Status of TRANSP/PTRANSP

Presented at APS-DPP 2011

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Abstract

D. McCune, R. Andre, E. Feibush, M. Gorelenkova, C. Ludescher-Furth, X. Yuan

This poster summarizes the status of TRANSP/PTRANSP code development and run production operations. Production system utilization rates, particularly for MPI jobs, continue to climb. The poster will show production system utilization history and describe status and plans for production facilities and supporting software, as well as the major areas of physics code development. The major physics areas are: simulation using free boundary MHD equilibrium (ISOLVER); neutral beam and fusion product fast ion heating and current drive (NUBEAM); RF heating and current drive (TORIC, GENRAY, and other codes); and predictive transport modeling (PTRANSP and associated modular solvers). In addition, there have been promising advances in capabilities for post-processing and analysis of TRANSP results, based on the SWIM Plasma State software; these too will be described.

http://w3.pppl.gov/transp/

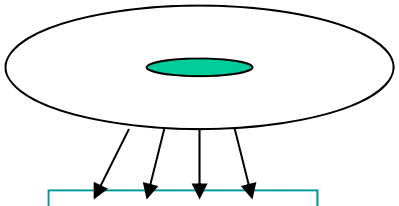
TRANSP: Vision Statement

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

Doug McCune

Traditional TRANSP: Overview

Experiments (Asdex-U, C-Mod, DIII-D, EAST, ITER, JET, MAST, NSTX, HL2A , IGNITOR)



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…

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

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TRANSP/PTRANSP Production Service

- The TRANSP/PTRANSP production service allows users around the world to submit TRANSP/PTRANSP jobs to PPPL compute nodes through the FusionGrid.
  - Tools available to aid in submitting new runs
  - User supplies data and namelist
  - Web based interface for monitoring the progress of jobs
    - http://w3.pppl.gov/transp/transpgrid_monitor
  - Several options available for retrieving results
  - Automatic analysis of run failures by TRANSP/PTRANSP developers

TRANSP/PTRANSP questions should be sent to

Transp_Support@pppl.gov

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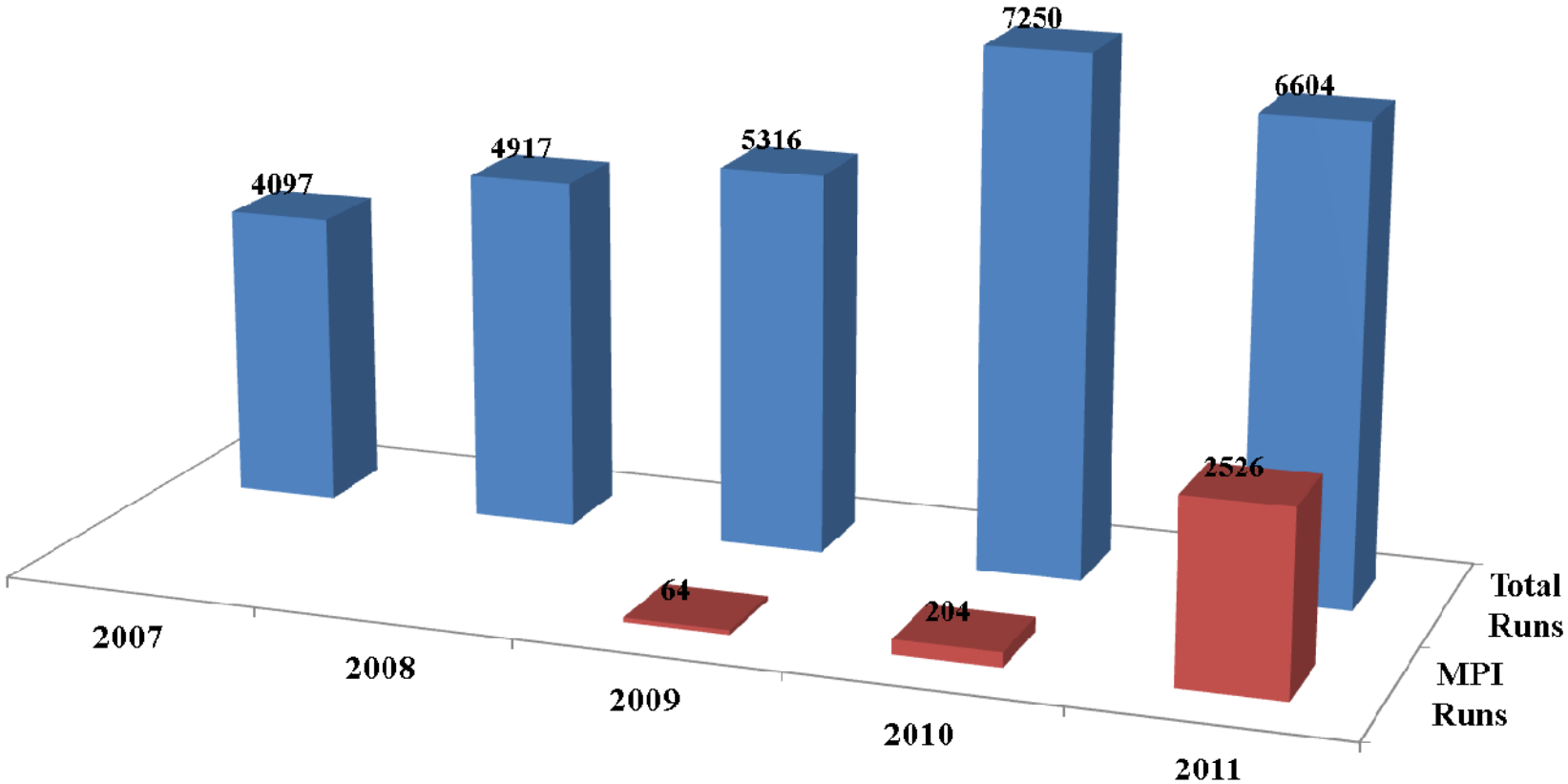
PPPL TRANSP Production 2007-2011



- The total number of production runs decreased slightly in 2011 compared to 2010.
- There was an order of magnitude increase in the use of MPI by runs using the parallel nubeam fast ion monte carlo code.
- Does not include TRANSP runs made at JET.

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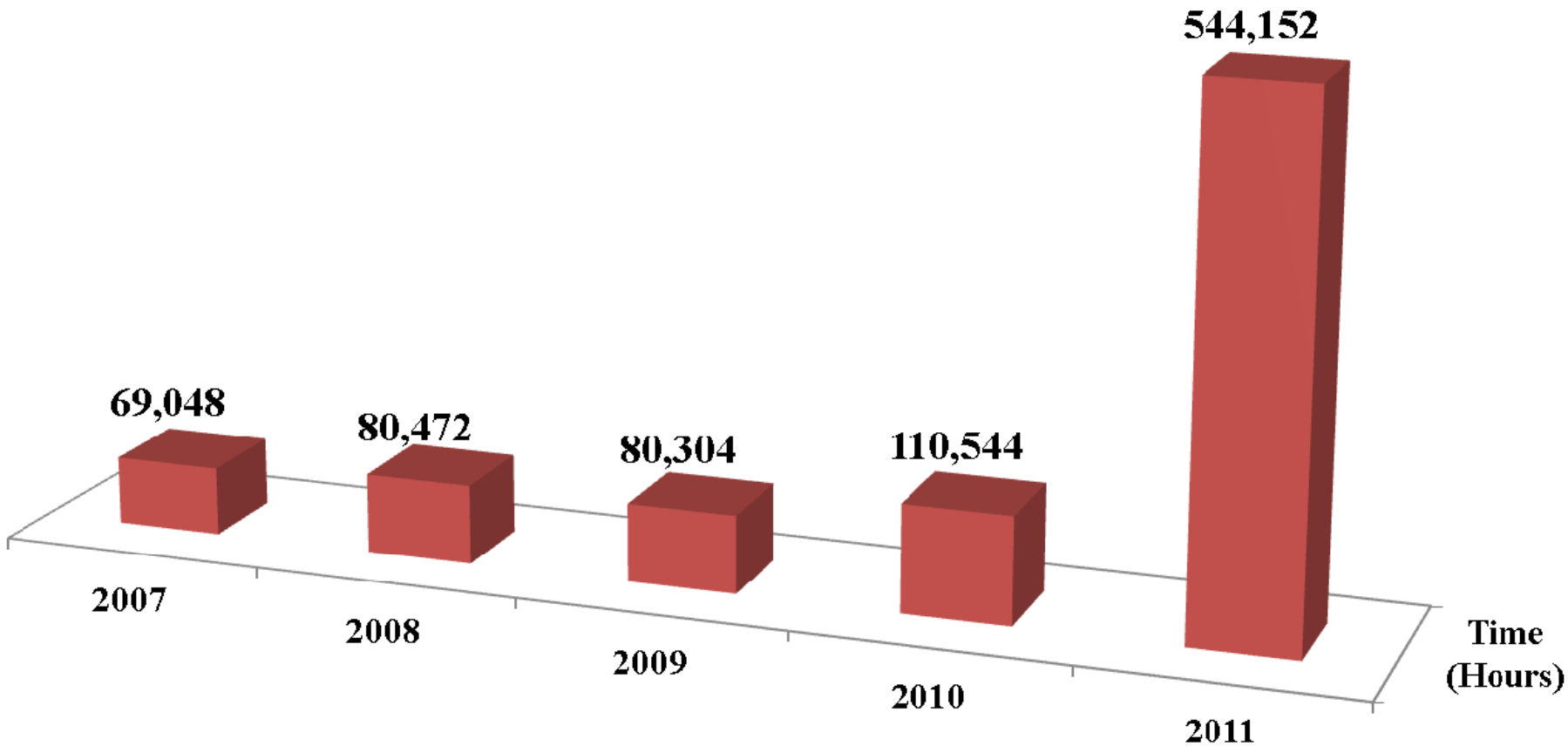
PPPL TRANSP Production Total Compute Time



