Manual for simulation of EB processing

Software ModeRTL

How to get results. Software ModeRTL.

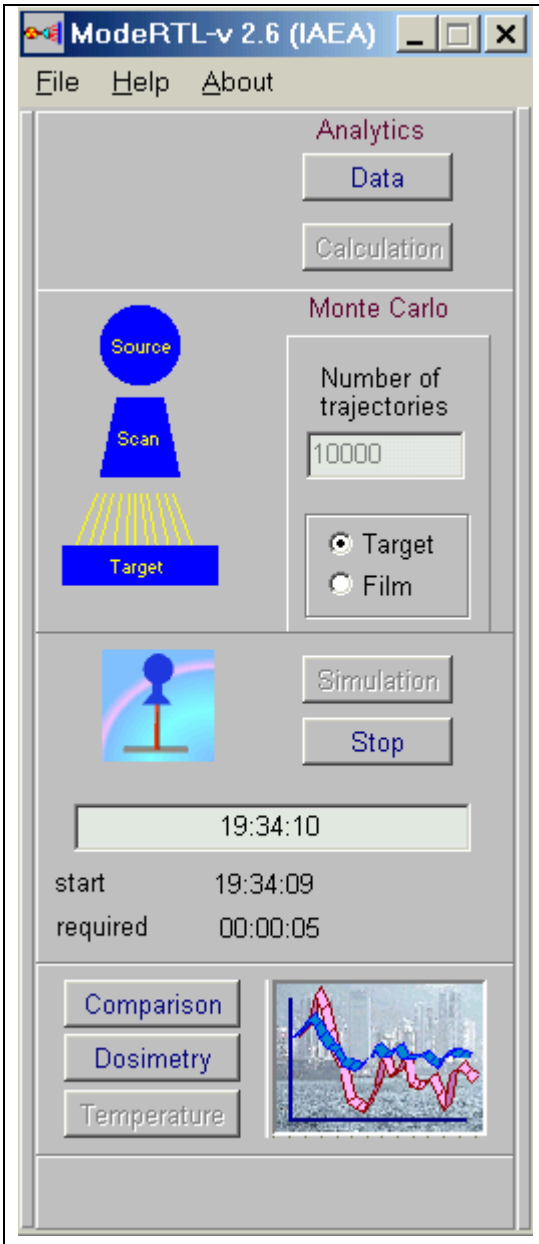


Fig.1. Main form of the Software ModeRTL

Software ModeRTL consists of five thematic modules and service blocks. (See Fig.1).

Analytic module is intended for fast analytic estimations of the absorbed dose distributions in target irradiated with scanned electron beam (EB) on moving conveyer.

• "Monte Carlo" (MC) simulation module is intended for exact calculations of absorbed dose and charge distributions in target irradiated with scanned electron beam (EB) on moving conveyer.

Temperature module is intended for analysis of the temperature fields during cooling of irradiated volume.

Comparison module is intended for scientific analysis and comparison calculated and prepared experimental data.

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.

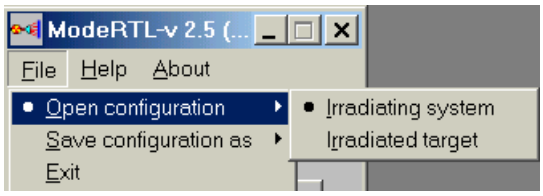


Fig.2. Frames "Open configuration

To work with software ModeRTL -

• Click the "File" then "Open configuration", then select "Irradiating system" and load the file "Test.rts".

• Again click the "File" then "Open configuration", then select , "Irradiated target" an load the file "Test.rtt". (See Fig.2).

• Again click the "File" then "Open configuration", then 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.

Input data

1. Analytic module

• Click the button "DATA" in Analytic module. See Fig.1.

The main form for entering of input data for EB source parameters and irradiated target characteristics will be opened. See Fig.3.

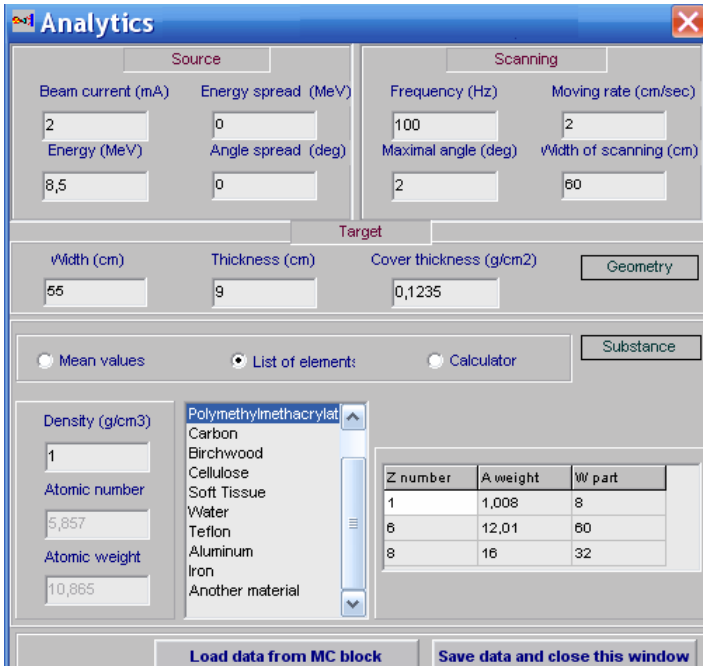


Fig.3. The form for entering of input data for EB source parameters and irradiated target characteristics in the Analytic module.

EB Source parameters

- Enter the Beam current in mA.
- Enter a value of the Energy in MeV.
- Enter a value of the Energy spread in MeV.
- Enter a value of the Angle spread in degree.

Scan and conveyer parameters

- **Enter the Scan Frequency in Hz.**
- **Enter a value of the Maximal Angle in degree.**
- **Enter the Width of scanning in cm.**
- **Enter the Moving rate of conveyer system in cm/sec.**

Target and cover characteristics

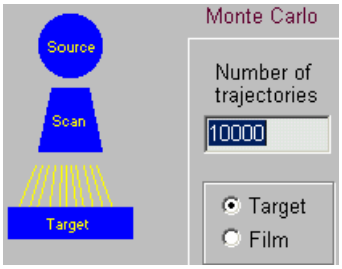
- **Enter the Width and thickness of the target in cm.**
- **Enter the Cover thickness in g/cm^2.**
- **Enter the target material density in g/cm^3.**
- **Click** the **"List of materials"** **with a tick.**
- **Select** a **material** for the **"Target"** from the **"List of materials".** The **atomic number Z** and the **atomic weight A** of the material appear in the corresponding boxes.
- **Click** the **"Mean values"** **with a tick.**
- **Enter** the mean values of **atomic number Z** and the **atomic weight A** for materials (**compounds and mixtures**) not given in the **" List of material".**

- **Module Analytic provides a loading of saved data from the MC module.**
  To do it, Click the button "Load data from MC block" .

- **After loading all input data in Analytic module,**
  Click the button "Save data and close this window".
- **Click the button "Calculation", to obtain analytic calculation results.**

2. Monte Carlo simulation module

2.1. Source



- **Click "Source" in the Scheme of MC Module.**
  See Fig.4.
  The main form for Source – Electron Accelerator parameters will be opened. See Fig.5.

