KSTAR simulation with TRANSP

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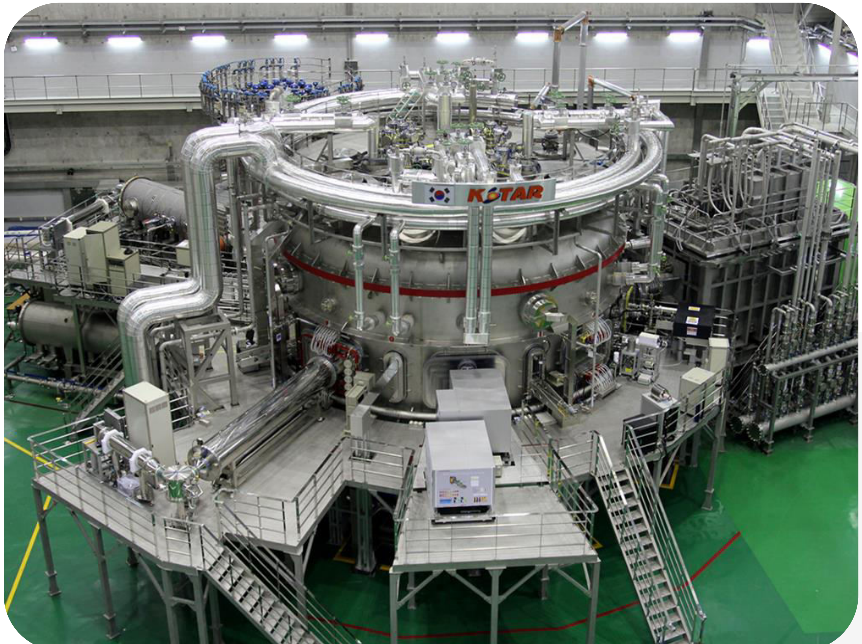
KSTAR

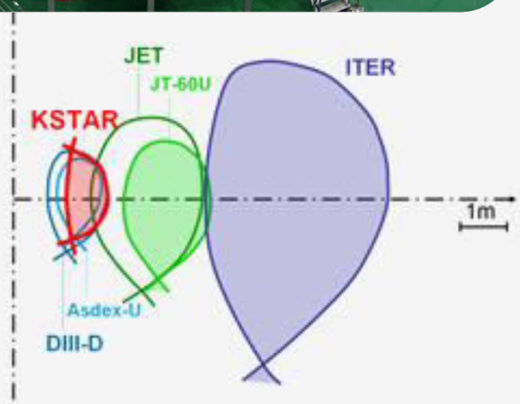
Contents

I. KSTAR Introduction

KSTAR [1]= **K**orea **S**uperconducting **T**okamak **A**dvanced **R**esearch



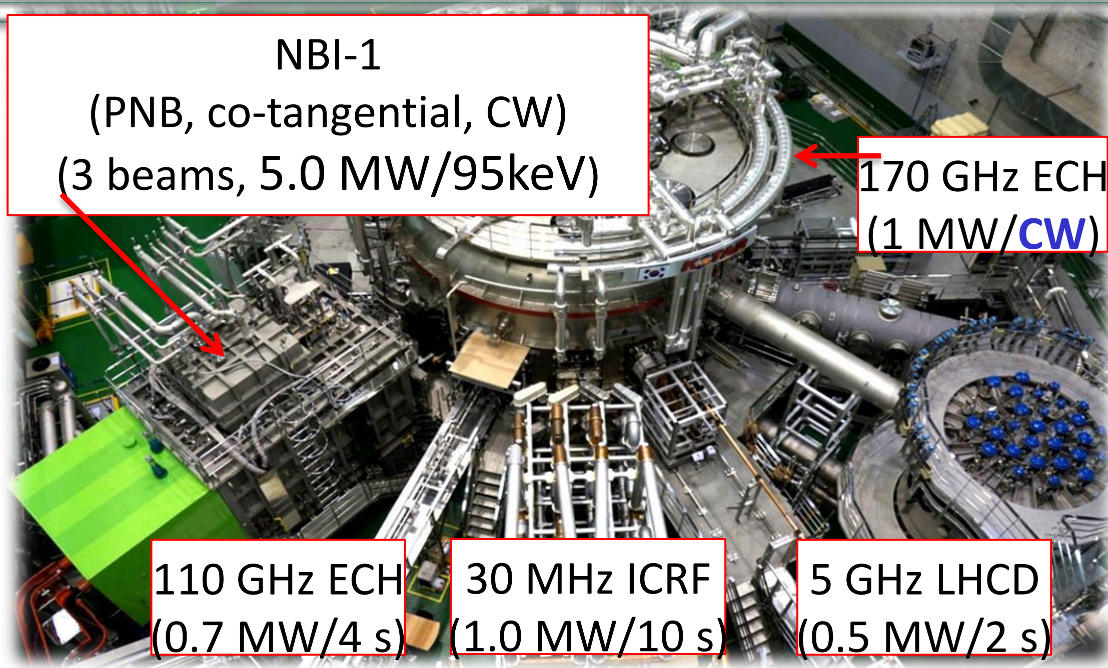
[www.nfri.re.kr]



PARAMETERS	KSTAR	ITER
Major radius, R_0	1.8 m	6.2 m
Minor radius, a	0.5 m	2.0 m
Elongation, κ	2.0	1.7
Triangularity, δ	0.8	0.33
Plasma volume	17.8 m^3	830 m^3
Plasma surface area	56 m^2	680 m^2
Plasma cross section	1.6 m^2	22 m^2
Plasma shape	DN, SN	SN
Plasma current, I_P	> 2.0 MA	15 (17) MA
Toroidal field, B_0	> 3.5 T	5.3 T
Pulse length	> 300 s	400 s
β_N	~ 5.0	1.8 (2.5)
Plasma fuel	H, D-D	H, D-T
Superconductor	Nb_3Sn, NbTi	Nb_3Sn, NbTi
Auxiliary heating /CD	~ 28 MW	73 (110) MW
Cryogenic	9 kW @4.5K	

I. KSTAR Introduction

Heating :



Diagnostic: **Black : installed** **Blue : plan for 2015**

- **Magnetic diagnostics** *(NFRI, ASIPP)*
- **Edge probe sensors** *(NFRI, HYU)*
- **Recip. Langmuir Probe** *(NFRI)*

- **Visible TV (3 sets)** *(NFRI)*
- **Survey IRTV** *(NFRI)*

- **D-alpha Monitor** *(NFRI)*
- **Visible Spectrometer** *(NFRI)*
- **Visible Filterscope** *(ORNL)*
- **VUV Survey Spec.** *(ITER KO, KAIST)*
- **Resistive Bolometer** *(NFRI, NIFS)*
- **Imaging Bolometer** *(NIFS)*

- **mm-Interferometer** *(NFRI)*
- **Thomson Scat.** *(NFRI, JAEA, NIFS)*
- **ECE** *(NFRI, KAERI, NIFS, Kyushu U.)*
- **Reflectometer** *(NFRI)*

- **Hard X-ray** *(NFRI)*
- **Ellipsometry** *(NFRI)*
- **Deposition** *(NFRI, HYU)*
- **Neutron** *(NFRI, HYU, ITER KO)*
- **Fast-ion loss** *(NFRI)*
- **NPA** *(KAERI)*

- **XICS** *(NFRI, PPPL, ASIPP)*
- **Charge Exch. Spec.** *(NFRI, NIFS)*
- **ECEI (2 sets)** *(POSTECH, UCD)*
- **MIR** *(UNIST, UCD)*
- **X-ray Pinhole** *(KAIST, KAERI, NFRI)*
- **SXR** *(KAIST, Far-Tech, JET, ENEA)*
- **BES** *(Wigner)*
- **Li-beam** *(Wigner)*
- **Coherence Image, iMSE** *(NFRI, ANU)*
- **Divertor IR TV** *(NFRI)*
- **FIR Interferometer** *(NFRI, SNU)*
- **DBS** *(NFRI, SWIP)*
- **MSE** *(NFRI, TU/e)*

I. KSTAR Introduction

Operation Phase I 2008 ~ 2012	Operation Phase II 2013 ~ 2017	Operation Phase III 2018 ~ 2022	Operation Phase IV 2023 ~
Superconducting Tokamak Operation	**Long-pulse H-mode and ITER pilot**	**High-performance Scenario related to DEMO**	**DEMO Advanced Technology**
• Integrated control of SC tokamak • First plasma • H-mode discharge • Experimental collaboration	• ITER priority research (ELM, Disruption, NTM) • High performance plasma study using KSTAR intrinsic tools (intermediate heating power, low density)	• Demonstrate advanced operation scenario (high power, high density) • Integrated control of profile and stability • Research applicable to DEMO	• Stabilization and optimization of advanced scenario • Technologies at extreme environments

Hardware Upgrade

- Heating : ~ 13MW
  - NBI ~ 6MW
  - ECH ~ 3MW
- PFC : graphite
- Density control: cryopump
- 3D field : IRC & RWM PS
- Electric : MG
- Cooling : PFC cooling
- Control & diagnostics

Upgrade

- Heating : ~ 30 MW
  - NBI ~ 12 MW
  - LHCD or Helicon CD
- PFC : metal wall
- Density control : pellet
- 3D field :
- Electric :
- Cooling : heating
- Control & diagnostics

Long-pulse discharges & ITER urgent issues was the main thrusts for 2013

I. KSTAR Introduction

❑ **Main research goal of KSTAR =**
Demonstrate steady-state operation of high-performance Advanced Tokamak (AT) modes

❑ **We need :**

- Understand the plasma comportment.
- Need to use a transport analysis code.

