working group for interface specification
  - Interface with existing codes and modules
    - Topics (JAERI), NTCC (USA)
  - Interface with experimental data base
    - MDSPlus
- **Development and Enhancement of Modules**
- **Elaborated User Interface**

New Physics

- **Transport-MHD Hierarchical Model**
  - Interaction between MHD and transport phenomena
  - Consistent modeling with plasma flow
  - Transport in the presence of magnetic island
- **Core-SOL Interface**
  - Modeling of edge transport barrier
  - Two-dimensional transport in edge region
- **Interaction with Energetic Particles**

Transport-MHD Model



Advanced Technique

- **Parallel Computing**
  - PC cluster
  - Vector-parallel super computer
- **Network Computing**
  - GRID computing
  - Effective use of computer resources
- **Visualization**
  - Parallel visualization
  - VisiGRID

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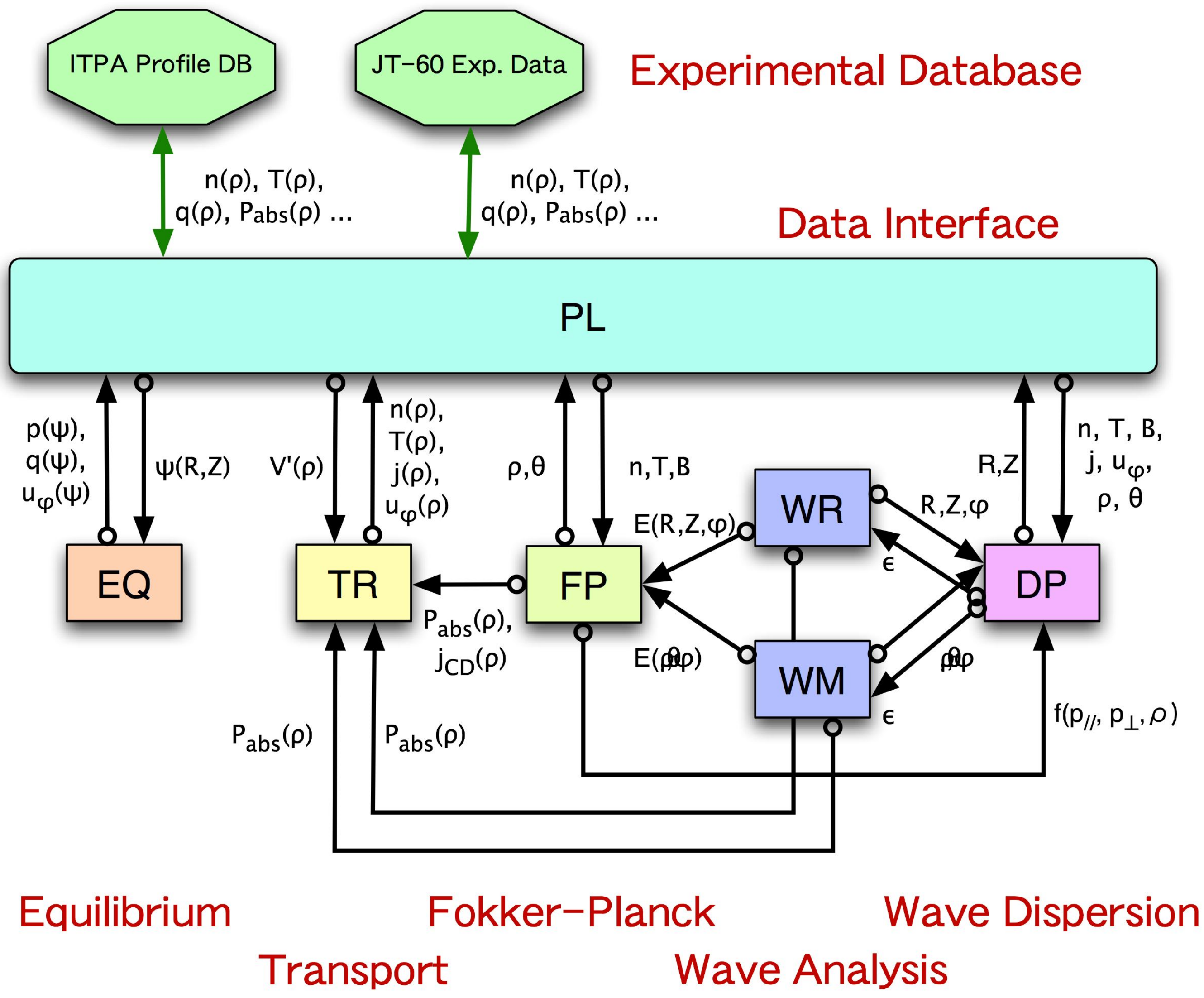
Structure of TASK code



