G4 Applications From Australian Users

B. Oborn[1,2], A. Rosenfeld[1], S. Guatelli[1]

[1]Centre for Medical Radiation Physics (CMRP),
University of Wollongong

[2]Illawarra Cancer Care Centre,
Wollongong Hospital, NSW Australia

B. Oborn: bmo03@uow.edu.au, A. Rosenfeld: anatoly_rosenfeld@uow.edu.au; S. Guatelli: susanna_guatelli@uow.edu.au

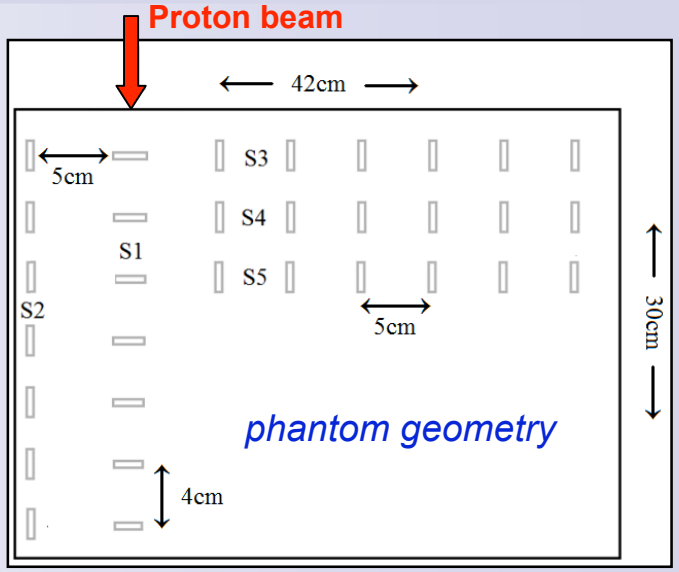
Geant4 applications in Australia - Overview

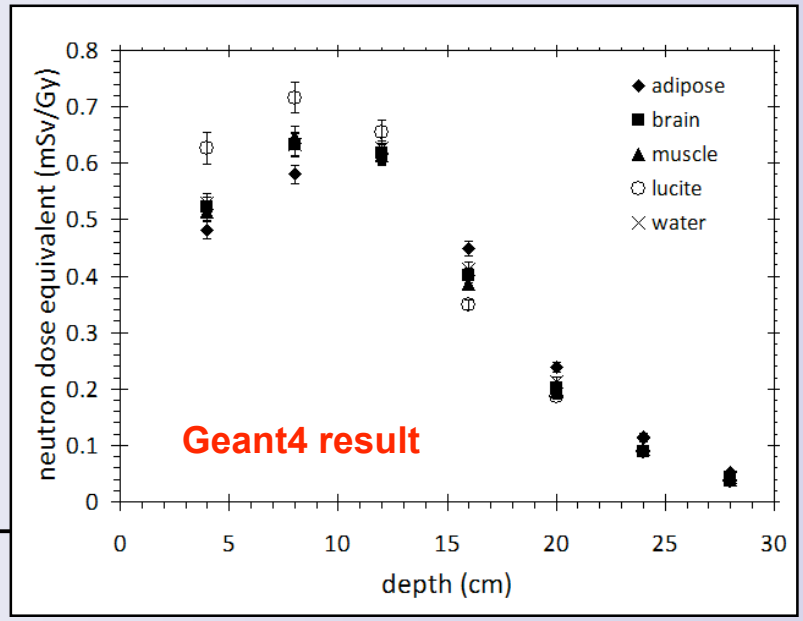
- Geant4 applications in
  - Dosimetry
  - Microdosimetry
  - Nanodosimetry
  - Imaging
  - Study and optimisation of novel detectors
- Studies to improve execution performance of Geant4 simulations

Dosimetry

Neutron doses in Proton therapy

- Compare neutron absorbed dose and dose equivalent in phantom substitutes to various ICRP defined tissues
- Neutrons generated in the treatment nozzle were ignored as they will be constant throughout
- **No single phantom material gives < 5% variation with tissue at all the points considered**
- Main author: S. Dowdell, CMRP, University of Wollongong

