# Geant4 in a Distributed Computing Environment

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# Vision

## Problem

How to obtain a quick response from a Geant4 simulation

- Case 1: quick response in few minutes

*i.e. dosimetry, study the efficiency of detectors*

- Case 2: reasonable time for response from G4 simulations requiring high statistics

*i.e. medical, space science, high energy physics applications, tests of Geant4 physics models*

## Solution

Parallelisation

- On dedicated pc clusters
- On the GRID

**Study a general approach, independent from the specific Geant4 application**

# Quick response

- Parallelisation

  **Transparent configuration in sequential or parallel mode**

- Access to distributed computing resources

  **Transparent access to the GRID through an intermediate software layer**

# Strategy

- Study the performance of two Geant4 applications as typical examples:
  - Geant4 Brachytherapy application
  - Geant4 IMRT application

Sequential mode on a Pentium IV, 3 GHz

**G4 Brachytherapy application**

Execution time of 20 M events ~ 5 hours

Goal: quick response ~ few minutes

**G4 IMRT application**

Execution time of $10^9$ events ~ 9 days and half

Goal: quick response ~ few hours

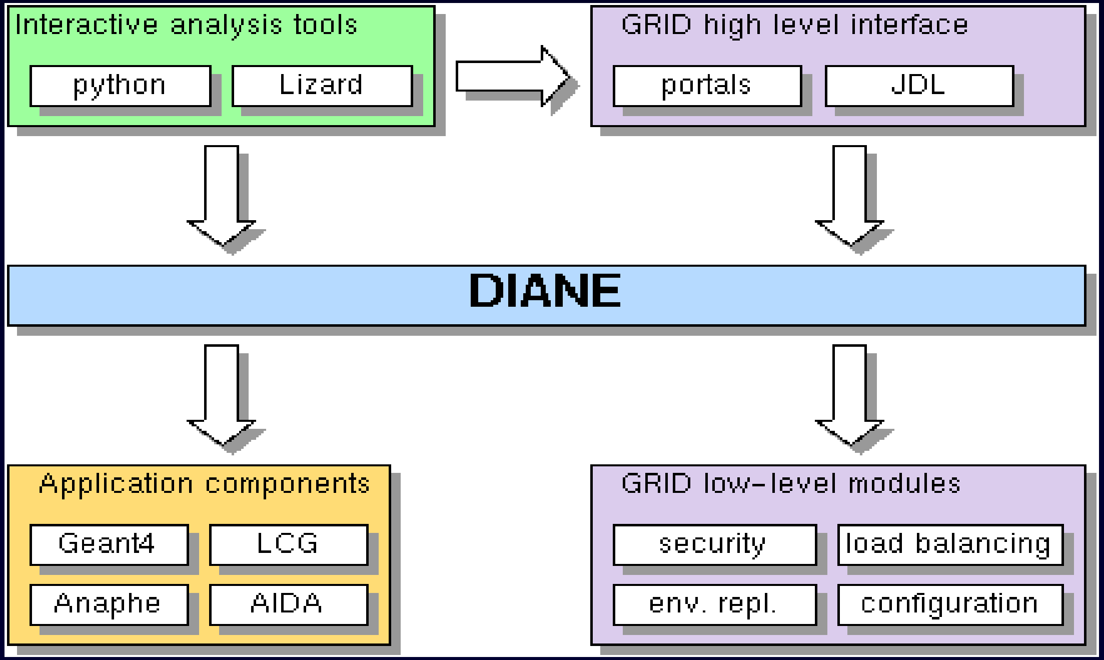
- Parallelisation through DIANE
- Performance tests
  - On a single CPU
  - On clusters
  - On the GRID
- Quantitative analysis of the results

# Outline

- Diane overview
- How to dianize a G4 application
- Results of performance tests
- Conclusions

# DIANE Overview

- DIANE R&D Project
  - started in 2001 in CERN/IT with very limited resources
  - collaboration with Geant 4 groups at CERN, INFN, ESA
  - succesful prototypes running on LSF and EDG



