

2008 UK eScience All Hands Meeting

# High Performance Computing for Monte Carlo Radiotherapy Calculations

P. Downes, G. Yaikhom, J. P. Giddy, D. W. Walker,  
E. Spezi, and D. G. Lewis

School of Computer Science, Cardiff University  
Department of Medical Physics, Velindre Cancer Centre  
Cardiff, Wales, United Kingdom

# Overview

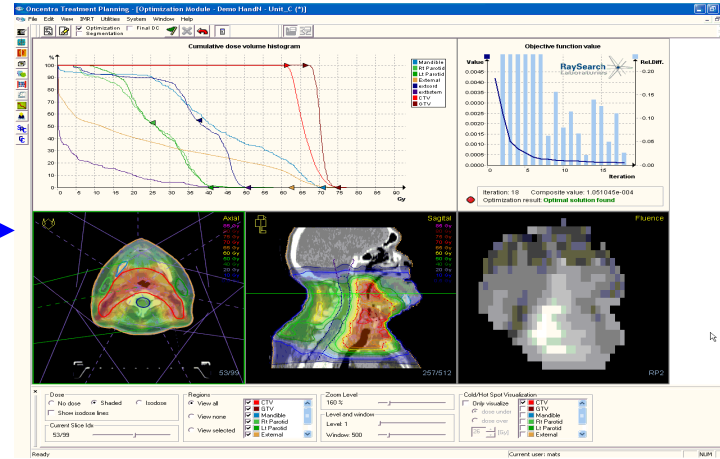
- Radiotherapy treatment.
- Traditional dose calculation.
- Why Monte Carlo simulations?
- What is the RTGrid portal?
- How does RTGrid work?
- Experimental results.

