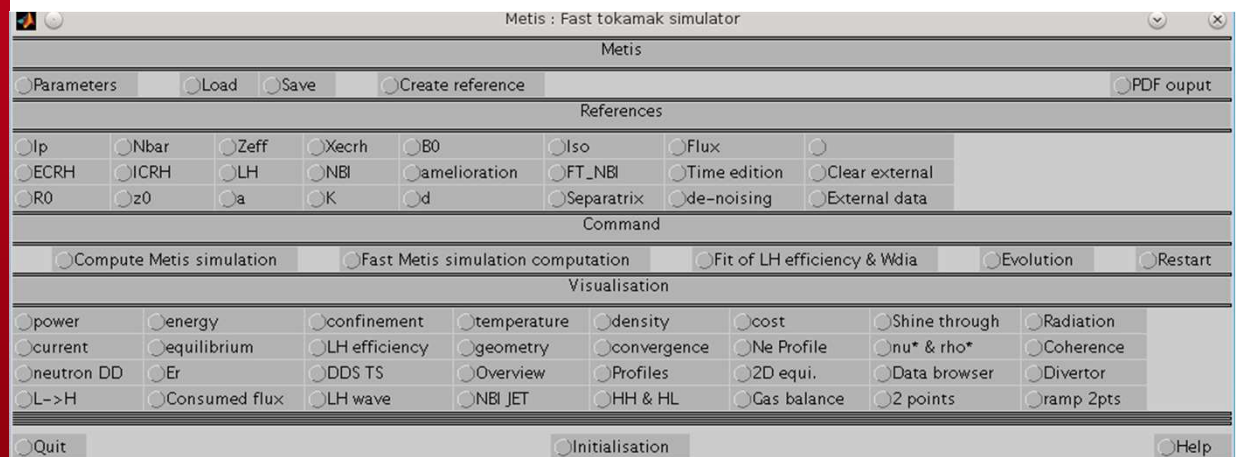


DE LA RECHERCHE À L'INDUSTRIE



www.cea.fr

HOWTO METIS



Introduction to METIS | Jean-François Artaud

MARDI 25 JUIN 2013

- The goal of this training is to learn how to run METIS :
 - Connected to Tore Supra and JET database
 - Compiled or inside Matlab
 - Inside Simulink

- Explains what METIS is but does not provide a detailed training on METIS Physics applications:
 - Only practice is useful
 - Manual
 - Study of a real case
 - Direct support in each case

METIS overview

METIS standalone

Inside METIS

Use METIS with GUI

Advanced METIS features

METIS in Simulink

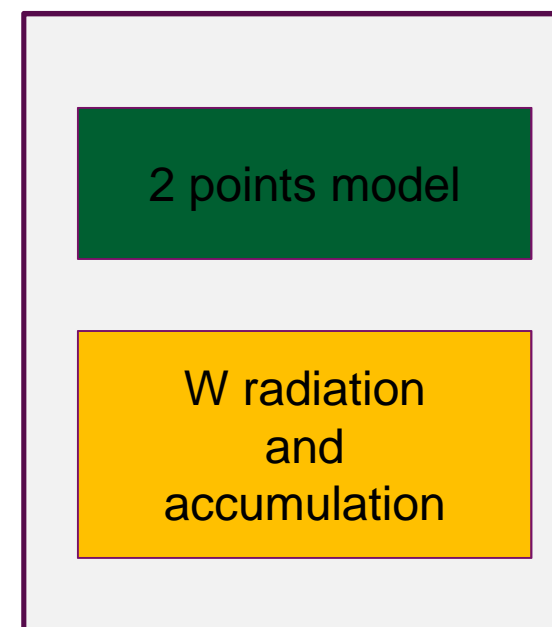
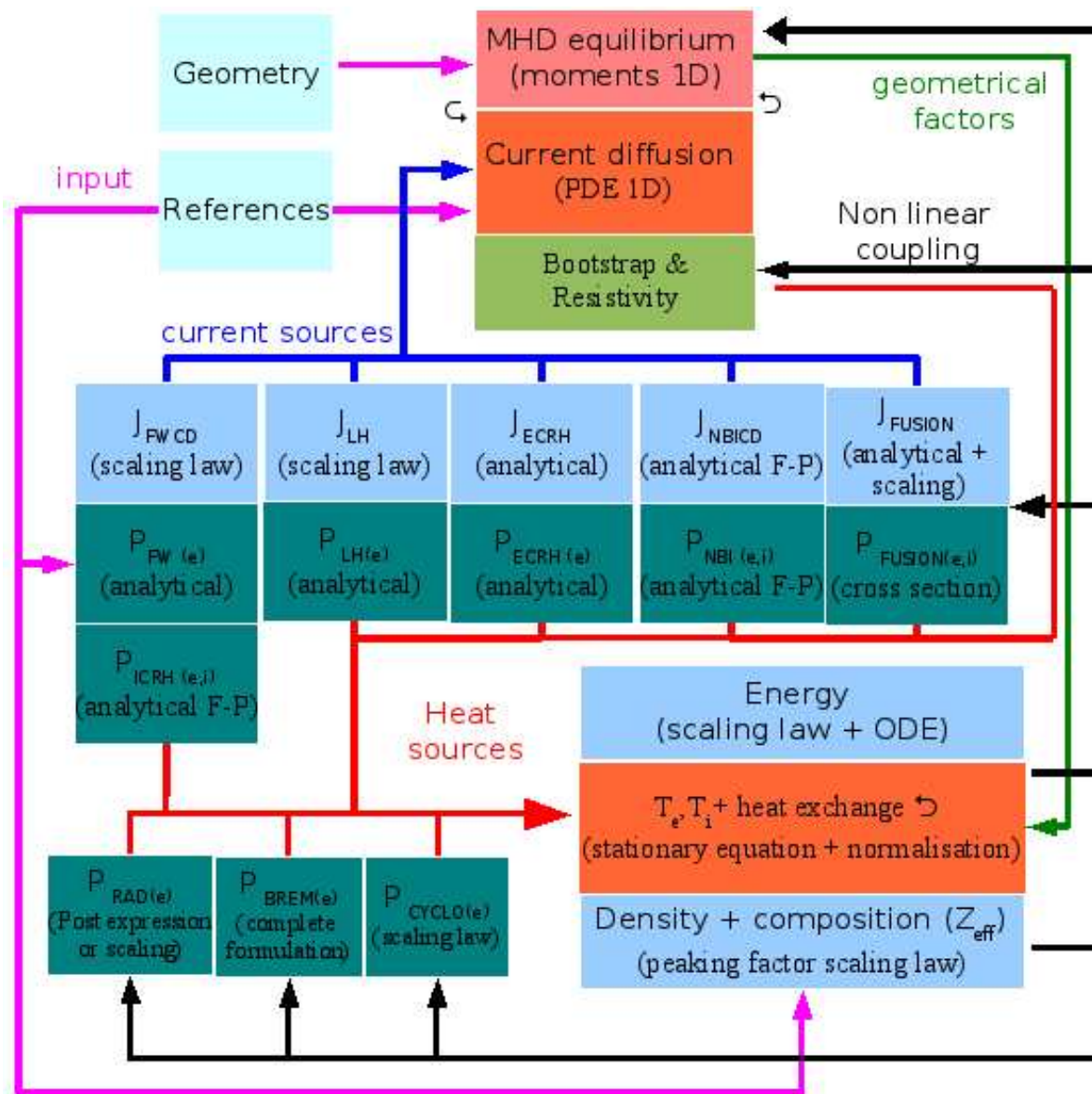
List of Parameters

METIS OVERVIEW

- **METIS is an fast Integrated Transport Code with simplified assumptions**
- **All parameters of an ITER discharge calculated in 1 minute (300 time slices)**
- **Design for**
 - **Scenario Design**
 - **Flight Simulator**
 - **First analysis of a discharge**
- **Mixture of 0D and 1.5D equations**
- **Highly convergent computing scheme**
- **Originally part of CRONOS**

- ✓ **Mixed 1D and 0D equations**
 - ✓ **Current diffusion 1.5D with moment equilibrium**
 - ✓ **Source profiles deduced from simple models**
 - ✓ **Global energy content from 0D ODE (scaling, transients)**
 - ✓ **Temperature profiles : stationary 1D solution, χ scaled to W_{th}**
 - ✓ **All non-linearities solved (dependence of sources on profiles, fusion power, He ash transport)**
 - ✓ **Bootstrap and resistivity : O. Sauter et al, Phys. Plasmas 6 (1999) 2834**
- ✓ **Input : Power references, I_p , plasma density, Z_{eff} , LCMS geometry**
- **Output : all standard 1D and 0D data that you would expect from a transport code**
- **Global time convergence (wave form relaxation)**

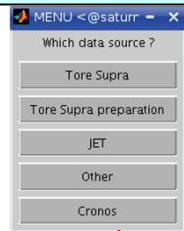
- Connected to Tore Supra, JET, DIII-D and ITM databases
- Existing tokamaks simulations:
Tore Supra, JET, DIII-D, SST1, EAST, KSTAR, ...
- Future tokamaks : WEST, FAST, JT60-SA, ITER, DEMOs, ...



