

**Software ModeGR for Quality Control
of Gamma Ray Processing**

User Manual

Software ModeGR

Modeling of 3D Gamma dose distribution with MC method.

The program **ModeGR** was designed specially for simulation of the **absorbed dose distribution** within multi-layer packages **irradiated with gamma ray from flat panoramic ^{60}Co source rack.**

The ^{60}Co source rack can be represented as a rectangular planar frame with number of modules from 4 up to 20, which should be mounted in two levels, with uniform/non uniform distribution of ^{60}Co strength.

The product on a conveyer platform can be irradiated in two modes:

- **continuous mode** - the container with product will continuously move on a conveyer platform in parallel with surface of source rack;
- **shuffle-dwell mode** - the container with product will discontinuously move on a conveyer platform in parallel with surface of source rack to a new irradiation position and then remaining at rest for a dwell time at that position. Where the dwell time is the time interval during which a process load is at rest at an irradiation position

Irradiated product can be represented in form of container with homogeneous materials as well as of container with stack of plates. The stack of plates can be interleaved with dosimetric films.

A source of gamma rays, a conveyor line, an irradiated product and a package are considered in uniform self-consistent **geometrical** and **physical** models.

Differential and integrated characteristics of an irradiation process are calculated with use of a Monte Carlo method.

The software **ModeGR** provides the end-user with data sets in the graphic and tabular form the 2D and 3D absorbed dose distribution within the product irradiated with a gamma rays **from flat panoramic ^{60}Co source rack.**

The **ModeGR** contains a set of tool means for the comparative analysis of the obtained data for absorbed dose of gamma ray. Service blocks of the program, in reporting forms, give the user the necessary and sufficient information for decision-making at:

- the choice of optimum conditions, the configuration, parameters and operating modes of the radiation facility;
- the configuration of the irradiated objects with taking into consideration of features irradiated materials;
- the organizations of a dosimetric control during materials processing;
- the confirmation of a correctness (verification) of results of the carried out irradiation.

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

1. Two levels for entering of input data via configuration files and manually.
2. Built-in tools for statistical analysis.
3. Built-in tools for uncertainties estimation of results simulation due to uncertainties of input data for radiation facility.
4. Estimation of uncertainties for physical models.
5. Built-in tools for dose volume histogram analysis.
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.

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

Software ModeGR. How to get results.

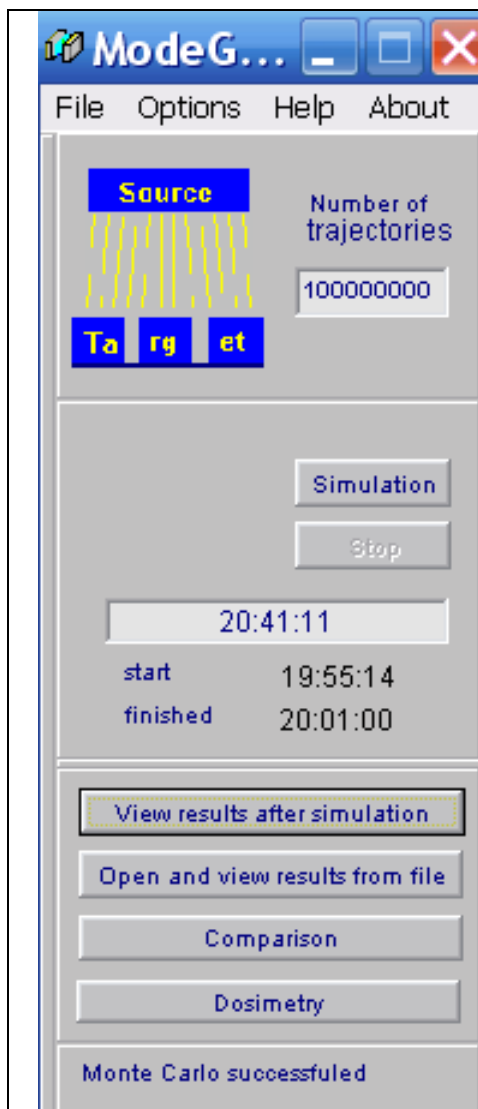


Fig.1. The main form of the Software ModeGR

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

- **“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 tool allows to load data files, invert and move each experimental curve, cut and scale, transform to format of Comparison module.

For work with **software ModeGR** -

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

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

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

- **Enter** the "**Number of trajectories**" and
- **Click** the button "**Simulation**".

In time simulation the **Software ModeGR** shows starting time and defines time required for calculation.

- **Click** "**Stop**" to interrupt your calculation and reenter data.
- When MC simulation will be finished, the button "**View results after simulation**" will be active.
- **Click** the button "**View results after simulation**" and work with results.

1. Geometrical model of Gamma ray facility and irradiated target

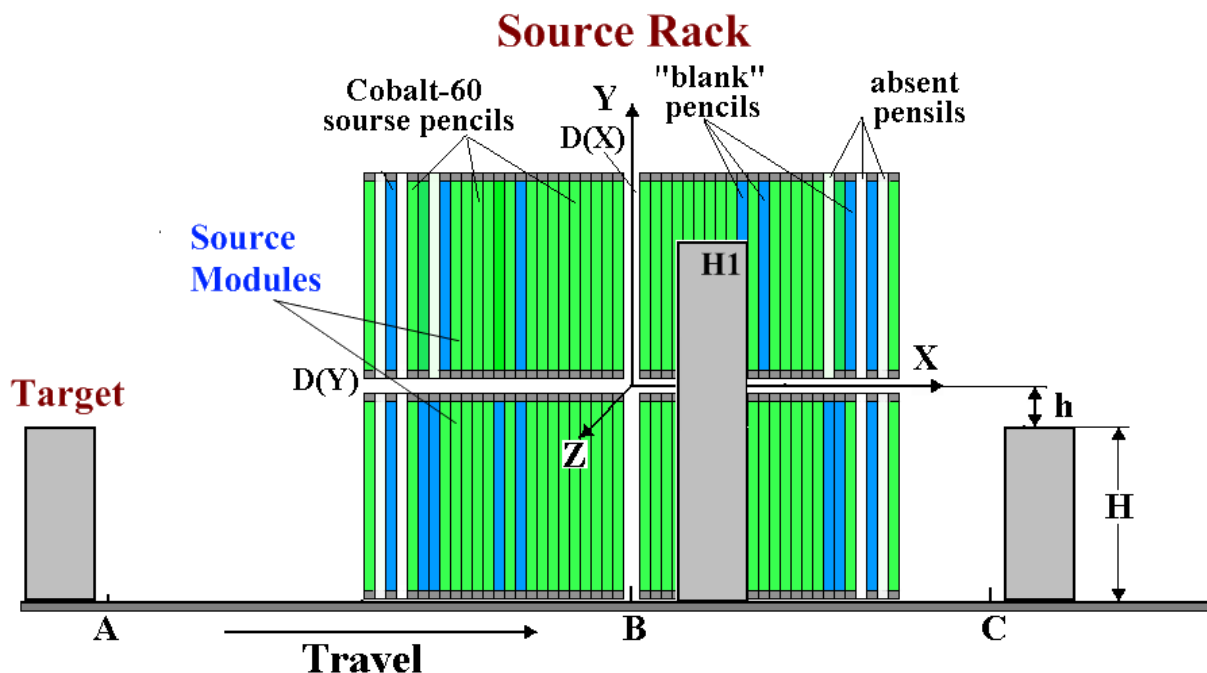


Fig.2. Geometrical arrangement of ⁶⁰Co pencils, four source modules, conveyor and containers with product.

The ⁶⁰Co source rack can be represented as a rectangular planar frame with number of modules from 4 up to 20, which should be mounted in two levels, with uniform/non uniform distribution of ⁶⁰Co strength.

Geometrical models of multi-layer targets

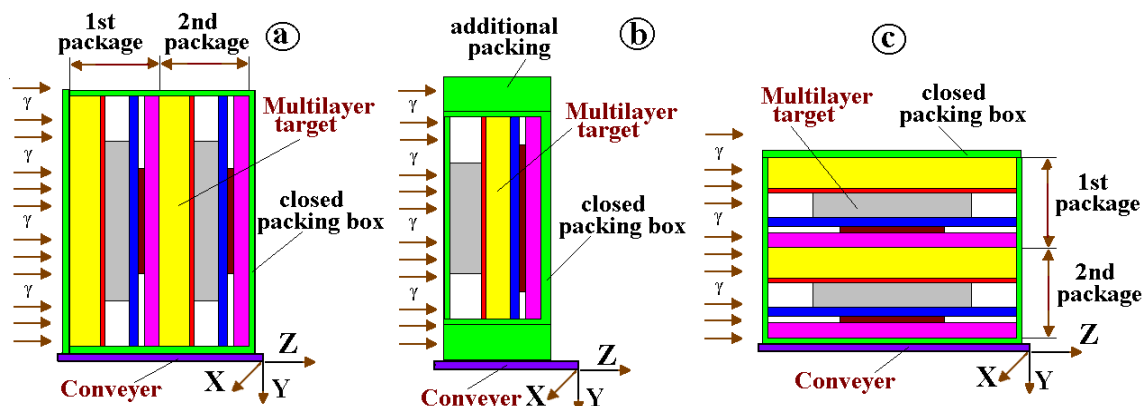


Fig.3-1. Geometrical models of multi-layer targets on moving conveyor irradiated with Gamma ray. Conveyer moves along axis X.