*Developed by J. Moscicki, CERN*

*http://cern.ch/DIANE*

**Parallel cluster processing**

– make fine tuning and customisation easy

– transparently using GRID technology

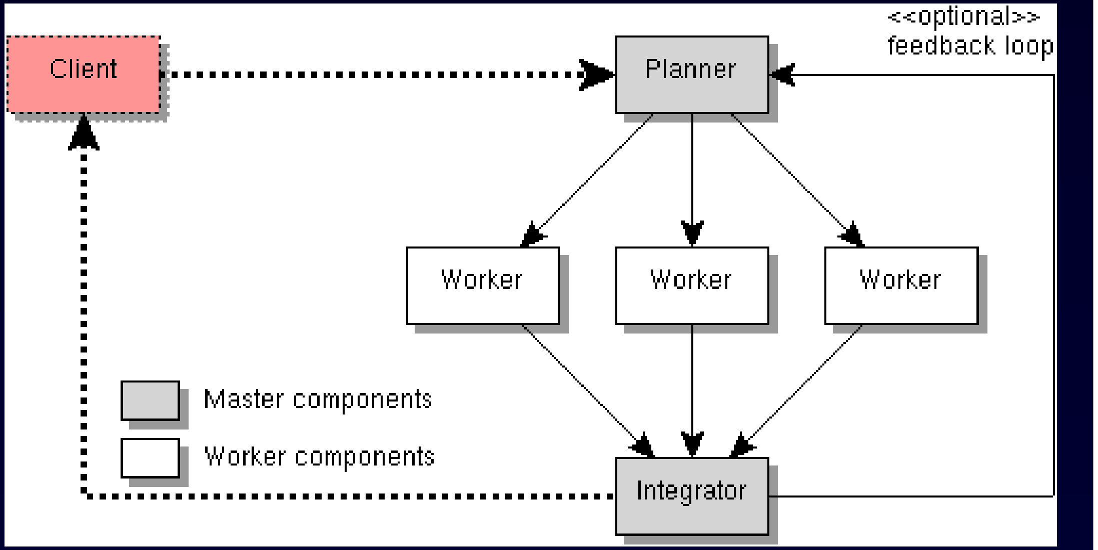
– application independent

*Susanna Guatelli*

# Practical Example

- Example: simulation with analysis
  - The job is divided into tasks
  - The tasks are executed on worker components
  - Each task produces a file with histograms
  - Job result = sum of histograms produced by tasks

- Master-worker model
  - Client starts a job
  - Workers perform tasks and produce histograms
  - Master integrates the results



# Running in a distributed environment

The application developer is shielded from the complexity of underlying technology via DIANE

- Not affecting the original code of the application
  - standalone and distributed case is the **same code**

- Good separation of the subsystems
  - the application does not need to know that it runs in a distributed environment
  - the distributed framework (DIANE) does not need to care about what actions an application performs internally

# How to *dianize* a G4 application

- Look at the Geant4 extended example: ExDIANE in the *parallel* directory

- Completely transparent to the user: same G4 code

- Documentation at http://www.cern.ch/diane specific for Geant4 applications
  - Installing  and compiling DIANE
  - Compiling and running a Geant4 application through DIANE

# Test results

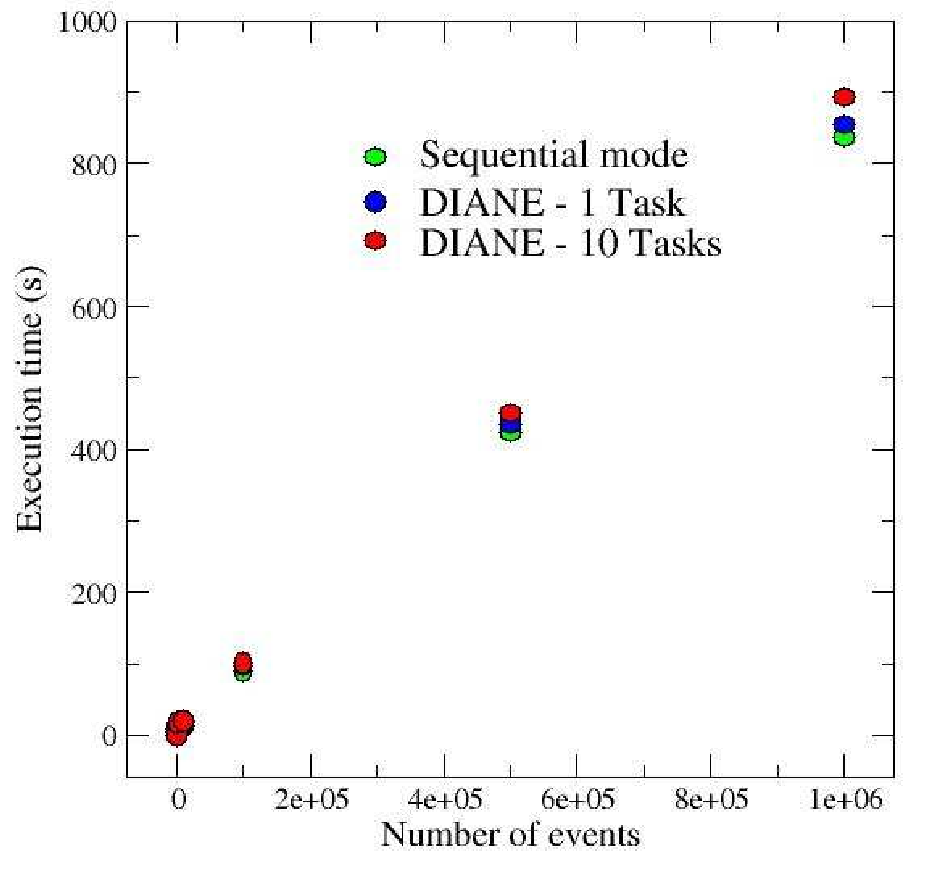
- Study the performance of the execution of the *dianized* G4Brachy:
  - Test on a single CPU
  - Test on a dedicated farm (60 CPUs)
  - Test on a farm, shared with other users (LSF, CERN)
  - Test on the GRID

