VALIDATED MONTE CARLO SIMULATION OF TRIODE – ELECTRON GUN EQUIPPED ELECTRONFLASH LINAC

Jake Harold Pensavalle, Maria Giuseppina Bisogni, Simone Capaccioli, Damiano Del Sarto, Giuseppe Felici, Federica Galante, Giulia Mariani, Giuliana Milluzzo, Matteo Pacitti, Fabiola Paiar, Francesco Romano, Fabio Di Martino

Outline

Introduction
- FLASH effect
- SIT ElectronFlash LINAC (CPRF)

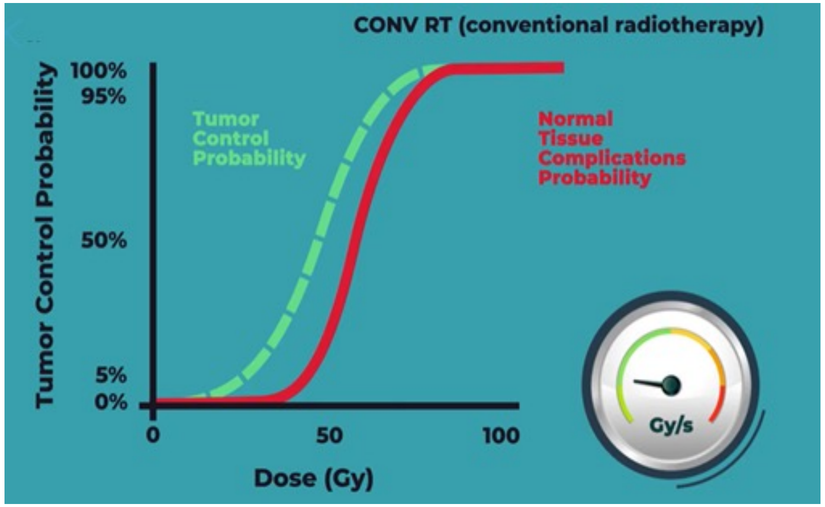
Simulation
- Importance for non-reference condition evaluations
- Validation

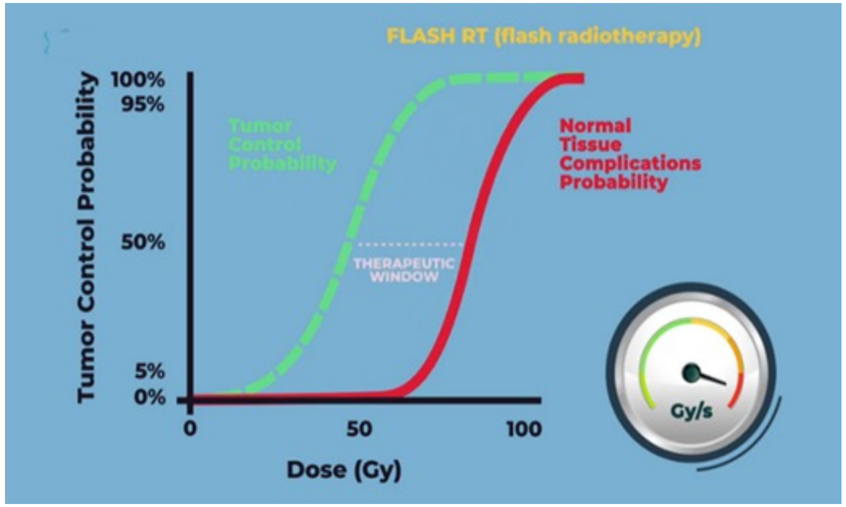
Application
- Work done with GEANT4
- Future Perspectives

The FLASH effect

- The FLASH effect consists in an **amplified healthy tissue sparing effect**, while maintaining the **same cancer tissue kill efficacy**.
- Using mainly electron beams: electrons of energy 4 -7 MeV
- Irradiation parameters: dose-rate > **40 Gy/s**, total irradiation time < **200 ms**
- It has been observed for different kind of normal tissues (lungs, skin, brain, ...) and tumors (breast, H&N, glioma, lung, GI) and has been confirmed in several animal species (mice, cats, zebrafish, ...)

