



**INTERNATIONAL MEDICAL PHYSICS & BIOMEDICAL ENGINEERING  
WORKSHOP**

**Imaging for diagnosis (mainly Ultrasound techniques)**

**Radiotherapy (mainly Brachytherapy)**

**ELBASAN, Albania 4 - 8 July 2016**

**TRAINING AND SIMULATIONS IN RADIOTHERAPY**

**Niko Hyka**

# Outlines 1

- ❑ **What is Radiotherapy**
- ❑ **Physicists in Radiotherapy**
- ❑ **Radiotherapy and equipments**
- ❑ **What and how to measure**
- ❑ **Software for training and simulations in RT**

## **Outlines 2**

- ❑ Radiotherapy training and simulation methods in Matlab**
- ❑ What is PPIR, structure and basic applications**
- ❑ Radiotherapy procedure simulation using PPIR**
  - Working with medical images**
  - Clinical structures**
  - contouring, measurements/visualization**
  - Dose specification and calculation, DVH, TPS,**
  - Linac virtual simulation**
- ❑ Conclusions and discussions**

# What is Radiotherapy?

I Radiotherapy (RT) is the use of ionizing radiation to treat cancer. RT uses high frequency radiation to damage the DNA of cancer cells, which usually replicate at a faster rate than normal cells in the body.

□ Typical modalities

- External beam radiotherapy, photon
- External beam radiotherapy – electron
- Brachytherapy, nuclear source

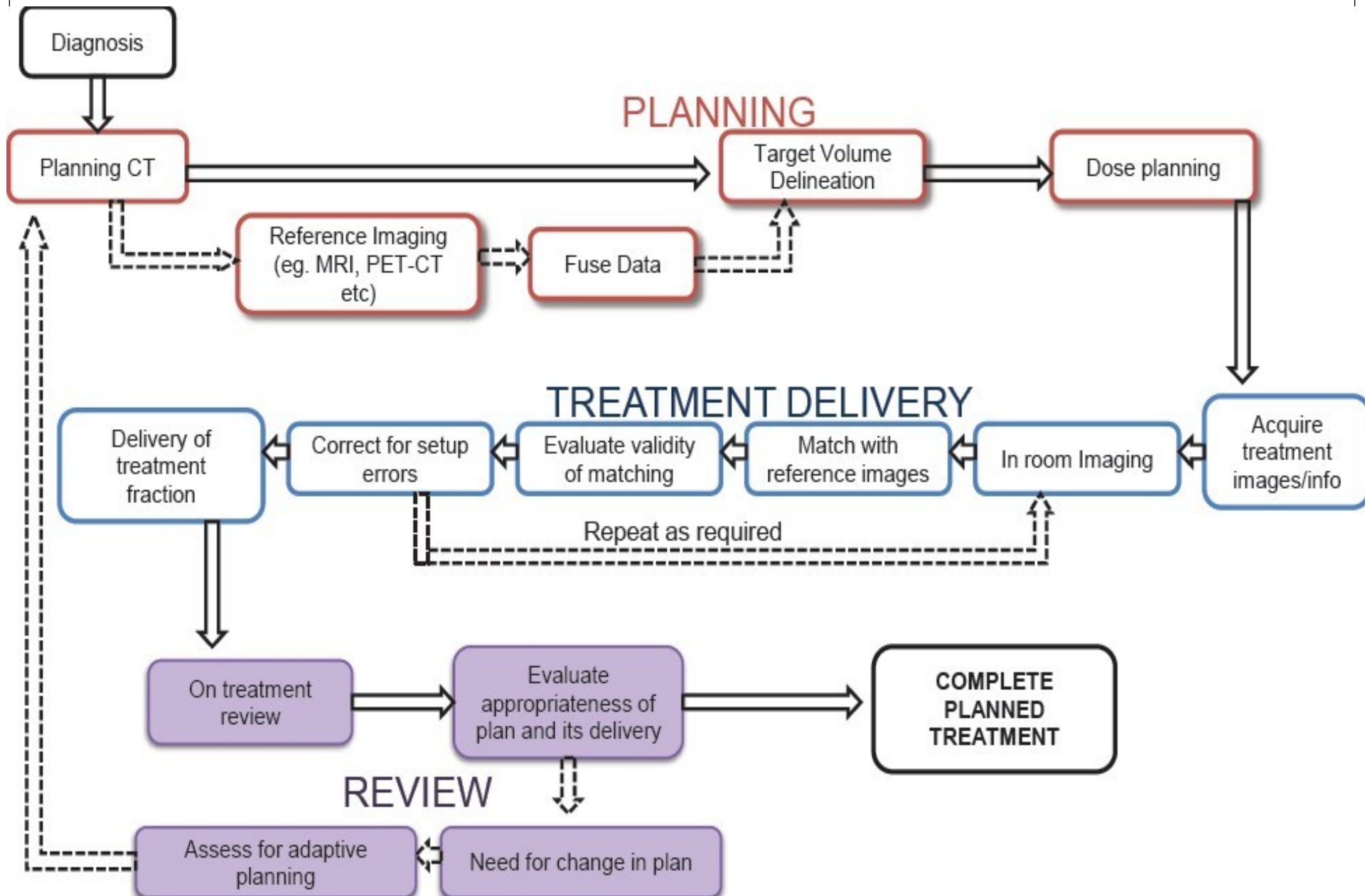
## What we need to know in RT?

