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Construction of the European Transport Solver under the European Integrated Tokamak Modelling Task Force

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The goal of the Integrated Tokamak Modelling (ITM) Task Force [1] is to provide the European fusion community with a suite of validated codes for the support of the European fusion program, ultimately, to enable the complete simulation of the discharge in a tokamak like ITER including the core, the edge and the scrape-off layer (tokamak simulator). Such a simulator should adopt a modular approach, when stand alone physics and numeric modules are communicating to each other via standardized interfaces linked with the ITM agreed data structure. These principles are used in the construction of the new European Transport Solver (ETS), prepared to solve 1-D transport equations for the core plasma. Besides of high degree of modularity, the ETS should meet other requirements: ability to treat several ion components, ultimately including all impurity species; ability to

use stiff transport models with reasonable CPU time; clear separation of physics and numeric parts; flexibility in organizing the work flow and clear programming. Although there are several core transport codes used by plasma modelling society, no one of them meets all requirements from above, thus the construction of ETS becomes a high priority task in the European fusion program.

The ETS solves transport equations for the density of current, the density, the temperature and the toroidal rotation velocity of ion components (1:NION), where NION is the number of considered ion species, and the electron temperature. The electron density and flux are estimated from quasi-neutrality conditions. Transport coefficients and sources in all equations are obtained from physics modules coupled to the ETS through the standardized interfaces. To preserve the same physics described by the ETS with various options for numerical solution, physics and numeric parts of the ETS have been decoupled. The physics part evaluates all transport equations adopting the standardised form with nine numerical coefficients, $a(\rho)\ b(\rho)\ c(\rho)\ldots$,

$$\frac{a(\rho)\cdot n(\rho,t)-b(\rho)\cdot n(\rho,t-1)}{h}+\frac{1}{c(\rho)}\frac{\partial}{\partial\rho}\left(-d(\rho)\cdot\frac{\partial n(\rho,t)}{\partial\rho}+e(\rho)\cdot n(\rho,t)\right)=f(\rho)-g(\rho)\cdot n(\rho,t)$$

and with boundary conditions on inner and outer boundary in the form,

$$v(\rho_{bnd})\cdot\left.\frac{\partial n(\rho,t)}{\partial\rho}\right|_{bnd}+u(\rho_{bnd})\cdot n(\rho_{bnd},t)=w(\rho_{bnd})$$

where $n(\rho,t)$ and $n(\rho,t-1)$ are profile of plasma parameter at the current and previous time step. Standardised numerical coefficients are passed to the numerical part, selected by user setting the work flow. At the moment there are several options for numerical solver, extracted from existing codes, COREDIF [2], CRONOS [3] and RITM [4]. The latter is prepared to solve transport equations as in the differential as in the integral form, which is aimed improve the stability for calculations done with stiff transport models.

The schematic view of the ETS is shown in fig.1. The physics part of the ETS receives various quantities, like transport coefficients or sources, from physics modules

using one of generic interfaces. TRANSPORT interface passes profiles of transport coefficients in the form of diffusion coefficient and convective velocity, profiles of parallel electrical conductivity and the ion poloidal velocity. SOURCES interface passes profiles of particle and heat sources in the form of explicit (independent on the variables used in transport equations) and implicit (proportional to the density, temperature and etc.) terms and profile of parallel electrical conductivity.

