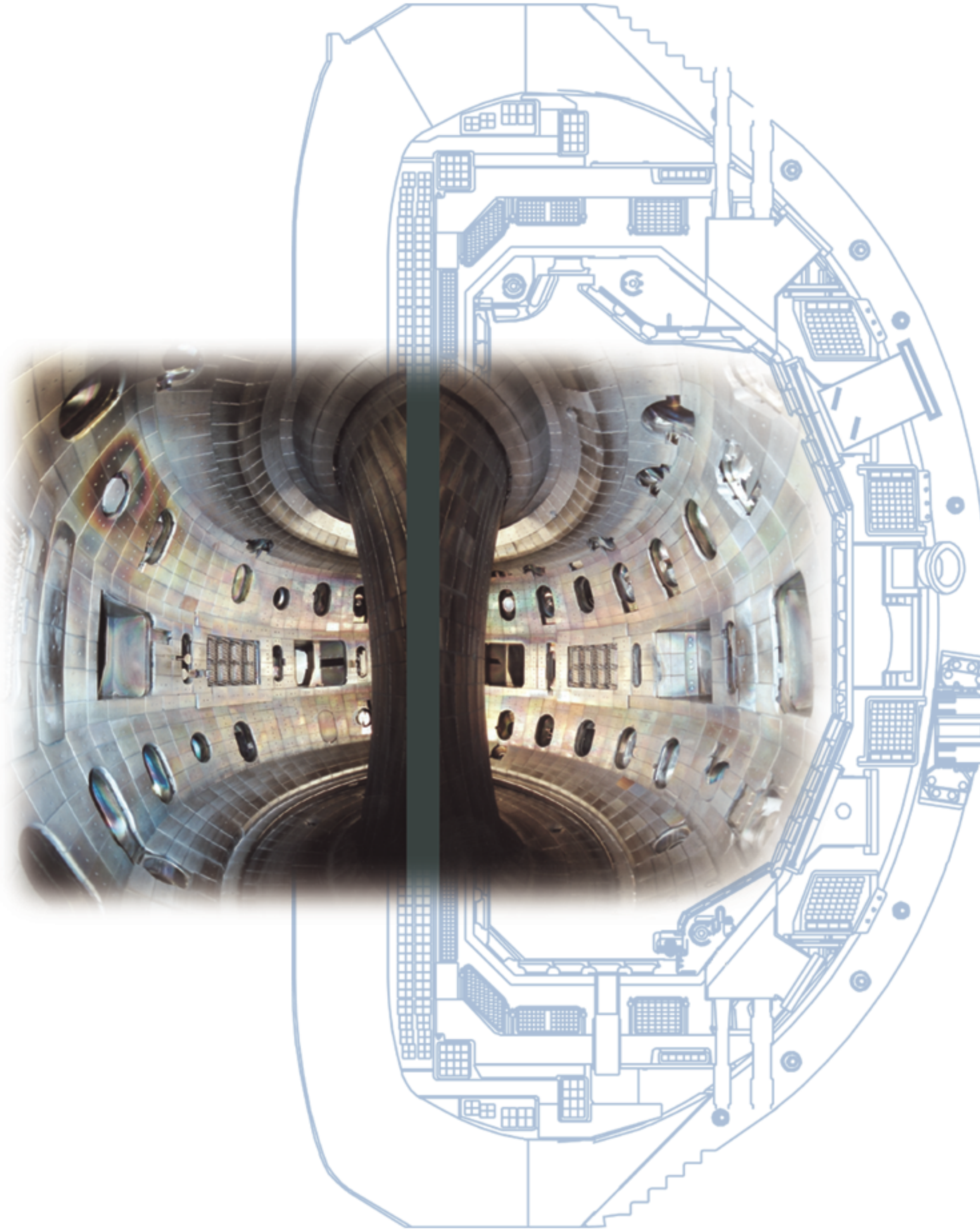
Predictive Modeling with TRANSP: Update

by

B.A. Grierson

PPPL



Presented at the TRANSP Meeting

13-512 (AIL)
General Atomics

Feb. 25th 2014

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PPPL PRINCETON PLASMA PHYSICS LABORATORY

We Have an Opportunity to Lead the Predictive Modeling Community: But There are Many Competitors

IOP PUBLISHING and INTERNATIONAL ATOMIC ENERGY AGENCY — NUCLEAR FUSION

Nucl. Fusion **51** (2011) 013001 (9pp) — doi:10.1088/0029-5515/51/1/013001

Validation of the thermal transport model used for ITER startup scenario predictions with DIII-D experimental data

T.A. Casper[1,4], W.H. Meyer[1], G.L. Jackson[2], T.C. Luce
A.W. Hyatt[2], D.A. Humphreys[2] and F. Turco[3]

We use the CORSICA code [17] for these studies. It is a 2D equilibrium and 1D transport predictive integrated modelling code that can operate in several modes [7] using either free-boundary or fixed-boundary solvers to simulate the discharge equilibrium evolution. For our studies here,

- **FASTRAN** at DIII-D
- **OMFIT+TGYRO**

IOP PUBLISHING — PLASMA PHYSICS AND CONTROLLED FUSION

Plasma Phys. Control. Fusion **55** (2013) 124028 (9pp) — doi:10.1088/0741-3335/55/12/124028

Novel free-boundary equilibrium and transport solver with theory-based models and its validation against ASDEX Upgrade current ramp scenarios

E Fable, C Angioni, F
R M McDermott, S Yu
W Treutterer, E Viezze

assessed. To this purpose, a novel full-discharge modelling tool has been developed, which couples the transport code ASTRA (Pereverzev *et al* 1991 *IPP Report* 5/42) and the free boundary equilibrium code SPIDER (Ivanov *et al* 2005 *32nd EPS Conf. on Plasma Physics*

