RSim Examples

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CHAPTER

ONE

OVERVIEW

These are examples for illustrating the capabilities of RSim.

RSim is an application for running Radiation Transport simulations. RSim comes with a built in radiation modeling code Geant4 and a Geant4-based executable, GORAD, and a GUI called RSimComposer.

CHAPTER

TWO

RSIM FOR BASIC SIMULATIONS EXAMPLES

These examples demonstrate the basic radiation problems.

2.1 Basic GORAD Examples

2.1.1 Complex Constructive Solid Geometry (CSG)

Keywords:

radiation, GORAD

Problem Description

This example illustrates how to set up complex geometries using CSG capabilities of RSim: boolean operations on them and creating arrays.

Opening the Simulation

The complex CSG example is accessed from within RSimComposer by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the *Basic Examples* option.
- Select Complex Constructive Solid Geometry and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.1. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown. There are several shapes in the setup which are used only for creation of the boolean and array operations. They can be viewed in addition to the real shapes (shapes having materials).

Simulation Properties

This example demonstrates two physics features, and how CSG can be incorporated into RSim Simulations.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the simulation model. Right now the only supported model is GORAD.

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Fig. 2.1: Setup Window for the complex CSG example.

The particle source selected is a planar monoenergetic source with 1D beam shape. The tally in this simulation is is the mesh flux.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.2.

Visualizing the Results

- Expand Scalar Data
- Select CellFlux0
- Select the Clip Plot checkbox

Further Experiments

2.1.2 Dish Antenna

Keywords:

radiation, GORAD



Fig. 2.2: The Run Window at the end of execution.



Problem Description

This problem illustrates how to import a basic STEP file, modify that CAD file and measure the energy deposition from ions.

Opening the Simulation

The Dish Antenna example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the *Basic Examples* option.
- Select Energy Deposit on Dish Antenna and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.3. If you expand the tree elements and navigate through the various properties, the dish becomes visibile after ******unchecking* the particle source (sphere), and tally energyDepositMesh (grid).



Fig. 2.3: Setup Window for the Dish Antenna example. The mesh tally used in this simulation can be seen in the 3D View, along with the sphere that will be shooting particles at it.

Simulation Properties

This example demonstrates use of a very simple CAD file and how it can be imported, moved in the simulation window, given materials, and bombarded with ions. Two parts of the Dish Antenna, the "Wall Bracket" and "Hex bolt" have been combined with a union operation. This is possible by selecting each, right clicking, and performing the boolean operation, union.

Under the Basic Settings tab the number of events to be simulated can be selected.

A particle source is created with 100 MeV energy.

Energy Deposit tallies have been assigned to all objects, as well as a 50x50x50 mesh covering the volume that encompasses the antenna. This can be used to view energy deposition at a higher fidelity.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.4.

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Fig. 2.4: The Run Window at the end of execution.

Visualizing the Results

After the run has completed the results of all tallies can be visualized.

To view the energy deposit on various parts of the dish, follow these instructions (Fig. 2.5):

- Expand Scalar Data
- Check EnergyDepositDish
- Check EnergyDepositHexBolt
- Check EnergyDepositLNB
- Check EnergyDepositWallBracket

• Rotate the visualization as shown in the image below



Fig. 2.5: A visualization of the volume tallies

Further Experiments

Try altering the ion used in the simulation to see how energy depositions are affected. Try altering the number of cells in the mesh to improve the granularity of the results. This can be used to help show the concentration of particles across a surface, as well as show penetration depth of the particles.

2.1.3 Energy Deposit Human

Keywords:

Energy Deposit, GORAD, CAD

Problem Description

This problem illustrates how to import a simple STEP file, assign materials and tallies to it and record the energy deposition on it from a monoenergetic source of electrons. It is a suitable introduction to using your own CAD files in RSim.

Opening the Simulation

The Energy Deposit Human example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting *Examples* window expand the *RSim for Basic Radiation* option.

- Expand the Basic Examples option.
- Select Energy Deposit Human and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the *Save* button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.6. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.



Fig. 2.6: Setup Window for the Energy Deposit Human example.

The human is visible with different colors to indicate the different body parts from the STEP file.

Simulation Properties

This example makes use of a basic spherical surface particle source, bombarding the human in the center of it with 100 GeV electrons.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the number of threads to make available to the simulation. For this example all verbosities are set to their lowest setting, 0. 1 million particles are to be simulated.

In the Physics setting, the most computationally efficient physics lists, of Op 0 and FTFP BERT are used.

Brain, Bone, Tissue and Water materials have been added into the simulation from the Materials database. Given this is a simplified example, all body parts are being modeled as water.

An *Energy Deposit* tally has been added for every body part, along with a mesh - the mesh filling a similar volume of the human.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.7.



