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# Evaluation of asymmetry collimator for a new generation of telecobalt machine

## Оцінювання асиметричного коліматора для нового покоління установок для лікування ізотопами кобальтових телегамматерапевтичних апаратів

***Цель работы***: Изучение распределения дозы и нормы справочной дозы симметричных и асимметричных полей.

***Материалы и методы***: Проведено исследование новой модели установки для лечения изотопами кобальта Theratron Equinox-100 (MDS Nordion, Canada),оснащенной одним клином с электроприводом (MW), а также верхней и нижней щекой. Симметричные щеки вводились в работу в системе планирования лечения Pinnacle³(Philips) 3D. Профили и доза на глубинах вдоль центральной оси (CADD) измерялись водным фантомом Wellhofer Blue для разных размеров, с использованием 0,13 см³ наперстковой ионизационной камеры (Scanditronix Wellhofer, Uppsala, Sweden). Полученные данные были введены в Pinnacle³.

***Результаты***: Эти профили и CADD симметричных щек сравнили с асимметричными щеками для разных размеров поля. Измерили также профили пучка в симметричных и асимметричных размерах поля 5×5, 10×10 и 20×20 см² на глубине 5 и 10 см с помощью 2D Array (двухмерная матрица детекторов с 729 оборудованными клапанами ионизационными камерами размером 5×5 мм²) (PTW, Германия) и сравнили с рассчитанным профилем. Однородный фантом получен в Pinnacle³. Доза в нем рассчитана на глубине 10 см для разных размеров поля симметрии и щек асимметрии, с использованием модели свертки сплющенного конуса с размером сетки 4 мм, и сравнена с измеренной дозой в водном фантоме на глубине 10 см и 0,6 см³ наперстковой ионизационной камерой FC-65-G и электрометром DOSE 1 для размеров поля 5 × 5, 10 × 10 и 20 × 20 см². Вариации измеренных и рассчитанных доз на глубине 10 см находились в пределах 1 %.

Асимметричные щеки были успешно введены в работу в Pinnacle³.

***Выводы***: В распределении дозы относительно полей маленького размера отмечены различия для симметричного и асимметричного поля. Для больших полей отклонения между симметрией и значениями лучей асимметрии составляют более чем 1 %.

Характеристики дозы для асимметричных полей подобны таким же для симметричных полей для различных степеней открытия коллиматора.

Абсолютные измерения дозы в водном фантоме для случая симметрии и лучей асимметрии показали отсутствие всяких различий. Для всех используемых размеров поля процентное отклонение не превышало 1 %.

Pinnacle³, TPS может использовать одни и те же данные о пучках для настроек симметричного коллиматора и моделирует распределение дозы для поля любого размера, с симметричными и асимметричными настройками коллиматора, без специальных поправочных коэффициентов, и не требует дополнительных измерений для внеосевых полей.

***Ключевые слова***: изотопный кобальт, луч симметрии, луч асимметрии, планирование лечения.

***Objective***: Evaluation of the dose distribution and of the reference dose rate of the symmetry and asymmetric fields.

***Material and Methods***: A new model of the telecobalt unit, Theratron Equinox-100, (MDS Nordion, Canada) equipped with a single 60 degree motorized wedge and upper (X) and lower (Y) asymmetric jaws have been evaluated. Symmetrical jaws were commissioned in Pinnacle³ (Philips), the 3D treatment planning system (TPS). The profiles and central axis depth dose (CADD) were measured with Wellhofer Blue Water Phantom for various field sizes using 0.13 cc thimble ionization chamber (Scanditronix Wellhofer, Uppsala, Sweden) and the data were commissioned in Pinnacle³.

***Results***: The profiles and CADD for symmetry jaws were compared with asymmetry jaws for various field sizes. Also beam profiles for 5×5, 10×10 and 20×20 cm² for symmetry and asymmetry field sizes at 5 and 10 cm depths measured with 2D-Array (two dimensional detector array with 729 vented ionization chambers with a size of 5×5 mm², PTW, Germany), are compared. A homogeneous phantom generated in Pinnacle³ .The dose calculated in this phantom at 10 cm depth for various field sizes of symmetry and asymmetry jaws using collapse cone convolution (cc convolution) model with a grid size of 4 mm , and compared with measured dose in a water phantom at 10 cm depth with a 0.6 cc thimble ion chamber FC-65-G and DOSE1 electrometer for field sizes of 5×5, 10×10 and 20×20 cm² using IAEA dosimetry protocol TRS-398.The variation of measured and calculated doses at 10 cm depth were within 1%.

The asymmetry jaws were successfully commissioned in Pinnacle³.

***Conclusion***: A dose distribution for small field sizes is a same for a symmetry and asymmetry field sizes. For large fields deviations between symmetry and asymmetry beams values were found to be more than 1%.

Depth-dose characteristics for asymmetric fields are similar to those of symmetric fields for the different collimator openings.

Absolute dose measurements in the water phantom for the symmetry and asymmetry beams show that there is no significant difference for all the field sizes used, the percentage deviation was never larger than 1%.

The Pinnacle³ TPS uses the same beam data for symmetric collimator setting and models the dose distribution for any shaped field, with symmetric or asymmetric collimator setting, without special correction factors and does not require additional measurements for off-axis fields.

***Key words***: telecobalt, symmetry beam, asymmetry beam, treatment planning and commissioning.

***Мета роботи***: Вивчення розподілу дози й норми довідкової дози симетричних і асиметричних полів.

***Матеріали і методи***: Досліджено нову модель установки для лікування ізотопами кобальту Theratron Equinox-100 (MDS Nordion, Canada), оснащеної одним клином з електроприводом (MW), а також верхньою і нижньою щокою. Симетричні щоки вводили в роботу в системі планування лікування Pinnacle³ (Philips) 3D. Профілі й дози на глибинах вздовж центральної осі (CADD) вимірювали водним фантомом Wellhofer Blue для різних розмірів, з використанням 0,13 см³ наперсткової іонізаційної камери (Scanditronix Wellhofer, Uppsala, Sweden). Отримані дані було введено до Pinnacle³.