⇒ **TRANSP [2]** : successfully used with other Tokamaks (TFTR, DIIID, Jet & NSTX, …).

TRANSP = Interpretive Code
⇒ Input Data are necessary

❑ Work is to generate UFILEs, by using as much experimental data as possible.

❑ For Now, we use **experimental data obtained** from different diagnostic devices: Reflectometer (NE), Charge Exchange Spectrocopy (TI, VT), Thomson Scattering (TE, NE), Electron Cyclotron Emission (TE), X-ray Crystal Spectrometer (TE, TI, VT) and Interferometer (NE)

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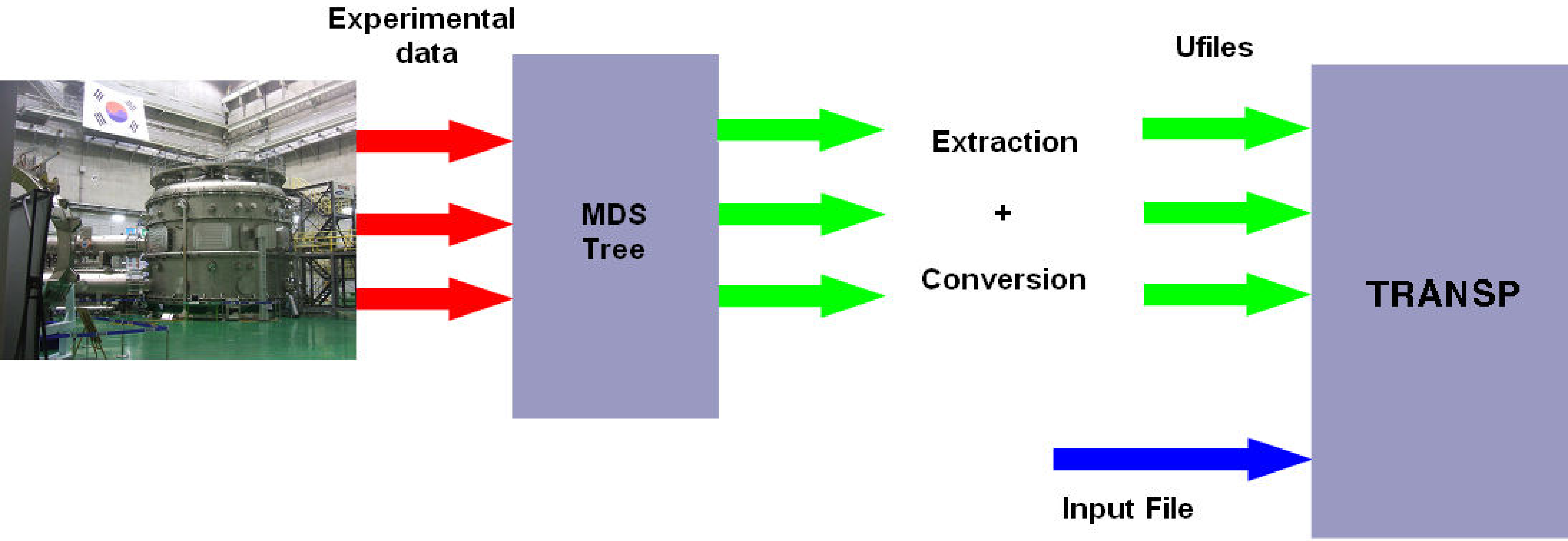
II. Inputs - MDSPlus Tree



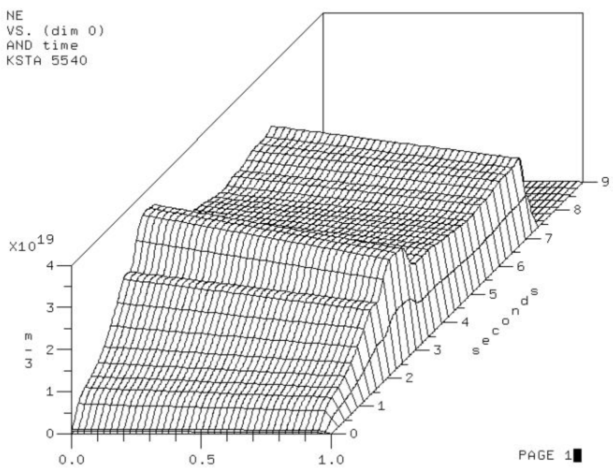
- Exp. data stored in MDSPlus Tree[3].
- Data extracted & converted into UFILE[4]

- **Input Data used UFILE Format :**
  - More than 150 kinds
  - In practice, only a few 2D (radial profile vs time - NE) and
    1D (scalar vs time - current) used

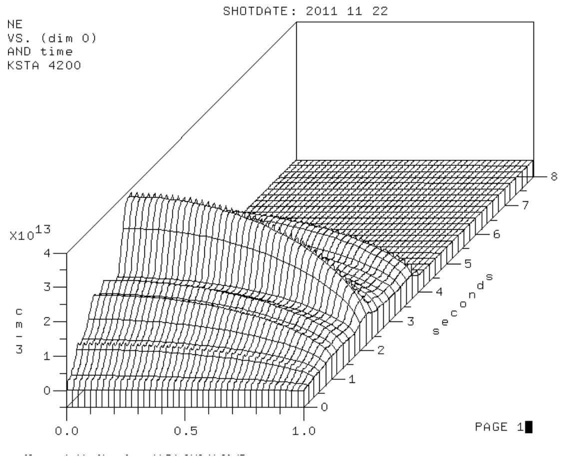
II. Generating UFILEs from KSTAR data

- For electron density profile, we can use the **Interferometer** data
  But, data = line average density.
- Synthetic profiles => 2 Different Methods:

Linear



Parabolic (1-r**2)**nu



Available in KSTAR MDSPlus Tree (NE_INTER01)

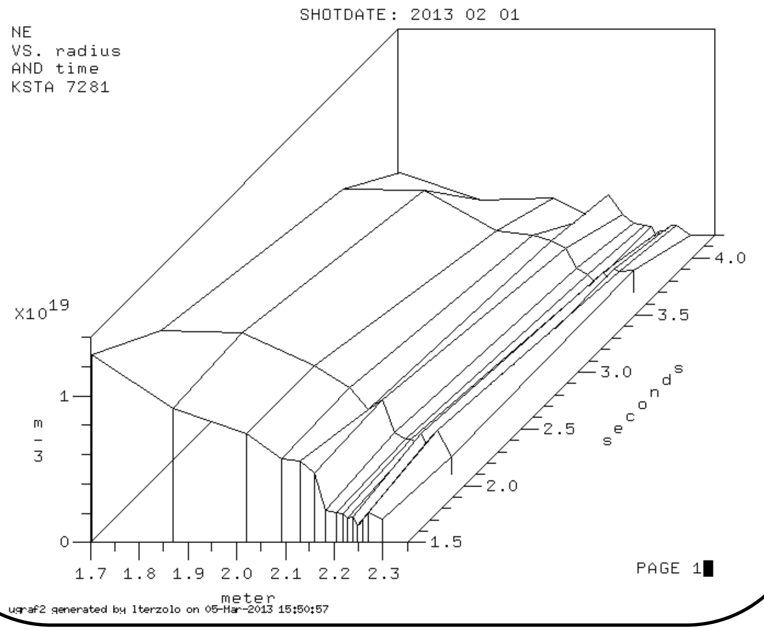
KSTAR

II. Generating UFILEs from KSTAR data

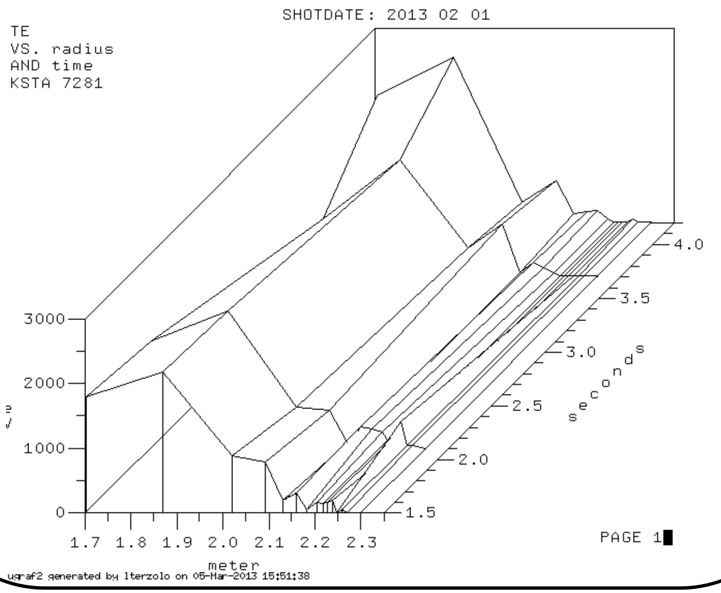
❑ For Electron density and temperature profiles,

