Monte Carlo Simulation of Linear Accelerator for Dosimetry Analysis

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Introduction - Problem Statement

Monte Carlo simulation of a linear accelerator for treatment planning of cancer:

- Simulation of radiation beam production in LINAC.
- Simulation of beam transport from LINAC head to phantom.
- Dosimetry analysis of radiation.

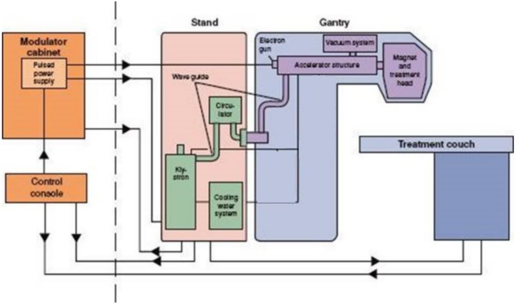


Figure: Components of Medical LINAC [1]

Introduction

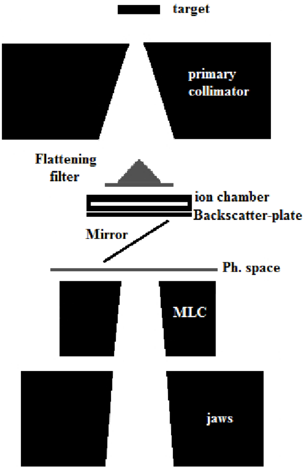


Figure: Geometry of the Elekta linac gantry. [3]

Work Plan

Work done so far

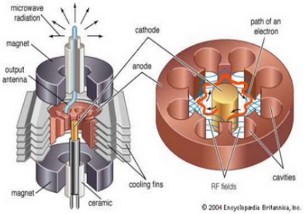
- Literature Survey: Understood the working and components of a LINAC head.
- Visited the MVR Cancer Centre: Attended a talk on LINAC and its internals.
- Installed and configured Geant4 simulation toolkit.
- Studied a simulation of the basic medical LINAC components.
- Met with Dr.Niyas (Chief Medical Physicist at MVR Cancer Centre) to discuss the LINAC specifications and working.
- Initiated simulation for a basic Elekta Synergy LINAC.

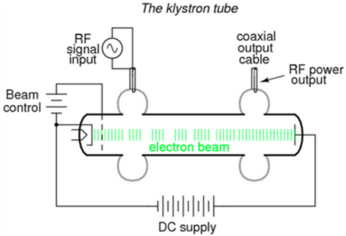
Comparison of commercial linacs

Accelerator items	Siemens	Varian	Elekta
RF power generators	Klystron	Klystron	Magnetron
Accelerating waveguide type	Standing wave	Standing wave	Traveling wave
Max. RF power levels	Low energy: 5 MW	Low energy: 7 MW	Low energy: 2.5 MW
	High energy: 10 MW	High energy: 12 MW	High energy: 5 MW
MLC types	Replacement of lower jaws	Attachment in addition to jaws	Replacement of upper jaws
MLC leave pairs	58, 80, 160	52, 80, 120	80, 160
Wedge types	Virtual wedge	Enhanced dynamic wedge	Omni physical wedge
Focusing magnet type	270 bending magnet	270 bending magnet	90 Slalom bending magnet
Available energies	2–3 photons: 4–23 MV	2–5 photons: 4–23 MV	2–3 photons: 4–25 MV
	6 electrons: 4–23 MeV	6 electrons: 4–23 MeV	6 electrons: 4–25 MeV

Figure: Comparison of linacs [1]

Microwave power generator





Magnetron – 5 MW Klystron – 7 MW

Accelerating waveguides

There are two types of accelerating waveguides : Travelling and Standing waveguide.

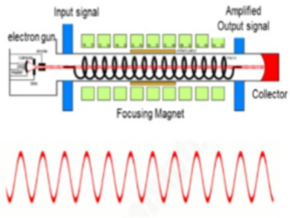


Figure: Travelling Waveguide [1]

- Microwaves enter on the gun side and propagate.
- Absorbed at the distal surface and thus forms a travelling wave pattern.
- It is longer than standing waveguide.

