Particle Therapy Simulation on GRID

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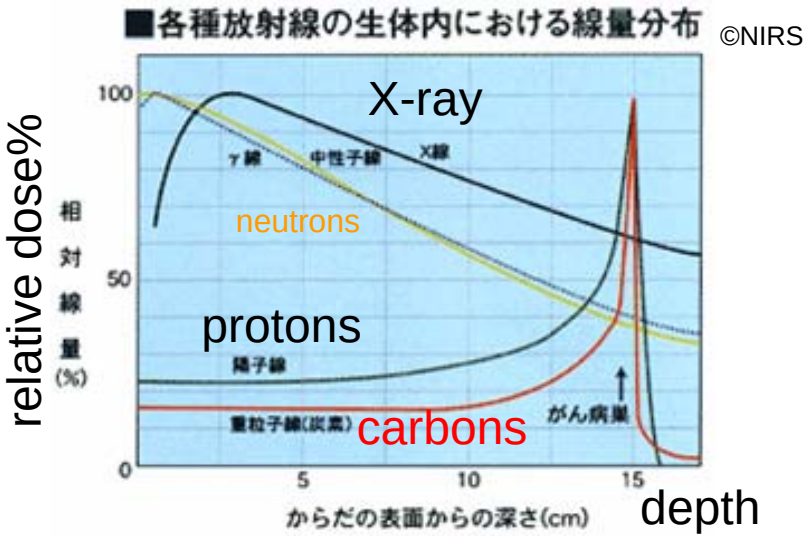
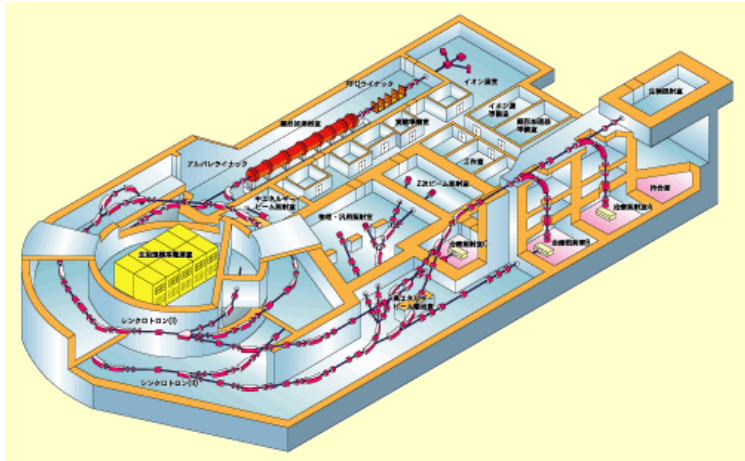
The project

- Collaboration between Medical Physicists and Geant4 developers in Japan
- Funded by Japan Science and Technology Agency during 2003-2008
- Development on the software suit for particle therapy simulation including
  - Dose calculation engine, visualization, GRID and so on
- Validation on the simulation results
  - Interaction of carbons (nuclear fragmentation) are not well known yet

Particle Therapy

- Mostly using protons or carbons, sometime heavier ions or neutrons for cancer therapy
  - Synchrotrons or cychrotrons are used
- Advantage in quality of life (less collateral side effects)





NIRS-HIMAC

Carbon therapy

- PROS
  - Carbons give narrower Bragg Peak than protons
    - Less side effects
  - Better biological effects than protons
    - Less dose, better efficiency
- CONS
  - More costs on construction for carbons than protons
    - Facility for protons is not cheap, anyway
    - 1B JPY vs 0.7B JPY

Contribution from particle physics

- Many of accelerator laboratories in the world are committing cancer therapy somehow
  - CERN
    - Accelerator developments
    - Research on anti-proton therapy
  - GSI
    - Heavy ion therapy
  - KEK
    - Proton therapy 1983-2000
    - Medical accelerator development

