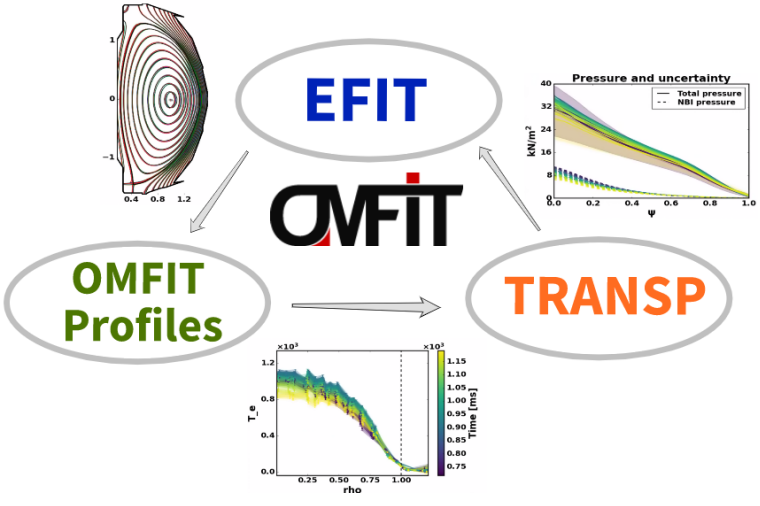
# Adapting the OMFIT kineticEFITtime workflow for NSTX/NSTX-U

G. Avdeeva[1], K. E. Thome[1], S. P. Smith[1], O. Meneghini[1], J. McClenaghan[1], D. J. Battaglia[2], D. Eldon[1], B. Grierson[1], N. Logan[1], T. Osborne [1] and the OMFIT team




[1]General Atomics
[2]Princeton Plasma Physics Laboratory

Virtually presented at the
NSTX-U/Magnetic Fusion Science Meeting

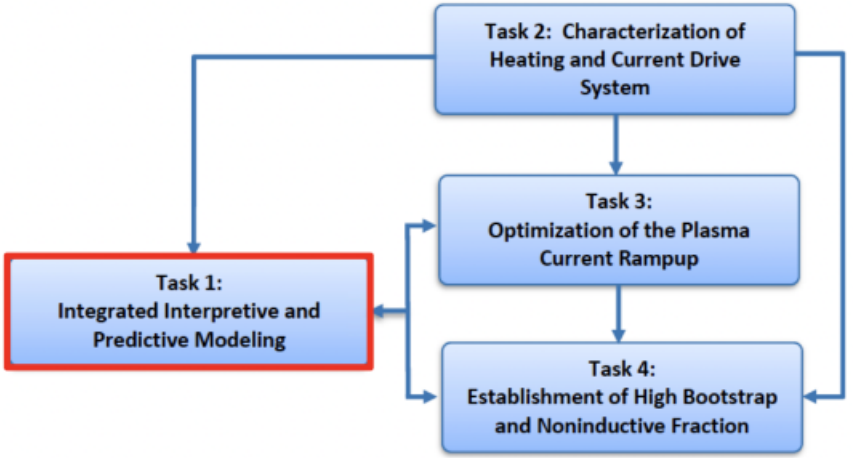
December 6, 2021

GENERAL ATOMICS

# GA is working with the NSTX-U team to create stationary, noninductive scenarios with high $\beta$ and $f_{BS}$ - K. Thome PI[A]

**Task 1** will streamline workflows and provide support to enable robust, routine equilibrium, transport and EP analysis/predictions

- **Year 1:** Adapt OMFIT-based integrated modeling workflows used on DIII-D to NSTX-U
  - Kinetic equilibrium reconstructions
  - Power, particle, momentum balance analyses
  - Predictive scenario development
- **Year 2 - 5:** Implement and validate improved H&CD and transport models, and apply predictive capabilities




**We need an efficient way to generalize OMFIT experimental analyses modules that started as very DIII-D centric**

Presentation by K.Thome February 15 2021

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# Equilibrium reconstruction is a starting point of tokamak data analysis and modeling

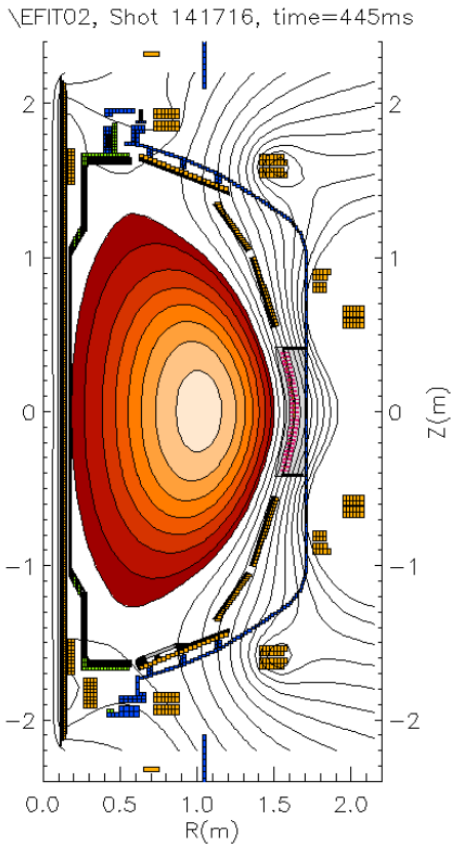
**EFIT**[A] reconstructs equilibrium by solving the GS equation.

EFIT with only external magnetic data

- stored energy, plasma boundary, and basic shape → **plasma operation and interpretation of experimental data, etc.**

kineticEFIT with magnetic data and kinetic profile information

- internal magnetic geometry, current and pressure profiles → **transport and stability studies, RF studies, power handling, etc.**




L. Lao, et al., Nucl. Fusion 25 (1985) 1611

# To make a full kinetic equilibrium reconstruction

1. Acquire **initial equilibrium** with only magnetic and MSE data
2. Acquire **pressure information** from TS, CHERS diagnostics and **map** onto flux surfaces
3. Aquire bootstrap current, total and beam pressure contribution from **transport code**
4. With all of this information make a **full kinetic** equilibrium

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What are the challenges?

- Fetching and analyzing (ELMs, uncertainties, robust fitting ...) a lot of diagnostic data
- Preparing inputs and managing code runs
- Data exchange between experimental data analysis tools, EFIT, and transport code
- Benchmark and data consistency check on each step

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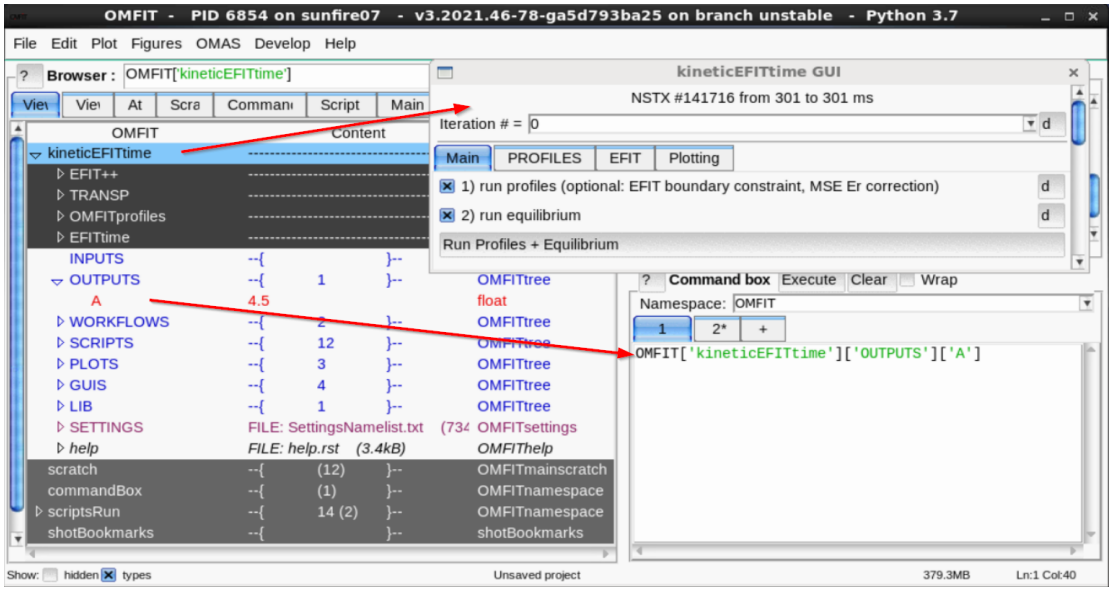
# OMFIT[A] is streamlining data preparation, diagnostic consistency, and interpretive → predictive workflows

