TRANSP and PTRANSP at PPPL: Status and Plans

Presented at the TRANSP Users Group Meeting,

APS/DPP – Oct. 30, 2006

Poster – JP1.00121

TRANSP and PTRANSP at PPPL: Status and Plans

JP1.00125 Abstract

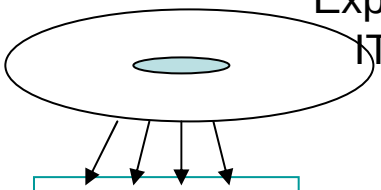
D. McCune, R. Andre, E. Feibush, K. Indireshkumar, S. Jardin, L. P. Ku, C. Ludescher-Furth, L. Randerson, *PPPL* – The PPPL TRANSP code suite is a set of tools for time dependent simulation of tokamak plasmas. The entire system consists of over a million lines of fortran-77, fortran-90, C, and C++ code. Although pieces of the code are over 25 years old, the code has been continually upgraded and modernized, now representing over 60 man-years of labor invested. TRANSP now runs as a service on the Fusion Grid, supporting plasma physics research groups around the world. In this poster, status and plans for TRANSP and associated predictive modeling upgrades (PTRANSP) are summarized. Recent TRANSP code development highlights include: (a) deployment of TRANSP heating modules (NUBEAM and TORIC) as MPI-parallel services, and (b) deployment of the entire TRANSP code as a service supporting separate free boundary predictive simulation of ITER and other future experiments. A summary of recent TRANSP utilization is presented, along with plans for future development of all aspects of the code. Posters covering TRANSP-related topics in greater detail are cross referenced.

Work Supported by US DOE Contract DE-AC02-76CH03073

TRANSP: Vision Statement

Provide a comprehensive end-to-end modeling capability for magnetic confinement fusion energy experiments of today and tomorrow.

TRANSP Overview



Experiments (Asdex-U, C-Mod, DIII-D, ITER, JET, KSTAR, MAST, NSTX)

Diagnostic Hardware

Preliminary data Analysis and Preparation (largely automated)

MDS+

20-50 signals {f(t), f(x,t)} Plasma position, Shape, Temperatures, Densities Field, Current, RF and Beam Injected Powers.

Pre- and Post-processing at the experimental site…

MDS+

Experiment simulation Output Database ~1000-2000 signals {f(t), f(x,t)}

Visualization

Load Relational Databases

Detailed (3d) time-slice physics simulations: GS2, ORBIT, M3D…

TRANSP Analysis*: Current diffusion, MHD equilibrium, fast ions, heating, current drive; power, particle and momentum balance.

*FusionGrid TRANSP on PPPL servers

Poster Session JP1: Tuesday pm

- PPPL:
- JP1.00121 – (This presentation)
- JP1.00122 – Web Interfaces to Fusion Codes
- JP1.00123 – Progress and Plans for Free Boundary PTRANSP
- JP1.00124 – XTranspin, a Visual Data Input Utility for TRANSP
- JP1.00125 – Status of TRANSP Parallel Services
- JP1.00129 – New MHD Equilibrium Solver options in TRANSP
- Lehigh U.:
- JP1.00126 – Progress in Verification & Validation of PTRANSP
- JP1.00127 – PTRANSP ITER Simulations using PEDESTAL module
- JP1.00128 – Comparison of Anomalous Transport Models
- General Atomics:
- JP1.00130 – Development of Transport Solvers for Stiff Systems

Contents of Presentation

- Programmatic Information.
- Run Production Statistics.
- Recent Examples of TRANSP Utilization.
- Status of Code Development Efforts:
  - Client Software
  - Parallelization of Heating Modules.
  - MHD Equilibrium Reconstruction.
  - Predictive Upgrades.
- Future Plans

PPPL TRANSP Funding

- Experimental Projects: ~3.3 FTE
  - NSTX (60%), DIII-D (25%), JET, C-Mod.
  - Covers: production system, client software development, physics development.
- SciDAC FusionGrid: terminated in FY06.
- PTRANSP: currently up for renewal.
- SciDAC Fusion Simulation Project (FSP):
  - SWIM, CPES, FACETS
  - Some degree of synergy with TRANSP effort.

