Validation of Monte Carlo Gate for IORT

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Overview

- Dosimetric Characterization of a mobile accelerator (LIAC) for IORT (periodical annual controls on LIAC)

- GATE Monte Carlo

- Results

Introduction to IORT

Three ways of treating cancer

1. RADIOTHERAPY
2. SURGERY

→ IORT

3. CHEMIOTHERAPY

Intraoperative Electron Beam Radiation Therapy

Very high radiation dose in one single fraction after tumor removal, on the tumor bed.

Dose to patient in IORT

Two different modalities:

- **Full-dose IOERT**
  - 21 Gy as a single delivered dose
- **Boost IOERT**
  - 9 – 12 Gy followed by WBI

Conventional RT delivers 50 Gy in 25 fractions of 2 Gy each

Typical dose rate range:

- IORT: (19.0 – 32.0) Gy/min
- Conventional RT: (0.5 – 5.0) Gy/min

Very high delivered doses require good commissioning and quality controls

Light Intraoperative Accelerator (LIAC),
Sordina IORt technologies, Vicenza Italy

- Linear electron accelerator dedicated to IORT
- Nominal energies: 6 – 8 – 10 – 12 MeV
- Beam collimation: PMMA applicators
- High dose rate: up to 70 mGy/min

Dosimetric Measurements

RELATIVE DOSIMETRY

- Percentage Depth Dose (PDD)
- Transverse Dose Profile (TDP)
- Output Factors (OFs)

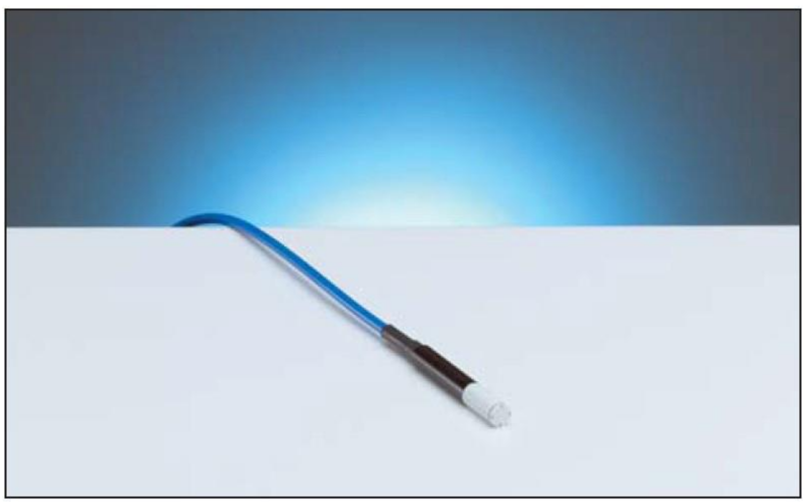
ABSOLUTE DOSIMETRY

- Absolute dose
  - Ion recombination correction factor (k_{sat})
  - Polarization correction factor (k_{pol})

Relative Dosimetry: PDD, TDP, OF

PTW 60019 microDiamond

- Small sensitive volume: 0.004 mm^3
- Thickness 1 µm
- Small field dosimetry for electrons
- Main use: dosimetry for radiotherapy beams



Water phantom

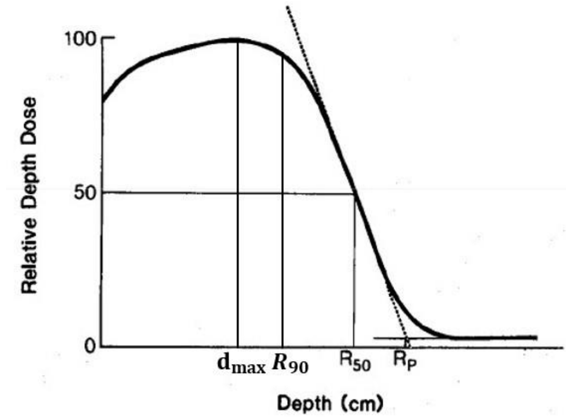
- Small size motorized 3D water phantom
- Acrylic walls 20 mm thick
- Dosimetry procedures of high electron beams in water

