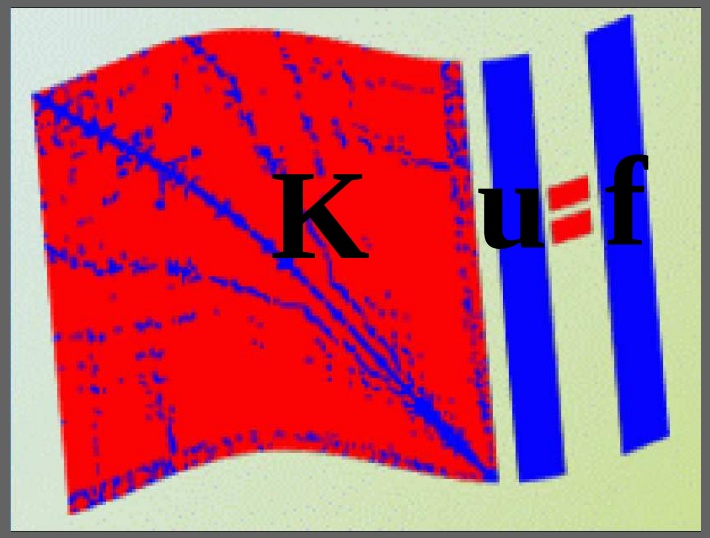


EDF participation to the ANR SOLSTICE

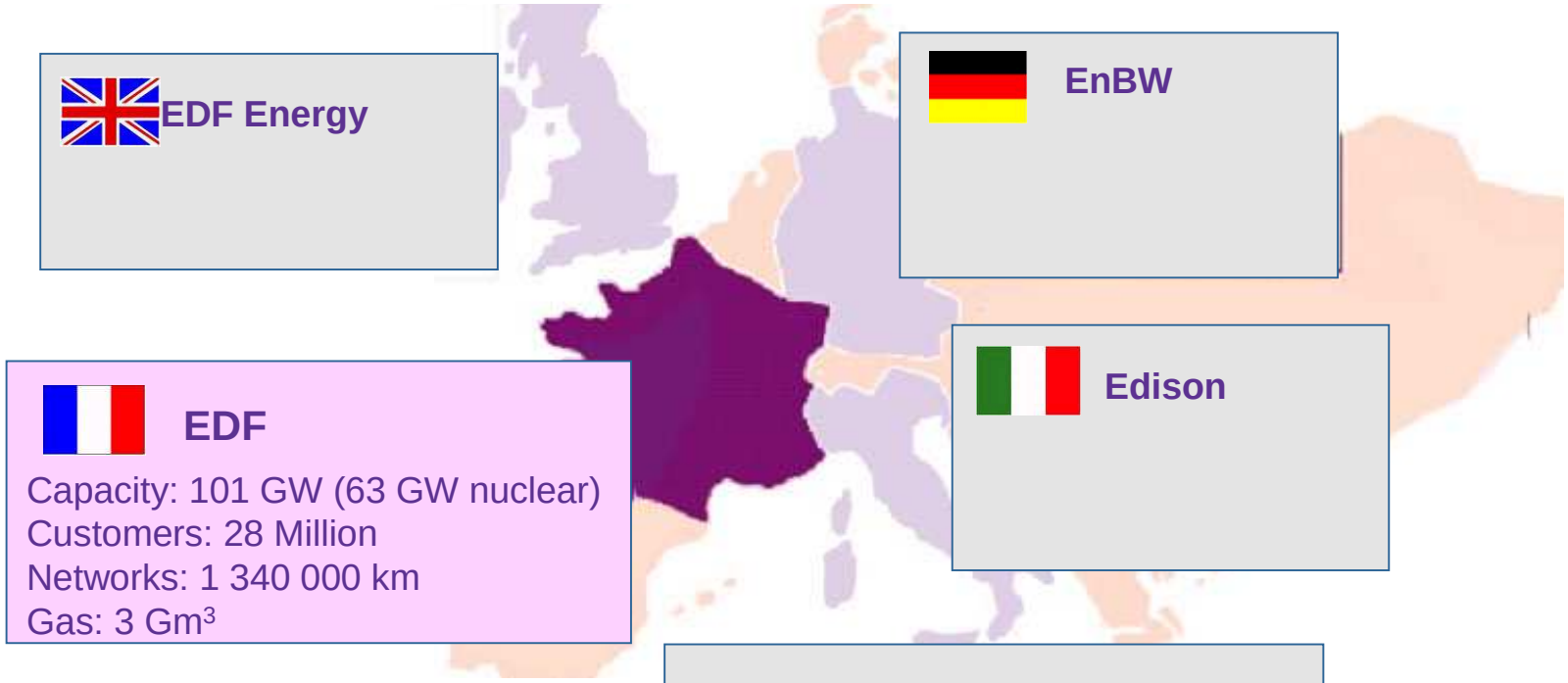
ANR SOLSTICE Final Workshop
Sparses Days
15 juin 2010
O.Boiteau

SOLSTICE
SOLveurs et SimulaTIons en Calcul Extrême
ANR CIS 2006

Agence Nationale de la Recherche
ANR
www.agence-nationale-recherche.fr

EDF R&D

1a. EDF Group: a European Electricity Utility with strong R&D involvment



EDF Energy

EnBW

Edison

EDF

Capacity: 101 GW (63 GW nuclear)
Customers: 28 Million
Networks: 1 340 000 km
Gas: 3 Gm^3

Sales: €64.3 billion
Global customer base: 38,1 million
Employees worldwide: 161,000
Installed capacity: 128.2 GW
R&D: €1 million/day

1b. Operation, Maintenance & Optimization of complex systems at EDF

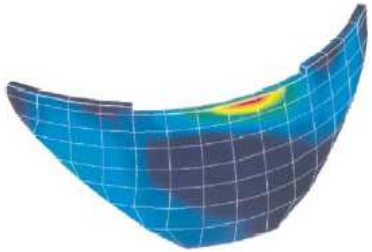
Software Quality Plan (requirements of the Nuclear Structures Safety Authority)

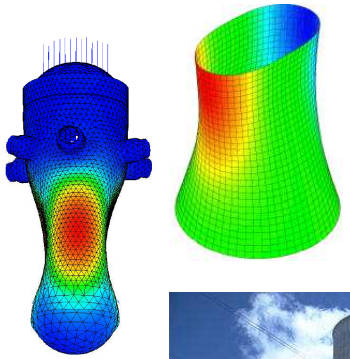
Permanent objective

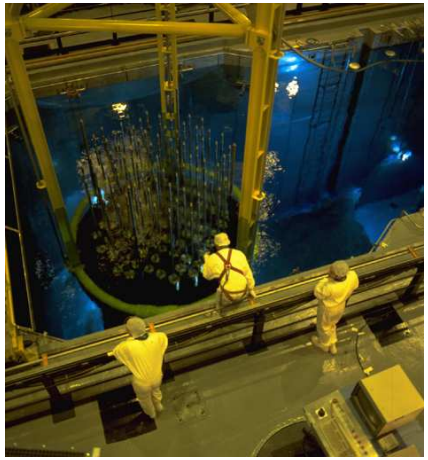
- guarantee safety,
- improve performances/costs,
- maintain assets.

