Evolution of the DINA-CH tokamak full discharge simulator

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<u>DINA-CH development path</u>: Developing a full tokamak discharge simulator will be essential for ITER. The work carried out using the DINA-CH code, a version of DINA adapted to function in an open-architecture model using the Matlab Simulink environment, provides a test-bed for the future continued development of such a tool. In previous presentations, DINA-CH was demonstrated for plasma equilibrium response modelling in TCV, ITER and MAST, ECH/ECCD modelling in TCV. VDE modelling in TCV was validated in a previous DINA version. Following the initial work carried out using DINA, the control modelling of DINA was removed from the DINA source and implemented in the open-architecture SIMULINK environment. Heating sources were removed and similarly implemented. Finally, transport which had been modelled in DINA was also implemented as an external module. The principle of opening DINA up to interface to more existing devices and more simulation codes has given rise to DINA-CH, which simulates TCV, ITER, MAST and (most recently) ASDEX-UG, all using the same core executable module and the same interface.

<u>Latest applications using DINA-CH:</u> We have used DINA-CH to develop an auto-calibration of the plasma position in the presence of unknown diagnostic drifts in TCV, by modulating the plasma position and current, and allowing the plasma to drift around the [R,Z] plane. This work is fully described in an accompanying paper [1]. Since this simulation requires the dynamics of the plasma movement in the vessel, including the full control circuitry, only a code such as DINA-CH or TSC can be used.

We have now implemented a diagnostics toolbox [2] to simulate the functioning of diagnostics of the free-boundary evolution of a TCV tokamak discharge, implementing the
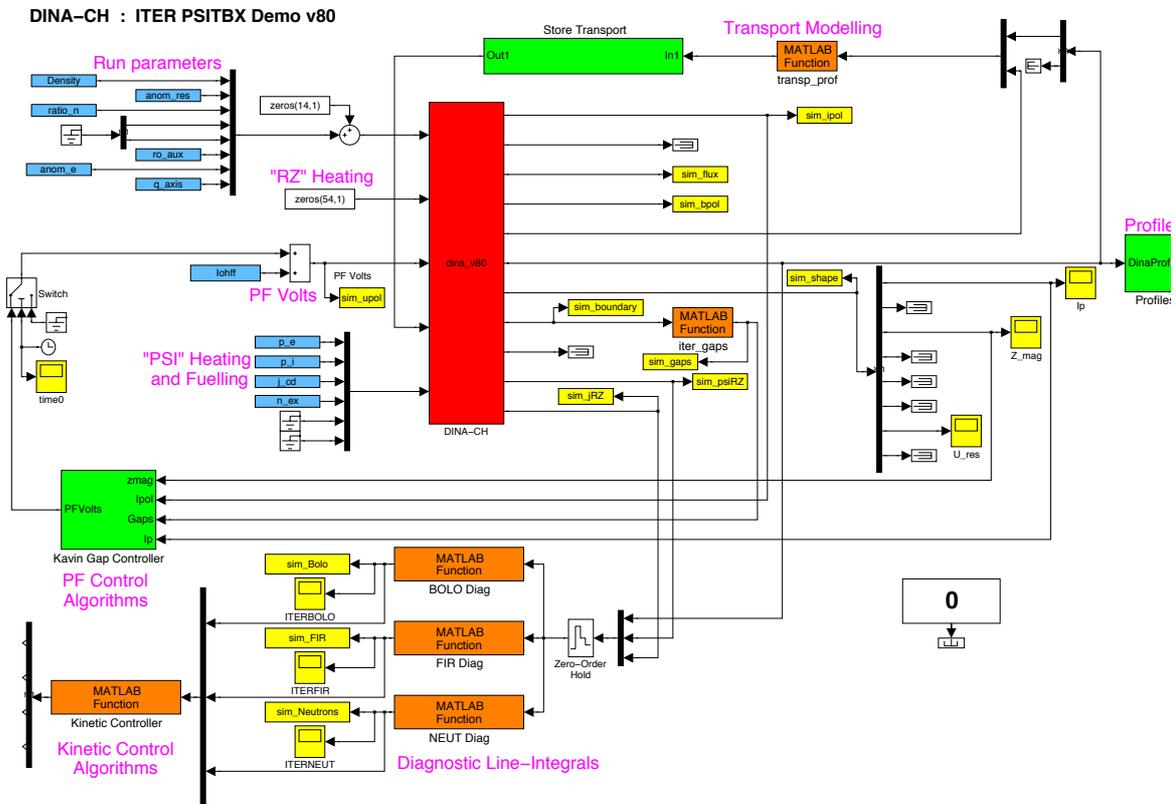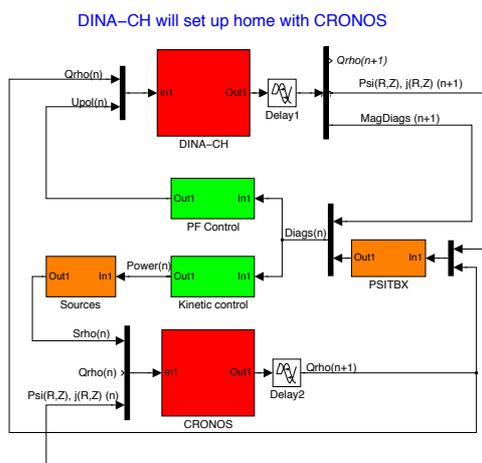

Fig.1 Implementation of the diagnostic toolbox (PSITBX) for simulating two diagnostics in the ITER tokamak.

