Symmetric branches of Geant4, how the medical and aerospace user communities bring common issues and solutions to the simulation toolkit

Joseph Perl

SLAC National Accelerator Laboratory

Geant4 Space Users Workshop

Seattle

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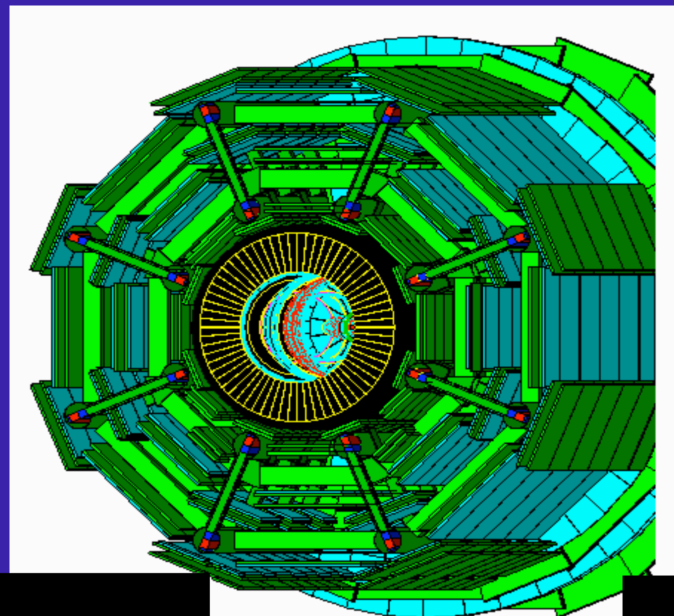
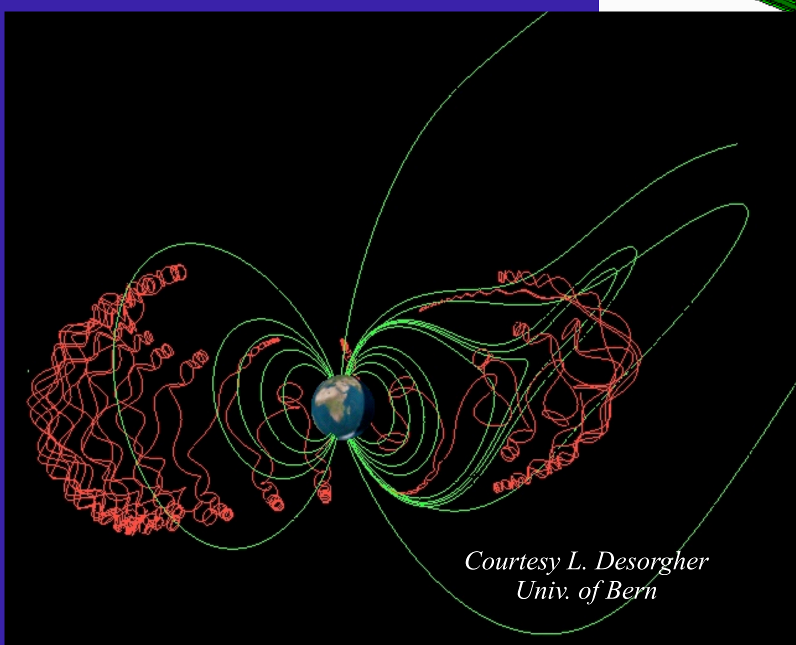
and by the U.S National Institutes of Health under contract number 1R01CA140735-01

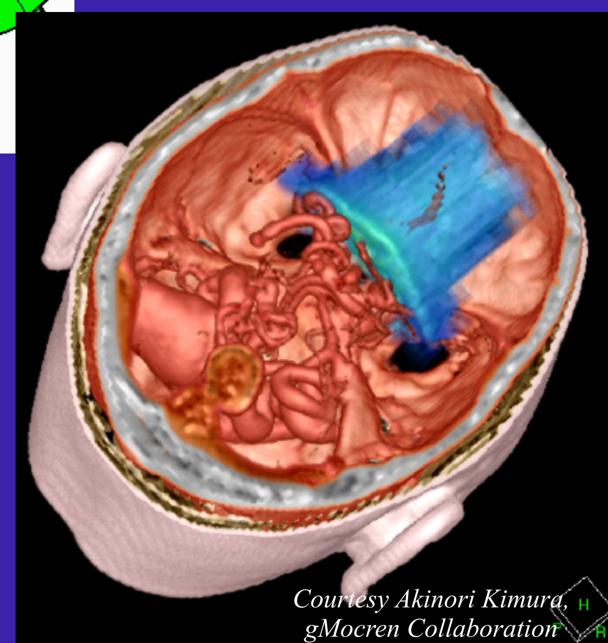
Three Main Branches of Geant4



Courtesy Makoto Asai, ATLAS Collaboration



Courtesy L. Desorgher Univ. of Bern



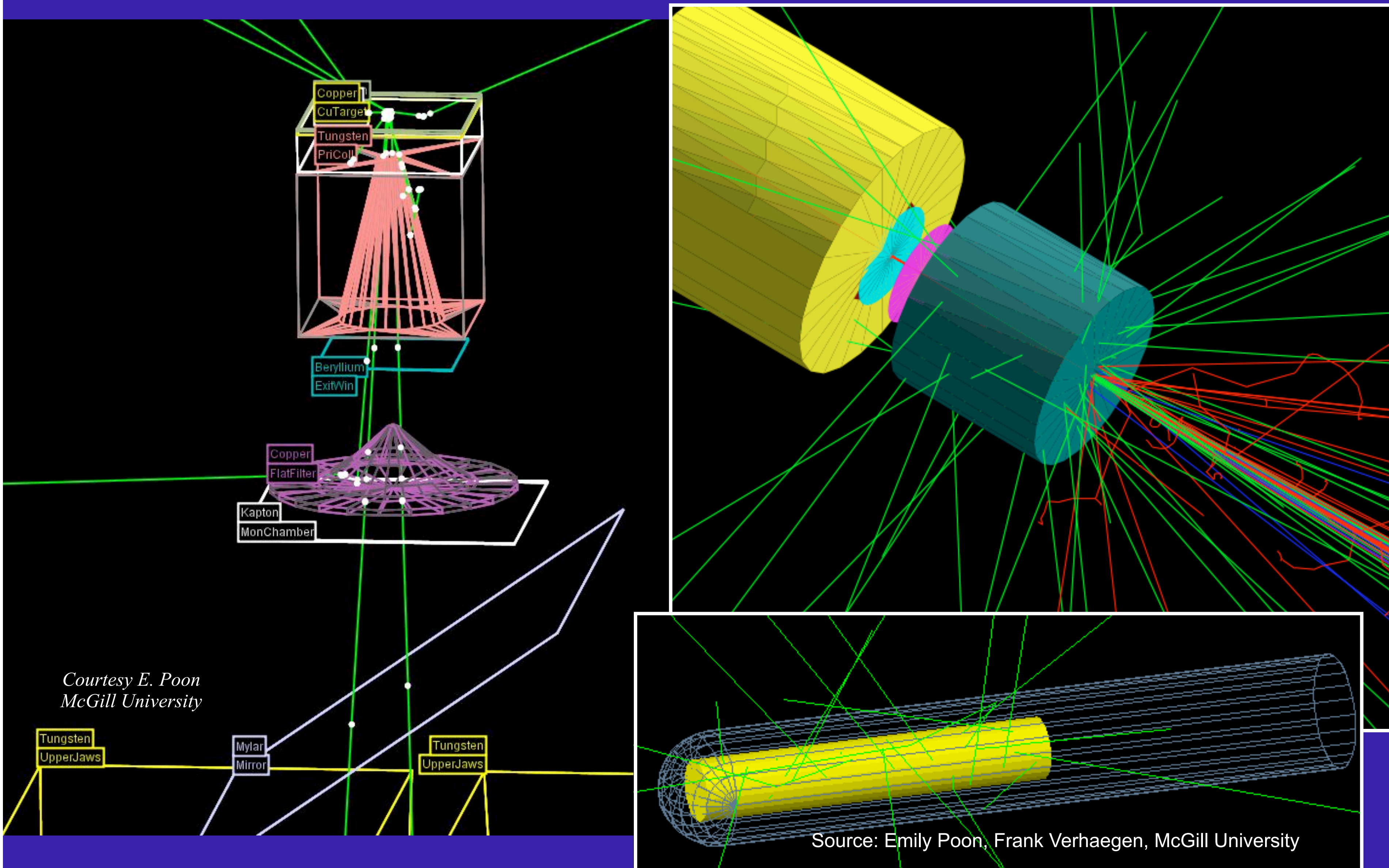
Courtesy Akinori Kimura, gMocren Collaboration

Aerospace and Medical have much in common compared to HEP

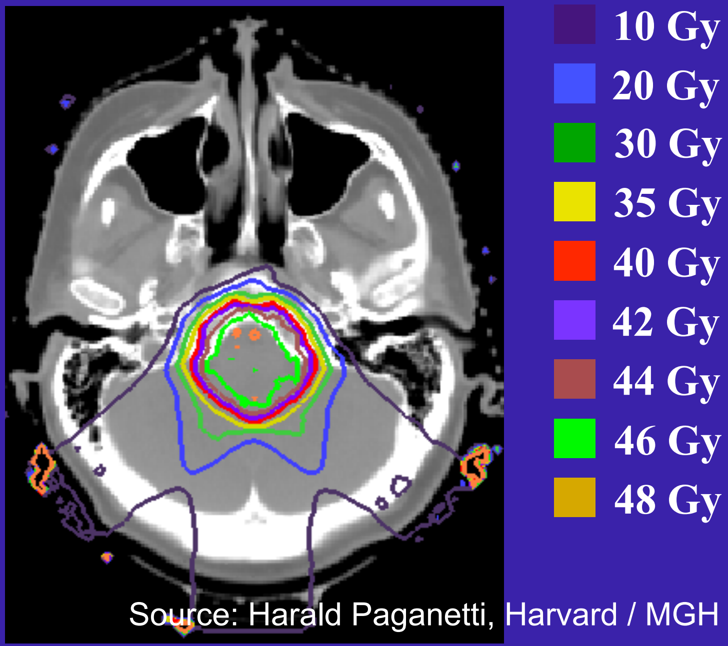
- Smaller collaborations
- Shorter funding cycles
- Sense that Geant4 is too hard to use.

How is Monte Carlo Used In Medical Physics

Characterizing Machines and Sources



Treatment Planning



Source: Harald Paganetti, Harvard / MGH

- Treatment sequence
  - 1) imaging
    Imaging Enables Conformality
  - 2) planning
  - 3) simulation
  - repeat 2 and 3 as needed
  - mostly use parameterized models
  - might use parameterized for first iterations of 2 and 3 and then MC for validating the plan
  - Time available depends on the kind of therapy, from 20 min to one day.
- Monte Carlo considered superior to parameterized models in cases of heterogeneity:
  - tissue/air interface, such as lung
  - complicated tissue/bone interfaces such as in head and neck cases

Combining Multiple Fields

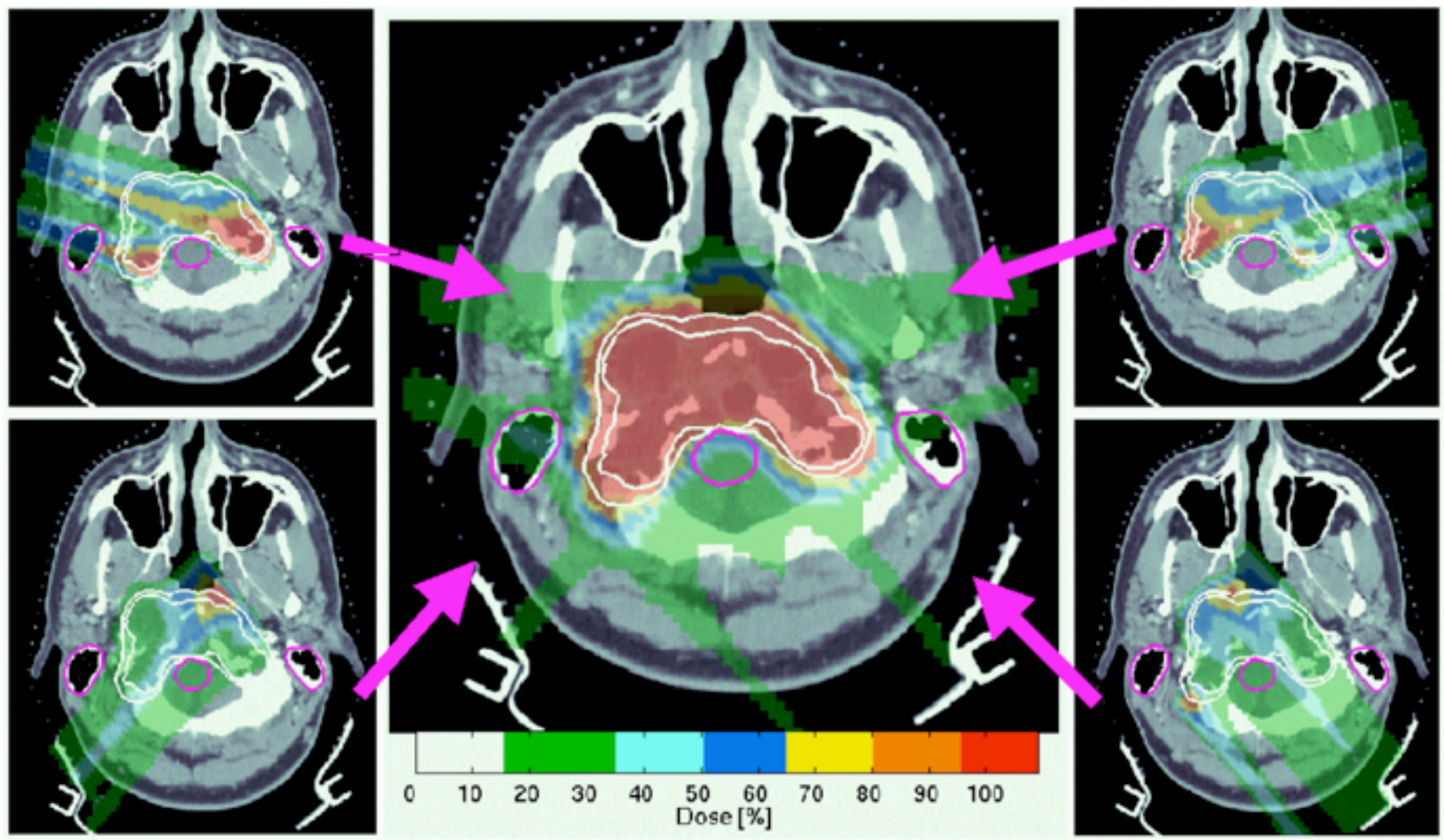
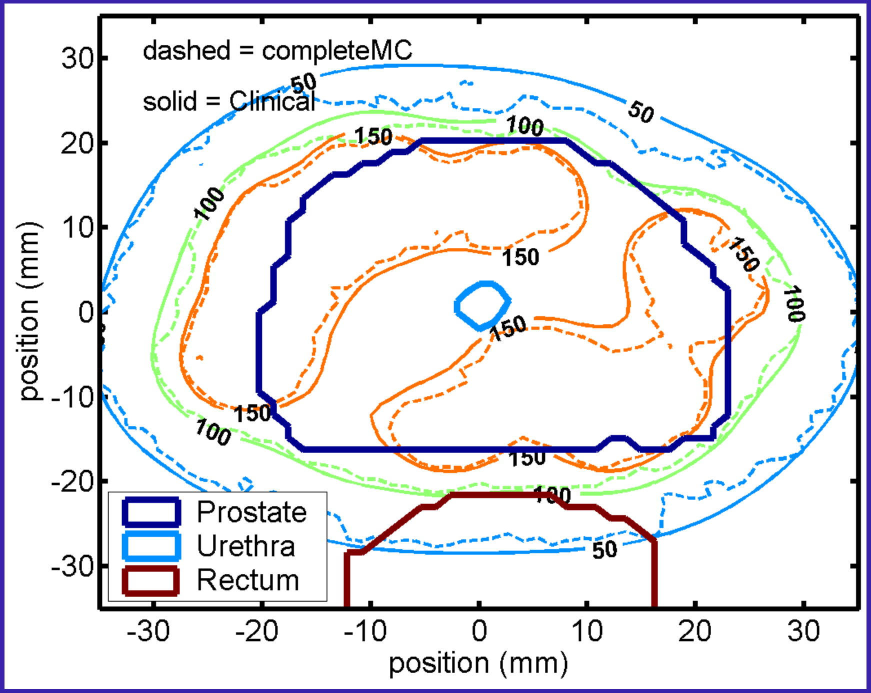


Figure 14: The principle of intensity modulated proton therapy (IMPT). Non-uniform dose distributions from a number of fields (4 in this case) yield the desired (uniform) target dose. Figure provided by Alex Trofimov (Massachusetts General Hospital).

Retrospective Studies

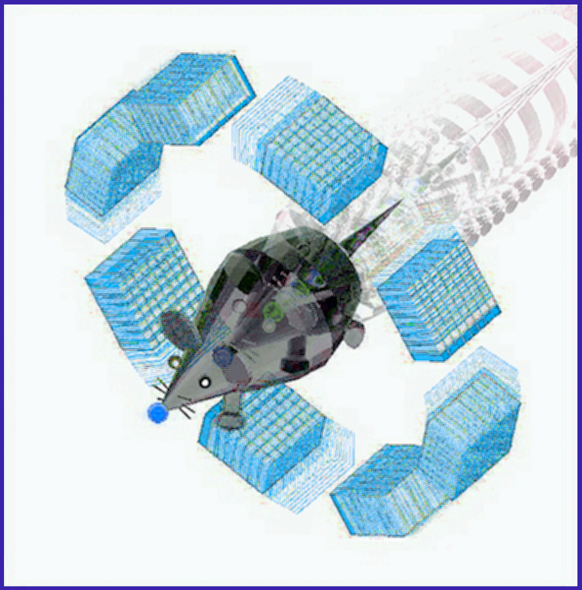
- Similar to treatment planning, but done after the fact, to look at whether we believe the dose given was correct.
- Even if we don't have sufficient speed for clinical treatment planning,
  Monte Carlo can be used to validate the faster parameterized calculations used in planning.
- May still be in time to affect decisions about how subsequent treatments (fractions) are given.
- Some studies involve actual patient data, others use

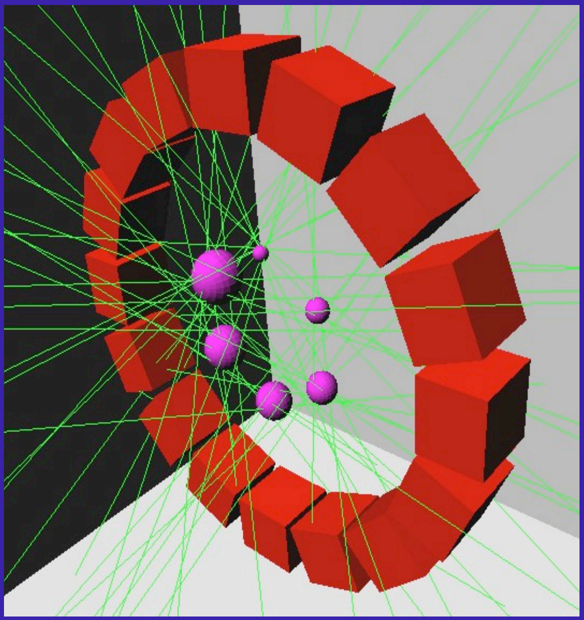


source: Jean-François Carrier, CHUM

Imaging

- Rapid advances in technology
  - Higher resolution
  - Higher speed
  - Lower dose
  - Better ability to differentiate tissue types
    - Dual Energy CT, etc.
  - On board imaging for setup, motion tracking, dose validation
    - x-ray
    - Linac/MRI
    - Proton Computed Tomography
    - Gamma Camera
    - etc.
- Monte Carlo is used extensively to evaluate new designs





Source: Irene Buvat, INSERM/CHU

Why Do Some Medical Physicists Choose Geant4?

Other Monte Carlos in Medical Physics

- EGSnrc (Electron Gamma Shower)
  - also came from HEP (the EGS project at SLAC, 1978)
- XVMC (Voxel Monte Carlo)
- MCNP (Monte Carlo N-Particle Transport Code)
- PENELOPE
- FLUKA

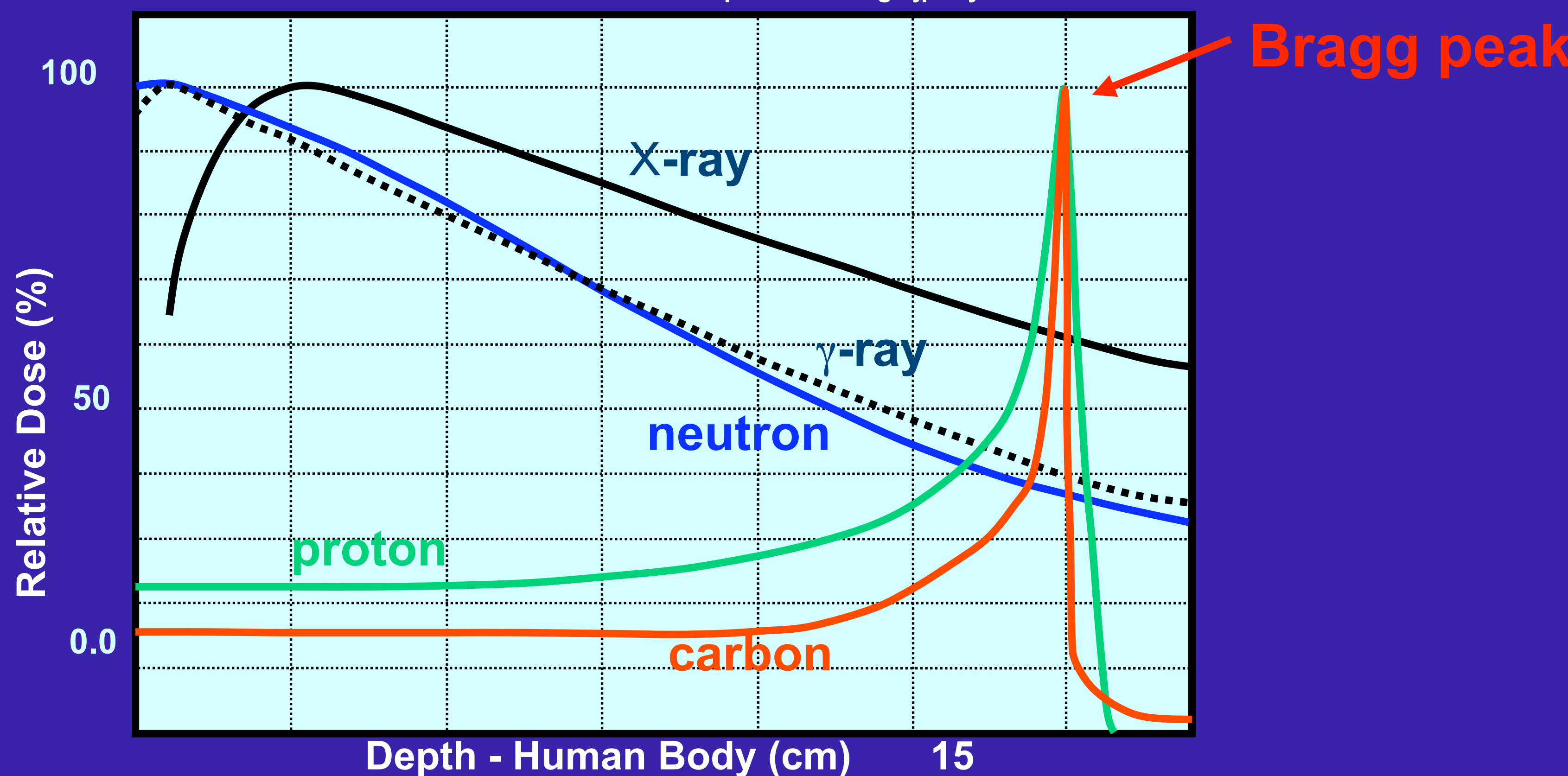
Geant4 is:

- an All Particle code
- able to handle Complex Geometry
- able to handle Motion
- able to handle Fields
- with a Modern Programming Language
- Open and Free

All Particle Code

- Current “Gold Standard” in Med Phys, EGS, is only for electron and gamma
- Growth of Proton and Ion Therapy