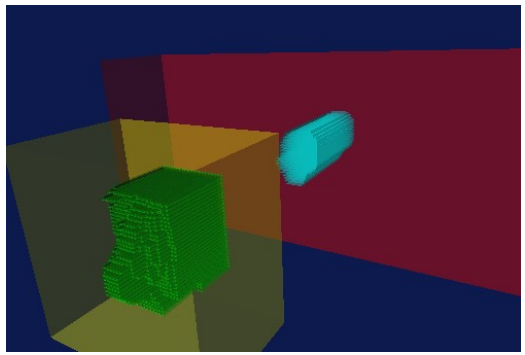
Particle therapy facility in operation

		WHAT	FIRST	TOTAL	DATE OF TOTAL
Canada	Vancouver (TRIUMF)	p	1995	111	Sep-06 eyes only
China	Wanjie (WPTC)	p	2004	270	July-06
England	Clatterbridge	p	1989	1584	Dec-06 eyes only
France	Nice (CAL)	p	1991	3129	Sep-06
France	Orsay (CPO)	p	1991	3126	Dec-06 eyes only
France	Orsay (CPO)	p	1991	640	Dec-06
Germany	Darmstadt (GSI)	C ion	1997	316	July-06
Germany	Berlin (HMI)	p	1998	829	Dec-06
Italy	Catania (INFN-LNS)	p	2002	114	Oct-06 eyes only
Japan	Chiba (HIMAC)	C ion	1994	2867	Aug-06
Japan	Kashiwa (NCC)	p	1998	462	Nov-06
Japan	Hyogo (HIBMC)	p	2001	1099	Sep-06
Japan	Hyogo (HIBMC)	C ion	2002	131	Sep-06
Japan	Tsukuba (PMRC, 2)	p	2001	930	July-06
Japan	WERC	p	2002	33	Aug-06
Japan	Shizuoka	p	2003	410	Nov-06
Russia	Moscow (ITEP)	p	1969	3858	Dec-05
Russia	St. Petersburg	p	1975	1320	Oct-06
Russia	Dubna (JINR, 2)	p	1999	318	July-06
South Africa	iThemba LABS	p	1993	486	Dec-06
Sweden	Uppsala (2)	p	1989	738	Dec-06
Switzerland	Villigen PSI (72 MeV-Optis)	p	1984	4646	Dec-06 eyes only
Switzerland	Villigen PSI (230 MeV)	p	1996	262	Dec-06
CA., USA	UCSF - CNL	p	1994	920	Mar-07
CA., USA	Loma Linda (LLUMC)	p	1990	11414	Nov-06
IN., USA	Bloomington (MPRI, 2)	p	2004	220	Sep-06
MA., USA	Boston (NPTC)	p	2001	2080	Oct-06
TX, USA	Houston (M.D. Anderson)	p	2006	114	Dec-06
FL, USA	Jacksonville (UFPTI)	p	2006	15	Dec-06

Facility under construction

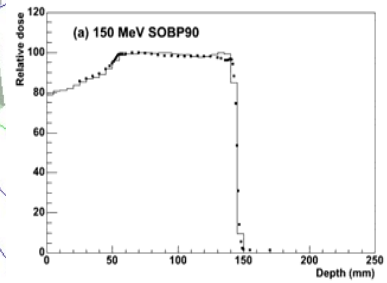
WHO, WHERE	COUNTRY	PARTICLE	MAX. CLINICAL ENERGY (MeV)	BEAM DIRECTION	NO. OF TREATMENT ROOMS	START OF TREATMENT PLANNED
RPTC, Munich*	Germany	p	250 SC cyclotron	4 gantries, with scanning, 1 horiz.	5	2007
PSI, Villigen*	Switzerland	p	250 SC cyclotron	Additional gantry, 2D parallel scanning, 1 horiz.	3	2007/08 (OPTIS2/ Gantry2)
NCC, Seoul*	Korea	p	230 cyclotron	2 gantries 1 horiz.	3	2007
CNAO, Pavia*	Italy	p, ion	430/u synchrotron	1 gantry? 3 horiz. 1 vert	3-4	2009?
Heidelberg/GSI Darmstadt*	Germany	p, ion	430/u synchrotron	1 gantry, raster scanning, 2 fixed beams	3	2007
Gunma Univ. Takasaki, Gunma	Japan	ion	400/u Synchrotron	1 vert+holiz., 1 vert 1 horiz.	3	2009
Fukui Pref. Fukui	Japan	p	synchrotron	?	?	2009?
Minami Tohoku Hospita l(priv.) Fukushima	Japan	p	synchrotron	1 vert 2gatry	3	Autumn 2008

