Common Data Interface for Integrated Simulation

A. Fukuyama

Department of Nuclear Engineering, Kyoto University

in collaboration with **BPSI Working Group**

Contents

- Motivation
- A Data Set for Integrated Modeling
- Program Interface for BPSI
- Summary

- **Integrated Simulation Code**

  ○ **To predict the behavior of burning plasmas**

  ○ **To develop reliable and efficient schemes to control them**

  ○ To test a new theoretical model

  ○ To use a realistic profile in a large-scale simulation

  ○ To analyze experimental data

- **Module Structure of Integrated Code**

  ○ **Independence of the modules**

  — Easy to develop a new module

  — Easy to maintain an existing module

  — Easy to compare similar modules

  ○ **Rule of data exchange and execution control**

ITPA Profile Database

- **The International Multi-Tokamak Confinement Profile Database**
  - `http://tokamak-profiledb.ukaea.org.uk/`
  - **Maintained mainly by ITPA/CDBM group**
  - Very convenient for transport modeler

- **Contents**
  - **1998 Public Release**
  - **Working Database** (Restricted)
  - **ITB Database** (Restricted)

- **Structure**
  - **0D data**: machine ID, shot ID
  - **1D data**: Time dependent global data
  - **2D data**: Time dependent profile data

List of Stored Data

- **Definition:**

  http://tokamak-profiledb.ukaea.org.uk/DOCS/PDBMAN/pdbman.html

- **0D data:**

TOK	UPDATE	DATE	SHOT	TIME	AUXHEAT	PHASE	STATE	PGASA	PGASZ
BGASA	BGASZ	BGASA2	BGASZ2	PIMPA	PIMPZ	PELLET	RGEO	RMAG	AMIN
SEPLIM	XPLIM	KAPPA	DELTA	INDENT	AREA	VOL	CONFIG	IGRADB	WALMAT
DIVMAT	LIMMAT	EVAP	BT	IP	VSURF	Q95	BEPMHD	BETMHD	BEPDIA
NEL	DNELDT	ZEFF	PRAD	POHM	ENBI	PINJ	BSOURCE	PINJ2	BSOURCE2
COCTR	PNBI	ECHFREQ	ECHMODE	ECHLOC	PECH	ICFREQ	ICSCHEME	ICANTEN	PICRH
LHFREQ	LHNPAR	LHPH	IBWFREQ	PIBW	TE0	TI0	WFANI	WFICRH	MEFF
ISEQ	WTH	WTOT	DWTOT	PL	PLTH	TAUTOT	TAUTH	TAUH	

- **1D data:**

IP	BT	AMIN	RGEO	KAPPA	DELTA	INDENT	PNBI	PECH	PICRH
PLH	PIBW	PFLOSS	PRAD	ZEFF	NEL	VSURF	LI	NMAIN0	THNT
WTH	WTOT	TE0	TI0	Q95	POHM	IBOOT	PHIA	PFUSION	

- **2D data: (+: error bar, *: raw, fitted, error bars)**

TE*	TI*	NE*	NM1*	NM2*	NM3*	NIMP*	VROT*
QNBIE	QICRHE	QECHE	QLHE	QIBWE	SNBIE	QFUSE	QWALLE
QNBII	QICRHI	QECHI	QLHI	QIBWI	SNBII	QFUSI	QWALLI
CURTOT+	CURICRH	CURECH	CURLH	Q+	IOTAVAC		
CURICRH	QEI	ZEFFR+	NFAST	QRAD	SWALL		
QOHM	CHII	DWER	DWIR	DNER	DELTAR		
CHIE	RMAJOR	RMINOR	VOLUME	KAPPAR		INDENTR	
BPOL	GRHO1	GRHO2					
SURF							

Necessary Data for Integrated Modeling

- **Machine ID, Shot ID, Model ID**

- **Equilibrium Data**: e.g. EFIT

- **Plasma Status Data**
  - **Plasma Fluid Data**: Fluid quantities
  - **Plasma Kinetic Data**: Momentum distribution
  - **Electromagnetic Data**: Quasi-static B, j, E

- **Wave Data**
  - **Wave Characteristics**: f, k, Power
  - **Electromagnetic Wave Data**: E, B, Ray characteristics

- **Transport Data**
  - **Particle Source and Sink**: S
  - **Momentum Source and Sink**: j_{CD}, M_ϕ
  - **Power Source and Sink**: P_{OH}, P_{abs}, P_{rad}
  - **Transport Coefficients**: D, χ

