Toolkit for Particle Therapy Simulation (PTSsim)

Takashi Sasaki
Professor
KEK
(High Energy Accelerator Research Organization)

The Project

- "The Development of Software Framework for Simulation in Radiotherapy"
  - funded by the Core Research for Evolutional Science and Technology (CREST) program organized by Japan Science and Technology Agency (JST) from JFY2003 to JFY2008
  - Ended in March 2009
  - Developed the software toolkit for particle therapy simulation
- Joint project between medical physicists and Geant4 developers in Japan
- This activity is out side of the Geant4 collaboration

Common problems seen

- Medical physicists are not MC experts often
- Geometry implementation is not easy to start
  - Users have to start the implementation of their geometry in the very early days after they become a user
- DICOM handling is difficult
- Validation of the result is a problem
  - Users easily doubt Geant4
    - Geant4 is wrong sometime
  - In reality, their measurements were not accurate enough sometime or they did not have enough information to implement the geometry precisely
    - There was a facility where they does not know the exact value of their beam energy

The spirit

- Geant4
  - We make it because we need it
  - We will be happy if others like and use it
    - People who cannot be satisfied with GEANT3 started the Geant4 project in 1994
    - The original project was started in 1992 at KEK
      - Geant4 is started based on our results of OOA/OOD
- This project
  - We (Geant4 developers) made it because you (medical physicists) need it and we could do it better
  - We will be very happy if you like and use it
  - Please help our life instead!

Achievements

- Software suite for hadron therapy
  - Toolkit to implement facilities
    - PTSsim
  - DICOM/DICOM-RT interface
  - Visualization
  - GRID for massive simulation
    - Including web interface
  - Geant4 enhancements
- Validation of simulation results and improvements of physics models in Geant4

Contributions to Geant4

- G4Scorer (joint efforts with M.Asai)
  - Scoring physics quantities easier
- Command line scorer (joint efforts with M.Asai)
  - Without recompiling, scoring geometry and types can be changed
- Python interface
- DICOM interface
- DICOM-RT interface (Mitubushi version)
- MPI interface (parallel execution)
- gMocren
- Improvements of physics
  - Ion physics

PTSsim

- Toolkit to implement particle therapy facilities
- Popular devices at the beam lines are provided as software parts
  - Easier implementation
- Well validated physics list are given
- DICOM interface
- Not generally distributed
  - Contact me if you have an interests

Basic design of Beam irradiation system

Purpose:

Widen the beam size to fit the tumor size with keeping lateral flatness of beam flux

Adjust the depth of Bragg peak in a patient volume with the tumor position

Other technology:

Double scattering, Spiral wobbling system for shortening the irradiation system

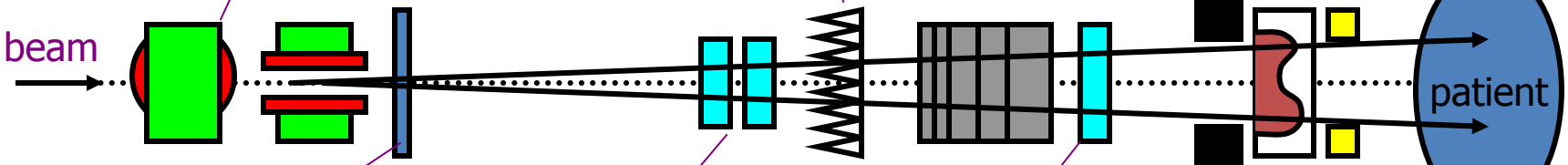
Beam scanning in three dimensions using small beam spot and variable beam energy

Wobbler magnets

Ridge filter

Range shifter

Range Compensator

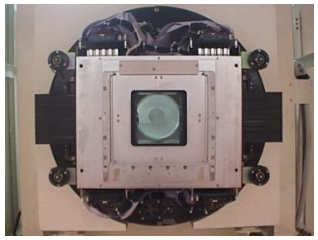


scatterer

Dose monitors

flatness monitor

MLC



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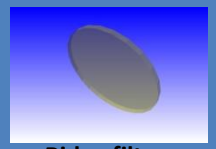
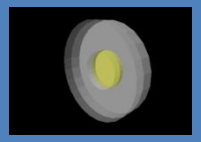
Example of irradiation systems

