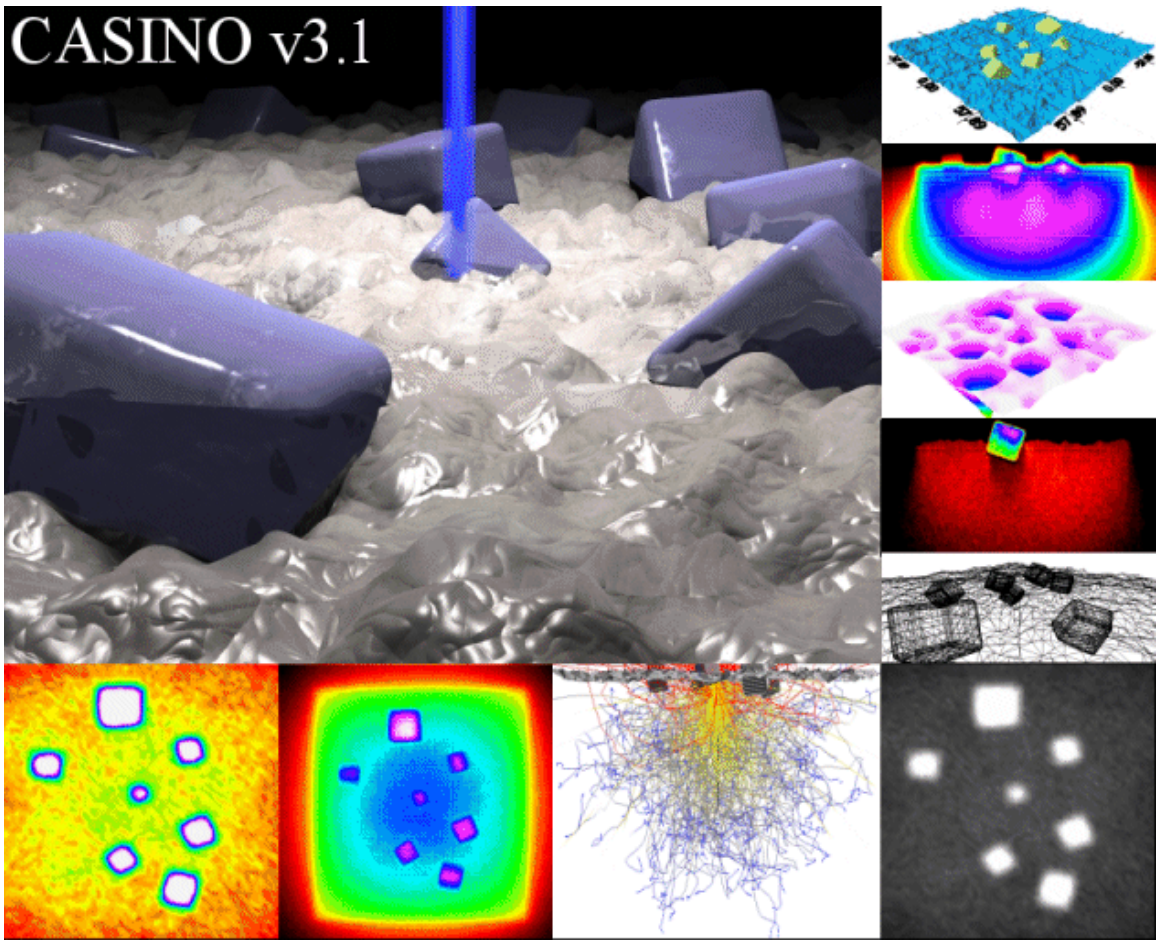

Casino 3.2 User Manual

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Sherbrooke, Quebec, Canada, Fall 2008

Table of Content

Introduction 4
Creating a Simulation 4
  Starting the simulation 4
  Creating the sample 4
Create Sample Dialog 5
Modify Sample Object Dialog 7
  Name 7
  Region 7
  Translation 7
  Rotation 7
  Scale 7
  Change 7
Edit Layers Dialog 8
Layer Chemical Composition Dialog 9
  Name 9
  Composition 9
  Density 9
  Virtual Element 10
  Add to library 10
  Color 10
Microscope and Simulation Properties Dialog 11
  Number of simulated electrons 11
  Conserve Data for each simulated point 11
  Simulate Noise 12
  Generate Secondary Electrons 12
  Generate X-Rays 12
  Advanced Beam Properties 12
  Beam Semi-angle 12
  Scanning properties 12
  Beam distribution 12
  Sample Angle 12
Distributions Dialog 13
  Distributions 13
  Collect data logarithmically 13
  Max Range Parameter 13
  Distribution of Energy 14
Toolbar explanation 15
Select Physics Model Dialog 17
  Secondary Electron Fine Tuning 18
  Minimum electron energy (no secondary electrons generation) 18
  Minimum Order of SE Generated 18
  Residual energy loss: 18

Minimum electron energy 18
Minimum generated secondary electron energy 18
Runtime Option Dialog 19
Number of displayed trajectories 19
Time between Status Bar Refresh 19
Number of CPU used 19
Number of scan points per thread 19
Conserve electrons trajectories 20
Thread priority level 20
ADF Sensor Settings 20
Enable ADF Sensor 20
Keep trajectories angle to allow post-simulation recalculation 20
Maximum number of points used when keeping angles 20
Detector Quantum Efficiency 20
Detector Semi-Angle 20
Display options Dialog 21
Graph Options Dialog 22
Graph Type 22
Number of tabs 22
Normalize data 22
Energy by Position Distribution Options Dialog 23
Sum over the projected axes 23
Diffuse 23
Normalize with the volume 23
Carrier surface recombination 23
Projection 23
Y plane / Z plane 23
Visible Energy 23
Region / Carrier Diffusion Length 24
Intensity Graph Properties Dialog 24
Intensity 24
Display Mode 24
Scale Coloration 24
Regions with check boxes 24
Max / Min 24
Licenses 25
Boost 25
smart_ptr 25
ezLogger 26
libfiff 26
ResizableLib 26
TreeCtrlEx 29
References 30

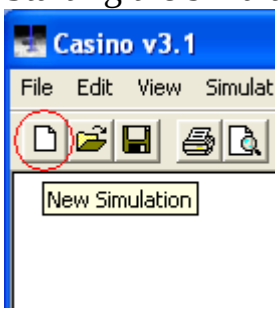
Introduction

The goal of this manual is to cover the Casino 3.1 program in depth. Note that Casino is rapidly growing and the current document might not be totally compatible with the most current release.

