Status and Plans for the TRANSP Interpretive and Predictive Simulation Code

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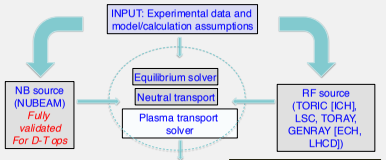
TRANSP is a time-dependent, 1 ½ D tool for interpretive and predictive analysis of tokamak, ST and RFP plasmas



Output of TRANSP (Plasma State File) is standardized for simplifying input to other computationally intensive codes

Kernel of the code is the solution of the particle, energy and momentum transport equations

Particle: $\frac{\partial}{\partial t}(nV') - \frac{\partial}{\partial \rho}\left(\langle\nabla\rho\rangle^2 V' D \frac{\partial n}{\partial \rho}\right) = V'\left(S_{gas} + S_{beam} - L_{-ir,recomb,cx}\right)$

Energy (e^-): $\frac{\partial}{\partial t}\left[\frac{3}{2}V' n_e k T_e\right] + \frac{\partial}{\partial \rho}\left[V'\langle\nabla\rho\rangle n_e k (T_e v_e - \chi_e \nabla T_e)\right] = V'(P_{OH} + P_{beam} - P_e - P_{rad})$

Momentum: $\frac{\partial}{\partial t}\left(n_i m_i V' \langle R^2\rangle \omega\right) + \frac{\partial}{\partial \rho}\left[V' \Gamma_\omega\right] = V'\left(\sum T_{input} - \nabla\cdot\Pi_\phi - mnR(\omega-\omega^*)\pi_{clamp}^{-1}\right)$

Interpretive:	INPUT: T_e, T_i, n_e, v_ϕ,.....	OUTPUT: $D_{\phi,i}$, $\chi_{\phi,i,\phi}$,.....
Predictive:	INPUT: $\chi_{\phi,i}$, $D_{\phi,i}$, ...	OUTPUT: $T_{e,i}$, n_e,.....

Comparisons of inferred transport coefficients against those from models can be made in "interpretive" mode

The compute intensive parts of TRANSP now make use of parallel processing

PTSOLVER: is a modular multivariable Newton-based solver used in the predictive mode that advances T_e, T_i, n_i, from one plasma-state to the next.
Choice: NCLASS, NEO, TGLF, GLF23, CDBM, RLW, MMM, ...
- TGLF is parallel over wave-numbers and flux surfaces
- Scales well to over 1000 cpu at NERSC
- Stand-alone version for benchmarking XPTOR/TGYRO

NUBEAM: can now be run with 1000's of processors to allow much improved statistics over past versions
- Recent benchmark performed with PENCIL and BBNBI
- GPU version under development

TORIC: MIT parallel version of TORIC5 is used that is parallel over poloidal modes

GENRAY and CQL3D: Parallel versions are being interfaced

TRANSP Development Highlights

PT_SOLVER speed-up using flux-based implicit solver

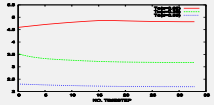
$$\frac{\partial \mathbf{W}}{\partial t} + \nabla\cdot\mathbf{F} = \mathbf{S} \quad \text{where} \quad \mathbf{W} = \begin{pmatrix} T_e \\ T_i \\ n_e \\ \dots \end{pmatrix}$$

$\mathbf{F}$ Is the flux from neoclassical and turbulent calculation

Apply implicit method, we have

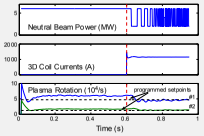
$$\frac{\mathbf{W}^{n+1} - \mathbf{W}^n}{\Delta t} + \nabla\cdot\left[\mathbf{F}^n + \frac{\partial \mathbf{F}}{\partial \mathbf{W}}\left(\mathbf{W}^{n+1} - \mathbf{W}^n\right) + \frac{\partial \mathbf{F}}{\partial \mathbf{W}}\left(\mathbf{W}^{n+1} - \mathbf{W}^n\right)\right] = \mathbf{S}^{n+1}$$

- Discretization in space uses finite difference method, the final
- resulting block tridiagonal matrix is solved by Thomas algorithm.
- Globalized Newton iteration method is used at each time-step to make sure convergent solution is achieved.
- Adaptive time-step control based on residual.



Control algorithms are presently being developed for NSTX-U

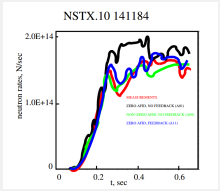
- Rotation profile control (NBI, NTV through application of 3D fields as actuators) – NTV physics model incorporated in algorithm (plan to implement in code proper)
- Plasma current profile control (NBI, current ramp rate as actuators)



(I. Guomiri, Princeton Univ.)