***Результати***: Ці профілі і CADD симетричних щік порівнювали з асиметричними щоками для різних розмірів поля. Також вимірювали профілі пучка в симетричних і асиметричних розмірах поля 5 × 5, 10 × 10, 20 × 20 см² на глибині 5 і 10 см за допомогою 2D-Array (двовимірна матриця детекторів з 729 обладнаними клапанами іонізаційними камерами розміром 5 × 5 мм²) (PTW, Німеччина) та порівнювали з розрахованим профілем. Однорідний фантом отримано в Pinnacle³. Доза в ньому розрахована на глибині 10 см для різних розмірів поля симетрії та щік асиметрії, з використанням моделі згортки сплющеного конусу з розміром сітки 4 мм, і порівняна з виміряною дозою у водному фантомі на глибині 10 см з 0,6 см³ наперстковою іонізаційною камерою FC-65-G і електрометром DOSE 1 для розмірів поля 5 × 5, 10 × 10, 20 × 20 см². Варіації виміряних і розрахованих доз на глибині 10 см перебували в межах 1 %.

Асиметричні щоки було успішно введено в роботу в Pinnacle³.

***Висновки***: У розподілі дози відносно полів маленького розміру існують відмінності для симетричного і асиметричного полів. Для великих полів відхилення між симетрією і значеннями променів асиметрії перевищують 1 %.
Характеристики дози для асиметричних полів подібні до таких для симетричних полів при різних ступенях відкриття коліматора.
Абсолютні вимірювання дози у водному фантомі для випадків симетрії і променів асиметрії показали відсутність будь-яких відмінностей. Для всіх використовуваних розмірів поля відхилення не перевищувало 1 %.
Pinnacle[3], TPS може використовувати одні і ті самі дані про пучки для настроювань симетричного коліматора, і моделює розподіл дози для поля будь-якого розміру з симетричними і асиметричними настроюваннями коліматора, без спеціальних поправкових коефіцієнтів, і не потребує додаткових вимірювань позаосьових полів.
***Ключові слова***: ізотопний кобальт, промінь симетрії, промінь асиметрії, планування лікування.

Knowledge of the dose distribution and of the reference dose rate of the asymmetric fields is necessary for their use in clinical practice [6]. The objective of this study is to evaluate the difference between symmetry and asymmetry beam collimation settings and to determine the accuracy to which the Treatment Planning System (TPS) calculates the absorbed dose for open asymmetric photon beams using the same beam data and the same approach for dose calculation for symmetric collimator setting.

The special objectives of the study were: to perform relative dose measure ments in water phantom and 2D-ARRAY for different symmetric and asymmetric field sizes over ranges of depths; to perform absolute dose measure ments in a water phantom following IAEA TRS-398 protocol for both, symmetric and asymmetric fields; to predict the difference between the symmetric and asymmetric fields values; to compare dose calculation for symmetry and asymmetry beams by the Treatment Planning Syste m (TPS).

## Material and Methods

### 1. Water phantom measurements:

The Blue Water Phantom [11] was placed on the electrical lift table. The lift table was moved to position the phantom to the desired location below the treatment head and to adjust the lines marked on the bottom of the phantom roughly to the cross lines of the light field and the vertical indicators on the phantom was aligned with the positioning lasers.

The empty phantom was roughly leveled with a spirit level, using the leveling handles on the lift table and then it was filled with water to its top edge.

The field detector (CC13 chamber) [12] was mounted in the phantom using the specified holder and then it was connected to CU500E control unit with the chamber connection cable.

Fine leveling of the water phantom was made using a CC13 chamber and the alignment cap shown in Fig. 1.

The lifting table was moved up and down as required to position the water surface to the desired SSD of 90 cm using a piece of paper on the water surface and switching on the treatment machine's light distance indicator.

In order to send the phantom's external limits to the CU500E control Unit, the 'Blue Phantom' as the active measuring device was selected in the OmniPro-Accept software [15] for analysis and handling of the dose distribution measurements.

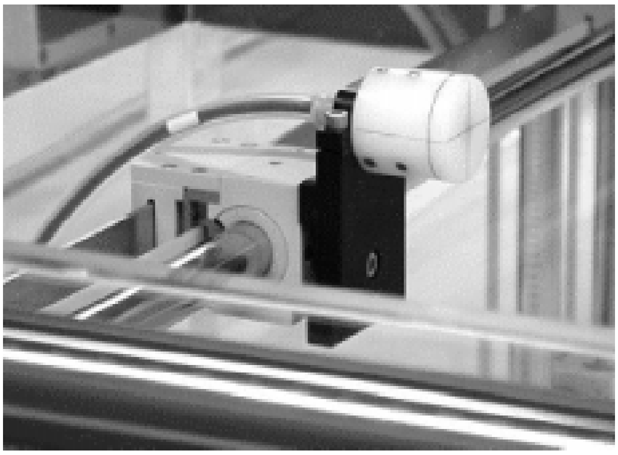


Fig. 1. Alignment cap mounted on the CC13 ion chamber used to fine leveling of the Blue Water Phantom

Co-ordinate system used in OmniPro-Accept was: in-plane, cross-plane, diagonal and depth. The in-plane axis is defined as parallel to the gantry arm, directed towards the gantry; the cross-plane axis goes from left to right when facing the gantry in an upright position and the depth axis goes from the collimator head and outwards.

In OmniPro-Accept software, all the scan groups (profiles and depth dose measurements) were defined and continuous mode was selected to perform measurements while moving the detector. The CC13 ion chamber was used for the scanning and the measured data were stored in files. These measured data were copied and converted to Excel spreadsheets for analysis and comparisons.

For symmetric collimator opening [16], where the beam axis is identical to collimator axis and $X_1 = X_2 = Y_1 = Y_2$, as shown in Fig. 2, central axis depth doses (CADD) were measured for depths down to 25 cm for square field sizes of $5 \times 5$, $10 \times 10$ and $20 \times 20$ cm$^2$ at SSD of 90 cm. Off-axis beam profiles in the in-plane, cross-plane and diagonal direction were also measured for the same squared fields at 0.75, 5, 10 and 20 cm depths.