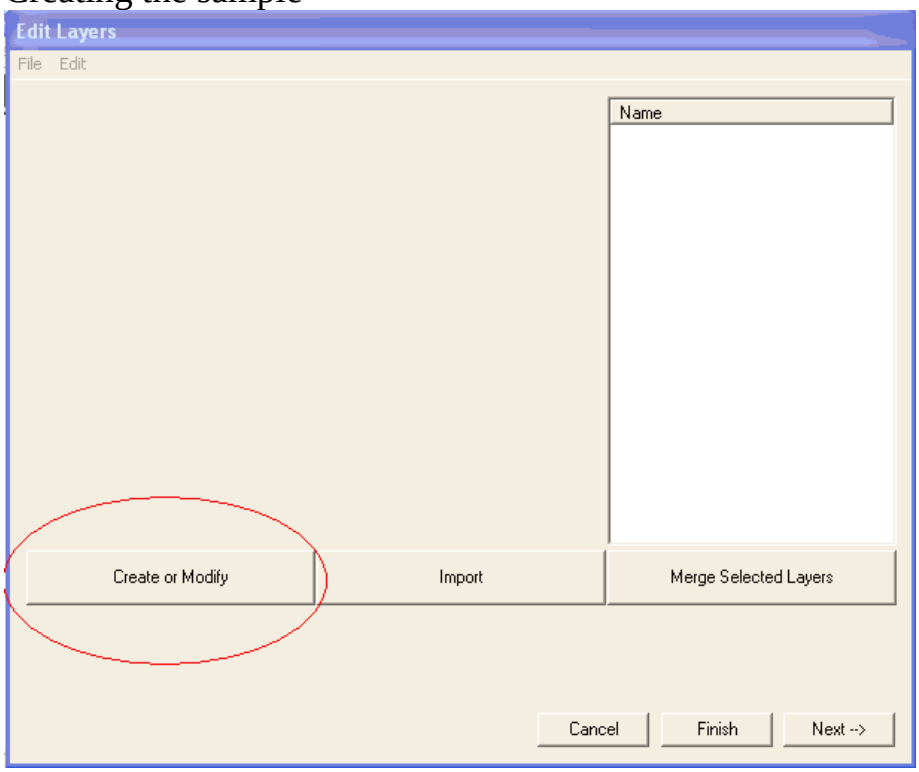
Creating a Simulation

Quickly creating a new simulation is one of the strong points of the Casino software. A few dialogs will quickly provide the necessary information to generate a simulation.

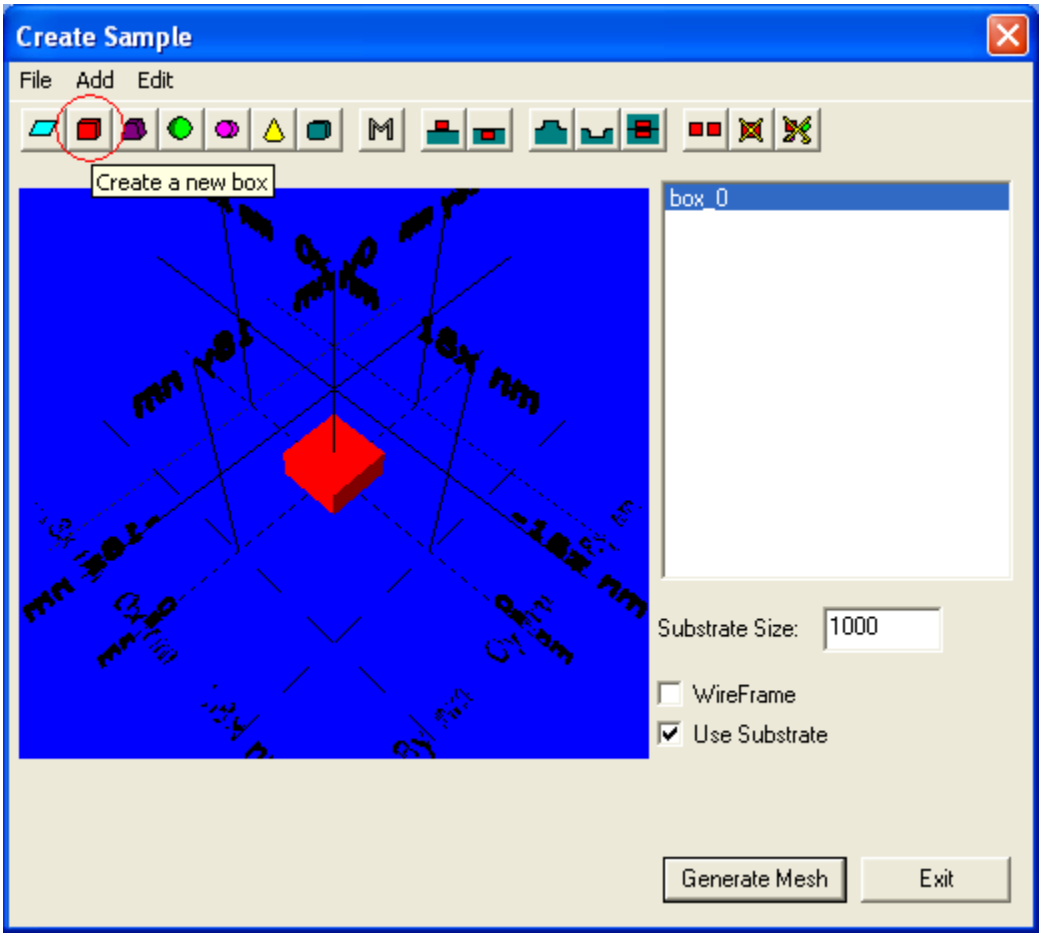
Starting the simulation



Creating the sample



Create Sample Dialog



In this dialog you can add multiple objects to the sample. Possible objects are simple planes that can be used to delimit a new region, boxes, truncated pyramids, spheres, cylinders, cones and rounded rectangles. You can change their properties with the "M" icon (modify) or by double clicking on them. You can also apply different actions to them like merging with the substrate, cutting with the substrate or translating them.

These actions can be applied to more than one object at the same time by selecting more than one of them using the shift key and the mouse. When more than one object is selected and the modify command is chosen, the modify dialog for each item will be called one after each other when the modify dialog for the current item is closed. This was done since each object has different properties so it did not make sense to be able to change them all at the same time.

Important notes:

Casino works the following way: when an electron crosses an object surface, a collision is detected. To determine the new region of the electron, the surface has an *inside* and an *outside* value determined in the Layers dialog. This way, if the box in the example (see the Create Sample Dialog screenshot) is made of Aluminium inside and of empty space outside, an electron passing through it from the top will be detected as being in empty space when leaving the box, when in fact it is in the substrate (the box is half over the substrate and half under the substrate)! The solution to this problem would be to cut the box in 2 with the "Cut by Substrate" button, and then the portion inside the substrate could have outside value different from the outside portion.

