RSim Examples

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CONTENTS

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* → *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.

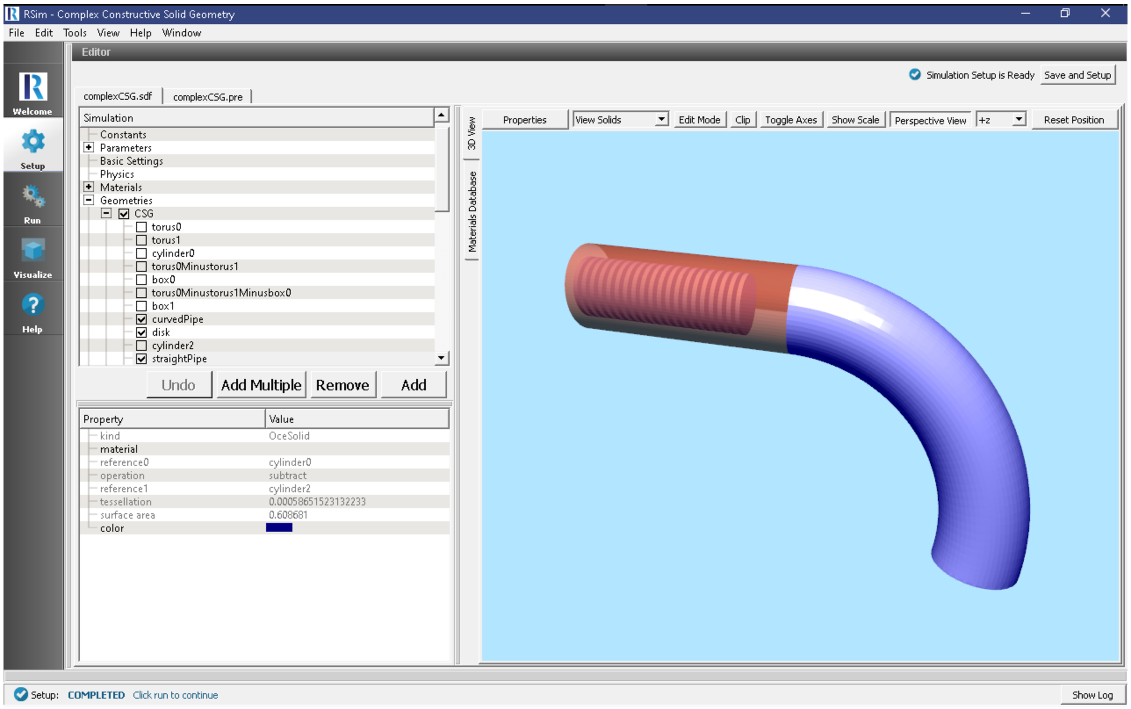


Fig. 2.1: Setup Window for the complex CSG example.

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

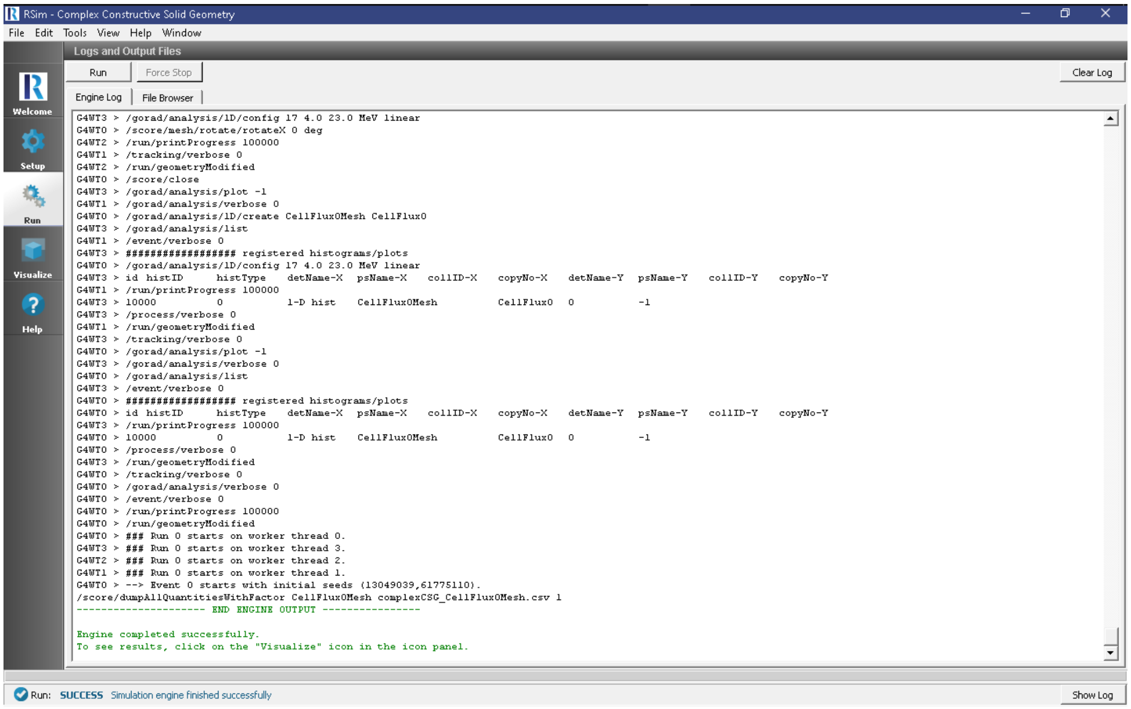
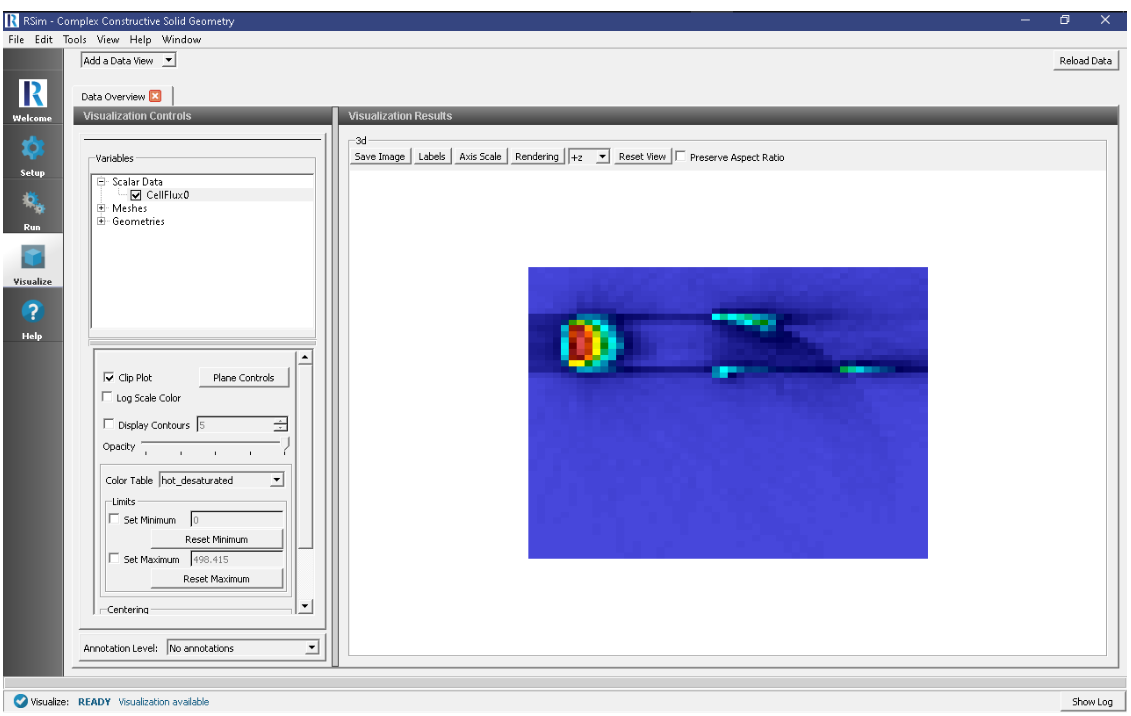


Fig. 2.2: The Run Window at the end of execution.



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 → 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 becomse visibile after **unchecking* the particle source (sphere), and tally energyDepositMesh (grid).

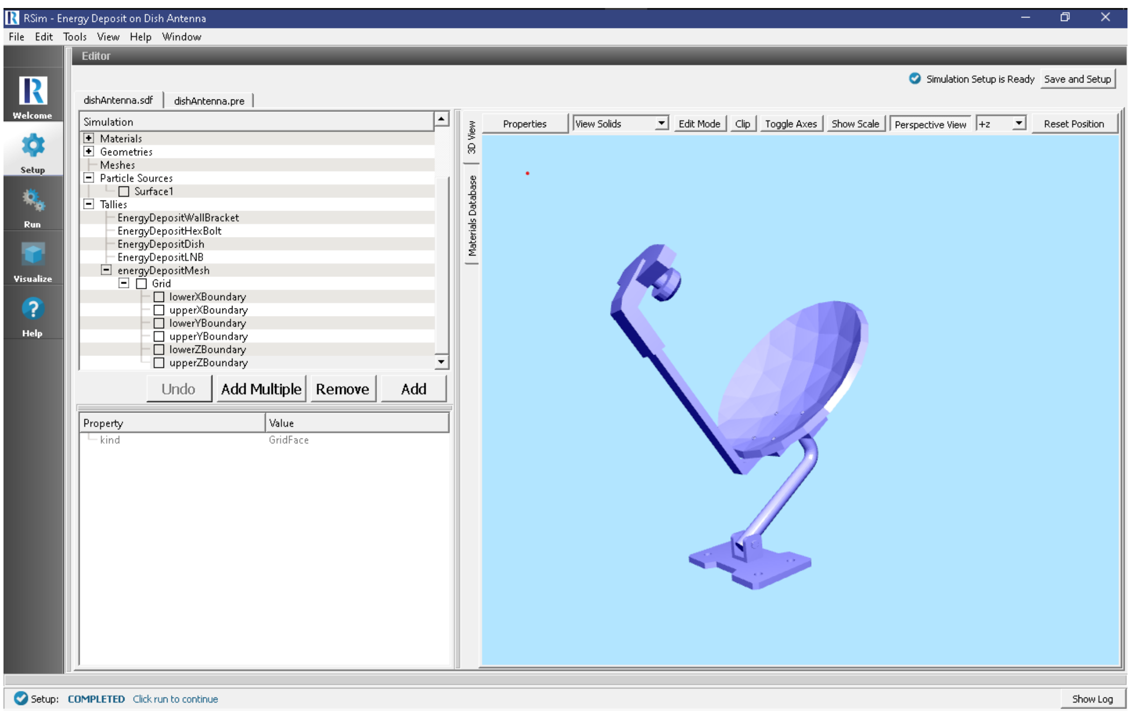


Fig. 2.3: Setup Window for the Dish Antenna example. The mesh tally used in this simulation can be seen in the 3D View, along with the sphere that will be shooting particles at it.

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.

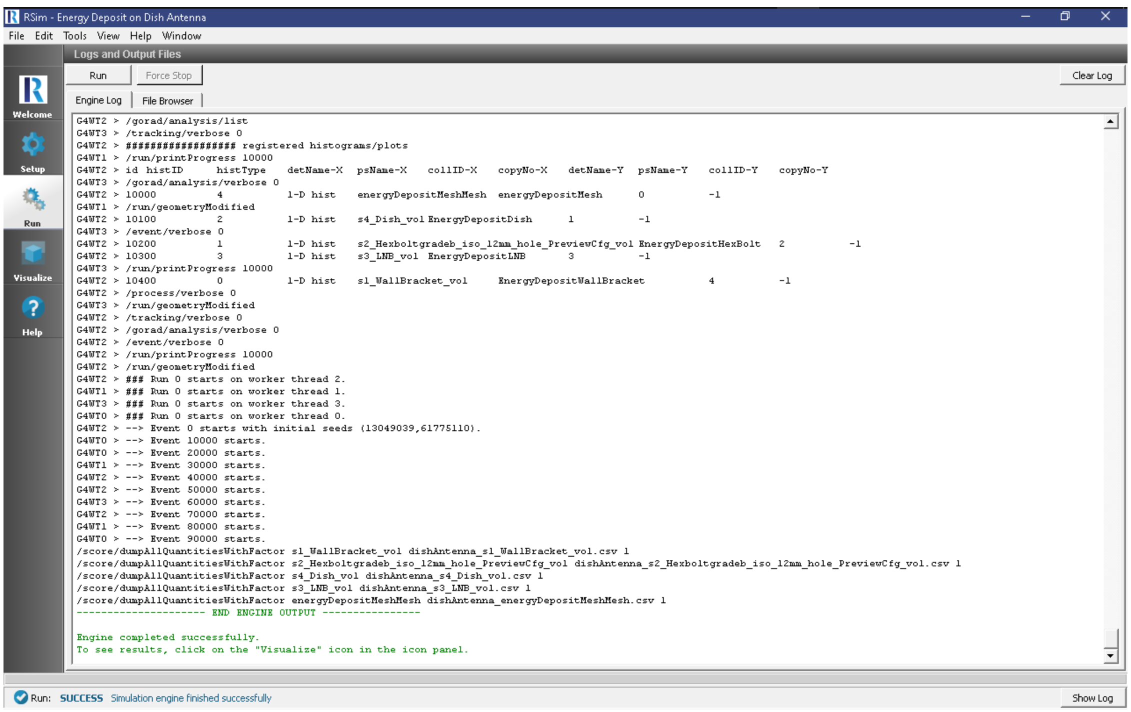


Fig. 2.4: The Run Window at the end of execution.

