

Manual for simulation of X-ray processing

Software ModeStXR

Modeling of 3D X-ray dose distribution with MC method. Software ModeStXR.

The program ModeStXR consideration

The **program ModeStXR** was designed specially for simulation of industrial radiation processes and calculation of the absorbed dose distribution within products irradiated by **stationary or scanned X-ray (bremsstrahlung) beams** on industrial radiation-technological lines (**RTL**) that is based on the pulsed or continuous type of electron accelerators in the **energy range** from **0.1 to 50 MeV**. Irradiated product is represented in form of stack of plates. The stack of plates can be interleaved with dosimetric films.

Developed software can be used for the following problem tasks in radiation processing:

1. Determination of dependence of an absorbed dose distribution in a layer as function of:
 - X-ray energy spectrum of X-ray converter;
 - density and a chemical composition of layer material;
 - width and thickness of a layer;
 - geometrical arrangement of a layer in a stack;
 - density and a chemical composition of a stack layer materials;
 - geometrical sizes of a stack;
 - an orientation angle of a stack relatively to incident electron beam.

2. Examination of dependence of an absorbed dose distribution in a layer as function of:
 - energy of incident EB;
 - an EB current and speed of a conveyer motion;
 - an angular distribution of electrons in a beam;
 - a spatial distribution of electrons in a beam;
 - a width of EB scanning;
 - an angular characteristics of a scan process;
 - a time sweep of the scanner;
 - an air gap between the scanner and X-ray converter and an irradiated target target.

3. The comparative analysis of visual and numerical difference of depth-dose distributions in a layer for:
 - various parameters of calculation;
 - various calculation models;
 - an experimental and calculated depth-dose distributions in a layer.

The features of the software **ModeStXR** are as follows:

1. Two levels for entering of input data via configuration files and manually.
2. Built-in tools for statistical analysis.
3. Built-in tools for uncertainties estimation of results simulation due to uncertainties of input data for radiation facility.
4. Estimation of uncertainties for physical models.
5. Comparison Modulus for visual and a numerical analysis of calculated and experimental data and for decision of optimization tasks in radiation processing.
6. Built-in tools for processing of experimental dosimetric data and their comparison with simulation predictions.

The software have intuitively clear graphical interface for the end-users with the following features:

1. Detailed decomposition of input data for main elements of source and target (including spectral characteristics for irradiation source).
2. Two levels for entering of input data via configuration files and manually.
3. Expert control for the range of input data and co-ordination for the set of geometrical and physical input data.
4. Compatibility of export an input data to different modules.

The software **ModeStXR** works on platform Windows98/Me/NT/XP/2000. Language of the interface - English.

Software ModeStXR. How to get results.

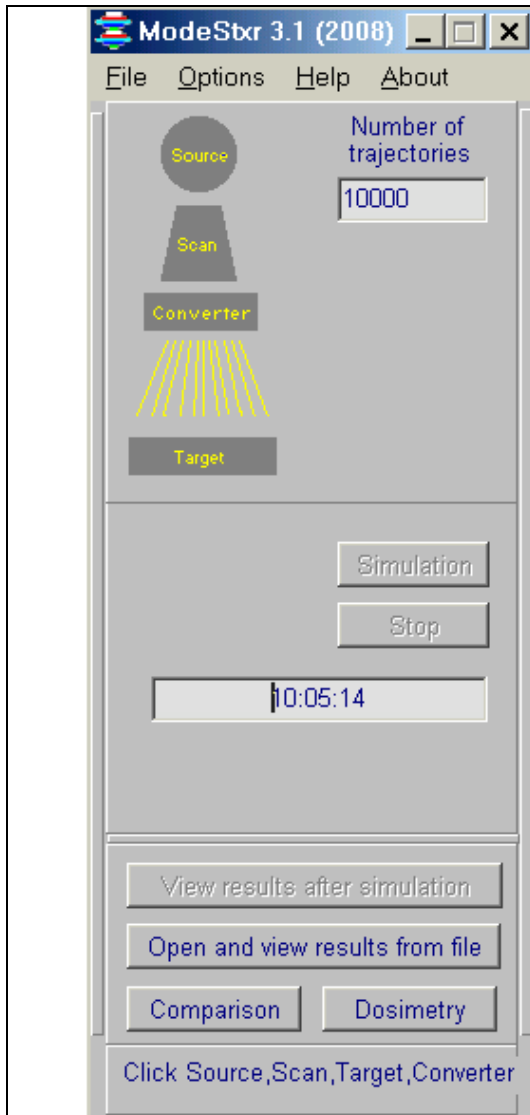


Fig.1. The main form of the Software ModeStXR

For work with **software ModeStXR** -

- Click the **"File"** then **"Open configuration"**, then to select **"irradiating system"** and load the file **"Test.rts"**.
- Again click the **"File"** then **"Open configuration"**, then to select **"irradiated target"** and load the file **"Test.rtt"**.
- Again click the **"File"** then **"Open configuration"**, then to select **"converter"** and load the file **"Test.rtc"**.

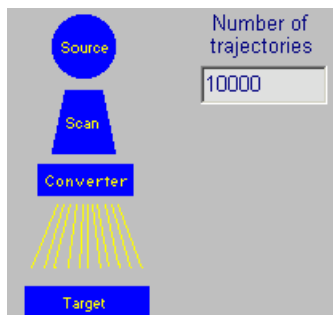
Only after loading the **"Test.rts"**, **"Test.rtt"** and **"Test.rtc"** files, user can change all characteristics of X-ray facility and irradiated target for simulation X-ray processing.

If all input data are saved, color of the scheme item changes to blue.

- Enter **"Number of trajektories"** and
 - Click the button **"Simulation"**.
- At this point the **Software ModeStXR** fixes starting time and defines time required for calculation.
- Click **"Stop"** to interrupt your calculation and reenter data.
 - When MC will be ended, the list of results will be opened.
- You can select item and work with results.

Input data

1. Source



- Click “**Source**” in the Scheme of **Monte Carlo Module, MC**. See **Fig. 2**.

The form for **Source** – Electron Accelerator parameters will be opened. See **Fig. 3**.

Fig.2. Scheme of MC Module

Energy	Insens.
8,000	0,000
10,000	1,000
10,800	0,000

Angle	Insens.
0,000	1,000
6,000	1,000

Fig. 3. The main form of “**Source**” for data input and correction of an Electron Accelerator parameters.

1.1. Beam current

The frame **Beam current** contains some fields.

There are two regimes for input data: “**Pulsed regime**” and “**Average current**”.

- Click the “**Pulsed regime**” by a tick, to work with **Pulsed regime data**.
- Enter the values **Impulse current in A, Impulse time in msec, Repetition frequency in Hz**.
- Delete a tick from window “**Pulsed regime**”, to work with “**Average current**” mode.
- Enter the value of **Average current in mA**.

1.2. EB energy spectrum

Fields for **EB energy** are placed into the frame **Spectrum**.

- Click the field “**MonoEnergy**” with a tick, to work with **MonoEnergy** mode.
- Enter a value of the **Energy**.
- Click the field “**Spectrum**” with a tick, to work with **EB energy spectrum** mode.
- Enter a rows number in the table, Click button "**Correct table**".
- Enter or edit table data.

A left mouse button allows to insert a row in the table or delete selected row.

When rows number is changed by left mouse button, the field **N rows** will change accordingly. At this point **Energy** field will be inaccessible.

1.3. Angular spread

- Click the field **MonoDirect** by a tick, to work with **MonoDirect** mode.
The target will be irradiated with non-divergent scanned electron beam.
- Click the field **Angular spread** by a tick, to work with **Angular spread** mode.
- Enter a rows number in the table, Click button "**Correct table**".
- Enter or edit table data for the beam angle spread.

You work with this table by analogy with the table of EB energy spectrum.

- Enter data of space spread, to work with the frame **Space spread**.
- Click the field “**Point beam**” by a tick, to work with **Point beam** mode.
- Click the field “**Distributive beam**” by a tick, to work with **space spread** mode.
- Enter data of **Beam diameter** in cm and **Full width on half maximum** in cm.
- Click the button "**Save data and close this window**".

Image of "**Source**" in the Scheme of Monte Carlo Module change into blue color.

2. Scanner

- Click “**Scan**” in the Scheme of Monte Carlo Module. See Fig. 2. The main form for **Scanner** and **Conveyer** parameters will be opened. See Fig. 4.
 - Enter values of **Speed** in cm/sec and **Width in cm** in the frame **Conveyer**.
 - Enter values of **Frequency** in Hz and **Height of scan horn in cm** in the frame **Scanning horn**.

Fig.4. The main form for the **Scanner** and **Conveyor** parameters.

- **Enter** values of **Distance scan-conveyor in cm** and **Width of scanning in cm** in the frame **Geometry**.
- If you have **linear time-current curve** in scan magnet (saw-tooth form of current), you need to mark the check box of “**Default mode**” by a tick.
- **Mark** the check box of “**Custom mode**” by a tick, if you have **nonlinear time-current curve**.
- **Enter** a rows number of the table, **press button "Correct table"** and work as well as with tables for an electrons source. The values of **time** and **current** are dimensionless.
- You can **Enter** the **foil parameters of the outlet window of scanner**. For this, you need to **mark** the frame “**Window of scanner**” by a tick. The frames for the foil parameters will be opened.
- **Enter** values of **Thickness in cm**, **Density of foil material in g/cm³**.
- **Enter** values of “**Atomic number**” and “**Weight part**” for the foil material.
- **Click** the button “**Save data and close this window**”. Image of “**Scan**” in the Scheme of MC Module change into **blue color**.

3. Converter

- Click “**Converter**” in the Scheme of Monte Carlo Module. The main form for **Converter** parameters will be opened. See **Fig.5.**

Elements	Layer 1		Layer 2		Layer 3		Layer 4		Layer 5	
Thickness [cm]	0,12		0,5		0,2					
Density [g/cm3]	16,6		1		7,9					
Material	Z	W	Z	W	Z	W	Z	W	Z	W
	73	1	1	2	26	1				
			8	16						

Fig.5. The main form for data input and correction of the **Converter** parameters.