Fig.4. Scheme of MC Module.

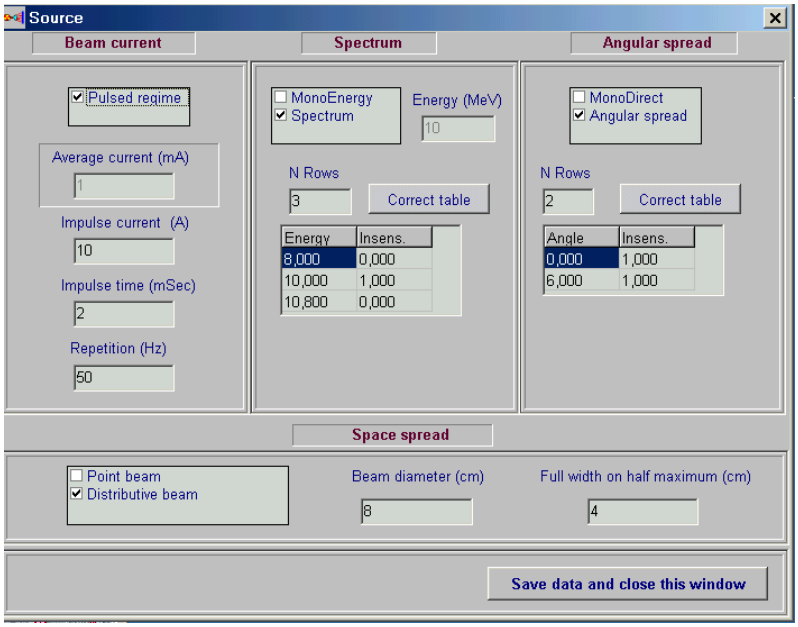


Fig.5. The main form of "Source" for input data and correction of an electron beam parameters.

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 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.

2.2. Scanner

• Click "Scan" in the Scheme of Monte Carlo Module. See Fig.4.
The main form for Scanner and Conveyer parameters will be opened.
See Fig.6.
• 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.

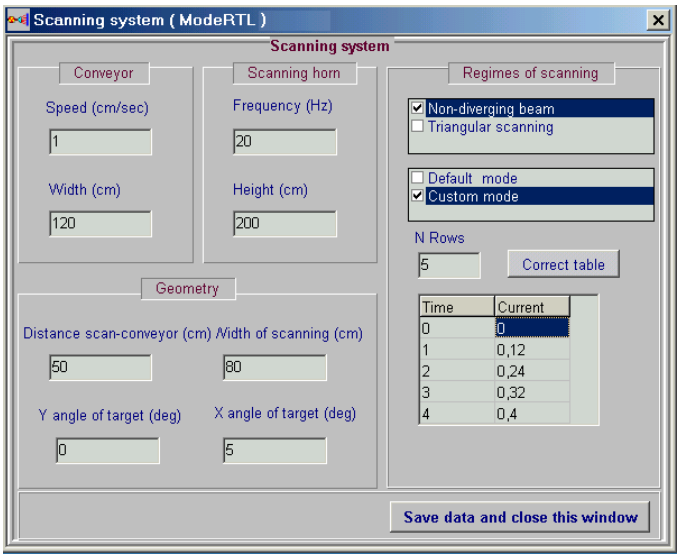


Fig.6. The main form for the Scanner and Conveyer parameters.

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

• **Values of fields Y angle of target and X angle of target depend on a chosen regime of scanning. (X and Y angles – angles of target orientations).**

You have possibility to choose four Regimes of scanning.
• **In the case of work with scan mode "Non-diverging beam" you can enter a value either Y angle of target or X angle of target.**
If Y angle of target greater than 0, X angle of target = 0 and inaccessible.
• **In the case of work with scan mode "Triangular scanning" you can enter a value X angle of target only.**

• **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.

2.3. Target

4.1. Input data for Target and Cover

• **Click "Target" in the Scheme of MC Module. (See Fig.4.).**
The form for entering of input data for irradiated Target (Irradiation object) and Packing materials (Cover) will be opened (See Fig.7).

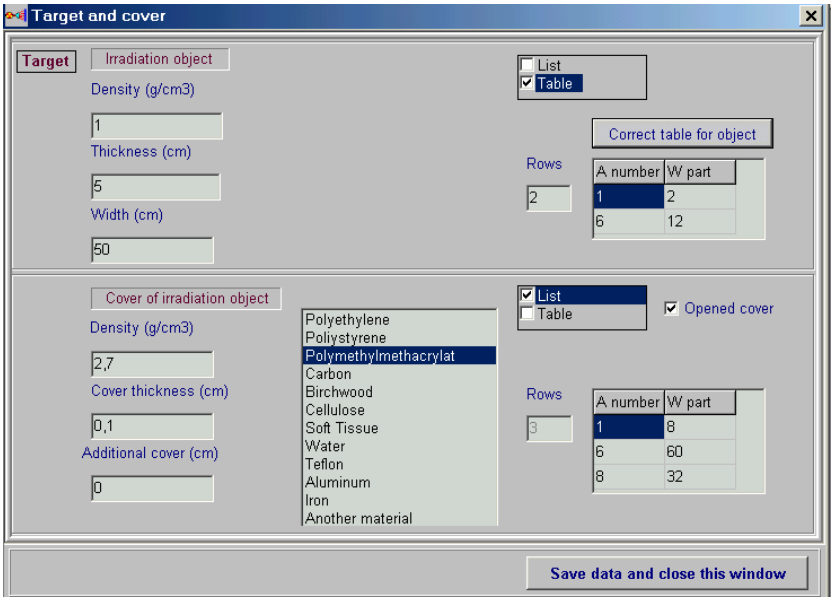


Fig.7. The form for entering of input data of irradiated Target (Irradiation object) and Packing materials (Cover).

4.2. Target model

Figs. 8 (a), (b), (c), and (d) demonstrate the different models for irradiated target within package which are used by the ModeRTL programs for simulation EB processing.

