BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

Teaching linear accelerator physics using simulation software

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Nicole Harnett, Princess Margaret Cancer Centre

October, 27, 2017

About the presenter

Linac Physics is Complicated

- Electron beam acceleration in waveguide is advanced physics.
- There is a convoluted relationship between the basic physics and clinical beam properties.

Teaching Linac Physics

- Should relate basic physical principles to clinical parameters.
- Needs a hands on component.
- Jargon issues between service engineers and physicists.
- Few teaching resources
  - Other than Karzmark text there is very little.

The Accelerated Education Program

Princess Margaret Cancer Centre

Upcoming Course

Accelerator Technology (ATec)
February 28 - March 3, 2017
Led By: Dr. Marco Carlone &
Mr. Bern Norrlinger

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putting innovation to work

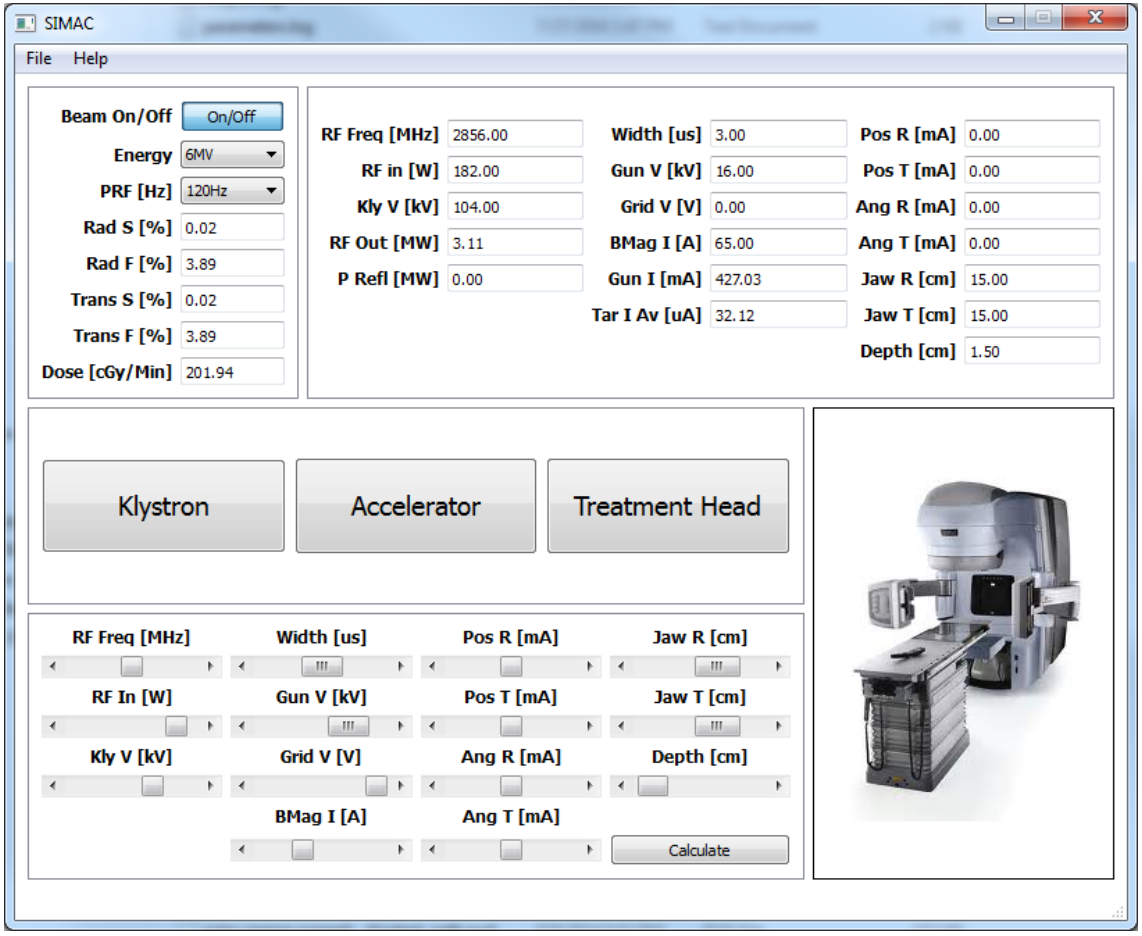
Radiation Oncology UNIVERSITY OF TORONTO

Challenges with the ATec Course

- 4 day length is too short for any in depth teaching.
- Relating linac theory to linac service/QA problems is difficult.
- Clinical linacs at PMH were not available.

SIMAC

Simulate Lin**ac**



- Most linac physics can be modeled using simple analytical approximations
- Response is consistent with a real linac response.
- Meant to simulate the service mode of a clinical linac