## One Modeling Framework for Integrated Tasks (OMFIT)

- Organized into modules, which can be easily combined
- Tree structure for easy manipulation with objects
- Graphical User Interface (GUI)
- Support of various machines

```
[gavdeeva@sunfire07 ~]$ module load mod_omfit; module load omfit/unstable
 omfit is maintained by Sterling Smith.
 If you have any problems, please contact him directly at smithsp@fusion.gat.com
[gavdeeva@sunfire07 ~]$ omfit
```




OMFIT O. Meneghini et al Nuclear Fusion 55 (2015)

**Webpage** https://omfit.io/index.html

**Github** https://github.com/gafusion/OMFIT-source

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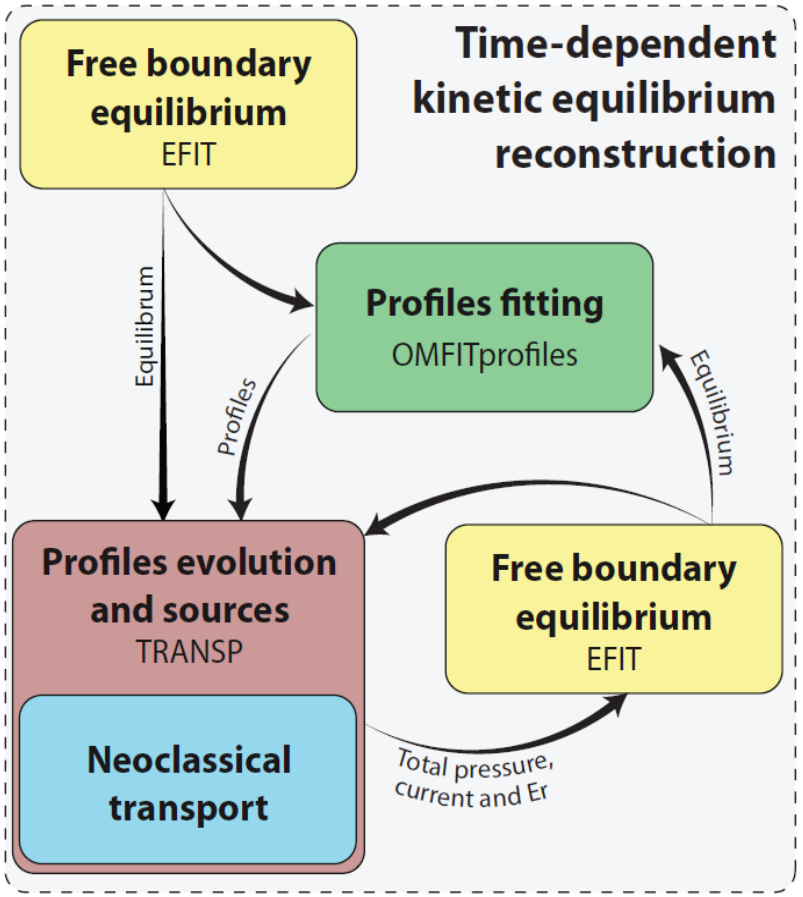
# Time-dependent kinetic equilibrium module in OMFIT kineticEFITtime: EFITtime + OMFITprofiles + TRANSP

Modular structure with data exchange workflow provides:

- Accurate **equilibrium**
- Fast and powerful **experimental data** analysis
- Automatic setup of **TRANSP** runs based on experiment



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# OMFIT EFITtime module

- Generates **input files** (k-files)
  - Loaded from MDS+ server
  - Generated through OMAS (O. Meneghini; June 21, 2021 )
- **Fetch** and **preview** of MSE and magnetic data with availability to **modify** the weight of each element (+ isothermal, rotation constraints)
- Automatically **add pressure and current constraints** as they are available from transport codes (TRANSP or ONETWO)
- Run code to **generate equilibrium** for a single time slice or multiple time slices
  - PHOENIX version of EFIT
  - EFIT-AI (J. McClenaghan; September 27, 2021 )

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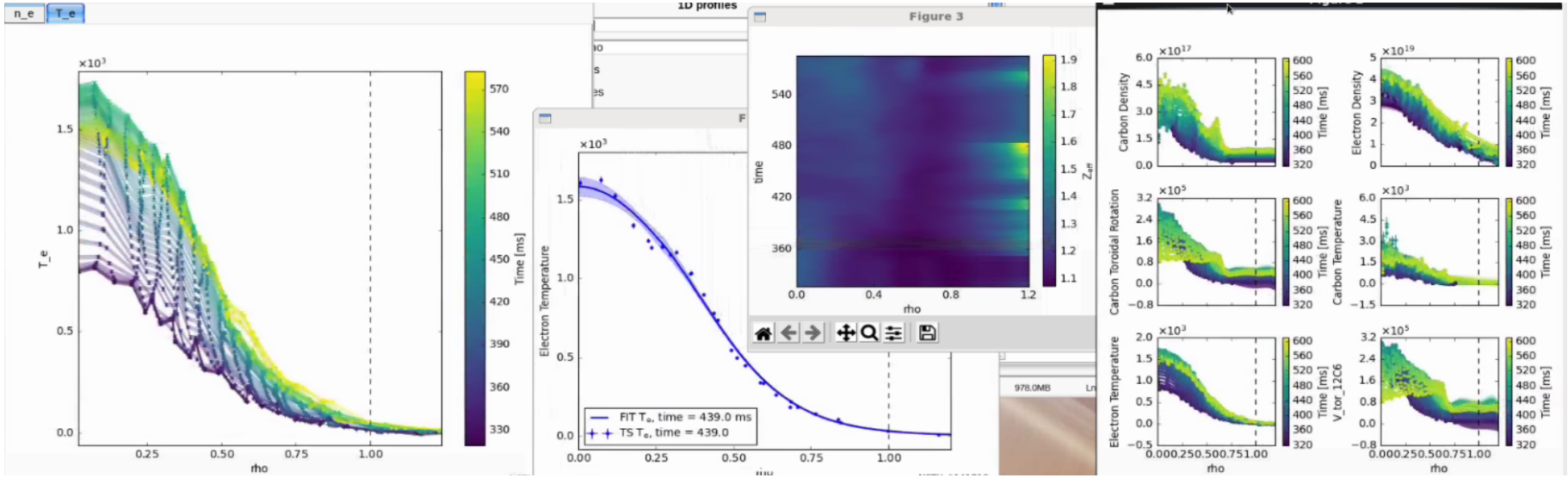
# Comprehensive analysis of experimental profiles ensures reasonable inputs for numerical codes