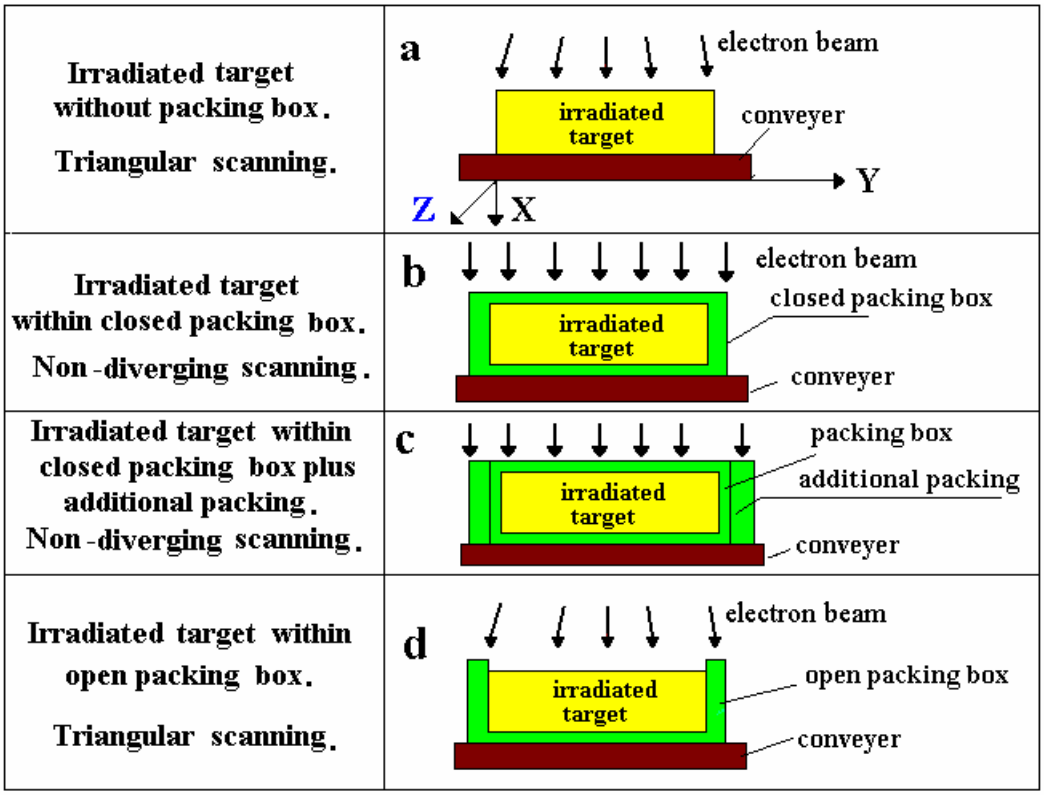


Fig.8. Geometrical models of irradiated targets and packing placed on moving conveyer and irradiated with EB beams.

• The target on a conveyer line was represented as a parallelepiped unlimited on length along a motion of the conveyer (axis Z). EB scans along axis Y.
• The material of the target is homogeneous.
• The target can be located on the conveyer platform with/without packing box.

• The target on moving conveyer can be oriented in parallel or under arbitrary angle in respect to electron beam axis in plane of scanning XY or in plane of conveyer travel XZ

4.3. Input data for Target size and Target materials

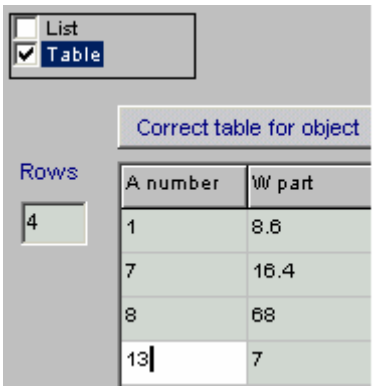
• **Enter** the **"Width of target"** in cm **(**left up corner in the **"Target"** frame**)** **(See Fig.7)**.
• **Enter** the **"Thickness"** in cm.
• **Enter** the **"Density of materials" in g/cm^3.**

• **Select** a **material** for the **"Target"** from the **"List of material" (**right up corner in the **"Target"** frame**).** The **atomic number Z** and the **atomic weight W** of the material appear in the corresponding boxes.

• **Select** the button **"Another material"** for materials not given in the **" List of material".**

• Enter the values of **Z** and **W for another material**.

• To enter the values of **Z** and **W** for **compounds and mixtures**, **Click** the window **"Table" (**right up corner in the **"Target"** frame**) (See Fig.7)**.
The frame **"Correct table for object"** will be opened **(See Fig.9)**.



• **Enter** the necessary number **N constituent elements** for compounds and mixtures in window **"Rows".**
• **Click** the button **"Correct table for object".**
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.**

Fig.9. Frame "Correct table for object".

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 target has not a **Cover Box**.

• **Select** a **material** for **cover materials** from the **"List of material"** **(**right down corner in the **"Target"** frame**).**
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 in the **" List of material".**
The selection button changes to **"Another material"**.

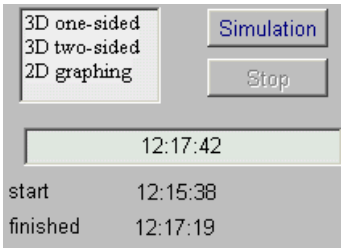
• Target can be irradiated with incident **EB beam** either in **closed or open** (**Click** the window **"Opened cover") Cover Box. (See Fig.7).**
• **Click the button "Save data and close this window".**
Image of "Target" in the Scheme of MC Module change into blue color.

4.5. Start calculation

After loading all input data for EB radiation facility and irradiated target,
• **Enter the "Number of trajectories" .**
• **Select the mode of calculations "Dose" or "Film". (Default mode is "Dose").**
• **Click the button "Simulation".**

The Software ModeRTL will show starting time and define time required for calculation. (See Fig.10).

Fig.10. Frame simulation.



• Click "Stop" to interrupt calculation and reenter data.
• When MC simulation will be ended, the list of results will be opened.
You can select item and work with results.
(See Fig.11).

Fig.11. Frame with simulation results.

5. Analysis and comparison of simulation results

Output data.

5.1. MC module.

After finish Simulation, Select the result in the frame "simulation results" (See Fig.11).

There are three variants for selection:

- **Select "2D graphing" - The form "Dose plots" after MC simulation for analysis of the 2D absorbed dose and charge distributions for irradiated target with package under one/two-sided in graphical and tabular forms will be opened (see Fig.12).**
- **Select "3D one-sided" - The form "one-sided dose map" after MC simulation with 3D view of the absorbed dose distribution for irradiated target with package irradiated under one-sided in graphical and tabular forms will be opened (see Fig.13 a).**
- **Select "3D two-sided" - The form "two-sided dose map" after MC simulation with 3D view of the absorbed dose distribution for irradiated target with package irradiated under two-sided in graphical and tabular forms will be opened (see Fig.13 b).**