SIMAC Downloads

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 16, NUMBER 3, 2015

Simulation of a medical linear accelerator for teaching purposes

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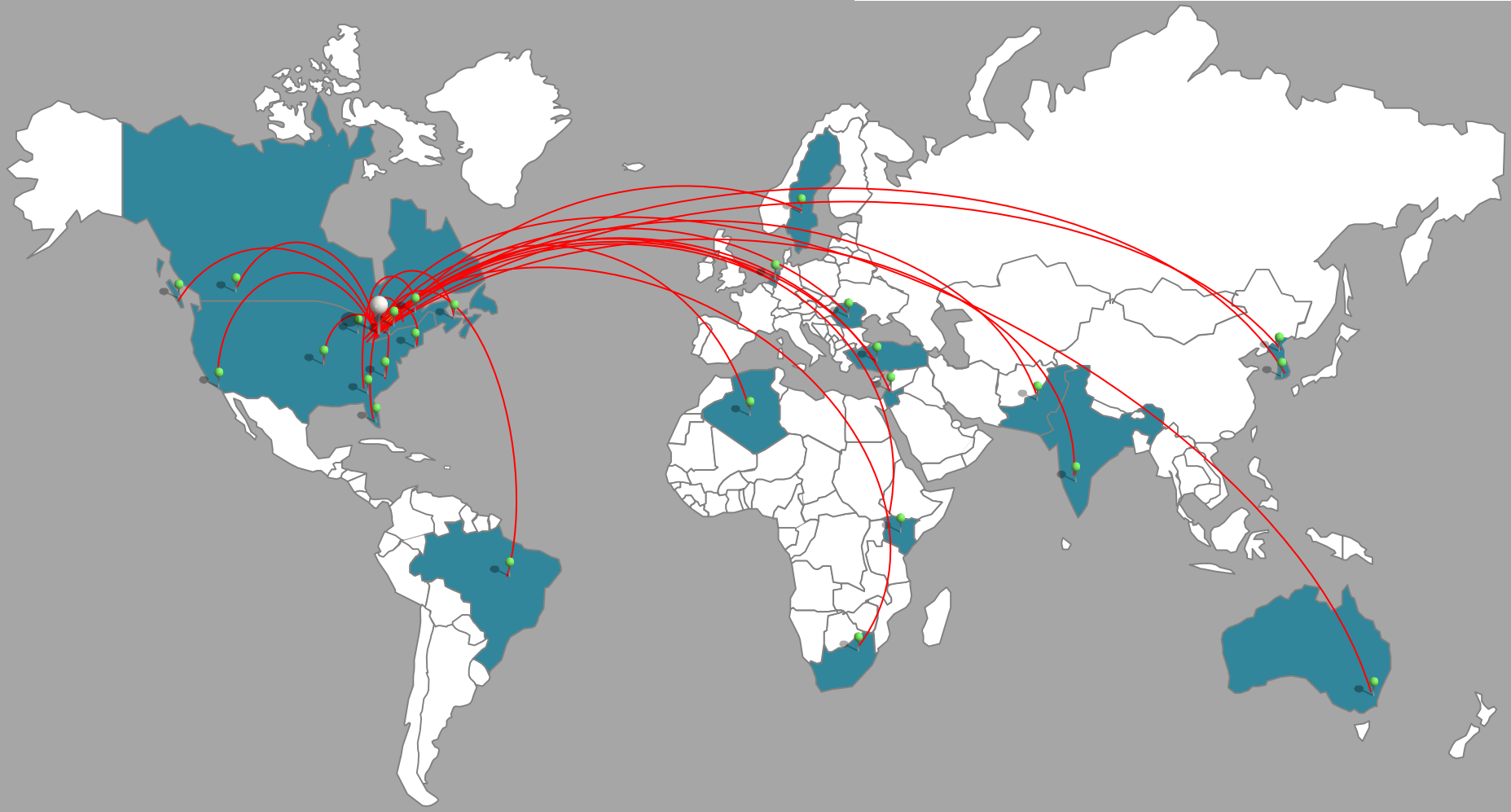
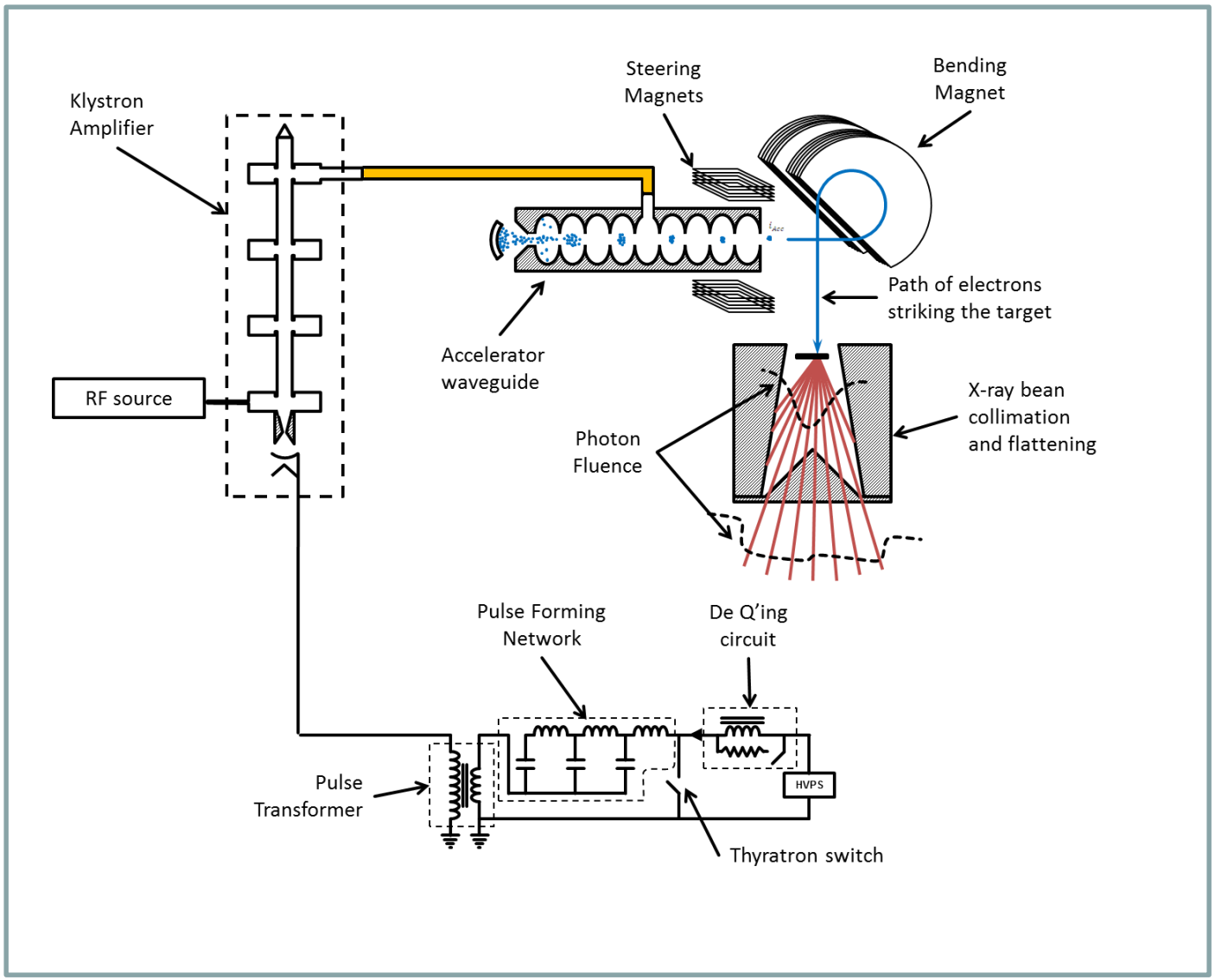
Received 12 June, 2014; accepted 26 January, 2015