(a) Multi-layer target consists of two 6-layer packages placed in closed packing box.

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

(c) multi-layer targets irradiated with Gamma ray in parallel with interface of contacting materials.

Irradiated product can be represented in form of container with homogeneous materials as well as of container with stack of plates. The stack of plates can be interleaved with dosimetric films.

The product on a conveyer platform can be irradiated in two modes:

- **continuous mode** - the container with product will continuously move on a conveyer platform in parallel with surface of source rack;
- **shuffle-dwell mode** - the container with product will discontinuously move on a conveyer platform in parallel with surface of source rack to a new irradiation position and then remaining at rest for a **dwell time** at that position.

Where the **dwell time** is the time interval during which a process load is at rest at an irradiation position.

Notes.

- Multi-layer target can be located on the conveyer platform **with/without packing box**.
- Front face of **packing box** can be **open** for all above targets.

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.

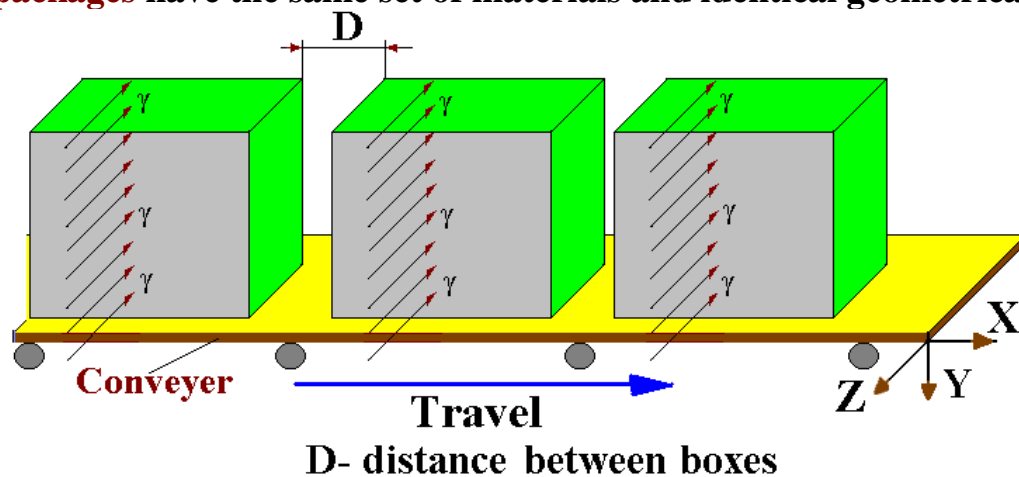


Fig. 3-2. Geometrical model of 3 identical Multi-layer targets with packing box on a conveyer platform irradiated with Gamma ray. The distance **D** between boxes with Multi-layer targets can be ≥ 0 .

2. Co^{60} multipass shuffle-dwell irradiator

The computer model allows calculate the absorbed dose distribution and optimize dose uniformity within product irradiated on Co^{60} multipass shuffle-dwell irradiator. The schematic model of a typical Co^{60} multipass shuffle-

dwelling irradiator with overlapping product to gamma source configuration is presented in Fig.4.

The 64 Aluminum containers with product are moved around the Co^{60} source rack on a conveyor 4 passes at two levels. Two levels are characterized by horizontal and vertical movements of the product containers.

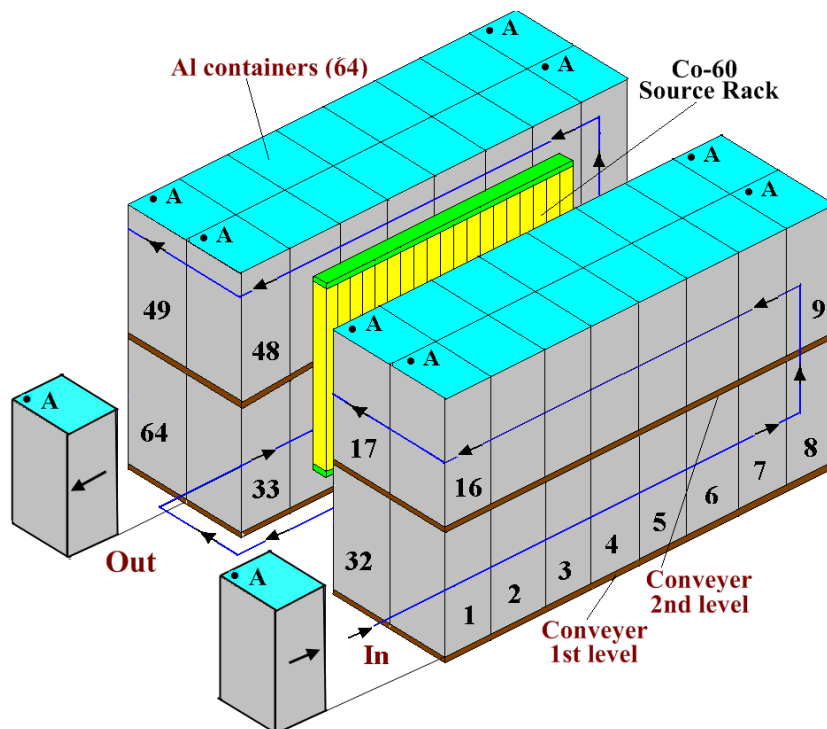


Fig.4. Sequence of irradiation in a flat panoramic Co^{60} source rack, multipass, two direction, multiposition. The 64 aluminum containers with product are moved around the Co^{60} source rack on a conveyor 4 passes at two levels. “A” is a fixed point on the side surface of the process load, which passes through the irradiation room on both sides of the Co^{60} source rack from position 1 to position 64, with two passes on each side of the source.

In multipass shuffle–dwell mode of operation, the product containers stay at the designated irradiation positions around the radiation source for a certain dwell time, and then they all move to the next positions, such that each container irradiated at each dwell position before leaving the irradiation room. There are 16 dwell positions for each of the four passes and 64 for the four passes. As a result, the product irradiated with gamma ray at two sided.

3. Input data

- Click the "File" in the main form of the Software ModeGR, then "Open configuration", then select "irradiating system" and load the file "Test.rts". The frame “Source of Gamma Ray” with characteristics of Gamma irradiator will be opened. (See Fig.5).

Source of Gamma Ray (ModeGR 1.2 2009)

1. Radius cobalt slug: 0,5
2. Height cobalt slugs: 20
3. Radius end cap: 0,7
4. Height end cap: 2
5. Radius of capsule: 0,55
6. Distance between pencils axes: 1,5

7. Distance X between modules: 2,5
Number of pencils: 20
8. Distance Y between modules: 2,5

Module 1		Module 2		Module 3		Module 4	
N	Activity.	N	Activity.	N	Activity.	N	Activity.
1	20	1	0	1	0	1	0
2	30	2	0	2	0	2	0
3	4	3	0	3	0	3	0
4	2	4	0	4	0	4	0
5	2	5	0	5	0	5	0
6	80	6	0	6	0	6	0

9. Distance Z source-packages: 5
10. Distance Y source-packages: -20
11. Left part of irradiation field: 1000
12. Right part of irradiation field: 1000

Continuous mode (selected)
Conveyor speed: 1
Discrete mode

Speed in [cm/sec], Time in [sec], other values in [cm] Save data and close this window

Fig.5. The main form of “Source of Gamma Ray” for entering of input data and correction of Gamma source rack parameters.

The form comprises three parts:

- **top part** contains of characteristics for gamma ray **source pencils**,
- **middle part** contains of characteristics for **source modules** and **source rack**,
- **lover part** contains of the parameters of mutual arrangement for **source rack** and container with **irradiated product**.

3.1. Input data of source pencils

There are two types of **source pencils** which are used in the gamma irradiator model:

- **active cobalt-60 slugs** encapsulated into stainless steel capsule, and
- a “blank,” **inactive stainless steel cylinder**.

The source pencil construction is presented in Fig.6.

All pencils types have the same geometrical characteristics.

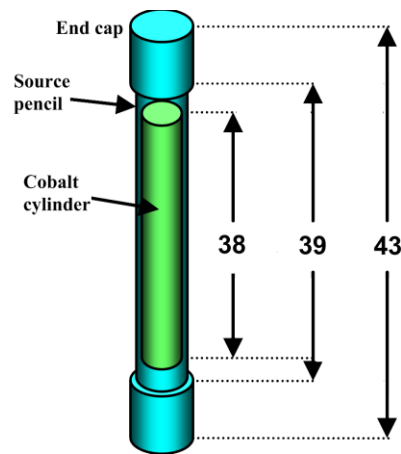


Fig.6 . Source pencil construction.

- Enter the value of the **radius** and **height** of **cobalt slugs** in cm.
- Enter the value of the **radius** and **height** of **end cap** in cm.
- Enter the value of the **radius** of capsule in cm.
- Enter the value of the **distance** between **axes** of **adjacent pencils** in cm.