# Radiotherapy Treatment

## 1. Scan the patient



## 2. Identify tumour regions



## 4. Administer the radiation



## 3. Calculate the dosage

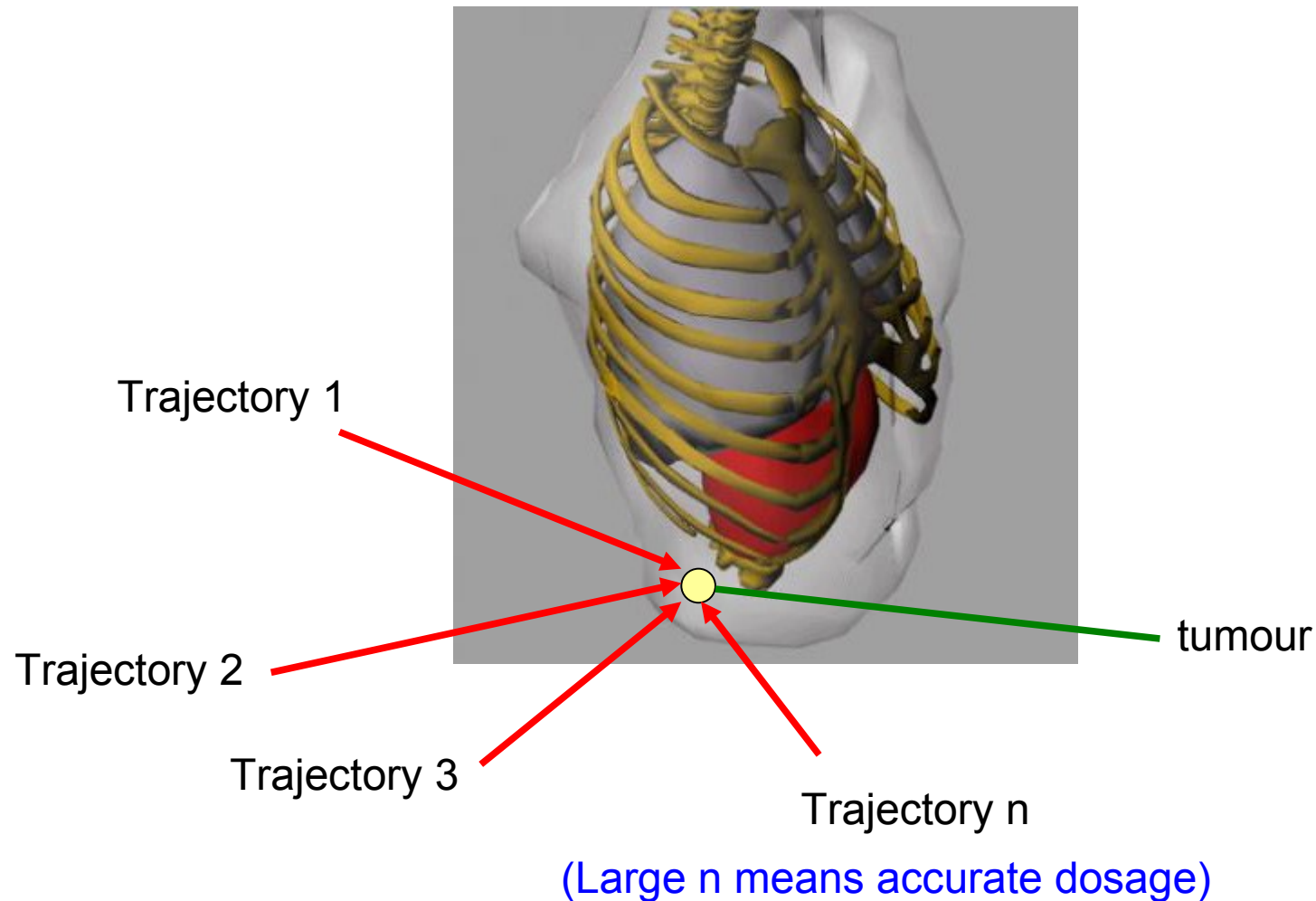
**Computation intensive**

The area which the RTGrid project aims to address

# Traditional dose calculation

- Typically performed on PCs and Workstations.
- Lacks computational power.
- Less accurate dosage.
- Higher chance of destroying healthy tissues.

# Monte Carlo simulation



# Why Monte Carlo simulations?

## Advantages:

- Accurate dosage.
- Low risk of destroying healthy tissues.

## Drawbacks:

- Takes a long time to simulate (several days).
- Thus, not clinically deployable.

# What is the RTGrid portal?

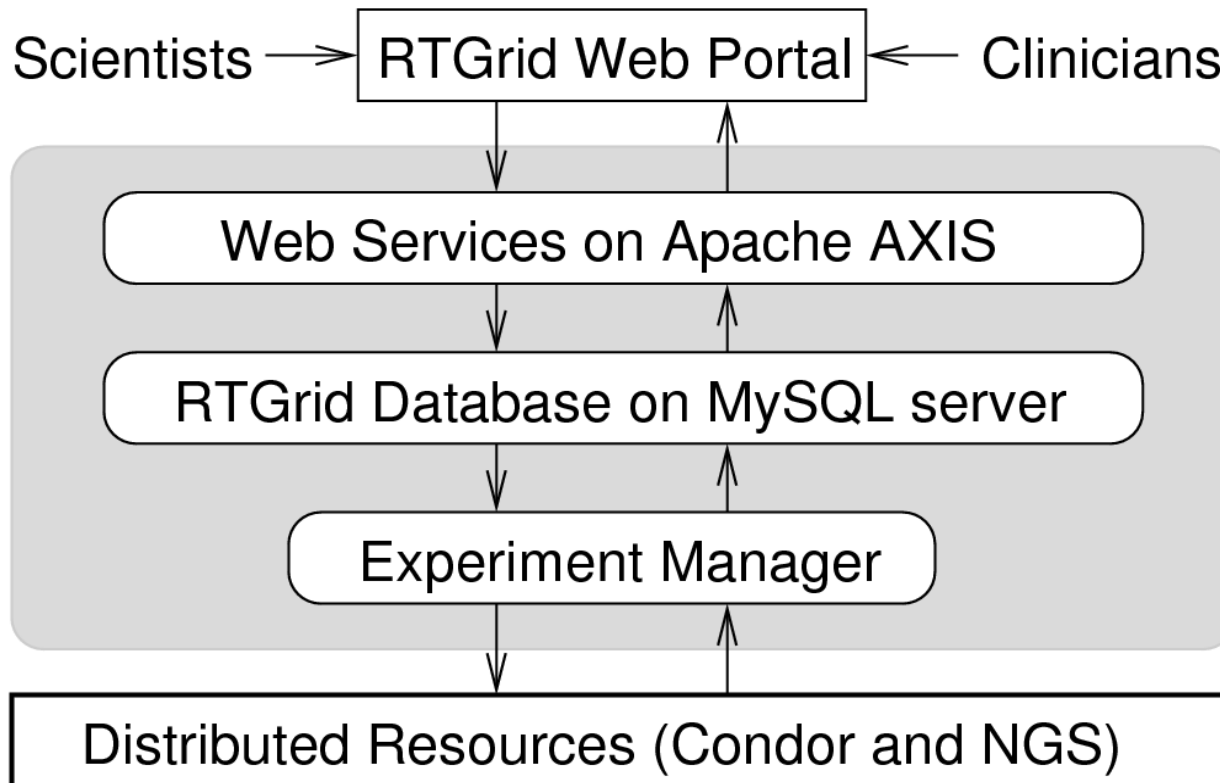
- A distributed simulation framework.
- Provides necessary computational power.
- Supports template-based simulation experiments.
- Making Monte Carlo dose calculations feasible.

