Outline

- Why source modeling for MCTP
- A multiple source model
- Electron beam modeling and commissioning
- Photon beam modeling commissioning
Monte Carlo treatment planning

Beam phase space

Prescription

Patient CT scan

MC dose calculation

Dose distribution

Processing

Plan evaluation

Source Modeling
How to Obtain Beam Phase Space

Four routes:

1. Measured data → Commissioning → Beam model → Sampling → Phase space
2. Measured data → Commissioning → Beam model → Linac simulation
3. Measured data → Commissioning → Beam model → Modeling → Linac simulation
4. Measured data → Commissioning → Beam model → Linac simulation → Modeling → Sampling → Phase space
Beam Models vs Phase Space

- Beam models are based on good understanding of phase space representation and reconstruction.
- Beam models can be more computationally efficient.
- Beam models require less storage space.
- Beam models are easier to commission and implement clinically.
A Multiple Source Model

- Individual linac components are considered as sub-sources
- Each sub-source has its own energy and fluence distributions
- Angular correlation is retained

Sub-source types

- Virtual point source
- Rings/cones for primary collimator
- Parallel bars for secondary collimator
- Rectangular sources for applicator
- Plane sources for mirror, monitor chamber, etc.
How many sources are enough?
- an example: a 2100C electron beam

- **model 1**: a monoenergetic electron point source
- **model 2**: electron point source + energy spectrum
- **model 3**: electron point source + energy spectrum + beam profile
- **model 4**: a multiple source model

A point source + spectrum + profile ⇒ 2-5% accuracy
Electron Beam Modeling
A four-source model for Varian 2100C

- Photon point source
- Electron point source
- Electron square ring source
- Fluence scoring plane

Linacs of the Same Model

A test of the commissioning approach

- Reference beam: $E_{in}=12.0$ MeV

  to match

- Beam A: $E_{in}=9.0$ MeV (simulated)
- Beam B: $E_{in}=15.0$ MeV (simulated)
- Beam C: published data (nominal 12 MeV?)
Match Different Energies

- **Beam A: 9 MeV beam**
  - Off-axis distance (cm)
  - Relative dose (%)
  - 2 cm
  - 3 cm

- **Beam B: 15 MeV**
  - Off-axis distance (cm)
  - Relative dose (%)
  - 3 cm
  - 5 cm

- Reference beam
- Beam A
- Beam B
- Model for beam A
- Model for beam B
- Depth (cm)
- Relative dose (%)
Match Unknown Dose Distributions

![Graphs showing dose distributions](image)
Advantages of Measurement-Based Source Modeling and Beam Commissioning

Less dependent on precise knowledge of linac geometry

- Fluence dist. ensured by profile measurement
- Energy spectra ensured by depth dose measurement
- Angular dist. ensured by source geometry (model)
- Beam output ensured by direct measurement
Photon Beam Modeling and Commissioning
A Three-Source Model for Clinical Photon Beams

- Point/extended source for primary photons
- Extrafocal source for scattered photons
- Extended source for contaminant electrons

Photon energy spectra

6 MV photon energy spectrum

Relative fluence vs. Energy (MeV)
Pre-calculated Monoenergetic PDD
Central Axis energy spectrum for a 6 MV beam

Relative weight

Energy (MV)

Monte Carlo

fitted

(a)
Mean energy versus off-axis distance for a 6 MV beam
Relative planar fluence versus off-axis distance for 6 MV beam

![Graph showing relative planar fluence versus distance from central axis for a 6 MV beam. The graph includes a line labeled Monte Carlo and a dotted line labeled fitted.]
Assumptions for Extrafocal Source

- The source plane emits photons isotropically over an angle.
Variation of head scatter factor due to monitor chamber backscatter

- Results of this model
  1.2% for 6 MV
  1.6% for 15 MV

- Measured results from Yu et al
  1.2 ± 0.3% for 6 MV
  1.8 ± 0.3% for 15 MV
Determination of Electron Energy Spectrum

- Calculate the CAX electron fluence as a function of field size using Fermi-Eyges theory
- Fit with the measured CAX electron surface dose
- Recent improvement for contaminant electrons by Yang et al. (Phys Med Biol, 2004 49: 2657-73)
Measured vs MC Reconstructed Dose Distributions

Summary

- An accurate source model can be built based on the simulated phase space data
- Measurement-based source modeling and beam commissioning is more suitable for widespread application
- The multiple source model has been proven to be accurate and practical for clinical implementation
References

Acknowledgments

The FCCC/Stanford Beam Characterization Team

Charlie Ma
Jinsheng Li
Ajay Kapur
Grisel Mora
Omar Chibani
James Fan

Steve Jiang
Jun Deng
Michael Lee
Lihong Qin
Jie Yang