Development and experimental validation of TPS software to determine the dose outside the radiation beam

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Development and experimental validation of treatment planning system software to determine the whole-body dose in radiotherapy

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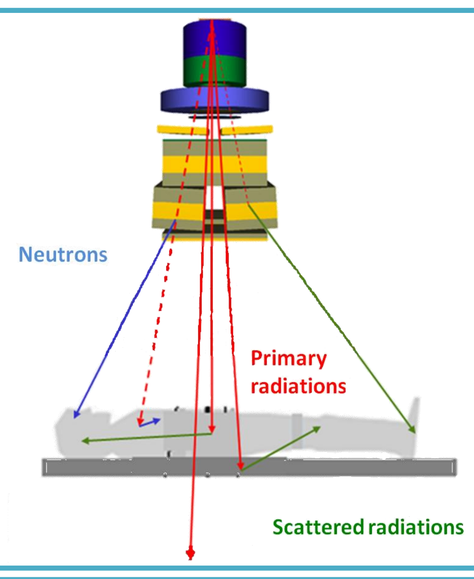
MOTIVATION

- In the fight against cancers, radiotherapy remains the most powerful and widespread technique.
- Risk of generating **second cancers and heart diseases** after a first treatment due to **x-rays leakages** and **scattered radiations** that depose **out-of-field dose**[1] .
- At the moment, TPS optimize the effectiveness of radiation therapy, based on dose distributions in the target volume, but the dose distributions to distant organs are not provided.
- It could help the therapist to **know the peripheral dose** before the treatment in order to predict and **reduce the iatrogenic effects**.

Our solution: **develop a Monte Carlo tool giving the whole-body dose in a reasonable time.**
The peripheral dose is low and consequently difficult to simulate with a small statistical uncertainty.



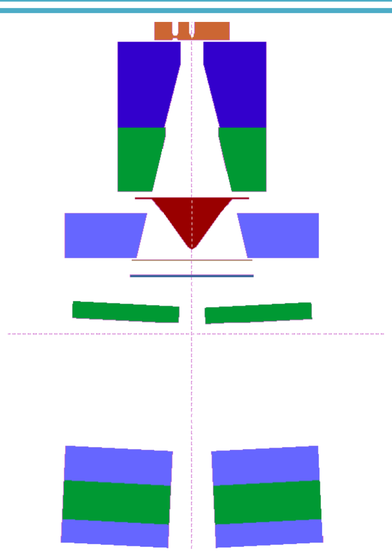
MATERIAL and METHODS

Code:

- Tool based on the *Penelope*[2] Monte Carlo particle transport code, high accuracy on the dose deposition.
- Calculation of the dose at any part of the patient's body while carrying out treatment planning.
- Implementation of variance reduction techniques to improve the efficiency: better uncertainty for the same simulation time.

Experimental validation:

On the GE *Saturne 43* conventionnal linac on a specific large water tank at 6, 12 and 20 MV with a 10 × 10 cm² field at the French Primary Standard Laboratory (done) and an IMRT accelerator on an anthropomorphic phantom (autumn 2011).
Use of the OSL (Optically Stimulated Luminescence) dosimeters: *Nanodot* from *LCIE Landauer*.



