IO STUDY OF CODE_SATURNE

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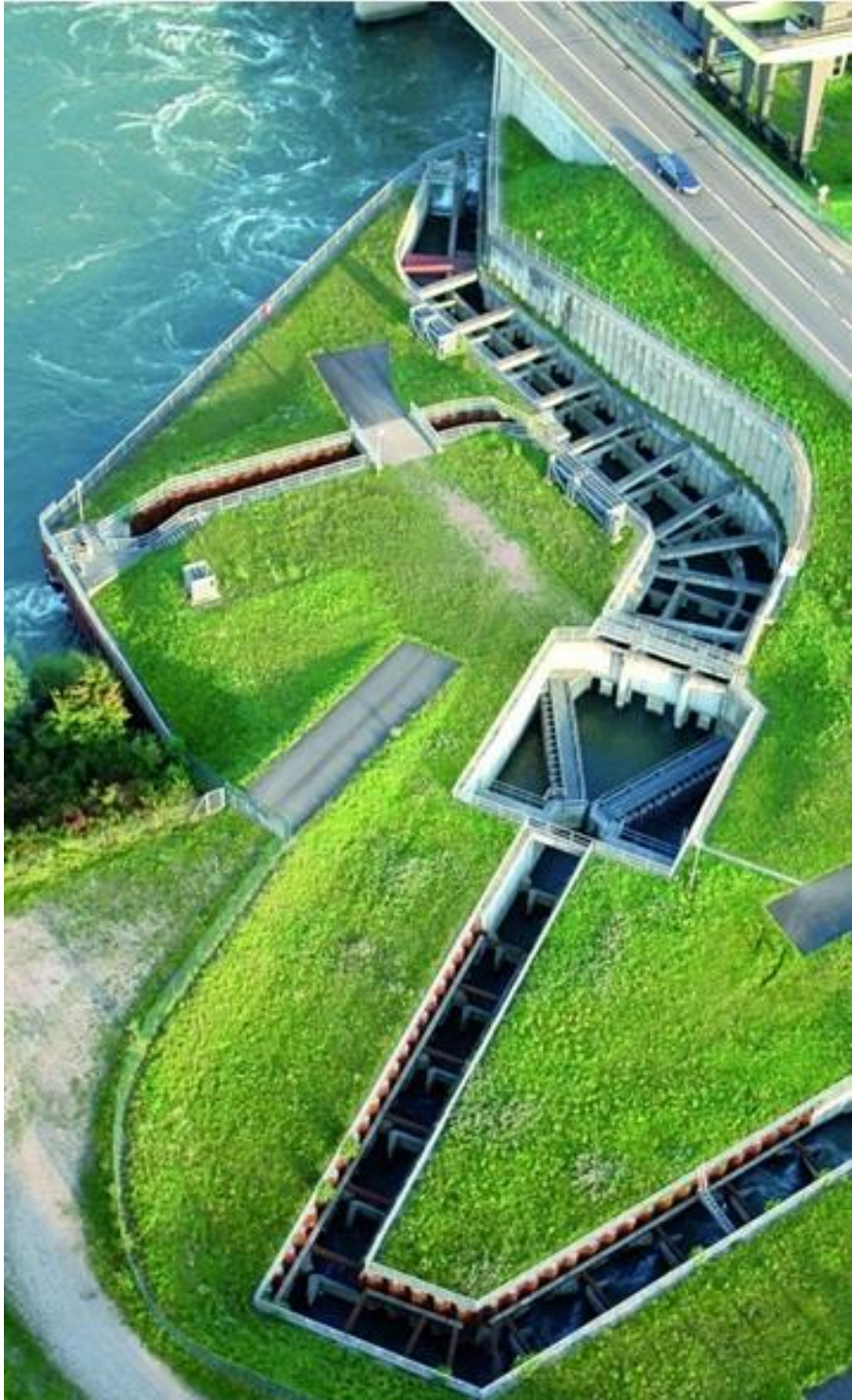


EDF : A leading french player in the energy market, active in **all areas** of electricity from **generation** to **trading** and **network management.**

Some contextual elements :

- Plants operated over 40 – 100 years
  - guarantee safety, minimize environmental footprint
  - maintain assets
- Fast changing operating conditions
  - more competitive markets,
  - tougher regulations, ageing, environment
- New business models and services
  - Smart meter
  - Cloud computing
  - Open Data / Big Data

