



# SALOME, an open platform for numerical simulations

EDF SALOME Team (EDF R&D)

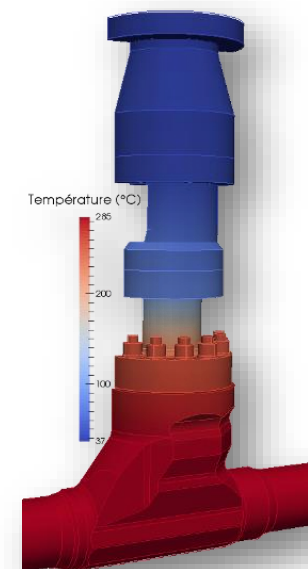
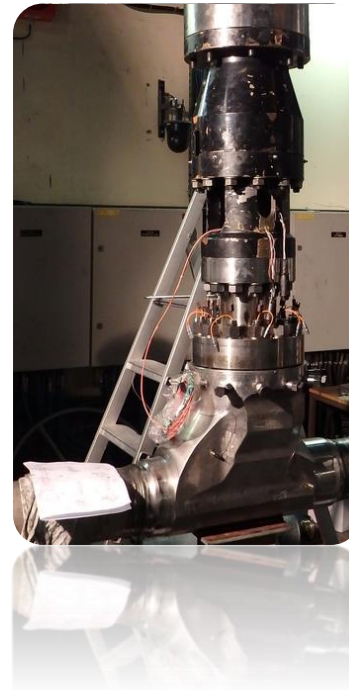
September 19, 2019



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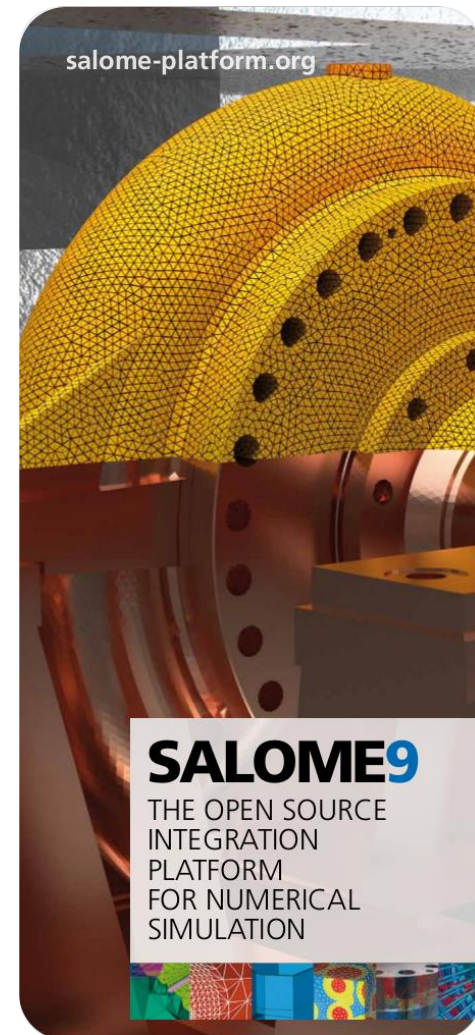
## Summary

1. SALOME, a middleware providing generic functions for numerical simulations
2. SALOME, an open framework to build domain specific solutions
3. Examples of SALOME applications





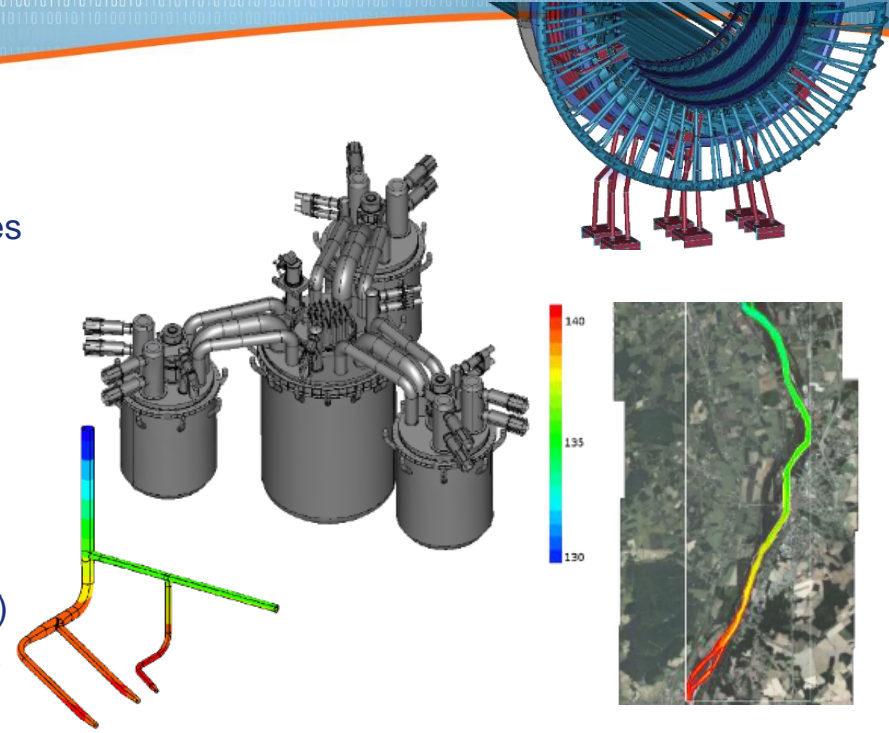
## SALOME, a middleware providing generic functions for numerical simulations





## General context

- ▶ Numerical modelling of EDF components and structures
  - ▶ Structural mechanics (*Code\_Aster*)
  - ▶ Thermohydraulics (*Code\_Saturne*, *NEPTUNE\_CFD*)
  - ▶ Electromagnetism (*Code\_CARMEL3D*)
  - ▶ Neutronics (*ANDROMEDE*)
  - ▶ Surface hydraulics (*TELEMAC-MASCARET*)
- ▶ All these physics domains require generic functions for numerical simulations



**3D Modelling**  
(CAD, meshing, visualisation)

+

**Computation scheduling**  
(workflow, distribution)

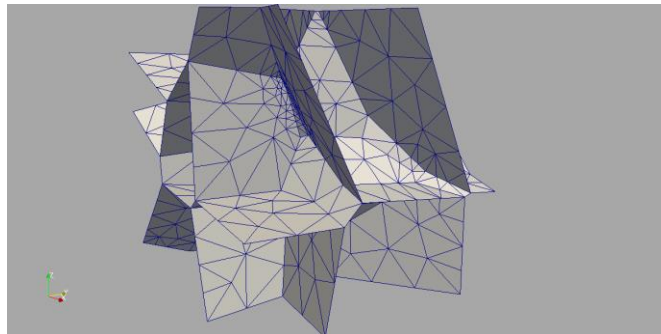
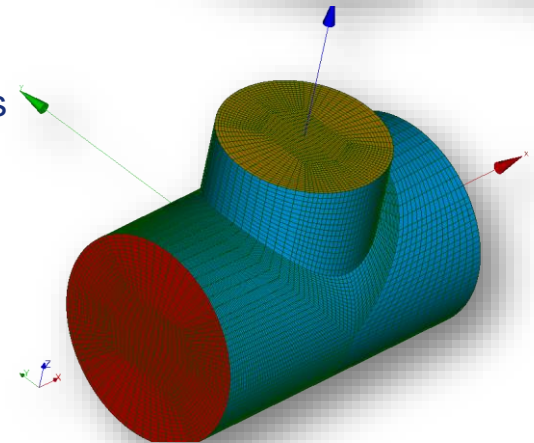
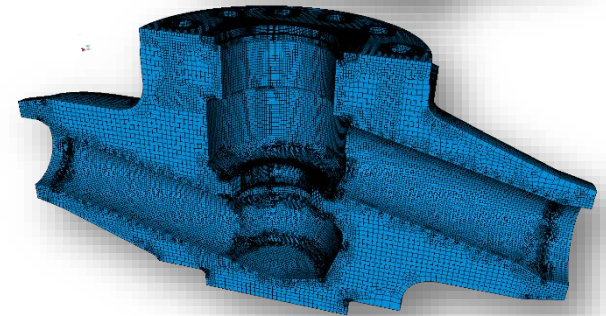
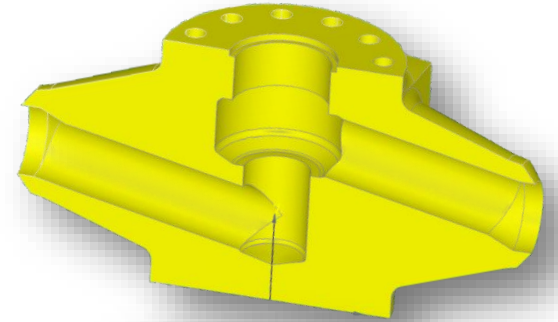
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**Complex data processing**  
(fields, matrix, etc)

