Report from ITM/IMP3 Code Camp: ETS V&V (December 6-17 2010, Innsbruck)

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IMP3 Code Camp activities:

- *ETS V&V: development of workflows (WF), tests, development of TRANSP-> CPO interface*
- *implementation of modules from IMP5 (ECRH, ICRH, NBI, LH)*
- *implementation of modules from IMP4 (anomalous transport, neoclassical transport)*
- *implementation of modules from IMP3 (pellets, impurities)*
- *edge codes: implement CPOs in the edge codes, visualisation*

Outline

1. ETS development: physics modules implemented in workflows (WF)

2. Tested workflows and simulation results:

   - *current diffusion*
   - *modelling of electron temperature*
   - *benchmarking of Bohm-gyroBohm model*

3. Summary

Physics modules in ETS (status before this CC):

- Development of WFs & integration of various physics modules/codes under Kepler is going at the same time – V&V is already needed at this stage

- Created & tested Fortran workflow [D. Kalupin *et al*, ITM GM 2010]:

  - *equations for transport (temperature, main species & impurities), current diffusion and equilibrium;*

  - transport & CD modules: constant D&V, Spitzer resistivity. Bohm-gyroBohm/ASTRA model has been implemented in Fortran workflow & benchmarked (D.Kalupin, I. Voitsekhovitch);

  - heat sources: arbitrary analytical function for the moment, coupling with NBI and RF codes is in progress (over 20 codes ported on the Gateway, 11 Kepler actors delivered)

  - equilibrium: EMEQ (ASTRA), HELENA

  - few transport solvers: ASTRA, CRONOS, RITM, …

  - boundary conditions: for simulated quantity and zero flux of simulated quantity. Non-zero boundary flux for solver 3 – in progress.

- Kepler workflows [V. Basiuk *et al* EPS 2010]: *equilibrium & current diffusion with NCLASS. Arbitrary analytical function with scaling-based LHCD efficiency for non-inductive current.*

This code camp: test of newly developed options for Kepler WF

-> *equilibrium (HELENA21) + current diffusion equation (CRONOS transport solver). NCLASS as an actor.*

-> *equation for Te has been implemented in Kepler WF [Ph. Huynh, V. Basiuk]: test of equilibrium (HELENA21) + current diffusion equation + Te (CRONOS transport solver).*

-> modelling assumptions: OH heating + off-axis Gaussian profile for H&CD evolving in time. Bohm-gyroBohm/CRONOS transport model for χ_e. Ti=Te (no collisional exchange)

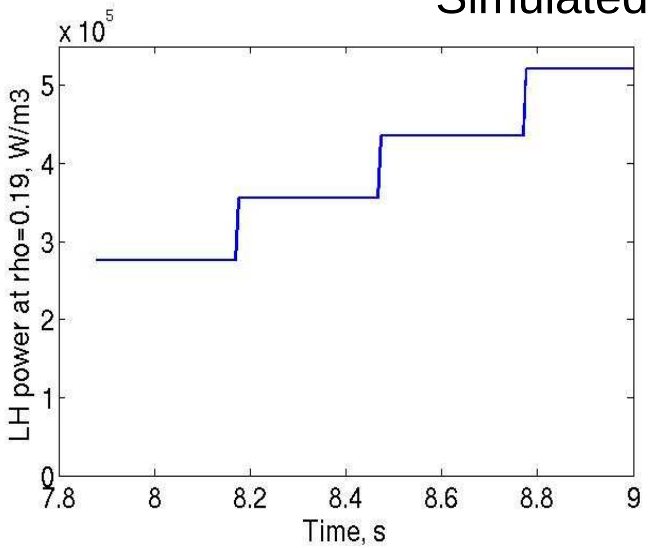
-> *input data: Tore-Supra-like discharge*

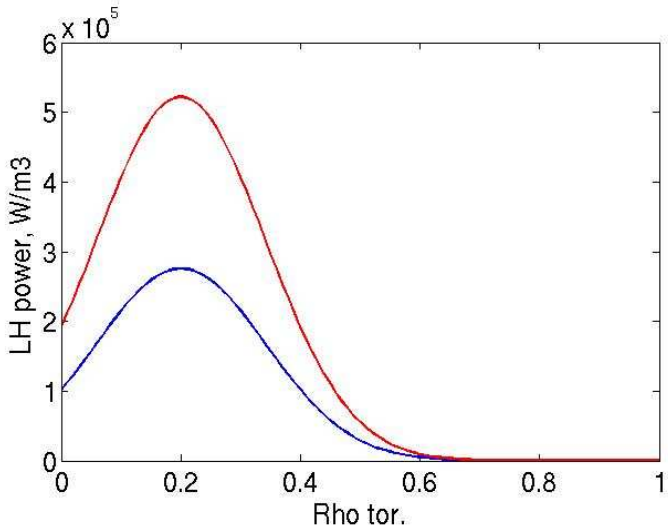
-> *visualisation: matlab scripts (thanks to Ph. Huynh)*