X-ray converter has multi-layer structure. The numbers of flat layers are in the range from 1 to 5.

The functions of layers are as follows:

- **X-ray converter plate,**
- **cooling agent and**
- **backing plate for absorbing of electron beam.**
- **Click** on layer 1 or 2 or 3 or 4 or 5.

In this point the column of corresponding layer will be activated and in the **Layer** field will be shown the layer number that will be corrected. Instead you can type the layer number in **Layer** field.

- **Enter** for this layer material: **Thickness** layer, **Density**, atomic number **Z**, and **W** ("weight part").
- **Enter Z** and **W** for each element of compound and mixtures .
- **Enter** values of **Distance between converter and scan in cm.**
- For clear data in selected layer, **enter** layer number in the **Layer** field and click the **Clear layer**
 - **Click** the button "**Save data and close this window**". Image of "**Converter**" in the Scheme of MC Module change into blue color.

4. Target

4.1. The form for entering of input data for irradiated Target and Cover

- Click "**Target**" in the Main form of the Software ModeSXR (See Fig.2). The form for entering of **input data** for irradiated **Target** and **Packing materials (Cover)** will be opened (See Fig.6).

Target and cover (ModeSbr 3.1 2008)

Number of packages: 1

Width of packages: 40.01

Stack length: 20

2D registration: package + layer

P	L
1	1
1	2
1	3
1	4
1	5
1	6

3D calculation:

3D registration: package + level

P	L
1	5

Orientation: Vertical, Along the scanning axis, Along the conveyor axis, Normal displacement, Turn on 90 deg

Current layer: 6

Layer	1	2	3	4	5	6
Thickness	5	2	0,5	5	8	5
Width	40	40	40	40	40	40
Density	3	2,7	7,9	3	1	2

Polyethylene

	Z	W	Z	W	Z	W	Z	W	Z	W	Z	W
Polyethylene	1	2	13	1	26	1	1	2	1	10	1	8
Polystyrene	8	16				8	16	6	72	6	60	
Carbon								8	80	8	32	
Birchwood												
Cellulose												
Soft Tissue												
Water												

Density: 1

Cover thickness: 0,5

Additional cover: 0

Polystyrene

List: Table: Opened cover:

Rows: 3

A number	W part
1	10
6	72
8	80

Thickness, width, additional cover [cm]; Density [g/cm3]

Save data and close this window

Fig.6. The form for entering of input data for an irradiated Target and Packing materials (Cover).

4.2. Multi-layer target model

• Multi-layer target consists of some identical packages with flat sheets of materials with various density and atomic number. (See Figs.7 and 8).

Geometrical models of multi-layer targets irradiated with scanned X-ray beam.

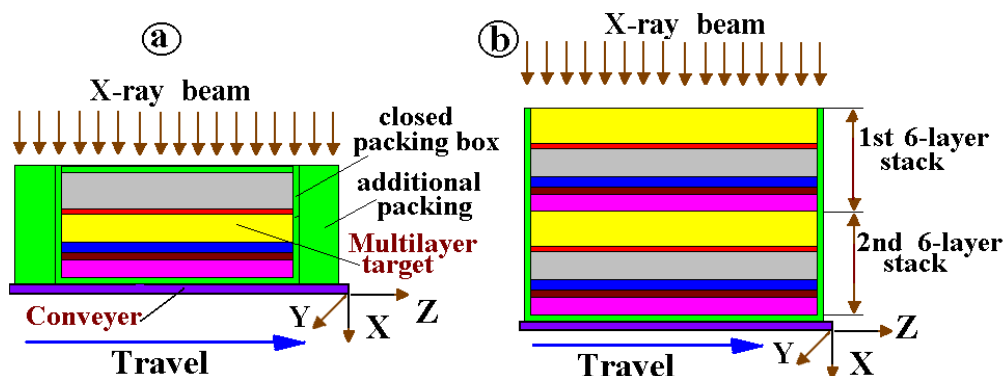


Fig. 7. Geometrical models of multi-layer targets placed on moving conveyor and irradiated by normally incident X-ray beam.

Conveyor moves along axis Y. X-ray beam scans along axis Z.

- Multi-layer target consists of 6-layer package placed in closed packing box with additional packing materials.
- Multi-layer target consists of two 6-layer packages placed in open packing box.

- **The number of packages** are in the range from **1 to 10**.
- **The number of layers** (flat sheets of materials with various density and atomic number) in the each package are in the range from **1 to 6**. (See Figs.7 and 8)
 - **The full number of layers** in Multi-layer target are in the range from **1 to 60**.
 - All **packages** have the same set of materials and identical geometrical sizes.
 - All **flat sheets** of 6 layers in the package can have **different thickness** (axis Z) **and width** (axis X, along scan direction), but all sheets have **identical length** (axis Y, along conveyer motion).
 - Multi-layer target can be located on the conveyer platform **with/without packing box**.
- **Several identical Multi-layer targets with/without packing box** can be located on the conveyer platform. (See Fig. 9).
The **distance between boxes** with Multi-layer targets can be ≥ 0 .

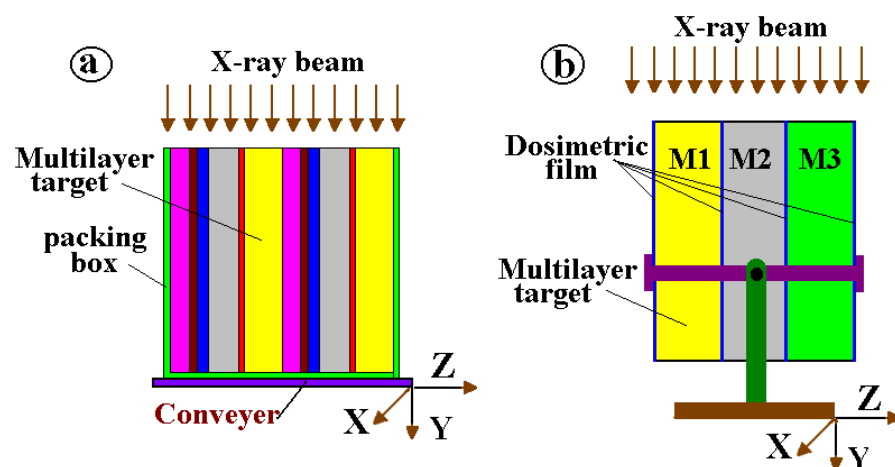


Fig. 8. Geometrical models of multi-layer targets irradiated by incident X-ray beam in parallel with interface of contacting materials. Conveyer moves along axis X. X-ray beam scans along axis Z.

- Multi-layer target consists of two identical 6-layer packages placed in open packing box and irradiated by incident X-ray beam in parallel with interface of contacting materials.
- Multi-layer target with dosimetric films inserted between interface of contacting materials and irradiated in parallel with X-ray beam.

Simulation of the dose distribution in the “**Several identical Multi-layer targets with/without packing box**” allows to investigate the mutual influence of the nearest neighbor boxes on dose field formation in the target layers.

- The **flat sheets of Multi-layer target** can be located on the conveyer platform **horizontal or vertical** relatively incident X-ray axis. (See Figs. 7 and 8).

Note. In any layer positions under X-ray irradiation, axis coordinates **X, Y, and Z** are hard connected with **width (X), length (Y), and thickness (Z)** of target layers (See Figs. 7 and 8).

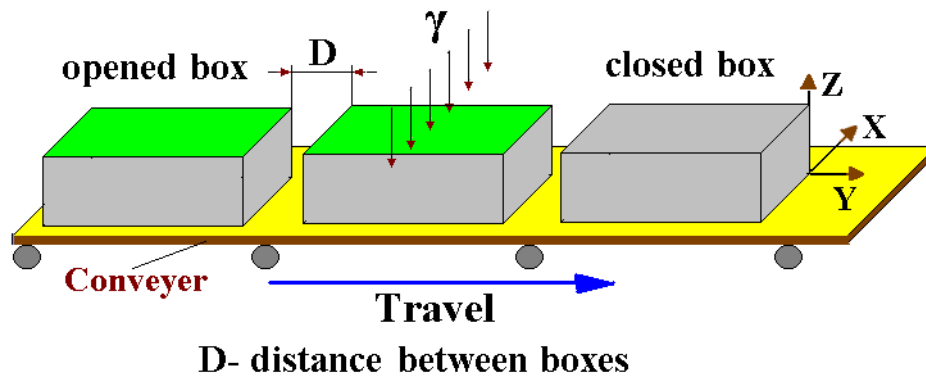


Fig. 9. Geometrical model of 3 identical Multi-layer targets with packing box located on the conveyer platform. The distance between boxes with Multi-layer targets can be ≥ 0 .

4.3. Input data for layers size and layers materials

- Enter the **number of packages** in multi-layer target in the range from **1 to 10**.
- Enter the **number of layers** in the package in the range from **1 to 6**.
For this, Click the button "**Insert**" (right up corner in the "**Target**" frame)
(See Fig. 6).
- Enter the "**Width of packages**" in cm (left up corner in the "**Target**" frame)
(See Fig. 6).
- Enter for each layer "**Thickness**" in cm.
- Enter for each layer "**Width**" in cm.

Note. The "**Width of packages**" can be \geq "**Width**" of each layer.

- Enter for each layer "**Density of materials**" in g/cm^3 .
- Select a **material** for each layer from the "**Table of material**". The **atomic number Z** and the **atomic weight W** of the material appear in the corresponding boxes.
- For materials not given in the "**Table of material**", enter the values of **Z** and **W**. The selection button changes to "**Another material**".
- Button "**Delete**" is used for deletion of the chosen layer.
- Button "**Clear**" is used for cleaning of the parameters in the chosen layer.

4.4. Input data for cover size and cover materials

- Enter characteristics for the "**Cover Box**": "**Cover thickness**" in cm, "**Additional cover thickness**" in cm, and "**Density of cover materials**" in g/cm^3 .
Note. In the case of **cover thickness = 0**, the multilayer target has not a **Cover Box**.
- Select a **material** for **cover materials** from the "**Table of material**".
The **atomic number Z** and the **atomic weight W** of the material appear in the corresponding boxes.