Hadron Therapy Simulation



Water Phantom

Multi-Leaf Collimator



Flatness Monitor

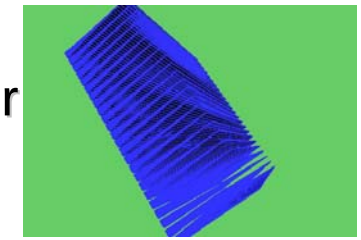
Main Monitor

Lead Scatter

Block Collimator

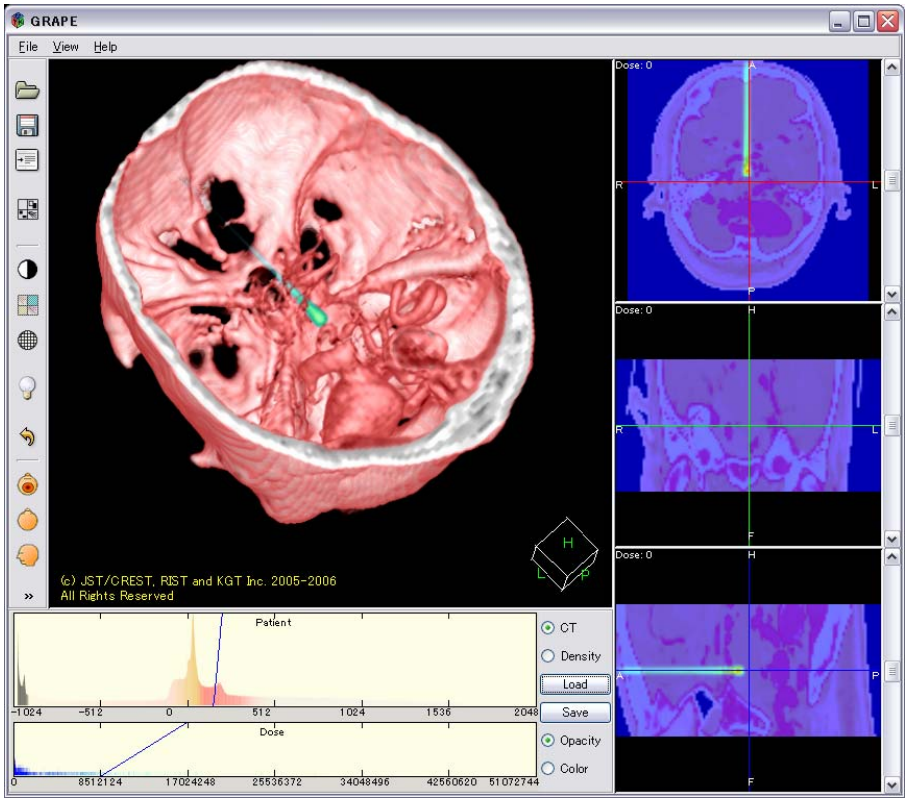
Ridge Filter

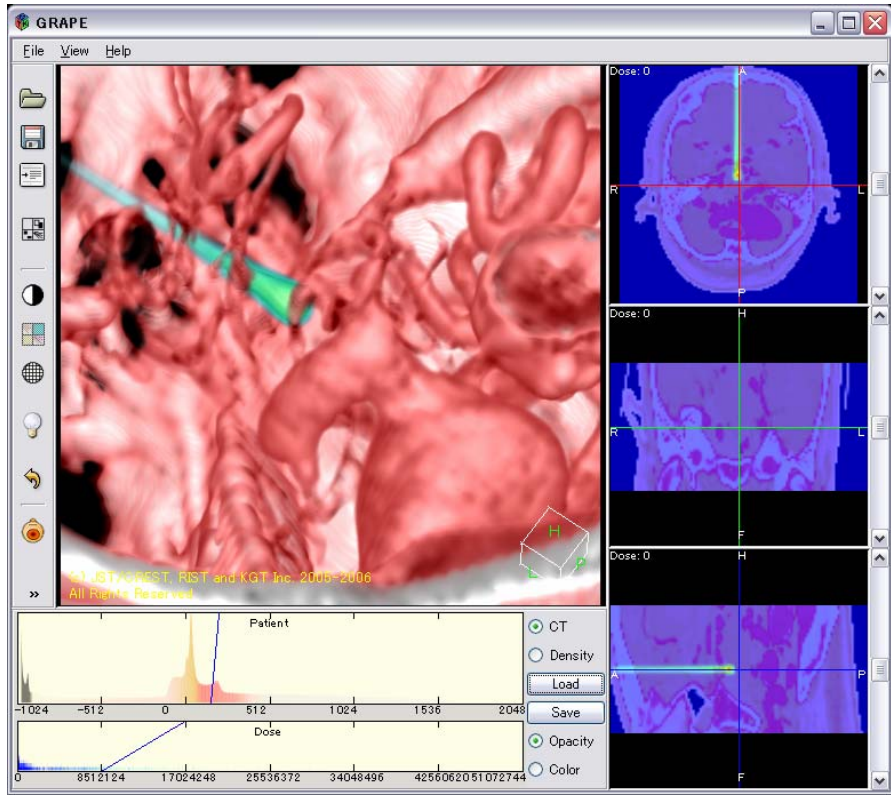
Secondary Monitor



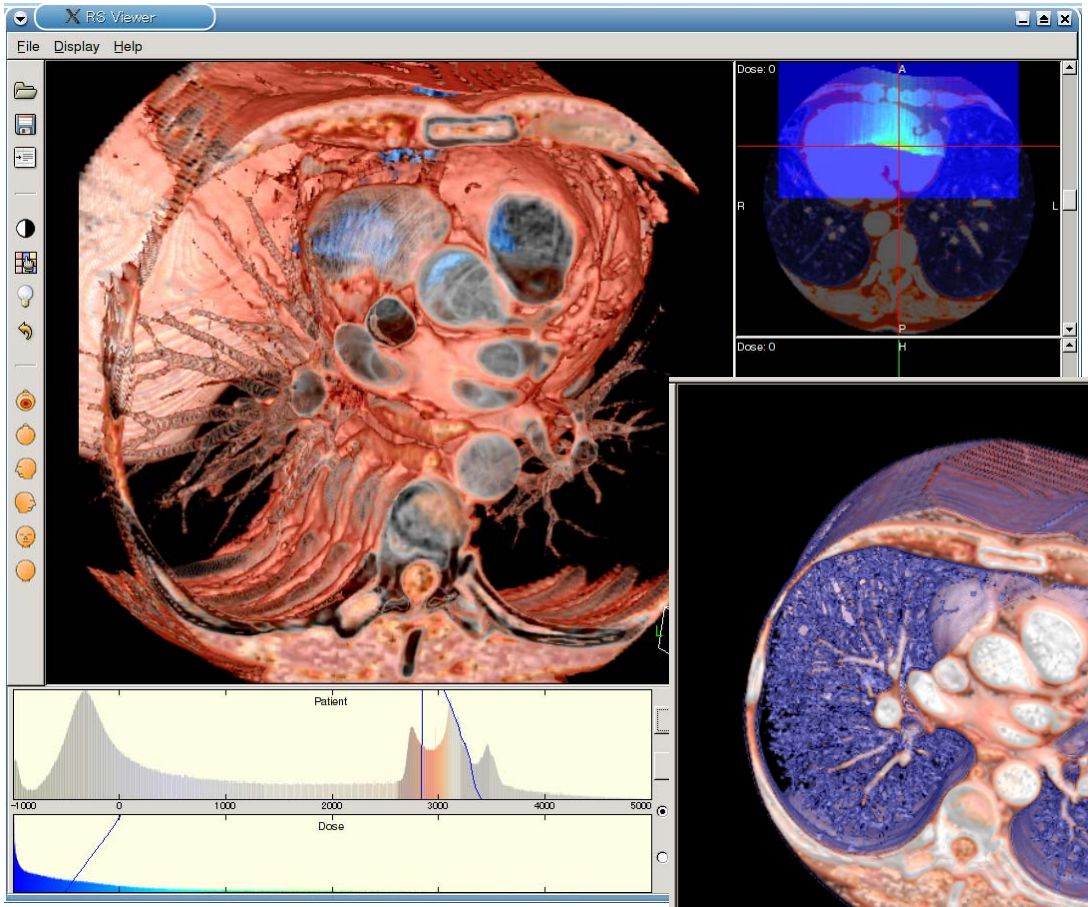
Wobbling field

HIBMC Gantry (Hyogo)





