US-Japan JIFT Workshop on
Integrated Modeling on Fusion Plasmas
ORNL, Oak Ridge, USA
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Recent Progress in Integrate Code TASK

— Integrated Modeling of —
– RF Heating and Current Drive in Tokamaks —

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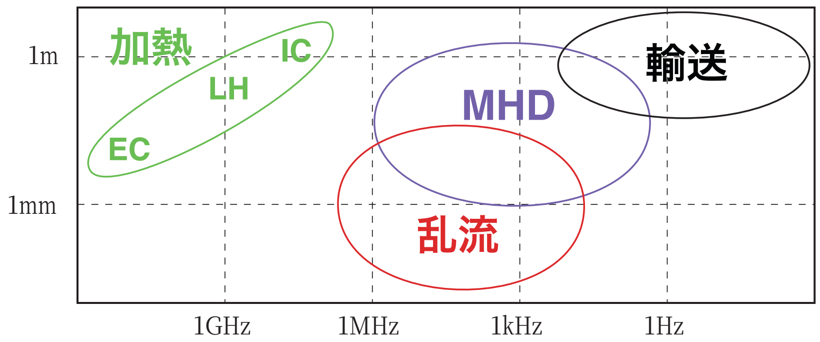
Outline

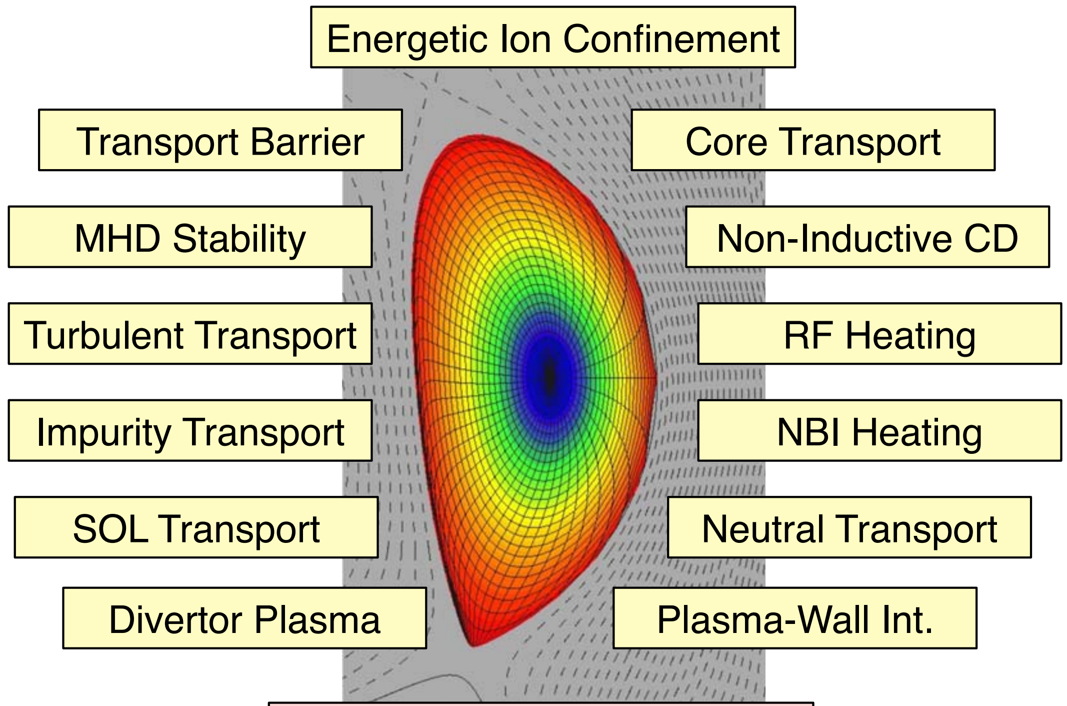
- Integrated Simulation of Fusion Plasmas
- Progress of TASK Code Development
- Self-Consistent Analysis of RF Heating and Current Drive
- Full Wave Analysis Including FLR Effects
- Future Plan of Integrated Modeling
- Summary

