Improving dosimetry in Molecular Radiotherapy (MRT) with Monte Carlo Simulation

Chris Oldfield, D. M. Cullen, A. Robinson and D. Rawlinson
Nuclear Physics Group, The University of Manchester

J. Tipping, D. Hamilton and E. Page
Christie Medical Physics and Engineering, The Christie NHS Foundation Trust

IoP - 31/03/15
Introduction

- What is Molecular Radiotherapy (MRT)
- SPECT and PET imaging for MRT
- 90Y therapy and imaging
- Monte Carlo simulation of 90Y
- A (de-)tour through validating Monte Carlo
- Conclusion
MRT - treatment

External

Internal
MRT imaging - historically
SPECT Camera

Diagram showing the components of a SPECT camera, including PMT array, scintillator crystal, collimator, and photons.
Positron emission and positron-electron annihilation

PET scanner

Positron-emitting radionuclide → Positron → Electron

511 keV gamma ray → Annihilation

Gamma ray detectors
Scatter correction

Experiment
Simulation (all)
Sim (unscattered)
Scatter correction

Counts

Energy (keV)

Experiment
Simulation (all)
Sim (unscattered)
• $^{90}$Y decays with 64 h half life via beta emission and deposits most energy released within $\sim$5 mm

• Delivered using chemistry as $^{90}$Y: DOTATE, Ibritumomab tiuxetan

• Or using human anatomy as Selective Internal Radiotherapy (SIRT)

• SPECT imaged on the produced Bremsstrahlung spectrum

• No simple gamma peak makes SPECT imaging harder
A Little Nuclear Physics

0.000032% pair production
2% >50 keV (detectable)
Bremsstrahlung production
Monte Carlo Simulation “GATE”

(a) $^{99m}$Tc

(b) $^{177}$Lu
GATE 6.2 for Bremsstrahlung
• Validation in a simpler and better understood system
• Calibrated with $^{152}$Eu and $^{133}$Ba
• Calculated efficiency and resolution
• Measured 90Y Bremsstrahlung spectrum
• Reproduced measurements in Geant4
Simulation validation

133Ba. Efficiency corrected

152Eu. Efficiency corrected
Bremss in different MC codes

Geant4

EGS (blue) vs Geant4 (red)

MCNP vs experiment

Monte Carlo codes over-estimate Bremsstrahlung production below ~300 keV!
• Simulation is only meaningful with good validation

• Simulation of Bremsstrahlung emission in this energy range is problematic, making activity localisation hard

• BUT, electron dose deposition is well validated, so if you know where the activity is dosimetry is comparatively easy.
Thanks for listening

Thanks to:
D. M. Cullen, A. Robinson and D. Rawlinson
Nuclear Physics Group, The University of Manchester

J. Tipping, D. Hamilton and E. Page
Christie Medical Physics and Engineering, The Christie NHS Foundation Trust