

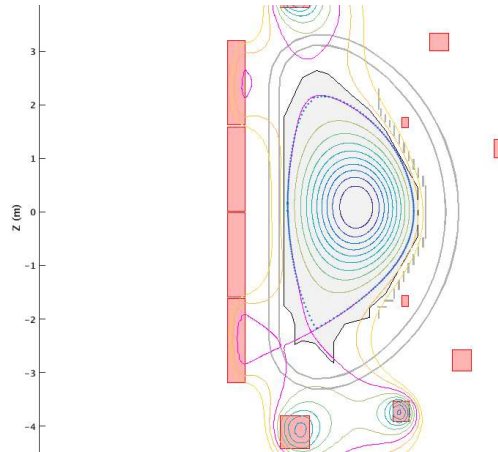
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WPSA JT-60SA DISCHARGE SIMULATOR STATUS AND PROGRESS



Jean-François Artaud on the behalf of discharge simulator team

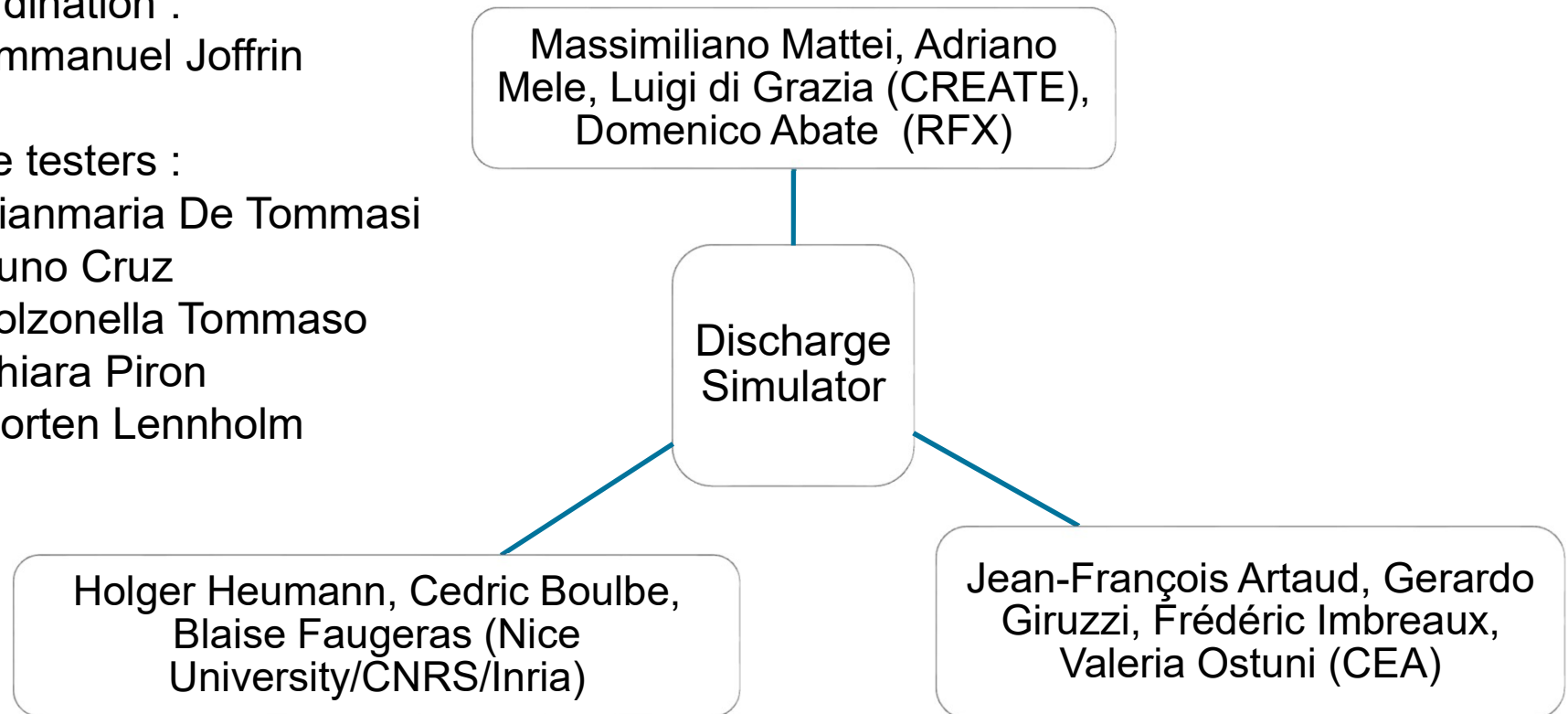
04/02/2020

Coordination :

- Emmanuel Joffrin

Code testers :

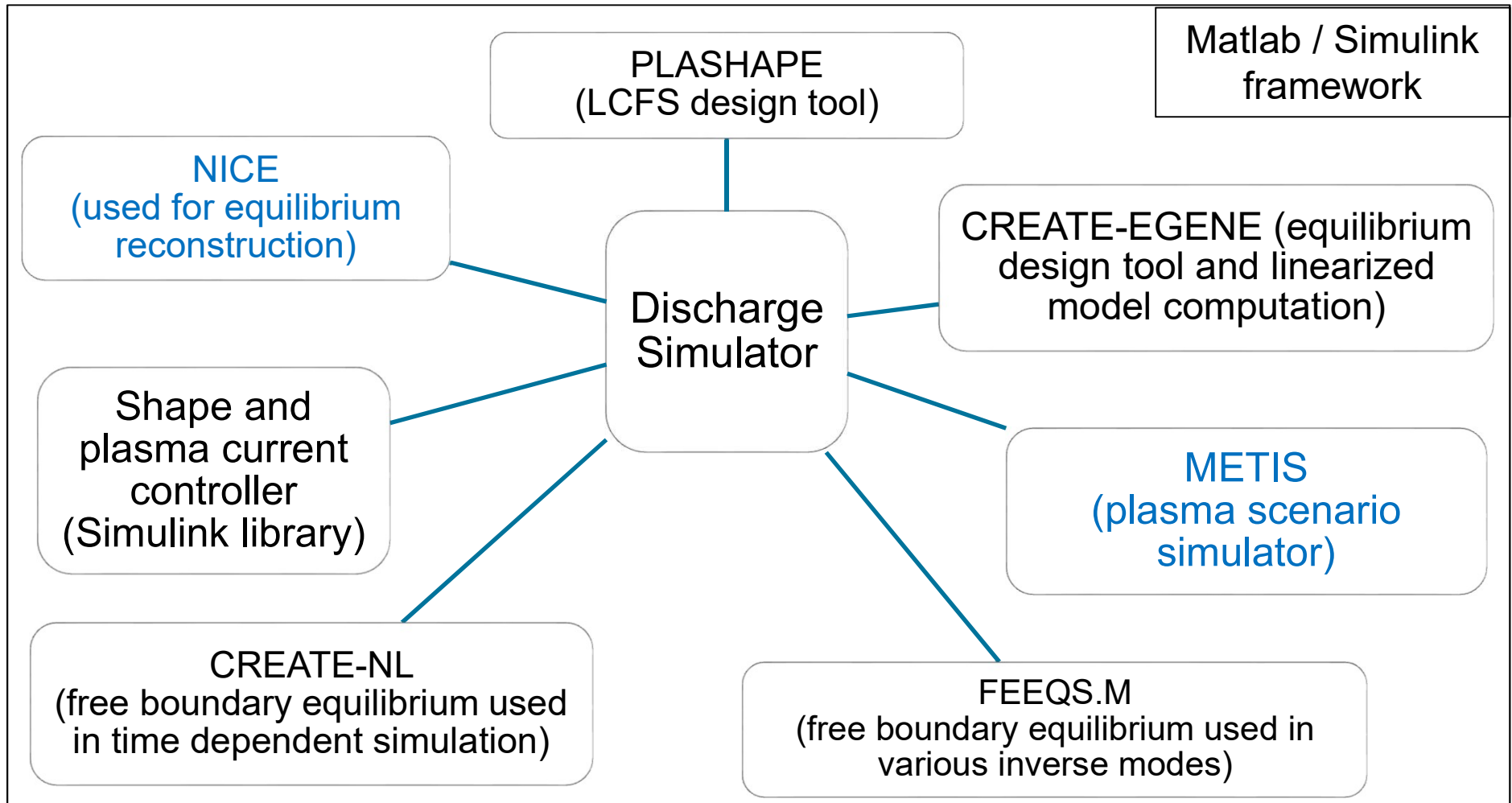
- Gianmaria De Tommasi
- Nuno Cruz
- Bolzonella Tommaso
- Chiara Piron
- Morten Lennholm