Visualized by gMocren
http://geant4.kek.jp/gMocren


RS Viewer
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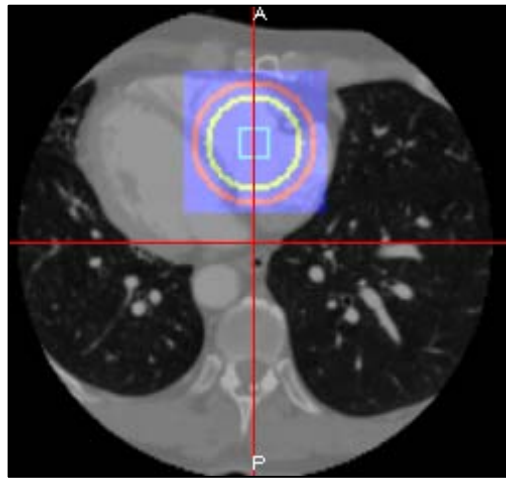
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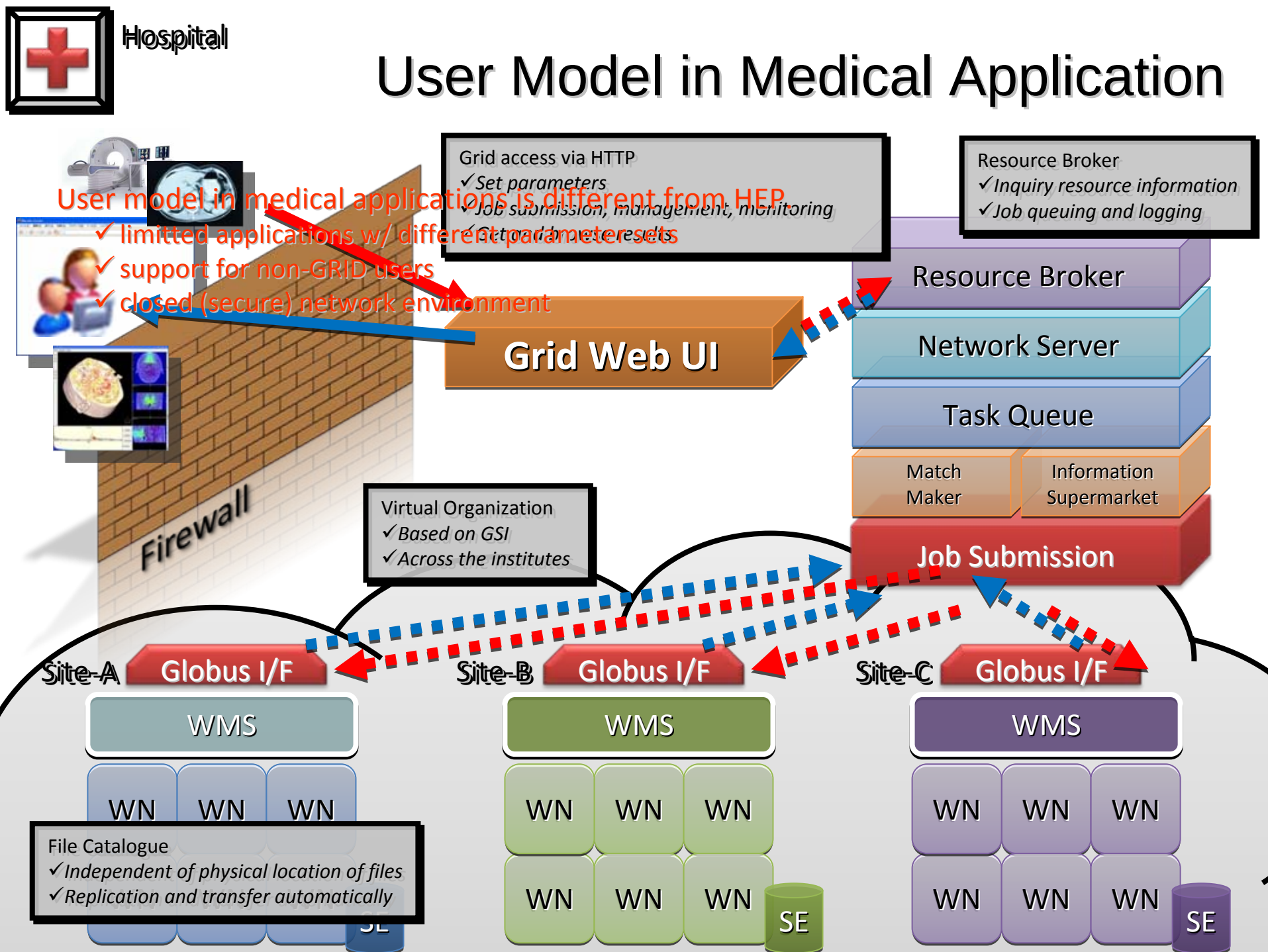
Boost Simulation Speed

- Massive computing power is required for precise simulation.
  - typical situation of hadron therapy simulation;
    - 1M events/~3days @ Pentium-4 3.0GHz processor
- Parallelization on local PC cluster
  - Event level parallelism has been implemented using MPI.
  - We can get performance gain almost linear to # processors.
- Distributed analysis on GRID