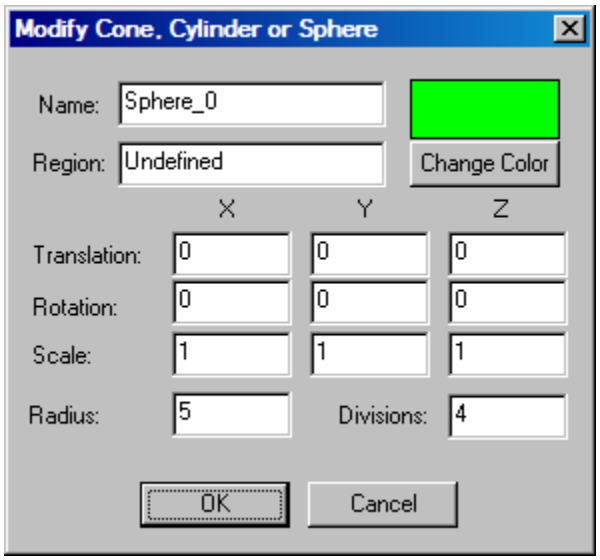
Another problem will arise. The two boxes surfaces are in the same plane as the substrate. This will cause an electron passing from one region to the other to miss one of the borders. For example, an electron coming from the top, passing through the Aluminium box, and then into the substrate will detect the collision with the box border, effectively passing from Aluminium into empty space, but the entrance into the substrate will NOT be detected. The solution to this problem is to use the "Place over Substrate" or "place under Substrate" button. This will create a very small empty space between the box and the substrate.

The 'Substrate size' option can be used to specify the size of the substrate. It will also be the sample size. You can also specify whether or not you want to use a substrate by ticking the 'Use substrate' box.

The 'Wireframe' option is used to display the sample showing only the wireframe. This can be used to see through objects that would otherwise hide other objects from you.

You can also apply a translation to one or more object by selecting them and right clicking on them and choosing 'Translate' or going to the Edit menu and clicking on 'Translate'. A dialog will then ask you the translation to apply to the objects.

Modify Sample Object Dialog



Name: Name of the object that you will be able to refer to when assigning a chemical composition to it later.

Region: ??

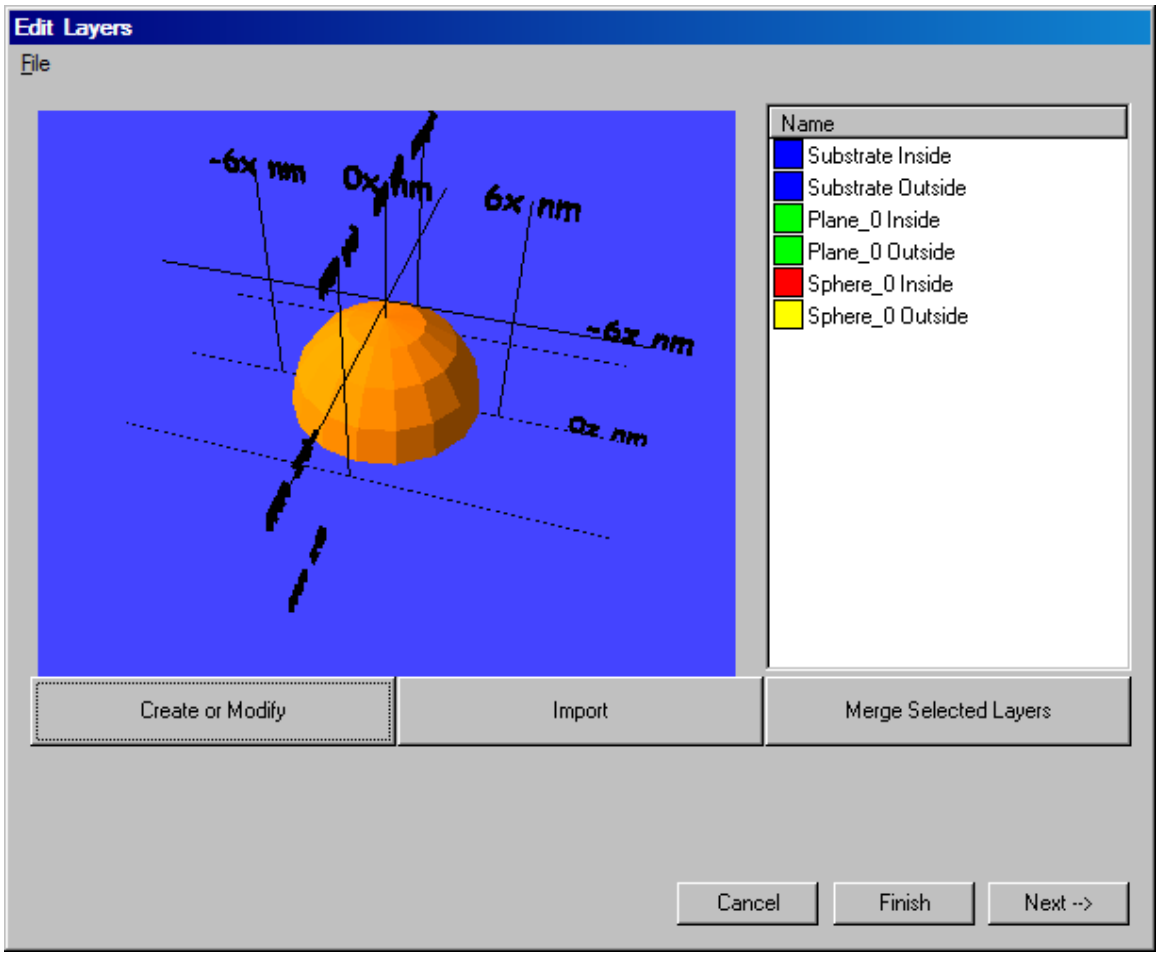
Translation: Position of the object in the X,Y,Z coordinates system, negative Z being upward.

Rotation: A rotation in respect to the X, Y or Z axis will be applied to the object (numbers are in degrees)

Scale: For planes and other similar objects this is the size of the object; for a sphere the scale will be multiplied by its radius so should be kept to 1.

Change Color: Pop up a dialog where you can change the color of the object.

Edit Layers Dialog



In this dialog you can import a sample from a 3DS files, create a new sample, modify an existing one (explained in the last section) or assign a chemical composition to each regions.

