

**Linear accelerator simulations for stable and sustainable operation of developing country radiotherapy linear accelerators**

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# Linac operability is an important consideration in any environment

- Training on linac service personnel is difficult at BC Cancer
- Communication between Medical Physicists and Linac Service technicians is challenging everywhere
- We suggest that this is a critical component of any linac operation plan, especially for challenging environments

# 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 aimed at the radiotherapy physicist

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# MEDICAL ELECTRON ACCELERATORS

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C.J. Karzmark  
Craig S. Nunan  
Eiji Tanabe

# 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

### Connect with Us!



Web: [www.aepeducation.ca](http://www.aepeducation.ca)



Email: [aep@rmp.uhn.ca](mailto:aep@rmp.uhn.ca)



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YouTube: AEP Education



LinkedIn: Accelerated Education Program

# 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 Linac

SIMAC

File Help

Beam On/Off

Energy

PRF [Hz]

Rad S [%]

Rad F [%]

Trans S [%]

Trans F [%]


Dose [cGy/Min]

RF Freq [MHz]	<input type="text" value="2856.00"/>	Width [us]	<input type="text" value="3.00"/>	Pos R [mA]	<input type="text" value="0.00"/>
RF in [W]	<input type="text" value="182.00"/>	Gun V [kV]	<input type="text" value="16.00"/>	Pos T [mA]	<input type="text" value="0.00"/>
Kly V [kV]	<input type="text" value="104.00"/>	Grid V [V]	<input type="text" value="0.00"/>	Ang R [mA]	<input type="text" value="0.00"/>
RF Out [MW]	<input type="text" value="3.11"/>	BMag I [A]	<input type="text" value="65.00"/>	Ang T [mA]	<input type="text" value="0.00"/>
P Refl [MW]	<input type="text" value="0.00"/>	Gun I [mA]	<input type="text" value="427.03"/>	Jaw R [cm]	<input type="text" value="15.00"/>
		Tar I Av [uA]	<input type="text" value="32.12"/>	Jaw T [cm]	<input type="text" value="15.00"/>
				Depth [cm]	<input type="text" value="1.50"/>

Klystron Accelerator Treatment Head

RF Freq [MHz]	Width [us]	Pos R [mA]	Jaw R [cm]
RF In [W]	Gun V [kV]	Pos T [mA]	Jaw T [cm]
Kly V [kV]	Grid V [V]	Ang R [mA]	Depth [cm]
	BMag I [A]	Ang T [mA]	

Calculate



- 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



# Using SIMAC

Mode selection

Clinical parameters

Linac parameter control

Linac operating values

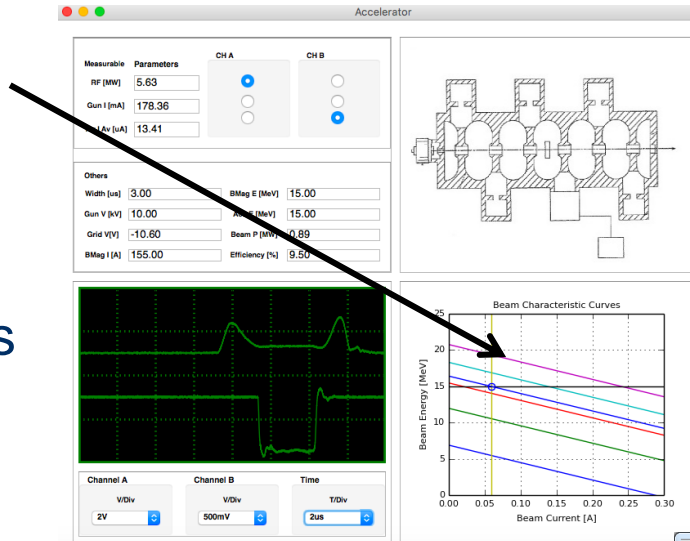
The SIMAC software interface is divided into several functional areas:

