

Hospital Radiophysics 3D Radiotherapy Wedges Simulations At [18 MeV, Z = 5,15 cm] With AAA Model Integral Equation Fluence Foils Method. Part I.

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ARTICLE INFO	ABSTRACT
Published Online: 23 July 2026	Further computational intelligence precision is applied for AAA foundational model radiotherapy photondose simulations in water. For 18 MeV Linac operation, Author's original-practical fluence implementation mathematical method, namely Fluence Foils Method (FFM) is demonstrated. It is based on metal foils experimental measurements. Results comprise: (1) Omega Factor mathematical algorithms review for wedge filters (WF), (2) AAA Fluence Foils Method, (FFM) proof, for fluence magnitude/rate integral equation implementation technique, (3) series of 3D improved imaging-processing for static wedges dose delivery at (z = 5 and 15 cm depth), (4) briefing hospital radiotherapy physics WF treatment planning optimization applications within planning system and MU calibration.
Corresponding Author: Francisco Casesnoves	Results/algorithms prospective applications to Monitor Units (MU) estimates for AAA photondose exactitude are shortly/initially included and formulated.
KEYWORDS: Fluence Foils Method (FFM), Omega Factor (OF), Radiation Dose, Attenuation Exponential Factor (AEF), Simulations, Nonlinear Optimization, Matrix Algebra, Spherical-Spatial Analytical Geometry, Organ at Risk (OAR), Wedge Filter (WF), Monitor Unit (MU), Anisotropic Analytic Model AAA, Intensity Modulated Radiotherapy (IMRT), Fluence Factor (FF), Treatment Planning Optimization (TPO), Computerized Thomography (CT).	

I.INTRODUCTION AND OBJECTIVES

Target-precision in Radiation Therapy is essential to obtain an optimal cancer treatment, [1-24]. It strongly depends on the accuracy physical-mathematical links between the applied model and experimental physics data. Provided this requirement be achieved, the other radio-oncology treatment factors get significant clinical benefits. Foremost among these, patient survival time, minimization/elimination of OARs side effects, avoid overdosage, post-radiation complications, and increase life quality, and several others. Not always the theoretical photon fluence/rate in LINACs corresponds to the experimental magnitude data verified. This study focuses on a few techniques to be used for AAA model integral equation precision improvements to achieve those objectives. Namely, the Fluence Foils Method (FFM) technique, based on accurate fluence experimental metal foils database. The article is more related to mathematical medical physics than oncological pathology concomitant to the

involved AAA model. All of these topics from a practical/useful point of view to provide TPO advances.

In this article, further reading recommended, in order to clarify/complement the study, comprises large number of references. In the field of computational intelligence and optimization methods applied in radiotherapy, [1-21] references can bring up practical knowledge for this area. For specific radiotherapy cancer medical physics, it is recommended further reading precision-details in several directions. The main radiotherapy dosimetry optimization physics, is included at [12-20,29,48,50,51,58,59,66-69,72,84]. Specifically, [66-69] involve formal optimization methods and inverse applied techniques useful for TPO. The biomodels for cancer are explained in [22-25,83-86]. Some related informative modern radiotherapy publications can be found at [52,70,75]. In the radioprotection field, when radiation therapy treatment is given, standard general and breast cancer norms for radioprotection, [79-81].

Mathematical inverse problems theory/algorithms to be applied with/for Tikhonov dosimetry optimization, [32,61,62,67,68,73,74]. For imaging and imaging-guided applications for tumors, [24,26,74] are useful. The 2D-AAA classical model publications along the literature are extensive, for example, [28,29,30,33,34,36,46]. Concepts about adjuvant radio-chemo-immuno therapy, are introduced in [41,55,69,70]. Radiobiological tumor concepts are included in [82-85]. Recent advances for Omega Factor with sharp algorithms/geometrical presentations can be found at [72-74, 76-79, 86, 87]. Initial dosimetry-conceptualization review and geometrical dataset for WF photondose are introduced in [88-89]. Comparisons theoretical/experimental of WF photondose, for example, at [90]. Definition/formulation of Omni Wedge can be specifically read at [91]. In the field of Monitor Units, [24,92,93], show formulation and numerical measurements. All this database constitute a useful tool in modern TPO.

Objectives

The objectives of the study are mainly related to AAA model computational intelligence TPO methods/formulas as follows,

1. Develop Author's algorithm/method for AAA fluence magnitude implementation by using experimental foils dataset. It is denominated/conceived as Fluence Foils Method (FFM), Equation 1, Appendix I. That can be done with coaxial gamma spectrometers to determine the specific metal activity induced in the irradiated foils by measuring its characteristic gamma lines (keV), [35, 37].
2. Improved software engineering design for more precision in 3D image-processing of static wedges photondose at ($z = 5$ and $z = 15$ cm depth, AAA model). Figures 1-6, Appendix
3. A review with sharp presentation of Omega Factor 3D corrections both integral equation and analytical geometry solutions. [1-21, 72-74, 76-79, 86,87]. Equation 2, Appendix II.
4. Briefing of TPO applications with initial MU planning system determinations for AAA model without tissue heterogeneities, secondary electrons and scatter radiation, Equation 3, Figure 7, Appendix IV. The rationale of this objective is based on the fact, that not always MU at planning system corresponds to an exact or approximately exact photondose delivery, [24,92,93].

Grosso modo, advances for algorithmic/formulas precision for photon fluence implementation and 3D wedge filters imaging-processing, photondose magnitude and TPO applications are demonstrated/presented.

II. MATHEMATICAL AND COMPUTATIONAL METHODS

An easy way to verify the photon fluence for the basic AAA integral equation is the Author's proposed Fluence

Foils Method (FFM) approach. It is conceived to precisely evaluate/determine the photon fluence magnitude. Provided this measurement is got, and the 3D Omega Factor is applied, the equation could give more exact values for photondose delivery, and specifically for photondose/time, that is, photon rate/flux. The utility of photondose delivery by time unit is intended be demonstrated. Here the essentials are shown with formulation and proper radiophysics parameters. Equation 1, Appendix III.

Omega Factor Mathematical Algorithm

Recently, for WF TPO, Omega Factor integral equation and approximations equations were improved and sharply explained, [1-21, 24, 72-74, 76-79, 86, 87]. At Appendix II, its basic development is presented with algorithms and analytic geometry for better understanding of this study method/results.

Measurement of High-energy Photon Flux with Specific Activation Foils

The essential purposive equations applied by [35, 37, Vagena, E; Stoulos, S; Manolopoulo, M, Equation 1; Haddad, K; Anjak, O; Yousef, B, Equations 5-8]. Those Authors' Equations were implemented in order to measure photon flux through coaxial gamma spectrometers. Those Authors' Radiophysics Equations/experimental got through were set in this study for FFM calculations and optimization/graphical-simulations.

Fluence Integral Equation Implementation Method

The Author's method (FFM) to implement directly/easily fluence within AAA model to obtain precise dose delivery calculations/checks, [Casesnoves, 2022, Equation 1, Appendix III], is based on experimental data got from absorbed dose measurements with metal foils, and guessed by author from experimental work/publications, e. g., [35, 37, Vagena, E; Stoulos, S; Manolopoulo, M; Haddad, K; Anjak, O; Yousef, B]. These authors used gold, nickel, indium, and natural uranium activation foils to determine the photon and neutron fluence at isocenter. This achievement gives a practical-useful experimental source to obtain important/correct beam magnitudes at isocenter, [77-79,86,87], Figure 7. The beam parameters magnitudes at isocenter are essential for dose delivery precision and MU calibration. Basically, FFM algorithm consists in approach the experimental foils data to deduce in a precise interval the fluence and fluence rate to be implemented within AAA integral equation. In this way, the AAA integral equation dose delivery can be calculated in [Gy/s] photondose. Ultimately, these determinations could be implemented to approximate the AAA monitor unit MU photondose [24,92,93]. That would constitute the practical application. Just remark that, for example, the AAA planning system Eclipse-Varian, [36], gets all this automatically with its specific software. Therefore, this method constitutes a checking-reference and simulations/optimization tool for

AAA model [24,92,93]. That is, 1 MU is defined as the irradiation of 1 cGy in water. In the shooting-time for 1 MU, there are variations, [24,92,93]. However, calculations for MU depend also on secondary electrons and scatter radiation, among several other parameters. See algorithms of Section IV. Figure 7, Appendix III.