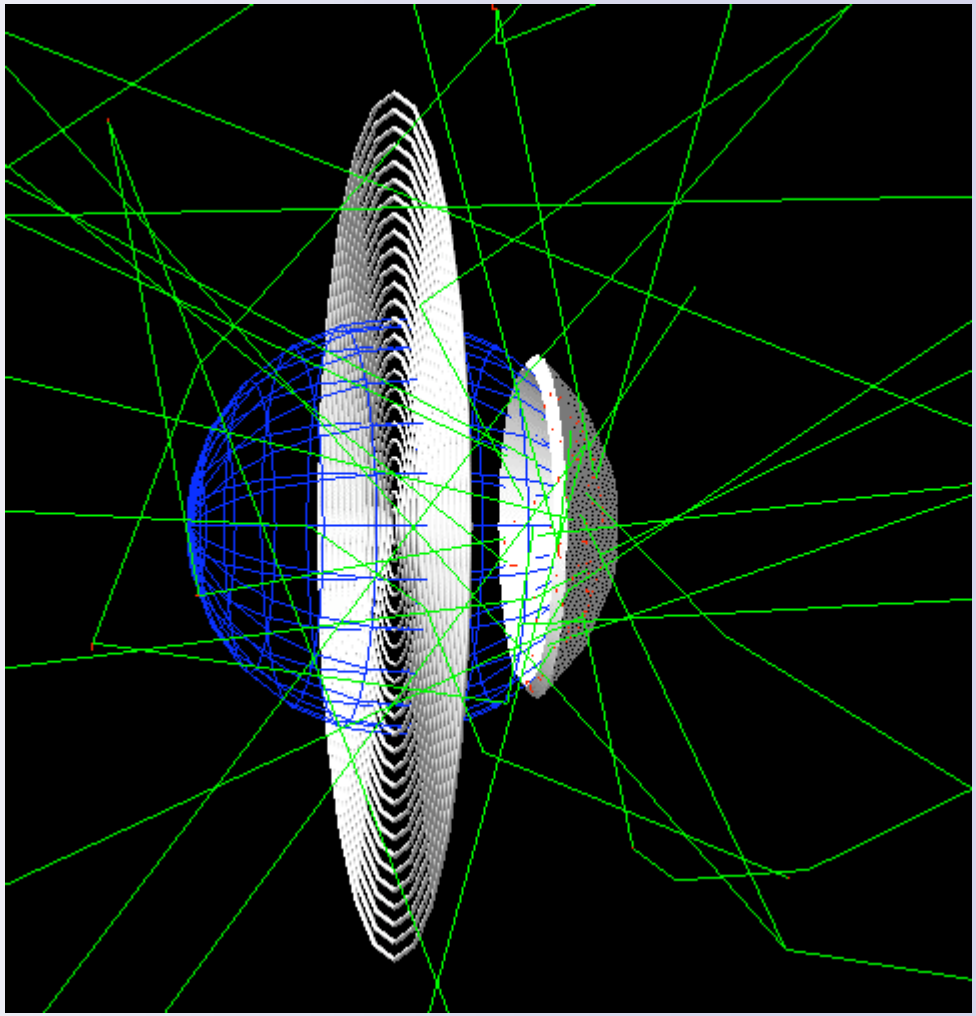




*S Dowdell, et al., Med Phys, **36**, 5412-5419, (2009)*

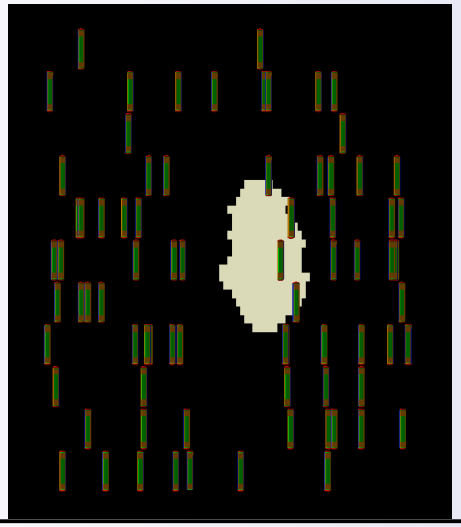
Ruthenium Eye Plaque

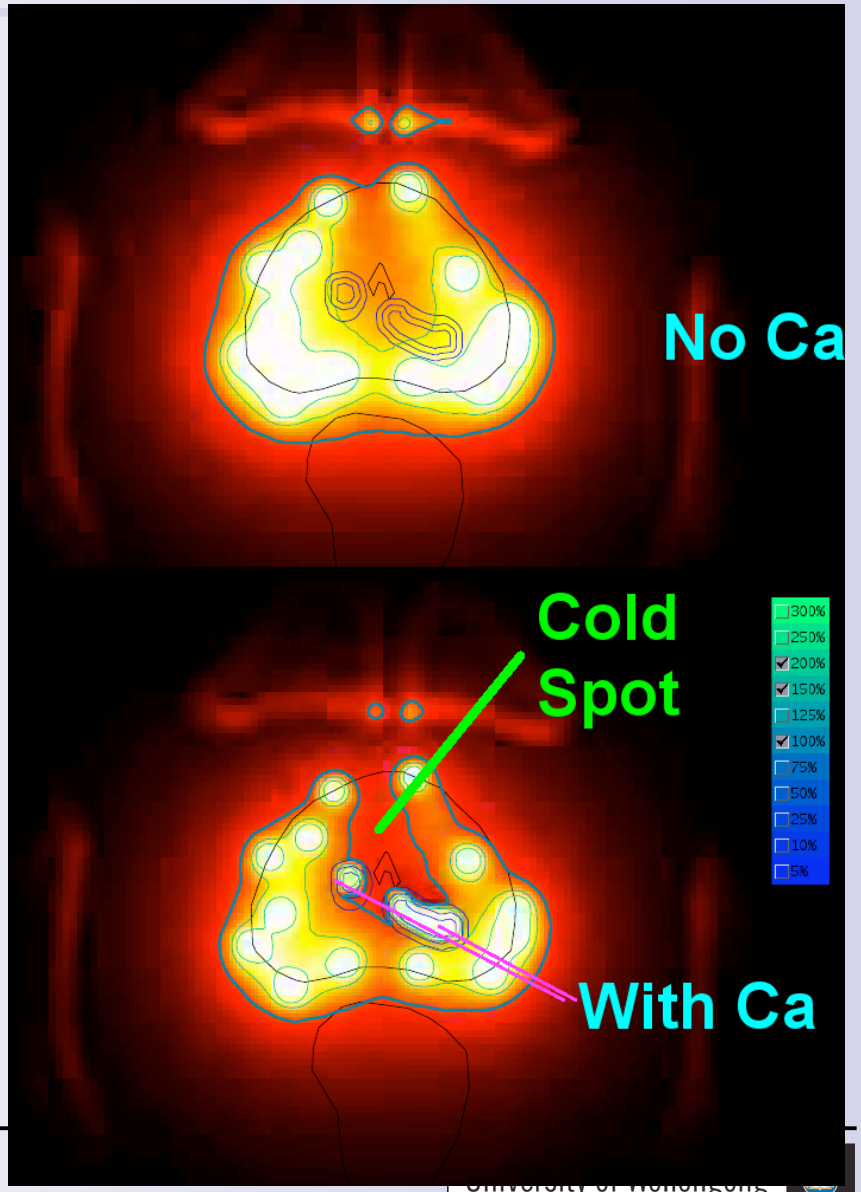
- Confirm dosimetry
- Characterise different sources
- Improve treatment
- Dean Cutajar, CMRP, University of Wollongong