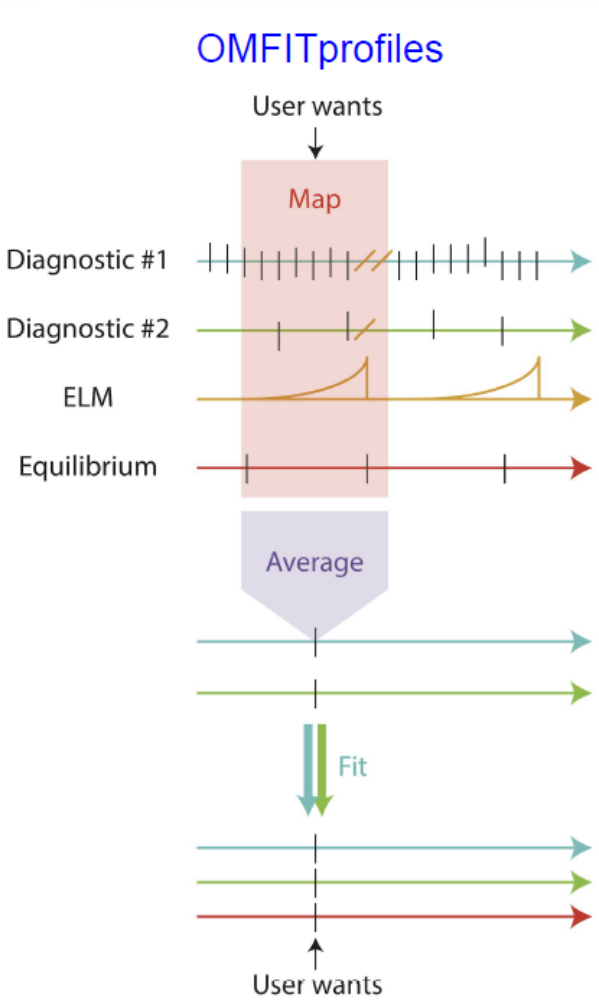
- OMFITprofiles [A] is a consistent tool for interfacing with, mapping, visualizing, and fitting tokamak profile measurements
- OMFITprofiles provides rapid, comprehensive time dependent profiles analysis




*N.C. Logan et al.*
*Fusion Science and Technology Volume 74, 2018*

# Some of the features of OMFITprofiles

- Integrated with experimental database
- Temporal treatment of data
- Library of fitting methods
- Postfitting analysis
- Automated or via interaction with data



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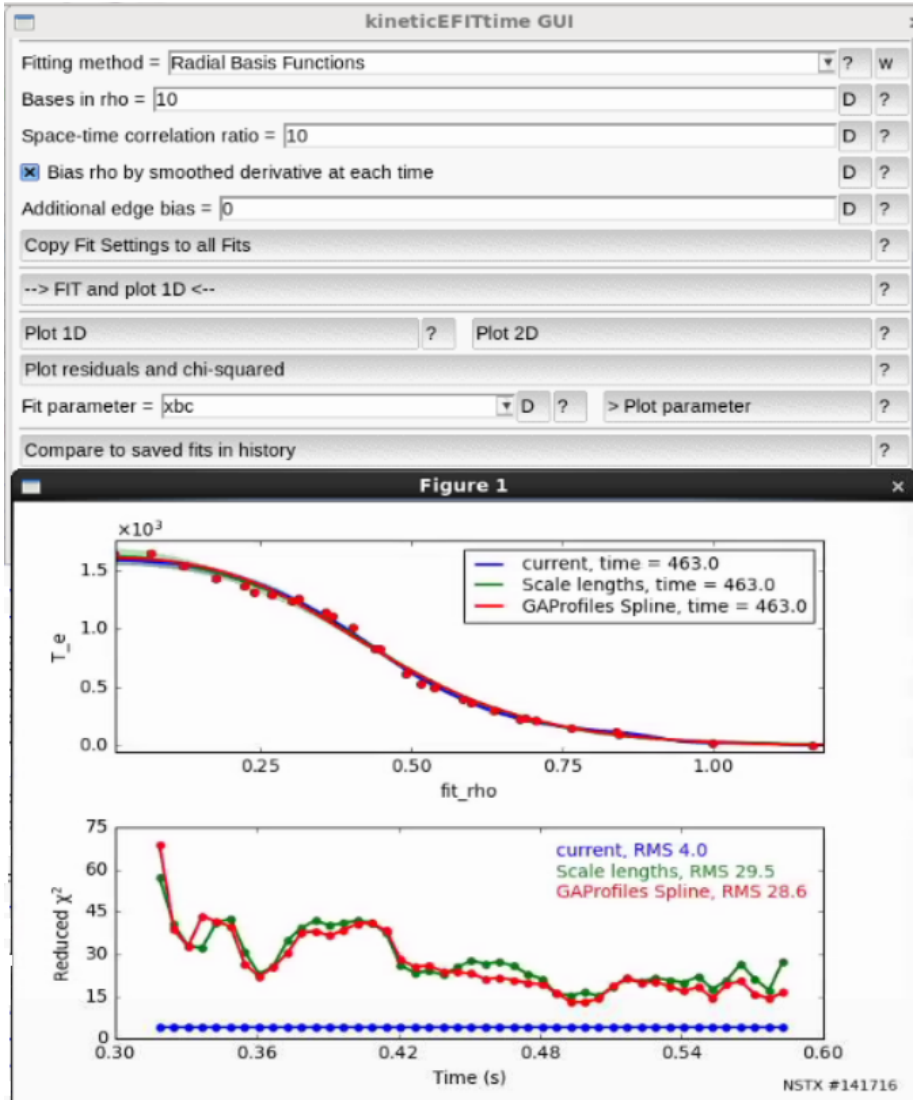

