SIMAC: A Simulation Tool for Teaching Linear Accelerator Physics

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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

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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.
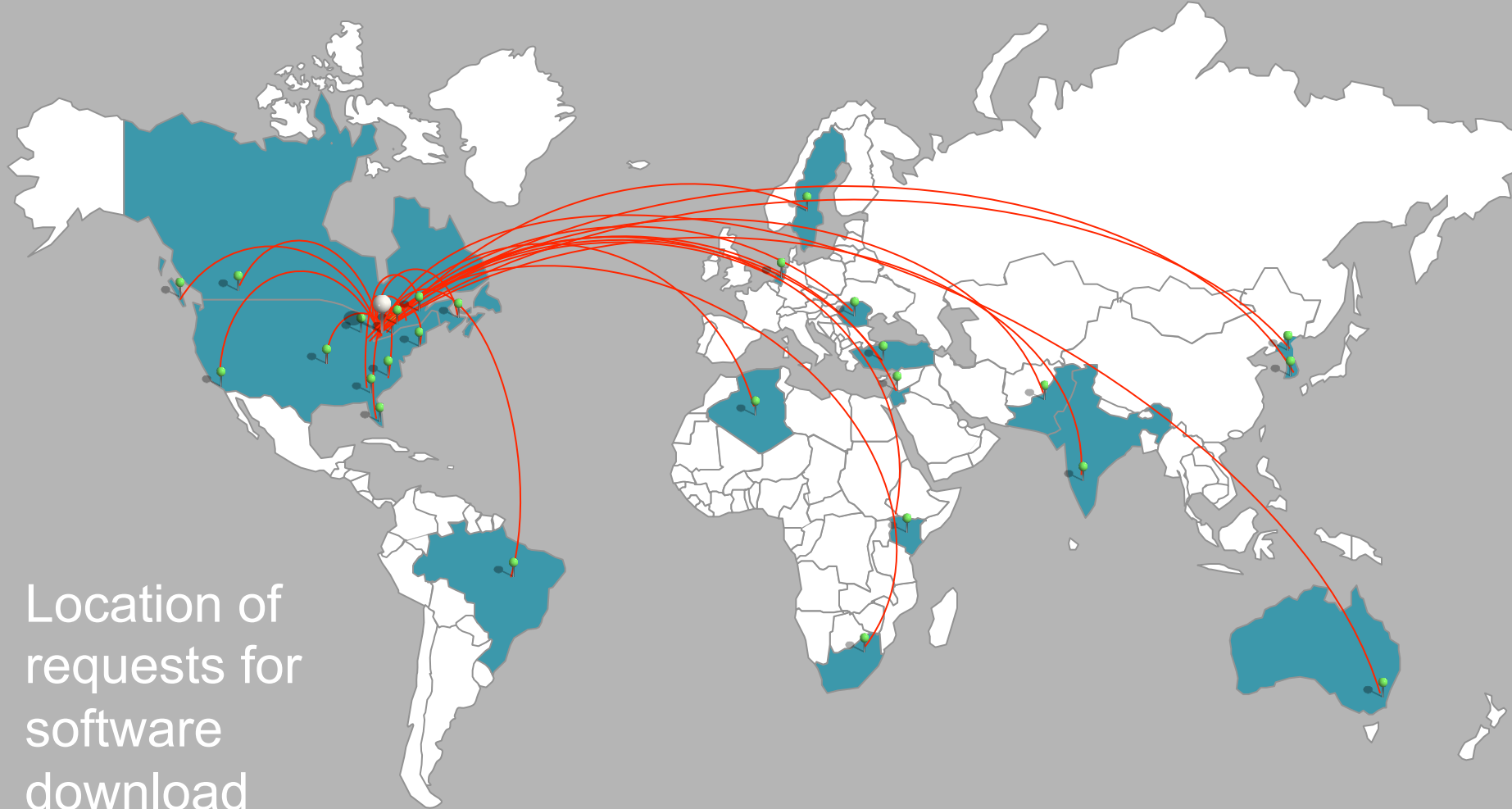
SIMAC
Simulate Lin**ac**

