

Manual for simulation of EB processing

Modeling of the 3D EB dose distribution with MC method

Software ModeStEB

Modeling of 3D EB dose distribution with MC method.

The program ModeStEB consideration

The program **ModeStEB** was designed specially for MC simulation of industrial radiation processing and calculation of the **3D absorbed dose distribution** within products irradiated by **stationary or scanned electron beams** on industrial radiation facility 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:

- 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 an irradiated target.

3. The comparative analysis of visual and numerical difference of 3D depth-dose distributions in a layer for:

- various parameters of calculation;
- various calculation models;
- an experimental and calculated depth-dose distributions in a layer.

4. Prediction and interpretation of measurement results in film dosimetry

- Simulation by a Monte Carlo method of a dose profile in dosimetric films located in objects with heterogeneous structure and irradiated with scanned electron beams.

- Treatment of measurement results of an electron beam dose profile in dosimetric films and their comparative analysis.
- Interpretation of measurement results of an electron beam dose profile in dosimetric films on the base of comparative analysis with simulation results.
- Refinements of parameters and operation regimes for radiation installation (EB Irradiator) on the base of comparative analysis of measurement results of an electron beam dose profile in dosimetric films with simulation results.

The features of the software **ModeStEB 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. Built-in tools for dose volume histogram (DVH) analysis.
5. Estimation of uncertainties for physical models.
6. Comparison Modulus for visual and a numerical analysis of calculated and experimental data and for decision of optimization tasks in radiation processing.
7. 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 of the RT-Office.

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

Software ModeStEB. How to get results.

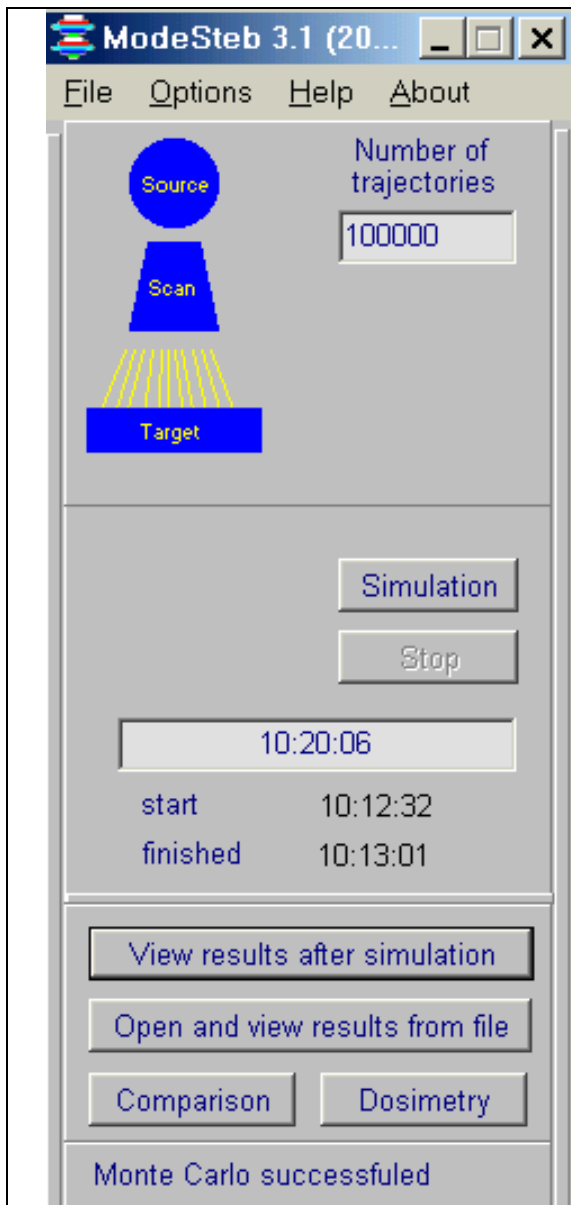


Fig.1. The main form of the Software ModeStEB

Software **ModeStEB** is intended for simulation of the 3D absorbed dose distribution in a product irradiated by stationary or scanned electron beams on industrial radiation facility that is based on the pulsed or continuous type of electron accelerators in the energy range from 0.1 to 50 MeV..

Software **ModeStEB** consists of four thematic modules and service blocks. See Fig. "The main form of the Software ModeStEB".

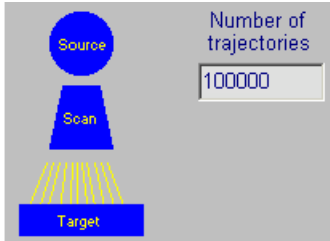
- "Monte Carlo" (MC) simulation module is intended for exact calculations of Gamma ray absorbed dose in irradiated target.
- "Comparison" module is intended for scientific analysis and comparison calculated and prepared experimental data for the 2D dose distributions.
- "Dosimetry" module is intended for preparing of experimental data. This tools allows to load data files, invert and move each experimental curve, cut and scale, transform to format of Comparison module.
- "Viewer of results" module is intended for visualization, analysis and handling the results after simulation and the previously obtained results stored in the files.

For work with software **ModeStEB** -

- Click the "File" then "Open configuration", then to select "irradiating system" and load the file "Test.rts".
- Click the "File" then "Open configuration", then to select "irradiating system" and load the file "Test.rtt".

After loading the "Test.rts" and "Test.rtt" files, user can change all characteristics of gamma ray facility and irradiated target for simulation of gamma ray processing.

1. Source



- Click “**Source**” in the Scheme of **Monte Carlo Module, MC**. See Fig. 1.1.

The form for **Source** – Electron Accelerator parameters will be opened. See Fig. 1.2.

Fig.1.1. 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. 1.2. The form of “Source” for input data and correction of an electron beam parameters.

Beam current

The frame Beam current consist of 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 Ampere (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.

EB energy spectrum

Fields for EB energy are placed into the frame Spectrum.

- Click the field “MonoEnergy” with a tick, to work with Mono Energy mode.
- Enter a value of the Energy in MeV.
- 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.

Angular spread

- **Click** the field MonoDirect by a tick, to work with MonoDirect mode.
- **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.

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".

2. Scanner and Conveyer

- **Click** "Scan" in the Scheme of Monte Carlo Module. See Fig. 1.1.
- The form for Scanner and Conveyer parameters appear. See Fig. 2.1.
- **Enter** values of Speed in cm/sec, Width in cm in the frame **Conveyer**.
 - **Enter** values of Frequency in Hz, scan horn Height in cm in the frame Scanning horn.

Fig.2.1. The form for the **Scanner** and **Conveyer** parameters.

- **Enter** values of Distance scan-conveyor in cm and Width of scanning in cm in the frame Geometry.

- **Click** the field “Non-divergent beam” by a tick, to work with parallel ray scanned EB. The target will be irradiated with non-divergent scanned electron beam.
- **Click** the field “Triangular scanning” by a tick, to work with triangular scanned electron beam.

The target will be irradiated with triangular scanned electron beam.

- **Click** the window “Default mode” by a tick, to work with linear time-current curve in scan magnet (saw-tooth form of current).
- **Click** the window “Custom mode” by a tick, to work with the nonlinear time-current curve.
- **Enter** a rows number of the table.
- **Click** the button "Correct table" and work as well as with tables for an electrons source. The values of time and current are dimensionless.
- **Click** the button "Save data and close this window".

- **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 Monte Carlo Module will changed into blue color.

3. Target

3.1. The form for enter of input data of irradiated Target and Cover

- Click “Target” in the Main form of the Software ModeStEB (See Fig.1.1). The form for enter of input data of irradiated Target and Packing materials (Cover) will be opened (See Fig.3.1).

Target and cover (ModeSteb 3.1 2008)

Number of packages Multi - Target
 Distance between targets

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

Width of packages
 Stack length

2D registration package + level

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

3D calculation
 3D registration package + level

P	L
1	3

Current layer Delete Insert Clear

Layer	1	2	3	4	5
Thickness	3	0,03	3	2	1
Width	10	1,6	10	8	5
Density	0,44	1,3	0,6	0,2	0,5

Birchwood
 Cellulose
 Soft Tissue
 Water
 Teflon
 Aluminum
 Iron
 Another material

	Z	W	Z	W	Z	W	Z	W	Z	W
1	6	1	10	1	8	1	1	1	2	
6	49	6	72	6	60	6	12	8	16	
7	1	8	80	8	32					
8	44									

Density
 Cover thickness
 Additional cover

List Opened cover
 Table

Correct table for a cover
 Rows

A number	W part
1	1
6	12

Fig.3.1. The form for enter of input data for an irradiated Target and Packing materials (Cover).