3.2. Input data of source modules and source rack

Typical source modules manufactured by firm MDS Nordian, Canada comprises **40-48** of the above **cobalt-60** source pencils.

The model of source module with pencils arrangement is presented in Fig.7. In this model the **number of pencils** in the **source module** can be in the **range from 0 to 200**.

It allows one **source module** to present (**reconstruct, simulate**) as **1-5 typical source modules**.

As a result, we can represent source rack with **20 typical source modules**, in **2 x 10** array.

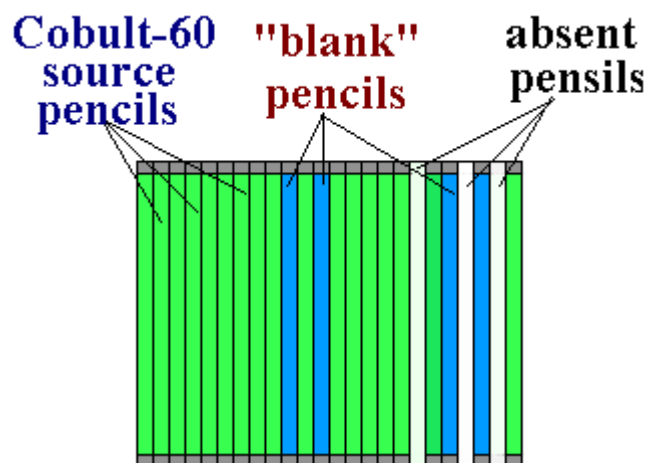


Fig.7. Scheme of arrangement of **sours pencils** in the **source module**.

The schematic model of the **panoramic source rack** with arrangement of **four source modules** is presented in Fig.8.

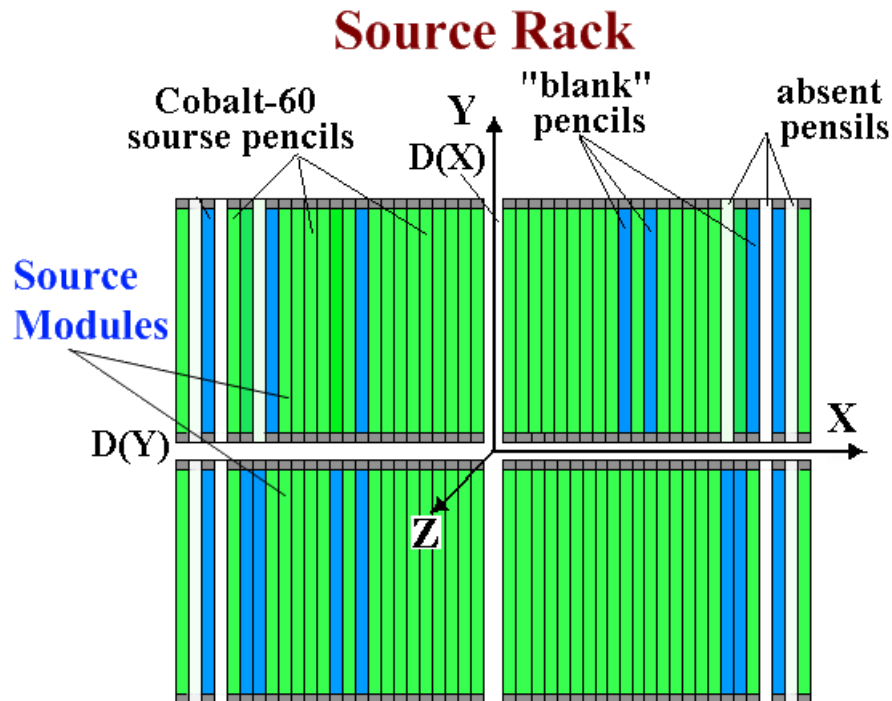


Fig.8. The model of **flat panoramic source rack** comprises of four above source modules, in 2 x 2 array.

- Enter the values into windows **“Distance X between modules”** and **“Distance Y between modules”** in cm.
Distance X and **Distance Y** characterize the displacement between modules along axis X and axis Y. (See Fig.8)
 - Enter the **“Number of pencils”** - the number of source pencils in each source modules. (See Fig.5. middle part.)
 The tables **“Module1”**, **“Module 2”**, **“Module 3”**, and **“Module 4”** will be opened. Each of tables have the rows number equal to the **“Number of pencils”**.
 These tables are used for entering of **Cobalt-60 Activity in Ci** for each source pencil in corresponding modules.
 - Enter the values of **Activity in Ci** to each **source pencil** in the tables **“Module1”**, **“Module 2”**, **“Module 3”**, and **“Module 4”**.
 - Enter **“0”** in rows of Modules, where the pencils with **cobalt slugs** and **“blank” pencils are absent**.
 - Enter **“-1”** in rows of Modules, where the **“blank” pencils** are located.
- In this way, you can **Enter** the values of **Activity in Ci** to **source pencils** step by step in all **source modules**.

There are **service** for accelerating of entering of the value of source pencil activity in the tables of **Modules**, for cases:

- when **source module** contains a big number the “**blank**” pencils, or
- when **source module** contains a big number the **absent pencils**,

For use service:

- **Select** Module with a big number of “**blank**” or **absent pencils**.

For do it, **Click** the number of selected Module “**1, 2, 3, or 4**” in down part of frame with **source rack** characteristics. (See **Fig.5**. middle part.)

- **Enter** the values of **Activity in Ci** only to each **active source pencils** in the table of selected **Module**.
- **Select** “**0**” or “**-1**” in the window located near the **button** “**Fill activity table**”.
- **Click** the **button** “**Fill activity table**”.

As a result, all empty rows in the **selected Module** will be filled with value “**0**” or “**-1**”.

3.3. Input data of source rack and target arrangement

- **Enter** the value of the “**Distance Z source-packages**” in cm.
- **Enter** the value of the “**Distance Y source-packages**” in cm.

“**Distance Z source-packages**” characterize the distance between planar surface of irradiator and frontal face of the product container.

“**Distance Y source-packages**” characterize the displacement of bottom part of the product container relatively axis X. (See **Fig.5**.)

Default mode characterize the location of the product container in a such position that center of the container in direction of axis Y is equal position $Y=0$.

- **Enter** the value of the “**Left part of irradiation field**” in cm.
“**Left part of irradiation field**” characterize the distance **AB** in **Fig.2**.
- **Enter** the value of the “**Right part of irradiation field**” in cm.
“**Right part of irradiation field**” characterize the distance **BC** in **Fig.2**.
- **Select** the **mode of conveyer movement**.
- **Select** the “**Continuous mode**” with a tick.
- **Enter** the value of “**Conveyer speed**” in cm/sec.

As a result, the packages with irradiated materials will continuously move on a conveyer platform in parallel with surface of source rack from first point of the “**Left part of irradiation field**” to the last point of the “**Right part of irradiation field**” with selected “**Conveyer speed**”. (See **Fig.2**.)

First point of the “**Left part of irradiation field**” (see **point A on Fig.2.**) characterize the **entrance** into gamma radiation field (into irradiation room) of front face of packing box in direction of conveyer movement.

Last point of the “**Right part of irradiation field**” (see **point C on Fig.2.**) characterize the **exit** out gamma radiation field (out of irradiation room) of back side of packing box in direction of conveyer movement.

- Select the “**Discrete mode**” with a tick.
- Enter the value of “**Number of positions**”.
- Enter the value of “**Dwell time**” in sec.

As a result, the **packages with material** will **discretely move** on a conveyer platform step by step from first point of the “**Left part of irradiation field**” to the last point of the “**Right part of irradiation field**”.

The “**Number of positions**” characterize the **number of rest** for the container with product on the distance between first point of the “**Left part of irradiation field**” to the last point of the “**Right part of irradiation field**”.

The “**Dwell time**” is the time interval during which a process load is at rest at an irradiation position

4. Target

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

- Click “**Target**” in the Main form of the Software ModeGR (See Fig.1). The form for entering of **input data** for irradiated **Target** and **Cover** (**Container materials**) will be opened (See Fig.9).