PDD – TDP

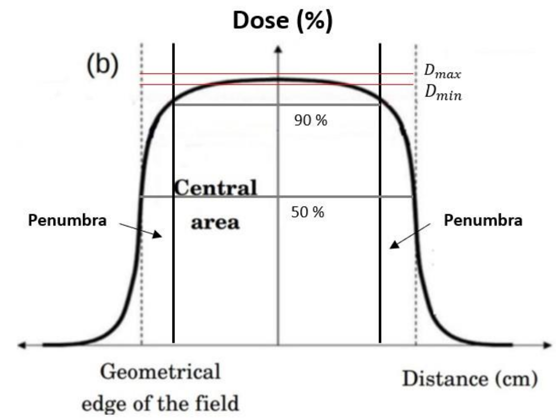
- PDD: Radiation absorption curve as a function of depth:

$$PDD = \frac{D(d)}{D(d_{\max})} \times 100$$

  - Information about quality electron beam
  - R_{90}, R_{50} and d_{max}



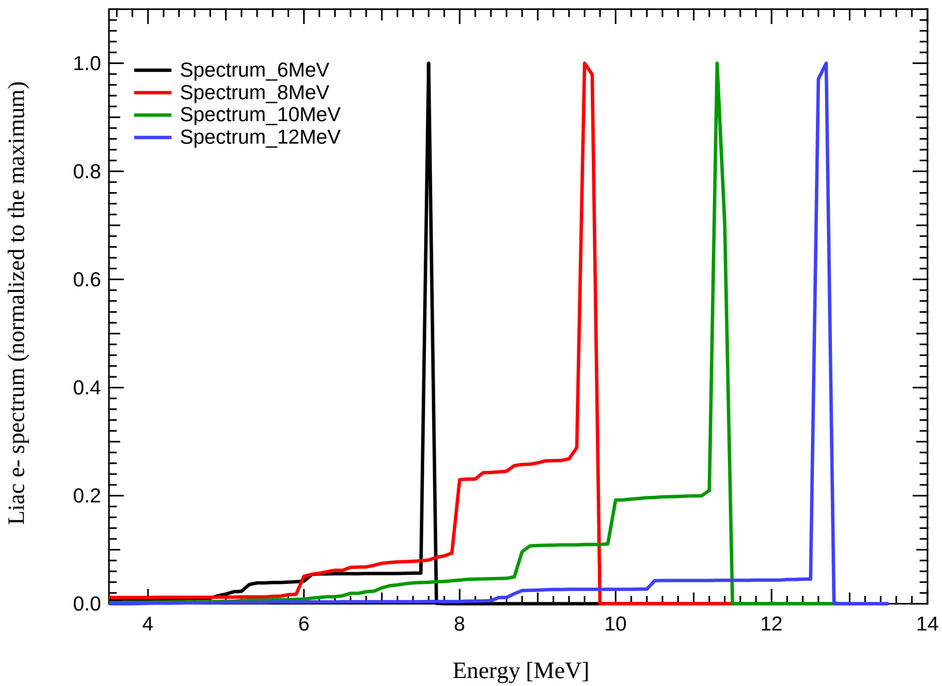
- TDP: Off-axis dose measurements in two orthogonal directions:
  - Field size (width at 50 % dose level)
  - Penumbra (region between 90% and 50% dose level)
  - Symmetry and Flatness (($S = \frac{A_L - A_R}{A_L + A_R} \times 100$) and ($F = \frac{D_{max} - D_{min}}{D_{max} + D_{min}} \times 100$))