Mainly, once got experimentally the dose magnitude and the dose delivery time data, the mathematical method reads,

AAA MODEL FLUENCE FOILS METHOD (FFM)
EXPERIMENTAL – ANALYTICAL
IMPLEMENTATION METHOD [Casesnoves 2023 – 2024];
EXPERIMENTAL FOILS DATA SOURCE:
[Vagena, E; Stoulos, S; Manolopoulos, M; Haddad, K; ...
...Anjak, O; Yousef, B, 2015 – 2019];

pones aqui formula

Definition : Given experimental Fluence result,
Number of photons, N , by cm^2 ,
obtained from laboratory – simulations
statistical – experimental foil(s) absorbed dose,
such as, $\left[\frac{N}{\text{cm}^2 \times \text{Gy}} \right]$ and
irradiation time experimental
magnitudes from an statistical
sample interval the method reads,

Fluence Rate per second (Photon – Flux),

$$\Phi/s \cong [\text{Experimental fluence/Gy}] \times \dots$$

$$\dots \frac{[\text{Statistical Photodose during foil irradiation}]}{[\text{Statistical irradiation time at foil}]};$$

Therefore, Photon – Flux $\cong \Phi/s$;

For calculations, AAA $I(z)$ units
are $[\text{Gy} \times \text{cm}^2]$ as depth functions;

hence, for 2D, the AAA Dose – deposition integral was,

$$D(x, y, z)/s = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \left[\frac{\Phi_U(u, v, z)}{s} \right] \frac{C_K}{\pi \sigma_K} e^{-\left[\frac{(x-u)^2}{\sigma_K^2} + \frac{(y-v)^2}{\sigma_K^2} \right]} dudv;$$

thus, modified for 3D with Omega Factor,

$$D(x, y, z)/s = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \left[\frac{\Phi_U(u, v, z)}{s} \right] \frac{C_K}{\pi \sigma_K} e^{-\left[\frac{(x-u)^2}{\sigma_K^2} + \frac{(y-v)^2}{\sigma_K^2} \right]} \times \dots$$

$$\dots \times e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{r+z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F; dudv;$$

where,

$$\left[\frac{\Phi_U(u, v, z)}{s} \right] \text{ is Fluence Rate calculated by FFM;}$$

(1)

where,

$D(z, y, z)/s$: Photondose delivery by second according to the $D(x, y, z)$ Equations [87, Equations 1-2] . At Figures 1-6, it is denoted in cGy for prospective MU determinations. Algorithm enhanced at Appendix III.

Other Parameters: Specified at [86,87, Equations 1-3] .

[Casesnoves Bioengineering laboratory Algorithms K-6-2026-1]

From [1-21, 86, 87], a review of the Omega Factor application for 3D complete integral equation analytic solution reads,

OMEGA FACTOR $[\Omega]_F$ EXACT ANALYTICAL INTEGRATION [Casesnoves 2015 – 2016]

Definition : Omega Factor, $[\Omega]_F$, is a convolution factor set exponentially to add 3D precision to the photon – beam pathway length – magnitude throughout the radiotherapy wedge – filter, as beam modification device;
The AEF in 3D for the thin part of the wedge, according AAA model foundation reads,

$$f(u, z, \phi, \alpha, L) = e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{r+z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F;$$

hence, for 2D, the AAA Dose – deposition integral was,

$$D(x, y, z) = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \Phi_U(u, v, z) \frac{C_K}{\pi \sigma_K} e^{-\left[\frac{(x-u)^2}{\sigma_K^2} + \frac{(y-v)^2}{\sigma_K^2} \right]} dudv;$$

thus, modified for 3D with Omega Factor,

$$D(x, y, z) = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \Phi_U(u, v, z) \frac{C_K}{\pi \sigma_K} e^{-\left[\frac{(x-u)^2}{\sigma_K^2} + \frac{(y-v)^2}{\sigma_K^2} \right]} \times \dots$$

$$\dots \times e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{r+z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F; dudv;$$

Separating the part of 3D wedge – path independent from integral variables, it is defined,

$$A = A([\Omega]_F) = e^{-\mu_w \left[L \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F; \text{corrected with } [\Omega]_F \text{ for 3D – path};$$

For the second part depending on variable u , [Ulmer, 1996],

it is necessary make a new quadratic change, which results,

$$\text{defining } S = S([\Omega]_F), \text{ thus,}$$

$$S = S([\Omega]_F) = \pm \frac{1}{2} \times \mu_w \frac{r^2 - u^2}{r^2} \times [\Omega]_F;$$

Hence, complete analytical dose – delivery integration,

$$D(x, y, z) = \frac{\Phi_0 I(z) A([\Omega]_F)}{4 \left(1 + \frac{r^2}{\sigma_K^2} \right)^2} \sum_{K=1}^{K=3} C_K e^{[\sigma_K^2 (S([\Omega]_F))^2 - 2S([\Omega]_F)z]} \times \dots$$

$$\dots \times \left[\left(\text{erf} \frac{y+b'}{\sigma_K} \right) - \left(\text{erf} \frac{y-b'}{\sigma_K} \right) \right] \times \left[\left(\text{erf} \frac{x+a'-\sigma_K^2 S([\Omega]_F)}{\sigma_K} \right) - \left(\text{erf} \frac{x-a'-\sigma_K^2 S([\Omega]_F)}{\sigma_K} \right) \right];$$

$[\Omega]_F$ fundamental equation added factor at exponent is,

$$[\Omega]_F = \left[1 + \frac{\tan^2 \phi_2}{1 + \tan^2 \phi_1} \right]^{\frac{1}{2}};$$

where,

ϕ_1 : Coronal plane angle of the photon – beam pathway;

ϕ_2 : Sagittal plane angle of the photon – beam pathway;

Note : If ϕ_2 angle is computed, the 3D precision is reached;

(2)

[3, Casesnoves Bioengineering Laboratory, 2015]

Complementary Equations and mathematical development is proven at Appendix II.

Dataset Calculations

Table 1 shows the implemented dataset for the software, updated and with more precision than previous publications, [1-21, 86, 87]. From [35, 37, Vagena, E; Stoulos, S; Manolopoulos, M, Equation 1; Haddad, K; Anjak, O; Yousef, B, Equations 5-8], the experimental foil fluence, 18 MeV, Varian Clinac 2100C is calculated with irradiation parameters, [photondose of 16 Gy for 240 seconds with the beam directed downwards (gantry angle 0°)] according to the former Authors.

Table 1.- Simulations-Graphical-Optimization radiophysics parameters [1-21, 28,29,30,33,34,36,46, 86, 87] . [Casesnoves Bioengineering Laboratory Algorithms K-6-2026-2] . Appendix I.

SOFTWARE COMPUTATIONAL NUMERICAL DATASET	
Radiation Parameter	Magnitude/Units
SSD	100 cm
Isocenter z	z = [5 and 15] cm
WF Angle and Field Size	15°, 12x12 $\simeq$ 10x10 cm ²
AAA Model I(z)	$I(z = 5, 15) \simeq [20.9505 \cdot 10^{-12}, 17.6951 \cdot 10^{-12}] \text{ Gy} \cdot \text{cm}^2$
Omega Factor Angle Maxima	$\varphi_1 \simeq 30^\circ \varphi_2 \simeq 30^\circ$
Foil Fluence Rate	$\simeq 0.6667 \frac{\text{Gy}}{\text{s}}$
Experimental Foil Fluence/Gy	$[4.16 \cdot 10^9, 2.82 \cdot 10^{10}]$

Software Engineering Design

The software was engineered based on previous publications, with further improvements [1-21, 86, 87]. Two systems are used, namely, Matlab and GNU-Octave. For applications on FFM technique, compulsory changes were set to get exactitude. Since one of the forthcoming objectives in next studies is the MU practical purpose, 3D imaging-processing photondoses are expressed in cGy. That is, by definition, 1 MU is equal to 1 cGy photondose in water, subject to a number of several radiophysics parameters [1-21, 24, 28,29,30,33,34,36,46 ,72-74, 76-79, 87,92,93].

