RAP CRETE 2025 INTERNATIONAL CONFERENCE ON RADIATION APPLICATIONS | IN PHYSICS, CHEMISTRY, BIOLOGY, MEDICAL SCIENCES, ENGINEERING AND ENVIRONMENTAL SCIENCES

May 26-30, 2025 | Hellenic Centre of Marine Research | Gournes - Heraklion | Crete | Greece

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Characteristics of High Energy Unflattened Photon Beams Using GATE/GEANT4 Simulations

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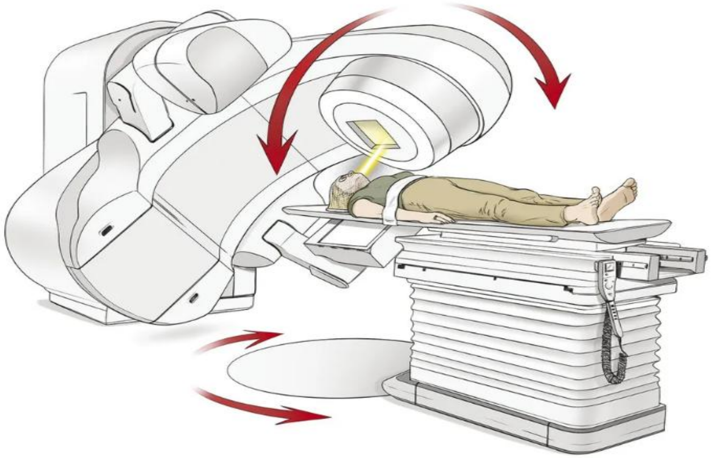
OUTLINE

Introduction

- In the last decades new radiation delivery techniques were developed with the aim to widen the therapeutic window, such as intensity modulated radiation therapy (IMRT), intensity modulated arc therapy (IMAT), tomotherapy and stereotactic treatments.

- Medical linear accelerators operating in photon mode are equipped with a flattening filter (FF), primarily designed to produce a flat beam profile at a given depth, it decreases the X-ray output considerably and produces quality changes within the primary beam by scattering and absorption of primary photons.

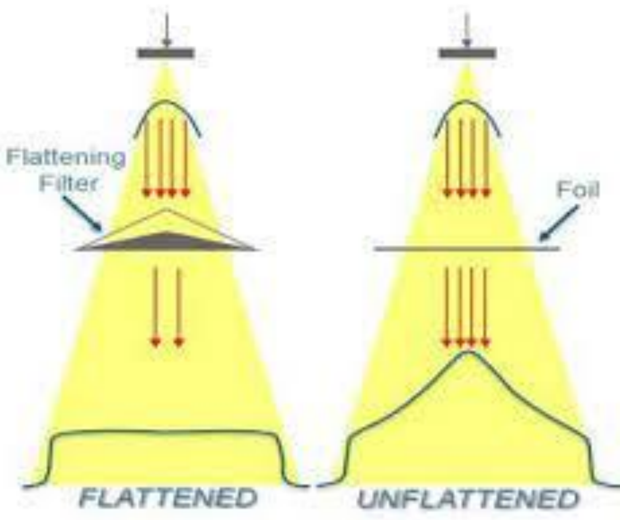
- For new techniques, the presence of the FF is not necessary due to modulated fluence distribution across the field by dynamic multileaf collimators (MLCs).



Introduction

The clinical use of unflattened photons beams (FFF) has many distinct dosimetric advantages over conventional (FF) photon beams, including:

- ✓ An increase in the dose rate by a factor of 2-4
- ✓ Reduced the long delivery time required for RT treatments
- ✓ A modified energy spectrum
- ✓ An anisotropic fluence
- ✓ A significant reduction in head scattered radiation