= SALOME Platform

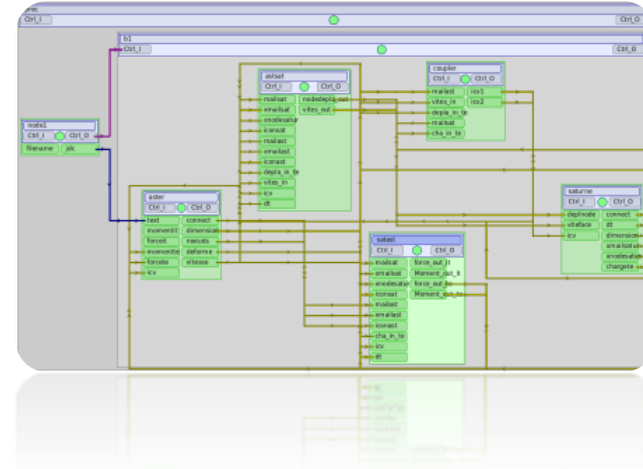
## modelling physical components

- ▶ Creating and/or importing the 3D design
  - Interactive CAD modeling and scripting capabilities
  - Importing/Repairing/Cleaning external models
- ▶ Meshing the CAD components using various algorithms
  - Standard opensource meshing functions
  - Integrate the commercial MeshGems suite (DISTENE)
- ▶ Preparing the geometrical model for computation
  - Localized refinement of parts of the mesh
  - Definition of geometric zones for the solver data settings



# Performing computing

- ▶ Supervision of computation workflow
  - ▶ Integration of domain specific solvers
  - ▶ Design of simulation workflow
  - ▶ Distributed computing using HPC
- ▶ Organizing parametric campaigns
  - ▶ Dedicated functions to run experimental plans
  - ▶ Distribution of computation units on HPC with failover management

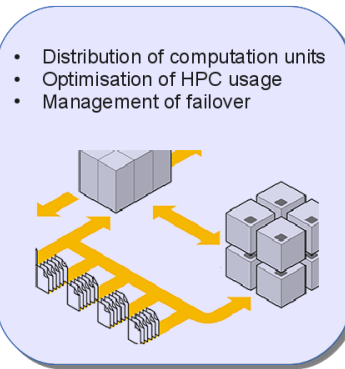


Experimental plan

#	C1	C2	C3	C4	C5	C6
1	105	65	2	2.0	20	2.3
2	95	75	3	1.5	20	4.1
3	105	65	3	1.5	20	4.0
4	95	65	2	1.5	20	2.5
5	95	65	3	2.0	20	3.2
6	95	75	3	2.0	3	3.2
7	105	75	2	1.5	20	4.0
8	105	75	3	2.0	20	4.1
9	105	65	3	2.0	3	1.9
10	95	65	3	2.0	20	4.5
11	95	65	3	1.5	3	2.3
12	95	65	2	2.0	3	4.1

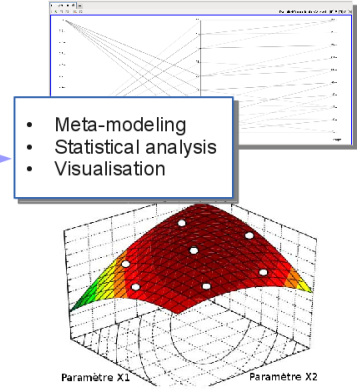
Parametric computation

$X_i$

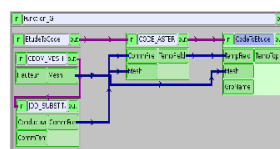


Analysis of parametric results

$(X_i, Y_i)$



Computation unit

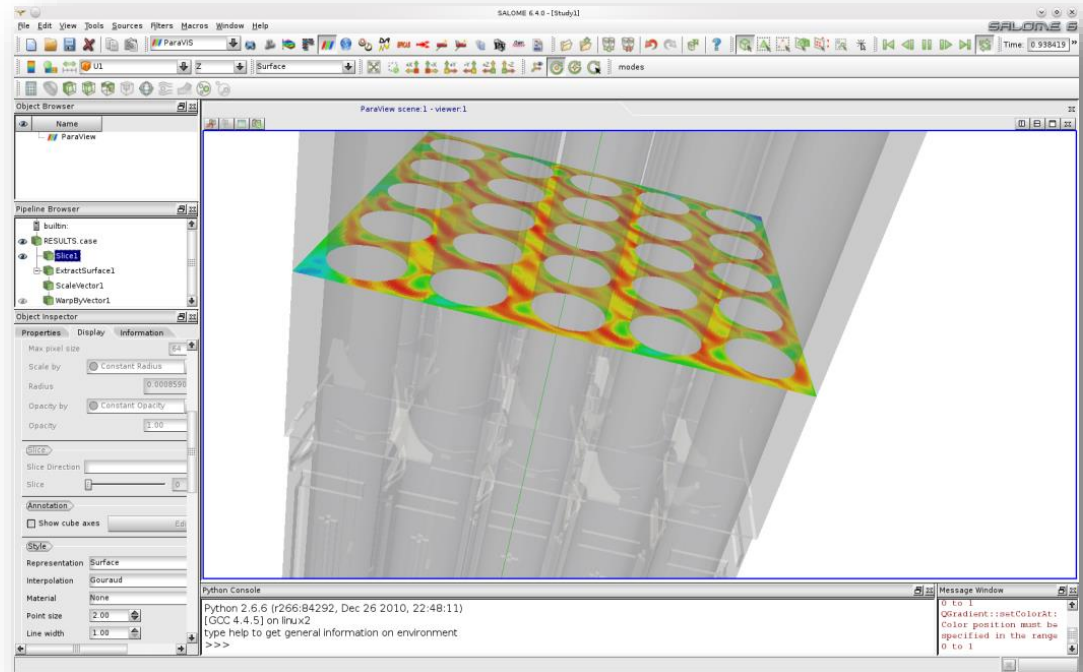
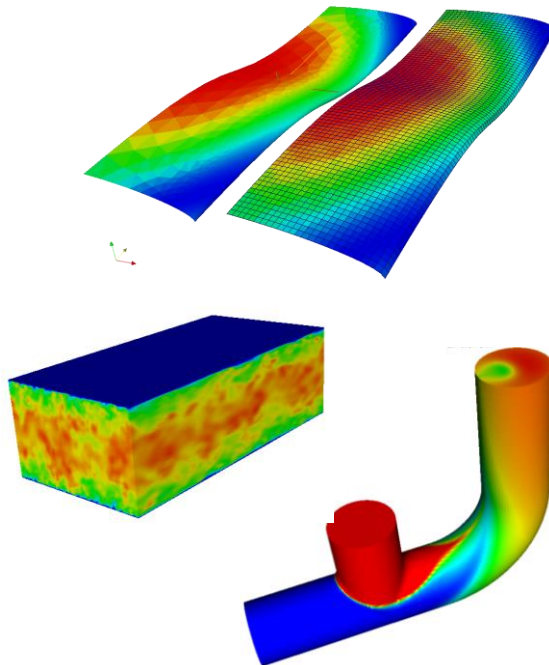