Funding and support :

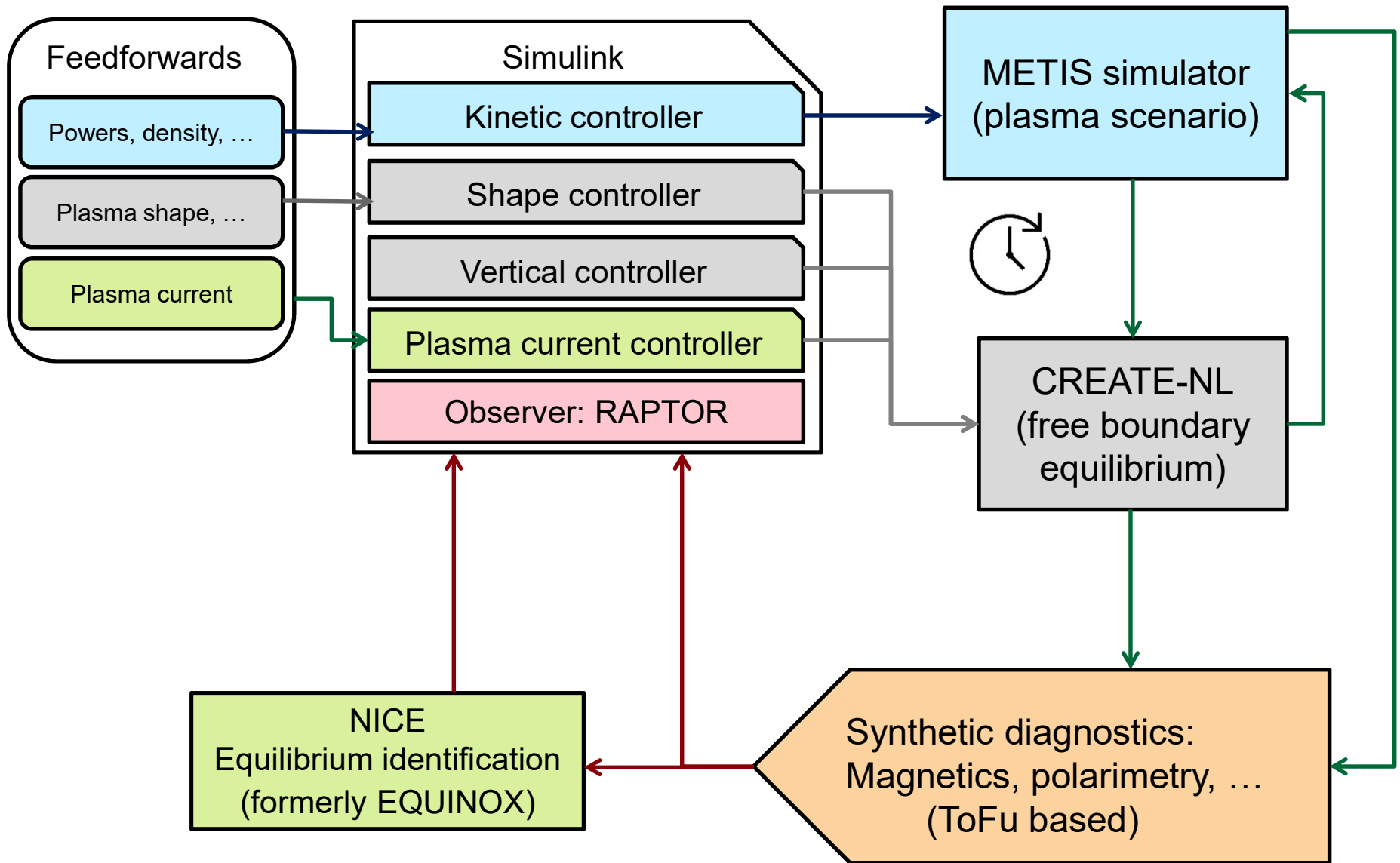
- F4E (Mario Cavinato, Filippo Sartori)
- EUROfusion (WPSA & WPCD)