Fig. 2.7: The Run Window at the end of execution.

Visualizing the Results

After the run has completed the results of all tallies can be visualized.

To view the energy deposit on various body parts use settings shown below and in Fig. 2.8.:

- Expand Scalar Data
- · Select all body parts, excluding the energyDepositMesh
- When selecting each body part, change the color table to *hot_and_cold*
- Check the Set Minimum box and set it to 440
- Check the Set Maximum box and set it to 8e4

This can be compared with the mesh results by using setting shown below and in Fig. 2.9.:

- Click on the Add a Data View Drop down
- Select Data Overview
- Expand Scalar Data



Fig. 2.8: A visualization of the volume tallies

- Select EnergyDepositMesh
- Select Display Contours and set the number of contours at 10
- Select the *Log Scale Color* box

Further Experiments

Try changing the materials of the body parts to some of the others in the simulation and see how the energy deposit values are effected.

2.1.4 Geometric Biasing

Keywords:

Geometric Biasing, GORAD

Problem Description

This example is designed to show how the geometric biasing feature of RSim functions with a simple theoretical problem. Geometric biasing works by creating a number of computational spheres in the simulation space, moving inwards from a standard spherical particle source to a defined innermost sphere. The number of spheres is selected by the user. As a particle crosses into a sphere, its weight will be cut in half and the number of particles doubled. This can be used to improve statistics in shielding problems, when large numbers of particles may be absorbed by the shield.



Fig. 2.9: A visualization of the mesh tally.

Opening the Simulation

The Geometric Biasing example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting *Examples* window expand the *RSim for Basic Radiation* option.
- Expand the Basic Examples option.
- Select Geometric Biasing and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.10. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

Simulation Properties

For this example 4 spherical shells are created, spaced at 1 meter increments between a radius of 1 and 4 meters. The shells themselves are of galactic material, so as to not impact the simulation.

A particle source is created, which makes use of the *geantino* particle. These are not physical particles, but can be used for testing problem setups without a concern for the physics in question. It is a radius of 4.6 meters, with the sphere bias selected with inner radius of 0.5 meters. 5 bias layers are set, this will create one bias layer outside the largest shell, and then between each shell. A focused angular distribution is used, this will aim all particles at the center of particle source.

Two Number of Track tallies have been added for each shell, one that will weight the results, and one that will not. This will track the number of particles that pass through each shell. Since we are using geantino's we do not have to

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Fig. 2.10: Setup Window for the Geometric Biasing example.

be concerned with a particle losing energy in any shell, and the number of particles will be consistent for each shell.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.11.

Visualizing the Results

After the run has completed the results of all tallies can be compared. For this example it is best to look at the number of tracks, which have been recorded in both a weighted and unweighted form.

The results for the * Expand Scalar Data * Select NumberOfTrackSphere1 * Select NumberOfTrackSphere2 * Select NumberOfTrackSphere3 * Select NumberOfTrackSphere4 * Select Clip Plot from the Scalar Data selection (as shown in figure 59) to apply to all data selections

Looking at these results, we can see the number of tracks in sphere 4 is 4e4. This doubles in track 3 to 8e4, again in sphere2 at 1.596e5, and again to sphere 1 at 3.198e5. This performs exactly as expected. To see the fact that the weights are cut in half for each track, repeat the procedure with the weighted tallies, we see all tallies are nearly identical between 1.995e4 and 2.004e4



Fig. 2.11: The Run Window at the end of execution.



Fig. 2.12: A visualization of the number of tracks

Further Experiments

Try adjusting the materials from galactic to aluminum, to see how this improve statistics on inner spheres as particles get absorbed on outer spheres.

2.1.5 Human in Orion

Keywords:

Weighted, Energy Deposit, GORAD, CAD

Problem Description

This problem serves as an evolution of the *Shielded Human* example.

It features critical upgrades of using a more realistic orion crew module, as well as a weighted distribution particle source. This example makes use of the KingSPE distribution of particles

Opening the Simulation

The Human in Orion example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the Basic Examples option.
- Select Human in Orion and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.13. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

The Orion crew module is visualized

Simulation Properties

This example makes use of a weighted spherical surface particle source, bombarding the human in the center of it with protons.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the number of threads to make available to the simulation. For this example all verbosities are set to their lowest setting, 0. 100,000 particles are to be simulated.

In the *Physics* setting, the physics lists, of Op 0 and Shielding are used.

Brain, Bone, Tissue and Water materials have been added into the simulation from the Materials database. Given this is a simplified example, all body parts are being modeled as water.

An *Energy Deposit* tally has been added for every body part, as well as the orion shield. A mesh tally filling a similar volume of the human is also used.



Fig. 2.13: Setup Window for the Human in Orion example.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.14.

