Application of GEANT4 to Ion therapy at HI BMC

Takashi Akagi
Hyogo Ion Beam Medical Center
JST CREST
Contents

- Introduction of the facility at Hyogo
- Applications of GEANT4
- Verifications of GEANT4
Hyogo Ion Beam Medical Center (HI BMC)
Number of patients treated

#patients treated (1035 patients by 2006/5)

<table>
<thead>
<tr>
<th>Year</th>
<th>Proton</th>
<th>Carbon-ion</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2001</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>FY2002</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>FY2003</td>
<td>250</td>
<td>5</td>
</tr>
<tr>
<td>FY2004</td>
<td>289</td>
<td>5</td>
</tr>
<tr>
<td>FY2005</td>
<td>323</td>
<td>37</td>
</tr>
<tr>
<td>FY2006</td>
<td>480</td>
<td>14</td>
</tr>
</tbody>
</table>
Accelerator complex

- Accelerator
  - Synchrotron
  - Protons (70-230 MeV)
  - Carbon-ions (70-320 MeV/u)

- Beam lines
  - 4 fixed-angle beam lines (proton&carbon)
  - 2 Gantries (proton only)
Accelerator complex
Broad-Beam delivery system

- Wobbler + scatterer as a lateral beam spreader
  - producing a laterally flat field at the isocenter
- Ridge filter as a range modulator
  - forming a SOBP
- MLC and Range compensator as beam modifying Devices
  - shaping and modifying the beam to conform the target
Broad-Beam delivery system
Treatment planning system

- planning software = FOCUS-M
  - GUI = FOUCS (CMS)
  - Beam design = MGH-proton
  - Dose engine = Pencil Beam algorithm (MELCO)
  - Data transfer = DICOM-RTPlanX (MELCO)
Treatment planning system
Application of G4 to Ion therapy

- Dose calculation in the patient
- Prediction of the machine output

Monte Carlo calculations for absolute dosimetry to determine machine outputs for proton therapy fields

Treatment planning system

G4++

CT images (DICOM3.0)
MR images (DICOM3.0)

Server

Treatment parameters (DICOM-RTPlanX)

CT, MR images

Dose disp, Parameters

Treatment planning (FOCUS-M)

G4 as a Dose engine

Dose distributions (DICOM-RTDose)

Parameters (DICOM-RTPlanX)
Verifications of G4 w/protons

- Physics
  - Energy loss (Range)
  - Nuclear Interactions
- DICOM-RT Interface
  - MLC
  - Range compensator (RC)
Bragg Peak

- full simulation in the nozzle and the water phantom

150MeV
- $R=0.74\text{mm}$

190MeV
- $R=0.76\text{mm}$

230MeV
- $R=1.47\text{mm}$
Effect of the Nuclear Interaction to Dose

50mm depth

250mm depth

MLC

Water phantom

beam

□ : Measurements
- : TPS calculations
□ : G4 (histograms)
DICOM-RTPlanX Interface

- Sample patient
  - Head & Neck region
  - Gantry, 150MeV, SOBP70mm
MLC, Range Compensator shapes

- Verification of the parameters transfer through RTPlanX
Dose distributions in water w/ the planned MLC and RC

Dose profiles on planes passing through the isocenter \((0,0,5.2)\). The doses were normalized at the isocenter.

- **lateral x**
- **lateral y**
- **depth z**

- Measurements
- TPS calculations
- G4 (histograms)
Summary

- The Physics verifications of GEANT4 was done.
- The DICOM-RT interface was implemented, and works well.
- GEANT4 can be utilized to calculate dose distributions.
Anatomical sites treated (2003-2005)
# Outcomes from the therapy

<table>
<thead>
<tr>
<th></th>
<th>H&amp;N</th>
<th>Lung (stage-I)</th>
<th>Liver</th>
<th>Prostate</th>
<th>Skull Base</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Local Control rate</strong>&lt;br&gt;(4 years)</td>
<td>71%</td>
<td>97%</td>
<td>91%</td>
<td>99%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Survival rate</strong>&lt;br&gt;(4 years)</td>
<td>36%</td>
<td>75%</td>
<td>60%</td>
<td>98%</td>
<td>100%</td>
</tr>
</tbody>
</table>

M Murakami, News Letter 122, 2006