Prostatic Calcifications in Seed Brachy

- Calcium deposits absorb dose
- Limited knowledge of calcifications
- Work in progress
- Brad Oborn, ICCC, CMRP, University of Wollongong



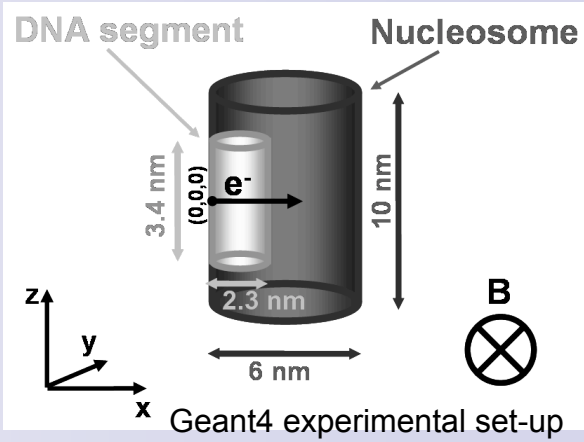


Nanodosimetry

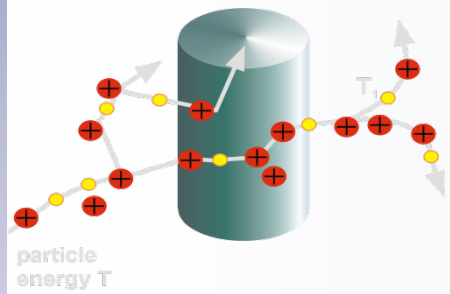
Study of enhancement of radiotherapy treatments by means of an external magnetic field

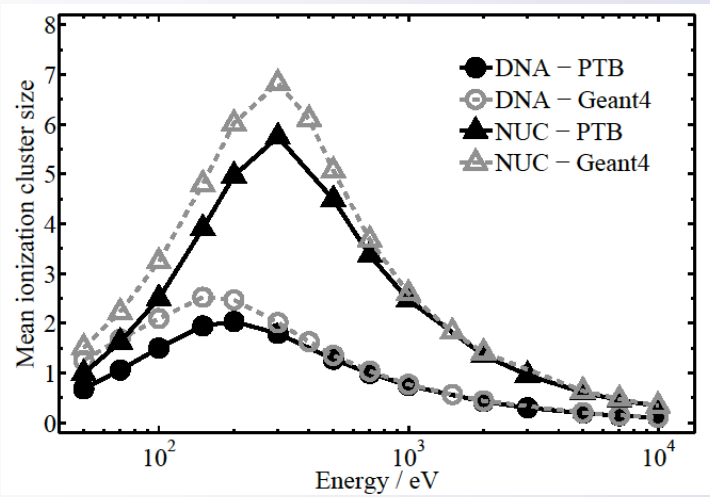
- Study of the effect of 1-10 T B-fields in cluster size distribution, at DNA scale
- Study by means of Geant4 Very Low Energy extensions
- Mean ionisation cluster-size varies up to **3%** in a MF for 50eV-10keV electrons. The enhancement of RBE observed in preliminary cell experiments seems to have different explanation than the *spatial redistribution* of the δ-e- deriving from the application of B. An experiment at PTB will be performed soon to investigate this possibility.

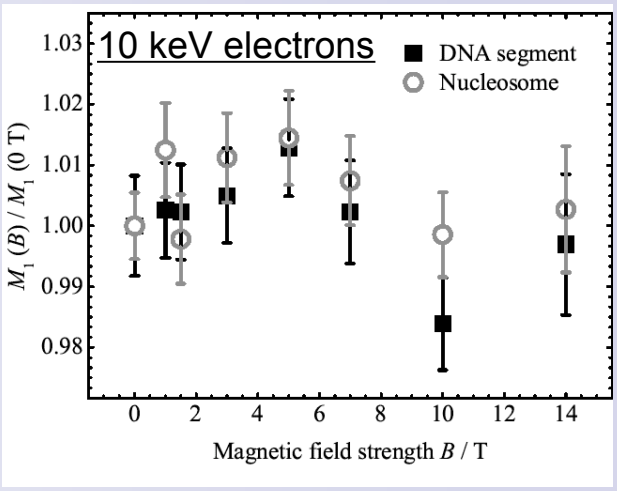
- Main author: M. Bug. Collaboration between CMRP, University of Wollongong, and PTB Germany