III.RESULTS

Results are divided into 3D imaging-processing group, and numerical ones. Figures 1-6, and Appendices I, IV, complementary/enhanced data-algorithms/images give sharp understanding of the achieved objectives.

3D Imaging-processing Results

Figures 1-6 show 3D imaging processing results, both with GNU-Octave and Matlab systems. Sharper-enhanced images in Appendix IV. Dataset enhanced tables at Appendix I.

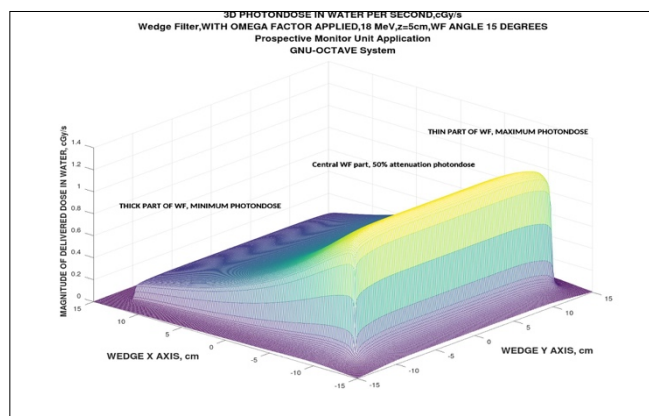


Figure 1.- GNU-Octave photondose/second simulation 3D image for 18 Mev photon-beam, in cGy, at 5 cm depth-dose with Omega Factor and I(z=5 cm) updated [28,29,30,33,34,36,46]. Beam divergence angles, $[\varphi_{1,2}$ are= 30°], and WF angle is 15° . All radiation physics parameters belong to Table 1. Inset, prospective MU applications can be guessed, since 1 cGy corresponds to a MU at isocenter.

Matrices for Image Processing have about [300 x 300] elements. Sharper-enhanced images in Appendix IV. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-3] .

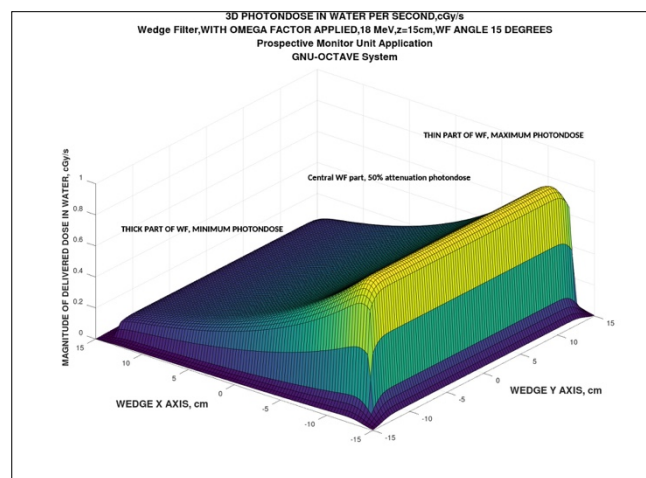


Figure 2.-GNU-Octave photondose/second simulation 3D image for 18 Mev photon-beam, in cGy, at 15 cm depth-dose with Omega Factor and I(z=15 cm) updated [28,29,30,33,34,36,46]. Beam divergence angles are 30° , and WF angle is selected at 15° . All radiation physics parameters belong to Table 1. Inset, prospective MU applications can be guessed, [24,92,93]. Matrices for Image Processing have about [100-300 x 100-300] elements. Sharper-enhanced images in Appendix IV. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-4] .

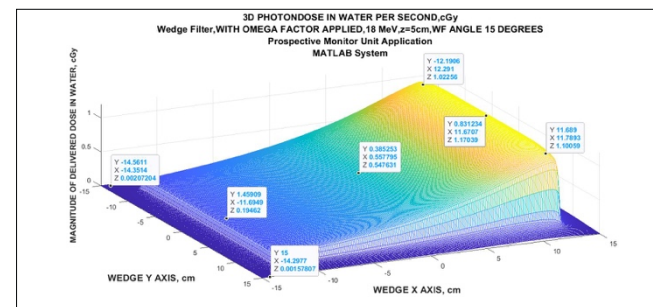


Figure 3.-Matlab 3D image-processing, with photondose/second illustrated inset showing numerical magnitudes of simulation. Done with 18 Mev photon-beam, in cGy, at 5 cm depth-dose with Omega Factor and I(z=5 cm) updated [28,29,30,33,34,36,46]. Beam divergence angles are 30° , and WF angle is 15° . All radiation physics parameters belong to Table 1. Inset, prospective MU applications can be guessed. Matrices for Image Processing have about [300 x 300] elements. Sharper-enhanced images in Appendix IV. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-5] .

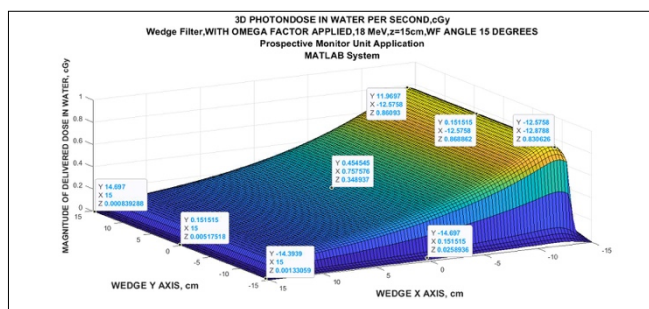


Figure 4.-Matlab 3D image-processing, with photondose/second illustrated inset showing numerical magnitudes of simulation. Done with 18 Mev photon-beam, in cGy, at 15 cm depth-dose with Omega Factor and I(z=15 cm) updated [28,29,30,33,34,36,46]. Beam divergence angles are 30° , and WF angle is 15° . All radiation physics parameters belong to Table 1. Inset, prospective MU applications can be guessed. Matrices for Image Processing have about [300 x 300] elements. Sharper-enhanced images in Appendix IV. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-6].

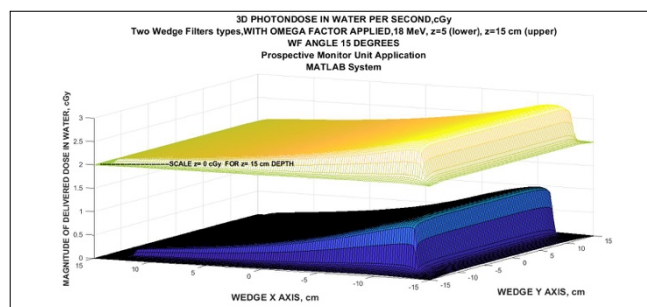


Figure 6.-Matlab double 3D image-processing to show the different/comparative photondose WF variations for [z=5 cm and z=15] cm model parameters. In general, Matlab 3D imaging-processing is superior than GNU-Octave. The photondose magnitude contrast can be verified and the 50% dose at isocenter is shown approximately in these lateral views. Parameters for [z = 5 cm and z= 15 cm] are the same than previous Figures 1-4. Note that for [z=2 cGy scale, z=15 cm depth] at image, the corresponding photondose magnitude is [z=0 cGy], because of upper image-translation. Sharper-enhanced images in Appendix IV. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-8].

Numerical Results

Table 2 shows a briefing of numerical results extracted from 3D Matlab-cursor images, enhanced at Appendix I. Approximations/trunkations are applied for [10^{-4}] magnitude order. Isocenter photondose, thin WF part and thick WF part magnitude differences can be verified according to computational calculation precision. Although the WF angle for simulations is rather small, 15° , the thick WF part almost attenuate all the beam intensity.

Table2.-Simulations-Graphical-Optimization radiophysics numerical results from Figures 1-6, with GNU-Octave and Matlab cursor inset method [1-21,87]. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-9]. Appendix I. Appendix IV enhanced images.