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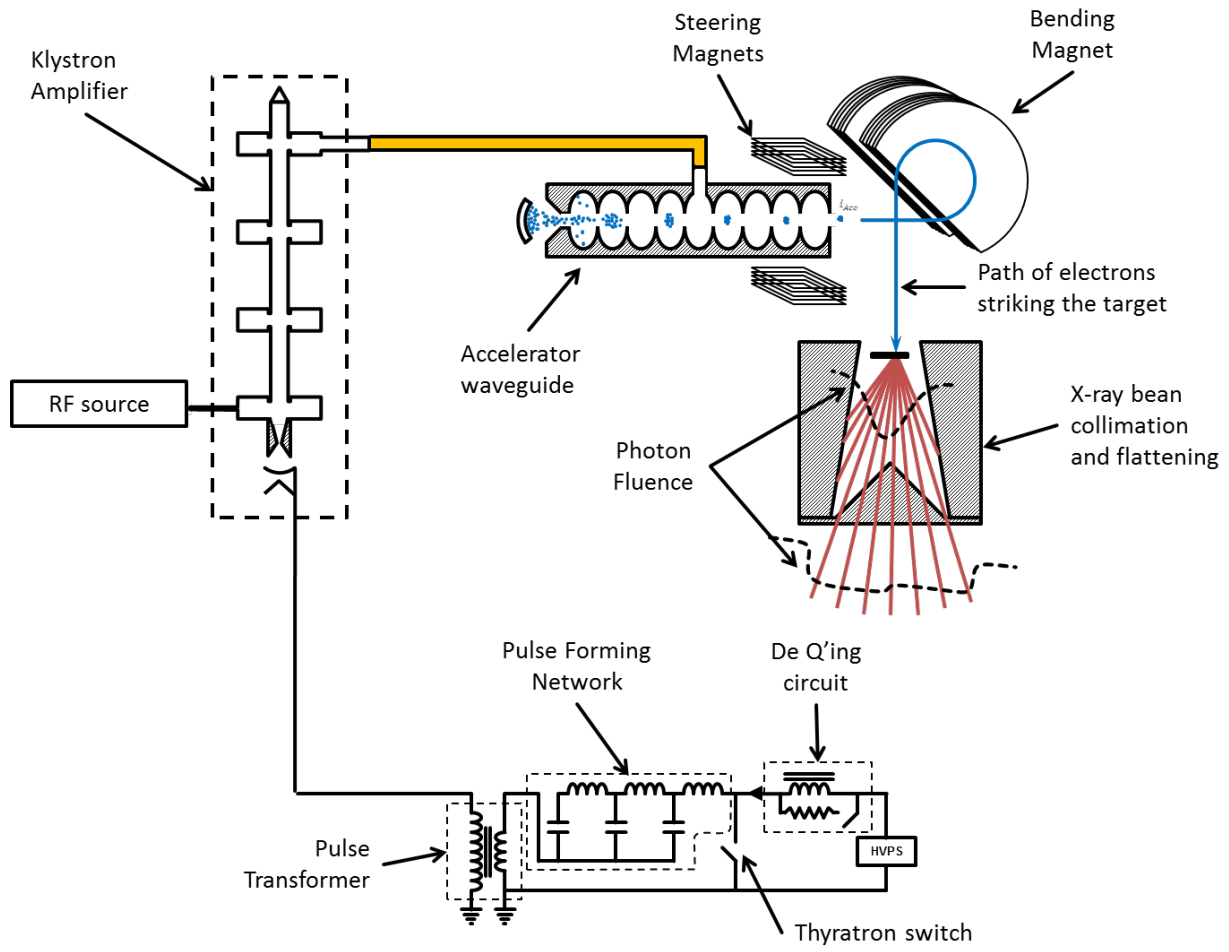- Meant to simulate the service mode of a clinical linac