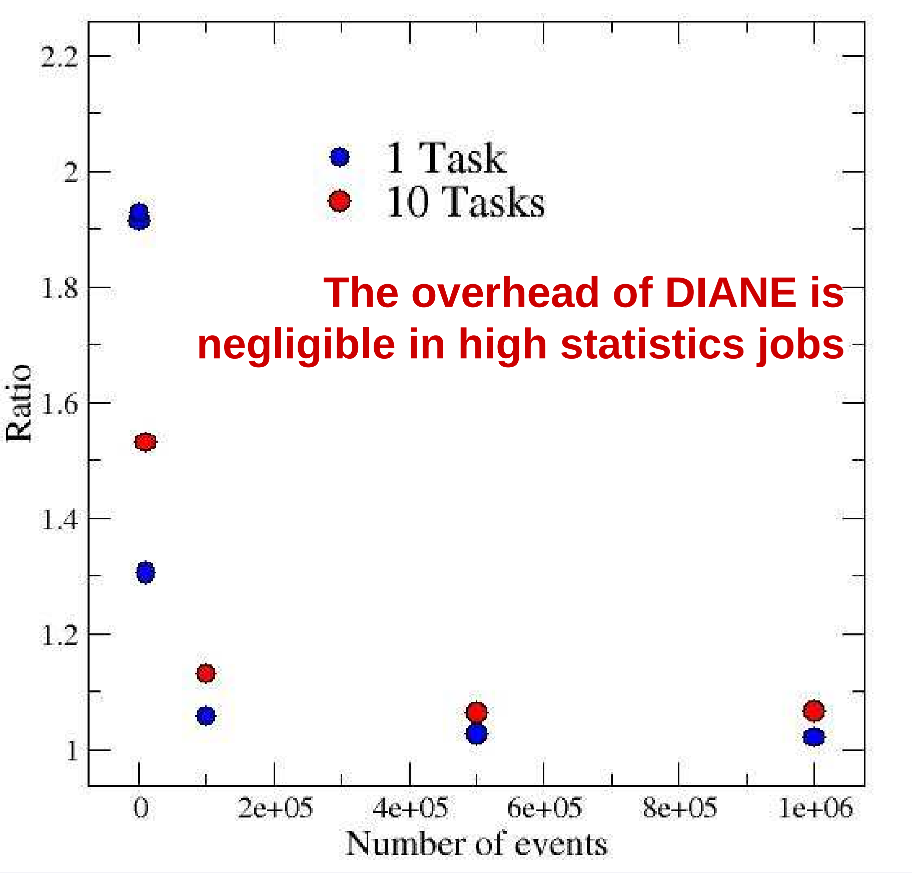
***Tools and libraries:***<br>
***Simulation toolkit:*** Geant4 7.0.p01<br>
***Analysis tools:*** AIDA 3.2.1 and PI 1.3.3<br>
***DIANE:*** DIANE 1.4.2<br>
***CLHEP:*** 1.9.1.2<br>
***G4EMLOW***2.3

# Results – G4Brachy: 1 CPU

Test on a single dedicated CPU (Intel ®, Pentium IV, 3.00 GHz)

Execution time with respect to the number of events of the job





**The overhead of DIANE is negligible in high statistics jobs**

$$\text{Ratio} = \frac{ExecutionTime_{DIANE}}{ExecutionTime_{SEQUENTIAL\_MODE}}$$