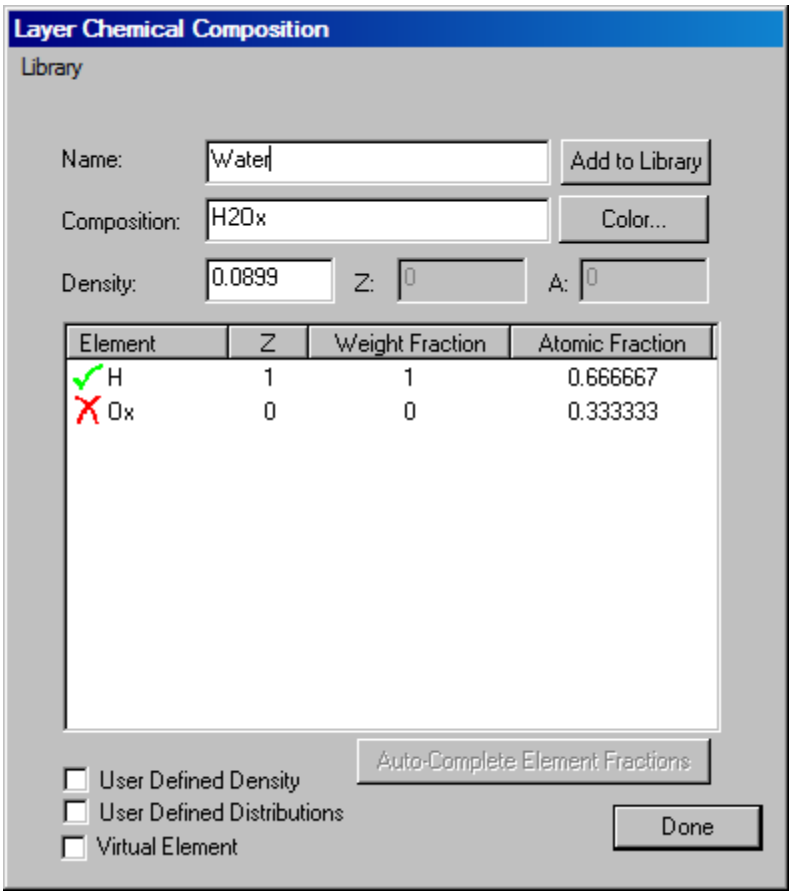
Like explained in the last section, casino use an inside and an outside region for each objects. To simplify the entering of the same composition to multiple regions, they can be merged using the 'Merge Selected Layers' option. To unmerge them in case you change your mind and need to change the composition of a region that is merged with others, you need to click on create or modify and regenerate the sample. All regions will then be unmerged.

You can also import models made with professional graphic programs such as 3D Studio Max™[1] by importing files in the 3DS format with the Import command. The 3DS format is supported by many different programs, some of them are free.

[1] http://www.discreet.com/

To specify or change the composition of a region, double click on them to get to the Layer Chemical Composition Dialog.

Layer Chemical Composition Dialog



Name: Name of the composition.

Composition: In this dialog you can enter the composition of a region. Just enter the chemical formula in the Composition text area and you should see casino trying to recognize the elements. A green check will be next to an element recognized by Casino and a red cross if it is not (In the example above you can see that a typo has been done and Casino cannot recognize the element).

Density: If you do not specify a density, casino will try to calculate it for you but it is not always really accurate. A better way is to manually specify a density (in g/cm3).

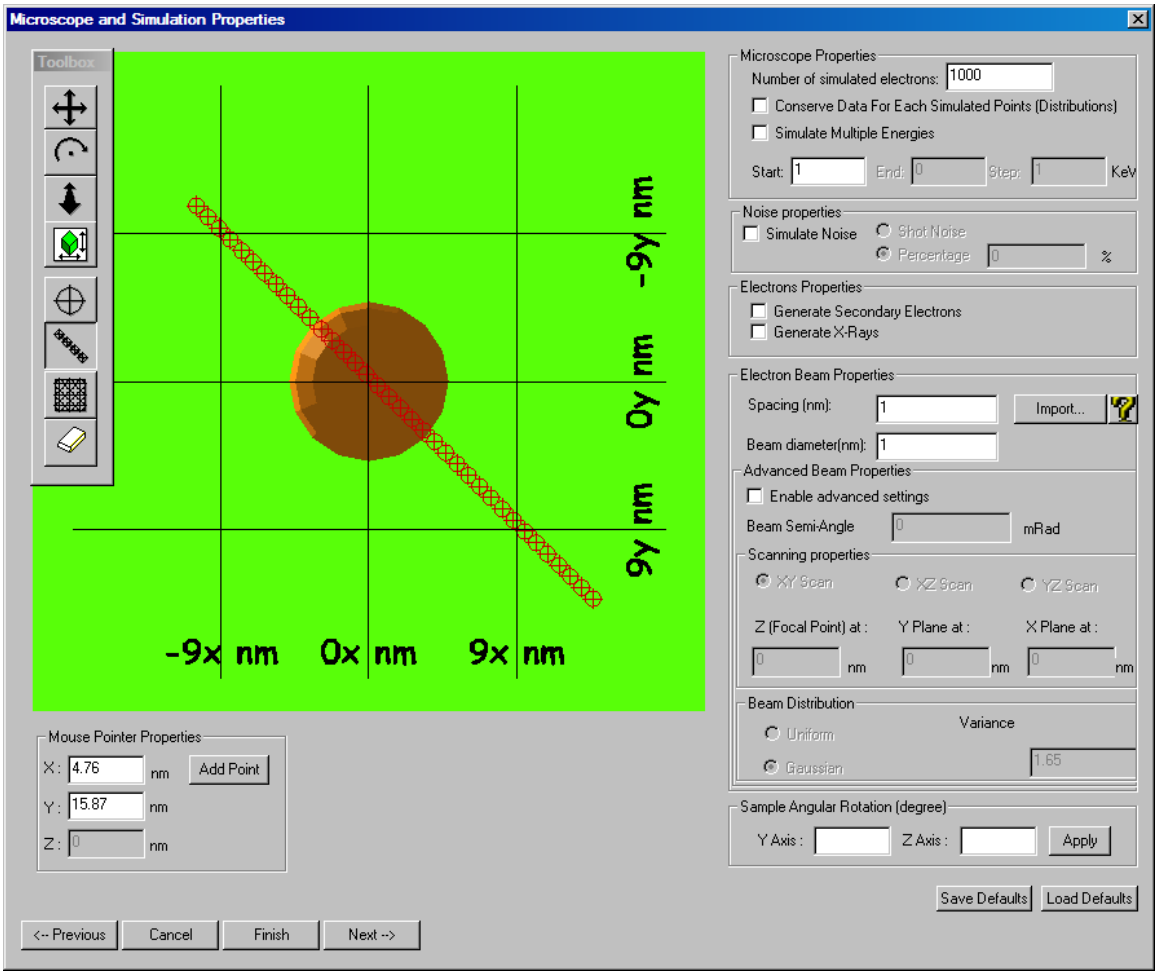
The weight fraction/atomic fraction can also be specified manually if the automatically calculated values are not what you want.

Virtual Element can also be used if you want to specify manually the average Z and A of the region instead of using the calculations made by casino.

Add to library: When you are satisfied with a region you can add it to the region library by clicking on add to library. You can later get back the same region by typing it's name in the Name box and if the region name exist in the library it will ask you if you want to replace the current composition with the one in the library.

Color: Ask a new color for the region.

Microscope and Simulation Properties Dialog



This dialog can be used to set up the different options of the beam. You can use the toolbar (on the left in the image) to select if you want a single point, a line scan or an image.

The spacing between points and the size of the pixel can be specified in the Electron Beam Properties group on the right.

Number of simulated electrons: Specify the number of electrons that will be simulated with each scan points.

Conserve Data for each simulated point: If you want to use the distributions of the Casino program, you **must** conserve the data for each point. It will take a tremendous amount of memory though.