# RTGrid provisions

- **Web portal interface:**  
For remote simulation management.
- **Pluggable resource modules:**  
For accessing distributed computational resources.
- **Profiles:**  
A reliable way to create Monte Carlo simulations from well-tested simulation **templates**.



# The System Architecture

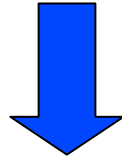


# The implementation

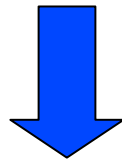
- Web server – Apache Tomcat, Ver. 5.0.28
- Web portal – Gridsphere, Ver. 2.2.9
- GSI credentials – Gridportlets, Ver. 1.4
- Web services – Apache Axis (SOAP), Ver. 1.4
- Database – MySQL, Ver. 5.0.22
- Experiment manager – Python, Ver. 2.4.3

# Using the RTGrid portal

Research Scientists create a simulation template



Clinical scientists use an existing template



Manage existing simulations

# Creating a simulation template

Menu

Create profile

List owned

List accessible

Set preferences

Help

Log out scmgy

Refresh

Create profile << Back to profile list

Name:

Description:

Access permissions:

Read	Edit	Use	Group	Description
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	resource	This user group allows users to share tasks that are related to the management
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	users	This user group allows users to share tasks that are in general allowed to
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	admin	This user group allows users to share access to administration related tasks.

Profile file:

Browse...

Upload

Profile extension XML:

Browse...

Upload




Create

Cancel

# Creating a simulation template

Profile file:

Uploaded profile files:

Filename	Type	Size	Action
 testarchive.tar.gz	application/x-gzip	184 bytes	<input type="button" value="Delete"/>
 RTGridDBWSTest.java	text/x-java	8 KB	<input type="button" value="Delete"/>
 rtgridws-0.1.jar	application/java-archive	37 KB	<input type="button" value="Delete"/>

## Simulation template data files

Executable code and configuration scripts.

Supports standard archive formats (.jar, .tar, .tar.gz, .tar.bz2, .zip) for uploading large file sets or directories. Archive files will be extracted automatically.

# Creating a simulation template

Profile extension XML:

Profile extension preview

Text:

Param:

Billy:

Selection:

Radio

☐ Alpha ☐ Beta

☐ Gamma ☒ Delta

Checkbox

☐ Alpha ☒ Beta

☒ Gamma

## Permitted template parameters

These values are specified by the user when a new simulation experiment is derived from this template.

What is being displayed here is a preview of what the template user will see when this template is selected.

# Creating a simulation experiment

Menu

Create experiment

List owned

List accessible

Set preferences

Help

Log out scmgy

Refresh

Create experiment

Name:

Description:

Resource:

Profile:  *Please select a profile.*

Access permission:

Read	Edit	Control	Group	Description
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	resource	This user group allows users to share tasks that are related to the
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	users	This user group allows users to share tasks that are in general allowed to
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	admin	This user group allows users to share access to administration related

Experiment file:

Select a resource

This is the distributed resource where the simulation must be run.

The RTGrid system conceals the complicated details from the user.