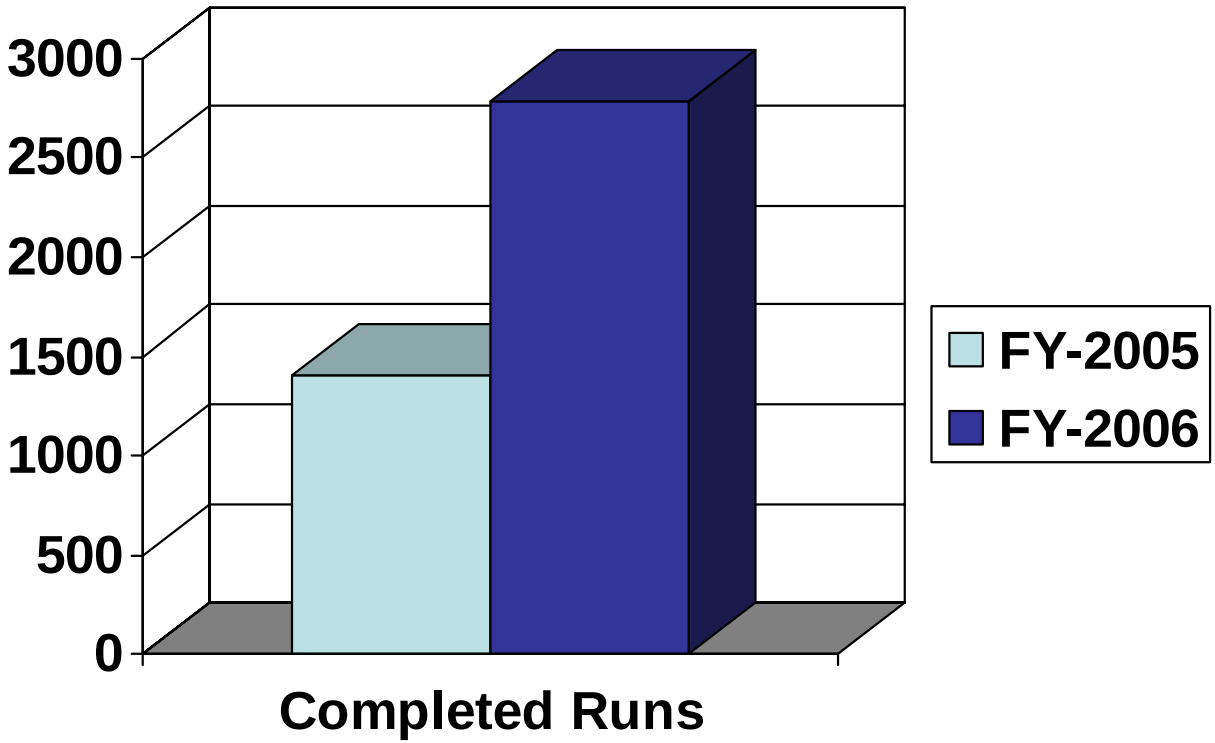
TRANSP Developers and Users

- PPPL TRANSP team:
  - Robert Andre
  - Eliot Feibush
  - Kumar Indireshkumar
  - Jae-Min Kwon*
  - Long-Poe Ku**
  - Christiane Ludescher
  - Doug McCune
  - Lew Randerson

- User Sites:
  - Culham (MAST)
  - GA (DIII-D)
  - HL2A (China)
  - IPP (Asdex-U)
  - JET
  - MIT (C-Mod)
  - PPPL (NSTX)
  - PPPL (Collaborations)

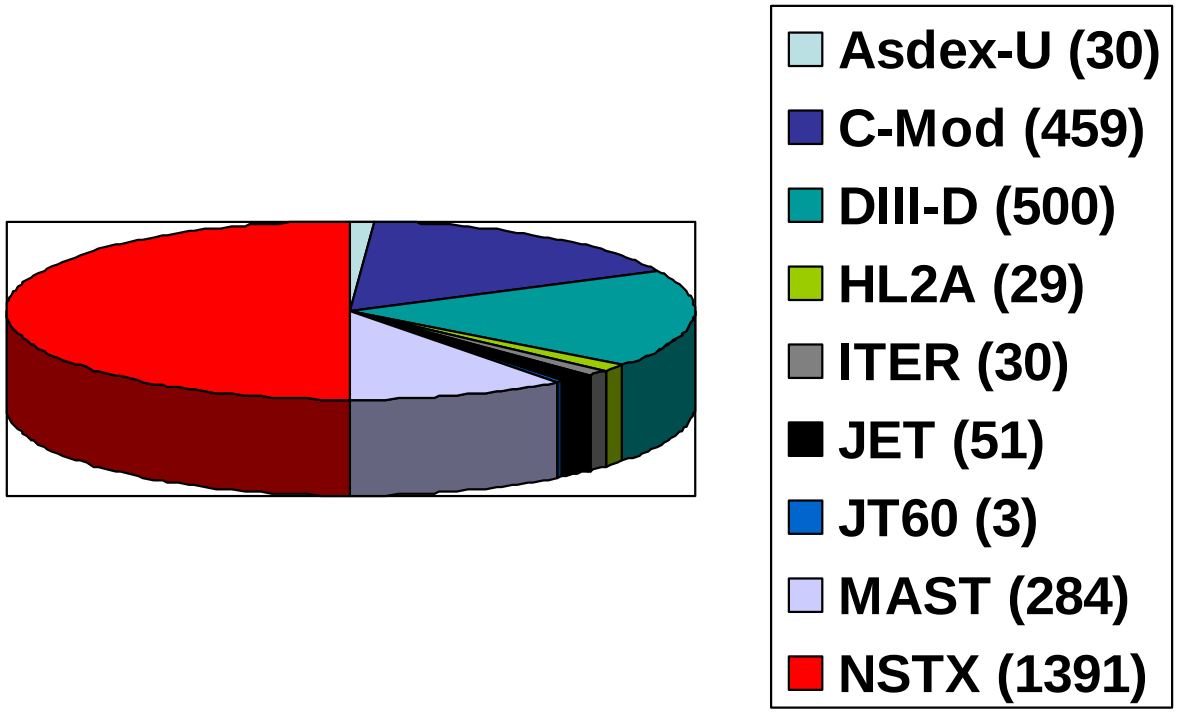
***new via KSTAR/KBSI **new via PTRANSP & FSP**

PPPL TRANSP Run Production



PPPL TRANSP Run Statistics

FY-2006: Oct. 1 2005 – Sep. 30 2006: Total of 2777 runs.



