TRANSP/PTRANSP USERS Group Meeting

APS-DPP

Westin Providence, RI -- Blackstone Room

October 31, 2012

12:30 PM

- Robert Andre*
- Marina Gorelenkova*
- Steve Jardin
- Stan Kaye
- Tina Ludescher-Furth
- Xingqiu Yuan*
- off-site developers (Lehigh, MIT, JET, …)

* TRANSP triage team

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AGENDA

S. Jardin	TRANSP FY12 Usage Statistics and Overview
for R. Andre	New Free Boundary Equilibrium Capability
for M. Gorelenkova	New NUBEAM Capabilities and plans
X. Yuan	New Solver Capability
All	User feedback and Open Discussion

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

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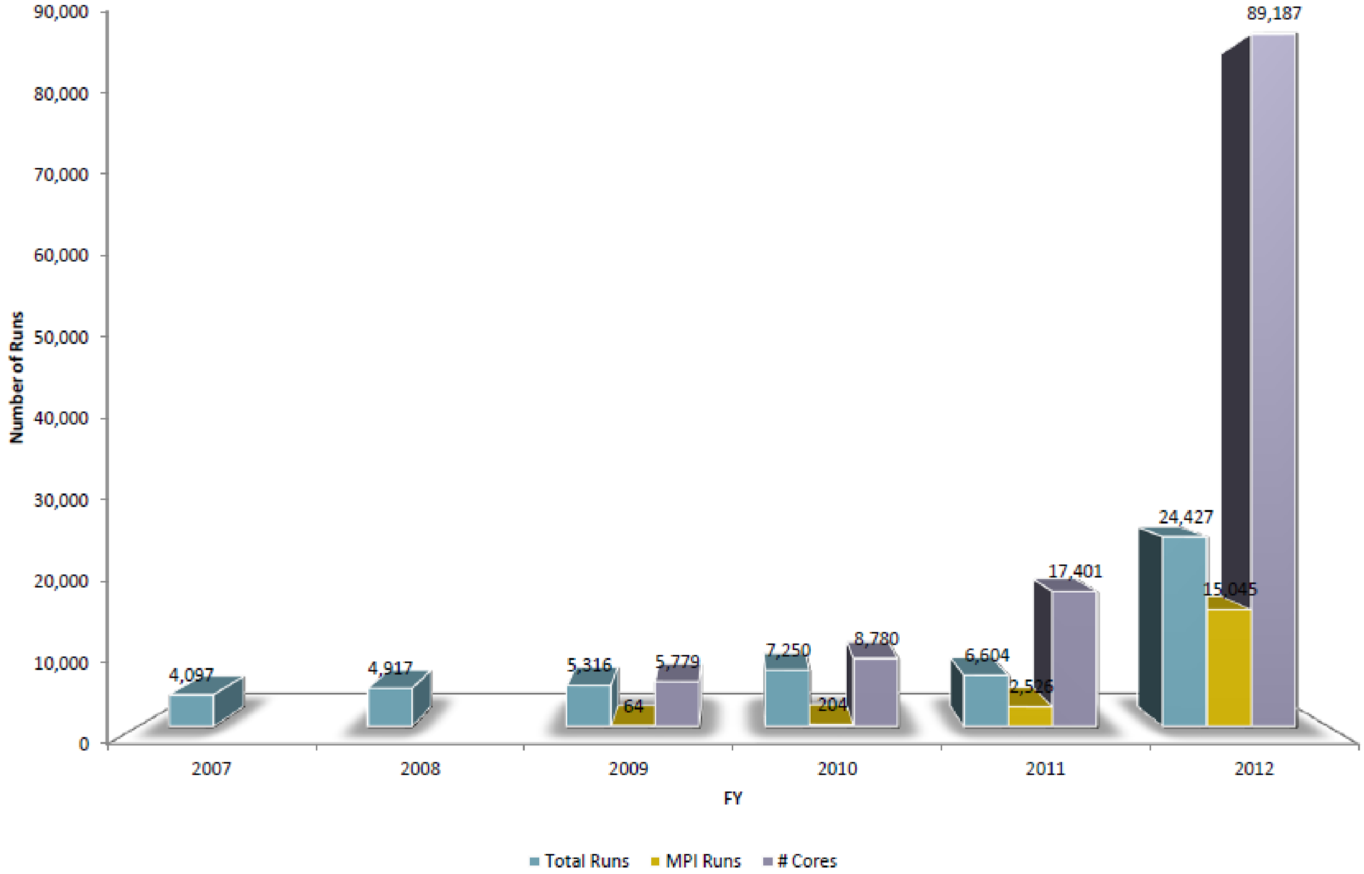
PPPL TRANSP Production 2007-2012



- The total number of production runs increased sharply in 2012 compared to 2011.
- The number of MPI runs (NUBEAM and/or TORIC) increased slightly.
- Does not include TRANSP runs made at JET.