Target and cover (ModeGR 1.1 2008)

Number of packages: Multi - Target
6

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

Width of packages: 21
Stack length: 20

2D registration package + layer

Layer	1	2	3	4	5	6
Thickness	10	15	12			
Width	20	20	10			
Density	1	1,5	1,1			

Material selection: Polyethylene, Polystyrene, PMMA, Carbon, Birchwood, Cellulose

Material properties: Density: 2,7; Cover thickness: 0,1; Additional cover: 0

Rows table:

A number	W part
13	1

Thickness, width, additional cover [cm]; Density [g/cm3] Save data and close this window

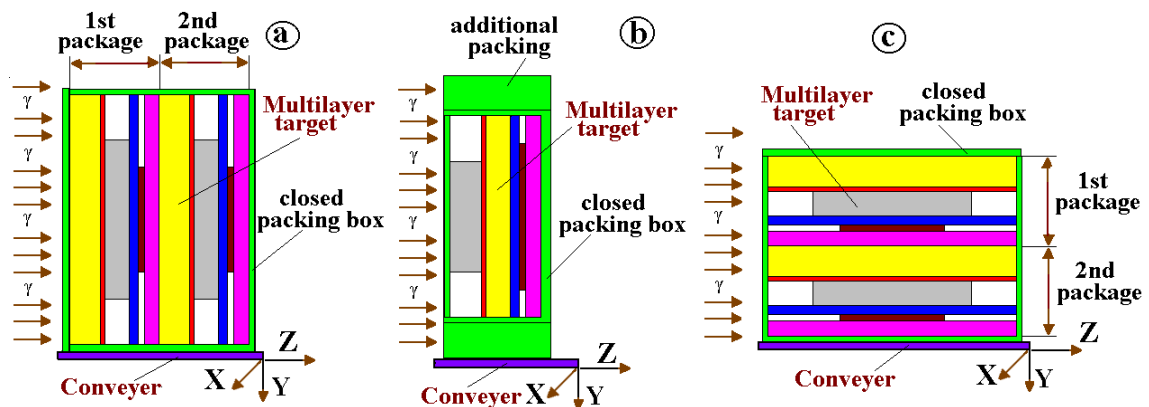
Fig.9. The form for entering of **input data** for irradiated **Target** and **Container materials** (Cover).

4. 2. Multi-layer target model

- **Multi-layer target** consists of some identical packages with **flat sheets** of materials with various density and atomic number.
- **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.10 a, b, c.)
- **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 Y, along source rack height), but all sheets have **identical length** (axis X, 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.11).

The **distance between boxes** with Multi-layer targets can be $\geq 0\text{cm}$.

Geometrical models of multi-layer targets irradiated with Gamma ray



Figs.10 a, b, c. Geometrical models of **multi-layer targets** on moving conveyer irradiated with **Gamma ray**. Conveyer moves along axis X.

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

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

(c) multi-layer targets irradiated with Gamma ray in parallel with interface of contacting materials.

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 Gamma ray axis. (See Figs.10 and 11).

Note. In any layer positions under Gamma ray irradiation, axis **coordinates X, Y, and Z** are hard connected with **width (Y), length (X), and thickness (Z)** of target layers (See Figs.10 and 11).

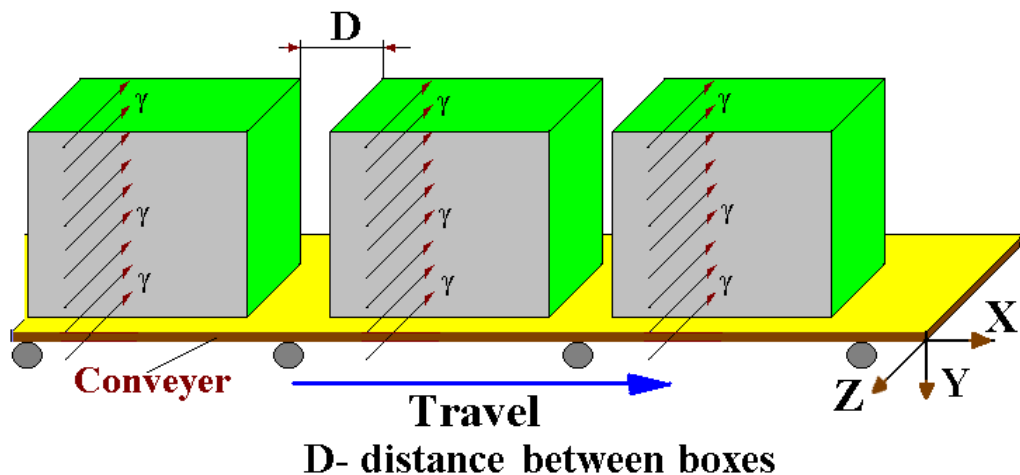


Fig. 11. Geometrical model of 3 identical Multi-layer targets with packing box on a conveyer platform irradiated with Gamma ray. The distance between boxes with Multi-layer targets can be ≥ 0 .

4.3. Input data for layers size and layers materials

- Enter the **number of packages** in multi-layer target in the range from **1 to 10**.
 - Enter the **number of layers** in the package in the range from **1 to 6**.
- For this, Click the button "**Insert**" (right up corner in the "**Target**" frame) (See Fig.9).
- Enter the "**Width of packages**" in cm (left up corner in the "**Target**" frame) (See Fig.9).
 - 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 selected layer.
- Button "**Clear**" is used for cleaning of the parameters in the selected layer.

4.4. Input data for cover size and cover materials

- **Enter** characteristics for the "**Cover Box**": "**Cover thickness**" in cm, "**Additional cover thickness**" in cm, and "**Density of cover materials**" in g/cm³.

Note. In the case of **cover thicknes = 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 **Gamma ray** either in **closed or open** (Tick window "**Opened cover**") **Cover Box**. (See Fig.9).

5. Input data for layers orientation on a conveyer platform under Gamma ray irradiation

- **Simulation model of the software ModeGR** for target irradiation allows to irradiate the box with flat layers from **any of six box sides**. **Selection of target orientation** relatively incident **Gamma ray** is realized with the **switch "Orientation"** (See Figs.9 and 12).

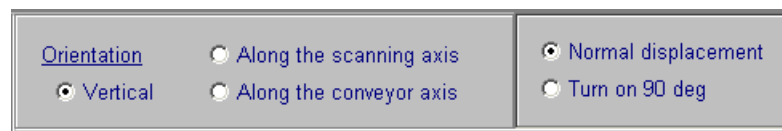


Fig.12. Frame with mode switch of orientation for target layers under Gamma ray irradiation

- **Switch positions ("Vertical" and "Normal displacement")** in Fig.12 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.13.1**.

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

- All possible positions of layers orientation on a conveyer platform under **Gamma ray** irradiation and corresponding switch positions are presented in **Figs. 13.1, 13.2, 13.3, 13.4, 13.5, 13.6**.

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

- All above possible positions under **Gamma ray** irradiation also can be realized for package of flat layers placed in open/closed box (**See Figs. 14.1 and 14.2**) and for package of flat layers placed in open/closed box with additional cover (**See Figs. 15.1 and 15.2**). Additional cover always covers only the box sides in direction of layers thickness (**along axis Z**).