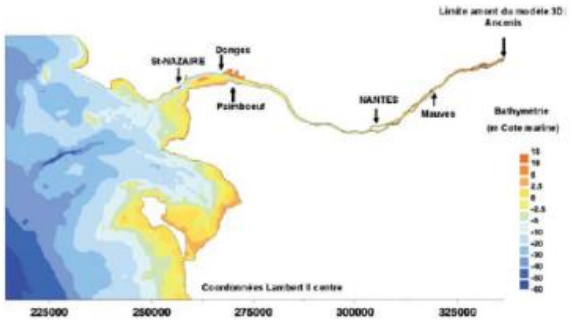
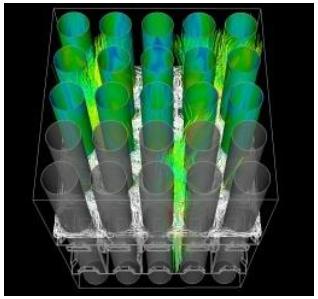
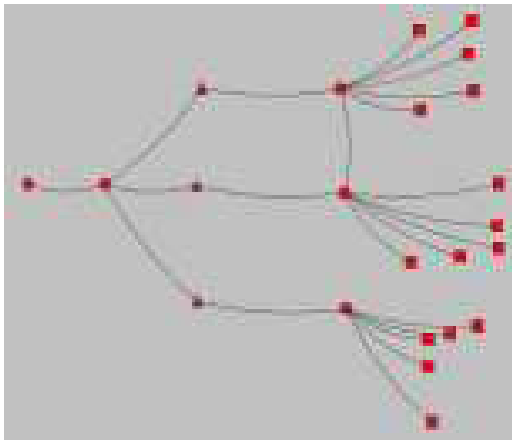


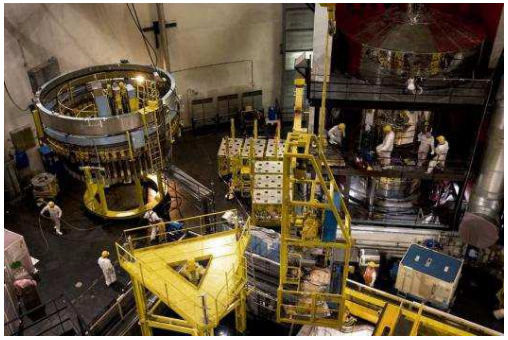
Figure 2 : Emprise et bathymétrie du modèle 3D.



HPC ENABLES US ….

- To simulate and then to understand
  ..to have a better understanding of system's complexity in order
  - To comply to new regulations
  - To find optimization opportunities
- To simulate and then to decide
  ..to obtain more predictive, more reliable & more trusted simulations of complex real systems in order
  - To find new margins
  - To help for decision making & business value
- To simulate and then to innovate
  ..to get more and more refined information in order
  - To open up new areas, new products and services
  - To improve methods and methodologies (studies)
  - To improve our in-house tools (most of them are Open-Source) : numerical methods, algorithms, models



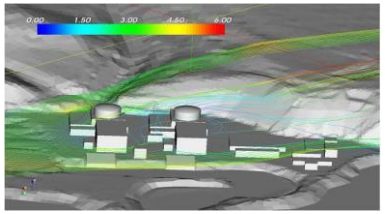


MAIN DOMAINS OF HPC APPLICATIONS (1/2)

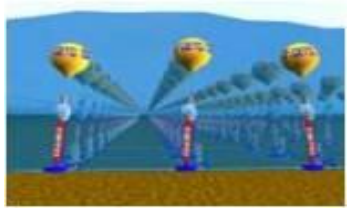
ENERGY PRODUCTION

- Nuclear
  - lifespan of power plants
  - Safety studies
  - Fuel management
- Hydraulics
  - Behavior of engineering structures
  - Optimisation of operations
  - Sediment transport

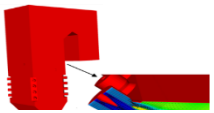
- Thermal
  - Environmental performance
  - Modelisation of combustion

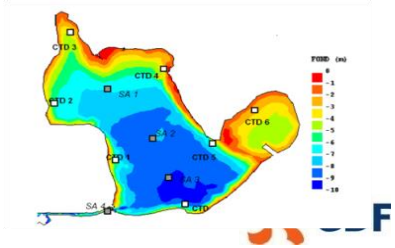


- Renewable
  - Wind power potential (InShore, Offshore)
  - Photovoltaic process