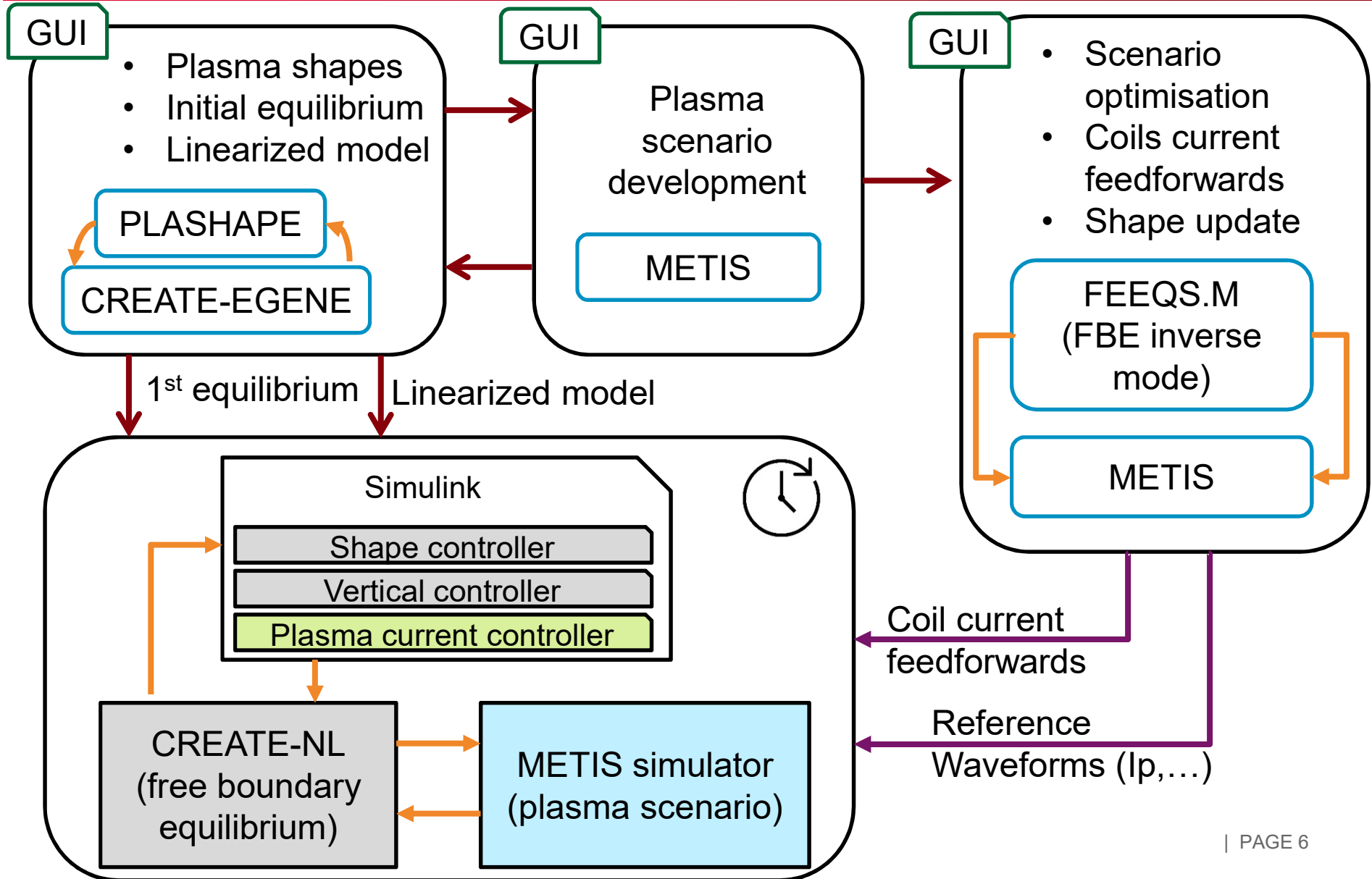
- Discharge simulator:
 - Prepare JT-60SA experiments
 - Assess feasibility of the scenario
 - Optimize scenario
 - Analyze JT-60SA experiment (when data will be available)
- Input:
 - Targeted plasma parameters (from research plan, ...)
 - JT-60SA measurements (when data will be available)
- Output:
 - Plasma reference waveforms (I_p , n_{bar} , P_{NBI} , ...)
 - Plasma shape snapshots
 - Coil currents feedforwards
 - Models for the position and current controller



In blue: code interfaced with IMAS

DISCHARGE SIMULATOR: FULL DISCHARGE WORKFLOW





Plasma shape design with Plashape tool

The screenshot shows the Plashape tool interface. At the top, it says "Status" and "Move the shape or choose another action." The main area is a 2D plot with axes from -4 to 4 on the y-axis and 0 to 6 on the x-axis. It displays several red and blue closed curves representing plasma shapes. To the left of the plot is a "View Tools" panel with icons for zoom, pan, and grid. Below that is a "Xp rotation (d/μ)" panel with two vertical sliders, both set to 30°. At the bottom left are three input fields for "z translation", "r translation", and "Shape rotation", each with a value of 0. To the right of the plot is an "Action" panel with buttons: "New", "Load", "BG snapshot", "BG equil", "Clear BG", "Lim point", "CREATE-EGENE", ".....", "Save", "CNL go", and "Home". Several callout boxes with arrows point to specific features: "View manager" points to the View Tools panel; "Interactive shape plot" points to the main plot; "Change the X point angle" points to the Xp rotation sliders; "Shape traslation and rotation" points to the bottom input fields; "Insert new shape by points" points to the "New" button; "Load a previuos built shape" points to the "Load" button; and "Run Fixed Buondary Equilibrium" points to the "Run Fixed Buondary Equilibrium" button.

Tool to prepare or import shape sequences and compute freeboundary equilibria in view of equilibrium current calculation



CREATE



Main GUI CREATE-EGENE

CREATE EGENE

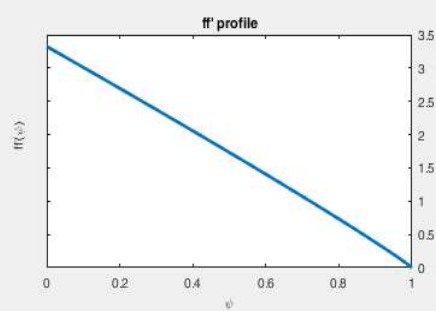
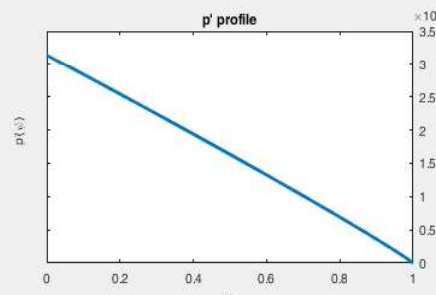
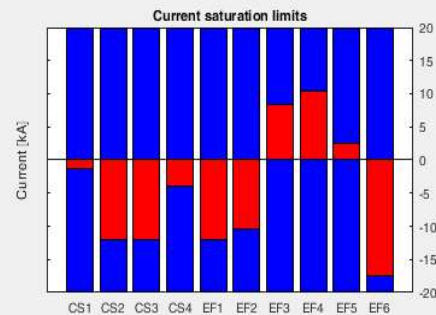
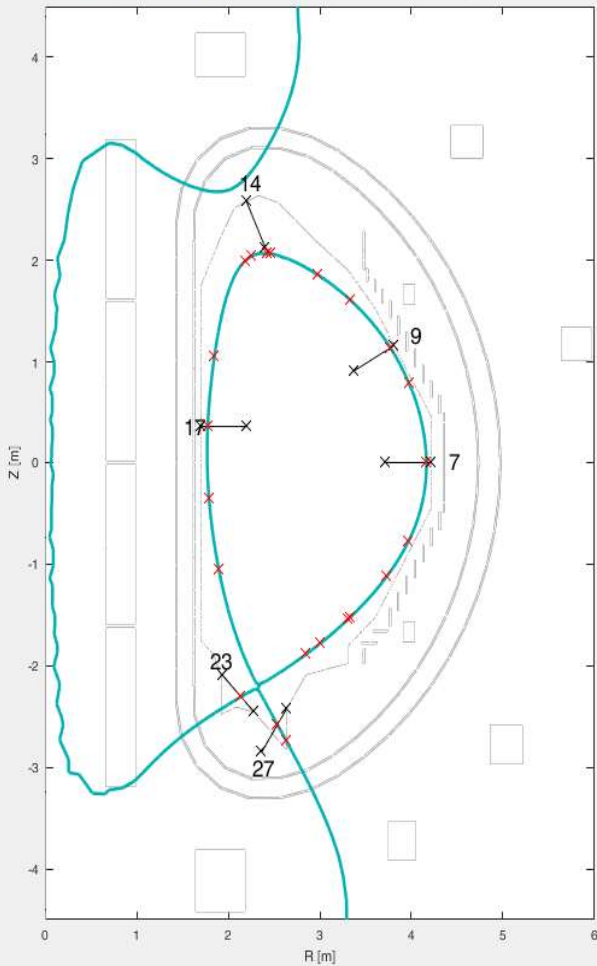
File Settings Actions