Integrated Code Development

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CDBM Turbulence Model

- **Marginal Stability Condition** $(\gamma = 0)$

$$\chi_{\rm TB} = F(s, \alpha, \kappa, \omega_{\rm E1})\,\alpha^{3/2}\,\frac{c^2}{\omega_{\rm pe}^2}\,\frac{v_{\rm A}}{qR}$$

Magnetic shear $\quad s \equiv \dfrac{r}{q}\dfrac{{\rm d}q}{{\rm d}r}$

Pressure gradient $\quad \alpha \equiv -q^2 R \dfrac{{\rm d}\beta}{{\rm d}r}$

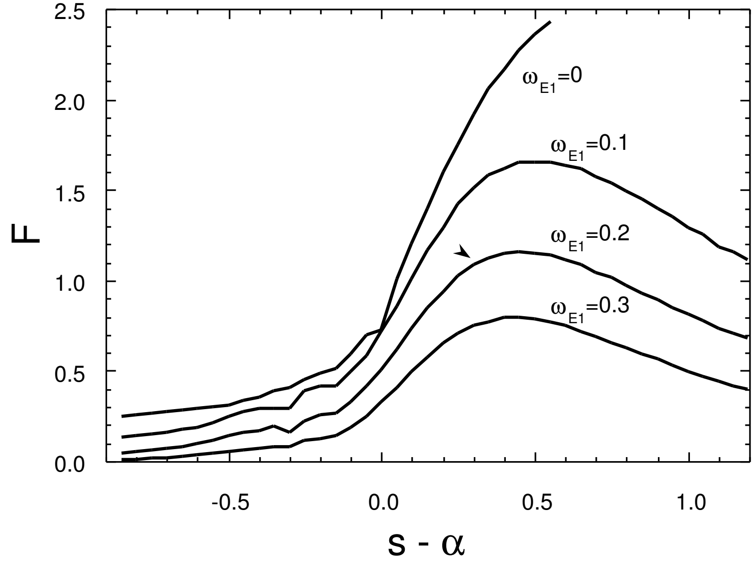
Magnetic curvature $\quad \kappa \equiv -\dfrac{r}{R}\left(1 - \dfrac{1}{q^2}\right)$

$E \times B$ **rotation shear** $\quad \omega_{\rm E1} \equiv \dfrac{r^2}{s v_{\rm A}}\dfrac{{\rm d}}{{\rm d}r}\dfrac{E}{rB}$

- **Weak and negative magnetic shear,**
  Shafranov shift and
  $E \times B$ **rotation shear**

reduce thermal diffusivity.