- <u>Significantly</u> more computing resources were required in 2011 compared to previous years

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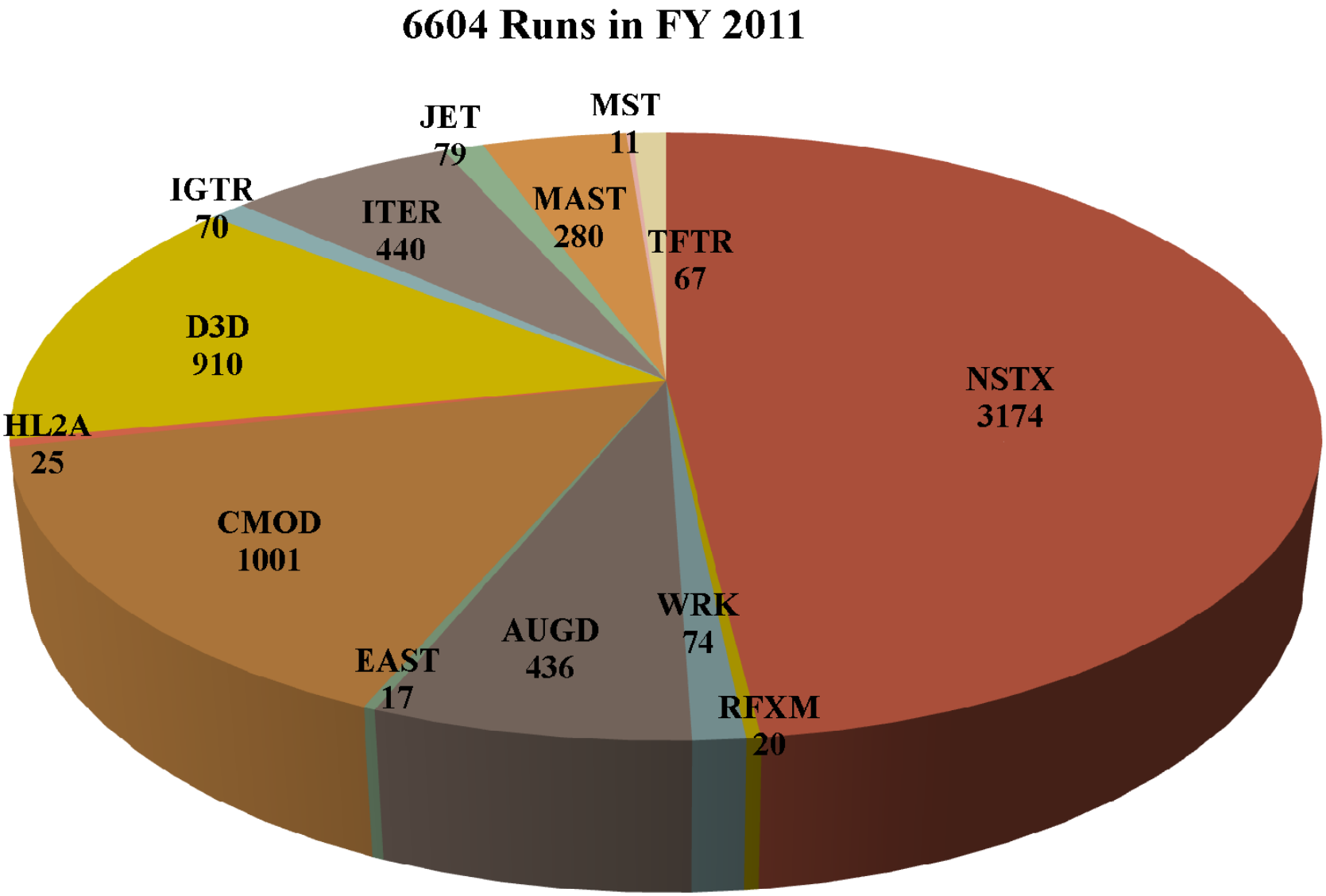
TRANSP/PTRANSP 2011 Runs by Device



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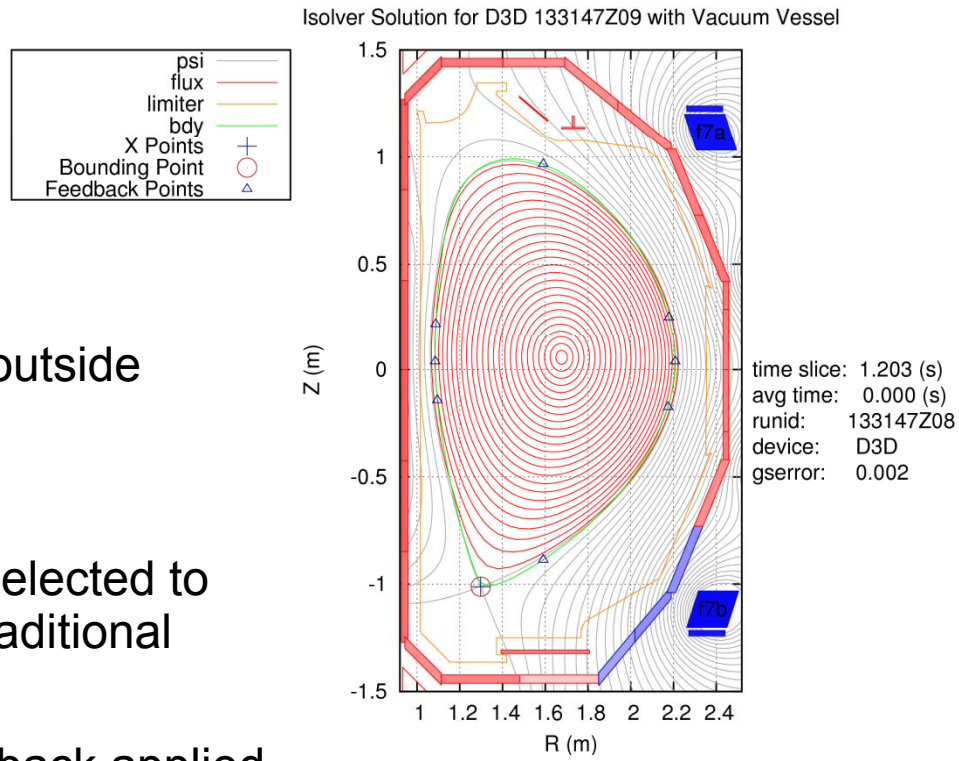
TRANSP/PTRANSP Isolver

- TRANSP Isolver is a free boundary, f90 based equilibrium solver derived from Jon Menard's IDL based Isolver code.
  - Used most recently by S. Gerhardt to generate over 9000 fully relaxed equilibria for the NSTX upgrade in TRANSP



- Features:
  - **Free Boundary** – flux solution available outside plasma boundary
  - **Coil Currents**
    - Least Squares Mode – coil currents selected to best match a prescribed boundary (traditional TRANSP mode)
    - Measured Coil Currents Mode – feedback applied to center the plasma at the prescribed boundary
  - **Passive Structures** – induced currents in vacuum vessel
  - **Coupled Flux Diffusion** – time evolution of q profile coupled to equilibrium solution.
- Supported Tokamaks
  - Coils and Vacuum Vessel: NSTX (current), D3D
  - Coils only: NSTX (upgrade), ITER, CMOD, EAST, IGTR, MAST

