International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2023	Issue 54	Volume 15	Number 1	Pages 18-25

OPTIMIZATION OF TG-43U1 DATABASE FOR HIGH DOSE RATE COBALT ^{60}Co SOURCE USED IN BRACHYTHERAPY

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Abstract- According to the AAPM and ESTRO recommendations, one of the most crucial elements in dosimetric planning to increase the success probability of clinical patient treatment is the reliable calculation of the dose rate distribution $\dot{D}(r,\theta)$ around the High Dose Rate (HDR) brachytherapy source. This study aims to use the GATE8.2/Geant4.10.5 Monte Carlo simulation code to optimize and complete the missed dosimetric parameters calculation of TG-43U1 via the SagiPlan® treatment planning system (TPS) database, and also generate a new high-resolution database dedicated to (Eckert and Ziegler BEBIG GmbH in Germany) ^{60}Co source model Co0.A86 that will be used during TPS quality assurance. In this research, the GATE8.2/Geant4.10.5 Monte Carlo simulation was run to find the 2D dose rate distribution $\dot{D}(r,\theta)$ produced by the BEBIG ^{60}Co HDR source respecting the latest AAPM TG-43U1 calculation formalism in a R=40 cm spherical water phantom. The TG-43U1 dosimetric parameters obtained from GATE8.2/Geant4.10.5 Monte Carlo simulation, mainly, the air kerma strength value per unit of activity $S_k/A = 3.041\times10^{-7}$ UBq^{-1}, the dose rate constant value $\Lambda =$ 1.090 cGy h^{-1} U^{-1}, the radial dose function $g_L(r)$, the anisotropy function $F(r,\theta)$ and the QA away-along data demonstrates good agreement with the reference values given in the most recent AAPM and ESTRO report. Conclusion: This new TG-43U1 database of the Eckert and Ziegler BEBIG Co0 A86 ^{60}Co HDR cobalt source provides an ideal solution for physicists to ensure the quality control of SagiPlan® TPS. Therefore, the assurance of high-resolution dosimetric planning of HDR brachytherapy clinical treatment, including the optimization of delivered doses to organs at risk (OAR).

Keywords: HDR Brachytherapy, ^{60}Co HDR, GATE8.2/Geant4.10.5 Monte Carlo, TG-43U1, SagiPlan® TPS.

1. INTRODUCTION

Developed by the Curie Institute, high dose rate (HDR) brachytherapy is considered as a radiotherapy modality. It is considered one of the most effective techniques to cure cancer, in particular, cervical and gynecological cancers, wherein sealed radioactive sources of high activity including ^{192}Ir and ^{60}Co, are inserted into the patient to deliver an adequate dose into the tumor within a short distance or by contact [1], [2].

Recently, the use of the ^{60}Co HDR cobalt source in brachytherapy cancer treatment is gradually increased compared to the use of ^{192}Ir iridium source, also ^{60}Co source results in a lower dose to the organs at risk (OAR) than ^{192}Ir, due to its smaller activity level (81.4 GBq) than that used by the Iridium (481 GBq) [3-5]. The success of this therapy techniques requires the validation of some dosimetric requirements referenced in both the AAPM and ESTRO recommendations. These are the dosimetric characteristics of the source used to avoid any unjustified exposure, leading to overdosing the organs at risk or underdosing the target volume [6]. Additionally, the determination of the dose rate distribution created by (Eckert and Ziegler BEBIG GmbH in Germany) ^{60}Co source model Co0.A86, mainly performed by SagiPlan® TPS based on the TG-43U1 database [7-9].

Granero, et al. [9], and Boukhari, et al. characterized the HDR BEBIG ^{60}Co cobalt source dosimetrically in a water phantom by means of Geant4 and MCNPX Monte Carlo codes, respectively [10], [11]. Guerrero, et al. performed the TG-43 calculations with the PENELOPE code and considered in their study two main different geometries of the studied source [5]. In this connection, the AAPM and ESTRO prepared a report to explain the dose calculation methodology based on Monte Carlo simulation techniques, including the TG-43U1 reference dosimetric data of ^{60}Co HDR cobalt source, model: Eckert and Ziegler BEBIG Co0 A86.