Summary table: ETS runs

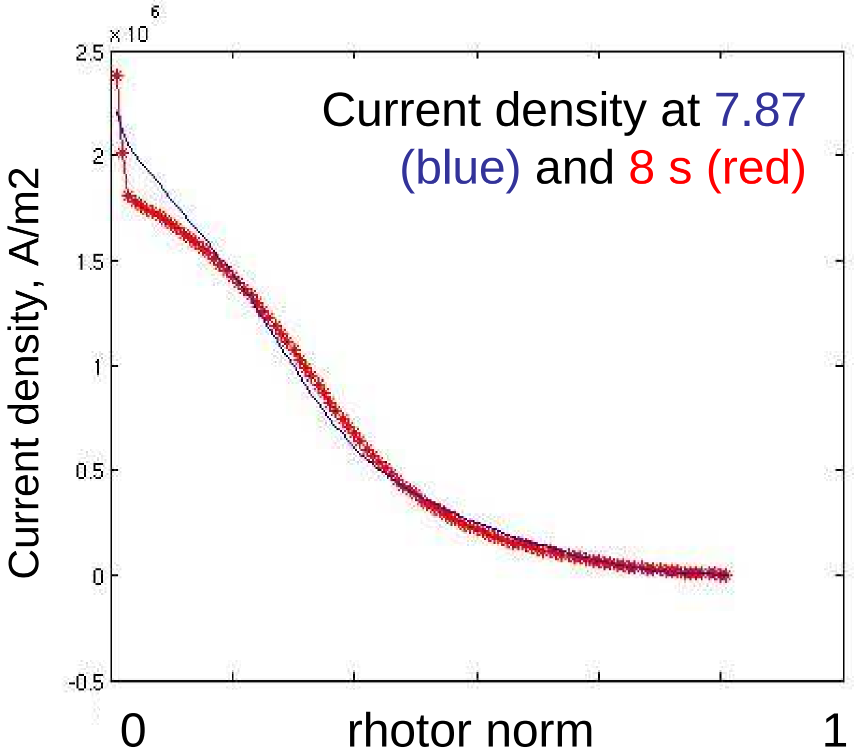
Transport solver	Equilibrium	Transport equations	Time interval
3	Evolving (recalculated for each 5th transport time step, 50 ms or less)	Current diffusion	7.87 – 8 s
3	Evolving (recalculated for each 2nd transport time step, 20 ms or less)	Current diffusion & Te	7.87 – 8.32 s,
3	Calculated at the first time step and frozen till the end of the run	Current diffusion & Te	7.87 – 9 s
10	Evolving (recalculated after 10 transport time steps (100 ms))	Current diffusion & Te	7.87 – 8.05 s