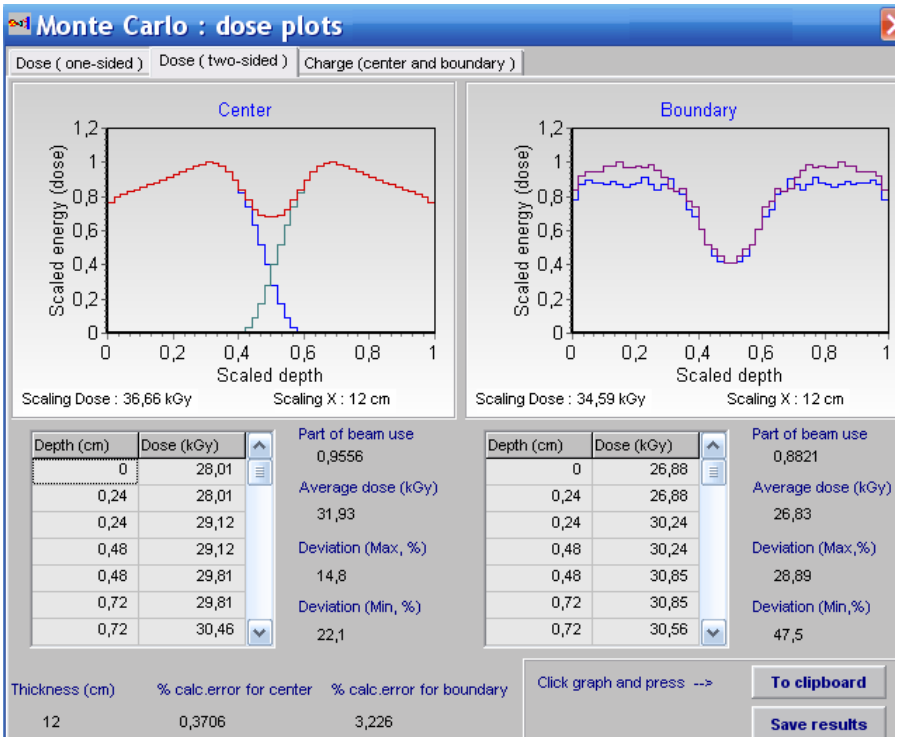


Fig.12. 2D view of the absorbed dose distributions under two-sided irradiated target with package in graphical and tabular forms.
Left graph - 2D depth dose distribution in the target Center.
Right graphs - 2D depth dose distributions near the Boundary of the irradiated object with packing material.
Blue curve near the boundary from left side, violet curve near the boundary from right side in direction of EB scanning.

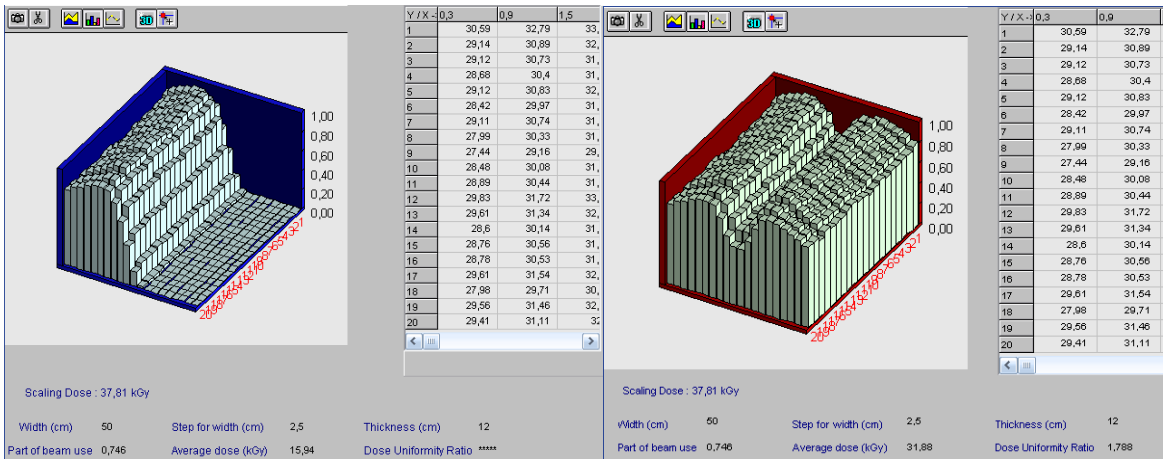


Fig.13 a, b. 3D view of the absorbed dose distribution for irradiated target with package.

a) under one-sided irradiated target,

b) under two-sided irradiated target.

• Additional information related to absorbed dose distributions are presented in this form:

• Dose uniformity ratio

• Average dose

• Dose minimum

• Dose maximum

• Statistical uncertainty

• Part of beam use.

• Click on Charge in the frame "Dose and charge distribution" (see Fig.12), the frame with 2D charge deposition in graphical and tabular forms for irradiated target will be opened (see Fig.14).

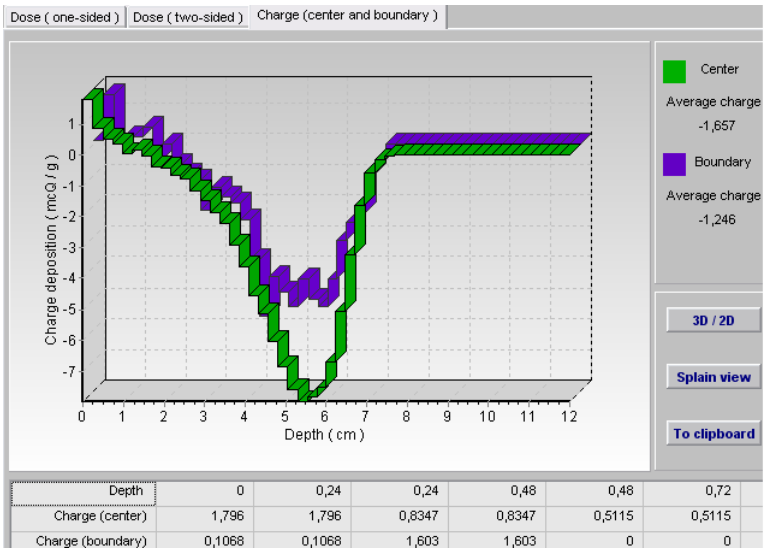


Fig.14. 2D charge depositions in irradiated target.

• Click the button "Splain view" in the frame "2D charge distributions" (see Fig.14), the frame with 3D view of charge distribution in graphical and tabular forms for irradiated object will be opened (see Fig.15).

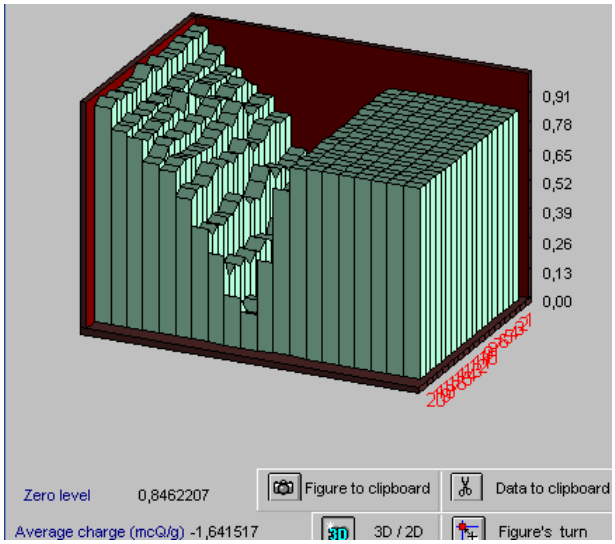


Fig.15. 3D view of charge deposition in irradiated object.

Output data.

5.2. Analytic module.

After download all input data for EB radiation facility and irradiated target in the Analytic module,

• Click the button "Calculation".

After finish Calculation, Select the result in the frame "simulation results" (See Fig.16).

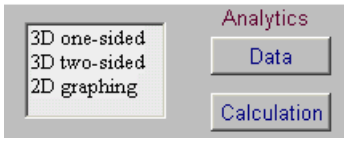


Fig.16. Frame with analytic calculation results.

There are three variants for selection:

• Select "2D graphing" - The form "Dose plots" after Analytic calculation for analysis of the 2D absorbed dose and charge distributions for irradiated target with package under one/two-sided in graphical and tabular forms will be opened (see Fig.17).

