DE LA RECHERCHE À L'INDUSTRIE

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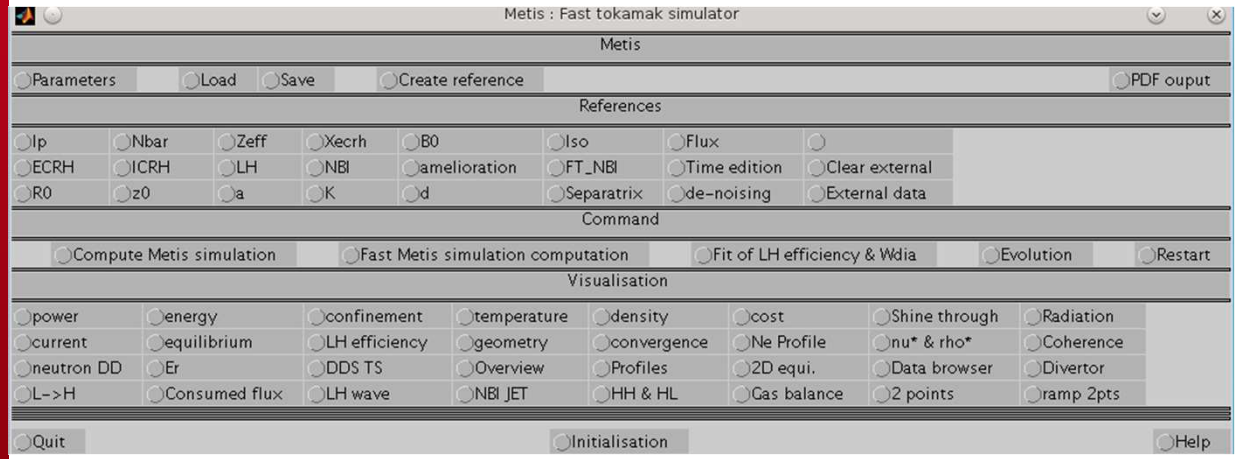
HOWTO METIS