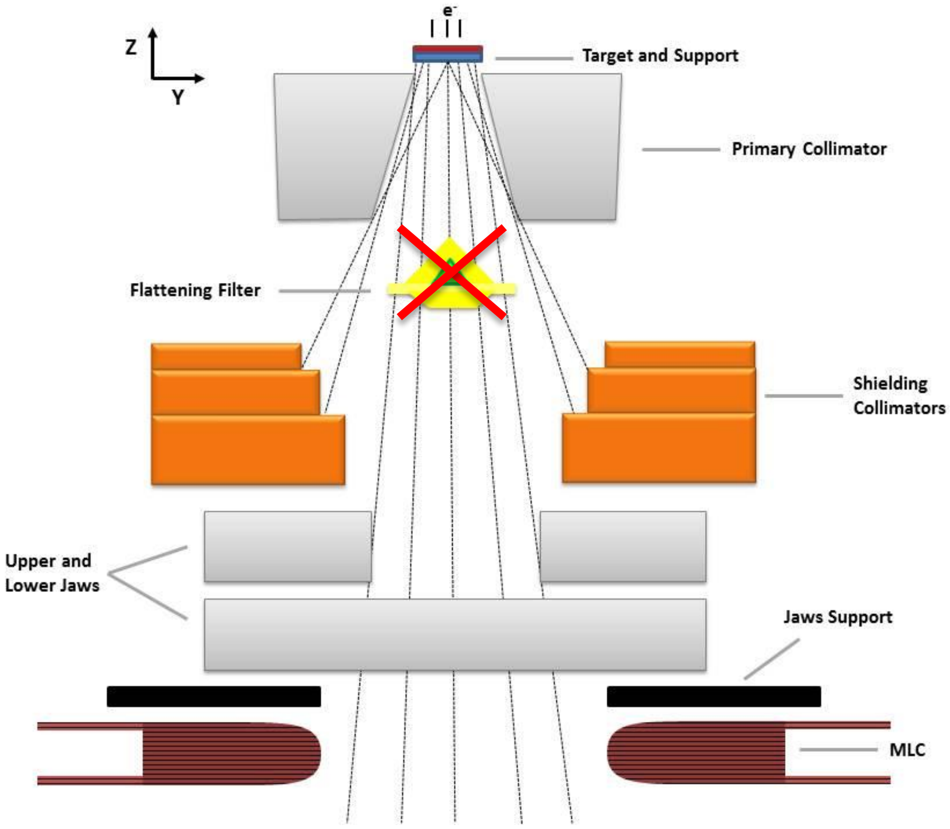
The aim of our study:

We used Monte Carlo simulations to investigate the effect of removing the Flatening Filter in a VARIAN Clinac 2100C 18 MV photon beam. Dosimetric properties of FFF beams were calculated using GATE/GEANT4 MC code. These includes : **Percentage depth dose, lateral beam profiles, photon energy spectra and beam quality indicators**.

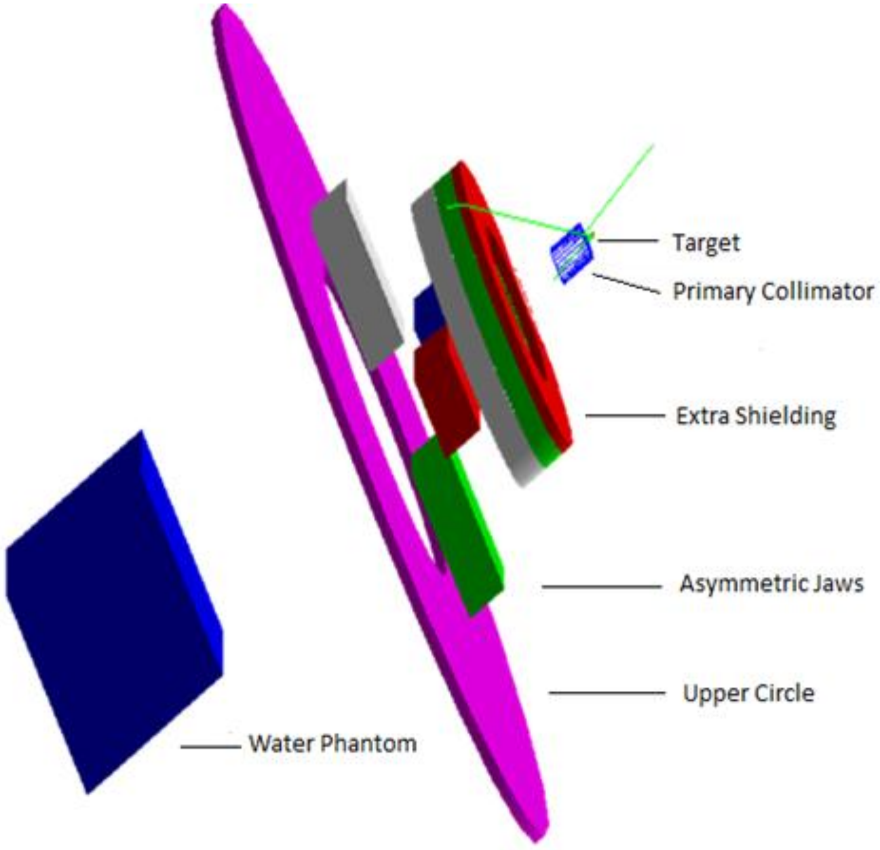
Materials & Methods

Linac head geometry

❖ All the linac head components located in the beam path were simulated. Physical and geometrical features of Varian Clinac 2100C components, in terms of shape, size, position, and material composition were implemented