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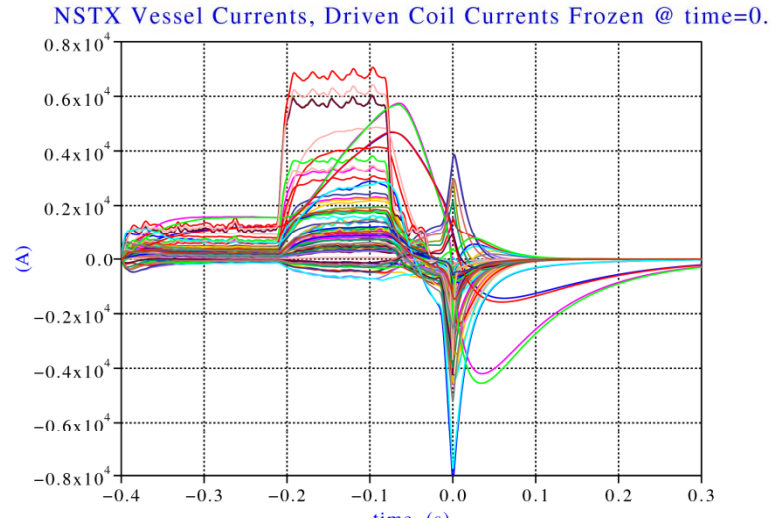
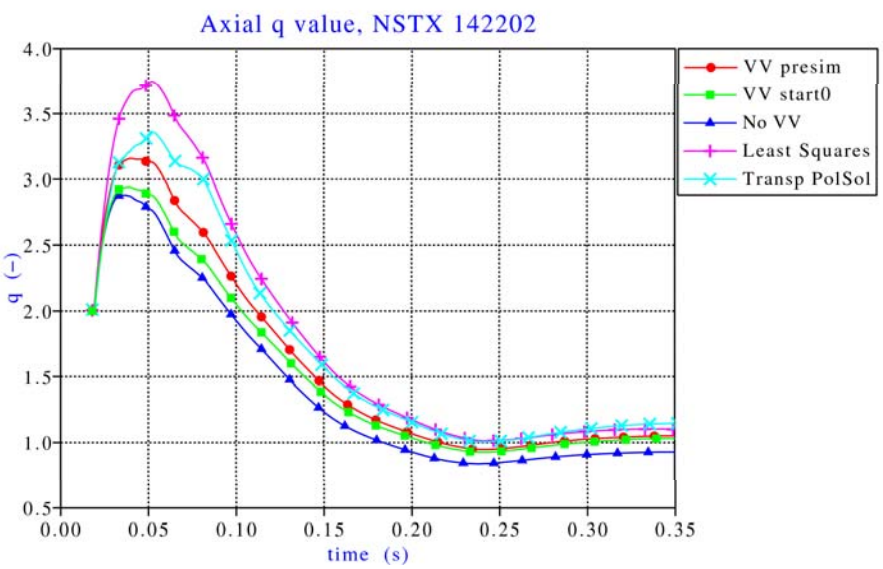
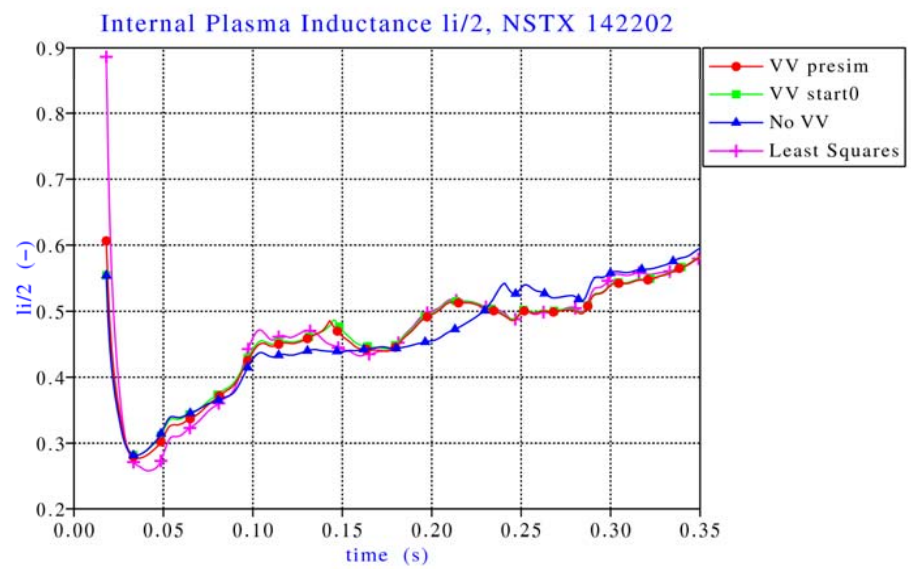
Isolver Passive Structures

- When using measured coil currents, the current induced in the vacuum vessel can be included in the equilibrium solution.
- Option available for calculating the induced currents up to the start of the TRANSP run or can start from zero.







Effect of the vacuum vessel on the NSTX q profile evolution using Isolver flux diffusion

- Presimulated induced currents, starting from zero induced currents and no vacuum vessel solutions based on measured coil currents
- Also shown is the prescribed boundary solution (no vacuum vessel) using least squares coil currents with Isolver flux diffusion and alternatively TRANSP's poloidal field diffusion

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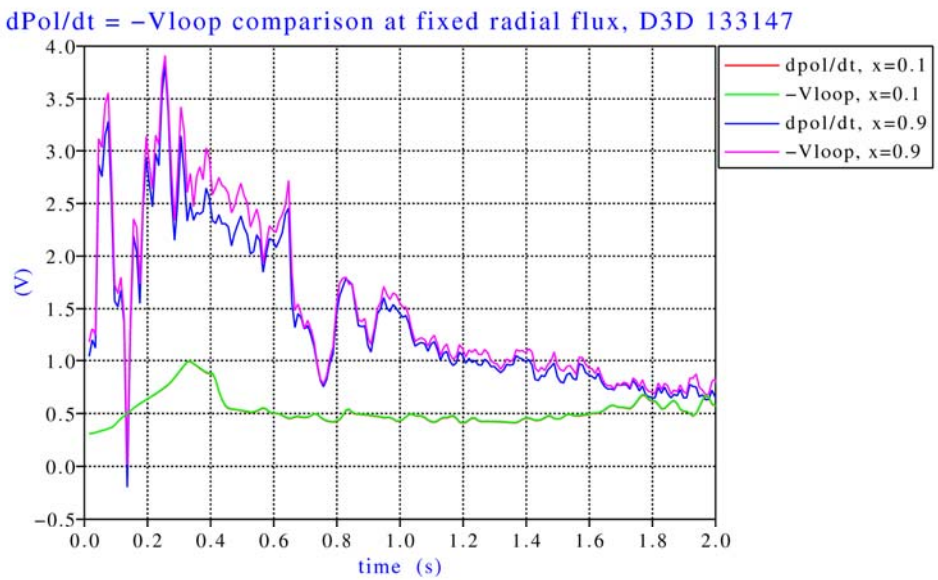
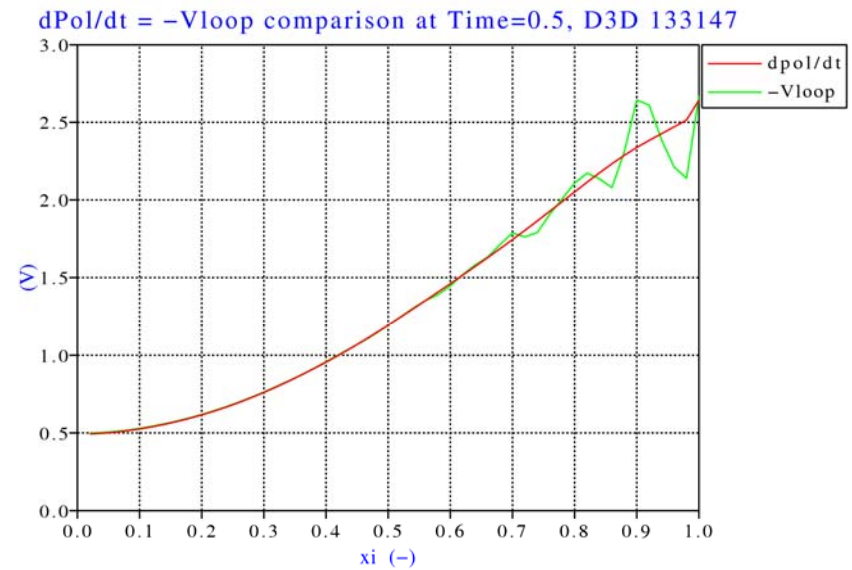
Isolver Flux Diffusion

- Isolver has the capability of advancing the q profile consistently with the equilibrium solution.
- This can be represented as a diffusion of the poloidal flux as driven by the loop voltage,

$$\left.\frac{\partial \Psi}{\partial t}\right|_{\Phi} = -V_{\text{loop}}$$

- The evolution of the q profile is traditionally done in TRANSP with TRANSP's poloidal field diffusion code which advances the q profile using time stepped delayed equilibrium metrics.
- Currently flux diffusion has a partial implementation in Isolver which only supports plasma current matching and does not enforce the axial poloidal flux time evolution.