SIMAC Global Reach

Location of requests for software download

Simulation of a medical linear accelerator for teaching purposes

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Klystron Amplifier

RF source

Accelerator waveguide

Steering Magnets

Bending Magnet

Path of electrons striking the target

i_{Acc}

X-ray bean collimation and flattening

Photon Fluence

Pulse Forming Network

De Q'ing circuit

Pulse Transformer

HVPS

Thyratron switch

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Using SIMAC

Using SIMAC

Using SIMAC

Linac Physics modules in SIMAC
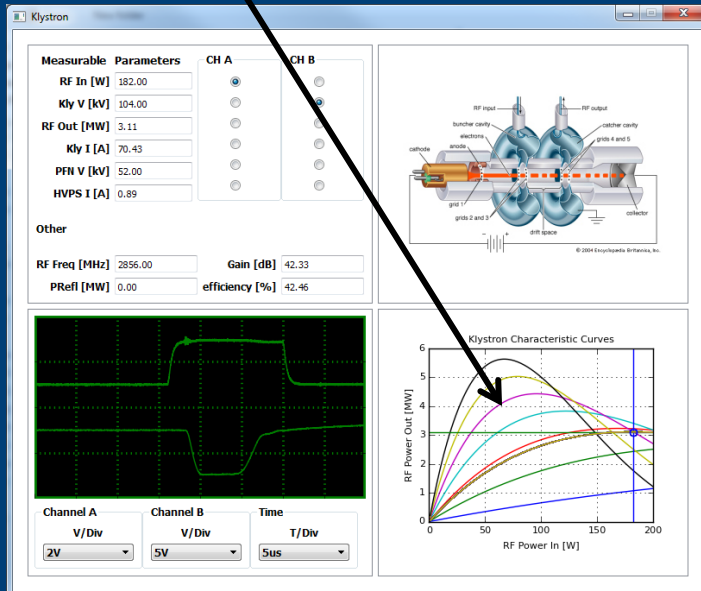
The linac Load line is modelled using the concept of "Shunt Impedance"
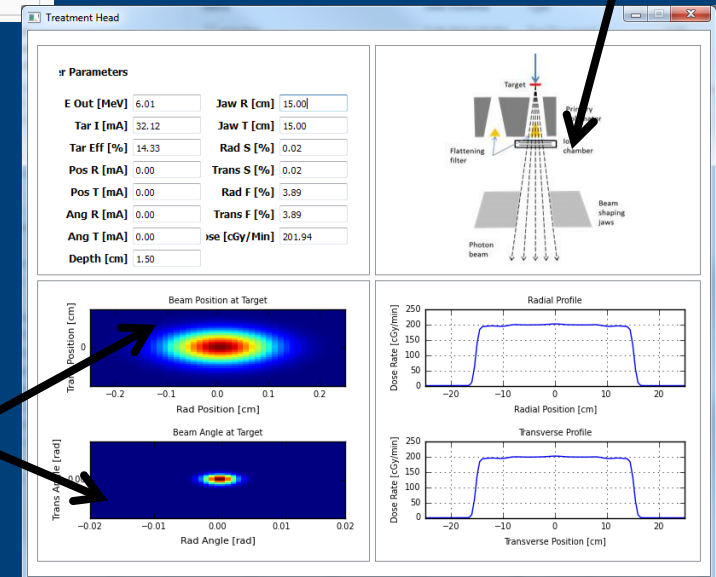
Klystron saturation is modelled using an analytical (Bessel) function
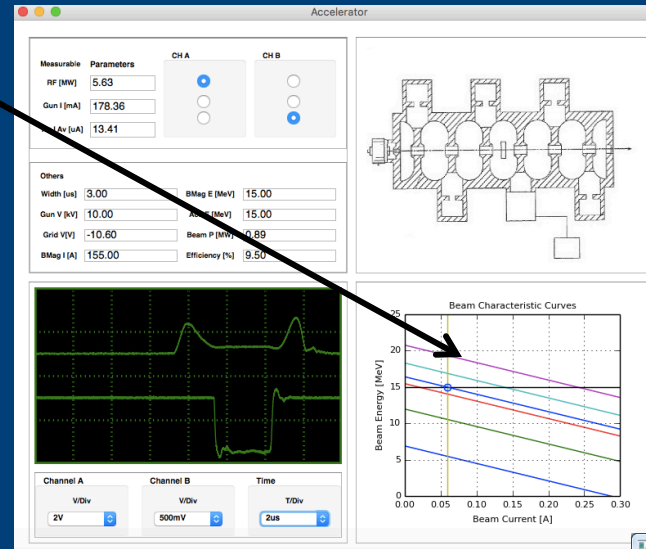
Photon transport is modelled using breamstallung yield tables (NIST) and linear attenuation in the FF and water phantom