Clinical Perspectives





Limitation of Conventional RT
Radiation-induced toxicities

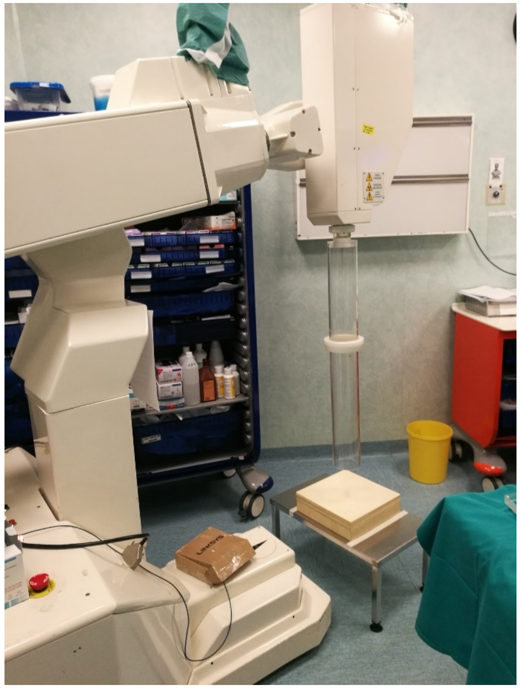
FLASH radiation therapy

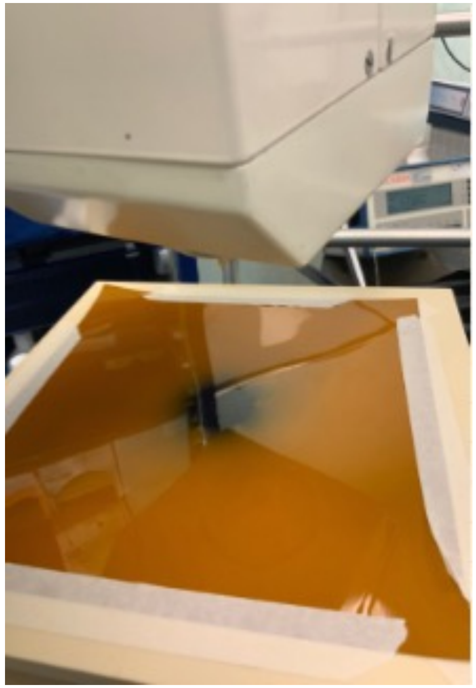
FLASH-RT would allow:

- To treat radio-resistant tumors increasing total dose without the associated surrounding tissue toxicity of CONV-RT
- To treat diffuse/non localized tumors where CONV-RT can not deliver tumoricidal doses
- To treat tumors where radiotherapy already offers good local control but without the side effects typical of CONV-RT
- Re-irradiation overcoming the dose limits of the first course of treatment

Electron FLASH accelerators: Importance of a dedicated LINAC

- FLASH accelerators have been modified medical or industrial LINACs.
- Such accelerators are not able to perform online beam monitoring, as well as to provide an accurate and reproducible output.
- A dedicated research LINAC is fundamental.





ElectronFlash @ CPFR (Centro Pisano Radioterapia FLASH)

SWITCH FROM CONV TO FLASH KEEPING THE EXPERIMENTAL SETUP UNCHANGED

- GREAT DECREASE OF **THE EXPERIMENTAL UNCERTANTIES**

EVALUATION OF BEAM PARAMETERS VARYING EACH ONE INDEPENDENTLY FROM ONE ANOTHER

- **VARIATION OF THE PULSE SIZE KEEPING FIXED THE DOSE-PER-PULSE TO STUDY THE DEPENDENCE FROM THE IDPP** (INSTANTANEOUS DOSE-PER-PULSE)
- **VARIATION OF THE IRRADIATED VOLUME KEEPING FIXED THE DOSE-PER-PULSE TO STUDY VOLUME EFFECT**