Changing operating conditions

- face unexpected events, ageing issues, maintenance,
- improve performance through new technologies, new operating modes and system-wide optimization,
- adapt to evolving set of rules (safety, environment, regulatory).







In-house technical backing

- expertise: strong Engineering and R&D Divisions,
- physical testing and simulation are key tools from the outset.

1c. Workflow of EDF physical simulation codes

Mesh generation, material, loadings…

Data distribution

Discretization time, space

Linear solver

Post-processing, visualization

Non linear loops

Time loop

CFD code

NUPTUNE

Code_Saturne

Code_Aster®

ANALYSE DES STRUCTURES ET THERMO-MÉCANIQUE POUR DES ÉTUDES ET DES RECHERCHES

Thermomechanical code

Thermics/Neutronics for nuclear, Electromagnetism…

telemac

Hydraulic code

SYRTHES

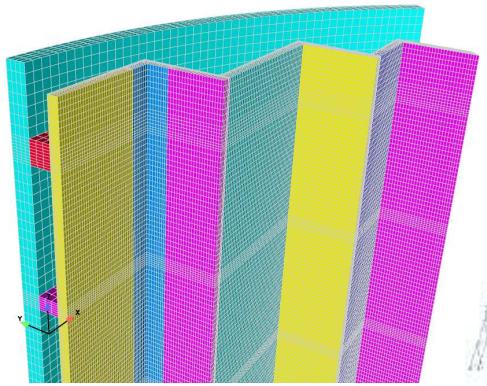
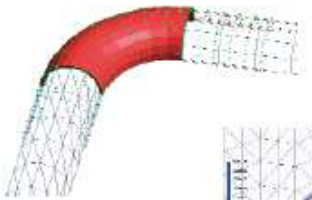
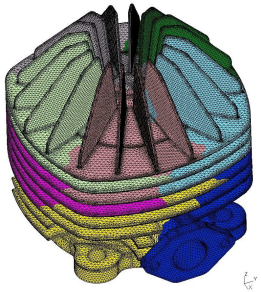
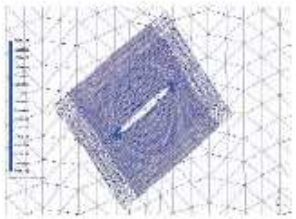
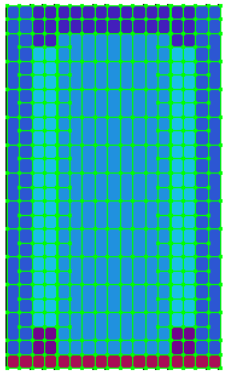
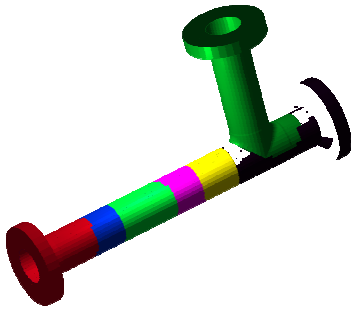
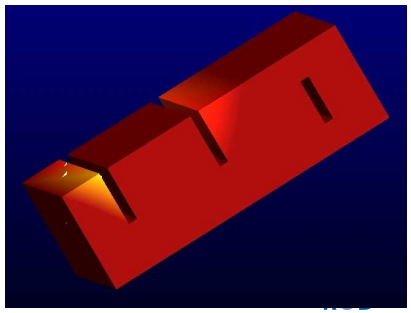
Cocagne

Code_Carmel…

EDF R&D

2a. EDF involvement in ANR SOLSTICE (1/2)

- **We provided almost 60 matrices from industrial tests to the TLSE database:**
  - Canonical models and fine meshes (bent pipe, RIS pump, engine crankcase, nuclear vessel…) ,
  - Sophisticated models and coarse meshes (arlequin method, contact and friction, eigenvalue analysis, domain decomposition with FETI method…).
- **Real symmetric matrices:**
  - Often, positive semidefinite (augmented system with Lagragian unknows for BC modelling),
  - Sometimes, singular (task T1.1)

2a. EDF involvement in ANR SOLSTICE (2/2)

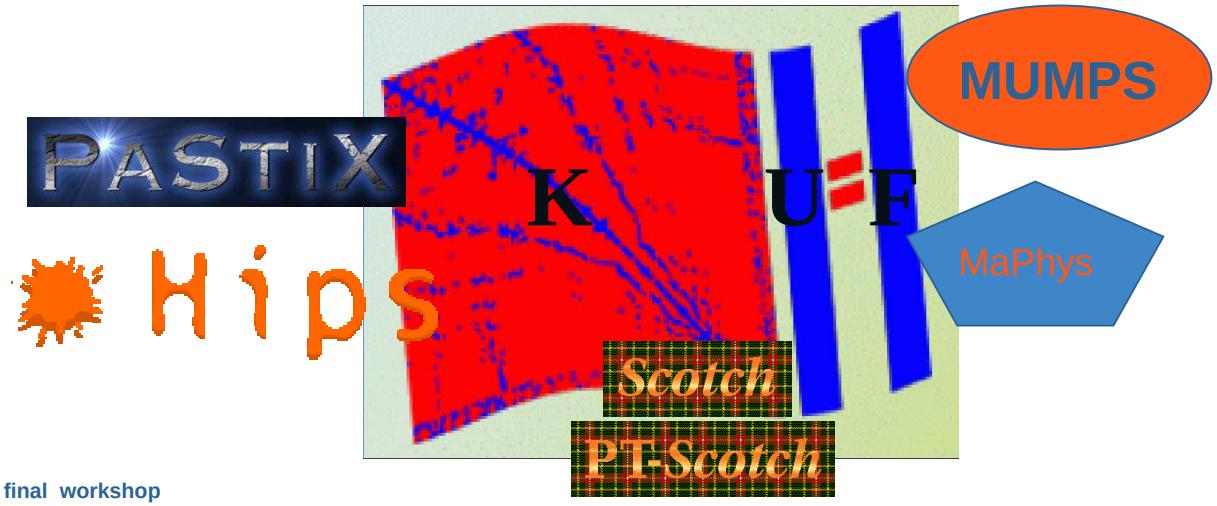
Task 1.1 (*Rank deficiency and null space computation*): provided specific matrices, technical exchanges with CERFACS and **MUMPS** teams, use of dedicated options of **MUMPS** package.

