Particle Therapy Simulation on GRID

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and
JST/CREST
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 cyclotrons are used
- Advantage in quality of life (less collateral side effects)
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

<table>
<thead>
<tr>
<th>Location</th>
<th>Facility Name</th>
<th>Type</th>
<th>Year</th>
<th>Total Patients</th>
<th>Date of Total</th>
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<tbody>
<tr>
<td>Canada</td>
<td>Vancouver (TRIUMF)</td>
<td>p</td>
<td>1995</td>
<td>111</td>
<td>Sep-06 eyes only</td>
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<td>China</td>
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<td>England</td>
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<td>p</td>
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<tr>
<td>FL, USA</td>
<td>Jacksonville (UFPTI)</td>
<td>p</td>
<td>2006</td>
<td>15</td>
<td>Dec-06</td>
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Compiled by PTCOG in Dec.2006
## Facility under construction

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

Wobbling field

Lead Scatter

Flatness Monitor

Main Monitor

Multi-Leaf Collimator

Block Collimator

Ridge Filter

Secondary Monitor

Water Phantom

HIBMC Gantry (Hyogo)
Visualized by gMocren
http://geant4.kek.jp/gMocren
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

User model in medical applications is different from HEP:
- Set parameters
- Inquiry resource information
- Job queuing and logging
- Job submission, management, monitoring
- Inquiry resource information
- Job queuing and logging

- Limited applications w/ different parameter sets
- Support for non-GRID users
- Closed (secure) network environment

- Independent of physical location of files
- Replication and transfer automatically

- Based on GSI
- Across the institutes

**Grid Web UI**

**Resource Broker**
- Get and browse results
- Job queuing and logging

**Network Server**
- Match Maker
- Information Supermarket

**Task Queue**
- Match Maker
- Information Supermarket

**Virtual Organization**
- Based on GSI
- Across the institutes

**Site-A Globus I/F**
- WMS
- WN

**Site-B Globus I/F**
- WMS
- WN

**Site-C Globus I/F**
- WMS
- WN

**File Catalogue**
- Independent of physical location of files
- Replication and transfer automatically

**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

✓ user login
✓ input parameters
✓ show results

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

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

![Proxy / Grid Resources Information](image-url)
Job Monitoring
**Job Status and History**

![Job Status and History](image)

### KEK GRID Web UI

<table>
<thead>
<tr>
<th>Job ID</th>
<th>Start Time</th>
<th>End Time</th>
<th>Status</th>
<th>Job Name</th>
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<td></td>
<td>Running</td>
<td></td>
</tr>
<tr>
<td>000046</td>
<td>Mon Feb 19 09:03:32 2007</td>
<td></td>
<td>Running</td>
<td></td>
</tr>
<tr>
<td>000057</td>
<td>Mon Feb 19 09:03:39 2007</td>
<td></td>
<td>Running</td>
<td></td>
</tr>
<tr>
<td>000065</td>
<td>Mon Feb 19 09:04:29 2007</td>
<td>Mon Feb 19 09:05:27 2007</td>
<td>Done</td>
<td></td>
</tr>
<tr>
<td>000065</td>
<td>Mon Feb 19 09:04:34 2007</td>
<td>Mon Feb 19 09:05:27 2007</td>
<td>Done</td>
<td></td>
</tr>
</tbody>
</table>

*KEK Grid Technology Accelerator Research Organization KEK (2007) Japan Science and Technology Agency*
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

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