Ref. http://www.nirs.go.jp/tiryo/himac/himac2.htm



Field Patching

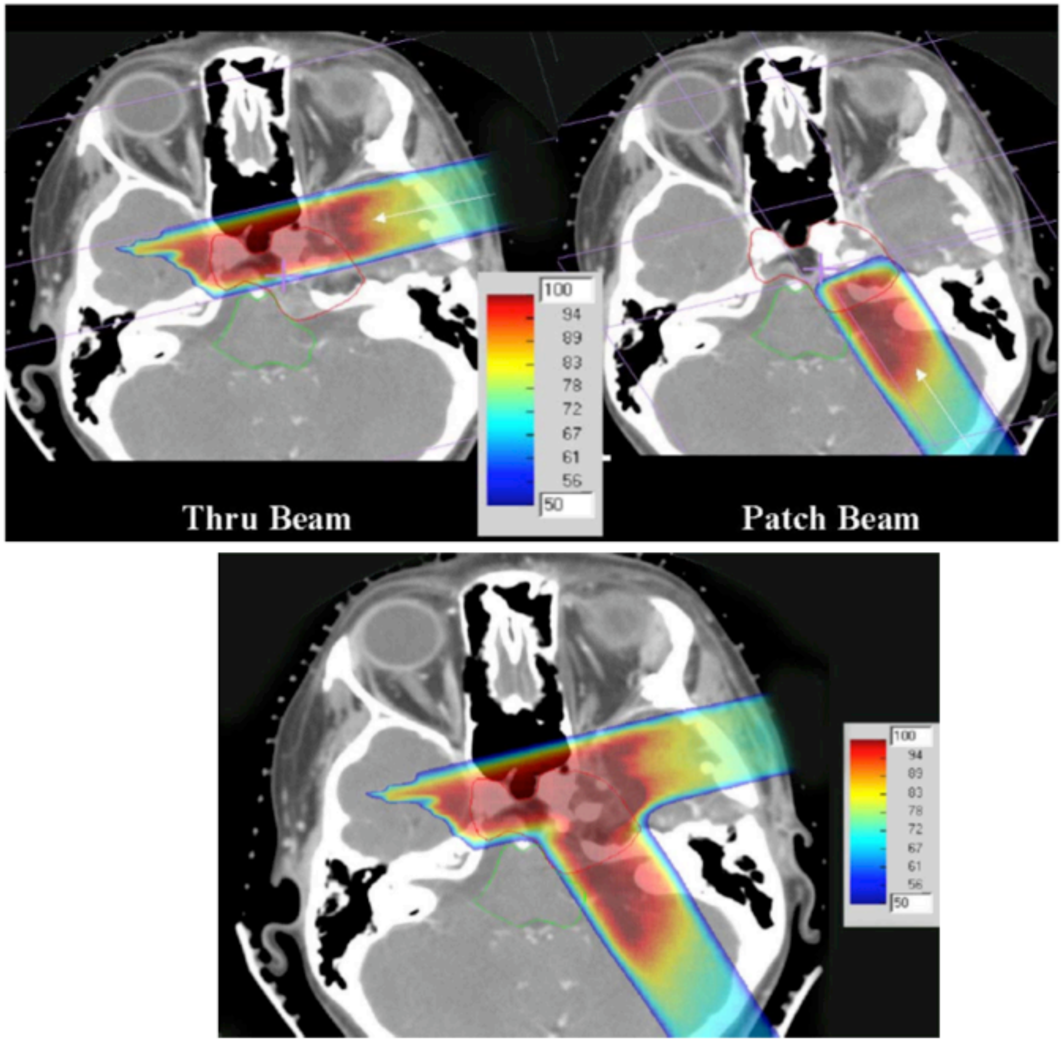
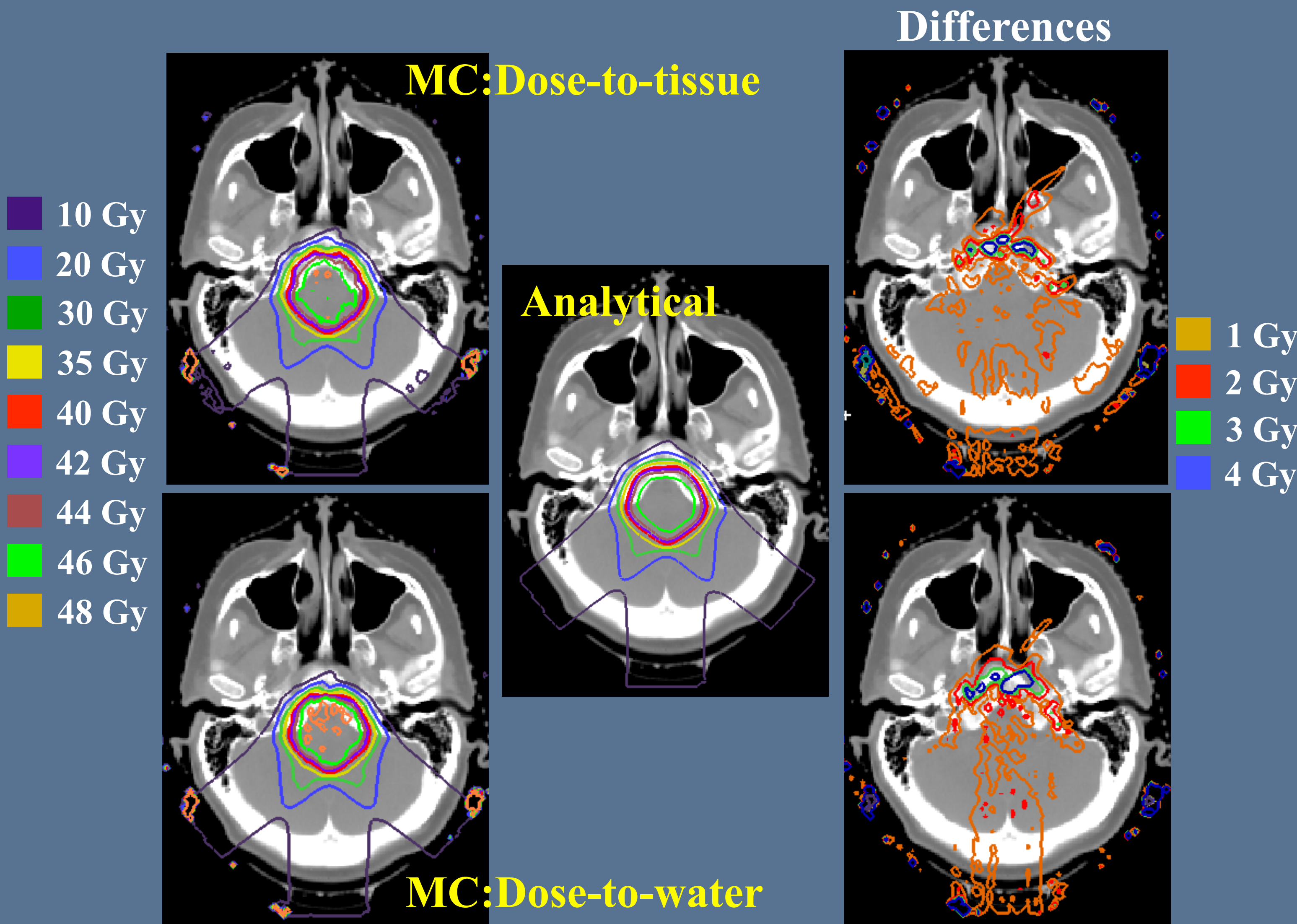


Figure 13: Axial CT image with color-wash dose display resulting from thru-field which irradiates the anterior portion of the target while avoiding the brainstem and patch-field which treats the remaining portion of the target while avoiding the brainstem. The lower figure shows the combined thru/patch field combination. All doses are given in percent. (Bussiere and Adams, 2003)

Patient simulation



Harald Paganetti, Harvard / MGH

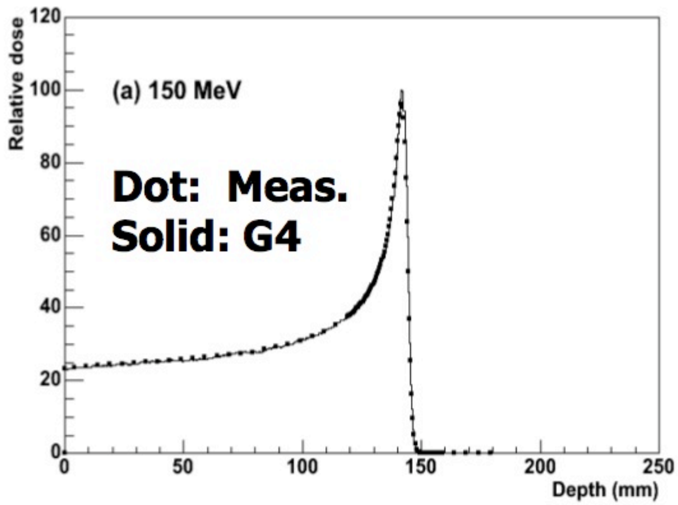
Proton Validation - Takashi Sasaki, KEK

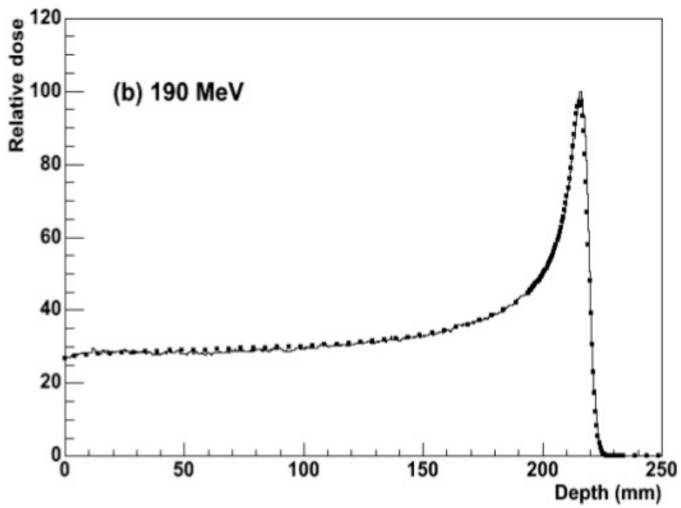
Bragg peak

IEEE Transaction on Nuclear Science,
Volume 52, Issue 4, Aug.2005, pp.896-901

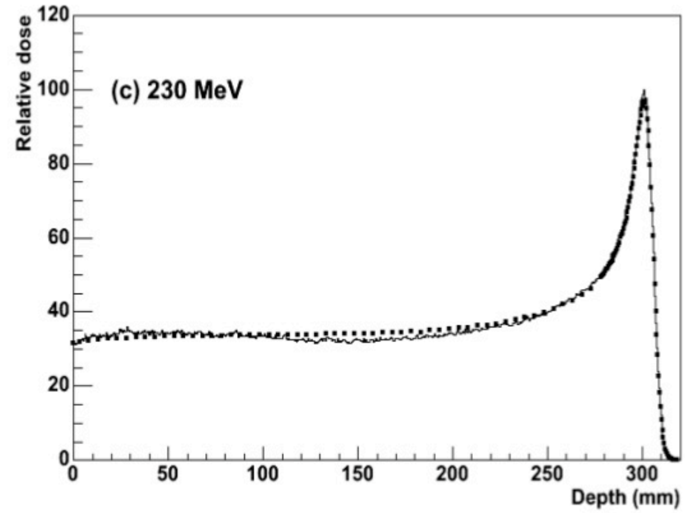
Comparison between measurement at HIBMC and Geant4 simulation

proton beam with 150, 190 and 230 MeV





shi.Sas



Simulation Framework for Advanced Radiotherapy

5 year project 2003-2008 to improve Geant4 for Medical Physics
funded by Japan Science and Technology Agency (JST)
Core Research for Evolutional Science and Technology (CREST)

Project leader: Takashi Sasaki

Geant4 Developers

Takashi Sasaki	KEK
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Setsuya Kawabata	KEK
Katsuya Amako	KEK
Koichi Murakami	KEK
Go Iwai	KEK
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Hisaya Kurashige	Kobe Univ.
Satoshi Tanaka	Ristumeikan Univ.
Ayumu Saito	Hyogo Prefecture Univ.
Akinori Kimura	Ashikaga Inst. of Tech.
Tsukasa Aso	Toyama National College
Hajime Yoshida	Shikoku Univ.
Kyoko Hasegwa	Ritsumeikan Univ.
Soh Suzuki	KEK
Yoshimi Iida	KEK
Shigeo Yashiro	KEK

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Nobuyuki Kanematsu	NIRS
Komori Masataka	NIRS -> Nagoya Univ.
Naruhiro Matsufuji	NIRS
Shunsuke Yonai	NIRS
Ken Yusa	Gunma Univ.
Koichi Maruyama	Kitasato Univ.
Tomoyuki Hasegawa	Kitasato Univ
Hiroshi Muraishi	Kitasato Univ
Teiji Nishio	Natonal Cancer Center
Takasih Akagi	Hyogo Ion Beam Medical Center
Tomohiro Yamashita	Kobe Univ-> Hyogo Ion Beam Medical Center
Satoru Kameoka	KEK-> National Cancer Center

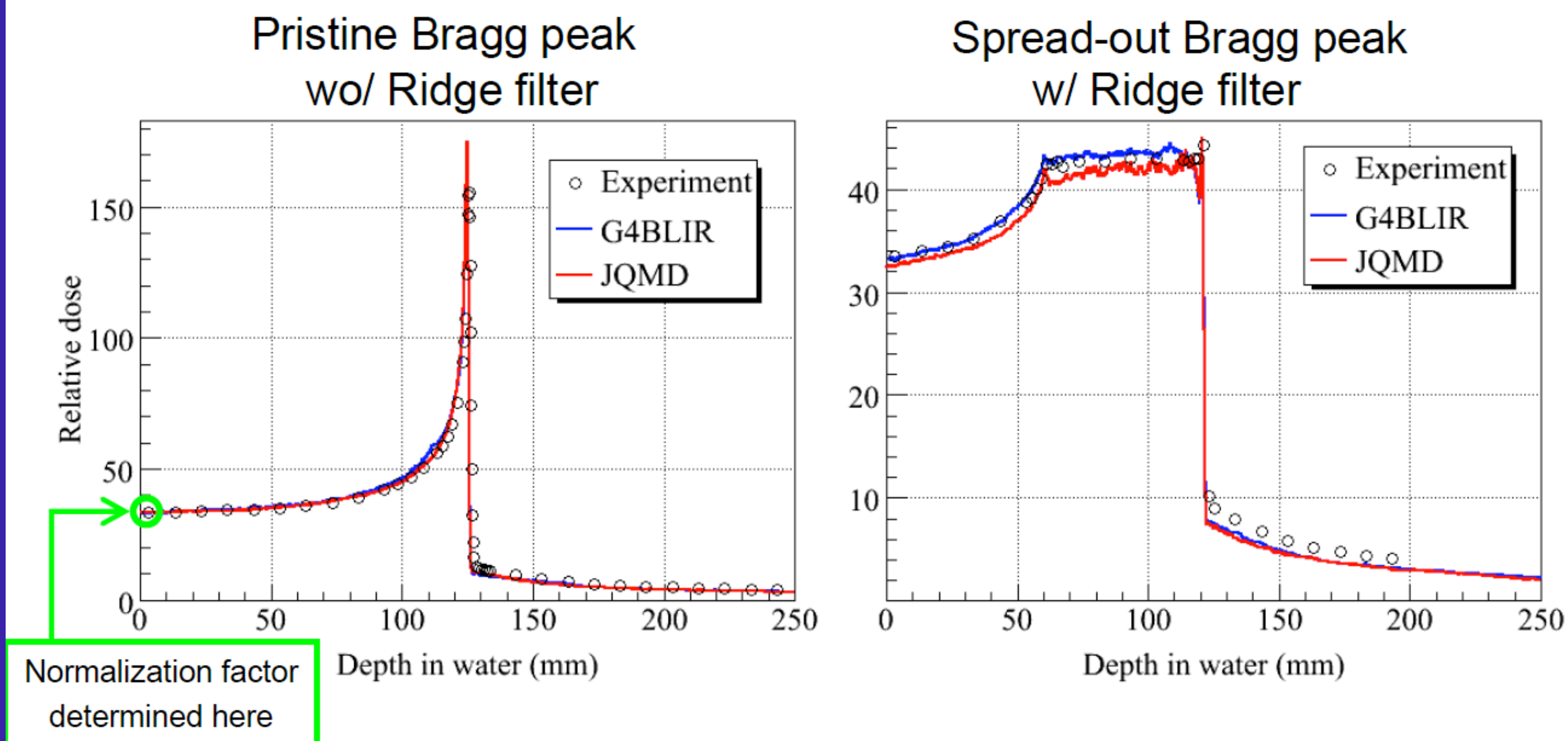
Space

Masanobu Ozaki	JAXA
Yoshikazu Maeda	JAXA
Shin Watanabe	JAXA
Tomohiro Nakazawa	JAXA

Carbon Validation - Takashi Sasaki, KEK

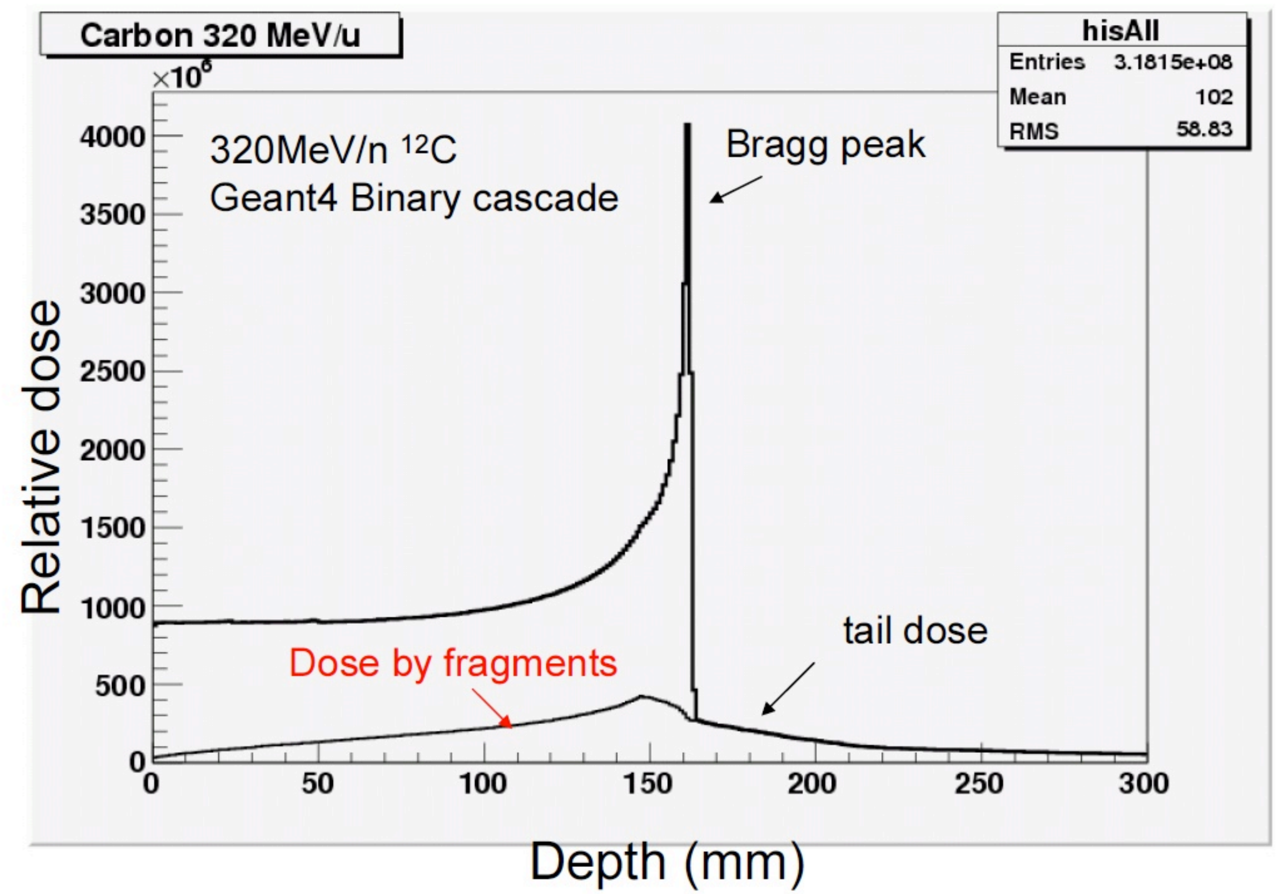
Depth-dose distribution (^{12}C 290 MeV/n)

Simulated dose is normalized to agree with the experimental data of pristine Bragg peak at the surface of the water target, and the same normalization factor is applied to SOBP.



Validation of Nuclear Reaction Models in Geant4 for the Purpose of Carbon Ion Radiotherapy

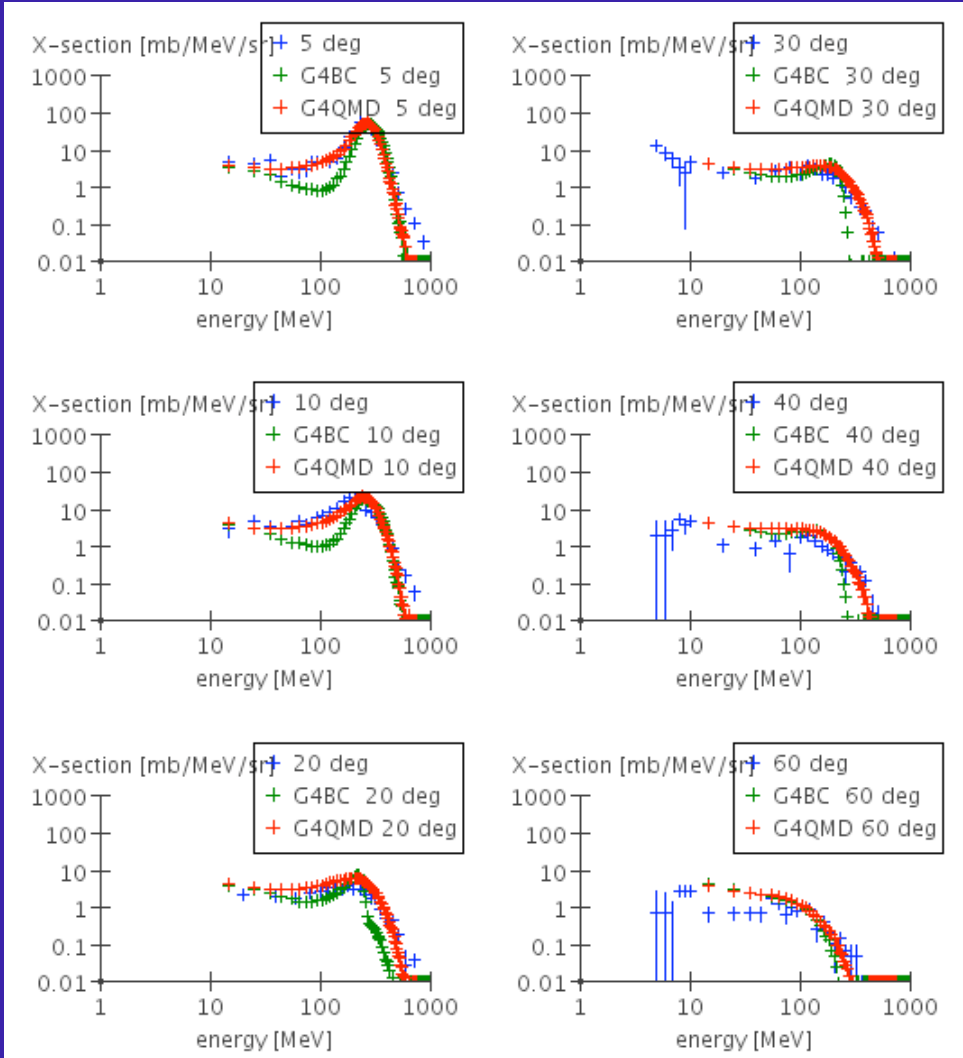
Toshiyuki Toshito for the NIRS-HIMAC P152 collaboration



Simulated depth-dose profile of 320MeV/n carbon in water.

Progress in Neutrons and Ions

- Work for Space, Medical and Shielding communities has focused on refining processes for neutrons and ions
- C12 290MeV/n on Carbon Secondary neutron spectra

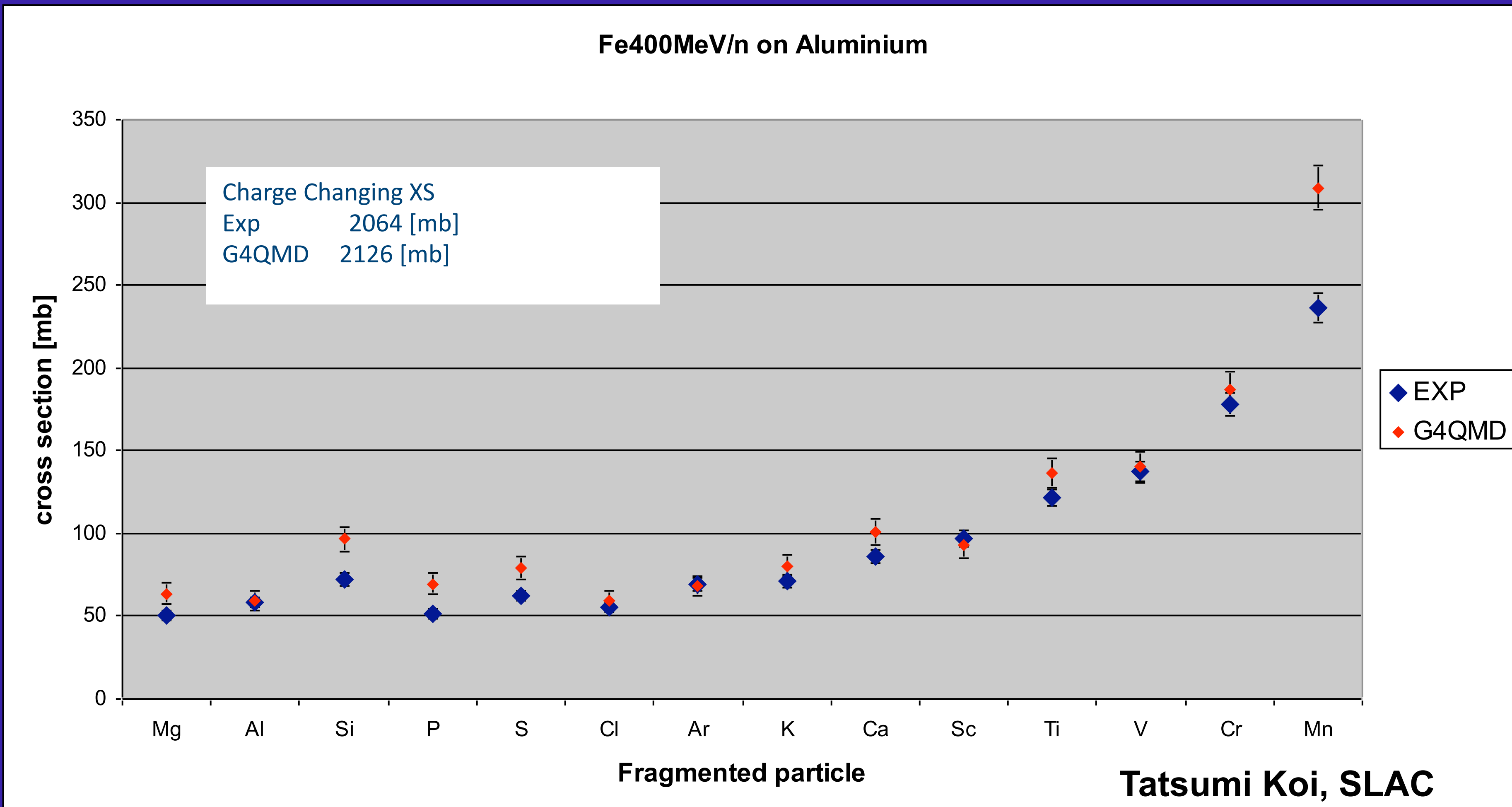


+ Data
+ G4BinaryCascade
+ G4QMD

Tatsumi Koi, SLAC

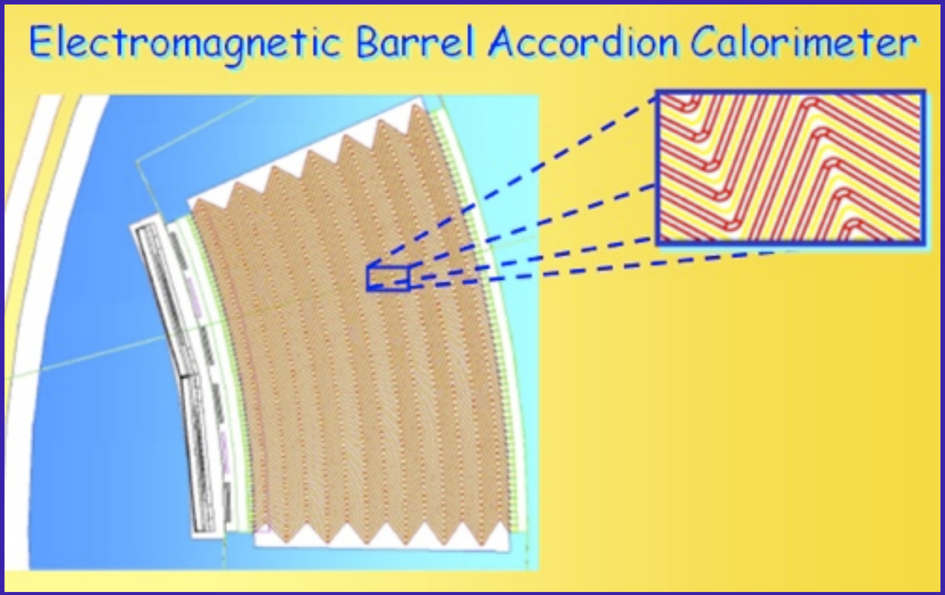
Progress in Neutrons and Ions

- Fragment Particle Production - Fe56 400MeV/n on Al



Able to Handle Complex Geometry

- Geant4 offers by far the most flexible geometry description of any Monte Carlo
  - Complex parts of proton IMRT machines
  - Multileaf collimators (MLCs)
  - Brachytherapy sources
    - » ...