Task 1.2 (*Out-Of-Core capability*): provided matrices and feedbacks (installation, use and consistency of the new options, scope of use, tricks, bugs…), technical exchanges with **MUMPS/PaStiX** teams, use of dedicated options of theses packages.

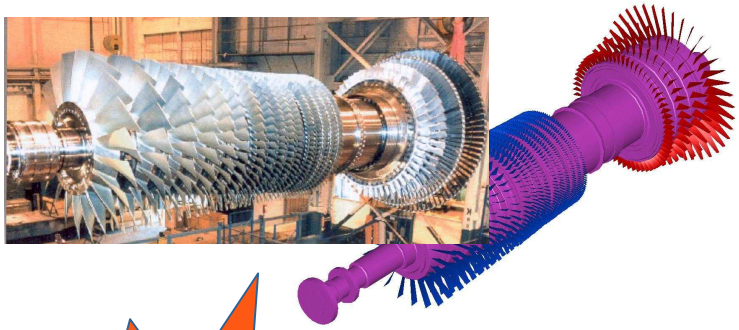
Task 1.3 (*Partitioning and ordering*): limited technical exchanges.

Task 1.4 (*Parallel analysis*): currently in test.

Task 1.5 (*Hybrid solvers*): provided matrices, **HIPS** in test.



2b. Uses of ANR SOLSTICE's packages in EDF physical simulation codes



Code_Aster
ANALYSE DES STRUCTURES ET THERMO-MÉCANIQUE POUR DES ÉTUDES ET DES RECHERCHES
www.code-aster.org

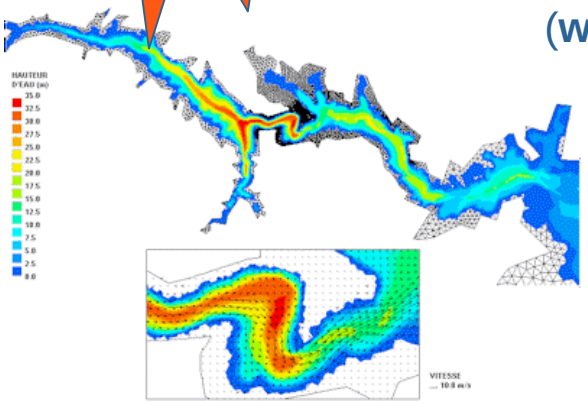
MUMPS
In production
T1.1/T1.2

PaStiX/HIPS
In test
(T1.2/T1.5)

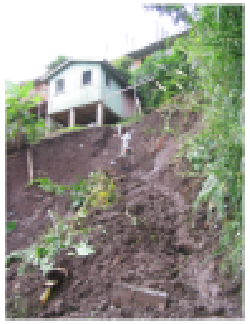
Code_Aster: A finite element code for analysis of structures and thermomechanics studies and researchs (**www.code-aster.org**).

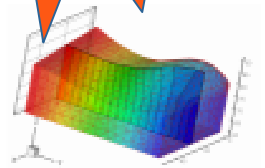
TELEMAC system: a group of numerical modeling softwares for free surface water, sedimentology, w water quality, underground flows (**www.telemacsystem.com**) …

PT-Scotch
In test
(T1.3/T1.4)



telemac





EDF R&D

3a. *Code_Aster* & MUMPS (1/4)
A story of sparse linear system !

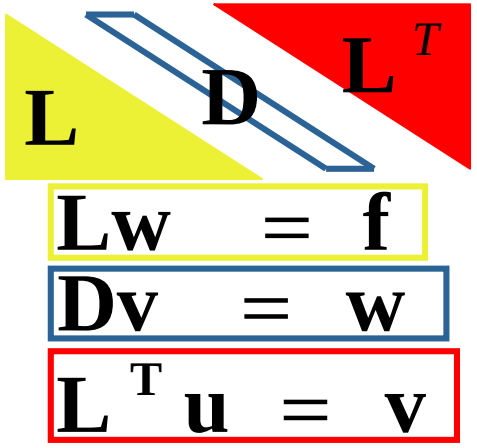
MUMPS

➢ **A particular productive collaboration:** numerous feedbacks, advices and matrices were shared.

→ *Code_Aster* can benefit from a modest parallelism (< 128 cores) but robust, all-purpose and user-friendly.

→ For 2 years, daily used by EDF R&D & Engineering.