Schematic Representation of Varian Clinac 2100C Head



Implemented Geometry in GATE

Materials & Methods

GEANT4 **A**pplication for **T**omographic **E**mission

GATE v8.0 built with **GEANT4 v10.3.0**

GEometry **AN**d **T**racking

- **Primary electron source:**
  - – Energy Distribution : E_0 = 17.8 MeV ; $FWHM_E$ = 0.2 MeV (3% of E_0).
  - – Spatial Distribution : X=Y=0 ; Z= +1 mm; $FWHM_S$ = 1 mm

- **Physics Package :** The Electromagnetic Standard Option3 Physics **(Emstandard_opt3)**
- **Water Phantom:** 50 × 50 × 50 cm^3 , DSS= 100 cm
- **Dose Scoring Volume:** Cubical Voxels (5 × 5 × 5 mm^3)

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- **Range Cuts:**
  - World: 1mm
  - Water: 0.1 mm

  } **e-, e+, γ**

HPC-MARWAN

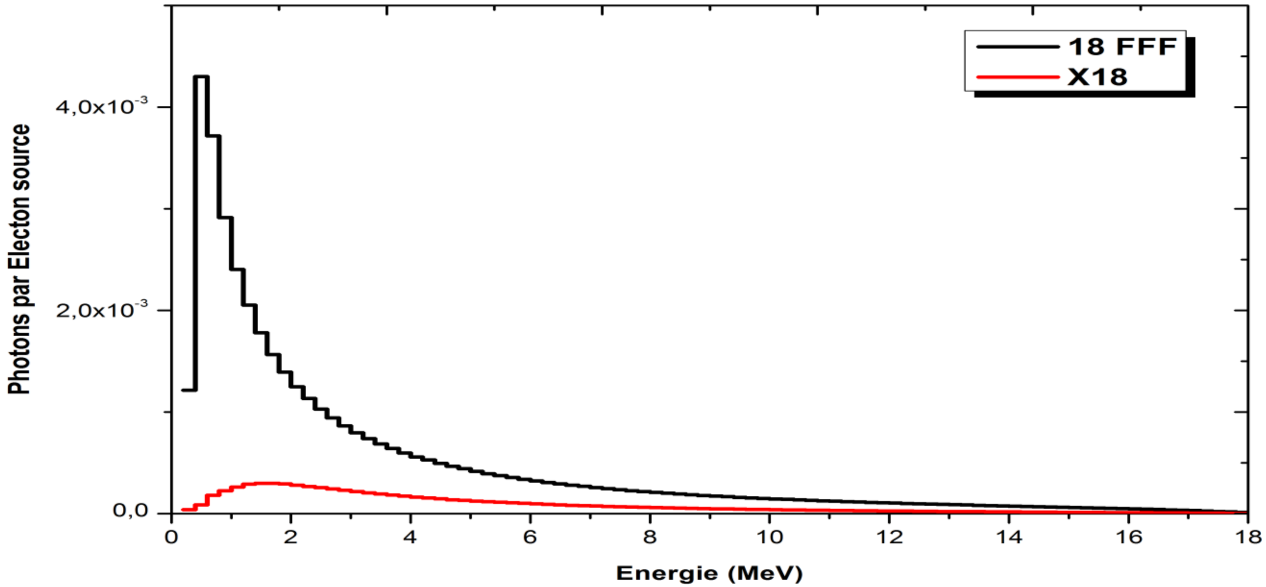
Infrastructure de Calcul Haute Performance

- **Events:**

A total of 14.10^{10} incident primary electrons were simulated and split up into several jobs running in parallel both on Intel Xeon Gold 6148 and Intel Core i7 3.60 GHz CPU.