Visualizing the Results

After the run has completed the results of all tallies can be visualized.

To view the energy deposit on various body parts use settings shown below and in Fig. 2.15.:

- Expand Scalar Data
- Check the body parts of interest

Further Experiments

The error of each tally is automatically calculated, though this information is not directly visualized. It can be accessed by opening the tally files, for example the energy deposit errors can be seen on the head (humanInO-rion_s1_detector_vol.csv, and humanInOrion_s13_orion_nofbcGeomSolid_vol.csv)

2.1.6 Point Source Volume Tally

Keywords:

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Fig. 2.14: The Run Window at the end of execution.



Fig. 2.15: A visualization of the volume tallies

radiation, GORAD

Problem Description

This problem illustrates how to set up a point source with an isotropic distribution within an angular range, measuring the energy deposited on a sphere and calculating fluence on a mesh.

Opening the Simulation

The Point Source Volume Tally example is accessed RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the *Basic Examples* option.
- Select Point Source Volume Tally and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.16. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

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Fig. 2.16: Setup Window for the point particle source example.

Simulation Properties

This example demonstrates two physics features, and how CSG can be incorporated into RSim Simulations.

Under the Basic Settings tab the number of events to be simulated can be selected.

The particle source selected is a point shooting electrons. It shoots particles on a monoenergetic spectrum from zero to forty five degrees on the Z axis at an energy of 100.0 MeV.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.17.

💦 RSim - Point Source Volume Tally	
File Edit Tools View Help Window	
Logs and Output Files	
Run Forre Stop	Clear Lon
Engine Log File Browser	
Wekome G4WTO > /score/mesh/rotate/rotateX 0 deg	-
GWTO > /score/close	_
C4WT0 > /score/create/realWorldLogVol sl_target_vol	
Setup G4WTO > /score/quantity/volueFlux FluereOnSphere 0 1	
G4WTO > /score/close	
C4WT0 > /gorad/analysis/1D/create sl target vol EnergyDepositOnSphere	
GWTU > /gorad/analysis/10/control 100 0. 100. MeV intear GWTU > /gorad/analysis/10/create st target you BluenceDrShere	
Run C4UTO > Previously opened histogram is closed.	
G4WTO > /gorad/analysis/1D/config 100 0. 100. HeV linear	
G4WT0 > /gorad/analyzis/1D/create CellFlux0Mesh CellFlux0	
Visualize (G4WT0 > /gorad/analysis/iD/config 100 0. 100. MeV linear	
G4WTO > /gorad/analysis/plot -1	
C4WTO > /gorad/analysis/list	
GAWTO > ###################################	
GAUTO > 10000 2 1-D hist CellFluxOMesh CellFluxO 0 -1	
G4WTO > 10100 0 1-D hist sl_target_vol EnergyDepositOnSphere 1 -1	
G4WT0 > 10200 1 1-D hist s1_target_vol FluenceOnSphere 2 -1	
CAWTO > /process/verses 0	
G4WTO > /gorad/analysis/verbose 0	
G4WTO > /event/verbose 0	
CAWTO > /run/yrintDrogress 10000	
64WT0 > /fam/yeoueofynddified 64WT0 > ### Run 0 starts on worker thread 0.	
G4WTO >> Event 0 starts with initial seeds (13049039,61775110).	
(44WT0 >> Bvent 10000 starts.	
CAWTO >> Revent 20000 Starts.	
C4WTO >> Event 40000 starts.	
C4WTO >> Event S0000 starts.	
GANTU >> Event 60000 starts.	
GAWTO >> Byent 8000 starts.	
G4WTO >> Event 90000 starts.	
/score/dumph11QuantitiesWithFactor s1_target_vol pointSource_s1_target_vol.csv 0.0366116539	
	- 1
Engine completed successfully.	
to see results, click on the 'visualize' icon in the icon panel.	•
Dup: SIFTEES Simulation and the Marked surgerfully	Show Log
The Success sense of the successfully	Show bog

Fig. 2.17: The Run Window at the end of execution.

Visualizing the Results

After the simulation is completed it is possible to visualize the sphere and the total energy depositon on the sphere as shown in Fig. 2.18.

To view this

- Expand Scalar Data
- Check EnergyDepositOnSphere

On a different data view

- Expand Scalar Data
- Check CellFlux0
- Check the Clip Plot box, and select Plane Controls Setting the Clip Plane Normal to X



Fig. 2.18: The visualization window with results of the volume tally.

- Rotate the image 90 degrees to the left
- Check the Set Minimum box and set it to 0
- Check the Set Maximum box and set it to 2e3

Further Experiments

Try altering the particles used in the source or min and max angles in the source: for example using [0,180] range.

