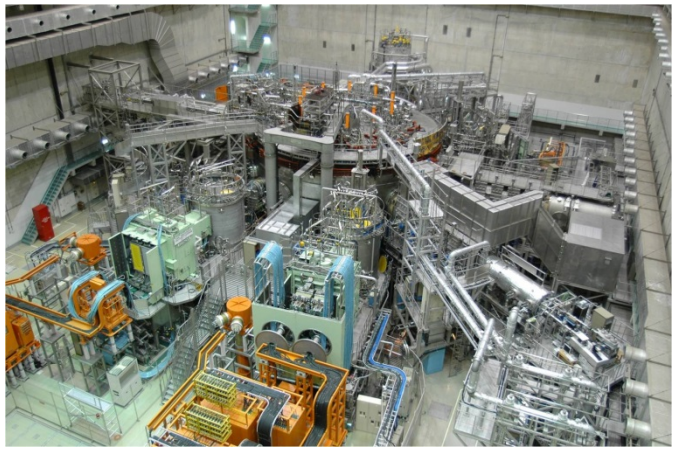
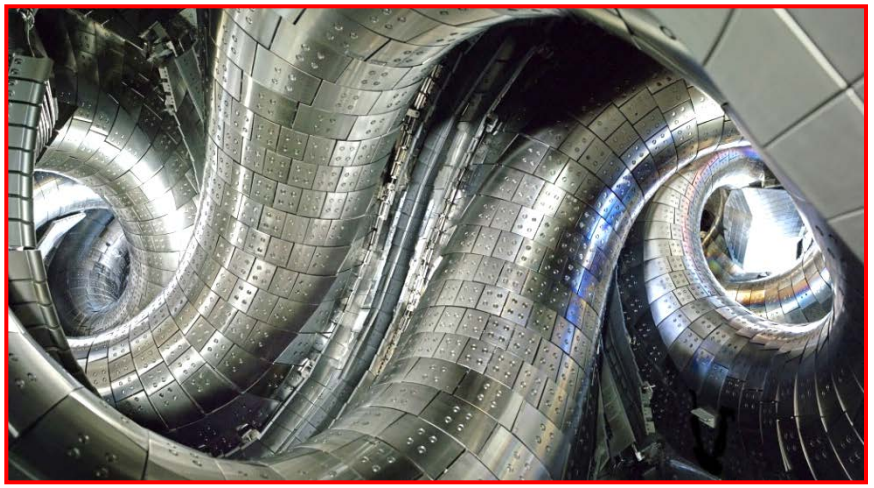
Status and Outlook of Integrated Transport Analysis Suite, *TASK3D-α*

M.Yokoyama for

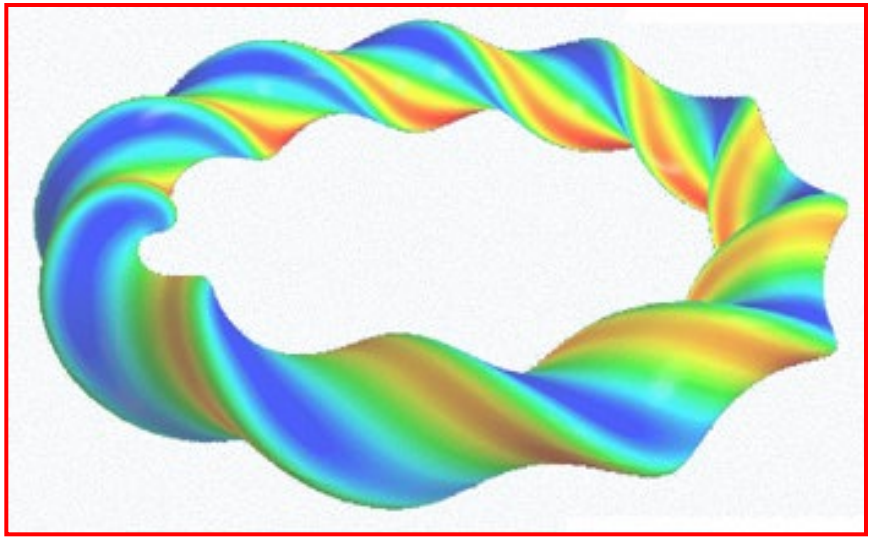
- integrated transport code group, Numerical Simulation Reactor Research Project
- TASK3D-UsersDevelopers (TASK3D-UD)
- close collaboration with LHD Experiment Group and Kyoto University

LHD, the world largest superconducting fusion device





Parameters	Achieved
Ti	8.1 keV@1×$10^{19}$$m^{-3}$
Te	20 keV@2×$10^{18}$$m^{-3}$ 10 keV@1.6×$10^{19}$$m^{-3}$
ne	1.2×$10^{21}$$m^{-3}$ with T_e =0.25 keV
β	5.1% @0.425 T 4.1% @ 1 T
Long Pulse	54min. 28sec (500kW) (1keV, 4×$10^{18}$$m^{-3}$) 47min. 30sec. (1,200 kW) (2keV, 1×$10^{19}$$m^{-3}$) → *3.36 GJ (world record)*



Objectives

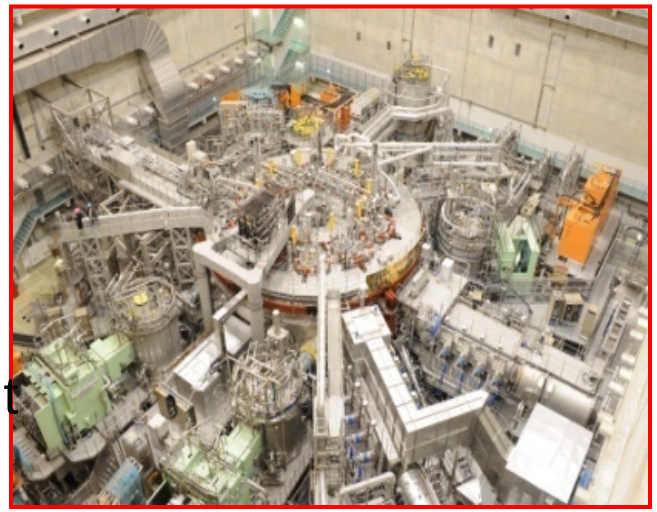
- Applicability extension of the integrated code, TASK (A.Fukuyama, Kyoto Univ.), to Stellarator-Heliotrons