Asymmetric fields [16] were obtained by shifting one or two of the collimator jaws across the collimator axis. Two geometries of asymmetric fields [8] were obtained as shown in Fig. 3 (a) and (b), one by moving $X_1$ and $Y_1$ jaws to the collimator axis to obtain quadratic asymmetric field and other geometry by moving $Y_1$ and $Y_2$ jaws to the collimator axis to obtain half asymmetric fields.

Central axes depth dose (CADD) were measured for these asymmetric fields after positioning the ion chamber at the beam axis at off-axis distance corresponding to each field as shown in Table 1 for field sizes of $5 \times 5$, $10 \times 10$ and $20 \times 20$ cm$^2$. Ion chamber movement to the beam axis was controlled by the CU500E control unit and OmniPro-Accept software.

Off-axis beam profiles in the in-plane, cross-plane and diagonal direction were also measured for the same asymmetric field at 0.75, 5, 10 and 20 cm depths.

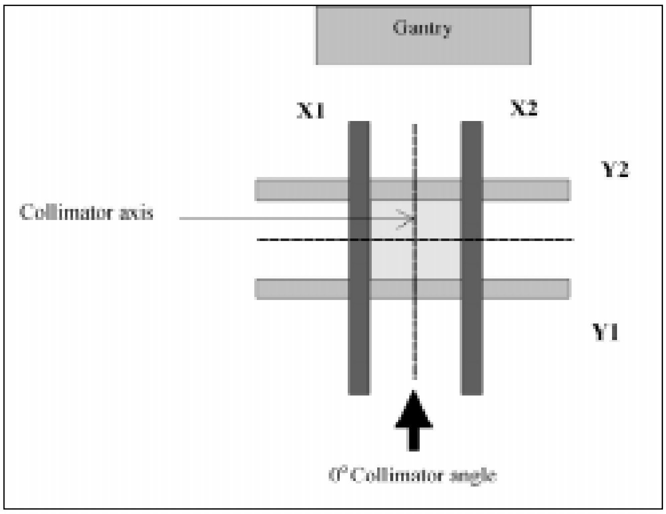



Fig. 2. Collimator jaws setting for symmetric fields where beam axis is identical to collimator axis ($X_1 = X_2$ and $Y_1 = Y_2$)

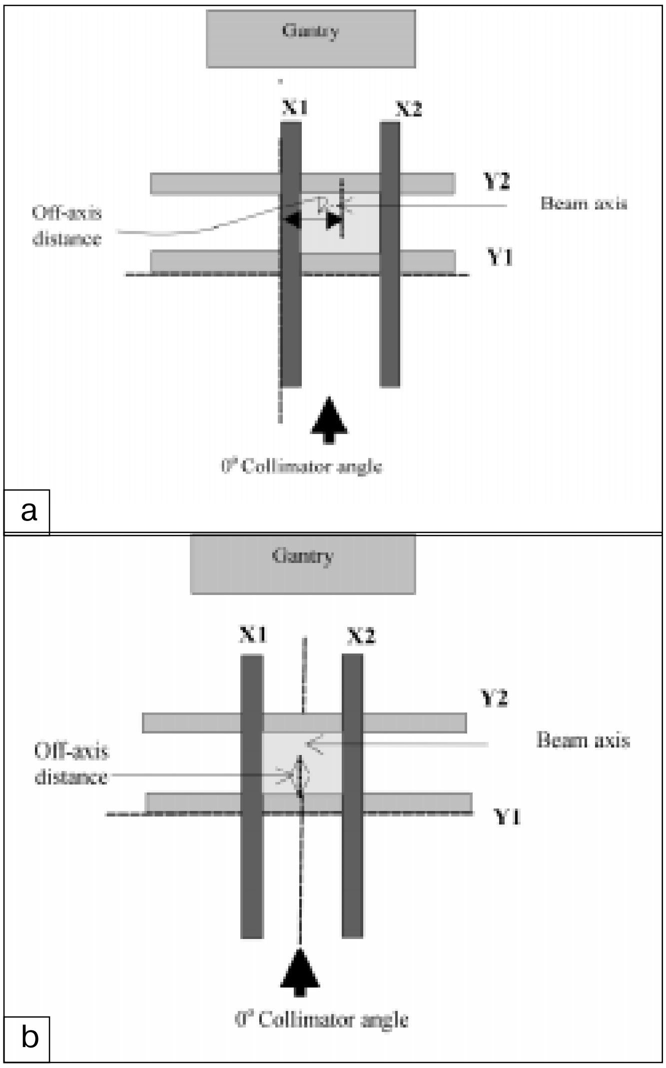



Fig. 3. Collimator jaws setting for asymmetry fields:
(a) At off-axis distance in the cross-plane direction. $X_1$ and $Y_1$ were moved to the collimator axis to obtain quadratic asymmetric field ($X_1 = Y_1 = 0$ and $X_2 = Y_2$);
(b) At off-axis distance in the in-plane direction where $Y_1$ moved to the collimator axis to obtain half asymmetric beam ($Y_1 = 0$ and $X_1 = X_2$)

Measured CADD and beam profiles for symmetric fields were then compared to the corresponding asymmetric fields with the same collimator opening.