Simulated scenario

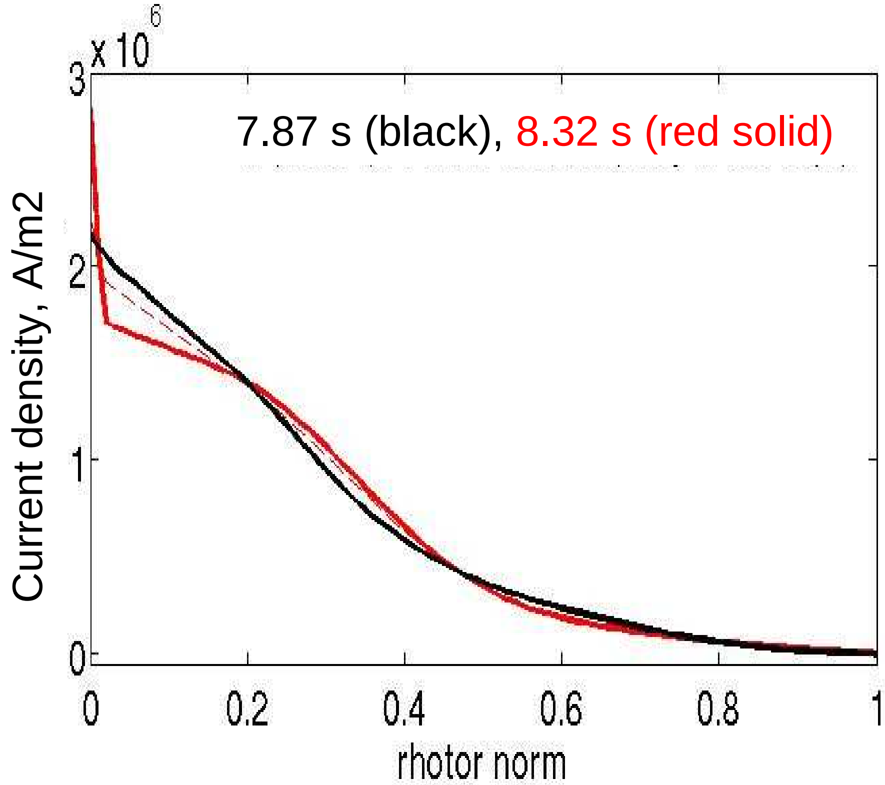




Current diffusion (solver 3) with evolving equilibrium

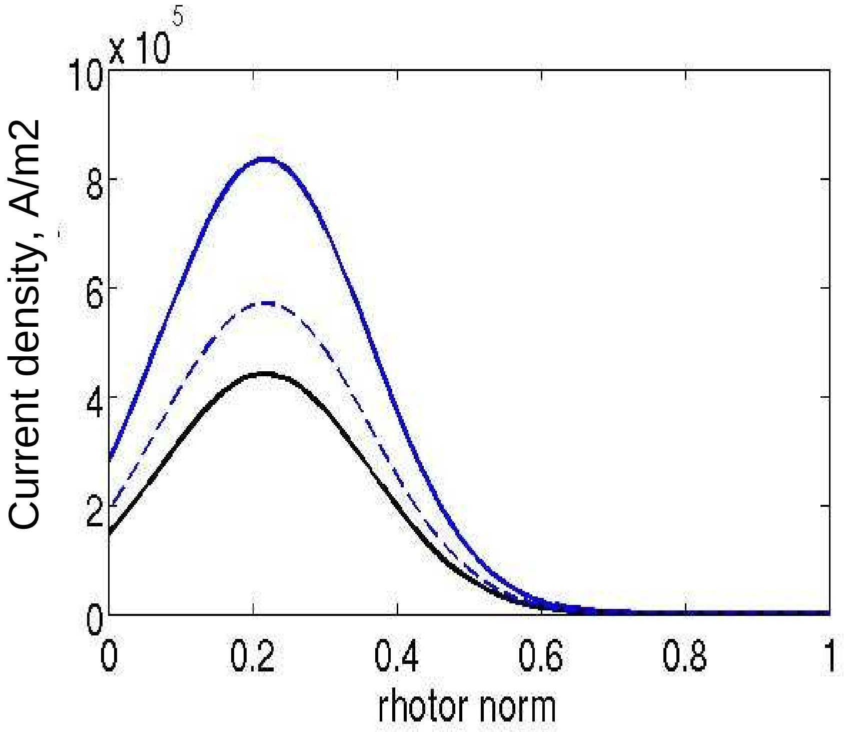


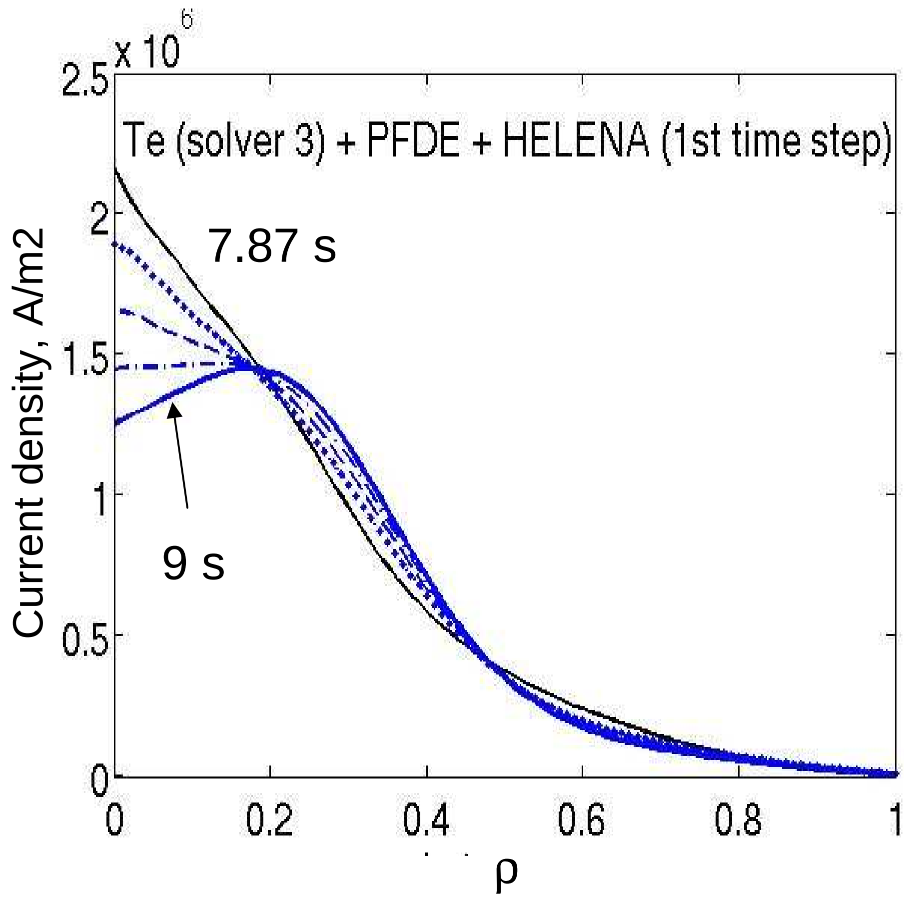
Current diffusion simulated with prescribed (constant in time) Te