IOP PUBLISHING and INTERNATIONAL ATOMIC ENERGY AGENCY — NUCLEAR FUSION

Nucl. Fusion **53** (2013) 123007 (8pp) — doi:10.1088/0029-5515/53/12/123007

Numerical analysis of JET discharges with the European Transport Simulator

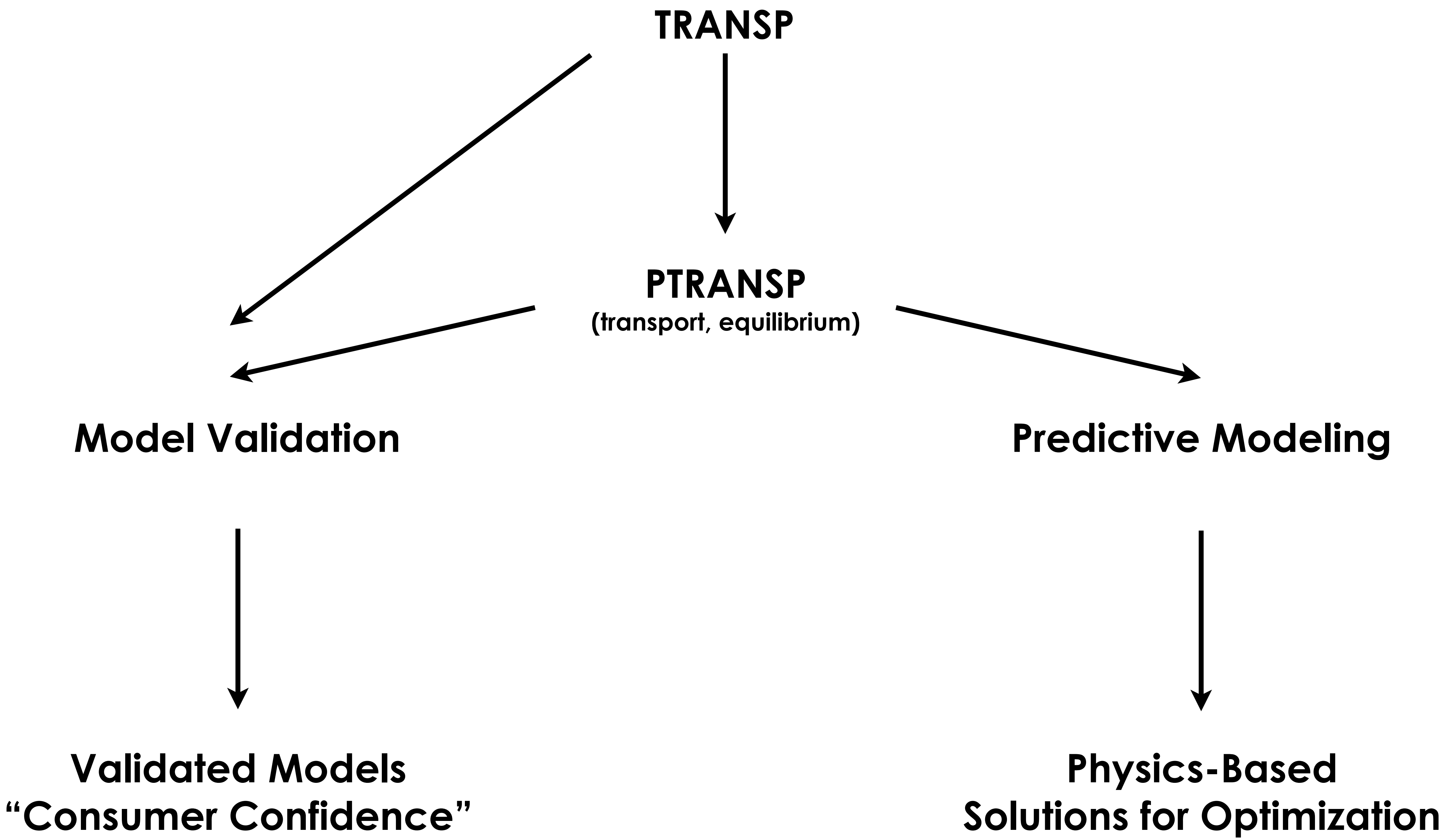
D. Kalupin[1,2,a], I. Ivanova-Stanik[3], I. Voitsekhovitch[4], J. Ferreira[5], D. Coster[6], L.L. Alves[5], Th. Aniel[7], J.F Artaud[7], V. Basiuk[7], João P.S. Bizarro[5], R. Coelho[5], A. Czarnecka[3], Ph. Huynh[5], A. Figueiredo[5], J. Garcia[7], L. Garzotti[4], F. Imbeaux[7], F. Köchl[8], M.F. Nave[5], G. Pereverzev[6,b], O. Sauter[9], B.D. Scott[6], R. Stankiewicz[3], P. Strand[10], ITM-TF contributors[c] and JET-EFDA Contributors[d]

The 'European Transport Simulator' (ETS) (Coster *et al* 2010 *IEEE Trans. Plasma Sci.* **38** 2085–92, Kalupin *et al* 2011 *Proc. 38th EPS Conf. on Plasma Physics (Strasbourg, France, 2011)* vol 35G (ECA) P. 4.111) is the new modular package for 1D discharge evolution developed within the EFDA Integrated Tokamak Modelling (ITM) Task

TRANSP Has Been Excellent for Sources and Power/Particle/Momentum Balance

- Typical workflow for many users has been to run TRANSP to get all the fluxes
- Then use their own code to do model validation
- We should do this all “in house” and eliminate the hand-off to other modeling codes

TRANSP with Model-based Predictions is a Tool for Model Validation and Optimization



Hurdles Remain Before Predictive TRANSP with PT_SOLVER exits beta-testing

- **Dissemination of code verification and performance expectations**
  - Compare to TGYRO
  - solver `dt` and number of `cpu`.
- **Provide end-user with convergence metrics via RPLOT variables**
  - Global residual, residual profiles
- **Establish optimized workflow for validation runs**
  - Spatial and temporal grid options

Flow-chart Visual Representation of Agorightm Would be Very Useful

- Convergence check most critical for consumer confidence
- Determines when solver gets stuck and exits, or solver obtains valid solution