RESULTS

Photon Energy Spectra

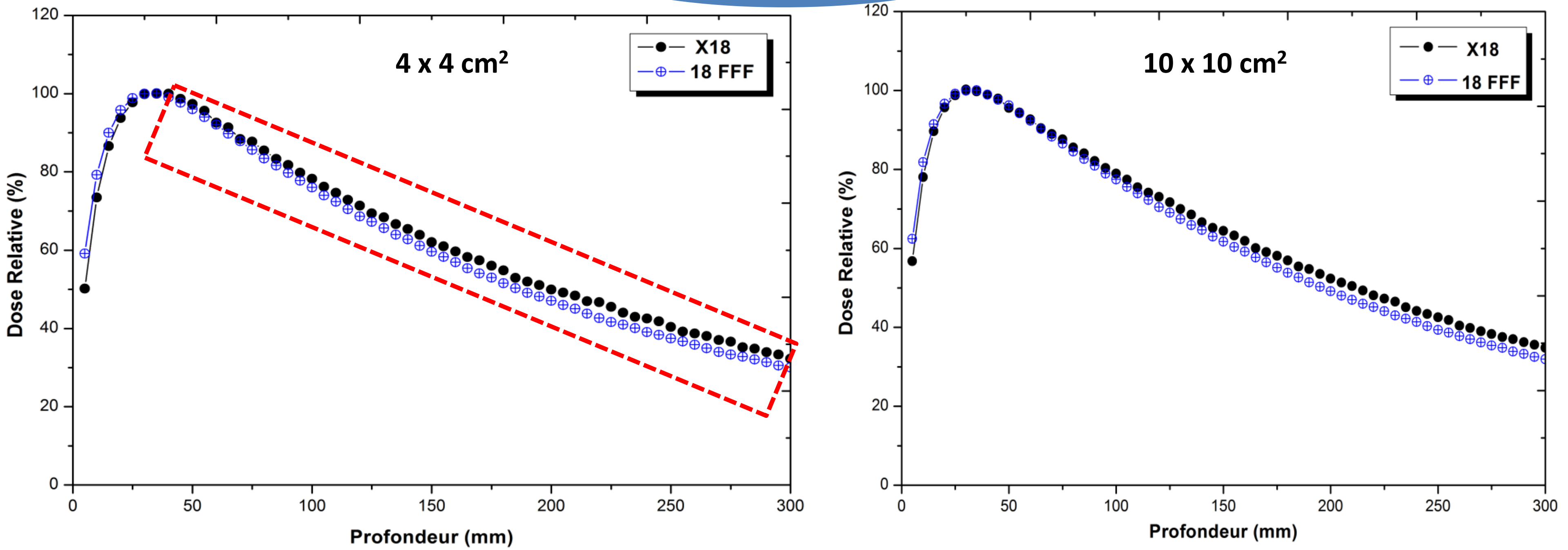


Calculated photon energy Spectra at the isocentre for the 18 MV flattened and unflattened photon beams, over 10 x 10 cm^2 field size

- ➢ The photon energy fluence spectrum for all field sizes gets increased for FFF beam mode. The photon fluence ratio: $\Phi_{FFF} / \Phi_{Standard} = 5.5$
- ➢ Removing the FF severely increases low-energy photons, which gives FFF beams a softer energy spectrum.
- ➢ After the FF removal, lack of scattering and hardening phenomena from filter considerably decreased the average energy of photon compared to the FF beam. **E_{mean} (Standard) = 4.47 MeV** VS **E_{mean} (FFF) = 3.18 MeV**

RESULTS

PDD Curves



PDD Normalized Percentage Depth dose curve comparison for 18 MV FF and FFF photon beams for 4x 4 cm^2 and 10x10 cm^2

- The depths greater than $\mathbf{d_{max}}$ depicts a steeper dose fall off in the exponential region for FFF beams comparing FF beams.
- The calculated surface dose $\mathbf{D_S}$ of FFF beams was found to be **9%** higher than FF one.
- A slight increase in the depth of maximum dose $\mathbf{d_{max}}$ is noted for unflattened FFF beams.