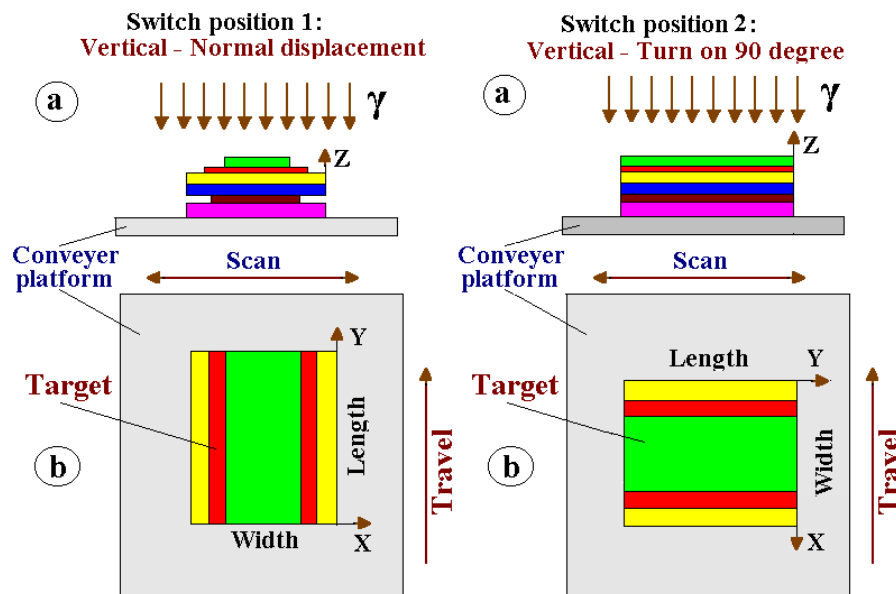


Fig. 13.1

Fig. 13.2

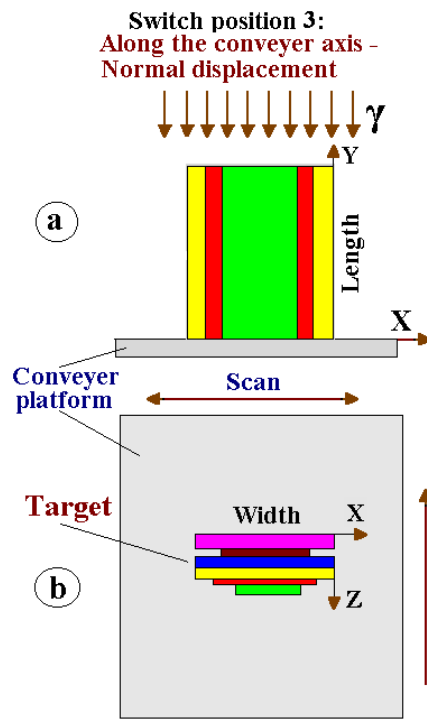


Fig. 13.3

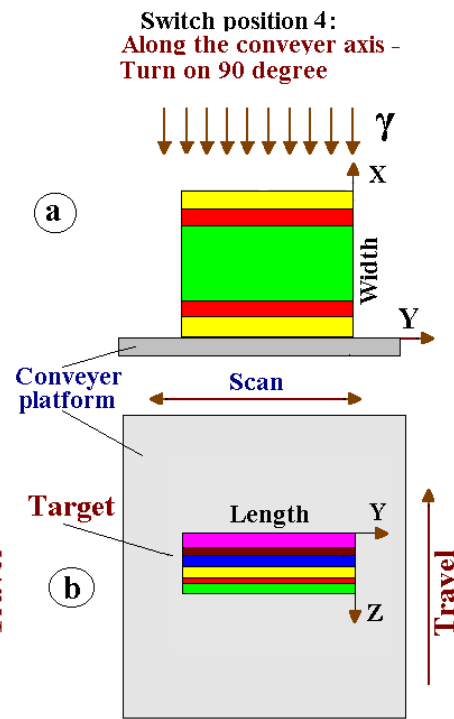


Fig. 13.4

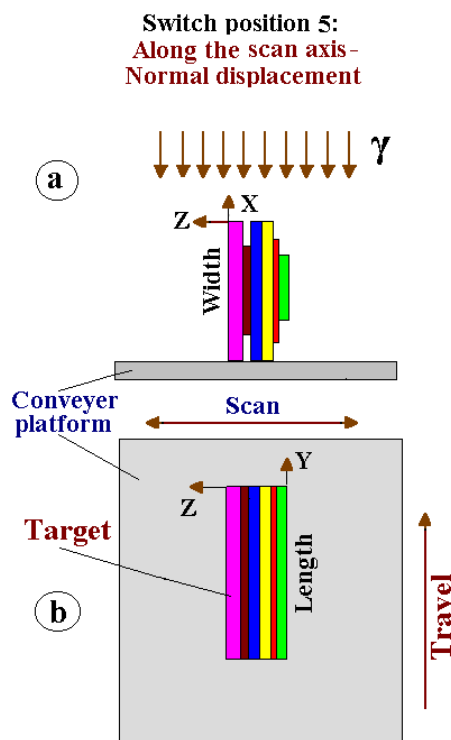


Fig. 13.5

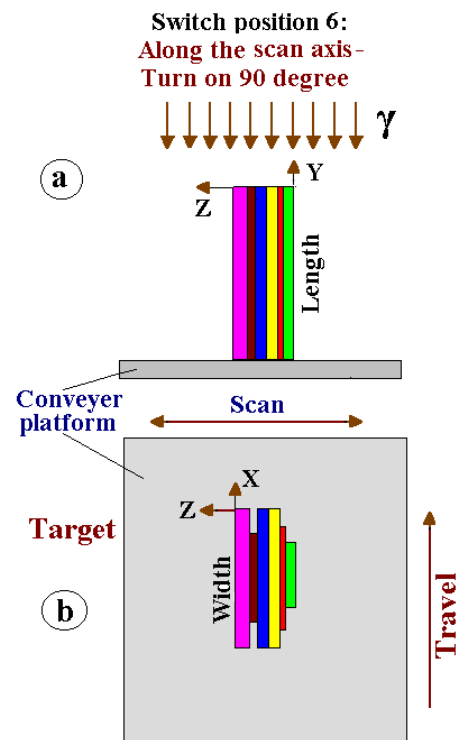


Fig. 13.6

Figs. 13.1, 13.2, 13.3, 13.4, 13.5, 13.6. Layers orientation on a conveyer platform under Gamma ray irradiation and corresponding switch positions

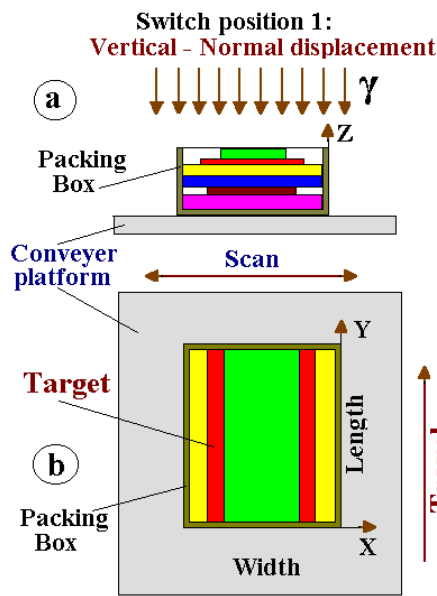


Fig. 14.1

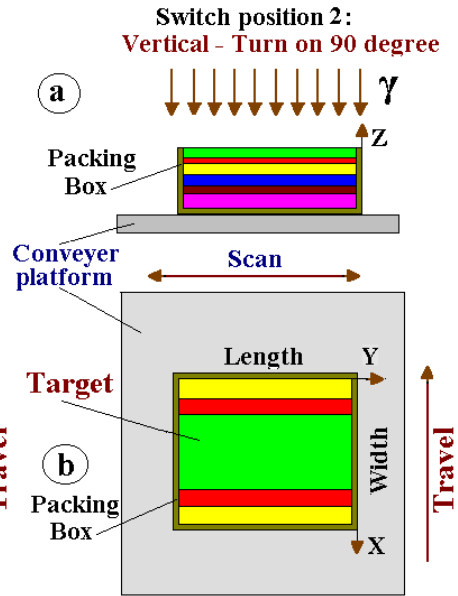


Fig. 14.2

Figs. 14.1 and 14.2. Some possible orientation positions on a conveyer platform for package of flat layers placed in open packing box

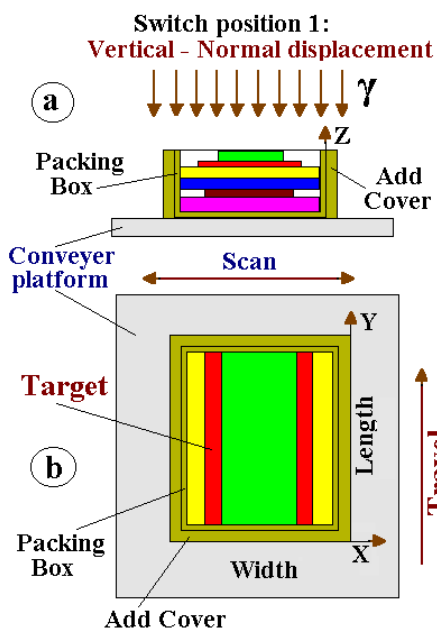


Fig. 15.1

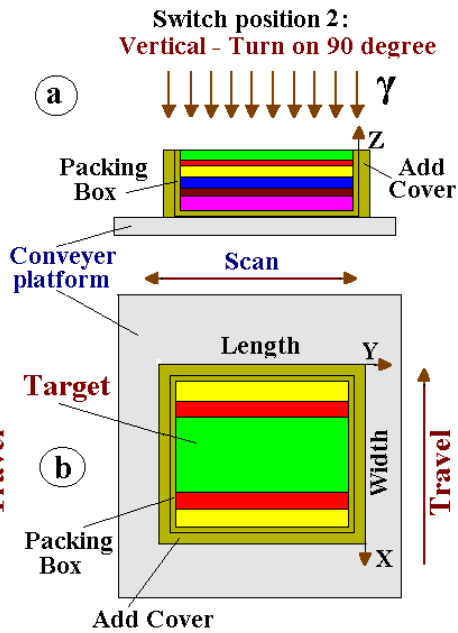


Fig. 15.2

Figs. 15.1 and 15.2. 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

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

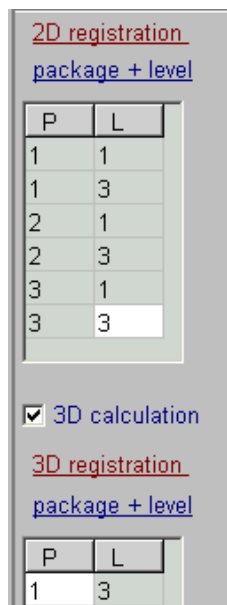
Simulation of the dose distribution in the “**Several identical Multi-layer targets with/without packing box**” allows to investigate the mutual influence of the nearest neighbor boxes on an **Gamma ray absorbed dose formation** in the target layers. (See Fig. 11)

- Click the window "Multi-target" with a tick. (See Figs. 2, 5 and 16).
- Enter the value “Distance between targets” in cm.
The distance between boxes with Multi-layer targets can be ≥ 0 .



Fig.16. The form for entering of input data for Multi-target.

7. Input data for Table “2D registration”



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

3D calculation

P	L
1	3

The Table “**2D registration**” allows to select 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. 2 and 17).

Fig.17. 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 selected 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 selected package "P".

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

8. Input data for Table "3D registration"

The **Table "3D registration"** allows to select the **number of one of packages** and the **number of one of layers in the selected package** for which the results of simulation for analysis of the **3D** absorbed dose distribution (**ADD**) of **Gamma ray** will be presented in the graphical and tabular forms. (See **Figs. 2 and 17**).

- **Tick** the window **"3D calculation "**. (See **Figs. 2 and 17**).
- **Select in the Table "3D registration"** the **number of package P** and the **number of layer L** in the selected package **P**, for which the results of simulation will be available for analysis of **3D** absorbed dose distribution (**ADD**) in graphical and tabular forms.
- For obtaining of the values for **3D ADD** in another packages and layers, you need to enter the number of appropriate package and layer in the **Table "3D registration "** and repeat the run simulation.