Source: ATLAS Collaboration

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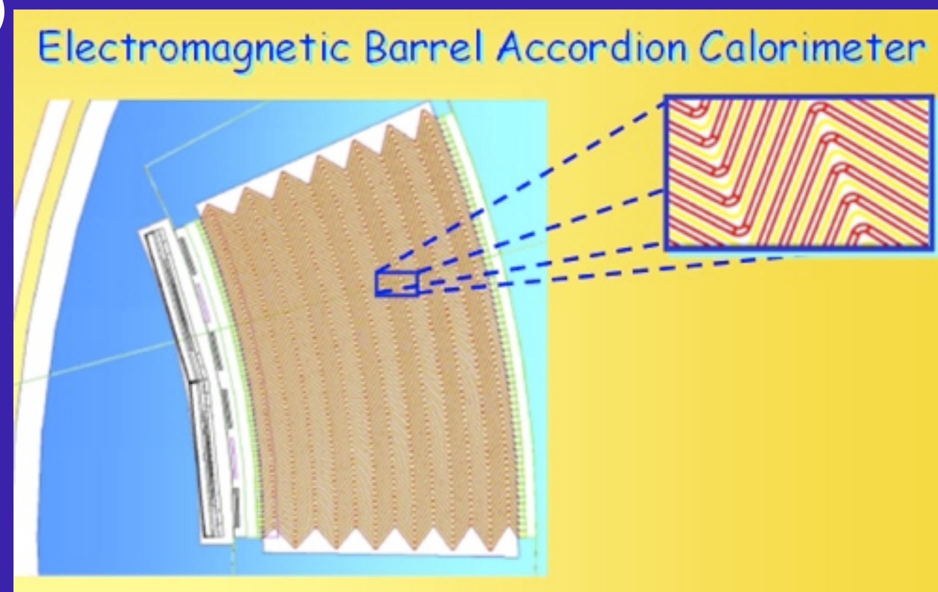
Source: Varian Medical Systems



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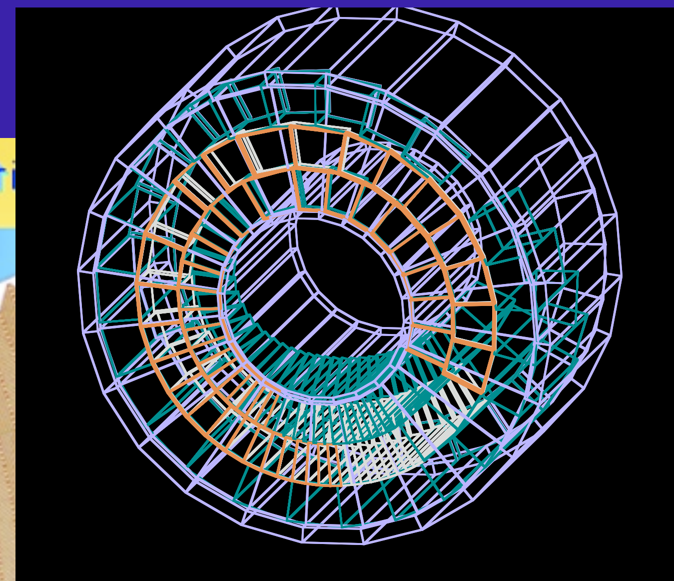
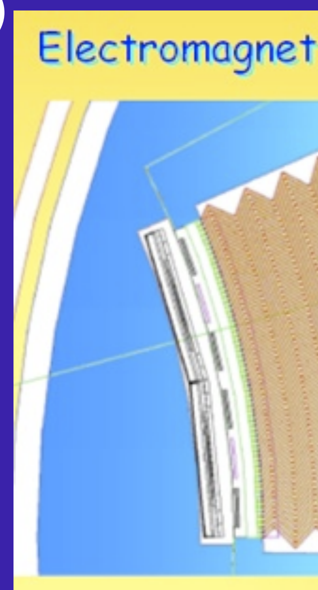


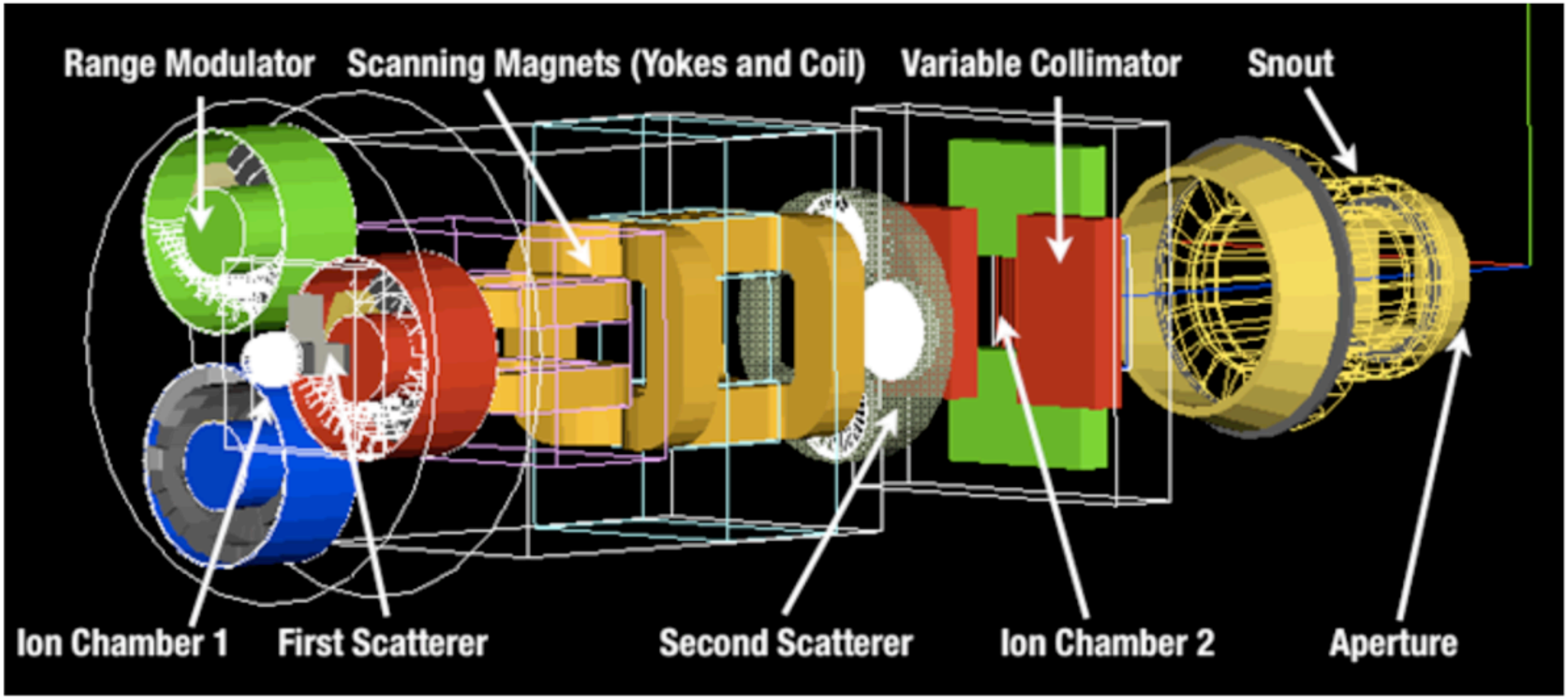
Source: Harald Paganetti, Harvard / MGH



Source: ATLAS Collaboration

Source: Varian Medical Systems

Proton Therapy IBA Universal Nozzle



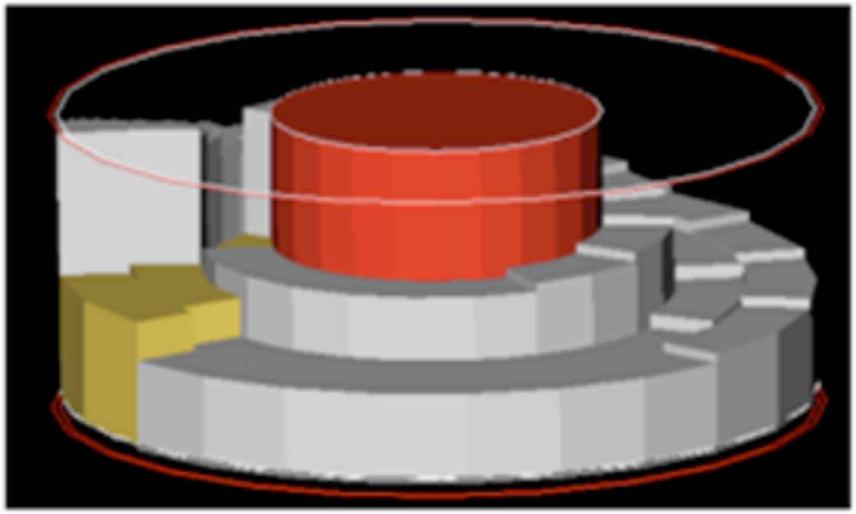
Monte Carlo Modeling and Simulation of a Passive Treatment Proton Beam Delivery System using a Modulation Wheel

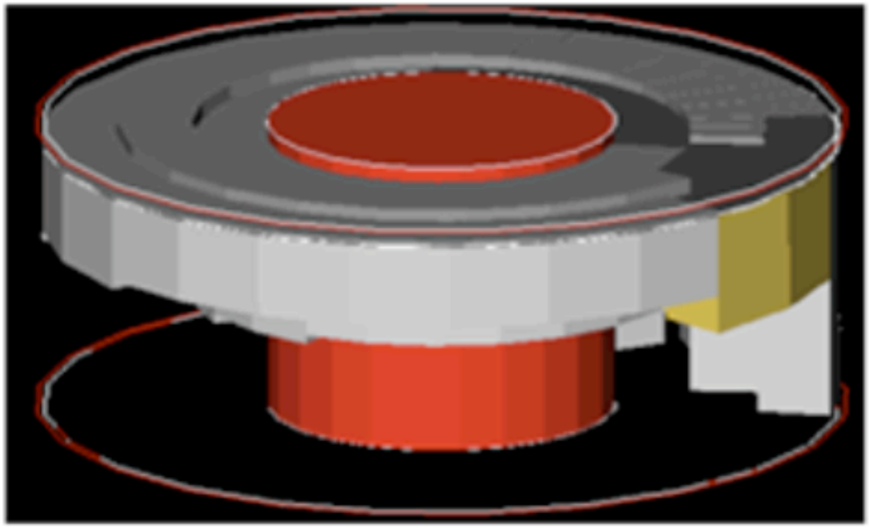
Jungwook Shin, Dongwook Kim, Young Kyung Lim, Sunghwan Ahn, Dongho Shin, Myong geun Yoon, Sung-Yong Park and Se Byeong Lee (Proton Therapy Center, National Cancer Center)

Jungwon Kwak (Asan Medical Center)

Dongchul Son (School of Physics and Energy Sciences, Kyungpook National University)

Range Modulator Wheel





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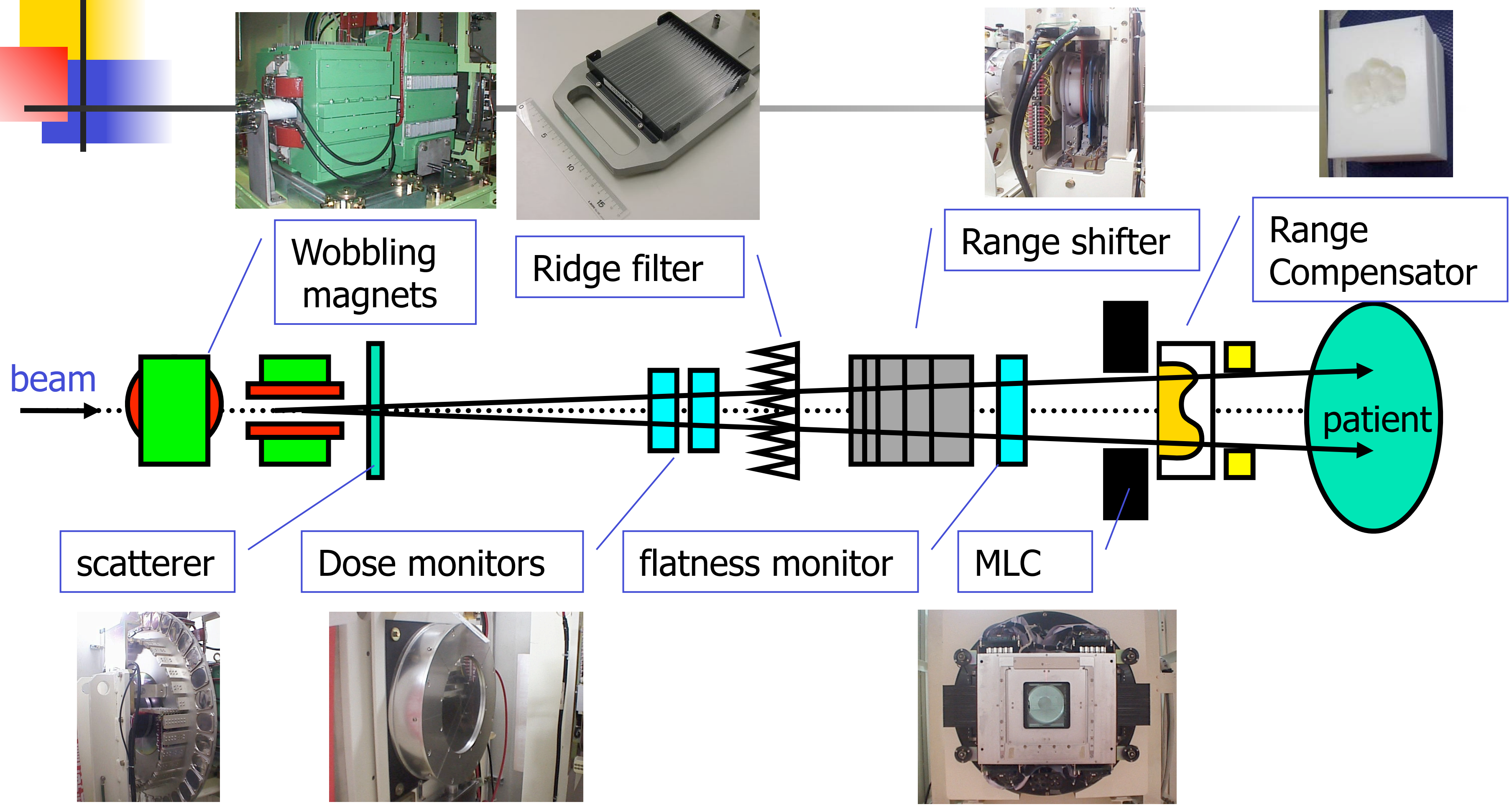
Jungwon Kwak (Asan Medical Center)

Dongchul Son (School of Physics and Energy Sciences, Kyungpook National University)

Beam Delivery System



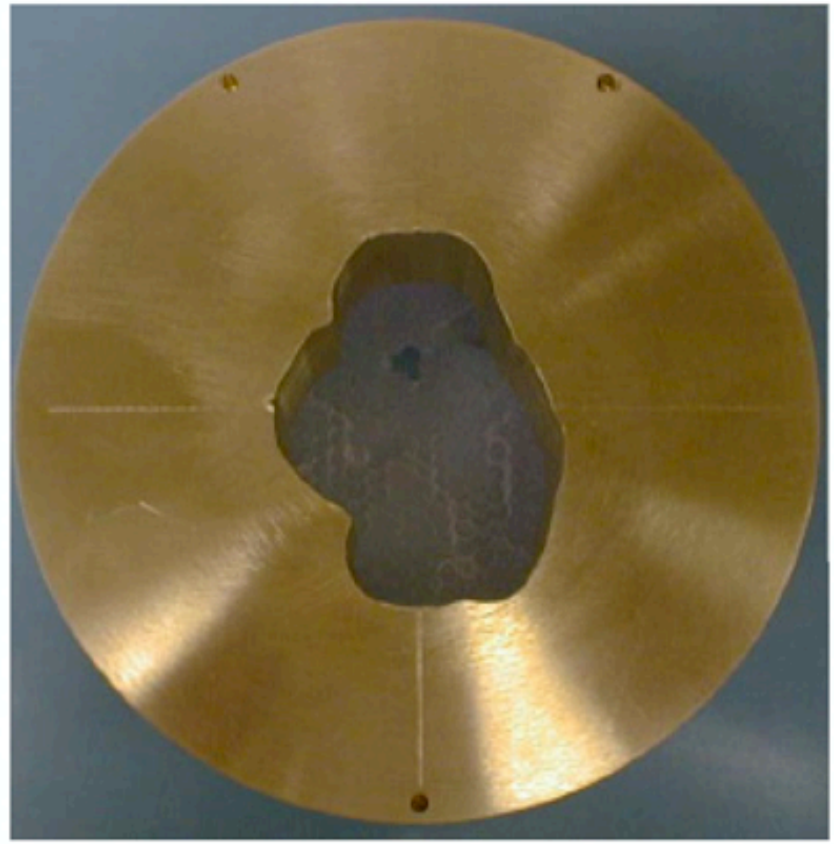
Courtesy of Takashi Akagi

Hyogo Ion Beam Medical Center (HIBMC)

Monte Carlo Simulation and Development of a Multileaf Collimator for Proton Therapy

C Ainsley, R Scheuermann, S Avery, D Dolney, R Maughan, and J McDonough,
University of Pennsylvania

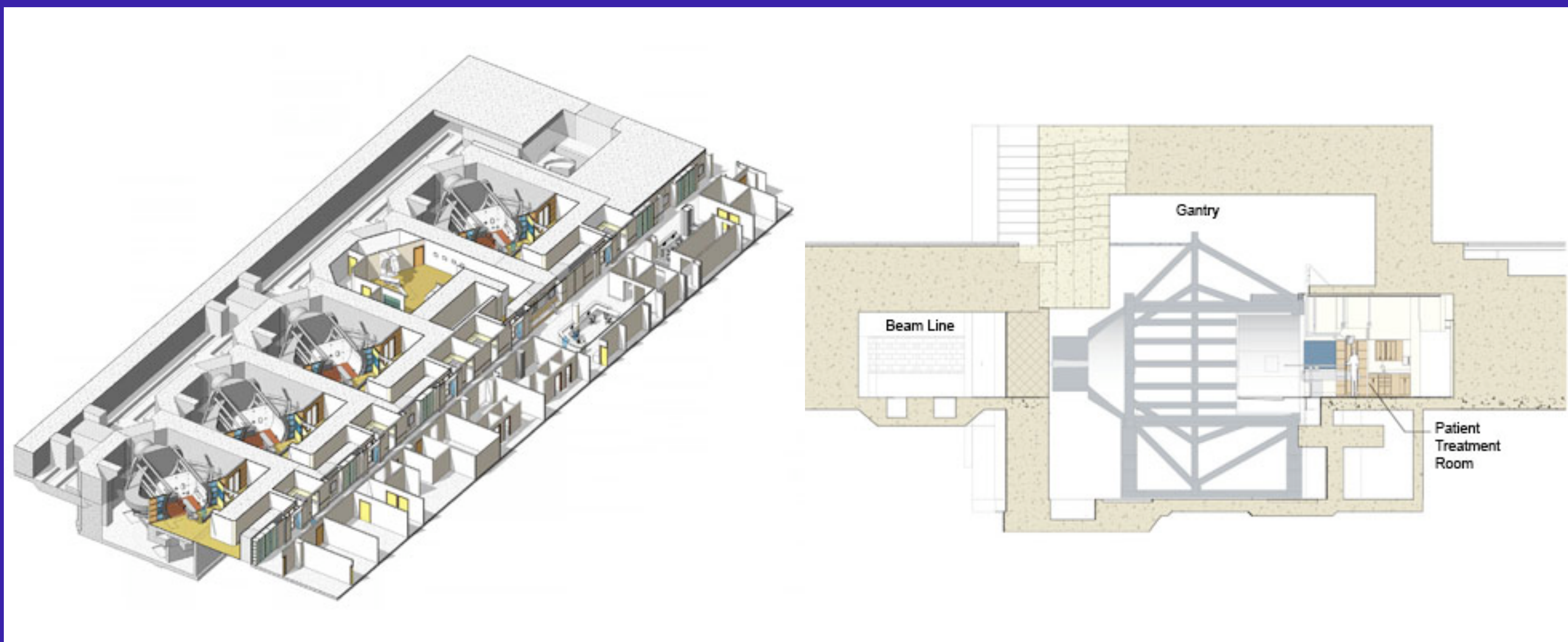
MLC



brass aperture

Novel Sources for Protons or Ion Beams

- Race is on to find a cheaper and/or more compact source for clinical proton or ion beams
  - Current Proton Therapy System costs $100 to $200 million, compared to $10 million for a conventional medical linac, and they require a purpose-built buildling



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  - Others
- Study of beam characteristics, neutron dose, etc. requires simulation

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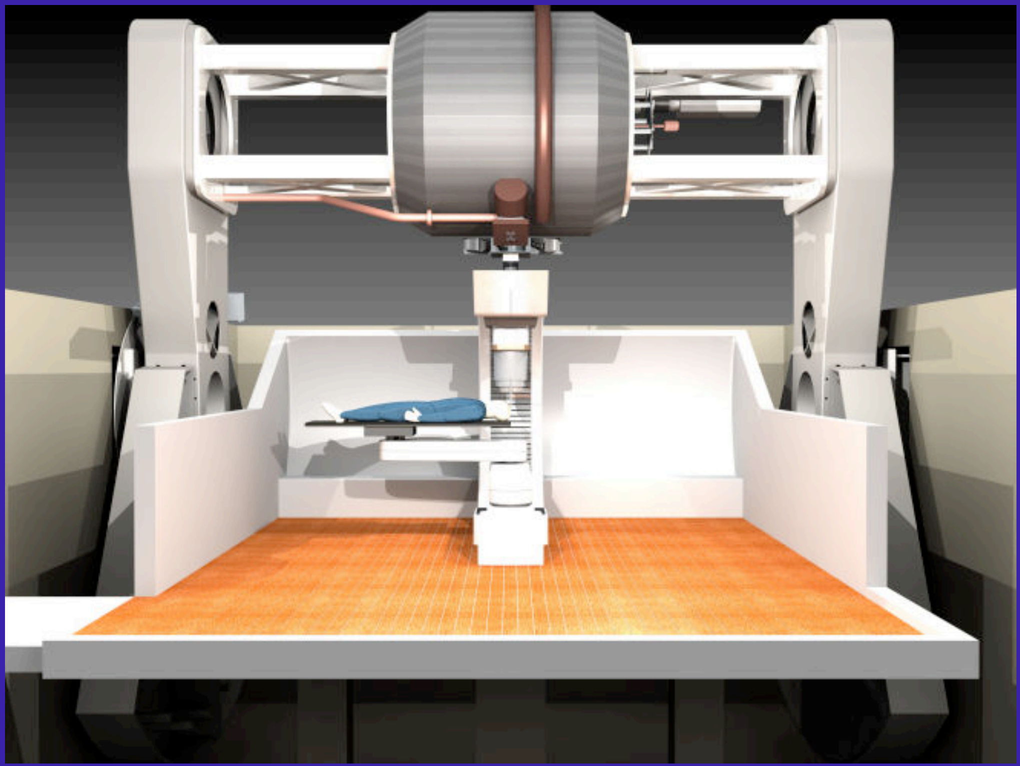

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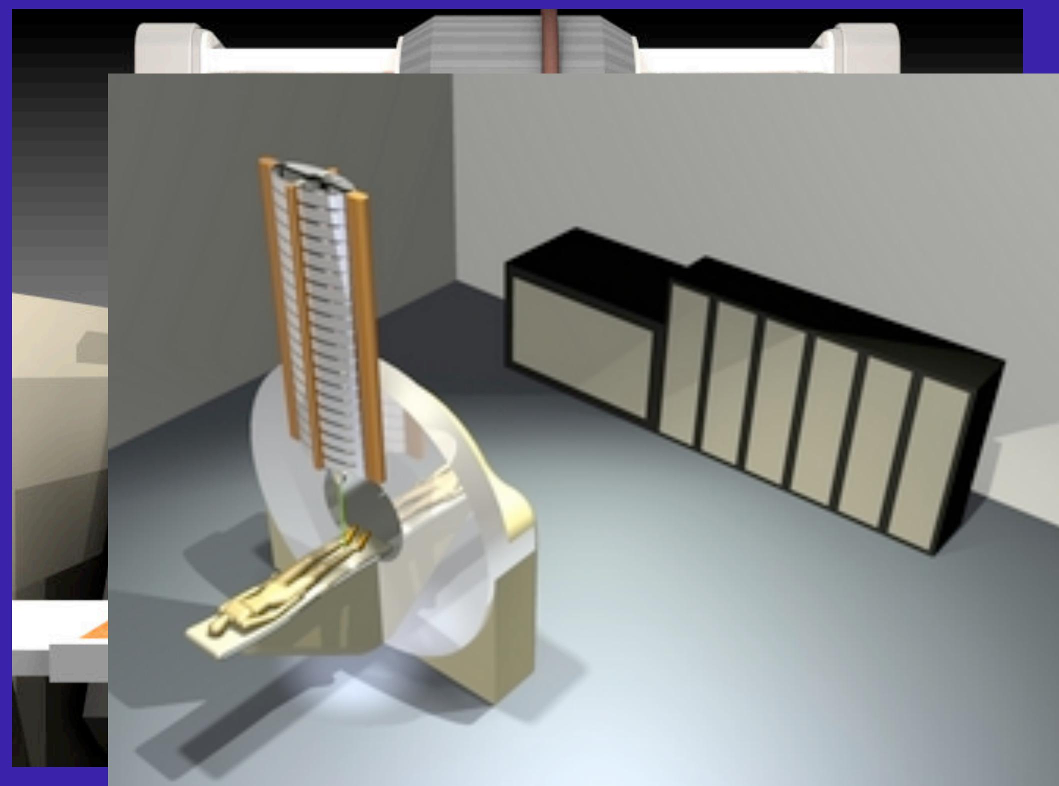