Simulate Noise: Simulate noise in the number of electrons simulated. Use shot noise to model a Poisson distribution of the number of electrons per scan points and percentage if you want a fixed percentage of noise to be simulated.

Generate Secondary Electrons: Will use the secondary electrons model to simulate secondary electrons. A box will also be displayed asking if you want to set the physical models to Monsel[2] settings.

Generate X-Rays: Broken in Casino 3 for the moment.

Advanced Beam Properties: To enable advanced properties, click on the advanced properties box. Else default value of a XY scan and a perfectly straight beam will be used.

Beam Semi-angle: Semi-angle of the beam.

Scanning properties: Specify whether the scan is in the XY, XZ or YZ plane. A value can also be specified for the third coordinate.

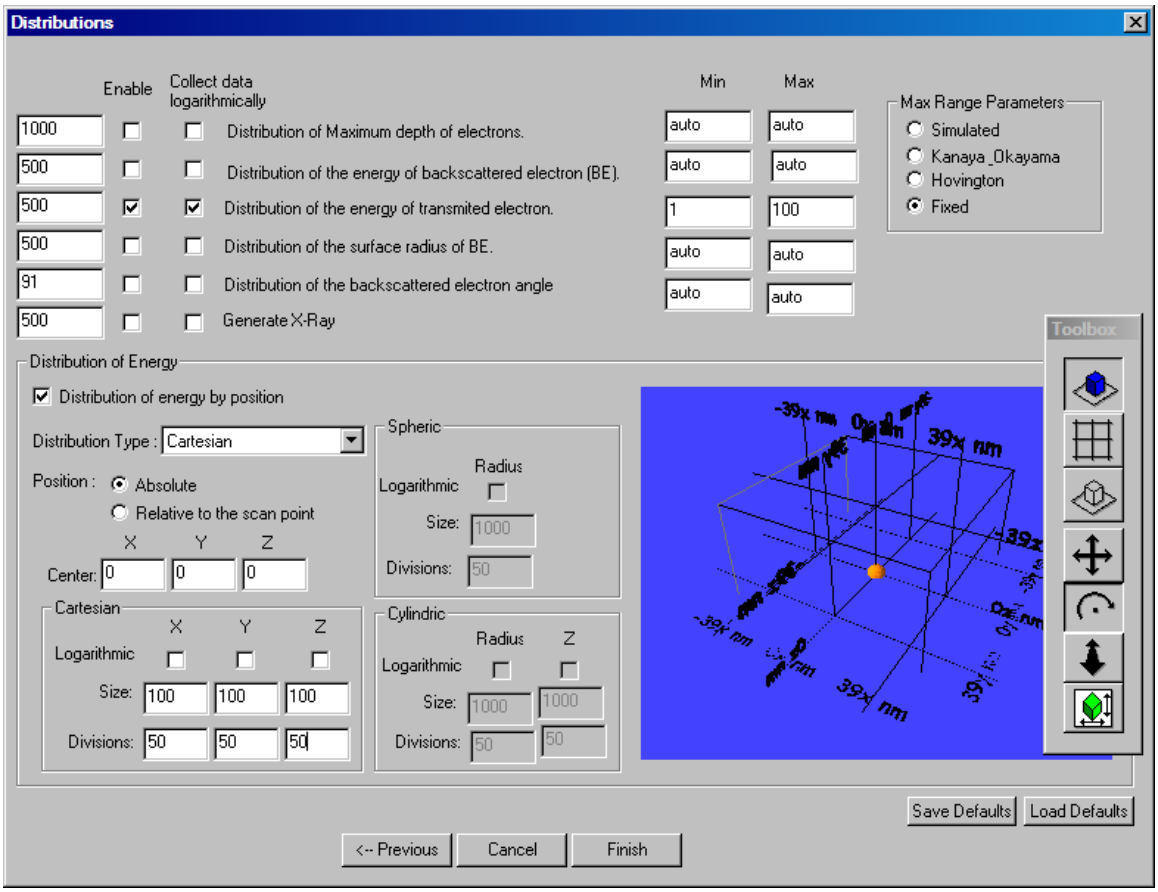
Beam distribution: Model for the distribution of the electrons in the beam. Electrons can either be distributed uniformly across the beam area or using a Gaussian distribution.

Sample Angle: To simulate an electron beam with an angle, it is possible to make the sample rotate in a specified axis.

[2] Lowney JR, Marx E: Semiconductor Measurement Technology: User's Manual for the Program MONSEL-I: Monte Carlo Simulation of SEM Signals for Linewidth Metrology. *Nist Special Publication* 400-495, USPGO, Washington, D.C. (1994)

Lowney JR: MONSEL-II: Monte Carlo Simulation of SEM Signals for Linewidth Metrology. *Microbeam Anal* 4, 131-136 (1995)

Distributions Dialog



Distributions: Many distributions are provided with Casino. They simplify the analysis of the results and are mostly used to evaluate the outcome of a future experiment with a real microscope.

The first column is used to specify the number of points in the distribution. Also you can enable only the distribution that interest you so you don't need to pay the cost in memory for the one you don't want.

Collect data logarithmically: You can set this option for the distribution you want the data to be collected logarithmically.

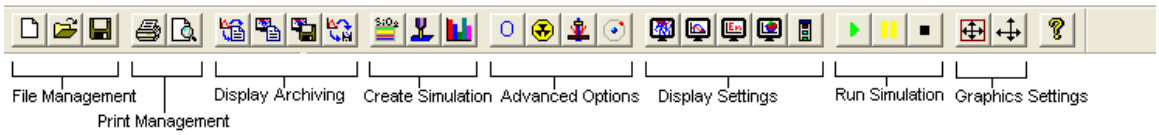
Max Range Parameter: Settings used to determine the min and max value for the distribution. Casino can try to automatically deduce the correct range to collect the data but the user can use the 'Fixed' option to manually enter values. Even when using the 'Fixed' option, user can choose individual values to be auto-calculated by casino by entering auto in the textbox.

Distribution of Energy: The distribution of the energy can be collected using cartesian, spherical or cylindrical coordinates. You can then set the corresponding size and number of divisions for each dimension.

You can also specify if the position of the center of the energy matrix is in absolute coordinate or relative to the scan point.

The view to the right can also be used to view the look of the energy matrix compared to the sample.

Toolbar explanation



 Create a new simulation tutorial. It will pass through all the necessary steps to create a new simulation.

 Open a simulation file stored in a .sim (not simulated yet) or .cas (simulation with results) file type.

 Save a simulation to a .sim (not simulated yet) or a .cas (simulation with results) file type.

 Print the current display.

 Preview the current display.

 Copy data to clipboard.

 Copy display to clipboard.

 Save display in a jpeg compressed image.

 Save data to an ASCII file.

 Create sample and edit the layers. It must be done before the simulation begins.

 Set microscope options. They must be set before the simulation begins.

 Select distributions to compute. They must be set before the simulation begins.

 Set simulation options related to the computation.