These data are mainly based on the studies carried out by Granero, et al., which described the geometry of the source studied in their research via Geant4 Monte Carlo simulation code [6], [10]. Besides, Selvam and Bhola used the EGSnrc Monte Carlo simulation code with a simplified geometry [12]. In the present work, a new GATE8.2/Geant4.10.5 Monte Carlo simulation code was used to complete some dosimetric calculations not performed before, to optimize and enrich the SagiPlan® TPS database from the new TG-43U1 calculation.

2. MATERIALS AND METHODS

2.1. Radioactive Source Geometry

The radioisotope of cobalt commercialized under E and Z BEBIG ^{60}Co model Co0.A86 and produced by Eckert and Ziegler BEBIG a high dosage rate has been utilized sealed radioactive source for therapeutic needs in high dose rate brachytherapy, with the following geometrical characteristics: this source contains of an active core in cylinder shape of 3.5 mm height and 0.5 mm diameter, as well as the core is encapsulated in a hollow cylinder with external and internal radii of 0.5 mm and 0.35 mm, respectively and by a hemispherical end of 0.5 mm radius [5, 6]. The source geometry simulated through GATE8.2/Geant4.10.5 following the HEBD working group report is shown in Figure 1.

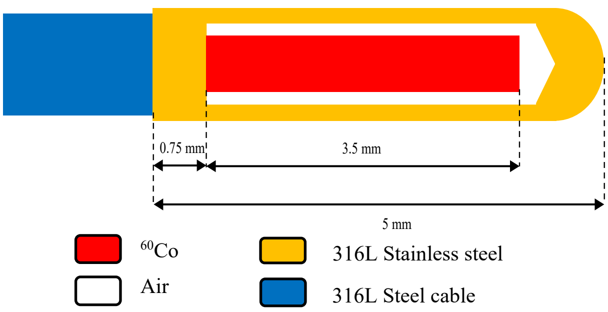

Figure 1. Geometric representation of the simulated Eckert and Ziegler BEBIG Co0 A86 ^{60}Co cobalt source via GATE8.2/Geant4.10.5 [10]

Table 1 is a list of the compositions and densities of the various materials used in this study. Besides, the energy spectrum of the photons emitted by the ^{60}Co cobalt source during this simulation is listed in Table 2, in units (keV) and in (%) for their intensities.

2.2. Monte Carlo Simulation

GATE8.2/Geant4.10.5 is an open-source Monte Carlo simulation software, based on the Geant4 C++ libraries, generated by the OpenGATE and specifically designed for the medical area, mainly in medical imaging and radiotherapy numerical simulations [16-18]. This code has good flexibility to model the geometrically complex shapes of the available radioactive sources in brachytherapy with good accuracy, also a variety of radiation-matter interaction modes including the ease of managing simulated events [16], [19].

Table 1. Proportions of chemical elements constituting the materials used [13]

Element	Material			
	Cobalt (%)	Stainless Steel (%)	Water (%)	Air (%)
^{1}H	-	-	11.1	0.0073
^{12}C	-	0.03	-	0.012
^{14}N	-	0.1	-	75.032
^{16}O	-	-	88.9	23.608
^{28}Si	-	0.75	-	-
^{31}P	-	0.0045	-	-
^{32}S	-	0.03	-	-
^{40}Ar	-	-	-	1.274
^{52}Cr	-	17.0	-	-
^{55}Mn	-	2.0	-	-
^{56}Fe	-	65.545	-	-
^{59}Ni	-	12.0	-	-
^{96}Mo	-	2.5	-	-
^{60}Co	100.0	-	-	-
Density (g/cm^3)	8.9	8.03 or 4.81	0.998	0.0012

Table 2. Energy spectrum of simulated ^{60}Co cobalt source [14], [15]

Energy (keV)	Absolute Intensity (%)
7.325	$5.6\ 10^{-9}$
7.461	$3.43\ 10^{-3}$
7.478	$6.7\ 10^{-3}$
8.265	$1.223\ 10^{-3}$
8.329	$7.4\ 10^{-7}$
8.333	$6.8\ 10^{-11}$
346.930	$7.6\ 10^{-3}$
826.060	$7.6\ 10^{-3}$
1173.237	99.9736
1332.501	99.9856
2158.570	$1.11\ 10^{-3}$
2505.000	$2.\ 10^{-6}$