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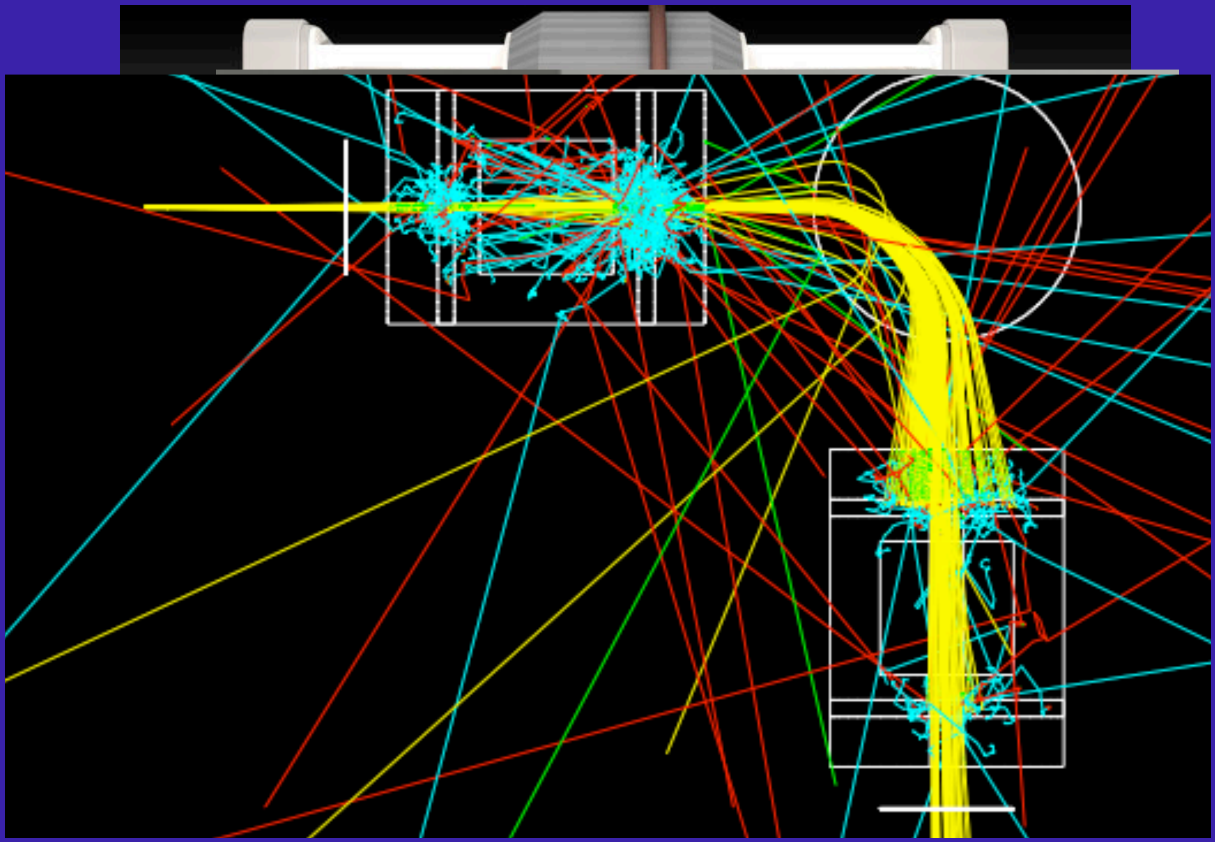
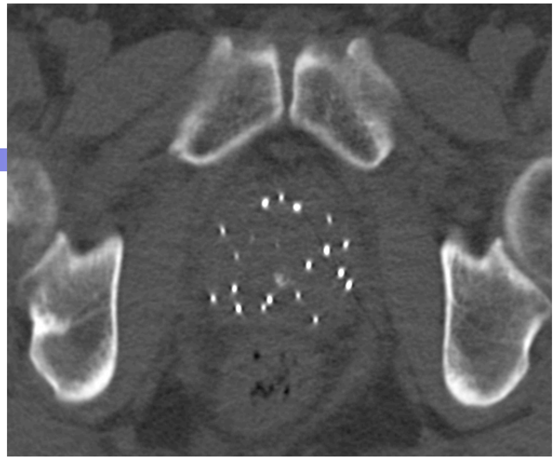
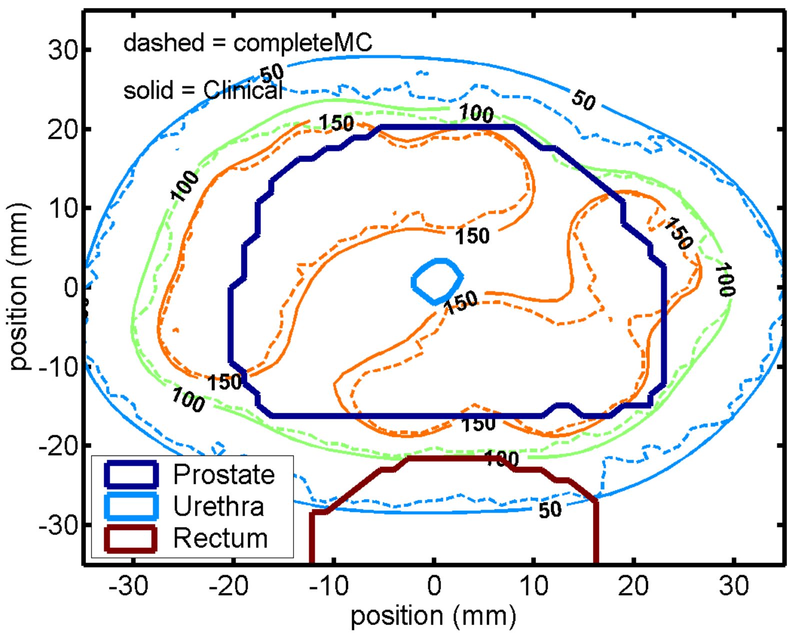
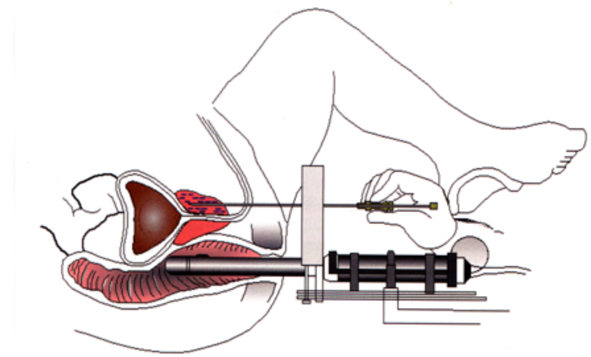


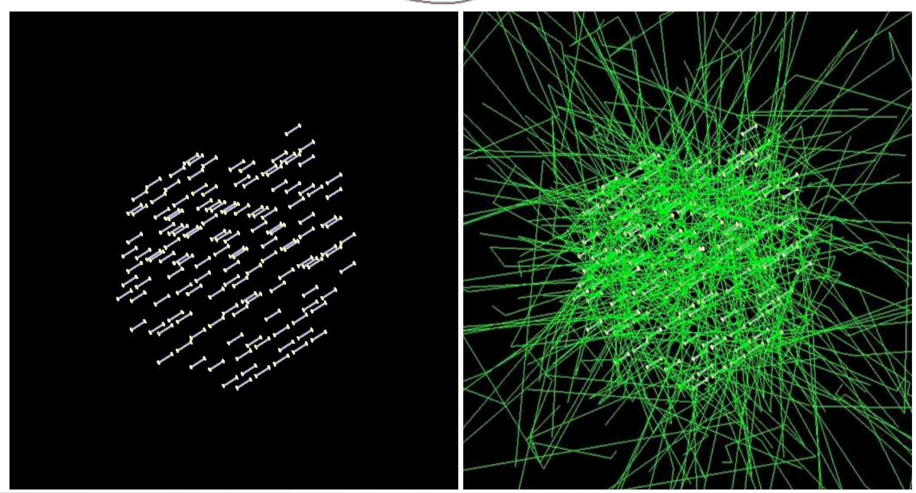
Collimator Simulation for Novel Particle Source that I Can’t Discuss

Prostate brachytherapy
Jean-François Carrier, CHUM







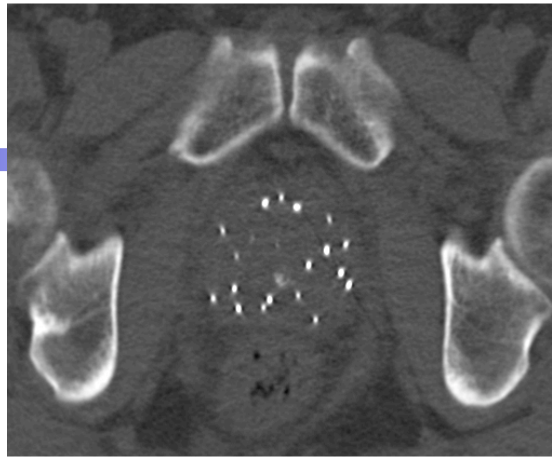


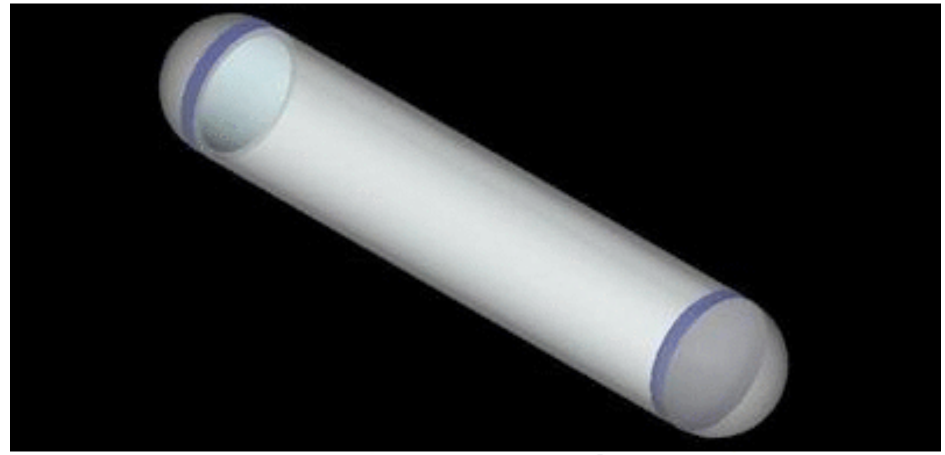
Carrier et al, IJROBP (68), 2007 pp.1190-1198

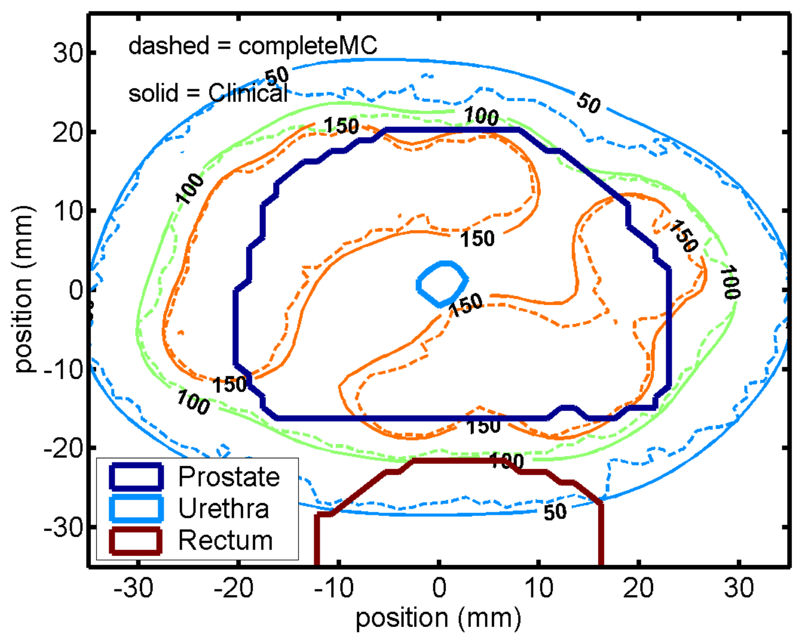
CHUM

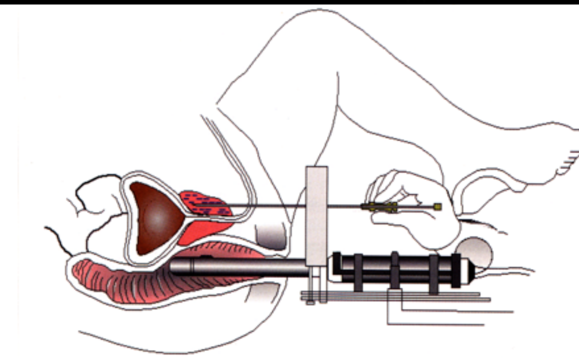
Prostate brachytherapy

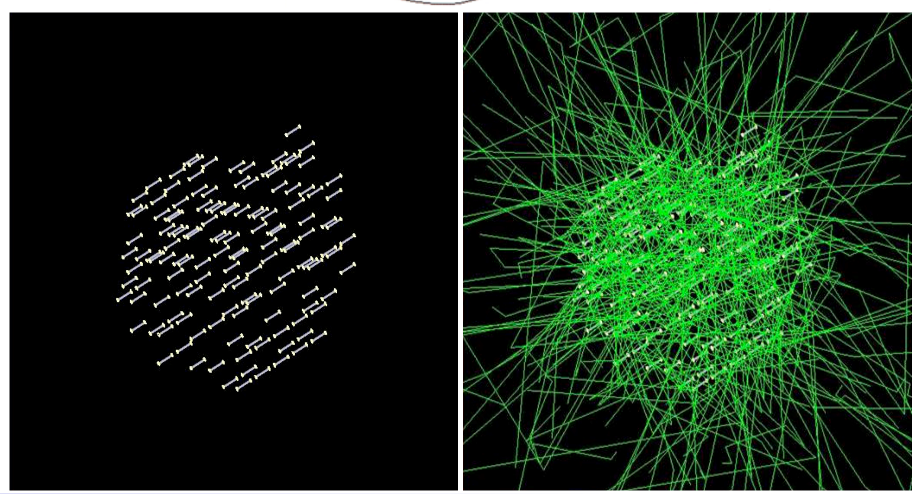
Jean-François Carrier, CHUM







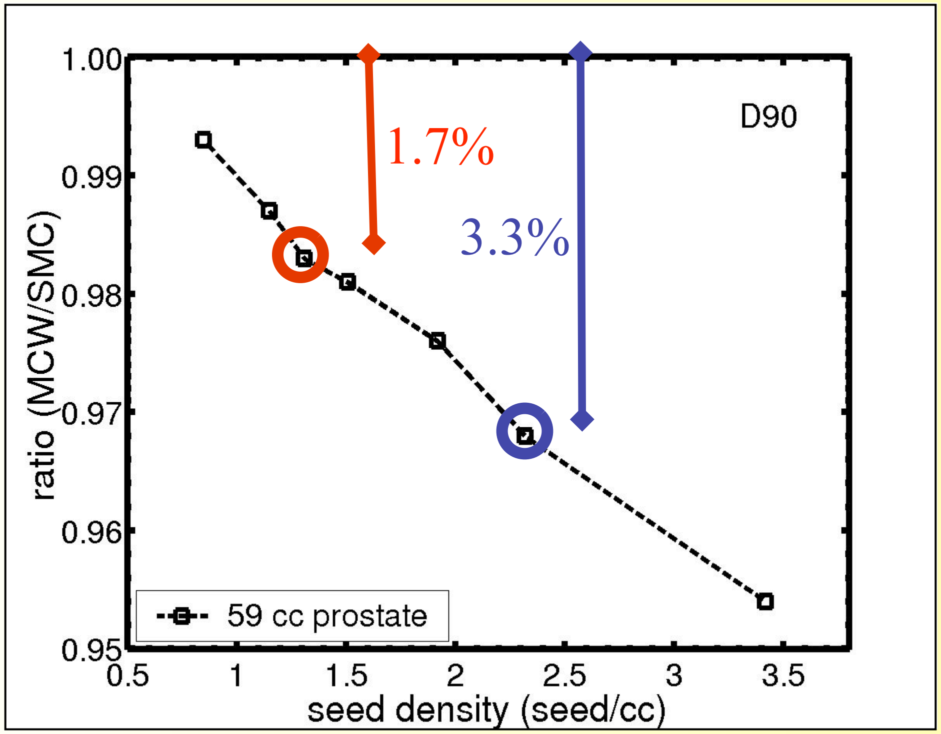




Carrier et al, IJROBP (68), 2007 pp.1190-1198

MC simulations on clinical treatment plans

1) Interseed attenuation



This interseed attenuation is not considered in TG43 (clinical) dose calculations

RED PLAN

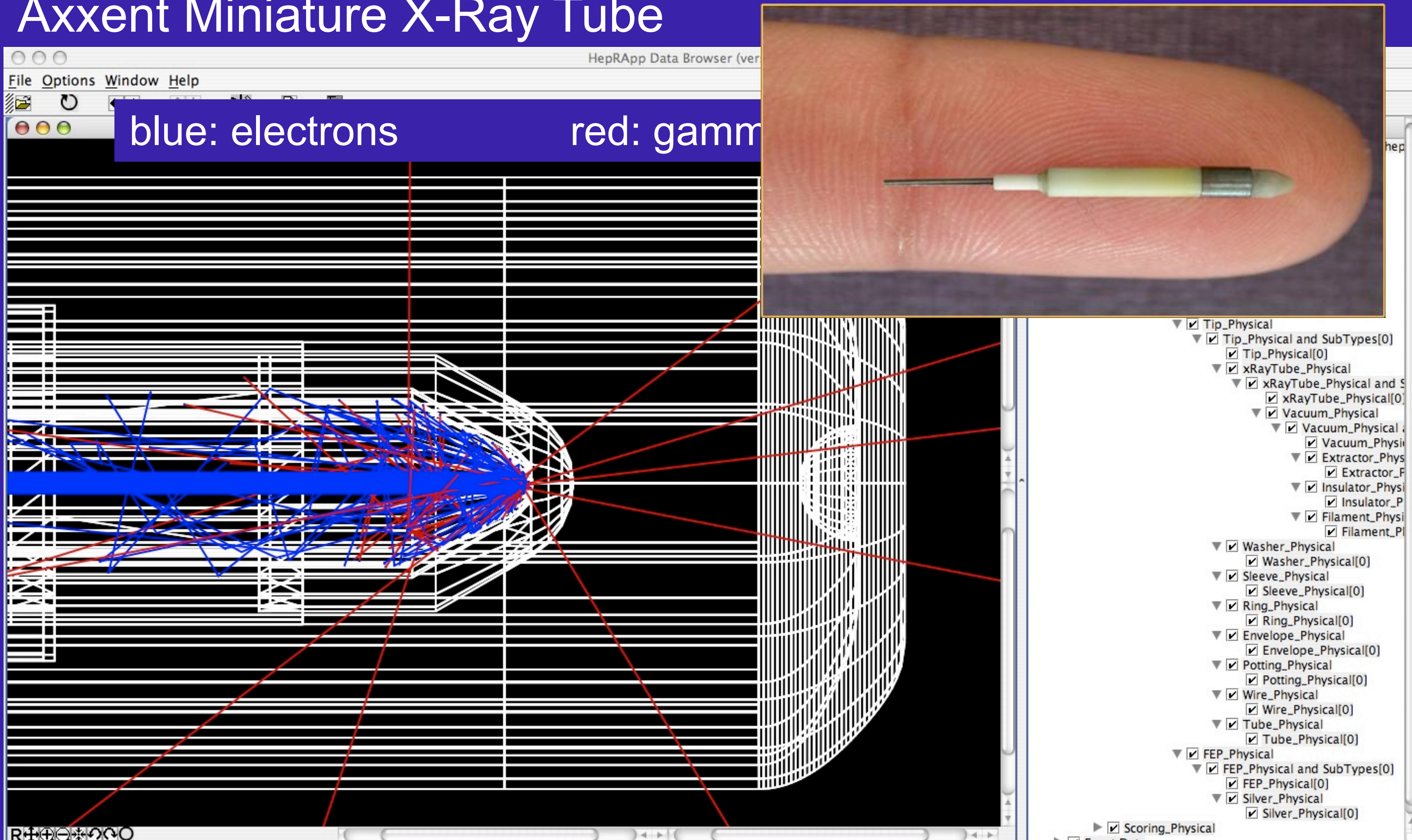
- **77 seeds**
- **0.6 mCi activity**
- **1.7% of the D90 value is lost due to interseed attenuation**

BLUE PLAN

- **137 seeds**
- **0.3 mCi activity**
- **3.3% of the D90 value is lost due to interseed attenuation**

Electronic Brachytherapy

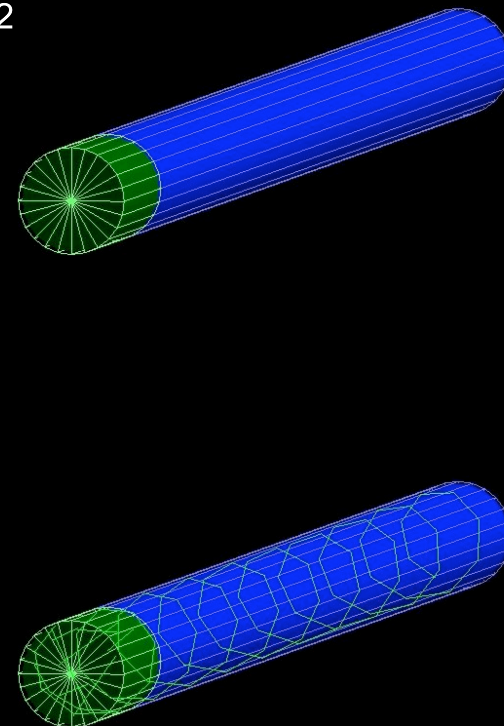
Axxent Miniature X-Ray Tube



Derek Liu, E. Poon, M. Bazalova, B. Reniers, M. Evans, J. Seuntjens, T. Rusch*, F. Verhaegen
McGill University, * Xoft, Inc.

Scintillation detectors for proton therapy

Louis Archambault[1], Jerimy C. Polf[1], Luc Beaulieu[2]
and Sam Beddar[1]



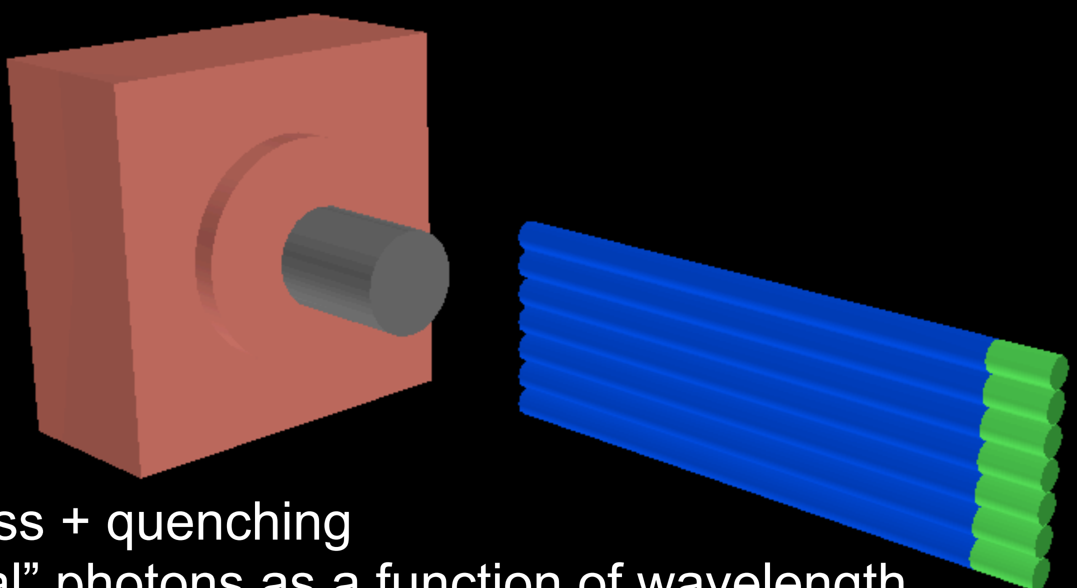
larchamb@mdanderson.org

(1) University of Texas, M. D. Anderson Cancer Center, TX
(2) Université Laval, QC, Canada

THE UNIVERSITY OF TEXAS
MD ANDERSON
CANCER CENTER

- Dosimetry of clinical proton beams is a delicate process
  - High sensitivity to density variation
  - Bragg peak
  - Small beam (beam scanning treatments, IMPT)

- Geant4 to investigate and optimize the design of scintillation detectors
  - Scintillator type, scintillator size, cladding, coating, coupling, choice of optical fiber, choice of photodetector response
  - Impact of detector array on surrounding dose distribution
  - Quenching correction

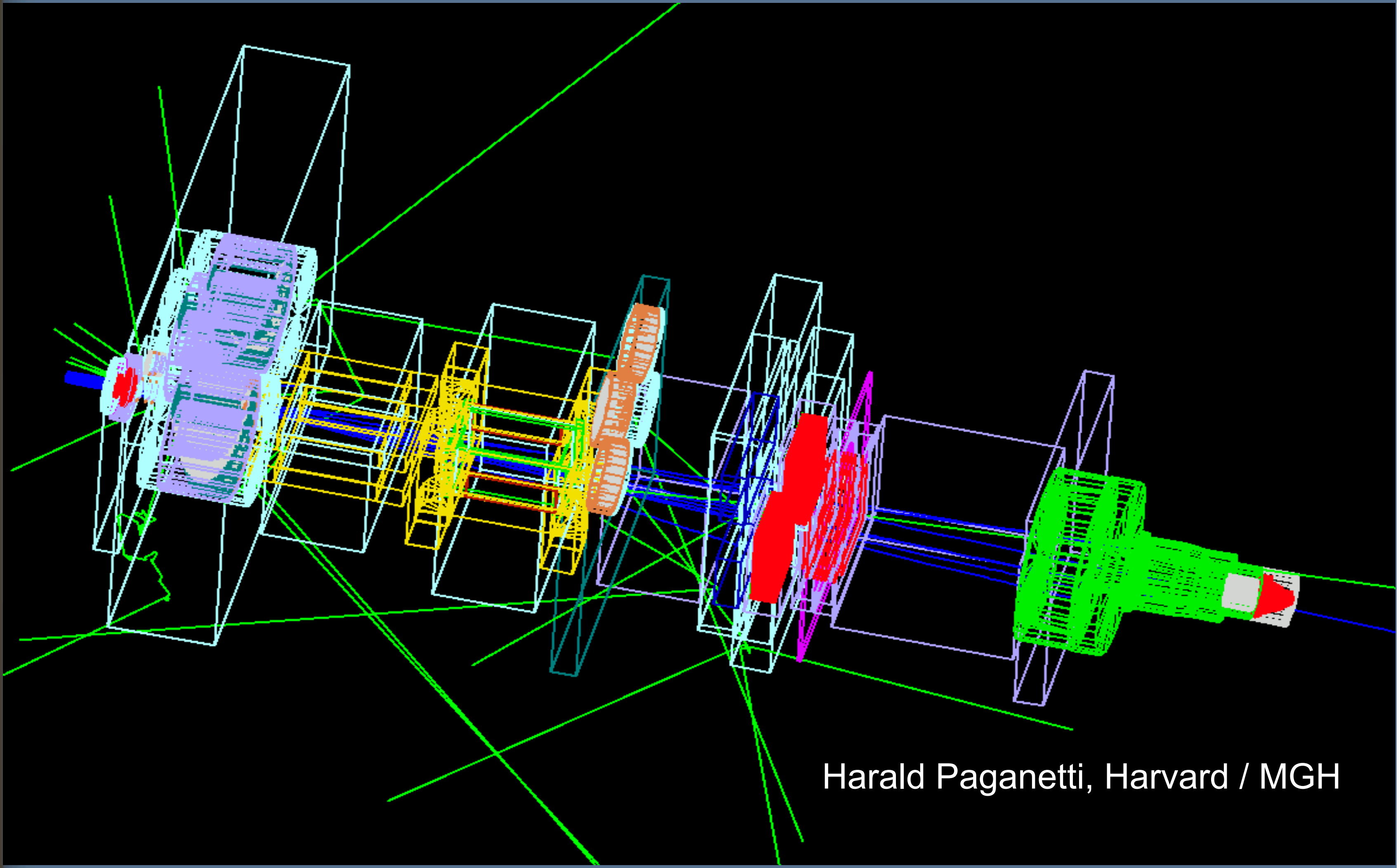


Complete simulation
- Proton beam
- Scintillation process + quenching
- Tracking of “optical” photons as a function of wavelength

Radiation Protection

increasingly important issue of leakage

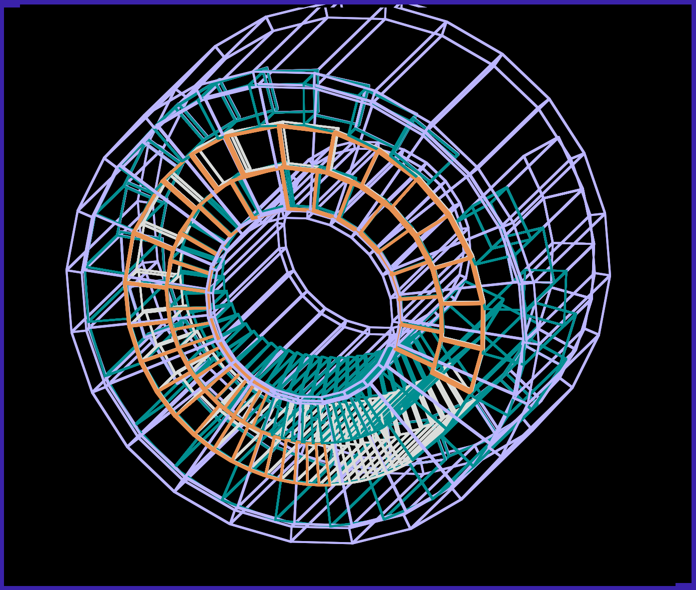
- increased survival from primary cancer
- secondary cancers - long time line (20 to 40 years)



Harald Paganetti, Harvard / MGH

Able to Handle Motion

- Geant4 can model sources and geometries that are in motion - *4D Monte Carlo*
  - Rotating parts of proton IMRT machine
  - Dynamic multileaf collimators (MLCs)
  - Brachytherapy source moving through a catheter
  - Imaging, moving scanners
  - Organ motion, respiration, etc.