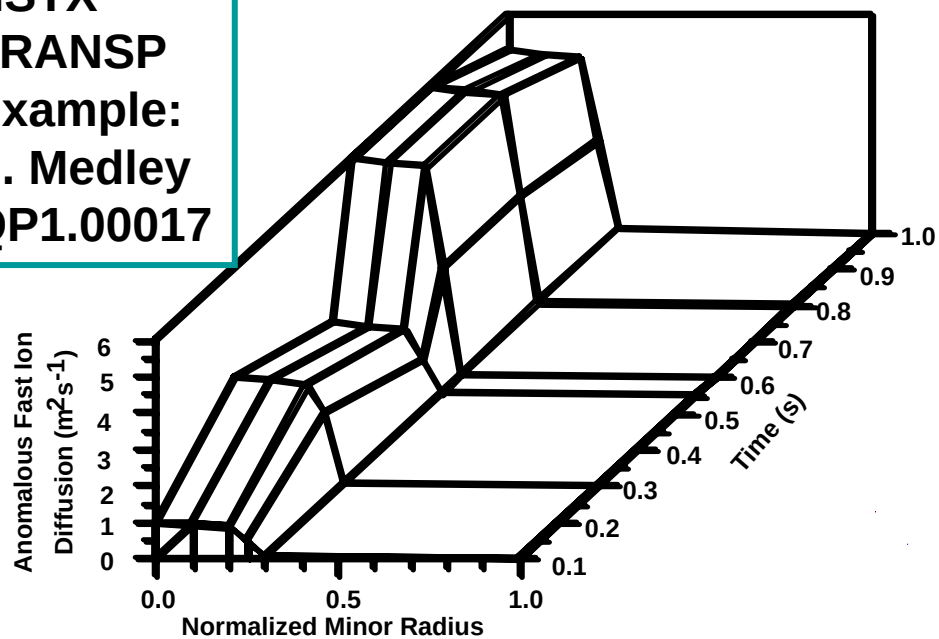
In addition, approximately 700 JET runs and an unknown number of MAST runs executed on the TRANSP “mirror” server at JET.

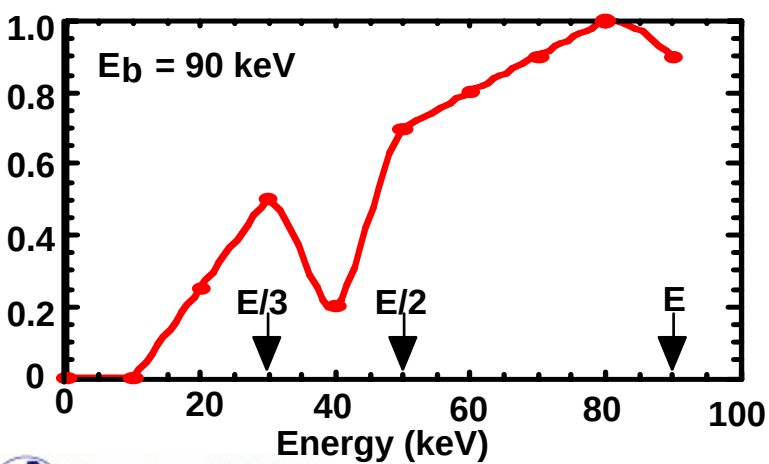
Examples of TRANSP Use

- APS Invited Talk
  - GI1.00005: Tuesday, 11:30 am
  - J. Degrassie, "Intrinsic Rotation in DIII-D"
- Physics of Plasmas (to appear in Nov.)
  - "Prompt Toroidal Momentum Balance with Collisionless NBI Torque in DIII-D"
  - J. Degrassie, R. Groebner, K. Burrell

TRANSP Uses Anomalous Fast Ion Diffusion (AFID) to Emulate MHD-induced Redistribution/Loss