COMPUTATIONAL SIMULATIONS – OPTIMIZATION NUMERICAL RESULTS [APPROXIMATIONS]	
Radiation Parameter	Magnitude/Units
SSD [z = 5 cm]	100 cm
Maxima	1.0350 cGy
Minima	$1.7812 \cdot 10^{-3}$ cGy
Isocenter	0.5263 cGy
SSD [z = 15 cm]	100 cm
Maxima	0.8409 cGy
Minima	$1.2000 \cdot 10^{-3}$ cGy
Isocenter	0.3490 cGy
Complementary	Approximations to 10^{-4} magnitude order

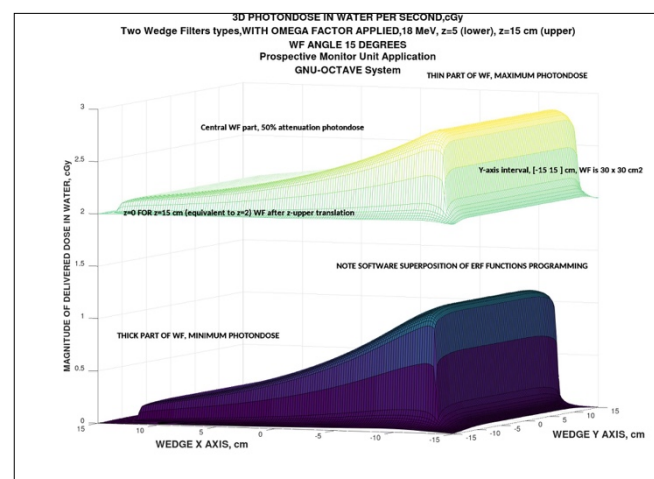


Figure 5.-GNU-Octave double 3D image-processing to show the different/comparative photondose WF variations for [z=5 cm and z=15] cm model parameters. The photondose magnitude contrast can be verified and the 50% dose at isocenter is shown approximately in these lateral views. Parameters for [z = 5 cm and z= 15 cm] are the same than previous Figures 1-4. Note that for [z=2 cGy scale, z=15 cm depth] at image, the corresponding photondose magnitude is [z=0 cGy], because of upper image-translation. Sharper-enhanced images in Appendix IV. [Casesnoves Bioengineering laboratory Algorithms K-6-2026-7].

IV. PROSPECTIVE MONITOR UNIT APPLICATIONS

Given one, among several [24] elemental MU equation for WF, MU can be calculated as follows,

MONITOR UNIT FOR ISOCENTRIC CALIBRATION

$$D [\text{reference isocenter}] = D [\text{calculated isocenter}] = \dots$$

$$\dots 1 \text{ cGy MU}^{-1};$$

(3)

where,

D [reference isocenter] : Dose Reference at Isocenter for WF . [cGy] .

D [calculated isocenter] : Dose Calculated at Isocenter for WF . [cGy] .

MU : Standard Monitor Unit parameter .

MU calibration depends on a rather large number of radiophysics parameters. MU, as said, is equivalent to 1 cGy, with the important constraint subject to measurement in water. At this prospective study it is considered the most elementary, [Equation 26.44, from 24]. More precise constants/parameters will be required for further next studies. Those are, for instance, the reference percent depth dose value, PDD_{ref} , SSD, [z = WF isocenter depth, for AAA model in cm], SAD [Source to isocentre distance], A_{ref} [Reference field size for calibration (usually 10 cm × 10 cm)], and others. In general, MU calibration is a rather difficult radiophysics task. Not always MU at planning system corresponds to an exact/approximately exact photondose delivery, [24,92,93] . At [93], it is described a variation of 15 ° WF [15 MeV] photondose of 0.78 % . In this approaching study, MU can be calculated with water photondose deposition at isocenter in cGy. For example, at Figure 7, [1 MU ≈ 1cGy for 2 seconds] would correspond approximately to the those at isocenter-central WF part, see cursor inset numbers, within the image.

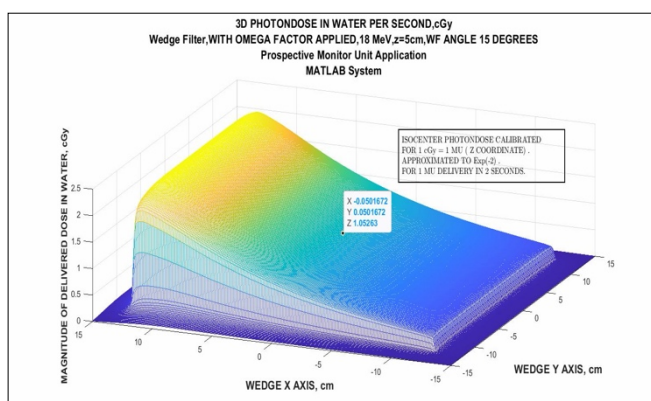


Figure 7.- Approximate calibration of MU for [z = 5 cm].

V. DISCUSSION AND CONCLUSIONS

The objectives of the study were formerly to improve AAA model WF dose delivery precision and demonstrate the new FFM technique with its applications. The first objective was to get precision in algorithms, 3D images, and numerical dataset for photondose per second. That is, this parameter can be used to get practical TPO usage. For example, introduction about formulation details to approximate Monitor Units with FFM algorithms [1-21, 86, 87]. Complementary, it was added some TPO applications briefing related to MU. For the most part, exactitude was improved compared to previous publications [1-21, 87].

Toward maximum divergence angle of 30°, the magnitude difference at negative exponential of AAA WF model, Equations 1-2, is of the order of [10⁻¹]. Without Omega Factor it is [≈ 0.3660]. With Omega Factor is [≈ 0.5000] . The difference between them is [≈ 0.1340] .

This implies that, as it was previously published, [12-21, 86, 87], the 2D AAA calculation algorithm, gives a numerically unsubstantially discordant photondose magnitude higher. Therefore, 2D AAA WF calculations overdo photondose delivery, which in the end makes a 2D numerical inconsistency [28,29,30,33,34,36,46] . Then, the patient, by using 2D AAA calculations, takes less optimal TPO photondose than necessary. Clinical radio-oncology applications emerge from all those advances. However, the magnitud difference of photondose delivery between 2D and 3D calculations, subject to Tables 1-2 constraints and Omega Factor algorithms, is not excessive [1-21,28,29,30,33,34,36,46] .

WF 3D imaging-processing and numerical data was presented/proven with two 3D imaging-processing subroutines. Fluence Foils Method was intended to be set, Equation 1, as functional. 3D imaging quality, both in GNU-Octave and Matlab is acceptable. Software engineering resulted be rather more difficult compared to previous publications. The calculations for photondose FFM are based on [35, 37, Vagena, E; Stoulos, S; Manolopoulo, M; Haddad, K; Anjak, O; Yousef, B]. MU calculations were initially determined, Equation 3, Figure 7.

At this primary FFM technique point in time, the WF photondoses can be considered an initial approximation, Table 2, and subject to next precision improvements. The complement, at this stage, should be the corrections for tissue heterogeneities, and further development for IMRT TPO beamlets matrices. Inconvenients when trying to improve the 3D precision are the programming arrays, related to implementation of Omega Factor, and the exact 3D imaging-processing matrices set. That is caused by the rather high number of erf functions at software, as every erf-part involve a large calculation series. Namely, the AAA WF foundations, [28,29,30,33,34,36,46], imply a number of constants and algebra operations. Those have to get simplified without losing accuracy, [27]. However, recently

both Matlab and GNU-Octave provide with fast subroutines for easy/fast Erf integral function computation.

Succintly, a new method algorithm, FFM, to improve the AAA model in photondose delivery by time was proven. 3D WF imaging-processing with numerical database was shown improved for TPO improvements in radiaton oncology.

SCIENTIFIC ETHICS STANDARDS

According to European Union and International Scientific Ethics [38,43-45]. All the software/algorithms were done by Author. No artificial intelligence (AI) was used for programming or any article-part. If were so, it is declared, both in tools/systems for software anyway, and AI browsers-direct-information. In this Part I article series, the essential purposive equations/measurements applied/obtained by [35, 37, Vagena, E; Stoulos, S; Manolopoulo, M, Equation 1; Haddad, K; Anjak, O; Yousef, B, Equations 5-8] are properly recognized . When any mathematical statement, algorithm/proposition/theorem is presented, proofs and parameters/units are detailed/referred. Earlier research database, algorithms/images, are selected from prior publications in order to sharp reading with further references included. If any inconsistency is found, it is clarified in subsequent publications. Any citation such as [Casesnoves, 'year'], is intended to clarify intellectual property at current times, without intention to brag. Article is exclusively scientific, without persuasive commercial, institutional, academic influences, deliberate obfuscation, religious/religious-influences, non-scientific theories, personal opinions, political ideas, or economical-conflict links. Author has no conflict of interest.