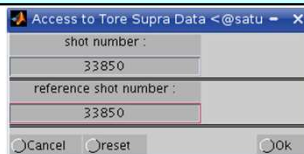
Flux, ...

Boundaries conditions,
density, Prad

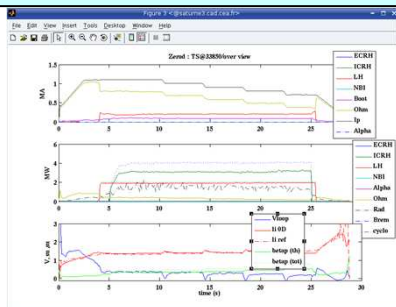
Data source



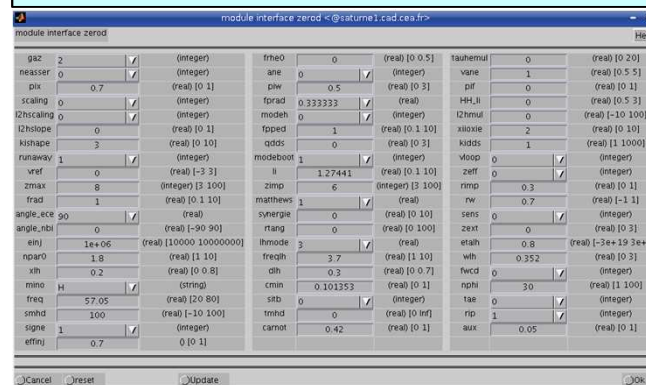
Shot choice



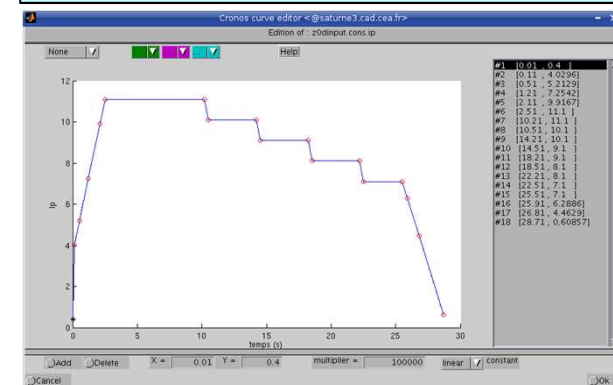
Visualisation



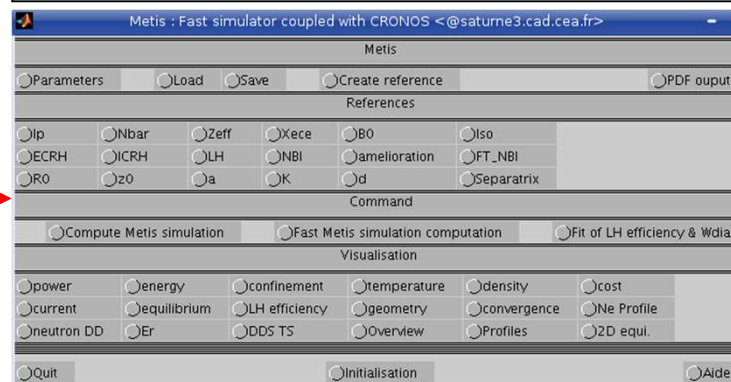
Parameters



References



METIS : main interface

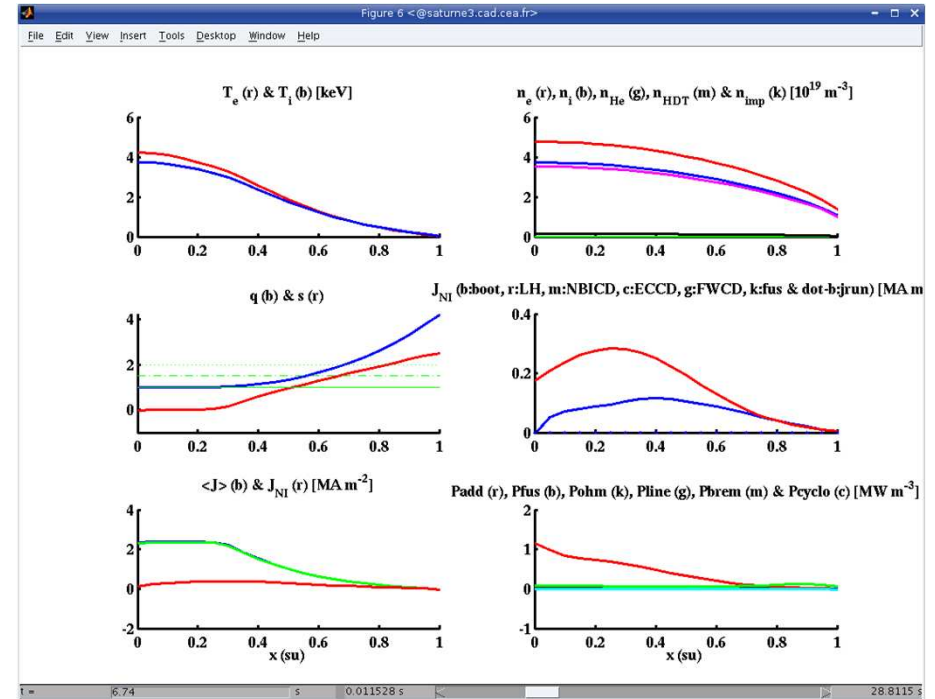
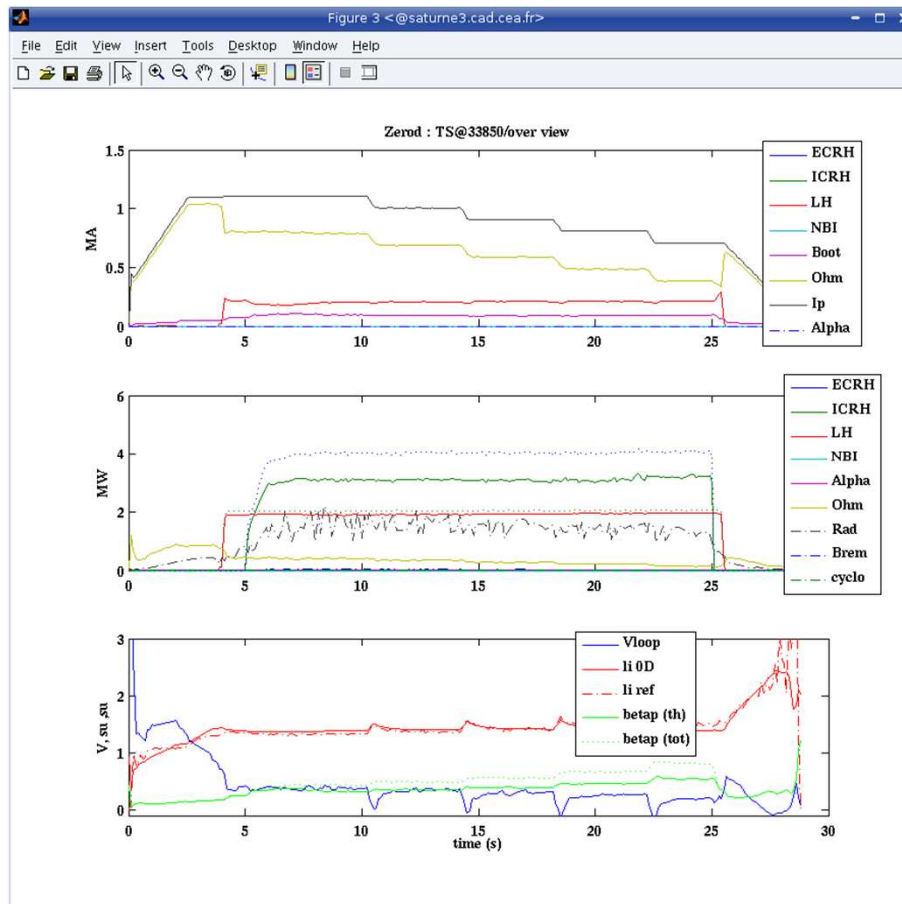