Beam profile measurements for different beam collimation settings (symmetric and asymmetric field geometry) are presented in Fig. 4

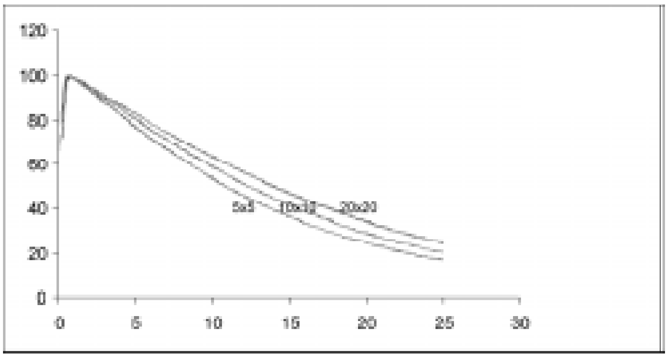



Fig. 4. Central axis depth dose curves for field sizes 5 × 5, 10 × 10 and 20 × 20 cm$^2$ with symmetric fields and asymmetric fields measured in the Blue Water Phantom

*Table 1*

*Collimator jaws setting to obtain two geometries of asymmetric fields. For measurements, ion chamber was positioned at off-axis distance in the in-plane (parallel to the gantry arm, directed towards the gantry) or cross-plane (from left to right)*

| (cm × cm) | Jaws setting | | | | Off-axis (cm) |
|---|---|---|---|---|---|
| | $X_1$ | $X_2$ | $Y_1$ | $Y_2$ | |
| 5 × 5 | 0 | +5 | 0 | +5 | 2.5 in the in-plane |
| 5 × 5 | -2.5 | +2.5 | 0 | +5 | 2.5 in the cross-plane |
| 10 × 10 | 0 | +10 | 0 | +10 | 5.0in the in-plane |
| 10 × 10 | -5 | +5 | 0 | +10 | 5.0in the cross-plane |
| 20 × 20 | 0 | +20 | 0 | +20 | 10in the in-plane |
| 20 × 20 | -10 | +10 | 0 | +20 | 10in the cross-plane |

**2. 2D-ARRAY measurements**

2D-ARRAY [10] was placed in the treatment table over a buildup material to account for the scatter photons. Laser and light beams were used to correct position of the 2D-ARRAY under the gantry head. Source to surface distance (SSD) of 90 cm was set at the 2D-ARRAY surface.

To measure dose profiles at 5 and 10 cm depths, build up materials of the desired thickness were used and placed over the 2D-ARRAY.

Measurements were collected under the "spotshoot" mode in the Matrixscan software. All the measured data were saved in the computer as a text format for further transfer to Excel spreadsheets for analysis.

Data were collected for symmetric and asymmetric beam collimation with field sizes of 5 × 5, 10 × 10 and 20 × 20 cm$^2$ at 5 and 10 cm depths.

From these data, beam profiles for symmetric beams in the in-plane, cross-plane and diagonal direction were obtained and compared with that for the corresponding asymmetric beams.

**3. Absolute dose measurement**

For open symmetric and asymmetric fields [4], absorbed dose to water was measured in the Blue Water Phantom using FC-65-G ion chamber [14] and DOSE1 electrometer [13] for field sizes of 5 × 5, 10 × 10 and 20 × 20 cm$^2$ at 10 cm depth. For dosimetry, TRS-398 protocol from IAEA was used [5].

For asymmetry field measurements, FC-65-G ion chamber movement to the beam axis (at off-axis distance) was controlled by the CU500E control unit and OmniPro-Accept software.

Absorbed dose to water for symmetric beams were compared to that for asymmetric beams and the percentage deviation was obtained.

**4. Treatment time calculation**

In the Pinnacle[3] treatment planning system [9], radiation beam was placed at SSD of 90 cm in the homogeneous water phantom. A dose of 2 Gy was prescribed at 10 cm depth. Dose calculation was carried out using collapsed cone convolution (cc convolution) with grid size of $4 \times 4$ mm [1-3].

The treatment time calculated by the model was predicted for open symmetric and asymmetric beams with different field sizes of $5\times 5$, $10 \times 10$ and $20 \times 20$ cm$^2$.

Treatment time for symmetric and asymmetric beams was then compared for all field sizes to find the percentage deviation.

## Results

### 1. Water phantom measurements

Measured CADD for symmetric and asymmetric beam collimation are shown in Fig. 4 for the different field sizes.

Measurements showed that the depthdose curves for symmetry and asymmetry beams of equivalent field sizes were identical and there is no difference in depth dose measured in the central beam axis for symmetry field or that measured at off-axis distance in beam axis of asymmetry field of the equivalent field sizes at depths ranging from 0 up to 25 cm.

Measured beam profiles for symmetric and asymmetric fields are compared and shown in Fig. 5 for in-plane profiles, Fig. 6 for cross-plane profiles and Fig. 7 for diagonal profiles for field sizes (a) $5\times5$ cm$^2$, (b) $10\times10$ cm$^2$ and (c) $20\times20$ cm$^2$.

Measurements showed that the shape of the symmetry beam profiles is in all cases almost identical to the corresponding asymmetry beam profiles as can be seen in the figures mentioned above.

Beam profiles in the in-plane, cross-plane and diagonal direction for asymmetry beams with field sizes $5\times5$ and $10\times10$ cm$^2$ show good agreement with symmetry beam profiles with the equivalent field sizes for all depths.

The difference between symmetry and asymmetry beams was only predicted for the largest field used here ($20\times20$ cm$^2$). This difference in the dose distribution for asymmetric fields, compared to the dose distribution for symmetric fields, is the "tilt" of the dose profiles towards the beam axis as shown in Fig. 5 (c), 6 (c) and 7 (c).