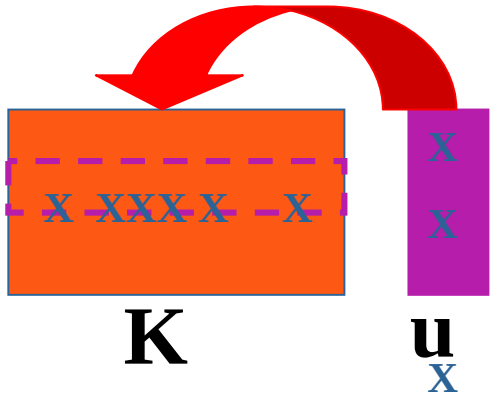
➢ Direct methods versus iterative ones



$$Ku = f$$

Aster keyword METHODE

LDLT	GCPC
MUMPS	PETSC
MULT_FRONT	FETI

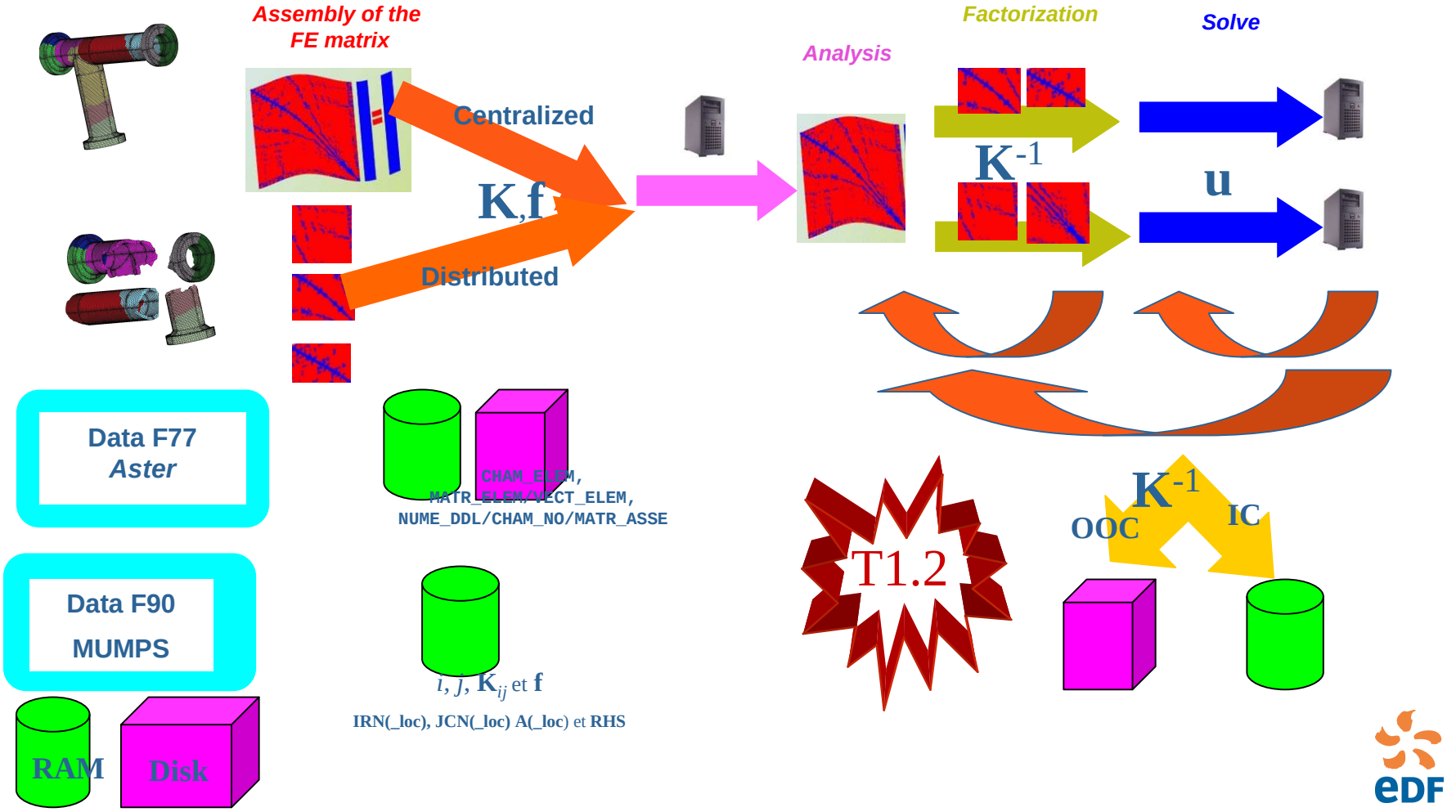


EDF R&D

3b. *Code_Aster* & MUMPS (2/4)
A story of sparse linear system !

- (Usually) General real symmetric < 5 millions dof;

Flexibility/Efficiency,
Distributed parallelism,
Out-of-core capabilty

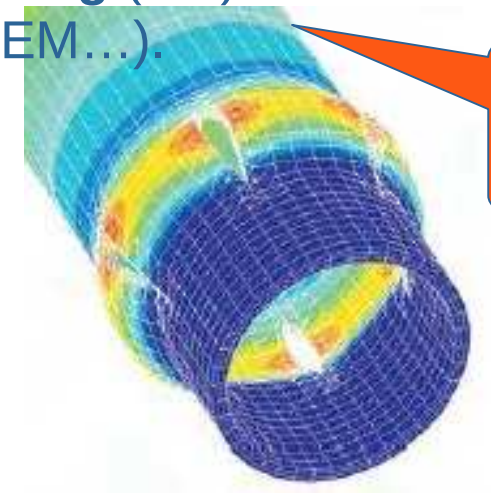


EDF R&D

3c. *Code_Aster* & MUMPS (3/4)
A story of sparse linear system !

➢ (Often) **Bad conditionning** (10^8) and indefinite matrix (mixte FE, Lagrange multipliers, X-FEM…).

***X-FEM on a pipe**: enriching the sane mesh with special FE to simulate multi-cracking.*



Numerical robustness, Pivoting/scaling strategies, Error analysis and iterative refinement.

➢Detection of **singular matrice** (lacks/excess of boundary conditions, eigenvalue problem, null space analysis…).

T1.1

Zero-pivot detection option

➢(Sometimes) Unsymmetric, SDP, complex arithmetic, reuse of the analysis phase for several solves.

Full range of possibilities

3d. *Code_Aster* & MUMPS (4/4)
A story of sparse linear system !

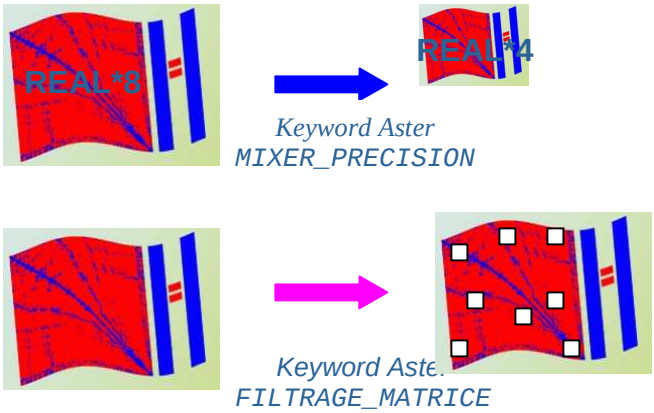
Matrix, RHS *Aster*

Matrix, RHS MUMPS

Solver Tool-kit

➢Mixte-precision strategies:

- Direct solver in non linear analysis with Newton-like algorithm,
- Krylov solver (linear or not): coarse/cheap/ robust preconditioner.

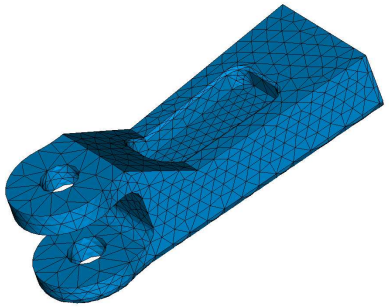


Non-linear analysis of a device holder :

N=0.2M, NNZ=6.5M, Facto=103 M, cond=2.10^6

Direct solver: RAM/CPU improvments 50% / 10%

Krylov preconditionner: 50% / 78%



➢Various kinds of linear systems:

- One-shot resolution,
- (Often) **Multiples right-hand sides** (Newton with periodic reactualization of the tangent matrix…),
- (Sometimes) Concurrent resolutions (Schur complement-like solves in contact-friction problems…).

