Manual for simulation of EB processing

Software ModePEB

Software ModePEB. How to get results.

Introduction

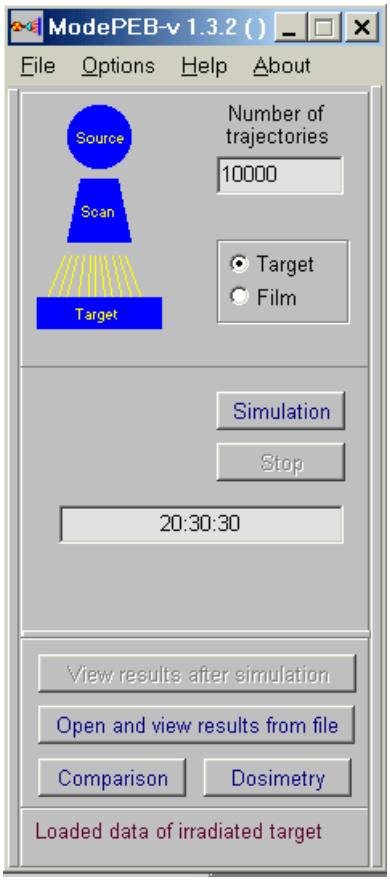


Fig.1. The main form of the Software ModePEB

Software ModePEB consists of three thematic modules and service blocks. (See Fig.1).

- **"Monte Carlo" (MC) simulation module is intended for exact calculations of an electron beam (EB) absorbed dose in an irradiated multilayer target.**

- **"Comparison" module is intended for scientific analysis and comparison calculated and prepared experimental data for the 2D dose distributions. The window for this block opens if you will click the button "Comparison".**

- **"Dosimetry" module is intended for preparing of experimental data. This block allows to load data files, invert and move each experimental curve, cut and scale, transform to format of Comparison module. The window for this block opens if you will click the button "Dosimetry".**

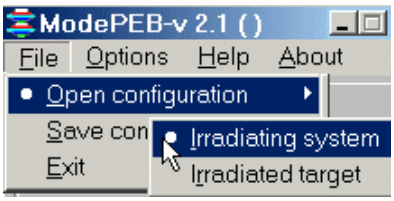


Fig.2. Frames "Open configuration"

To work with software ModePEB -

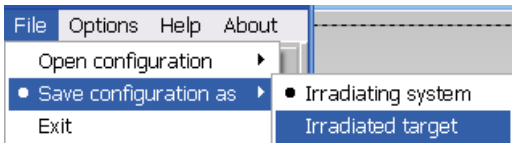
- **Click the "File" then "Open configuration", then to select "irradiating system" and load the file "Test.rts".**
- **Click the "File" then "Open configuration", then to select , "irradiated target" and load the file " Test.rtt". (See Fig.2).**

Note. Only after loading the" Test.rts" and " Test.rtt" files, user can change all characteristics of EB facility and irradiated target for simulation EB processing.

If all input data are saved, color of the scheme MC simulation module changes to blue.

• **Enter the "Number of trajectories" and Click the button "Simulation".**
The Software ModePEB will show starting time and define time required for calculation.
• **Click "Stop" to interrupt calculation and reenter data.**
• **When MC simulation will be ended, the list of results will be opened. You can choose item and work with results.**

To save the current configuration for further work,
• **Click the "File" then "Save configuration", then to choice "irradiating system" and save the file "New.rts".**

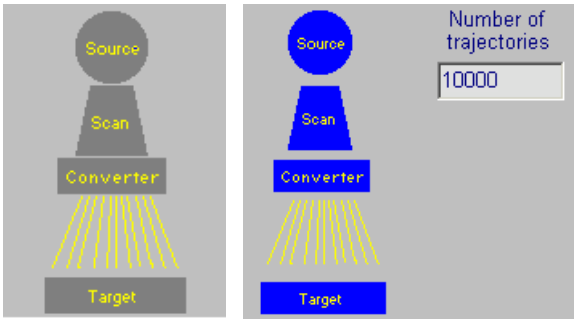


• **Again click the "File" then "Save configuration", then to choice , "irradiated target" and save the file "New.rtt". (See Fig.3).**

Fig.3. Frames "Save configuration"

Input data

1. Source



• **Click "Source" in the Scheme of MC Module. (See Fig.1.1. a).**

The main form for Source – Electron Accelerator parameters will be opened. (See Fig.1.2).

Fig.1.1. a, b. Scheme of MC simulation module.
a) Scheme view before entering input data.
b) Scheme view after entering input data.