Klystron
Amplifier
Steering
Magnets
Bending
Magnet
Path of electrons
striking the target
Accelerator
waveguide
RF source
X-ray bean
collimation
and flattening
Photon
Fluence
Pulse Forming
Network
De Q'ing
circuit
HVPS
Pulse
Transformer
Thyratron switch

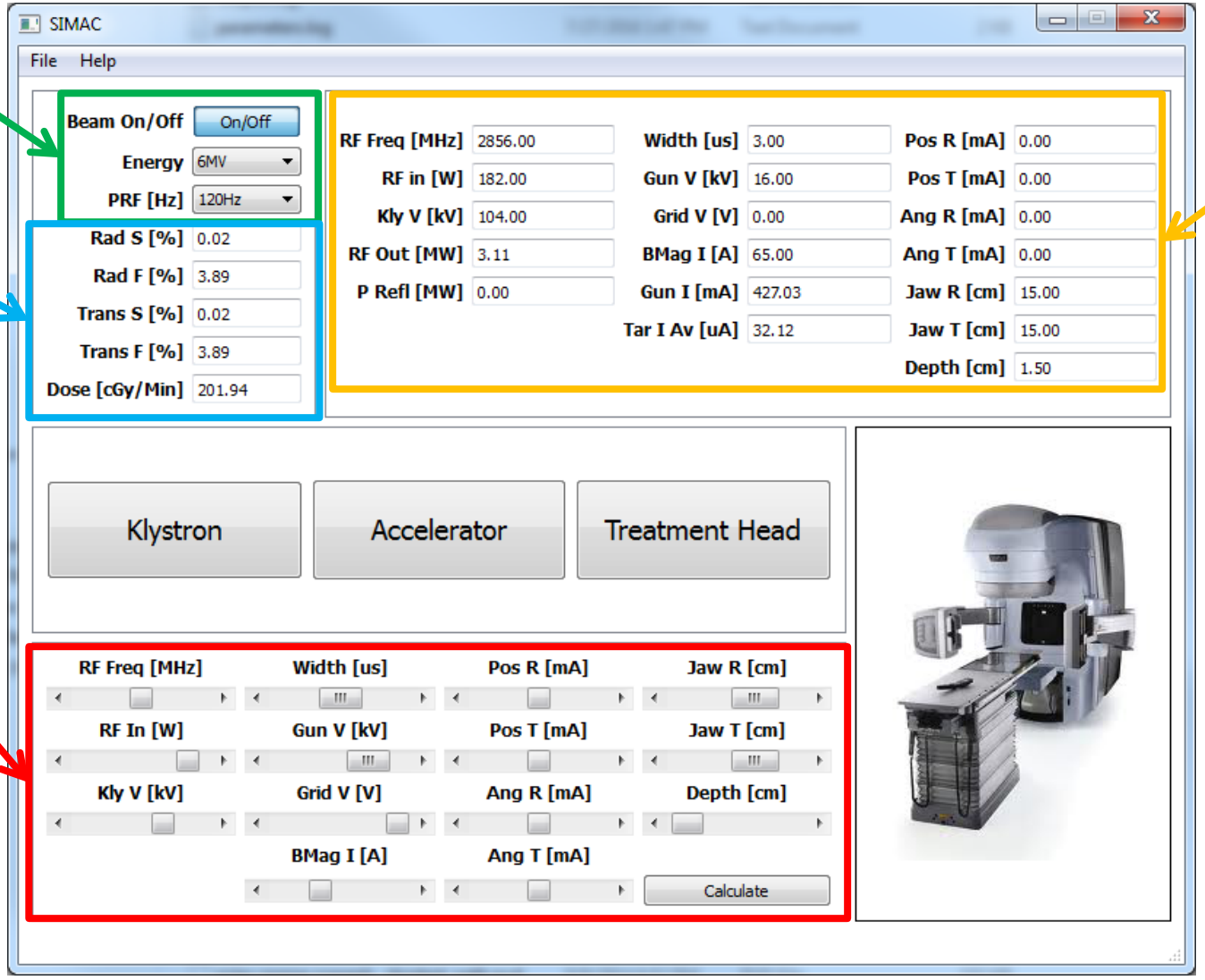
Using SIMAC

Mode selection

Clinical parameters

Linac parameter control

Linac operating values



Using SIMAC

Mode selection

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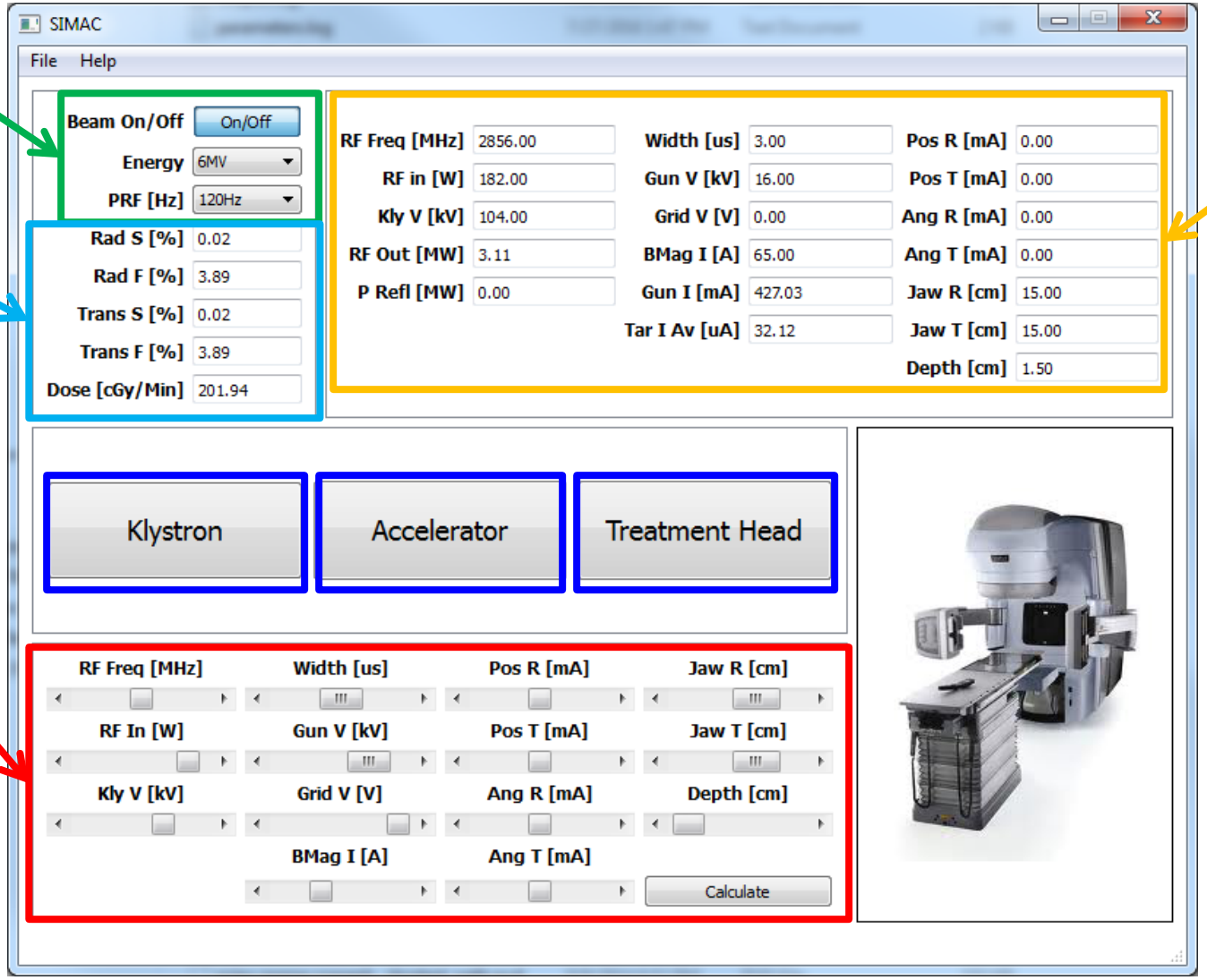