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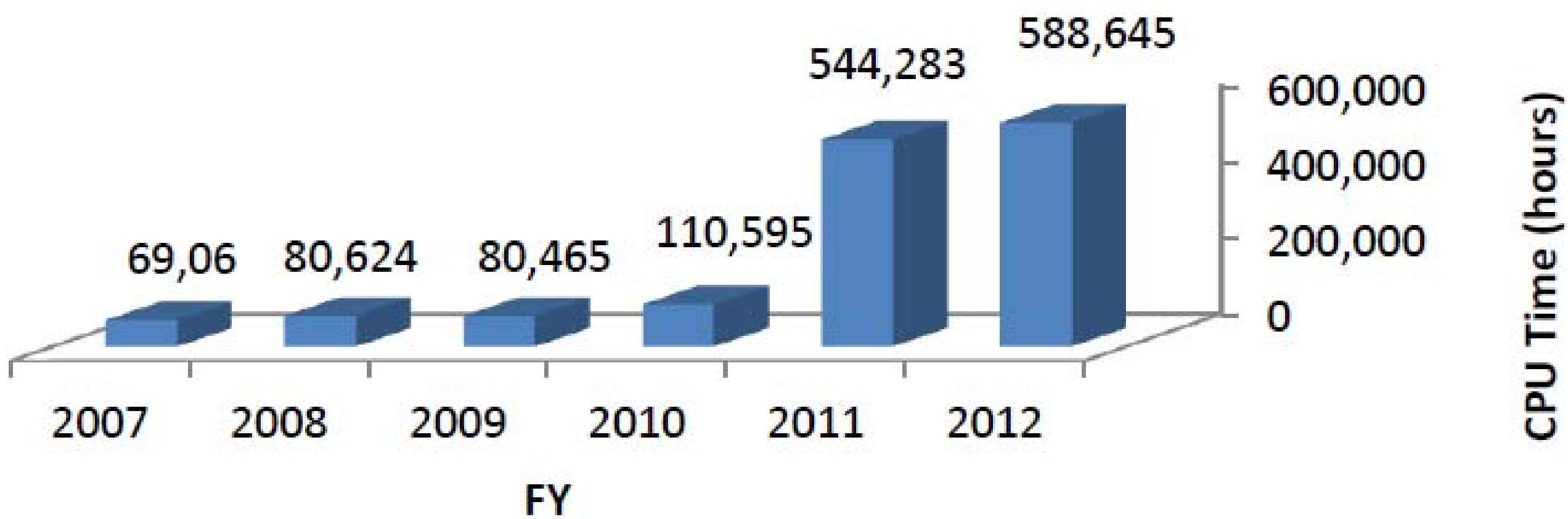
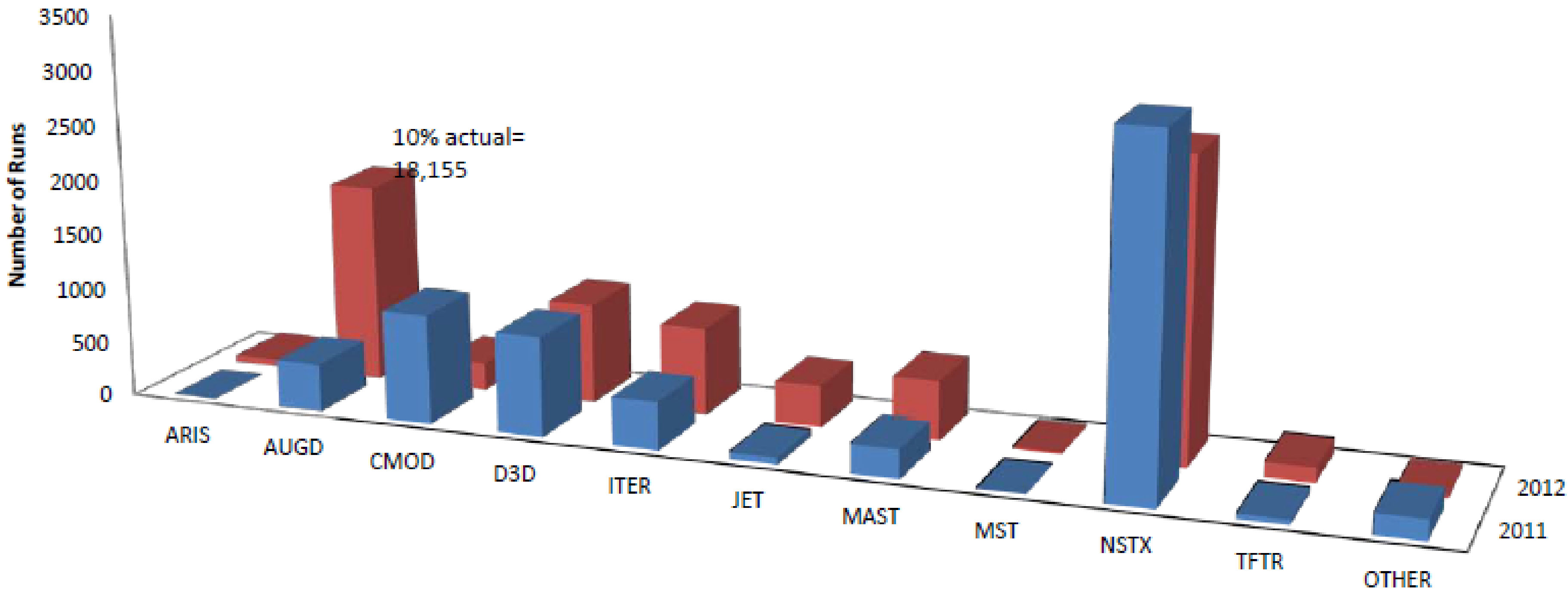
PPPL TRANSP Production Total Compute Time



- Slightly more computing resources were required in 2012 than in 2011. Much more than in previous years

TRANSP/PTRANSP 2011, 2012 Runs by Device



	ARIS	AUGD	CMOD	D3D	ITER	JET	MAST	MST	NSTX	TFTR	OTHER
2011	0	436	1,001	910	440	79	280	11	3,174	67	206
2012	64	1,815	251	909	796	382	540	35	2,726	153	49

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(P)TRANSP Development

- Increased effort has been going into Predictive TRANSP --- PTRANSP
    - PTRANSP and TRANSP are same code…different options
    - All the same source routines are available in the predictive mode
    - Includes parallel TORIC and NUBEAM

- A state-of-the-art nonlinear profile SOLVER package has been implemented
    - Allows predictive solutions using very stiff anomalous transport routines
    - Including GLF23, TGLF, …

- A state-of-the-art free-boundary equilibrium capability has been implemented
    - Allows real free-boundary predictive simulations using coil currents
    - PTRANSP now has most of the free-boundary capabilities of TSC, CORSICA, DINA.

- A new coupling has been implemented between TORIC and NUBEAM
    - accounts for the interaction of RF and fast ions

- We are maintaining a (P)TRANSP planning document
    - Used for planning and prioritization of code development activities.
    - (now 13 pages)

(P)TRANSP Planning Document

1.0 Production Support

2.0 Solver Development

3.0 Free Boundary Equilibrium Evolution

4.0 Neutral Beam Injection (NUBEAM)

5.0 Automated Regression Testing

6.0 Parallel Architecture

7.0 Output Pipeline

8.0 Input

9.0 Upgraded RF routines

10. Additional Physics Modules (as requested)

11. Longer Term Physics Capabilities

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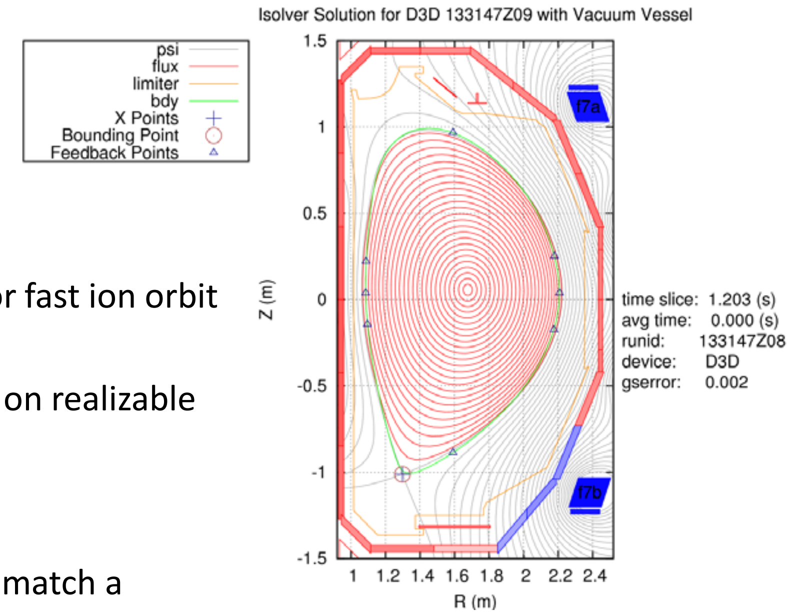
TRANSP/PTRANSP Isolver