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

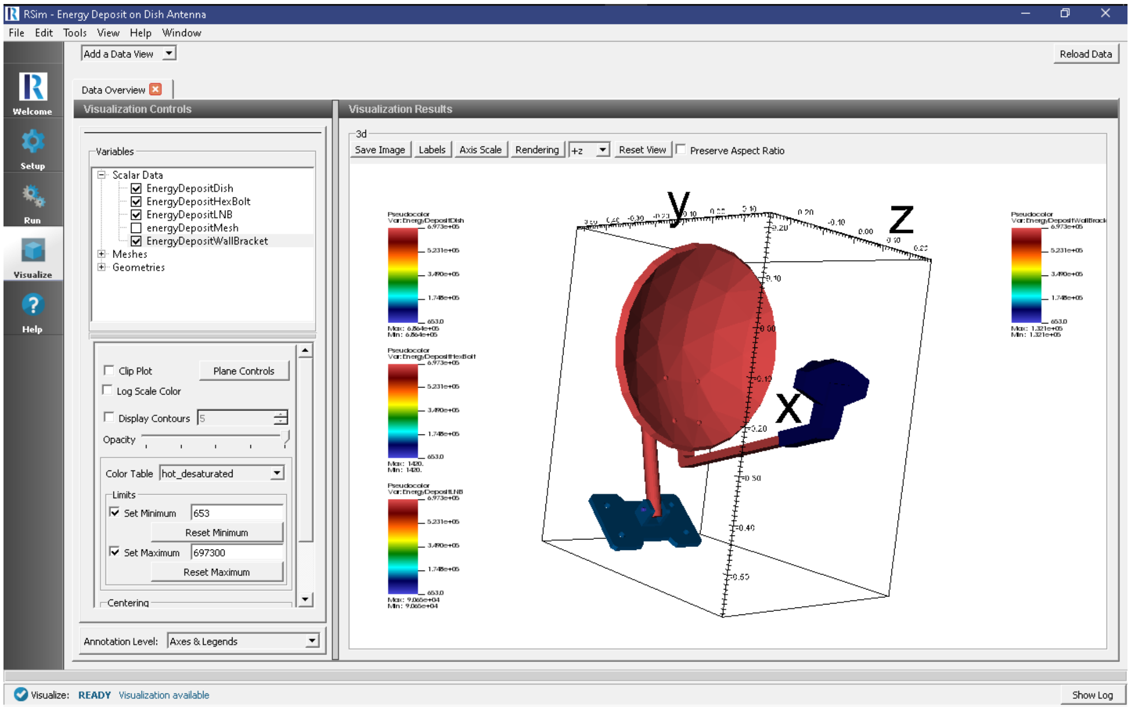


Fig. 2.5: A visualization of the volume tallies

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* → *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.

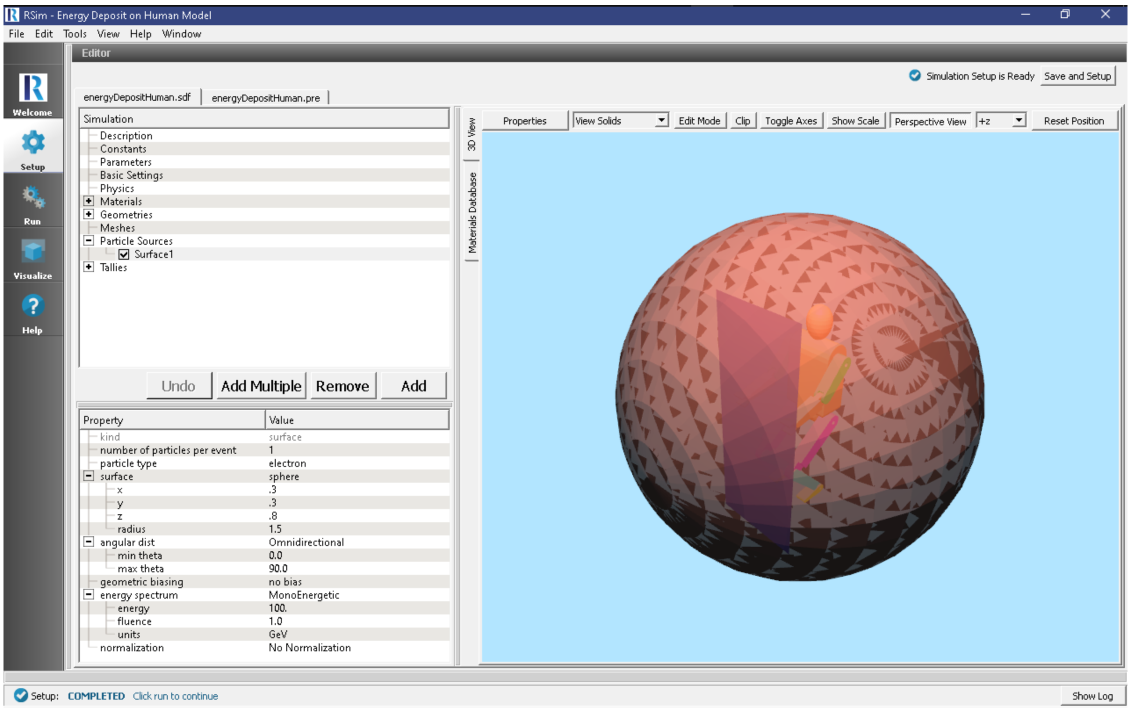


Fig. 2.6: Setup Window for the Energy Deposit Human example.

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 simplifed 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.

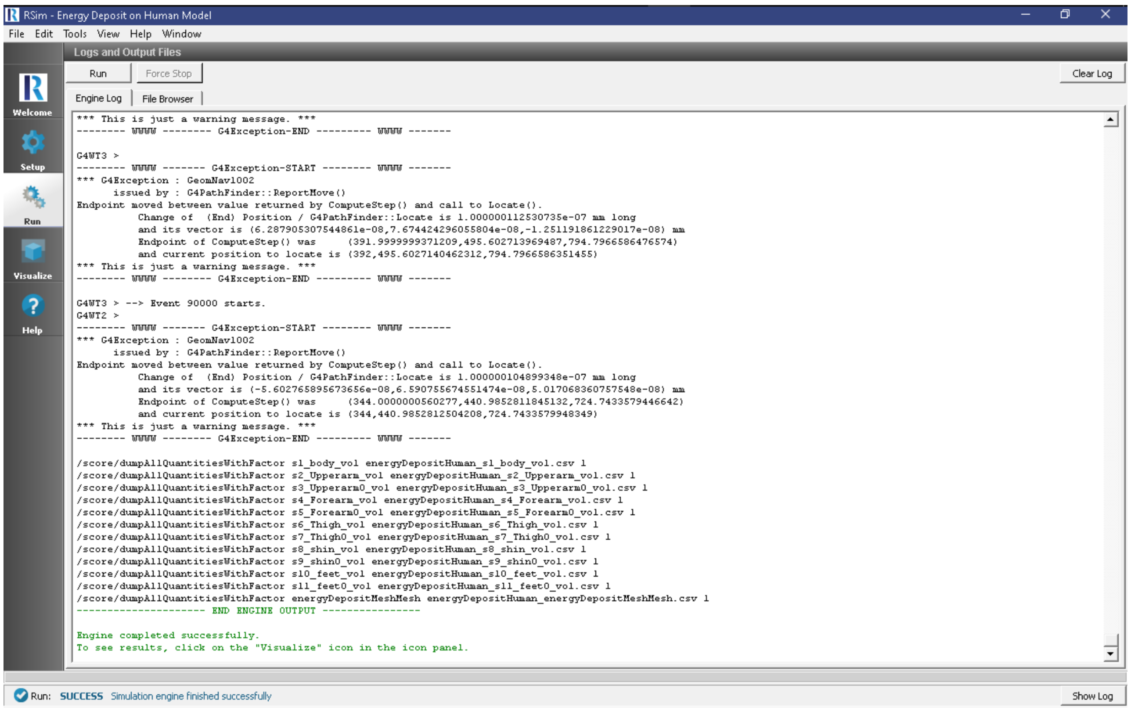


Fig. 2.7: The Run Window at the end of execution.

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*

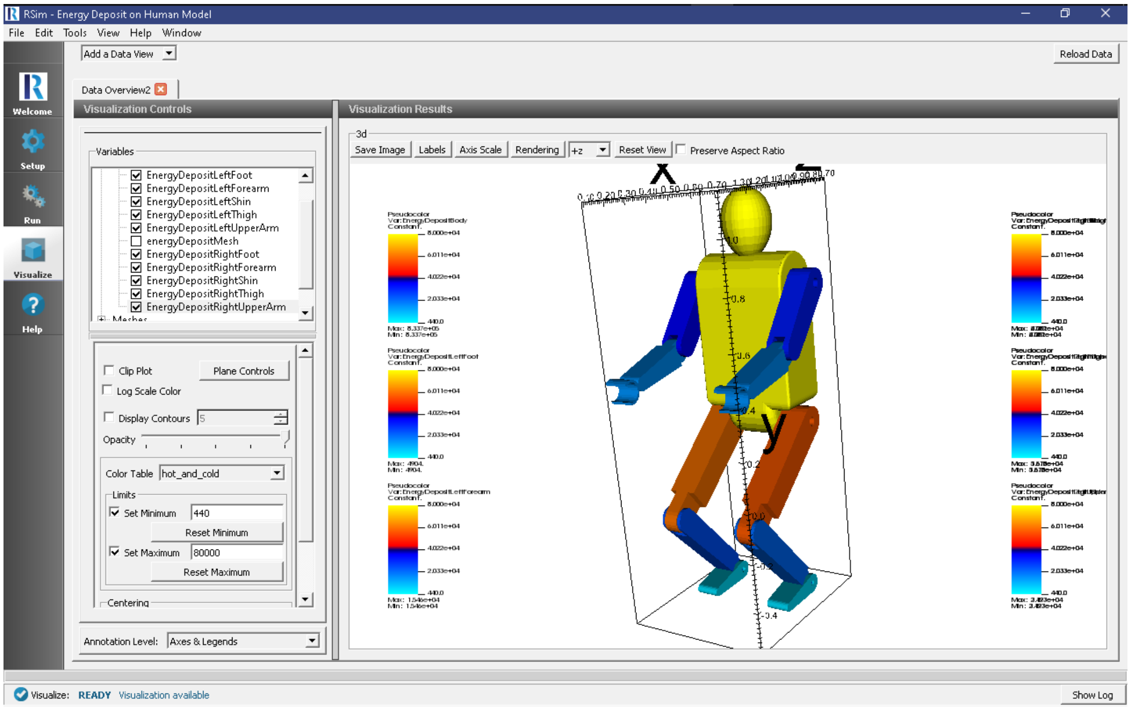


Fig. 2.8: A visualization of the volume tallies

- 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.

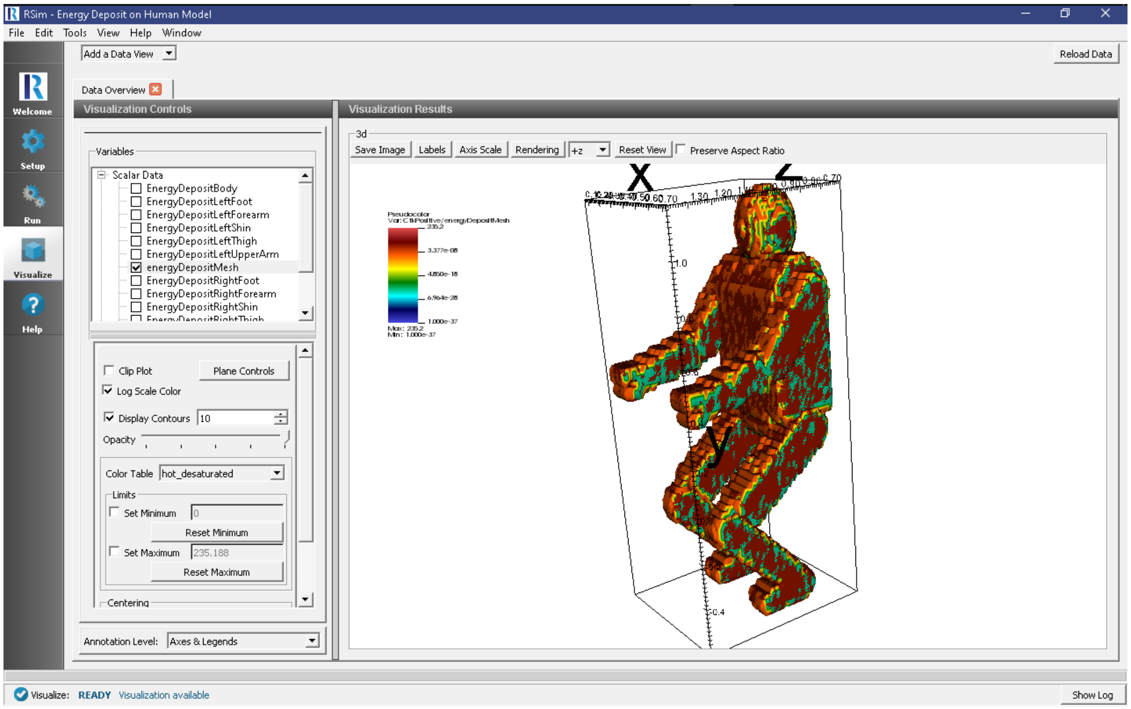


Fig. 2.9: A visualization of the mesh tally.