- **Enter** the values of **Z** and **W** for materials not given. The selection button changes to **“Another material”**.
- Multilayer target can be irradiated by incident **X-ray beam** either in **closed or open** (Tick window **“Opened cover”**) **Cover Box**. (See Fig. 6).

4.5. Input data for layers orientation on a conveyer platform under X-ray irradiation

- **Simulation model of the software ModeSXR** for target irradiation allows to irradiate the box with flat layers from **any of six box sides**. **Selection of target orientation** relatively incident **X-ray beam** is realized with the **switch “Orientation”** (See Figs. 6 and 10).

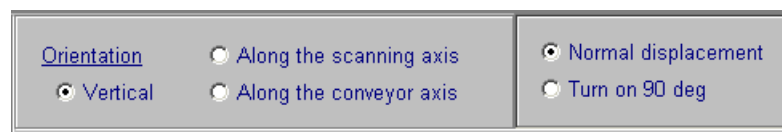


Fig. 10. Frame with mode switch of orientation for target layers under X-ray beam irradiation

- **Switch positions (“Vertical” and “Normal displacement”)** in Fig.6 are used as default mode. This target position is mean that all flat target layers are located on conveyer platform in accordance with position in Fig.11.1.

I.e. the planes of all layers are perpendicular to axis of incident **X-ray beam**. The **length** of layers is located in direction of conveyer motion (**axis Y**), the **width** – in direction of **X-ray beam** scanning (**axis Y**), the **thickness** – in direction of **X-ray beam** incidence (**axis Z**). (in parallel with an incident **X-ray beam (axis Z)**)

- All possible positions of layers orientation on a conveyer platform under **X-ray beam** irradiation and corresponding switch positions are presented in **Figs. 11.1, 11.2, 11.3, 11.4, 11.5, 11.6**.

• **Note.** In any layer positions under **X-ray beam** irradiation, **axis coordinates X, Y, and Z** are hard connected with **width (X), length (Y), and thickness (Z)** of target layers.

- All above possible positions under **X-ray beam** irradiation also can be realized for package of flat layers placed in open/closed box (See Figs. 12.1 and 12.2) and for package of flat layers placed in open/closed box with additional cover (See Figs. 13.1 and 13.2). Additional cover always covers only the box sides in direction of layers thickness (**along axis Z**).

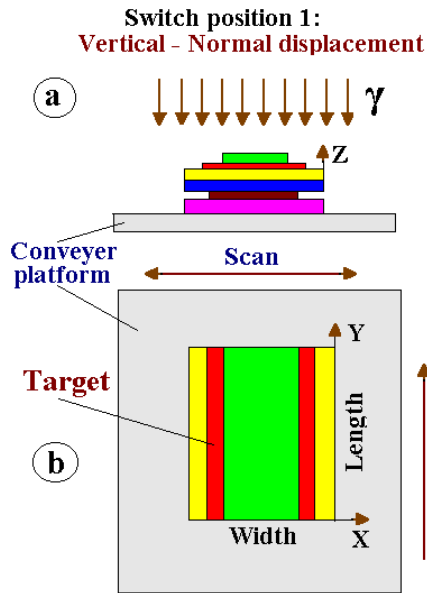


Fig.11.1

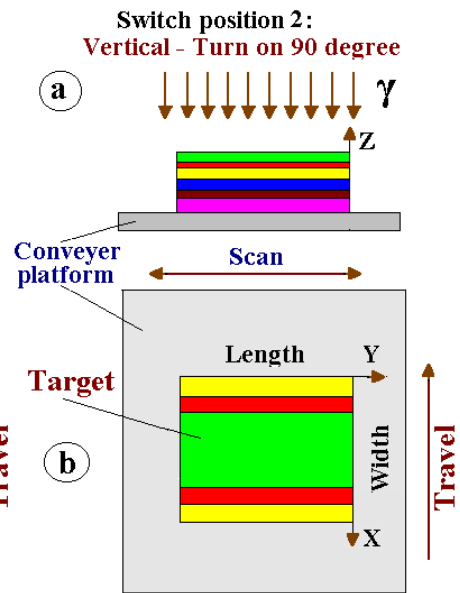


Fig. 11.2

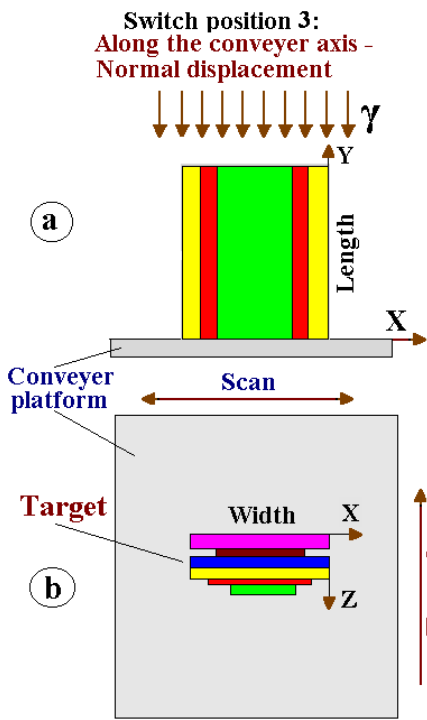


Fig. 11.3

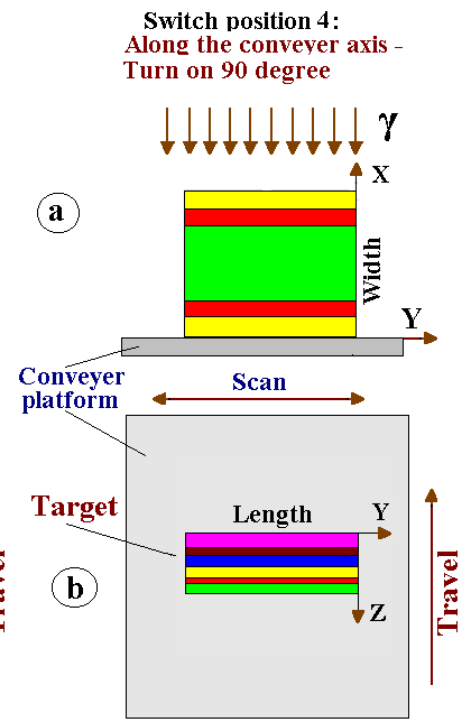


Fig. 11.4

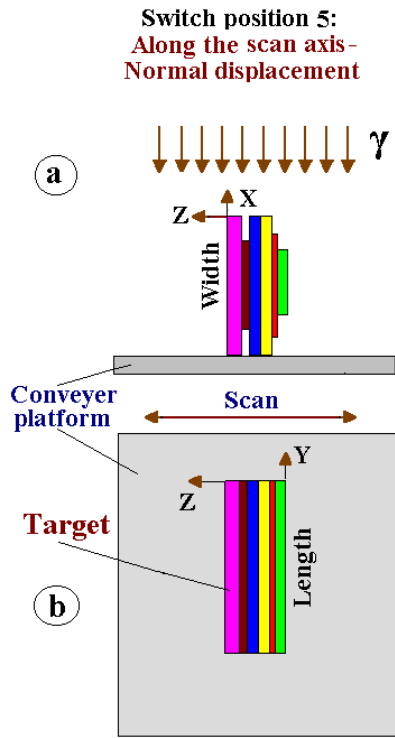


Fig. 11.5

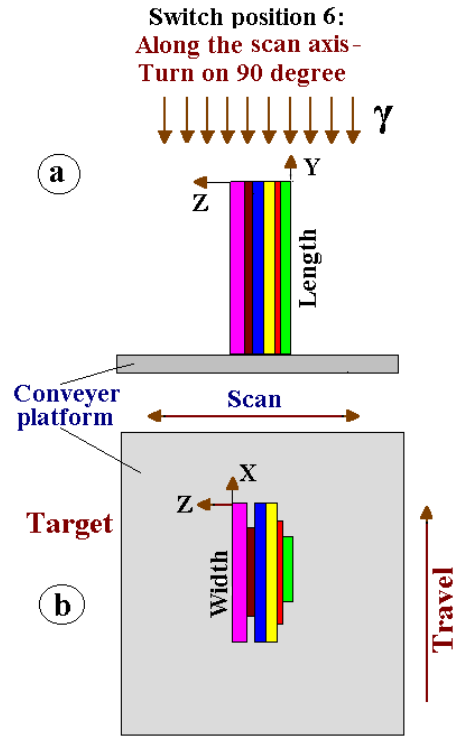


Fig. 11.6

Figs. 11.1, 11.2, 11.3, 11.4, 11.5, 11.6. Layers orientation on a conveyer platform under X-ray beam irradiation and corresponding switch positions

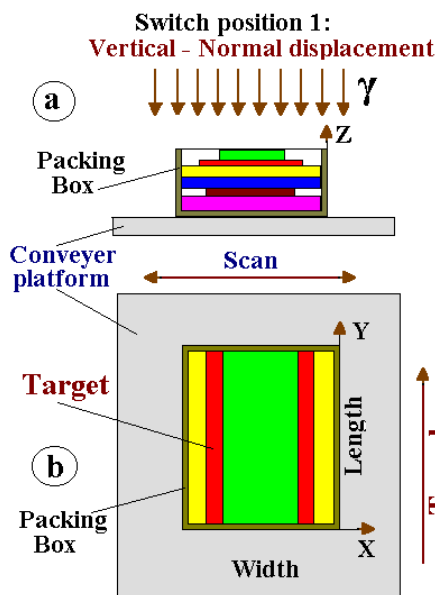


Fig. 12.1

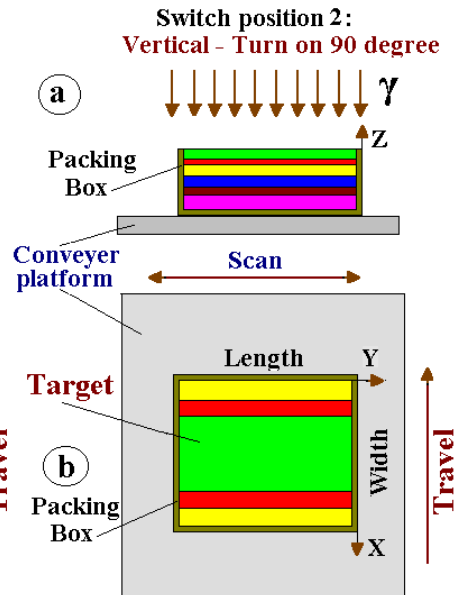


Fig. 12.2

Figs. 12.1 and 12.2. Some possible orientation positions on a conveyer platform for package of flat layers placed in open packing box