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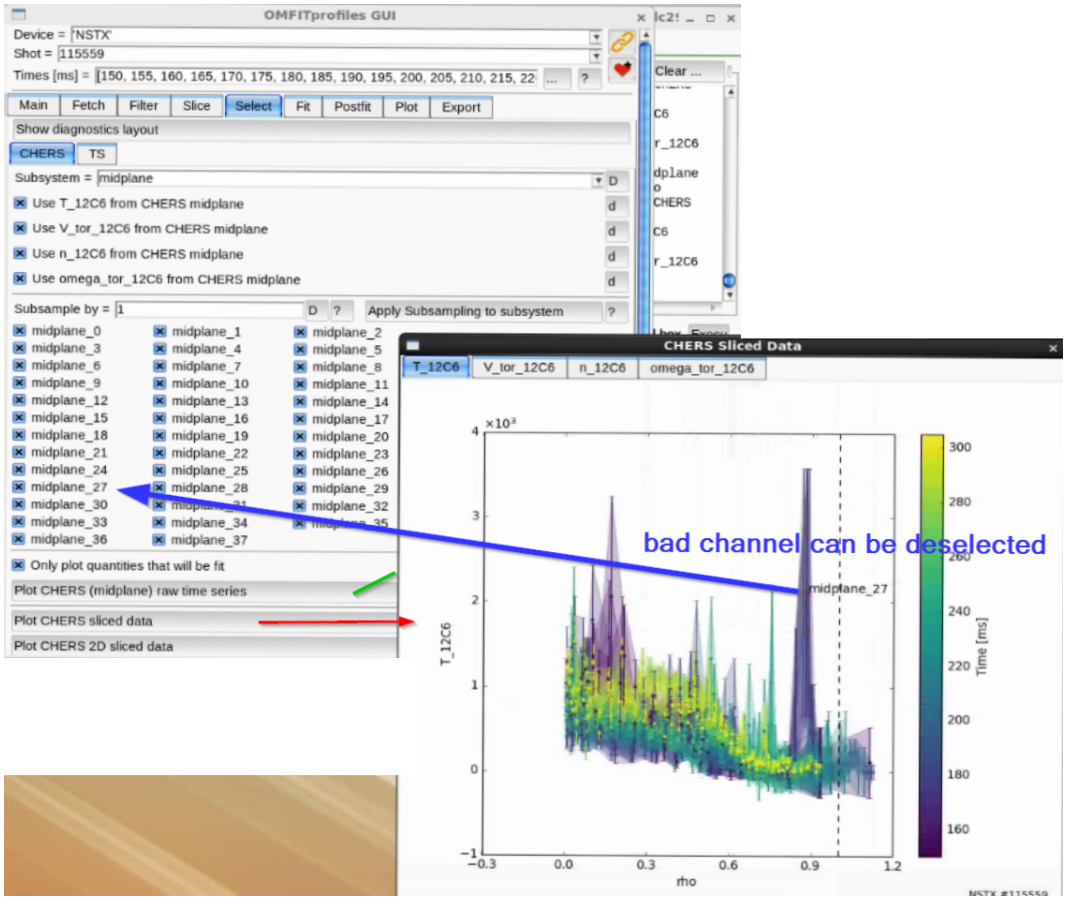
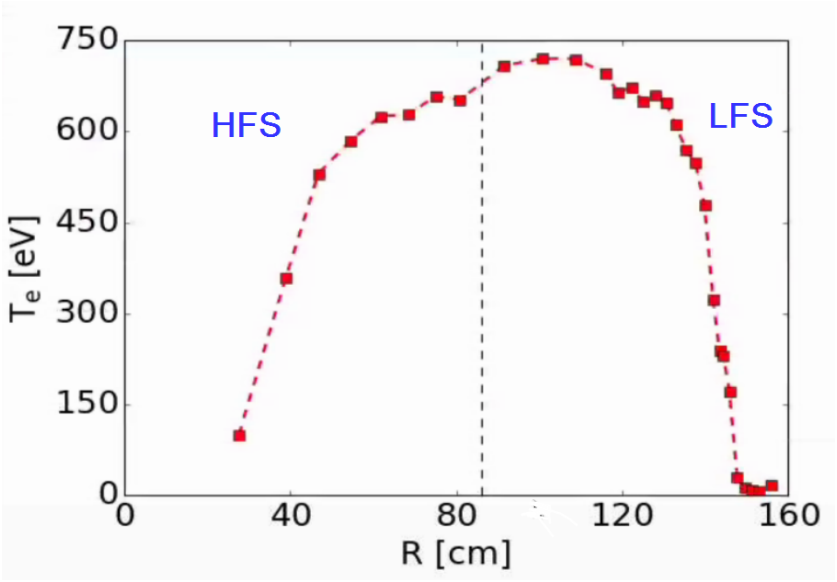
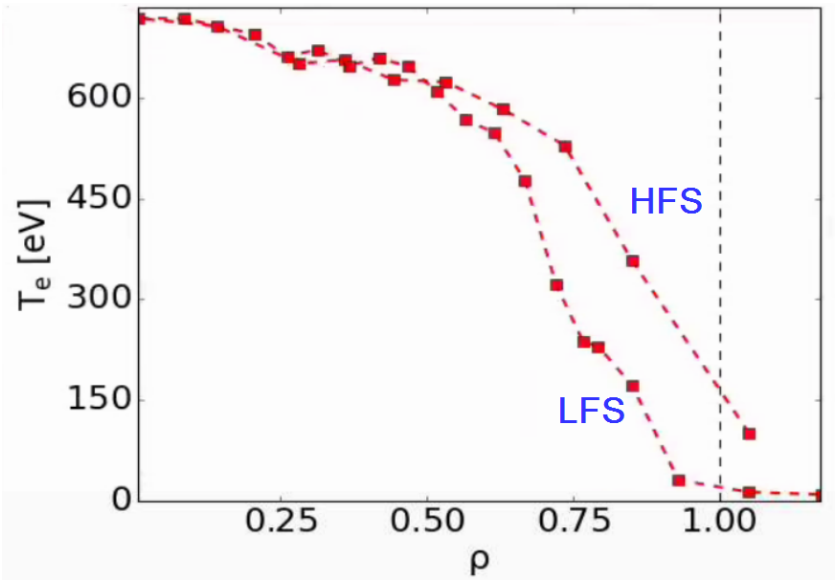


# OMFITprofiles is easily extensible: symmetrization routine is added as on option for NSTX

Problem: NSTX has full radial coverage for Thomson scattering and the high-field and low-field side profiles do not always align