- **S-H specific physics**
- **3D feature**
- **Module extension/modification based on TASK**

TASK3D

•Physics understandings
•Accurate discussion
•Scientific systemization

•Model validation/improvement
•Module extension



Logo (Spirit of TASK3D collaboration)

- “3D” blocks **(modules for “3D” physics)**
- Piling Up -> making shape **(integration)**
- bright colors **(friendly and productive collaboration)**

TASK3D development strategy

Systematic understandings
Accurate discussion

Model Validation

Given conditions
Transport models, Sources,,,

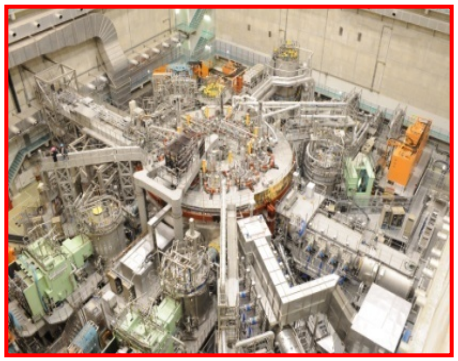
TASK3D-a
(Analysis of LHD experiment)

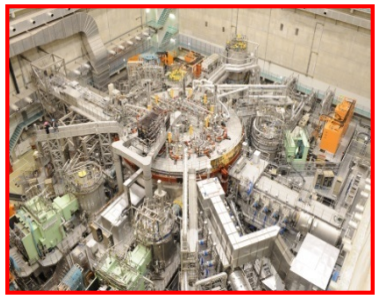
common modules

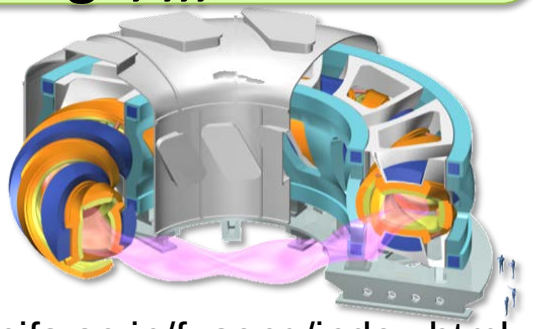
TASK3D-p
(Predictive analysis)

Experimental condition
Profiles, Sources, ,,,

- **Extension of high-performance plasmas in LHD**
- **FFHR-d1 design, ,,,**







http://www.nifs.ac.jp/fuseng/index.html

Release of the 1st Version of Experimental Analysis Suite

TASK3D-a01

(2012.9)

- **Automated Experimental Energy Balance Analysis**

→ **Significant progress on**

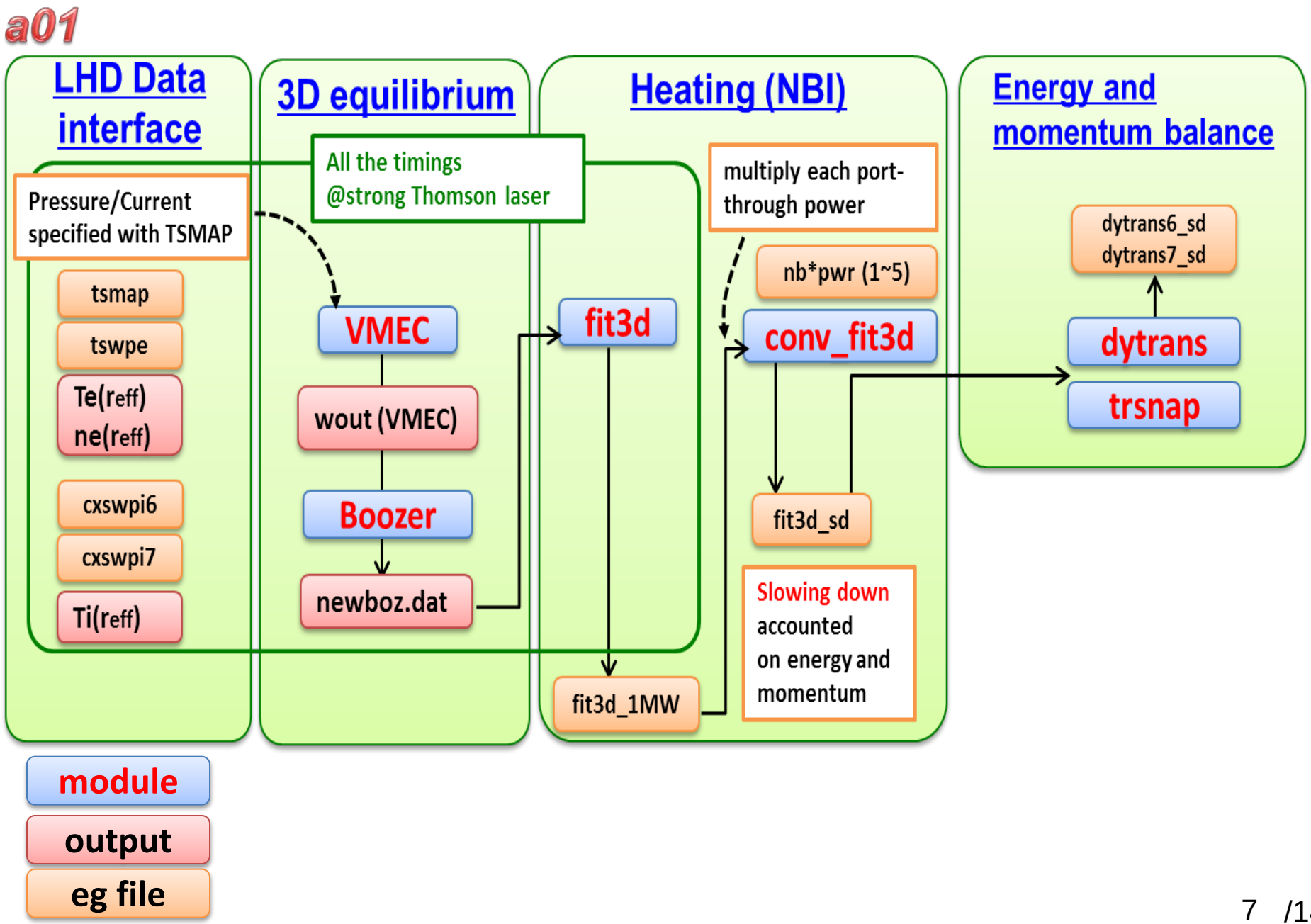
  - **Detailed time-series analyses in an individual shot**
  - **Analyses in many shots**