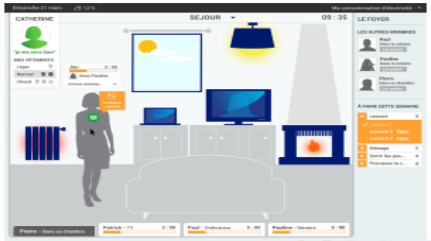
- Environment
  - Quality of water
  - Quality of air
  - Natural risks management





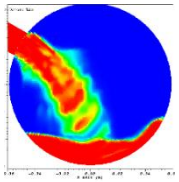
MAIN DOMAINS OF HPC APPLICATIONS (2/2)

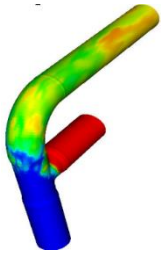
- Network / Smarties
  - Smart Grids : Impact of distributed and intermittent power generation on our networks
  - Smart-Cities : Optimization of power ressources, water, waste, ...
- Marketing
  - Knowledge of the load curve
  - Custumer behavior simulation
  - Analysis of customer data
- Energy Management
  - Generation / consumption balance
    - Weekly forecast
  - European Electrical System for 2020, 2030
  - Weather and climate forecast adjustments



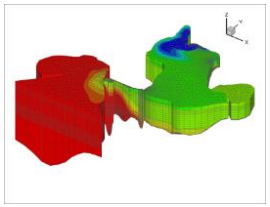
IN-HOUSE TOOLS DEVELOPED BY EDF R&D

- CFD
  - Code_Saturne
  - NEPTUNE_CFD

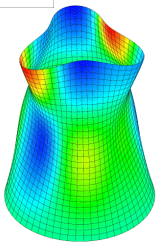




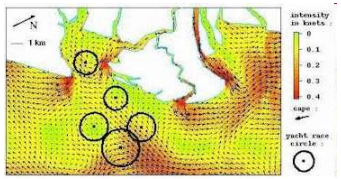
- Thermal Code
  - SYRTHES



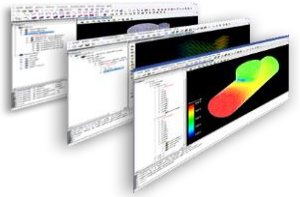
- Structural mechanics
  - Code_Aster



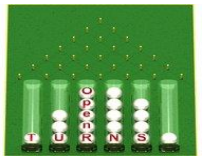
- Free surface hydraulics:
  - TELEMAC system