- Implementation works well near the axis but deteriorates towards the edge. This can cause problems with the <J.B> profile near the edge.
- Planned future work:
  - Self consistent poloidal flux at the axis to enable plasma current prediction
  - Improve edge behavior of the solution

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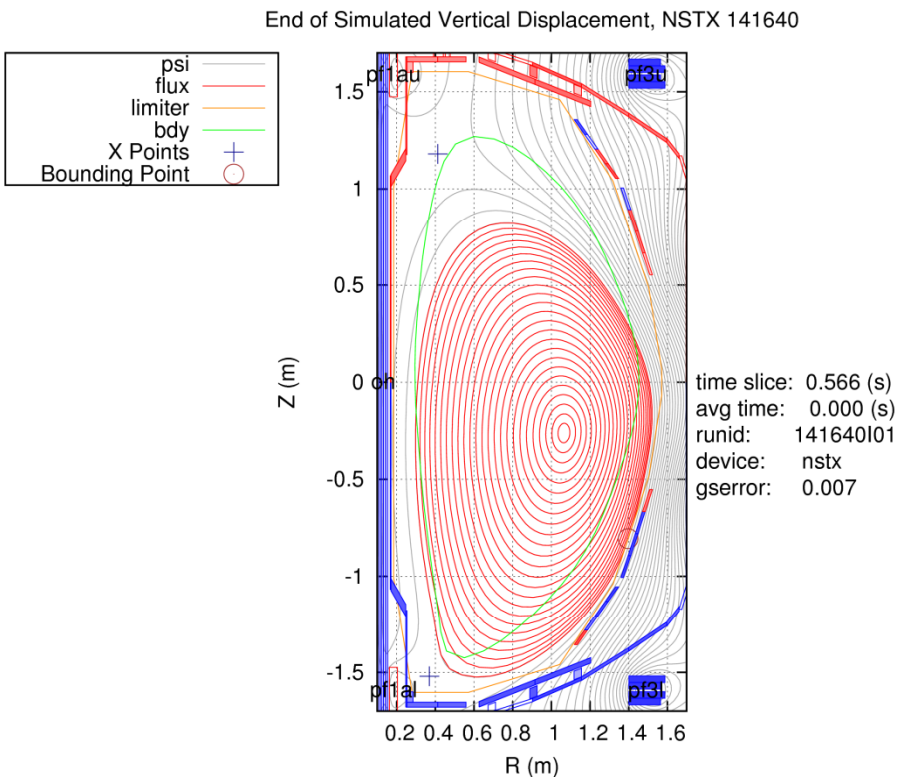
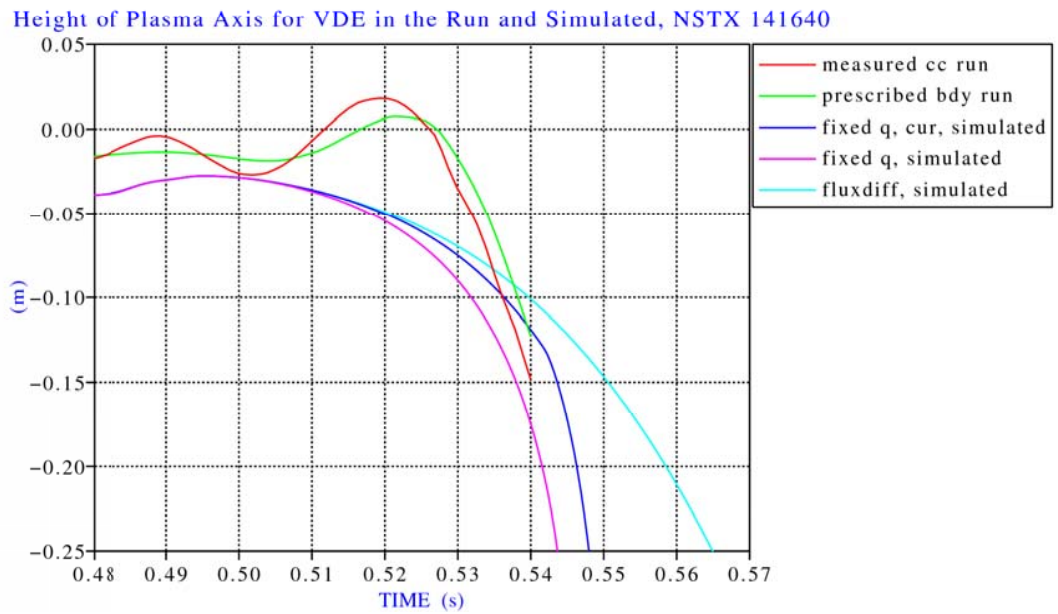
Isolver Simulations

- Isolver can be run outside of TRANSP through jython (python implemented in java) scripts
  - Aid in triage of equilibrium related crashes in TRANSP production runs
  - Simulation of equilibrium evolution outside of TRANSP based on existing TRANSP runs
- An example of this is the modeling of a vertical displacement of the plasma equilibrium when the feedback used to center the plasma is turned off.
  - NSTX 141640 had plasma control turned off at t=0.5 (s)
  - Simulated outside of TRANSP with various options for handling the q profile after t=0.5 (s). Other q profile simulations resulted in the plasma crashing toward the top of the vessel.
  - Also included for comparison are two TRANSP runs based on measured currents and a prescribed boundary each run to the end of the shot data (t=0.54).





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MPI TORIC

- D. McCune, with the help of C. Ludescher-Furth installed and tested the parallel version of the ICRF wave code TORIC in TRANSP/PTRANSP (Brambilla, Plasma Phys. Contr. Fusion 41 (1999) 1).
  - Parallelized in the number of poloidal modes
  - Enables the use of more modes and antennas than were practical with the serial version
- Example CPU times for a single time slice run of TORIC (Nmod = number of poloidal modes)

Cores	Nmod=255 (min)	Nmod=127 (min)
1	281	60
8	70	14
16	33	10
32	15	3.5
48	12	3
64	8	2
96	7	1.6