Opening the Simulation

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

- Select the *New → 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

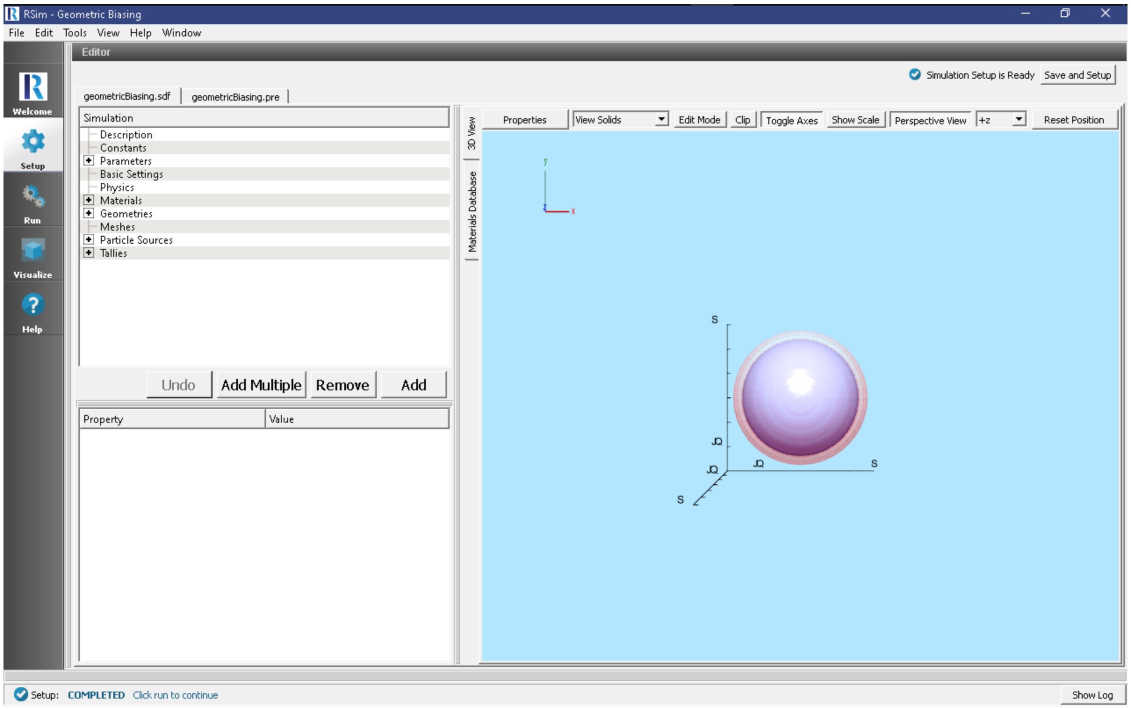


Fig. 2.10: Setup Window for the Geometric Biasing example.

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

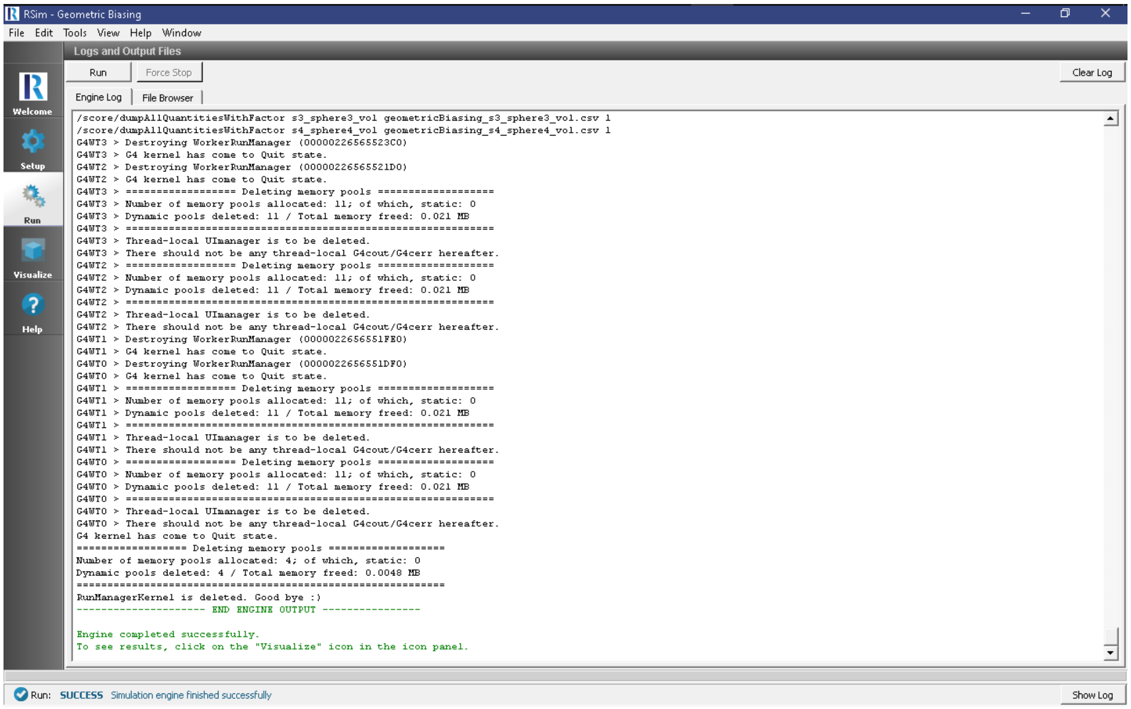


Fig. 2.11: The Run Window at the end of execution.

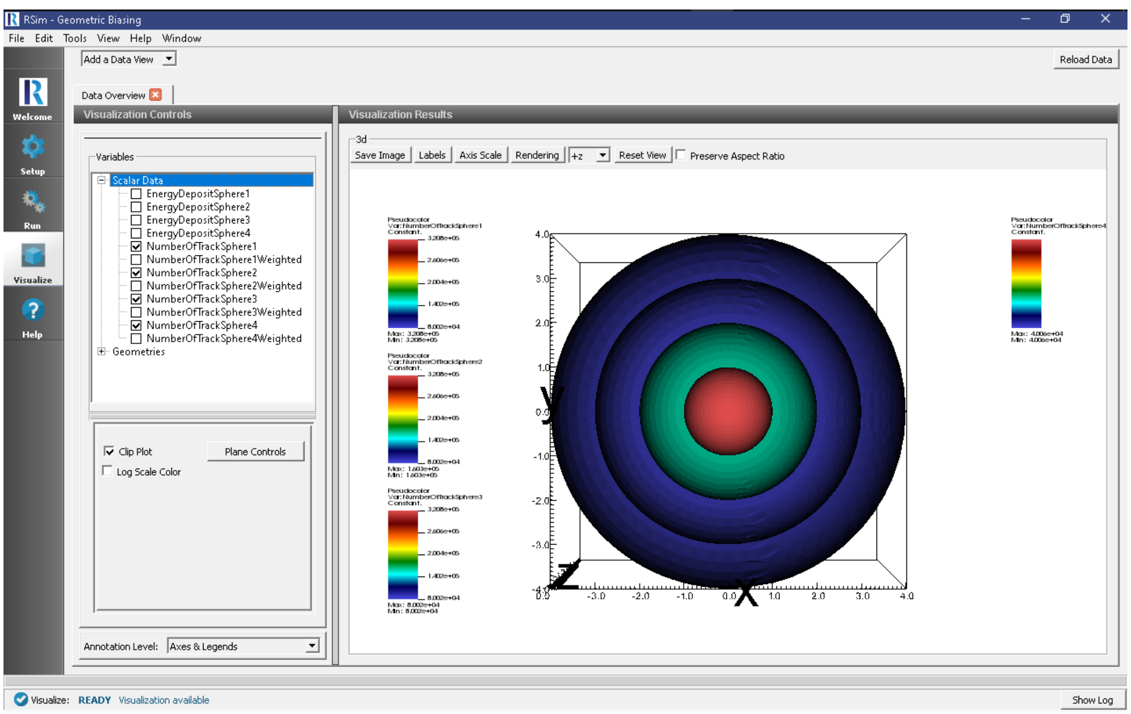


Fig. 2.12: A visualization of the number of tracks

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 → 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 simplifed 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.

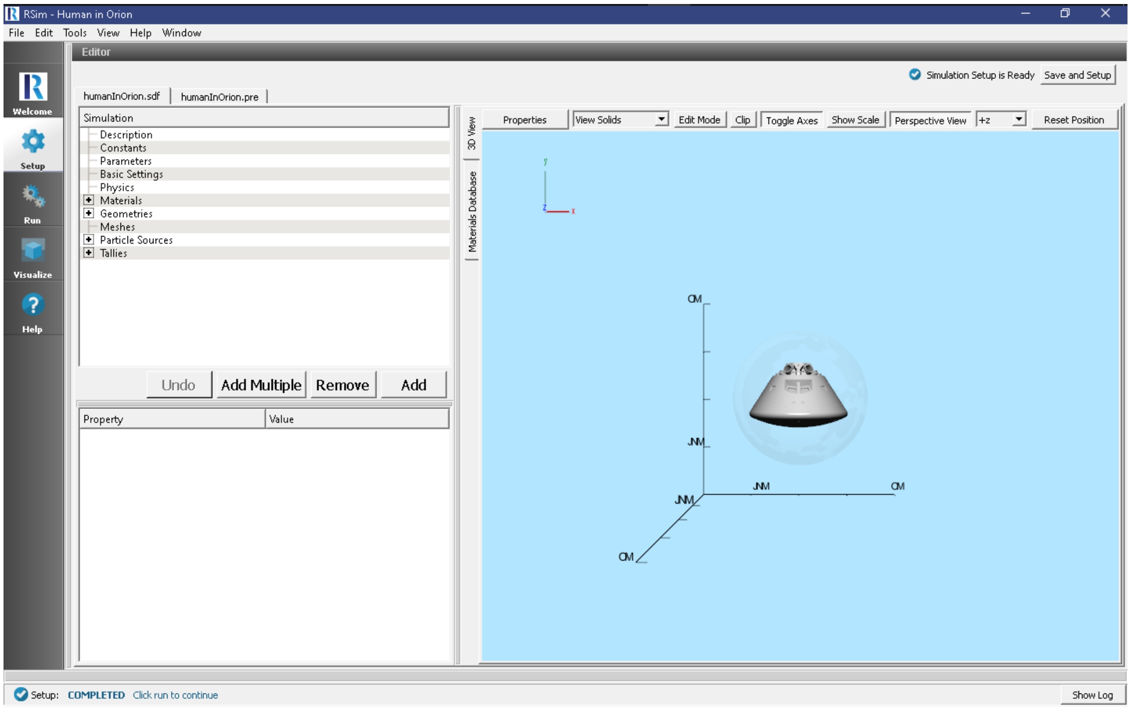


Fig. 2.13: Setup Window for the Human in Orion example.

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 (humanInOrion_s1_detector_vol.csv, and humanInOrion_s13_orion_nofbcGeomSolid_vol.csv)

2.1.6 Point Source Volume Tally

Keywords:

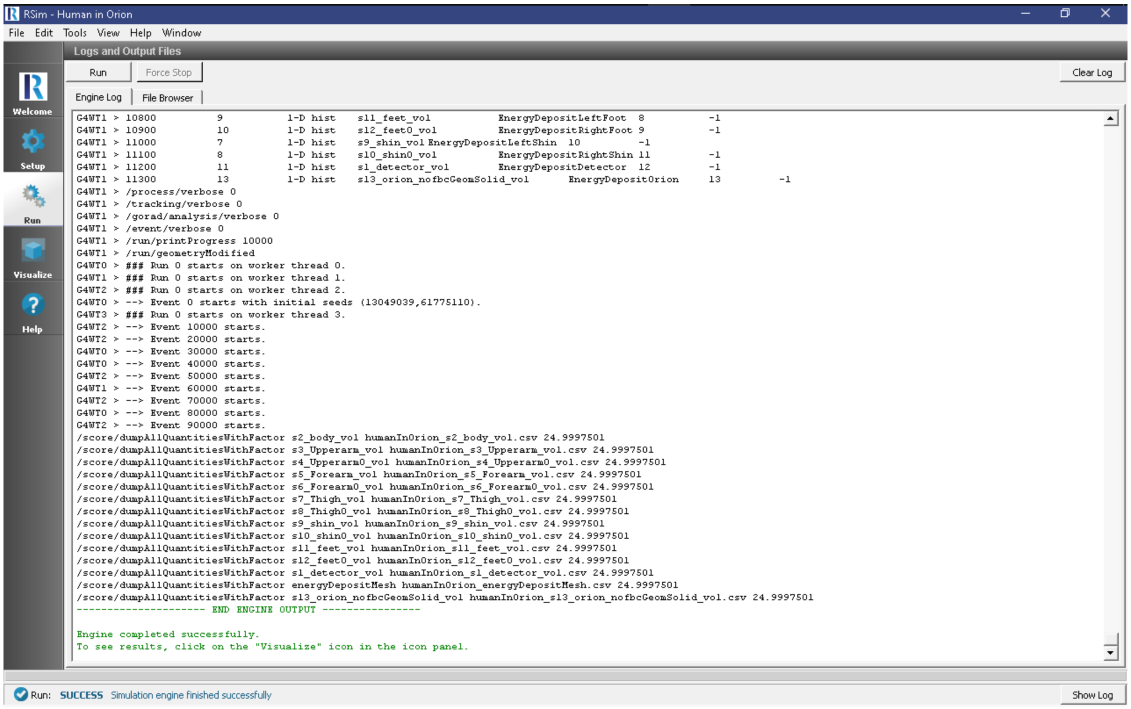


Fig. 2.14: The Run Window at the end of execution.