MARDI 25 JUIN 2013

FOREWORD

- 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

OUTLINE

METIS overview

METIS standalone

Inside METIS
Use METIS with GUI
Advanced METIS features

METIS in Simulink

List of Parameters

METIS OVERVIEW

WHAT IS METIS

- **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**

MAIN METIS FEATURES

- ✓ **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)**

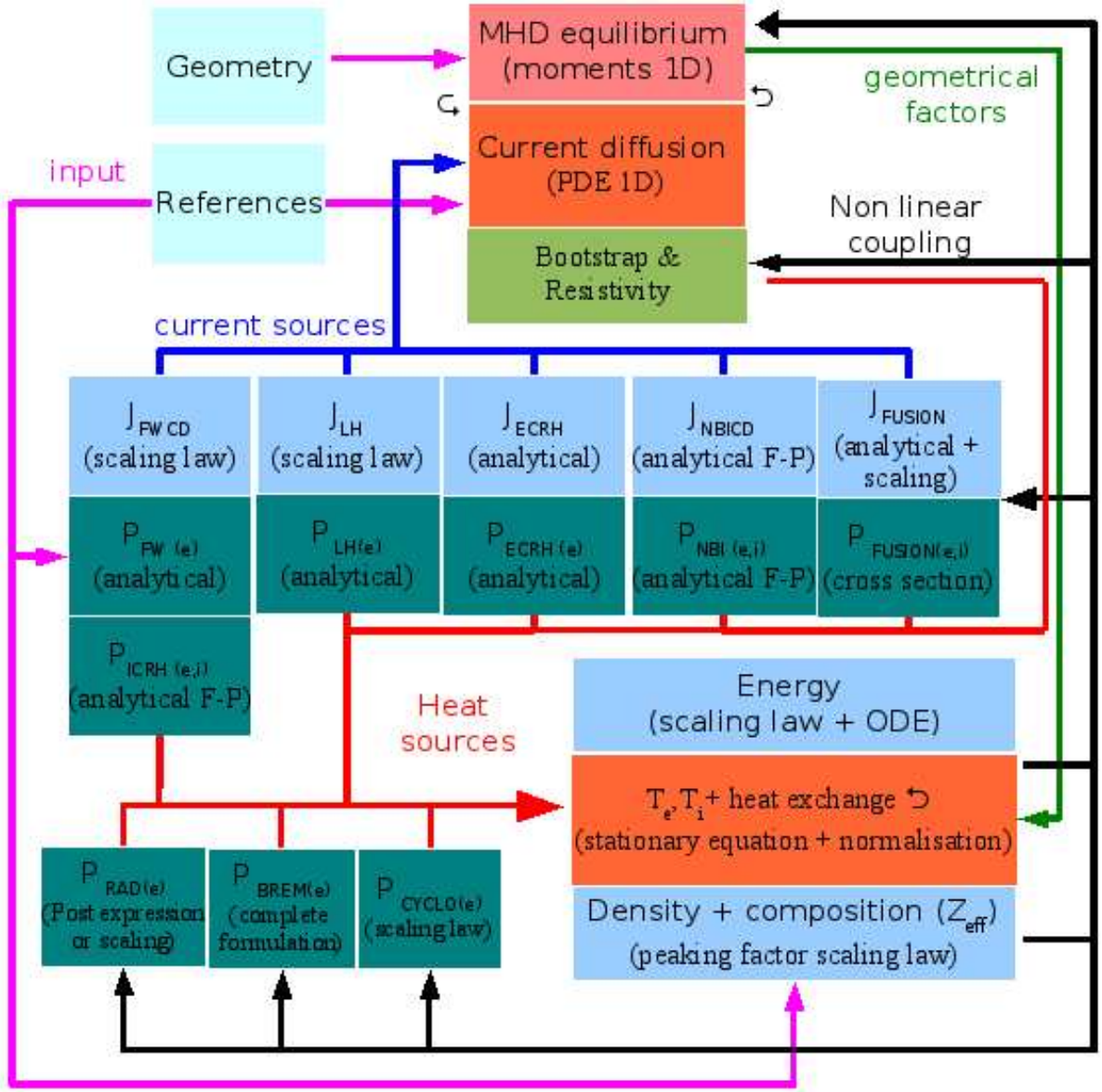
WORLDWIDE METIS USE

- 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, …

METIS INTERNAL WORKFLOW



2 points model

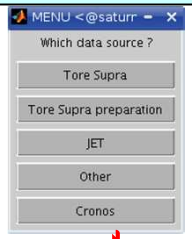
W radiation and accumulation

Flux, …

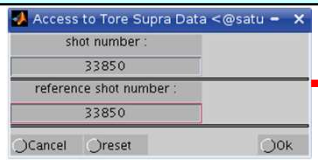
Boundaries conditions, density, Prad

GUI OVERVIEW

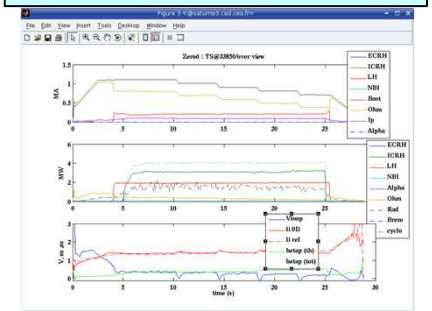
Data source



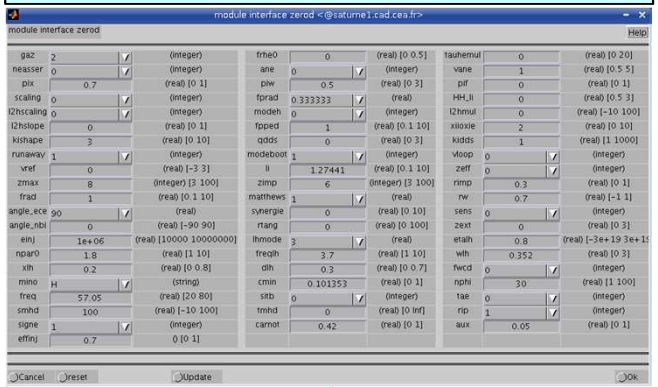
Shot choice



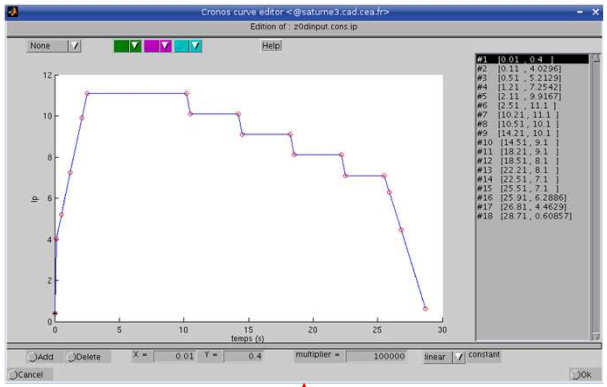
Visualisation



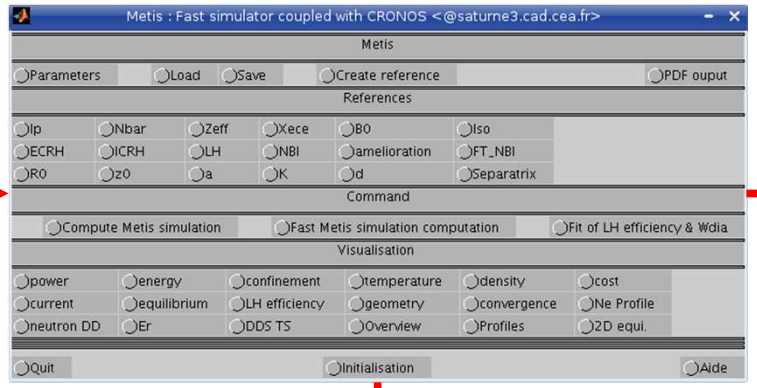
Parameters



References



METIS : main interface



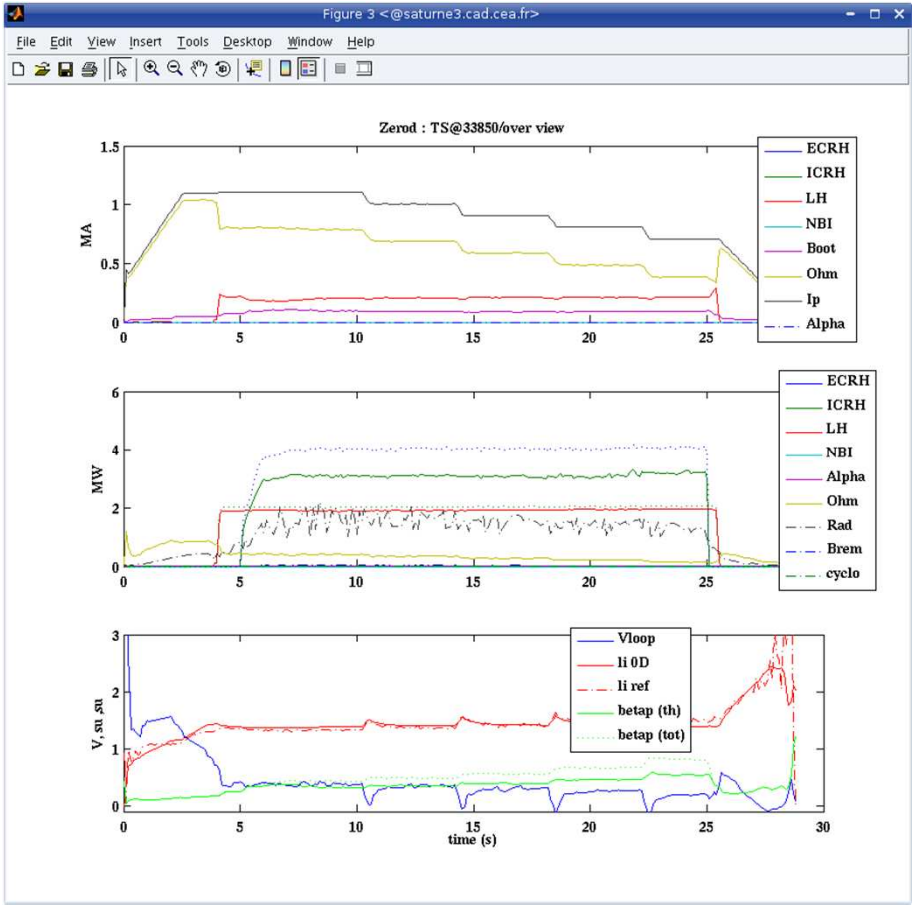
Run (~ 1mn)

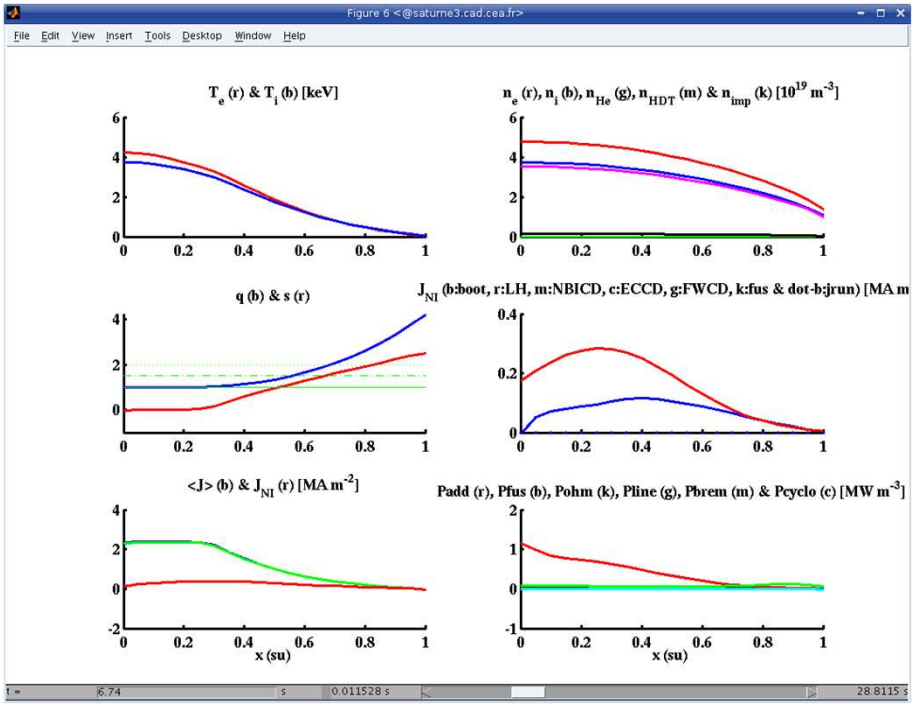
Results

Export to database

METIS OUTPUT EXAMPLE (1/2)