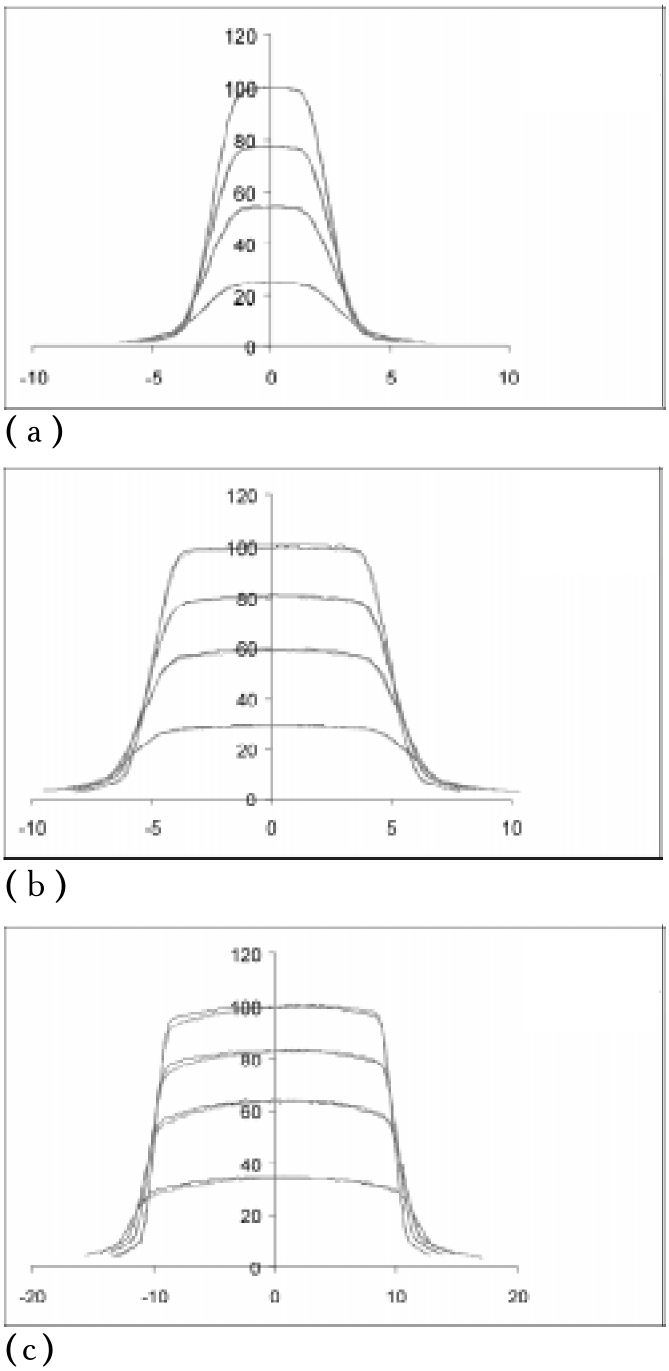
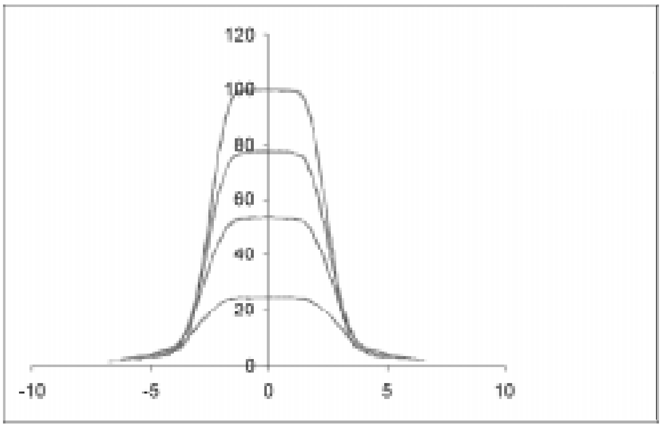


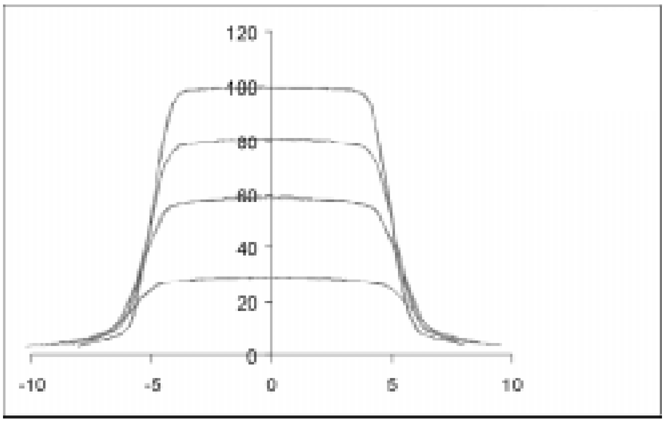

Fig. 5. In-plane beam profiles at 0.75, 5, 10 and 20 cm depths for symmetric and asymmetric fields for (a) $5\times5$, (b) $10\times10$ and (c) $20\times20$ cm$^2$ field size measured in the Blue Water Phantom

In this large field size, across the center of the field, there is no difference in the profile values. At the field edge, the difference is more than 1 % due to off-axis softening. This is caused by the oblique incidence of the asymmetric beam at off-axis locations, causing less beam hardening compared to that along the central axis.

Compares between beam specifications for symmetry and asymmetry fields and the percentage




( a )

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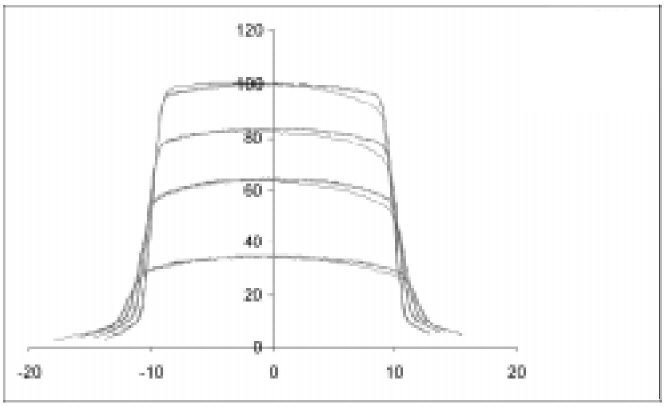
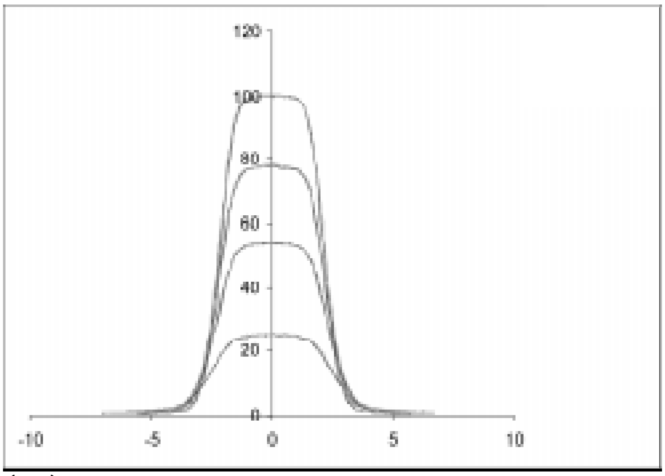
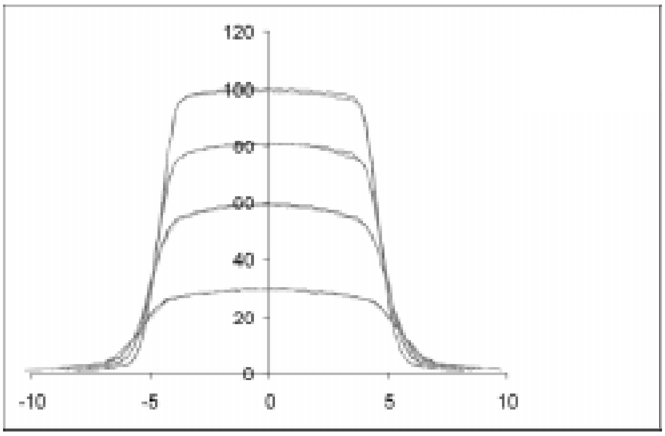