$s - \alpha$ dependence of $F(s, \alpha, \kappa, \omega_{\rm E1})$



Fitting Formula

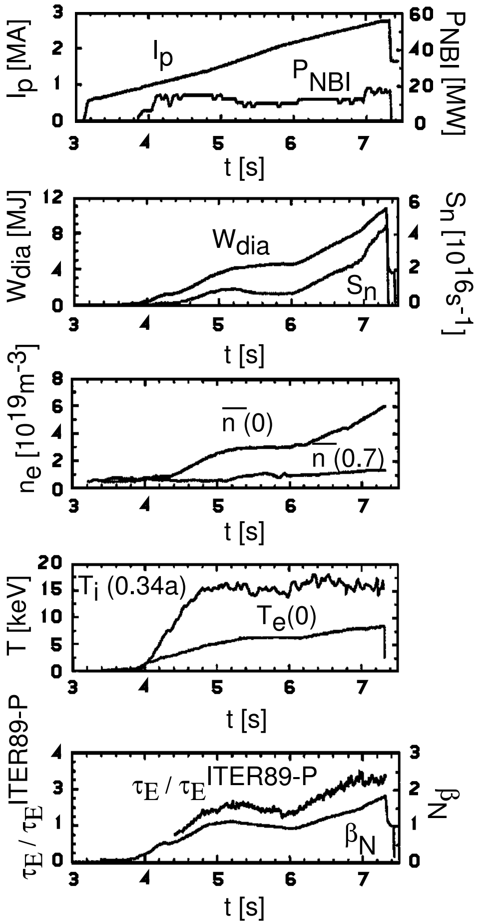
$$F = \begin{cases} \dfrac{1}{1 + G_1 \omega_{\rm E1}^2}\,\dfrac{1}{\sqrt{2(1-2s')(1-2s'+3s'^2)}} & \text{for}\quad s' = s - \alpha < 0 \\[2ex] \dfrac{1}{1 + G_1 \omega_{\rm E1}^2}\,\dfrac{1 + 9\sqrt{2}s'^{5/2}}{\sqrt{2}(1-2s'+3s'^2+2s'^3)} & \text{for}\quad s' = s - \alpha > 0 \end{cases}$$

Simulation of ITB Formation

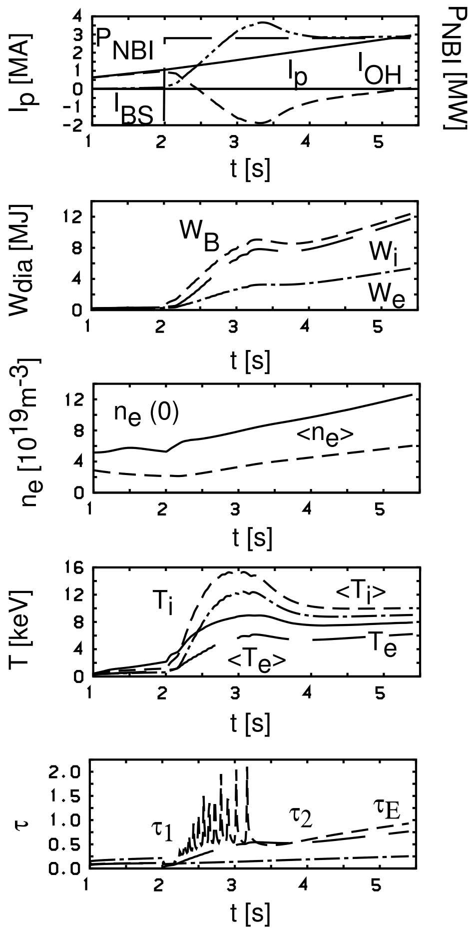
Comparison with JT-60U experimental data: on-going