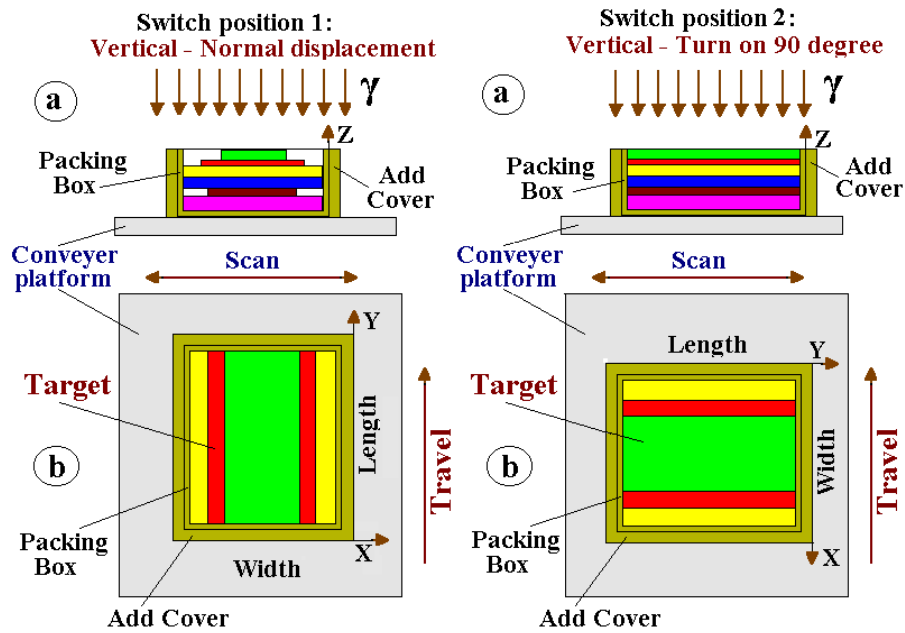


Fig. 13.1

Fig. 13.2

Figs. 13.1 and 13.2. Some possible orientation positions on a conveyer platform for package of flat layers placed in open packing box with additional cover and corresponding switch positions

4.6. Input data for irradiation of some identical Multi-layer targets with/without packing box

Simulation of the dose distribution in the “**Several identical Multi-layer targets with/without packing box**” allows to investigate the mutual influence of the nearest neighbor boxes on an X-ray dose field formation in the target layers.

- Tick the window "**Multi-target**". (See Figs. 2, 6 and 14).
- Enter the value “**Distance between targets**” in cm.
The **distance between boxes** with Multi-layer targets can be ≥ 0 .

The screenshot shows a software window with a checked checkbox labeled "Multi - Target". Below it, there is a text input field labeled "Distance between targets" with the number "5" entered.

Fig.14. The form for entering of input data for Multi-target.

4.7. Input data for Table “2D registration”

The Table “2D registration” allows to chose the **number of packages** and the **number of layers** for which the results of simulation for absorbed dose distribution (**ADD**) will be presented in the 2D graphical and tabular forms. (See Figs. 6 and 15).

The screenshot shows a software window titled "2D registration" with a sub-link "package + level". It contains a table with two columns, "P" and "L", and six rows of data. Below the table is a checked checkbox labeled "3D calculation" and another link "3D registration package + level". At the bottom, there is a smaller version of the table with "P" and "L" columns and one row with values "1" and "3".

P	L
1	1
1	3
2	1
2	3
3	1
3	3

3D calculation

[3D registration package + level](#)

P	L
1	3

Fig.15. The form for entering of input data for Table “2D registration and 3D registration”.

- Select in the Table "2D Registration" the **number of packages** and the **number of layers** in chosen package for which the results of simulation for absorbed dose distribution (**ADD**) will be presented in graphical and tabular forms.

- **Note.** The Table "2D Registration" includes the **number of packages "P"** and the **number of layers "L"** in chosen package "P".

- For **one run simulation** the **number of packages "P"** can be chosen in the range from **1 to 6 of 10 packages**, and the **number of layers in chosen package "L"** can be chosen in the range from **1 to 6**.

- For obtaining of the values for **ADD** in another packages and layers, you need to enter the number of appropriate packages and layers in the **Table "2D Registration"** and repeat the run simulation.

In this way, you can obtain step by step the **ADD** in all layers of multilayer target.

4.8. Input data for Table “3D registration”

The Table “3D registration” allows to chose the **number of one of packages** and the **number of one of layers in the chosen package** for which the results of simulation for analysis of the **3D** absorbed dose distribution (**ADD**) of **X-ray beam** will be presented in the graphical and tabular forms. (See Figs. 6 and 15).

- Tick the window "3D calculation". (See Figs. 6 and 15).

- Select in the Table “3D registration” the **number of package P** and the **number of layer L** in the chosen package **P**, for which the results of simulation will be available for analysis of **3D** absorbed dose distribution (**ADD**) in graphical and tabular forms.

• For obtaining of the values for **3D ADD** in another packages and layers, you need to enter the number of appropriate package and layer in the **Table "3D registration "** and repeat the run simulation.

In this way, you can made analysis of the **3D ADD of X-ray beam** step by step in all layers of multilayer target.

At the end, Click "**Save data and close this windows**".

The selected parameters for multilayer target will be saved and ready for simulation.

5. Options

Options are intended for:

- **optimization of simulation regimes,**
- **optimization of parameters visualization of calculated results,**
- **scientific research of transport irradiation through heterogeneous targets.**

Options includes tree thematic parts:

- **Expert modes of simulation:** "Normal" and "Without scattering".
- **Parameters simulation:** "Electron energy cut off", "Photon energy cut off", "Angle grouping", and "Splitting on axis X, Y, Z".
- **Parameters of visualization of results:** Joined cells for center and boundary, Coordinate system "normal" and "turn 90".

In the default mode "Automatic parameters" of the Software ModeSXR work, all simulation parameters are working in an optimal automatic regimes which were installed in the physical, operational and in calculation models of the Software. See Fig.16a.

All parameters of Options can be changed only in regime "Manual parameters". See Fig.16b.

5.1. Expert modes of simulation: "Normal" and "Without scattering".

Mode simulation "Normal". It is standard regime with automatic choice of the parameters simulation such as Electron energy cut off, Photon energy cut off, and Angle grouping.

The source of photons in X-ray facility is an X-ray converter irradiated with electron beam from electron accelerator.

"Normal" mode characterise the full MC scheme which includes simulation:

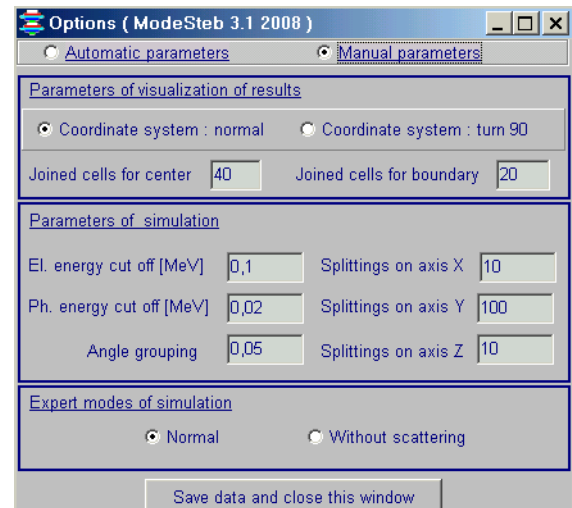
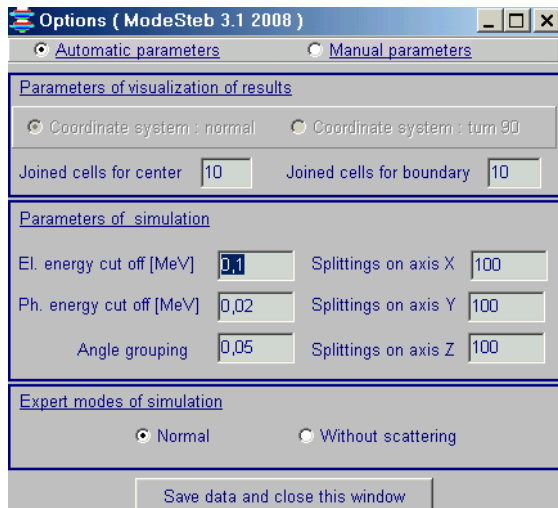
- **conversion of EB into X-ray, and**
- **transport of X-ray beam in an irradiated target with taking into consideration the scattering effects of photons.**

"Without scattering" mode characterise MC scheme which includes:

- **full MC simulation the conversion of EB into X-ray, and**

- MC simulation the transport of X-ray beam in an irradiated target without taking into consideration the scattering effects for photons.

Such MC simulation the transport of X-ray beam in an irradiated target without taking into consideration the scattering effects of photons is equivalent so called point kernel method without taking into consideration of the build-up factor.



Figs.16a, b. Main form of “Options” for enter input data for simulation.
 a) default mode “Automatic parameters”. b) regime “Manual parameters”.

5.2. Parameters of visualization of results.

5.2. 1. “Joined cells for center and boundary” define the number of cells, which were combined in the Center or Boundary of irradiated layer at calculation and visualization of **2D dose distribution**.

The cells are combined in direction transversely to axis of X-ray dose distribution visualization.

5.2. 2. Coordinate system “normal” and “turn 90”.

Under visualization of results, regime “turn 90” rotate the **Coordinate system for the irradiated target on 90 degree** around axis **Z** in comparison with regime “normal”.

Regime “turn 90” is working only under visualization of **2D absorbed dose distribution**.