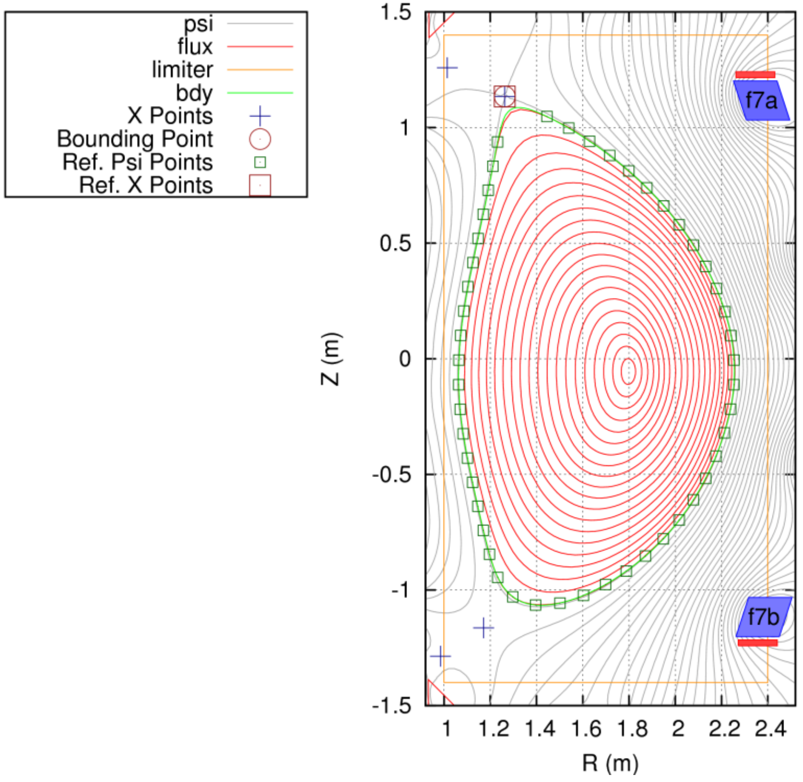
- TRANSP Isolver is a free boundary equilibrium solver available in TRANSP in both the interpretive and the fully predictive mode (PTRANSP)
- Features:
  - **Free Boundary**
    - Magnetic field representation outside plasma is useful for fast ion orbit and RF heating codes
    - Boundary may adjust to heating and current drive based on realizable PF coil currents
  - **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 (analysis and predictive mode)
  - **Passive Structures** – induced currents in vacuum vessel
    - Affects plasma evolution and shape particularly during current ramp up
  - **Coupled Flux Diffusion** – time evolution of q profile coupled to equilibrium solution.
    - Self consistent solution of coupled plasma and coil circuit equations for predictive modeling



- Supported Tokamaks:
  - Coils and Vacuum Vessel: NSTX (current), D3D
  - Coils only: NSTX (upgrade), ITER, CMOD, EAST, IGTR, MAST

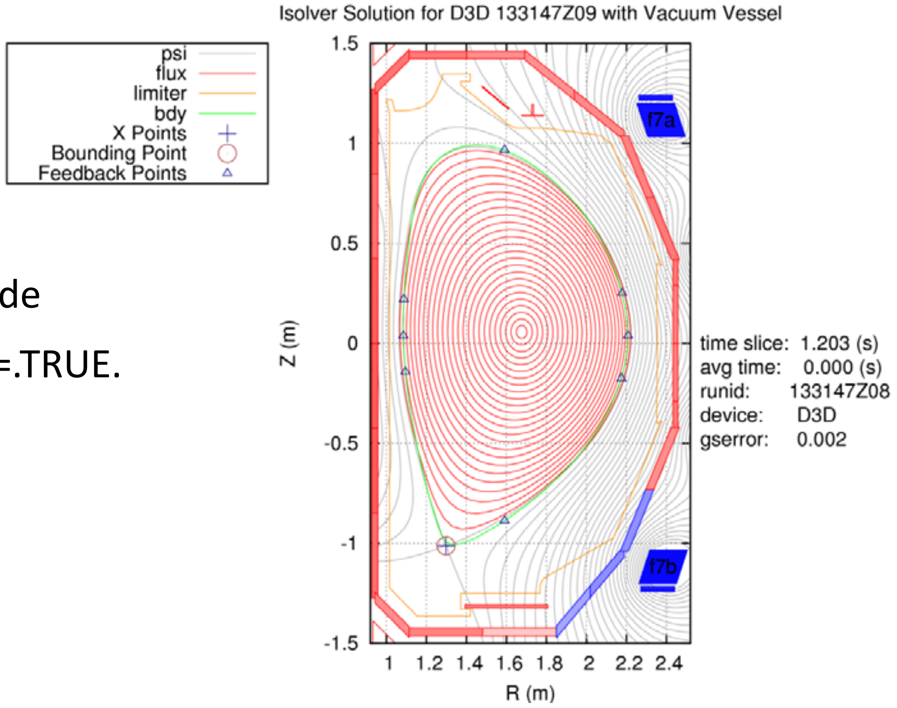
Isolver Least Squares Mode

- In Least Squares Mode, the coil currents will be chosen to best match the prescribed boundary.
- Required namelist
  - **LEVGEO=12**
- Other useful namelist options
  - NEQ_XGUESS = n
    - Guess upper (1) lower(-1) or both Xpoints (2)
  - NISO_NRZGRID = nr, nz
    - Set R,Z grid size, usually 65,129 – 129,129 also useful (2^k+1)
  - PFC_NAMES = ‘pf1al’, ‘pf1au’,…
    - Coil names to use in solution (see transp.hlp)
- Optional Ufile
  - PFC
    - coil/circuit currents to use with PFC_NAMES
  - NLPFC_CIRCUIT = .TRUE.
    - True if PFC are circuit currents, .FALSE. for total coil current



Isolver Circuit Equation Mode

- In Circuit Equation Mode, the coil currents are driven from measured data and vessel currents are available.
- Required namelist
  - **LEVGEO=12**
  - **PFC_NAMES = 'pf1al', 'pf1au',…**
  - **FB_NAMES = 'iver', 'ihor'**
    - Names of feedbacks – turns on circuit mode
    - 'ioh' might also be useful when NLISODIF=.TRUE.
- Required Ufile
  - **PFC**
- Other useful namelist options
  - XBDYCHK = 0.
    - Turn off boundary checks
  - PASS_NAMES = '@pass'
    - Include passive structures, @pass->list of parts of vessel
  - TINIT_PRECOIL = time
    - Set to a time before TINIT for modeling induced vessel currents – can be negative



Isolver Flux Diffusion

- In TRANSP, the q profile can be given as input data
  - **NLQDATA=.TRUE.** ! Input data
- … or evolved with the poloidal field diffusion equation option – these still exist with Isolver
  - **NLMDIF=.TRUE.** ! Evolve with poloidal field diffusion
    - **NLPCUR=.TRUE.** ! Match to plasma current
    - ~~**NLVSUR=.TRUE.**~~ ! Does not work with Isolver
- The q profile can now be evolved within the equilibrium time step of Isolver in least squares mode or circuit equation mode
  - **NLMDIF=.TRUE.** ! Want to evolve q profile, still set this namelist variable

    NLISODIF=.TRUE. ! But now evolve q in Isolver when using LEVGEO=12
    - **NLPCUR=.TRUE.** ! Match to plasma current
      - Also **FB_NAMES(3)='ioh'** may be added for predicting ohmic coil current when in circuit equation mode
    - **NLVSUR=.TRUE.** ! Match to surface loop voltage
      - Also **FB_NAMES(3)='ioh'** may be added for predicting ohmic coil current when in circuit equation mode
    - **NLINDUCT=.TRUE.** ! Predict plasma current from OH inductive coupling
      - Circuit equation mode only

Isolver Status and Next Steps

Status **Available**

- Least Squares Mode will give you a field outside the boundary for nubeam
- Predict plasma shape and current using Circuit Equation Mode with vertical & horizontal control

Next Steps

- Drive coil circuits using voltage sources with voltage swing limits
- Calibrate NSTX model
- Implement shape control to supplement the existing positional control in circuit equation (predictive) mode
  - Goal is to provide equivalent equilibrium functionality as exists in TSC
- (?) Implement more realistic circuit model with ability to plug in actual controller
- Rotation modified pressure
  - An implementation already exists in Isolver but it is poor and has not been maintained

Poster: http://w3.pppl.gov/~randre/mhd/APS2012.pdf
Animation: http://w3.pppl.gov/~randre/mhd/128013I03_anim.gif

New Features in NUBEAM for Users

Coupled MC and ICRF full wave

•Guiding center orbit integrator based on (R,Z) coordinate

- interpolate geometric quantities using EZSPLINE and XPLASMA
- time step control based on the error estimate from 3rd and 4th Runge-Kutta schemes
- orbit can be followed beyond plasma boundary
- switches to activate (R,Z) integrator

NLFI_ORBRZ = .TRUE.

