The Uranie platform

The CEA/DEN Uncertainty and Sensitivity platform

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Outline

- Introduce the ROOT framework
- Present the Uranie platform
- Applications of Uranie

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CERN Large Hadron Collider (LHC)

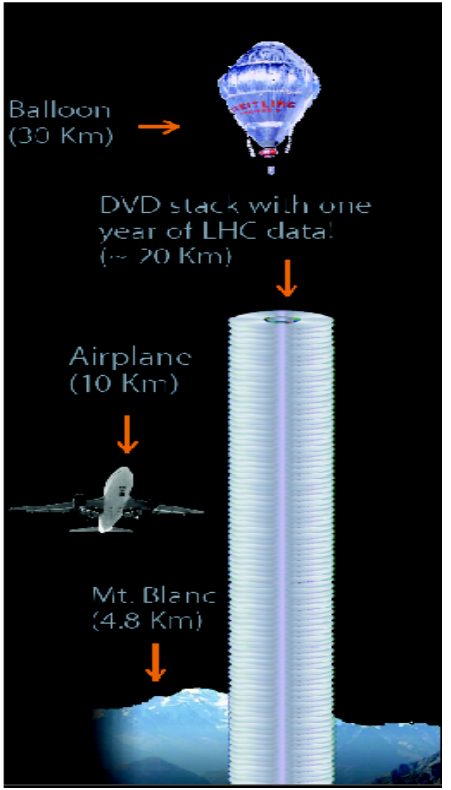
- particle accelerator
- 27 km circumference tunnel in Geneva
- 4 experiments (ATLAS, CMS, ALICE, LHCb)

  Study the structure of matter

  – Search for the Higgs boson

  – Search for new physics

- Data quantity generated : 20 PetaBytes/year
- ROOT is the framework to store, treat and analyze this data

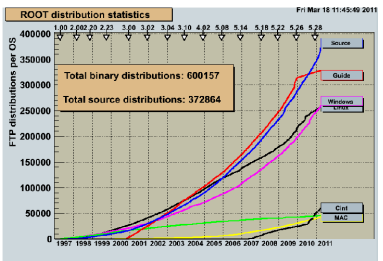


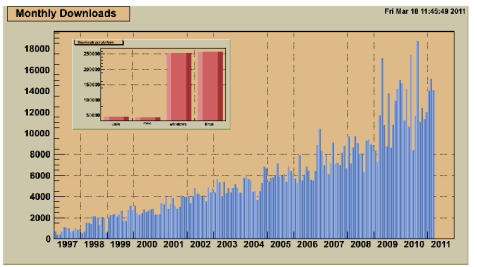
Fons Rademakers / CERN

ROOT (http://root.cern.ch)

ROOT is an object-oriented framework for large scale data analysis and data mining.

- 20 years of development (C++ with 3-4 releases/year)
- multi-plateform (Unix, Windows, Mac OS X)
- Offer :
  - A C++ interpreter, but also python (PyROOT), ruby
  - A hierarchical object-oriented database (machine independent, highly compressed, supporting schema evolution and object versioning)
  - Shared librairies (*automatic loading with "rootmap"*)
  - Advanced statistical analysis tools (subprojects *RooStats*, *RooFit*, *TMVA*)
  - Advanced visualization tools
- **LGPL License**

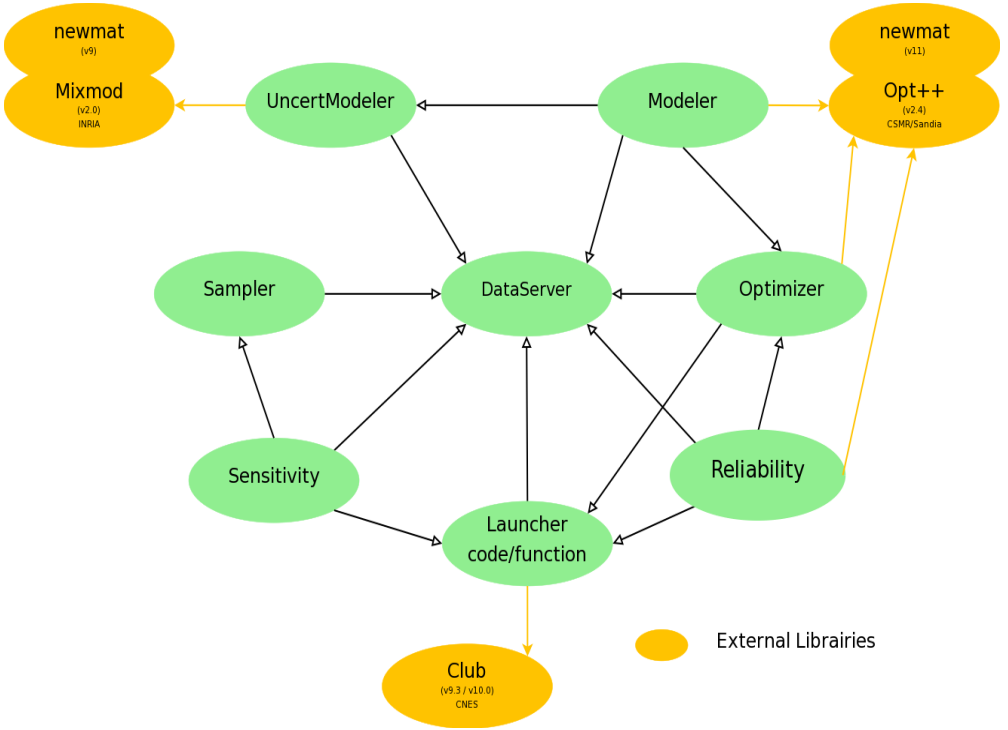


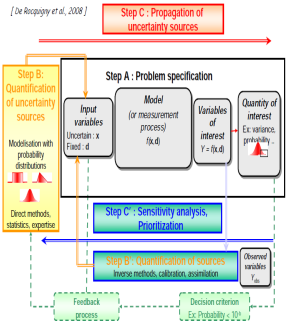


URANIE : CEA/DEN Uncertainty Platform

- ROOT (CERN), MIXMOD (Gaussian Mixtures - INRIA), OPT++ (Optimization - Sandia), CLUB (Text parsing - CNES)
- Data access :
  - Flat file with header ("Salomé Table")
  - TTree (internal ROOT)
  - SQL Data base (MySQL, PostgreSQL, ...)
- Uncertainty/Sensitivity methods in URANIE
  - Design Of Experiments (SRS, LHS, ROA, qMC, MCMC, Copulas)
  - Clustering methods
  - Surrogate models (Polynomial, Artificial Neural Networks, Splines)
  - Non Intrusive Spectrale Projection : Generalized Polynomial Chaos
  - Sensitivity Analysis (Pearson, Spearmann, Morris, Sobol, FAST & RBD)
  - Optimization, Multi-Criteria (**Vizir** library : Genetic Algorithms)
  - Computing distribution

URANIE : Fonctional diagram





ROOT ...

