Status of TRANSP

Presented at the TRANSP Users Group Meeting,

APS/DPP – Oct. 25, 2005

Poster – LP1.00025

Status of TRANSP/PTRANSP

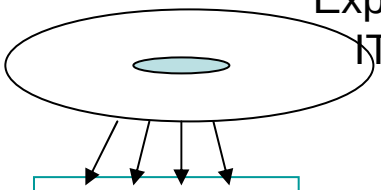
LP1.00025 Abstract

D. McCune, R. Andre, E. Feibush, K. Indireshkumar, C. Ludescher-Furth, L. Randerson, *PPPL* – The status of the TRANSP integrated tokamak modeling effort is described. This will include the status of TRANSP FusionGrid operations and client software as well as development of the core physics model. Physics modeling topics to be covered include: (1) status of the effort to parallelize the NUBEAM Monte Carlo fast ion model; (2) installation of RF and related modules in TRANSP: TORIC, GenRay, CQL3D; (3) status of equilibrium solver upgrades particularly for ST tokamaks; (4) status of predictive upgrades to TRANSP (i.e. PTRANSP). Examples of recent TRANSP modeling results and applications will be shown.

TRANSP: Vision Statement

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

FusionGrid TRANSP Overview



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

Diagnostic Hardware → Preliminary data Analysis and Preparation (largely automated) → 20-50 signals {f(t), f(x,t)} Plasma position, Shape, Temperatures, Densities Field, Current, RF and Beam Injected Powers.

MDS+

Pre- and Post-processing at the experimental site…

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

*FusionGrid TRANSP on PPPL servers

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… (Could also be FusionGrid Services).

Contents of Presentation

- Programmatic Overview.
- Run Production Statistics.
- Recent examples of TRANSP Results.
- Status of Code Development Efforts:
  - Client Software
  - NUBEAM MPI Parallelization.
  - RF Codes.
  - MHD Equilibrium Reconstruction.
  - Predictive Upgrades.

New Programmatic Highlights

- PTRANSP (Predictive TRANSP) Initiative:
  - 2 years, $640K/year, PPPL, GA, LLNL, Lehigh.
  - Leverage NTCC, FusionGrid and experimental support to build a better predictive capability.
- Fusion Simulation Project:
  - 5 years, $2M/year, PPPL, ORNL et al.
  - Involves use and development of TRANSP/NTCC software components.
- KSTAR collaboration– 2 year post doc visit.

PPPL TRANSP Funding

- Experimental Projects: ~3.5 FTE, OFES:
  - NSTX (60%), DIII-D (25%), JET, C-Mod.
  - Covers: production system, client software development, physics development.
- SciDAC FusionGrid: ~0.75 FTE, OASCR:
  - Collaborative production and client software.
  - FY06 may be last year.
- PTRANSP & FSP: ~1.0 FTE, OFES:
  - Integration of multiple physics models.

TRANSP Developers and Users

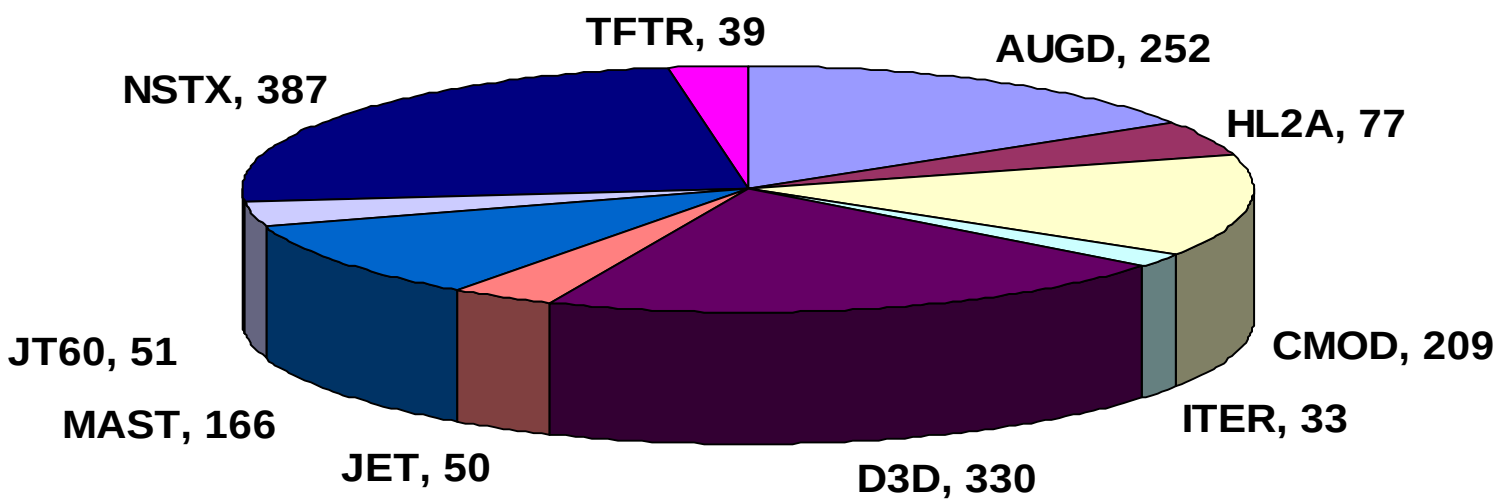
- PPPL TRANSP team:
  - Robert Andre
  - Eliot Feibush
  - Kumar Indireshkumar
  - Jae-Min Kwon*
  - Long-Poe Ku**
  - Christiane Ludescher
  - Doug McCune
  - Lew Randerson