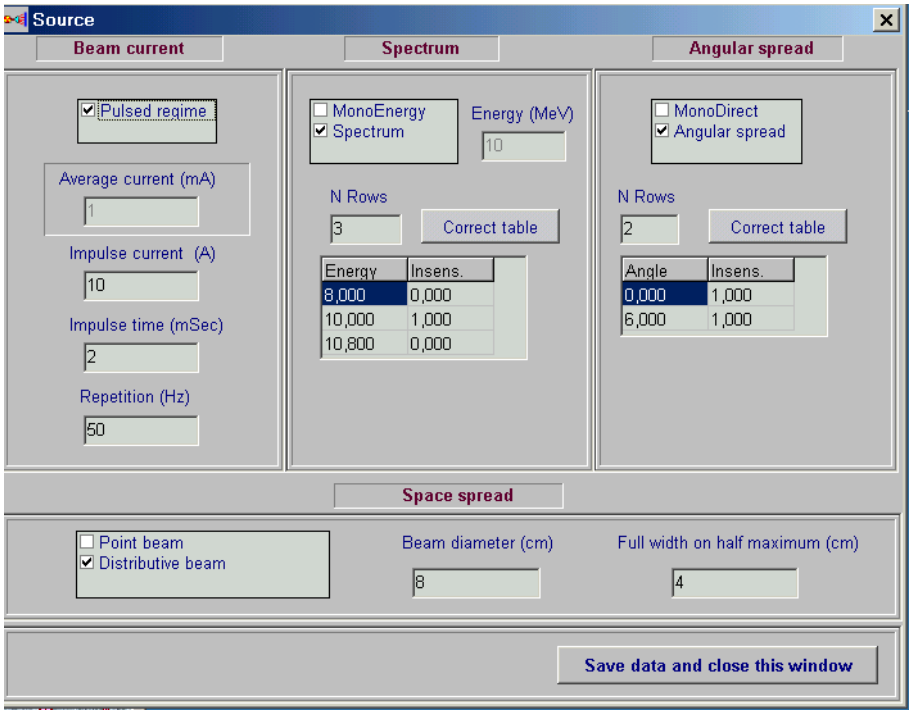


Fig.1. 2. The main form of "Source" for input data and correction of an electron beam parameters.

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.**

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.

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. (See Fig.1.1. b).

2. Scanner

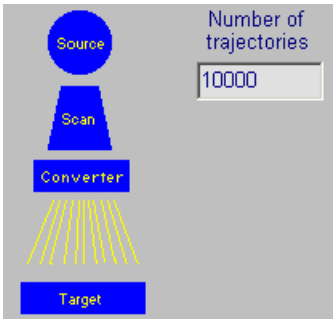


Fig.2.1. Scheme of MC Module

- **Click "Scan" in the Scheme of Monte Carlo Module. (See Fig.2.1).**

The main form for Scanner and Conveyer parameters will be opened. See Fig.2.2.

- **Enter the values of Speed in cm/sec and Width in cm in the frame Conveyer.**
- **Enter the values of Frequency in Hz and Height of scan horn in cm in the frame Scanning horn.**

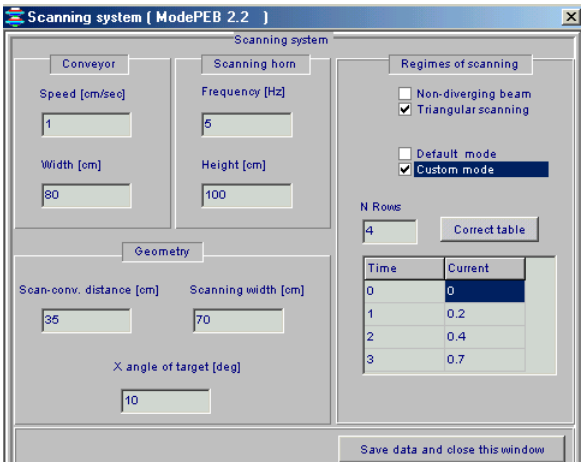


Fig.2.2. The main form for the Scanner and Conveyer parameters.

• Enter the values of Distance scan-conveyor in cm and Width of scanning in cm in the frame Geometry.
• Enter the value "X angle of target" in degree.
The target will be placed on moving conveyer under inclination angle X (in direction of EB scanning) relatively axis of incident electron beam.

• Click the field "Non-divergent beam" by a tick, to work with parallel ray scanned electron beam.
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".
Image of "Scan" in the scheme of MC Module change into blue color.

3. Target

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

- **Click "Target" in the Main form of the Software ModePEB (See Fig.1).**

The form for entering of input data for irradiated Target and Packing materials (Cover) will be opened (See Fig.3.1).

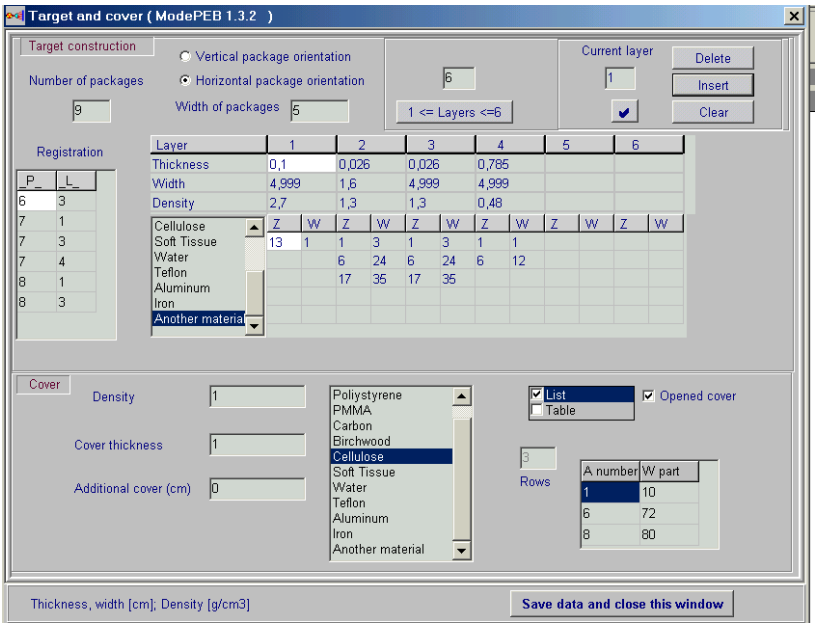


Fig.3.1. The form for entering of input data of irradiated Target and Packing materials (Cover)

3.2. Target model

Fig.3.2. and Fig.3.3. demonstrate the different models for irradiated multi-layer target within package which are used by the ModePEB programs for simulation EB processing.

Multi-layer target can be located on the conveyer platform horizontal, vertical or under arbitrary angle relatively incident EB axis.

Geometrical models of multi-layer targets irradiated with EB, which are used for simulation of the absorbed dose distribution with Software ModePEB.