- **English Manual (NIFS-Memo 61, Nov. 2012)**

  http://www.nifs.ac.jp/report/nifsmemo.html

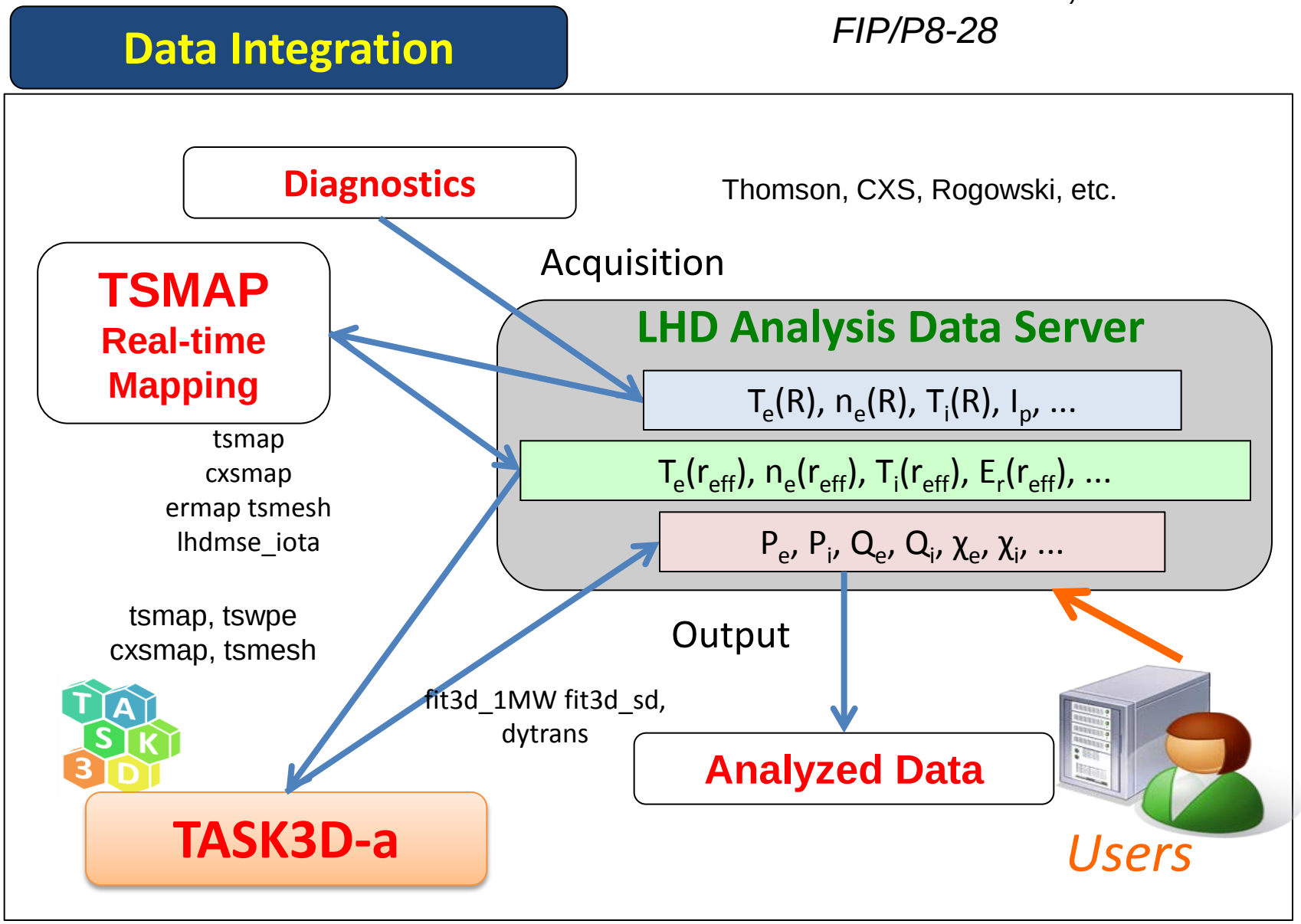
  - **basis for international collaboration**