- Mode selection:** A green-bordered box containing 'Beam On/Off' (On/Off), 'Energy' (6MV), and 'PRF [Hz]' (120Hz).
- Clinical parameters:** A blue-bordered box containing 'Rad S [%]' (0.02), 'Rad F [%]' (3.89), 'Trans S [%]' (0.02), 'Trans F [%]' (3.89), and 'Dose [cGy/Min]' (201.94).
- Linac operating values:** A yellow-bordered box containing a grid of numerical values for parameters such as RF Freq [MHz], Width [us], Pos R [mA], RF in [W], Gun V [kV], Pos T [mA], Kly V [kV], Grid V [V], Ang R [mA], RF Out [MW], BMag I [A], Ang T [mA], P Refl [MW], Gun I [mA], Jaw R [cm], Tar I Av [uA], Jaw T [cm], and Depth [cm].
- Linac parameter control:** A red-bordered box containing sliders for the same parameters as the yellow box, plus a 'Calculate' button.
- Linac parameter control buttons:** Three buttons labeled 'Klystron', 'Accelerator', and 'Treatment Head' are located below the clinical parameters.
- Linac image:** A photograph of a medical linear accelerator is shown on the right side of the interface.

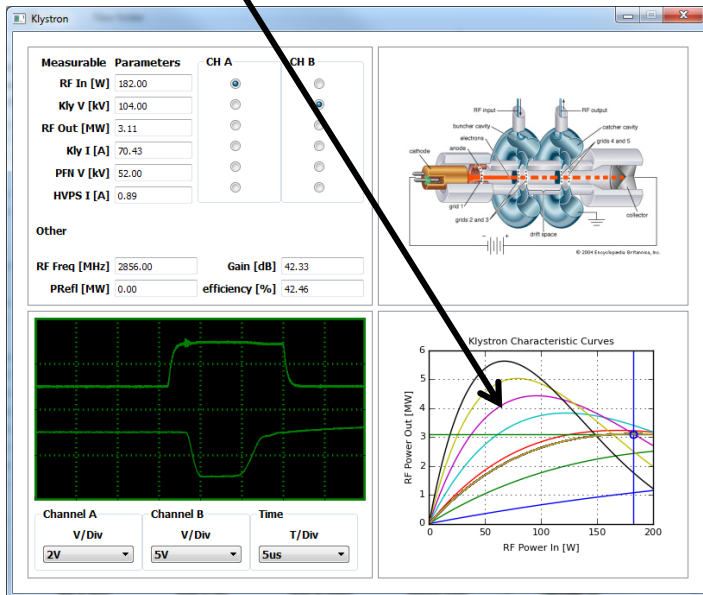
# Linac Physics modules in SIMAC

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

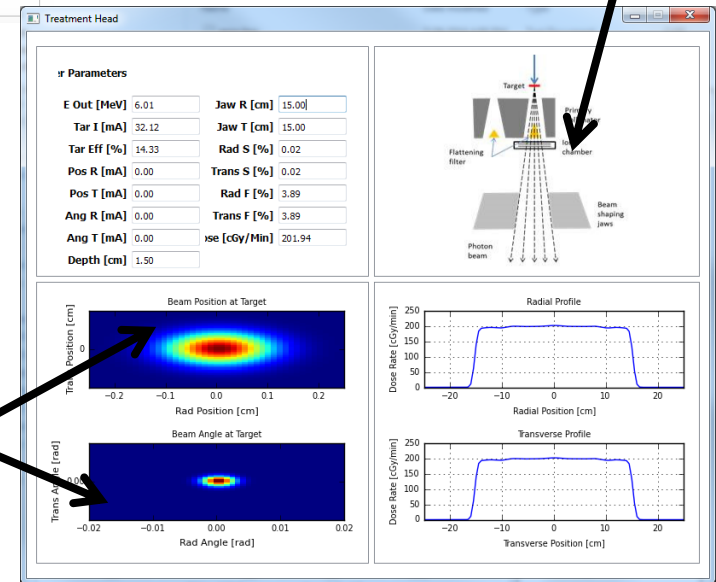
Klystron saturation is modelled using an analytical (Bessel) function