R points for field profiles

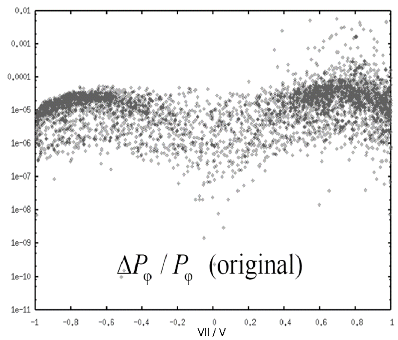
NR_ORBRZ = 160

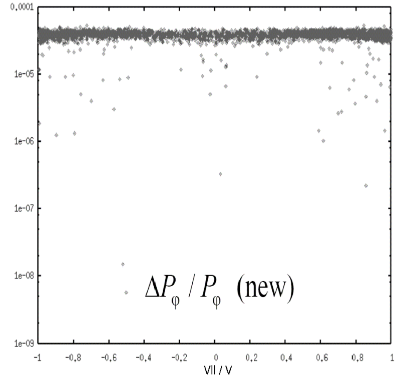
Z points for field profiles

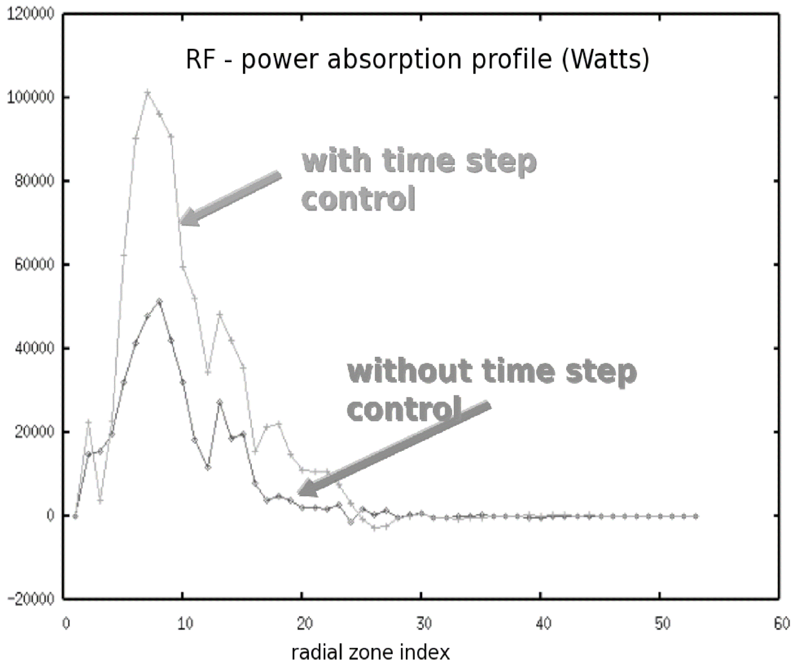
NZ_ORBRZ = 160

error control

ORBRZ_ACC = 1.0D-4



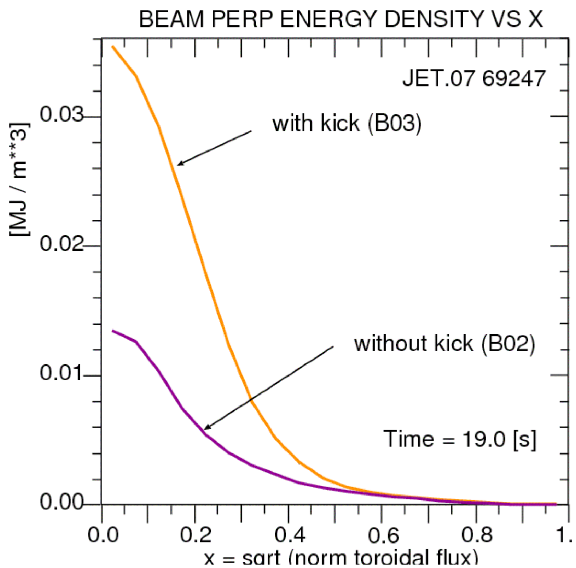


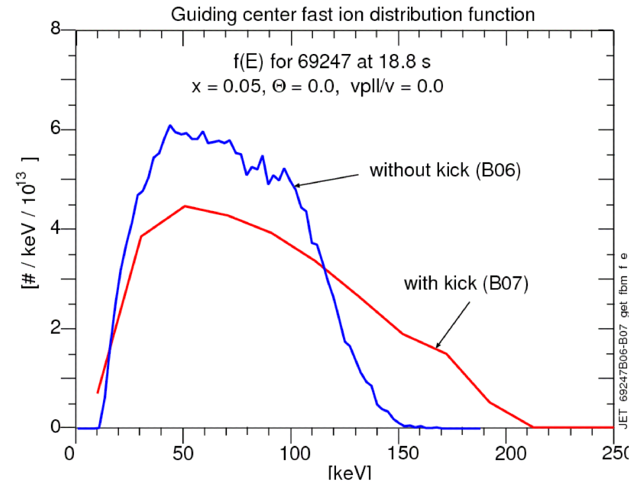


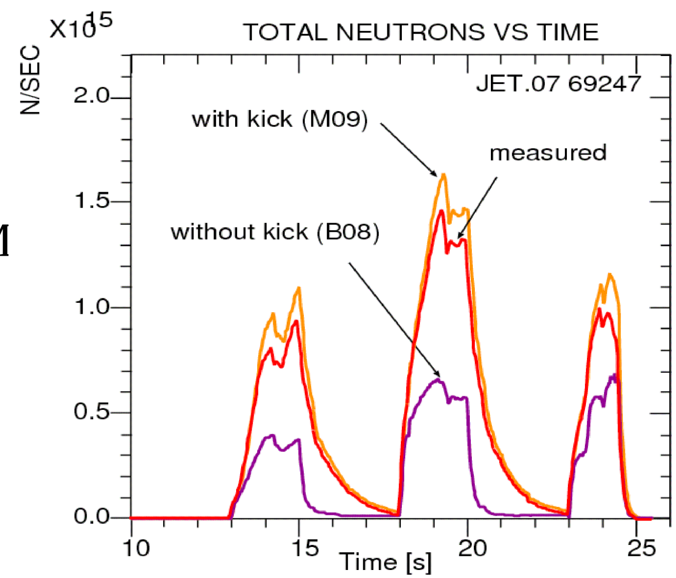
New Features in NUBEAM for Users

• Spatially localized Kennel-Engelman quasi-linear RF 'kick off' operator

- Uses $E_{\pm}(\mathbf{x}, \mathbf{k}_{\pm})$, $\mathbf{k}_{\perp}(\mathbf{x}, \mathbf{k}_{\parallel})$ field data from TORIC







-Control switches to run RF operator in NUBEAM

NLFI_MCRF = .TRUE.