3.2. Multi-layer target model

Geometrical models of multi-layer targets irradiated with electron beam are presented in Figs.3.2 and Figs.3.3.

- **Multi-layer target** consists of some identical packages with **flat sheets** of materials with various density and atomic number.
 - **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.3.2 and Figs.3.3).
 - **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.3.4).

The **distance between boxes** with Multi-layer targets is not limited.

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 EB axis. (See Figs.3.2 and Figs.3.3).

Note. In any layer positions under EB irradiation, axis **coordinates X, Y, and Z** are hard connected with **width (X), length (X), and thickness (Z)** of target layers. (See Figs.3.2 and Figs.3.3).

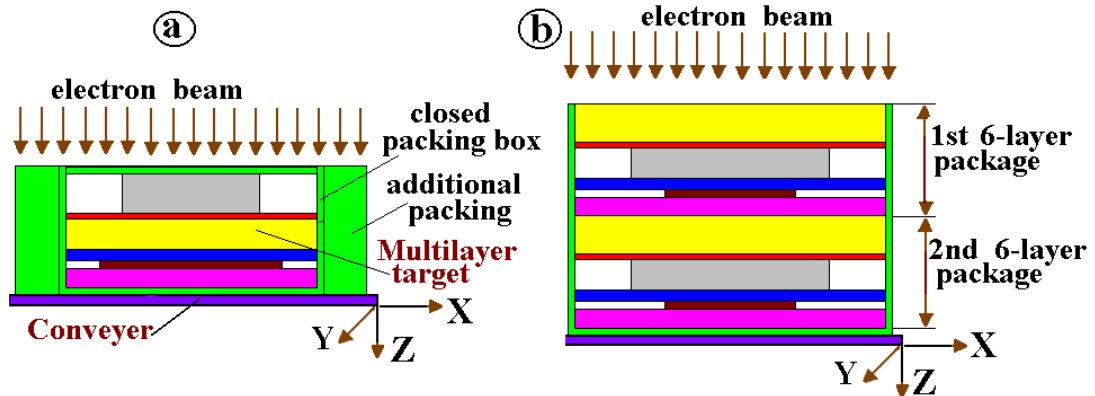


Fig.3.2. Geometrical models of multi-layer targets placed on moving conveyer and irradiated by normally incident electron beam.

Conveyer moves along axis Y. Electron beam scans along axis X.

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

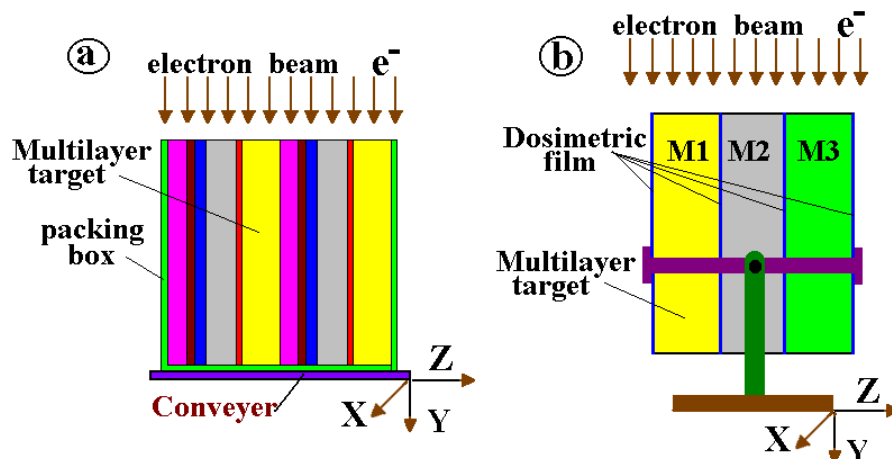


Fig. 3.3. Geometrical models of multi-layer targets irradiated by incident EB in parallel with interface of contacting materials.

Conveyer moves along axis X. Electron beam scans along axis Z.

- (a) Multi-layer target consists of two identical 6-layer packages placed in open packing box and irradiated by incident EB in parallel with interface of contacting materials.
- (b) Multi-layer target with dosimetric films inserted between interface of contacting materials and irradiated in parallel with EB.

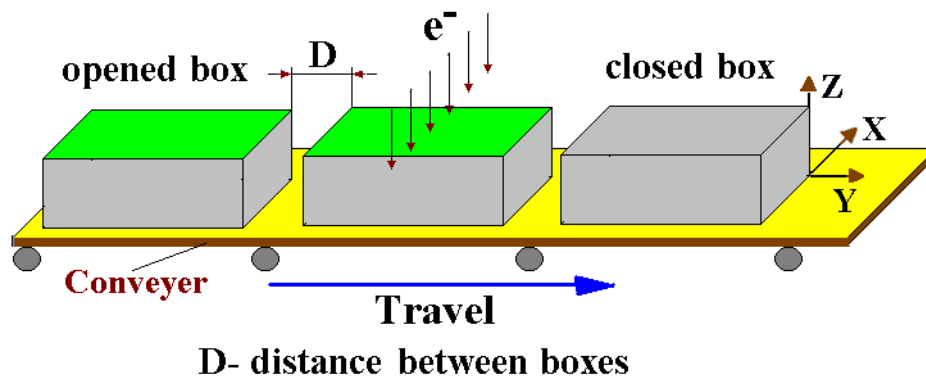


Fig. 3.4. Geometrical model of 3 identical Multi-layer targets with packing box located on the conveyer platform.

3.3. Input data for layers size and layers materials (Fig.3.1)

- 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.3.1).
- Enter the **"Width of packages"** in cm (left up corner in the **"Target"** frame) (See Fig.3.1).
 - 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.

3.4. 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 EB either in **closed or open** (Tick window "**Opened cover**") **Cover Box**. (See Fig.3.1).

3.5. Input data for layers orientation on a conveyer platform under EB irradiation

- **Simulation model of the software ModeStEB** for target irradiation allows to irradiate the box with flat layers from all of six box sides (**any of six box sides**). **The choice of target orientation** relatively incident EB is realized with the **switch "Orientation"** (See Fig.3.1. and Fig.3.5).

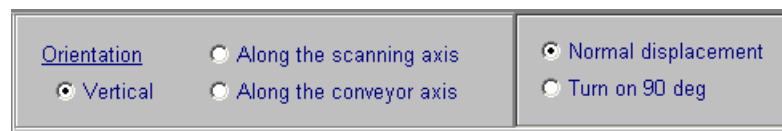


Fig.3.5. Frame with mode switch of orientation for target layers under EB irradiation

- **Switch positions ("Vertical" and "Normal displacement")** in Fig.3.5. 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.3.6.1.

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

- All possible positions of layers orientation on a conveyer platform under EB irradiation and corresponding switch positions are presented in

Figs. 3.6.1, 3.6.2, 3.6.3, 3.6.4, 3.6.5, 3.6.6.

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

- All above possible positions under EB irradiation also can be realized for package of flat layers placed in open/closed box (**See Figs.3.7.1 and 3.7.2**) and for package of flat layers placed in open/closed box with additional cover (**See Figs.3.8.1 and 3.8.2**). Additional cover always covers only the box sides in direction of layers thickness (**along axis Z**).

