

Interdyscyplinarne Studia Doktoranckie RadFarm - Radiofarmaceutyki dla ukierunkowanej molekularnie diagnostyki i terapii medycznej



# Monte Carlo verification of ArcCHECK® detector output to radiation of Ir-192 sources in brachytherapy.

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### Introduction and aim.

Verification is a key component of treatment safety and effectiveness in radiation beam therapy, but there is no comparable accepted standard method of verification in brachytherapy. This study undertook to assess the potential usefulness of a proven beam therapy verification detector, ArcCHECK® (Fig. 1.), to verify brachytherapy. A Monte Carlo simulation of an experimental setup was performed to provide a reference data to compare with detector output.

Aim: to determine if the ArcCHECK® detector response to radiation from Ir-192 brachytherapy is consistent with data obtained from Monte Carlo simulation.



**Fig. 1.** The ArcCHECK® detector with CavityPlug phantom. The device contains 1386 semiconducting diodes arranged in spiral pattern around the detector's central cavity. Total length of 3D diode array is 21 cm, and detector distance from center of cylinder is 10.4 cm. Diameter of central cavity is 15 cm.



Fig. 2. A 3D model of ArcCHECK® diodes surrounding the BrachyPlug PMMA phantom (gray transparent cylinder) with sources positions marked inside. This study modeled 120 source positions, located in 6 canals along the edge of the phantom. Distance between source positions in each active line was 0.25 cm. A total of 1386 semiconducting diodes, placed in a spiral pattern around the phantom were modeled. Distance between the closest diodes was 1 cm. Each circle of the spiral corresponds to 66 diodes. The value assigned to each diode as a result of a simulation run became the reference dataset for comparison with dosimetric measurement.

# Method description.

- A four-step research method was used in this study:
- · Preparation of an **experimental treatment plan** to assess in an ArcCHECK® detector, using the BrachyPlug phantom. The treatment plan included 120 source positions placed along the edge of the phantom (Fig. 2).
- · Implementation of the experimental treatment plan on the BrachyPlug phantom and export of the output values from the diodes in the ArcCHECK® detector.
- ✓ Monte Carlo simulation of the experimental setup to obtain reference data. Simulation was performed in egs\_brachy, an EGSnrc module designed for MC calculations in brachytherapy.
- ✓ **Comparison** of data measured by ArcCHECK® detector with Monte Carlo calculation results.

## **Results and conclusions**

The simulation result - the value assigned to each simulated diode was obtained based on the following definitions:

$$\bar{D}^{j} = \sum_{i}^{N_{h}} \frac{K_{coll}^{j}}{N_{h}/n_{s}}$$

where  $D^{j}$  is normalized dose in j-th voxel,  $N_{h}$  is number of histories (all particles initialized in each source),  $n_s$  is number of sources and



collision kerma in j-th voxel  $K_{coll}^{j}$  is calculated as:

$$K_{coll}^{j} = rac{\sum_{i} E_{i} t_{i} \left(rac{\mu_{en}}{
ho}
ight)}{V^{j}}$$

where  $E_i$  is energy of i-th photon crossing i-th voxel,  $t_i$  - tracklength of that photon in the voxel,  $\left(\frac{\mu_{en}}{\rho}\right)$  is the mass energy absorption for energy  $V^{j}$  the is the volume of the voxel. Measurement results are and presented as number of counts in each diode. To avoid unit inconsistency, both the simulation results and the values measured in experiment were normalized to maximum value.

All results are summarized in Figures 3-5. In Fig. 3. is a graphic display of output values from each comparison pair of diodes, with those measured experimentally in green and those calculated in the simulation shown in red. Both datasets exhibit nearly identical accordance. Each "period", i.e. the segment between the closest minimum and peak, corresponds to one circle of the spiral. In Fig. 4. differences between corresponding pairs of diodes are shown. Fig. 5. is a histogram of the different values in Fig. 4, where 90% of the diodes show differences within an interval of  $\pm 7\%$ .

Accuracy of the measured and calculated data was considered satisfactory, suggesting the potential usefulness of the ArcCHECK® detector in brachytherapy measurements.

#### References

1. Thomson R.M., Taylor R.E.P., Chamberland M.J.P., Rogers D.W.O User manual for egs\_brachy. A vesatile and fast EGSnrc application for brachytherapy, last edited 2017-10-02,