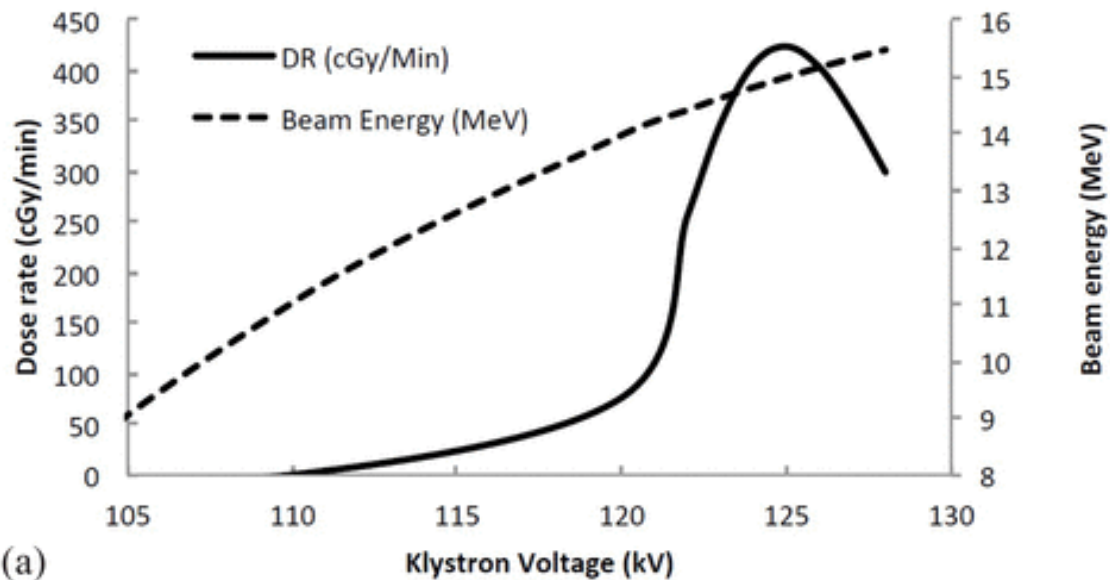
Photon transport is modelled using bremsstrahlung yield tables (NIST) and linear attenuation in the FF and water phantom



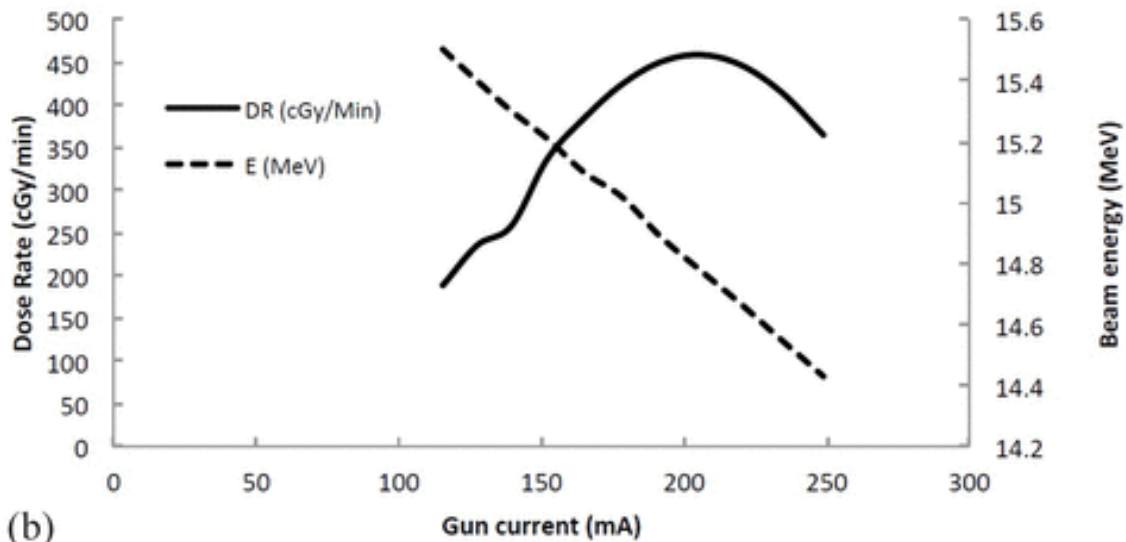
Electron beam position and angle on the target