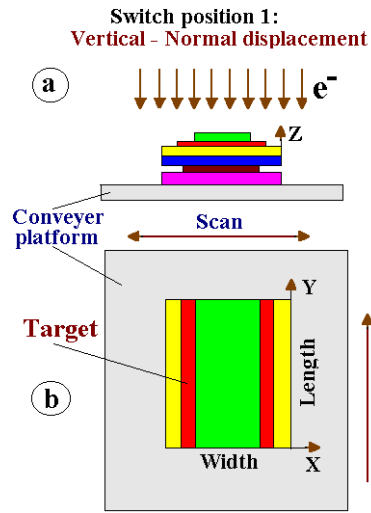


Fig. 3.6.1

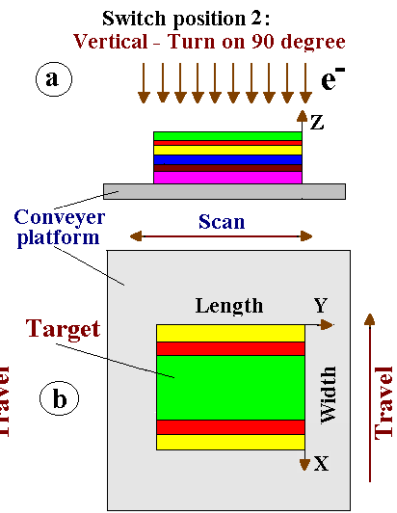


Fig. 3.6.2

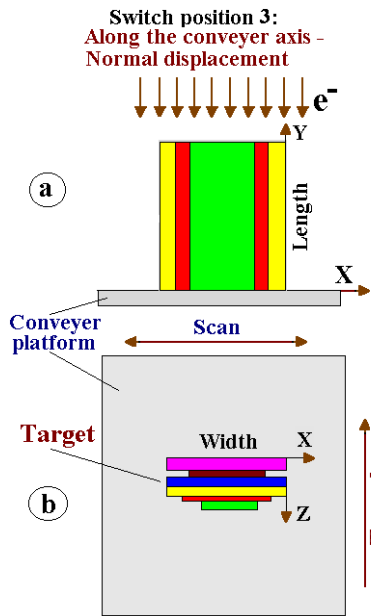


Fig. 3.6.3

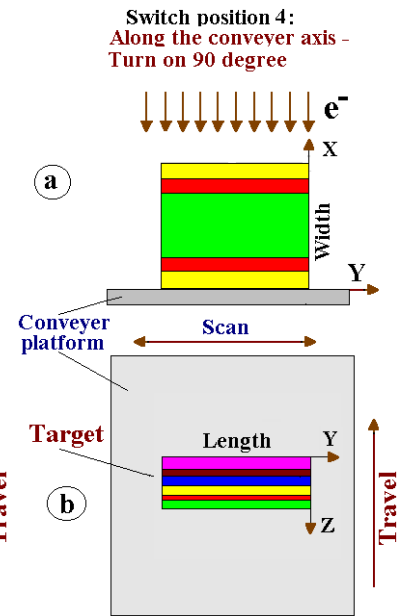


Fig. 3.6.4

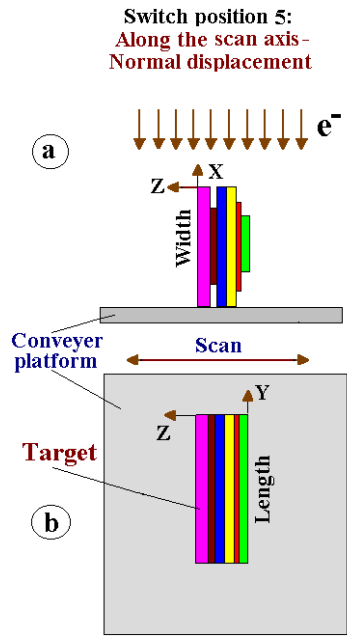


Fig. 3.6.5

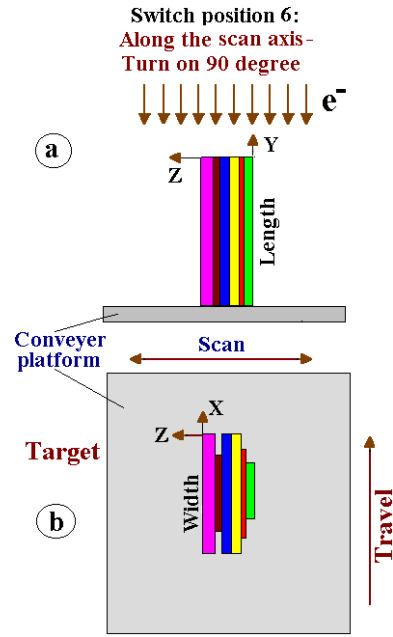


Fig. 3.6.6

. Figs. 3.6.1, 3.6.2, 3.6.3, 3.6.4, 3.6.5, 3.6.6. Layers orientation on a conveyer platform under EB irradiation and corresponding switch positions

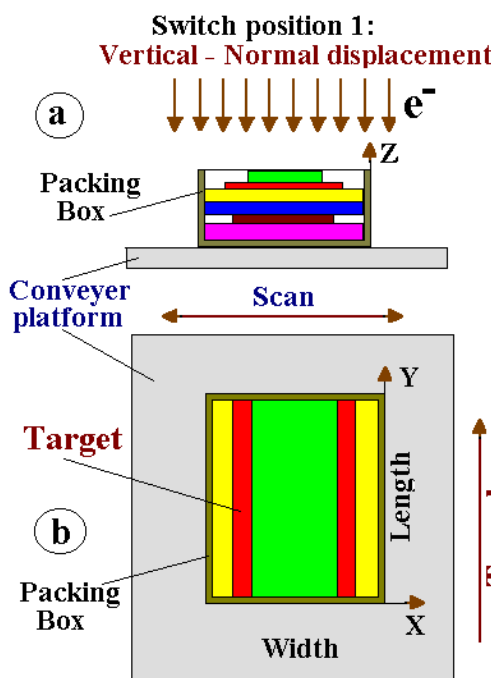


Fig. 3.7.1

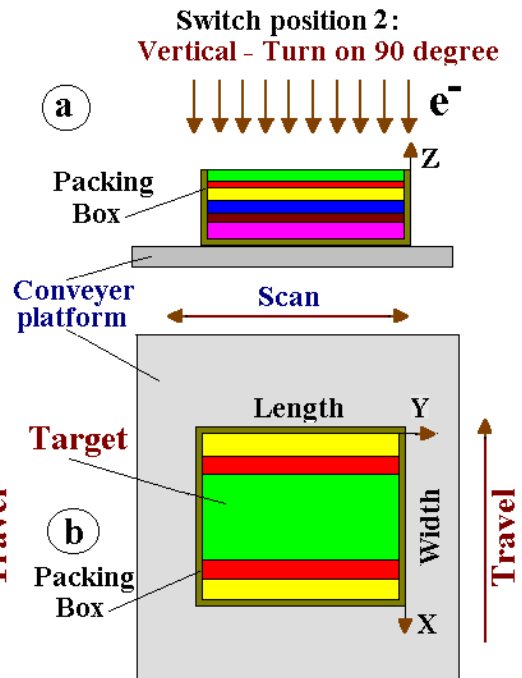
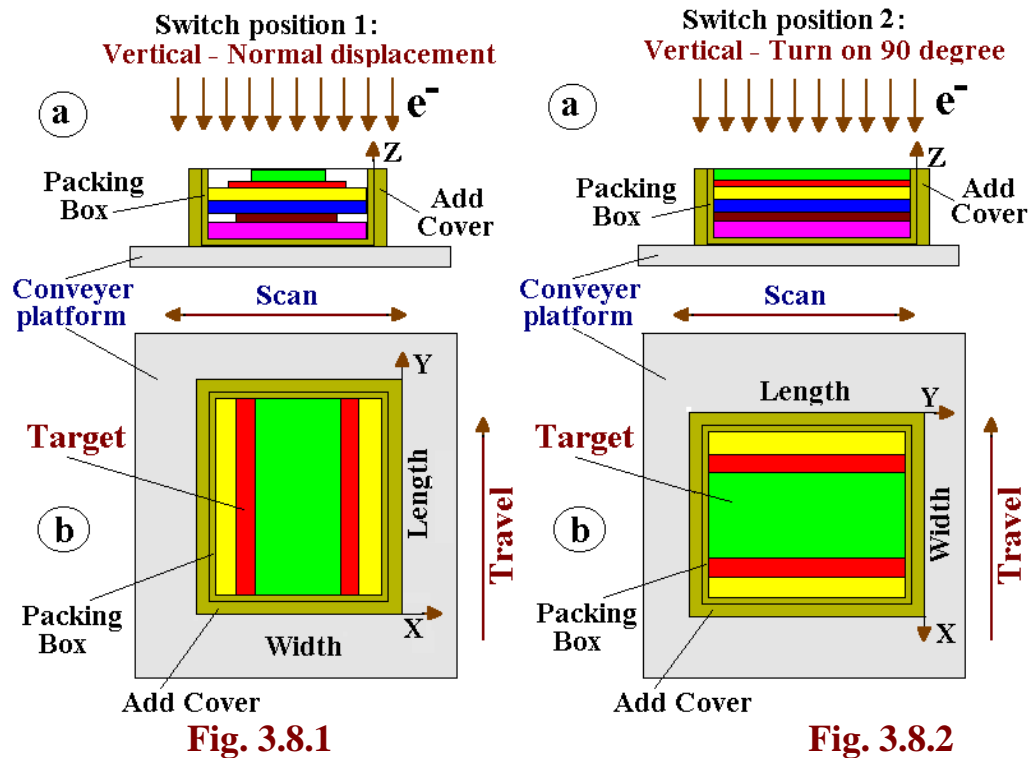


Fig. 3.7.2

Figs. 3.7.1 and 3.7.2. Some possible orientation positions on a conveyer platform for package of flat layers placed in open packing box



Figs. 3.8.1 and 3.8.2. 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

3.6. Input data for irradiation of several 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 dose field formation in the target layers.