Ref. ICRU Report 78

GATE MC simulation inputs

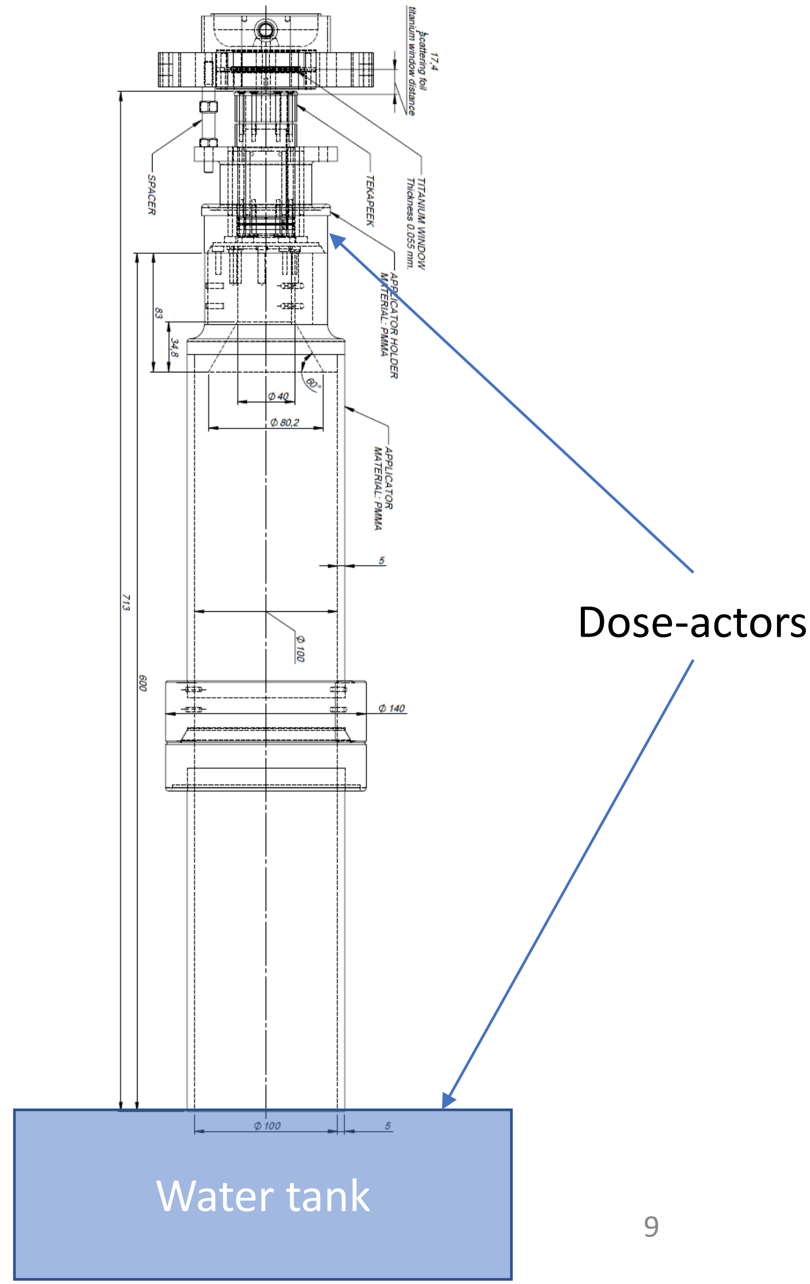
e- spectrum



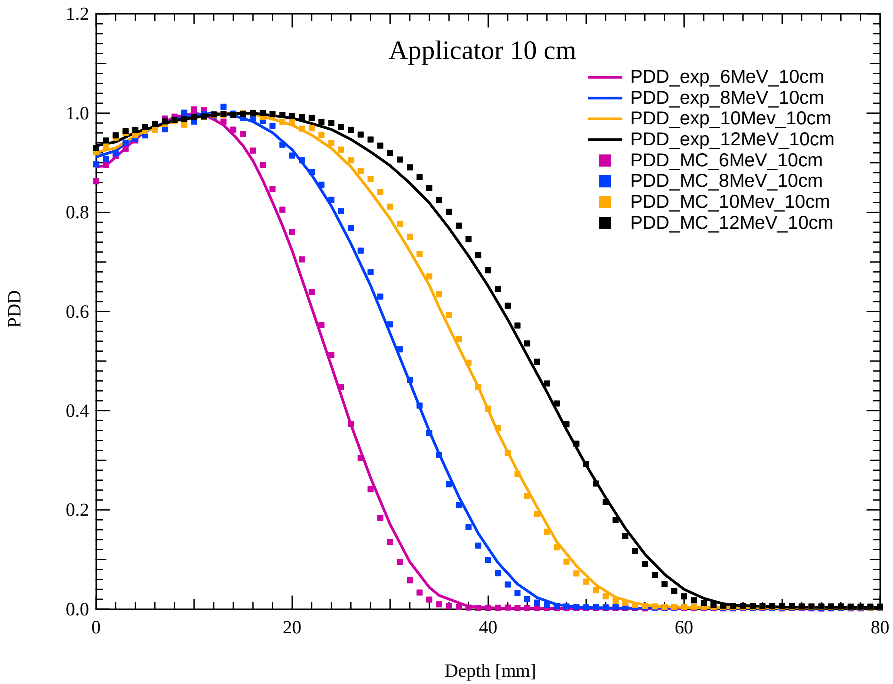