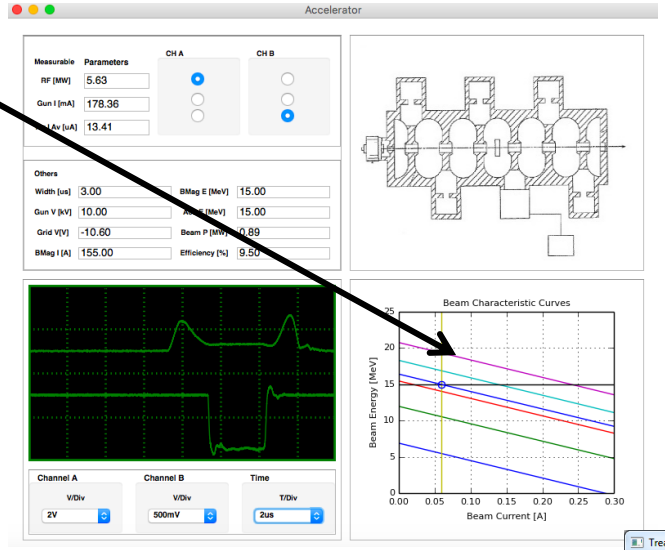
Linac Physics modules in SIMAC

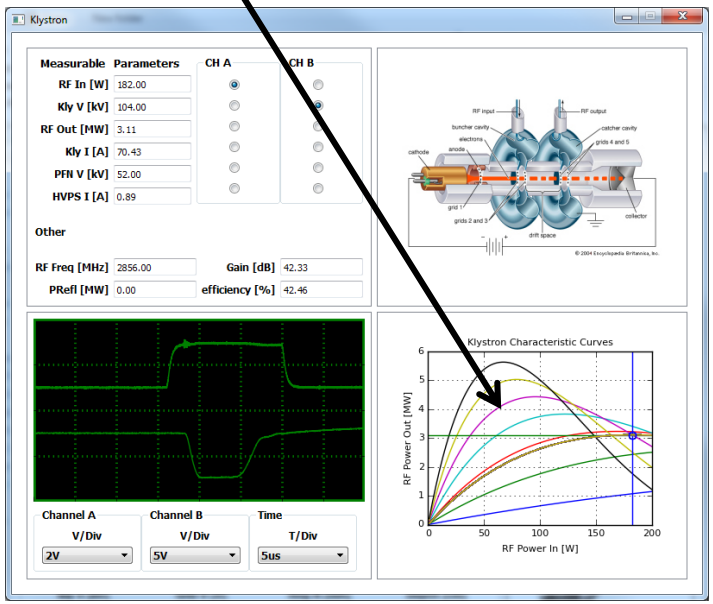
The linac Load line is modelled using the concept of “Shunt Impedance”

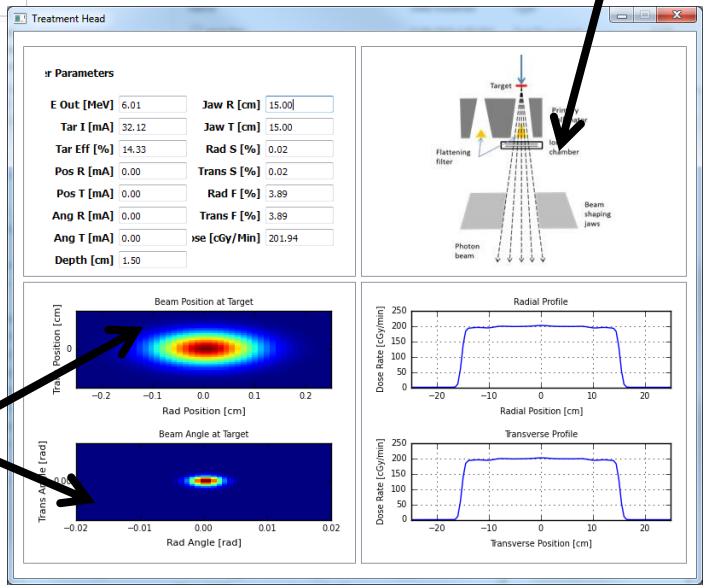
Klystron saturation is modelled using an analytical (Bessel) function

Photon transport is modelled using breamstallung yield tables (NIST) and linear attenuation in the FF and water phantom

Electron beam position and angle on the target

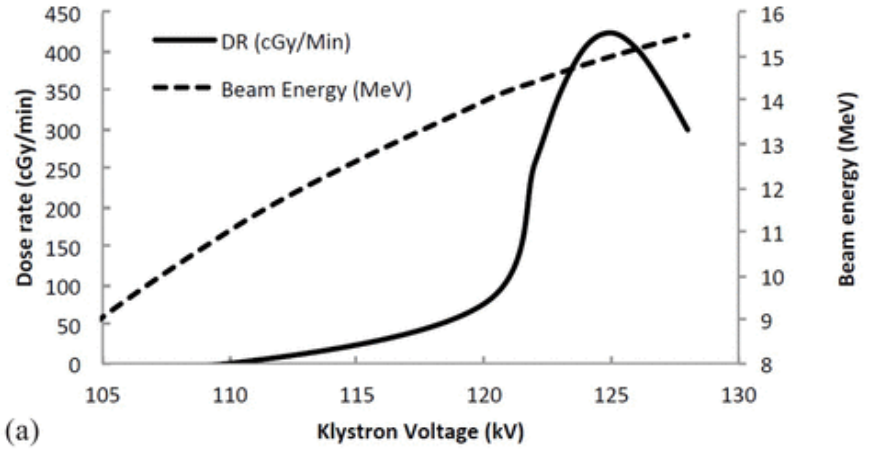




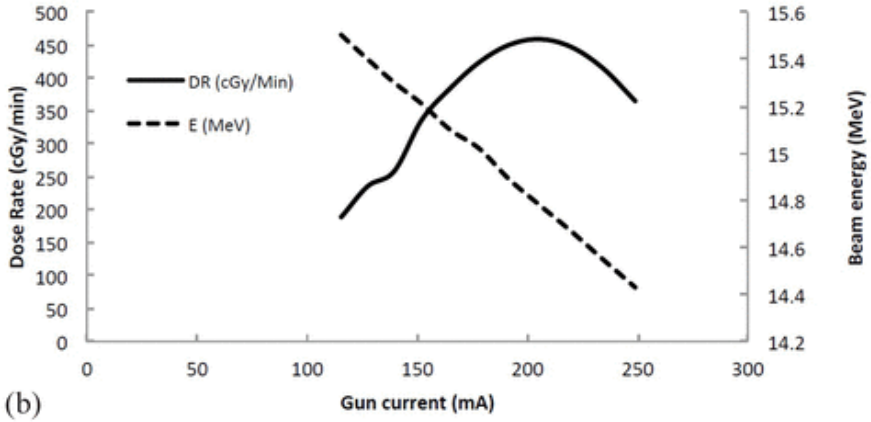


Atec Lab Exercise 1:

Teaching of beam “tuning” with SIMAC



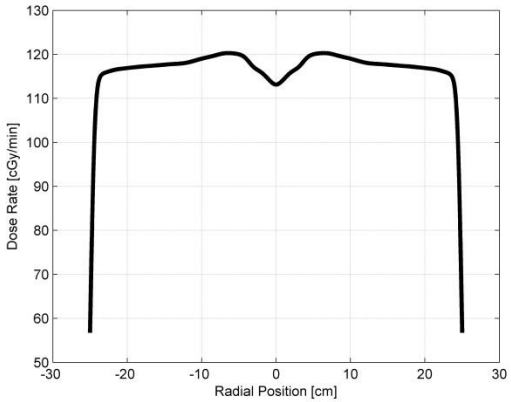
(a)

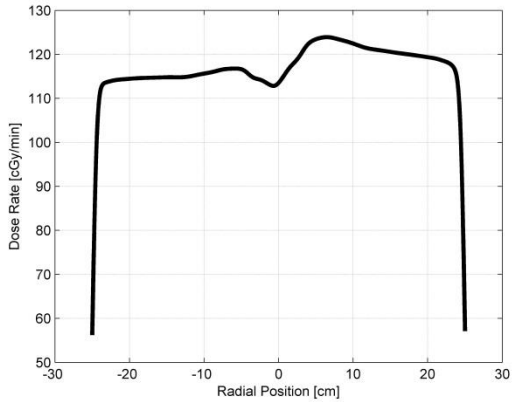


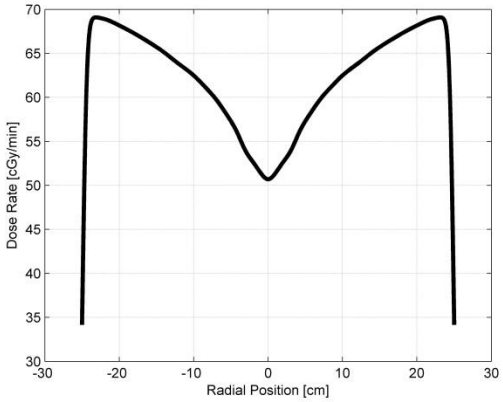
(b)

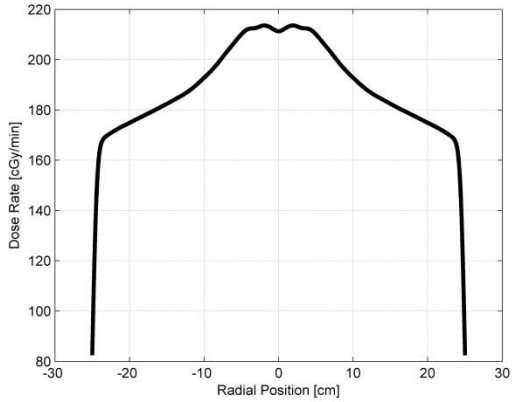
ATec Lab Exercise 2:

Using SIMAC to teach Flatness & Symmetry as a response to beam steering and energy