2.3. TG-43U1 Formalism

In this work, we applied the TG-43U1 calculation protocol that was published in 2004 by the AAPM to calculate the dosimetric parameters affecting the calculation of the (2D) two-dimensional dose rate distribution $\dot{D}(r,\theta)$ created by the ^{60}Co HDR cobalt source at each point $P(r,\theta)$, in a homogeneous phantom via the Monte Carlo simulation code GATE8.2/ Geant4.10.5. In a polar coordinate system, its origin is equivalent to the source center and according to the TG-43U1 line-source approach, the dose rate $\dot{D}(r,\theta)$ of ^{60}Co HDR cobalt is given by the following Equation (1) [8], [9]:

$$\dot{D}(r,\theta)=S_k \wedge \frac{G_L(r,\theta)}{G_L(r_0,\theta_0)} g_L(r)F(r,\theta) \tag{1}$$

where, r_0=1 cm and θ_0=90° reference point coordinates.

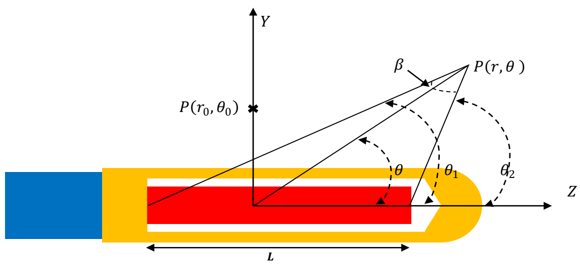

Figure 2. Representation of the polar coordinate system applied during the dose rate $\dot{D}(r,\theta)$ calculation

2.3.1. Air-Kerma Strength S_k

Air-kerma strength parameter S_k is described as the product between the air-kerma rate $\dot{K}_\delta(d,\theta_0)$ and the square distance d is expressed in U and given by the Equation (2) [8], [9]:

$$S_k = \dot{K}_\delta(d,\theta_0).d^2 \tag{2}$$

where, $1\,\text{U}=1\,\mu\text{Gy}\,\text{m}^2\,\text{h}^{-1}=1\,\text{cGy}\,\text{cm}^2\,\text{h}^{-1}$.

Therefore, the air-kerma strength per unit activity S_k/A is given by Equation (3) in $\text{Gym}^2\text{s}^{-1}\text{Bq}^{-1}$ [20]:

$$S_k/A = K_\delta(d,\theta_0)\ d^2\ N \tag{3}$$

where, A represents the source activity and N is the number of photons per decay, such as N=2 for ^{60}Co.

2.3.2. Dose Rate Constant Λ

The dose rate constant Λ is the ratio between the dose rate $\dot{D}(r_0,\theta_0)$ at the reference point $P(r_0,\theta_0)$ and the air kerma strength S_k, noted Λ and calculated from Equation (4) [8], [9]:

$$\Lambda = \frac{\dot{D}(r_0,\theta_0)}{S_K} \tag{4}$$

2.3.3. Geometry Function $G_L(r,\theta)$

Geometry function $G_L(r,\theta)$ determines how much the radionuclide physical distribution has an impact on the dose distribution and given by the following expression [8], [9]:

$$G_L(r,\theta) = \begin{cases} \dfrac{\beta}{r\,L\sin\theta} & \text{if } \theta \neq 0^\circ \\ (r^2 - L^2/4)^{-1} & \text{if } \theta = 0^\circ \end{cases} \tag{5}$$

2.3.4. Radial Dose Function $g_L(r)$

The radial dose $g_L(r)$ describes the influence of photon absorption and scattering on the dose rate distribution $\dot{D}(r,\theta)$ in the media at the source transverse axis. The $g_L(r)$ is given by Equation (6) [8], [9]:

$$g_L(r) = \frac{\dot{D}(r,\theta_0)}{\dot{D}(r_0,\theta_0)}.\frac{G_L(r_0,\theta_0)}{G_L(r,\theta_0)} \tag{6}$$

2.3.5. Anisotropy Function $F(r,\theta)$

The anisotropy function $F(r,\theta)$ describes the impacts of photon attenuation in the active source core and the encapsulation materials including the cable. The latter is defined by Equation (7) [8], [9].

$$F(r,\theta) = \frac{\dot{D}(r,\theta)}{\dot{D}(r,\theta_0)}.\frac{G_L(r,\theta_0)}{G_L(r,\theta)} \tag{7}$$

3. RESULTS AND DISCUSSION

In the present work, the results obtained of the dosimetric correction parameters for the $\dot{D}(r,\theta)$ created by the cobalt ^{60}Co HDR source were calculated in a polar coordinate system (r,θ) via GATE8.2/Geant4.10.5 Monte Carlo simulation code [9], [19].