At visualization of simulation results in regime **Coordinate system “normal”**, the **2D absorbed dose distribution** is presented along “**layer width**”.

At visualization of simulation results in regime **Coordinate system “turn 90”**, the **2D absorbed dose distribution** is presented along “**layer length**”.

5.3. Parameters simulation: Electron energy cut off, Photon energy cut off, Angle grouping, and Splitting on axis X, Y, Z.

• **Change of simulation parameters** Electron energy cut off, Photon energy cut off, and Angle grouping can be used for scientific researches of transport irradiation through heterogeneous targets.

Note. In all above the **Expert modes of simulation** “Normal”, “Without scattering”, parameters simulation such as **Electron energy cut off, Photon energy cut off, Angle grouping** are automatic installed.

• **Parameters simulation** “Splitting on axis X, Y, Z” are used for the choice of optimal value of 3D grid for target layer at analysis of 3D absorbed dose distribution in this layer.

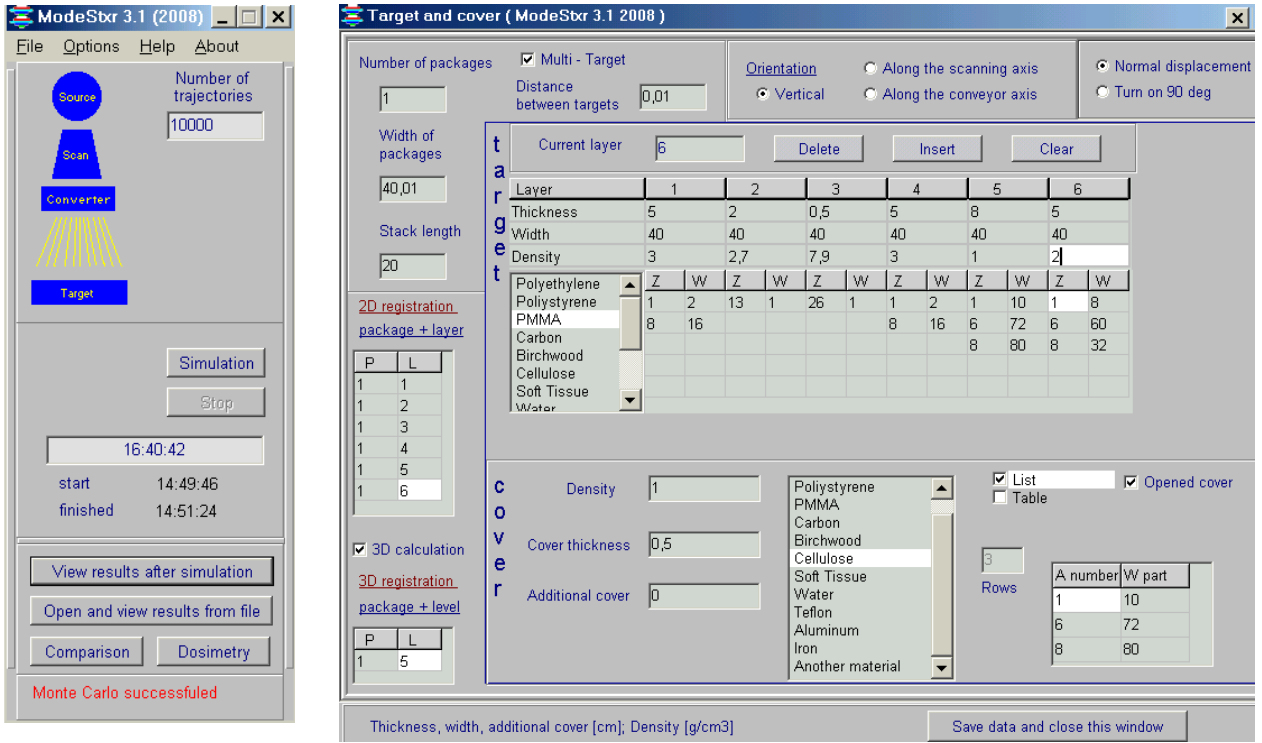
All parameters of **Options** can be changed only in regime “**Manual parameters**”.

6. The features of output data representation

6.1. Example. Configuration data for simulation of X-ray dose distribution in an irradiated target

The Main form of the Software **ModeStXR** is presented in **Fig.1**. Example of **target parameters data**, for which simulation and preparation of output data will be made, is presented in **Fig.17**. **Position of target** on a conveyer platform is presented in **Fig.18**.

Full **configuration data** which are used **at simulation** are presented in **Fig.19**. **X-ray converter** structure is presented in **Fig.20**.



Main form of the Software ModeStXR

Fig.17. Example of Multilayer target.

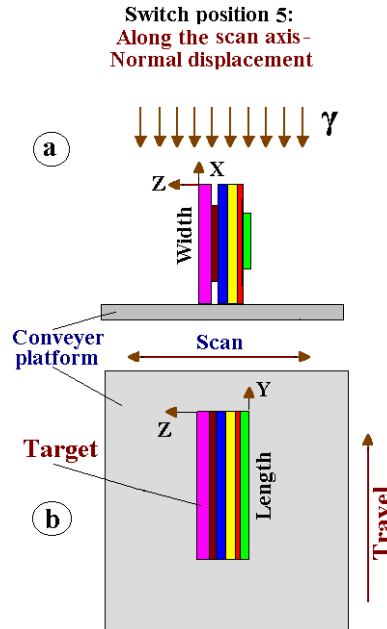


Fig.18. Position of target on a conveyer platform.

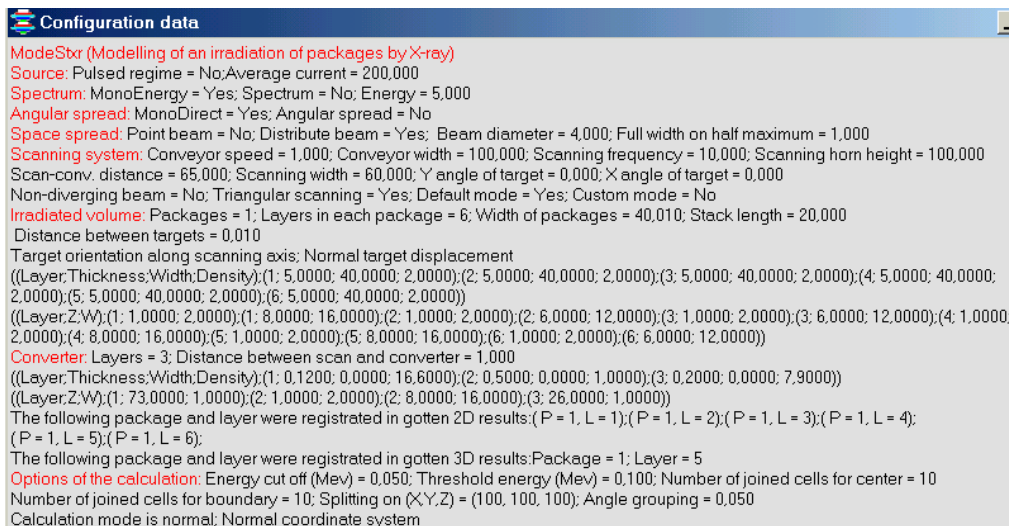


Fig.19. Full set of configuration data which is used at simulation of an X-ray absorbed dose distribution.

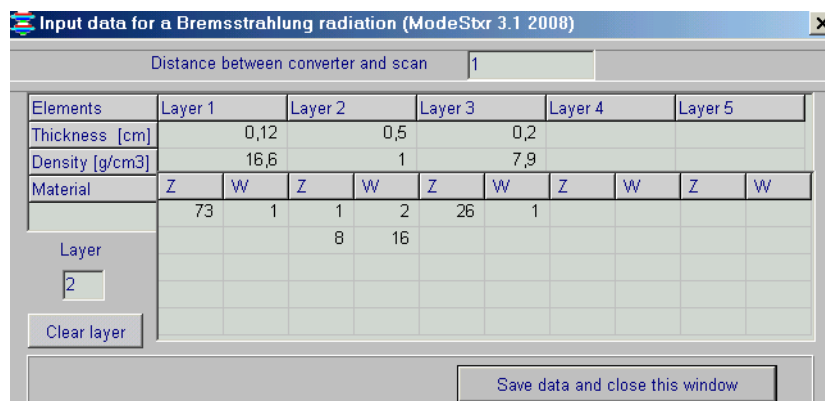


Fig.20. X-ray converter structure.

The functions of the converter layers are as follows:

- Layer 1 - X-ray converter plate –Tantalum plate, thickness – 1.2 mm,
- Layer 2 - cooling agent - water layer, thickness – 5 mm,
- Layer 3 - backing plate for absorbing of EB – Fe plate, thickness – 2 mm.

6.2. Output Data for 2D dose distributions

- After finish Simulation, Click the button “View results after simulation” in the Main form of the Software ModeStXR. The form "Dose distributions after MC simulation" with 2D absorbed dose distributions in graphical and tabular forms for chosen packages and layers in the Table “2D registration” will be opened (see Fig.21).

Note 1. On all curves of 2D dose distributions of X-ray in any target positions on a conveyer platform the dose value is the function of layer width (axis X).

Note 2. On all curves of 2D dose distributions of X-ray in any target position on a conveyer platform the dose value is integrated along layer thickness (axis Z).