GATE configuration:

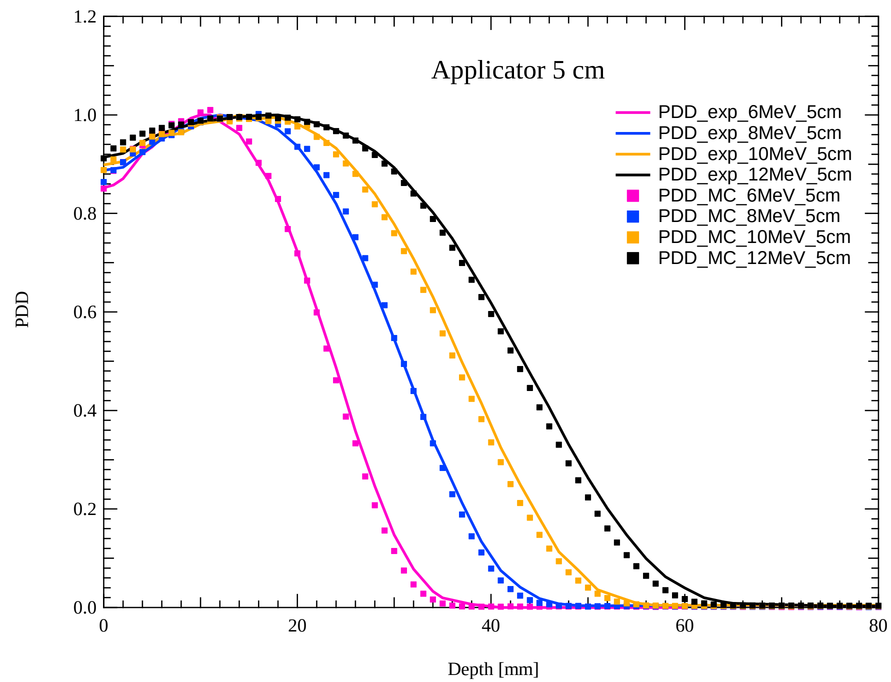
emstandard_opt3;
1e^8 electrons;
cut is set to 0.1 mm;