Calculation procedure of TASK3D-a01



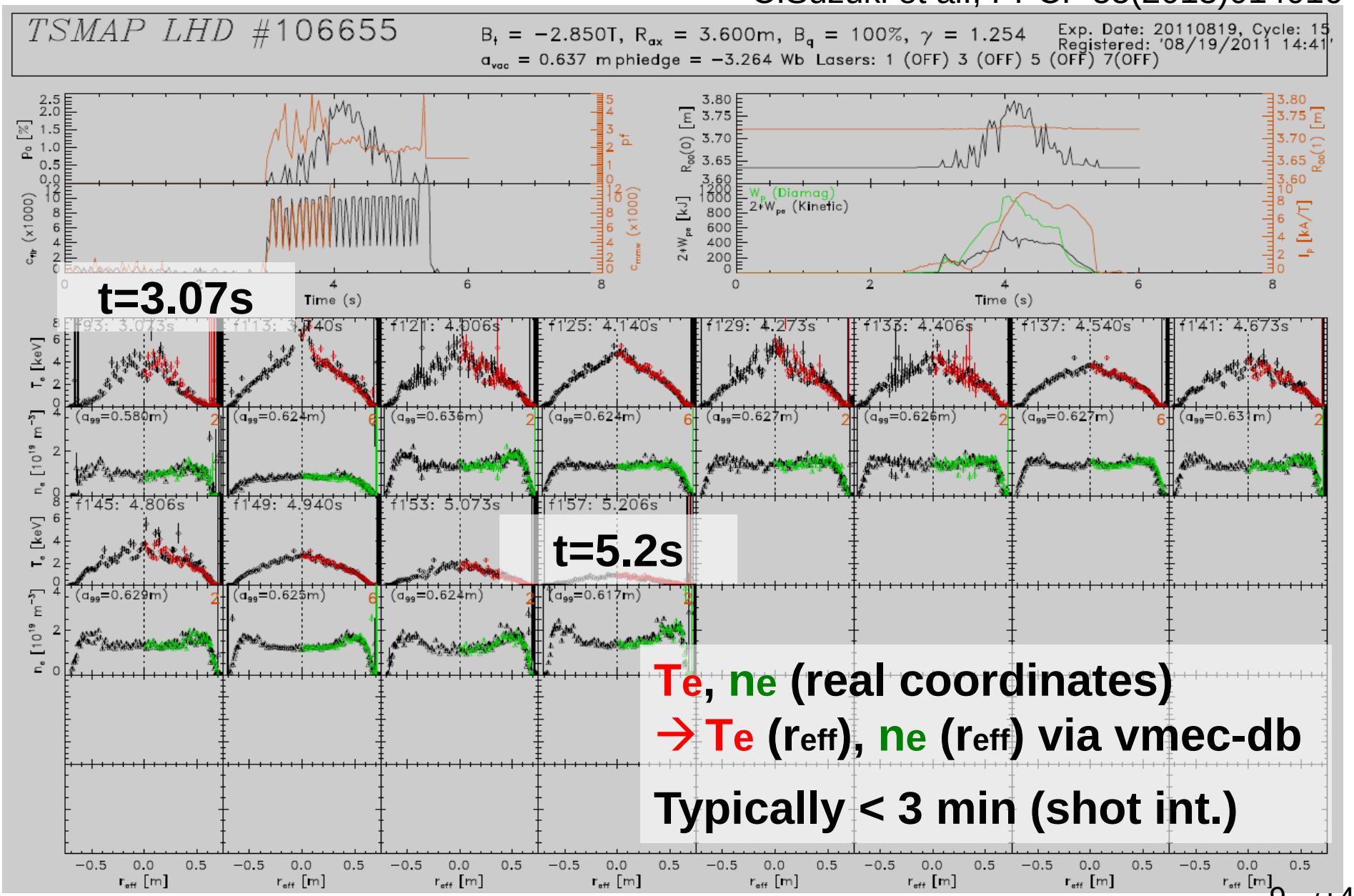
"Data integration" transport analysis

M.Emoto et al., IAEA-FEC 2014
FIP/P8-28



TSMAP, real-time coordinate mapping (r_{eff})