2.1.7 Proton Therapy

Keywords:

radiation, GORAD, proton therapy

Problem Description

This problem illustrates a highly simplified version of proton therapy.

In this example a simplified human skeleton is modeled with a tumor embedded in adipose tissue and covered with skin on the back. A circular proton beam of 90 MeV energy is centered on the tumor. The energy deposited on the skin, fat, tumor and torso are all recorded.

For materials, the ICRP models built into RSim are used.



Fig. 2.19: The second visualization window with the results of the mesh tally.

Opening the Simulation

The proton therapy example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting *Examples* window expand the *RSim for Basic Radiation* option.
- Expand the Basic Examples option.
- Select *Proton Therapy* and press the *Choose* button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.20. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

Simulation Properties

This example makes use of the Op 3 electromagnetics physics list, which is best for medical applications.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the number of threads to devote to the simulation.

The particle source selected is an elliptic plane. In this case it is a 1D Beam with 3 degrees of dispersion, and a monoenergetic energy distribution at 90 MeV.

Running the Simulation

After performing the above actions, continue as follows:



Fig. 2.20: Setup Window for the proton therapy example.

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.21.

Visualizing the Results

After the simulation has completed, click on the Visualize button as shown in Fig. 2.22):

- Expand Scalar Data
- Check doseFat, doseSkeleton and doseSkin.

This can show how the dosage on the Fat is higher than that of the Skin or Skeleton.

In order to visualize tumor, it is better to see the mesh tally result.

- Click Add a Data View
- Choose Data Overview
- Expand Scalar Data
- Choose doseGrid
- Select the *hot_and_cold* color table
- Click on Clip Plots
- Click on Plane Controls
- Choose settings shown in Fig. 2.23:
- Expand *Geometries



Fig. 2.21: The Run Window at the end of execution.



Fig. 2.22: The visualization results.

- Click on *s7_TORSO_1
- Click on Clip Plots
- Click on Plane Controls
- Choose settings shown in Fig. 2.23:

R Clip Plane Control	?	×
Clip Plane Normal		
C X (plane normal to x-axis)		
 Y (plane normal to y-axis) 		
C Z (plane normal to z-axis)		
C Custom Normal (oblique clip)		
Custom Clip Plane Normal		
X: 0		
Y: 1		
Z: 0		
Origin of Normal Vector		
X: 0		_
Y: 0		_
Z: 0		
Apply Cancel	Ok	

Fig. 2.23: Settings of the cut plane.

The resulting image shows the tumor deposit as shown in Fig. 2.24:.

Further Experiments

Try altering the energy of the beam to see an increase in the dose on the "tumor" or increasing the thickness of the fat block to see how it may reduce the ionizing dose.

2.1.8 Circuit Shielding

Keywords:



Fig. 2.24: The visualization of the volume tally.

radiation, GORAD, shielding, Dose Deposit

Problem Description

This problem demonstrates how the Deposited Dose on an integrated circuit may be reduced through the use of boron shielding.

To do this, three simplified integrated circuits modeled as silicon boxes are placed on a FR-4 substrate. One of the silicon boxes is shielded by a thick box of boron, one is shielded by a thin box of boron, and one is unshielded.

Opening the Simulation

The Sensitive Circuit example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting *Examples* window expand the *RSim for Basic Radiation* option.
- Expand the Basic Examples option.
- Select Circuit Shielding and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.25. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

Note that several custom materials created through RSim are available for material assignment.

<u> R</u> Sim - Cir	cuit Shielding		– o x)
File Edit To	ols View Help Window		
	Editor		
D			Simulation Setup is Ready Save and Setup
K	sensitiveCircuit.sdf sensitiveCircuit.pre		
Welcome	Simulation	3	Properties View Solids 💌 Edit Mode Clip Toggle Axes Show Scale Perspective View +z 💌 Reset Position
22	Description	0 Vie	
	Parameters		
Setup	- Basic Settings	ase	
×.	Physics Materials	atabi	
Run	Geometries	o se	
	Meshes Particle Sources	ateri	
	Interpretation → Tallies	W.	
Visualize			
2			
Help			U V
			U
	Lindo Add Multiple Remove Add		
	Property Value		
	short description Circuit Shielding		
	long description Inis simulation shows three circuit e Iong description This simulation shows how three par		
	- image		
	version 3.0.0dev		
	1		
O c t a c			
Secup: 1	CITIENTED CITIC FUEL CO CONTINUE		Show Log

Fig. 2.25: Setup Window for the Sensitive Circuit example. The PCB is colored green, the aluminum IC models red, and boron shields green

Simulation Properties

This example demonstrates how Dose Deposit is impacted by the thickness of a boron shield.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the simulation model. Right now the only supported model is GORAD.