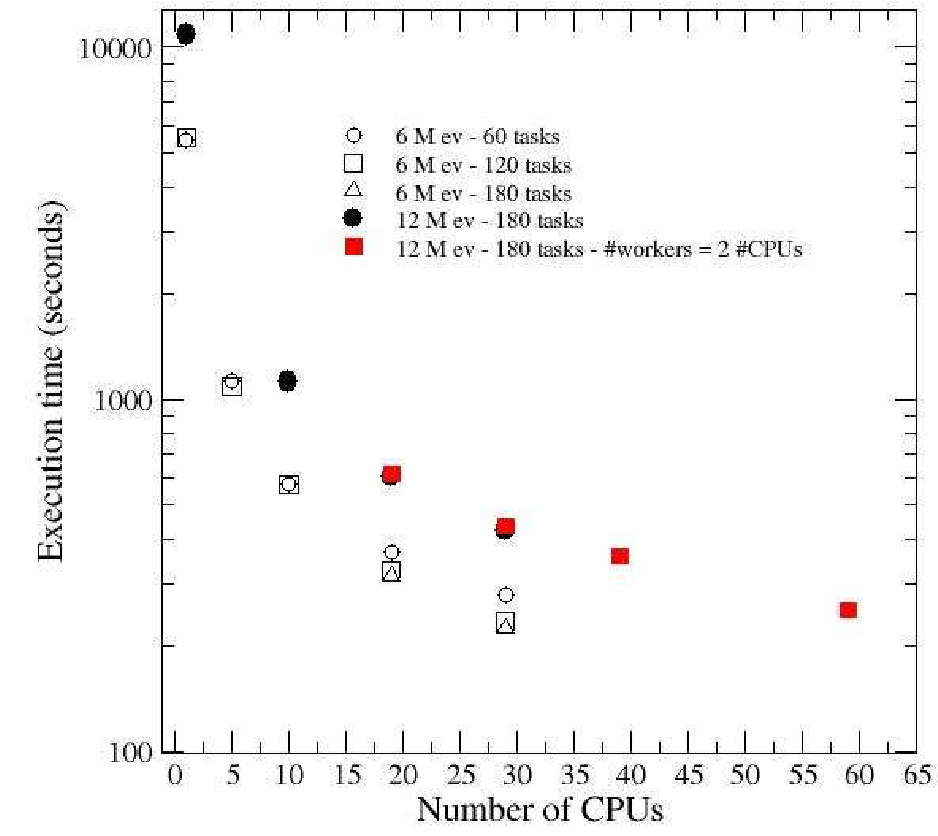
with respect to the number of events

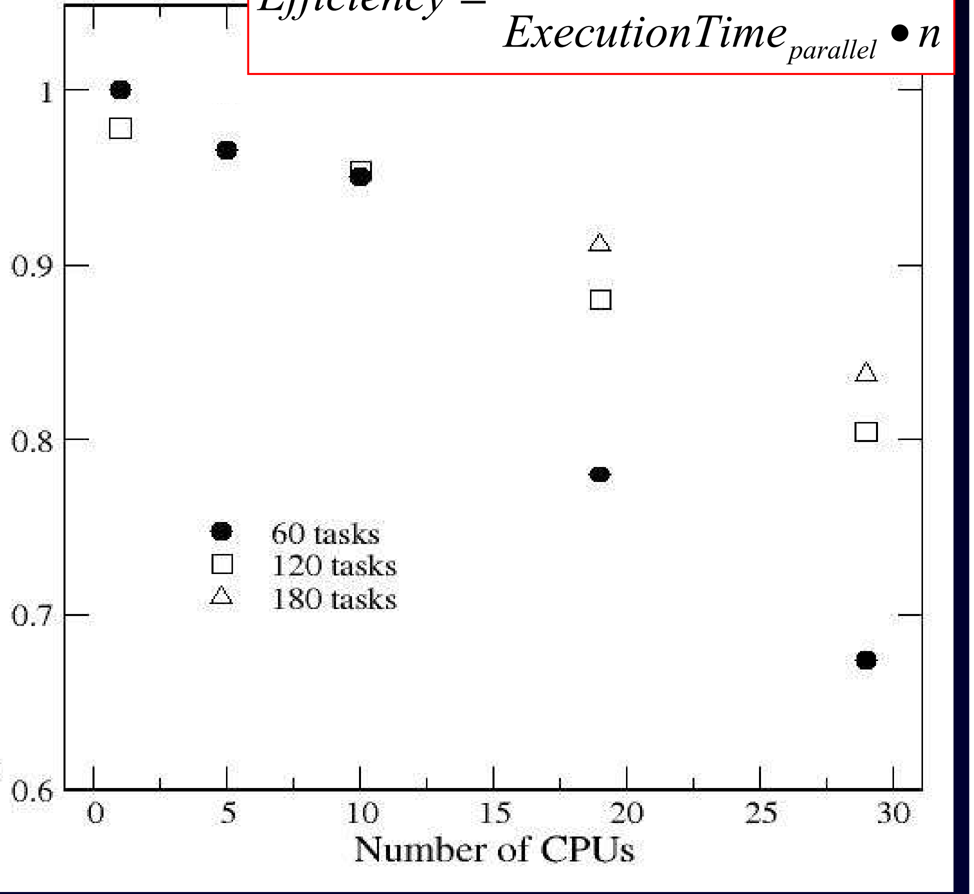
*Susanna Guatelli*

# Results – G4Brachy: farm

- Dedicated farm : 30 identical biprocessors (Pentium IV, 3 GHz)
- Thanks to Hurng-Chun Lee (Academia Sinica Grid Computing Center, Taiwan)
- Thanks to Regional Operation Centre (ROC) Team, Taiwan