New Modular Structure of TASK
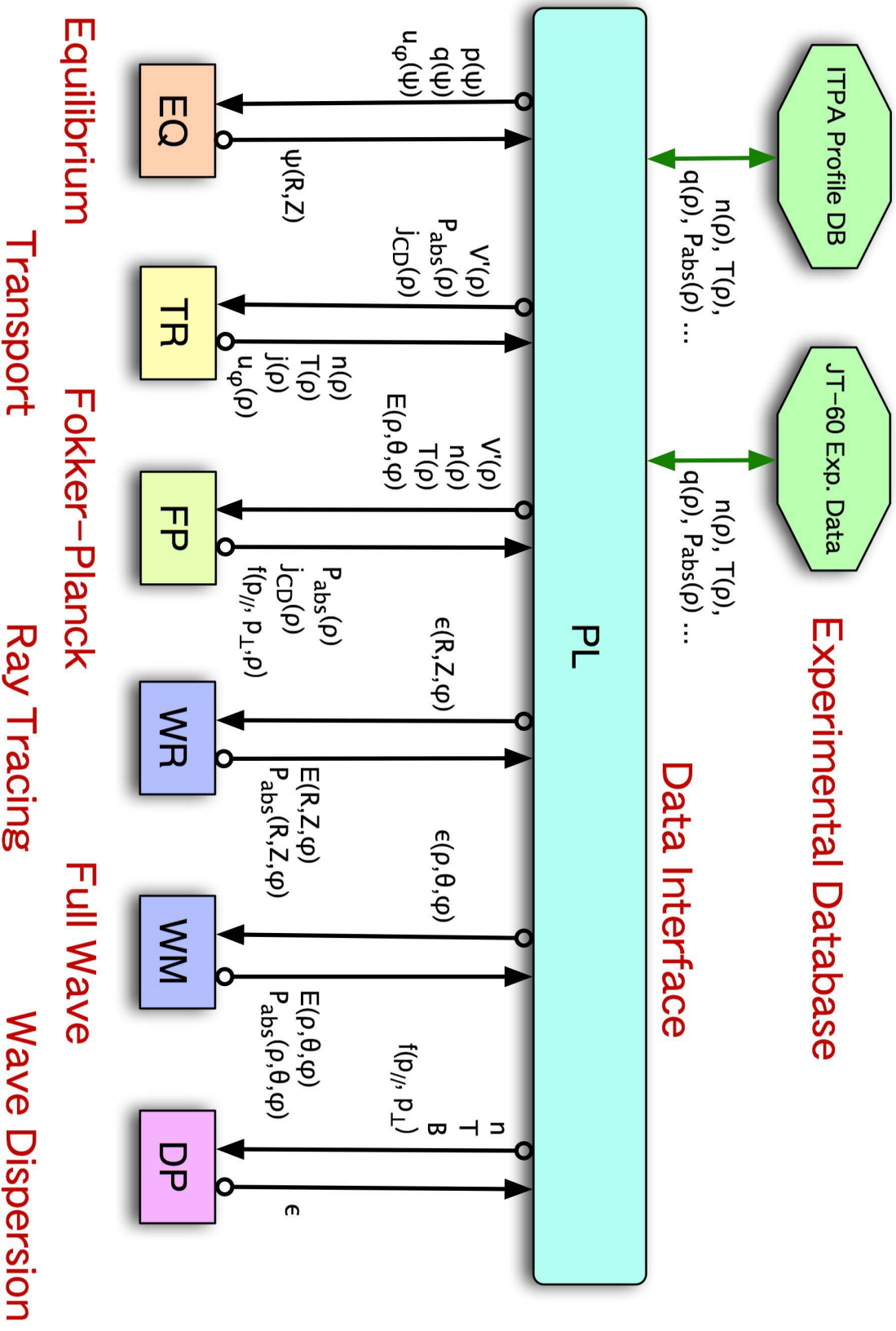
Coordinates

- **One dimensional**

  RHO   Radial (ρ)   Square root of normalized toroidal magnetic flux: $\rho = \sqrt{\phi_t / \phi_{t}|_{\text{surface}}}$

- **Two dimensional**

  RZ   Cylindrical (R, Z)

  RT   Toroidal (r, θ)

  RC   Flux (ρ, χ)

- **Three dimensional**

  XYZ   Rectangular (X, Y, Z)

  RPZ   Cylindrical 1 (R, ϕ, Z)

  RZP   Cylindrical 2 (R, Z, ϕ)

  RTP   Toroidal 1 (r, θ, ϕ)

  RCP   Flux 1 (ρ, χ, ϕ) VMEC

  RCX   Flux 2 (ρ, χ, ξ) Boozer

Example of Data Interface (1)