Flexibility

EDF R&D

4. Feedbacks of the software integration/use in *Code_Aster*

- More than 100 *Aster* test-cases (seq. and //) using MUMPS, dozens of MUMPS parameters available to the Aster'User.

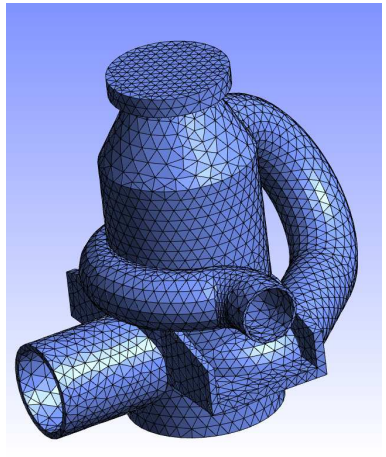
- **Steady software workings in the Aster/MUMPS'** links: bug tracking, optimization, upgrade, user training…

Often questioning/debugging about exterior librairies induce improvment in the caller code (data workflow…)

Year	2006	2007	2008	**2009**
# Works about *Code_Aster*/MUMPS	28	36	56	**103**

- Daily use throught *Code_Aster* at EDF R&D/Engineering

5a. MUMPS in *Code_Aster*, some results (1/2)



N=0.8 M

nnz=4,5 M / $\mathbf{K}^{fact}$=372M

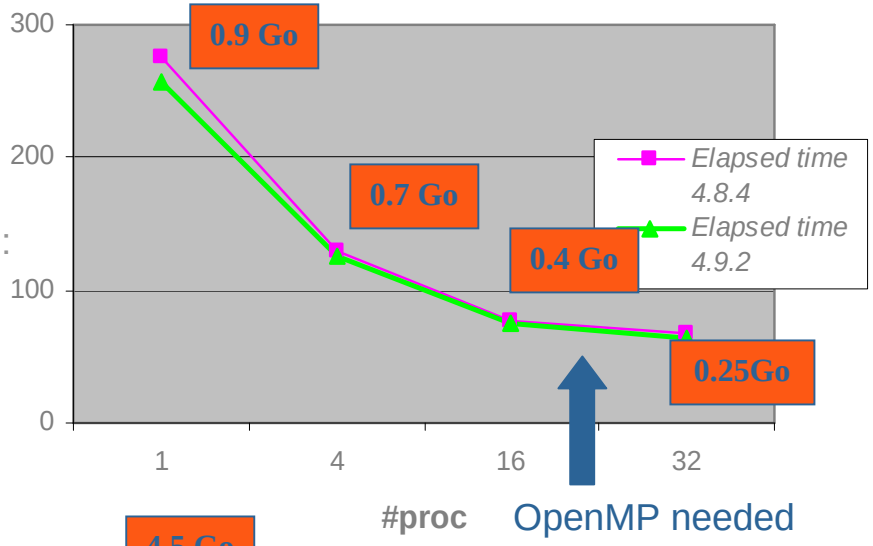
(77%) **Th. speed-up** 4/16/32 procs:

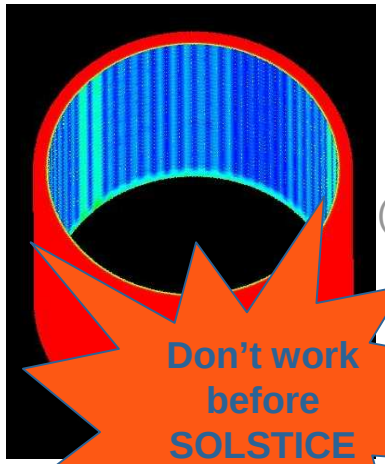
2.4/ 3.6/ 3.9

Real speed-up 4/16/32 procs:

2.1/2.0 3.6/3.6 3.9/3.9

Good Speed-ups





Don't work before SOLSTICE

N=0.8 M

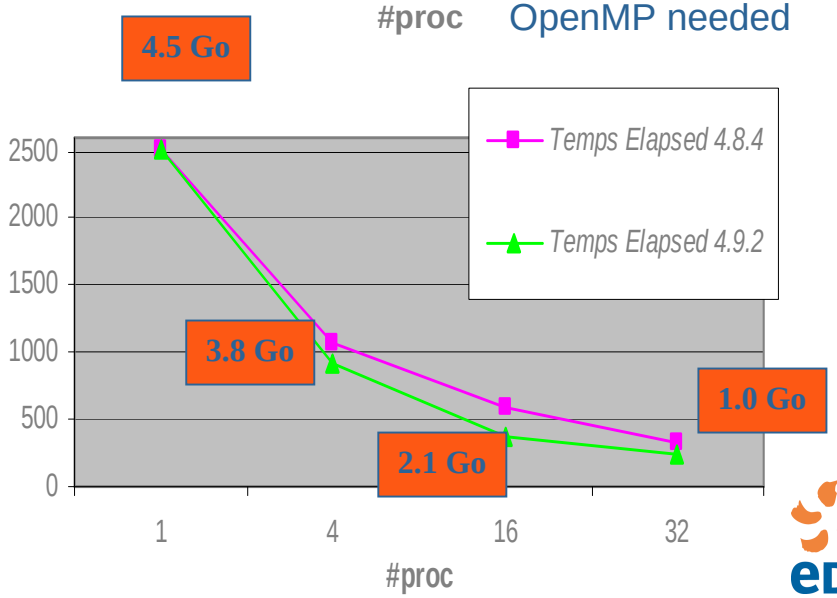
nnz=71 M / $\mathbf{K}^{fact}$=1900M

(95%) **Th. speed-up** 4/16/32 procs:

3.5/ 9.1/ 12.5

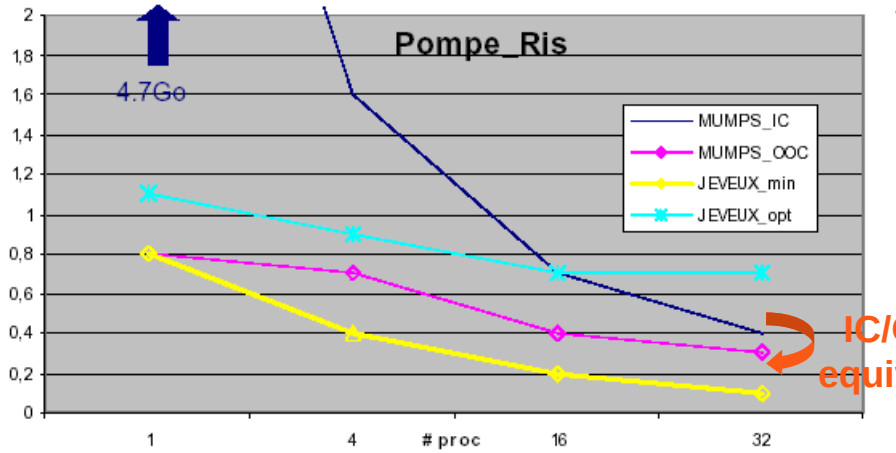
Real speed-up 4.8.4/4.9.2:

2.4/2.7 4.3/ 6.7 7.7/10.3

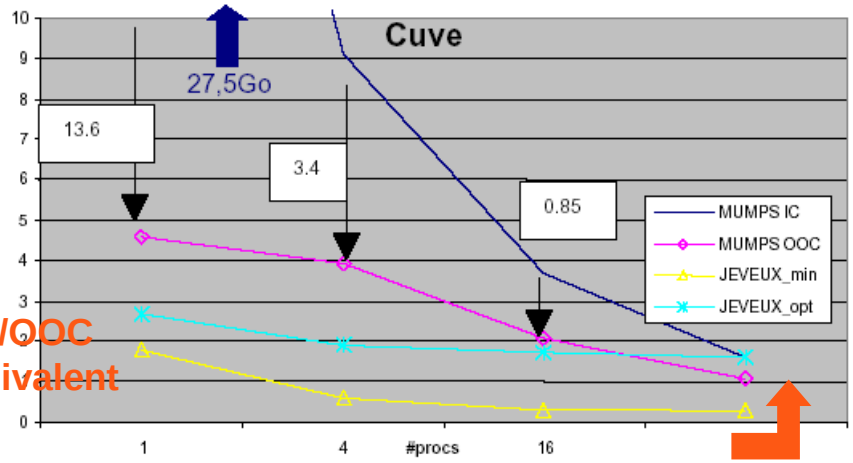


5b. MUMPS in *Code_Aster*, some results (2/2)

➢ RAM memory consumption



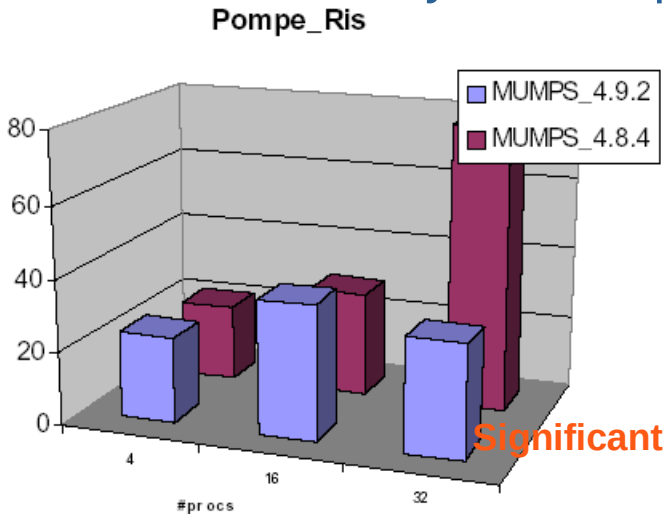
IC/OOC equivalent

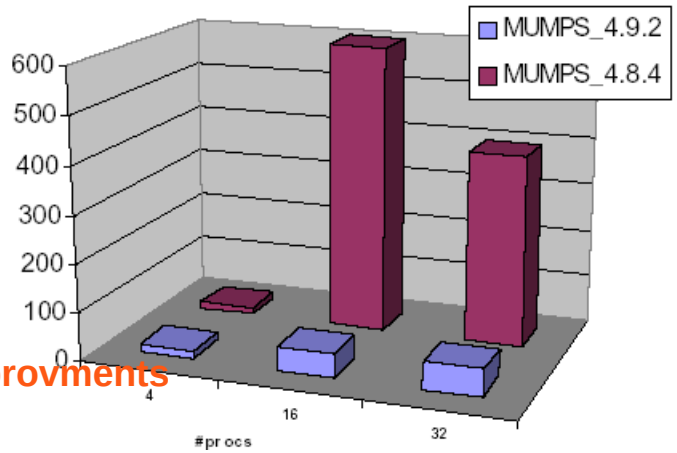


x4 on MUMPS OOC

x6 on Aster memory

➢ **Unbalance RAM** memory consumption between cores





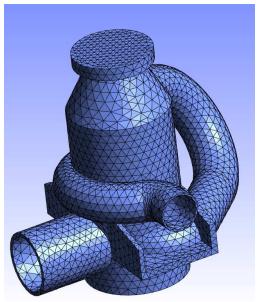
Significant improvments

7a. First results of a benchmark MUMPS/PaStiX (1/3)

Itanium 1.7Ghz+Quadrics <

Xeon 2.93Ghz+Infiniband

Elapsed time, MPI: MUMPS > PaStiX (10/30%)