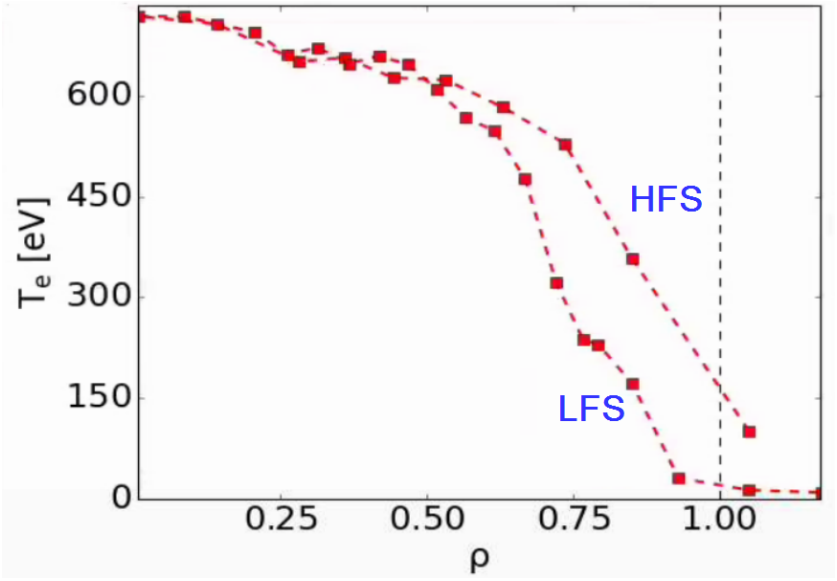


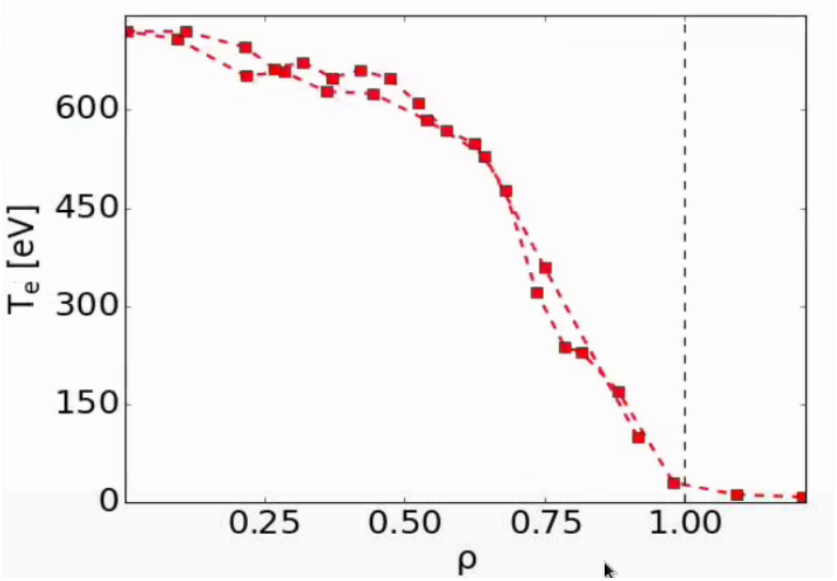



# OMFITprofiles is easily extensible: symmetrization routine is added as on option for NSTX

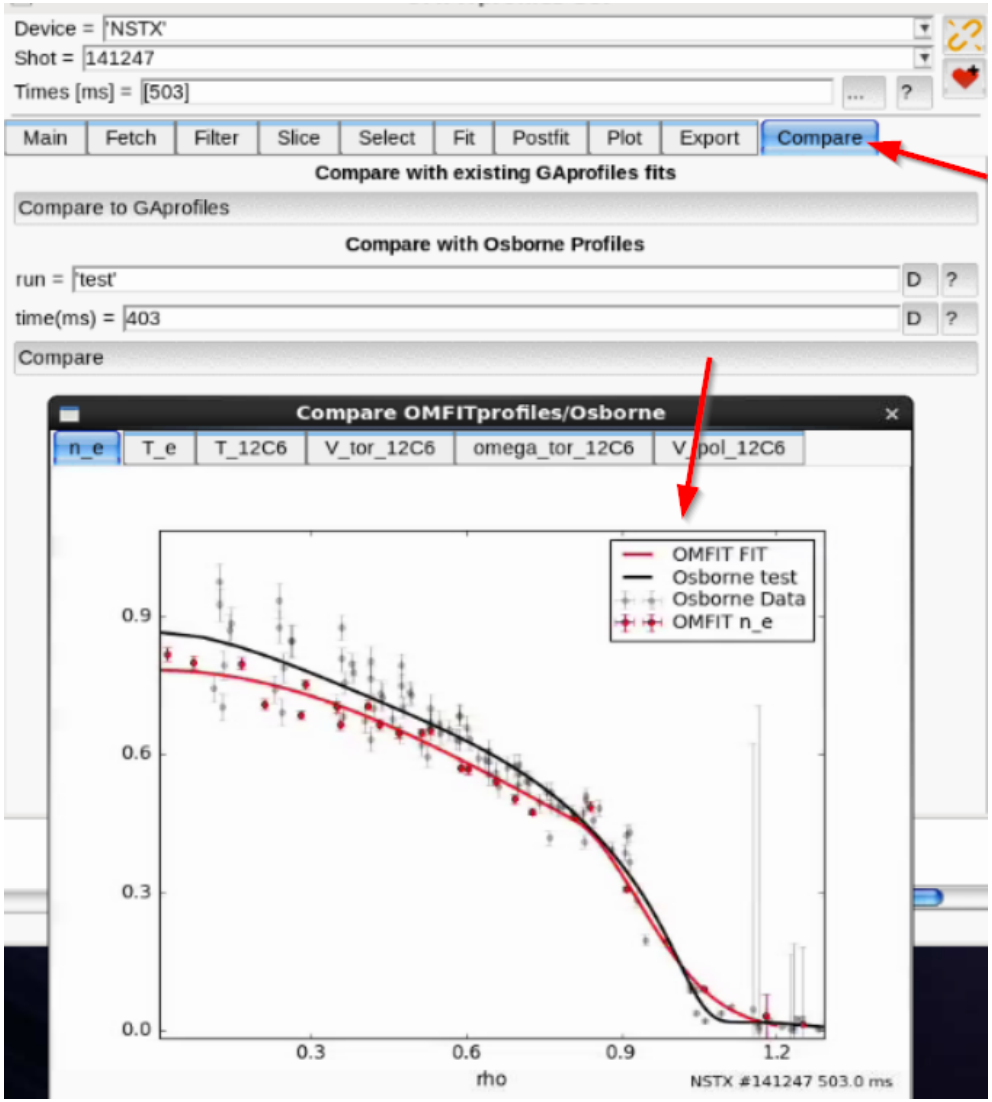
Problem: NSTX has full radial coverage for Thomson scattering and the high-field and low-field side profiles do not always align

Solution:Applies a radial shift function to the TS data based on either trying to optimise the match between the LFS and HFS measurements or on the separatrix temperature constraint



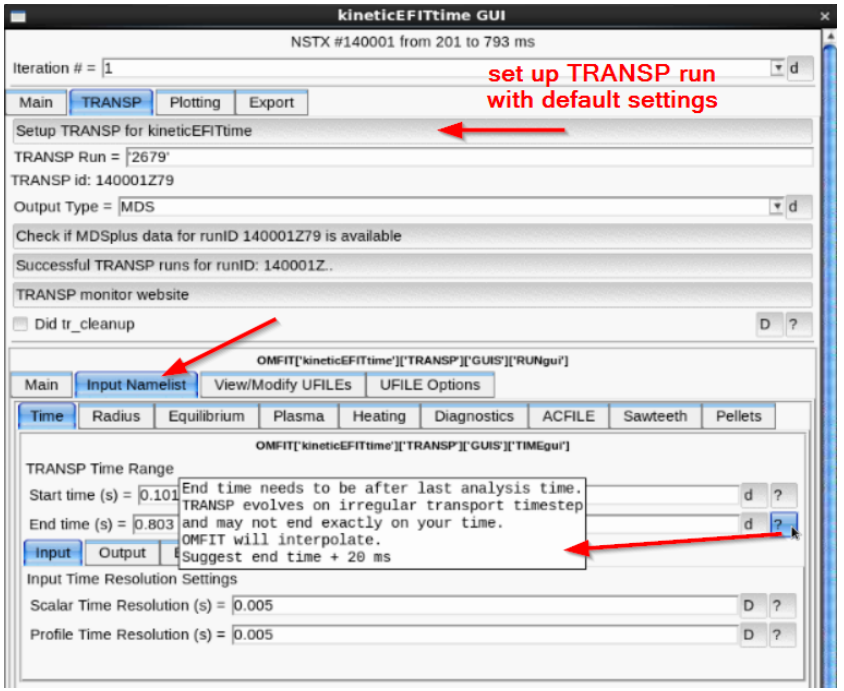



# Benchmark and consistency tests are important parts of data analysis



# OMFIT provides automatic setup of TRANSP runs[A] based on experimental data

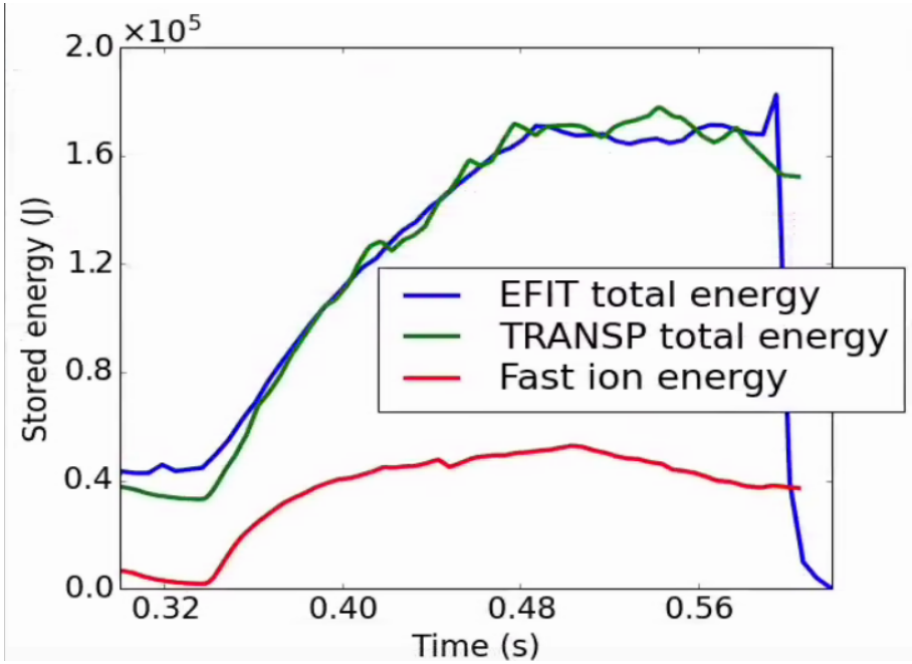
- Handles the complexity of TRANSP namelist
- Integration with EFITtime and OMFITprofiles modules
- Generation of U-files based on profiles analysis
- Code submission and fetching TRANSP output is automated