Nucl. Fusion **53** (2013) 123007 D. Kalupin *et al*

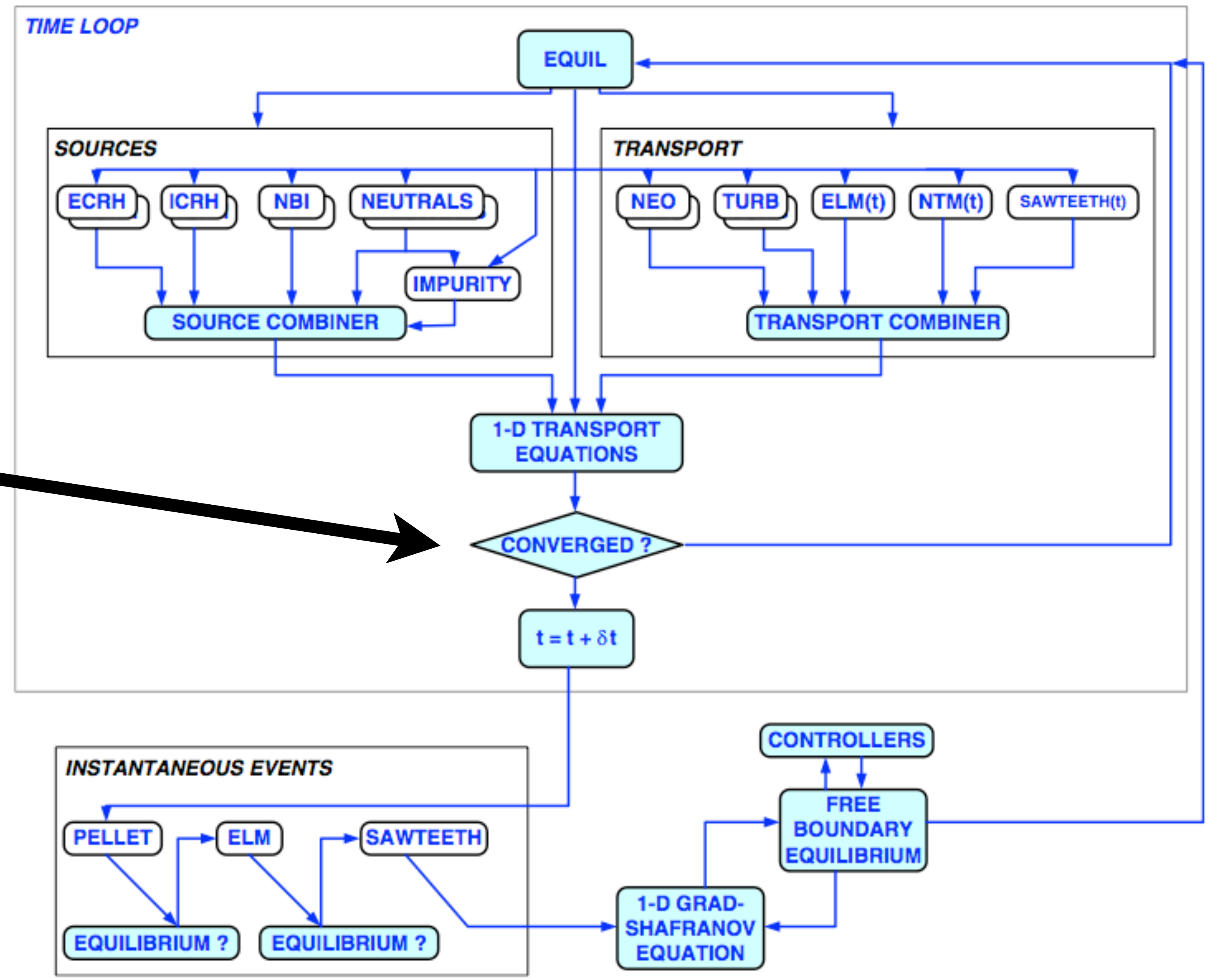


Figure 1. European Transport Solver: a schema of the workflow.

Verification of PT_SOLVER's TGLF Calls Complete

- **Usage of the TGLF "dump" interface critical for this study**

My Code
$r, R, q, T_e, \nabla T_e, \ldots$

→ TGLF

out.tglf.localdump
Regurgitates what was passed to TGLF

$Q_{e,i}$ $\Gamma_{e,i}$ $\Pi_{e,i}$

γ, ω

- **Dump plots should be included on PT_SOVLER help pages**

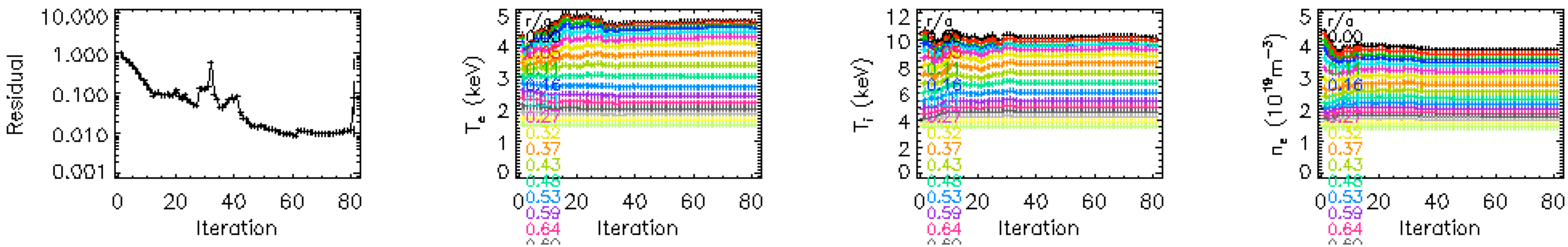
See additional attachment tglf_plot_dump.ps