$$Y = f_c(X)$$

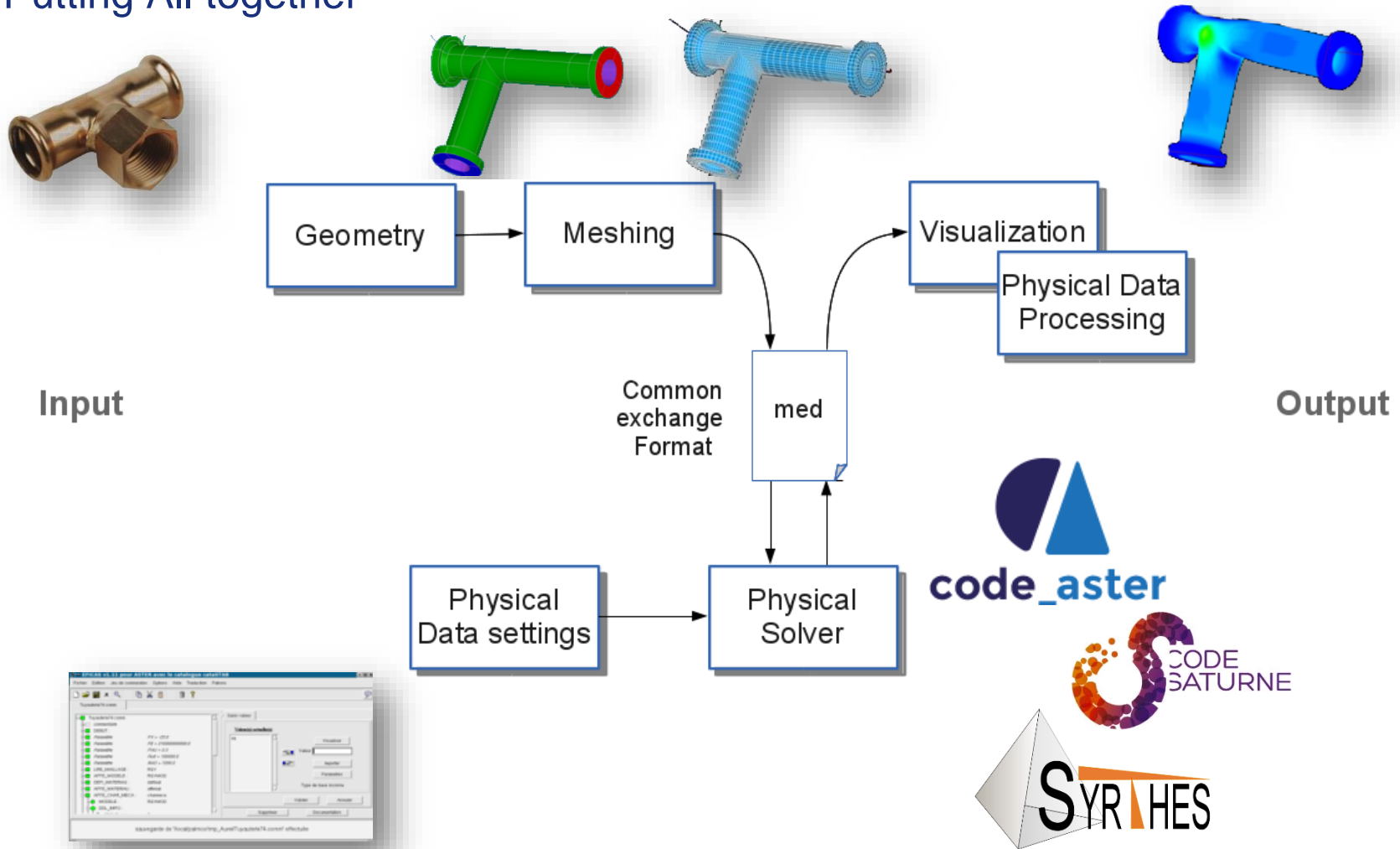


## Analysis and visualization of data

- ▶ Processing fields and meshes
  - ▶ Loading data from several file formats (**med**, unv, vtk, etc)
  - ▶ Exploring the data using a rich set of visualization functions (based on paraview)
  - ▶ Processing field data through various algorithms (c++ or python)