Results: 0D data

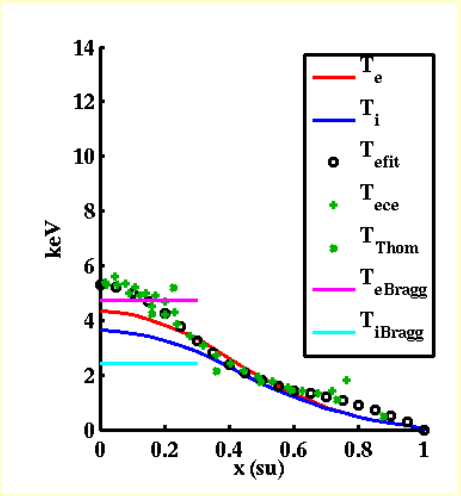


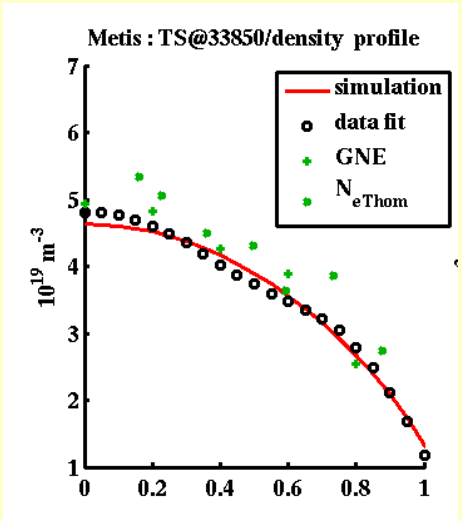


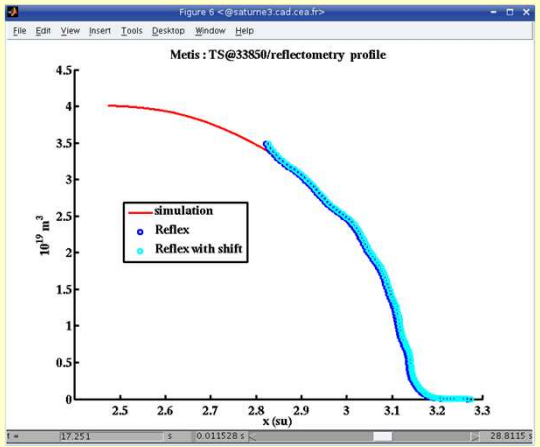
Results: profiles

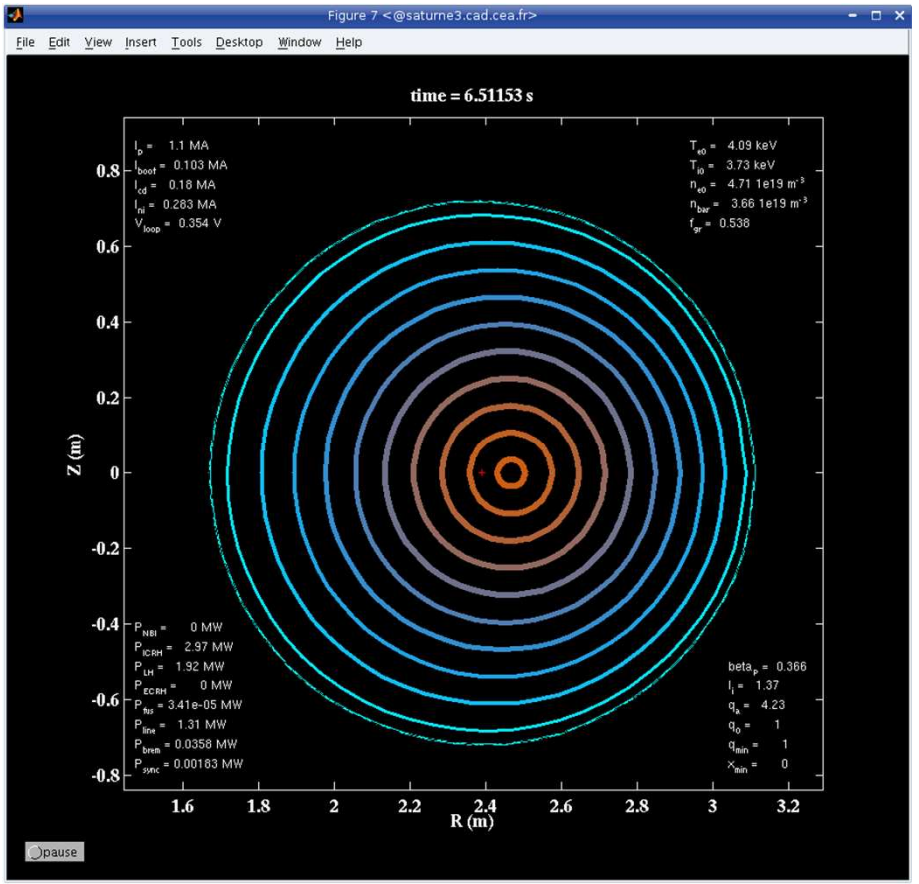
METIS OUTPUT EXAMPLE (2/2)

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)

HELP AND MANUAL

- **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**

MATLAB WORKSPACE (1/2)

- **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**

MATLAB WORKSPACE (2/2)

- **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 : plama geometry
    - z0dinput.exp0d: experimental data + LCFS pts

WHERE FIND METIS ?

- **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

WHERE FIND METIS ?

- **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

WHERE FIND METIS ?

- **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

DIFFERENCE BETWEEN VERSIONS

- **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)**

LAUNCH METIS

- **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**

LAUNCH METIS

- **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

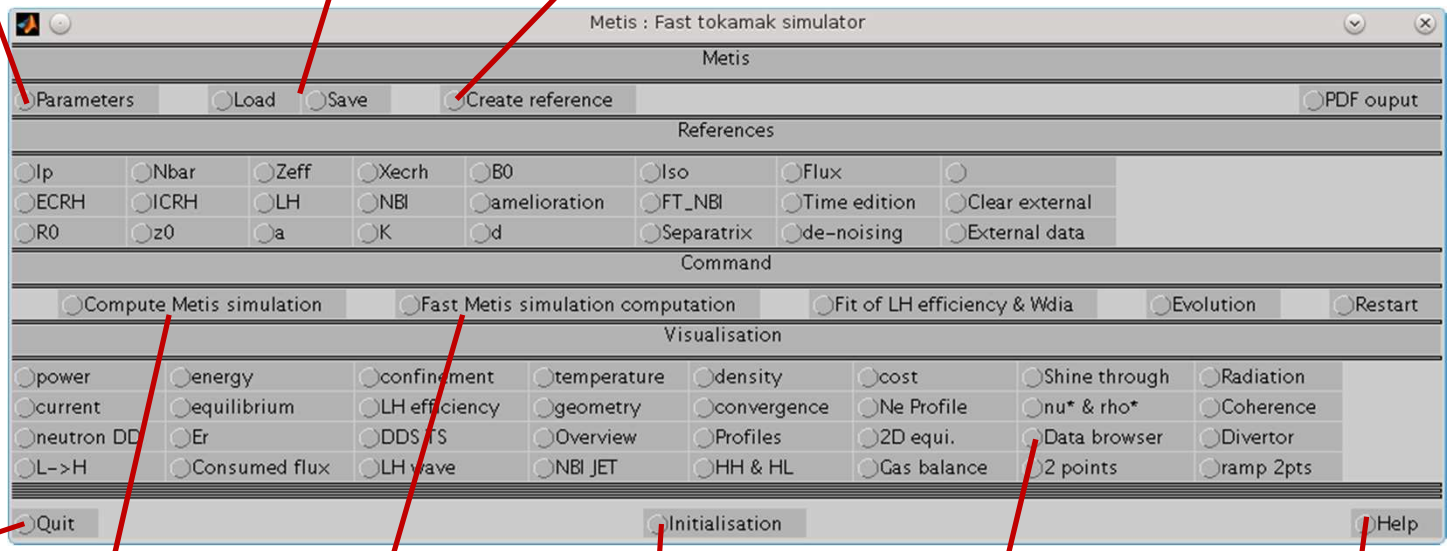
USE METIS WITH GUI

MAIN GUI WINDOWS (1/2)

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)

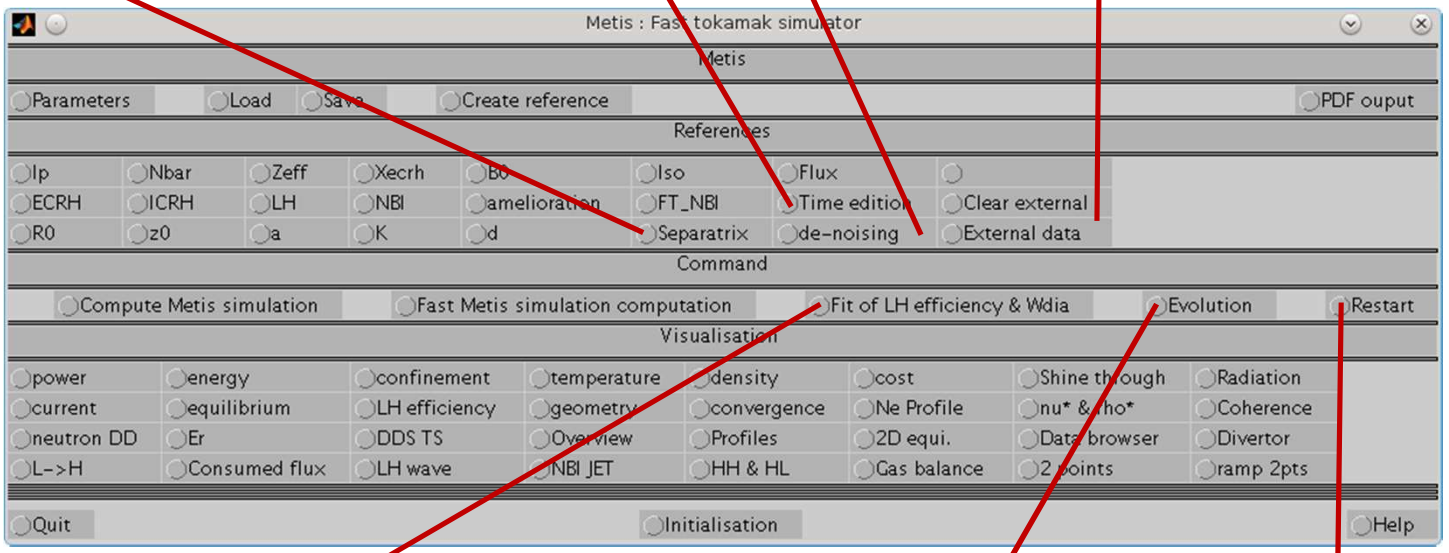
MAIN GUI WINDOWS (2/2)