N=0.8 M

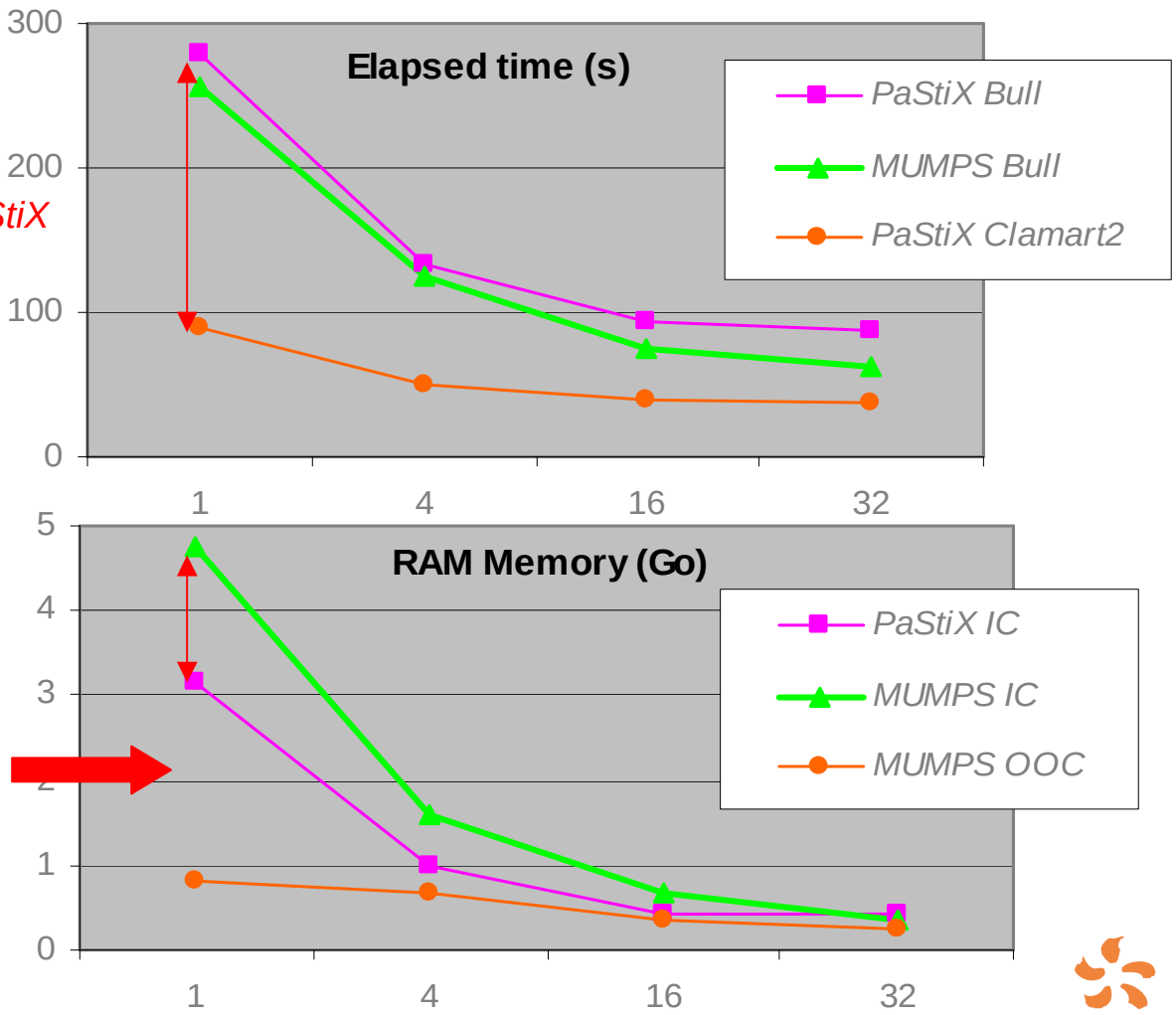
nnz=28.2 M

K^{fact}=372M

In-Core: PaStiX > MUMPS (50%)

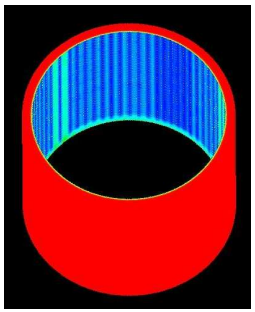
Out-Of-Core: good properties of MUMPS (value, speed-up, balancing)

Above 16 core: similar results



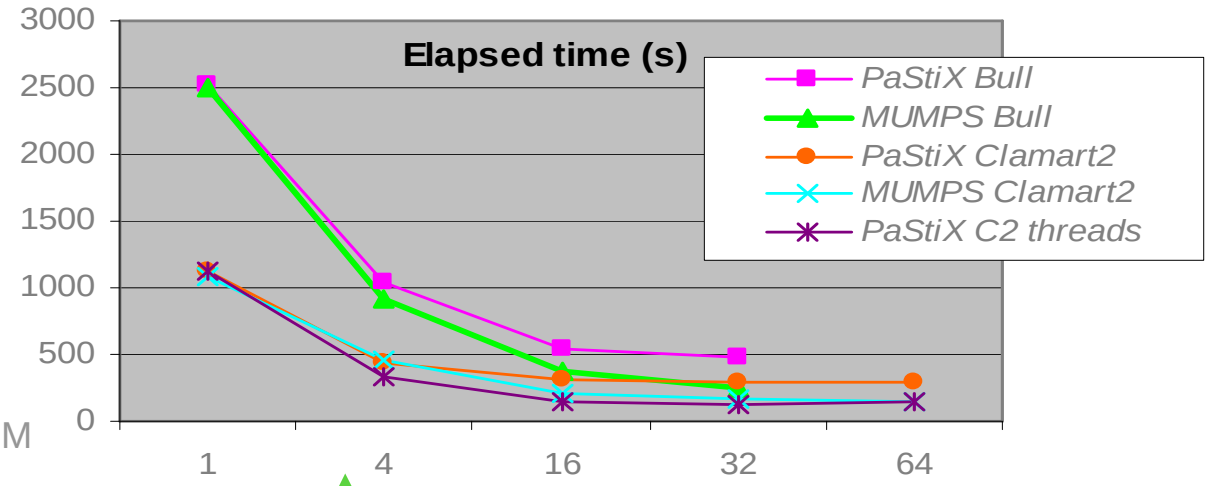
7a. First results of a benchmark MUMPS/PaStiX (2/3)

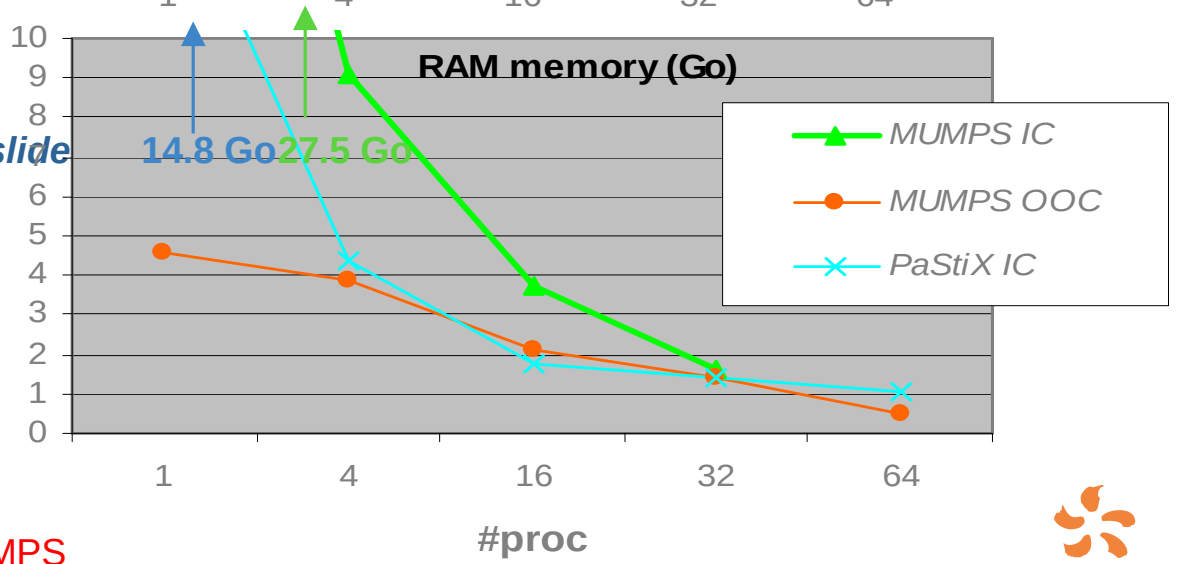
With our new machine (Clamart 2), sometimes stranges results (analysis step of MUMPS, OOC PaStiX)