Electron beam position and angle on the target

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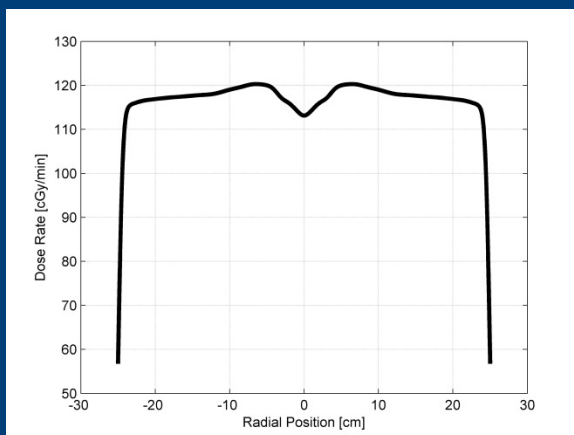
Atec Lab Exercise 1:
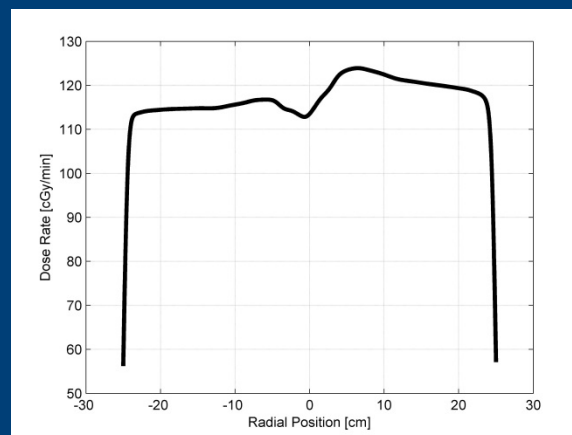
Teaching of beam "tuning" with SIMAC
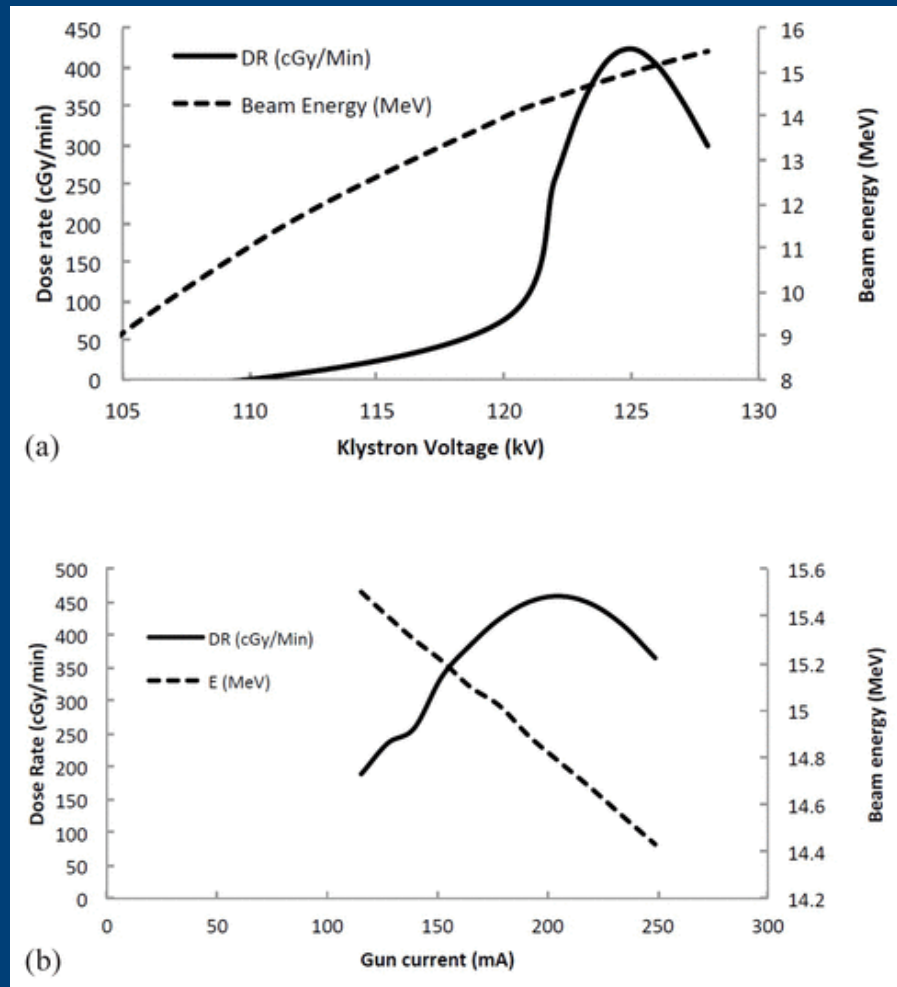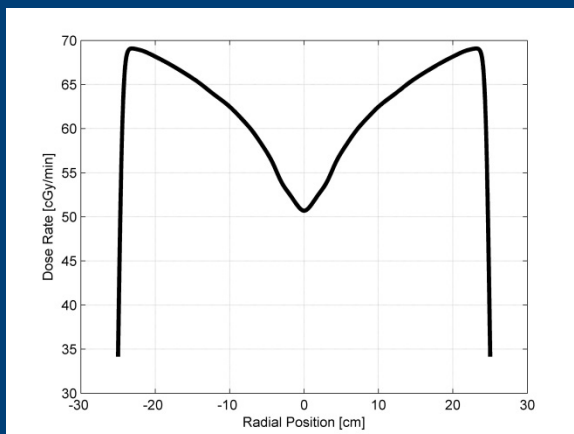
ATec Lab Exercise 2:

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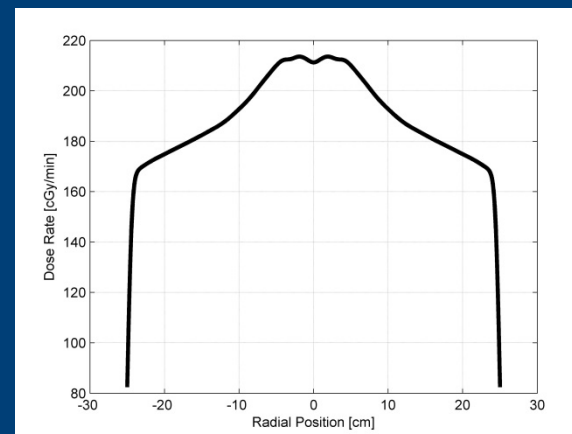

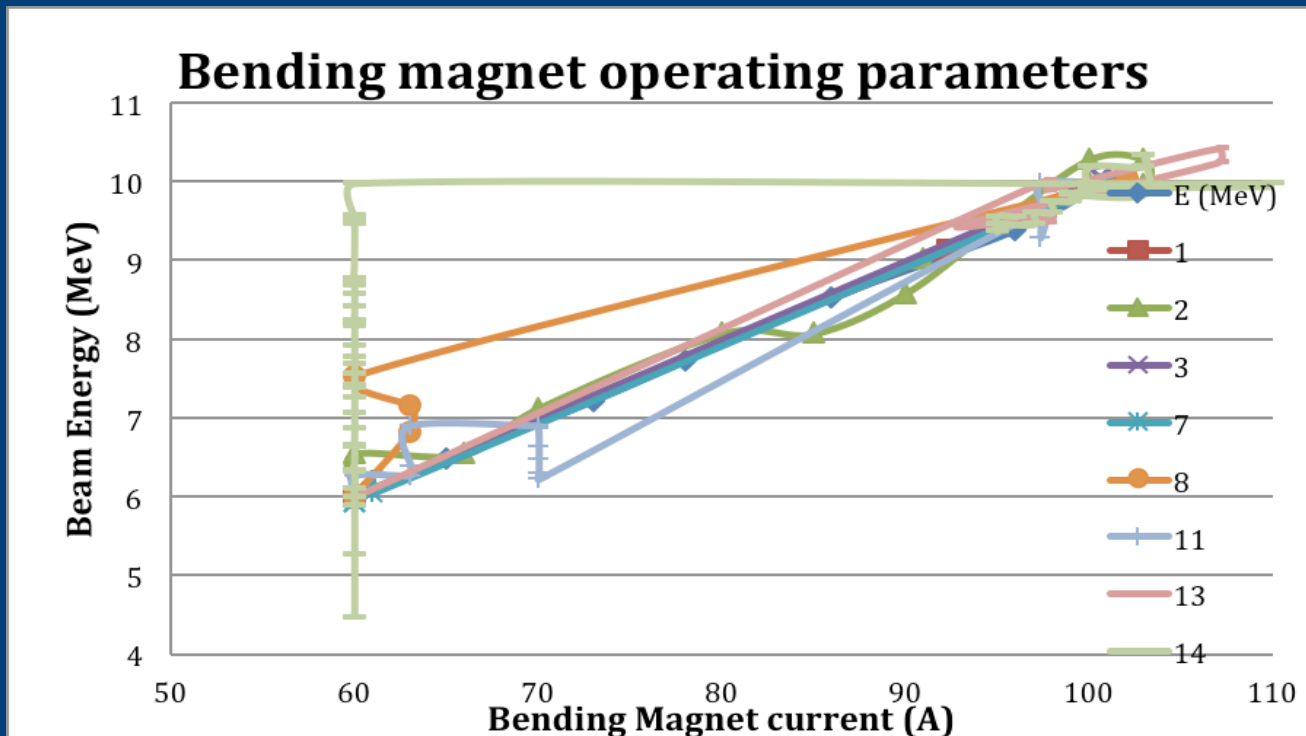6 MeV beam on 6MV flattening filter

Pos_R = 100 mA, Ang_R = 0

4.5 MeV beam on 6MV flattening filter

7.5 MeV beam on 6MV flattening filter

Laboratory teaching with SIMAC

Setting up a new energy

User feedback and Testimonials

- Found this lab extremely useful. Really helped me understand all topics discussed so far.

- The SIMAC software is great to work with. Whom ever worked on creating it did an amazing job.

- The lab was very helpful in bringing all the concepts together.

- Excellent! Found both really helped my understanding of topics in course.

- Very informative and interesting. More scenarios/ exercises would be fun.

- The simulation program is extremely useful and a great learning tool. It helped me to understand and connect many of the concepts.

- The lab was excellent; learning the various traits to work a linac.

www.simaclinac.com

Four levels of learning effectiveness

1. Reaction

   Were the users satisfied?

2. Learning

   Was knowledge gained?

3. Behaviour

   How knowledge gain applies to work.

4. Results

   Work habits changed.