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APPENDIX I

Enhanced Dataset and Numerical Results. Note the Matlab extracted numerical results in Figures 3,4,6.

SOFTWARE COMPUTATIONAL	
NUMERICAL DATASET	
<i>Radiation Parameter</i>	<i>Magnitude/Units</i>
<i>SSD</i>	100 cm
<i>Isocenter z</i>	$z = [5 \text{ and } 15] \text{ cm}$
<i>WF Angle and Field Size</i>	$15^\circ, 12 \times 12 \simeq 10 \times 10 \text{ cm}^2$
<i>AAA Model $I(z)$</i>	$I(z = 5, 15) \simeq [20.9505 \cdot 10^{-12}, 17.6951 \cdot 10^{-12}] \text{ Gy} \cdot \text{cm}^2$
<i>Omega Factor Angle Maxima</i>	$\varphi_1 \simeq 30^\circ \varphi_2 \simeq 30^\circ$
<i>Foil Fluence Rate</i>	$\simeq 0.6667 \frac{\text{Gy}}{\text{s}}$
<i>Experimental Foil Fluence/Gy</i>	$[4.16 \cdot 10^9, 2.82 \cdot 10^{10}]$

COMPUTATIONAL SIMULATIONS – OPTIMIZATION	
NUMERICAL RESULTS [APPROXIMATIONS]	
<i>Radiation Parameter</i>	<i>Magnitude/Units</i>
<i>SSD $[z = 5 \text{ cm}]$</i>	100 cm
<i>Maxima</i>	1.0350 cGy
<i>Minima</i>	$1.7812 \cdot 10^{-3} \text{ cGy}$
<i>Isocenter</i>	0.5263 cGy
<i>SSD $[z = 15 \text{ cm}]$</i>	100 cm
<i>Maxima</i>	0.8409 cGy
<i>Minima</i>	$1.2000 \cdot 10^{-3} \text{ cGy}$
<i>Isocenter</i>	0.3490 cGy
<i>Complementary</i>	<i>Approximations to 10^{-4} magnitude order</i>

OMEGA FACTOR $[\Omega]_F$ FUNDAMENTAL FORMULA [Casesnoves 2015 – 2016]

Definition : Omega Factor, $[\Omega]_F$, is a convolution factor set exponentially to add 3D precision to the photon – beam pathway length – magnitude throughout the radiotherapy wedge – filter beam modification device;

The AEF in 2D for the thin part of the wedge, according AAA model foundation reads,

$$f(u, z, \phi, \alpha, L) = e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{F \pm z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi)} \right) \right]} ;$$

hence, for 3D,

$[\Omega]_F$ fundamental equation added factor at exponent is,

$$[\Omega]_F = \left[1 + \frac{\tan^2 \phi_2}{1 + \tan^2 \phi_1} \right]^{\frac{1}{2}} ;$$

where,

ϕ_1 : Coronal plane angle of the photon – beam pathway ;

ϕ_2 : Sagital plane angle of the photon – beam pathway ;

Note : If ϕ_2 angle is computed, the 3D precision is reached ;

APPENDIX II

Omega Factor Review [87]. Equations and formulas development. Analytic geometry 3D images at Figure 1s 1-2 Appendix.

(1, Casesnoves Bioengineering Laboratory, 2015)

OMEGA FACTOR ANALYTIC GEOMETRY

According to Figure,

The proportional segments, (Figure), quotients,

$$\frac{Y_1}{M_1} = \frac{X_1}{M} ; \frac{Y_2}{Y_1} = \frac{X_2}{X_1} ; \frac{Y_2}{M_1} = \frac{X_2}{M} ;$$

hence,

Attenuation 3D – path exponential along wedge material,

$$[AEF]_{Exact} = e^{-\mu_w \times [X_1 + X_2]} = e^{-\mu_w \times [Y_1 + Y_2] \times \left[\frac{M}{M_1}\right]} = \dots$$

$$\dots = \left[[AEF]_{Approximated} \right]^{[\Omega]_F} ;$$

hence,

$$\text{Omega Factor } [\Omega]_F = \left[\frac{M}{M_1} \right] ;$$

Then, forgetting a practical algorithm, by setting coordinates u and v (Figure),

$$\left[\frac{M^2}{M_1^2} \right] = \frac{s^2 + u_1^2 + v_1^2}{s^2 + u_1^2} = \left[1 + \frac{v_1^2}{s^2 + u_1^2} \right] ; \text{ or,}$$

$$[\Omega]_F = \left(\left[\frac{M^2}{M_1^2} \right] \right)^{\frac{1}{2}} = \left[1 + \frac{v_1^2}{s^2 + u_1^2} \right]^{\frac{1}{2}} = \left[1 + \frac{S^2 \tan^2 \phi_2}{S^2 + S^2 \tan^2 \phi_1} \right]^{\frac{1}{2}} = \dots$$

$$\dots = \left[1 + \frac{\tan^2 \phi_2}{1 + \tan^2 \phi_1} \right]^{\frac{1}{2}} \cong (\text{series}) \cong 1 + \frac{1}{2} \times \frac{\tan^2 \phi_2}{1 + \tan^2 \phi_1} ;$$

Thus, the complete exponential factor for integrand ,

$$f(u, z, \phi_1, \phi_2, \alpha, L) = e^{-\mu_w \left[\left(L \pm \frac{c u}{F + z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi)} \right) \right] \times [\Omega]_F} ;$$

and the previous series approximation is applicable ;

OMEGA FACTOR $[\Omega]_F$ EXACT ANALYTICAL INTEGRATION [Casesnoves 2015 – 2016]

Definition : Omega Factor, $[\Omega]_F$, is a convolution factor

set exponentially to add 3D precision to

the photon – beam pathway length – magnitude

throughout the radiotherapy wedge – filter,

as beam modification device;

The AEF in 3D for the thin

part of the wedge, according AAA model foundation reads,

$$f(u, z, \phi, \alpha, L) = e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{F+z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F;$$

hence, for 2D, the AAA Dose – deposition integral was,

$$D(x, y, z) = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \Phi_U(u, v, z) \frac{C_K}{\pi \sigma_K^2} e^{-\frac{(x-u)^2 + (y-v)^2}{\sigma_K^2}} dudv;$$

thus, modified for 3D with Omega Factor,

$$D(x, y, z) = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \Phi_U(u, v, z) \frac{C_K}{\pi \sigma_K^2} e^{-\frac{(x-u)^2 + (y-v)^2}{\sigma_K^2}} \times \dots$$

$$\dots \times e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{F+z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F; dudv;$$

Separating the part of 3D wedge – path independent from integral variables, it is defined,

$$A = A([\Omega]_F) = e^{-\mu_w \left[L \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F; \text{corrected with } [\Omega]_F \text{ for 3D-path};$$

For the second part depending on variable u , [Ulmer, 1996],

it is necessary make a new quadratic change, which results,

defining $S = S([\Omega]_F)$, thus,

$$S = S([\Omega]_F) = \pm \frac{1}{2} \times \mu_w \frac{c \cdot u}{F+z} \times [\Omega]_F;$$

Hence, complete analytical dose – delivery integration,

$$D(x, y, z) = \frac{\Phi_0 I(z) A([\Omega]_F)}{4 \left(1 + \frac{z}{F} \right)^2} \sum_{K=1}^{K=3} C_K e^{[\sigma_K^2 (S([\Omega]_F))^2 - 2S([\Omega]_F)x]} \times \dots$$

$$\dots \times \left[\left(\operatorname{erf} \frac{y+b'}{\sigma_K} \right) - \left(\operatorname{erf} \frac{y-b'}{\sigma_K} \right) \right] \times \left[\left(\operatorname{erf} \frac{x+a' - \sigma_K^2 S([\Omega]_F)}{\sigma_K} \right) - \left(\operatorname{erf} \frac{x-a' - \sigma_K^2 S([\Omega]_F)}{\sigma_K} \right) \right];$$