 Launch the X-Rays settings dialog (not working right now).

 Launch the backscattered electron sensor settings dialog.

 Launch the physical models selection dialog.

 Settings related to the main 3D display.

 Settings related to the distributions display.

 Settings related to the Energy by Position distribution

 Settings related to the Intensity distribution.

 Launch the visualisation toolbar. Useful to manipulate the main sample view camera.

 Launch the simulation.

 Pause the simulation. Clicking on it a second time or clicking on play will launch back the simulation where it was stopped.

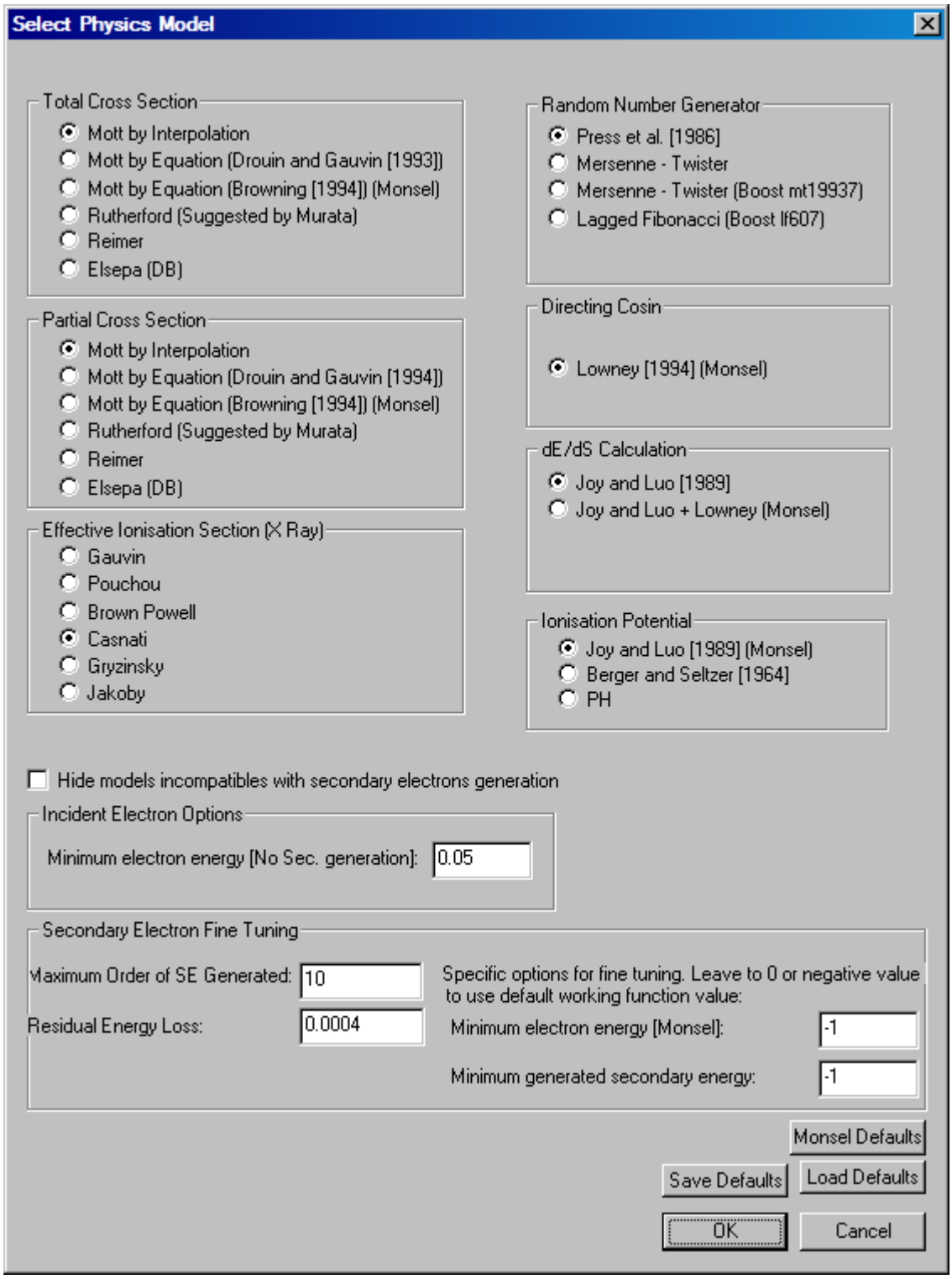
 Stop the simulation. The simulation will be terminated.

 Auto resize the display.

 Manual resize of the display.

 About Casino box.

Select Physics Model Dialog



Casino can simulate many different physical models. The default settings are quite optimal for most users, but it is possible to use many different models that might have different strengths.

One point to notice is that Casino has integrated the Monsel program in a contract with the NIST and can now simulate ionisation and plasmon secondary electrons thanks to the Monsel algorithms. Not every model is compatible with the Monsel algorithms. More particularly, the continuous energy loss in Monsel must be Joy & Luo modified by Lowney.

Secondary Electron Fine Tuning:

Minimum electron energy (no secondary electrons generation): The current state of the energy loss models cannot permit us to simulate electrons at energy lower than 0.05 KeV. At energy lower than that, the energy loss curve become positive and generates an energy gain.

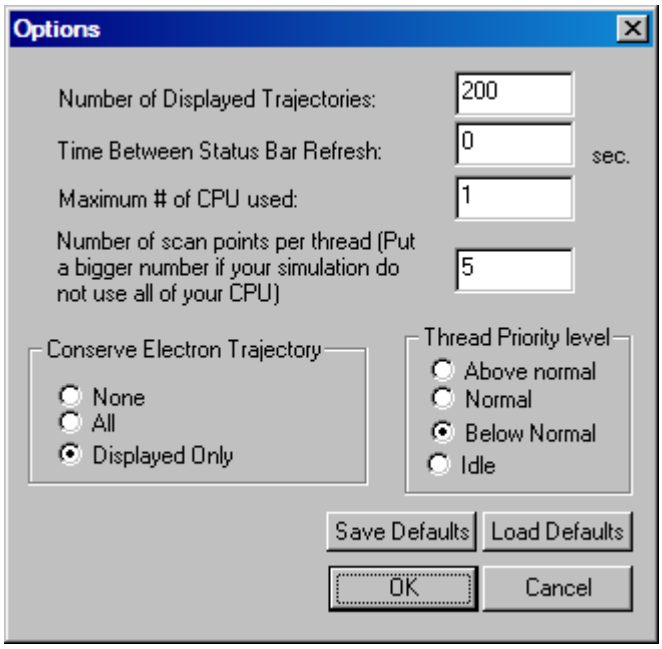
Minimum Order of SE Generated: Casino puts a limit on the maximum order of a generated electron. Putting this setting too low will limit the secondary yield as each energy level has a decreasing impact on the secondary yield.