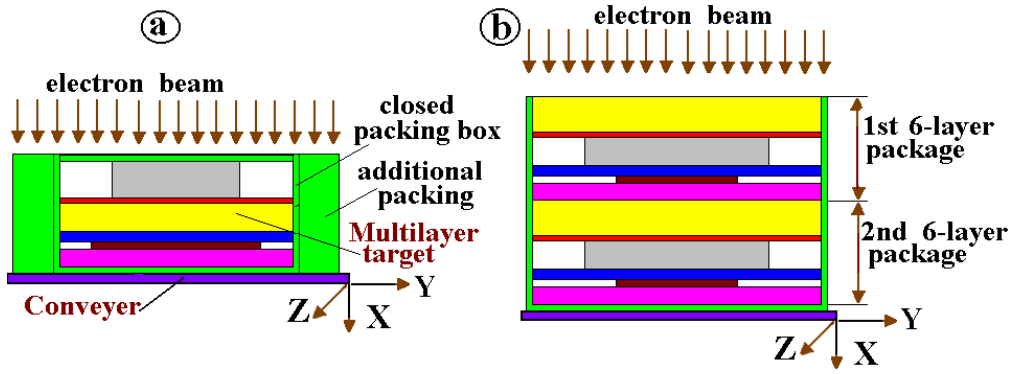


Fig.3.2. Geometrical models of multi-layer targets placed on moving conveyer and irradiated by normally incident electron beam. Conveyer move along axis Z.
(a) Multi-layer target consists of 6-layer package placed in closed packing box with additional packing materials.
(b) Multi-layer target consists of two 6-layer packages placed in open packing box.

Multi-layer target consists of 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.**
- **The 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.

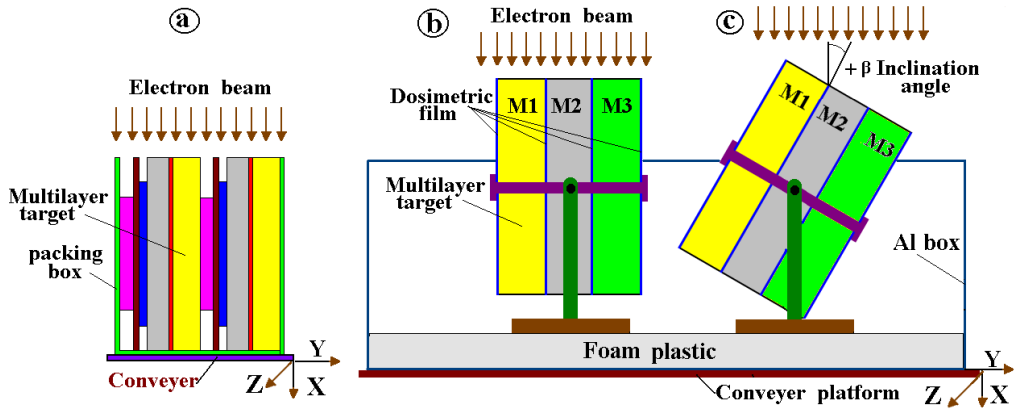


Fig. 3.3. Geometrical models of multi-layer targets irradiated by incident electron beam in parallel (a), (b) and under inclination angle ß (c) with interface of contacting materials. Conveyer moves along axis Z.

(a) Multi-layer target placed in open packing box and irradiated with incident electron beam 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 electron beam.

(c) Multi-layer target with dosimetric films inserted between interface of contacting materials and irradiated under inclination angle β relatively with electron beam axis.

3.3. Input data for Target and Cover

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.**
- **The 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.

Multi-layer target can be located on the conveyer platform **horizontal, vertical or under arbitrary angle** relatively incident EB axis.

• **Enter** the **number of packages** in multi-layer target in the range from **1 to 10.** **(L**eft up corner in the **" Number of packages "** window**).**
• **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**).**
• **Enter** the **"Width of packages"** in cm.
• **Enter** for each layer **"Thickness"** in cm.
• **Enter** for each layer **"Width"** in cm.
Note. The **"Width of packages"** can be ≥ **"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, enter the values of **Z** and **W**.
The selection button changes to Another materials.
• **Enter** the values of **Z** and **W** for **compounds and mixtures.**

• Button **"Delete"** is used for deletion of the chosen layer. **(**Right up corner in the **"Target"** frame**).**
• Button **"Clear"** is used for cleaning of the parameters in the chosen layer. **(**Right up corner in the **"Target"** frame**).**
• 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.

• For materials not given, enter the values of **Z** and **W**. The selection button changes to Another material.

• To enter the values of **Z** and **W** for **compounds and mixtures**, **Click** the window **"Table"** with tick **(**right down corner in the **"Target"** frame**) (See Fig.3.1)**.
• **Enter** the necessary number **N constituent elements** for compounds and mixtures in window **"Rows".**
• **Click** the button **"Correct table for cover".**
The table with N rows will be opened.
• **Enter** the **atomic number Z_i** and the **atomic weight W_i**
for **i^{th} constituent elements**

• Multilayer target can be irradiated by incident EB either in **closed or open** (**Tick** window **"Opened cover") Cover Box.**

• **Select** the layers orientation in multilayer target relatively with an incident EB:
• **Click "Vertical package orientation" -** the interfaces of contacting materials in multilayer target are oriented in parallel with an incident EB. **(**Right up corner in the **"Target"** frame**)**
• **Click "Horizontal package orientation" -** the interfaces of contacting materials in multilayer target are oriented perpendicularly with an incident EB.
• **Select in the Table "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 "Registration" includes the **number of packages "_P_"** and the **number of layers in chosen package "_L_".**