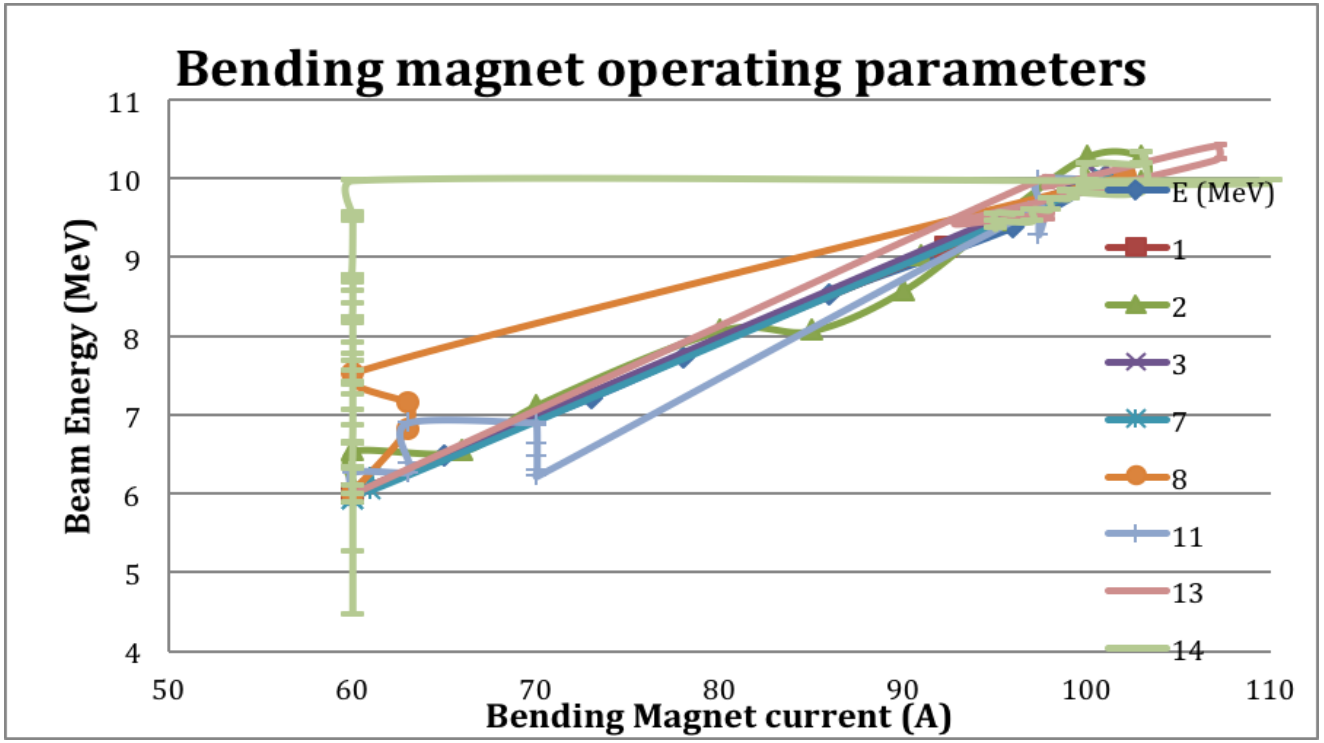






Laboratory teaching with SIMAC

Setting up a new energy