MPX diagnostic and an interferometer. This step now brings us to the point where we can model the use of diagnostic information to generate kinetic control feedback loops. Figure 1 shows how this diagnostic toolbox is simply connected to the outputs of the DINA-CH code, namely the full profile information and the (R,Z) gridded values of the shifted poloidal flux, zero at the last closed flux surface and the (R,Z) gridded toroidal current. By passing an instruction to a general interface, describing the function of the kinetic parameters, the module returns the chord-by-chord line-integral of this quantity, corresponding to a large class of passive diagnostics. Examples of this function implemented for ITER are "ne" to simulate a FIR interferometer,"1e-44 * ne.^2 .* Te.^1.5" to crudely simulate the soft X-ray signal of a multi-wire proportional chamber. The evolution of the profile can be visualised, or acted upon in a feedback loop, during the simulation. The advantage of this toolbox is that it provides a unique definition of a diagnostic, being a set of chords (defined in a single

initialisation call) and a functional dependence on modelled parameters, of unlimited complexity). Full toroidal geometry and even non-axis3metry are handled by this toolbox which functions inside Matlab under the Linux and IBM AIX operating systems [2].

This interface was simply reproduced for ITER, emulating the bolometry diagnostic design and a schematic interferometer and neutron camera, illustrated in Fig.2. During the simulation, the diagnostic data are available as inputs to a kinetic control algorithm controlling the external power sources, shown in Fig.1. Figure 3 shows a time-slice of these ITER diagnostics during a full simulation.

Fig.4 Illustration of the marriage of two solvers, avoiding the development of monolithic codes and drawing upon the strong features of each.

Most recently, we have implemented the ASDEX-UG tokamak under DINA-CH, with a realistic model of the plasma position and current control and a primitive approximation of the plasma shape control algorithm. The aim is to study the recently reported ELM toggling results in an accompanying paper at this conference [3], reproducing the earlier TCV results [4].

Future orientation: The present strength of the DINA code resides in its extensive use and benchmarking for plasma equilibrium response modelling. The DINA-CH modular implementation in a graphical environment has shown considerable flexibility, once the details of a specific tokamak were removed from the core source, allowing all modelling to advance around a single code. This structure allowed the inclusion of additional heating for TCV, and transport modules to be specified externally as well. However, there remains a wealth of codes describing heating sources and transport available and it is pointless to try and redevelop these physics codes. It is essential to provide a simple method for allowing these codes, which generally function in a 1-D representation for transport and a 2-D representation for heating, to collaborate in full DINA-CH simulations.
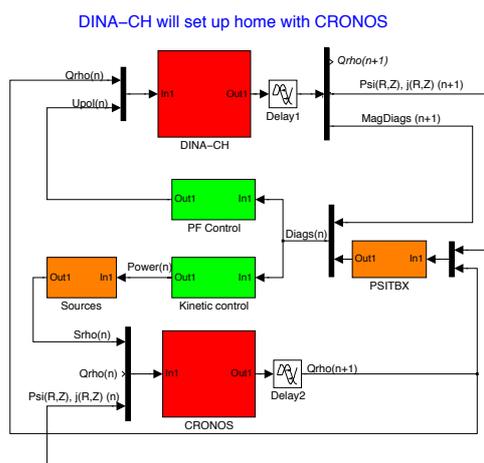
Fig.4 Illustration of the marriage of two solvers, avoiding the development of monolithic codes and drawing upon the strong features of each.

We are therefore presently providing the features to allow the DINA 1.5D solver to evolve in the environment of the Cronos code, and for the Cronos sources and transport modules to be evaluated within the DINA-CH environment, a marriage assisted by both codes already running under Matlab [5]. Modifications are already underway to provide the requisite information from one solver to the other. It is expected that fully integrated simulations of ITER combining the strengths of DINA-CH and Cronos will become available in the near future. Figure 4 illustrates the combination of the two solvers, including the integration of the PSITBX diagnostics package together with the modelling of the sources and the equilibrium and kinetic controllers. We expect this to become a powerful simulation platform, ideal for testing on existing tokamaks and for predictive modelling for ITER.

References

[1] J.B. Lister et al., paper P2.144, this conference

[2] J-M. Moret, private communication http://crppwww.epfl.ch/~moret

[3] Y. Martin et al., paper P4.133, this conference

[4] A.W. Degeling et al., Plasma Physics and Controlled Fusion, 45, 1637 (2003)

[5] Cronos, CEA Cadarache, private communication