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 "Registration"** and repeat the run simulation.
In this way, you can obtain step by step the **ADD** in all layers of multilayer target.
• **Click "Save data and close this windows". The selected parameters for multilayer target will be saved and ready for simulation.**

4. Options

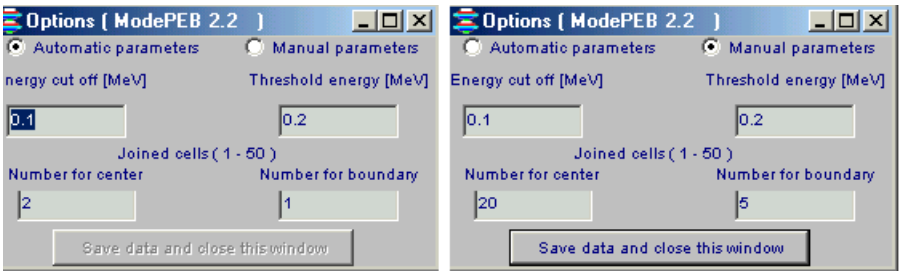
Options are intended for:
- **optimization of simulation regimes,**
- **optimization of parameters visualization of calculated results,**
- **scientific research of transport irradiation through heterogeneous targets.**

Options includes two parts:

- **Parameters simulation: "Electron energy cut off" and "Threshold energy".**
- **Parameters of visualization of results: "Joined cells for center and boundary".**

In the default mode "Automatic parameters" of the Software ModePEB 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 Options parameters can be changed only in regime "Manual parameters". See Fig.4.1 b.



Figs.4.1 a, b. Main form of "Options" for enter input data for simulation.
a) default mode "Automatic parameters". b) **regime "Manual parameters".**

Parameters simulation: "Electron energy cut off" and "Threshold energy".

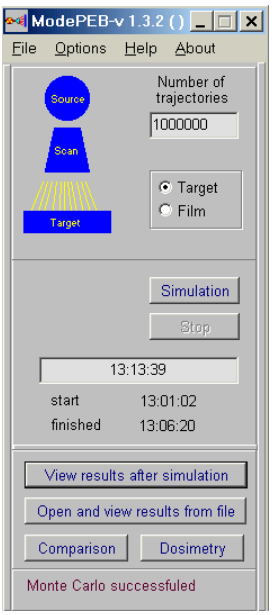
- **Change of simulation parameters "Electron energy cut off" and "Threshold energy" can be used for scientific researches of transport irradiation through heterogeneous targets.**

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.

The cells are combined in direction transversely to axis of EB dose distribution visualization.

5. Output Data



- **After finish Simulation, Click the button "View results after simulation" in the Main form of the Software ModePEB (see Fig.5.1).**

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 will be opened (see Fig.5.2).

Fig.5.1. Main form of the Software ModePEB

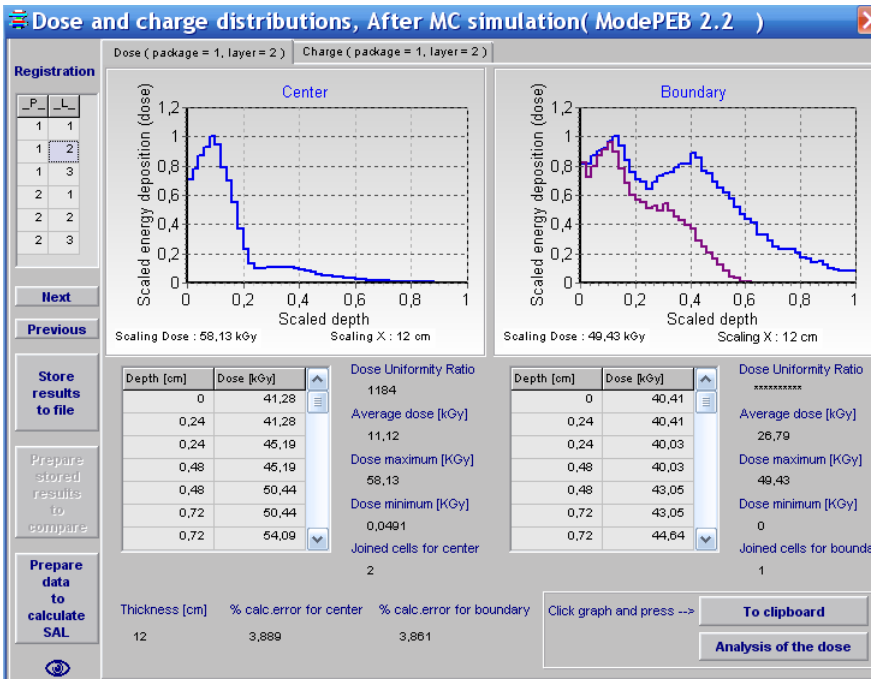


Fig.5.2. Form with 2D view of dose and charge distributions in graphical and tabular forms for the 2nd layer in 1st package.
Left graph - 2D depth dose distribution in the Center of the 2nd layer.
Right graphs - 2D depth dose distribution near the Boundary of the 2nd layer with 1st layer (blue curve) and near the Boundary of with 3d layer (violet curve).