At the beginning of this simulation, the detailed geometry of the Eckert and Ziegler BEBIG Co0 A86 ^{60}Co cobalt source was modeled according to the data referenced in the report of HEBD working group, as well as the spherical water phantom and the source having a common center. The emission energy spectrum by the studied source (Table 2) and the radiation-matter interaction processes were also simulated.

Furthermore, a very large number $N = 7.5\times10^9$ of primary particles has been generated via the HPC-MARWAN high-performance computing infrastructure endowed by GATE8.2/Geant4.10.5 Monte Carlo software, and to obtain the high resolution dose rate data the following voxel volumes were used [19], [21]: $V_1 = 0.1\times0.1\times0.1\ \text{mm}^3$ when $r \le 1\,\text{cm}$, $V_2 = 0.2\times0.2\times0.2\ \text{mm}^3$ when $1\,\text{cm} < r \le 2\ \text{cm}$, $V_3 = 0.4\times0.4\times0.4\ \text{mm}^3$ when $2\,\text{cm} < r \le 5\ \text{cm}$ and $V_4 = 1\times1\times1\ \text{mm}^3$ when $5\,\text{cm} < r \le 20\ \text{cm}$. Finally, specific programs written in C have been developed to calculate the TG-43U1 dosimetric data, especially the radial dose function $g_L(r)$ and the anisotropy function $F(r,\theta)$ [9]. These results are compared to reference data using the relative difference δ_D and ratio R_D which have defined by Equations (8) and (9), respectively [11], [13].

$$\delta_D(\%) = \frac{D_c - D_r}{D_r}\times100 \tag{8}$$

$$R_D = \frac{D_r}{D_c} \tag{9}$$

Such as D_r and D_c are the reference and calculated TG-43U1 dosimetric parameters of the Eckert and Ziegler BEBIG Co0 A86 ^{60}Co cobalt source, respectively.

3.1. Air-Kerma Strength S_k and Dose Rate Constant Λ

In this first part, the air kerma strength per unit activity S_k/A calculated inside vacuum phantom of radius $R = 120\,\text{cm}$ and 0% humidity at a distance $d = 100\,\text{cm}$ measured from the ^{60}Co HDR cobalt source center. In addition, the dose rate calculation $\dot{D}((r_0,\theta_0)$ was executed in water of specific density 0.998 g/cm^3 (Table 1) and radius $R = 40\,\text{cm}$ at the reference point, such as r_0=1 cm and $\theta_0 = \pi/2$ to obtain the dose rate constant $S_k/A = 3.041\times10^{-7}\ \text{UBq}^{-1}$. The obtained values of S_k/A and Λ are compared to reference data as shown in Table 3 [10], [12].

From the findings in Table 3, the dose rate constant Λ calculated presents a relative difference δ_Λ ranging from 0.638% at the maximum to 0.276% at the minimum compared to the literature of Granero, et al. / SagiPlan® TPS and Selvam and Bhola, respectively [7], [10], [12]. Therefore, this dosimetric parameter is acceptable in the dose rate distribution calculation according to the TG-43U1 formalism [9].

3.2. Radial Dose Function

Dataset illustrated in Table 4, represents the radial dose function $g_L(r)$ calculated from the Monte Carlo simulation code GATE8.2/Geant4.10.5 and defined by Equations (5) and (6), in a homogeneous water phantom at radial distances varying from r=0.1 cm to r=20 cm, with a constant Theta polar angle θ_0=90° during this calculation. Were also compared to the relevant literature in high dose rate brachytherapy using ^{60}Co HDR cobalt source model Eckert and Ziegler BEBIG Co0 A86 (Figure 3) [10], [12].

In general, the analysis and comparison of the results obtained from the calculated radial dose function $g_L(r)$ in this simulation (Table 4) showed a good agreement with the investigations performed by Granero, et al. / TPS SagiPlan® and Selvam and Bhola, which have chosen the detailed and simplified geometry of cobalt source respectively. Besides, a slight relative difference δ_g was obtained, with a maximum of 5.41% at r=0.25 cm and 1.68% at r=0.1 cm when comparing the results of $g_L(r)$ calculated in this research with those found by previous research of Granero, et al. / SagiPlan® TPS and Selvam and Bhola, respectively [13].