- Additional information related to X-ray absorbed dose distributions are presented in this form:
- Dose uniformity ratio, DUR

- Average dose
- Dose minimum
- Dose maximum
- Statistical uncertainty
- Joined cells for centre and for boundary

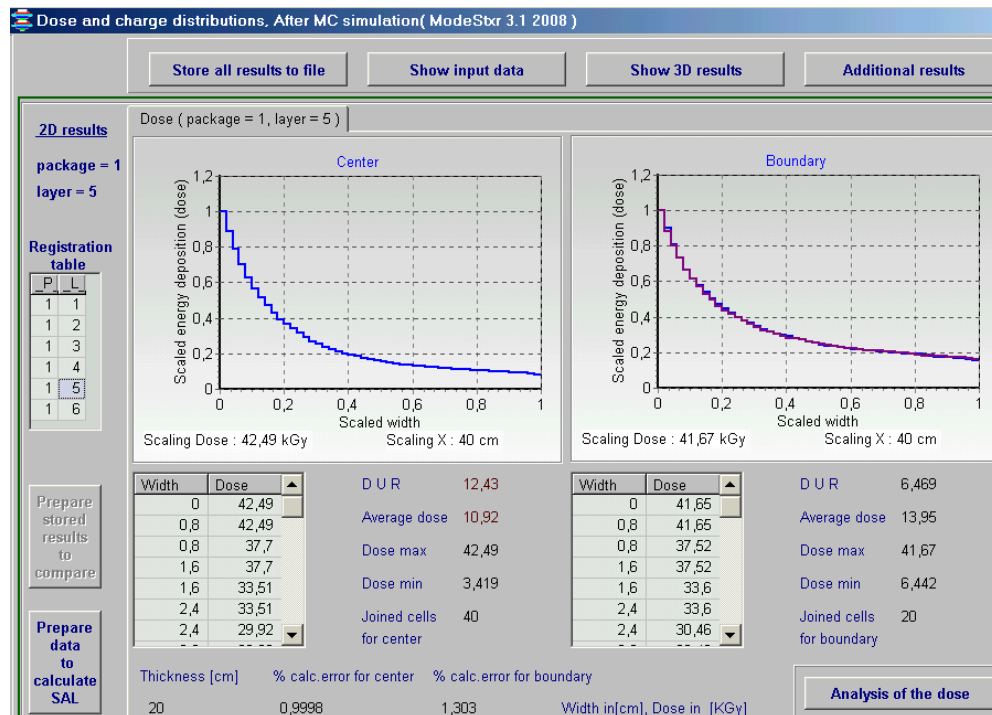


Fig.21. Form with 2D view of the depth dose distribution of X-ray in graphical and tabular forms for the 5th layer in the package.

Left graph - 2D view of the depth dose distribution in the Centre of the 5th layer in the package. I.e. in the area Length/2.

Right graphs - 2D view of the dose distribution near the Boundary of the 5th layer with Air in plane XZ, **blue curve** - for first XZ plane in direction of conveyer motion, **violet curve** – for the back XZ plane in direction of conveyer motion (See Figs. 18 a, b).

- Click on any package **_P_** and any layer **_L_** number in the Table “2D registration”, the 2D depth dose distributions for corresponding package and layer will be appear in the form.

In this way, you can see step by step the 2D depth dose distributions for all chosen packages and layers in the Table “2D registration”.

- Click the button "Store all results to file", the results simulation in graphical and tabular forms will be stored for further analysis.
- To processing simulation results previously stored in the files, Click the button "Open and view results from the file", in the Main form of the Software ModeStXR (Fig.1).
- The button "Prepare store results to compare" is used to select the 2D depth dose distributions for certain layer and package from simulation results

previously stored in the **files** and **to prepare their for use** in the **module Comparison**.

Note. The button **"Prepare store results to compare"** is active only after **operation in the privies point**.

- **To copy** the graphical depth-dose results into your document, **Click** graph either of the **Center** or **Boundary**, **Click** the button **"To clipboard"** and paste them to your document.

- The button **"Prepare data to calculate SAL"** is used for preparation of the dose map data in the chosen layer. Further, the dose map data can be used as input data **in the software ModeSAL** for calculation **a sterility assurance level (SAL)**.

The software **ModeSAL** and **ModeStXR** are the simulation modulus of the **RTOffice** information system. Input and output data for all simulation modulus of the **RTOffice** are self-consistent between themselves.

6.3. Output Data for X-ray spectrum

- **Click** the button **"Additional results"** in the form **"Dose distributions after MC simulation"** (see Fig.21).

- The form with **X-ray spectrum** generated with **5 MeV electron beam** in **Tantalum converter** (see Fig.20.) in graphical and tabular form will be opened (see Fig.22).

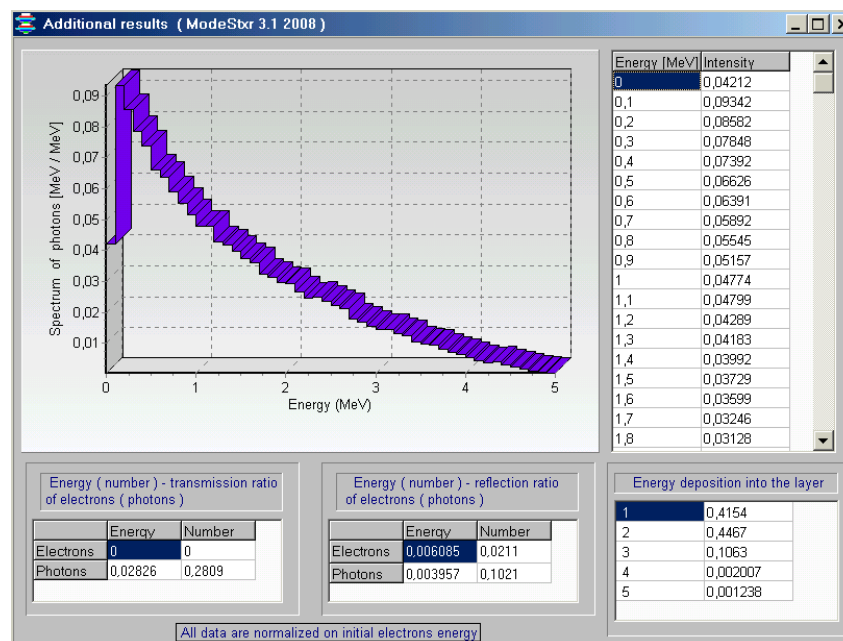


Fig.22. X-ray spectrum generated with **5 MeV electron beam** in **Tantalum converter**.

6.4. Output Data for 3D view of an X-ray absorbed dose distributions

- **Click** the button "Analysis of the dose", the form "Dose map for corresponding layer and package " will be opened (see Fig.23).

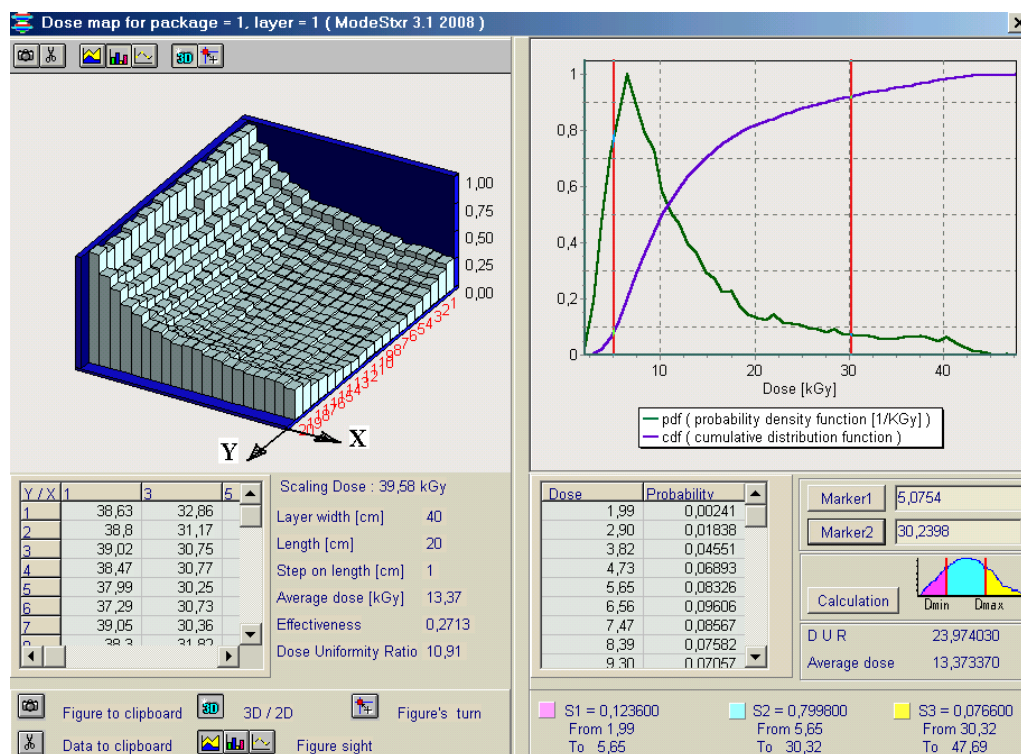


Fig.23. Left Graph -3D view of the X-ray depth dose distributions (Dose Map, along layer length (axis Y) and along layer width (axis X)) in graphical and tubular forms for the 1st layer in 2nd package. The dose value is integrated along layer thickness (axis Z).

Right graphs: Cumulative distribution function – cdf (violet curve), and Probability density function in 1/kGy – pdf (green curve).

- To make analysis of the functions “Probability density function” and “Cumulative distribution function” you can use **two Markers** located under **Right graphs: Marker 1 and Marker 2.**

Click the button “**Marker 1**”, **enter** a cursor in the plot field. **Locate** the **vertical red line** on the one point of the dose axis by clicking mouse in the chosen point.

Click the button “**Marker 2**”, **enter** a cursor in the plot field. **Locate** the **vertical red line** on the second point of the dose axis by clicking mouse in the chosen point.

The plot will be separated with markers on three parts accordingly with scheme near the button “**Calculation**”.

Click the button “**Calculation**”.

The integral of function “pdf” for the three parts will be appeared in the right downside of the “Dose map” form.

• Additional information related to 3D view of an X-ray absorbed dose distribution in the selected layer are presented in the form:

- Average dose
- Effectiveness
- Dose uniformity ratio

6.5. Output Data for 3D dose calculation

• Click the button "Show 3D results" in the Form with 2D depth dose distribution, the form of "Results of 3D calculation" will be opened for analysis of 3D absorbed dose distribution for the 5th layer in the package. (See Fig.24).

This layer was enter as input data in the Target example for simulation. (See Fig.17).

