Status and Plans for the TRANSP Interpretive and Predictive Simulation Code

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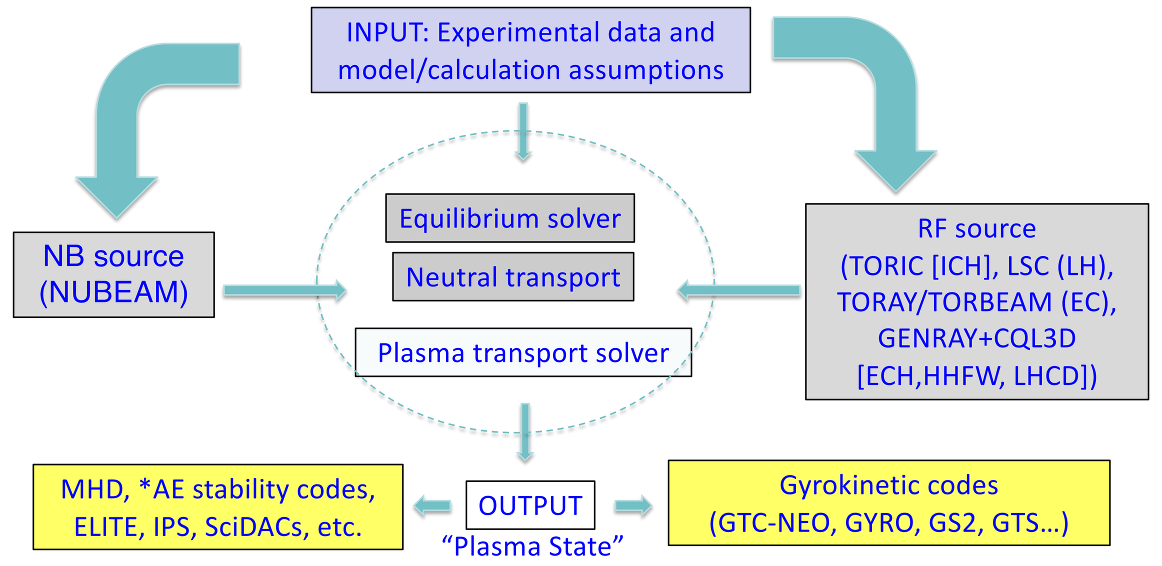
TRANSP is a time-dependent, 1.5 D solver for interpretive and predictive analysis of tokamak and RFP plasmas



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

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

Particle: $$\frac{\partial}{\partial t}(nV') - \frac{\partial}{\partial \rho}\left(|\nabla\rho|^2 V'D\frac{\partial n}{\partial \rho}\right) = V'\left(S_{gas} + S_{beam} - L_{c-x,recomb,etc}\right)$$

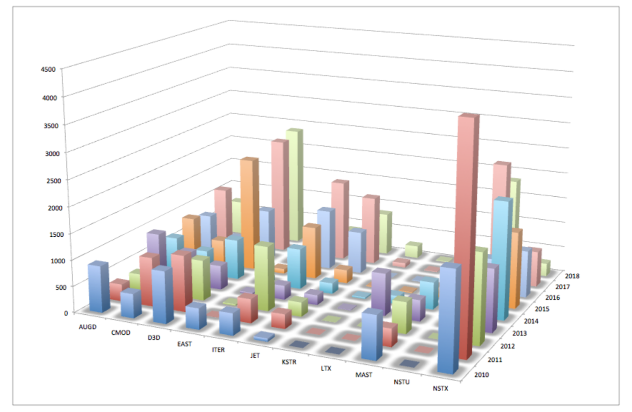
Energy (e^-): $$\frac{\partial}{\partial t}\left[\frac{3}{2}V'n_e kT_e\right] + \frac{\partial}{\partial \rho}\left[V'\left\langle|\nabla\rho|^2\right\rangle n_e k\left(T_e v_e - \chi_e \nabla T_e\right)\right] = V'\left(P_{OH} + P_{beam} - P_{ie} - P_{rad}\right)$$

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

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

Upgrades and improvements to the experience of users

International pool of users:
350 active users in 2018
about 6000 jobs/year run at PPPL



Two approaches to runs:
- **Standard** – submit to PPPL cluster
- **NEW** – local install of disk image

Advantages:
- expand use of TRANSP to Universities and small institutions
- does not need a trusted connection with PPPL