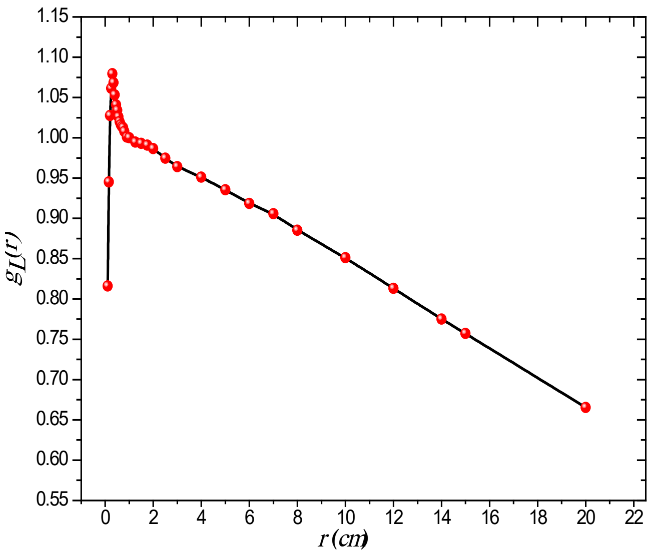

Figure 3. Curve showing the variation of calculated radial dose function $g_L(r)$ during the radial distance r (cm)

Figure 4 represents the ratio R_g, an additional method to describe the homogeneity of our calculation in comparison with other $g_L(r)$ calculations. Regarding the origin of the observed difference is mainly due to the geometric design of the simulated source, the photon spectrum simulated, the mode of physical interaction processes used, also the voxel size used in the dose calculation during this Monte Carlo simulation compared to those used by Granero et al. and Selvam and Bhola [5] [13], [20].

3.3. Anisotropy Function and QA Along-Away Data

Concerning the last part of this work, the anisotropy function $F(r,\theta)$ of the studied source is calculated from Equation (7) in terms of radial distance r(cm) and the polar angle theta θ(°) in a polar coordinate system by the 2D line-source approach, such as the dimension r varies from $r = 0.1$cm to $r = 10$cm and the polar angle theta from $\theta = 0°$ to $\theta = 180°$ (Table 5).

In addition, the results of the 2D dose rate distribution along-away per air-kerma strength (cGy h^{-1} U^{1}) is presented in Table 6 [9]. The results obtained in Table 5, Figure 5 and Table 6 about the anisotropy function $F(r,\theta)$ and the QA away-along data showed good stability among them, also an excellent similarity to data obtained by Granero, et al. / TPS SagiPlan®, with some exceptions near the source longitudinal axis (OZ), mainly due to the radiation attenuation effect by the encapsulation and the source cable on the dose rate [10].

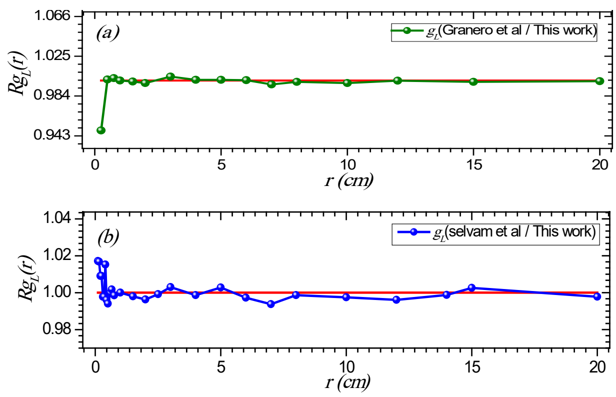

Figure 4. (a) and (b) curves representing the R_g ratio variation between the radial dose function $g_L(r)$ calculated in this study and of reference [10], [12]

4. CONCLUSIONS

The dosimetric characterization of the Eckert and Ziegler for BEBIG Co0 A86 ^{60}Co cobalt source by means of GATE8.2/Geant4.10.5 Monte Carlo techniques, respecting the recent recommendations of the AAPM and ESTRO, shows a good coherence, also a slight difference is found compared with reference data notably Grannero et al. and Selvam and Bhola using Geant4 and EGSnrc, respectively.

The good results obtained during the computation of the TG-43U1 dose rate correction by applying the 2D line–source approximation, namely the air-kerma strength per unit activity S_k/A, dose rate constant Λ, radial dose function $g_L(r)$, anisotropy function $F(r,\theta)$ and QA away-along data provides a novel database for physicists to ensure the quality control of SagiPlan® TPS, and other TPS practiced in high dose rate brachytherapy. Therefore, helps the radiotherapists to optimize dosimetric treatment planning for their patients.