User Model in Medical Application



Grid Web Portal for Medical Application

- We will provide web interface as an easy-to-access way to GRID resources.
  - managing GRID jobs across firewalls
    - Intra-networks of universities/hospitals are closed under firewalls in most cases.
  - Users applications are served as Web applications
    - fixed application (hadron therapy simulation) changing different parameter sets

- Note:
  - Potentially, a toolkit for constructing GRID web applications

Structure of GRID Web Interface

implemented in PHP

User Applications

GRID access

GRID middleware gLite/LCG

- ✓ *issue of proxy certificate*
- ✓ *job submission / monitoring*
- ✓ *post-process for job outputs*

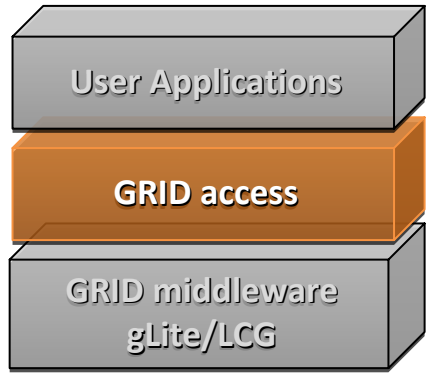
- ✓ *user login*
- ✓ *input parameters*
- ✓ *show results*

web server

UI node

Storage Element

GRID Access Layer



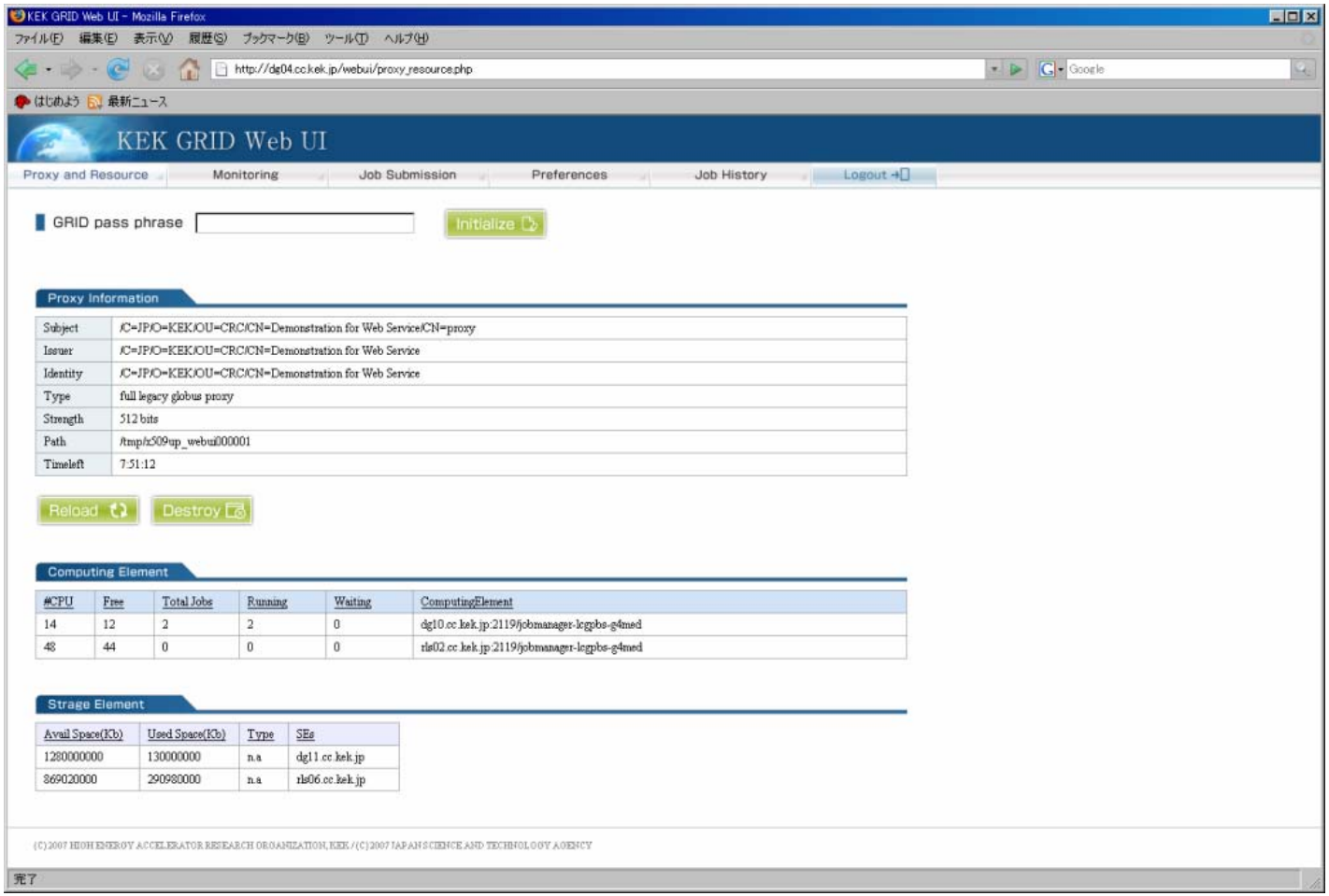
- Implemented in *PHP*.
- GRID API/commands are wrapped out:
  - issue of proxy certificates
    - *xxx-proxy-init/info/destroy*
  - job management
    - submission/cancellation
      - *xxx-job-submit/xxx-job-cancel*
  - job monitoring
    - *xxx-job-status*
  - post-process for job outputs
    - merging job outputs (histogram, etc.)
    - collection/replication of results
      - *xxx-job-get-output, lfc-xxx, lcg-cp, lcg-cr, etc*.