# Teaching of beam “tuning” with SIMAC

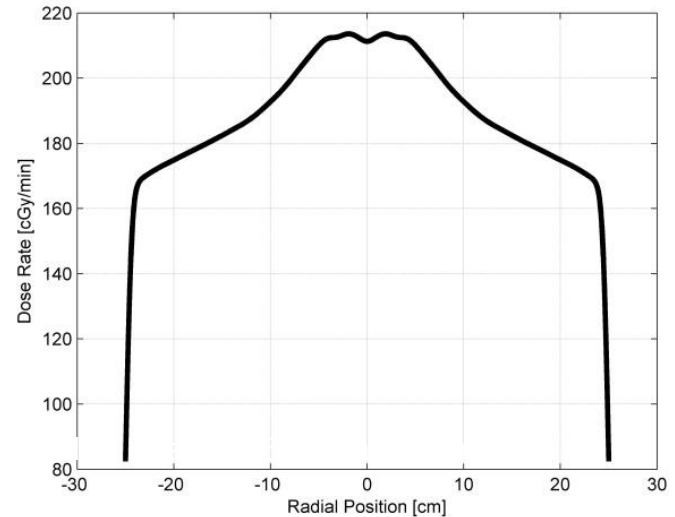
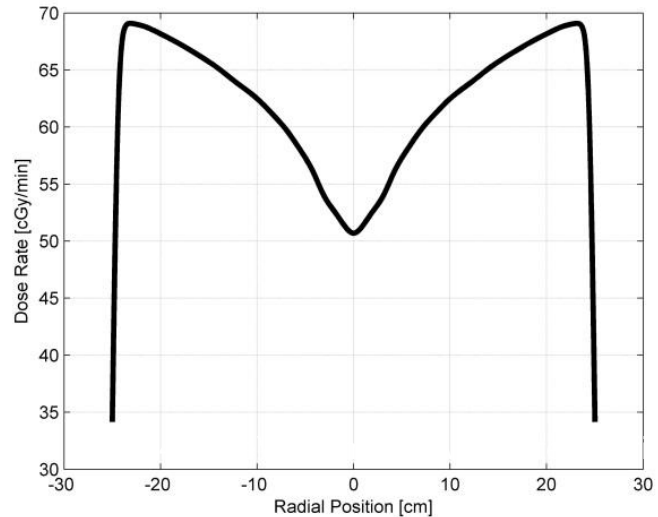
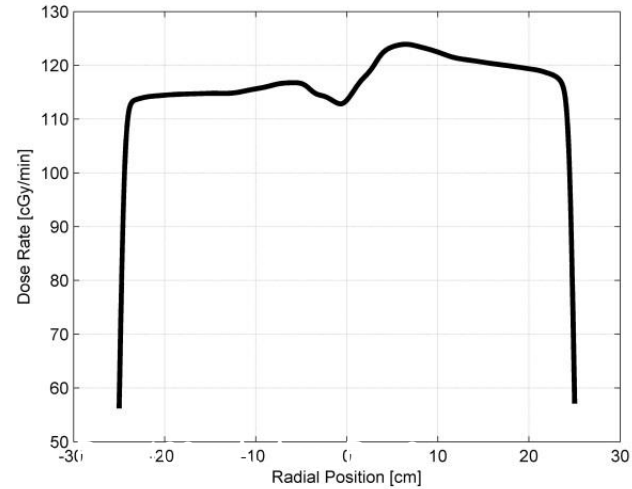
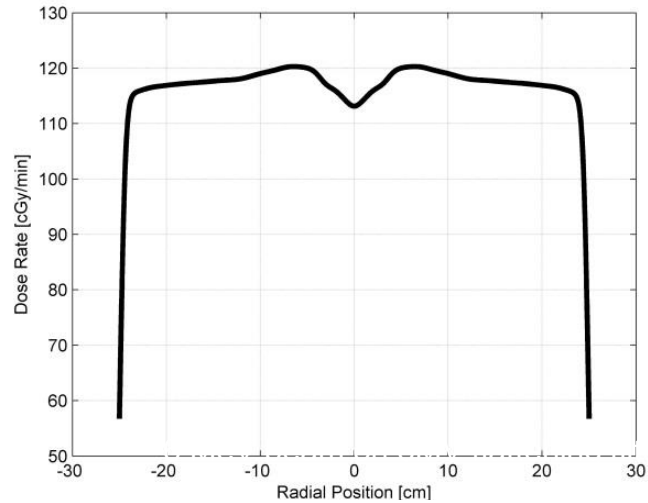