=> we can use the **Thomson Scattering** data

Electron Density



Electron Temperature



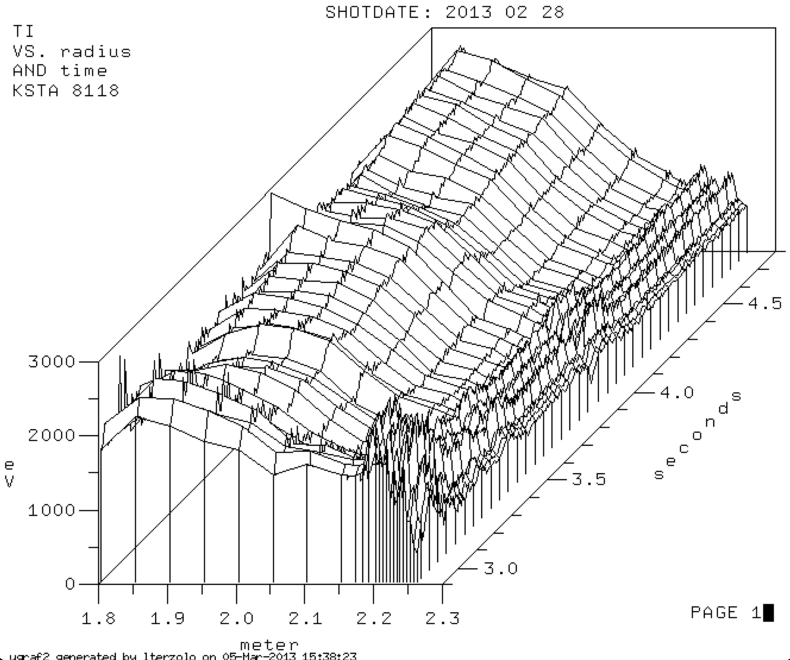
Available in KSTAR MDSPlus Tree (COREX_NE, COREX_TE)

Ⅱ. Generating UFILEs from KSTAR data

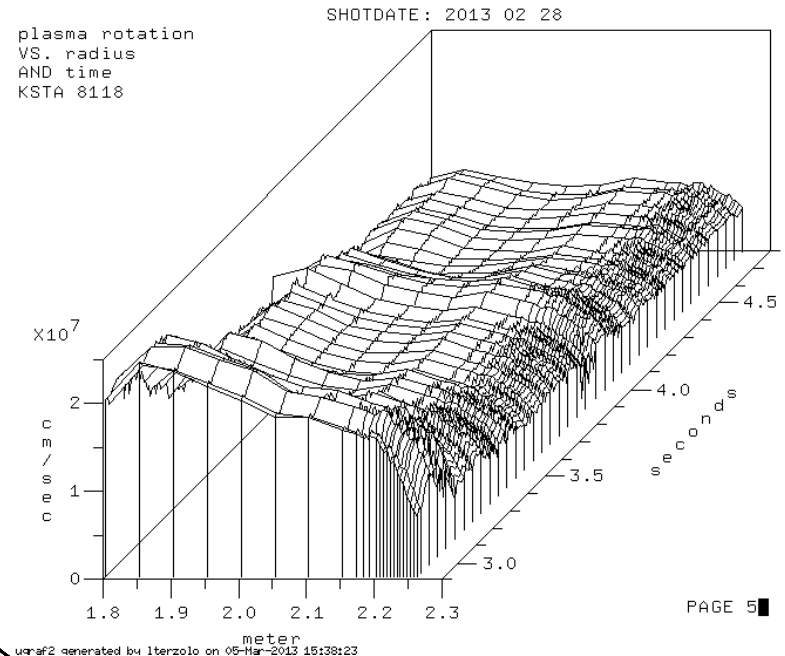
- ❑ For Ion temperature and Plasma toroidal velocity profiles,

  => we can use **Charge Exchange Spectroscopy (CES)** data

Ion Temperature



Plasma toroidal velocity



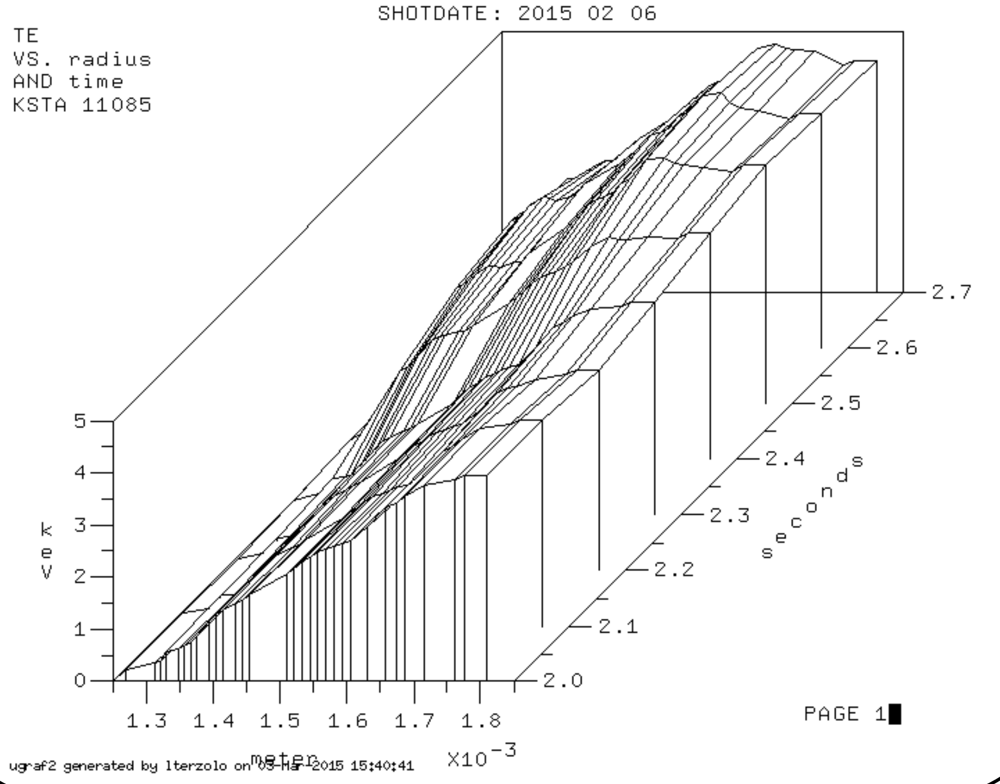
Available in KSTAR MDSPlus Tree (CES_Tixx, CES_VTxx)

II. Generating UFILEs from KSTAR data

- For Electron temperature profile,

  => we can use the **Electron Cyclotron Emission (ECE)** data

Electron Temperature



Available in KSTAR MDSPlus Tree (ECExx)

II. Generating UFILEs from KSTAR data

- For Electron & Ion temperature and plasma toroidal velocity profiles,

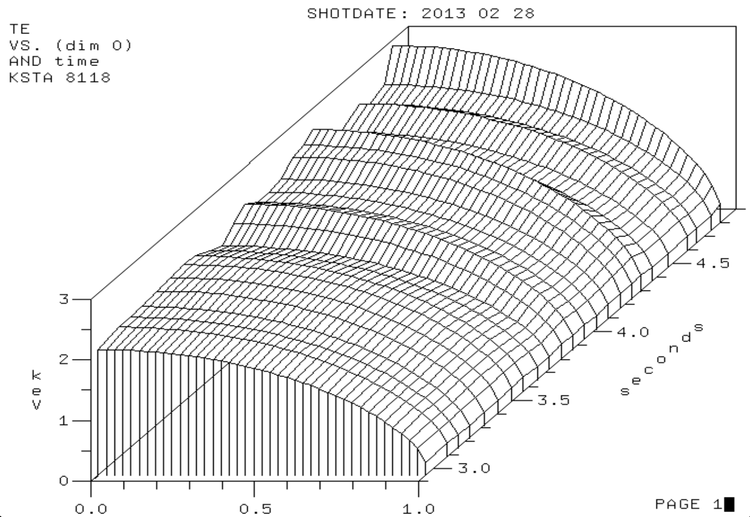
  => we can use **X-ray Crystal Spectrometer (XCS)** data

  => But, data only in the core plasma.