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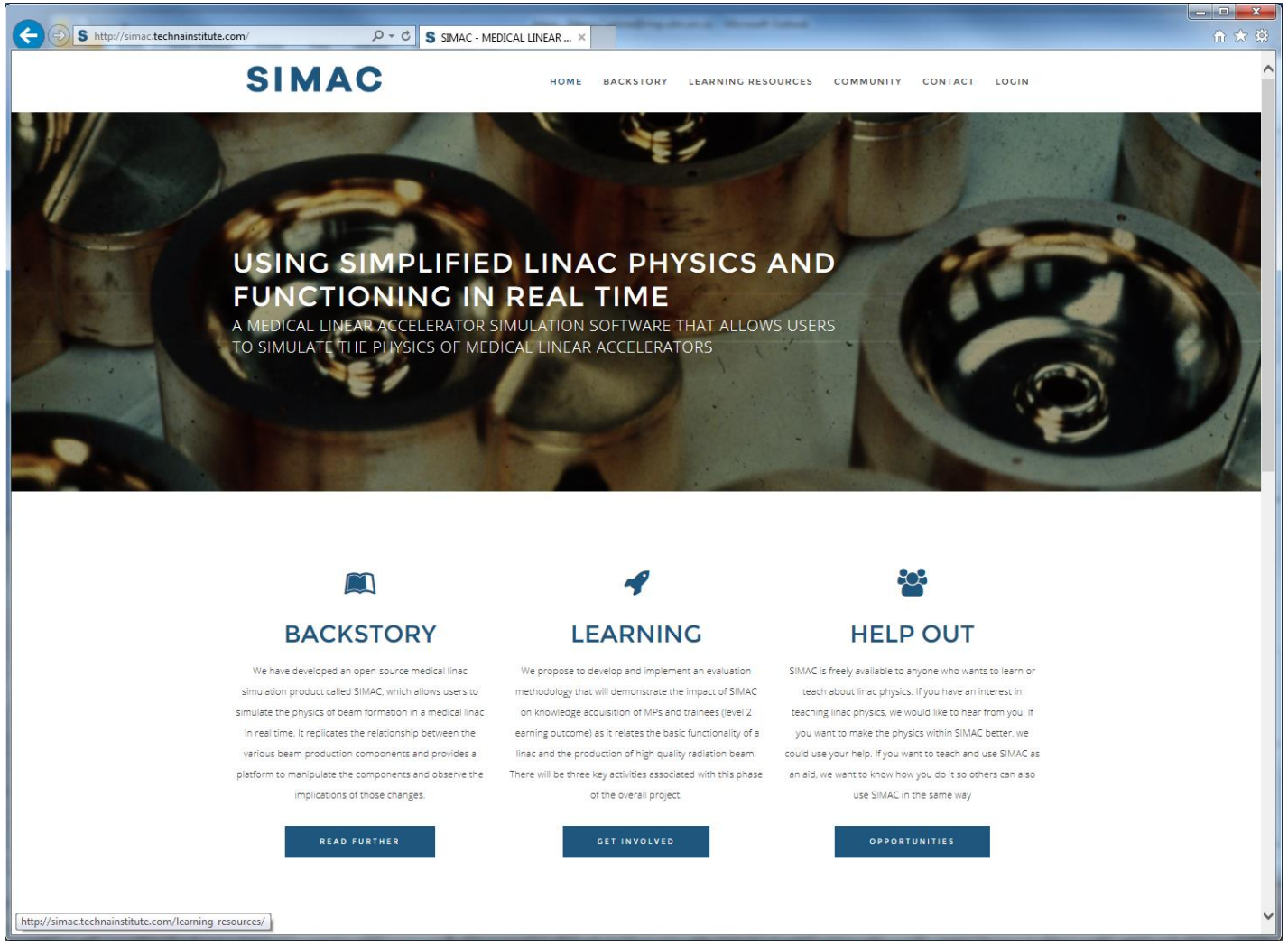
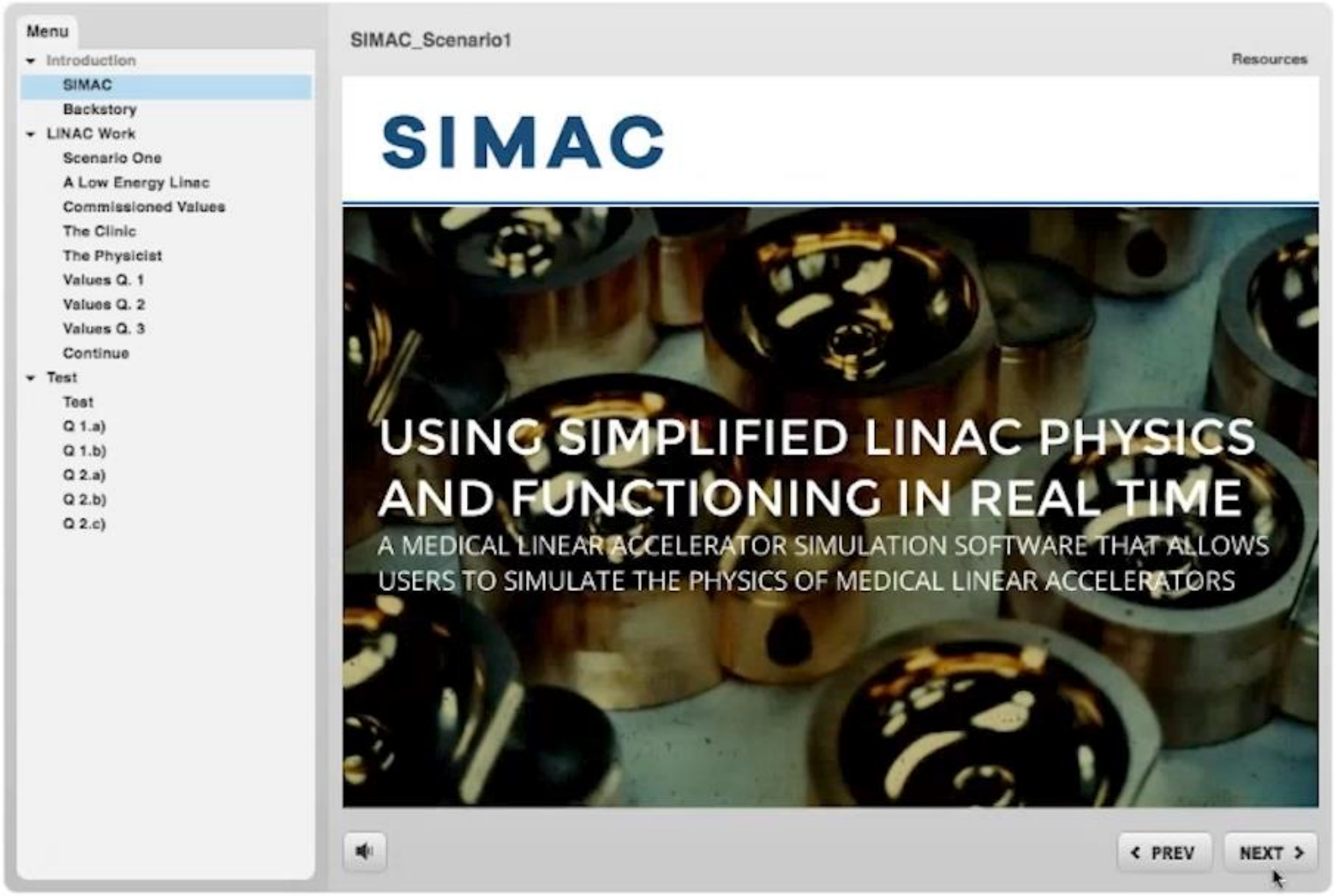