Noise filter for references

Generate separatrix (LCFS) with X-point

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)

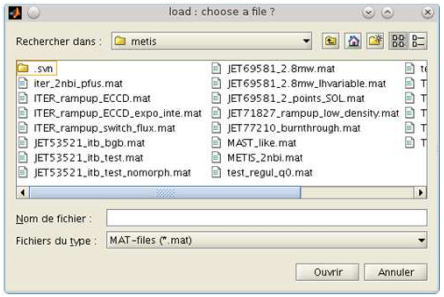
RECIPE FOR A SIMULATION

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

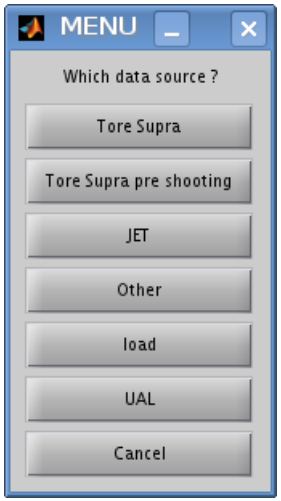
LOAD DATA

- 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



READ DATA FROM DATABASES

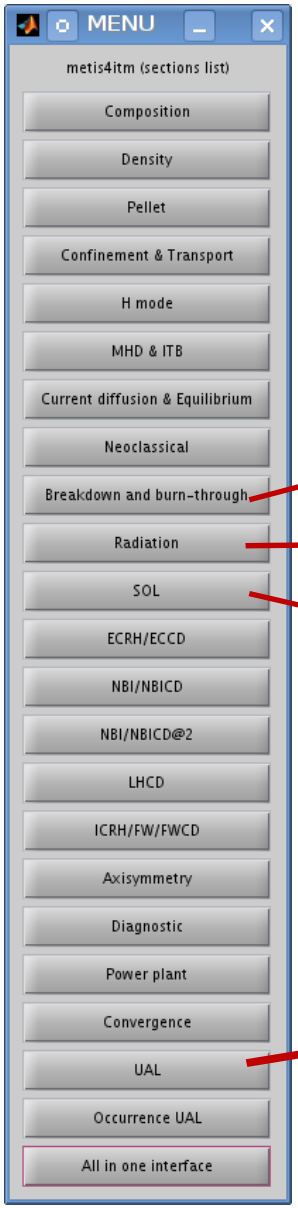


- From « initialization » :
  - access to Tore Supra and JET database
  - Possibility to create a simulation ab initio
  - With pre-processing, access to DIII-D data
  - Under CRONOS, create a METIS simulation from CRONOS data (if available)

➢ Create a new simulation

✓ Data are only in memory : must be saved !

EDIT PARAMETERS



Density and composition

Transport

Plasma initiation

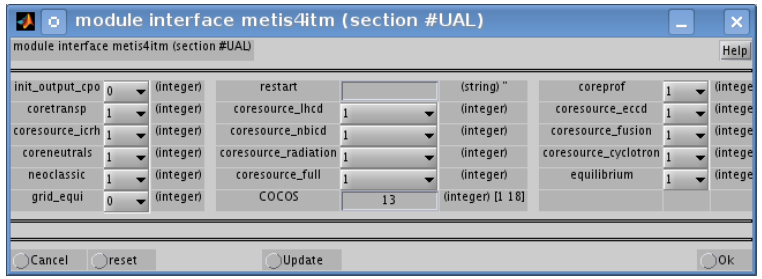
Radiation

SOL

Heat sources

UAL parameters

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



EDIT REFERENCE

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

Grid selector

Superimposes other reference

Add control points of other reference

Graphically editable points (right click for edition menu)

Zoom in/out by selection and double click

Selectable list of control points

Add one point or delete selected point

Save new reference

Cancel edition

Editable point coordinates

Exponent

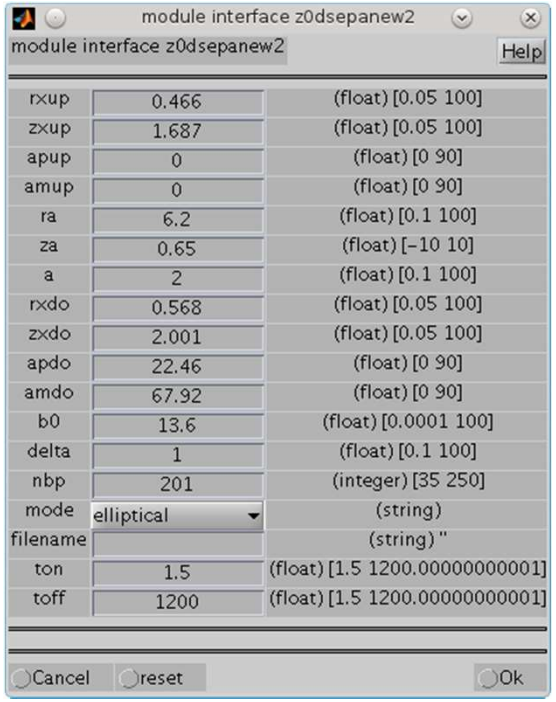
Interpolation methods

LIST OF REFERENCES

- Plasma parameters:
  - ip : plasma current
  - flux : edge poloidal flux
  - nbar : line averaged density
  - zeff : line averaged effective chage
  - 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 GENERATOR

- LCFS parameters:
  - rxup : upper triangularity (normalized)
  - zxup : upper elongation (normalized)
  - apup, amup : upper X-point angles
  - ra : major radius
  - za : vertical shift
  - a : minor raduis
  - 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



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

RUN METIS

- 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

VISUALIZE RESULTS

- 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→ H, Consumed flux, LH wave , …
- Machine dependent graphs :
  - Neutron DD, DDS TS, NBI JET, Ne profile
- Generic data browser and plotter.

DATA BROWSER

Matlab figure menu

Graphs options (superimpose, …)