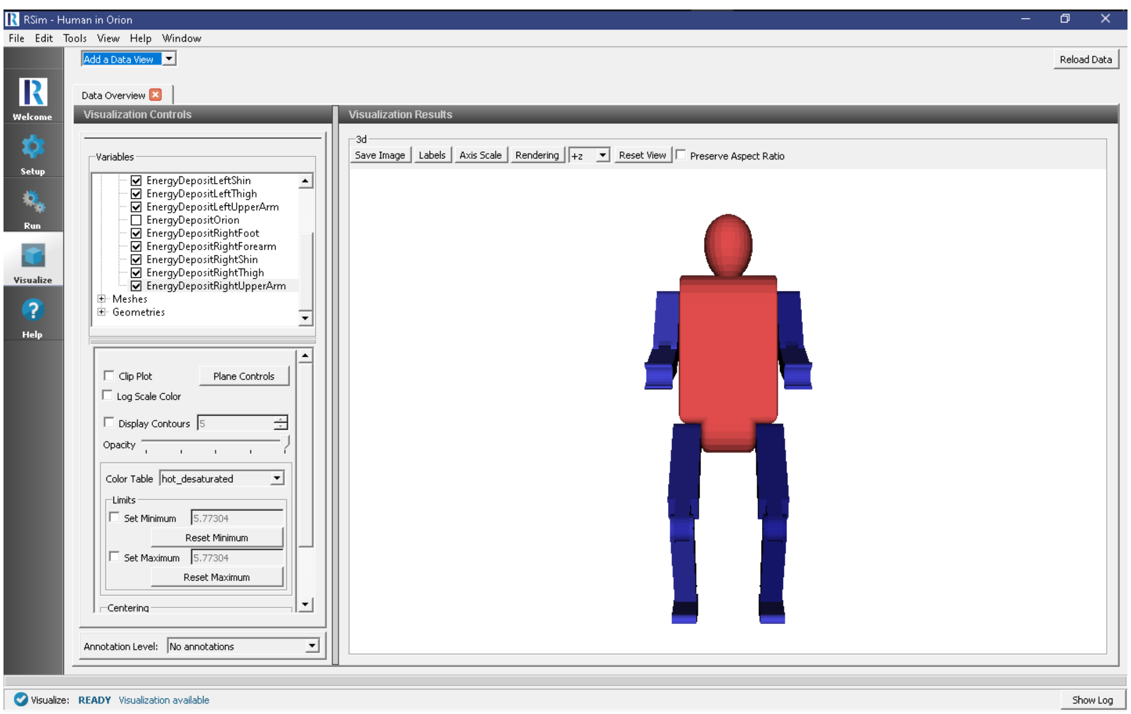


Fig. 2.15: A visualization of the volume tallies

`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 → 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.

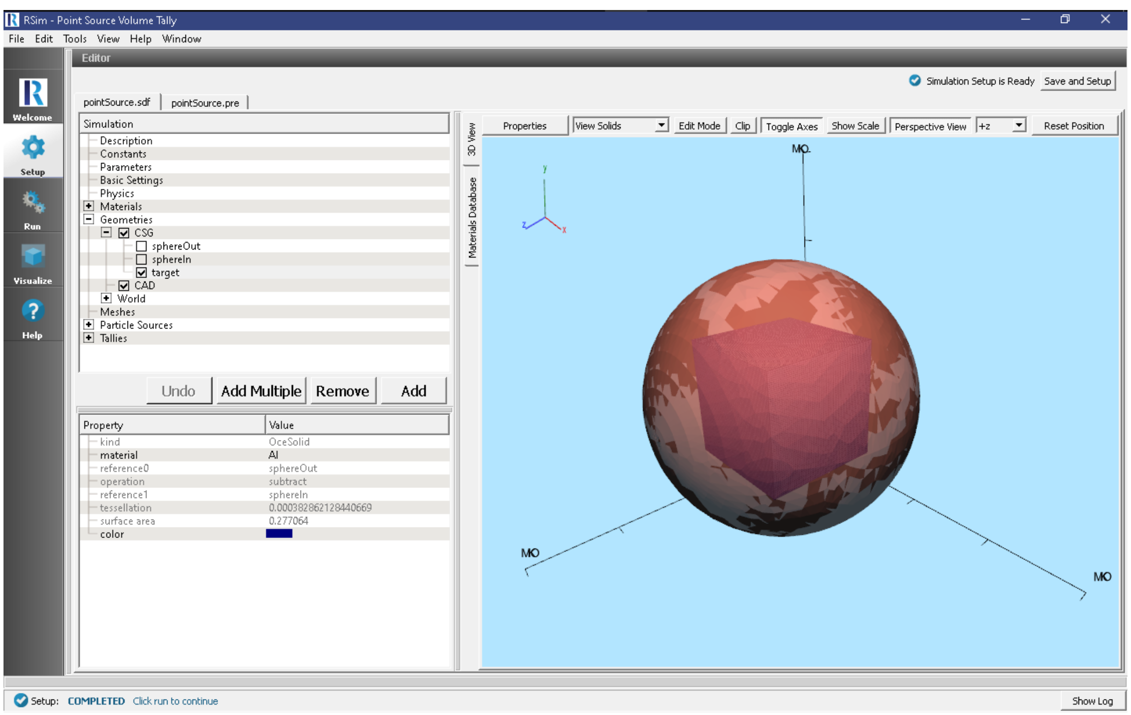


Fig. 2.16: Setup Window for the point particle source example.

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.

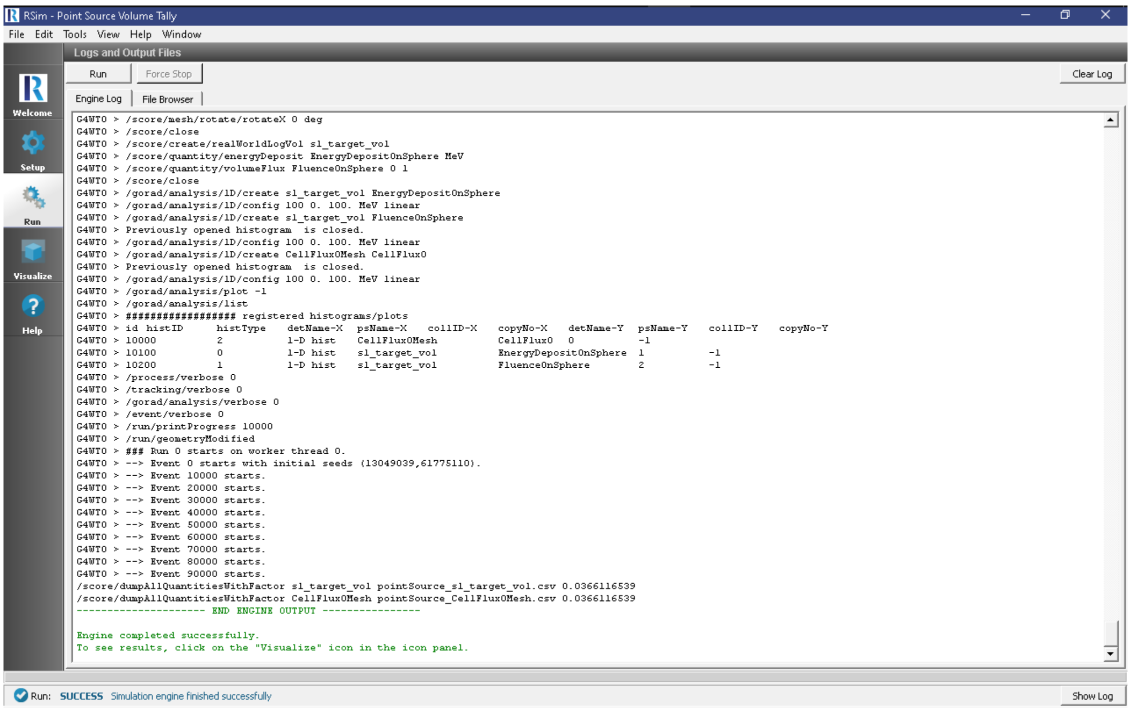


Fig. 2.17: The Run Window at the end of execution.

Visualizing the Results

After the simulation is completed it is possible to visualize the sphere and the total energy depostion 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

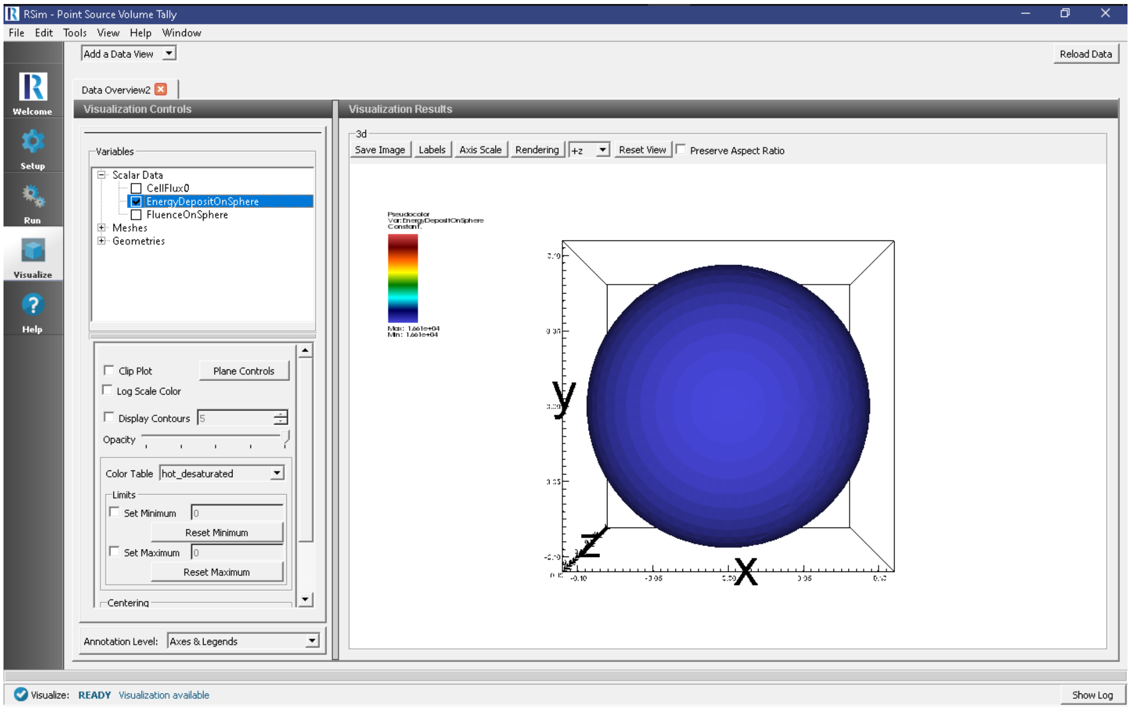


Fig. 2.18: The visualization window with results of the volume tally.

- 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.

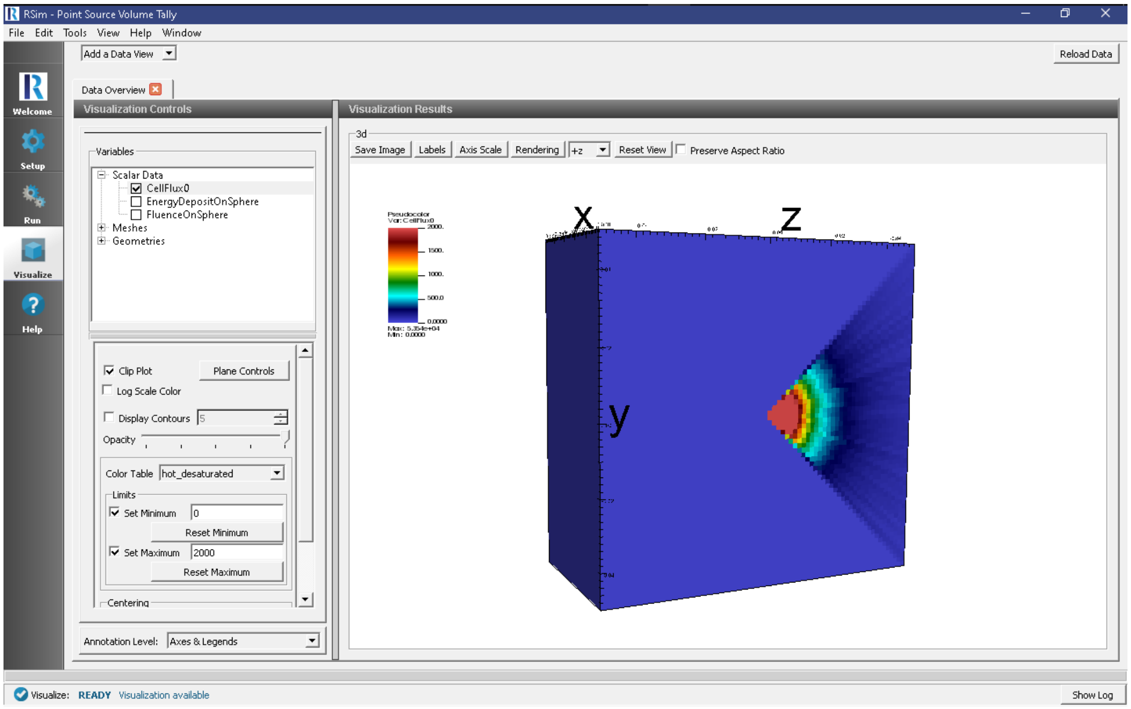


Fig. 2.19: The second visualization window with the results of the mesh tally.