Geant4 experimental set-up





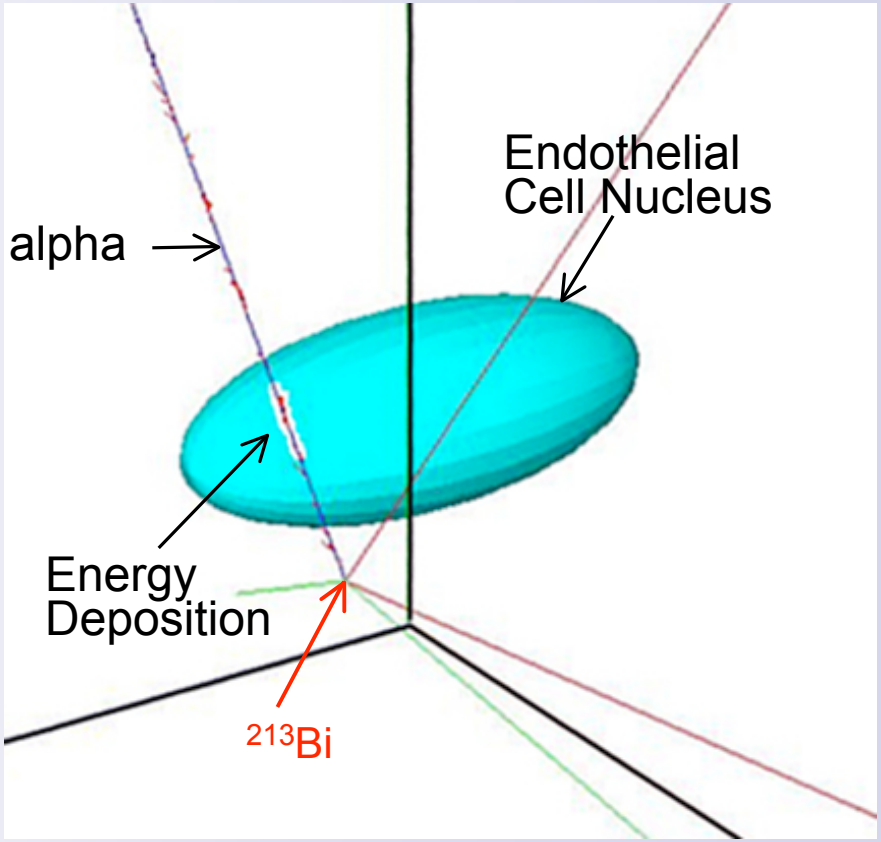


M. U. Bug, et al, Eur. Phys. J. D, DOI 10.1140/epjd/e2010-00145-1
Published online 26 May 2010

University of Wollongong

Tumour Anti-vascular Alpha Therapy

- TAVAT
- Geant4 simulation to:
  - Model ^{213}Bi decay in capillary endothelial cell
  - Calculate the energy deposition in the endothelial cell nucleus
  - By means of Geant4 Low Energy extensions
- Chen-Yu Huang, Brad Oborn, Susanna Guatelli, Barry Allen
- University of New South Wales and CMRP

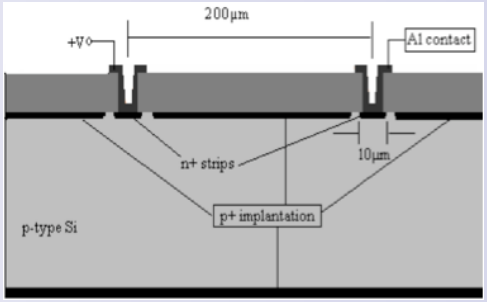


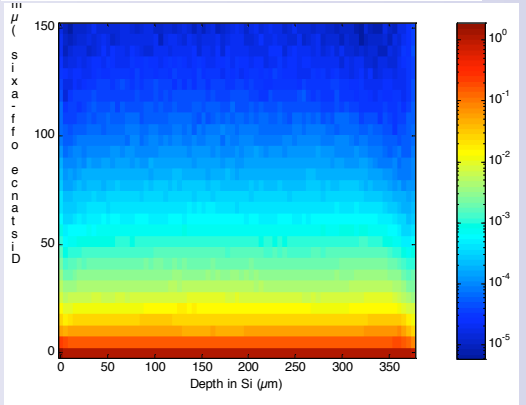
Geant4 simulation experimental set-up

Study and optimisation of detectors

Microbeam Radiotherapy (MRT)

- 128 channel silicon strip detector used to monitor beam properties
  - Configured as transmission detector upstream of patient.
  - Real-time monitoring for use as beam-stop trigger
- Beam is changed due to presence of detector, which must be minimal – simulate what effect it has
  - 1.97% interaction with incident photon beam
  - 1.41% average reduction in depth dose to water
- Effect to Radiobiological Important Peak-to-Valley Ratio, PDD, Spatial Distribution of Dose within Detector (*see Figure*)
- A. Cullen, M. Lerch, M. Petasecca, H. Requardt, A Rosenfeld