Burning Plasma Simulation

Broad time scale:
100GHz ~ 1000s

Broad Spatial scale:
10 μm ~ 10m



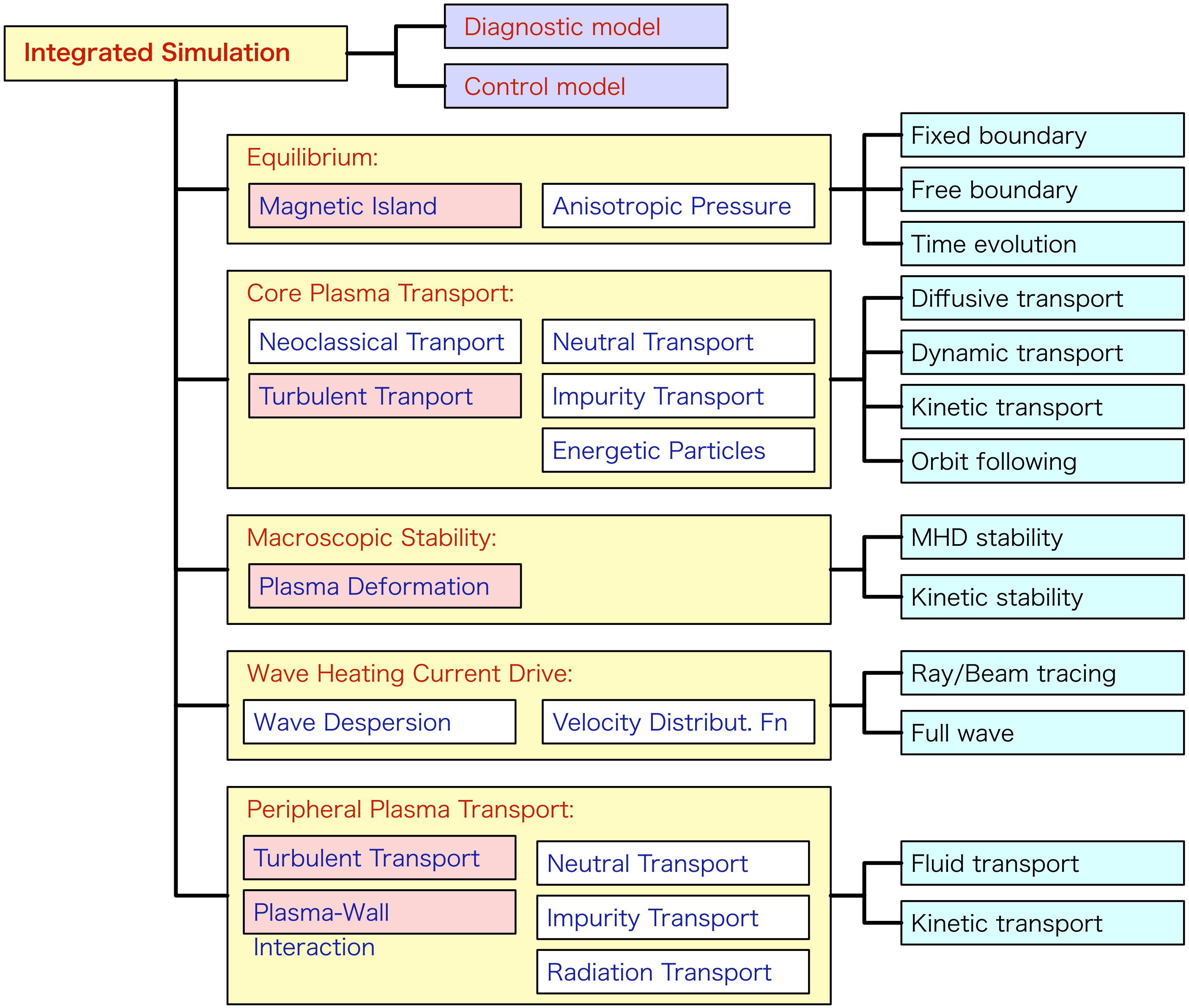


Blanket, Neutronics, Tritium,
Material, Heat and Fluid Flow

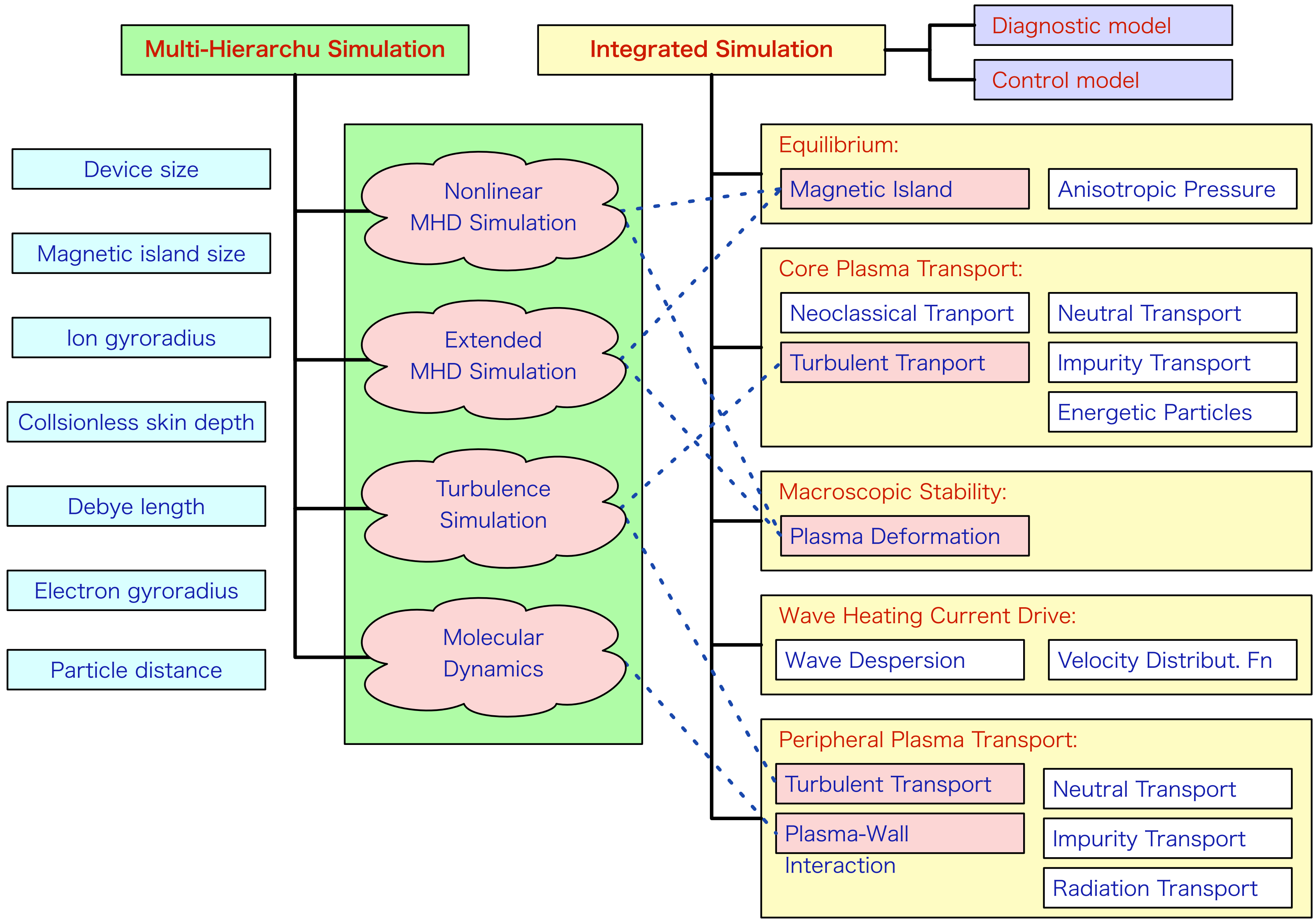
One simulation code never covers all range.