$[\Omega]_F$ fundamental equation added factor at exponent is,

$$[\Omega]_F = \left[1 + \frac{\tan^2 \phi_2}{1 + \tan^2 \phi_1} \right]^{\frac{1}{2}};$$

where,

ϕ_1 : Coronal plane angle of the photon – beam pathway;

ϕ_2 : Sagittal plane angle of the photon – beam pathway;

Note : If ϕ_2 angle is computed, the 3D precision is reached;

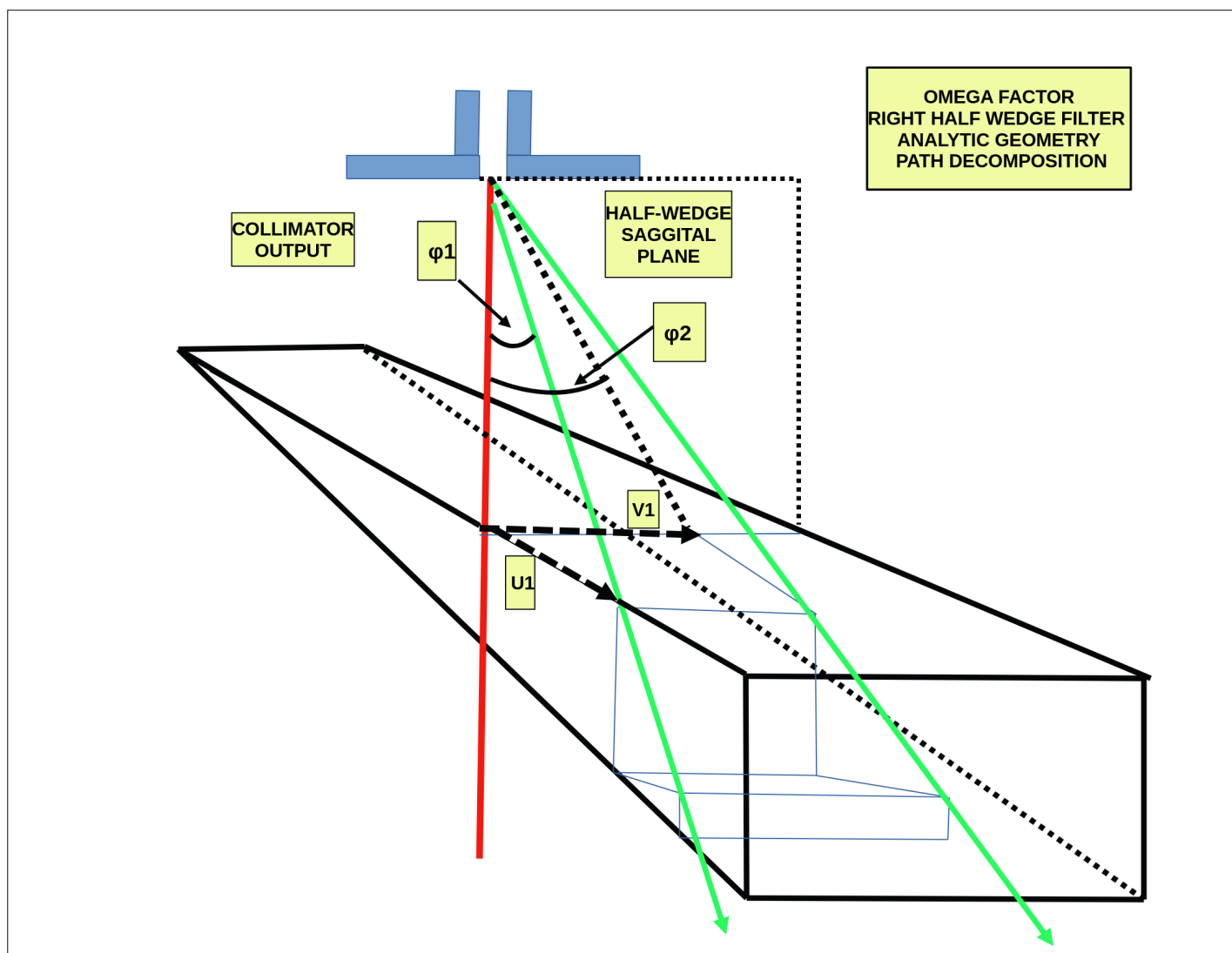


Figure 2 Appendix.- The analytic geometry sketch of the spatial-3D geometric al analysis carried out to determine Omega Factor $[\Omega]_F$ for complete/exact resolution of the integral of [30,33,34,36]. The wedge is divided into two parts. This right one has the positive coordinates for V_1 and X according to [limited 2D-AAA model, Ulmer, 1996]. It was intended a sharp simplification of the geometry in order to get a caption of the proportional segments of the pyramid corresponding to coordinates U_1 and V_1 . The WF is divided into two halves to show the coordinates center better, showing here the half part and in Figure 2 the section of right half-part to get geometrical 3D Omega Factor precision.

APPENDIX III

FFM technique mathematical development.

AAA MODEL FLUENCE FOILS METHOD (FFM)
EXPERIMENTAL – ANALYTICAL
IMPLEMENTATION METHOD [Casesnoves 2023 – 2024];
EXPERIMENTAL FOILS DATA SOURCE :
[Vagena, E; Stoulos, S; Manolopoulo, M; Haddad, K; ...
...Anjak, O; Yousef, B, 2015 – 2019];

pones aqui formula

Definition : Given experimental Fluence result,
Number of photons, N , by cm^2 ,
obtained from laboratory – simulations
statistical – experimental foil(s) absorbed dose,
such as, $\left[\frac{N}{\text{cm}^2 \times \text{Gy}} \right]$ and
irradiation time experimental
magnitudes from an statistical
sample interval the method reads,

Fluence Rate per second (Photon – Flux),

$$\Phi/s \cong [\text{Experimental fluence}/\text{Gy}] \times \dots$$

$$\dots \frac{[\text{Statistical Photondose during foil irradiation}]}{[\text{Statistical irradiation time at foil}]},$$

Therefore, Photon – Flux $\cong \Phi/s$;

For calculations, AAA $I(z)$ units
are $[\text{Gy} \times \text{cm}^2]$ as depth functions;

hence, for 2D, the AAA Dose – deposition integral was,

$$D(x, y, z)/s = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \left[\frac{\Phi_U(u, v, z)}{s} \right] \frac{C_K}{\pi \sigma_K^2} e^{\left[-\frac{(x-u)^2 + (y-v)^2}{\sigma_K^2} \right]} dudv ;$$

thus, modified for 3D with Omega Factor,

$$D(x, y, z)/s = I(z) \int_{-a'}^{a'} \int_{-b'}^{b'} \sum_{K=1}^{K=3} \left[\frac{\Phi_U(u, v, z)}{s} \right] \frac{C_K}{\pi \sigma_K^2} e^{\left[-\frac{(x-u)^2 + (y-v)^2}{\sigma_K^2} \right]} \times \dots$$