Uranie ...

Application

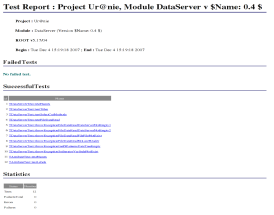
The URANIE project : v2.3.0 - 2011/01 1/2

- **62 000** lines & **111** classes
- Version of ROOT :
  v5.26 (2009 Dec.)
  v5.30 (2011 Jan.)
- Compilation with **cmake**

  (Linux-Makefiles/Windows-Visual Project)
- Unitary tests with **CppUnit**
- **Exceptions**

  (Warning, Error, Deprecated)
- **User Manual** with **DocBook**

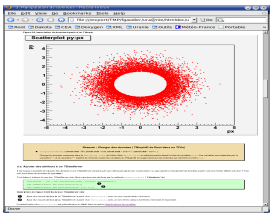
  Generate the HTML and PDF documents from the same `XML` files
- **Developper Manual** with **Doxygen**



XML Resume for tests

```
--- <WARNING> URANIE::MessageLogger : ===================== WARNING =========================
--- <WARNING> URANIE::MessageLogger : Deppreciated constructor since v0.3 to v0.5
--- <WARNING> URANIE::MessageLogger : Using the same constructor with a TDataServer object
--- <WARNING> URANIE::MessageLogger : ================= End Of Warning =====================
```

Deprecated message



HTML document

ROOT ...
Uranie ...
Application

The URANIE project : Training 2/2

- Uranie Training sessions
  - 2011/10/17-19 : session **"user"** session - SAC CEA/DEN (8)
  - 2011/04/4-6 : session **"user"** session - NURISP (5)
  - 2011/01/19-21 : **"user"** session - SAC CEA/DEN (12)
  - 2010/10/13-15 : **"user"** session - SAC CEA/DEN (12)
  - 2010/02/25-26 : **"user"** session - MAR CEA/DEN (15)
  - 2009/10/19-20 : **"integrator"** session - NURISP (2)
  - 2009/09/7-8 : **"user"** session - projet ESS + DSM (5)
  - 2009/06/10 : **"user"** session - NURISP (3)
  - 2009/04/06 : Areva-TA (4)
  - 2008/10/28-29 : Areva-TA (6)
  - 2006-2008 : CEA/DEN ($\sim$ 50 persons)
- ROOT Training sessions at INSTN (12 students, 3 days)
  - February 2011 : **DEN-SAC**
  - February 2010 : **DEN-SAC**
  - June, 17-19 2009 : **DEN-CAD**
  - December, 3-5 2008 : **DEN-SAC**
  - March, 26-28 2008 : **DEN-SAC**
- Developpment is piloted by user request

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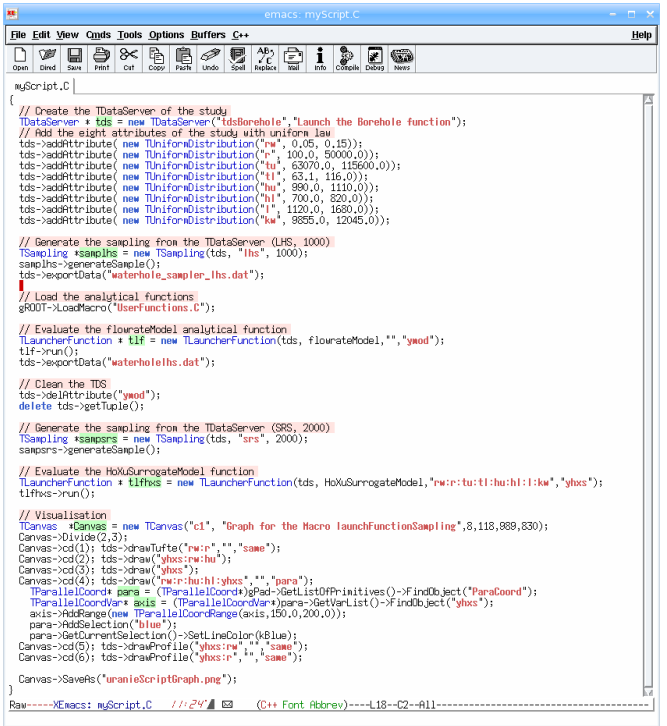
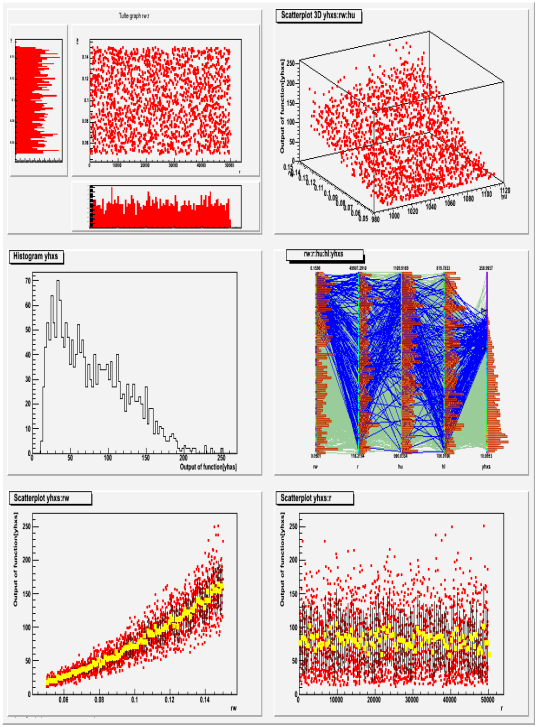
URANIE : Batch mode

```
> root myScript.C
```





ROOT ...

Uranie ...

Application

URANIE - XML User Interface

```
1<?xml version="1.0" encoding="iso-8859-1"?>
2<!DOCTYPE Problem SYSTEM "/uranie.dtd">
3<Problem>
4  <Header name="boreholeXML" title="Launch the Borehole function in XML" debug="0">
5    <Application name="uranie" version="1.0"/>
6  </Header>
7  <DataDictionary>
8    <DataField name="rw" law="uniform" min="0.05" max="0.15"/>
9    <DataField name="r"  law="uniform" min="100.0" max="50000.0"/>
10   <DataField name="tu" law="uniform" min="63070.0" max="115600.0"/>
11   <DataField name="tl" law="uniform" min="63.1" max="116.0"/>
12   <DataField name="hu" law="uniform" min="990.0" max="1110.0"/>
13   <DataField name="hl" law="uniform" min="700.0" max="820.0"/>
14   <DataField name="l"  law="normal" mean="1120.0" std="12.25"/>
15   <DataField name="kw" law="uniform" min="9855.0" max="12045.0"/>
16 </DataDictionary>
17 <Sampler method="LHS" N="1000" export="waterhole_sampler_lhs.dat"/>
18 <Launcher macro="UserFunctions.C" function="flowrateModel" output="ymod" export="waterholelhs.dat"/>
19 <Sampler method="SRS" N="2000"/>
20 <Launcher function="HoXuSurrogateModel" input="rw:r:tu:tl:hu:hl:l:kw" output="yhxs"/>
21</Problem>
```

```
void evaluateXMLFile (TString xmlFile = "uranieproblem.xml")
{
TXMLProblem * xmlProblem = new TXMLProblem(xmlFile);
xmlProblem->submit();
}
```