- 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**

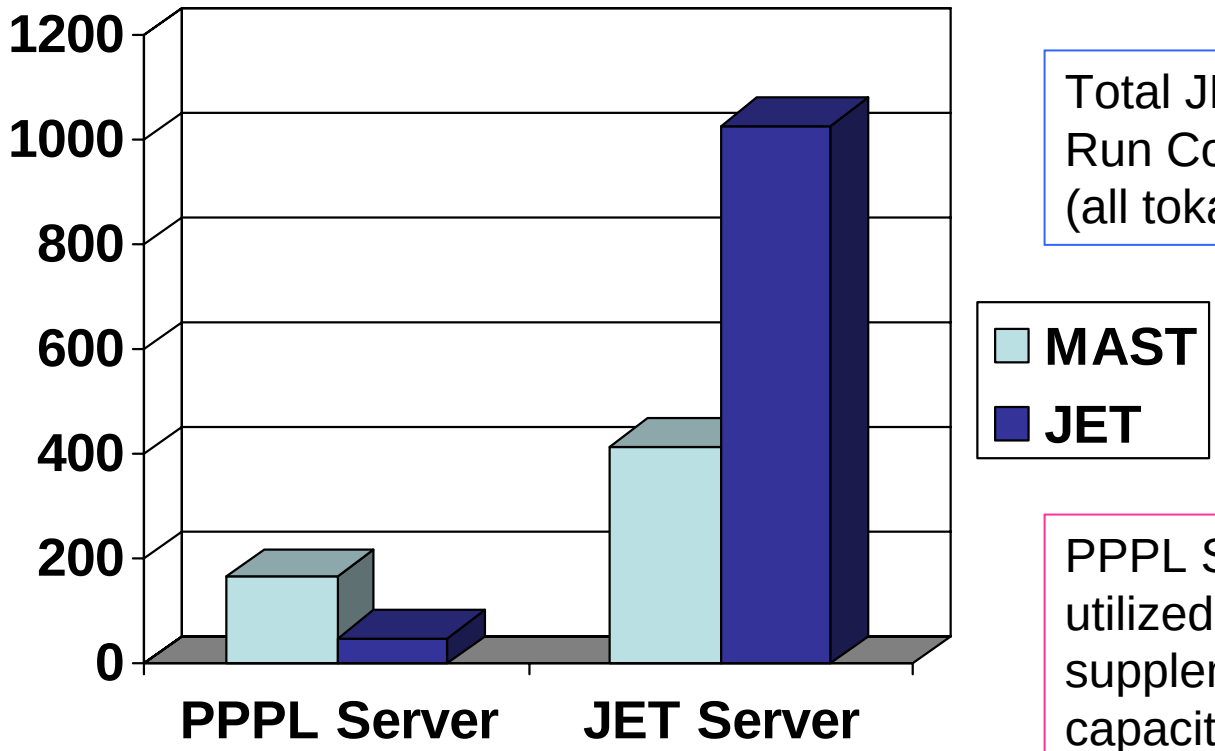
1594 TRANSP Production Runs on PPPL Servers

By Tokamak, Nov. 1, 2004 – Oct. 15, 2005



Most JET and MAST Runs Execute on JET Production Server

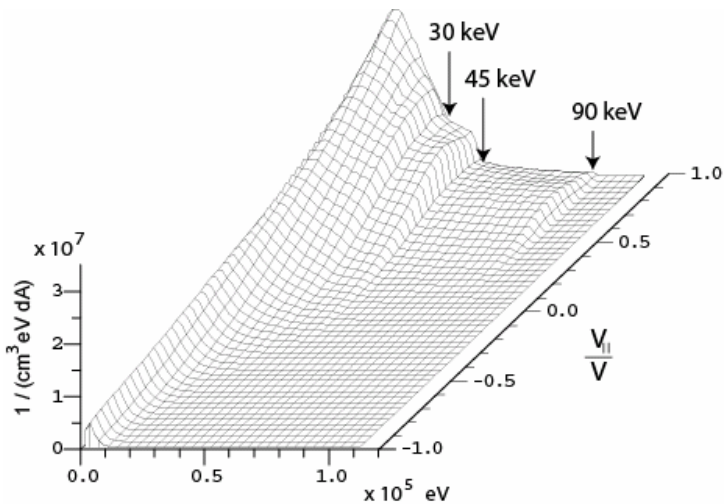
Run Counts, Nov. 1, 2004 – Oct. 15, 2005