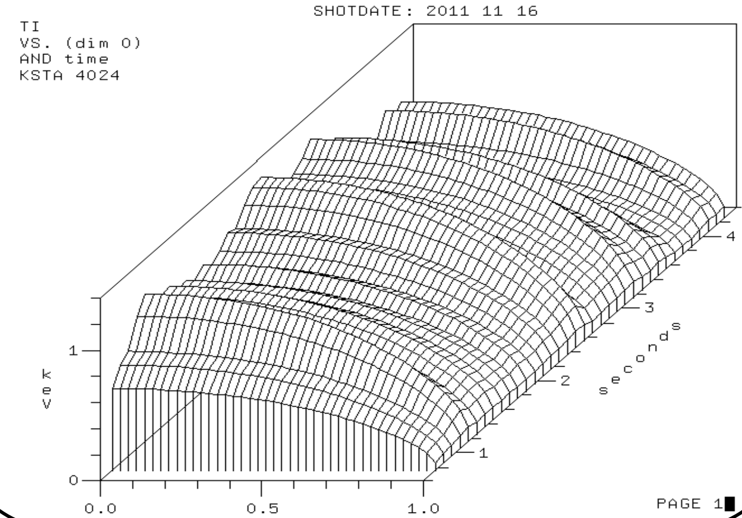
- Use synthetic profiles,

  => we need to extrapolate the data by using a parabolic function

Electron Temperature



Ion Temperature



In KSTAR MDSPlus Tree (TXCS_TE053, TXCS_TI053, TXCS_VR053)

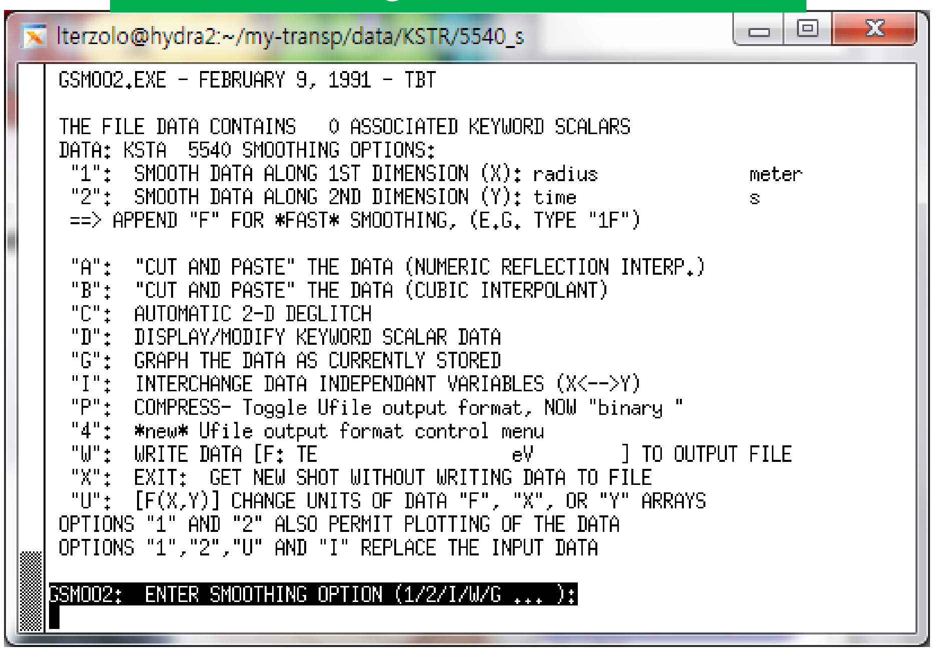
II. Generating UFILEs - Smoothing

❑ Experimental data are noisy

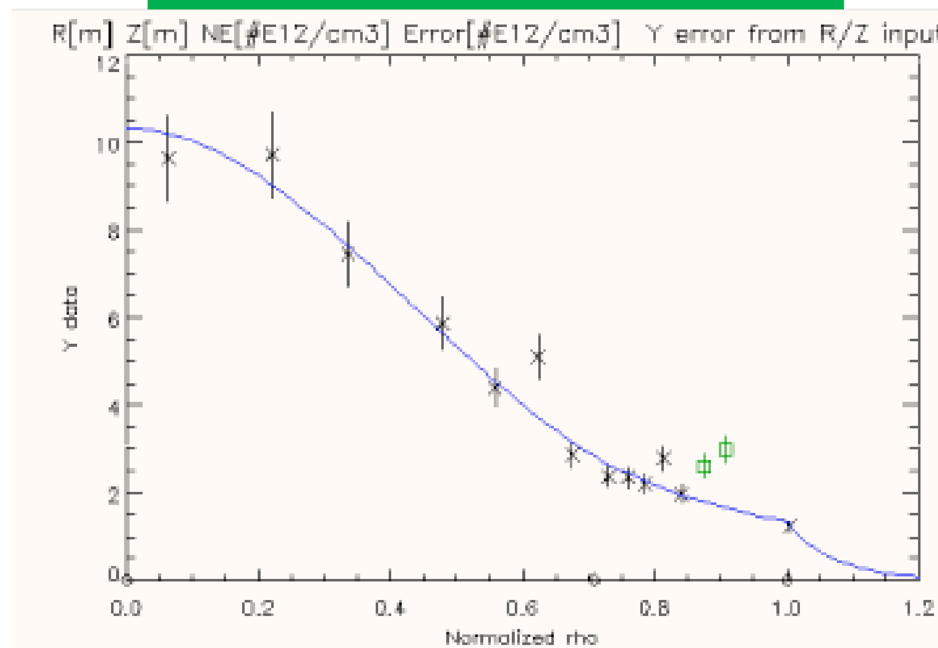
=> Need for smoothing

❑ UFILEs can be smoothed by using:

gsmoo2



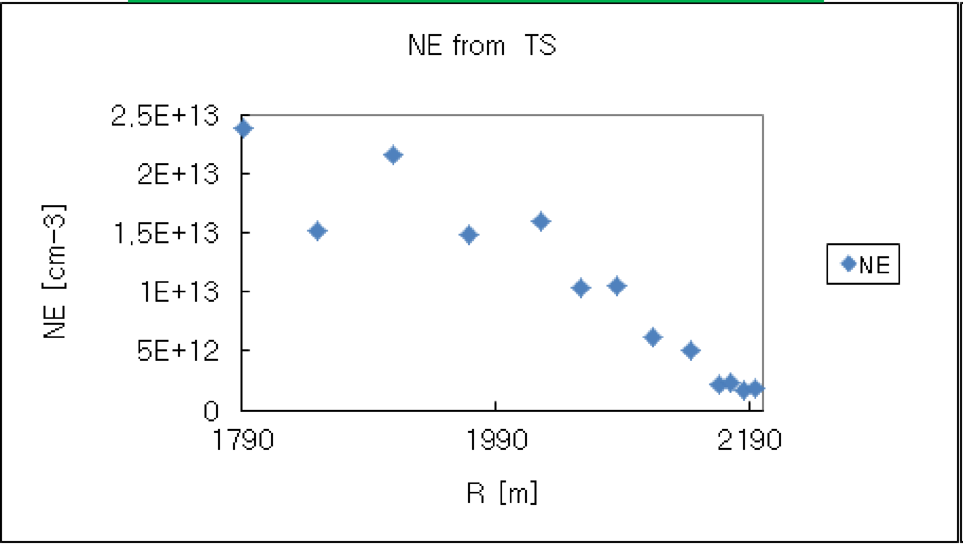
Kprofiles (GAprofiles)