Performance (speed) of PT_SOLVER Remains an Issue

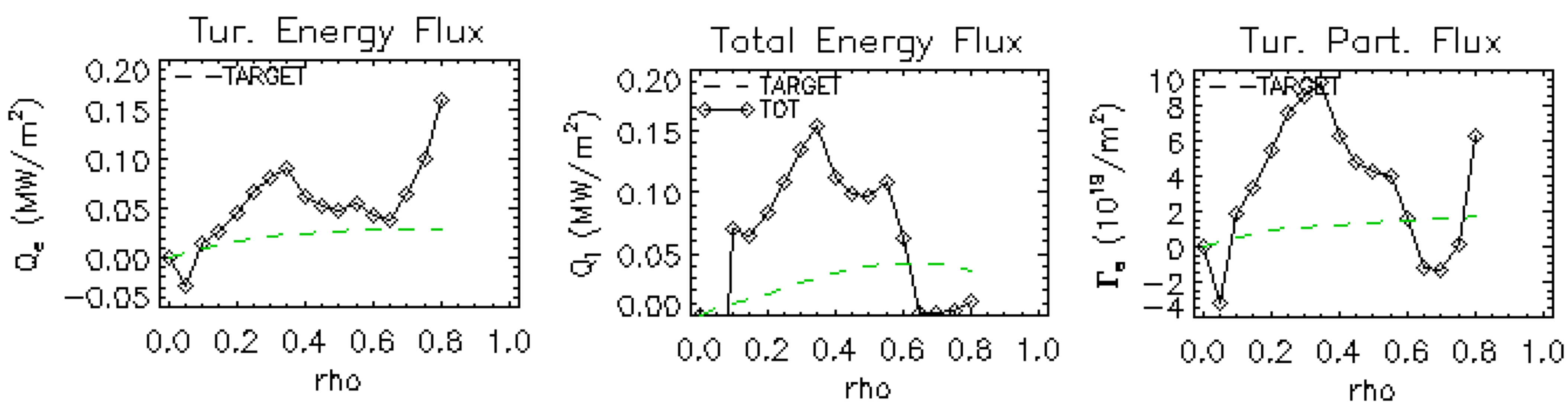
- **PT_SOLVER solves a more complex set of equations so we don't expect it to beat TGYRO**
  - Time-dependent $\partial/\partial t \neq 0$
- **Case study: TRANSP run with 20 radial zones output with TRXPL and run through TGYRO and PT_SOLVER**
- **Solution for x=[0,0.8] (16 points)**

