Evaluation of Quad Wedge and IC-Profiler to Calculate R50 for Non-Standard Electron Energies

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Purpose

To develop a procedure to efficiently measure electron R_{50} utilizing the Sun Nuclear IC-Profiler Quad Wedge accessory for non-standard energies. Currently, methods to calculate R_{50} are only provided for energies 6, 9, 12, 15, 16, 20 and 22MeV.

Introduction

- Energy checks for Monthly QA or after machine service is time consuming
  - Uncertainty solid water measurements can be close to 1mm
- Typically after major machine repair, water tank scans are necessary to verify beam quality

ENERGY	7 MeV e-	9 MeV e-	10 MeV e-	11 MeV e-	13 MeV e-
Physical Depth	1.68	2.09	2.44	2.83	3.23
RDG 1	20.390	20.490	20.750	20.690	20.650
RDG 2	20.380	20.480	20.750	20.690	20.650
RDG 3					
AVG RDG	20.385	20.485	20.750	20.690	20.650
cGy/MU	1.007	1.008	1.011	1.008	1.007

ENERGY CHECK

Physical Depth	2.8	3.5	4.1	4.7	5.4
ENERGY RDG1	12.100	10.650	10.320	11.330	11.440
ENERGY RDG2					
ENERGY RDG3					
MEASURED RATIO	0.594	0.520	0.497	0.548	0.554
Acceptable Range	0.464-0.712	0.449-0.665	0.450-0.650	0.459-0.636	0.471-0.625
DTA (cm)	0.009	-0.069	-0.105	0.000	0.016

The following figures and explanations can be found in:

"Beam Quality Verification Using IC Profiler with Quad Wedge Accessories"

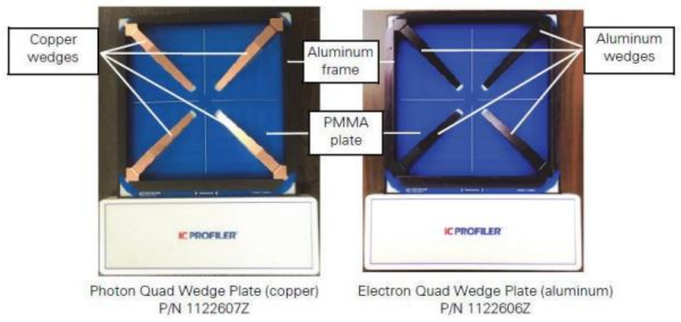

Figure 1. IC Profiler Quad Wedge plate accessories mounted on IC Profiler

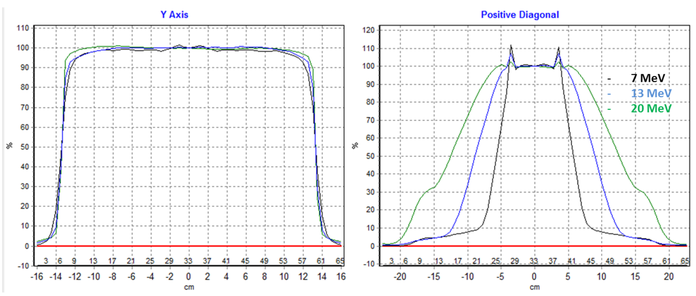

Figure 2. Example wedged profiles. Y Axis Profile and Positive diagonal profile for 7, 13, and 20 MeV

$$AreaRatio = \frac{PDArea + NDArea}{XArea + YArea}$$

AreaRatio is meant to mitigate any effects on profile shape on the area calculations. PDArea, NDArea, XArea, and YArea represent the sum of corrected counts for positive diagonal, negative diagonal, X and Y axes, respectively

$$Area_{ax} = \sum_{i=LtStart}^{LtEnd} CC_{i,ax} + \sum_{k=RtStart}^{RtEnd} CC_{k,ax}$$

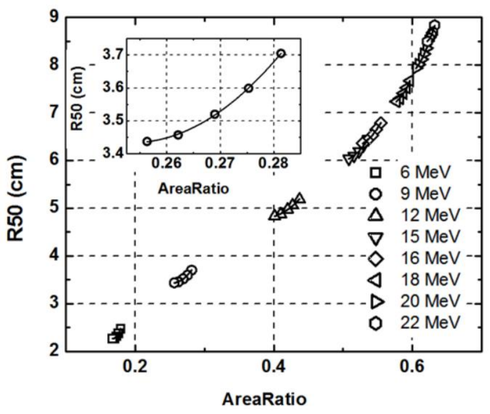

Figure 3. Electron beam R50 measured in water phantom versus AreaRatio for all electron energy modes and the quadratic fits. Inset: quadratic relationship between R50 and AreaRatio for 9 MeV beam.

Electron Beams	
Energy Mode (MeV)	R50 Standard Deviation (mm)
6	0.014
9	0.013
12	0.018
15	0.032
16	0.043
18	0.050
20	0.064
22	0.086

- Orders of magnitude better than solid water
- No Water Tank!
- 1 measurement to get R50

Methods

The energies investigated have been tuned off the standard settings to achieve specified R_{90} values.

Table 1. Electron radiation penetrative quality. Vendor provided standard specifications are in bold.