Integrated simulation combining modeling codes interacting each other

Integrated Tokamak Simulation

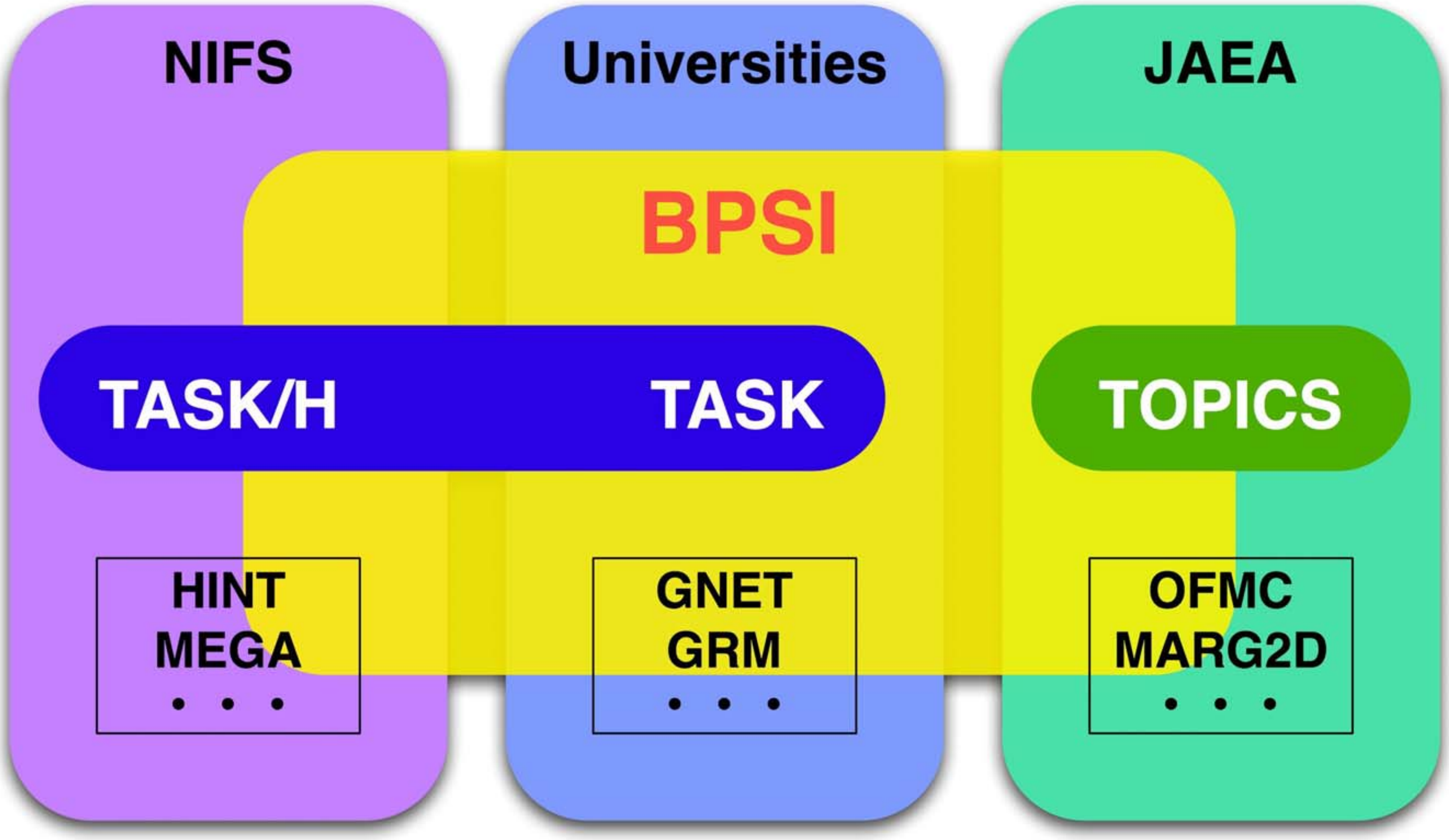


Multi-Hierarchy and Integrated Approaches



BPSI: Burning Plasma Simulation Initiative

Integrated code: TASK and TOPICS



TASK Code

- **Transport Analysing System for TokamaK**
- **Features**
  - **Core of Integrated Modeling Code in BPSI**
    - **Modular structure**
    - **Reference data interface and standard data set**
    - **Uniform user interface**
  - **Various Heating and Current Drive Scheme**
  - **High Portability**
  - **Development using CVS** (Concurrent Version System)
  - **Open Source**: **http://bpsi.nucleng.kyoto-u.ac.jp/task/**)
  - **Parallel Processing using MPI Library**
  - **Extension to Toroidal Helical Plasmas**

Recent Progress of TASK

- **Fortran95**
  - **TASK V1.0**: Fortran95 compiler required (g95, pgf95, xlf95, ifort,...)
  - **TASK/EQ, TASK/TR**: Fortran95 (Module, Dynamic allocation)
- **Module structure**
  - **Standard dataset**: partially implemented
  - **Data exchange interface**: prototype
  - **Execution control interface**: prototype
- **New module**: from TOPICS **by M. Azumi**
  - **TOPICS/EQU**: Free boundary 2D equilibrium
  - **TOPICS/NBI**: Beam deposition + 1D Fokker-Planck
  - **MHD stability component**: coming
- **Self-consistent wave analysis**
- **Dynamic transport analysis**: **by M. Honda**

Modules of TASK

EQ	**2D Equilibrium**	Fixed/Free boundary, Toroidal rotation
TR	**1D Transport**	Diffusive transport, Transport models
WR	**3D Geometr. Optics**	EC, LH: Ray tracing, Beam tracing
WM	**3D Full Wave**	IC, AW: Antenna excitation, Eigenmode
FP	**3D Fokker-Planck**	Relativistic, Bounce-averaged
DP	**Wave Dispersion**	Local dielectric tensor, Arbitrary $f(\boldsymbol{v})$
PL	**Data Interface**	Data conversion, Profile database
LIB	**Libraries**	LIB, MTX, MPI

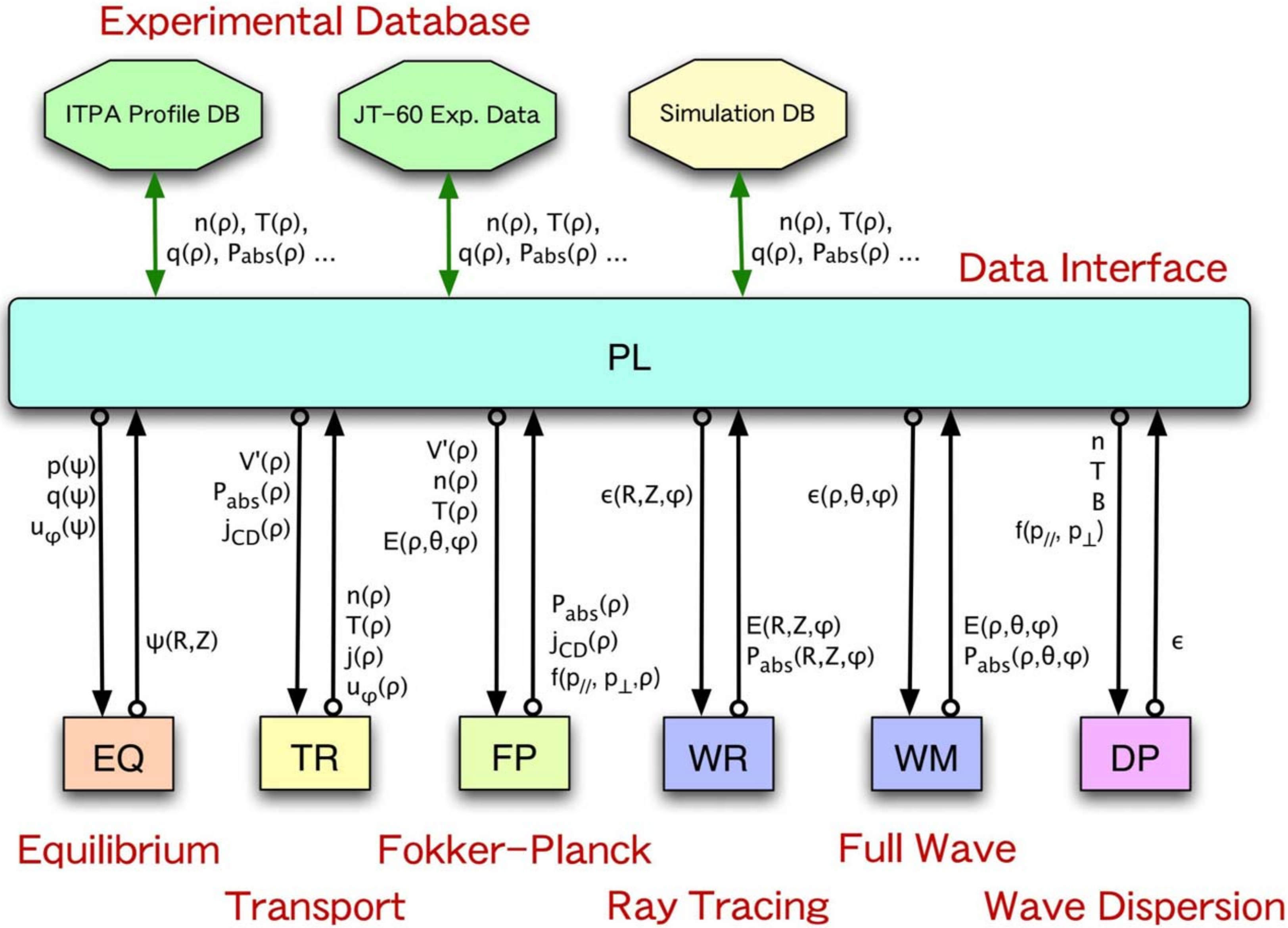
Under Development

TX	Transport analysis including plasma rotation and E_r

Collaboration with TOPICS

EQU	Free boundary equilibrium
NBI	NBI heating

Structure of TASK



Inter-Module Collaboration Interface: TASK/PL

- **Role of Module Interface**
  - **Data exchange between modules**:
    - **Standard dataset**: Specify set of data (cf. ITPA profile DB)
    - **Specification of data exchange interface**: initialize, set, get
  - **Execution control**:
    - **Specification of execution control interface**: initialize, setup, exec, visualize, terminate
    - **Uniform user interface**: parameter input, graphic output
- **Role of data exchange interface: TASK/PL**
  - **Keep present status of plasma and device**
  - **Store history of plasma**
  - **Save into file and load from file**
  - **Interface to experimental data base**

Standard Dataset (interim)

Shot data

Machine ID, Shot ID, Model ID

Device data: (Level 1)