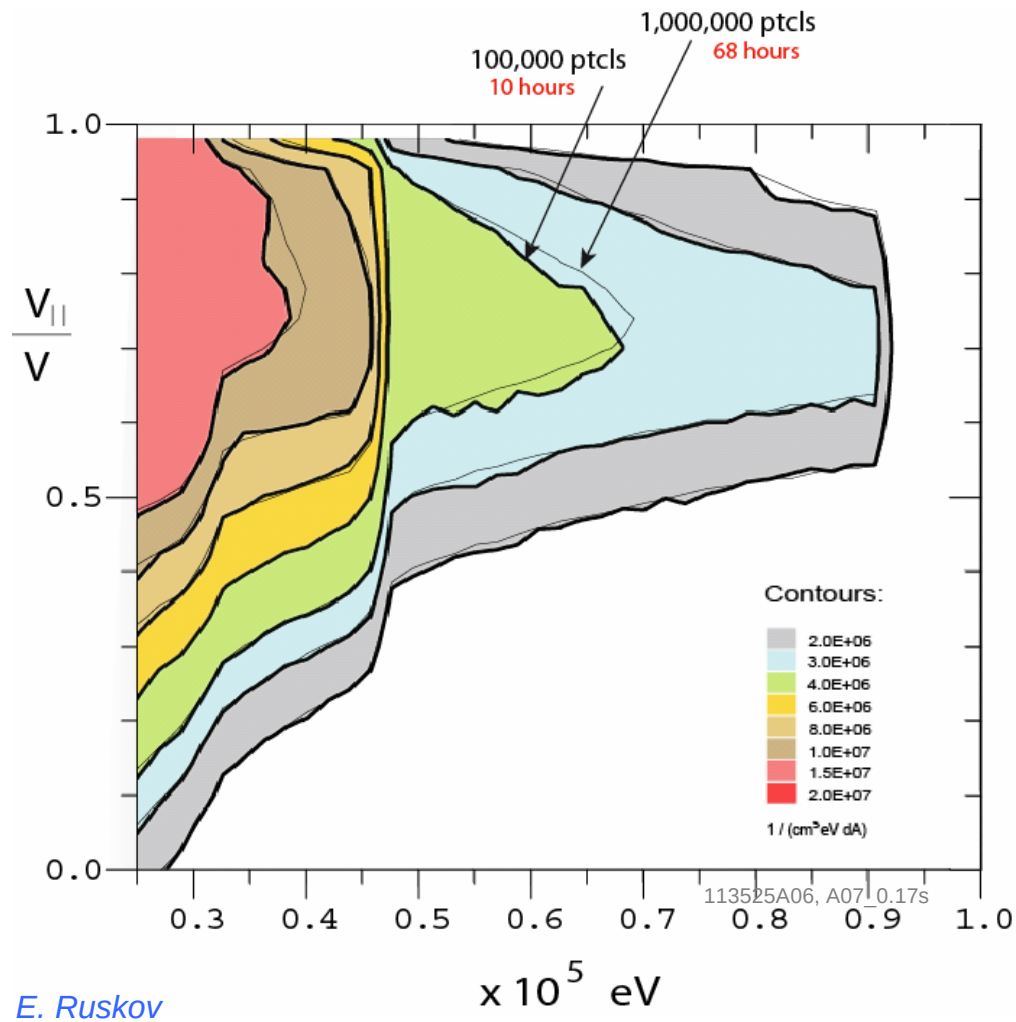


Total JET +PPPL Run Count: 3036 (all tokamaks).

PPPL Servers utilized for supplemental capacity and for debugging.

Beam-ion distribution function for NSTX beam source A as calculated by TRANSP: 100,000 vs. 1,000,000 Monte Carlo beam particles





Typically NPTCLS=5-10,000:

fast execution (1-2 hours) on the sunfire cluster, but beam distribution output is noisy (not shown)

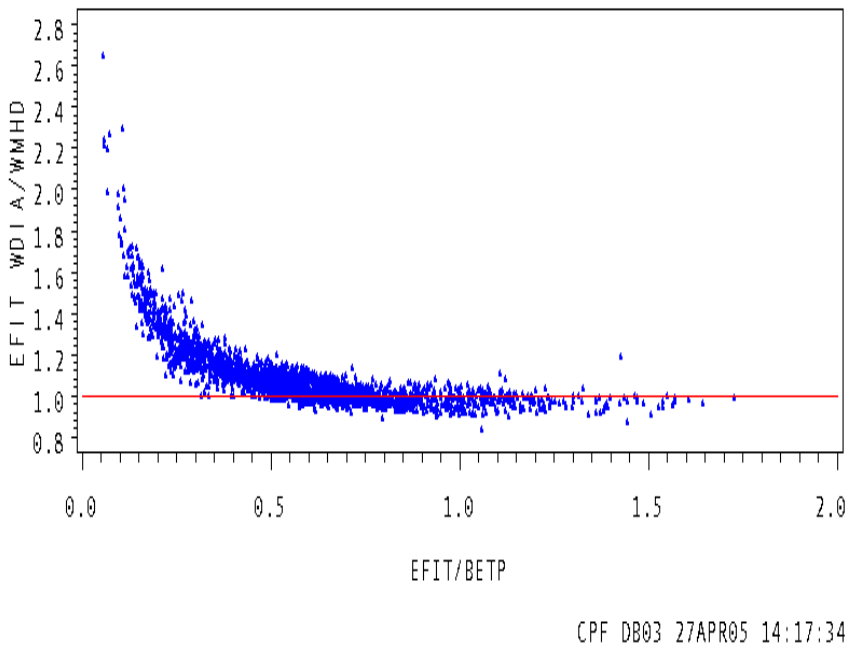
Runs with NPTCLS=100,000:

finish in reasonable time (~10 hours CPU time) and have good beam-ion distr. function resolution.

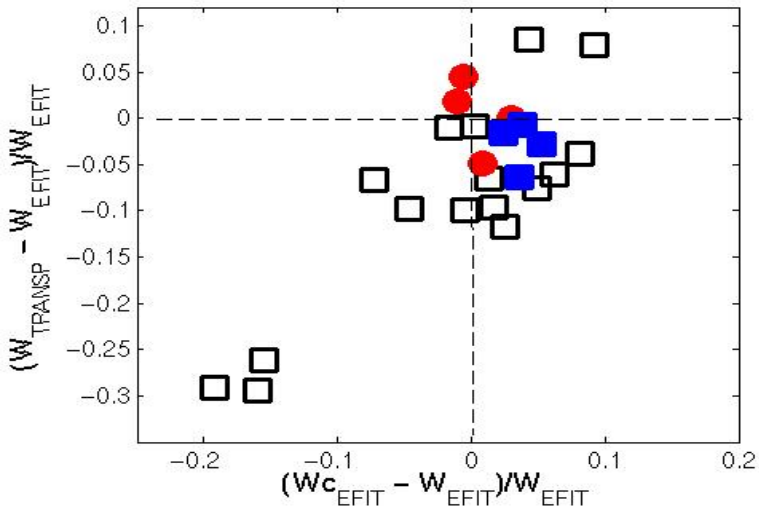
E. Ruskov

Consistency of stored energy measurements (*S. Arshad et al, EPS 2005*)