Opening the Simulation

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

- Select the *New* → *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:

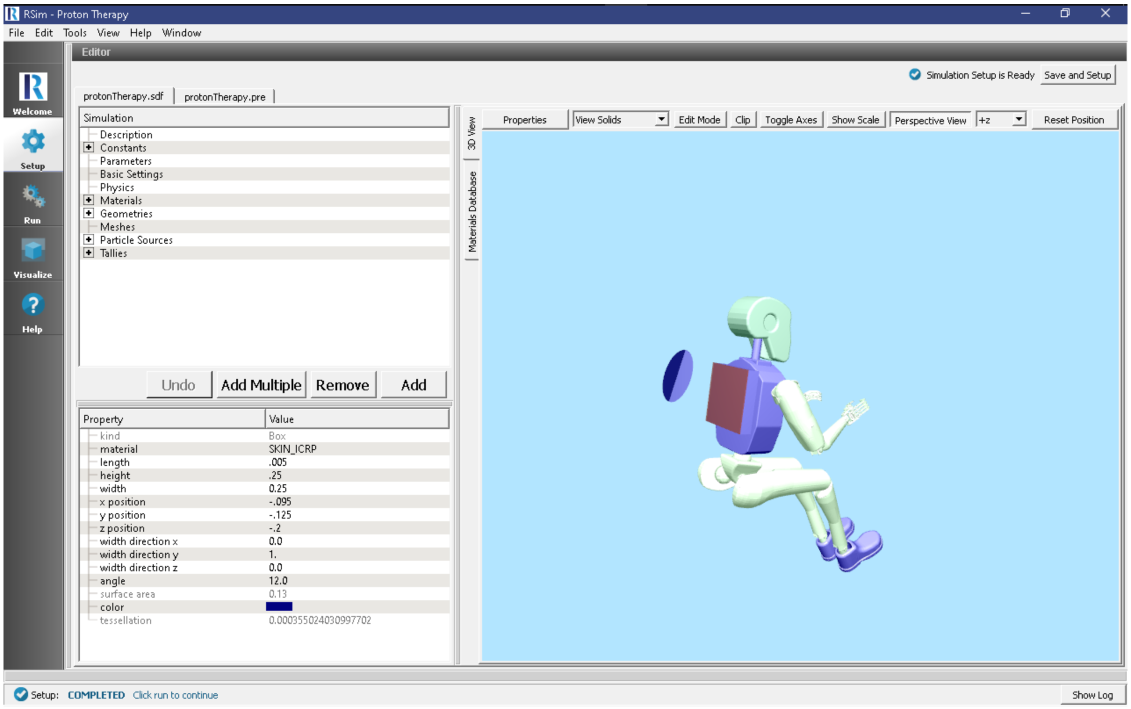


Fig. 2.20: Setup Window for the proton therapy example.

- 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

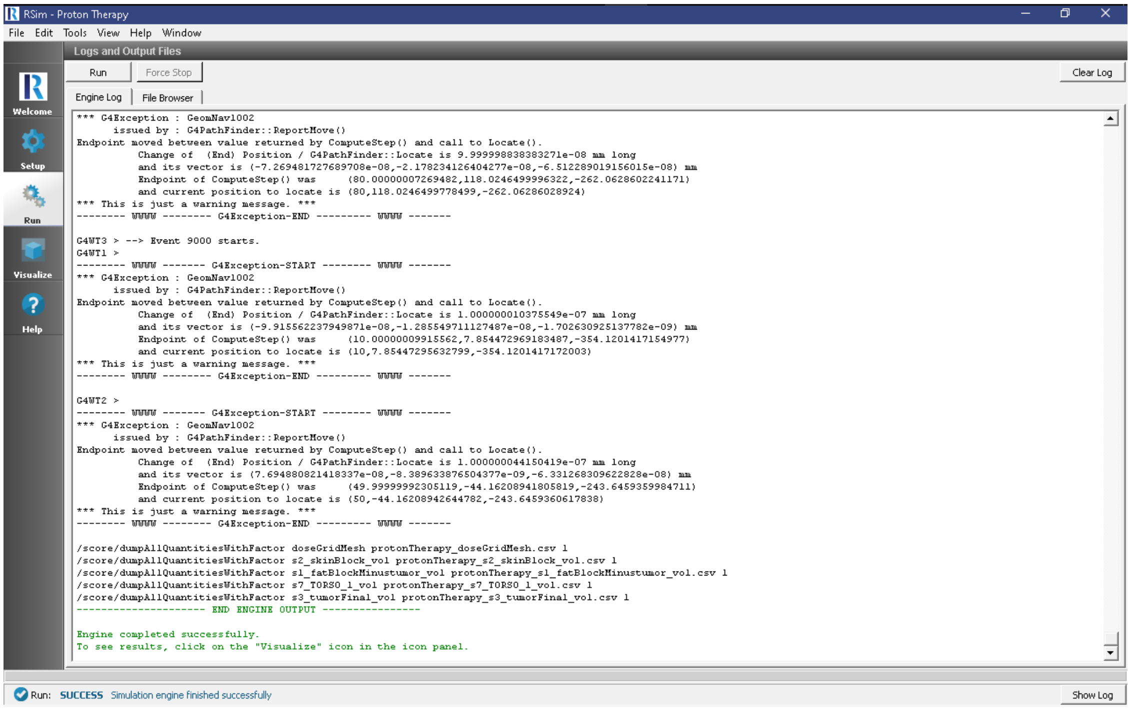


Fig. 2.21: The Run Window at the end of execution.

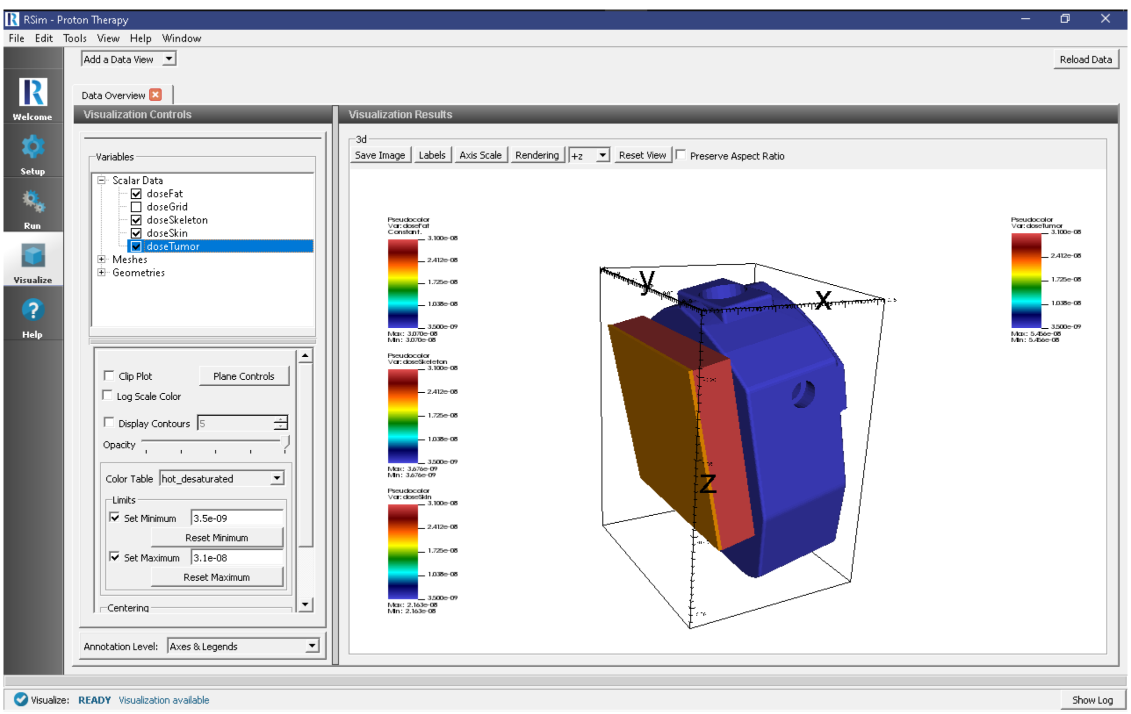


Fig. 2.22: The visualization results.

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

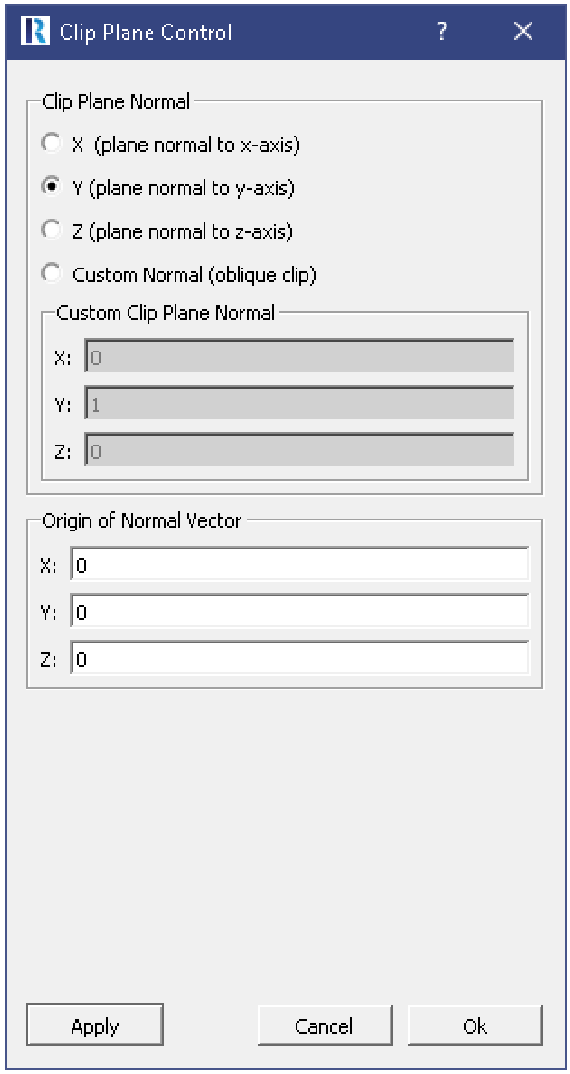


Fig. 2.23: Settings of the cut plane.

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:

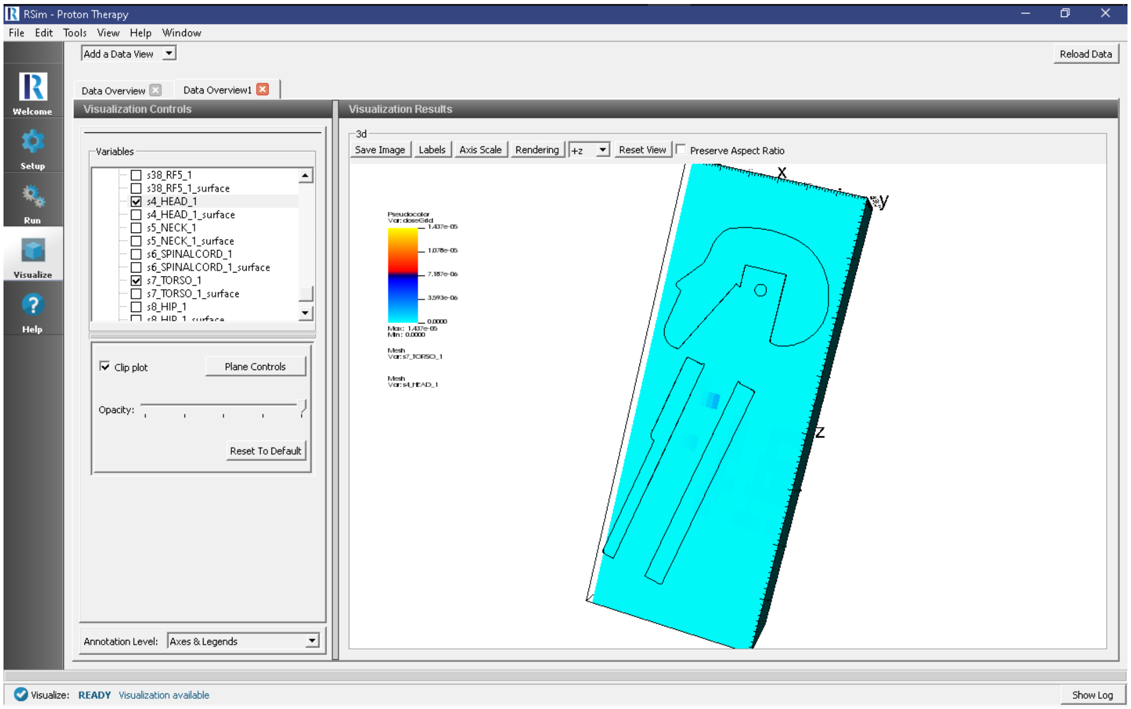


Fig. 2.24: The visualization of the volume tally.

`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* → *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.

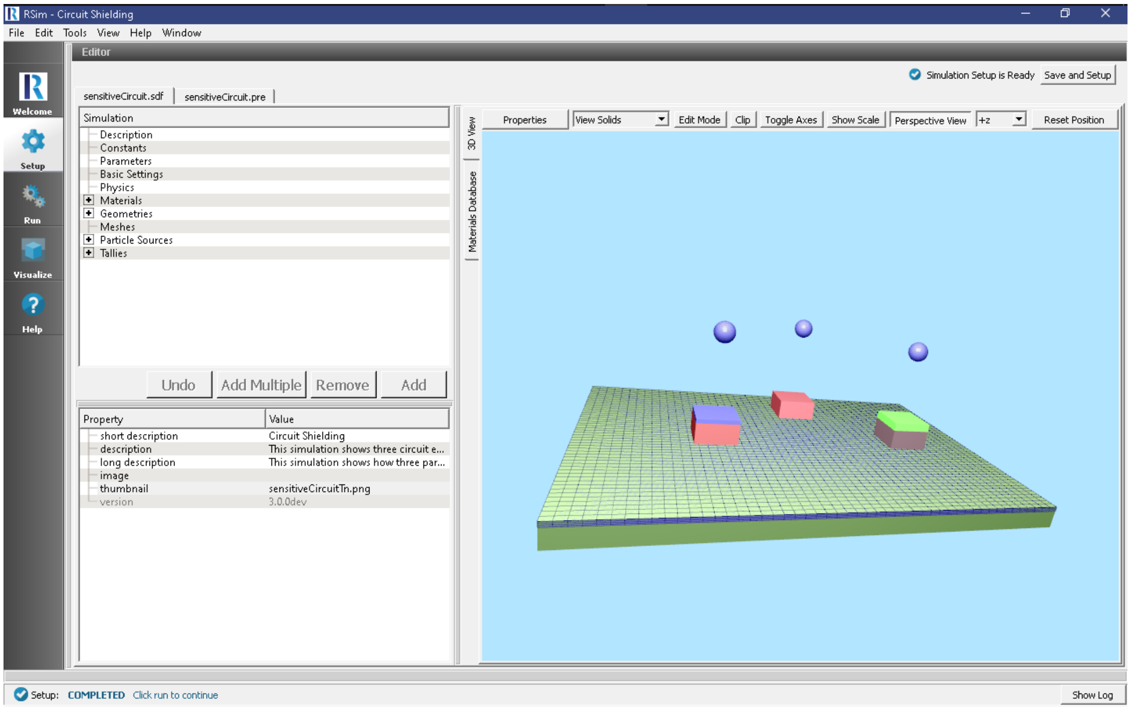


Fig. 2.25: Setup Window for the Sensitive Circuit example. The PCB is colored green, the aluminum IC models red, and boron shields green

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 depostion as shown in Fig. 2.27.