RR	R	m	Geometrical major radius
RA	a	m	Geometrical minor radius
RB	b	m	Wall radius
BB	B	T	Vacuum toroidal mag. field
RKAP	κ		Elongation at boundary
RDLT	δ		Triangularity at boundary
RIP	I_p	A	Typical plasma current

Equilibrium data: (Level 1)

PSI2D	$\psi_\mathrm{p}(R,Z)$	Tm^2	2D poloidal magnetic flux
PSIT	$\psi_\mathrm{t}(\rho)$	Tm^2	Toroidal magnetic flux
PSIP	$\psi_\mathrm{p}(\rho)$	Tm^2	Poloidal magnetic flux
ITPSI	$I_\mathrm{t}(\rho)$	Tm	Poloidal current: $2\pi B_\phi R$
IPPSI	$I_\mathrm{p}(\rho)$	Tm	Toroidal current
PPSI	$p(\rho)$	MPa	Plasma pressure
QINV	$1/q(\rho)$		Inverse of safety factor

Metric data

1D: $V'(\rho)$, $\langle\nabla V\rangle(\rho)$, $\cdots$

2D: g_{ij}, $\cdots$

3D: g_{ij}, $\cdots$

Fluid plasma data

NSMAX	s		Number of particle species
PA	A_s		Atomic mass
PZ0	Z_{0s}		Charge number
PZ	Z_s		Charge state number
PN	$n_s(\rho)$	m^3	Number density
PT	$T_s(\rho)$	eV	Temperature
PU	$u_{s\phi}(\rho)$	m/s	Toroidal rotation velocity
QINV	$1/q(\rho)$		Inverse of safety factor

Kinetic plasma data

FP	$f(p,\theta_p,\rho)$		momentum dist. fn at $\theta = 0$

Dielectric tensor data

CEPS	$\overleftrightarrow{\epsilon}(\rho,\chi,\zeta)$		Local dielectric tensor

Full wave field data

CE	$\boldsymbol{E}(\rho,\chi,\zeta)$	V/m	Complex wave electric field
CB	$\boldsymbol{B}(\rho,\chi,\zeta)$	$\mathrm{Wb/m}^2$	Complex wave magnetic field

Ray/Beam tracing field data

RRAY	$R(\ell)$	m	R of ray at length ℓ
ZRAY	$Z(\ell)$	m	Z of ray at length ℓ
PRAY	$\phi(\ell)$	rad	ϕ of ray at length ℓ
CERAY	$\boldsymbol{E}(\ell)$	V/m	Wave electric field at length ℓ
PWRAY	$\boldsymbol{P}(\ell)$	W	Wave power at length ℓ
DRAY	$\boldsymbol{d}(\ell)$	m	Beam radius at length ℓ
VRAY	$\boldsymbol{v}(\ell)$	1/m	Beam curvature at length ℓ

Data Exchange Interface

- **Data structure**: **Derived type** (Fortran95): structured type

	time	`plasmaf%time`
	number of grid	`plasmaf%nrmax`
e.g.	square of grid radius	`plasmaf%s(nr)`
	plasma density	`plasmaf%data(nr)%pn`
	plasma temperature	`plasmaf%data(nr)%pt`

- **Program interface**

	Initialize	`bpsd_init_data(ierr)`
e.g.	**Set data**	`bpsd_set_data('plasmaf',plasmaf,ierr)`
	Get data	`bpsd_get_data('plasmaf',plasmaf,ierr)`

- **Other functions**:
  - Save data into a file, Load data from a file, Plot data

Execution Control Interface

- **Example for TASK/TR**

`TR_INIT`	Initialization (Default value)	`BPSX_INIT('TR')`
`TR_PARM(ID,PSTR)`	Parameter setup (Namelist input)	`BPSX_PARM('TR',ID,PSTR)`
`TR_SETUP(T)`	Profile setup (Spatial profile, Time)	`BPSX_SETUP('TR',T)`
`TR_EXEC(DT)`	Exec one step (Time step)	`BPSX_EXEC('TR',DT)`
`TR_GOUT(PSTR)`	Plot data (Plot command)	`BPSX_GOUT('TR',PSTR)`
`TR_SAVE`	Save data in file	`BPSX_SAVE('TR')`
`TR_LOAD`	load data from file	`BPSX_LOAD('TR')`
`TR_TERM`	Termination	`BPSX_TERM('TR')`

- **Module registration**

```
TR_STRUCT%INIT=TR_INIT
TR_STRUCT%PARM=TR_PARM
TR_STRUCT%EXEC=TR_EXEC
   ...
BPSX_REGISTER('TR',TR_STRUCT)
```

Example of data structure: plasmaf

```
type bpsd_plasmaf_data
   real(8) :: pn      ! Number density [m^-3]
   real(8) :: pt      ! Temperature [eV]
   real(8) :: ptpr    ! Parallel temperature [eV]
   real(8) :: ptpp    ! Perpendicular temperature [eV]
   real(8) :: pu      ! Parallel flow velocity [m/s]
end type bpsd_plasmaf_data
type bpsd_plasmaf_type
   real(8) :: time
   integer :: nrmax      ! Number of radial points
   integer :: nsmax      ! Number of particle species
   real(8), dimension(:), allocatable :: s
                         ! (rho^2) : normarized toroidal flux
   real(8), dimension(:), allocatable :: qinv
                         ! 1/q : inverse of safety factor
   type(bpsd_plasmaf_data), dimension(:,:), allocatable :: data
end type bpsd_plasmaf_type
```

Examples of sequence in a module

- **TR_EXEC(dt)**

```
call bpsd_get_data('plasmaf',plasmaf,ierr)
call bpsd_get_data('metric1D',metric1D,ierr)
local data <- plasmaf,metric1D
advance time step dt
plasmaf <- local data
call bpsd_set_data('plasmaf',plasmaf,ierr)
```

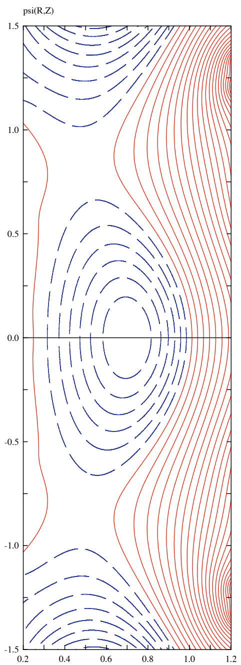
- **EQ_CALC**

```
call bpsd_get_data('plasmaf',plasmaf,ierr)
local data <- plasmaf
calculate equilibrium
update plasmaf
call bpsd_set_data('plasmaf',plasmaf,ierr)
equ1D,metric1D <- local data
call bpsd_set_data('equ1D,equ1D,ierr)
call bpsd_set_data('metric1D',metric1D,ierr)
```

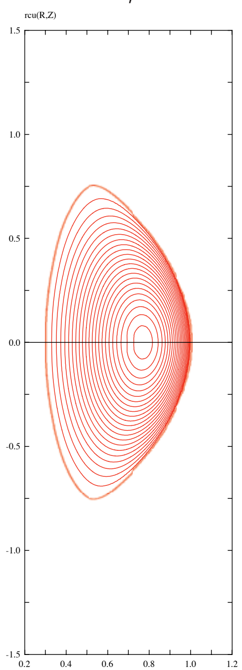
Example: Coupling of TASK/TR and TOPICS/EQU

- **TOPICS/EQU**: Free boundary 2D equilibrium
- **TASK/TR** Diffusive 1D transport (CDBM + Neoclassical)
- **QUEST** parameters:
  - $R = 0.64\,\mathrm{m}$, $a = 036\,\mathrm{m}$, $B = 0.64\,\mathrm{T}$, $I_\mathrm{p} = 300\,\mathrm{kA}$, OH+LHCD