experimental data

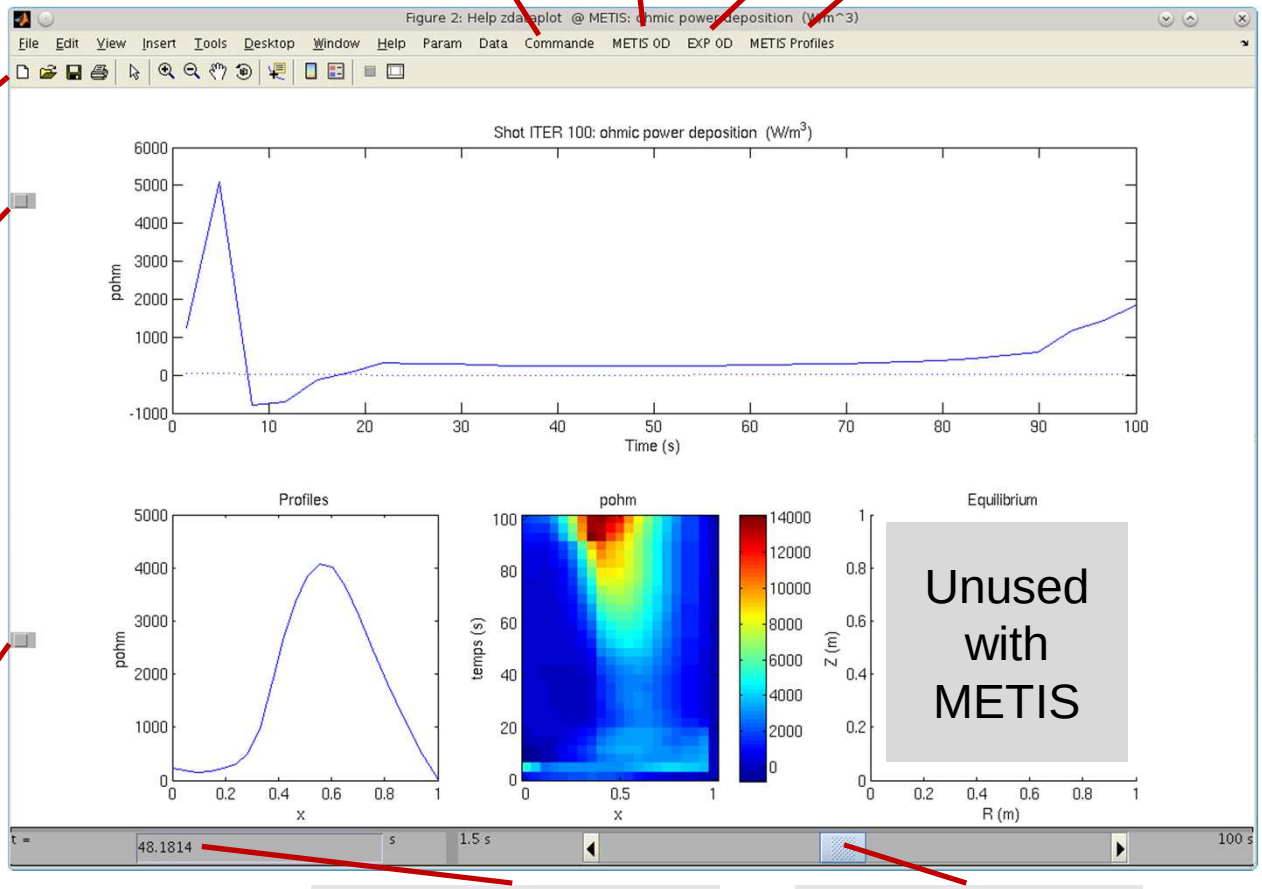
profile data

0D data

Matlab figure toolbar

time selection With cursor

Memorize profile and superimpose



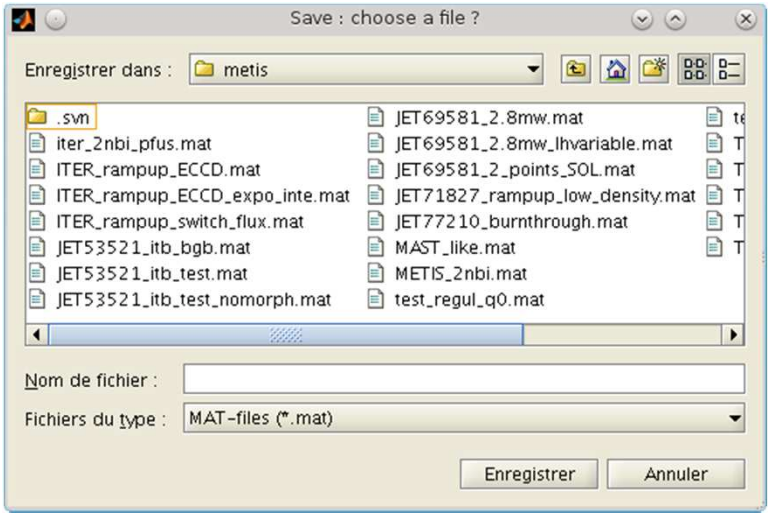
Unused with METIS

Time (edit field)

Time slider

SAVE DATA

- 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 WITHOUT GUI

- 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_upadate_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 & EXTERNAL DATA

- 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 IN SIMULINK

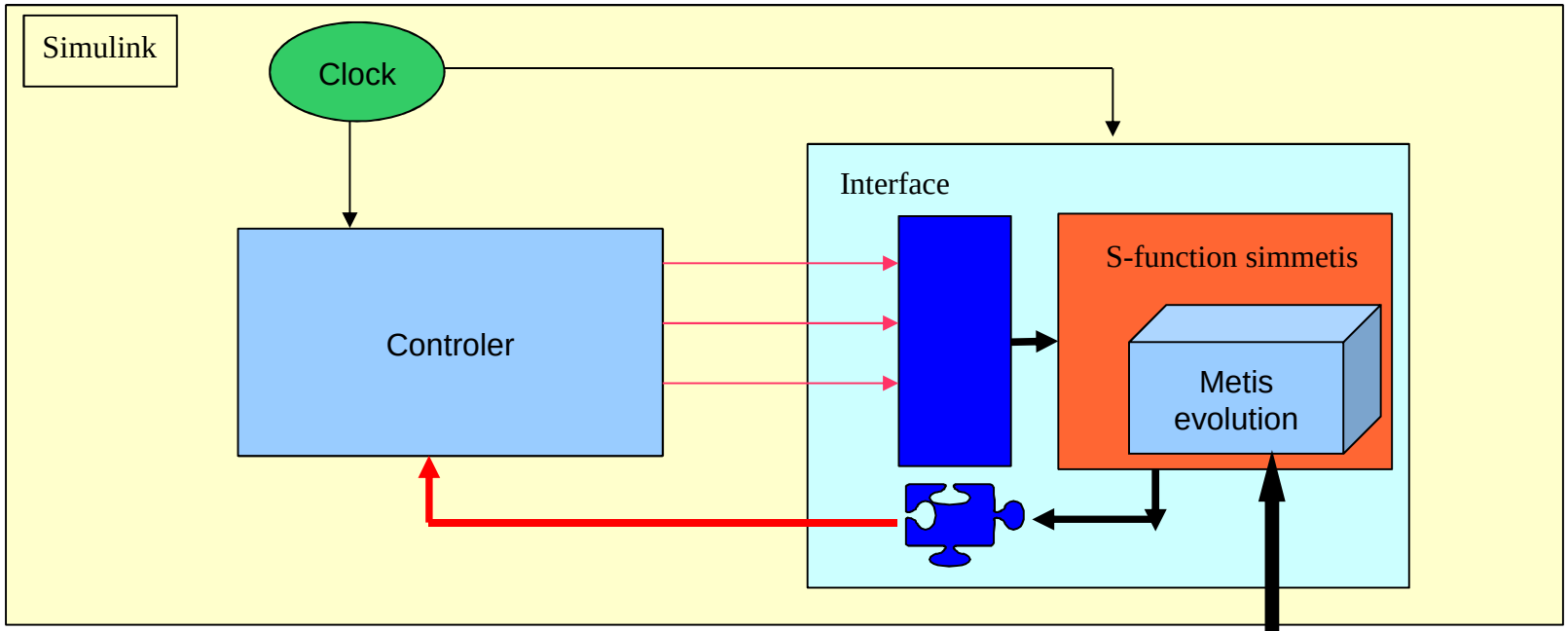
- ✓ METIS call from Simulink = S-function simmetis
- ✓ Standard S-function Input & output

o simmetis use one time step METIS computation : zerodevolution .

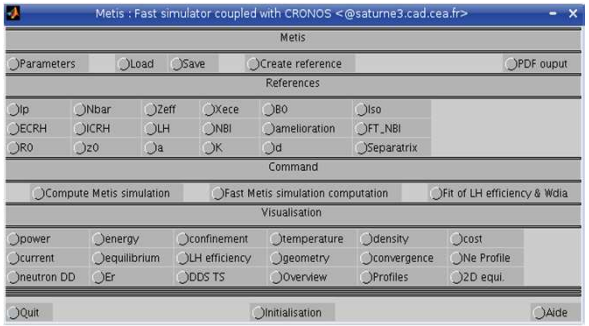
➢ Some documentation is written inside functions
  - ✓ help simmetis or help zerodevolution (in Matlab)
  - ✓ S-function documentation :

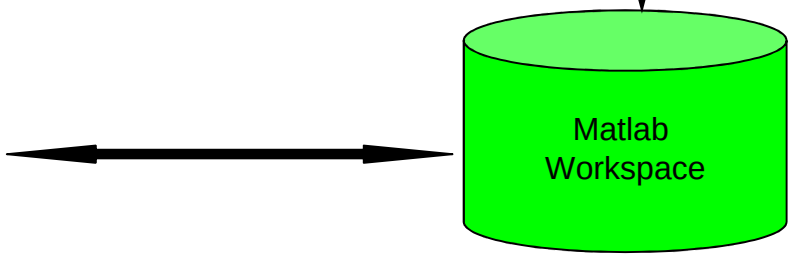
    http://www.mathworks.fr/fr/help/simulink/slref/sfunction.html