Geometry + materials



Results - PDD



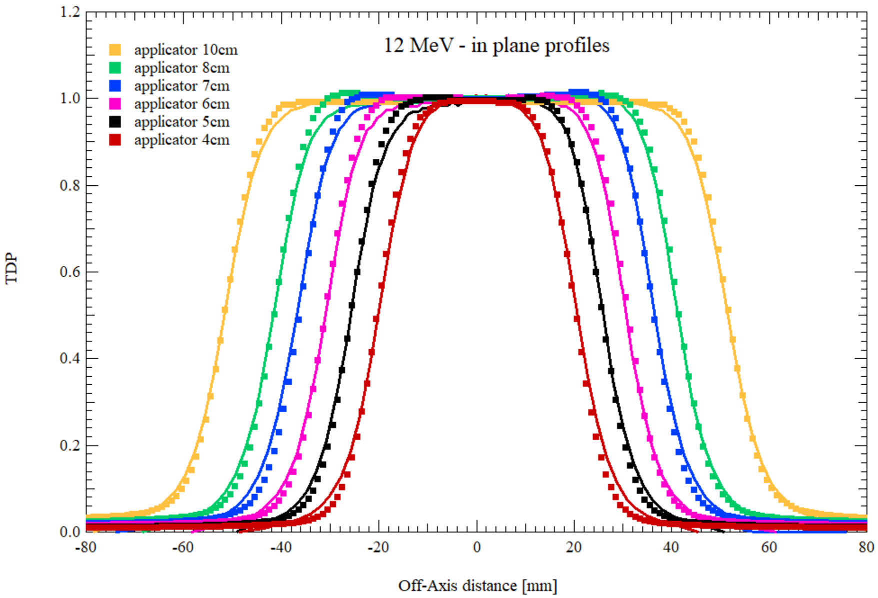


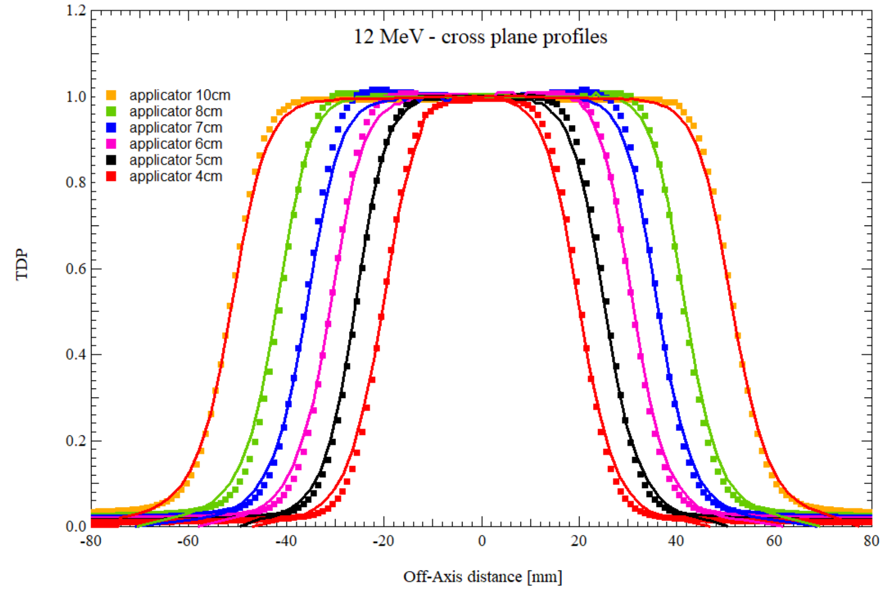
Exp.	6 MeV	8 MeV	10 MeV	12MeV
R_{100} (mm)	10.3 ± 0.8	12.6 ± 1.0	15.0 ± 0.5	16.6±0.5
R_{50} (mm)	23.7 ± 0.1	30.9 ± 0.2	37.4 ± 0.5	43.7±1.0
R_{90} (mm)	16.0 ± 0.2	21.2 ± 0.3	25.2 ± 05	29.1±0.7

GATE	6 MeV	8 MeV	10 MeV	12MeV
R_{100} (mm)	10.0±0.2	12.7±0.4	14.5±0.6	16.2±0.8
R_{50} (mm)	23.7±0.1	30.7±0.6	36.8±0.9	43.3±1.3
R_{90} (mm)	16.1±0.3	21.2±0.6	24.9±1.0	29.3±1.5

Winkler et. al (2020)
Baghani et al. (2019)