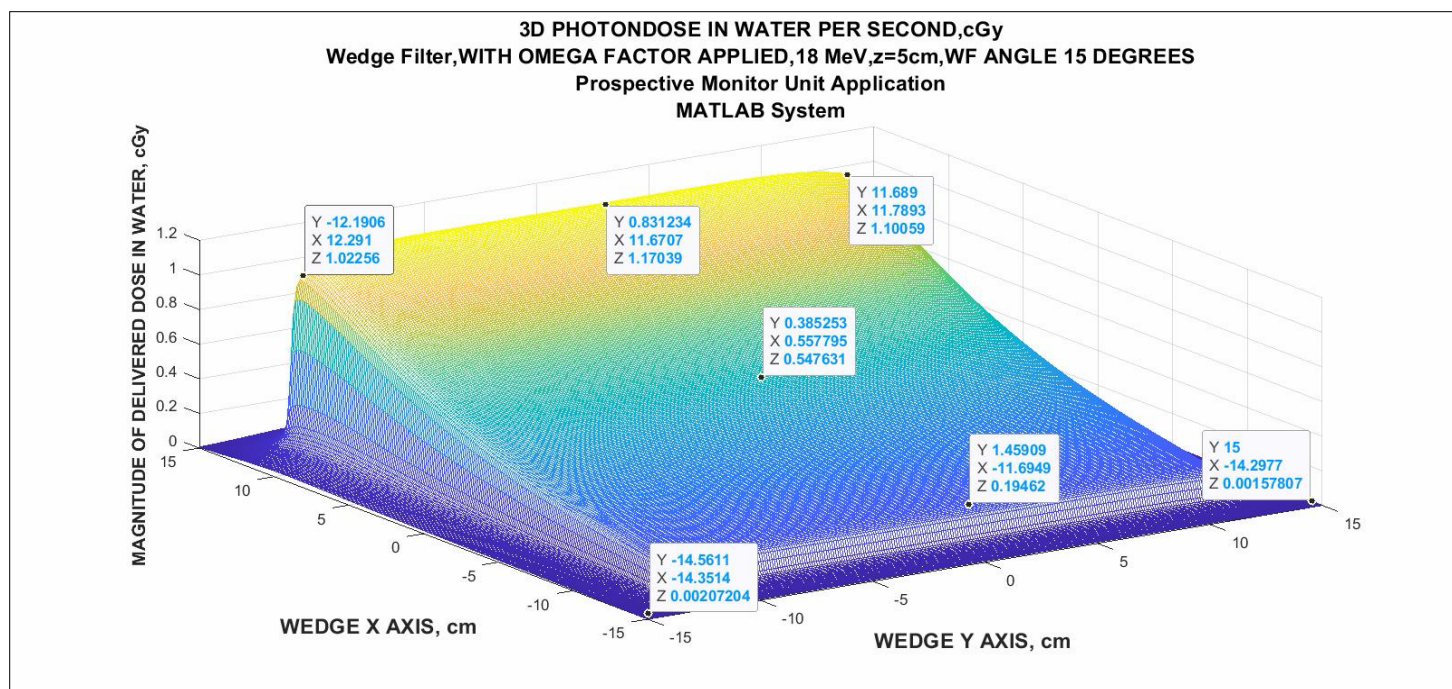
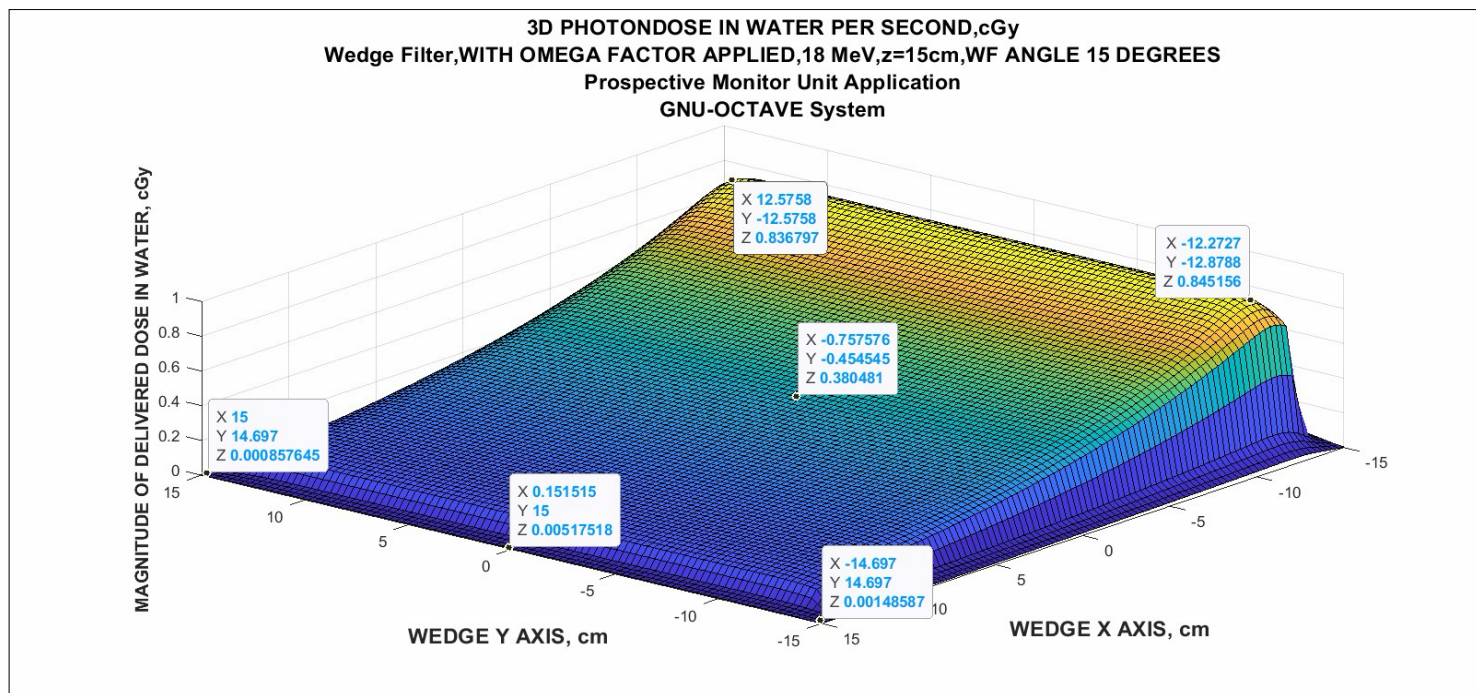
$$\dots \times e^{-\mu_w \left[\left(L \pm \frac{c \cdot u}{F + z} \right) \times \left(\frac{\sin \alpha}{\cos(\alpha - \phi_1)} \right) \right]} \times [\Omega]_F ; dudv ;$$