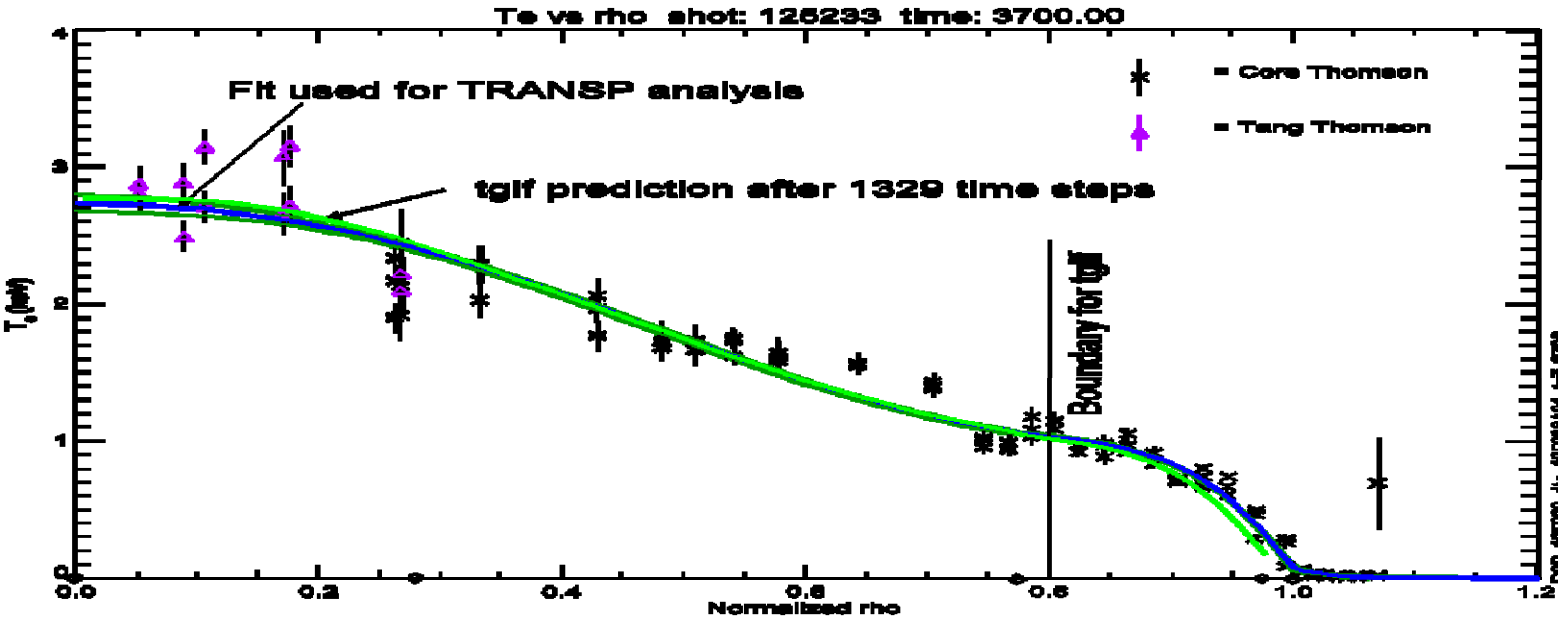
MPI TORIC Usage

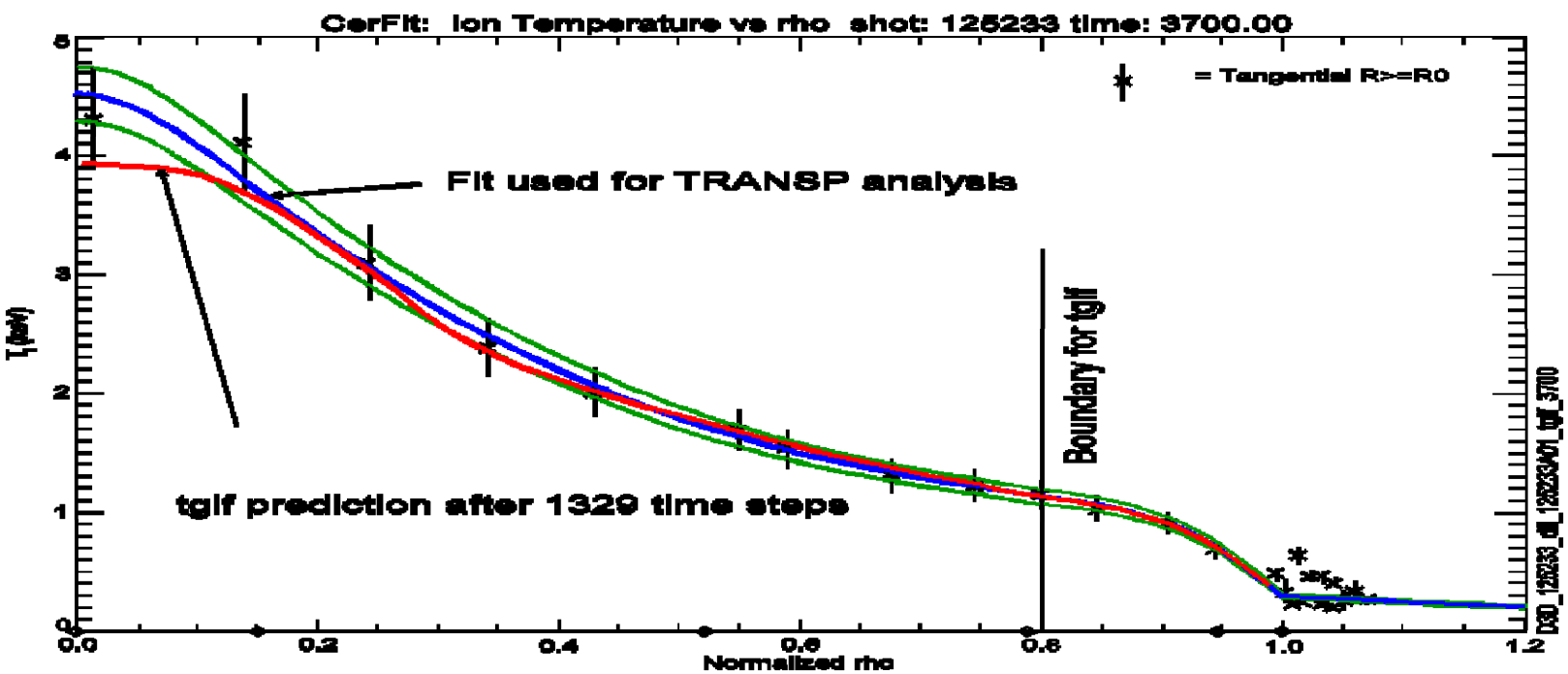
- Set Namelist Variable: **NTORIC_PSERVE = 1**
- If you start the run with “tr_start” or “xtranspin”, the program will ask how many processors you would like
- Non-PPPL Sites which generate their own request file see http://w3.pppl.gov/transp/request_file.html
- Suggested usage based on Nmod (TRANSP namelist variable NMDTORIC)
  - NMDTORIC >=127 should use parallel Toric
  - NMDTORIC >=64 may use a few cpus, e.g. Np=4
  - NMDTORIC =31 leave as serial
- Other Namelist options
  - NICRF=8, full equilibrium (recommended)
  - NICRF=9, full equilibrium lower resolution allowed

PT-SOLVER: a new PTRANSP solver

1) Modular, parallel, multi-regional, implicit solver for stiff transport equations
2) Integrates highly nonlinear time-dependent equations
3) Wide range of transport models (GLF23, TGLF, MMM series, ETG, PALEO, NCLASS and Chang-Hinton et al.)
4) Built on Plasma State and other publicly available libraries
5) Intended for installation in the NTCC modules library and PTRANSP
6) Developed by D. McCune, Xingqiu Yuan, and S. Jardin

PT-SOLVER Examples predicting Te, and Ti for real (DIII-D) plasmas





Compare predicted Ti and Te with data and fits used for the TRANSP run

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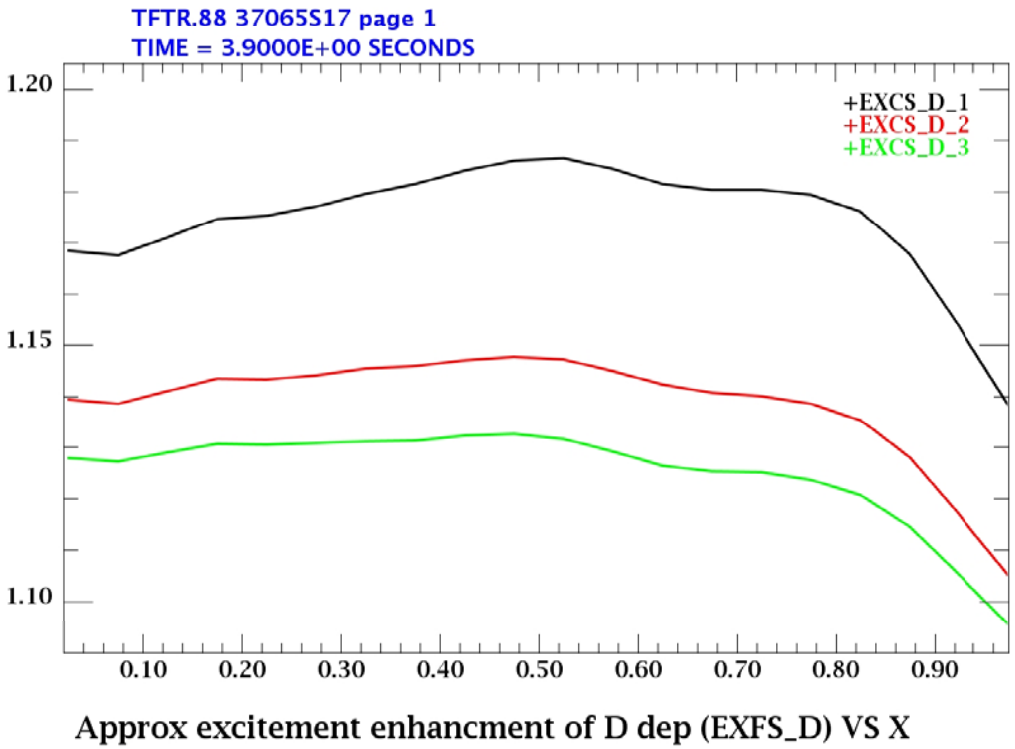
ADAS excited state model in NUBEAM

TRANSP/NUBEAM code enhanced with full implementation of ADAS atomic physics excited state data for H-like beams and Z=1...10 mixed species plasma targets.