Equilibrium file: default_equil.mat

Linearization: CREATE-NL

Linearization wrt Eddy Currents



CREATE

- Gap 7
- Gap 9
- Gap 14
- Gap 17
- Gap 23
- Gap 27

	Value[kA]	Lock
CS1	-1.3997	<input type="checkbox"/>
CS2	-12.0590	<input type="checkbox"/>
CS3	-11.9270	<input type="checkbox"/>
CS4	-3.9035	<input type="checkbox"/>
EF1	-12.0610	<input type="checkbox"/>
EF2	-10.3280	<input type="checkbox"/>
EF3	8.3397	<input type="checkbox"/>
EF4	10.4740	<input type="checkbox"/>
EF5	2.4518	<input type="checkbox"/>
EF6	-17.4480	<input type="checkbox"/>

	Value
betap	0.5296
li	0.8494

- Plasma current [MA]
- Flux at Boundary [Wb/rad]
-
-

■ 2 next presentations :

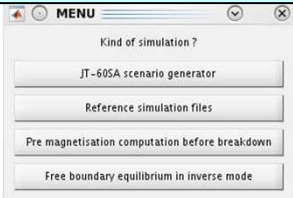
- CREATE-EGENE tutorial and simulations of scenario 2

by Adriano Mele

- CREATE-EGENE simulations of scenario 4.2

by Domenico Abate

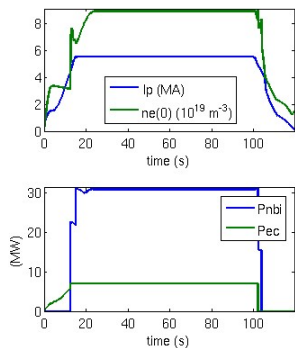
Data source



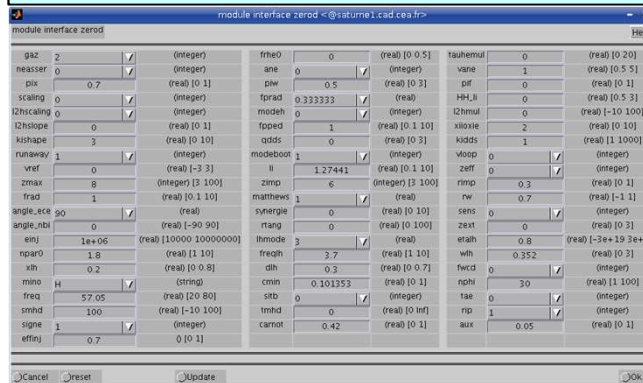
Scenario choice



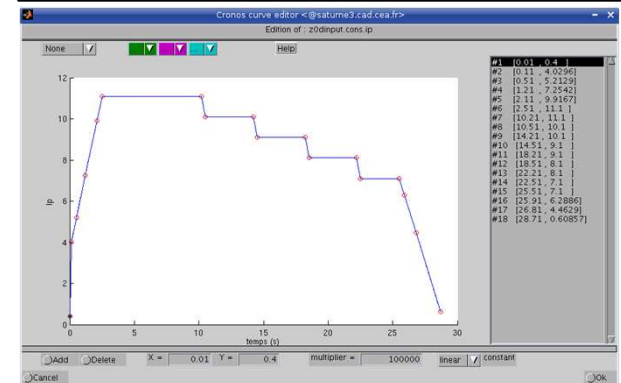
Visualisation



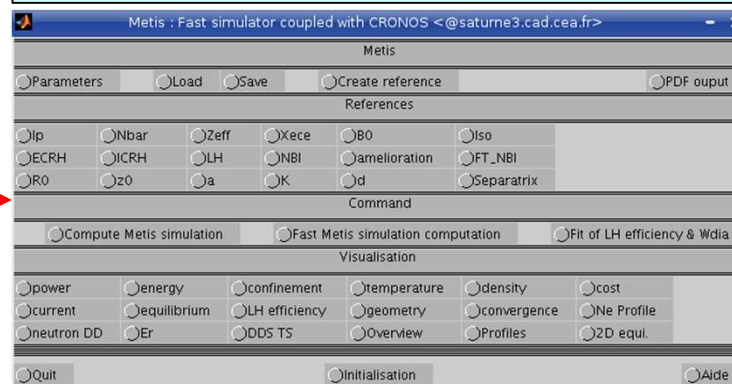
Parameters



References



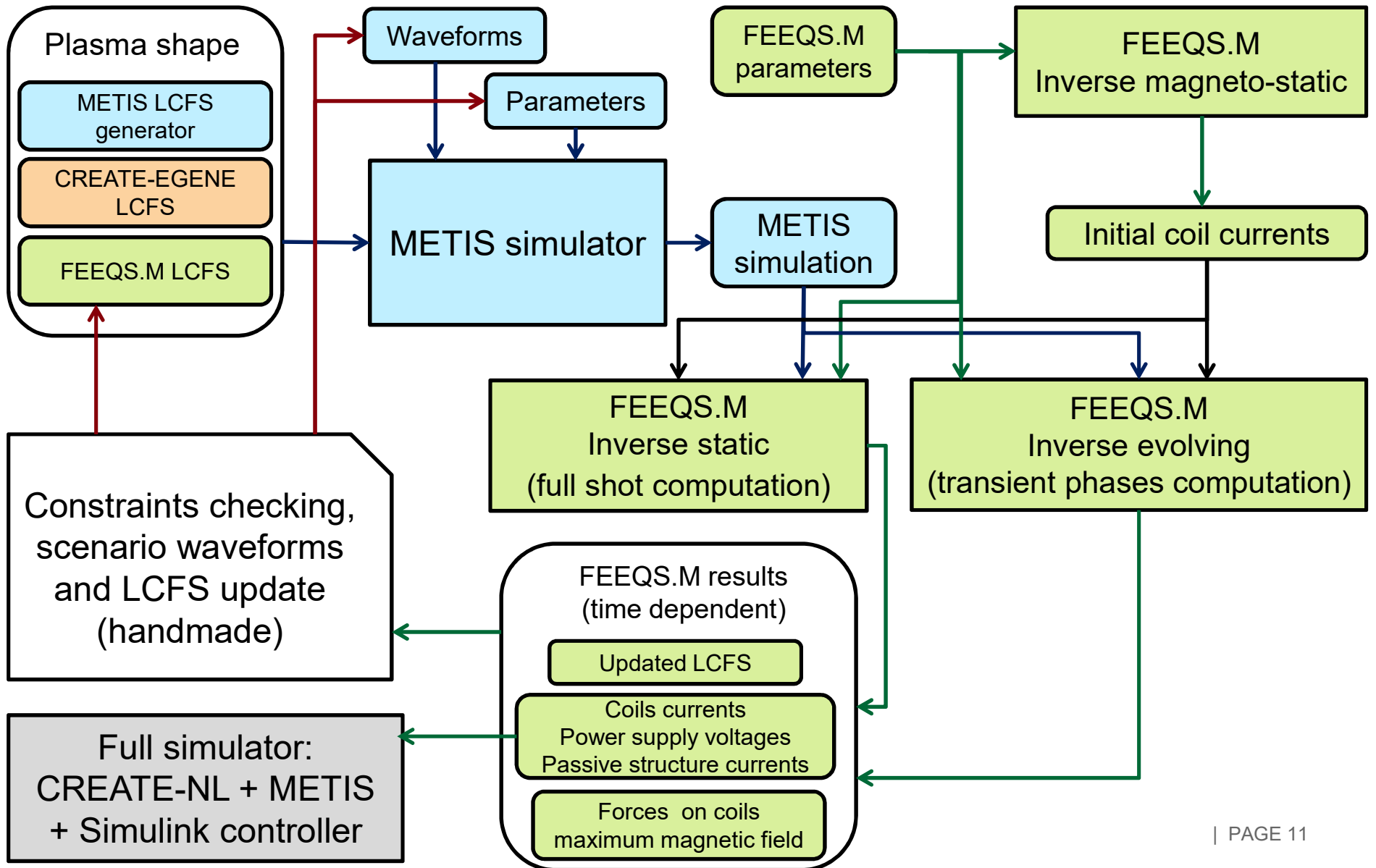