( c )

Fig. 6. Cross-plane beam profiles at 0.75, 5, 10 and 20 cm depths for symmetric and asymmetric fields for (a) 5 × 5, (b) 10 × 10 and (c) 20 × 20 cm² field size measured in the Blue Water Phantom




( a )

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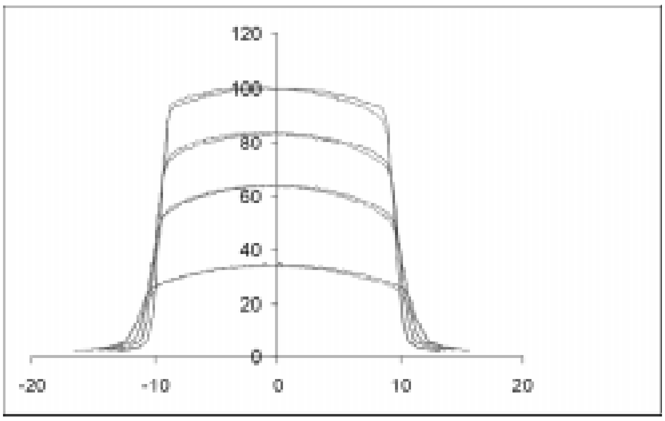



( c )

Fig. 7. Diagonal beam profiles at 0.75, 5, 10 and 20 cm depths for symmetric and asymmetric fields for (a) 5 × 5 ,(b) 10 × 10 and (c) 20 × 20 cm² field size measured in the Blue Water Phantom

differences between these values are shown in Table 2 for the different field sizes.

Symmetry ratios obtained for symmetry and asymmetry fields in in-plane, cross-plane and diagonal direction for field sizes 5 × 5 and 10 × 10 cm² fall within the tolerance level (less than 103 %) as indicated in the AAPM quality control report [7]. However, for the large asymmetry field 20 × 20 cm² this level was exceeded due to the tilt of the beam profile mentioned above.

Dose variations across the beam for symmetry fields were found to be within the tolerance level (less than 106 %) and this is not the case for asymmetry beams as shown in Table 2 (b) where the flatness values ranged from 107.8 to 108.9 %.

*Table 2*

*Beam specifications (a) Symmetry %, (b) Flatness % and (c) Penumbra (cm) values in all directions: comparison between symmetry and asymmetry fields*

| | 5 × 5 cm² | | 10 × 10cm² | | 20 × 20cm² | |
|---|---|---|---|---|---|---|
| | Symmetry | Asymmetry | Symmetry | Asymmetry | Symmetry | Asymmetry |
| In-plane | 102.4 | 100.5 | 100.7 | 101.0 | 100.8 | 105.5 |
| Cross-plane | 101.3 | 100.5 | 100.7 | 100.8 | 100.4 | 106.9 |
| Diagonal | 101.3 | 100.3 | 100.6 | 101.7 | 100.6 | 107.0 |

(a)

| | 5 × 5 cm² | | 10 × 10cm² | | 20 × 20cm² | |
|---|---|---|---|---|---|---|
| | Symmetry | Asymmetry | Symmetry | Asymmetry | Symmetry | Asymmetry |
| In-plane | 103.3 | 107.5 | 108.7 | 108.8 | 104.0 | 107.8 |
| Cross-plane | 101.7 | 104.5 | 105.5 | 105.6 | 103.4 | 108.8 |
| Diagonal | 101.7 | 100.7 | 102.0 | 103.1 | 104.9 | 108.9 |

(b)

| | 5 × 5 cm² | | 10 × 10cm² | | 20 × 20cm² | |
|---|---|---|---|---|---|---|
| | Symmetry | Asymmetry | Symmetry | Asymmetry | Symmetry | Asymmetry |
| In-plane | 1.05, 1.02 | 1.27, 1.23 | 1.32, 1.30 | 1.31, 1.30 | 1.39, 1.38 | 1.45, 1.37 |
| Cross-plane | 0.91, 0.91 | 1.10, 1.12 | 1.14, 1.15 | 1.15, 1.17 | 1.22, 1.25 | 1.17, 1.31 |
| Diagonal | 0.91, 0.91 | 1.29, 1.29 | 1.32, 1.34 | 1.35, 1.36 | 1.44, 1.46 | 1.34, 2.17 |

(c)