TGYRO Converges in ~2.5 Hours with Eight CPUs

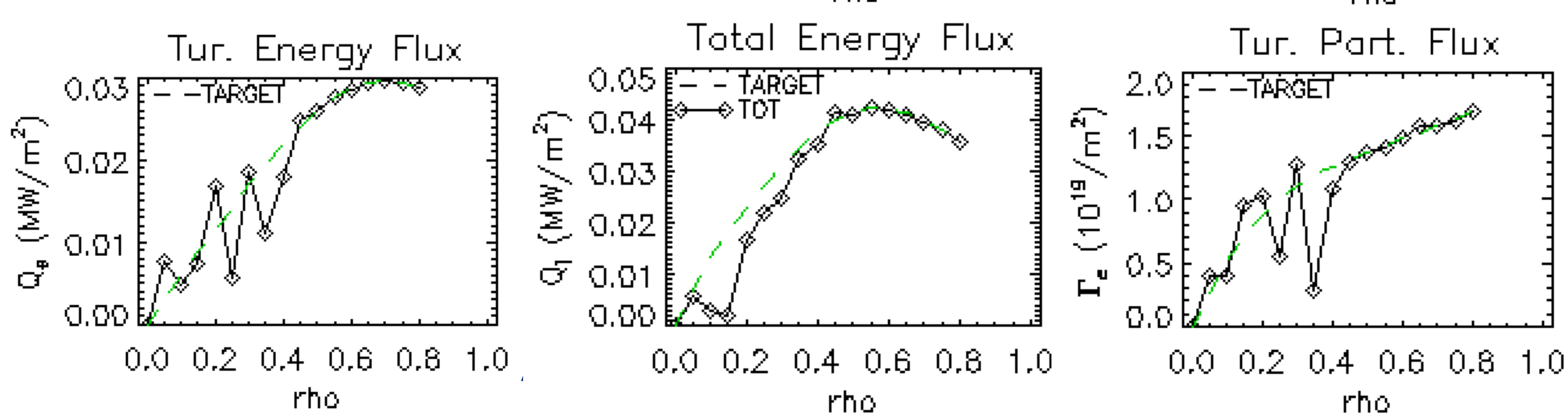
- **Predict Te, Ti, ne with TGLF+NEO**



Initial Fluxes



Final Fluxes not "perfect" but sufficiently converged



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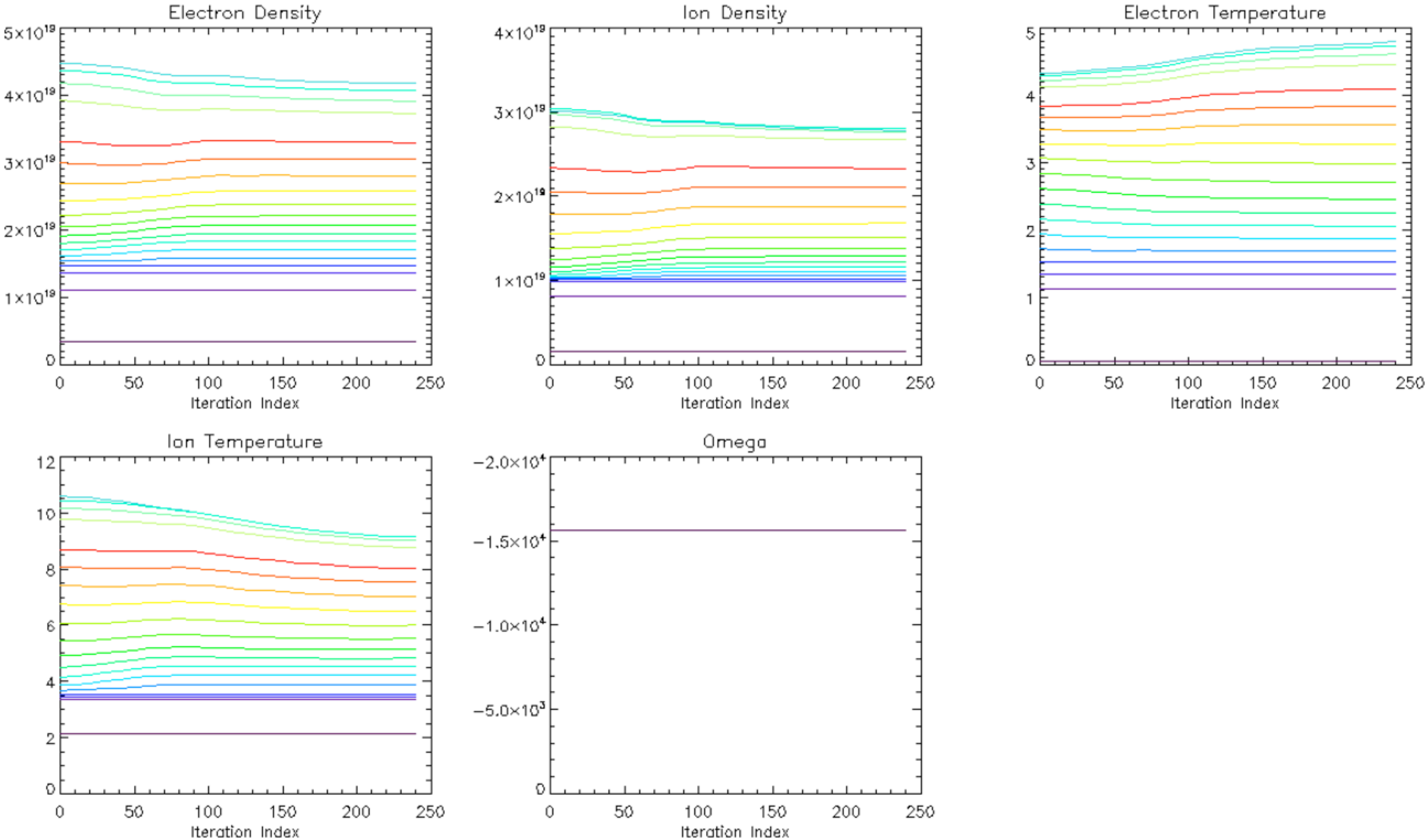
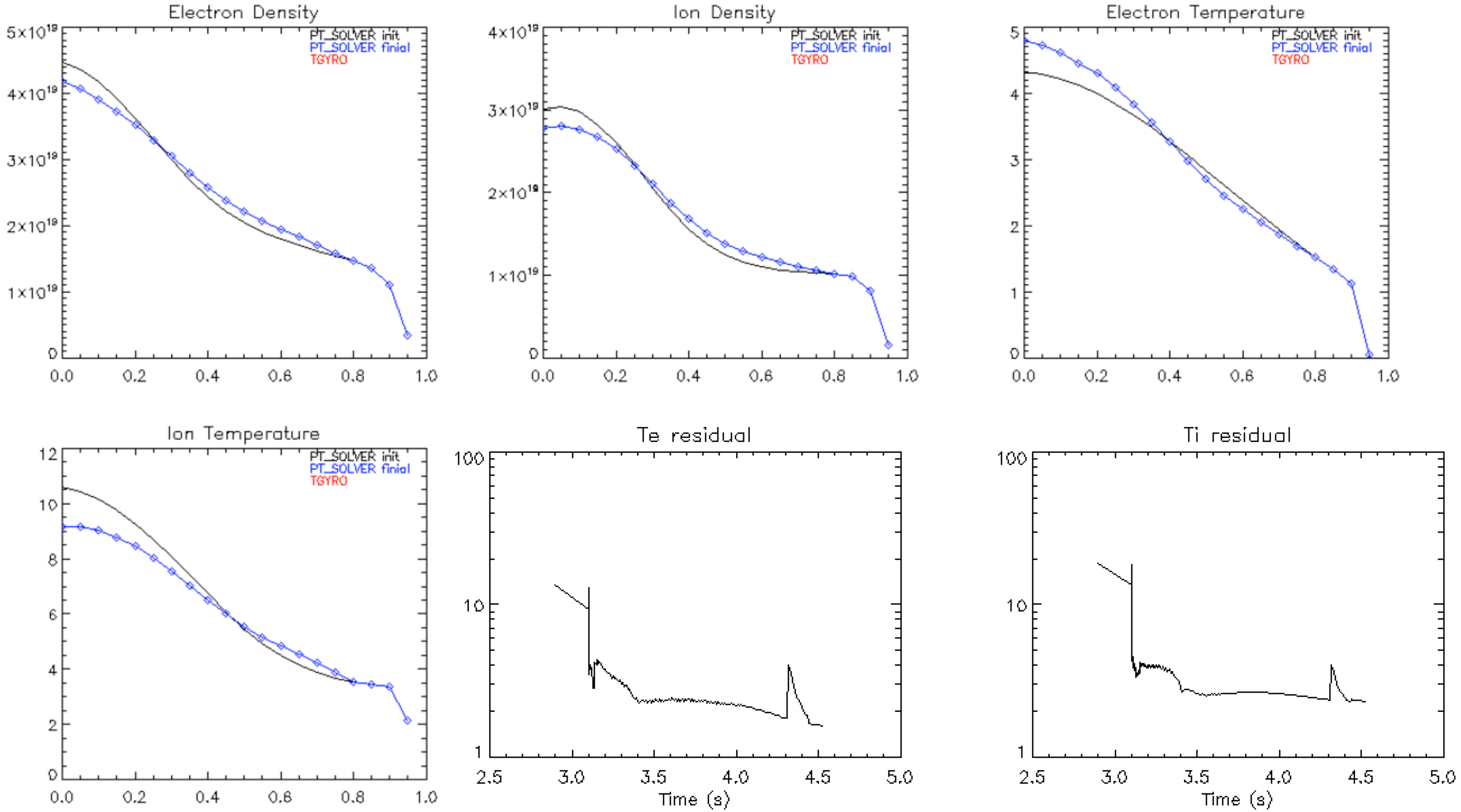
PT_SOLVER After 16 Hours with 16 CPUs