Simulations of current diffusion and electron temperature

Current profile evolution (solver 3) with frozen equilibrium and evolving Te

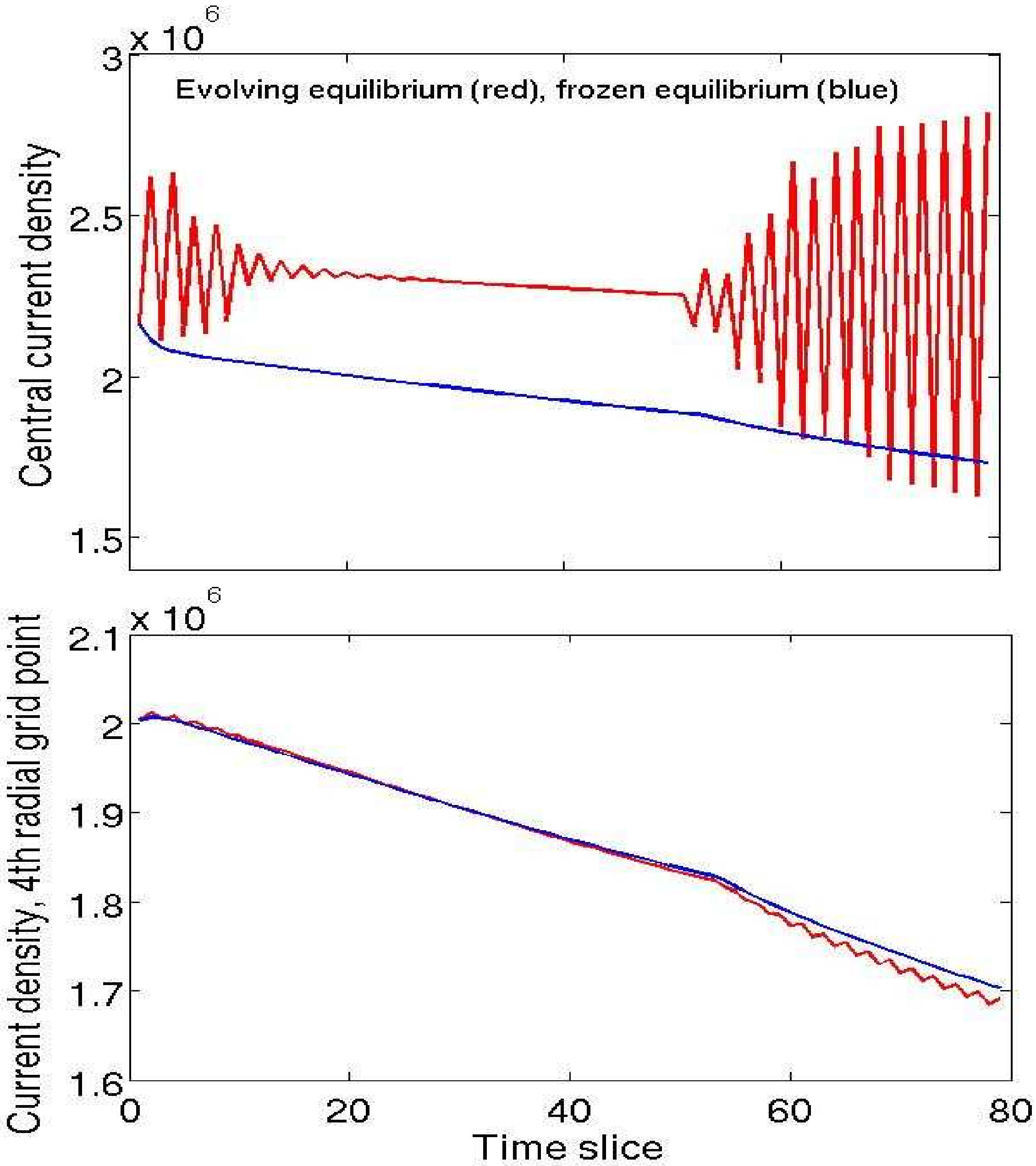




- *broadening of current density and formation of