The Shielding hadronic physics list is used for this simulation, with GEANT4 standard cuts at 0.7 um.

Three point particle sources are placed above our three test coupons, which are on the PCB substrate. Each particle source has only a 1 degree angular distribution in order to prevent them from interfering with each other. Remember that zero degrees corresponds to the negative Z direction. The neutrons are emitted at a monoenergetic 14 MeV.

An energy deposit tally is placed for each of the three sensitive components, as well as each shield. In addition there is a mesh tally placed over the entire PCB substrate.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.26.

Visualizing the Results

After the simulation is completed it is possible to visualize the energy depositon as shown in Fig. 2.27.

💦 RSim - C	ircuit Shieldir	ng								
File Edit	Tools View	Help Window								
	Logs and (Output Files								
	Run	Force Stop								Clear Log
K	Engine Log	File Browser								
Welcome	CANT2 >	/ no cronsor	aress 10000							
	G4WT3 >	id histID	histType	detName-X	psName-X collID-X	copyNo-X detName-Y	psName-Y co	ollID-Y copyNo	-Y	
	G4WT3 >	10000	5	1-D hist	energyDepositHeshMesh	energyDepositMesh	0 -1	1		
Calue	G4WTO >	/tracking/ver	bose O							
secup	G4012 >	/run/geometry 10100	4	1-D hist	s4 boronShieldThick v	ol EnergyDepos	itThickShield	1	-1	
- 65	G4WT3 >	10200	3	1-D hist	s6 boronShieldThin vo	1 EnergyDepositThinShiel	d 2	-1	-	
100	G4WT3 >	10300	0	1-D hist	s2_sensComponent_vol	EnergyDepositSensCompo	nent 3	-1		
Run	G4WTO >	/gorad/analys	is/verbose O							
	G4WT3 >	10400	1	1-D hist	s3_sensComponent2_vol	EnergyDepositSensCompo	nent2 4	-1		
	G4WT3 >	10500	2	1-D hist	s5_sensComponent3_vol	EnergyDepositSensCompo	nent3 5	-1		
	GANTO >	/process/verb	050 0							
Visualize	G4WT3 >	/tracking/ver	bose O							
	G4WTO >	/run/printPro	gress 10000							
?	G4WT3 >	/gorad/analys	is/verbose O							
•	G4WTO >	/run/geometry	Modified							
Help	G4WT3 >	/event/verbos	e 0							
	G4WT3 >	(run/geometry	Modified							
	G4WT1 >	fff Run 0 sta	rts on worke	r thread 1.						
	G4WT3 >	fff Run 0 sta	rts on worke	r thread 3.						
	G4WTO >	### Run 0 sta	rts on worke	r thread 0.						
	G4WT2 >	fff Run 0 sta	rts on worke	r thread 2.						
	G4WT1 >	> Event 0 s	tarts with i	nitial seeds	s (13049039,61775110).					
	CAWTI >	> Event 100	00 starts.							
	G4WT2 >	> Event 300	00 starts							
	G4WT1 >	> Event 400	00 starts.							
	G4WT1 >	> Event 500	00 starts.							
	G4WTO >	> Event 600	00 starts.							
	G4WT1 >	> Event 700	00 starts.							
	G4WT2 >	> Event 800	00 starts.							
	/score/d	umpAllQuantit	iesWithFacto	r s2 sensfor	moment vol sensitiveCi	rouit s2 sensCommonent a	rol csw l			
	/score/d	umpAllQuantit	iesWithFacto	r s3 sensCor	mponent2 vol sensitiveC	ircuit s3 sensComponent	vol.csv 1			
	/score/d	iumpAllQuantit	iesWithFacto	r s5_sensCom	mponent3_vol sensitiveC	ircuit_s5_sensComponent3	vol.csv l			
	/score/d	lumpAllQuantit	iesWithFacto	r s6_boronSh	hieldThin_vol sensitive	Circuit_s6_boronShieldTh	in_vol.csv l			
	/score/d	lumpAllQuantit	iesWithFacto	r s4_boronSh	hieldThick_vol sensitiv	reCircuit_s4_boronShield	Thick_vol.csv 1	1		
	/score/d	iumpAllQuantit	iesWithFacto	r energyDepo	ositHeshMesh sensitiveC	Circuit_energyDepositMesh	Mesh.csv 1			
	1		NUL ANGINE	001F01						
	Engine g	completed succ	essfully.							- 1
	To see r	esults, click	on the "Vis	ualize" icon	n in the icon panel.					
	1									<u> </u>
💙 Run: 🖻	UCCESS Sim	ulation engine finish	hed successfully							Show Log
-										

Fig. 2.26: The Run Window at the end of execution.