Four levels of learning effectiveness

1. **Reaction**

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2. Learning

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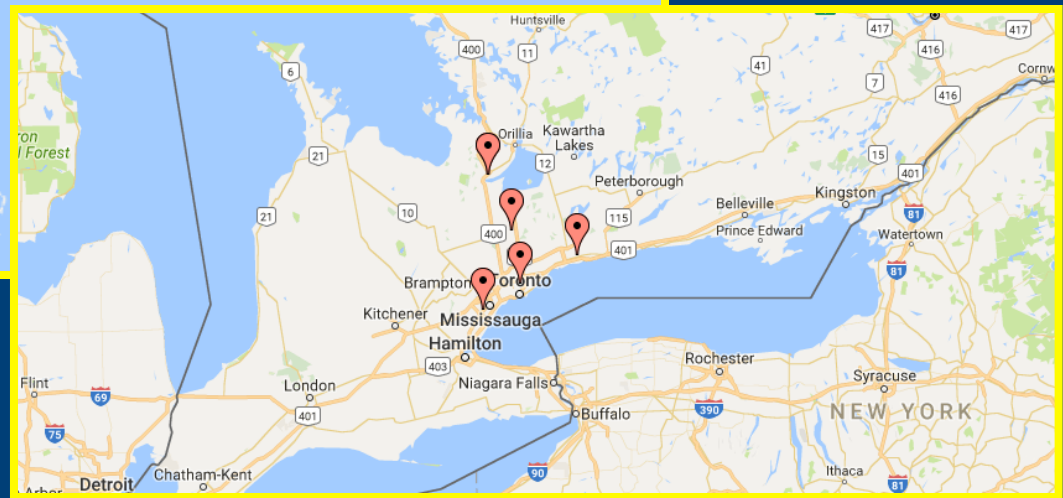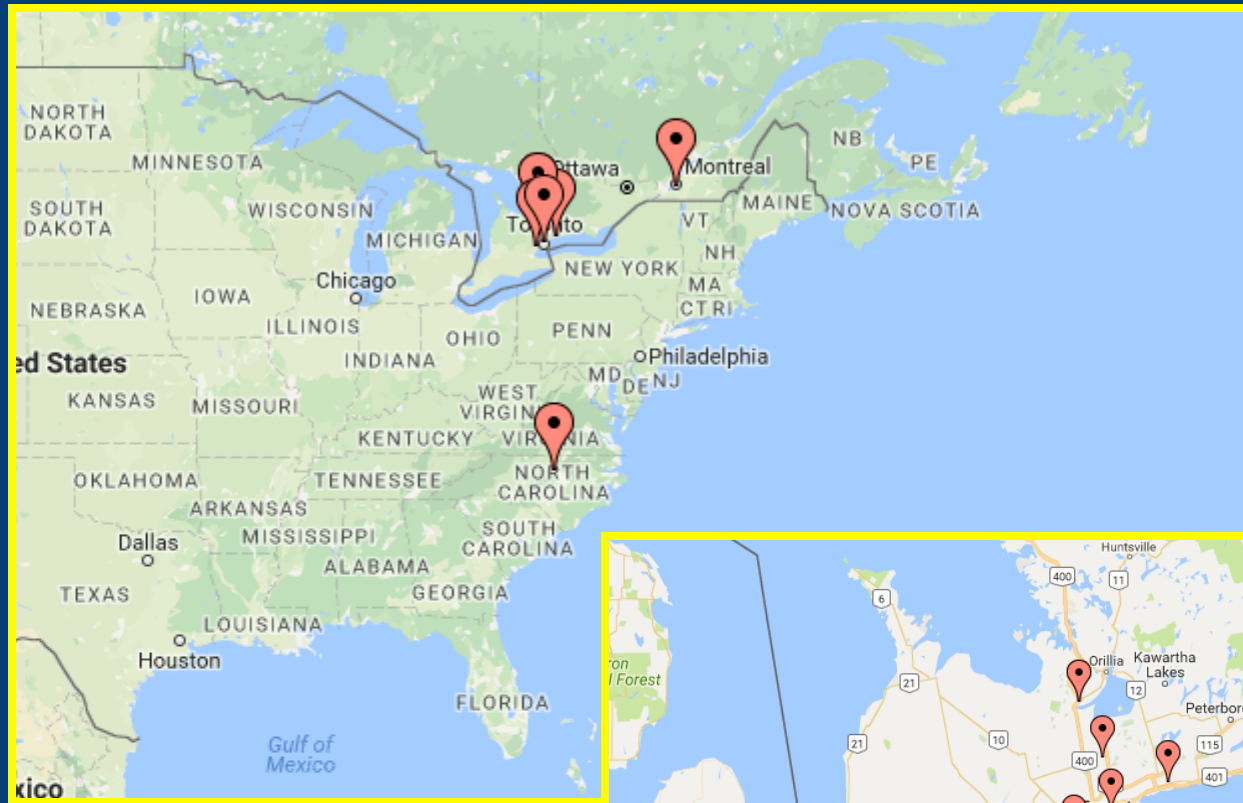   How knowledge gain applies to work.