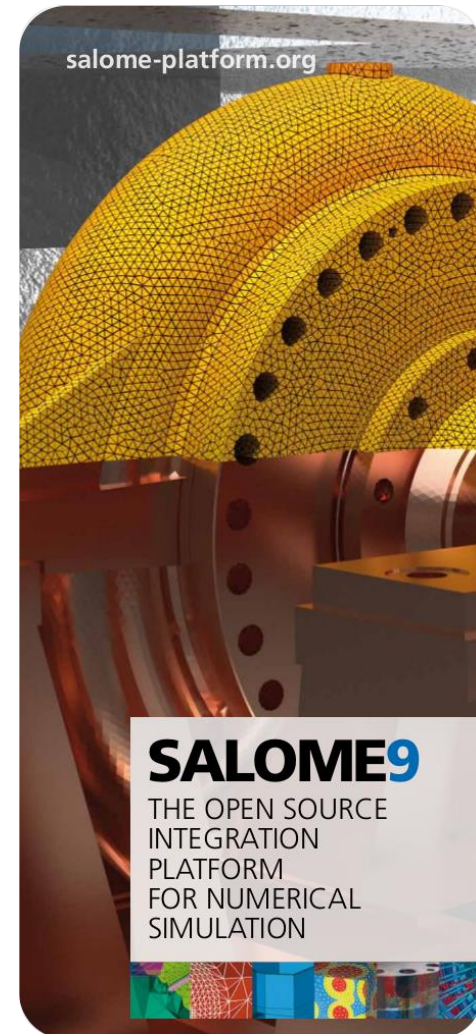
# Putting All together





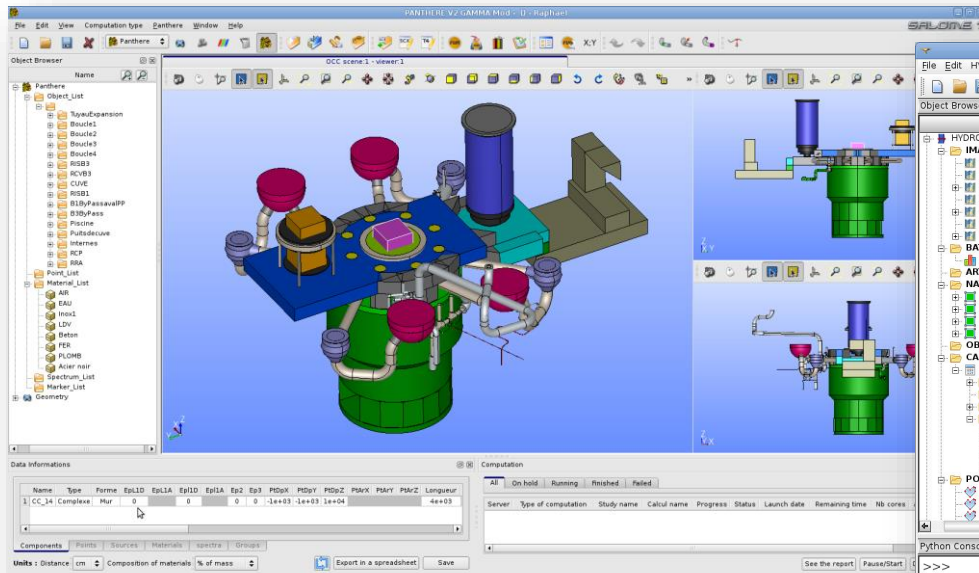


## SALOME, an open framework to build domain specific solutions



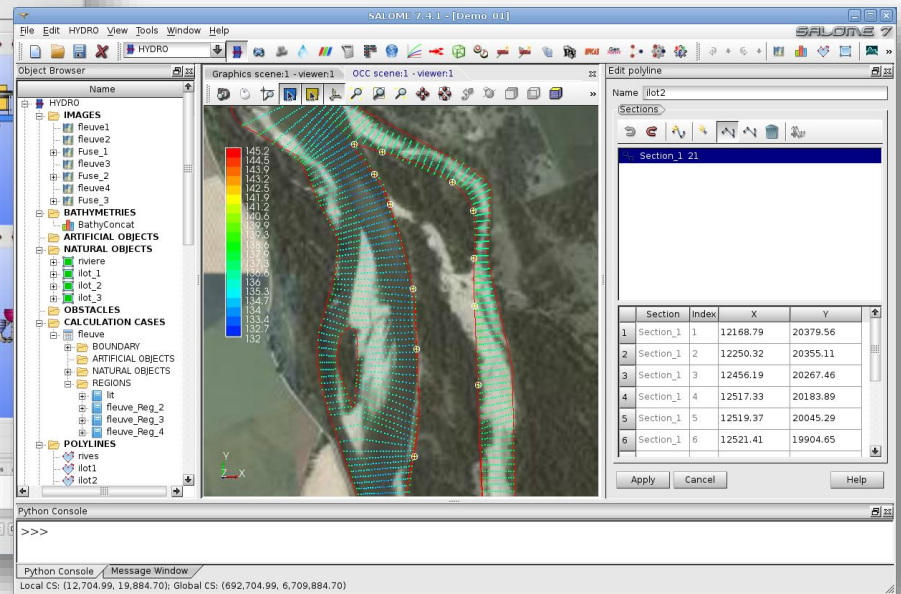
## Domain specific solutions

- ▶ SALOME = modular simulation platform to compose integrated and customized simulation environments:



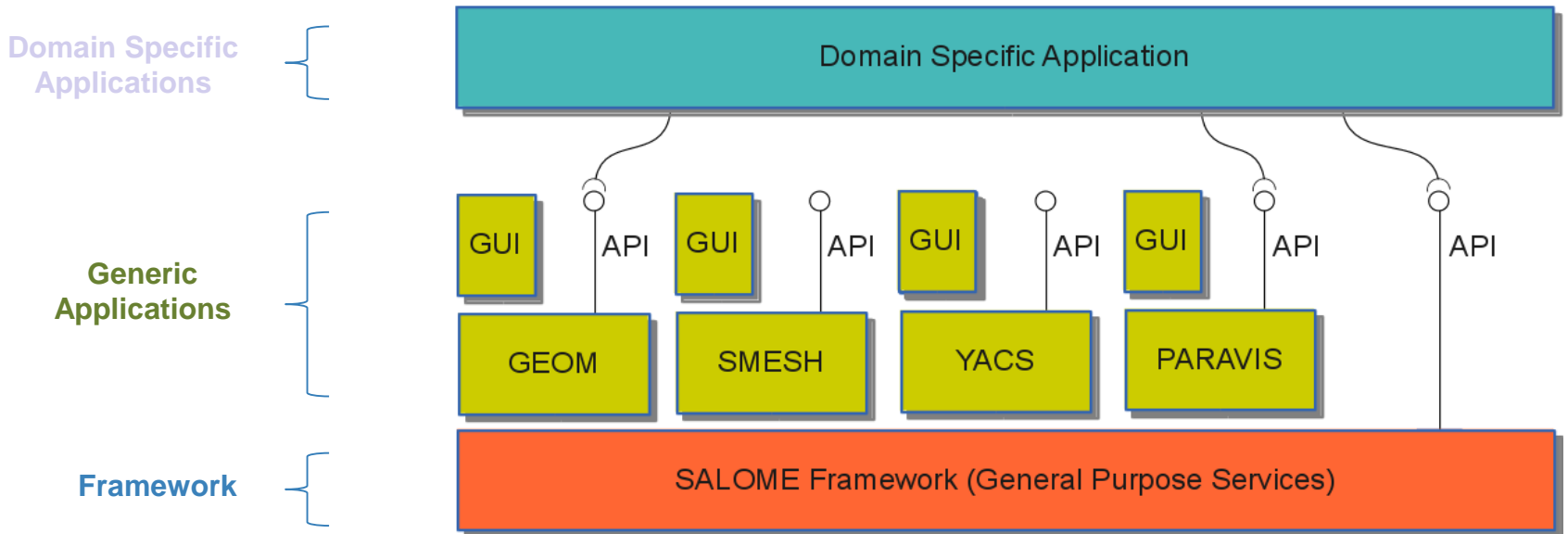
*PANTHERE V2 (radiation protection)*

## SALOME-HYDRO (free surface hydraulics)



# A Framework to build custom applications

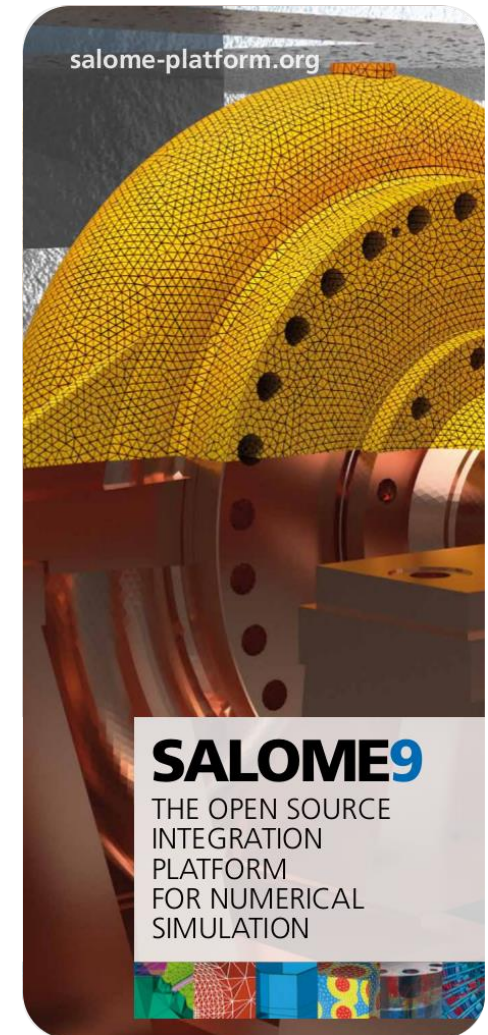
- ▶ The SALOME framework is organized as a modular set of services
  - ▶ Geometry, Meshing, Field processing, Visualisation, Data analysis
  - ▶ Common Exchange Format (MED) for intercommunication with physical solvers
- ▶ Each module provides several interfaces:
  - ▶ graphical interface for interactive usages (C++, Qt, PyQt)
  - ▶ textual interface for scripting the process (domain specific language based on Python)
  - ▶ programming interface to build custom applications (API C++ and Python)