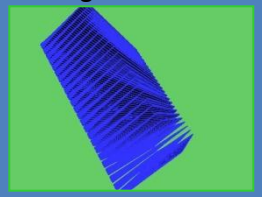
Scatter



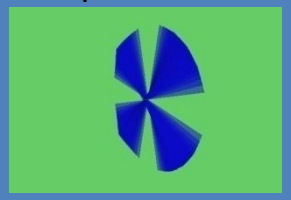
Double Scatter



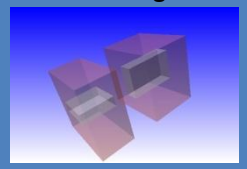
Ridge filter



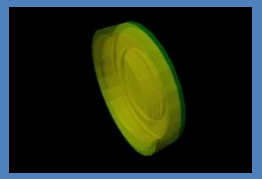
Propeller blade



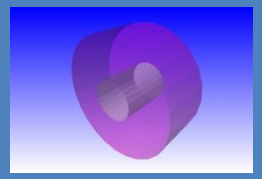
Wobbler Magnets



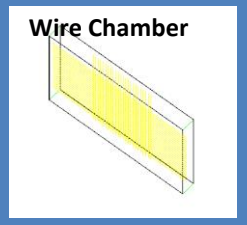
Ionization Chamber



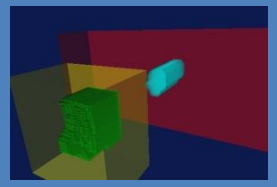
Collimator



Wire Chamber



Multi-leaf collimator

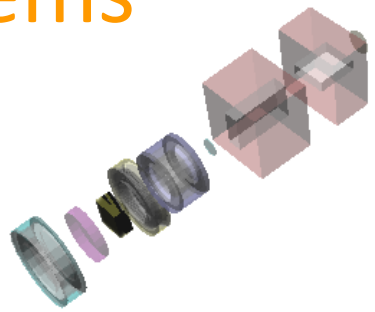


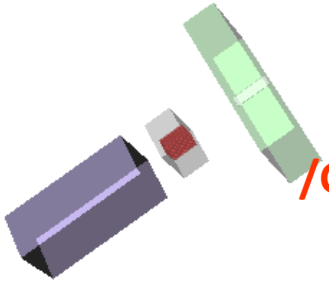
Water phantom

Bolus

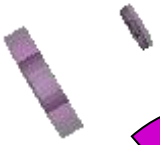
DICOM data

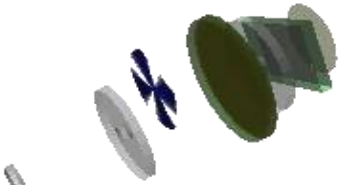
/G4M/System HIBMCGantry





/G4M/ChangeSystem NCCGantry





/G4M/ChangeSystem UCSFSetup

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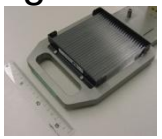
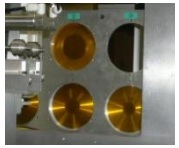
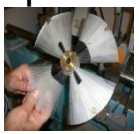
Implemented irradiation systems using PTSsim

Facility	Accelerator	Beam Energy (MeV)	Lateral Spreading System	Range Modulator
HIBMC Gantry	Synchrotron	Proton 150,190,230	Wobbler magnets and scatter  	Ridge filter 
NCC Gantry	Cyclotron	Proton 150,190,235	Scatter and double scatter 	Ridge filter 
UCSF	Cyclotron	Proton 67.5	N/A 	Propeller blades 
HIMAC	Synchrotron	Carbon 400 MeV/u	Wobbler magnets and scatter	Ridge filter
HIBMC	Synchrotron	Carbon 320 MeV/u	Wobbler magnets and scatter	Ridge filter
GSI	Synchrotron	Carbon ~400 MeV/u	Beam scanning	Fine Ridge filter 