• **Additional information related to absorbed dose distributions are presented in this form:**
• **Dose uniformity ratio**
• **Average dose**
• **Dose minimum**
• **Dose maximum**
• **Statistical uncertainty**

• **Click on any package number in the Table "Registration" or buttons "Next" and "Previous", 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 "Registration".**
• **Click the button "Store results to file", create** the **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 file", in the Main form of the Software ModePEB (Fig.8.1).**
• **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 - downloading file "Prepare store results to compare".**
• **Click the button "Eye" (see Fig.8.2).** The **Table "Configuration data"** with all input data for the selected layer in the selected package **will be opened (see Fig.5.3).**

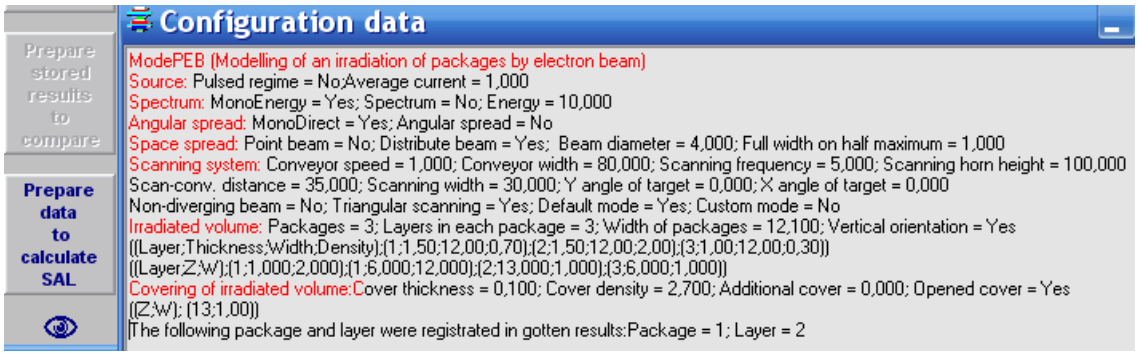


Fig.5.3. The **Table "Configuration data"**

• **To copy** the graphical depth-dose results into your document, **Click** graph either of the **Center** or **Boundary** **(Graph change colour on yellow), Click the button "To clipboard"** and paste them to your document.

• **Click the button "Analysis of the dose" (see Fig.5.2),** the form **"Dose map for corresponding layer and package" will be opened (see Fig.5.4 a, b).**

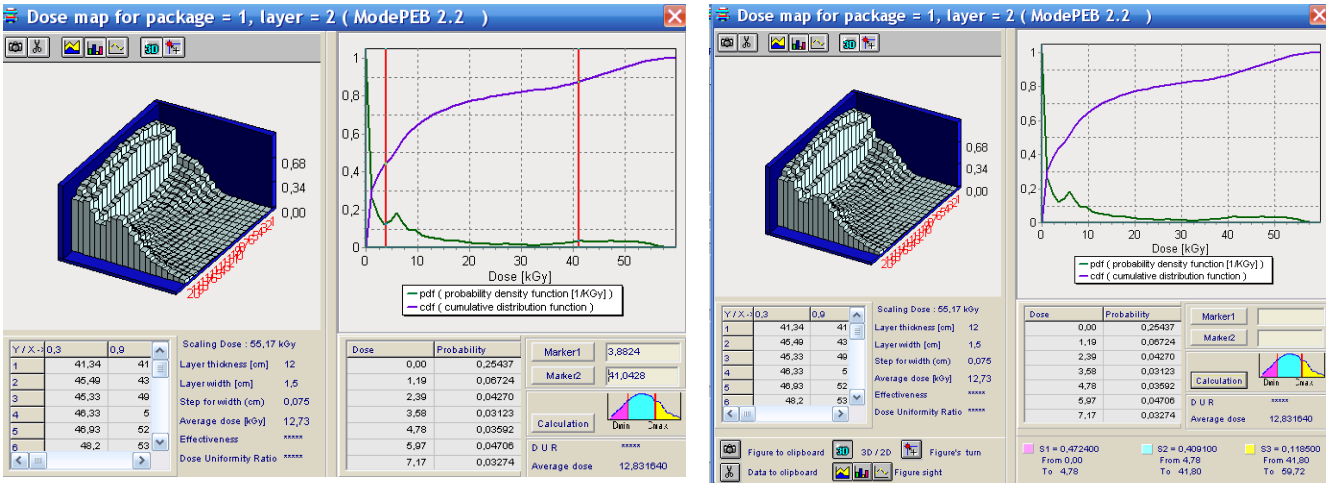


Fig.5.4 a, b. Left Graph - 3D view of depth dose distributions (Dose Map, along depth and along scan direction) in graphical and tubular forms for the 1st layer in 1st package. Right graphs - Function of the probability (violet curve), and Density of the dose probability (green curve).

• **Additional information related to 3D absorbed dose distribution are presented in the form:**
• **Average dose**
• **Effectiveness**
• **Dose uniformity ratio**

• **Click on Charge in the frame "Dose and charge distribution" (see Fig.5.2), the frame with 2D charge distributions in graphical and tabular forms for chosen packages and layers will be opened (see Fig.5.5 a).**
• **Click the button "Charge map" in the frame "2D charge distributions" (see Fig.5.5 a), the frame with 3D view of charge distribution in graphical and tabular forms for chosen packages and layers will be opened (see Fig.5.5 b).**