- Simulation environment
  - SALOME



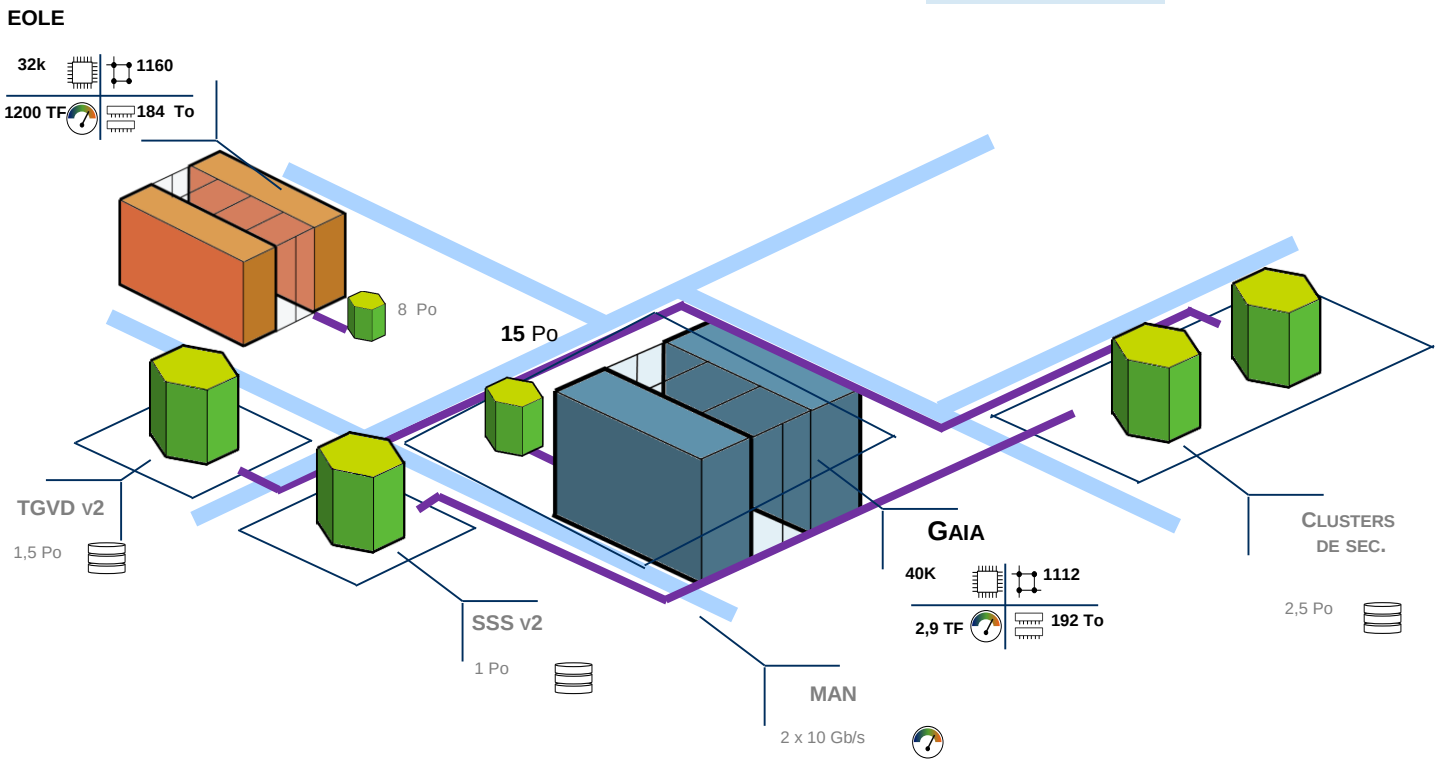
- Uncertainties
  - Open TURNS



- …. And many others
  - neutronic, electromagnetism,
  - ….

EDF HIGH PERFORMANCE COMPUTING FACILITY, 2019

2019 : 4 PFlops



HPC IN PRACTICE

- 2 clusters with DEBIAN and SLURM
- OPA for the low latency network, IBM spectrum scale and … DDN
- A wide range of code and usage
  - More than 200 different codes
  - From sequential / parametric to massively parallel code
  - Large IO files, small IO but in large numbers

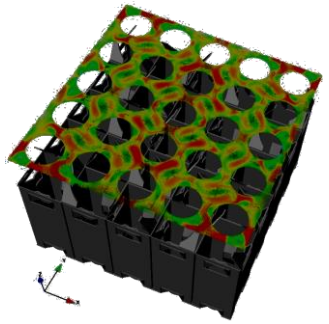
SOME QUESTIONS

- How to meet all these needs / usage for storage ?
- How to evaluate characteristics for the future system (IOPS, bandwidth, …) ?
- 1 FS, 2 FS ? One specific for compilation?

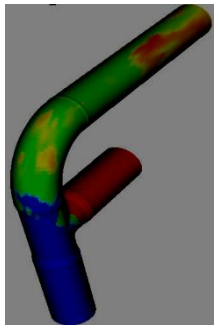
Study IO of the main codes running on HPC :

Code_Saturne, Code_Aster, …

CODE_SATURNE : EDF'S GENERAL PURPOSE CFD TOOL



- open source (GPL), https://code-saturne.org
- general usage single phase CFD, plus specific physics :
  - Coal, heavy-fuel and gas combustion,
  - Electric arcs and Joule effect,
  - Lagrangian module for particles tracking,
  - Atmospheric modeling,
  - ALE method for deformable meshes,
  - Rotor / stator interaction for pumps modeling



- Code_Saturne is one of the 12 codes selected for the PRACE and DEISA Unified European Application Benchmark Suite (UEABS)

IO ON CODE_SATURNE

- Input : xml file, mesh file (med, …), …
- Output : restart, log, post-processing, probes, …
- IO setup in XML input file :
  - min_block_size
  - rank_step : control number of MPI rank for IO
  - read_method
  - write_method