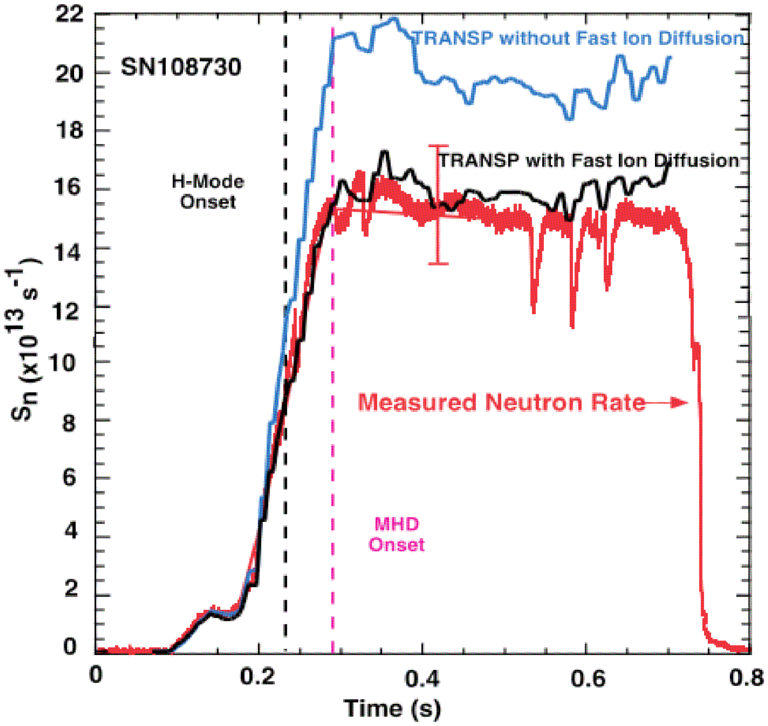
NLFI_ORBRZ = .TRUE.

New Features in NUBEAM for Users

• 3D Halo model

• Motivation

-To improve agreement between calculated and measured neutron emission rates since proper inclusion of halo neutrals would produce fast ion loss thereby decreasing the calculated rate.



New Features in NUBEAM for Users

- To model 3d effects on plasma charge-exchange flux for diagnostic such as NPA

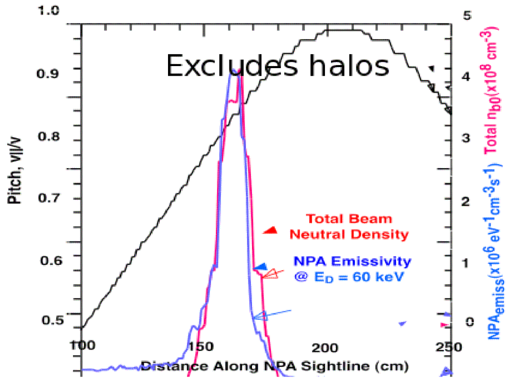
  -NPA diagnostic measured the energy spectra of escaping charge exchange neutral particles:

  T_{ion} of the bulk ion component of the plasma

  energy spectrum of the beam-injected fast ion

  the NPA flux is spatially localized by CX

  on the beam and halo neutrals



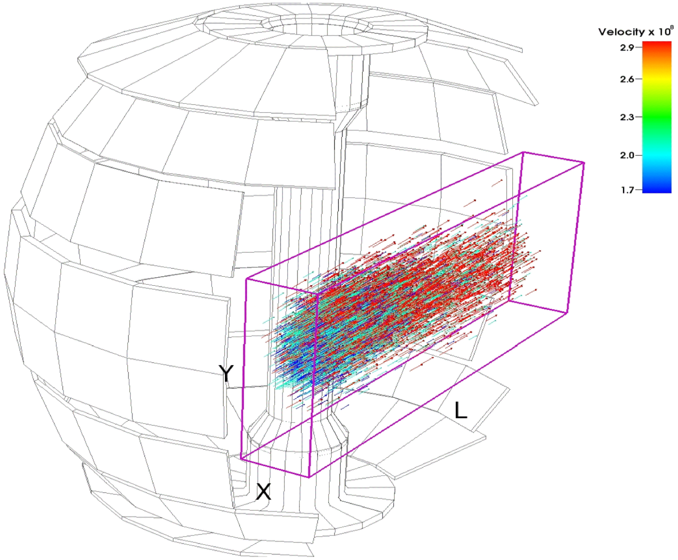
- 3d halo design

  - 3d neutral source: includes neutrals from CX reactions

    thermal ions + beam neutrals and fast neutrals

    fast ions + beam neutrals and thermal ion

  - 3d Cartesian boxes (X,Y,L) along each beam line



New Features in NUBEAM for Users

- Switches to set 3d halo model

  -set ‘beam-in-box’ to define boxes's size and grids

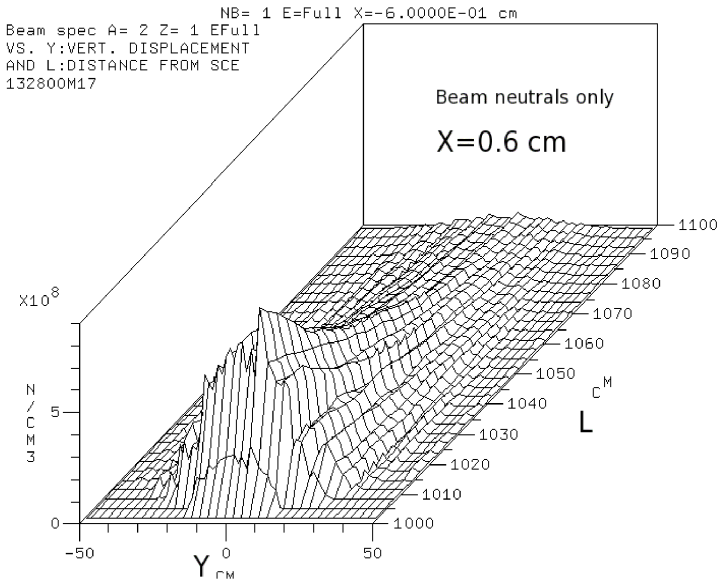
  - set statistics control

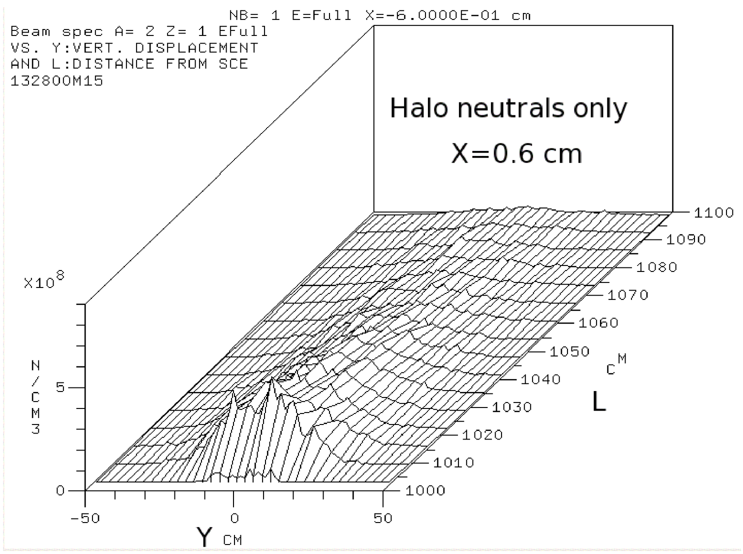
  NDEPBOX=50000 Number of track for beam neutrals