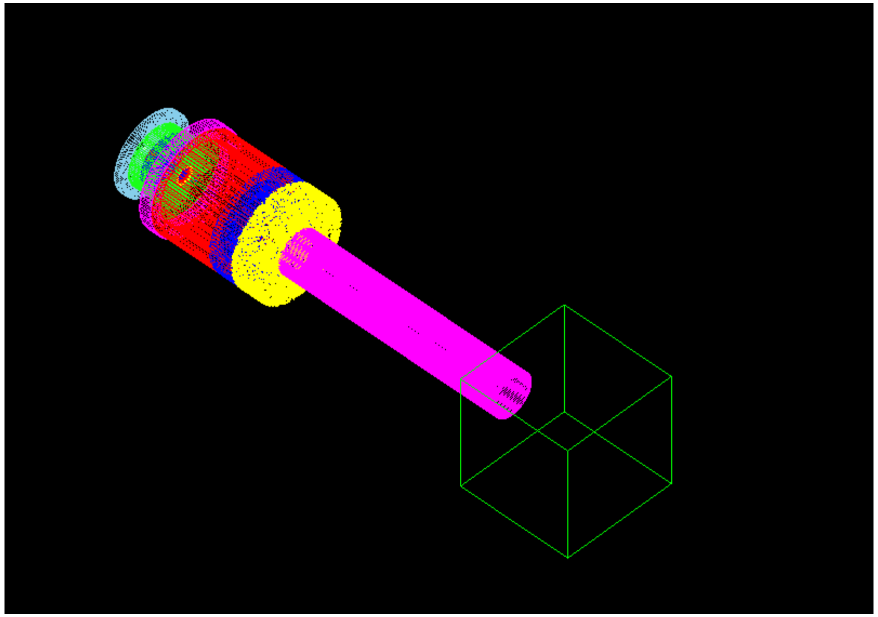
Importance of Monte Carlo Simulations

- Monte Carlo simulations are used to calculate corrective factors or to evaluate measurements in non-reference conditions, which are difficult or impossible to evaluate experimentally.

- We accurately replicated the most relevant components of the LINAC, all the beam optics by following the manufacturing specifications and we implemented the energy spectrum provided by Sordina Iort Technologies S.p.A.

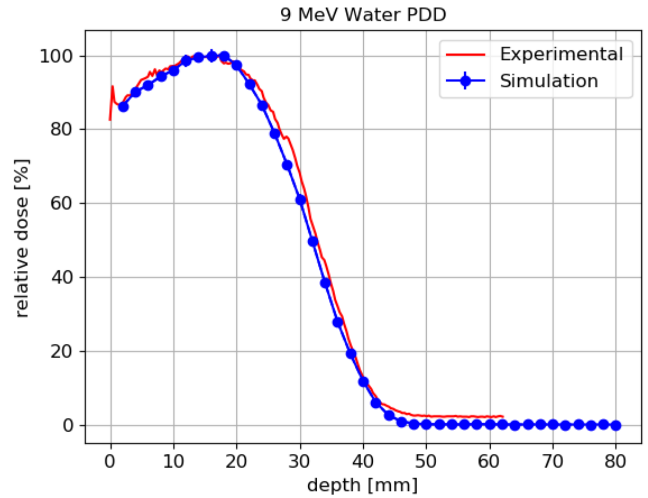
Methods

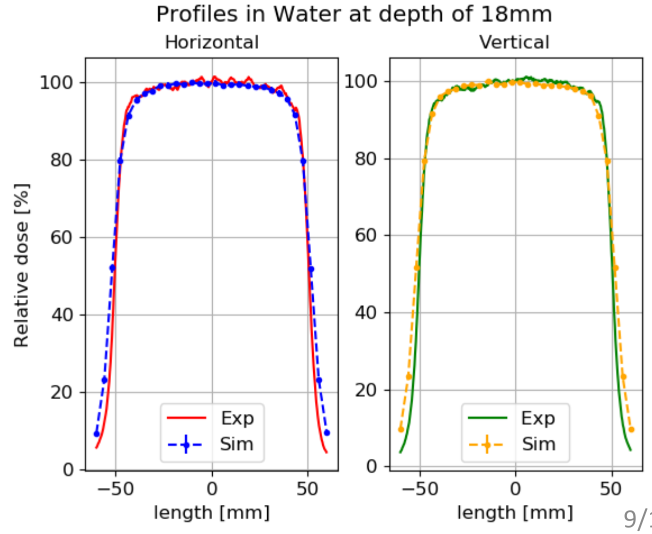
- We simulated a $30 \times 30 \times 30$ cm^3 water phantom, 9 MeV beam with SSD =100 cm and the 10 cm diameter PMMA applicator.
- Penelope physics list was used.
- Selected cut: 100 μm
- We validated the simulations with gafchromic measurements of the PDD and dose profiles.