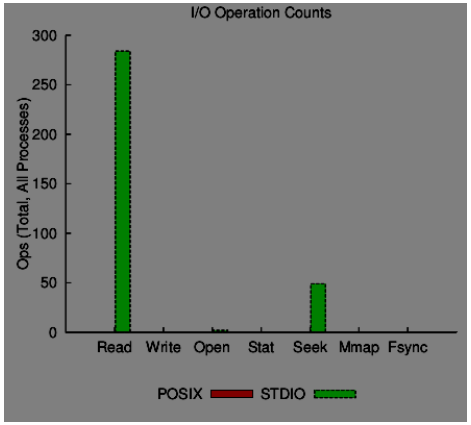
DARSHAN AND CODE_SATURNE

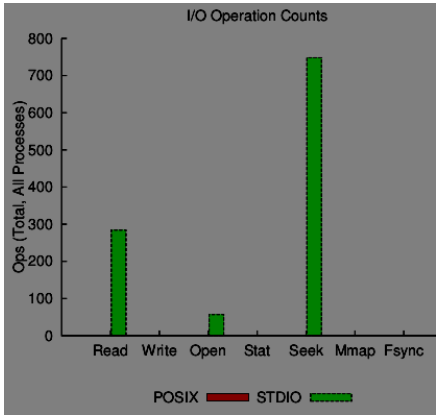
- darshan-runtime
  - Pre-require : zlib and MPI C compiler
  - Personal installation
  - Use dynamically with preload or statistically (modify mpi wrapper)
- darshan-utils
  - C compiler / zlib-dev/ libbz2-dev/ Perl/ pdflatex/ gnuplot 4.2/ epstopdf/ liburi-encode-perl

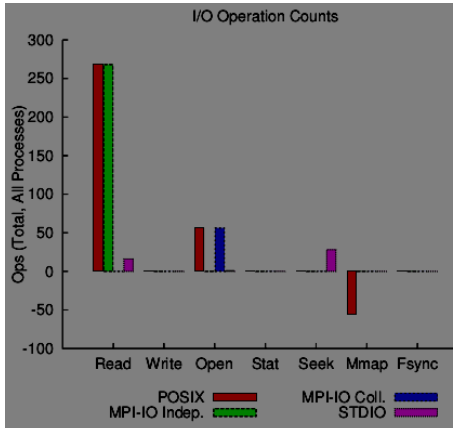
DARSHAN AND CODE_SATURNE

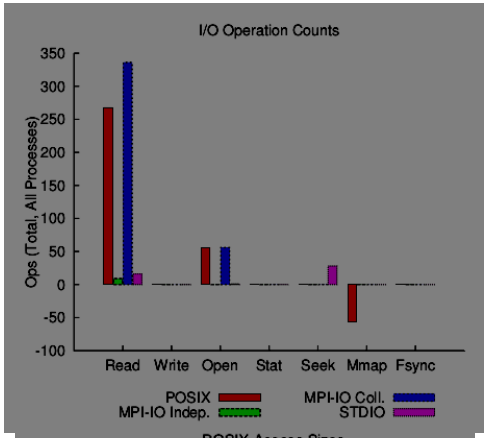
- test cases :
  - Bundle C-016-1 (mesh_input 3.7Mo, 16 000 cells)
  - Bundle F-128-1 (mesh_input 1.7Go, 12,8 million cells)
- parameters :
  - t_rank_step=(1 2 4 8 14 16 28 32)
  - t_min_block_size M=(0 1 2 4 8 16 32 64)
  - t_method=("mpi collective" "mpi independent" "mpi noncollective" "stdio parallel" "stdio serial")

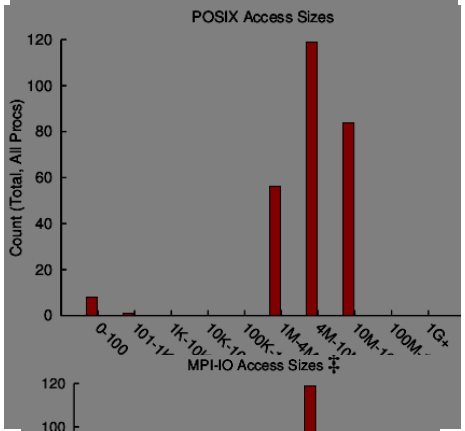
Rank_step: 1 WMPIcoll	F 128-1	mesh_input	1,7 Go	56 MPI process (2 nodes)
RStdioSer	RStdioPar	RMPInc	RMPIcoll	