Source: Harald Paganetti, Harvard / MGH

Source: GATE Collaboration

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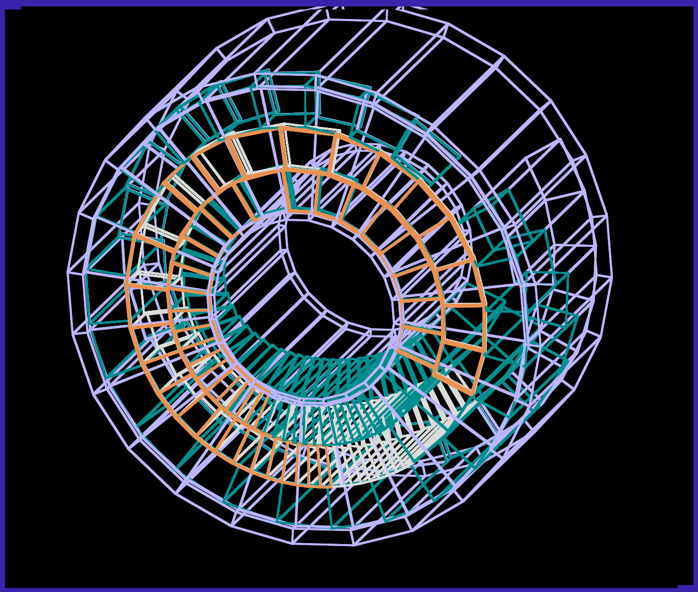
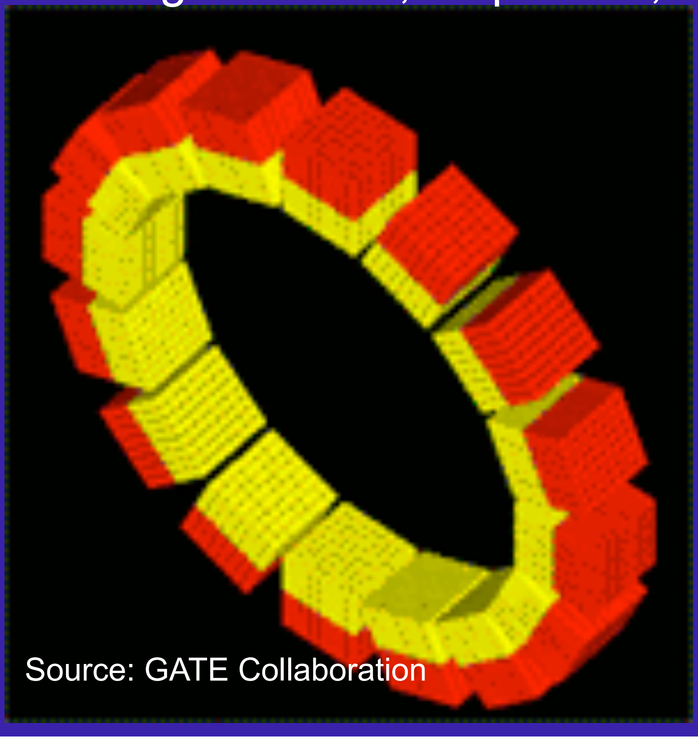


Source: Harald Paganetti, Harvard / MGH



Source: GATE Collaboration

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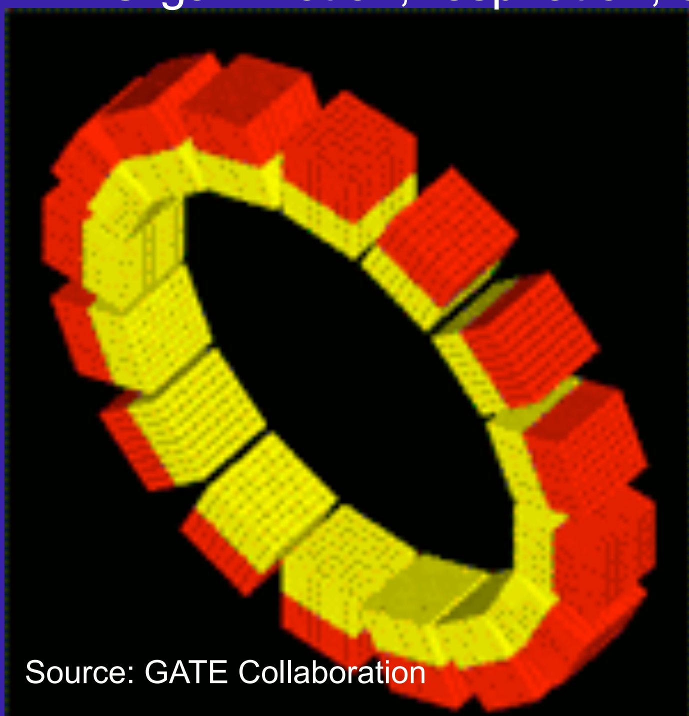
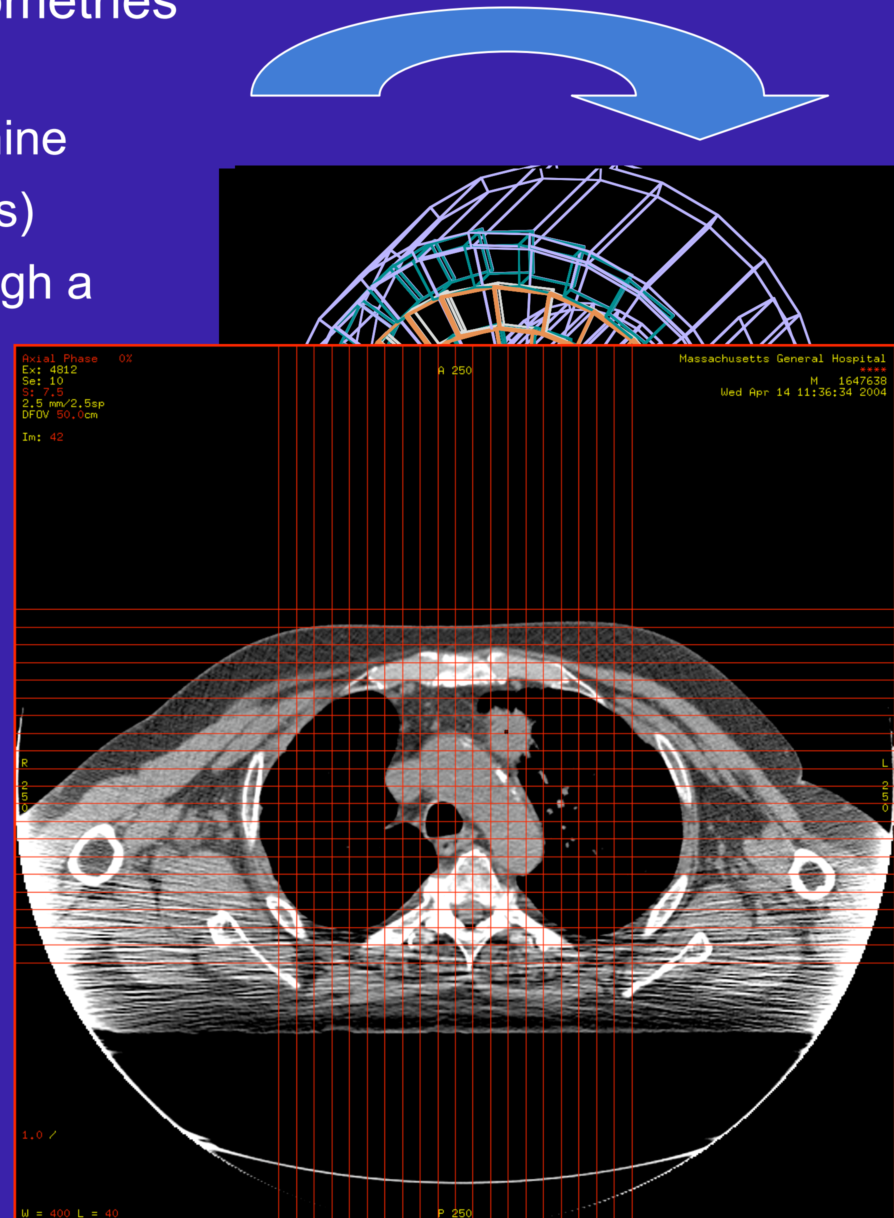


Source: GATE Collaboration



Proton Therapy

Source:

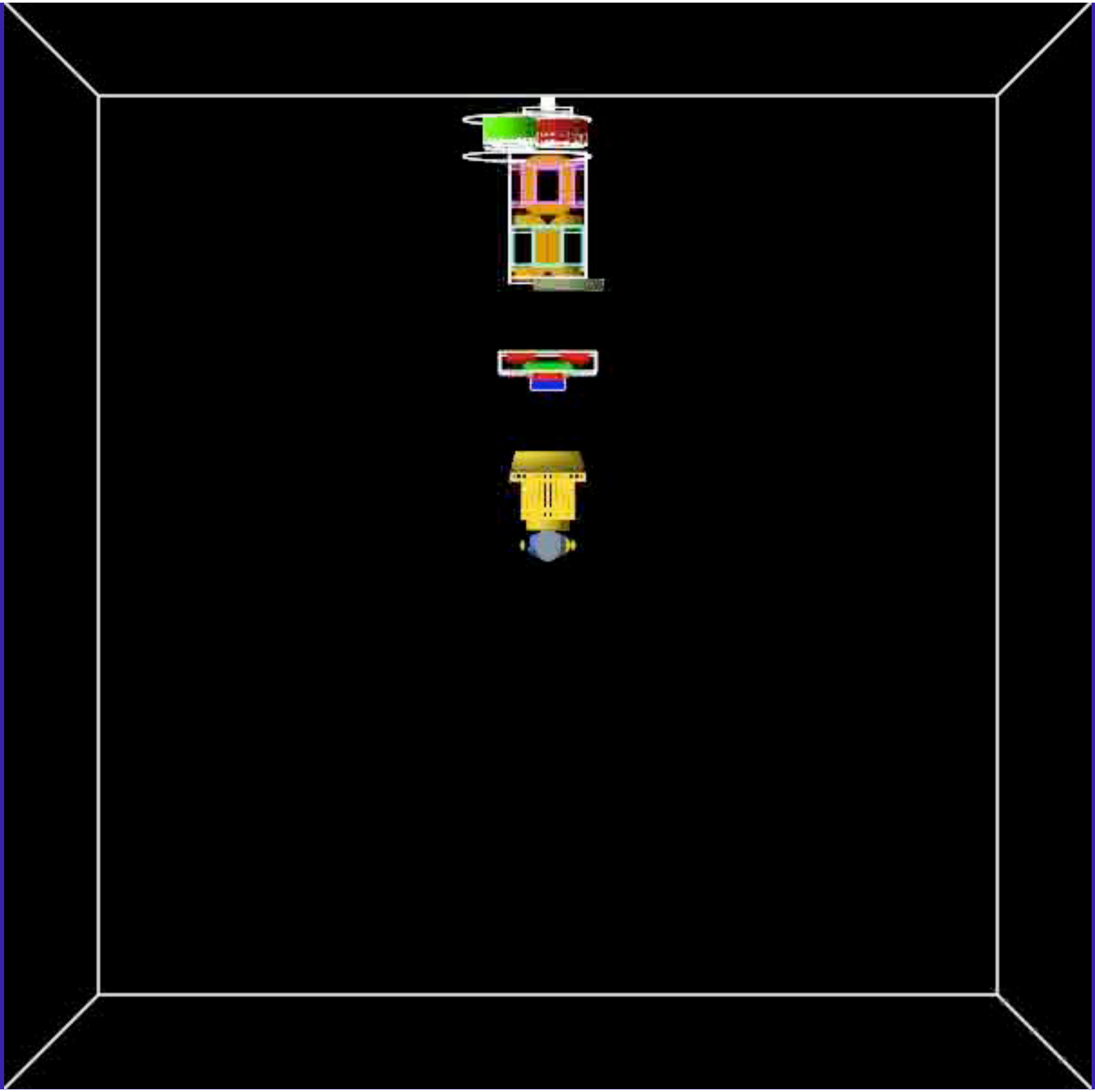
Jungwook Shin

Proton Therapy
Center, NCC,
Goyang,
South Korea
(and now at
UCSF)

Source:

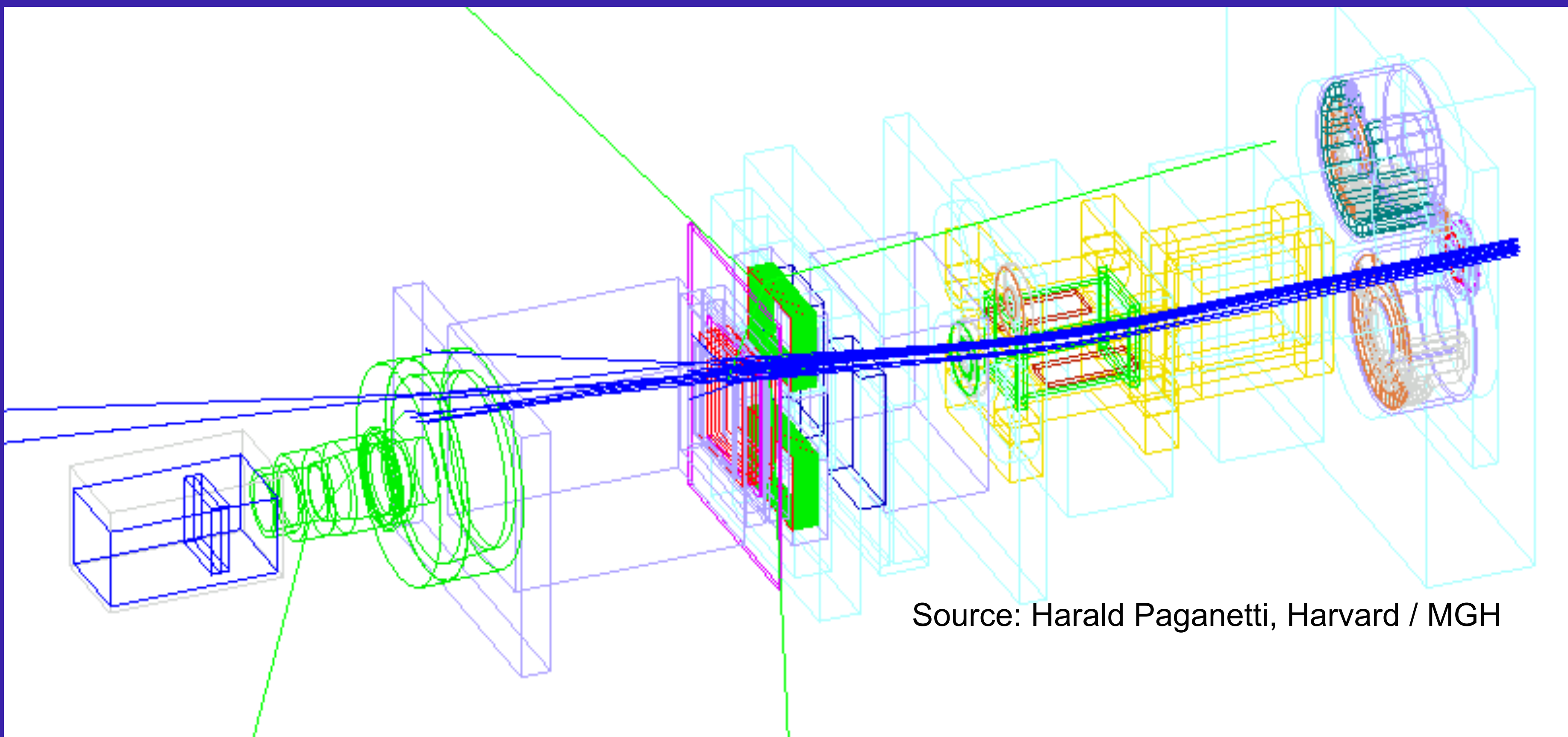
Jungwook Shin

Proton Therapy
Center, NCC,
Goyang,
South Korea
(and now at
UCSF)



Able to Handle Fields

- Geant4 can track through electric and magnetic fields
  - In the treatment head
  - Beam steering
  - Or when entire treatment is within a field, as in novel techniques where MRI is done in real time during treatment



Source: Harald Paganetti, Harvard / MGH

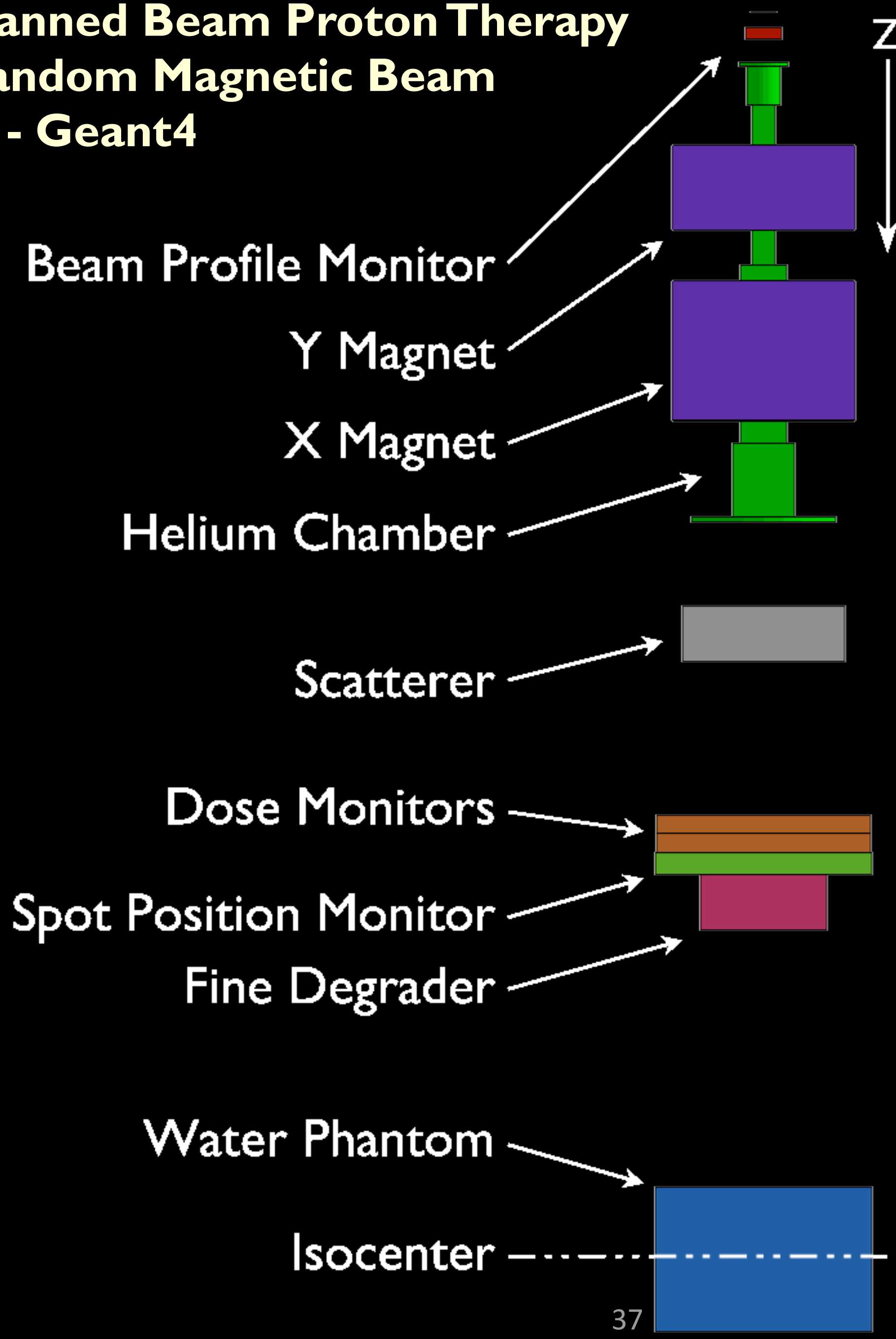
THE UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER

Variations in Scanned Beam Proton Therapy Doses due to Random Magnetic Beam Steering Errors - Geant4

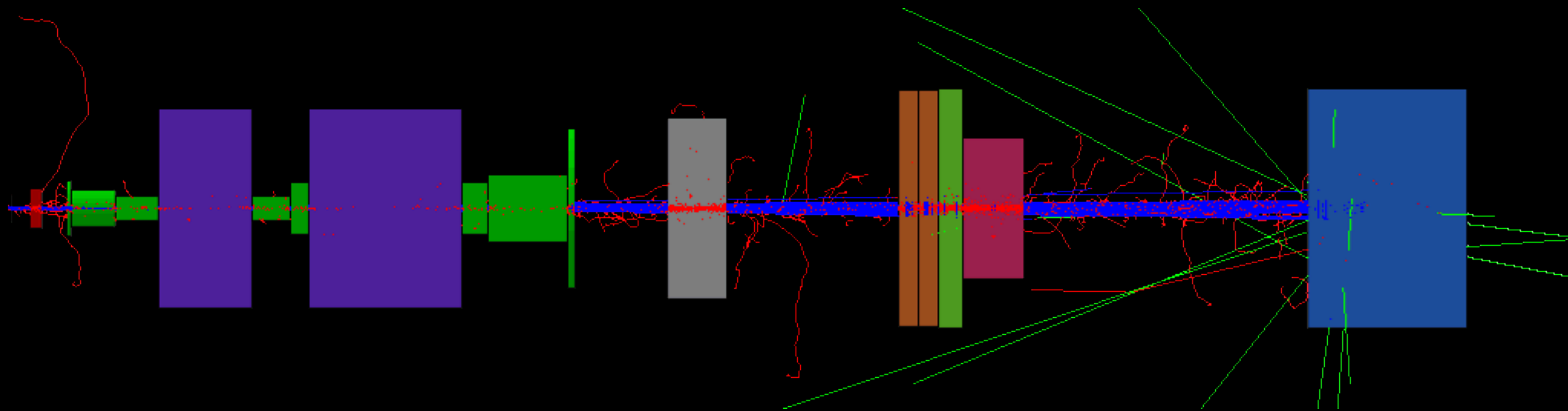
Stephen Peterson, Jerimy Polf,
Steven Frank, Martin Bues, Alfred Smith

Scanned Beam Nozzle

- Beam scanning achieved by magnetic fields (X,Y) and changing incident beam energy (Z)
- Magnetic field values
  - Y magnet: 0.72 T (max)
  - X magnet: 0.39 T (max)
- Purpose: Determine magnetic field uncertainty that produces significant dose impact