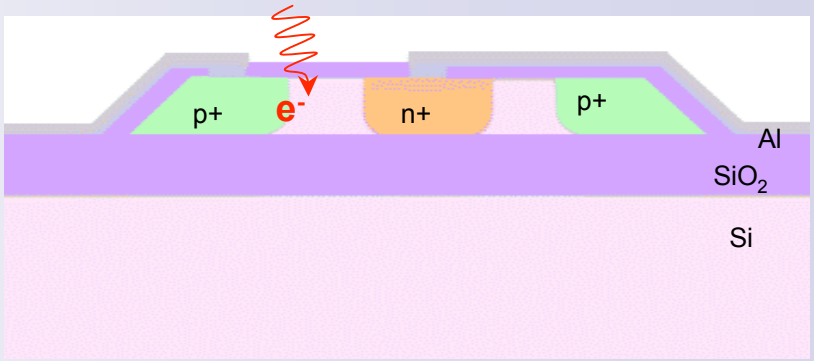




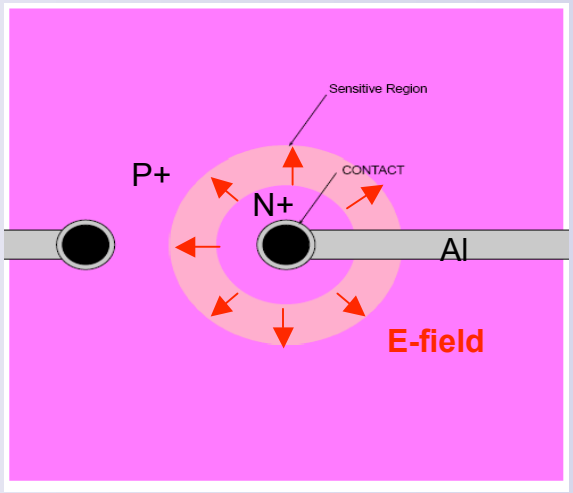
Spatial distribution of microbeam dose deposition in the detector in free air.

Silicon-On-Insulator (SOI) Microdosimetry

- Research started and guided by Prof. Anatoly Rosenfeld
- I. M. Cornelius, S. Guatelli, D. Prokopovich, A. Wroe
- Characterization of SOI technology microdosimeters in fields of interest for:
  - Proton therapy
  - Fast neutron therapy
  - Radiation protection in earth labs, aviation and space



~ 20 um



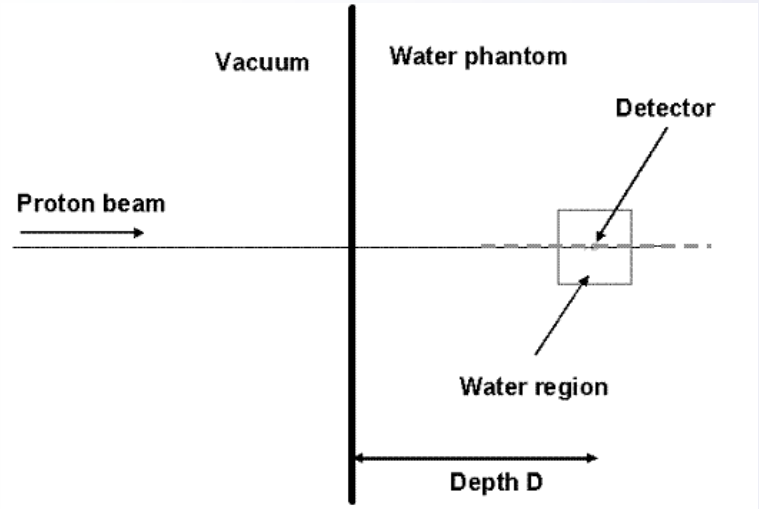
Second generation SOI microdosimeter

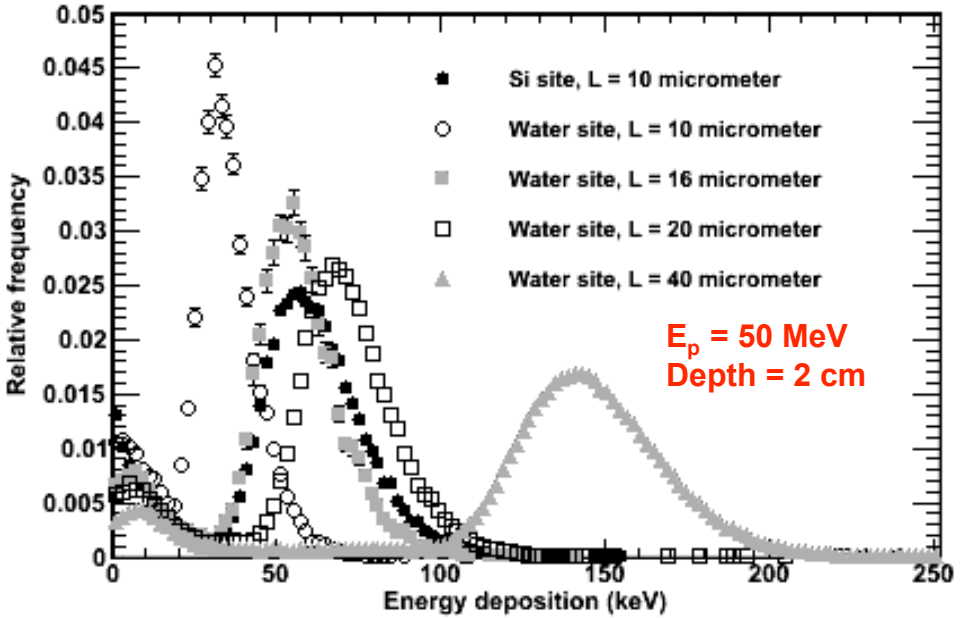
Geant4 study on the tissue equivalence of SOI