Magnetics measurements on JET offer two separate measurements of energy, the MHD energy, W_{MHD}, and diamagnetic energy, W_{DIA}. Both of these rely on the equilibrium reconstruction, calculated from EFIT with data taken from magnetics coils alone. W_{MHD} is calculated directly from the resulting EFIT equilibrium itself, by integrating the pressure profile over volume. W_{dia} is calculated from the compensated diamagnetic flux loop measurement.



Discrepancy between W_{dia} and W_{MHD} in EFIT correlates with β_{pol} (data are taken from JET 2003 campaign)



Discrepancy in Wdia between TRANSP and EFIT correlates with the discrepancy in EFIT itself, it is observed at low β_{pol} $\Rightarrow$ similar problem in TRANSP and EFIT?

I. Voitsekhovitch

D. McCune

Client Software: SPLITN

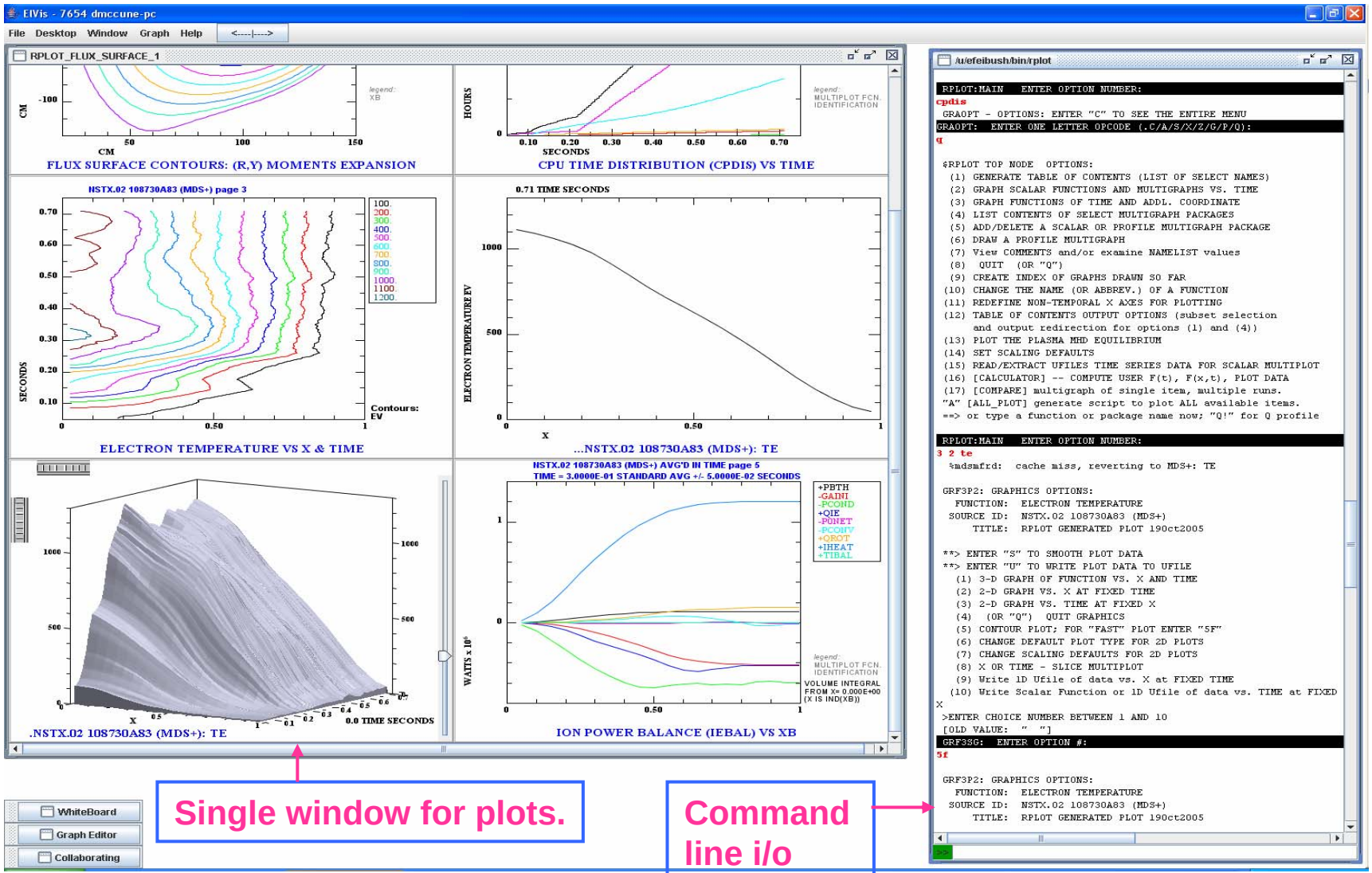
- Fortran library API to access and/or modify TRANSP namelists.
- Namelist modifications done in minimalist style (all comments & ordering left intact).
  - SPLITN now used by xtranspin!
- Command line namelist editor: usplitn.

```
➢usplitn 37065Z10TR.DAT ftime 5.2 q 37065Z11TR.DAT q
➢diff 37065Z10TR.DAT 37065Z11TR.DAT
  < ftime=5.3
  -----------
  > ftime=5.2
```

Namelist modified by command line with minimal change to text.