Time Evolution

JT-60U EXP

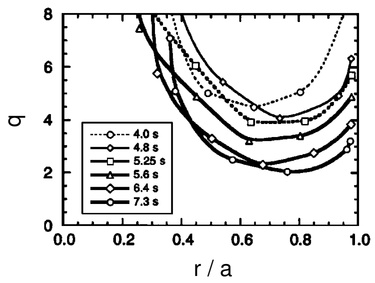


Simulation

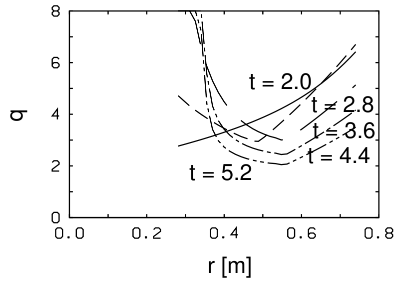


Safety Factor

JT-60U EXP

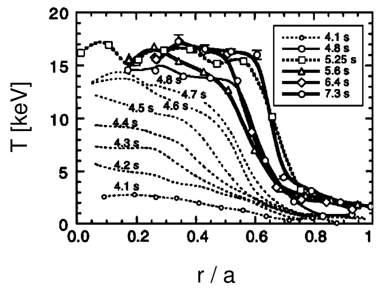


Simulation

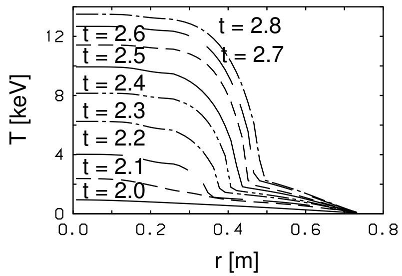


Ion Temperature

JT-60U EXP

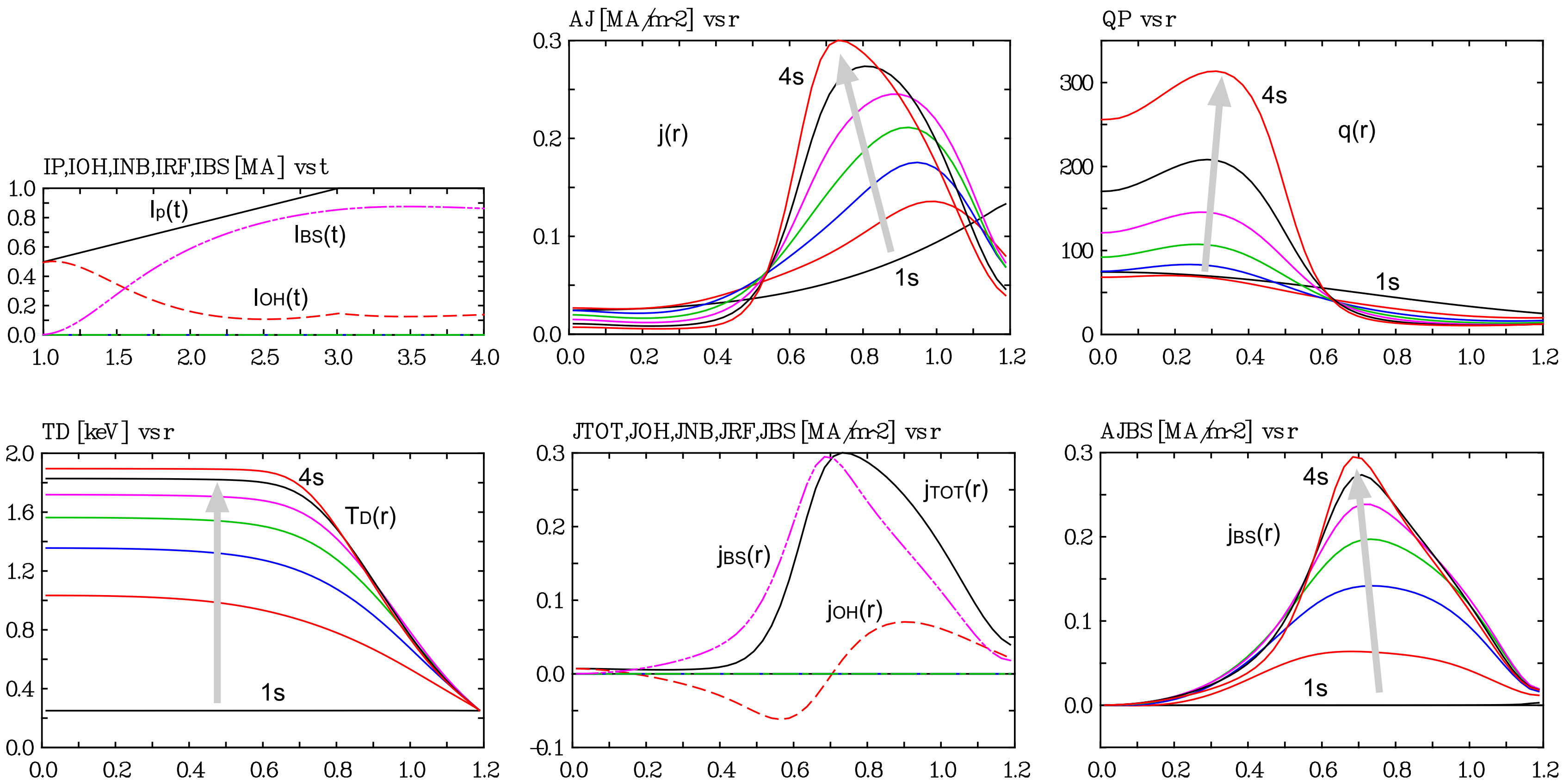


Simulation



Simulation of Current Hole Formation