We must have a good understanding of the equipment available for pre-treatment imaging purposes and the use of DICOM and PACS systems

We must be able to describe the design of the basic conventional radiotherapy simulator equipment

We must have a good understanding of computed radiography, SIM-CT and CT simulation

# RT work flow

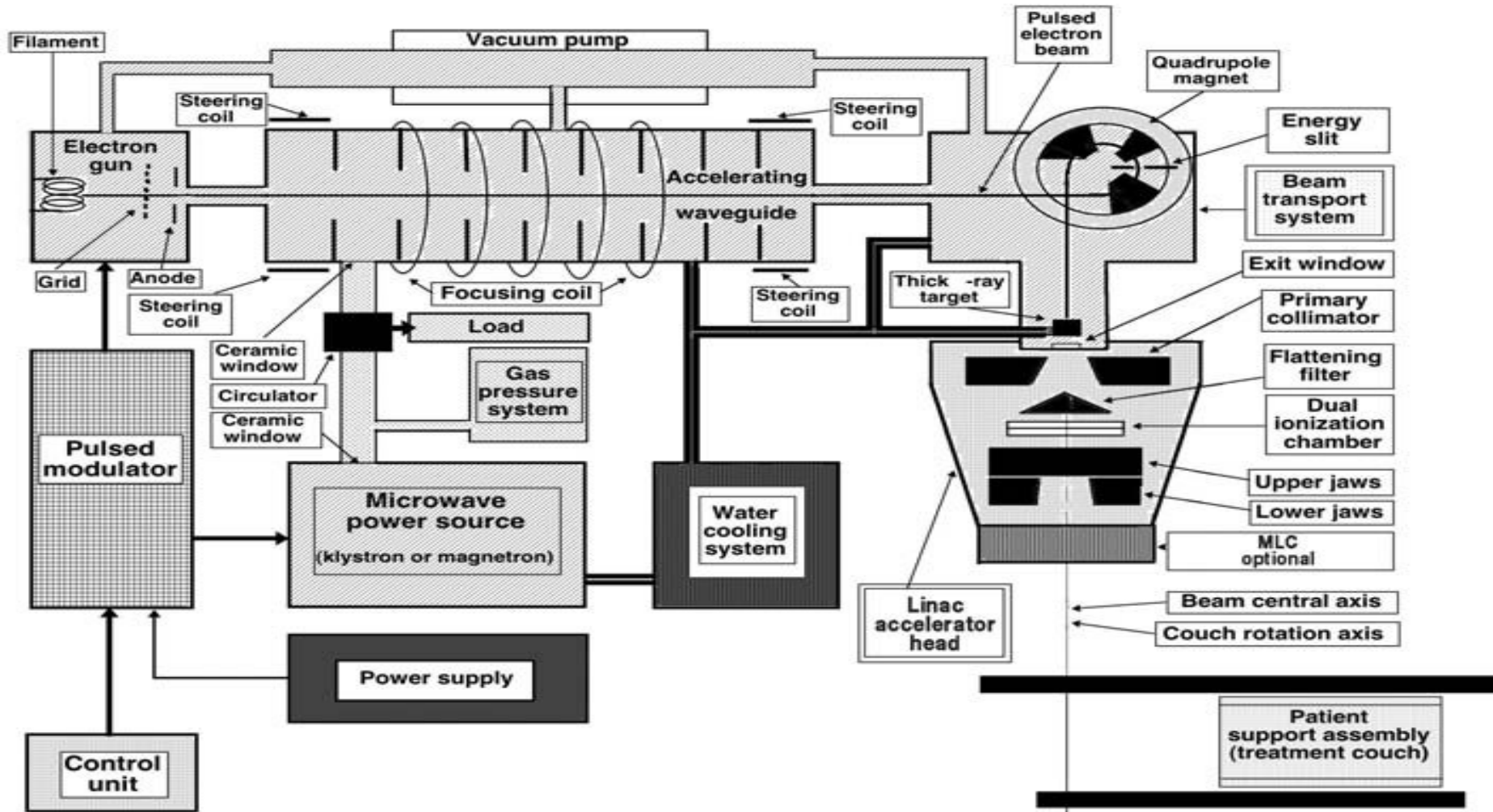


# Medical Physicists in Radiotherapy

A therapeutic **Medical Physicist** is a qualified medical physicist who works directly with the doctor in treatment planning and delivery. Therapeutic medical physicists oversee the work of dosimetrists and help ensure that complex treatments are properly tailored for each patient. They are responsible for developing and directing quality control programs for equipment and procedures that ensure the equipment works properly. They also take precise measurements of radiation beam characteristics and do other safety tests on a regular basis. Therapeutic medical physicists have doctorates or master's degrees and have completed four years of college, two to four years of graduate school and typically one to two years of clinical physics training

# Radiotherapy and equipments

## LINAC



# Dosimetric equipments:

Absolute dosimetry, [beam calibration]

Relative dosimetry, [PDD and profile]

- | Phantoms
- ▣ Radiation detection equipments
- ▣ Electrometer
- ▣ Radiochromic film
- ▣ Thermometer
- ▣ Barometer



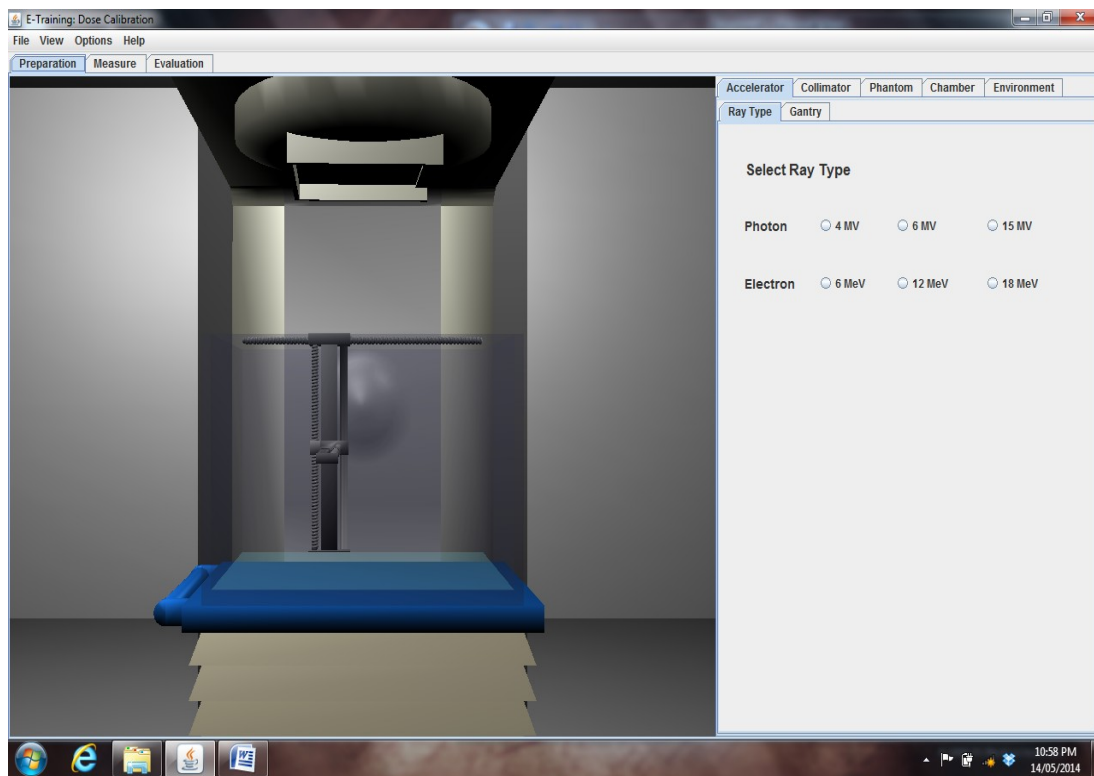
# Software for training and simulations in RT