Energy Level [MeV]	Depth of 90% Dose [mm]	Depth of 80% Dose [mm]
7	20.2	- 22.5
9	25.1	**30** 27.9
10	30.2	- 33.3
11	35.2	- 38.8
13	40.3	- 44.6
16	49.8	**54.2** 55.2
20	59.9	**66.7** 68.4

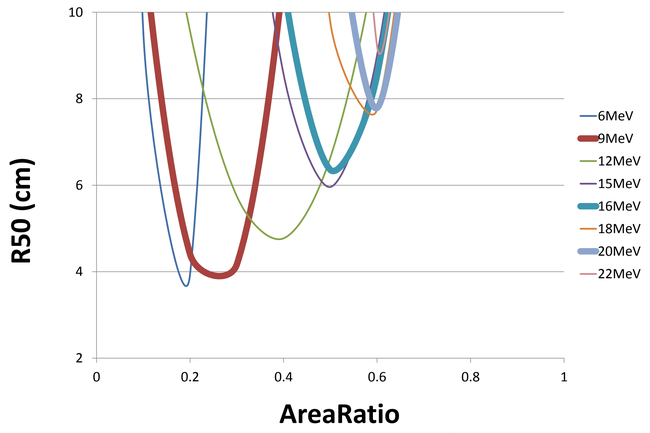

Figure 4. 2nd Degree Polynomials based on Sun Nuclear Provided Coefficients. Energies available at our facility with Sun Nuclear provided polynomials are shown in bold.

- R_{50} values were calculated for overlapping energies (9, 16, 20MeV) and compared to water tank scans
- PDDs were measured at 100cm SSD using a water tank for nominal electron energies of 7, 9, 10, 11, 13, 16, and 20MeV with 1, 2, 3, 4 and 5mm of PVC placed in a 25x25cm² cone as close to the linear accelerator head as possible
- Measurements were made on two matched Elekta machines (VersaHD and Infinity upgraded to an MLC head). Machine 1 only has 5 electron energy positions due to the FFF modes.

Figure5. IC-Profiler set to 100cm SSD with Quad Wedge placed on the surface and 5mm of PVC placed in 25cm x 25cm cone

- Plots of the water tank measured R_{50} versus the AreaRatio (a metric used by Sun Nuclear) for each energy were fitted with a quadratic. R^2 values were used to determine the accuracy of the fitted regression. Lastly, IC-Profiler calculated R_{50} values were compared to solid water spot measurements

Results

- The average distance-to-agreement for 9, 16, and 20 MeV using the coefficients provided by Sun Nuclear was:

-0.17 ± 0.83 mm

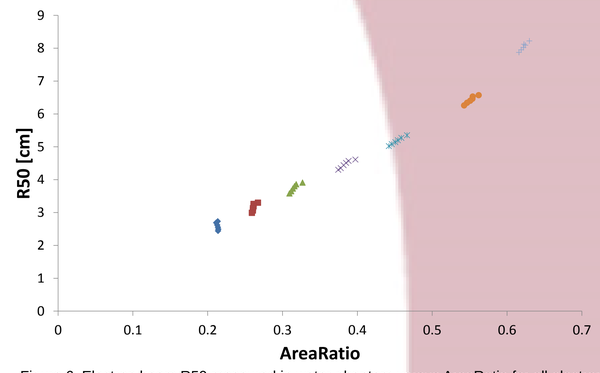

Figure 6. Electron beam R50 measured in water phantom versus AreaRatio for all electron energy modes

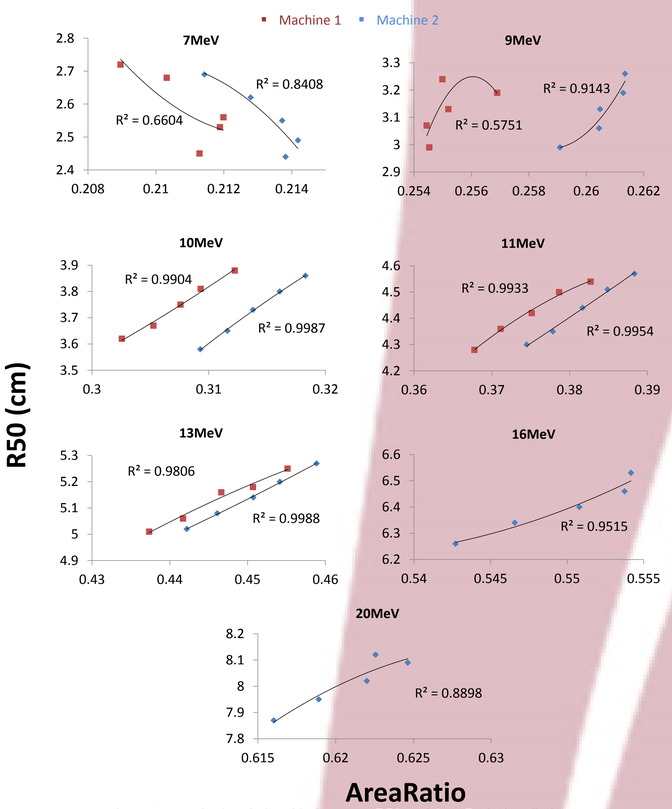

Figure 7. Quadratic relationship between R50 and AreaRatio for all electron energy modes

- The average distance-to-agreement for 7, 9, 10, 11, 13, 16, and 20 MeV using the coefficients from our measured data was:

0.13 ± 0.65 mm

Conclusions

We were not able to replicate the precision demonstrated by Sun Nuclear using the IC-Profiler Quad Wedge accessory to measure R50. The uncertainty in calculating R50 was only marginally better than using the two depth measurement technique in solid water. Further investigation is needed to determine if our results stem from using PVC to modulate range rather than altering the bending magnet current.

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