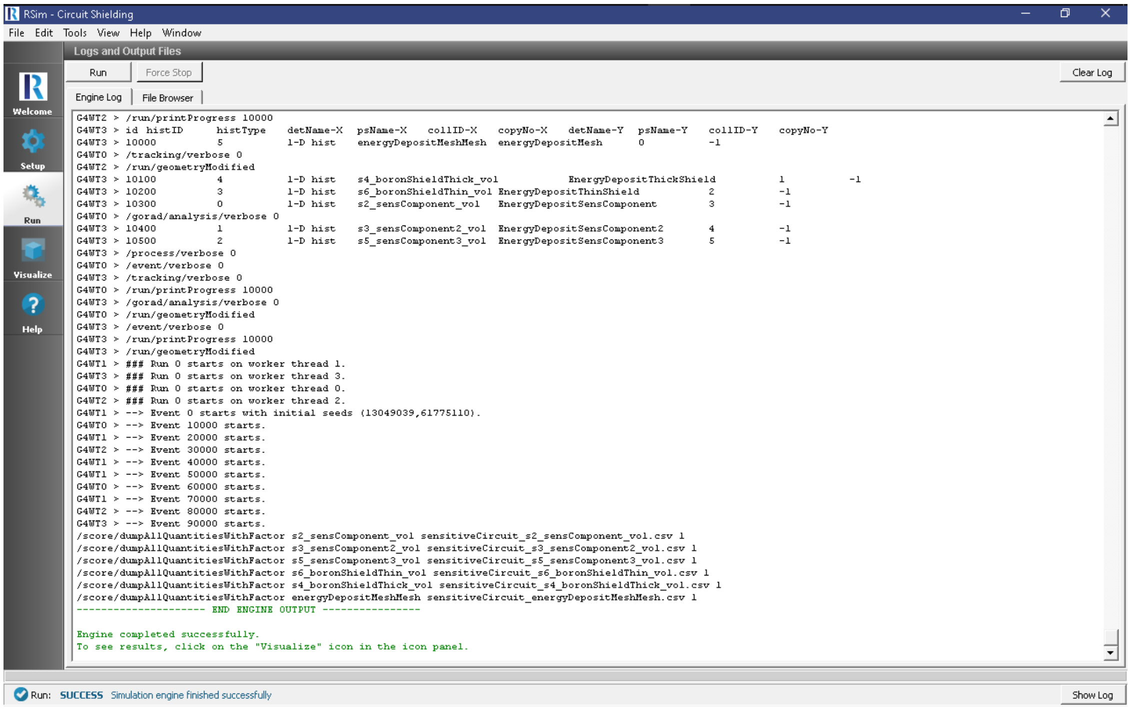


Fig. 2.26: The Run Window at the end of execution.

- 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.

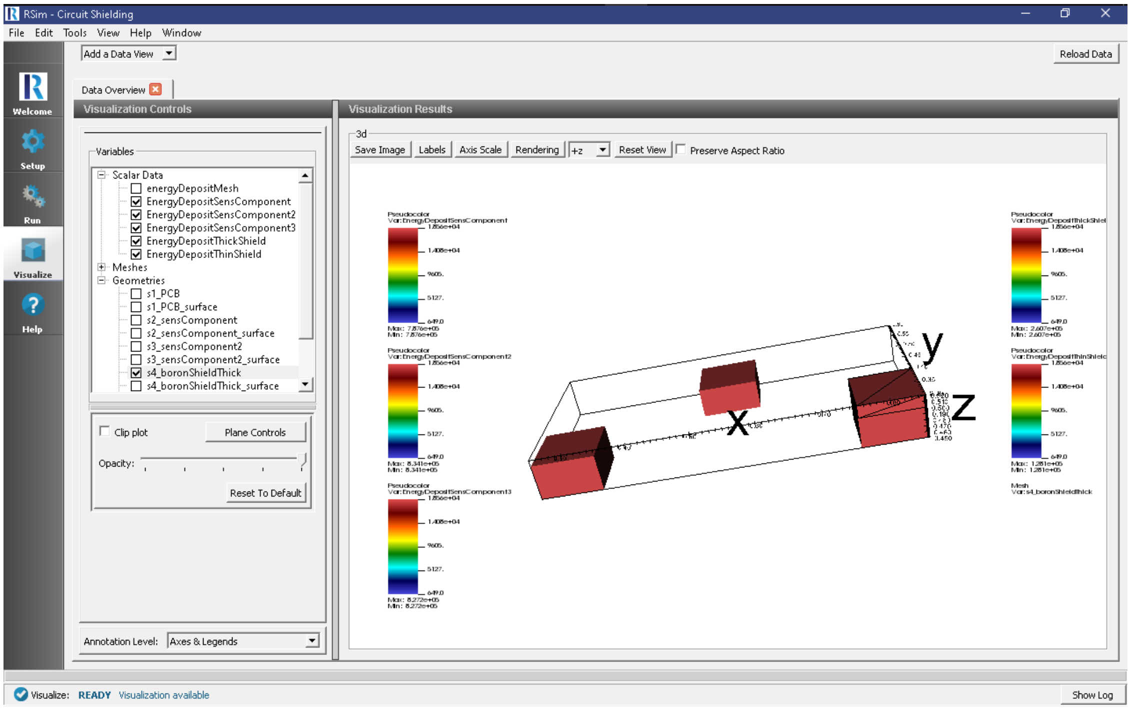


Fig. 2.27: The total deposited energy of the shield + sensitive component underneath will match up for all three test coupons.

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* → *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 followi

- Right-click on the *Geometries*

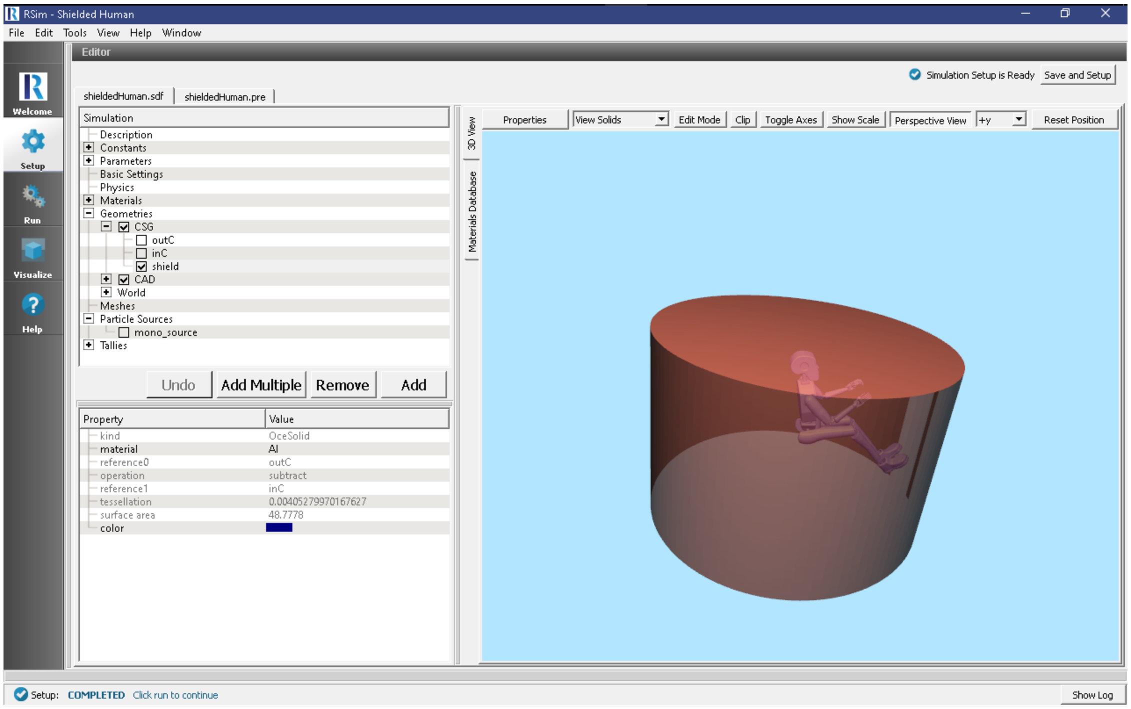


Fig. 2.28: Setup Window for the shielded human example.

- 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

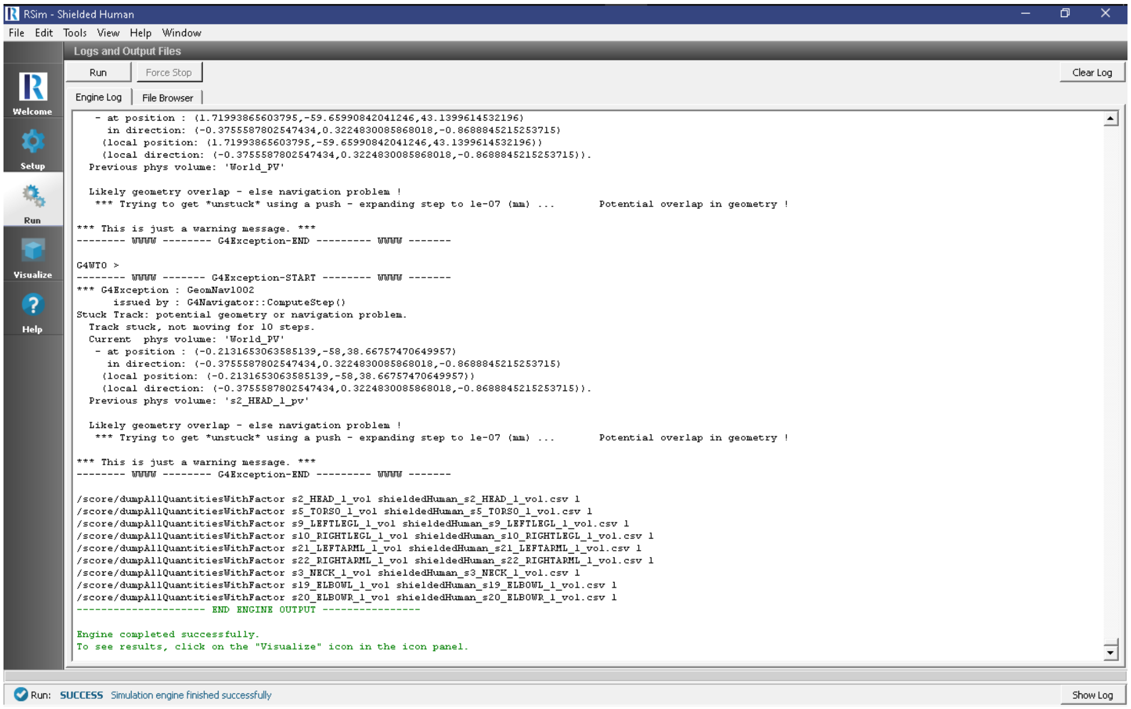


Fig. 2.29: The Run Window at the end of execution.

- 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)

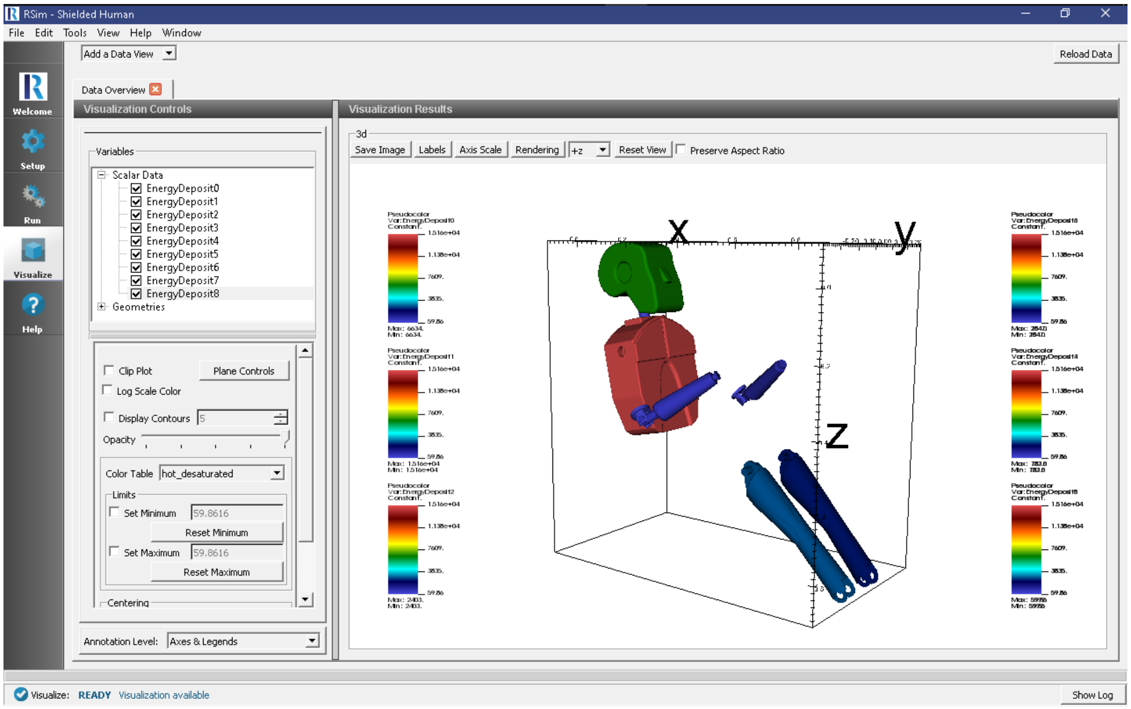


Fig. 2.30: Visualization results of the volume tally.