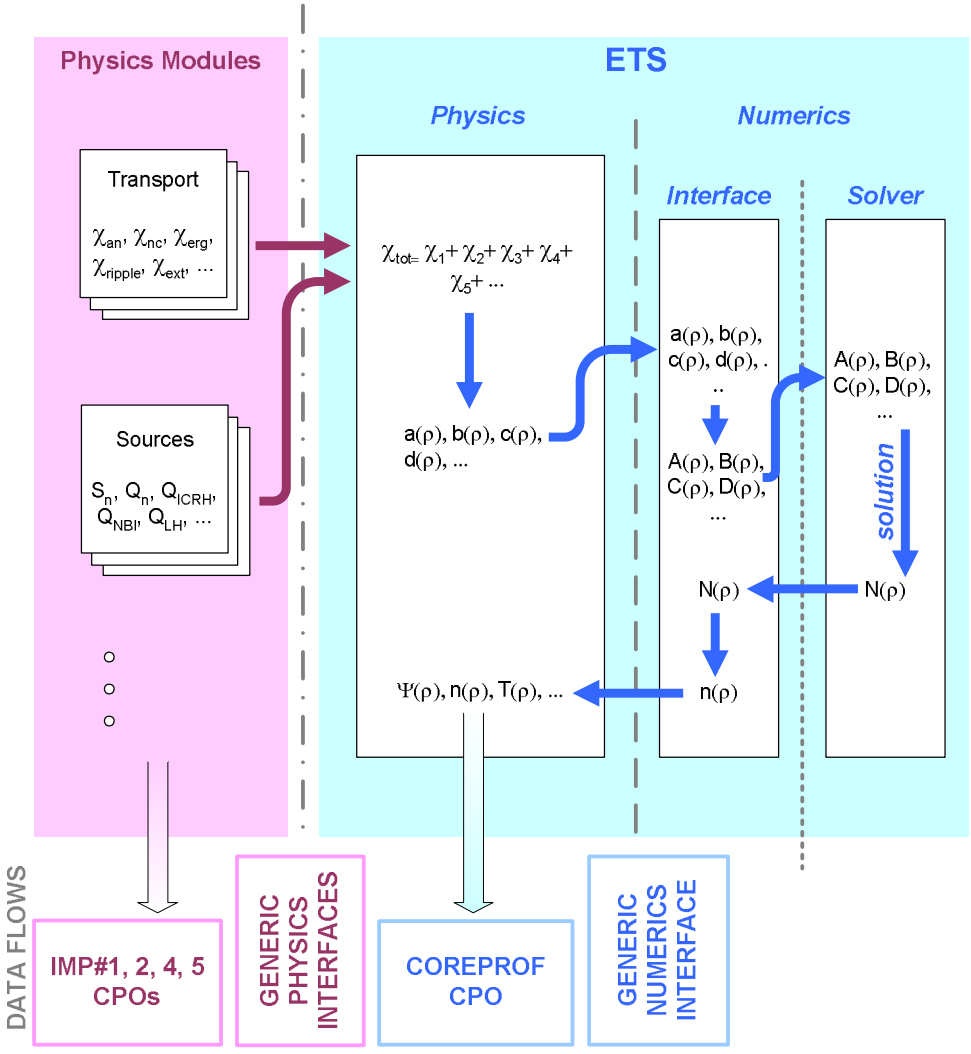

Fig.1 The modular structure and data flows of the European Transport Solver

PROFILE interface passes the instant change of profiles of plasma parameters. It is important to note that, depending on the modelling goal, the same physics module might be coupled to the ETS through the one of these interfaces. For instance, the module for non-linear MHD activity can provide the transport coefficients, or the sources, or the instant change of plasma profiles as an input to the ETS.

Generalised numerical coefficients are derived by the physics part of the ETS, $\chi(\rho)\ S(\rho)\ Q(\rho)\ldots \rightarrow a(\rho)\ b(\rho)\ c(\rho)\ldots$, and passes through the generic interface to the numeric part. Since different numerical solvers are used with ETS, the interface in the numeric part translates generalised coefficients to internal coefficients used by the particular solver, $a(\rho)\ b(\rho)\ c(\rho)\ldots \rightarrow A(\rho)\ B(\rho)\ C(\rho)\ldots$ In some cases the variable used by numerical solver is different from the one in physics equation. For instance the solution for the total number of particles, $N(\rho)$, within a certain flux surface in stead of density of particles, $n(\rho)$, at this flux surface can be the output of numeric solver. In this case, a translation back to the quantity required by physics part is done, $N(\rho)\ldots \rightarrow n(\rho)$. The new plasma state is saved in to the COREPROF data structure (called Consistent Physical Object or CPO [5]) and passed in memory to attached physics modules to update the equilibrium, sources and transport coefficients. When the converged solution for the new time step is found, the ETS stops and the COREPROF CPO is saved to disc.

The ETS has a well defined modular structure, allowing for easy integration of newly developed modules and providing the flexibility in organising the work flow in the most efficient way. It has a number of numeric solvers attached to it, that the user can treat the non-linearity of the system with the appropriate numerics. The further development of the ETS will consist of preparation of various physics modules and coupling them through standardized interfaces to the physics part of the ETS.

[1] http://www.efda-taskforce-itm.org/

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