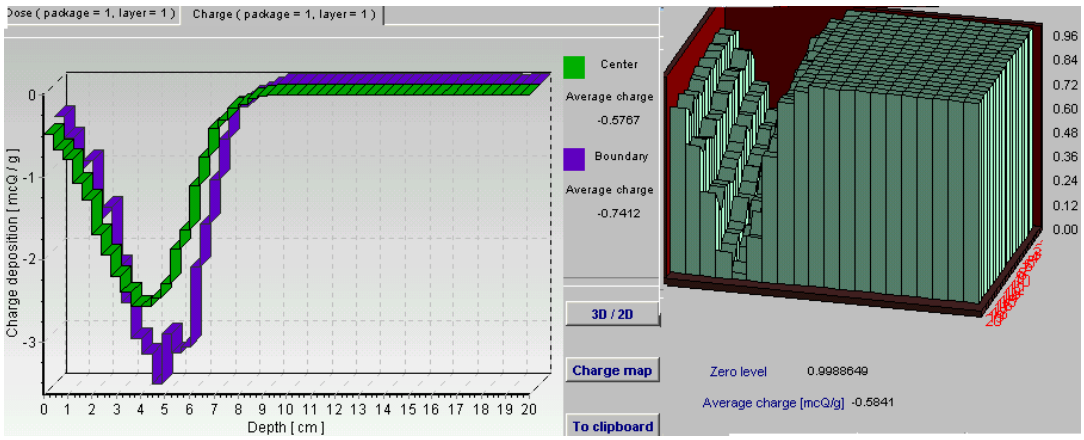
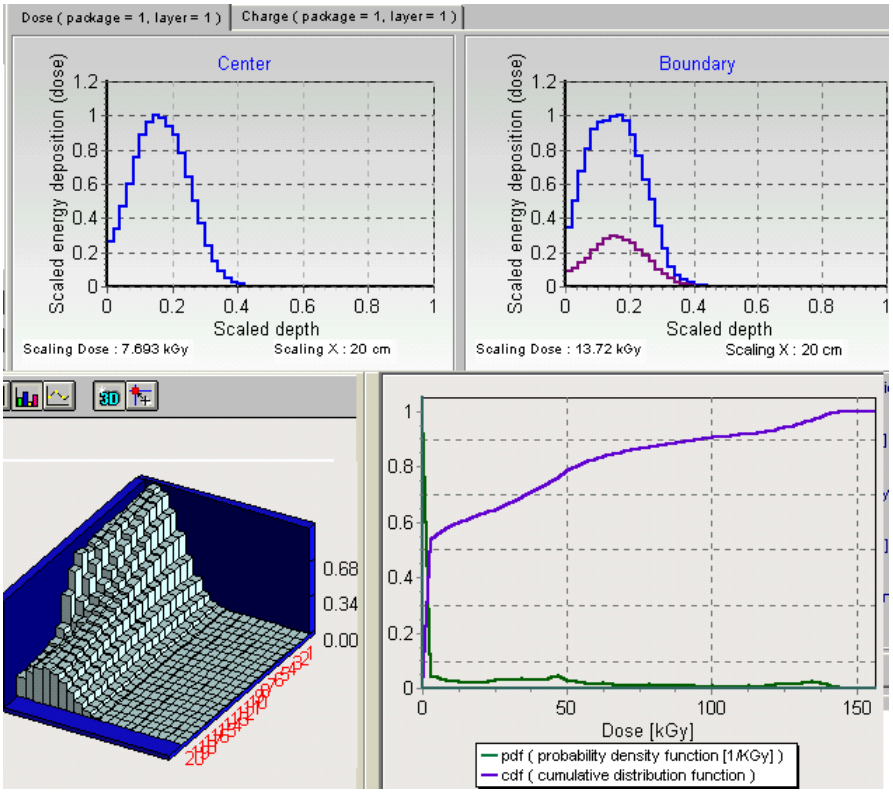


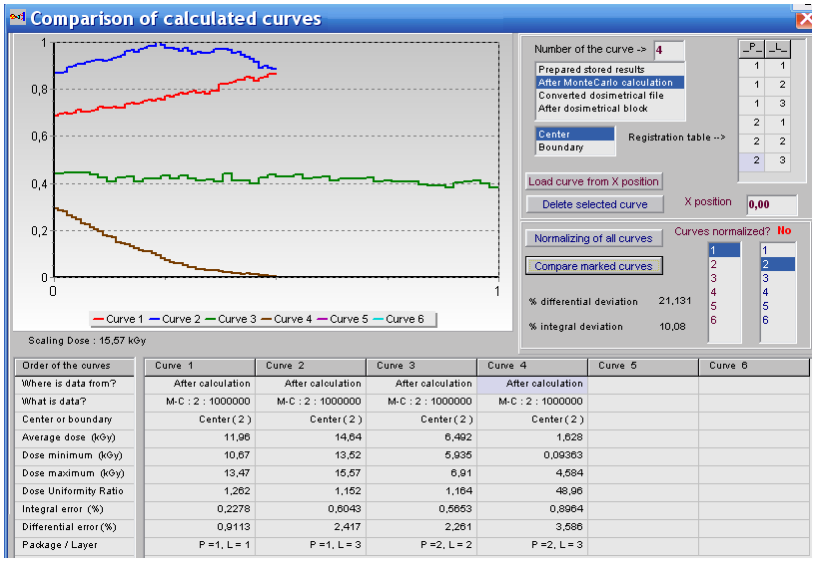
Fig.5.5 a, b. a) 2D charge distributions. b) 3D view of charge distributions



6. Analysis and comparison of simulation results

Module "Comparison" is intended for the scientific analysis and comparison of calculated and experimental data of 2D absorbed dose distributions in the target irradiated with electron beam.

• Click the button "Comparison" in the Main form of the Software ModePEB (See Fig.1). The form of " Comparison of calculated curves" will be opened for analysis of calculated and experimental data of 2D absorbed dose distributions in an irradiated target (See Fig.6.1).



Order of the curves	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5	Curve 6
Where is data from?	After calculation	After calculation	After calculation	After calculation		
What is data?	M-C : 2 : 1000000	M-C : 2 : 1000000	M-C : 2 : 1000000	M-C : 2 : 1000000		
Center or boundary	Center (2)	Center (2)	Center (2)	Center (2)		
Average dose (kGy)	11,96	14,64	6,492	1,628		
Dose minimum (kGy)	10,67	13,52	5,935	0,09363		
Dose maximum (kGy)	13,47	15,57	6,91	4,584		
Dose Uniformity Ratio	1,262	1,152	1,164	48,96		
Integral error (%)	0,2278	0,6043	0,5653	0,8964		
Differential error (%)	0,9113	2,417	2,261	3,586		
Package / Layer	P =1, L = 1	P =1, L = 3	P =2, L = 2	P =2, L = 3		

Fig.6.1. The form of "Comparison of calculated curves". Example of 2D EB dose distributions in some layers of irradiated target.