- Expand Scalar Data
- Check all of the energy deposit tallies
- Expand Geometries
- Select s4_boronShieldThick

Further Experiments

You can increase the thickness of Boron layer from 1cm to 5cm or 10cm and notice the reduction of the energy deposited into the sensitive part under the layer.

By changing the material used in the protective layer (for example, to Aluminum), this reduction in dose can be changed.

2.1.9 Shielded Human

Keywords:

radiation, GORAD

Problem Description

This problem illustrates a common problem, measuring the energy deposited on the head of a human shielded in an aluminum cylinder.

The particle source uses a JPL dataset for modeling a mission to Europa, with the normalization computed based on the maximum and minimum integral flux.



Fig. 2.27: The total deposited energy of the shield + sensitive component underneath will match up for all three test coupons.

This example demonstrates how to import a step file, annotate the materials of the parts of the step file, and it will be automatically converted into gdml for use in the simulation.

Opening the Simulation

The shielded human example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the Basic Examples option.
- Select Shielded Human and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.28. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

Simulation Properties

This example demonstrates two physics features, and how CSG and CAD can be incorporated into RSim Simulations.

In order to rapidly set a material for all 35 parts of the CAD file Materials Annotation can be used. This is done with the following

• Right-click on the Geometries

<u> R</u> RSim - Shi	elded Human					– Ö X
File Edit To	iols View Help Window					
	Editor					
D						Simulation Setup is Ready Save and Setup
K	shieldedHuman.sdf shieldedH	luman.pre				
Welcome	Simulation		3	Properties	View Solids	Edit Mode Clip Toggle Axes Show Scale Perspective View +y Reset Position
100	Description		- e			
~	Constants Barprostors		8			
Setup	Basic Settings		Ð			
*	- Physics		sed			
***	Materials		Oate			
Run	Geometries		岩			
	□ ₩ C30		ateri			
	- inC		Ϋ́			
Vicualiza	Shield					
visuality.	CAD		4			
2	Meshes					
	Particle Sources					
Help	mono_source		4			
	Iallies					
	1	1 1	ī.			
	Undo	Add Multiple Remove Add				
			1			
	Property	Value				
	kind	OceSolid				
	reference0	autC				
	- operation	subtract				
	- reference1	inC				
	tessellation	0.00405279970167627	4			
	color	46.///6				
	<u> </u>					
Setup: C	OMPLETED Click run to continue					Show Log

Fig. 2.28: Setup Window for the shielded human example.

- Select Annotate Materials From File
- In the dialog box, select the .csv file that corresponds to the materials annotation.

This .csv file is a 2 column list, comma separated, of the name of the part and the material to be assigned to it The materials data itself should be stored in a .xml file of the same name.

After this is complete there should be new .xml file created, named simulationName_materials.xml. This will be used by the .gdml file.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the simulation model. Right now the only supported model is gras.

The particle source selected is a spherical surface. In this case it simulates 1 electron per event. The energy is based on a 2 column text file supplied with the example.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.29.

Visualizing the Results

After the simulation is completed it is possible to visualize the energy deposited on each part of the body.

To view this



Fig. 2.29: The Run Window at the end of execution.

- Expand Scalar Data
- Check EnergyDeposit0 to EnergyDeposit8

Further Experiments

Try altering the shielding material from aluminum to see how the Deposited Energy on the head may be changed.

2.1.10 Space Radiation Simulation

Keywords:

radiation, GORAD

Problem Description

This problem illustrates how to set up a simulation for a typical space radiation environment. Quite often the space radiation is specified in tables with differential and integral flux. An example is shown on a figure Fig. 2.31.

This differential spectrum is copied into a text file spectrum.txt and is used for the definition of the source. Since the space radiation is omnidirectional, we use cos angular dependency for the source. To make the statistics better the spherical surface used for the source is placed as close to the geometry as possible and the angles are limited by 0 and 90 degrees as shown on Fig. 2.32.

Space radiation source shown in RSim GUI: the spectrum is specified in spectrum.txt file created from the differential fluence data. This is then integrated by GORAD for normalization.

The simulation results are normalized by multiplying the total integral flux calculated by GORAD, the angular factor from the cosine distribution, surface area of the source and then divided by the number of events (beamOn = 1e+7)



Fig. 2.30: Visualization results of the volume tally.

The problem geometry consists of a 1cm Silicon target inside a hollow Aluminum sphere with radius 10cm and thickness 1mm.

Opening the Simulation

The shielded target example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the *Basic Examples* option.
- Select Space Radiation Volume Tally and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.33. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.

Simulation Properties

This example demonstrates two physics features, and how CSG can be incorporated into RSim Simulations.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the verbosity of the output.

The particle source selected is a spherical surface and simulates 1 electron per event. The energy of each particle is based on a 2 column text file supplied with the example, giving a energy and differential fluence at that energy.