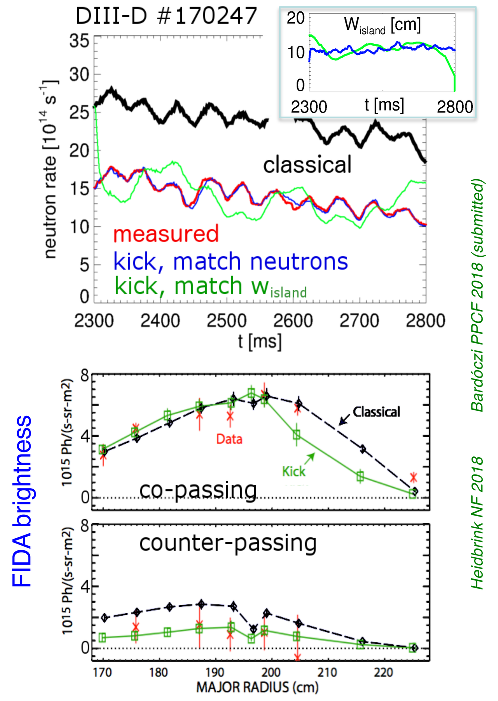
TRANSP has DOI and version number => check @ https://transp.pppl.gov

Plans for improving calculations of anomalous fast ion transport

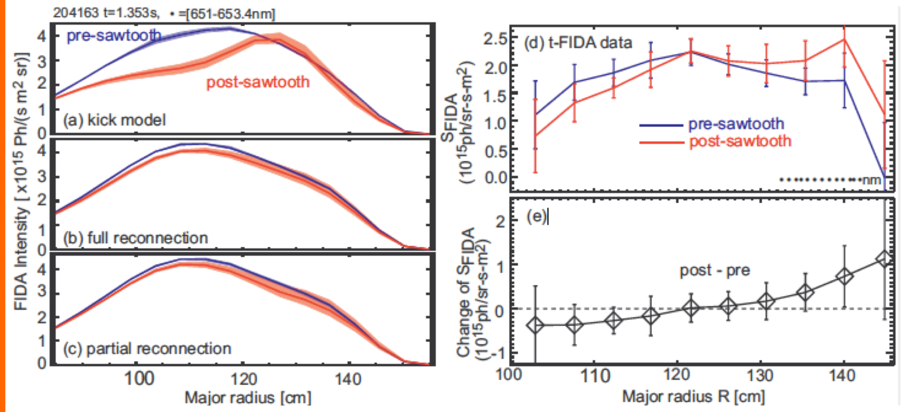
[with M. Podesta' and N. Gorelenkov (PPPL)]

The kick model is becoming a workhorse for the analysis of discharges with Neutral Beam Injection.

- Kick "interpretive" run:
  - Scale kicks to match measured neutrons
  - Mode amplitude related to w_{island}
- Inferred NTM island width agrees with measured w_{NTM} (ECE)
  - *a posteriori check, validation*
- Favorable comparison with phase-space resolved data (FIDA)
  - Acceptable for co-passing, good for counter-passing
  - ***Key exercise for model validation***
    - *Ad-hoc diffusion would give same drop for co/cntr*



Analysis being extended to sawtooth instabilities [*D. Kim, Nucl. Fusion 2017*]

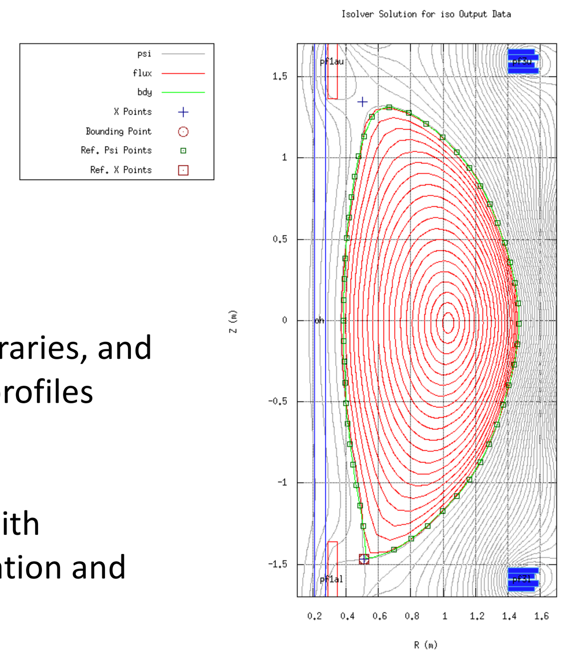


The kick model reproduces the observed asymmetry in the FIDA diagnostics, with a drop inside the inversion radius.
⇒ energy dependent model needed
⇒ to describe energy-dependent reconnection fraction in Porcelli model
⇒ For more realistic description of effects on fast ion redistribution