B. A. Grierson et al.
Fusion Science and Technology Vol. 74 (2018)

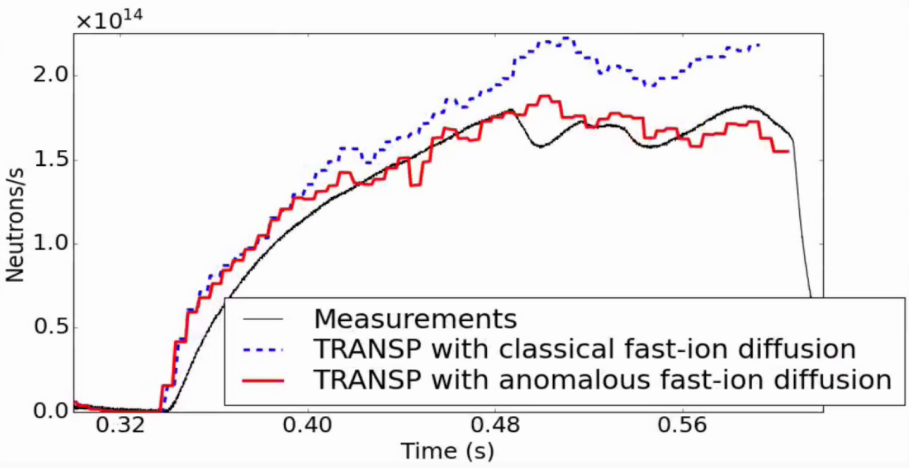
# OMFIT TRANSP module includes various visualisation tools including data consistency check

- Good agreement is observed for **plasma energy** (TRANSP vs EFIT)

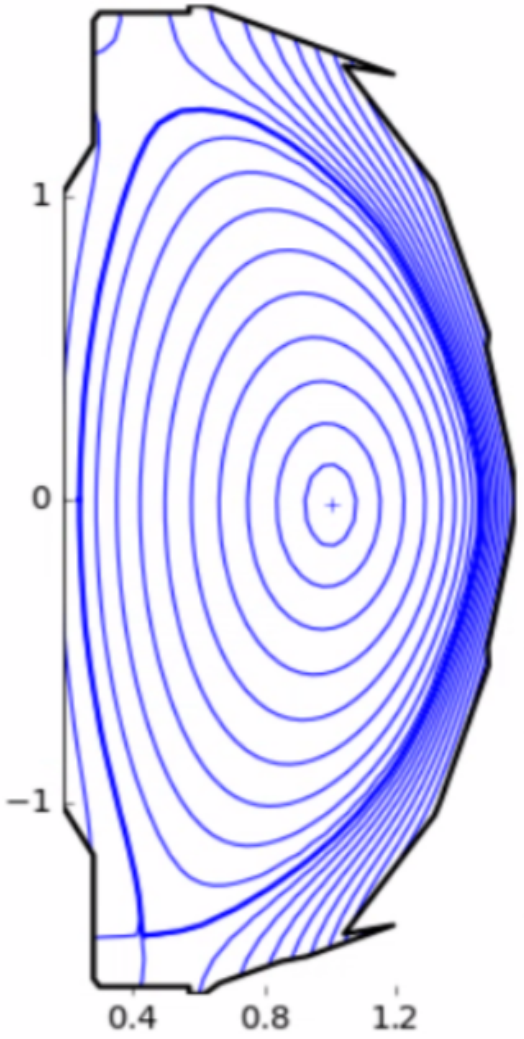


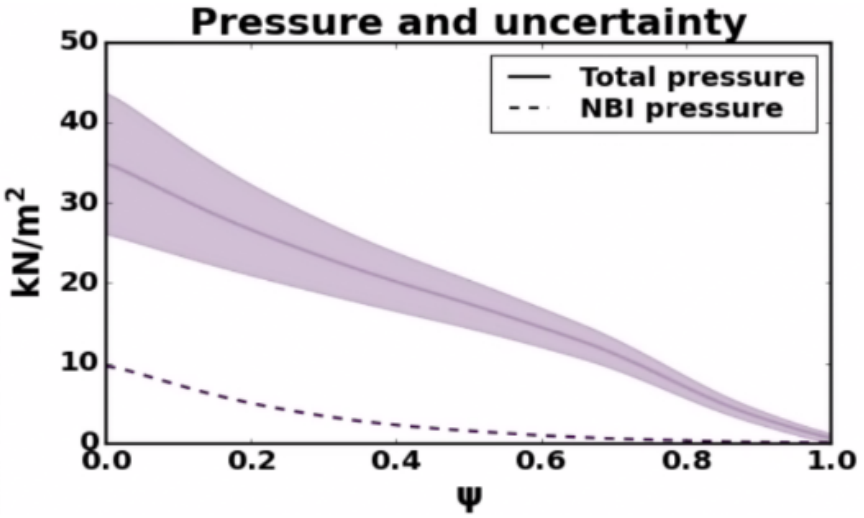
# OMFIT TRANSP module includes various visualisation tools including data consistency check

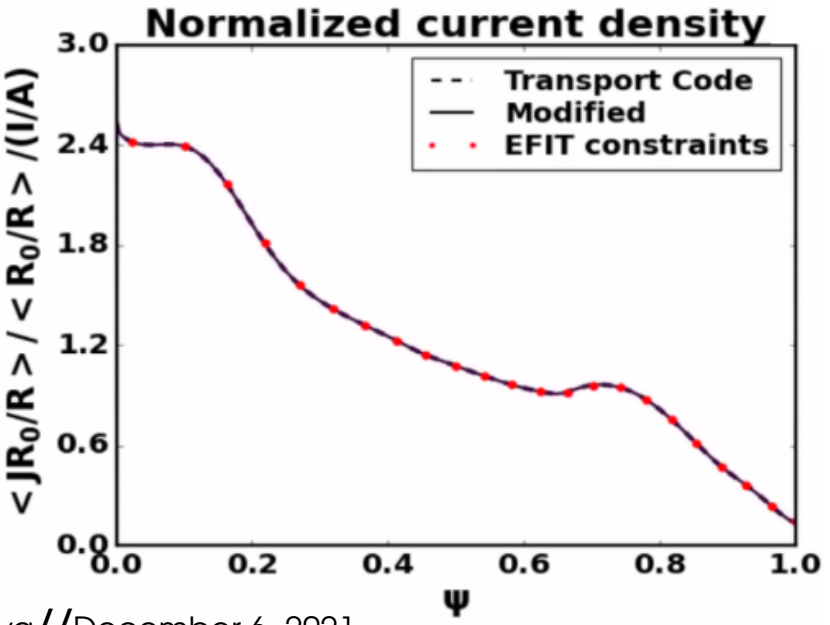
- Good agreement is observed for **plasma energy** (TRANSP vs EFIT)
- To match **neutron rate** we adjust fast ion diffusion
  - Constant value of the fast ion diffusion
  - PID controller
  - Inferred time dependant diffusion coefficient from runs with a constant values