**Run
(~ 1mn)**

**Export to
database**

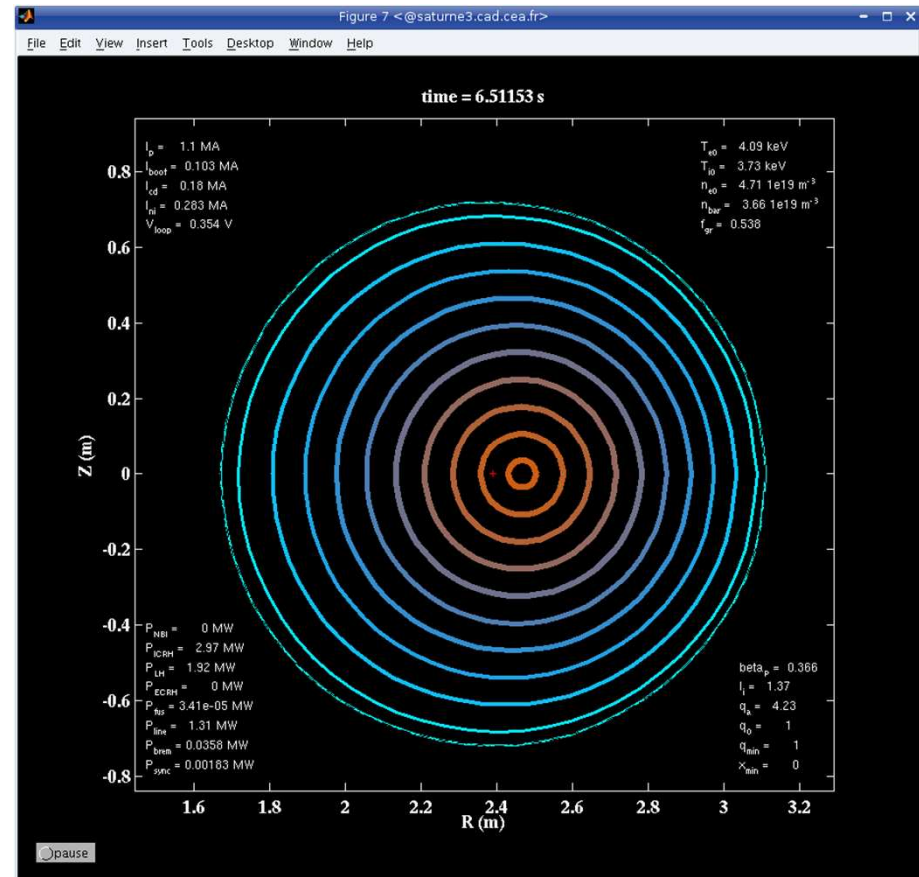
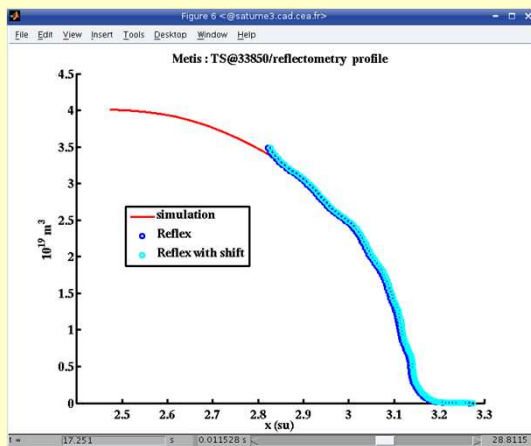
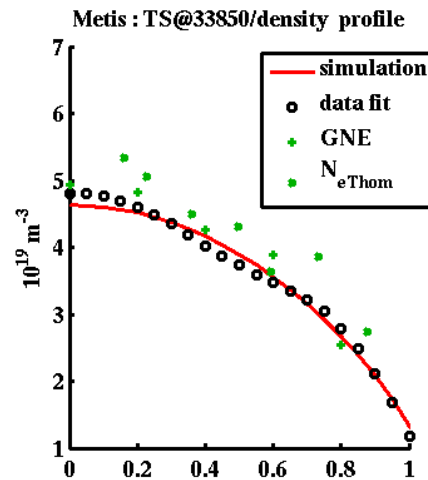
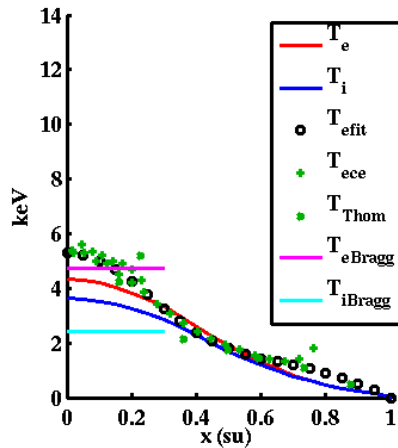
Results

Results: 0D data



Results: profiles

comparaison with diagnostics data



Internal 2D METIS equilibrium

INSIDE METIS

METIS has 2 mains Use Cases:

- **Stand-alone full scenario simulation**
 - CRONOS module
 - Matlab function with data base access or UAL connection
 - Standalone runtime (no Matlab license need) with data base access or UAL connection
- **One time step solver in a workflow**
 - Use inside Simulink workflow (simmetis)
 - Use inside Kepler workflow through Matlab actor
 - **Incoming: service for Kepler
(no Matlab license need)**

- METIS is provided with **METIS_HELP.pdf** file
→ details technical manual and instruction
(not completely up-to-date with current METIS version)
- In the GUI and in Matlab command line :
 - ✓ Parameters tooltip
 - ✓ Data description
- For evolution mode in Matlab command line :
 - ✓ Simulink help : **simmetis, zerodevolution**
 - ✓ ITM help : **metis4itm, training, wiki page of the project**

- **Standalone METIS data structure :**
 - **Input data : `z0dinput`**
 - **Output data : `post`**
 - `post.zerod` : 0d data
 - `post.profil0d` : profiles
 - `post.z0dinput` : input data use during simulation
- **Evolution mode data structure : `z0dstruct`**

- **z0dinput structure :**
 - **Information :**
 - **z0dinput.info** : parameter tooltips
 - **z0dinput.zsinfo** : 0D data descriptions
 - **z0dinput.profinfo** : 1D data descriptions
 - **Data :**
 - **z0dinput.option** : parameters
 - **z0dinput.cons** : references (Ip, powers, ...)
 - **z0dinput.geo** : plasma geometry
 - **z0dinput.exp0d**: experimental data + LCFS pts

- **Source of the code :**
 - **On wikicronos server :**
<https://wikicronos.partenaires.cea.fr/wiki/index.php/METIS>
 - **Inside CRONOS :**
everywhere CRONOS is installed
 - **In ITM Gforge server:**
<http://gforge.efda-itm.eu/gf/project/metis4itm>

- **Compiled versions :**

- **On wikicronos server :**

- <https://wikicronos.partenaires.cea.fr/wiki/index.php/METIS>

- **In ITM server :**

- </pfs/home/jfa/public/>

- See the ITM training document :**

- <https://gforge.efda-itm.eu/gf/project/metis4itm/docman/?subdir=90>

- **Pre-installed version :**
 - **On IRFM server : Cephee, Andromede**
(we can install it, on demand, on any server that have access to Matlab)
 - **On ITM server :**
/pfs/home/jfa/public/metis4itm
See the ITM training document :
<https://gforge.efda-itm.eu/gf/project/metis4itm/docman/?subdir=90>

- **METIS as a CRONOS module :**
 - Exchange data between CRONOS ↔ METIS
 - Access to more data bases : DIII-D, ...
 - Complementary tools : HELENA, NCLASS direct call
- **METIS for ITM :**
 - Access to UAL
 - Coupling with Kepler
- **METIS standalone :**
 - Simpler installation
 - Can be call from Simulink
- **METIS runtime (compiled version) :**
 - No Matlab license need (= no Matlab workspace)
 - Work on many OS (available for Linux, Windows)

- **Pre-installed version :**
 - outside matlab : just launch **metis** script
@ root of **CRONOS** installation
@ inside directory **.../metis4itm/trunk**
 - Inside matlab :
addpath to **CRONOS** or **metis4itm**
addpath .../Projet_Cronos or
addpath .../metis4itm/trunk
launch **metis**
- ✓ **If you can, to more easily follow the presentation, launch METIS now**

- **Compiled version :**
 - **For ITM version : see training**
 - **Otherwise : read the readme.txt file and follows instruction**
 - **Some help is provide on METIS page of wikicronos :**