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 → 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.

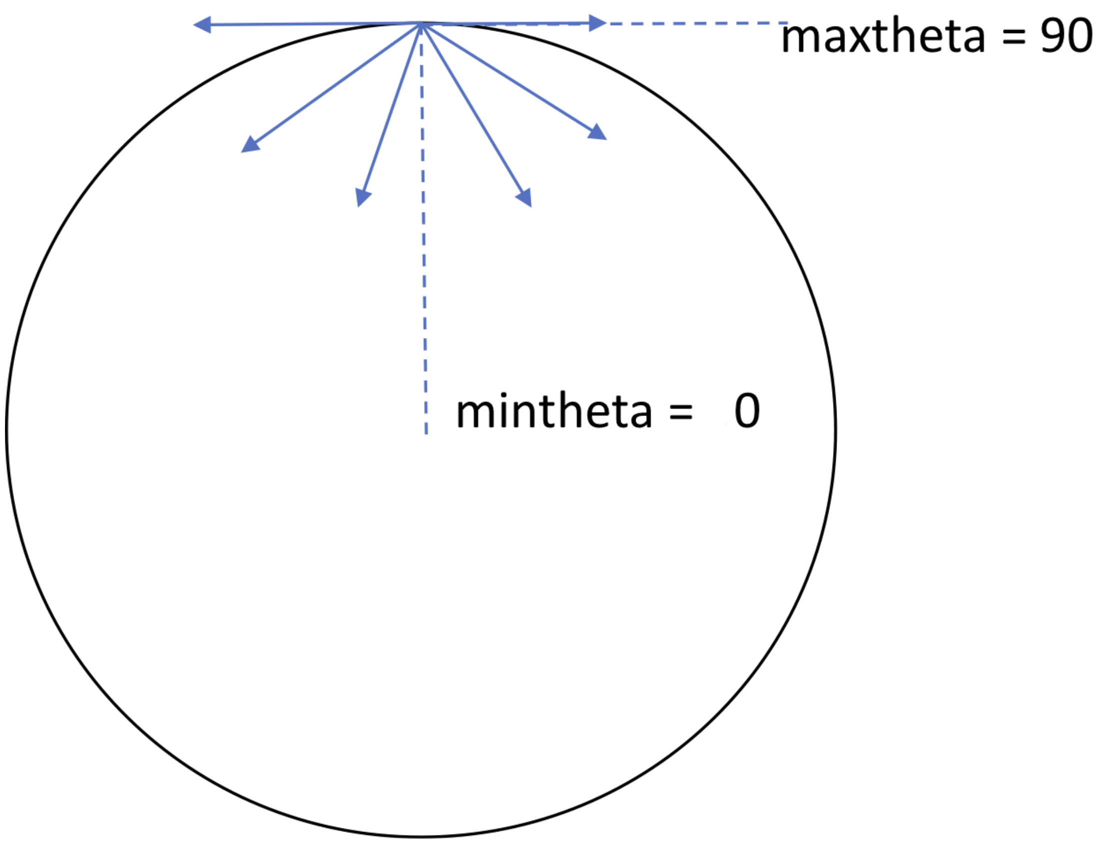


Fig. 2.32: Space radiation is modeled by an omnidirectional spherical surface close to the target with the particles going inside the sphere, which is controlled by the min and max angle in the source specification. Each point of the sphere emits particles limited by the angles, so particles mostly go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

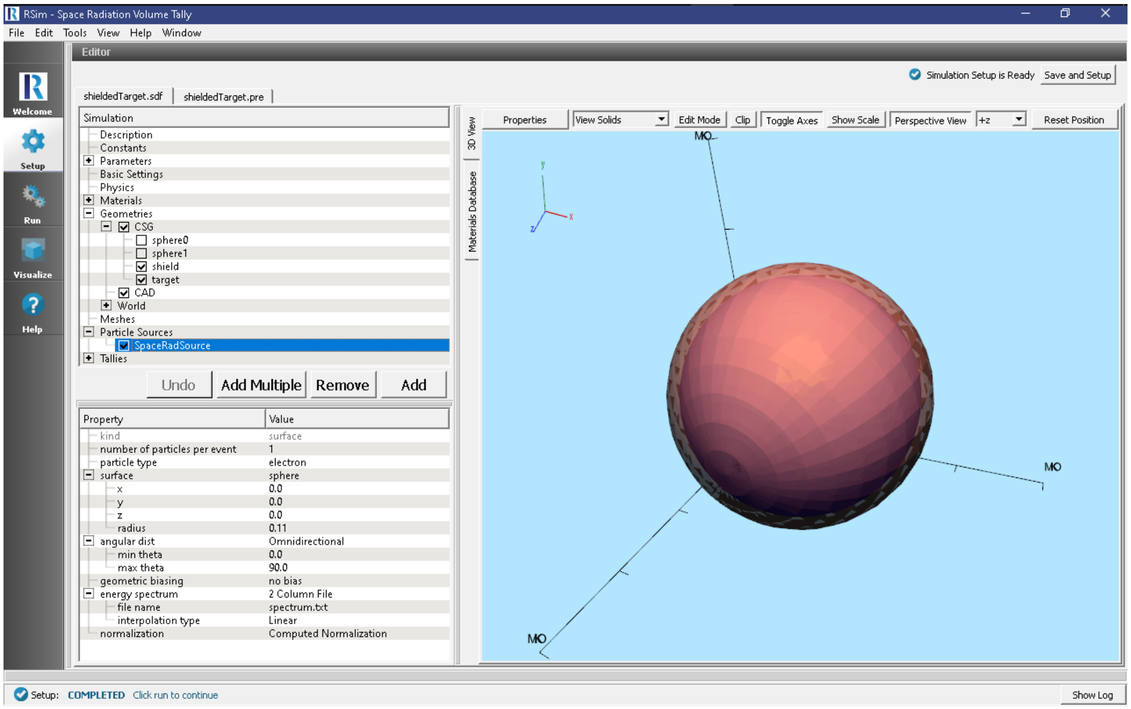


Fig. 2.33: Setup Window for the shielded target example.

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*

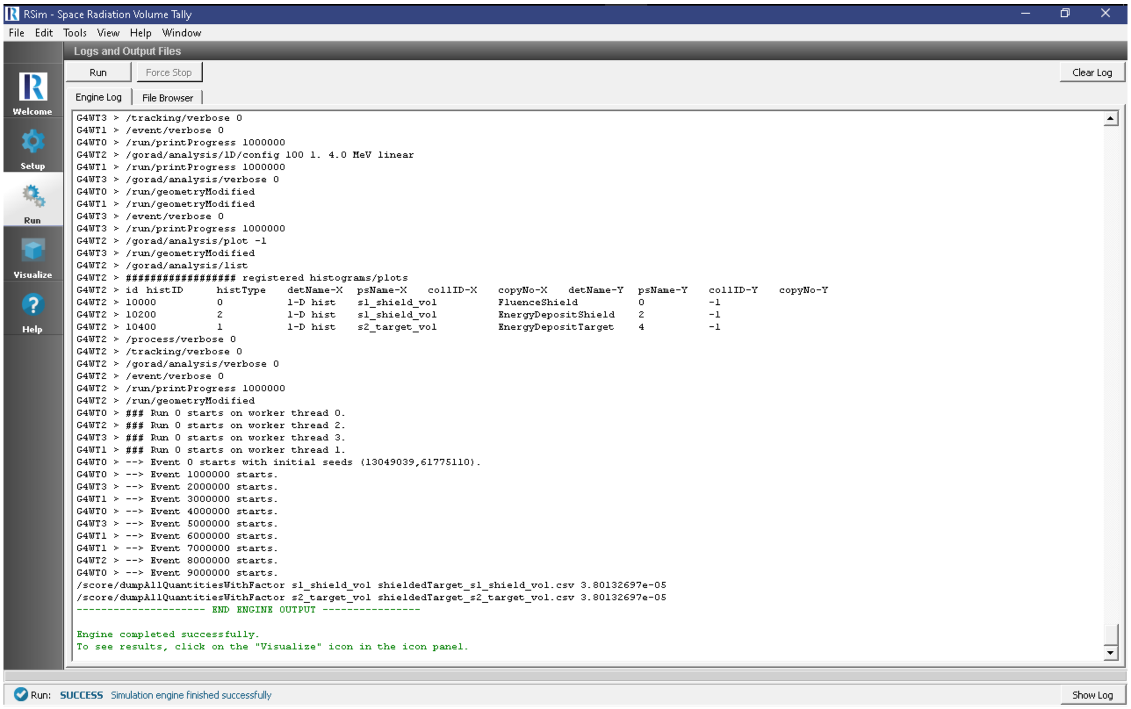


Fig. 2.34: The Run Window at the end of execution.

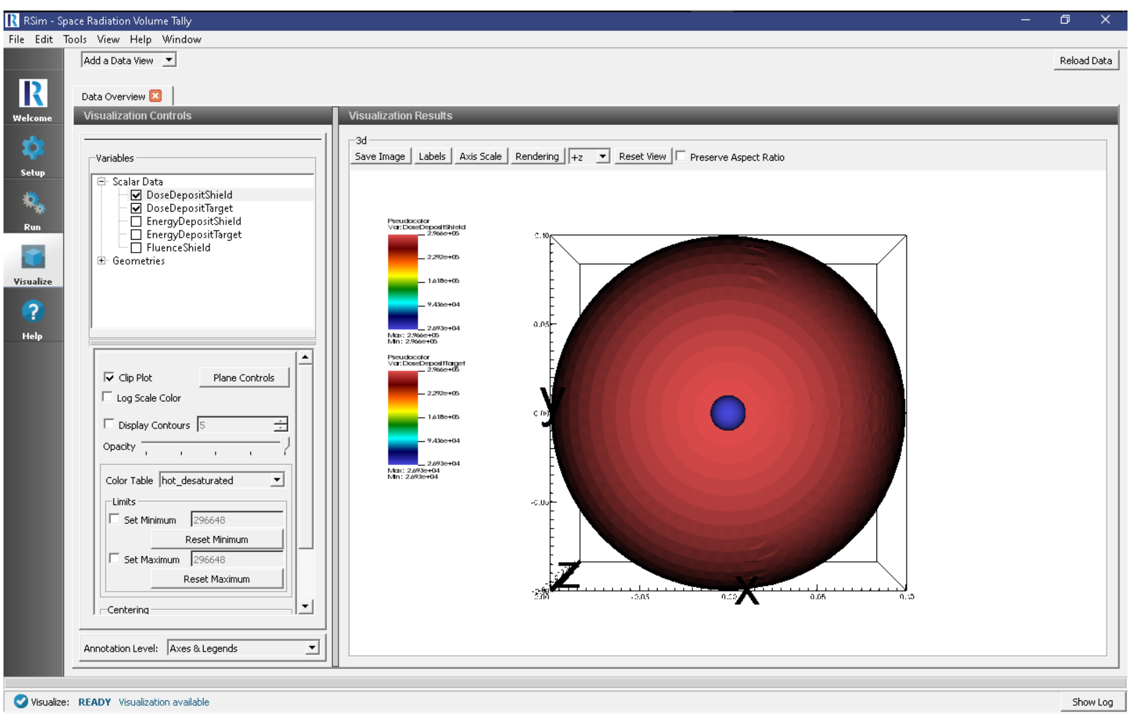


Fig. 2.35: Energy deposit on the target and the shield.

And visualize this result as shown on Fig. 2.36.

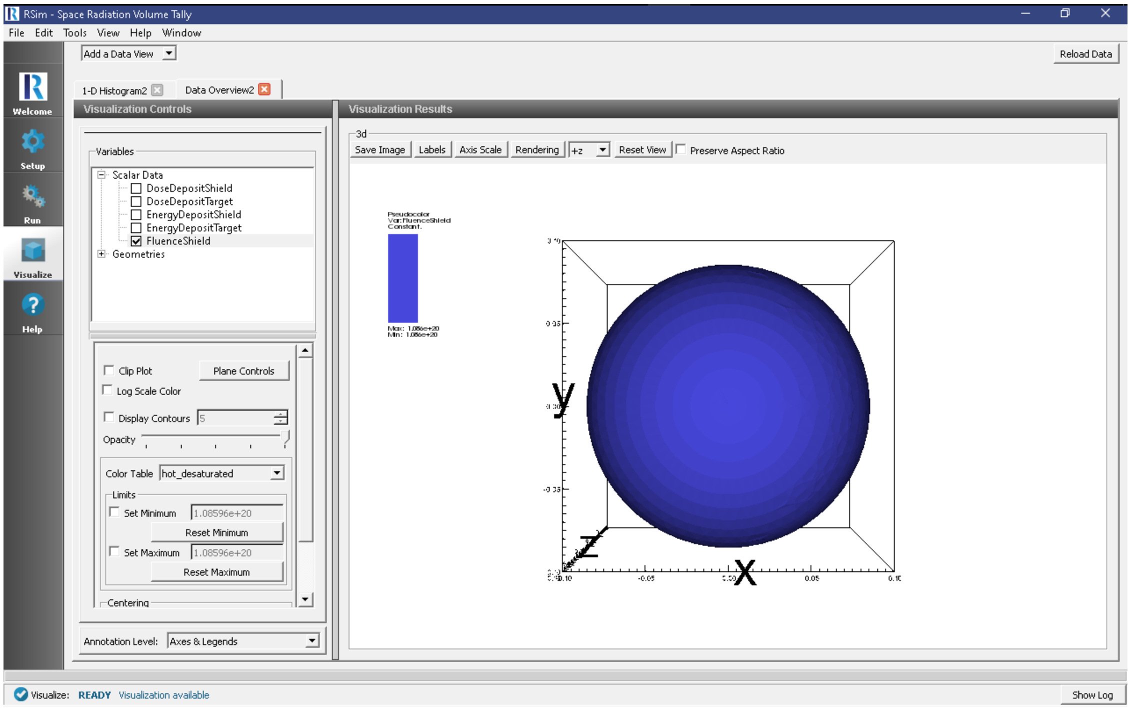


Fig. 2.36: Fluence on the shield.