- **Beam atoms in excited states (enhancement factor)**



Beam stopping coefficient is a linear superposition of pure impurity solutions

Enhancement factor is computed and applied for II and EI reaction

LEV_NBIDEP = 2

NSIGEXC = 1

- **Beam atoms in excited states (self consistent model)**

ADAS310 FORTRAN driver is used to compute <σV> for II and CX reactions in excited state model

LEV_NBIDEP = 2

NSIGEXC = 3

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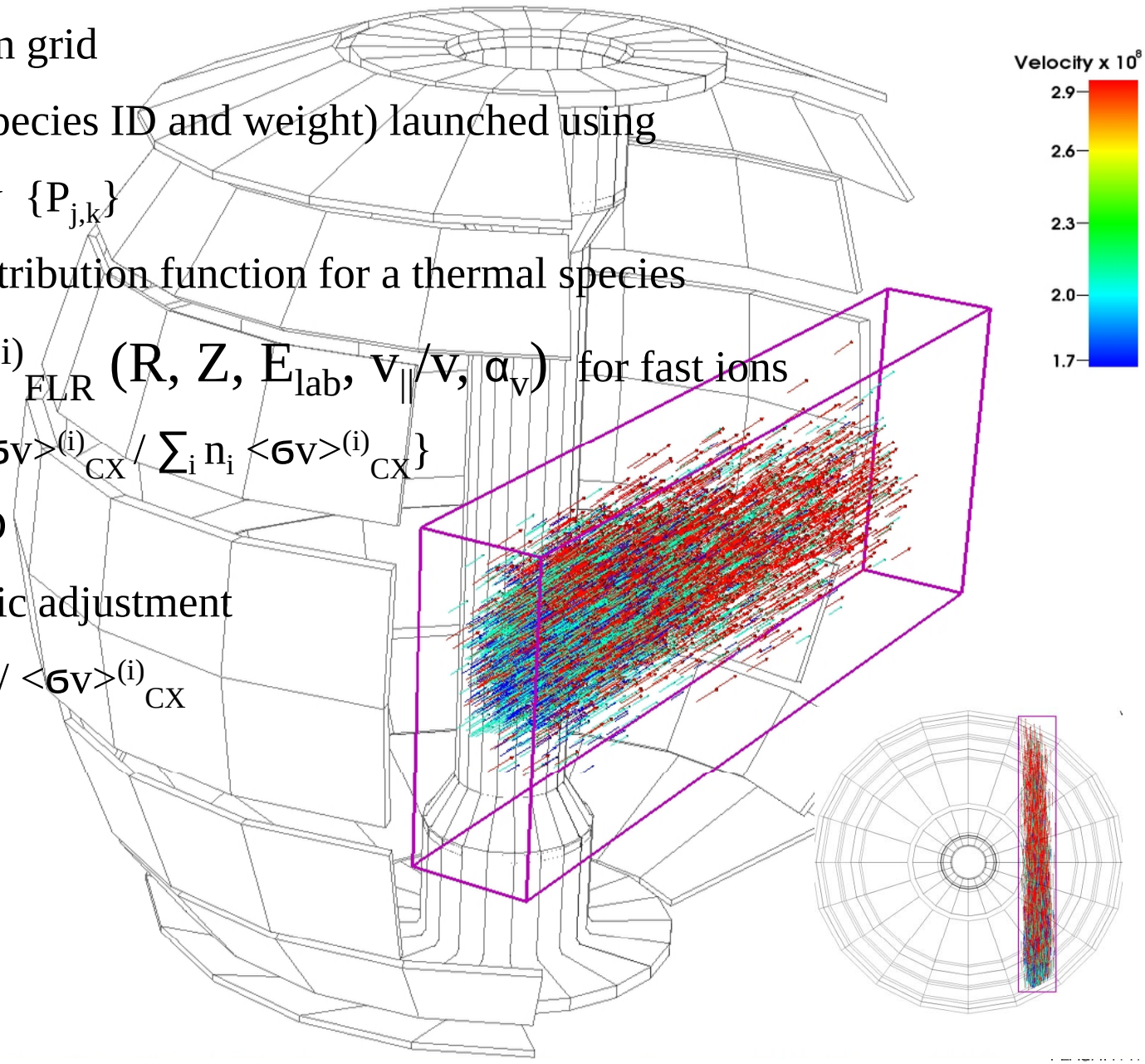
3d halo model (in progress)

Outline 3d halo model:

- 3d boxes, Cartesian grid
- new track ($\mathbf{x}_l$, $\mathbf{v}_l$, species ID and weight) launched using
  - survival probability $\{P_{j,k}\}$
  - Maxwellian ion distribution function for a thermal species
  - non-Maxwellian $f^{(i)}_{FLR}(R, Z, E_{lab}, v_{||}/v, \alpha_v)$ for fast ions
  - probabilities $\{ n_i \langle\sigma v\rangle^{(i)}_{CX} / \sum_i n_i \langle\sigma v\rangle^{(i)}_{CX}\}$
  - to assign species ID
  - weight with a kinetic adjustment
  - $\sigma^{(i)}_{CX}(|\mathbf{v}_l-\mathbf{v}_j|)\,|\mathbf{v}_l-\mathbf{v}_j|\,)/\langle\sigma v\rangle^{(i)}_{CX}$

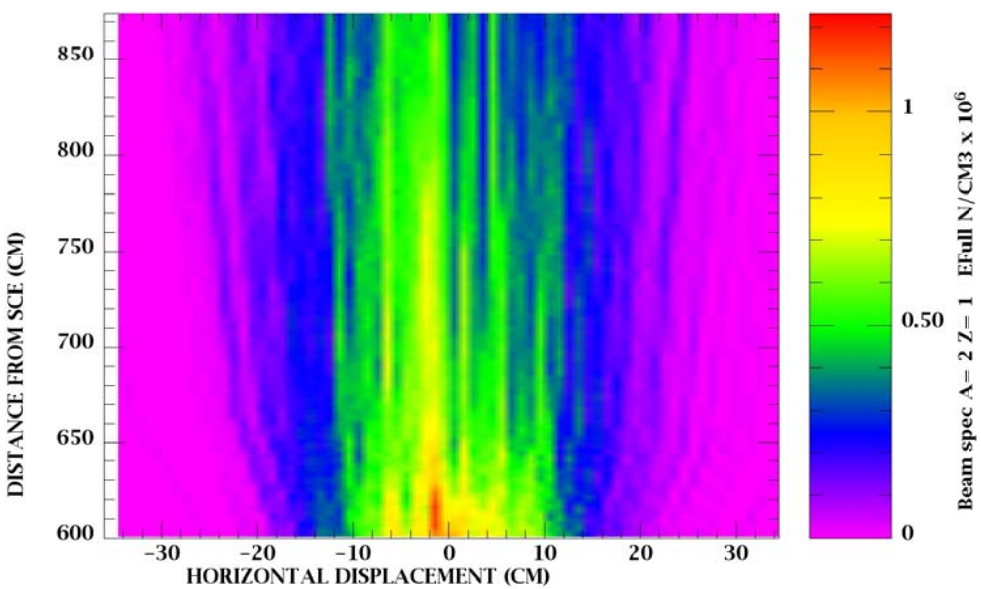


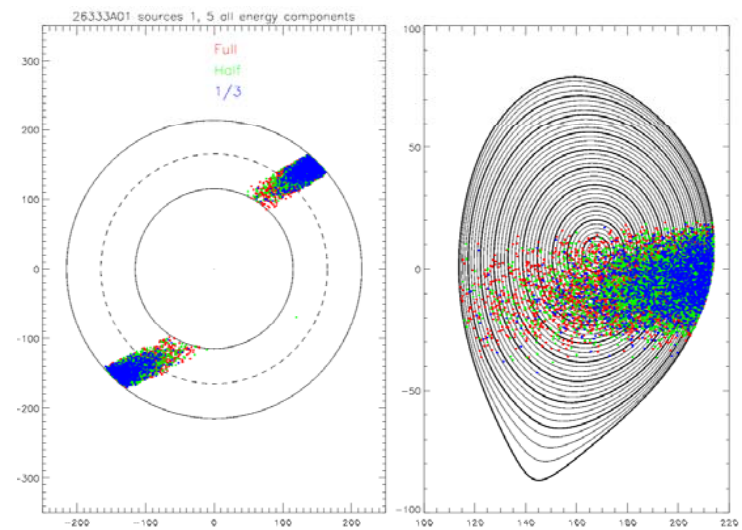
New outputs

- **NEW in TRANSP/NUBEAM:**
  - Outputs for scalar deposition momentum balance (BPHDEPB multigraph) and for an explicit power deposition balance (PBDEPB multigraph);
  - List of ions actually deposited for subsequent following in orbiting.