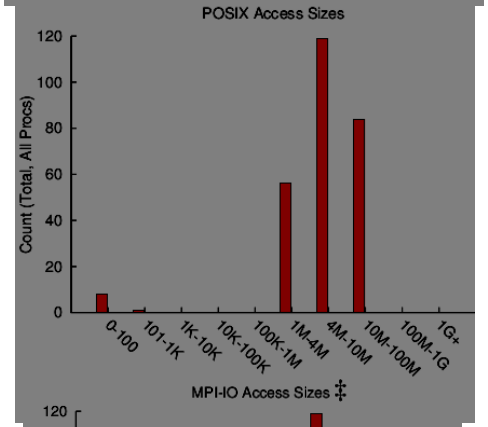


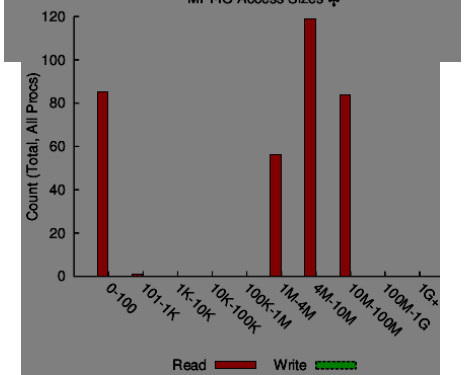


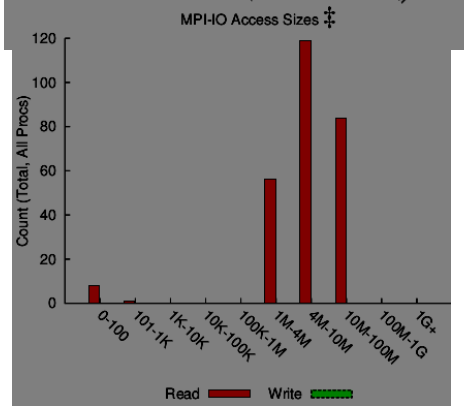












RStdioSer

Average I/O per process (POSIX and STDIO)		
	Cumulative time spent in I/O functions (seconds)	Amount of I/O (MB)
Independent reads	0.0111707321428571	29.9019831759589
Independent writes	0	0
Independent metadata	1.55714285714286e-05	N/A
Shared reads	0	0
Shared writes	0	0
Shared metadata	0	N/A

RStdioPar

Average I/O per process (POSIX and STDIO)		
	Cumulative time spent in I/O functions (seconds)	Amount of I/O (MB)
Independent reads	0	0
Independent writes	0	0
Independent metadata	0	N/A
Shared reads	0.0458517142857143	29.9019831759589
Shared writes	0	0
Shared metadata	0.0914458392857143	N/A