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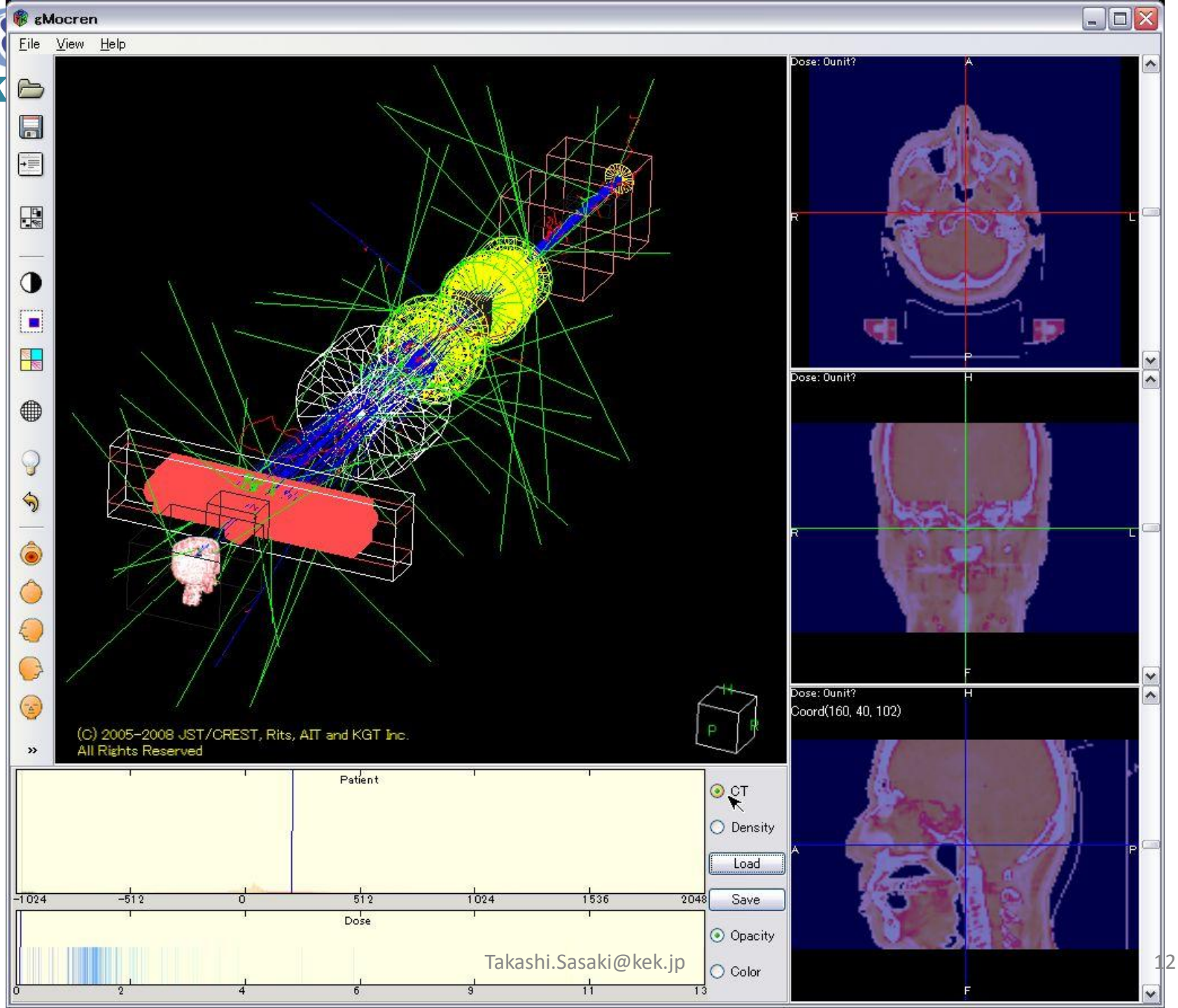
gMocren