- Tick the window "**Multi-target**". (See Figs. 3.1 and 3.9).
- Enter the value “**Distance between targets**” in cm.

The **distance between boxes** with Multi-layer targets is not limited.

Multi - Target

Distance between targets

Fig.3.9. The form for entering of input data for Multi-target.

3.7. Input data for Table “2D registration”

The screenshot shows a software window titled "2D registration" with a sub-label "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 smaller version of the "2D registration" table.

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

Below the table, there is a checked checkbox labeled "3D calculation".

Below the checkbox, there is a smaller version of the "2D registration" table with the same structure and data.

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. 3.1 and 3.10).

Fig.3.10. 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.

3.8. 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**) will be presented in the graphical and tabular forms. (See Figs. 3.1 and 3.10).

- Tick the window "3D calculation". (See Figs. 3.1 and 3.10).
- 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** 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.

4. Options

4.1. Options. General description.

Some parameters of interaction processes of ionizing radiation with product which are essential influence on value of absorbed dose are included as input data of software in form of “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”, “Air detail”, and “Automatic”.**
- **Parameters simulation: Energy cut off, Threshold energy, 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 ModeStEB 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.4.1a.

All parameters of Options can be changed only in regime “Manual parameters”. See Fig.4.1b.

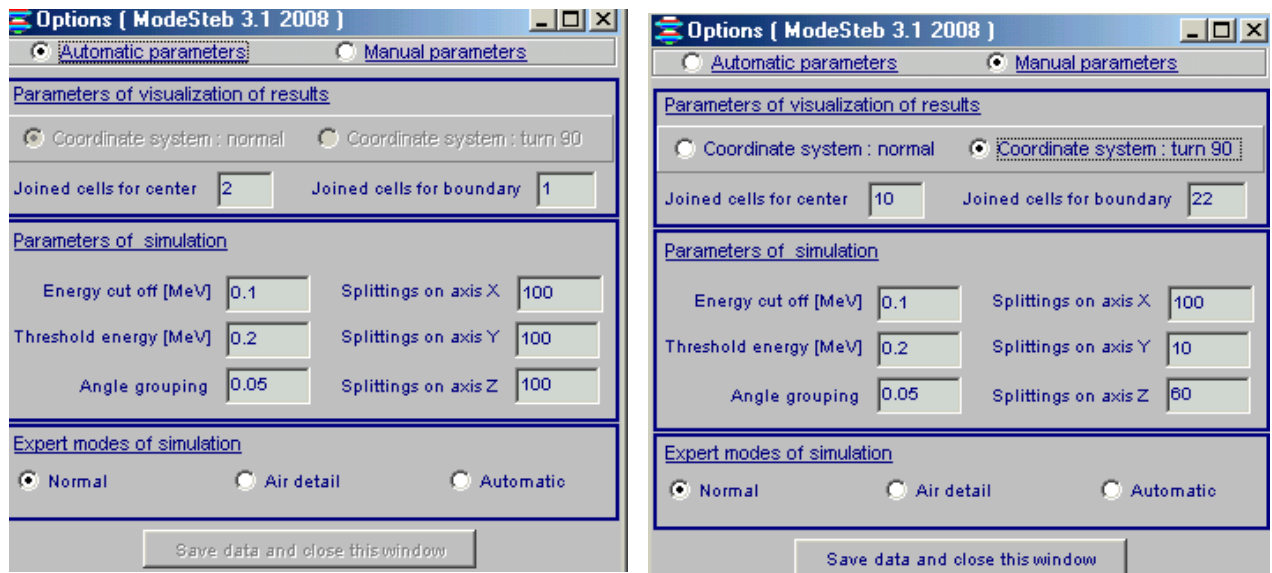
4.2. Expert modes of simulation: “Normal”, “Air detail”, and “Automatic”.

Mode simulation “Normal”. It is standard regime with automatic choice of the parameters simulation such as Energy cut off, Threshold energy, Angle grouping. In this regime the errors can be appeared only in case of the transport of stationary EB through big volume of materials with low density like air.

Mode simulation “Air detail”. In this regime additional to **“Normal” regime** the transport of stationary EB through big volume of materials with low density like air is considered in detail.

Mode simulation “Automatic”. It is precise regime with automatic choice of the parameters simulation such as **Energy cut off, Threshold energy, Angle grouping**. In this regime the influence of materials with low density like air gap between layers and very thin foils are taken into consideration in detail at calculation of EB dose distribution in the multilayer package of irradiated target.

Note . The run time of simulation in **“Automatic” regime”** is greater in about 3 times in comparison with **“Normal” regime.**



Figs.4.1. a, b. Form of “Options” for enter of input data for simulation EB processing.

a) default mode “Automatic parameters”. b) regime “Manual parameters”.

4.3. Parameters of visualization of results.

“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**.

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”**.

4.4. Parameters simulation: Energy cut off, Threshold energy, Angle grouping, and Splitting on axis X, Y, Z.

- **Change of simulation parameters “Energy cut off, Threshold energy, Angle grouping”** can be used for scientific researches of transport irradiation through heterogeneous targets.

Because in all above the **Expert modes of simulation “Normal”, “Air detail”, and “Automatic”**, parameters simulation such as **Energy cut off, Threshold energy, 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.

Note. In all **Expert modes of simulation** such as “Normal”, “Air detail”, and “Automatic”, parameters simulation such as **Energy cut off, Threshold energy, Angle grouping** are automatic installed as optimal values.

5. Dosimetry module

Module “Dosimetry” is intended for processing of dosimetric films with experimental data and for preparing these data for **“Comparison”** module. **Module “Dosimetry”** is intended for calculation and analysis of the EB absorbed dose distributions.

- Click the button **“Dosimetry”** in the Main form of the **Software ModeStEB**. 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.5.1.a).

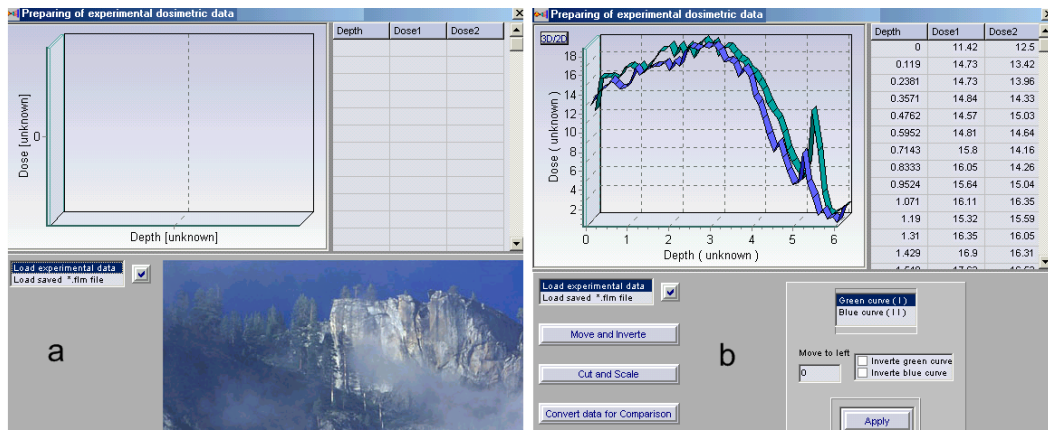


Fig.5.1. a, b. The forms for “Preparing of experimental dosimetric data”.

- Load a text file with experimental dosimetric data from dosimetric films which are located on hard disk. A file may contains three or two columns (X and Y, or X, Y1, Y2). (See Fig. 5.1. b).

Loaded data in graphical and tubular forms will be appeared in the form “Preparing of experimental dosimetric data” (See Fig.5.2. a, b).