  NSPLT=1000 max splitting of each neutral track

  NSPLT_GEO=2 max geometrical splitting of each neutral track

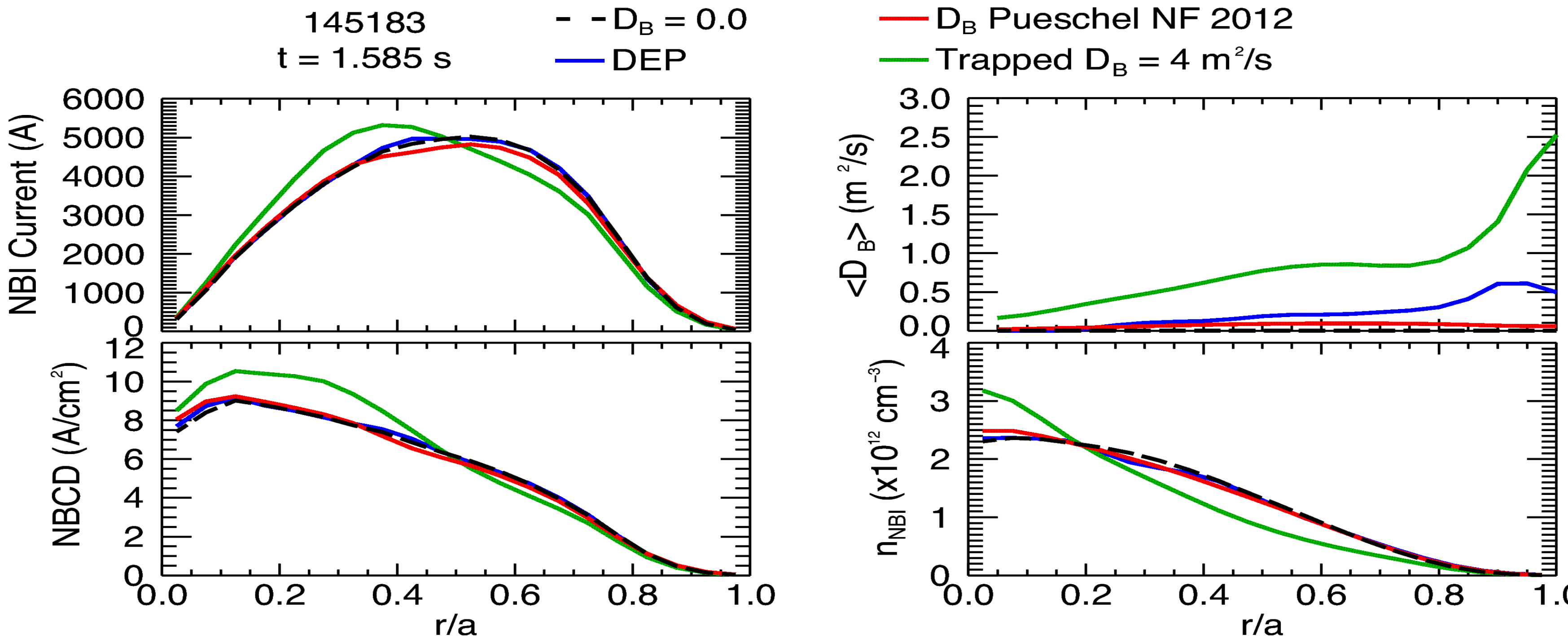
  NSPLT_KIN=2 max kinetic splitting (in velocity space)





New Features in NUBEAM for USERS

- **DEP code has been implemented to TRANSP**
  - NUBEAM get anomalous diffusion coefficients due to turbulence $D_f(x, E, v\|/v, t)$ from TGLF/DEP
  - Control switch will be available soon



New Features in NUBEAM for Users

- Future plans

-Verify RF operator in NUBEAM with ORBIT-RZ, sMC

-Develop synthetic FIDA diagnostic simulator to post-process NUBEAM

-Verify 3d halo model with LOCUST and FIDASIM

-To validate RF orbit integrator and 3d halo model

VOLUNTEERS are wanted!

-Develop a model of anomalous diffusion of the fast particles due to Alfven-like instabilities

-Accurate tracking of fast ion orbits beyond the plasma boundary

-Extend NUBEAM to full account for He^4 excited states using ADAS data

PTRANSP solver (PT-SOLVER) development

1): PT-SOLVER is modular, parallel, multi-regional solver for PTRANSP.

2): It integrate the highly nonlinear time-dependent equations for electron and ion temperatures, densities, and angular momentum.

3): multilevel parallelization (over flux-surface and wave number in TGLF). No longer limited by the number of zones in flux-surface. Flexible number of CPUs can be used depending on the problem.

4): Data exchange to PT-SOLVER through “plasma state” .

5): Upto five kinetic species can be used for TGLF.

6): available neoclassical and turbulent models are:
TGLF, GLF23, NEO, NCLASS, Chang-Hinton

Governing equations

Ion energy conservation equation

$$\frac{\partial}{\partial t}\left[\frac{3}{2}V'n_i kT_i\right]+\frac{\partial}{\partial \rho}\left[V'\left\langle|\nabla\rho|^2\right\rangle n_i k\left(T_i v_i-\chi_i\nabla T_i\right)\right]-\dot{\xi}\frac{\partial}{\partial \rho}\left[\rho V'\frac{3}{2}n_i kT_i\right]=S_{ti}V'$$

electron energy conservation equation

$$\frac{\partial}{\partial t}\left[\frac{3}{2}V'n_e kT_e\right]+\frac{\partial}{\partial \rho}\left[V'\left\langle|\nabla\rho|^2\right\rangle n_e k\left(T_e v_e-\chi_e\nabla T_e\right)\right]-\dot{\xi}\frac{\partial}{\partial \rho}\left[\rho V'\frac{3}{2}n_e kT_e\right]=S_{te}V'$$

where S_{te}, S_{ti} are source terms, which include radiation loss source, neutral gas source, edge source, Nubeam contributed source, and fusion reaction source terms, ICRF, ECRF, and LHW contributed source terms.

χ_e, χ_i are thermal conductivity, calculated by turbulent model which are highly nonlinear, computational intensively, and requires massively parallel computing.

$v_{te}, v_{ti}, v_{\varphi}$ is pinch velocity

Standard implicit time integration algorithm will lead to unphysical oscillations

Current status of PT-SOLVER development

1): Stand-alone version of PT-SOLVER with TGLF for Te & Ti prediction with two-level parallelization

(over flux-surface and wave number in TGLF)

2): Implementation of PT-SOLVER into PTRANSP for Te & Ti prediction (maximum 3 regions, axial, confinement, and edge region)