    It doesn't depend on NDEP0 but based on census control NPTCLS.

    Output file is <RUNID>_birth.cdf;





Provided by G. Tardini (MPI-IPP ASDEX)

Detailed 3d information on the profile of beam neutral density is available through 'beam in box model' with post processing 'pboxn0' program.

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ElVis Developments Requested by TRANSP Users

- Integrated plotting in NUBEAM user interface
- Automated plotting for between shots TRANSP
- RPLOT scripts added to user interface

http://w3.pppl.gov/elvis

Eliot Feibush

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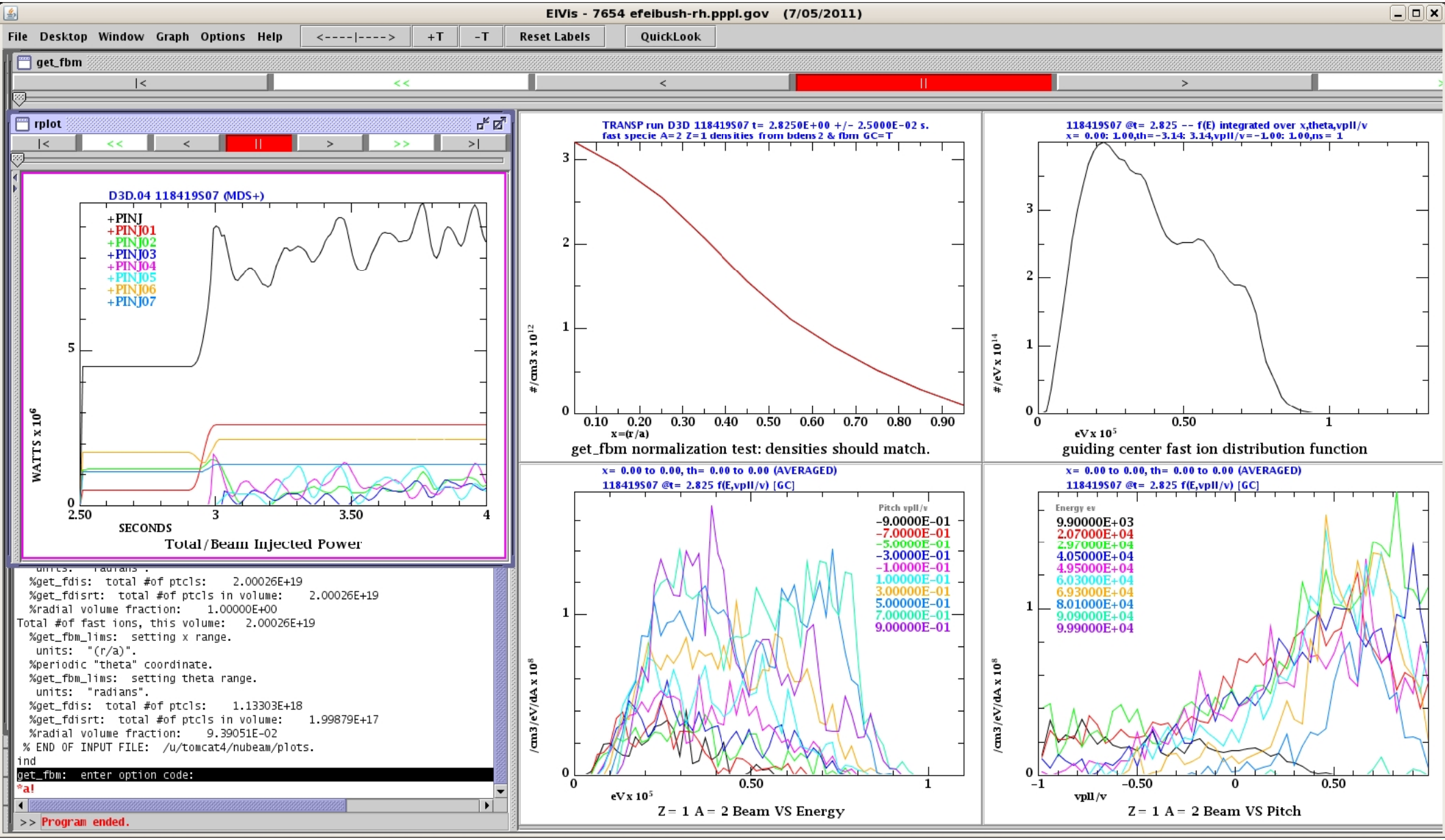


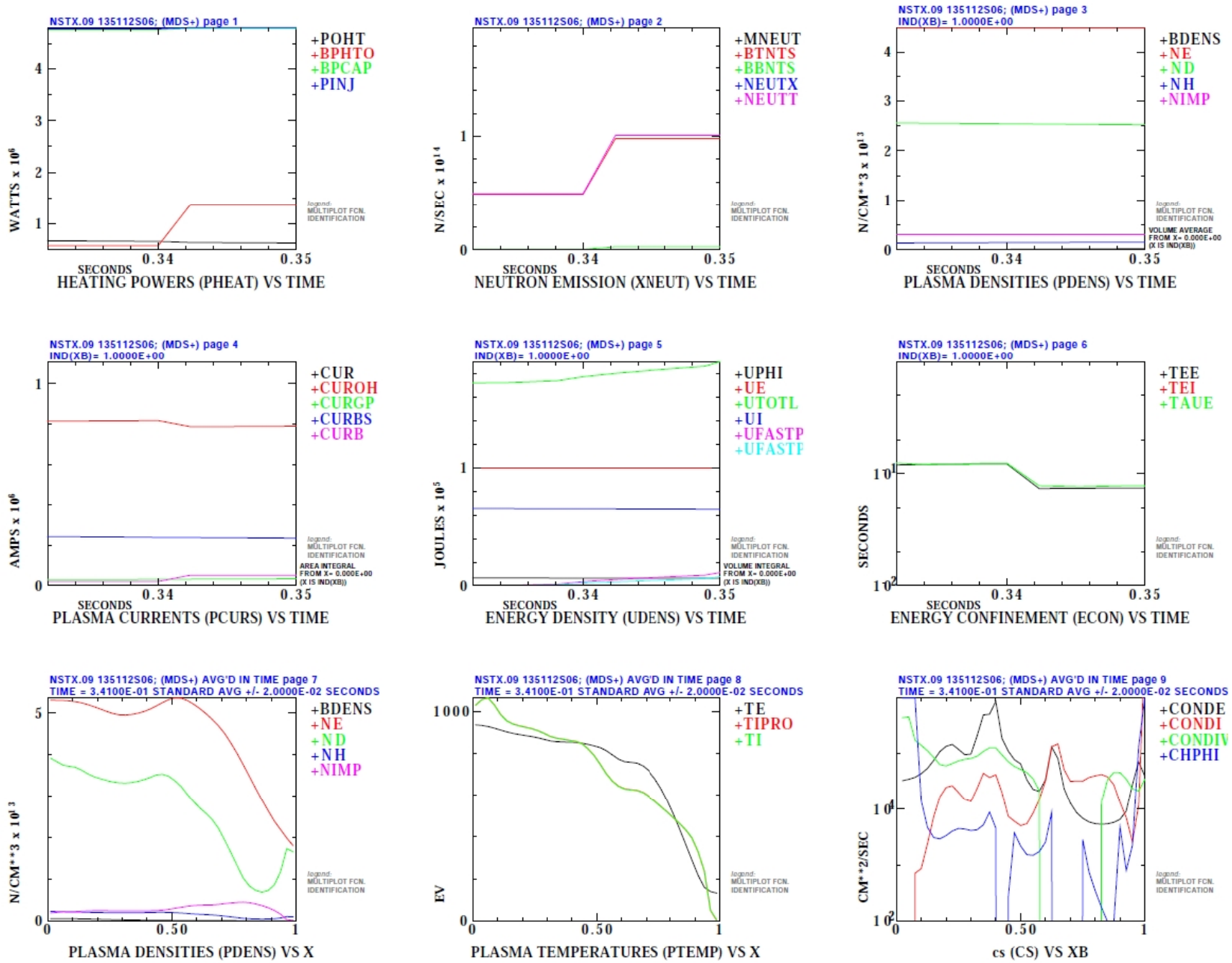
NUBEAM Graphical User Interface in ElVis -- Analyze distribution functions from TRANSP run