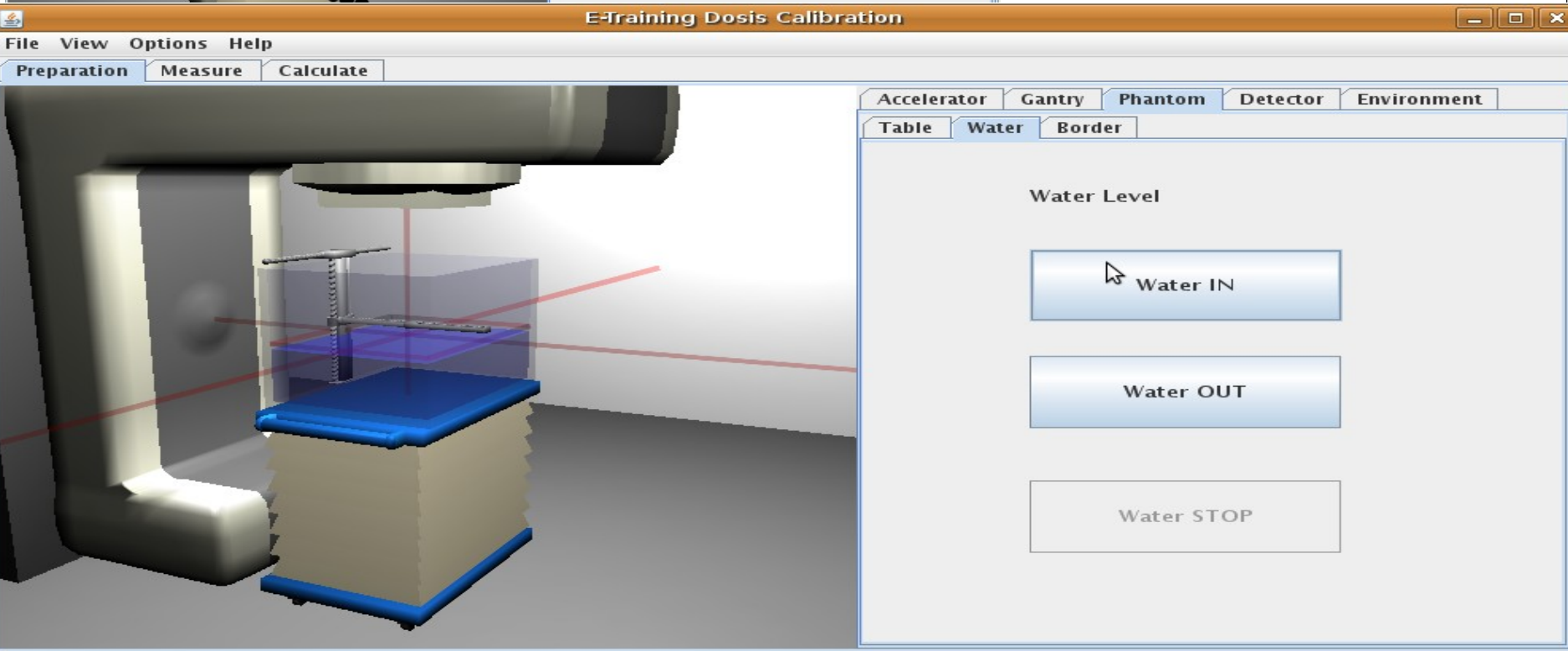
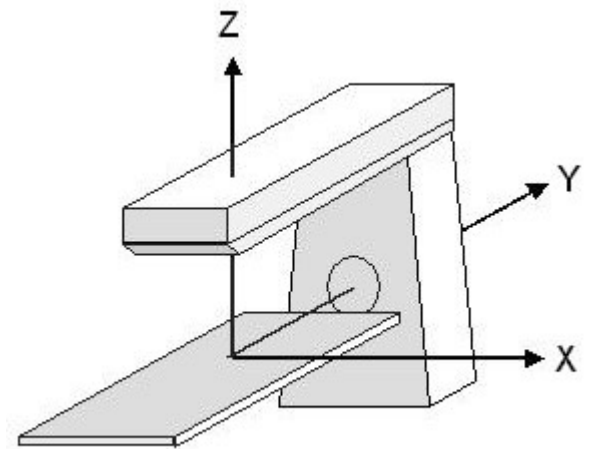
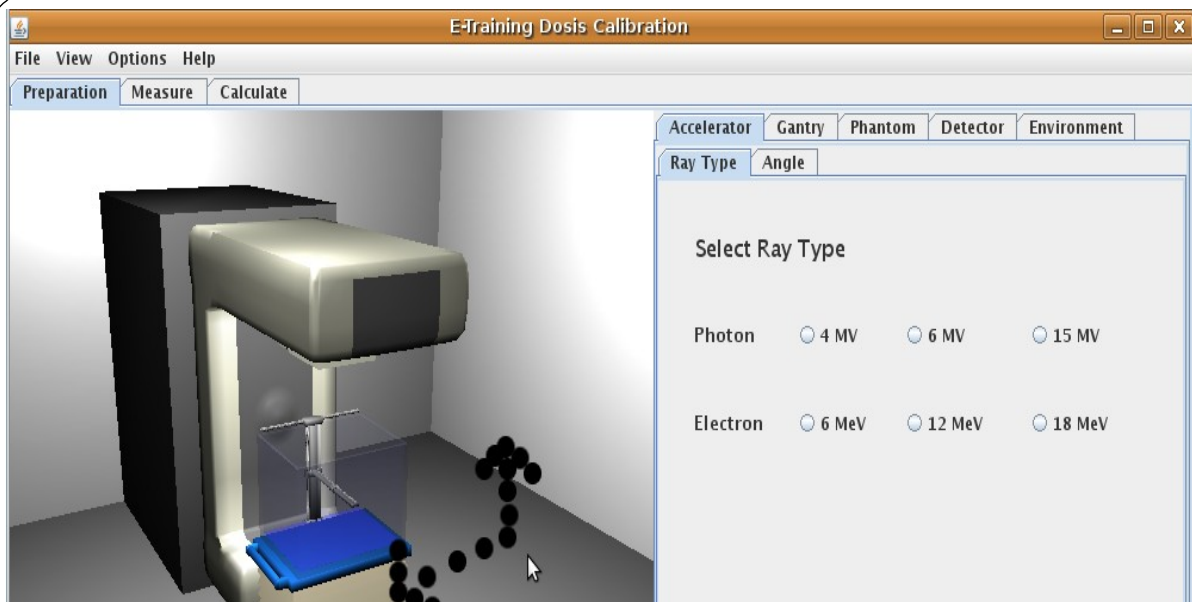
Sophisticated software/ programs known as treatment planning systems (TPS) are commercially available to make treatment plans for individual patients. But for students and researchers, its very difficult to have these expensive programs for pre-clinical training or simulations in the field or RT.