METIS EVOLUTION IN SIMULINK



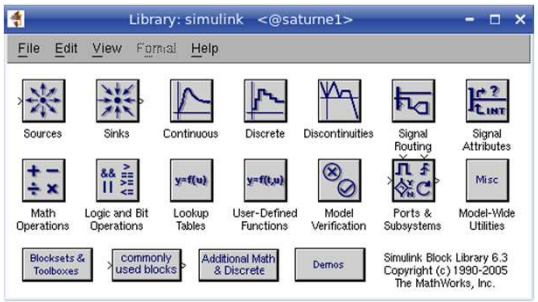
METIS : main interface

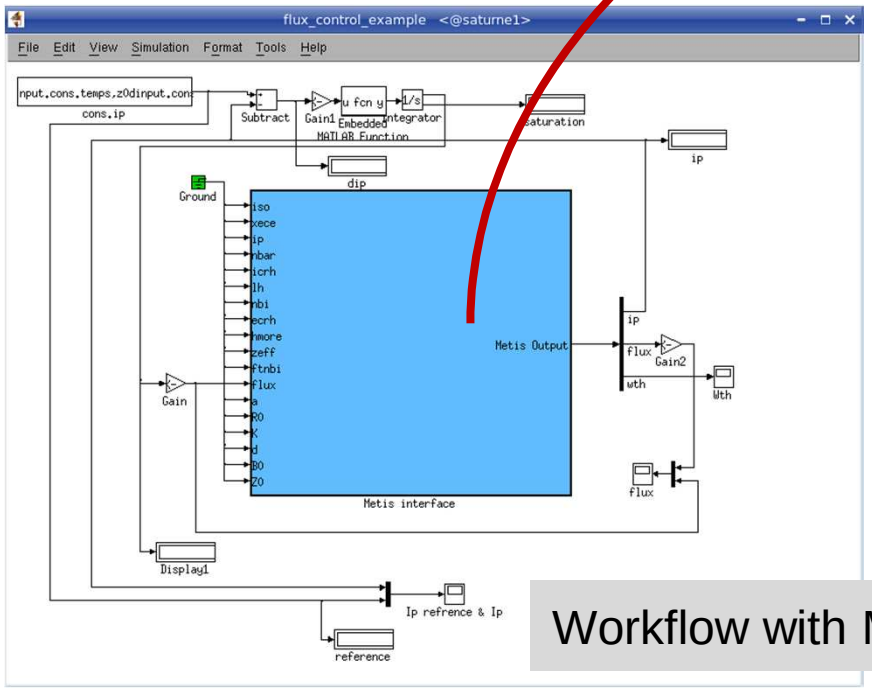




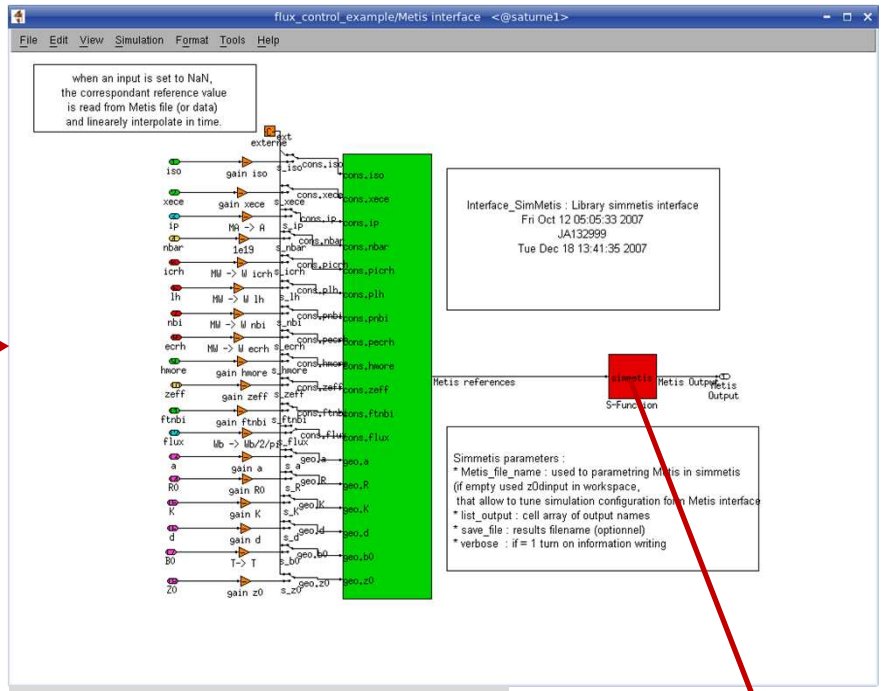
METIS INTERFACE TO SIMULINK

Simulink





Workflow with METIS



Interface to simmetis

S-function simmetis

SAMPLE SIMULINK WORKFLOW

- 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

MATLAB WORKSPACE (IN EVOLUTION MODE)

- 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

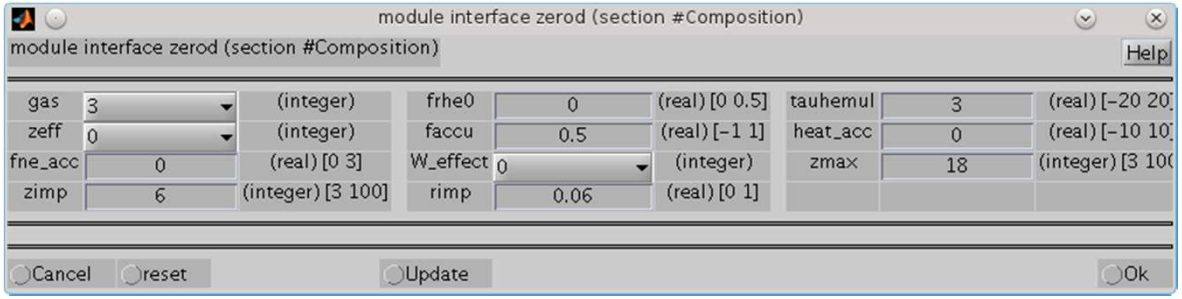
➢ Simulink can access to any METIS data

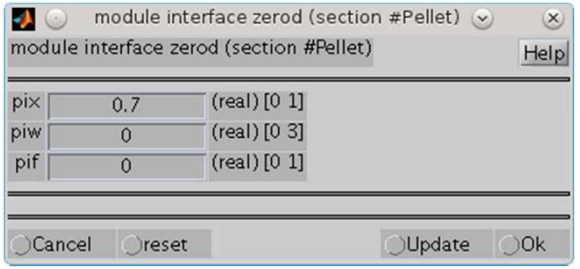
METIS DATA STRUCTURES FOR SIMULINK

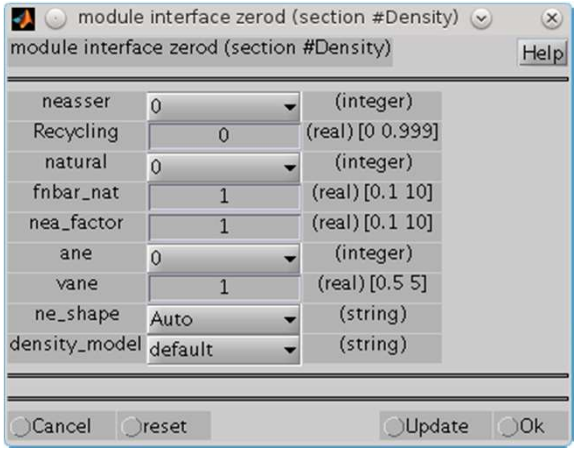
- **Last (current time) METIS data are available in Matlab workspace from Simulink :**
  - **zerod_simmetis : 0D METIS data**
  - **profil0d_simmetis : 1D METIS data**
  - **cons_simmetis: references (use by METIS)**
  - **geo_simmetis: geometry (use by METIS)**
  - **sepa_simmetis : if LCFS given by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

LISTE OF PARAMETERS

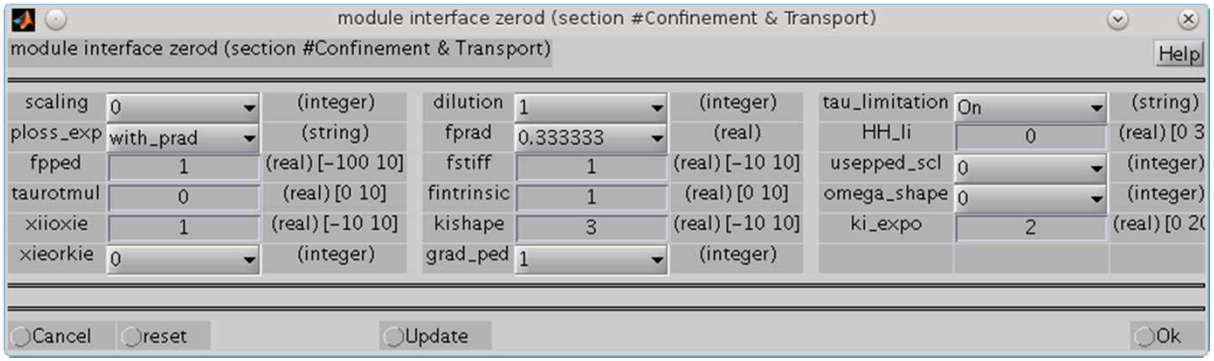
PARAMETERS INTERFACES (1/6)