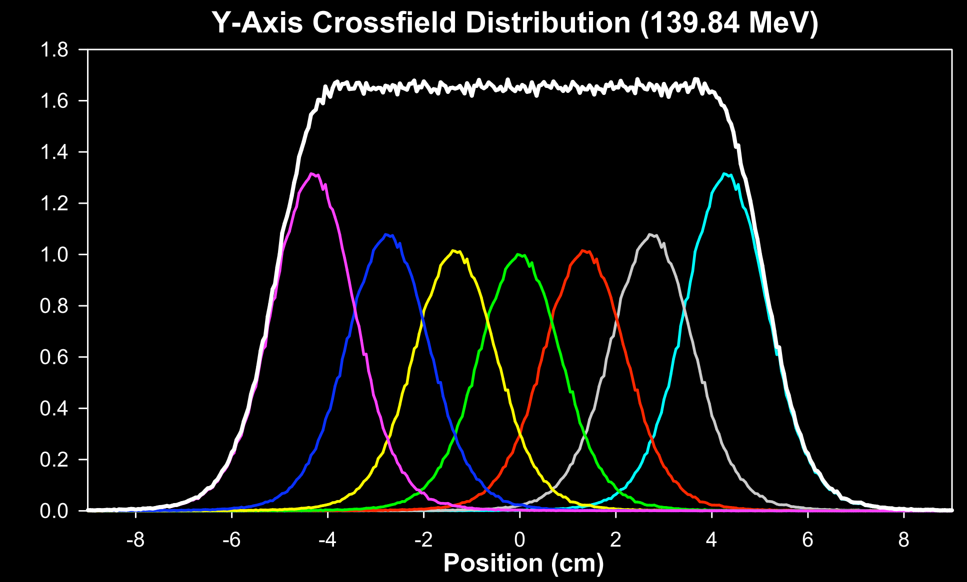


Monte Carlo Simulation

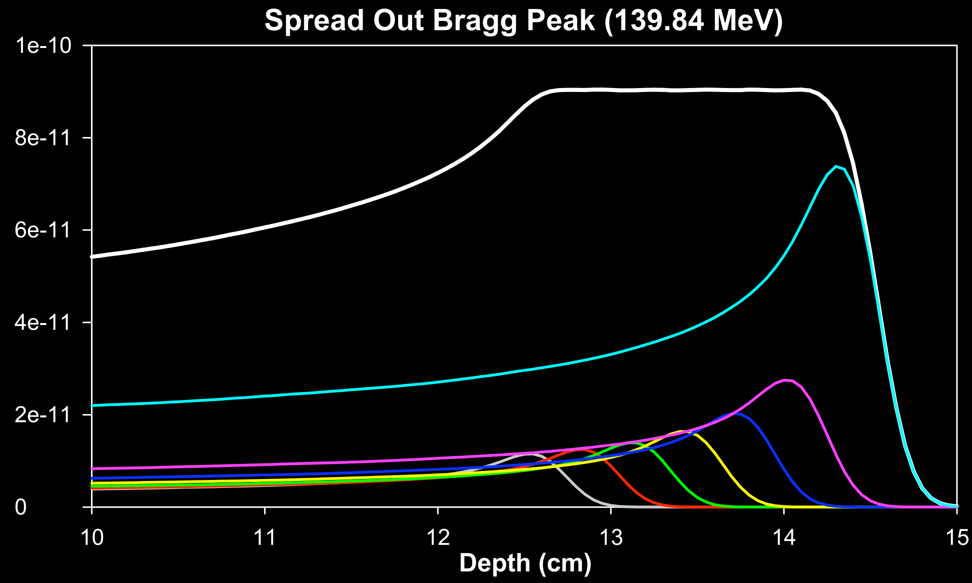


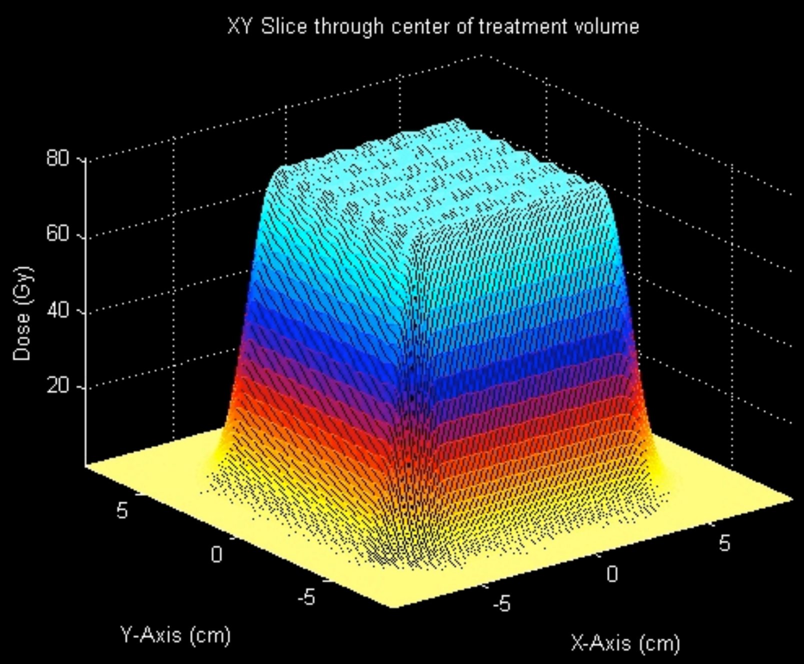
- Monte Carlo simulations performed using the Geant4 software toolkit version 8.1.p01
- Geant4 chosen for ability to model the beam steering magnetic fields

Creating 3D Dose Distribution



- The dose distribution is assembled during simulation by adjusting the spot energy and steering magnetic fields





Modern Programming - hence Flexible

MC code	Particle types	Class	Programming language
ETRAN/ITS	Photons, electrons	I	FORTRAN
MCNP	Photons, electrons, neutrons	I	FORTRAN
MCNPX	All particles	I	FORTRAN
EGS4	Photons, electrons	II	FORTRAN
EGSnrc	Photons, electrons	II	FORTRAN*
PENELOPE	Photons, electrons	II	FORTRAN
GEANT3	All particles	II	FORTRAN
GEANT4	All particles	II	C++

Table 3.1. *General-purpose Monte* Source: Emily Poon, McGill University *ions.*

Open and Free

- Open - physicists like to have the ability to get in under the hood and make changes
- Free - not only free for user, but also freely available for redistribution (including commercial use)
  - Even for private companies to build Geant4 into their own systems
  - License is so simple and clear it fits on a single page

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Similarities of User Requirements / Challenges between Aeropace and Medical

Similarities

- Not just counting particles or scoring energy, but studying Dose
  - Volumetric effects
- Common interests in EM, all pushing very usefully on validation,
  - Such as in talks from Edward Mitchell's and Danielle Hohreiter
- Lower-than-HEP energies
  - Robert Reed, 250eV, 22nm sram upset with 2 keV
- Smaller-than-HEP distance scales
  - Robert Reed, 10nm cubes
- Single Event Effects/Upsets, Damage to DNA
  - Major area, but enough already said this week

Similarities (continued)

- Speed
  - CPU improvements will NOT dig us out of this since the resolution of medical imaging will increase along with CPU improvements.
- Variance Reduction (event biasing)
  - We care about 1 to 2 percent effects
- Push to more quantify calculation accuracy
  - We want to know the error bars
- Problem of proprietary geometry information
  - As mentioned by Masanobu Ozaki, Sergio Ibarmia and others
  - In the case of radiation therapy, such as the work I was involved in with Varian, a solution was for them to trust one small group of developers with exact CAD information, who then created precise phase space that could be safely shared with others (but this will not solve many of your cases)

Wrapping Geant4

- To address the “Geant4 is too hard to use” issue, some of you have wrapped Geant4 into more domain-specific applications such as:
  MRED, CREME, SPENVIS, GRAS, etc.

- In medicine, the acceptance of Monte Carlo was heavily influenced by one such wrapping activity, the Omega project, which wrapped EGS into the tools BEAMnrc and DOSxyz
  (received Coolidge award at last month’s AAPM)

- Activities to wrap Geant4 for medical physics include:
  GATE, PTSim, GAMOS, TOPAS

Geant4 Tech Transfer from Aerospace to Medicine

G4GeneralParticleSource

QinetiQ

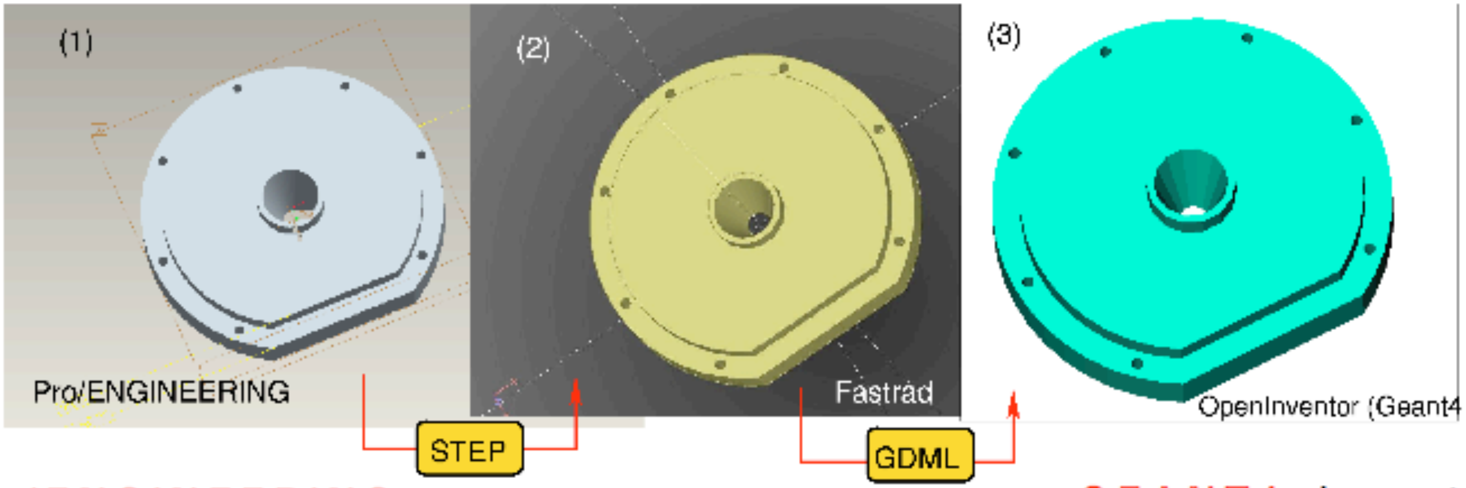
Geant4 General Particle Source

Whilst the default particle generator within Geant4 (G4ParticleGun) may be suitable for simple studies in accelerator physics, the potential complexity of the primary particle distributions within the space environment necessitates a more sophisticated sampling algorithm. The General Particle Source (GPS, G4 class name: G4GeneralParticleSource) allows the user to utilise standard energy, angular and spatial distributions:

- **Spectrum**: linear, exponential, power-law, Gaussian, blackbody, or piece-wise fits to data.
- **Angular distribution**: unidirectional, isotropic, cosine-law, beam or arbitrary (user defined).
- **Spatial sampling**: on simple 2D or 3D surfaces such as discs, spheres, and boxes.
- **Multiple sources:** multiple independent sources can be used in the same run.

CAD to GDML

Operating Procedure: 3 Steps



Pro/ENGINEERING: Choose AP203-IS for STEP EXPORT FORMAT. Create the STEP files.

FASTRAD: Associate materials to the STEP regions. Export files as GDML.

GEANT4: Import GDML (**G**eneralized **D**ynamic **M**arkup **L**anguage) and define the coordinates.

By interfacing Pro/ENGINEERING with GEANT4 we created an accurate model of the treatment head.

Varian TrueBeam

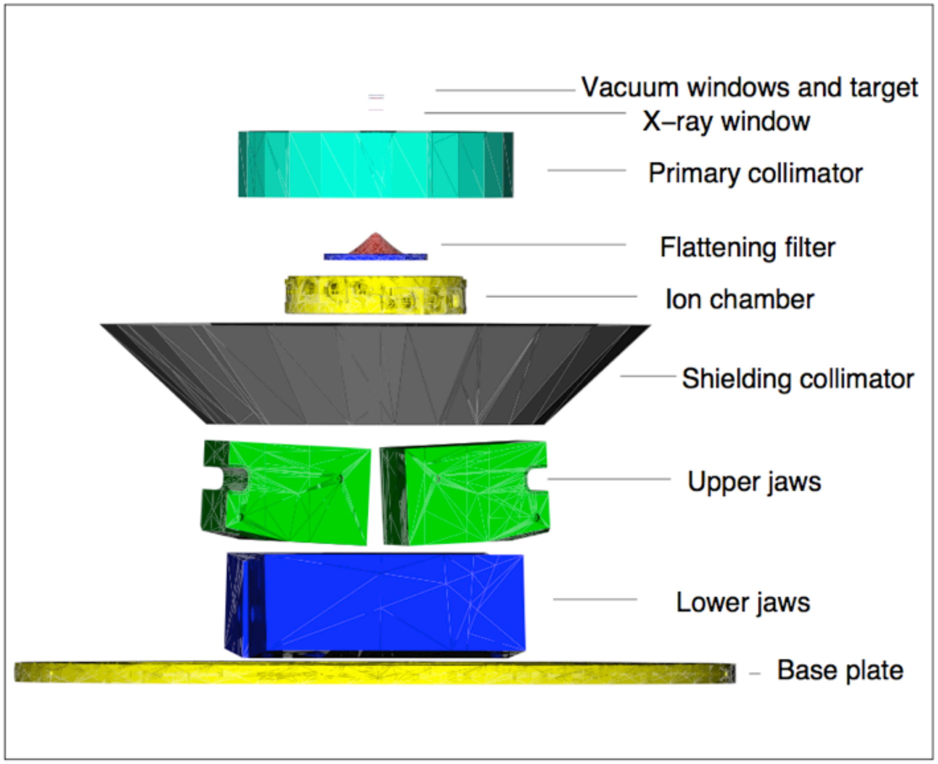


FIG. 3: Visualization of the treatment head components using OpenInventor in Geant4. All the components have been imported in Geant4 as GDML input files.

Linking Computer-Aided Design (CAD) to Geant4-based Monte Carlo Simulations for Precise Implementation of Complex Treatment Head Geometries
Magdalena Constantin, Dragos E. Constantin, Paul J. Keall - Stanford Univ
Anisha Narula, Michelle Svatos - Varian Medical Systems
Joseph Perl - SLAC
Phys. Med. Biol. 55 N211
doi: 10.1088/0031-9155/55/8/N03

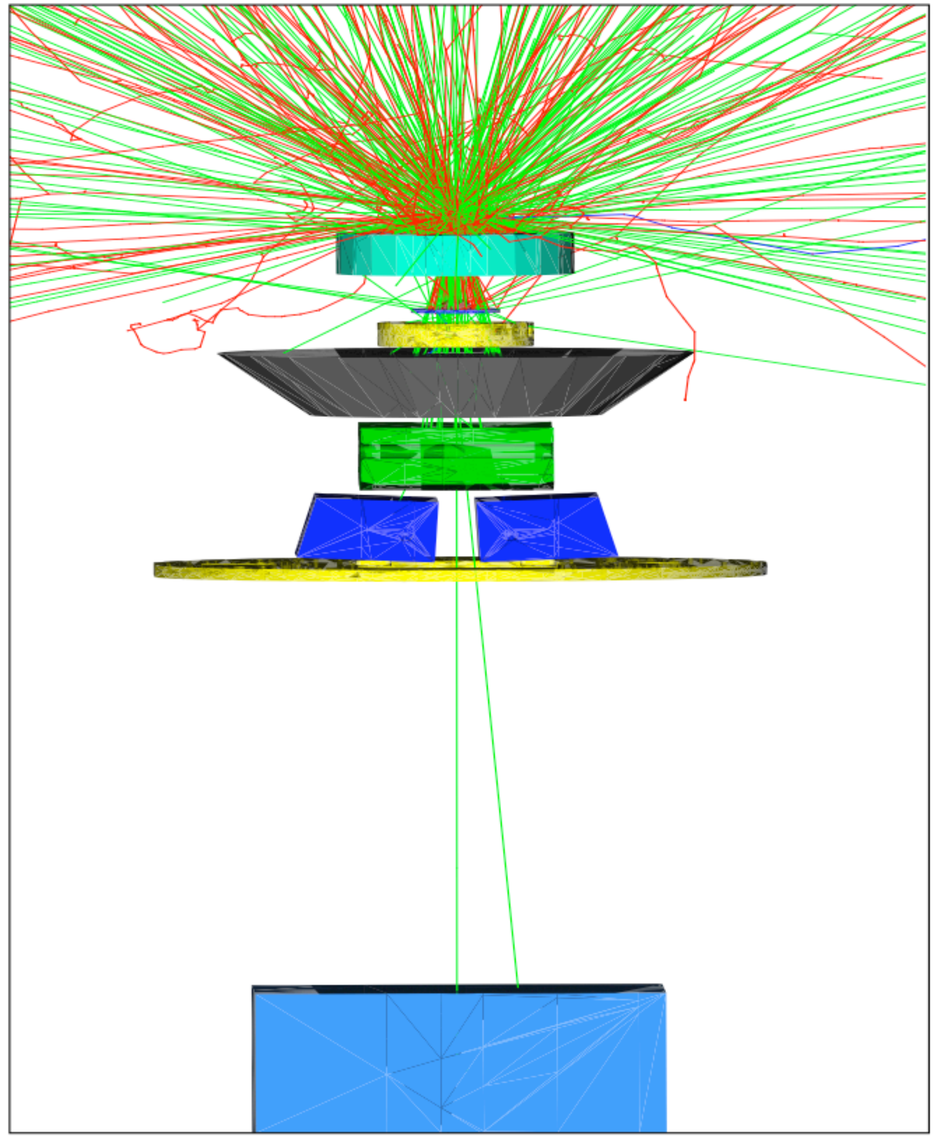


FIG. 4: Visualization of Geant4 particle trajectories along the treatment head components using OpenInventor. Electrons are photons shown in red and green, respectively. Field size was set to $10 \times 10\text{cm}^2$ and SSD to 100 cm. Note that for proprietary reasons, the appearance of some of the components in this figure has been modified.

Medical will Steal ASAP

- Improved Step format
  - Medical Physics users would be very pleased to get the new step format being pushed by ESA which adds hierarchy and materials
- DICOM to STL to STL2GDML
  - This code shown this week by Francisco Garcia has obvious immediate uses in Medical Physics
    - Delineate medical implants in the patient
    - Delineate patient positioning devices included in the scan
    - etc.

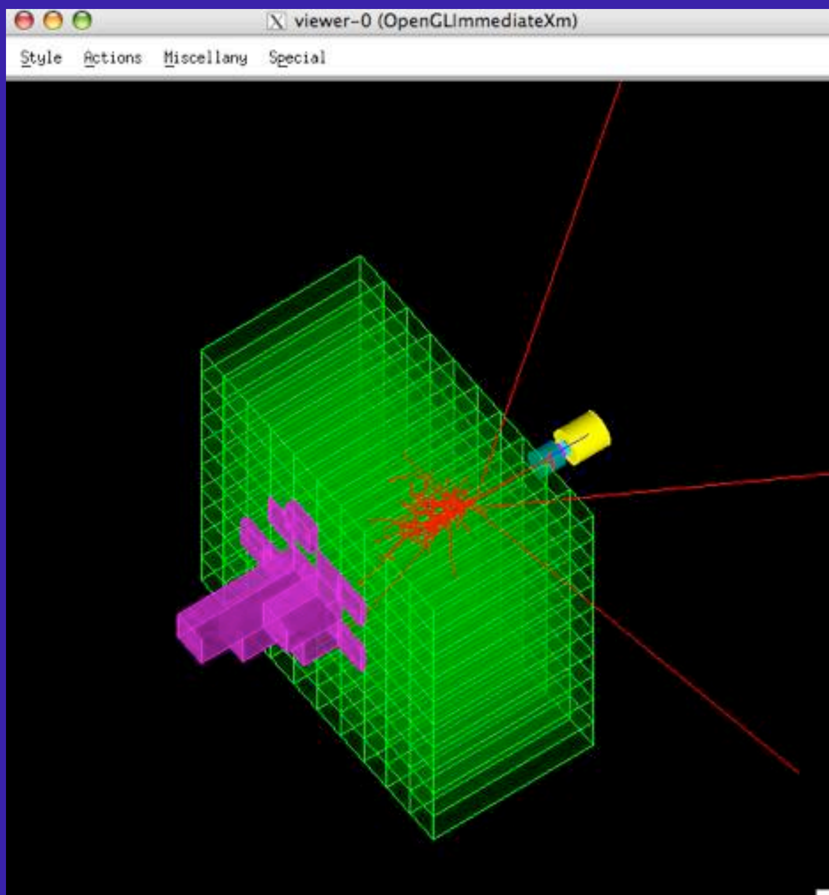
New Initiative

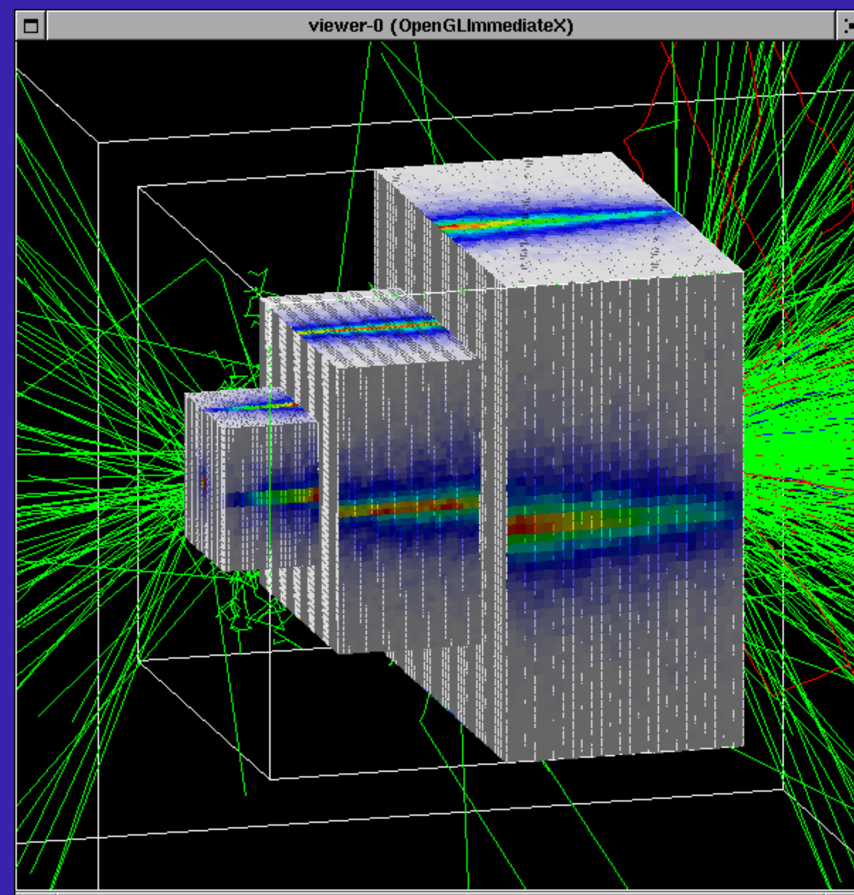
- Coming out of this week's meeting, some of us are discussing how we can combine funding from Space and Medical users to accelerate improvements in the CAD to GDML pathway.
  - Steven Dreiker, Lockheed Martin
    - outreach to Aerospace Community
  - Joseph Perl, SLAC
    - outreach to Medical Community (such as Varian Medical Systems, IBA Group, etc.)
  - Norman Graf, SLAC
    - GDML expertise
  - Giovanni Santin, ESA
    - coordinate with TRAD (makers of FASTRAD)

Geant4 Tech Transfer from Medicine to Aerospace

Simplified Scoring

- HEP: every detector is a novel design
  - user designs own “hit” classes to record relevant data
    or pass that data on to the rest of a special-purpose analysis system
- Space or Med Phys: may just want to score dose or flux in standard ways
- Significant funding for this work from from the JST/JCREST project in Japan for Particle Therapy

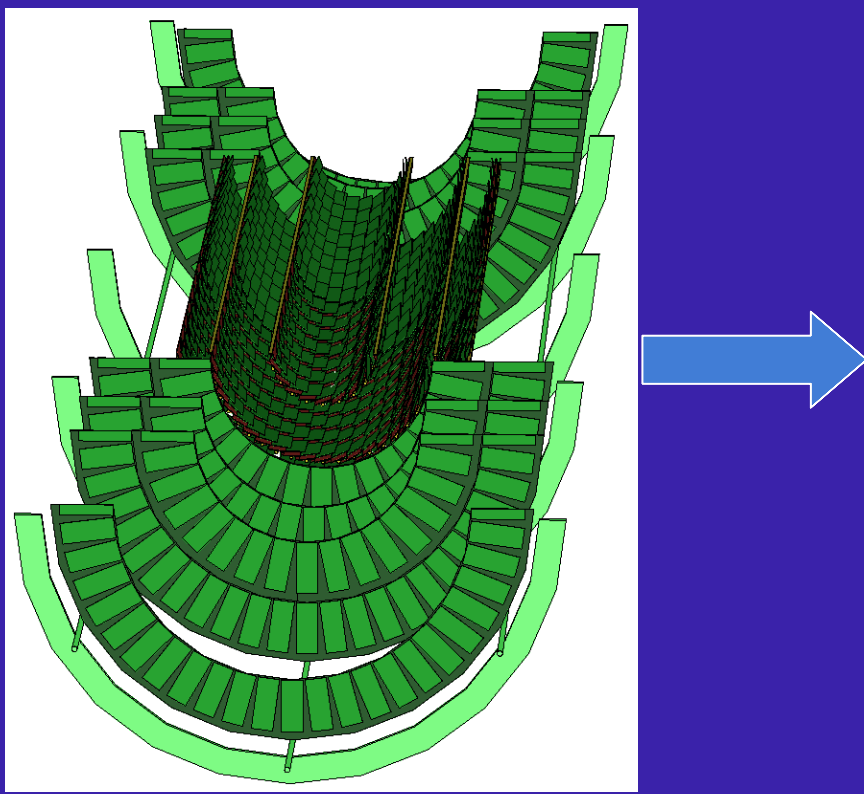


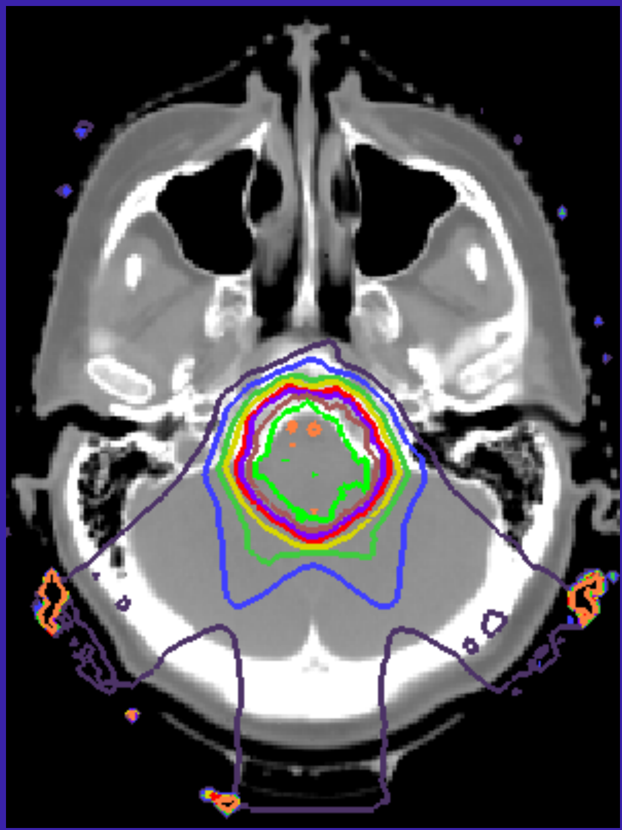


Tools for Visualizing Volumetric Data

Support for Voxel Geometries

- HEP: constructive solid geometry
- Med Phys: constructive solid geometry + imported voxel data (DICOM)
  - different strategies for geometry and navigators

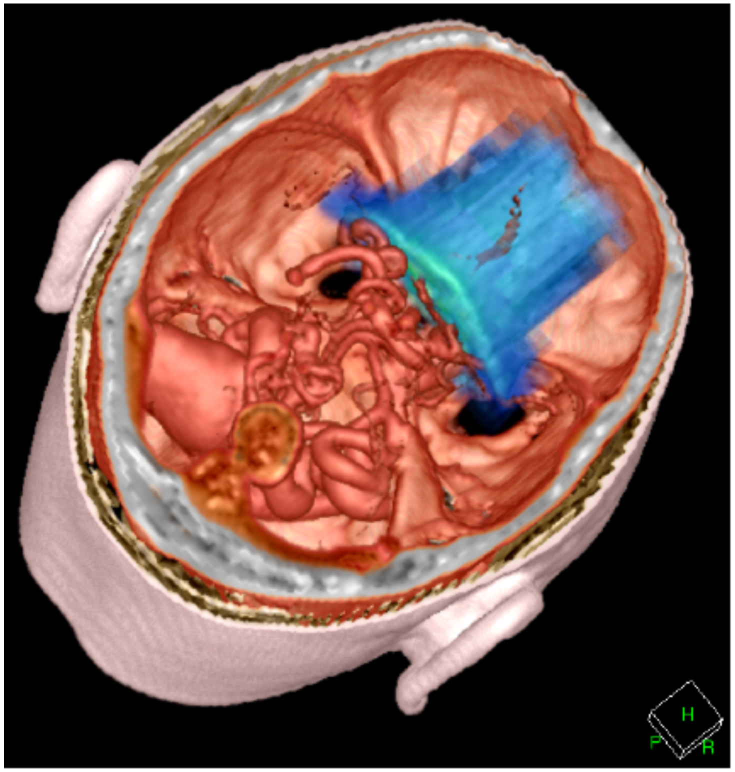




gMocren

Great tool available for volume visualization

- From JST/CREST project (Japan) to improve Geant4 for medical physics
- Able to visualize:
  - Volume data
    (including overlay of more than one set)
  - Trajectories
  - Geometry
- Runs on:
  - Windows and Linux
  - Mac will likely happen soon
  - Based on a commercial package but offered freely to all Geant4 users
  - http://geant4.kek.jp/gMocren
  - Installation is straightforward, follow the Download link on the above page
    - First run gMocren's one-click installer
    - Then, inside C:\Program Files\gMocren\gtk, you will find the one-click installer for gtk



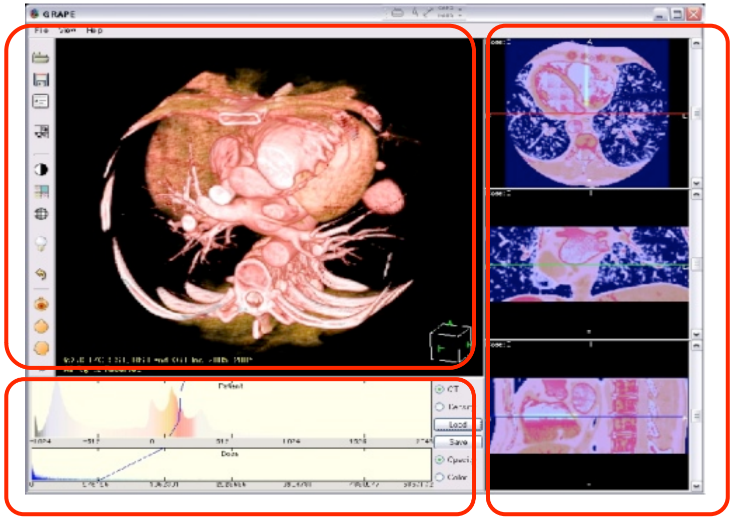
gMocren : A Visualization Tool

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

gMocren and utility software are freely available.