RPLOT and TRDAT in ElVis

RPLOT session shown:



Single window for plots.

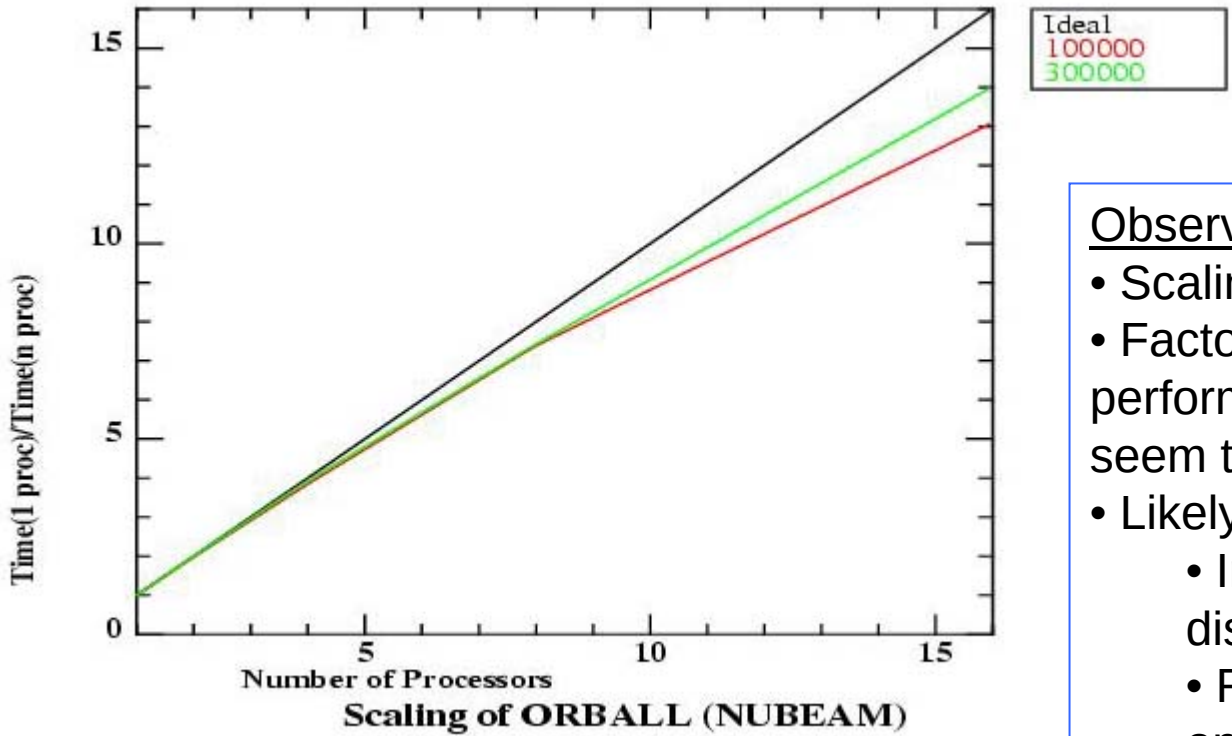
Command line i/o

NUBEAM Development

- MPI Parallelization Nearly Complete.
  - Orbit Loop.
  - Deposition Loop.
  - Book-keeping Operations.
- Standalone Code: nubeam_driver:
  - Executes TRANSP's NUBEAM timesteps.
  - Can run as MPI-parallel NUBEAM server.
- MPI Performance Test Results…

MPI Scaling of NUBEAM…

For 100,000 ptcls/species & 300,000 ptcls/species…



Observations:

- Scaling not perfect but...
- Factors of 10x to 20x performance enhancements seem to be achievable.
- Likely applications:
  - Improved statistics for distribution functions.
  - RF Monte Carlo operator
- Work is continuing.

Monte Carlo RF Operator

- Identified by users as top priority*.
- Initiated PPPL/KSTAR collaboration:
  - Dr. Jae-Min Kwon (KBSI) 2 year visit to PPPL.
  - Goals:
    - Port MC RF Operator from standalone code to NUBEAM; use TORIC5 wave fields.
    - Become expert TRANSP user and TRANSP code developer.
    - Initial use of NUBEAM with MC RF in research applications.