NSTX TRANSP Example: S. Medley QP1.00017



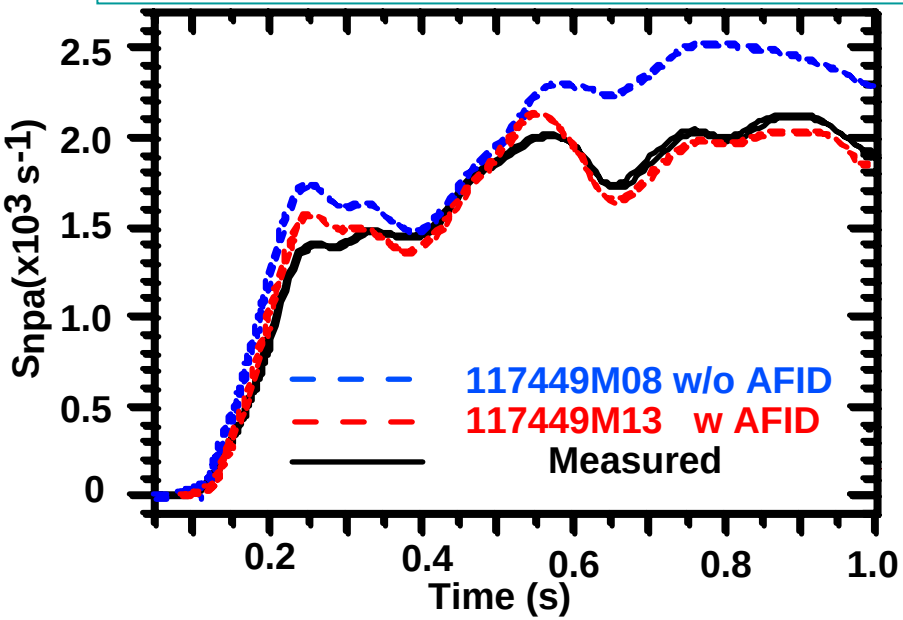


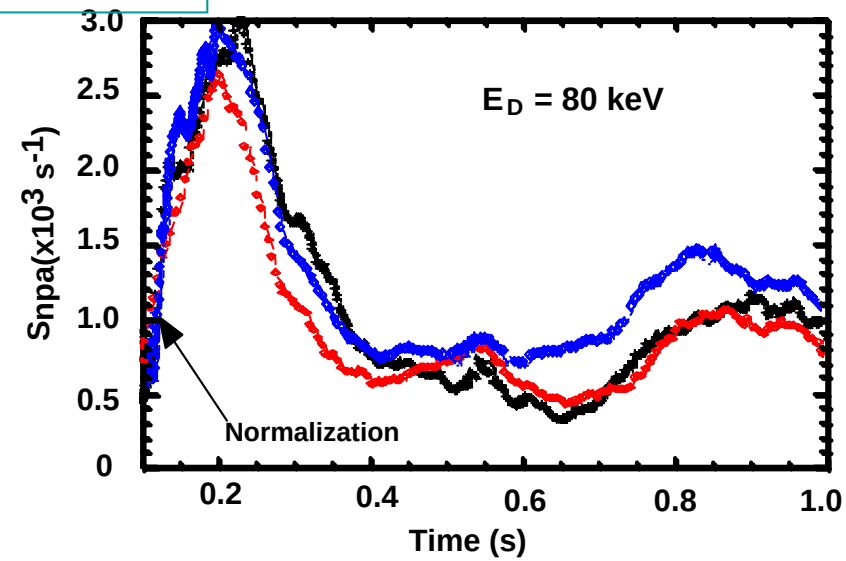
- In TRANSP, anomalous fast ion diffusion can be specified in time, space and fast-ion energy.
- Core-weighted anomalous fast ion diffusion is appropriate for MHD-induced redistribution. In H-mode discharges, outwardly displaced NB ions remain confined in a region of comparable n_e, T_e so neutron yield is minimally affected.
- Outboard-weighted AFID favors ion loss and significantly reduces the neutron yield.
- Energy dependence is chosen to emulate the measured NPA spectrum distribution.

D. McCune

TRANSP Anomalous Fast Ion Diffusion (AFID) Can Simultaneously Match $S_n(t)$, $S_{npa}(t)$ and $f_{npa}(E)$

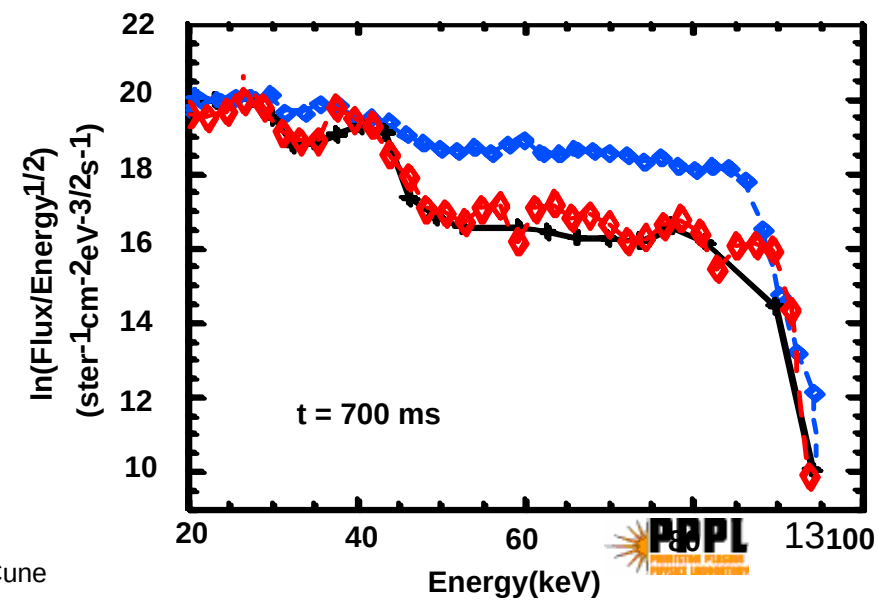
S. Medley QP1.00017 Wednesday Afternoon





- In this TRANSP analysis, the AFID model was optimized for a time of interest (TOI) period t = 0.6-1.0 s during n=1, f = 5-10 kHz kink-type MHD.

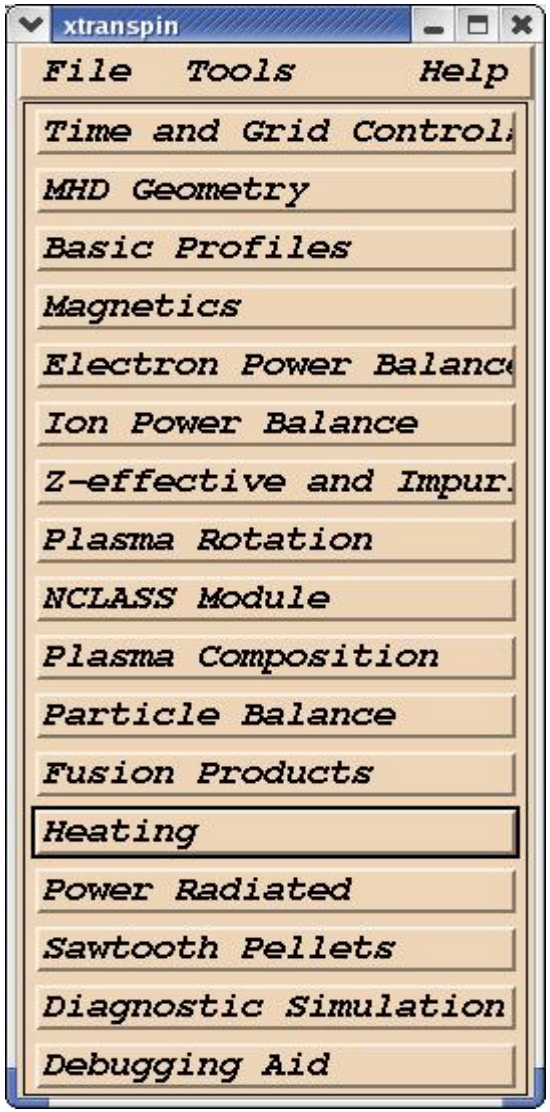
- In the TOI, good matching of neutron rate and the NPA efflux evolution and energy spectra are obtained.