• Select "3D one-sided" - The form "one-sided dose map" after Analytic calculation with 3D view of the absorbed dose distribution for irradiated

target with package irradiated under one-sided in graphical and tabular forms will be opened (see Fig.18 a).

• Select "3D two-sided" - The form "two-sided dose map" after Analytic calculation ith 3D view of the absorbed dose distribution for irradiated target with package irradiated under two-sided in graphical and tabular forms will be opened (see Fig.18 b).

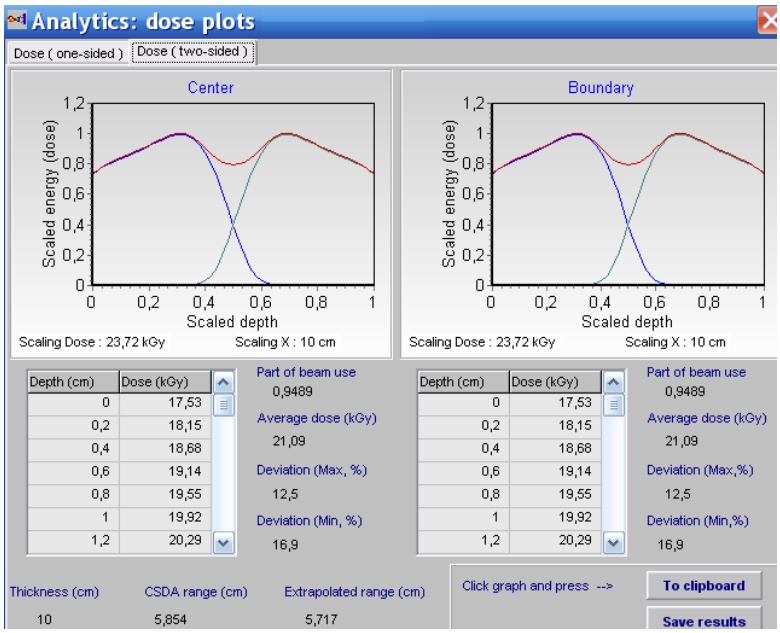


Fig.17. 2D view of the absorbed dose distributions under two-sided irradiated target with package in graphical and tabular forms.
Left graph - 2D depth dose distribution in the target Center.
Right graphs - 2D depth dose distributions near the Boundary of the irradiated object with packing material.

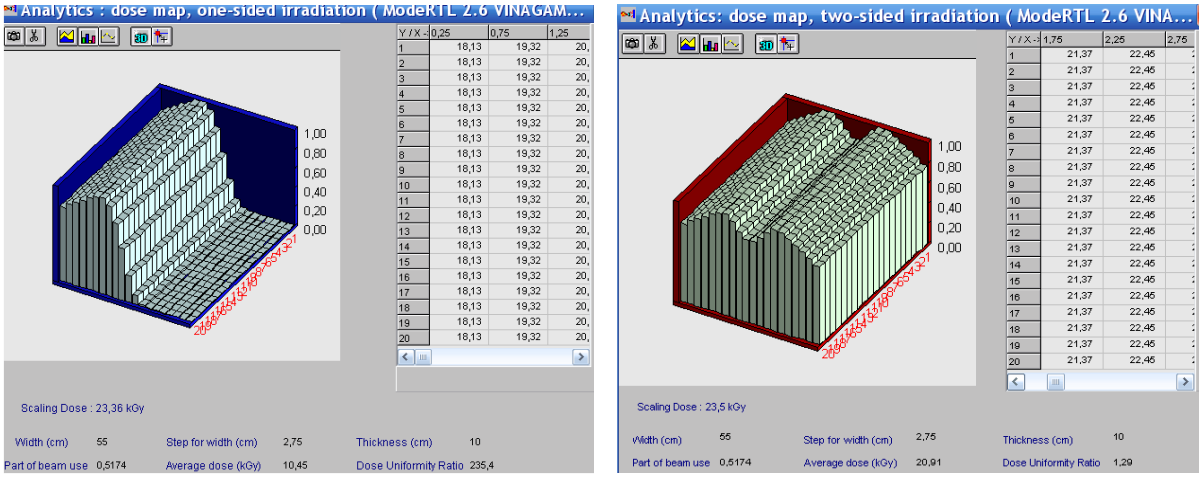


Fig.18 a, b. 3D view of the absorbed dose distribution for irradiated target with package.
c) under one-sided irradiated target,
d) under two-sided irradiated target.

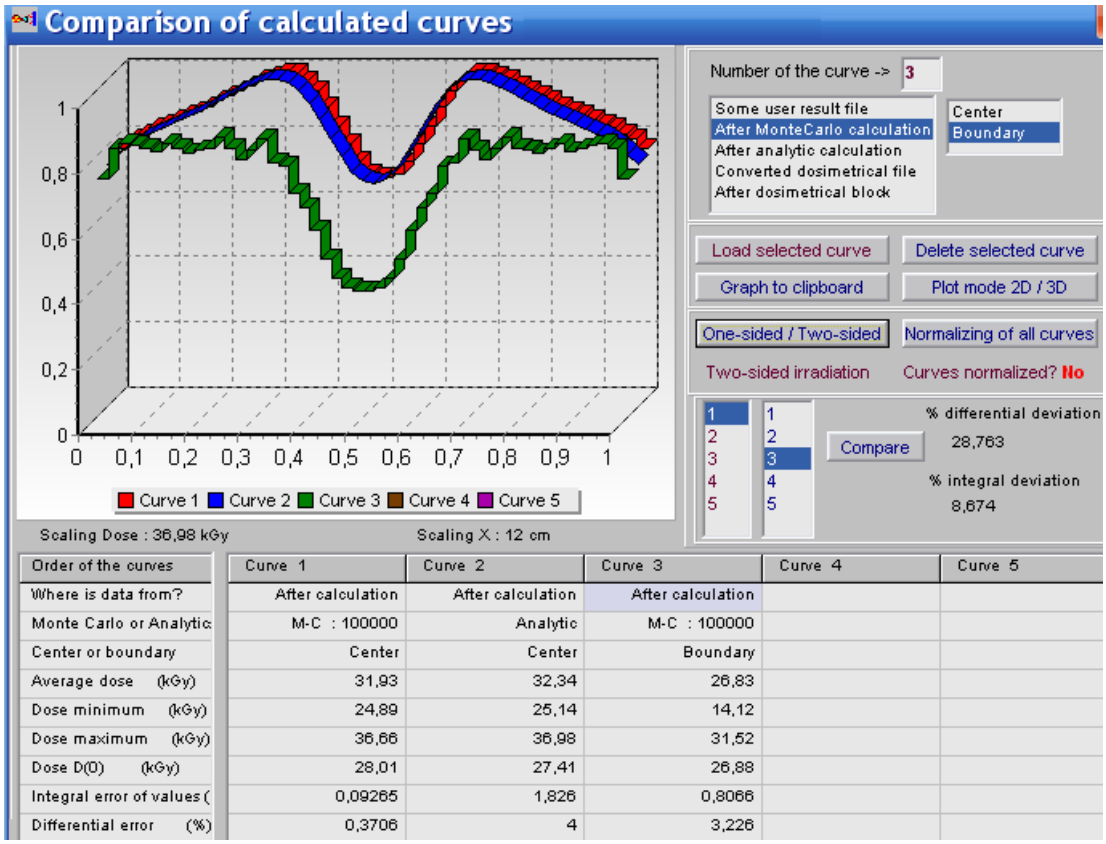
• Additional information related to EB absorbed dose distributions are presented in this form:

• Dose uniformity ratio
• Average dose
• Dose minimum
• Dose maximum
• Part of beam use.
• CSDA range.
• Extrapolated range.