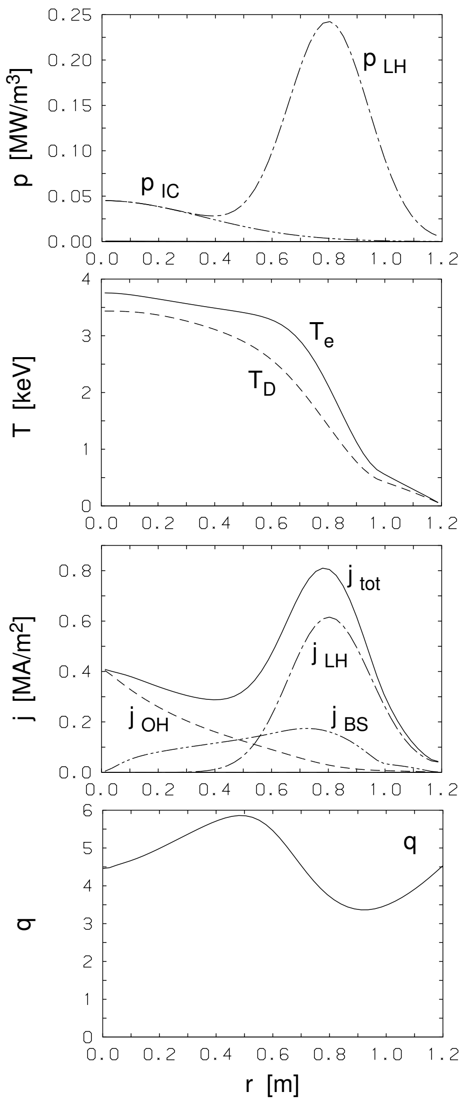
- Current ramp up: $I_\mathrm{p} = 0.5 \longrightarrow 1.0\,\mathrm{MA}$
- Moderate heating: $P_\mathrm{H} = 5\,\mathrm{MW}$
- **Current hole** is formed.
- The formation is sensitive to the edge temperature.



Sustainment of Negative Shear Configuration

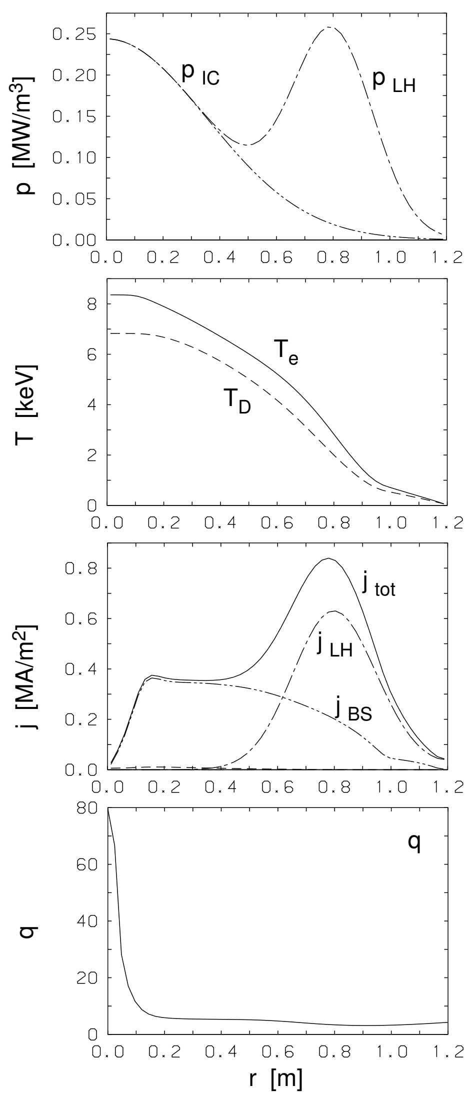
Off-Axis CD ($H \simeq 1.2$)