***Per visit by D. McCune to JET, 12/2004**

RF Codes

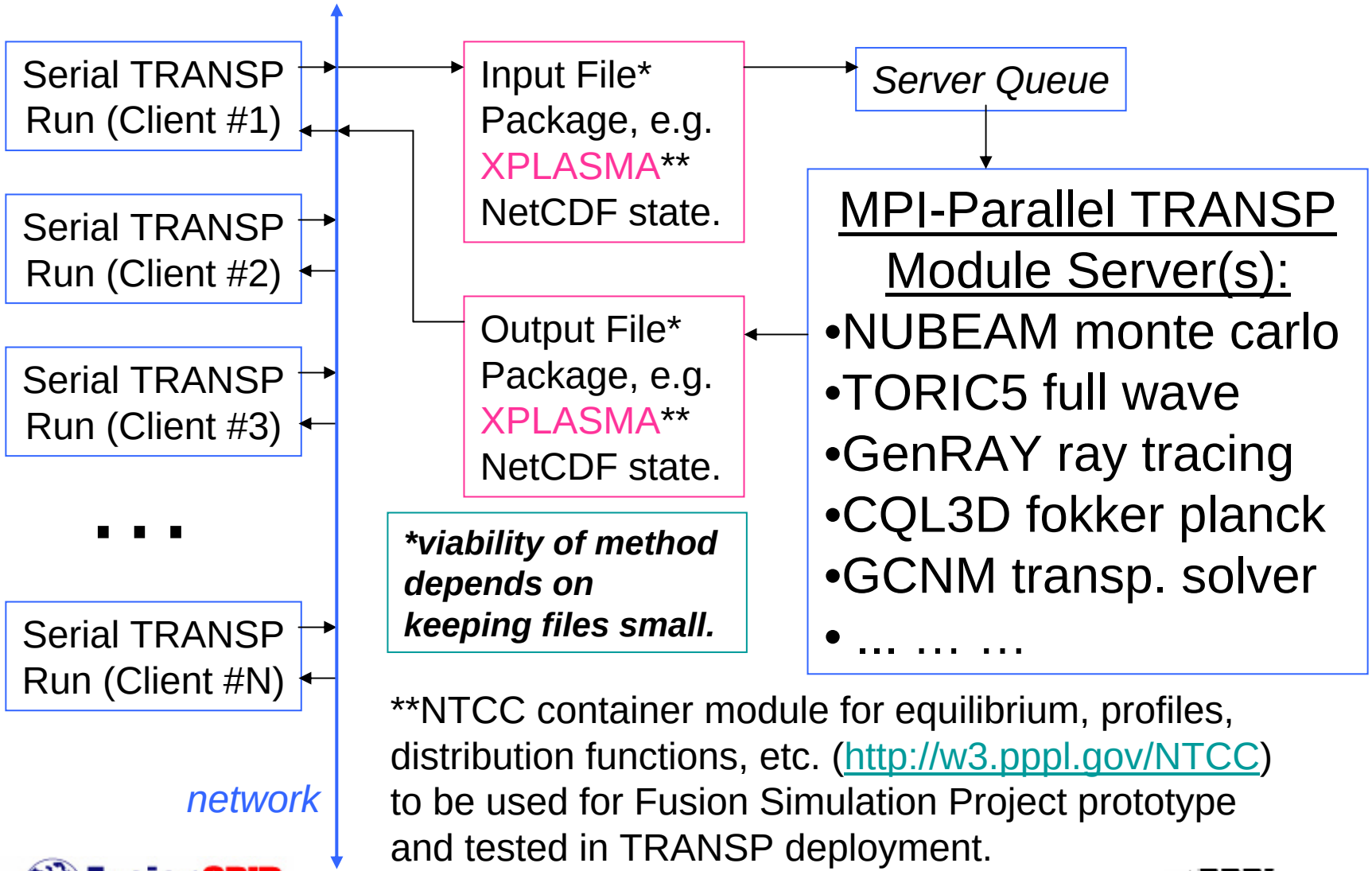
- TORIC5* –
  - Source repository (cvs) established at MIT.
  - TRANSP-related modifications committed; current cvs version installed in TRANSP.
  - Several C-Mod based time dependent test runs completed; troubleshooting in progress.
- GenRay** – in cvs; ported to PPPL Cluster.
- CQL3D** – in cvs; ported to PPPL Cluster.

*Brambilla et al., IPP/Garching & MIT **Harvey et al., Comp-X

Ideas for Deployment

- Time dependent serial TRANSP runs request numerous MPI calculations:
  - Now: timesteps of NBI and various RF.
  - Future: MHD, turbulent transport?
- Cannot endure long queue wait for each timestep.
- Therefore: client uses reserved server:
  - Communication via small file packets.
  - Multi-purpose server (NUBEAM & TORIC5 ready now).