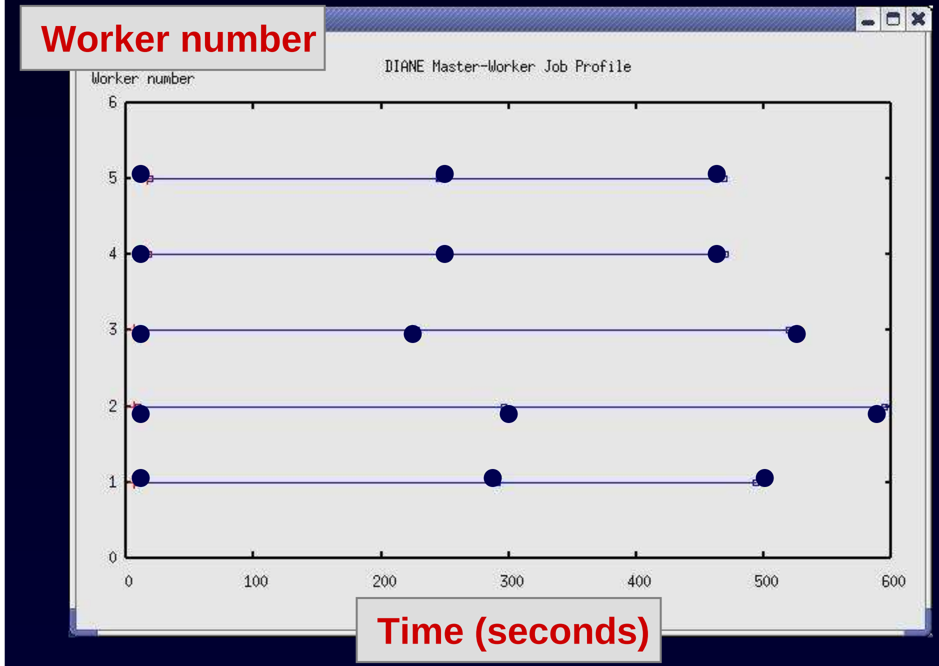
$$Efficiency = \frac{ExecutionTime_{sequential}}{ExecutionTime_{parallel} \bullet n}$$





# Comment

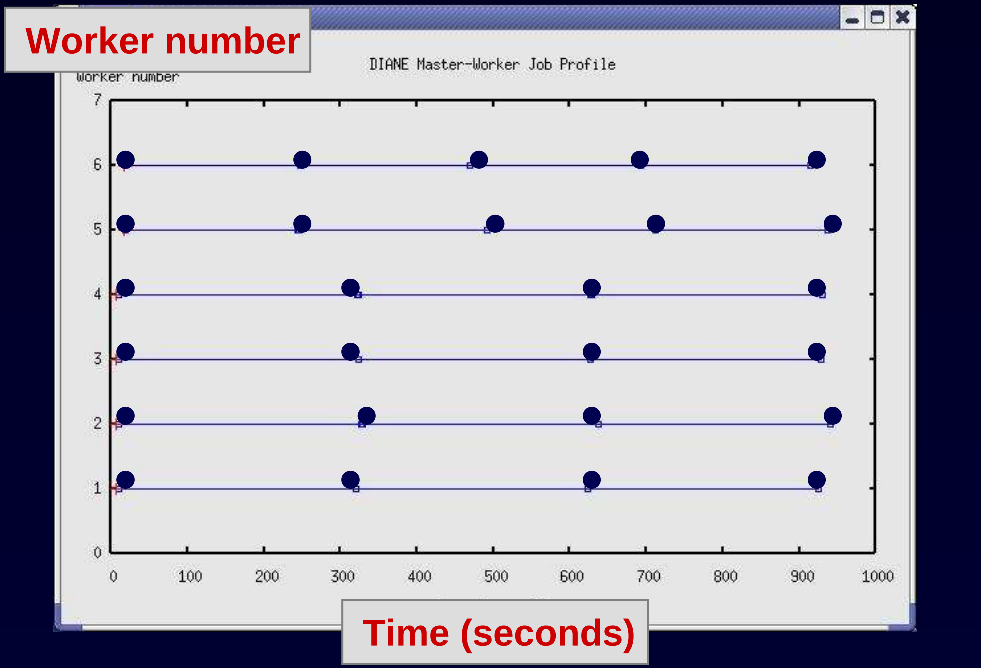
- The job ends when all the tasks are executed on the workers
- If the job is split into a higher number of tasks, there is a higher chance that the workers finish the tasks at the same moment



Worker number

Time (seconds)

Example of a job that can be improved from a performance point of view



Worker number

Time (seconds)

Example of a good job balancing

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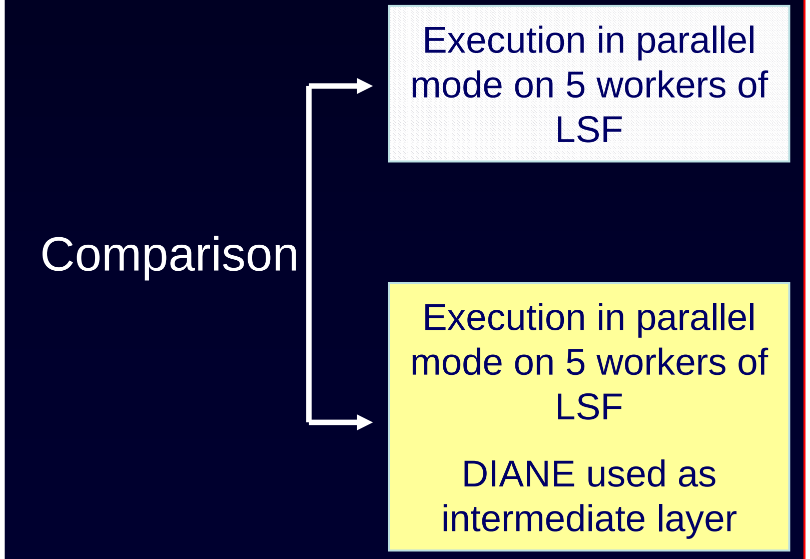
# Results - G4Brachy: farm (3)