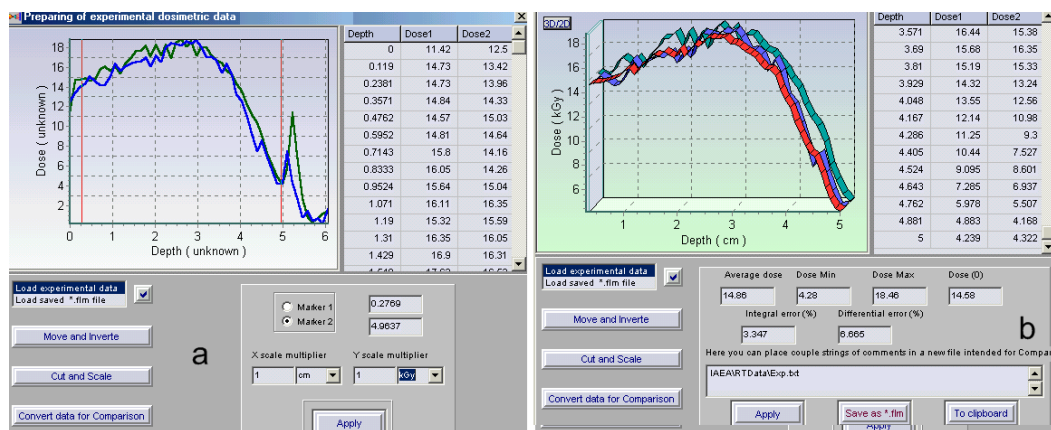


Fig.5.2. a, b. The forms for “Processing of experimental dosimetric data”.

- 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, select by a tick the **Marker 1** and move a mouse pointer to the plot. In this point a vertical red line appears into 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. 5.2. a).

- **Click** the **button “Apply”**, to scale the curves. A part of curve placed between two Markers will saved, a plot will repaint and a grid will rewrite (See Fig.5.2. b).

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 show new data in the grid.

(See Fig.5.2. b).

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

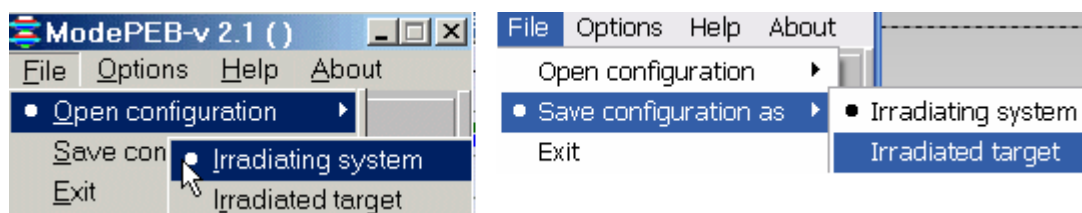
You can work with a film file if load it.

6. Service blocks

Tools for data manipulation (**service blocks**) are used in the Software ModeStEB.

The Software ModeStEB has block **to save and open input data** related with configuration of irradiation process.

- **Click** the **File** in the main form of Software ModeStEB.
- Select “**Save configuration**”.
- Enter file name and save input data for “**Irradiation system**” and “**Irradiated target**”.
- To work with previously saved configuration, Select “**Open configuration**”, then “**Irradiation system**”/ “**Irradiated target**” from the list of configuration files.



The Software ModeStEB has some viewers of calculated results.

- The viewer "**Dose and Charge distributions after MC simulation**" with **2D absorbed dose and charge distributions** in graphical and tabular forms for chosen packages and layers in the Table “**2D registration**”.

This viewer is intended for showing of the plots with **2D absorbed dose and charge distributions** for center and boundary of the target layers. There are tables of calculated results and some important characteristics.

- The viewer “**Dose Map**” is used for analysis of **3D view of dose distribution** in the target layers:

1. **3D view of the dose distributions (Dose Map)** in graphical and tubular forms for the chosen layer and package.
2. **Dose volume histogram (DVH) analysis: Cumulative distribution function and Probability density function.**
3. **Results of spokes method analysis.**

There are some service blocks to processing of calculated results in graphical forms. You can turn figure of diagram and select optimal angle, you can send figure to clipboard and paste in any documents. At the bottom of viewers screen form there are hints about buttons actions.

- Every page has button “To clipboard”.
- You can save calculated result on hard disk as file “*.mon” after MC calculations.
- You can see all “Configuration data” of radiation facility parameters, target characteristics, regimes irradiation for current calculation with use the button “Eye”.
- You can increase some area selected on the plot to have the better view. To do it, you need to place cursor above this area. Press left mouse button (it is the left top corner of rectangle) and holding down this button, draw down rectangle around plot area. The point where you release left mouse button is right bottom corner of rectangle.

For increasing of selected area, to move down cursor from left to right corner. For decreasing of the selected area, to move upwards cursor from right to left corner.

Output Data Representation (Results simulation)

General information.

The program **ModeStEB** for simulation of 3D absorbed dose distributions in multilayer targets irradiated with EB comprise the built-in tools for comprehensive output data analyzing and processing.

The built-in tools for analyzing and processing of output data are as follows:

- Tools for dose volume histogram (DVH) analysis.
- Tools for 3D absorbed dose analysis with spokes method.
- Comparison module for scientific analysis and comparison calculated with experimental dosimetric data.
- Dosimetry module for preparing of experimental data for comparison between themselves or between simulated and experimental data. This module allows to load experimental data files, invert and move each experimental curve, cut and scale, transform to format of Comparison module.

1. Example. Configuration data for simulation of dose distribution in an irradiated target

The Main form of the Software **ModeStEB** 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.2**. **Position of target** on a conveyer platform is presented in **Fig.3**.

Full configuration data which are used at simulation are presented in **Fig.4**.

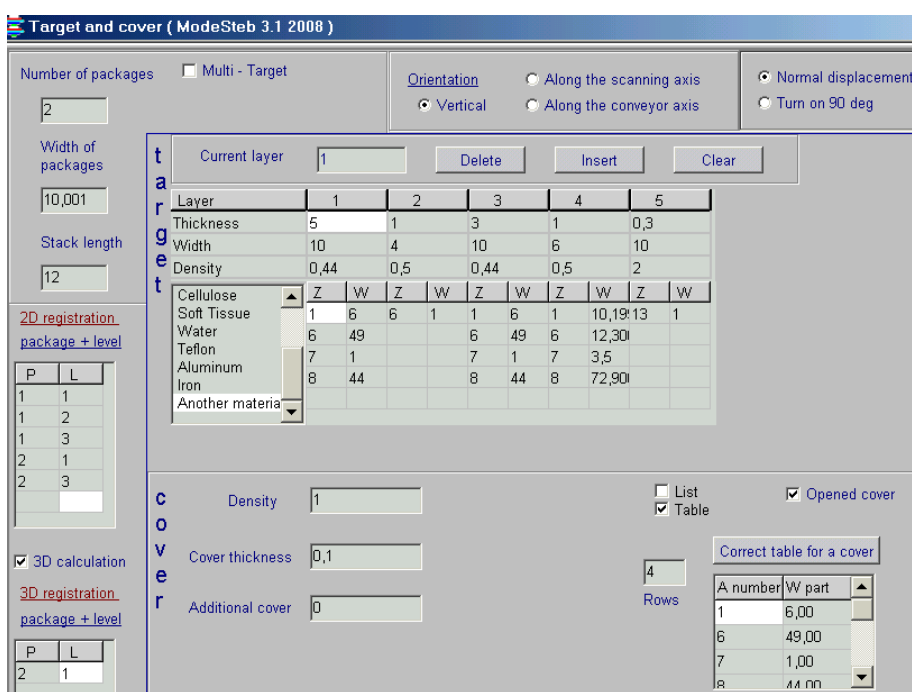


Fig.1. Main form of the Software **ModeStEB**

Fig.2. Example of Multilayer target.