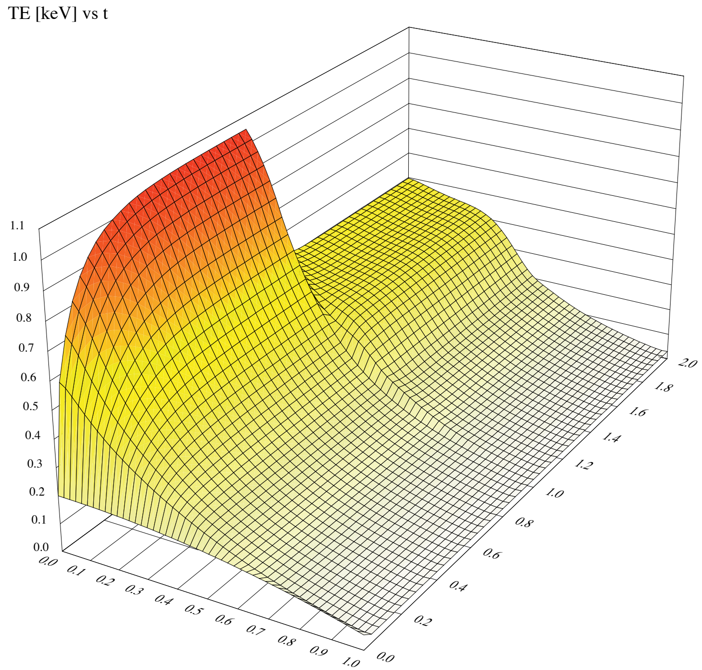
$\psi_\mathrm{p}(R, Z)$



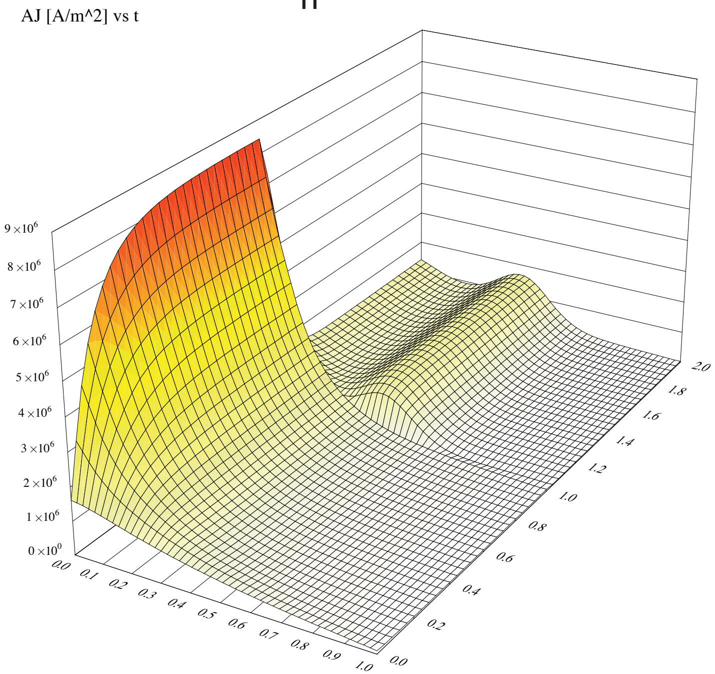
j_ϕ



$T_\mathrm{e}(\rho, t)$

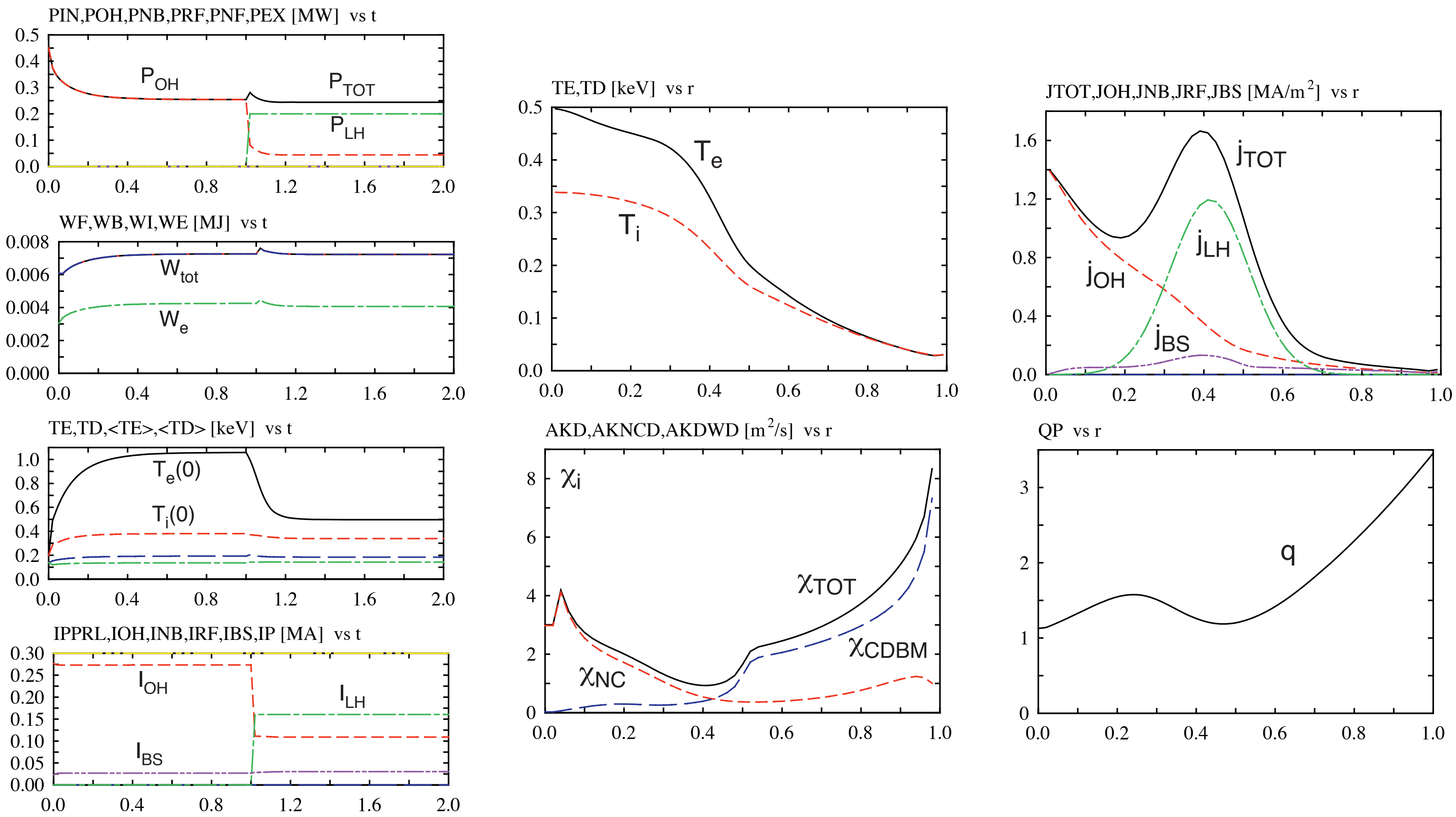


$j_{||}(\rho, t)$



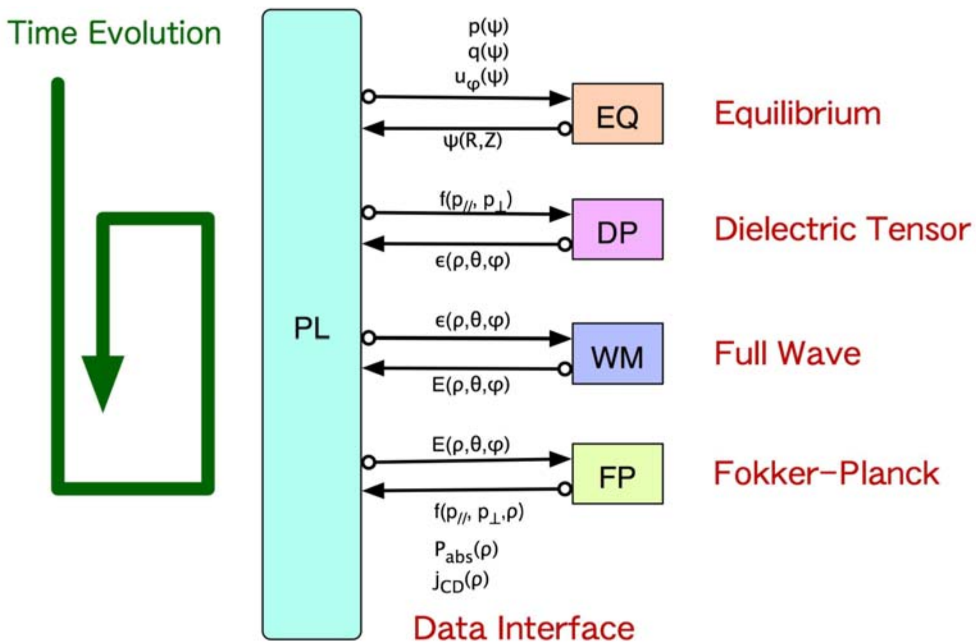
Transport simulation

- **OH + off-axis LHCD**: 200 kW
- **Formation of internal transport barrier** (equilibrium not solved)



Self-Consistent Wave Analysis with Modified $f(v)$

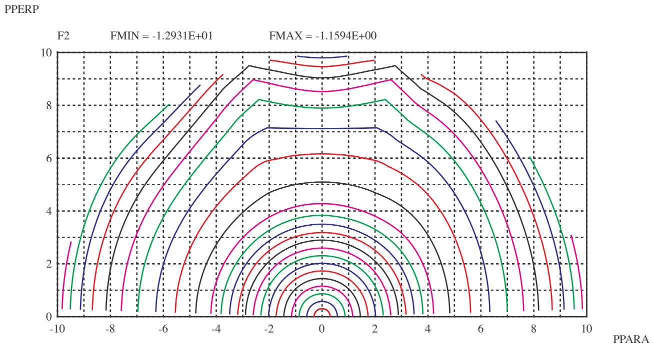
- **Modification of velocity distribution from Maxwellian**
  - Absorption of ICRF waves in the presence of energetic ions
  - Current drive efficiency of LHCD
  - NTM controllability of ECCD (absorption width)
- **Self-consistent wave analysis including modification of $f(v)$**

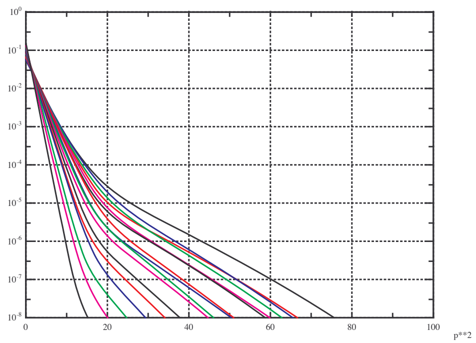


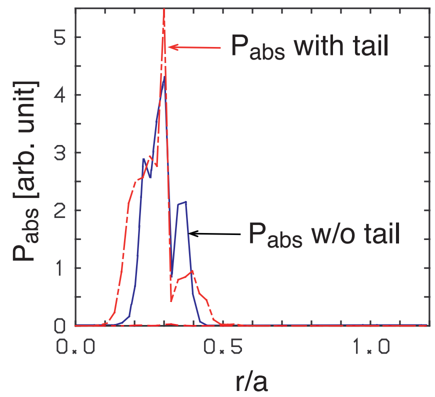
Self-Consistent ICRF Minority Heating Analysis

- **Analysis in TASK**
  - Dielectric tensor for arbitrary $f(v)$
  - Full wave analysis with the dielectric tensor
  - Fokker-Plank analysis of full wave results
  - Self-consistent iterative analysis: **Preliminary**