Test on LSF cluster of CERN: case of farm shared with other users

$$\text{Ratio} = \frac{ExecutionTime_{PARALLEL\_MODE\_Diane}}{ExecutionTime_{PARALLEL\_MODE\_NoDiane}}$$

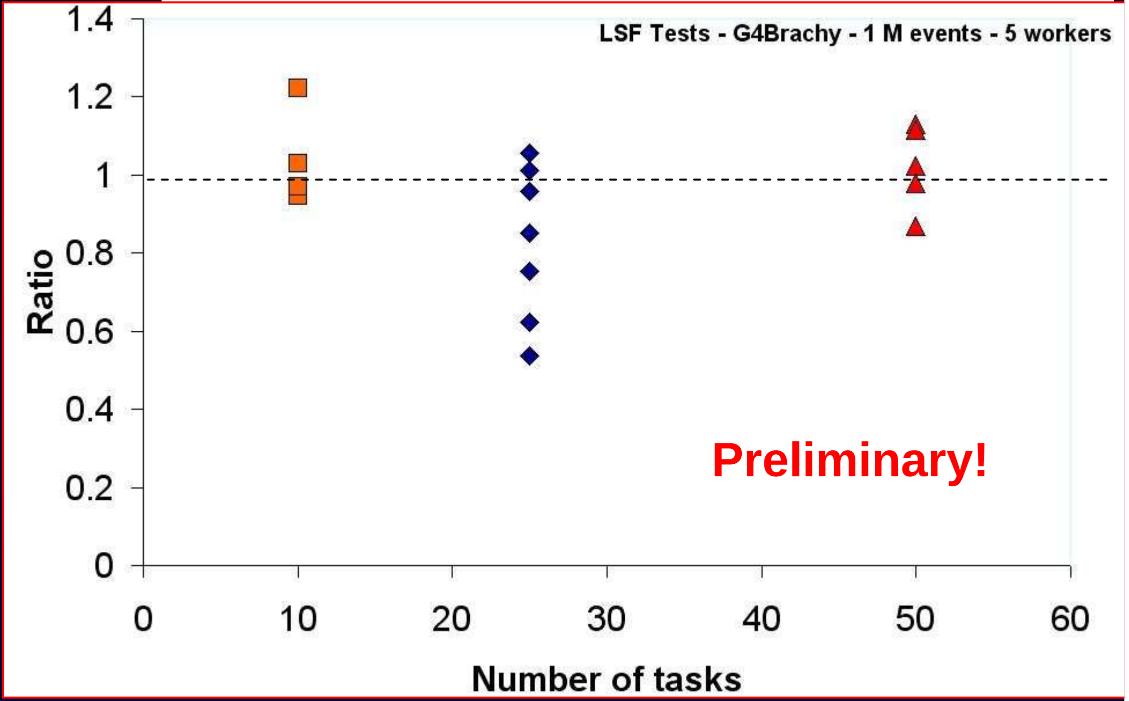


Comparison

Execution in parallel mode on 5 workers of LSF

Execution in parallel mode on 5 workers of LSF

DIANE used as intermediate layer



Preliminary!

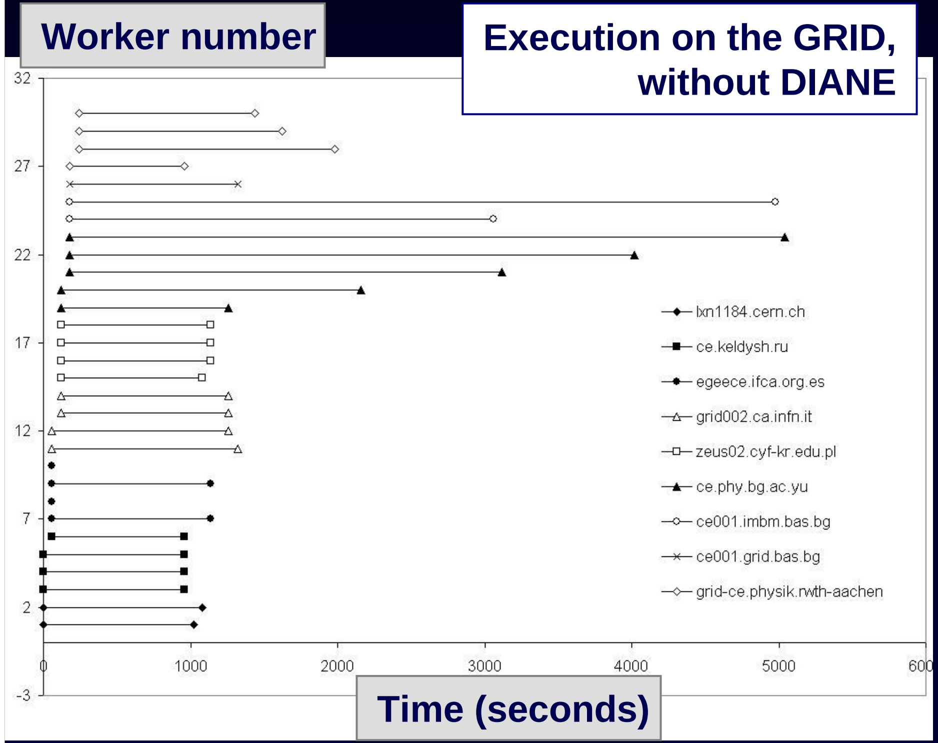
The load of the cluster changes quickly in time
The conditions of the test are not reproducible