## Examples of SALOME applications (mainly in the nuclear energy domain)

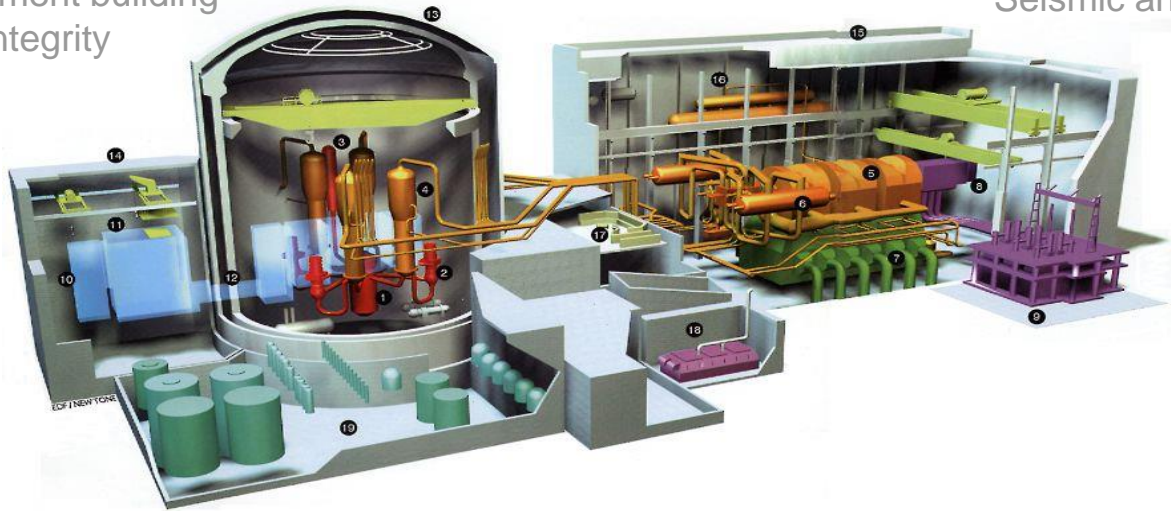


# Numerical simulations INVOLVING MECHANICS AND salome – meca

Containment building Integrity



Storage



Seismic analysis

Alternator behaviour



Turbine behaviour



Core vessel integrity



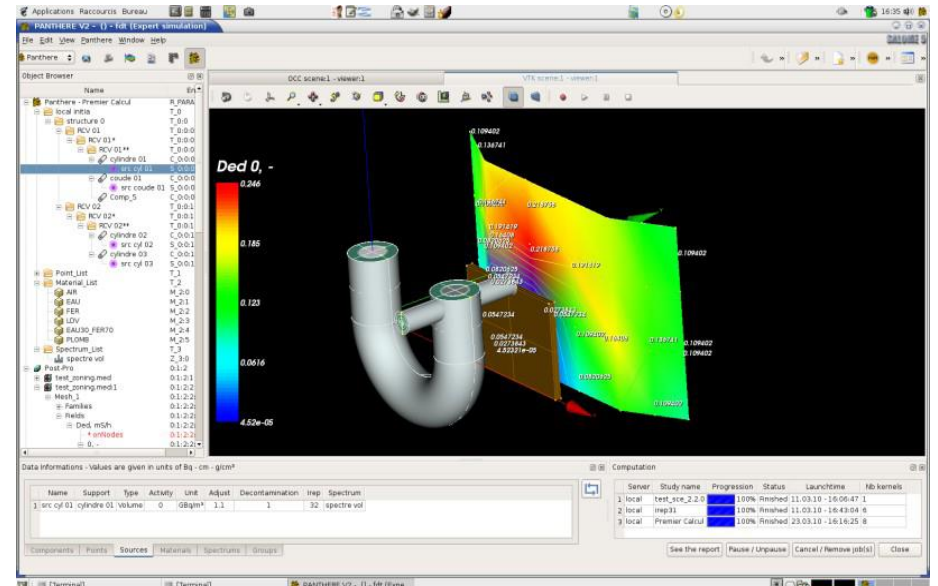
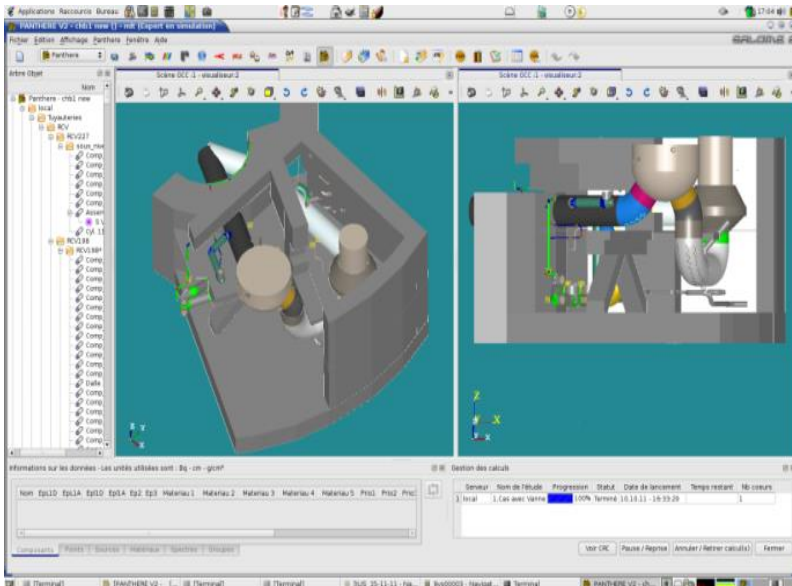
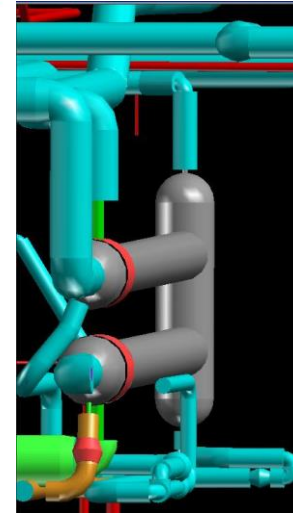
Primary circuit integrity





# RADIOPROTECTION: PANTHERE V2

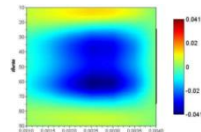
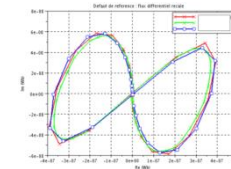
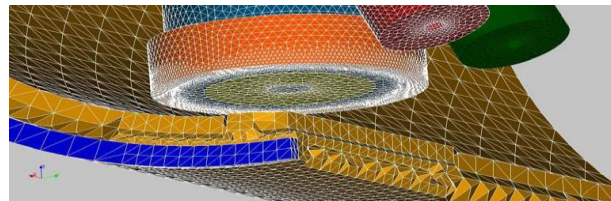
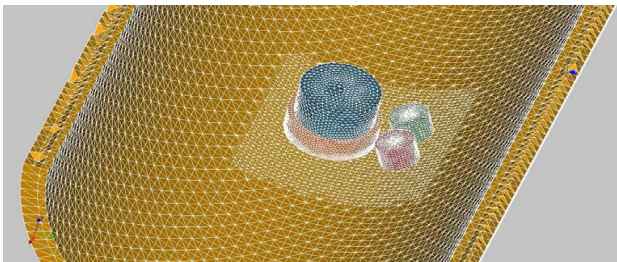
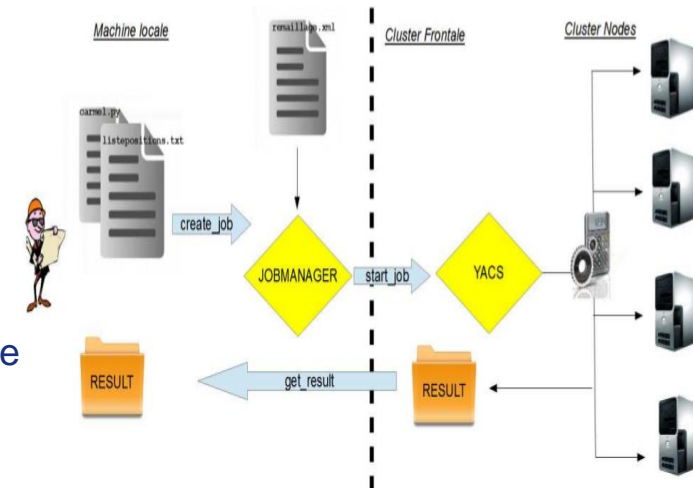
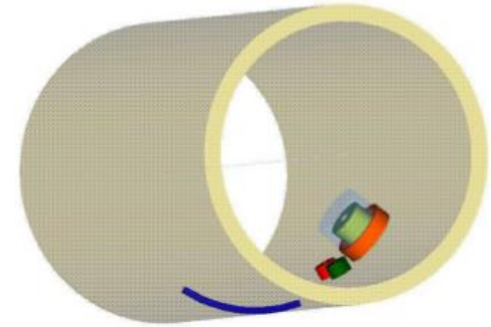
- ▶ Simulation analysis for radioprotection
  - ▶ 3D actual description of the plant
  - ▶ Simulate the dosimetry associated to an intervention