## Virtual Simulator

Virtual simulator (open source java module) “*E-training Dose Calibration*”, used for virtual simulation for LINAC calibration.

[Hyka et al, *Linac photon beam calibration using virtual simulator program*]





# Radiotherapy training and simulation methods in Matlab environment

Matlab is a high-level language and interactive environment for numerical computation, visualization, and programming. Using Matlab, we can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable us to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java

Matlab toolbox:

- ▮ Image Processing Toolbox
- ▮ Image Acquisition Toolbox
- ▮ Signal Processing Toolbox.

*<https://www.mathworks.com>*

- **Matlab and medicine:**

- DIRART (DIRART is a Matlab toolbox, as well as a stand-alone Matlab application, for deformable image registration (DIR) and adaptive radiotherapy (ART))
- CERR (Computational Environment for Radiotherapy Research), CERR is an open source-code Matlab-based tool for developing and sharing research results using radiation therapy treatment planning information
- DRESS (Dose response explorer system, an open source-code Matlab-based tool for:
  - *Modeling* tumor control probability (TCP) and normal tissue complication probability (NTCP)
  - *Evaluating* robustness of radiobiological models
  - *Graphing/plotting* results for purposes of outcomes analysis for practitioners, training for residents, and hypothesis-testing for further research

# What is PPIR?, structure and basic applications

## PPIR

- PPIR is a module in Matlab which integrate main applications and functions of **CERR** and **DRESS** and is the **first application in Matlab adapted in Albanian language**
- **General functionalities of PPIR are:**
  - **Medical images importing**
  - **Vizualisation**
  - **Image Procesing**
  - **Clinical structure contouring and dose calculations**
- **Name: “Program për Procesim Imazhesh në Radioterapi - PPIR”**. The main function is *“ppir.m”*. This module can be called by typing *“ppir”* in CW of Matlab. This function set the visual graphics of PPIR in Albanian language.

# PPIR...

PPIR is organized and adapted to perform the most important procedures that are applied in radiotherapy in the treatment of tumors such as: medical images import, delineation of structures, treatment dose, DVH management etc

Two mathematical models are included in PPIR, **TCP** (*Tumor Control Probability*) and **NTCP** (Normal Tissue Complication Probability), [High probability of local tumor control (tumor control probability, TCP) at a low risk of normal tissue complications (normal tissue complication probability, NTCP). (EUD model in Matlab)



# PPIR - graphical user interface (GUI)



Figure 2. PPIR Graphical users interface

# Simulation procedure in Radiotherapy using PPIR

## Working with Medical images:

Image importing and visualizations in three different plans (coronal, sagittal, transversal)

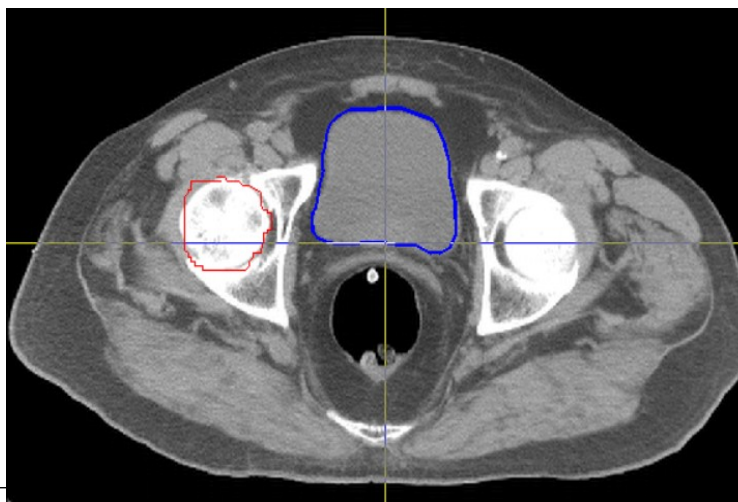
Visualization of intensity and contrast, color or gray (0 - 255 level)

Medical image processing enables quantitative analysis and visualization of medical images of numerous modalities such as PET, MRI, CT. Using the PPIR user-interface and analysis tools, students can easily make analyses and processing with different algorithms to remove artifacts or study in details the areas of interest in medical images.