- **Energetic ion tail formation**
  - **Broadening of power deposition profile**

Momentum Distribution　　Tail Formation　　Power deposition







FLR Effects in Full Waves Analyses

- Several approaches to describe the FLR effects.
- **Differential operators**: $k_\perp \rho \rightarrow i\rho\partial/\partial r_\perp$
  - This approach cannot be applied to the case $k_\perp \rho \gtrsim 1$.
  - Extension to the third and higher harmonics is difficult.
- **Spectral method**: Fourier transform in inhomogeneous direction
  - This approach can be applied to the case $k_\perp \rho > 1$.
  - All the wave field spectra are coupled with each other.
  - Solving a dense matrix equation requires large computer resources.
- **Integral operators**: $\int \epsilon(x - x') \cdot E(x')\mathrm{d}x'$
  - This approach can be applied to the case $k_\perp \rho > 1$
  - Correlations are localized within several Larmor radii
  - Necessary to solve a large band matrix

Full Wave Analysis
Using an Integral Form of Dielectric Tensor

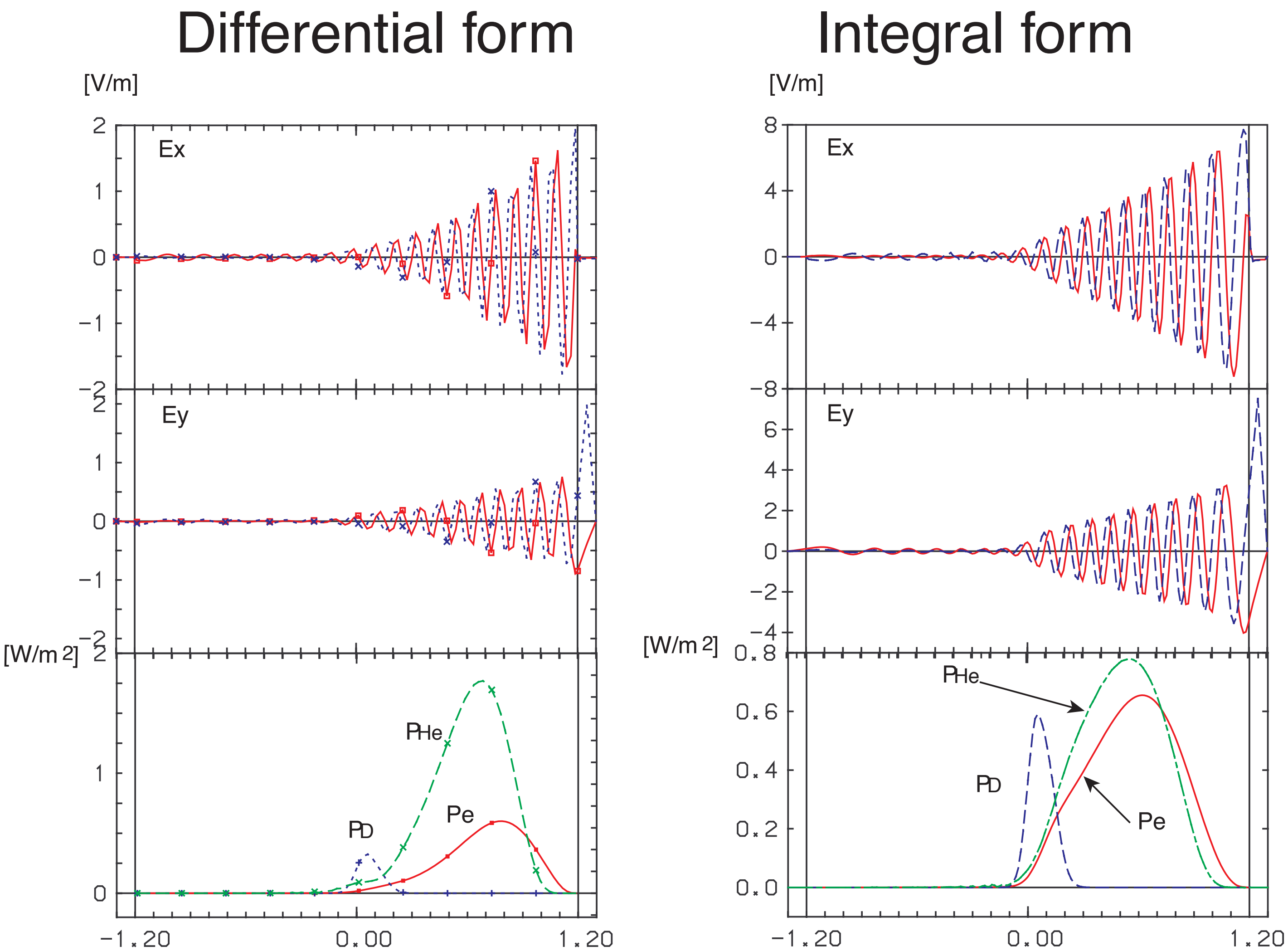
- **Maxwell's equation**:

$$\nabla \times \nabla \times \boldsymbol{E}(\boldsymbol{r}) + \frac{\omega^2}{c^2} \int \overleftrightarrow{\epsilon}(\boldsymbol{r}, \boldsymbol{r}') \cdot \boldsymbol{E}(\boldsymbol{r}')\mathrm{d}\boldsymbol{r} = \mu_0 \boldsymbol{j}_{ext}(\boldsymbol{r})$$

- **Integral form of dielectric tensor**: $\overleftrightarrow{\epsilon}(\boldsymbol{r}, \boldsymbol{r}')$
  - Integration along the unperturbed cyclotron orbit
- **1D analysis in tokamaks** (in the direction of major radius)
  - To confirm the applicability of an integral form of dielectric tensor
  - **Another formulation in the lowest order of ρ/L**
    — Sauter O, Vaclavik J, Nucl. Fusion **32** (1992) 1455.
- **2D analysis in tokamaks**
  - In more realistic configurations

One-Dimensional Analysis

ICRF minoring heating with α-particles ($n_D : n_{He} = 0.96 : 0.02$)



$$R_0 = 3.0\text{m}$$

$$a = 1.2\text{m}$$

$$B_0 = 3\text{T}$$

$$T_{e0} = 10\text{keV}$$

$$T_{D0} = 10\text{keV}$$

$$T_{\alpha 0} = 3.5\text{MeV}$$

$$n_{s0} = 10^{20}\text{m}^{-3}$$

$$\omega/2\pi = 45\text{MHz}$$

Absorption by α may be overestimated by differential approach.

2-D Formulation

- **Coordinates**
  - **Magnetic coordinate system**: (ψ, χ, ζ)
  - **Local Cartesian coordinate system**: (s, p, h)
  - **Fourier expansion**: poloidal and toroidal mode numbers, m, n
- **Perturbed current**

$$\boldsymbol{j}(\boldsymbol{r}, t) = -\frac{q}{m} \int \mathrm{d}\boldsymbol{v}\, q\boldsymbol{v} \int_{-\infty}^{\infty} \mathrm{d}t' \left[\boldsymbol{E}(\boldsymbol{r}', t') + \boldsymbol{v}' \times \boldsymbol{B}(\boldsymbol{r}', t')\right] \cdot \frac{\partial f_0(\boldsymbol{v}')}{\partial \boldsymbol{v}'}$$

- **The time evolution of χ and ζ due to gyro-motion**

$$\begin{cases} \chi(t-\tau) = \chi(t) + \dfrac{\partial \chi}{\partial s}\dfrac{v_\perp}{\omega_c}\{\cos(\omega_c\tau + \theta_0) - \cos\theta_0\} + \dfrac{\partial \chi}{\partial p}\dfrac{v_\perp}{\omega_c}\{\sin(\omega_c\tau + \theta_0) - \sin\theta_0\} - \dfrac{\partial \chi}{\partial h} v_\parallel \tau \\ \zeta(t-\tau) = \zeta(t) + \dfrac{\partial \zeta}{\partial s}\dfrac{v_\perp}{\omega_c}\{\cos(\omega_c\tau + \theta_0) - \cos\theta_0\} + \dfrac{\partial \zeta}{\partial p}\dfrac{v_\perp}{\omega_c}\{\sin(\omega_c\tau + \theta_0) - \sin\theta_0\} - \dfrac{\partial \zeta}{\partial h} v_\parallel \tau \end{cases}$$

Variable Transformations

- **Transformation of Integral Variables**
  - Transformation from the velocity space variables $(v_\perp, \theta_0)$ to the particle position s' and the guiding center position s_0.
  - Jacobian: $J = \dfrac{\partial(v_\perp, \theta_0)}{\partial(s', s_0)} = -\dfrac{\omega_c^2}{v_\perp \sin \omega_c \tau}$.
- **Integration over τ**
  - Integral in time calculated by the Fourier series expansion with cyclotron period, $2\pi/\omega_c$
- **Integration over $v_{||}$**
  - Interaction between wave and particles along the magnetic field lines described by the plasma dispersion function.

Final Form of Induced Current

- **Induced current**:

$$\overleftrightarrow{\mu}^{-1} \cdot \begin{pmatrix} J_1^{mn}(\psi) \\ J_2^{mn}(\psi) \\ J_3^{mn}(\psi) \end{pmatrix} = \int \mathrm{d}u' \int \mathrm{d}u_0 \, \overleftrightarrow{\sigma}(u, u', u_0) \cdot \begin{pmatrix} E_1^{m'n}(\psi) \\ E_2^{m'n}(\psi) \\ E_3^{m'n}(\psi) \end{pmatrix}$$

- **Electrical conductivity**:

$$\overleftrightarrow{\sigma}(u, u', u_0) = -i \left(\frac{1}{2\pi}\right)^{\frac{7}{2}} n_0 \frac{q^2}{m} \sum_{m'n'} \sum_{l} \int_0^{2\pi} \mathrm{d}\chi \int_0^{2\pi} \mathrm{d}\zeta \exp i \left\{(m' - m)\chi + (n' - n)\zeta\right\} \overleftrightarrow{H}(u, u', \chi)$$