<https://wikicronos.partenaires.cea.fr/wiki/index.php/METIS>

USE METIS WITH GUI

Edition of
simulation
parameters

Load & Save
simulation

Create reference data set
for comparison

Edition
references

Pre-defined
graphs

Quit METIS

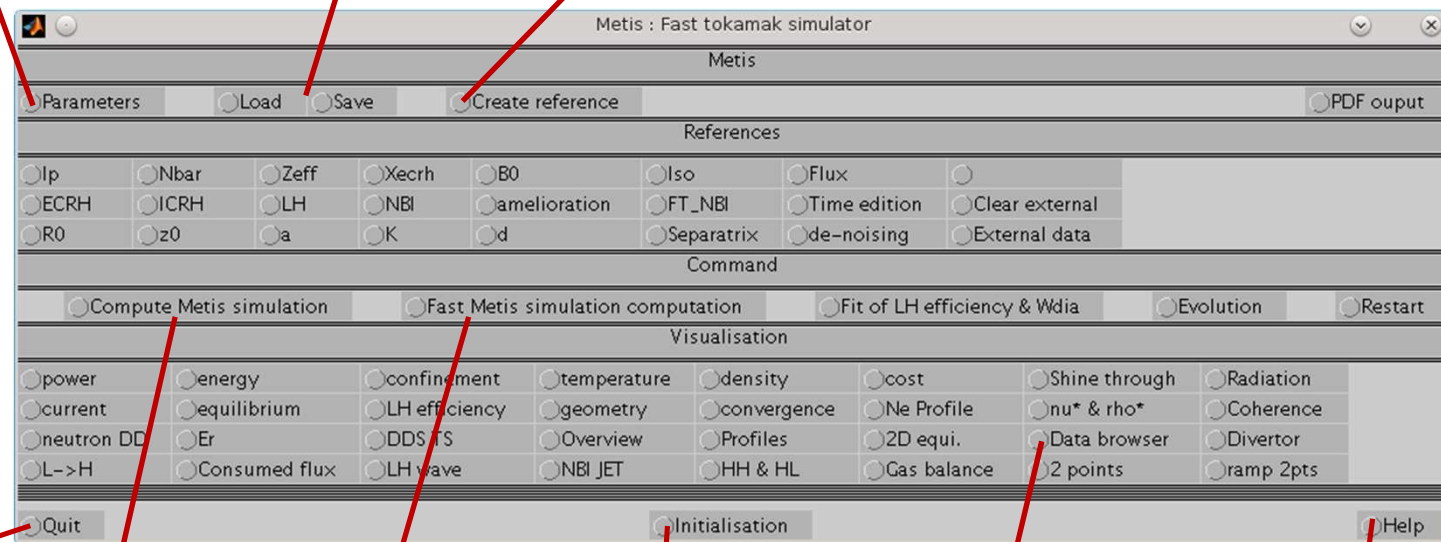
Full simulation
(all time slices)

Fast simulation
(selected time slices)

Initialization
(create a new simulation)

Data browser
(plot any METIS data)

Open METIS manual
(need a pdf reader installed)



Generate separatrix (LCFS) with X-point

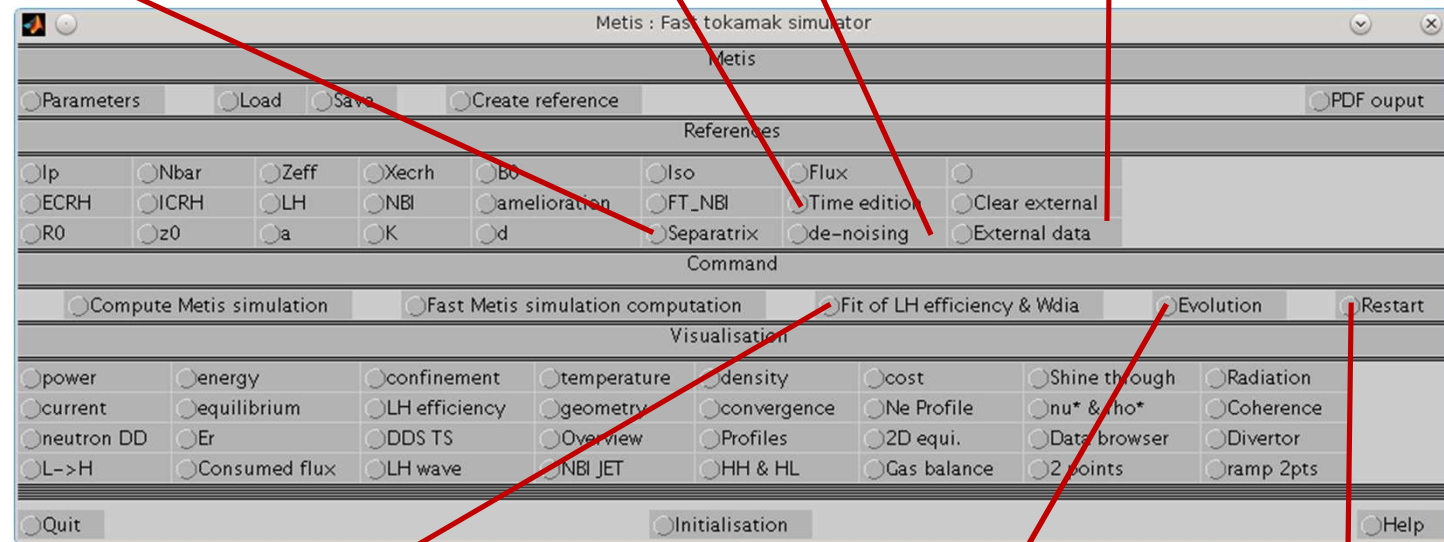
Noise filter for references

Time resampling (input)

Handle external data (measurement, ...)

Edition references

Pre-defined graphs



Fit experimental energy content and search LHCD efficiency (is present)

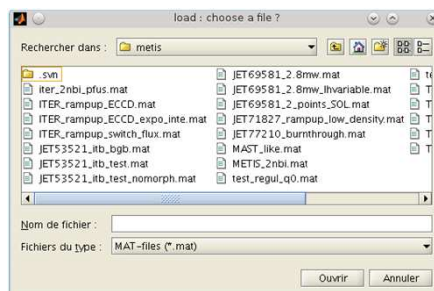
Run in evolution mode (for testing)

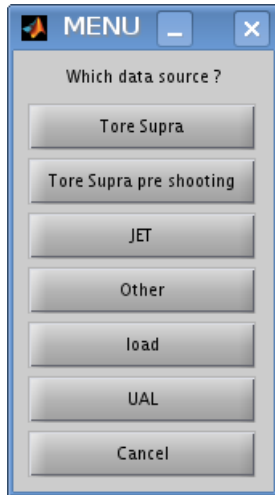
Restart evolution mode (to continue the simulation)

1. Create or load a data set
2. Edit and modify references
3. Optionally, edit the LCFS (if X-point)
4. Edit and modify parameters
5. Run the simulation in fast mode
6. Visualize results
7. Come back to 2, if change are needed
8. Run complete simulation
9. Visualize and check results
10. Save results

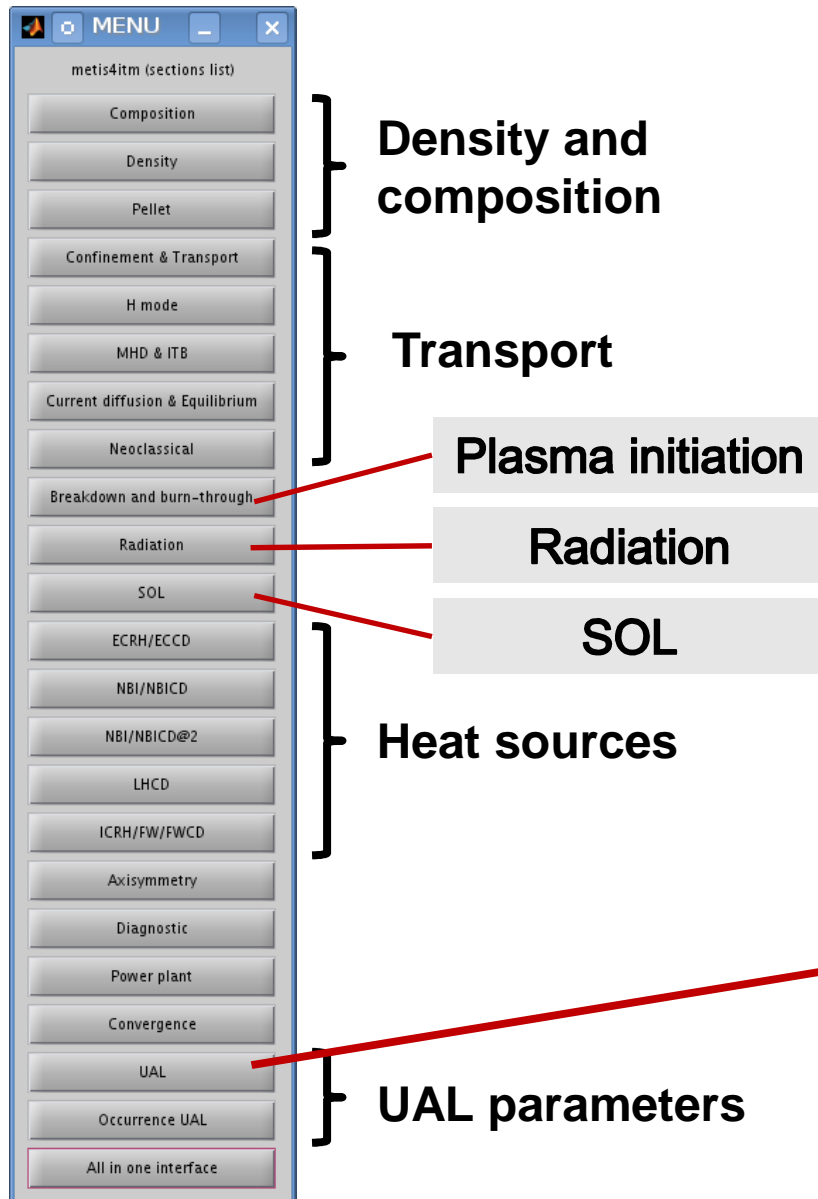
- Button load open a file selector :
 - Just selected a file and open it
- METIS have unified file for input/output
- All METIS files are compatible with new METIS versions (ascendant compatibility)
- Some sample files (used for non-regression tests) are in the directory certification/metis :

.../metis/certification/metis

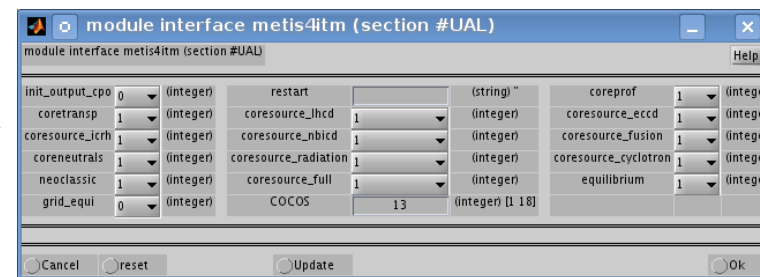




- From « initialization » :
 - access to Tore Supra and JET database
 - Possibility to create a simulation ab initio
 - With pre-processing, access to DIII-D data
 - Under CRONOS, create a METIS simulation from CRONOS data (if available)
- Create a new simulation
- ✓ Data are only in memory : must be saved !