In this way, you can made analysis of the **3D ADD of Gamma ray** 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.

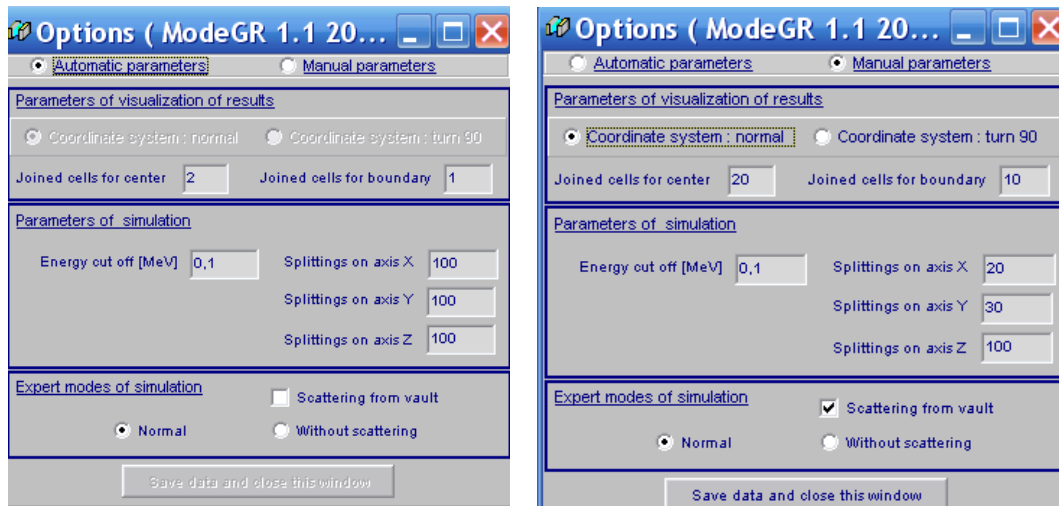
9. Options

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", "Without scattering" and "Scattering from vault"**.
- **Parameters simulation:** **"Energy cut off", and "Splitting on axis X, Y, Z"**.
- **Parameters of visualization of results:** **"Joined cells for center and boundary", "Coordinate system "normal" and "turn 90". See Fig.18 a, b.**



Figs.18 a, b. Main form of “Options” for entering of input data for MC simulation.

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

In the default mode “Automatic parameters” of the Software ModeGR 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.18a.

All parameters of Options can be changed only in regime “Manual parameters”. See Fig.18 b.

9.1. Expert modes of simulation: “Normal”, “Without scattering” and “Scattering from vault”.

Mode simulation “Normal”. It is standard regime with automatic choice of the parameters simulation such as **Photon energy cut off.**

“Normal” mode characterise the full MC scheme which includes simulation:
• transport of Gamma ray beam in an irradiated target with taking into consideration the scattering effects of photons.

“Without scattering” mode characterise MC scheme which includes:

• MC simulation the transport of Gamma ray in an irradiated target without taking into consideration the scattering effects for photons.

Such MC simulation is equivalent so called point kernel method without taking into consideration of the build-up factor.

“Scattering from vault” mode takes into consideration additional to the “Normal” mode the contribution into absorbed dose of scattering photons from targets located in the opposite side of source rack.

9.2. Parameters of visualization of results.

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

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

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

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

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

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

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

9.3. Parameters simulation: “Energy cut off” and “Splitting on axis X,Y, Z”.

• **Change of simulation parameters “Energy cut off”** can be used for scientific researches of transport irradiation through heterogeneous targets. **Note.** In all above **Expert modes of simulation “Normal”, “Without scattering”**, parameter simulation such as **“Energy cut off”** is automatic installed.

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

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

10. The features of output data presentation

10.1. Example. Configuration data for simulation of Gamma ray dose distribution in an irradiated target

The Main form of the Software **ModeGR** is presented in **Fig.19**. Example of **target parameters data**, for which simulation and preparation of output data will be made, is presented in **Fig.20**. **Position of target** on a conveyer platform is presented in **Fig.21**.

Full **configuration data** which are used **under simulation** are presented in **Fig.22**.

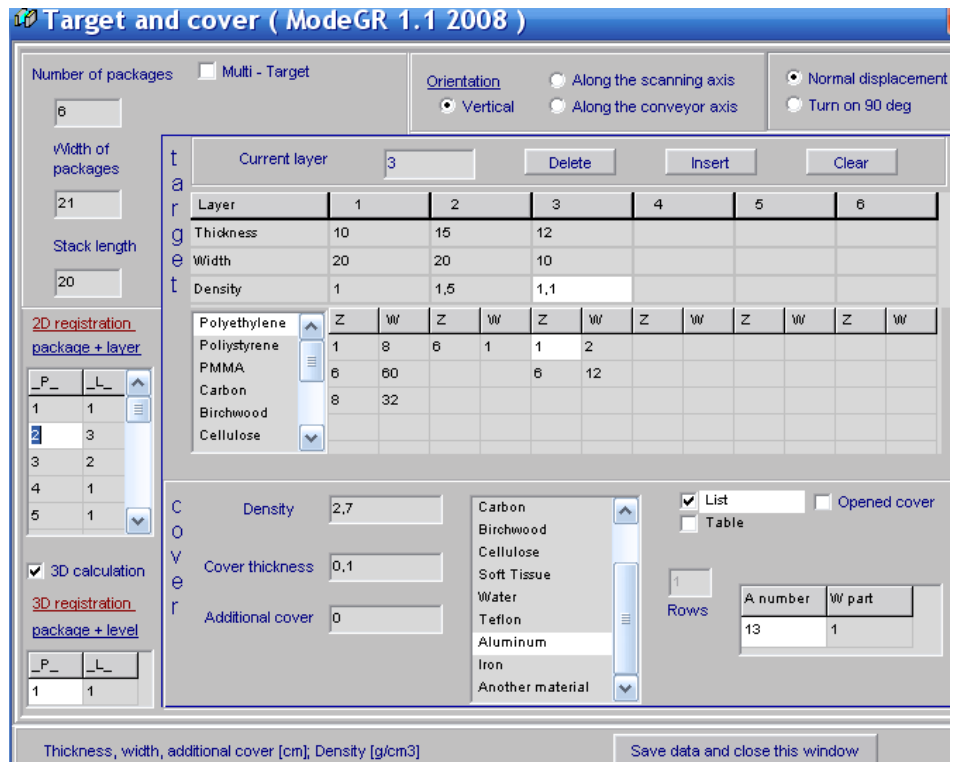
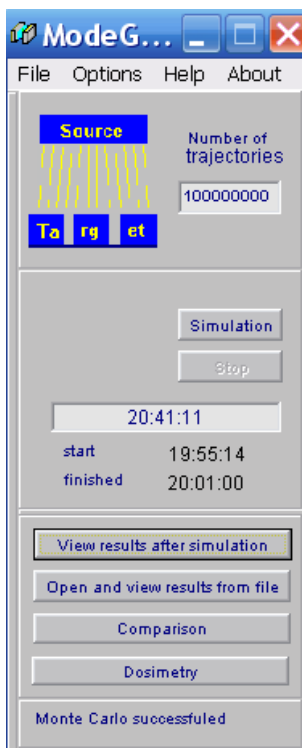


Fig.19. Main form of the Software ModeGR

Fig.20. Example of Multilayer target.

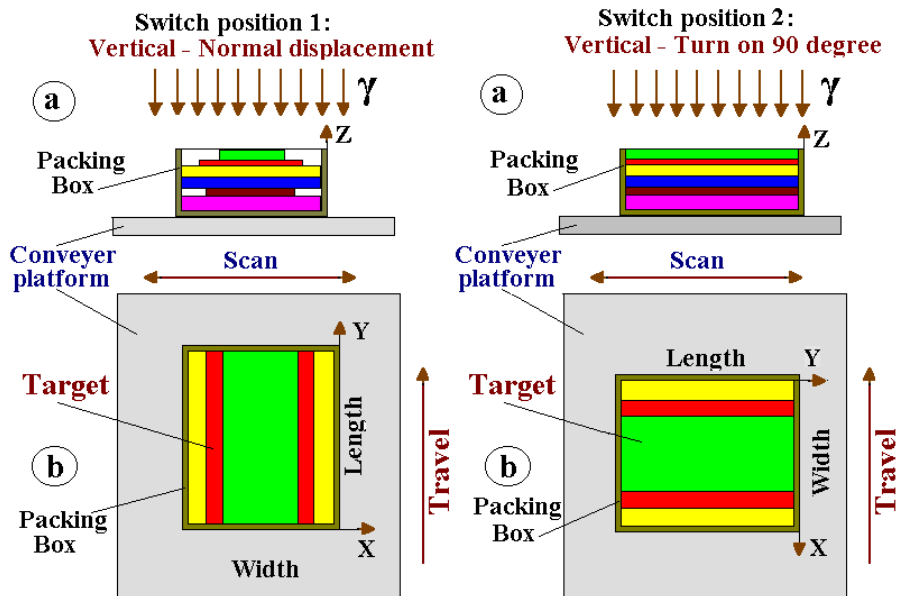


Fig.21. Target positions on a conveyer platform.