Projects using URANIE

- LEONAR tool for severe accidents in french nuclear reactor (**CEA-EDF**)
- PSI-Matador Methodology : Dosimetry computation in french nuclear reactor (**CEA-EDF**)
- EHPOC project : Meteor code (**CEA**)
- Sensitivity Analysis for Cathare code (**Areva TA**)
- Multi-criteria optimization (**CEA CESTA/CELIA**)
- Optimization Design for ESS

  The *"European Spallation Source"* is a project to design and construct (Lund - Sweden) a next generation facility for research with neutrons.
- ALLIANCES platform (**CEA/ANDRA/EDF**)

  is to provide a working environment for the simulation and analysis of phenomena to be taken into account for waste storage and disposal studies.
- European project **NURESIM/NURISP**

  The European Platform for NUclear REactor SIMulations, NURESIM, is a Common European Standard Software Platform for modeling, recording, and recovering computer data for nuclear reactors simulations.

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Uranie Application with ANDRA : GdR MoMaS

- Context

  Make Sensitivity Analysis with Surrogate Model : Artificial Neurals Networks ("ANN")

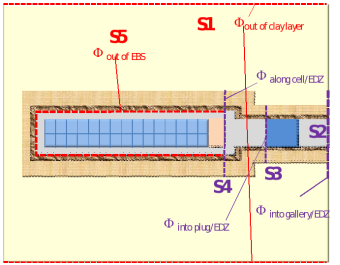
- CPU time single calculation : 1 < t < 5 hours (Cluster)

- Original DataSet

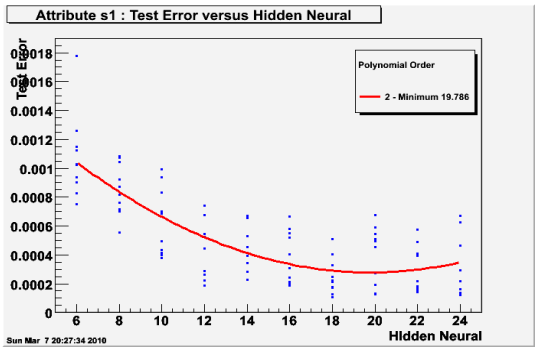
  – nX = 17 input variables
  – nY = 5 output variables
  – Build the 5 ANN : nS = 1500 patterns

- Neural networks

  – different architectures (MLP)
  – Input with a logarithm PDF $x := \log(x)$
  – Output $y := \frac{1}{1+log(y)}$
  – cross validation
  – Validate the 5 ANN on another dataset with nS = 1000 patterns



Guillaume Pépin (ANDRA)



Computation Sensitivity Indexes (SI)

First Order : $$S_i = \frac{Var[\,\mathbb{E}[\,Y \mid x_i\,]\,]}{Var[Y]}$$

1. Regression Analysis $$\hat{y} = b_0 + \sum b_i\, x_i$$

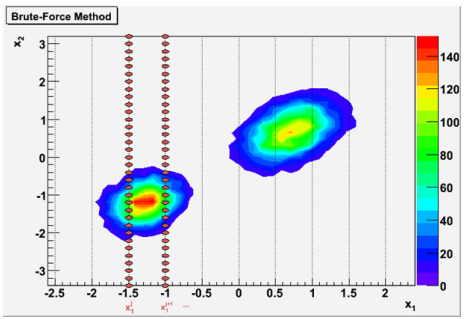
   – on the Values : "SRC" ("Standardised Regression Coefficient")
   – on the Ranks : "SRRC" ("Standardised Rank Regression Coefficient")

   The regression is valid when $R^2 = \frac{\sum(\hat{y}_i - \bar{y})^2}{\sum(y_i - \bar{y})^2}$ close to 1.0 (≥ 0.7)

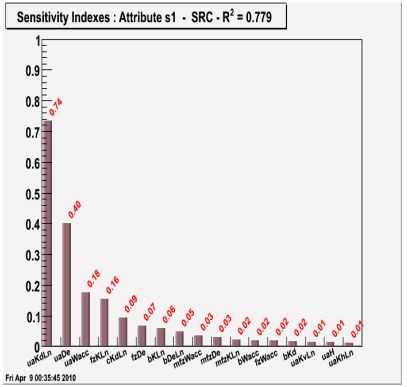
2. Brute-Force Method
   Cost : nX * nCV * nPts

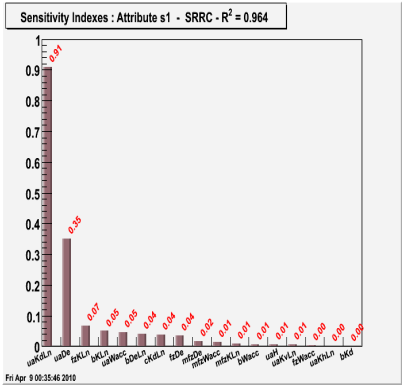
   – nX = number of inputs parameters
   – nCV = n. of conditionnal values
   – nPts = n. of pts over cond. values

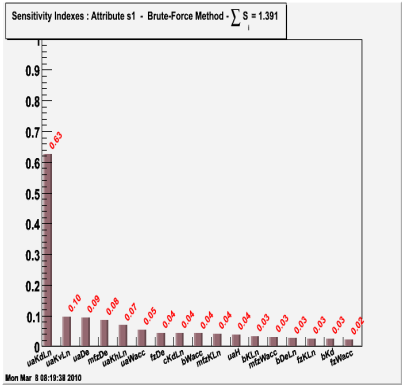
   Use the surrogate model ("ANN") in place of the true code

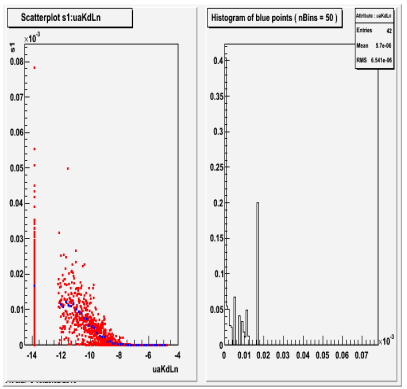


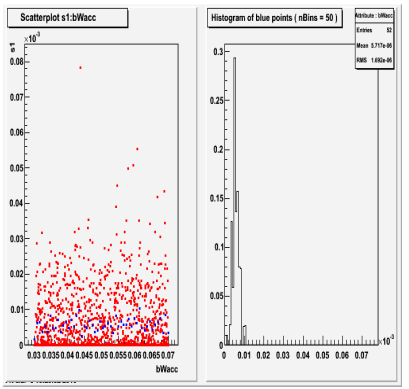
Original Database (nS = 1500) & "s1"