(a)



(b)

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



# www.simaclinac.com

The screenshot shows a web browser window displaying the SIMAC website. The browser's address bar shows the URL <http://simac.technainstitute.com/>. The website's header features the SIMAC logo on the left and a navigation menu with links for HOME, BACKSTORY, LEARNING RESOURCES, COMMUNITY, CONTACT, and LOGIN. Below the header is a large hero image of a medical linear accelerator component with the text: "USING SIMPLIFIED LINAC PHYSICS AND FUNCTIONING IN REAL TIME" and "A MEDICAL LINEAR ACCELERATOR SIMULATION SOFTWARE THAT ALLOWS USERS TO SIMULATE THE PHYSICS OF MEDICAL LINEAR ACCELERATORS". The main content area is divided into three columns: "BACKSTORY" (with a book icon), "LEARNING" (with a person icon), and "HELP OUT" (with a group icon). Each column contains a short paragraph and a "READ FURTHER" button. The browser's address bar at the bottom shows the URL <http://simac.technainstitute.com/learning-resources/>.

**SIMAC**    HOME    BACKSTORY    LEARNING RESOURCES    COMMUNITY    CONTACT    LOGIN

**USING SIMPLIFIED LINAC PHYSICS AND FUNCTIONING IN REAL TIME**  
A MEDICAL LINEAR ACCELERATOR SIMULATION SOFTWARE THAT ALLOWS USERS TO SIMULATE THE PHYSICS OF MEDICAL LINEAR ACCELERATORS

**BACKSTORY**

We have developed an open-source medical linac simulation product called SIMAC, which allows users to simulate the physics of beam formation in a medical linac in real time. It replicates the relationship between the various beam production components and provides a platform to manipulate the components and observe the implications of those changes.

**LEARNING**

We propose to develop and implement an evaluation methodology that will demonstrate the impact of SIMAC on knowledge acquisition of MPs and trainees (level 2 learning outcome) as it relates the basic functionality of a linac and the production of high quality radiation beam. There will be three key activities associated with this phase of the overall project.

**HELP OUT**

SIMAC is freely available to anyone who wants to learn or teach about linac physics. If you have an interest in teaching linac physics, we would like to hear from you. If you want to make the physics within SIMAC better, we could use your help. If you want to teach and use SIMAC as an aid, we want to know how you do it so others can also use SIMAC in the same way.

[READ FURTHER](#)    [GET INVOLVED](#)    [OPPORTUNITIES](#)

<http://simac.technainstitute.com/learning-resources/>

# Simac is freely available

**SIMAC**

[SIMAC](#)

[BACKSTORY](#)

[DOWNLOAD SIMAC](#)

[LEARNING RESOURCES](#)

[COMMUNITY](#)

[CONTACT](#)

[LOGIN](#)

## SIMAC BETA DOWNLOAD

SIMAC is going through many changes, as we're always working to make it a better learning tool.