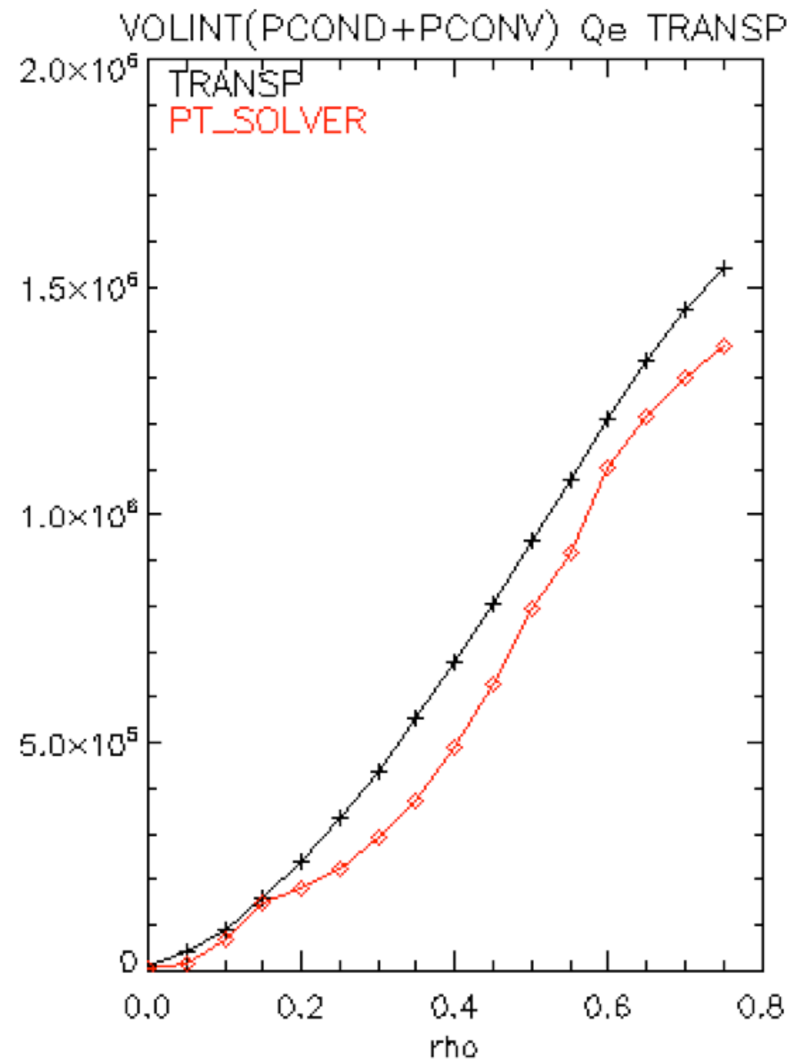
PT_SOLVER After 16 Hours with 16 CPUs

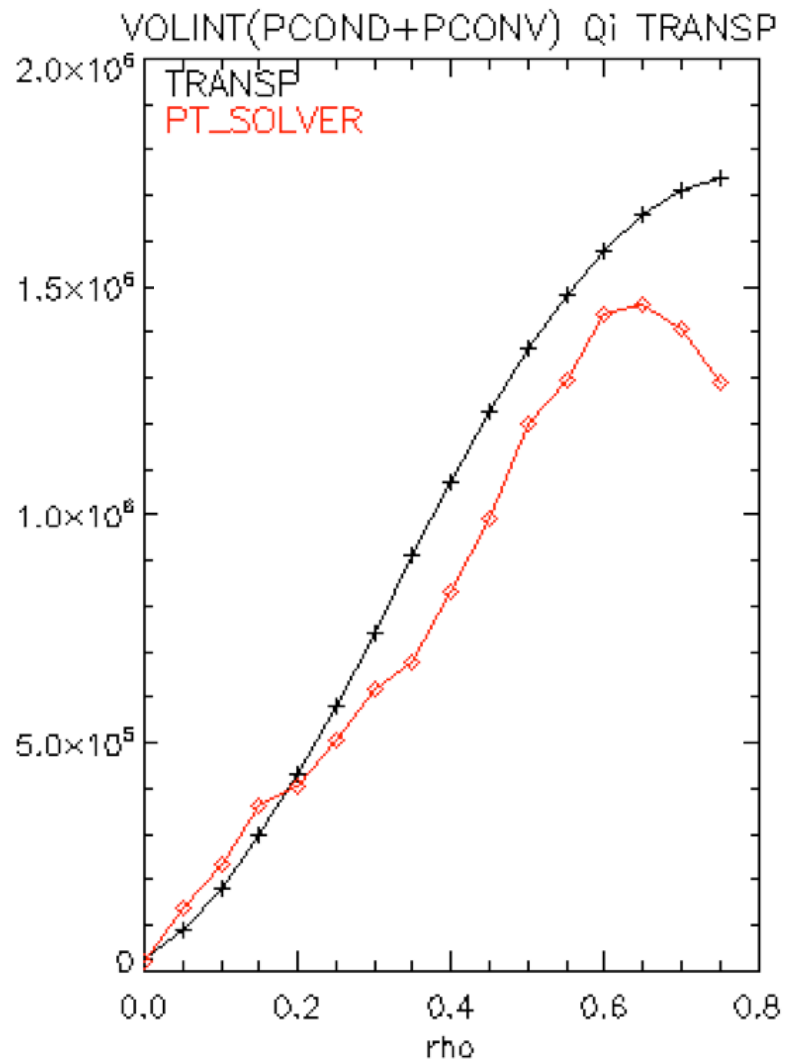


PT_SOLVER After 16 Hours with 16 CPUs

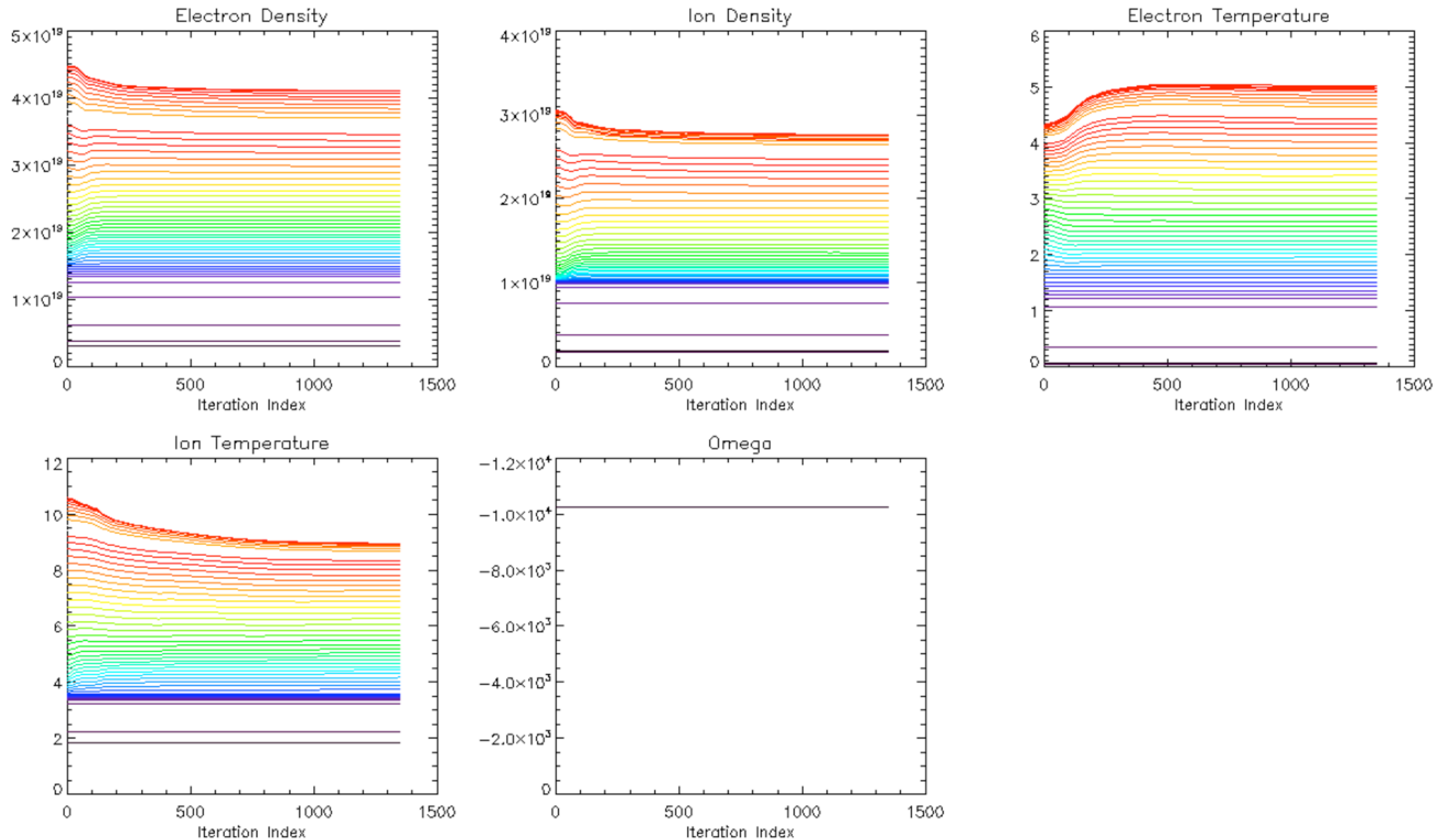
- **PT_SOLVER is approaching a match to the power