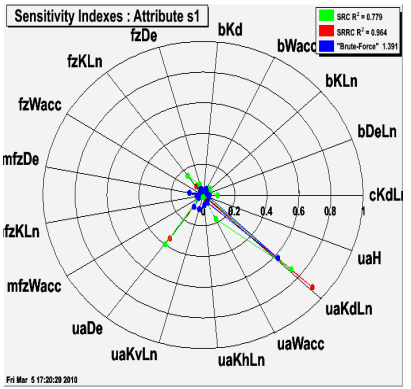










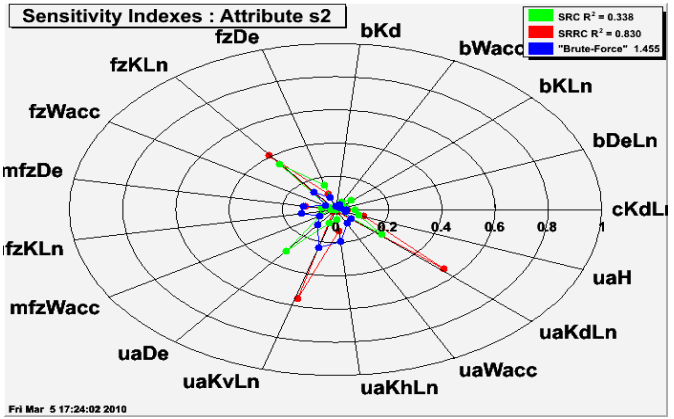


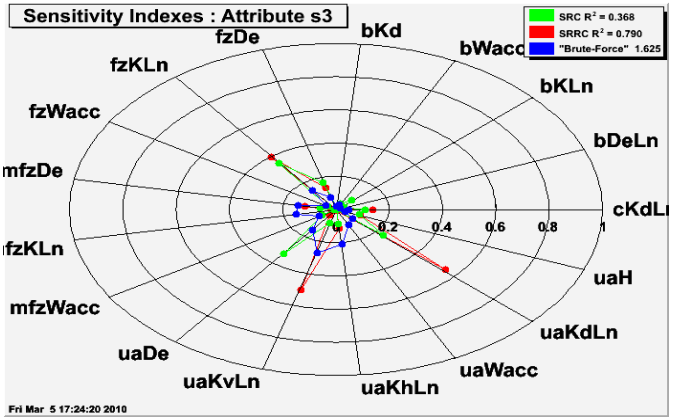
ROOT ...

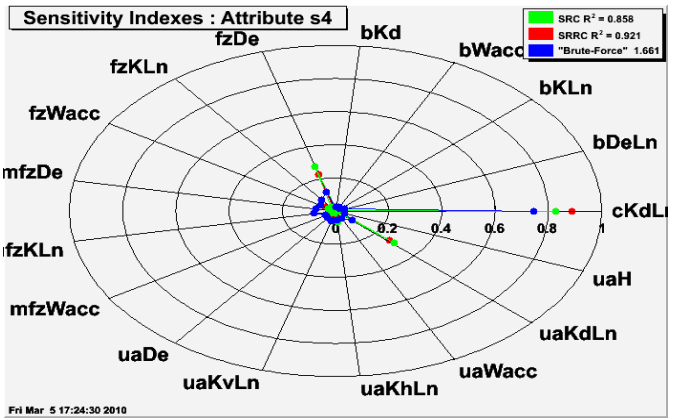
Uranie ...

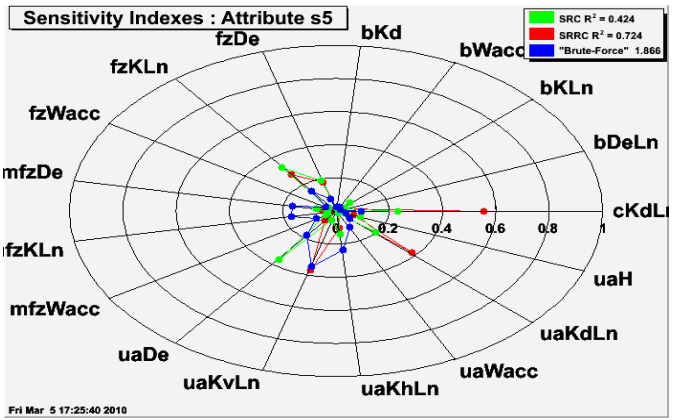
Application

Original Database (nS = 1500) & other outputs









ROOT ...

Uranie ...

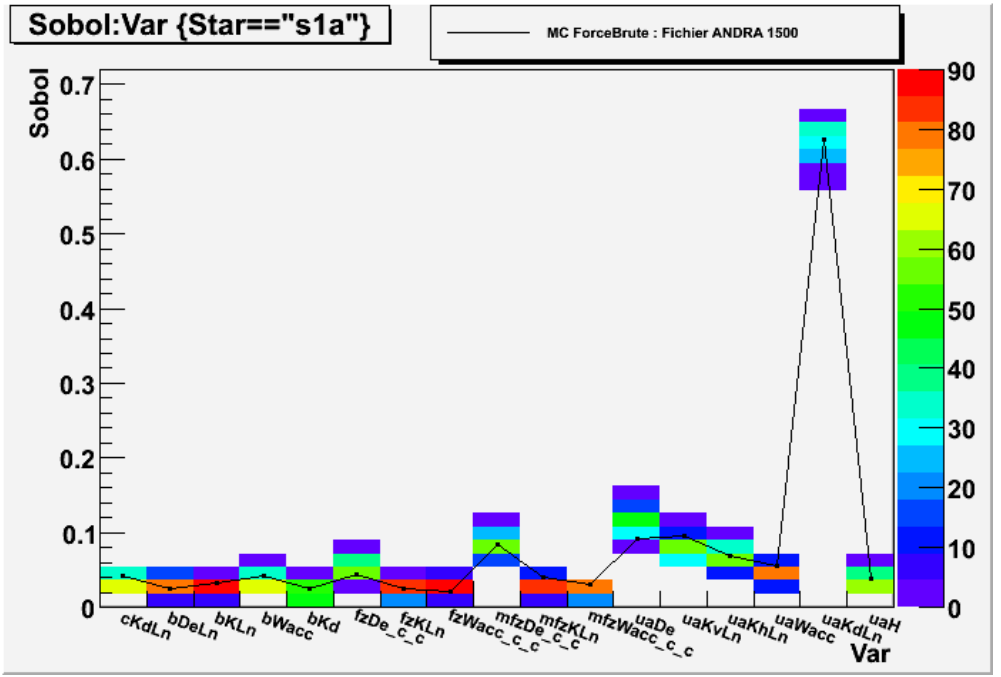
Application

Estimation of SI with ANN and nS = 1500

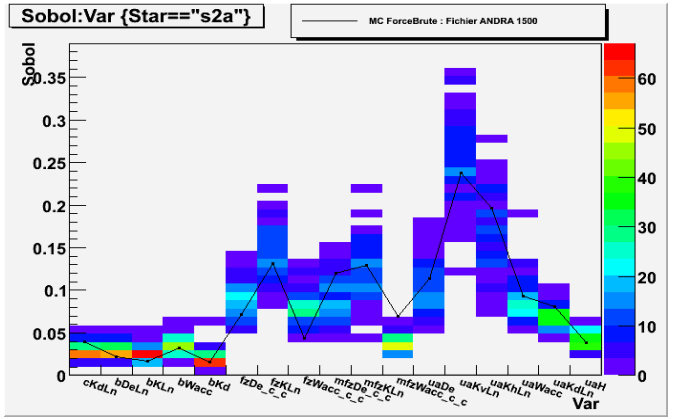
Design nL = 100 databases with size nS = 1500 points