# Clinical structure contouring using PPIR 2014

- **Clinical structures:** GTV, CTV, ITV and PTV, are part of TPS
  - GTV (Gross Tumor Volume).
  - CTV (Clinical Target Volume) e cila duhet të eliminohet.  $CTV = GTV + 1 \text{ cm}$ .
  - ITV (Internal Target Volume)
  - *PTV* (Planning Target Volume) is a geometrical concept, and it is defined to select appropriate beam arrangements, taking into consideration the net effect of all possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV.  $PTV = CTV + 1 \text{ cm}$ . Parameters and PTV geometry depended from immobilization and iso-centric equipment's
- OAR (Organs at risk)



# Simulation procedure in Radiotherapy using PPIR

## Working with Medical images:

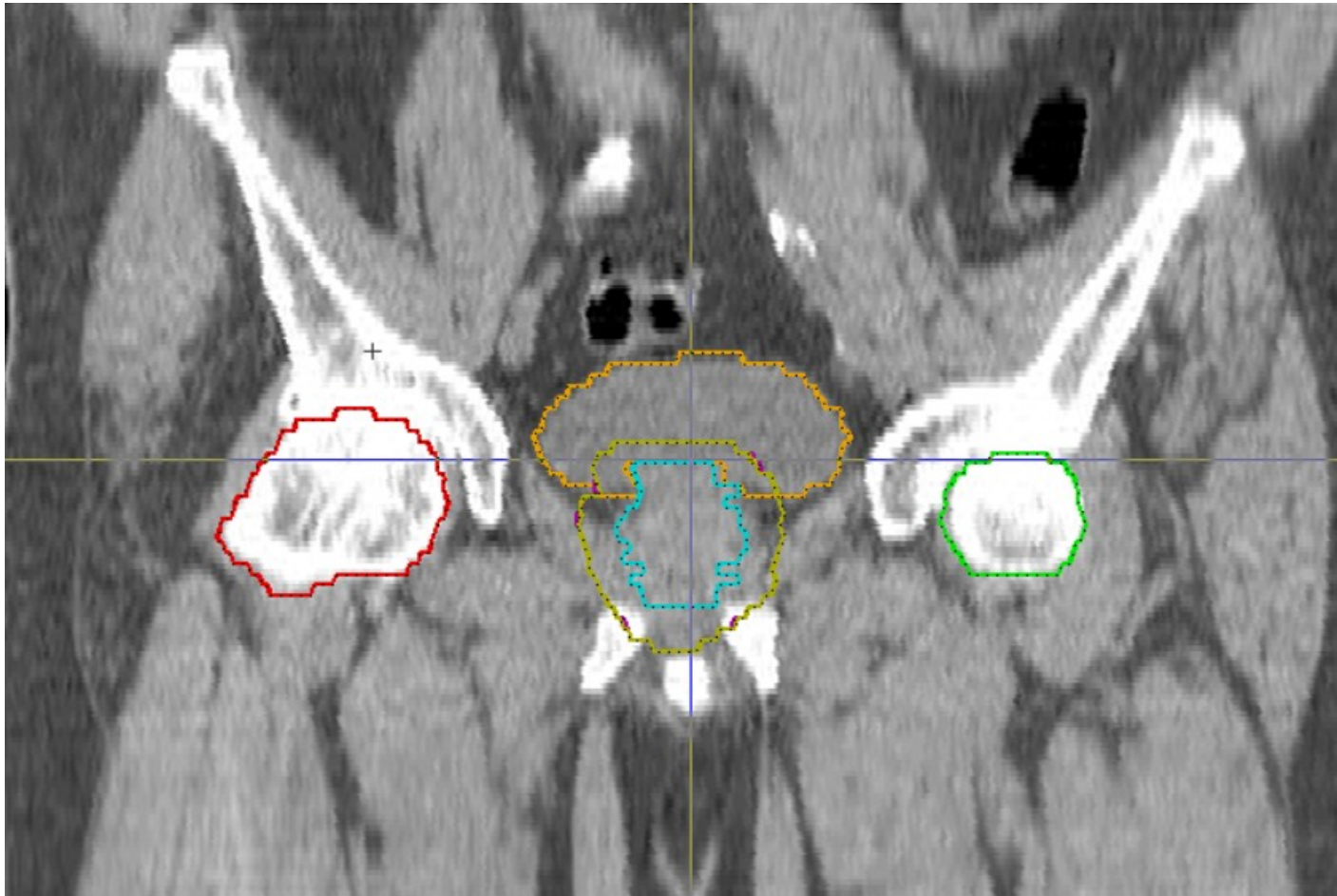
Image importing and visualizations in three different plans (coronal, sagittal, transversal)

Visualization of intensity and contrast, color or gray (0 - 255 level)