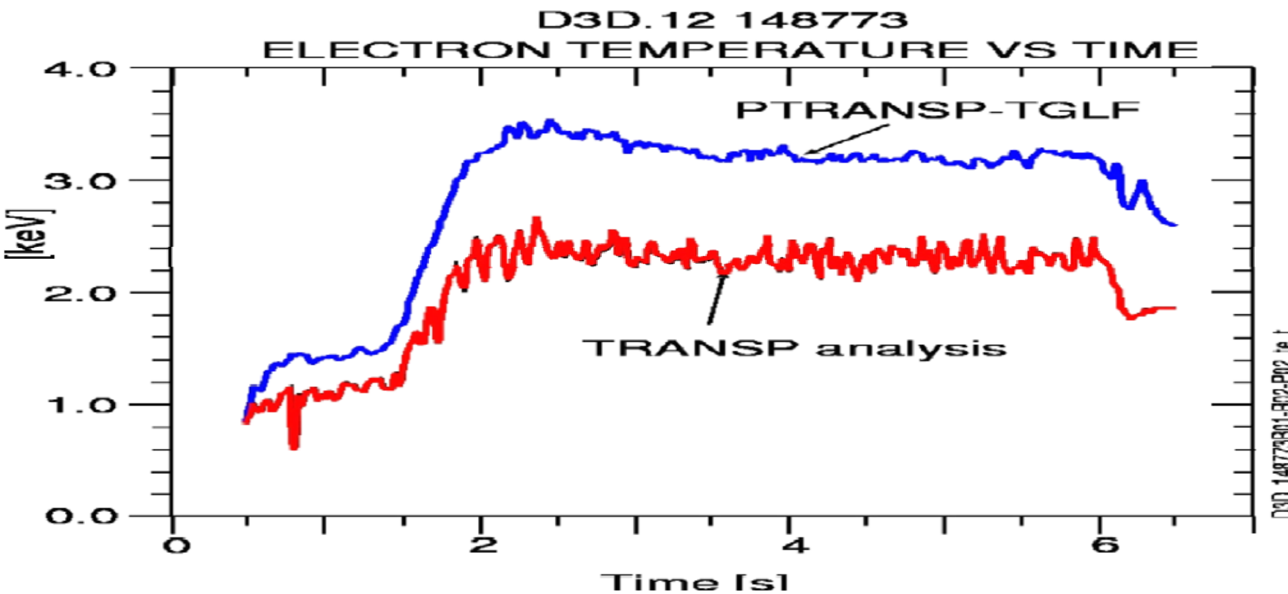
3): Initial capability of ne prediction

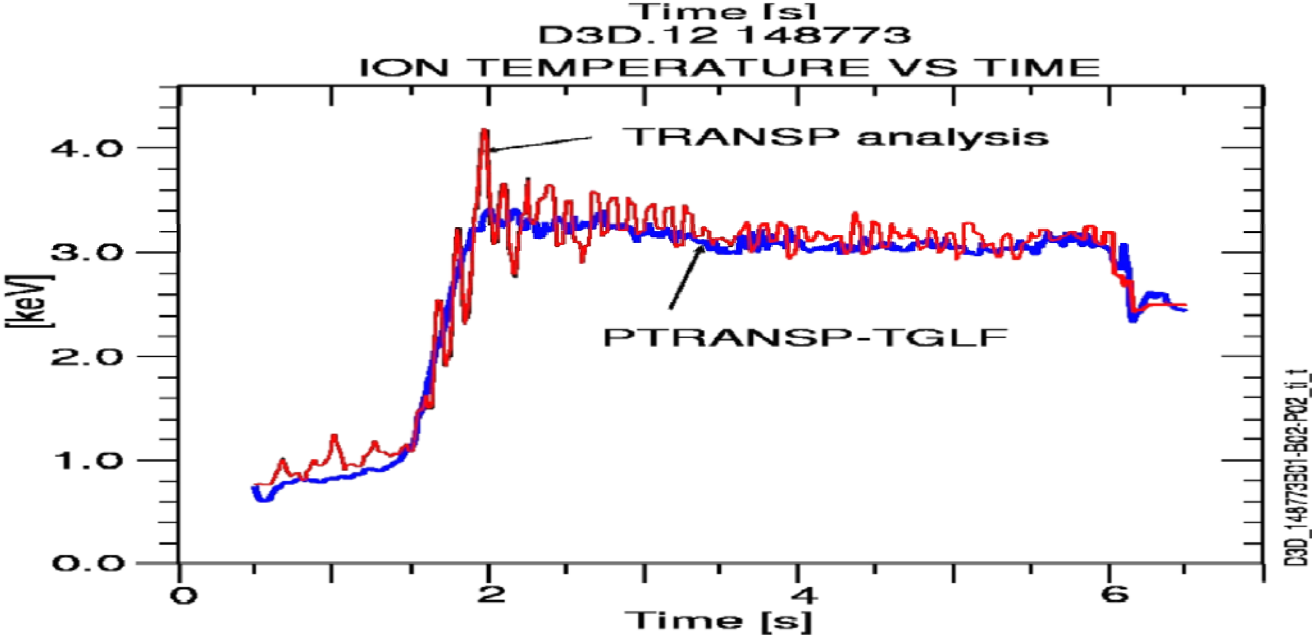
ne predicted, ni, and nimp derived

4): These capabilities are at beta stage, users who want to be beta tester, please contact: sjardin@pppl.gov.

Publical releasement to TRANSP community will be approximately half year later.

TRANSP runs with PT-SOLVER





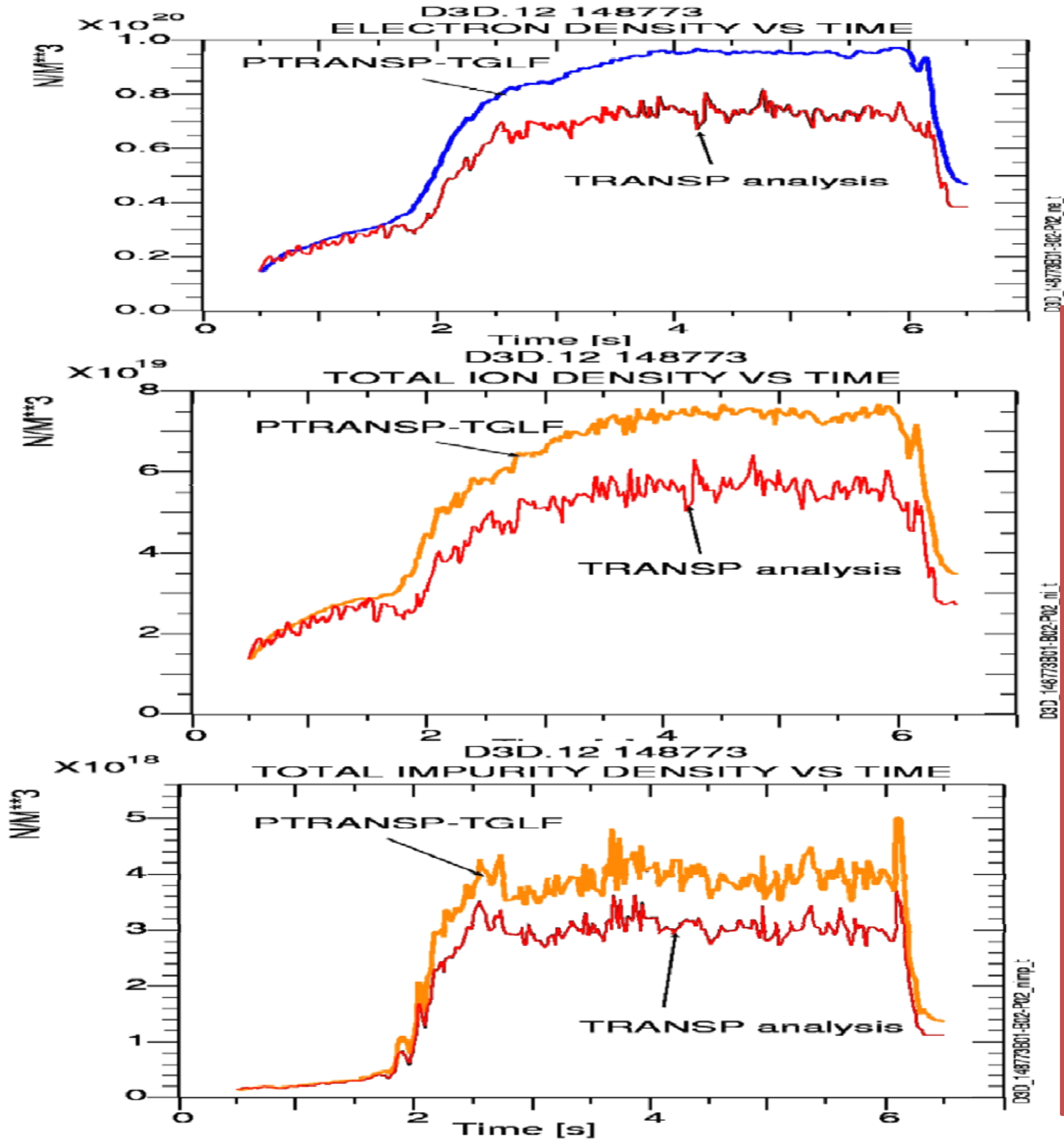
Parallel PT-SOLVER, and parallel NUBEAM used.