- DCIOM visualizer based on volume rendering
  - 2D, 3D, color, monochrome, contour, traks
- Freely available at http://geant4.kek.jp/gMocren after the registration of yourself
- Can be used for other purpose also
  - Flux, density, temperature and etc
  - DNA level dose distribution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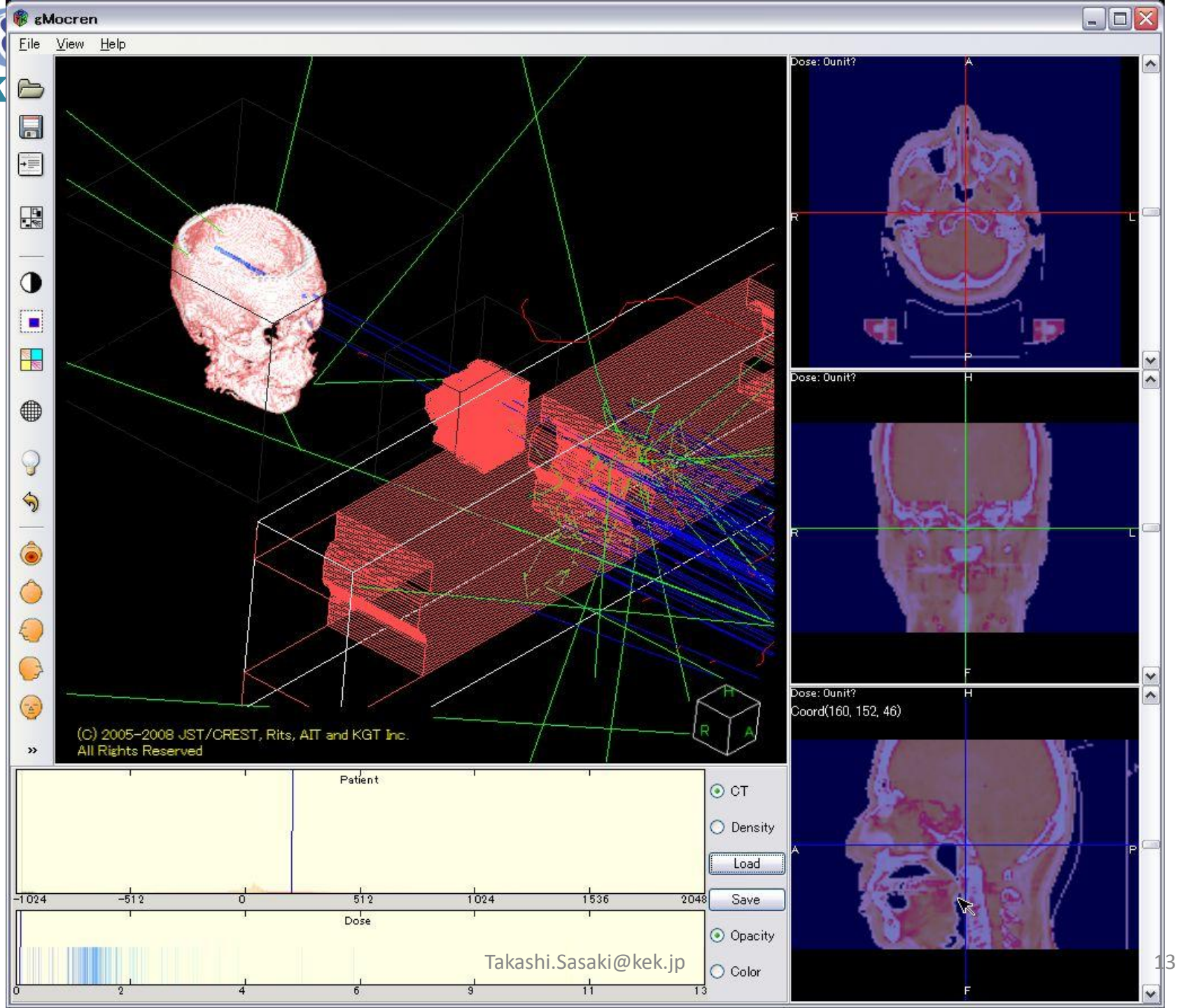
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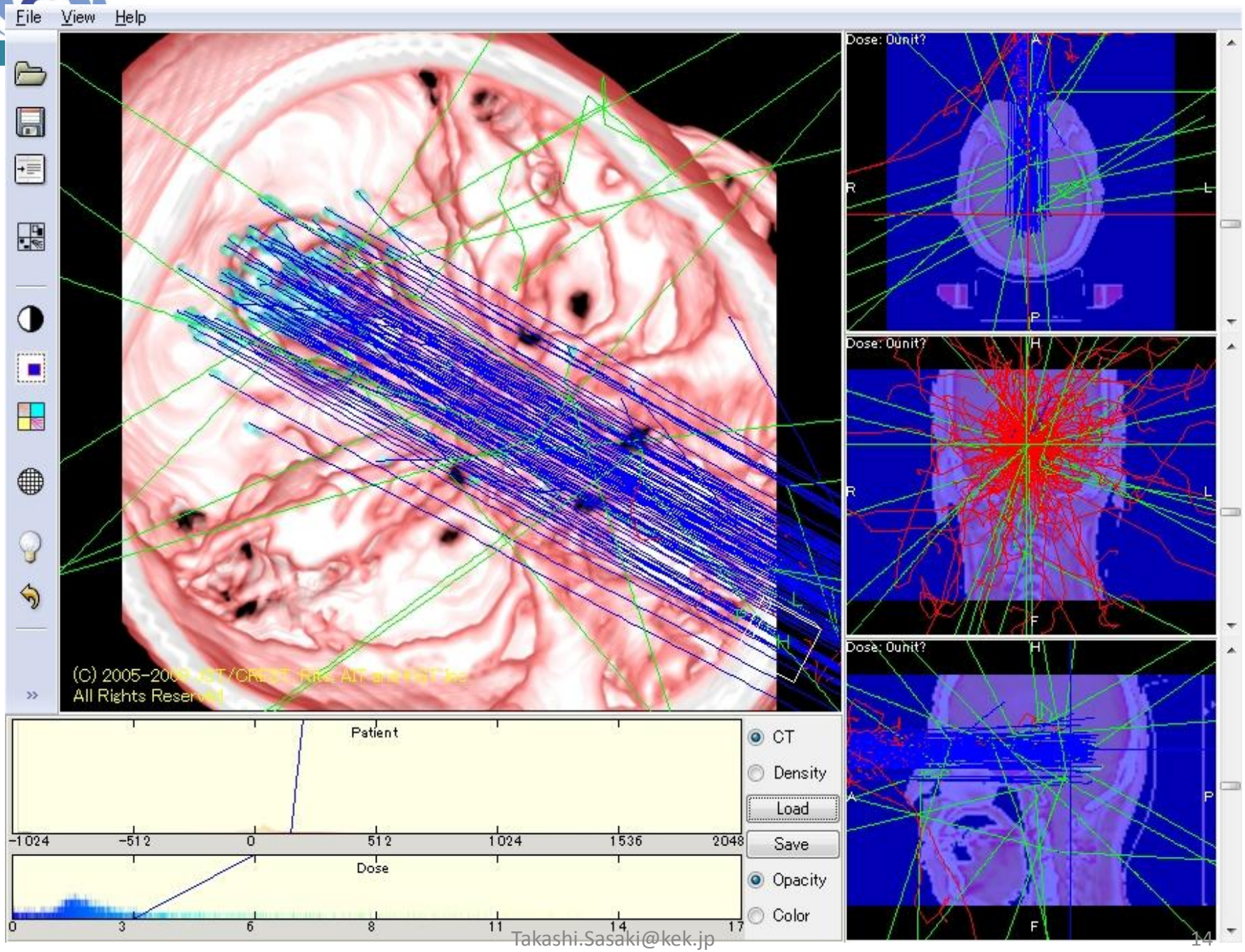
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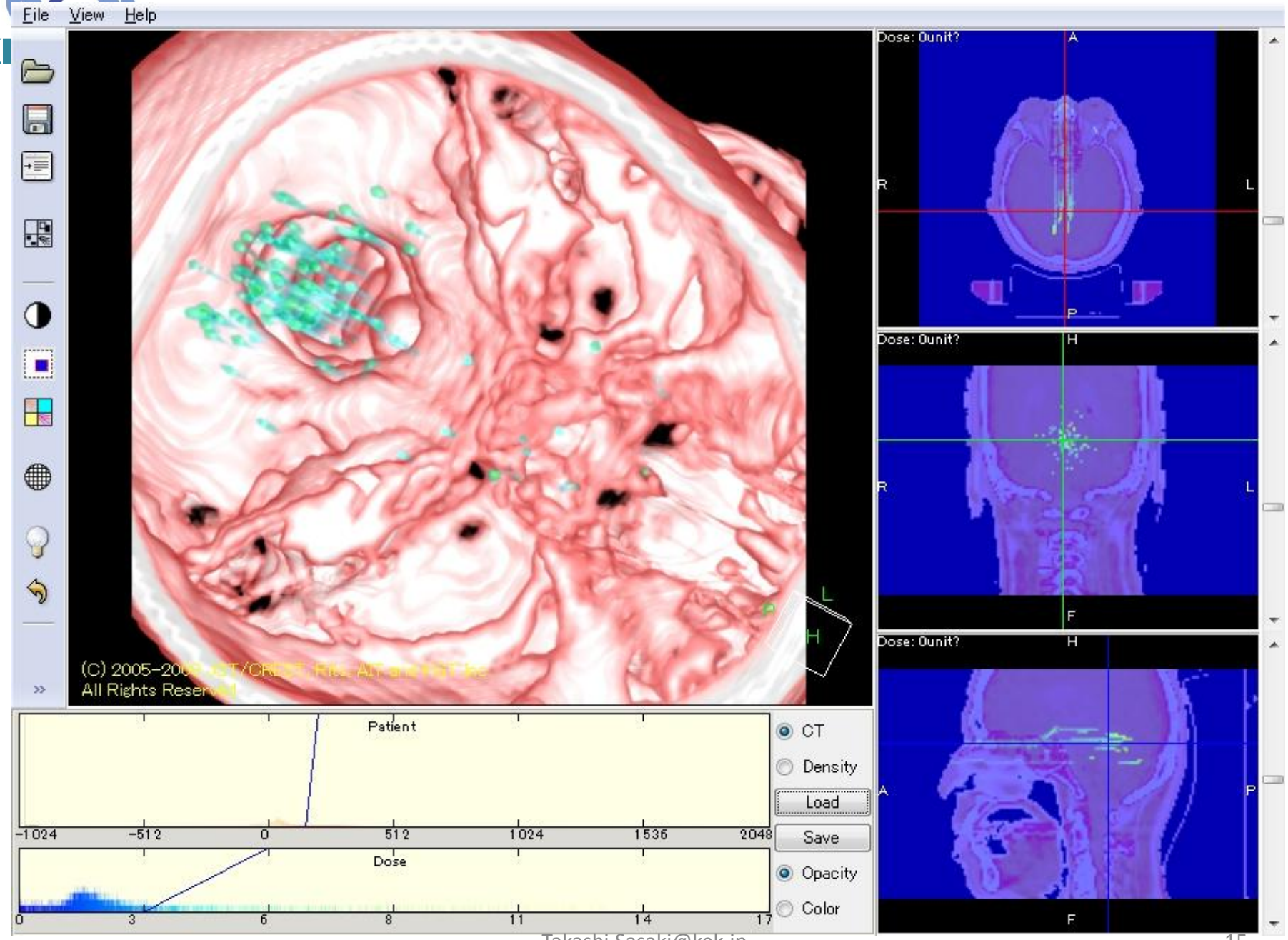
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Clinical application

- Verification of the treatment planning system
- Design of a new beam delivery method
  - Beam scanning method
- etc.

- Slides of real patient cases are shown only for the audiences

Benefits to use PTSsim

- Well validated against measurements at multiple facilities
  - We actually spent more time to improve the measurements and have enough information to implement the facilities
  - Inter facilities comparison have been done
    - Help to find where is your problem
- Knowledge and expertise of core Geant4 developers are well reflected

The next step

- Validation and improvement of Geant4 physics for bones (calcium)
  - No good data to be compared with MC
- Integrating other radiotherapy technique
  - γ, e, n
  - Especially medical linac and IMRT
- Providing a tool for fair comparison among different radiotherapy technique
- DNA level simulation
  - To understand biological effects

Summary

- PTSsim will be a good starting point if you want to start the simulation of your particle therapy facility
  - http://g4med.kek.jp
  - Still many software parts are already inside Geant4
  - GRID is also supported
    - Globus, gLite and NAREGI
- gMocren can be used for volume graphics to visualize the simulation results
  - Not only DCIOM, but also other purpose
  - http://geant4.kek.jp/gMocren