C.Suzuki et al., PPCF 55(2013)014016

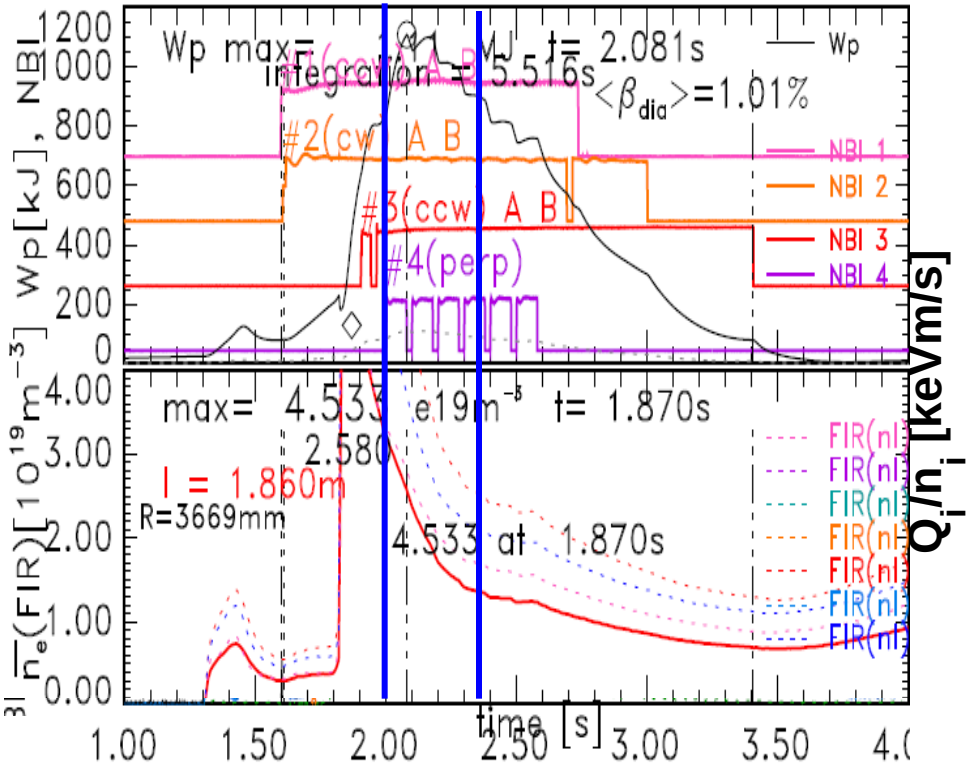


Features of TASK3D-a01

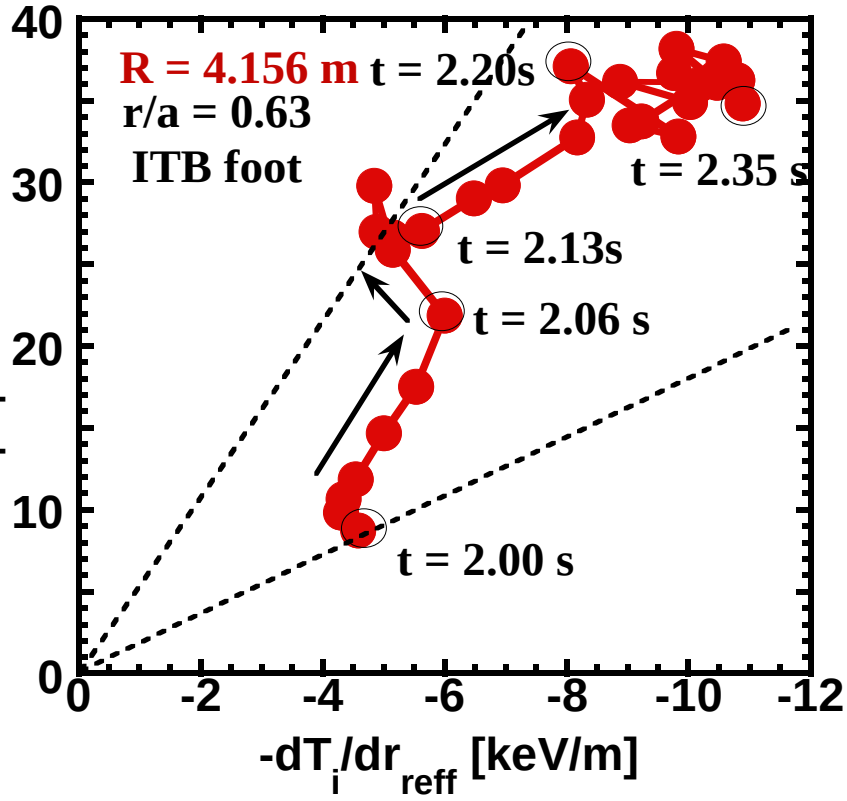
- Gateway established : **tsmap-task3d.lhd.nifs.ac.jp**
  - ✓ open to collaborators *(but accessible only in LHD-LAN)*
  - ✓ no need to download the suite nor set-up the environment in your own computer
- Default usage :
  - ✓ simply "**go, #shot**"
  - ✓ results do not depend who to run the suite
- Output: ***eg*** file format (on **LHD Analysis Data Server**)
  - ✓ accessible from collaborators
  - ✓ validity check can be enhanced with a lot of "eyes and senses"
- Flexible structure
  - ✓ easy update of modules, improvement
  - ✓ impact of module replacement can be easily checked

Usefulness of TASK3D-a01

Number of analysis-cases can be significantly enhanced
→ Systematic understandings, accurate discussion



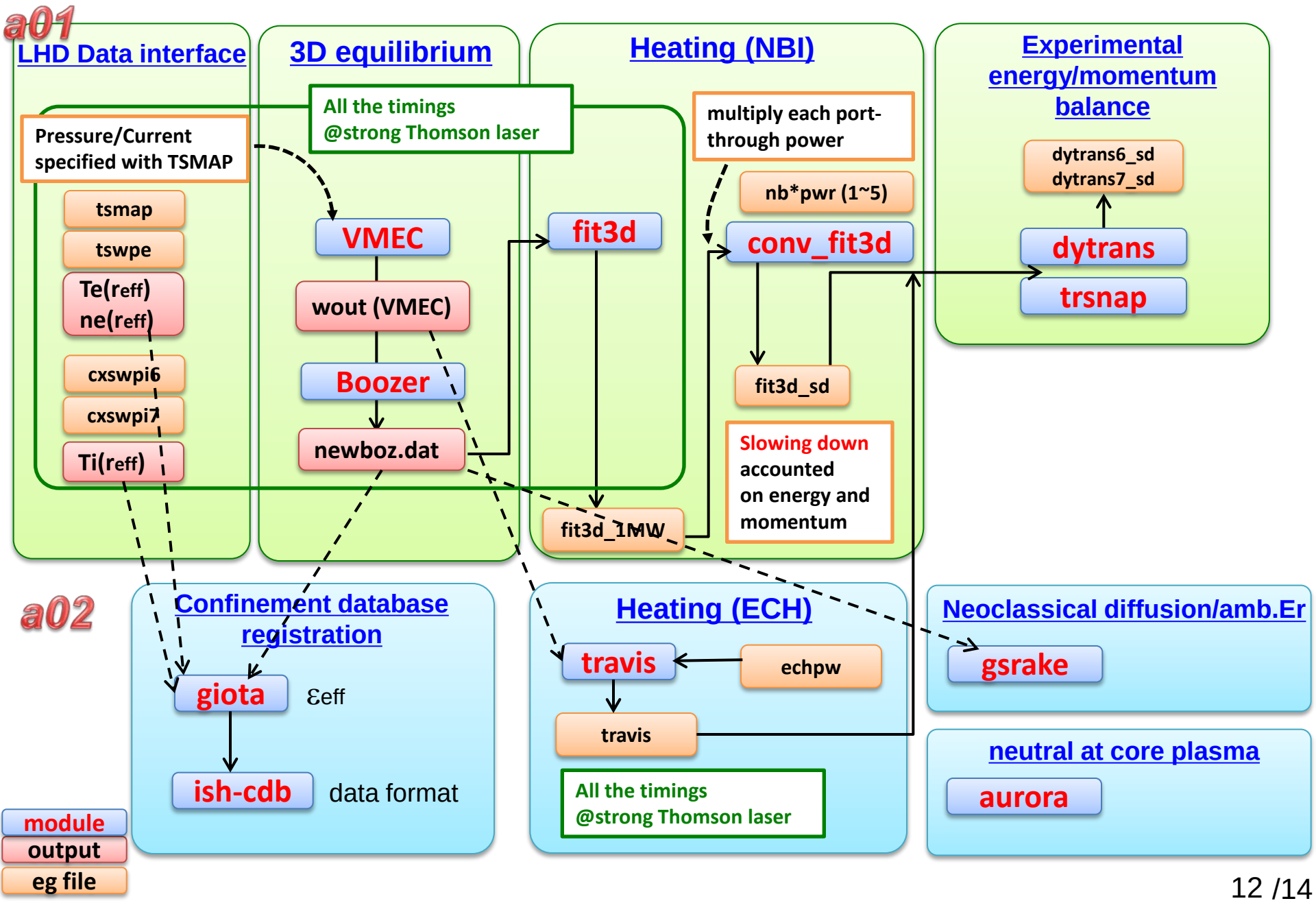
(ex.) when does the confinement improvement occur