GRID Access Layer (Cont.)

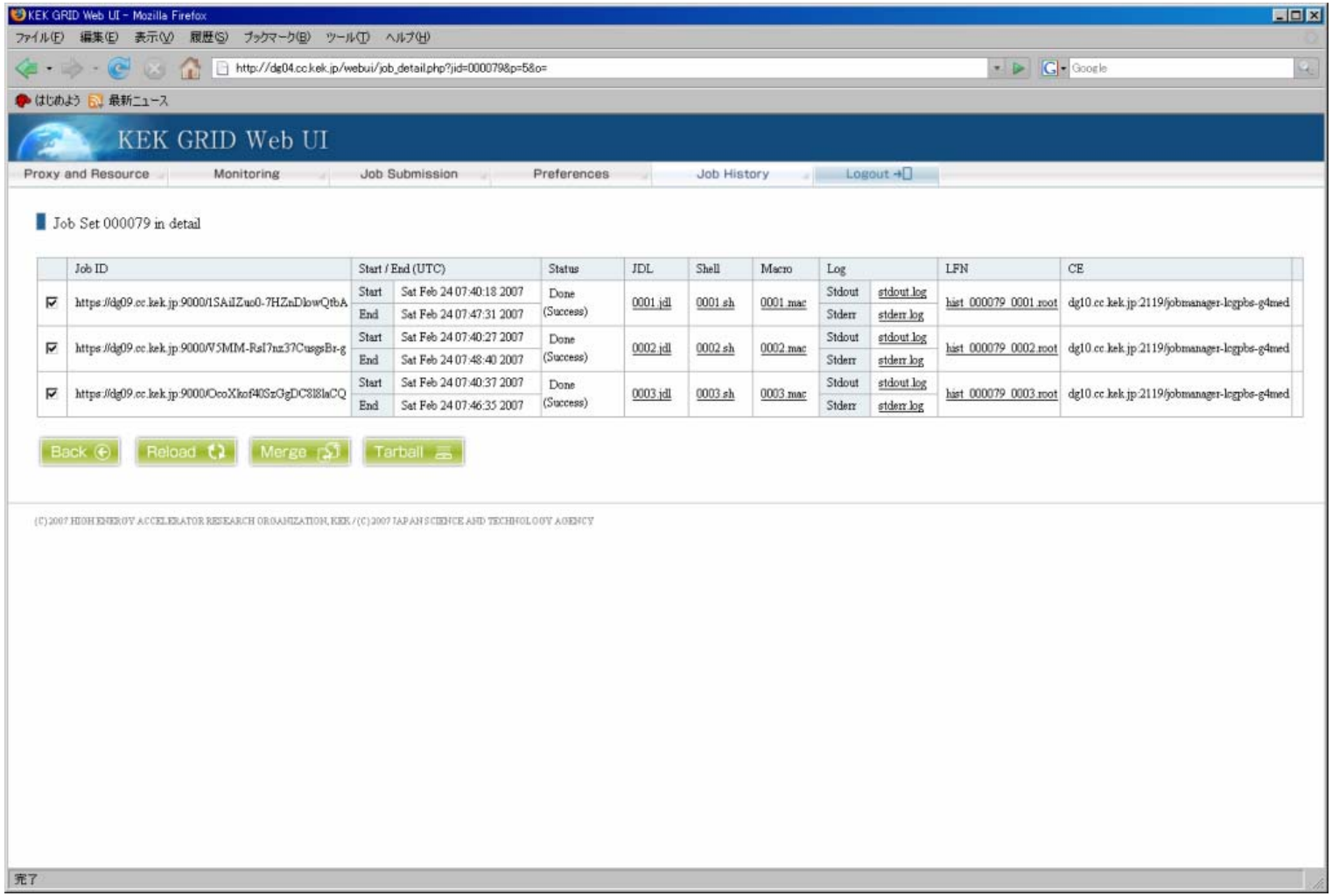
- HTML generation
  - showing information of proxy / Grid resources
  - for submitting / monitoring jobs

- Note:
  - Currently, users' certificates are supposed to be uploaded on the UI node (web server).
  - Hopefully, this should be improved, so that users certificates imported in a web browser can be used.