# Creating a simulation experiment

The screenshot shows a web-based configuration interface for a simulation experiment. At the top, there is a 'Resource' dropdown menu set to 'Oxford NGS Grid2'. Below it is a 'Profile' dropdown menu set to 'Profile 1: Allows you to test the installation.', followed by a green status message: 'Profile extension has been generated.' Under the 'Profile extension:' heading, there are several input fields: 'Text' with the value 'Hello', 'Param' with the value 'Hello', and 'Billy' with the value 'Hello'. Below these is a 'Selection' dropdown menu set to 'Gamma'. Further down are two groups of controls: a 'Radio' group with four options (Alpha, Beta, Gamma, Delta) where 'Delta' is selected, and a 'Checkbox' group with three options (Alpha, Beta, Gamma) where 'Beta' and 'Gamma' are checked. A yellow callout box with a black border points from the 'Param' field to the text 'Specialise the template'.

Resource:

Profile:  Profile extension has been generated.

Profile extension:

Text:

Param:

Billy:

Selection:

Radio

☐ Alpha ☐ Beta

☐ Gamma ☒ Delta

Checkbox

☐ Alpha ☒ Beta

☒ Gamma

## Specialise the template




When a template is selected, the user is displayed with the associated template extension and default parameters. The user can supply new parameters.



# Creating a simulation experiment

Experiment file:

Uploaded experiment files:

Filename	Type	Size	Action
 rtgridws-0.1.jar	application/java-archive	37 KB	<input type="button" value="Delete"/>
 testarchive.tar.gz	application/x-gzip	184 bytes	<input type="button" value="Delete"/>
 RTGridDBWSTest.java	text/x-java	8 KB	<input type="button" value="Delete"/>