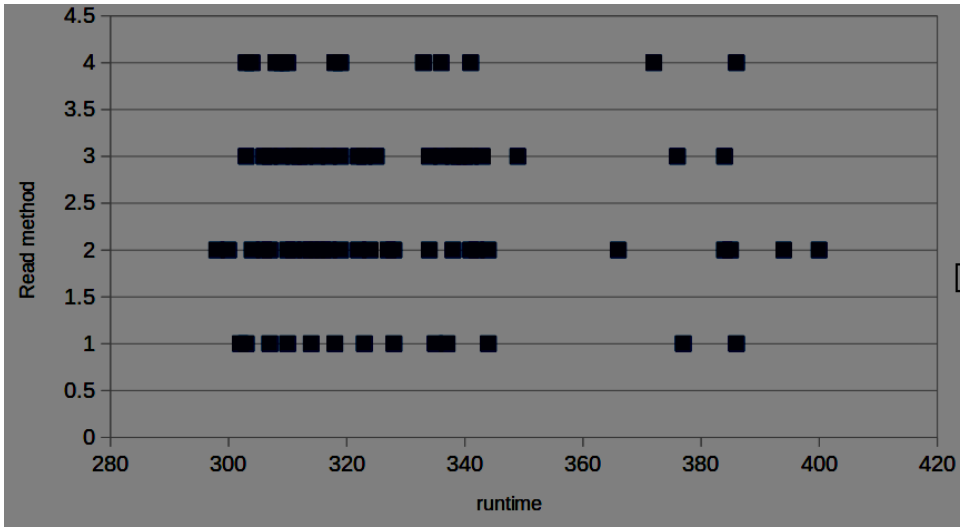
RMPInc

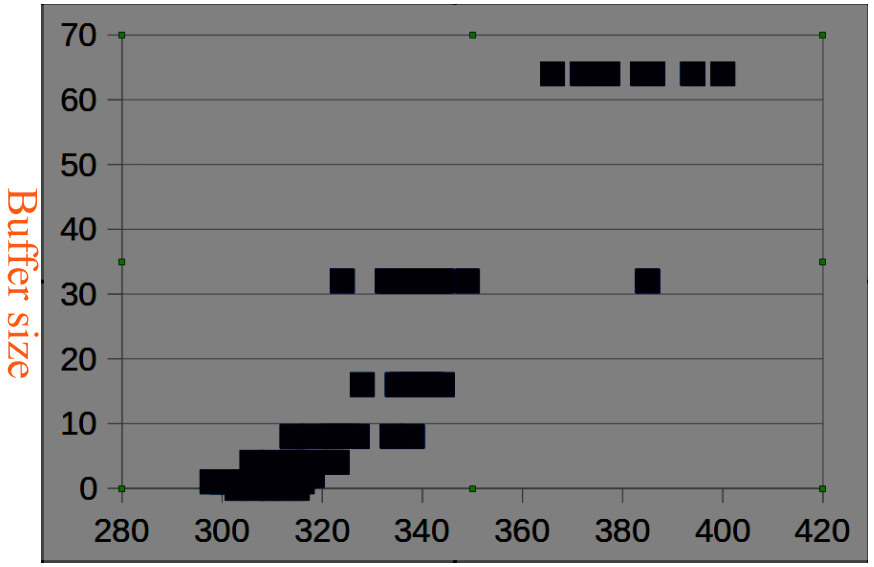
Average I/O per process (POSIX and STDIO)		
	Cumulative time spent in I/O functions (seconds)	Amount of I/O (MB)
Independent reads	0.000120910714285714	2.25305557250977e-05
Independent writes	0	0
Independent metadata	4.08928571428571e-06	N/A
Shared reads	0.0522137142857143	29.9019606454032
Shared writes	0	0
Shared metadata	0.000294392857142857	N/A

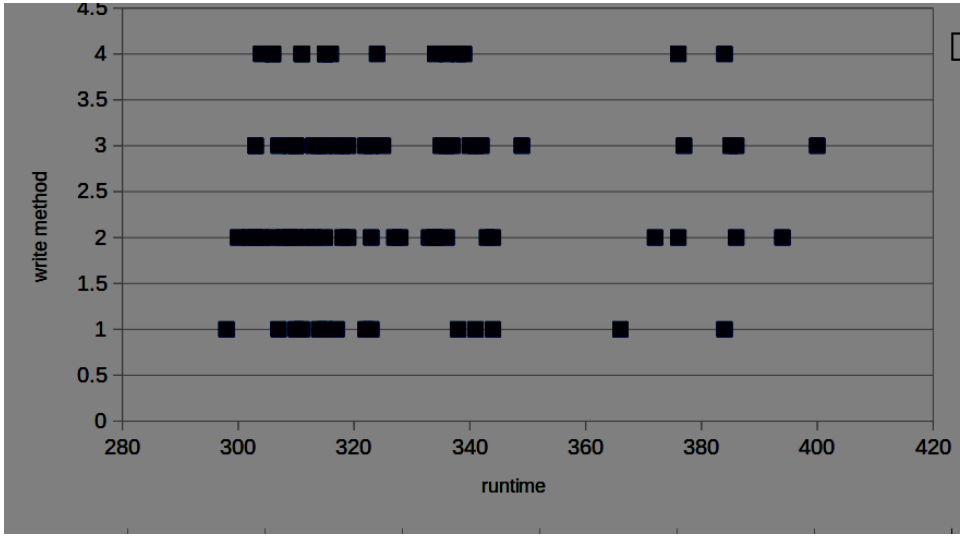
RMPIcoll

Average I/O per process (POSIX and STDIO)		
	Cumulative time spent in I/O functions (seconds)	Amount of I/O (MB)
Independent reads	0.000124375	2.25305557250977e-05
Independent writes	0	0
Independent metadata	3.23214285714286e-06	N/A
Shared reads	0.0351530714285714	29.9019606454032
Shared writes	0	0
Shared metadata	0.000302053571428571	N/A

GLOBAL ANALYSIS







- 1 : std IO serial
- 2 : MPI non collective
- 3 : MPI collective
- 4 : std IO parallel