Authors: S. Guatelli, M. Reinhard, B. Mascialino, D. Prokopovich, A. Dzurak, M. Zaider, and A. B. Rosenfeld
Collaboration: CMRP, ANSTO, University of New South Wales, Karolinska Institutet (Stockholm), Department of Medical Physics, Memorial Sloan-Kettering Cancer Center (New York)

- A **simple geometrical scaling factor** (~0.56) is adequate to convert microdosimetric energy deposition spectra in silicon to equivalent microdosimetric energy deposition spectra in water, along the Bragg peak curve in water phantom
- In protontherapy and in LEO space environment (E_{proton}< 250 MeV)

Experimental set-up



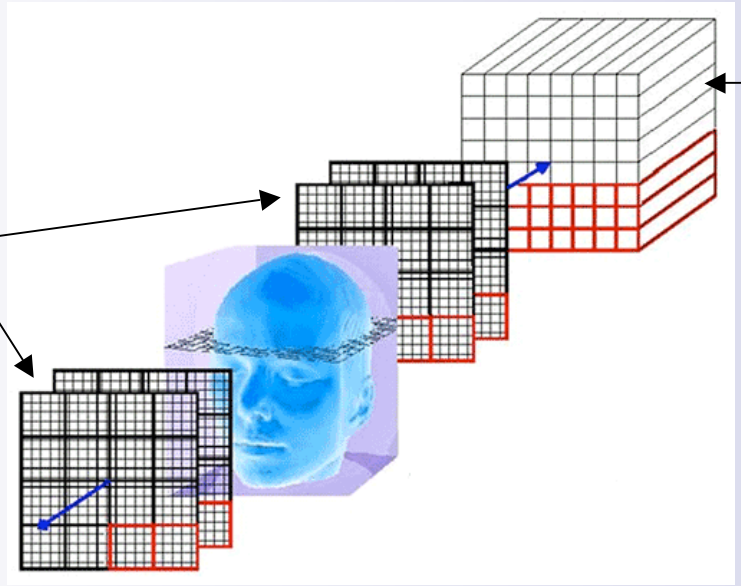


S. Guatelli,et al, "IEEE Transactions On Nuclear Science, *Vol. 55, pp. 3407 - 3413*

Imaging

Proton Computed Tomography

- Imaging modality being developed to reduce range uncertainty in proton radiation therapy
- GEANT4 being used to optimize scanner design and test custom designed image reconstruction software



Silicon tracking planes to record position and direction of individual protons pre and post patient

Calorimeter to measure energy lost by protons as they traverse the patient

Protons energetic enough to traverse patient (200 MeV for head)

Image courtesy of Northern Illinois Center for Accelerator and Detector Development

Proton Computed Tomography

- Scanner design replicated in GEANT4 to provide transmission data for image reconstruction software testing
- Mathematical representation of a head phantom created and "imaged"

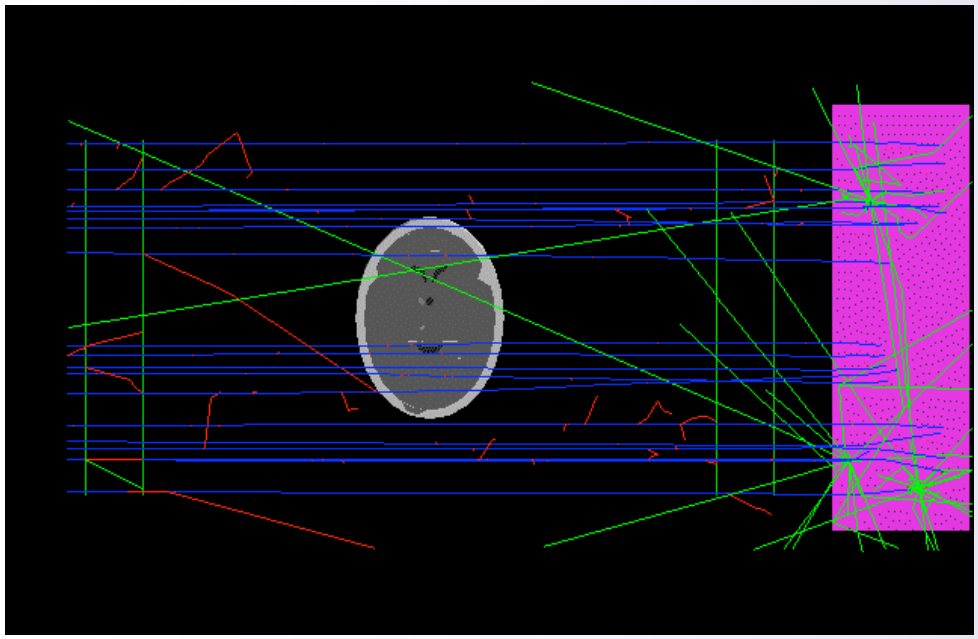
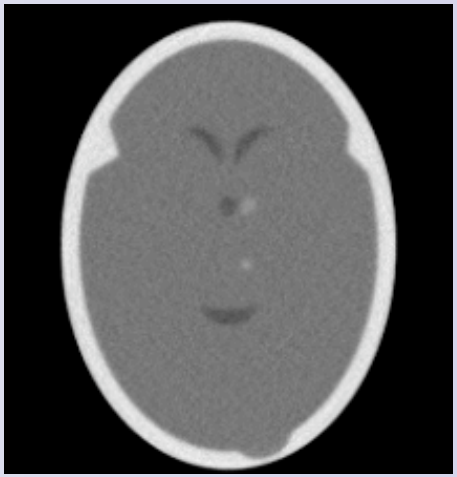
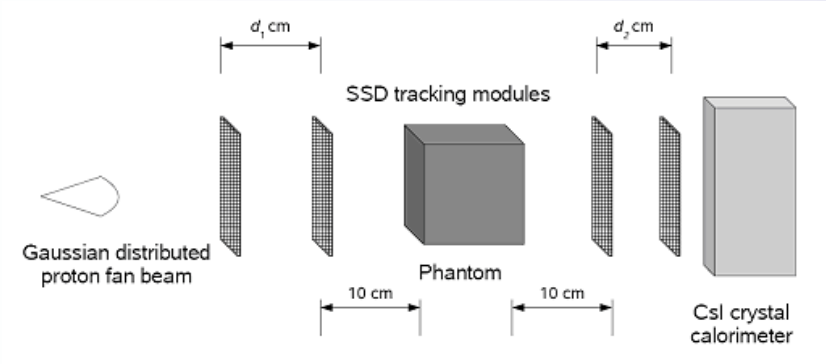