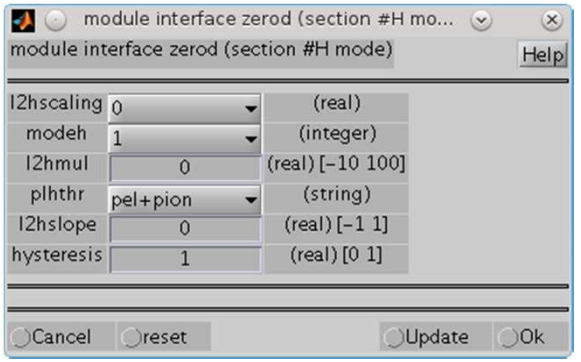


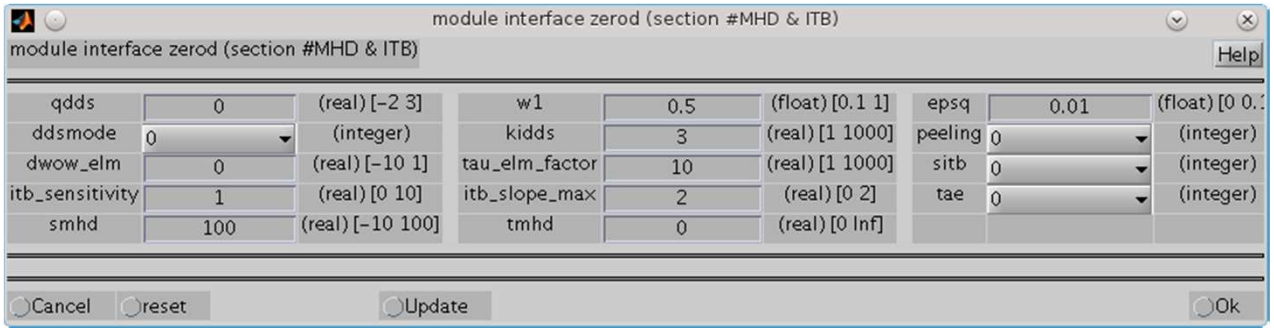




PARAMETERS INTERFACES (2/6)







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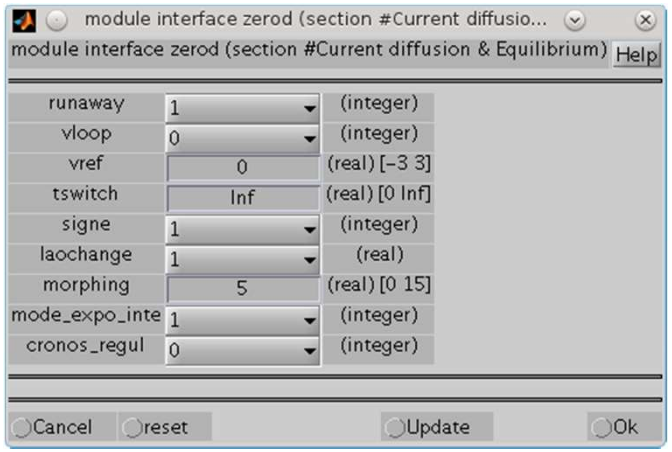

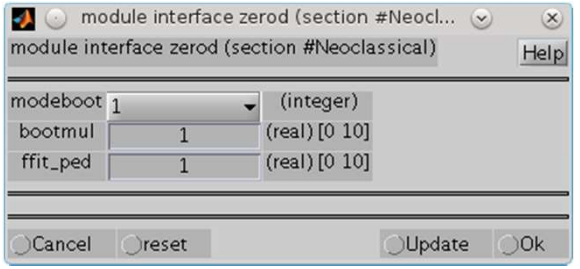

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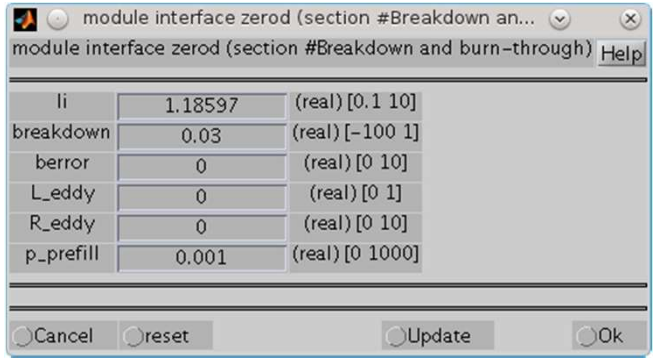