- Parameters group by topic
- Each button open a form
- Change the input parameters



- Time dependent reference can be edit with the help of graphic editor

The screenshot shows the 'Cronos curve editor' window. The main plot area displays a curve with red control points. The x-axis is labeled 'temps (s)' and ranges from 40 to 65. The y-axis is labeled 'Ip' and ranges from 0.2 to 2.2. A list of control points is visible on the right side of the window. The interface includes a menu bar with 'None', 'vide', 'vide', 'vide', and 'Help'. Below the plot, there are buttons for 'Add', 'Delete', 'Cancel', and 'Ok'. The status bar shows 'X = 40.4984', 'Y = 0.228523', 'multiplier = 1e+06', and 'linear'.

Annotations and their corresponding features:

- Grid selector**: Points to the 'None' menu item.
- Superimposes other reference**: Points to the 'vide' menu items.
- Add control points of other reference**: Points to the 'vide' menu items.
- Graphically editable points (right click for edition menu)**: Points to a red control point on the curve.
- Zoom in/out by selection and double click**: Points to the plot area.
- Add one point or delete selected point**: Points to the 'Add' and 'Delete' buttons.
- Cancel edition**: Points to the 'Cancel' button.
- Editable point coordinates**: Points to the 'X' and 'Y' fields in the status bar.
- Exponent**: Points to the 'multiplier' field in the status bar.
- Interpolation methods**: Points to the 'linear' and 'constant' options in the status bar.
- Selectable list of control points**: Points to the list of control points on the right.
- Save new reference**: Points to the 'Ok' button.

Point #	X (s)	Y (Ip)
#1	40.498	0.22852
#2	40.664	0.47438
#3	40.912	0.63793
#4	41.119	0.80923
#5	41.492	0.88209
#6	41.878	1.0788
#7	42.237	1.1488
#8	43.314	1.4451
#9	44.224	1.7106
#10	44.473	1.8316
#11	44.804	1.9283
#12	45.052	2.0184
#13	45.48	1.9948
#14	46.115	2.0458
#15	46.971	1.9684
#16	47.633	2.0176
#17	49.951	1.9989
#18	50.365	2.0269
#19	51.442	1.9656
#20	51.939	2.0315
#21	52.932	2.0121
#22	53.125	1.9743
#23	53.374	1.8642
#24	53.429	1.9171
#25	53.622	2.0175
#26	53.871	1.9486
#27	54.119	1.9944
#28	54.616	1.9787
#29	54.892	1.8616
#30	55.389	1.6512
#31	57.072	1.0231

- Plasma parameters:

- ip : plasma current
- flux : edge poloidal flux
- nbar : line averaged density
- zeff : line averaged effective charge
- iso : isotopic plasma composition (n_D/n_T)
- picrh : ICRH/FW input power
- plh : LFCD input power
- pnbi : NBI input power (can open 2 reference editors)
- pecrh : ECRH input power
- hmore : enhancement factor
- ftnbi : NBI composition
- xece : ECRH maximum deposition position.

- Plasma geometry :

- a : minor radius
- r : major radius
- z0 : vertical shift
- K : elongation
- d : averaged triangularity
- b0 : toroidal magnetic field at the major radius

- Separatrix generator for X-point :

- More moments
- Real X-point
- For given interval of time

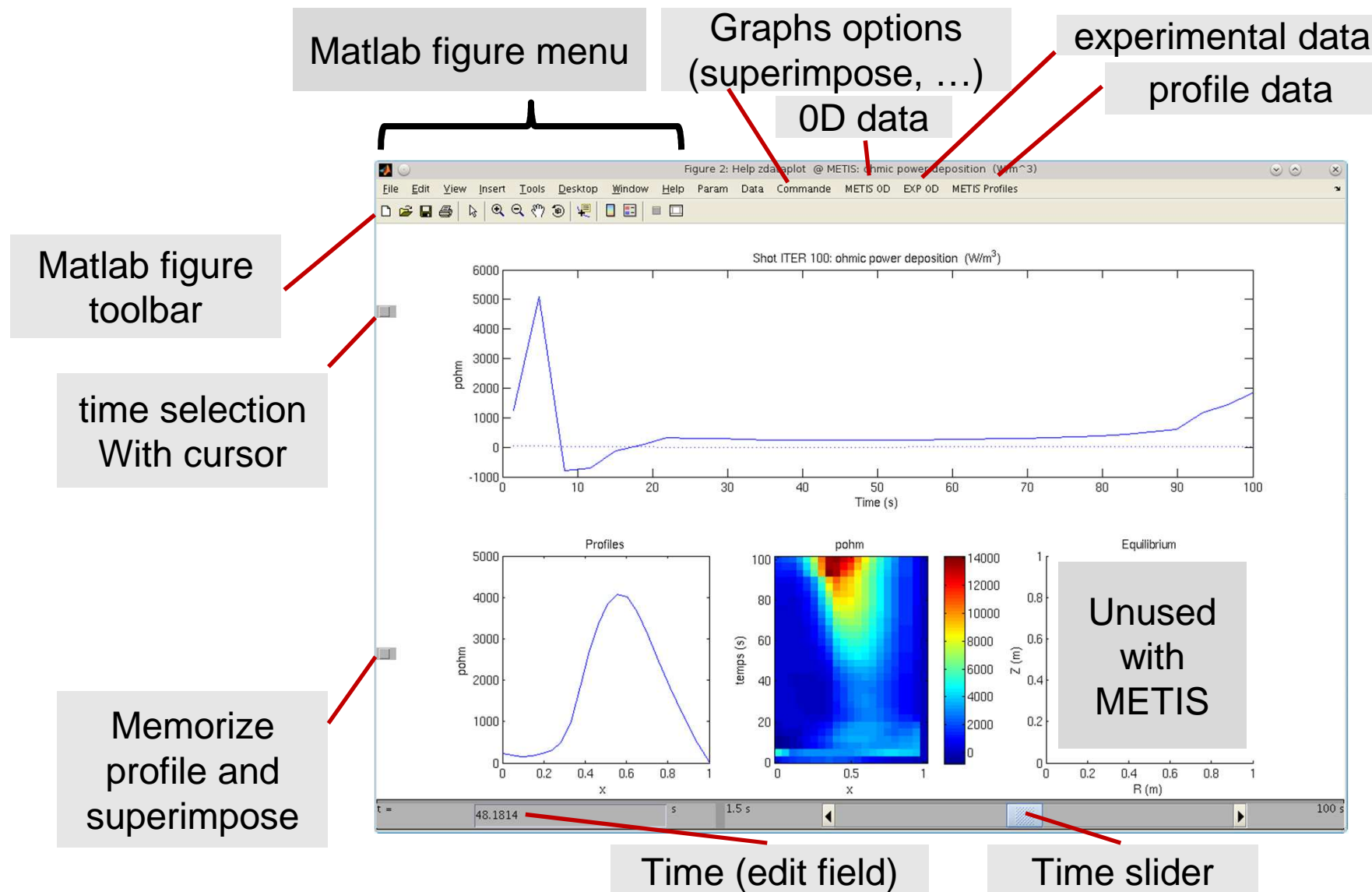
- LCFS parameters:
 - rxup : upper triangularity (normalized)
 - zxup : upper elongation (normalized)
 - apup, amup : upper X-point angles
 - ra : major radius
 - za : vertical shift
 - a : minor radius
 - rxdo : lower triangularity
 - zxdo : upper triangularity
 - apdo, amdo : lower X-point angles
 - b0 : maximum magnetic field on TF conductor
 - delta : gap between TF and inner plasma point
 - nbp : number points in LCFS
 - mode : interpolation curve type
 - filename : filename of LCFS given by point
 - ton : first time for X-point LCFS
 - toff : last time for X-point LCFS