flows from the power balance calculation**

- **But it requires many more iterations**





When PT_SOLVER Converges Then it Nearly Matches the TGYRO Solution



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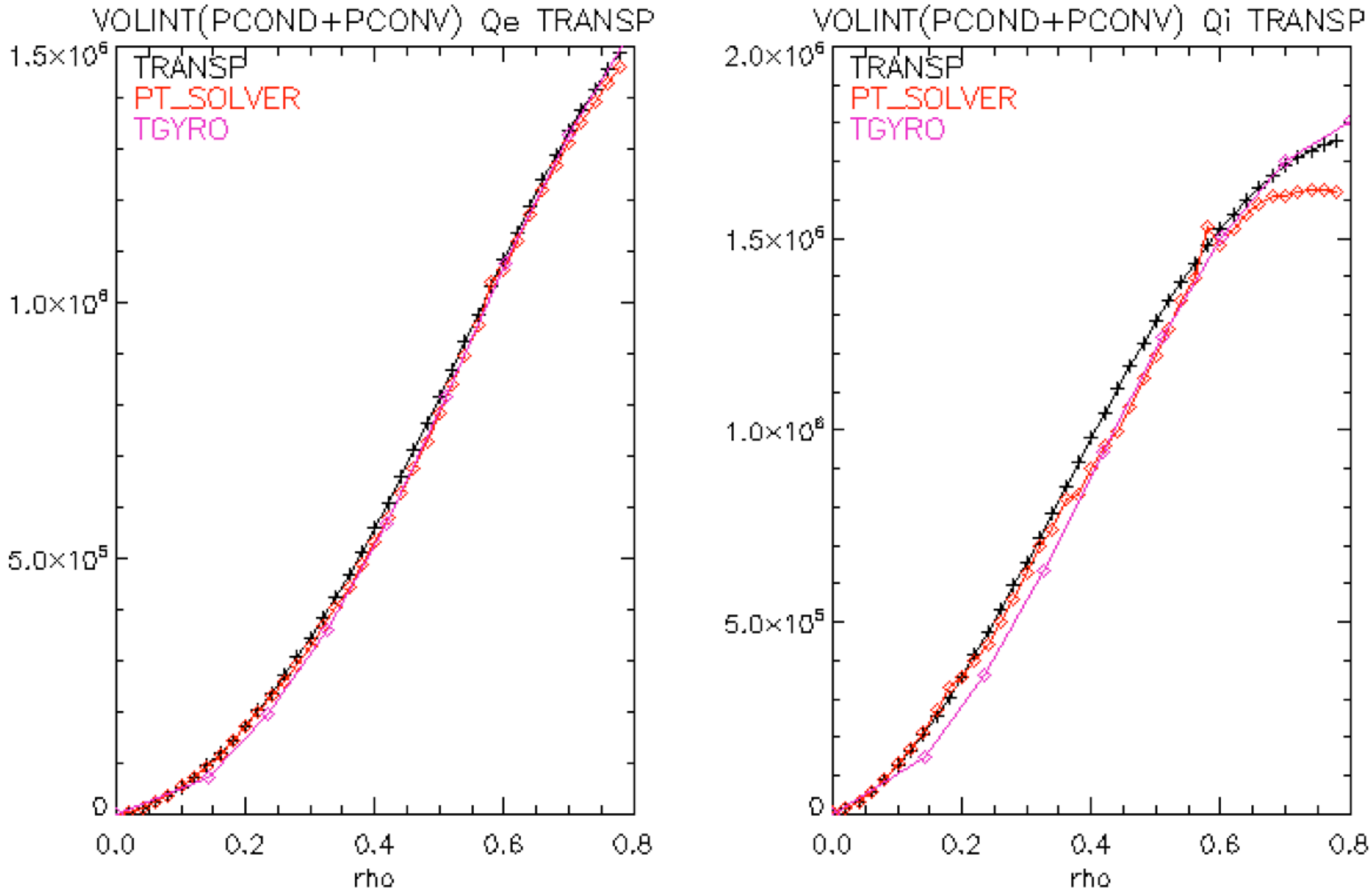