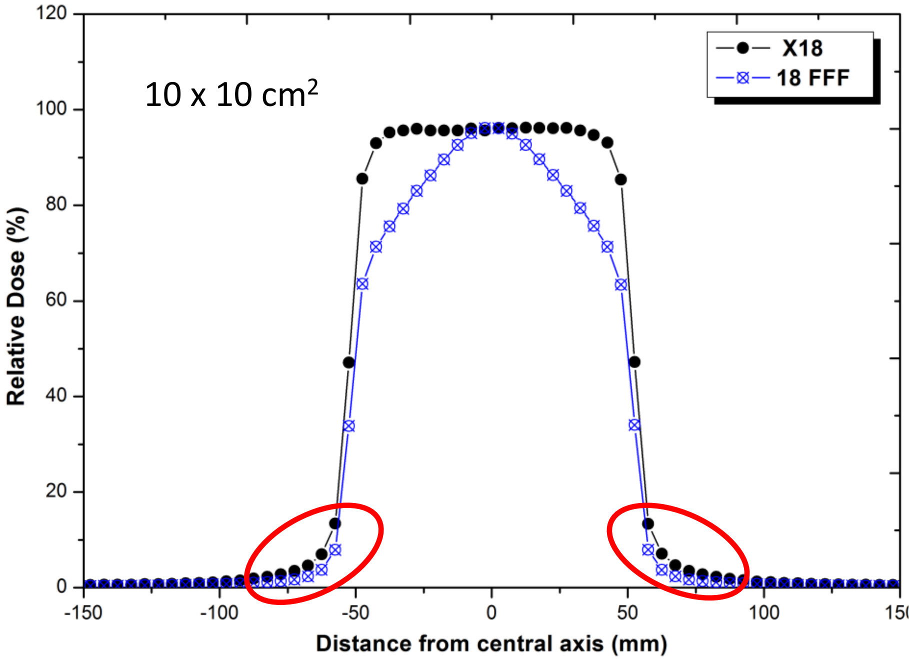
- The 18 MV unflattened depth dose characteristics are similar to those for a 15 MV flattened beam.

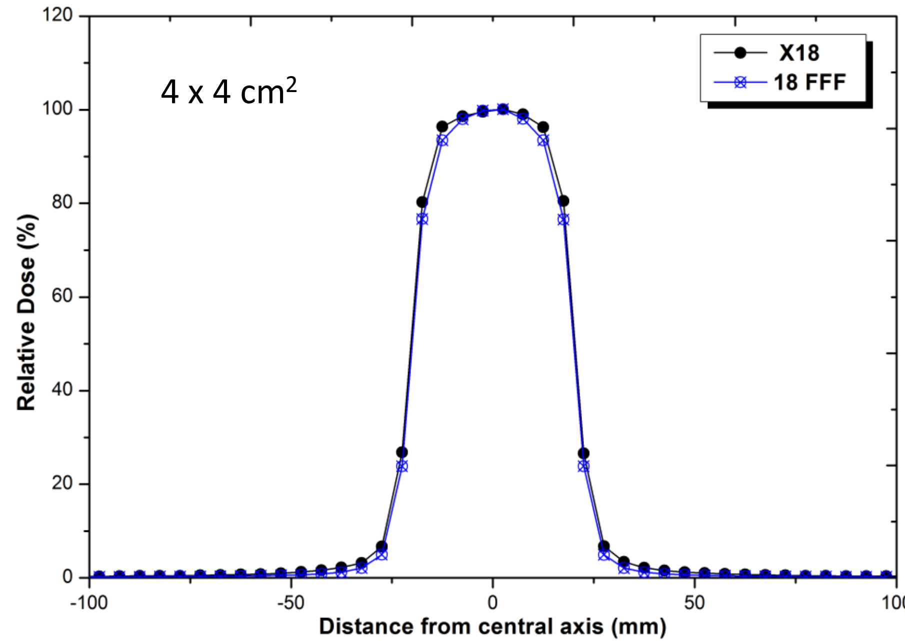
Photon beam quality indicators for 10×10 cm2 field

	D_S (%)	d_{max}(mm)	D_{10} (%)	$TPR_{20,10}$
X18	56.8	32	78.96	0.780
X18 FFF	62.4	34	77.45	0.743

RESULTS

Dose Profiles





Comparison of beam profiles for the 18-MV FFF and FF photon beams at 5 cm depth

- ➔ Removing the flattening filter causes a significant unflatness in dose profile for the large field sizes.
- ➔ A significant reduction in out-of-field dose is noted for FFF photon beams.
- ➔ Beam penumbra width for FFF beams is less than FF ones.
- ➔ In the case of smaller field size (4x4 cm^2)the beam profile shape remains similar for FF and FFF beams.

CONCLUSION

- GATE/GEANT4 Monte Carlo (MC) code was used to simulate the 18 MV photon beam of Clinac 2100 C Varian linear accelerator (LINAC) for the FF and FFF modes.
- Dose distributions were calculated and compared for unflattened and standard photon beams.
- Removing the flattening filter from the LINAC's head improves most of the dosimetric characteristics of the 18MV therapeutic beam.
- Our results for FFF beams are in good agreement with those published in the litterature.
- Further work is underway to estimate the production of undesirable contaminant radiations, such as electrons and neutrons, generated around this facility.

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Thank you for your attention

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