Results - TDP





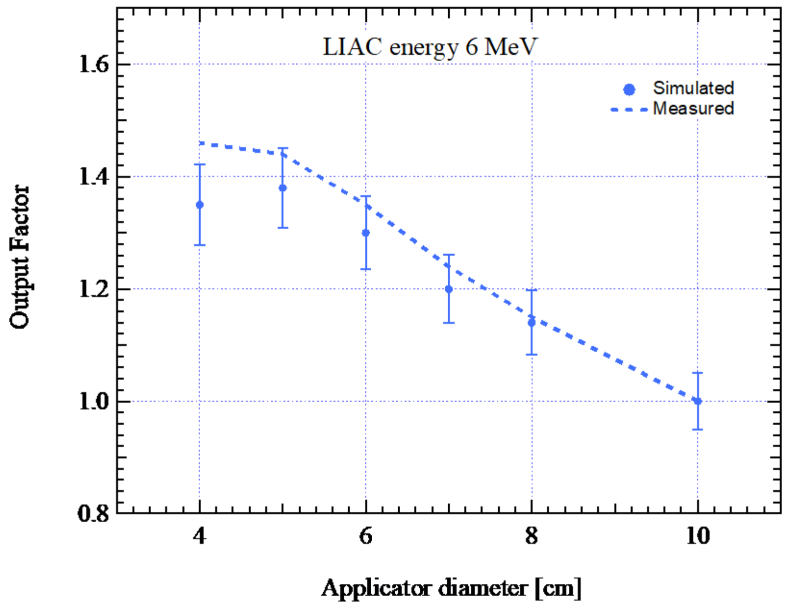
Experimental	6 MeV	8 MeV	10 MeV	12 MeV
Flatness	(2.8 ± 1.1)%	(1.3 ± 0.4) %	(0.9 ± 0.3) %	(1.9 ± 0.3)%
Symmetry	(1.3 ± 1.0) %	(1.4 ± 0.2) %	(1.1 ± 0.3) %	(0.3 ± 0.2) %
Penumbra [mm]	(6.2 ± 0.6)	(8.1± 1.1)	(9.9± 0.6)	(10.2 ± 0.4)

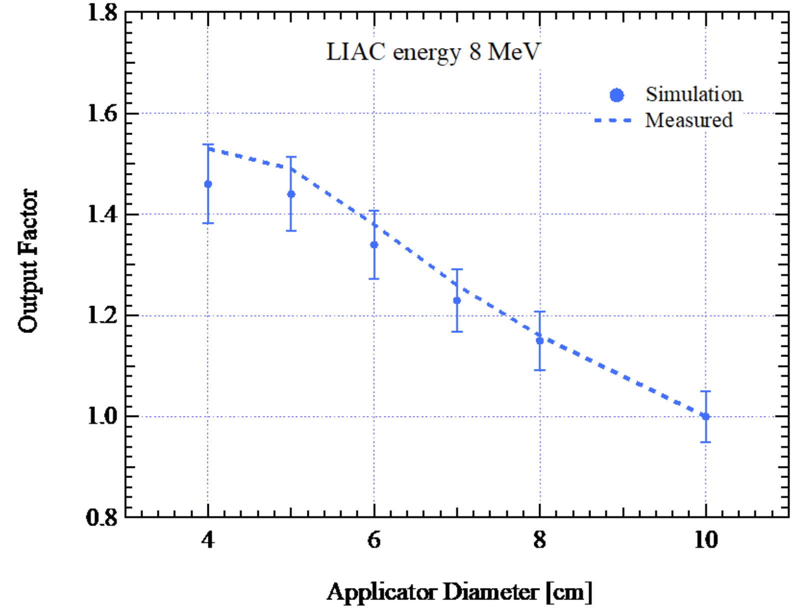
GATE	6 MeV	8 MeV	10 MeV	12 MeV
Flatness	(4.8 ± 0.8)%	(3.8 ± 0.6) %	(3.2 ± 0.3) %	(2.3 ± 0.7) %
Symmetry	(0.9 ± 0.6) %	(1.0 ± 0.9) %	(0.5 ± 0.4) %	(0.2 ± 0.2) %
Penumbra [mm]	(6.0±0.3)	(6.2±0.4)	(6.4±0.6)	(6.3 ± 0.4)