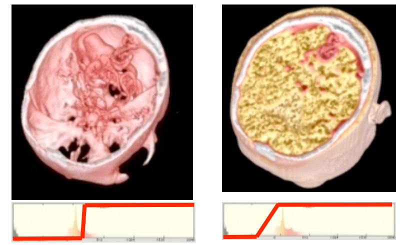
Supported system :
- Windows 2k/XP or PC Linux OS
- Pentium 4 or faster
- more than 1 GB (recommend)

3D (ray casting) 2D (MPR)



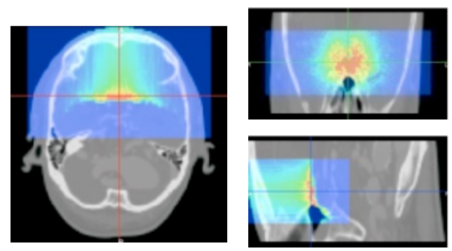
Opacity curve and color map editor

Opacity curve and color map editor



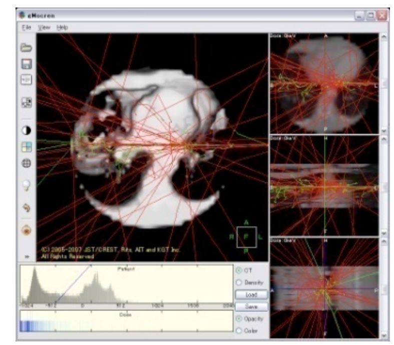
free hand or templates with WW&WL editing

Calculated dose distribution

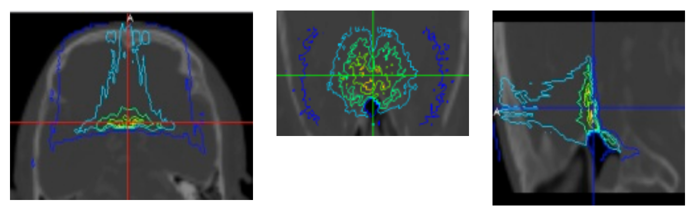


color mapping

Particle trajectories



Trajectory information in the simulation is available.

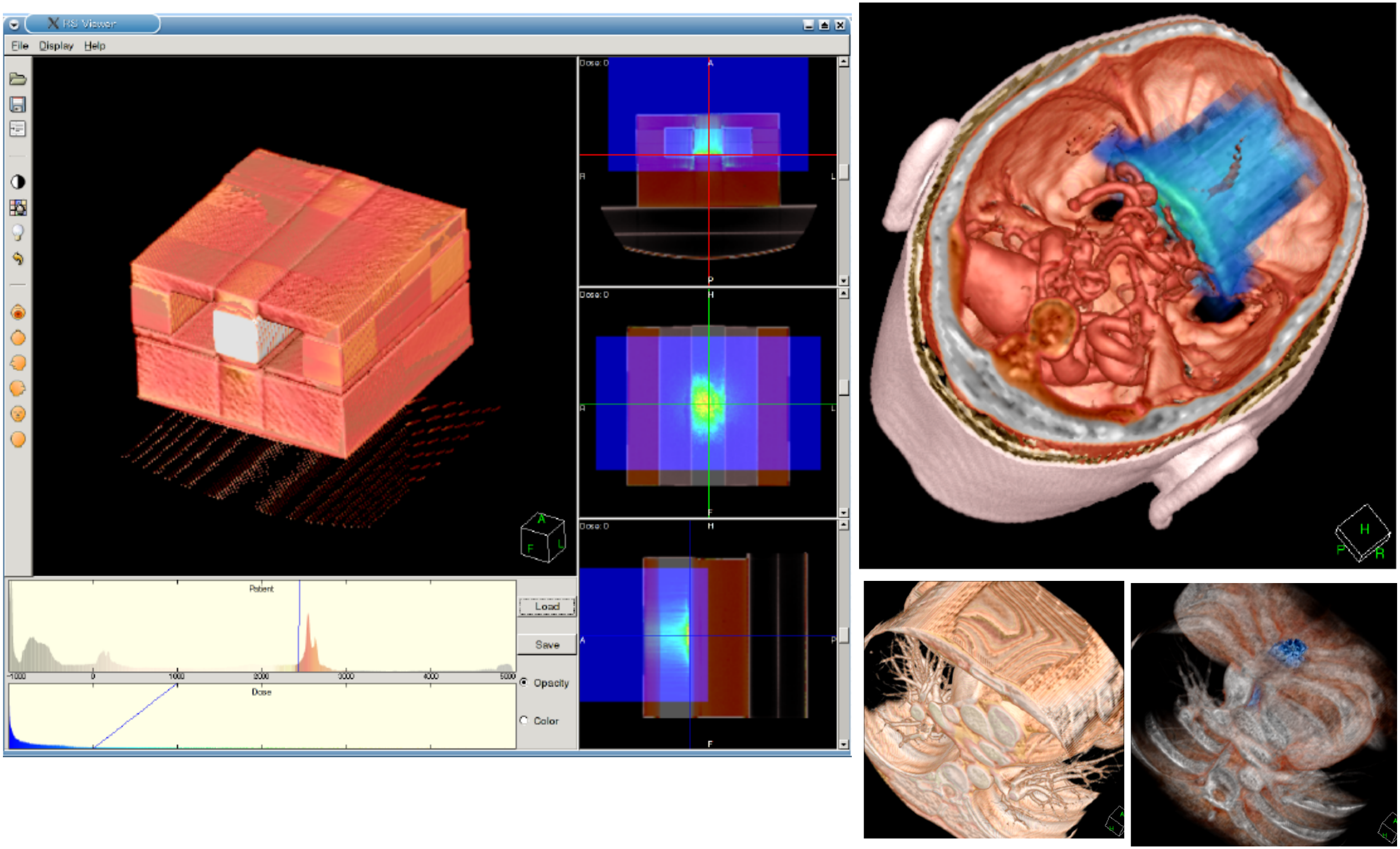


contour plot

***Functionality Requirements* :**

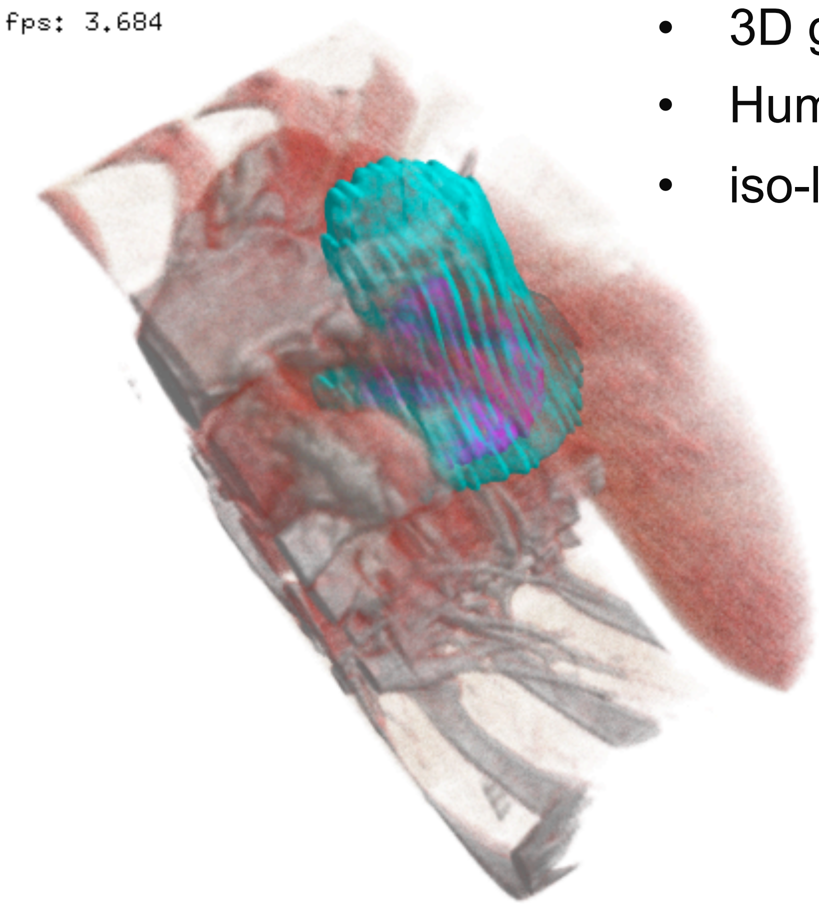
- To visualize
  - the modality image used by the simulation,
  - the calculated dose distribution and
  - the particle trajectories
  - in an agreeable speed
- Transfer function editor
- Multi-platform

Screen shots of gMocren visualization tool

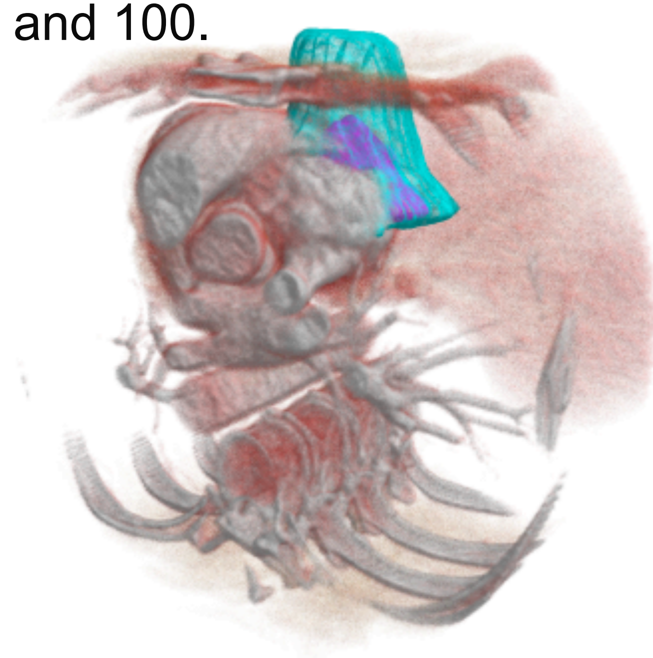


Coming Soon: New Method to Display Dose Distribution Tranparently over CT image

- Satoshi Tanaka, Kyoko Hasegawa - Ritsumeikan University
- Akinori Kimura - Ashikaga Institute of Technology



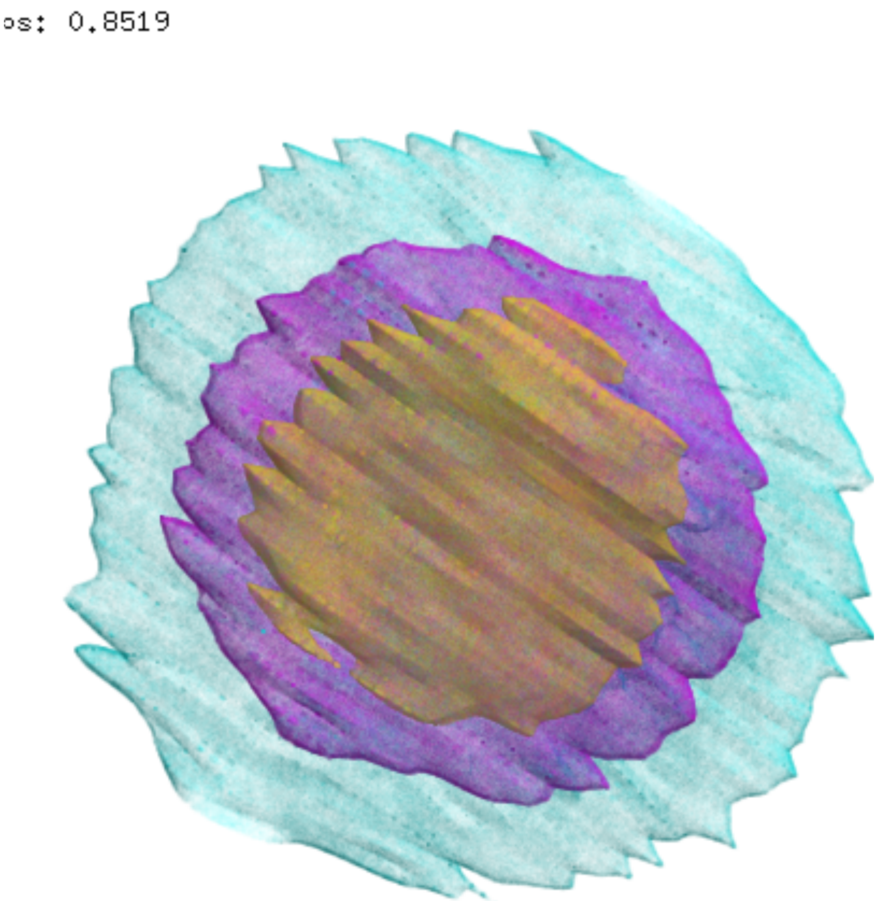
- 3D gaussian smoothing for the noisy dose data.
- Human Breast: multiple-iso-surface with
- iso-levels 50 and 100.

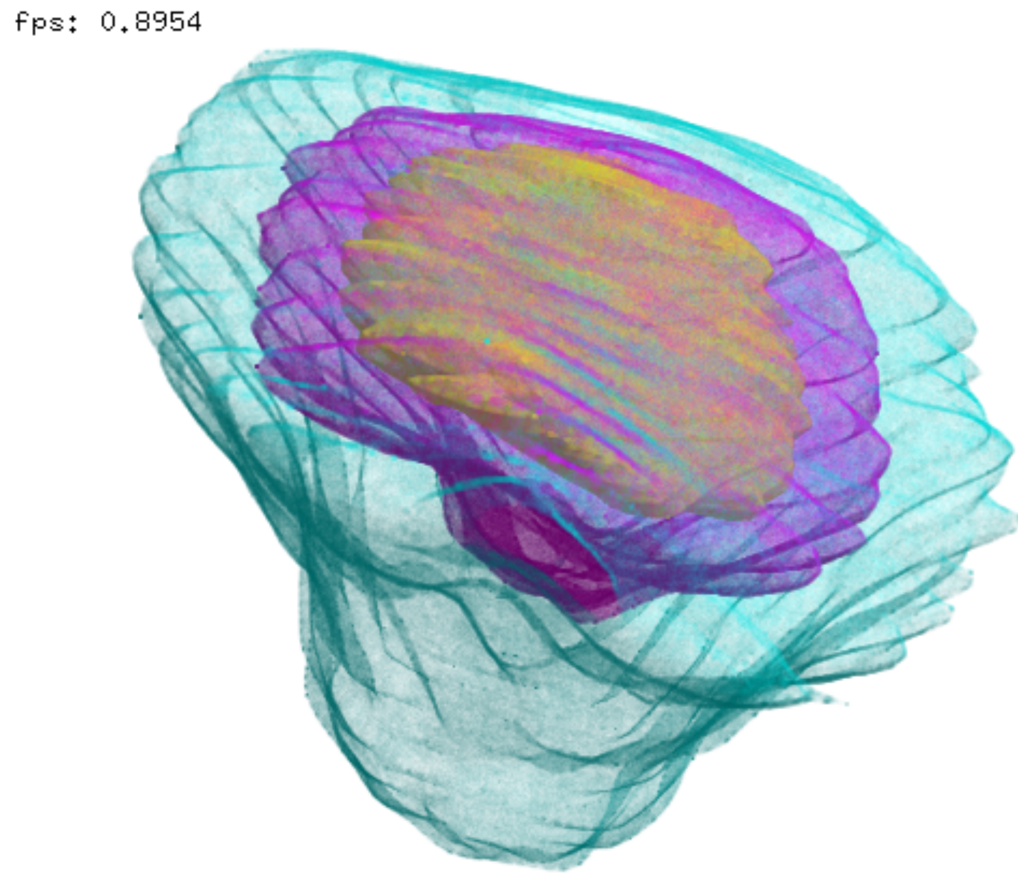


- Cubic voxels now, will eventually also support tetrahedral

Volume Data Visualization

- 3D gaussian smoothing for the noisy dose data.
- multiple-iso-surface with iso-levels 50, 100 and 150





- Satoshi Tanaka, Kyoko Hasegawa - Ritsumeikan University
- Akinori Kimura - Ashikaga Institute of Technology

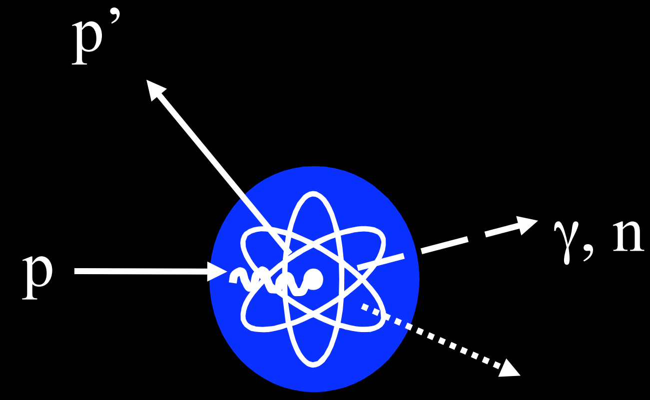
Additional Current Hot Topics in Medical Geant4

Solutions for Throughput

- Cloud computing
  - Since use is very "bursty"
- GPU
  - since medical imaging experts are already moving that direction, hence there is significant GPU experience in house at major medical physics research centers

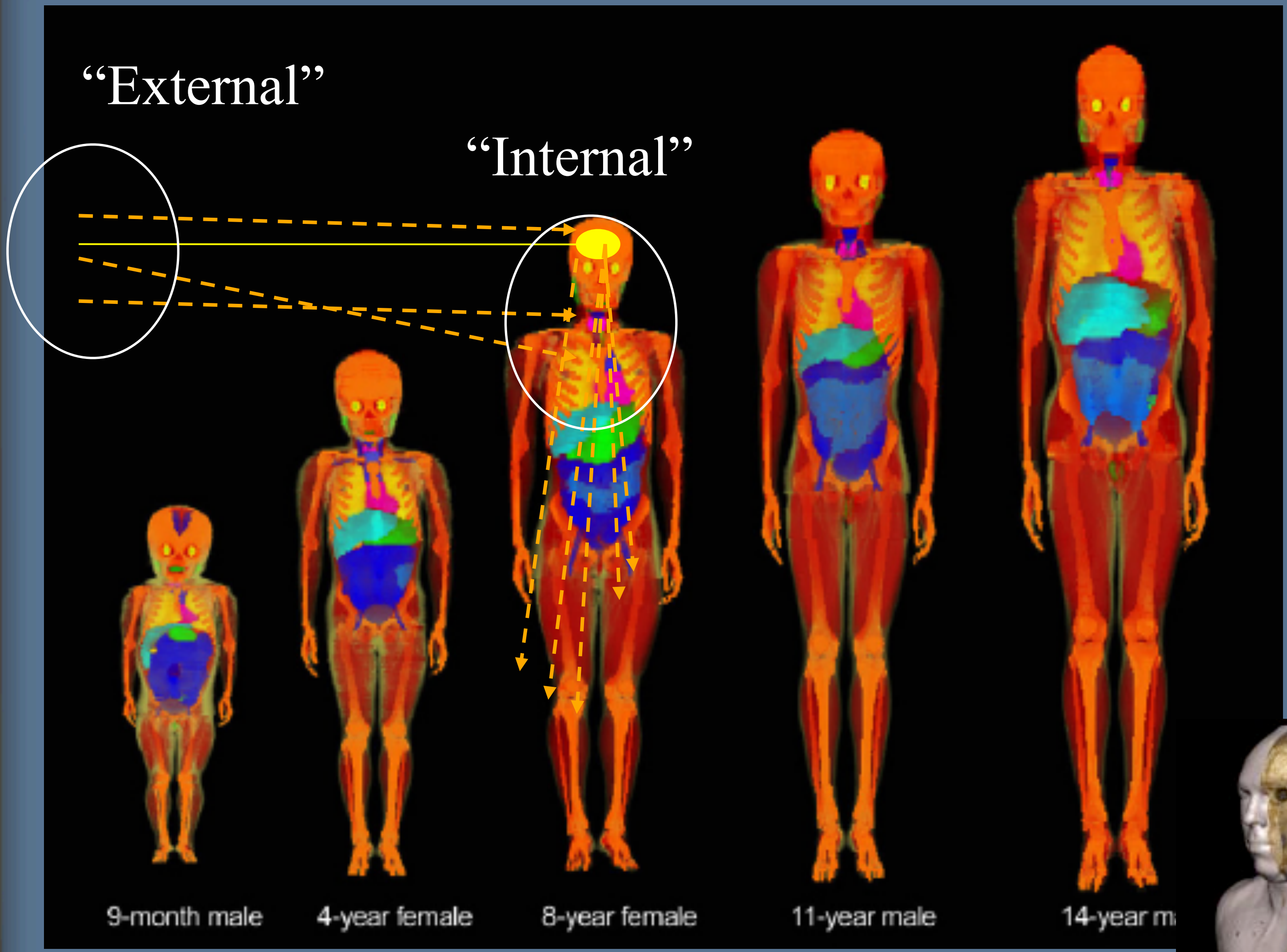
BREPS Geometry

The risk associated with neutron radiation in proton therapy



C. Z. Jarlskog, C. Lee, H. Jiang, W. Bolch, X.G. Xu, H. Paganetti

MASSACHUSETTS GENERAL HOSPITAL
HARVARD MEDICAL SCHOOL
UNIVERSITY OF FLORIDA
Rensselaer



Existing Phantoms implemented into the Geant4 Monte Carlo dose calculation environment at Mass. Gen. Hosp.