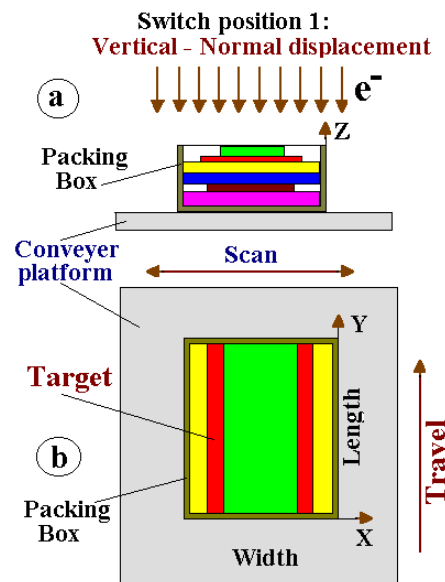


Fig.3. Position of target on a conveyer platform.

```

Configuration data
ModePEB (Modelling of an irradiation of packages by electron beam)
Source: Pulsed regime = No; Average current = 1,000
Spectrum: MonoEnergy = Yes; Spectrum = No; Energy = 10,000
Angular spread: MonoDirect = Yes; Angular spread = No
Space spread: Point beam = Yes; Distribute beam = No
Scanning system: Conveyor speed = 1,000; Conveyor width = 100,000; Scanning frequency = 10,000; Scanning horn height = 300,000
Scan-conv. distance = 40,000; Scanning width = 20,000; Y angle of target = 0,000; X angle of target = 0,000
Non-diverging beam = Yes; Triangular scanning = No; Default mode = Yes; Custom mode = No
Irradiated volume: Packages = 3; Layers in each package = 5; Width of packages = 10,001; Stack length = 12,000
Distance between targets = 5,000
Vertical target orientation; Normal target displacement
((Layer;Thickness;Width;Density):(1; 5,0000; 10,0000; 0,4400):(2; 1,0000; 4,0000; 0,5000):(3; 3,0000; 10,0000; 0,4400):(4; 1,0000; 6,0000; 0,5000):(5;
0,3000; 10,0000; 2,0000))
((Layer;Z;W):(1; 1,0000; 6,0000):(1; 6,0000; 49,0000):(1; 7,0000; 1,0000):(1; 8,0000; 44,0000):(2; 6,0000; 1,0000):(3; 1,0000; 6,0000):(3; 6,0000;
49,0000):(3; 7,0000; 1,0000):(3; 8,0000; 44,0000):(4; 1,0000; 10,2000):(4; 6,0000; 12,3000):(4; 7,0000; 3,5000):(4; 8,0000; 72,9000):(5; 13,0000; 1,0000))
Covering of irradiated volume: Cover thickness = 0,100; Cover density = 1,000; Additional cover = 0,000; Opened cover = Yes
((Z;W): (1;6,00); (6;49,00); (7;1,00); (8;44,00))
The following package and layer were registered in gotten 2D results:(P = 1, L = 1):(P = 1, L = 2):(P = 1, L = 3):(P = 2, L = 1);
(P = 2, L = 3):(P = 3, L = 3);
The following package and layer were registered in gotten 3D results:Package = 2; Layer = 1
Options of the calculation: Energy cut off (Mev) = 0,100; Threshold energy (Mev) = 0,200; Number of joined cells for center = 2
Number of joined cells for boundary = 1; Splitting on (X,Y,Z) = (100, 40, 40); Angle grouping = 0,050
Calculation mode is normal; Normal coordinate system

```

Fig.4. Full set of configuration data which is used at simulation of absorbed dose distribution.

2. Output Data for 2D dose distributions

- After finish Simulation, Click the button “View results after simulation” in the Main form of the Software ModeStEB (see Fig.1). The form "Dose and Charge distributions after MC simulation" with 2D absorbed dose and charge distributions in graphical and tabular forms for chosen packages and layers in the Table “2D registration” will be opened (see Fig.5).

Note 1. On all curves of 2D dose distributions 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 in any target position on a conveyer platform the dose value is integrated along layer thickness (axis Z).

- Additional information related to **absorbed dose distributions** are presented in this form are as follows:
 - **Dose uniformity ratio**
 - **Average dose**
 - **Dose minimum**
 - **Dose maximum**
 - **Statistical uncertainty**
 - **Joined cells for centre and for boundary**

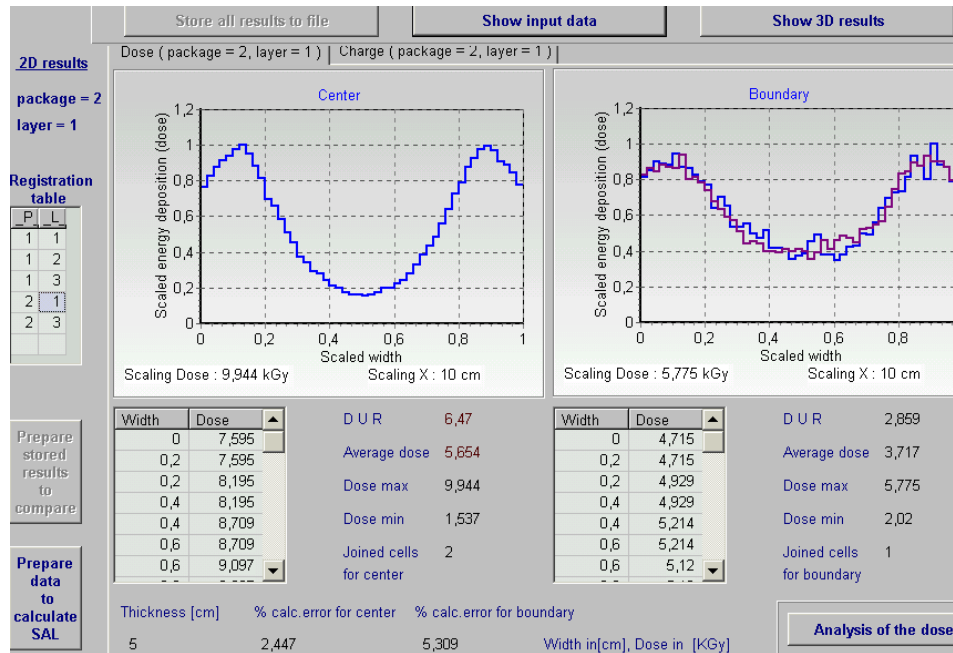


Fig.5. Form with 2D depth dose distribution in graphical and tabular forms for the 1st layer in the 2nd package.

Left graph - 2D depth dose distribution in the **Centre** of the 1st layer in the 2nd package. I.e. in the area Length/2.

Right graphs - 2D depth dose distribution near the **Boundary** of the 1st layer with Cover box side 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. 3a, 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 ModeStEB (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 ModeStEB are the simulation modulus of the RTOffice information system. Input and output data for all simulation modulus of the RT Office are self-consistent between themselves.

3. Output Data for 3D view of an absorbed dose distributions

Output Data for 3D view of an absorbed dose distributions can be analyzed with dose volume histogram (DVH) analysis and with spokes method.

The purpose of a DVH is to summarize 3D dose distributions in a graphical 2D format. DVHs can be visualized in either of two ways: differential "pdf" or cumulative (integral) "cdf".

- **Click the button "Analysis of the dose"**, the form **"Dose map for corresponding layer and package "** will be opened (see Fig.6).

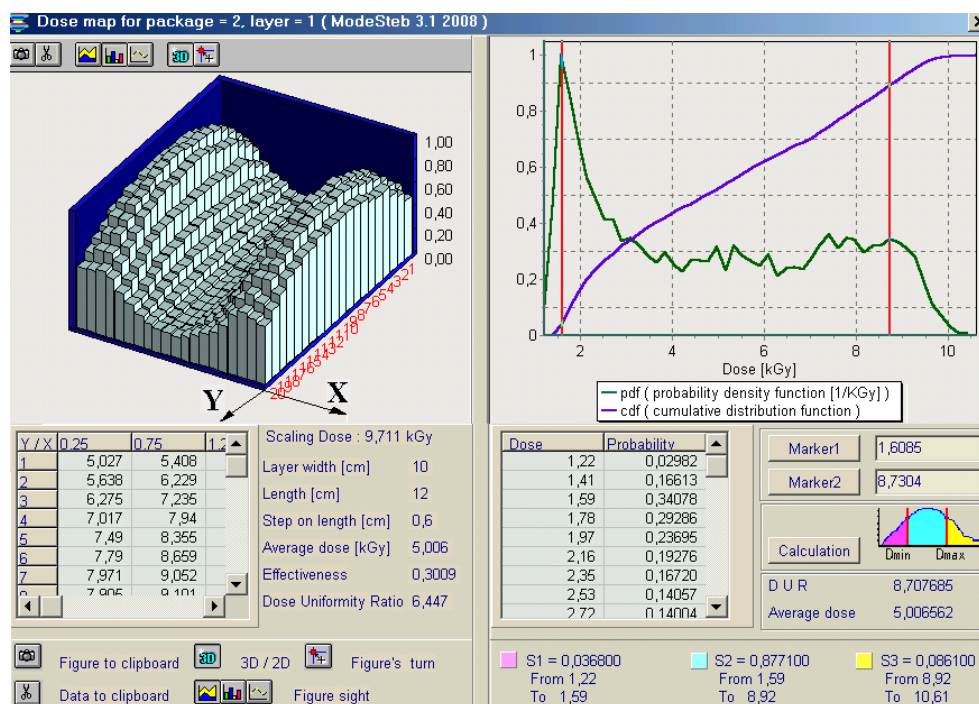


Fig.6. Left Graph -3D view of the depth dose distributions (Dose Map, along layer length (axis Y) and along layer width (axis X)) in graphical and tubular forms for the 1st layer in 2nd package. The dose value is integrated along layer thickness (axis Z). Right graphs: Cumulative distribution function – cdf (violet curve), and Probability density function in 1/kGy – pdf (green curve).