ACKNOWLEDGEMENTS

Part of this work was carried out at the National Center of Scientific and Technical Research (CNRST), in particular at MARAWAN division which has equipped by the (HPC) High Performance Computing.

Table 3. Comparison of calculated & reference data of air-kerma strength per unit activity S_k/A and dose rate constant Λ for ^{60}Co HDR cobalt source [10, 12]

Monte Carlo simulation software	$S_k/A(10^{-7} \times \mathrm{UBq^{-1}})$	$\Lambda(\mathrm{cGycm^2h^{-1}})$	$\delta_\Lambda(\%)$
GATE8.2/Geant4.10.5 (this work)	3.041	1.090	-
TPS SagiPlan®/Geant4 (Granero et al. [3])	-	1.087	0.276
EGSnrc (Selvam and Bohla [4])	3.043	1.097	0.638

Table 4. Results of calculated $g_L(r)$ at varying radial distances r (cm) and reference data of cobalt source [10], [12]

r (cm)	$g_L(r)$		
	GATE8.2/Geant4.10.5 (this work)	SagiPlan® /Geant4 (Granero, et al. [3])	EGSnrc (Selvam and Bohla [4])
0.10	0.8160	-	0.830
0.15	0.9451	-	0.961
0.20	1.0277	-	1.037
0.25	1.0615	1.007	1.072
0.30	1.0794	-	1.077
0.35	1.0683	-	1.066
0.40	1.0533	-	1.050
0.45	1.0409	-	1.037
0.50	1.0342	1.036	1.028
0.55	1.0260	-	-
0.60	1.0201	-	1.019
0.65	1.0162	-	1.018
0.70	1.0138	-	-
0.75	1.0125	1.015	1.011
0.80	1.0079	-	-
0.90	1.0009	-	-
1	1.0000	1.000	1.000
1.25	0.9947	-	-
1.5	0.9930	0.992	0.991
1.75	0.9908	-	-
2	0.9866	0.984	0.983
2.5	0.9748	-	0.974
3	0.9641	0.968	0.967
4	0.9513	0.952	0.950
5	0.9354	0.936	0.938
6	0.9186	0.919	0.916
7	0.9057	0.902	0.900
8	0.8852	0.884	0.884
10	0.8512	0.849	0.849
12	0.8131	0.813	0.810
14	0.7750	-	0.774
20	0.6654	0.665	0.664

Table 5. Results of the $F(r,\theta)$ obtained in this work

$\theta(°)$	r (cm)													
	0.10	0.25	0.50	0.75	1.00	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	10.00
5	-	-	0.948	0.971	0.964	0.963	0.963	0.961	0.964	0.968	0.966	0.967	0.969	0.971
10	-	-	0.962	0.980	0.975	0.970	0.969	0.970	0.972	0.972	0.972	0.974	0.971	0.973
15	-	-	0.972	0.980	0.978	0.977	0.976	0.978	0.978	0.979	0.980	0.982	0.980	0.982
20	-	0.727	0.979	0.988	0.988	0.984	0.983	0.984	0.985	0.985	0.983	0.986	0.987	0.987
25	0.163	0.770	0.987	0.989	0.989	0.988	0.985	0.990	0.987	0.989	0.989	0.990	0.991	0.990
30	0.501	0.804	0.994	0.993	0.990	0.991	0.991	0.992	0.994	0.992	0.991	0.992	0.992	0.990
40	0.838	0.879	1.000	0.997	0.996	0.993	0.995	0.995	0.996	0.995	0.995	0.993	0.994	0.995
50	0.920	0.933	1.002	1.000	0.998	0.998	0.998	0.996	0.997	0.996	0.996	0.997	0.997	0.997
60	0.954	0.970	1.001	1.001	0.999	0.999	0.999	0.999	0.997	0.999	0.998	0.998	0.997	0.999
70	0.978	0.986	0.999	0.999	1.000	0.999	0.999	0.999	0.998	1.000	1.000	1.000	1.000	0.998
80	0.998	0.995	0.998	1.000	1.001	0.999	1.000	1.001	1.000	0.999	1.001	1.001	0.999	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	0.999	0.997	0.999	1.001	0.999	1.000	1.000	0.999	1.001	1.001	0.998	1.000	1.000	1.001
110	0.981	0.991	1.000	0.999	0.999	0.999	0.999	0.999	1.000	0.998	0.999	0.999	0.999	0.999
120	0.955	0.971	1.001	1.001	0.996	0.998	0.999	0.998	0.998	1.000	0.998	0.999	0.998	0.997
130	0.917	0.936	1.001	0.998	0.994	0.998	0.997	0.997	0.997	0.997	0.995	0.997	0.997	0.997
140	0.825	0.882	0.998	0.995	0.991	0.994	0.993	0.995	0.996	0.995	0.995	0.996	0.996	0.996
150	0.508	0.817	0.996	0.991	0.989	0.990	0.987	0.990	0.993	0.992	0.991	0.991	0.990	0.991
160	−	0.749	0.962	0.979	0.978	0.979	0.977	0.982	0.982	0.980	0.980	0.980	0.981	0.981
165	−	−	0.948	0.961	0.971	0.972	0.970	0.972	0.969	0.971	0.972	0.972	0.973	0.973
170	−	−	0.937	0.953	0.955	0.956	0.954	0.958	0.959	0.961	0.960	0.962	0.959	0.957
175	−	−	−	−	0.911	0.910	0.911	0.916	0.918	0.920	0.921	0.925	0.931	0.936
179	−	−	−	−	0.907	0.901	0.903	0.899	0.905	0.905	0.909	0.908	0.919	0.919