$P_{\rm LH}/P_{\rm IC} = 12/2\,{\rm MW}$



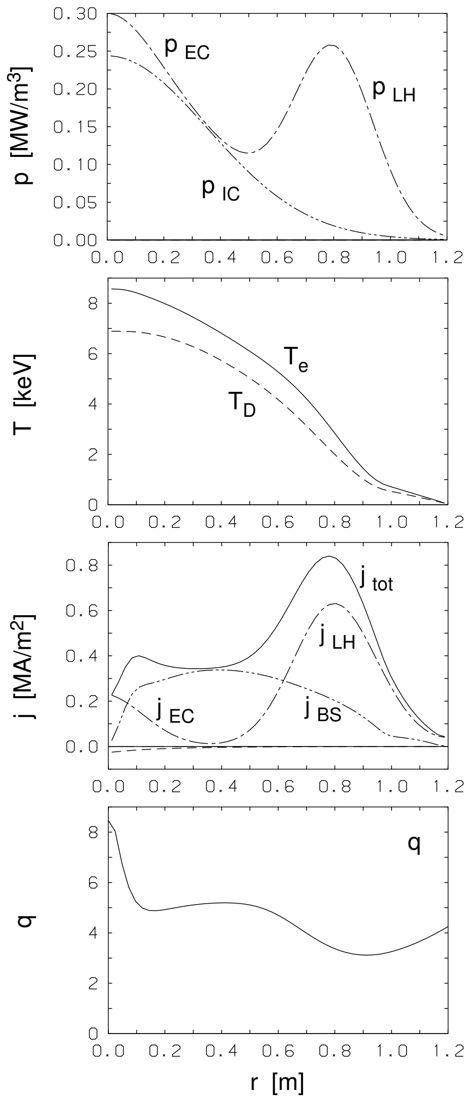
Full CD ($H \simeq 1.6$)

$P_{\rm LH}/P_{\rm IC} = 12/10.8\,{\rm MW}$



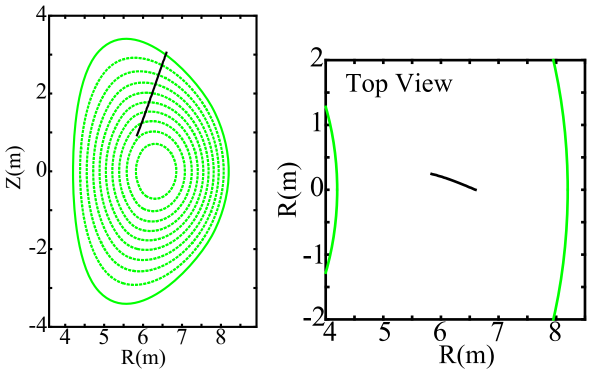
Full CD + On-Axis CD

$P_{\rm LH}/P_{\rm IC}/P_{\rm EC} = 12/10.8/0.2\,{\rm MW}$



Analysis of ECCD by TASK Code

Poloidal angle	70°
Toroidal angle	20°
Initial beam radius	0.05 m
Initial beam curvature	2 m