Example Learning Scenario

- New Low energy Linac to replace ^{60}Co unit
- Desire to drop beam energy to match to Cobalt
- Student must:
  - Complete the exercise using SIMAC and retune the unit for a lower energy
  - Report on Clinical parameters (Beam flatness, 2 point PDD)
  - Describe the operating condition at the lower energy
  - Is it a realistic operating point, and why?

Scenario based evaluation



The future

- Expand the physics within SIMAC:
  - Model temperature, ion chambers, magnetron linacs, frequency control, dose rate servo, etc.
- Find a permanent home for the project through an educational institution.
  - Has mandate for educating in the medical devices domain.

Table 1. New Linac component models to be applied.

Type of model	Brief description	Source material
Accurate modulator model	Component level model of Pulse Forming Network, Charging and discharging circuits	Lamey and colleagues[1]. Glasoe[2].
Magnetron model	Employ a modeled or digitized magnetron performance chart.	Manufacturer specifications, Collins[3].
Microwave frequency control	Linac resonant frequency depends on temperature (50kHz per degree Celsius). Linac reflected power can be modeled with impedance change as a function of frequency.	Description of Stanford Linear Accelerator[4]. Automatic Frequency Control circuits from schematics.
Linac ion chamber	Convert exposure to dose assuming ion chamber size and use for dose rate servoing.	AAPM TG21 dosimetry protocol[5].
Steering servo	Model beam steering servo circuits.	Standard beam steering circuits from linac schematics

Table 2. Virtual laboratories to be developed.

Laboratory topic	Brief description	Source material
Microwave circuits	Waveguide measurements, wave reflection, impedance matching, and other concepts.	Ginzton[6], Slater[7], Marcuvitz[8]. Moreno[9].
RF generation	Virtual RF generation from a Klystron and magnetron	Collins[3], Hamilton[10]
Electron optics	Space charge and temperature limited effects. Charged particle focusing.	EGUN[11]
Beam steering	Dipole magnets. Effect of beam energy on particle trajectory. Energy measurement using a bending magnet.	Anderson and colleagues[12]
Modulator	Explore charging and discharging of a pulse-forming network. Effects of clamping diodes, pulse shaping with a PFN load line.	Lamey and colleagues[1]. Glasoe[2].
Heat dissipation	Relationship between water flow, heat transfer, and the microwave properties of device: frequency changes, impedance change, power transfer change.	Stanford accelerator design[4]
Photon transport	Alignment of beam and flattening filter. Filters shape. Target thickness.	Anderson and colleagues[12].

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Overview

Note: The September 2017 intake is now closed for new applications to Level 1. Applications for direct entry and re-admission may be submitted. Applications for the September 2018 intake will be accepted starting November 1, 2017.

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› November 29, 2017

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Can we use a linac model to improve linac repair?

If we can have a self driving car, why not a linac that can fix itself?

An idea

- Apply basic linac physics model (like in SIMAC) to a baysean based linac fault model.
- Use the model to predict the nature of the linac failure after it is detected.
- The machine can then suggest a repair procedure that can be executed by a service technician with less training
  - Reduce the skill level required for the service technician.

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