Proxy / Grid Resources Information

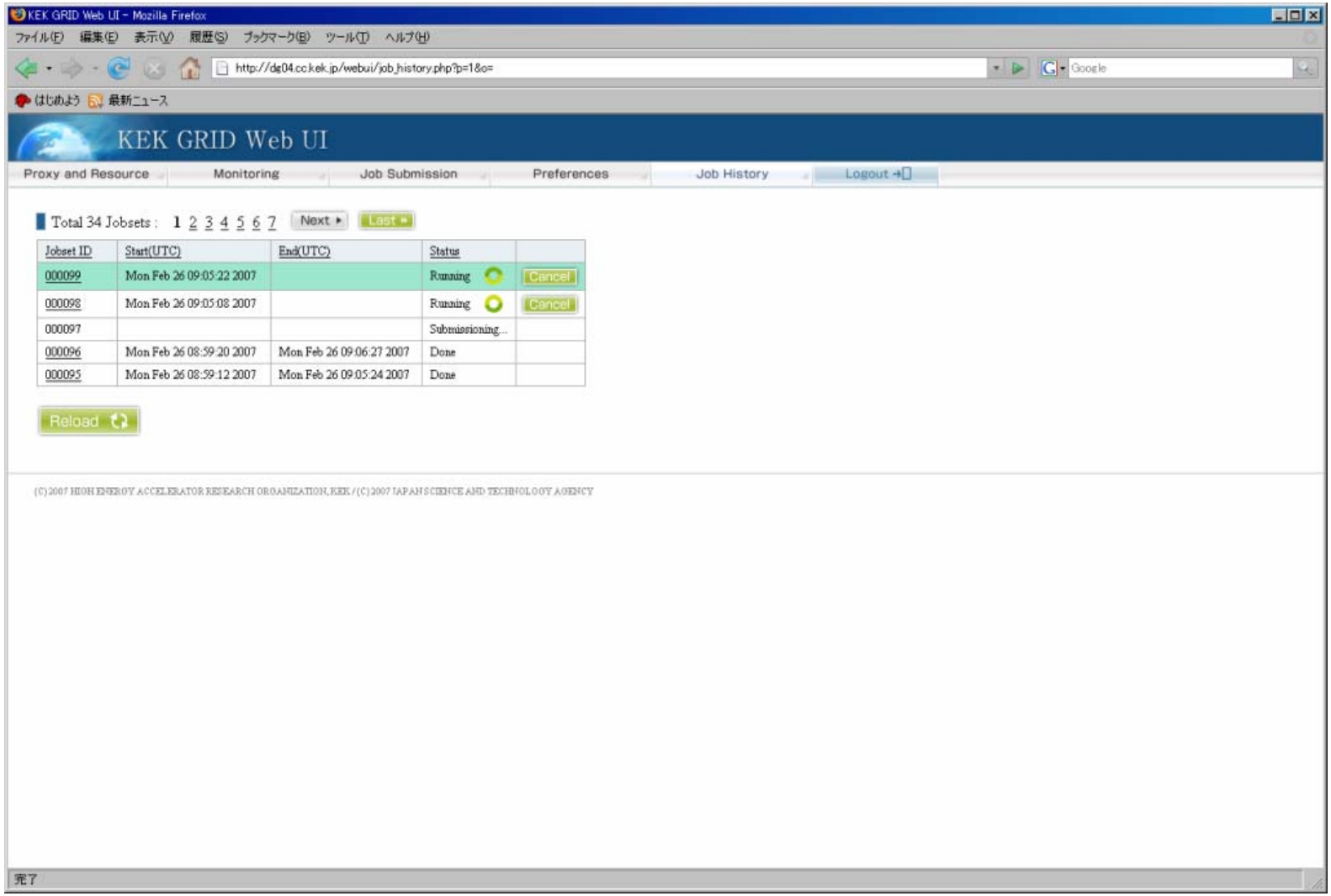


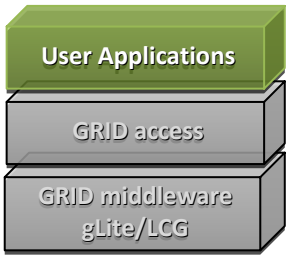
Job Monitoring



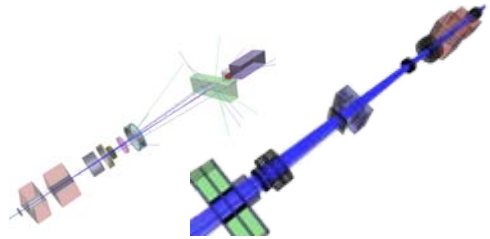
	Job ID	Start / End (UTC)		Status	JDL	Shell	Macro	Log		LFN	CE
☑	https://dg09.cc.kek.jp:9000/1SAilZuo0-7HZnDlowQfbA	Start	Sat Feb 24 07:40:18 2007	Done (Success)	0001.jdl	0001.sh	0001.mac	Stdout	stdout.log	hist_000079_0001.root	dg10.cc.kek.jp:2119/jobmanager-lcgpbs-g4med
		End	Sat Feb 24 07:47:31 2007					Stderr	stderr.log		
☑	https://dg09.cc.kek.jp:9000/V5MM-RsI7nz37CusgsBr-g	Start	Sat Feb 24 07:40:27 2007	Done (Success)	0002.jdl	0002.sh	0002.mac	Stdout	stdout.log	hist_000079_0002.root	dg10.cc.kek.jp:2119/jobmanager-lcgpbs-g4med
		End	Sat Feb 24 07:48:40 2007					Stderr	stderr.log		
☑	https://dg09.cc.kek.jp:9000/OcoXkof40SzGgDC8I8laCQ	Start	Sat Feb 24 07:40:37 2007	Done (Success)	0003.jdl	0003.sh	0003.mac	Stdout	stdout.log	hist_000079_0003.root	dg10.cc.kek.jp:2119/jobmanager-lcgpbs-g4med
		End	Sat Feb 24 07:46:35 2007					Stderr	stderr.log		