# Electromagnetic Non Destructive control : FLAW detection

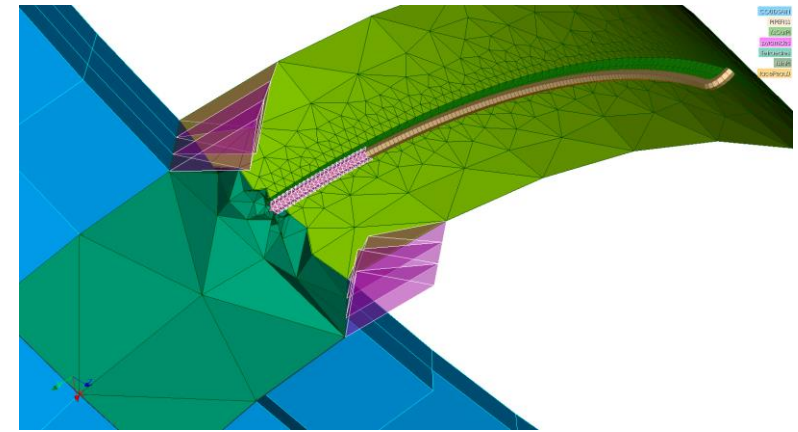
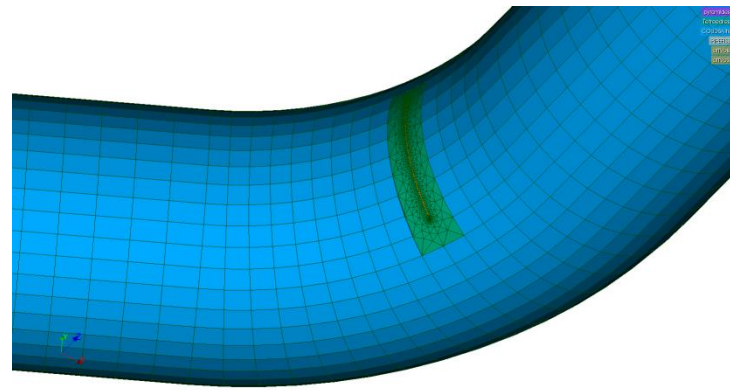
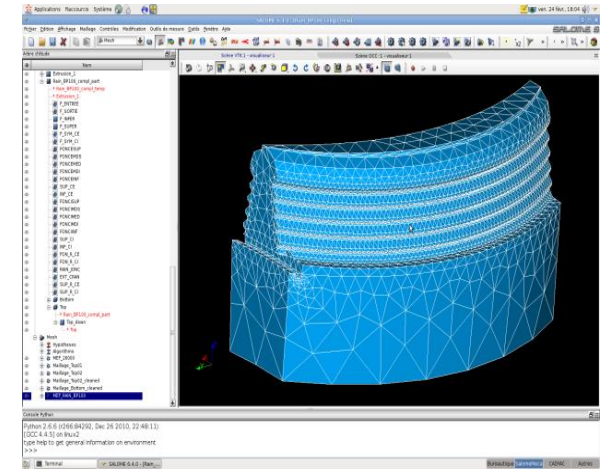
- ▶ Modelling of steam generator tubes inspection
  - ▶ Compare actual and simulated electromagnetic response
    - ▶ Actual experiment with probe and cracks on a tube
    - ▶ Simulation of the same
      - ▶ Needs local refinement for each probe position
      - ▶ Parametric study launched on a cluster
- ▶ The simulation helps to qualify the electromagnetic non destructive control method.





# Crack NOCIVITY

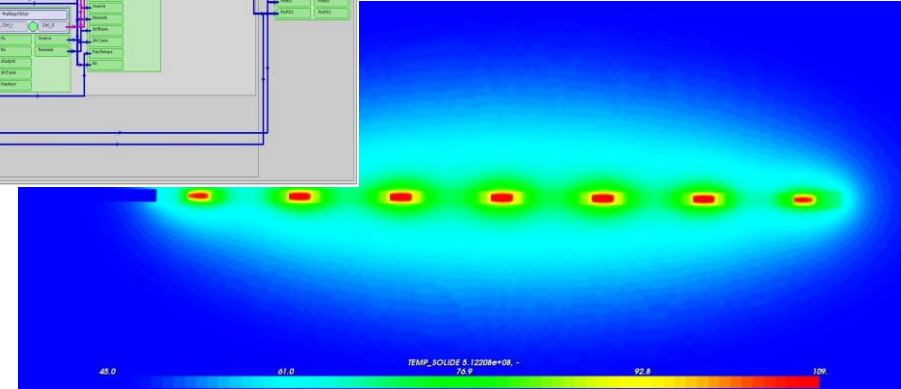
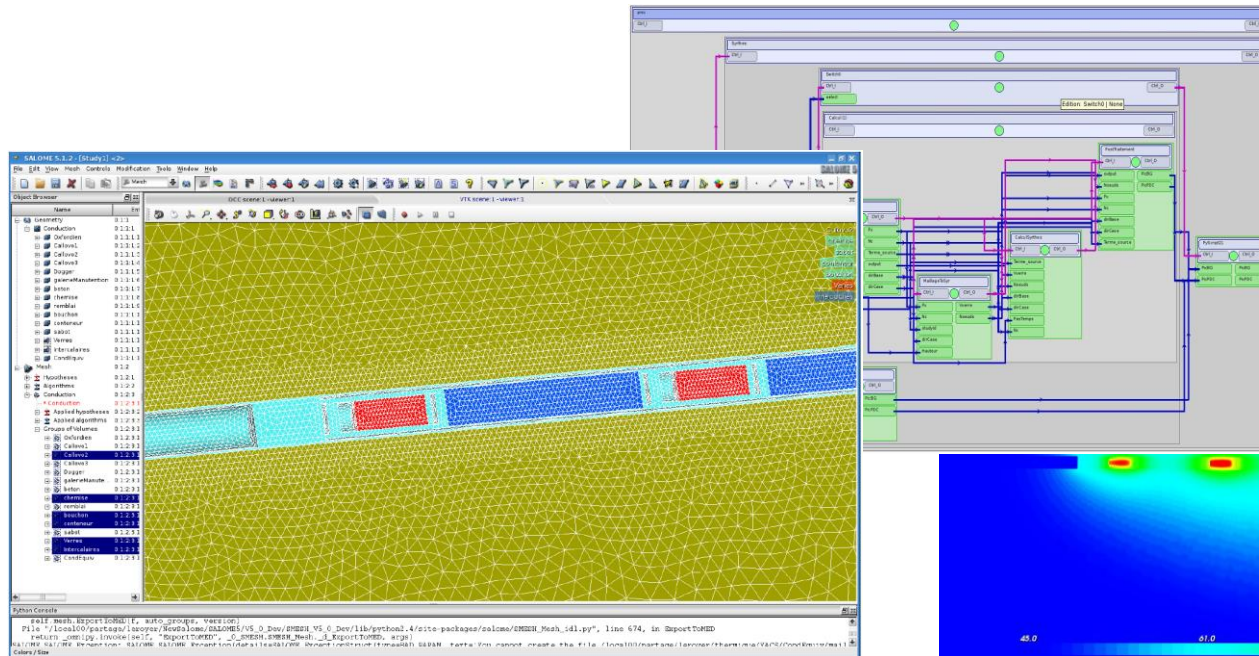
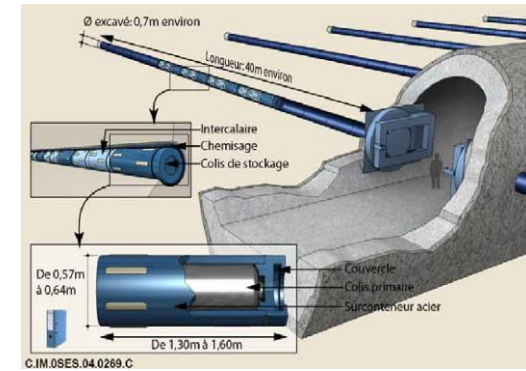
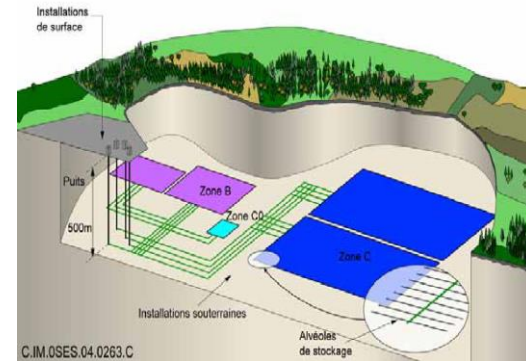
- ▶ Crack detection during inspections
- **Impact of the crack: do we need to change the equipment ?**
- ▶ Fast response required: dedicated tools
  - ▶ Local refinement without actual crack meshing
- ▶ Insertion of a crack on an existing mesh: automatic tool
  - ▶ generic meshes without cracks
  - ▶ crack description: geometry of the crack
  - ▶ Automatic local remeshing