6. Module "Comparison

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 ModeRTL (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.19).



Order of the curves	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5
Where is data from?	After calculation	After calculation	After calculation		
Monte Carlo or Analytic	M-C : 100000	Analytic	M-C : 100000		
Center or boundary	Center	Center	Boundary		
Average dose (kGy)	31,93	32,34	26,83		
Dose minimum (kGy)	24,89	25,14	14,12		
Dose maximum (kGy)	36,66	36,98	31,52		
Dose D(0) (kGy)	28,01	27,41	26,88		
Integral error of values (	0,09265	1,826	0,8066		
Differential error (%)	0,3706	4	3,226		

Fig.19. The form of "Comparison of calculated curves". Example of 2D EB dose distributions in two-sided irradiated target.

Curve 1 – EB dose distribution in the center of irradiated target calculated with MC method.

Curve 2 – EB dose distribution in the center of irradiated target calculated with Analitical method.

Curve 3 – EB dose distribution near the boundary of irradiated target with packing material calculated with MC method.

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

There are the following variants of curves for the selection:

1. **"Some user result file"- simulation results of the EB 2D dose distributions which were previously stored in the files.**
2. **"After Monte Carlo calculation" –the results of current Monte Carlo calculation of the EB dose distributions in the target.**
3. **"After analytic calculation" - the results of current Analytic calculation of the EB dose distributions in the target.**
4. **"Converted dosimetric file" –results with dosimetric experimental data which were prepared and saved after processing of dosimetric films with the Dosimetry module.**
5. **"After dosimetric block" - results related with dosimetric experimental data.**

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

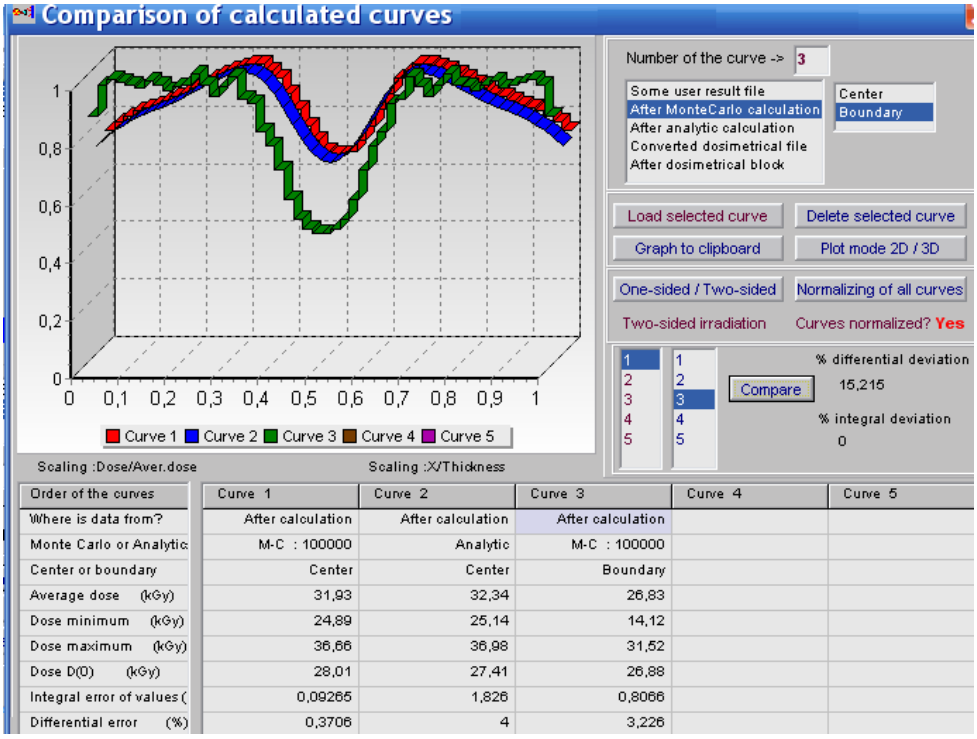
• Select by cursor the any of 5 columns of the table in the bottom part of the form the "Comparison of calculated curves". The selected column number will be automatically entered to the window "Number of the curve".

• 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 5 curves of 2D dose distributions in the graph area. (See Fig.19).

You can "Delete selected curves" and make for all curves "Normalization". (See Fig.20).



Order of the curves	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5
Where is data from?	After calculation	After calculation	After calculation		
Monte Carlo or Analytic	M-C : 100000	Analytic	M-C : 100000		
Center or boundary	Center	Center	Boundary		
Average dose (kGy)	31,93	32,34	26,83		
Dose minimum (kGy)	24,89	25,14	14,12		
Dose maximum (kGy)	36,66	36,98	31,52		
Dose D(0) (kGy)	28,01	27,41	26,88		
Integral error of values (	0,09265	1,826	0,8066		
Differential error (%)	0,3706	4	3,226		

Fig.20. Example of "Normalization" for dose distributions presented in Fig.19.

• 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. 19. and 20).**

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

• To copy the results comparison into your document, **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.

7. Temperature module

Temperature module is intended for analysis of the temperature fields during heating and cooling of an irradiated target with EB.

• Click the button "Temperature" in the main form of the Software ModeRTL, to calculate of a temperature cooling of an irradiated target. (See Fig. 1).
The main form "Control panel for temperature calculations" will be opened. (See Fig. 21).