*Susanna Guatelli*

# Results - G4Brachy: GRID (1)

- The load of the GRID changes quickly in time
- The conditions of the test are not reproducible
- G4Brachy executed on the GRID on nodes located in Spain, Russia, Italy, Germany, Switzerland

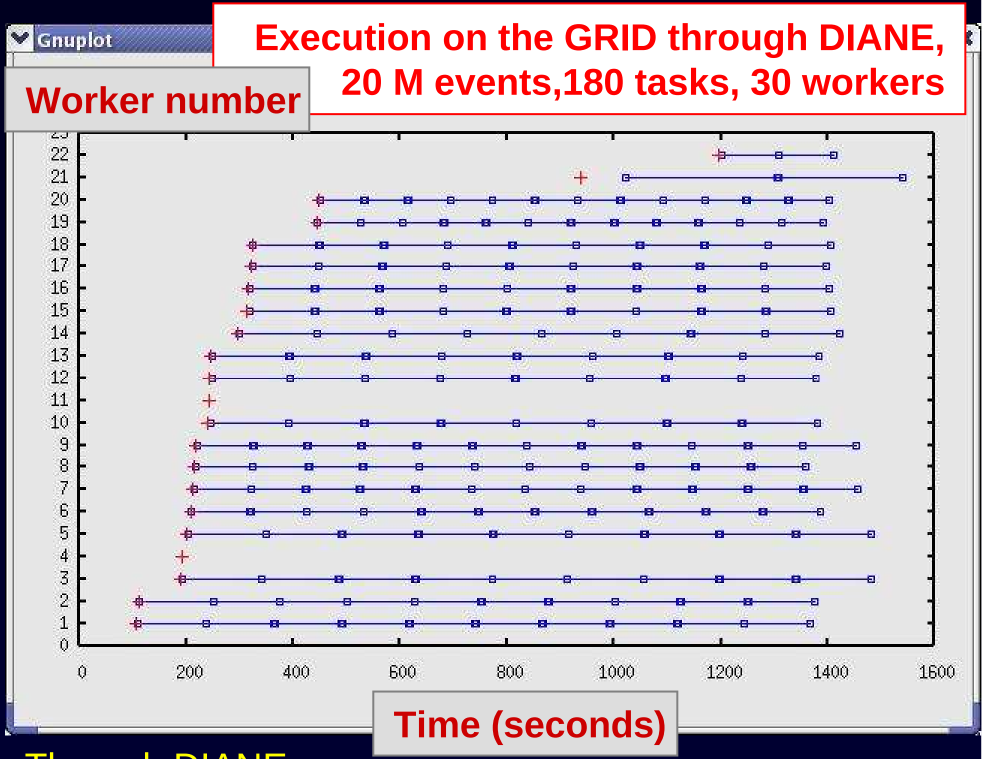
$$\frac{ExecutionTime_{PARALLEL\_MODE\_Diane}}{ExecutionTime_{PARALLEL\_MODE\_NoDiane}} \approx 0.3$$



Worker number

Execution on the GRID, without DIANE

Time (seconds)