- **Matrix coefficients**:

$$H_{1i} = \left(Q_3 \mu_{1i}^{-1} - u' Q_1 \mu_{2i}^{-1}\right) \frac{\sqrt{\pi}}{k_\parallel v_{T_\parallel}} Z(\eta_l) + \left[-\frac{Q_1 v_{T_\perp}}{v_{T_\parallel}^2} \mu_{3i}^{-1} + \left(1 - \frac{v_{T_\perp}^2}{v_{T_\parallel}^2}\right) \left\{Q_3 \kappa_{2i} + Q_1 u' \kappa_{1i}\right\}\right] \sqrt{\frac{\pi}{2}} \frac{1}{k_\parallel} Z'(\eta_l)$$

$$H_{2i} = \left(-Q_2 u \mu_{1i}^{-1} + Q_0 u u' \mu_{2i}^{-1}\right) \frac{\sqrt{\pi}}{k_\parallel v_{T_\parallel}} Z(\eta_l) + \left[\frac{Q_0 u v_{T_\perp}}{v_{T_\parallel}^2} \mu_{3i}^{-1} - \left(1 - \frac{v_{T_\perp}^2}{v_{T_\parallel}^2}\right) u \left\{Q_2 \kappa_{2i} + Q_0 u' \kappa_{1i}\right\}\right] \sqrt{\frac{\pi}{2}} \frac{1}{k_\parallel} Z'(\eta_l)$$

$$H_{3i} = \left(-\frac{Q_2}{v_{T_\perp}} \mu_{1i}^{-1} + \frac{Q_0 u'}{v_{T_\perp}} \mu_{2i}^{-1}\right) \sqrt{\frac{\pi}{2}} \frac{1}{k_\parallel} Z'(\eta_l) + \left[-\frac{Q_0}{v_{T_\parallel}} \mu_{3i}^{-1} + \frac{v_{T_\parallel}}{v_{T_\perp}} \left(1 - \frac{v_{T_\perp}^2}{v_{T_\parallel}^2}\right) \left\{Q_2 \kappa_{2i} + Q_0 u' \kappa_{1i}\right\}\right] \frac{\sqrt{\pi}}{k_\parallel} \eta_l Z'(\eta_l)$$

Kernel Functions

- **Kernel functions**

$$Q_{\left\{\begin{matrix}0\\1\\2\\3\end{matrix}\right\}}(u,u',\chi_0,l) = \int_0^{2\pi} \mathrm{d}\lambda \frac{1}{|\sin\lambda|}\left\{\begin{matrix}1\\V_1\\V_2\\V_1V_2\end{matrix}\right\} \times \exp i\left[\frac{k_\perp v_{T_\perp}}{\omega_\mathrm{c}}\left\{(V_2-V_1)\cos\alpha-(u-u')\sin\alpha\right\}+l\lambda-\frac{V_0^2}{2}\right]$$

$$V_0^2 = \left(\frac{u+u'}{2}\right)^2\frac{1}{\cos^2\frac{1}{2}\lambda}+\left(\frac{u-u'}{2}\right)^2\frac{1}{\sin^2\frac{1}{2}\lambda}$$

$$V_1 = \frac{u-u'}{2}\frac{1}{\tan\frac{1}{2}\lambda}-\frac{u+u'}{2}\tan\frac{1}{2}\lambda$$

$$V_2 = \frac{u-u'}{2}\frac{1}{\tan\frac{1}{2}\lambda}+\frac{u+u'}{2}\tan\frac{1}{2}\lambda$$

$$\overleftrightarrow{h} = \frac{1}{J\omega}\begin{pmatrix}0 & -n & m'\\ n & 0 & i\frac{\partial}{\partial\psi}\\ -m' & -i\frac{\partial}{\partial\psi} & 0\end{pmatrix}$$

$$u \equiv \frac{s-s_0}{v_{T_\perp}}\omega_\mathrm{c}$$

$$u' \equiv \frac{s'-s_0}{v_{T_\perp}}\omega_\mathrm{c}$$

where $\overleftrightarrow{\kappa} = \overleftrightarrow{\mu}^{-1}\cdot\overleftrightarrow{g}\cdot\overleftrightarrow{h}$, $\overleftrightarrow{\mu}$ is the transformation matrix for $(s,p,h)\to(\psi,\chi,\zeta)$, and $\overleftrightarrow{g}$ is the metric tensor.

Consistent Formulation of Integral Full Wave Analysis

- **Analysis of wave propagation**
  - **Dielectric tensor**:

$$\nabla\times\nabla\times\boldsymbol{E}(\boldsymbol{r})-\frac{\omega^2}{c^2}\int \mathrm{d}\boldsymbol{r}_0\int \mathrm{d}\boldsymbol{r}'\,\frac{\boldsymbol{p}'}{m\gamma}\frac{\partial f_0(\boldsymbol{p}',\boldsymbol{r}_0)}{\partial \boldsymbol{p}'}\cdot\boldsymbol{K}_1(\boldsymbol{r},\boldsymbol{r}',\boldsymbol{r}_0)\cdot\boldsymbol{E}(\boldsymbol{r}')=\mathrm{i}\,\omega\mu_0\boldsymbol{j}_{\mathrm{ext}}$$

  where $\boldsymbol{r}_0$ is the gyrocenter position.

- **Analysis of modification of momentum distribution function**
  - **Quasi-linear operator**

$$\frac{\partial f_0}{\partial t}+\left(\frac{\partial f_0}{\partial \boldsymbol{p}}\right)_{\boldsymbol{E}}+\frac{\partial}{\partial \boldsymbol{p}}\int \mathrm{d}\boldsymbol{r}\int \mathrm{d}\boldsymbol{r}'\,\boldsymbol{E}(\boldsymbol{r})\,\boldsymbol{E}(\boldsymbol{r}')\cdot\boldsymbol{K}_2(\boldsymbol{r},\boldsymbol{r}',\boldsymbol{r}_0)\cdot\frac{\partial f_0(\boldsymbol{p}',\boldsymbol{r}_0,t)}{\partial \boldsymbol{p}'}=\left(\frac{\partial f_0}{\partial \boldsymbol{p}}\right)_{\mathrm{col}}$$

- The kernels $\boldsymbol{K}_1$ and $\boldsymbol{K}_2$ are closely related and localized in the region $|\boldsymbol{r}-\boldsymbol{r}_0|\lesssim\rho$ and $|\boldsymbol{r}'-\boldsymbol{r}_0|\lesssim\rho$.

Extension to TASK/3D

- **3D Equilibrium**:
  - **Interface to equilibrium data from VMEC or HINT**
  - **Interface to neoclassical transport coefficient codes**
- **Modules 3D-ready**:
  - **WR**: Ray and beam tracing
  - **WM**: Full wave analysis
- **Modules to be updated**:
  - **TR**: Diffusive transport (with an appropriate model of E_r)
  - **TX**: Dynamic transport (with neoclassical toroidal viscosity)
- **Modules to be added**: (**by Y. Nakamura**)
  - **EI**: Time evolution of current profile in helical geometry

Road map of TASK code

	Present Status	In 2 years	In 5 years
Equlibrium	Fixed/Free Boundary	Equilibrium Evolution	Start Up Analysis
Core Transport	1D Diffusive TR	Kinetic TR	2D Fluid TR
	1D Dynamic TR		
SOL Transport		2D Fluid TR	Plasma-Wall Interaction
Neutral Tranport	1D Diffusive TR	Orbit Following	
Energetic Ions	Kinetic Evolution	Orbit Following	
Wave Beam	Ray/Beam Tracing	Beam Propagation	
Full Wave	Kinetic ϵ	Gyro Integral ϵ	Orbit Integral ϵ
Stabilities	Sawtooth Osc.	Tearing Mode	Systematic Stability Analysis
	ELM Model	Resistive Wall Mode	
Turbulent Transport	CDBM Model	Linear GK + ZF	Nonlinear ZK + ZF
		Diagnostic Module	
		Control Module	

Summary

- We are developing **TASK** code as a reference core code for integrated burning plasma simulation based on transport analysis.
- We have developed a part of **standard dataset, data exchange interface and execution control** and implemented them in TASK code. An example of coupling between TOPICS/EQU and TASK/TR was shown, though not yet completed. Some other modules of TOPICS will be incorporated soon.
- Preliminary results of **self-consistent analysis of wave heating and current drive** describing the time evolution of the momentum distribution function and **Integro-differential full wave analysis including FLR effects** have been obtained.
- Further continuous development of integrated modeling is needed for comprehensive ITER simulation.