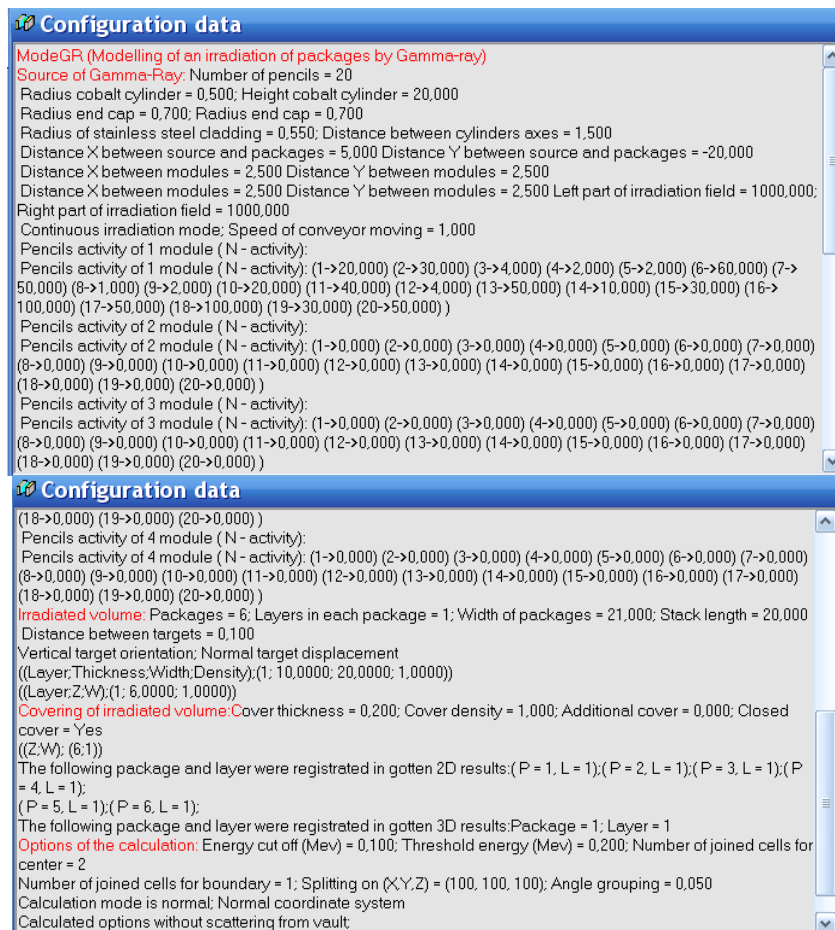


Fig.22. Full set of configuration data which is used at simulation of an Gamma ray absorbed dose distribution.

10.2. Output Data for 2D dose distributions

• After finish **Simulation**, **Click** the button “**View results after simulation**” in the Main form of the Software **ModeGR** (see Fig.19). The form "**Dose distributions after MC simulation**" with **2D absorbed dose distributions** in graphical and tabular forms for selected packages and layers in the Table “**2D registration**” will be opened (see Fig.23).

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

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

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

- **Average dose**
- **Dose minimum**
- **Dose maximum**

- **Statistical uncertainty**
- **Joined cells for centre and for boundary**

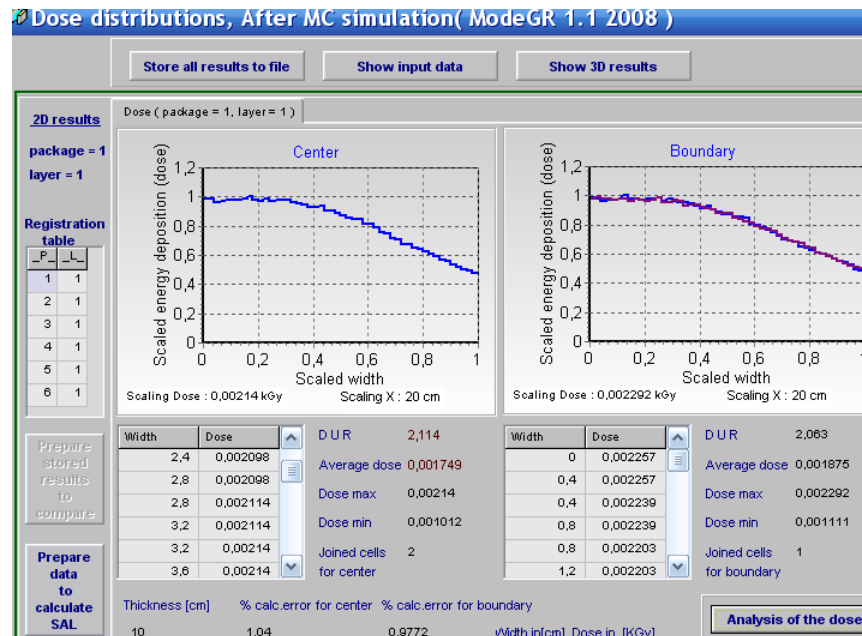


Fig.23. Form with **2D view of the depth dose distribution** of Gamma ray in graphical and tabular forms for the 1st layer in the 1st package.

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

Right graphs - **2D view of the dose distribution** near the **Boundary** of the 1st layer with Air in plane XZ,

blue curve - for first XZ plane in direction of conveyer motion,
violet curve – for the back XZ plane in direction of conveyer motion.

- **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 selected 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 file**", in the Main form of the Software ModeGR (Fig.19).
- 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 ModeGR** are the simulation modulus of the **RTOOffice** information system. **Input and output data for all simulation modulus of the RTOOffice** are self-consistent between themselves.

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

- **Click the button "Analysis of the dose"**, the form **"Dose map for corresponding layer and package "** will be opened (see Fig.24).

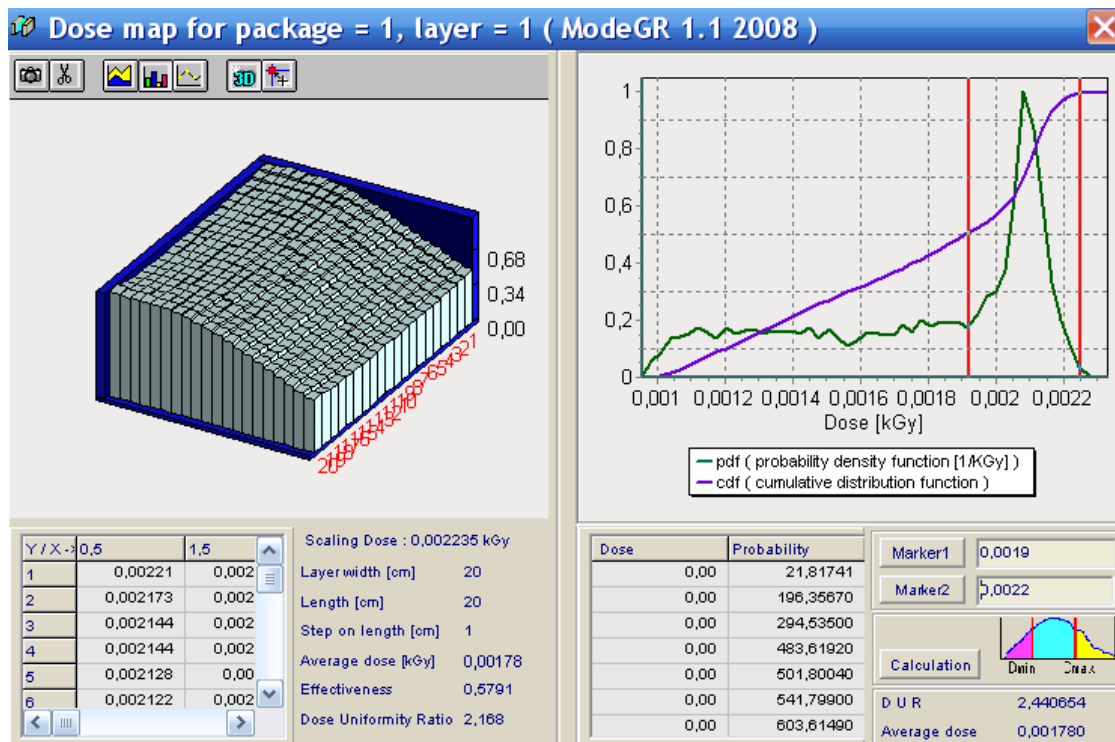


Fig.24. Left Graph -3D view of the depth dose distributions of Gamma ray (Dose Map, along layer length (axis Y) and along layer width (axis X)) in graphical and tubular forms for the 1st layer in 1st package. The dose value is integrated along layer thickness (axis Z).

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**.

- **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 divided Markers will be appeared in the right downside of the “**Dose map**” form. (see Fig.25 – Right part).