Image reconstruction software

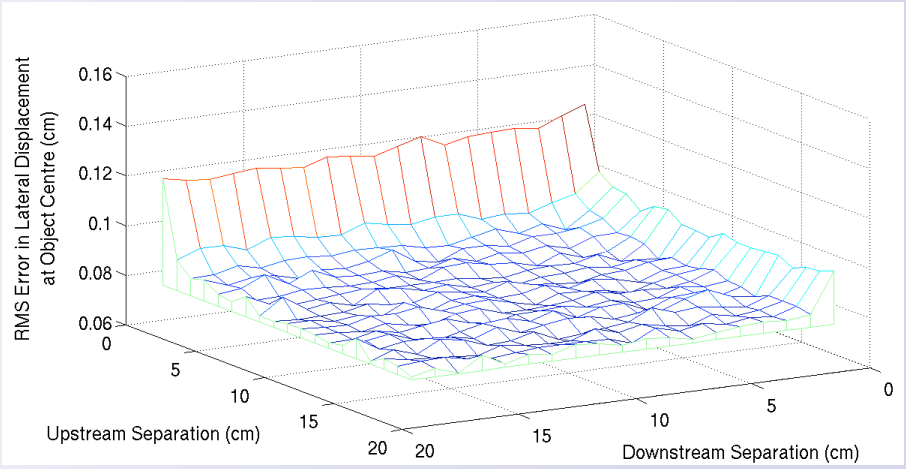


Proton Computed Tomography

- Optimization of 1st generation pCT scanner geometry to be installed on Loma Linda Proton Treatment and Research Center beamline