- To make Dose-Volume-Histogram (DVH) analysis via the functions the “Probability density function, pdf” and the “Cumulative distribution function, cdf”, you should use two Markers located under Right graphs: **Marker 1** and **Marker 2** (See Fig.6).

In “cdf” type of DVH, the vertical axis represent the relative value of total target volume that receives a dose less than a specified dose selected with marker.

- 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.

In a such way you can made DVH analysis step by step for each of 5 selected for calculation layers. (see Registration Table “_P_ and _L_” in Fig.5)

- Additional information related to **3D view of an absorbed dose distribution** in the chosen layer are presented in the form:
 - Average dose
 - Effectiveness
 - Dose uniformity ratio

4. 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 1st layer in 2nd package. (See Fig.7).

This layer was enter as input data in the Target example for simulation. (See Fig.2).

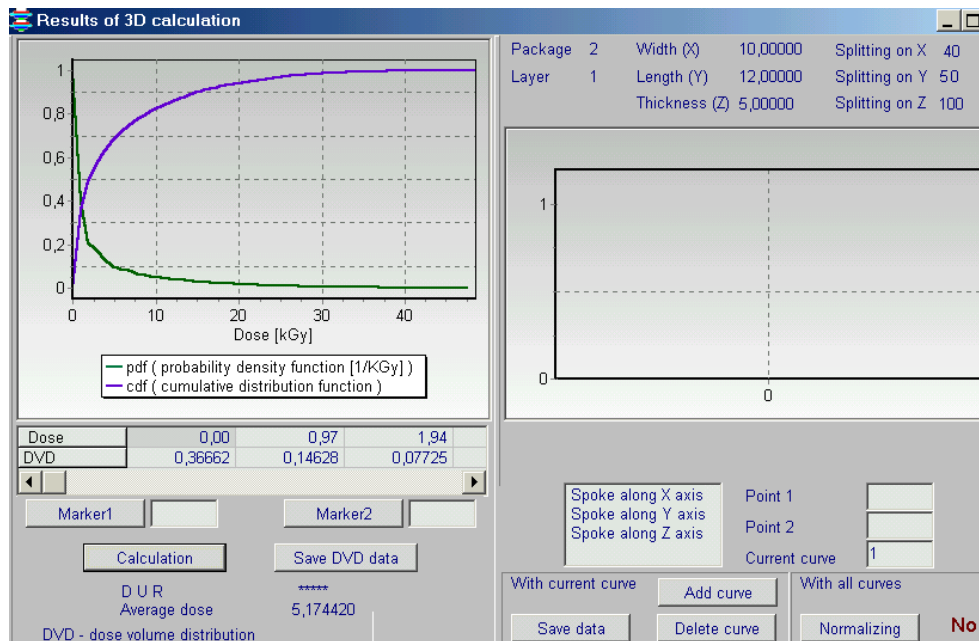


Fig.7. The form of "Results of 3D calculation" for analysis of 3D absorbed dose distribution in the 1st layer of 2nd package.

3D absorbed dose distribution 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 $\Delta V = \Delta X \cdot \Delta Y \cdot \Delta Z$. (see Fig.8).
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 intercross 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.8. Layer is located on a conveyer platform.

Spoke A intercross a layer thickness along axis Z.

Spoke B intercross a layer length along axis Y.

Spoke C intercross a layer width along axis X.

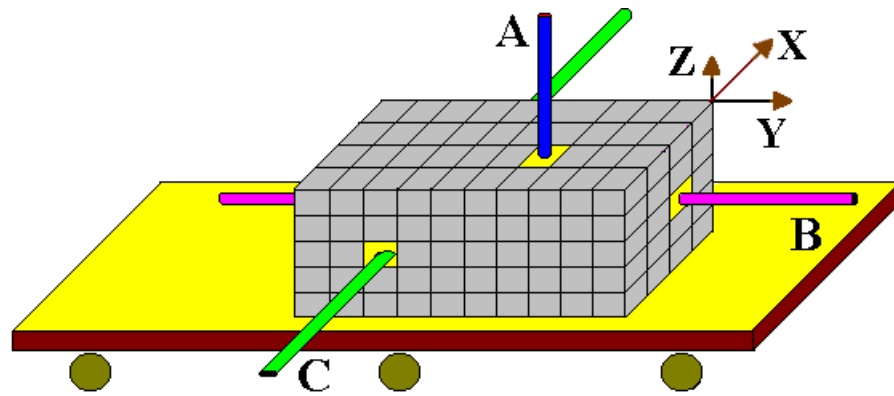


Fig.8. Target layer with grid and spokes located on a conveyor platform.

For above example (see Figs. 2 and 7) 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.7 (right upside).

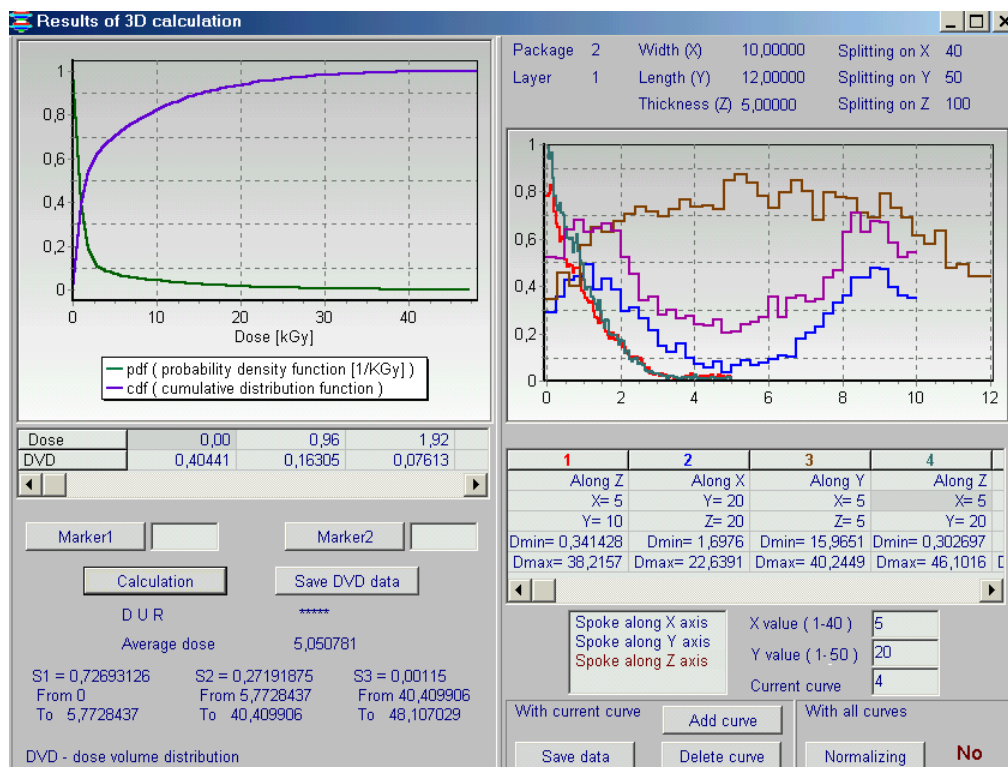


Fig.9. The form of "Results of 3D calculation" for analysis of 3D absorbed dose distribution.

The sequence of operations to calculate an absorbed dose distribution along any spokes is the following (see Figs. 7 and 9) :

- Choose and Click on direction of the "Spoke along axis X, Y, or Z".

Chosen direction will be painted in brown color.

- For example, Chosen direction is "Spoke along axis Z". (see Fig. 9).

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 color 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.9).

- 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.

Chose 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 chosen layer. (see Figs. 7 and 9).

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 DVH analysis 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”.

5. Output Data for 2D charge deposition distributions

Click the button “Charge” in the form "Dose and Charge distributions after MC simulation" (see Fig.5). The form with 2D charge deposition in graphical and tabular forms for chosen packages and layers in the Table “2D registration” will be opened (see Fig.10). The 2D charge deposition is presented for the Layer Center (green curve) and for the layer Boundary (violet curve).

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

Note 2. On all curves of 2D charge deposition in any target position on a conveyer platform the charge deposition value is integrated along layer thickness (axis Z).

- Click on any package and any layer number in the Table “2D registration”, the 2D charge depositions for corresponding package and layer will be appear in the form.