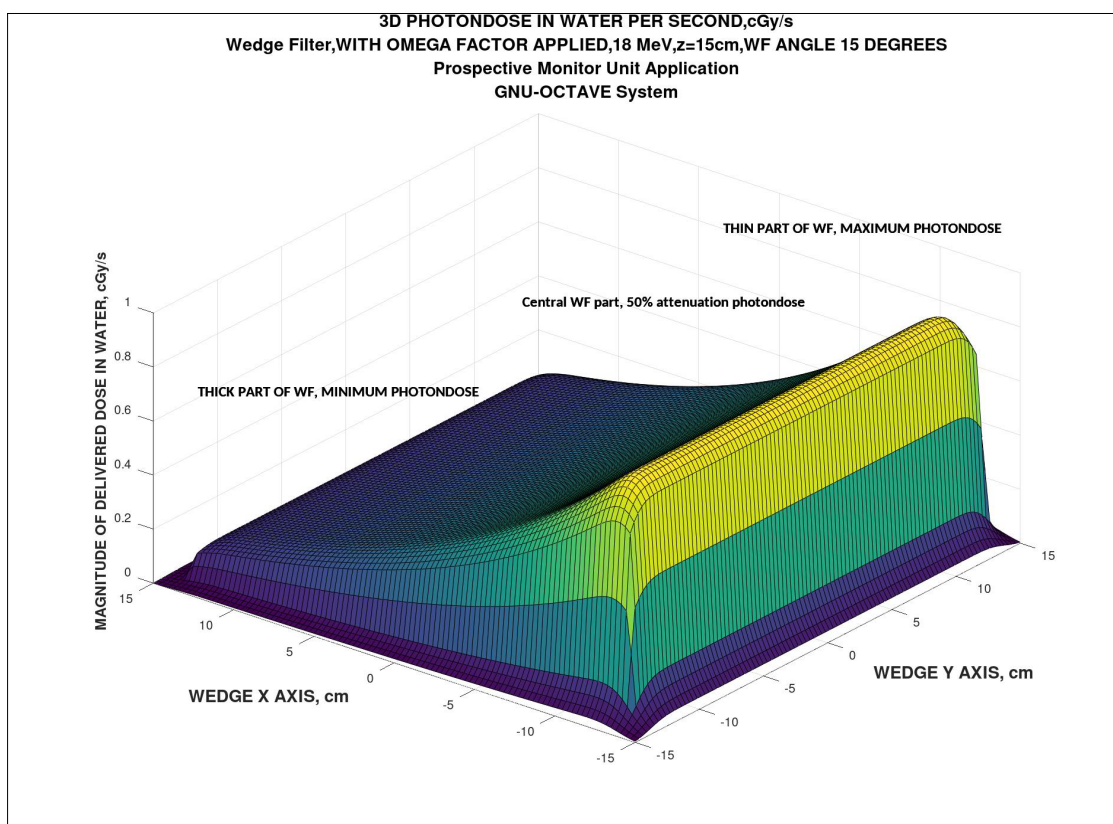
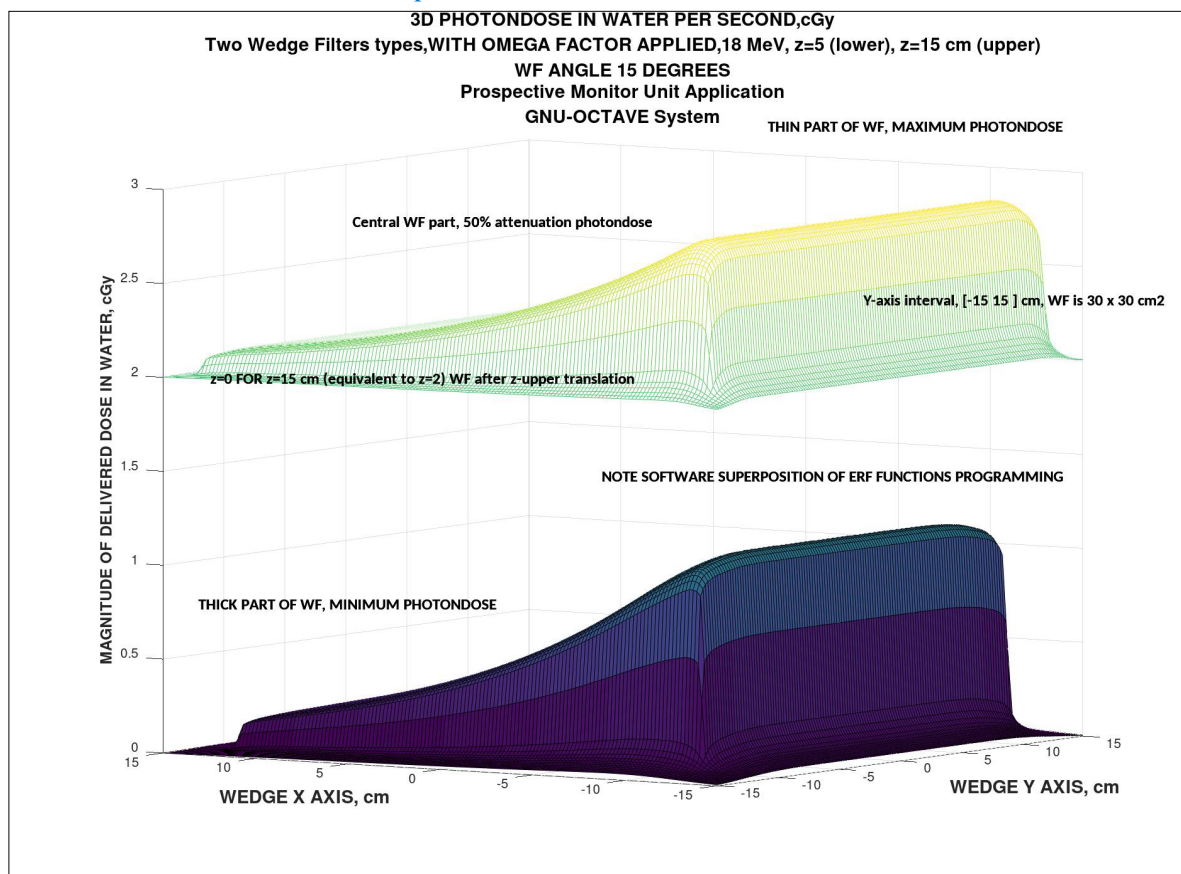
where,

$$\left[\frac{\Phi_U(u, v, z)}{s} \right] \text{ is Fluence Rate calculated by FFM;}$$

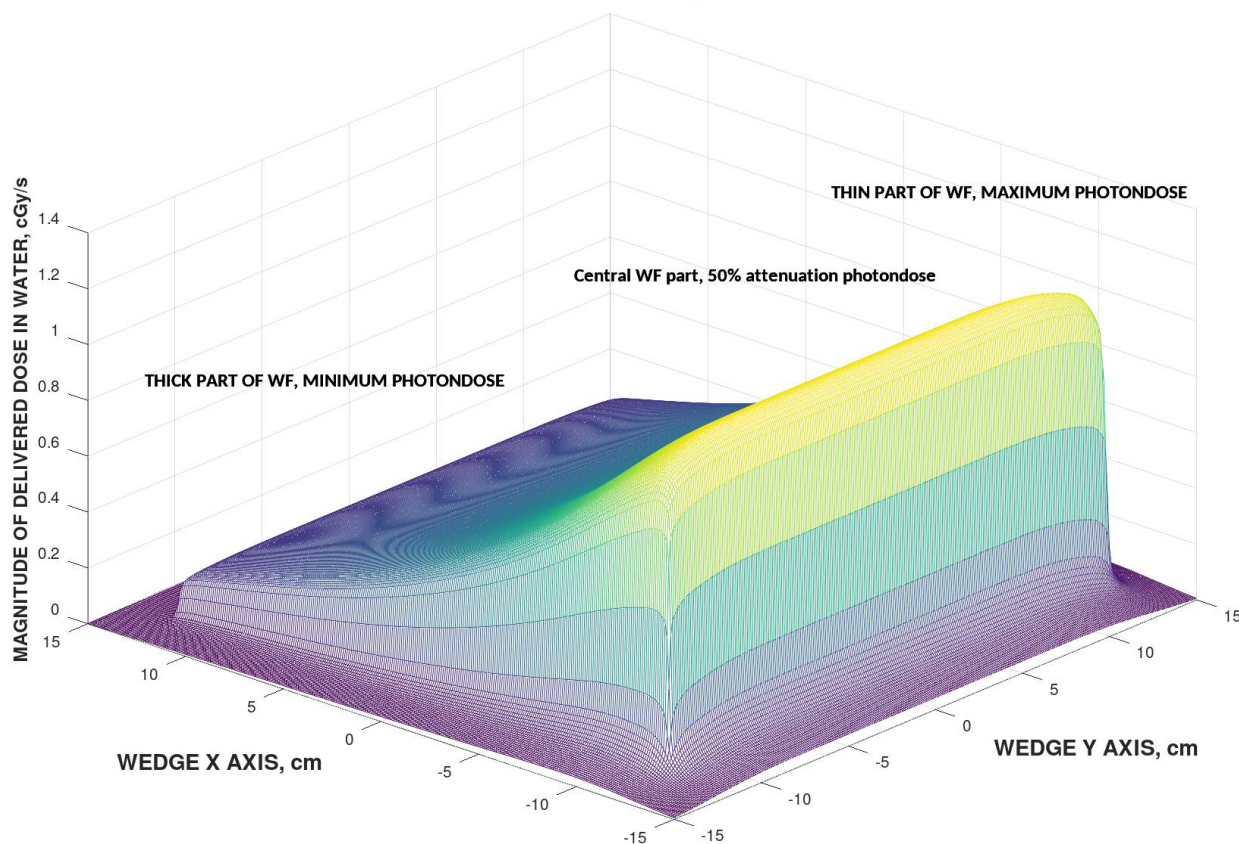
APPENDIX IV

WF Figures 1-6 enhanced and complemented.





3D PHOTONDOSE IN WATER PER SECOND,cGy/s
Wedge Filter,WITH OMEGA FACTOR APPLIED,18 MeV,z=5cm,WF ANGLE 15 DEGREES
Prospective Monitor Unit Application
GNU-OCTAVE System



3D PHOTONDOSE IN WATER PER SECOND,cGy
Wedge Filter,WITH OMEGA FACTOR APPLIED,18 MeV,z=5cm,WF ANGLE 15 DEGREES
Prospective Monitor Unit Application
MATLAB System