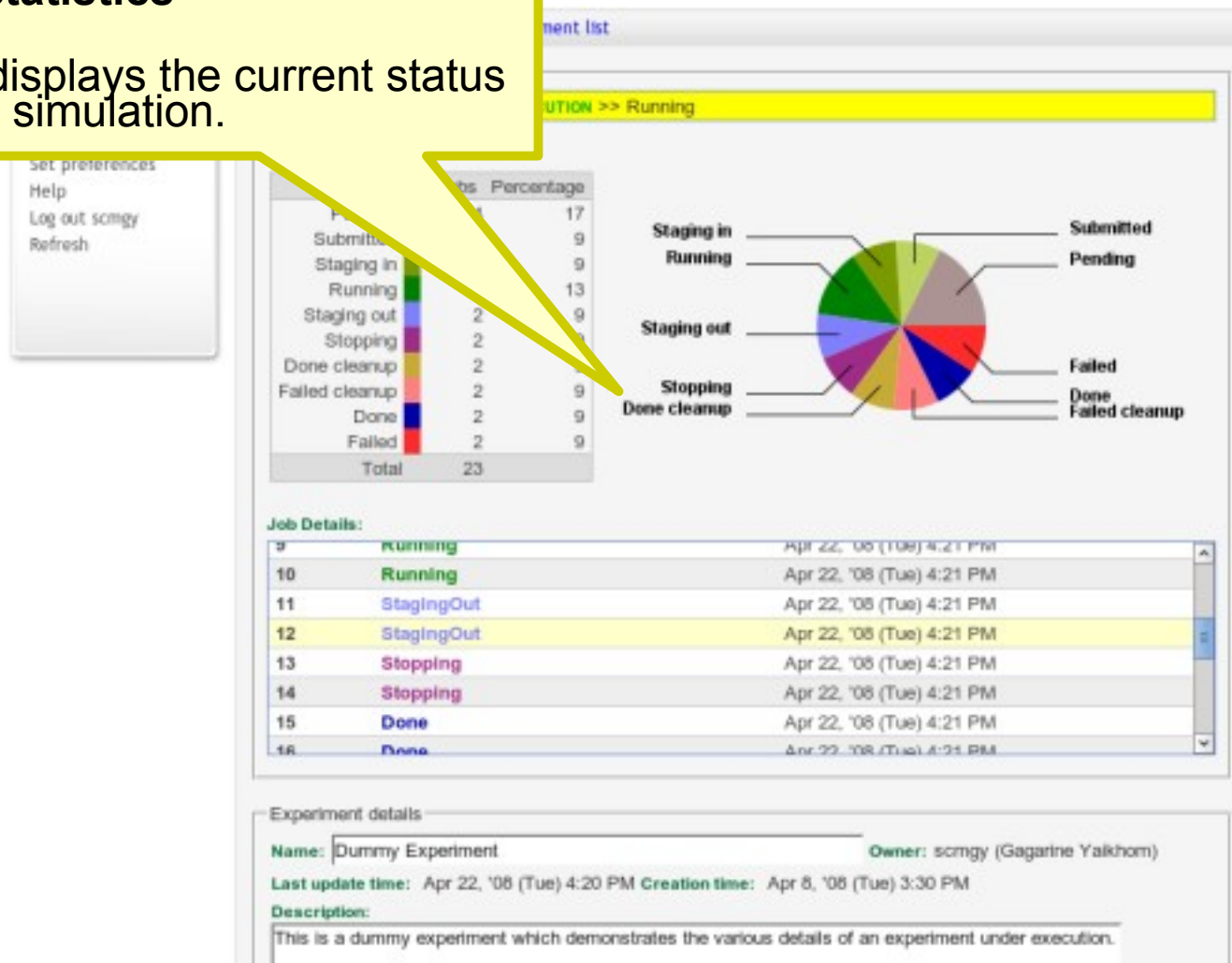
## Upload experiment files

Some experiments might require special files that are not available with the chosen template.

# Managing a simulation experiment

## Job statistics

This displays the current status of the simulation.



# Managing a simulation experiment

**Menu**

- Create experiment
- List owned
- List accessible
- Help
- Log out scmpd1
- Refresh

Experiment details << Back to experiment list

Experiment state

**EXECUTING EXPERIMENT >> COMPLETED**

Restart Delete

File management

File:  Browse... Upload Delete Archive

home/\_share/

Name	Size	Last modified	Action
BEAM_Clinac21CDb_photon		Jun 20, '08 (Fri) 3:04 PM	Delete Archive
FILES	5 KB	Jun 20, '08 (Fri) 3:05 PM	Delete Edit
bin		Jun 20, '08 (Fri) 3:04 PM	Delete Archive
ct_filelist.egsphant	12 MB	Jun 20, '08 (Fri) 3:04 PM	Delete Edit
		May 14, '08 (Wed) 1:50 PM	Delete Archive

Experiment details

File: TPSload 16

(Patrick Downes)