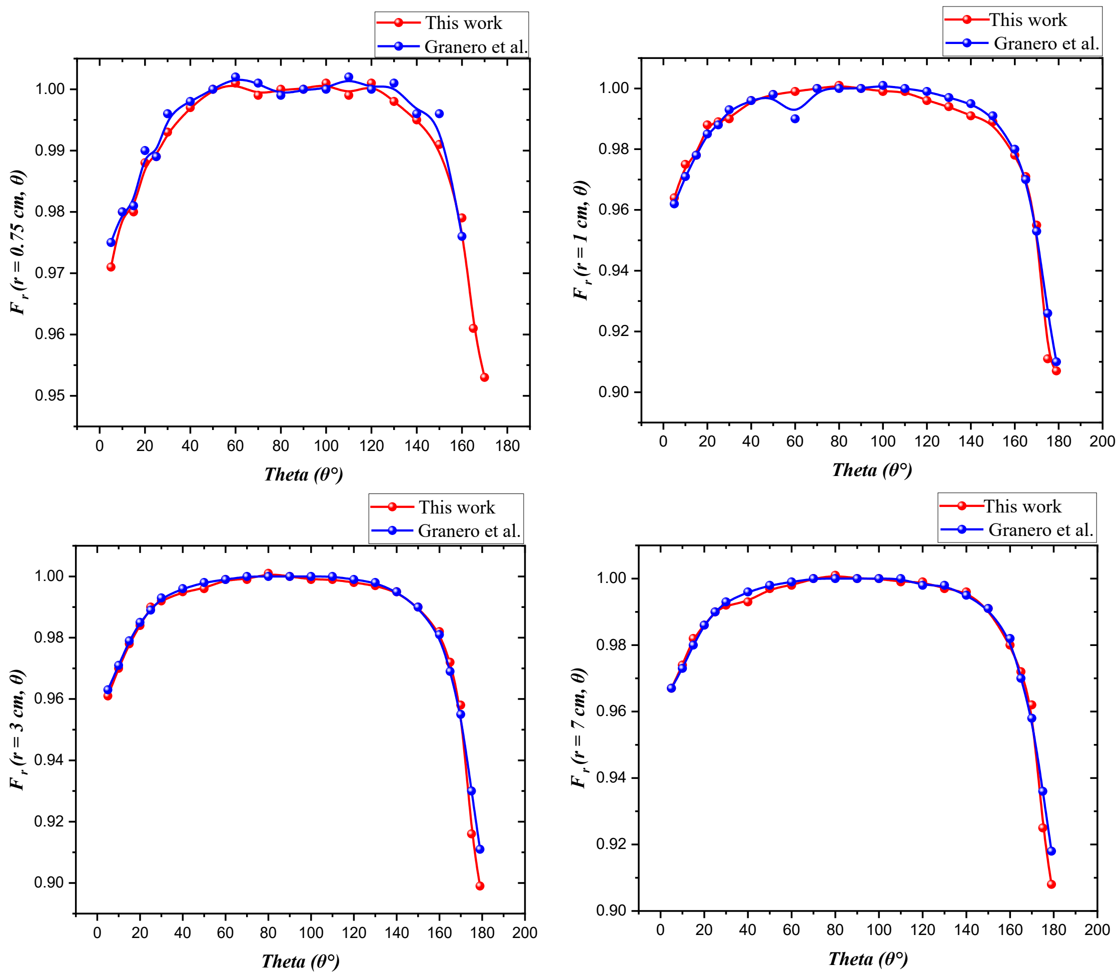

Figure 5. Graphical comparison between the anisotropy function $F(r,\theta)$ [10]