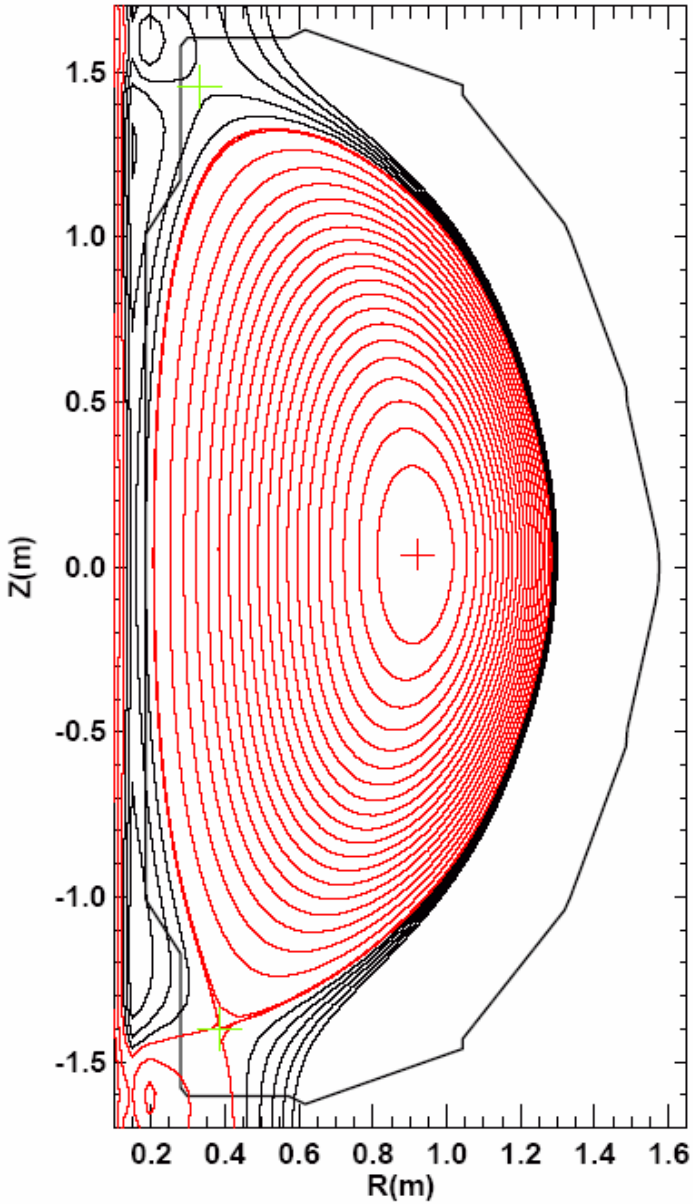
MPI-Parallel Module Server



**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.

MHD Equilibrium Solvers

- LLNL TEQ to be imported into TRANSP.
  - Status: troubleshooting fixed boundary mode in standalone code with TRANSP data.
- Isolver (J. Menard) code to be rewritten in F90 instead of IDL.
  - Status: in progress.
  - Code built from ground up, will enable TRANSP team to incorporate effects important to STs, e.g. rotation.



NSTX equilbrium from Isolver

Seek to study ST Features:
- Strong rotation
- Poloidal pressure asymmetry

J. Menard

D. McCune

Predictive TRANSP Upgrades

- Stiff solver upgrades in progress:
  - GCNM (St. John, GA).
  - PPPL internal effort (S. Jardin, L. P. Ku).
- TRANSP software upgrades:
  - Data modules– all TRANSP input data visible without recourse to TRANSP internals:
    - SPLITN – namelist (see p. 13).
    - TRDATBUF_LIB – time dependent data.
    - Available at http://w3.pppl.gov/NTCC as always.
- Steering upgrade.

Stiff Solvers

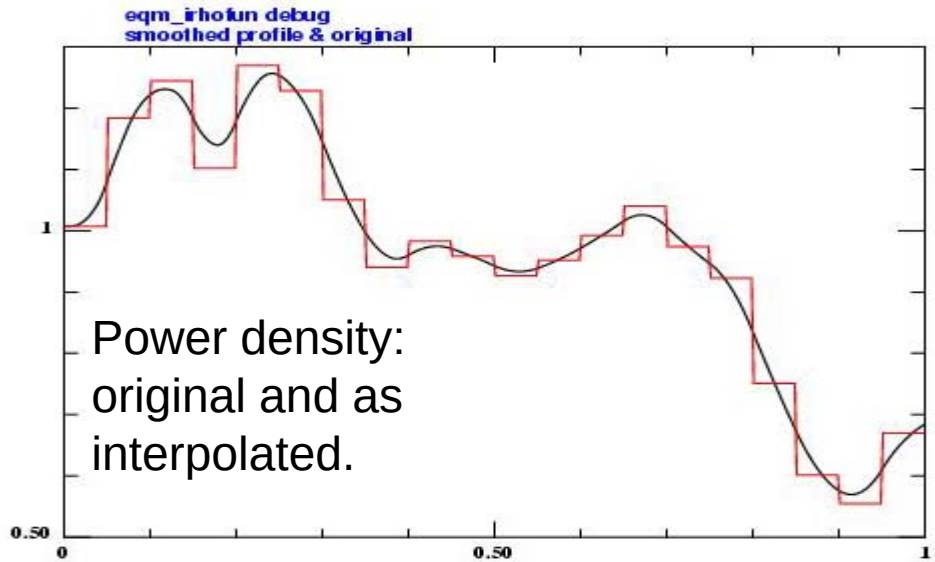
- Ad hoc methods fail; advanced solvers needed.
- Execute solvers as separate modules:
  - TRANSP provides sources and connection to experimental data.
  - XPLASMA transmits equilibrium and profiles.
  - Natural leveraging of past NTCC effort.
- Density prediction and free or fixed boundary operating modes to be provided.

TRANSP Data Modules

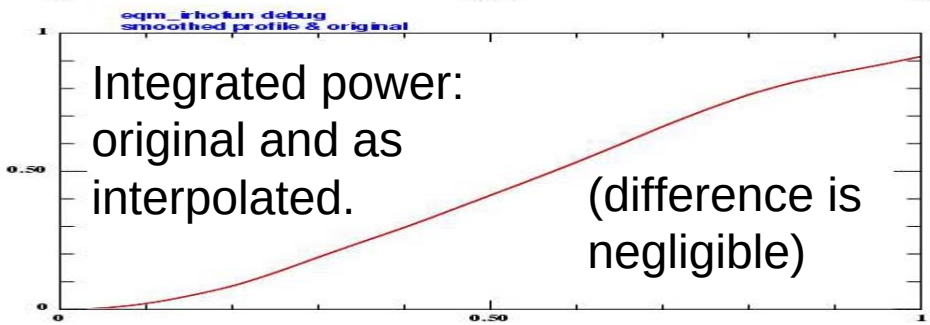
- Facilitate use of 10000s of archived TRANSP runs on 10s of tokamaks.
- Enable access to more TRANSP data:
  - Namelist & configuration information (SPLITN* in TR_CLIENT module).
  - Time dependent measurements– TRANSP input datasets (TRDATBUF_LIB*).
  - TRANSP output datasets accessible as before (TRREAD*).
- Direct access by solver modules without recourse to TRANSP internal methods.

*http://w3.pppl.gov/NTCC

XPLASMA for Intermodule Communication



Power density: original and as interpolated.



Integrated power: original and as interpolated.

(difference is negligible)

Beam electron heating (small # of MC ptcls)

Total power is conserved.