# Storage: waste management

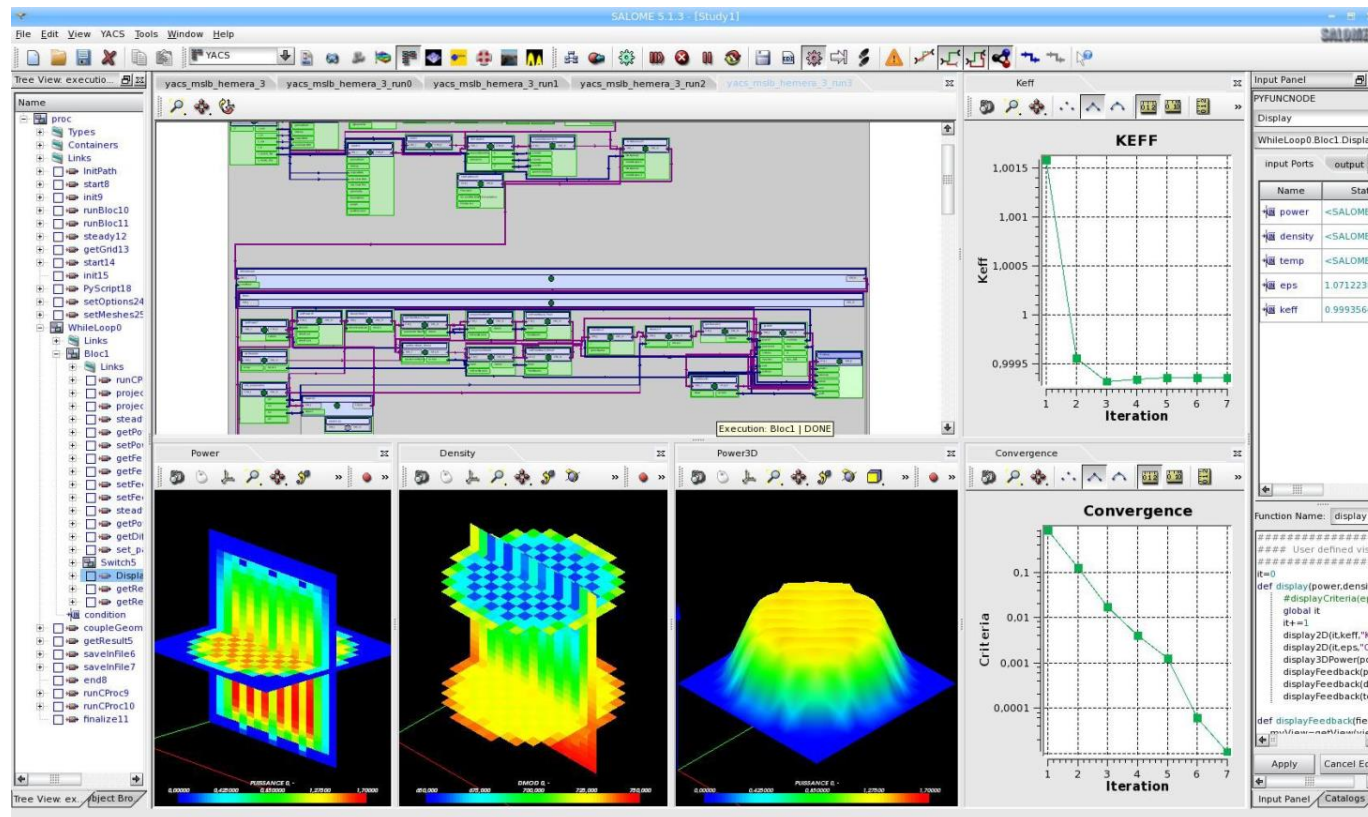
- ▶ Economic study on storage optimisation
  - ▶ Constraint: maximum temperature limit
  - ▶ Several sources of uncertainties
  - ▶ Uncertainties impact: heavy parametric studies



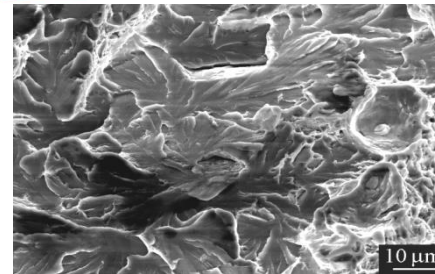


# NEUTRONICS-THERMAL-HYDRAULICS COUPLING

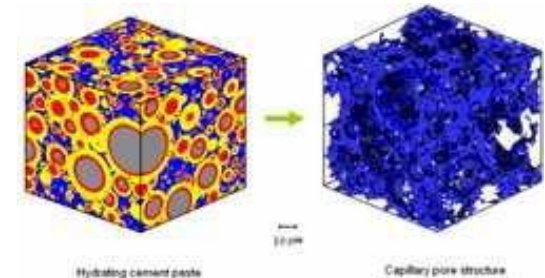
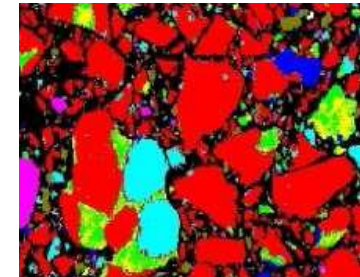
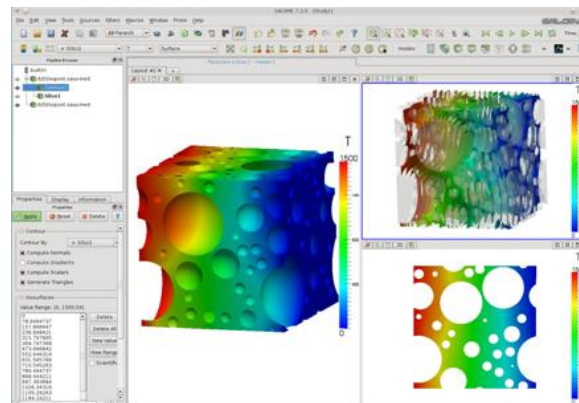
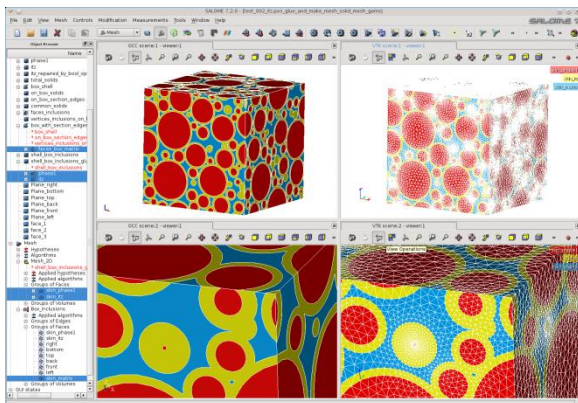
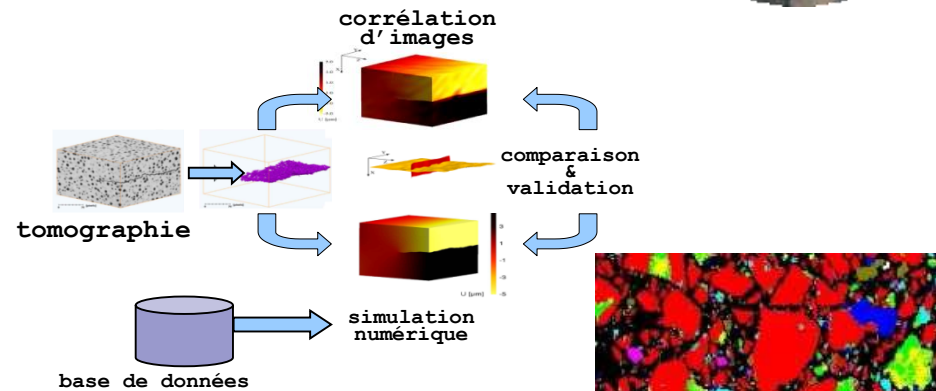
- CEA: Execution graph of a coupled neutronics thermal-hydraulics simulation
  - Yacs workflow allows to show convergence history and 2D or 3D maps during calculation