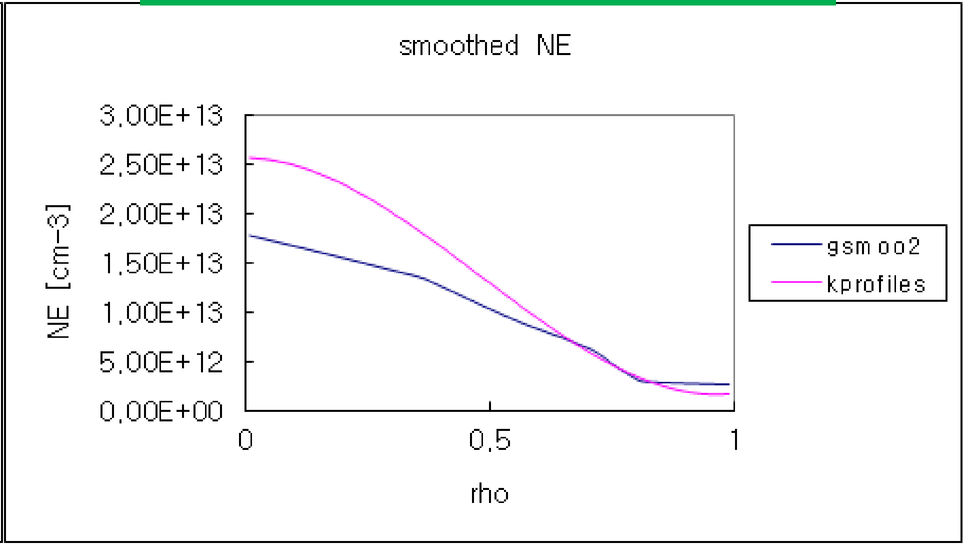
II. Generating UFILEs - Smoothing

- ❑ Smoothing example of TS data.
- ❑ For KSTAR shot #10107 at t=3.6s

Raw data



Data smoothed with kprofiles and gsmoo2

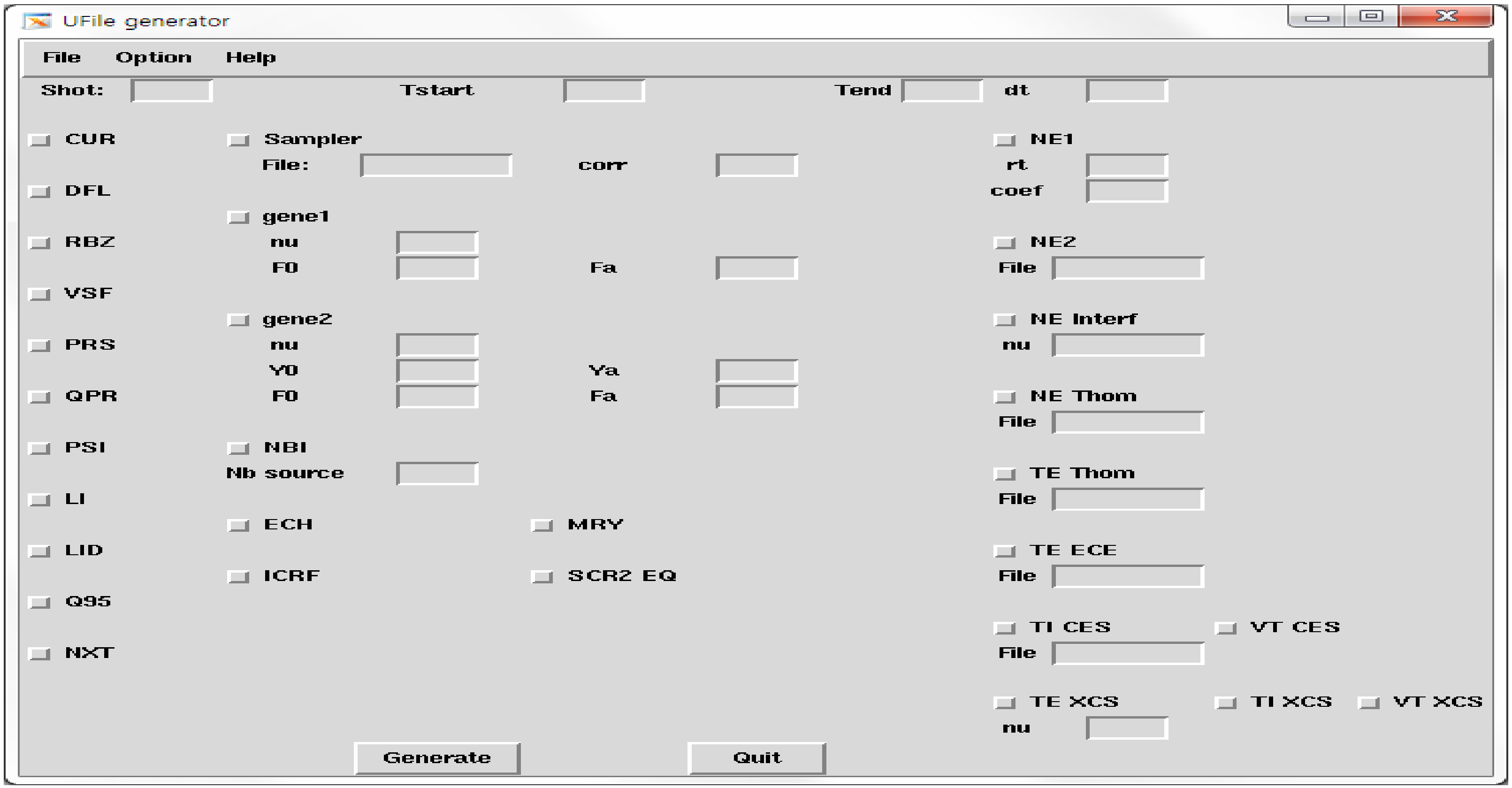


- **kprofiles** : Spline interpolation, but we need :
  - run EFIT
  - smooth the data for each time step
- **gsmoo2 :** Simpler interpolation, but treat all the data in 1 step and no need for EFIT

KSTAR

II. Generating UFILEs - Other UFILEs

❑ In order to make the UFILE generation process easy to use,
I created a GUI (python) that generates UFILE
by calling different Fortran programs that extract data
from KSTAR MDSPlus Tree (previously presented programs + others)



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III. TRANSP simulation - Preparation

❑ In order to run TRANSP, we need to follow these steps :

- Prepare UFILEs (ikstar)
- Smooth(if needed): gsmoo2 or kprofiles (ikstar)
- Copy all the files on Hydra2
- Prepare the input file (*TR.DAT) (Hydra2)
- Test input+UFILEs (Hydra2): trdat shot_number
- Create execution file (Hydra2): pretr shot_number
- Run (Hydra2): runtr shot_number

=> Need to juggle with 2 different clusters

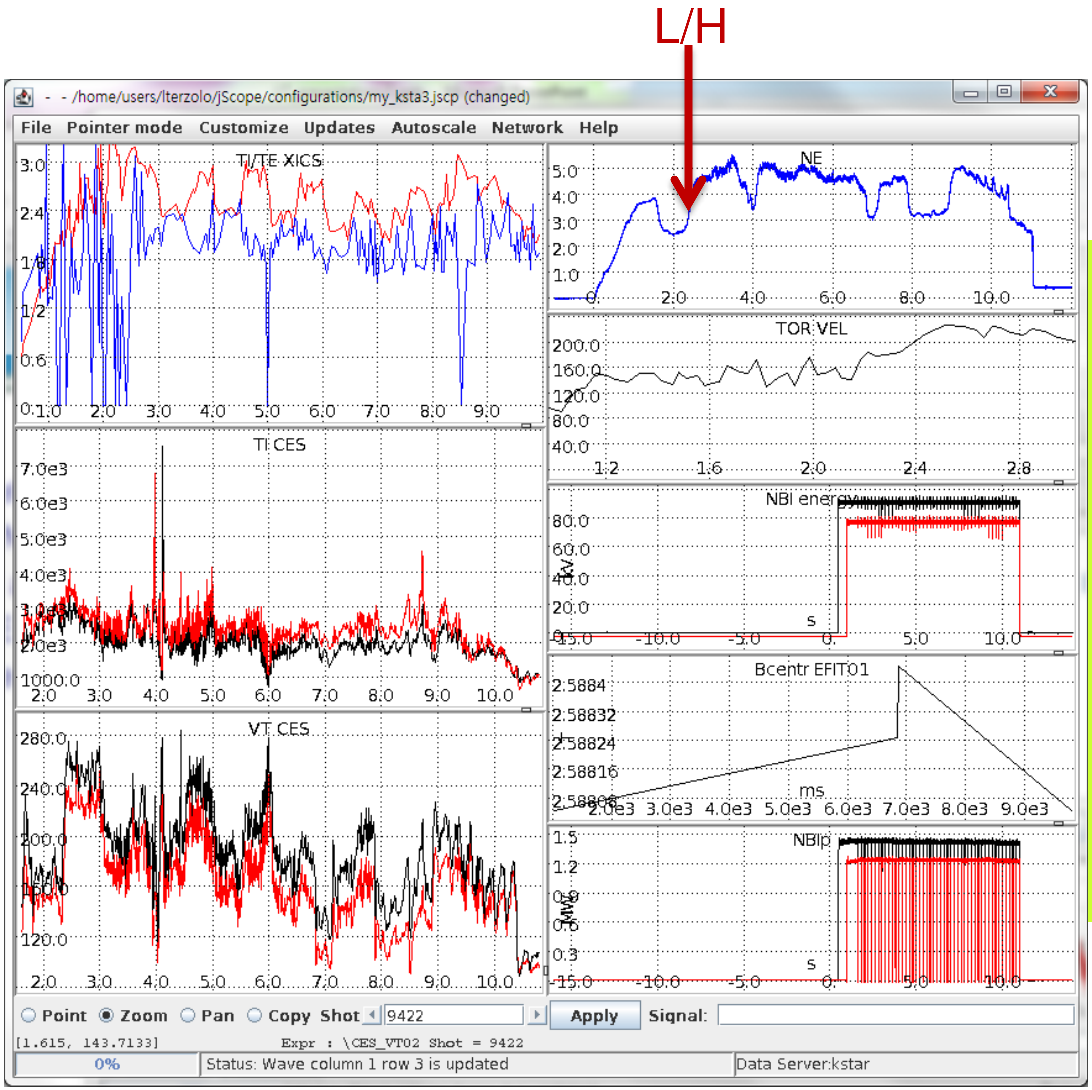
❑ Output :

- A lot of results (more than 1000)
- Visualization: rplot shot_number

=> Not straightforward (lot of options) :

I created a program that extracts interesting data from the result file (NETCDF format) and converts into ascii

III. TRANSP Results : Shot 9422 during L/H transition

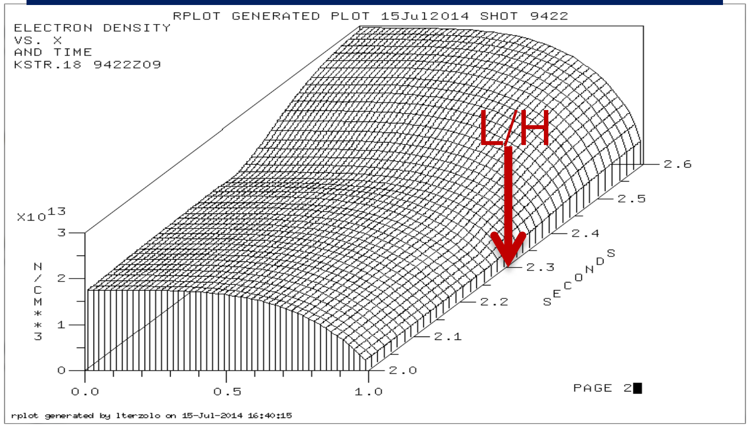


❑ KSTAR shot 9422

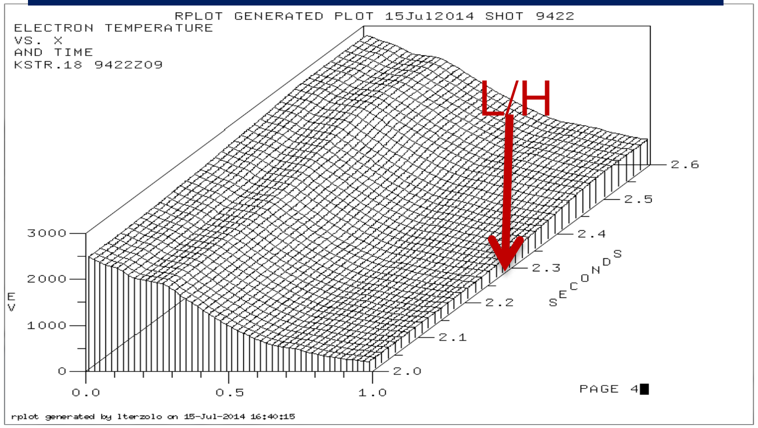
- L/H transition (around 2.3s)
  - Simulation from 2 to 2.6 s
- Heating
  - 2 NBI sources
- Profiles
  - TI and VT from CES
  - TE from ECE
  - Ne from interfer. + TS