Deformable Human Phantoms

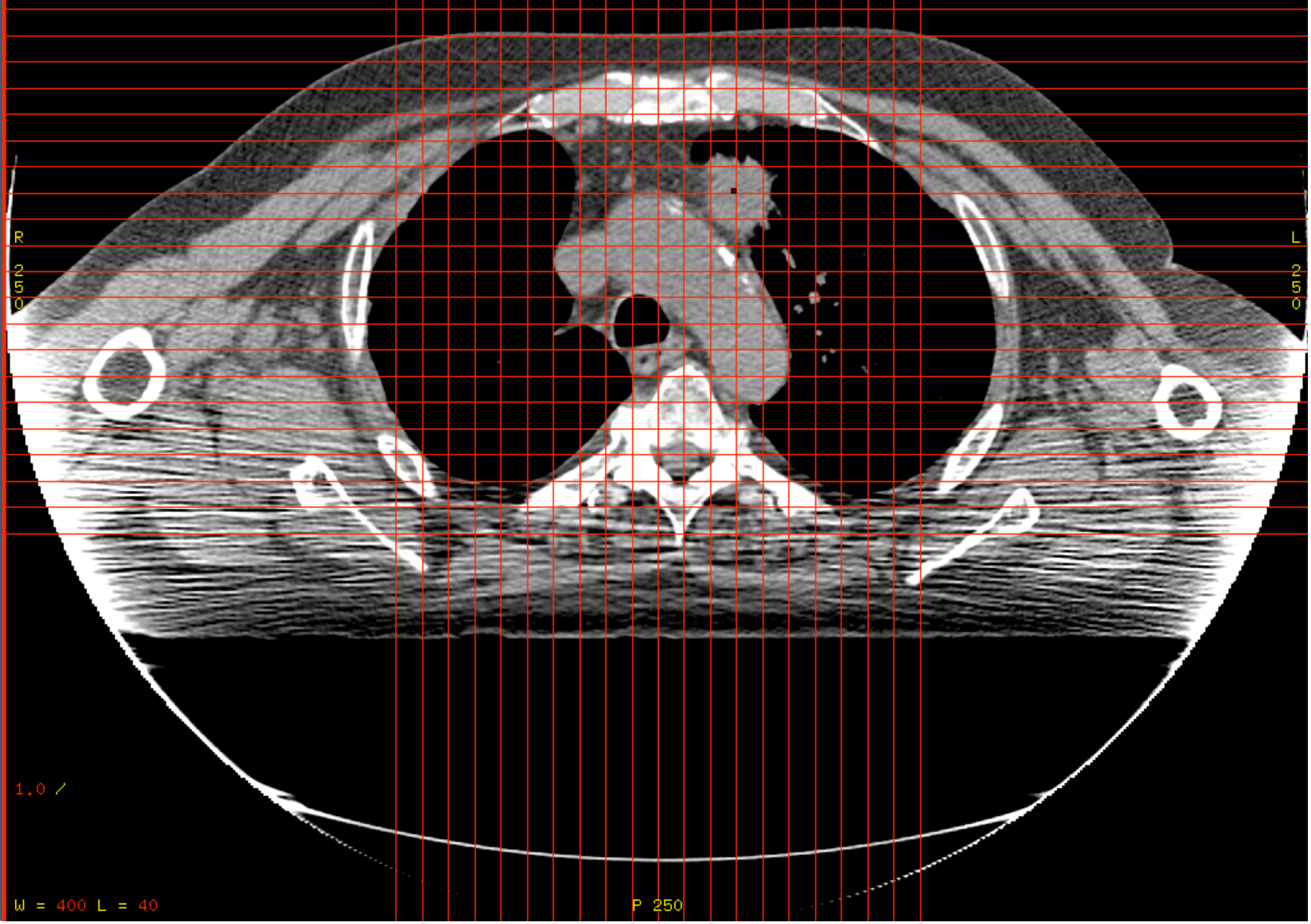
- Next step in phantoms, allowing it to be customized based on flexible body metrics

4D Monte Carlo, i.e., Motion

- Towards more conformal therapy
- Obvious case is lung cancer, but to the 1mm level of accuracy demanded by the most conformal therapies, every organ is in motion all the time
- I’m not sure how this could be relevant to your field, possibly not at all, but it’s worth knowing what challenging parts of the Geant4 puzzle are being solved elsewhere

Lateral Motion of Lung Tumor

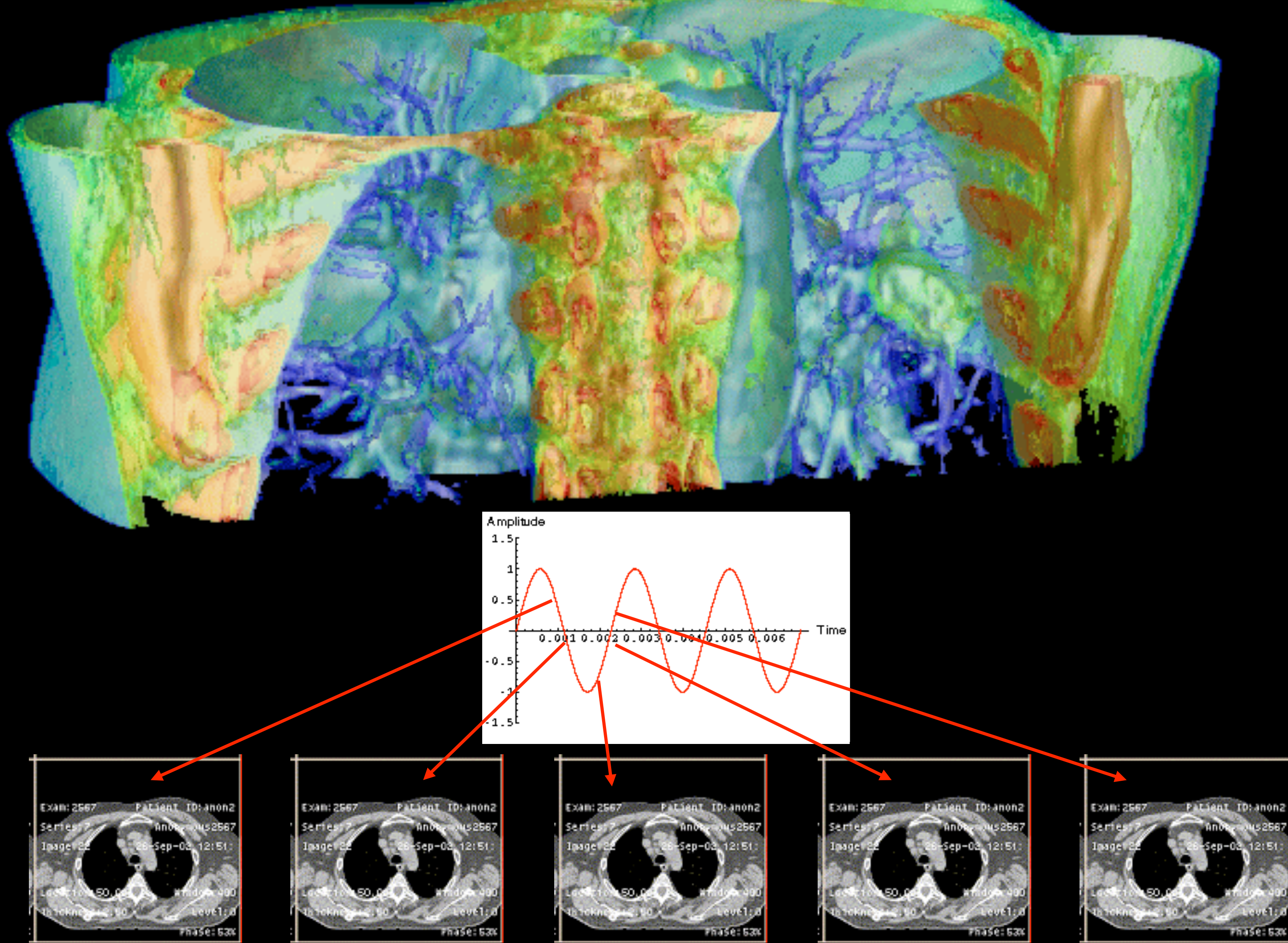
4D Patient



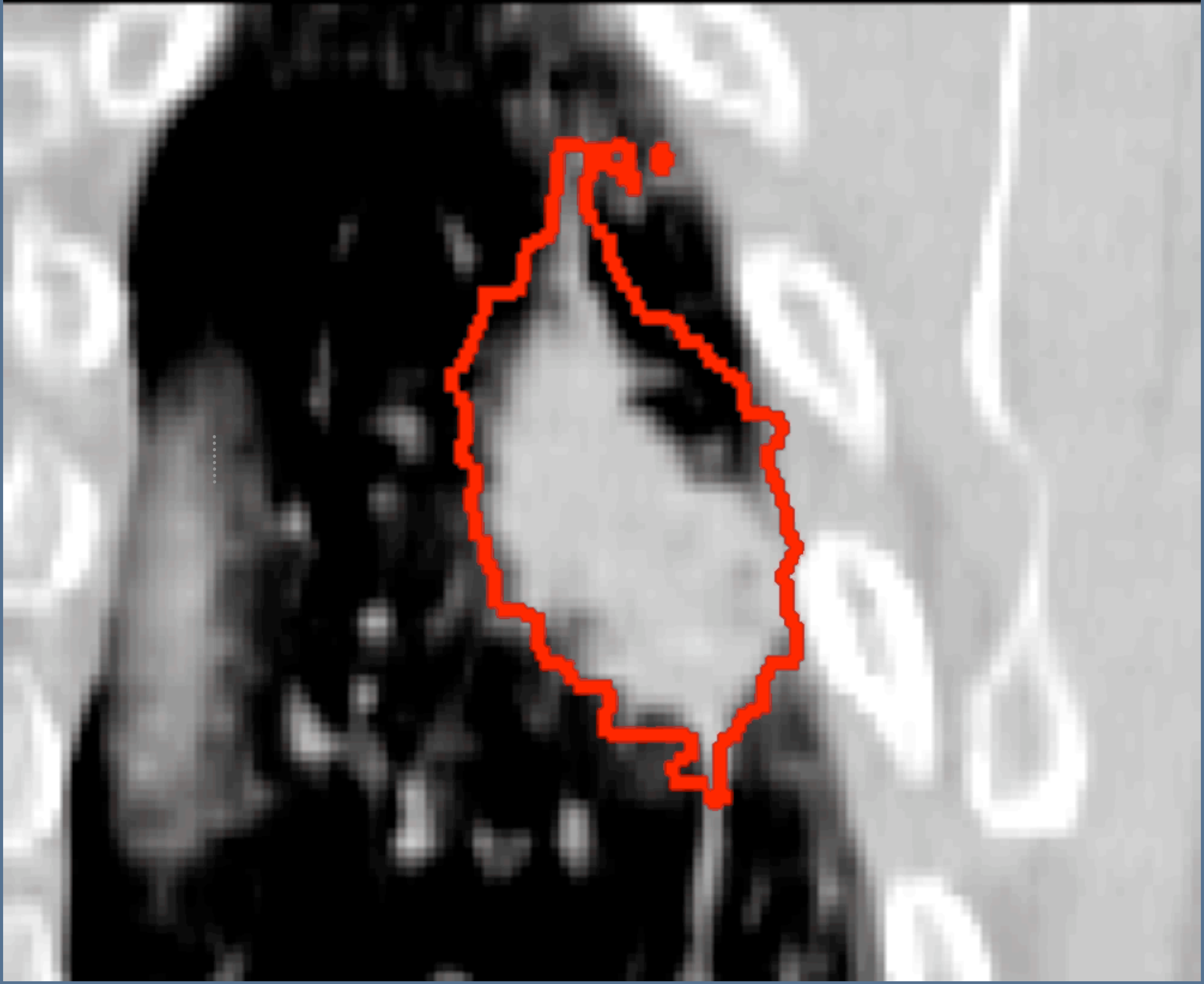
- Breathing Patient -

© Eike Rietzel

4D Patient

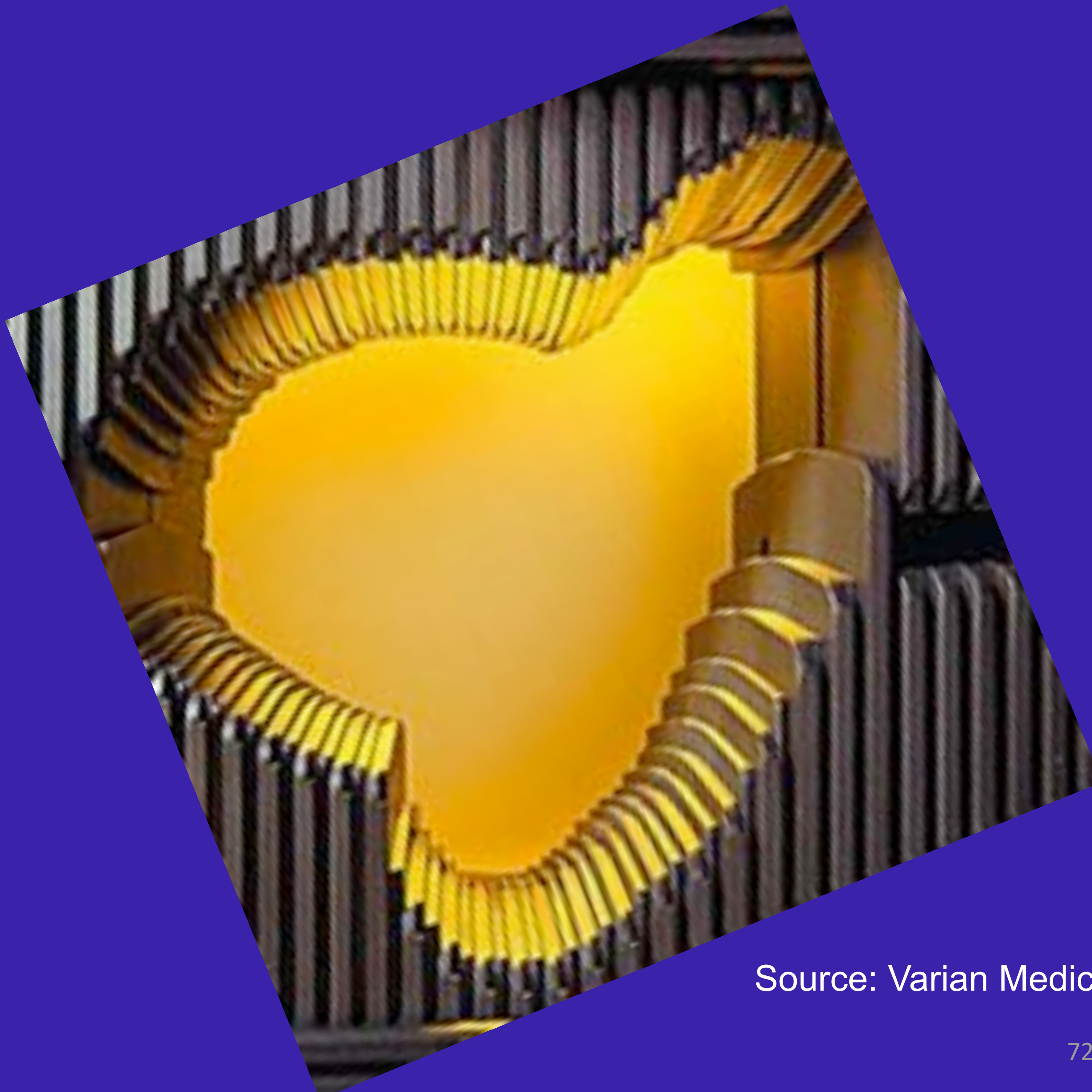


Characterize Tumor Motion



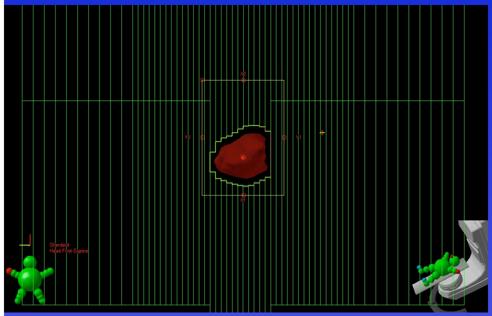
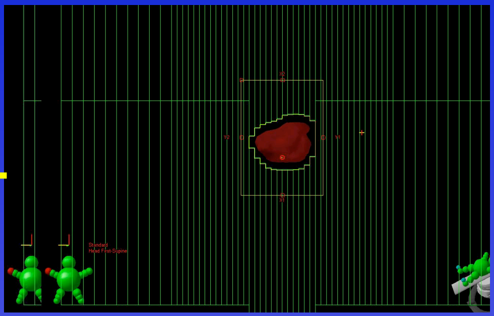
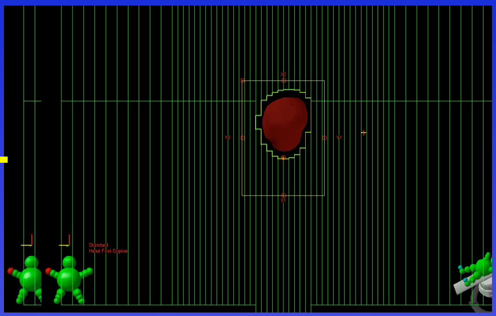
4D Patient

Multileaf Collimator



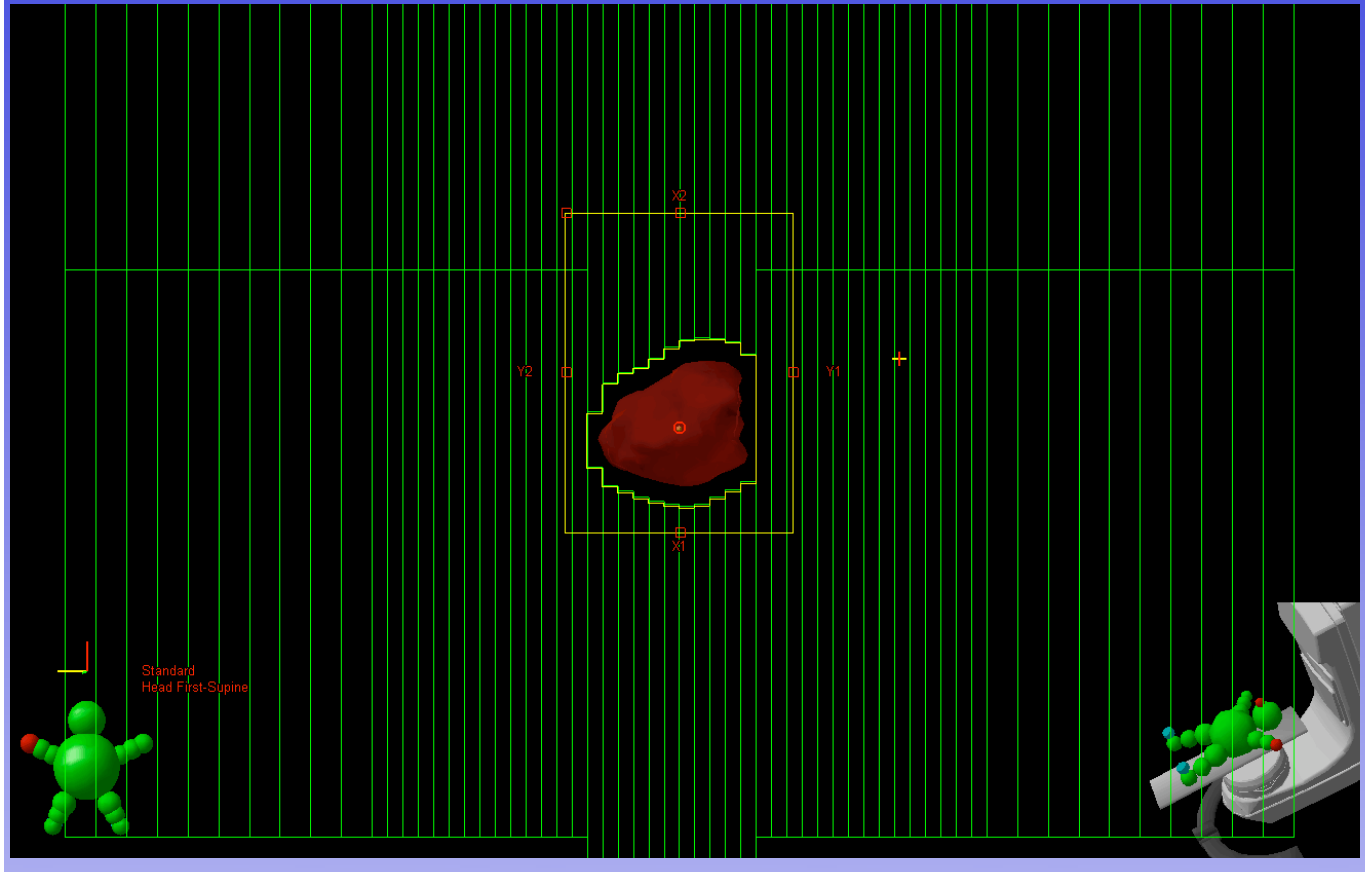
Source: Varian Medical Systems

4D RT Treatment Plan

 +  +  + ……

Source: Lei Xing, Stanford University

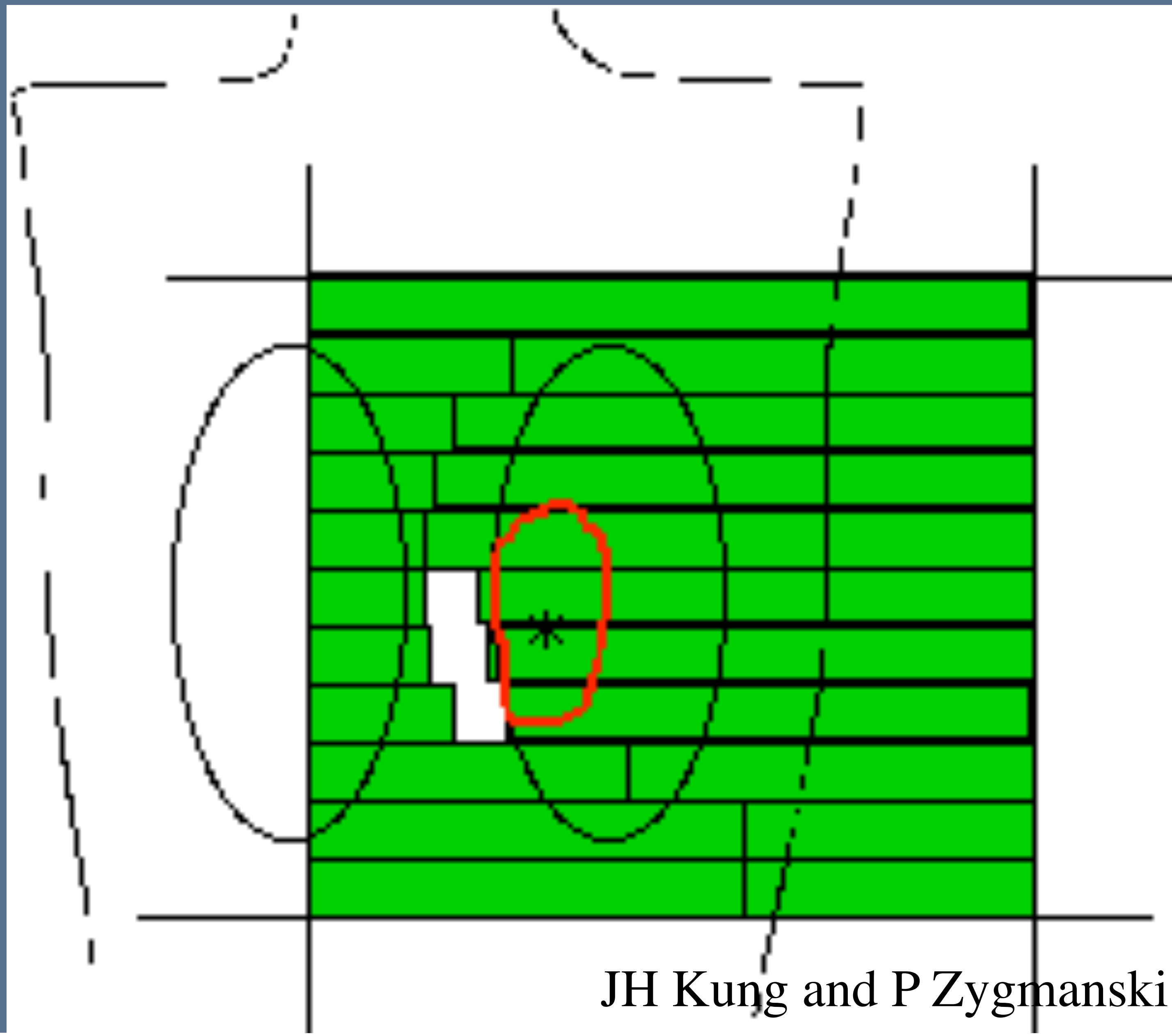
Y. Yang, S. Huq, L Xing, Med. Phys, 2006



Optimize dose distribution in spatial and temporal domains

This slide is just to explain patient motion, but the work shown here is not using Geant4

Interplay effects between organ motion



JH Kung and P Zygmanski

4D Solutions

- Tumor tracking
  - combining therapy and imaging
  - Linac + MRI
  - Particle Therapy + PET and/or Prompt Gamma
- Deformable grids
  - Warping the DICOM grid
  - Or remapping dose from one voxel to another based on knowledge of motion

TOPAS - TOol for PArticle Simulation

- Wrap Geant4 for Particle Therapy
- Massachusetts General Hospital, SLAC, UCSF

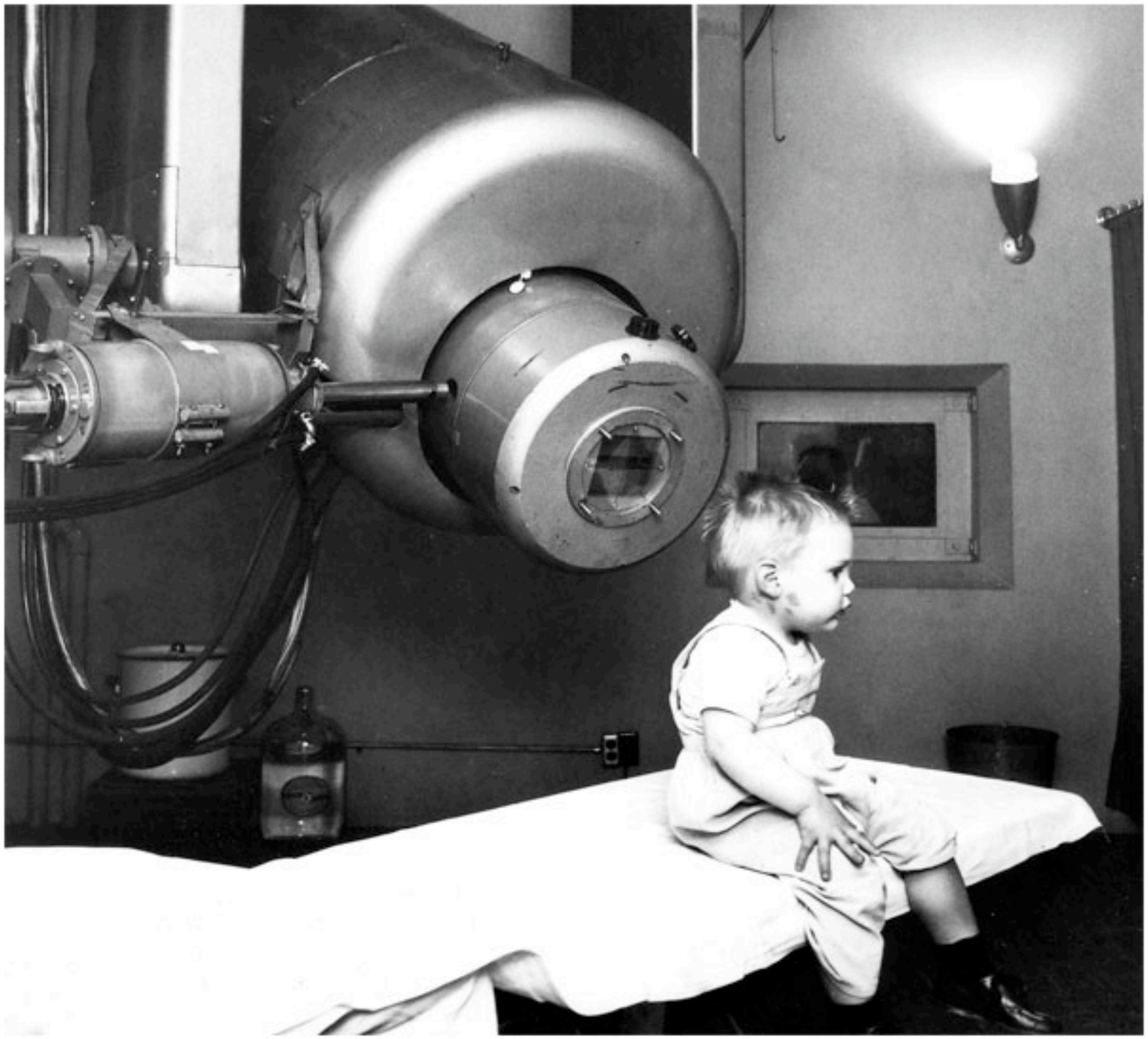
- Specific scope of the TOPAS NIH grant is Protons, but since it is based on Geant4, switching to Electron, Gamma or even Carbon is trivial.

- To use Geant4 well for particle therapy today, one must be both an expert in Gean4 and an expert in medical physics
- With TOPAS, it will be sufficient to be an expert in medical physics

- TOPAS seeks to do for particle therapy what the OMEGA project (BEAMxyz and DOSxyz) did for electron & gamma therapy.

- Specific Aims:
  - Build TOPAS
  - Make it fast
  - Validate TOPAS against existing experimental data from several proton therapy centers
    - Note that underlying physics models are already in Geant4 and have already been validated against already measured data
  - Distribute, free of charge, for Linux, Mac and Windows

Onwards



The first patient to receive radiation therapy from the medical linear accelerator at Stanford was a 2-year-old boy.

Stanford University Dept of Radiation Oncology