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

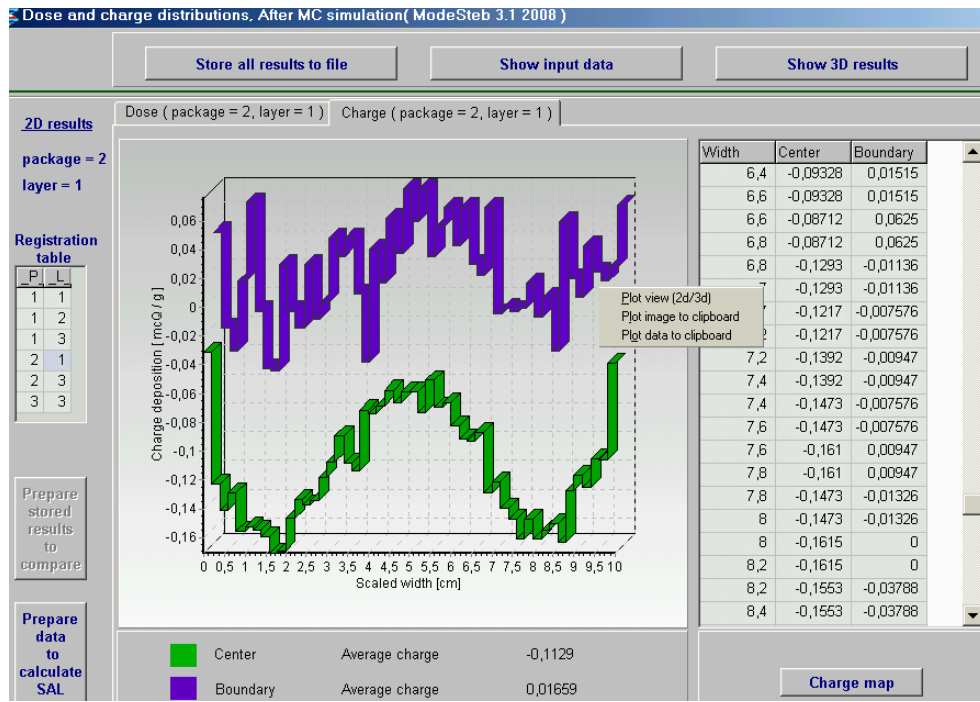


Fig.10. Form with 2D charge depositions in graphical and tabular forms for the 1st layer in the 2nd package.

- Click the button “Charge map” in the form with 2D charge depositions. The form with 3D view of charge depositions for chosen packages and layers in the Table “2D registration” will be opened (see Fig.11).

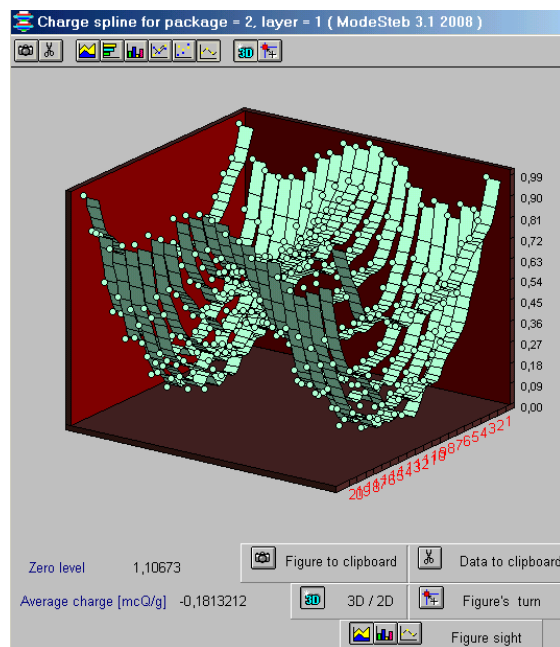


Fig.11. The form with 3D view of charge depositions

- To copy the results with 2D charge depositions into your document, Click the graph by right mouse button. Then Click the button “Plot mode 2D/3D”, if it is necessary an then Click the button "Plot to clipboard" or "Plot data to clipboard" and paste them to your document.

6. 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 ModeStEB (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.12). 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 and Charge distributions after MC simulation”** from the chosen file.

- **Click** the button **“Prepare store results to compare”** in the form **“Dose and Charge distributions after MC simulation”**. (See Fig.5).
- 3. **“Converted dosimetric file”** – it is results which were 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.9).
- 4. **“After dosimetric block”** - it is results for dose distributions which were obtained and saved after processing of dosimetric films with the block **“Dosimetry”**.

- **Choose** the position of dose distribution in the **Center** or **Boundary** of irradiated layer for the chosen curve of 2D dose distribution.
 - **Choose** 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**.
 - **Choose** 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.12).

You can **“Delete selected curves”** and make for all curves **“Normalization”**. (See Fig.13).

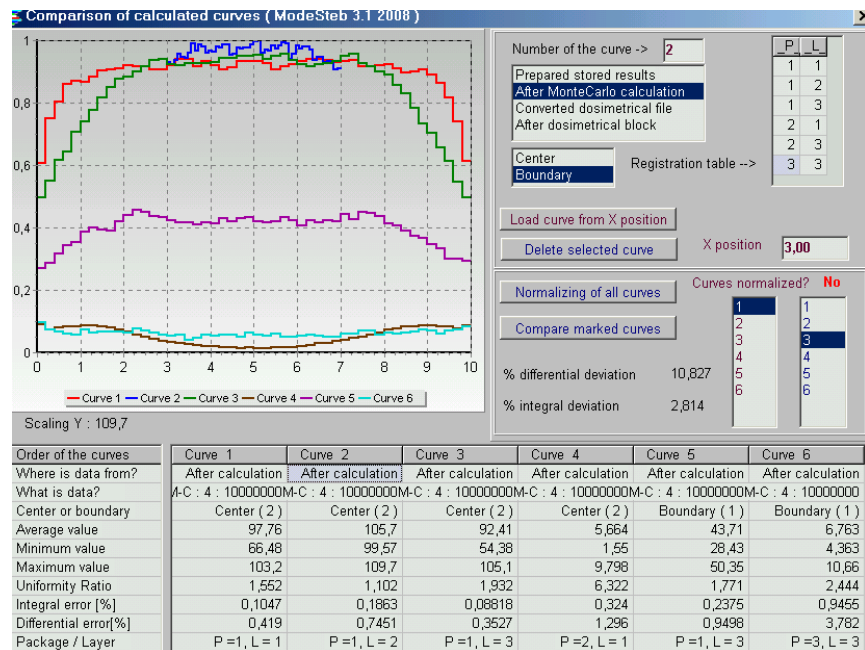


Fig.12. The form of "Comparison of calculated curves".

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

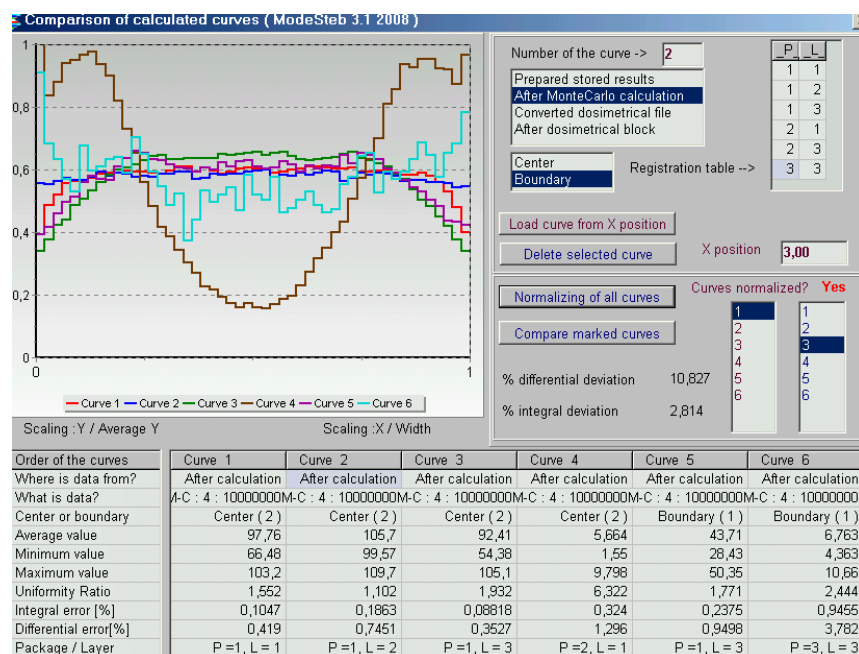


Fig.13. Example of "Normalization" all curves of 2D dose distributions presented in Fig.12.

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 Figs. 12 and 13). For that, choose 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.