METIS : main interface



Run (~ 1mn)

Export to database

Results



- METIS +FEEQS tool has been validated & benchmarked
 - a bug in the coupling between codes has been solved
 - optimization method has been improved to prevent non optimal solutions (current dipole).
- The tool is now user friendly and available for any user
 - FEEQS.M is now under GPL v3 license
- Next presentation :
 - JT-60SA tokamak scenario optimization with METIS & FEEQS by Valeria Ostuni.

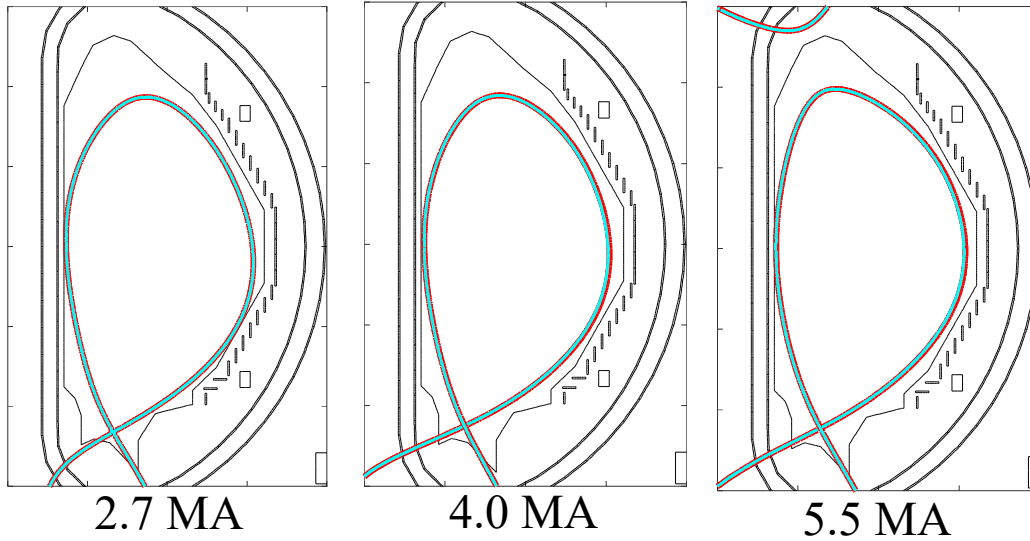
- Time dependent simulations with CREATE-NL coupled to METIS with a Simulink controller:
 - Dedicated to transient phase study (ramp-up, ramp-down, X-point formation, L to H and H to L transition, perturbation mitigation, ...)
- Two possible modes:
 - Weak coupling (faster and more stable but but only I_p , β_p & l_i exchanged)
 - Strong coupling (slower and less stable: P' and FF' exchanged)
- Work in progress:
 - Ramp-up case start to run correctly
 - Feedback control has to be adjusted for each scenario
 - Not yet user friendly (still tool for experts)
 - No GUI
- Luigi di Grazia working on this task ⇒ rapid progresses