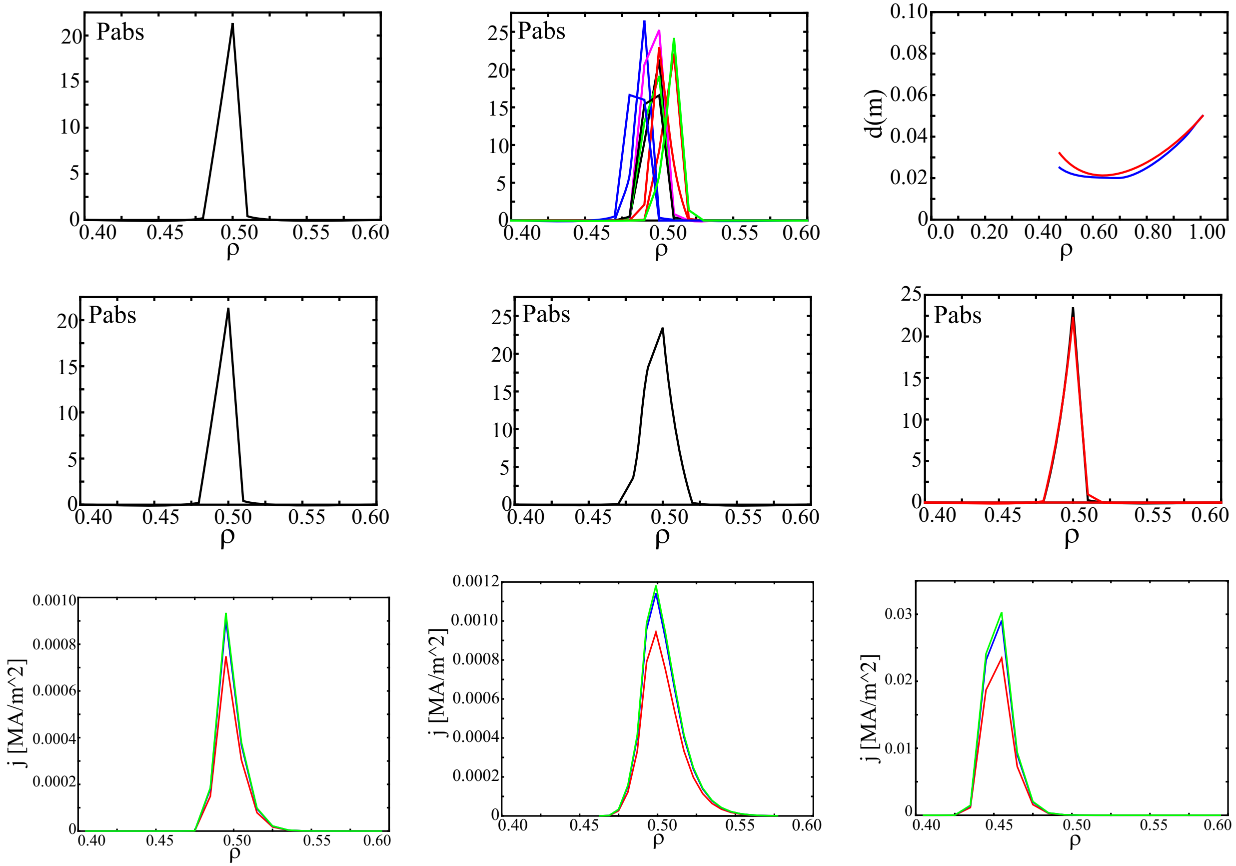


One Ray | **Nine Rays** | **Beam Tracing**

Ray/Beam Profile

P_{abs} **Profile**

j_{CD} **Profile**



Summary

- Integrated simulation codes, TOPICS and TASK, are under development. Benchmark test between the codes and comparison with JT-60U data and ITPA profile database in on-going.
- Improvement of physics models, such as interaction between transport and MHD phenomena, and transport model, is also going in parallel.
- Ballooning-type transport model which depends on $s - \alpha$ reproduces ITB and current hole. The formation of the current hole is sensitive to the edge temperature through the current penetration time scale. Initial currnet profile control by localized edge heating may be possible.
- ECCD in ITER configuration was carried out by beam tracing method. Result of benchmark calculation will be reported within a month.