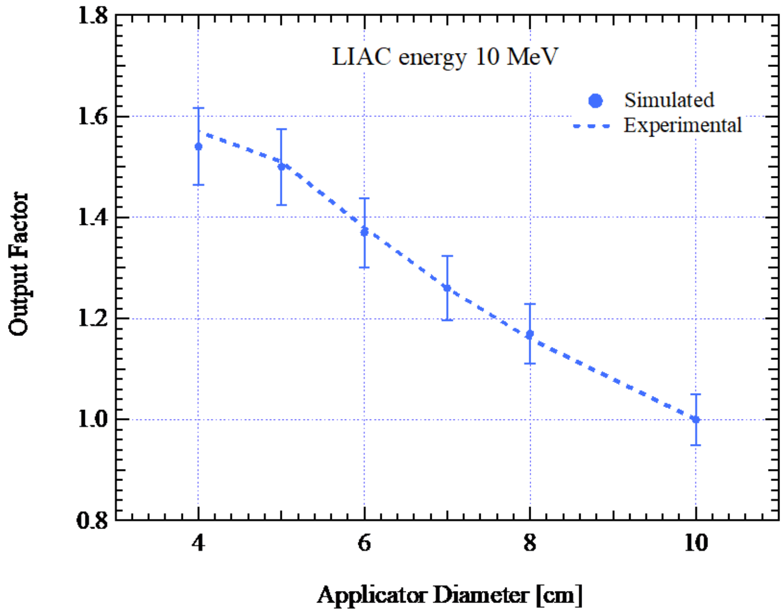
Output Factor

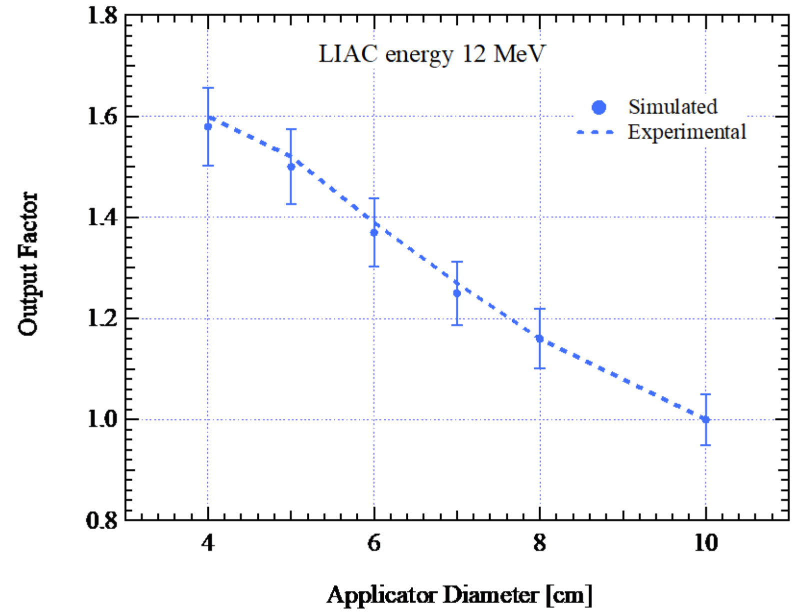
$$OF(E, A, d_{max}) = \frac{M(E, A, d_{max})_{field}}{M(E, A_{ref}, d_{max})_{ref}}$$

Gungor et al. (2019)









Conclusions

- The results show a good agreement among experimental data and GATE simulation both for PDD curves, Transverse Dose Profiles and Output Factor.

- Next steps are:
  - MC simulation of dosimetric characteristic of the beveled IORT applicators.
  - MC simulation of the PTW micro-diamond angular dependence response .