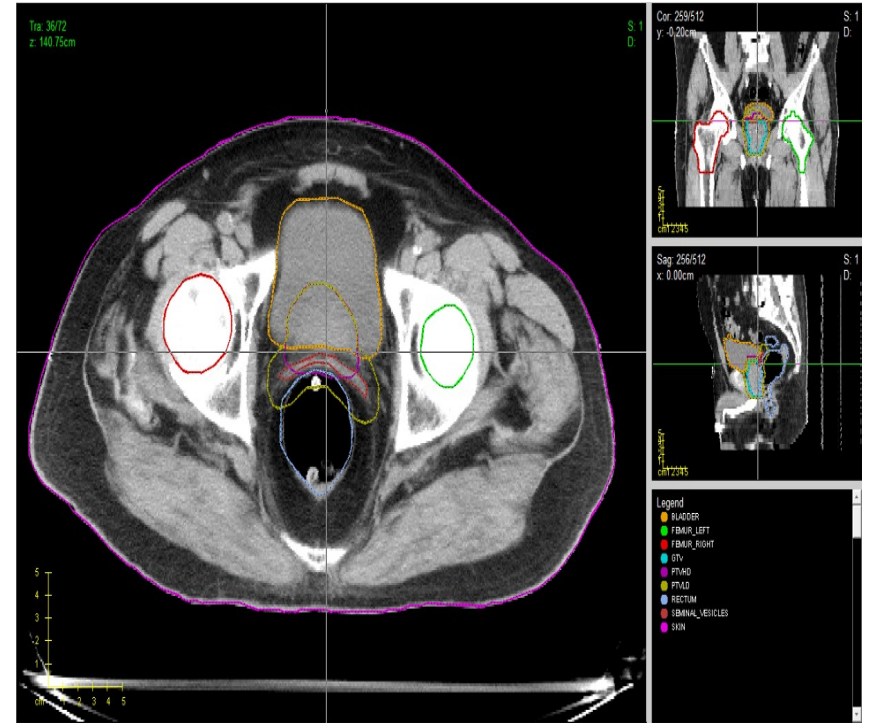
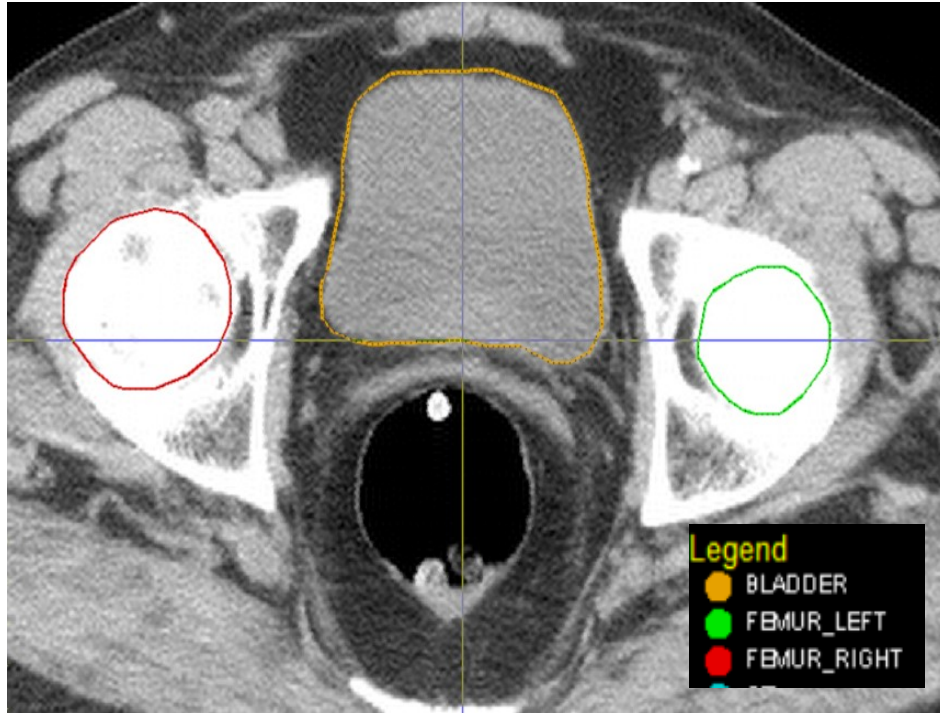
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## Contouring the clinical structures...

Contouring usually is a “homemade” process but for regular structures, this can be performed automatically. As is shown in figure (a transversal, b coronal) we use different colors for different structures