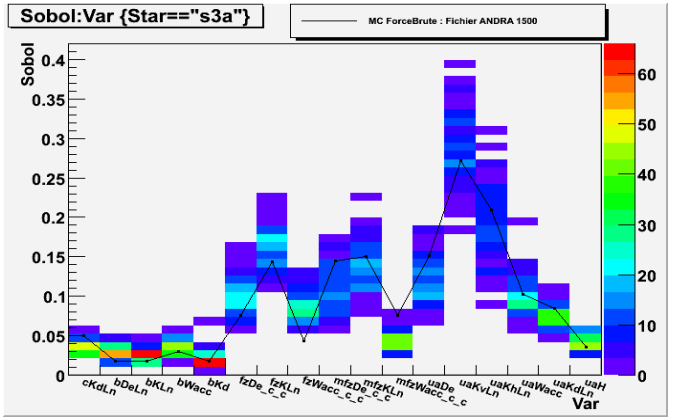
Simulate these databases using ANN surrogate models

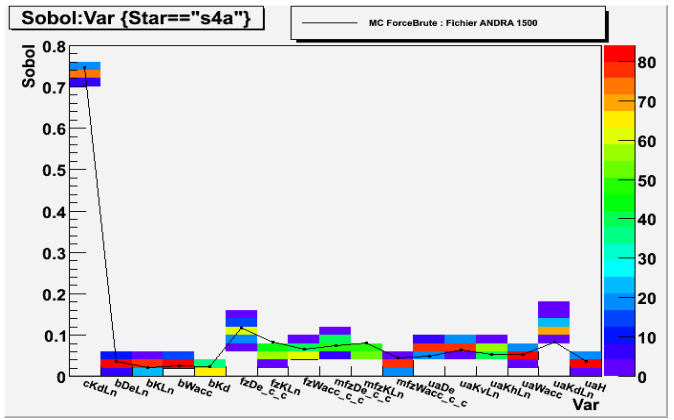
Compute the first order SI by the Brute-Force method

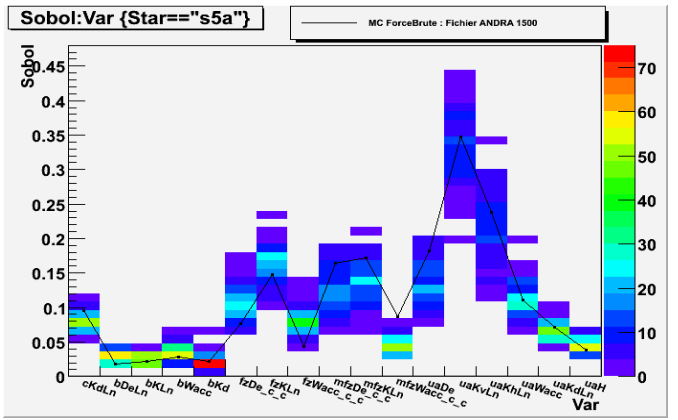


Estimation of SI with ANN and nS = 1500









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ROOT ...

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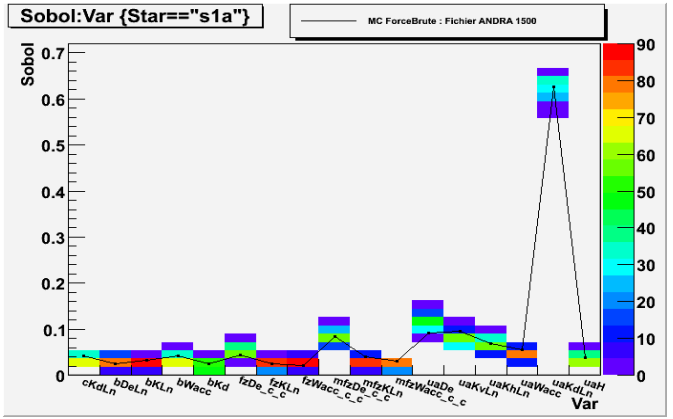
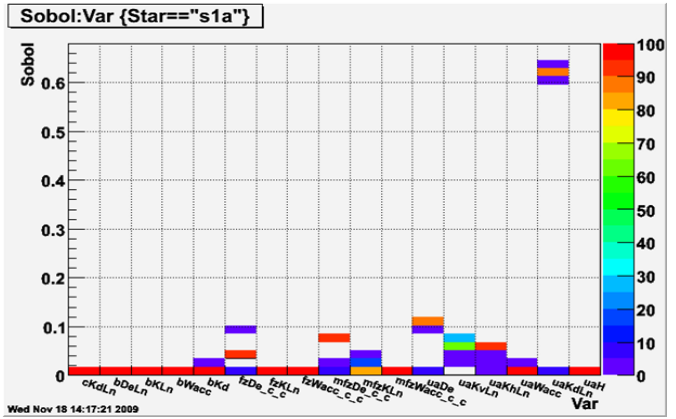
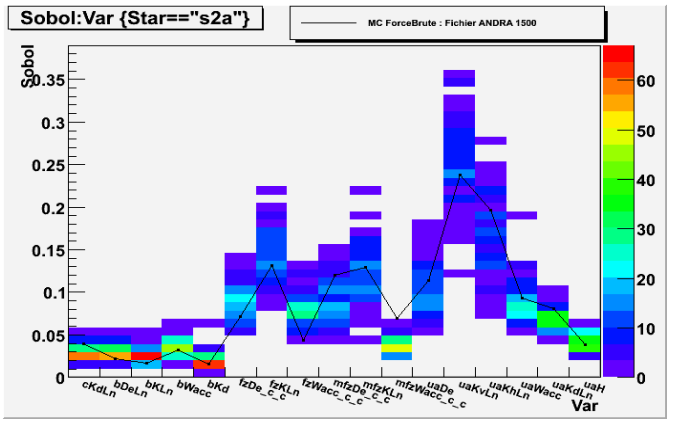
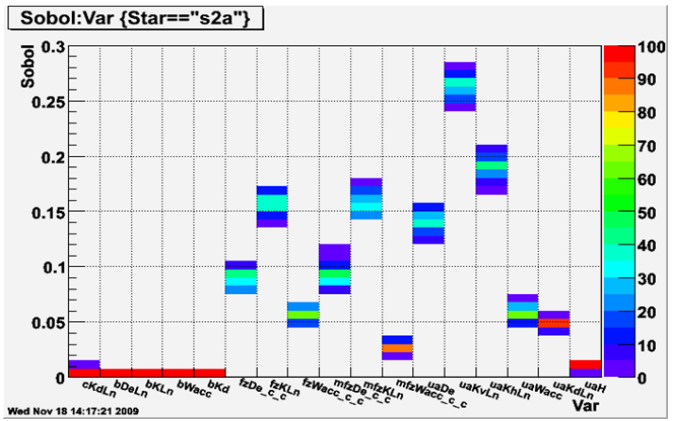
Application