*Table 3*

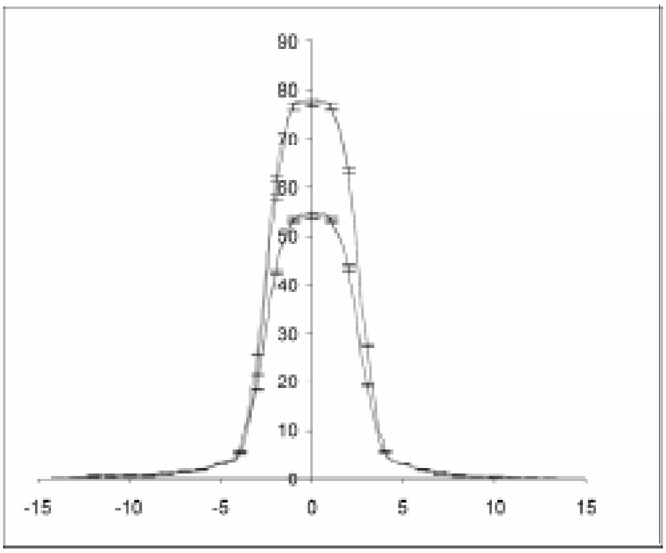
*Percentage difference in (a) Symmetry % and (b) Flatness % values between symmetry and asymmetry fields*

| | 5 × 5 cm² | 10 × 10cm² | 20 × 20cm² |
|---|---|---|---|
| In-plane | 1.86 | 0.30 | 4.66 |
| Cross-plane | 0.79 | 0.10 | 6.47 |
| Diagonal | 0.99 | 1.09 | 6.36 |

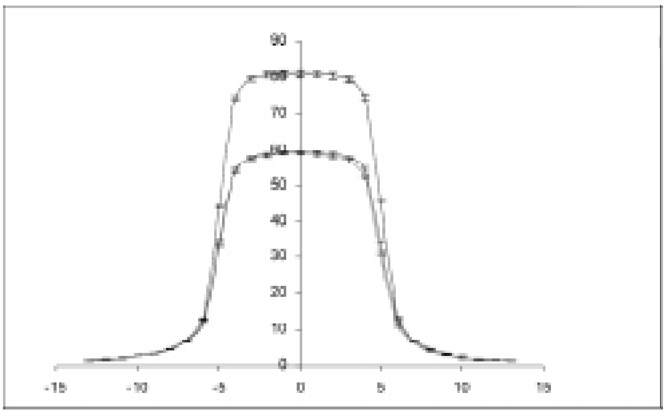
(a)

| | 5 × 5 cm² | 10 × 10cm² | 20 × 20cm² |
|---|---|---|---|
| In-plane | 4.07 | 0.09 | 3.65 |
| Cross-plane | 2.75 | 0.09 | 5.22 |
| Diagonal | 0.98 | 1.08 | 3.81 |

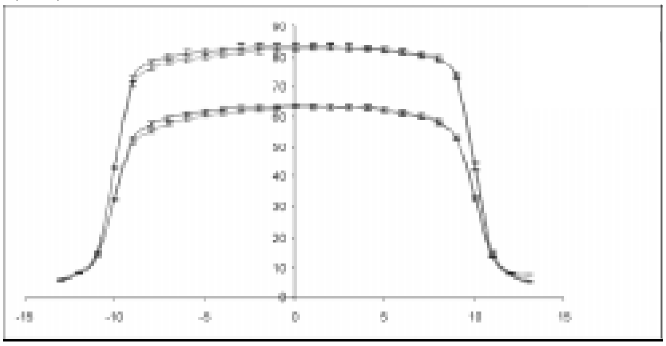
(b)




(a)



(b)



(c)

Fig. 8. In-plane beam profiles at 5 and 10 cm depths for symmetric and asymmetric fields for (a) 5x5, (b) 10x10 and (c) 20x20 cm² field size measured with 2D-ARRAY and build up material

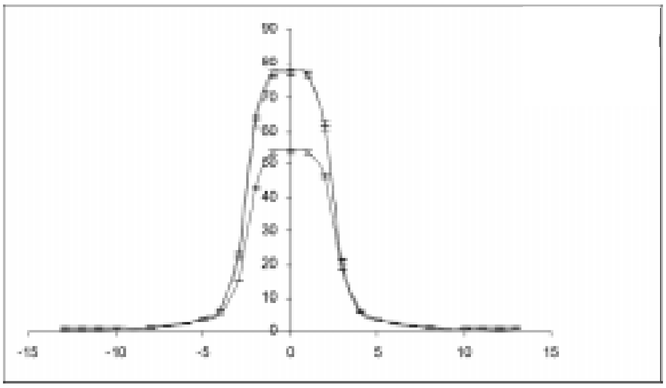
## 2. 2D-ARRAY measurements

Beam profiles at 5 and 10 cm depths for symmetry and the corresponding asymmetry beams in the in-plane, cross-plane and diagonal direction are compared and shown in Fig. 8 for in-plane profiles, Fig. 9 for cross-plane profiles and Fig. 10 for diagonal profiles for (a) 5×5 cm², (b)10×10 cm² and (c) 20×20 cm² field sizes.

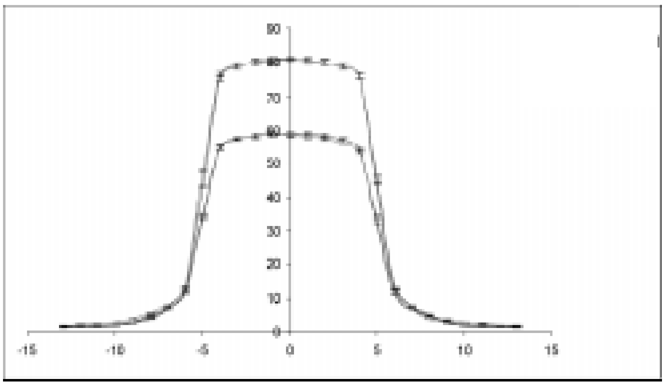
2D-ARRAY measurements show the same results as obtained by the water phantom measurements.

