Validation of a new GATE module for radiation therapy : simulation of a 6 MV Elekta Precise linear accelerator head.

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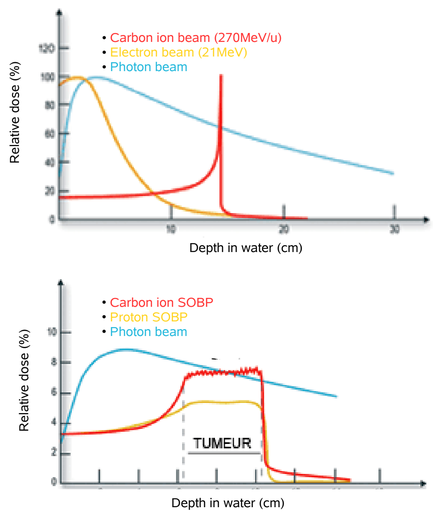
INTRODUCTION

GATE : a dedicatd toolkit for medical physics

GATE is the **Geant4-based Monte Carlo toolkit** initiated by several collaborative international institutions. [S. Jan 2004]

The main **assets** of **GATE** are:

- Quicker learning phase for novices.
- Simplicity of simulations : no C++, only user-friendly macro files.
- Dedicated tools for medical physics applications: SPECT & TEP imaging, Radiotherapy (e^-,γ), Hadron therapy (^1H, ^{12}C).



GATE : a validated tool for TEP/SPECT simulations

Initialy developed for TEP and SPECT, the **new release v6.0 (October 2009) present a new module for radiotherapy and hadrontherapy applications.**

In the present work, a set of tools dedicated to conventional radiotherapy has been validated and applied for the **simulation of a 6MV Elekta precise Linac**.

GATE

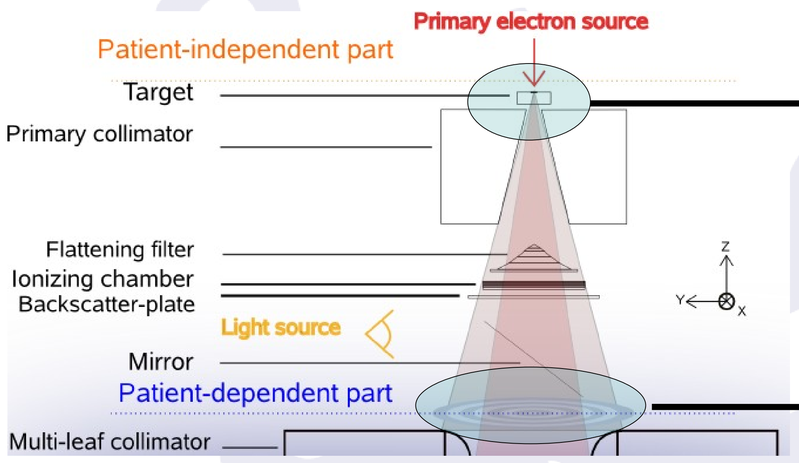
Gate is a collaboration of several international institutions working together for the common development and validation of the GATE software.

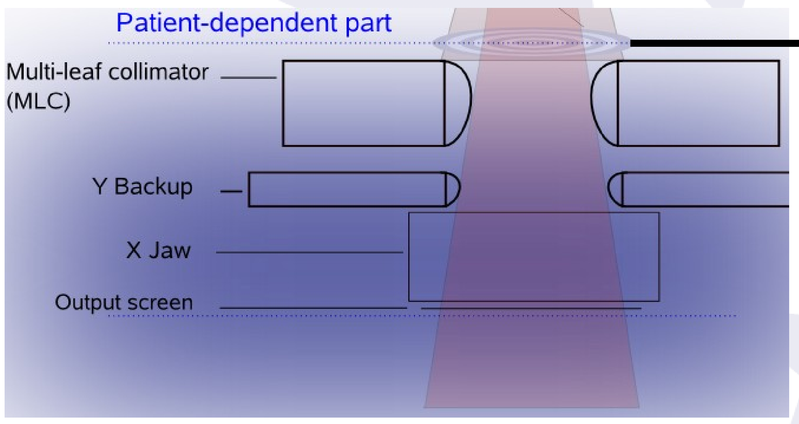
www.opengatecollaboration.org

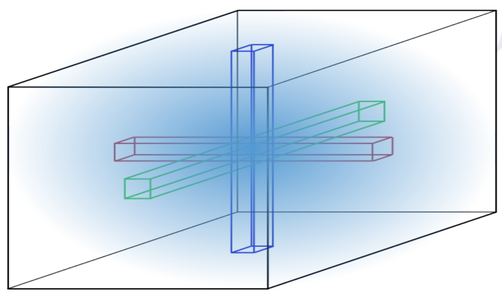
MATERIALS & METHODS

A two stages simulation :

Simulation of the **exact geometry** according to constructor specifications.
First stage: from the electron beam down to the secondary collimator.
Second stage : until the water phantom.