***XPLASMA* is an *NTCC** tool for communication of axisymmetric MHD *equilibria* and *profiles* portably and conveniently between modules.**

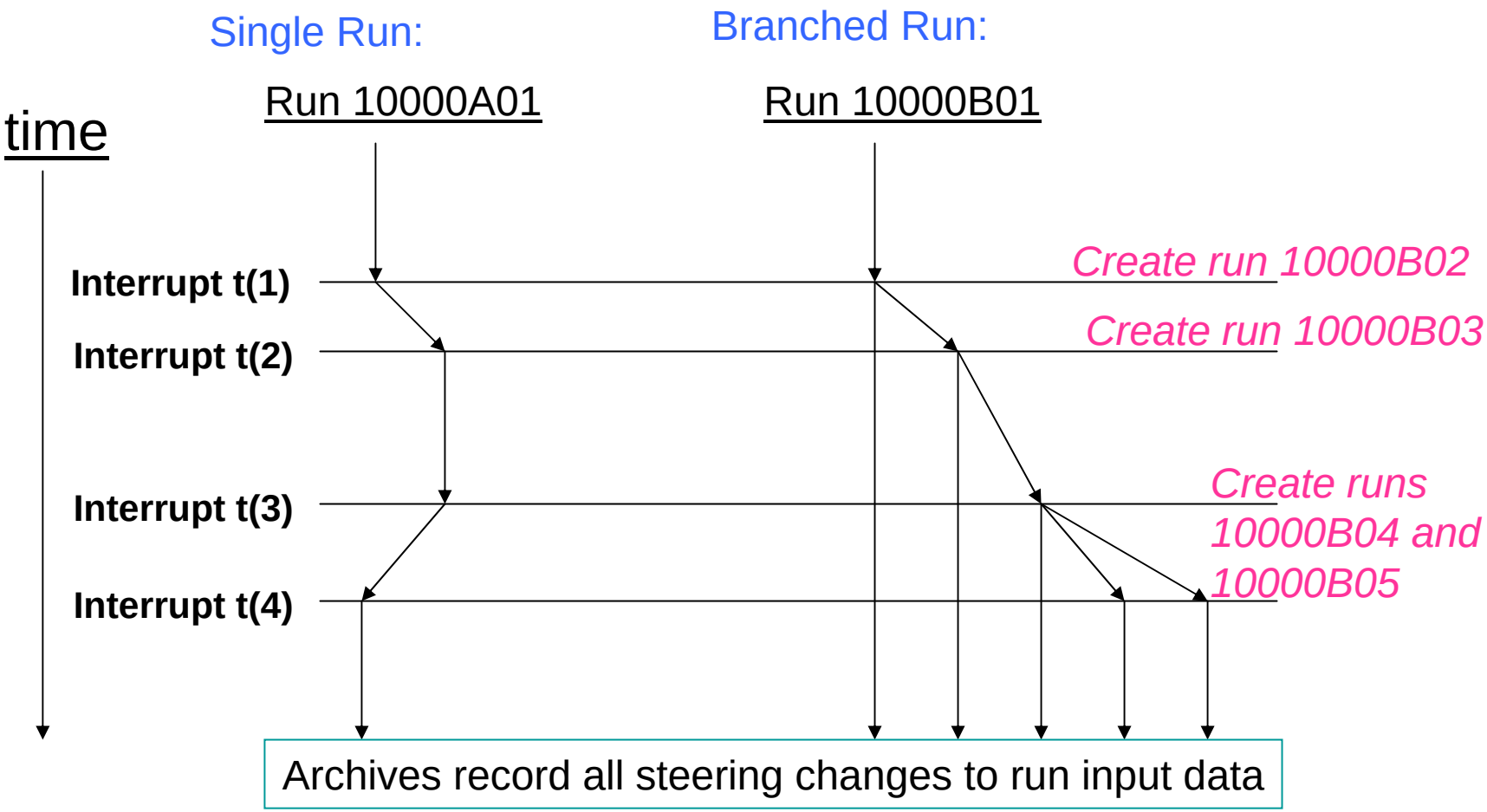
- **It supports numerous mapping and interpolation methods.**
- **Example: accurate, conservative rebinning of heating profiles (as shown).**
- **Planned for use in Fusion Simulation Project.**

* http://w3.pppl.gov/NTCC

Steering Upgrade

- Ability to interrupt a TRANSP run and restart with modified input data.
  - Motivation: adjust heating and current drive profiles in course of predictive simulation.
  - *Time dependent* data can be modified.
    - Modifications take effect at time of interruption.
    - Merged input data & namelist archived with run.
  - Input data archived, so steered run is *reproducible*– just reuse namelist.
- Steer a single run or create variant runs.

Two Steering Modes



Interrupts can be pre-programmed in the namelist or requested asynchronously via the FusionGrid client interface.

Predictive TRANSP Outlook

- To be added:
  - Free boundary equilibrium (LLNL TEQ or PPPL module).
  - Edge physics in free boundary (LLNL UEDGE).
  - Pedestal and Sawtooth Trigger (Lehigh U.).
- Validation & Verification:
  - Lehigh U. (use ITPA database and compare with alternative predictive codes).
  - Stiff solver solutions require careful V&V.
- Synergy with Fusion Simulation Project.

Review of Contents

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- Run Production Statistics.
- Recent examples of TRANSP Results.
- Status of Code Development Efforts:
  - Client Software
  - NUBEAM MPI Parallelization.
  - RF Codes.
  - MHD Equilibrium Reconstruction.
  - Predictive Upgrades.

Summary

- TRANSP effort touches on a wide range of activities in plasma physics research:
  - Analysis of experimental data.
  - Validation and application of theory.
  - Predictive simulation for new devices.
- The effort can branch in many directions.
- Community input is sought to guide the future direction of the TRANSP effort.