# With pressure and current information we can obtain a full kinetic equilibrium reconstruction



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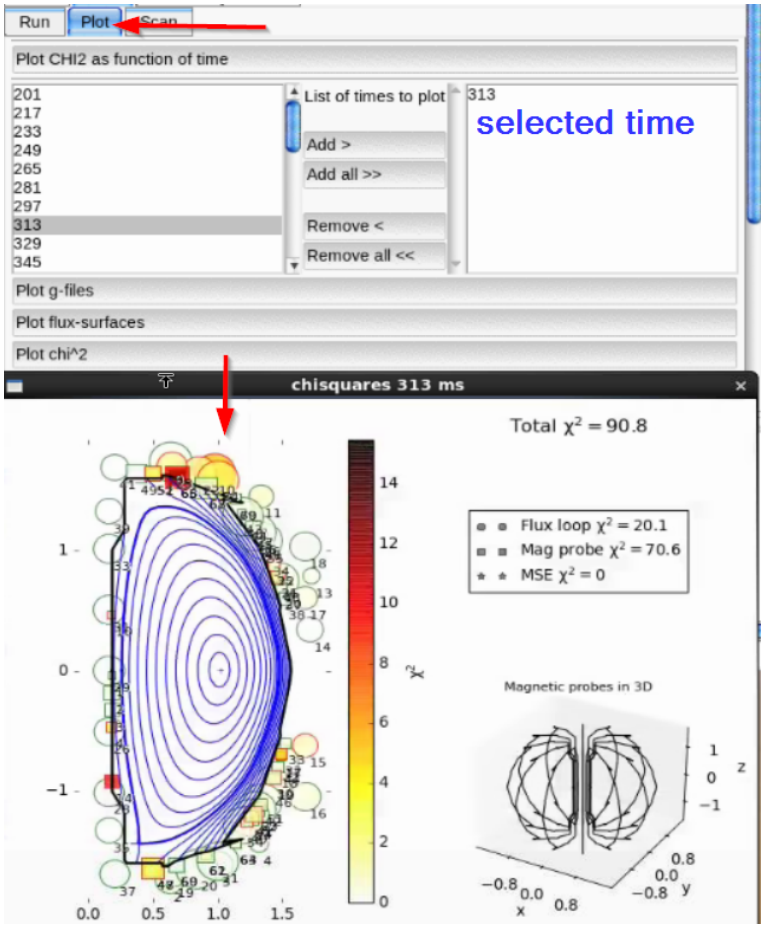
# Benchmark and consistency tests are important parts of equilibrium reconstruction

EFITtime module provides visualisation tools for

- Convergence error
- GS error and $\chi^2$ as functions of time
- $\chi^2$ for magnetic diagnostics
- Comparison of MSE measurements with reconstruction



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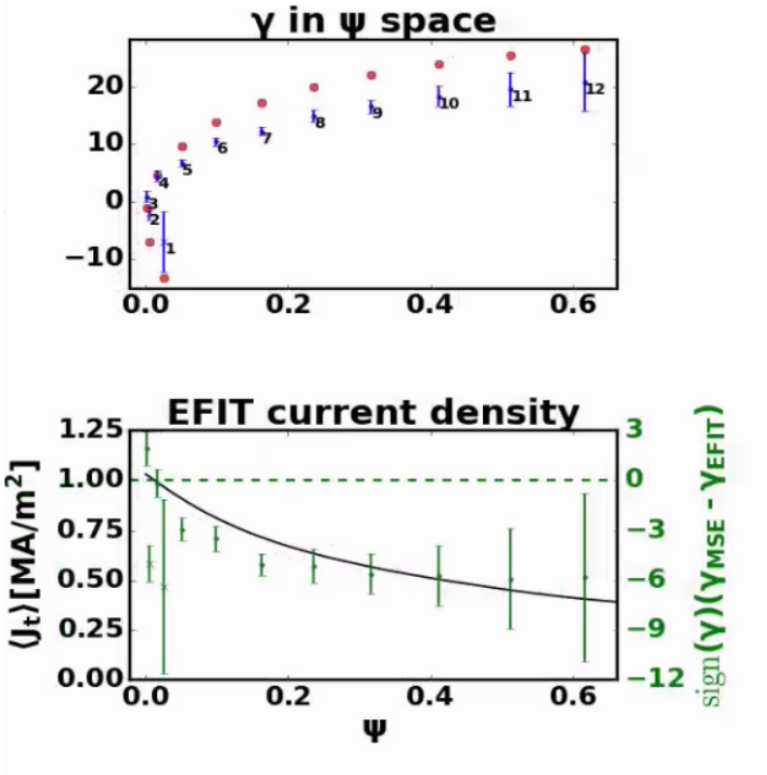
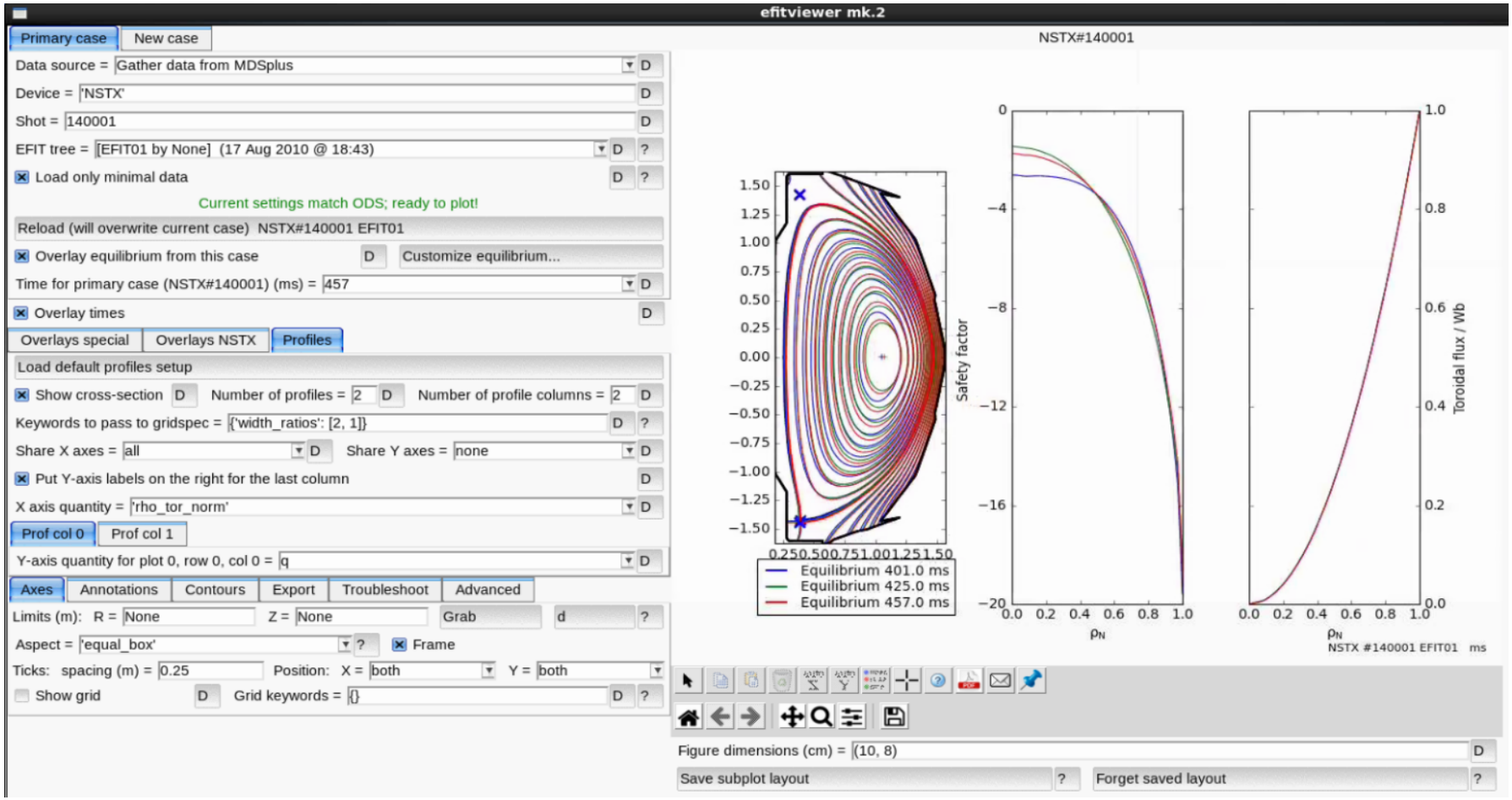