Feedback on fast ion diffusivity

- Feedback algorithm to adjust dynamically the Anomalous Fast Ion Diffusion (AFID) in order to match the measured neutron rate
- This feature will allow for a reduced number of runs necessary for matching experimental conditions
- The algorithm uses a proportional-integral-derivative (PID) feedback control algorithm



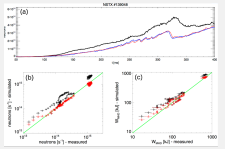
(M. Boyer, PPPL)

Fast ion transport "kick" model implemented in NUBEAM/TRANSP

- Model being tested and validated for different NSTX and DIII-D scenarios
- For a variety of scenarios with strong Alfvénic instabilities, the model can reproduce the measured neutron rate and stored energy (W_{MHD})

Panel (a) shows an example of simulation results from NSTX, with measured neutron rate (blue) and simulations ("classical" in black, using kick model in red).

Panels (b,c) show initial results from a NSTX/DIII-D database for neutron rate and W_{mhd} vs. measurements. Better agreement with the measurements is achieved with the kick model with respect to "classical" simulations.



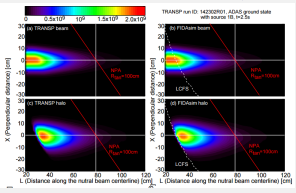
3D halo neutral model has been added to NUBEAM/TRANSP

- Model being benchmarked with Fast-Ion D_α simulation code (FIDASIM) and Neutral Particle Analyzer (NPA)

(D. Liu, U. Irvine)

(a) TRANSP and (b) FIDAsim simulated *beam neutral* density on the midplane.

(c) TRANSP and (d) FIDAsim simulated *halo neutral* density on the midplane.

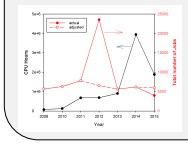


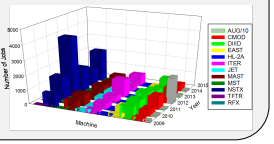
Status and Progress of TRANSP modules

Black: available to users
Red: under development

	2014	2015	2016
RF	• EC: TORAY, GENRAY • IC: TORIC • LH: LSC	• EC: TORBEAM • LH: GENRAY + CQL3D	• HHFW: GENRAY-AORSA
NUBEAM	• Halo neutrals for multiple CX events • Initial fast ion diffusion due to MHD (TAE)	• Feedback on fast ion diffusivity to match measured neutron rate • Improved fast ion diffusion due to MHD (TAE) • 3D Halo neutrals can have multiple CX	• GPU support • Add orbital gradient model for interaction of fast ions with MHD
RF & Fast Ions	• TORIC → NUBEAM (with kick operator)	• TORIC ⇔ NUBEAM (gas distribution function)	• TORIC ⇔ NUBEAM (gas distribution function)
Solver FB equilibrium	• Evolve q and fP consistent with coil and vessel currents	• Shape Control	• Ion dia rotation in equilibrium solution • Including multiple species
PTSolver	• MMM, GLF23, TGLF, RLW, NEO, Chang-Hinton, Pablo	• EPED based pedestal model • Flux-based implicit solver • NEO bootstrap current	• Impurity density prediction • Parallel momentum prediction

Usage Statistics





Development plan for installing TRANSP at the ITER IO

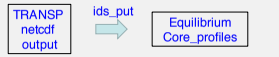
Phase I: Runs are submitted to the FUSIONGRID
- Runs are made at PPPL and results returned
- TRANSP developers can monitor runs and debug
- Requires installation of GLOBUS at IO
- Translators to/from ITER Data Model

Phase II: Runs can be made locally at IO
- TRANSP has been installed and compiled at ITER
- PPPL SVN access from IO required "Trusted Host" status for ITER cluster from PPPL

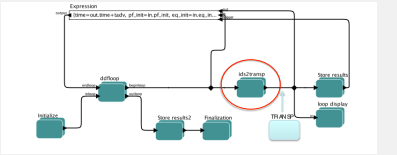
Phase III: TRANSP run as Kepler component
- First step is to make NUBEAM IMAS compliant (underway)
- Incrementally factor code into additional IMAS compliant components
- It would help to have IMAS installed at PPPL

Program ids2transp translates data in ITER IMAS data structure into TRANSP input data: (Ufiles and geqdsk files)
- Stand alone version takes 2 arguments:
  - Run number (3 digit integer)
  - Shot number (3 digit integer)

Program transp2ids translates data from TRANSP output <runid>.cdf into ITER IMAS data structure
- Stand alone version takes 1 argument: run id



Workflow to initialize TRANSP run from IDS



Summary and Miscellaneous

- RF, Beam, equilibrium, solvers being upgraded
- Diverse user base: both US and worldwide
- About 6000 jobs/year run at PPPL
- Outreach via users-group meetings and WIKI
- Conversion SVN → GIT to take place in FY16
- 1000 core (4GB/core) upgrade in Oct 2015
- Now installed at ITER