*SIMAC 0.3.4 was released Oct. 6th, 2016*

DOWNLOAD THE 64 BIT BETA VERSION  
OF SIMAC FOR WINDOWS

DOWNLOAD

DOWNLOAD THE 32 BIT BETA VERSION  
OF SIMAC FOR WINDOWS

DOWNLOAD

DOWNLOAD THE BETA VERSION  
OF SIMAC FOR MAC

DOWNLOAD

# Work Package 5

Address the operability of a medical linac

1. Address the knowledge issues around linac service by improving the SIMAC experience
  - (Have good linac drivers)
2. Provide automation tools to assist linac repairs by modeling include linac failures
  - (Provide a driver assist mode for already good drivers)

# Work Package 5

- Deliverable 1: Help expand the online SIMAC community by making SIMAC fully web-based.
- Deliverable 2: Demonstrate the feasibility of a diagnostic data collection system.
- Deliverable 3: Report on potential algorithms to implement a machine learning model to interpret fault data.



# Deliverable 1

- SIMAC is mature and has been used
- Assemble a complete set of linear accelerator physics modules
  - Building a comprehensive “flight simulator” for LINACS
  - Maintain code in GitHub repository to maximize community involvement

# Deliverable 2

Install data loggers on existing linacs and demonstrate the feasibility of collecting this data

jitaya

Community Help About us [Shop & b](#)

The image shows a promotional banner for the STEMlab website. The background is a blue sky with a white contrail from a rocket or satellite. On the left, there is a close-up of a red circuit board with various components. On the right, there is a close-up of a blue and white connector. The text is centered and reads: "STEMlab" in red and black, followed by "SWISS ARMY KNIFE FOR ENGINEERS" in large red letters. Below this, it says "Start remote measuring, learning, teaching, developing or even HF radio communicating like the best in class do!". A red "Shop" button is centered below the text. At the bottom, it says "Works with your favourite OS" and shows icons for Windows, Apple, and Linux. The "jitaya" logo is in the top left, and navigation links "Community", "Help", "About us", and "Shop & b" are in the top right.

**STEMlab**

**"SWISS ARMY KNIFE FOR ENGINEERS"**

Start remote measuring, learning, teaching, developing or even HF radio communicating like the best in class do!

[Shop](#)

Works with your favourite OS

Windows Apple Linux

# Deliverable 3


- Collection of data from existing machines
- Consultation on potential machine learning algorithms and implementations
- Demonstration of simple predictive model of known failures

# Linac failure categories

- Modulator/injector failure
- Beam delivery error (steering)
- MLC malfunctions
- Power supply failures
- Control system failures
- Mechanical failures
- Broken wires
- Many others (some simple, some not)

# Linac failure categories

- Modulator/injector failure
- Beam delivery error (steering)
- **MLC malfunctions**
- **Power supply failures**
- **Control system failures**
- Mechanical failures
- Broken wires
- Many other smaller categories



I would guess these are the majority

# Linac failure categories

- **Modulator/injector failure**
- **Beam delivery error (steering)**
- MLC malfunctions
- Power supply failures
- Control system failures
- Mechanical failures
- Broken wires
- Many other smaller categories

} These are the most intimidating, and most difficult to teach

# The Art of Linac Maintenance

There is a challenging learning curve

- Service technicians are not physicists
- Distinguishing between electronics/control system problems and linac physics problems can be challenging when learning

# Objective with deliverable 3

- To assist service technicians with diagnosis problems involving linac physics.
- To reduce the “fear factor” of a large complicated machine.
- It is not intended to provide a comprehensive linac fault diagnosis repair automation





Deliverable 3 is more like driver assist as opposed to a driverless car.

Questions/comments?