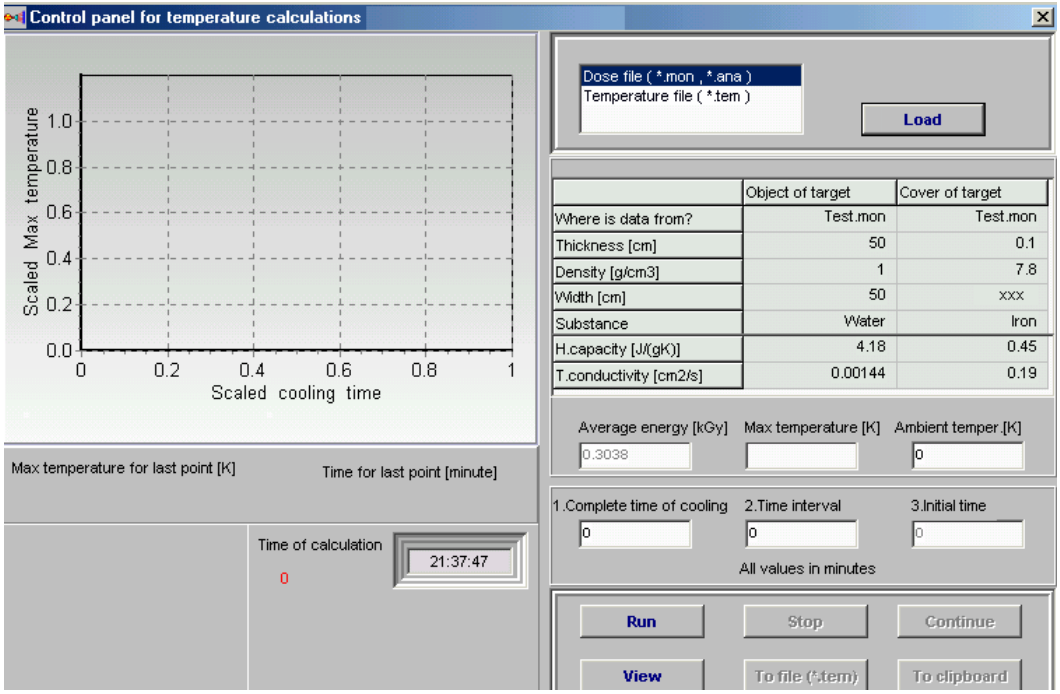


Fig. 21. Control panel for analysis of heating and cooling of an irradiated target.

• Select the file in the frame "Load". (See Fig. 22).
"Dose file (*.mon, *.ana)" is a file with data of current or before calculated and saved the X-ray dose distribution in an irradiated target..
"Temperature file (*.tem)" is a file with data of calculated temperature fields which were saved on the hard disk during the previously session of the "Temperature" module.

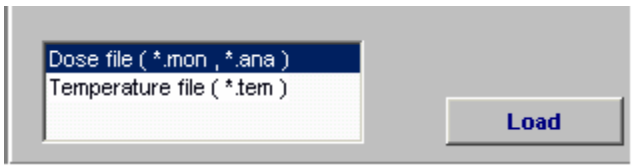
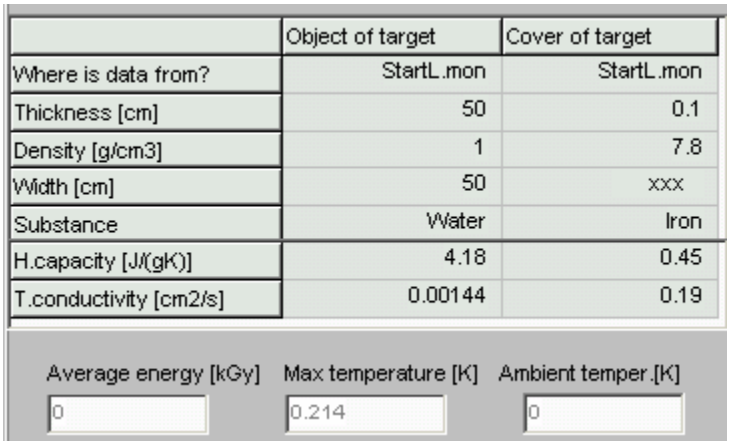


Fig. 22. Frame "Load".

• Click the button "Load" for the choose file.
The Table for chosen file will be opened with following data:
sizes, density, Heat capacity (H_c) and Temperature conductivity (T_c) for target and cover materials. (See Fig. 23).



	Object of target	Cover of target
Where is data from?	StartL.mon	StartL.mon
Thickness [cm]	50	0.1
Density [g/cm3]	1	7.8
Width [cm]	50	xxx
Substance	Water	Iron
H.capacity [J/(gK)]	4.18	0.45
T.conductivity [cm2/s]	0.00144	0.19

Fig. 23. Table with characteristics of target and cover materials.

• **Enter** the value of $\mathbf{H_c}$ and $\mathbf{T_c}$ by hand for materials not given in the Table **" List of material" in the frame "Target" .**
• **Enter data to fields "Complete time of cooling" (CTime), "Time interval" (Int), and "Initial time" (ITime).**

Note. ITime = 0 always, if you only begin to calculate temperature fields.

• **Enter values to fields CTime and Int and Press button "Run".**
• **Leave CTime = 0 and Int = 0 and press the button "Run", if you don't know these values.**
•In this case the expert program takes start, message window appears at the screen.
• **Click "Yes".**
• **When calculation of a temperature has started , the red curve appears upon the plot and Max Temperature, Cooling Time for last calculated point for the every step. (See Fig. 24).**

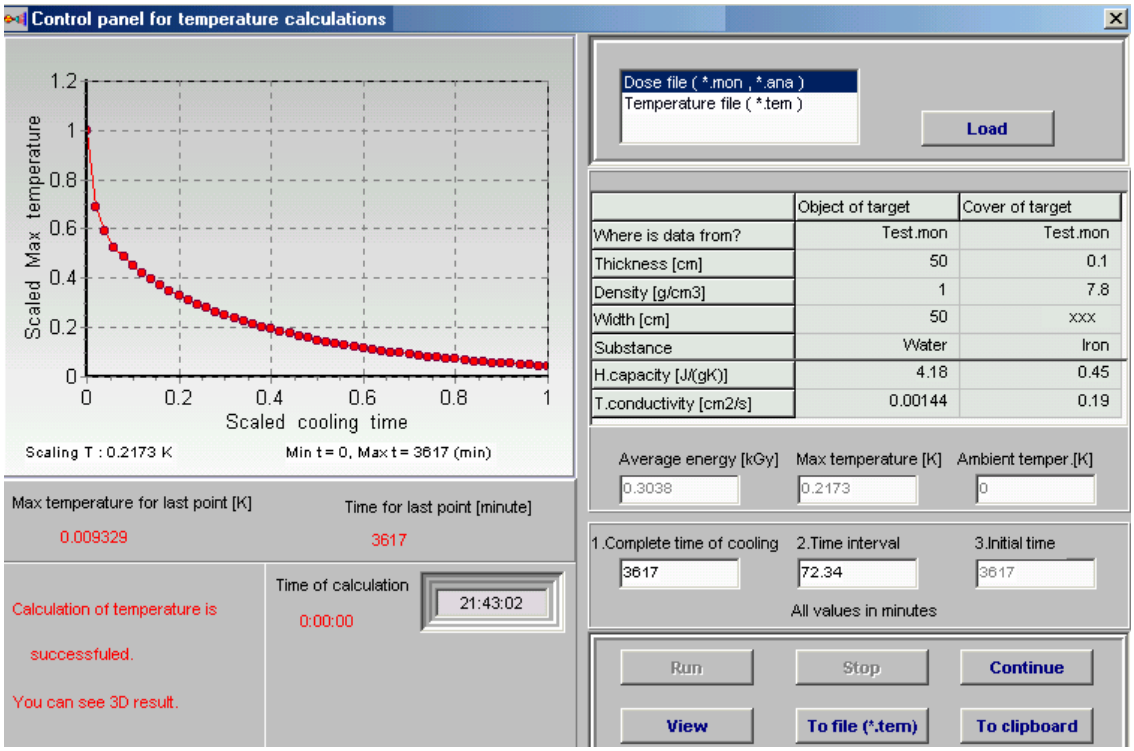


Fig. 24. Control panel for analysis of heating and cooling of an irradiated target. End results.