# Contouring...



# DVH - Volume histogram of dose distribution for different structures

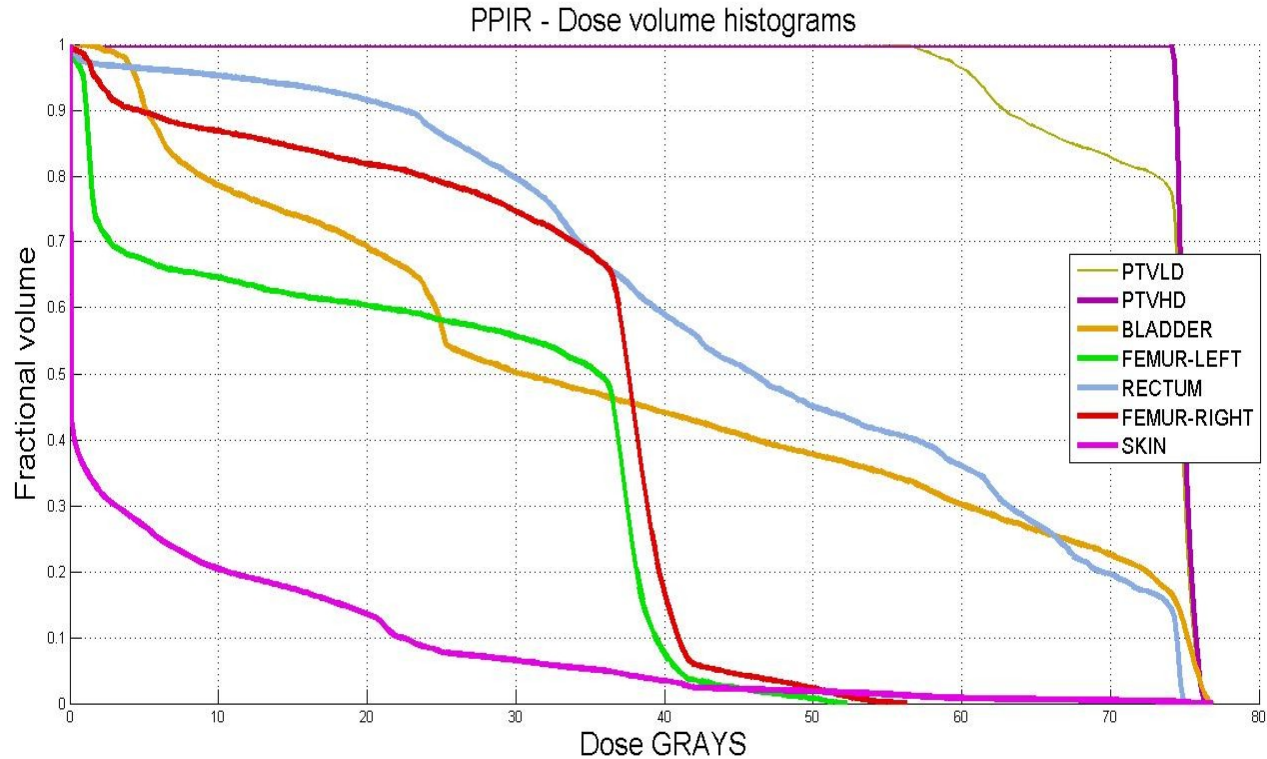


Figure 5- Graph of DVH for each structure (cumulative plot)

# Normal tissue complication modeling based on EUD

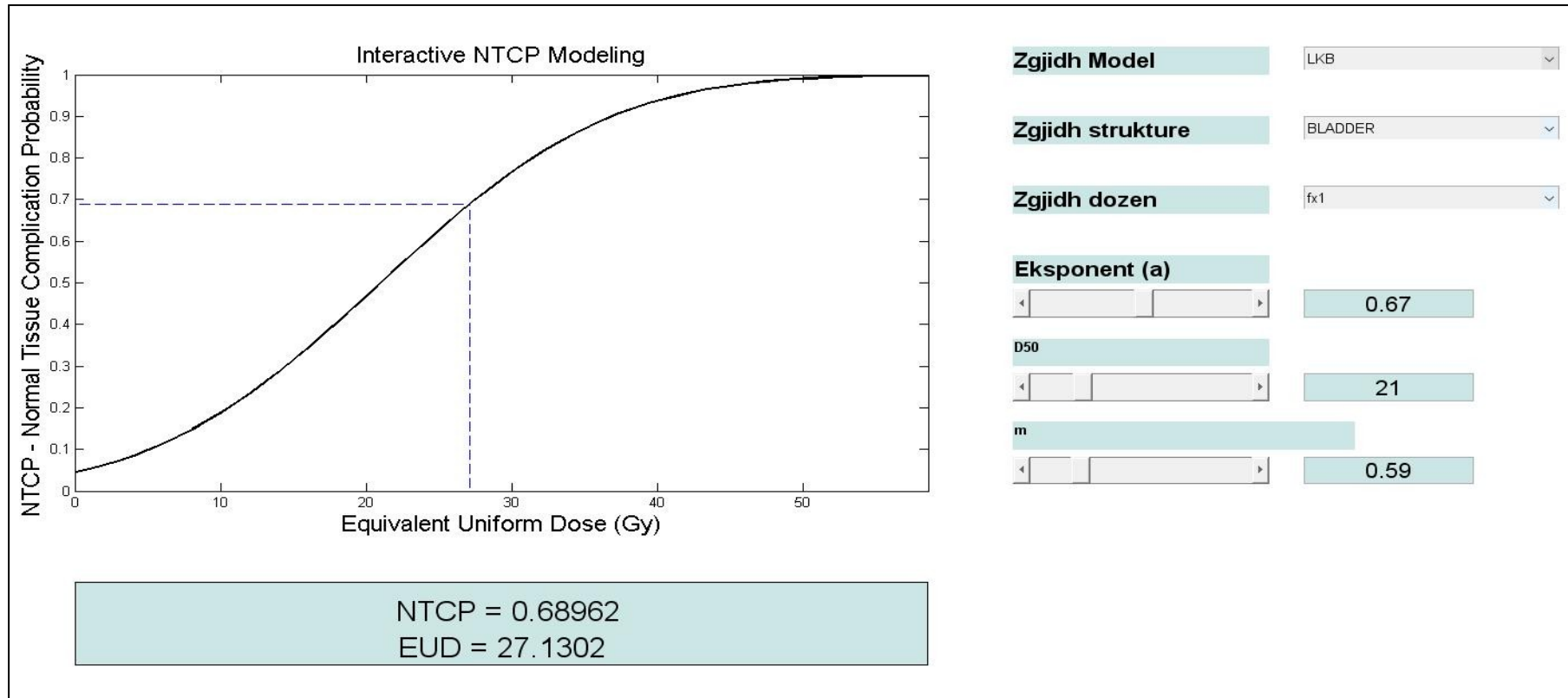


Figure 6- NTCP calculation, based on EUD

$$NTCP(EUD_a, D_{50}, m) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^t e^{(-u^2/2)} du$$