Parameter	Value	Range
rxup	0.466	(float) [0.05 100]
zxup	1.687	(float) [0.05 100]
apup	0	(float) [0 90]
amup	0	(float) [0 90]
ra	6.2	(float) [0.1 100]
za	0.65	(float) [-10 10]
a	2	(float) [0.1 100]
rxdo	0.568	(float) [0.05 100]
zxdo	2.001	(float) [0.05 100]
apdo	22.46	(float) [0 90]
amdo	67.92	(float) [0 90]
b0	13.6	(float) [0.0001 100]
delta	1	(float) [0.1 100]
nbp	201	(integer) [35 250]
mode	elliptical	(string)
filename		(string) "
ton	1.5	(float) [1.5 1200.000000000001]
toff	1200	(float) [1.5 1200.000000000001]

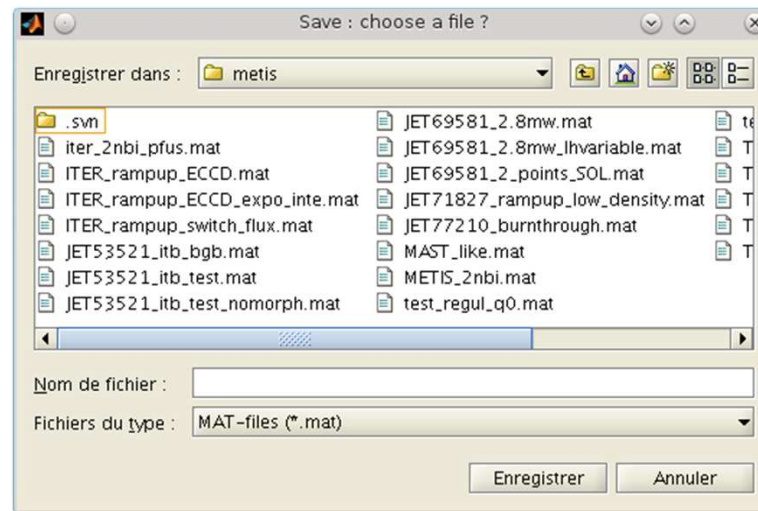
Before and after, use
references R, a, K, d

- Main modes :
 - Fast : just to have a look and tune parameters and references
 - Compute : Full computation for final results
 - Fit : Compute energy using measurement (and optionally search for LHCD current drive efficiency)
- Other modes (for test) :
 - Evolution : test the simulation in evolution mode
 - Restart : restart a simulation in evolution mode

- At the end of the simulation overview graph is opened.
- Generic graph (0D) : just push the button
 - Power, energy, current, confinement, temperature density, equilibrium, geometry, convergence, ...
- 2D plot :
 - equi 2D, Profiles, Er
- Specialize graphs :
 - $L \rightarrow H$, Consumed flux, LH wave , ...
- Machine dependent graphs :
 - Neutron DD, DDS TS, NBI JET, Ne profile
- Generic data browser and plotter.



- Button load open a file selector :
 - Just selected a file or enter a new name and save it
- METIS have unified file for input/output.



ADVANCED METIS FEATURES

- METIS commands :
 - metis_load : load and update a simulation
 - metis_save : save a simulation (from workspace)
 - metis_fast : fast simulation (selected time slices)
 - metis_run : full simulation (all time slices)
 - metis_update_tests : update non regression tests
- Call METIS functions in a mfile :
 - zerod_init : initialise a simulation
 - zerod_fast : fast simulation (selected time slices)
 - zerod : full simulation (all time slices)
 - zerodevolution : one time step simulation

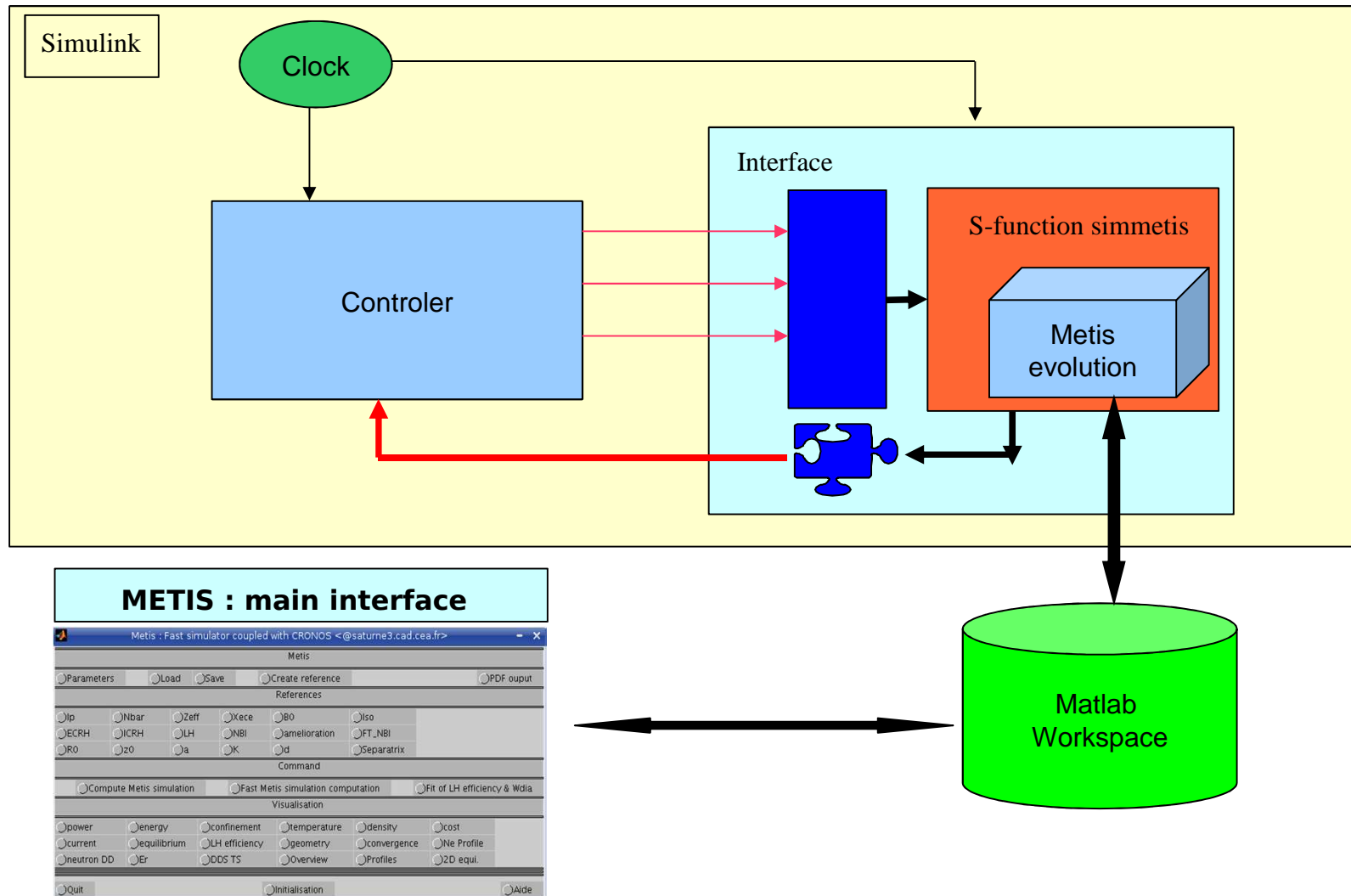
- METIS can use external data for :
 - Heat sources : LHCD, ICRH, ECCD, NBICD, Pline
 - Kinetic profiles : Ne, Te, Ti
 - External data override internal METIS computation
 - Heat sources are renormalized on references.
 - Density is renormalized on n_bar reference
- Details available in file :

.../zerod/external_data_rule_for_METIS.m

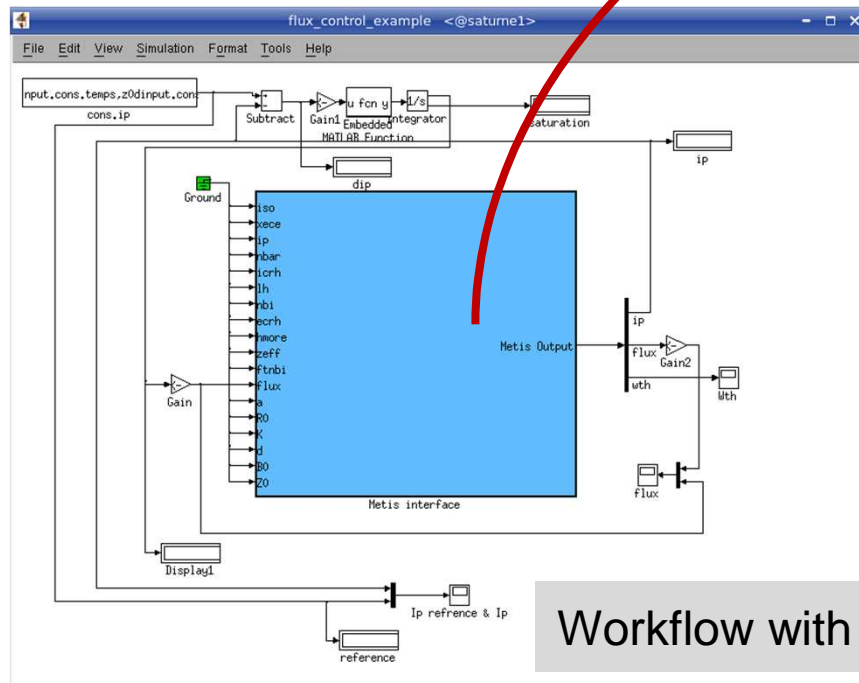
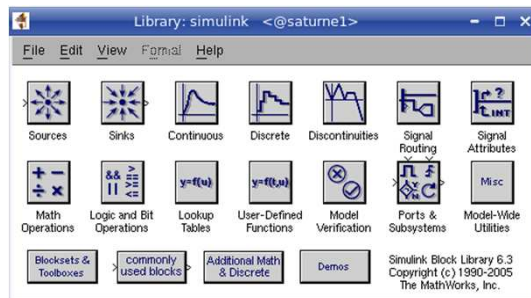
METIS IN SIMULINK