reversed q-profile with increased off-axis non-inductive current*

- *no sharp core current density gradient*

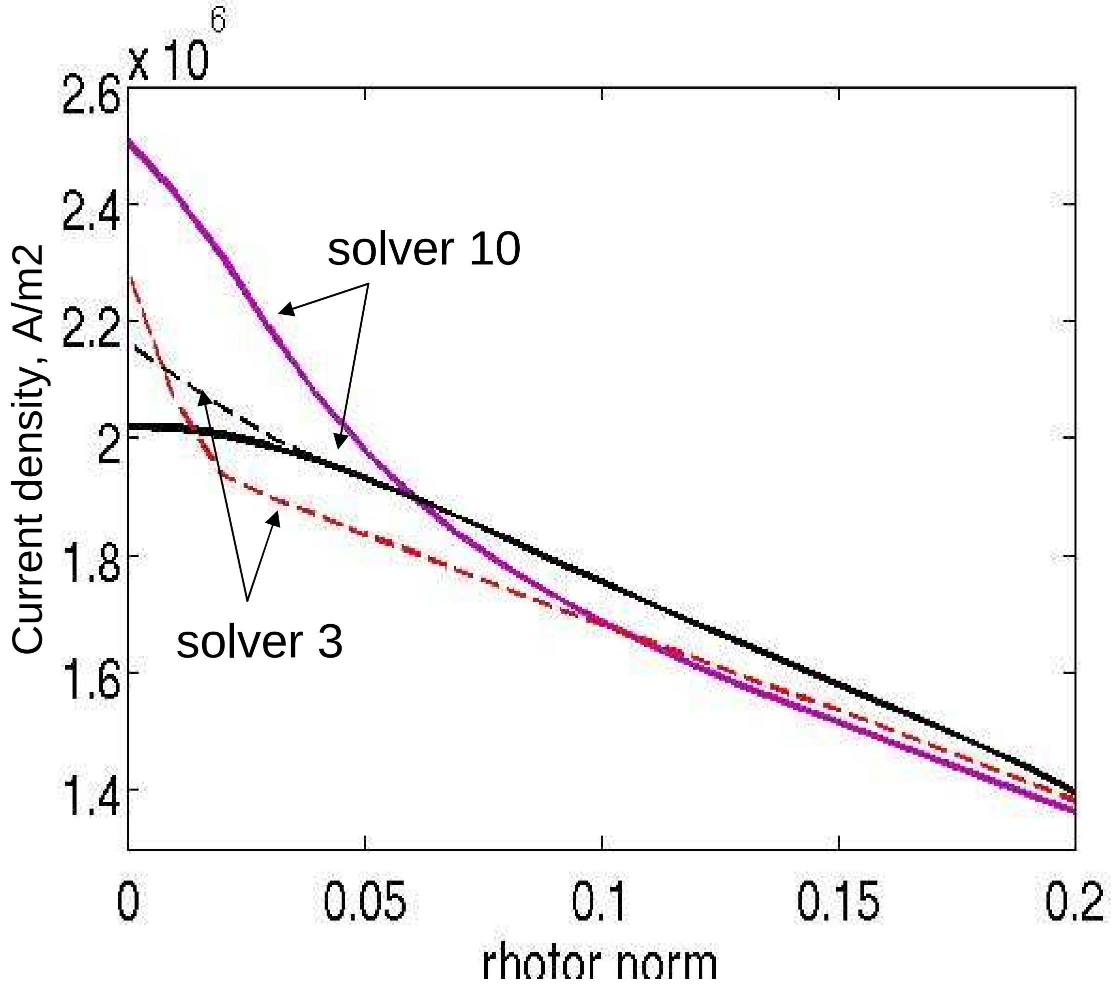
Comparison of current diffusion with **evolving** and **frozen** equilibrium



j(ρ=0)