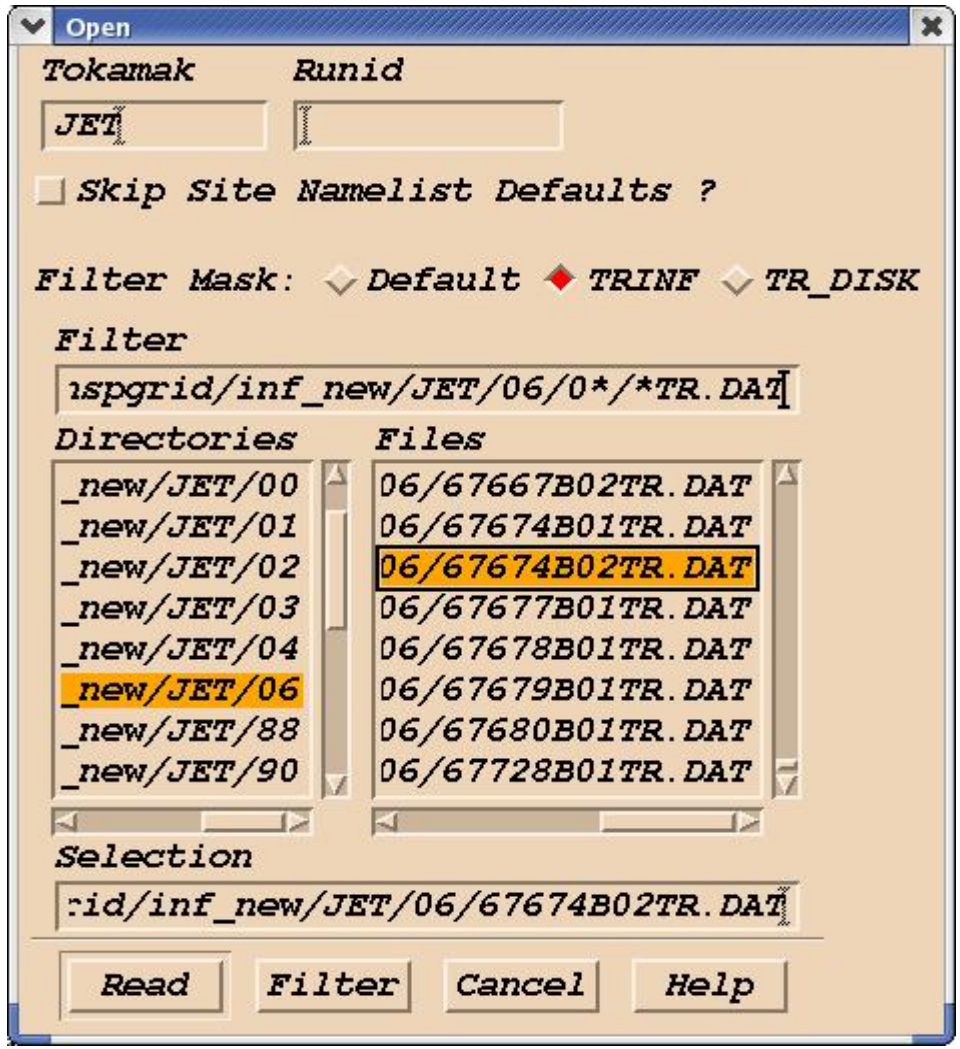


TRANSP Client Software Development

- C. Ludescher-Furth, "XTranspin, a Visual Data Input Utility for TRANSP", JP1.00124
  - Recent developments & use examples of the XTranspin C-Motif GUI.
- E. Feibush, "Web Interfaces to Fusion Codes", JP1.00122
  - Progress in making TRANSP results available through a browser applet– and related topics.