Following recent success, we are working on the development of:
⇒ general model for anomalous fast ion transport driven by low-n instabilities
⇒ self-consistent MHD calculations
⇒ synergy between RF and fast ions
⇒ extension of fast ion losses to the SOL (with reduced model for the SOL)
GOAL: focus over next 2 years on self-consistent calculations in TRANSP for anomalous fast ion transport

Standalone version of ISOLVER

- TRANSP free boundary tokamak equilibrium component, calculating coil currents or feedback for select devices to match plasma LCFS to a prescribed boundary, based on known q, pressure profiles.
- Now available on the PPPL cluster as a standalone equilibrium solver.
  - **Executable version**: A minimal subset of TRANSP scripts, libraries, and executables, with Jython scripts available to read supplied profiles from text files and generate equilibrium files and plots.
  - **Source version**: A minimal subset of ISOLVER source code with makefiles linking to the NTCC library, available for customization and incorporation into alternate workflows, e.g. OMFIT.



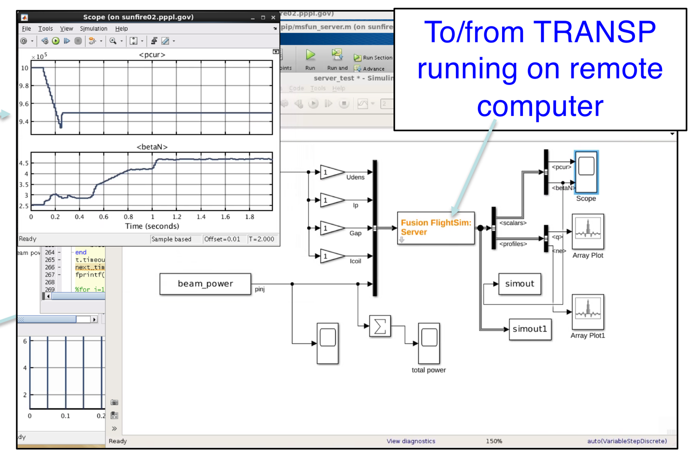
Plans for the development of a fusion flight simulator

GOAL: develop user-friendly interface that allows steering TRANSP simulations from Simulink.
⇒ TRANSP provides the plasma response and Simulink provides the actuator input
⇒ Capability of monitoring the run and allow human intervention to control the discharge

Initial 'open loop' test case successful

Plasma current and β_N measured from TRANSP run (plot updates in 'real-time' as the TRANSP run progresses)

Beam power waveforms programmed in Simulink, sent to TRANSP run at each timestep

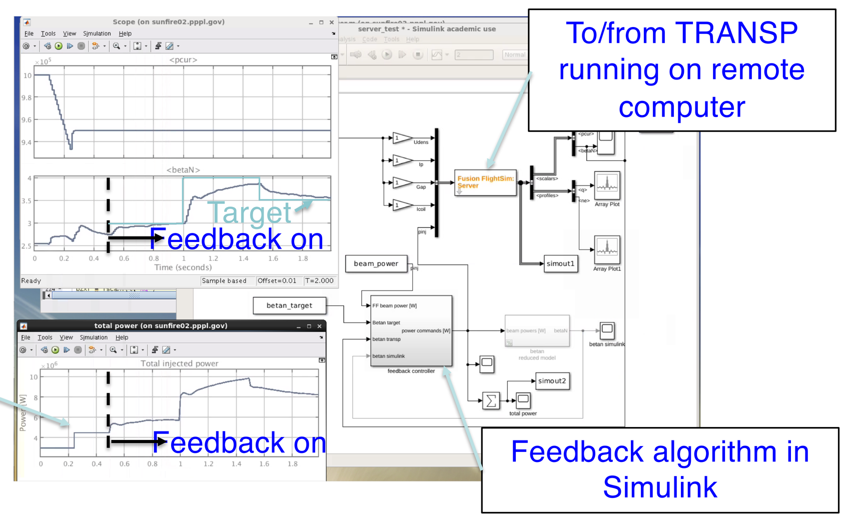


Demonstrated communication and time stepping control

Initial 'closed loop' test case successful

Plasma current and β_N measured from TRANSP run (plot updates in 'real-time' as the TRANSP run progresses)

Beam power commands modified by Simulink control algorithm to track target β_N, sent to TRANSP