- **Device data**

RR	R m	Geometrical major radius
RA	a m	Average minor radius $(R_{max} - R_{min})/2$
RB	b m	Wall radius
BB	b T	Vacuum toroidal magnetic field at $(RR, 0)$
RKAP	κ	Elongation of plasma boundary
RDLT	δ	Triangularity of plasma boundary
RIP	I_p MA	Typical plasma current

- **Equilibrium data**

PSIP	$\psi_p(R, Z)$ Tm^2	2D poloidal magnetic flux
PSIR	$\psi(\rho)$ Tm^2	Poloidal magnetic flux
PPSI	$p(\rho)$ MPa	Plasma pressure
TPSI	$T(\rho)$ Tm	$B_\phi R$
QPSI	$1/q(\rho)$	Safety factor
JPAV	$j_\parallel^{ave}(\rho)$	Averaged parallel current density

Example of Data Interface (2)

- **Fluid plasma data**

NSMAX	s	Number of particle species
PA	A_s	Atomic mass
PZ0	Z_s	Charge number
PZ	Z_s	Charge state number
PNR	$n(\rho)\,10^{20}\,\mathrm{m}^3$	Number density
PTR	$T(\rho)\,\mathrm{keV}$	Temperature
PUR	$u_\phi(\rho)\,\mathrm{m/s}$	Toroidal rotation velocity

  ○ Example: **PROF1D(NR)%SPECIES(NS)%PNR**

- **Kinetic plasma data**

FP	$f(p, \theta_p, \rho)$	momentum distribution at $theta = 0$

- **Full wave field data**

CE	$E(\rho, \chi, \xi)$	Complex wave electric field
CB	$B(\rho, \chi, \xi)$	Complex wave magnetic field

Data Exchange Interface in BPSI

- **Language**
  - **Fortran95**: Derived type data, Module inheritance, Namelist

- **Data category**
  - **Predefined Data**
  - **Additional Data**

- **Data manipulation**
  - **Specify data**: machine, shot, model, time
  - **Acquire data**: 0D, 1D(ρ), 2D(ρ,χ), 2D(R, Z), 0D(t), 1D(ρ,t), 2D(ρ,χ,t), 2D(R, Z,t),
  - **Change data**: 0D, 1D(ρ), 2D(ρ,χ), 2D(R, Z)
  - Define data
  - Save data in file
  - Load data from file
  - Plot data

Execution Control Interface in BPSI (1)

- **Example for TASK/TR**

TR_INIT	Initialization (Default value, Read file)	**BPSM_INIT('TR')**
TR_PARM(PSTR)	Parameter setup (Namelist input)	**BPSM_PARM('TR', PSTR)**
TR_PROF(T)	Profile setup (Spatial profile, Time)	**BPSM_PROF('TR', T)**
TR_EXEC(DT)	Exec one step (Time step)	**BPSM_EXEC('TR', DT)**
TR_GOUT(PSTR)	Plot data (Plot command)	**BPSM_GOUT('TR', PSTR)**
TR_SAVE	Save data in file	**BPSM_SAVE('TR')**
TR_LOAD	load data from file	**BPSM_LOAD('TR')**
TR_TERM	Termination	**BPSM_TERM('TR')**

Execution Control Interface in BPSI (2)

- **Example for transport module**

CDBM_INIT	Initialization (Default value, Read file)	
	Define data	**BPSM_DEFINE('CDBM1D', CDBM1D)**
CDBM_PARM(PSTR)	Parameter setup (Namelist input)	
CDBM_CALC	Set data	**BPSM_SET('CDBM1D', CDBM1D)**
	Calculate	
	Get profile	**BPSM_GET('PROF1D', T, PROF1D)**

- **Calling sequence of the transport module**

  BPSM_REGISTER('CDBM', CDBM_INIT, CDBM_PARM, CDBM_CALC)
  BPSM_INIT('CDBM')
  BPSM_PARM('CDBM', PSTR)
  BPSM_CALC('CDBM')
  BPSM_GET('CDBM1D', CDBM1D)

Summary

- In order to realize the modular structure of BPSI, we are proposing a standard set of data for integrated modeling and implementing it in TASK as a first trial.

- A program interface for data exchange and execution control will be also implemented for new modular structure of TASK.

- The data set and the program interface will require improvement in order to be more module-maker friendly and extension to helical configuration.