Execution on the GRID through DIANE, 20 M events,180 tasks, 30 workers

Worker number

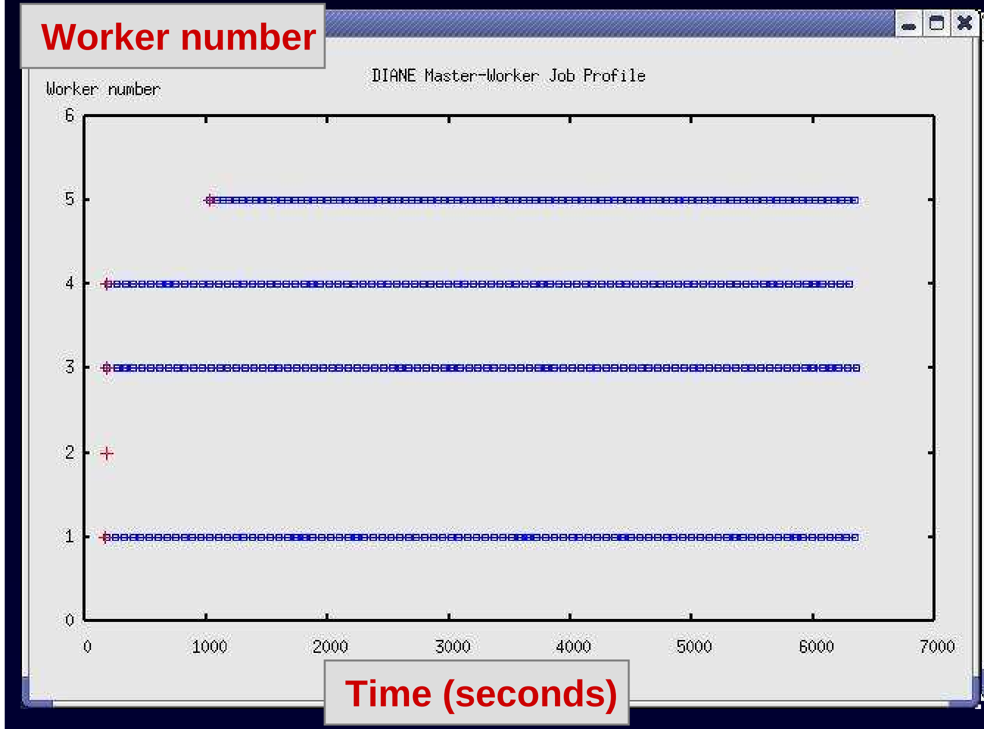
Time (seconds)

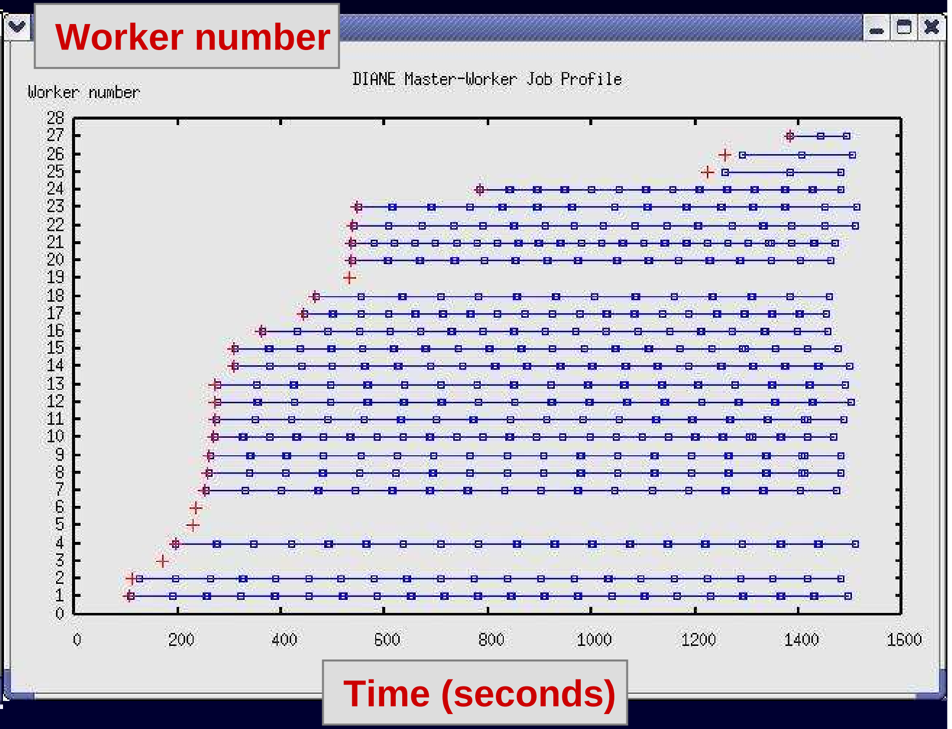
Without DIANE:
- 2 jobs not successfully executed due to set-up problems of the workers

Through DIANE:
- All the tasks are executed successfully on 22 workers
- Not all the workers are initialized and used: on-going investigation

# How the GRID load changes

Execution time of G4Brachy in two different conditions of the GRID
DIANE used as intermediate layer





20 M events, 60 workers initialized, 360 tasks

*Susanna Guatelli*

# Conclusions

- **General approach** to obtain quick response from Geant4 simulations

- Advantage of using DIANE as intermediate layer in a dedicated farm or GRID
  - Transparency
  - Good separation of the subsystems
  - Good management of the CPU resources

- DIANE is very advantageous as an intermediate layer to the GRID from a performance point of view

- A quantitative analysis of the performance results is in progress

- Submission of this work for publication in IEEE Trans. Nucl. Sci.

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