Effect of SSD separation on spatial resolution

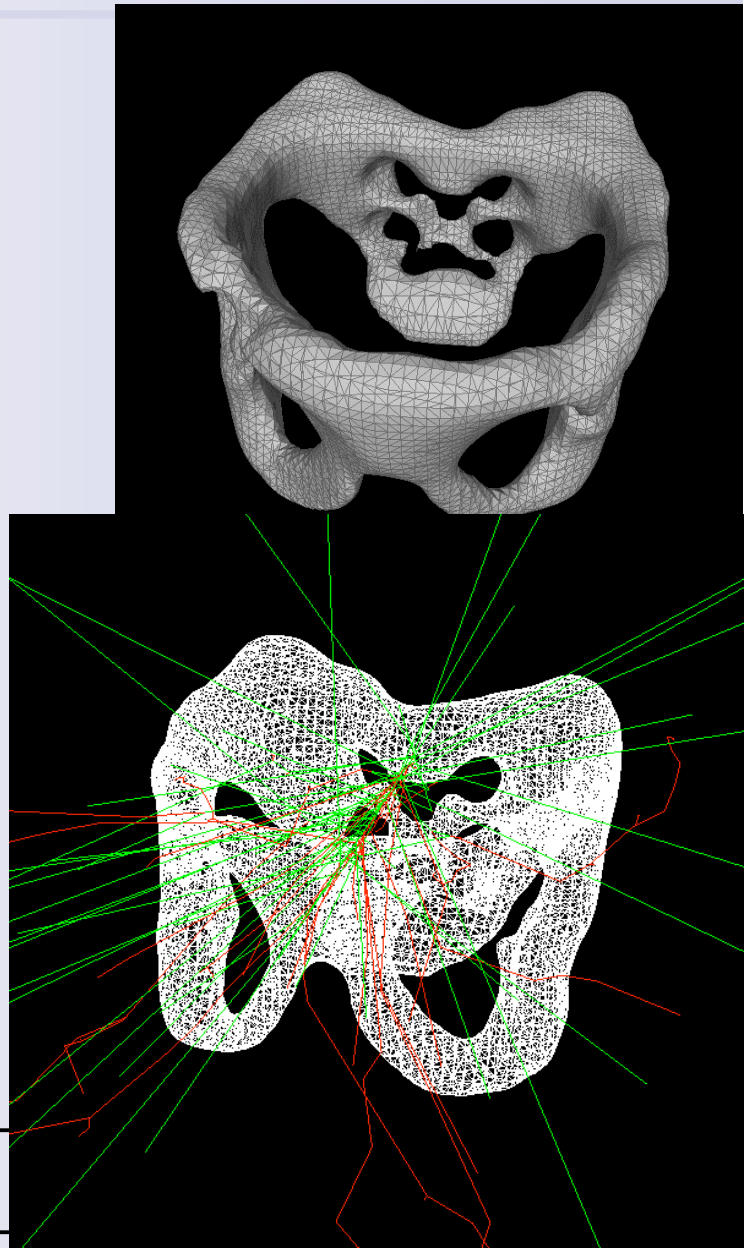


Researcher: Scott Penfold
University of Wollongong
Royal Adelaide Hospital
scott.penfold@health.sa.gov.au

Supervisors: Reinhard Schulte (Loma Linda University Medical Center, CA, USA) and Anatoly Rosenfeld (CMRP, University of Wollongong)

DICOM ROI's to G4Tesselated Solids

- Memory reductions
- Speed increases
- Density/Material from CT numbers
- Chris Poole, Queensland Uni of Technology.

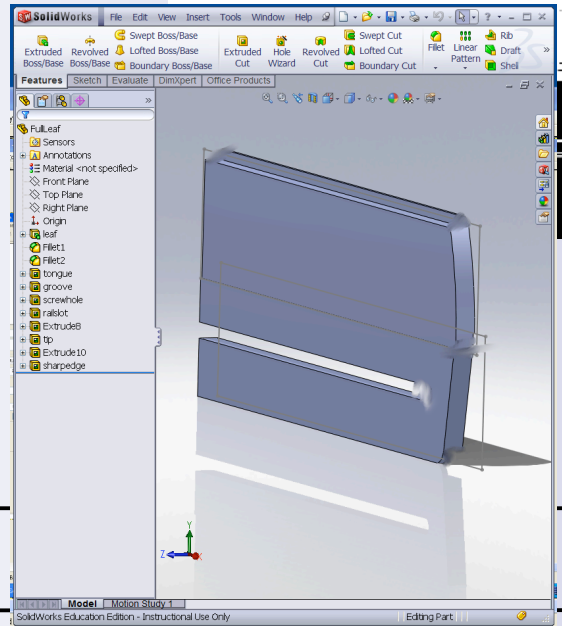


Improve performance

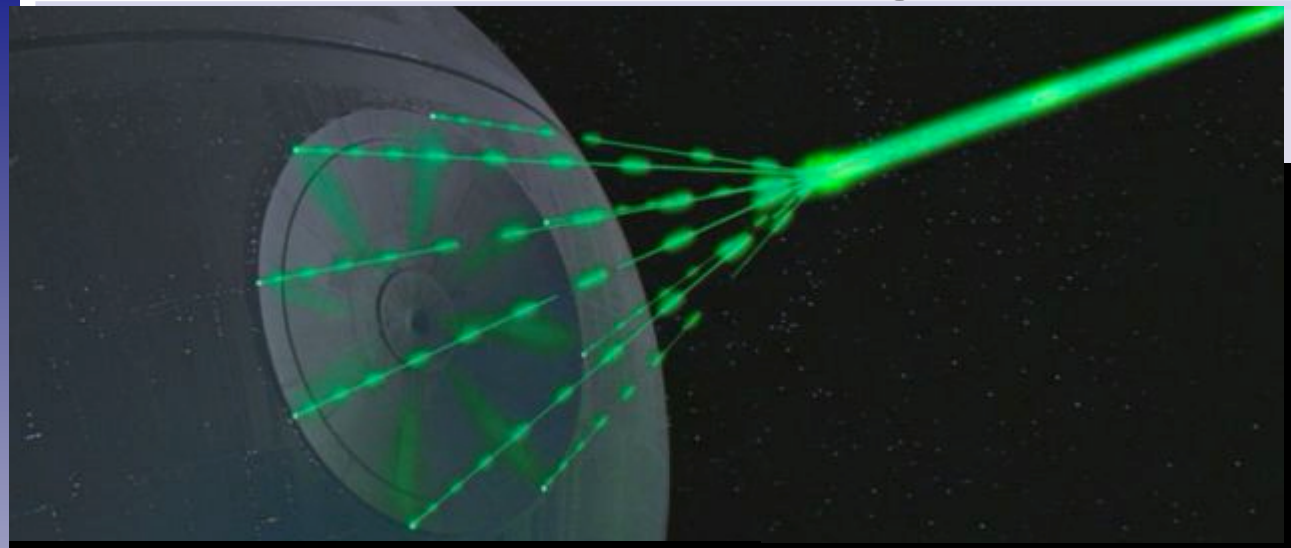
Achieve quick response, required by medical physics application

MC based radiotherapy plan check system

- Varian 2100C, IMRT
- Accurate geometry:
  - CAD→G4 conversion
- Utilize Multi-core CPU and GPU systems:
  - work in progress
- Dr Iwan Cornelius, Queensland Uni of Technology



Intergalactic Domination!



- Dean Cutajar, CMRP, University of Wollongong