Accelerating waveguides

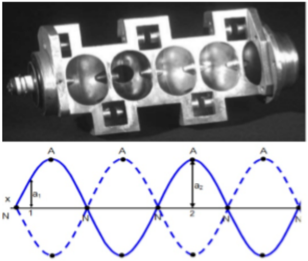


Figure: Standing Waveguide [1]

- Each end is terminated with a conducting disc to reflect the microwave power.
- Results in formation of standing waves.
- Can effectively shorten the accelerating waveguide by 50%.

Bending Magnets

At the exit of the waveguide the electron beam passes through a bending magnet system which is directed towards the treatment head.

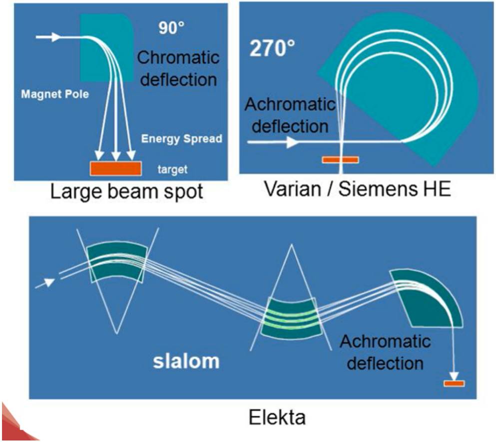


Figure: Comparison of bending magnet systems [1]

Multi-Leaf Collimators

The position of multi leaf collimators vary among the vendors.

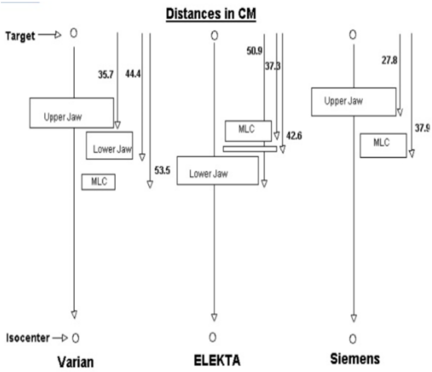


Figure: Comparison of Multi Leaf Collimator Positions [1]

Design

A brief description of the flow of control of the Elekta simulation program.