III. TRANSP Results : Inputs

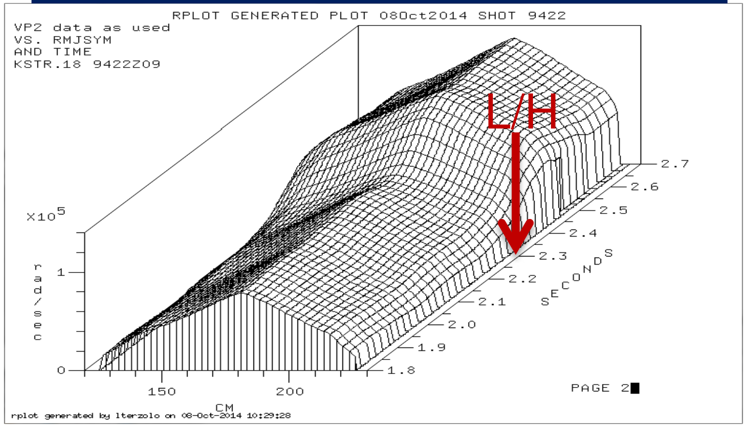
Electron Density



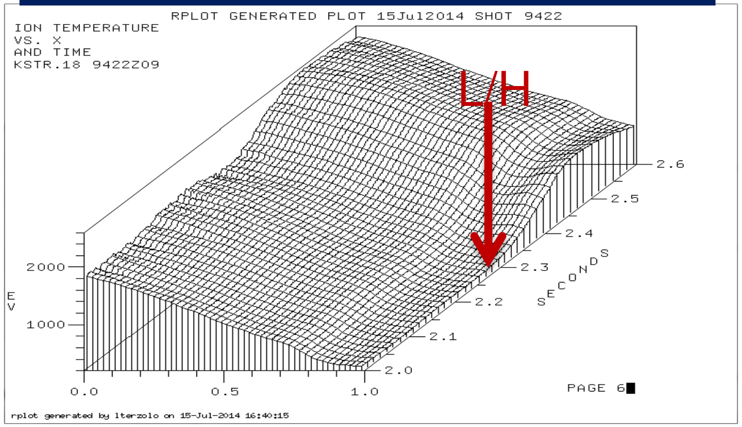
Electron Temperature



Toroidal Velocity

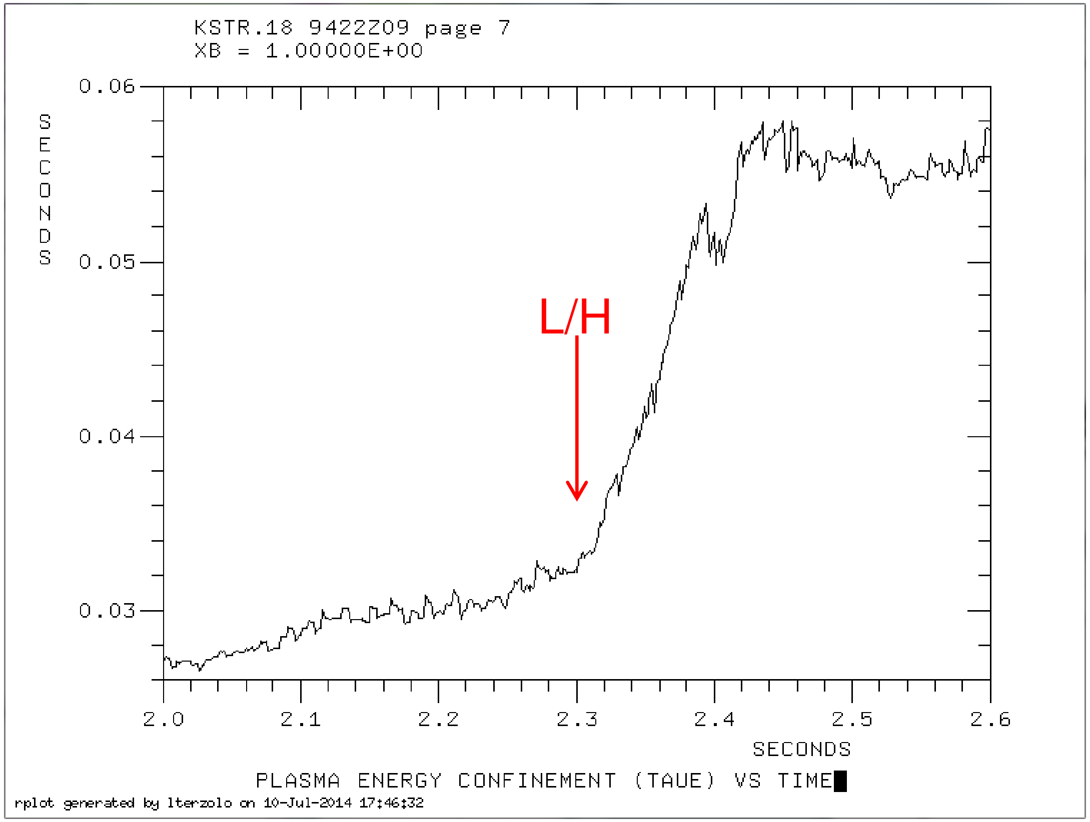


Ion Temperature



III. TRANSP Results

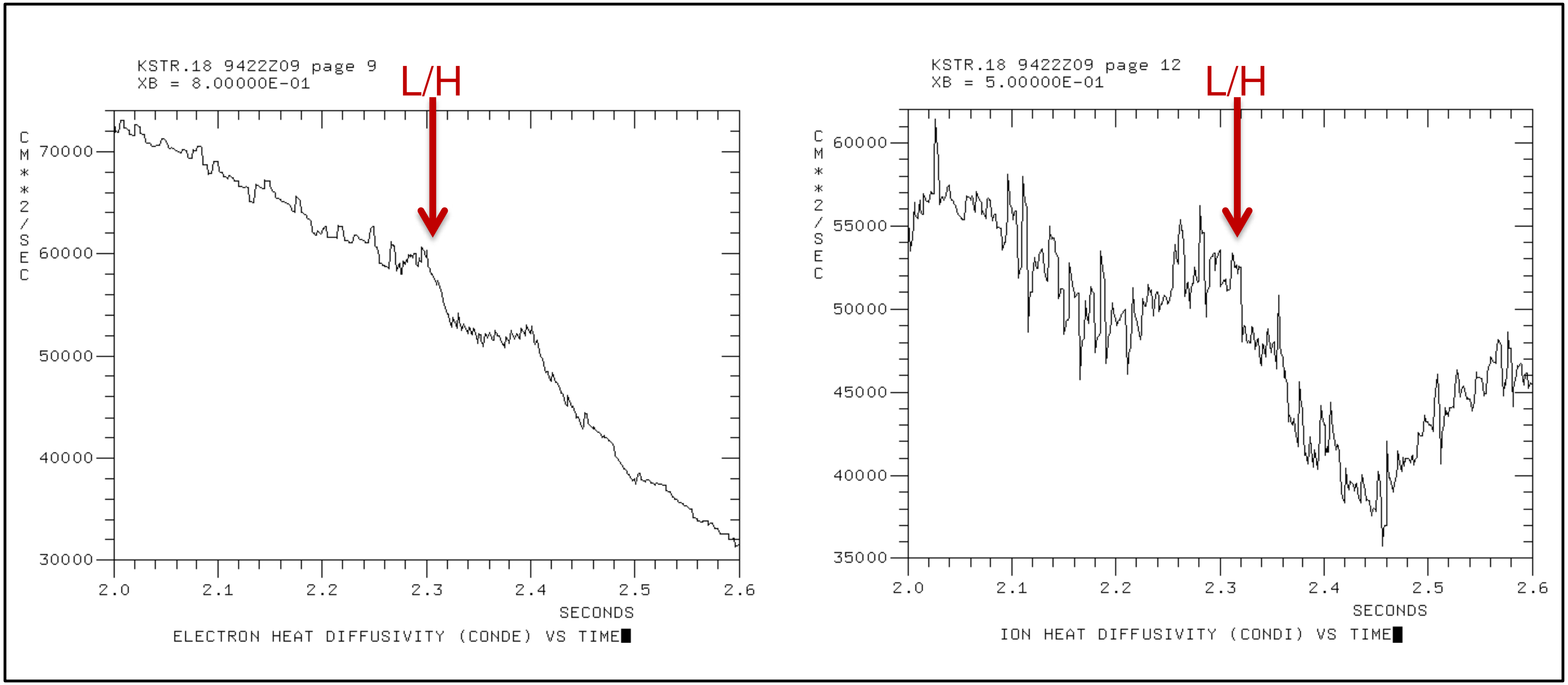
❑ Confinement Time:



- Increase of confinement time during L/H transition
- H-mode = 2 times higher than L-mode

III. TRANSP Results

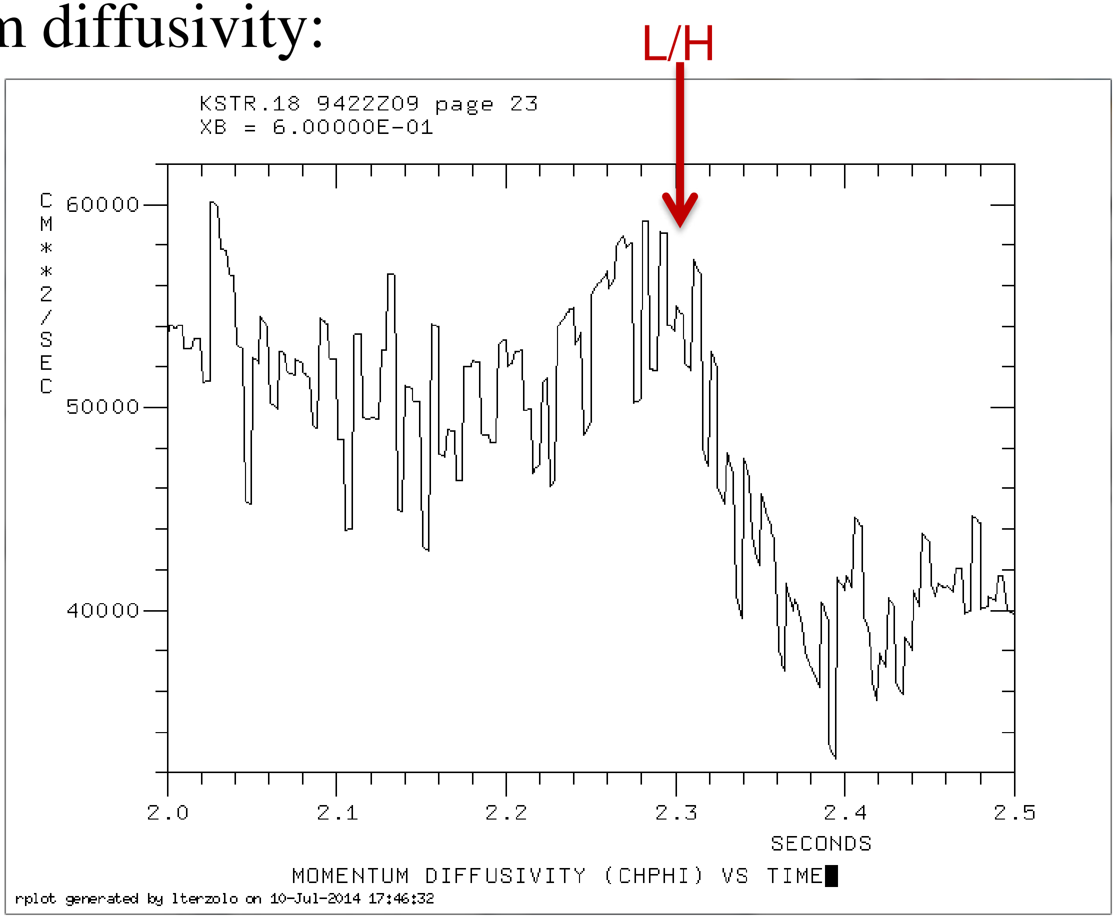
❑ Electron and Ion diffusivities:



Electron & Ion diffusivities decrease during L/H transition => confinement improved

III. TRANSP Results

❑ Momentum diffusivity:

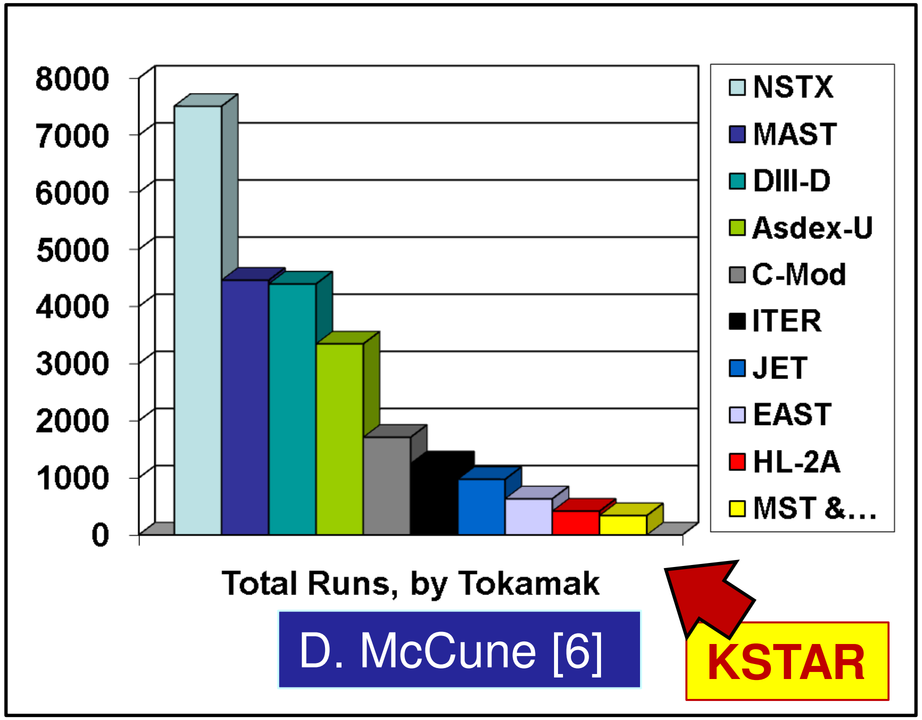


Diffusivities decrease during L/H transition => confinement improved

III. TRANSP Results

- Until now, we were using TRANSP installed in NFRI (2007 version)
  But, we can use TRANSP-GRID (PPPL server) [5]

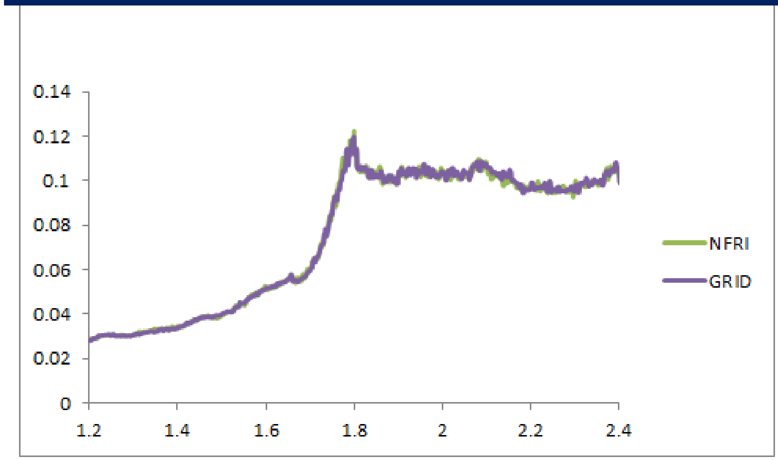
- Most recent version of the code
  - Less bug
  - Predictive TRANSP
  - New features
    - GENRAY code
    - GLF23, MMM08
    - …