The analysis can be carried out with current calculated data, data calculated before and dosimetric experimental data.

• Choose for analysis the calculated curve in the frame under the window "Number of the curve". For that, click the chosen curve with cursor.

There are the following variants of curves for the choice:

1. **"Prepared stored results"- it is simulation results of the electron beam 2D dose distributions which were previously stored in the files.**
2. **"After Monte Carlo calculation" – it is the results of current Monte Carlo calculation of the EB dose distributions in the target.**
3. **"Converted dosimetric file" – it is results with dosimetric experimental data which were prepared and saved after processing of dosimetric films with the Dosimetry module.**

• Choose the position of dose distribution in the Center or Boundary of irradiated target for the chosen curve of 2D dose distribution.

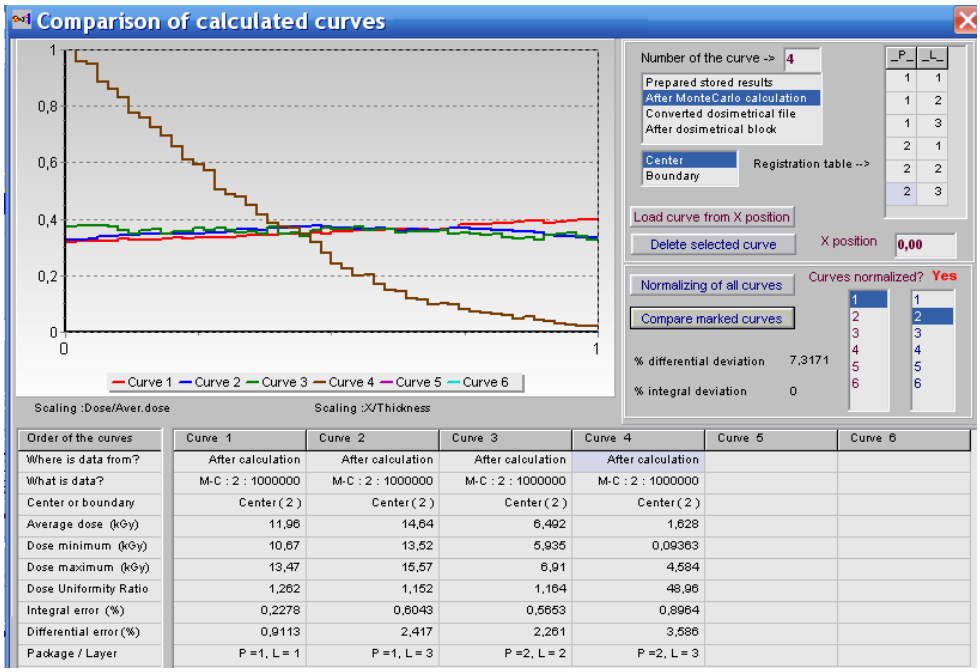
• **Choose by cursor the any of 6 columns of the table in the bottom part of the form the "Comparison of calculated curves". The chosen column number will be automatically entered to the window "Number of the curve".**

• **Click the button "Load selected curve".**

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.6.1).

You can "Delete selected curves" and make for all curves "Normalization". (See Fig.6.2).



Order of the curves	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5	Curve 6
Where is data from?	After calculation	After calculation	After calculation	After calculation		
What is data?	M-C : 2 : 1000000	M-C : 2 : 1000000	M-C : 2 : 1000000	M-C : 2 : 1000000		
Center or boundary	Center (2)	Center (2)	Center (2)	Center (2)		
Average dose (kGy)	11,96	14,64	6,492	1,628		
Dose minimum (kGy)	10,67	13,52	5,935	0,09363		
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Integral error (%)	0,2278	0,6043	0,5653	0,8964		
Differential error (%)	0,9113	2,417	2,261	3,586		
Package / Layer	P =1, L = 1	P =1, L = 3	P =2, L = 2	P =2, L = 3		

Fig.6.2. Example of "Normalization" for dose distributions presented in Fig.6.1.

• **The function of button "Compare" (**right down side in the **"Comparison of calculated curves " frame) 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. 6.1. and 6.2).**

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

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

7. 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 ModePEB (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.7.1.a).