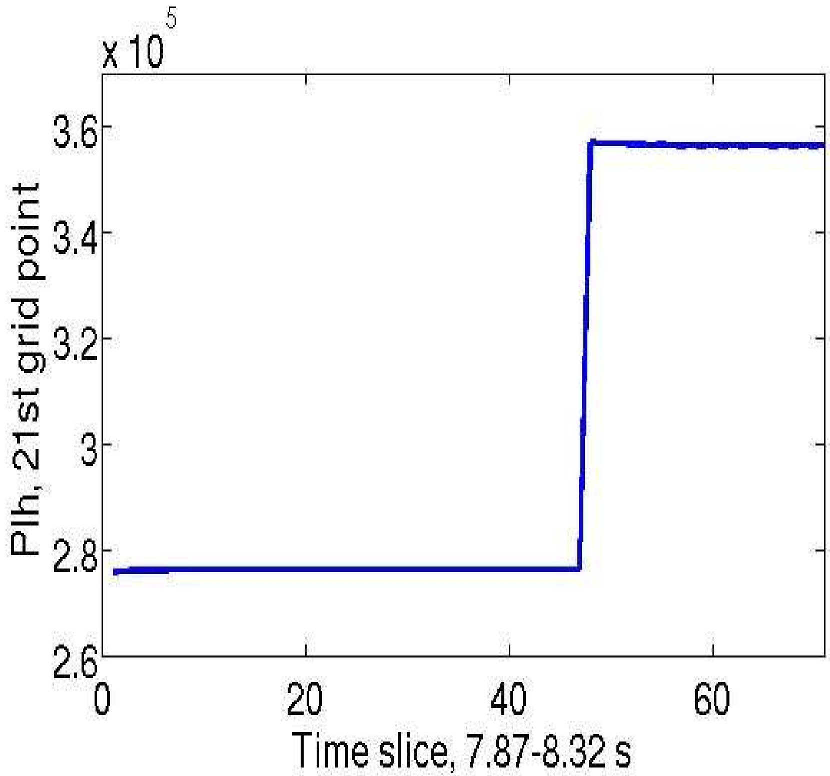
j(ρ=0.03)

Current diffusion with evolving equilibrium & Te: comparison of solver 3 (dashed curves) and solver 10 (solid curves)

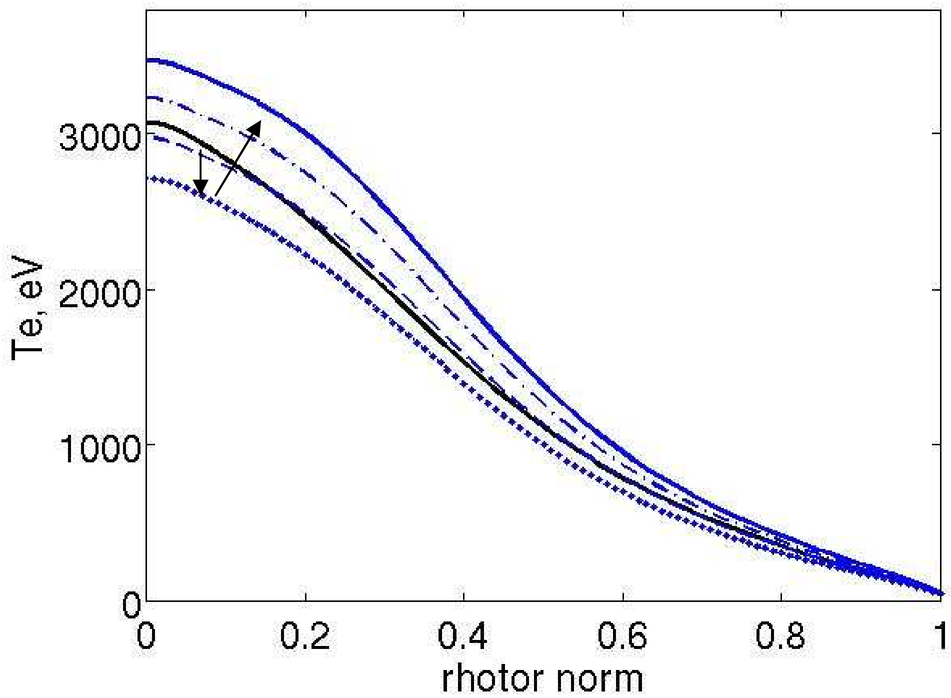


- same run assumptions, but different solvers;
- different central current density at the first time step (black solid & dashed curve);
- strongly different core current density already after 200 ms