Preliminary Results

- From both the PDD and dose profiles, we can see a good agreement between simulation and validation.
- Uncertainties are kept under 2%.
- We also compared the simulated and experimental R50 values. We found that the **simulated R50 = 31.94 ± 0.11 mm** is in good agreement with the **experimental R50 = 32 ± 2 mm**

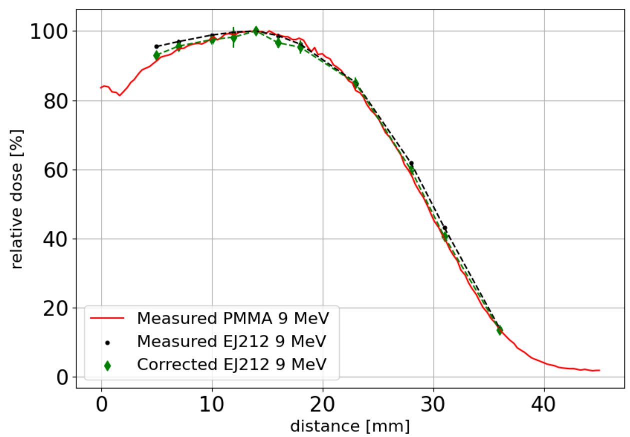


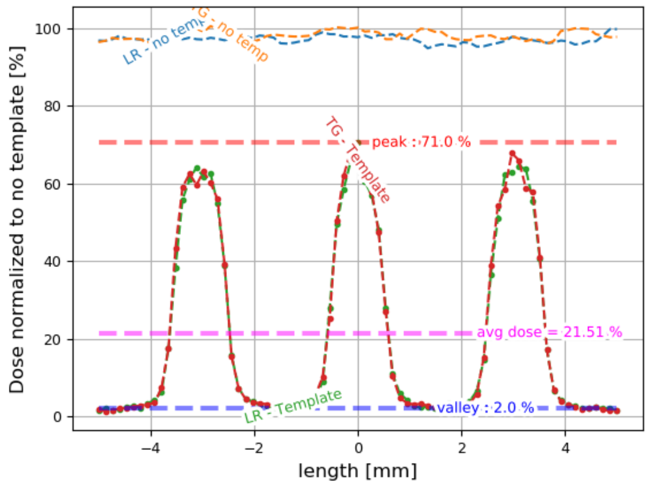


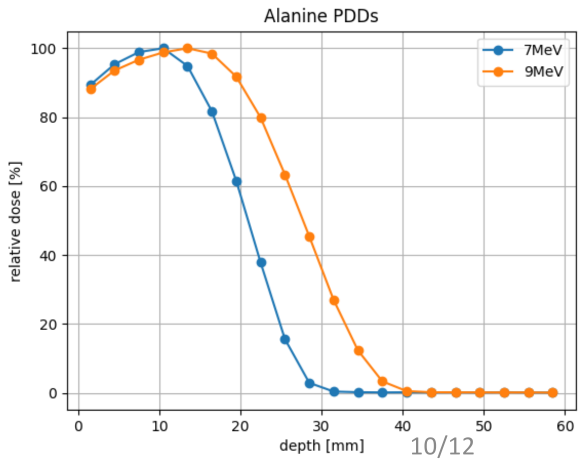
Applications of the code

The code has been used in various non-reference condition evaluations:

1. Dosimeter dose corrective factor evaluation (Morrocchi et al., 2022);
2. Spatial fractionation (Mini-beam) dose distribution optimization (To be presented at FPRT);
3. Alanine dosimeter reference response for evaluating corrections.







Conclusions

- In conclusion, the simulation code reliably replicates with high level of accuracy the experimental set-up.
- This is further proven by the agreement with the data. Additional experimental dose measurements with the triode-Electron Gun equipped ElectronFlash LINAC are under way.
- The code will be integrated in GEANT4 as an advanced example in future releases.

Thank you for your attention!

Jake Harold Pensavalle, Maria Giuseppina Bisogni, Simone Capaccioli, Damiano Del Sarto, Giuseppe Felici, Federica Galante, Giulia Mariani, Giuliana Milluzzo, Matteo Pacitti, Fabiola Paiar, Francesco Romano, Fabio Di Martino