Jun 29, '08 (Sun) 11:08 AM

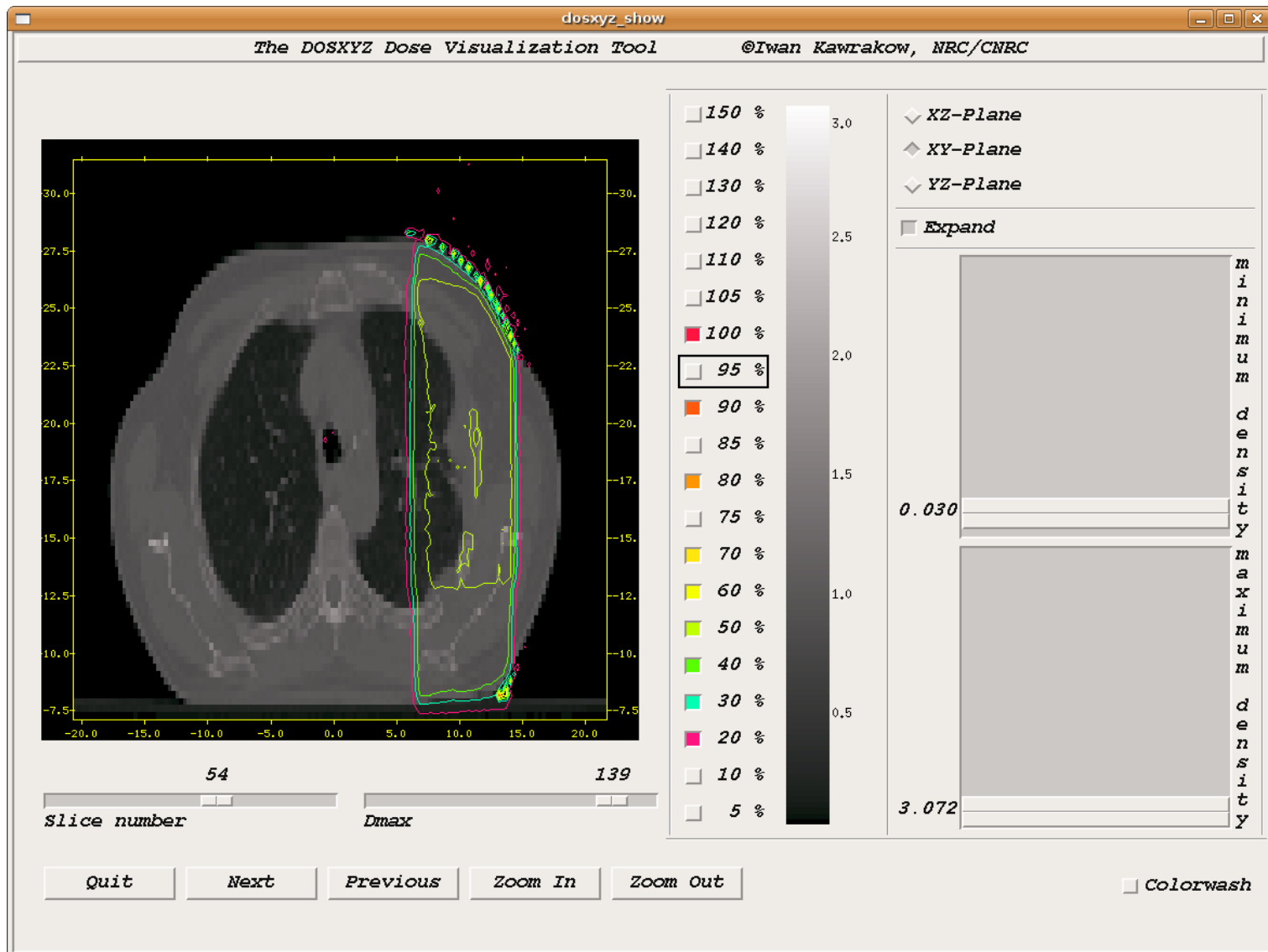
Jun 20, '08 (Fri) 1:59 PM

Experiment plan, no wedges