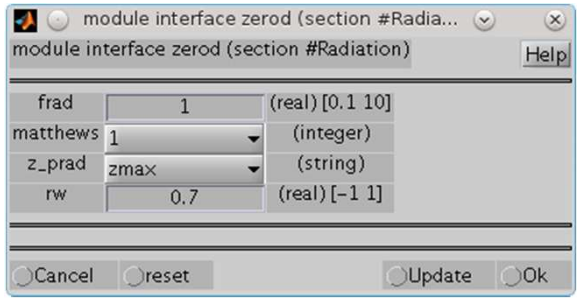

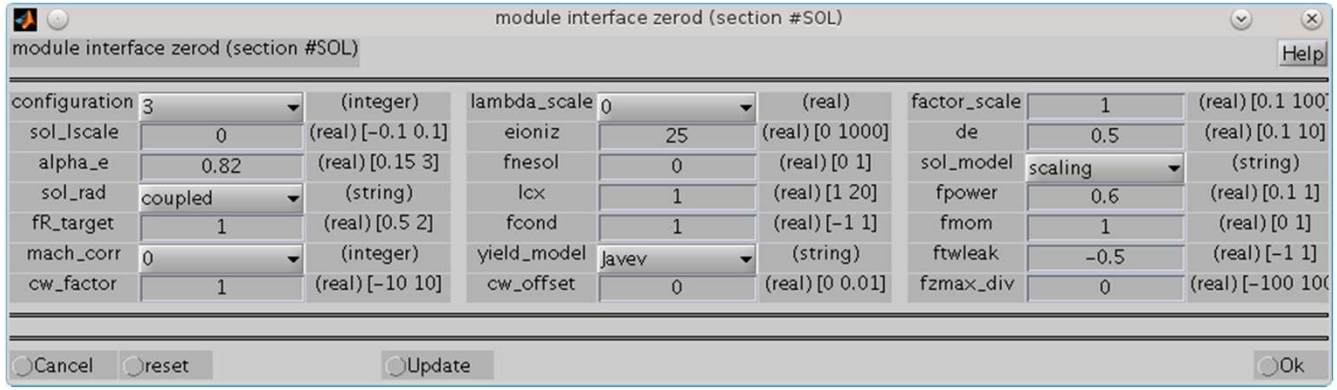

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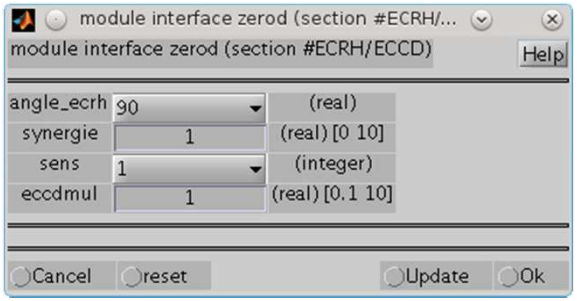
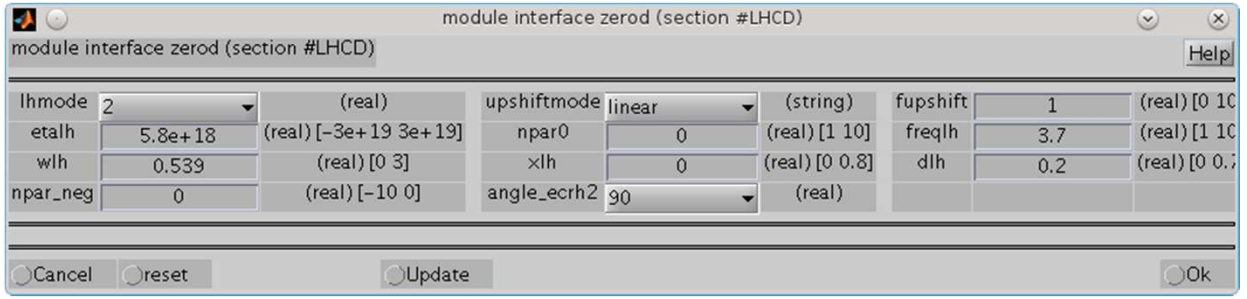
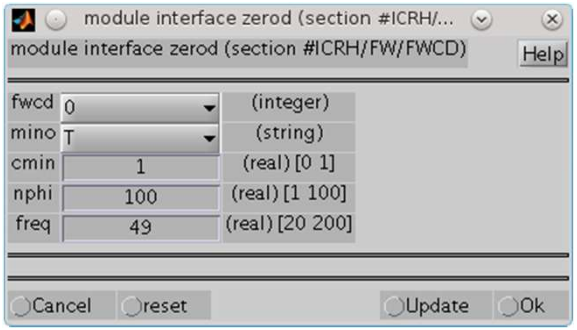
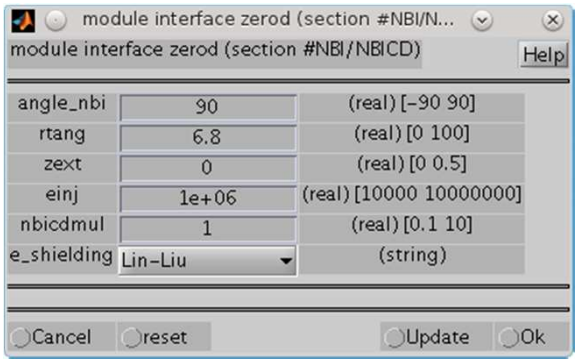
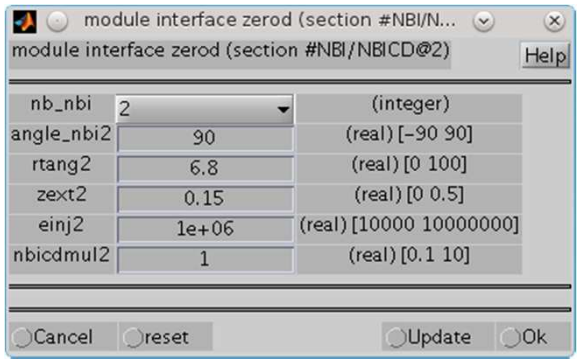


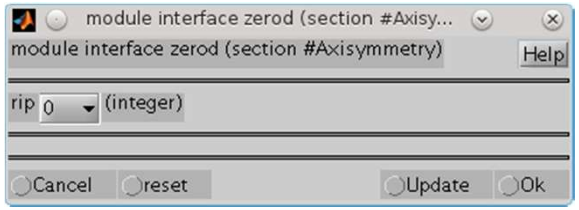


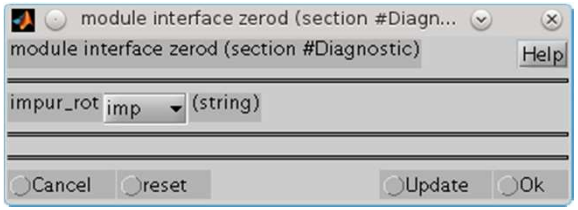


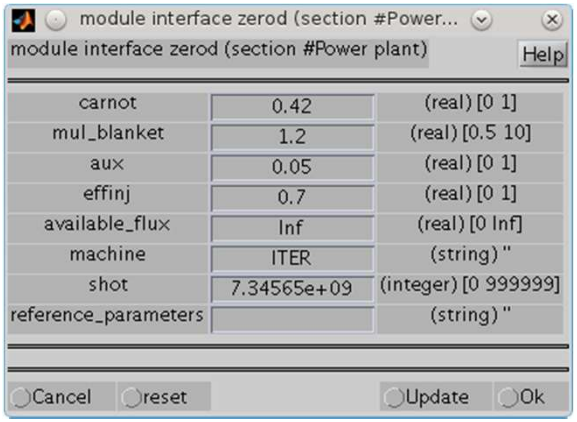


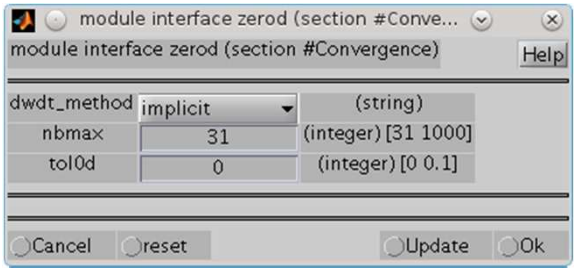


PARAMETERS INTERFACES (6/6)

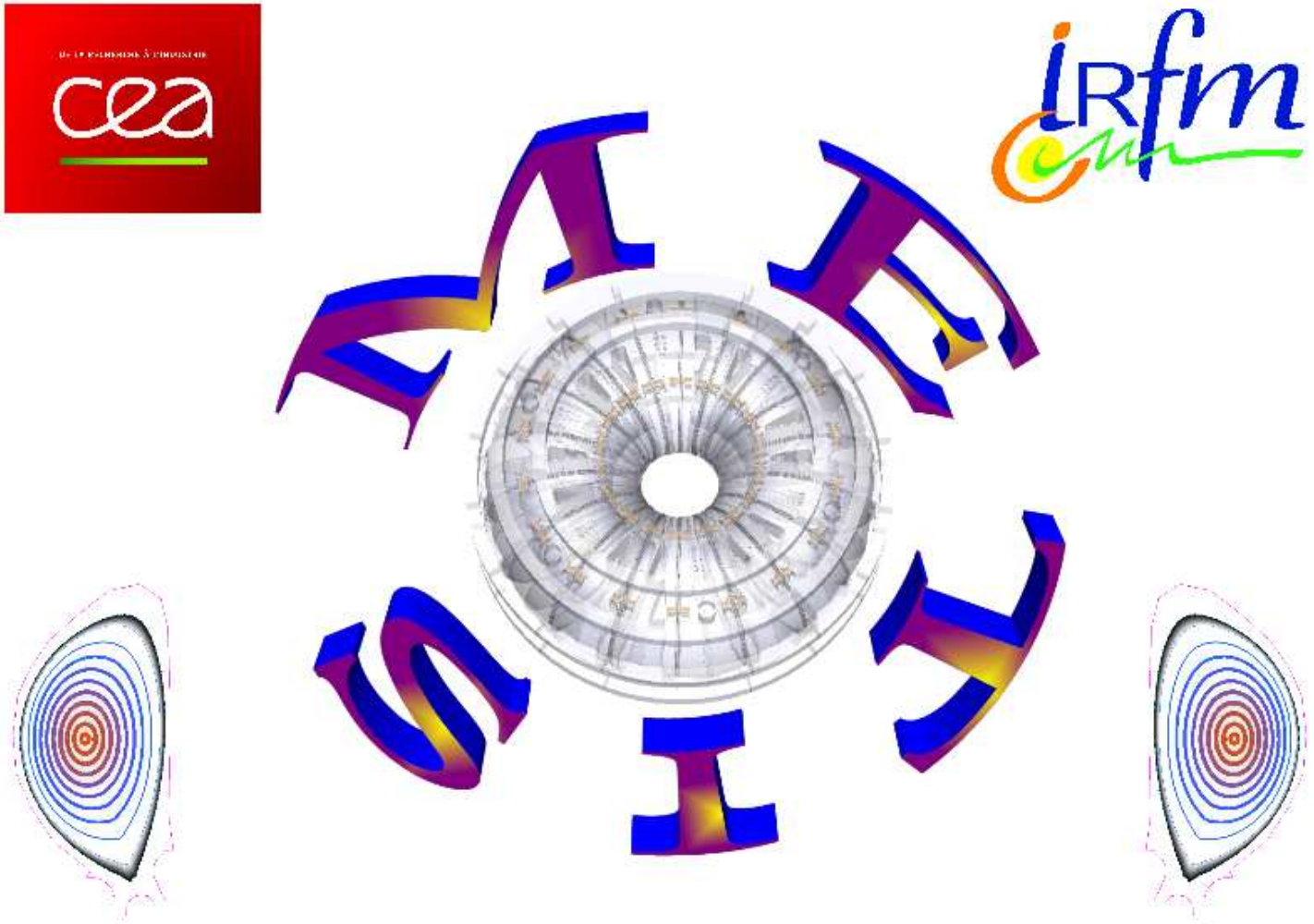








COMPILED METIS SPLASH SCREEN



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