- Integrated plots of injected neutral beam power & NUBEAM output.
- User can specify number of deposition particles.
- Advanced users can modify name list parameters within ElVis interface.

plot.pdf - Adobe Reader (on sunfire04.pppl.gov)

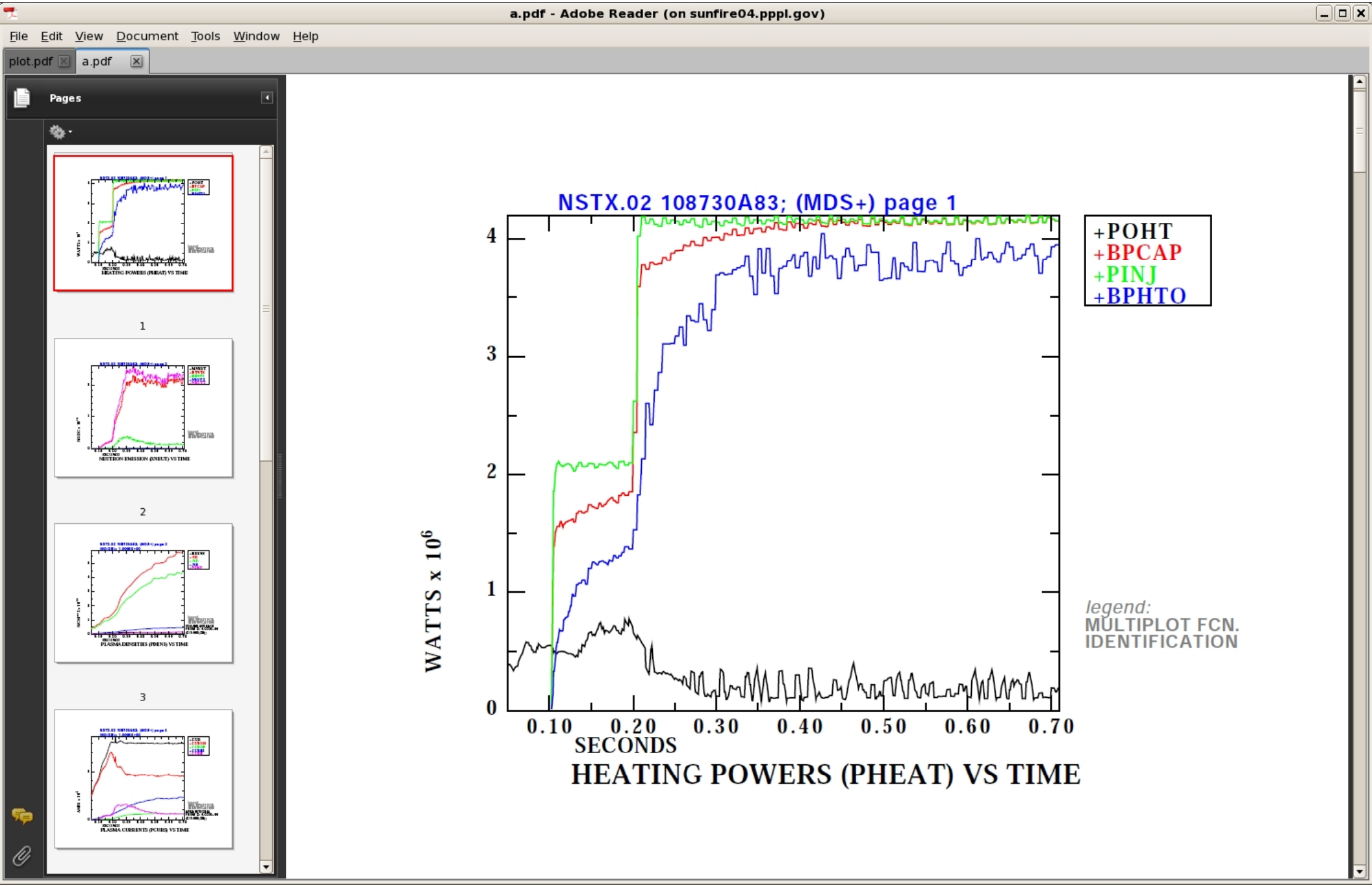
File Edit View Document Tools Window Help

plot.pdf



11.00 x 8.50 in

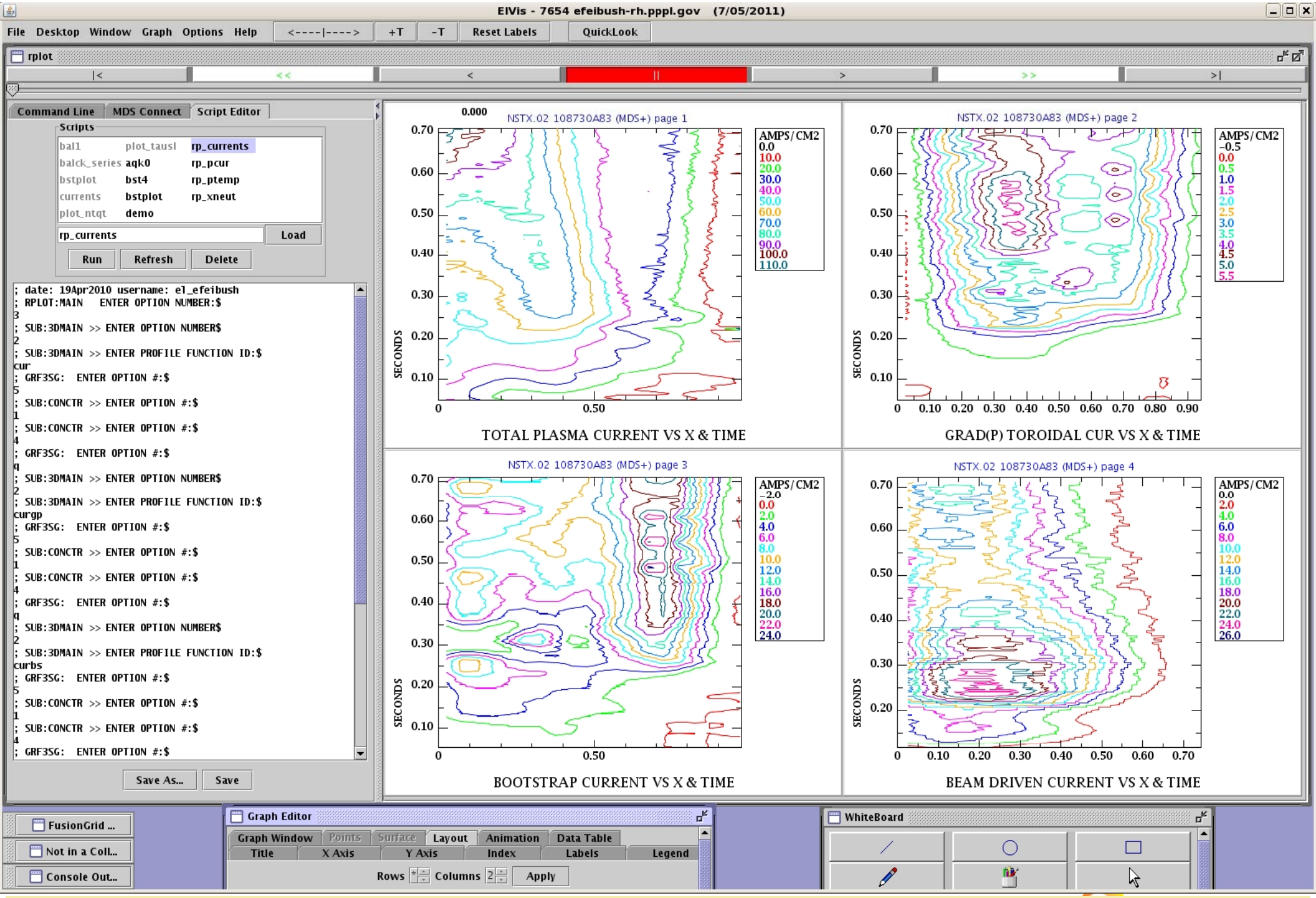
RPLOT in ElVis – Automated plotting of key graphs to PDF file for between shots TRANSP runs



RPLOT in ElVis: Plot 9 graphs on 1 page

or

1 graph per page in a 9 page PDF file



RPLOT in ElVis – Scripts for frequently used plotting functions, e.g. Current vs. Time. Scripts are configured so they can be applied sequentially to the same TRANSP run.

APS TRANSP User Group Meeting

Thursday, Nov 17 @ 12:30 pm
Marriott, Deer Valley 1

- A short presentation
- Opportunity for Users to provide feedback and make code development requests
- See you there …

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