# Bonus: EFITviewer mk 2 can be run inside the OMFIT framework



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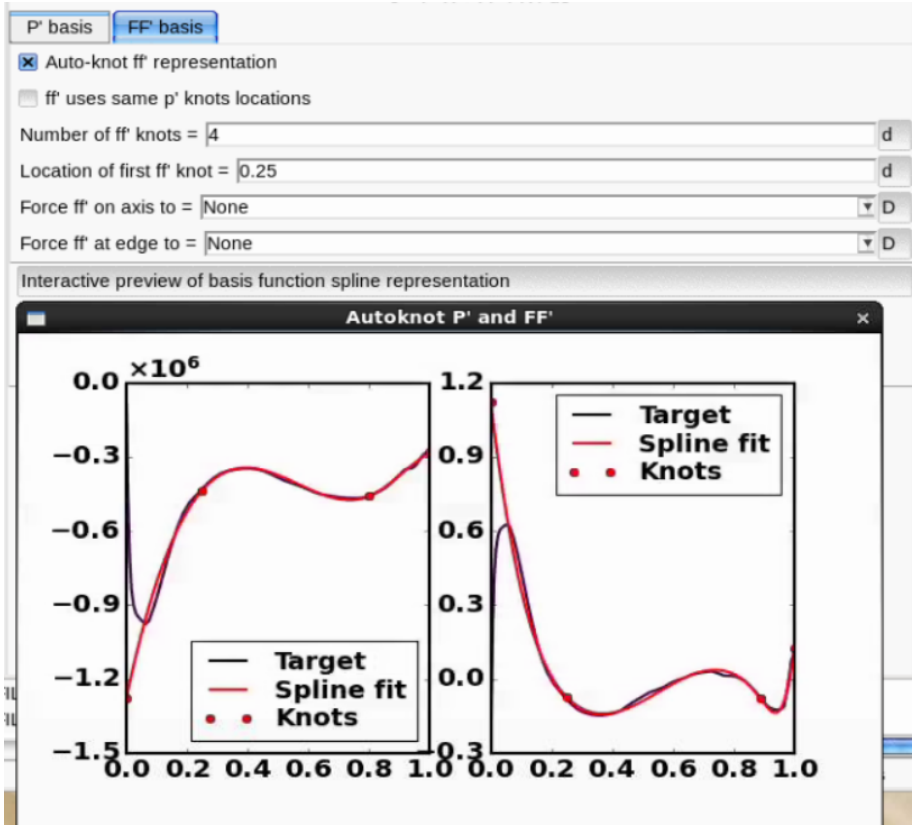
# Applications such as MHD stability analysis have stringent equilibrium requirements

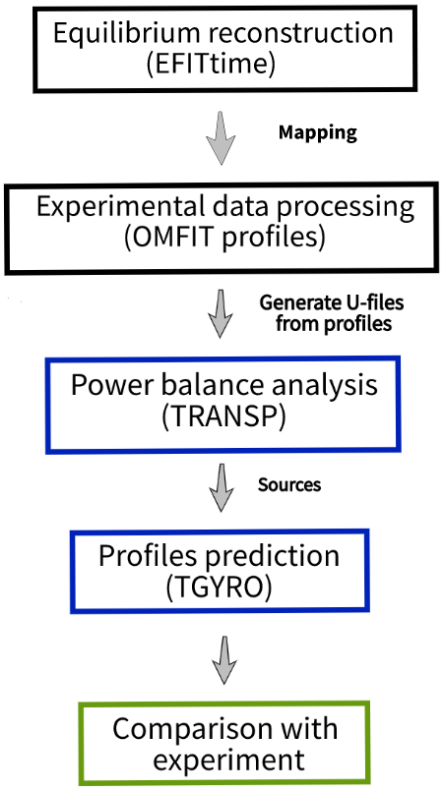
EFITtime module has the following options to increase the accuracy of reconstruction

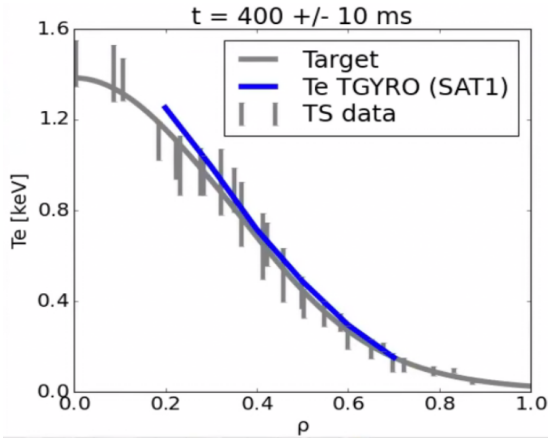
- Higher grid resolution with EFIT-AI
- GUI interface to work with basis function options (e.g. change the location and number of spline knots)
- refineGS - runs EFIT multiple times with perturbed the P’ and FF’ spline knots

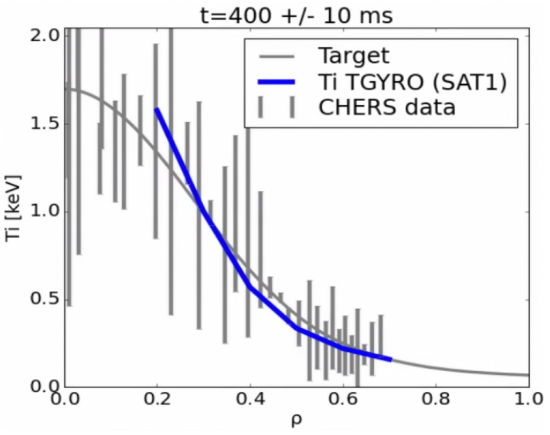


# It doesn't stop at kineticEFITtime. OMFIT provides the interface necessary to integrate outputs into your modeling workflows

Example of using the obtained results for **profile prediction** with TGYRO module **#141716**



# Conclusion

- **OMFIT kineticEFITtime workflow provides useful tools to generate full kinetic equilibrium reconstruction**
- **OMFIT kineticEFITtime workflow is adapted for NSTX**
  - Written NSTX-specific tutorial can be found at `https://omfit.io/modules/mod_kineticEFITtime.html`
  - Live Demo of the OMFIT kineticEFITtime module December 9 at 11 AM ET
  - If you have any questions feel free to contact me avdeevag@fusion.gat.com
- **If you are interested in live demo of other OMFIT modules contact Sterling Smith smithsp@fusion.gat.com**