# MATERIAL STUDIES

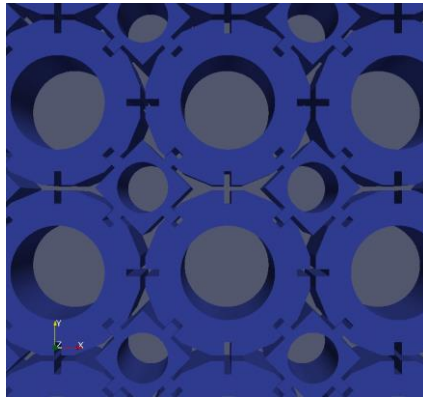
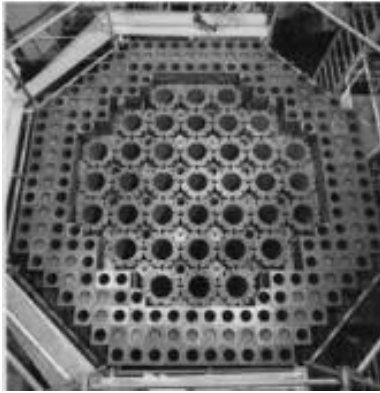


- ▶ EDF: SALOME Platform MAP
  - ▶ Integrates a lot of existing tools
  - ▶ Industrialisation of very complex studies

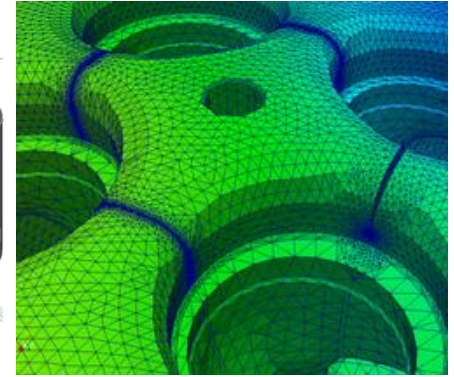
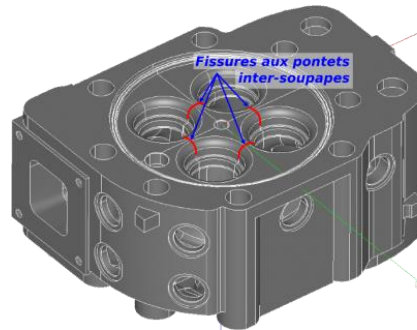




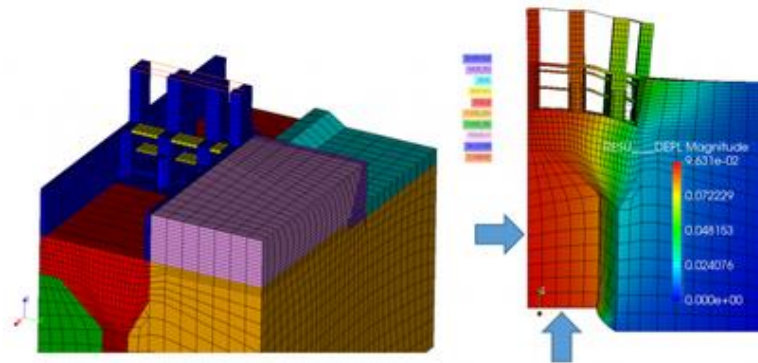
## Some other examples (structural Mechanics)



Local effects of cracking in graphite cores



Emergency diesel engines:  
Cracks impacts on cylinders behavior?

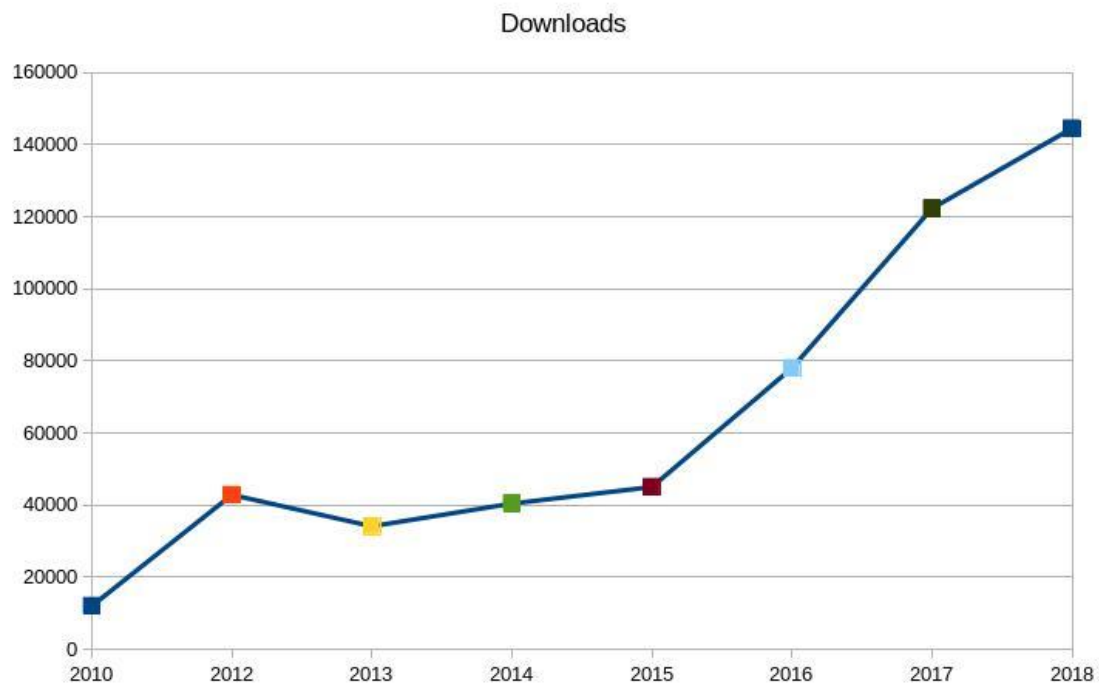


Modeling a dam subjected to geological effects



## SALOME by Numbers

- ▶ Downloads on <http://www.salome-platform.org>
  - ▶ 200 000 visits
  - ▶ 145 000 downloads
- ▶ Development team
  - ▶ 30 regulars developers
  - ▶ CEA-EDF core team
    - ▶ 10 part-time contributors





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