	Trapped Electrons						
Energy	Integral	Differential					
(MeV)	(cm ⁻²)	(cm ⁻² MeV ⁻¹)					
0.0001	2.783E+17	3.895E+20					
0.0003	2.033E+17	3.646E+20					
0.0005	1.472E+17	2.210E+20					
0.001	8.632E+16	6.845E+19					
0.003	4.333E+16	6.564E+18					
0.005	3.375E+16	3.569E+18					
0.01	2.164E+16	1.709E+18					
0.03	8.891E+15	2.480E+17					
0.05	5.739E+15	1.011E+17					
0.1	3.013E+15	2.991E+16					
0.2	1.523E+15	7.415E+15					
0.3	1.029E+15	3.372E+15					
0.5	6.172E+14	1.266E+15					
1	2.912E+14	3.338E+14					
2	1.255E+14	8.110E+13					
3	7.247E+13	3.349E+13					
5	3.450E+13	1.054E+13					
10	1.036E+13	2.083E+12					
20	2.151E+12	2.610E+11					
30	7.942E+11	6.519E+10					
50	2.263E+11	1.106E+10					
100	4.167E+10	1.011E+09					

Fig. 2.31: Space radiation is specified using differential and integral fluxes.



Fig. 2.32: Space radiation is modeled by an omnidirectional spherical surface close to the target with the particles going inside the sphere, which is controlled by the min and max angle in the source specification. Each point of the sphere emits particles limited by the angles, so particles mostly go inside. One can also make maxtheta smaller to improve statistics.



Fig. 2.33: Setup Window for the shielded target example.

This example has tallies to record the dose deposited on the shield and target, as well as the number of tracks that get absorbed in the shield before reaching the target.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.34.

Visualizing the Results

After the run has completed the results of all tallies can be visualized.

- Expand Scalar Data
- Select EnergyDepositShield
- Check Clip Plot
- Select EnergyDepositTarget
- Click Add a Data View
- Choose Data Overview
- Expand Scalar Data
- Choose FluenceShield

💦 RSim - Sj	pace Radiatior	n Volume Tally									- 6) X	
File Edit	Tools View	Help Window											
	Logs and C	Output Files											
	Run	Force Stop										Clear Log	
R	Feelentee		1								-		
Welcome	Engine Log	File browser	1									1	
Meleonic	G4UT3 > /tracking/verbose 0												
1	CANTO >	/event/verbos /rum/nrintBro	se u ografic 100000	0									
- ** *	G4WT2 >	/gored/enelys	sis/ID/confid	100 1 4 0	MeV lineer								
Setup	G4WT1 >	/run/printPro	ogress 100000	0	nev men								
	G4WT3 > /gorad/analysis/verbose 0												
	G4WTO > /run/geometryHodified												
	G4WIl > /run/geometryHodified												
Run	G4WT3 > /event/verbose 0												
	C4WT3 > /run/printProgress 1000000												
	C4HT2 >	/gorad/analys /run/geometry	sis/piot =1										
	overs / //an/geometrynosities												
Visualize	G4WT2 > #		###### regist	ered histog	rams/plots								
	G4WT2 > 5	id histID	histType	detName-X	psName-X collID-X	copyNo-X detName-Y	psName-Y	collID-Y	copyNo-Y				
?	G4WT2 > 1	10000	0	1-D hist	sl_shield_vol	FluenceShield	0	-1					
•	G4WT2 > 1	10200	2	1-D hist	sl_shield_vol	EnergyDepositShield	2	-1					
Help	G4WT2 > 1	10400	1	1-D hist	s2_target_vol	EnergyDepositTarget	4	-1					
	C4WT2 >)	/process/verr /trocking/wor	pose u rhoco O										
	G4WT2 > /	/gorad/analys	sis/verhose (1									
	G4WT2 >	/event/verbos	se O										
	G4WT2 > ,	/run/printPro	ogress 100000	00									
	G4WT2 > ,	/run/geometry	yModified										
	C4WTO > #	ff# Run 0 sta	arts on worke	er thread 0.									
	C4UT2 > #	### Run 0 sts	arts on worke	er thread 2.									
	G4013 > 3	### Run U sta fff Run O sta	arts on worke	er thread 3.									
	G4WTO >	> Event 0 s	starts with i	initial seed	<pre>(13049039.61775110).</pre>								
	G4WT0 > -	> Event 100	00000 starts.										
	G4WT3 > -	> Event 200	00000 starts.										
	G4WT1 > -	> Event 300	00000 starts.										
	G4WTO > -	> Event 400	00000 starts.										
	G4013 > -	> Event SUL	00000 starts.										
	Gault >> Avent Sububub starts.												
	G4WT2 > -	> Event 800	00000 starts.										
	G4WTO >> Event 9000000 starts.												
	/score/dumpAllQuantitiesWithFactor sl_shield_vol shieldedTarget_sl_shield_vol.csv 3.80132697e-05												
	/score/dumpAllQuantitiesWithFactor s2_target_vol_shieldedTarget_s2_target_vol.csv 3.80132697e-05												
			- END ENGINE	OUTPOT									
	Engine co	ompleted succ	cessfully.									1	
	To see results, click on the "Visualize" icon in the icon panel.												
]												
Run: 9	UCCESS Simi	dation engine finis	thed successfully									ShowLon	
- roam a		and a second second second									_	I.I.I. Log	