## 3. Absolute dose measurement

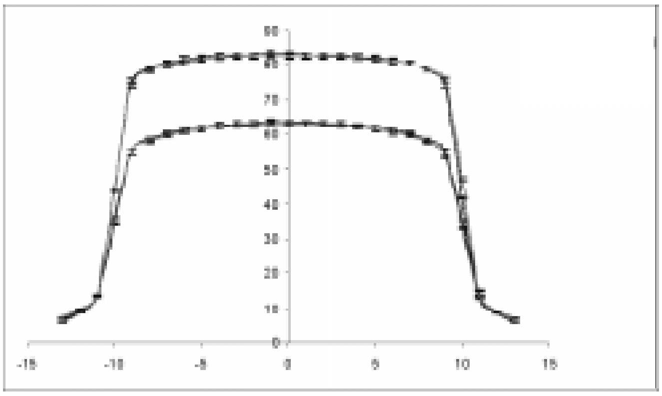
Absolute dose measurements in the Blue Water Phantom for the symmetry and asymmetry beams at 10 cm depth show that there



( a )

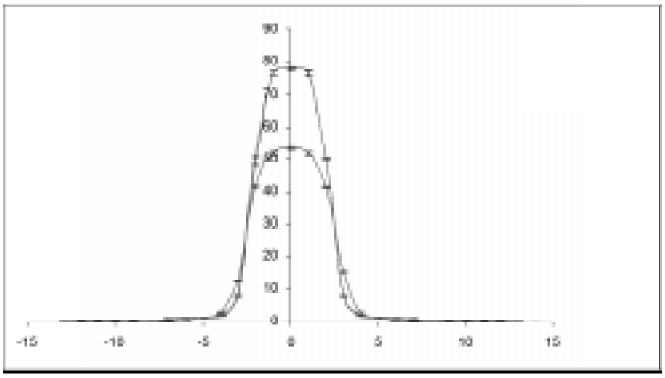


( b )

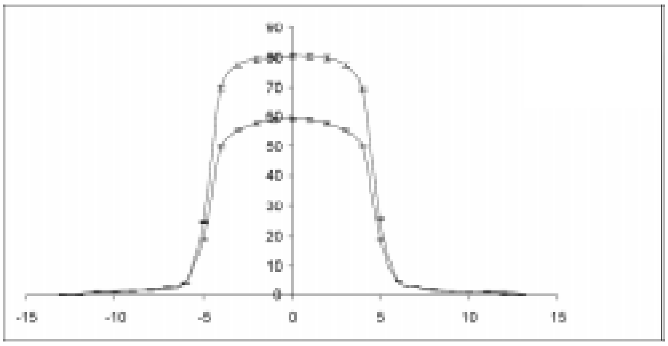


( c )

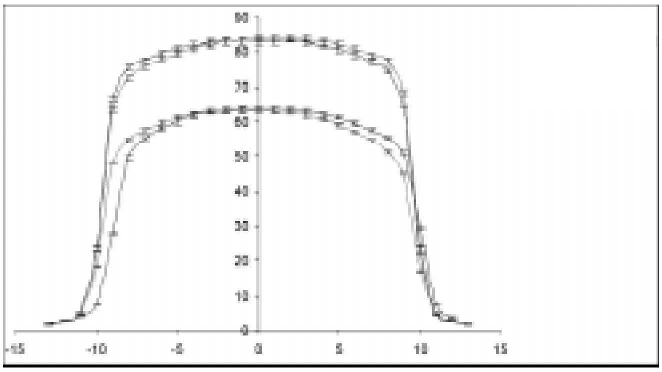
Fig. 9. Cross-plane beam profiles at 5 and 10 cm depths for symmetric and asymmetric fields for (a) 5 × 5, (b) 10 × 10 and (c) 20 × 20 $cm^2$ field size measured with 2D-ARRAY and build up material



( a )



( b )



( c )

Fig. 10. Diagonal beam profiles at 5 and 10 cm depths for symmetric and asymmetric fields for (a) 5 × 5, (b) 10 × 10 and (c) 20 × 20 $cm^2$ field size measured with 2D-ARRAY and build up material

is no significant difference for all the field sizes used and as shown in Table 4, the percentage deviation was never larger than 1 % which is within the tolerance level for absorbed dose determination in the AAPM quality control report. [7]

**4. Treatment time calculation**

To determine the accuracy to which the Pinnacle[3] model gives the dose distribution for any shaped fields, treatment time calculations for symmetric and asymmetric beams were compared in Table 5 and the percentage deviation was found to be less than 2 %, which is within the tolerance level for absorbed dose determination in the AAPM quality control report. [7]

## Conclusion

A comparison was drawn between symmetry and asymmetry dose distributions using water phantom and 2D-ARRAY with build up

*Table 4*

*Absorbed doses to water for symmetric and asymmetric beams measured at 10 cm depth in the Blue Water Phantom using FC-65-G ion chamber and DOSE1 electrometer following TRS-398 protocol from IAEA*

| Field size (cm × cm) | Absorbed dose towater (Gy) | | % Deviation |
|---|---|---|---|
| | symmetry | asymmetry | |
| 5 × 5 | 2.000 | 2.017 | 0.84 |
| 10 × 10 | 2.000 | 1.998 | 0.10 |
| 20 × 20 | 2.000 | 1.996 | 0.20 |

*Table 5*

*Treatment time calculated in the Pinnacle$^3$ TPS using cc convolution for symmetric and asymmetric beams with different field sizes at 10 cm depth*

| Field size (cm × cm) | Treatment time (min) | | % Deviation |
|---|---|---|---|
| | symmetry | asymmetry | |
| 5 × 5 | 1.92 | 1.93 | 0.52 |
| 10 × 10 | 1.72 | 1.75 | 1.74 |
| 20 × 20 | 2.11 | 2.13 | 0.95 |

materials. No difference was found for small field sizes. For large fields, and due to the off-axis softening, the effect of asymmetric collimation is the tilt of the isodose curves where the deviations between symmetry and asymmetry beams values were found to be more than 1 %.

Depth-dose characteristics for asymmetric fields are similar to those of symmetric fields for the different collimator openings.

Absolute dose measure ments in the Blue Water Phantom for the symmetry and asymmetry beams at 10 cm depth show that there is no significant difference for all the field sizes used, the percentage deviation was never larger than 1 % which is within the tolerance level for absorbed dose determination in the AAPM quality control report [7].

The Pinnacle$^3$ TPS uses the same beam data for symmetric collimator setting and models the dose distribution for any shaped field, with symmetric or asymmetric collimator setting, without special correction factors and does not require additional measure ments for off-axis fields.

The Pinnacle$^3$ has these advantages and can be used to calculate dose distribution in asymmetric fields to the same degree of accuracy as for symmetric fields.

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