XTranspin

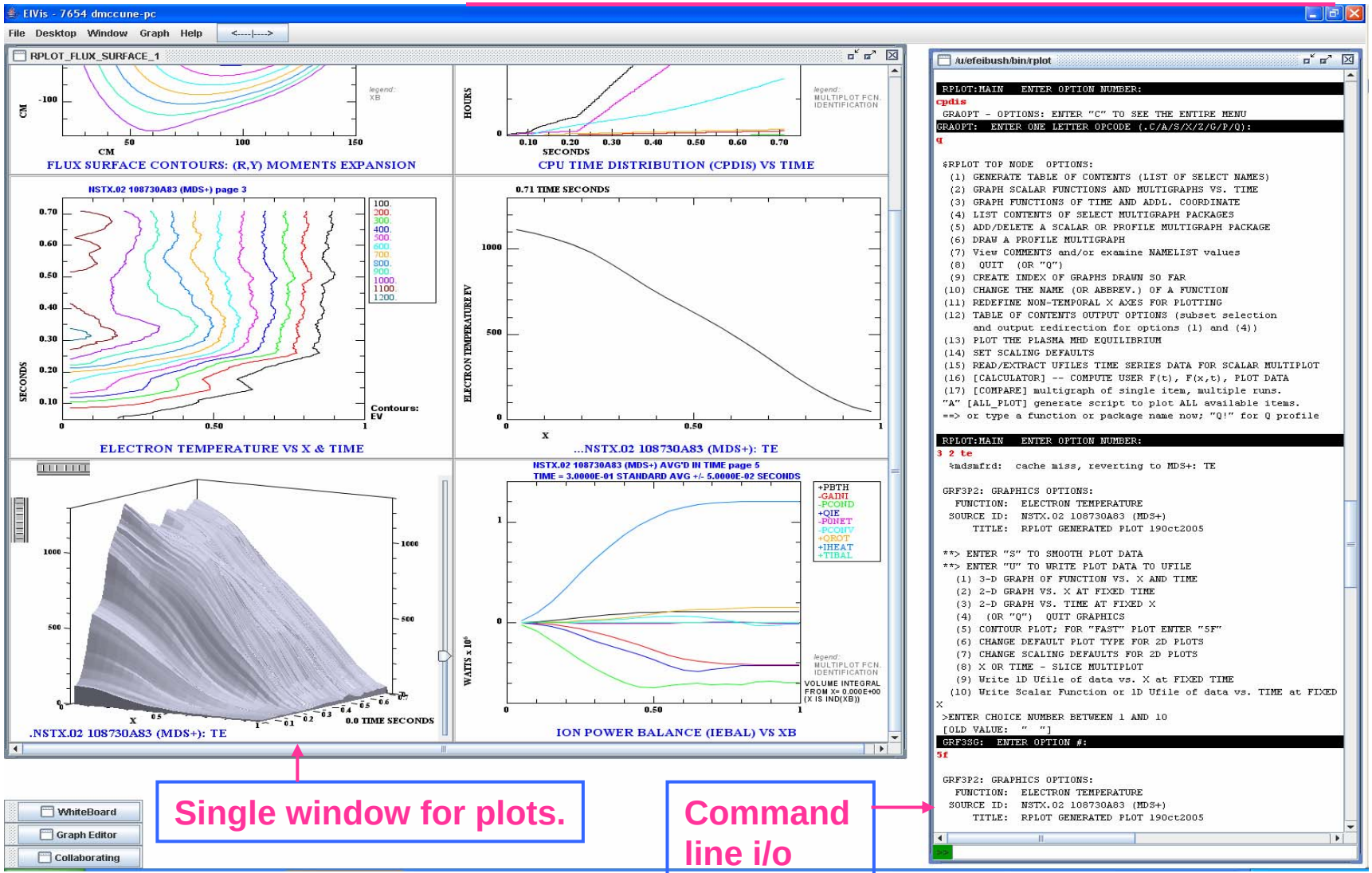




See JP1.00122: XTranspin

RPLOT and TRDAT in ElVis

RPLOT session shown: **See JP1.00122: Web Interfaces to Fusion Codes**



Single window for plots.

Command line i/o

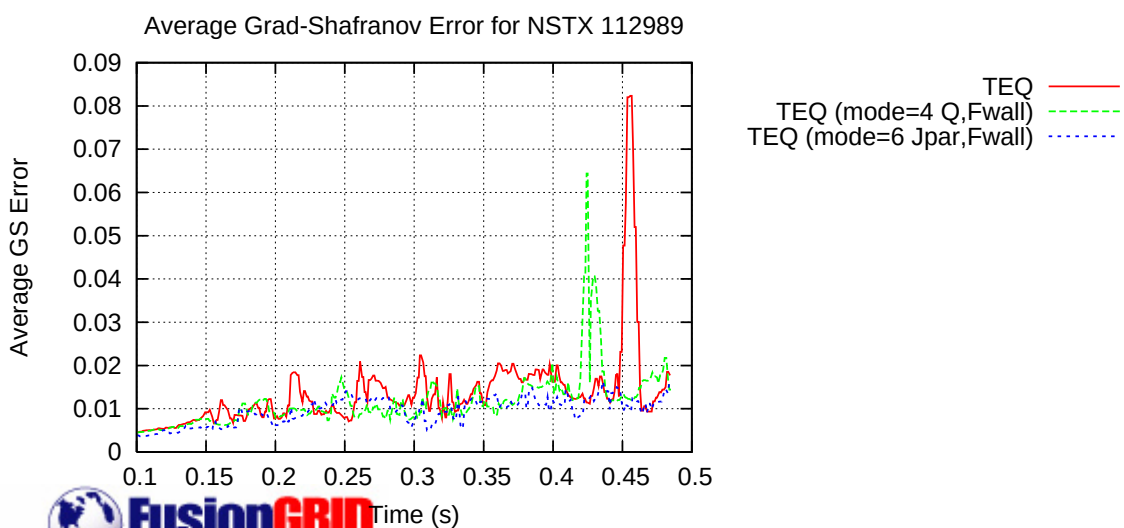
Development of TRANSP Physics Modules

- <u>MHD Equilibrium Reconstruction:</u>
  - TEQ running in “prescribed boundary mode”.
  - Accurate, Robust, Recommended: **LEVGEO = 11**
  - R. Andre, JP1.00129
- <u>Parallel Module Server:</u>
  - Multiple timesteps of MPI-parallel Calculation
  - Launch once (one queue wait)
  - Implemented for NUBEAM
  - K. Indireshkumar, JP1.00125

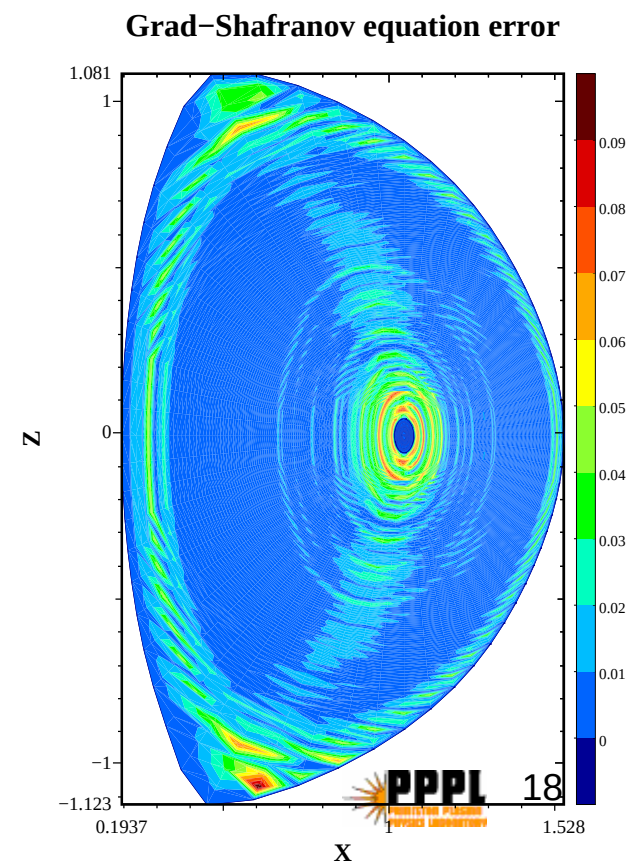
NSTX 112989 with TEQ

- TEQ exhibits a very low Grad-Shafranov error throughout this shot
- Three modes of running TEQ are shown
  - NTEQ_MODE=5 (default), Q and F edge are input and Q is adjusted to match the plasma current
  - NTEQ_MODE=4, Q and F edge are input
  - NTEQ_MODE=6, <J.B> and F edge are input

See JP1.00125: New MHD Equilibrium Solver Options in TRANSP



Time = 0.350



D. McCune

MPI-Parallel Module Server

See JP1.00125: Status of TRANSP Parallel Services

Serial TRANSP Run (Client #1)

Serial TRANSP Run (Client #2)

Serial TRANSP Run (Client #3)

. . .