Residual energy loss: Lowney made some modifications to the Joy & Luo model of energy loss. These modifications include a fixed energy loss. The impact is minimal at energies higher than 0.05 KeV if the loss is small, but it prevents positive energy loss at lower energy.

Minimum electron energy: The minimal energy when using the Lowney model for energy loss is the working function of the element in the region of the collision. It is still possible to override the working function and specify a different value. If the minimum electron energy has a value equal or lower than 0 will make Casino use the working function instead of the override value.

Minimum generated secondary electron energy: Like the minimum electron energy, this setting overrides the working function value. It corresponds to the minimal energy a secondary electron can have when it is generated.

Runtime Option Dialog



Here are many options related to the Casino program. These options can greatly affect the performance (in calculation time) of the simulation and thus, the user is encouraged to try different settings.

Number of displayed trajectories: If you have an older / slower video card, you can reduce the number of trajectories displayed (mostly when generating secondary electrons, the screen will get clogged with secondary electrons trajectories). It will also affect memory consumption if you only conserve displayed trajectories.

Time between Status Bar Refresh: Time interval that the status bar will be refreshed while simulation is running.

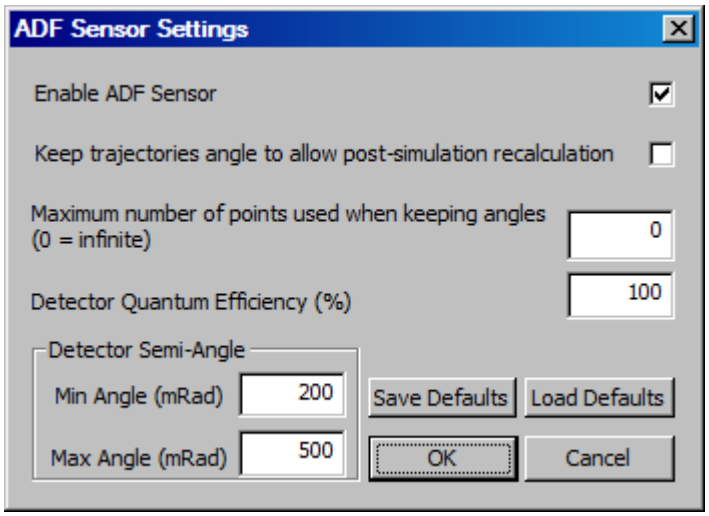
Number of CPU used: If your system has multiple CPUs/cores, Casino can create many threads to use more than one. You should usually put this to the number of cores in your system. This option can be changed on the fly while the simulation is running and the number of core used should respond accordingly.

Number of scan points per thread: When simulating scan points with few electrons, it can happen that the thread creation/destruction take a noticeable chunk of time compared to the time spend simulating. If you notice that you have put the 'Number of CPU used' option to the number of core in your system and Casino is not using all of you CPU, try putting a higher number here (you will need to restart the simulation if you want it to take effect).

Conserve electrons trajectories: The simulation trajectories take a lot of memory space. As of now, it is thus impossible to conserve all the information in every trajectory. You can choose to save all of them, only the number of trajectories displayed (see corresponding option) or none at all.

Thread priority level: Priority for the calculation threads (should normally be set to below normal or even idle so it doesn't clog your CPU when other application needs it. It will still use the maximum of it if other applications don't use it).

ADF Sensor Settings



Enable ADF Sensor: Enable the Transmitted Electron Detector.

Keep trajectories angle to allow post-simulation recalculation: This option enable the user to change the Detector Semi-Angle and Detector Quantum Efficiency parameters after the simulation and see the new results without having to do the whole simulation again. This will cost some memory.

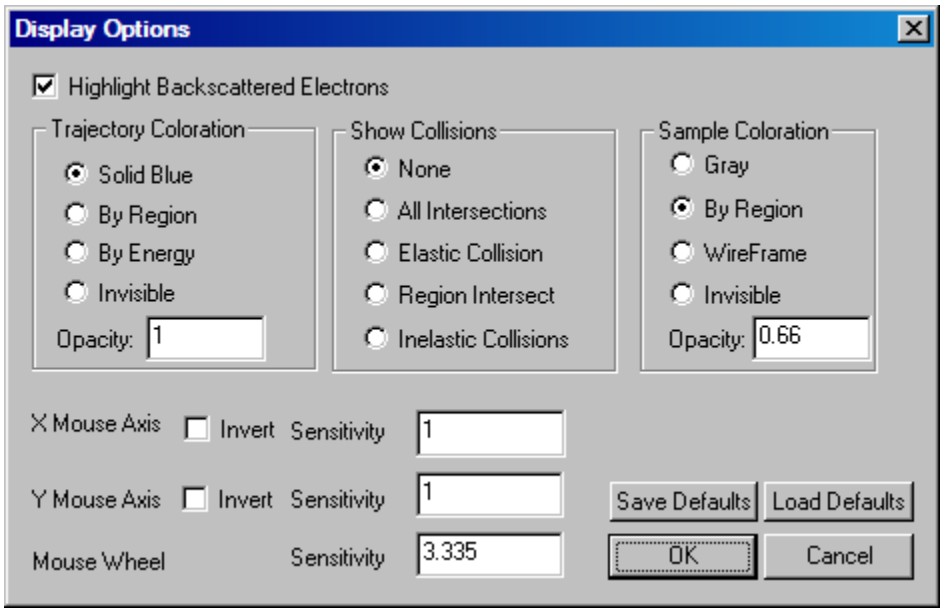
Maximum number of points used when keeping angles: Number of points used when keeping angles. Angles are calculated between 0 and PI/2 so this is the number of points in the distribution of the angles. A higher number will add some precision but cost memory so you should try to put a small number while keeping a reasonable precision.

Detector Quantum Efficiency: Simulate the detector quantum efficiency by throwing a random number and comparing it with this value for each angles before considering it has detected.

Detector Semi-Angle: Semi-angles of the detector.

Display options Dialog

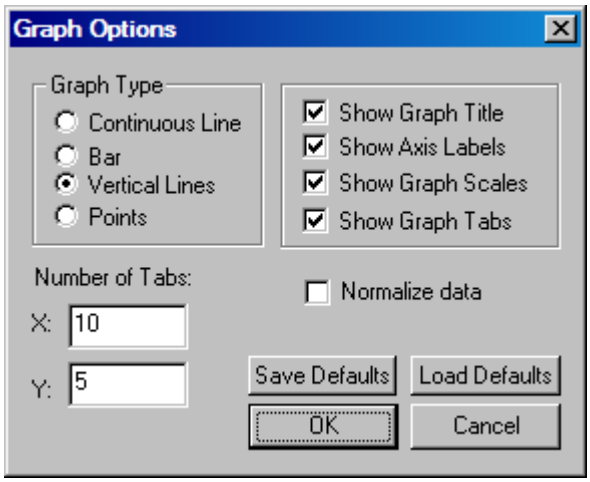
.



This dialog can be used to specify some options for the display of the sample and trajectories. You can choose to highlight all backscattered electrons, choose the color of the trajectories, show collisions or change the sample display to wireframe. The opacity of the sample can also be adjusted here so you can see through it.