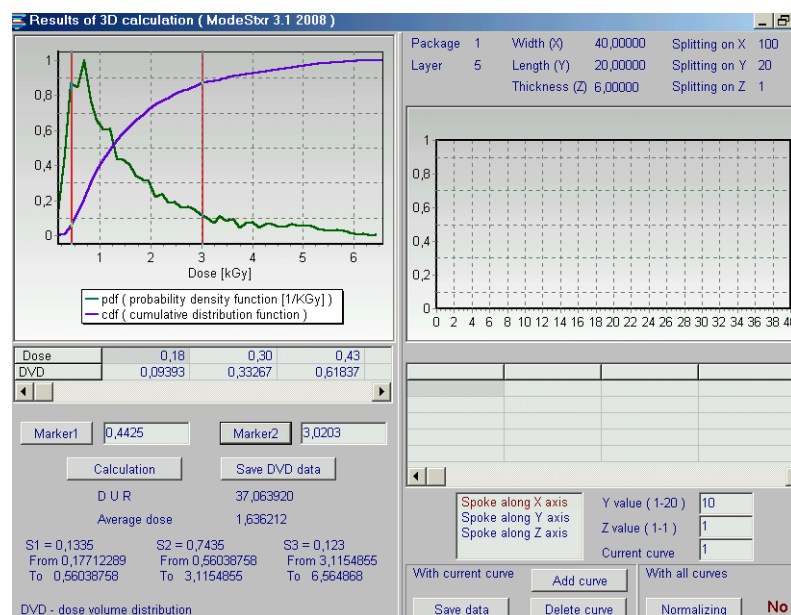


Fig.24. The form of "Results of 3D calculation" for analysis of 3D absorbed dose distribution in the 5th layer of the package.

3D absorbed dose distribution of X-ray for any target layers can be analyzed with "spokes method".

The method includes the following operations:

- the layer volume is splitted by 3D grid with bin (cell) size $\Delta V = \Delta X \cdot \Delta Y \cdot \Delta Z$. Where $\Delta X = \text{Width} / N(x)$, $\Delta Y = \text{Length} / N(y)$, $\Delta Z = \text{Thickness} / N(z)$. $N(x)$, $N(y)$, $N(z)$ – the number of splitting along the Layer Width (axis X), Length (axis Y) and Thickness (axis Z) respectively.
- the "spokes" can cross over the layer in any point of its surface in directions of axis X, axis Y, and axis Z perpendicularly to planes of a layer.
- the absorbed dose distribution is calculated in the "spokes" volume in directions of axis X, axis Y, and axis Z.

- the “spoke” volume (size) in directions of axis X, $V(X) = \text{Width} \cdot \Delta Y \cdot \Delta Z$
 - the “spoke” volume in directions of axis Y, $V(Y) = \text{Length} \cdot \Delta X \cdot \Delta Z$
 - the “spoke” volume in directions of axis Z, $V(Z) = \text{Thickness} \cdot \Delta X \cdot \Delta Y$
- at calculation the dose distribution along spokes, the absorbed dose averaging in each splitting point along spoke is realized in volume $\Delta V = \Delta X \cdot \Delta Y \cdot \Delta Z$.

Example of target layer with grid and spokes is presented in Fig.25. Layer is located on a conveyer platform.

Spoke A cross over a layer thickness along axis Z.

Spoke B cross over a layer length along axis Y.

Spoke C cross over a layer width along axis X.

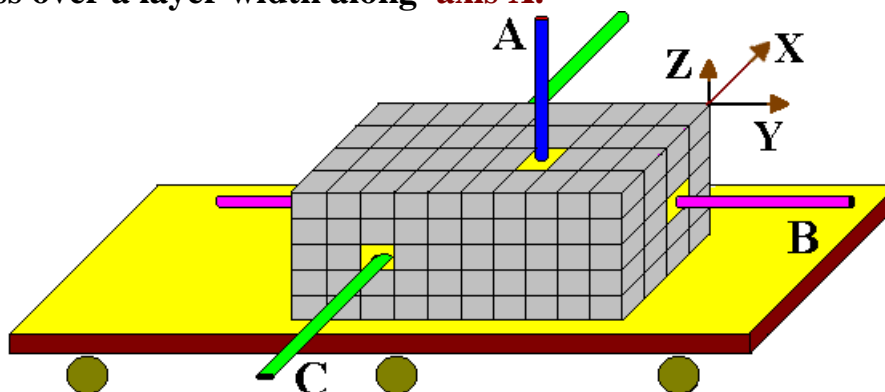


Fig.25. Target layer with grid and spokes located on a conveyer platform.

For above example (see Figs. 2 and 24) all geometrical characteristics (Thickness, Width, and Length) and splitting along axis X, axis Y and axis Z for the 1st layer in 2nd package are presented in Fig.24 (right upside).

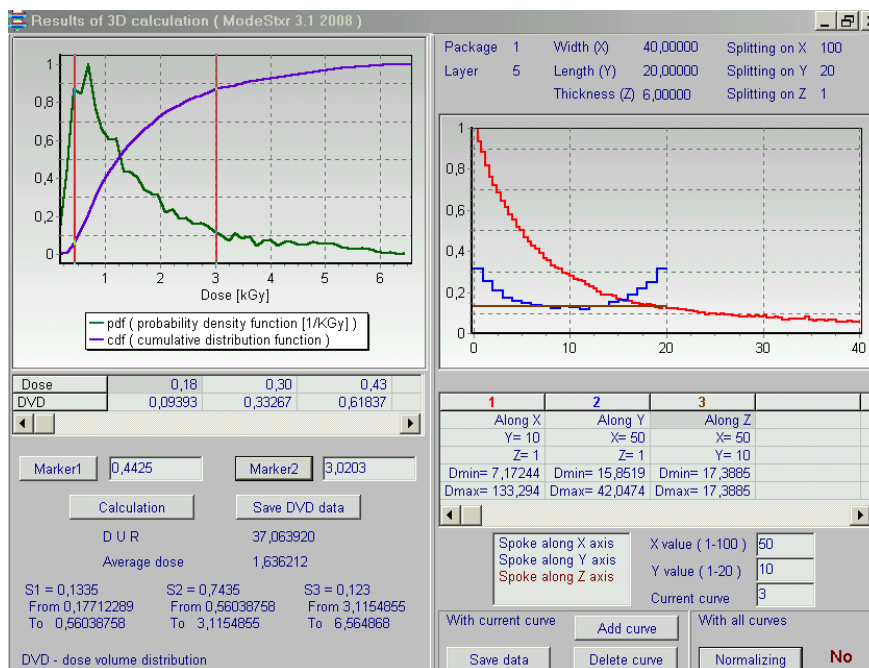


Fig.26. The form of "Results of 3D calculation" for analysis of 3D absorbed dose distribution.

The sequence of operations to calculate an absorbed dose distribution along any spokes is the following (see Figs. 24 and 26):

- **Select and Click on direction of the “Spoke along axis X, Y, or Z”.**
Selected direction will be painted in **brown colour**.
- For example, Chosen direction is “Spoke along axis Z”. (see Fig. 26).
For X and Y directions the possible values of coordinates in the XY plane will be appeared.

The cells number along axis X are in the range from 1 to 40.

The cells number along axis Y are in the range from 1 to 50.

The cells number along axis Z are in the range from 1 to 100.

Maximal number splitting cells along any axis is 100.

- **Enter the number of cells in the range from 1 to 40 into window “X value (1-40)”.**
- **Enter the number of cells in the range from 1 to 50 into window “Y value (1-50)”.**
- **Click the button “Add curve”.**

The **6 windows** with colour identification and for general characteristics of dose distribution for 6 curves will be opened. The general characteristics for the first dose distribution will be located in the first window frame.

The graph for the first curve for dose distribution will be appeared in the special window (see right upside Fig.26).

- Another curves for calculated dose distributions along spokes can be located in any of 6 windows. Maximal number of curves for simultaneously analysis is six.

- **For this, mark by cursor any of 6 windows.**

Select and Click on direction of the “Spoke along axis X, Y, or Z”.

Enter the number of cells in plane which will be intercrossed by spoke.

Click the button “Add curve”.

- **You can “Delete curve”, “Add curve” make “Normalization” of all curves.**
- **You can “Save data” for any of curves for further analysis.**

- **In the left frames of the “Results of 3D calculation” form, you can make the dose volume histogram analysis, DVH, in the selected layer.**
(see Figs. 24 and 26).

DVH is characterized by functions “pdf” and “cdf”.

- **To make analysis of the functions “Probability density function” and “Cumulative distribution function” you can use two Markers located under Left graphs: Marker 1 and Marker 2.**

Click the button “Marker 1”, enter a cursor in the plot field. Locate the vertical red line on the one point of the dose axis by clicking mouse in the chosen point.

Click the button “Marker 2”, enter a cursor in the plot field. Locate the vertical red line on the second point of the dose axis by clicking mouse in the chosen point.

The plot will be separated with markers on three parts along **axis Dose**.

Click the button “Calculation”.

The analysis of **DVH data results** for the three parts will be appeared in the left downside of the form **"Results of 3D calculation"**.

- You can **save** the analysis of **DVH data** by use the button **“Save DVH data”**.

7. Comparison of simulation results

Module “Comparison” is intended for the scientific analysis and comparison of calculated data of 2D absorbed dose distributions in an irradiated multilayer target.

- **Click the button “Comparison”** in the Main form of the **Software ModeStXR** (See Fig.1).

The form of **" Comparison of calculated curves"** will be opened for analysis of calculated 2D absorbed dose distributions in an irradiated target layers (See Fig.10).

The analysis can be carried out with **current calculated data** or **data calculated before**.

- **Choose** for analysis the calculated curve in the frame under the window **“Number of the curve”**. For that, tick the chosen curve with cursor.

There are the following variants of calculated curve for the choice:

1. **“After Monte Carlo calculation”** – it is the results of current calculation of the dose distributions in the multilayer target.
2. **“Prepared stored results”**- it is simulation results of the 2D dose distributions which were previously stored in the files.

These results can be selected for comparison only when the following sequence operations will be done before the selection:

- **Click the button “Open and view results from the file”** in the Main form of the Software **ModeStEB**. (See Fig.1).