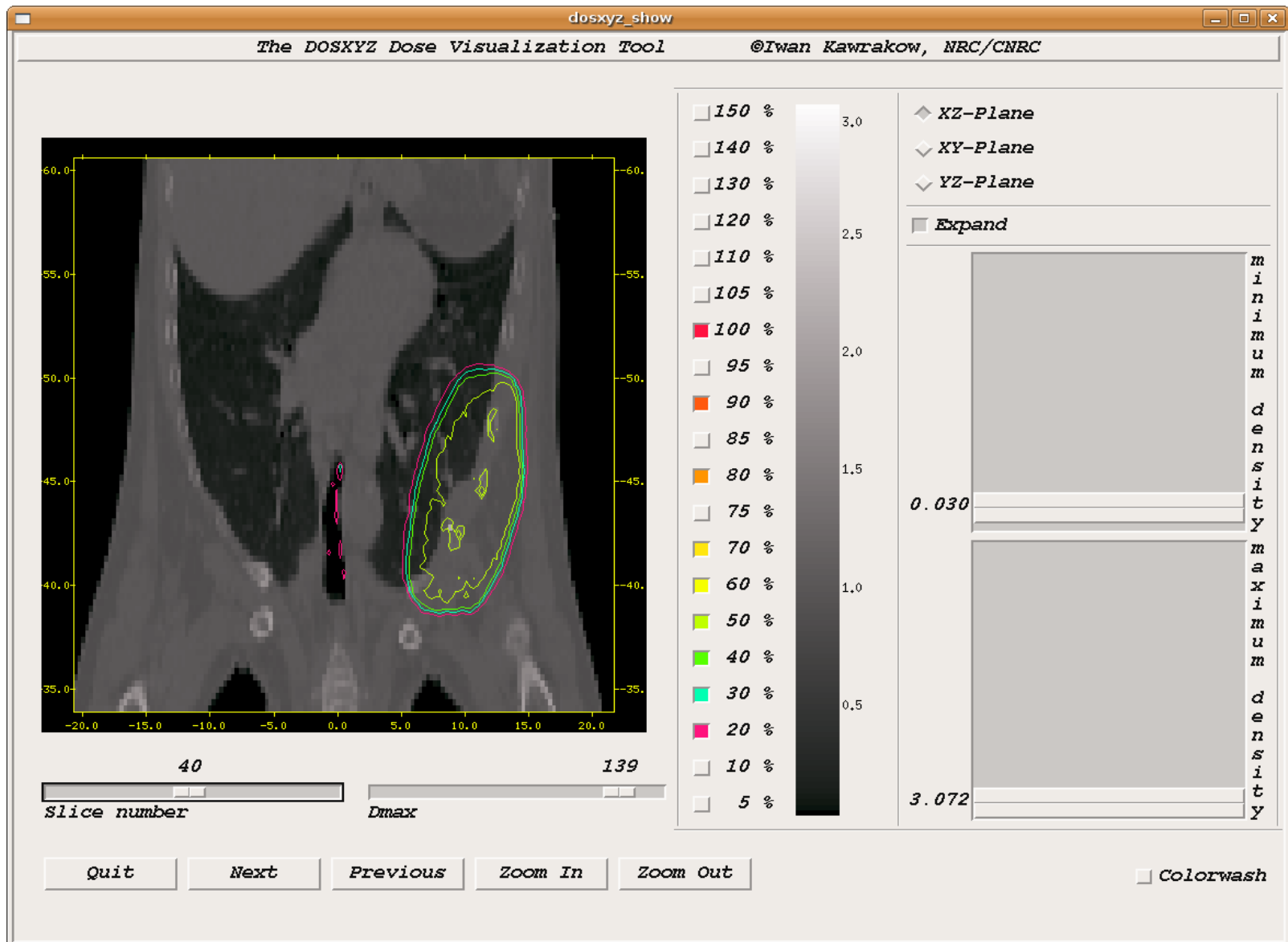
## File browser

The user can download or view output and experiment-specific data files from this file browser.