eg.,

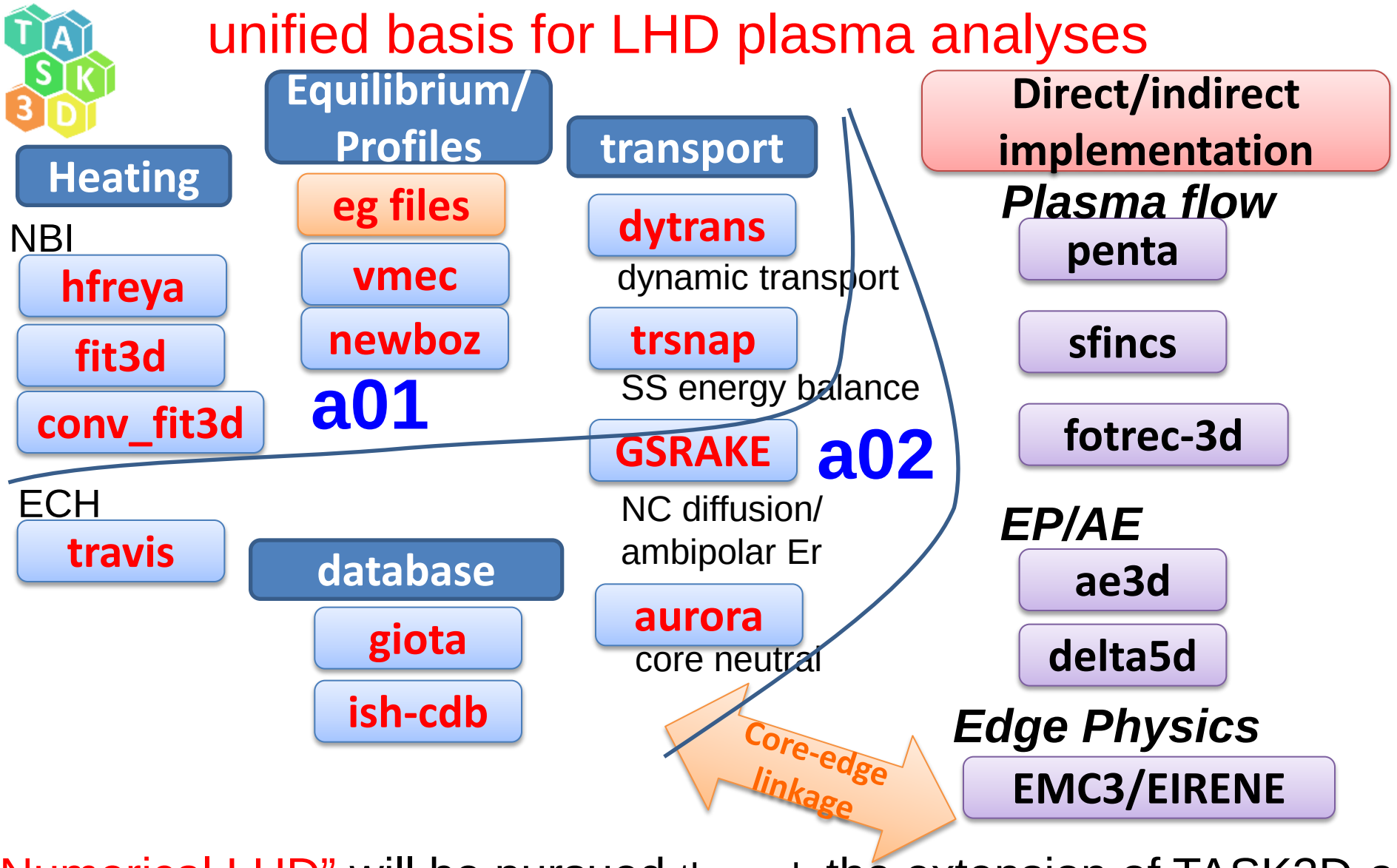
- H.Lee (NFRI), K.Ida et al., PPCF 55 (2013) 014011
- K.Ida et al., PRL 111 (2013) 055001 etc…

Calculation procedure of TASK3D-a02



Extension of TASK3D-a → "Numerical LHD"

unified basis for LHD plasma analyses



"Numerical LHD" will be pursued through the extension of TASK3D-a

Summary

- ***TASK3D*** has been programmatically developed as “extension” of TASK to LHD Plasmas

- Analysis Suite, ***TASK3D-a***, has been utilized to conduct automated energy balance analyses of NBI-heated LHD plasmas (now including ECH in ***a02***)

- There have been already a number of contributions to LHD papers by providing “***nucleus***” results

- International collaborations have also been conducted

PPPL PRINCETON PLASMA PHYSICS LABORATORY

TECH-X SIMULATIONS EMPOWERING YOUR INNOVATIONS

CONSORZIO RFX Ricerca Formazione Innovazione

- TRANSP-TASK3D collaboration based on this TUG Meeting is anticipated !

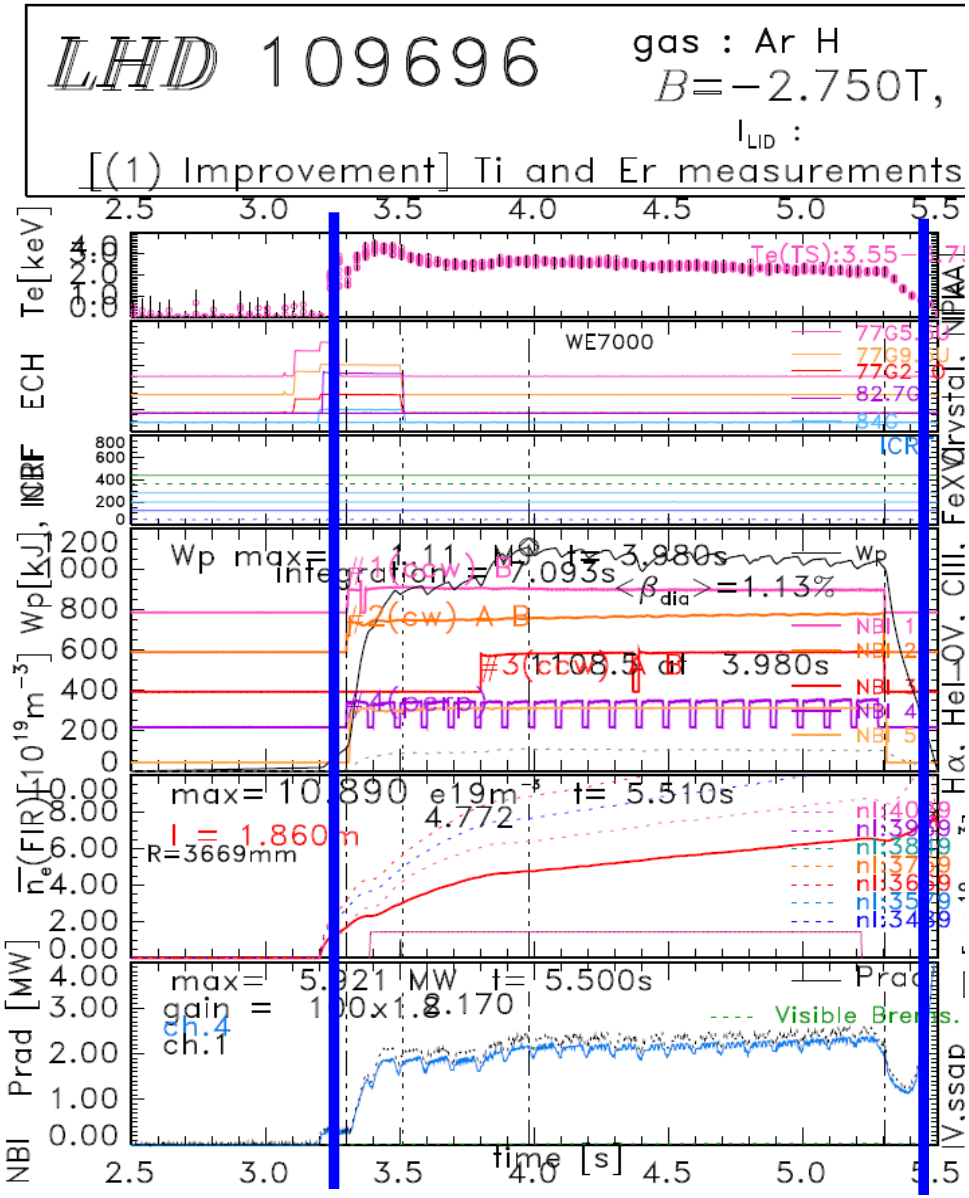
Description on modules implemented in task3d-a01