You can also choose to invert the mouse X or Y axis and change the sensitivity of it or the mousewheel.

Graph Options Dialog



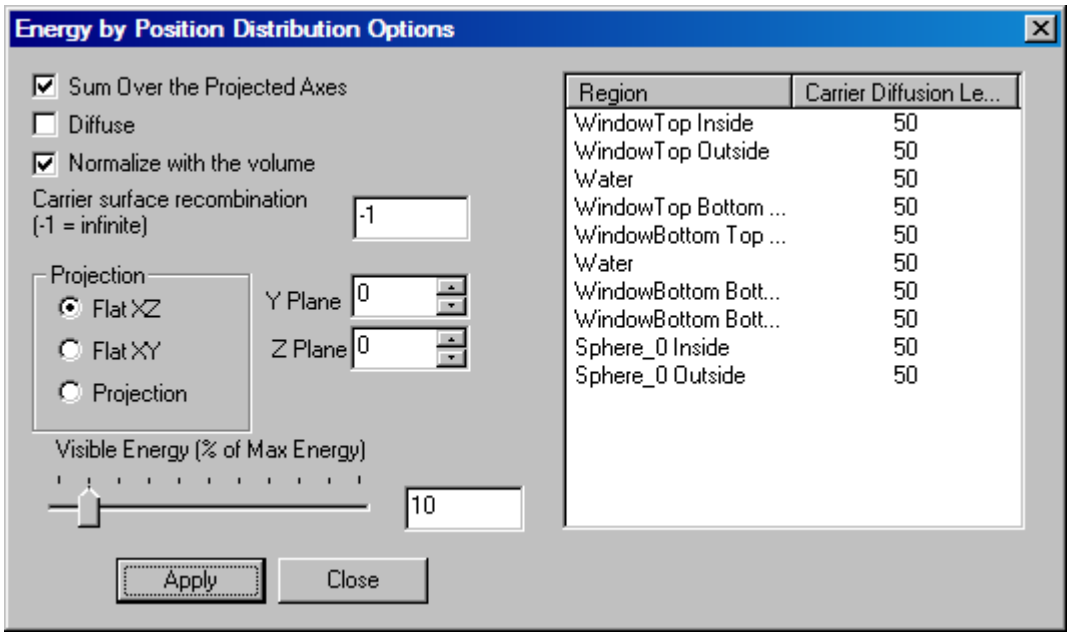
In this dialog you can specify some parameters relating to how the graphs are displayed in Casino.

Graph Type: Specify the type of graph: histogram, a continuous line, points or vertical lines.

Number of tabs: specify the number of tabs in the axis.

Normalize data: Specify if you want the data normalized by the total number of electrons in each scan points (detected electrons divided by the total number of simulated electrons) or only the raw data in electrons.

Energy by Position Distribution Options Dialog



Here you can specify some options relating to the energy by position distribution.

Sum over the projected axes: This options sums all the planes in the third dimension (i.e. when using the XZ view, it will sums all values from the Y planes)

Diffuse: specify whether to display the raw energy by position distribution or the one with the diffusion model.

Normalize with the volume: This option is used when using the spherical/cylindrical coordinates so that the energy values are normalized with the volume of each boxes (this has no effects in the cartesian distribution since all boxes have the same volume)

Carrier surface recombination: Parameter for the diffuse model (not implemented yet)

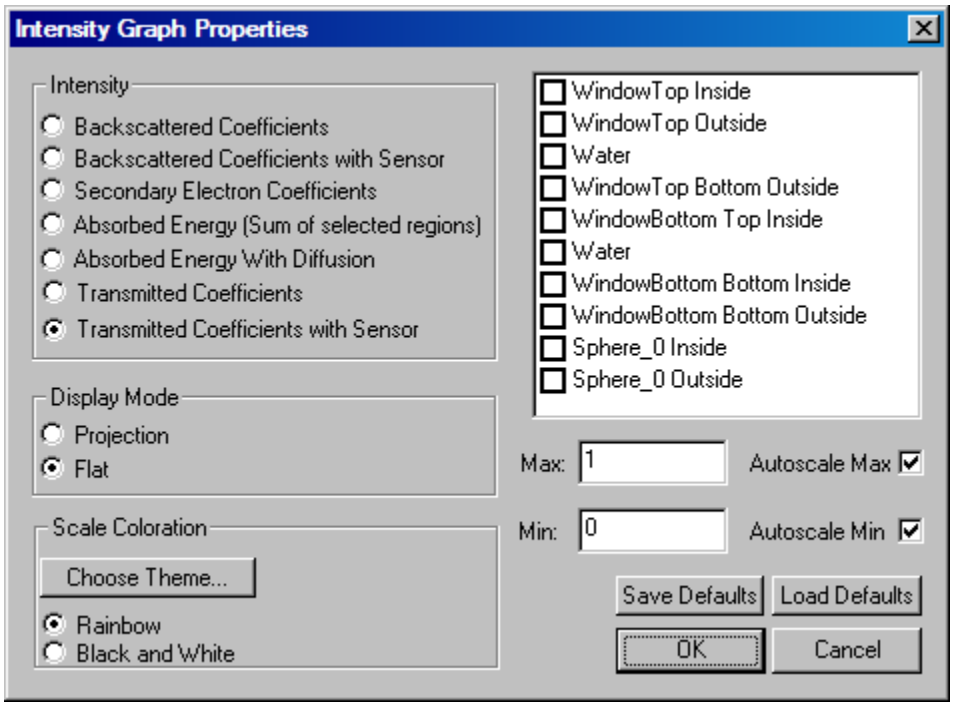
Projection: specify to display the 2D view of the energy by position matrix by XZ or XY, or view a 3D view of the matrix.

Y plane / Z plane: when the 'Sum over the projected axes' is unticked, specify which plane to display.

Visible Energy: Used in the 3D view of the energy by position display.

Region / Carrier Diffusion Length: Specify the carrier diffusion length parameter for the diffusion model for each region. Changing this parameter should force the diffused energy distribution to be recalculated.

Intensity Graph Properties Dialog



Here you can set the parameters related to the intensity display.

Intensity: Choose which type of data you want displayed.

Display Mode: Choose if you want the data to be displayed in 3D or 2D (only for images).

Scale Coloration: Choose the color you want the data to be displayed (images only).

Regions with check boxes: Used to specify which region you want the energy intensity to be displayed (only for Absorbed Energy / Absorbed Energy with Diffusion).

Max / Min: Specify the Max and Min value for the intensity display with the option to automatically calculate it. For example, if you specify a Max value lower than the maximal data, all values higher than Max will be clipped.

Licenses

This program uses the following software libraries: boost, smart_ptr, ezLogger, libtiff, ResizableLib, and TreeCtrlEx. The copyright notices and license information for each are given below or see licenses folder.

Boost

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ezLogger

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TreeCtrlEx

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