Fig. 2.34: The Run Window at the end of execution.





And visualize this result as shown on Fig. 2.36.



Fig. 2.36: Fluence on the shield.

In order to normalize energy deposit to a mass, one can use the information from the run log shown in Fig. 2.37.

This would allow users to obtain the energy deposit in the target in rad: 1.335e+15/9.75988e-3/6.2415e+10=2.2e+5 rad.

It is also possible to view a histogram of the energy of particles which contributed to the total fluence on the shield

- Click Add a Data View
- Choose 1-D Histogram
- Select the Base Variable s1_shield_vol_FluenceShield
- Click Draw

This shows how the vast majorit of particles are of low energy. This can be compared with the fluence on the target, showing how the shield very effectively shielded it from the low energy particles.

Further Experiments

The dose on the target can be greatly changed by altering the thickness and material of the shield. To do this, switch to the Setup window and change the value of parameter "thickness".

2.1.11 Planar Source Volume and Mesh Tally Comparison

Keywords:

radiation, GORAD, mesh tally, volume tally

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Fig. 2.37: The standard output in the run tab contains information of the masses.



Problem Description

This problem shows the tallies available in RSim, and a comparison of the results of a mesh and volume tally in the same space. In this example a planar proton beam source is used to shoot particles at a $10 \times 10 \times 10$ cm silicon box. The mesh tally is composed of a single grid cell, the same dimensions as the silicon box.

Opening the Simulation

The Tally Diagnostic example is accessed from within RSim by the following actions:

- Select the $New \rightarrow From Example...$ menu item in the *File* menu.
- In the resulting Examples window expand the RSim for Basic Radiation option.
- Expand the Basic Examples option.
- Select Planar Source Volume and Mesh Tally Comparison and press the Choose button.
- In the resulting dialog, create a New Folder if desired, and press the Save button to create a copy of this example.

All of the properties and values that create the simulation are now available in the Setup Window as shown in Fig. 2.38. You can expand the tree elements and navigate through the various properties, making any changes you desire. The right pane shows a 3D view of the geometry, if any, as well as the grid, if actively shown.



Fig. 2.38: Setup Window for the Tally Diagnostic example. The mesh itself can be seen in the 3D View, along with the plane that will be shooting particles at it.

Simulation Properties

This example demonstrates a comparison between volume and mesh tallies.

Under the *Basic Settings* tab the number of events to be simulated can be selected, as well as the simulation model. Right now the only supported model is GORAD.

The planar particle source will emit one particle per event. The plane itself is on the XY-axis and will shoot particles in the positive z direction, with no angular distribution as a 1D beam source is used with no distribution. The particles are emitted with 10 MeV and no normalization.

100000 events are to be simulated, which with the specified particle source using 1 particle per event will have 100000 protons in the simulation.

The tallies in this simulation are a $1 \ge 1 \ge 1$ mesh. This is done to provide the easiest comparison against the volume tallies. The grid cell of the mesh will correspond to a $0.1 \ge 0.1 \ge 0.1 \ge 0.1$ meter box as can be seen in the 3D view. The two tallies will record the energy deposited by particles and flux of particles crossing the surface of the grid cell.

Running the Simulation

After performing the above actions, continue as follows:

- Proceed to the Run Window by pressing the Run button in the left column of buttons.
- To run the file, click on the *Run* button in the upper left corner of the *Logs and Output Files* pane. You will see the output of the run in the right pane. The run has completed when you see the output, "Engine completed successfully." This is shown in Fig. 2.39.



Fig. 2.39: The Run Window at the end of execution.

Visualizing the Results

After the run has completed the results of all tallies can be visualized as shown in Fig. 2.40.

To compare the results of the mesh and volume tally

- Expand Scalar Data
- Check the *meshDose* box

• Check the *volumeDose* box



Fig. 2.40: The visualization window showing results of the simulation.

Further Experiments

To further test the comparison of results between the volume and mesh tallies try changing the angular distribution. Add more grid cells to the meshDose tally to see the distribution of the dose in the mesh

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