Function	Code	Functions, Remarks
3D Equilibrium	**VMEC**	It calculates MHD equilibrium (fixed boundary). The VMEC equilibrium database for TSMAP has been prepared with VMEC2000_8.0. The equilibrium solution used for each time slice is re-calculated by utilizing parameters of so-called “best-fit” TSMAP.
	BOOZER	It performs the mapping from VMEC coordinated to Boozer coordinates.
Heating	**fit3d**	It was developed (“reduced” version of GNET) to evaluate radial profiles of NBI absorbed power, beam pressure, beam source and induced momentum. The calculation consists of three parts: •HFREYA: calculations of the birth profile (from the generation of the beam particles in the beam source to ionization in the plasma) •MCNBI: birth-ions are followed (shorter than the energy slowing-down time, but longer than the orbit effects such as prompt loss can be reflected) •Steady-state solution of Fokker-Plank equation is obtained analytically without orbit effects taken into account
	Conv_fit3d	It has been developed to evaluate the NBI absorbed power and induced momentum by taking the beam slowing down (SD) effect into account, based on fit3d (SS) results.
Energy balance	**TRsnap**	It has been modified based on TASK/TR to evaluate steady-state energy balance. NB.) currently (in task3d-a01), •Pin,e is evaluated just for NBI. ECH and ICH have not been available. Other losses (=negative contribution) like radiation loss have not been included. • energy-transfer considered.
Energy and Momentum balance	**dytrans**	It evaluates “dynamic transport”, in which energy flows due to the temporal variation of plasma profiles are also taken into account.

Example of “eg” file

```
# [Parameters]
# Name = 'THOMSON'
# ShotNo =130000
# Date ='01/23/2015 09:53'
#
# DimNo = 2
# DimName = 'Time', 'R'
# DimSize =418, 140
# DimUnit = 'ms','mm'
#
# ValNo = 6
# ValName = 'Te', 'dTe', 'n_e',  'dn_e', 'laser', 'laser number'
# ValUnit = 'eV', 'eV', 'arb', 'arb', 'arb', 'arb'
#
# [Comments]
# Calibrated By Rayleigh scattering but not yet fully accurate.
# High Voltage is set at 0.90 times
#
#  time(ms)       Radius(mm)   Te(eV)   dTe(eV)  n_e(arb) dn_e(arb) laser power(arb) laser number
# [data]
    33,2420,    9,    3,    14,     3, 1056,2
    33,2445,12702,30574,    54,    21, 1056,2
    33,2471,   25,99999,     1,     2, 1056,2
    33,2496,   14,    9,    53,    15, 1056,2
    ------------------------------------------------
```

Computational time of TASK3D-a01



- t=3.24s ~ 5.44s
- 23 timing selected
- 1 timing ~ 10-15 min.
  (mostly fit3d module)

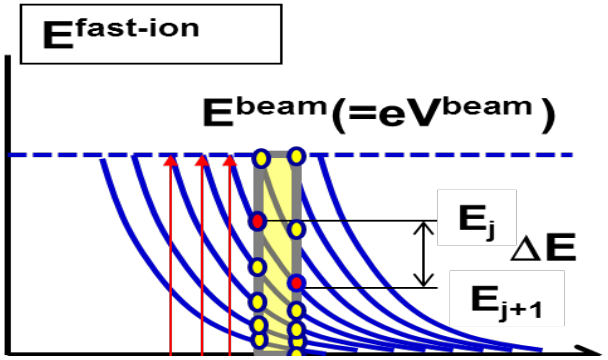
  → ~ 4 h

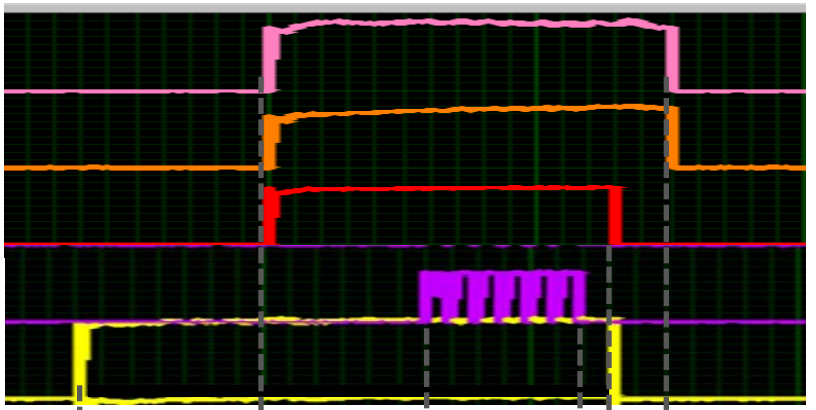
NBI power deposition calculation (SS → SD)