• In calculation time the button "Run" is inaccessible, but the button "Stop" is accessible. You can stop the calculation by click of the button "Stop".
At this point all other buttons of the control panel become accessible.
• If you have stopped process of the calculation, you can change values of CTime and Int, can look the temperature diagram by click the button "View", can save temperature fields at this step as the temperature file (*.tem) on the hard disk by click the button "To file (*.tem)", can send data to clipboard with click the button "To clipboard".
• After stop or finish of the calculation process you may change parameters and continue a temperature research by Click the button "Continue".

Note.
There are some differences between continuation after stop and finish of calculations.
If you continue calculations after stop, a plot takes continuation from the last point which was calculated at the previous step.
If you continue calculations after finish, a plot starts from the first point.
Because a plot has 50 points for results presentation, your one calculation session can have only 50 steps.
If you need more steps, you have to finished the first session, to change values CTime and Int and to start the next session by Click the "Continue".

8. Dosimetry module

Block "Dosimetry" is intended for processing of dosimetric films with experimental data and for preparing data for "Comparison" module.

• Click the button "Dosimetry" in the Main form of the Software ModeRTL (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.25.a).

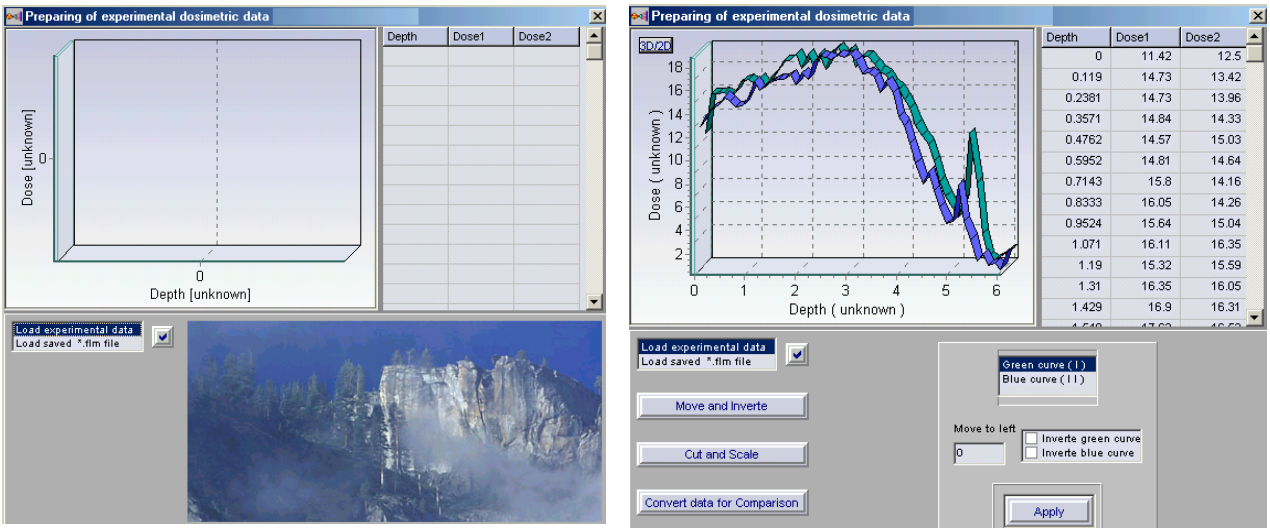


Fig.25 a, b. The forms for "Preparing of experimental dosimetric data".

• 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.25 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.26 a, b).

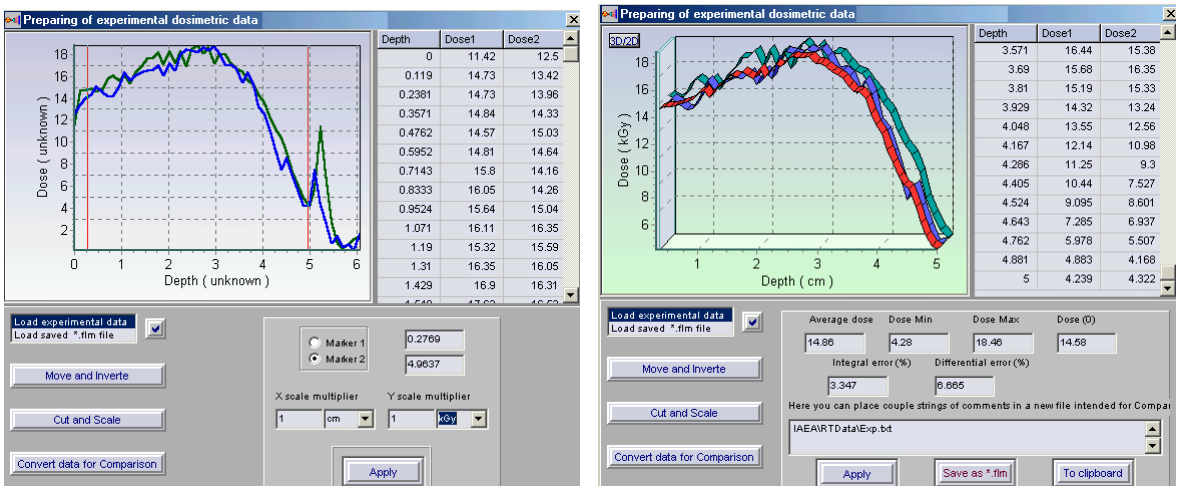


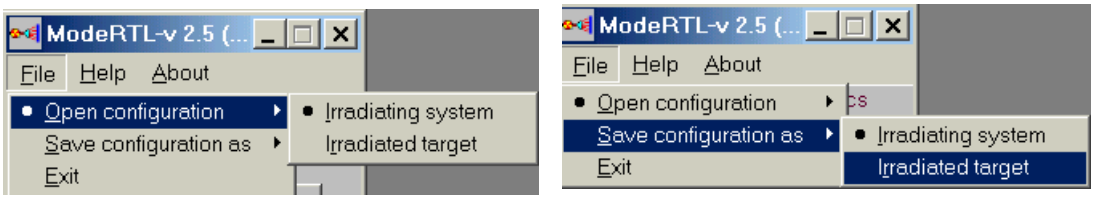
Fig.26 a, b. The forms for "Processing of experimental dosimetric data".

• 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.26. 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.26. 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.26. 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.

9. Service blocks

The Software ModeRTL has service blocks: open and save input data about configuration of irradiation process.
Click the File in the Software ModeRTL master menu.
Select "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 ModeRTL master menu and selecte item "Open configuration" from list.



The Software ModeRTL has some programs for visualization of calculated results. There are two viewers:
• The 2D viewer "Dose distributions after MC and Analytic calculation" with 2D absorbed dose distributions in graphical and tabular forms for irradiated target.
This viewer is intended for analysis of the plots with 2D absorbed dose distributions for target center and near the boundary of target with packing materials or with air.

• **The 3D viewer "Dose Map" is used for analysis of 3D view of dose distribution in irradiated target.**

"Dose Map" is viewer for showing:

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

You can see diagram, data table, and 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 with figures has button To clipboard. To send plot to clipboard you need to click on this plot and to press To clipboard.

• You can write calculated result on hard disk as file "*.mon" or "*.ana" after MC or analytic calculations respectively.

•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.