$$t = \frac{EUD_a - D_{50}}{m * D_{50}}$$

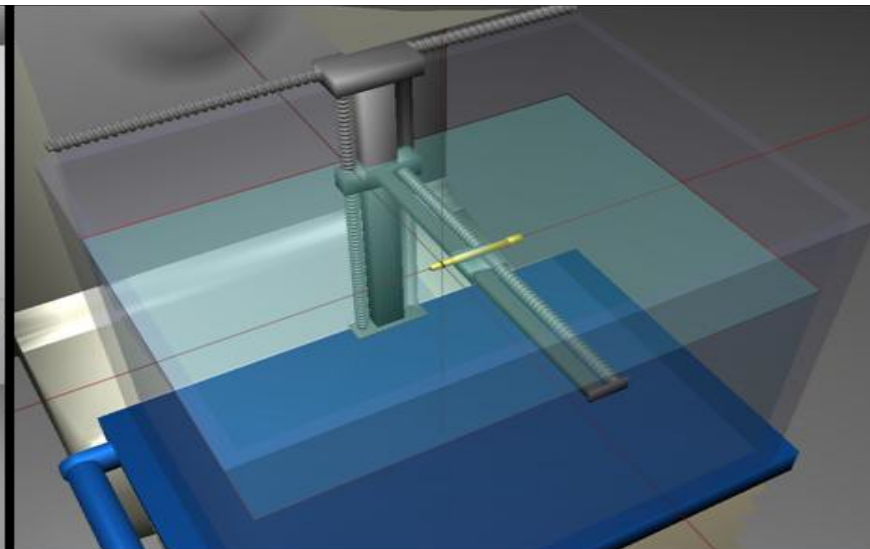
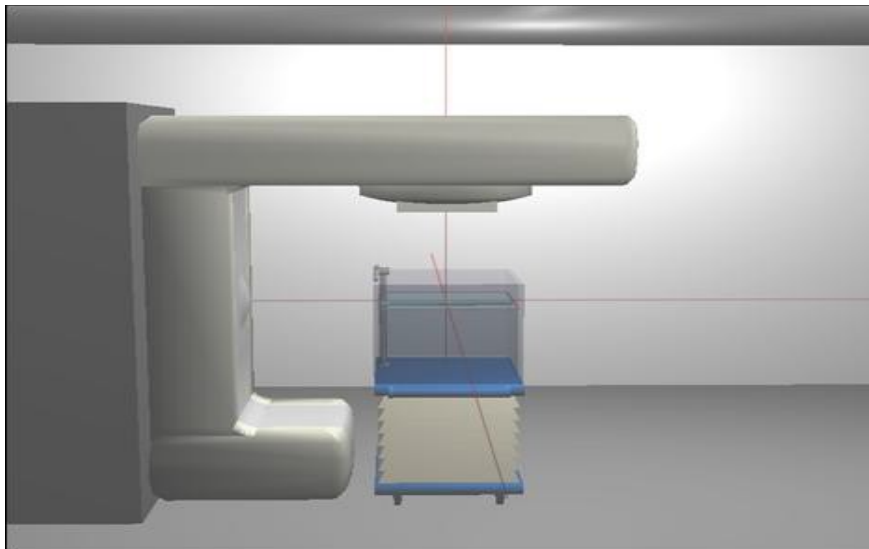
$$EUD = \left( \sum_{i=1}^n (v_i D_i^a) \right)^{1/a}$$

# Treatment process

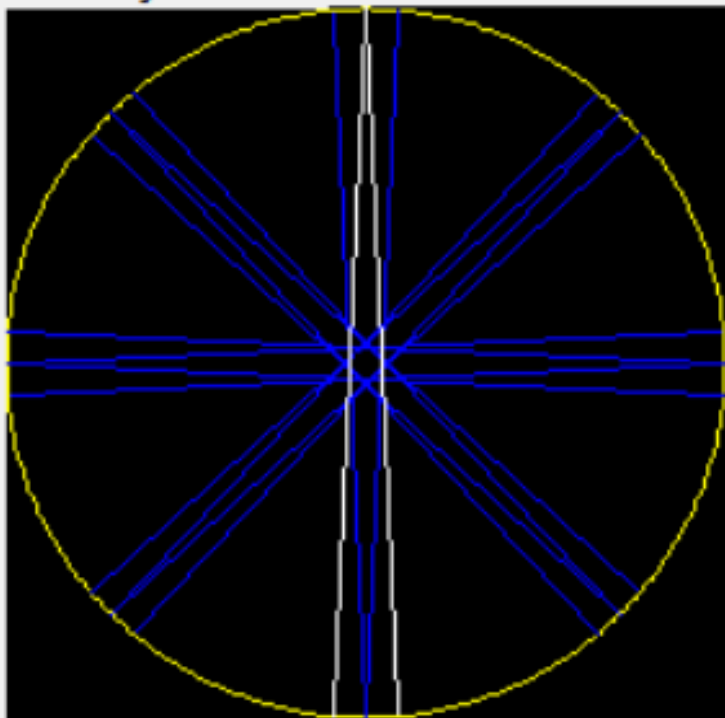
Before a treatment procedure we have to ensure that our machine will deliver the right dose to tumor. With “virtual simulator” we can simulate Linac and QA equipment's for measurements following these steps:

- *Preparation of accelerator \**
- *Preparation of water phantom \**
- *Chamber preparation \**
- *T and P Measurements \**
- *Calculation under IAEA TRS-398 (Absorbed Dose Determination in External Beam Radiotherapy) \**
- *Tumor treating*

*\* Niko Hyka et al, IJLLIS 2013, |Volume: 2 | Issue: 4: Linac Photon Beam Calibration Using Virtual Simulator Program*



## Geometry Preview



<i>Beam Number:</i>	8
<i>Beam Description:</i>	
<i>Beam Modality:</i>	X-RAY
<i>Beam Energy:</i>	MeV: 15
<i>Beam Type:</i>	STATIC
<i>Nominal Isocenter Distance:</i>	100
<i>Collimator Type:</i>	Asymmetric
<i>Isocenter coordinate:</i>	-0.2, 0.6, 143.0
<i>Asymmetric Collimator Setting X:</i>	6.00, 6.00
<i>Asymmetric Collimator Setting Y:</i>	4.50, 6.00
<i>Collimator Angle:</i>	0
<i>Couch Angle:</i>	0
<i>Gantry Angle:</i>	135
<i>Wedge Angle:</i>	na
<i>Wedge Rotation Angle:</i>	na



# Conclusions

- Students can use different open source software or Matlab for students to simulate before using clinical equipments and software
- PPIR with interface (GUI) in Albanian language it's organized and adapted to perform the most important procedures that are applied in radiotherapy for computation and simulation.
- This module will be very necessary for students to develop medical physics practice in medical image processing and radiotherapy.

- PPIR gives the opportunities to manipulate treatment plans within a powerful data analysis and programming environment, for example for dose-volume-outcomes analyses, to visualize plans review tools (axial, sagittal, and coronal viewers).
- 
- M-file format helps users to edit, modify and improve the functions. Most of them are adapted into Albanian language.
- A standart commissoning procedure can be done using Virtual simulator

**Thank you!**

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