Modules of TASK

|		
EQ	**2D Equilibrium**	Fixed 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, Eigen mode
FP	**3D Fokker-Planck**	Relativistic, Bounce-averaged
DP	**Wave Dispersion**	Local dielectric tensor, Arbitrary $f(v)$
PL	**Data Interface**	Data conversion, Profile database
LIB	**Libraries**	

Associated Libraries

GSAF	2D Graphic library for X Window and EPS
GSGL	3D Graphic library using OpenGL

All developed in Kyoto U

Present Structure of TASK
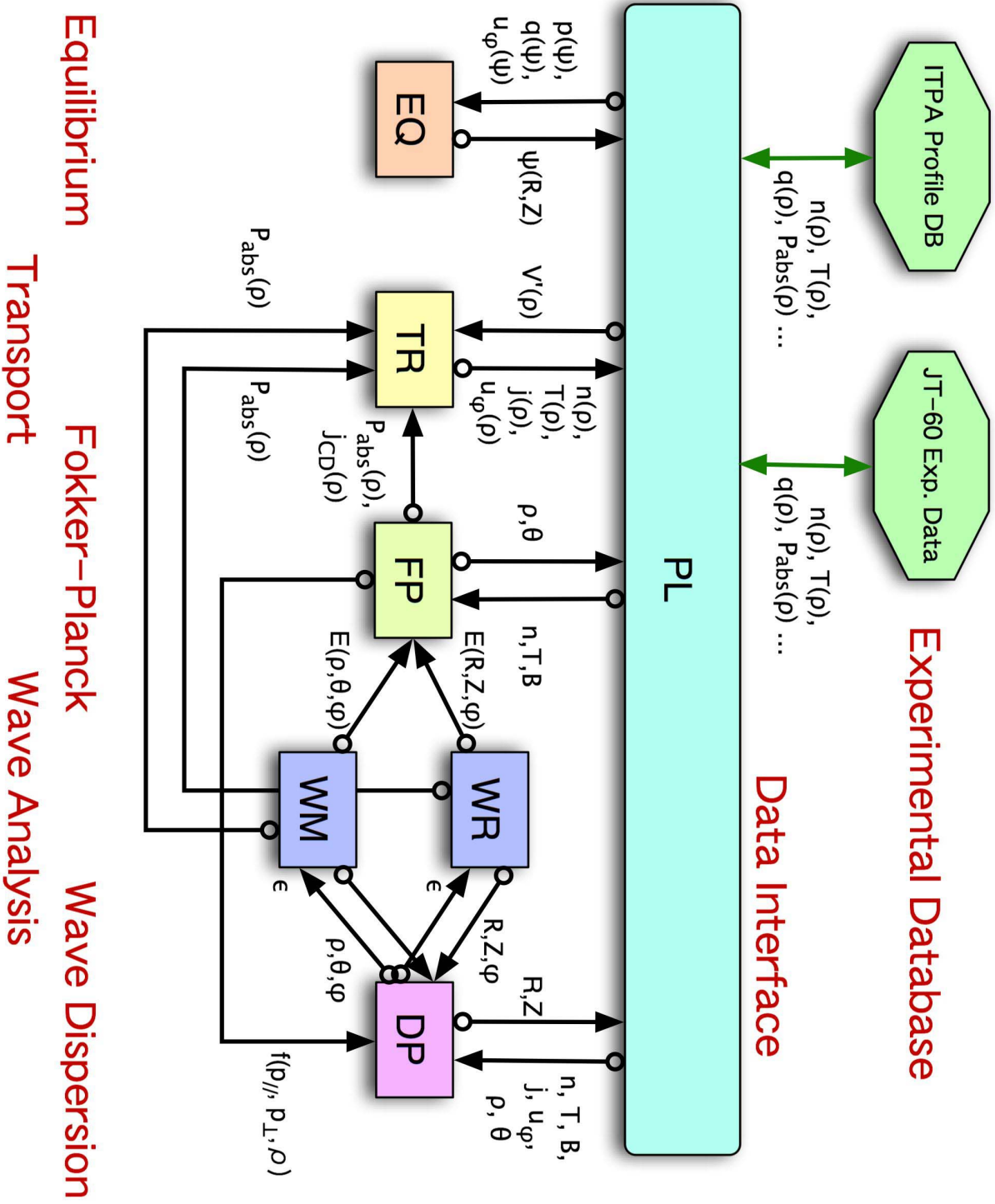
Under Development

- **New Modules**
  - **EX**: 2D equilibrium with free boundary
  - **TX**: Transport analysis based on flux-averaged fluid equation
  - **WA**: Global linear stability analysis
  - **WI**: Integro-differential wave analysis (FLR, $\kappa \cdot \nabla B \neq 0$)

- **Extension to 3D Helical System**
  - **3D Data Structure**
  - **3D Equilibrium**: VMEC, HINT
  - **Wave Analysis**: Already 3D
  - **Transport Analysis**: New transport model

- **New Modular Structure**