Same with nS = 20000 (« s1 » and « s2 »)









1 500 points

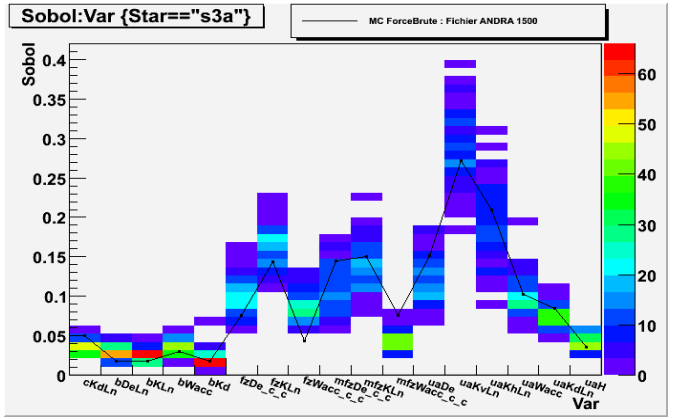
20 000 points

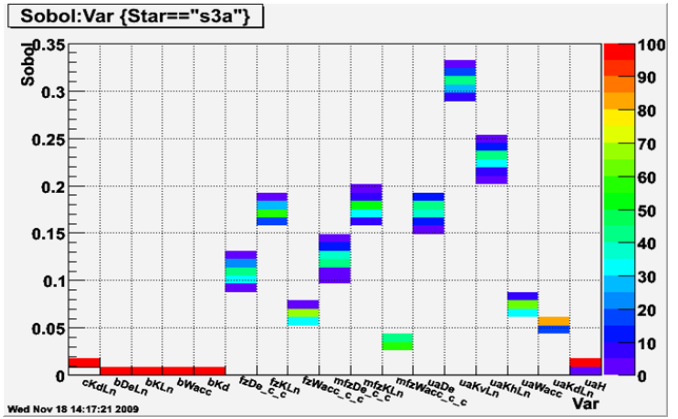
ROOT . . .

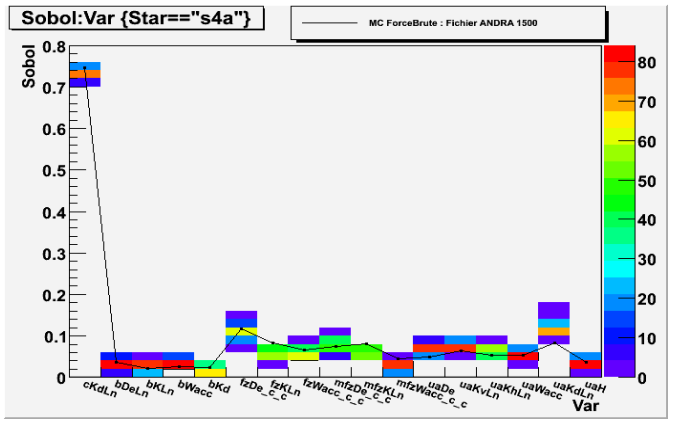
Uranie . . .

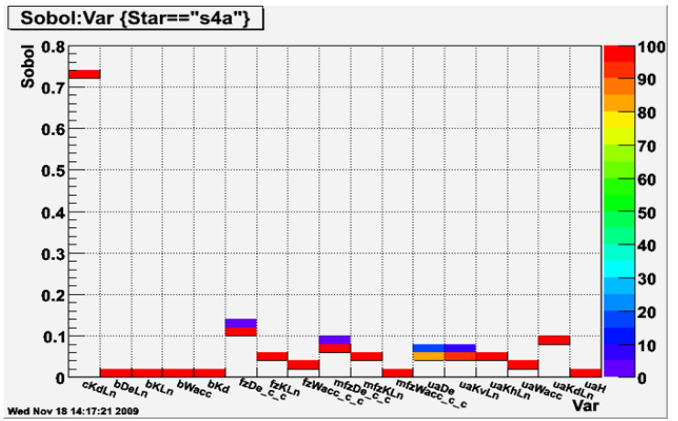
Application

Same with nS = 20000 (« s3 » and « s4 »)









1 500 points

20 000 points

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ROOT ...

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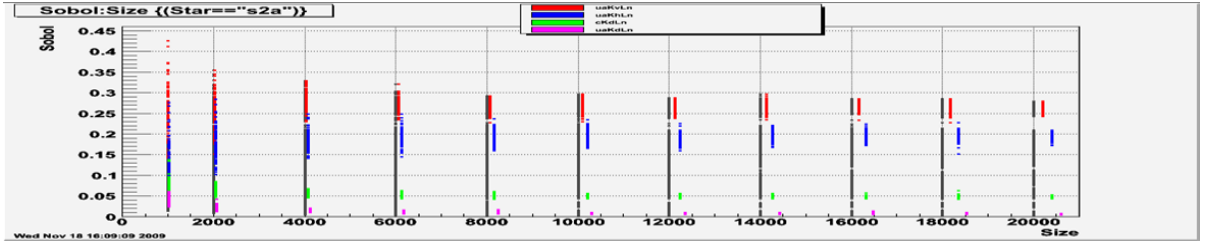
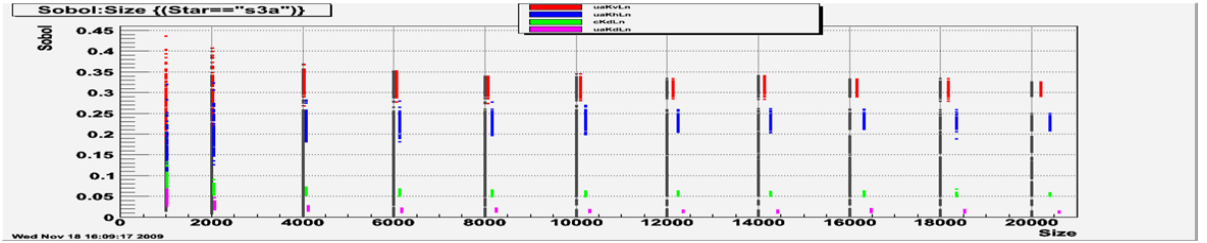
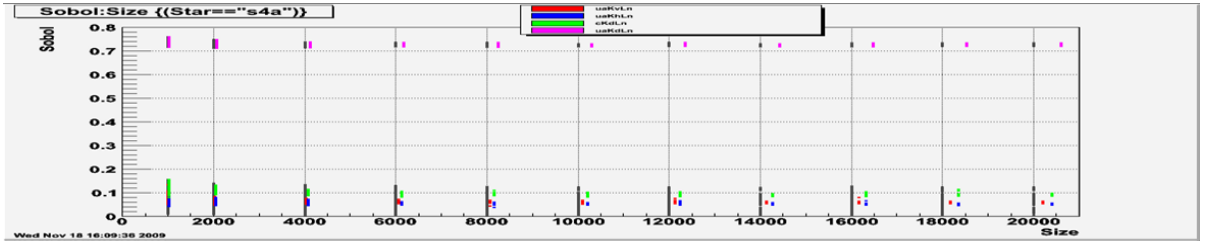
Application