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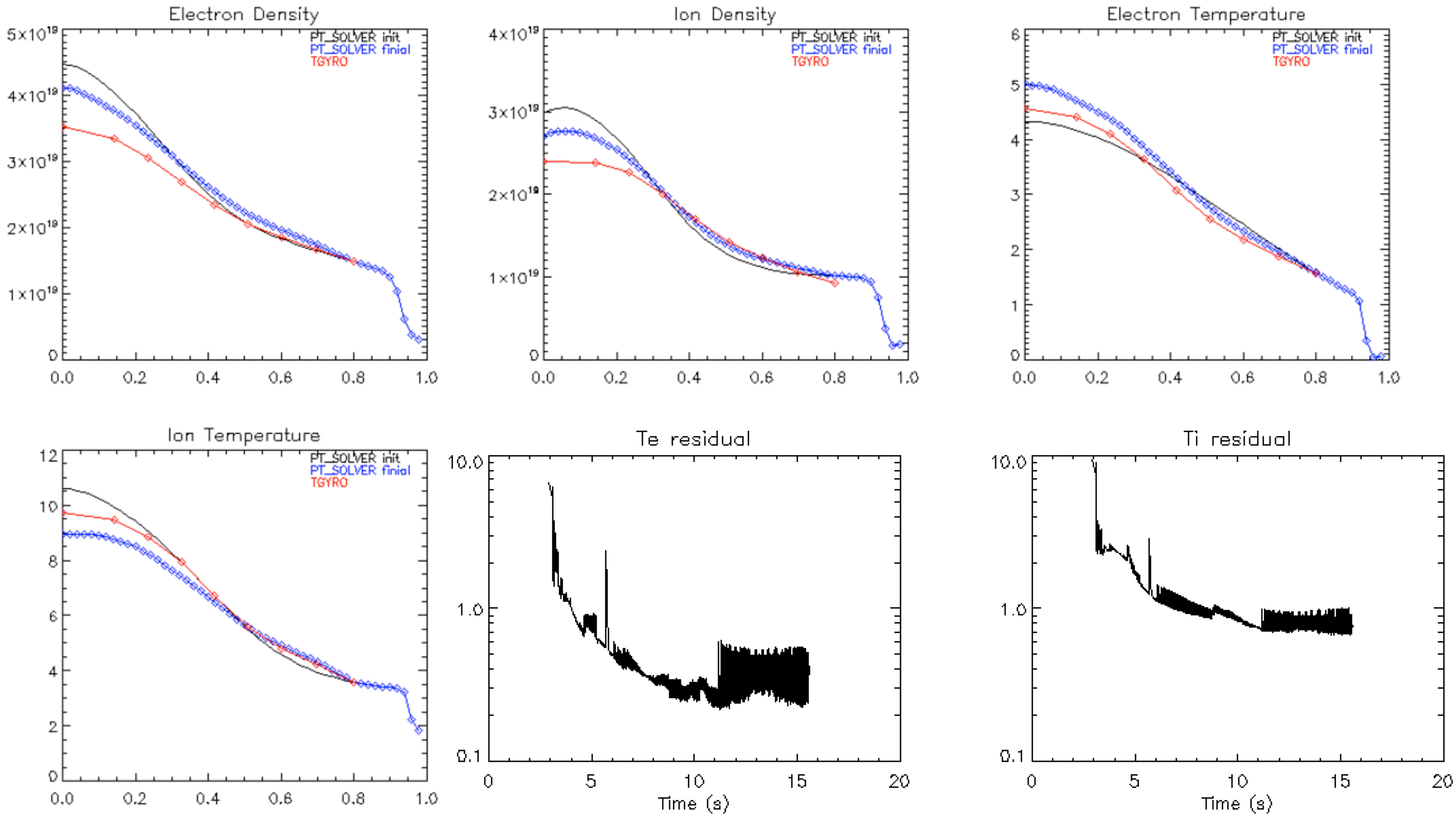

These Convergence Metrics are Not Available when PT_SOVLER is Used in TRANSP

- **I have a completed TRANSP run, but did PT_SOLVER converge?**
- **Running TGYRO after the fact to check the run is not a solution to this issue**
  - Not solving the same equations
- **Need convergence metrics output to RPLOT**
  - Global residual
  - Profile multiplot of Q^{PT_SOLVER} and Q^{PB}

See additional attachment tglf_plot_dump.ps

Experience Indicates that Many Radial Gridpoints is Unnecessary (NZONES=20 good)

- **Unless the simulation is expected to trigger a very sharp transport barrier, more than 16 radial gridpoints interior to ϱ=0.8 is a waste of time**
- **TRANSP runs should be done first at high fidelity**
  - 1. Re-run on coarse space/time domain
  - 2. Re-run in predictive
  - Compare 1,2 directly for validation metrics

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Predictive TRANSP has the Opportunity to Lead Validation and Optimization Efforts

- **Algorithms, verification, performance and convergence metrics need to be published first**
- **Leveraging the large TRANSP user base enables crowd-sourced debugging and built-in clientele**