4. Results

   Work habits changed.

Evaluating the effectiveness of SIMAC

- Received Funding through University of Toronto.

- Develop an assessment tool and validate
  - using physicists and residents from the U of T affiliated cancer centre and two other centres.

Map of center participants

Study methodology

1. Establish Learning Outcomes

    a) Ability to understand linac physics in relation to linac QA after servicing.

2. Develop Evaluation Methods

    a) Pre/post knowledge test design using clinical based scenarios.

3. Conduct Scale Assessment

    a) Recruiting Residents & physicists from the participating centers

    b) Complete in the Fall, 2016.

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?

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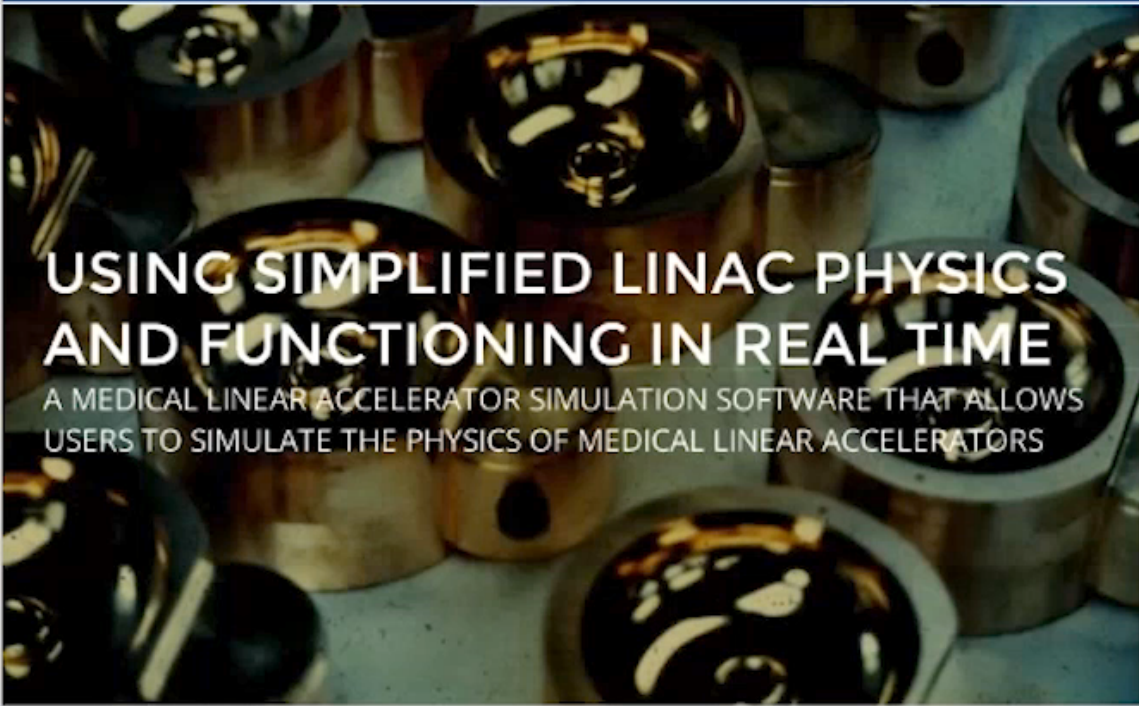UNIVERSITY OF TORONTO

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Scenario based evaluation

The future

- Expand the physics within SIMAC:
  - Model temperature, ion chambers, magnetron linacs, frequency control, dose rate servo, etc.
- Distribute SIMAC package to Medical Physics community

Thank You!
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