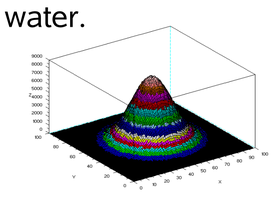




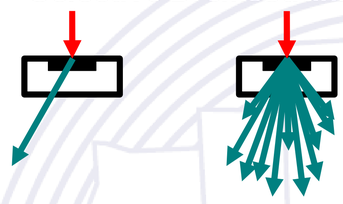


Dedicated tools for radiothearpy :

- **Primary electron beam**
  - Gaussian energy distribution adjusted to match depth dose in water.
  - Gaussian spot of electrons (FWHM = 3mm) adjusted to match transverse profiles in water. [Verhaegen 2003]

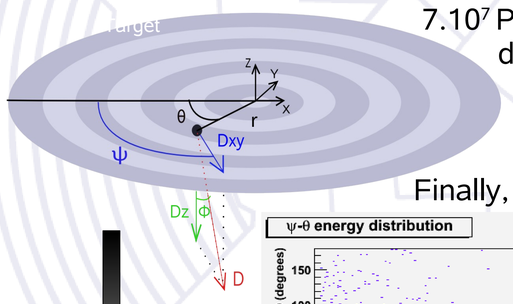


- **Selective Bremsstrahlung Splitting (SBS)**



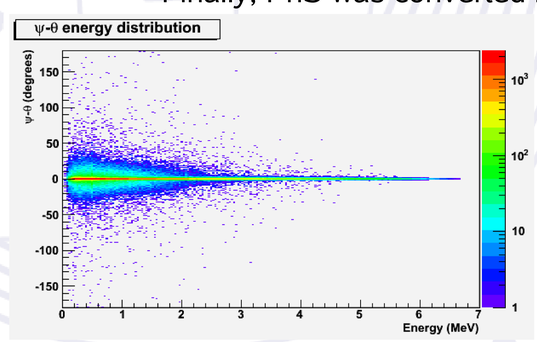
Instead of one, **hundred photons are sampled at once** when the following conditions are fulfilled:
  - **Energy criterion**: Electron energy > Threshold (5,7 MeV).
  - **Direction criterion** : No backward photons.

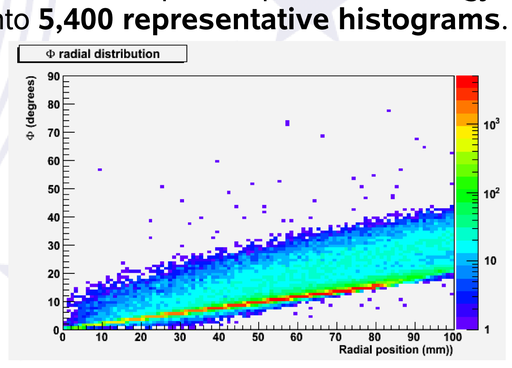
- **Phase Space (PhS) storage : Stage1**



7.10^7 Photons were stored in the PhS during the patient dependent part simulation. [A. E. Schach von Wittenau 1999]
Then, **photon beam properties** were investigated :
  - Energy spectrum correlated with photon position.
  - Direction correlated to both: photon position & energy.

Finally, PhS was converted into **5,400 representative histograms**.





- **Multiple source model : Stage 2** [Michael K. Fix 2004]
  1. Photon position (r,θ) is sampled in the phase space.
  2. Photon energy (E) is sampled according to photon radial position (r).
  3. Photon direction (Φ,Ψ) is sampled according to photon energy (E) and position (r).

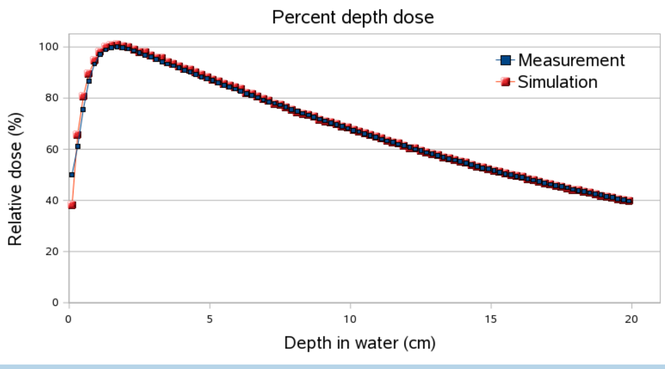
This process is looped until the required number of events is reached.

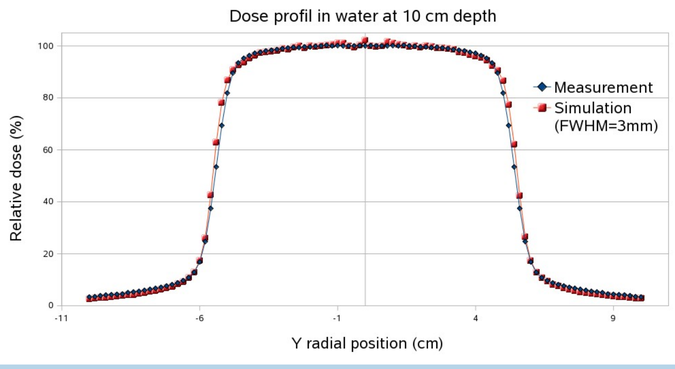
- **Energy/Dose scoring tool with statistical uncertainty**

A matrix of voxels of dimensions: 20x20x2 mm³ were created to score depth dose and transverse profiles. The lowest dimension (2mm) was in the direction of scoring interest. Statistical uncertainty is also computed. [Indrin J Chetty 2006]

RESULTS & DISCUSSION

Percent depth dose and profile at 10 cm depth simulations :





- **0.5% statistical uncertainty** reached in 22 hours (3.10^8 events).
  - **Depth dose and profile errors** : 0.5% and 1.1%
  - **SBS efficiency:** 7.9 times faster than without
    No significant bias was introduced (difference<0.5%)
- **1% statistical uncertainty** reached in 6 hours (8.10^7 events).
- Additional investigations at different energies and depth, with different field sizes as well as non-squared fields will follow.
- **In conclusion, the GATE toolkit can be used efficiently for radiotherapy applications.**

References

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GATE release V6.0

► **Toward a simulation toolkit dedicated for medical physics applications:**
TEP/SPECT imaging & radiotherapy with beam of electrons, photons and ions.

► *DICOM RT Plan integartion - CT voxel integration - Fast voxel navigation [Sarrut2008] Dynamic MLC - Dedicated tools for hadrontherapy (protons and ions).*