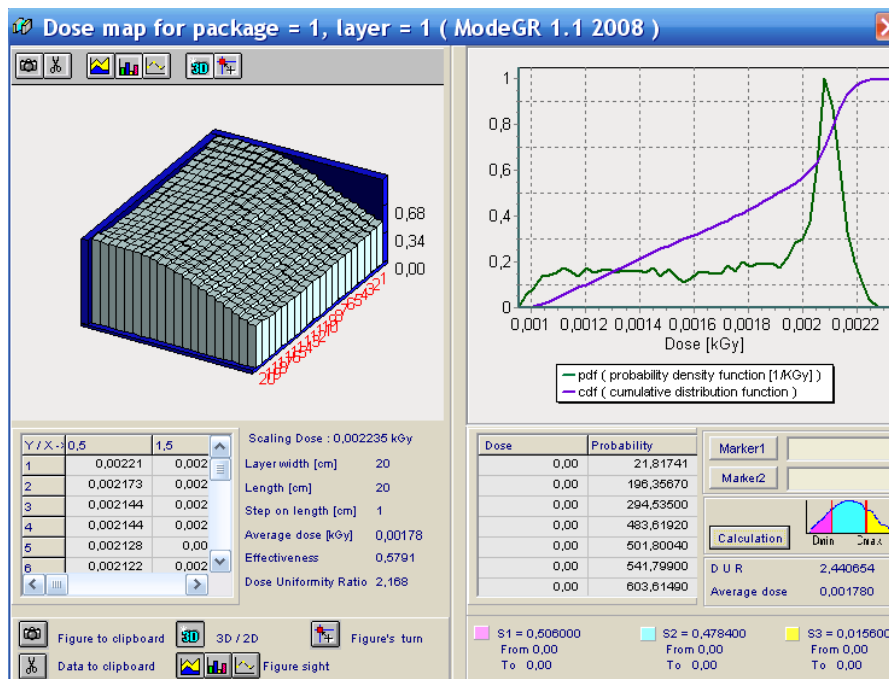


Fig.25. Results of the Dose-Volume-Histogram analysis.

In a such way you can made **DVH analysis** step by step for each of six selected for calculation layers. (see Registration Table “**P_ and _L_**” in Fig.17)

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

10.4. Output Data for 3D dose calculation

10.4.1. Dose-Volume-Histogram (DVH) analysis

• **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 the **DVH and 3D absorbed dose distributions** for the 1st layer in the 1st package. (See Fig.26).

This layer was enter as input data in the Target example for simulation. (See Fig.20).

You can made the **DVH** analysis via the functions **"pdf"** and **"cdf"** in a such way as it was made in the above part, see Fig.25. Results of the **DVH** analysis for the 1st layer in the 1st package are presented in Fig.26.

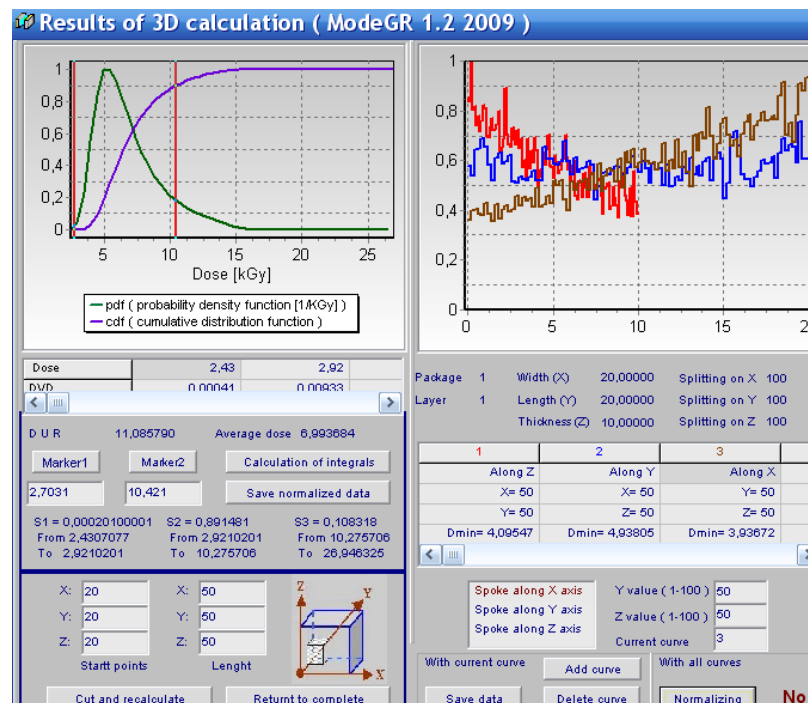


Fig.26. The form of **"Results of 3D calculation"** for analysis of the **DVH and 3D absorbed dose distributions** in the 1st layer of the 1st package.

Additional you can made the **detailed DVH analysis** for each volumetric part in the 1st layer of the 1st package.

For this purpose, **Select the coordinates of interesting volumetric part** of the layer.

The frame for selection **the coordinates of interesting volumetric part** in form of tables

"Start points" and **"Length"** is located in the left down part of the frame **"Results of 3D calculation"**. (See Fig.26)

- **Enter** the values of **X, Y and Z coordinates** in the table **"Start points"** in cm.
- **Enter** the values of **X, Y and Z coordinates** in the table **"Length"** in cm.

- Click the button “Cut and recalculate”.
- Then with help the **Marker 1 and Marker 2** you can carry out **DVH calculation** for selected volumetric part of the layer.
- In a such way you can made **DVH analysis** step by step for another **interesting volumetric part** of the layer.

10.4.2. 3D absorbed dose distribution analysis

3D absorbed dose distribution of Gamma ray for any target layers can be analysed with “**spokes method**”.

The method includes the following operations:

- the layer volume is splitted by 3D grid with bin (cell) size $\Delta V = \Delta X \cdot \Delta Y \cdot \Delta Z$.

Where $\Delta X = \text{Width} / N(x)$, $\Delta Y = \text{Length} / N(y)$, $\Delta Z = \text{Thickness} / N(z)$.

$N(x)$, $N(y)$, $N(z)$ – the number of splitting along the Layer Width (axis X), Length (axis Y) and Thickness (axis Z) respectively.

- the “spokes” can 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.27. 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.

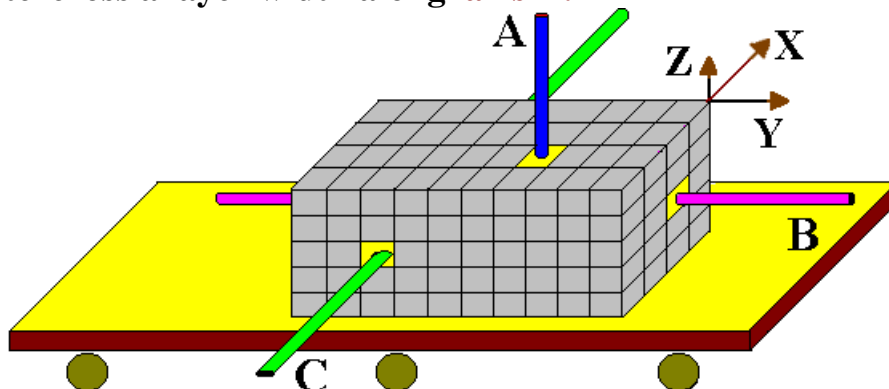


Fig.27. Target layer with grid and spokes located on a conveyer platform.

For above example (see Figs. 20 and 26) 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.26 (right upside).

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

- **Choose and Click on direction of the “Spoke along axis X, Y, or Z”.**
Chosen direction will be painted in **brown color**.
- For example, Selected direction is “Spoke along axis Z”. (see Fig. 27).
For X and Y directions the possible values of coordinates in the XY plane will be appeared.
The cells number along axis X are in the range from 1 to 40.
The cells number along axis Y are in the range from 1 to 50.
The cells number along axis Z are in the range from 1 to 100.
Maximal number splitting cells along any axis is 100.
- **Enter the number of cells in the range from 1 to 40 into window “X value (1-40)”.**
- **Enter the number of cells in the range from 1 to 50 into window “Y value (1-50)”.**
- **Click the button “Add curve”.**

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

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

- Another curves for calculated dose distributions along spokes can be located in any of 6 windows. Maximal number of curves for simultaneously analysis is six.
- **For this, mark by cursor any of 6 windows.**
- **Select and Click on direction of the “Spoke along axis X, Y, or Z”.**
- **Enter the number of cells in plane which will be intercrossed by spoke.**
- **Click the button “Add curve”.**
- **You can “Delete curve”, “Add curve” make “Normalization” of all curves.**
- **You can “Save data” for any of curves for further analysis.**
- **In the left frames of the "Results of 3D calculation" form, you can make DVH analysis in the chosen layer. (see Fig.26).**
DVH is characterized by functions “pdf” and “cdf”.
 - **To make DVH analysis of the functions “Probability density function - pdf” and “Cumulative distribution function - cdf” you can use two Markers located under Left graphs: Marker 1 and Marker 2.**

- **Click the button “Marker 1”, enter a cursor in the plot field. Locate the vertical red line** on the one point of the dose axis by clicking mouse in the chosen point.
- **Click the button “Marker 2”, enter a cursor in the plot field. Locate the vertical red line** on the second point of the dose axis by clicking mouse in the chosen point.

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

- **Click the button “Calculation”**.

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

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