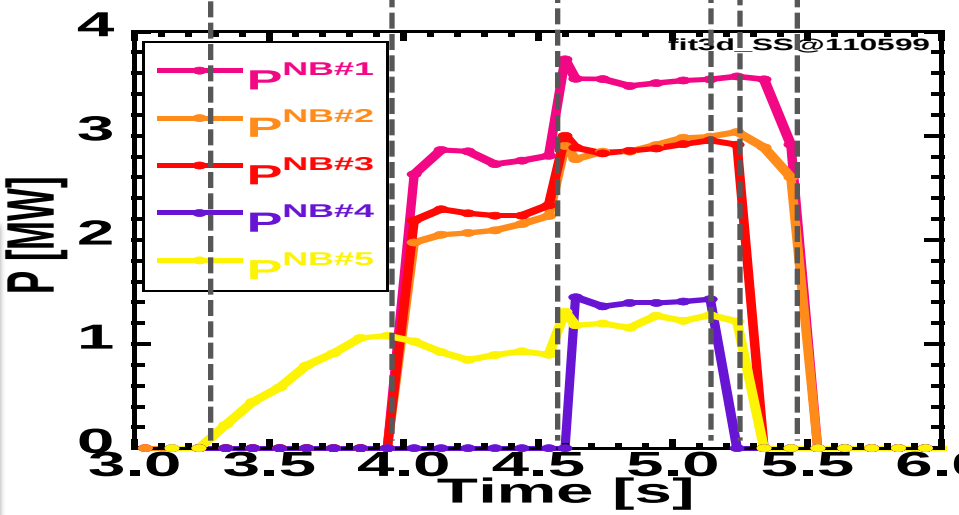
fit3d

SS solution of the Fokker-Planck eq., based on the birth profile of fast ions calculated by the Monte-Carlo method

All the timings @strong Thomson laser







conv_fit3d

Correction due to SD process:

transient phase where the SD time is comparable to the confinement time.

- just after the onset of the NBI especially
  - ✓ in the low density discharge
  - ✓ density decay phase after the pellet injection

NBI group → code modification by simulation G. → implementation

TASK3D-p：説得力のある結果を出す必要

今、Prediction：

LHD重水素実験、FFHR-d1が大きなターゲット

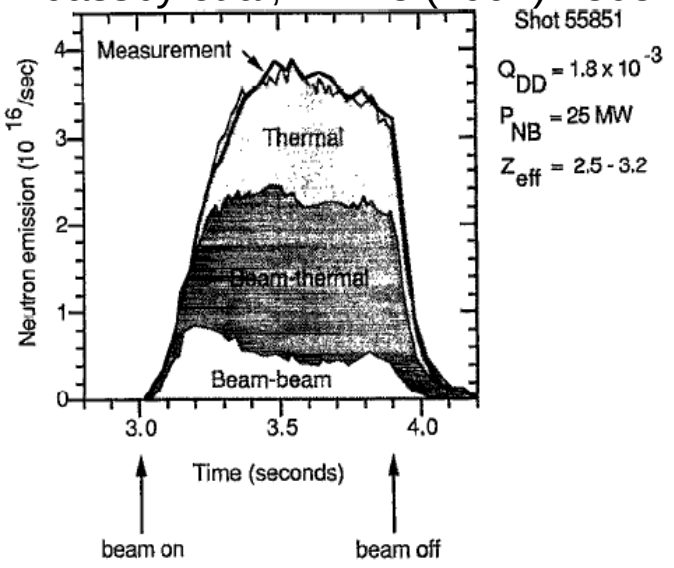
重水素実験：(喫緊)中性子発生数“予測”のための簡易ツール整備

- fit3d -> fit3d_dd(beam-bulk, bulk-bulk反応)に置換
- さらに、beam-beam反応による発生分の追加
  (寄与小さいことがTFTRで示されてはいるが)
- ビーム打ち分け(H/D)への対応
- 放電を通しての温度変化予測が必要
  (統計的に得られたχi, χeを利用予定)
- もちろん検証も必要

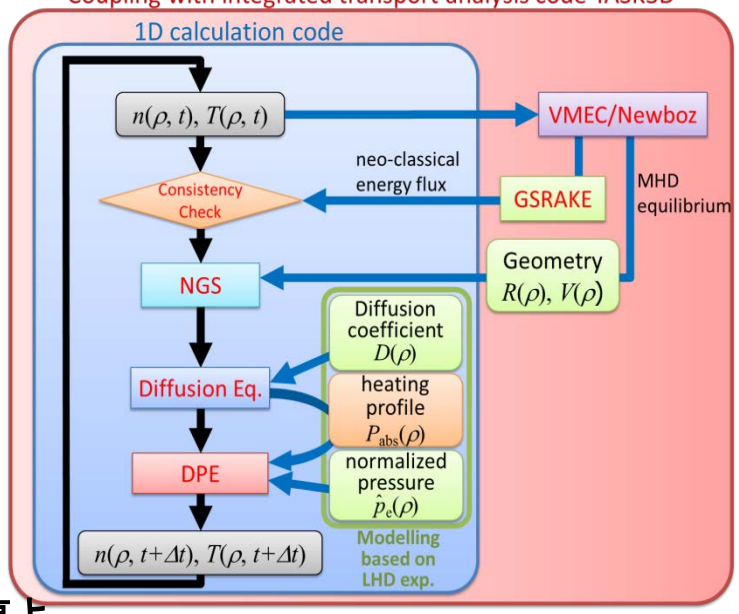
FFHR-d1：

- 核融合炉工学P(後藤拓也氏ら)による、立ち上げ時におけるエネルギーバランス成立性の検討
  (IAEA→NF論文提出へ)
- ペレット入射(NGSモデル)も加味されている

TRANSP SIMULATION
D.L.Jassby et al, PF B3 (1991) 2308



Coupling with integrated transport analysis code TASK3D



T.Goto et al., IAEA-FEC NF論文原稿よ