Te, Ti & Ne Predicted
Ni, Nimp derived from quasi-neutrality, and Zeff

3 species in TGLF (electrons, ions, and impurities)

Alpha_E = 0.5
Alpha_P = 0.5
Quench_rule used

Nzones = 50
64 cores used in dawson cluster for 7 days



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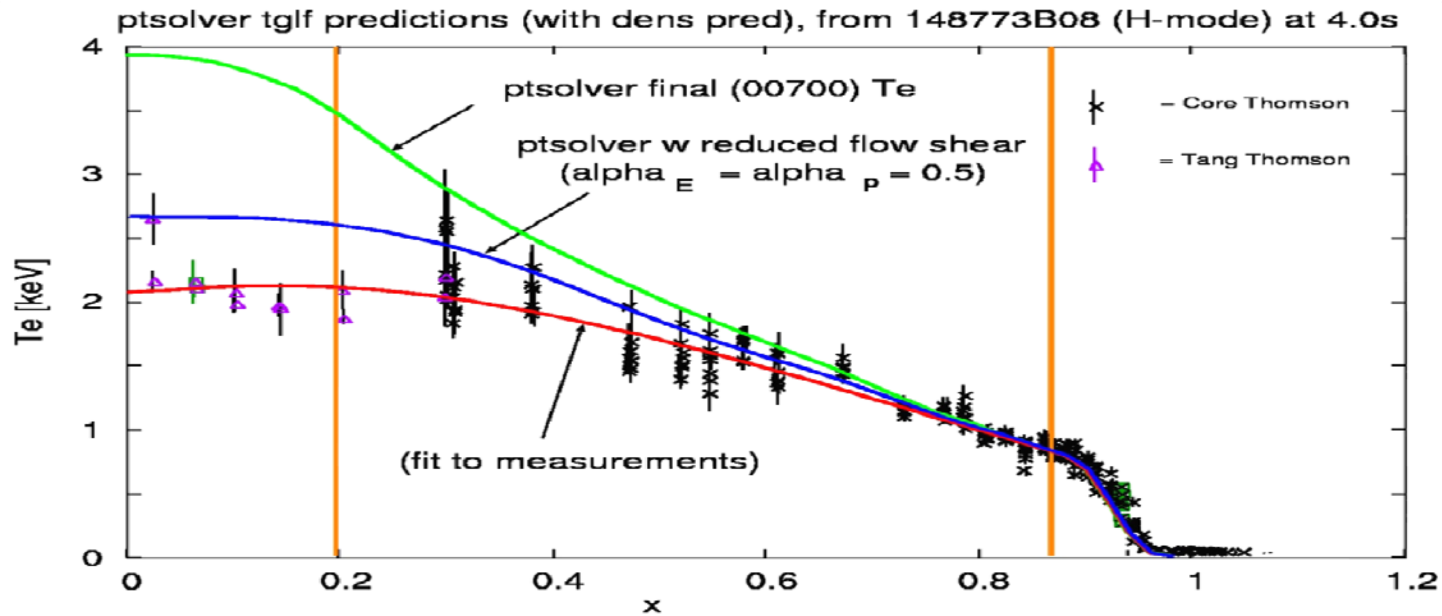
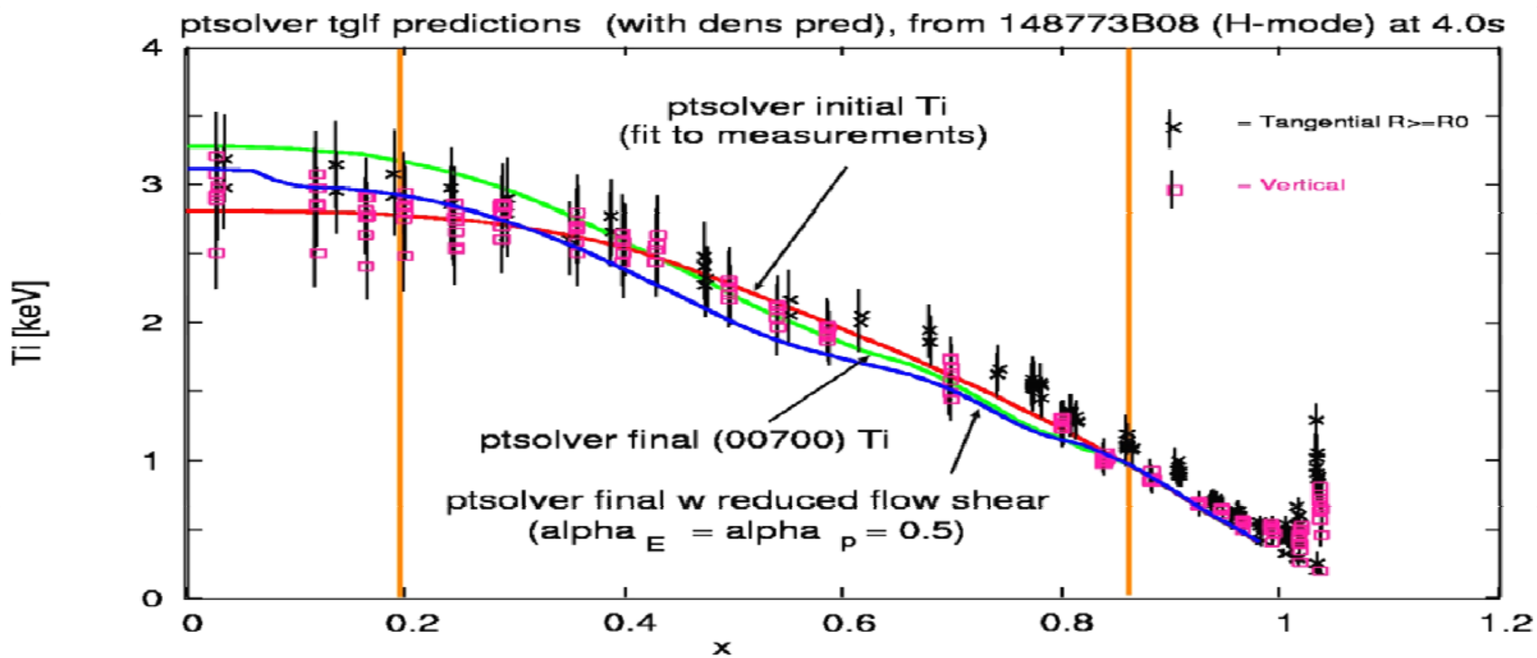
Runs with standalone PT-SOLVER





Future PT-SOLVER development

- Development and benchmarking density prediction capability.
- Development and benchmarking angular momentum prediction.
- Install and test more turbulent, and neoclassical models.
- Development and testing more robust nonlinear stiff solver (for example multigrid method).
- Testing more cases in TRANSP with the combination of different components.