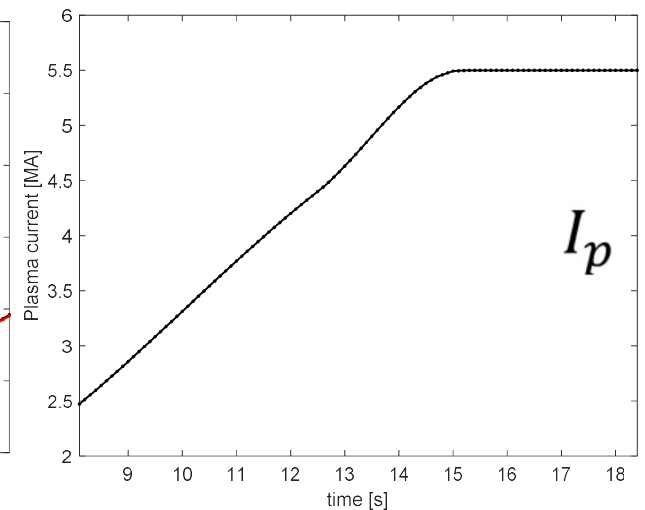
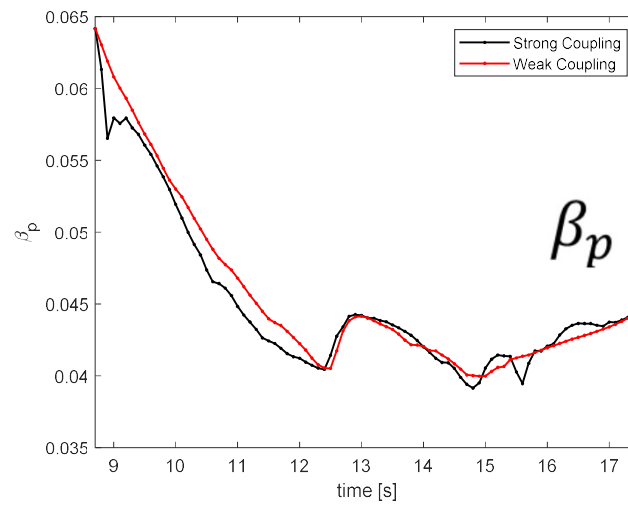
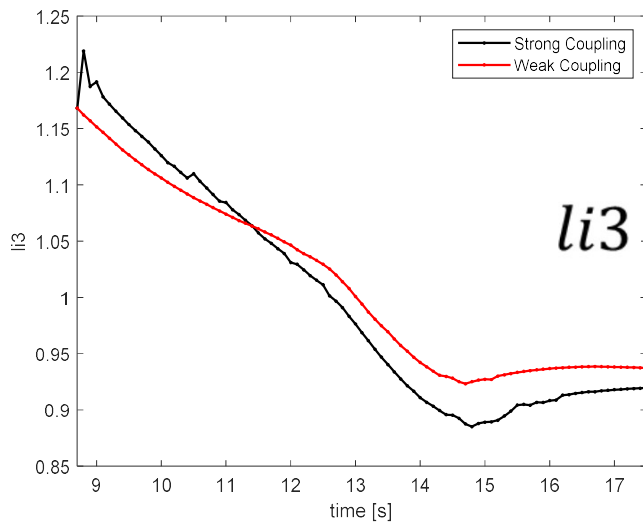
Latest developments

- Shape Tool (Plashape)
 - Algorithm based on splines to produce a sequence of plasma shapes to be used for scenario simulations
 - User interface to produce diverted, limited, double null plasma shapes
- Equilibrium currents calculation
 - Set of functions to acquire shape sequences from Plashape and waveforms of I_p , profile parameters (ff' and p' or poloidal beta and I_i), flux consumption and compute equilibrium currents and voltages for free boundary equilibria
- Strong coupling METIS-CREATENL
 - Coupling still diverging after a while.
 - Review of the interaction scheme (definition of the interaction variables, numerical integration scheme,...)
 - Test of new scenarios. Now ohmic Scenario is under testing

Strong and Weak Coupled simulations comparison for Ohmic Scenario



- Red line: Weak Coupled simulation
- Cyan line: Strong Coupled simulation

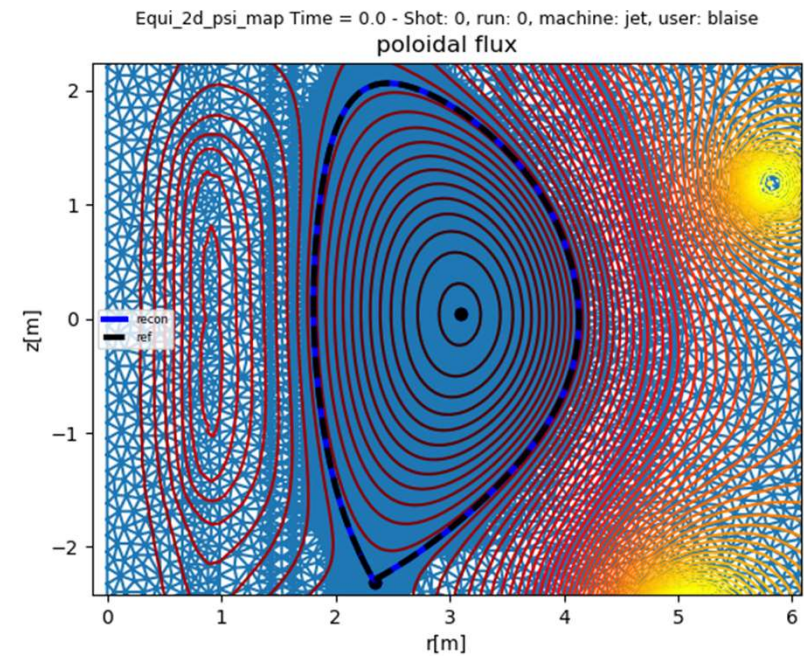
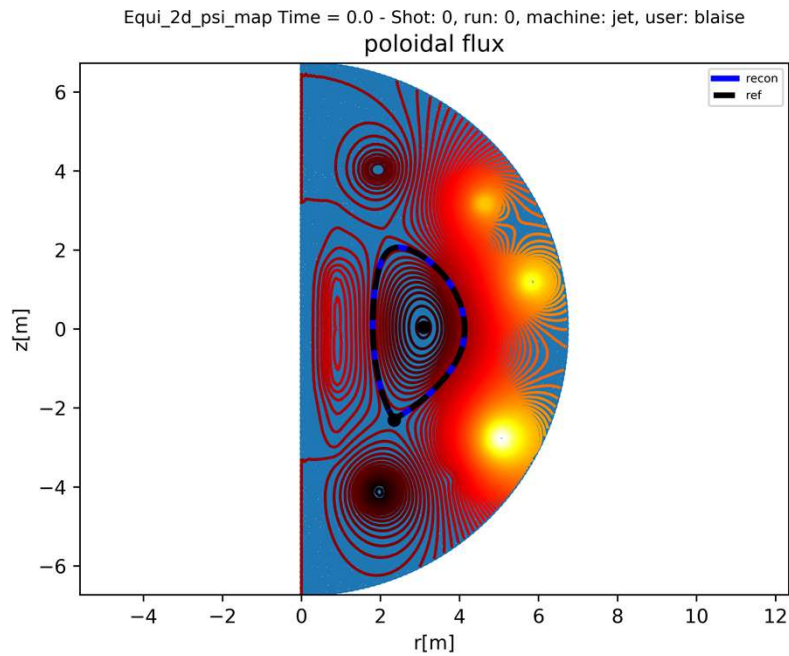