- ✓ METIS call from Simulink = S-function **simmetis**
- ✓ Standard S-function Input & output
- **simmetis** use one time step METIS computation :
zerodevolution .
- Some documentation is written inside functions
 - ✓ **help simmetis** or **help zerodevolution** (in Matlab)
 - ✓ S-function documentation :

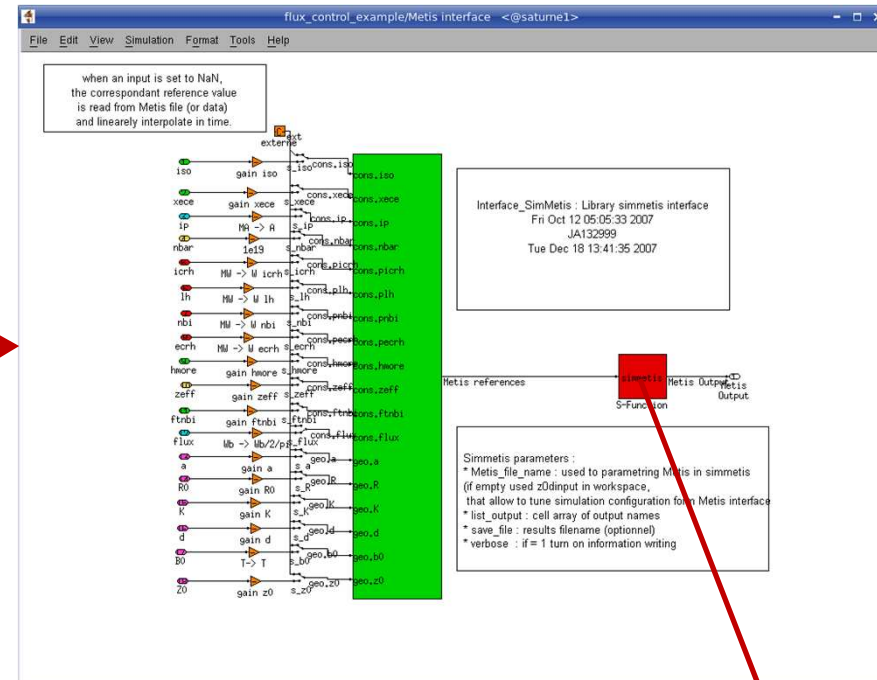
<http://www.mathworks.fr/fr/help/simulink/slref/sfunction.html>



Simulink



Workflow with METIS



Interface to simmetis

S-function simmetis

- Sample workflow for simmetis testing (under .../zerod/) :
 - test_simmetis.mdl : simple test
 - flux_control_example.mdl : poloidal flux feedback test
- Sample interface between Simulink and simmetis (under .../zerod/) :
 - interface_simmetis.mdl : switches, multiplexor + S-function call
- For testing :
 - Launch METIS + load a simulation
 - Open Simulink workflow, tune simulation parameters, and run it

- **METIS takes default parameters and references in Matlab workspace**
 - **METIS GUI still active with Simulink**
 - ✓ **Only active selected references and parameters are override by Simulink data**
- **All METIS internal data copy in Malab workspace**
 - **Simulink can access to any METIS data**

- **Last (current time) METIS data are available in Matlab workspace from Simulink :**
 - **zerod_simmetis : 0D METIS data**
 - **profil0d_simmetis : 1D METIS data**
 - **cons_simmetis: references (use by METIS)**
 - **geo_simmetis: geometry (use by METIS)**
 - **sepa_simmetis : if LCFS given by points**
- **More data available in global structure : see simmetis online help**

LISTE OF PARAMETERS

module interface zerod (section #Composition)

gas	3	(integer)	frhe0	0	(real) [0 0.5]	tauhemul	3	(real) [-20 20]
zeff	0	(integer)	faccu	0.5	(real) [-1 1]	heat_acc	0	(real) [-10 10]
fne_acc	0	(real) [0 3]	W_effect	0	(integer)	zmax	18	(integer) [3 100]
zimp	6	(integer) [3 100]	rimp	0.06	(real) [0 1]			

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #Pellet)

pix	0.7	(real) [0 1]
piw	0	(real) [0 3]
pif	0	(real) [0 1]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #Density)

neasser	0	(integer)
Recycling	0	(real) [0 0.999]
natural	0	(integer)
fnbar_nat	1	(real) [0.1 10]
nea_factor	1	(real) [0.1 10]
ane	0	(integer)
vane	1	(real) [0.5 5]
ne_shape	Auto	(string)
density_model	default	(string)

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #Confinement & Transport)

scaling	0	(integer)	dilution	1	(integer)	tau_limitation	On	(string)
ploss_exp	with_prad	(string)	fprad	0.333333	(real)	HH_li	0	(real) [0 3]
fpped	1	(real) [-100 10]	fstiff	1	(real) [-10 10]	usepped_scl	0	(integer)
taurotmul	0	(real) [0 10]	fintrinsic	1	(real) [0 10]	omega_shape	0	(integer)
xiioxie	1	(real) [-10 10]	kishape	3	(real) [-10 10]	ki_expo	2	(real) [0 2]
xiexkie	0	(integer)	grad_ped	1	(integer)			

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #H mode)

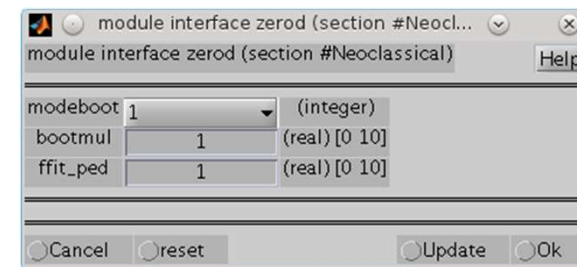
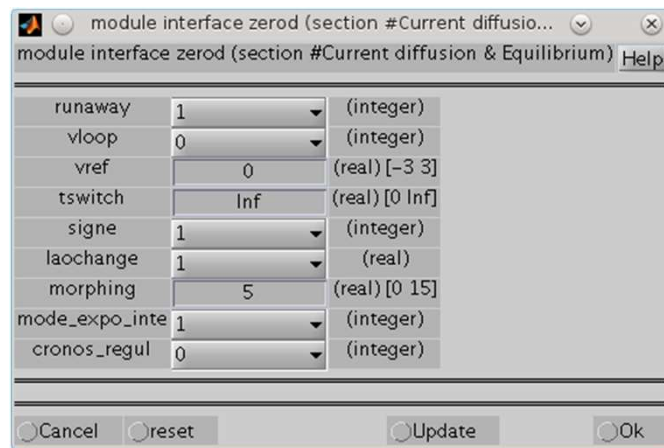
I2hscaling	0	(real)
modeh	1	(integer)
I2hmul	0	(real) [-10 100]
plhthr	pel+pion	(string)
I2hslope	0	(real) [-1 1]
hysteresis	1	(real) [0 1]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #MHD & ITB)

qdds	0	(real) [-2 3]	w1	0.5	(float) [0.1 1]	epsq	0.01	(float) [0 0.1]
ddsmode	0	(integer)	kidds	3	(real) [1 1000]	peeling	0	(integer)
dwow_elm	0	(real) [-10 1]	tau_elm_factor	10	(real) [1 1000]	sitb	0	(integer)
itb_sensitivity	1	(real) [0 10]	itb_slope_max	2	(real) [0 2]	tae	0	(integer)
smhd	100	(real) [-10 100]	tmhd	0	(real) [0 Inf]			

☐ Cancel ☐ reset ☐ Update ☐ Ok



module interface zerod (section #Breakdown an...)

module interface zerod (section #Breakdown and burn-through) Help

li	1.18597	(real) [0.1 10]
breakdown	0.03	(real) [-100 1]
berror	0	(real) [0 10]
L_eddy	0	(real) [0 1]
R_eddy	0	(real) [0 10]
p_prefill	0.001	(real) [0 1000]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #Radiation...)