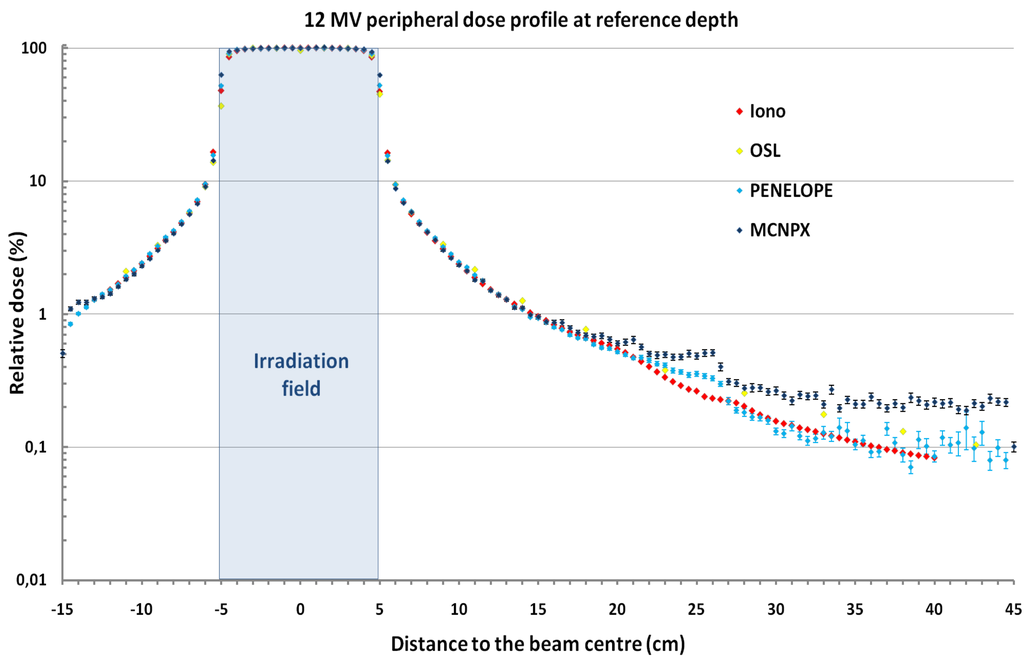
RESULTS

Measurements and calculations on the *Saturne 43*:

Considering that the ionization chamber dose is the reference value,
OSL over-estimate the dose at large distance from the beam centre. It is due to the energy dependence of the dosimeter's response at low energies.

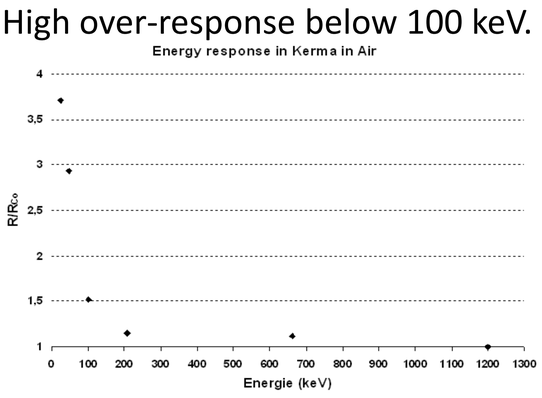
The *Penelope* code fits better (mean error 3 %) with the reference than the *MCNPX* code (mean error 30 %).
But *Penelope* is too slow and time consuming for a clinical application (26 hours on 108 processors to calculate the dose in the water tank).

Consequently, we need to **accelerate the calculation** by implementing the Dxtran variance reduction technique.

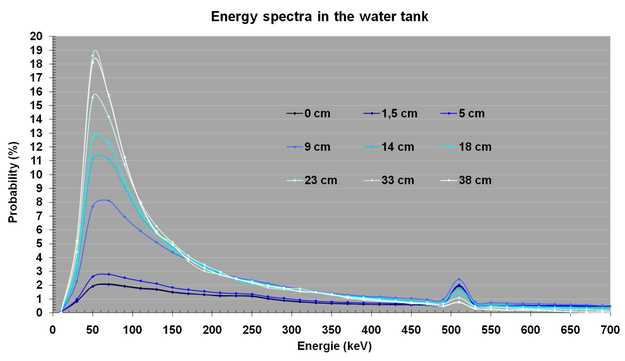


OSL energy dependence correction:

High over-response below 100 keV.



Importance of low energy photons far from the field (*Penelope* calculations).

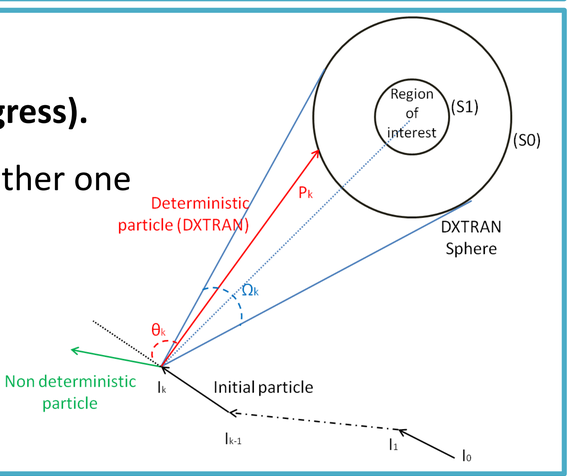


After correcting the energy dependence, the OSL dosimeters will give satisfaying results so that they could be used to validate the code in a real IMRT configuration.

OUTLOOK

- **Implementation of the pseudo deterministic transport variance reduction technique in Penelope (in progress).**
  Subdivision of particle at each interaction: one is forced to reach a region of interest (virtual particle), the other one is the real one that follow its history (non deterministic transport).

- **Measurements and validation on an anthropomorphic phantom with OSL detectors.**



REFERENCES

1. Xu G X, Bednarz B & Paganetti H, 2008, A review of dosimetry studies on external-beam radiation treatment with respect to second cancer induction, *Phys. Med. Biol*. **53** 193-241.
2. Salvat F, Fernandez-Varea J-M, Acosta E & Sempau J, 2001, *PENELOPE - A Code System for Monte Carlo Simulation of Electron and Photon Transport*