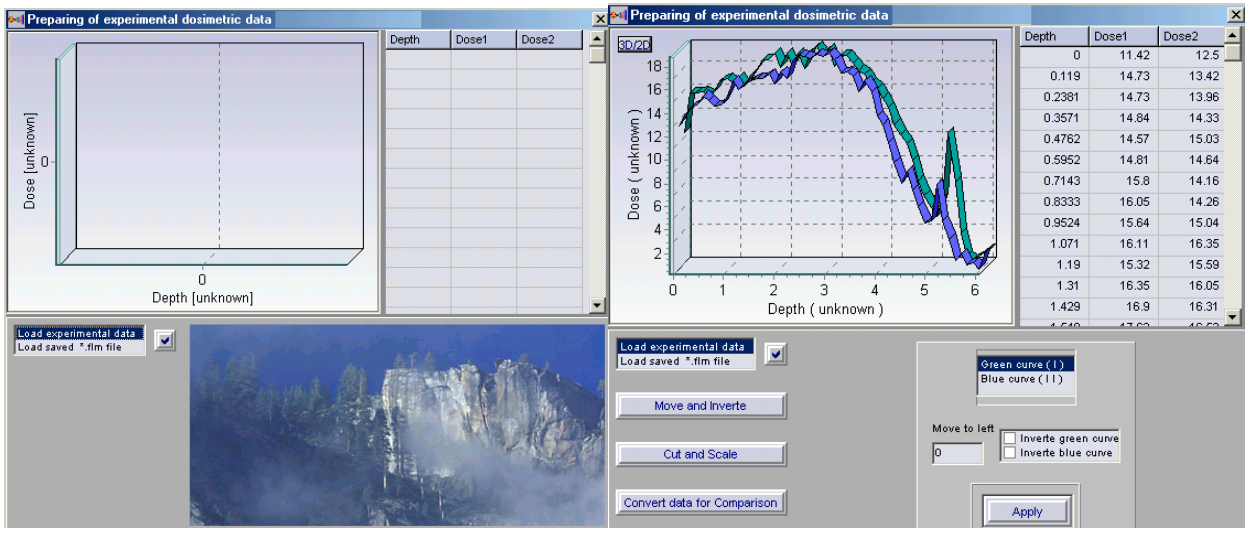


Fig.7.1 a, b. The forms for "Preparing of experimental dosimetric data".

• 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.7.1 b).
Loaded data are showing onto the plot and into a grid and the buttons Move and Invert, Cut and Scale, Convert data for Comparison appear. (See Fig.7.2 a, b).

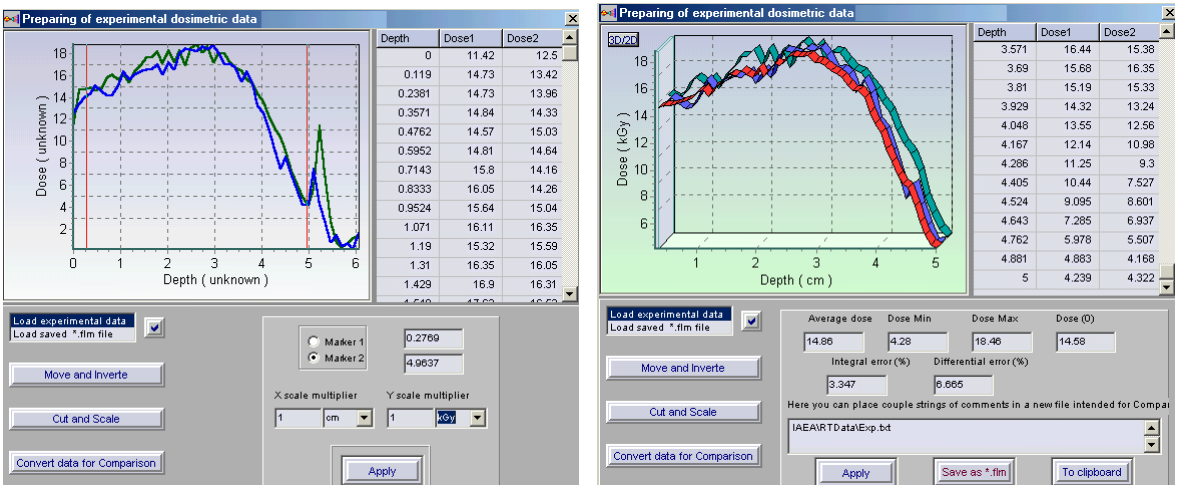
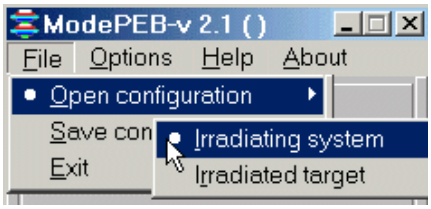


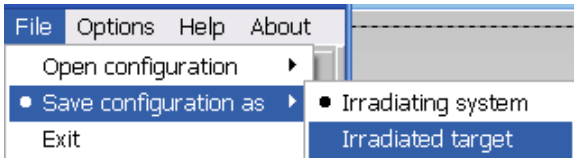
Fig.7.2 a, b. The forms for "Processing of experimental dosimetric data".

• 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 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.7.2. a).
You must scale the curves and press Apply. A part of curve placed between two red lines will 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 show new data in the grid.
(See Fig.7.2. 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.

8. Service blocks

The Software ModePEB has block to save and open input data about configuration of irradiation process. To save formed input data you need to open the File in the Software ModePEB master menu. In opening menu list you choose item Save configuration, enter file name and save input data for MC calculations. If you want to continue calculation that you made earlier and saved data configuration, you need click File in the Software ModePEB master menu and choose item Open configuration from list.





The Software ModePEB has some programs for visualization of calculated results. There are two viewers:
• The viewer "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".
This viewer is intended for showing of the plots with 2D absorbed dose 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.

"Dose Map" is viewer for showing:

1. 3D view of the dose distributions (Dose Map, along layer length (axis Y) and along layer width (axis X)) in graphical and tubular forms for the chosen layer and package.

2. Cumulative distribution function and Probability density function.

You can see diagram, data table, some important characteristics. You can turn figure of diagram and choose optimal angle, you can send figure to clipboard. At the bottom of viewers screen form there are hints about buttons actions.

To exit viewer you can use button Close.

• Every page has button To clipboard. To send plot to clipboard you need to click on this plot and to press To clipboard.

• You write calculated result on hard disk as file "*.mon" after MC calculations.

•You can increase some area selected on the plot to have the better sight. To do it you need to place cursor above this area. You 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.

The increasing of selected area is a moving down cursor from left corner to right corner. The decreasing of the area (coming back), is a moving upwards cursor from right corner to left corner.