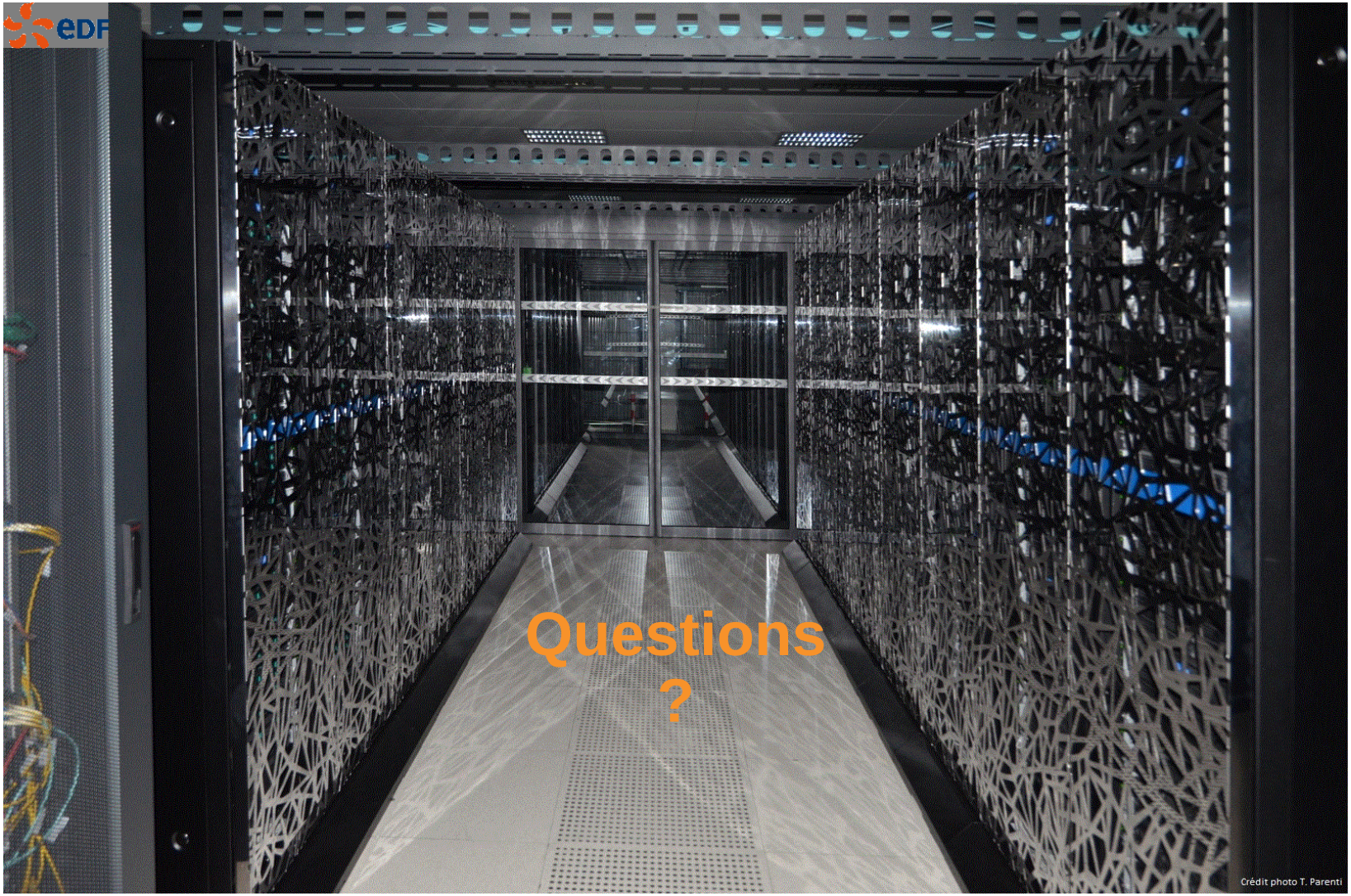
SOME FUTURE CHALLENGES FOR SIMULATION

- Simulation of multi-scales and/or multi-physics phenomena
  - Ex : simulation of flow behaviour inside a PWR core vessel and its consequences : Thermal-Hydraulic + Neutronic + Mechanics
  - Ex : simulation of a whole primary circuit of a nuclear power plant (vessel, steam generator, pressurizer,…) : Thermal-Hydraulic + Mechanics + Chemistry

- Probabilistic simulation : the use of uncertainties / calibration / assimilation methods
  - Ex : impact of intermittency on the network
  - Can lead to a factor 10 to 1000 of needed computing ressources … and storage !

SOME FUTURE CHALLENGES FOR SIMULATION

- Pre-processing of input data and post-processing of simulation results
  - What future tools to mesh complex geometries in a refined and simple way?
  - What future tools to visualize a deluge of results (including uncertainties)?
- Connection between HPC and Big Data (Data Analytics)
  - Real time calculation and analysis
  - Analysis of significant amount of data
    - Ex: Smart meter data (Linky)
  - Interconnection between datalake (Hadoop, …) and HPC ?
  - Containers use on HPC for datascience ?
- What is the best FS for us ?


Questions
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Crédit photo T. Parenti