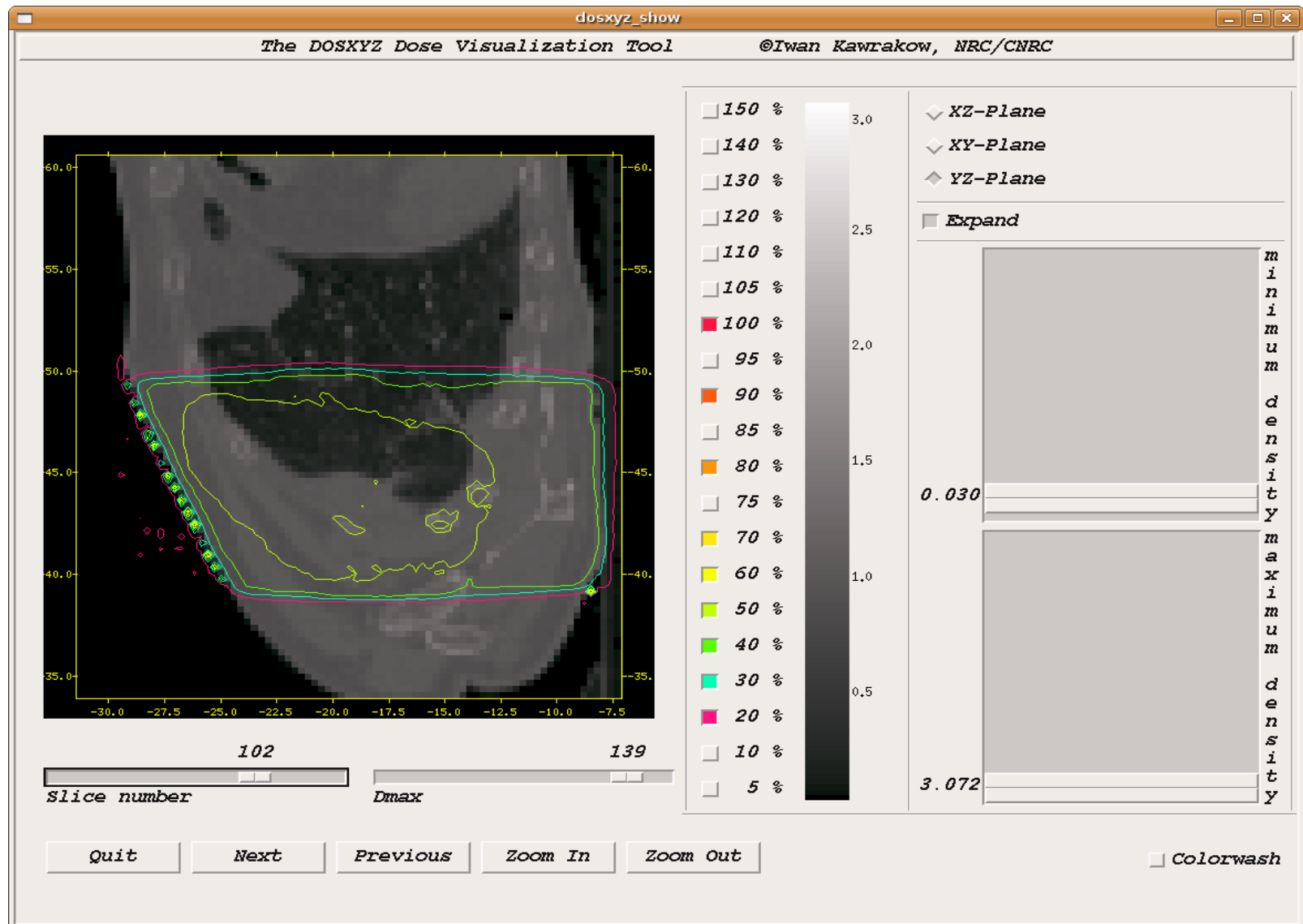
# The Radiotherapy dose



# The Radiotherapy dose



# The Radiotherapy dose



# Experimental Results (Condor)

Breakdown of the execution times for each of the experiments which ran on the Cardiff Condor Pool.

Jobs	Pre(%)	Run(%)	Post(%)	Speedup	Efficiency
20	15 seconds (0.06)	7.15 hours (99.79)	38 seconds (0.15)	11.48	0.57
40	30 seconds (0.21)	3.92 hours (99.30)	70 seconds (0.49)	20.55	0.51
80	50 seconds (0.37)	3.75 hours (98.62)	139 seconds (1.01)	21.35	0.27
120	71 seconds (0.60)	3.17 hours (97.25)	252 seconds (2.15)	24.89	0.21
160	108 seconds (1.94)	1.38 hours (89.09)	500 seconds (8.97)	52.22	0.33

The percentage of the execution time of each phase against the total execution time is given in parentheses.

# Experimental Results (NGS)

Breakdown of the execution times for each of the experiments which ran on the National Grid Service.

Jobs	Pre(%)	Run(%)	Post(%)	Speedup	Efficiency
20	14 seconds (0.10)	3.83 hours (99.83)	10 seconds (0.07)	21.07	1.05
40	28 seconds (0.38)	2.03 hours (99.25)	27 seconds (0.37)	39.49	0.99
80	42 seconds (0.40)	2.88 hours (99.23)	39 seconds (0.37)	26.39	0.33
120	163 seconds (1.68)	2.63 hours (97.81)	51 seconds (0.51)	30.21	0.25
160	106 seconds (1.16)	2.47 hours (98.09)	68 seconds (0.75)	32.09	0.2

The percentage of the execution time of each phase against the total execution time is given in parentheses.

The highlighted experiments were affected by an unpredictable file transfer problem which degraded the performance.



# Conclusions

- Significant speedup achievable.
- Some of the main issues:
  - ♦ Condor: pre-emption, suspension, and eviction.
  - ♦ NGS: unpredictable file transfer problem.

# Future Work

- Investigate approaches for splitting into jobs.
- Investigate physical factors in MC models.
- Further experimentation with treatment plans.

Email: [rtgrid@cs.cf.ac.uk](mailto:rtgrid@cs.cf.ac.uk)

Demonstration:

Booth 13 Appleton Tower,  
Wednesday 15:10 – 18:10

Thank you for your kind attention.