- NICE code as been adapted to JT-60SA :
 - JT-60SA machine description has been added
 - optimized 2D mesh has been created
 - Magnetic probes and flux loops description has been added

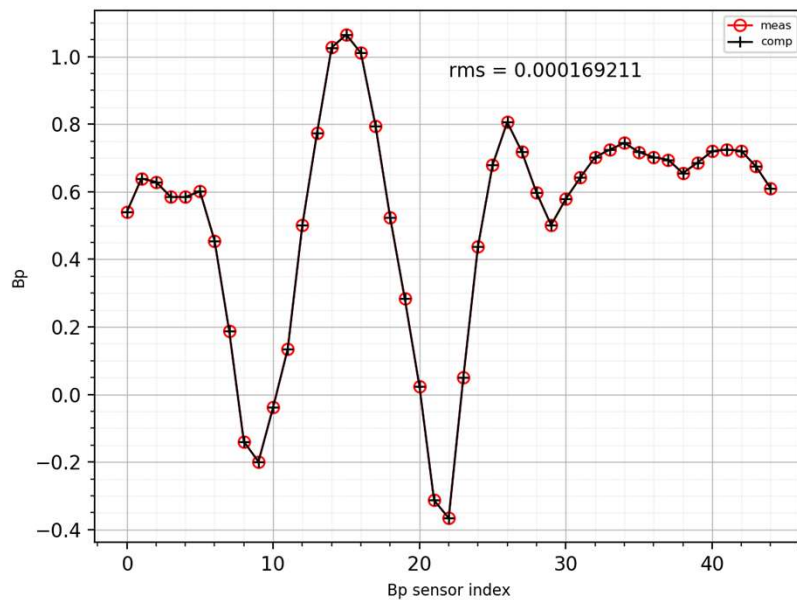
- NICE code can be used for equilibrium identification / reconstruction
 - Full domain mode
 - Inside magnetic probes contour (not sensitive to error in coil current measurements and not sensitive to currents in passive structures outside magnetic probes contour)
 - Already widely used for JET and WEST equilibrium reconstruction

- Reconstruction test:
 - use of synthetic data generated from NICE/FEEQS equilibrium

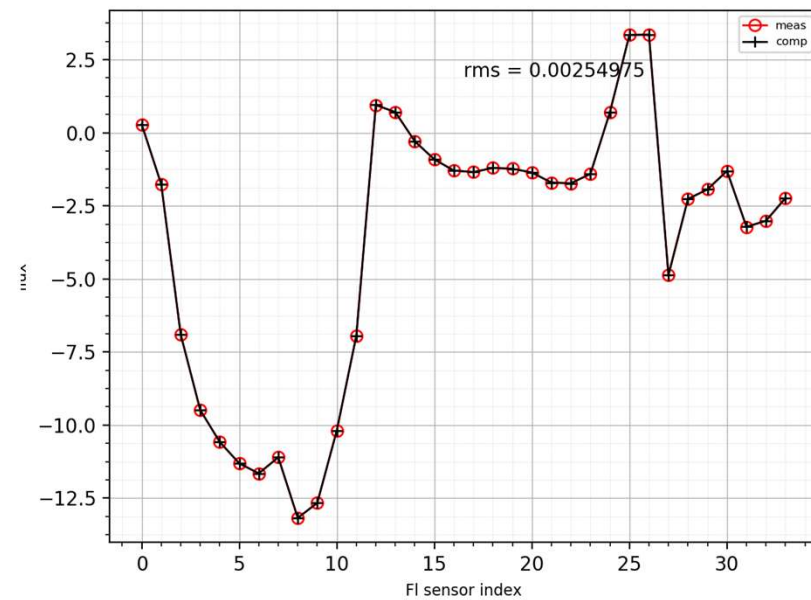
equilibrium reconstruction with comparison of initial and identified LCFS



Measurements matching (without noise):

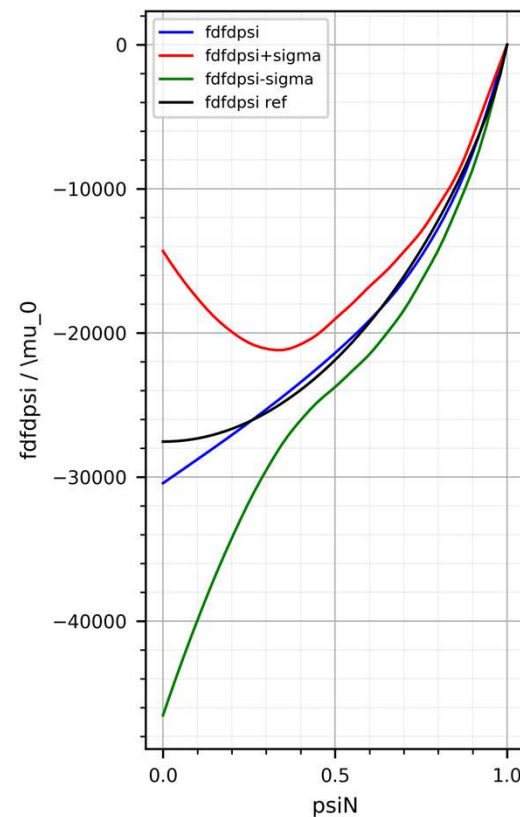
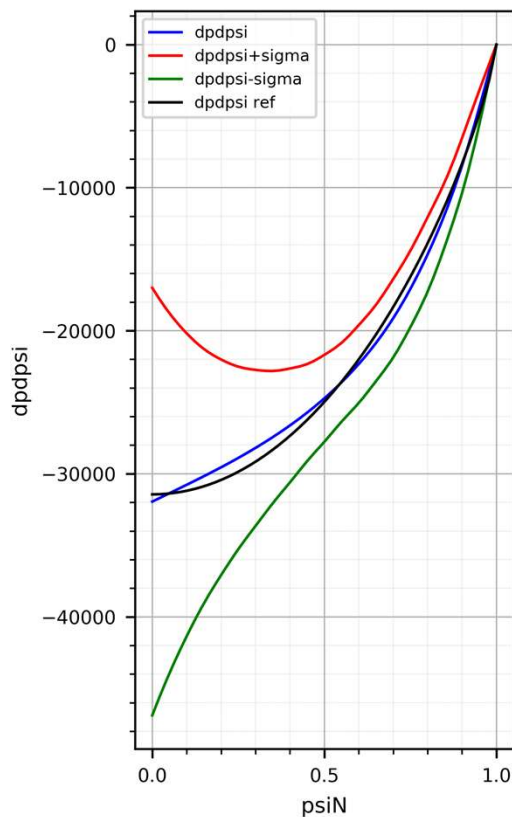


Magnetic probes



Flux loop

Profiles identification (magnetic measurements alone):