N=0.8 M

nnz=71 M / K^{fact}=1900M





Same conclusions of the previous slide

Elapsed time:

MPI: MUMPS > PaStiX (10/50%)

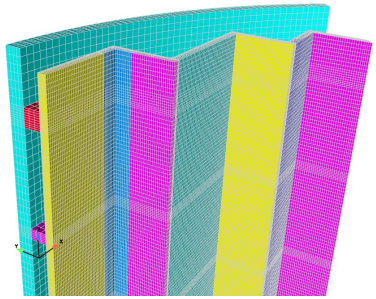
MPI+Threads: the opposite

RAM memory:

In-Core: PaStiX > MUMPS

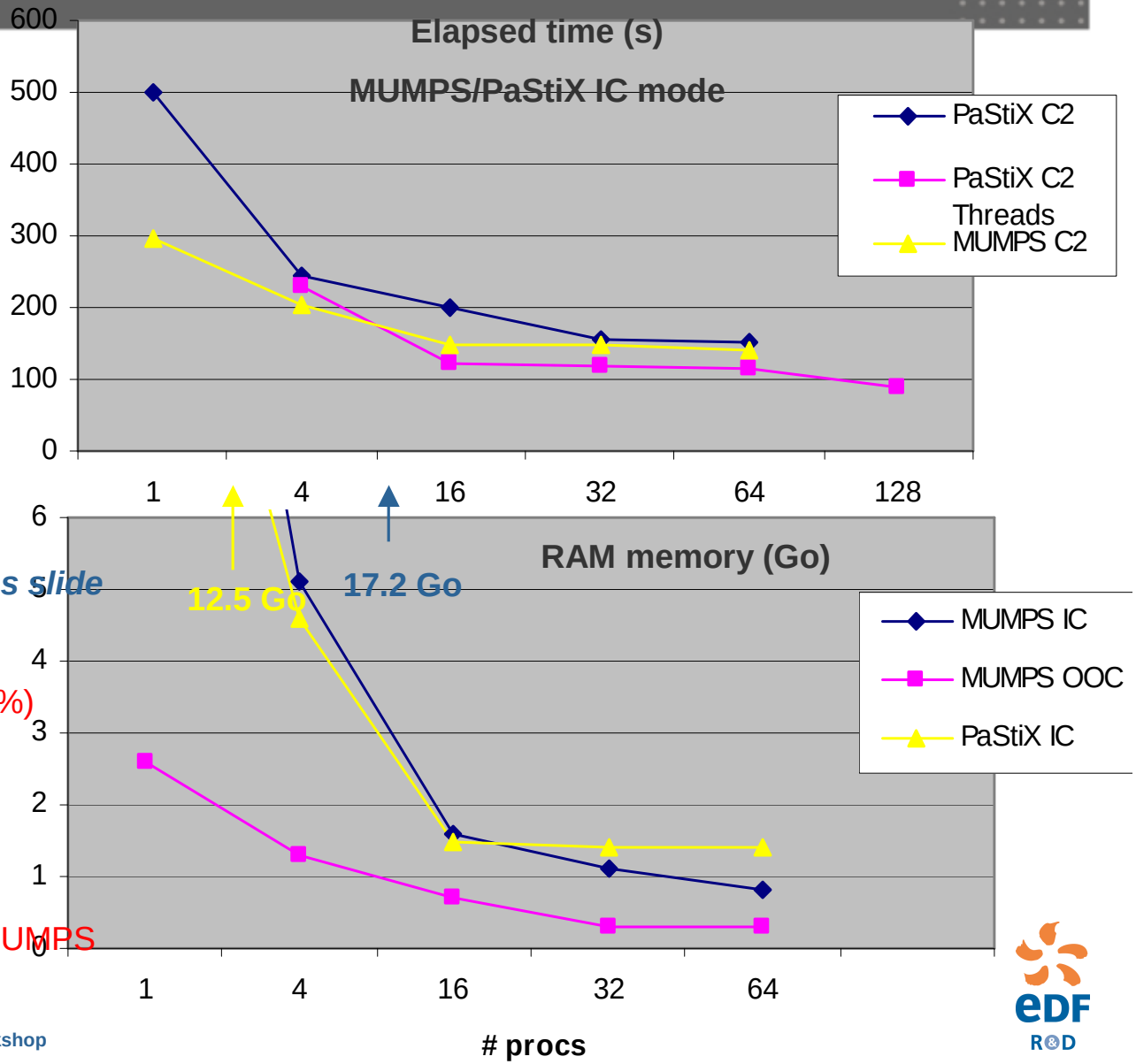
Out-Of-Core: Good behaviour of MUMPS

7a. First results of a benchmark MUMPS/PaStiX (3/3)



N=2.8 M

nnz=96 M / K^{fact}=1500M



Same conclusions of the previous slide

Elapsed time:

MPI: MUMPS > PaStiX (10/50%)

MPI+Threads: the opposite

RAM memory:

In-Core: PaStiX > MUMPS

Out-Of-Core: good behaviour of MUMPS

8. Conclusions

SOLSTICE
SOLveurs et SimulaTIons en Calcul Extrême
ANR CIS 2006

www.agence-nationale-recherche.fr

➢ **Daily use of MUMPS throught *Code_Aster/TELEMAC* at EDF R&D/Engineering**. We've been continuing to test PaStiX as a complementary solution to MUMPS (and HIPS/MaPhyS for bigger systems).

➢**We strengthened our partnership with the academic teams** involved in SOLSTICE. Thanks to the discussions during the ANR, we improve our knowledge on linear solvers and our ability to use these ANR tools.

➢ **This ANR really accelerated the transfer academic-industry in the domain of high performance parallel linear solver**.

➢ Much more important than performances, we particulary appreciate the reactivity/friendliness of the ANR teams.

EDF R&D