Design

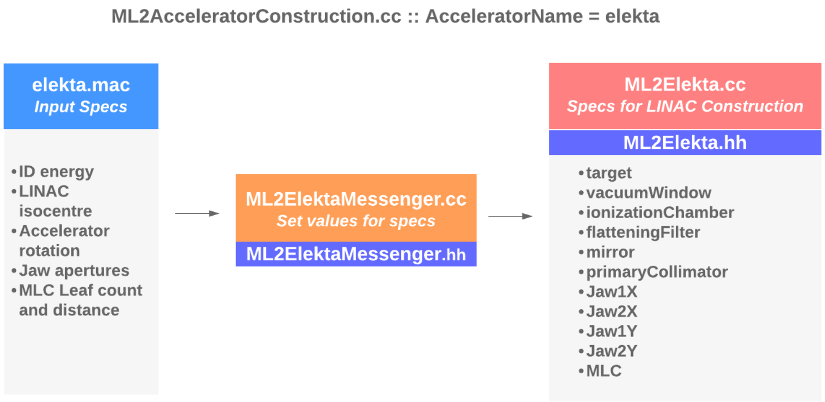


Figure: Elekta Linac Simulation

Visuals of the simulation

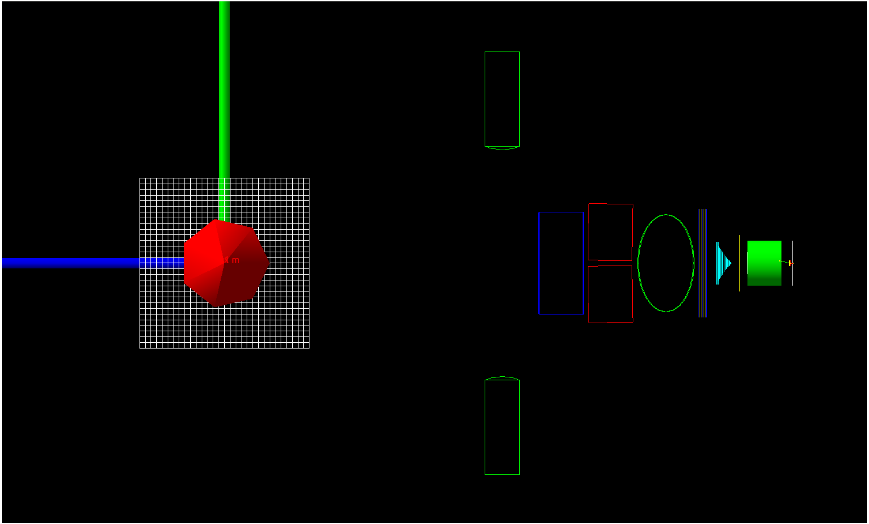


Figure: Varian Linac Simulation

Visuals of the simulation

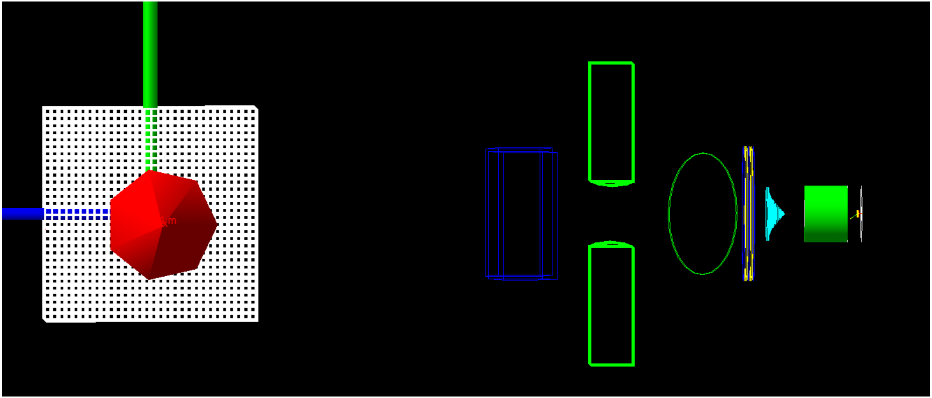


Figure: Elekta Linac Simulation

Visuals of the simulation

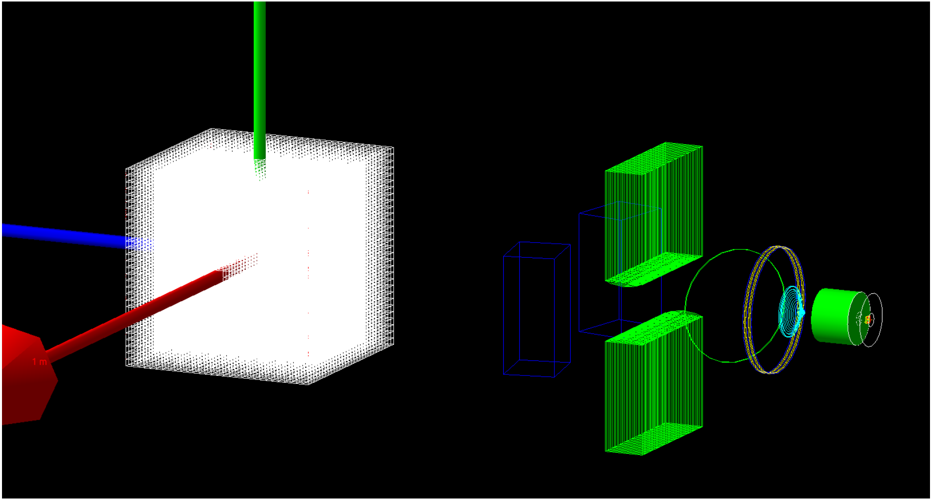


Figure: Cross-sectional view of Elekta Linac

Work Plan

Work to be done

- Obtain the specifications of the required Elekta LINAC and complete the simulation.
- Understand the electron beam behaviour before it hits the target and simulate the components for beam generation if required.
- Simulation of radiation beam transportation from the LINAC treatment head to the phantom.

Conclusion

- Compatibleness with Geant4 simulation toolkit.
- Thorough understanding of the flow of control of the medical linac code.
- Started simulation of basic Elekta Synergy LINAC.

References

[1] Niyas Puzhakkal.(2019) 'The many shapes of a LINAC'[PowerPoint presentation]

[2] Geant4 homepage, `https://geant4.web.cern.ch/`. Last accessed 19 November 2019

Didi S, Moussa A, Yahya T, Mustafa Z. Simulation of the 6 MV Elekta Synergy Platform linac photon beam using Geant4 Application for Tomographic Emission. J Med Phys 2015;40:136-43

Thank You