Uranie Application : All simulations (1/2)

Same loop (nL = 100 DoE) but for nS=2000 to 20000 by step 2000 :

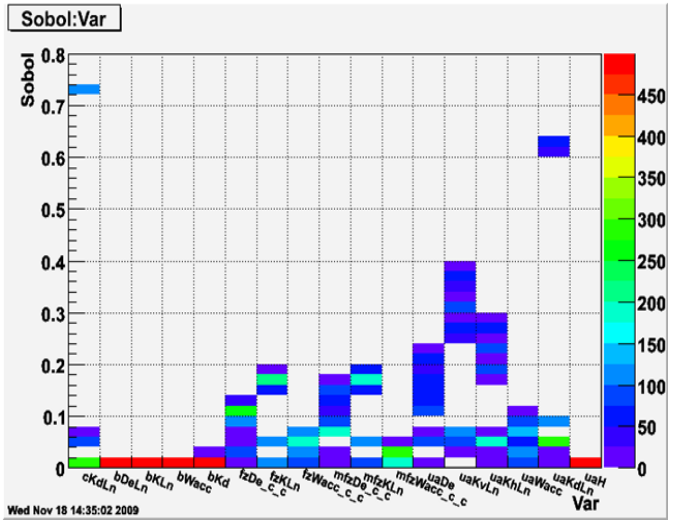




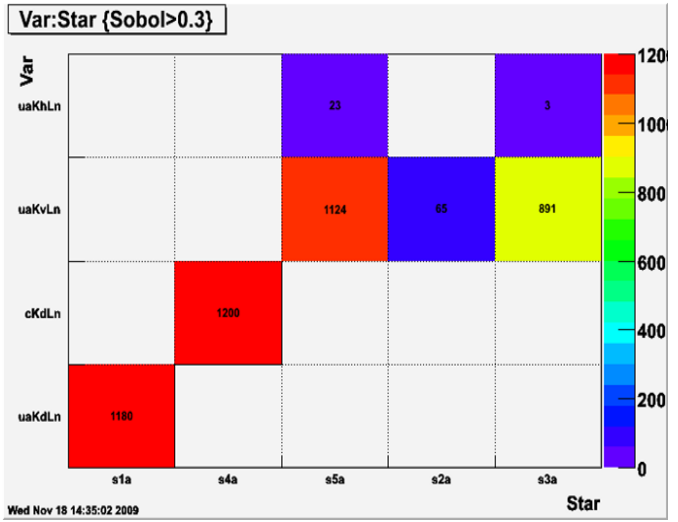


Uranie Application : All simulations (2/2)

1. 5 inputs parameters are not influence (first order) on all the 5 outputs
2. Only 4 inputs parameters are sensitives (for all 5 outputs)



ttre->Draw("Sobol:Var","","BOXCOL2Z")



ttre->Draw("Var:Star","Sobol>0.3","BOXCOL2Ztext")

ROOT ...
Uranie ...
Application

GPU - Description of the test

- Output : **st4** with $nH = 16$ neurons in the hidden layer ($\mathbb{R}^{17} \rightarrow \mathbb{R}^{16} \rightarrow \mathbb{R}$)
- Learning :
  - 1 database with 1 400 patterns
  - 100 learning
- Running :
  - 6 databases with 1 500, 5 000, 10 000, 20 000 and 50 000 patterns
  - 10 running for each databases
- criteria for comparison : time (t) and error (e)

1. CPU : 2 quadri cores Xeon 5500 (Boost.uBLAS)
2. GPU : 8 Fermi Tesla C2050 (CUDA/cuBLAS)

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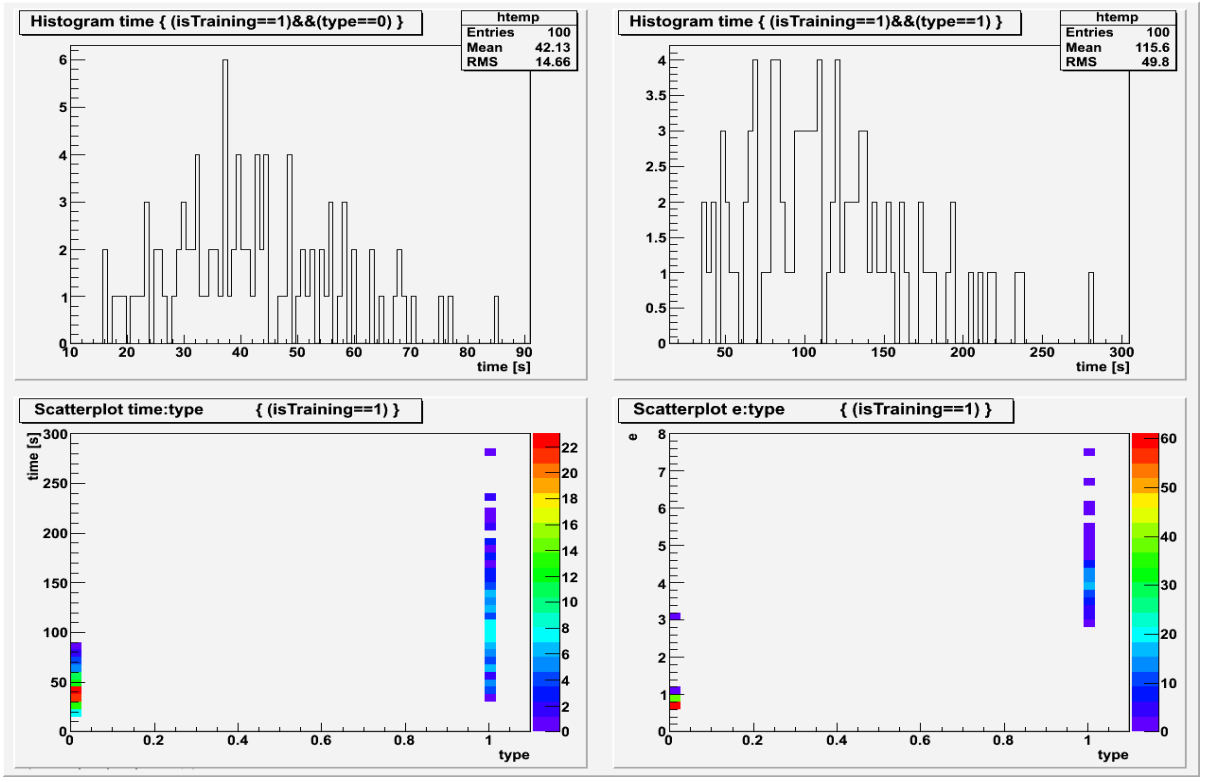
GPU - Learning Performance