Serial TRANSP Run (Client #N)

network

Input File* Package, e.g. XPLASMA** NetCDF state.

Output File* Package, e.g. XPLASMA** NetCDF state.

viability of method depends on keeping files small.

Server Queue

MPI-Parallel TRANSP Module Server(s):

- NUBEAM monte carlo
- TORIC5 full wave
- GenRAY ray tracing
- CQL3D fokker planck
- GCNM transp. solver
- … … …

**NTCC container module for equilibrium, profiles, distribution functions, etc. (http://w3.pppl.gov/NTCC) to be used for Fusion Simulation Project prototype and tested in TRANSP deployment.

Monte Carlo RF Operator

- Techniques developed in a separate code (XGC-RF) to be ported to **MPI-NUBEAM**.
  - See JP1.00115, "Development of XGC-RF for Global Guiding Center Particle Simulation of Minority ICRH Heated Plasmas in General Tokamak Geometry" by Jae-Min Kwon et al., Thursday afternoon.
  - An accurate (R,Z) GC integrator has been added to NUBEAM as a preliminary step.

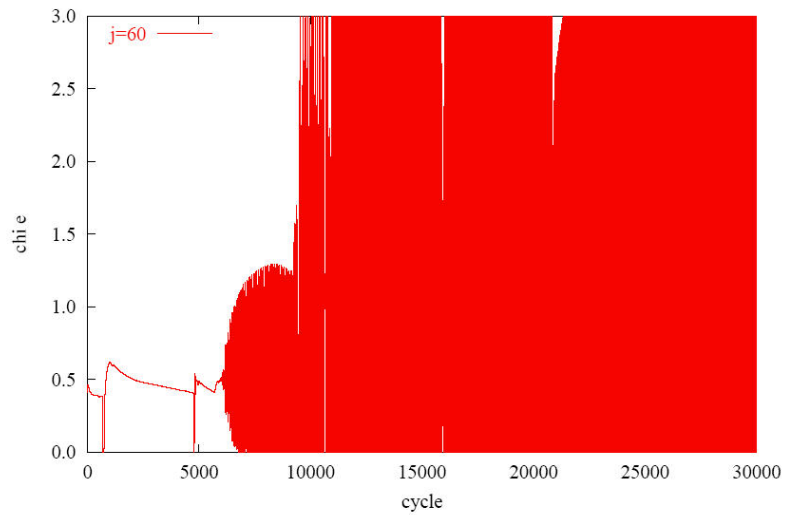
Predictive TRANSP Upgrades

- Stiff solver upgrades completed:
  - Free Boundary: L. P. Ku, JP1.00123
  - Prescribed Boundary: G. Bateman, JP1.00126
- PTRANSP Client-Server Configuration:
  - FSP free boundary predictive code client:
    - Compute evolution of equilibrium and profiles;
  - TRANSP server:
    - Compute heating and current drive sources;
    - Standard analysis of predictive code results.
  - See JP1.00123.

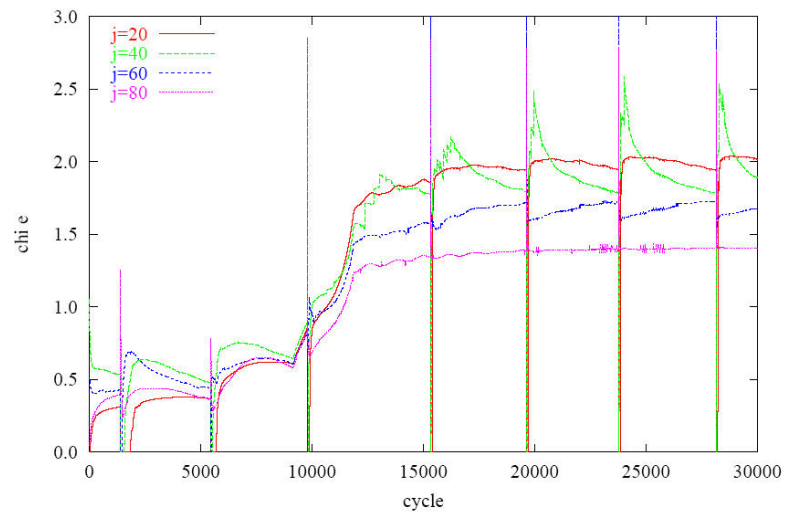
The PTRANSP FSP Solver

This has been implemented in the full solver in the FSP:

See L. P. Ku, et al.: JP1.00123



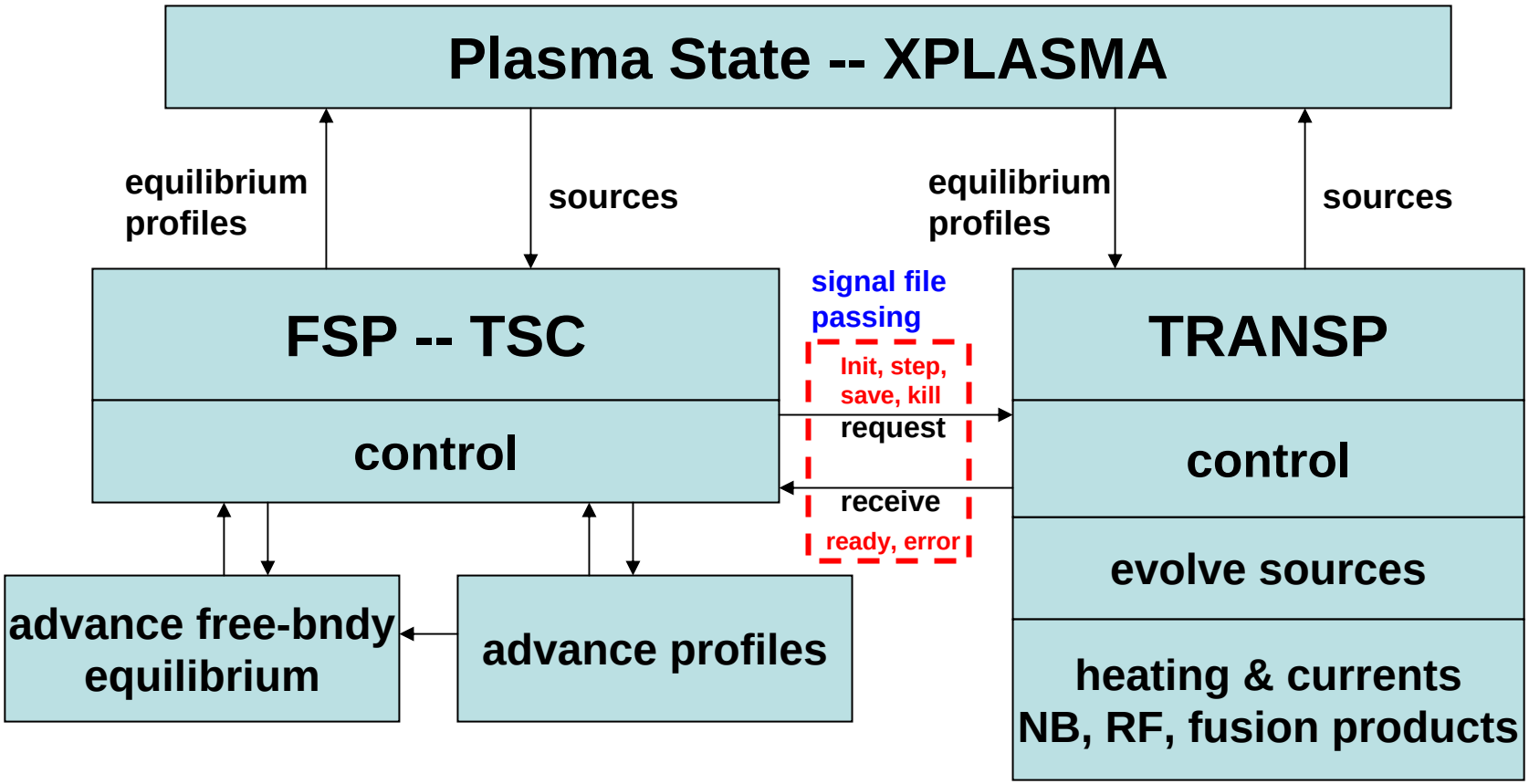
Without linearization



With linearization

PTRANSP Client-Server Mode of Operation

See L. P. Ku, et al.: JP1.00123



(P)TRANSP Future Plans (1)

- Continued Support and Improvement of Production System:
  - Maintenance of Fusion Grid;
  - User access to MPI parallel services;
  - User support, improvements to documentation and website;
  - Trouble shooting of crashed runs.
- User feedback is requested.

(P)TRANSP Future Plans (2)

- Continued Development of Client Software:
  - Tools for data preparation, run submission, monitoring, and visualization of results.
  - Web accessible services; ElVis graphics.
  - AutoTRANSP / PreTRANSP / XTranspin integration, perhaps.
- User feedback is requested.

(P)TRANSP Future Plans (3)

- MHD Equilibrium & Improvements for STs:
  - Validated MHD equilibrium reconstruction with toroidal rotation for ST experiments.
  - Then: T & P (with toroidal centrifugal term included) instead of T & n as flux surface constants– as seen in ST experiments.
  - More realistic geometry in model for neutral gas fueling and transport.
- User feedback on priorities is requested.

(P)TRANSP Future Plans (4)

- RF Modeling:
  - MPI Parallel TORIC as production option;
  - Coupling of FP & MC generated fast ion distribution functions into TORIC wave solver;
  - RF Monte Carlo Operator;
  - Access to MPI-parallel GENRAY ray tracer;
  - Replacement of FPPMOD (legacy TRANSP FP code) with better validated CQL3D model.
- User feedback on priorities is requested.

(P)TRANSP Future Plans (5)

- Free Boundary PTRANSP:
  - Creation of FSP control datasets on a per tokamak basis (improve user access to free boundary simulation).
  - FSP Sawteeth in TRANSP server.
  - Fast ion density and pressure in FSP client.
  - Improved verification techniques for predictive transport models.
  - Coupling to realistic edge models.

(P)TRANSP Future Plans (6)

- Prescribed Boundary PTRANSP:
  - Full support for density prediction;
  - Performance improvements:
    - “Equilibration” of sources,
    - Or, simplified source model options.
    - Major issue for 1000 second ITER simulations.
  - Physics enhancements:
    - Pedestal Model, …
    - TGLF predictive transport when available.

TRANSP/PTRANSP Summary

- Powerful code and production system.
- FY-2006 run production doubled FY-2005.
- Significant code improvements every year.
- Broad program for continued improvement, but:
  - Real development investment flat or declining consistent with flat funding of fusion research.
  - Flat funding not consistent with FSP requirements and ITER needs.