module interface zerod (section #Radiation) Help

frad	1	(real) [0.1 10]
matthews	1	(integer)
z_prad	zmax	(string)
rw	0.7	(real) [-1 1]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #SOL)

module interface zerod (section #SOL) Help

configuration	3	(integer)	lambda_scale	0	(real)	factor_scale	1	(real) [0.1 100]
sol_yscale	0	(real) [-0.1 0.1]	eioniz	25	(real) [0 1000]	de	0.5	(real) [0.1 10]
alpha_e	0.82	(real) [0.15 3]	fnesol	0	(real) [0 1]	sol_model	scaling	(string)
sol_rad	coupled	(string)	lcx	1	(real) [1 20]	fpower	0.6	(real) [0.1 1]
fR_target	1	(real) [0.5 2]	fcond	1	(real) [-1 1]	fmom	1	(real) [0 1]
mach_corr	0	(integer)	yield_model	javev	(string)	ftwleak	-0.5	(real) [-1 1]
cw_factor	1	(real) [-10 10]	cw_offset	0	(real) [0 0.01]	fzmax_div	0	(real) [-100 100]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #ECRH/...)
module interface zerod (section #ECRH/ECCD) Help

angle_ecrh	90	(real)
synergie	1	(real) [0 10]
sens	1	(integer)
eccdmul	1	(real) [0.1 10]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #LHCD)
module interface zerod (section #LHCD) Help

lhmode	2	(real)	upshiftmode	linear	(string)	fupshift	1	(real) [0 10]
etalh	5.8e+18	(real) [-3e+19 3e+19]	npar0	0	(real) [1 10]	freqlh	3.7	(real) [1 10]
wlh	0.539	(real) [0 3]	xlh	0	(real) [0 0.8]	dlh	0.2	(real) [0 0.7]
npar_neg	0	(real) [-10 0]	angle_ecrh2	90	(real)			

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #ICRH/...)
module interface zerod (section #ICRH/FW/FWCD) Help

fwcd	0	(integer)
mino	T	(string)
cmin	1	(real) [0 1]
nphi	100	(real) [1 100]
freq	49	(real) [20 200]

☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #NBI/N...)
module interface zerod (section #NBI/NBICD) Help

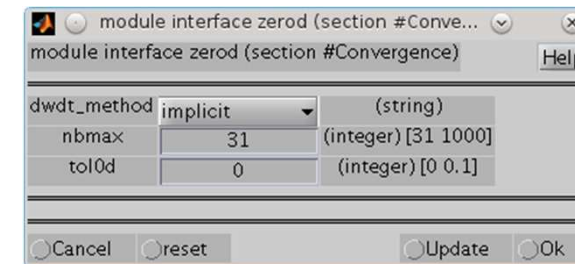
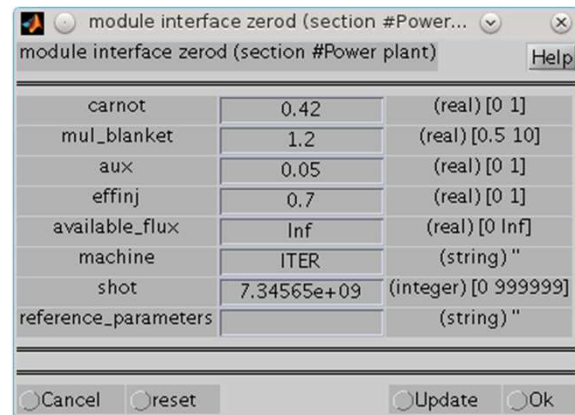
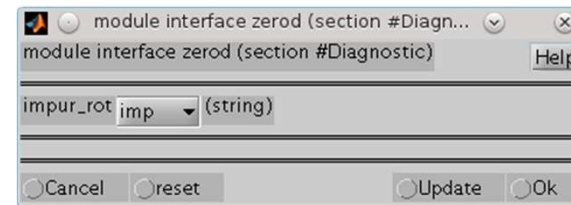
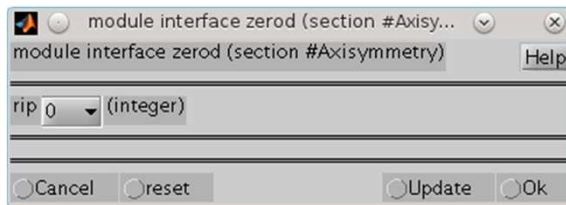
angle_nbi	90	(real) [-90 90]
rtang	6.8	(real) [0 100]
zext	0	(real) [0 0.5]
einj	1e+06	(real) [10000 10000000]
nbicdmul	1	(real) [0.1 10]
e_shielding	Lin-Liu	(string)

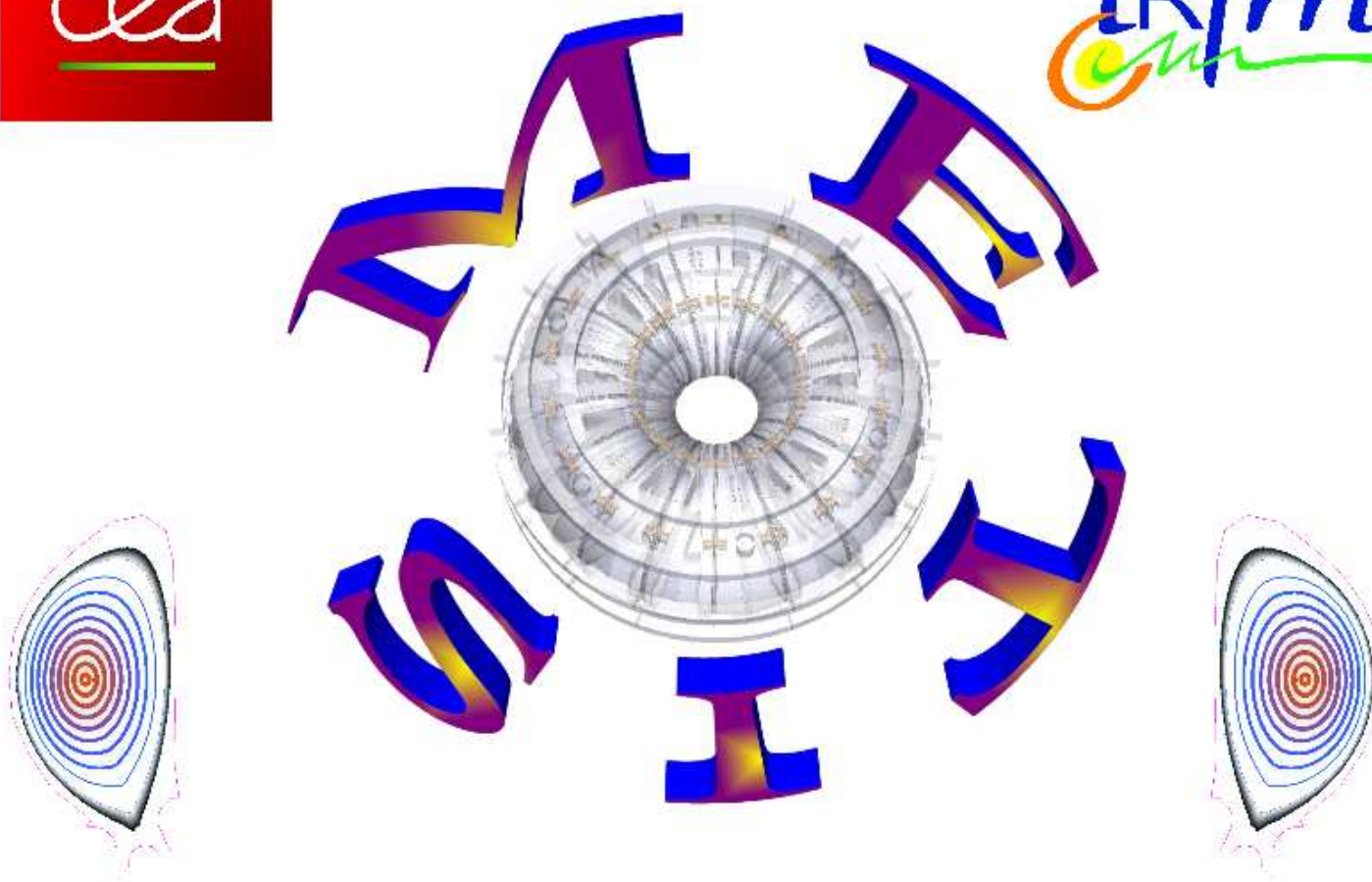
☐ Cancel ☐ reset ☐ Update ☐ Ok

module interface zerod (section #NBI/N...)
module interface zerod (section #NBI/NBICD@2) Help

nb_nbi	2	(integer)
angle_nbi2	90	(real) [-90 90]
rtang2	6.8	(real) [0 100]
zext2	0.15	(real) [0 0.5]
einj2	1e+06	(real) [10000 10000000]
nbicdmul2	1	(real) [0.1 10]

☐ Cancel ☐ reset ☐ Update ☐ Ok






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