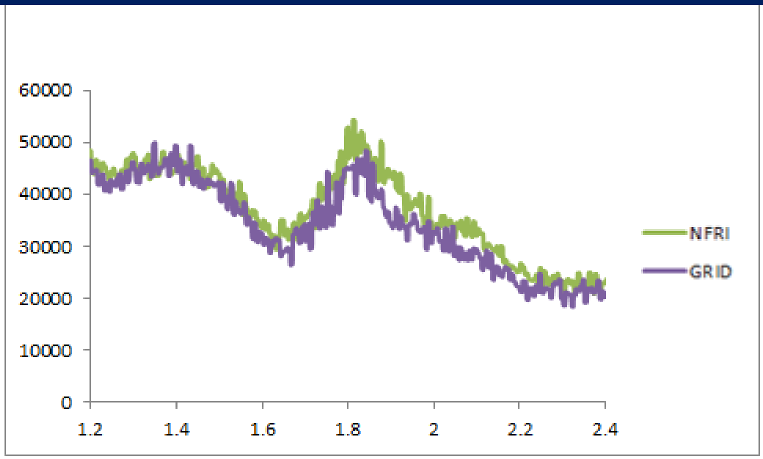
III. TRANSP Results

❑ KSTAR shot 7300 Comparison: Our TRANSP vs TRANSP GRID

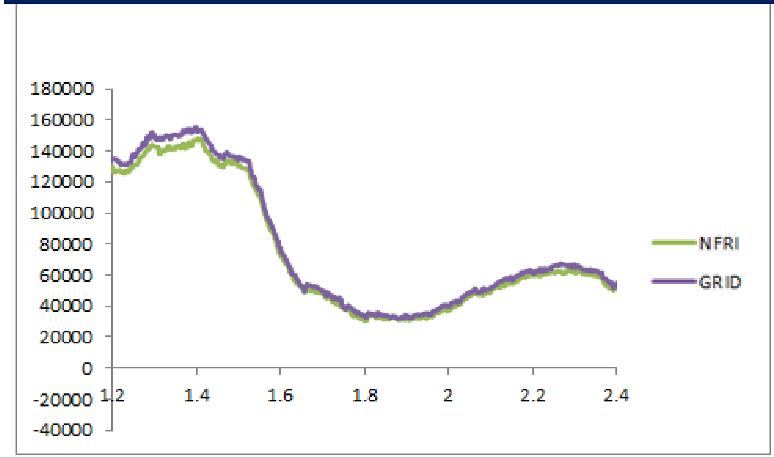
Energy Confinement Time Diffusivity



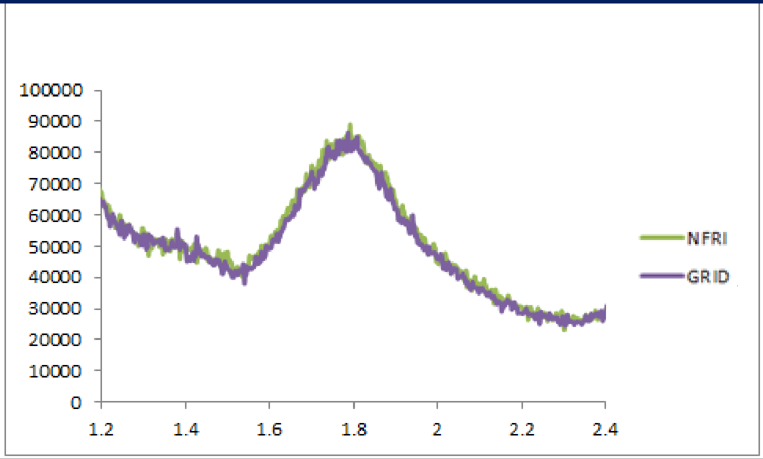
Momentum Diffusivity



Electron Heat Diffusivity



Ion Heat Diffusivity



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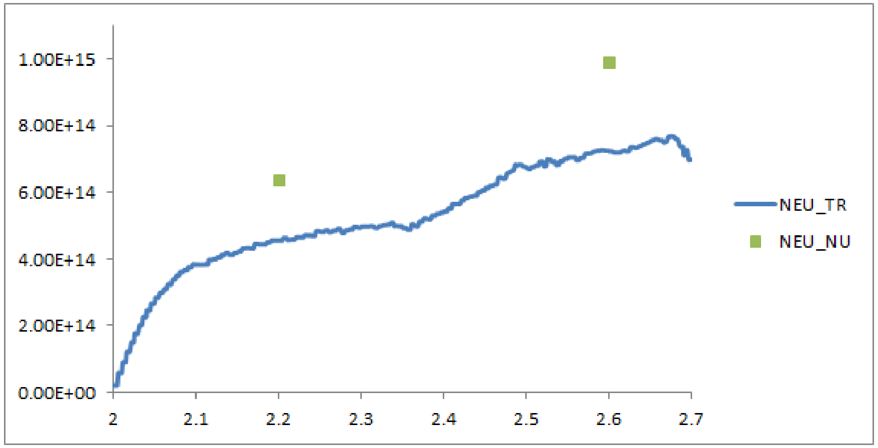
IV. Issues – input/output

❑ In order to run TRANSP, we need good UFILEs but also a good TR.DAT file. For now, we are using a TR.DAT file adapted from an old NSTX case.

❑ How to check output data (figure of merit, …)



=> Need to learn how to run TRANSP

"Ignorance is a wonderful thing- it's the state you have to be in before you can really learn anything" – Terry Pratchett

IV. Issues - TRANSP GRID

- In order to run TRANSP-GRID,
  - Prepare UFILEs/input file on ikstar
  - Copy the files on Hydra2
  - Check the data: trdat runID
  - Copy the files on PPPL's server
  - Prepare the run: tr_start runID
  - Submit the launch (send data and run): tr_send_pppl.pl runID KSTR NOMDSPLUS
  - Check the run: http://w3.pppl.gov/transp/transpgrid_monitor
  - Get the data: tr_fetch KSTR.yy runID
  - Copy the result files on Hydra2
  - Visualize: rplot runID

=> Need to juggle with 3 different clusters

Hope to solve the connection problem NFRI/PPPL

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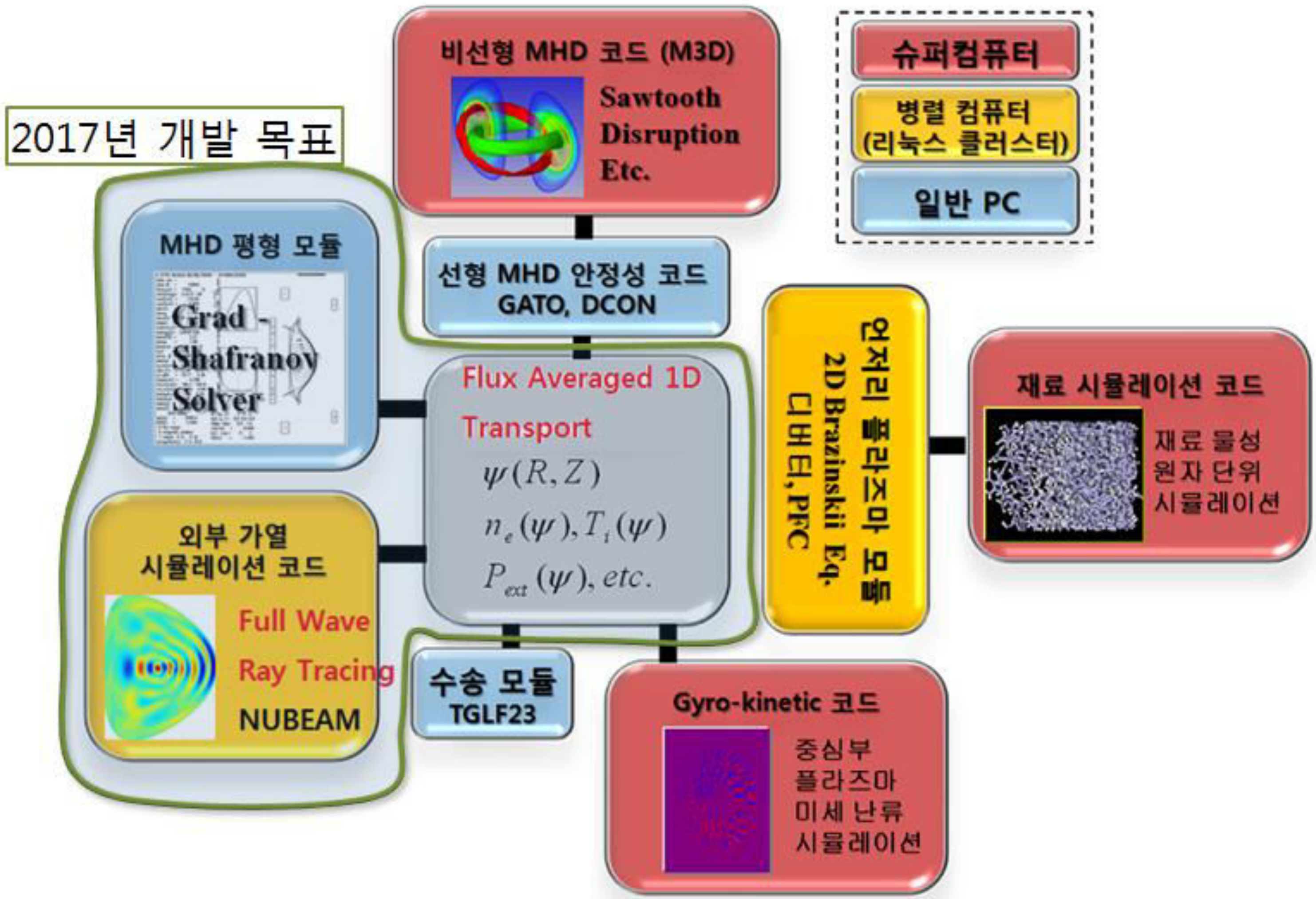
V. Perspective – Integrated modeling



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VI. Conclusion

- For now, we succeeded to create the main UFILE from the KSTAR experimental data
- However, the results depend strongly on these input data
  - Need for accurate experimental data
  - Simple smoothing => Big differences
- When new diagnostic devices are available, we must generate new kinds of UFILEs (the more, the happier)
- Next step => to use TRANSP GRID and PTRANSP
- Later: use PTRANSP for benchmarking our integrated code

Acknowledgement:
We would like to thank S.G. Lee for providing some slides and all the KSTAR experimental team for the experimental data used for the simulations

Thank you for your attention

Bibliography

[1] G.S. Lee, et al., Nucl. Fusion **41** (2001)

[2] R. V. Budny, et al., Nucl. Fusion **35** (1995)

[3] J. Stillerman, T.W. Fredian, Fus. Eng. and Design 43 (1999)

[4] http://w3.pppl.gov/~pshare/help/ufiles.htm

[5] http://w3.pppl.gov/transp/ComputeServerAccess.html

[6] D. McCune, Status of TRANSP, presented at APS-DPP 2010