Mean : GPU 42 s versus CPU 115 s

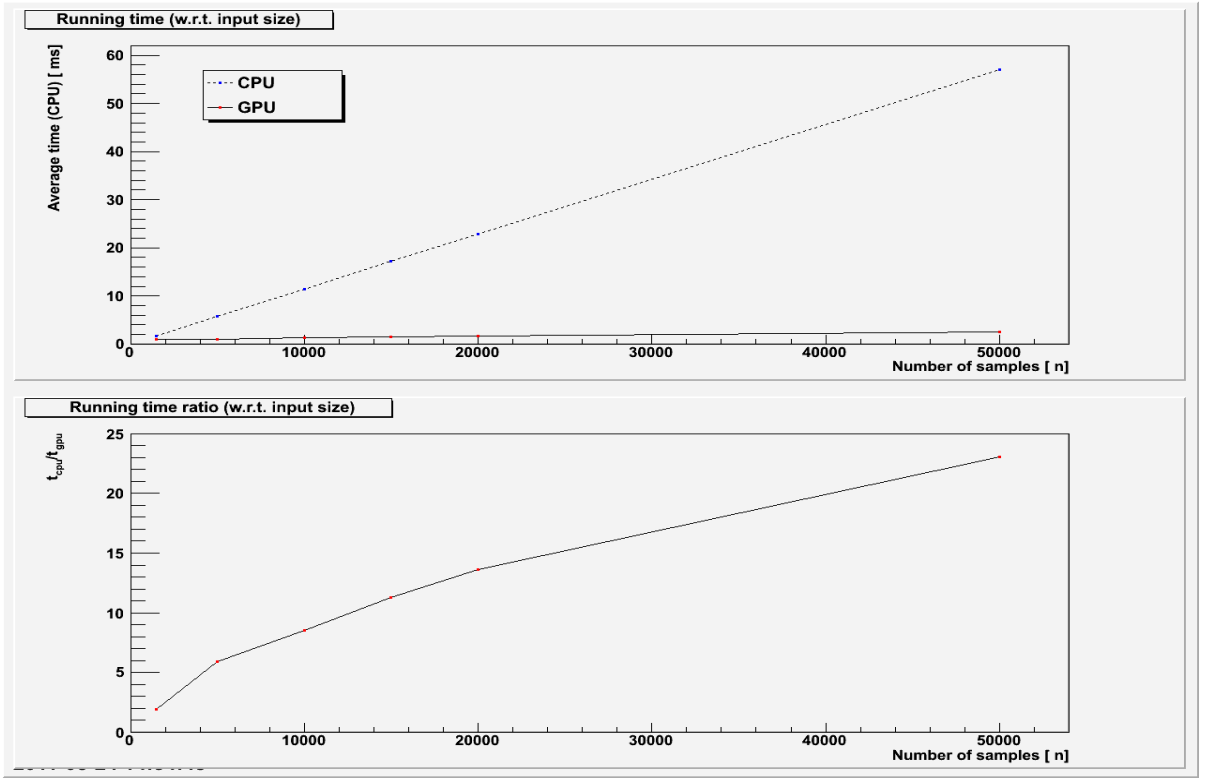


ROOT ...

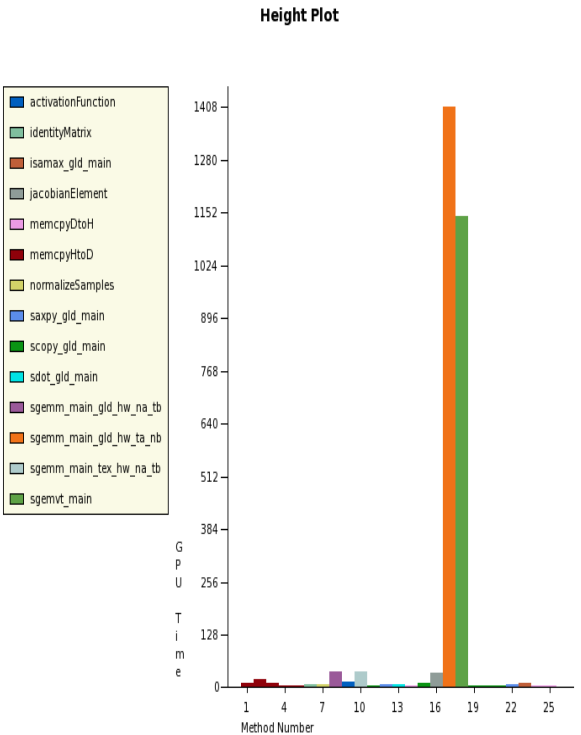
Uranie ...

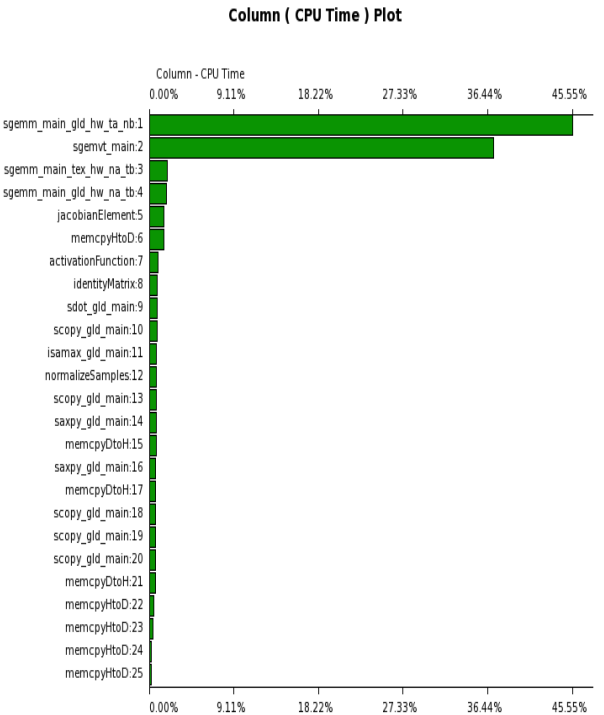
Application

GPU - Evaluation Performance



GPU - Profiling





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ROOT ...

Uranie ...

Application

GPU - Conclusions

1. GPU is 2 → 23 faster than CPU for evaluation ANN
2. GPU is <u>only</u> 3 faster than CPU for learning ANN for small database
   same speed-up for large database ?
3. main time consumer : matrix computing

Conclusions

- Introduce the ROOT framework
- Present some librairies of the Uranie platform
- Applications of Uranie :
  - Sensitivity Analysis with Artificial Neurals Networks
  - Learning and Running ANN on GPU

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