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`

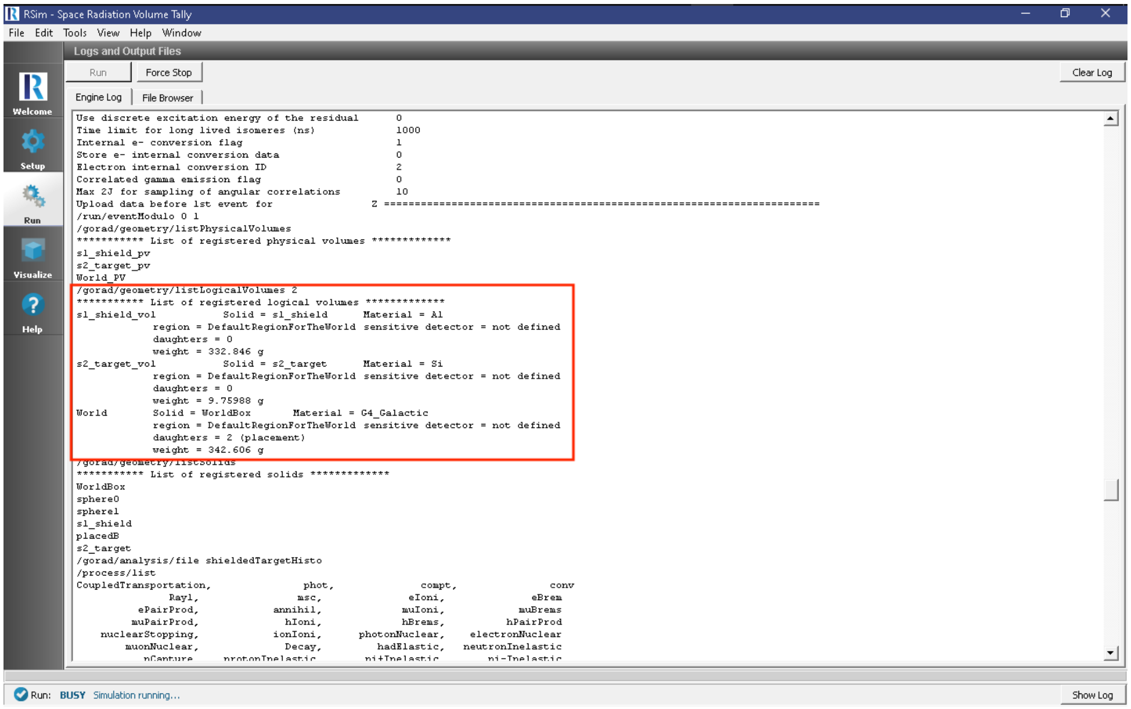
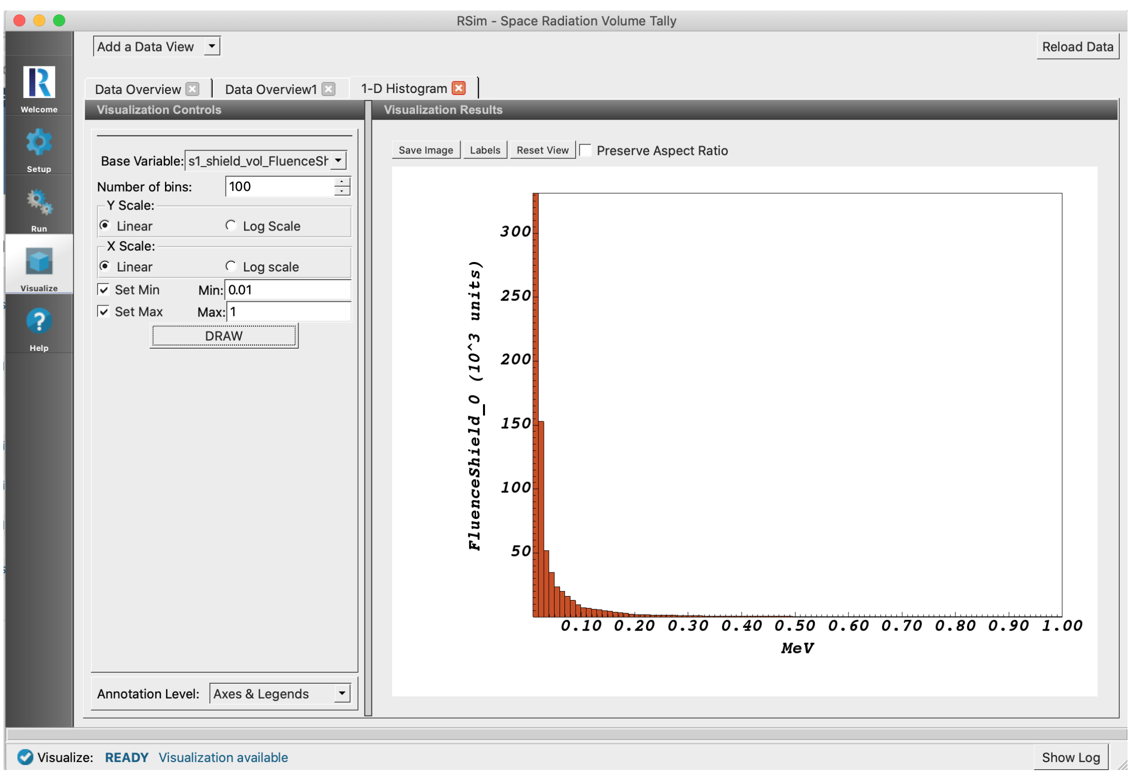


Fig. 2.37: The standard output in the run tab contains information of the masses.



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 x 10 x 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 → 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.

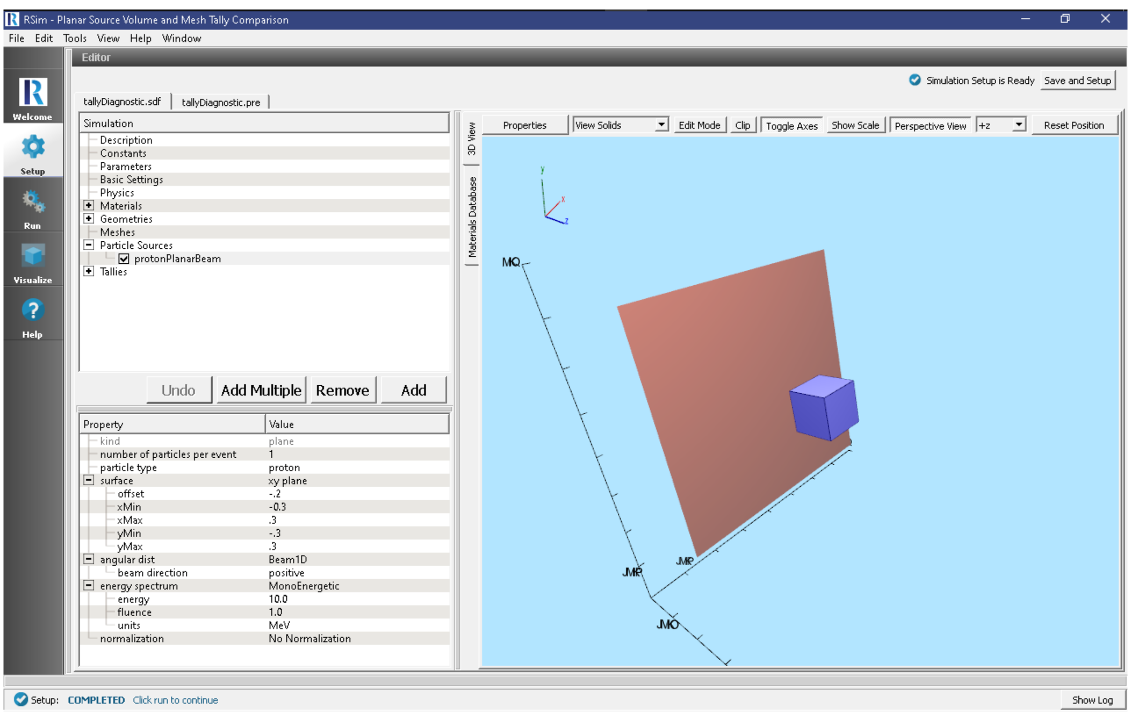


Fig. 2.38: Setup Window for the Tally Diagnostic example. The mesh itself can be seen in the 3D View, along with the plane that will be shooting particles at it.

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 x 1 x 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 x 0.1 x 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.

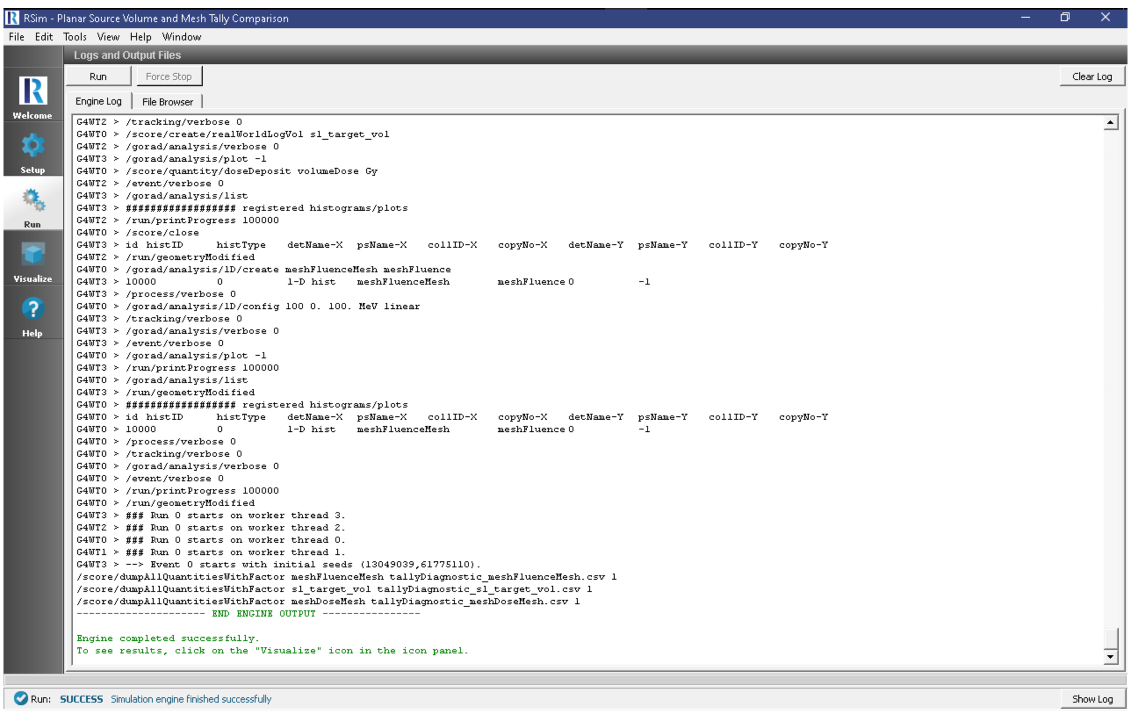


Fig. 2.39: The Run Window at the end of execution.

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

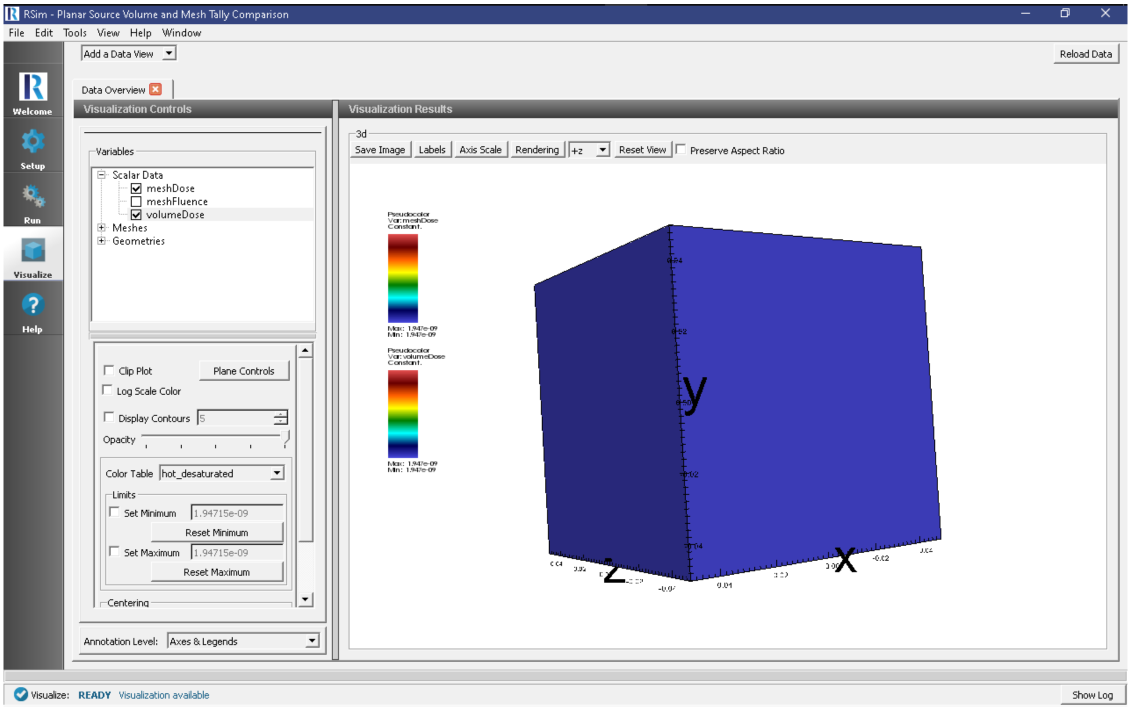


Fig. 2.40: The visualization window showing results of the simulation.

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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