The 2D dose distribution will be appeared in the form **"Dose distributions after MC simulation"** from the chosen file.

- **Click the button "Prepare store results to compare"** in the form **"Dose distributions after MC simulation"**. (See Fig.21).

3. **“Converted dosimetric file”** – it is result which was calculated and saved for the EB dose distribution along any spokes in the form of **"Results of 3D calculation"** and further converted through the **block “Dosimetry”**. (See Fig.24).
4. **“After dosimetric block”** - it is results for dose distributions which were obtained and saved after processing of dosimetric films with the **block “Dosimetry”**.

- **Select** the position of dose distribution in the **Center** or **Boundary** of irradiated layer for the chosen curve of 2D dose distribution.

- **Select** the number of package **_P_** and number of layer **_L_** in the **Registration table**.

- **Enter** the value X in cm in the window "X position" for the chosen curve, if it is necessary. X position is characterized the displacement of curve of 2D dose distribution along axis X relatively the value X=0. In the **default mode** the value of "X position" = 0.
- **Select** by cursor the any of 6 columns of the table in the bottom part of the form the "Comparison of calculated curves". The chosen column number will be automatically entered to the window "Number of the curve".
- **Click** the button "Load curve from X position".

The characteristics of the 2D dose distribution curve will be appeared in the chosen column. And the graph of the 2D dose distribution curve will be appeared in the graph area.

In a such way you can enter for analysis up to 6 curves of 2D dose distributions in the graph area. (See Fig.27).

You can "Delete selected curves" and make for all curves "Normalization". (See Fig.27).

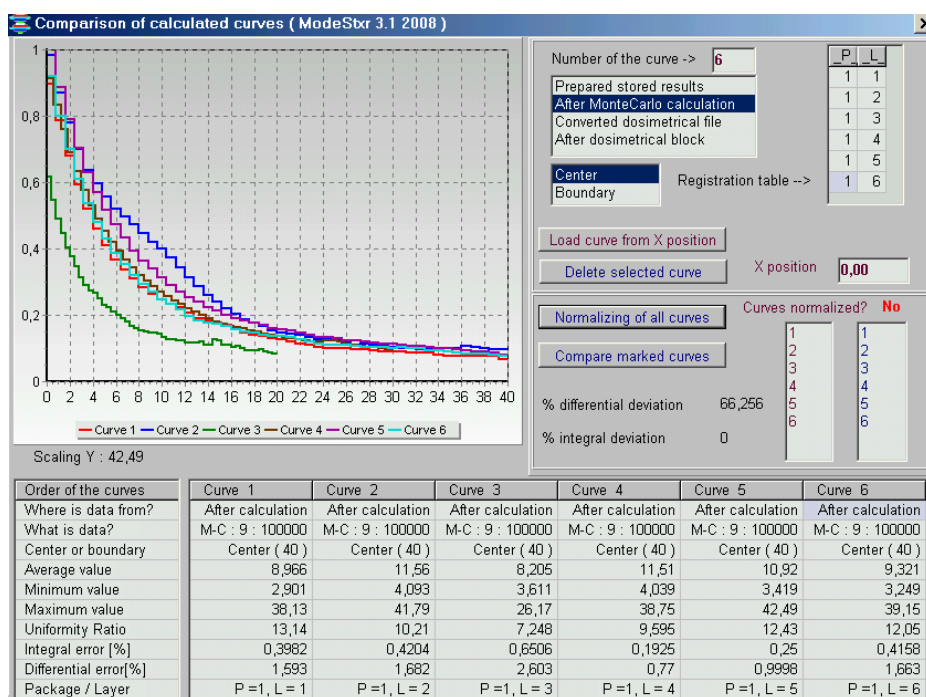


Fig.27. The form of "Comparison of calculated curves".

Example of 2D dose distributions for some layers calculated along layer width for multilayer target with composition presented in Fig.17.

The function of button "Compare marked curves" allows to make comparison of 2D dose distributions for 2 any curves to obtain the values of differential and integral deviations in % between compared curves. (see Fig. 27).

For that, **select** the numbers of 2 compared curves and **click** the button "Compare marked curves".

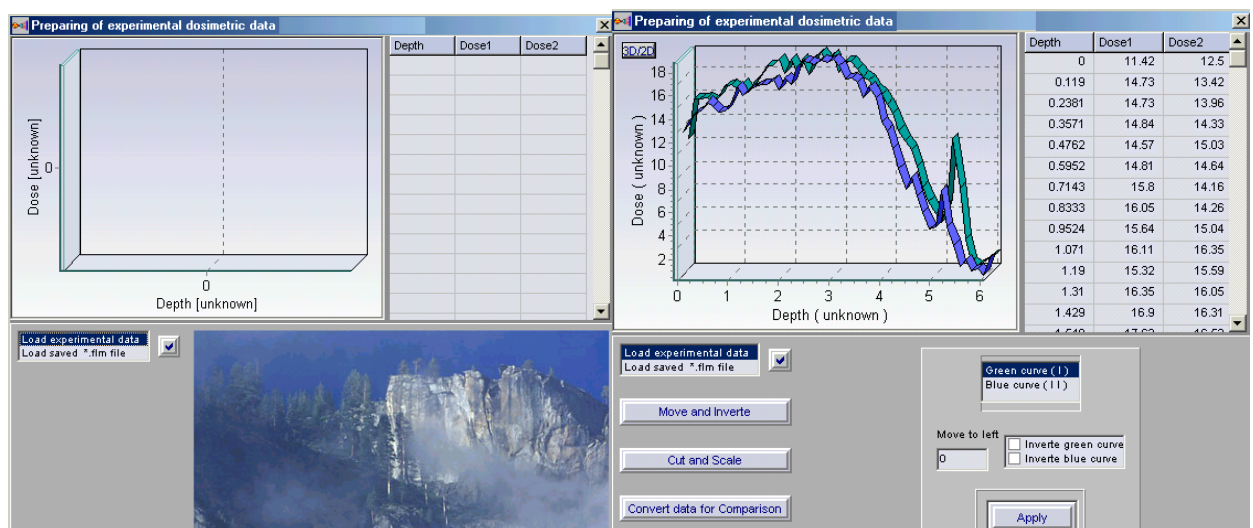
• **To copy** the results comparison into your document, **Click** the graph by right mouse button.

Then **Click** the button **“Plot mode 2D/3D”**, if it is necessary, and then **Click** the button **“Plot to clipboard”** and **paste them** to your document.

8. Dosimetry module

Block **“Dosimetry”** is intended for processing of dosimetric films with experimental data and to prepare data for **“Comparison”** module.

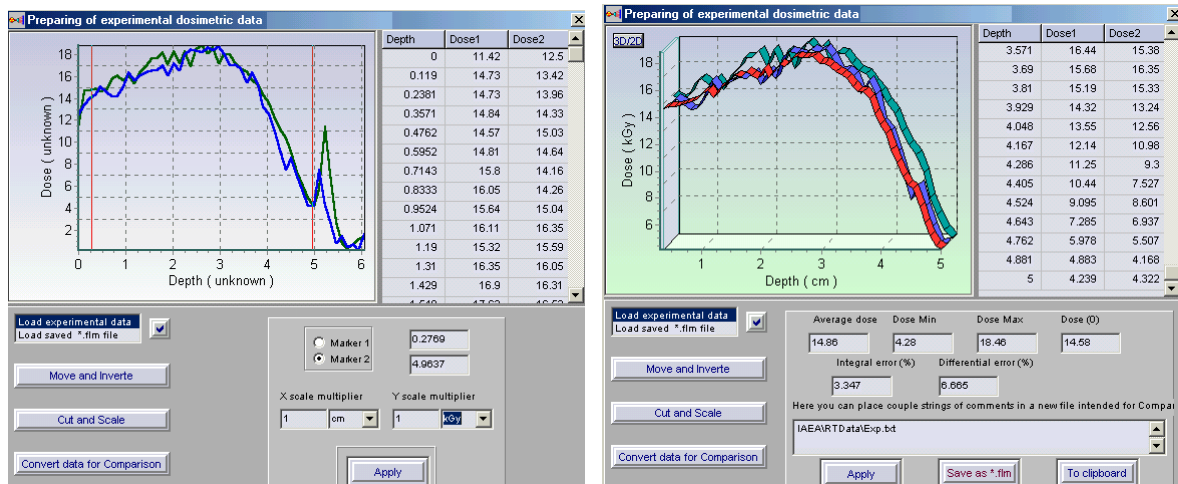
• **Click** the button **“Dosimetry”** in the Main form of the **Software ModeStXR** (See Fig.1). The form of **“Preparing of experimental dosimetric data”** will be opened for analysis of calculated and experimental data of 2D absorbed dose distributions in an irradiated target (See Fig.28.a).



Figs. 28 a, b. The forms for **“Preparing of experimental dosimetric data”**.

• **Load a text file** with experimental data from hard disk. A file may contains three or two columns (X and Y, or X, Y1, Y2). (See Fig.28 b).

Loaded data are showing onto the plot and into a grid and the buttons **Move and Inverte**, **Cut and Scale**, **Convert data for Comparison** appear. (See Figs.29 a, b).



Figs. 29 a, b. The forms for “Processing of experimental dosimetric data”.

- To move selected curve to left or invert one you need to use the control panel that will open when the button **Move and Invert** is pressed. To save changes, press the button **Apply**.
- Click the button **Cut and Scale**, to cut and scale curves data.
- To cut a part of curves you mark by a circle **Marker 1** and move a mouse pointer to the plot. In this point a vertical red line appears onto plot. You move it and place by left mouse clicking. It is a first limited line. You make the same with **Marker 2** and place a second red line. (See Fig.29. a).

You must scale the curves and press **Apply**. A part of curve placed between two red lines will be saved, a plot will repaint and a grid will rewrite.

The button **Convert data for Comparison** and its control panel provides the data for **Comparison** block. If you have made a scale of curves the pressing of **Apply** creates a new red curve onto plot and shows new data in the grid.

(See Fig.29. b).

These data may be stored to a file with using **Save as “*.flm”** file.

You can work with a film file if load it.