Run with temperature and current profile evolution (solver 3, frozen equilibrium)

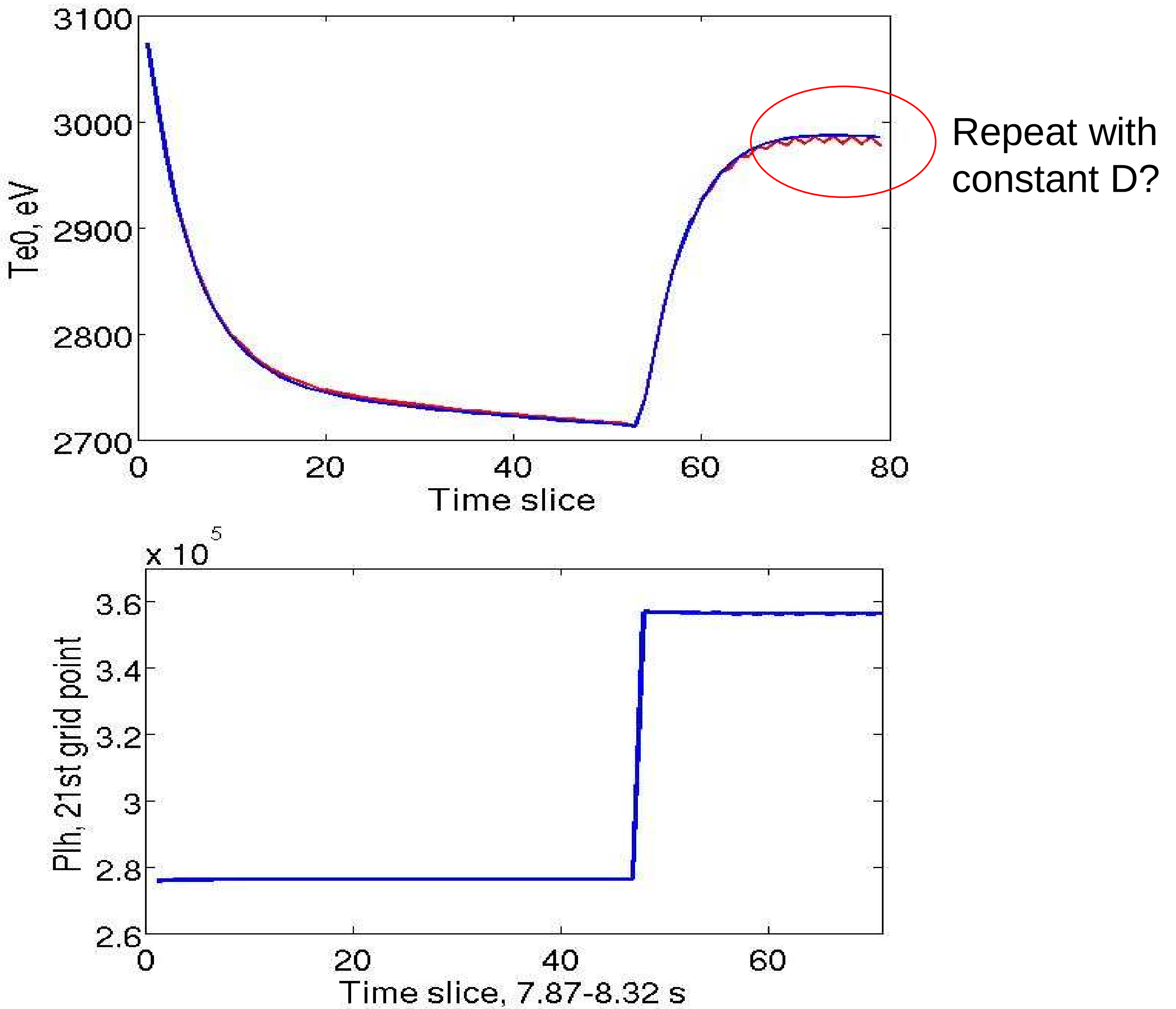


Peak heating power as a function of time



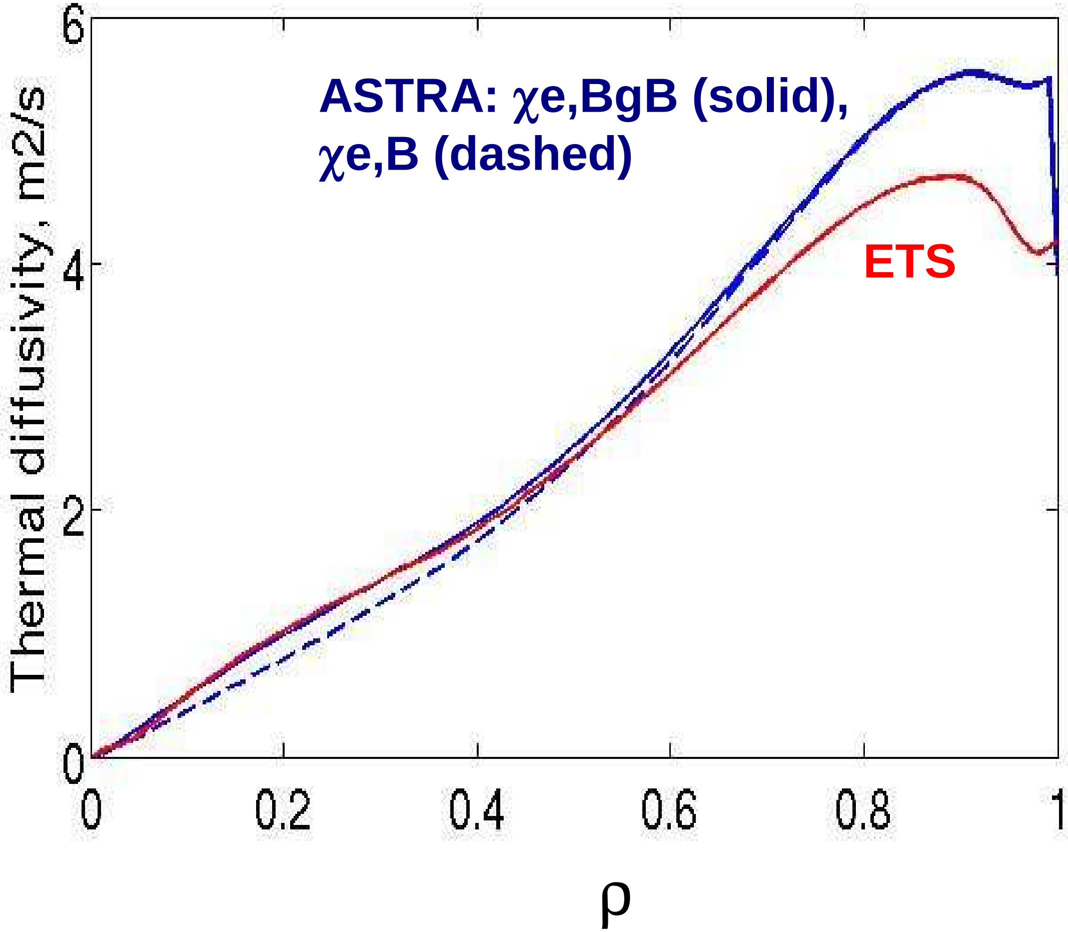
Evolution of temperature profile: 7.87 s (black), 9 s (blue solid curve)

Temperature evolution with **evolving** and **frozen** equilibrium



Benchmarking of Bohm-gyroBohm model in simulations with prescribed Te

$$\chi BgB \sim (T_e/B_{tor})(\nabla p_e/p_e)q^2$$



- output of ETS has been used as an input for ASTRA (ne, Te, q, global parameters);

- different equilibrium in ASTRA (3 moments) and ETS (HELENA21);

- good agreement for BgB model at $\rho < 0.6$, discrepancy at the outer part of plasma

Summary

- Self-consistent simulations of current diffusion, Te and equilibrium with ETS Kepler WF have been performed
- Reasonable response of current diffusion to non-inductive current drive - formation of reversed q with off-axis non-inductive current (frozen equilibrium or solver 10)
- Reasonable response of Te to increasing heating
- Benchmarking of the Bohm-gyroBohm model → reasons for obtained difference to be investigated
- Current density & Te oscillations during the transient heating phase with solver 3 & evolving equilibrium. Solution?
- Numerically stable solution with solver 10 / evolving equilibrium, large difference in core current density between solver 3 and 10
- Next step – benchmarking of steady state with other codes for JET discharge