Job Status and History

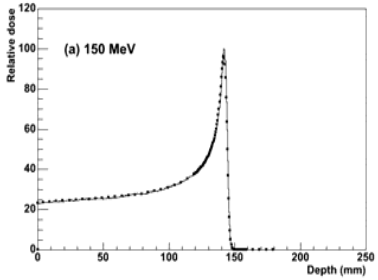




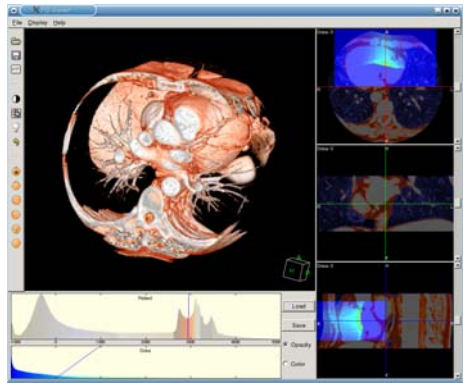
Web User Application



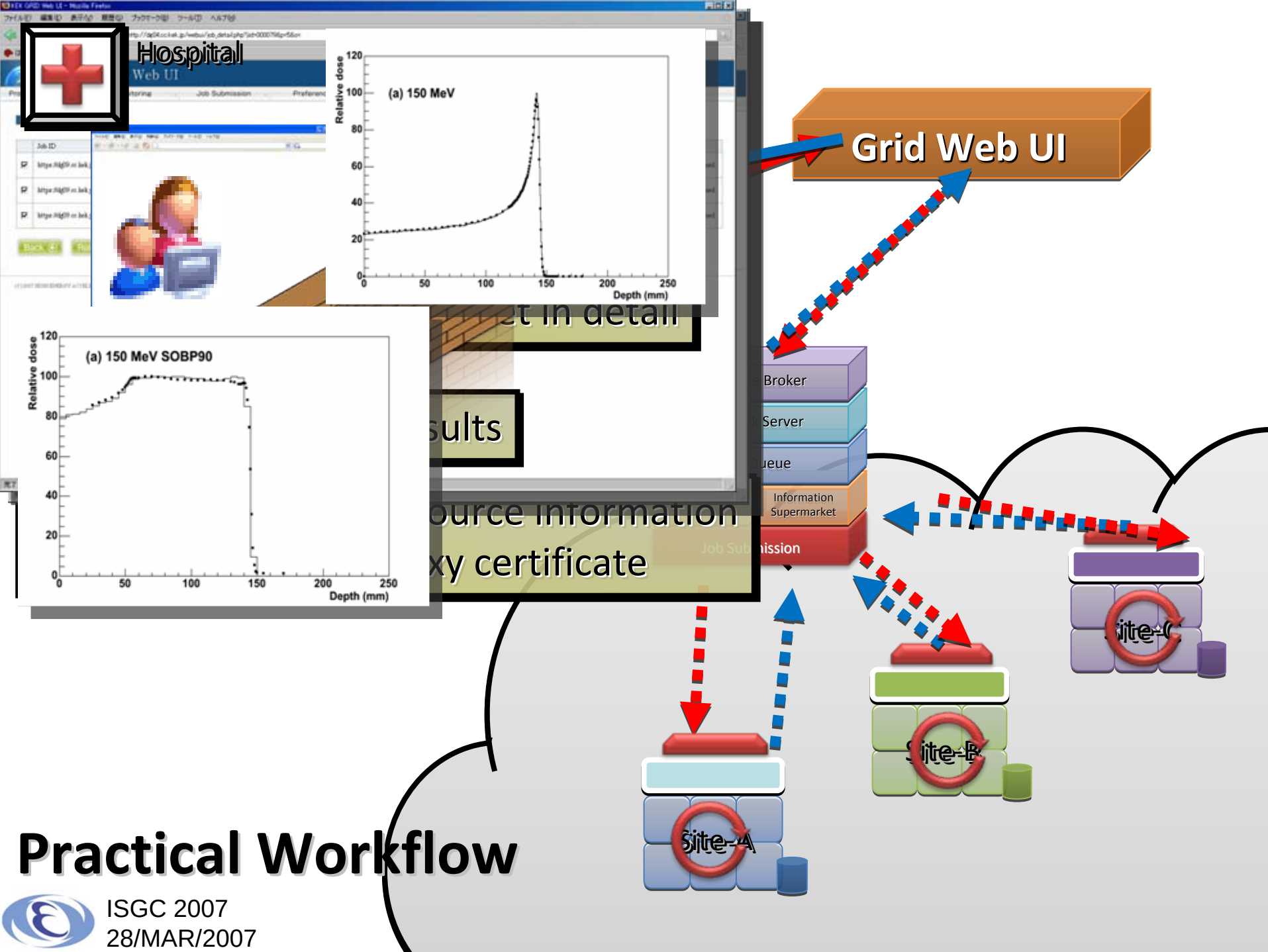
- Input parameters
  - Facility
    - HIBMC/NIRS-IHI/NCC-East/…. (Japanese facilities)
  - Geometry (beamline modules)
    - collimator/wobler magnet/scatterer/range shifter/ridge filter/MLC/…
  - Target
    - water phantom / human body (DICOM)
  - Beam condition
    - beam energy/beam spread
  - Simulation parameters
    - physics lists
    - cut values



gMocren



- Outputs
  - ROOT file
    - Dose distribution
  - GDD file
    - CT image w/ dose map
  - …



Practical Workflow

Current Status & Future Prospects

- Medical application of Geant4 and GRID
  - MC-based dose calculation system in radiotherapy requires large amount of computing power.
- Gridification is a solution to boost simulation speed.
  - We are developing an easy-to-use web portal for hadron therapy simulation on a GRID environment,
    - providing a secure and efficient way of distributed analysis in the context of GRID technology.
  - We will improve functionality/usability.
    - migration of user applications
    - DICOM file sharing
    - use user certificates in web browsers (instead of uid/passwd)

Side project

- Education application
  - Course material on radiology and particle physics
  - web based application
  - Not yet GRIDaware