Table 6. QA along-away data of ^{60}Co HDR cobalt source

Z (cm)	*Y* (cm)													
	0.10	0.25	0.50	0.75	1.00	1.50	2.00	3.00	4.00	5.00	6.00	7.00	8.00	10.00
-7	0.0189	0.0187	0.0188	0.0187	0.0185	0.0180	0.0179	0.0161	0.0145	0.0126	0.0109	0.0095	0.0077	0.0050
-6	0.0271	0.0266	0.0250	0.0249	0.0241	0.0235	0.0230	0.0200	0.0183	0.0145	0.0121	0.0106	0.0093	0.0057
-5	0.0408	0.0392	0.0395	0.0370	0.0361	0.0358	0.0338	0.0297	0.0227	0.0199	0.0145	0.0122	0.0095	0.0064
-4	0.0631	0.0639	0.0625	0.0617	0.0592	0.0546	0.0509	0.0393	0.0310	0.0253	0.0183	0.0152	0.0114	0.0077
-3	0.1204	0.1151	0.1062	0.1036	0.1058	0.0940	0.0839	0.0611	0.0397	0.0269	0.0190	0.0159	0.0132	0.0078
-2	0.2621	0.2506	0.2277	0.2250	0.1899	0.1682	0.1047	0.0871	0.0403	0.0350	0.0236	0.0172	0.0133	0.0084
-1.5	0.4752	0.4604	0.4528	0.4483	0.3197	0.2513	0.1646	0.1105	0.0989	0.0355	0.0234	0.0179	0.0139	0.0085
-1	1.0578	1.0765	0.9350	0.6811	0.4903	0.3228	0.2064	0.1117	0.0623	0.0364	0.0248	0.0185	0.0137	0.0089
-0.5	4.9115	3.9538	2.3104	1.3647	0.9217	0.4703	0.2609	0.1091	0.0601	0.0406	0.0250	0.0189	0.0144	0.0093
0	54.0163	16.322	4.3831	1.9478	1.0904	0.4839	0.2710	0.1178	0.0654	0.0411	0.0280	0.0203	0.0152	0.0093
0.5	4.9327	3.9574	2.3186	1.3647	0.9229	0.4711	0.2605	0.1094	0.0608	0.0400	0.0257	0.0190	0.0149	0.0093
1	1.0650	1.0700	0.9259	0.6826	0.4903	0.3345	0.2131	0.1120	0.0622	0.0373	0.0251	0.0188	0.0137	0.0091
1.5	0.4742	0.4611	0.4524	0.4491	0.3204	0.2530	0.1643	0.1099	0.0989	0.0365	0.0247	0.0185	0.0136	0.0088
2	0.2624	0.2520	0.2283	0.2253	0.1910	0.1674	0.1060	0.0876	0.0412	0.0351	0.0238	0.0178	0.0135	0.0085
3	0.1213	0.1151	0.1066	0.1035	0.1058	0.0943	0.0864	0.0616	0.0407	0.0272	0.0195	0.0159	0.0132	0.0081
4	0.0640	0.0636	0.0628	0.0619	0.0593	0.0547	0.0515	0.0396	0.0314	0.0256	0.0183	0.0151	0.0115	0.0077
5	0.0412	0.0394	0.0400	0.0372	0.0360	0.0358	0.0339	0.0301	0.0224	0.0199	0.0145	0.0122	0.0095	0.0070
6	0.0276	0.0269	0.0252	0.0249	0.0241	0.0237	0.0233	0.0196	0.0182	0.0147	0.0124	0.0107	0.0091	0.0055
7	0.0195	0.0190	0.0191	0.0187	0.0183	0.0182	0.0179	0.0163	0.0146	0.0127	0.0108	0.0095	0.0077	0.0050

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