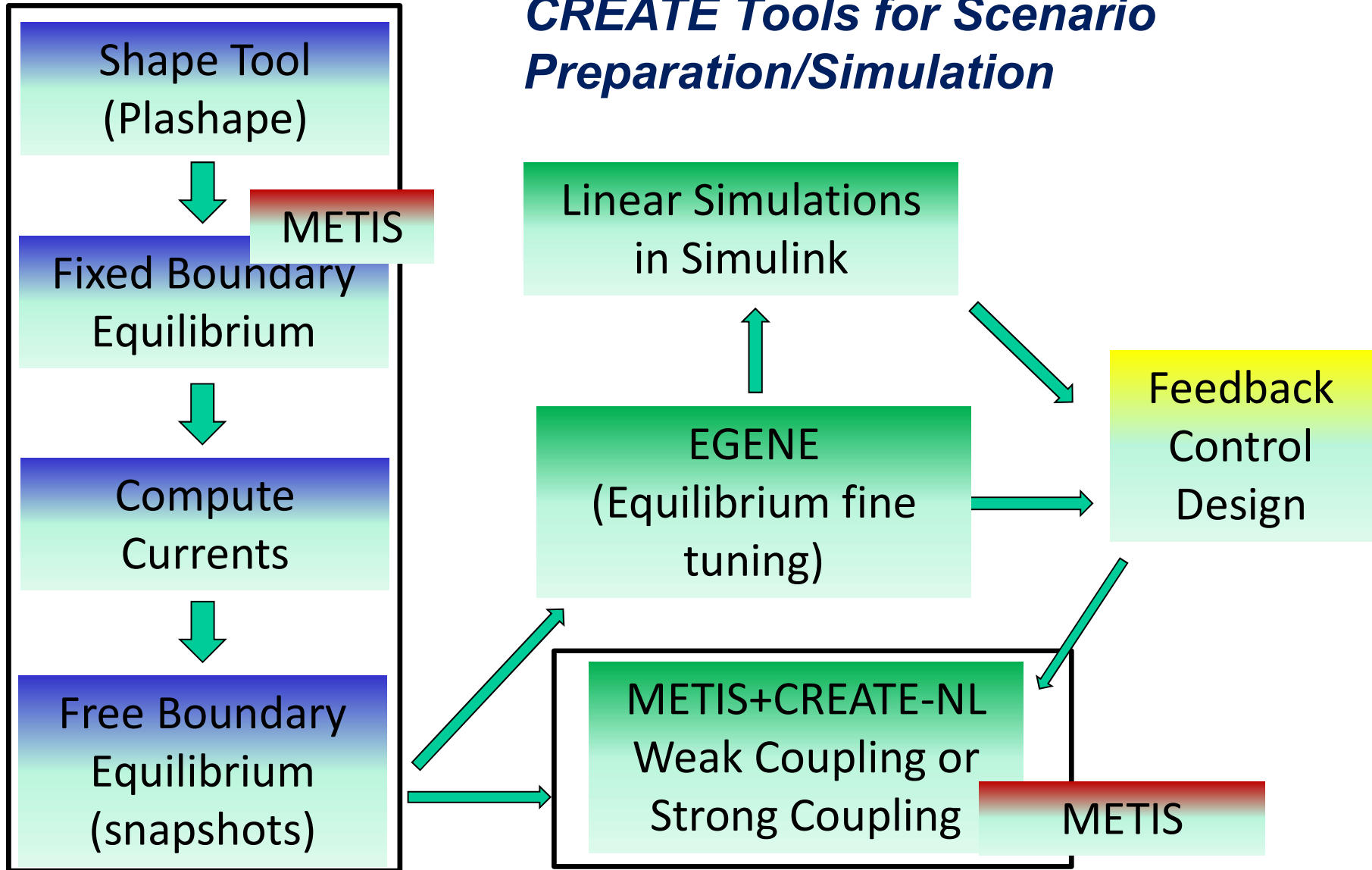


- Scenario development tools (PLASHAPE/CREATE-EGENE & METIS) are available → **users are welcome to used it**
(One year later, there is still some concerns to install it on IM gateway ...)
- Scenario optimization tool (based on METIS and FEEQS.M) is available for all users:
 - Integration with METIS has been finished
 - Use of FEEQS.M has been made user friendly
 - Codes coupling has been validated and benchmarked
 - FEEQS.M has been released under GPL v3 license
- Full simulator (CREATE-NL + METIS + Simulink controller)
 - Large progresses have been done
 - Ramp-up simulation start to work fine
 - Work will continue

- Documentation of optimization tools
- Preparation of JT-60SA early scenarios (reduce field, current, power, density, ...) → **planned but not done**
- Tests by users of the tools → **problems on IM gateway have still to be solved**
- Work to develop the full simulator (CREATE-NL + METIS + Simulink controller) continue.
- Try to improved computation time of full simulator
- Benchmark of passive structure model between CREATE-NL and FEEQS.M/NICE
- Complete the workflow: add synthetic diagnostics (magnetic, polarimetry, ...) and identification equilibrium code NICE in the workflow
- Later: training of future session leaders and scientific coordinators
- JT-60SA data access to compare experiments and simulations

BACKUP SLIDES

CREATE Tools for Scenario Preparation/Simulation



WHO WILL USE THESE TOOLS ?

- METIS and CREATE-EGENE:
 - Easy and fast to run (user friendly GUI)
 - Available for EU physicists
 - Well documented

- FEEQS.M code in inverse evolution mode:
 - Now quite user friendly
 - More expert tool, but can be used by any with some training

- Coupled simulation with CREATE-NL + METIS:
 - Not yet a user friendly tool
 - requests more development for :
 - GUI, configuration set, pre-tune controller, documentation, ...
 - Need some expertise level (in particular for controller tuning)

- Metis: a fast integrated tokamak modelling tool for scenario design, J.F. Artaud et al 2018 Nucl. Fusion 58 105001.
- Quasi-static free-boundary equilibrium of toroidal plasma with CEDRES++: Computational methods and applications, H. Heumann et al, J. Plasma Physics (2015), vol. 81, 905810301 , doi:10.1017/S0022377814001251.
- Equilibrium reconstruction at JET using Stokes model for polarimetry, Blaise Faugeras et al 2018 Nucl. Fusion 58 106032 .
- JT-60SA Research Plan, Research Objectives and Strategy, Version 3.3, 2016, March: JT-60SA Research Unit (http://www.jt60sa.org/pdfs/JT-60SA_Res_Plan.pdf)
- <https://idm.f4e.europa.eu/Portal/Pages/ContentView.aspx?uid=2AAZGM>
- H. Urano et al, Fusion Engineering and Design 100 (2015) 345–356
- T Wakatsuki et al, Plasma Phys. Control. Fusion 57 (2015) 065005 (12pp)

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