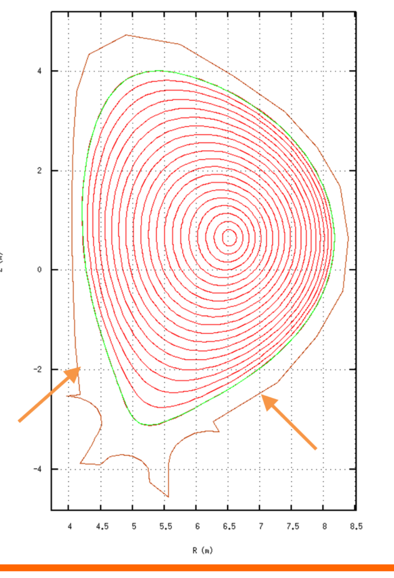
Demonstrated Simulink control of β_N using total beam power

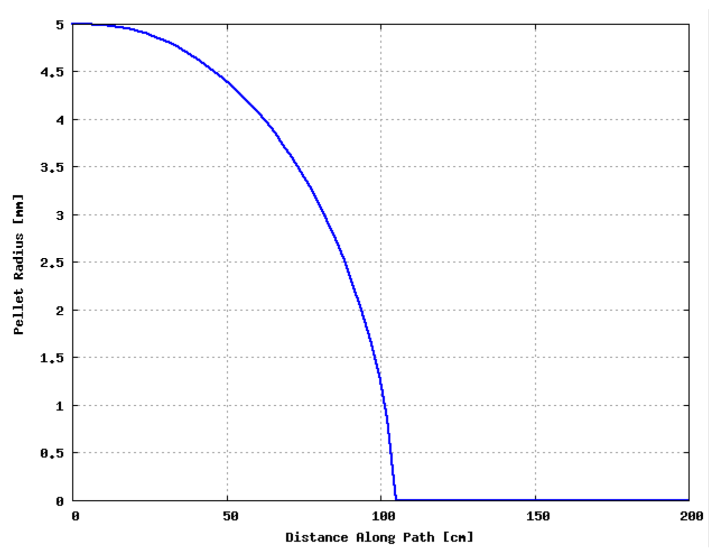
[with M. Boyer (PPPL)]

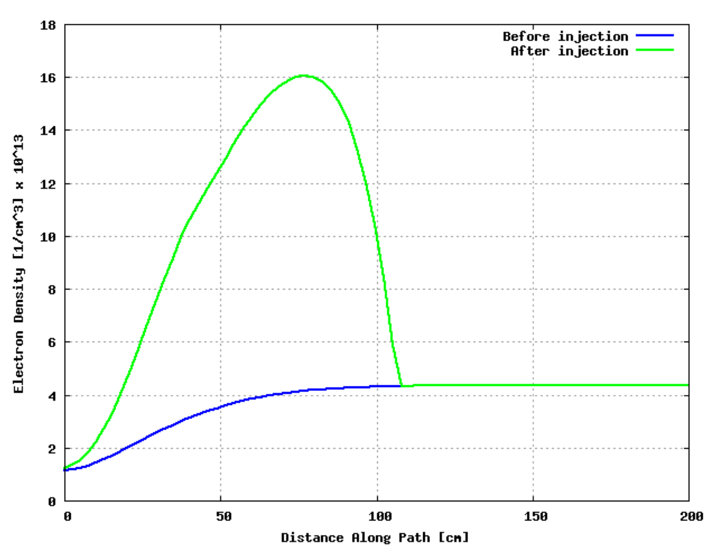
Plans for self-consistent pellet injection and ablation for predictive modeling

⇒ Goal over the next FY is to finalize implementation of a pellet injection and ablation model for self-consistent predictive models
⇒ Time-dependent source terms for the density and energy equations as the pellet penetrates the plasma
⇒ Initial focus on hydrogenic pellets for fueling studies
⇒ Extension for impurity pellets pursued in coordination with upgrades to the impurity transport model
⇒ Current implementation only effective for penetration depth studies for interpretive simulations
  ⇒ TRANSP simulation stopped and pellet injected
  ⇒ Contribution from ablation to the density and energy equations not included back into the plasma

Inputs for a hydrogenic pellet injection into an ITER-like discharge	
Pellet injection time	50 s
Pellet starting r-position	4.15 m
Pellet starting y-position	-2 m
Toroidal aiming angle	132°
Poloidal aiming angle	0°
Initial pellet radius	5 mm
Magnitude of pellet velocity	30 m/s







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