The Octa:
a Geant4 investigation

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Stereotactic radiotherapy - SRT

SRT (SABR/SBRT) – radiotherapy treatments

linear accelerator (linac) delivers MV photon beams
typically 6/10 MV FB/FFF beams

hypo-fractionated treatments & high doses (45 Gy/fraction)
small radiation fields (5, 7.5, 10 mm diameter) with steep dose gradients

careful time-consuming & **small-field specific** quality assurance measurement procedure

The Accuray CyberKnife linac

State-of-the-art robotic radiosurgery

linac mounted on a robotic arm

radiation beams:

collimated to form circular fields
&
delivered with **sub-mm positional accuracy**

imaging to check target positioning
&
correct displacement in **real-time**

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Small field dosimetry with silicon diodes

Quality assurance for the Accuray CyberKnife linac

silicon diode detectors **recommended by the AAPM Task Group 135** to perform CyberKnife relative dosimetry

silicon diodes over-respond at **small fields** and require **corrections**

Quality assurance measurements

Output factors

ratio between the dose in a clinical field to the dose in the standard reference field

$$\mathrm{OF}_{z_\mathrm{ref}}(f_\mathrm{clin}) = \frac{D(z_\mathrm{ref}, f_\mathrm{clin}, \mathrm{SAD})}{D_\mathrm{ref}(z_\mathrm{ref}, 10 \times 10, \mathrm{SAD})}$$

for broad beams ratio **approximated** by ratio of detector readings

$$\approx \frac{M(z_\mathrm{ref}, f_\mathrm{clin}, \mathrm{SAD})}{M_\mathrm{ref}(z_\mathrm{ref}, 10 \times 10, \mathrm{SAD})}$$

approximation OK if
stopping-power ratio water-to-detector
&
perturbation correction factor
are field-size independent

Output factors

Small field dosimetry

for **small beams** this is no longer true
(lack of CPE, …)

perturbation factors
&
volume averaging effects
depend considerably on

- detector type/size
- field size
- accelerator type (effective source size)

Output factors

Correction factors

$$\Omega^{f_{clin},f_{ref}}_{Q_{clin},Q_{ref}} = \frac{D^{f_{clin}}_{w,Q_{clin}}}{D^{f_{ref}}_{w,Q_{ref}}} = \frac{M^{f_{clin}}_{Q_{clin}}}{M^{f_{ref}}_{Q_{ref}}} k^{f_{clin},f_{ref}}_{Q_{clin},Q_{ref}}$$

determined using **Monte Carlo simulations** / experimental comparisons with the response of an "ideal" detector taken as reference

key:
correction factors are
detector / treatment head design / measurements conditions
dependent!

Output factors

Correction-free detectors

silicon detectors have a relatively high density
sensitive media

Benmakhlouf et al. - Spectral distribution of particle fluence in small field detectors and its implication on small field dosimetry, Med. Phys. (2016)
Charles et al. - Design and experimental testing of air slab caps which convert commercial electron diodes into dual purpose, correction-free diodes for small field dosimetry, Med. Phys. (2014)

correction-free detectors
by incorporating low-density components to the detector design

The Octa

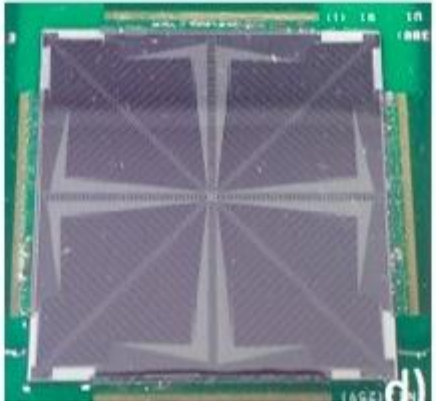
2D silicon array detector designed at CMRP (UOW)

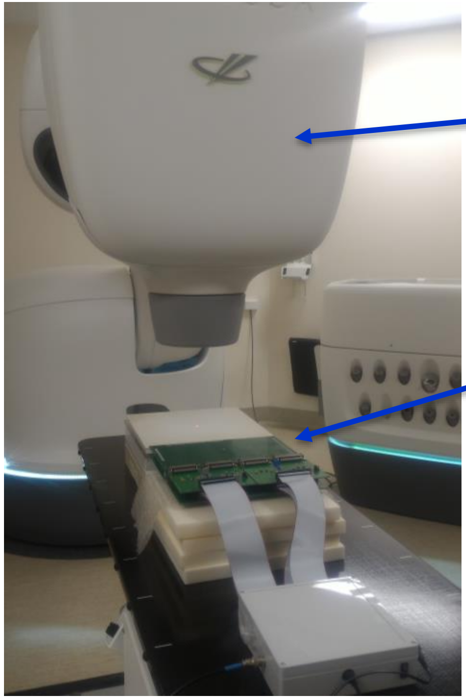
512 silicon diodes (SVs)

arranged on 4 arrays

300/430 um spatial resolution

correction free (air gap)





CyberKnife linac

Octa

Conclusions

Geant4 + IAEA PHSP = investigation tool for small field dosimetry

- novel investigation on perturbation effects for monolithic silicon array detectors
- Monte Carlo simulations support current correction-free design of the CMRP Octa detector (at least for this specific beam quality…)

Acknowledgments

NCI for computing time (nci.org.au)
Gross Foundation for scholarship funding
SCGH for reference data and beam time (scgh.health.wa.gov.au)
IAEA for PHSP files (https://www-nds.iaea.org/phsp/photon1/)
Cortés-Giraldo et al[1]. for the basis of the C++ classes used for reading IAEA PHSP files & CMRP PhD student **T. Causer** for his help in updating them
CMRP research fellows **D. Bolst** & **B. Oborn** for useful discussions

[1]Cortés-Giraldo et al, An implementation to read and write IAEA phase-space files in GEANT4-based simulations, Int Journal of Rad Bio (2012)

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